APPENDIX A

CODING SCHEME FOR DIARY ACTIVITIES FOR THE CALIFORNIA CHILDREN'S ACTIVITY STUDY

November, 1990

CODING SCHEME FOR ARB KIDS STUDY (11/90)

**indicates activities added specifically for Kids study

01-09 Work and Other Income Producing Activities

***For the most part, these codes will not be used that often in the Kids study since most children will not have a "main" job. For children with a job, code "05" should be used. If a child accompanies his/her parent or other adult in activities related to that adult's job, interviewers should probe to determine the specific activity of the child. If the child was merely watching the adult work, and doing nothing else, code "08" will be used to indicate that the child was simply watching (or accompanying).

01 NOT ASCERTAINED ACTIVITIES (not accessible to interviewers)

Not ascertained personal activities, "time not accounted for"

Time gap of more than 10 minutes

"None of your business"

02 UNEMPLOYMENT

**Child's job search: looking for work, including visits to employment agencies, phone calls to prospective employers, answering want ads.

03 TRAVEL DURING WORK

**child traveling during his/her work

05 CHILDREN'S PAID WORK

**Part time job for child
Babysitting for pay, paper route.

06 EATING AT WORK/SCHOOL/DAYCARE

**Meal or snack at school or day care.
(includes eating away from school during school day).

08 Accompanying or watching adult at work.

09 TRAVEL TO WORK/SCHOOL MEALS

Travel to workplace, including time spent waiting for transportation. **Includes travel made by child to his/her own workplace or travel time accompanying parent (or other adult) to work.

Travel related to job search, to obtain unemployment benefits, welfare, food stamps, and waiting for related travel. **Includes travel by child alone and travel made accompanying parent (or other adult).

Travel related to meals during school day.

10-19 Household Activities

For the most part, these codes shouldn't create any problems. As a general rule, the use of codes 10-17 and 19 require that the child was actually engaged in the activity, or in assisting another person with the activity. If the child was watching someone else do the activity, however, code 18 would be used, indicating he/she was simply "watching."

10 FOOD PREPARATION (**includes actually doing activity or assisting an adult with task)

Meal preparation, cooking, fixing lunches

Serving food, setting the table

Preserving foodstuffs (canning, pickling, etc.)

11 MEAL CLEANUP (**includes actually doing activity or assisting an adult with task, does not include watching someone else do task)

Doing dishes, rinsing dishes, loading dishwasher

Meal cleanup, clearing table, unloading dishwasher

12 INDOOR HOUSE CLEANING (**includes actually doing activity or assisting an adult with task, does not include watching someone else do task)

Routine <u>indoor</u> cleaning and chores, picking up, dusting, making beds, washing windows, vacuuming, "fall/spring cleaning," taking out garbage, "housework."

Miscellaneous "work around the house" (not specified whether indoor or outdoor work), "running around picking up things"

13 OUTDOOR HOUSE CLEANING (**includes actually doing activity or assisting an adult with task, does not include watching someone else do task)

Routine outdoor cleaning and chores; yard work, raking leaves, mowing lawn, garbage removal, snow shoveling, putting on storm windows, cleaning garage, cutting wood.

149 WASHING CLOTHES AT LAUNDROMAT (**includes actually doing activity or assisting with task, does not include watching someone else do task)

14 CLOTHES CARE (** includes actually doing activity or assisting with task, does not include watching someone else do task)

Washing clothes

Other clothes care, including mending and other clothing repairs, (does not include sewing or needlework done for recreational purposes)

15 CAR REPAIR/MAINTENANCE (**includes actually doing activity or assisting an adult with task, but does not include watching someone else do task)

Routine car care at home; repairs, tune-up, other car care done by R (does not include car care done by professional garage)

Car maintenance; changed oil, changed tires, washed car, "worked on car"

Customize car, body work on car done at home

16 HOME REPAIRS (**includes actually doing activity or assisting an adult with task, but does not include watching someone else do task)

Indoor repairs: maintenance, fixing, furnace, plumbing

Outdoor repairs: maintenance of house exterior, fixing the roof, repairing the driveway

Home improvements: additions to and remodeling done to the house or garage, putting on a new roof

Carpentry or wood working to repair the home (does not include carpentry or woodworking done as a hobby)

Repairing appliances in the home

Repairing furniture or leisure equipment, "fixing bike," working on bike

Improvements to the grounds around the house, putting in a garden, laying sod, repaving the driveway

Wrapping packages; packing clothes

166 Repairing boats

167 Painting a room or home (interior and/or exterior)

169 Building a fire, "lighting firecrackers"

17 PLANT CARE (**includes actually doing activity or assisting someone else with task, but does not include watching someone else do task)

Picking flowers, fertilizing, weeding, maintaining plants or garden, picking fruit

Care of house plants

18 OTHER HOUSEHOLD

Watching another person do household tasks (any tasks codes 10-17 and 19)

Conducting garage sales (does not include shopping at garage sales)

Loading or unloading the car, putting away groceries, pulling baggage, showing what was purchased

"Getting backpack ready", "got ready for school", packed up to go home

Other household chores (including those not ascertained whether cleaning or repair) (This category will be excluded from the scheme the interviewers get. If something falls here it should first be reviewed by coders to make sure it can't be coded someplace else.)

19 PET CARE (**includes actually doing activity or assisting someone else with task, but does not include watching someone else do task)

Playing with animals, "collecting worms"

Care of domestic household pets (feeding the dog, walking the dog, running with the dog, brushing the cat, changing the hamster's cage, etc.)

Feeding and care of farm animals (feeding and care of chickens, cows, pigs, etc.). Feeding ducks in park, looking at mice.

199 Travel to home, travel to household activities, "travel to help gramma at laundromat."

20-29 Child Care

These codes are to be used only when the child being interviewed tells you he/she had responsibility for or assisted someone else in taking care of another child (e.g., babysitting for a neighbor, taking care of the baby, etc.). NOTE: Do not include child care done for pay. They should not be used if the child being interviewed was the recipient of care by another person.

20 BABY CARE

Providing routine care to children age 4 and under (feeding baby, changing diapers, etc.)

Babysitting when child's age is unspecified

21 CHILD CARE

Helping sister try on clothes

Taking routine care of children of mixed ages, where at least one child is between the ages of 5 and 18

22 HELPING/TEACHING CHILDREN

Helping (other) children learn, fix, or make things

Helping other children with homework

23 TALKING AND READING (IN THE CONTEXT OF CHILD CARE)

Giving other children orders or instructions; asking them to help, telling them to behave

Disciplining other children; yelling at kids, spanking children

Reading to another child

Conversations with other children in the household, listening to other children

24 INDOOR PLAYING WHILE CARING FOR A CHILD

**Indoor playing with babies and/or children as part of child care responsibility; includes games and other forms of indoor play

25 OUTDOOR PLAYING WHILE CARING FOR A CHILD

**Leading outdoor activities as part of child care responsibility; coaching

**Playing outdoors with other children as part of child care responsibility, including sports, walks, biking, other outdoor games

26 MEDICAL CARE FOR OTHER CHILDREN

**Providing medical care (at home or outside the home) for children for whom R has child care responsibility

**Activities associated with providing health care or assisting in the provision of health care to children

27 OTHER CHILD CARE

Coordinating other child's social or instructional non-school activities

Unpaid babysitting or other childcare of children outside of R's home (Paid babysitting is coded "05")

Time spent picking up or dropping off other children (not including travel time)

28 Watching someone provide any kind of child care to another child. (not used in children's survey)

29 TRAVEL RELATED TO CHILD CARE

30-39 Obtaining Goods and Services

For the most part, these codes are concerned with general shopping activities as well as efforts to obtain services. These codes should be used when R was actually doing the task. If R was simply accompanying someone else, code "38."

301 PICKING UP OR DROPPING OFF DRY CLEANING

30 GROCERY SHOPPING

Shopping for food, picking up takeout order at fast food restaurant, grocery shopping, picking up grocery order

31 SHOPPING FOR DURABLE GOODS AND HOUSEHOLD ITEMS

Shopping for clothing, small appliances, at drug stores, hardware stores, department stores, shopping centers, the mall. Also includes window shopping, shopping at a flea market

Walking at the mall is considered like window shopping, thus is coded here (otherwise, walking in a store is coded as walking - 82), at the mall, looking around store or mall

Shopping for durable goods, large appliances, furniture

Shopping for a house or apartment; activities connected to buying, selling, renting, looking for a house or apartment. This includes phone calls made to buy or rent, as well as time spent looking at homes for residential use

NOTE: If child is 3 years or older and activity is listed as shopping code as shopping (30 or 31). If under 3 years, code as accompanying adult to shop or "38"

32 PERSONAL CARE SERVICES

Going to the beauty parlor, barber shop, hairdressers

33 MEDICAL APPOINTMENTS

Obtaining medical services for self; going to the doctor; getting prescriptions filled, waiting for doctors appointment

34 GOVERNMENT AND FINANCIAL SERVICES

Seeking financial services; activities related to taking care of financial business, going to the bank, paying utility bills (in person), going to accountant, tax office, loan agencies

35 CAR REPAIR SERVICES

Buying gasoline

Seeking repair and other automobile services, including waiting for such services

Having work done by someone else on a car -- "not necessary to their running, customizing, painting"

Shopping for new cars, test driving cars

36 OTHER REPAIR SERVICES

Seeking services to have clothing repaired, altered (not including mending activities that R may engage in him/herself)

Seeking services to have appliances repaired, including major and small appliances (e.g., furnaces, water heaters, electric or battery operated appliances).

37 TIME SPENT SEEKING OR OBTAINING OTHER SERVICES

Other professional services such as seeing a lawyer, psychological counseling, etc.

Going to the dump

Renting and picking up (not purchasing various media and leisure materials, e.g., videos, records, sports equipment, fishing gear, etc.

Picking up mail (at post office)

38 ERRANDS

Accompanying parents on errands, or any shopping

Running errands; not ascertained whether for goods or services. Includes borrowing goods.

Watching someone else obtain goods and services or run errands.

"Riding in a shopping cart", riding in stroller while parent runs errands"

"Sitting on tire stand (at auto repair)"

39 TRAVEL RELATED TO GOODS AND SERVICES

40-49 Personal Needs and Care

40 WASHING

Bathing, washing, showering, personal hygiene, going to the bathroom, "drying off", brushing teeth, "sitting in hot tub"

Diaper changed, if over one year

Listening to story while trying to go to bathroom

Throwing up

41 MEDICAL CARE

Providing medical care to self, taking medicine

Having someone else provide medical care to you

Providing medical care to others in household

42 HELP AND CARE (NOT ACCESSIBLE TO INTERVIEWERS)

Non-medical care to adults in HH; routine non-medical care to adults in HH

Help to relatives not living in HH; helping, caring for, providing for needs of relatives; helping move, bringing food, assisting in emergencies, doing housework for relatives, visiting relatives when they are sick.

Dropping adults at work or other locations

Help to neighbors, friends

Help to others, relationship to R not ascertained

43 MEALS AT HOME

Meals at home, including coffee, drinking non-alcoholic or alcoholic beverages, food from a restaurant eaten at home, "breakfast," "lunch"

44 MEALS OUT

Meals at friends' home, including coffee, drinking beverages

Meals at a restaurant

Eating in car while stationary (eating while driving/riding gets travel code)

Eating at Marine World

NOTE: If R is in a bar having a drink, code "77."
Meals at school are "06."
Playing while eating is "875." (Eating at a place like Chuck E. Cheese is coded 711)

45 "NIGHT" SLEEP

**Sleep that lasts for three hours or longer (regardless of the time of day it occurs) There is one exception, however. If sleep occurs for fewer than three hours and occurs between 8:00 p.m. and 8:00 a.m., it will also be coded as "night sleep." This is done to handle infants who may wake up several times during a night. This is a change from the adult study, where "night sleep" was defined as the longest sleep of the day.

46 NAPS

Naps
**Sleep that lasts for fewer than three hours (and does not occur between the hours of 8:00 p.m. and 8:00 a.m.)

47 DRESSING AND GROOMING

Getting dressed or getting ready for bed, setting hair, blow-drying hair at home, being put to bed, "tucked in," having home permanent

474 WASHING AND DRESSING

Not accessible to interviewers.

48 WATCHING PERSONAL CARE

Other personal care activities, watching personal care activities of someone else

49 TRAVEL RELATED TO PERSONAL CARE

Travel related to helping, including travel which is the helping activity, waiting for related travel

Other personal travel

Travel when purpose is not clear

50-59 Education and Professional Training

50 STUDENTS' CLASSES (Code pre-kindergarten activities to the activity)

All classes other than physical education (except pre-school, where we code to the activity) even in the case of courses like arts and crafts.

Student attending classes full-time, except for physical education (Probe P.E. class for physical activity, and code to activity)

51 OTHER CLASSES

Other academic or professional classes, courses, lectures. (To be used when R is not a full time student or not ascertained whether a student.)

Receiving tutoring

52 UNSPECIFIED DAY CARE (to be used when more specific activity cannot be ascertained) includes unspecified babysitting time

54 DOING HOMEWORK

Reading for classes, doing homework, studying, doing research. (To be used when homework done in school, at friend's house, at home, or any location.)

549 Doing Homework While Watching TV

55 USING THE LIBRARY

Time spent at library (not including time spent doing homework in library, or time spent socializing with friends on library)

56 OTHER EDUCATION

Breaks between classes (not including "recess" which should be probed for specific activity)

Gathering up belongings at end of school day

Other education-related activities

57 At day care/nursery before or after school, hanging out before and after school

58 Watching someone else receive educational training

59 TRAVEL RELATED TO EDUCATION

Travel directly from home to class

Travel to day care

Waiting for related travel

Travel to library

**Travel related to school field trips

60-69 **Organizational Activities**

60 ATTENDING MEETINGS OF ORGANIZATIONS

Meetings for team sports (not including playing sports), special interest identity groups

Meetings of political/citizen organizations; including city council meetings

Meetings of volunteer or helping organizations

Meetings of religious groups, Sunday School

Attending services of a church or synagogue (code to specific activity except for the following), including participating in the service, ushering, singing in the choir, leading youth groups, going to church, funerals

Work for religious groups

Work for child/youth/family organizations, including such organizations as Girl Scouts, Boy Scouts, "selling Girl Scout cookies"

Knocking on doors selling chocolates

68 Watching others engaged in or accompanying others engaged in organizational activity

Other organizational activities, "signing up for tennis tournament"

69 TRAVEL RELATED TO ORGANIZATIONAL ACTIVITY

Travel related to all other organizational activities, waiting for related travel, travel to tending to ministry

70-79 **Entertainment/Social Activities**

70 SPORTS EVENTS

Watching sports

Watch other people do active leisure activities

Attending sports events, "getting autographs"

71 MISCELLANEOUS EVENTS

Miscellaneous spectacles, events, circus (sat and watched clown), fairs and amusement parks, rock concerts (includes listening to music at a rock concert), accidents

711 Eating and amusements (i.e., Chuck E. Cheese)

72 MOVIES

Attending movies

73 THEATER

Attending theater, opera, classical music concerts, ballet

74 VISITING MUSEUMS, ZOOS, ART GALLERIES, EXHIBITIONS

"Watching dolphins at Marine World"

75 VISITING WITH OTHERS

Conversations with relatives - grandparents, aunt, uncle - when not ascertained HH or not and when not HH member)
Socializing with people other than members of R's own household, (or if relationship is unspecified) either at R's home or another home; talking/chatting in the context of receiving a visit or paying. (Visiting with household members should not be included. Household visiting is coded "96.")

Affection with non-household members, "sitting on lap", etc.
Conversations with unspecified persons

76 PARTIES

Attending parties, receptions, weddings

Picnicking

77 BAR/LOUNGES/COFFEE SHOPS

Drinking, socializing or hoping to socialize at a bar or cocktail lounge, coffee shop (Does not include activities where R eats a meal)

78 OTHER SOCIAL EVENTS

Watching someone else engaged in social activities

Other events not coded above

79 TRAVEL RELATED TO EVENT/SOCIAL ACTIVITY

80-89 **Recreation**

80 ACTIVE SPORTS

Swimming (including wading or playing in water, playing in pool - not swimming, floating in inner tube, went to pool, playing with water-hose or water balloons), tennis, skating, skateboarding, roller skating, including lessons

"Playing cowboy - running - climbing stairs"

Football, basketball, baseball, volleyball, hockey, soccer, field hockey

Tennis, squash, racquetball, paddleball, handball

Skiing, ice skating, sledding

Trampoline

Riding on hobby horse, on rides/riding horse in front of a dry cleaners, hop scotch, hula hoops, merry-go-round at MacDonald's, jumping rope

Frisbee, catch

Exercises, weightlifting, "practicing cheers"

Judo, boxing, wrestling, "rough-housing with Dad and brother, being spun by Dad, "jumping on bed", bouncing on bed, playing around on water bed

Gymnastics

Amusement park rides, including roller coasters, Pirates of the Caribbean

Swinging (indoors or outdoors)

Playing on playground equipment, "climbing a tree"

801 Golf, miniature golf, golf lessons

802 Bowling, pool, ping pong, pinball

803 Yoga

81 OUTDOOR LEISURE

Hunting, fishing, boating, sailing, canoeing, camping (code to specific activity whenever possible), at the beach, snowmobiling, dune-buggies, gliding, ballooning, flying, kite flying

811 Outdoor play not specified elsewhere, "playing in dirt or sandbox", counting rocks, building forts, looking for something to do - got into boxes, playing make believe, playing house, just played, hide and seek outside (code 811 only if outside - if activity occurs inside, code 87)

82 WALKING/RUNNING/BIKING

Eating and walking

Walking for pleasure (not transportation), hiking, jogging, running, playing tag, bicycling or riding on back of bicycle, motorcycling for pleasure, horseback riding, march in parades, crawling around, running around (can be indoors or outdoors)

Walking in a walker, playing on a trike, big wheel or bike

Walking around grounds at Marine World, walking around store, running around store, walking with mom while tending to ministry

83 HOBBIES

Taking photographs, collections, scrapbooks, making movies

84 DOMESTIC CRAFTS

Knitting, needlework, weaving, crocheting, crewel, embroidery, quilting, quilling, macrame, wrapping gifts

This category also includes taking classes in these areas

85 ART

Sculpture, painting potting, drawing, including taking classes (but not school classes)

86 MUSIC/DRAMA/DANCE

Playing a musical instrument (including practicing), whistling, singing, acting and rehearsing for a play, social and non-social dancing, ballet, modern dance, body movement

Taking classes (not in school) in music, drama, or dance, (including time spent waiting for classes to begin)

Other active leisure

87 INDOOR GAMES

Hide and seek inside

Child under 5 years reading books, choosing books to read

Got face painted

Playing card games (bridge, poker)

Playing board games (monopoly, Yahtzee, Bingo, Dominoes, Trivial Pursuit, etc.)

Playing social games (scavenger hunts), "played games" (kind not ascertained)

Puzzles

Play and fight with brother, 2 year old fighting with friend

Played with toys (indoors)

Played indoors (any unspecified)

Played computer games, such as Pacman, Kong, video games at store, etc.

875 Playing and eating

877 Playing and talking with family members (at the same time) "played and tickled by Dad"

879 Playing and watching TV (at the same time)

88 WATCHING OTHERS ENGAGED IN RECREATION

[Includes being pushed in stroller as leisure activity (not travel)]

89 TRAVEL RELATED TO ACTIVE LEISURE

Related travel, including pleasure drives, rides with family, excursions

90-91 Communication and passive leisure

90 RADIO USE

Radio transmitting, CB radios

Listening to the radio

91 TV USE

TV viewing, including VCR and home movies, cable TV

NOTE: Watching TV and doing homework is coded 549
TV viewing and playing is coded 879
TV and reading is 937

914 TV and eating

915 TV viewing and something not listed above

92 RECORDS/TAPES

Recording music

Listening to records, tapes, stereo; listening to music, listening to others playing musical instruments

93 READING BOOKS

Reading - if child is over five years of age (if under, code as 87 or 94)

Reading books for pleasure

934 Reading books and eating

937 Reading and TV

938 Reading and listening to music

94 READING MAGAZINES/NOT ASCERTAINED

Reading magazines, reviews, pamphlets

Reading (not ascertained what)

Being read to

944 Reading magazines and eating

95 READING A NEWSPAPER

Reading newspaper

954 Reading newspaper and eating a meal or snack

96 CONVERSATIONS

Receiving instructions, being disciplined

Conversations/arguing with HH members

Other passive leisure, pestering, teasing, joking, messing around, laughing, crying (if over 1 year old), "playing pattycake" with family members

Affection between household members, giving and getting hugs, sitting on laps, having sex.

Conversations on the telephone with anyone (not just household members)

97 LETTERS, WRITING, PAPERWORK

Typing letters, writing letters, literature, poetry, writing in a diary, sending cards

971 Household paperwork, paying bills, balancing the checkbook, making lists, getting mail (at home), working on budget

98 OTHER PASSIVE LEISURE

Being a baby (to be used for children 1 year and under and includes diaper change, playing by him/herself or with parent, and all activities other than eating, walking (including "walking in walker") crawling, traveling, sleeping, or accompanying parents to an activity), and ALL PRE-CODED activities. Thus activities will often be coded "98" even when there is a more specific code, such as "87" for "playing with toys." Do not change pre-coded categories (watching TV, eating, etc.) to "98." Also remember that even though we are coding this way, we still need to probe thoroughly those activities -- even though we know it will be coded "98" we still must probe "playing," for example.

Having photos taken

Crying if 1 year old or under

Relaxing "lying in bed", got in bed, thinking, planning, reflecting, "quiet time," doing nothing, "sat around," smoking cigarettes, pipes, dope

Saying prayers

"Watching eclipse", "rocking in rocking chair"

"Just laid there and took rest, not nap"

"Rested in different bed upstairs"

Rocked to sleep

Watching others engaged in passive leisure

"Waiting" if connection to next activity is unclear

99 TRAVEL RELATED TO PASSIVE LEISURE

Related travel, waiting for related travel

APPENDIX B

MAIN BODY OF CATI INSTRUMENT USED FOR THE CALIFORNIA CHILDREN'S ACTIVITY SURVEY

```
%W%     %G%
*****************************************************************************
                        1988-89 Air Resources Board Survey
                             Survey Research Center
                        University of California, Berkeley

            main.q -- Begin substantive interview questions with the
                        child's designated adult primary caretaker
*****************************************************************************

>MAIN<  [allow 1][equiv rmon position 3]


>hous<  To begin, would you describe the building you live in as...


            <1> a separate single-family house,
            <2> a single-family home attached to other dwellings,
            <3> an apartment building,
            <4> a mobile home or trailer, or
            <5> something else?  (SPECIFY)  [specify]

        ===>


>hsnm<  [allow 27][equiv ntm3 position 31]

>ptst<  [if tim1 is <>]
            [settime tim1]
            [endif]
        [if hous is <1>]
            [store <your house> in hsnm]
            [endif]
        [if hous is <2>]
            [store <the building you live in> in hsnm]
            [endif]
        [if hous is <3>]
            [store <your apartment building> in hsnm]
            [endif]
        [if hous is <4>]
            [store <your mobile home or trailer> in hsnm]
            [endif]
        [if hous is <5>]
            [store <the building you live in> in hsnm]
            [endif]
```

>cons< In what year was [fill hsnm] constructed? [equiv hous position 2]

IF NEEDED: What would be your best guess?

<1700-1989> Year of construction

<9998> Don't know; can't say
<9999> Refused

===>

>park< Does [fill hsnm] have an attached garage or a parking area underneath it?

<1> Yes [goto prk2]
<5> No, neither

<8> Don't know; can't say
<9> Refused

===>[goto moth]

>prk2< While [fill name] was at home yesterday, were ANY cars, trucks, motorcycles, or other motor vehicles parked in the attached garage (or under-building parking area)?

<1> Yes (FOR ANY PART OF THE DAY)
<5> No

<8> Don't know; can't say
<9> Refused

===>

>moth< Are any of the following used in your home nowadays:

Any mothballs, or moth crystals or cakes?

<1> Yes
<5> No

<8> Don't know; can't say
<9> Refused

===>

>deod< Any toilet bowl deodorizers?

<1> Yes
<5> No

<8> Don't know; can't say
<9> Refused

===>

>rmfr< Any SCENTED room fresheners?

<1> Yes
<5> No

<8> Don't know; can't say
<9> Refused

===>

>htys< Was the heat turned on at any time in your home yesterday?
Do NOT include using a gas oven for heat.

IF NEEDED: I'll be asking about gas ovens separately a little later.

<1> Yes [goto htfl]
<5> No

<8> Don't know; can't say
<9> Refused

===>[goto open]

>htfl< What kind of heat was it -- gas, electricity, oil, or what?

IF COMBINATION: Which kind was used for heat the longest yesterday?
[allow 2]

<1> Gas
<2> Electricity
<3> Fuel oil or kerosene
<4> Wood
<5> Coal or coke
<6> Solar energy

<7> Other (SPECIFY) [specify]

<98> Don't know; can't say
<99> Refused

===>

>heat< What type of heater was turned on for the longest amount of time? Was it a wall furnace, a floor furnace, forced air, radiator, portable space heater, or something else?
[allow 2]

<1> Wall furnace
<2> Floor furnace
<3> Forced air
<4> Radiator
<5> Wood stove
<6> Fireplace
<7> Gravity heater
<8> Portable space heater

<9> Something else (SPECIFY) [specify]

<98> Don't know; can't say
<99> Refused

===>

```
>open<  Were any doors or windows in your home open for more than a
        minute or two at a time yesterday?

            <1> Yes  [goto opn1]
            <5> No

            <7> VOLUNTEERED ONLY: Yes - have a window open all the time

            <8> Don't know; can't say
            <9> Refused

        --->


>arst<  [if open is <7>]                  ** store maximum minutes
            [store <720> in opn1]         ** when window open ALL the time
            [store <720> in opn2]
            [endif]
        [goto fan1]


>opn1<  For about how long during the day, that is, from 6am to 6pm,
        (were they/was it) open?
                                                  Hours=Minutes

            <1-720> Number of minutes             1= 60   7=420
                                                  2=120   8=480
                <0> Not open between 6am and 6pm  3=180   9=540
                                                  4=240  10=600
              <998> Don't know; can't say         5=300  11=660
              <999> Refused                       6=360  12=720

         [##bla=997][##min=0][##max=720]--->


>opn2<  For about how long during evening or night hours, that is,
        from 6pm to 6am, (were they/was it) open?
                                                  Hours=Minutes

            <1-720> Number of minutes             1= 60   7=420
                                                  2=120   8=480
                <0> Not open between 6pm and 6am  3=180   9=540
                                                  4=240  10=600
              <998> Don't know; can't say         5=300  11=660
              <999> Refused                       6=360  12=720

         [##bla=997][##min=0][##max=720]--->
```

Date printed: 4/10/89

>fan1< Was any kind of fan used in your home yesterday?

<1> Yes [goto fan2]
<5> No

<8> Don't know; can't say
<9> Refused

===>[goto airc]

>fan2< Was that a ceiling fan, window fan, portable room fan, or something else? [allow 2]

<1> ceiling fan
<2> window fan
<3> portable room fan
<4> VOLUNTEERED ONLY: exhaust fan in bathroom or kitchen

<5> something else (SPECIFY) [specify]

<98> Don't know; can't say
<99> Refused

===>

>airc< (Not counting the fan you just told me about) Was any kind of air cooling system used in your home yesterday, such as an air conditioner? [loc 2/8]

<1> Yes [goto ACtp]
<5> No

<8> Don't know; can't say
<9> Refused

===>[goto vac]

>ACtp< What type is it? [allow 2]

<1> Evaporative cooler (swamp cooler)
<5> Refrigeration type (air conditioner)

<7> Other (SPECIFY) [specify]

<98> DK - Have air conditioning but don't know what kind
<99> Refused

===>

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>vac< What type of vacuum cleaner do you use, is it...

[allow 2]

<1> an upright,
<2> a canister,
<3> a canister with a powerhead,
<4> an electric broom, or
<5> some other kind of vacuum cleaner? (SPECIFY) [specify]

<6> Does not own or use a vacuum cleaner [goto flr]

<98> Don't know; can't say [goto flr]
<99> Refused [goto flr]

===>

>vac2< Is your vacuum cleaner working?

<1> Yes
<5> No

<8> Don't know; can't say
<9> Refused

===>

>flr< Yesterday, did [fill name] spend any time down on the floor in your home?

(Please don't include any time [fill name] spent walking from one place to another, but do include any time spent (crawling,) lying, or playing down on the floor.)

<1> Yes [goto flr2]
<5> No

<8> Don't know; can't say
<9> Refused

===>[goto out]

>flr2< Thinking of that floor area where [fill name] spent most of (his/her) time yesterday, was that area carpeted?

<1> Carpeted [goto flr3]
<5> Not carpeted
<7> Equal time on carpeted and uncarpeted [goto flr3]

<8> Don't know; can't say
<9> Refused

===>[goto cln]

>flr3< What type of carpet is on that floor area? Is it...

<1> plush carpet,
<2> level loop carpet,
<3> flat carpet,
<4> multi-level carpet,
<5> shag carpet, or
<6> some other type of carpet? (SPECIFY) [specify]

<8> Don't know; can't say
<9> Refused

===>

>cln< How many days has it been since that floor area was swept or vacuumed?

<0> Was swept or vacuumed today
<1-96> Number of days ago
<97> 97 days or more

<98> Don't know; can't say
<99> Refused

[##bla=99][##min=0][##max=97]===>

>out< Did [fill name] spend any time yesterday playing outdoors?

<1> Yes [goto surf]
<5> No

<8> Don't know; can't say
<9> Refused

===>[goto hum]

>surf< When [fill name] was outdoors yesterday, did (he/she) spend MOST of (his/her) time playing on sand or gravel, dirt, grass, asphalt, or concrete, or some other type of surface?

IF R MENTIONS MORE THAN ONE TYPE OF SURFACE, PROBE: On what surface did (he/she) spend MOST of (his/her) time yesterday?

[allow 2]

<1> sand or gravel
<2> dirt
<3> grass
<4> asphalt or concrete
<5> some other type of surface (SPECIFY) [specify]

<6> AFTER PROBE: combination of surfaces (SPECIFY) [specify]

<98> Don't know; can't say
<99> Refused

--->

>hum< Now, thinking about the time [fill name] spent indoors yesterday -- either at home or someplace else -- was (he/she) in a room where either a humidifier or vaporizer was in use?

IF YES: Was it a humidifier or a vaporizer?

<1> Yes, around a humidifier
<2> Yes, around a vaporizer
<3> Yes, around BOTH a humidifier and vaporizer

<4> No, not around a humidifier or vaporizer

<8> Don't know; can't say
<9> Refused

--->

>ill< Did [fill name] have to limit his/her activity yesterday because of asthma symptoms, cold, flu or any other illness or disability?

<1> Yes [goto ill2]
<5> No

<8> Don't know; can't say
<9> Refused

--->[goto tmsp]

>ill2< What kind of illness or disability did [fill name] have?
[allow 2]

<1> Asthma or asthma symptoms
<2> Cold
<3> Flu
<4> Sore throat
<5> Ear ache
<6> Cough

<7> Some other illness or disability (SPECIFY) [specify]

<98> Don't know; can't say
<99> Refused

--->

>tmsp< How much time did you personally spend with [fill name] yesterday?

<0> No time at all
<1-1439> Number of MINUTES

<1440> 24 Hours

<9998> Don't know; can't say
<9999> Refused

Hours = Minutes		
1= 60	8=480	15=900
2=120	9=540	16=960
3=180	10=600	17=1020
4=240	11=660	18=1080
5=300	12=720	19=1140
6=360	13=780	20=1200
7=420	14=840	21=1260
		22=1320
		23=1380
		24=1440

[##bla=9997][##min=0][##max=1440]--->

>rsex< CODE OR ASK IF NECESSARY:

Is [fill name] a boy or a girl?

<1> Boy
<2> Girl

--->

>SEG1< [allow 3] ** End of interview segment 1

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****
INTRODUCTION TO CHILDREN'S QUESTIONS
****

```
>tpx<   [if rage ge <9>][#and][if rage le <11>]      ** Determine intro to use for
            [goto px9]                               ** children's items, based
            [endif][endif]                           ** on child's age (rage).
        [if rage ge <6>][#and][if rage le <8>]
            [goto px6]
            [endif][endif]
        [if rage ge <0>][#and][if rage le <5>]
            [goto px0]
            [endif][endif]
```

>px9< Those are all the questions I have for you at this point. Now I would like to ask some questions of [fill name]. You may stand by and listen if you'd like. When we're done, I'll have a few more questions for you.

Could I please speak to [fill name]?

<1> Yes and [fill name] comes to phone [goto exp9]

<5> [fill name] not available or can't come to phone
<8> [fill name] refuses to come to phone or be interviewed
<9> Adult refuses to allow [fill name] to be interviewed

===>[goto px9b]

>px6< For the next questions, it would be helpful if [fill name] is nearby so you can ask (him/her) about (his/her) activities during the time when you weren't around yesterday.

IF NECESSARY: (He/She) can be playing or doing something to keep busy as long as (she/he) stays within earshot. [equiv px9]

<1> [fill name] is nearby, proceed with interview
<5> [fill name] not available, proceed with interview anyway

===>[goto ywho]

>px0< Next a few questions about [fill name]'s activities yesterday. [equiv px9]

TYPE <g> TO PROCEED WITH INTERVIEW

===>[goto ywho]

>px9b< In that case, I can just ask YOU those questions about [fill name]'s activities yesterday.

IF ADULT REFUSES OR SOME OTHER PROBLEM PREVENTS CONTINUATION OF INTERVIEW, USE ":sk cb" TO EXIT.

TYPE <1> TO CONTINUE INTERVIEW WITH ADULT

===>[goto ywho]

>exp9< Hello, my name is [fill unam] and I've been talking to [fill whpl] about things that have to do with air pollution and the quality of the air we breathe. We're doing a study for a group called the Air Resource Board that is part of the California state government. They want to understand more about the things that kids do and the kind of air kids breathe.

I'm going to ask you some questions about what you did and where you went yesterday. If there's anything you don't want to tell me about, that's fine, just say so. And if I ask a question you don't understand, tell me and I'll try to explain it better.

Before we start, do you have any questions you want to ask me?
ANSWER ALL QUESTIONS AS BRIEFED, THEN: Allright, ready to start?
[equiv px9b]

<1> Yes, ready to start, proceed with interview [goto ywho]
<8> [fill name] not able to be interviewed now
<9> [fill name] refuses to be interviewed

===>

>ex9b< That's okay. Just let me speak to [fill whpl] again, please.

IF ADULT REFUSES TO COME BACK OR SOME OTHER PROBLEM PREVENTS CONTINUATION OF INTERVIEW, USE ":sk cb" TO EXIT THIS CASE.

<g> Adult ([fill whpl]) comes back to phone

===>

>ex9c< I spoke with [fill name] and (he/she) (can/will) not be interviewed right now. However, if you agree, I can just ask YOU about [fill name]'s activities yesterday.

IF ADULT REFUSES OR SOME OTHER PROBLEM PREVENTS CONTINUATION OF INTERVIEW, USE ":sk cb" TO EXIT.

TYPE <1> TO CONTINUE INTERVIEW WITH ADULT

===>[goto ywho]

```
*****************************************************************************
                        BEGIN CHILDREN'S QUESTIONS
  (Ask of adult caretaker for 0-8 year olds; 9-11 year olds respond directly)
*****************************************************************************


>ywho<  INTERVIEWER CHECKPOINT:  WHO IS BEING INTERVIEWED NOW?

            <1>  [fill name], the child respondent

            <5>  the adult primary caretaker

        --->


>yres<  [allow 1]                    ** summary var: respondent for child questions
                                                     1 = child,  5 = adult

>rpro< [allow 12][equiv hsnm position 28]   ** respondent name or pronoun (you)
>rvrb< [allow 4]                            ** conjugation (was/were)
>rpri< [allow 3]                            ** respondent pronoun (you/he/she)


>tyfi<  [if ywho is <1>]
            [store <1> in yres]
            [store <you> in rpro]
            [store <were> in rvrb]
            [store <you> in rpri]
            [endif]
        [if ywho is <5>]
            [store <5> in yres]
            [store name in rpro]
            [store <was> in rvrb]
            [if rsex is <1>]
                [store <he> in rpri]
                [endif]
            [if rsex is <2>]
                [store <she> in rpri]
                [endif]
            [endif]
```

>pgar< (Now) I am going to ask you some general questions about places where [fill rpro] [fill rvrb] yesterday.

Did [fill rpri] spend ANY time yesterday at a gas station or in a parking garage or auto repair shop?

[equiv yres position 2]

<1> Yes [goto pgys]
<5> No

<8> Don't know; can't say
<9> Refused

===>[goto prkt]

>pgys< About how long in all yesterday did [fill rpri] spend in those places?

<1-840> number of minutes

<841> more than 14 hours

<998> Don't know; can't say
<999> Refused

Hours = Minutes	
1= 60	8=480
2=120	9=540
3=180	10=600
4=240	11=660
5=300	12=720
6=360	13=780
7=420	14=840

[##bla=0][##min=1][##max=841]===>

>pcar< While at the gas station, parking garage or auto repair shop yesterday, did [fill rpri] stay in the car the whole time or did (he/she) get out of the car?

<1> Stayed in car whole time [goto prkt]
<5> Out of the car some of the time

<8> Don't know; can't say
<9> Refused

===>

```
>pgas<  (Did [fill rpri] pump or pour any gasoline (yesterday)
        or) [fill rvrb] [fill rpri] nearby while someone else pumped gas?


            <1> Yes
            <5> No

            <7> VOLUNTEERED ONLY: Someone else pumped or poured gas,
                but [fill name] was there.

            <8> Don't know; can't say
            <9> Refused

        ===>


>prkt< [if rage ge <9>][#and][if prk2 ge <8>]
           [goto prk9]
           [endif][endif]
       [goto gstv]


>prk9<  While [fill rpro] [fill rvrb] at home yesterday, were ANY cars, trucks,
        motorcycles, or other motor vehicles parked in the attached garage
        (or under-building parking area) where you live?


            <1> Yes (FOR ANY PART OF THE DAY)
            <5> No

            <8> Don't know; can't say
            <9> Refused

        ===>


>gstv<  Did [fill rpri] spend any time yesterday in a room where an
        oven, range or stove was turned on?


            <1> Yes                     [goto gore]
            <5> No

            <8> Don't know; can't say
            <9> Refused

        ===>[goto glue]
```

>gore< Was that a gas or electric oven, range, or stove?

IF BOTH GAS AND ELECTRIC, CODE "GAS"

<1> Gas [goto nstv]
<3> Electric

<8> Don't know; can't say
<9> Refused

===>[goto glue]

>nstv< Was that just one or more than one gas oven, range, or stove that [fill rpri] [fill rvrb] around yesterday?

<1> Only one [goto gspr]
<5> More than one [goto msl]

<8> Don't know; can't say
<9> Refused

===>[goto glue]

>msl< Was the gas oven, range, or stove [fill rpro] [fill rvrb] around for the longest time yesterday being used for cooking, for heating the room, for cleaning the oven, or for some other purpose?

[allow 2]

<1> Cooking
<3> Heating the room

<5> (PROBE ONCE FIRST) Both cooking and heating the room

<6> Cleaning the oven

<7> Some other purpose (SPECIFY) [specify]

<98> Don't know; can't say
<99> Refused

===>

>mstm< Roughly how much time IN ALL [fill rvrb] [fill rpri] in rooms where gas ovens, ranges, or stoves were turned on (yesterday)?

(IF NEEDED: About how many minutes or hours?)

<1-840> number of minutes
<841> more than 14 hours

<998> Don't know; can't say
<999> Refused

Hours = Minutes	
1= 60	8=480
2=120	9=540
3=180	10=600
4=240	11=660
5=300	12=720
6=360	13=780
7=420	14=840

[##bla=0][##min=1][##max=841]===>

>ms2< Does the oven, range, or stove that [fill rpri] [fill rvrb] around the longest have a gas pilot light, pilotless ignition, or something else?

[allow 2]

<1> Gas pilot

<3> (VOLUNTEERED RESPONSE ONLY) Light with matches or sparker

<5> Pilotless ignition (makes click-click-click sound)

<7> Other (SPECIFY) [specify]

<98> Don't know; can't say
<99> Refused

===>[goto glue]

>gspr< Was the gas oven, range, or stove being used for cooking, for heating the room, for cleaning the oven, or for some other purpose?

[allow 2]

<1> Cooking
<3> Heating the room

<5> (PROBE ONCE FIRST) Both cooking and heating the room

<6> Cleaning the oven

<7> Some other purpose (SPECIFY) [specify]

<98> Don't know; can't say
<99> Refused

===>

>gstm< Roughly how much time IN ALL [fill rvrb] [fill rpro] in a room where a gas oven, range, or stove was turned on (yesterday)?

IF NEEDED: About how many minutes or hours?

<1-840> number of minutes
<841> more than 14 hours

<998> Don't know; can't say
<999> Refused

[##bla=0][##min=1][##max=841]===>

Hours = Minutes	
1= 60	8=480
2=120	9=540
3=180	10=600
4=240	11=660
5=300	12=720
6=360	13=780
7=420	14=840

>plot< Does the oven, range, or stove have a gas pilot light, pilotless ignition, or something else?

[allow 2]

<1> Gas pilot light
<3> VOLUNTEERED ONLY: Light with matches or sparker
<5> Pilotless ignition (makes click-click-click sound)

<7> Other (SPECIFY) [specify]

<98> Don't know; can't say
<99> Refused

===>

>glue< Did [fill rpri] use or [fill rvrb] [fill rpri] around anyone while they were using any of the following yesterday:

Any glues or liquid or spray adhesives?

(NOT INCLUDING ADHESIVE TAPE)

[# (e.g., see pnt below)

<1> Yes
<5> No

<8> Don't know; can't say
<9> Refused

===>

>pnt< (Did [fill rpri] use or [fill rvrb] [fill rpri] around anyone while they were using:)

Any paint products (yesterday)?

INTERVIEWER: If R volunteers what kind of paint product was used, make a note.

<1> Yes [goto pnt1]
<5> No

<8> Don't know; can't say
<9> Refused

===>[goto solv]

>pnt1< Were they water based paints or oil based paints?

<1> Oil based paints
<2> Water based paints
<3> Both oil based and water based paints

<8> Don't know; can't say
<9> Refused

===>

>solv< (Did [fill rpri] use or [fill rvrb] [fill rpri] around anyone while they were using:)

Any solvents like paint thinner, cleaning fluids, or kerosene (yesterday)?

<1> Yes
<5> No

<8> Don't know; can't say
<9> Refused

===>

>pest< (Did [fill rpri] use or [fill rvrb] [fill rpri] around anyone while they were using:)

Any pesticides (yesterday) like bug strips or bug sprays?

<1> Yes [goto pst2]
<5> No

<8> Don't know; can't say
<9> Refused

===>[goto soap]

>pst2< When [fill rpro] [fill rvrb] around pesticides yesterday, [fill rvrb] [fill rpro] indoors or outdoors most of that time?

<1> Indoors
<5> Outdoors

<7> (CODE ONLY AFTER PROBE) Both indoors and outdoors equally

<8> Don't know; can't say
<9> Refused

===>

>soap< (Did [fill rpri] use or [fill rvrb] [fill rpri] around anyone while they were using:)

Any soaps or detergents (yesterday) -- including bath soaps?

<1> Yes
<5> No

<8> Don't know; can't say
<9> Refused

===>

>Ocln< (Did [fill rpri] use or [fill rvrb] [fill rpri] around anyone while they were using:)

Any other household cleaning agents such as Ajax, other cleansers, ammonia, or anything like that (yesterday)?

<1> Yes
<5> No

<8> Don't know; can't say
<9> Refused

===>

>aero< Yesterday, [fill rvrb] [fill rpro] in a room where someone was using personal care aerosol spray products such as deodorants or hair spray?

IF RSC SAYS NO, PROBE: Did you use any of them?

<1> Yes
<5> No

<8> Don't know; can't say
<9> Refused

===>

>shwr< Did [fill rpro] take a hot shower yesterday?

<1> Yes
<5> No

<8> Don't know; can't say
<9> Refused

===>

>bath< Did [fill rpri] take a hot bath, use an indoor hot tub, or go swimming in an INDOOR swimming pool yesterday?

<1> Yes
<5> No

<8> Don't know; can't say
<9> Refused

===>

```
*****************************************************************************
                    BRANCH TO CHILD'S 24 HOUR ACTIVITY DIARY
                   (refer to "diary.q" for text of questions)
*****************************************************************************

>clc3<  [if dia2 is <> goto clc5]        ** automatically branch first time **

>diar<  INTERVIEWER:  Do you want to branch to the activity diary?

            <1> Yes, branch to the diary to continue adding     [goto clc5]
                  activities (interview is in progress)

            <3> Yes, branch to the diary, but only for review   [goto clc5]
                  or to check coding (R is not on phone now)

            <5> No, bypass the diary                            [goto tdyc]

         IF NECESSARY, USE  :ca  TO ENTER YOUR CHOICE
       ===>


>clc5<  [store <2> in cp04]
        [store <T "> in cmto]
        [store name in cmtn]
        [store rage in cmta]
        [store <y> in cmtm]
        [if rage is <0>]
            [store rmon in cmta]
            [store <m> in cmtm]
            [endif]
        [store yres in cmtt]
        [store <" > in cmtc]
        [store csid in cmti]
        [store <1> in cmts]
        [call cmt]
        [settime din]
        [call com5]                  ** execute diary instrument (diary.q)
        [settime dout]
        [subtime din from dout into CALC]
        [if diar is <1>][addtime CALC to dcum][endif]
        [if diar is <>][addtime CALC to dcum][endif]
        [store <5> in diar]
```

****

RETURN FROM ACTIVITY DIARY

****

>dia2< INTERVIEWER: Describe the condition of the diary, as YOU left it:

<1> Diary completed; entire 24 hour period accounted for

<3> Diary not completed; some time not accounted for

NOTE: ALWAYS ANSWER THIS ITEM - DO NOT USE THE :sk cb COMMAND HERE.
===>

>dcum< [allow 4] ** diary time accumulator

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****
INTERVIEW CONTINUES HERE AFTER ACTIVITY DIARY
****

>tdyc< [if rage ge <9> goto ystu]

>dycr< INTERVIEWER: Does the time diary contain any unspecified "daycare," "babysitting," or "school" activities? [loc 3/8]

<1> Yes
<5> No [goto tyst]

--->

>dc1< Thinking only about the time [fill name] spent (in daycare/ with the babysitter/at school) yesterday, how much time did [fill rpri] spend eating snacks or meals?

<0> No time spent
<1-180> Number of minutes
<181> More than 3 hours

<998> Don't know; can't say
<999> Refused

Hours = Minutes

1 = 60
2 = 120
3 = 180

[##bla=997][##min=0][##max=181]--->

>dc2< Again, thinking only about the time [fill name] spent (in daycare/with the babysitter/at school) yesterday, how much time did [fill rpri] spend napping or resting (during rest periods)?

<0> No time spent
<1-720> Number of minutes
<721> More than 12 hours

<998> Don't know; can't say
<999> Refused

Hours = Minutes

1= 60	7=420
2=120	8=480
3=180	9=540
4=240	10=600
5=300	11=660
6=360	12=720

[##bla=997][##min=0][##max=721]--->

>dc3< And how much time did [fill rpri] spend watching TV while [fill rpri] was (in daycare/with the babysitter/at school) yesterday?

		Hours = Minutes	
<0>	No time spent	1= 60	7=420
<1-720>	Number of minutes	2=120	8=480
<721>	More than 12 hours	3=180	9=540
		4=240	10=600
<998>	Don't know; can't say	5=300	11=660
<999>	Refused	6=360	12=720

[##bla=997][##min=0][##max=721]===>

>dc4< How much time did [fill rpri] spend doing arts and crafts while [fill rpri] was (in daycare/with the babysitter/ at school) yesterday?

		Hours = Minutes	
<0>	No time spent	1= 60	7=420
<1-720>	Number of minutes	2=120	8=480
<721>	More than 12 hours	3=180	9=540
		4=240	10=600
<998>	Don't know; can't say	5=300	11=660
<999>	Refused	6=360	12=720

[##bla=997][##min=0][##max=721]===>

>dc5< When [fill name] was (in daycare/with the babysitter/at school) yesterday, how much time was [fill rpri] actively playing outdoors?

		Hours = Minutes	
<0>	No time spent	1= 60	7=420
<1-720>	Number of minutes	2=120	8=480
<721>	More than 12 hours	3=180	9=540
		4=240	10=600
<998>	Don't know; can't say	5=300	11=680
<999>	Refused	6=360	12=720

[##bla=997][##min=0][##max=721]===>

>ftrp< Did [fill name] go on any field trips yesterday while [fill rpri] was (in daycare/at school)?

<1> Yes [goto ftp2]
<5> No

<8> Don't know
<9> Refused

===>[goto tyst]

>ftp2< Approximately how long was [fill name] on the field trip?

<1-720> Number of minutes
<721> More than 12 hours

<998> Don't know; can't say
<999> Refused

Hours = Minutes	
1= 60	7=420
2=120	8=480
3=180	9=540
4=240	10=600
5=300	11=660
6=360	12=720

[##bla=0][##min=1][##max=721]===>

>tyst< [if rage le <8> goto pend] ** ask ystu of 9-11 year olds only

>ystu< Now that we're finished with the diary, I have just a couple more questions for you. Are you currently in school?

<1> Yes [goto yedu]
<5> No

<8> Don't know; can't say
<9> Refused

===>[goto pret]

>yedu< What grade are you in?

<0-6> Elementary grades

<7-9> Junior high grades

<98> Don't know; can't say
<99> Refused

[##bla=97][##min=0][##max=9]===>

>pret< Those are all the questions I have for you, but I would like to speak to your [fill whpl] again for a few minutes. Would you ask (him/her) to come to the phone.

<g> [fill whpl] returns to phone, continue

IF [fill whpl] IS NOT AVAILABLE OR SOME OTHER PROBLEM PREVENTS CONTINUATION OF INTERVIEW, USE ":sk cb" TO EXIT.

===>[goto pend]

****

CONCLUDE INTERVIEW WITH THE ADULT

****

```
>pend<  Now I have just a few more questions for you, to be sure we talk to
        people from all walks of life.

        TYPE <g> TO PROCEED


        ===>

>tys8<  [if rage ge <9> goto ethn]        ** ask adult ystu for 0-8 yr olds
        [if rage le <3> goto ethn]        ** don't ask children under 4 years

>yst2<  CODE OR ASK AS NECESSARY:

        Is [fill name] currently in school?

        IF NEEDED DURING SUMMER: Was [fill name] in school during
                                 this past school year?


            <1> Yes  [goto yed2]
            <5> No

            <8> Don't know; can't say
            <9> Refused

        ===>[goto ethn]


>yed2<  What grade is [fill name] in?

        IF NEEDED DURING SUMMER: What grade was [fill name] in during
                                 this past school year?


            <0-9> Elementary grades

             <98> Don't know; can't say
             <99> Refused

         [##bla=97][##min=0][##max=9]===>
```

>ethn< Which of the following terms best describes [fill name]'s ethnic background? Is (he/she)...

[allow 2]

<1> White or Caucasian,
<2> Black,
<3> Hispanic or Mexican American,
<4> Asian, or
<5> something else? (SPECIFY) [specify]

<98> Don't know; can't say
<99> Refused

===>

>wght< How much does [fill name] weigh? (What would be your best guess?)

<1-350> pounds

<998> Don't know; can't say
<999> Refused

===>

>arel< ASK IF NOT CLEAR: How are you related to [fill name]?

[allow 2]

<1> Father
<2> Mother
<3> Step-father
<4> Step-mother
<5> Grandfather
<6> Grandmother
<11> Uncle
<12> Aunt
<13> Brother
<14> Sister

<7> Other relative (SPECIFY) [specify]
<8> Other non-relative (SPECIFY) [specify]

<98> Don't know
<99> Refused

===>

>mrtl< CODE OR ASK AS NECESSARY:

Are you now married, living with someone in a marriage-like relationship, widowed, divorced, separated, or have you never been married?

<1> Married and living with spouse (or spouse in military)
<2> Living in a marriage-like relationship
<3> Widowed
<4> Separated
<5> Divorced
<6> Never married

<8> Don't know
<9> Refused

===>

>wkjb< Are you currently working, unemployed and looking for work, on layoff from a job, retired, going to school, keeping house, or something else?

[allow 2]

<1> Working [goto wkj2]
<2> Looking for work
<3> On layoff from work
<4> Retired
<5> Going to school
<6> Keeping house
<7> Something else (SPECIFY) [specify]

<98> Don't know; can't say
<99> Refused

===>[goto aedu]

>wkj2< Are you working full time or part time?

<1> Full time (30 or more hours per week)
<2> Part time (fewer than 30 hours per week)

<8> Don't know; can't say
<9> Refused

===>

>aedu< What is the highest grade of school or year of college you COMPLETED?

<0> No school

ELEMENTARY SCHOOL
<1> 1st grade
<2> 2nd grade
<3> 3rd grade
<4> 4th grade
<5> 5th grade
<6> 6th grade
<7> 7th grade
<8> 8th grade

HIGH SCHOOL
<9> 9th grade (freshman)
<10> 10th grade (sophomore)
<11> 11th grade (junior)
<12> 12th grade (senior)

COLLEGE (for credit only)
<13> 1 year (freshman)
<14> 2 years (sophomore)
<15> 3 years (junior)
<16> 4 years (senior)
<17> 5 or more years

<98> Don't know
<99> Refused

[##bla=97][##min=0][##max=17]===>

>asex< INTERVIEWER, CODE OR ASK AS NECESSARY: Sex of ADULT respondent

<1> male
<2> female

===>

>tmr1< [if mrtl le <2> goto swk1] ** ask swk1 if married/marriage-like
[goto zip]

>swk1< Is your (husband/wife/partner) currently working, unemployed and looking for work, on layoff from a job, retired, going to school, keeping house, or something else?
[allow 2]

<1> Working [goto swk2]
<2> Looking for work
<3> On layoff from work
<4> Retired
<5> Going to school
<6> Keeping house

<7> Something else (SPECIFY) [specify]

<98> Don't know; can't say
<99> Refused

===>[goto saed]

Date printed: 4/10/89

>swk2< Is (he/she) working full time or part time?

<1> Full time (30 or more hours per week)
<2> Part time (fewer than 30 hours per week)

<8> Don't know; can't say
<9> Refused

===>

>saed< What is the highest grade of school or year of college your (husband/wife/partner) COMPLETED?

<0> No school

ELEMENTARY SCHOOL
<1> 1st grade
<2> 2nd grade
<3> 3rd grade
<4> 4th grade
<5> 5th grade
<6> 6th grade
<7> 7th grade
<8> 8th grade

HIGH SCHOOL
<9> 9th grade (freshman)
<10> 10th grade (sophomore)
<11> 11th grade (junior)
<12> 12th grade (senior)

COLLEGE (for credit only)
<13> 1 year (freshman)
<14> 2 years (sophomore)
<15> 3 years (junior)
<16> 4 years (senior)
<17> 5 or more years

<98> Don't know
<99> Refused

[##bla=97][##min=0][##max=17]===>

>zip< What is the postal ZIP code for your home address?

<90000-99999> Adult's home ZIP code

<7> Other (SPECIFY) [specify]

<8> Don't know; can't say
<9> Refused

[##md1=9][##md2=8][##min=90000][##max=99999]===>

Date printed: 4/10/89

>cnty< What county do you live in? (ASK R TO SPELL IF UNCLEAR)

<1> Alameda
<2> Alpine
<3> Amador
<4> Butte
<5> Calaveras
<6> Colusa
<7> Contra Costa
<8> Del Norte
<9> El Dorado
<10> Fresno
<11> Glenn
<12> Humboldt
<13> Imperial
<14> Inyo
<15> Kern
<16> Kings
<17> Lake
<18> Lassen
<19> Los Angeles
<20> Madera
<21> Marin
<22> Mariposa
<23> Mendocino
<24> Merced
<25> Modoc
<26> Mono
<27> Monterey
<28> Napa
<29> Nevada
<30> Orange
<31> Placer
<32> Plumas
<33> Riverside
<34> Sacramento
<35> San Benito
<36> SanBernardino
<37> San Diego
<38> SanFrancisco
<39> San Joaquin
<40> SanLuisObispo
<41> San Mateo
<42> SantaBarbara
<43> Santa Clara
<44> Santa Cruz
<45> Shasta
<46> Sierra
<47> Siskiyou
<48> Solano
<49> Sonoma
<50> Stanislaus
<51> Sutter
<52> Tehama
<53> Trinity
<54> Tulare
<55> Tuolomne
<56> Ventura
<57> Yolo
<58> Yuba

<98> Don't know; can't say
<99> Refused

===>

>area< Would you say the area you live in is rural, suburban, or a city?

IF R SAYS "small town", PROBE: Is it within 25 miles of a city?
(WITHIN 25 MILES, CODE AS SUBURBAN; FARTHER AWAY CODE AS RURAL)

<1> rural
<3> suburban
<5> a city

<8> Don't know; can't say
<9> Refused

===>

>bg15< How many telephones, counting extensions, do you have in your home?

<1> One [goto SY15]
<5> Two or more [goto bg16]

<8> Don't know, not sure
<9> Refused

===>

>tb15< [if bg15 is <8>][store <98> in bg17][endif]
[if bg15 is <9>][store <99> in bg17][endif]
[goto EOY]

>bg16< Do (both/all) the telephones have the same number? [indirect]

<1> Yes [goto SY15]
<5> No [goto bg17]

<8> Don't know, not sure
<9> Refused

===>

>tb16< [if bg16 is <8>][store <98> in bg17][endif]
[if bg16 is <9>][store <99> in bg17][endif]
[goto EOY]

>bg17< How many different numbers are there? [indirect] [no erase]

<2-25> ENTER NUMBER

<98> Don't know, not sure
<99> Refused

===> [goto EOY]

>SY15< [store <1> in bg17]

>EOY< [allow 1][end]

>i30< Think of the income BEFORE TAXES of ALL MEMBERS of your household living with you in 1988, and include income from all sources including wages, pensions, dividends, interest, and all other income.

Was the total income from all sources, (including your own,) under or over $30,000?

(IF UNCERTAIN: What would be your best guess?)

<1> Under $30,000 [goto i10]
<3> Exactly $30,000
<5> Over $30,000 [goto i50]

<8> Don't know; can't say
<9> Refused

===>[goto tin1]

>i50< Was it under or over $50,000?

(IF UNCERTAIN: What would be your best guess?)

<1> Under $50,000 [goto i40]
<3> Exactly $50,000
<5> Over $50,000 [goto i70]

<8> Don't know; can't say
<9> Refused

===>[goto tin1]

>i70< Was it under or over $70,000?

(IF UNCERTAIN: What would be your best guess?)

<1> Under $70,000 [goto i60]
<3> Exactly $70,000
<5> Over $70,000

<8> Don't know; can't say
<9> Refused

===>[goto tin1]

>i40< Was it under or over $40,000?

(IF UNCERTAIN: What would be your best guess?)

<1> Under $40,000
<3> Exactly $40,000
<5> Over $40,000

<8> Don't know; can't say
<9> Refused

===>[goto tin1]

>i60< Was it under or over $60,000?

(IF UNCERTAIN: What would be your best guess?)

<1> Under $60,000
<3> Exactly $60,000
<5> Over $60,000

<8> Don't know; can't say
<9> Refused

===>[goto tin1]

```
>i10<   Was it under or over $10,000?

        (IF UNCERTAIN: What would be your best guess?)

                <1> Under $10,000
                <3> Exactly $10,000
                <5> Over $10,000            [goto i20]

                <8> Don't know; can't say
                <9> Refused

        ===>[goto tin1]


>i20<   Was it under or over $20,000?

        (IF UNCERTAIN: What would be your best guess?)

                <1> Under $20,000
                <3> Exactly $20,000
                <5> Over $20,000

                <8> Don't know; can't say
                <9> Refused

        ===>[goto tin1]


>ISUM<  [allow 2]

>tin1<  [if i30 is <8>][store <88> in ISUM][goto stm4][endif][#Don't know
        [if i30 is <9>][store <99> in ISUM][goto stm4][endif][#Refused
        [if i10 is <8>][store <81> in ISUM][goto stm4][endif][#DK - lt 20K
        [if i10 is <9>][store <91> in ISUM][goto stm4][endif][#RF - lt 20K
        [if i20 is <8>][store <82> in ISUM][goto stm4][endif][#DK - lt 30K
        [if i20 is <9>][store <92> in ISUM][goto stm4][endif][#RF - lt 30K
        [if i40 is <8>][store <83> in ISUM][goto stm4][endif][#DK - 10-30K
        [if i40 is <9>][store <93> in ISUM][goto stm4][endif][#RF - 10-30K
        [if i50 is <8>][store <84> in ISUM][goto stm4][endif][#DK - gt 30K
        [if i50 is <9>][store <94> in ISUM][goto stm4][endif][#RF - gt 30K
        [if i60 is <8>][store <85> in ISUM][goto stm4][endif][#DK - 50-70K
        [if i60 is <9>][store <95> in ISUM][goto stm4][endif][#RF - 50-70K
        [if i70 is <8>][store <86> in ISUM][goto stm4][endif][#DK - gt 50K
        [if i70 is <9>][store <96> in ISUM][goto stm4][endif][#RF - gt 50K
```

```
>tin2<  [if i10 is <1>][store <01> in ISUM][goto stm4][endif][#Under   10K
        [if i10 is <3>][store <02> in ISUM][goto stm4][endif][#Exactly 10K
        [if i20 is <1>][store <03> in ISUM][goto stm4][endif][#gt10-lt 20K
        [if i20 is <3>][store <04> in ISUM][goto stm4][endif][#Exactly 20K
        [if i20 is <5>][store <05> in ISUM][goto stm4][endif][#gt20-lt 30K
        [if i30 is <3>][store <06> in ISUM][goto stm4][endif][#Exactly 30K
        [if i40 is <1>][store <07> in ISUM][goto stm4][endif][#gt30-lt 40K
        [if i40 is <3>][store <08> in ISUM][goto stm4][endif][#Exactly 40K
        [if i40 is <5>][store <09> in ISUM][goto stm4][endif][#gt40-lt 50K
        [if i50 is <3>][store <10> in ISUM][goto stm4][endif][#Exactly 50K
        [if i60 is <1>][store <11> in ISUM][goto stm4][endif][#gt50-lt 60K
        [if i60 is <3>][store <12> in ISUM][goto stm4][endif][#Exactly 60K
        [if i60 is <5>][store <13> in ISUM][goto stm4][endif][#gt60-lt 70K
        [if i70 is <3>][store <14> in ISUM][goto stm4][endif][#Exactly 70K
        [if i70 is <5>][store <15> in ISUM][goto stm4][endif][#Over    70K


>stm4<  [goto din]

>din<   [allow 4][equiv rpri position 4] ** diary timer
>dout<  [allow 4]                        ** diary timer

>cmt<   [allow 26]            [##T]
>cmto<  [allow 3][equiv cmt]
>cmtn<  [allow 12]
>cmta<  [allow 2]
>cmtm<  [allow 1]
>cmtt<  [allow 1]
>cmtc<  [allow 2]
>cmti<  [allow 4]
>cmts<  [allow 1]


>yzzx<  [goto chck]
```

>int1< ATTENTION INTERVIEWER: [indirect]

There are currently [fill used] activities recorded in this diary.
The reference date for those activities is [fill ddmo]/[fill ddda]/[fill ddyr
The entire 24-hour period has[fill DSTS] been accounted for.

Why have you accessed the activity diary?
[loc 0/116]

<1> To continue adding activities for the date shown
<2> To review and possibly edit the activity list
<3> To perform post-interview activity/location data coding

<7> To delete all existing diary data and re-ask all diary questions
WARNING: A supervisor must be consulted BEFORE this option is selected. The diary reference date will be re-set, if necessary, to yesterday's date.

<9> MISTAKE! Don't really want to access the diary - take me out.

===>

>tin1< [if int1 is <1> goto next]
[if int1 is <2> goto next]
[if int1 is <3> goto code]
[if int1 is <7> goto int2]
[if int1 is <9> goto EX1]

>int2< WARNING!!! YOU MUST HAVE SUPERVISOR APPROVAL BEFORE PROCEEDING!
[indirect]

ALL EXISTING DIARY DATA WILL BE DESTROYED AND THE DIARY REFERENCE DATE WILL BE RE-SET TO YESTERDAY'S DATE. YOU'LL THEN BE TAKEN TO THE BEGINNING OF THE DIARY QUESTION SEQUENCE.

ARE YOU SURE YOU WANT TO CONTINUE?

