Cloud Lifecycle Working Group

Tony Del Genio

ARM-ASR PI Meeting, 5/3/16

Historically, CLWG has organized around science theme groups:

- Mesoscale convective organization
- Ice cloud physical and radiative properties
- Warm low clouds
- Cloud phase partitioning/mixed-phase clouds

Currently in transition as composition of science team changes

Nonetheless, several joint CLWG-CAPI group activities in past year:

- Marine low clouds workshop
- Deep convection workshop
- Arctic mixed-phase cloud case study

Marine low clouds workshop (Jan. 27-29, BNL)
Jensen, Wood, Wang, organizers

Precipitation:

- Climatology of precip and condensate profiles from ARM records
- Role of precip in dynamical changes (e.g., cold pools, transitions)
- Understand drizzle initiation process in Sc, Cu and improve parameterizations

Entrainment:

- Quantify relation between 3-D turbulence and entrainment
- Robust entrainment rate estimates for varying conditions
- Determine response of PBL depth, other macrophysical properties of Sc, Cu to a warming climate
- Quantify impact of entrainment and mixing on microphysics

Marine low clouds (cont.)

Mesoscale organization:

- Determine how important mesoscale variability is for the cloud response to meteorological and climate forcing
- Use ground-based and satellite remote sensing to develop metrics to characterize mesoscale variability

Deep convection workshop (Feb. 3-5, PNNL)
Hagos, Houze, organizers

Cloud process understanding:

- Boundary layer evolution leading to deep and mesoscale convection, including cold pool dynamics
- Intensities, sizes, internal variability of updrafts and downdrafts
- Microphysical feedbacks
- Conditions for aggregation of convection
- Drivers of mesoscale circulation, adjustment to stability, shear
- Role of stochastic processes

Deep convection (cont.)

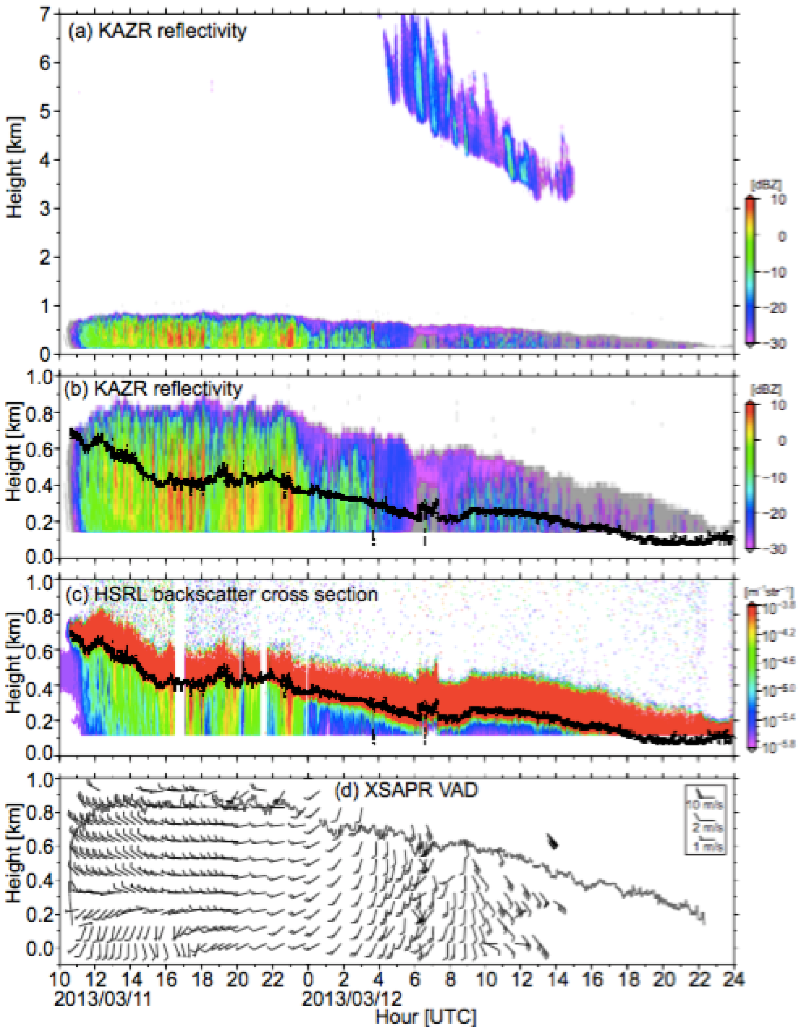
Parameterizations:

