Dust Effects on California Winter Orographic Clouds by Serving as Ice Nuclei (IN)

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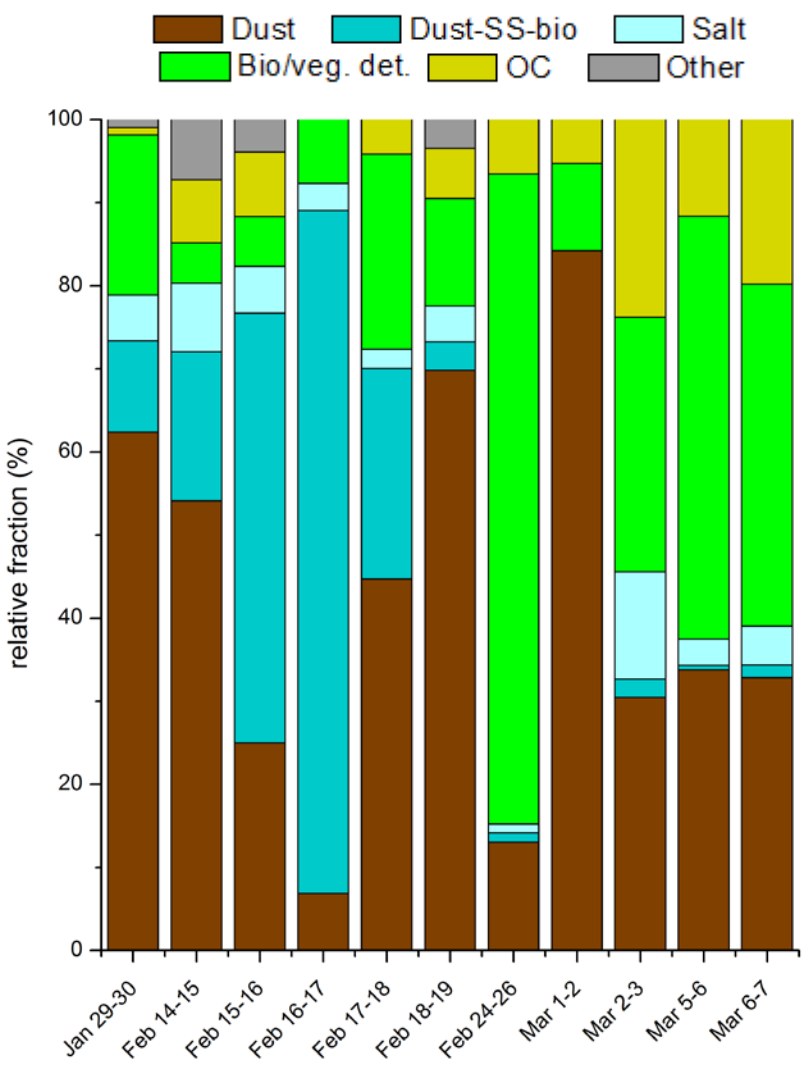
Background

- Dust components are often detected in the precipitation samples from the winter clouds in California.
- The dust is found to originate from Asian dust source regions and reach to the US west coast by the long-time transport (Ault et al. 2011).
- Enhanced precipitation is observed in the cases with dust compared with those without dust. The hypothesis from the observational study is that dust enhances ice formation and precipitation (Ault et al. 2011).

Motivation

- **To validate the above hypothesis.**
- **To look into how the mountain precipitation is susceptible to increases in aerosols and Asia dust.**

CalWater (Feb-Mar,2011)