<1> Yes -- proceed with diary erase and re-set

<5> No -- do not continue

<d> Simply display the existing list of activities (nothing will be changed or deleted)

===>

```
>tin2<  [if int2 is <1> goto rasa]
        [if int2 is <5>]
            [store <> in int1]
            [store <> in int2]
            [goto int1]
            [endif]
        [if int2 is <d>]
            [store <> in int2]
            [goto int3]
            [endif]


>int3<  [display t single][allow 1]TYPE <g> TO CONTINUE   ===>

>tin3<  [store <> in int3]
        [goto int2]


>rasa<  WHY IS THIS DIARY BEING ERASED?                          [indirect]

        Include your name and the name of the supervisor who approved this
        action.  End your comment by typing 3 slashes, ///.
                                                                 [allow 1]


TEXT    ===>[specify]


>rasb<  [if int2 isnt <1> goto int1]
>rasc<  [roster begin actv]
>rasd<  [store <> in mov1]
        [store <> in mov2]
        [store <> in ddat]
>rase<  [roster end]
>rasf<  [store <0> in used]
        [store otot in free]
        [store <> in int2]
        [goto setd]
```

```
>setd<   [setdate date]                          ** preserve current date
         [store date in DDAT]                    ** DDAT to be adjusted
         [if tdda isnt <1>]
             [subtract <1> from ddda]            ** adjustment is simple when
             [goto intr]                         ** today isnt 1st of month
             [endif]
         [if tdmo is <1>]                        ** New Year's Day is special
             [store <12> in ddmo]
             [store <31> in ddda]
             [subtract <1> from ddyr]            ** roll back the year, too
             [goto intr]
             [endif]
         [subtract <1> from ddmo]                        ** set the month
         [store <31> in ddda]                            ** default end of month
         [if ddmo is <2>][store <28> in ddda][endif]     ** adjust the exceptions
         [if ddmo is <4>][store <30> in ddda][endif]
         [if ddmo is <6>][store <30> in ddda][endif]
         [if ddmo is <9>][store <30> in ddda][endif]
         [if ddmo is <11>][store <30> in ddda][endif]
         [goto intr]


>intr<   Now, we're going to start with midnight, night before last, and go
         through the 24 hours ending at midnight last night.  For each
         thing [fill name] did during that period, I'll ask you to tell me
         what [fill name] [fill vcon] doing, where [fill name] [fill vcon],
         and what time [fill name] finished and turned to something else.

         Please tell me about everything [fill name] did yesterday in the same
         order that it happened -- there shouldn't be any gaps in time between
         activities.


         TYPE <g> TO BEGIN THE ACTIVITY QUESTIONS

         ===>[goto sint]


>sint<   [store <a> in next][goto tcon]


>DO1<    What [fill vcon] [fill name] doing at midnight, night before last?
         (12:01 A.M. on [fill ddmo]/[fill ddda]/[fill ddyr])
                                                    [allow 1][loc 0/143]
             <1> School or childcare related activity          [goto do2b]
             <2> Travel, going from one place to another
             <3> Eating meals or snacks
             <4> Sleeping or napping
             <5> Watching TV
             <6> Bathing, showering, "going to the bathroom"
             <7> Getting dressed, personal grooming

             <x> Some other activity, not codeable above       [goto do3]

          ===>[goto tdo2]
```

```
>do2<   What did [fill name] do next?  (On [fill ddmo]/[fill ddda]/[fill ddyr])
                                                          [allow 1][equiv DO1]

          <1> School or childcare related activity          [goto do2b]
          <2> Travel, going from one place to another
          <3> Eating meals or snacks
          <4> Sleeping or napping
          <5> Watching TV
          <6> Bathing, showering, "going to the bathroom"
          <7> Getting dressed, personal grooming

          <x> Some other activity, not codeable above       [goto do3]

        ===>[goto tdo2]

>do2b<  ENTER THE SPECIFIC SCHOOL/CHILDCARE RELATED ACTIVITY
                                                     [allow 1][loc 0/144]

          <1> Attending a regular school class/activity
          <2> Recess/break between school classes
          <3> "Hanging out" (before or after school only)
          <4> Doing school homework
          <5> Eating lunch/snacks (school or childcare)
          <6> Childcare (specific activity unknown)

          <x> Some other activity, not codeable above        [goto do3]

        ===>[goto tdo2]
```

```
>tdo2<
        [if DO1 is <1>]
            [if do2b is <1>]
                [store <attending that class/school activity> in do3]
                [endif]
            [if do2b is <2>]
                [store <taking a break/having recess> in do3]
                [endif]
            [if do2b is <3>]
                [store <'hanging out' (before or after school)> in do3]
                [endif]
            [if do2b is <4>]
                [store <doing that homework> in do3]
                [endif]
            [if do2b is <5>]
                [store <eating that meal/snack> in do3]
                [endif]
            [if do2b is <6>]
                [store <doing that childcare activity> in do3]
                [endif]
            [endif]
        [if DO1 is <2>]
            [store <traveling/going from (PLACE) to (PLACE)> in do3]
            [endif]
        [if DO1 is <6>]
            [store <bathing/showering/going to the bathroom> in do3]
            [endif]
        [if DO1 is <7>]
            [store <getting dressed/grooming self> in do3]
            [endif]
        [if DO1 is <3>]
            [store <eating that meal/snack> in do3]
            [endif]
        [if DO1 is <5>]
            [store <watching TV> in do3]
            [endif]
        [if DO1 is <4>]
            [store <sleeping/napping> in do3]
            [endif]
        [goto twhr]


>do3<   INTERVIEWER: TYPE A BRIEF DESCRIPTION OF THE ACTIVITY
                                                [allow 44][loc 0/146]

            (must use 44 characters or less)

TEXT    ===>
```

```
>twhr<  [if DO1 is <2>]                    ** automatic branch for travellers
            [store <5> in whr1]
            [goto whr8]
            [endif]


>whr1<  ASK IF NECESSARY:

        Where [fill vcon] [fill name] when (he/she/you) [fill vcon]
        "[fill do3]",
        (at home, at school, in a store, going to or from somewhere, or what)?
                                                                    [loc 0/135]

            <1> Home                                                [goto whr3]
            <2> School/Childcare location                           [goto whr2]
            <3> Friend/Other's house                                [goto whr5]

            <4> Stores, places related to                           [goto whr4]
                  shopping, eating, errands

            <5> Traveling, going from one place to another          [goto whr8]

            <7> Other location not codeable above                   [goto whr6]

        ===>


>whr2<  IF NECESSARY: Where [fill vcon] [fill name] when (he/she/you) [fill vcon]
        "[fill do3]"?
                                                        [allow 3][loc 0/136]
            <251> At school

            <253> Childcare at a HOUSE (e.g., babysitter's house)
            <255> Childcare at a COMMERCIAL BLDG. (not at a home or school)

            <259> Other school/childcare location, not codeable above [goto whr9]

            <998> Don't know; can't say
            <999> Refused

        ===>[goto io]
```

```
>whr3<  ASK IF NECESSARY:

        Where in the house [fill vcon] [fill name] when (he/she/you) [fill vcon]
        "[fill do3]"?
                                                          [allow 3] [equiv whr2]
           <1> Kitchen                          <7> Garage
           <2> Living rm, family rm, den        <8> Basement
           <3> Dining room                      <9> Utility/laundry room
           <4> Bathroom                        <10> Pool, spa OUTDOORS
           <5> Bedroom                         <11> Yard, patio, other
           <6> Study/office                           OUTSIDE house

          <12> Moving from room to room in the house
          <13> Other house location, not codeable above          [goto whr9]

          <998> Don't know    <999> Refused


        ===> [goto io]


>whr4<  IF NECESSARY: Where [fill vcon] [fill name] when (he/she/you) [fill vcon]
        "[fill do3]"?
                                                          [allow 3][equiv whr2]
             <23> Grocery store (incl supermarkets, convenience stores)
             <24> Shopping mall, other non-grocery store
             <21> Office building (e.g., bank, post office)

             <28> Restaurant
             <29> Bar, nightclub

             <36> Dry cleaners
             <37> Beauty parlor, barber shop, hairdresser
             <33> Auto repair shop, gas station, indoor parking area

             <39> Other location, not codeable above [goto whr9]
           [# (40) Other OUTDOOR location, not codeable above (goto whr9)

            <998> Don't know; can't say
            <999> Refused

        ===>[goto io]
```

```
>whr5<  ASK IF NECESSARY:

        Where in the house [fill vcon] [fill name] when (he/she/you) [fill vcon]
        "[fill do3]"?
                                                        [allow 3] [equiv whr2]
         <301> Kitchen                        <307> Garage
         <302> Living rm, family rm, den      <308> Basement
         <303> Dining room                    <309> Utility/laundry room
         <304> Bathroom                       <310> Pool, spa OUTDOORS
         <305> Bedroom                        <311> Yard, patio, other
         <306> Study/office                         OUTSIDE house

         <312> Moving from room to room in the house
         <313> Other house location, not codeable above [goto whr9]

         <998> Don't know    <999> Refused


        ===> [goto io]


>whr6<  IF NECESSARY: Where [fill vcon] [fill name] when (he/she/you) [fill vcon]
        "[fill do3]"?
                                                        [allow 3][equiv whr2]
             <34> Park, playground
             <27> Hospital, doctor's office, health care facility
             <31> Indoor gym, sports/health club
             <35> Hotel or motel
             <22> Industrial plant, factory

             <21> Office building (e.g., bank, post office)
             <26> Public building (e.g., museum, library, theater)

             <30> Church, Synagogue, Temple, Mosque

             <39> Other place, not codeable above                    [goto whr9]
          [# (40) Other OUTDOOR location, not codeable above         (goto whr9)
            <998> Don't know; can't say
            <999> Refused

        ===>[goto io]
```

```
>whr8<  IF NECESSARY: How [fill vcon] [fill name] travelling?

        ([fill vcon] [fill name] in a car, on a bus, in a truck, walking,
        on a bike, or travelling in some other way?)
                                                        [allow 3][equiv whr2]

            <51> Car
            <52> Pick-up truck or van
            <57> Other kind of truck
            <55> On a bus
            <54> At bus/train/ride STOP
            <53> Walking
            <59> Bicycle/skateboard/rollerskates
            <63> In a stroller or carried by adult
            <56> On train/rapid transit
            <58> Airplane
            <60> Motorcycle/motorized scooter

            <69> Other travel/transit, not codeable above        [goto trv2]
           <998> Don't Know          <999> Refused

        ===>[goto io]


>trv2<  INTERVIEWER: TYPE A BRIEF DESCRIPTION OF HOW R WAS TRAVELLING
                                                [no erase][allow 25][loc 0/204]


           (use 25 characters or less)
           ________________________
TEXT    ===>


>trv3<  [goto io]

>whr9<  INTERVIEWER: TYPE A BRIEF DESCRIPTION OF WHERE ACTIVITY TOOK PLACE
                                                [no erase][allow 25][equiv trv2]


            (use 25 characters or less)
            ________________________
TEXT    ===>


>twh9<  [goto io]
```

>io< CODE OR ASK IF NOT SURE: [fill vcon] [fill name] (mostly) inside or (mostly) outside (when [fill vcon] [fill name] "[fill do3]")?

[allow 1][loc 0/145]

<1> Inside (or mostly inside)
<3> Outside (or mostly outside)
<5> Equal time inside and outside

<8> Don't know, no idea
<9> Refused

--->

```
>gosb<  [if do2 is <> goto QBRa]
        [if stop is <> goto QBRa]
        [if mode is <i>]
            [if mod2 is <n> goto RINa]
            [goto RIUa]
            [endif]
        [if mode is <a>]
            [if mod2 is <n> goto RANa]
            [goto RAUa]
            [endif]
        [if mode is <r> goto RRWa]
        [goto QBRa]
```

```
>next<                          MODE MENU

        INTERVIEWER: To continue the activity question cycle, use code a or
        code i.  To make adjustments, use code d or code r.  Use code c to
        stop the activity question cycle.
                                                        [allow 1][loc 0/237]

            <a> ADD an activity to end of list
            <i> INSERT an activity between other activities

            <d> DELETE an activity completely
            <r> REVISE an activity, (description, location, finish time, etc.)

            <c> CLOSE the activity list and return to main interview

            <s> SHOW the current list of activities

        ===>
```

```
>gosb<  [if do2 is <> goto QBRa]
        [if stop is <> goto QBRa]
        [if mode is <i>]
            [if mod2 is <n> goto RINa]
            [goto RIUa]
            [endif]
        [if mode is <a>]
            [if mod2 is <n> goto RANa]
            [goto RAUa]
            [endif]
        [if mode is <r> goto RRWa]
        [goto QBRa]
```

>next<

MODE MENU

INTERVIEWER: To continue the activity question cycle, use code a or code i. To make adjustments, use code d or code r. Use code c to stop the activity question cycle.

[allow 1][loc 0/237]

<a> ADD an activity to end of list
<i> INSERT an activity between other activities

<d> DELETE an activity completely
<r> REVISE an activity, (description, location, finish time, etc.)

<c> CLOSE the activity list and return to main interview

<s> SHOW the current list of activities

===>

APPENDIX C

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APPENDIX C

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APPENDIX D

SAMPLING REPORT FOR THE CALIFORNIA CHILDREN'S ACTIVITY SURVEY

SAMPLING METHODS AND FIELD RESULTS

FOR THE

1989-90 ACTIVITY PATTERN SURVEY OF CALIFORNIA CHILDREN

by

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and
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Introduction

The 1989-90 Activity Pattern Survey of California Children was designed to measure the time spent in activities and locations of California children, aged 11 or younger, on a typical day, and to assess their potential exposure to sources of air pollution in the home and at school. A major part of the study was the generation of a time diary of a day's activities for each sampled child. This information on activities was obtained either from a parent, or from the child, or from both, depending on the age of the child.

The survey was funded by the Air Resources Board of the State of California. The Survey Research Center of the University of California, Berkeley, contracted to design a telephone sample of households of the State of California, assist in questionnaire construction, conduct the interviewing, and prepare the data for analysis. This report summarizes the sampling methods used for this study. The general design of the sample is given first. Then various aspects of the design are described in more detail.

1. General Design of the Sample

The sample is a clustered random-digit telephone sample of all households in California. The sample was generated using procedures described by J. Waksberg ("Sampling Methods for Random Digit Dialing," Journal of the American Statistical Association, vol. 73, March 1978, pp. 40-46). Households with no telephone, of course, are excluded. Households with no English-speaking adults (about 3 percent of our sample) were also excluded by design, in order to avoid the cost of translating the questionnaire and hiring bilingual or multi-lingual interviewers.

Prior to selection, all of the telephone exchanges in the state were grouped into three strata: Los Angeles and the Southern Coast, the San Francisco Bay Area, and the rest of the state. When clusters of telephone numbers were selected for the study, the sampling fraction was doubled for the Bay Area, in comparison with Los Angeles and the Southern Coast; the sampling fraction was doubled again for the rest of the state. This oversampling was carried out in order to spread the selected households more widely over a variety of climatic zones.

Within each selected household, an enumeration of children aged 11 or younger residing in the household was carried out. If more than one child aged 11 or younger resided in the household, one of them was selected at random to be the focus of the interview. If a child in that age range resided there, the appropriate parent or guardian was administered a short interview and asked about the child's activities; the child was also interviewed if he or she was at least 9 years old.

2. Stratification

A goal of this study was to obtain information from households in a wide variety of climatic zones. Since most of the California population is clustered in a few metropolitan areas, an unrestricted sample would result in the completion of very few interviews in other more sparsely populated, but climatically diverse, areas of the state. A stratification of all the telephone exchanges in the state was carried out, therefore, in order to provide a means of oversampling the non-metropolitan areas and of distributing the sample over as many climatic zones as possible. There are two aspects of this stratification: the creation of three explicit major strata, and an implicit geographic stratification within each of the major strata. We now review each of these aspects in turn.

2.1 Creation of Three Major Strata

A list of all the central office telephone codes (prefixes) in California was taken from the February 1989 American Telephone and Telegraph V & H Coordinate Tape (produced monthly by AT&T). The record for each prefix includes the area code, the prefix (first three digits of a phone number), the name of the city or billing location, and two geographic coordinates (north-south and east-west). After deletion of prefixes for directory assistance and time, and of a few other prefixes known to be non-residential, the remaining prefixes were divided into three groups or strata.

1. The first stratum was the Southern Coast area, comprising the Los Angeles air basin and part of San Diego County. Information on the boundaries of the Los Angeles air basin was obtained from the South Coast Air Quality Management District. That information was then compared with the city names on the prefix records (after sorting them on geographic coordinates) in order to decide into which stratum to

place each telephone prefix. It turned out that the prefixes in the 818, 213, and 714 area codes cover that area almost exactly. As for San Diego County, prefixes in the southern part of the 619 area code were sorted from east to west; then place names were compared with a map; and the western portion was placed into the Southern Coast stratum.

2. The second stratum was the San Francisco Bay Area. Boundary information for that air basin was obtained from the Bay Area Air Quality Management District. The five-county center of that area coincides with the 415 area code. However, the air basin also includes Napa County, the southern portions of Sonoma and Solano counties, and the northern portion of Santa Clara County (principally San Jose). Prefixes in the 707 and 408 area codes were therefore sorted from north to south; then place names were compared with a map; and the appropriate prefixes were placed into the Bay Area stratum.

3. The third major stratum consisted of all the California prefixes left over, after creating the first two strata. Because of the heterogeneity of this third stratum, we found it desirable to carry out some further stratification, as described next.

2.2 Further Implicit Stratification

Prior to the selection of primary clusters, prefixes within each area code (or within each part of an area code, if it had been divided between major strata) were sorted geographically, using the north-south and the east-west coordinates on the AT&T tape. The direction of the sort for each area code is shown in Table 1. For example, all of the prefixes in area code 818 fall within the Southern Coast major stratum, and they were sorted from north to south (n-s).

Table 1

STRATA FOR AIR RESOURCES BOARD TELEPHONE SAMPLE

(Treatment of 10 California Area Codes)

Area code	Portion	Sort	Location
1. Southern Coast			
(818)	all	n-s	Los Angeles Co.
(213)	all	n-s	Los Angeles Co.
(714)	all	w-e	Orange, Riverside, part of S. Bern. counties
(619)	SW part	e-w	San Diego County
2. San Francisco Bay Area			
(707)	S part	n-s	Napa Co., S. parts of Sonoma and Solano
(415)	all	n-s	S.F., Alameda, Contra Costa, S. Mateo, Marin
(408)	N part	n-s	Santa Clara Co.
3. Rest of State			
(707)	N part	s-n	North coast
(916)	all	n-s	Northern valley and mountains
(619)	N & SE	n-s	Desert
(209)	all	n-s	Central valley
(805)	all	e-w	Central valley and coast
(408)	S part	s-n	Central coast

Note: Prior to systematic random selection of primary clusters, prefixes within each (part of an) area code were sorted geographically in the direction indicated; the sorted area code lists were then put together in the order shown into one list for each major stratum.

The purpose of this sorting was to distribute the sample proportionately over the various regions within each major stratum. The third stratum in particular (the "rest of the state") includes several regions of distinct interest. This sorting procedure ensured that each of the regions was included in the sample in proportion to its number of telephone prefixes.

After the prefixes were sorted within area code, all of the prefix lists within a major stratum were put together into one list, in the order given in Table 1. The lists for each major stratum were then ready for the selection of primary clusters.

3. Selection of Primary Clusters

Our goal for the first stage of sampling was to identify approximately 250 clusters of residential telephone numbers throughout the state. Most random telephone numbers are either non-working, business, or government numbers. In order to identify 250 residential numbers, we estimated (based on past experience) that we should start with about 940 numbers. Since it is preferable to subsample an equal number of units within each cluster, the oversampling of certain parts of the state was done at this stage of primary cluster selection.

Within each of the three major strata we selected a certain proportion of possible telephone numbers by systematic random sampling -- that is, by setting a selection interval, taking a random start, and then selecting every *n*th number. The systematic nature of the procedure ensured that the implicit geographic stratification of the prefixes would be preserved.

The proportion of telephone numbers selected from each major stratum is shown in Table 2. In the Southern Coast stratum, for example, we selected 200 out of 1668 prefixes (each of which has 10,000 possible telephone numbers), or .12 of the prefixes. The proportion selected was doubled for the San Francisco Bay Area, and doubled again for the rest of the state. This disproportionate sampling was carried out in order to spread the sample over a wide variety of climatic zones. Without such disproportionate selection, the sample would have been clustered primarily in a few large urban areas. Note that a weight inversely proportional to the rate of oversampling must be used in the data analysis if statewide estimates of statistics are made.

After the primary telephone numbers were selected, each was called and administered a short screening interview to determine if the number was a residence. If it

Table 2

SELECTION OF PRIMARY CLUSTERS

	No. Prefixes	Selections	Fraction
Major Stratum			
Southern Coast	1668	200	0.120
S.F. Bay Area	819	197	0.241
Rest of State	1133	544	0.480
	3620	941	

was not, that cluster was dropped from the sample. If, on the other hand, the number was a residence, additional telephone numbers within that cluster were generated for the main study. Of the 941 original telephone numbers, 279 were determined to be residences and formed the clusters for our sample.

4. Selection of Telephone Numbers

The telephone numbers within each cluster were generated by varying at random the last two digits of the primary number. For example, if the primary number for a cluster was (415) 642-6578, additional telephone numbers within the cluster were generated by replacing the "78" with one of the 99 other two-digit possibilities.

Under the clustered sampling procedure, a set of telephone numbers is prepared for interviewing from each cluster. If a telephone number turns out to be non-residential, it is replaced. The total number of residences in each cluster, consequently, remains fixed. The probability of selecting a household is constant across clusters (within major strata), provided that the same number of residential telephone numbers has been set up for interviewing in each cluster. For this study, we assigned 23.5 residential numbers to each cluster (a random half had 23, and the other half had 24). A few clusters, however, exhausted the pool of 100 available numbers and therefore had fewer residences for interviewing; an adjustment for this variation could be made, but its effect would not be substantial. Note that although an original cluster size of 23.5 may appear large, most households do not include a child aged 11 or younger. In terms of completed interviews, the average cluster size was only about 4.4.

5. Creation of Weights for Each Case

Weights were computed to adjust for unequal probabilities of selection and also to balance results by season and day of the week. We will describe each of these two types of weights.

5.1 Adjustment for Selection Probabilities

Households in the three major strata were selected into the sample at different rates, as described above in Section 3. Analyses which pool data from different strata, consequently, should use a weight to adjust for those different selection probabilities. Otherwise the resulting statistics will disproportionately reflect persons residing in the oversampled rural areas and the San Francisco Bay Area.

Another factor affecting the probabilities of selection is the number of eligible children (aged 11 or younger) in each selected household. Since only one eligible child was selected to be the focus of the interview in each household, children residing in households with fewer children of that age were more likely to be selected than children in households with more children of the target age.

One other factor that should be taken into account is the number of distinct telephone numbers that ring in each household. A person who can be reached on two telephone numbers has twice the chance of being selected as a person with only one number. The former should therefore receive half the weight of the latter in computing statistics.

All three of these factors were taken into account in computing a weight to adjust for unequal probabilities of selection. The distribution of these factors is shown in Table 3. The relative weight assigned to cases at each level of the factors is also

Table 3

DISTRIBUTION OF COMPONENTS OF SAMPLING WEIGHT

Number of Eligible Children	Relative Weight	Cases
1	1	580
2	2	444
3	3	137
4	4	30
5	5	5
6	6	3
7	7	1
		1200

Region of State		
Southern Coast	1	224
S.F. Bay Area	1/2	263
Rest of State	1/4	713
		1200

Number of Telephone Lines		
1	1	1053
2	1/2	127
3	1/3	15
4	1/4	3
5 or more	1/5	2
		1200

given in the table. The weight for each case was computed as follows:

$$W = kp/gt$$

where,

p = number of eligible children (aged 11 or under) in the household
g = geographic factor (Southern Coast=1; Bay Area=2; Rest of State=4)
t = number of telephone numbers into the household
k = a constant, the same for all cases, selected to make the weighted number of cases equal the actual unweighted number of cases.

This weight is contained in the data record for each case. It is identified in the codebook as "sampwt," the household sampling weight.

5.2 Adjustment for Season and Day of Week

The activities asked about during the interview always referred to "yesterday." Since activity patterns vary by season and day of the week, it is necessary to take into account just when the interview was done. A disproportionate number of interviews were planned to be done on weekends. The distribution of interviews over the four seasons was also not exactly the same.

In order to adjust for the distribution of interviews over days of the week and seasons, a weight for each respondent was computed. For purposes of computing this weight, we classified each completed interview by the day of the week on which the reported activities took place (not the day of the interview itself, which was a day later); the days were combined into three categories: Saturday, Sunday, and weekday. Similarly, we classified each completed interview by the season during which the reported activities took place; the seasons were defined by the four sets of calendar quarters: January-March, April-June, July-September, and October-December.

If the interviews had been spread perfectly evenly over the year, we would expect that the proportion reporting on activities for a Sunday in spring, for example, would

be (1/7)*(1/4) = (1/28). The same proportion applies to a Saturday or a Sunday in each of the four seasons. The corresponding expected proportion for a weekday in each season is (5/7)*(1/4) = (5/28).

To compute the appropriate adjustment, we generated the actual distribution of respondents across the three day-categories and the four season-categories. Since we wanted to combine this adjustment with the adjustment for unequal selection probabilities into a single weight, we used the sampling weight in generating the season-by-day distribution. That distribution is shown in Table 4.

The proportion expected in a given category (if the interviewing had been perfectly spread out), divided by the proportion actually obtained, is the adjustment factor. For example, we expect 5/28 = .1786 of the cases to report on activities referring to a weekday in the winter(January - March). Since the actual proportion referring to a weekday in that season is only .1648, the adjustment factor is .1786/.1648 = 1.084. This means that every completed case that reports on activities for a weekday in the summer would be assigned a weight which incorporates that adjustment factor.

This second weight for each child respondent was then computed as follows:

$$W' = hfW$$

where,

f = the season-by-day adjustment factor, as described above
W = the weight to adjust for selection probabilities
h = a constant, the same for all children, selected to make the weighted number of cases equal the actual unweighted number of cases

The weight to adjust for season and day of the week is included in the data record for each case. Note that this weight includes the adjustment for selection probability. It is identified in the codebook as "timewt," the season-day weight for households.

Table 4

DISTRIBUTION OF COMPONENTS OF SEASON-DAY WEIGHT

(Proportion After Adjusting for Sampling Weight)

CALENDAR QUARTER	DAY OF WEEK Weekday	Saturday	Sunday	Total
Jan - Mar	.1648	.0453	.0524	.2625
Apr - Jun	.0970	.0346	.0226	.1541
Jul - Sep	.2457	.0448	.0597	.3503
Oct - Dec	.1337	.0385	.0610	.2331
Total	.6412	.1631	.1957	1.0000

5.3 Which Weight to Use

The sample was deliberately designed, at the request of the sponsor, to over-represent the non-metropolitan parts of the state, and the San Francisco Bay Area, relative to the Southern Coast area. If statistics are being computed separately for geographic areas that do not pool cases from more than one of the major strata, one might consider not using any weights at all. The values of the weight for selection probability do not vary much within each major stratum. And since the adjustment for season and day of the week was done on the basis of the full statewide sample, the corresponding weight may not be appropriate for a given subsample.

On the other hand, if statistics are being computed for the entire state, it is quite important to use at least the weight to compensate for unequal probabilities of selection ("sampwt"). Otherwise there is likely to be a bias because of the over-representation of certain parts of the state.

The weight to adjust (also) for seasonal and day-of-week effects could be important if a statewide analysis is focusing on variables or activities which are sensitive to the weekend/weekday distinction or to the particular time of the year. Since much of this study concerns such variables, it is probably a good idea to use that weight ("timewt") most of the time.

6. Field Outcome and Response Rates

The disposition of each sampled household and each selected child is summarized in this section. We will discuss each of these two outcomes in turn.

Table 5 shows the results for each of the telephone numbers selected as described above in Section 4. As shown in Table 5, a total of 11,414 telephone numbers was set up for interviewing. Of that number, 5,172 were not eligible households. Of the remaining 6,242 valid sample units, 91.7 percent were successfully enumerated -- that is, an interviewer was able to determine whether any eligible children (aged 11 or younger) resided there and, if so, how many there were. We found 1,413 housing units with one or more eligible children.

Interviews were attempted with (or concerning) a randomly selected child in each of those 1,413 households. Table 6 shows the results for the children selected. For the 1,413 children, 1,200 interviews were completed, or 84.9 percent. The overall response rate is the product of the rate of successful enumeration (.917) and the rate of completion among children selected (.849); that product gives an overall response rate of 77.9 percent.

Table 5

OUTCOME FOR HOUSEHOLDS

	Number	% of Total	% of Eligible
Total Selections	11414	100.0	
Ineligible for the Sample			
Not a residence*	4976	43.6	
Not English speaking	196	1.7	
Total ineligible	5172	45.3	
Eligible Sample Units	6242	54.7	100.0
Refused enumeration	367	3.2	5.9
Unresolved status	149	1.3	2.4
Enumerated households			
No eligible children	4313	37.8	69.1
One or more eligibles	1413	12.4	22.6
Total enumerated	5726	50.2	91.7

*Includes a few numbers never answered after at least 25 calls; most of those are disconnected business numbers, although a small proportion could be residential.

Table 6

OUTCOME FOR CHILDREN SELECTED

	Number	% of Selected
Total Children selected	1413	100.0
Non-response		
Refusals	139	9.8
Respondent never home	54	3.8
Incomplete diary	20	1.4
Total non-response	213	15.1
Completed Interviews	1200	84.9

3.0 CHARACTERIZATION OF OZONE, PARTICLE CHEMISTRY AND METEOROLOGY MEASUREMENTS IN SUPPORT OF CANOPY DEPOSITION ESTIMATES

P. Miller, A. Bytnerowicz, D. Jones, S. Schilling

3.1 Introduction

The purpose of this section is to describe the vertical gradients of microclimate variables and pollutants in a mixed conifer forest. The variables measured include air concentrations of some of the gases and particles at different positions, including above, within, and below the canopy. Also, the vertical profiles of winds, temperature and relative humidity were determined for a typical forest canopy at plot 2. The measurements were made either at the Barton Flats monitoring station using a 15m triaxial tower or at the 29m climbable scaffold located within 1 mile South of the monitoring station at vegetation plot #2 (See Figure 1-1).

3.2 Methods

3.2.1 Micrometeorology of the Forest Canopy

The first profile comparison was done in all months of the year in 1993 and 1994 at the Barton Flats monitoring site. Temperatures were sensed by a shielded thermistor mounted at 15 m, a shielded thermocouple at 2 m, a small thermocouple inserted in a ponderosa pine needle at 2 m, and thermocouples at 10 cm and 50 cm in the soil. The air, leaf, and soil temperatures, measured by thermocouples were supplied by Dr. Nancy Grulke. There is a 0.3 to 0.5 ° C difference between the sensors with the thermocouples being higher. This correction was not applied to the data. Hourly temperatures were reduced to daily averages and representative results were prepared for February-March 1993 and July-September 1993.

At plot 2 a data logger and sensors provided hourly averages for winds, temperature, and relative humidity at the top of the 29m scaffold and at 2m above the ground. Wind direction was measured at 2m but was not included in the analysis because nearby obstructions caused excessive variability in this measurement. Detailed procedures for the data logging systems are included in Volume 1 of the Standard Operating Procedures (1995).

3.2.2 Ozone Measurements Above and Below Canopy at the Monitoring Station and Between the Monitoring Station and Nearby Locations

Continuous measurements of ozone were made at the Barton Flats monitoring site where the ozone monitor (DASIBI) was located in an air-conditioned shelter. Teflon sample lines of equal length were employed. The intake of one line was placed at a height of 15 m on a triaxial tower. Air flow was completely unobstructed because there were no nearby trees of equivalent height. The intake of the second line was placed at 1.5 m in the understory of a stand comprised of ponderosa pine, white fir and black oak at a distance of 20 m North and slightly downslope from the triaxial tower.

Comparison of ozone concentrations between the monitoring station and other sites required that a solar-charged battery pack, mounted on a trailer, be used as a power source for the DASIBI ozone analyzer. Prior to test periods the second DASIBI was calibrated against the station DASIBI for several days. The two

Table A2-8 (cont.)

Chemical Analysis Data Validation Flags for the Forest Response Study

Validation Flag	Sub Flag	Description
	i1	inhomogeneous sample deposit.
	i2	deposit smeared or scraped after sampling.
	i3	deposit appears to have fallen off.
	i4	abnormal deposit area, possible air leakage during sampling
	i5	non-white carbon punch after carbon analysis.
	i6	large particles on fine particle sample.
	i7	particles on filter holder.
	i8	visible deposition on the back of the filter.
	i9	deposit trapped between layers of filters; layers separated prior to chemical analysis.
j		abnormal deposit area, possible leakage during sampling.
k		(reserved)
l		analysis value lower than minimal detection limit.
m		(reserved)
n		various dilution factors used in ion analyses.
	n0	1:10 dilution was made on sample extract.
	n1	1:20 dilution was made on sample extract.
	n2	1:2 dilution was made on sample extract.
	n3	1:3 dilution was made on sample extract.
	n4	1:4 dilution was made on sample extract.
	n5	1:5 dilution was made on sample extract.
	n6	1:100 dilution was made on sample extract.
	n7	1:50 dilution was made on sample extract.
	n8	1:110 dilution was made on sample extract.
	n9	1:21 dilution was made on sample extract.
	n10	1:11 dilution was made on sample extract.
o		(reserved)
p		(reserved)
q		quality control standards.
	q1	routine quality control standard.
	q2	Environmental Resources Associates (ERA) quality control standard.
	q3	(NBS) simulated rainwater standard.
	q4	calibration standard.

Table A2-8

Chemical Analysis Data Validation Flags for the Forest Response Study

Validation Flag	Sub Flag	Description
a		(reserved)
b		blanks.
	b0	unspecified field blank.
	b1	field/dynamic blank.
	b2	laboratory control blank.
	b3	distilled-deionized water blank.
	b4	method blank.
	b5	extract/solution blank.
	b6	transport blank
c		sample spectrum being reprocessed or recalculated.
	c1	carbon run recalculated.
	c2	ion run reprocessed due to integration failure.
	c3	ion run recalculated with high concentration range calibration curve.
	c4	average of several replicate runs.
	c5	ion analyses were performed with high concentration range calibration curve.
	c6	XRF spectrum reprocessed using manually adjusted background.
d		data point deleted from main data base.
e		use of IC filter in ion analyses.
	e1	extract analyzed with IC filter.
	e2	extract analyzed without IC filter.
f		filter damaged.
	f1	filter damaged, outside of analysis area.
	f2	filter damaged, within analysis area.
	f3	Teflon membrane substrate separated from the ring.
	f4	filter deposit side facing down in Petri slides.
	f5	filter dropped during handling.
	f6	filter stuck to Petri slide.
g		(reserved)
h		(reserved)
i		abnormal sample deposit.

Table A2-7 (cont.)

Ambient Field Sampling Data Validation Flags[a]
For the Forest Response Study

Validation Flag	Sub Flag	Description
	T5	Sample ran during prescribed period, plus part of next period.
	T6	More than one sample was run to account for the prescribed period.
U		Unusual local particulate sources during sample period.
	U1	Local construction activity.
	U2	Forest fire or slash or field burning.
V		Void sample, Invalid.
W		Wet Sample.
X		No sample was taken this period, sample run was skipped.
Y		(reserved)
Z		
	Z1	Teflon and quartz filters were loaded reversely in SFS.
	Z2	$PM_{2.5}$ and PM_{10} filter pack switched.
	Z3	Fine and Coarse filters were loaded reversely in dichotomous sampler.

[a] Flagged samples are categorized as valid, suspect, or invalid. Any flags except 'S' and 'V' or no flags at all indicate valid samples. The 'S' flag in combination with any other flags indicates samples of suspect validity. The 'V' flag in combination with any other flags indicates invalid samples.

Table A2-7 (cont.)

Ambient Field Sampling Data Validation Flags[a]
For the Forest Response Study

Validation Flag	Sub Flag	Description
K		(reserved)
L		(reserved)
M		Sampler malfunction.
	M1	Dichotomous sampler assembled with virtual impactor 180° out of phase; only PM_{10} data reported.
N		Foreign substance on deposit.
	N1	Insects on deposit, removed before analysis.
	N2	Particles on deposit much larger than inlet device allows.
	N3	Metallic particles observed on deposit.
O		Sampler operation error.
	O1	Pump was not switched on after changing samples.
	O2	Timer set incorrectly.
	O3	Filter loaded in wrong port.
P		Power failure during sampling.
Q		Flow rate error.
	Q1	Initial or final flow rate differed from nominal by > ±10%.
	Q2	Final flow rate differed from initial by > ±10%.
	Q3	Initial or final flow rate not recorded, used estimated flow rate.
	Q4	Nominal flow rate assumed.
	Q5	Initial flow readjusted prior to sampling.
	Q6	Initial flow exceeded ±15% of nominal flow.
R		Replacement filter used.
	R1	Filter that failed flow rate or QC checks replaced with spare.
	R2	Filter sampling sequence changed from order designated on field data sheet.
S		Sample "suspect", but not invalid
T		Sampling time error.
	T1	Sampling duration error of > ±10%.
	T2	Sample start time error of > ±10% of sample duration.
	T3	Elapsed time meter reading not recorded or recorded incorrectly. Sample duration estimated based on readings from previous or subsequent sample.
	T4	Nominal sample duration assumed.

Table A2-7

Ambient Field Sampling Data Validation Flags[a]
For the Forest Response Study

Validation Flag	Sub Flag	Description
A		Sampler adjustment or maintenance.
	A1	Sampler audit during sample period.
	A2	Sampler cleaned.
	A3	Particle size cut device regreased or replaced.
B		Field Blank.
D		Sample dropped.
	D1	Sample dropped after sampling.
	D2	Filter dropped during unloading.
F		Filter damaged or ripped.
	F1	Filter damaged in the field.
	F2	Filter damaged when removed from holder.
	F3	Filter wrinkled.
	F4	Filter torn due to over-tightened filter holder.
	F5	Teflon membrane separated from support ring.
	F6	Pinholes in filter.
G		Filter deposit damaged.
	G1	Deposit scratched or scraped, causing a thin line in the deposit.
	G2	Deposit smudged, causing a large area of deposit to be displaced.
	G3	Filter returned to lab with deposit side down in PetriSlide.
	G4	Evidence that part of deposit has fallen off filter.
	G5	Finger touched filter in the field (without gloves).
	G6	Finger touched filter in the lab (with gloves).
H		Filter holder assembly problem.
	H1	Filter misaligned in holder - possible air leak.
	H2	Filter holder loose in sampler - possible air leak.
	H3	Filter holder not tightened sufficiently - possible air leak.
	H4	Filter support grid upside down.
I		Inhomogeneous filter deposit.
	I1	Evidence of impaction - deposit heavier in center of filter.
	I2	Random areas of darker or lighter deposit on filter.
	I3	Light colored deposit with dark specks.
	I4	Non-uniform deposit near edge - possible air leak.
	I5	Discoloration on sample.
J		Filter misaligned, possible leakage.

Table A2-6

Data Base Structure Definition for
South Coast Air Basin Meteorological Site Data

Structure for table: SCSITES.DBF
Number of data records: 33
Date of last update: 03/22/95
Missing value code: -99

Field	Field Name	Type	Width	Dec	Description
1	STATION	Character	4		South Coast Air Quality Management District site code
2	SITEABB	Character	5		Site name abbreviation
3	NAME	Character	18		Site name
4	ADDRESS	Character	32		Site street address
5	LATF	Numeric	8	4	Site location, degrees North latitude
6	LONF	Numeric	8	4	Site location, degrees West longitude

Table A2-5

Data Base Structure Definition for Supplementary South Coast Air Basin Meteorological Data

Structure for table: SCMET.DBF
Number of data records: 578,962
Date of last update: 03/22/95
Missing value code: -99

Field	Field Name	Type	Width	Dec	Description
1	STATION	Character	4		South Coast Air Quality Management District site code
2	DATE	Date	8		Date of sample collection
3	HR	Numeric	2		Time in hours at beginning of hourly average observation, i.e. 5 is for data collected 0500 through 0600
4	TAC	Numeric	3		Ambient temperature, degrees C
5	RHP	Numeric	3		Relative humidity, %
6	WVM	Numeric	3		Vector wind speed, m/s
7	WDV	Numeric	3		Vector wind direction, degrees of angle
8	FDAT	Numeric	7	3	Fractional Julian day, i.e. Julian day + HR/24

Table A2-4 (continued)

Database Structure Definition for Meteorological/Ozone Data

Field	Field Name	Type	Width	Dec	Description
27	TESTFLAGS	Character	17		Data evaluation flags. Each column contains the flag for a single parameter, as follows:
28	FDAT	Numeric	7	3	Fractional Julian day, i.e. Julian day + HR/24
29	COMMENTS	Memo	10		Data validation notes

Column	Field
1	TAC
2	RHP
3	WSM
4	WDS
5	SGD
6	WVM
7	WDV
8	WHM
9	WLM
10	O3B
11	LWF
12	SRW
17	TSC
18	PSV
19	MCT
20	OCT
21	SNT

Table A2-4

Data Base Structure Definition for Meteorological/Ozone Data

Structure for table: FOMET.DBF
Number of data records: 27,063
Date of last update: 03/20/95
Missing value code: -99

Field	Field Name	Type	Width	Dec	Description
1	ID	Numeric	1		Record type, 1=hourly average
2	YRCC	Numeric	4		Year of sample collection
3	JDAT	Numeric	3		Julian day
4	HEC	Numeric	4		Time in HHMM format at end of hourly average observation, i.e. 0500 is for data collected 0400 through 0500
5	TAC	Numeric	5	1	Ambient temperature, degrees C
6	RHP	Numeric	5	1	Relative humidity, %
7	WSM	Numeric	5	1	Scalar windspeed, m/s
8	WDS	Numeric	3		Scalar wind direction, degrees of angle
9	SGD	Numeric	3		Sigma theta (standard deviation of wind direction), degrees of angle
10	WVM	Numeric	5	1	Vector wind speed, m/s
11	WDV	Numeric	3		Vector wind direction, degrees of angle
12	WHM	Numeric	5	1	Maximum instantaneous windspeed during hour, m/s
13	WLM	Numeric	5	1	Minimum instantaneous windspeed during hour, m/s
14	O3B	Numeric	3		Ozone concentration, ppb
15	LWF	Numeric	5	3	Fraction of hour that leaf wetness sensor was wet
16	SRW	Numeric	4		Solar radiation, w/m^2
17	TSC	Numeric	5	1	Shelter temperature, degrees C
18	PSV	Numeric	5	1	Datalogger battery voltage
19	MCT	Numeric	4		Number of observations in hourly average (except for ozone)
20	OCT	Numeric	4		Number of observations in hourly average for ozone
21	SNT	Numeric	6	1	Datalogger program ID
22	SITE	Character	2		Site code, BF= Barton Flats
23	HR	Numeric	2		Time in hours at beginning of hourly average observation, i.e. 5 is for data collected 0500 through 0600
24	DATE	Date	8		Sampling date
25	DPC	Numeric	5	1	Dew point temperature, degrees C
26	VALFLAGS	Character	12		Data validation flags. Each column contains the flag for a single parameter, as follows:

Column	Field
1	TAC
2	RHP
3	WSM
4	WDS
5	SGD
6	WVM
7	WDV
8	WHM
9	WLM
10	O3B
11	LWF
12	SRW

Table A2-3 (continued)

Database Structure Definition for Wet Deposition Data

Field	Field Name	Type	Width	Dec	Description
37	CLIC	Numeric	10	4	Cl^- concentration, µg/ml
38	CLIU	Numeric	10	4	Cl^- uncertainty, µg/ml
39	N3IC	Numeric	10	4	NO_3^- concentration, µg/ml
40	N3IU	Numeric	10	4	NO_3^- uncertainty, µg/ml
41	S4IC	Numeric	10	4	$SO_4^=$ concentration, µg/ml
42	S4IU	Numeric	10	4	$SO_4^=$ uncertainty, µg/ml
43	N4CC	Numeric	10	4	NH_4^+ concentration, µg/ml
44	N4CU	Numeric	10	4	NH_4^+ uncertainty, µg/ml
45	NAAC	Numeric	10	4	Na^+ concentration, µg/ml
46	NAAU	Numeric	10	4	Na^+ uncertainty, µg/ml
47	MGAC	Numeric	10	4	Mg^{++} concentration, µg/ml
48	MGAU	Numeric	10	4	Mg^{++} uncertainty, µg/ml
49	KPAC	Numeric	10	4	K^+ concentration, µg/ml
50	KPAU	Numeric	10	4	K^+ uncertainty, µg/ml
51	CAAC	Numeric	10	4	Ca^{++} concentration, µg/ml
52	CAAU	Numeric	10	4	Ca^{++} uncertainty, µg/ml
53	COMMENT	Memo	10		Field sampling and laboratory analysis comments

Table A2-3

Data Base Structure Definition for Wet Deposition Data

Structure for table: FOWET.DBF
Number of data records: 116
Date of last update: 03/23/95
Missing value code: -99
Precisions: Reported with values

Field	Field Name	Type	Width	Dec	Description
1	WID	Character	10		Sample ID
2	STRTDATE	Date	8		Sample start date
3	STRTTIME	Numeric	4		Sample start time, (HHMM)
4	STOPDATE	Date	8		Sample stop date
5	STOPTIME	Numeric	4		Sample stop time, (HHMM)
6	RAINT1	Numeric	4	2	Precipitation on STRTDATE (Tuesday) from STRTTIME to 2400, inches
7	RAINWE	Numeric	4	2	Precipitation on STRTDATE + 2 (Wednesday), inches
8	RAINTH	Numeric	4	2	Precipitation on STRTDATE + 3 (Thursday), inches
9	RAINFR	Numeric	4	2	Precipitation on STRTDATE + 4 (Friday), inches
10	RAINSA	Numeric	4	2	Precipitation on STRTDATE + 5 (Saturday), inches
11	RAINSU	Numeric	4	2	Precipitation on STRTDATE + 6 (Sunday), inches
12	RAINMO	Numeric	4	2	Precipitation on STRTDATE + 7 (Monday), inches
13	RAINT2	Numeric	4	2	Precipitation on STOPDATE (Tuesday) from 0000 to STOPTIME, inches
14	RAINTOT	Numeric	5	2	Precipitation from STRTDATE, STRTTIME through STOPDATE, STOPTIME, inches
15	TYPET1	Character	1		Precipiation type for RAINT1; R = rain, S = snow, M = mixed, U = unknown
16	TYPEWE	Character	1		Precipiation type for RAINWE
17	TYPETH	Character	1		Precipiation type for RAINTH
18	TYPEFR	Character	1		Precipiation type for RAINFR
19	TYPESA	Character	1		Precipiation type for RAINSA
20	TYPESU	Character	1		Precipiation type for RAINSU
21	TYPEMO	Character	1		Precipiation type for RAINMO
22	TYPET2	Character	1		Precipiation type for RAINT2
23	RINSEBLANK	Logical	1		Is wet deposition sample a bucket rinse? Y = yes, N = no
24	NETWEIGHT	Numeric	5		Weight of sample, g
25	VOLUME	Numeric	4		Volume of sample, ml
26	PRECIP	Numeric	6	3	Precipitation based on wet bucket, inches
27	CONDSMP	Numeric	7	3	Conductivity of sample, field measurement, µsiemens/cm
28	CONDLAB	Numeric	7	3	Conductivity of sample, lab measurement, µsiemens/cm
29	PHSMP	Numeric	4	2	pH of sample, field measurement
30	PHLAB	Numeric	4	2	pH of sample, lab measurement
31	ANIF	Character	5		Anion analysis flag
32	N4CF	Character	5		NH_4^+ analysis flag
33	NAAF	Character	5		Na^+ analysis flag
34	MGAF	Character	5		Mg^{++} analysis flag
35	KPAF	Character	5		K^+ anlysis flag
36	CAAF	Character	5		Ca^{++} analysis flag

Table A2-2 (continued)

Database Structure Definition for Dry Deposition Data

Field	Field Name	Type	Width	Dec	Description
48	N3IDC	Numeric	10	4	Denuded nylon filter NO_3^- concentration, $\mu g/m^3$
49	N3IDU	Numeric	10	4	Denuded nylon filter NO_3^- uncertainty, $\mu g/m^3$
50	N3IBC	Numeric	10	4	Backup nylon filter NO_3^- concentration, $\mu g/m^3$
51	N3IBU	Numeric	10	4	Backup nylon filter NO_3^- uncertainty, $\mu g/m^3$
52	HNO3C	Numeric	10	4	HNO_3 concentration, $\mu g/m^3$
53	HNO3U	Numeric	10	4	HNO_3 uncertainty, $\mu g/m^3$
54	SPSUMC	Numeric	10	4	Sum of particulate species concentration except mass, $\mu g/m^3$
55	SPSUMU	Numeric	10	4	Sum of particulate species uncertainty, except mass, $\mu g/m^3$
56	COMMENT	Memo	10		Field sampling and laboratory analysis comments

Table A2-2

Data Base Structure Definition for Dry Deposition Data

Structure for table: FOCON.DBF
Number of data records: 304
Date of last update: 03/24/95
Missing value code: -99
Precisions: Reported with values

Field	Field Name	Type	Width	Dec	Description
1	DATE	Date	8		Sample start date
2	SITE	Character	10		BF = Barton Flats
3	SIZE	Character	3		2.5 = $PM_{2.5}$
4	FIELDNO	Character	12		Internal code
5	TKID	Character	10		TK filter pack ID
6	DNID	Character	10		DN filter pack ID
7	QNID	Character	10		QN filter pack ID
8	GTID	Character	10		GT filter pack ID
9	STRTHHMM	Character	4		Sample start hour (HHMM)
10	STOPHHMM	Character	4		Sample stop hour (HHMM)
11	TIMENET	Numeric	8	1	Elapsed time, minutes
12	TKFLG	Character	5		TK filter pack field flag
13	DNFLG	Character	5		DN filter pack field flag
14	QNFLG	Character	5		QN filter pack field flag
15	GTFLG	Character	5		GT filter pack field flag
16	MSGF	Character	5		Mass analysis flag
17	ANIF	Character	5		Anion analysis flag
18	N4CF	Character	5		NH_4 + analysis flag
19	NHCF	Character	5		NH_3 analysis flag
20	S2IF	Character	5		SO_2 analysis flag
21	N2CF	Character	5		NO_2 analysis flag
22	N3IDF	Character	5		Denuded NO_3^- analysis flag
23	N3IBF	Character	5		Backup NO_3^- analysis flag
24	TKVOC	Numeric	10	4	TK filter pack volume, m^3
25	TKVOU	Numeric	10	4	TK volume uncertainty, m^3
26	DNVOC	Numeric	10	4	DN filter pack volume, m^3
27	DNVOU	Numeric	10	4	DN volume uncertainty, m^3
28	QNVOC	Numeric	10	4	QN filter pack volume, m^3
29	QNVOU	Numeric	10	4	QN volume uncertainty, m^3
30	GTVOC	Numeric	10	4	GT filter pack volume, m^3
31	GTVOU	Numeric	10	4	GT volume uncertainty, m^3
32	MSGC	Numeric	10	4	Mass concentration, $\mu g/m^3$
33	MSGU	Numeric	10	4	Mass uncertainty, $\mu g/m^3$
34	CLIC	Numeric	10	4	Cl^- concentration, $\mu g/m^3$
35	CLIU	Numeric	10	4	Cl^- uncertainty, $\mu g/m^3$
36	N3IC	Numeric	10	4	NO_3^- concentration, $\mu g/m^3$
37	N3IU	Numeric	10	4	NO_3^- uncertainty, $\mu g/m^3$
38	S4IC	Numeric	10	4	$SO_4^=$ concentration, $\mu g/m^3$
39	S4IU	Numeric	10	4	$SO_4^=$ uncertainty, $\mu g/m^3$
40	N4CC	Numeric	10	4	NH_4^+ concentration, $\mu g/m^3$
41	N4CU	Numeric	10	4	NH_4^+ uncertainty, $\mu g/m^3$
42	NHCC	Numeric	10	4	NH_3 concentration, $\mu g/m^3$
43	NHCU	Numeric	10	4	NH_3 uncertainty, $\mu g/m^3$
44	S2IC	Numeric	10	4	SO_2 concentration, $\mu g/m^3$
45	S2IU	Numeric	10	4	SO_2 uncertainty, $\mu g/m^3$
46	N2CC	Numeric	10	4	NO_2 concentration, $\mu g/m^3$
47	N2CU	Numeric	10	4	NO_2 uncertainty, $\mu g/m^3$

Table A2-1

Database Structure Definition for Field Name Description File

Structure for table: FOFLDNAM.DBF
Number of data records: 133
Date of last update: 03/24/95

Field	Field Name	Type	Width	Dec	Description
1	FIELD_NAME	Character	10		The name of the field as it appears in the data base files.
2	FIELD_TYPE	Character	1		The code that identifies the type of field in the data base.
3	FIELD_LEN	Numeric	3		The width of the field.
4	FIELD_DEC	Numeric	3		The number of decimal places used in numeric fields.
5	DESCRIPT	Character	60		An explanation field describing the meaning of a particular field.
6	UNITS	Character	30		The units of measurement in a field.

Appendix A.2 **Aerometric Data Base Structures and Flag Definitions**

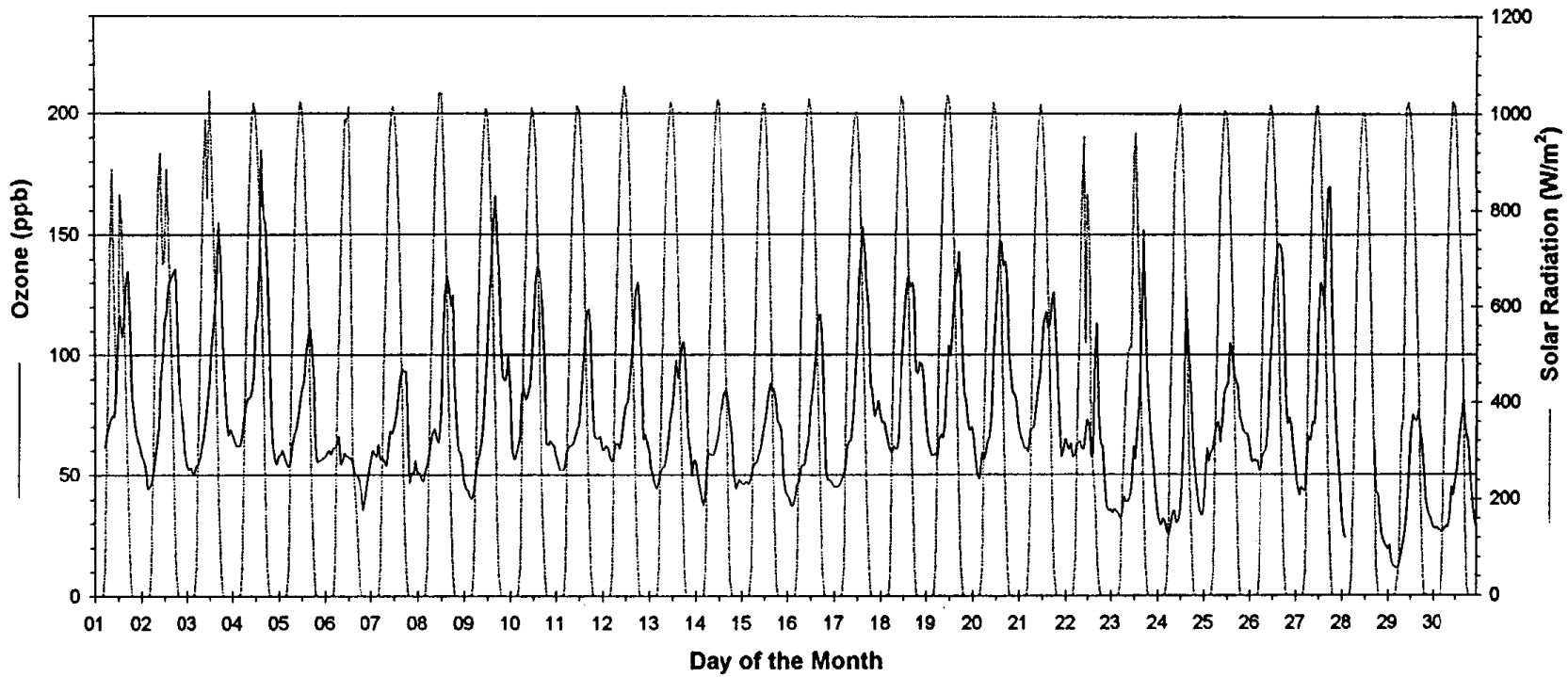


Figure 2-25. Time Series Plot of Ozone and Solar Radiation Measurements at the Barton Flats Station, CA, Between 06/01/92 and 06/30/92.

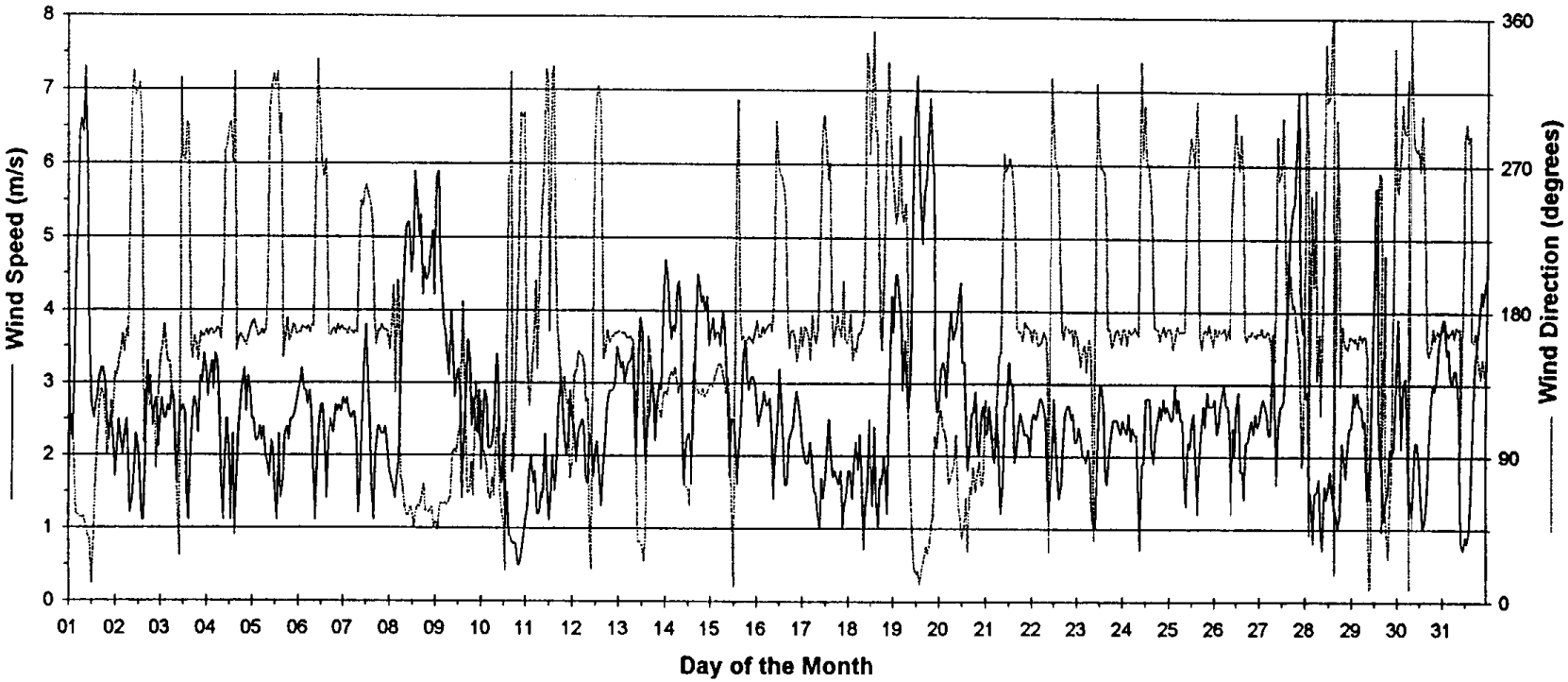


Figure 2-24. Time Series Plot of Wind Speed and Wind Direction Measurements at the Barton Flats Station, CA, Between 12/01/91 and 12/31/91.

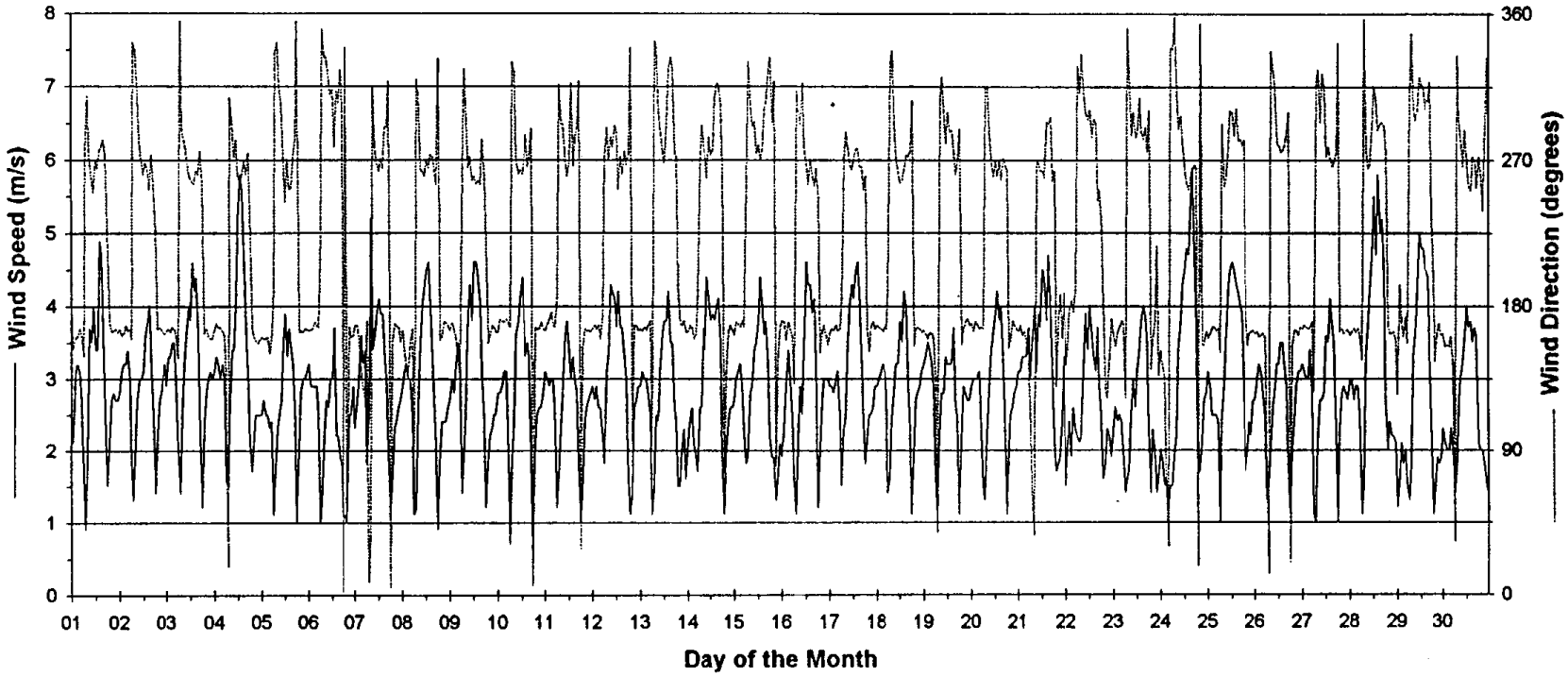
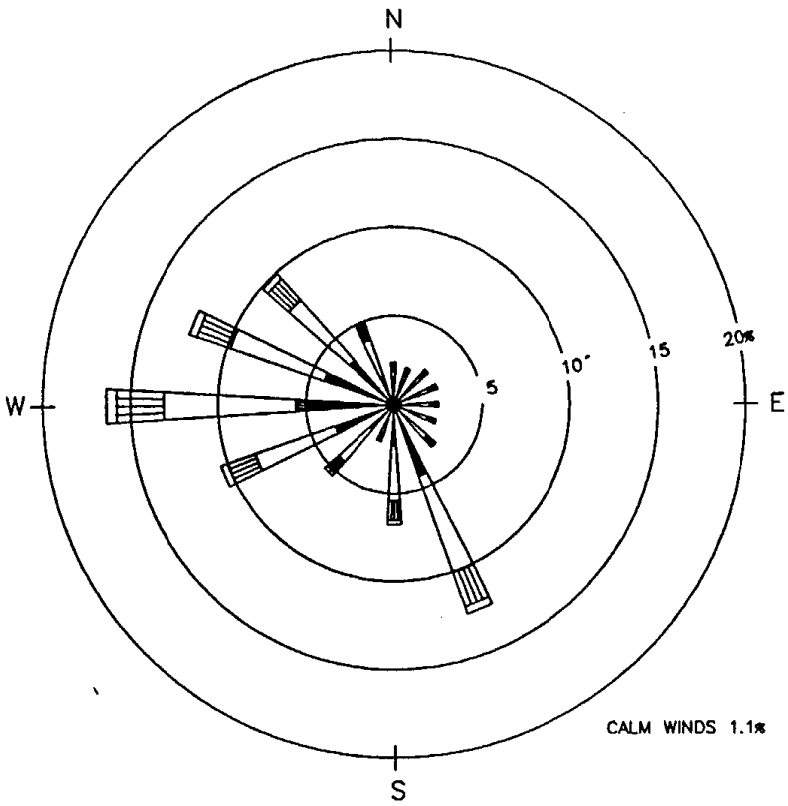
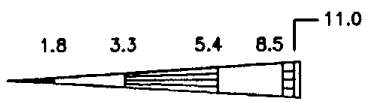


Figure 2-23. Time Series Plot of Wind Speed and Wind Direction Measurements at the Barton Flats Station, CA, Between 06/01/92 and 06/30/92.

