ARM Cloud-Aerosol-Precipitation Experiment (ACAPEX)

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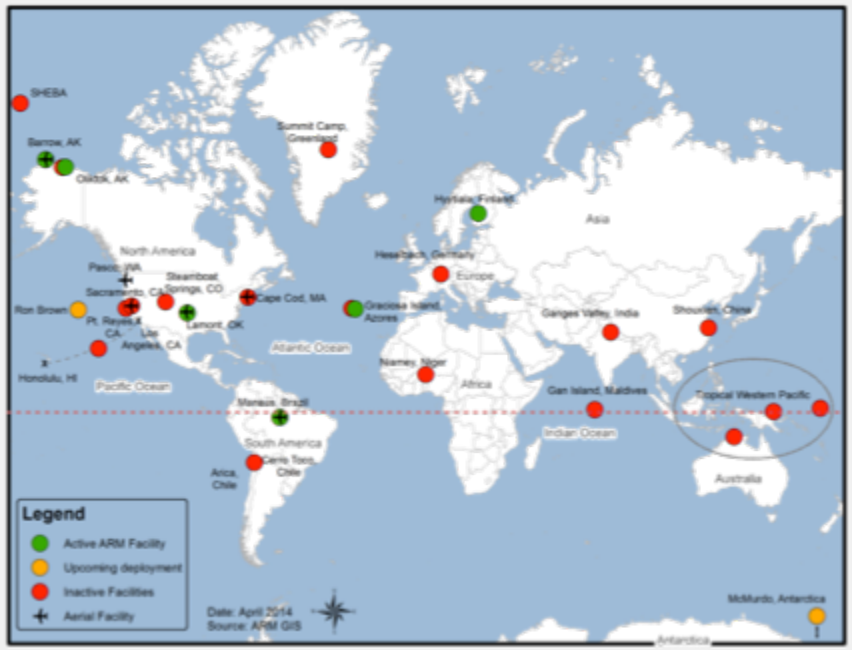
Pacific Northwest National Laboratory

Organizing Committee:
Paul DeMott, Chris Fairall, Jiwen Fan, Samson Hagos, Mimi Hughes, Kimberly Prather, Marty Ralph, Daniel Rosenfeld, Ryan Spackman, Duane Waliser

Translating Process Understanding to Improve Climate Modeling
CLIVAR Webinar 23 March 2016

The ARM Climate Research Facility

Atmospheric Radiation Measurement (ARM) is an observation user facility to support DOE's Climate and Environmental Mission



ARM Mission

Use strategically located in situ and remote sensing observatories designed to improve the understanding and representation, in climate and earth system models, of clouds and aerosols as well as their interactions and coupling with the Earth's surface.

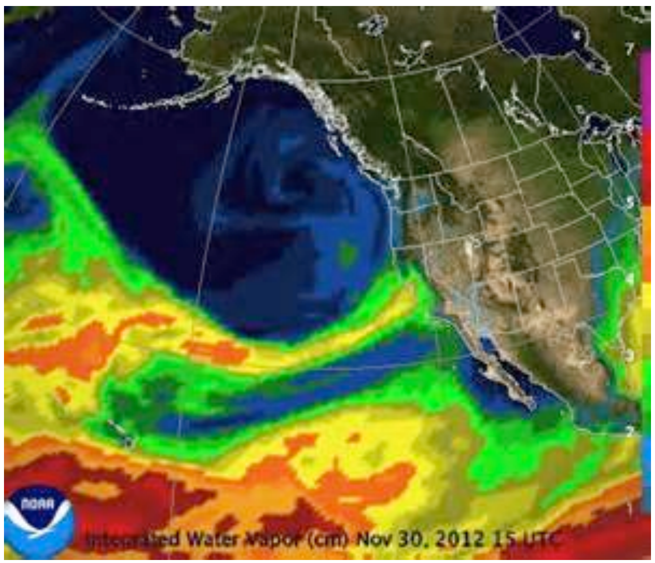
www.arm.gov

How much precipitation?

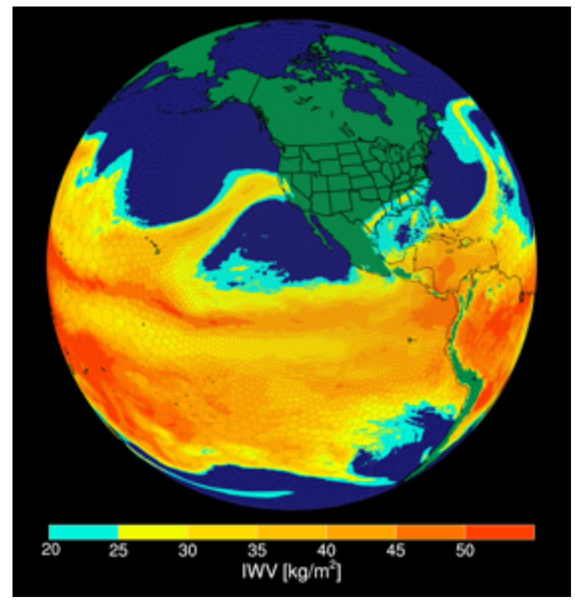
Wind speed, moisture amount, and atmospheric stability are important ingredients for producing heavy precipitation

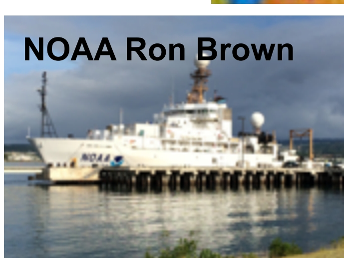
- ► Do models get them right for short term forecasting and projections of future changes?

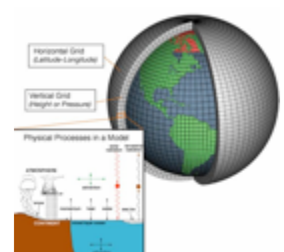
Observation



Model simulation



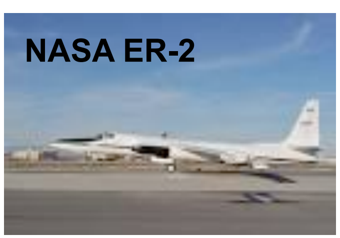




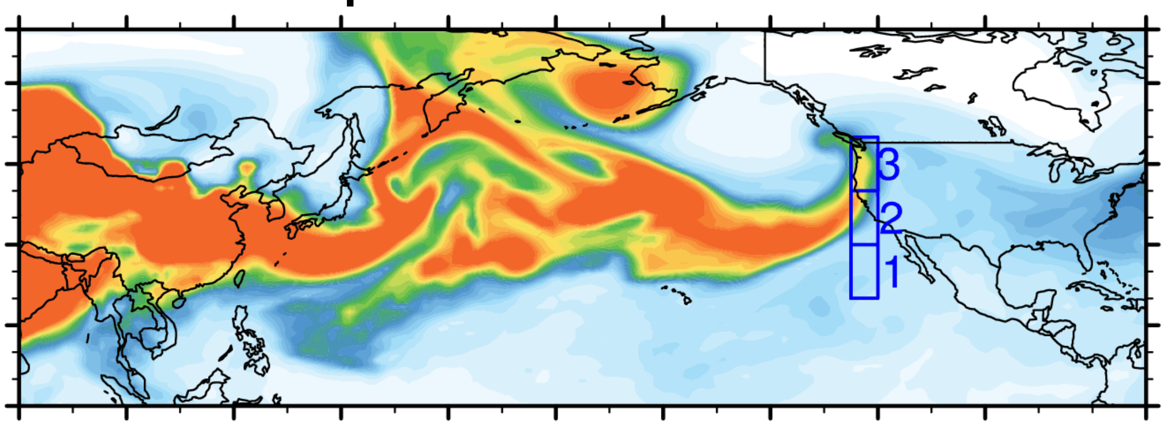
Rain or snow?

Dust is a determinant of rain vs. snow

Snowpack provides water supply in summer

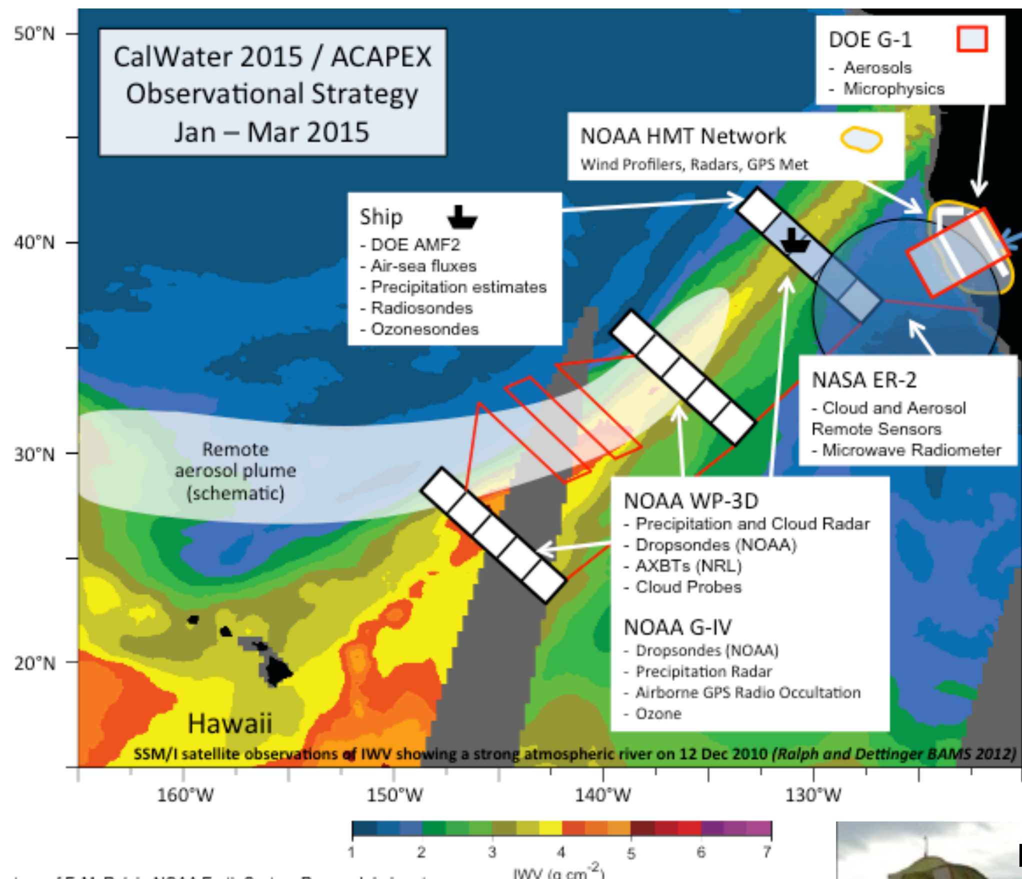


Atmospheric rivers or aerosols?