DOE/PNNL G1 Research Aircraft

Sugar Pine: 1064 m ATOFMS measurements

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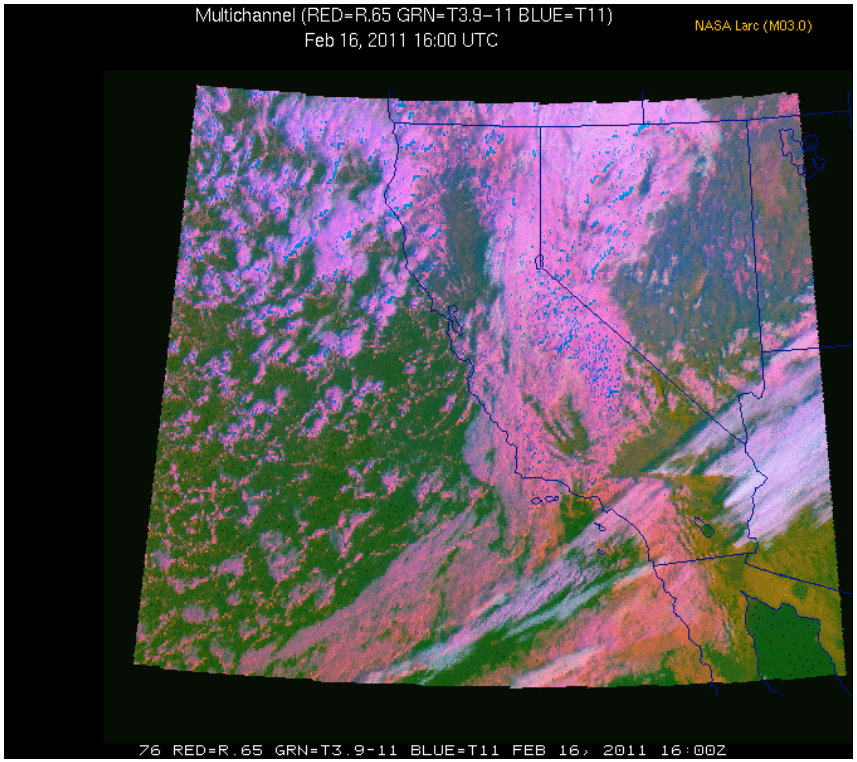
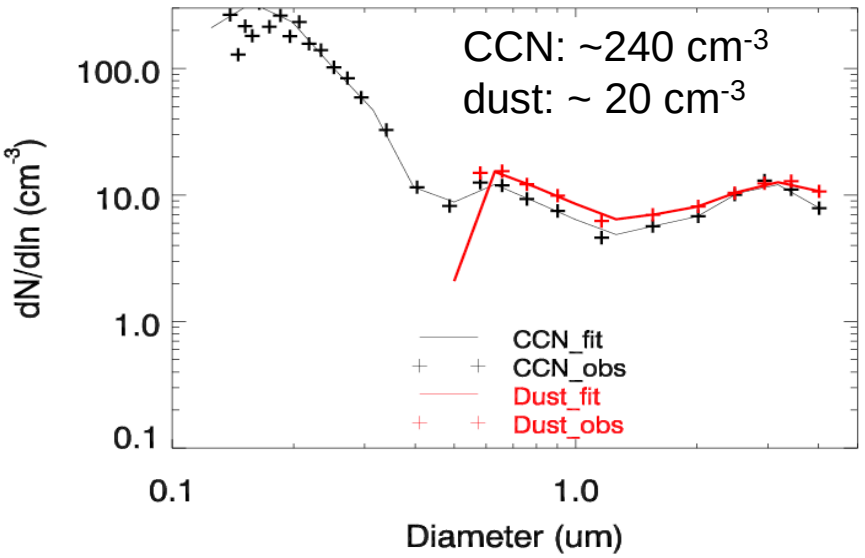
Feb 16 2011



PCASP measurement



Feb16 16:00 UTC: Boundary layer clouds fed into elevated cloud base over the Sierra foothills