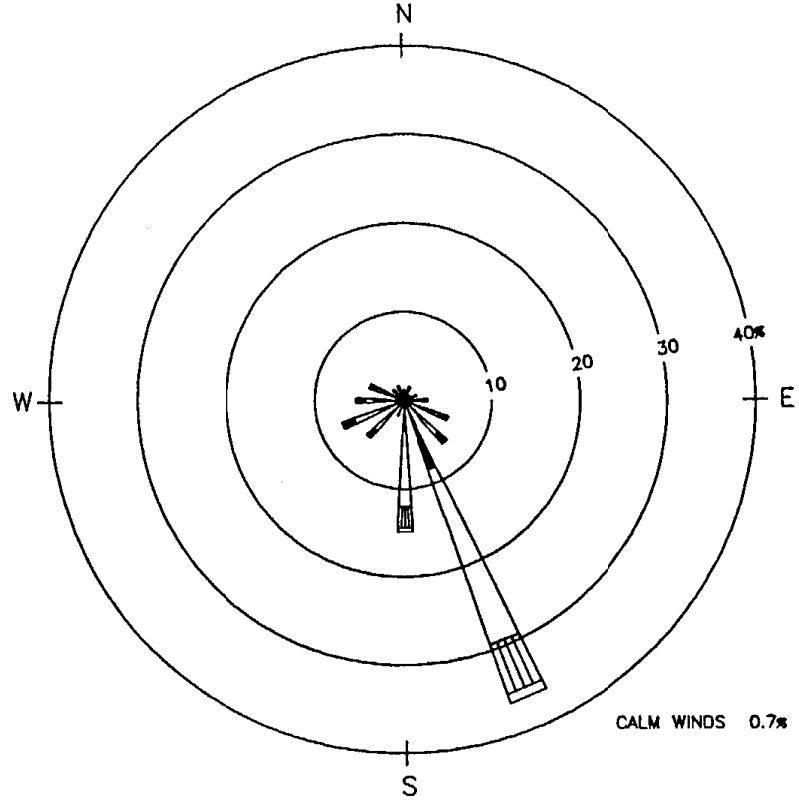


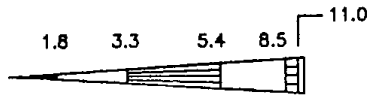


WIND SPEED CLASS BOUNDARIES
(METERS/SECOND)

NOTES:
DIAGRAM OF THE FREQUENCY OF OCCURRENCE FOR EACH WIND DIRECTION. WIND DIRECTION IS THE DIRECTION FROM WHICH THE WIND IS BLOWING. EXAMPLE – WIND IS BLOWING FROM THE NORTH 2.4 PERCENT OF THE TIME.

Site: Barton Flats
Season: Winter
Daytime
07:00 – 19:00



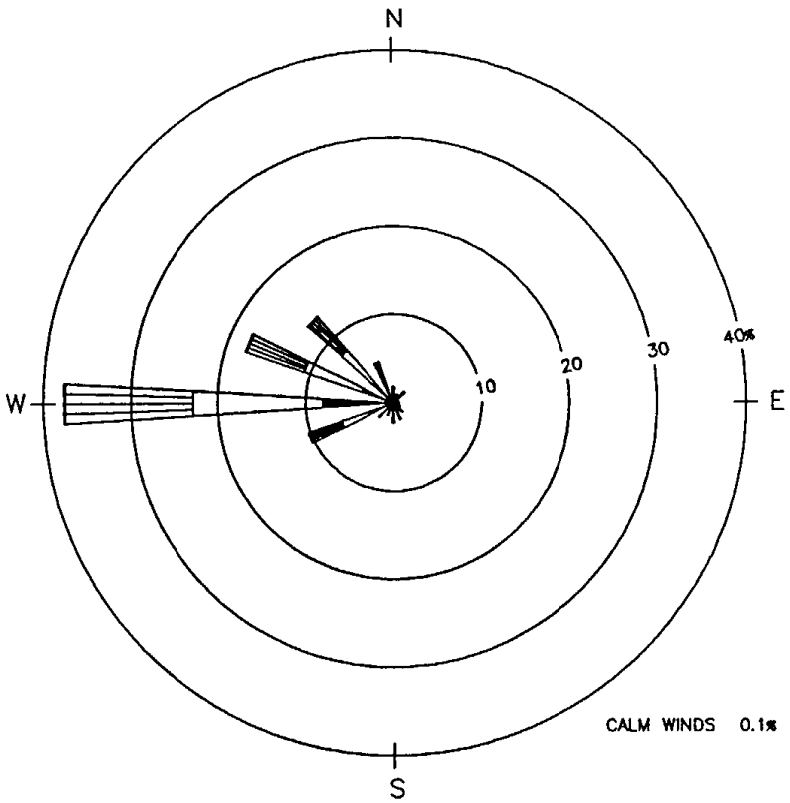


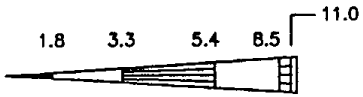
WIND SPEED CLASS BOUNDARIES
(METERS/SECOND)

NOTES:
DIAGRAM OF THE FREQUENCY OF OCCURRENCE FOR EACH WIND DIRECTION. WIND DIRECTION IS THE DIRECTION FROM WHICH THE WIND IS BLOWING. EXAMPLE – WIND IS BLOWING FROM THE NORTH 1.2 PERCENT OF THE TIME.

Barton Flats
Season: Winter
Nighttime
19:00 – 0:700

Figure 2-22. Wintertime Wind Roses at the Barton Flats Station, CA, Between 12/01/92 and 02/28/93.

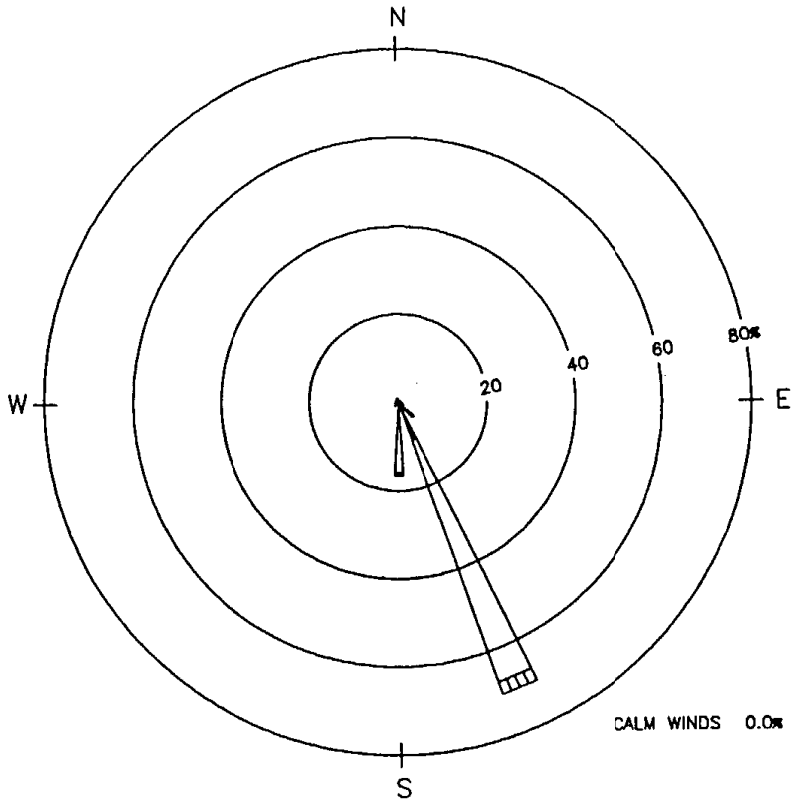


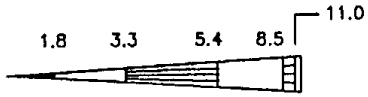


WIND SPEED CLASS BOUNDARIES
(METERS/SECOND)

NOTES:
DIAGRAM OF THE FREQUENCY OF OCCURRENCE FOR EACH WIND DIRECTION. WIND DIRECTION IS THE DIRECTION FROM WHICH THE WIND IS BLOWING. EXAMPLE – WIND IS BLOWING FROM THE NORTH 1.8 PERCENT OF THE TIME.

Barton Flats
Season: Summer
Daytime
07:00 – 19:00



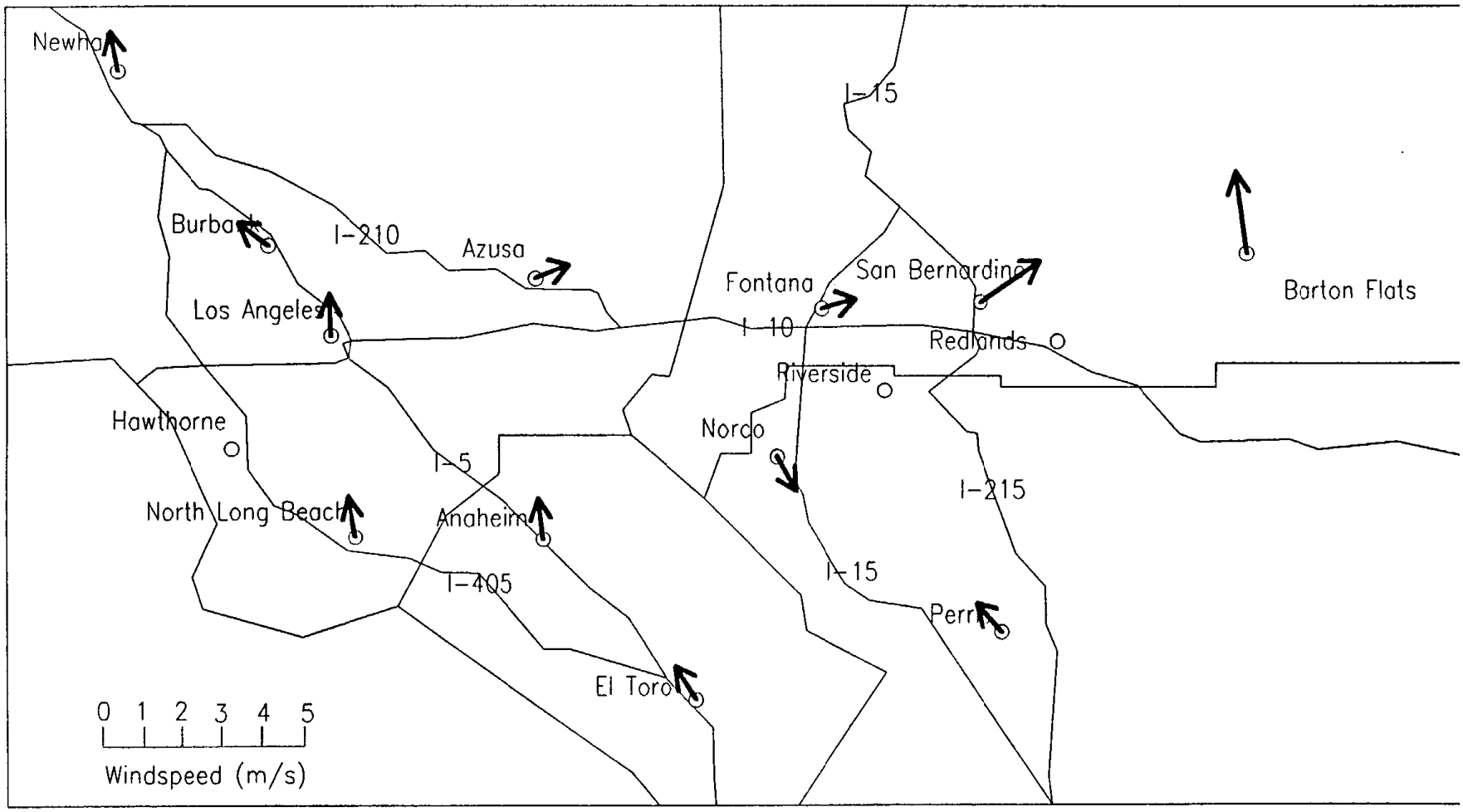


WIND SPEED CLASS BOUNDARIES
(METERS/SECOND)

NOTES:
DIAGRAM OF THE FREQUENCY OF OCCURRENCE FOR EACH WIND DIRECTION. WIND DIRECTION IS THE DIRECTION FROM WHICH THE WIND IS BLOWING. EXAMPLE – WIND IS BLOWING FROM THE NORTH .0 PERCENT OF THE TIME.

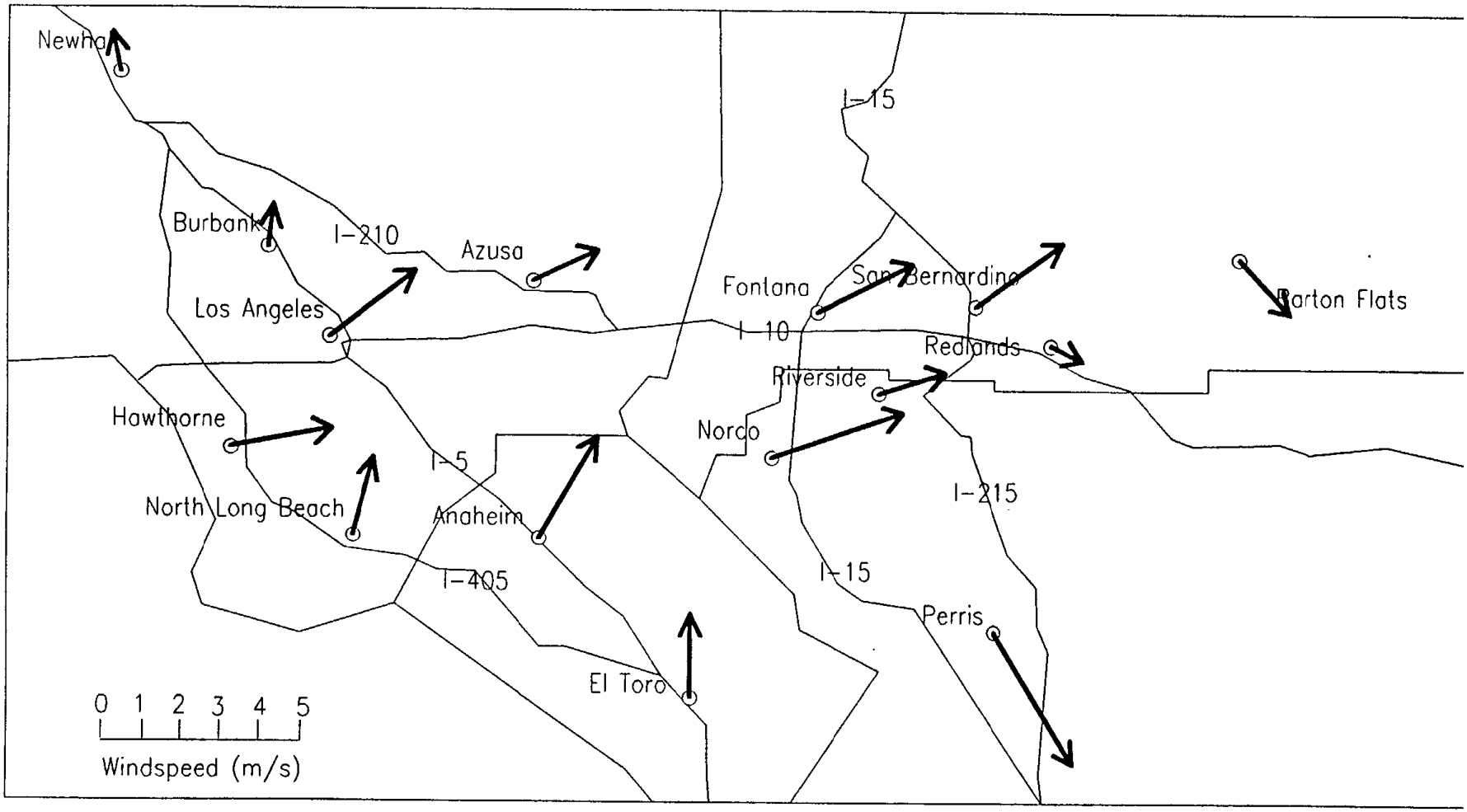
Barton Flats
Season: Summer
Nighttime
19:00 – 07:00

Figure 2–21. Summertime Wind Roses at the Barton Flats Station, CA, Between 06/01/92 and 08/31/92.



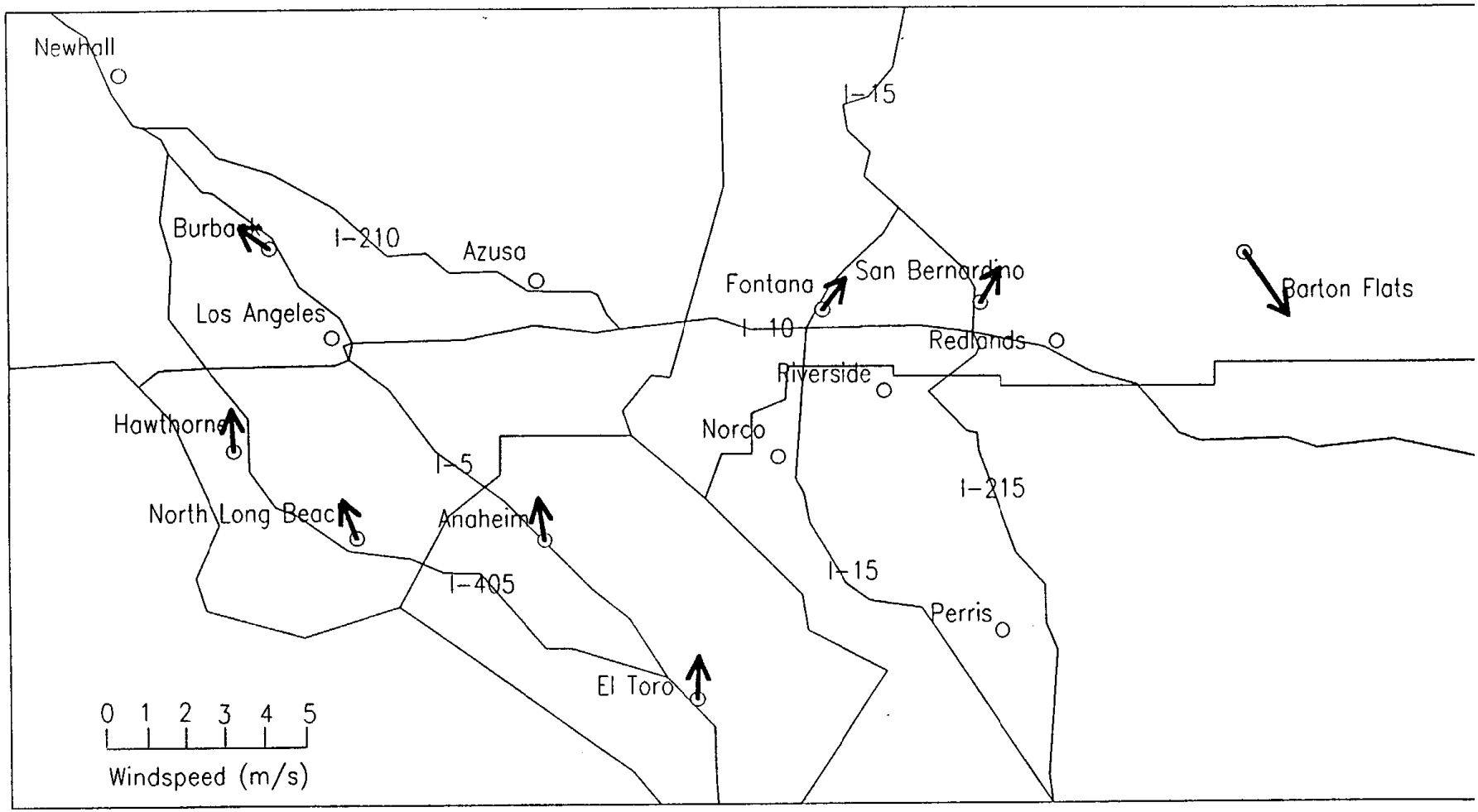
July 24, 1993 22:00

Figure 2-20. Wind Field in California's South Coast Air Basin Between 22:00 and 23:00 PST on 07/24/93. (Each arrow represents vector wind direction, the length of the arrow represents the wind speed).



July 24, 1993 16:00

Figure 2-19. Wind Field in California's South Coast Air Basin Between 16:00 and 17:00 PST on 07/24/93. (Each arrow represents vector wind direction, the length of the arrow represents the wind speed).



July 24, 1993 08:00

Figure 2-18. Wind Field in California's South Coast Air Basin Between 08:00 and 09:00 PST on 07/24/93. (Each arrow represents vector wind direction, the length of the arrow represents the wind speed).

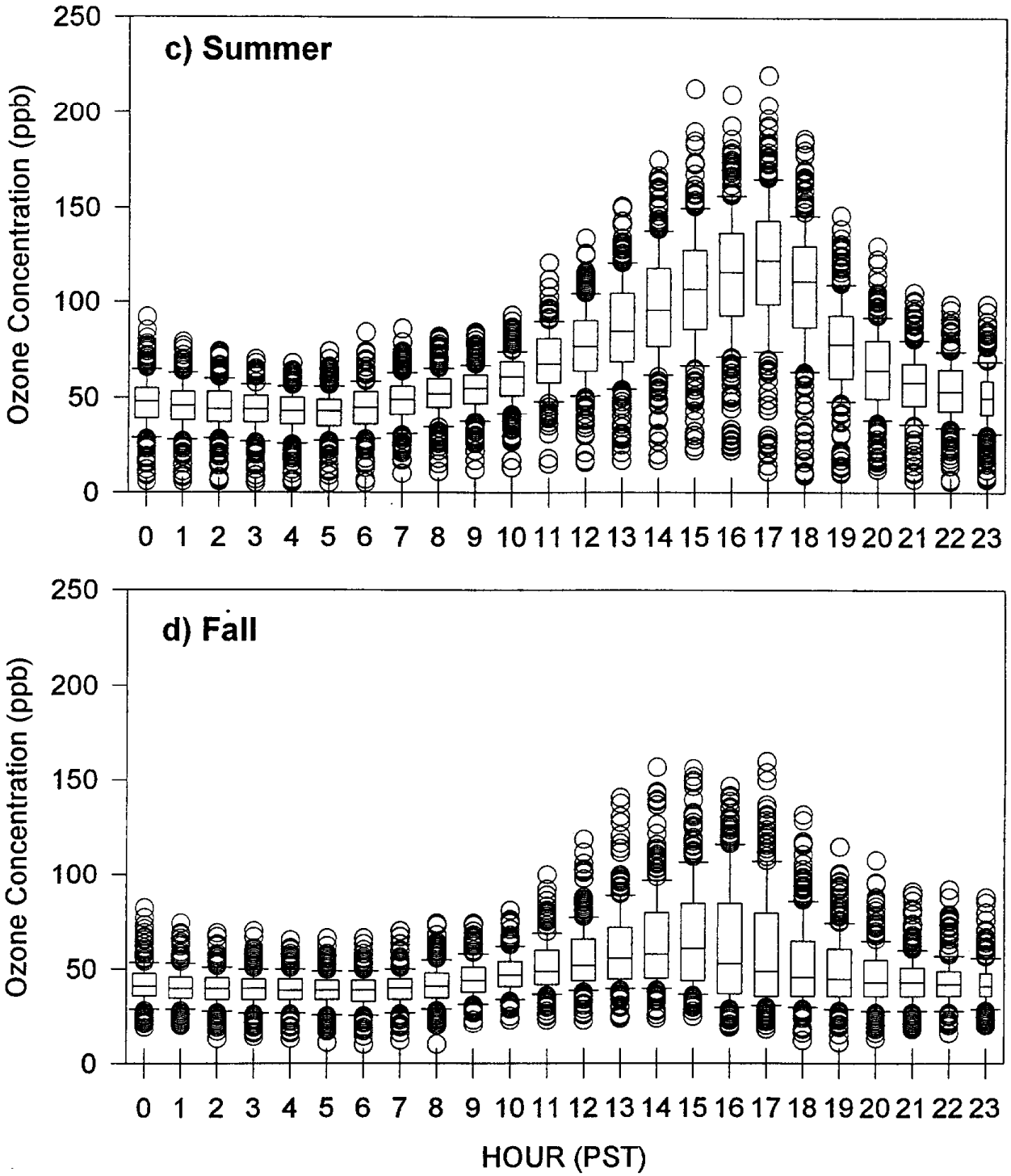


Figure 2-17. Diurnal Box Plots of Hourly Average Ozone Concentration at the Barton Flats Station, CA, During: a) Winter (December of 1991, January, February, and December of 1992 and 1993, and January and February of 1994), b) Spring (March, April, and May of 1992, 1993, and 1994), c) Summer (June, July, and August of 1992, 1993, and 1994), and d) Fall (November of 1991, September, October, and November of 1992, 1993, and 1994).

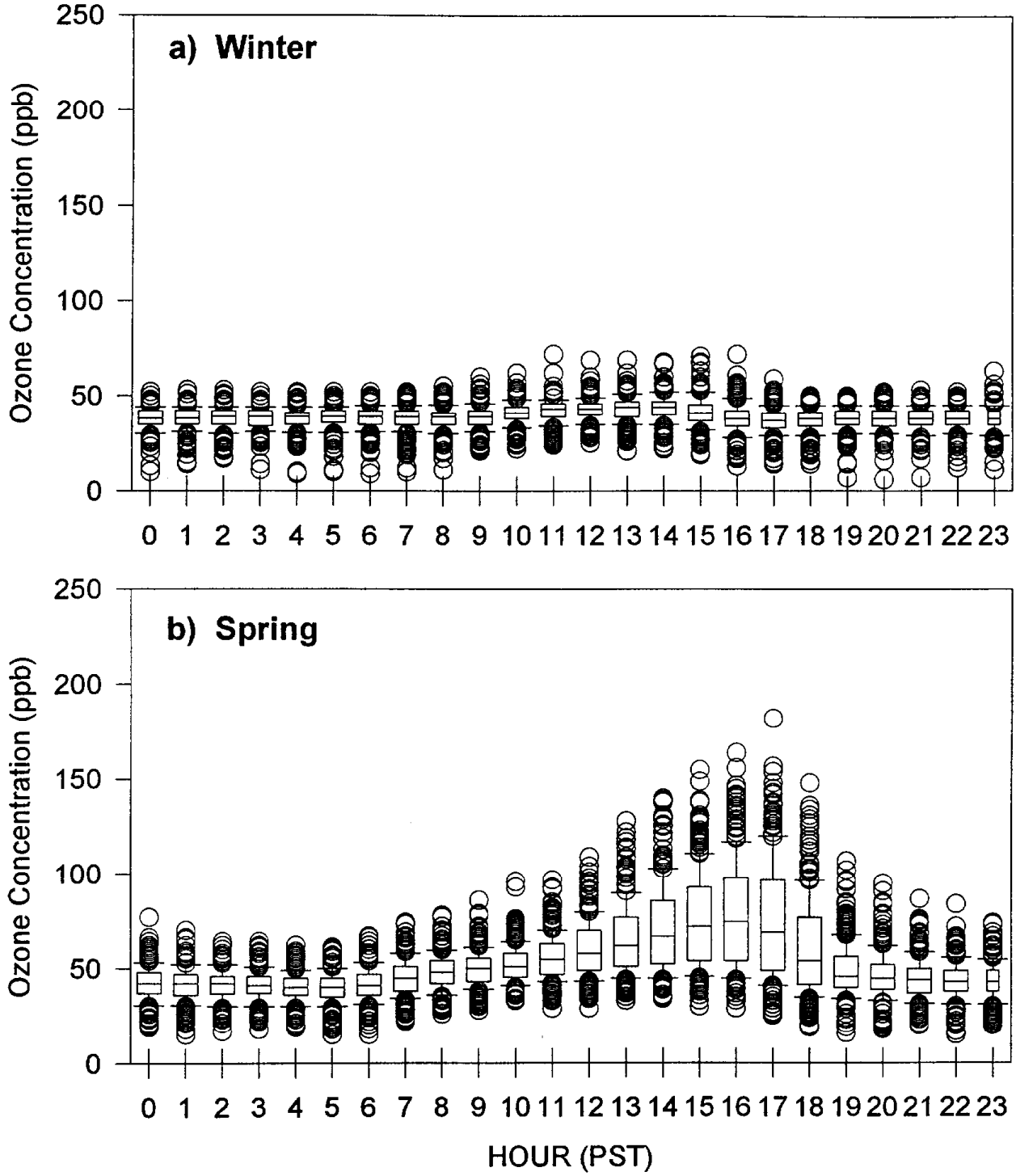
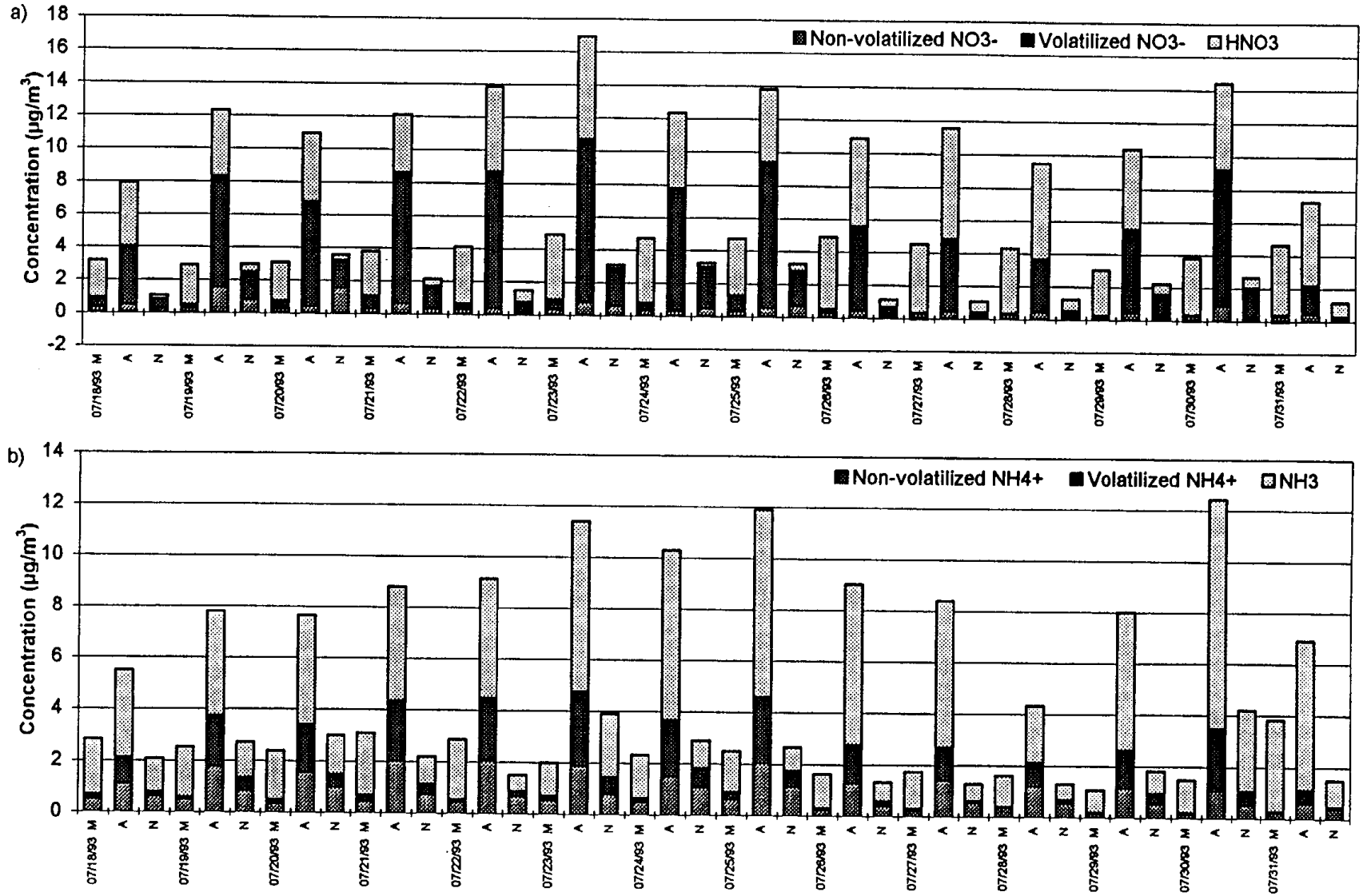


Figure 2-17. Diurnal Box Plots of Hourly Average Ozone Concentration at the Barton Flats Station, CA, During: a) Winter (December of 1991, January, February, and December of 1992 and 1993, and January and February of 1994), b) Spring (March, April, and May of 1992, 1993, and 1994), c) Summer (June, July, and August of 1992, 1993, and 1994), and d) Fall (November of 1991, September, October, and November of 1992, 1993, and 1994).



Figrue 2-16. Diurnal Variations of a) $PM_{2.5}$ Non-volatilized Particulate Nitrate, $PM_{2.5}$ Volatilized Particulate Nitrate and Nitric Acid, and b) $PM_{2.5}$ Non-volatilized Particulate Ammonium, $PM_{2.5}$ Volatilized Particulate Ammonium and Gaseous Ammonia at the Barton Flats Station, CA, During the 1993 Summer Intensive (M = 06:00 - 12:00, A = 12:00 - 18:00, N = 18:00 - 06:00 the next day).

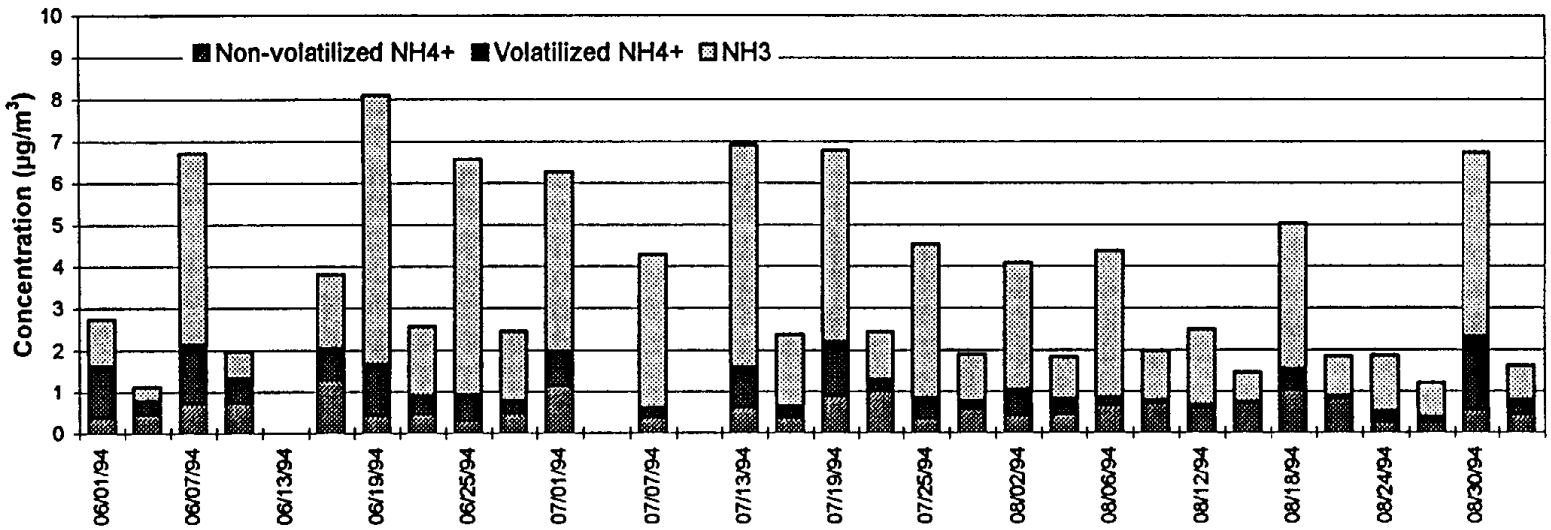


Figure 2-15. Variations of $PM_{2.5}$ Non-volatilized Ammonium, $PM_{2.5}$ Volatilized Ammonium, and Gaseous Ammonia at the Barton Flats Station, CA, During the Summer of 1994 (June, July, and August, 1994).

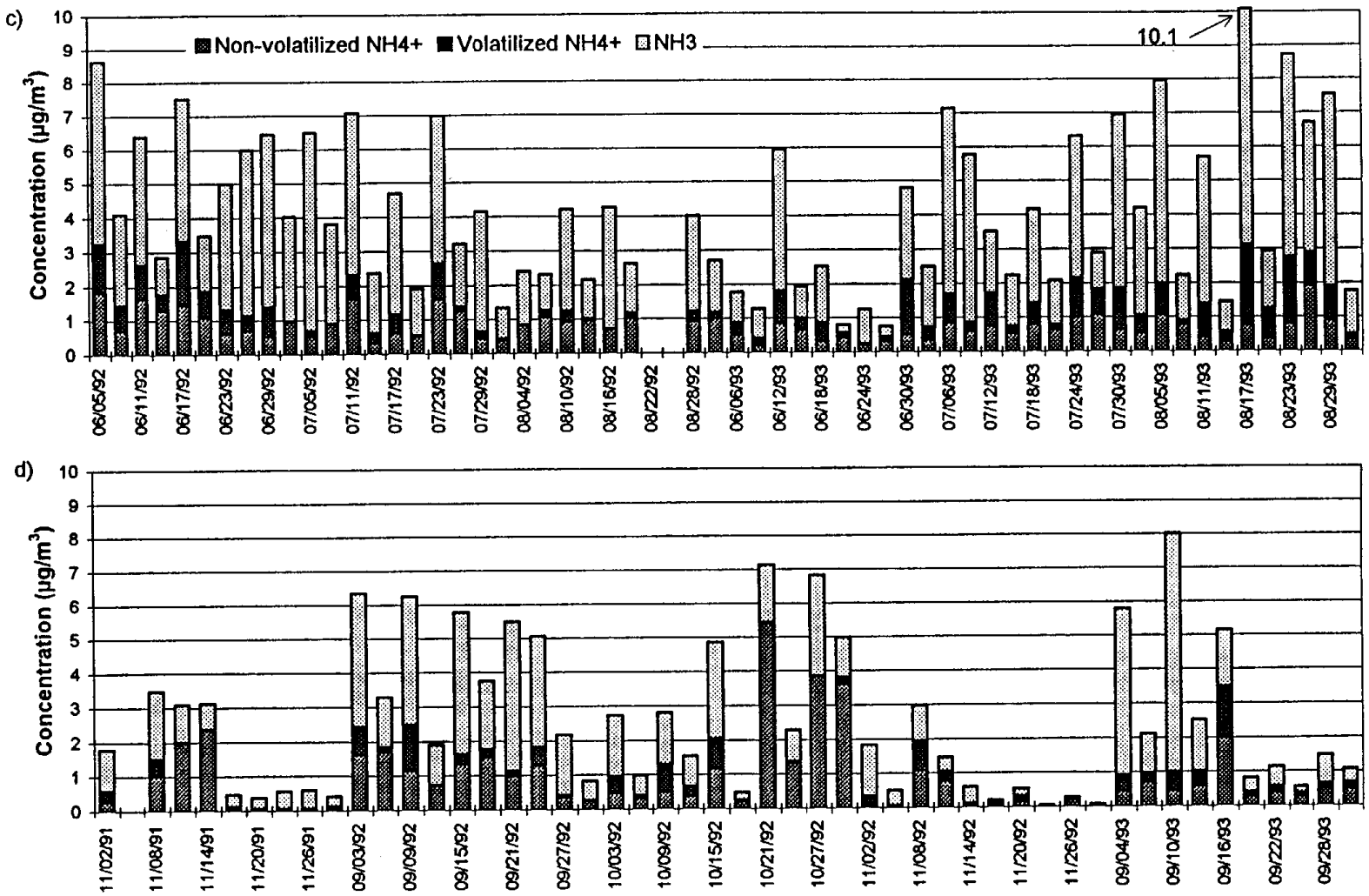


Figure 2-14. (continued). Variations of $PM_{2.5}$ Non-volatilized Ammonium, $PM_{2.5}$ Volatilized Ammonium, and Gaseous Ammonia at the Barton Flats Station, CA, for: a) Winter (December of 1991, January, February, and December of 1992, and January and February of 1993), b) Spring (March, April, and May of 1992 and 1993), c) Summer (June, July, and August of 1992 and 1993), and d) Fall (November of 1991, September, October, and November of 1992, and September of 1993).

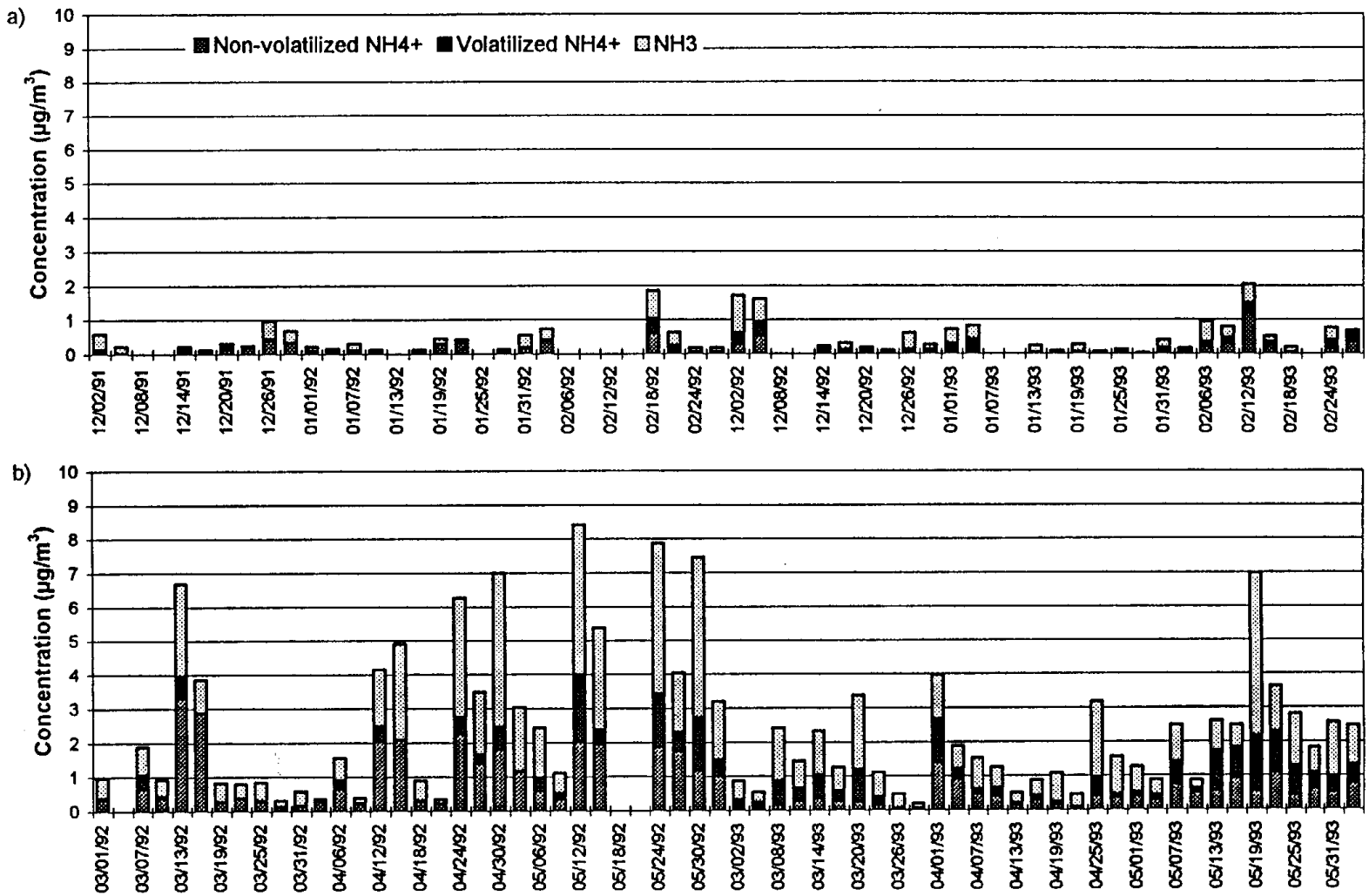


Figure 2-14. Variations of $PM_{2.5}$ Non-volatilized Ammonium, $PM_{2.5}$ Volatilized Ammonium, and Gaseous Ammonia at the Barton Flats Station, CA, for: a) Winter (December of 1991, January, February, and December of 1992, and January and February of 1993), b) Spring (March, April, and May of 1992 and 1993), c) Summer (June, July, and August of 1992 and 1993), and d) Fall (November of 1991, September, October, and November of 1992, and September of 1993).

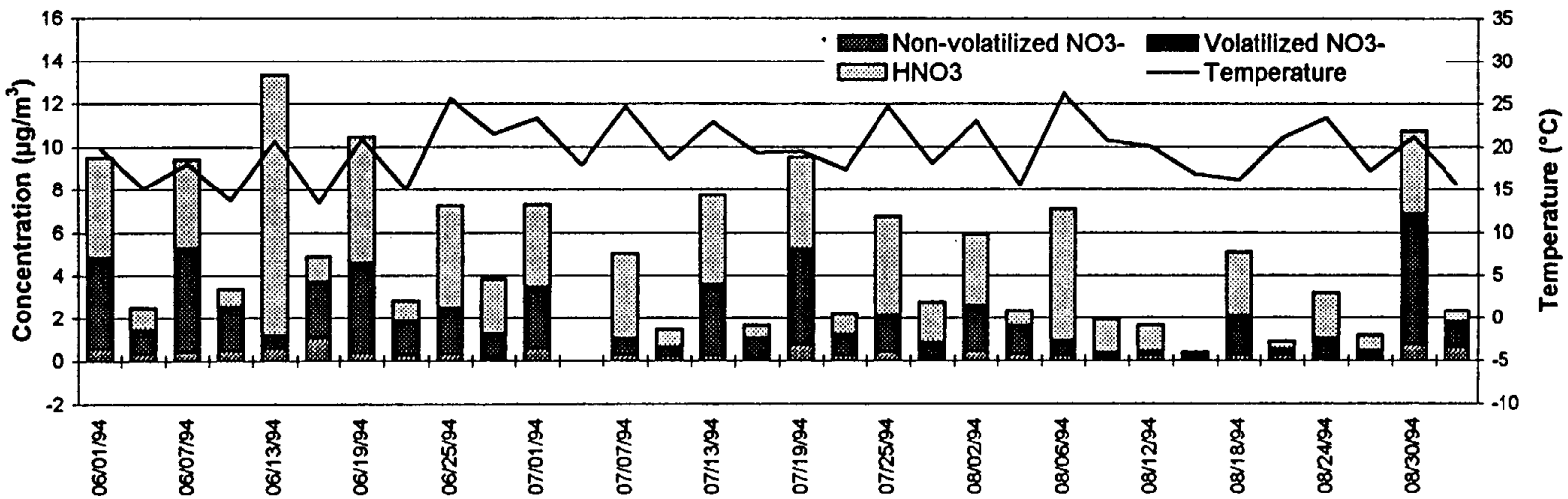


Figure 2-13. Variations of $PM_{2.5}$ Non-volatilized Nitrate, $PM_{2.5}$ Volatilized Nitrate, Gaseous Nitric Acid and Temperature at the Barton Flats Station, CA, During the Summer of 1994 (June, July, and August, 1994).

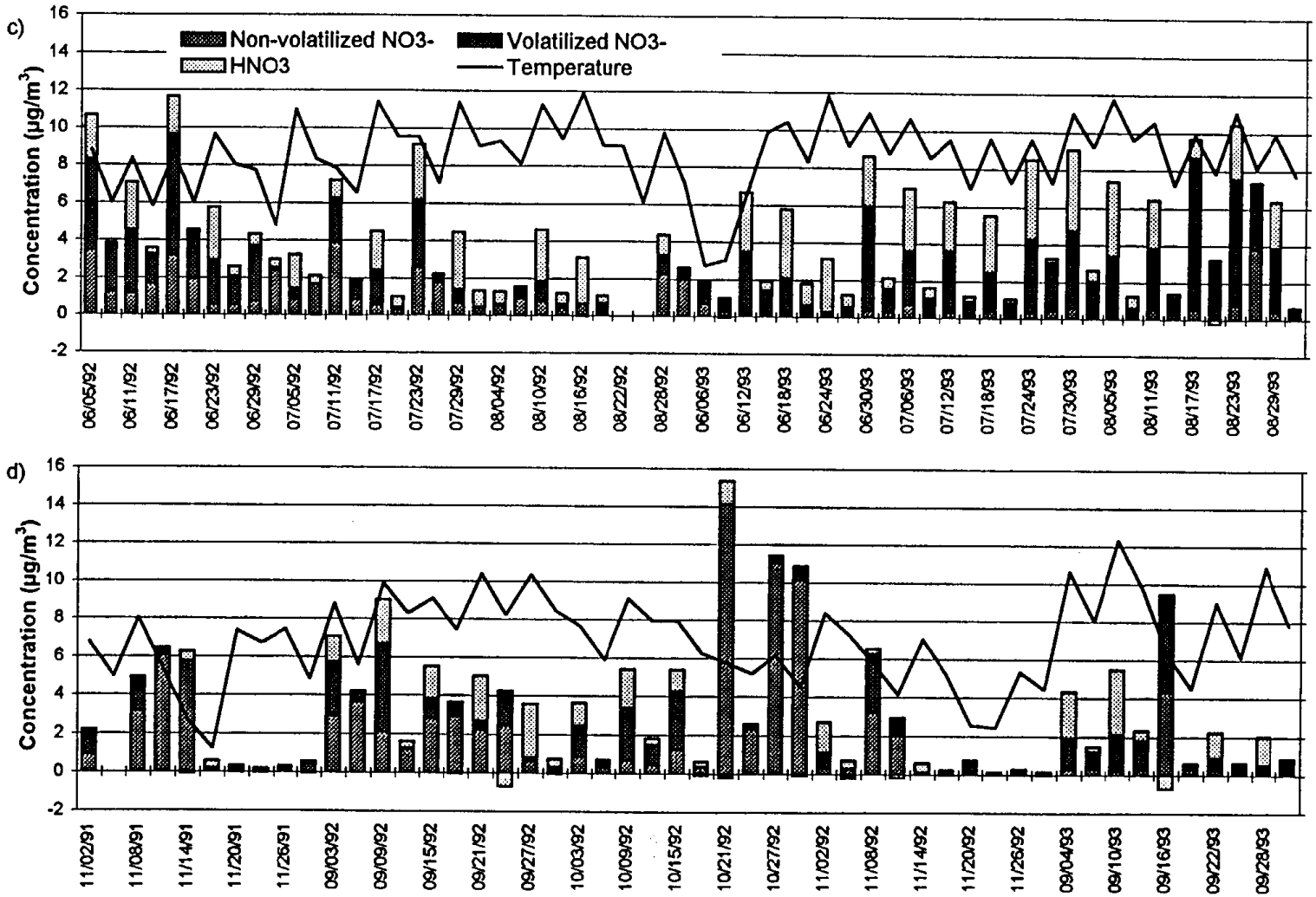


Figure 2-12. (continued). Variations of $PM_{2.5}$ Non-volatilized Nitrate, $PM_{2.5}$ Volatilized Nitrate, Gaseous Nitric Acid, and Temperature at the Barton Flats Station, CA, for: a) Winter (December of 1991, January, February, and December of 1992, and January and February of 1993), b) Spring (March, April, and May of 1992 and 1993), c) Summer (June, July, and August of 1992 and 1993), and d) Fall (November of 1991, September, October, and November of 1992, and September of 1993).

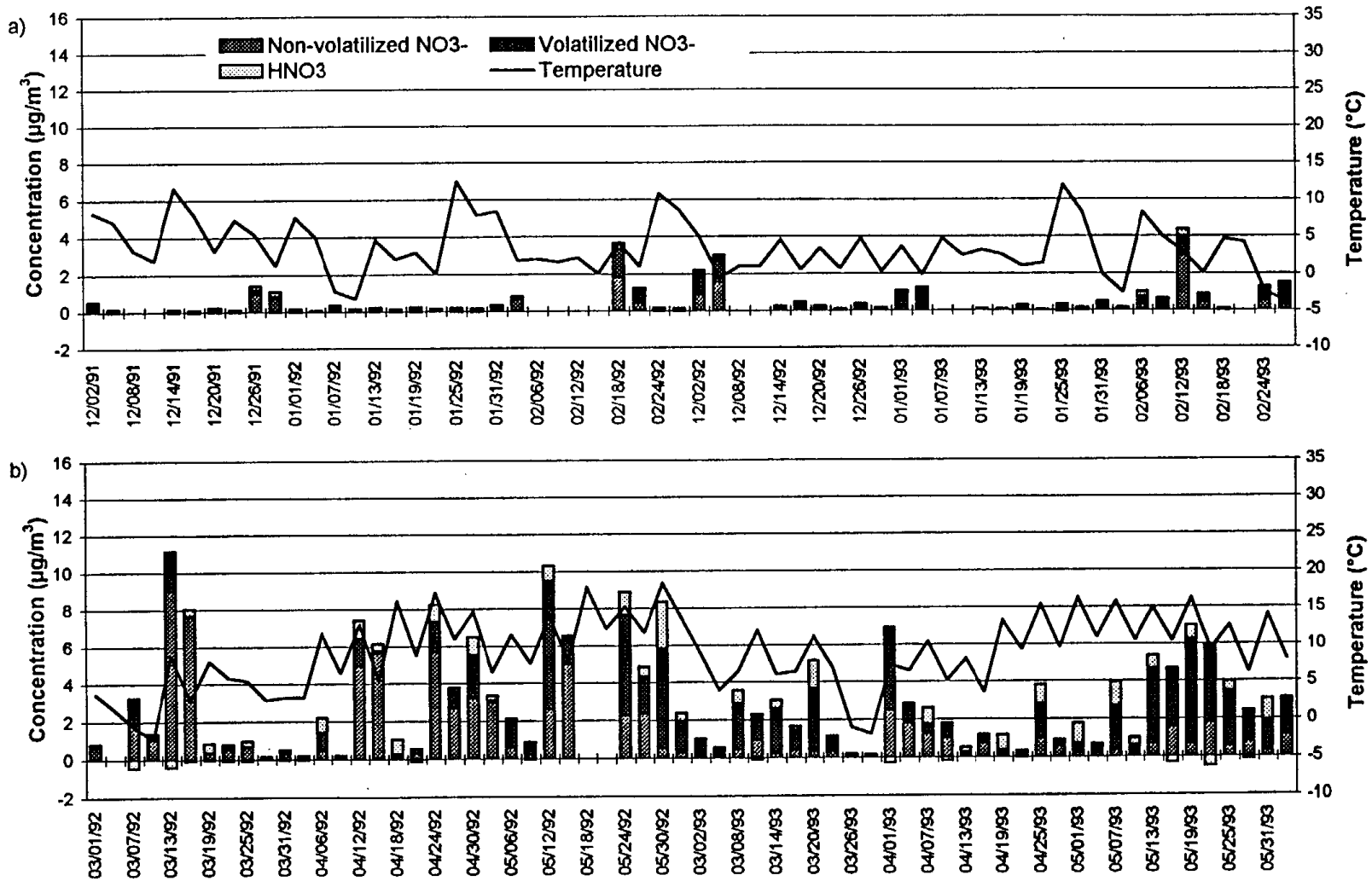


Figure 2-12. Variations of $PM_{2.5}$ Non-volatilized Nitrate, $PM_{2.5}$ Volatilized Nitrate, Gaseous Nitric Acid and Temperature at the Barton Flats Station, CA, for: a) Winter (December of 1991, January, February, and December of 1992, and January and February of 1993), b) Spring (March, April, and May of 1992 and 1993), c) Summer (June, July, and August of 1992 and 1993), and d) Fall (November of 1991, September, October, and November of 1992, and September of 1993).

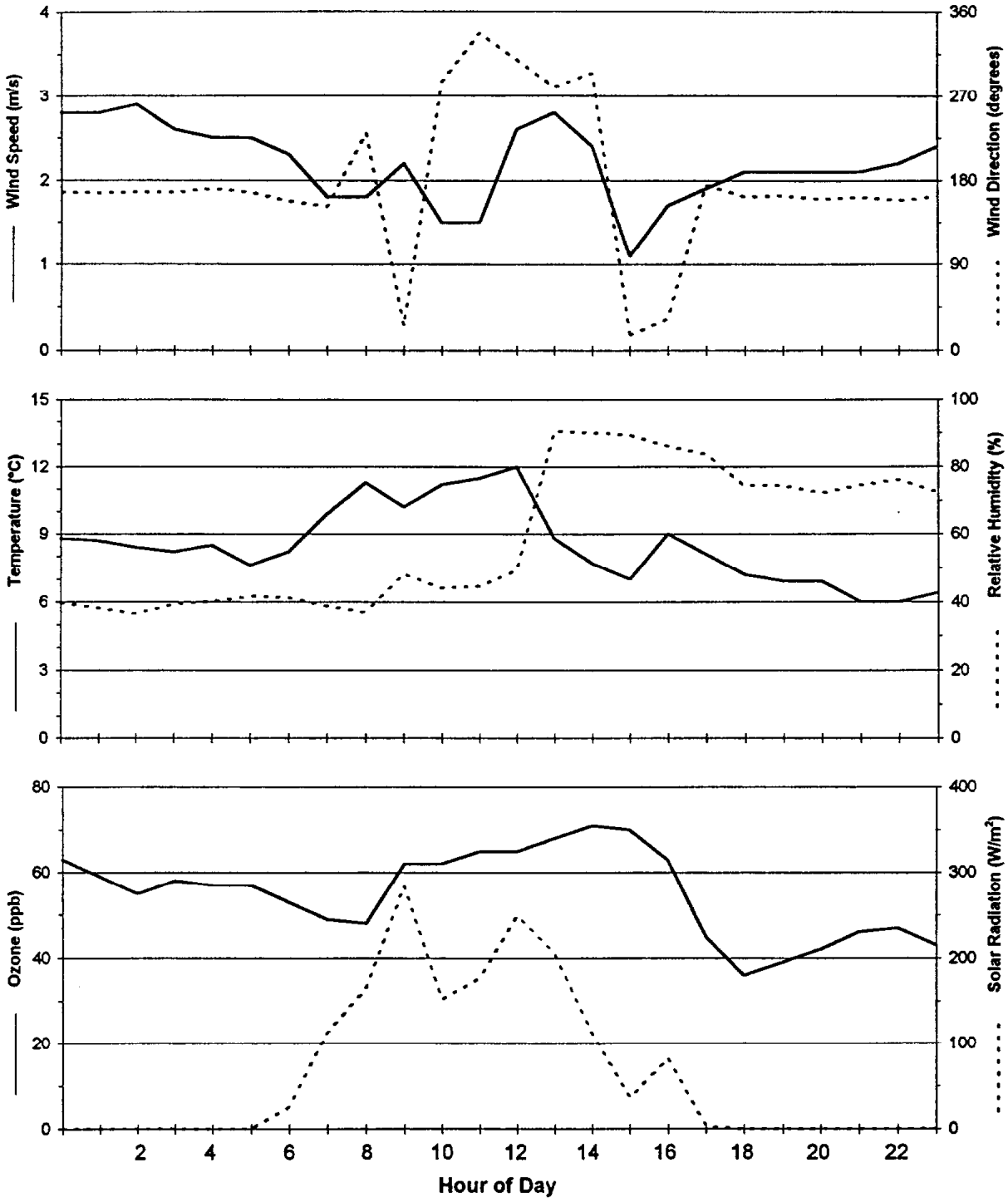
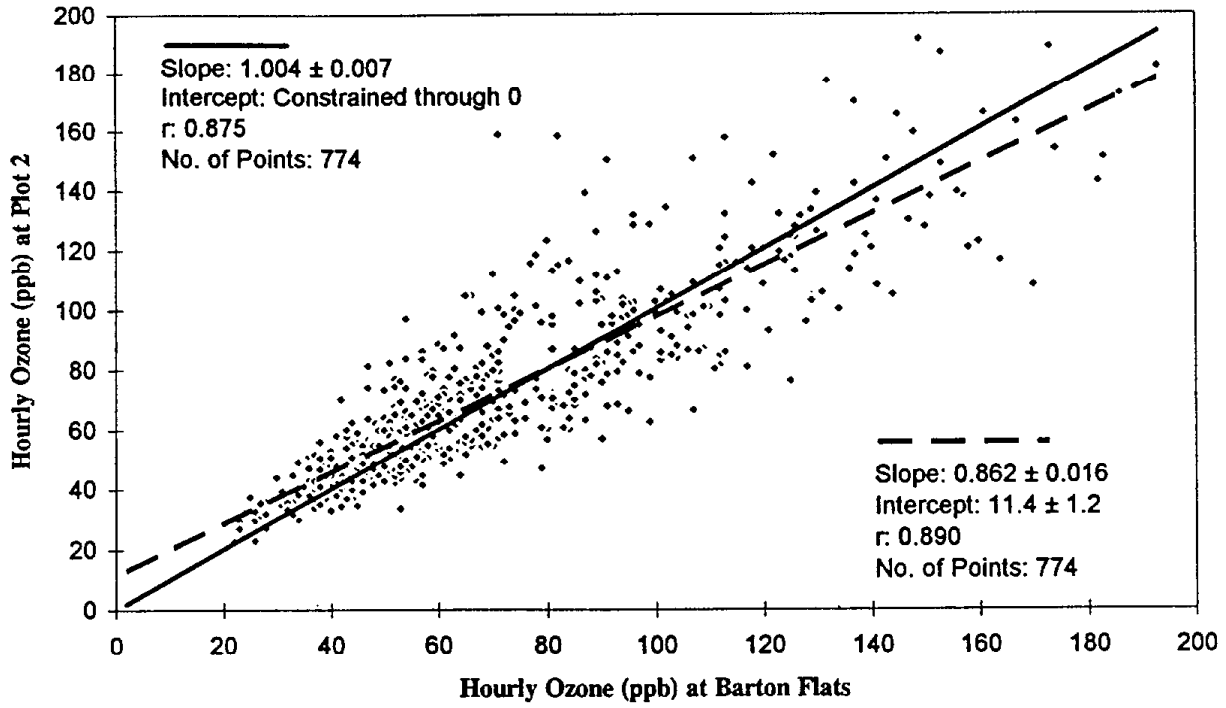


Figure 2-11. Comparison of Wind Speed, Wind Direction, Temperature, Relative Humidity, Ozone Concentration, and Solar Radiation at the Barton Flats Station, CA on 10/21/92.



