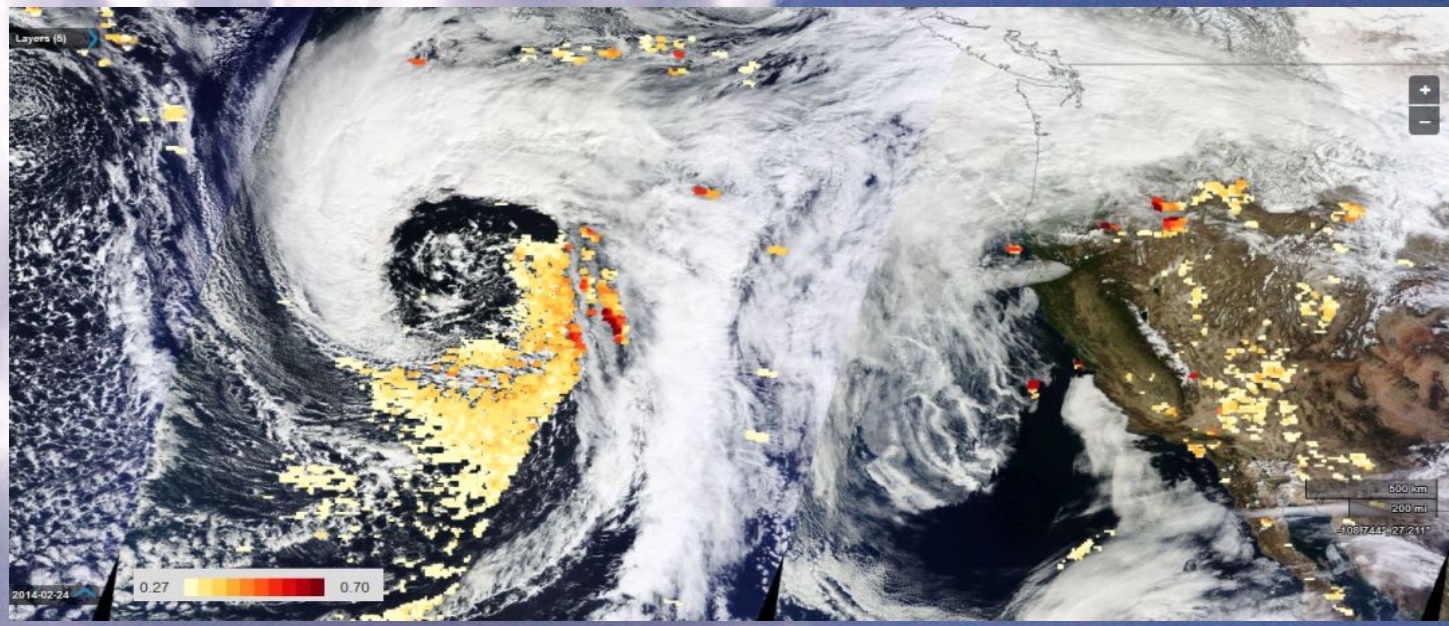
Impact of local versus long range transported aerosols on California clouds and precipitation



Kimberly A. Prather, Distinguished Professor

UC San Diego

June 27, 2018

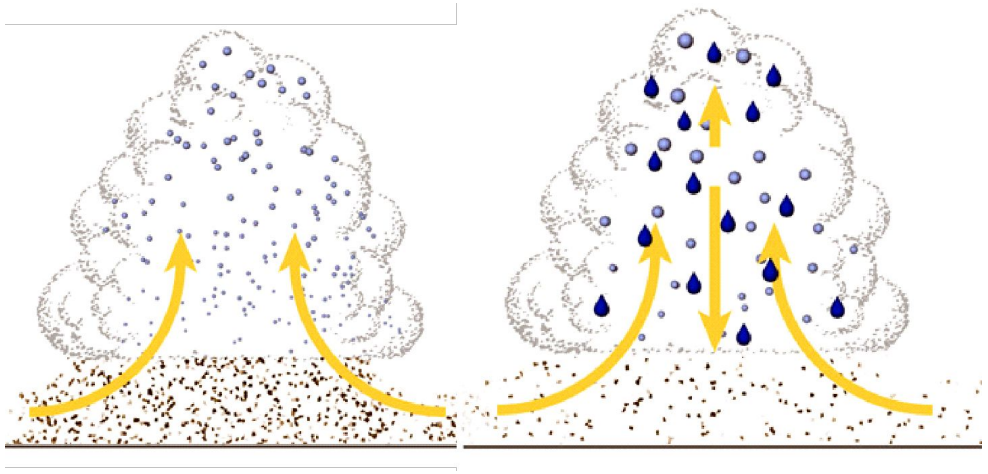
UC San Diego

SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego

CalWater (2009 - present)

Goal: To better understand the impacts of specific sources of aerosols on cloud microphysics and precipitation processes

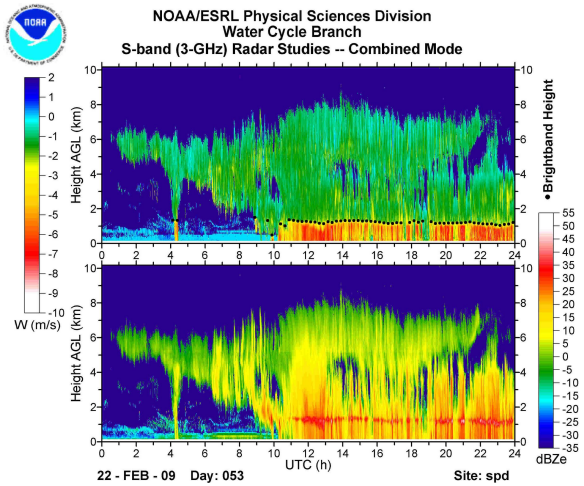
- Identify sources of aerosols seeding clouds
  - Precipitation and in-situ residual composition
- Link specific aerosol chemistry/sources with observed changes in cloud microphysics



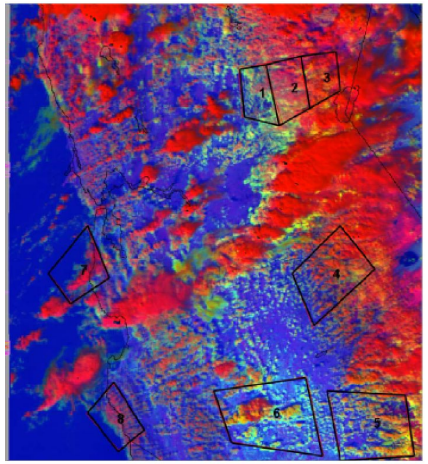
Timing and Locations

- Sierra Nevada Range in California (2009-2015)
- Coastal locations: Bodega Bay and Cazadero (2015-present)

S-band Radar



Satellite

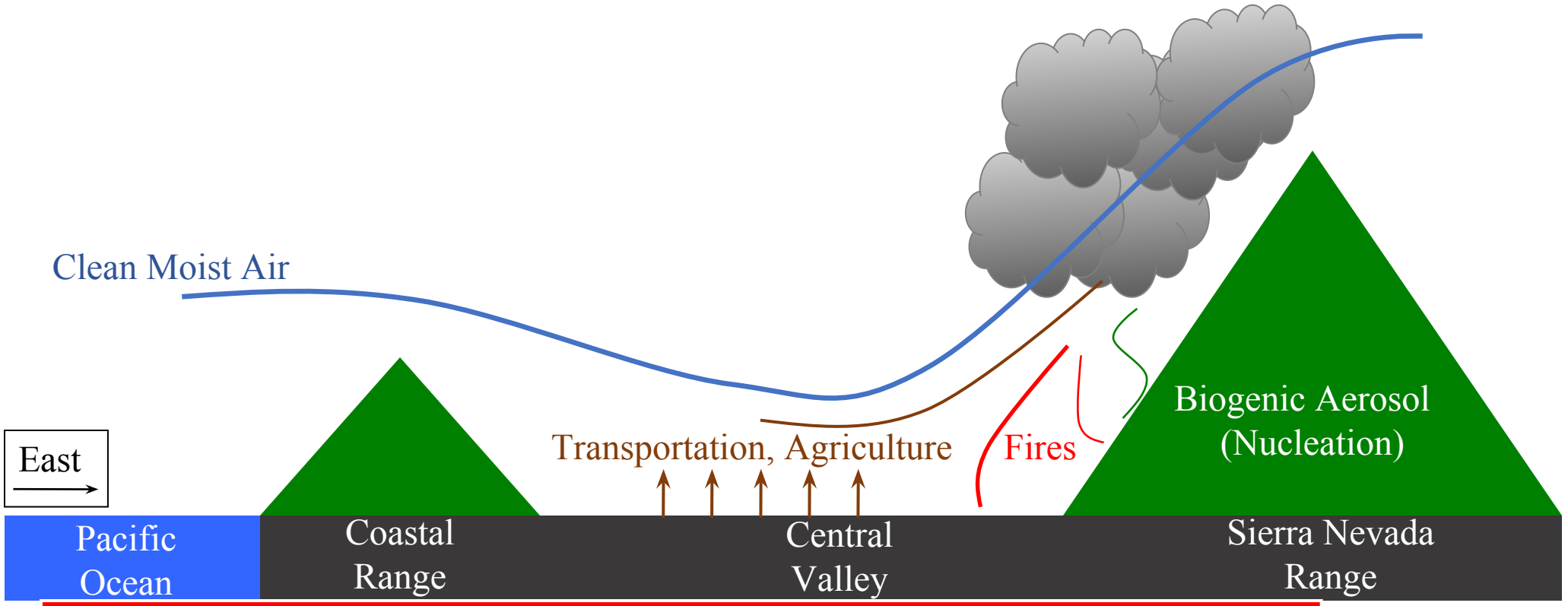


In-situ DOE-G1 measurements

Orographic Precipitation in California

Possible Sources of Cloud Condensation Nuclei (CCN) and Ice Nuclei (IN)

