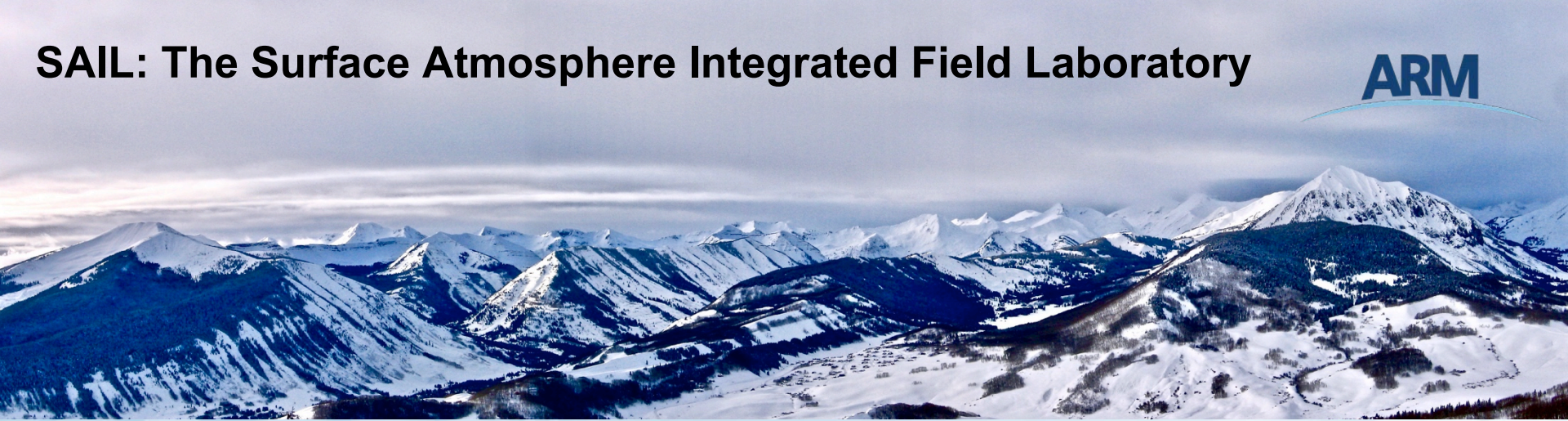
SAIL: The Surface Atmosphere Integrated Field Laboratory



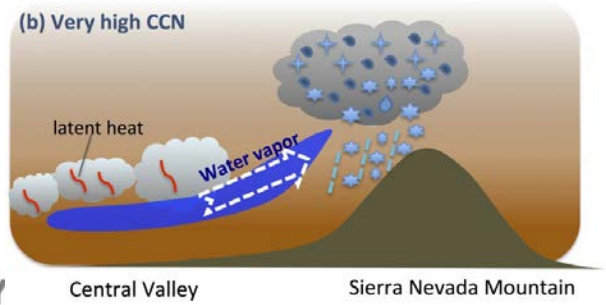
Science Objective on Aerosol-Cloud-Precipitation

Jiwen Fan, Paul DeMott

Aerosol-orography-precipitation interaction

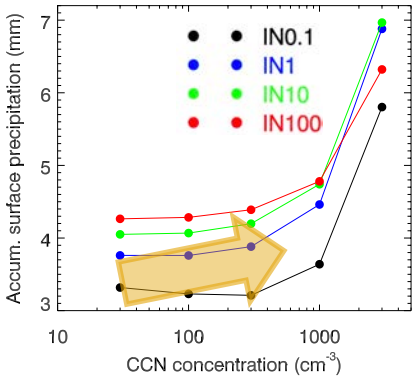
Aerosol impacts on precipitation over mountainous regions depend on

1. Aerosol properties (e.g. Givati and Rosenfeld, 2004; Fan et al., 2014; 2017)
2. Atmospheric conditions, particularly relative humidity and temperature (e.g. Lynn et al., 2007; Saleeby et al., 2009; Fan et al., 2014, 2017)

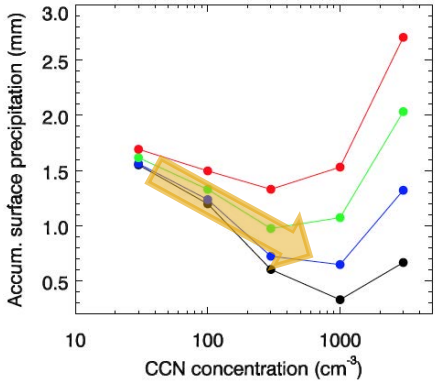


CCN and INP (dust) impacts on precip of mixed-phase clouds impacted by atmospheric river