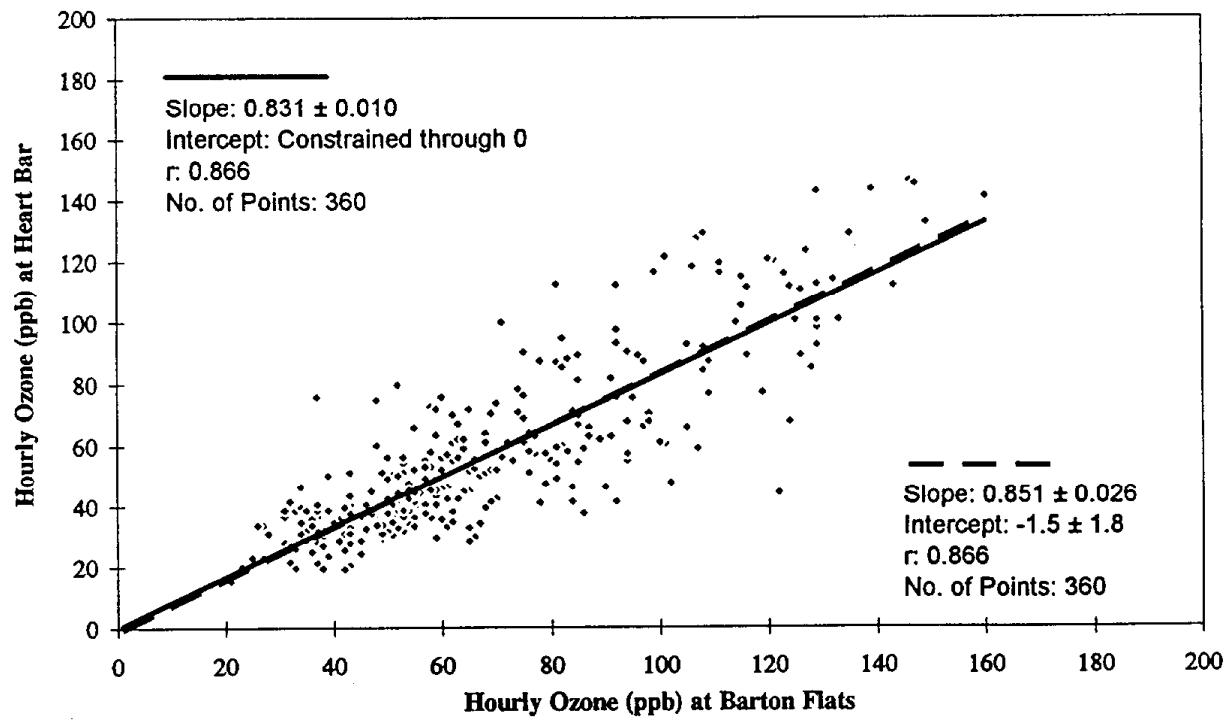


Figure 2-10. Scatter Plot Comparisons of Ozone Concentrations at the Barton Flats Station with those Acquired at the Plot 2 and Heart Bar Stations.

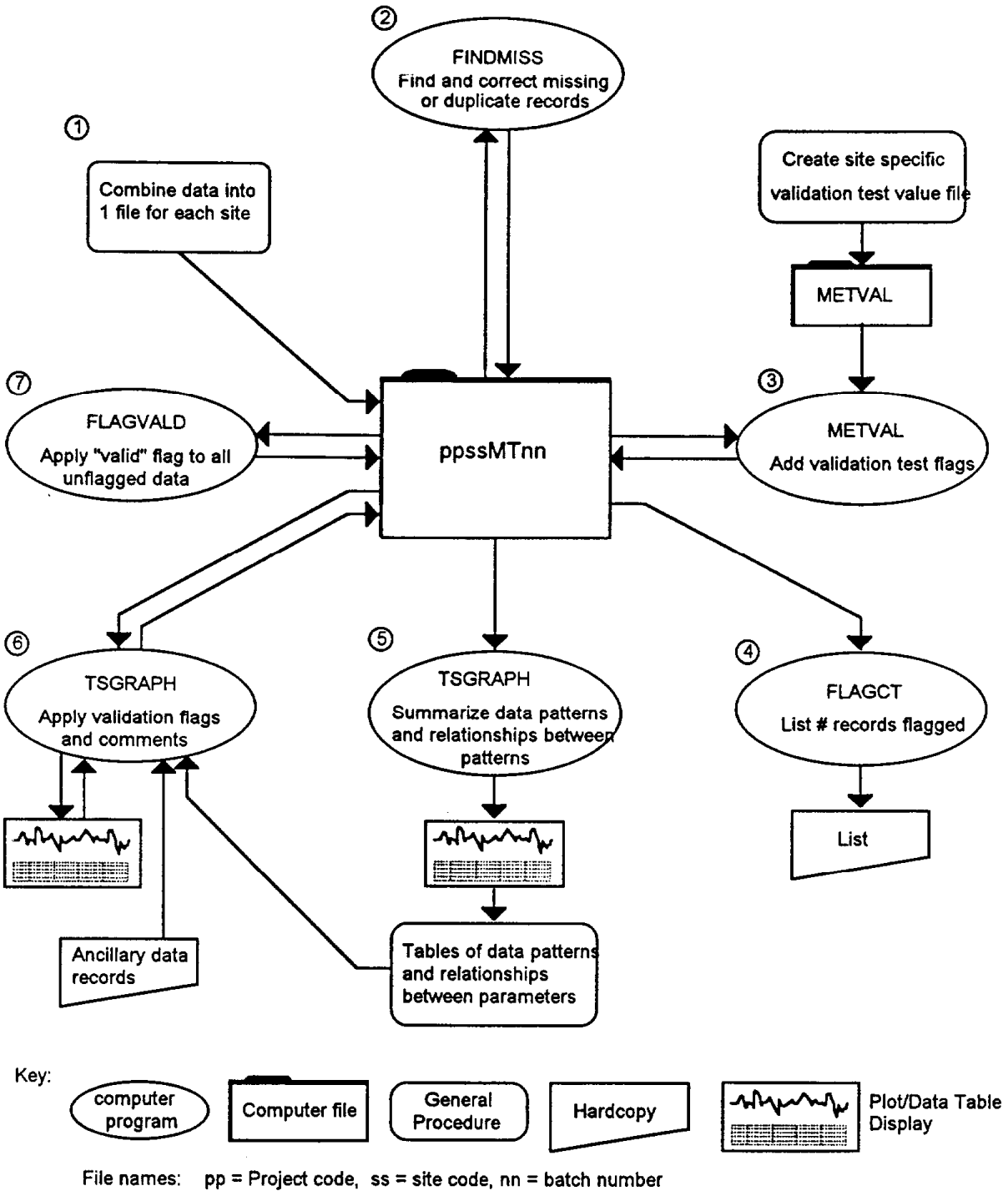


Figure 2-9. Flow Diagram of Hourly Data Processing Steps.

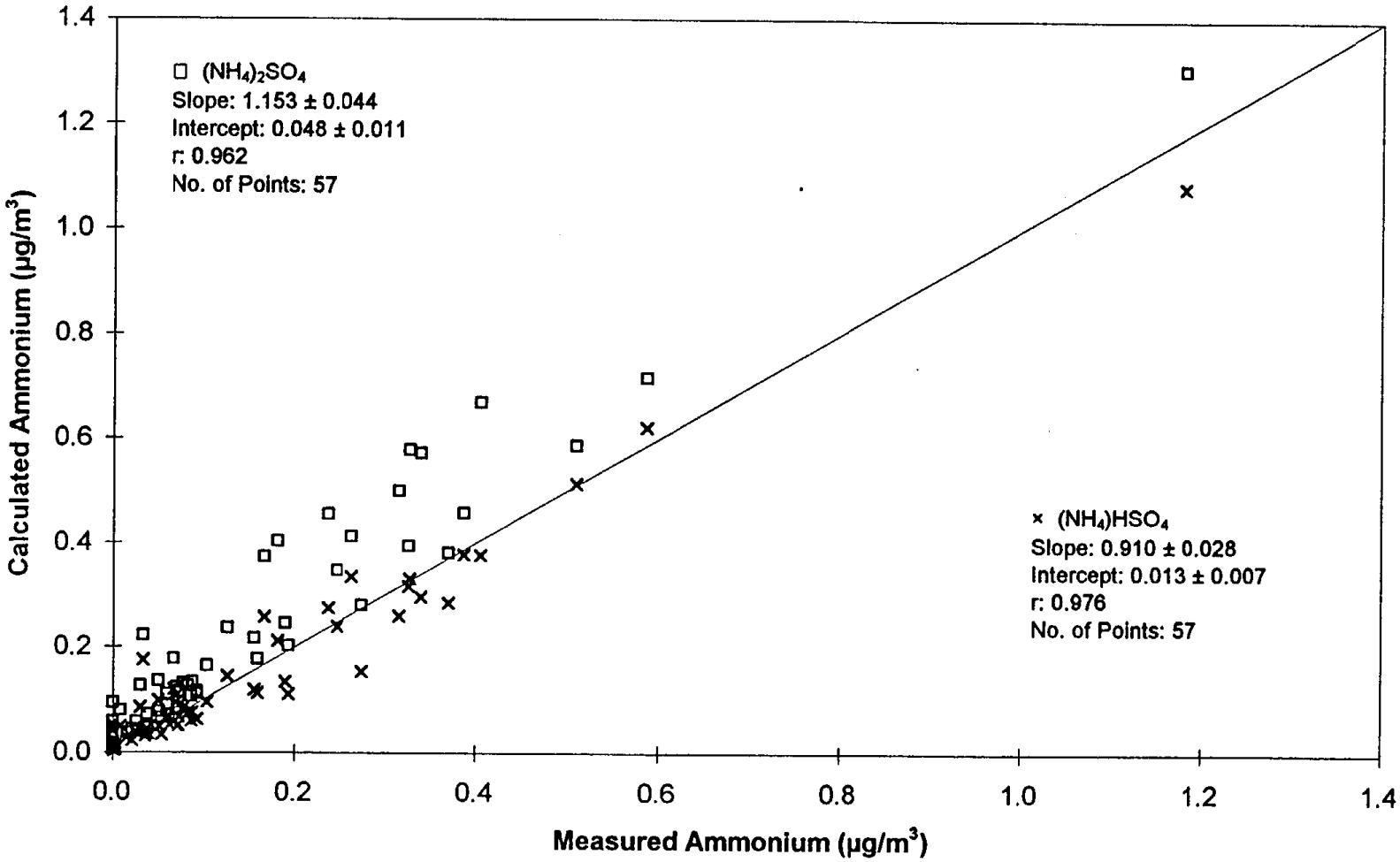


Figure 2-8. Scatter Plot of Calculated Versus Measured $PM_{2.5}$ Ammonium at the Barton Flats Station, CA, during Winter (December, 1991, January, February and December, 1992, and January and February, 1993).

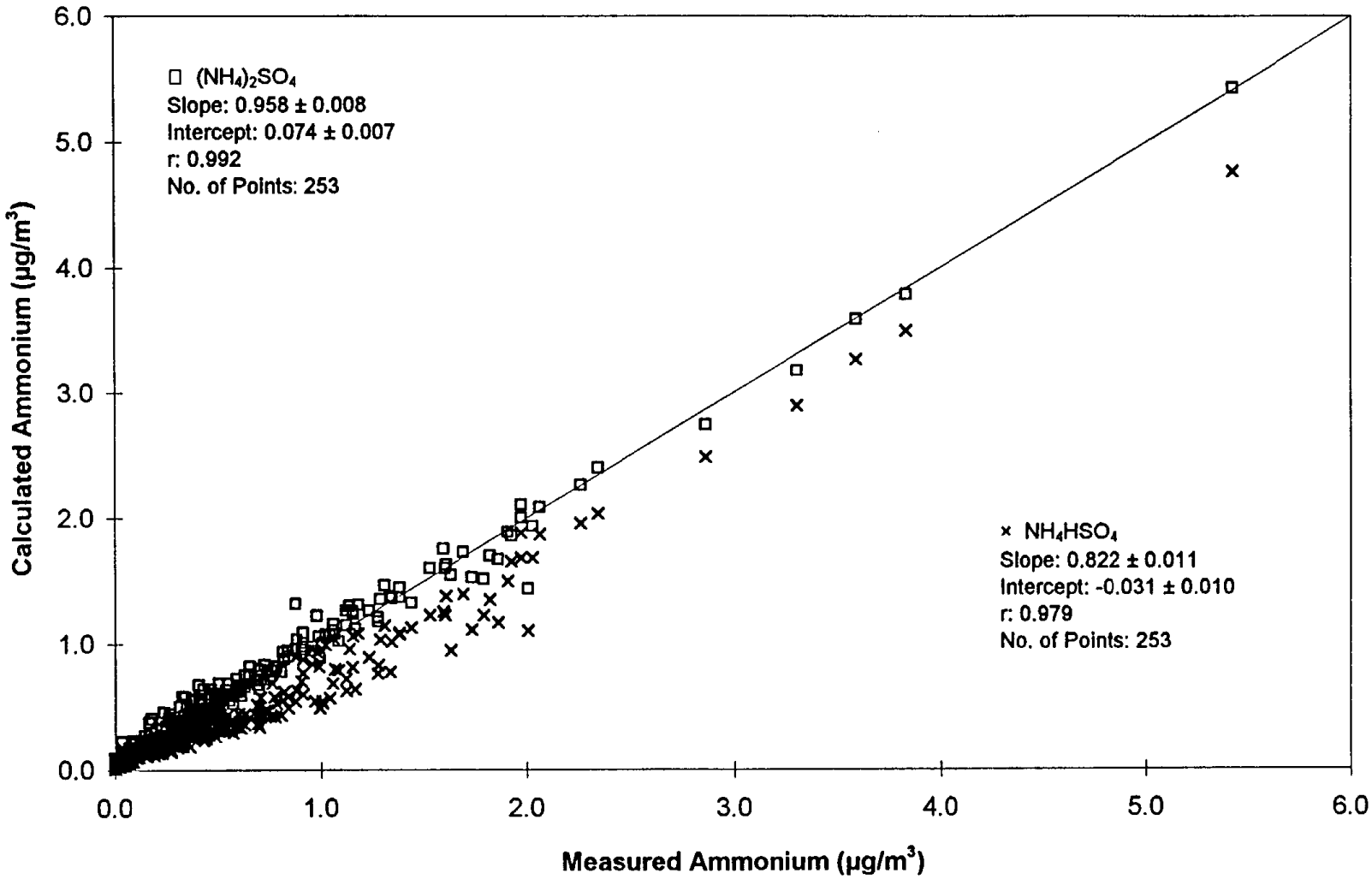


Figure 2-7. Scatter Plot of Calculated Versus Measured $PM_{2.5}$ Ammonium at the Barton Flats Station, CA, Between 11/02/91 and 09/28/93 and Between 06/01/94 and 08/30/94.

3.0 CHARACTERIZATION OF OZONE, PARTICLE CHEMISTRY AND METEOROLOGY MEASUREMENTS IN SUPPORT OF CANOPY DEPOSITION ESTIMATES

P. Miller, A. Bytnerowicz, D. Jones, S. Schilling

3.1 Introduction

The purpose of this section is to describe the vertical gradients of microclimate variables and pollutants in a mixed conifer forest. The variables measured include air concentrations of some of the gases and particles at different positions, including above, within, and below the canopy. Also, the vertical profiles of winds, temperature and relative humidity were determined for a typical forest canopy at plot 2. The measurements were made either at the Barton Flats monitoring station using a 15m triaxial tower or at the 29m climbable scaffold located within 1 mile South of the monitoring station at vegetation plot #2 (See Figure 1-1).

3.2 Methods

3.2.1 Micrometeorology of the Forest Canopy

The first profile comparison was done in all months of the year in 1993 and 1994 at the Barton Flats monitoring site. Temperatures were sensed by a shielded thermistor mounted at 15 m, a shielded thermocouple at 2 m, a small thermocouple inserted in a ponderosa pine needle at 2 m, and thermocouples at 10 cm and 50 cm in the soil. The air, leaf, and soil temperatures, measured by thermocouples were supplied by Dr. Nancy Grulke. There is a 0.3 to 0.5 ° C difference between the sensors with the thermocouples being higher. This correction was not applied to the data. Hourly temperatures were reduced to daily averages and representative results were prepared for February-March 1993 and July-September 1993.

At plot 2 a data logger and sensors provided hourly averages for winds, temperature, and relative humidity at the top of the 29m scaffold and at 2m above the ground. Wind direction was measured at 2m but was not included in the analysis because nearby obstructions caused excessive variability in this measurement. Detailed procedures for the data logging systems are included in Volume 1 of the Standard Operating Procedures (1995).

3.2.2 Ozone Measurements Above and Below Canopy at the Monitoring Station and Between the Monitoring Station and Nearby Locations

Continuous measurements of ozone were made at the Barton Flats monitoring site where the ozone monitor (DASIBI) was located in an air-conditioned shelter. Teflon sample lines of equal length were employed. The intake of one line was placed at a height of 15 m on a triaxial tower. Air flow was completely unobstructed because there were no nearby trees of equivalent height. The intake of the second line was placed at 1.5 m in the understory of a stand comprised of ponderosa pine, white fir and black oak at a distance of 20 m North and slightly downslope from the triaxial tower.

Comparison of ozone concentrations between the monitoring station and other sites required that a solar-charged battery pack, mounted on a trailer, be used as a power source for the DASIBI ozone analyzer. Prior to test periods the second DASIBI was calibrated against the station DASIBI for several days. The two

remote sites of interest were plot 2 and Heart Bar Ranger Station, five miles to the east of the monitoring station (Figure 1-l).

A complete description of the design and specifications of the sampling scheme and equipment for above and below canopy measurements, and for the solar-powered unit, are provided in Volume 1 of the Standard Operating Procedure (1995).

3.2.3 Determinations of Concentrations of Gases and Particles with Annular Denuder Systems.

Average 24-hour concentrations of nitric acid (HNO_3) vapor, nitrous acid vapor (HNO_2), ammonia (NH_3), sulfur dioxide (SO_2) as well as particulate nitrate (NO_3^-), ammonium (NH_4^+), and sulfate (SO_4^{2-}) were determined with annular denuder systems (Possanzini et al., 1983; Peake and Legge, 1987). Constant air flow of 17 L min^{-1} through the systems was provided by the Constant Flow Anderson Pumps (Atlanta, GA). This allowed for quantitative determination of gaseous compounds deposited inside annular denuder tubes and separation of fine fraction of particles (<2.2 micrometers in diameter) deposited on the Teflon and nylon filters and coarse particles (>2.2 micrometers in diameter). Concentrations of nitrate, ammonium and sulfate in the annular denuder tube extracts and filter extracts were determined with ion chromatography (Dionex 4000i ion chromatograph). Concentrations of the pollutants were calculated as $\mu g\ m^{-3}$. Details of the procedure are described in Volume 1 of the Standard Operating Procedure (1995).

Single annular denuder systems were placed at each of four levels on the tower in Plot 2: 29m (tower/canopy top), 24 m (third level), 16 m (second level), and 12 m (bottom of the canopy). In addition, concentrations of the pollutants were measured at the monitoring site (Plot 1) in order to compare their concentrations at Plots 1 and 2. The air samples were collected for 24 hours on five dates during the 1992 season, eight dates during the 1993 season, and four dates during the 1994 season.

Differences between concentrations at different levels on the tower and between different collection times for each season were determined with a two-way analysis of variance and the Bonferroni t-test (SigmaStat, 1994).

3.3 Results

3.3.1 Measurements of Meteorological Variables Above and Within the Canopy

3.3.1.1 Summer and Winter Comparisons at the Barton Flats Monitoring Site

Data are available for both 1993 and 1994 but for this report we include only daily averages for February-March, and July, August and September 1993 to represent typical winter and summer conditions. Figures 3-1, 3-2, and 3-3 compare the shielded thermistor at 15 m with thermocouples for 2 m (air and leaf), and soil during February and March. Figures 3-4, 3-5, and 3-6 display the same variables for July, August and September.

The thermistor (station temperature) at 15m is consistently higher than air or leaf temperatures at 2 m in both seasons. The exception is a cold period in February 1993 when the difference decreased between these positions. In both seasons there was no detectable difference between leaf temperature and air temperature at 2 m.

During the February 1993 cold period the 50 cm deep soil temperature was slightly warmer than the 10 cm soil temperature. Summer period soil temperature was available only for 10 cm depth and seemed to be slightly above or to track air temperature at 15 m. This difference reversed as air temperatures warmed up in March.

3.3.1.2 June through October Monthly Average Temperature, Relative Humidity and Wind Speed for Day and Night Periods in a 29m Profile at Plot 2.

Table 3-1 shows the monthly day/night differences for 1993. When these data are interpreted as differences from the measured values at 29 m we see that for daytime hours the temperature at 29 m was less in June and July, about the same in August and greater in September and October than at 2m. Night temperatures at 29 m ranged from 4 to 6 C higher than at 2m in all months. For relative humidity the daytime values at 2 m were higher by 1-4 percent, while night values were 7-17 percent lower than at 2m in all months. During the day wind speeds at 29 m were higher (1.8-2.6 m/s) than at 2 m, while at night the difference was much less (in the range of 0.4 to 1.3 m/s).

The general diurnal pattern for winds as described in Section 2.0 is very helpful in understanding the day/night temperature difference between 29 m and 2 m. The cooler night temperature (4-6 C) at 2m indicates the downslope flow (from the southeast) of a surface layer of cool air coming from the higher terrain in that direction. The night temperature environment for foliage at the top of the canopy (29 m) is much warmer than at the near surface position where temperatures are usually monitored. Wind speed is important in the dry deposition process. These data provide an estimate of the magnitude of the wind speed change from the top of the canopy to near ground level.

3.3.2 Ozone Measurements Above and Below Canopy at the Monitoring Station and Between the Monitoring Station and Nearby Locations.

3.3.2.1 Above and Below Canopy

The hourly ozone concentrations at the monitoring site were compared during four consecutive day periods in 1992 from July 27-30, September 12-15, and October 11-14 (Figures 3-7, 3-9, and 3-11). The comparisons of individual ozone measurements for the daylight period and night period for a single 24 hour period are shown for July 28-29, September 13-14, and October 13-14 (Figures 3-8, 3-10, and 3-12). The latter group of figures amplify the differences shown between diurnal concentration differences above and below the canopy for the July, September and October periods. The principal result is that in July both night and day concentrations were reduced in the lower canopy (1.5 m) compared to above the canopy (15 m). During the September and October sample periods there was no difference in daytime concentrations above canopy and in the lower canopy, a difference developed only at night.

The day and night changes of ozone concentration between 1.5 m and 15 m is contributed to by a mixture of factors. First during July there were several small rains. The residual moisture could have contributed to more dew formation and wetness of the surfaces which in turn increased night-time and early morning deposition of ozone. Second the level of soil moisture availability was higher, stomatal conductance was

higher and a greater ozone flux to leaf tissue kept lower canopy ozone concentrations lower than above canopy. In September and October there was no rain, soils were dryer, and stomatal conductance was lower and ozone flux to leaf tissue was much less. Another controlling variable which is common to all three periods is the difference in vertical mixing of ozone into the canopy between night and day periods. Daytime heating creates vertical circulation which constantly replenishes lower canopy ozone. At night with general cooling a boundary layer develops and downward mixing is at a minimum. Indeed, ozone flux calculations performed as part of the companion ARB-sponsored project at this site show that the early summer flux rates are much higher than those of late summer (Temple, Personal Communication)

3.3.2.2 Ozone Concentration Differences Between the Barton Flats Monitoring Station, Plot 2 and Heart Bar.

The purpose of the supplementary monitoring task was to help estimate the representativeness of the ozone data at the monitoring station with respect to nearby vegetation plots. A solar-charged lead-acid battery pack, mounted in a customized trailer, allowed measurements to be made at sites without line power. Periodic measurements were made at plot 2 in both 1993 and 1994, at Heart Bar in 1994 (Figure 1-1). Some regression comparisons of these data sets are reported in Section 2, however, here we report additional ozone exposure indices for these locations (Table 3-2 and 3-3).

Tables 3-2 shows that 24 hr averages were usually similar between these sites which are approximately 1 mile apart. The Sum 60 and Sum 80 indices appear to be lower at plot 2 during July and early August but not in September measurement periods. The same trend applies to Sum 80 comparisons. Both comparison periods at Heart Bar (Table 3-3), which is located 5 miles to the east, indicate an expected decrease in all indices, particularly the Sum 60 and Sum 80 values.

Under the conditions of air pollution transport in this drainage it appears that one could extrapolate monitoring station values confidently out to one mile or perhaps slightly more (based on the data in Tables 3-2 and 3-3). At 5 miles distance (Heart Bar) the decrease of ozone concentration along this transport and diffusion path would make it necessary to have an independent monitoring site.

3.3.3 Particle and Gas Chemistry at Four Height Intervals in a 30 m Profile at Plot 2 Determined by Annular Denuder Air Samplers.

3.3.3.1 Nitric Acid

Concentrations of nitric acid vapor at different heights on the tower and the monitoring plot are presented in Figures 3-13 through 3-15. During the 1992 season the highest concentrations of HNO_3 were determined on the top of the tower and the lowest on the two lower levels. The highest concentrations were determined during on May 28 (Figure 3-13). During the 1993 season no significant difference between concentrations at the three upper levels of the tower were seen. Concentrations at the third level were significantly higher than at the bottom of the tower. The lowest concentrations were determined on May 31 and August 28 and the highest on June 30 (Figure 3-14). During the 1994 season no significant differences in concentrations between various levels on the tower were determined. Concentrations measured on June 9 and August 6 were

higher than the values determined on July 7 and August 30 (Figure 3-15). Ranges of HNO_3 concentrations in the 1992 and 1993 seasons and July 7 and August 30, 1994 periods were generally similar. Concentrations during the June 9 and August 6, 1994 periods were about two times higher than during the remaining measurement periods.

3.3.3.2 Nitrous Acid

Concentrations of nitrous acid vapor during the 1992 season on the tower were in a range of 0.097 - 0.425 $\mu g\ m^{-3}$ (average 0.21 $\mu g\ m^{-3}$); 1993 season in a range of 0.00 - 0.35 $\mu g\ m^{-3}$ (average 0.05 $\mu g\ m^{-3}$); and in 1994 season in a range of 0.00 - 0.12 $\mu g\ m^{-3}$ (average 0.03 $\mu g\ m^{-3}$).

3.3.3.3 Ammonia

Concentrations of NH_3 are presented in Figures 3-16 through 3-18. During the 1992 no significant effect of position on the tower was determined. The highest concentrations were found on July 23, followed by June 17 and August 28. The lowest values were found on May 28 and September 27 (Figure 3-16). During the 1993 season no significant effect of position on the tower was found. The highest concentrations were found on June 30 and the lowest on September 28. No significant differences between the other dates of measurement were determined (Figure 3-17). Similarly as for the 1992 and 1993 seasons, also during the 1994 season position on the tower did not affect concentrations of NH_3. The highest concentrations were determined on August 30. No significant differences were found for the remaining dates (Figure 3-18). The ranges of NH_3 concentrations during the three seasons were similar.

3.3.3.4 Sulfur Dioxide

Concentrations of SO_2 are presented in Figures 3-19 through 3-21. During the 1992 season position on the tower did not affect concentrations of SO_2. The highest concentrations were determined on June 17, followed by August 28. No differences were found between the July 23 and September 27 determinations. The lowest concentrations were determined on May 28 (Figure 3-19). During the 1993 season no significant effects of position on the tower were found. The highest concentrations were determined on August 29 measurements, followed by June 30. Concentrations of SO_2 during the remaining dates were similar (Figure 3-20). Similarly as for the two other seasons, in 1994, position on the tower did not affect SO_2 concentrations. The highest concentrations were determined on June 9 and the lowest during on July 7 (Figure 3-21). The ranges of SO_2 concentrations during the three seasons were similar.

3.3.3.5 Nitrate Ion

Concentrations of NO_3^- are presented in Figures 3-22 through 3-24. Position on the tower did not affect concentrations measured in the 1992 season. The highest concentrations were determined on June 17 and the lowest on May 28 and September 27 (Figure 3-22). During the 1993 season position on the tower did not affect the measured concentrations. Concentrations on June 30, July 19 and July 22 were the highest while concentrations measured on September 28 the lowest (Figure 3-23). Similarly as for the two other seasons, during the 1994 season, position on the tower did not affect the NO_3^- concentrations. The highest

concentrations were determined on August 30 and the lowest on July 7 and August 6 (Figure 3-24). Except the June 17, 1992 measurements, concentrations of NO_3^- during the three seasons were similar.

3.3.3.6 Ammonium Ion

Concentrations of NH_4^+ are presented in Figures 3-25 through 3-27. During the 1992 season position on the tower did not affect the NH_4^+ concentrations. The highest concentrations were determined on June 17 and July 23 and the lowest during the May 28 and September 27 measurements (Figure 3-25). No effects of position on the tower on concentrations on NH_4^+ were determined during the 1993 season. The highest concentrations were determined on July 22 and the lowest on July 22, August 29 and September 28 (Figure 3-26). During the 1994 seasons neither position on the tower nor date of measurements affected the NH_4^+ concentrations (Figure 3-27). The ranges of NH_4^+ concentrations were similar during the three seasons.

3.3.3.7 Sulfate Ion

Concentrations of SO_4^{2-} are presented in Figure 3-28 through 3-30. During the 1992 season position on the tower did not affect the SO_4^{2-} concentrations. The highest concentrations were determined on July 23, followed by the June 17, May 28 and August 28 measurements. The lowest concentrations were determined on September 27 (Figure 3-28). During the 1993 season position on the tower did not affect the SO_4^{2-} concentrations. The highest concentrations were determined on June 30 and July 19, and the lowest during the July 26 and August 29 measurements (Figure 3-29). During the 1994 season position on the tower did not affect the SO_4^{2-} concentrations. Significantly higher levels were determined on June 9 and August 6 compared with the July 7 and August 30 measurements (Figure 3-30). Similar ranges of SO_4^{2-} concentrations occurred in the 1992 and 1994 seasons. Values determined in the 1993 season were the lowest and stayed below 1 $\mu g\ m^{-3}$.

3.4 Discussion

The purpose of this section was to sample some of the expected variability in stand microclimate and the concentrations of gases and particles above and below the forest canopy. The term "canopy" is more appropriately applied to those forests in the eastern or northwest parts of the United States where the leafy crowns of trees form an almost continuous cover over the forest floor. In our study area the tree cover is much more discontinuous including many sunlit openings between trees. This configuration presents a much more complex problem when estimating the deposition of gases and particles to a forest community. In recognition of this complexity we have undertaken this suite of measurements to help assess the variability and to provide information to supplement model predictions described in Section 8.

Measuring vertical gradients of temperature, relative humidity, and wind speed in a forest stand is important because these variables, acting in concert with light penetration, all influence pollutant uptake by leaves occupying different vertical strata. An extreme example is the difference in pollutant uptake that may exist between large seedlings (less than 2 m in height) and foliage of mature trees at the top of the canopy (at approximately 30 m). There could also be a difference in uptake for foliage at different heights on a mature tree. Vertical gradients were observed for ozone concentration which seem to be changing with season,

partially as a function of the stomatal conductance. The comparisons of temperature, relative humidity and wind speeds at 29 m and 2 m on a scaffold show the expected decline of wind speed from top to bottom, which in turn influences the deposition of pollutants, including ozone, nitric acid, nitrous acid, ammonia, sulfur dioxide, and fine particles containing nitrate, ammonium and sulfate.

Though wind speed is expected to influence pollutant deposition rates over time, there was no evidence of a consistent significant effect of sampling position on the tower on air concentrations of the pollutants sampled by annular denuder systems. One reason is probably the openness of the canopy upwind from the 29m scaffold. In the westerly direction from which pollutants are transported there was no nearby canopy to inhibit vertical mixing. In more densely forested locations it may have been possible to observe a vertical concentration gradient. Nevertheless these measurements provide an excellent basis for comparison with pollutant concentrations at other sites.

Nitric acid concentrations at Barton Flats were moderately high. For a comparison, the summer average concentrations determined in Oak Ridge, TN, and Gottingen, Germany, were 3.0 and 5.8 $\mu g\ m^{-3}$, respectively (Lindberg et al., 1990). At Tanbark Flat of the San Gabriel Mountains, the mountain site which is considered as one of the most polluted in the United States (Bytnerowicz et al., 1987), the average 24-hour concentrations during the 1988 - 1991 seasons were in a range of 6.7 - 11.7 $\mu g\ m^{-3}$ (Grosjean and Bytnerowicz, 1993). At various locations in the Sierra Nevada the average 24-hour summer concentrations were below 1 $\mu g\ m^{-3}$ (Ashbaugh et al., 1991).

Concentrations of nitrous acid vapor were lower than the summer average concentrations at Tanbark Flat (0.55 - 0.65 $\mu g\ m^{-3}$) (Grosjean and Bytnerowicz, 1993), however, higher than the concentrations at the remote location of Fortress Mountain in the Canadian Rockies (Legge and Krupa, 1989).

Concentrations of ammonia were elevated and similar to the values determined at Tanbark Flat, San Gabriel Mountains (Grosjean and Bytnerowicz, 1993) and Gottingen, Germany (Lindberg et al., 1990). The measured concentrations were several times higher than those measured at Fortress Mountain (Legge and Krupa, 1989) and Oak Ridge (Lindberg et al., 1990). However, concentrations measured in various locations in the Netherlands and Great Britain may be several times higher than the Barton Flats values (Keuken et al., 1988; Draaijers et al., 1989).

Concentrations of sulfur dioxide were low and at the levels normally occurring in southern California (Bytnerowicz et al., 1987). The measured concentrations were typical for the U. S. western states and stayed well below phytotoxicity levels (Bohm, 1992).

Concentrations of nitrate in fine particles were high and similar to the values determined at Tanbark Flat of the San Gabriel Mountains (Bytnerowicz et al., 1987; Grosjean and Bytnerowicz, 1993). These values many times exceeded the values determined for Fortress Mountain (Legge and Krupa, 1989) and Oak Ridge (Lindberg et al., 1990). The reported values were similar to the concentrations determined at other locations of the San Bernardino Mountains (Fenn and Bytnerowicz, 1993) as well as the values measured in the Los Angeles Basin (Sickles et al., 1988; Pierson and Brachaczek, 1988).

Concentrations of ammonium in fine particles were similar to the values determined at Tanbark Flat (Bytnerowicz et al., 1987; Grosjean and Bytnerowicz, 1993), and Camp Paivika of the San Bernardino Mountains (Fenn and Bytnerowicz, 1993). The determined concentrations were also similar to the values observed in the urban Los Angeles area (Sickles et al., 1988). Ammonium concentrations reported for Oak Ridge and Gottingen (Lindberg et al., 1990) were higher than the Barton Flats values.

Concentrations of sulfate in fine particles were similar to the values determined at Tanbark Flat (Bytnerowicz et al., 1987) and at Camp Paivika (Fenn and Bytnerowicz, 1993). They were similar to the values determined at Fortress Mountain of the Canadian Rockies (Legge and Krupa, 1989).

In general, position on the tower did not affect concentrations of the measured atmospheric species. Significant differences occurred between individual sampling events. Also, concentrations of the measured species were in similar ranges during the three seasons.

3.5 Summary

- Measurement of vertical gradients of pollutants and associated microclimate in the canopy helps identify strata with maximum pollutant uptake.
- The vertical concentration gradients of several gas and particle pollutants were measured. No significant differences were seen in concentrations at different heights ranging up to 29 m for nitric acid, nitrous acid, ammonia, sulfur dioxide, and particles containing nitrate, ammonium and sulfate. Significant differences occurred during the individual sampling events. The ranges of gases and particles were similar during the three seasons.
- Ozone concentrations in the lower canopy at 2 m were slightly lower than at 15 m during both day and night in the early July and only at night in September and October. Daytime reductions may be related to higher stomatal conductance and more ozone uptake by foliage in the early and mid-summer.
- The above canopy air temperature at 15 m was compared in both summer and winter months with air and leaf temperature at 2 m (usually slightly cooler) and soil temperature at 10 cm.
- Ozone measurements at vegetation plots up to one mile from the permanent monitoring site showed that it was possible to extrapolate monitoring site ozone data at least one mile under this set of conditions. Concentration-weighted ozone exposure indices (Sum 60) begin to show differences sooner as compared with the 24 hr average, as one gets more distant from the monitoring site.

3.6 References

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Table 3-1. Summer month comparisons of day/night differences for temperature, relative humidity and wind speed at 29 m and 2 m on a climbable scaffold at Plot 2 in 1993. Day/night length for each month was computed from light sensor record.

Temperature °C

	Day		Night	
MONTH	29m	2m	29m	2m
JUNE	16.8	17.9	13.7	9.7
JULY	18.8	19.1	16.1	10.0
AUG	19.5	19.2	16.4	11.0
SEPT	18.3	17.5	15.1	8.8
OCT	13.1	12.2	10.4	5.5

Relative Humidity %

	Day		Night	
MONTH	29m	2m	29m	2m
JUNE	46	42	46	58
JULY	43	40	38	55
AUG	42	41	42	57
SEPT	36	32	33	43
OCT	45	42	45	52

Wind Speed m/sec

	Day		Night	
MONTH	29m	2m	29m	2m
JUNE	3.6	1.0	2.3	1.0
JULY	2.6	.8	1.5	1.1
AUG	2.9	.8	1.6	1.1
SEPT	3.0	1.0	2.0	1.4
OCT	3.0	.8	2.3	1.0

Table 3-2. Comparisons of several ozone exposure indices (ppb or ppb-hr) at the Barton Flats monitoring site and Plot 2 in 1993 and 1994.

			Solar Trailer			Monitoring station		
Location	#obs	Dates	24hr average	Sum 60	Sum 80	24hr average	Sum 60	Sum 80
1993								
Plot 2	186	7/16-7/24	73.0	10078 (115)[1]	6061 (56)	70.0	8414 (95)	5808 (54)
	167	7/25-8/1	62.9	5682 (64)	3657 (35)	58.6	5080 (57)	3404 (33)
	81	8/3-8/6	89.4	5946 (56)	4422 (34)	84.3	5187 (46)	4212 (32)
	173	9/10-9/17	58.7	4756 (56)	2712 (27)	57.9	4927 (58)	3062 (31)
	69	9/21-9/24	58.8	1942 (25)	807 (8)	56.3	1464 (18)	801 (8)
1994								
Plot 2	132	8/15-8/21	72.3	6664.6 (72)	4623.9 (41)	72.6	6676 (70)	5030 (45)

[1] Numbers in parentheses are the number of hours over the threshold (60 or 80 ppb).

Table 3-3. Comparisons of several ozone exposure indices (ppb or ppb-hr) at the Barton Flats monitoring site and Heart Bar Ranger Station in 1994.

		Heart Bar Ranger Station			Barton Flats Station		
#obs	Dates	24hr average	Sum 60	Sum 80	24hr average	Sum 60	Sum 80
155	8/30-9/5	59.9	5563 (57)[1]	4366 (40)	74.7	8379 (88)	6238 (56)
205	9/12-9/21	49.2	3750 (47)	1744 (17)	58.3	6303 (77)	3532 (36)

[1] Numbers in parentheses are the number of hours over the threshold (60 or 80 ppb).

Figure 3-1. Daily average air temperature (C) difference between a thermocouple at 2 m and thermistor at 15 m during February-March 1993.

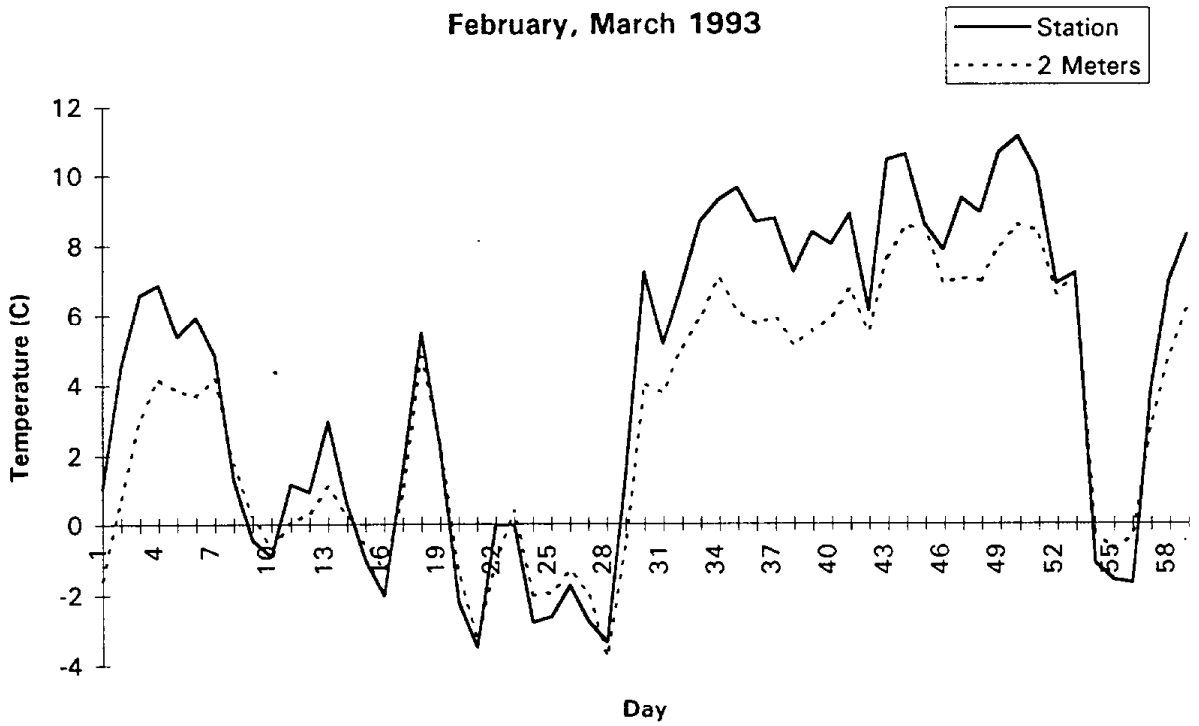


Figure 3-2. Daily average temperature (C) difference between a leaf thermocouple at 2 m and thermistor at 15 m during February-March 1993.

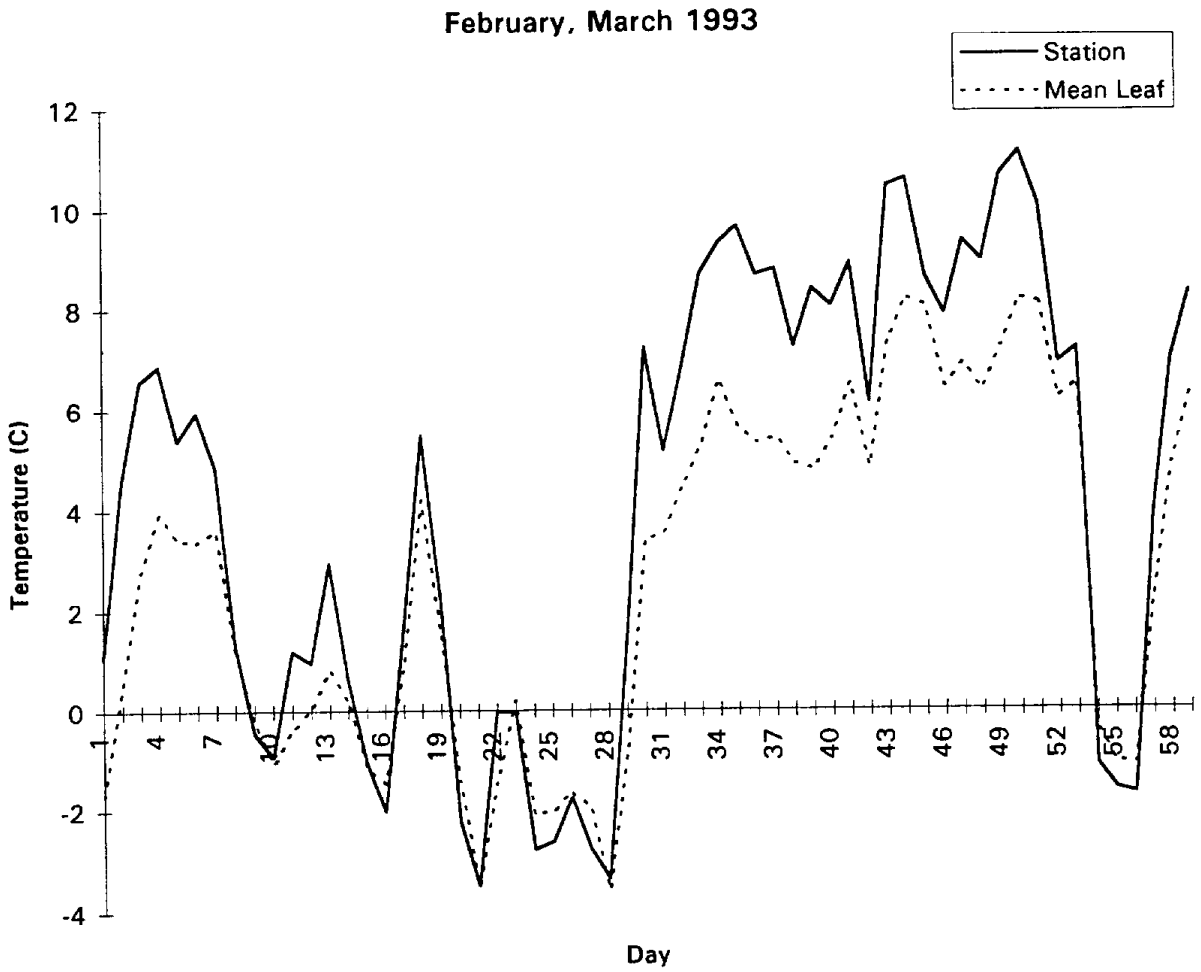


Figure 3-3. Daily average difference between a thermistor at 15 m and thermocouples at 10 and 50 cm in soil during February-March 1993.

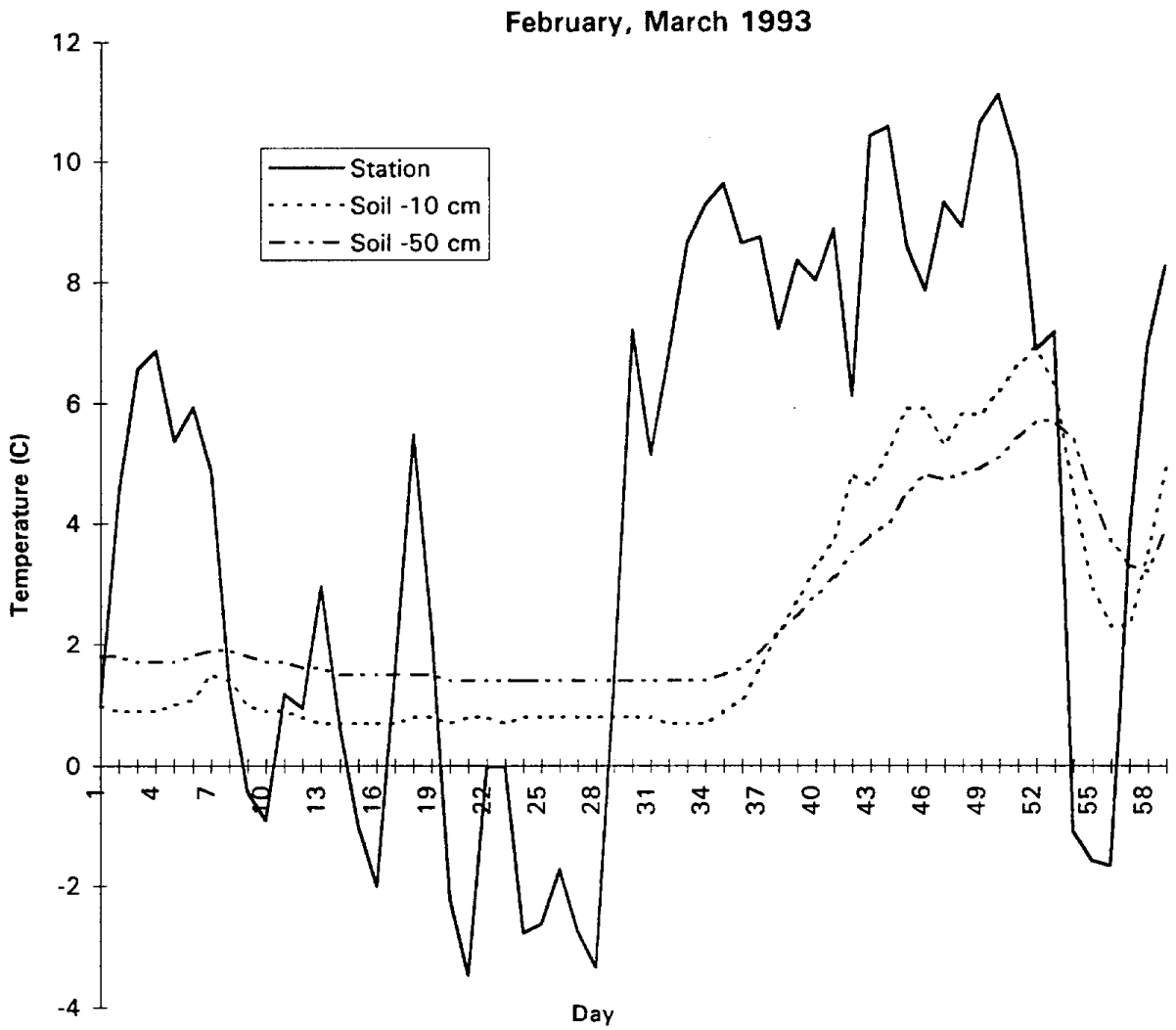


Figure 3-4. Daily average air temperature (C) difference between a thermocouple at 2 m and thermistor at 15 m during July -September 1993.

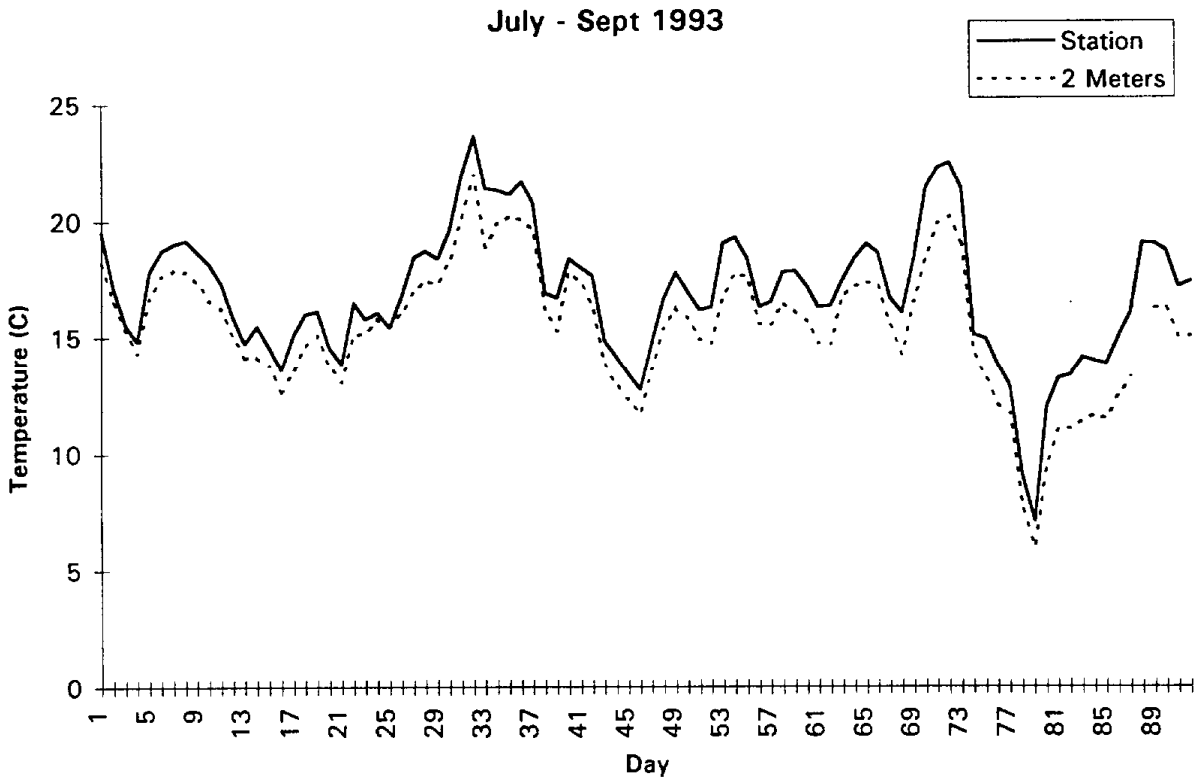


Figure 3-5. Daily average temperature (C) difference between a leaf thermocouple at 2 m and thermistor at 15 m during July-September 1993.

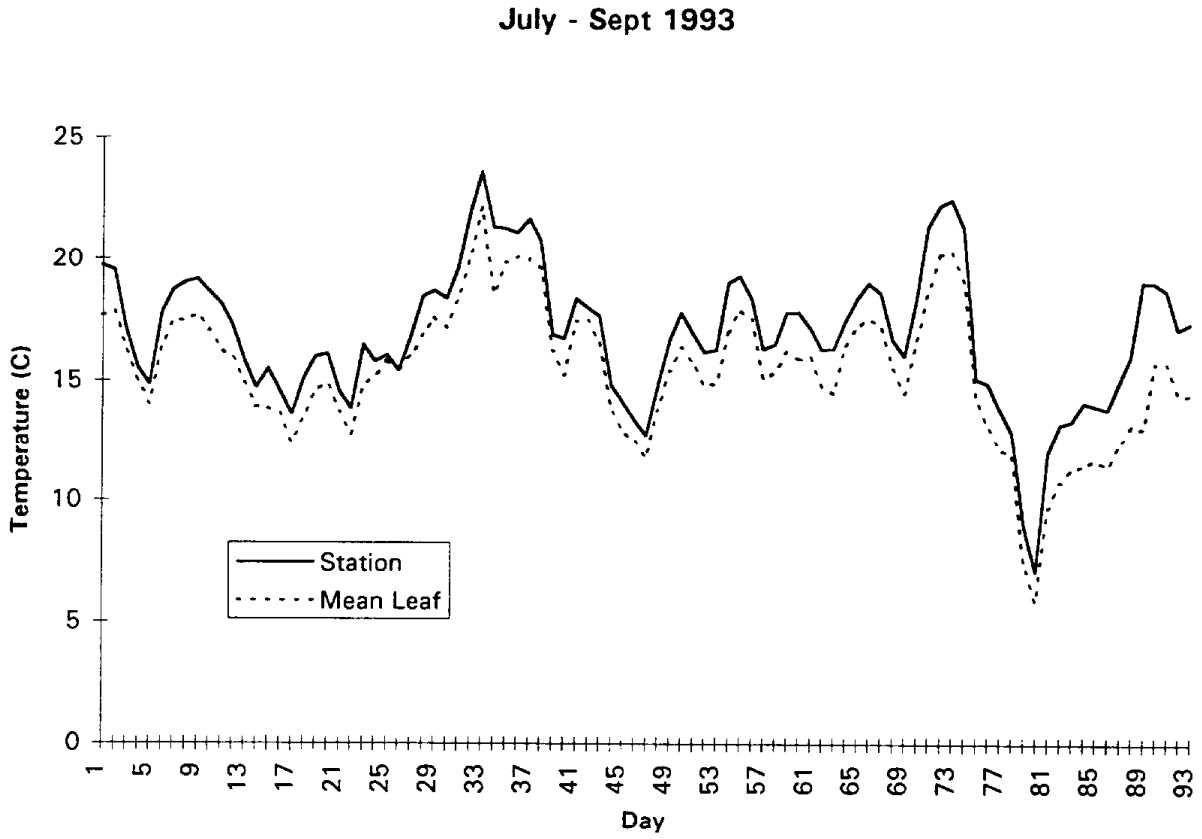


Figure 3-6. Daily average difference between a thermistor at 15 m and a thermocouple at 10 cm in soil during July-September 1993.

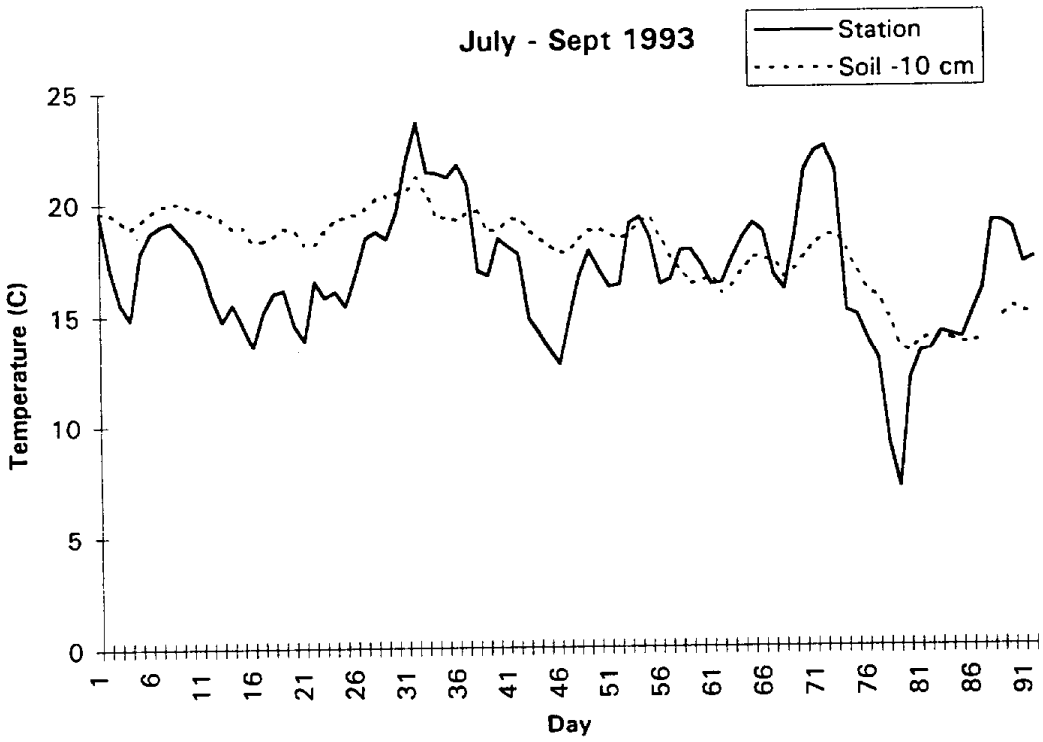


Figure 3-7. Hourly average ozone above and below canopy at the Barton Flats monitoring station during July 27-30, 1992.

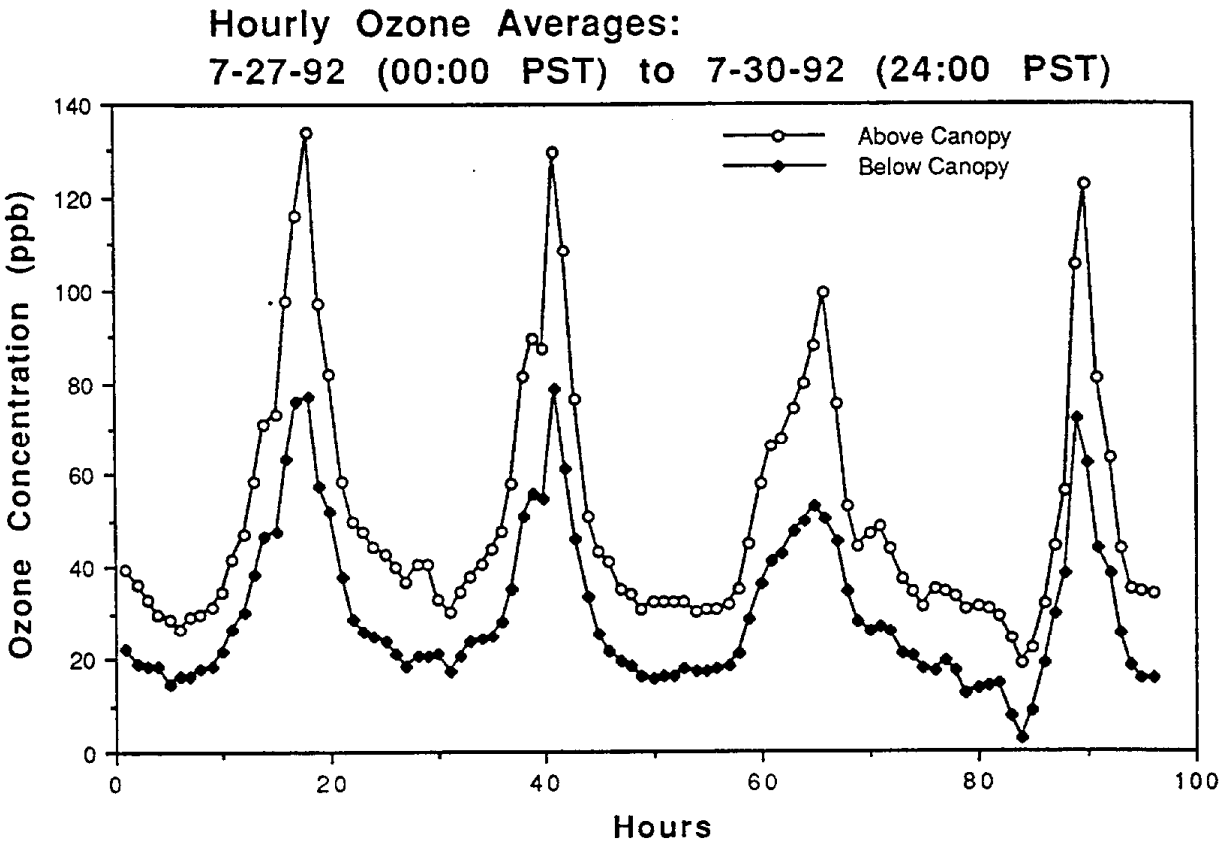
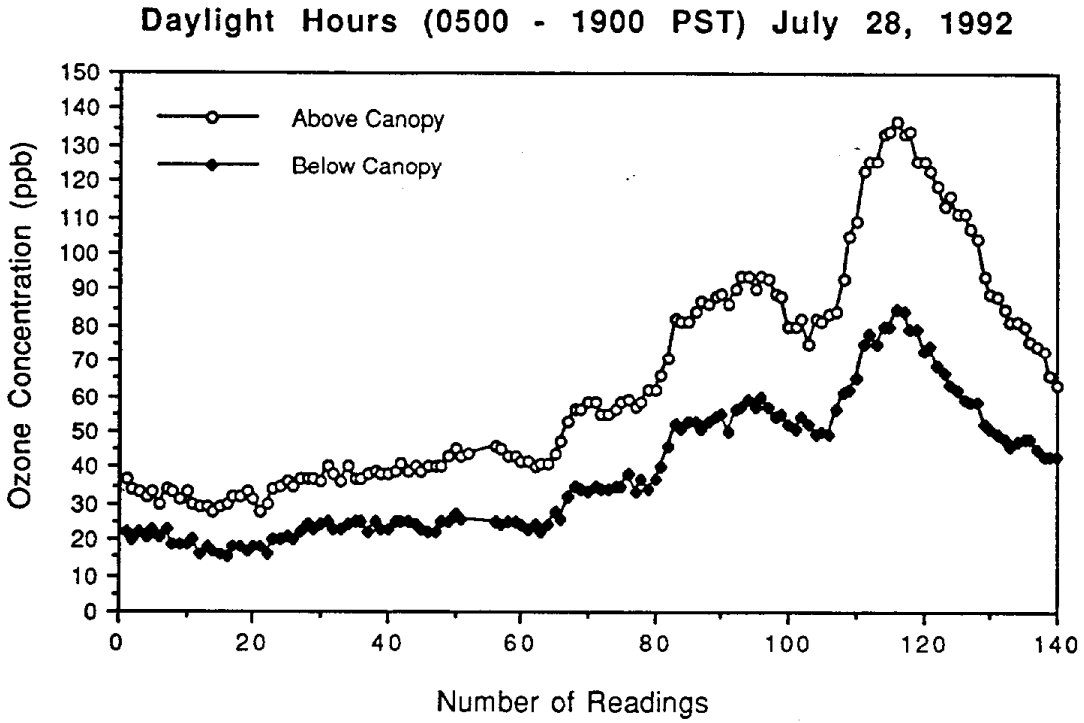


Figure 3-8. Ozone concentration by individual DASIBI measurements (3 averaged) above and below canopy at Barton Flats monitoring station during day and night hours on July 28-29, 1992.



