Impact of Asian aerosols on precipitation over California: An observational and model-based approach

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Asian Aerosols and Atmospheric Rivers

- During the winter, the Siberian High over East Asia influences strong low-level winds that propagate pollution and dust emissions from Asia to over the Pacific Ocean.
- Strong mid-to-upper level westerly winds over the Pacific transport the aerosols to the western United States.
- The submicron aerosol particles act as cloud condensation nuclei (CCN) which can modify the precipitation processes.
- Figure 1 shows an example of an Asian dust plume that crossed the Pacific.

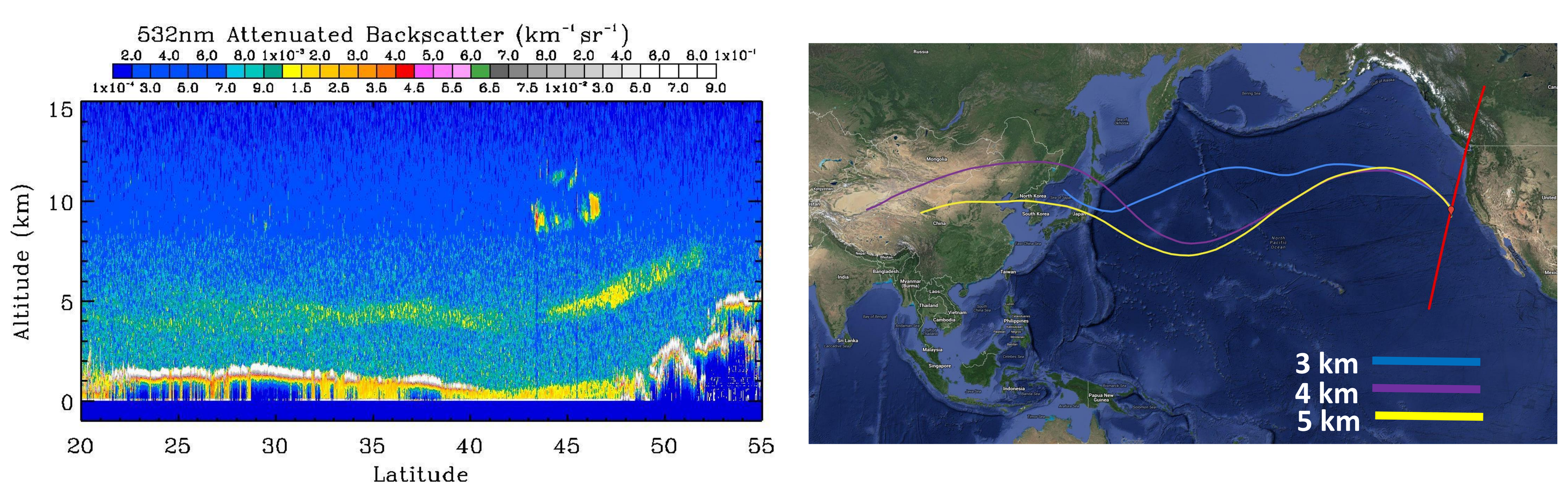

Figure 1. (left) CALIPSO 532nm attenuated backscatter revealing dust plume on 24 January 2013. (right) NOAA HYSPLIT backward trajectories starting from dust location along CALIPSO track (red line) at heights of 3, 4, and 5 km.

- Atmospheric rivers (ARs) are plumes of deep moisture that extend northward from tropics (Figure 2).
- They can occur at anytime but have the strongest water vapor fluxes during winter when they contribute nearly half of California's total precipitation.
- Coincides with period of high Asian aerosol concentration across the Pacific.

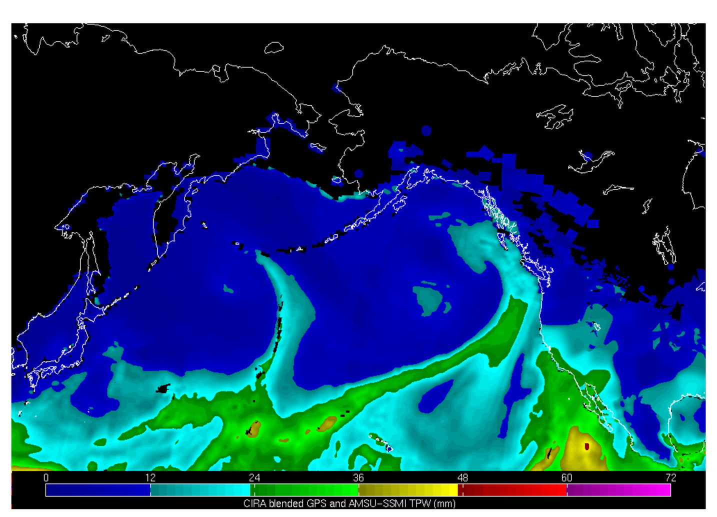

Figure 2. CIRA total precipitable water (TPW) product showing an atmospheric river on 24 January 2013.

