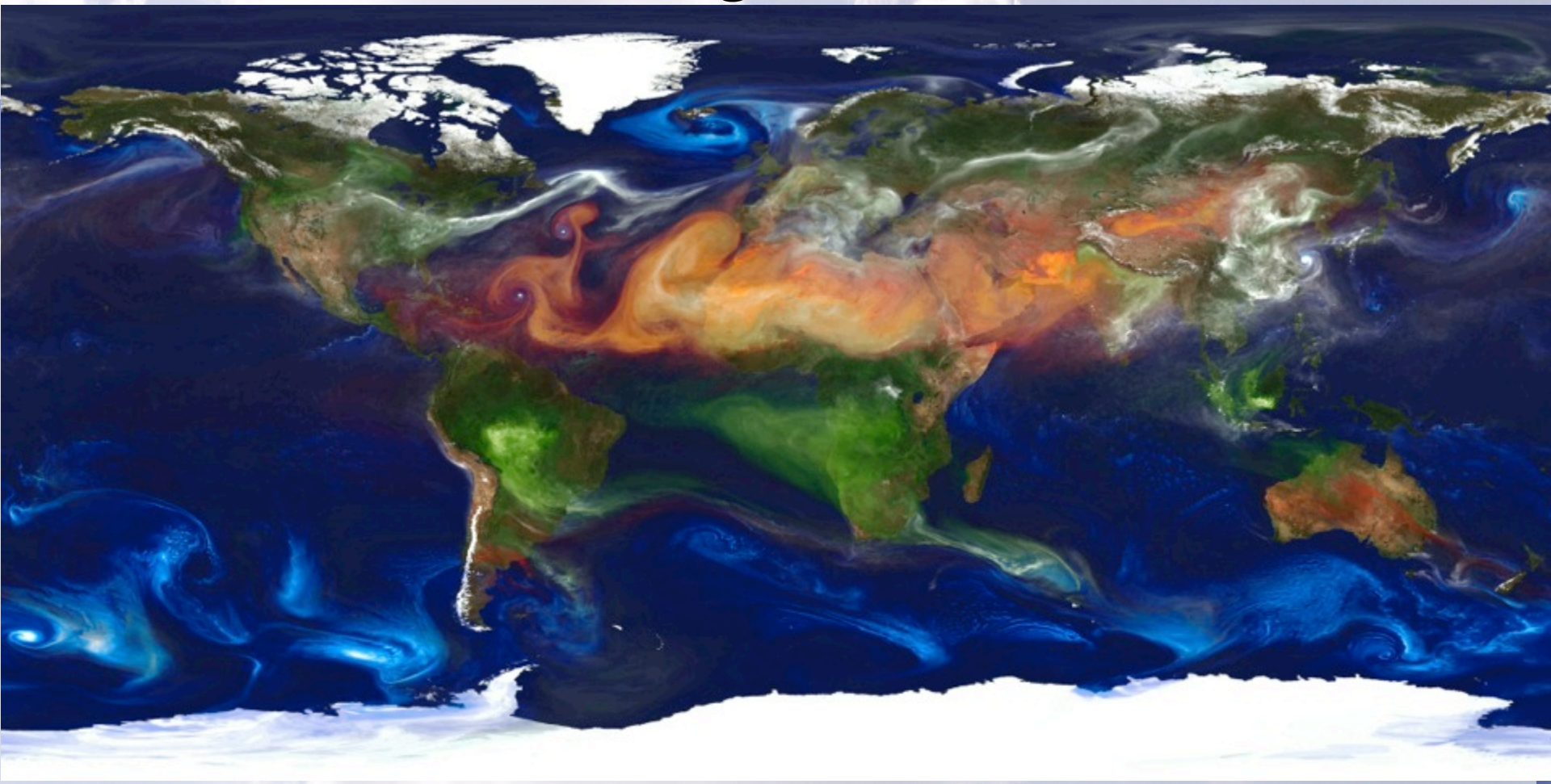
Global connections:
What is controlling California's rainfall?



Kimberly A. Prather
Distinguished Chair in Atmospheric Chemistry
Haagen-Smit Award Presentation
May 18, 2016

UC San Diego
Chemistry & Biochemistry

SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego

Measurement of atmospheric aerosol impacts on human health, climate, and weather in California

Human health

- **1996:** California Air Resources Board funded first major field project focusing on determining major sources of air pollution (w/ Glen Cass and Susanne Hering)
  - Development of "transportable" ATOFMS instruments ("Jake" and "Elwood") for determination of major sources of air pollution
  - Subsequent field studies in Sacramento, Riverside, Fresno, Bakersfield, Los Angeles, San Diego

Regional climate and water resources (hydroelectric power)

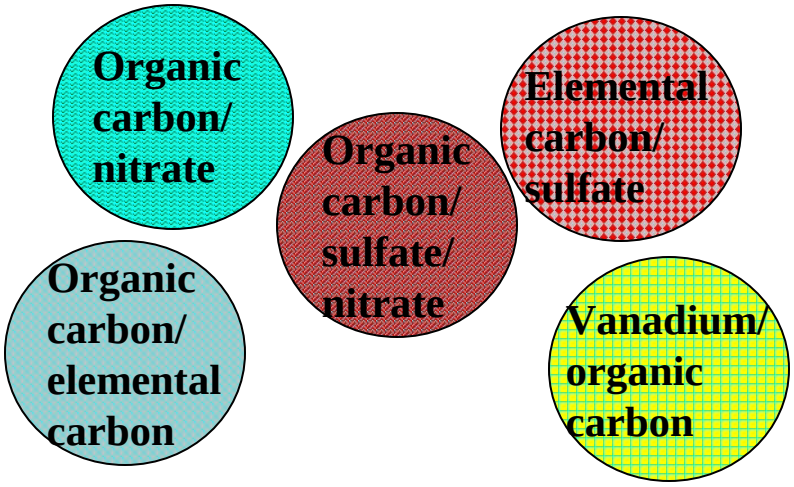
- **2009:** California Energy Commission funded studies aimed at understanding how aerosols impact clouds and precipitation in California

