Deep convection and the boundary layer

Acknowledgements:

Interactions of the PBL with deep convection

- This is one of the most important "jobs" of the PBL.
- It has been neglected by us modelers.
- We should be ashamed of ourselves.

Still the one

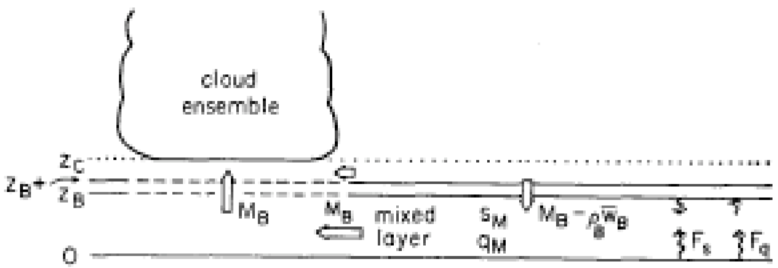


FIG. 9. A schematic diagram of the subcloud mixed layer in which s and q are constant with height. The transition layer (the layer between $z=z_B$ and $z=z_B+$) just above the top of the mixed layer is assumed to be infinitesimally thin and discontinuities in s and q are assumed to occur at z_B. We assume that the mixed layer is unsaturated so that z_C is above z_B. $M_B-\rho_B\bar{w}_B$ is the downward environmental mass flux at z_B. In typical situations the surface turbulent fluxes of s and q are upward, while at z_B the turbulent flux of s is downward and the turbulent flux of q is upward.

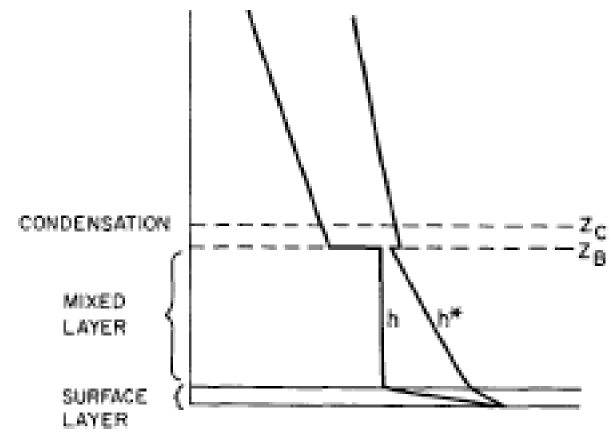


FIG. 10. A schematic diagram of typical vertical profiles of h and h^* near the mixed layer. h is constant with height in the mixed layer, and h^* decreases rapidly with height in the mixed layer since the temperature lapse rate is dry adiabatic.

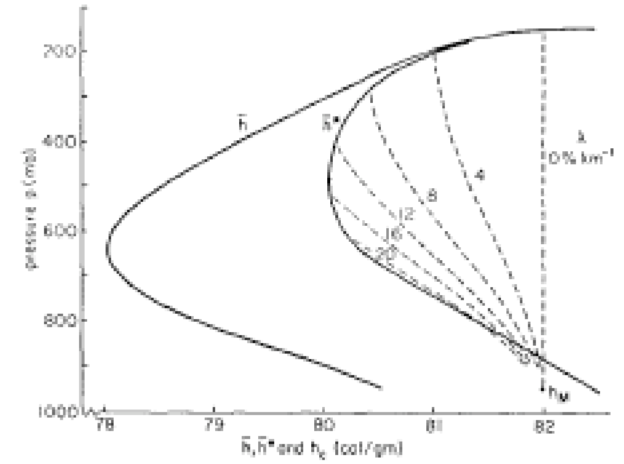


FIG. 6. Vertical profiles of $\bar{h}(p)$, $\bar{h}^*(p)$ and $h_c(p,\lambda)$; $h_c(p,\lambda)$ lines are dashed and labeled with the value of λ in percent per kilometer. Profiles of $\bar{h}$ and $\bar{h}^*$ were obtained from Jordan's (1958) "mean hurricane season" sounding. The top p_B of the mixed layer is assumed to be 950 mb; h_M is assumed to be 82 cal gm^{-1}.

What AS Included

Explicit PBL sub-model

CIN (PBL-top inversion, etc.)