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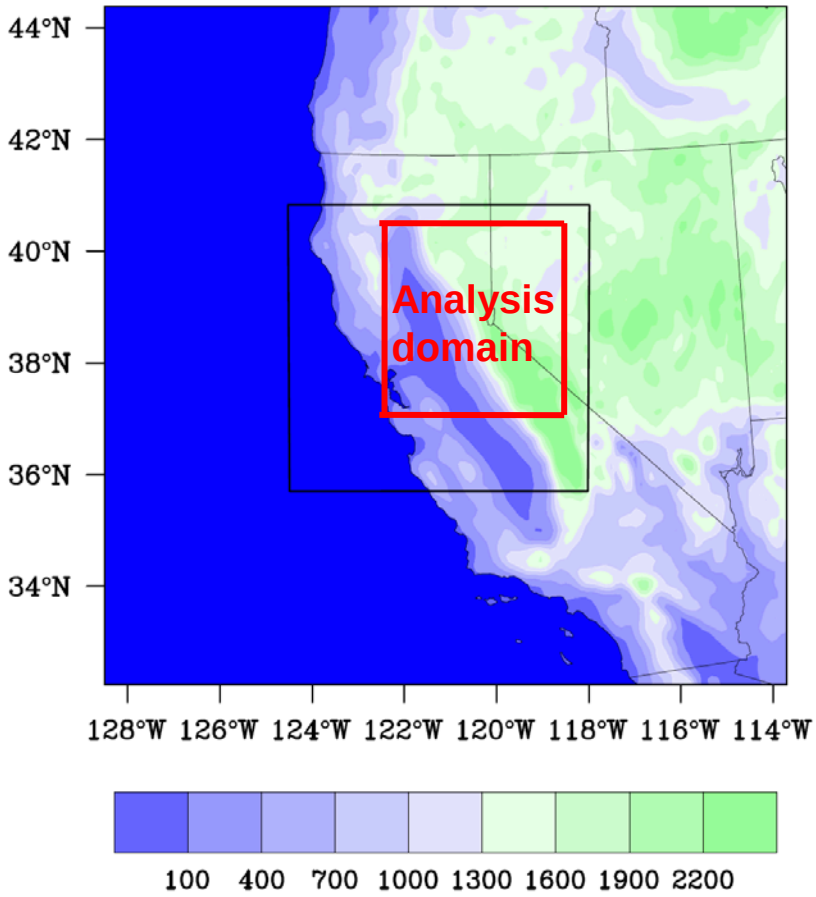
Simulation setup

- WRF with spectral bin microphysics (WRF-SBM) at 2 km resolution
- Simulations were performed for 2 days with dust applied on Feb.16



	CCN (cm^{-3})	Background IN (L^{-1})	Dust layer (L^{-1})
Base	**a0**	**in0**	**d0**
Base_CCN	**a0*3**	**in0**	**d0**
Base_ND	**a0**	**in0**	**No**

- a0 = 120 cm^{-3}
- in0 = 1 L^{-1}
- d0 = 100 L^{-1} (meaning IN fraction of dust is ~ 4-5x10^{-3}, consistent with Mohler studies)
- dust layer: 3.5-6.5 km.

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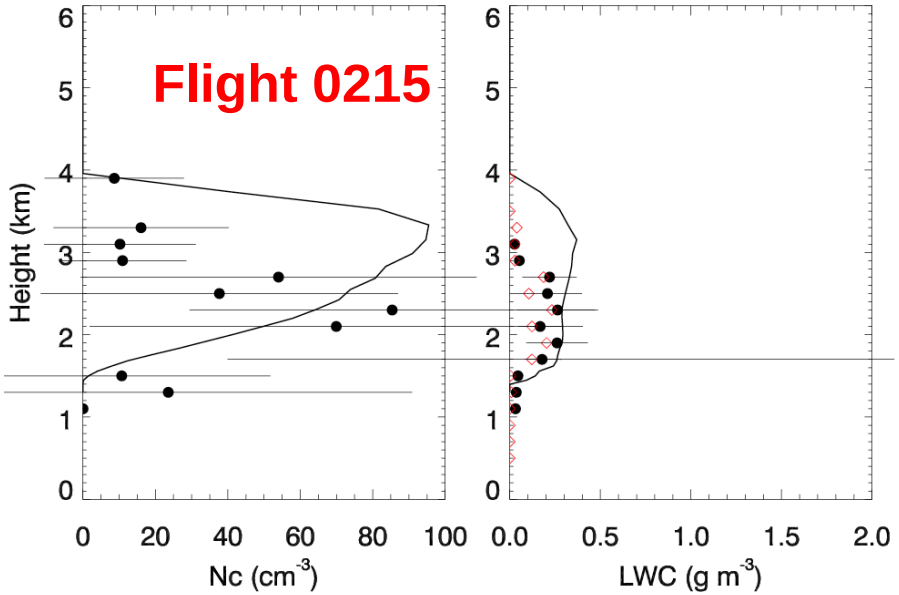
Ice nucleation mechanisms