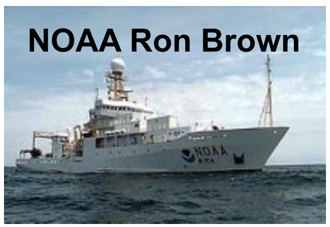


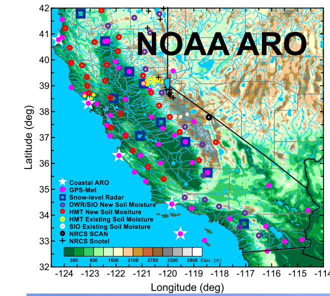
CalWater 2 - ACAPEX (Jan – Mar 2015)

- **Objective:** Improve understanding and modeling of the role of atmospheric rivers and aerosols on precipitation in California



Courtesy of F. M. Ralph, NOAA Earth System Research Laboratory





NRL
AXBT

Calwater 2015 key science questions

- Atmospheric rivers
  - How much water vapor is transported by atmospheric rivers and what are their sources?
  - What processes control precipitation at landfall?
- Aerosol- cloud-precipitation interactions
  - What are the distribution, characteristics, and sources of aerosols affecting winter precipitation in California?
  - How do aerosols influence precipitation in different storm environments?
- Atmospheric river – aerosol connections
  - How may aerosols influence the evolution and structure of atmospheric rivers?
- How well can models capture all of the above?

ACAPEX observing platforms

ARM Mobile Facility (AMF) on NOAA Ron Brown

ARM Aerial Facility (AAF)

Instruments on AMF2

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- Aerosol Observing System (AOS)
- Clouds:
  - Vertically pointing W-band cloud radar (WACR)
  - Ka-band zenith pointing radar (KAZR)
  - Microwave radiometer (MWR)
  - Ceilometer, micropulse lidar (MPL), and high spectral resolution lidar (HSRL)
  - 3-channel microwave radiometer (MWR3C)
- Meteorology:
  - Radar Wind Profiler (RWP)
  - Atmospheric Sounder
  - Meteorological instruments (MET) and atmospheric profiling (SONDE)
- Portable Radiation Measurement Package (PRP2) and sun pyranometer (SPN)
- Bulk aerodynamics fluxes (BAF)

G-1 payload (~ 40 instruments)

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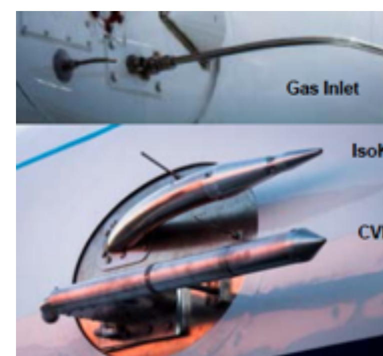
- Aircraft and Atmospheric State Parameters
- Cloud Properties
  - Liquid water, total water, ice water content
  - Size Distribution (2 µm to 2 cm)
- Aerosol Properties (interstitial and residual)
  - Total Concentration
  - Size Distribution (60 nm – 50 µm)
  - Optical Properties (absorption, scattering)
  - Physico-chemical composition (single particle)
  - Cloud Condensation Nuclei Concentration
  - Ice Nuclei Concentration
- Trace Gases
  - H_2O, CO, O_3, N_2O



CalWater 2015 platform activities

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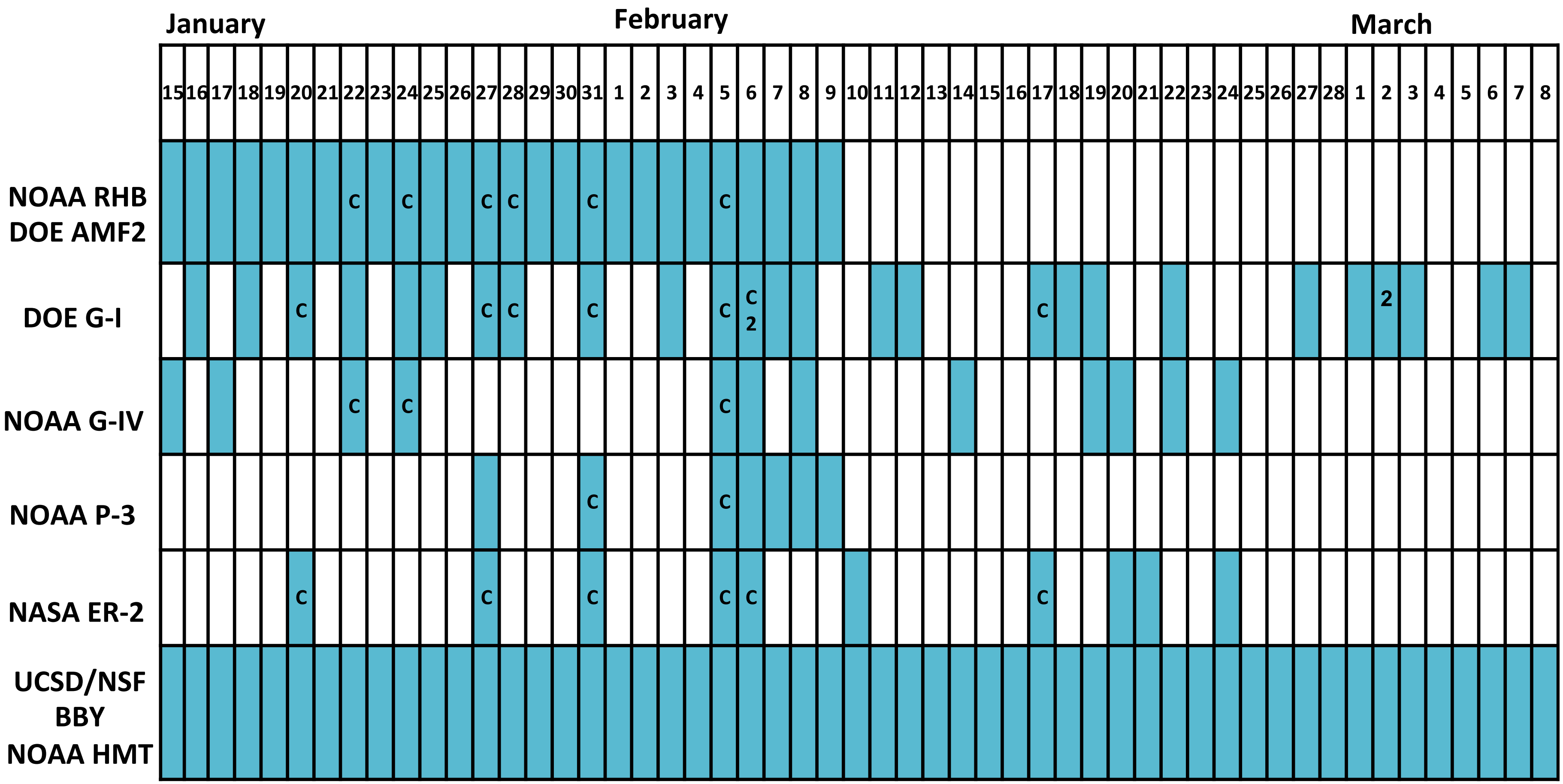

C = Coordinated Platform Activities

2 = Two flight day

ACAPEX platform activities

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G-1 flew a total of 28 flights:

- 8 flights in atmospheric rivers (over the ocean, along the coast, and in Sierra Nevada)
- 6 flights in coastal stratus and stratocumulus
- 4 flights in frontal orographic clouds
- 10 flights to characterize aerosols, CCN, INP from local sources and long range transport
- Of the 28 flights, 6 were coordinated with NASA ER-2, of which 2 were also coordinated with NOAA G-IV and P-3 for comprehensive moisture, cloud, and aerosol measurements

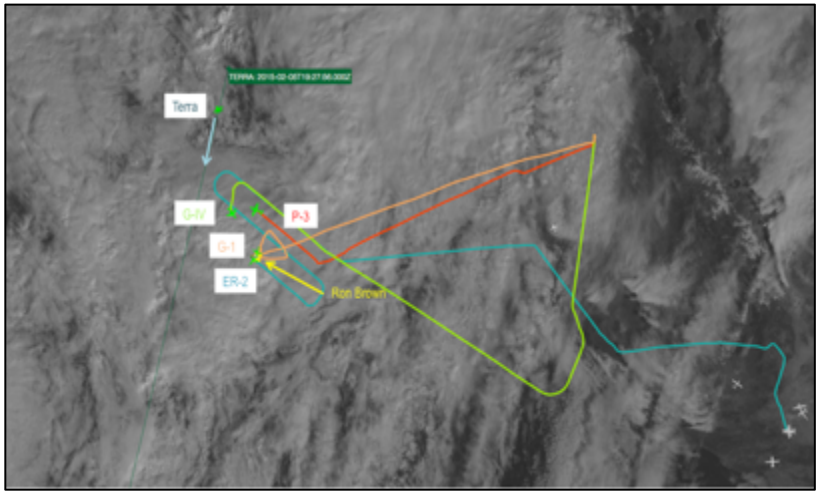
AMF2 on Ron Brown:

- Deployed from Jan 15 – Feb 9 from Honolulu to San Francisco; measured atmosphere, aerosols/clouds, and surface fluxes in 3 atmospheric rivers

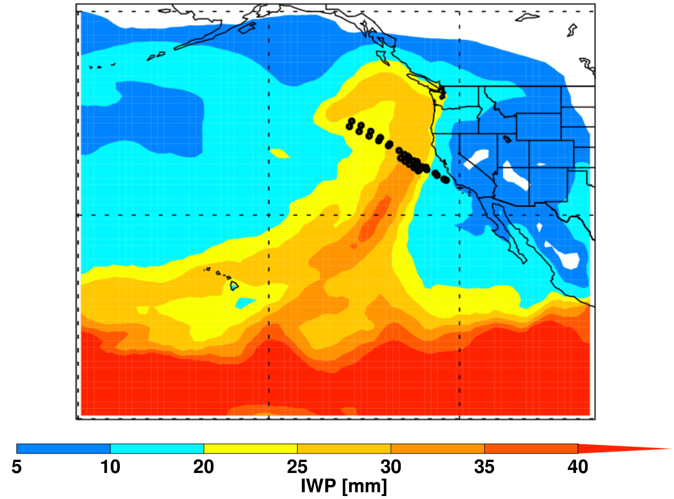
February 5: Stratiform clouds of an AR

- Multiple measurements to constrain or evaluate simulations of cloud macrophysical and microphysical properties for mixed-phase clouds

