Breakout summary: Aerosol Deep Convection-Cloud Interactions (ADCI)

Overarching question: ***What aerosol-related processes influence deep convection cloud properties relevant to climate (precipitation, cloud radiative forcing, latent heating profiles)?***

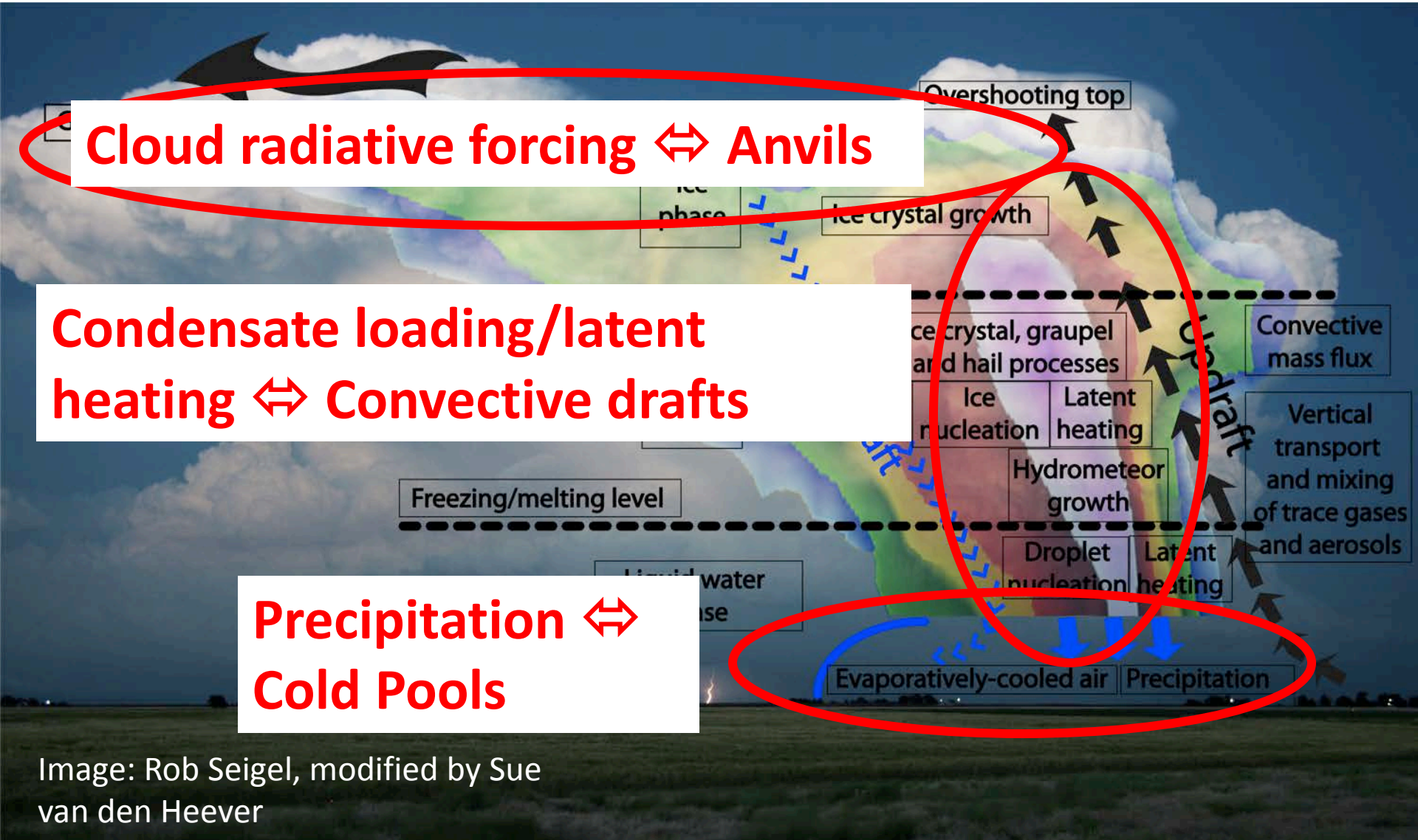
ASR Cloud Lifecycle WG Plenary

November 8, 2013

Objectives

- To investigate relationships between aerosols and anvil radiative forcing, convective characteristics, latent heating, precipitation, etc. through rigorous analysis of **observations** from both ARM data and other datasets.
- To improve our understanding of the mechanisms governing aerosol-deep convection interactions using **models** in conjunction with observational data.
- Identify differences in aerosol impacts on convection across **models**, and understand specific processes responsible for explaining these differences.