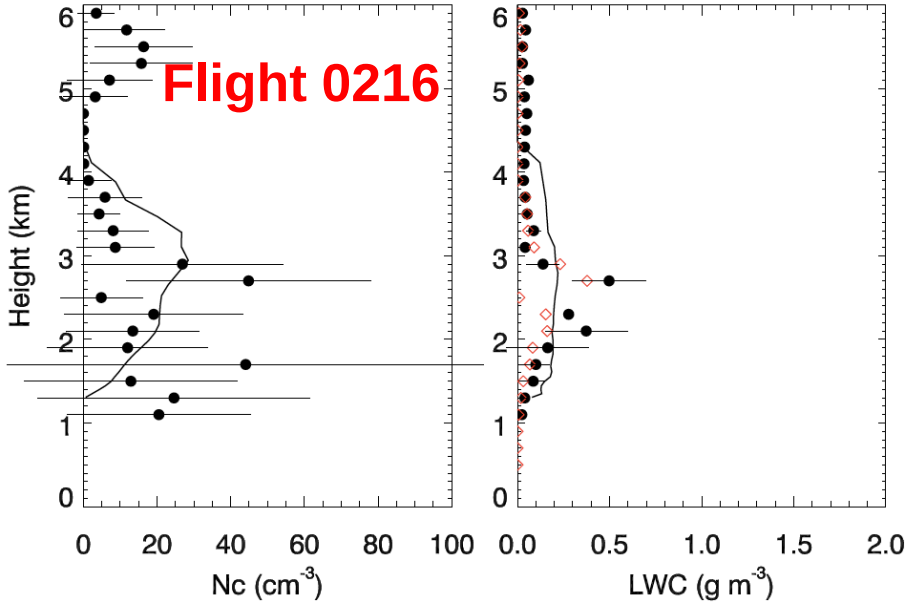
- **Condensation/deposition nucleation**
  van den Heever et al. 2006 implementation of Meyer's parameterization (link with IN) .
- **Immersion freezing and homogeneous droplet freezing**
  (Bigg 1953); link with IN for immersion freezing.
- **Contact freezing**

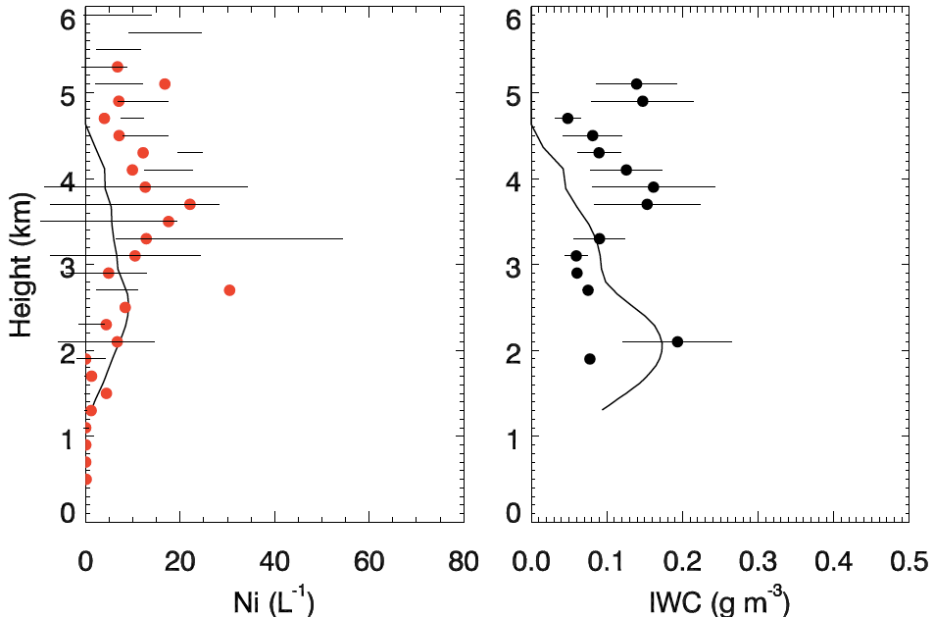
  Based on Young 1974 and Cotton et al. 1986; Link with IN also.

