NCAR TIIMES Weather-Climate Retreat on Tropical Convection and Two-Way Scale Interaction: Collaborations with CMMAP

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CMMAP, 17 August 2006

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NCAR TIIMES Weather-Climate Retreat, 10-14 July 2006

- Sought to identify key research opportunities in convective research at weather/climate interface
- Reviewed research on observational, modeling, and theoretical aspects of convection, with emphasis on implications from synoptic to climate time scales
- Organizing committee: Brian Mapes, Mitch Moncrieff, David Parsons, Joe Tribbia, Chidong Zhang

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TIIMES Retreat Outcome

- Modeling initiative to use large-domain cloud-system resolving modeling to explicitly represent interactions between convection and flows with spatial scales large enough to contain important climate phenomena (*e.g.*, Amazon and western tropical Pacific precipitation) and time scales from synoptic through sub-seasonal (*e.g.*, MJO) and seasonal-annual means
- Strong theory and observational component
- Broad academic participation

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SP, NRCM, and LD CSRM

- Super-parameterization (SP) and Nested Regional Climate Modeling (NRCM) have improved some aspects of tropical simulation, *e.g.,* diurnal cycle of precipitation in SP
- Other aspects of tropical simulation, *e.g.,* precipitation biases in western Pacific and Amazon, have persisted in both SP and NRCM

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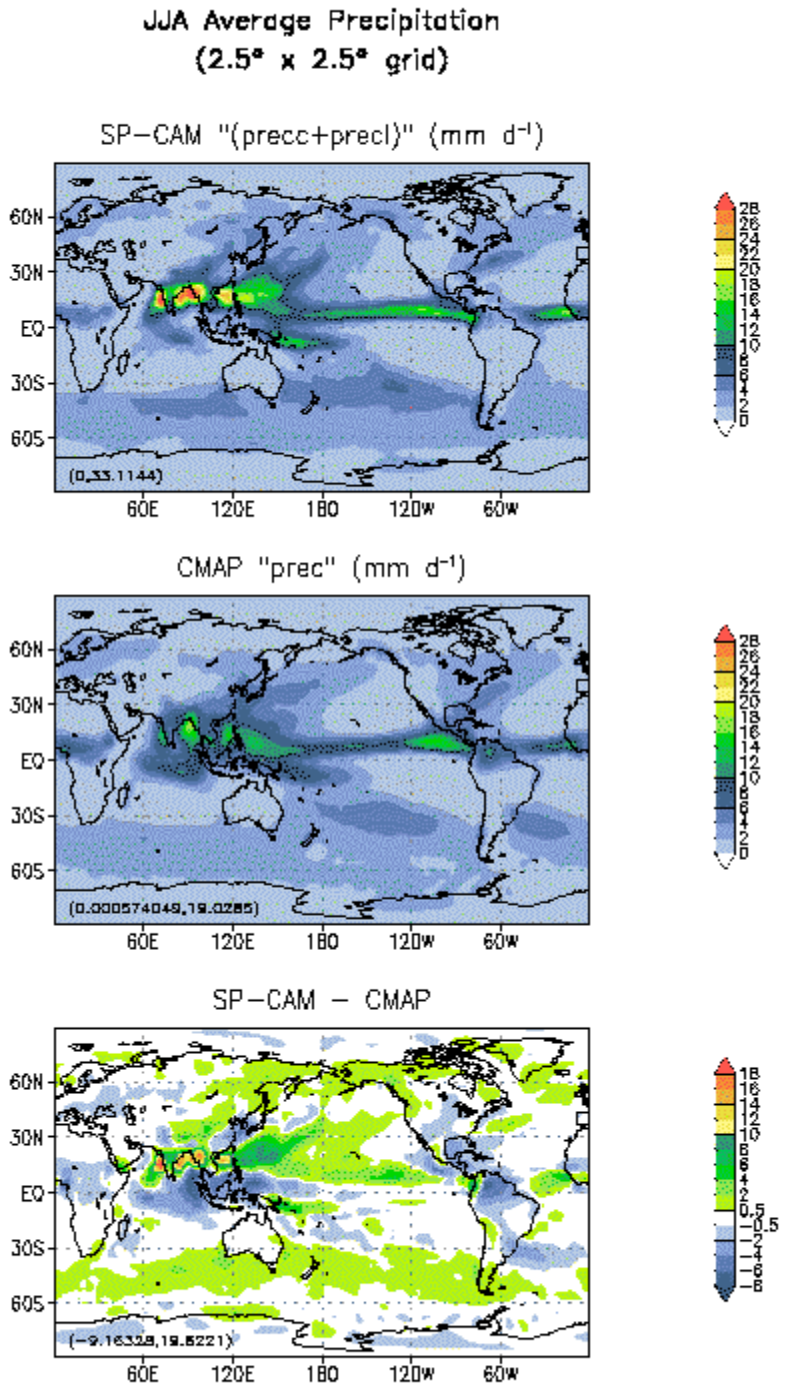