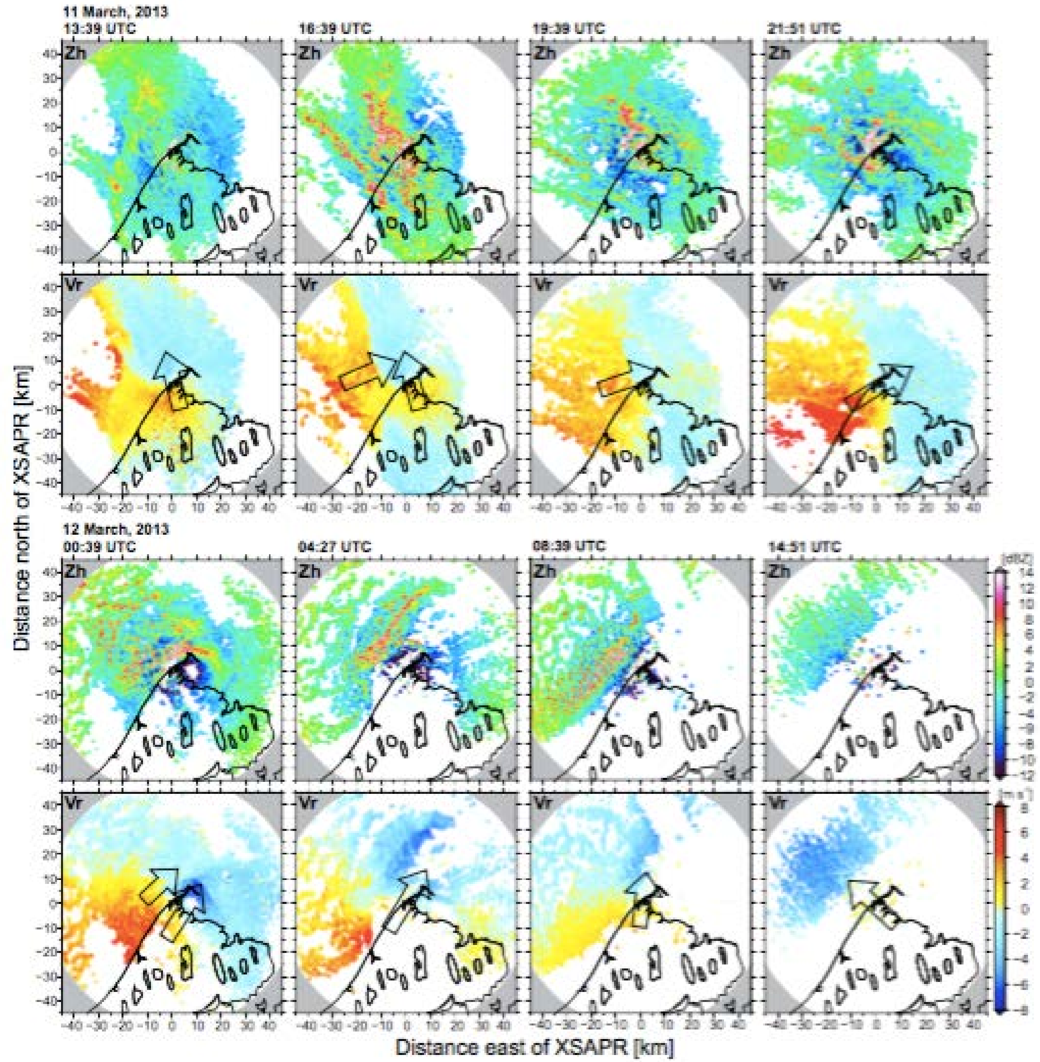
- Fundamental re-thinking in response to increasing resolution, diverse forms of convection; scale separation to scale awareness
- Elevated convection as well as PBL-generated
- Hierarchical approach to modeling