- Our goal is to fully diagnose the Asian aerosol impact on precipitation processes by examining satellite and field campaign measurements along with model simulations.

Multi-sensor satellite observations

- A high amount of cloud coverage across the Pacific often makes it difficult to track the Asian aerosols as the visible reflectance of clouds can completely mask the aerosol signal.
- Retrievals should be avoided in cloud contaminated regions since clouds can cause high biases in aerosol optical depth (AOD).
- In order to more effectively determine the spatial variability of aerosol concentration across the Pacific, we take advantage of the high temporal resolution of geostationary satellites along with the high spatial and spectral resolution from polar-orbiting satellites.
- We develop near-real time (NRT) AOD retrieval algorithms for the NOAA GOES and JMA MTSAT geostationary satellites through the procedure in Figure 3.

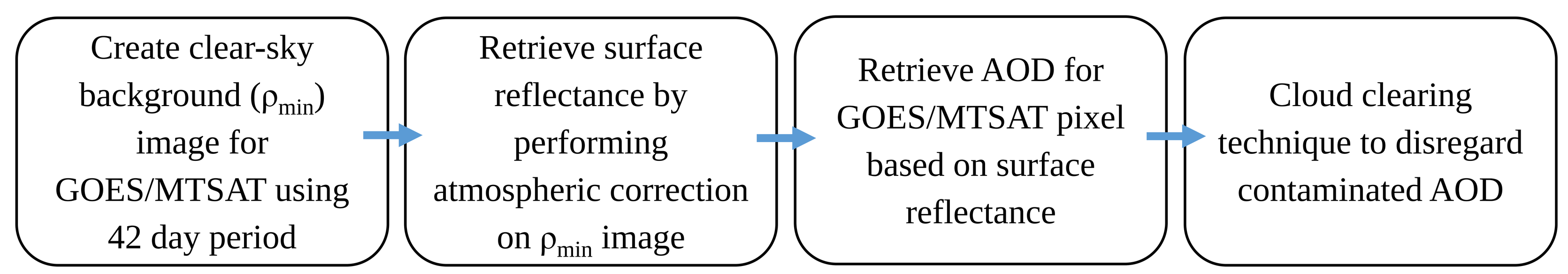

Figure 3. Four major steps in the GOES and MTSAT retrieval algorithms.

- Our geostationary retrievals are combined with NRT LANCE-MODIS AOD and Suomi-NPP VIIRS AOD where available.
- Final NRT SPoRT product consists of a 6 hourly and daily AOD composite on a 0.5° grid and latency of 3 hours (Figure 4).
- The NRT SPoRT product will help support flight planning during the NOAA CalWater 2 field campaign from January-March 2015.
- We will also archive the 6 hourly composite which will assist in modeling cases when aerosols interacted with ARs during CalWater 2.

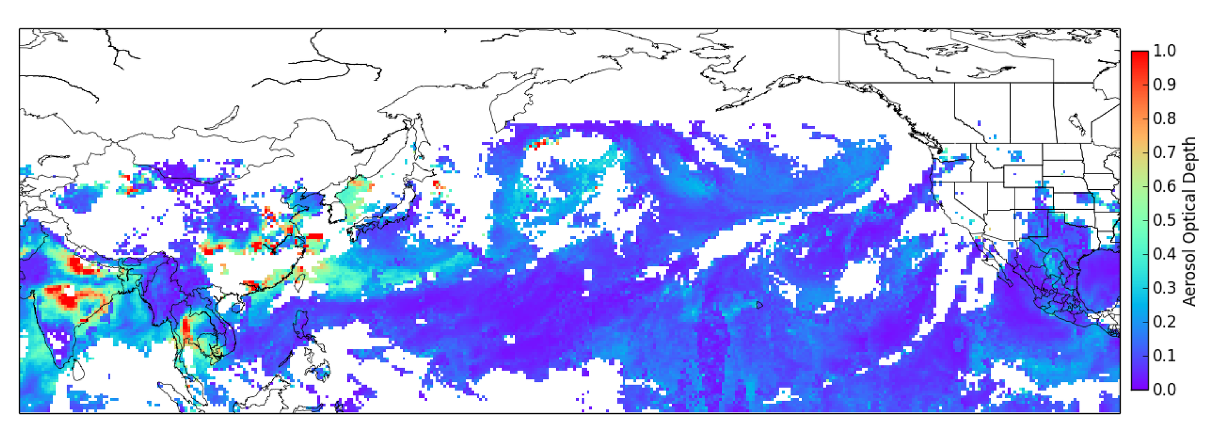

Figure 4. Example of the SPoRT daily AOD composite on 24 January 2013 (VIIRS not included).