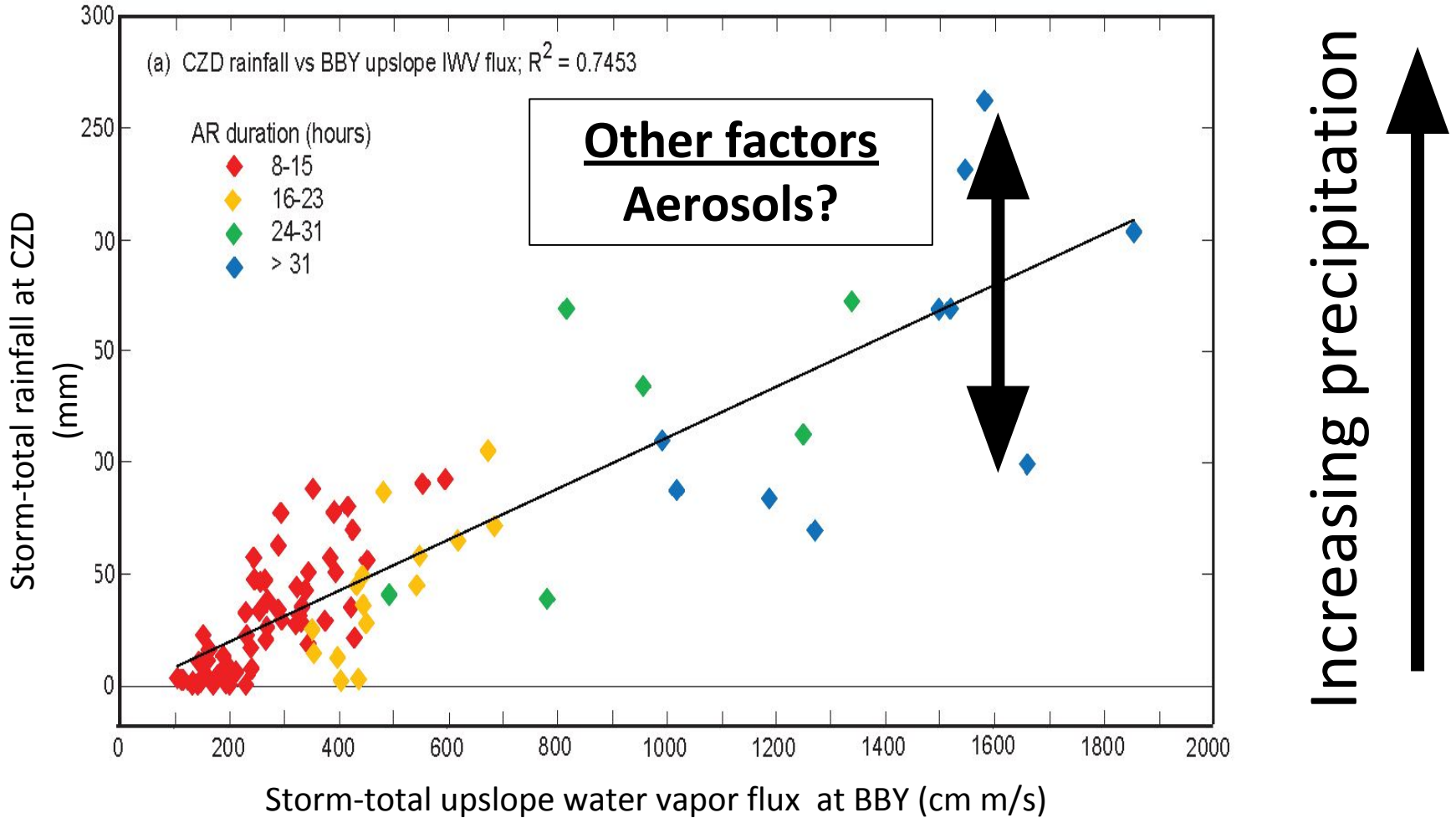
Ocean	Terrestrial Biosphere	Central Valley Pollution	Biomass Burning	Terrestrial Biosphere



What are the important sources of CCN and IN in the Sierra Nevada?

Rosenfeld et al., JGR, 2008 (SUPRECIP-2005)
Ault, et al., JGR, 2011; Creamean et al., Environ. Sci. Technol., 2011;
Creamean, et al., Science, 2013.

Do we see evidence of specific aerosol sources impacting AR's over California?



Increasing precipitation

Increasing AR strength and duration

Ralph et al. 2013, *J. Hydrometeorology*

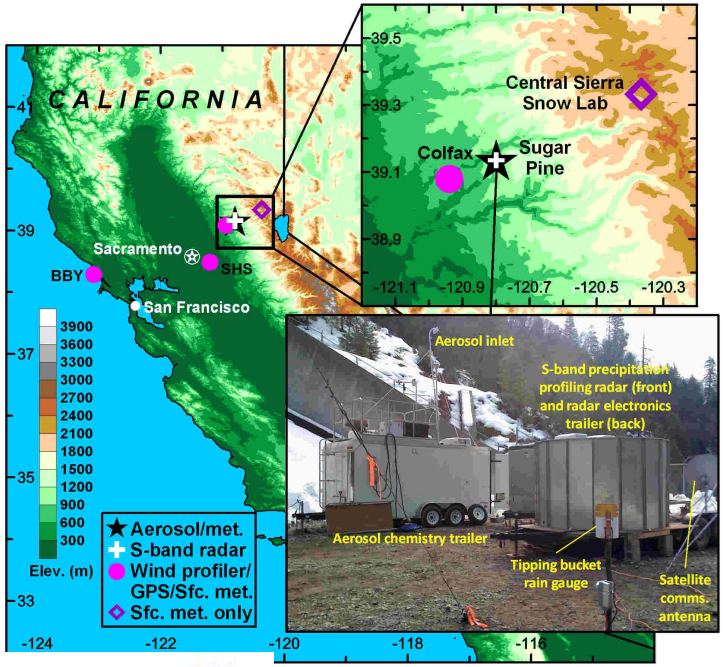
CalWater (2009)

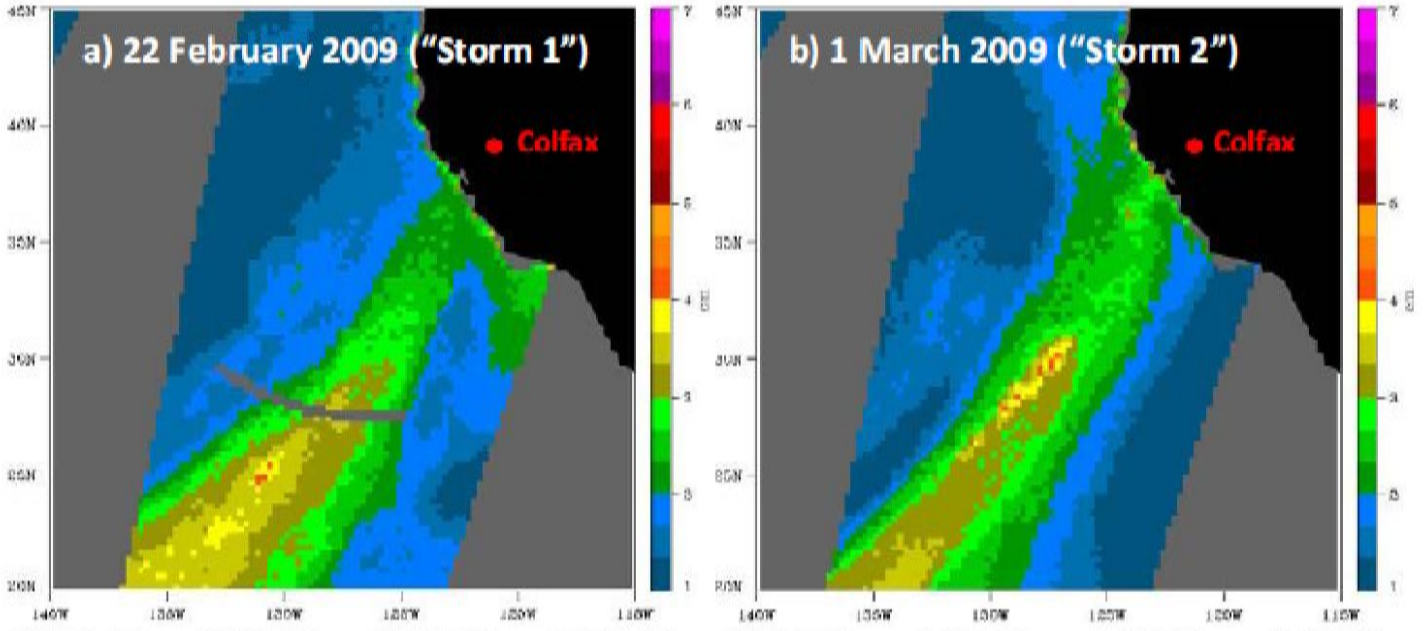
A Tale of Two Storms

Produced 23% of annual precipitation and 38% of CA snowpack

Back to Back: Storms 1 and 2

- Storm 1 seeded by pollution
- Storm 2 seeded by dust + bioparticles
- Storm 2 produced 40% more rain and 60% more snow

