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AN AEROSOL – METEOROLOGICAL OBSERVATORY IN SUPPORT OF THE CALWATER EXPERIMENT

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1. INTRODUCTION

Our current understanding of how climate is changing in California and how it may change in the future is hampered by incomplete scientific knowledge of how aerosols (small solid or liquid particles in the air) affect the distribution of energy in the atmosphere and the formation of clouds and ultimately the hydrologic cycle. The treatment of aerosols in global and regional climate models is one of the main sources of uncertainty in climate science (ICCP 2007).

While it was assumed that aerosols exert only a minor influence in "clean" areas of the world such as California, a modeling study concluded that aerosols are already affecting precipitation levels and surface temperatures in California (Jacobson and Kaufman 2006). Some preliminary field measurements suggest that aerosols may be reducing precipitation levels in the Sierra Nevada by 10 to 20 percent (Rosenfeld and Givati 2006). Also, black carbon (BC) that falls along with the snow may be contributing to the already observed early melting of snow (Flanner et al. 2007).

However, it has been questioned if aerosols act alone in reducing orographic precipitation (Alpert et al. 2008). Therefore, a field campaign is being designed to help evaluate the impact of aerosols on precipitation levels in California. This field campaign requires coordinated meteorological and aerosol observations to better isolate the impact of pollution (aerosols) on the precipitation processes from the naturally occurring meteorological processes.

2. CALWATER – A NEW FIELD CAMPAIGN

The California Energy Commission (CEC) and NOAA are leading an effort to implement a field research project called CalWater. CalWater is a campaign that includes scientists from NOAA, University of California, Scripps Institution of Oceanography, California Department of Water Resources, California Air Resource Board (CARB) and other US and international universities.

The CalWeter field campaign is scheduled for the 2010 winter season (Dec '09 – Mar '10).

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CalWater will address the question: *Does anthropogenic pollution reduce wintertime precipitation in the Sierra Nevada, thereby causing a negative impact on California's annual water supply?*

3. AEROSOL-MET OBSERVATORY

Special observing stations and transects of observing stations will be used in CalWater to isolate the role of aerosols from meteorological processes in orographic precipitation. An Aerosol – Meteorological Observatory (Aerosol – Met Observatory) consists of sampling instruments to identify the chemical content and size of aerosols inside individual raindrops and snowflakes along with remote sensing radars to diagnose the precipitation vertical structure.

The instruments to determine the chemistry and size of aerosols include the University of California at San Diego (UCSD) Aerosol Time of Flight Mass Spectrometer (ATOFMS) and the University of California at Davis (UCD) 8-stage Rotating Drum Impactor (8-RDI). NOAA's vertically pointing Doppler radar provides information on the dynamics and vertical structure of the precipitating system that generated the surface rainfall and snowfall.

4. TRANSECTS: FROM VALLEY TO SUMMIT

The observations collected along transects from the valley to the summit provide dynamical context to help isolate the role of aerosols in the precipitation processes. Three transects are planned for the CalWater 2010 winter field campaign as shown in Figure 1. The Aerosol – Met observing station will be located at the mid-mountain site in order to sample the precipitation that has experienced some orographic influences. The vertically-pointing radar will provide information about the height of the freezing level and if the surface rain had ice processes aloft or was entirely ice-free.

The upwind valley location provides horizontal wind and meteorological conditions including GPS integrated water vapor. And the high-mountain site is expected to be in the snow regime with rain only occurring at the beginning and end of the season and during extremely warm weather events. The coastal transect only needs two observing stations because the top of the coastal mountain remains below the freezing level for most of the winter season.

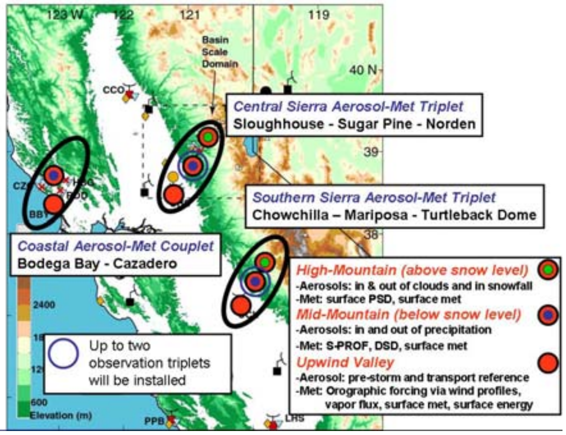

Figure 1. Aerosol – Meteorological Observatory Transects planned for the 2010 winter (Dec '09 – Mar '10) CalWater field Campaign.

