UCSD

Impacts of Asian Dust on Cloud Microphysics and Precipitation during an Atmospheric River during the CalWater Early Start Campaign

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Background

The link between aerosols, clouds, and precipitation has received considerable attention in recent years due to the potential for changes in the transfer of solar radiation and the alteration of precipitation patterns. Despite the importance of these processes the large uncertainties associated with the aerosol indirect effect and lack of reliable predictions for precipitation pattern changes necessitates a more detailed understanding of cloud droplet and rain drop properties on a chemical and microphysical level. The research on this poster describes a collaborative effort between the University of California, San Diego, Scripps Institution of Oceanography, NOAA, and the California Energy Commission. This work is part of the CalWater experiment, which includes two major science elements focused on California precipitation in a changing climate, i.e., the role of aerosols in modulating orographic precipitation and the role of atmospheric rivers in creating extreme events and in providing a major portion of the region's water supply. This poster focuses on the aerosol-precipitation topic.

Aerosol Time-of-Flight Mass Spectrometry (ATOFMS)

- ATOFMS measures the aerodynamic size and chemical composition of individual aerosol particles in real time
- Particles are introduced to a differentially pumped vacuum chamber through a converging nozzle, accelerated to a terminal velocity, sized by 2 continuous wave lasers (532 nm), desorbed and ionized by a 266 nm Nd:YAG laser, and positive and negative ions are detected by MCP detectors

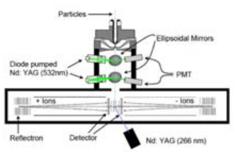


Figure 1: Diagram of the ATOFMS

CalWater Early Start - Winter 2009

Figure 2: Map of pre-CalWater sites

- **ATOFMS Mobile Laboratory**
  - **ATOFMS** – Single Particle Size and Chemical Composition
  - **Additional Aerosol Instruments:** CPC, APS, SMPS, CCN, and BAM-$PM_{2.5}$
  - **Rainwater** was collected in glass beakers, atomized, and sampled into the instrument immediately after collection
- **NOAA Portable Laboratory**
  - **Meteorological Station**
  - **2875-MHz Vertical S-Prof Radar**
    - Vertical Structure of Precipitation
  - **Parsivel Disdrometer**
    - Raindrop momentum

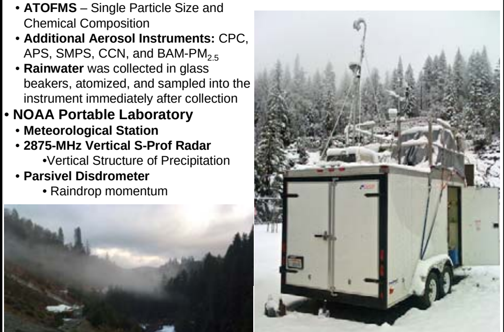


Figure 3: Pictures ATOFMS Mobile Laboratory at Sugar Pine Reservoir

Water Vapor Transport to California (Atmospheric Rivers)

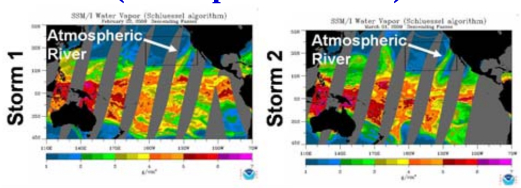


Figure 4: Measurements of integrated water vapor (IVR) for a) Storm 1 and b) Storm 2

- Atmospheric River Background
  - Atmospheric Rivers have been linked to flooding rains and are a significant contributor to precipitation on the western coast of the United States.
  - Orographic enhancement has been shown for Atmospheric Rivers that make landfall during the winter.[1]
  - Wintertime Atmospheric Rivers with the largest integrated water vapor (IVR) have in the past been linked to more intense storms, stronger flows and vapor fluxes, and more precipitation.[1]
- Atmospheric Rivers observed during CalWater Early Start
  - The Atmospheric River s shown here were identified using Special Sensor Microwave Imager (SSM/I) satellite measurements.
  - Atmospheric Rivers from Storms 1 and 2 can be seen reaching the California coast
  - Both storms qualify as atmospheric rivers using the criteria established in the Neiman et al. 2008 climatology study.[2]
  - Each storm shows a connection to the tropics, as is common for winter atmospheric rivers, but not summer ones.[1]