Observations:

- Concurrent convection-microphysical products, humidity profiles at different scales, cloud/precip morphology and organization, cold pool properties, latent/radiative heating
- Adaptive observation strategy using forecasts
- Meaningful use of observations (see ACME-ARM-ASR report)
- Instrument simulators
- Characterization of convection over open tropical oceans

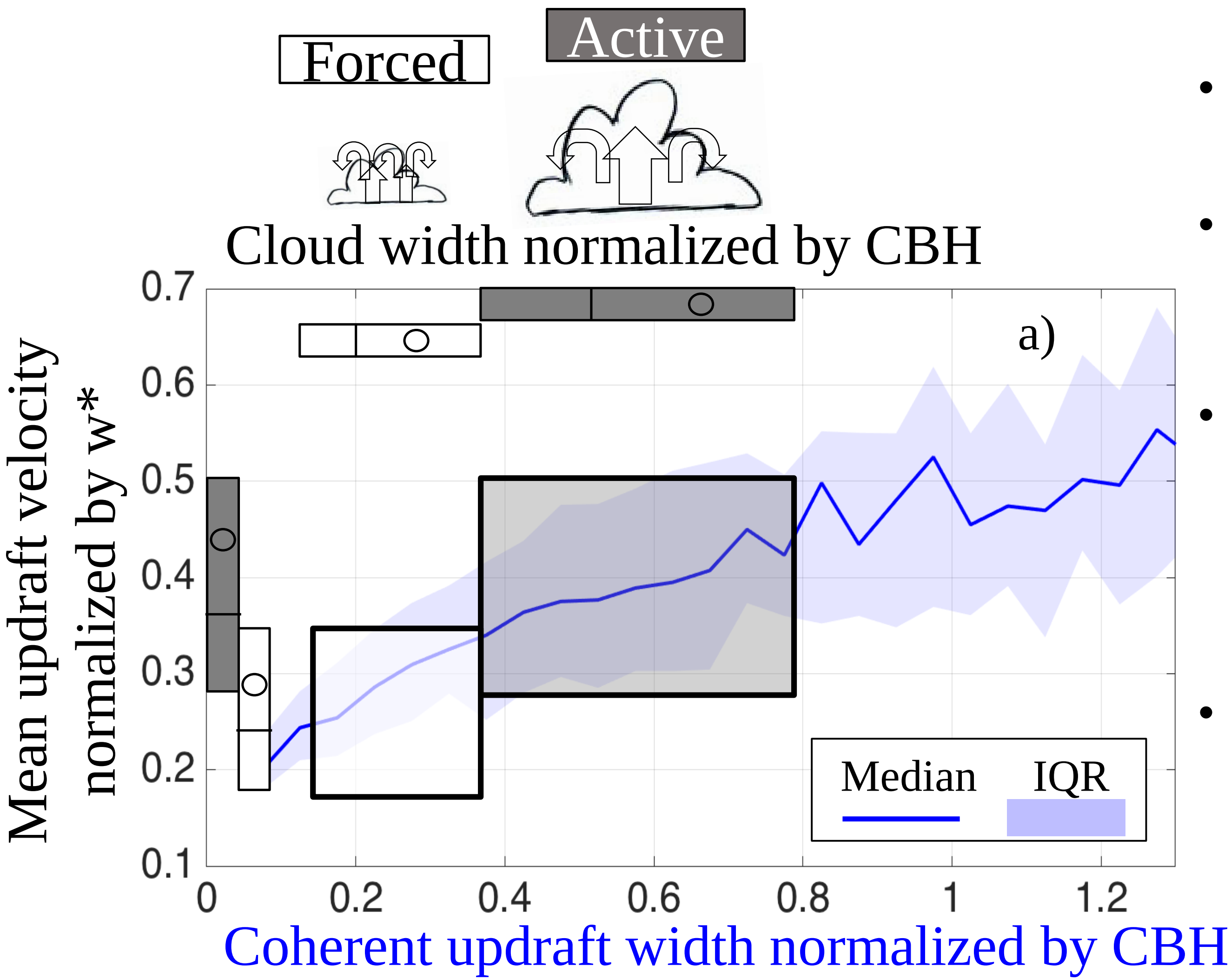
Cloud Phase Group





Reference: Kalesse, H., G. de Boer, A. Solomon, M. Oue, M. Ahlgrimm, D. Zhang, M.D. Shupe, E. Luke and A. Protat (2016): Understanding rapid changes in phase partitioning between cloud liquid and ice in stratiform mixed-phase clouds: An Arctic Case Study, *Mon. Wea. Rev.*, submitted.

Observations of **fair-weather cumuli over land**:
Dynamical factors controlling cloud size and cover
Lamer and Kollias 2015



- Deeper/wider coherent mixed layer updrafts have higher velocities (w)
- Size, w related to cumulus characteristics