cf., Khairoutdinov *et al.* (2005, *J. Atmos. Sci.*)

NCAR Nested Regional Climate Model

- WRF forced by NCEP analysis
- 36-km resolution
- Deep convection parameterized
- Applied over tropical “channel”

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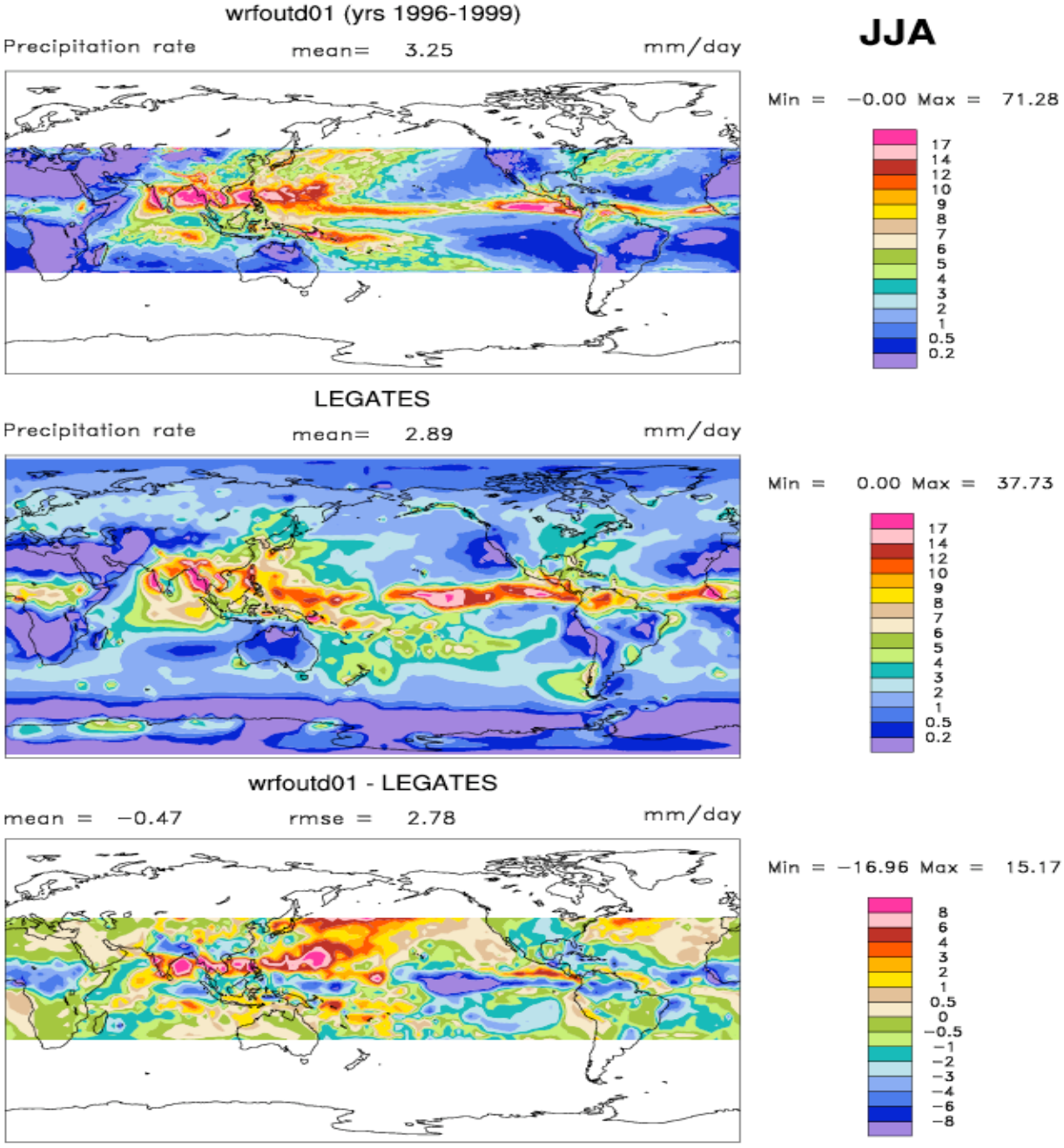
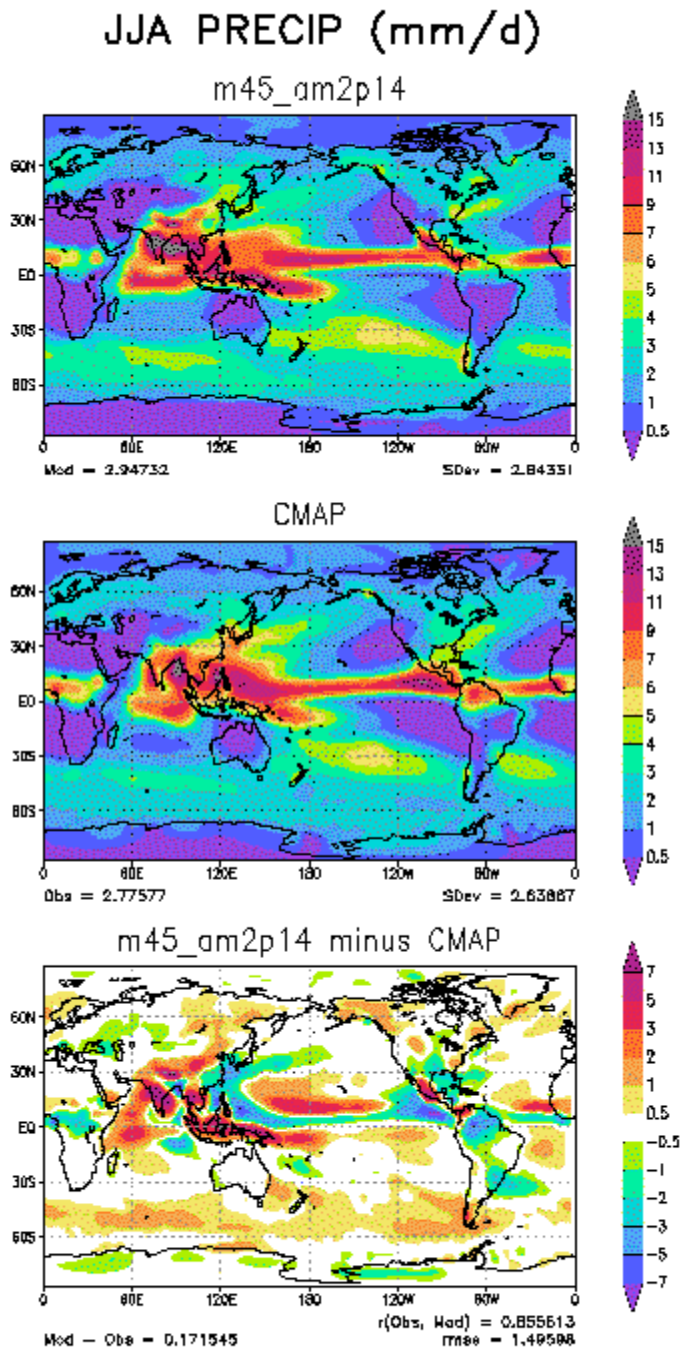
(results provided by Julie Caron, NCAR)





cf., Delworth *et al.* (2006, *J. Climate*)

Robust Convection Errors

- Some unrealistic characteristics of GCMs with much simpler parameterizations for convection persist in super-parameterization (SP) and nested regional climate model (NRCM)
- SP and NRCM still either impose scale separation or use “classical” parameterization