Both shallow and deep convection

What AS left out

Downdrafts

Bubble variability
- Thermodyn properties
- Diameter

Unmixedness

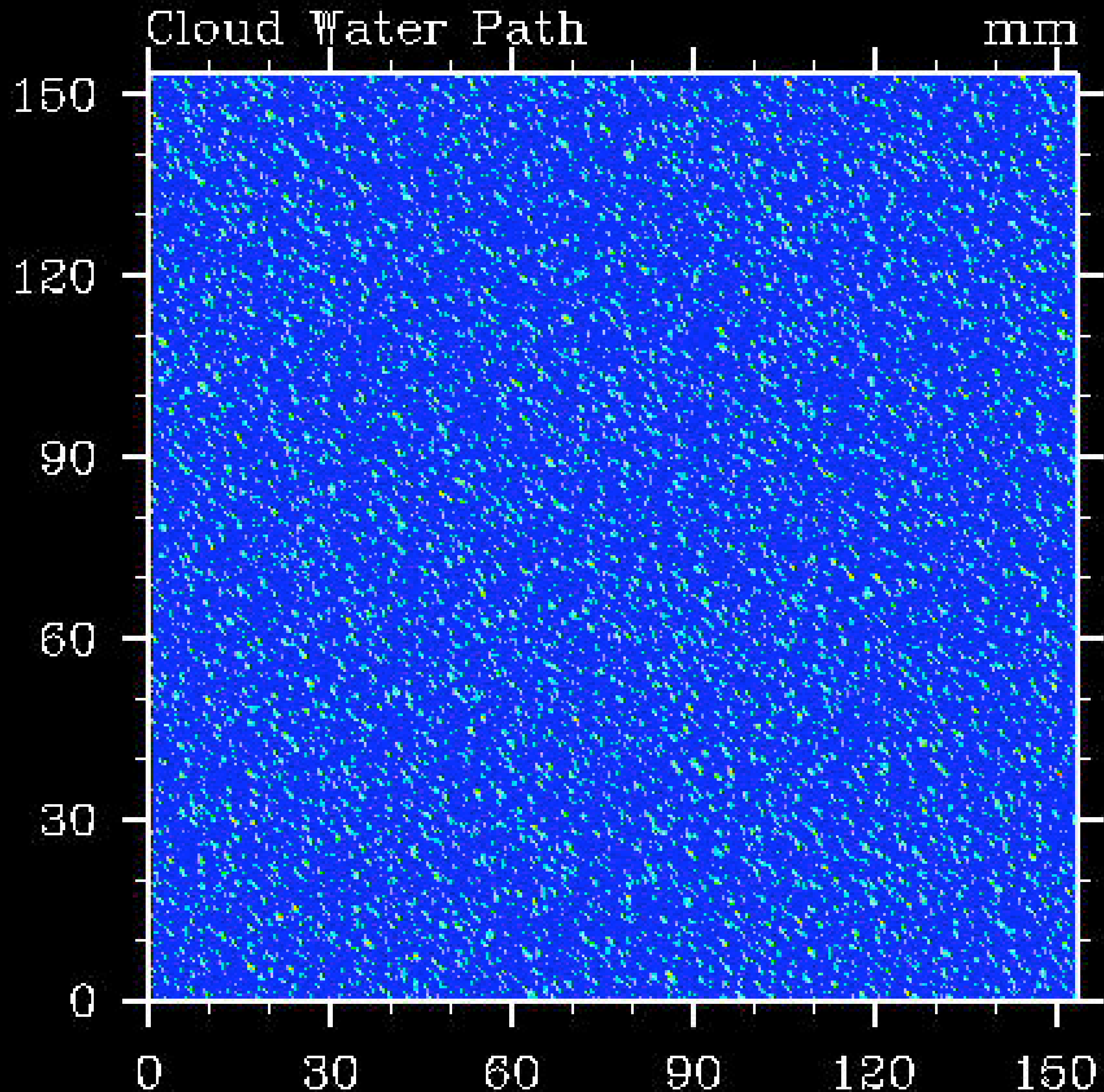
Surface-flux enhancement

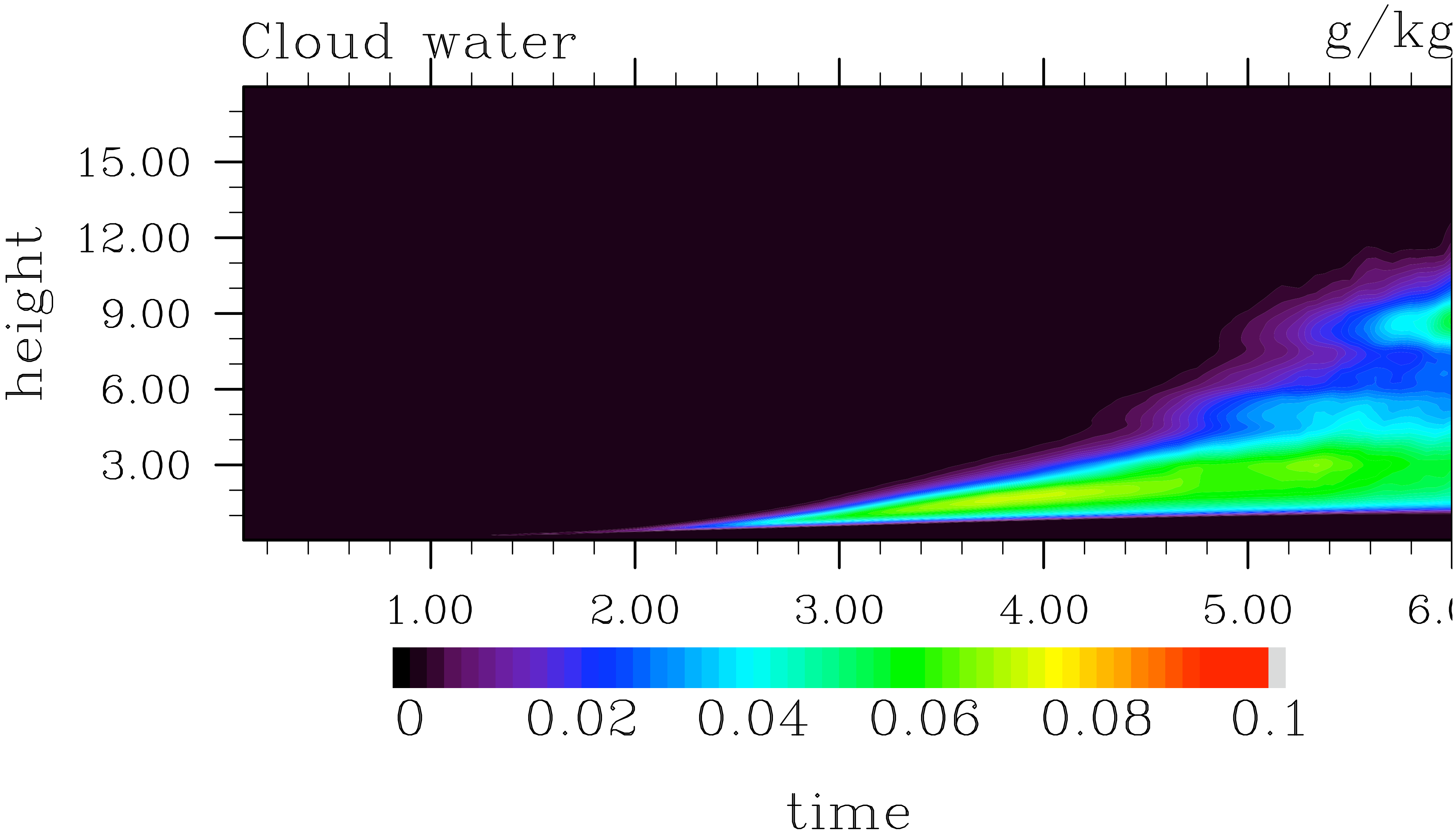
Deep convection that starts above the PBL