Atmospheric Aerosol Particles

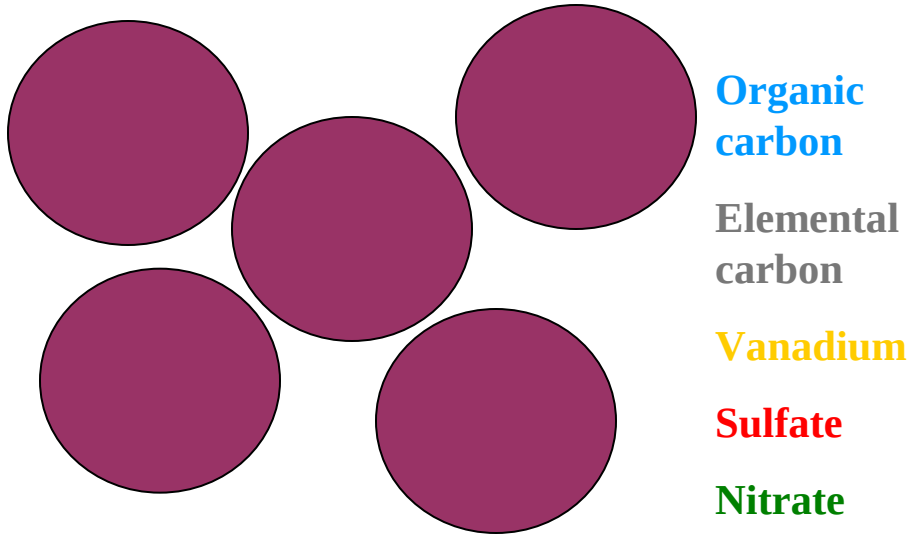
Understanding Aerosol Mixing State

Aerosol mixing state impacts:

- Identification of sources
- Absorption/scattering properties (radiative forcing)
- Cloud condensation and ice nucleation
- Human health impacts

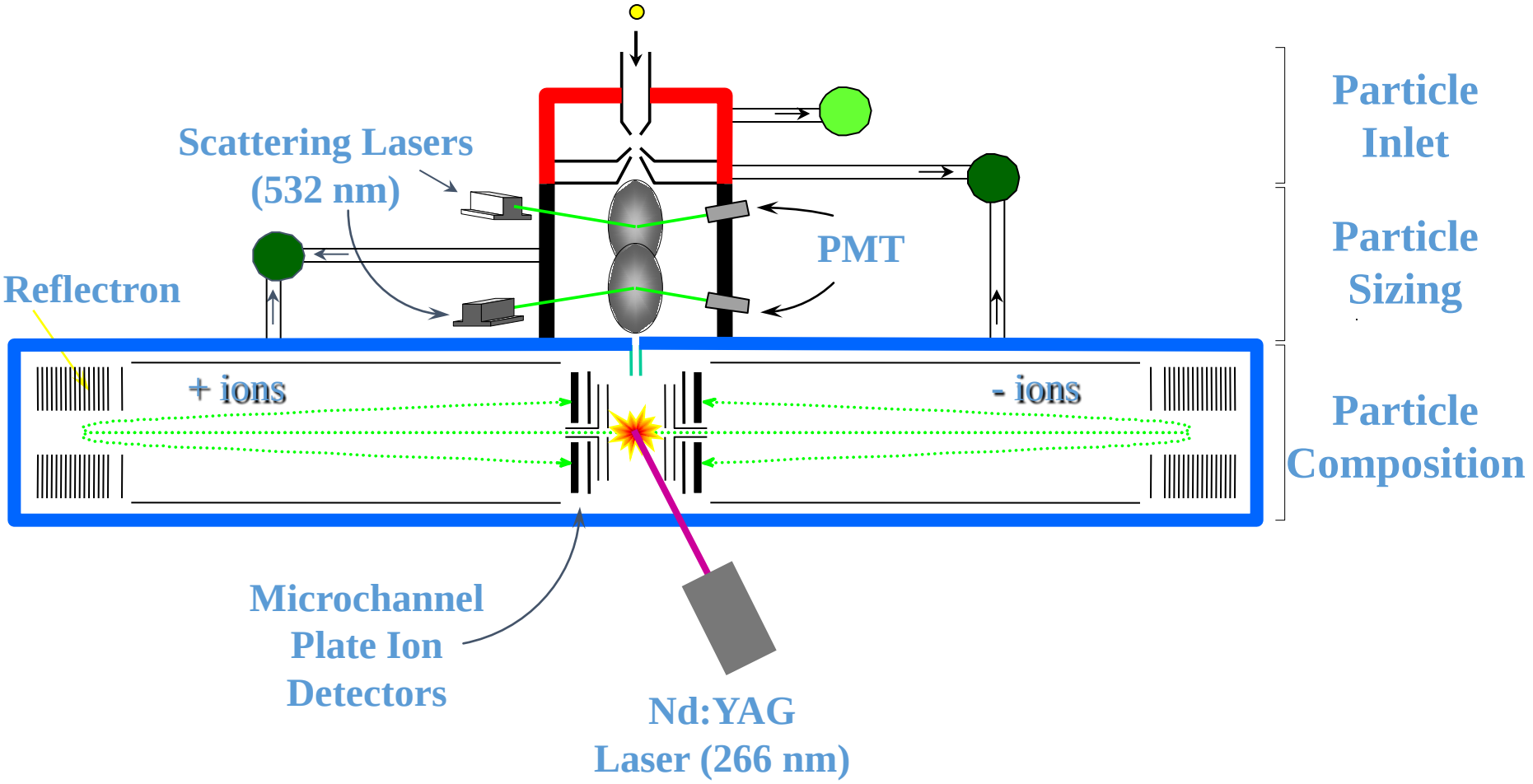


Single particle measurements



Traditional filter-based measurements

Aerosol Time-of-Flight Mass Spectrometry



Gard, E.; Mayer, J. E.; Morrical, B. D.; Dienes, T.; Fergenson, D. P.; Prather, K. A. *Anal. Chem.* **1997**, *69*, 4083-4091.