- Active fair-weather cumuli are deeper, wider, more intense w at cloud base
- Fair weather cumuli cloud cover strongly correlated to w skewness (R=0.26) and coherent updraft fraction (R=0.31)
- In-cloud structure information limited due to sensor sensitivity, partial beam filling

Exploring Entrainment Processes and Parameterizations in Stratocumulus Clouds Using Doppler Cloud Radar Observations

Bruce Albrecht[1], Ming Fang[1], and Virendra Ghate[2]

Vertically pointing SGP Doppler cloud radar (MMCR), 14 continuous hr of Sc turbulence observations

VV variance (VAR) and energy diss. rate (EDR) used to examine parameterized TKE budget of entrainment zone.

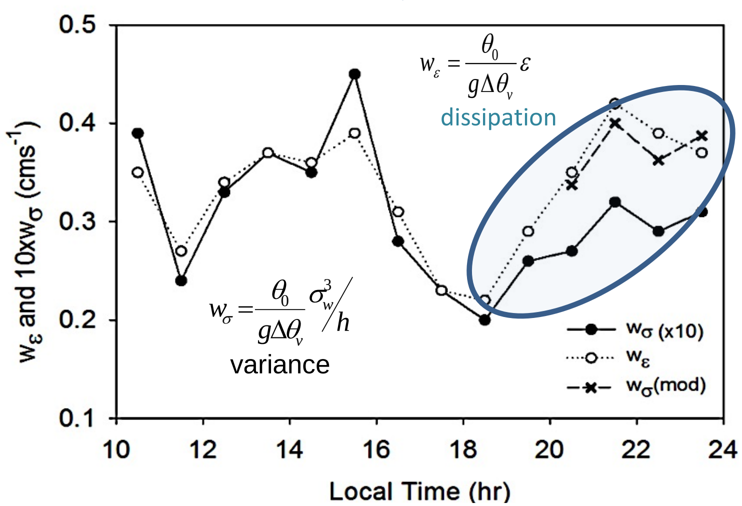
Inversion height budget using ARM obs and ECMWF vertical velocity provides mean entrainment rate (0.74 cm s^{-1}) used to define bulk coefficients for three entrainment parameterizations.

Potential for estimating entrainment rate directly from radar VAR and EDR with no scaling height needed.