Feb 15-16: Cloud water and cloud ice

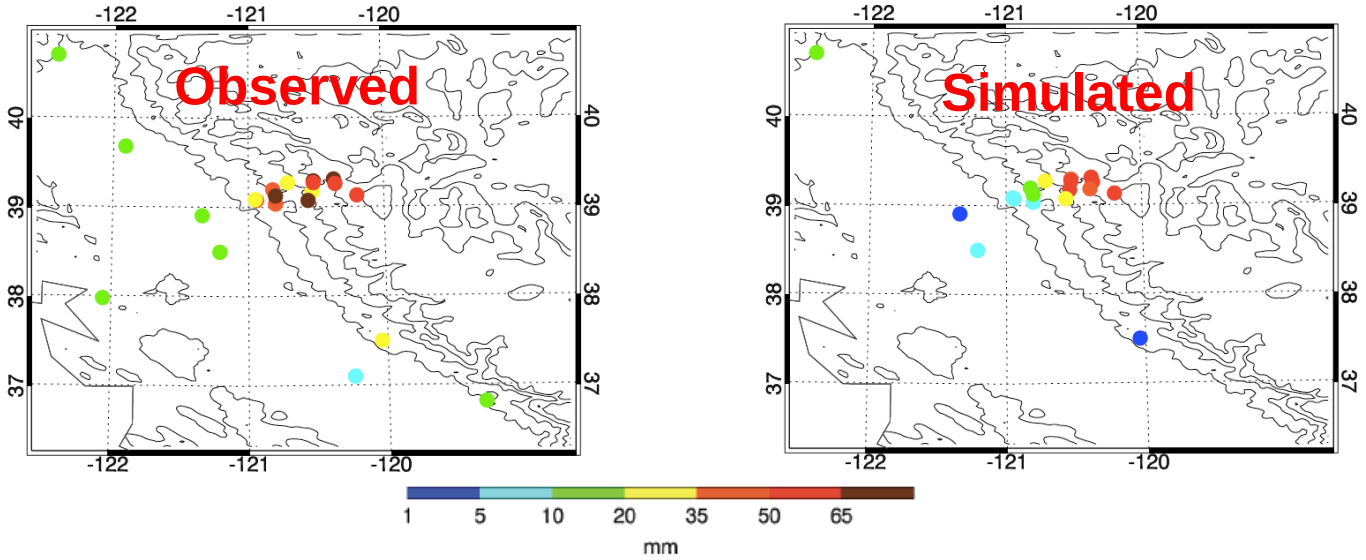


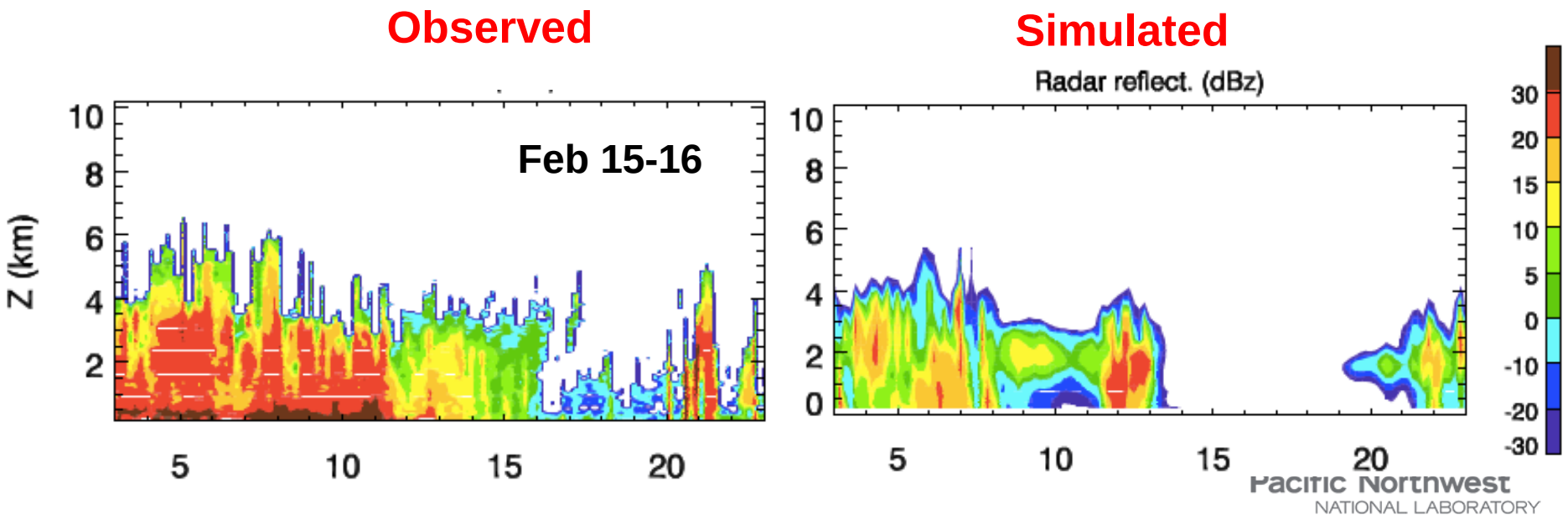
- Very little ice was observed on 2/15
- Hydrometeors were distinctly different between 2/15 and 2/16