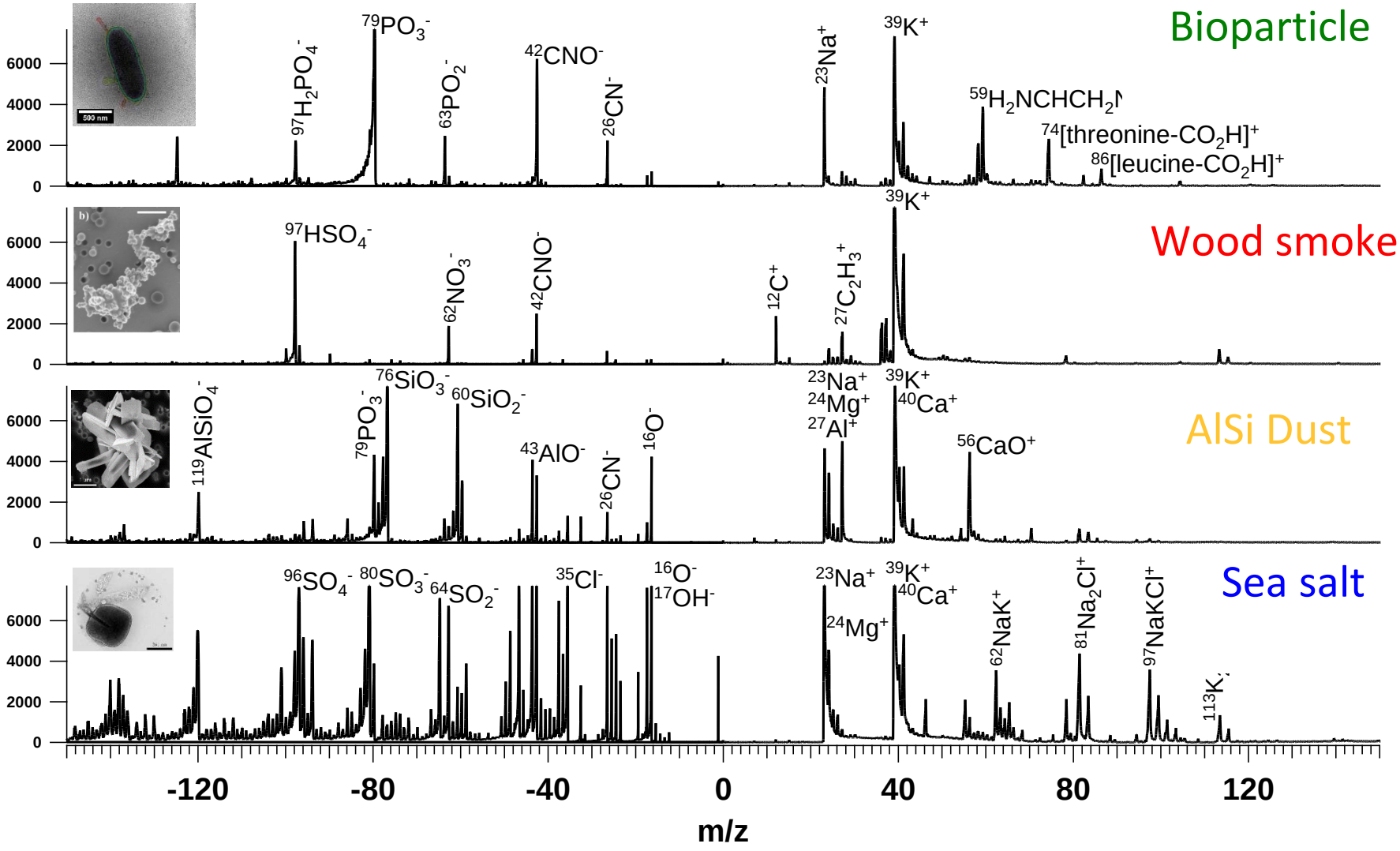
ATOFMS Development

REFINEMENT, CALIBRATION, AND FIELD STUDIES INVOLVING TRANSPORTABLE AEROSOL TIME-OF-FLIGHT MASS SPECTROMETERS

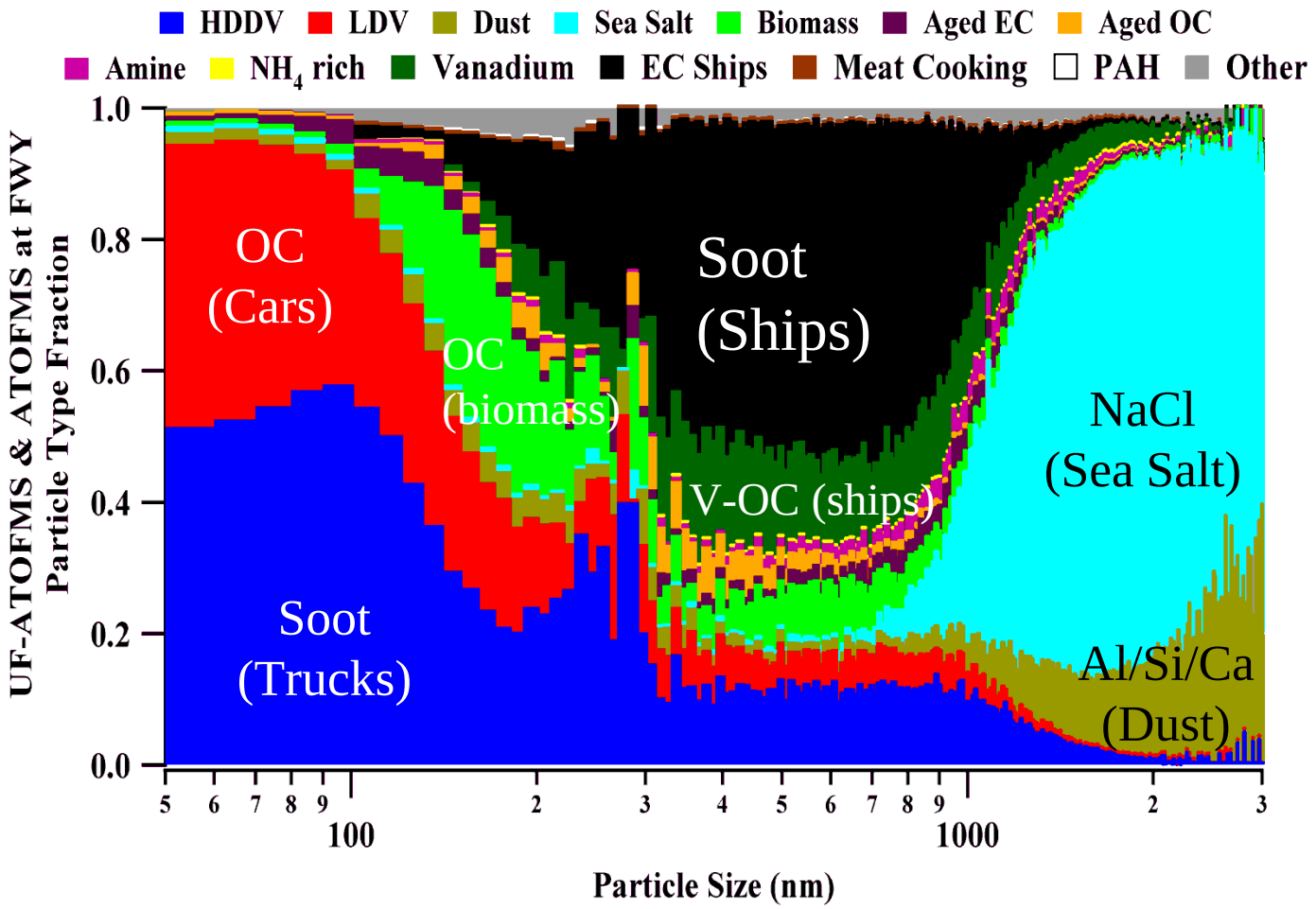
Final Report (Contract 96-307)
Prepared for the California Air Resources Board and the California Environmental Protection Agency
Final Version: August 19, 2003