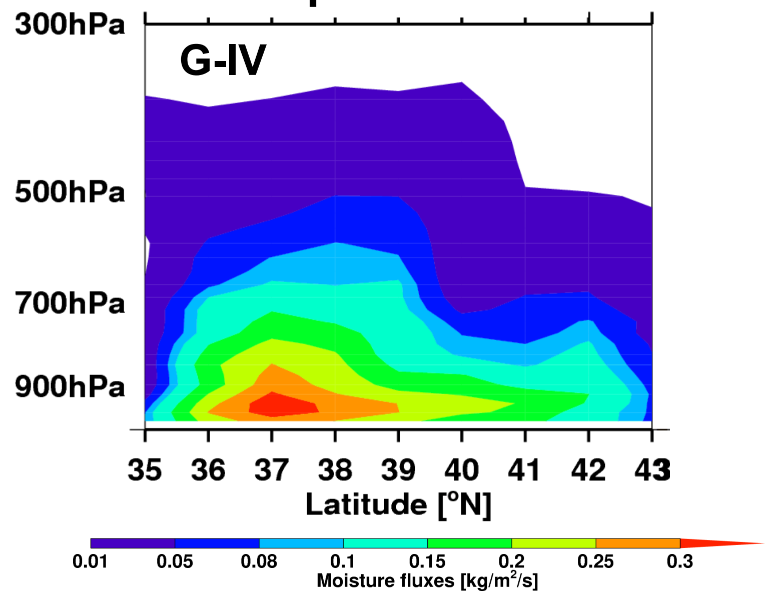
Coordinated flights over RHB



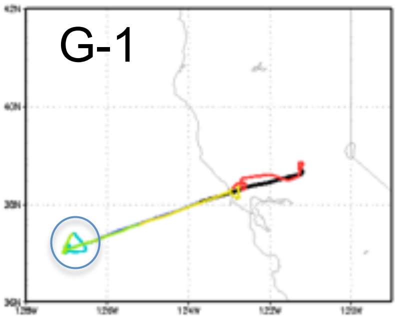
ERA IWV

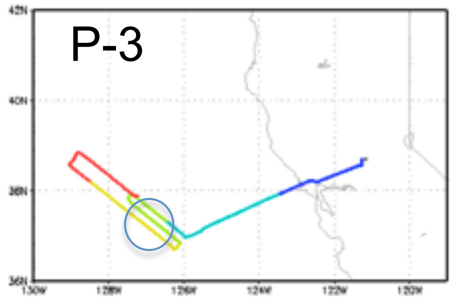


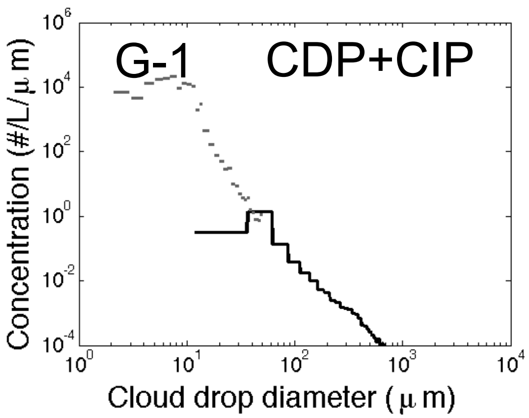
Dropsonde IVT

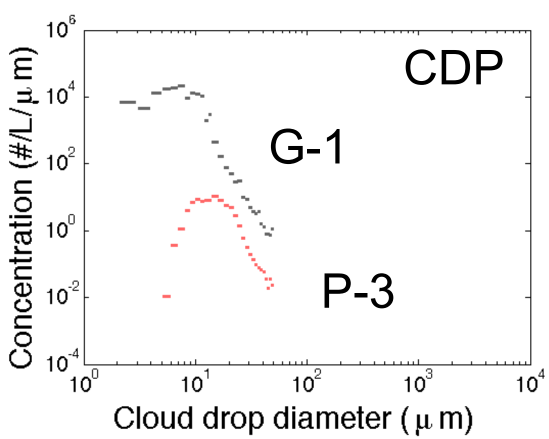


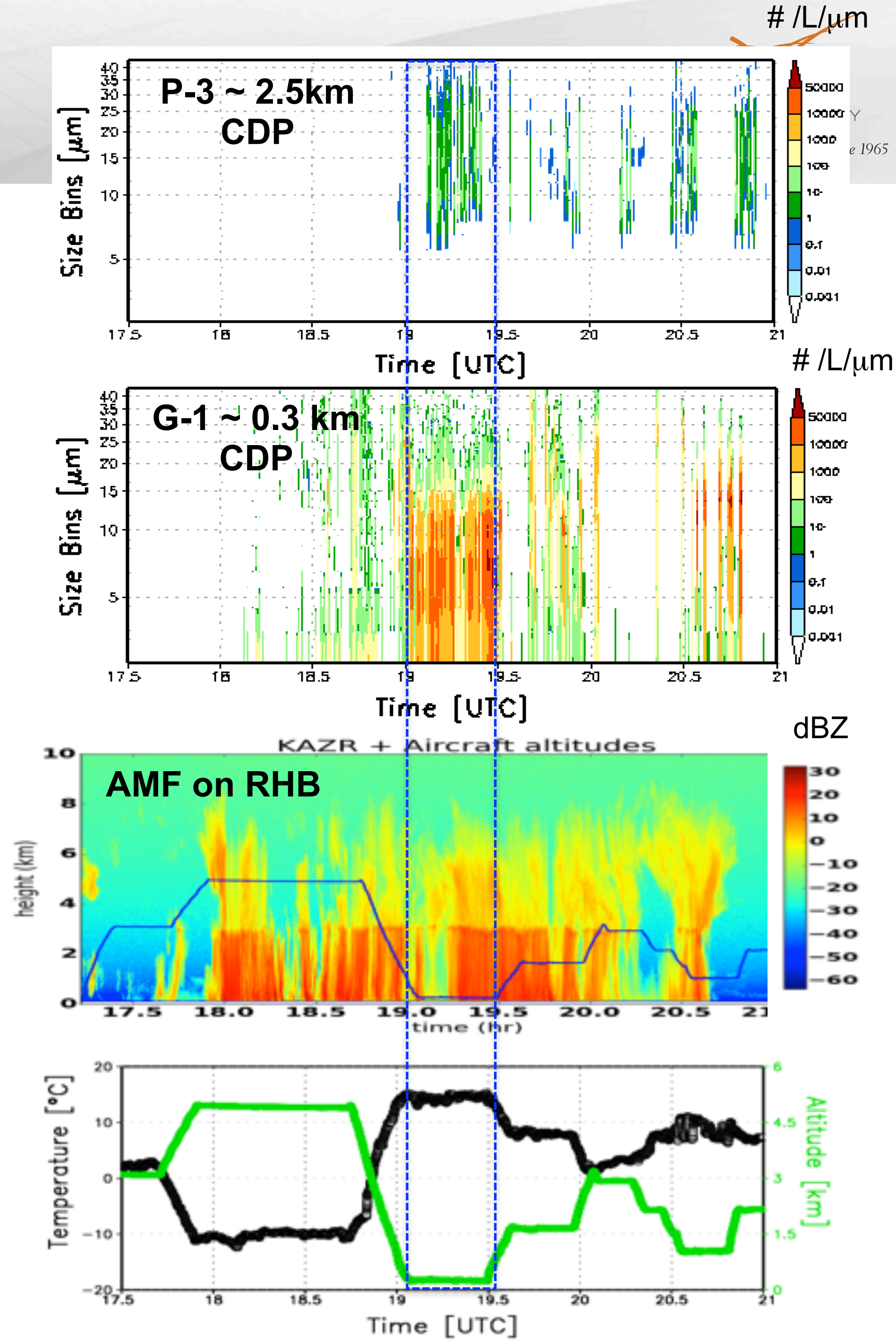
February 5: Stratiform clouds of an AR











Orographic clouds on February 6 - 8

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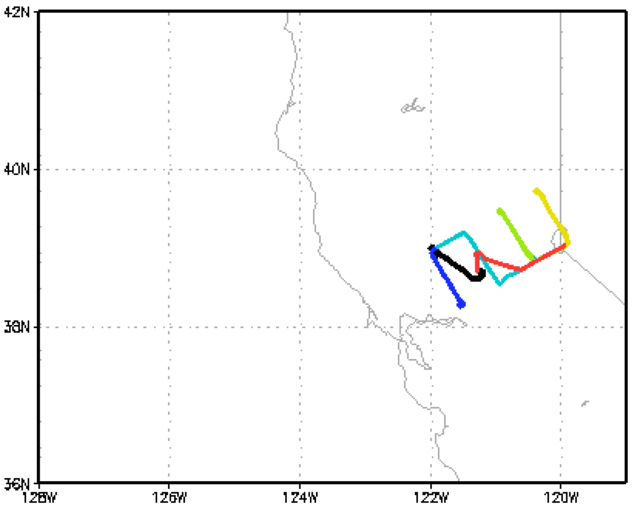
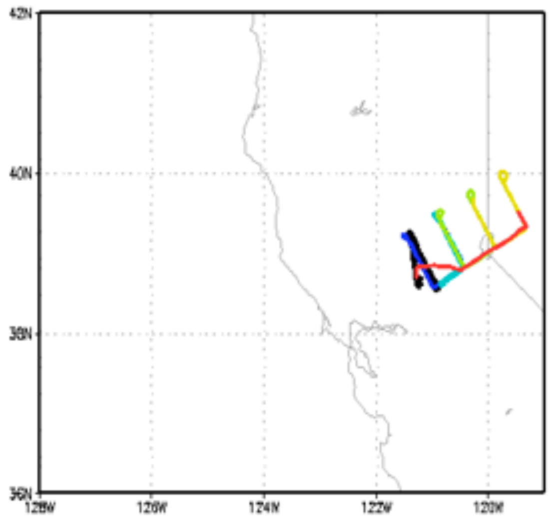
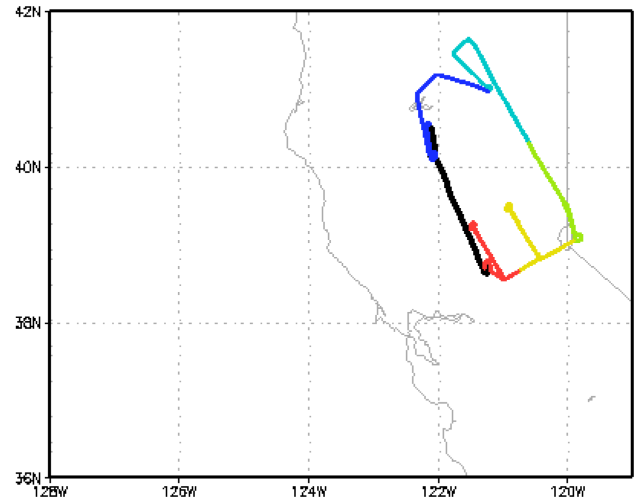
February 6