Orographic effects

Bubbles

TRMM-LBA, morning




Cloud water
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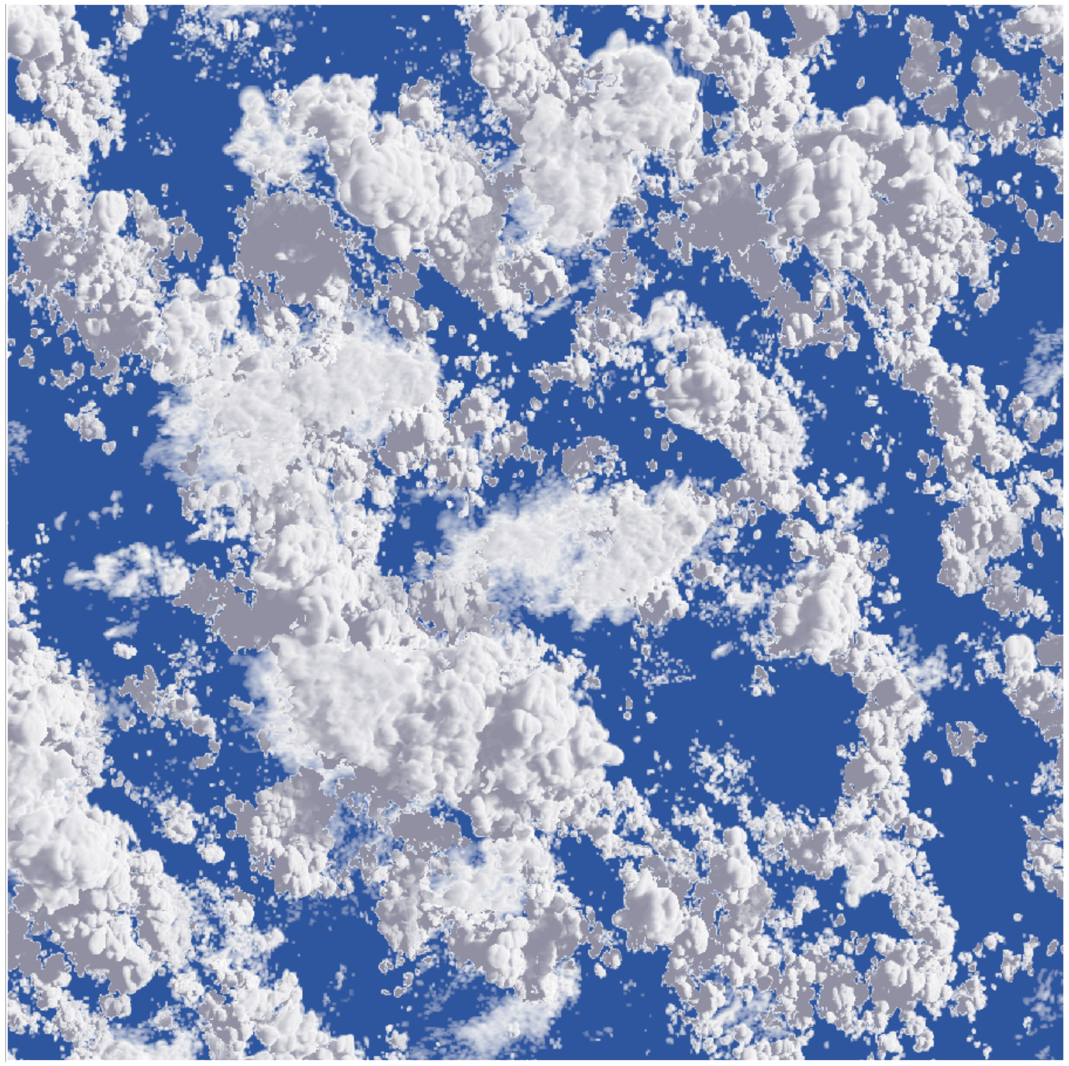
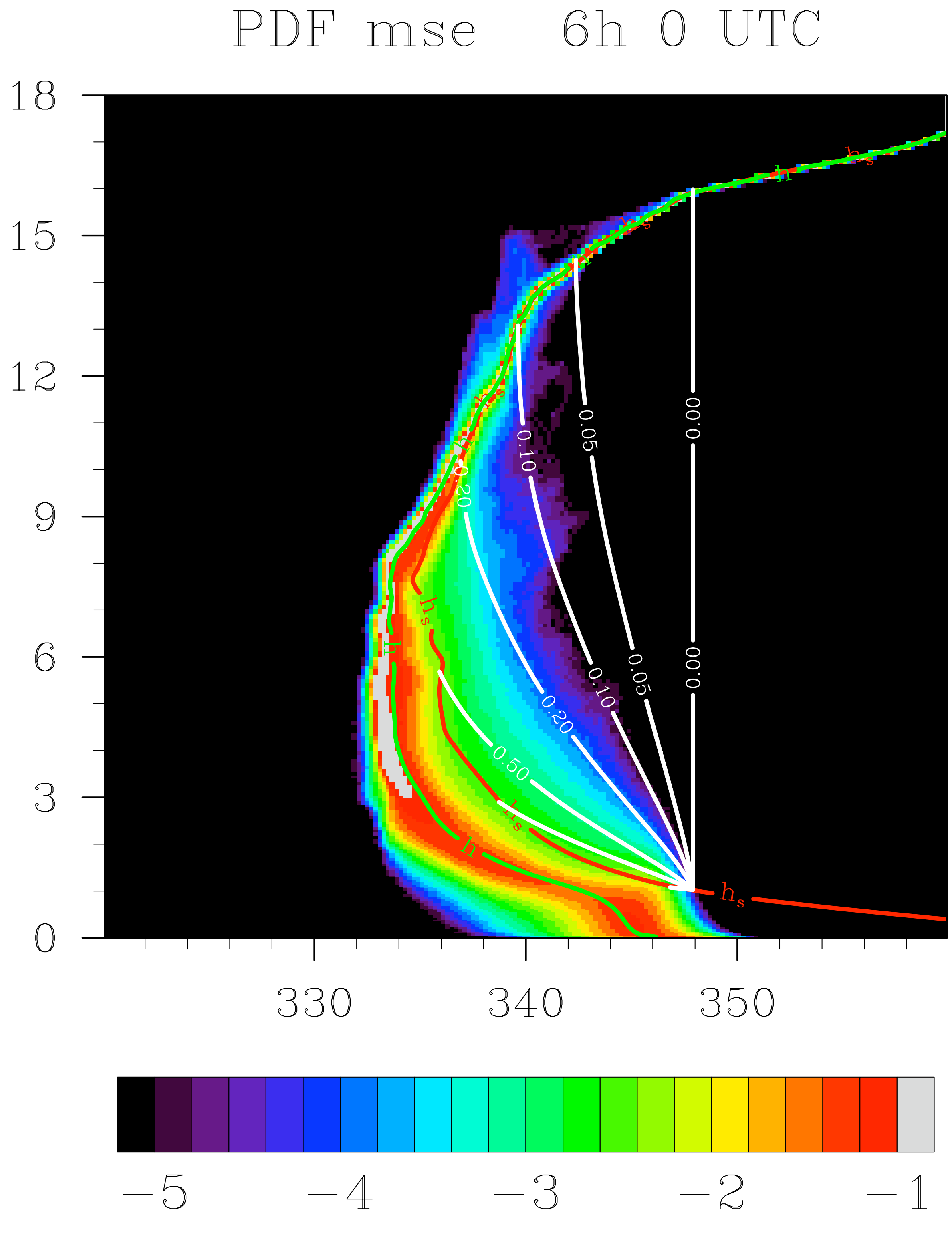
time





