Oral Session

Tuesday, 06 December 2011

Time	Session Info
1:40 PM-3:40 PM, Room 3002 (Moscone West), **A23E. Aerosol, Cloud Properties, Atmospheric Rivers, and Precipitation in California: CalWater II**	
1:40 PM-1:55 PM	**A23E-01. Determination of the sources and impacts of aerosols on clouds and orographic precipitation during CalWater** K.A. Prather; K. Suski; A. Cazorla; J.F. Cahill; J. Creamean; D.B. Collins; F.M. Ralph; D.R. Cayan; D. Rosenfeld; P.J. DeMott; R.C. Sullivan; J.M. Comstock; L. Leung; J.M. Tomlinson; G.C. Roberts; A. Nenes; J.J. Lin
1:55-2:10 PM	**A23E-02. CALWATER Overview of the G1 aircraft measurements of cloud-aerosol interactions within winter storms** ***(Invited)*** D. Rosenfeld; K.A. Prather; J.M. Comstock; P.J. DeMott; A. Cazorla; R. Chemke; K. Suski; E. Freud; L. Leung
2:10-2:25 PM	**A23E-03. Dependence of Ice Formation in Sierra Winter Orographic Clouds on the Mixing State of Aerosols Serving as Ice Nuclei** ***(Invited)*** P.J. DeMott; K.A. Prather; R.C. Sullivan; K. Suski; J.M. Comstock; J.M. Tomlinson; D. Rosenfeld; A.J. Prenni; A. Cazorla
2:25-2:40 PM	**A23E-04. Multiyear Evidence from Ground-based Observations and Modeling of the Impact of Dust on Snowfall in the Sierra Nevada** J. Creamean; A.P. Ault; D.B. Collins; J.F. Cahill; E. Fitzgerald; A.B. White; P.J. Neiman; G.A. Wick; J. Fan; L. Leung; F.M. Ralph; K.A. Prather
2:40-2:55 PM	**A23E-05. Initial Steps Toward Understanding the Interactions between the Sierra Barrier Jet and Landfalling Atmospheric Rivers** ***(Invited)*** P.J. Neiman; M.R. Hughes; E. Sukovich; B. Moore; D. Kingsmill; F.M. Ralph
2:55-3:10 PM	**A23E-06. Representation of the Sierra Barrier Jet in 11 years of a high-resolution dynamical reanalysis downscaling** M.R. Hughes; P.J. Neiman; E. Sukovich; F.M. Ralph
3:10-3:25 PM	**A23E-07. Physical Controls on Spatial Variations of the Rain-Snow Boundary over the Northern Sierra Nevada** J.R. Minder; D. Kingsmill
3:25-3:40 PM	**A23E-08. Modeling aerosol effects on winter storms: Case studies from the SUPRECIP2 and CalWater field experiments in central California** ***(Invited)*** L. Leung; J. Fan; B.H. Lynn; D. Rosenfeld; A. Khain; K.A. Prather

Final ID: A23E-01

Determination of the sources and impacts of aerosols on clouds and orographic precipitation during CalWater

K. A. Prather; [1, 2]; *K. Suski;* [1]; *A. Cazorla;* [1]; *J. F. Cahill;* [1]; *J. Creamean;* [1]; *D. B. Collins;* [1]; *F. M. Ralph;* [6]; *D. R. Cayan;* [2]; *D. Rosenfeld;* [5]; *P. J. DeMott;* [3]; *R. C. Sullivan;* [3]; *J. M. Comstock;* [4]; *L. Leung;* [4]; *J. M. Tomlinson;* [4]; *G. C. Roberts;* [2]; *A. Nenes;* [7]; *J. J. Lin;* [7];

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Body: Climate projections for the remainder of this century for the U.S. Southwest, including parts of California, suggest a drying trend (reductions ~ 10 -15 %). Thus, understanding factors which could potentially influence the amount and type of precipitation is critical to future water resources in California. Previous studies suggest aerosols transported from the Central Valley into the mountains may be reducing the amount of orographic precipitation in the Sierra Nevada mountain range, the key region for water storage in the snowpack. CalWater, which commenced in the Winter of 2009, is an ongoing multi-year, multi-agency field campaign to investigate the primary sources of aerosols influencing clouds and precipitation in this region. Single particle measurements, used in both ground as well as PNNL G1 aircraft measurements, in the recent campaign provide insight into the sources of aerosols impacting the clouds and precipitation. Biomass burning, Central Valley pollution, long range transported Asian dust and pollution, locally generated newly formed particles, and marine aerosols all show strong impacts on the cloud microphysical properties. This presentation will provide a brief overview of the objective and key findings from CalWater measurements of aerosols, precipitation, clouds, and meteorology conducted from 2009-2011 in this region.