Aerosol Effects on Deep Convection



Cloud radiative forcing ⇔ Anvils

Condensate loading/latent heating ⇔ Convective drafts

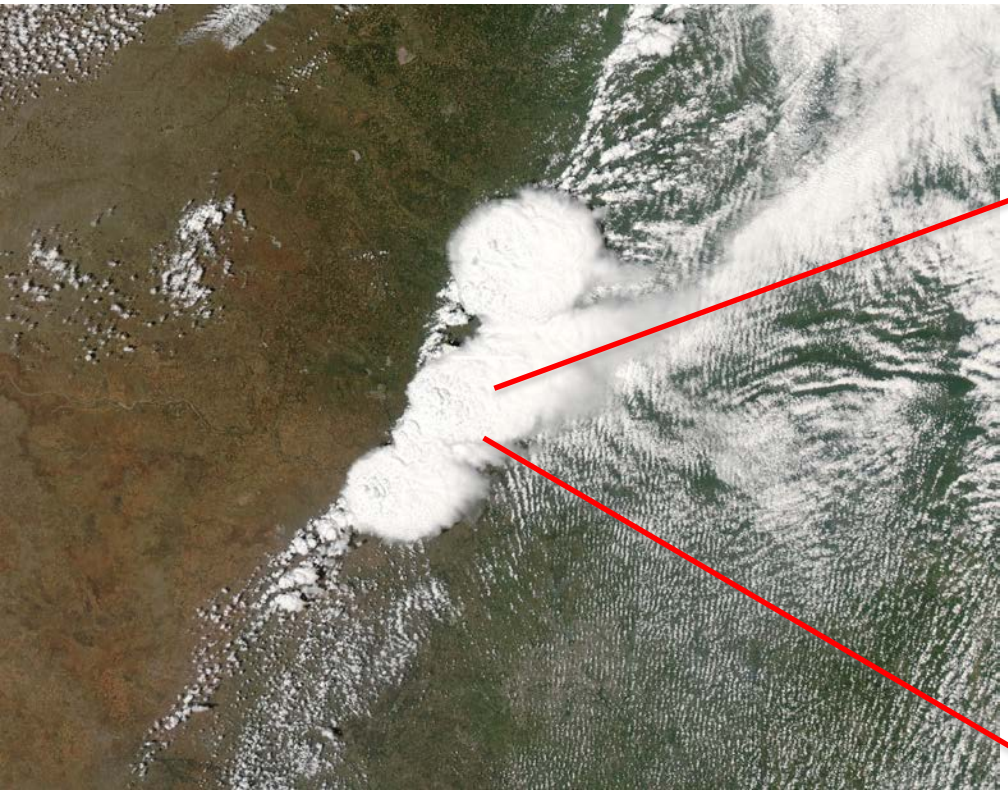
Precipitation ⇔ Cold Pools

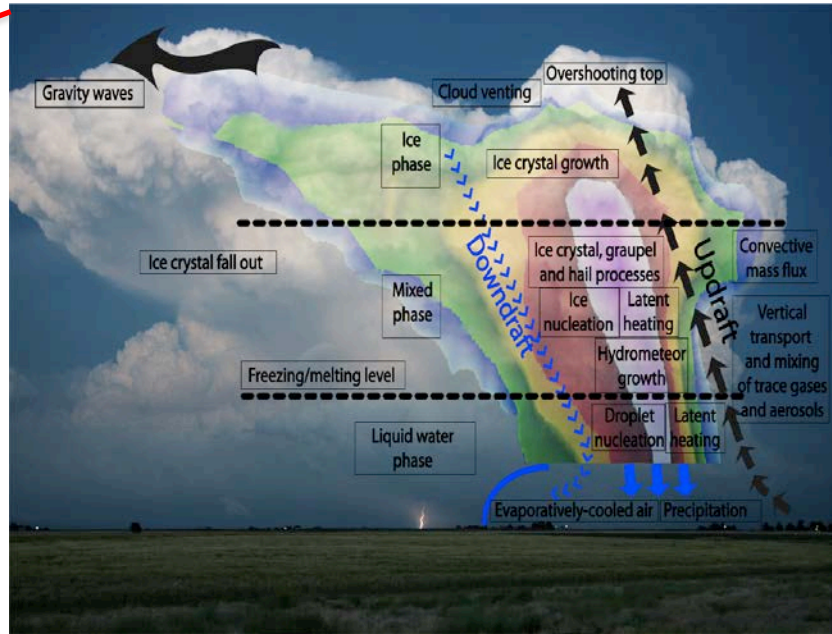
Image: Rob Seigel, modified by Sue van den Heever

This is a multi-scale problem

- *Need to consider interaction of clouds and their environment; clouds don't evolve in isolation!*

- Modeling evidence of reduced aerosol impacts over larger spatio-temporal scales → feedback with environment





Jiwen Fan, *A new mechanism of aerosol 's impact on ADCI*

Zhanqing Li, *Estimation of ADCI-iuduced changes in cloud radiative forcing of DCCs*

Susan van den Heever, *The impacts of aerosols on MCSs observed during MC3E – preliminary results*

Guang Zhang, *Aerosol effects on convection in NCAR CAM5*

Danny Rosenfeld, *Satellite retrial of vertical microphysical profile of convective clouds and retrieving their cloud drop number concentrations*

Xiquan Dong, *Diurnal and Life Cycles of DCS and associated precipitation and TOA CRFs*

Marcus van Lier-Walqui, *Analysis of storm-to-storm and within-storm variability of C-band and S-band polarimetric signatures in MC3E deep convection*

Pierre Gentine, *Representing the diurnal cycle of continental convection with an ensemble of plumes*

M.G. Manoj, *Aerosol effects on deep convection over the Indian region during ARM GVAX Campaign*

Key issues and uncertainties

- Co-variability of aerosol and meteorology make it difficult to separate correlation from causation

- Large spread of aerosol effects among CRMs; evidence that convective characteristics from CRMs can be much different from observations (e.g., bias in updraft velocity for TWP-ICE shown by Adam Varble et al.)

