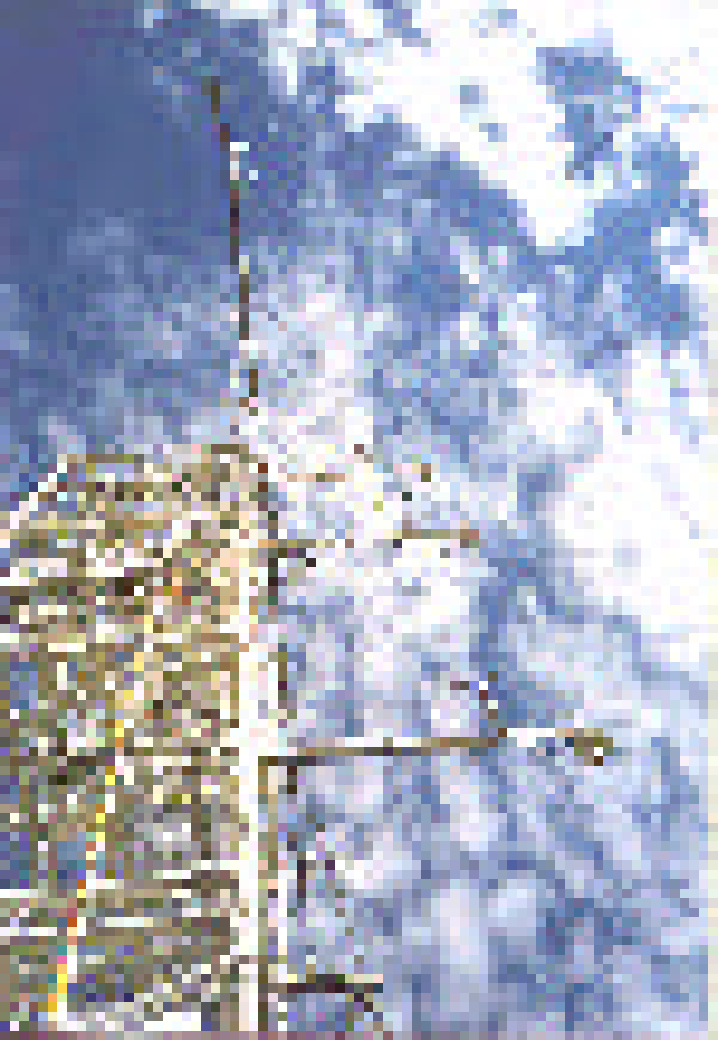

Interactions Between Air Pollution and Forests

Allen Goldstein

Presenting work from my research group: Markus Bill, *Gabrielle Dreyfus, *Rupert Holzinger, *Meredith Kurpius, Anita Lee, *Mark Lamanna, *Megan McKay, Dylan Millet, Laurent Misson, Jeanne Panek, *Gunnar Schade, Stephanie Shaw, *Brent Williams

(*major contributors to presentation)

ESPM, Ecosystems Sciences Division
University of California at Berkeley

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California Air Resources Board
National Science Foundation – Atmospheric Chemistry
Environmental Protection Agency – STAR program
University of California – Agricultural Experiment Station
Lawrence Berkeley National Laboratory

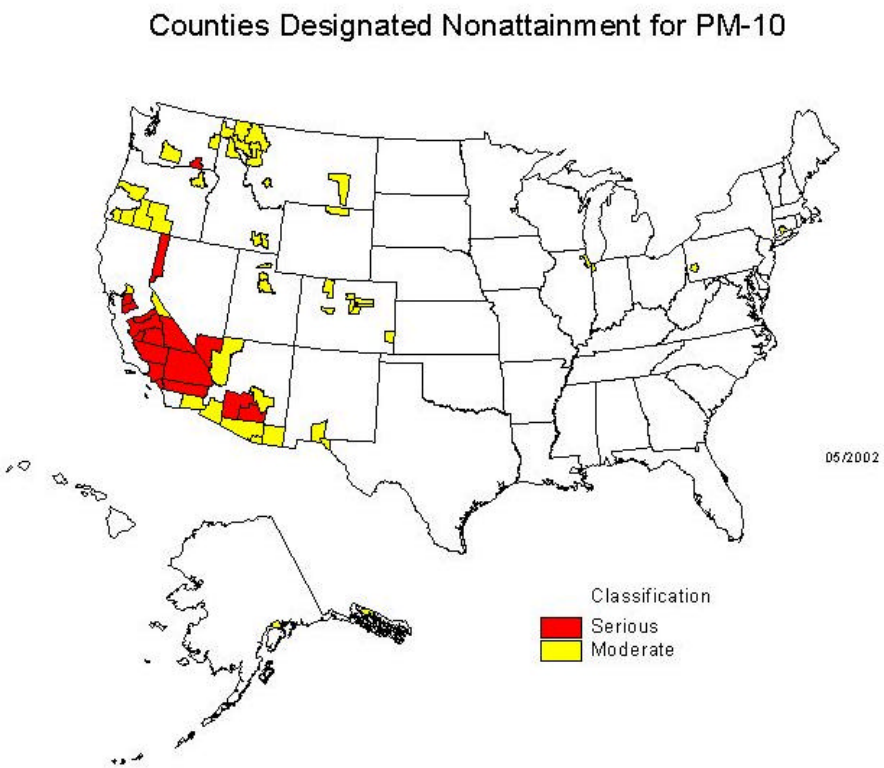
Research Objectives

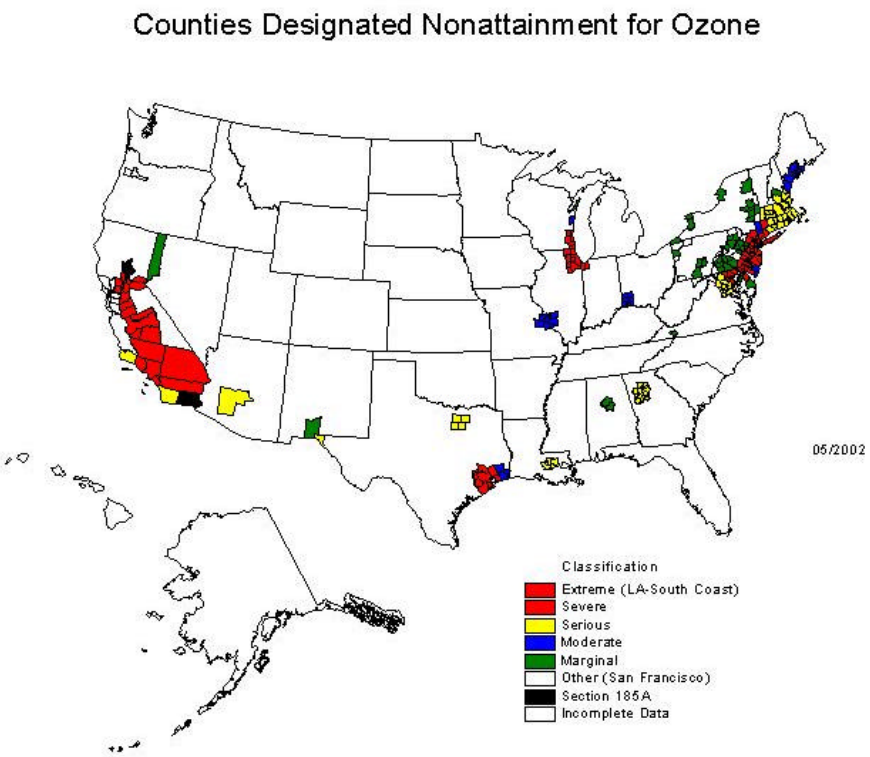
Natural Processes → **Anthropogenic Impacts** → **O_3 and Particles** → **Ecosystem Response**

- Understand natural processes of biosphere-atmosphere exchange: O_3, CO_2, H_2O, N, & Volatile Organic Compounds (VOC's).
- Understand the response of atmospheric O_3 and particles to natural and anthropogenic emissions.
- Understand processes of atmospheric deposition to sensitive ecosystems and evaluate impacts.
- Evaluate impacts of ecosystem management on biosphere-atmosphere exchange processes.

California contains ~ half the US counties federally designated as SERIOUS or SEVERE Non-Attainment areas for Particulate Matter and Ozone.

Sierran Forests include or are downwind of many of these counties.





Environmental Protection Agency (www.epa.gov/oar/oaps/greenbk/)

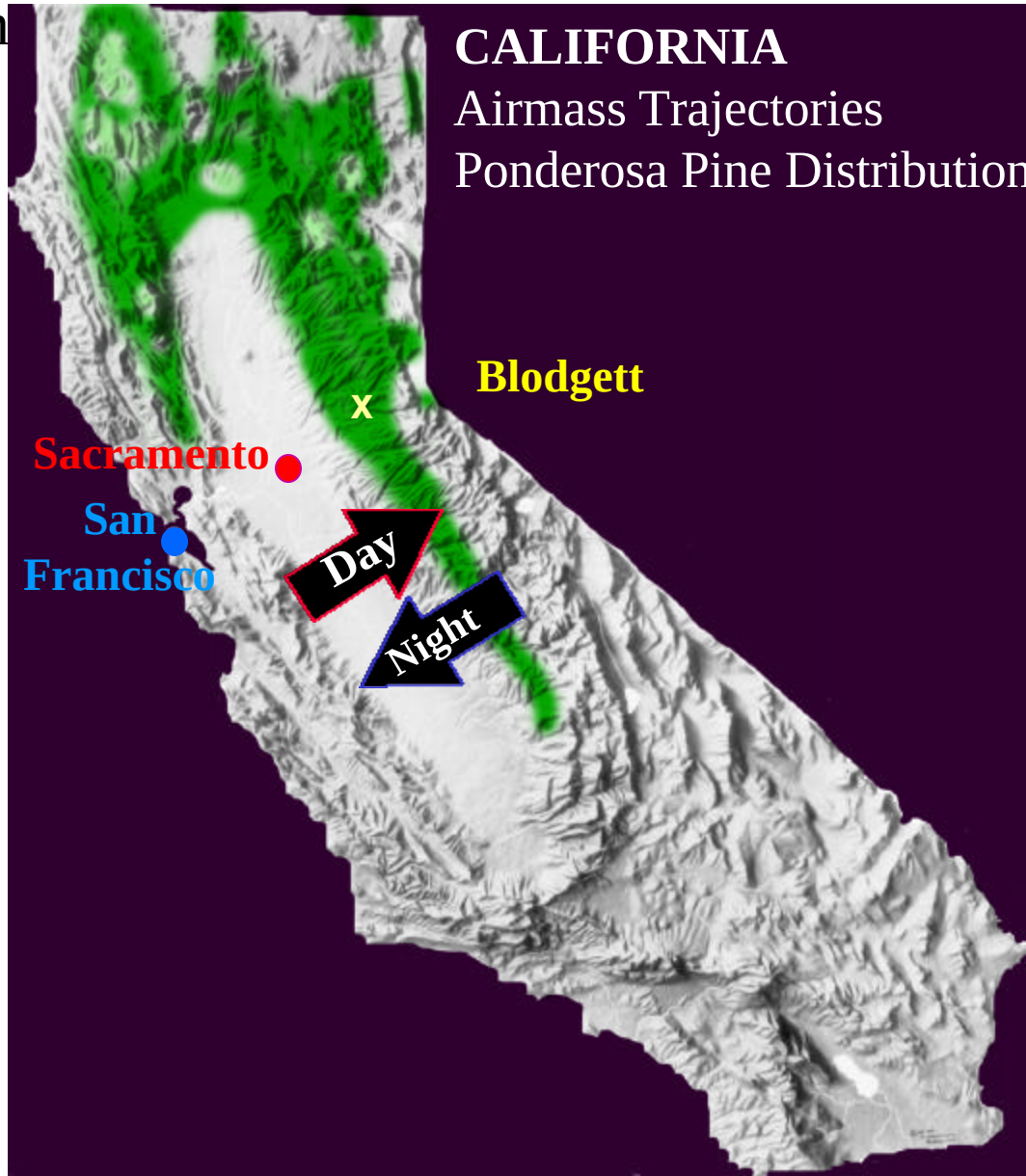
Why Study Atmospheric Interactions With Ponderosa Pine in the Sierra Nevada Mountains?