February 7



February 8

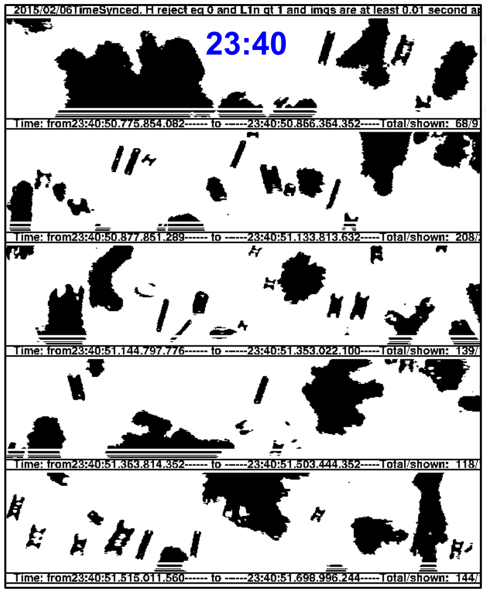


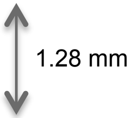
Flooded area in Central Valley

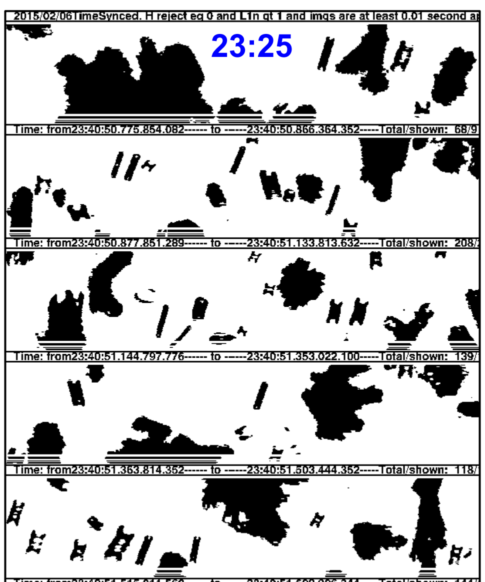
Above Lake Tahoe

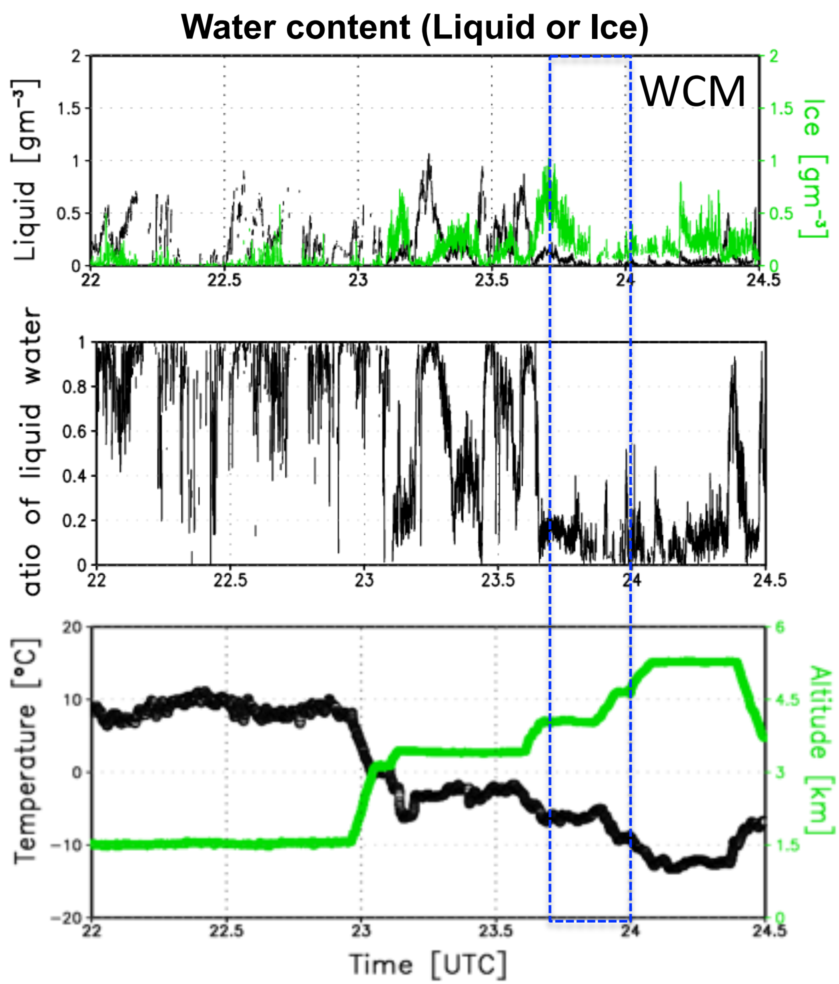
Above Sugar Pine Reservoir

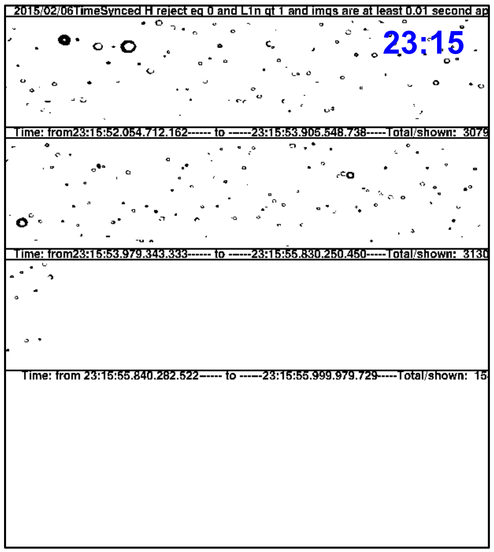
February 6: orographic cloud properties

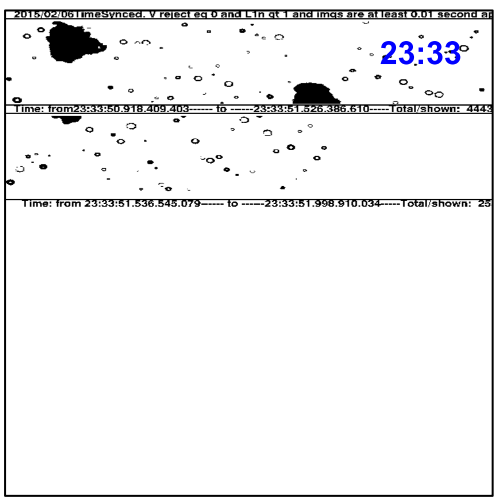












February 6: aerosol properties and sources

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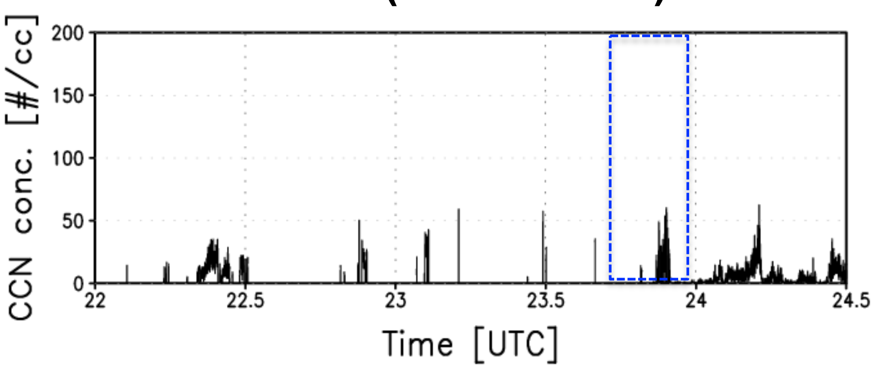
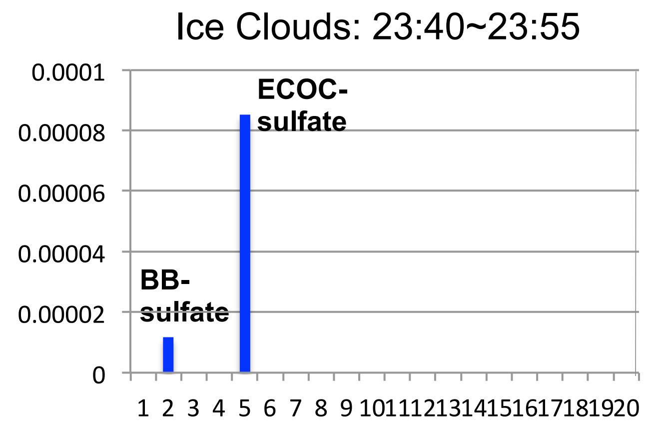
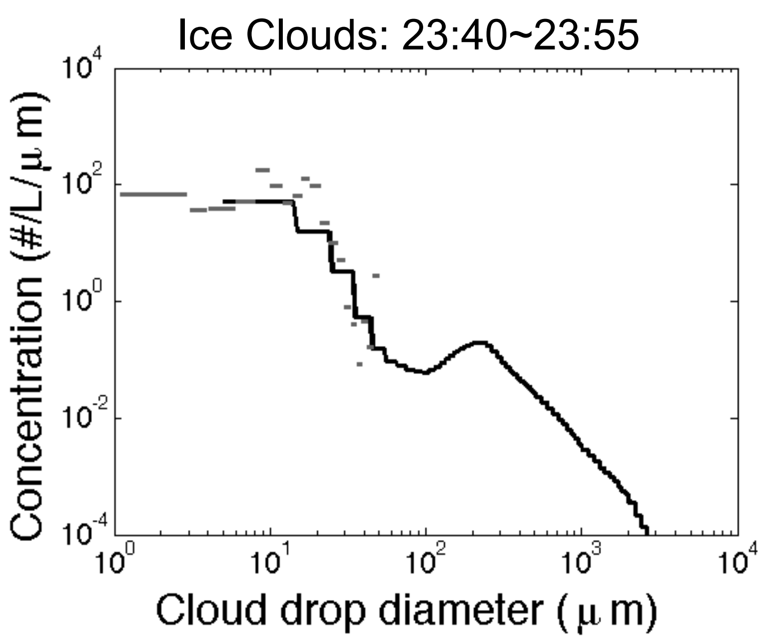
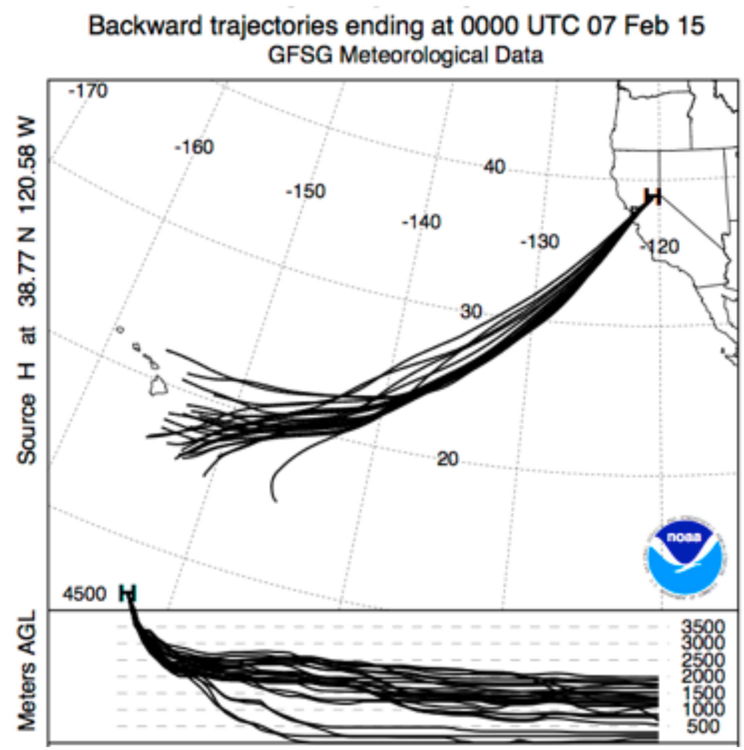