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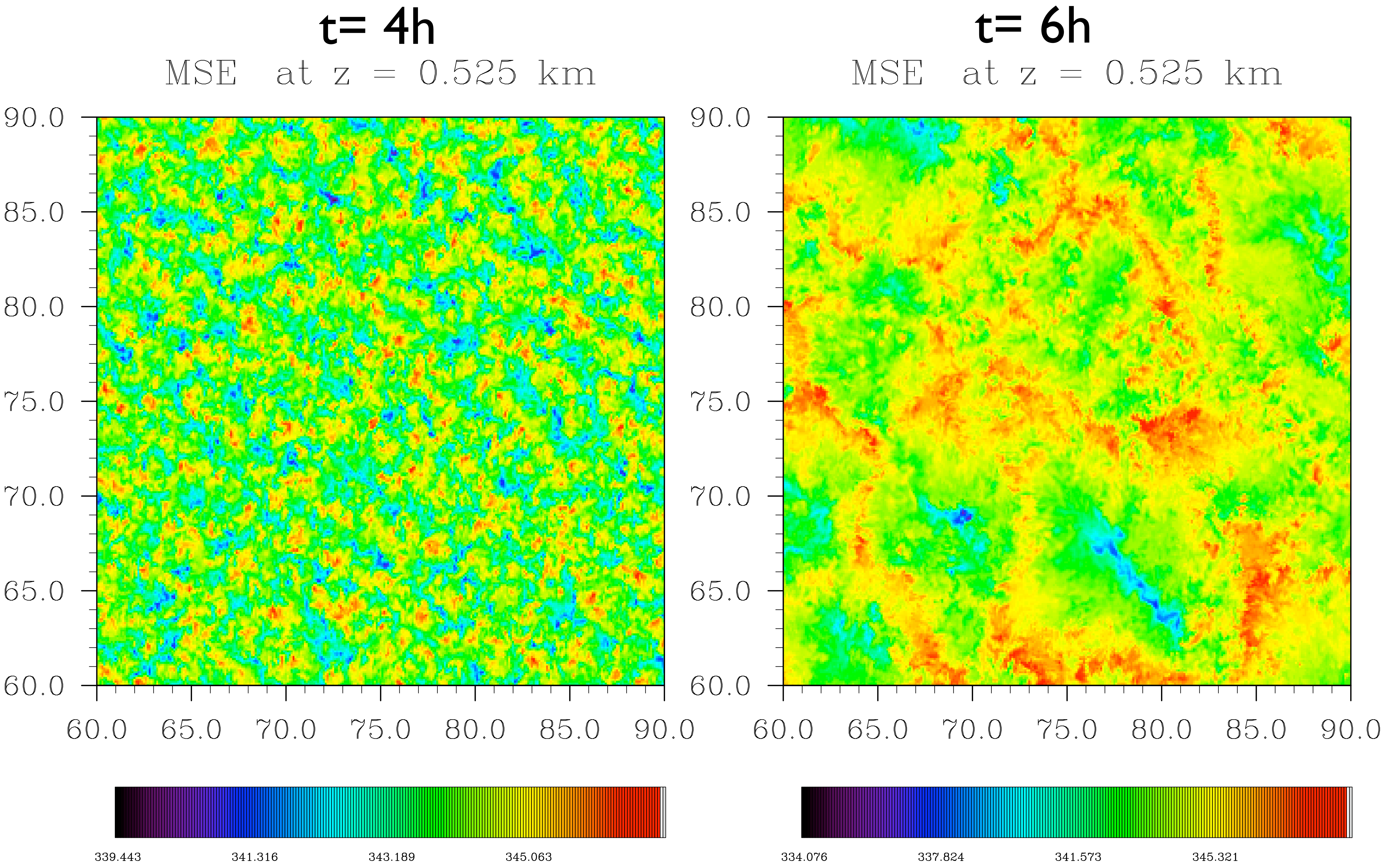
PBL moist static energy

