Combined observational and modeling efforts to better understand aerosol-cloud-precipitation interactions over land: Preliminary results from 7-SEAS/BASELInE 2013

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Global frequency distribution of Smoke in the presence of Clouds

- West coast of California: Ship tracks, a small-scale aerosol-cloud interaction
- South America: Convective "fumulus" clouds, diurnal cycle plays important role
- Southern Africa: Distinct, decoupled aerosol-cloud layers over west coast
- Southeast Asia: Upwind smoke and downwind coupled-aerosol-cloud system

<table>
<thead>
<tr>
<th>Day/Year</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 Feb. 2000</td>
<td>Terra/MODIS</td>
</tr>
<tr>
<td>3 April 2001</td>
<td>Terra/MODIS</td>
</tr>
<tr>
<td>0630 UTC 9 April 2013</td>
<td>CALIOP: 532 nm Attenuated Backscatter (km$^{-1}$sr$^{-1}$)</td>
</tr>
<tr>
<td>04 August 2007</td>
<td>Aqua/MODIS</td>
</tr>
</tbody>
</table>

*Tsay, Hsu, et al., 2013, Atmos. Environ., 78, 20-34.

Aqua/MODIS: 0630 UTC 9 April 2013

e-DB Aerosol Optical Thickness $\tau_{0.55\mu m}$

Daytime
Nighttime

March
April
7-SEAS/BASELInE deployment 2013-2015: along the “river of smoke aerosols”
Aerosol-cloud-precipitation interactions

• Importance to weather/climate; hydrologic cycle, energy budget

• Cause and effect not well established by observations
  • Satellite observations only provide snapshots of atmospheric state, long time periods between overpasses - CAN’T show processes
  • Measurements of co-existing aerosols and clouds very difficult [Stevens and Feingold 2009]; (typically only one or the other)
  • Aerosol observing sensors generally can’t penetrate clouds of $\tau_c > \sim 3-5$; can’t ‘see’ what’s on the other side

• Representation of cloud properties still primary contributor to uncertainties in GCMs [Lohmann and Feichter 2005; Wyant et al. 2006; IPCC, 2007; 2014]
ACHIEVE: Aerosol-Cloud-Humidity Interactions Exploring and Validating Enterprise

- ACHIEVE is one of 3 mobile laboratories comprising SMARTLabs (Surface-based Mobile Atmospheric Research and Testbed Laboratories; http://smartlabs.gfsc.nasa.gov)
  - SMART – radiative transfer
  - COMMIT – in-situ aerosol and trace gas properties
- Suite of instruments to cover spectral range associated with aerosols, clouds, and precipitation

COMING SOON!
Summary of ACHIEVE Observations

- 26 March – 9 April 2013
  - Power outages led to gaps in data
- Low-level clouds and drizzle/light rain most frequent at night

![Graph showing MRR-derived accumulated rainfall (mm) from March 26 to April 10.](image)

![Heatmaps showing radar reflectivity (dBZ) for Daytime (7am-7pm local) and Nighttime (7pm-7am local).](image)
7 April 2013: ‘Golden scenario’
Stratocumulus (Sc) case

- Development/encroachment
- Drizzling
- Dissipation

W-band copolar reflectivity
K-band (MRR)
W-band mean Doppler velocity
9 April 2013: A-Train overpass

Smoke and biomass-burning aerosols evident above low-level clouds

*Surface clutter effects reduce CloudSat/CPR sensitivity below ~1km AGL [Christensen et al., 2013]
28 March 2013: Sc

W-band copolar reflectivity

Mean Doppler velocity [m s\(^{-1}\)]

Linear Depolarization Ratio (LDR) [dB]

Elevated deep convection passing above drizzling Sc
Rain rates ~1 mm hr\(^{-1}\) associated with convection
Deep convection appears to have little impact on Sc cloud deck - decoupled dynamics?
Modeling aerosol-cloud interactions

• Goddard Cumulus Ensemble (GCE) cloud-resolving model [Tao et al. 2009, 2014]
  – Numerous studies of aerosol impacts on convection [e.g., Tao et al. 2003; Li et al. 2009; Lee et al. 2009]

• Goddard Satellite Data Simulator Unit (G-SDSU) [Matsui et al. 2009, 2013; Masunaga 2010]
  – Forward model to simulate active and passive signals from model output (e.g., radiance, Tb, backscatter/reflectivity).
  – Model evaluation
Model setup: 7 April 2013 case

- LES-like setup
  - Domain: 14x14x13 km
  - Resolution: $\Delta x=\Delta y=200$ m, $\Delta$
  - 3M bulk microphysics
  - No aerosol sources/sinks
  - precipitation not expected based on sounding, no additional forcing
- Initialized with static aerosol concentration profiles, $100-2000$ cm$^{-3}$, maximum at surface
- COMMIT data from Son La, Vietnam revealed steady increase in biomass-burning aerosols prior to this event

12 UTC skew-T sounding for Hanoi, Vietnam
Aerosol concentrations increase

[Loftus et al. 2015, to be submitted to AAQR: 7-SEAS/BASELInE 2nd special issue]
Planning for the future

• Yen Bai region – confluence of BB aerosols and low-level Sc
  – ACHIEVE + COMMIT: co-located or COMMIT upstream for added in-situ aerosol information
  – SMART: network... (Si-Chee)

• Improved observations
  – More constraints (MWR: LWP), X-band for precipitation events
  – T, RH, p profiles for modeling
  – UAV for sampling in-cloud and near-cloud environment (entrainment of aerosols from above)
Future model work

- Regional model (WRF): several week-long simulations – provide meteorological forcing, BB aerosol transport to GCE
- Include full aerosol prediction in GCE

**WRF Grid 1:**
1200x1200x20 km
30 km horiz resolution (40x40 grid pts)

**WRF Grid 2:**
400x400x20 km
10 km horiz resolution (40x40 grid pts)

**WRF Grid 3:**
120x120x20 km, centered at Yen Bai, Vietnam
3 km horiz resolution (40x40 grid pts)

**GCE grid:** 30x30x14 km, centered at Yen Bai, Vietnam
200 m horiz resolution (150x150 grid pts)
Thank-you.
Cam on.

To be continued...