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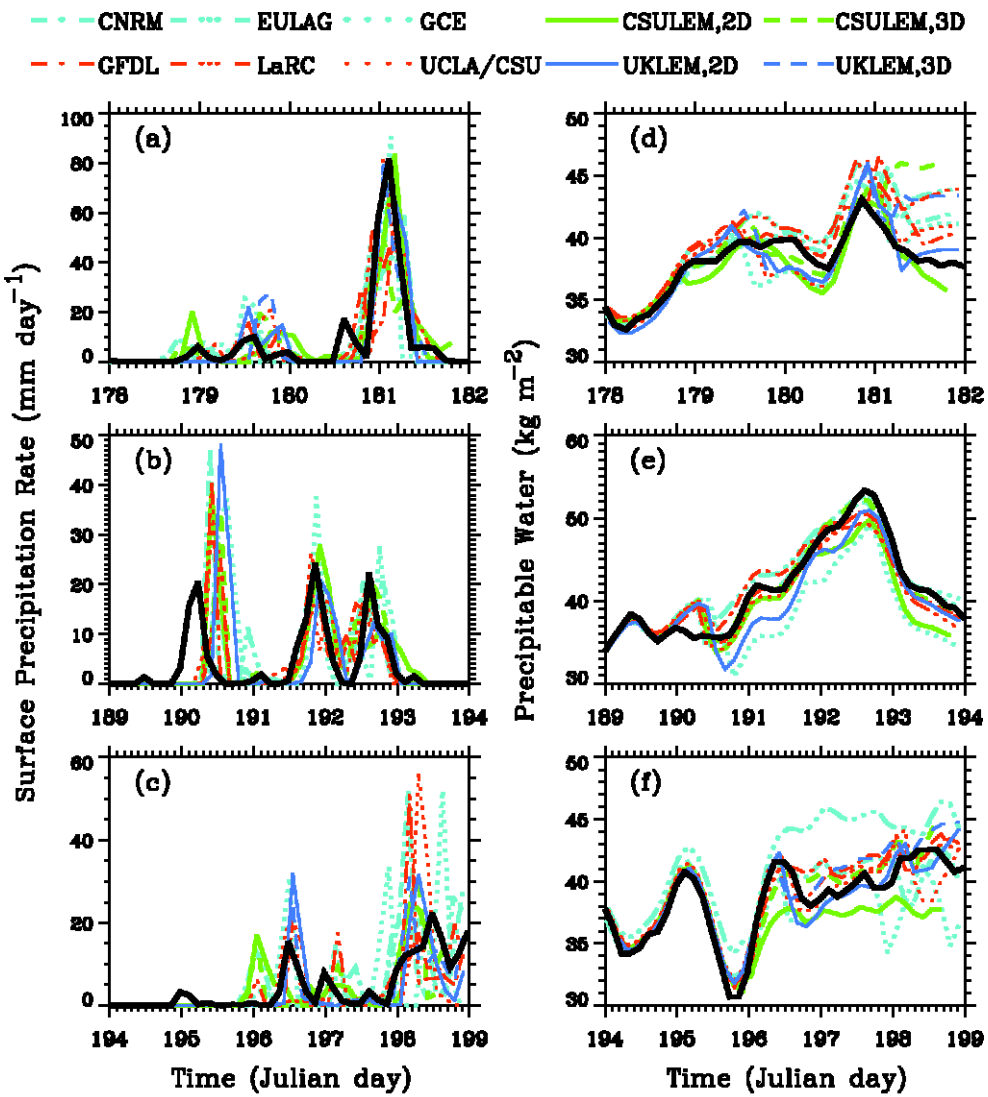

Figure 3. Time series of observed and simulated surface precipitation rates ((a), (b) and (c)) and precipitable water ((d), (e) and (f)) for Sub-cases A ((a) and (d)), B ((b) and (e)) and C ((c) and (f)). The black solid lines show the observations. See Table 2 for explanation of acronyms.

from Xu *et al.* (2002, *QJRMS*)

Biases in Small-Domain, Forced CSRMs

- Errors in small-domain, forced CSRMs appear more random than robust biases in SP and NRCM, except at initial stages of convection
- Experimental design (imposed horizontally uniform advective tendencies) may restrict CSRM solution; no feedback from convection onto mean flow

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Global Convection-Resolving Model

- Non-hydrostatic, 3.5-km resolution aqua planet
- Frontier Research Center for Global Change Earth Simulator
- Eliminates issues related to topography, dimensionality, and propagation across grids associated with “super-parameterization”

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The structure and motion of the organized group of cloud clusters (super cloud cluster) as well as individual cloud clusters in the equatorial belt region are reproduced realistically showing their characteristic features. It is seen that detailed structures of extratropical cyclones are represented as well.