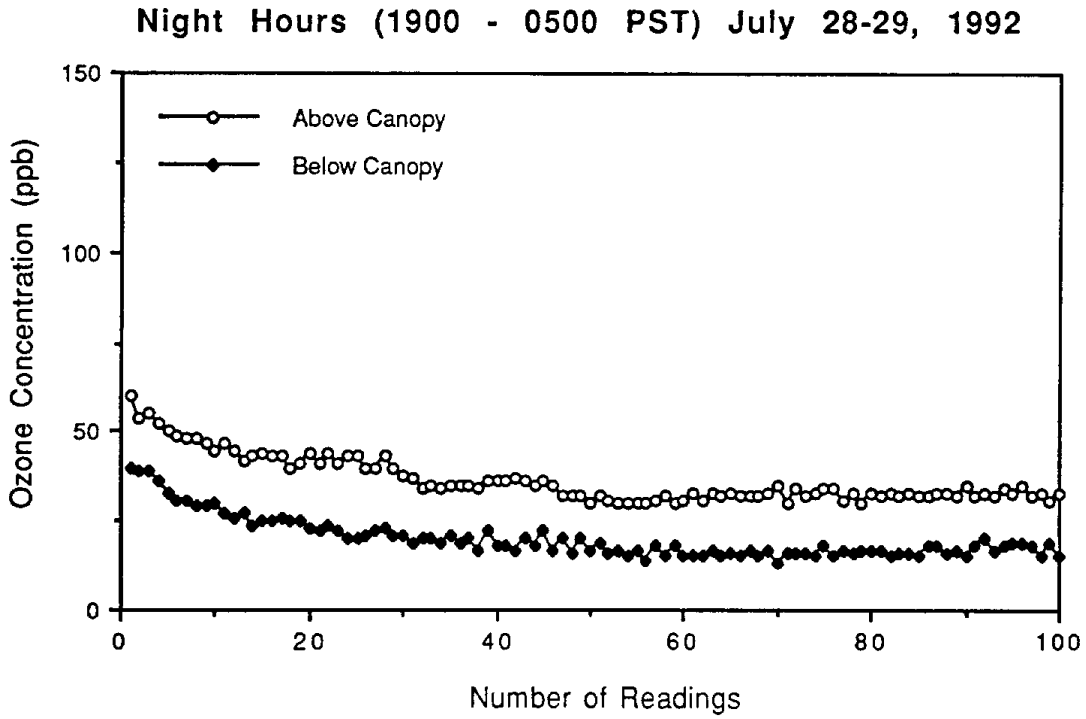


Figure 3-9. Hourly average ozone above and below canopy at the Barton Flats monitoring station during September 12-15, 1992.

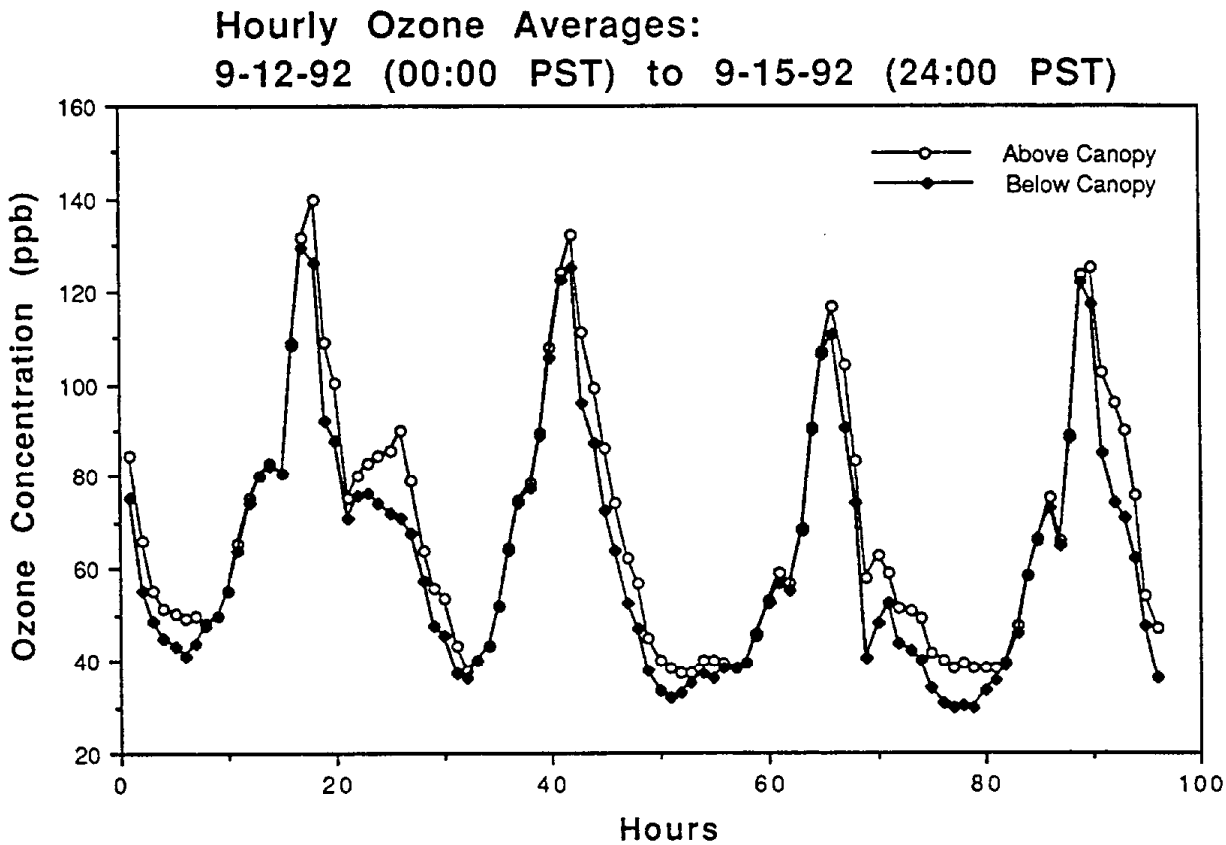
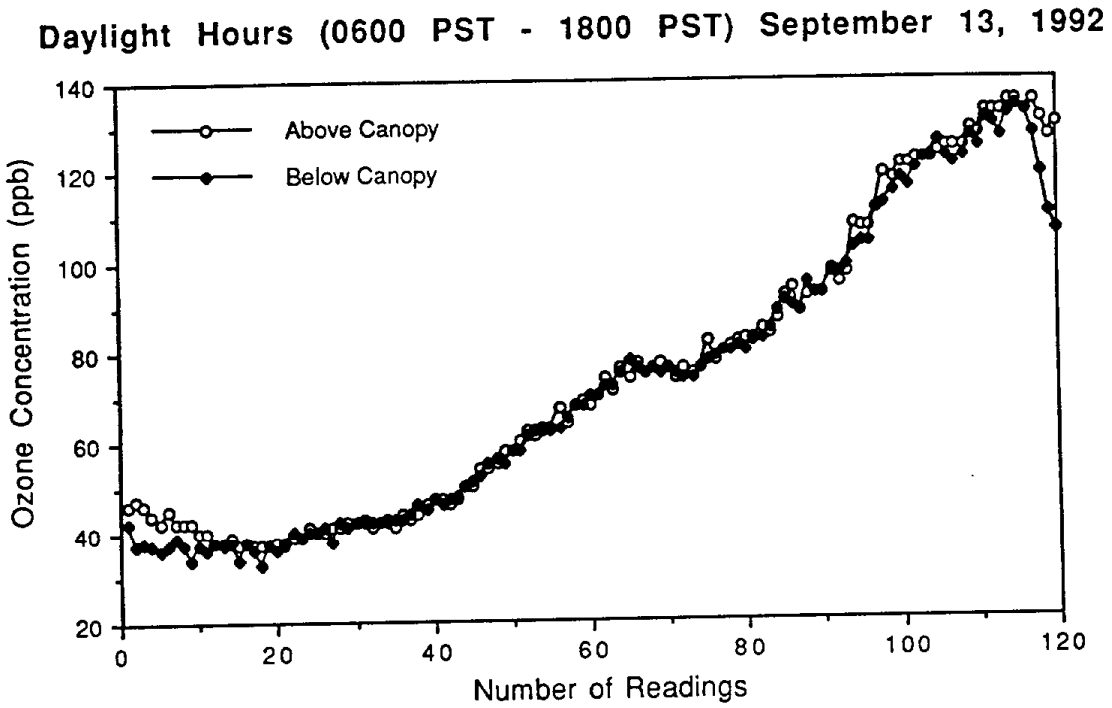


Figure 3-10. Ozone concentration by individual DASIBI measurements (3 averaged) above and below canopy at Barton Flats monitoring station during day and night hours on September 13-14, 1992.



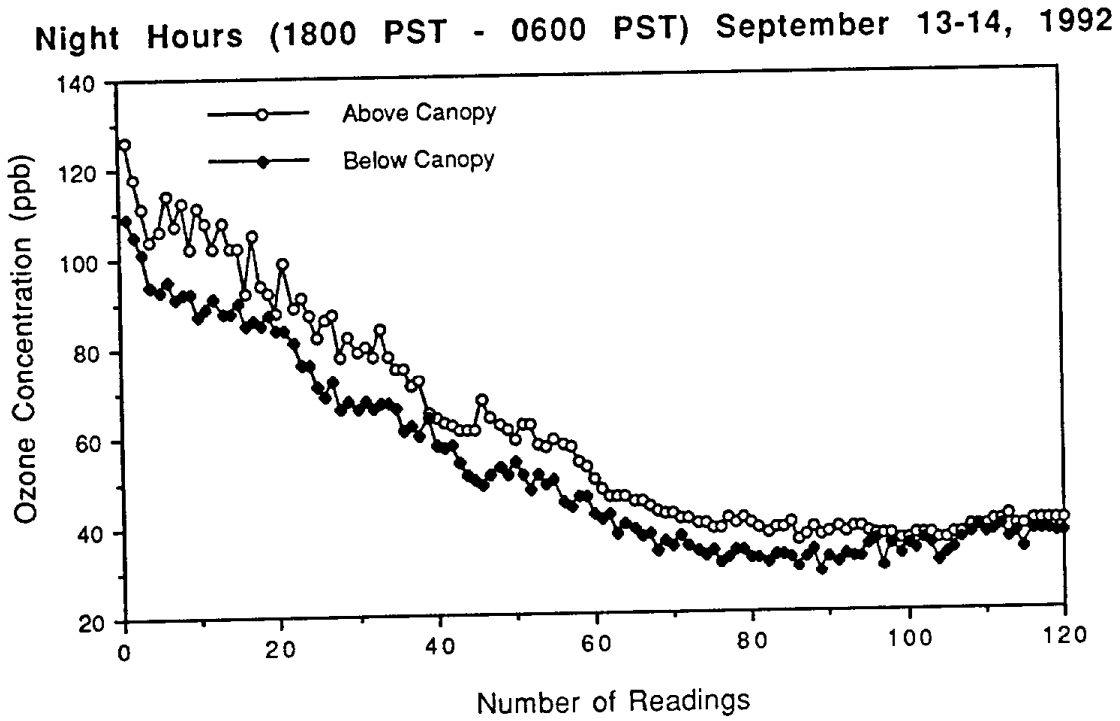


Figure 3-11. Hourly average ozone above and below canopy at the Barton Flats monitoring station during October 11-14, 1992.

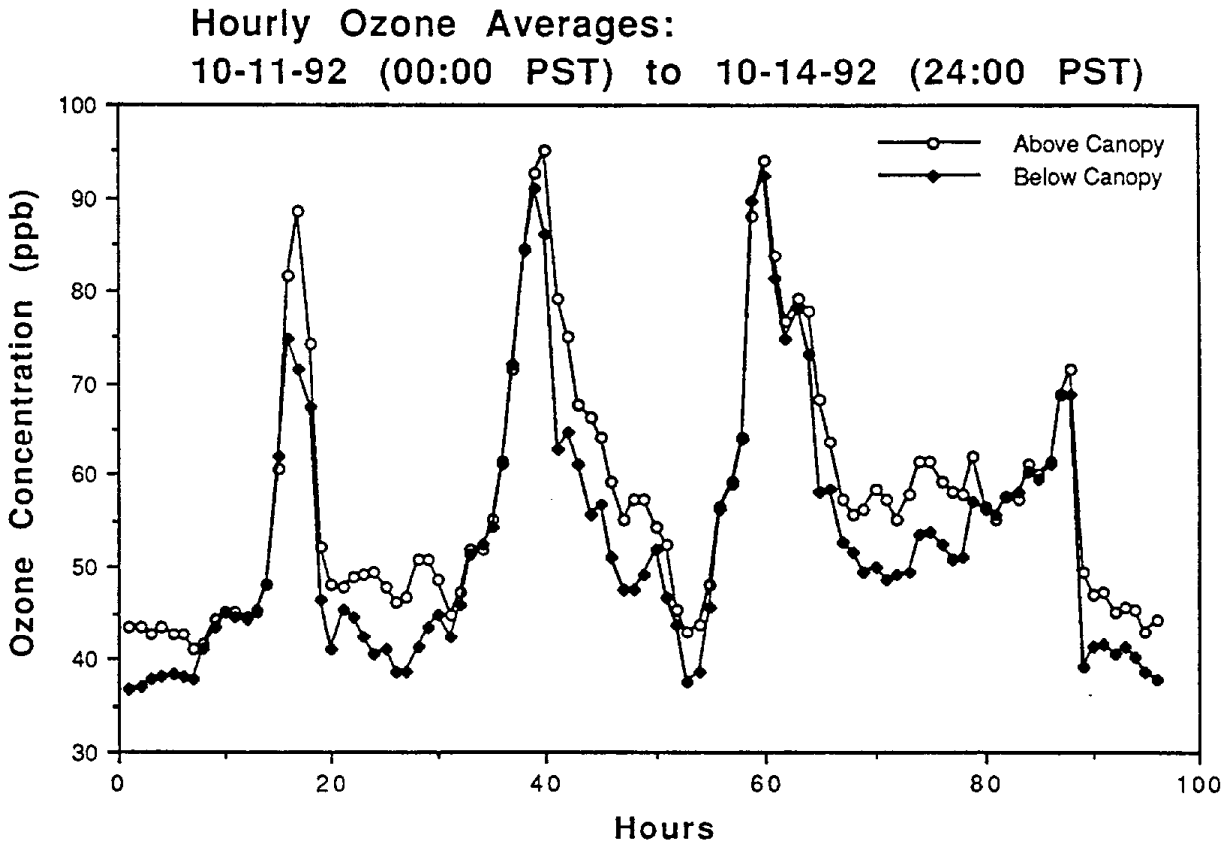
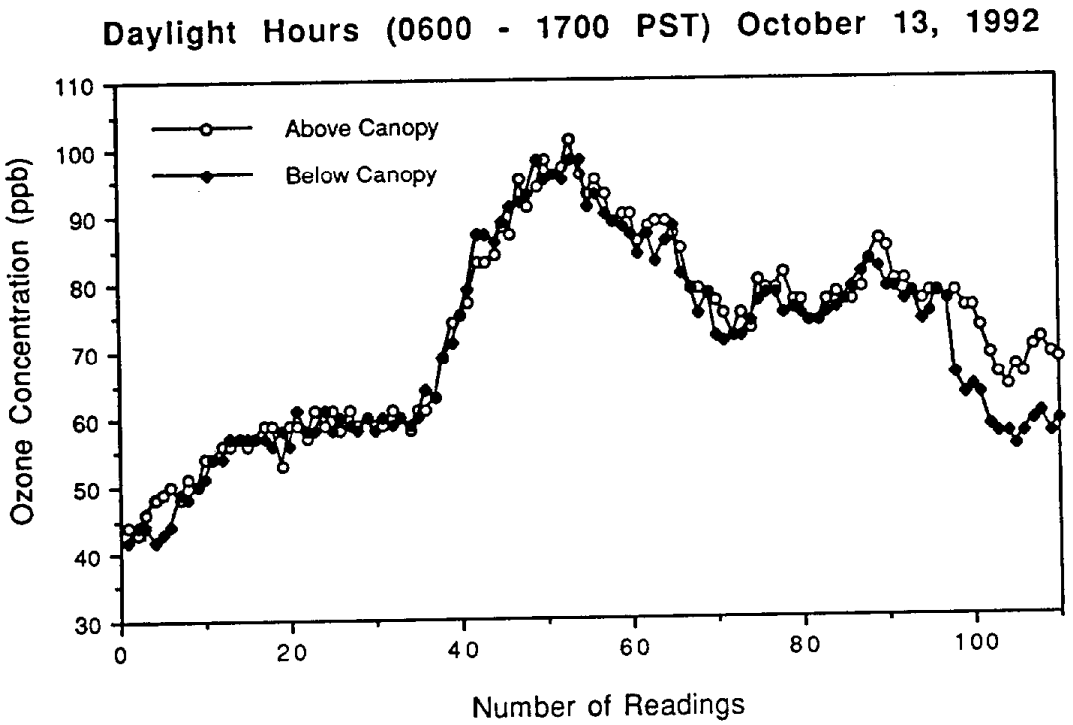


Figure 3-12. Ozone concentration by individual DASIBI Measurements (3 averaged) above and below canopy at Barton Flats monitoring station during day and night hours on October 13-14, 1992.



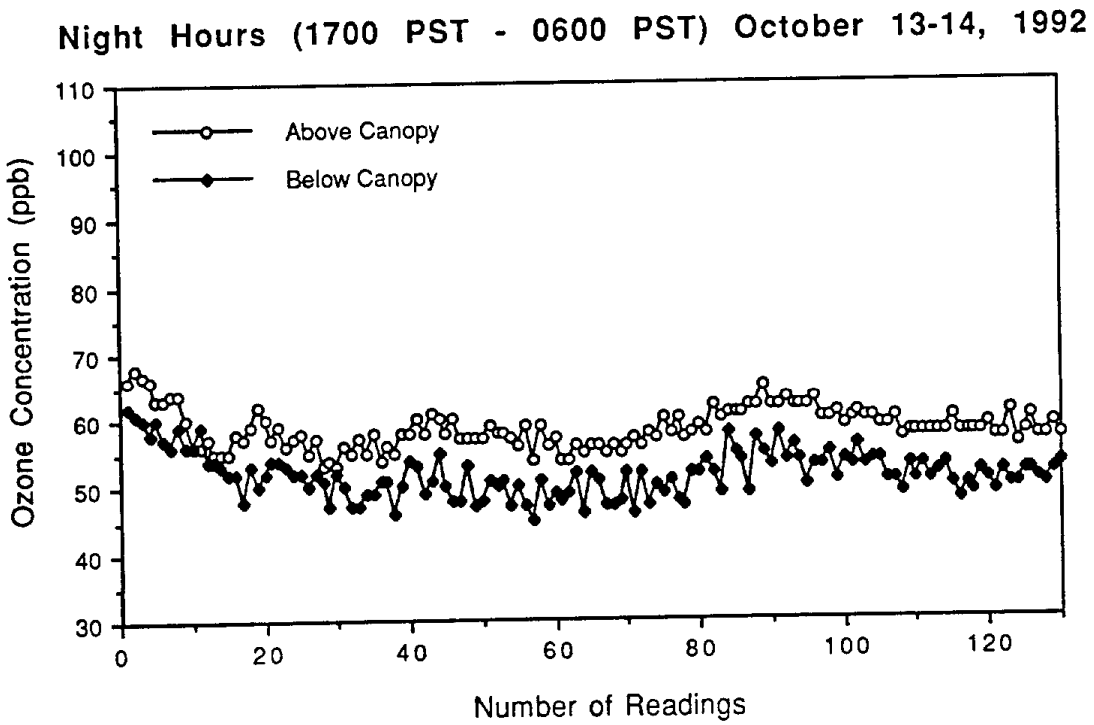


Figure 3-13. 24 hour average concentrations of HNO_3 vapor at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1992 season. Letters indicate statistically significant differences at $p \leq 0.05$

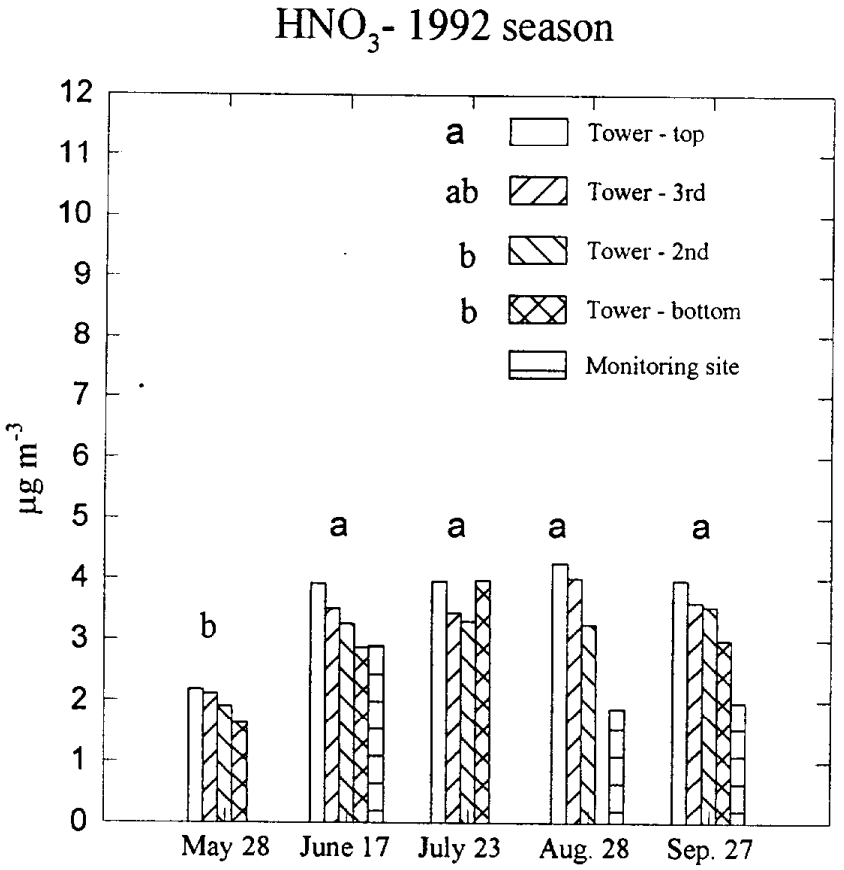


Figure 3-14. 24 hour average concentrations of HNO_3 vapor at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1993 season. Letters indicate statistically significant differences at $p \leq 0.05$

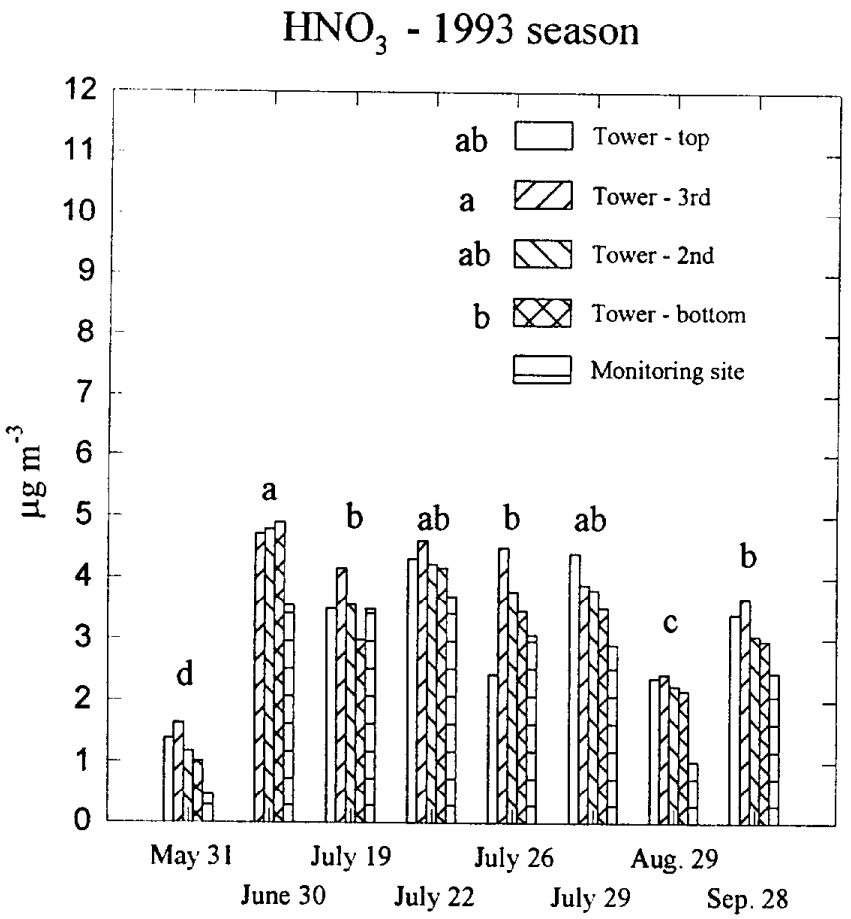


Figure 3-15. 24 hour average concentrations of HNO_3 vapor at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1994 season. Letters indicate statistically significant differences at $p \leq 0.05$

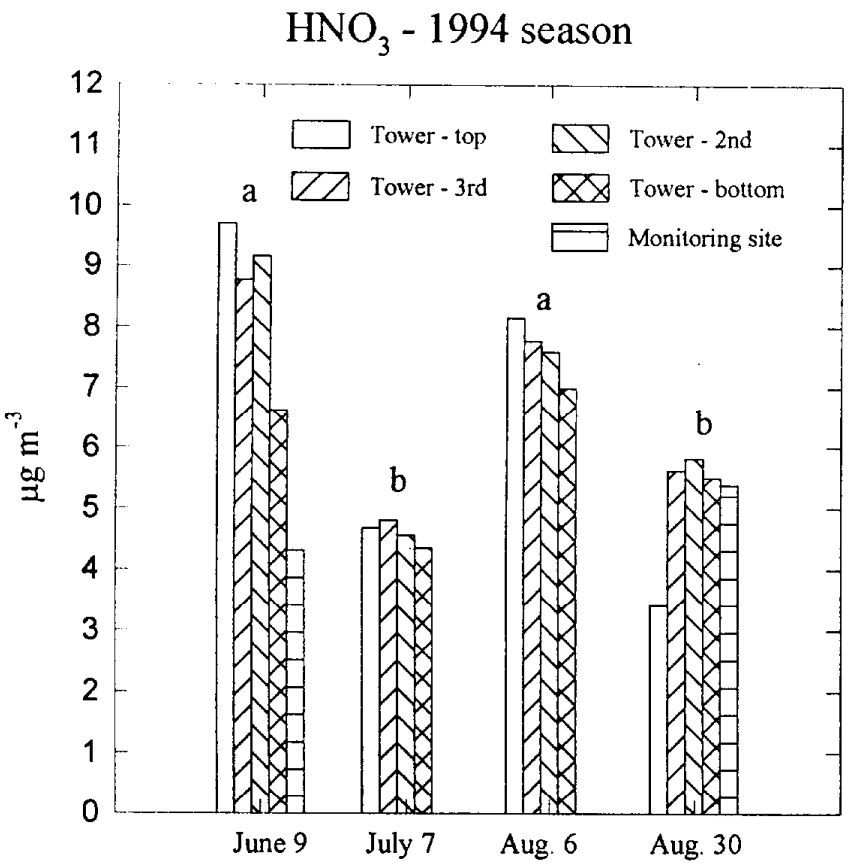


Figure 3-16. 24 hour average concentrations of NH_3 at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1992 season. Letters indicate statistically significant differences at $p \leq 0.05$

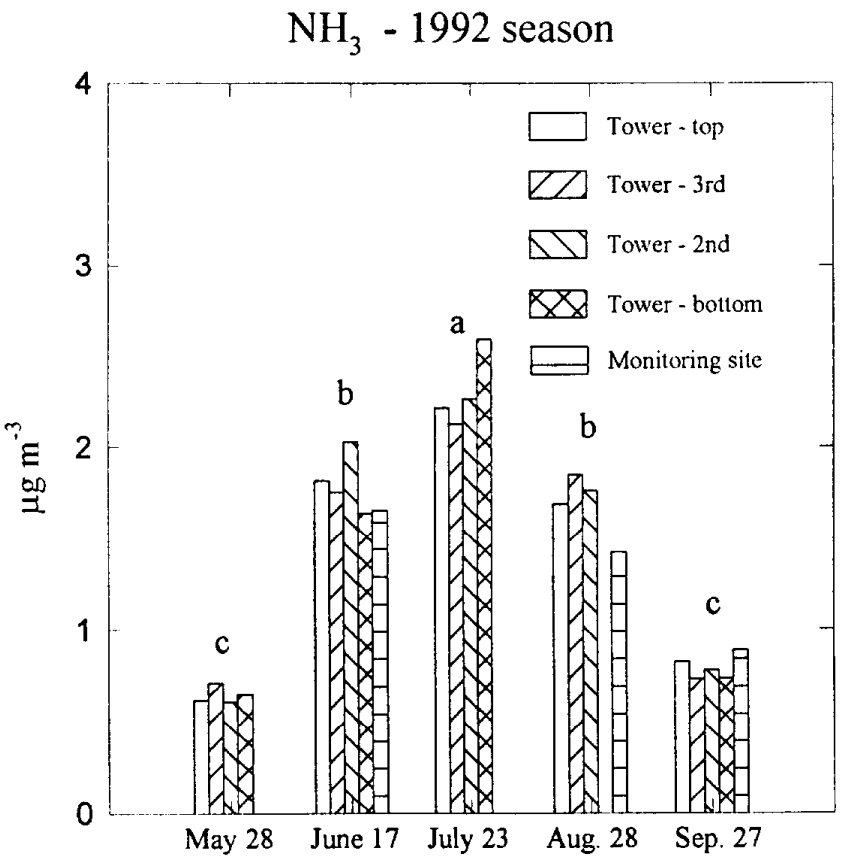


Figure 3-17. 24 hour average concentrations of NH_3 at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1993 season. Letters indicate statistically significant differences at $p \leq 0.05$

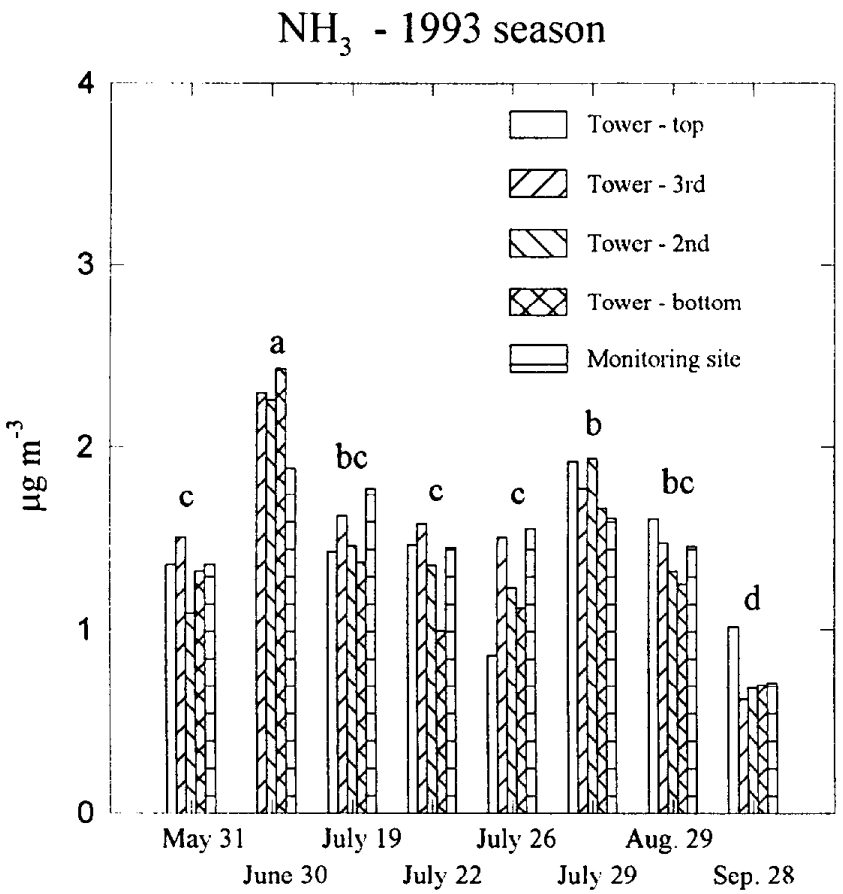


Figure 3-18. 24 hour average concentrations of NH_3 at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1994 season. Letters indicate statistically significant differences at $p \leq 0.05$

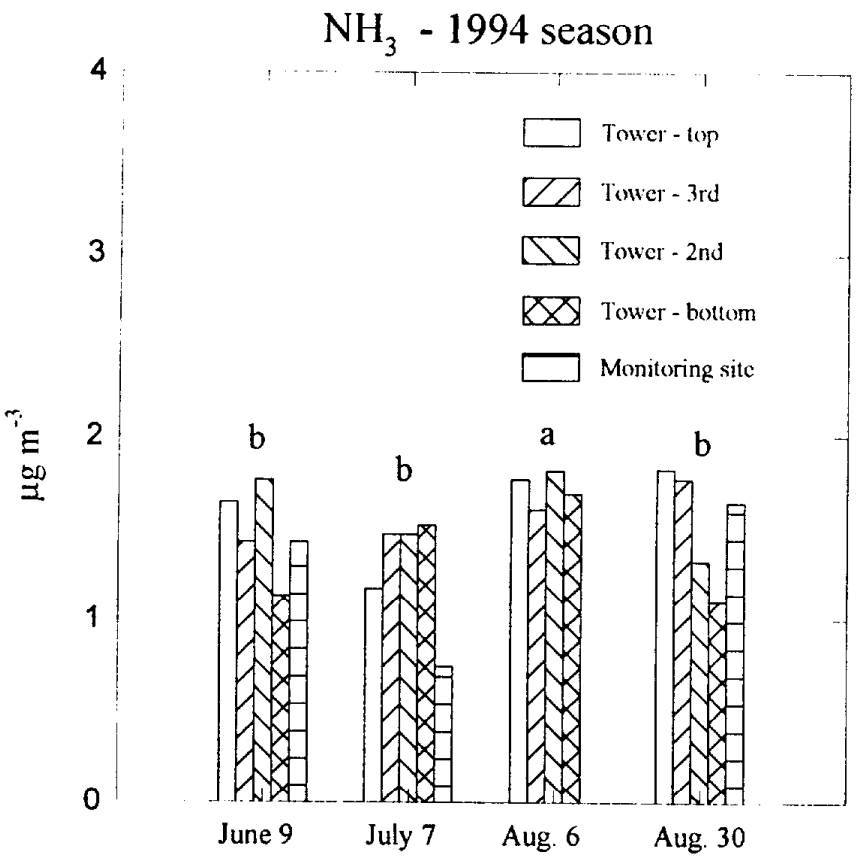


Figure 3-19. 24 hour average concentrations of SO_2 at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1992 season. Letters indicate statistically significant differences at $p \leq 0.05$

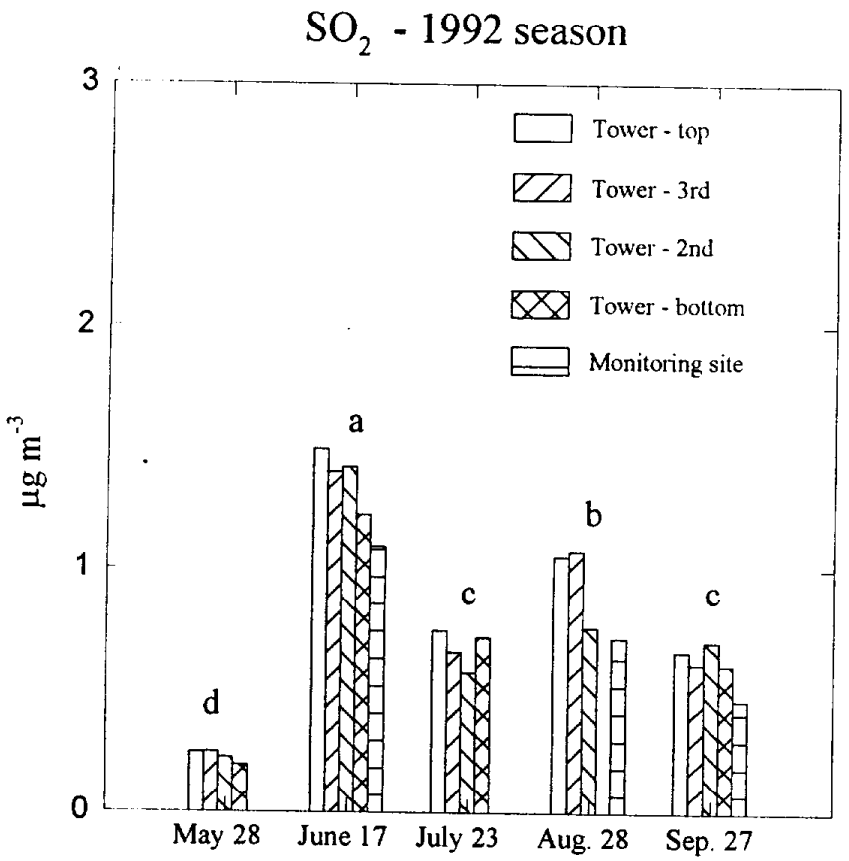


Figure 3-20. 24 hour average concentrations of SO_2 at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1993 season. Letters indicate statistically significant differences at $p \leq 0.05$

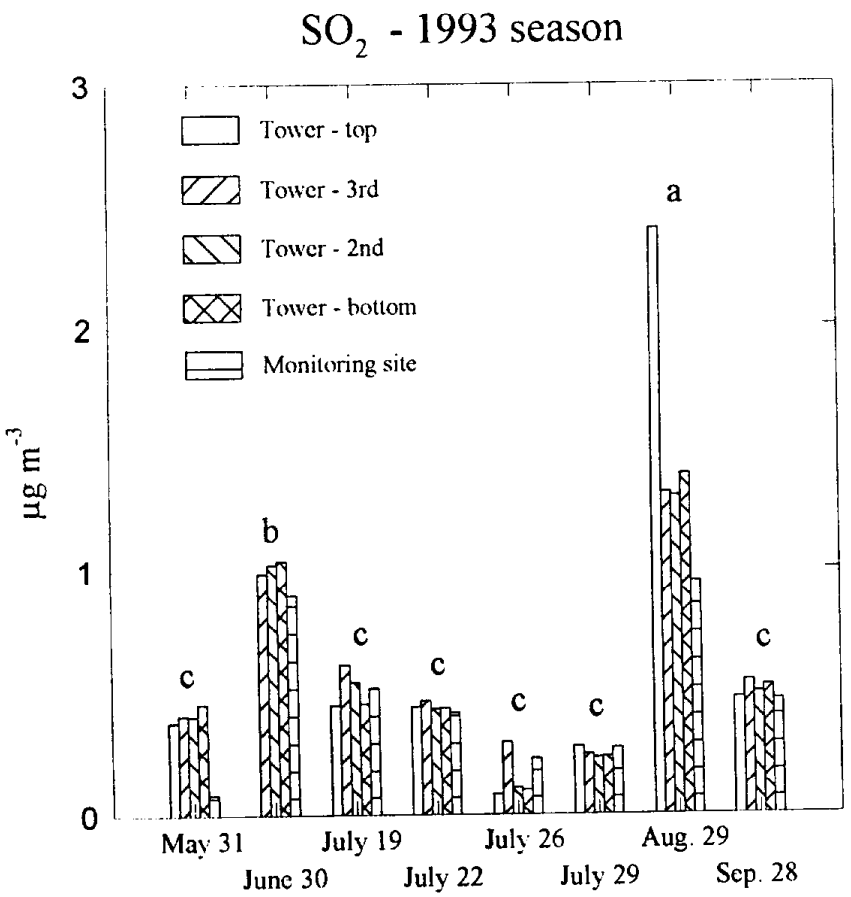


Figure 3-21. 24 hour average concentrations of SO_2 at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1994 season. Letters indicate statistically significant differences at $p \leq 0.05$

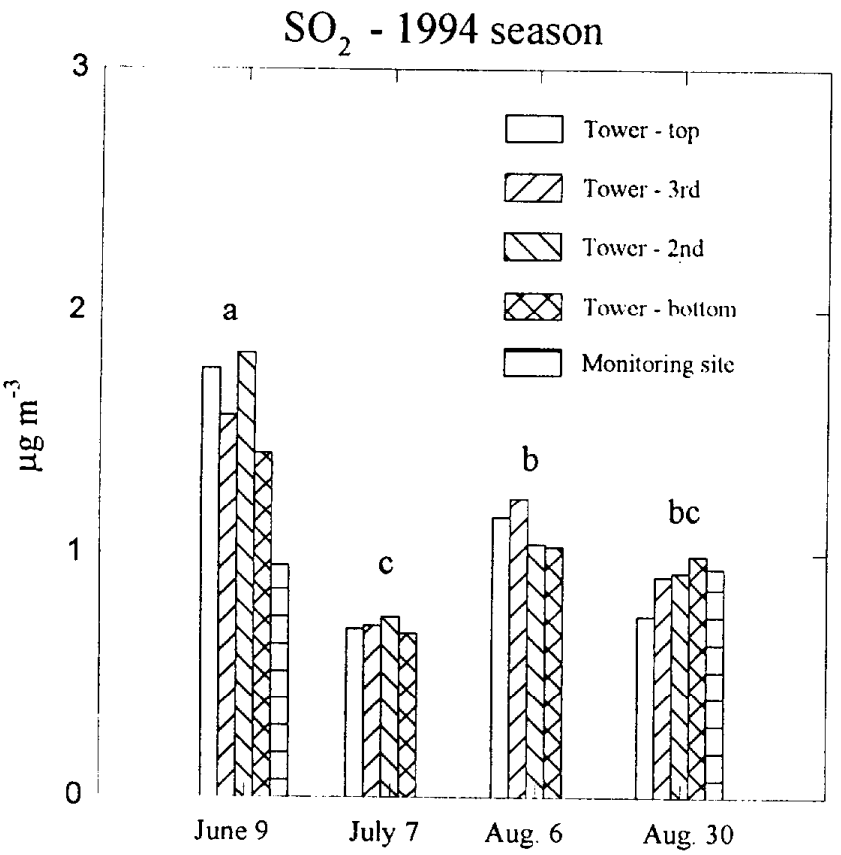


Figure 3-22. 24 hour average concentrations of NO_3^- at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1992 season. Letters indicate statistically significant differences at $p \leq 0.05$

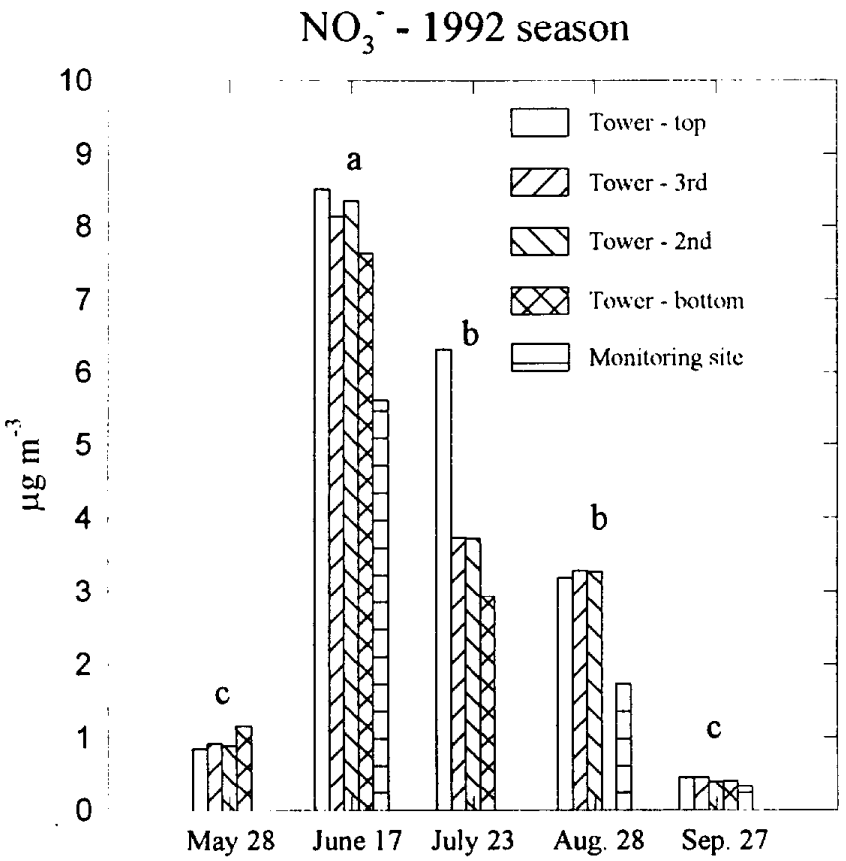


Figure 3-23. 24 hour average concentrations of NO_3^- at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1993 season. Letters indicate statistically significant differences at $p \leq 0.05$

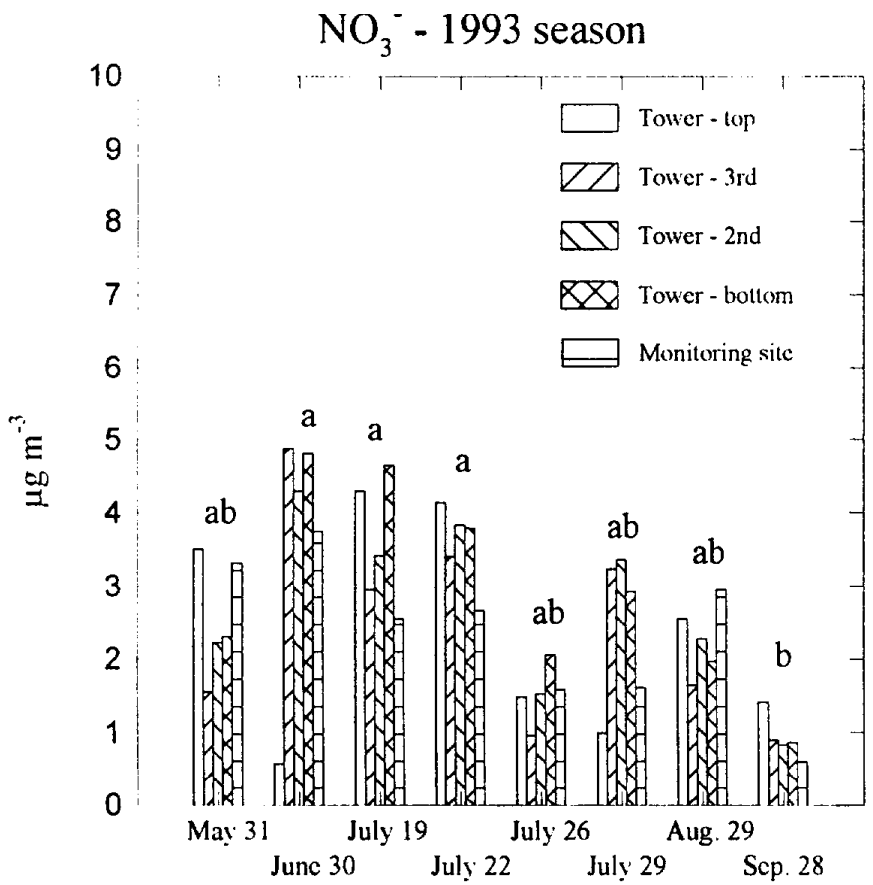


Figure 3-24. 24 hour average concentrations of NO_3^- at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1994 season. Letters indicate statistically significant differences at $p \leq 0.05$

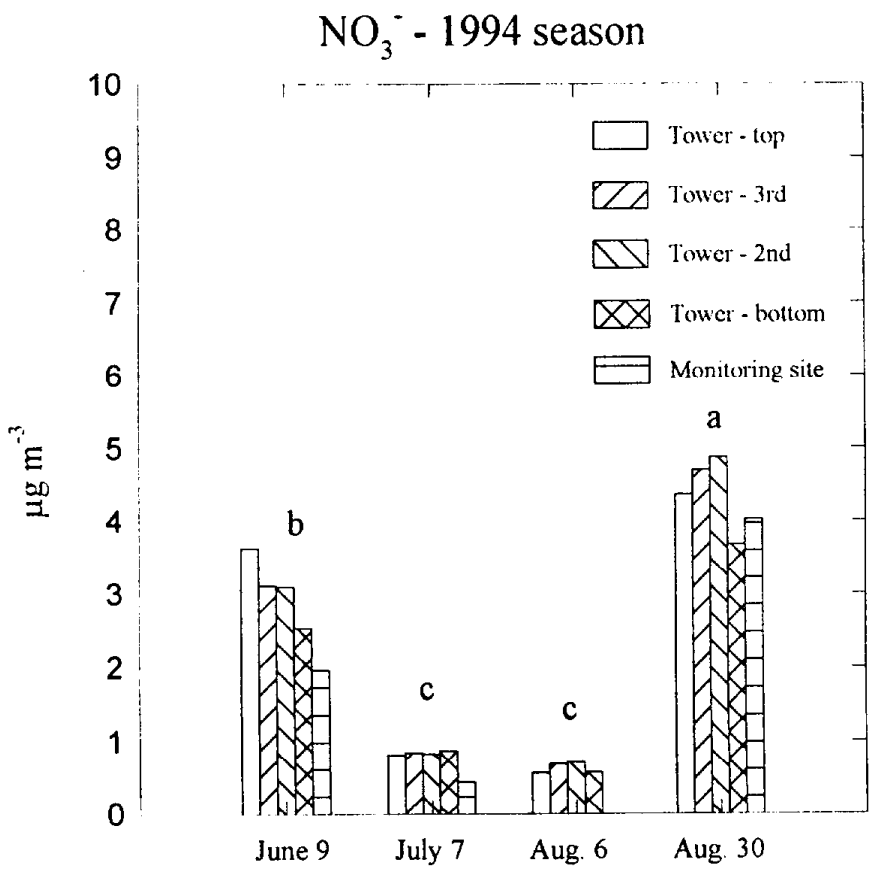


Figure 3-25. 24 hour average concentrations of NH_4^+ at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1992 season. Letters indicate statistically significant differences at $p \leq 0.05$

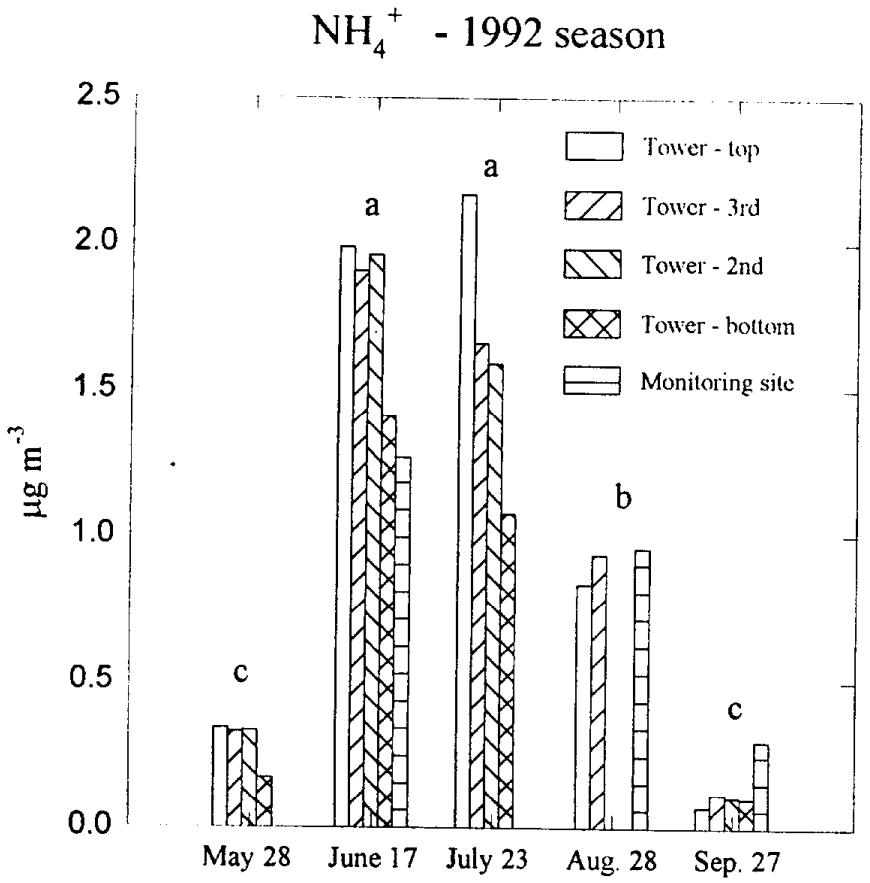


Figure 3-26. 24 hour average concentrations of NH_4^+ at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1993 season. Letters indicate statistically significant differences at $p \leq 0.05$

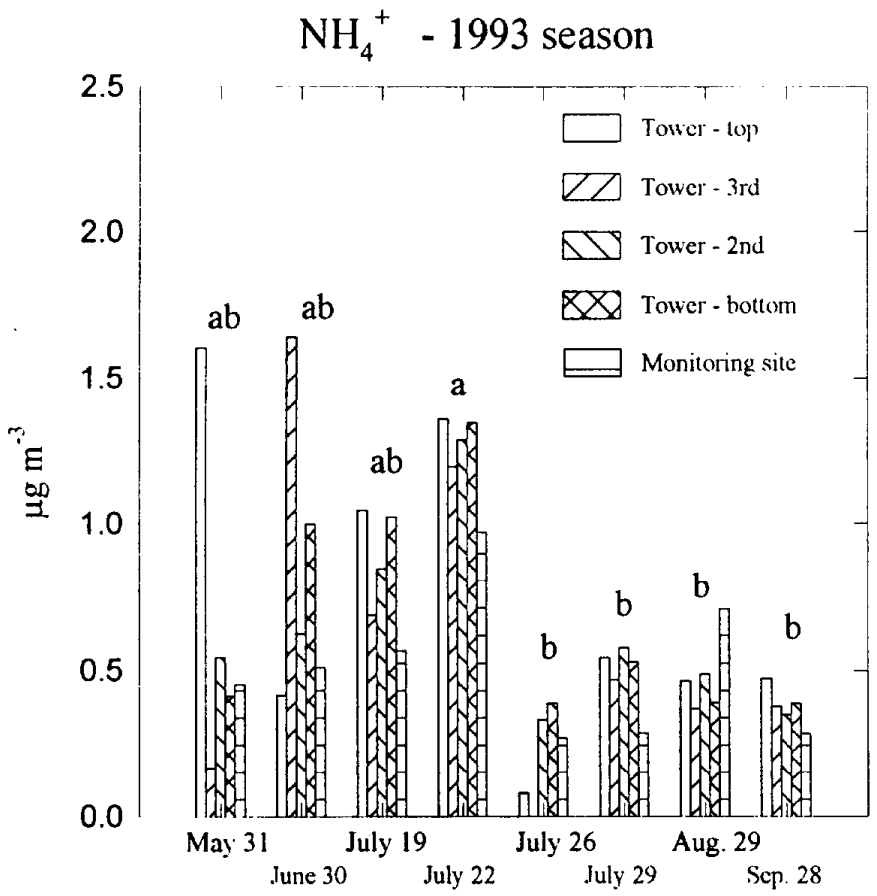


Figure 3-27. 24 hour average concentrations of NH_4^+ at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1994 season.

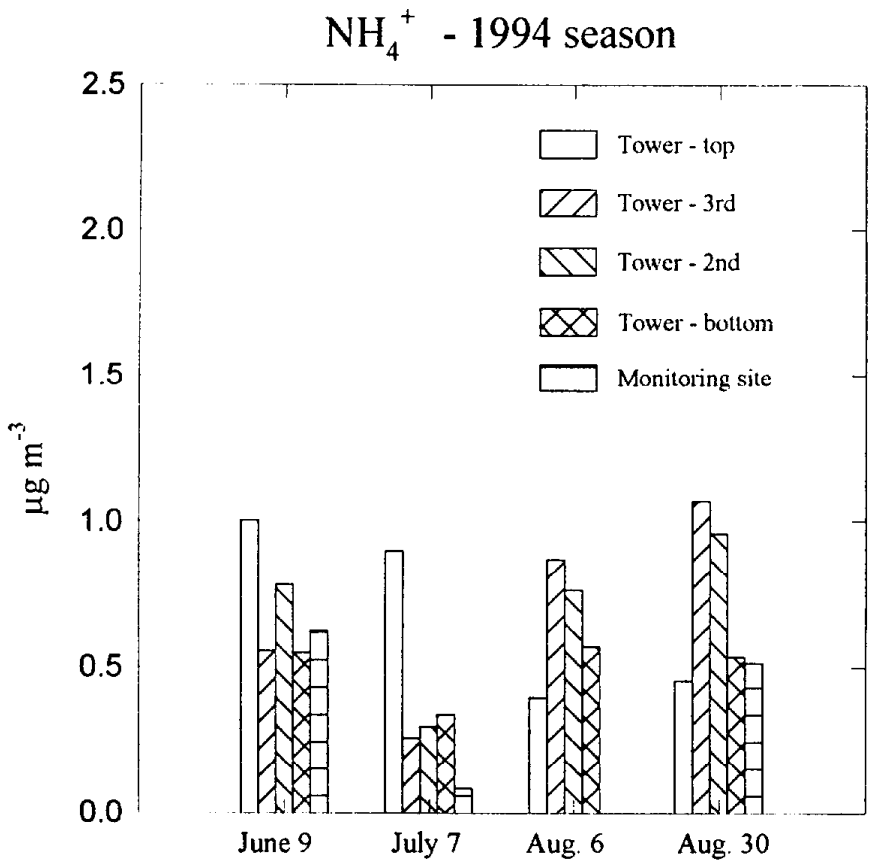


Figure 3-28. 24 hour average concentrations of SO_4^{2-} at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1992 season. Letters indicate statistically significant differences at $p \leq 0.05$

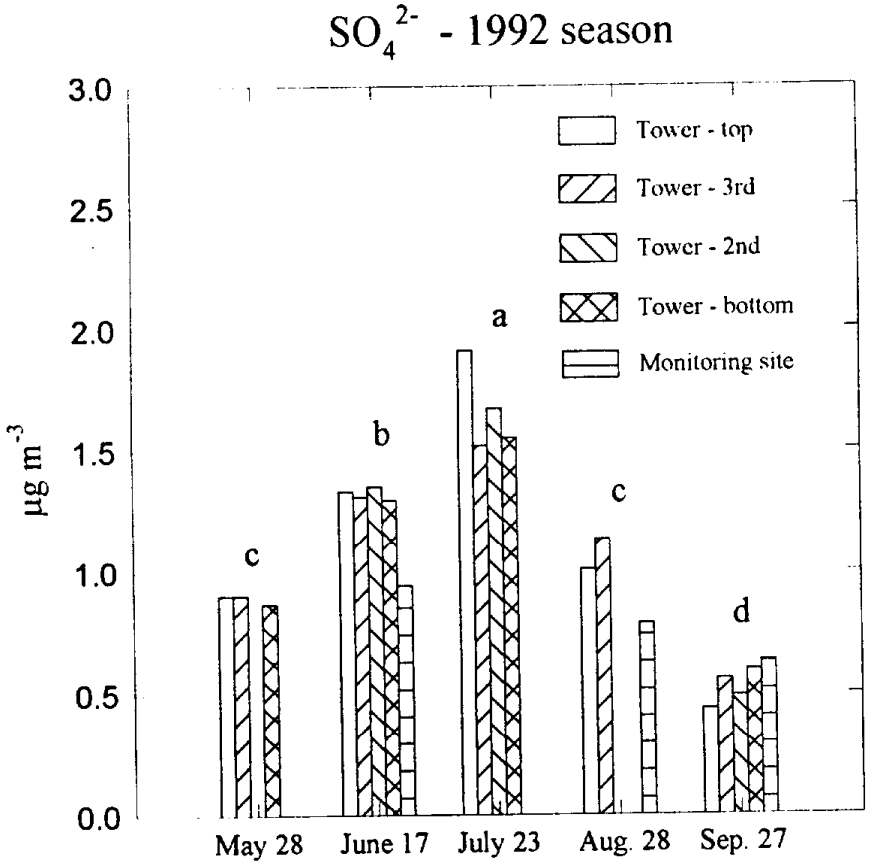


Figure 3-29. 24 hour average concentrations of SO_4^{2-} at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1993 season. Letters indicate statistically significant differences at $p \leq 0.05$

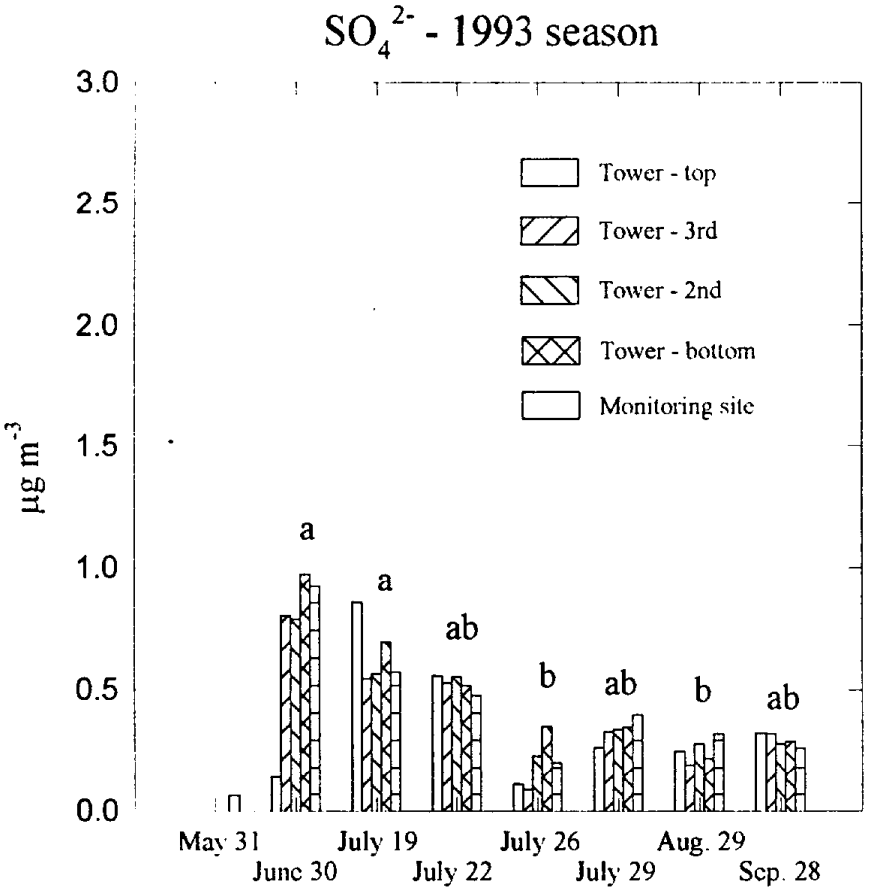
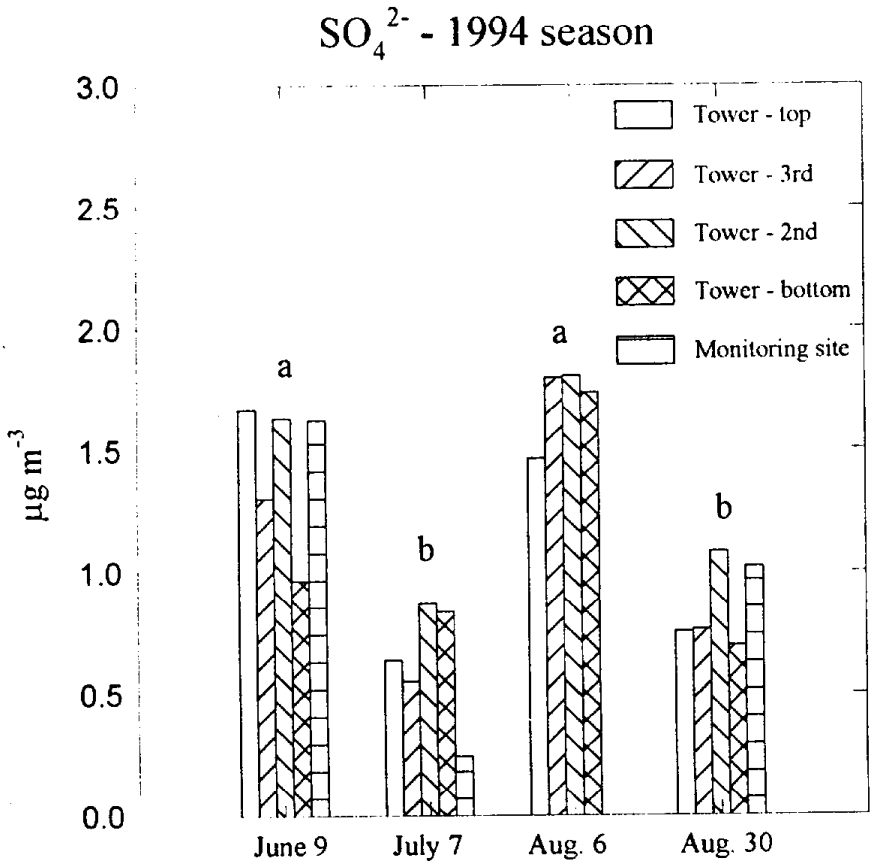


Figure 3-30. 24 hour average concentrations of SO_4^{2-} at different levels of the tower (Plot 2) and at the monitoring site (Plot 1) during the 1994 season. Letters indicate statistically significant differences at $p \leq 0.05$



4.0 DRY DEPOSITION OF NITROGEN AND SULFUR TO FOREST CANOPIES AT THREE PLOTS (CALCULATED ON THE BASIS OF FOLIAGE RINSING, INTERNAL UPTAKE OF GASEOUS POLLUTANTS, AND ESTIMATES OF DEPOSITION TO GROUND)

A. Bytnerowicz, M. Fenn, R. Glaubig

4.1 Introduction

In arid climates of the California mountains dry deposition is one of the major mechanisms of ion transfer from the atmosphere to biosphere (Rundell and Parsons, 1977). Foliage rinsing techniques (Lindberg et al., 1986; Bytnerowicz et al., 1987) have been successfully used for determinations of atmospheric deposition of various ions to trees. The technique is especially valuable in dry climates of southern California where in the spring-summer-fall period, precipitation (which would allow for throughfall collection) is scarce. In this study a foliage rinsing technique was used to determine how position in the canopy of a mature tree affects deposition of nitrogenous and sulfurous pollutants, to compare deposition to branches of mature trees and seedlings, and to compare deposition among three tree species. Deposition of nitrate, ammonium and sulfate to branches of seedlings and mature trees of ponderosa pine at various levels of the canopy were measured during the 1992 - 1994 seasons. In addition, during two 1-week long periods of intensive studies in summer 1993, deposition to ponderosa pine, California black oak, and white fir seedlings and mature trees near the forest floor in three different sites was determined. Results of these intensive studies allowed the calculation of inputs of nitrogen and sulfur to the mixed coniferous forest stand.