-Dominant forest tree in Western North America.

-One of the most sensitive tree species to ozone damage

-Major emitter of natural terpenes, methylbutenol, and other VOCs, leading to ozone and aerosol production.

-Site downwind of urban area: learn about chemistry of natural and anthropogenic emissions interacting in pollution plumes.



Year-Round Measurements of Concentrations and Biosphere-Atmosphere Fluxes

CO_2, H_2O, O_3, CO, VOC's (Goldstein)

NO, NO_2, NO_y, speciated NO_y (Cohen)

Aerosol size distribution and physical properties (Lunden)

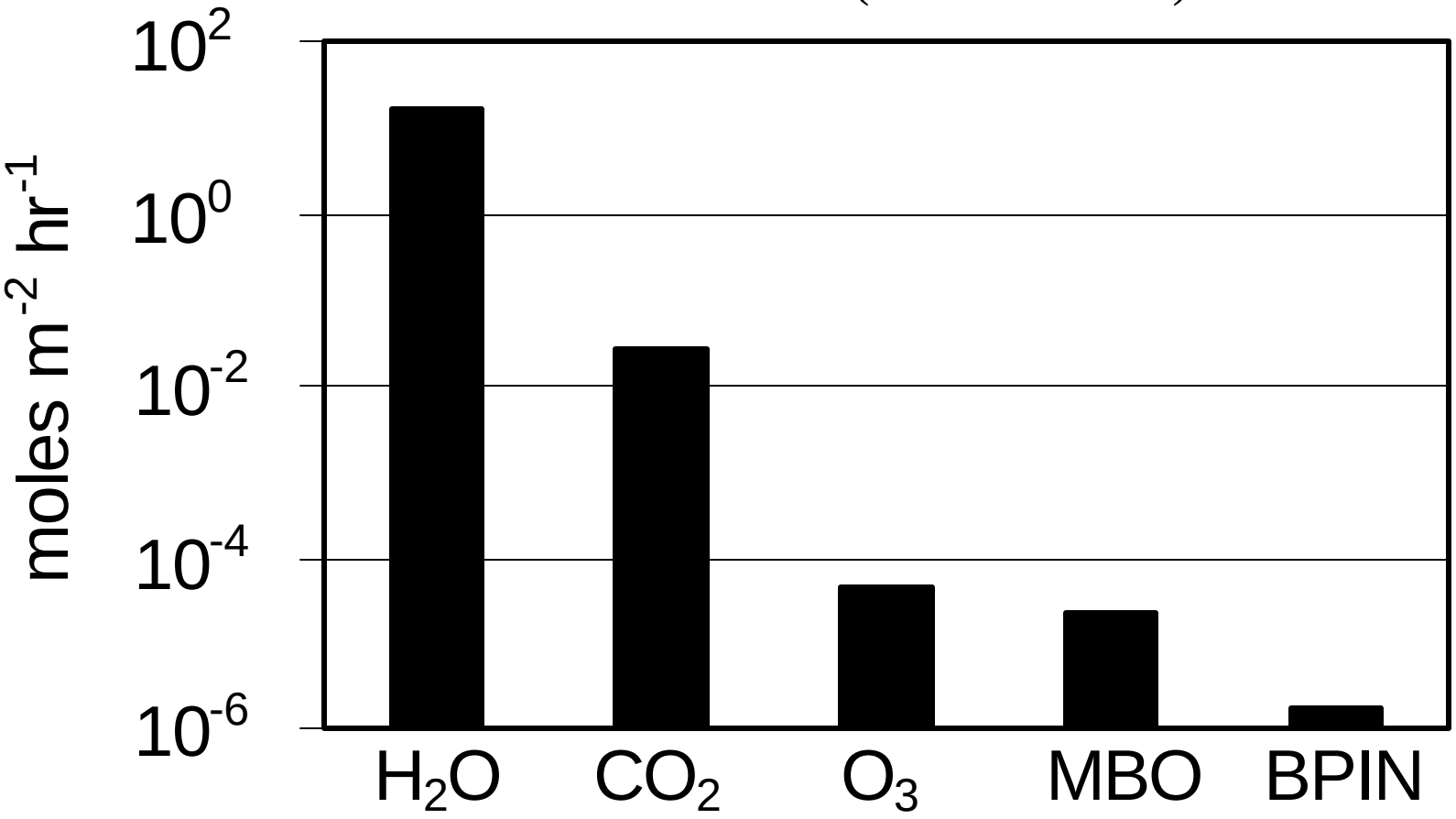
Hydroxy carbonyls (Charles)

Meteorological and Ecosystem Variables (Goldstein)

View from the Measurement Tower

Research site adjacent to Blodgett Forest Research Station.
Planted in 1990. Owned and managed by Sierra Pacific Industries.

Median Ecosystem Scale Fluxes
Blodgett Forest
July 6 - September 8 1999
9:00 – 16:00 PST (Absolute Value)

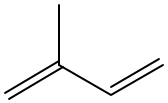


Goldstein et al., 2003

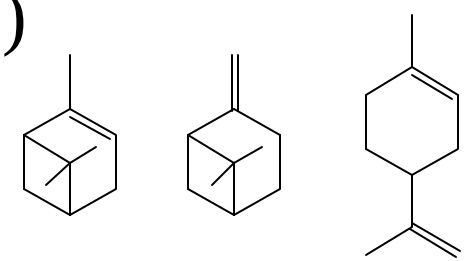
Biogenic Volatile Organic Compounds (BVOCs, 1000's of compounds)

Amount Known

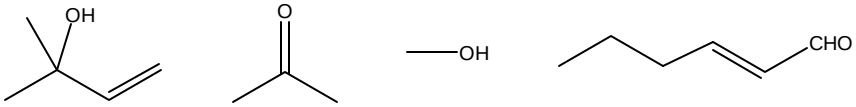
- Isoprene (C_5H_8)



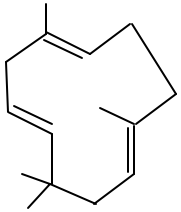
- Monoterpenes ($C_{10}H_{16}$)



- Oxygenated VOC



- Sesquiterpenes ($C_{15}H_{24}$)



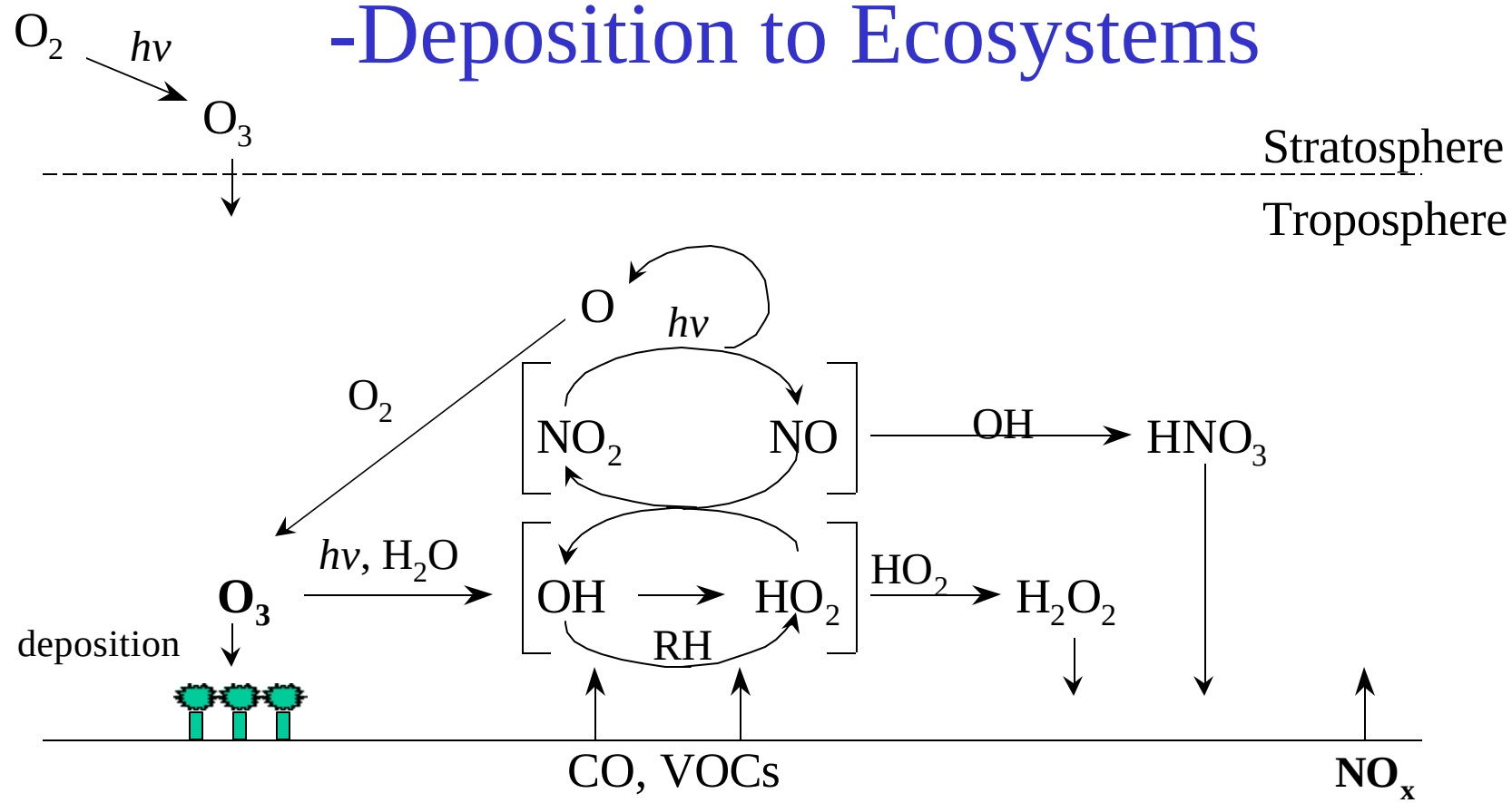
Research Highlights

- Ozone production from biogenic isoprene oxidation: Field observations.
- Ozone deposition to the forest:

  Stomatal uptake vs gas phase chemical loss?
- Aerosol growth events:

  Links to biogenic mono- or sesquiterpene emissions and ozone deposition?