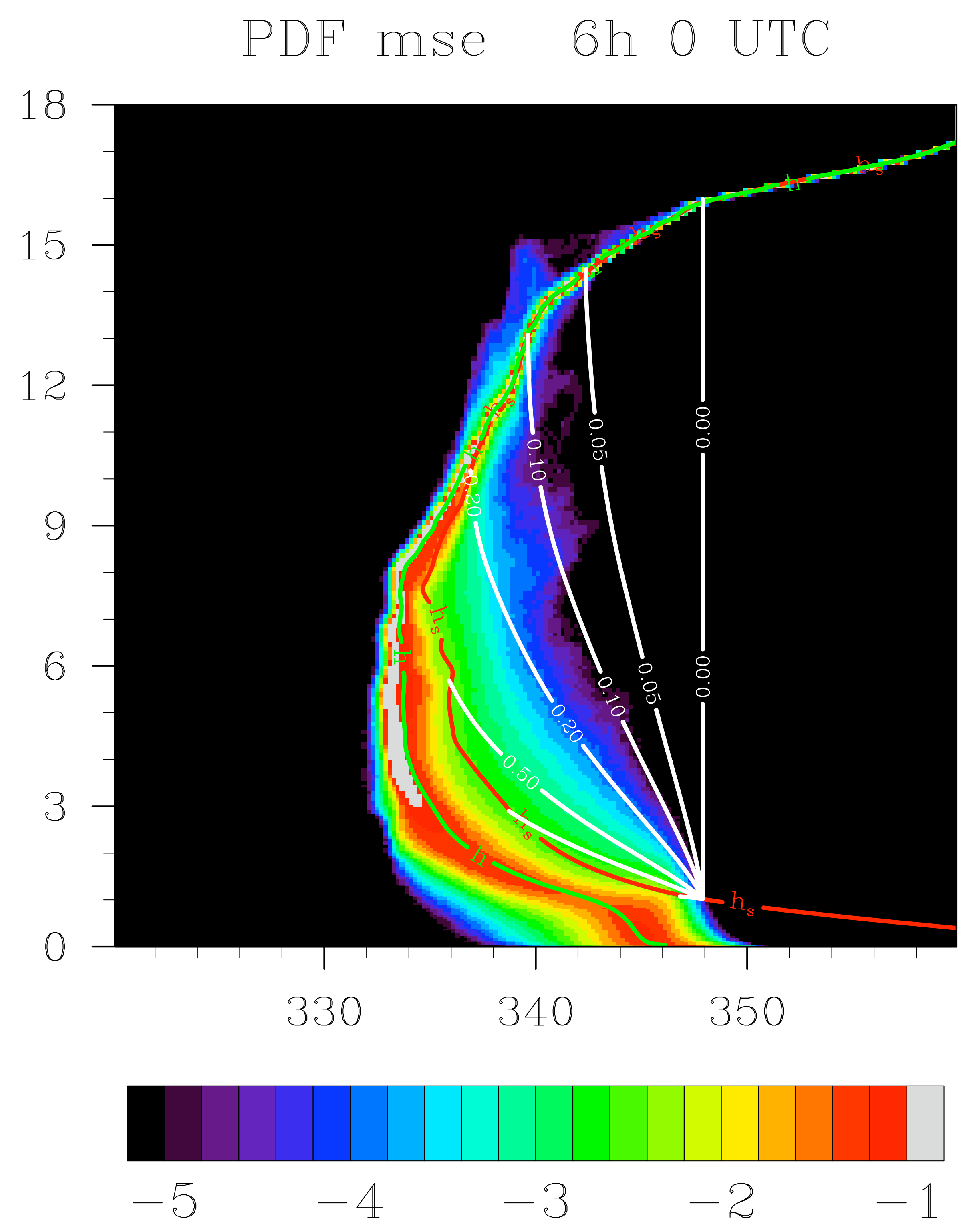


Bubble variability

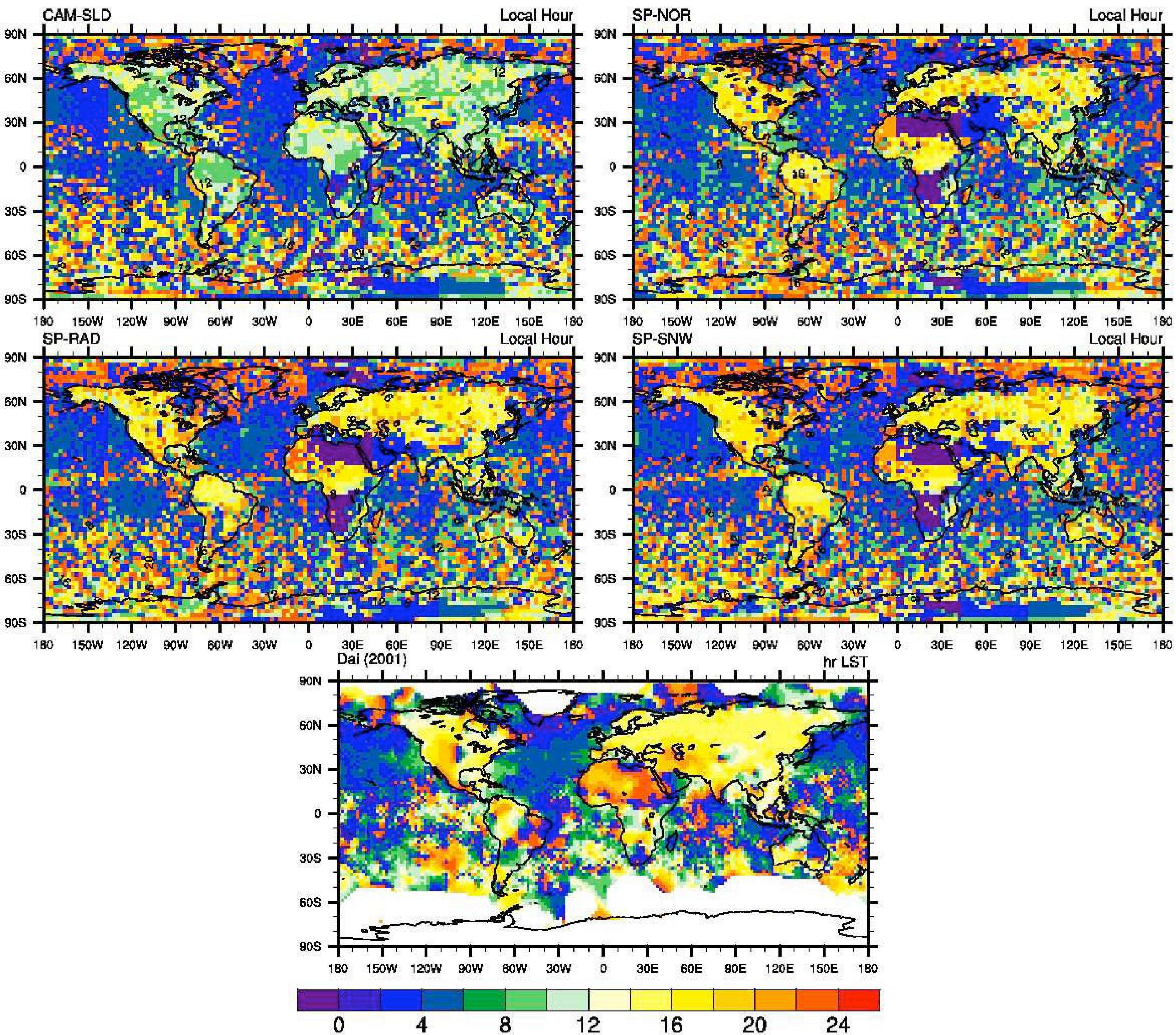
Tokioka et al.

$$Minimum\, \lambda \sim 1/h$$

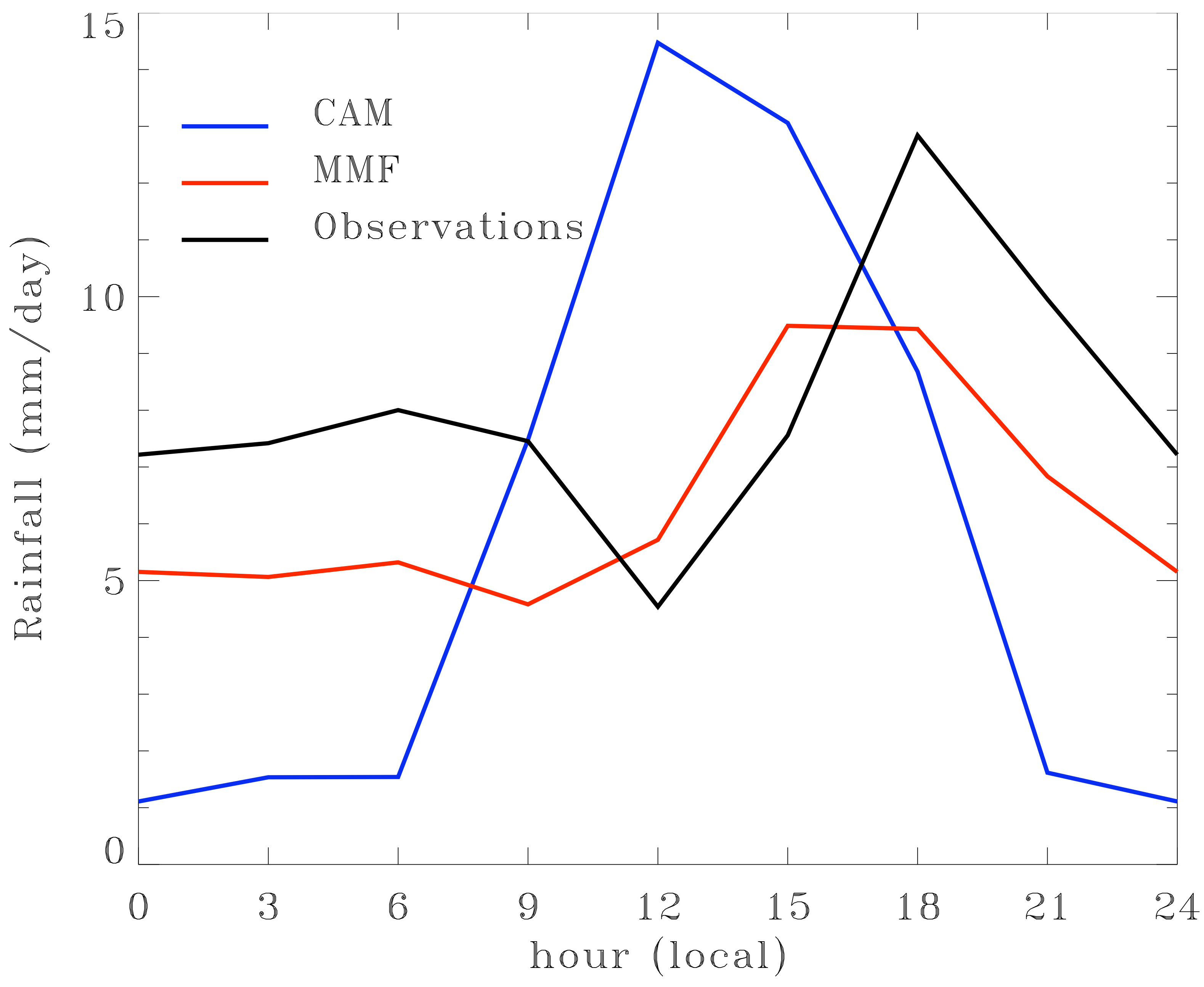
Do we need an additional dependence on precipitation?