Air Mass Back Trajectories at Sugar Pine Reservoir

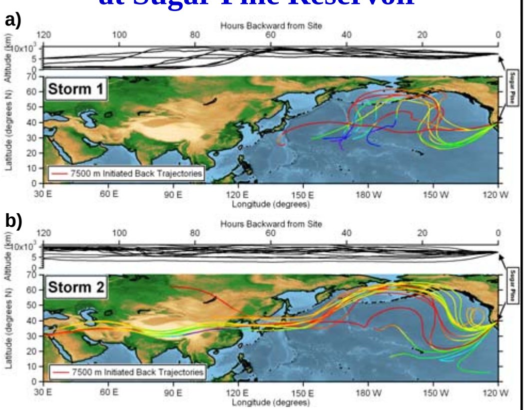


Figure 5: a) 5 day HYSPLIT Back Trajectories every 6 hours during Storm 1 (Feb 22-23, 2009) initiated at 7500 meters b) 5 day HYSPLIT Back Trajectories every 6 hours during Storm 2 (Mar 1-4, 2009) initiated at 7500 meters.

- Storm 1 was characterized by back trajectories scattered over the Pacific Ocean without a consistent pattern
- Storm 2 back trajectories began with trajectories ending over the Pacific (March 1), but for March 2-4 had a consistent path from Asia over the Pacific Ocean to the sampling site
- Storm 2 back trajectories passing over Asia have the fastest transport to North America on March 2 and March 3 before becoming less direct on March 4

Chemistry of Rainwater Residues

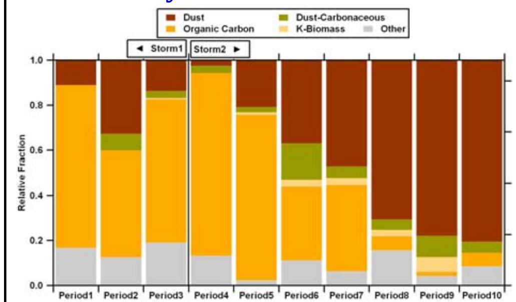


Figure 6: Chemistry of particle residuals for each rainwater sample that was run into the ATOFMS. The particle types are shown as a relative fraction for each sample.

- The chemical composition of the particles sampled by atomizing rainwater samples is fairly consistent during Storm 1 with a high fraction of organic carbon residues.
- During Storm 2 a shift is observed from primarily organic carbon residues to primarily dust residues. This shift occurs as the back trajectories show transport pattern from Asia building in.

Radar and Rain Chemistry

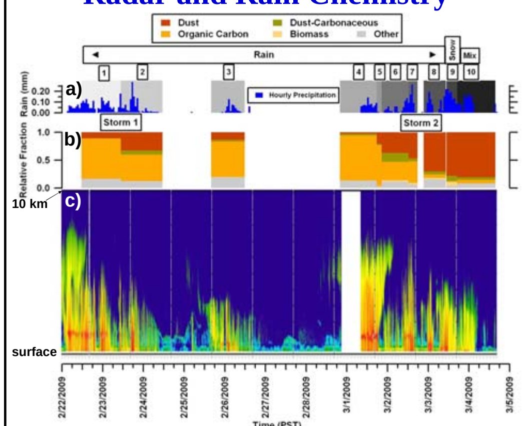
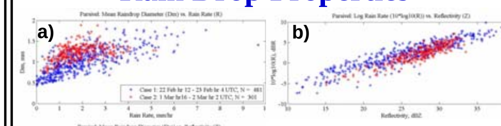


Figure 7: a) Hourly precipitation amounts and rainwater sampling periods b) rainwater particle residues by type over time c) radar reflectivity by height (0-10 km).