4.2 Methods

4.2.1 Measurements of Deposition Fluxes on a Vertical Gradient

Deposition measurements were performed during three photochemical smog seasons (1992, 1993 and 1994). Fluxes of NO_3^-, NH_4^+ and SO_4^{2-} to branches of ponderosa pine seedlings were determined on the tower located in Plot 2, in a stand of mature ponderosa/Jeffrey pines. Four seedlings were located at each of four different levels of the tower (29 m - at the top of the canopy; 24 m and 16 m - in the middle of the canopy; and 12 m - at the canopy bottom).

In addition, starting at the stage of the complete development of needles on the mature trees (end of July), deposition to branches of mature pine trees at three different levels of the tower (12, 16, and 24 m) was determined and compared with deposition to the seedlings' branches.

In the beginning of each collection period, branches about 10 cm long were thoroughly rinsed with double deionized water. The branches were re-rinsed at the end of the collection period with about 100 mL of double deionized water and the rinses were collected in 250 mL Nalgene bottles. Bottles were placed on ice, immediately transferred to the laboratory and placed at -18 °C. Concentrations of nitrate and sulfate were determined with ion chromatography (Dionex 4000i ion chromatograph) and concentrations of ammonium colorimetrically (TRAACS instrument). Details of the procedures are described in the Standard Operating

Procedure.

4.2.2 Determinations of Nitric Acid Conductance (k_{HNO3}) Values for the Ponderosa Pine Seedlings at Different Levels of the Canopy

Nitric acid conductance (k_{HNO3}) is described as deposition velocity of gases at a leaf/branch level (Hanson and Lindberg, 1991). For scaling between canopy and leaf/branch measurement the following conversion has been suggested:

$$V_d = k_{HNO3} \times LAI$$

where LAI is the leaf area index of the canopy and V_d is the overall deposition velocity to that canopy (Hanson and Lindberg, 1991).

In order to calculate k_{HNO3} the deposition fluxes of NO_3^- to branches which could be attributed only to HNO_3 were divided by ambient concentrations of HNO_3 during the deposition periods. Deposition fluxes of nitrate attributed to HNO_3 were obtained by subtracting the portion of particulate NO_3^- deposition from the total NO_3^- deposition. Particulate NO_3^- deposition was calculated by multiplying ambient concentrations of particulate NO_3^- (determined with an annular denuder method) by the reported value of NO_3^- deposition velocity to conifer foliage (Davidson and Wu, 1990).

4.2.3 Measurements of Deposition Fluxes to Ponderosa Pine, White Fir and California Black Oak at Three Plots

In order to calculate deposition to other important tree species for the study area (white fir and California black oak) branches of mature trees and seedlings of pine, fir and oak at the forest floor level were rinsed at study plots 1, 2, and 3 during two periods of intensive studies in summer 1993.

4.2.4 Estimates of Leaf Area Indices

Leaf Area Measurements

Leaf area index (LAI) for Plot 2 at Barton Flats was estimated by the two methods described below:

Ceptometer Method: This is an indirect optical method of estimating LAI in which the method of Pierce and Running (1988) and the Decagon Sunfleck Ceptometer were used. The ceptometer is composed of 80 light sensors placed at 1 cm intervals. The ceptometer measurements were taken on July 26, 1994. Radiation measurements were taken in twenty circular "sweeps" along each transect (every 6 m) of the plot. Each sweep consisted of 16 measurements covering an area $\sim 9\ m^2$. The 16 measurements per sweep were averaged and stored in memory. Eight transects were run through the length of the plot. Eight transects represent over 200,000 point samples of photosynthetically active radiation (PAR). Total incoming PAR was measured periodically as we encountered open areas along the transects.

Average canopy transmittance for each stand was converted to LAI using the Beer-Lambert Law:

$$LAI = -\ln(Q_i/Q_o)K$$

where LAI = projected LAI, Q_i/Q_o = canopy transmittance, and K = light extinction coefficient. The literature value of 0.52 was used for K in calculating LAI (Pierce and Running, 1988) was used.

The ceptometer method gives a single projected LAI value for the entire plot--all species combined. Ceptometer LAI values for ponderosa pine, oak species and other forest types have been shown to underestimate LAI compared to direct destructive harvest estimates of LAI (Fassnacht et al., 1994). With the ceptometer method a projected LAI value of 1.21 in Plot 2 was obtained (Table 4-1). This value was doubled in order to convert LAI to all-sided LAI (including branches, cones, stems etc.; this is referred to as total surface area index, or total SAI by Fassnacht et al., 1994). The estimated SAI was multiplied by 1.58 to account for the degree to which the ceptometer underestimates SAI in ponderosa pine and oak stands (1.58 correction factor was calculated from the data of Fassnacht et al., 1994). Following this procedure an all-sided SAI of 3.8 for Plot 2 was obtained.

Litterfall Method: A modified version of the litterfall method described by Marshall and Waring (1986) was used. The method was modified because the litter collectors were placed only under large trees, and thus might not collect litter from areas representative of the overall conditions of the plot. Therefore, our strategy was to estimate the total annual litterfall per tree, determine the surface area of the annual litterfall, and estimate the leaf area of the tree by factoring in the number of annual whorls on the tree (the "t" or annual turnover rate used by Marshall and Waring). Stated in another way, the average surface area of the litter produced by a tree in one year multiplied by the number of years of foliage left on the tree, approximates the leaf area of that tree. Mathematically this can be presented as:

$$LAI = \text{litter LAI} \times f$$

where f = average years of foliage retained on the tree. Litter LAI is the total surface area of the litter ÷ the area of the litter collector.

The number of years of foliage retained by white fir was determined by harvesting a branch from the top, middle and bottom third of the crown of relatively small (about 6-7 m in height), medium, and large trees throughout the plot. The number of years of foliage on the branches was counted and averaged for each tree. This resulted in a plot average of 4.1 years of foliage retained for white fir. For ponderosa pine the average number of years of foliage retained was determined from data collected previously by Paul Miller. An average of 3.03 years of foliage retained for ponderosa pine in Plot 2 was calculated.

Since the litter collectors were placed only under trees, the amount of the litter that fell outside of the canopy drip area was also calculated in order to estimate total litterfall per tree. The mass of L-litter (undecomposed recently fallen pine needle litter) on the ground under the drip line and outside of the drip line for a number of trees was determined. Results of this survey indicated that 16% of the litter fell outside of the canopy drip

area. This estimate may have considerable uncertainty because of erratic litterfall caused by factors such as wind effects on litterfall and subsequent litter mobility on the ground, input from other trees, and due to branches interfering with litterfall.

From the total annual mass of litterfall per tree the litter surface area per tree was determined. The surface area of litter was calculated using an equation regressing foliar dry weight versus total sided leaf area. Needle leaf areas were determined from geometric calculations. For black oak, leaf areas were determined with a Li-Cor area meter.

The leaf area of trees without litter collectors was estimated. For ponderosa pine, the regression relationship between DBH and total leaf area of the collector trees was used to estimate leaf area of the pine trees without litter collectors. For white fir, live crown volume (LCV) versus total leaf area was a stronger relationship, and was used to estimate leaf area of the fir trees without litter collectors. We also estimated the surface area of the untagged fir and pine trees ("understory trees" with DBH < 10 cm) in a similar manner as with the overstory trees. LAI in Plot 2 for fir and pine was determined by adding up the total leaf surface area of all the overstory and understory trees in the plot and dividing this value by the total land surface area of the plot.

No useful relationship between leaf area and tree parameters (DBH, LCV) was found for black oak. It was decided the best way to estimate LAI for oak was to treat the data as if the litter collectors were placed along transects in the plot. This conclusion was based on the fact that large amounts of oak foliage were found in collectors placed under ponderosa pine and fir trees as well as under oak trees. Therefore, for black oak, LAI was calculated simply as the average surface area of the oak litter per collector divided by the surface area of the litter collector.

The all-sided LAI of pine and fir, based on the litterfall method (described above), was 1.89, equal to about half of the Ceptometer method SAI value of 3.8. SAI and LAI values are usually similar. In ponderosa pine forests in Colorado, branch surface areas were about 4.5% of the foliar surface area (Mike Arbaugh, personal communication). Lang et al. (1991) also found branches and stems to represent 5% and 1.6% of the tree surface area in Monterey pine. Thus SAI in our study is expected to be approximately 5-6% greater than LAI.

Both methods used in this study for estimating stand LAI entail considerable uncertainty. Determining stand LAI from litterfall is a well accepted method based on solid theory, assuming that litterfall and foliage production is relatively close to steady state (Marshall and Waring, 1986) and the litter collected is representative of the stand. All indirect methods, such as the light interception method (Ceptometer), can be questioned unless reliable direct measurements of LAI are also made within the same stands. However, application of the litterfall method at BF may be more uncertain than the Ceptometer method because of the unorthodox placing of the litter collectors. The collectors were placed only under mature individual trees for purposes other than determining LAI. We had to adjust our litterfall data (as described above) since collectors were not placed so as to be representative of the entire stand.

We expect that the Ceptometer estimates of LAI at BF are closer to reality than the litterfall measurements.

Based on LAI data from a number of xeric Western ponderosa pine forests (Fassnacht et al., 1994; Gholz, 1982; McLeod and Running, 1988; Wu and Strahler, 1994), it seems clear that the litterfall method underestimated stand LAI. However, based on the open nature of the stands at Barton Flats, but we don't expect the LAI of the three plots to be greater than five. The Ceptometer estimates are likely to be within ±50% of real-world values suggesting that true LAI values for Plot 2 may range from 1.9 to 5.7.

4.2.5 Statistical Analysis of Data

Significance of the effects of position on the tower and time of collection on deposition fluxes of nitrate, ammonium and sulfate to the branches of ponderosa pine seedlings for the 1992, 1993 and 1994 seasons were evaluated with a Two Way Analysis of Variance and a Bonferroni t-test (SigmaStat, 1994).

4.2.6 Calculation of Nitrogen and Sulfur Dry Deposition to Forest Stand

Deposition of N and S compounds to a mixed coniferous stand were calculated for Plot 2 during the 1992 - 1994 seasons. During the 1993 season an intensive study comparing deposition between mature trees and the seedlings of three tree species and within and between three forest plots was conducted. During the 1992 and 1994 seasons deposition was monitored only to ponderosa pine mature trees and seedlings. Because for calculation of deposition of N and S at the forest stand level information on deposition to mature trees and seedlings of three different species, both at the forest floor and in the canopy was required, that was done for the 1993 season. At Plot 2, where the tower was located, most information on deposition has been gathered. A comparison of deposition at different levels of the canopy, a comparison of deposition to branches of seedlings and mature trees, and a comparison of deposition to three major tree species allowed for such calculations. In addition, a comparison of deposition to branches and mature trees of the three species in Plots 1, 2, and 3 may also allow for estimates of atmospheric deposition in Plots 1 and 3 (this comparison is not a part of the report). In order to calculate N and S dry deposition to the mixed coniferous forest stand various assumptions were made and are presented in Appendix A.4.1.

4.3 Results

4.3.1 Leaf Area Indices

Table 4-1 presents the LAI values for each species and total for Plot 2 (1.89) as determined by the litterfall method. The ceptometer method provided a total LAI (3.82) for all vegetation/species combined. The ceptometer results were corrected for published underestimates of ceptometer-derived LAI values compared to direct measurements of LAI in ponderosa pine and oak forests (Fassnacht et al., 1994). Based on litterfall data the calculated total foliar surface area for Plot 2 are as follows:

Ponderosa pine	1827 m^2
White fir	4424 m^2
Black oak	2832 m^2

However, as discussed above, the ceptometer LAI estimate suggests that actual leaf surface values may be twice as great as these values from the litterfall method.

4.3.2 Surface Deposition of Washable Nitrate and Ammonium to Ponderosa Pine Seedlings in a Vertical Gradient

Deposition fluxes of nitrate to the branches of the ponderosa pine seedlings were significantly affected by position within the canopy. The highest deposition flux values were determined at the canopy top, lower at the third level, and lowest at the second level and at the canopy bottom. Significant differences were determined between various collection periods. These effects were consistent during all three seasons. Nitrate deposition flux values were similar during the individual years and generally did not exceed 200 $\mu g\ m^{-2}\ h^{-1}$. Results for the 1993 season are presented in Figure 4-1. During the 1992 season nitrate deposition fluxes ranged from 30 $\mu g\ m^{-2}\ h^{-1}$ at the canopy bottom to 164 $\mu g\ m^{-2}\ h^{-1}$ at the canopy top. During the 1994 season the deposition values ranged from 38 to 198 $\mu g\ m^{-2}\ h^{-1}$. Results of the analysis of variance (effect of position within a tree crown and effect of time on nitrate deposition) are presented in Tables 4-2 through 4-4.

Deposition fluxes of ammonium to branches of ponderosa pine seedlings were also strongly affected by position within the canopy. The highest deposition flux values occurred at the canopy top, lower at the third level, and the lowest at the second level and the canopy bottom. Significantly different deposition fluxes occurred between the individual collection periods. Similarly as for the nitrate, these two effects occurred during all three seasons. The values of ammonium deposition flux were similar for all three seasons and were generally below 20 $\mu g\ m^{-2}\ h^{-1}$. Results for the 1993 season are presented in Figure 4-2. During the 1992 season ammonium deposition fluxes ranged from 5 $\mu g\ m^{-2}\ h^{-1}$ at the canopy bottom to 20 $\mu g\ m^{-2}\ h^{-1}$ at the canopy top. During the 1994 season the deposition values ranged from 3 to 19 $\mu g\ m^{-2}\ h^{-1}$. Results of the analysis of variance (effect of a position within a tree crown and effect of time on nitrate deposition) are presented in Tables 4-5 through 4-7.

Results of a comparison of nitrate and ammonium deposition to branches of mature pines and pine seedlings at different canopy levels are presented in Figures A4-1 through A4-6. Results of these comparisons allowed for calculating correction factors needed to extrapolate results from the foliage of the seedlings to the foliage of mature trees (correction factors of 1.05 for NO_3^- and 1.35 for NH_4^+) -- see Appendix A.

4.3.3 Calculation of HNO_3 Conductance (kHNO3) to Ponderosa Pine Branches in a Vertical Gradient

The estimated values of conductance of HNO_3 (k_{HNO3}) to ponderosa pine branches at different canopy levels during the 1993 season are presented in Figure 4-3. The highest values were always recorded at the canopy top and the lowest at the bottom of the canopy. The range of the calculated K_1 values was 0.2 cm s^{-1} - 3.5 cm s^{-1}. The average K_1 value for the entire season for the entire canopy was 0.93 cm s^{-1}.

4.3.4 Surface Deposition of Washable Nitrate and Ammonium to Ponderosa Pine, White Fir and California Black Oak at Three Plots

Nitrate deposition fluxes to branches of pine seedlings in Plots 1, 2, and 3 are presented in Figures 4-4 and A4-7. Ammonium deposition fluxes to branches of pine seedlings in Plots 1, 2, and 3 are presented in Figures 4-5 and A4-8. These comparisons indicate that deposition fluxes of the two ions to the seedlings placed at the forests floor were similar at all the study sites. Deposition fluxes of nitrate and ammonium to branches of the seedlings located at the top of the canopy (tower top) were much higher than at the forest floor. The presented comparison could be used for estimates of deposition of nitrate and ammonium to Plots 1 and 3 (calculations not included in this report).

Deposition flux values of nitrate to branches of mature trees and seedlings of three tree species in Plots 1, 2, and 3 during two periods of the intensive study are presented in Figures 4-6 and A4-9 through A4-13. Results of these comparisons for Plot 2 were used for calculating correction factors needed for estimates of nitrate deposition to the forest canopy and ground. Deposition fluxes of ammonium to branches of mature trees and seedlings of three tree species in Plots 1, 2, and 3 during two periods of the intensive study are presented in Figures 4-7 and A4-14 through A4-18. Summary of the results of deposition fluxes of nitrate and ammonium to branches of mature ponderosa pine, California black oak, and white fir measured at the forest floor during the intensive study period in summer 1993 are presented in Table 4-8. Results of these comparisons from Plot 2 were used for calculating correction factors needed for estimates of nitrate deposition to the forest canopy and ground (see Appendix A and Section 4.3.5).

4.3.5 Estimation of Nitrogen Dry Deposition to Forest Stand

As an example of estimates of nitrogen deposition to different forest tree species the calculations made for ponderosa pine are presented. Because the calculations for the two other species, California black oak and white fir, were analogous, only the final results of these estimates are presented (other calculations are contained in Appendix A). In addition, calculations of deposition of nitrogen to ground and the entire forest stand at Plot 2 are presented in this section.

4.3.5.1 Deposition to Ponderosa Pine

Surface deposition of washable NO_3^- and NH_4^+ to foliage.

Surface N deposition to mature ponderosa pine trees (foliage and branches) was estimated by scaling average deposition measured to seedling foliage at four different crown positions (12, 16, 24 and 29 m aboveground) during the polluted (May to October) and clean (November - April) seasons.

Fluxes to foliage of mature trees were determined using the following equation:

$$F_{N\text{-mature tree, f.}} = C \times F_{N\text{-seedling, f.}}$$

where: $F_{N\text{-mature tree, f.}}$ = deposition flux of NO_3^- or NH_4^+ to foliage of mature trees ($\mu g\ m^{-2}\ h^{-1}$)

C - correction factor for extrapolating seedling deposition flux to deposition to mature trees ($C = 1.05$ for NO_3^- and 1.35 for NH_4^+)

$F_{N\text{-seedling, f.}}$ = average deposition flux of NO_3^- or NH_4^+ to foliage of seedlings on the tower during the polluted or clean season ($\mu g\ m^{-2}\ h^{-1}$)

Polluted Season

$$F_{NO3\text{-mature tree, f.}} = 1.05 \times F_{NO3\text{-seedling, f.}} = 1.05 \times 16.92\ \mu g\ m^{-2}\ h^{-1} = \underline{17.77\ \mu g\ N\ m^{-2}\ h^{-1}}$$

$$F_{NH4\text{-mature tree, f.}} = 1.35 \times F_{NH4\text{-seedling, f.}} = 1.35 \times 7.73\ \mu g\ m^{-2}\ h^{-1} = \underline{10.44\ \mu g\ N\ m^{-2}\ h^{-1}}$$

Clean Season

Branch washings were not made during the cleaner months of the year (November - April). To estimate deposition fluxes to foliage ($F_{N\text{-mature tree, f.}}$) during the clean season, the following additional assumptions were applied:

(1) NO_3^- deposition was proportional to HNO_3 in the clean and polluted seasons:

$F_{NO3\text{-mature tree, f.}} = [HNO_3]_{clean}/[HNO_3]_{polluted} \times F_{NO3\text{-mature tree, f.}}$ in the polluted season = $(0.354/3.624) \times 17.77\ \mu g\ N\ m^{-2}\ h^{-1} = \underline{1.74\ \mu g\ N\ m^{-2}\ h^{-1}}$

(2) NH_4^+ deposition was proportional to NH_3 in the clean and polluted seasons:

$F_{NH4\text{-mature tree, f.}} = [NH_3]_{clean}/[NH_3]_{polluted} \times F_{NH4\text{-mature tree, f.}}$ in the polluted season $=(0.268/1.422) \times 10.44\ \mu g\ N\ m^{-2}\ h^{-1} = \underline{1.97\ \mu g\ N\ m^{-2}\ h^{-1}}$

Stand level N deposition to foliage ($g\ ha^{-1}$) as determined by the following equation:

$$\text{Stand level N deposition} = 2.08 \times S \times T\ (F_{NO3\text{-mature tree, f.}} + F_{NH4\text{-mature tree, f.}})$$

where: $F_{NO3\text{-mature tree, f.}}$ = NO_3^- deposition flux in the polluted or clean season

$F_{NH4\text{-mature tree, f.}}$ = NH_4^+ deposition flux to foliage in the polluted or clean season

S - surface area of ponderosa pine foliage in Plot 2 (1,827 m^2)

T - time of deposition during the polluted or clean season (182.5 days x 24 h = 4,380 h)

2.08 = "hectare/Plot 2 area" correction factor (10,000 m^2/4,800 m^2)

Stand level N deposition to foliage in the polluted season = 2.08 x 1,827m^2 x (17.77 + 10.44 $\mu g\ m^{-2}\ h^{-1}$) = <u>470.3 g N ha^{-1}</u>

Stand level N deposition to foliage in the clean season = 2.08 x 1,827m^2 x (1.74 + 1.97 $\mu g\ m^{-2}\ h^{-1}$) = <u>61.7 g N ha^{-1}</u>

<u>Surface deposition of washable NO_3^- and NH_4^+ to branches</u>

Deposition of N to branches of mature pines was calculated by extrapolating the results calculated for the foliage (see the above section). Surface area for ponderosa pine branches (S) was estimated as about 4.5% of the foliar surface in Plot 2 (1,827 m^2 x 4.5% = 82.2 m^2; see Appendix A for explanation). It was assumed that deposition flux of both NO_3^- and NH_4^+ was 7.9 x higher to branches than to foliage (see Appendix A for explanation). Therefore, fluxes to branches of mature trees ($F_{N\text{-mature tree, b.}}$) were calculated using the following equation:

$$F_{NO3\text{-mature tree, b.}} = 7.9 \times F_{NO3\text{-mature tree, f.}}$$

$$F_{NH4\text{-mature tree, b.}} = 7.9 \times F_{NH4\text{-mature tree, f.}}$$

Polluted season

$F_{NO3\text{-mature tree, b.}}$ = 7.9 x 17.77 $\mu g\ m^{-2}\ h^{-1}$ = <u>140.38 μg N $m^{-2}\ h^{-1}$</u>

$F_{NH4\text{-mature tree, b.}}$ = 7.9 x 10.44 $\mu g\ m^{-2}\ h^{-1}$ = <u>82.48 μg N $m^{-2}\ h^{-1}$</u>

$F_{N\text{-mature tree, b.}}$ = 140.38 $\mu g\ m^{-2}\ h^{-1}$ + 82.48 $\mu g\ m^{-2}\ h^{-1}$ = <u>222.86 $\mu g\ m^{-2}\ h^{-1}$</u>

Stand level N deposition to branches of mature trees = 2.08 x $F_{N\text{-mature tree, b.}}$ x S x T (see above for explanations of the used correction factor and symbols), and therefore = 2.08 x 222.86 μg N $m^{-2}\ h^{-1}$ x 82.2 m^2 x 4,380 h = <u>167.2 g N ha^{-1}</u>

Clean season

$F_{NO3\text{-mature tree, b.}}$ = 7.9 x 1.74 μg N $m^{-2}\ h^{-1}$ = <u>13.75 $\mu g\ m^{-2}\ h^{-1}$</u>

$F_{NH4\text{-mature tree, b.}}$ = 7.9 x 1.97 μg N $m^{-2}\ h^{-1}$ = <u>15.56 $\mu g\ m^{-2}$ h-1</u>

$F_{N\text{-mature tree, b.}}$ = 13.75 $\mu g\ m^{-2}\ h^{-1}$ + 15.56 $\mu g\ m^{-2}\ h^{-1}$ = <u>29.31 $\mu g\ m^{-2}\ h^{-1}$</u>

Stand level N deposition to branches of mature trees = 2.08 x 29.31 $\mu g\ m^{-2}\ h^{-1}$ x 82.2 m^2 x 4,380 h = <u>21.9 g N ha^{-1}</u>

Summary of deposition flux and stand level deposition of the surface deposited nitrogen is provided in Table 4-9.

<u>Internal stomatal uptake</u>

Internal uptake of pollutants to mature trees in Plot 2 were calculated based on the available information on ambient concentrations of gases of interest and stomatal conductance to H_2O vapor measurements both from the field measurements and literature. Correction factors for stomatal conductance of individual gases were calculated and applied (see Appendix A.4.1).

A general equation was applied:

$$F_{stomatal} = A \times [C]_{gas} \times c_s$$

where: A - correction factor for stomatal conductance of a gas of interest (see Appendix A.4.1)

$[C]_{gas}$ - ambient daytime concentration of a gas of interest (see section 3.3.3.)

c_s - stomatal conductance to H_2O vapor of a given tree species

Stand level deposition of individual N gases were calculated as follows:

Stand level deposition = 2.08 x $F_{stomatal}$ x S x T

Where: 2.08 - "hectare/Plot 2" correction factor (see above)

$F_{stomatal}$ - see above

S - foliar surface area (see Appendix A.4.1)

T - time of exposure (182.5 days x 12 h = 2,190 h)

Polluted season

$F_{stomatal\text{-}HNO3}$ = 0.54 x 4.700 $\mu g\ HNO_3\ m^{-3}$ x 0.065 cm s^{-1} = 5.94 $\mu g\ HNO_3\ m^{-2}\ h^{-1}$ = 1.32 $\mu g\ N\ m^{-2}\ h^{-1}$.

Stand level HNO_3 deposition = 2.08 x 1.32 $\mu g\ N\ m^{-2}\ h^{-1}$ x 1827 m^2 x 2,190 h = <u>11.0 g ha^{-1}</u>.

$F_{stomatal\text{-}NH3}$ = 1.03 x 1.838 $\mu g\ HNO_3\ m^{-3}$ x 0.065 cm s^{-1} = 4.43 $\mu g\ NH_3\ m^{-2}\ h^{-1}$ = 3.64 $\mu g\ N\ m^{-2}\ h^{-1}$.

Stand level NH_3 deposition = 2.08 x 3.64 μg N m^{-2} h^{-1} x 1827 m^2 x 2,190 h = = 30.3 g ha^{-1}.

$F_{stomatal\text{-}NO2}$ = 0.63 x 2.764 μg NO_2 m^{-3} x 0.065 cm s^{-1} x = 4.08 μg NO_2 m^{-2} h^{-1} = 1.24 μg N m^{-2} h^{-1}.

Stand level NO_2 deposition = 2.08 x 1.24 μg N m^{-2} h^{-1} x 1827 m^2 x 2,190 h = 10.3 g N ha^{-1}.

Clean season

$F_{stomatal\text{-}HNO3}$ = 0.54 x 0.509 μg HNO_3 m^{-3} x 0.035 cm s^{-1} x = 0.346 μg HNO_3 m^{-2} h^{-1} = 0.077 μg N m^{-2} h^{-1}.

Stand level HNO_3 deposition = 2.08 x 0.077 μg N m^{-2} h^{-1} x 1827 m^2 x 2,190 h = 0.7 g N ha^{-1}.

$F_{stomatal\text{-}NH3}$ = 0.035 cm s^{-1} x 1.03 x 0.330 μg NH_3 m^{-3} = 1.26 m h^{-1} x 1.03 x 0.330 = 0.428 μg NH_3 m^{-2} h^{-1} = 0.352 μg N m^{-2} h^{-1}.

Stand level NH_3 deposition = 2.08 x 0.352 μg N m^{-2} h^{-1} x 1827 m^2 x 2,190 h = 3.0 g N ha^{-1}.

$F_{stomatal\text{-}NO2}$ = 0.63 x 1.341 μg NO_2 m^{-3} x 0.035 cm s^{-1} = 1.064 μg NO_2 m^{-2} h^{-1} = 0.324 μg N m^{-2} h^{-1}.

Stand level NO_2 deposition = 2.08 x 0.324 μg N m^{-2} h^{-1} x 1827 m^2 x 2,190 h = 2.7 g N ha^{-1}.

Summary of the results of calculations of the stomatal deposition fluxes of individual N gases and estimates of the stand level deposition of these gases to mature ponderosa pines is presented in Table 4-10.

Summary of the deposition calculations for all the three species is presented in Table 4-11. Surface deposition of NO_3^- and NH_4^+ provided most of the deposited nitrogen. Only a small portion of the entire deposition could be attributed to the stomatal uptake of the gaseous N compounds. For the stand level the highest deposition occurred to California black oak (1916.6 g ha^{-1}), followed by white fir (1252.2 g ha^{-1}), and ponderosa pine (779.2 g ha^{-1}).

4.3.5.2 Deposition to Ground

For calculation of ground deposition an assumption was made that the ground surface was flat and that the deposition flux was equal to the average deposition to mature trees of 3 species at the ground level in Plot 2 ($F_{NO3 + NH4}$) = 7.16 μg N m^{-2} h^{-1} for the polluted season (see Table 4-8) and 0.97 μg m^{-2} h^{-1} for the clean season.

Therefore the general formula used for those calculations was as follows:

Ground deposition = $F_{NO3 + NH4}$ x S x T

Where: $F_{NO3 + NH4}$ (see above)

S - area of 1 hectare (10,000 m^2)

T - time for polluted or clean season (182.5 days x 24 h = 4,380 h)

Polluted season

Ground deposition = 7.16 μg N m^{-2} h^{-1} x 10,000 m^2 x 4,380 h = 313.6 g N ha^{-1}.

Clean season

Ground deposition = 0.97 μg N m^{-2} h^{-1} x 10,000 m^2 x 4,380 h = = 42.5 g N ha^{-1}.

Total ground deposition = 313.6 + 42.5 = 356.1 g ha^{-1} yr^{-1}.

4.3.5.3 Total Nitrogen Dry Deposition

Total estimated atmospheric dry deposition of N pollutants to the forest in Plot 2 = 721.2 (surface deposition to pine) + 58.0 (stomatal uptake by pine) + 1755.6 (surface deposition to oak) + 160.3 (stomatal uptake by oak) + 1111.9 (surface deposition to fir) + 140.3 (stomatal uptake by fir) + 356.1 (ground deposition) = **4303.4 g N ha^{-1} yr^{-1}**.

In Table 4-12 a summary of calculations for a forest stand (Plot 2) using two values of a leaf area index (LAI = 1.89 determined with a litterfall analysis and 3.82 obtained with a ceptometer method) and wet deposition is presented. Total amount of deposited N at Plot 2 assuming that the LAI = 1.89 was **4834.1 g ha^{-1}**. At the higher LAI = 3.82 that estimate increased to **8869.7 g ha^{-1}**.

4.3.6 Surface Deposition of Washable Sulfate to Ponderosa Pine Seedlings on a Vertical Gradient

Deposition fluxes of sulfate to the branches of ponderosa pine seedlings at different canopy levels during the 1992 - 1994 seasons are presented in Figures 4-8 through 4-10. During the 1992 (Figure 4-8) season and sulfate deposition had a similar pattern as nitrate and ammonium (Figure 4-1) - the highest deposition occurred at the canopy top (tower top), followed by the third level. The lowest deposition was observed at the second and first levels of the canopy. However, during the 1993 season (Figure 4-9) and 1994 season (Figure 4-10) significant differences in deposition of sulfate occurred between the individual sampling events during all three seasons. Results of the analysis of variance (effect of position within a crown and effects of time on sulfate deposition) are presented in Tables 4-13 through 4-15.

Deposition fluxes of sulfate to the branches of mature trees and branches of the seedlings during the 1993 season at three different levels of the canopy are presented in Figures A4-18 through A4-20. Results of these

comparisons from Plot 2 were used to calculate a correction factor needed for estimates of sulfate deposition to branches of mature trees (1.20) -- see Appendix A.

4.3.7 Surface Deposition of Washable Sulfate to Ponderosa Pine, White Fir and California Black Oak at Three Plots

Deposition of sulfate to branches of the ponderosa pine seedlings in Plots 1, 2, and 3 during the first period of the intensive study is presented in Figure 4-11, and during the second period in Figure A4-22. During the first event deposition of sulfate to the seedlings located at the forest floor was similar at all sites. During the second period the variability between the plots was very high and the highest deposition occurred at Plot 2 (Figure A4-22).

Deposition of sulfate to seedlings and mature trees of all the species in Plots 1, 2, and 3 during two periods of the intensive study is presented in Figures 4-12 and A4-23 through A4-27. Summary of these results is presented in Table 4-16. Results of this comparison from Plot 2 were used for calculating correction factors needed for estimates of sulfate deposition to the forest canopy and ground at the forest stand level.

4.3.8 Estimation of Sulfur Dry Deposition to Forest Stand

Calculations of sulfate deposition to Plot 2 were analogous to the calculations of nitrate and ammonium deposition. The assumptions used for the calculations and detailed calculations are presented in Appendix A.4.4. Summary of deposition fluxes to three tree species at Plot 2 is presented in Table 4-17 and indicates that surface washable sulfate was the major contributor in the total sulfur deposition.

Total dry deposition of sulfur to Plot 2 (canopy and ground) = 958.8 (canopy) + 98.1 (ground) = **1056.9 g ha^{-1} yr^{-1}**.

4.4 Discussion

The results of this study clearly indicate that nitrate and ammonium deposition fluxes in a mixed coniferous forest strongly depend on position of branches within canopy. The higher the position of the branches the higher was the deposition of these ions. A similar phenomenon (with the exception of the 1993 season) was also determined for sulfate deposition. Because concentrations of the gaseous and particulate pollutants did not depend on position in a canopy (Section 3.3.4), the observed distribution of deposition fluxes within the forest canopy could not be related to the air pollution concentrations differences. The observed differences in deposition fluxes could be attributed to differences in wind speed occurring in a vertical gradient within the canopy - the highest deposition values occurred at the canopy top where wind speeds were always the highest. Correlations between wind speed and fluxes of nitrate, ammonium and sulfate to branches will be determined for peer-reviewed articles planned for this part of the study.

As a result of the study, we were able to calculate conductance (k_{HNO3}) values for HNO_3 throughout the 1993 season for four levels of the canopy. The highest values were always recorded at the canopy top and

they could reach about 3.5 cm s^{-1}. The average k_{HNO3} value for the entire season for the canopy was 0.93 cm s^{-1}. The range of these values is very similar to the k_{HNO3} values of 0.6 - 3.4 cm s^{-1} determined for loblolly pine in Tennessee (Hanson and Garten, 1992). The k_{HNO3} values determined in this study can be used to estimate NO_3^- deposition to ponderosa pine canopies, if ambient concentrations of the HNO_3 and leaf area index are known. These values can also be used for comparing estimates of gaseous inputs to forest stand the Big Leaf Model (see Section 8 of this document).

Based on literature values of LAI for western ponderosa pine forests, which range from 4.8 to 20, although this latter value is highly atypical (Fassnacht et al., 1994; Gholz, 1982; Grier and Running, 1977; McLeod and Running, 1988) it seems likely that the LAI of the litterfall method (1.89) was an underestimate of the true LAI of Plot 2. The litterfall method could have underestimated LAI due to underestimates of the proportion of litter falling outside of the drip area, underestimating the "t" value or number of whorls on plot trees, litter being lost from the litter collectors due to wind or other disturbance, or inaccuracies in converting litter mass to litter surface area. The litterfall method used at Barton Flats has greater uncertainty than normal due to the unorthodox placing of litter collectors for purposes of determining stand LAI, and because of uncertainty in the proportion of litter that falls outside of the tree drip areas. The original primary intent of collecting litterfall data was for comparing litterfall of individual trees in relation to tree vigor and stress effects, and not for LAI determinations. It was concluded that the ceptometer estimates of LAI were probably closer to the true LAI than the litterfall-based estimates. Nonetheless, the litterfall method provided an estimate of the relative leaf areas of the three dominant overstory species in the plots, while the optical method provided only an indirect measure of total LAI.

In general, deposition fluxes of nitrate and ammonium to the branches of mature trees and the seedlings were similar -- with the exception of the August 30 - September 7, 1993 period when deposition of NO_3^- and NH_4^+ to mature branches was higher. This indicates that deposition fluxes determined for the seedlings could be extrapolated to the mature trees. Deposition fluxes of NO_3^-, NH_4^+ and SO_4^{2-} to California black oak were the highest, and the lowest for white fir. Large differences in deposition between the species indicate that for realistic estimates of deposition on a forest stand level deposition determinations on all the dominant tree species have to be made.

No big differences in deposition fluxes between the individual plots were determined for all the studied ions. These findings indicate that inputs of NO_3^-, NH_4^+ and SO_4^{2-} in Plots 1, 2, and 3 were similar. Comparison of deposition fluxes of NO_3^-, NH_4^+, and SO_4^{2-} between the plots could be used for calculating N and S deposition at Plots 1 and 2. This finding indicates for investigations of the effects of N deposition on mixed coniferous forest stands a steeper gradient of N deposition should be selected. This could be accomplished by extending the existing gradient westward (closer to the Los Angeles Basin pollution source area) and eastward (more pristine environment). Judging from concentrations of N pollutants and deposition of nitrate and ammonium to tree branches recorded at some heavily polluted sites in the San Bernardino (Crestline) and San Gabriel Mountains (Tanbark Flat), Barton Flats is located in the middle of the N air pollution gradient.

During three seasons similar values of nitrate deposition were observed. The deposition of nitrate to seedlings varied from about 30-40 $\mu g\ m^{-2}\ h^{-1}$ at the bottom of the canopy to about 200 $\mu g\ m^{-2}\ h^{-1}$ at the canopy top.

The fluxes determined at the tower were elevated - the highest values were similar to the value of 180 $\mu g\ m^{-2}\ h^{-1}$ determined for the mature ponderosa pines in Camp Paivika of the San Bernardino National Forest (Fenn and Bytnerowicz, 1993). Higher nitrate deposition values were determined at the Tanbark Flat site of the San Gabriel Mountains -- deposition to *Ceanothus crassifolius* was in a range of 88 - 455 $\mu g\ m^{-2}\ h^{-1}$ (Bytnerowicz et al., 1987). Deposition of nitrate to native pines in other parts of the state were much lower: Eastern Brook Lake, Eastern Sierra Nevada -- about 4-6 $\mu g\ m^{-2}\ h^{-1}$ (Bytnerowicz et al., 1992); Emerald Lake, western Sierra Nevada -- 27-30 $\mu g\ m^{-2}\ h^{-1}$ (Bytnerowicz et al., 1991); and Whitaker Forest, western Sierra Nevada -- 6-31 $\mu g\ m^{-2}\ h^{-1}$ (Bytnerowicz and Riechers, 1995).

Similarly as for nitrate, deposition fluxes of ammonium (ranging from about 5 at the canopy bottom to about 20 $\mu g\ m^{-2}\ h^{-1}$ at the top) were elevated. The highest values were similar to an average deposition of 21 $\mu g\ NH_4^+\ m^{-2}\ h^{-1}$ determined at Camp Paivika (Fenn and Bytnerowicz, 1993). Deposition of ammonium to *Ceanothus crassifolius* at Tanbark Flat was higher -- 17-46 $\mu g\ m^{-2}\ h^{-1}$ (Bytnerowicz et al., 1987). Deposition to native pines at some other forest sites in California were lower: at Eastern Brook Lake -- 0.8-1.6 $\mu g\ m^{-2}\ h^{-1}$ (Bytnerowicz et al., 1992), Emerald Lake -- 6-9 $\mu g\ m^{-2}\ h^{-1}$ (Bytnerowicz et al., 1991), and Whitaker Forest -- 1.0-1.5 $\mu g\ m^{-2}\ h^{-1}$ (Bytnerowicz and Riechers, 1995).

Sulfate deposition to pine seedlings (ranging from about 5 $\mu g\ m^{-2}\ h^{-1}$ at the bottom of the canopy to about 20 $\mu g\ m^{-2}\ h^{-1}$ at the canopy top) was also elevated and in a range of the values determined for *Ceanothus crassifolius* (7.7 - 43 $\mu g\ m^{-2}\ h^{-1}$) at the Tanbark Flat site (Bytnerowicz et al., 1987). The average sulfate deposition to ponderosa pine branches at Camp Paivika was about 6.9 $\mu g\ m^{-2}\ h^{-1}$ (Fenn and Bytnerowicz, 1993); to native pines at Eastern Brook Lake about 1.5 $\mu g\ m^{-2}\ h^{-1}$ (Bytnerowicz et al., 1992), and at Emerald Lake in a range of 3.2 - 4.9 $\mu g\ m^{-2}\ h^{-1}$ (Bytnerowicz et al., 1993).

Using two different leaf area index values and adding wet deposition the total N deposition for Plot 2 in the 1993 season was in a range of 5 - 9 kg $ha^{-1}\ yr^{-1}$. The majority of that was in a form of dry deposited materials to plant surfaces. Only very small fraction of the total deposition could be attributed to stomatal uptake of N and S gases. Similarly, only a small portion of total deposition could be attributed to wet deposition. The determined values of total N deposition indicate that the Barton Flat site experiences elevated N deposition. For a comparison -- at the pristine Eastern Brook Lake site of the eastern Sierras the total N deposition was about 0.5 kg $ha^{-1}\ yr^{-1}$ (Bytnerowicz et al., 1992). However, the reported total N deposition is much lower than the N deposition determined for Camp Paivika (about 29 kg $ha^{-1}\ yr^{-1}$) (Fenn and Bytnerowicz, 1993) or Tanbark Flat (about 20 - 35 kg $ha^{-1}\ yr^{-1}$ (Bytnerowicz et al. 1987; Riggan et al., 1985). Our estimates indicate a potential for serious ecological consequences if elevated N deposition continues. Various changes such as initial improved forest growth, changes in species composition, modified responses to various environmental stresses (including ozone), changes in nutritional status of soils, increase of contamination of ground water with nitrogen, and others can be expected (Aber et al., 1989; Nihlgard, 1990).

4.5 Summary

This study indicated that nitrate, ammonium and sulfate deposition fluxes in a mixed coniferous forest

strongly depended on position of branches within canopy. The highest deposition of these ions was determined at the canopy top and the deposition at the canopy bottom was often 3-4 times lower. The observed differences in deposition fluxes were related to higher wind speeds at the upper parts of plant canopies.

HNO_3 conductance (k_{HNO3}) to ponderosa pine branches were calculated at various levels of the canopy. The highest values were recorded at the canopy top and reached 3.5 cm s^{-1}. The average K_{HNO3} value for the entire summer 1993 season was 0.93 cm s^{-1}. The HNO_3 conductance values can be used for future estimates of NO_3^- deposition to ponderosa pine canopies when information on ambient concentrations of HNO_3 is provided.

In general, deposition fluxes of nitrate and ammonium to the branches on mature trees and seedlings were similar. This indicated a possibility of extrapolating the results obtained for the seedlings to canopies of mature trees. Comparison of deposition fluxes on NO_3^-, NH_4^+ and SO_4^{2-} among the studied species indicated that deposition fluxes were the highest for California black oak. The lowest fluxes were determined for white fir. These large differences in deposition to various species indicate that for realistic estimates of atmospheric dry deposition at a forest stand level deposition to all the dominant forest trees has to be determined.

The ranges of deposition fluxes of NO_3^-, NH_4^+ and SO_4^{2-} were similar between the three seasons of investigations. A comparison of the results of this study with other sites in California indicated that deposition fluxes of the studied ions were much higher than in the pristine areas of the State. Our calculations showed that between 5 to 9 kg N ha^{-1} yr^{-1} was deposited at the Barton Flat site in 1993. Most of that deposition was in a form of dry deposition to plant surfaces. Although the reported values are lower than values determined at the more polluted sites of the San Bernardino and San Gabriel Mountains, over a long time serious ecological changes in forest ecosystems caused by elevated N inputs should be expected.

4.6 References

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Table 4-1. LAI values estimated for Plot 2 at Barton Flats.

Species	Litterfall, Sum of Tree Areas	Litterfall, Assuming a Transect*	Ceptometer# Method
White Fir	0.92	0.26	
Black Oak	0.59*	0.59	
Ponderosa Pine	0.38	0.61	
Total LAI	1.89	1.46	3.82

*Black oak LAI was determined only by the litterfall method assuming that collectors were placed along a transect. LAI for white fir and ponderosa pine were computed with this assumption (violated in this study) only for comparative purposes.

#Strictly speaking this is vegetation surface area index (SAI) since in addition to foliage, optical measurements also account for area of branches, stems, cones, etc.

Table 4-2. Summary of the ANOVA for the results of nitrate deposition ($\mu g\ m^{-2}\ h^{-1}$) to branches of ponderosa pine seedlings at four levels of the canopy during three periods in the 1992 season.

	Effect of position		Effect of time	
p value	<0.0001		<0.0001	
Mean				
top	126.2	a	July 16-	89.1 a
third	67.6	b	Aug. 21-	63.9 b
second	40.7	c	Sep. 18-	49.5 c
bottom	35.4	c		

Table 4-3. Summary of ANOVA for the results of nitrate deposition ($\mu g\ m^{-2}\ h^{-1}$) to branches of ponderosa pine seedlings at four levels of the canopy during six periods in the 1993 season.

	Effect of position		Effect of time	
p value	<0.0001		<0.0001	
Mean				
top	118.6	a	May 27-	91.0 b
third	79.8	b	June 23-	61.2 c
second	51.9	c	July 19-	79.2 bc
bottom	52.4	c	July 23	68.9 c
			Aug. 30-	115.7 a
			Sep. 24-	37.9 d

Table 4-4. Summary of ANOVA for the results of nitrate deposition ($\mu g\ m^{-2}\ h^{-1}$) to branches of ponderosa pine seedlings at four levels of the canopy during four periods in the 1994 season.

	Effect of position		Effect of time	
p value	<0.0001		<0.0001	
Mean				
top	132.6	a	June 3-	87.4 b
third	84.0	b	July 5-	82.5 b
second	62.9	bc	Aug. 19-	51.3 c
bottom	54.7	c	Aug. 29-	113.0 a

Table 4-5. Summary of ANOVA for the results of ammonium deposition ($\mu g\ m^{-2}\ h^{-1}$) to branches of ponderosa pine seedlings at four levels of the canopy during three periods in the 1992 season.

	Effect of position		Effect of time	
p value	<0.0001		<0.0001	
Mean				
top	13.29	a	July 16-	13.03 a
third	9.77	b	Aug. 21-	6.39 b
second	6.61	c	Sep. 18-	7.59 b
bottom	6.33	c		

Table 4-6. Summary of ANOVA for the results of ammonium deposition ($\mu g\ m^{-2}\ h^{-1}$) to branches of ponderosa pine seedlings at four levels of the canopy during six periods in the 1993 season.

	Effect of position		Effect of time	
p value	<0.0001		<0.0001	
Mean				
top	14.57	a	May 27-	7.19 b
third	10.01	b	June 23-	8.52 b
second	8.13	c	July 19-	13.07 a
bottom	7.02	c	July 23-	11.51 a
			Aug. 30-	12.16 a
			Sep. 24-	7.15 b

Table 4-7. Summary of ANOVA for the results of ammonium deposition ($\mu g\ m^{-2}\ h^{-1}$) to branches of ponderosa pine seedlings at four levels of the canopy during four periods in the 1994 season.

	Effect of position		Effect of time	
p value	<0.0001		<0.0001	
Mean				
top	12.00	a	June 3-	5.96 c
third	9.02	b	July 5-	9.79 b
second	8.28	b	Aug. 19-	6.96 c
bottom	5.74	c	Aug. 29-	12.32 a

Table 4-8. Deposition of nitrate and ammonium ($\mu g\ m^{-2}\ h^{-1}$) to branches of mature trees at the forest floor level during the intensive study. Results are presented as means and standard deviations (in parantheses).

Plot Number	Pine		Oak		Fir	
	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+
July 19-23, 1993						
1	12.88 (4.68)	4.10 (1.38)	32.80 (5.67)	5.80 (1.59)	13.45 (1.11)	2.92 (0.75)
2	12.65 (3.99)	4.14 (1.13)	35.30 (11.32)	5.74 (1.61)	9.32 (6.45)	1.78 (1.55)
3	18.33 (9.95)	4.96 (2.37)	22.23 (8.94)	4.75 (2.44)	7.80 (4.80)	1.64 (1.54)
July 23-30, 1993						
1	13.21 (3.26)	3.80 (0.92)	29.70 (5.70)	5.53 (1.56)	15.06 (1.29)	2.90 (0.76)
2	16.10 (1.45)	4.84 (0.55)	30.37 (6.80)	5.08 (0.50)	8.18 (1.36)	1.21 (0.34)
3	19.58 (6.98)	4.71 (1.72)	24.89 (8.74)	4.16 (1.42)	10.08 (3.34)	2.14 (0.52)

Table 4-9. Various forms of surface nitrogen deposition to mature ponderosa pines at Plot 2.

Deposition	foliage		branches	
	polluted season	clean season	polluted season	clean season
F_{NO3} (μg N m^{-2} h^{-1})	17.77	1.74	140.38	13.75
F_{NH4} (μg N m^{-2} h^{-1})	10.44	1.97	82.48	15.56
F_N (μg N m^{-2} h^{-1})	28.21	3.71	228.86	29.31
Stand level (g N ha^{-1})	470.3	61.7	167.2	21.9

Table 4-10. Deposition fluxes and stand level deposition of N gases to mature ponderosa pines in Plot 2.

Nitrogenous gas	$F_{stomatal}$ ($\mu g\ N\ m^{-2}\ h^{-1}$)		Stand level deposition ($g\ N\ ha^{-1}$)	
	Polluted season	Clean Season	Polluted Season	Clean Season
HNO_3	1.32	0.08	11.0	0.7
NH_3	3.64	0.35	30.3	3.0
NO_2	1.24	0.32	10.3	2.7

Table 4-11. Nitrogen dry deposition to trees at Plot 2 during the 1993 season (g N ha^{-1} yr^{-1}) assuming LAI = 1.89.

Parameter	Pine	Oak	Fir	Total
$NO_3^- + NH_4^+$, foliage washable, polluted season	470.3	1234.7	730.3	2435.3
$NO_3^- + NH_4^+$, foliage washable, clean season	61.7	-	90.0	151.7
$NO_3^- + NH_4^+$, branch washable, polluted season	167.2	465.1	259.6	891.9
$NO_3^- + NH_4^+$. branch washable, clean season	22.0	56.5	32.0	110.5
HNO_3, stomatal uptake, polluted season	11.0	34.1	26.6	71.7
HNO_3, stomatal uptake, clean season	0.7	-	1.5	2.2
NH_3, stomatal uptake, polluted season	30.3	94.2	73.5	198.0
NH_3, stomatal uptake, clean season	3.0	-	7.1	10.1
NO_2, stomatal uptake, polluted season	10.3	32.0	25.1	67.4
NO_2, stomatal uptake, clean season	2.7	-	6.5	9.2
Total	779.2	1916.6	1252.2	3948

Table 4-12. Calculated total nitrogen deposition at Plot 2 during the 1993 season (g N ha^{-1} yr^{-1}) - summary.

Parameter	LAI=1.89	LAI=3.82
NO_3^- washable	2511.7	5076.6
NH_4^+ washable	1077.7	2178.2
HNO_3 stomatal	73.9	149.4
NH_3 stomatal	208.1	420.6
NO_2 stomatal	76.6	154.8
Rain, summer	420	420
Rain+snow, winter	110	110
Ground	356.1	356.1
Total	4834.1	8865.7

Table 4-13. Summary of the ANOVA for the results of sulfate deposition ($\mu g\ m^{-2}\ h^{-1}$) to branches of ponderosa pine seedlings at four levels of the canopy during three periods in the 1992 season.

	Effect of position		Effect of time	
p value	<0.0001		<0.0001	
Mean				
top	14.67	a	July 16-	10.05 a
third	8.73	b	Aug. 21-	9.15 a
second	5.01	c	Sep. 18-	5.75 b
bottom	4.85	c		

Table 4-14. Summary of the ANOVA for the results of sulfate deposition ($\mu g\ m^{-2}\ h^{-1}$) to branches of ponderosa pine seedlings at four levels of the canopy during six periods in the 1993 season.

	Effect of position		Effect of time	
p value	<0.0084		<0.0001	
Mean				
top	14.61	a	May 27-	14.20 b
third	12.77	ab	June 23-	7.03 c
second	8.95	b	July 19-	11.56 bc
bottom	12.42	ab	July 23-	10.85 bc
			Aug. 30-	21.73 a
			Sep. 24-	7.76 c

Table 4-15. Summary of the ANOVA for the results of sulfate deposition ($\mu g\ m^{-2}\ h^{-1}$) to branches of ponderosa pine seedlings at four levels of the canopy during four periods in the 1994 season.

	Effect of position		Effect of time	
p value	<0.0001		<0.0001	
Mean				
top	13.08	a	June 3-	7.46 b
third	7.36	b	July 5-	9.65 ab
second	6.22	b	Aug. 19-	5.11 c
bottom	6.49	b	Aug. 29-	10.92 a

Table 4-16. Deposition of sulfate to branches of mature trees at the forest floor level during the intensive study ($\mu g\ m^{-2}\ h^{-1}$). Results are presented as means and standard deviation (in parentheses).

Plot Number	Pine	Oak	Fir
July 19-23, 1993			
1	2.31 (1.17)	5.90 (2.26)	3.79 (4.10)
2	2.15 (0.30)	5.68 (2.12)	5.23 (0.23)
3	2.08 (0.62)	4.78 (3.22)	1.88 (0.20)
July 23-30, 1993			
1	2.02 (2.25)	3.13 (1.28)	0.68 (0.39)
2	1.70 (1.22)	4.00 (0.48)	1.35 (0.88)
3	2.48 (0.59)	8.67 (4.22)	1.25 (1.09)

Table 4-17. Sulfur dry deposition (g S ha^{-1} yr^{-1})to trees at Plot 2 during the 1993 season.

Parameter	Pine	Oak	Fir	Total
SO_4^{2-},foliage washable	150.7	289.7	405.3	845.7
SO_4^{2-}, branch washable	6.8	58.5	18.1	83.4
SO_2 internal	6	9.2	14.5	29.7
Total	163.5	357.4	437.9	958.8

Figure 4-1. Nitrate deposition flux to foliage of ponderosa pine seedlings in a vertical gradient during the 1993 season (presented as means and standard deviations).

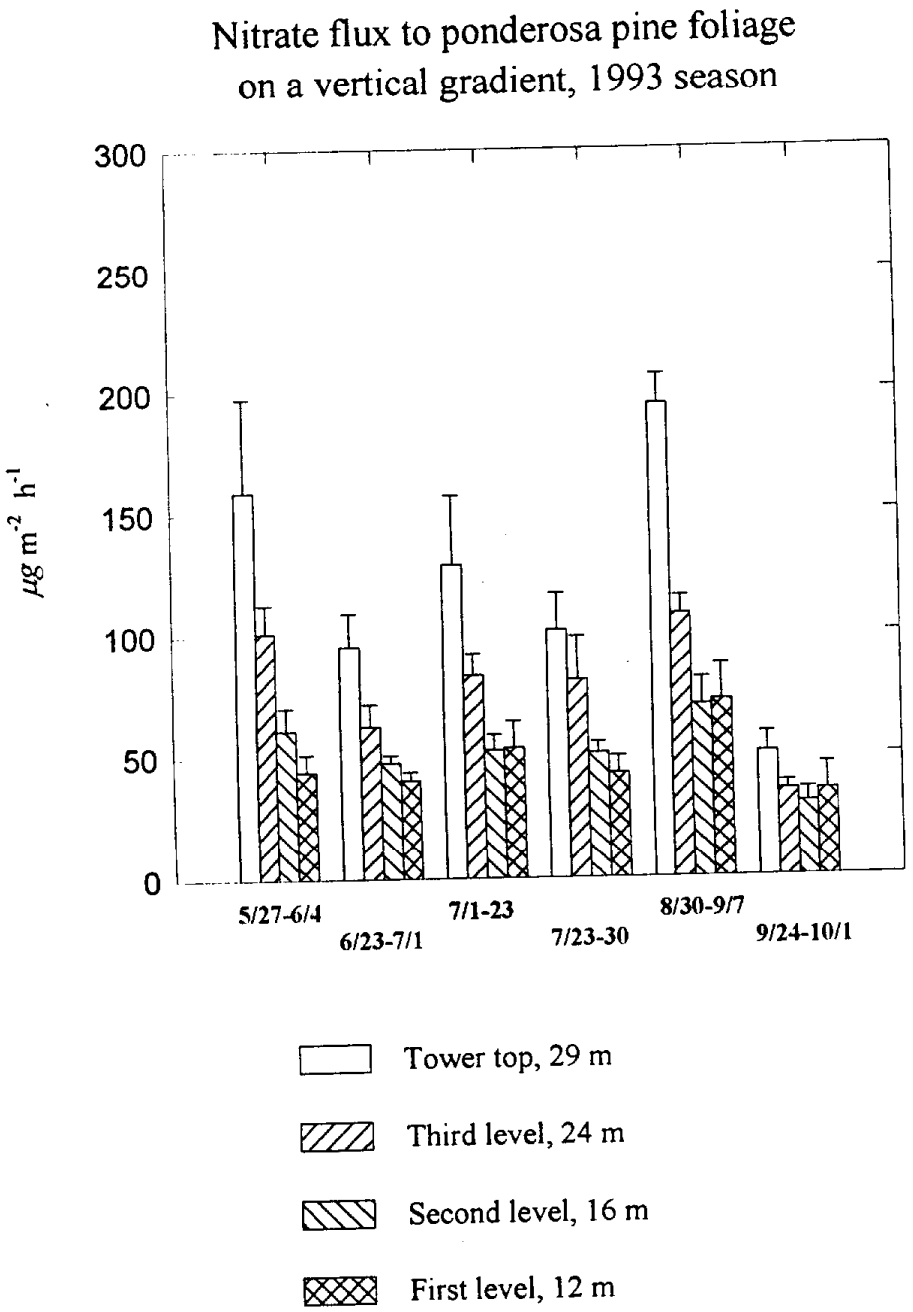


Figure 4-2. Ammonium deposition flux to foliage of ponderosa pine seedlings in a vertical gradient during the 1993 season (presented as means and standard deviations).

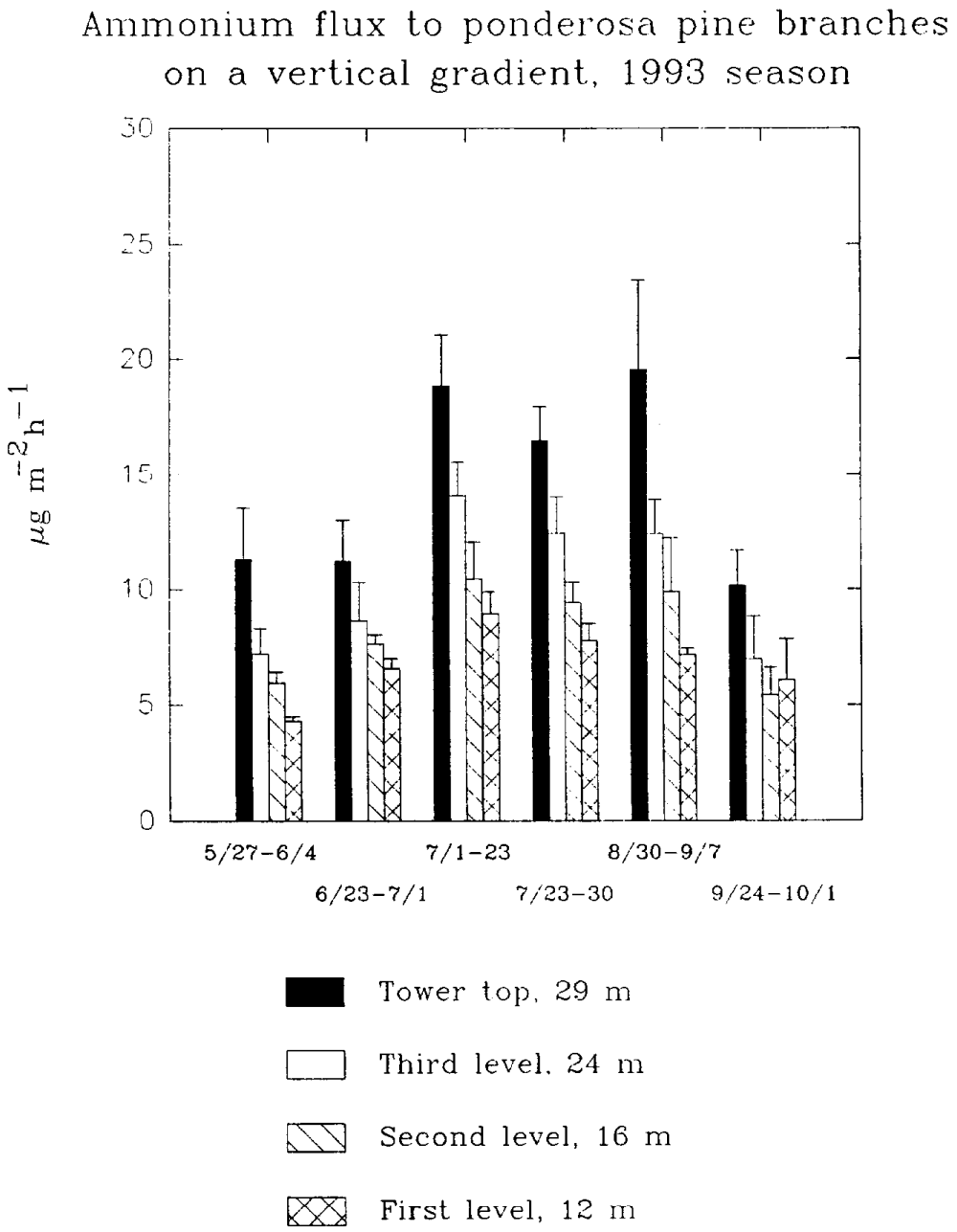


Figure 4-3. Estimated conductance (k_{HNO3}) of nitric acid vapor to ponderosa pine foliage for different height on the tower during the 1993 polluted season.

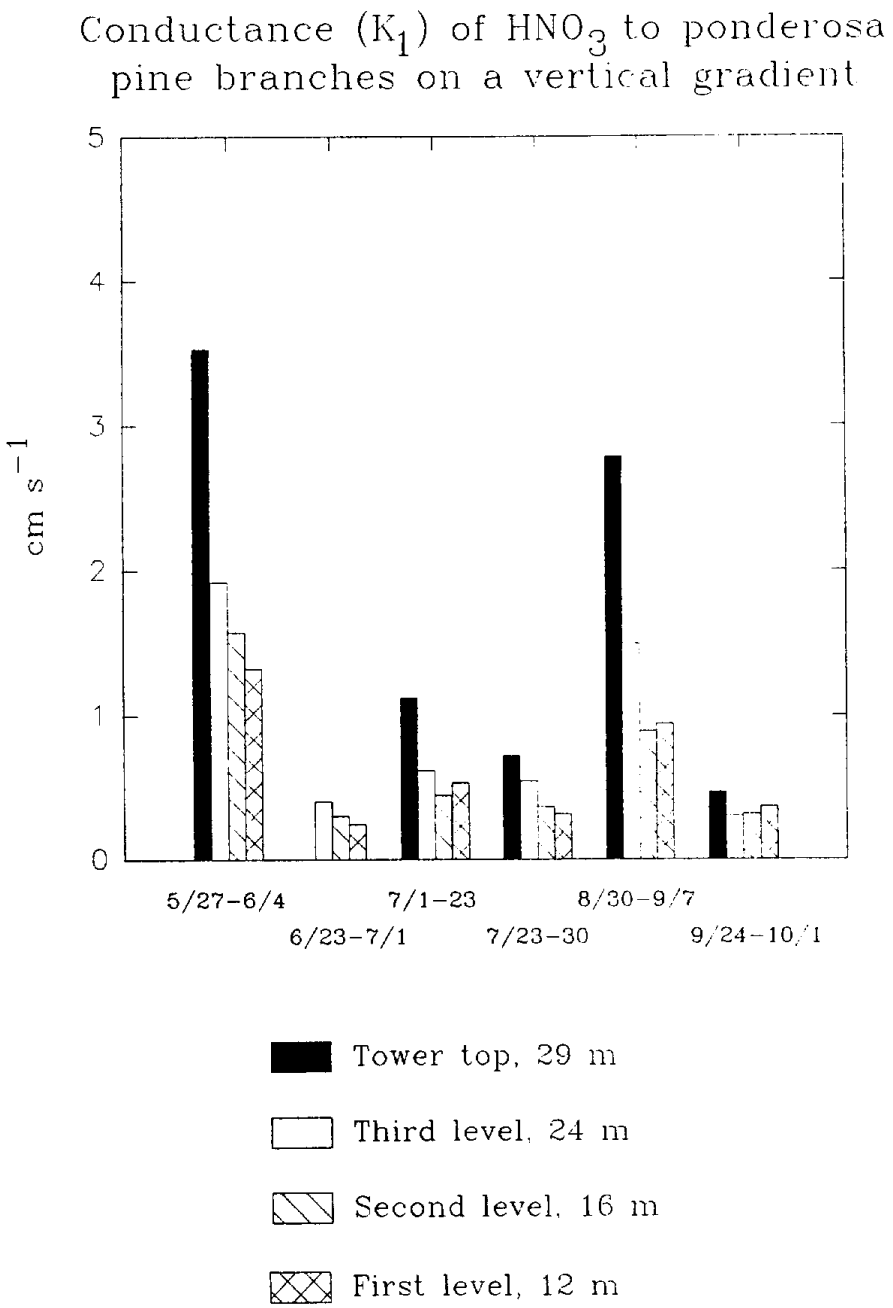


Figure 4-4. Deposition of nitrate to foliage of ponderosa pine seedlings located at the forest floor of Plots 1, 2, and 3, roof of the monitoring station and tower top (Plot 2) during the July 23 - 30, 1993 period of the intensive study (presented as means and standard deviations).