5. CALWATER THEMES

To help identify the meteorological and chemistry aspects of orographic precipitation, CalWater has two major research themes: Aerosol Precipitation (AP) and Atmospheric Rivers (AR).

5.1 Aerosol Precipitation (AP)

The objective of the Aerosol Precipitation (AP) theme is to study potential impacts of anthropogenic aerosols on precipitation in California via state-of-the-art meteorological observations and physical understanding of orographic precipitation, and to determine how much of the surface precipitation may be caused by pollution modifying the precipitation processes versus how much of this variability can be explained by naturally occurring atmospheric phenomena. The Aerosol – Met Observatory was developed to directly focus on this objective.

5.2 Atmospheric River (AR)

The objective of the Atmospheric River (AR) theme is to study the impacts and variability of surface precipitation during atmospheric river events as they make landfall in the California coastal ranges and as the moisture transports across the Central Valley to the Sierra Nevada. During these events, cold air masses, caused by barrier jets, can be trapped on the upwind side of the mountains increasing the orographic foot-print of the mountains altering the amount and the position of surface rainfall or snowfall on the mountains.

Barrier jets along the California coastal mountains and along the Sierra Nevada are not well understood and are not well represented in the global and regional scale models. Understanding how barrier jets are represented in the models is central to testing the alternative hypothesis that the barrier jet can alter the orographic rain ratio more than the affects due to aerosols.

6. CALWATER EARLY START CAMPAIGN

There was an opportunity to instrument the Central Sierra Aerosol – Met Triplet shown in Figure 1 for a three-week period in the 2009 winter season. The Aerosol – Met observatory was placed about half-way up the Sierra Nevada in the American River Basin (ARB) at the Sugar Pine Reservoir. Figure 2 shows UCSD's ATOFMS trailer and NOAA's S-band profiler antenna during the Early Start deployment in February – March 2009.

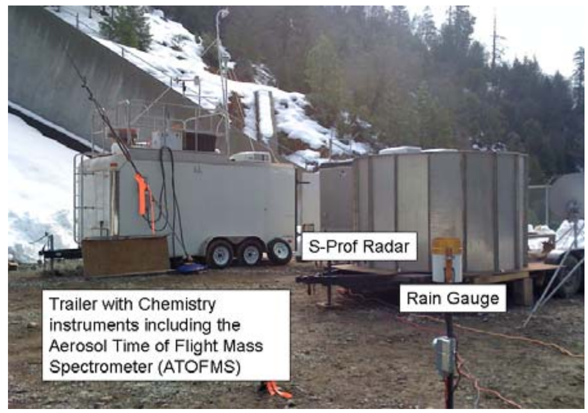

Figure 2. Photograph of UCSD's ATOFMS trailer and chemistry instruments, and NOAA's S-band profiler (S-Prof) and surface rain gauge. (Photo credit: Jessie Creamean.)

A transect of observations from the valley to the summit were possible by using observations collected in NOAA's Hydrometeorological Testbed (HMT, hmt.noaa.gov) along the I-80 corridor. The HMT observations provide meteorological context to determine how much of the surface precipitation may be caused by pollution modifying the precipitation processes versus how much of this variability can be explained by naturally occurring atmospheric phenomena.

During the three-week CalWater Early Start campaign in late February to early March 2009, over 10 inches of surface rain and Snow Water Equivalent (SWE) accumulated at the Sugar Pine Reservoir with up to 20 inches of SWE falling at higher elevations in the Sierra Nevada.

7. INITIAL ANALYSIS

The initial analysis of the meteorological and aerosol chemistry from the Early Start Campaign has just begun. But initial analyzes of Aqua Aerosol Optical Depth at 550 nm and air-parcel back trajectories suggest that the chemical composition of a snow event in the Central Sierra Nevada can be traced back to Asian dust that was transported across the Pacific. Also, initial analyzes suggest that an Atmospheric River event at the same time was supplying moisture from the Tropics into California. Observations from the winter 2010 CalWater field campaign and more in-depth analysis will be needed to better isolate the impact of pollution (aerosols) on the precipitation processes from the naturally occurring meteorological processes.

8. REFERENCES

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