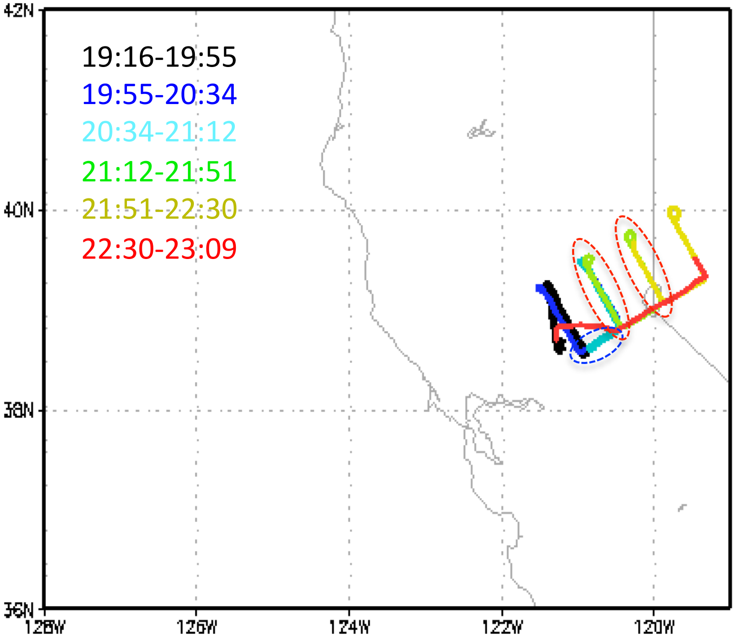




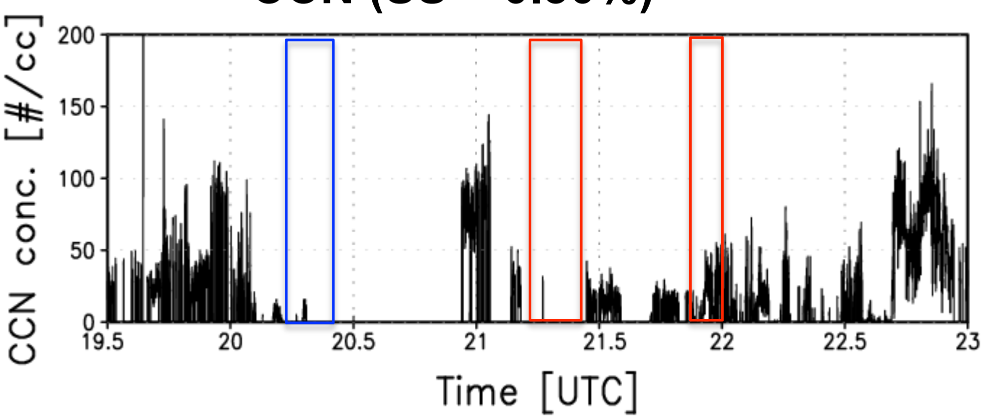


February 7

Flight Track



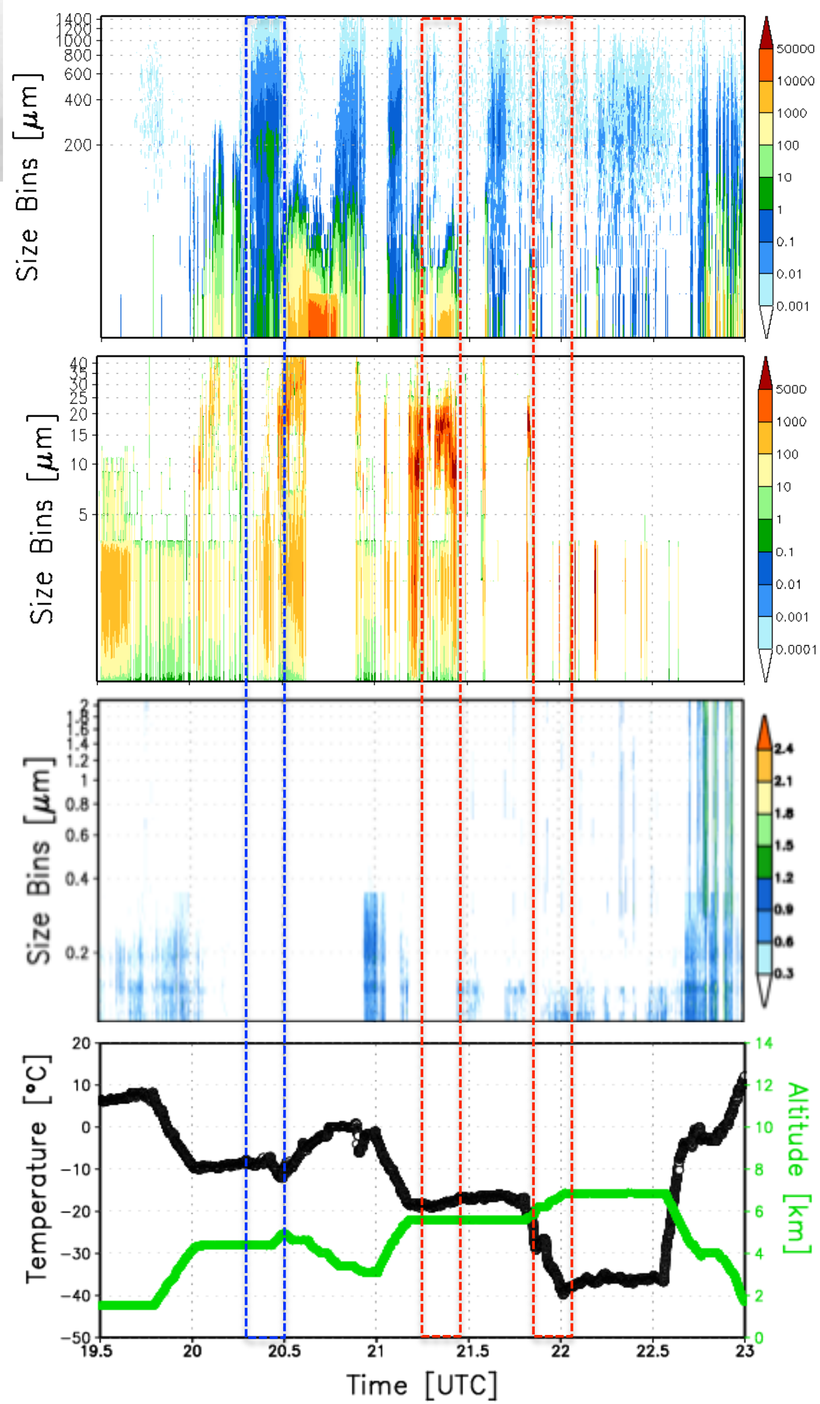
CCN (SS = 0.30%)



2DS:
Droplet concentration (#/L/μm)

FCDP:
Droplet concentration (#/L/μm)

PCASP:
Aerosol concentration (#/cm³/μm)



