Improving CSRMs in the Next Five to Ten Years

Discussion session

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Major Building Blocks of a New CSRM

- Dynamics:
  - Anelastic or fully compressible
  - Ooyama's framework (Wayne Schubert's presentation in Hawaii)
  - Two dimensionality of CSRMs in MMF (vs. 3-D CSRMs)
- Microphysics
  - Single-moment Bulk (predicting mixing ratio of hydrometeors)
  - Double-moment Bulk (also predicting number of concentration)
  - Bin (detailed distributions)
- Turbulence Closure
- Radiation
- Aerosols/Chemical Transport Model
- Land Surface Model

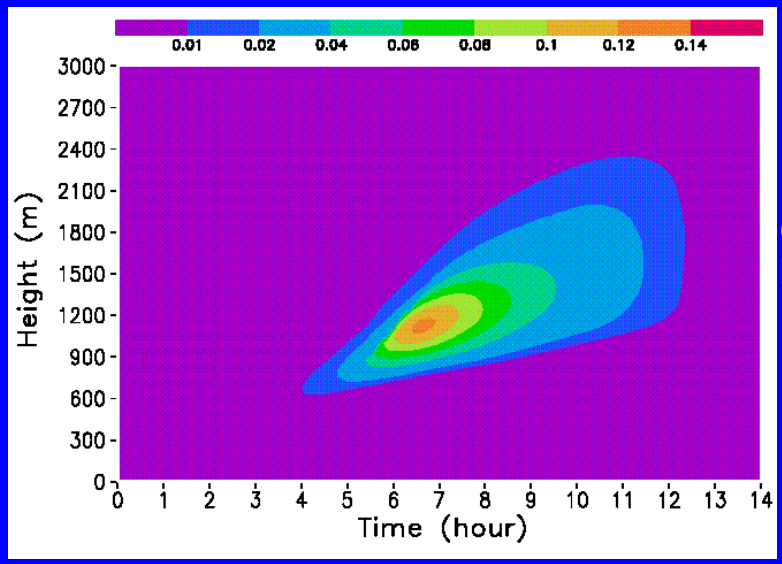
Numerics, Resolution and Boundary-layer clouds

- What types of finite differencing schemes?
  - Depending upon dynamics chosen
- What is the adequate spacing resolution?
  - Horizontal grid spacing: 1 – 2 km
  - Vertical grid spacing: 0.1 - 0.5 km
- What is the adequate temporal resolution?
  - Dynamics and microphysics (seconds), radiation (minutes)
  - Aerosols (seconds), land-surface (minutes)
- Are these grid spacings smaller enough to resolve boundary-layer clouds?
  - If not, how to improve boundary-layer physics in CSRMs?