JJA Local time of precipitation frequency maximum



Diurnal cycle of precip in the Amazon Basin




But wait!
What about AS?

JAS, 1985, p.656

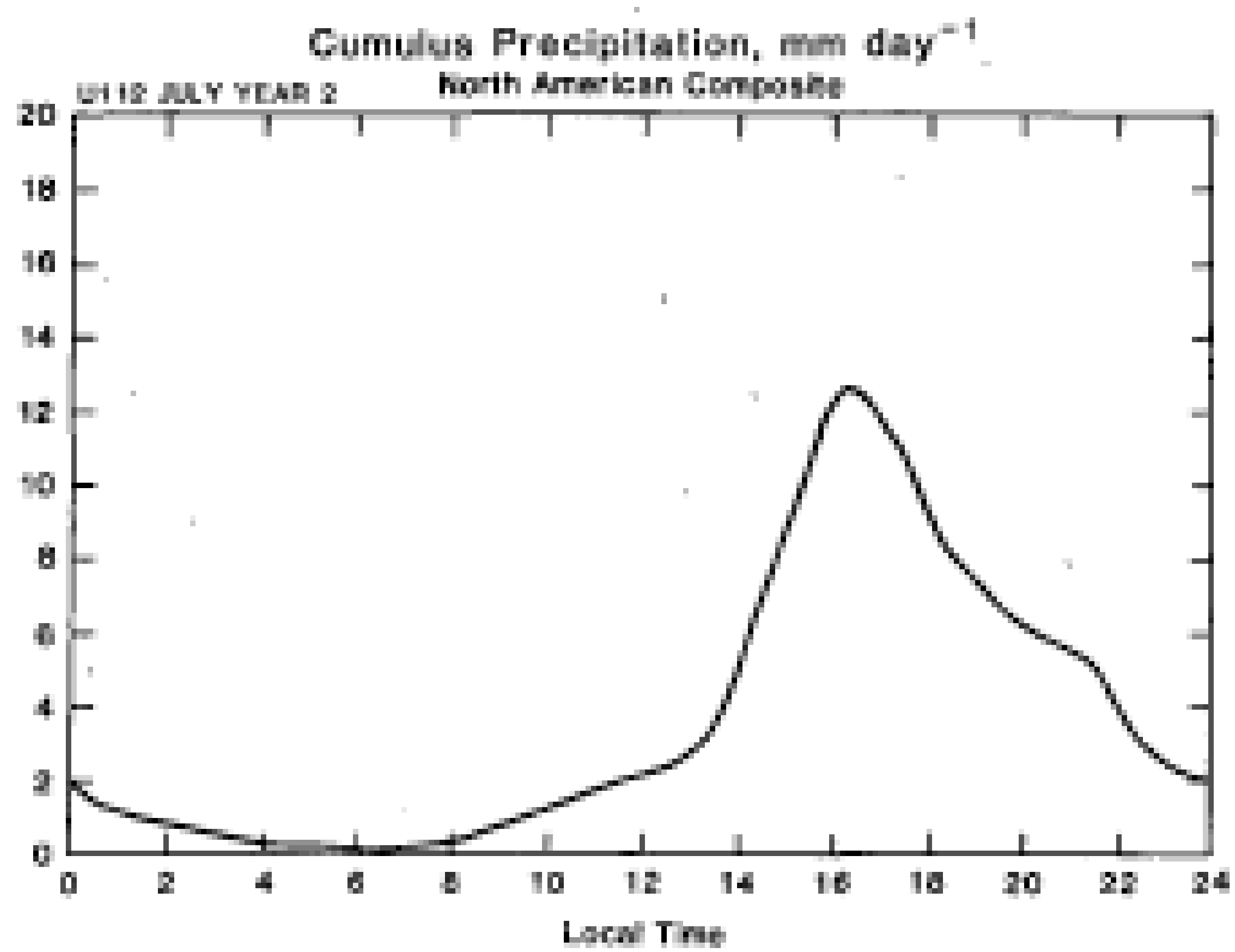


FIG. 19. Simulated diurnal variation of cumulus precipitation, composited by local time, for the North American grid points indicated in Fig. 1, and for July of the second year of the three-year simulation.