Funded by CARB

Single Particle Source Fingerprints



Size-resolved Source Apportionment
San Diego, California (Freeway)



50 nm ⟶ 3 μm

Los Angeles Times

May 24, 2011

CalWater: Study of impacts of aerosols on clouds and precipitation

COLUMN ONE

With clouds, it's burst or bust

Rain researchers try to figure out why some storms give up their moisture and others don't as they roll across the Sierra.

BETTINA BOXALL
REPORTING FROM SACRAMENTO

A Gulfstream turboprop sits on the McClellan Airport runway under gray, gloomy skies. Kim Prather has waited two weeks for this day.

"I can't believe there are finally clouds," she says gratefully as she and her research team check and calibrate several million dollars' worth of equipment stacked in the plane's cabin.

After the plane takes off, it slices through a 9,000-foot-thick layer of storm clouds, zigzagging up the western slope of the Sierra Nevada to probe the mysteries of California's rain and snow.

Onboard, a special instrument that Prather invented and named "Shirley" will blow apart atmos-

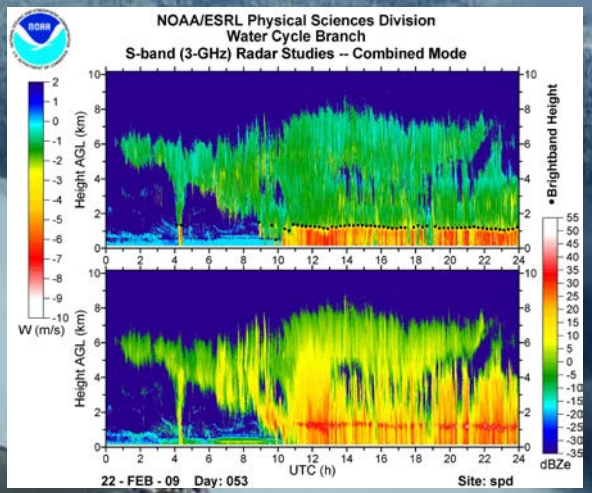
CalWater: 2009-2016

Developing a better understanding of aerosol sources and processes impacting cloud properties and precipitation in California

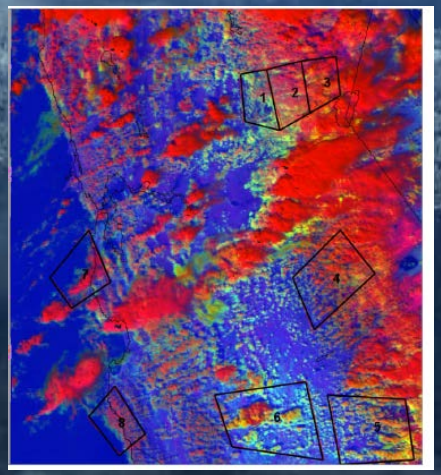
Simultaneously measure aerosols, meteorology, cloud physics

<u>Key question</u>: Are there differences in the aerosols that lead to rain, snow, or no precipitation?