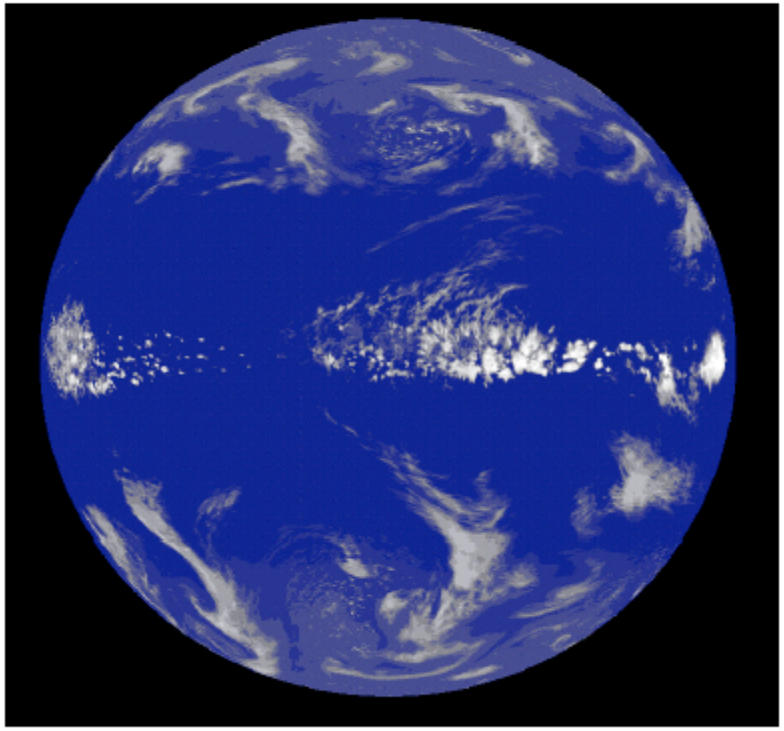

Figure 1: Global cloud image by NICAM, next-generation model

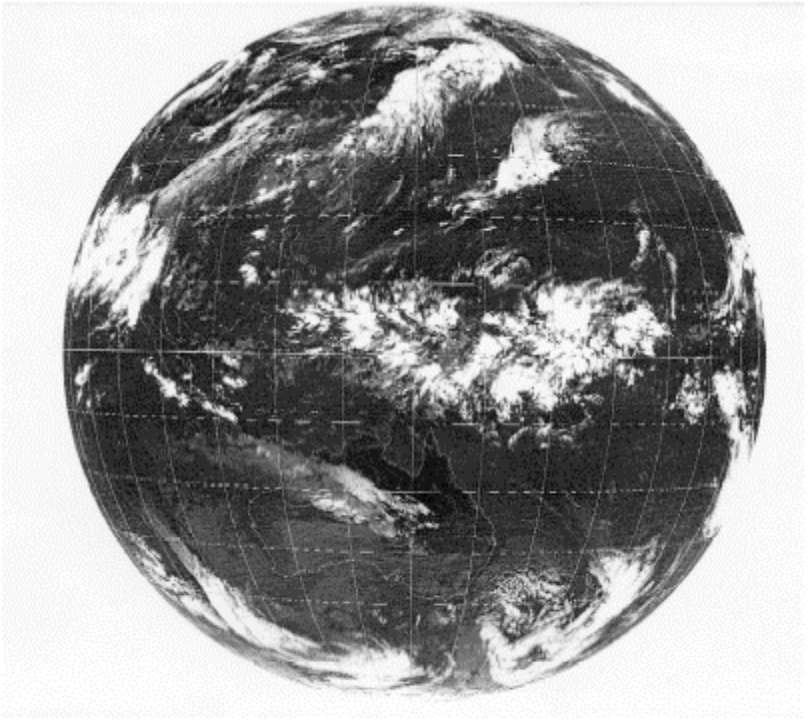

Figure 2: Cumulus ensemble in the tropics by HIMAWARI, weather satellite
13 June, 1998, Japan Meteorological Agency

Source: Frontier Research Center for Global Change

Research Goal: Large-Domain Cloud-System-Resolving Model

- Nested
- Avoid scale-separation (parameterization) framework
- If driven by analysis, energy and mass conservation constraints must hold-unclear whether true for NCEP, EC
- Other possible causes for robust convection errors, which would be evident in such calculations?

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Blythe *et al.* (1988, ***JAS***) and others observations of *non-precipitating* convection support buoyancy sorting.