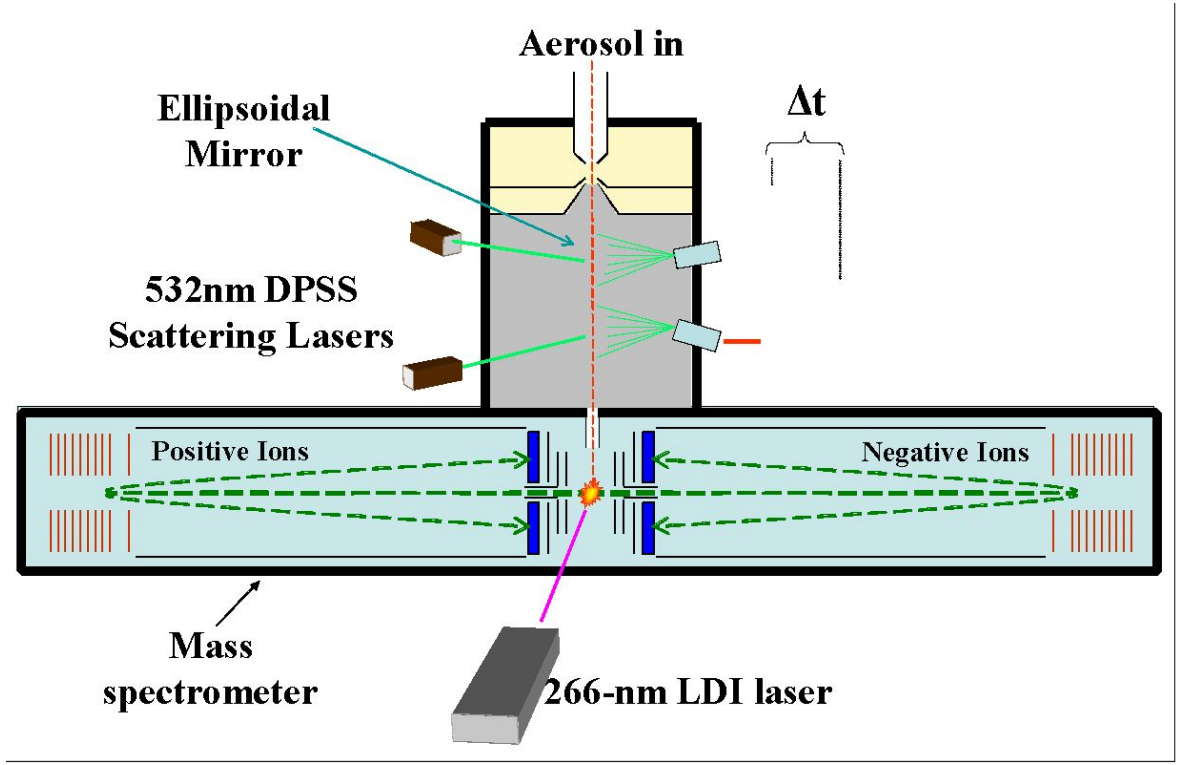




Ault et al. JGR 2011

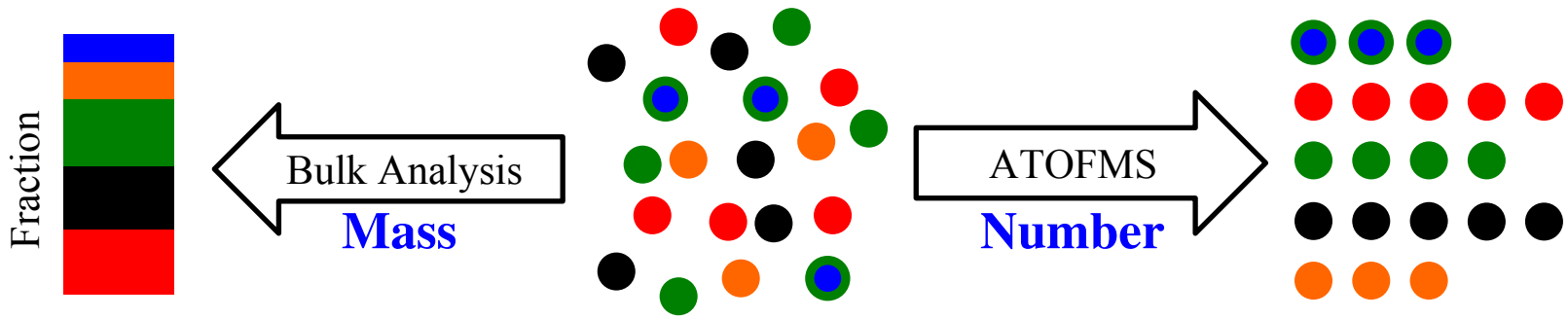
How are dust/bio aerosols affecting precipitation?
CalWater-2011

ATOFMS: In-situ measurements of aerosol sources of ice and cloud condensation nuclei



Particle Size

Particle/residual Composition



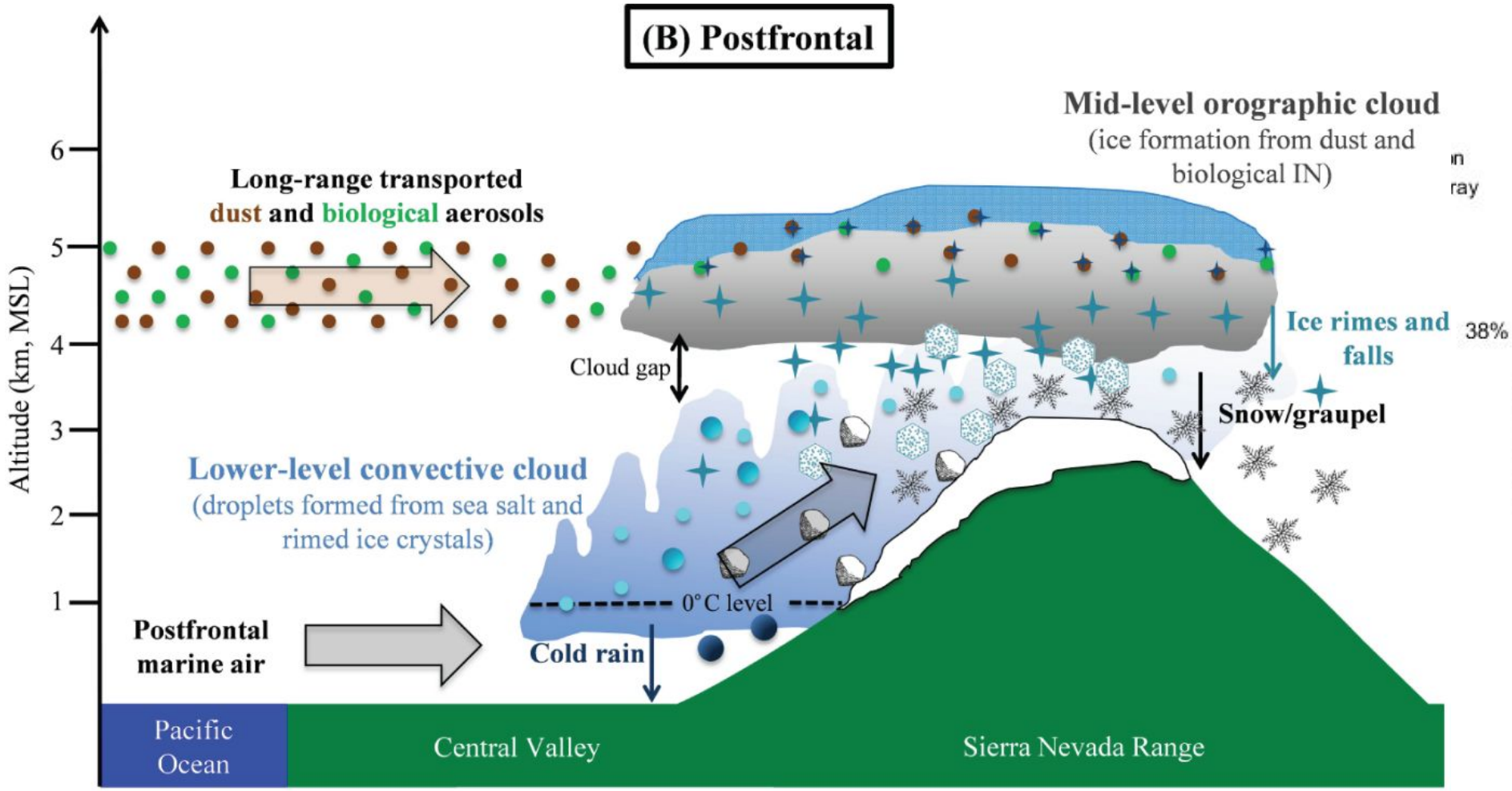
Prather et al, *Anal. Chem.*, 1994; Gard et al, *Anal. Chem.*, 1997; Pratt, et al. A. Chem, 2009.

CalWater (February 16, 2011)
Liquid Water (CDP)

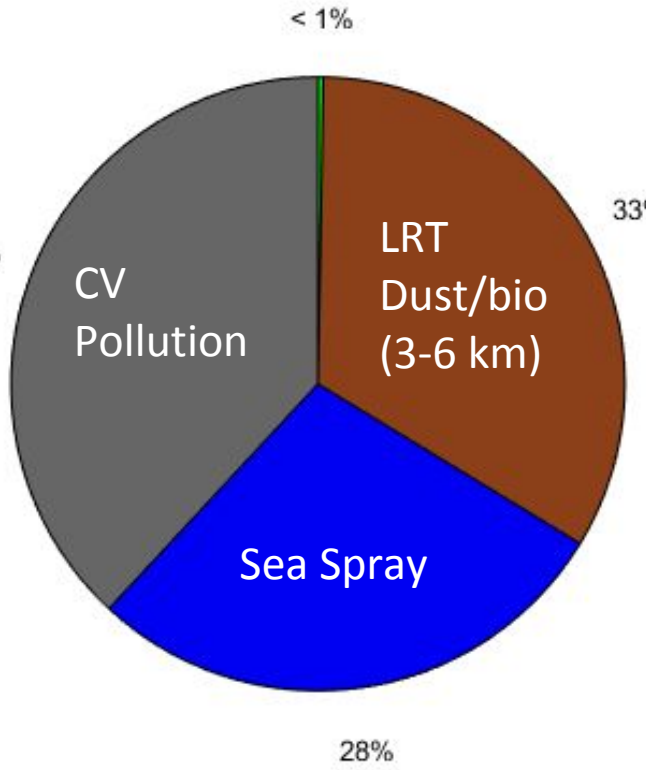
- Dust/bio occur at same altitude as ice in clouds
- CFDC IN concentrations peak
- Is ice due to colder temps or due to composition of aerosol cloud seeds?
- Supercooled liquid exists at highest altitude above dust/bio layer—thus, it appears dust/bio playing key role in ice formation

Creamean, et al.
Science, 2013

Dust and Biological Aerosols from the Sahara and Asia Influence Precipitation in the Western U.S.