Final ID: A23E-02

CALWATER Overview of the G1 aircraft measurements of cloud-aerosol interactions within winter storms *(Invited)*

D. Rosenfeld; [1]; *K. A. Prather;* [2]; *J. M. Comstock;* [3]; *P. J. DeMott;* [4]; *A. Cazorla;* [2]; *R. Chemke;* [1]; *K. Suski;* [2]; *E. Freud;* [1]; *L. Leung;* [3];

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4. Atmospheric Science, Colorado State University, Fort Collins, CO, United States.

Body: A major component of CalWater 2011 was an aircraft campaign with an extensive suite of cloud physics, aerosol, and trace gases instruments. The aircraft flew nearly 70 hours mainly during winter storms over the Sierra Nevada, Central Valley, the Bay area, coastal range and ocean between 1 Feb and 7 Mar 2011. Some of the unique aspects of this campaign that were the basis for the reported initial findings here were: (1) aerosol time-of flight mass spectrometry (ATOFMS) that provided particle by particle chemical composition; (2) Continuous Flow Diffusion Chamber for detecting ice nuclei; (3) Counterflow virtual impactor (CVI) for sampling the residues of evaporated cloud particles or interstitial aerosol; (4) Cloud drop and hydrometeor probes; (5) 3-D winds and thermodynamic parameters. The aircraft was able to document the clouds from the foothills to the crest of the Sierra Nevada at the section between Sacramento and Fresno during several major winter storms and obtain an unprecedented dataset of the cloud dynamics, microphysics and aerosols during fair weather, atmospheric rivers, barrier jet, pre-frontal, frontal and post frontal conditions.

Convective clouds are very often triggered at the foothills of the Sierra Nevada by the start of the rising motion. This triggering is often advanced upwind (westward) due to the blocking effect that is typically associated with a barrier jet. When cloud bases are decoupled from the boundary layer they do not ingest the locally generated aerosols, but rather the pristine air that comes from the ocean. With more southerly back trajectories local decoupling can still bring air pollution from the LA basin, for example. Profound differences in aerosol and cloud microstructure were observed between the coupled and decoupled clouds at the Sierra foothills, where, as expected, the decoupled clouds had a more marine nature.

In addition to triggering convective clouds at the foothills, the orographic lifting of the air mass creates cap clouds over the upper slopes and the crest. These clouds form in air that is decoupled from the boundary layer and contains aerosols that originated from somewhere over the Pacific and/or in many cases of long range transport from Asia. Conspicuous events of air pollution, mineral dust and other biogenic aerosols were documented to affect profoundly the cloud drop size distributions and ice forming processes in the cap clouds.

Often the convective clouds grow into the cap clouds and penetrate them, creating situation of embedded convection, where the convective elements are embedded in very different types of clouds. Being able to directly measure the different aerosol types and origins is critical for disentangling these mixes of clouds that are affected quite differently by aerosols from very different sources.

Specific examples will be presented.

Final ID: A23E-03

Dependence of Ice Formation in Sierra Winter Orographic Clouds on the Mixing State of Aerosols Serving as Ice Nuclei *(Invited)*

P. J. DeMott; [1]; *K. A. Prather;* [2]; *R. C. Sullivan;* [1]; *K. Suski;* [2]; *J. M. Comstock;* [3]; *J. M. Tomlinson;* [3]; *D. Rosenfeld;* [4]; *A. J. Prenni;* [1]; *A. Cazorla;* [2];
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Body: The CalWater study of February to March 2011 offered the opportunity for observations of aerosols from local, regional and long distance sources as they were integrated into clouds and precipitation in the Sierra Nevada. Single particle chemical analysis of cloud particle residual nuclei and surface precipitation, and their association with changes in cloud microphysical differences, suggest that ice initiation and precipitation formation were strongly affected by intrusions of Asian dust. This is consistent with coincident processing of aerosols present in ambient air and cloud particle residuals as ice nuclei. Elevated ice nuclei concentrations were associated with the presence of dust detected in cloud particle residuals, and dust particles dominated ice nuclei chemical compositions assessed by transmission electron microscopy x-ray analyses at these same times. Evidence of the role of Asian dust as ice nuclei during 2011 are consistent with back trajectory analyses and with recently published observational findings from CalWater Early Start data from 2009. The relative roles of aerosols from the marine boundary layer, biomass burning, and pollution as ice nuclei will also be discussed.