Field campaign measurements

- Major goal of CalWater 2 is to improve the understanding of the impact of aerosols on precipitation associated with landfalling ARs. Advanced aircraft and ground-based instruments will measure the chemical composition of precipitation and cloud residues.
- Measurements will play a critical role in validating the cloud microphysical processes of our WRF-Chem model simulations.

WRF-Chem simulations

WRF-Chem model configuration			
Vertical Resolution	42 Levels		
Shortwave Radiation	RRTMG		
Longwave Radiation	RRTMG		
Cloud microphysics	Morrison double-moment		
Aerosol chemistry	8-bin MOSAIC		
Domains	Domain 1	Domain 2	Domain 3
Horizonal Resolution	9 km	3 km	1 km
Grid Points	600x600	499x499	598x748
Cumulus scheme	Kain-Fritsch	Turned off	Turned off
Cloud-aerosol interactions	Turned off	Turned on	Turned on

Table 1. WRF-Chem model configuration

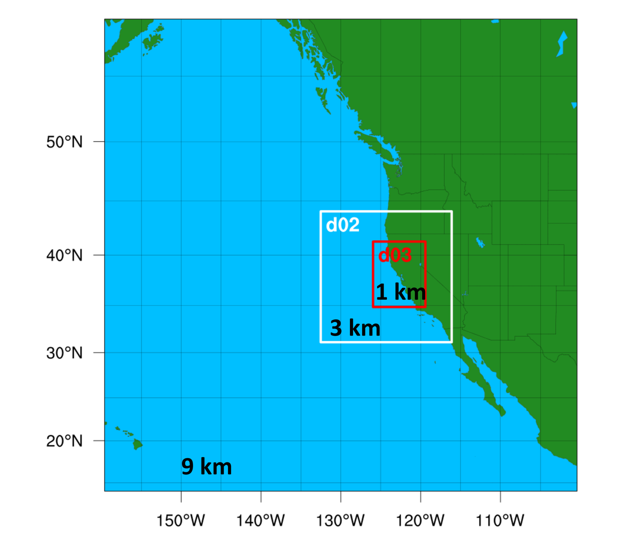

Figure 5. WRF-Chem triple-nested domain configuration.

- Control run: MOZART GCM data provides the initial and lateral boundary conditions for the aerosol fields of domain 1.
- Experimental run: Same as control but we assimilate the SPoRT 6 hourly AOD composites via an objective analysis approach.
- One-way nesting approach using ndown generates aerosol fields for domains 2 and 3.
- We simulate a case from CalWater 1 where dust interacted with a strong AR (Figure 6).
- Heavy precipitation was observed over California which WRF-Chem realistically simulates.
- Large dust mass concentrations were simulated over region.

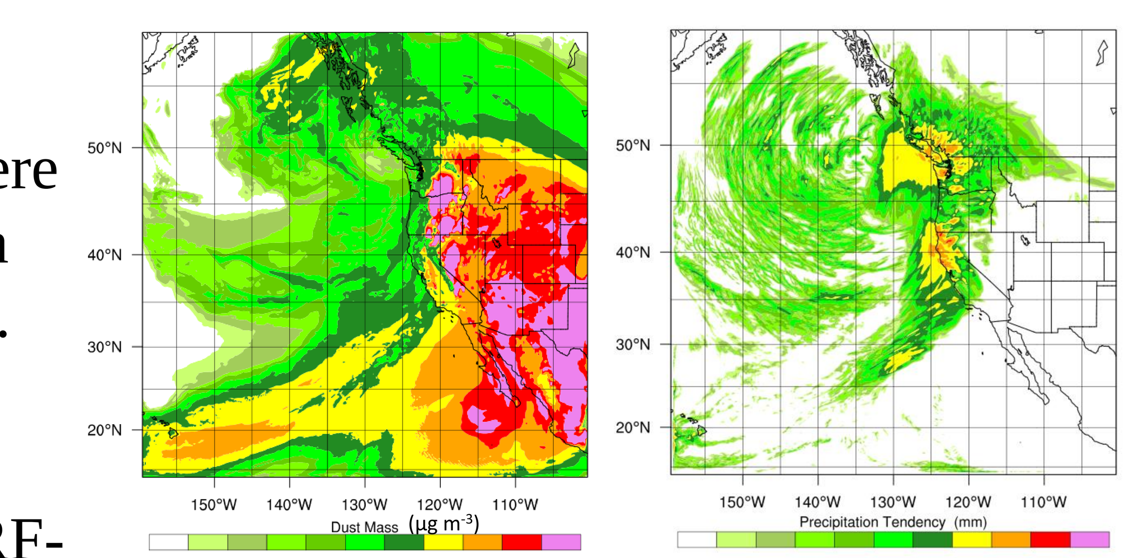

Figure 6. WRF-Chem 60 hour forecast valid on 2 March 2011 at 12 UTC for domain 1 (control run). (left) Sum of dust mass in all model levels and (right) 12 hour precipitation tendency.