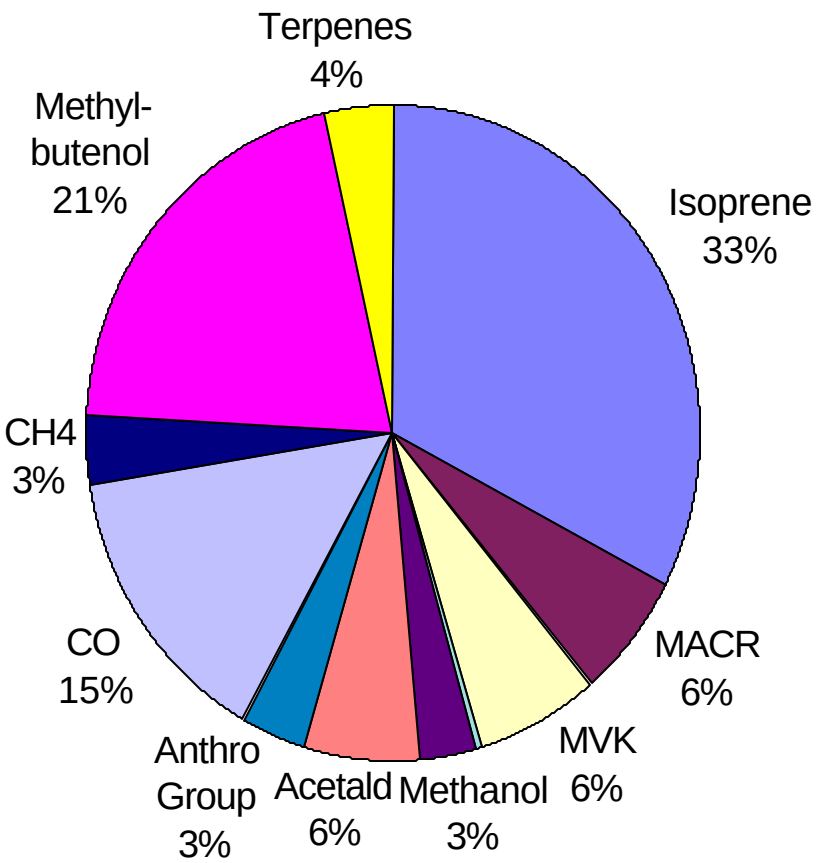
What do we need to know about O_3?
-Chemical Production & Loss
-Deposition to Ecosystems

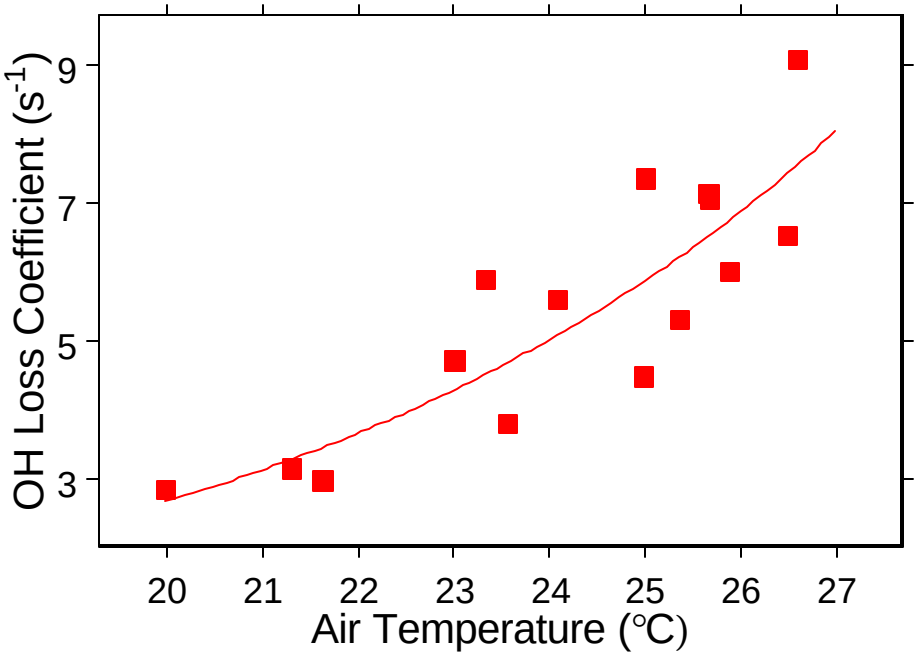


$$OPE = \frac{PO_3}{ENO_x}$$

Contribution to OH loss at Blodgett (k_{OH}[VOC])