S-band Radar



Satellite

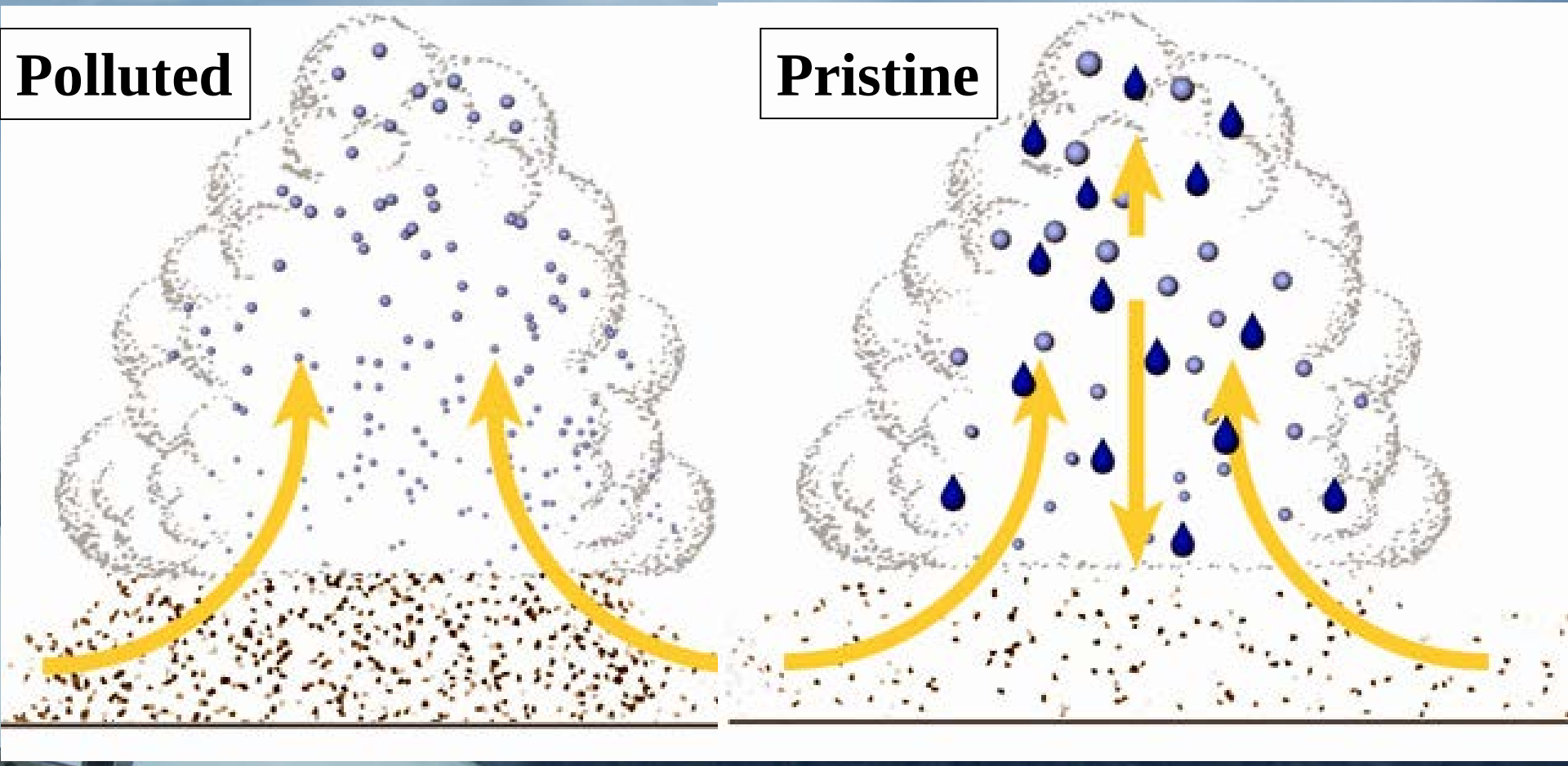


In-situ measurements

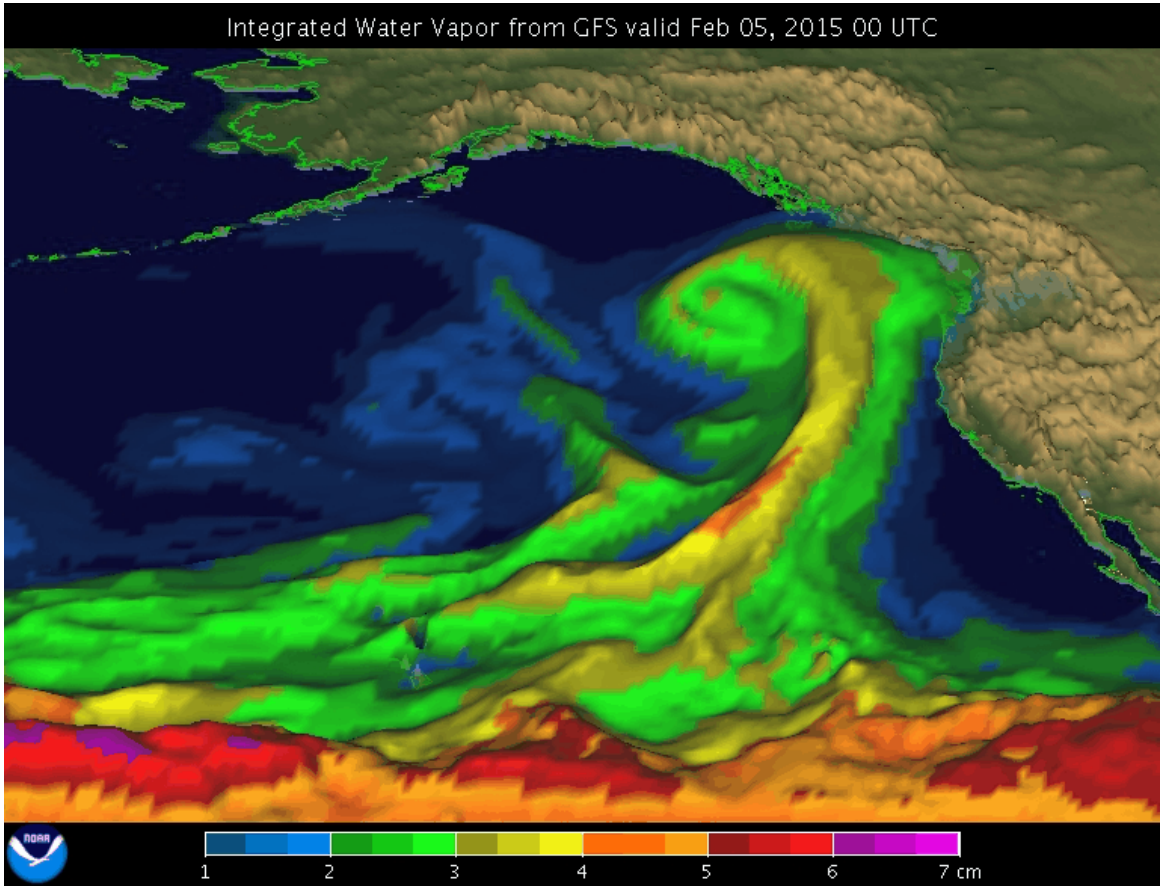
Impact of air pollution on clouds and regional climate

??

Aerosol Impacts on Clouds and Precipitation



Aerosols can impact the amount of precipitation California receives (Feb 5-9, 2015)



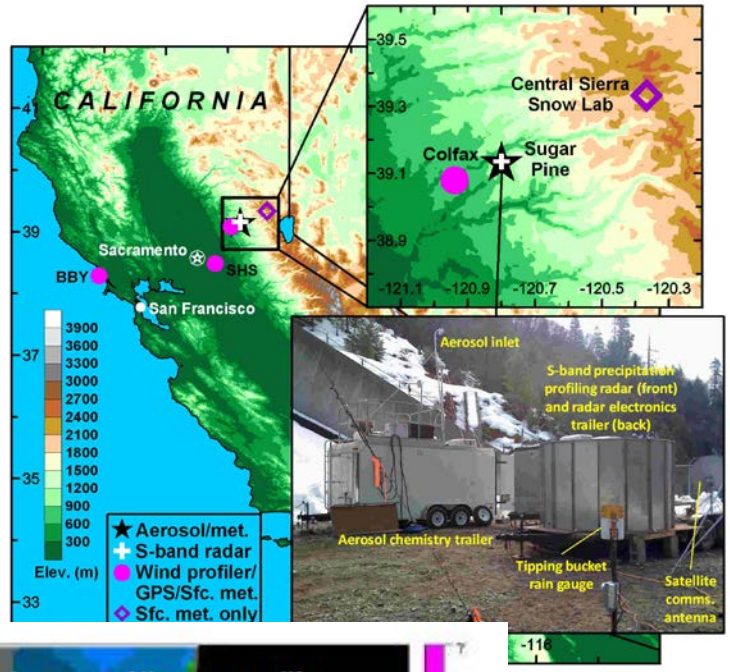
50% of California's annual water budget comes from just 3-4 winter storms termed "atmospheric rivers"