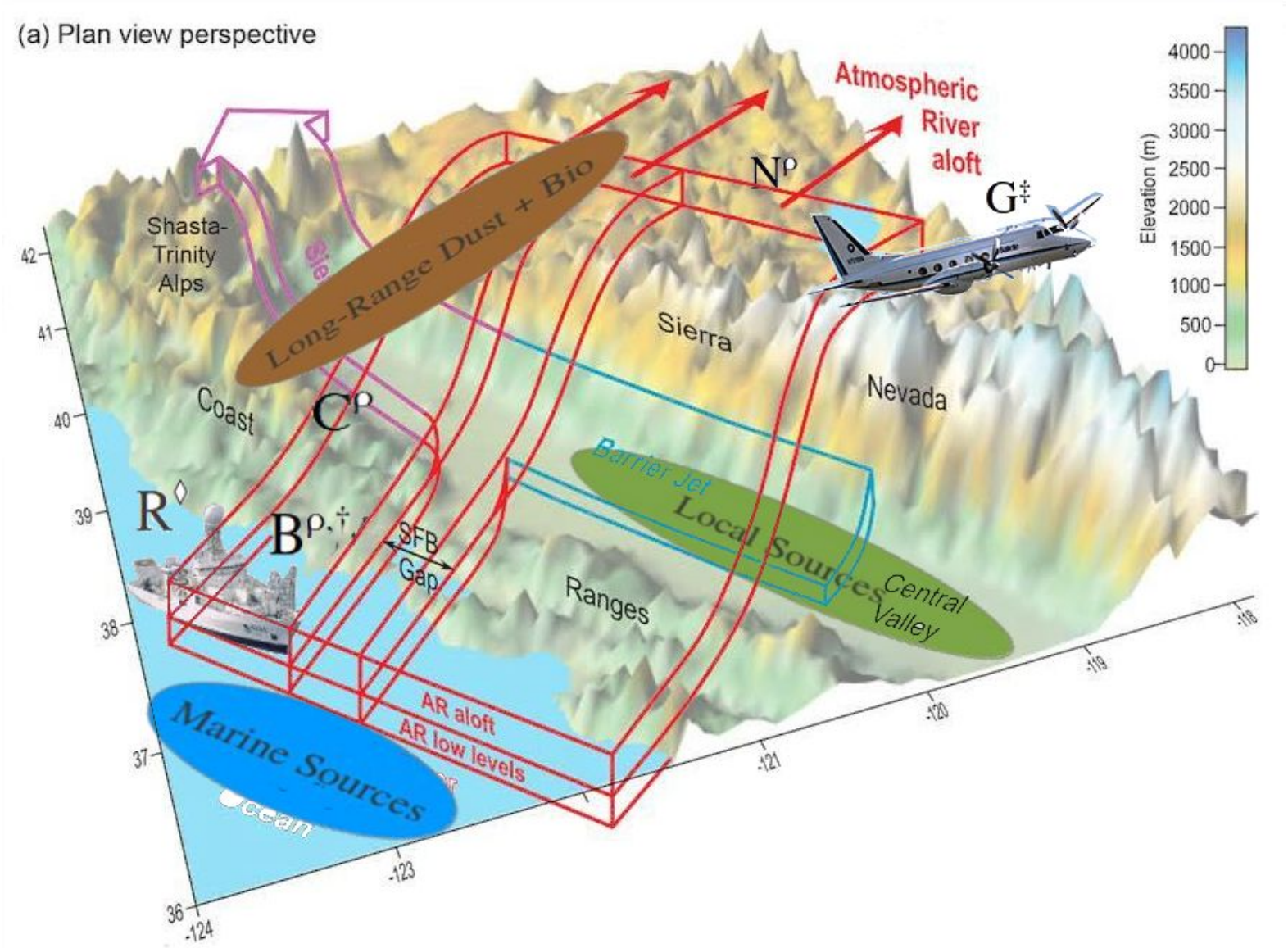
AR Cloud Seeds 2011



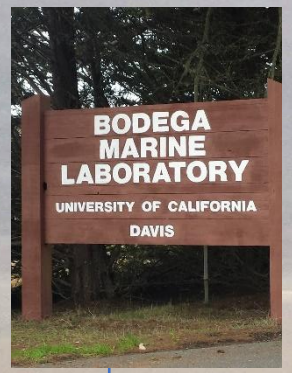
Dust + Pollution

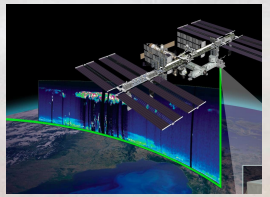
CalWater-2011 field observations showed days with dust and bioparticles experienced extensive snowfall

Aerosol Sources: Vision for CalWater-2015

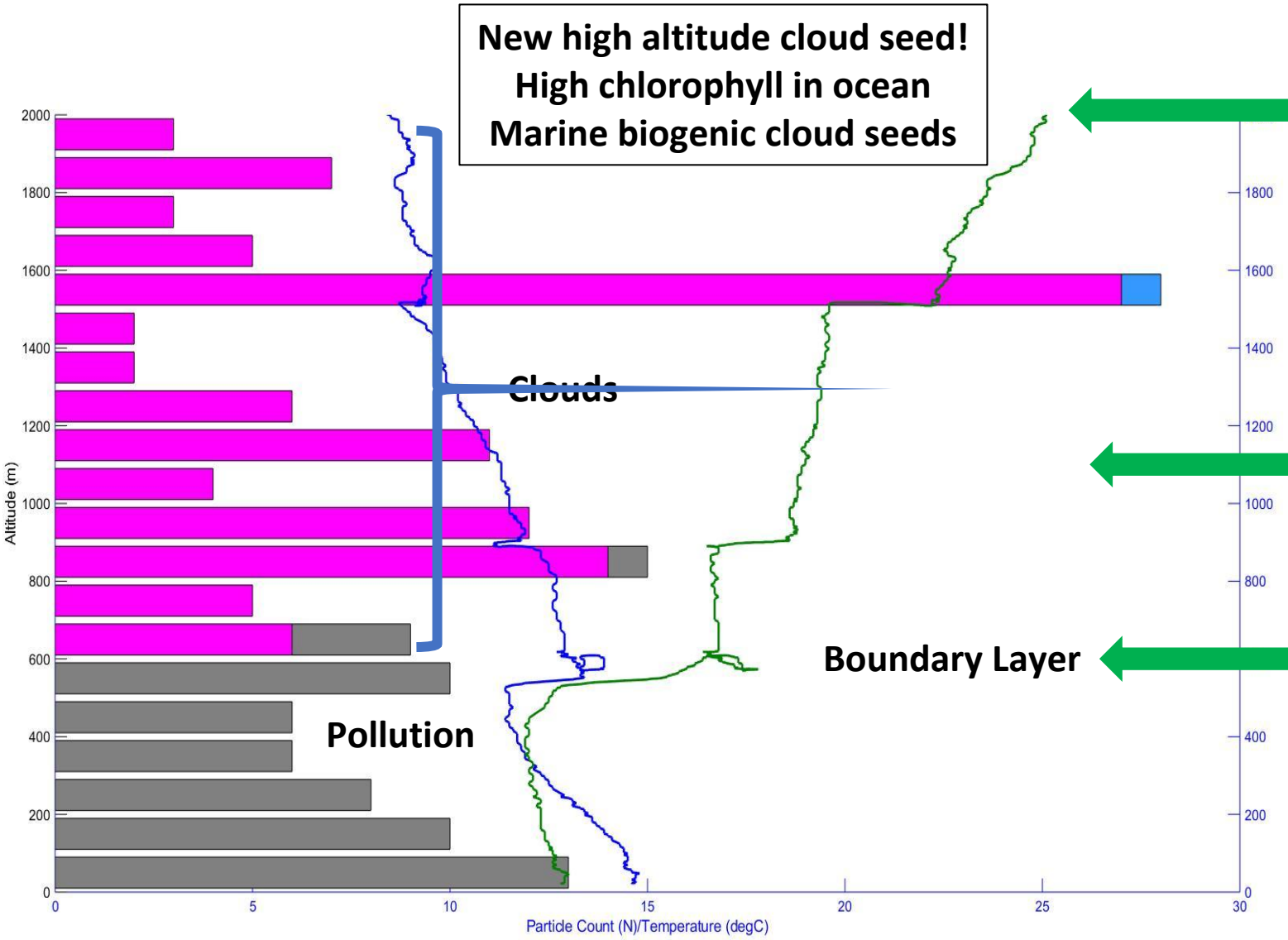


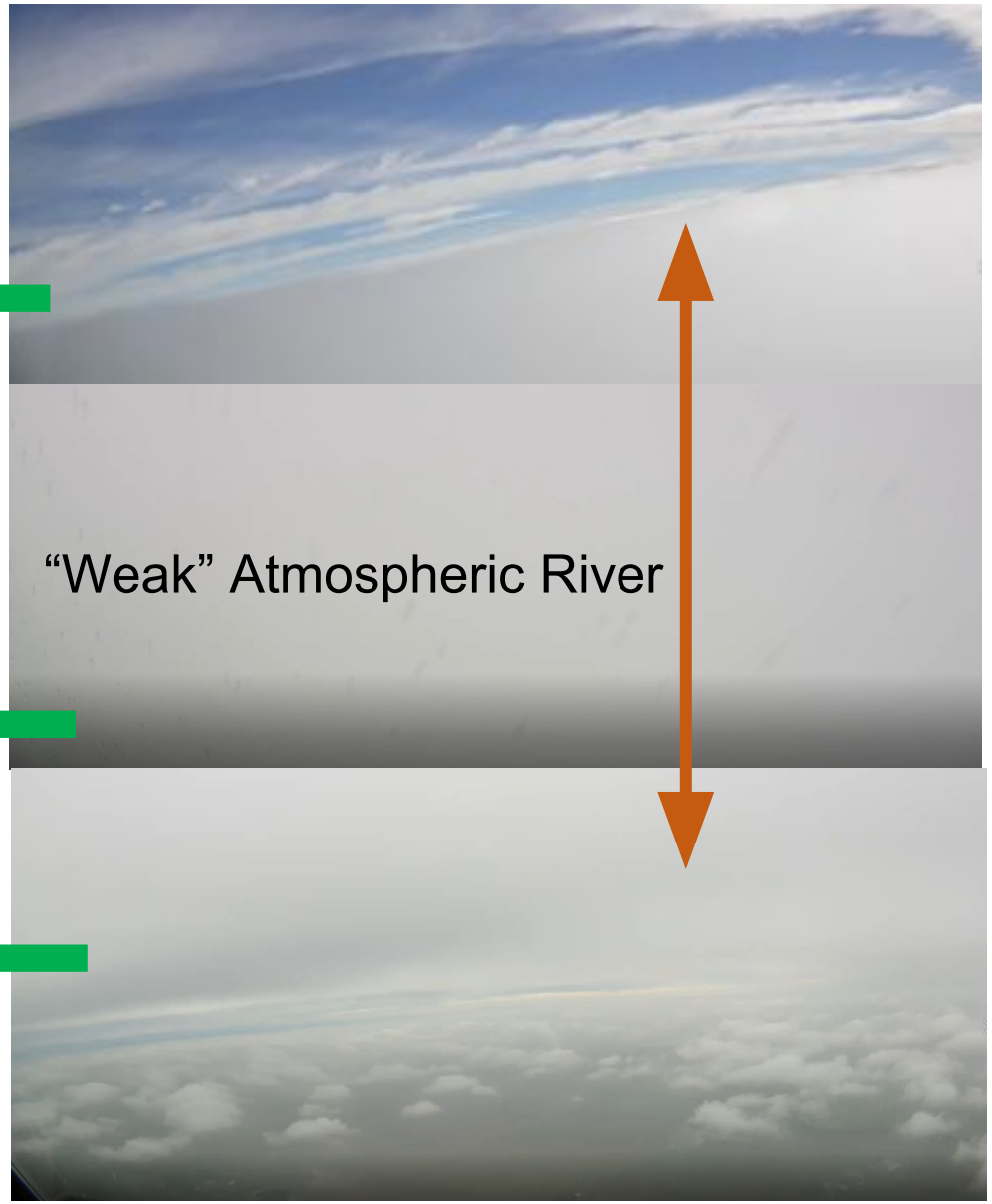
CalWater-2 (January – March 2015)
NSF, NOAA, DOE, NASA