JAS, 1991, p. 44

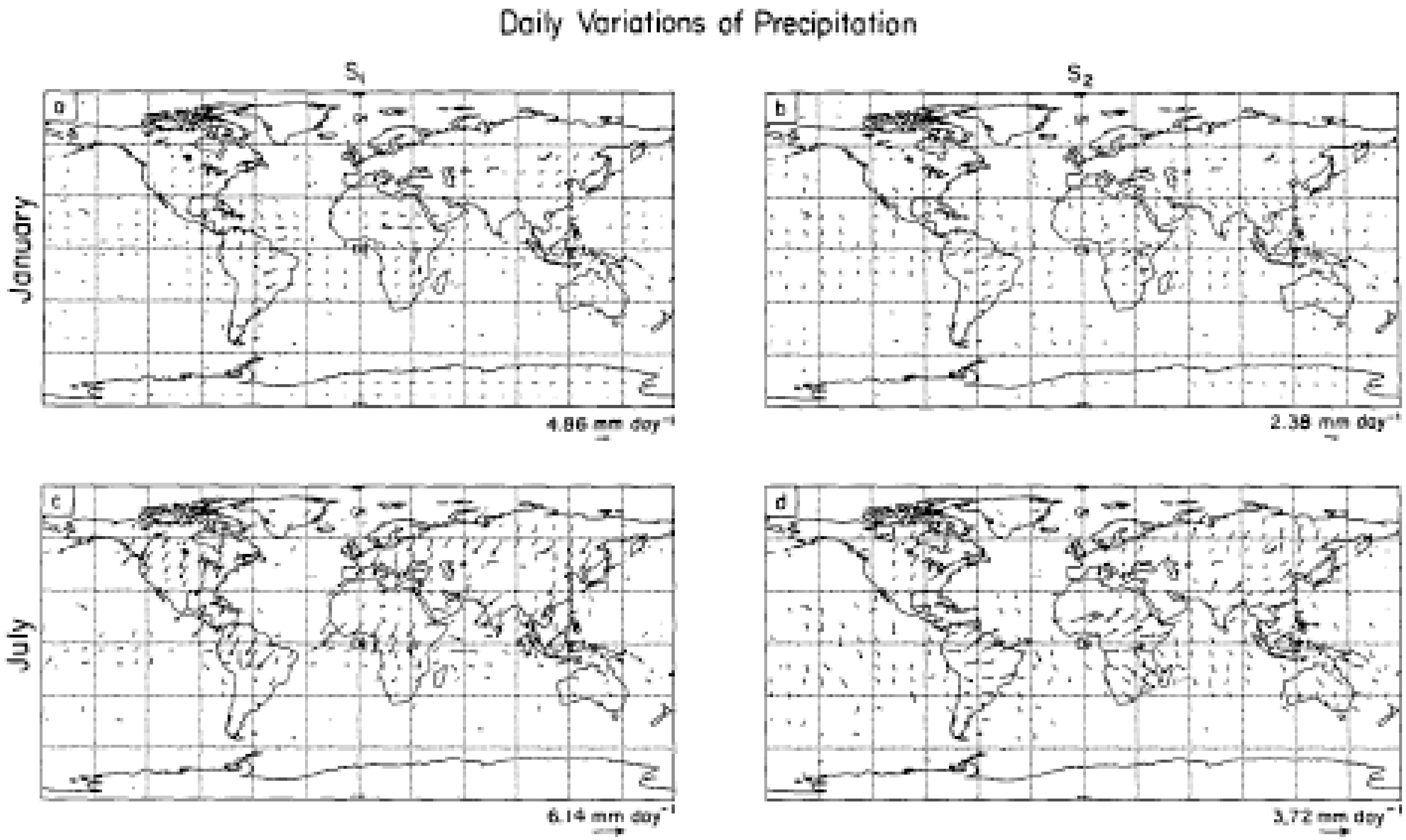


FIG. 2. The simulated phase and amplitude of $S_1(P)$ and $S_2(P)$, for January and July. The units are mm day^{-1}. Arrows are plotted only where the statistical significance parameter M exceeds 6; see Appendix for explanation. For $S_1(P)$, arrows pointing upward indicate maxima at local midnight, those pointing to the right indicate maxima at 0600 LST, etc. For $S_2(P)$, arrows pointing upward indicate maxima at local midnight, those pointing to the right indicate maxima at 0300 LST, etc. (a) $S_1(P)$ for January. (b) $S_2(P)$ for January. (c) $S_1(P)$ for July. (d) $S_2(P)$ for July.

Some inferences:

- A simple PBL model that is explicitly coupled to deep convection can give a realistic diurnal cycle of precipitation over both land and sea.
- Without such a model, the results are considerably worse.
- To go further, we may need to simulate the thermodynamic variances in the PBL, which are strongly affected by precipitation.

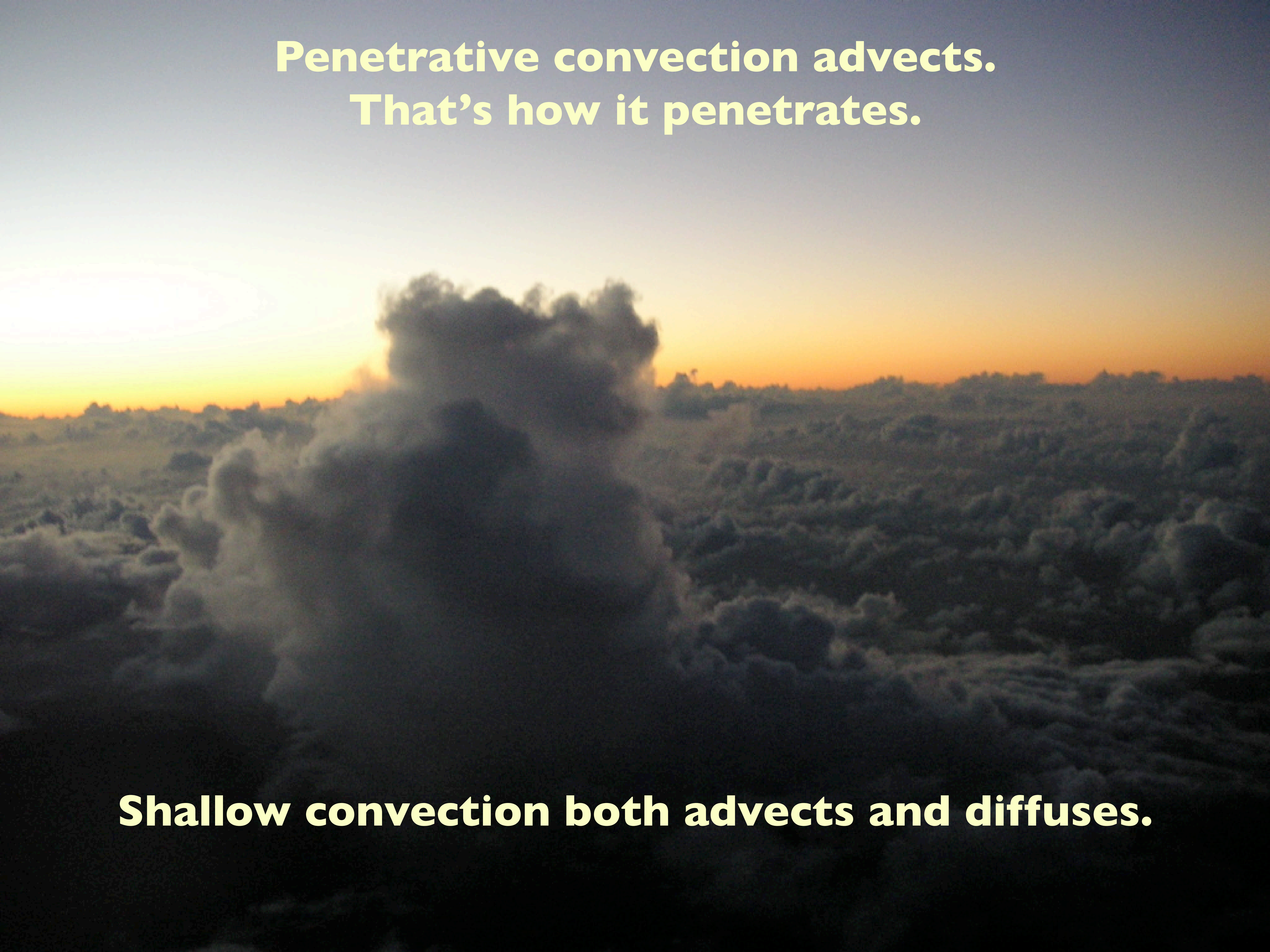
Unification?

Advection or diffusion?

$$Advective\ flux = \rho w_c A$$

These can transport not only averages, but higher moments.

$$Diffusive\ flux = -K \frac{\partial A}{\partial z}$$


Penetrative convection advects.
That's how it penetrates.
Shallow convection both advects and diffuses.


A unified model must both advect and diffuse.

Randall, D. A., Q. Shao, and C.-H. Moeng 1992: A Second-Order Bulk Boundary-Layer Model. *J. Atmos. Sci.*, 49, 1903-1923.

Lappen, C.-L, and D. A. Randall, 2001: Towards a unified parameterization of the boundary layer and moist convection. Part I. A new type of mass-flux model. *J. Atmos. Sci.*, 58, 2021-2036.