Parameterized Entrainment Zone TKE Budget

$$\frac{g}{\theta_0} w_e \Delta\theta_v = C_T \frac{\sigma_w^3}{h} - \varepsilon_i \qquad w_e = \left(C_T \frac{\sigma_w^3}{h} - \varepsilon_i \right) \frac{\theta_0}{g \Delta\theta_v}$$

Buoyancy Variance Dissipation Entrainment Velocity

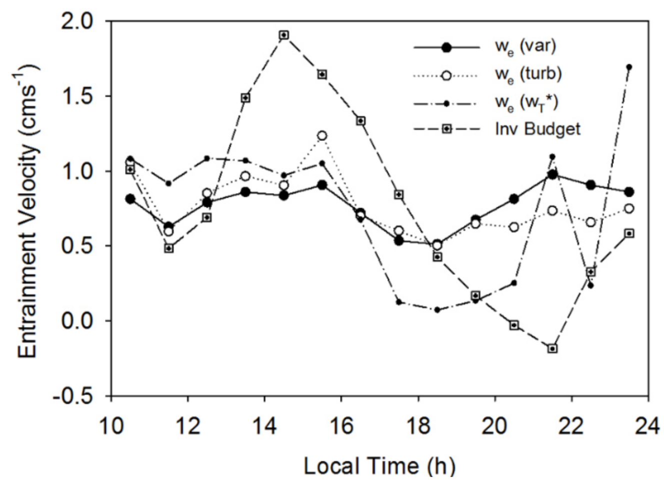


Unscaled velocities from EDR and VAR terms in TKE budget. BL decoupled from 2000-2400 LST (blue shaded area)

Entrainment Parameterizations

$$w_e = A_\sigma \sigma_w^3 \frac{\theta_0}{g\,h\,\Delta\theta_v} \qquad w_e = A_\varepsilon \frac{\theta_0}{g} \frac{\varepsilon}{\Delta\theta_v} \qquad w_e = A_{w*} {w^*_t}^3 \frac{\theta_0}{g\,h\,\Delta\theta_v} \qquad w_e = \frac{\partial z_i}{\partial t} + \vec{V}_h \cdot \nabla z_i - w_i$$

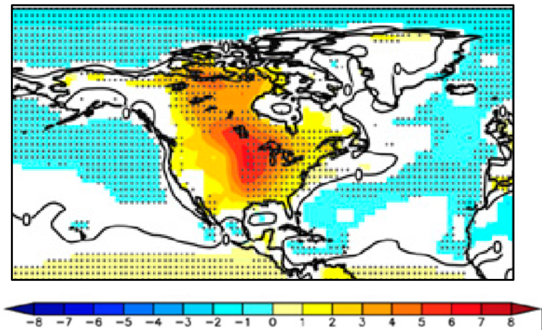
Variance Dissipation Conv Velocity z_i Budget



Entrainment velocities with A_σ=26, A_ε=2.3, and A_{w*}=3 and entrainment velocity from the mean height budget.

(*J. Atmos.Sci;2016; [1]Univ. Miami; [2] Argonne National Lab*)