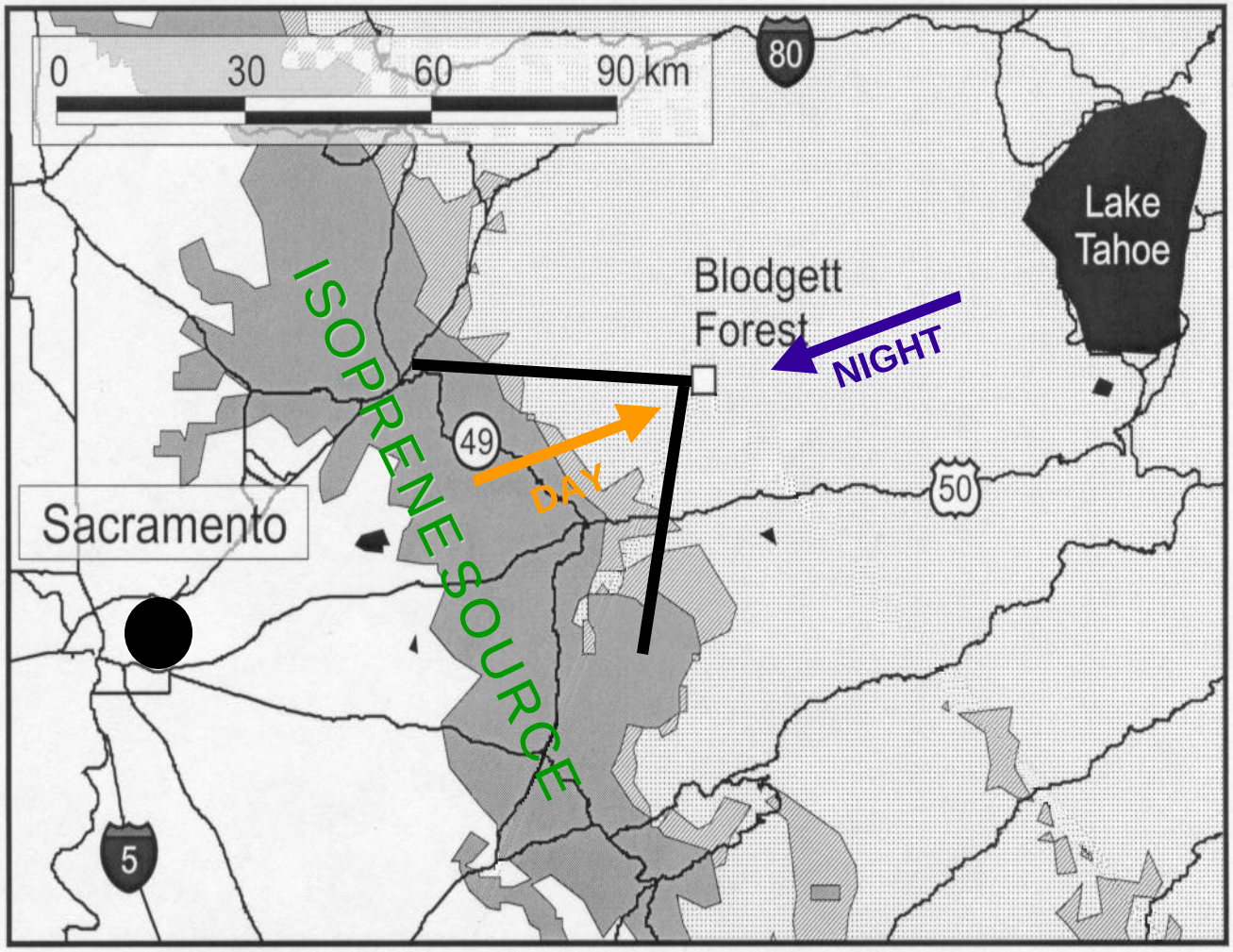
> 70% biogenic



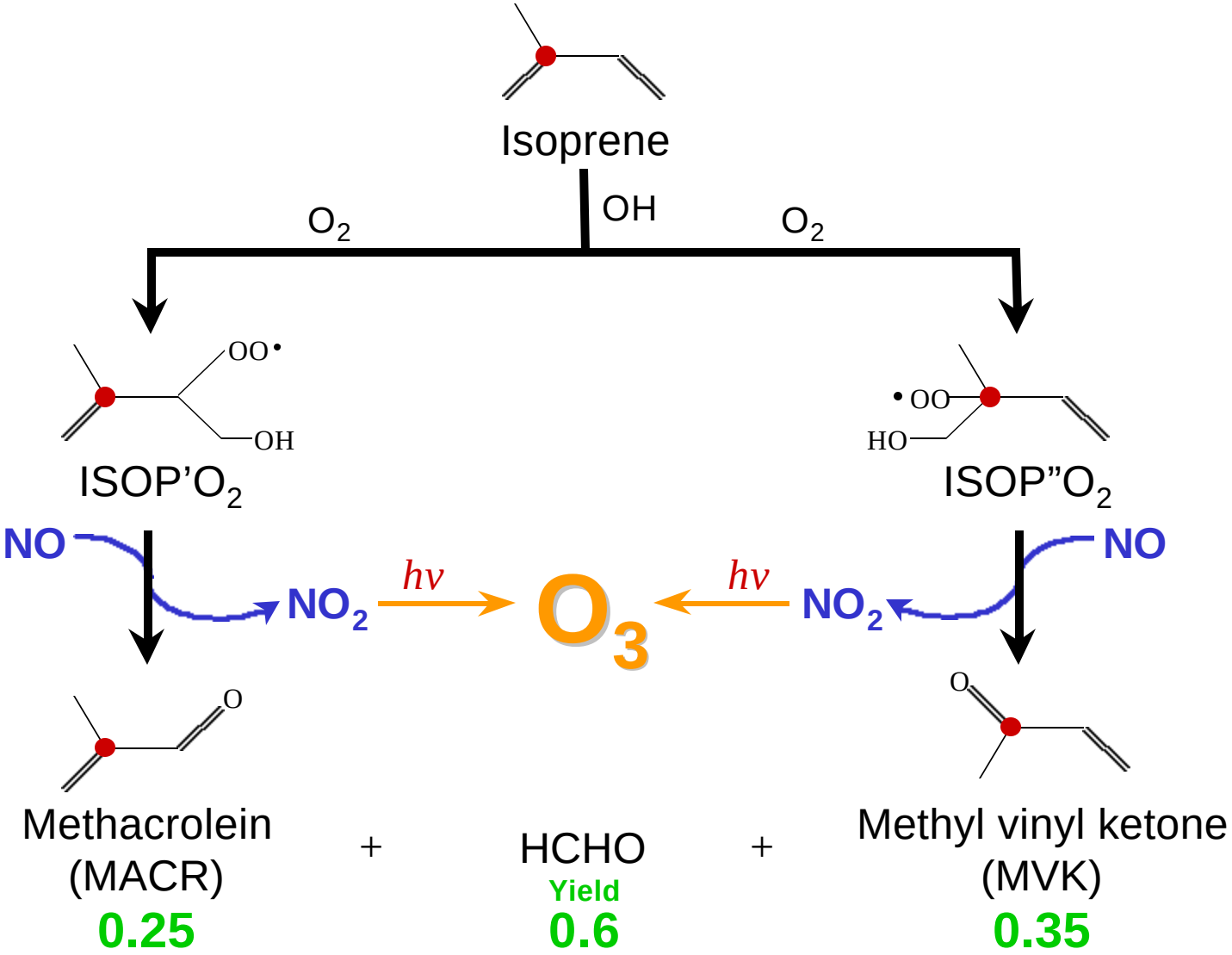


Lamanna & Goldstein, JGR, 1999

Diurnal Wind Flow Pattern and Emission Sources

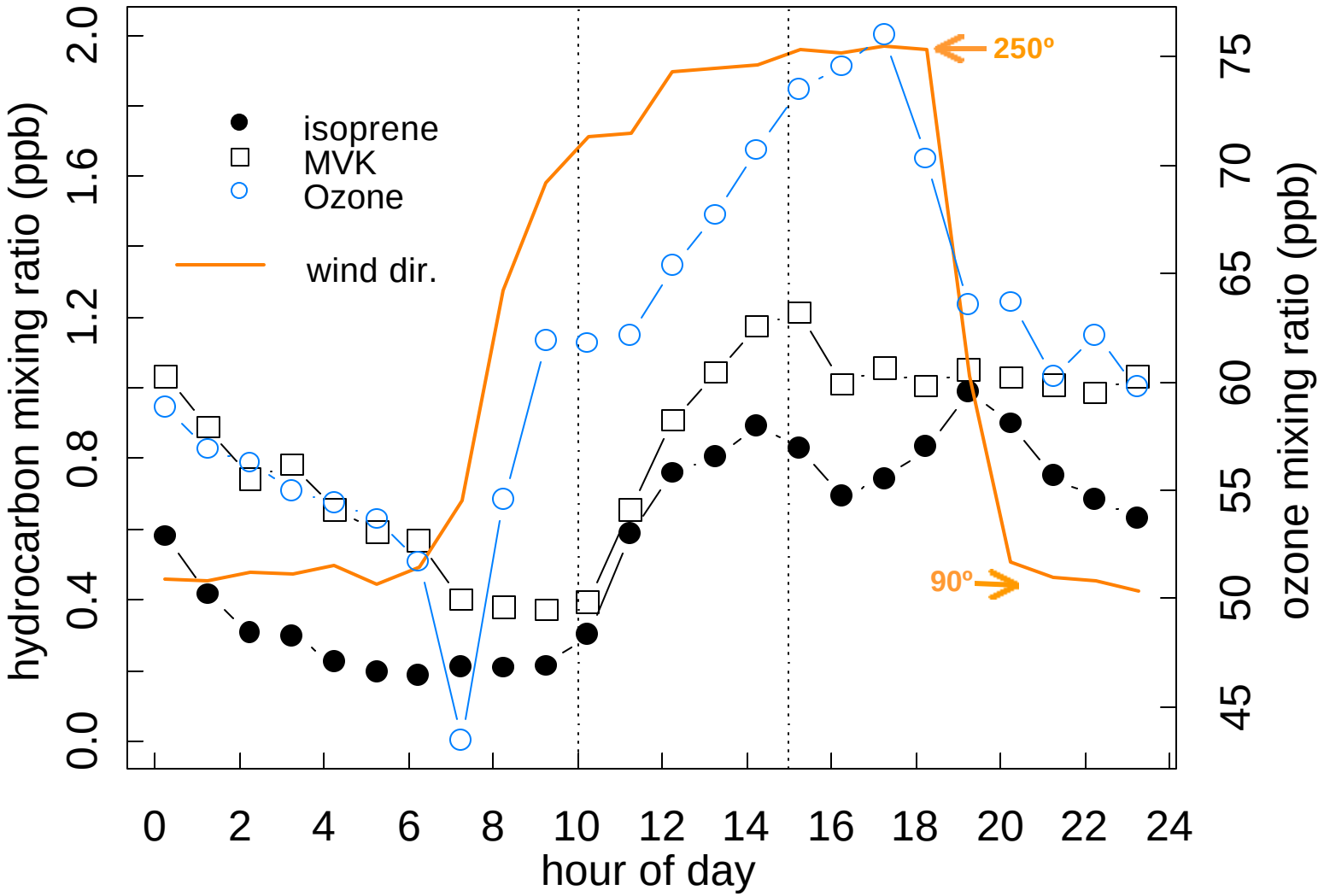


How Much of the O_3 produced in the Sacramento urban plume is produced during isoprene oxidation?



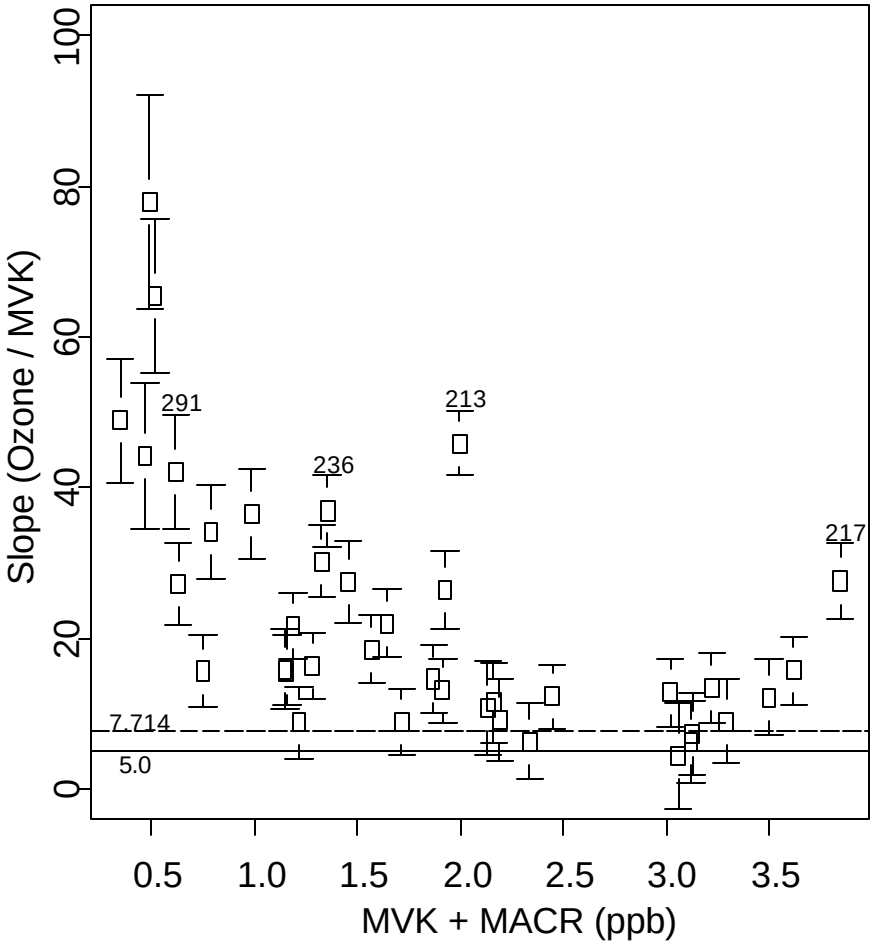
Dreyfus, Schade & Goldstein, JGR 2002

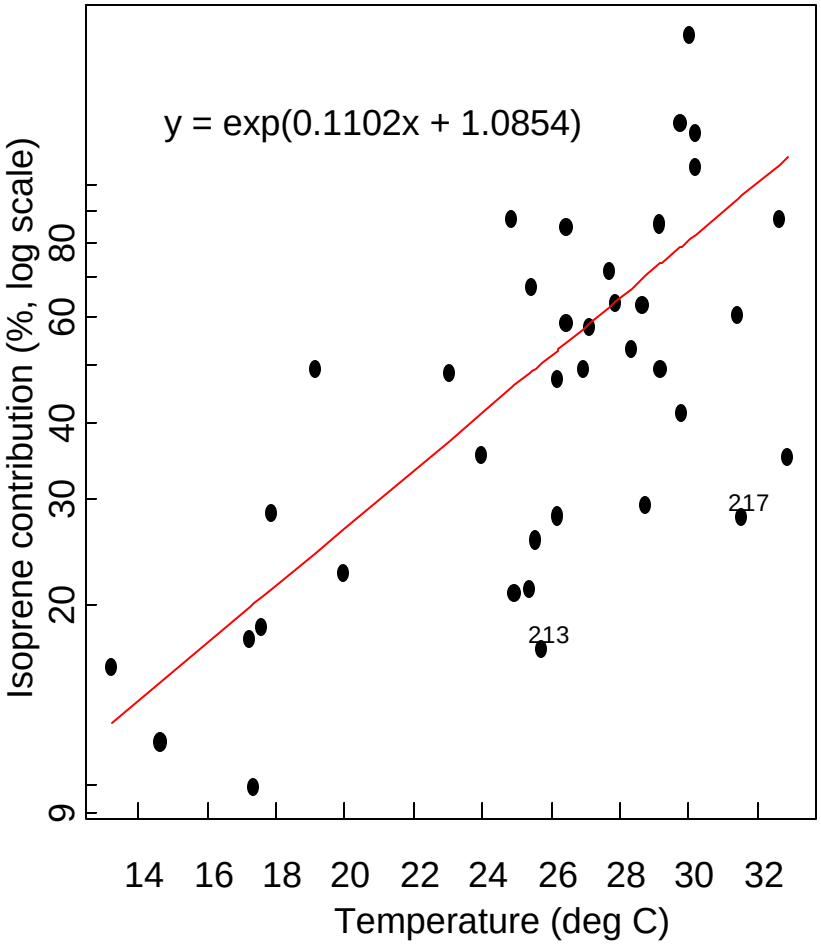
Typical Diurnal Mixing Ratios for Isoprene, MVK and Ozone, and Wind Direction



Dreyfus, Schade & Goldstein, JGR 2002

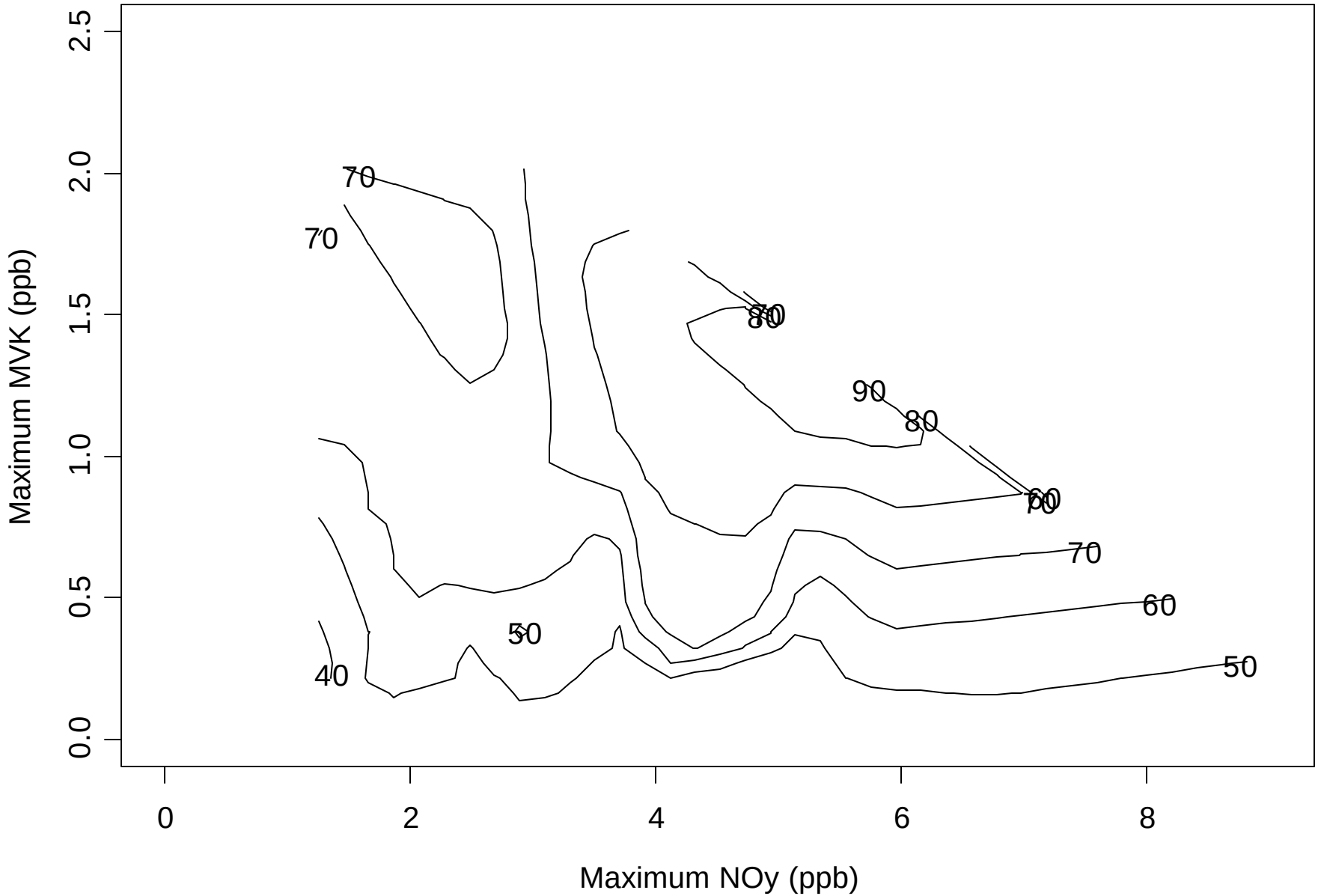
Regional Ozone Production From Isoprene Oxidation