These papers show that:

- Mass flux methods can be married with higher-order closure.
- With this approach, the triple-moment terms of the second moment equations can either advect or diffuse, depending on the regime.

BOMEX

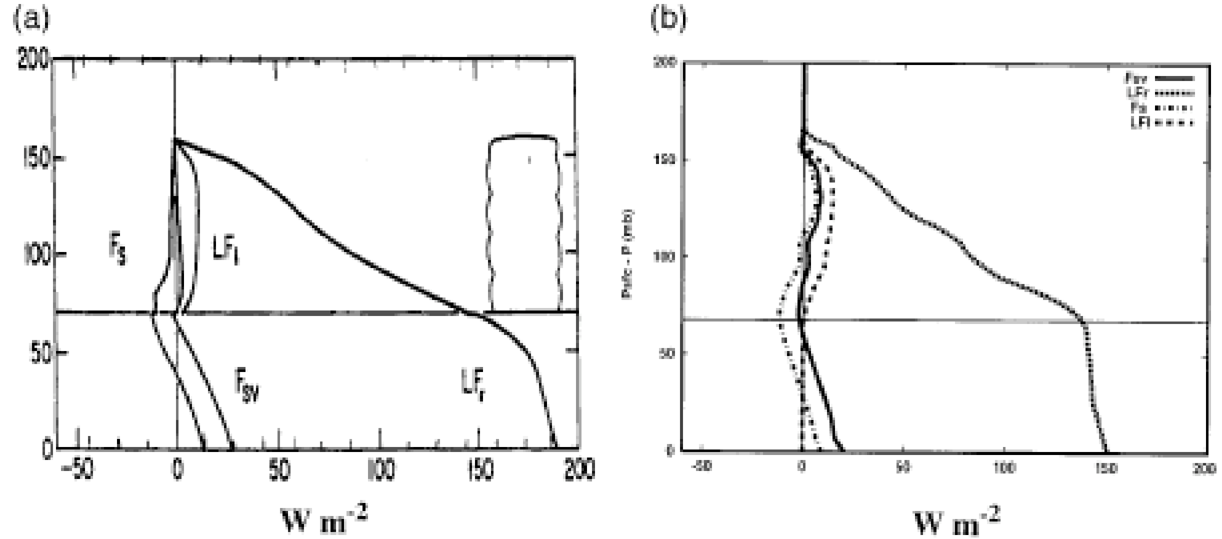


FIG. 9. Comparison of the (b) BOMEX-simulated and (a) observed fluxes of dry static energy (Fs), virtual dry static energy (Fsv), total water (LFr), and liquid water (LFl). The observed profiles are from Esbensen (1978).

ASTEX

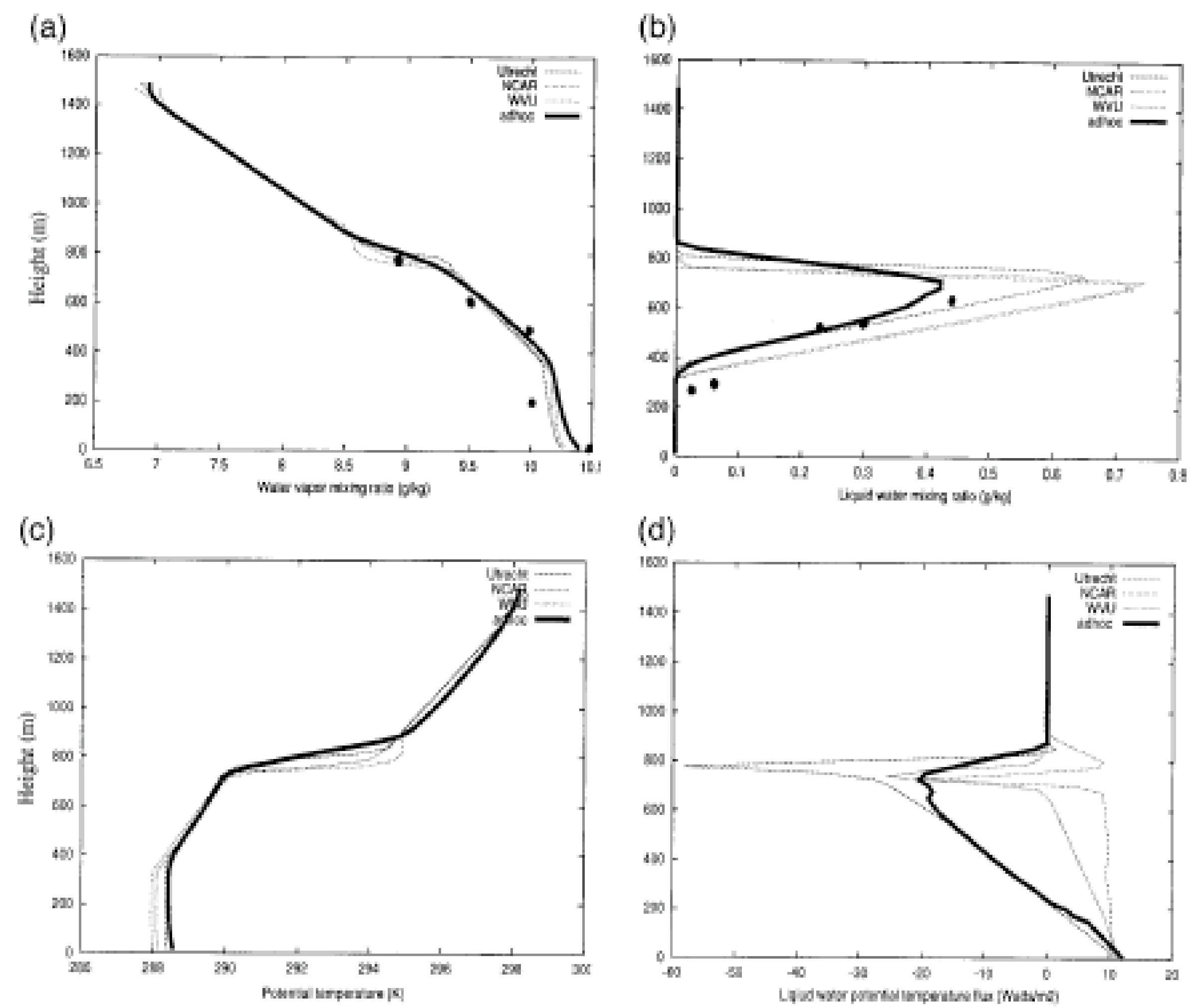


FIG. 12. Comparison of the (a) simulated mean water vapor and (b) liquid water mixing ratios, (c) liquid water potential temperature, and (d) liquid water potential temperature flux for ASTEX with that of LES and observations. The darkest line is ADHOC, the lighter lines are the indicated LES models, and the dots are observations from the NCAR Electra as analyzed by de Roode and Duynkerke (1997).

LR did only shallow convection.

To do deep, we need:

- **Variability within the cloud field**
- **Both convective and broken but stratiform clouds**
- **Simplified vertical structure -- explicit PBL top?**
- **Precipitation, etc.**

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