CAUSES: Attribution of temperature errors to cloud deficiencies in GCMs

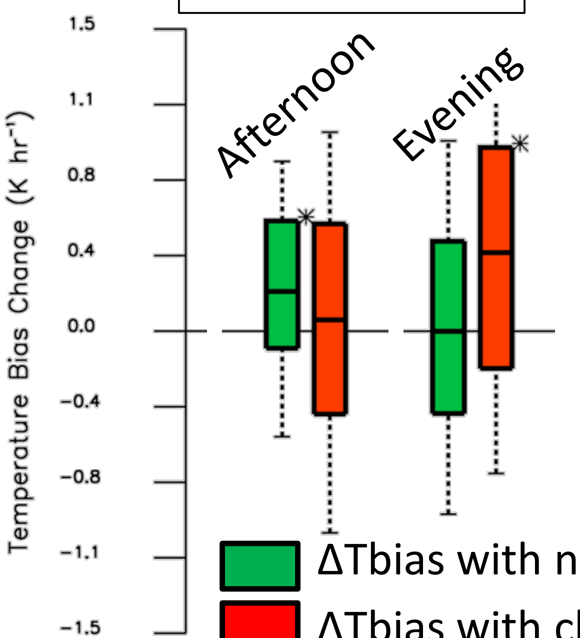


Ma et al. 2014

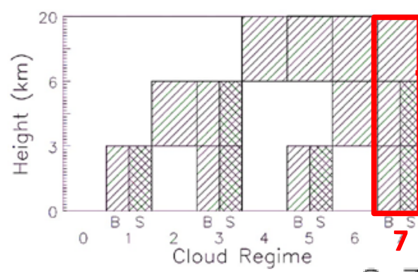
→ Land-atmosphere interaction?
→ Low cloud?
→ Deep convection triggered off the lee of the Rockies

Run GCMs in NWP-mode and compare T-bias growth with concurrent biases in other model variables

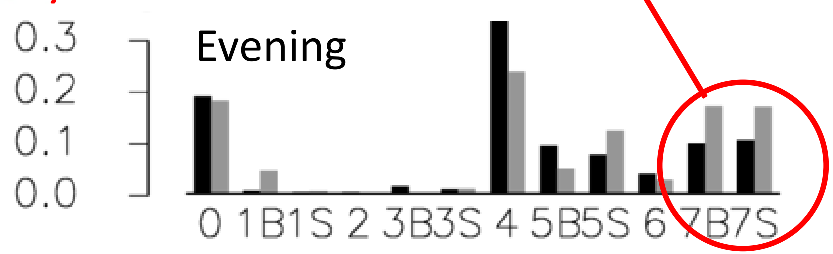
CAM5, MC3E



→ Afternoon Tbias growth: <u>too low albedo</u>
→ Evening Tbias growth: <u>cloud issues</u>



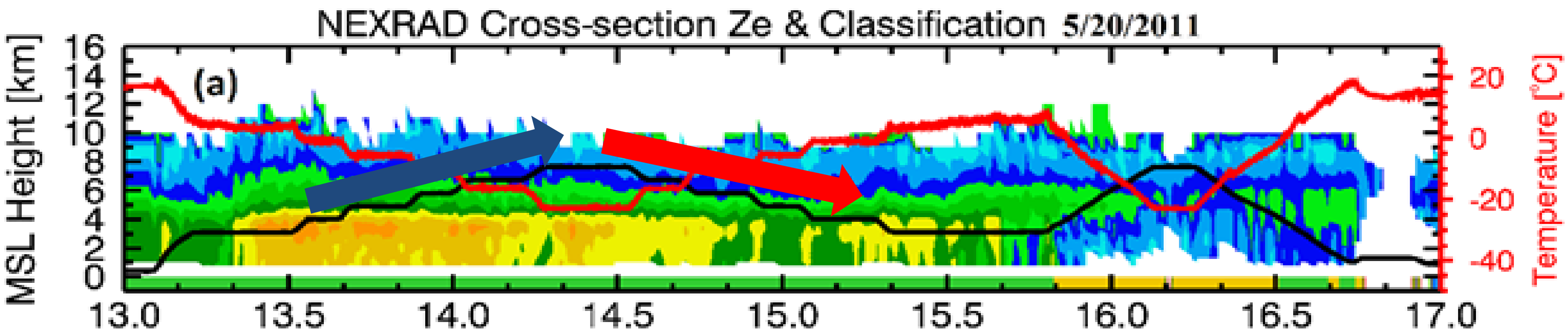
Too many deep (convective) clouds lingering in evening → Tbias growth