Final ID: A23E-04

Multiyear Evidence from Ground-based Observations and Modeling of the Impact of Dust on Snowfall in the Sierra Nevada

J. Creamean; [1]; *A. P. Ault;* [2]; *D. B. Collins;* [1]; *J. F. Cahill;* [1]; *E. Fitzgerald;* [1]; *A. B. White;* [3]; *P. J. Neiman;* [3]; *G. A. Wick;* [3]; *J. Fan;* [4]; *L. Leung;* [4]; *F. M. Ralph;* [3]; *K. A. Prather;* [1, 5];

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Body: Aerosols that have the ability to act as ice nuclei (IN) can impact cloud formation and alter the type, amount, and location of precipitation. IN such as dust and biological aerosols can lead to early initiation of the ice phase that enhances riming and thus precipitation. Depending on temperature conditions, this can lead to increased snowfall at the surface. Potential snowfall enhancement in mountainous regions such as California’s Sierra Nevada has large implications on regional water supply, which in turn can affect agricultural and ecosystem productivity, the amount of renewable energy from hydropower, and many other water uses. However, the magnitude of the effect of IN on precipitation intensity, form, and patterns during intense winter storms in the Sierra Nevada is poorly understood. During three consecutive winters (2009-2011) of the CalWater field campaign, the chemical composition of precipitation residues were measured at Sugar Pine Dam, a remote rural site in the Sierra Nevada. Some precipitation events occurred during storms that were characterized by atmospheric river (AR) conditions, which are ideal for generating copious amounts of orographic precipitation. Large fractions of dust and biological aerosols were measured as residues in precipitation samples collected during storms with increased snowfall and lower surface temperatures. In most cases, higher fractions of dust were measured in samples during stronger ARs, while higher fractions of biological or water-insoluble organic residues were measured during weaker ARs throughout all three winters. During the winter storms of CalWater, we observed an increase over time in the fraction of dust and biological residues combined, from 20% in 2009 to 82% in 2011 of the total residues in all precipitation samples, in addition to a decrease in average surface temperature (from 4.8 to 2.3 °C), an increase in the total amount of precipitation (from 253 to 374 mm), and an increase in the frequency of storms with snow at the surface (from 10% to 36% of the total storms). In addition, in 2011, precipitation samples collected and analyzed from sites at several elevations in Yosemite compared to Sugar Pine Dam show higher fractions of dust with increasing elevation. The unique combination of experimental meteorological and aerosol measurements during CalWater will be used, along with standard meteorological data, to explore how variations of the meteorological forcings affected these changes, and how aerosols could have contributed. Observational data from CalWater will be used to evaluate model predictions of snowfall patterns and rates in the Sierra Nevada based on chemical composition of IN and meteorological observations. The overarching goal is to better understand aerosol-cloud-precipitation interactions in the Sierra Nevada and the impacts of aerosols on California’s water supply during winter ARs.

Final ID: A23E-05

Initial Steps Toward Understanding the Interactions between the Sierra Barrier Jet and Landfalling Atmospheric Rivers *(Invited)*

P. J. Neiman; [1]; *M. R. Hughes;* [2]; *E. Sukovich;* [2]; *B. Moore;* [2]; *D. Kingsmill;* [2]; *F. M. Ralph;* [1];
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Body: We have begun to analyze data recorded at multiple observing platforms in California to explore interactions between the orographically blocked Sierra barrier jet (SBJ) and landfalling atmospheric rivers (ARs), and to investigate the modulation of AR precipitation by the SBJ. The first step in this research path involves documenting the evolution of specific SBJ cases during the Calwater winters of 2010 and 2011. Preliminary case-study results based on a network of 915 MHz wind profilers, vertically pointing S-band radars, and surface meteorological observing sites reveal a vertically suppressed SBJ east of the Carquinez Strait near Sacramento relative to the concurrently observed SBJ in the Sacramento Valley to the north and in the San Joaquin Valley to the south. To investigate the representativeness of these case study results, we are generating multi-winter SBJ composites from wind profilers located throughout the Central Valley. [Recent published work by Jessica Lundquist shows an inverse relationship between the altitude of the SBJ at the Chico wind profiler and the orographic precipitation gradient along the windward slope of the northern Sierra Nevada.] Additional preliminary case-study analyses suggest that landfalling ARs ride over the top of the SBJ. Also, the SBJ erodes more quickly in the San Joaquin Valley than in the Sacramento Valley, at least for one of the cases explored. Finally, a wind-profiler-based orographic precipitation analysis (the first of its kind in the Sierra) quantitatively links the SBJ to heavy precipitation at the north end of the Sacramento Valley, and it establishes a statistical connection between the incoming AR air stream above the SBJ and orographic precipitation along the windward slope of the Sierra. We will present case-study observational results from at least two SBJ events. Through follow-on numerical modeling sensitivity studies, we will attempt to quantify the role of California's unique orography (e.g., the laterally confined Carquinez Strait, the northward constriction of the Sacramento Valley, and the western protrusion of the northern Sierra toward the Sacramento Valley) in modulating SBJ characteristics, show the entrainment of AR water vapor into the SBJ environment, and document the resulting redistribution of precipitation.