Cold mixed-phase clouds
CTT < -20˚C



Warm mixed-phase clouds
CTT > -20˚C



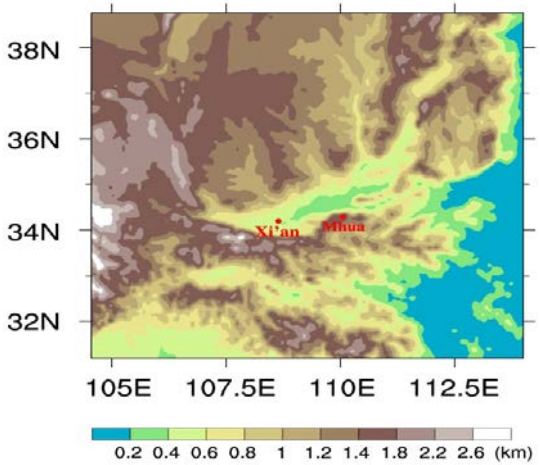
More shallow clouds in the valley → **Enhance local circulation** → **More zonal transport of moisture and invigorated mixed-phase cloud**

Fan et al. 2017, ACP

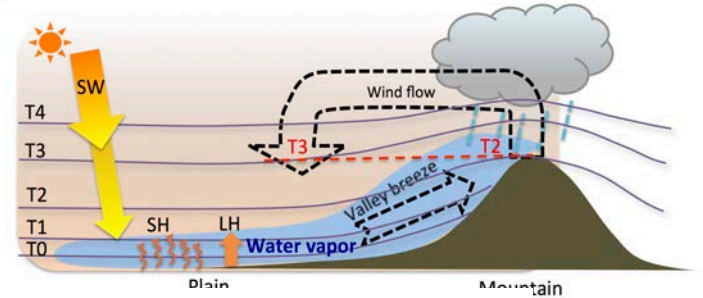
Aerosol-orography-precipitation interaction

With absorbing aerosols, aerosol-radiation interaction (ARI) leads to suppressed precipitation, because of weakened mountain-valley circulation

Mt. Hua of Central China

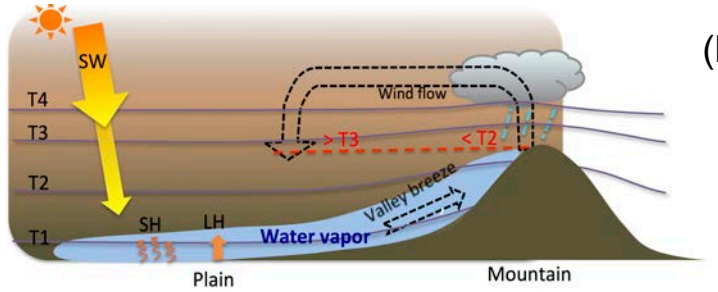


Clean condition



Temperature: T0>T1>T2>T3>T4

Polluted (absorbing aerosols)



Weakened mountain-valley circulation due to

(a) strong absorbing aerosols leads to increased temperature at the elevated layer over the valley but reduced T at the mountain top, leading to smaller T differences

(b) Aerosols strongly cool surface at the valley, which goes against air rising

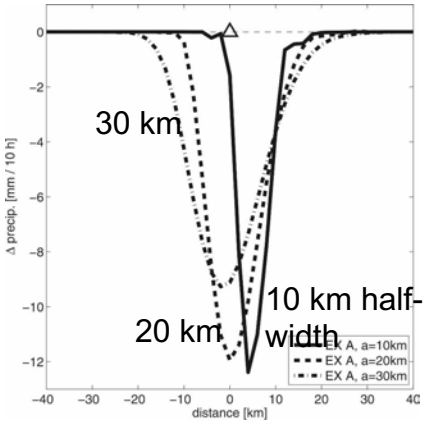
Yang et al., JAS, 2016

Aerosol-orography-precipitation interaction

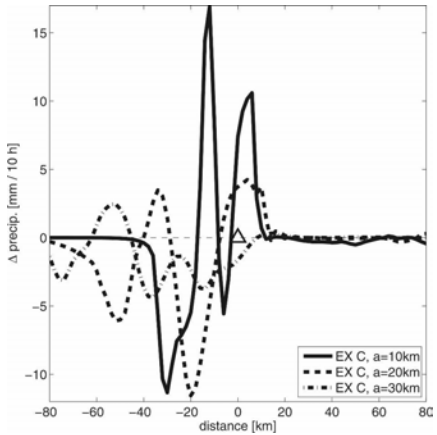
3. The terrain features (e.g., mountain height and cross-mountain width) and dynamic flow and synoptic conditions.