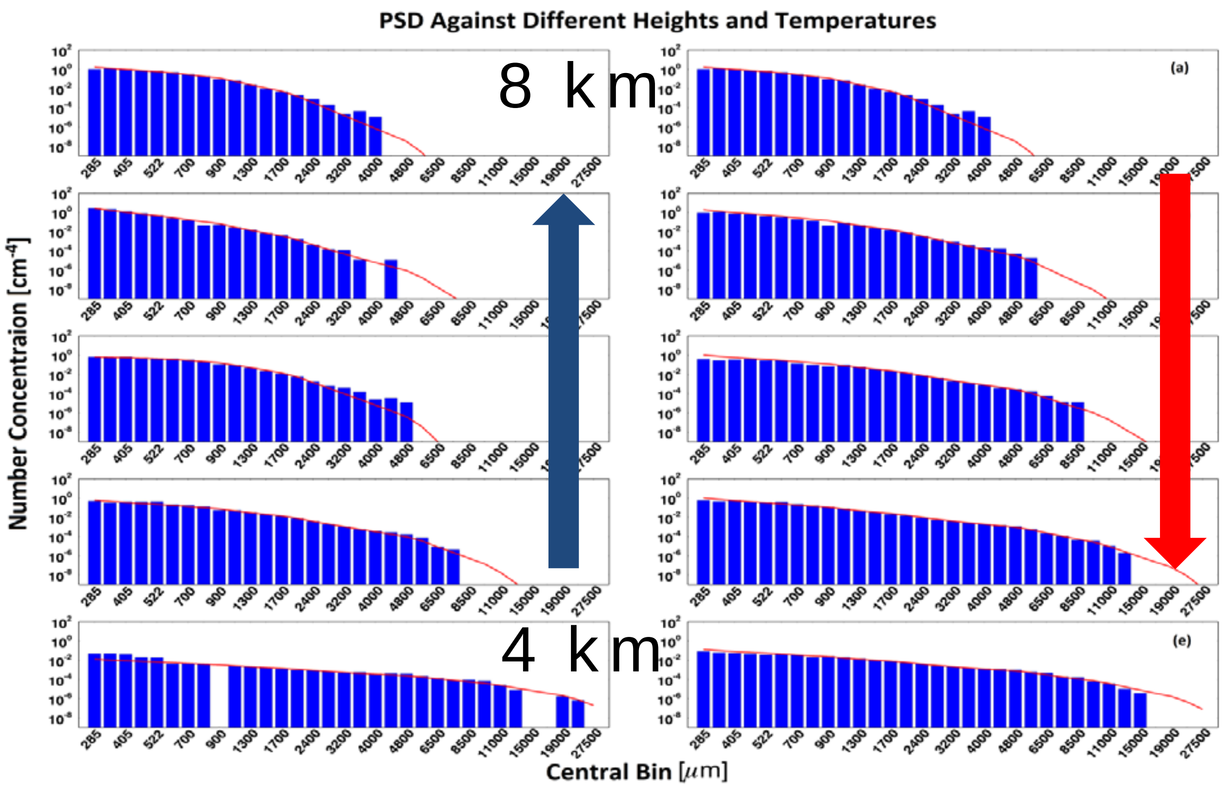


Van Weverberg et al. 2015

Full spectrum of PSDs from 2DC+HVPS and derived Gamma-Distribution

Xiquan Dong and JingYu Wang, Uni. of North Dakota





1. Max diameters decrease from 28 mm to 4 mm, whereas the number concentrations increase about 100 times when the aircraft ascended from 4 km to 7.6 km
2. Gamma-type-size-distributions have been derived from original PSDs for remote sensing and modeling communities.

Wang, J., X. Dong, and B. Xi, 2015: Investigation of Ice cloud microphysical Properties of DCS using Aircraft in-Situ Measurements. JGR, 120, 3533-3552, 10.1002/2014JD022795.