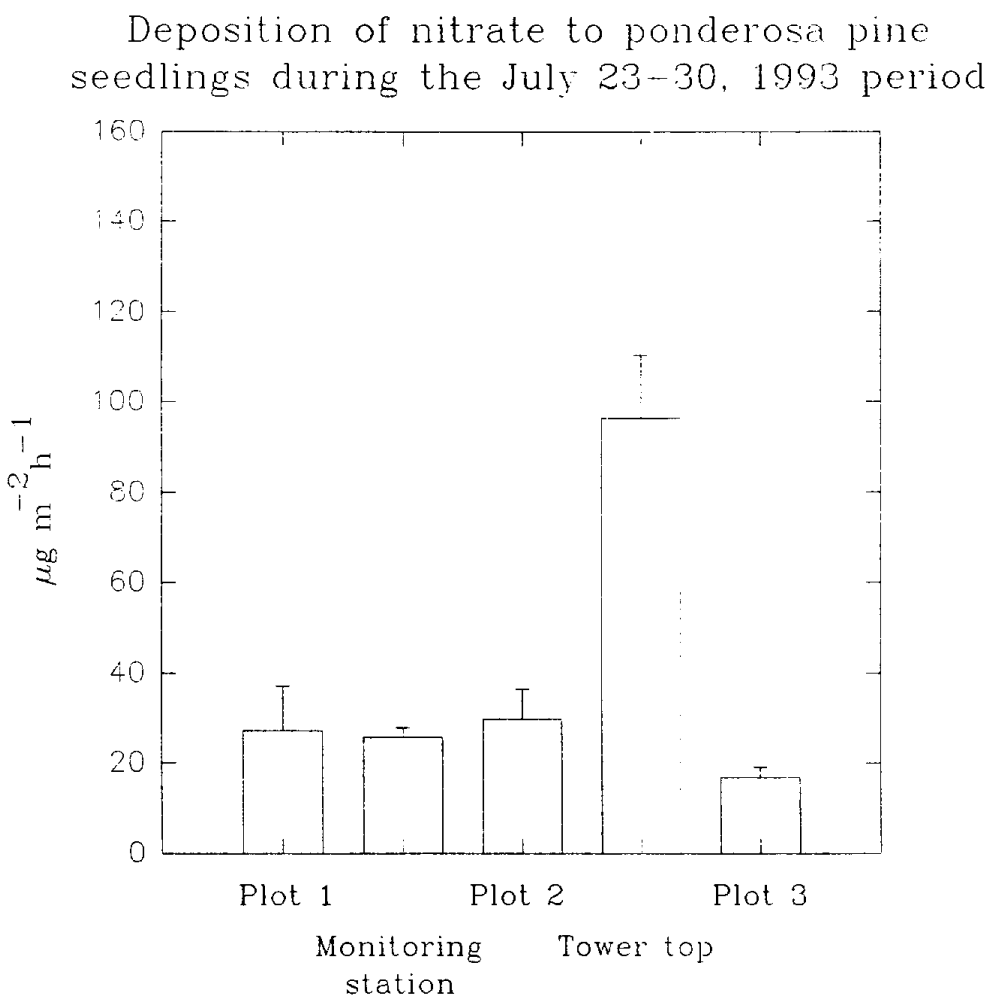


Figure 4-5. Deposition of ammonium to foliage of ponderosa pine seedlings located at the forest floor of Plots 1, 2, and 3, roof of the monitoring station and tower top (Plot 2) during the July 23 - 30, 1993 period of the intensive study (prsenetd as means and standard deviations).

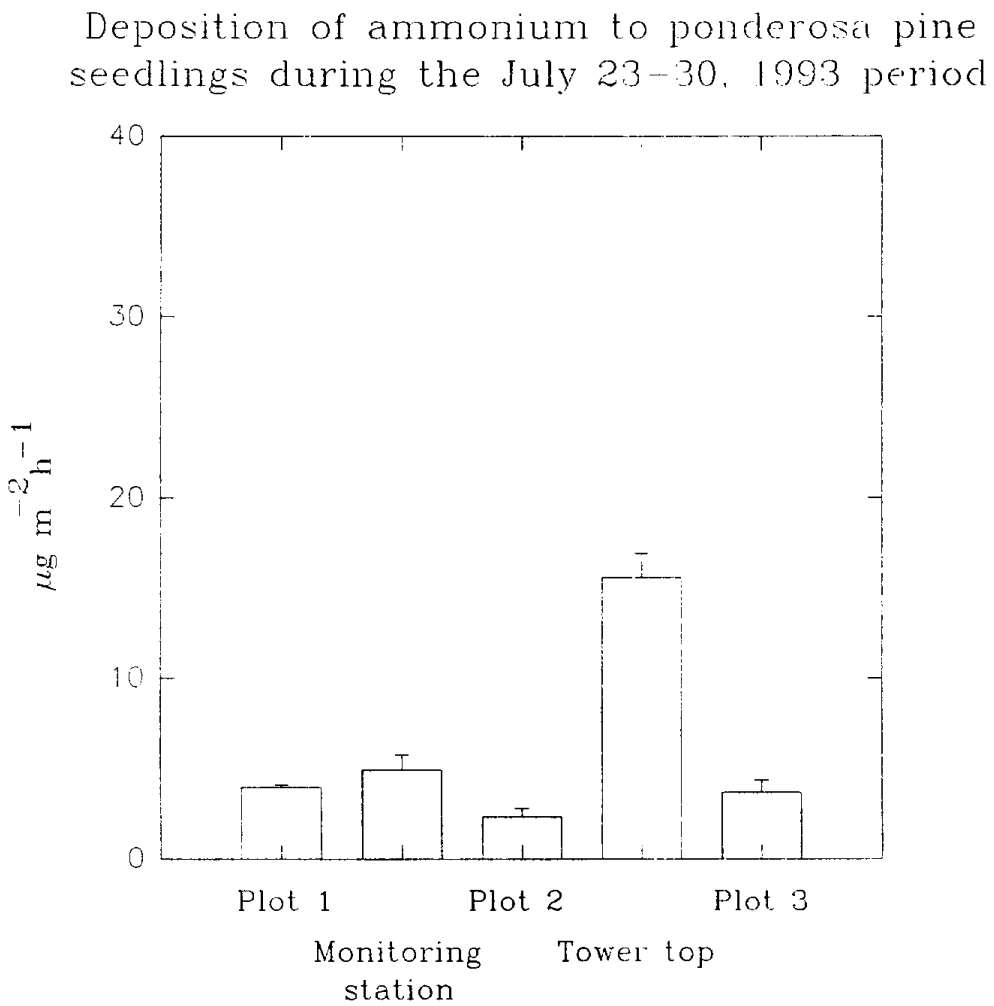


Figure 4-6. Comparison of nitrate deposition to foliage of mature trees vs. seedlings of various species at Plot 1 during the July 19 - 23, 1993 period of the intensive study (presented as means and standard deviation).

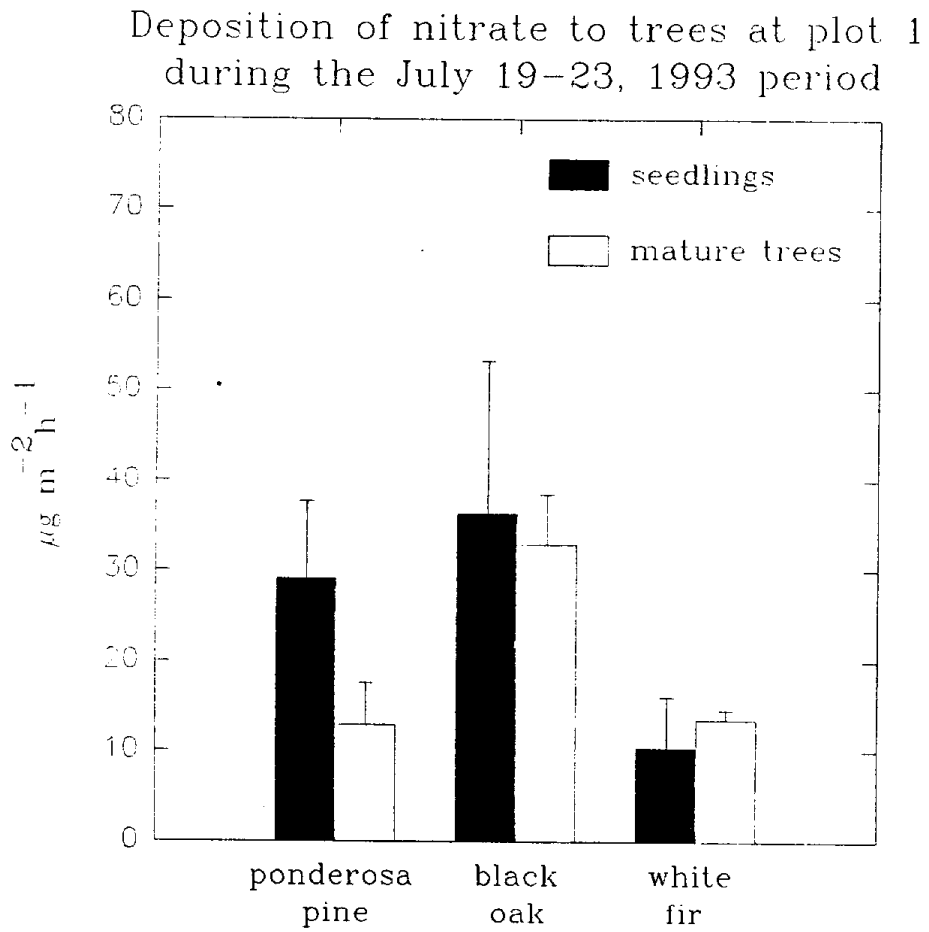


Figure 4-7. Comparison of ammonium deposition to foliage of mature trees vs. seedlings of various species at Plot 1 during the July 19 - 23, 1993 period of the intensive study (presented as means and standard deviations).

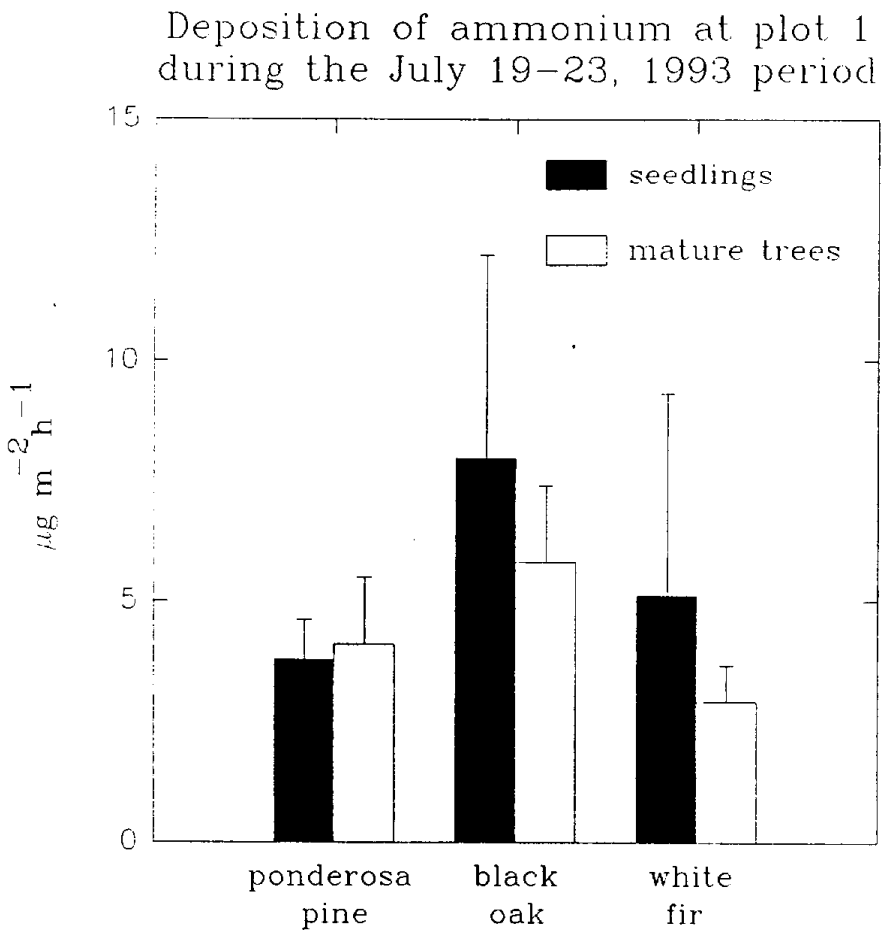


Figure 4-8. Sulfate deposition flux to ponderosa pine seedlings in a vertical gradient during the 1992 season (presented as means and standard deviations).

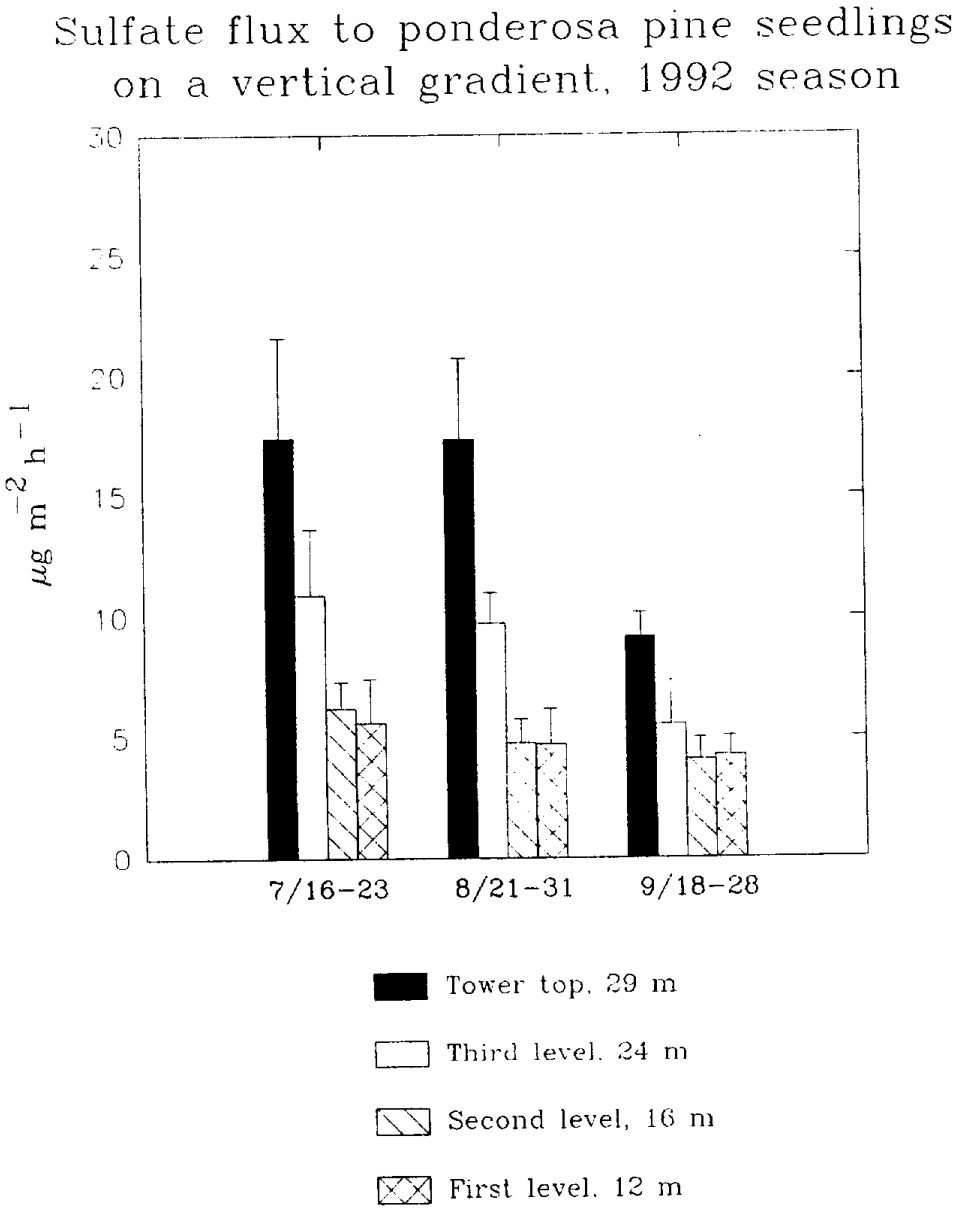


Figure 4-9. Sulfate deposition flux to ponderosa pine seedlings in a vertical gradient during the 1993 season (presented as means and standard deviations).

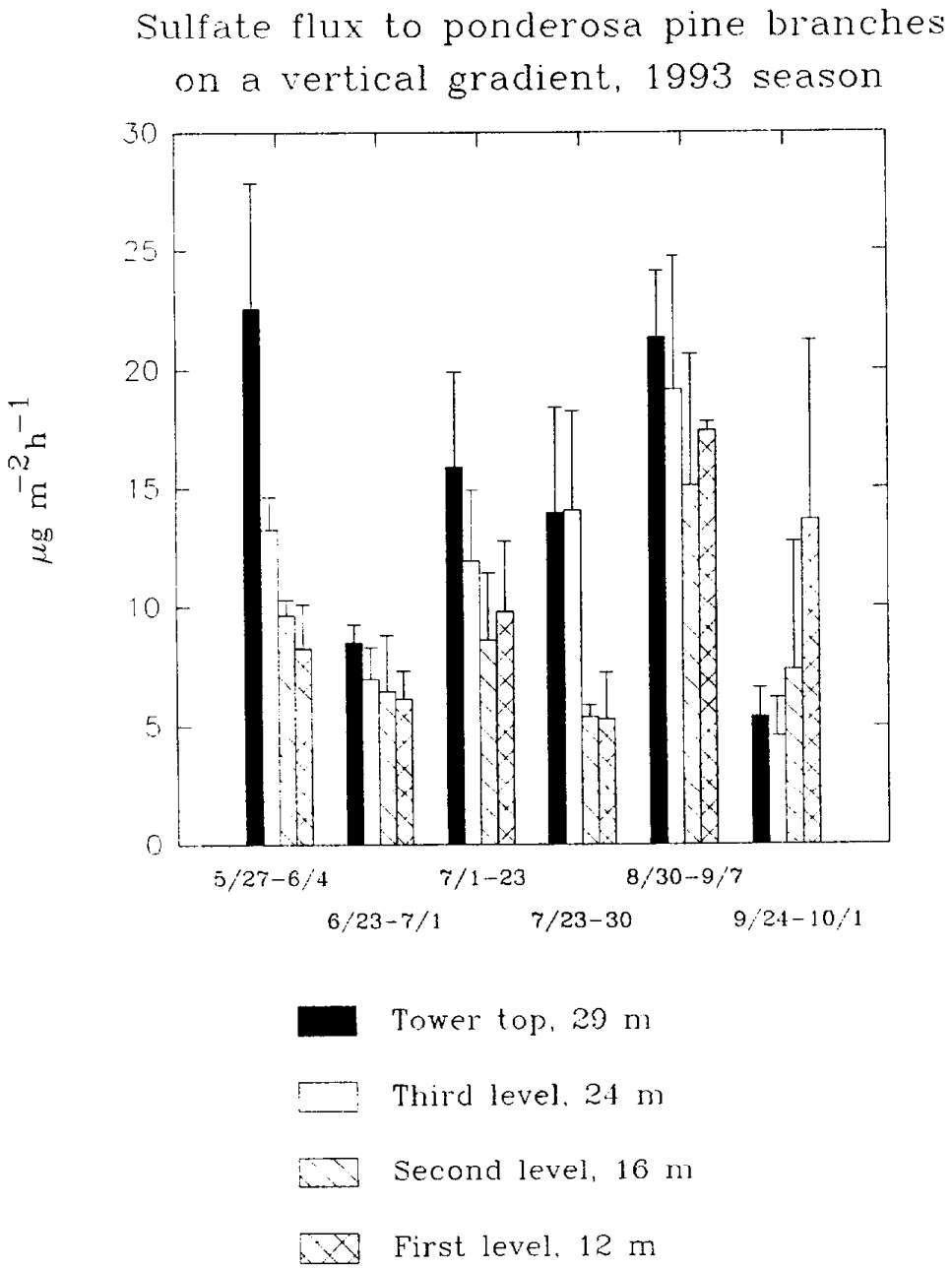


Figure 4-10. Sulfate deposition flux to ponderosa pine seedlings in an vertical gradient during the 1994 season (presented as means and standard deviations).

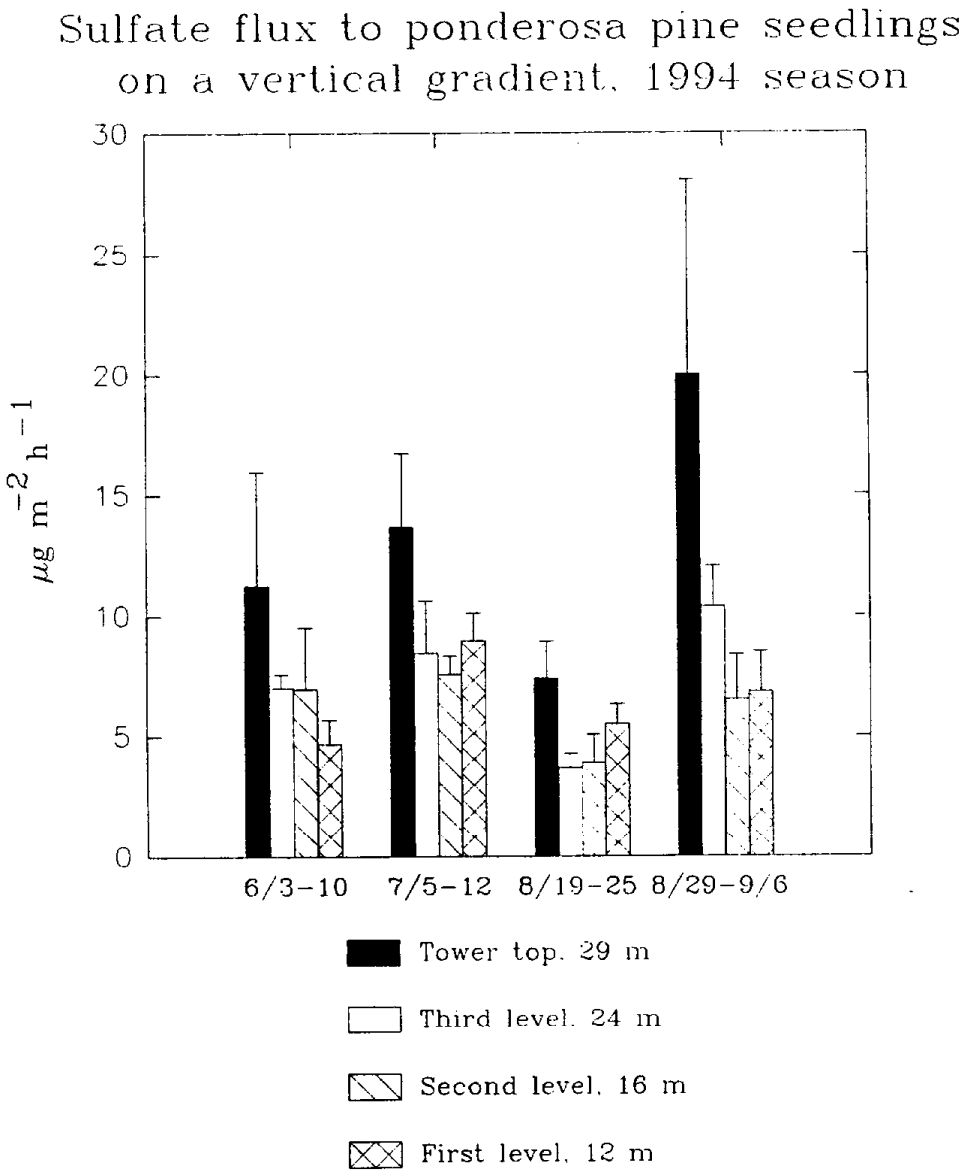


Figure 4-11. Deposition of sulfate to ponderosa pine seedlings located at forest floor of Plots 1, 2, and 3, roof of the monitoring station and tower top (Plot 2) during the July 19 - 23, 1993 period of the intensive study (presented as means and standard deviations).

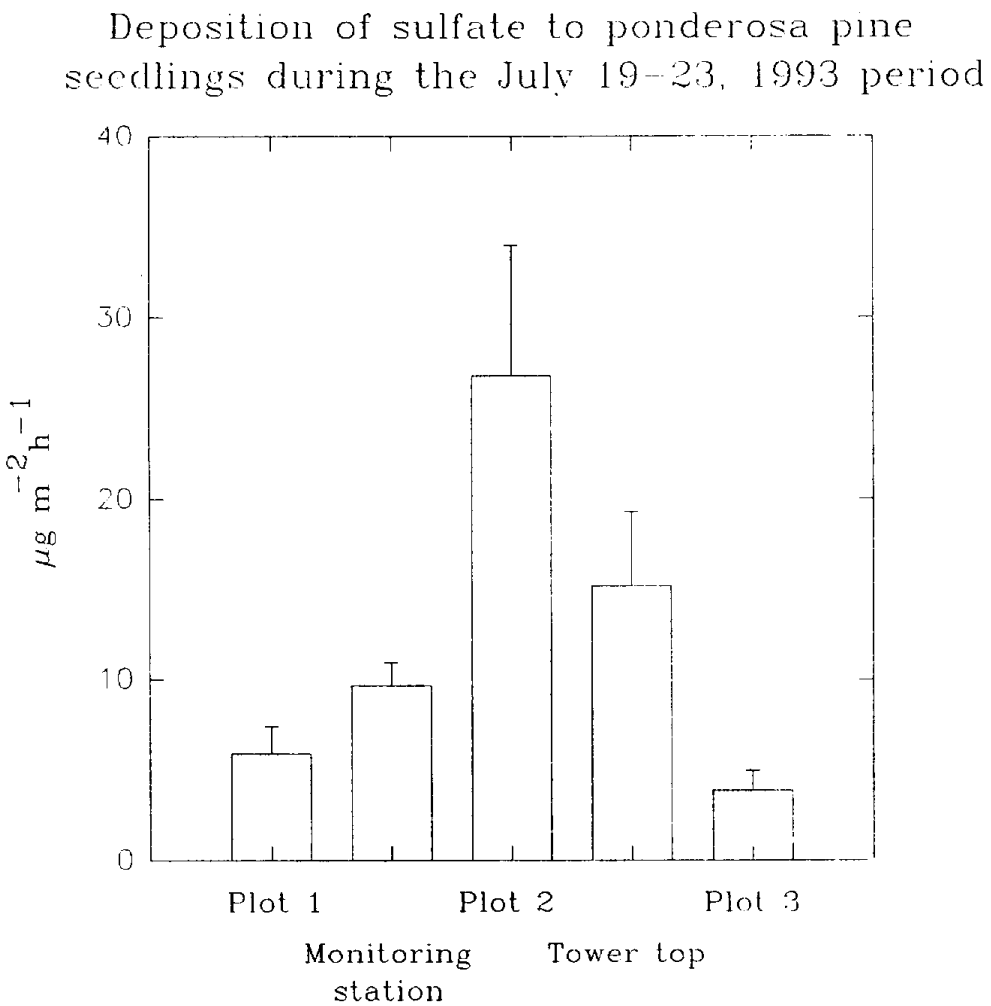
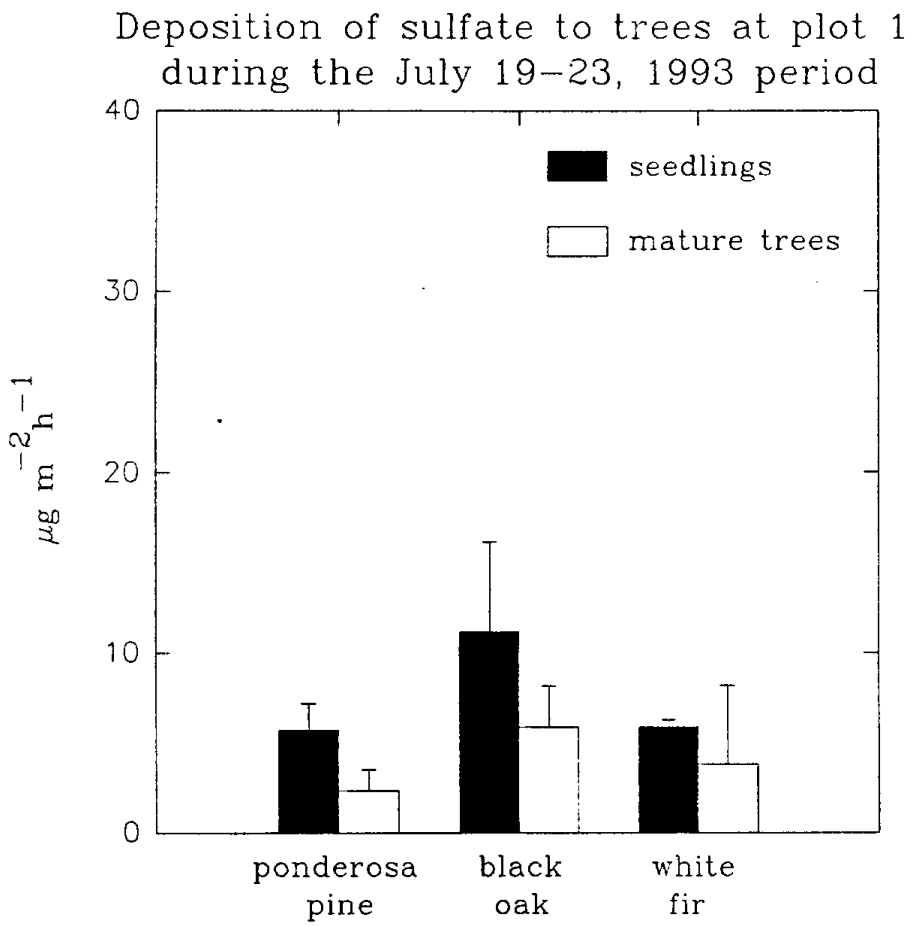


Figure 4-12. Deposition of sulfate to foliage of mature trees vs. seedlings of various species at Plot 1 during the July 19 - 23, 1993 period of the intensive study (presented as means and standard deviations).



APPENDIX A

A.4.1. Assumptions Made for Calculations of N and S Dry Deposition to Plot 2

a. Based on the results presented in Table 4-8 and 4-9, overall correction factors for estimating deposition fluxes to oak and fir were determined by averaging individual correction factors from each plot/time period:

	Pine	Oak	Fir
NO_3^-	1.00	1.99	0.73
NH_4^+	1.00	1.19	0.49
SO_4^{2-}	1.00	2.48	1.10

b. Based on comparisons of deposition to foliage of the ponderosa pine seedlings and ponderosa pine mature pine trees the following correction factors were derived: NO_3^-, 1.05; NH_4^+, 1.35; SO_4^{2-}, 1.20. These factors have been used for extrapolating the seedling data to mature trees (in order to estimate total deposition to foliage of trees the seedlings' results were multiplied by the above values).

c. Total surface foliage area values for Plot 2 was: ponderosa pine, 1827 m^2; white fir, 4424 m^2; and California black oak, 2832 m^2. These values are based on a stand leaf area index (LAI) of 1.89 determined with a litterfall analysis (see Section 4.3.1).

d. Surface area for ponderosa pine branches is about 4.5% of the foliar surface (based on experimental measurements on ponderosa pines in the Colorado Rockies, Mike Arbaugh, personal communication). Therefore the area of branches was equal to: 1827 m^2 x 4.5% = 82.2 m^2. Deposition flux of nitric acid vapor was about 7.9 x higher to branches than to foliage (Marek Krywult, personal communication). This correction factor was used both for NO_3^- and NH_4^+ deposition calculations.

e. For California black oak the area of branches was about 10.1% of the surface area of the foliage and equal 286.0 m^2. Deposition flux of nitric acid vapor was 3.73 x higher to branches than to foliage (Marek Krywult, personal communication). This correction factor was used both for NO_3^- and NH_4^+ deposition calculations.

f. For white fir the surface area of branches was about 4.5% of the foliage (similar to pine). Therefore the area of the branches was: 4424 m^2 x 4.5% = 199.1 m^2. It was also assumed that nitric acid vapor deposition flux to branches was about 7.9x higher than to the foliage (similar to pine).

g. Due to a lack of determinations of deposition to branches during the clean season it was assumed, both for pine and fir, that deposition of NO_3^- was proportional to ambient concentrations of HNO_3 vapor and that deposition of NH_4^+ was proportional to ambient concentrations of NH_3 (see the above section for pine for more details). For SO_4^{2-} calculations it was assumed that the results from the summer season could be extrapolated to the entire year.

h. No literature information on NH_3 deposition to bark is available and we assume that this deposition is similar to deposition of HNO_3 vapor. Since no literature information on SO_2 deposition to bark is available fluxes obtained for the foliage were used.

i. The total ground surface area of Plot 2 is 4800 m^2.

j. For NO_3^- and NH_4^+, calculations were done for 2 seasons: (a) polluted season (April 15 - October 15), and (b) clean season, the remainder of the year. For SO_4^{2-}, calculations were made for the entire year.

k. Concentrations of N and S pollutants used for estimates of stomatal uptake (12 h daytime averages): HNO_3, 4.700 $\mu g\ m^{-3}$ (polluted season) and 0.509 $\mu g\ m^{-3}$ (clean season); NH_3, 1.838 $\mu g\ m^{-3}$ (polluted season) and 0.330 $\mu g\ m^{-3}$ (clean season); NO_2, 2.764 $\mu g\ m^{-3}$ (polluted season) and 1.341 $\mu g\ m^{-3}$ (clean season); SO_2, 0.56 $\mu g\ m^{-3}$.

l. Internal uptake of pollutants were calculated based on stomatal conductance to H_2O vapor measurements. Approximate values for ponderosa pine during the polluted season and the clean season were 0.065 cm s^{-1} and 0.035 cm s^{-1}, respectively (Patrick Temple, personal communication). Based on a comparison of gas exchange of ponderosa pine and white fir (Takemoto and Bytnerowicz, 1993) we assumed the same values for white fir. For California black oak during the polluted season we assumed stomatal conductance of 0.13 cm s^{-1} (Kramer and Kozlowski, 1979).

m. Correction factors for stomatal conductances of individual gases were derived by dividing the square root of the molecular weight of H_2O by the square root of the molecular weight of the gas of interest. The corrections factors were as follows: HNO_3, 0.54; NH_3, 1.03; NO_2, 0.63; SO_2, 0.54.

n. For calculation of ground deposition an assumption was made that the ground surface was flat and that the deposition to the ground was equal to the average deposition to mature trees of 3 species at the floor level in Plot 2 ($F_{NO3 + NH4}$ = 7.16 μg N m^{-2} h^{-1} for the polluted season (see Table 4-8) and 0.97 μg N m^{-2} h^{-1} for the clean season). Similarly derived SO_4^{2-} deposition of 1.12 μg S m^{2-} h^{-1} was used for calculations of SO_4^{2-} calculations to ground for the entire year.

A.4.2. **Calculation of Nitrogen Deposition to California Black Oak**

<u>Surface deposition of washable NO_3^- and NH_4^+ to foliage</u>

Polluted season

F_{NO3} = 17.77 μg N m^{-2} h^{-1} x 1.99 = 35.36 μg N m^{-2} h^{-1}

F_{NH4} = 10.44 μg N m^{-2} h^{-1} x 1.19 = 12.42 μg N m^{-2} h^{-1}

$F_{NO3 + NH4}$ = 35.36 + 12.42 = 47.78 μg N m^{-1} h^{-1}

Deposition of nitrate and ammonium = 47.78 μg N m^{-2} h^{-1} x 24 x 182.5 x 2832 x 10000/4800 = <u>1234 g N ha^{-1}</u>

Clean season

No foliage present, no deposition occurring.

Surface deposition of washable NO_3^{-1} and NH_4^+ to branches

Polluted season

Nitrate deposition = 17.77 μg N m^{-2} h^{-1} x 1.99 x 3.73 x 286.0 m^2 x 182.5 days x 24 h x 10000/4800 = 344.2 g N ha^{-1}

Ammonium deposition = 10.44 μg N m^{-2} h^{-1} x 1.19 x 3.73 x 286.0 m^2 x 182.5 days x 24 h x 10000/4800 = 120.9 g N ha^{-1}

Clean season

Nitrate deposition = 1.74 μg N m^{-2} h^{-1} x 1.99 x 3.73 x 286.0 m^2 x 182.5 days x 24 h x 10000/4800 = 33.7 g N ha^{-1}

Ammonium deposition = 1.967 μg N m^{-2} h^{-1} x 1.19 x 3.73 x 286.0 m^2 x 182.5 days x 24 h x 10000/4800 = 22.8 g N ha^{-1}

Total surface (washable) N deposition to California black oak foliage and branches = 1234 + 344.2 + 120.9 + 33.7 + 22.8 = 1755.6 g ha^{-1} yr^{-1}.

Internal stomatal uptake

Polluted season

HNO_3 deposition flux = 0.13 cm s^{-1} x 0.54 x 4.700 μg HNO_3 m^{-3} = 4.68 m h^{-1} x 0.54 x 4.700 = 11.88 μg HNO_3 m^{-2} h^{-1} = 2.64 μg N m^{-2} h^{-1}.

HNO_3 deposition = 2.64 μg N m^{-2} h^{-1} x 2832 m^2 x 182.5 days x 12 h x 10000/4800 = 34.1 g N ha^{-1}.

NH_3 deposition flux = 0.13 cm s^{-1} x 1.03 x 1.838 μg N m^{-3} = 4.68 m h^{-1} x 1.03 x 1.838 = 8.86 μg N m^{-2} h^{-1} = 7.29 g N m^{-2} h^{-1}.

NH_3 deposition = 7.29 μg N m^{-2} h^{-1} x 2832 m_2 x 182.5 days x 12 h x 10000/4800 = 94.2 g N ha^{-1}.

NO_2 deposition flux = 0.13 cm s^{-1} x 0.63 x 2.764 μg NO_2 m^{-3} = 4.68 m h^{-1} x 0.63 x 2.764 = 8.15 μg NO_2 m^{-2} h^{-1} = 2.48 g N m^{-2} h^{-1}.

NO_2 deposition = 2.48 μg N m^{-2} h^{-1} x 2832 m^2 x 182.5 days x 12 h x 10000/4800 = 32.0 g N ha^{-1}.

Clean season

Foliage not present - deposition assumed to be equal to 0.

Total stomatal uptake of N pollutants by California black oak = 34.1 + 94.2 + 32.0 = 160.3 g ha^{-1} yr^{-1}.

A.4.3. Calculation of Nitrogen Deposition to White Fir

Surface deposition of washable NO_3^- and NH_4^+ to foliage

Polluted season

F_{NO3} = 17.77 μg N m^{-2} h^{-1} x 0.73 = 12.97 μg N m^{-2} h^{-1}

F_{NH4} = 10.44 μg N m^{-2} h^{-1} x 0.49 = 5.12 μg N m^{-2} h^{-1}

$F_{NO3 + NH4}$ = 12.97 + 5.12 = 18.09 μg N m^{-2} h^{-1}

Deposition of nitrate and ammonium = 18.09 μg N $m^{-3}h^{-1}$ x 182.5 days x 24 h x 4424 m^2 x 10000/4800 = 730.3 g N ha^{-1}.

Clean season

F_{NO3} = 1.74 μg N m^{-2} h^{-1} x 0.73 = 1.27 μg N m^{-2} h^{-1}

F_{NH4} = 1.97 μg N m^{-2} h^{-1} x 0.49 = 0.96 μg N m^{-2} h^{-1}

$F_{NO3 + NH4}$ = 1.27 + 0.96 = 2.23 μg N m^{-2} h^{-1}

Deposition of nitrate and ammonium = 2.23 μg N m^{-2} h^{-1} x 182.5 days x 24 h x 4424 m^2 x 10000/4800 = 90.0 g N ha^{-1}.

Surface deposition to branches

Polluted season

Nitrate deposition = 17.77 μg m^{-2} h^{-1} x 0.73 x 7.90 x 199.1 m^2 x 182.5 days x 24 h x 10000/4800 = 186.2 g N ha^{-1}

Ammonium deposition = 10.44 μg N m^{-2} h^{-1} x 0.49 x 7.90 x 199.1 m^2 x 182.5 days x 24 h x 10000/4800 = 73.4 g N ha^{-1}

Clean season

Nitrate deposition = 1.74 μg N m^{-2} h^{-1} x 0.73 x 7.90 x 199.1 m^{-2} x 182.5 days x 24 h x 10000/4800 = 18.2 g ha^{-1}

Ammonium deposition = 1.97 μg N m^{-2} h^{-1} x 0.49 x 7.90 x 199.1 x 182.5 days x 24 hours x 10000/4800 = 13.8 g N ha^{-1}

Total surface (washable) deposition for white fir foliage and branches = 730.3 + 90.0 + 186.2 + 73.4 + 18.2 +13.8 = 1111.9 g N ha^{-1} yr^{-1}.

Internal stomatal uptake

Polluted season

HNO_3 deposition = 1.32 μg N m^{-2} h^{-1} (the same value as for the pine) x 4424 m^2 x 182.5 days x 12 h x 10000/4800 = 26.6 g N ha^{-1}.

NH_3 deposition = 3.64 μg N m^{-2} h^{-1} (the same value as for the pine) x 4424 m^2 x 182.5 days x 12 h x 10000/4800 = 73.5 g N ha^{-1}.

NO_2 deposition = 1.24 μg N m^{-2} h^{-1} (the same value as for the pine) x 4424 m^2 x 182.5 days x 12 h x 10000/4800 = 25.1 g N ha^{-1}.

Clean season

HNO_3 deposition = 0.077 μg N m^{-2} h^{-1} (the same value as for the pine) x 4424 m^2 x 182.5 days x 12 h x 10000/4800 = 1.5 g N ha^{-1}.

NH_3 deposition = 0.352 μg N m^{-2} h^{-1} (the same value as for the pine) x 4424 m^2 x 182.5 days x 12 h x 10000/4800 = 7.1 g N ha^{-1}.

NO_2 deposition = 0.324 μg N m^{-2} h^{-1} (the same value as for the pine) x 4424 m^2 x 182.5 days x 12 h x 10000/4800 = 6.5 g N ha^{-1}.

Total stomatal uptake of the N pollutants = 26.6 + 73.5 + 25.1 + 1.5 + 7.1 + 6.5 = 140.3 g ha^{-1} h^{-1}.

A.4.4. Calculation of Sulfur Dry Deposition to Ponderosa Pine

Surface deposition of washable SO_4^{2-} to foliage

F_{SO4} = 3.76 μg S m^{-2} h^{-1} x 1.20 = 4.52 μg S m^{-2} h^{-1}.

Deposition of sulfate = 4.52 μg S m^{-2} h^{-1} x 24 h x 365 days x 1827 m^2 x 10000/4800 = 150.71 g ha^{-1} yr^{-1}.

Surface deposition of washable SO_4^{2-} to branches

Sulfate deposition = 4.52 μg S m^{-2} h^{-1} x 82.2 m^2 x 365 days x 24 h x 10000/4800 = 6.78 g S ha^{-1}.

Internal stomatal uptake of SO_2.

SO_2 deposition flux = 0.065 cm s^{-1} x 0.54 x 0.56 μg SO_2 m^{-3} = 2.34 m s^{-1} x 0.54 x 0.56 = 0.71 μg SO_2 m^{-2} h^{-1} = 0.36 μg S m^{-2} h^{-1}.

SO_2 deposition = 0.36 μg S m^{-2} h^{-1} x 1827 m^2 x 365 days x 12 h x 10000/4800 = 6.00 g S ha^{-1} yr^{-1}.

Total deposition of sulfur (both surface and internal) to ponderosa pine foliage and branches = 150.71 + 6.78 + 6.00 = 163.5 g S ha^{-1} yr^{-1}.

A.4.5. Calculation of Sulfur Deposition to California Black Oak

Surface deposition of washable SO_4^{2-} to foliage

F_{NO3} = 4.52 μg S x 2.48 = 11.21 μg S m^{-2} h^{-1}.

Sulfate deposition = 11.21 μg S m^{-2} h^{-1} x 24 h x 182.5 days x 2832 m^2 x 10000/4800 = 289.69 g S ha^{-1} yr^{-1}.

Surface deposition of washable SO_4^{2-} to branches.

Sulfate deposition = 4.52 μg S m^{-2} h^{-1} x 2.48 x 286.0 m^2 x 365 days x 24 h x 10000/4800 = 58.51 g S ha^{-1} yr^{-1}.

Internal stomatal uptake of SO_2.

SO_2 deposition flux = 0.13 cm s^{-1} x 0.54 x 0.56 μg SO_2 m^{-3} = 4.68 m h^{-1} x 0.54 x 0.56 = 1.42 μg SO_2 m^{-2} h^{-1} = 0.71 μg S m^{-2} h-1.

SO_2 deposition = 0.71 μg S m^{-2} h^{-1} x 2832 m^2 x 182.5 days x 12 h x 10000/4880 = 9.17 g S ha^{-1} yr^{-1}.

Total deposition of S (both surface and internal) to California black oak = 289.69 + 58.51 + 9.17 = 357.4 g S ha^{-1} yr^{-1}.

A.4.6. Calculation of Sulfur Deposition to White Fir

Surface deposition of washable SO_4^{2-} to foliage

F_{SO4} = 4.52 μg S m^{-2} h^{-1} x 1.10 = 5.02 μg S m^{-2} h^{-1}.

Deposition of sulfate = 5.02 μg S m^{-2} h^{-1} x 365 days x 24 h x 4424 m^2 x 10000/4800 = <u>405.3 g S ha^{-1} yr^{-1}</u>.

<u>Surface deposition of washable SO_4^{2-} to branches</u>

Sulfate deposition = 4.52 μg S m^{-2} h^{-1} x 1.10 x 199.1 m^2 x 365 days x 24 h x 10000/4800 = <u>18.07 g S ha^{-1} yr^{-1}</u>.

<u>Internal stomatal uptake of SO_2</u>.

SO_2 deposition flux = 0.065 cm s^{-1} x 0.54 x 0.56 μg SO_2 m^{-3} = 2.34 m h^{-1} x 0.54 x 0.56 = 0.71 μg SO_2 m^{-2} h^{-1} = 0.36 μg S m^{-2} h^{-1}.

SO_2 deposition = 0.36 μg S m^{-2} h^{-1} x 4424 m^2 x 365 days x 12 h x 10000/4800 = <u>14.53 g S ha^{-1} yr^{-1}</u>.

Total deposition of S (surface and internal) to white fir = 405.3 + 18.07 + 14.53 = <u>437.9 g S ha^{-1} yr^{-1}</u>.

A.4.7. Calculation of Sulfur Deposition to Ground

1.45 μg S m^{-2} h^{-1} x 10000 m^2 x 365 days x 24 h = <u>127.0 g S ha^{-1} yr^{-1}</u>.

Figure A4-1. Comparison of nitrate deposition to foliage of mature ponderosa pine trees vs. seedlings at the bottom of the canopy, level 1 (12 m height on the tower).

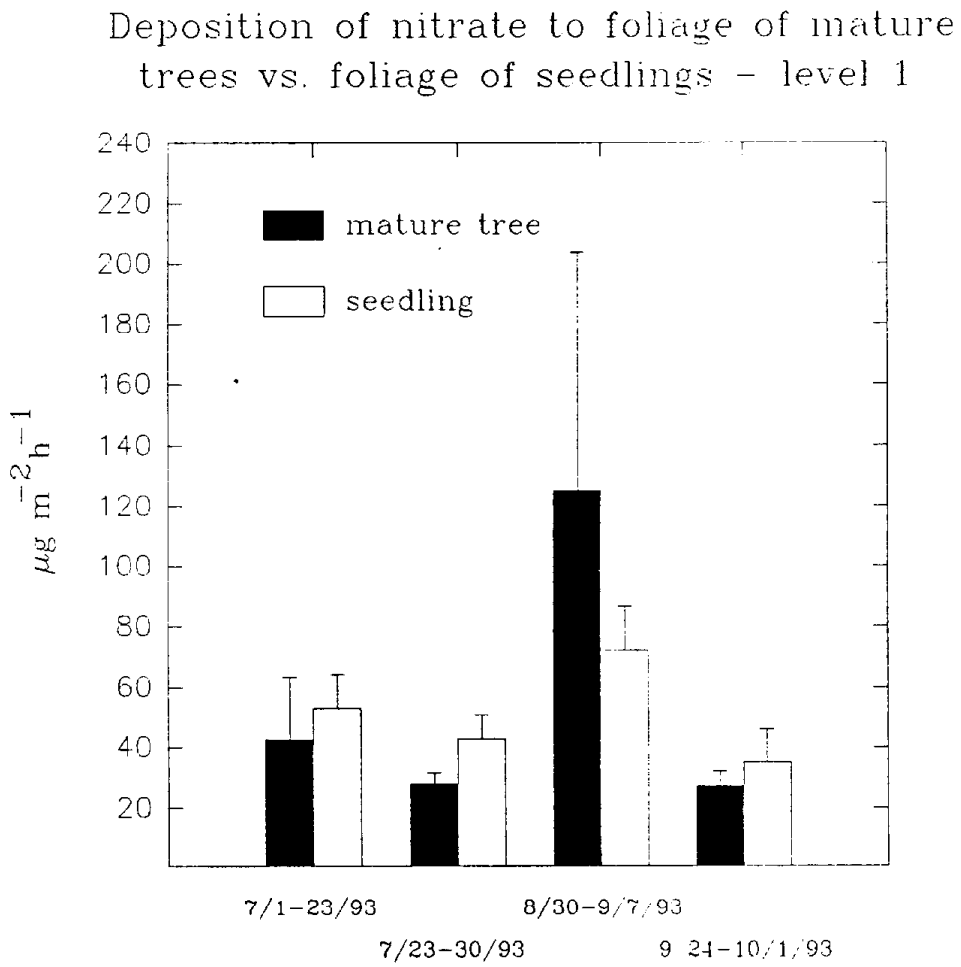


Figure A4-2. Comparison of nitrate deposition to foliage of mature ponderosa pine trees vs. seedlings at the second level of the canopy (16 m height on the tower).

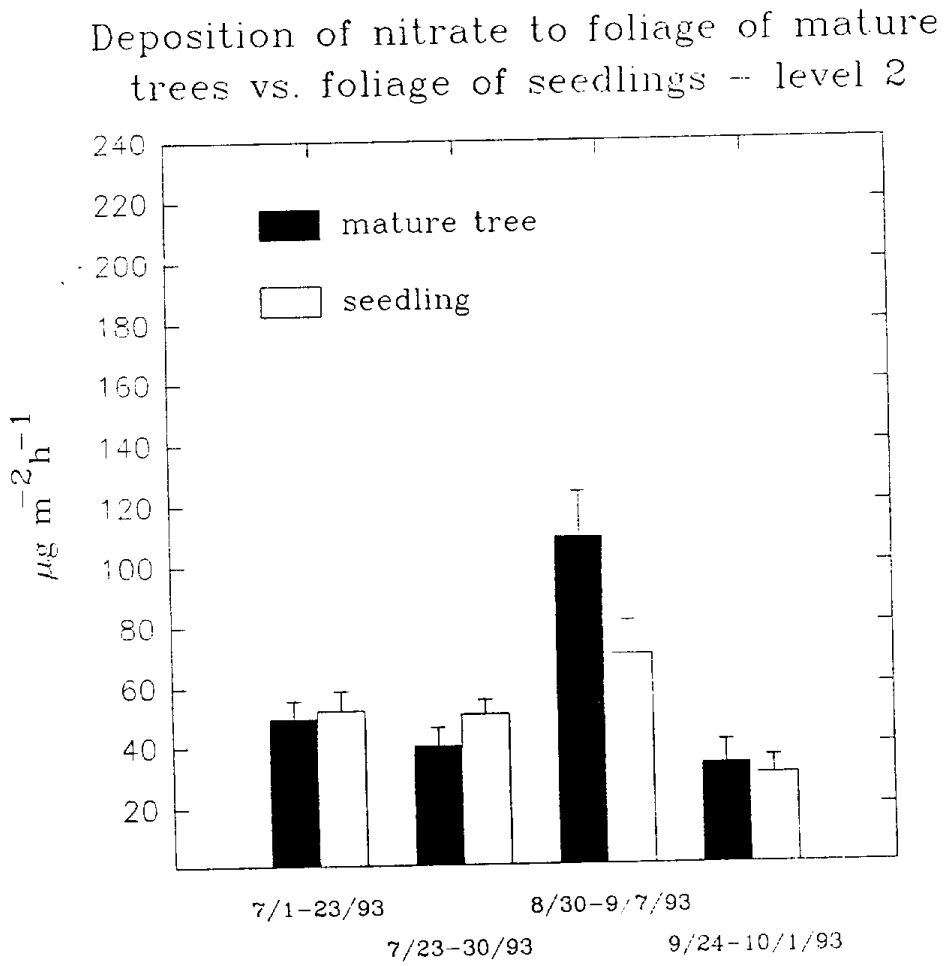


Figure A4-3. Comparison of nitrate deposition to foliage of mature ponderosa pine trees vs. seedlings at the third level of the canopy (24 m height on the tower).

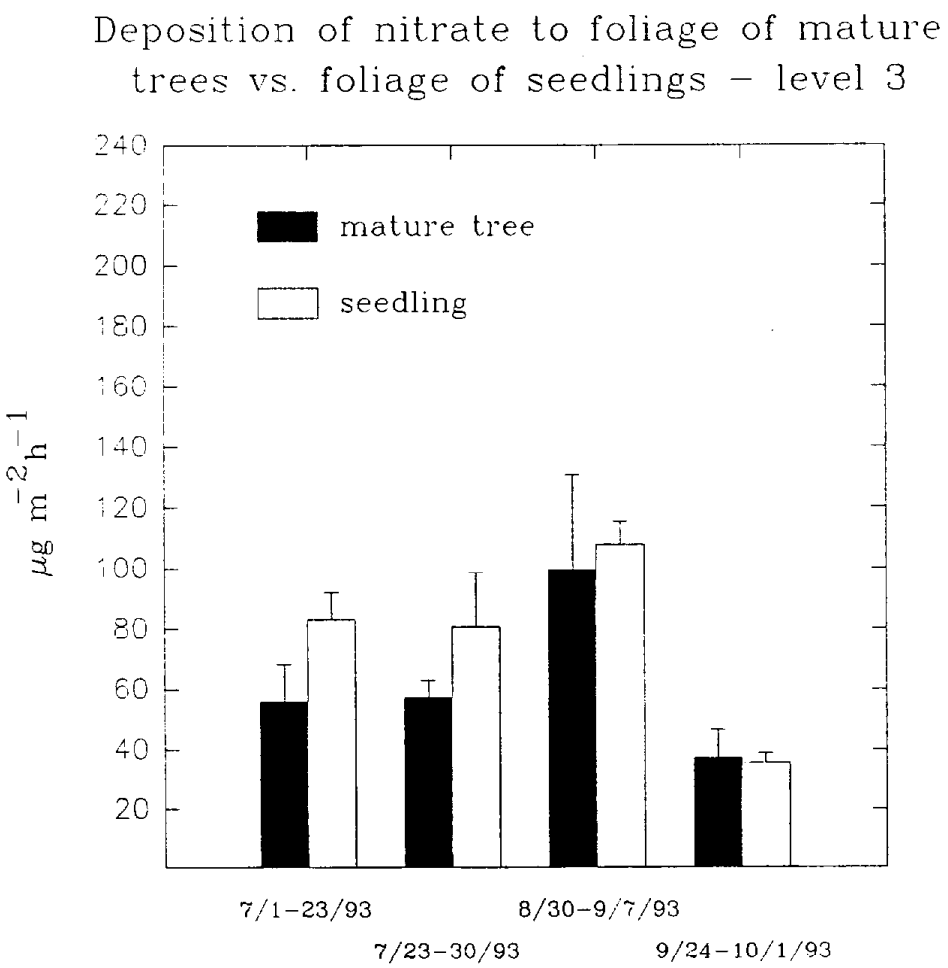


Figure A4-4. Comparison of ammonium deposition to foliage of mature ponderosa pine trees vs. seedlings at the bottom of the canopy, level 1 (12 m height on the tower).

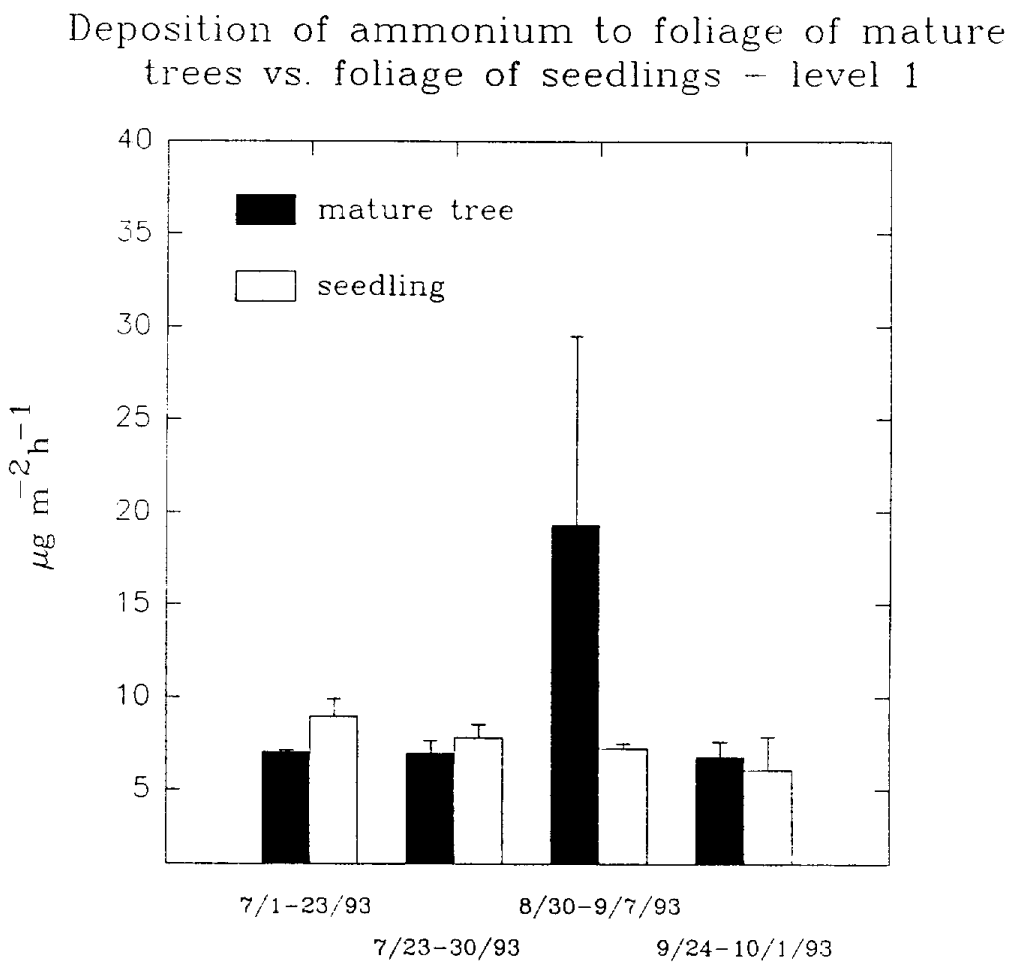


Figure A4-5. Comparison of ammonium deposition to foliage of mature ponderosa pine trees vs. seedlings at the second level of the canopy (16 m height on the tower).

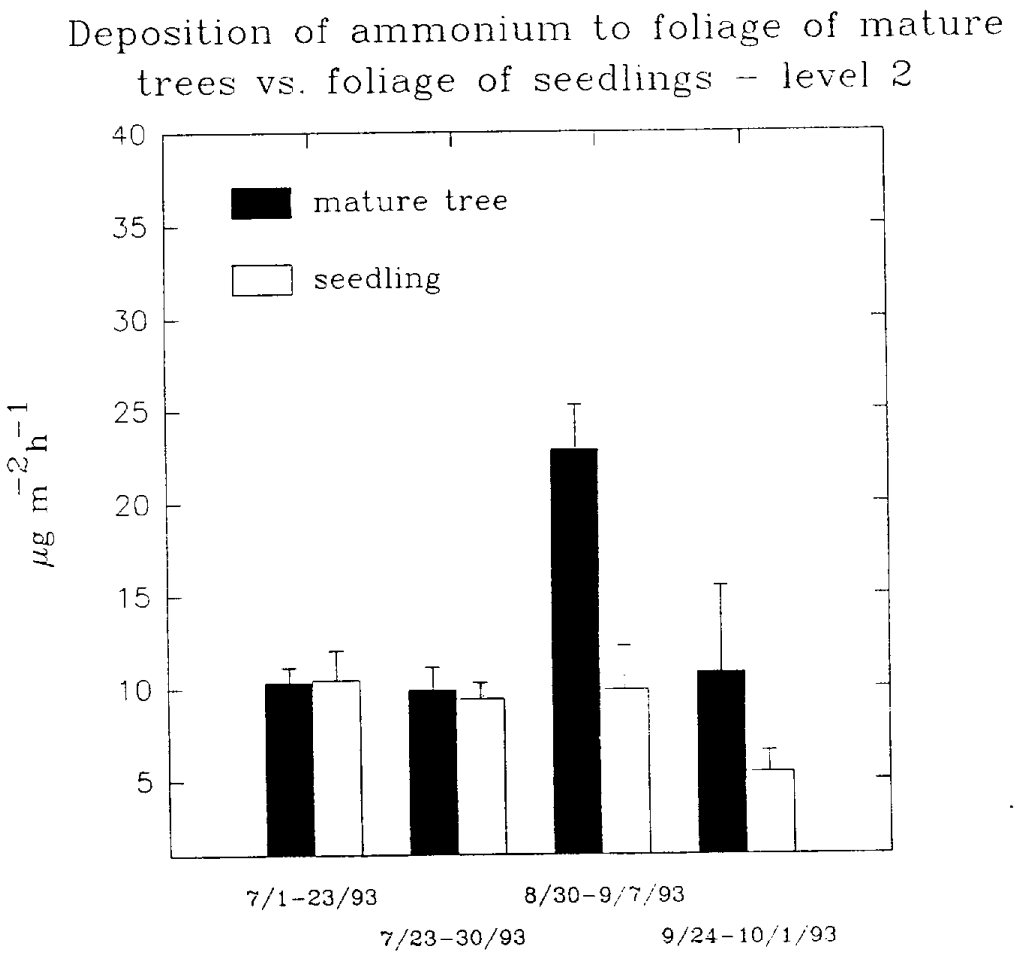


Figure A4-6. Comparison of ammonium deposition to foliage of mature ponderosa pine trees vs. seedlings at the third level of the canopy (24 m height on the tower).