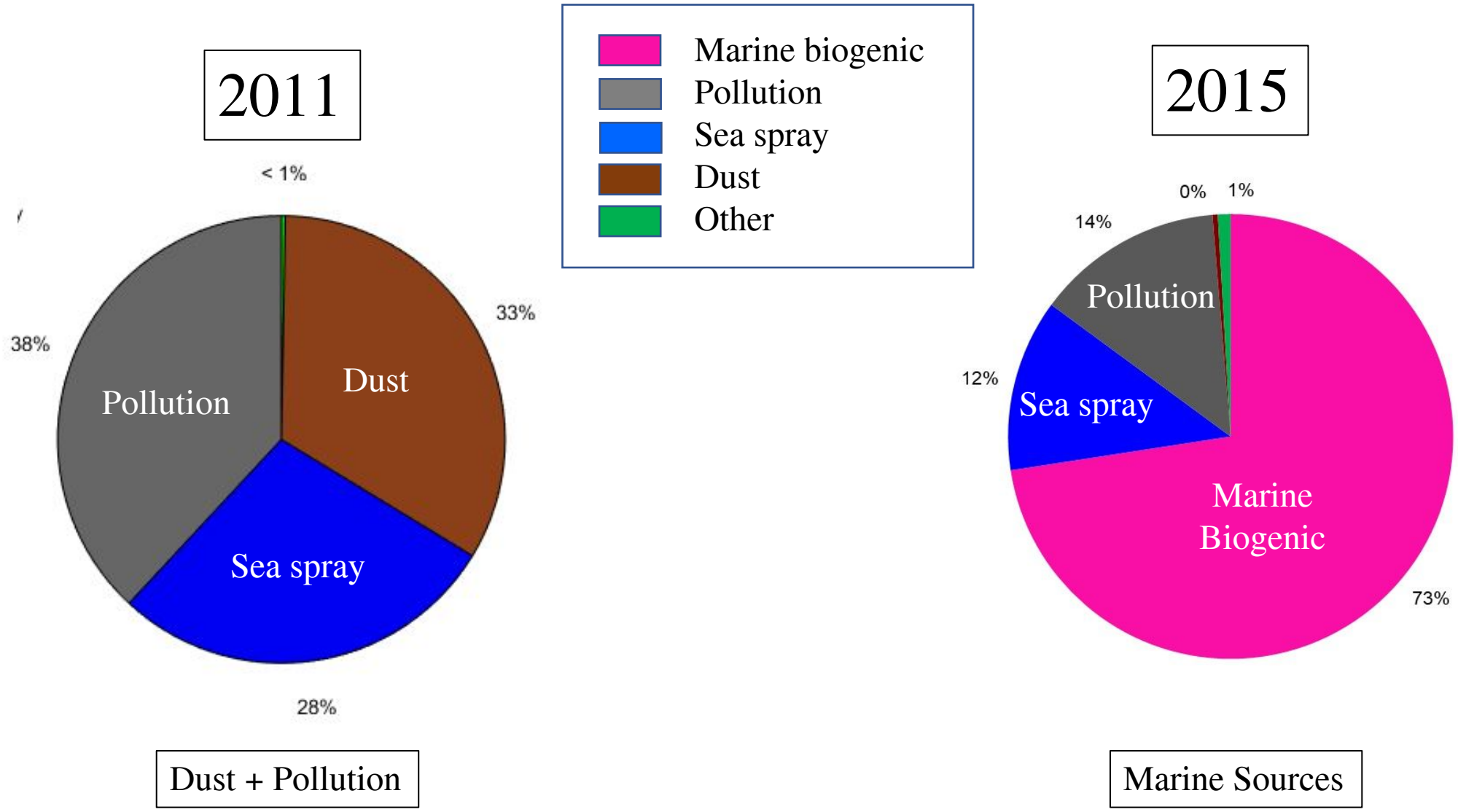


CalWater 2015: Jan 22nd (RF1)

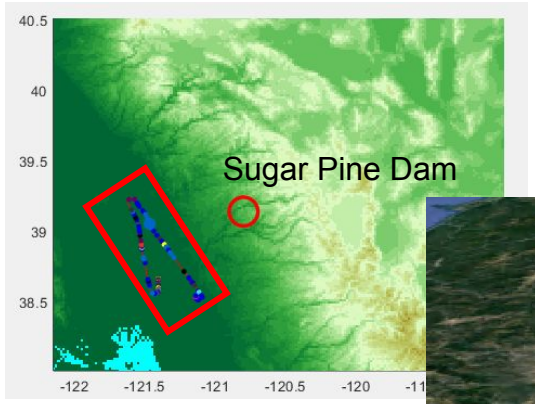


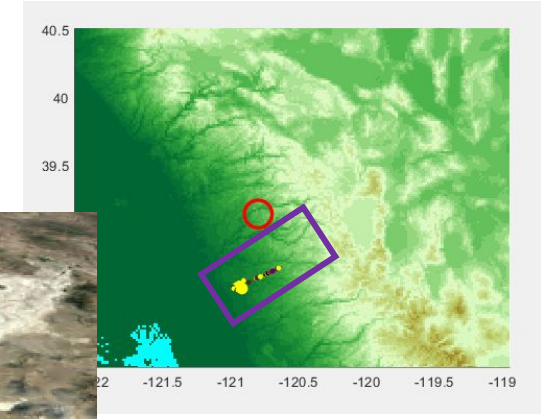


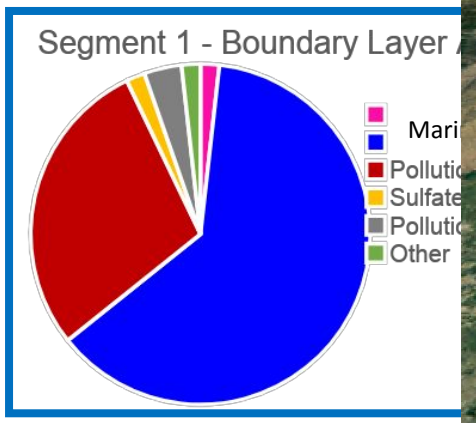
Aerosol Sources Seeding AR's: Calwater-2011 and 2015

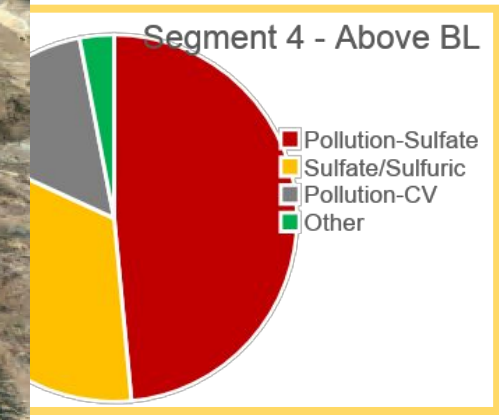


CalWater-2015: Aerosols seeding ARs completely de-coupled from Central Valley pollution aerosols (which remain trapped in boundary layer)