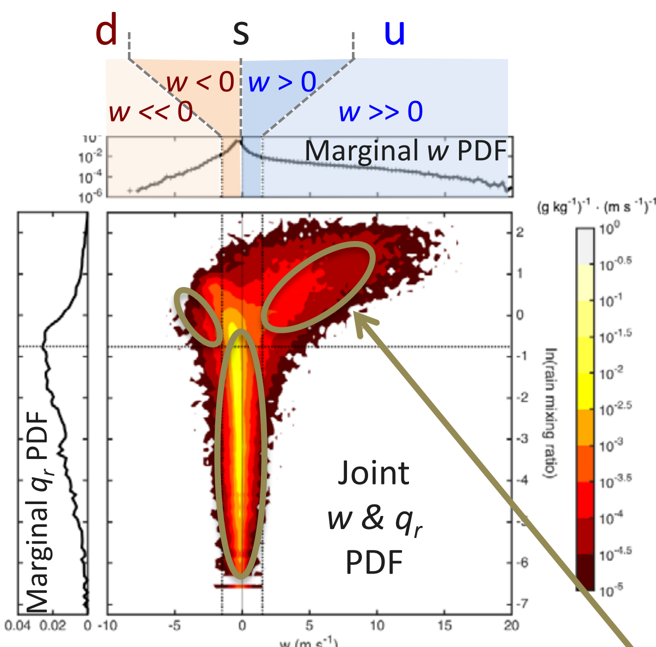
Hydrometeor transport in a PDF-based convection scheme (CLUBB)

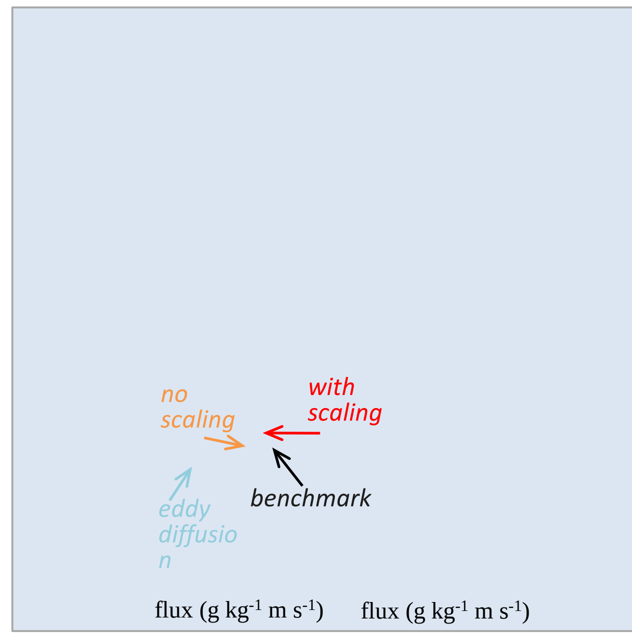
Mikhail Ovchinnikov (PNNL) and May Wong (NCAR)

- Hydrometeor transport affects precipitation formation and cloud water profile
- Joint subgrid PDFs of vertical velocity (*w*) and HM mixing ratios (q_x's) are not known, so that the fluxes need to be parameterized
- Eddy-diffusivity approximation generally does not work for **precipitating deep convection**
- A new scheme parameterizes fluxes using conditional sampling of ***marginal (1D) PDFs*** of *w* and q_x

Decomposition of the net flux into contributions from stratiform (s) regions, updrafts (u), and downdrafts (d) produces realistic profile shapes

$$\overline{w'q'_x} \approx \sum_{i=d,s,u} \sigma_i \overline{w'_i}^{*} \, \overline{q'_{x_i}}^{*}$$





Power-law scaling accounts for **sub-plume correlations** and improves the **magnitude** of the fluxes

$$\overline{\phi_i}^{*} = \left[\frac{\overline{|\phi|^{\alpha}\phi}}{\overline{|\phi|^{\alpha}}}\right]_i$$

Wong & Ovchinnikov, 2016: A PDF-based parameterization of subgrid-scale hydrometeor transport in deep convection, JAS (to be submitted)