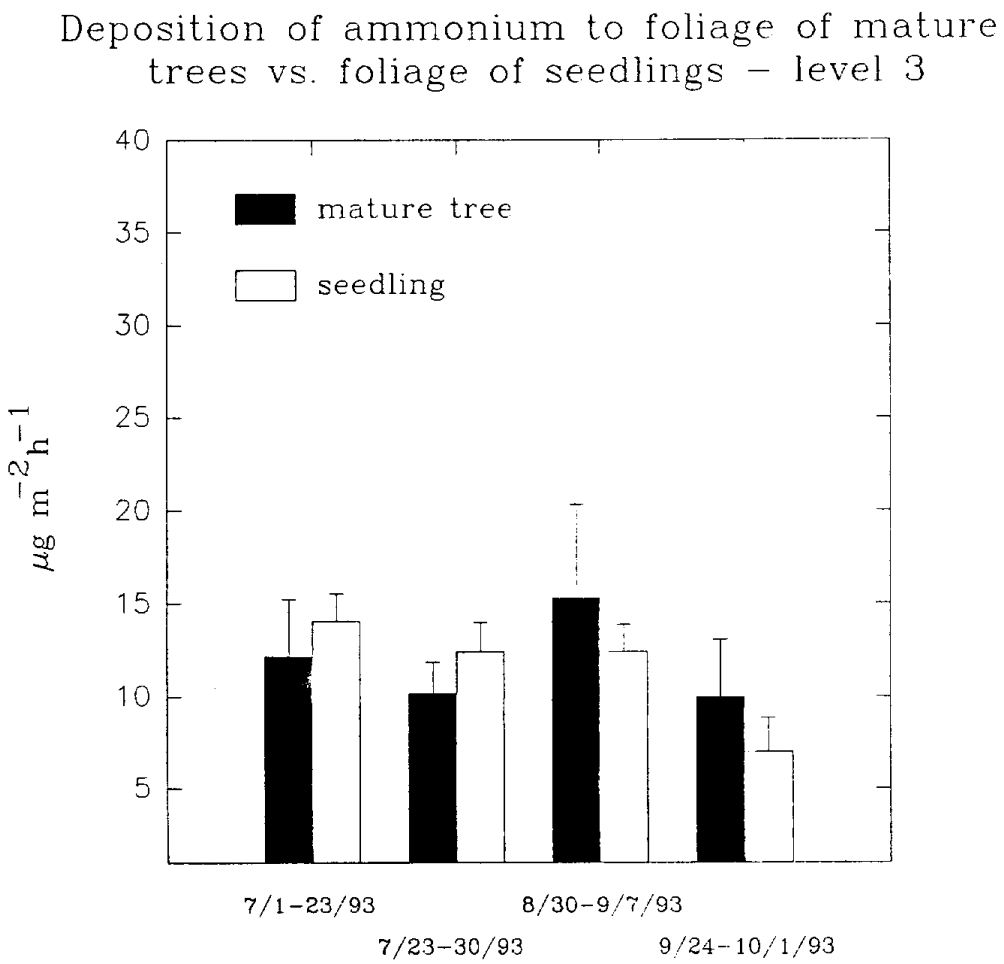


Figure A4-7. Deposition of nitrate to foliage of ponderosa pine seedlings located at the forest floor of Plots 1, 2, and 3, roof of the monitoring station and tower top (Plot 2) during the July 19 - 23, 1993 period of the intensive study.

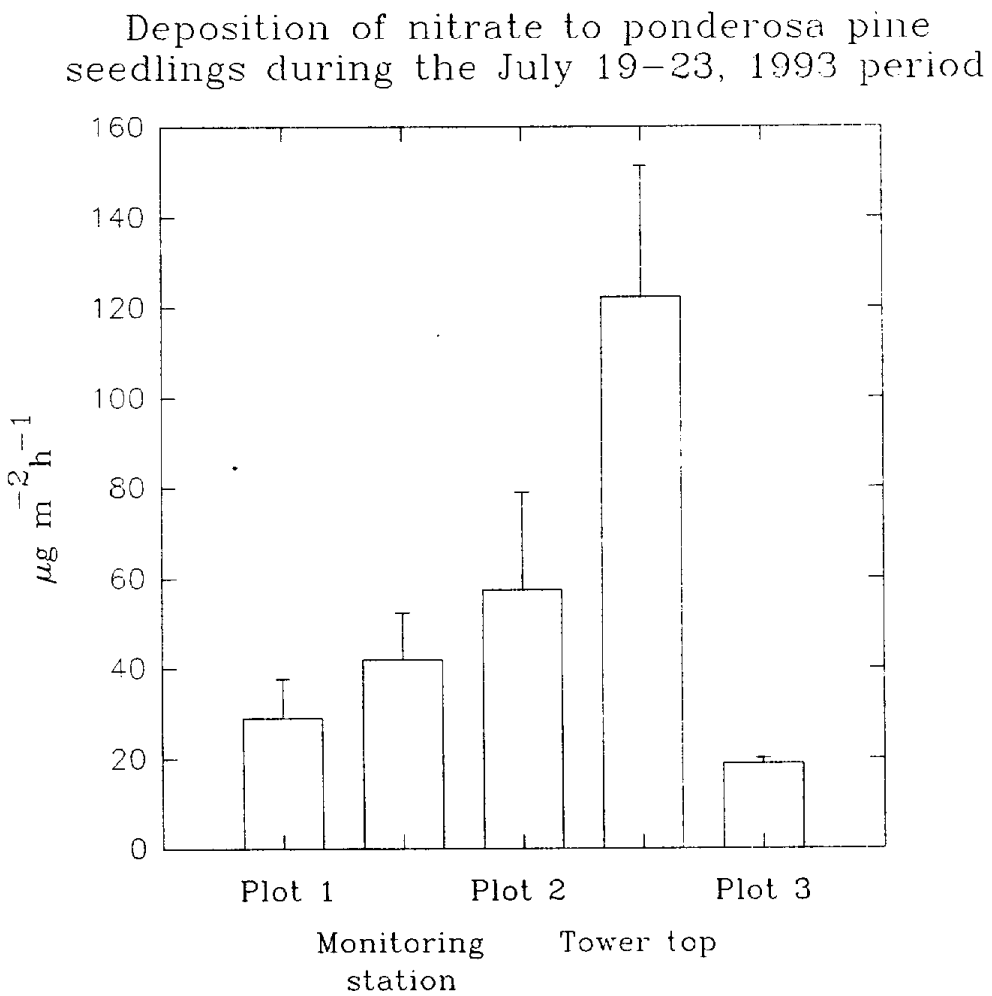


Figure A4-8. Deposition of ammonium to foliage of ponderosa pine seedlings located at the forest floor of Plots 1, 2, and 3, roof of the monitoring station and tower top (Plot 2) during the July 19 - 23, 1993 period of the intensive study.

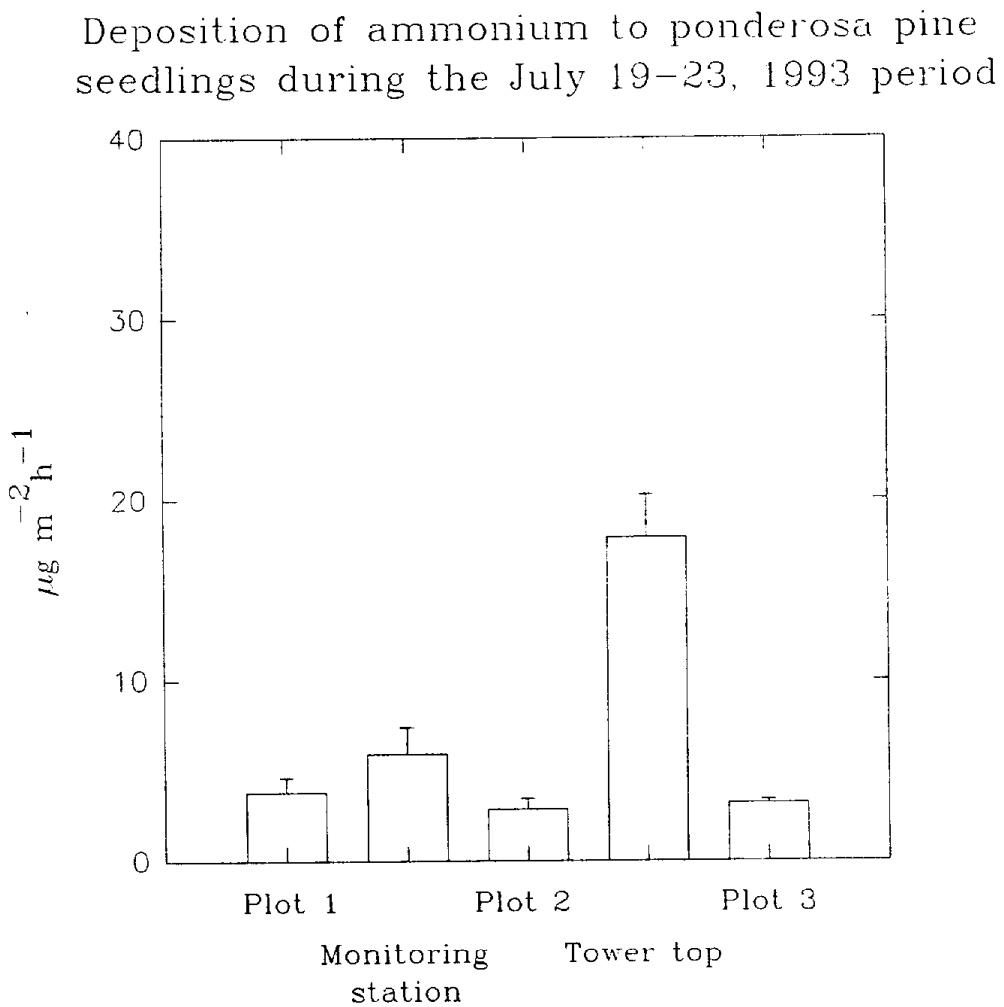


Figure A4-9. Comparison of nitrate deposition to foliage of mature trees vs. seedlings of various species at Plot 2 during the July 19 - 23, 1993 period of the intensive study.

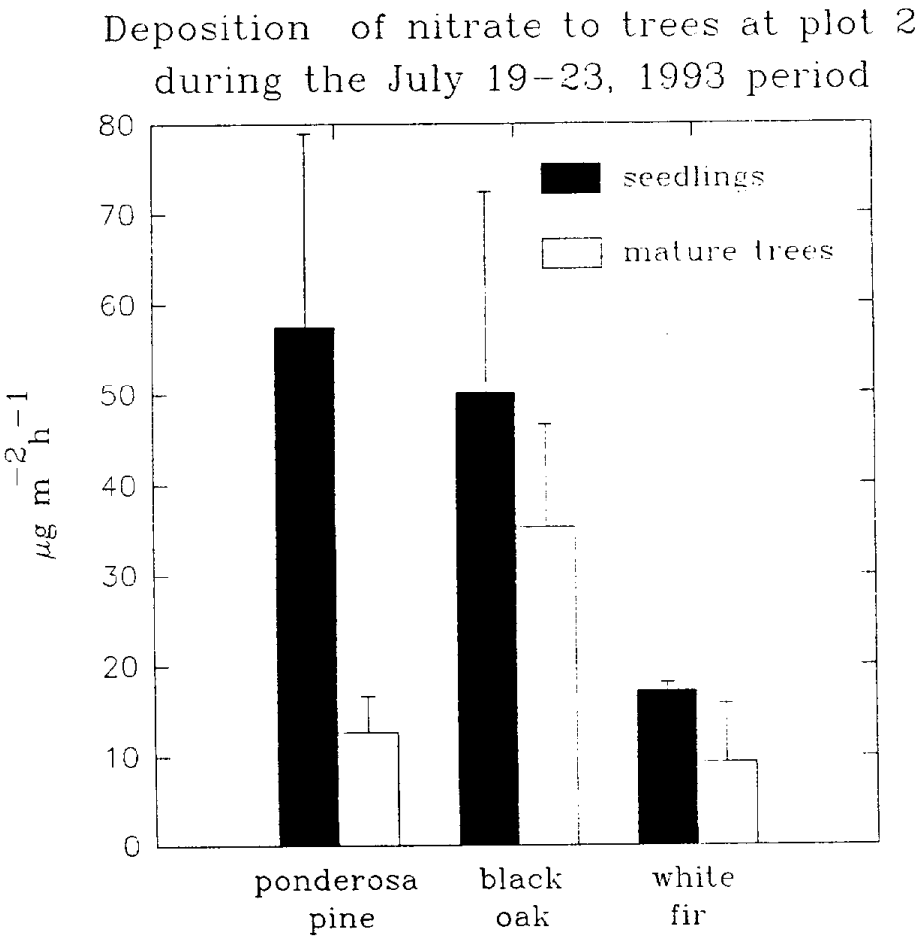


Figure A4-10. Comparison of nitrate deposition to foliage of mature trees vs. seedlings of various species at Plot 3 during the July 19 - 23, 1993 period of the intensive study.

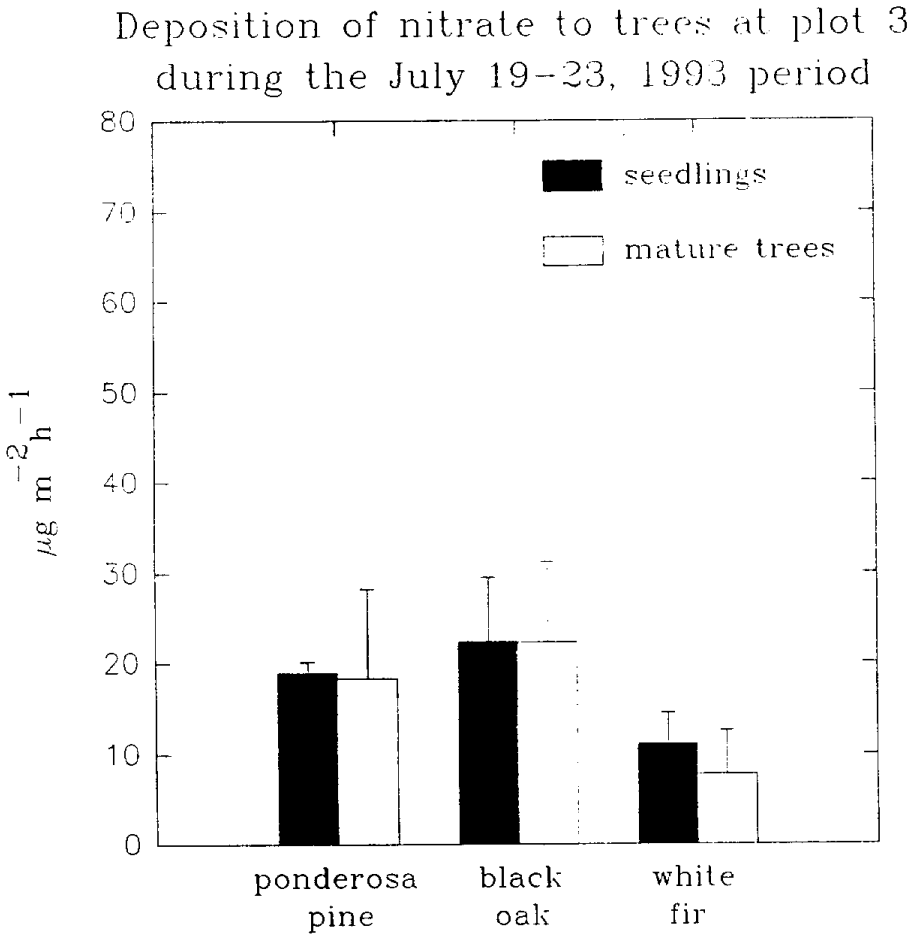


Figure A4-11. Comparison of nitrate deposition to foliage of mature trees vs. seedlings of various species at Plot 1 during the July 23 - 30, 1993 period of the intensive study.

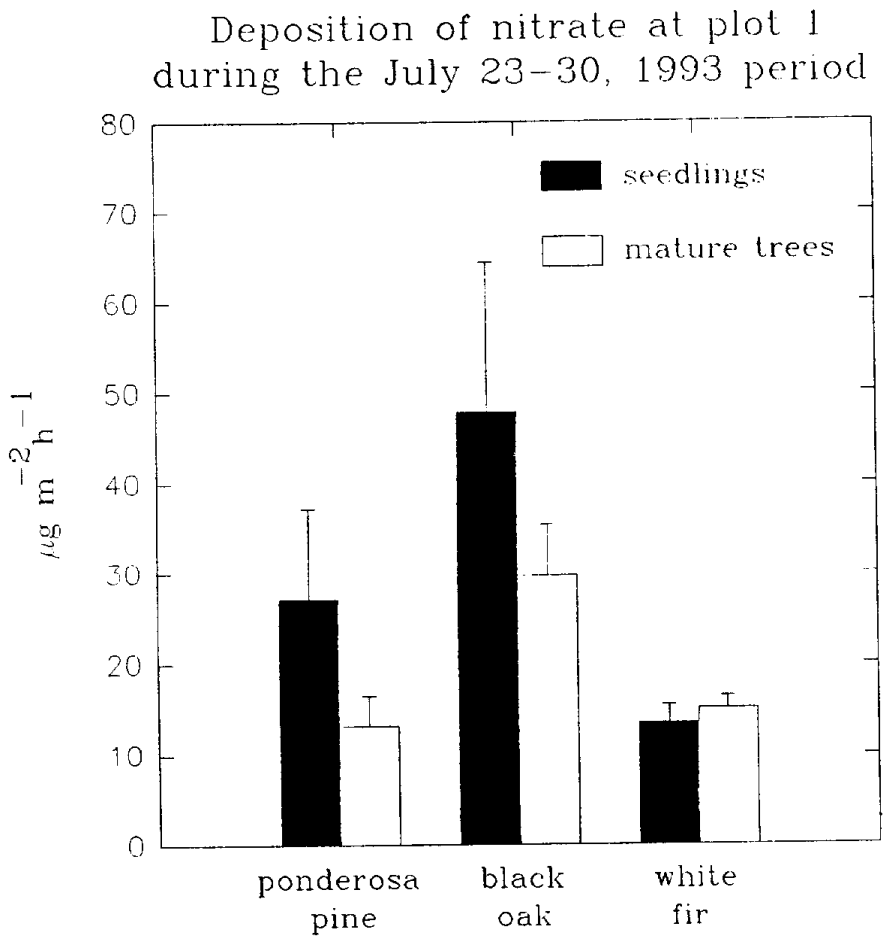


Figure A4-12. Comparison of nitrate deposition to foliage of mature trees vs. seedlings of various species at Plot 2 during the July 23 - 30, 1993 period of the intensive study.

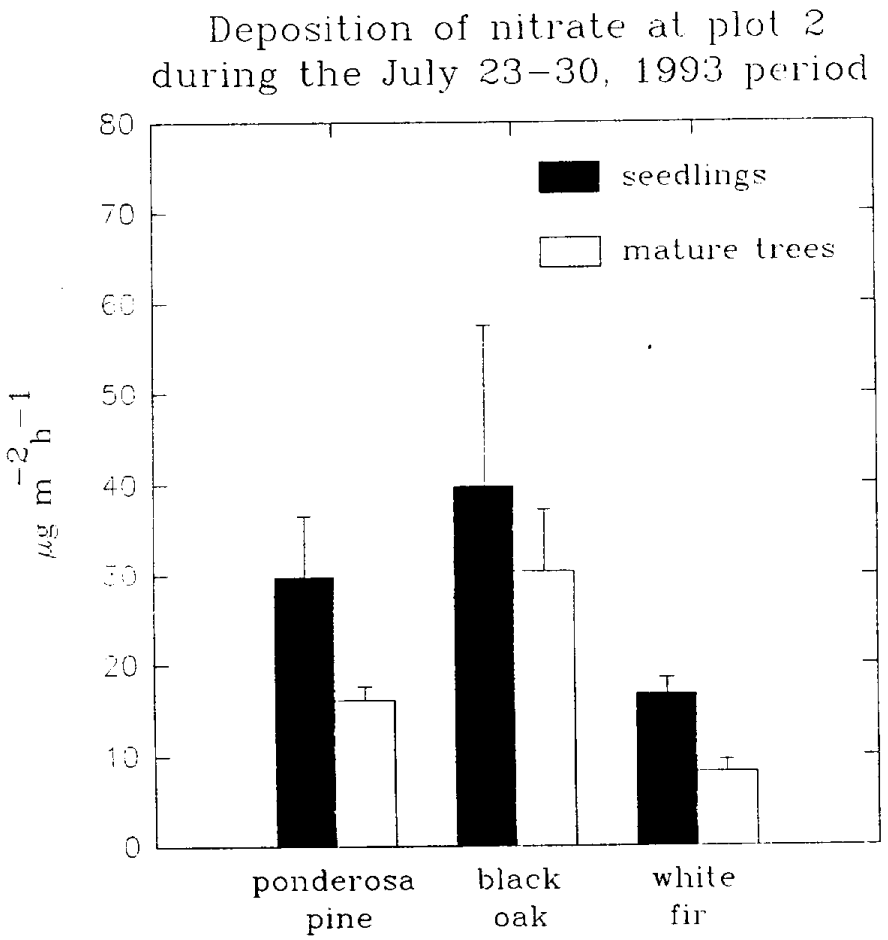


Figure A4-13. Comparison of nitrate deposition to foliage of mature trees vs. seedlings of various species at Plot 3 during the July 23 - 30, 1993 period of the intensive study.

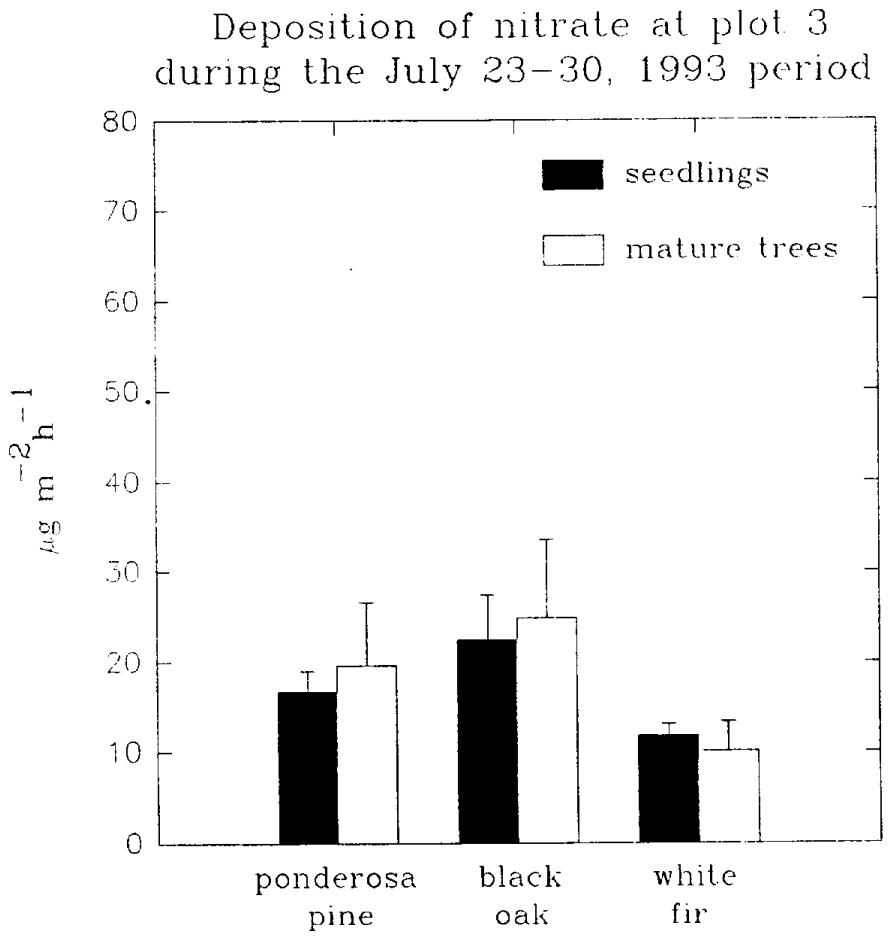


Figure A4-14. Comparison of ammonium deposition to foliage of mature trees vs. seedlings of various species at Plot 2 during the July 19 - 23, 1993 period of the intensive study.

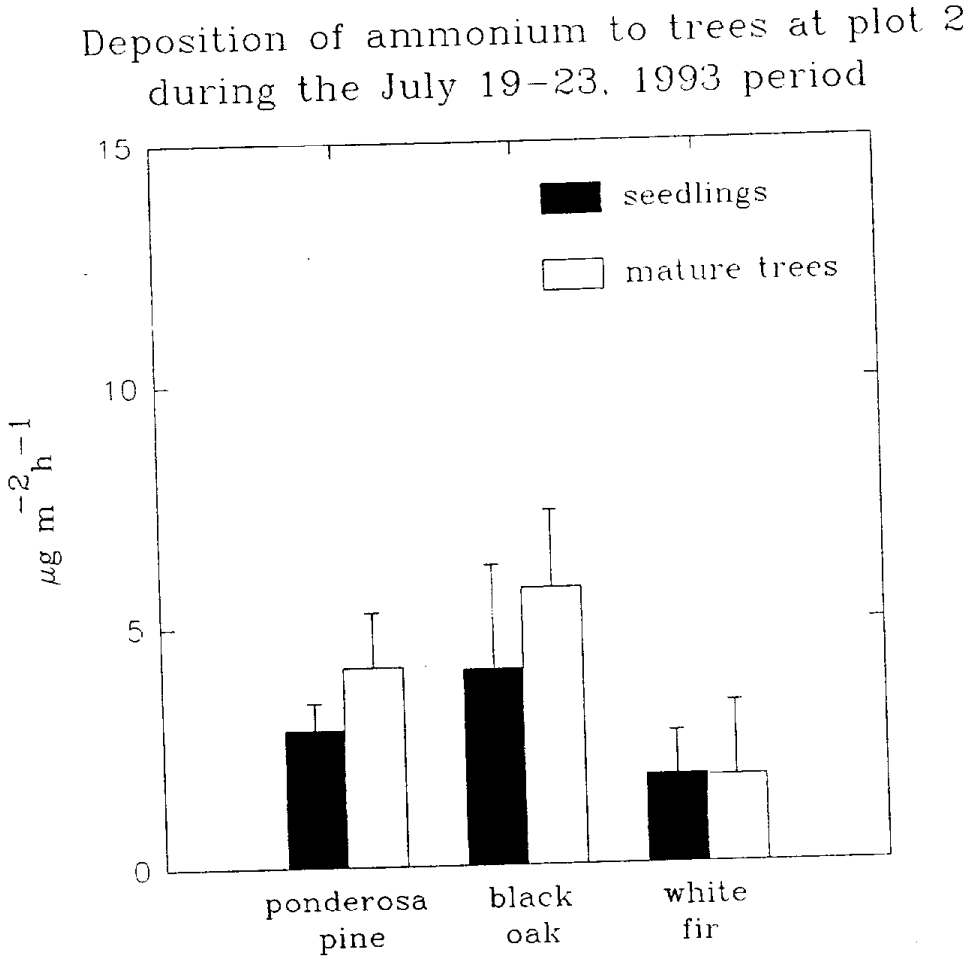


Figure A4-15. Comparison of ammonium deposition to foliage of mature trees vs. seedlings of various species at Plot 3 during the July 19 - 23, 1993 period of the intensive study.

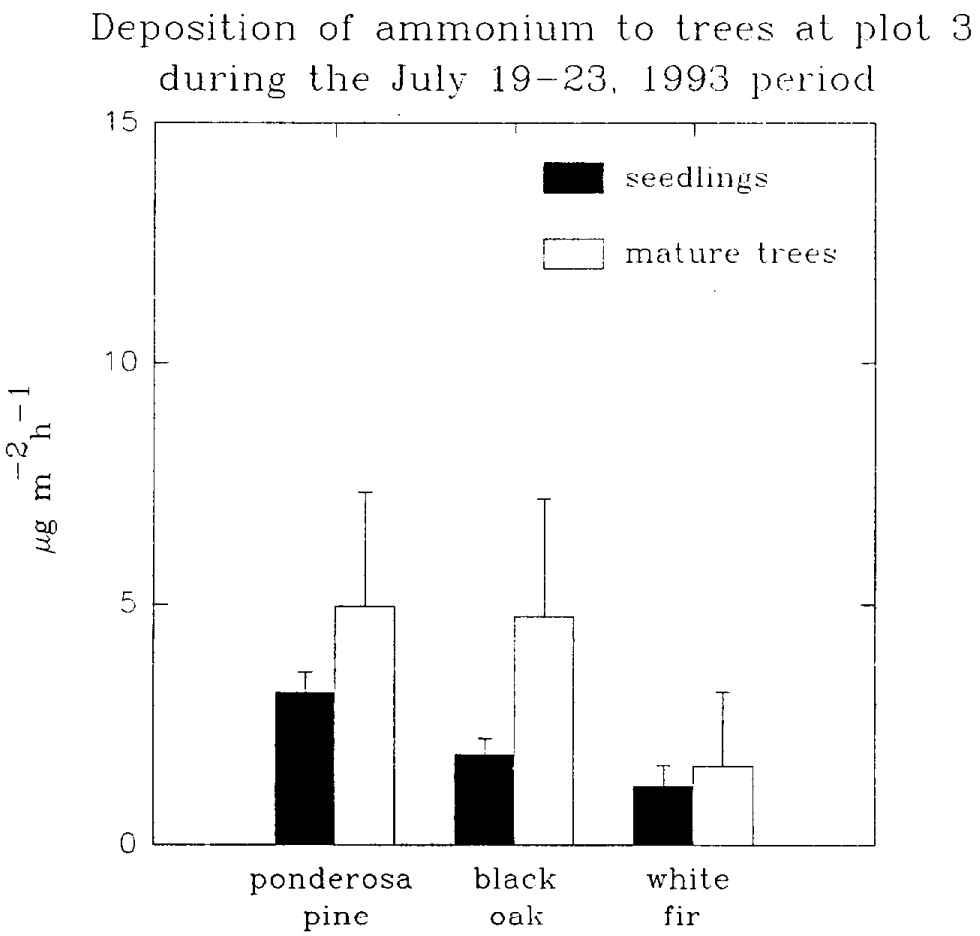


Figure A4-16. Comparison of ammonium deposition to foliage of mature trees vs. seedlings of various species at Plot 1 during the July 23 - 30, 1993 period of the intensive study.

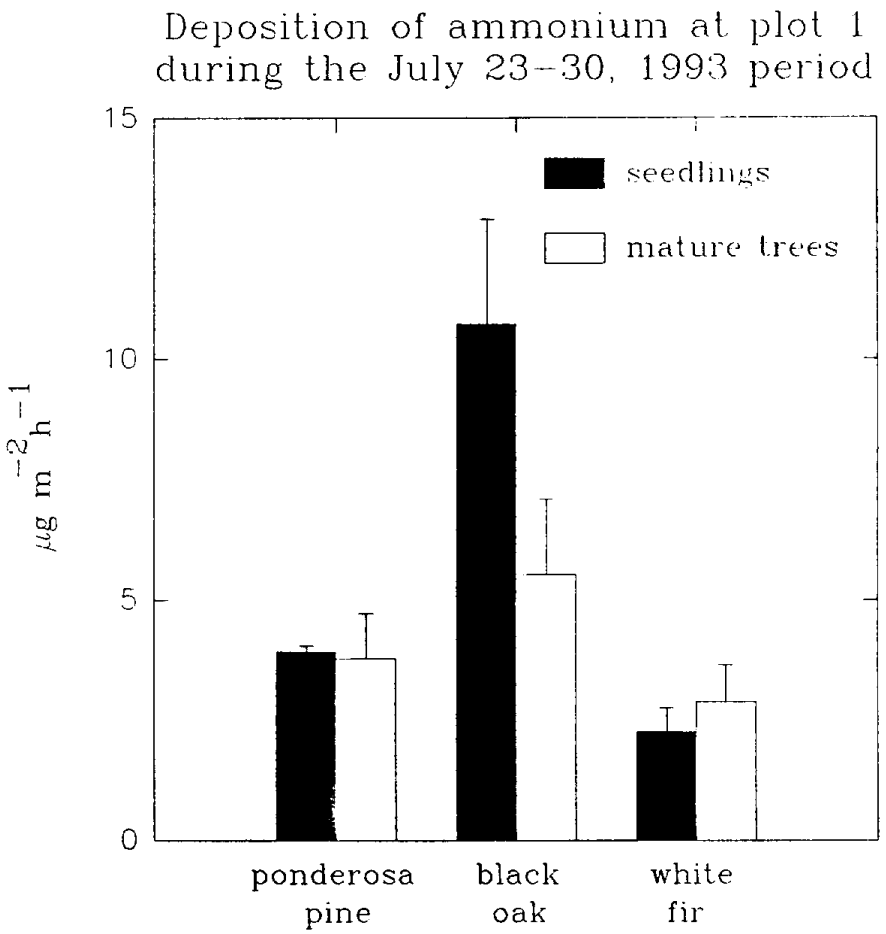


Figure A4-17. Comparison of ammonium deposition to foliage of mature trees vs. seedlings of various species at Plot 2 during the July 23 -30, 1993 period of the intensive study.

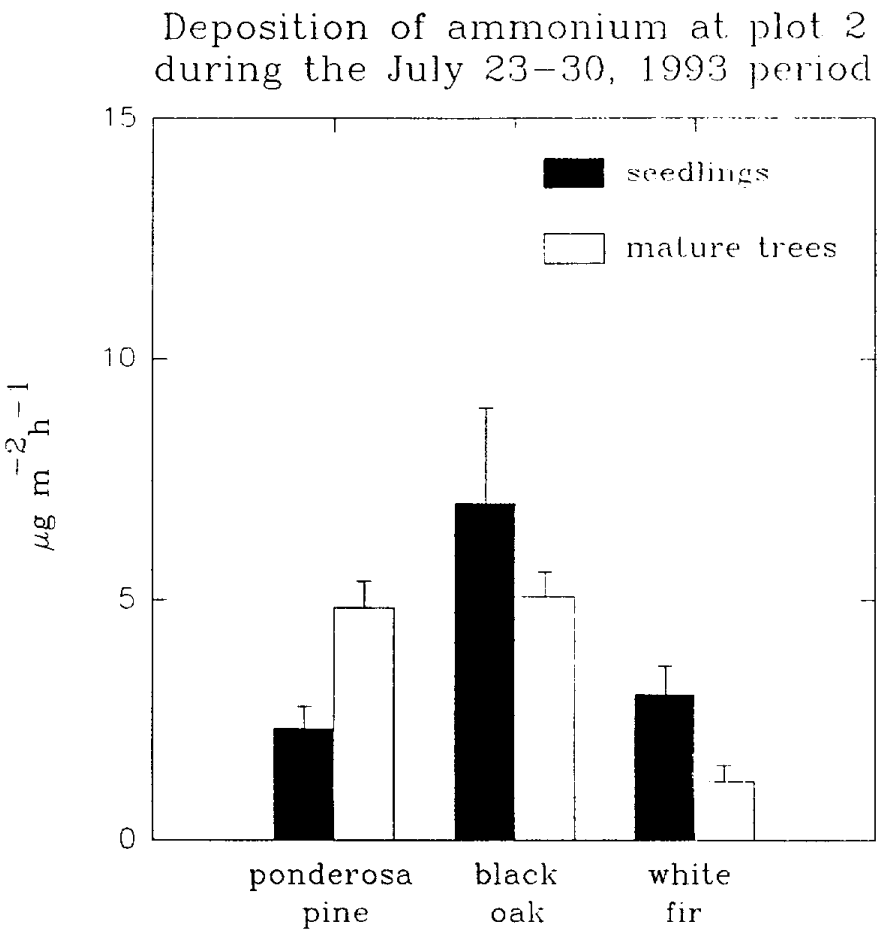


Figure A4-18. Comparison of ammonium deposition to foliage of mature trees vs. seedlings of various species at Plot 3 during the July 23 - 30, 1993 period of the intensive study.

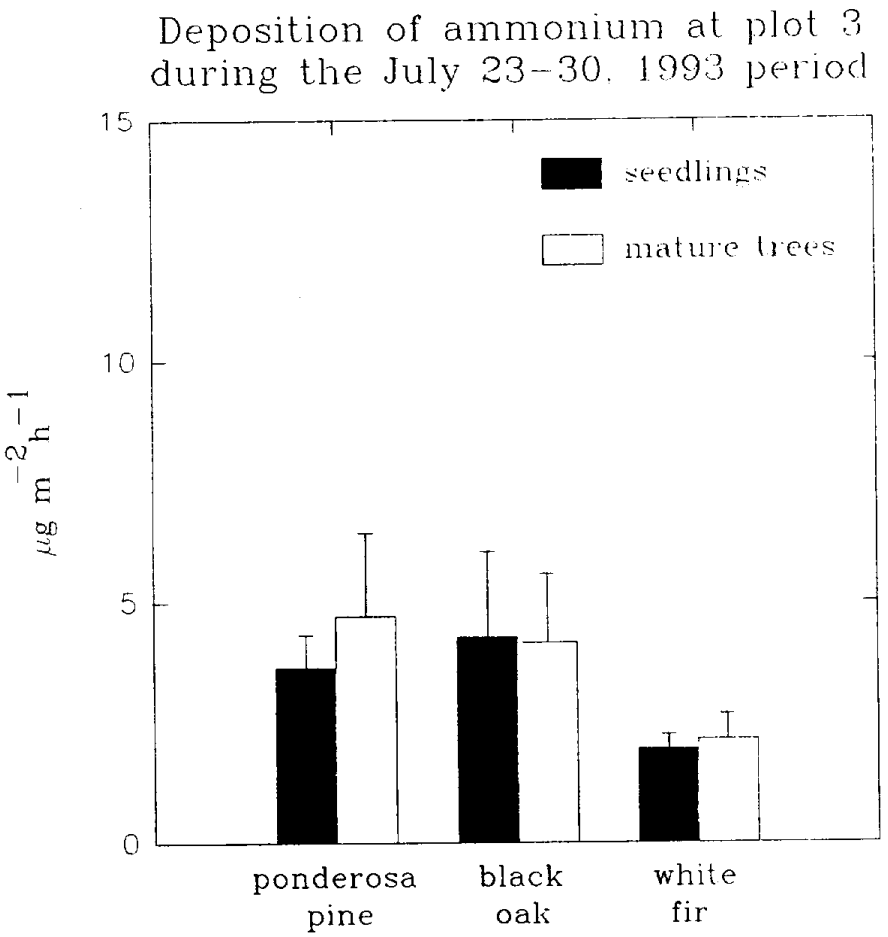


Figure A4-19. Comparison of sulfate deposition to foliage of mature ponderosa pine trees vs. seedlings at the bottom of the canopy, level 1 (12 m height on the tower).

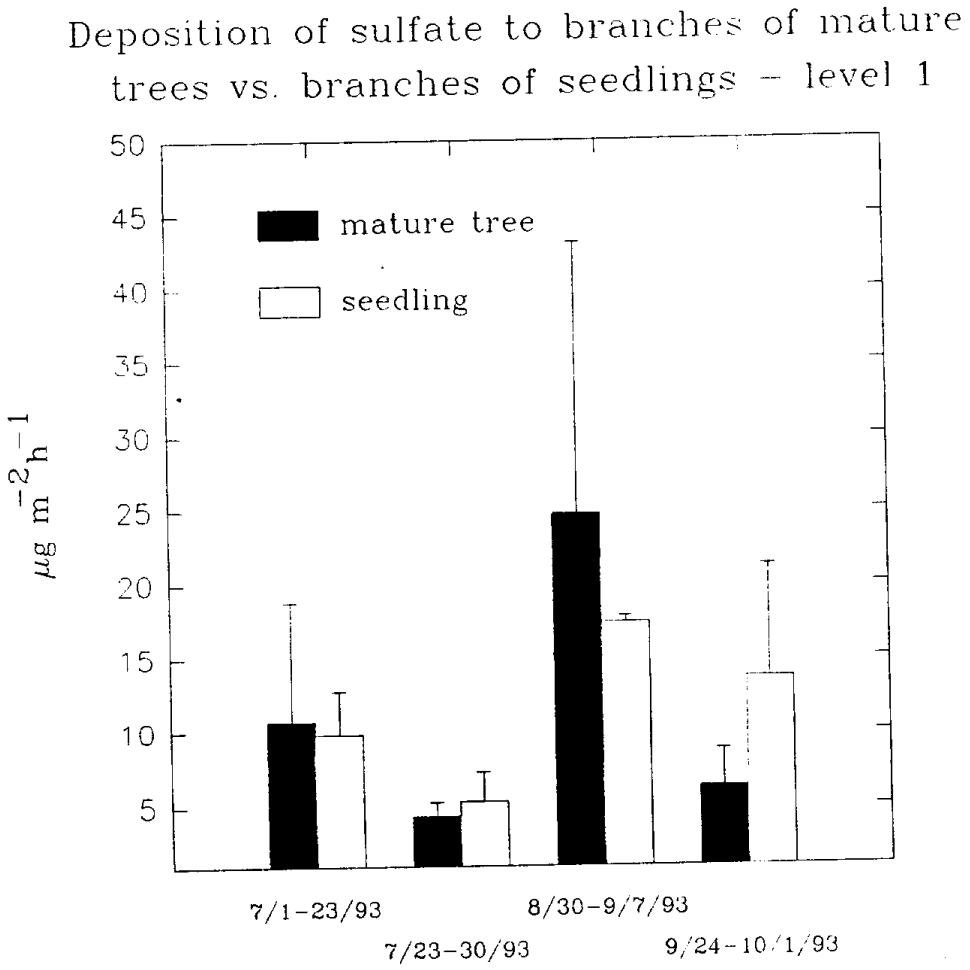


Figure A4-20. Comparison of sulfate deposition to foliage of mature ponderosa pine trees vs. seedlings at the second level of the canopy (16 m height on the tower).

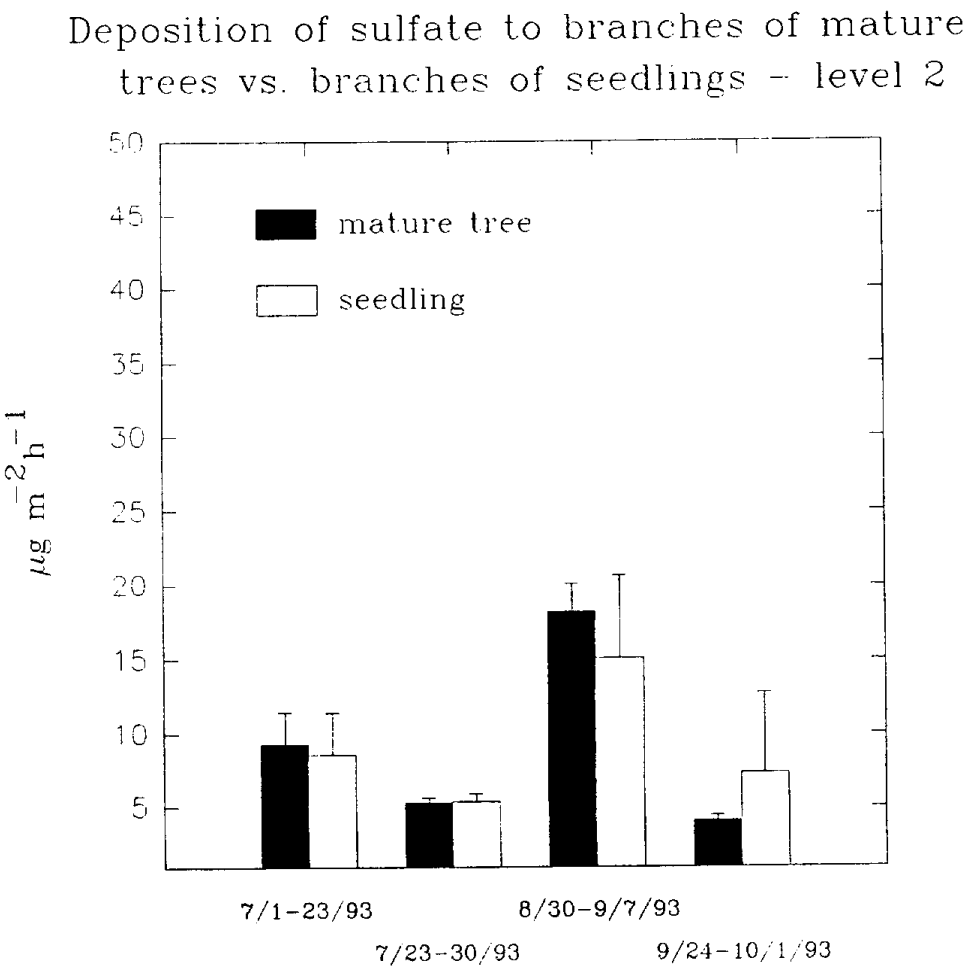


Figure A4-21. Comparison of sulfate deposition to foliage of mature ponderosa pine trees vs. seedlings at the third level of the canopy (24 m height on the tower).

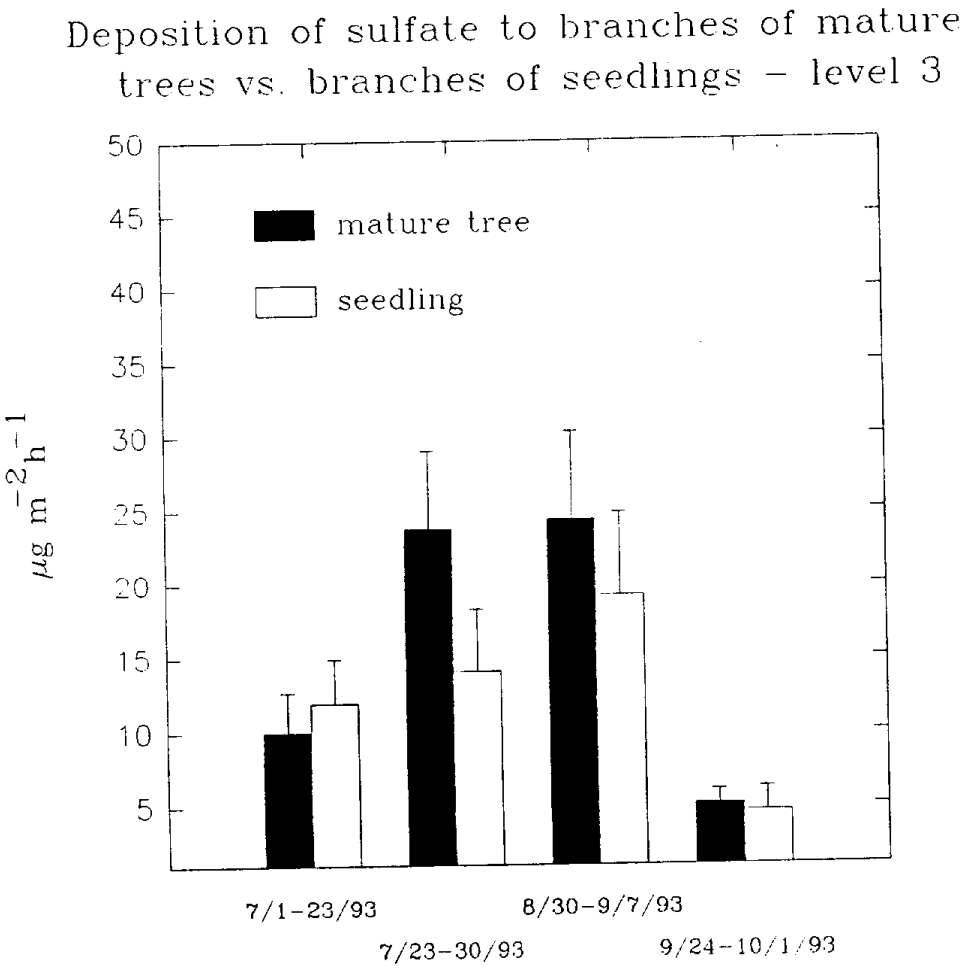


Figure A4-22. Deposition of sulfate to ponderosa pine seedlings located at forest floor of Plots 1, 2, and 3, roof of the monitoring station and tower top (Plot 2) during the July 23 - 30, 1993 period of the intensive study.

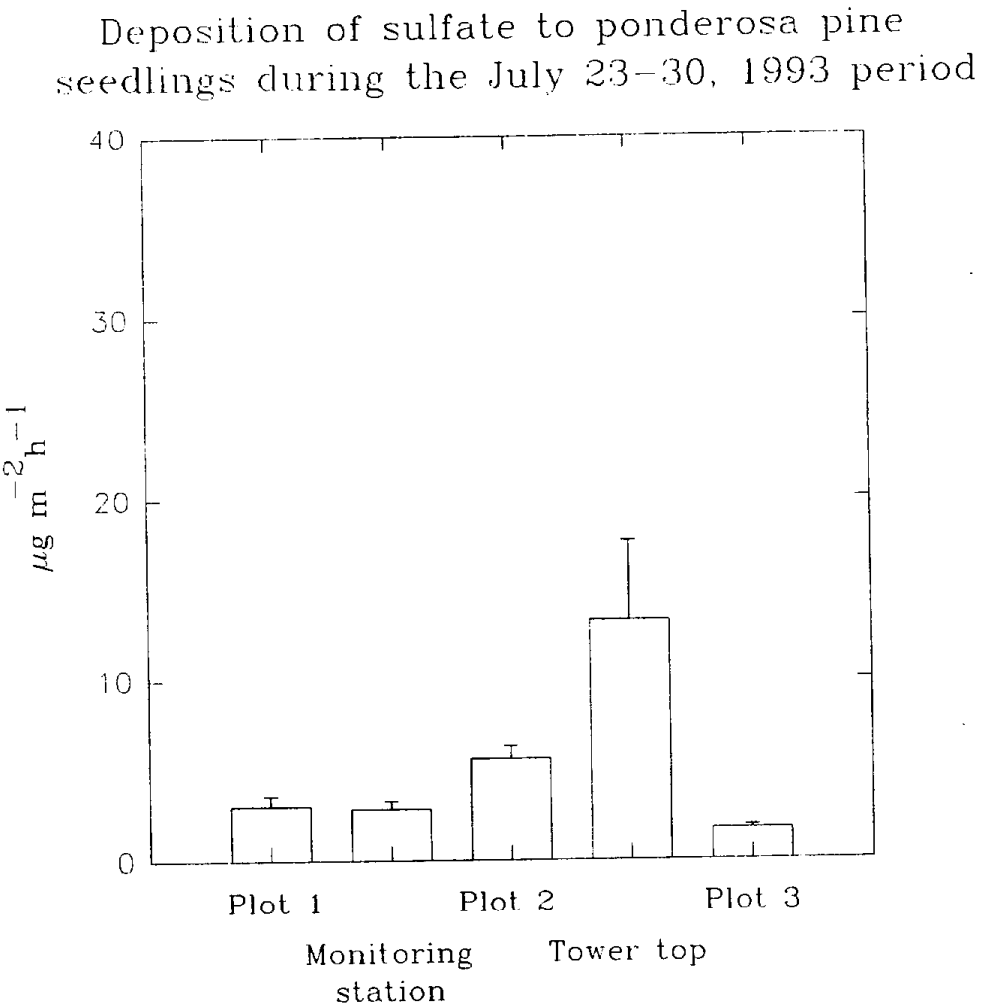


Figure A4-23. Deposition of sulfate to foliage of mature trees vs. seedlings of various species at Plot 2 during the July 19 - 23, 1993 period of the intensive study.

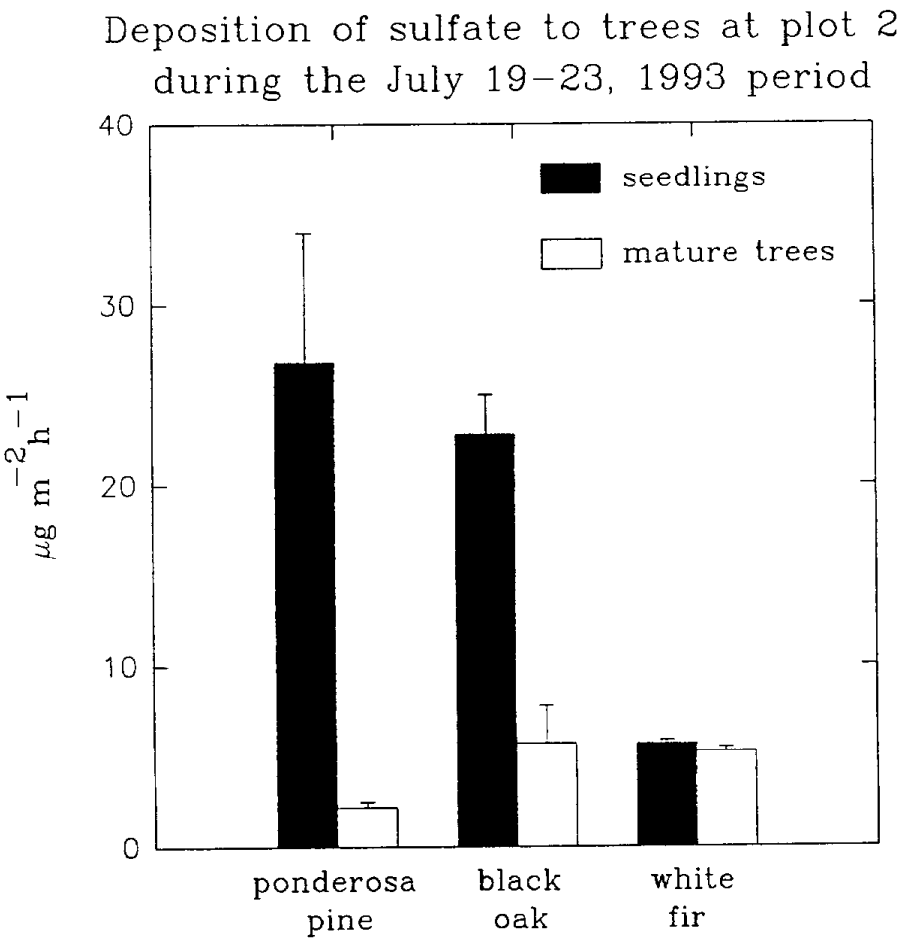


Figure A4-24. Deposition of sulfate to foliage of mature trees vs. seedlings of various species at Plot 3 during the July 19 - 23, 1993 period of the intensive study.

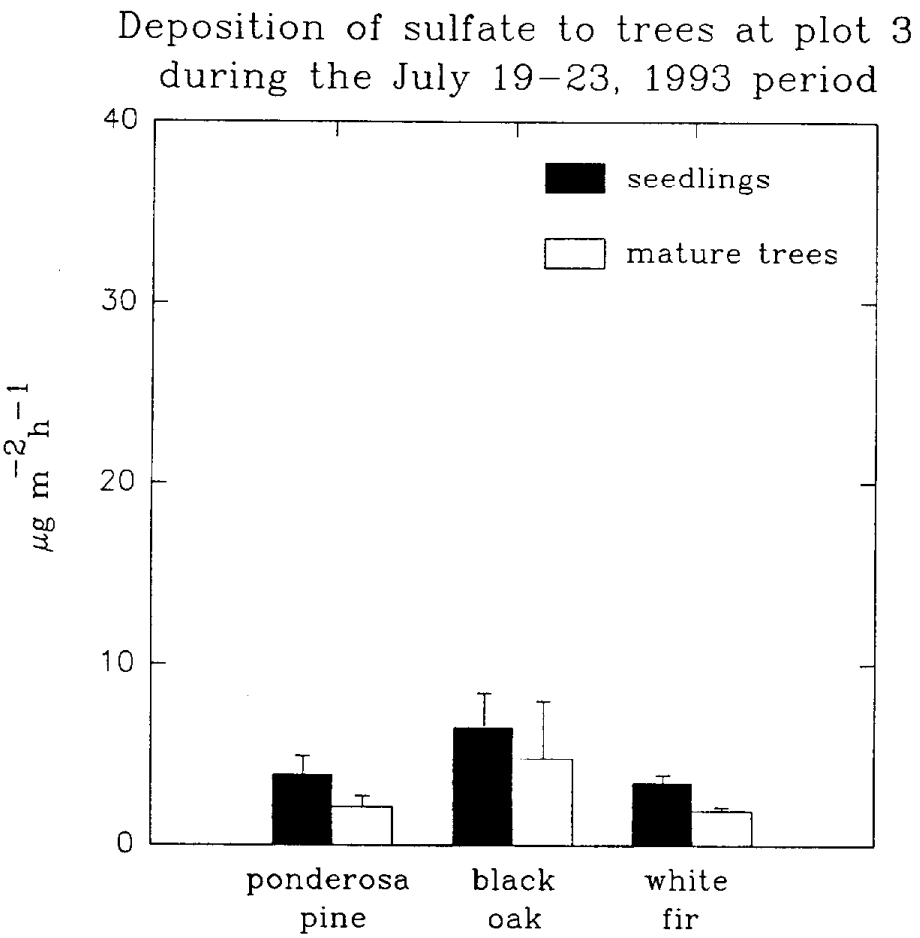


Figure A4-25. Deposition of sulfate to foliage of mature trees vs. seedlings of various species at Plot 1 during the July 23 - 30, 1993 period of the intensive study.

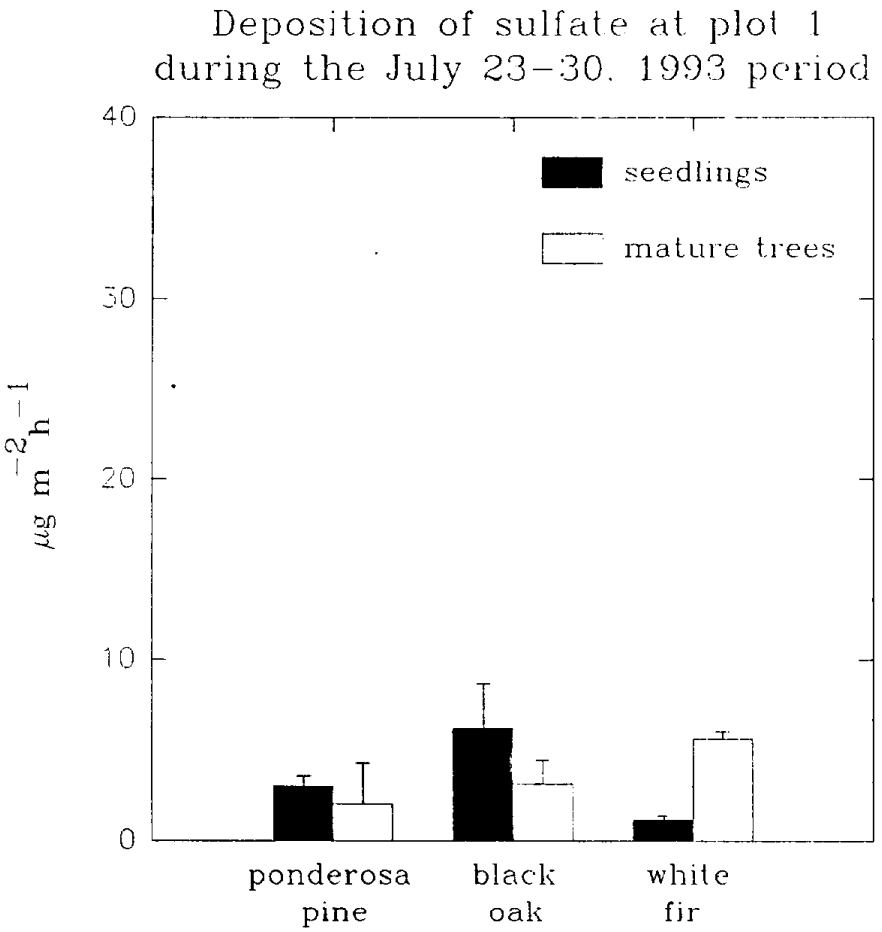


Figure A4-26. Deposition of sulfate to foliage of mature trees vs. seedlings of various species at Plot 2 during the July 23 - 30, 1993 period of the intensive study.

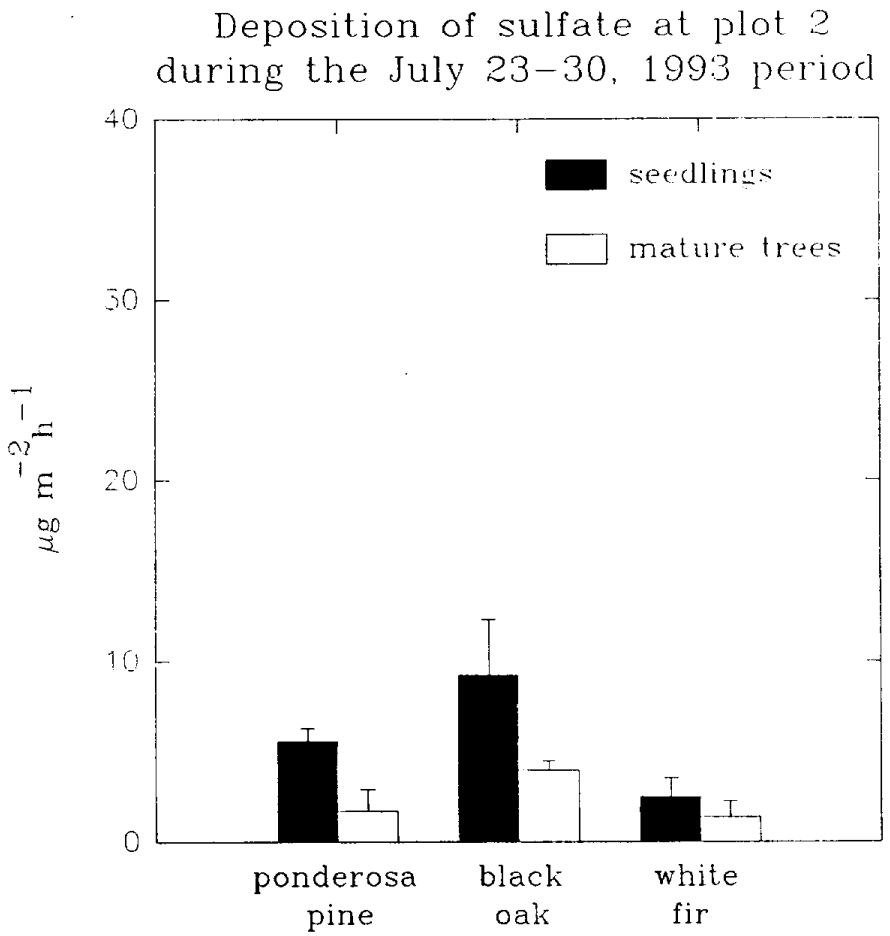
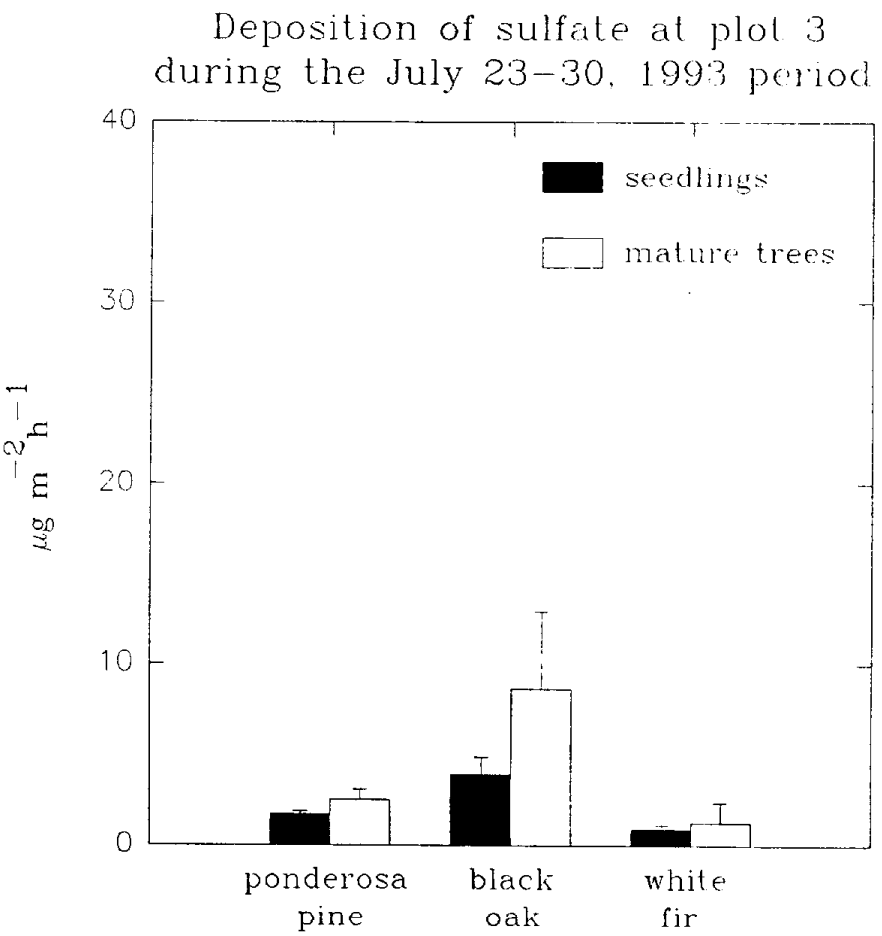



Figure A4-27. Deposition of sulfate to foliage of mature trees vs. seedlings of various species at Plot 3 during the July 23 - 30, 1993 period of the intensive study.