Final ID: A23E-06

Representation of the Sierra Barrier Jet in 11 years of a high-resolution dynamical reanalysis downscaling

M. R. Hughes; [1, 2]; *P. J. Neiman;* [2]; *E. Sukovich;* [1, 2]; *F. M. Ralph;* [2];
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Body: The Sierra Barrier Jet (SBJ) is a dynamically-generated low-level jet along the windward (i.e., western) slope of the Sierra Nevada of California that influences precipitation distribution and aerosol/water vapor transport in California's Central Valley. Because of its importance to local climate and weather conditions, its representation in numerical models is critical. However, the climatic representation of the SBJ within numerical models is undocumented. This project investigates how well the SBJ is represented in numerical models, primarily documenting its representation within a high-resolution, 11-year WRF reanalysis downscaling. We undertake a comprehensive validation of this dynamical downscaling during 11 cool seasons (water years 2001-2011, Oct.-Mar.) with available wind profiler data at Chico, CA (CCO). Using the SBJ objective identification tool described in Neiman et al. (2010), we identify SBJ cases in the CCO wind profiler data, as well as in the WRF data at the gridpoint nearest this site; WRF's representation of the SBJ is compared with that of other reanalysis products with different horizontal resolutions (e.g., the North American Regional Reanalysis) to assess the spatial resolution necessary to correctly capture this topographically-induced low-level jet. The modeled timing, strength, altitude, and duration of the SBJ at CCO are compared with observations. A catalog of modeled events that have significant timing overlap with the observations is created and used to further assess the model's representation of the winds during SBJ events. In addition, observation-model comparisons of other meteorologically important variables during wintertime storms that impact California (e.g., bright band height at CCO, profiles of winds throughout CA, and Central Valley boundary layer temperature profiles) are performed in order to evaluate WRF's ability to capture the dynamical evolution of the SBJ.

Final ID: A23E-07

Physical Controls on Spatial Variations of the Rain-Snow Boundary over the Northern Sierra Nevada

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Body: Observations from several major mountain ranges reveal that the height of the transition from snowfall to rainfall, the snowline, can intersect the terrain at an elevation hundreds of meters below its elevation in the free air upwind. By altering the distribution of precipitation phase across the landscape, this mesoscale lowering of the snowline may have major implications for both the accumulation of mountain snowpack and the generation of storm runoff. Previous work attributes such modifications of the snowline to some combination of spatial variations in latent cooling from melting hydrometeors, in adiabatic cooling from lifting, and in hydrometeor melting distance.

A unique climatological view of this behavior comes from from profiling radars in the northern Sierra Nevada deployed as part of NOAA's Hydrometeorlogical Testbed. They show that the mesoscale lowering of the snowline is a robust feature common to most storms. On average the snowline drops by at least 200 m as it approaches the terrain, but snowline drops of over 1 km are not uncommon.

For case studies over the northern Sierra, the physical processes responsible for the lowering of snowline are diagnosed using a synthesis of mesoscale numerical model output and observations. Comparisons of high resolution simulations using the WRF model with radar profilers and sondes show the model is capable of reproducing the observed lowering of the snowline. The role of different mechanisms is quantified in the model through a detailed analysis of modeled airflow, thermodynamics, and microphysics as well as through additional sensitivity experiments. For one case, with a snowline lowering similar to the climatological mean, it is shown that adiabatic cooling from lifting is the dominant mechanism acting to lower the snowline. Exploring the differences between cases such as this and those with kilometer-scale drops will be used to understand storm-to-storm variability in the snowline's behavior and the attendant hydrological impacts.

Final ID: A23E-08

Modeling aerosol effects on winter storms: Case studies from the SUPRECIP2 and CalWater field experiments in central California *(Invited)*

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Body: The western U.S. receives precipitation predominantly during the cold season when storms approach from the Pacific Ocean. The snowpack that accumulates during winter storms provide more than 70% of water supply for the region. Recent studies have documented the role of aerosols to influence clouds and precipitation, with the potential to redistribute and alter the characteristics of precipitation in the mountainous region. These studies have motivated several field experiments to investigate the role of aerosols in cloud microphysical processes and precipitation formation associated with winter storms. Analyses of field measurement data have yielded significant insights and provided the basis to formulate and test different hypotheses about aerosol effects on precipitation. Using data collected from the SUPRECIP2 and CalWater field campaigns, several cases have been selected for modeling aerosol effects under different synoptic environments ranging from postfrontal shallow clouds to deep convective clouds associated with atmospheric rivers in central California. Results from modeling using an explicit bin microphysics scheme will be discussed, with the goal to combine data and modeling to improve our understanding of the linkages between aerosols and precipitation in the topographically diverse region.