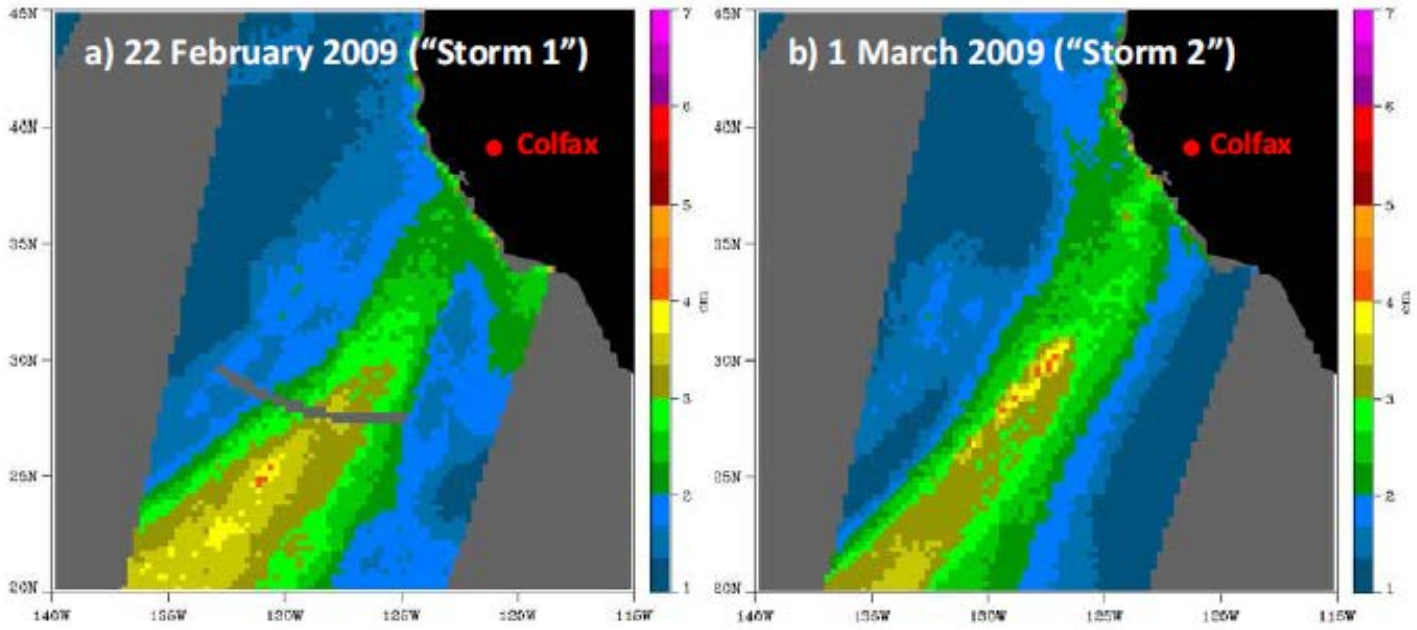
CalWater (2009)

A Tale of Two Storms

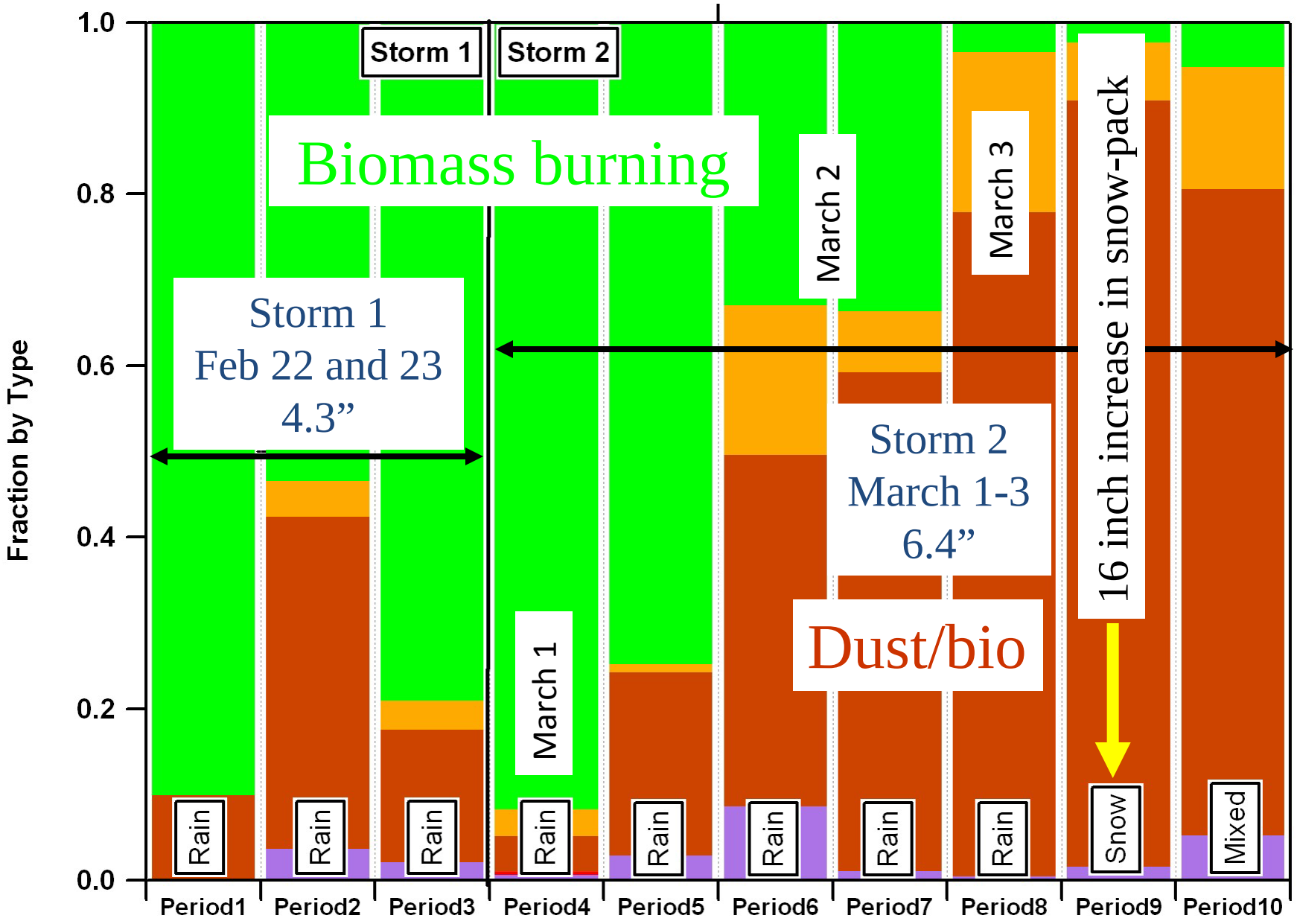
Produced 23% of annual precipitation and 38% of the snow pack