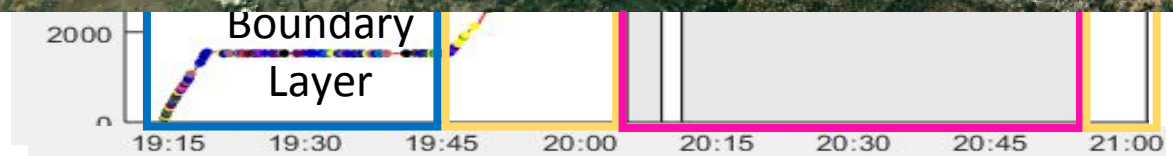




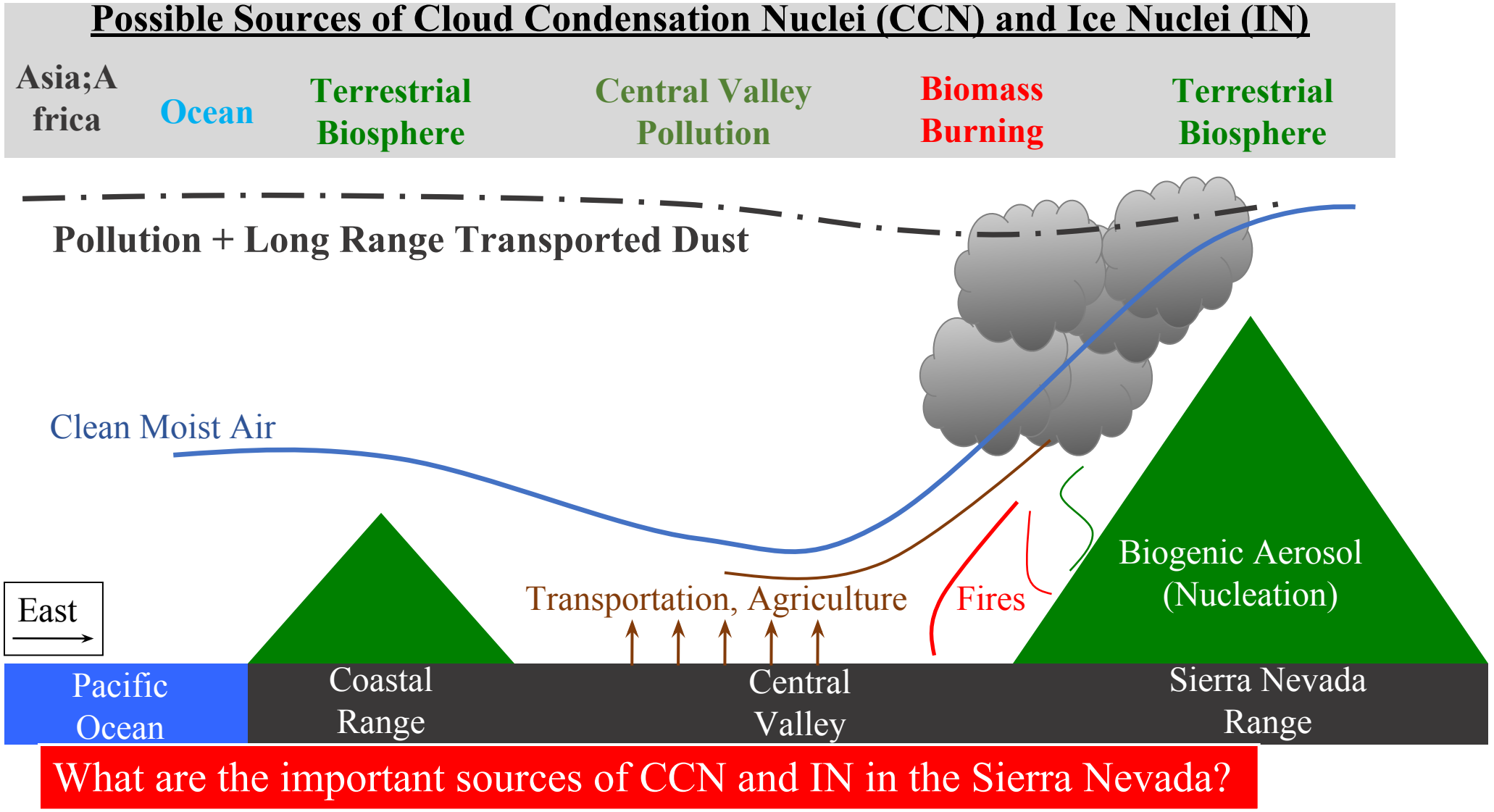


Feb 7th (RF14)–Mo

Aerosols vs Altitude



Original Concept : Orographic Precipitation



Rosenfeld et al., JGR, 2008 (SUPRECIP-2005)
Ault, et al., JGR, 2011; Creamean et al., Environ. Sci. Technol., 2011;
Creamean, et al., Science, 2013.

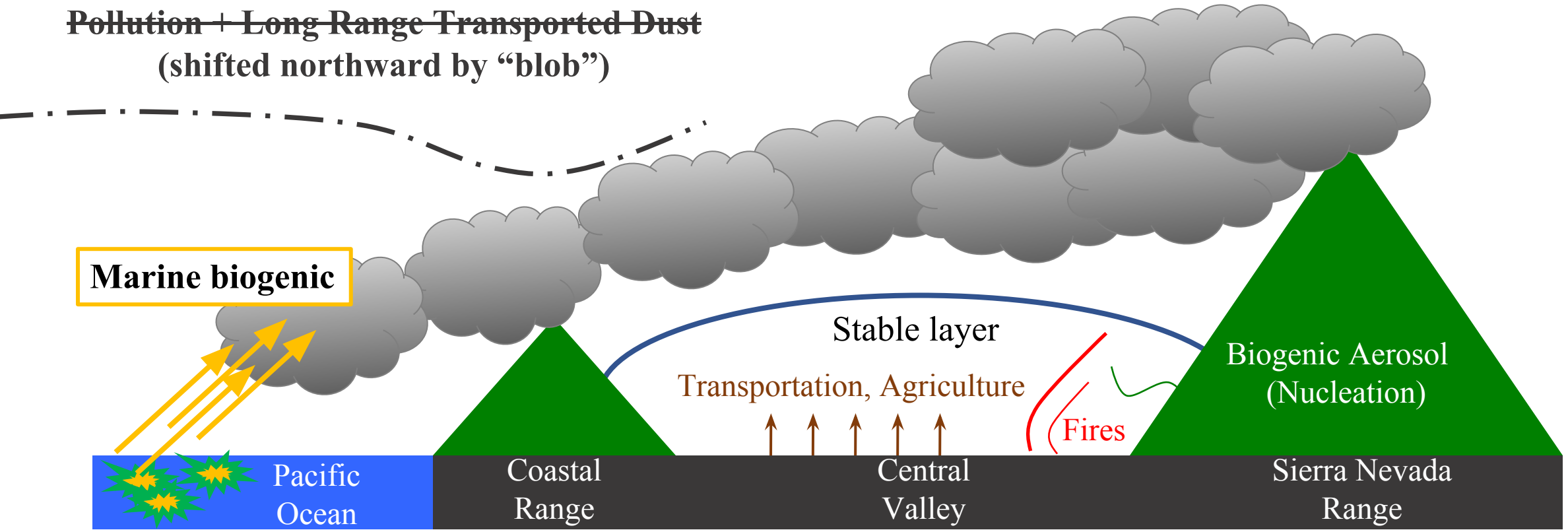
CalWater-2015: Atmospheric River Precipitation in California

Possible Sources of Cloud Condensation Nuclei (CCN) and Ice Nuclei (IN)

Asia; Africa

Ocean

~~**Pollution + Long Range Transported Dust**~~
(shifted northward by "blob")



What are the important sources of CCN and IN during **Atmospheric Rivers?**

Aerosol sources seeding AR's during 2011 and 2015 very different

2011

Long range transported dust + bioparticles seed AR storms
Local CA pollution does not go into clouds until post-frontal conditions

Aerosols affect precipitation efficiency by forming ice in clouds (enhance)

2015

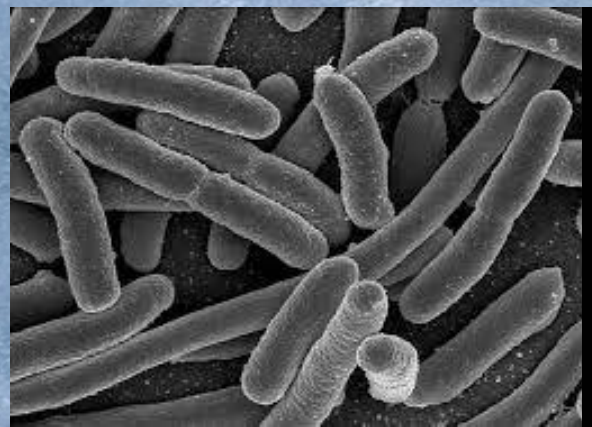
Warm band of moisture from AR caps local pollution aerosols, preventing them from entering clouds

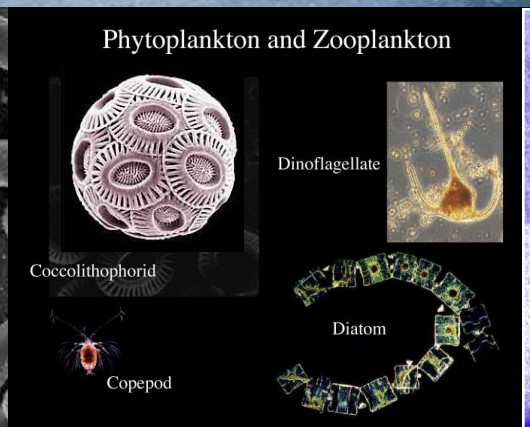
Biogenic ocean-sources (formed in clouds) play important role in seeding clouds
Local CA pollution does not go into clouds until post-frontal conditions

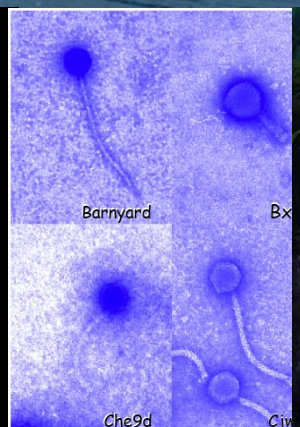
Long range transport (dust + pollution) and ocean sources are more prevalent sources at higher altitudes
Meteorological conditions (AR) control when and which aerosol sources seed clouds

How important is the ocean as a source of CCN and IN?

The Living Ocean: One drop of seawater contains hundreds of millions of viruses, bacteria, phytoplankton, proteins, lipids, even enzymes…. all enriched at ocean surface in thin microlayer

