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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7 October 2015

Many thanks to: Si-Chee Tsay, Nguyen M. Cuong, Peter Pantina, Colby S. Goodloe, Michael Fritsch, Philip M. Gabriel, Toshihisu Matsui, Wei-Kuo Tao, Nguyen X. Anh, VAST and the Yen Bai Meteorological Station staff
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
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

![MRR-derived accumulated rainfall (mm)](image)

![Daytime 7am-7pm local](image)

![Nighttime 7pm-7am local](image)
7 April 2013: ‘Golden scenario’
Stratocumulus (Sc) case

W-band copolar reflectivity

K-band (MRR)

W-band mean Doppler velocity

Reflectivity (dBZ)

Mean Doppler velocity (m s$^{-1}$)

Development/encroachment
Drizzling
Dissipation

Height AGL (km)

Time (UTC)

Time (Local)

17:12 UTC

18:23 UTC

18:27 UTC

NW ← Distance (km) → SE

$\phi = 140^\circ$

$\theta = 30^\circ$

$\phi = 140^\circ$

$\theta = 30^\circ$

18 April

18:27 UTC
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

Deep convection appears to have little impact on Sc cloud deck - decoupled dynamics?
Modeling aerosol-cloud interactions

  - 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
Aerosol concentrations increase

[Droplet number concentrations](#)

Droplet effective radius

W-band radar reflectivity

Droplet number concentrations

Droplet effective radius

W-band radar reflectivity

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…