- Aerosol impacts on deep convection have generally been neglected in GCMs; this is starting to be addressed but challenges remain in how to best represent the relevant physics in convection parameterizations

Key issues and uncertainties

- *Co-variability of aerosol and meteorology make it difficult to separate correlation from causation*

→need lots of statistics

→not necessarily clear what variables are meteorological "controls" (CAPE, shear, RH, etc.), and how this might vary among regimes

→issues with co-location of aerosol/cloud observations

Key issues and uncertainties

- *Large spread of aerosol effects among CRMs; evidence that convective characteristics from CRMs can be much different from observations (e.g., bias in updraft velocity for TWP-ICE shown by Adam Varble et al.)*

What might explain spread of results?

→ different case studies and environmental conditions

→ different models (e.g., bulk versus bin microphysics)

→ inherent low level of predictability at convective scales

Key issues and uncertainties

- *Aerosol impacts on deep convection have generally been neglected in GCMs; this is starting to be addressed but challenges remain in how to best represent the relevant physics in convection parameterizations*

→ How do we evaluate aerosol effects on deep convection in GCMs? Can GCMs reproduce observed correlations from satellite, w/ or w/o aerosol effects on deep convection included?

→ Use of multiple frameworks: traditional GCMs w/ modified convection parameterizations, SCMs, MMF

→ Development of newer approaches such as PDF-based schemes to represent convection

What are we doing collectively?

1. Obtain observational estimation and constraints of both ERDari and ERFaci using ARM and Satellite data (Li)
2. Estimation of CCN at cloudbase (Rosenfeld)
3. 3-D wind and hydrometeor retrievals (Kumjian, Ghate, Cmostock, North, Collis, Giangrande, van Lier-Walqui)
4. Multi-platform datasets tailored for DCS (Dong)
5. CRM simulations (Fan, van den Heever, Fridlind, van Lier-Walqui, Tao, Morrison)
6. Convection/sub-grid parameterization and global and/or SCM simulations (Zhang, Gentine, Donner, Wang, Ovchinnikov)

A focused problem: Understanding large *inter-model differences* in CRM deep convection simulations

(a related but likely harder problem to solve: large biases in CRM convective drafts relative to observations)

- ***A general microphysics/dynamics problem*** – not just aerosol effects → strong links to Cloud Lifecycle Working Group (e.g., Mesoscale Convective Organization, Vertical Velocity Focus Group)
- Spread of models means we don't have anything close to a "benchmark" for developing deep convective parameterizations in GCMs

- Very difficult to isolate causes of model differences because of system complexity

- Suggests the need for constrained framework for testing (e.g., neglect microphysics-dynamics *feedbacks*)

- test different microphysics in a specified flow field model of deep convection consistent with observations → different microphysics schemes are forced by identical dynamics

- Data assimilation to constrain dynamics using observations (u,v Doppler winds) → could be done in a common framework (WRF-DART)

Proposed approach: An MC3E-based intercomparison

We don’t want to reinvent the wheel → need to try new ideas for intercomparisons!

- two-pronged approach using both *constrained* and *fully dynamical* models

- **focused on microphysics-dynamics interactions in deep convection**, of which aerosols are a component

Step 1: Constrained simulations

- Use constrained dynamical framework and test multiple microphysical schemes (bulk and bin)
- Identify causes of model differences in terms of specific microphysical processes
- Compare impacts on latent heating + condensate loading, but w/o feedback to dynamics
- Improve simplified schemes (bulk) based on detailed schemes (bin)

Step 2: Dynamical simulations

- Detailed comparisons with ARM observations for case studies
- Investigate how aerosol effects vary among models
- Identify processes and feedbacks important to represent in GCM parameterizations

Key observations for constraining models

- 3D vertical velocity (convective drafts)
- 3D condensate and microphysical profiles (especially in updrafts to quantify condensate loading)
- 3D latent heating
- Cold pool properties (integrated through depth)
- Size, number, and morphology of convective drafts
- CCN (and IN) profiles

Broader efforts

•Longer-term observational analysis and modeling centered around ARM sites

→ CRMs, SCMs, GCMs, but need to have confidence in CRMs before committing to long runs due to computational expense

→ long-term analysis means lots of statistics

→ can models reproduce observed correlations between aerosols and clouds/deep convection?

→ use models to test correlation vs. causation

•New field experiments? → advantage of a relatively simple meteorological setting…

Broader efforts

- Impact of convection of aerosols (aerosol processing, convective transport) → can we get observations of aerosol fluxes in/around clouds?
- Impacts on upper troposphere lower stratosphere water vapor transport