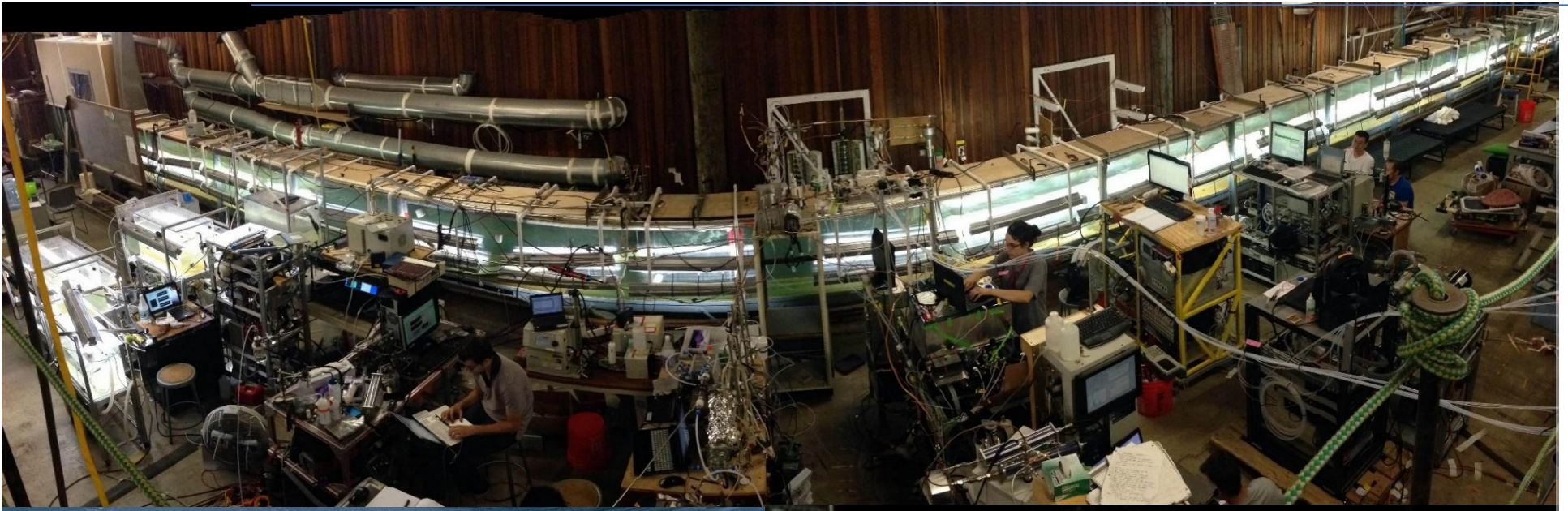


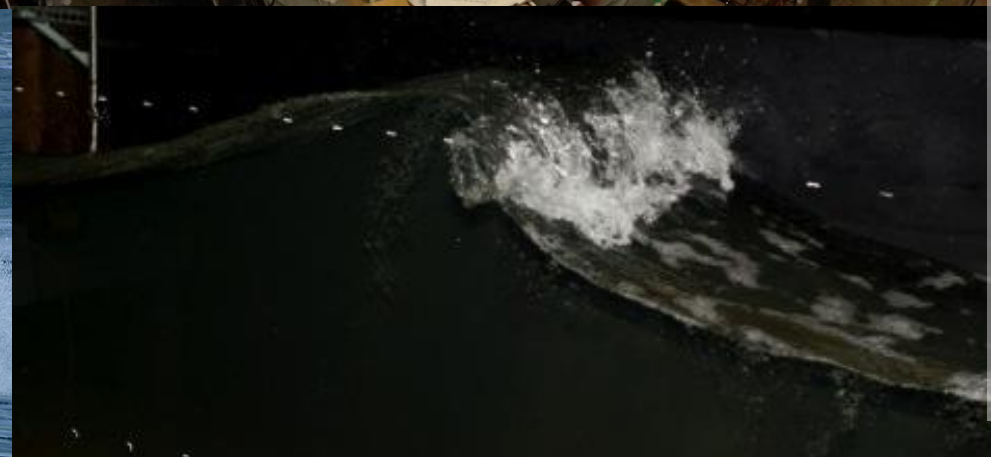




NSF Center for Aerosol Impacts on Chemistry of the Environment (CAICE)
Center for Chemical Innovation

UC San Diego





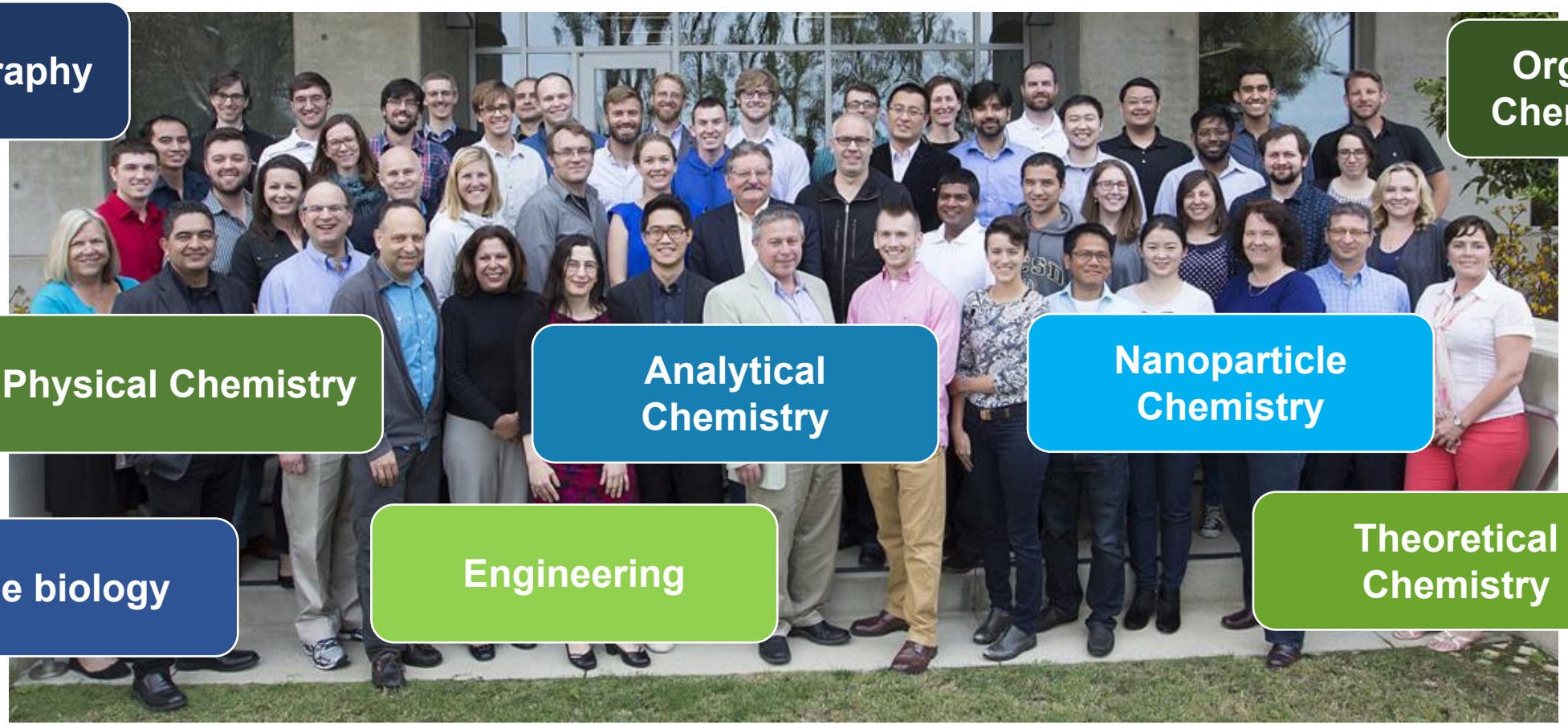
To transform our ability to accurately predict the impact of aerosols on climate and our environment by bringing real-world chemical complexity into the laboratory

Center for Aerosol Impacts on Chemistry of the Environment

Centers for Chemical Innovation

CAICE center for aerosol impacts on chemistry of the environment

UC San Diego · The University of Iowa · The University of Utah · Ohio State · Colorado State University · The University of Wisconsin Madison · Yale · UC Davis



Oceanography

Organic Chemistry

Physical Chemistry

Analytical Chemistry

Nanoparticle Chemistry

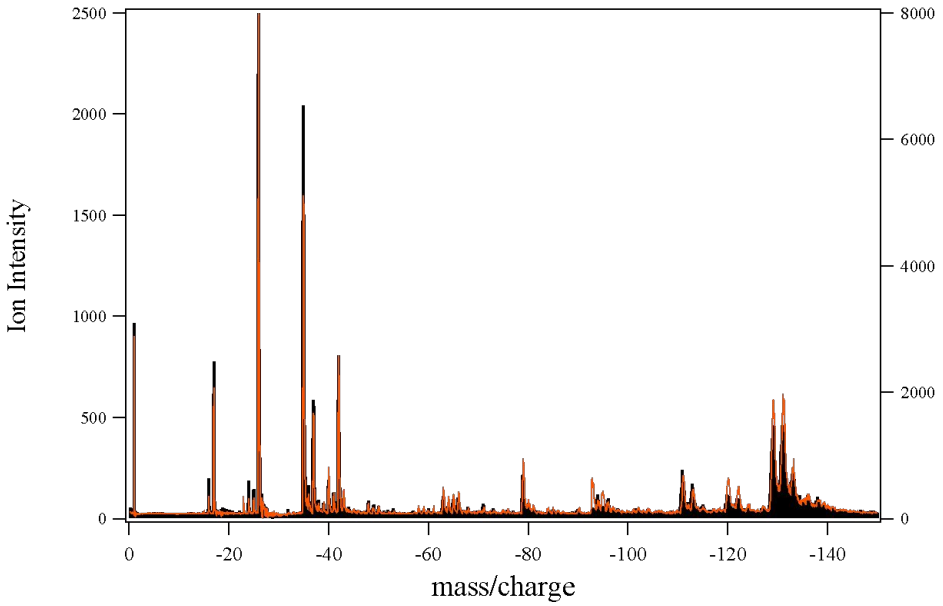
Marine biology

Engineering

Theoretical Chemistry

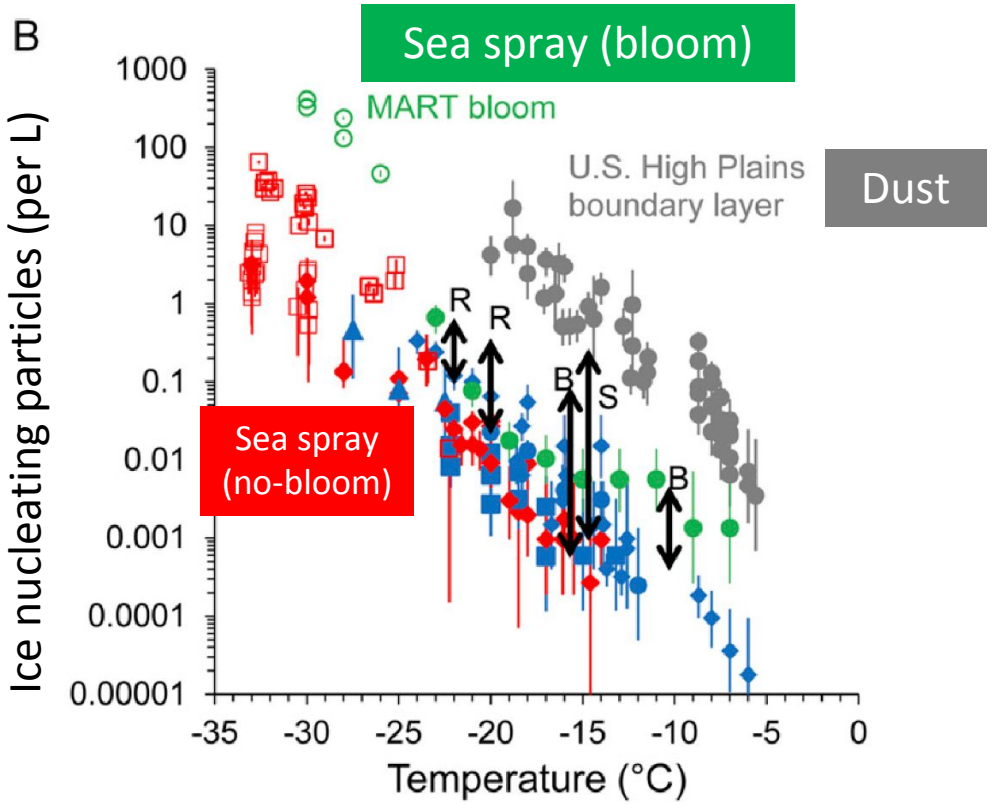
CAICE: Ocean/Atmosphere Studies
How important is the ocean as a source of CCN and IN?