Dreyfus, Schade & Goldstein, JGR 2002

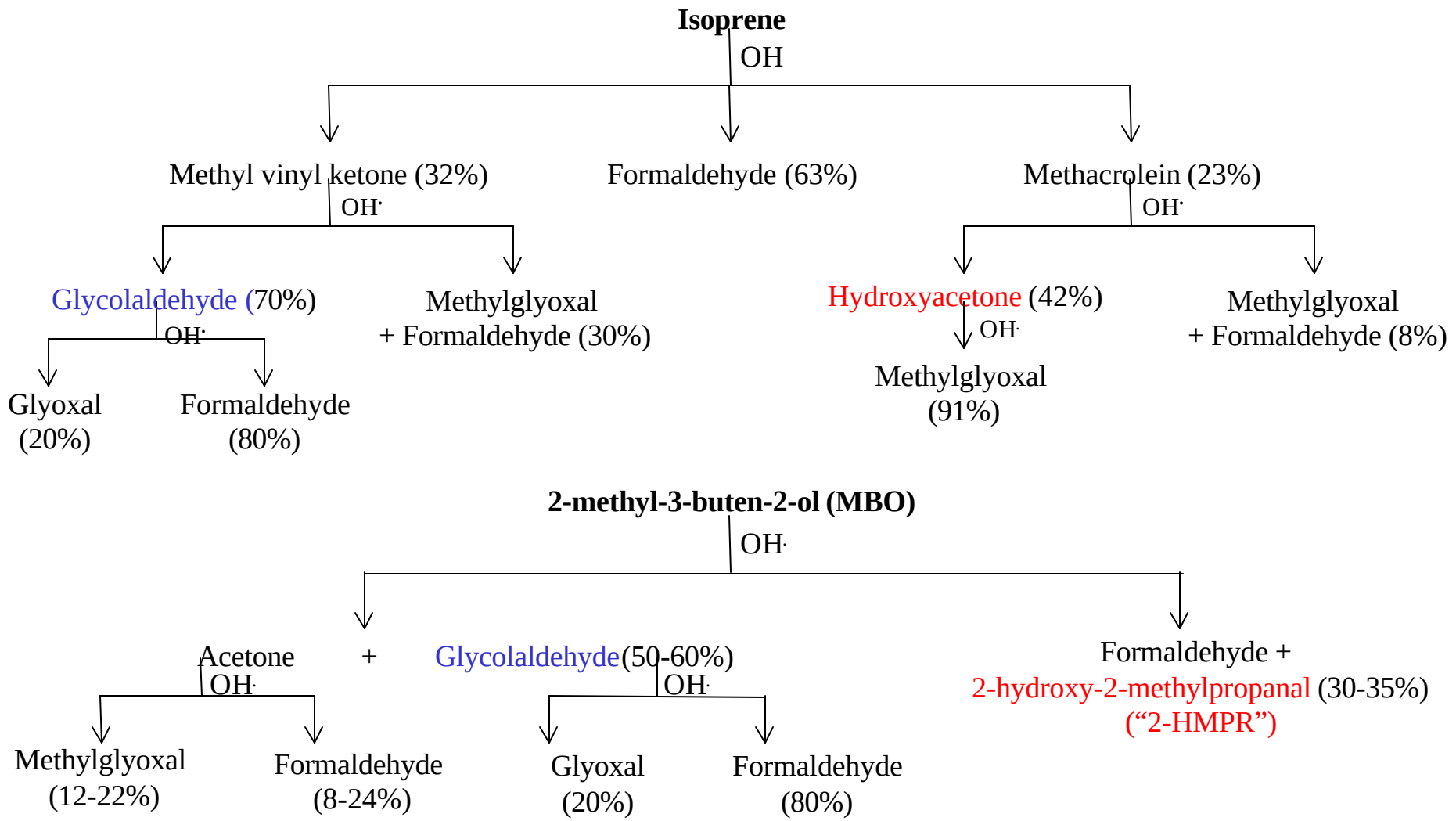
Maximum Ozone Isopleths 1998 (ppbv)
Dependence on NOy and Isoprene Oxidation



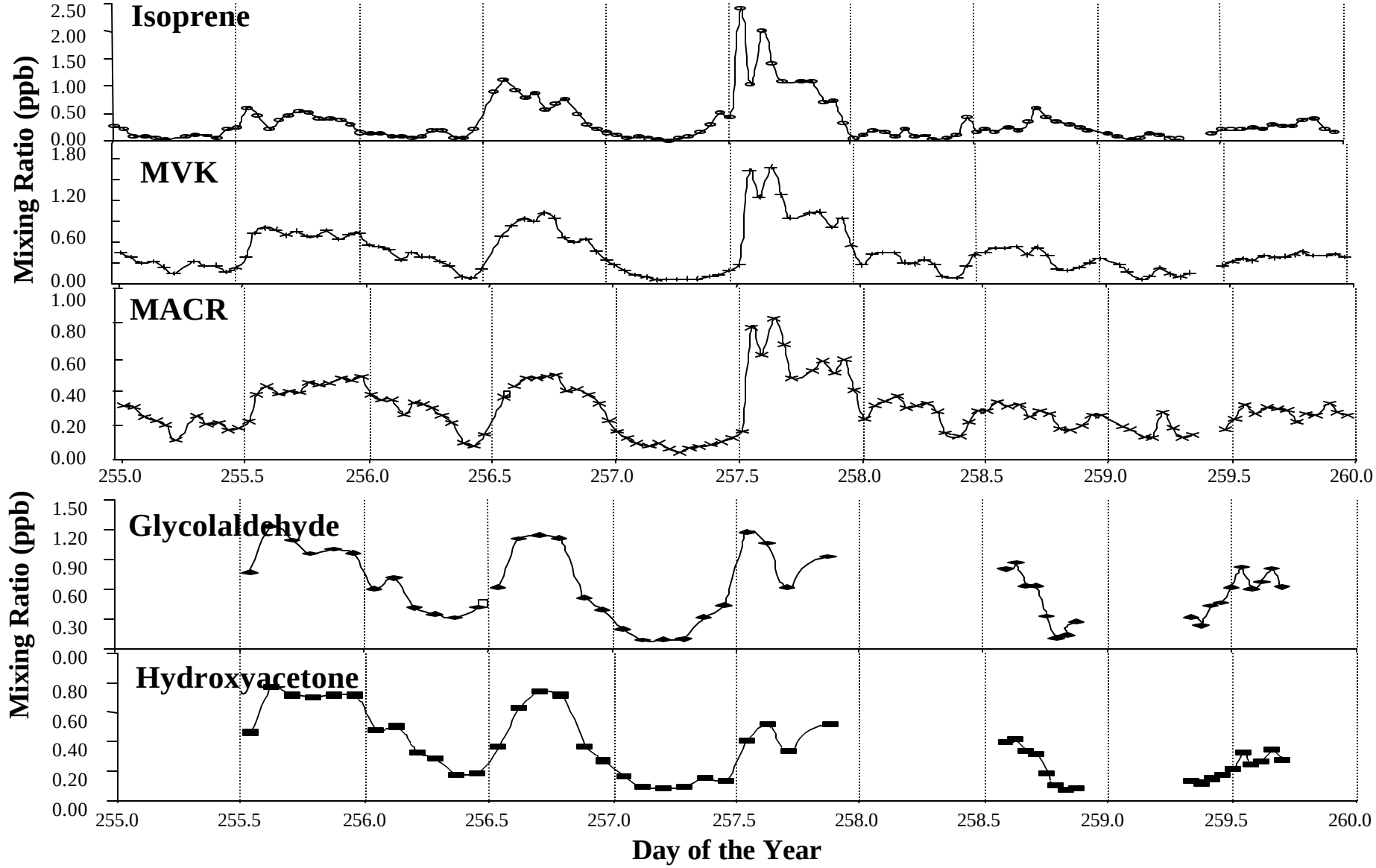
The whole story of ozone formation has not yet been told…

New Field Measurements of Multifunctional Oxidation Products

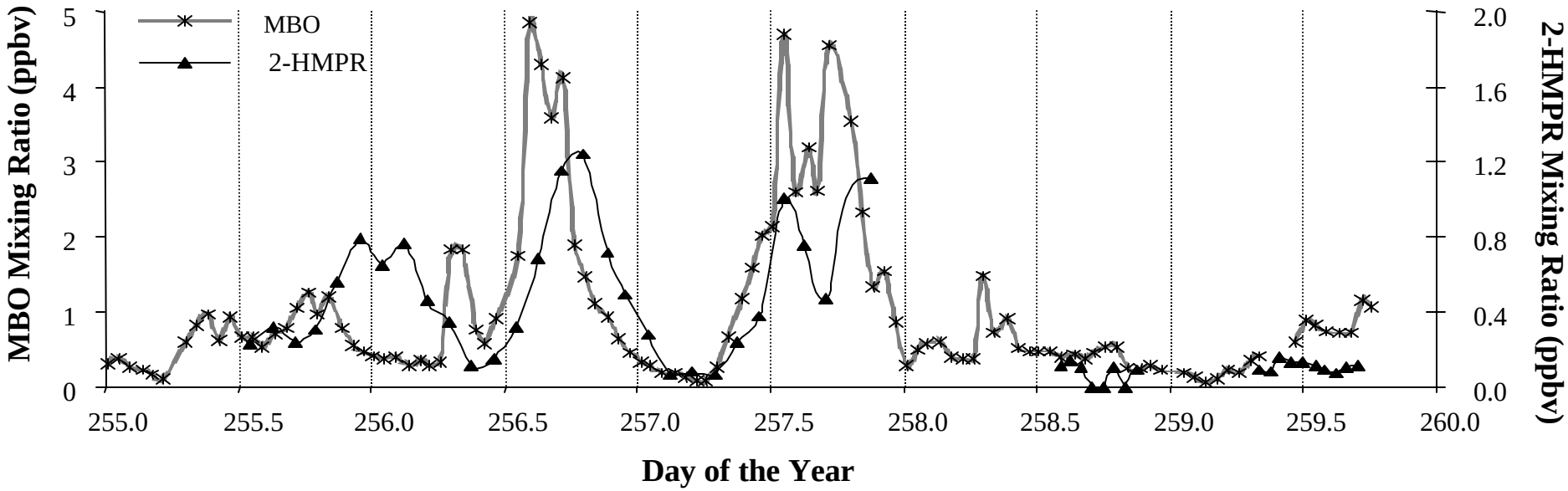
Spaulding et al, JGR 2003 (& J. Charles, collaborators at UC Davis)



From: Tuazon, E.C..; Atkinson, R. *Int. J. Chem. Knet.* 1990, 22:1221-1236;
Tuazon, E. C., Atkinson, R. *Int. J. Chem. Knet*. 1990, 22:591-602;
Tuazon, E. C., Atkinson, R. *Int. J. Chem. Knet*. 1989, 21: 1141-1152.
Alvarado et al., 1999. Atmos. Env. 33:2893-2905.