Storm 2 produced 40% more precipitation and increased snowpack by 1.6 times





Precipitation Chemistry (Calwater-2009)



Rain and snow melt (Insoluble residue) chemistry

How are dust/bio aerosols affecting precipitation?
CalWater-2011

Sampling individual cloud droplets/ice crystals

NCAR Counterflow Virtual Impactor (CVI) removed < 8 µm particles

→

Evaporated water from cloud droplets/ ice crystals

→

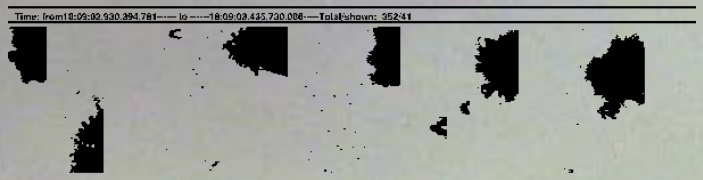
Size and Chemical Composition of Individual Particles

Pratt, et al. Analytical Chemistry, 2009

2/16/2011 17:58 UTC 3,820 m, -21.5°C

CalWater: 2011

Ice in clouds



Dust/ Bioparticles

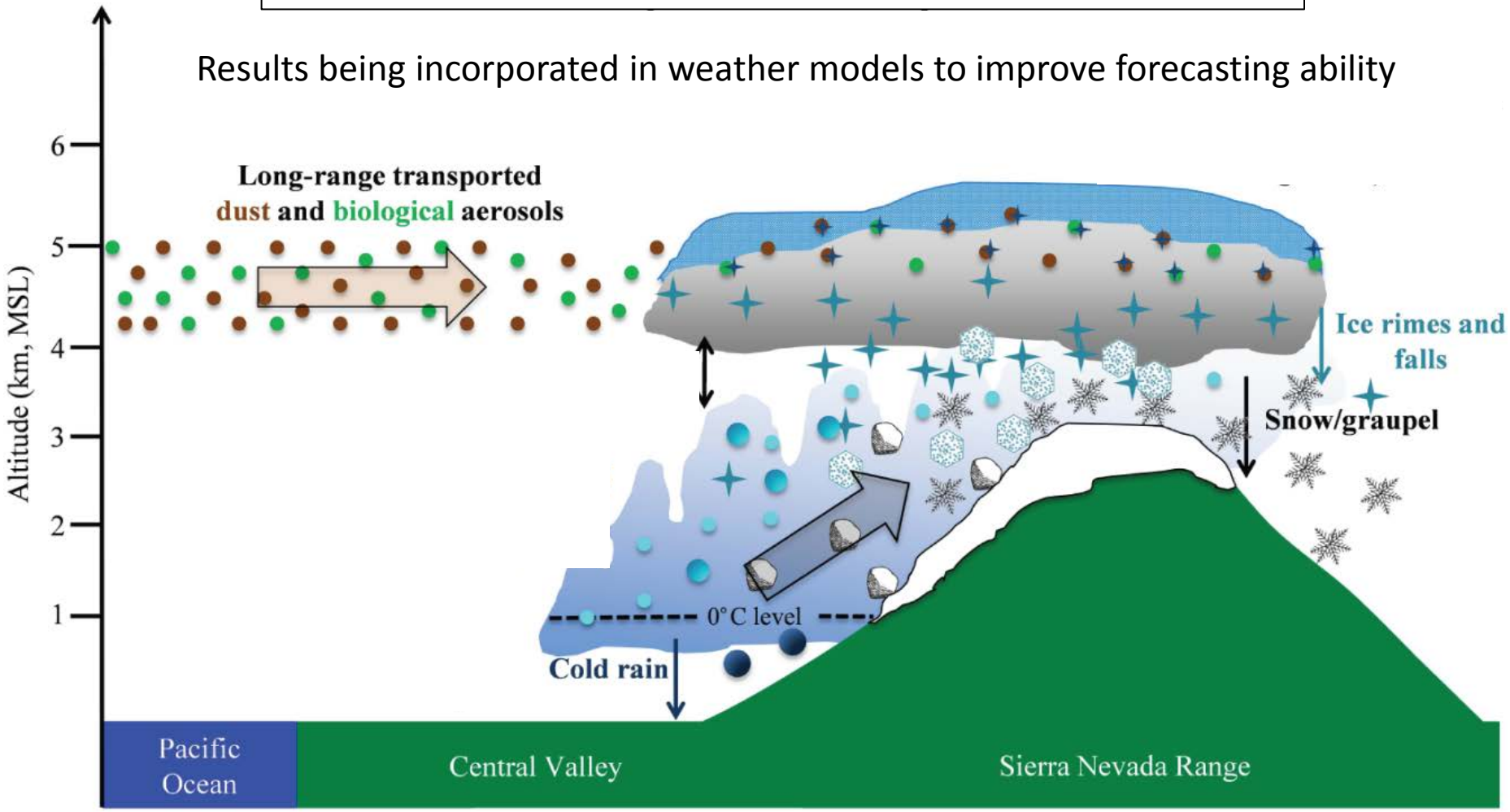
Sea Salt

Liquid clouds

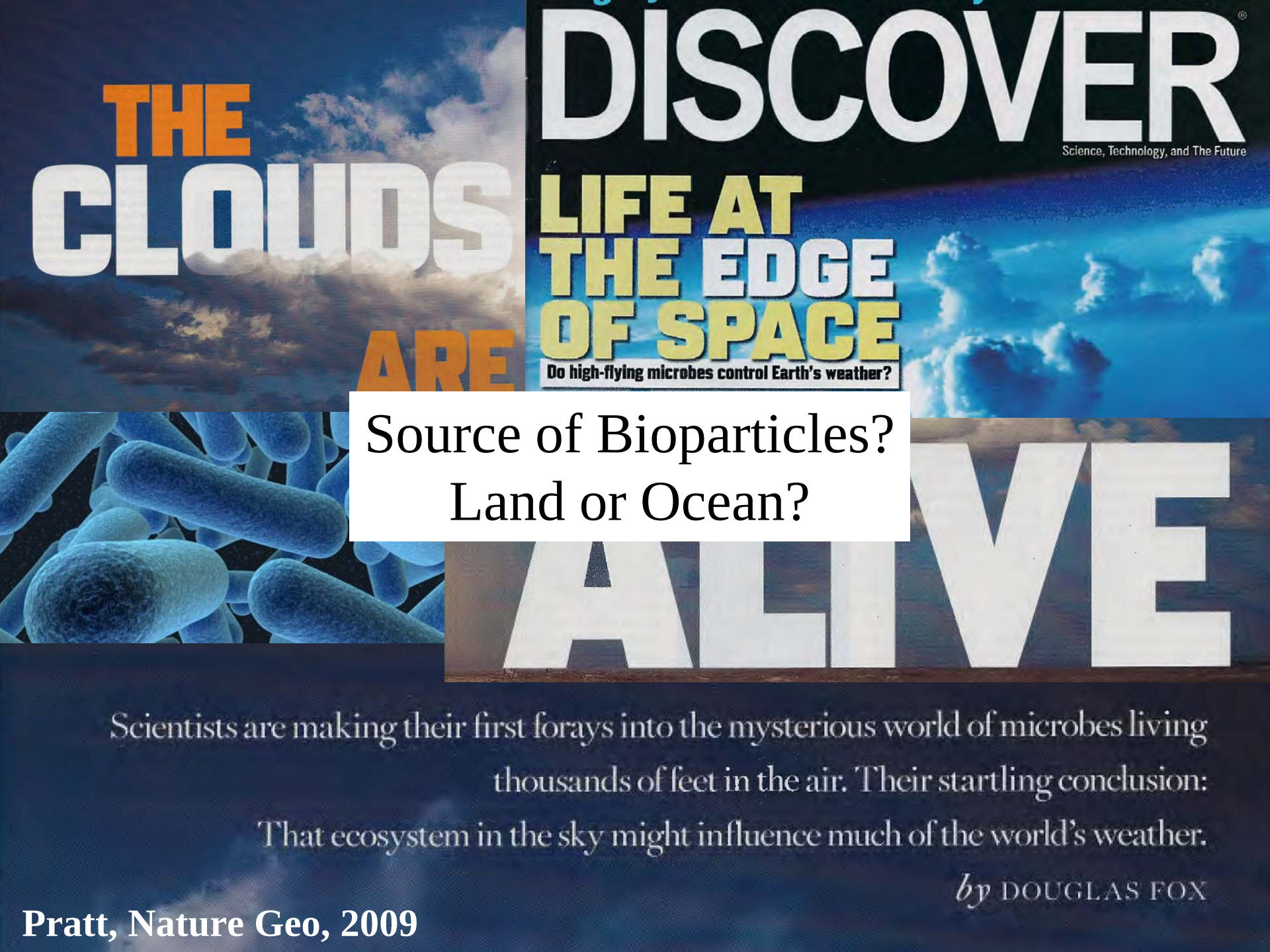
Dust from Africa Affects Precipitation Over California

Prather and co-workers, *Science*, 2013

Results being incorporated in weather models to improve forecasting ability



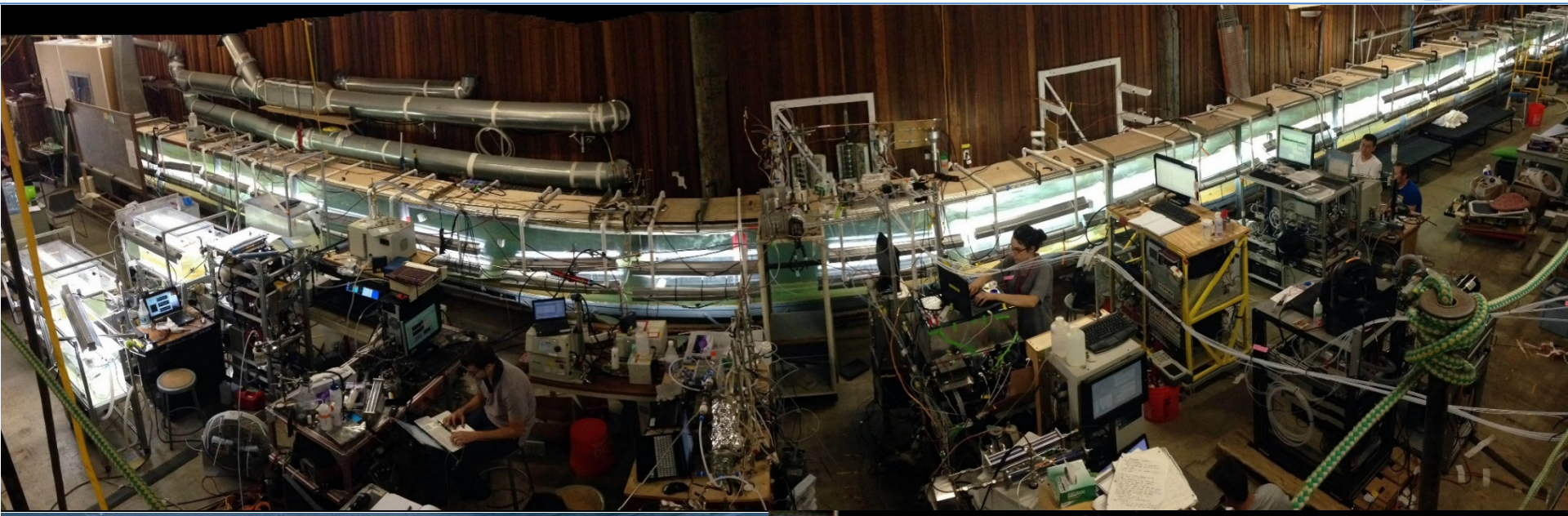
Some aerosols (dust and bioparticles) enhance snowfall while others (agricultural burning and pollution) reduce precipitation



Source of Bioparticles?
Land or Ocean?

Pratt, Nature Geo, 2009

Center for Aerosol Impacts on Climate and the Environment (CAICE)
University of California, San Diego



Summary

California Air Quality

- Aerosol sources in California have changed over the years
- Ground-level pollution impacted by local sources

California Regional Climate

- Dynamics, meteorology, and aerosol impacts on precipitation challenging to unravel – but ice formation has profound impacts
- Upper level atmosphere and clouds impacted by long range transport
- Mother Nature has established effective cloud seeding recipe….
- Findings being used to improve weather forecast models

Center for Aerosol Impacts on Climate and the Environment

- "Ocean-atmosphere in the lab" approach being used to understand natural aerosols and improve aerosol treatment in models

Thank you….