ATOFMS Chemical Fingerprints
Bioparticle Mass Spectra



CAICE wave flume vs. CalWater cloud seeds
Linking sea spray aerosol chemical fingerprints

Ice nucleation parameterization
Marine **field** studies **match** CAICE **lab** studies



More effective as ice nuclei

DeMott, et al. PNAS 2016

Aerosol sources seeding AR's during 2011 and 2015 very different

2011

Long range transported dust + bioparticles seed AR storms

Aerosols can affect precipitation efficiency by forming ice in clouds (enhance) or over-seeding clouds (suppression)

2015

Warm layer from AR conditions caps local Central Valley pollution aerosols and prevents it from entering clouds

Biogenic ocean-sources (formed in clouds) play important role in seeding clouds

Meteorology conditions of AR impact aerosols which seed clouds (LRT and ocean sources more important at higher altitudes)

Next steps:

Use parameterizations as inputs for CalWater dust (2011) and CAICE ocean-derived particles (2015) in climate models (w/ Paul DeMott (CSU) and Ruby Leung, PNNL) to investigate precipitation impacts.

Investigate longer term trends in frequency of long range dust transport to the West Coast in Jan-March (w/ Amato Evan and Kara Voss, SIO).

Acknowledgements

California Energy Commission (2009-2014)—Guido Franco
National Science Foundation (2015-present)

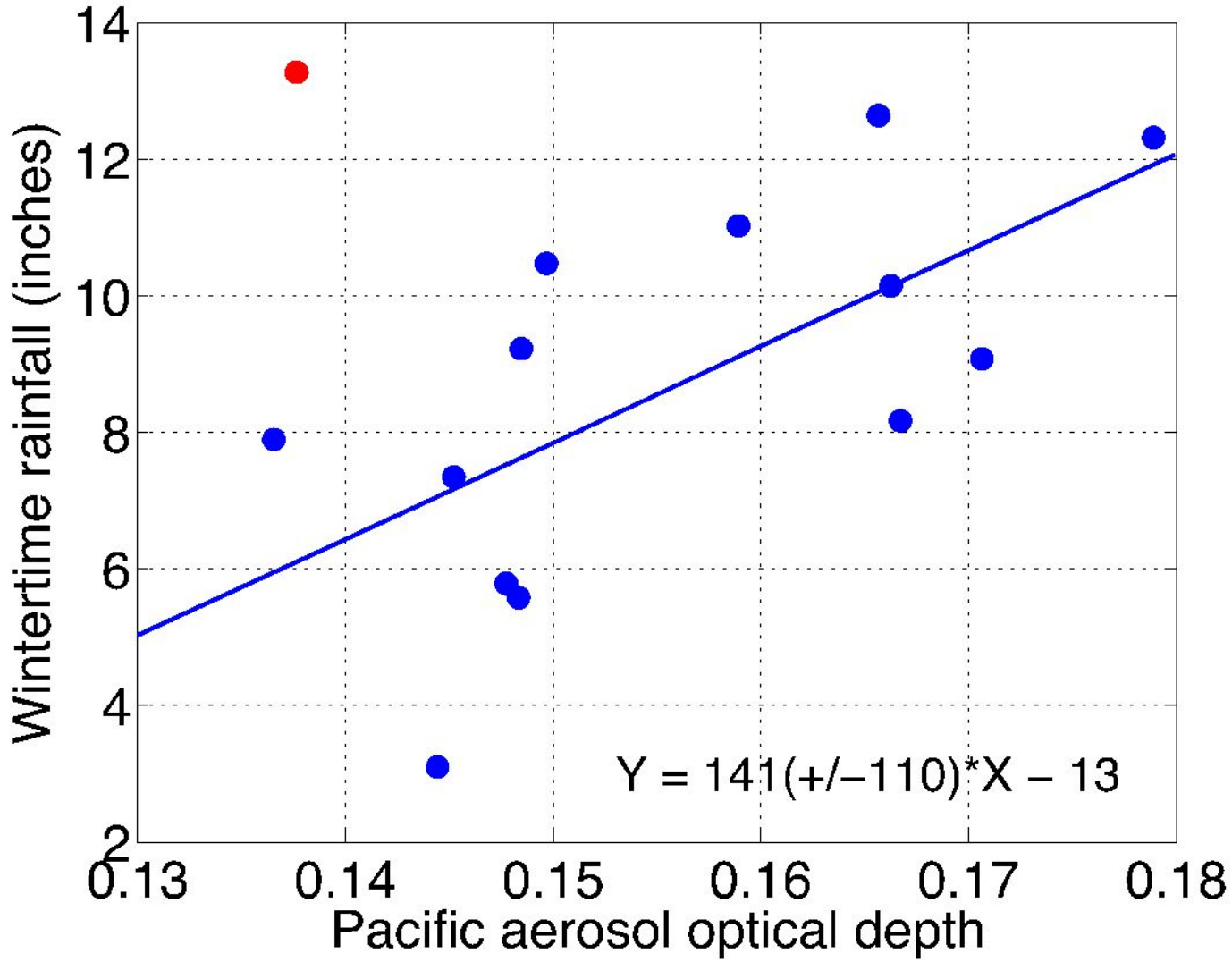
Marty Ralph (UCSD/SIO)
Andrew Martin (UCSD/SIO)
Ruby Leung (PNNL)
Danny Rosenfeld (Hebrew University)
Paul DeMott (CSU)

<u>Former and Current Prather Group Members:</u>
Prof. Doug Collins (Bucknell)
Dr. Jack Cahill (ORNL)
Dr. Jessie Creamean (CSU)
Prof. Andy Ault (U Michigan)
Dr. Kaitlyn Suski (PNNL)
Dolan Lucero (UCSD)
Kathryn Mayer (UCSD)
Kara Voss (UCSD/SIO)
Hash Al-Mashat

Gavin Cornwell
UCSD

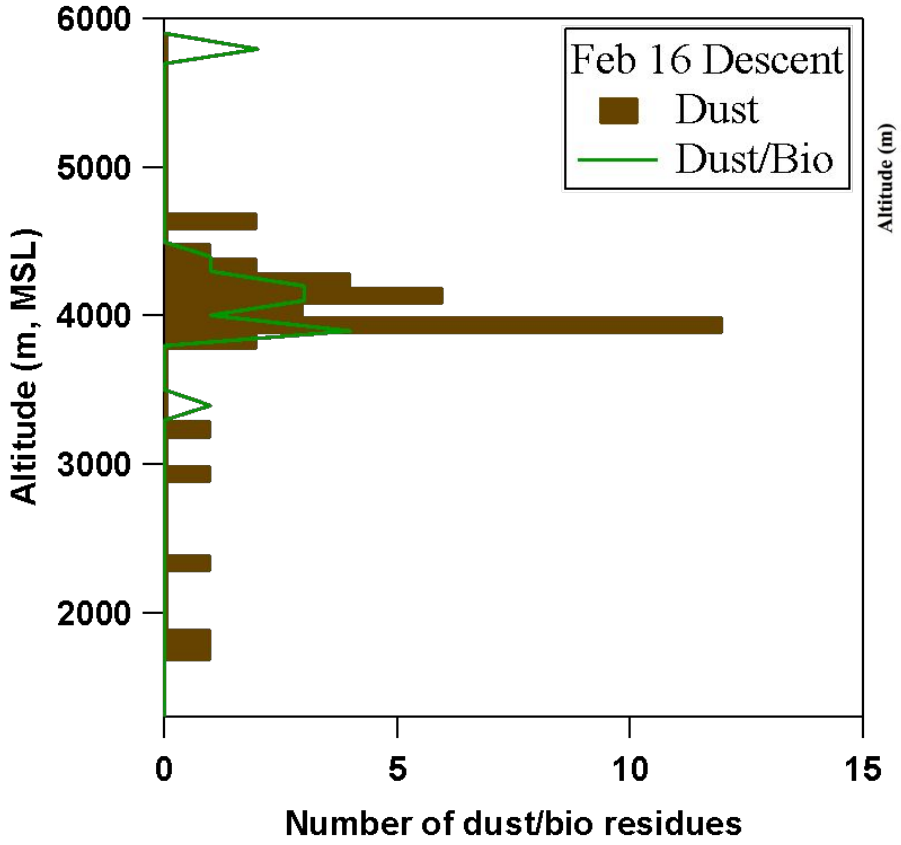
Dr. Louise Kristensen
UCSD

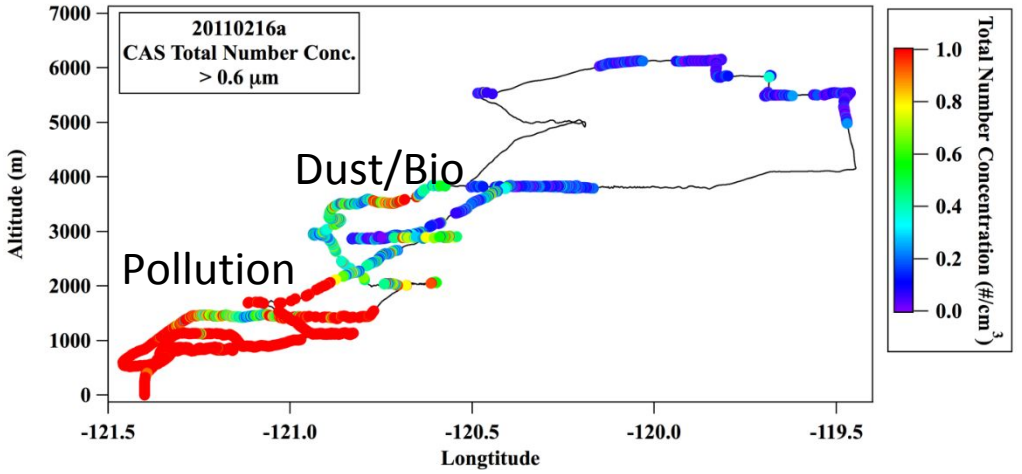
Eastern Pacific Ocean AOD vs. California Rainfall 2001-2014 (Jan-March)



Amato Evan (SIO/UCSD)

CalWater (February 16, 2011)
Cloud Residual Composition





- Dust/bio appear in layer at same altitude as ice in clouds

CalWater (February 16, 2011)
Ice Fraction (WCM)

- Dust/bio appear at same altitude as ice in clouds
- CFDC IN concentrations peak
- Is ice due to colder temps or due to composition of aerosol cloud seeds?