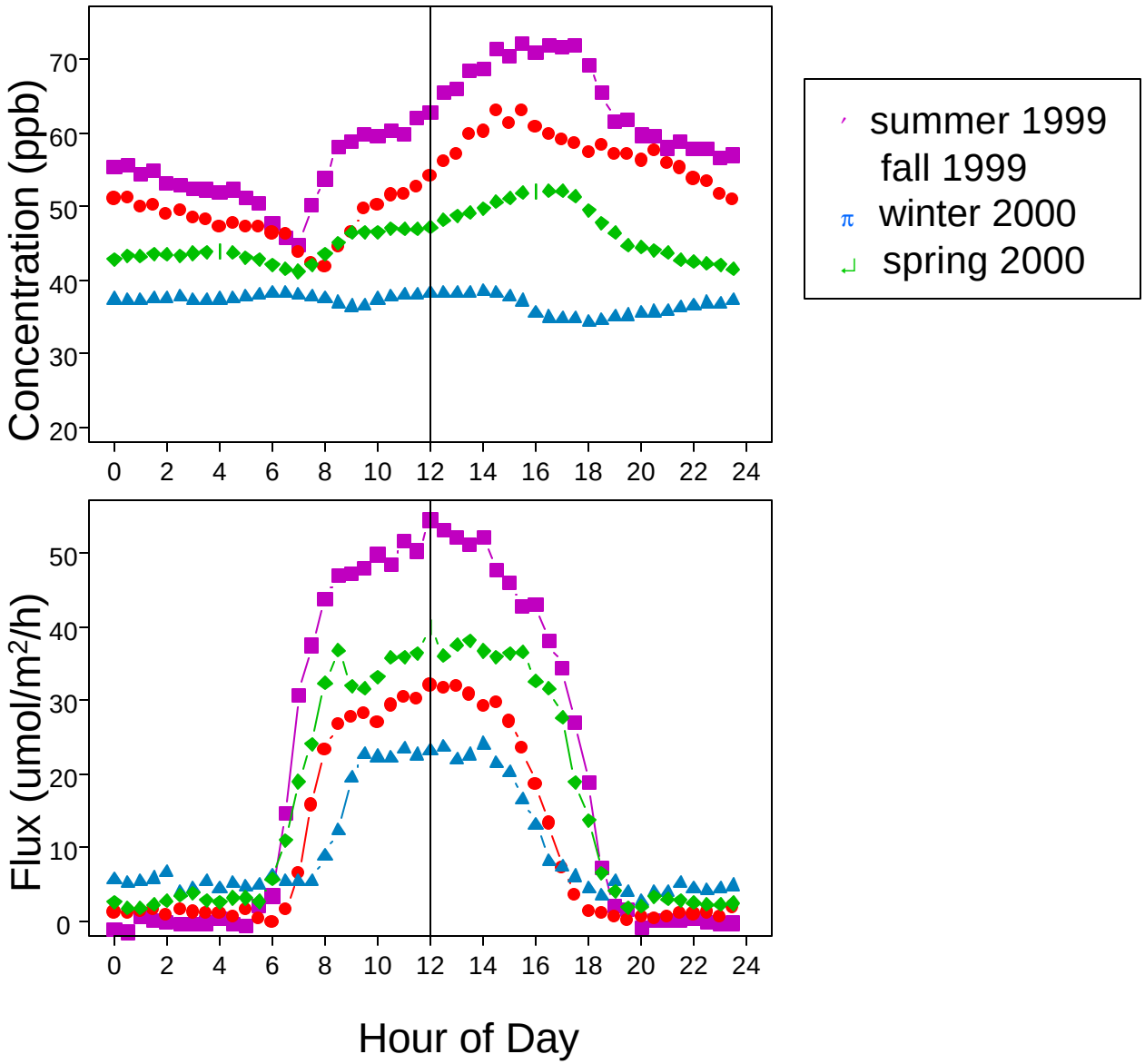


Spaulding et al., JGR 2003



Spaulding et al., JGR 2003

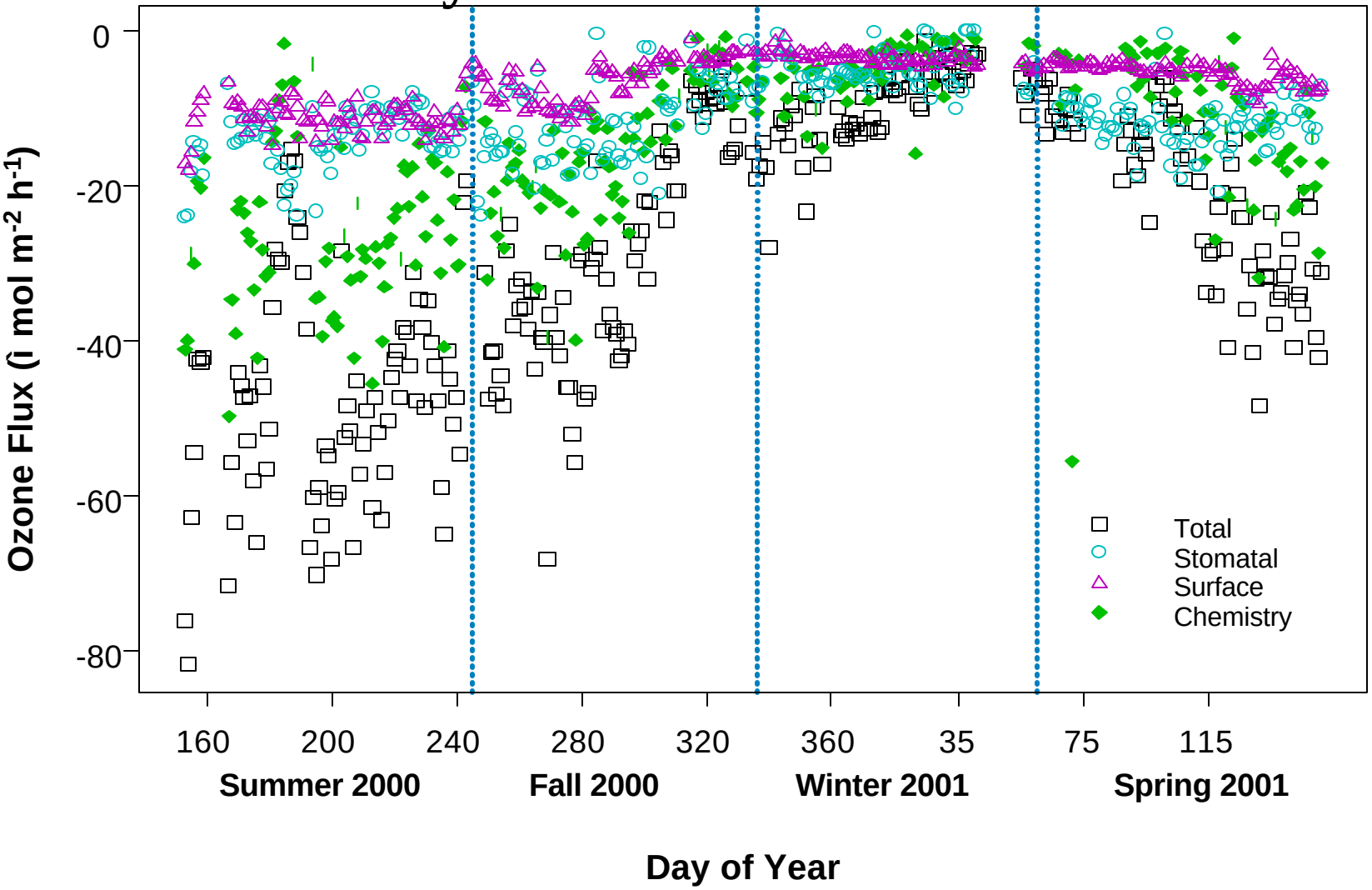
OZONE CONCENTRATION AND DEPOSITION



Kurpius, McKay, and Goldstein, Atmospheric Environment, 2002

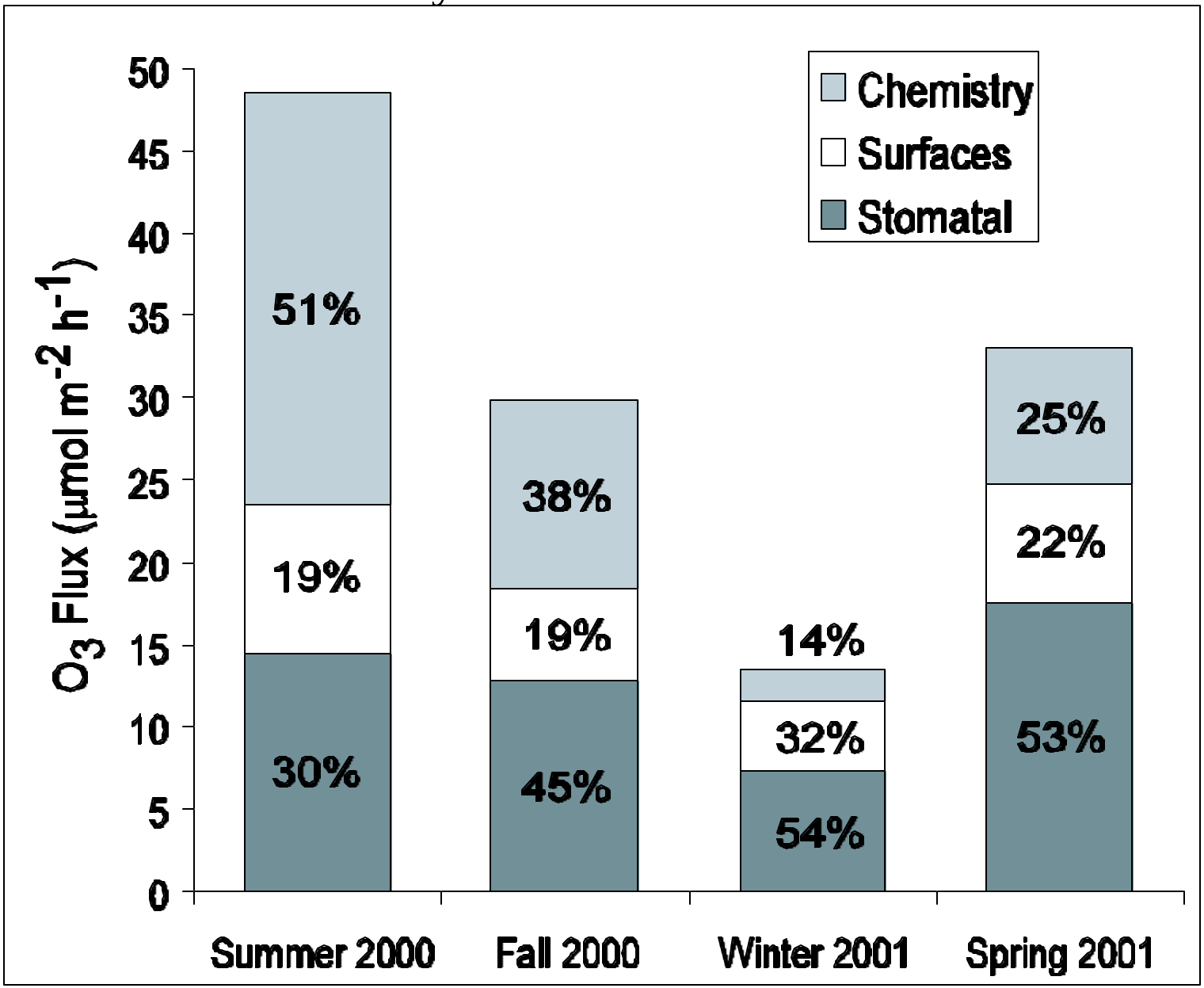
$$F_{O3T} = F_{O3stom} + F_{O3surf} + F_{O3chem}$$