February 7: orographic cloud properties

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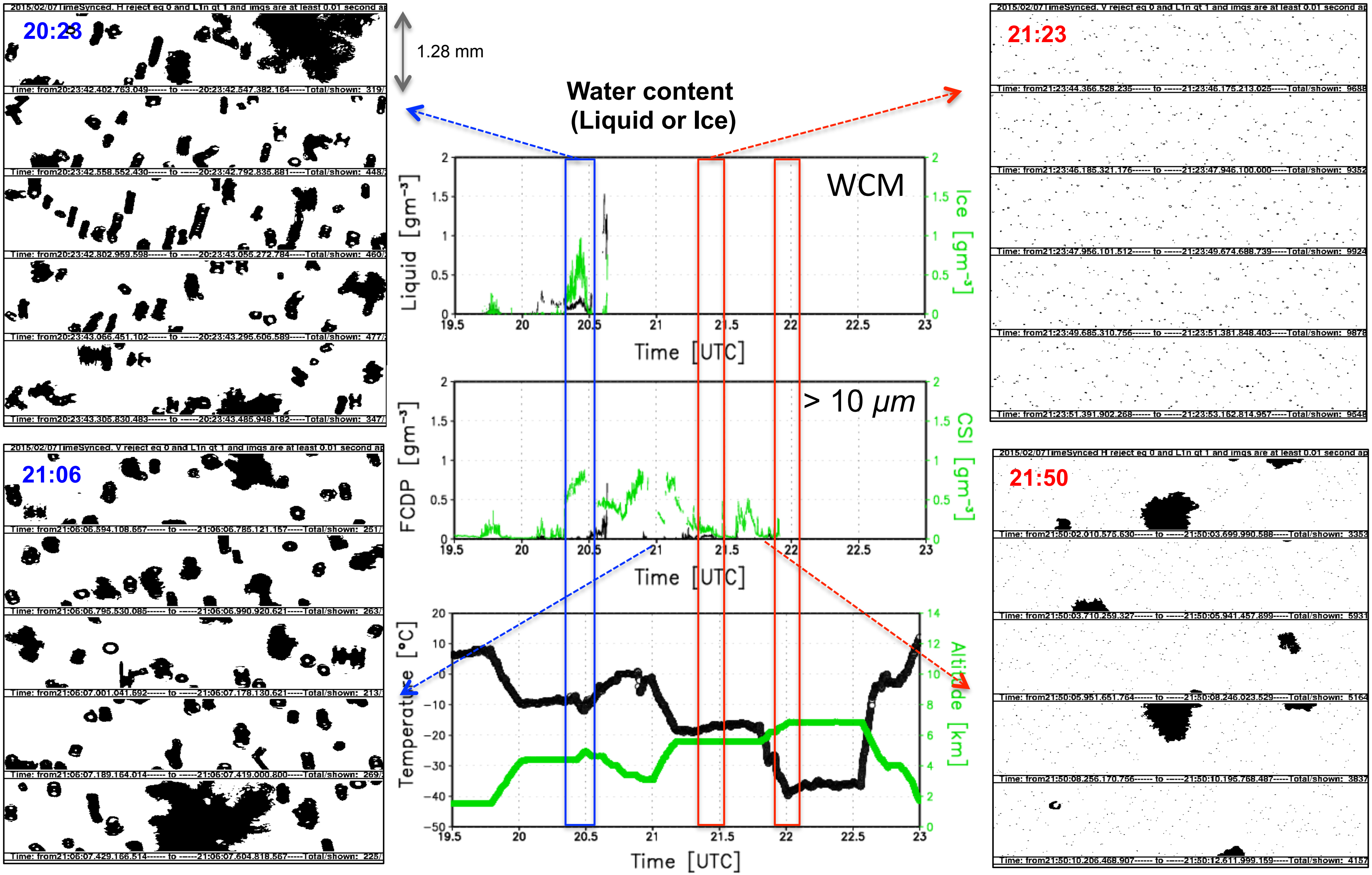
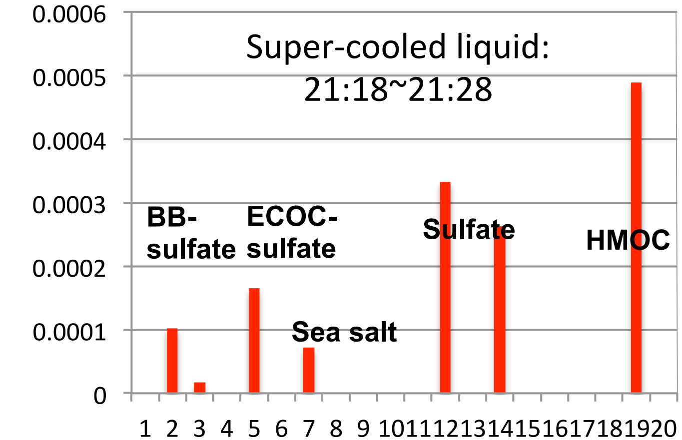
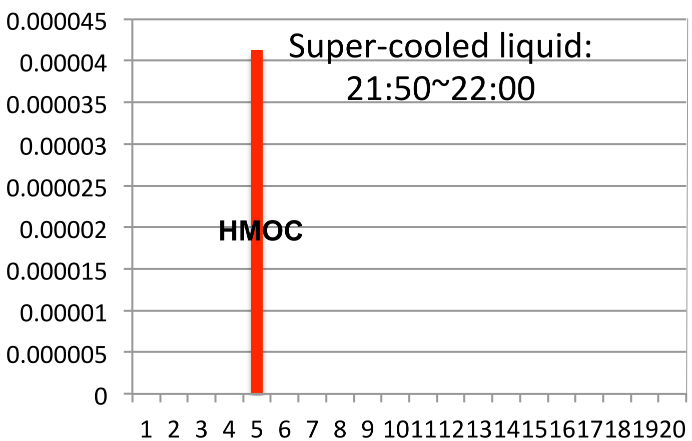


February 7: aerosol properties

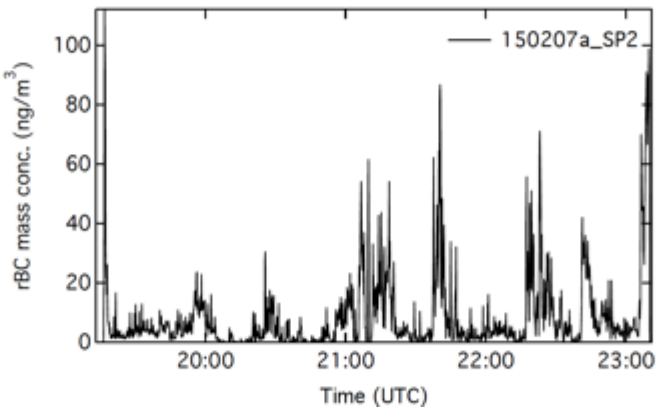
- Measurements of aerosol chemical composition, BC concentration, and light absorption suggest the presence of aerosols with low hygroscopicity

Aerosol chemical composition

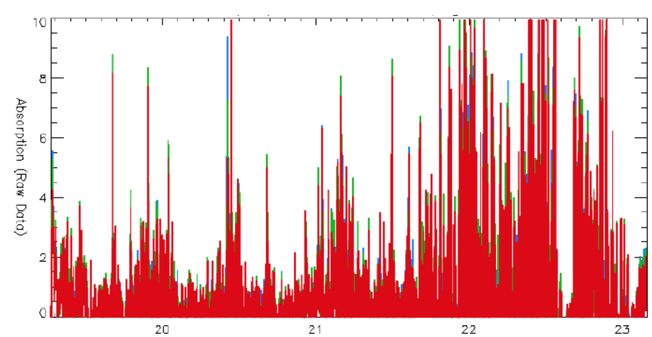




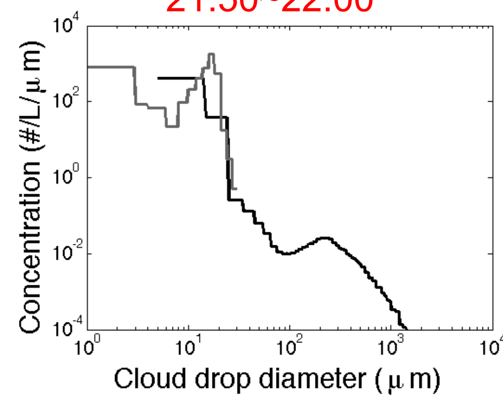
BC concentration

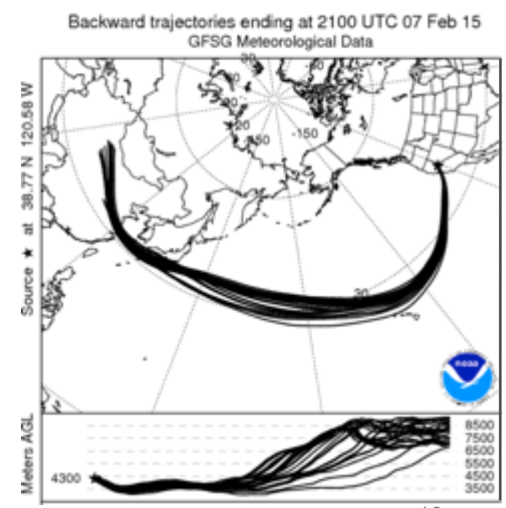


Light absorption coefficient



Super-cooled liquid:
21:50~22:00





February 8: orographic cloud properties

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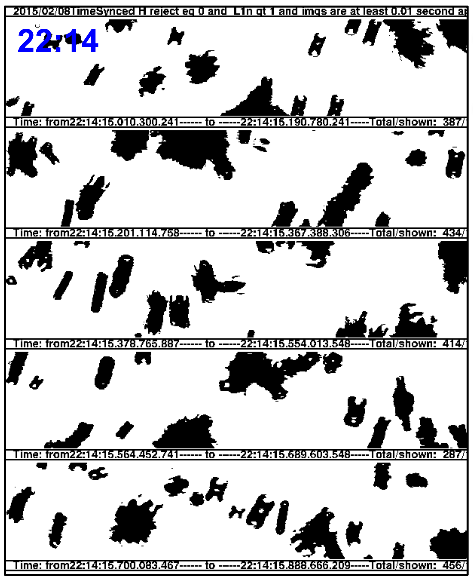