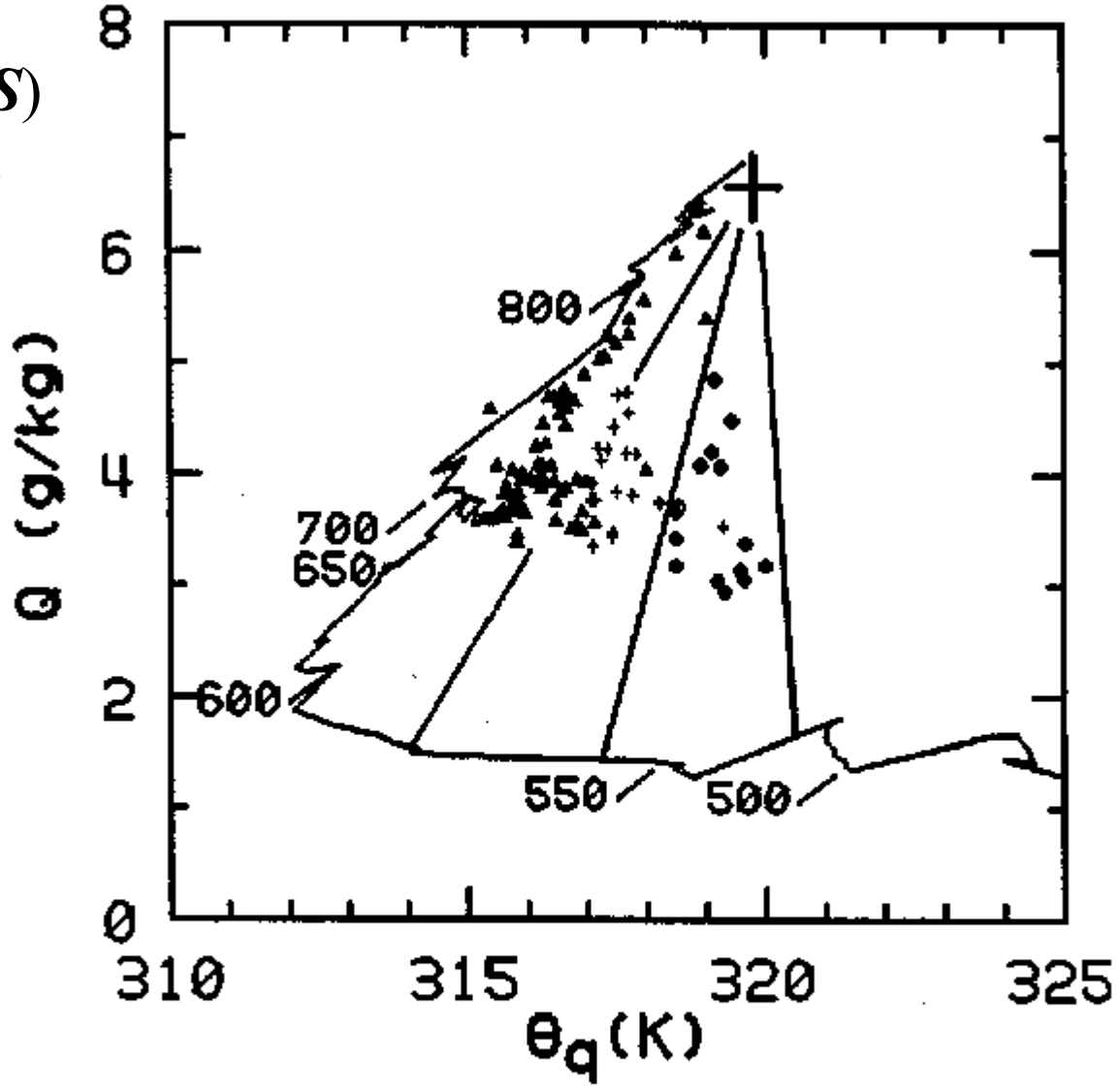
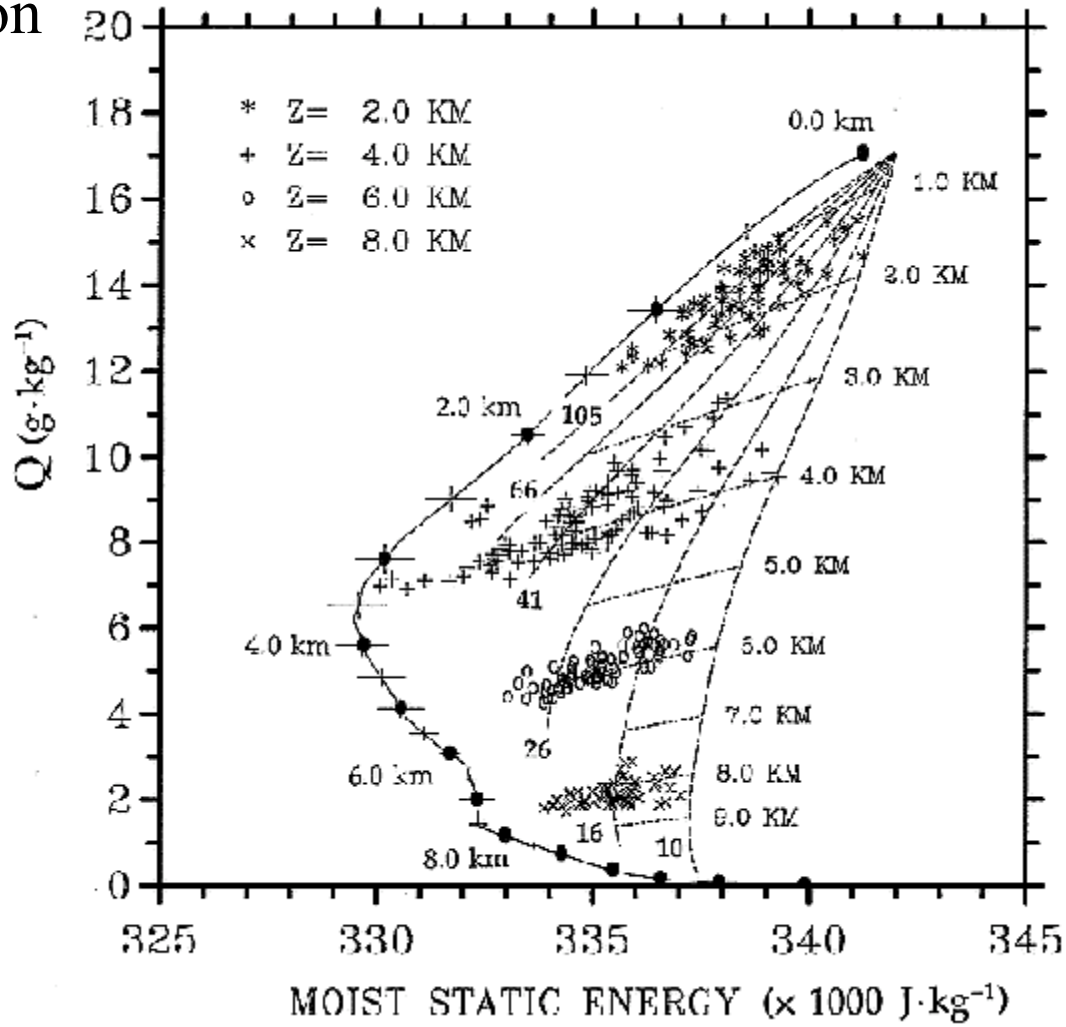


FIG. 6. As in Fig. 4, but for cloud 3 on 20 July 1978. The in-cloud observations from three passes are shown as ● (535 mb), + (575 mb) and Δ (615 mb). The cloud-base value is shown with a large + and the lines indicate the approximate separation between the points on the three passes.

Lin and Arakawa's (1997, ***JAS***) analysis of a CRM showed deep *precipitating* convection behaved like an entraining plume, at least away from cloud base.



Proposal: Analyze Mixing Behavior in CSRMs against Observations

- Shallow, non-precipitating cumulus can be analyzed using mixing diagrams like those generated by Blythe and colleagues for comparison with field data
- Trajectory analysis can be employed for both deep and shallow cumulus
- Will CSRMs reproduce observed behavior in shallow limits for which observations exist?

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TIIMES Initiative and CMMAP

- Both projects require that issues related to fundamental realism of CRMs be addressed, *e.g.,* resolution required to accurately capture heat and moisture transports by convection, appropriate representation of microphysics and sub-grid turbulence.
- Although early strategies differ-scale separation with global domain *vs.* explicit simulation across scales with limited large domain-ultimately, a global, cloud-system resolving model should emerge.
- Significant collaboration will benefit both endeavors.

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