Daytime Mean Ozone Flux

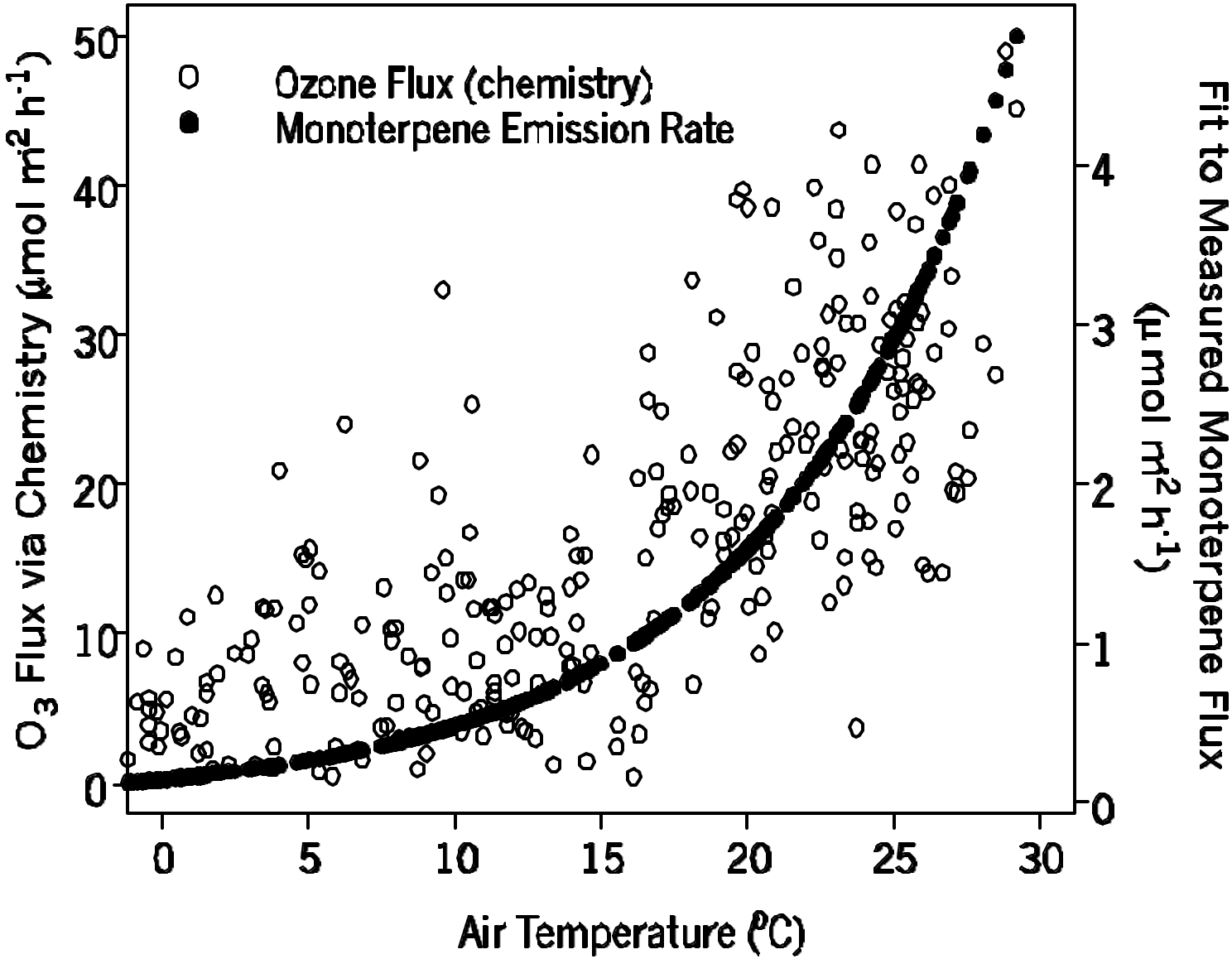


Kurpius and Goldstein, GRL, 2003

Seasonal daytime mean ozone fluxes.



Kurpius and Goldstein, GRL, 2003

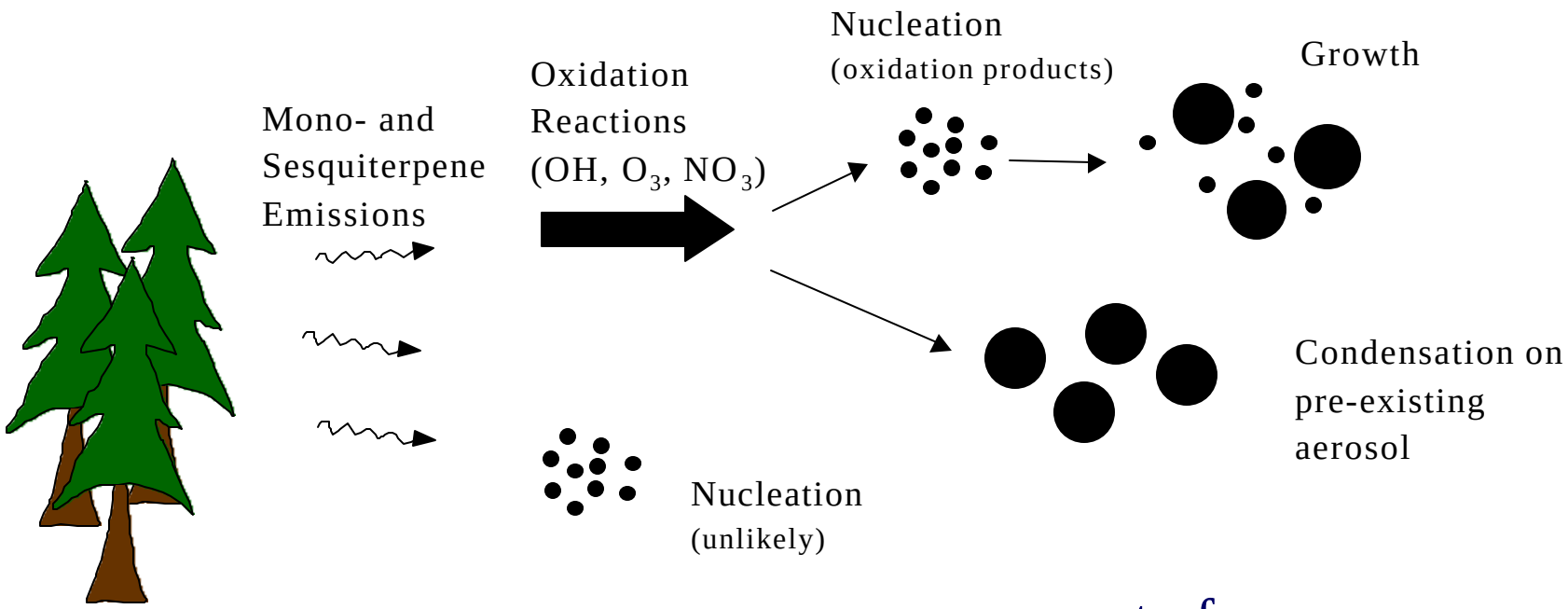


Why is T dependence exponential?

- Terpene emissions are exponential - could be missing 85%?
- Could NO be important? (probably accounts for < 20%)

Kurpius and Goldstein, GRL, 2003

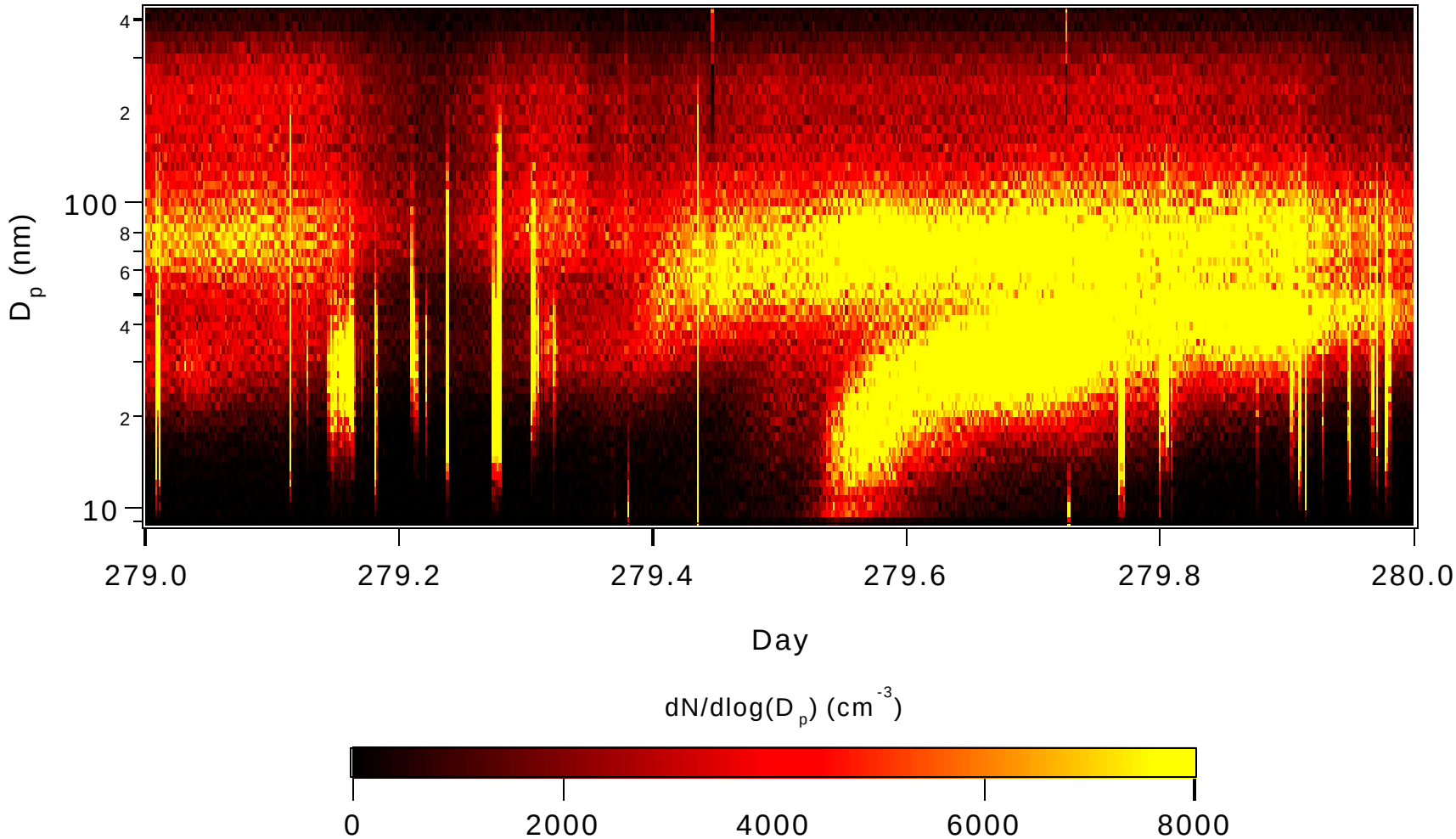
Secondary Organic Aerosol (SOA) Production from biogenic VOC emissions