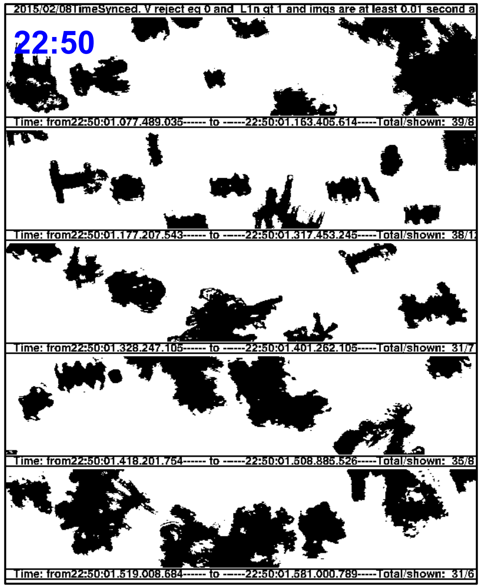

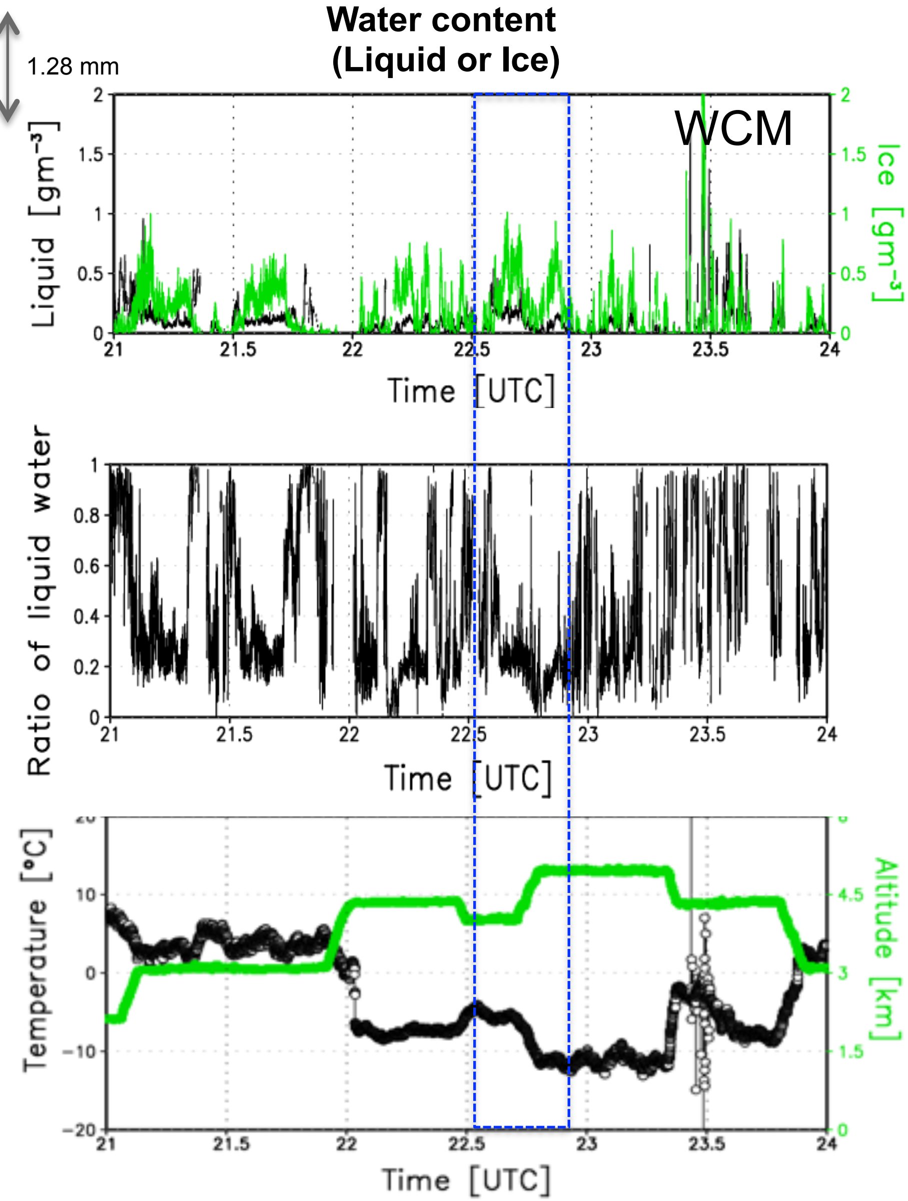

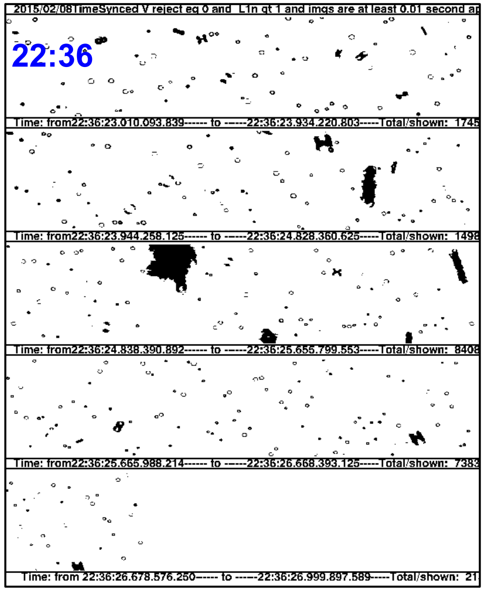

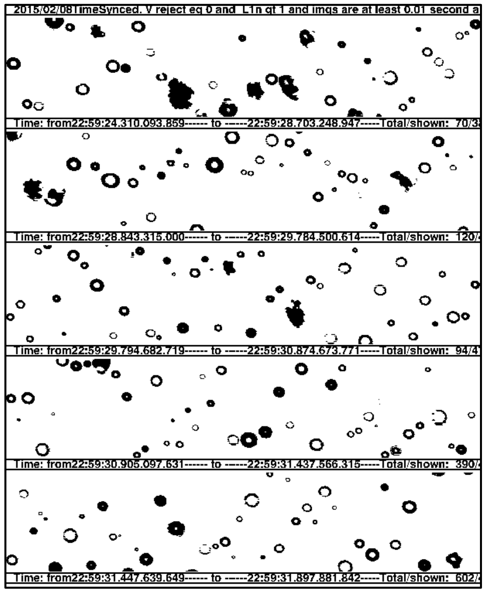

February 8: aerosol properties and sources

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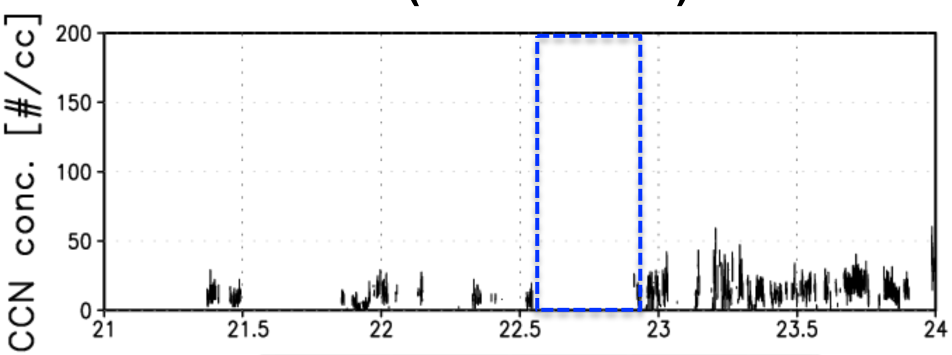
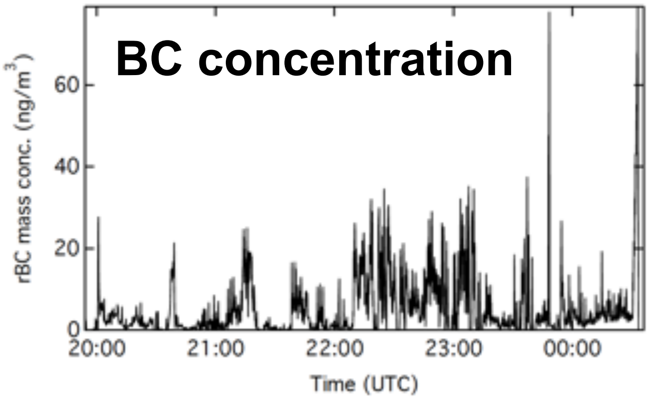
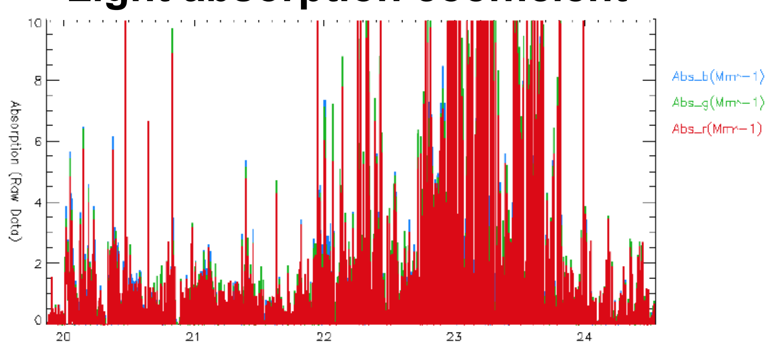
CCN (SS = 0.30%)