- During the 11 days period of precipitation captured by the CalWater Early Start campaign, over 10 inches of rainfall (including liquid equivalent from snow) fell at the Sugar Pine site and was sampled by the meteorological and aerosol sensors
- S-Prof Observed Vertical Structure of Precipitation
  - Storm 1 is characterized primarily by brightband rain at a consistent height (1 km)
  - Storm 2 begins with brightband position at 1 km, midday on March 2nd the bright band begins to decrease in altitude reaching the surface midday on March 3rd.
  - An echo at ~ 8 km was observed for both Storm 1 and Storm 2
  - Storm 2 has greater reflectivity for an extended altitude above the brightband and Storm 1 has intermittent precipitation above the brightband. These differences could be due to dynamical or chemical processes that need further investigation.
  - Greater reflectivity during Storm 2 could be due to larger snow particles above the melting layer that melt and reach the ground as larger rain drops, a possible connection to chemistry in generating this increased reflectivity structure is currently being studied

Rain Drop Properties



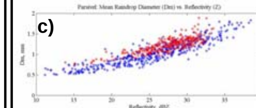
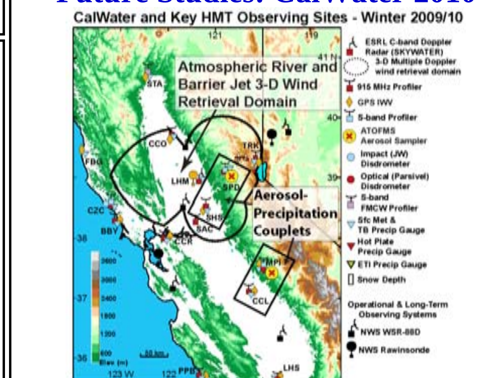


Figure 8: Rain drop properties as measured by the Parsivel Disdrometer for Case 1 (blue) and Case 2 (red). a) drop diameter (mm) vs. rain rate, b) drop diameter vs. reflectivity, and c) log rain rate vs. reflectivity

- A subset of measurements from Storm 1 are shown as Case 1 and for Storm 2 as Case 2, each case is entirely within a rain period
- Case 1 falls within Period 1 shown in Figures 6 & 7, Case 2 falls within Periods 4 & 5
- Differences can be seen between the populations sampled during Case 1 and Case 2
- Storm 1 has a more scattered distribution than Storm 2 in each of the plots
- Storm 2 had larger drops versus rain rate and larger drops versus reflectivity
- The larger rain drops for Case 2 may be due to larger snow particles melting and forming larger rain drops that reach the surface

Future Studies: CalWater 2010



- Other NOAA surface measurements are being deployed across California to help observe atmospheric rivers as they move across the state

Figure 9: UCSD-SIO and NOAA-HMT aerosol-met deployment plans for Winter 2009-2010

Conclusions and Future Directions

- Results are shown from the multidisciplinary effort combining meteorology, aerosol chemistry, and atmospheric science.
- Two atmospheric rivers of moisture transported from the tropics to the mid-latitudes were observed.
- Rainwater analysis comparing the two storms showed Storm 1 has primarily organic carbon as residues, while Storm 2 started with organic carbon residues, but shifted to a strong influence from dust.
- Hysplit back trajectory analysis suggests that the dust sampled in the rainwater may have been transported from Asia.
- Vertical S-prof radar showed the consistent bright-band height of storm 1 compared with the drop in bright-band height during storm 2.
- Two rain drop populations were observed with different properties between Storm 1 and the beginning of Storm 2, further analysis is needed to determine the contribution from dynamics and chemistry
- Additional IC, UV-Vis, and fluorescence measurements have been performed and will be analyzed in the future.
- These findings suggest that transported Asian dust may be influencing precipitation patterns in North America

References: (1) Neiman, P.J., F.M. Ralph, G.A. Wick, Y.H. Kuo, T.K. Wee, Z.Z. Ma, G.H. Taylor, and M.D. Dettinger, *Monthly Weather Review*, *136* (11), 4398-4420, 2008a.
(2) Neiman, P.J., F.M. Ralph, G.A. Wick, J.D. Lundquist, and M.D. Dettinger, *Journal of Hydrometeorology*, *9* (1), 22-47, 2008b.

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