SOA formation from biogenic precursors depends upon

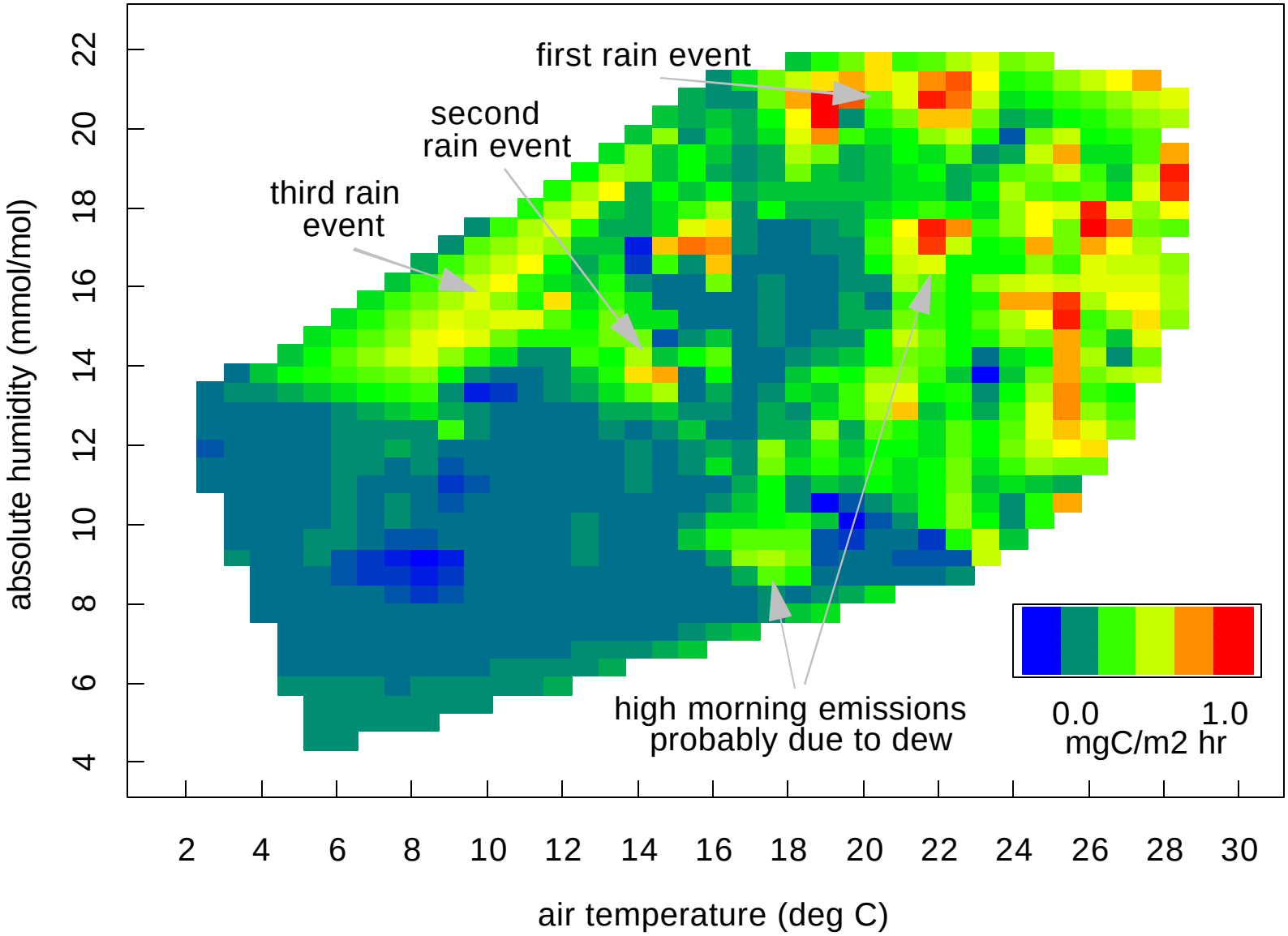
- amount of precursor
- amount of radical species
- volatility of products
- ambient aerosol concentrations

Nucleation Burst on 10/6/01



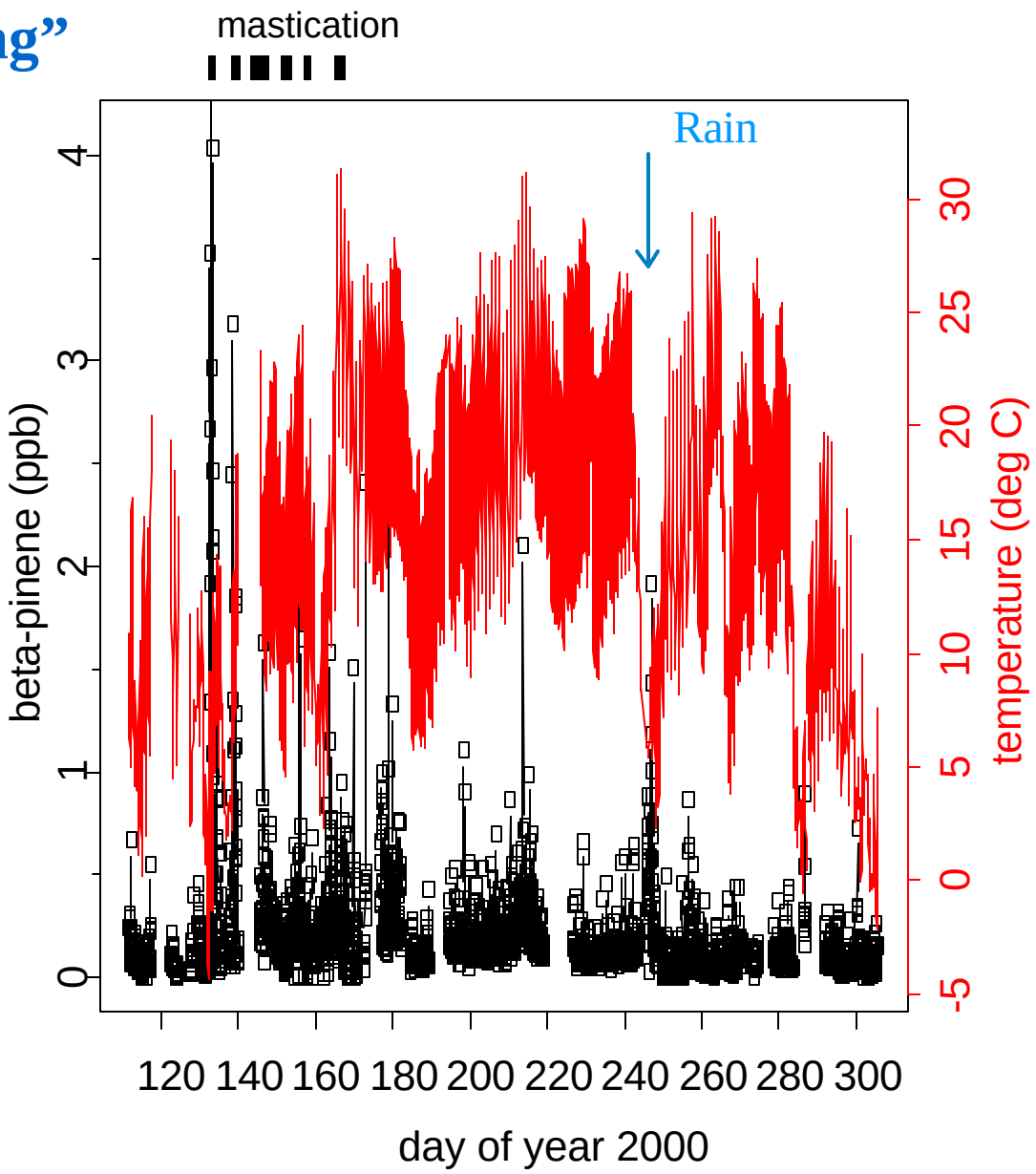
(M. Lunden and D. Black)

alpha-pinene flux vs. temperature and humidity data

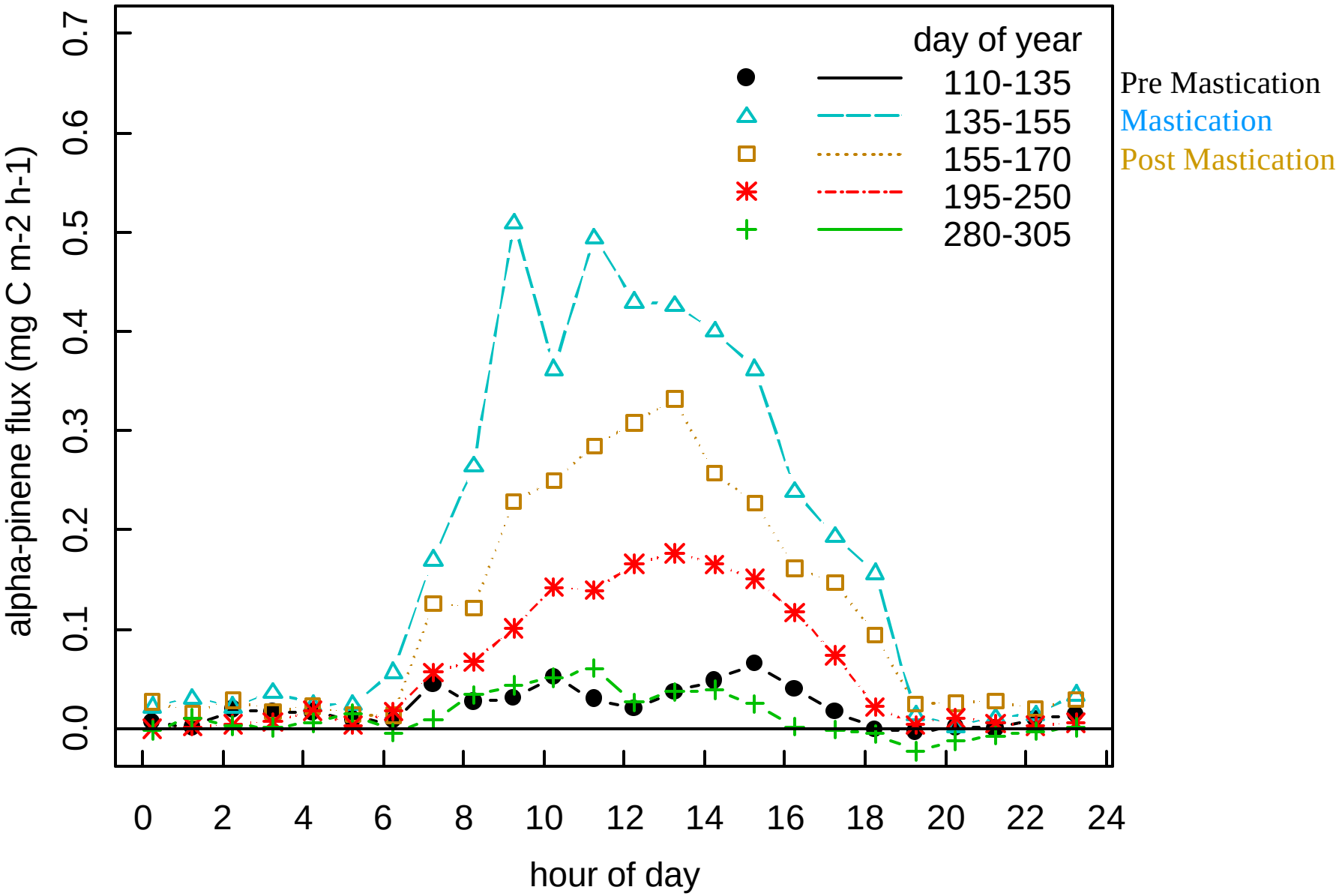


Schade and Goldstein, GRL 1999

Impacts of Forest Management
"Pre-Commercial Thinning"



Schade and Goldstein, GRL, 2003



Schade and Goldstein, GRL, 2003

Conclusions and Questions

- On ozone episode days (max O_3 > 90 ppb), isoprene oxidation leads to > 70% of ozone production in the Sacramento Plume leading to Blodgett Forest. Must control NO_x emissions!

- ~50% of ozone flux is due to gas phase chemical loss in the forest canopy. Likely reactions are with unmeasured terpenes. Could this contribute to observed aerosol growth events?

- Forest management practices such as pre-commercial thinning (mastication) enhance terpene emissions for periods of weeks to months, potentially increasing aerosol growth and impacting regional air quality.