Difference in rain for warm clouds (Pollu - Clean)

1 km height

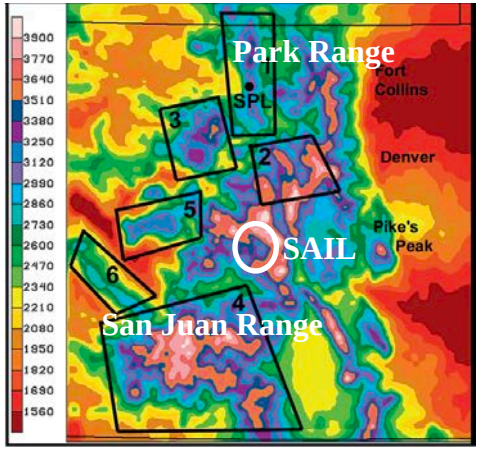


3 km height

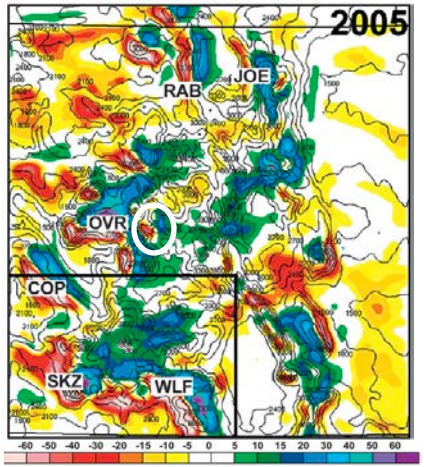


Mühlbauer and Lohmann, 2008, JAS

Topography



Snow increase (blue) and decrease (red) by CCN



- Snow increase and spillover effect is more significant over the high mountains in the south where moisture is also more ample.
- The effect varies by season. Greatest in heavy snowfall seasons.

Saleeby et al., 2010, JAMC

Science question

Overall: How strongly do aerosols affect the surface energy and water balance by altering clouds, precipitation, and surface albedo, and how do these impacts vary seasonally?

- Do **new particle formation events** control the variability of aerosol hygroscopicity and CCN concentrations?
- What are the contributions of **biological particles, wildfires, and long-range transported dust to INP concentrations**, do they vary seasonally, and are they linked strongly to precipitation efficiency of clouds?
- How does the **aerosol-precipitation relationship vary** with different aerosol regimes, and atmospheric dynamic and thermodynamic conditions?

Instruments and data

Aerosol

- Aerosol radiative and hygroscopic properties, PSD, CCN, and the ARM ice nucleating particle (INP) filters for immersion freezing (new mentorship)

Cloud and precipitation

- Precipitation rate, types,
- Cloud phase, hydrometeor types, cloud microphysical processes (deposition, riming, and aggregation)

Meteorology

- Profiles of P, T, Qv, wind
- Surface meteorology

Key instruments:

Aerosols: AOS measurements including the SMPS, ACSM, UHSAS, PCASP, CPCF, HTDMA, CCN and INPs.
Guest SP2, SMPS

Cloud/precipitation: ARM radar (KAZR), surface distrometer, surface hydrology observations
Guest: X-band scanning radar

Planned study

Observational analysis

- Quantify relationships of **aerosol** characteristics (e.g., size distribution, composition, and hygroscopicity) **with CCN and INP** under different aerosol scenarios
- Quantify **relationships of CCN** with precipitation, cloud microphysical properties (e.g., LWC, IWC, cloud phase, hydrometeor type), and updrafts under typical meteorological conditions of warm and cold seasons
- Same as above, but for the **relationships of INP**.

Modeling study

- L**ES/CRM study:** conduct process-level model simulations of well-observed cases for mechanistic investigation and evaluating microphysics parameterizations by selecting the most common aerosol and meteorological scenarios (for ARI, ACI via CCN and INP)
- **E3SM evaluation**: particularly on cloud microphysical parameterizations and aerosol effects (e.g., relationships of aerosols with precipitation at different seasons).

Question?

We would like to know:

- What science would you be interested and how SAIL can help?
- What suggestions/experience do you have to better coordinate/collaborate between aerosol and precipitation components?
- Any other feedback is appreciated…