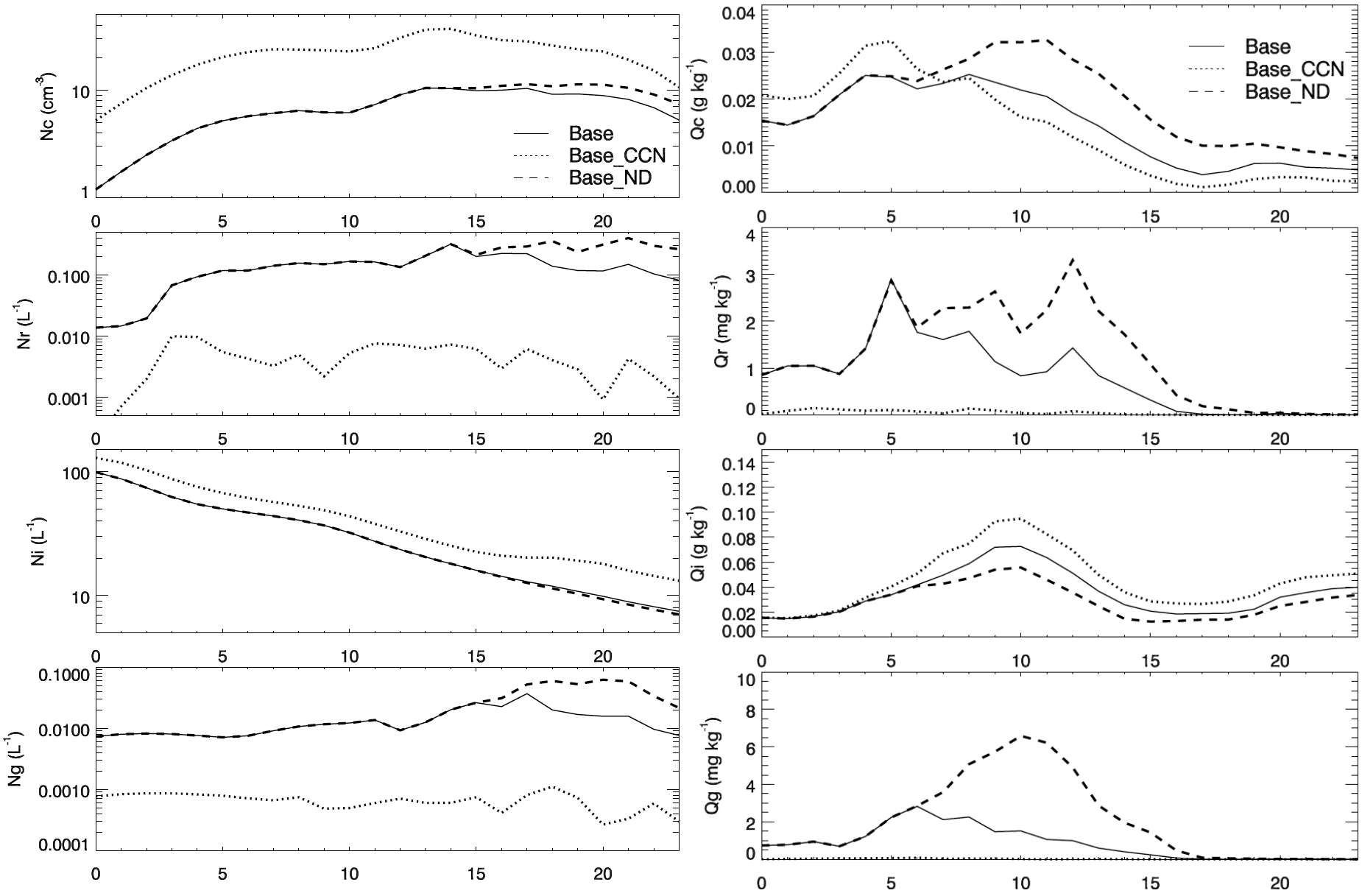


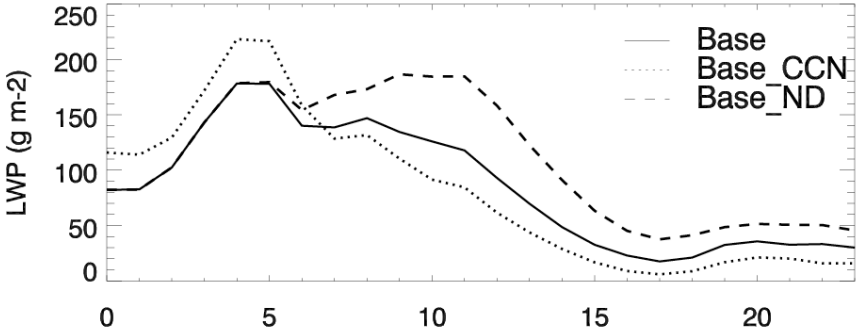
Precipitation

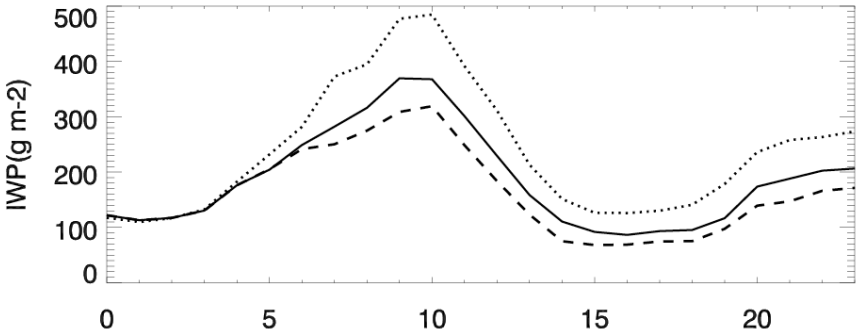


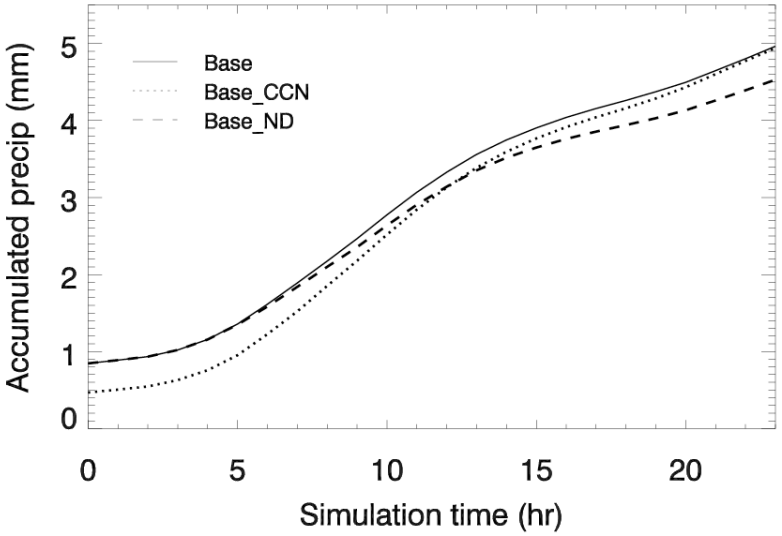


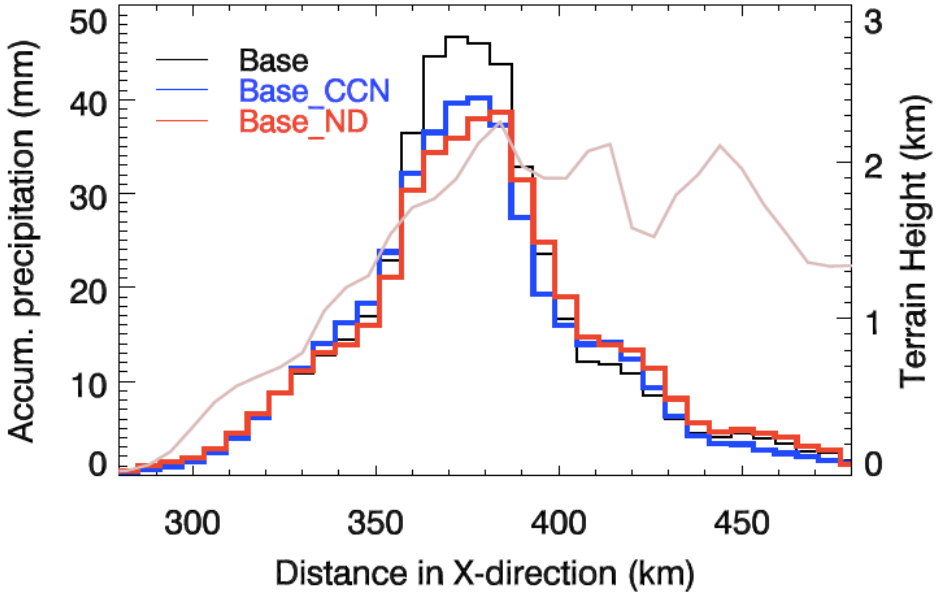
Sensitivity experiments











- Dust increases IWP and precipitation, but reduces raindrop and graupel due to glaciation effect; more significant effect than CCN.
- Increasing CCN reduces precipitation on the both windward and lee sides.
- Dust increases precipitation on the windward side but reduces precipitation slightly on the lee side

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Summary

- The impact of dust as IN on precipitation is more significant than increasing CCN by 3 times: dust significantly increases snow, especially on the mountain windward side.
- Dust increases Ni and IWP but reduces rain water and graupel due to glaciation – frozen precipitation increases by about 20% on the windward slope
- CCN suppress precipitation by decreasing raindrop and graupel formation.