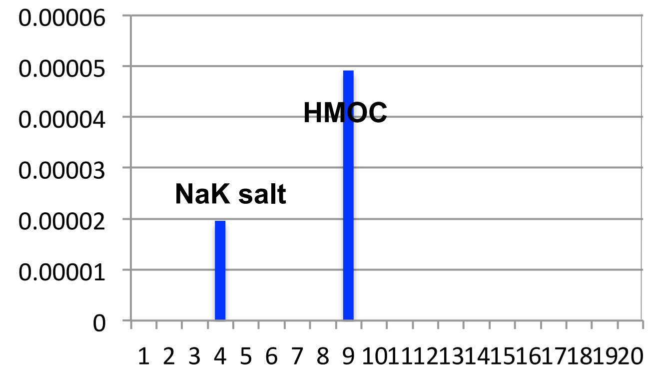


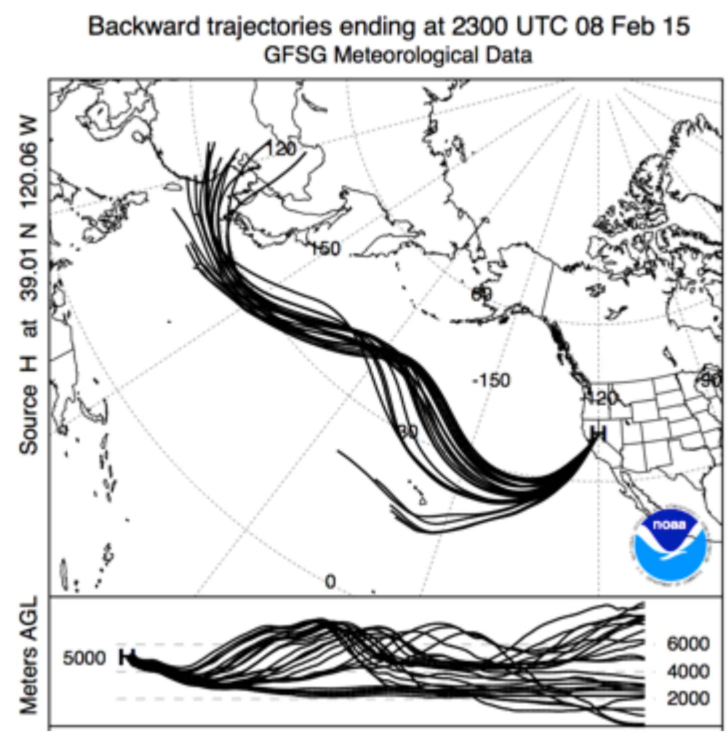


Light absorption coefficient



Ice Clouds: 22:35~22:55





CCN and IN impacts on supercooled liquid and cloud phase

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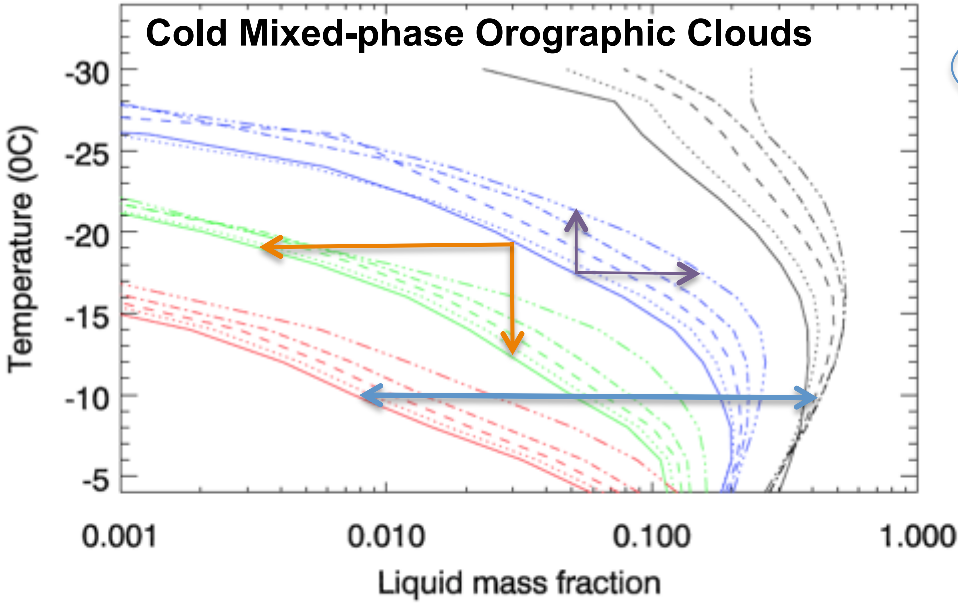
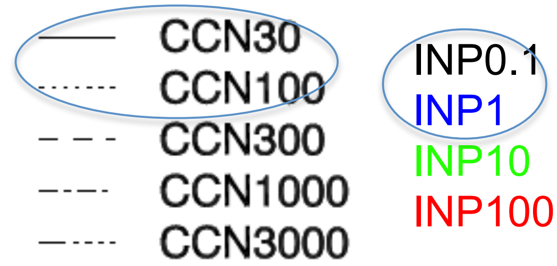
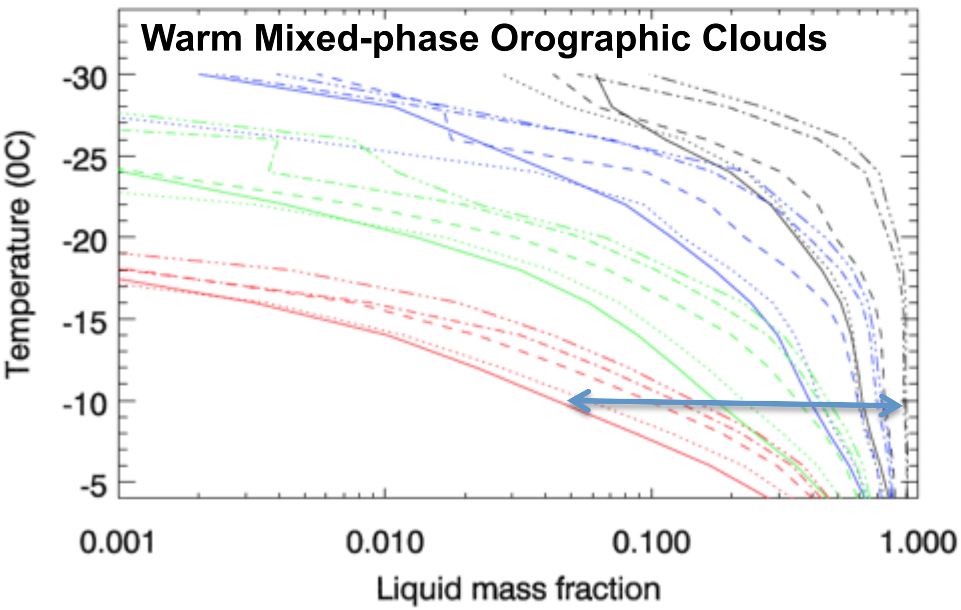
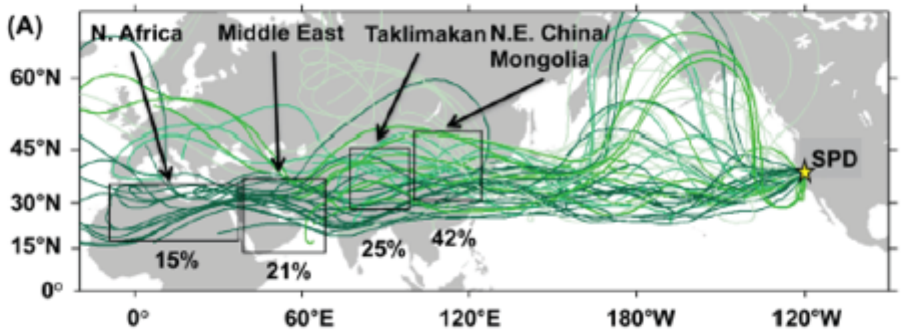




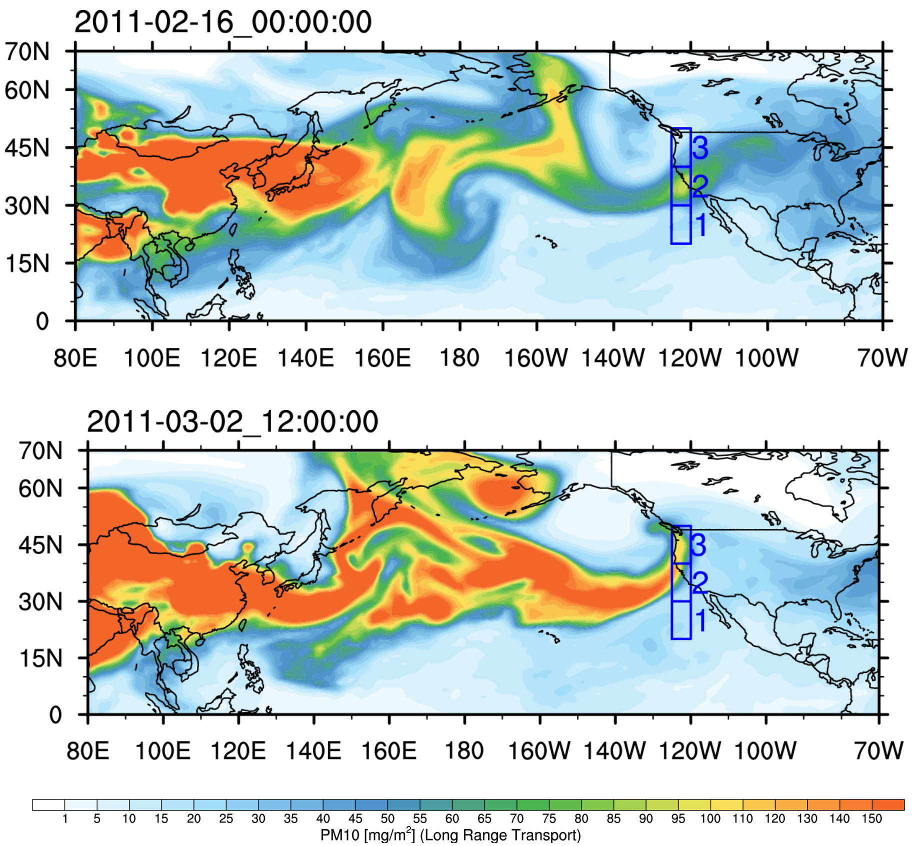


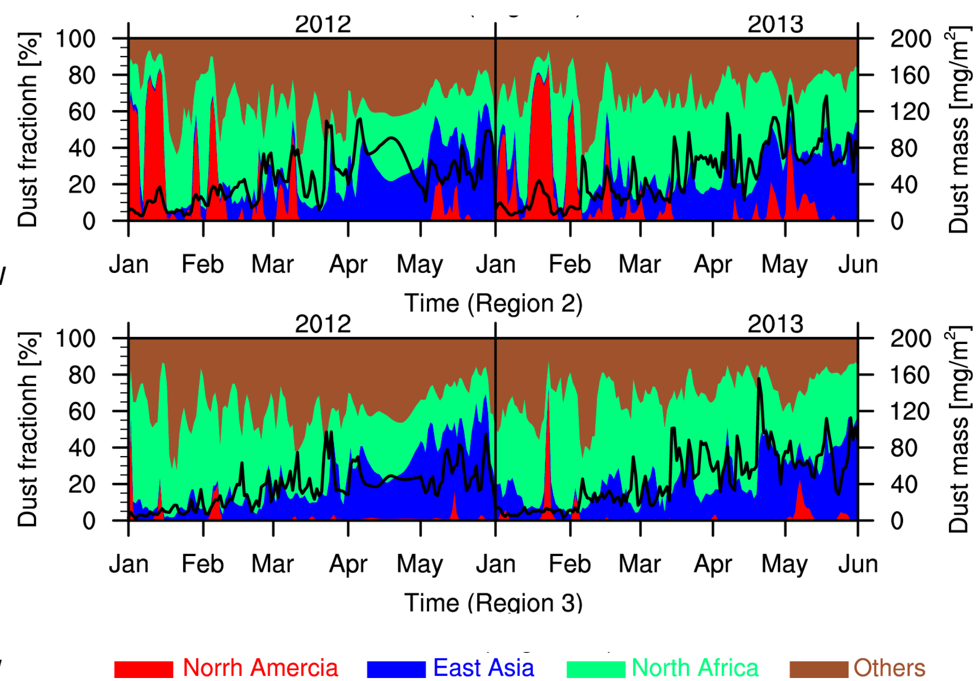
- Increasing CCN increases supercooled water (SCW), decreases cloud glaciation temperature (CGT) and expands the mixed-phase zone.
- Increasing INP for immersion freezing more dramatically reduces SCW, increases CGT and narrows the mixed-phase zone.
- SCW is less sensitive to INP for warm than cold mixed-phase clouds.

Dust transported along with AR



(Creamean et al. 2013)





Summary

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- ARM campaign:
  - http://www.arm.gov/campaigns/amf2015apexACAPEX
  - http://www.arm.gov/sites/amf/acx/news
- ARM feature story:
  - http://www.arm.gov/news/features/post/33667
- CalWater 2015 field campaign, including the daily weather forecasts, can be found in:
  - http://mead.ucsd.edu/?page_id=400
  - http://www.esrl.noaa.gov/psd/calwater/index.html
- ARM data repository
  - http://www.arm.gov/campaigns/amf2015apex
- AGU 2015 sessions (Precipitation, Weather, and Climate: Atmospheric Rivers and Aerosol-Cloud-Interaction Studies (A44C: Oral; A51L: Poster)

Summary

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Proudly Operated by **Battelle** *Since 1965*

- Aerosol and cloud microphysical data were collected before, during, and after a landfalling AR between February 5 – 8, 2016
- Generally low CCN of 10 – 100 per cc, low INP ~ 0.1 – 1 per L, cloud drop concentrations ~ 10 – 50 per cc per μm, and cloud drop size < 10 – 50 μm
- Despite low concentrations, aerosols have absorbing properties with chemical composition of organics and dust, and are likely transported over long range across the Pacific Ocean
- Because of low CCN hygroscopicity and low concentration of INP, very small supercooled cloud drops exist at low temperature and the mixed phase zone is large
- Important data for studying the impacts of CCN and IN on supercooled liquid and cloud phase, ice nucleation mechanisms, and precipitation forming mechanisms