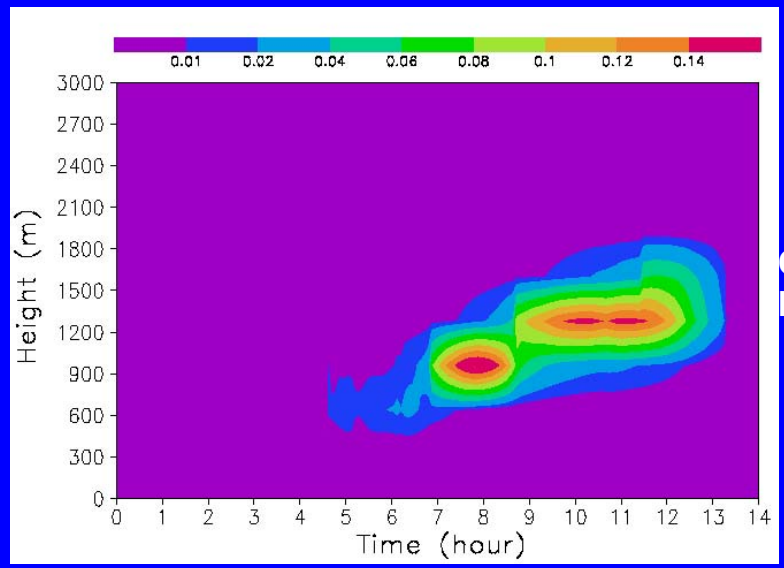
Boundary-layer Physics

- Embedded an “Mini”-LES in parallel
- ADHOC (Mass flux/higher-order closure; Lappen and Randall 2001)
- Simplifed third-order turbulence closure (Cheng and Xu 2004)
  - Fully prognostic, third-order turbulence closure (35 prognostic equations and one diagnostic equation; Krueger 1988)
  - Sommeria-Deardorff (1977) turbulence-scale condensation scheme, with Gaussian probability density function (PDF)
  - Partially prognostic third-order turbulence closure model that predicts $\theta_l'^3$, $q_w'^3$, in addition to w'^3 ; the rest of 3rd, all 4th and all 2nd moments are diagnosed from the double-Gaussian PDF
  - Double-Gaussian PDF for turbulence-scale condensation
  - Consistent treatment of in-cloud turbulence in the free troposphere, where lower-order closure cannot do

Example of BLC simulations with different vertical grid spacings



CRM Dz=40m



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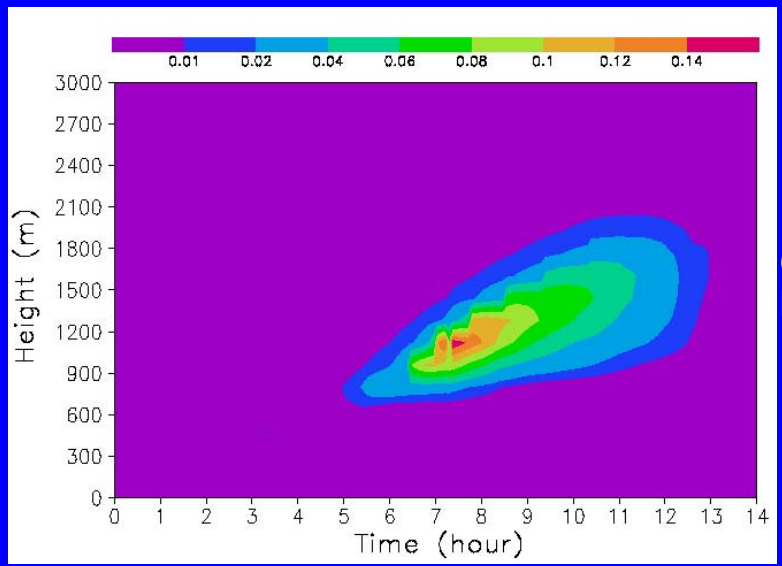
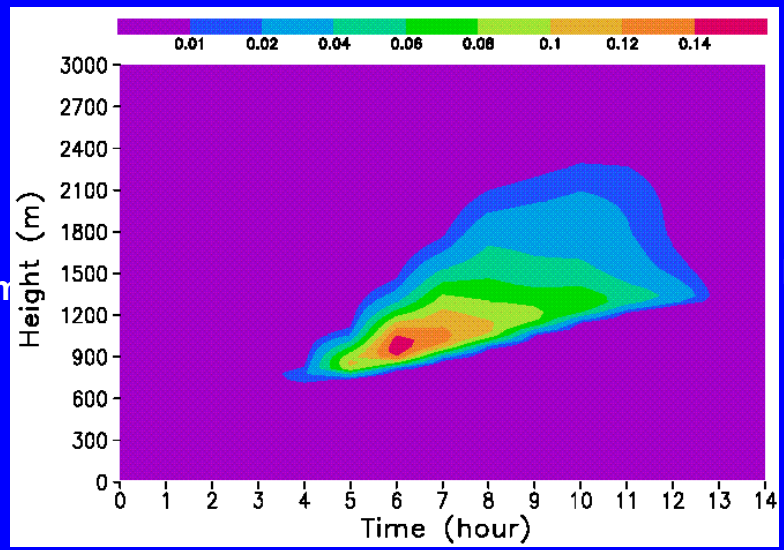


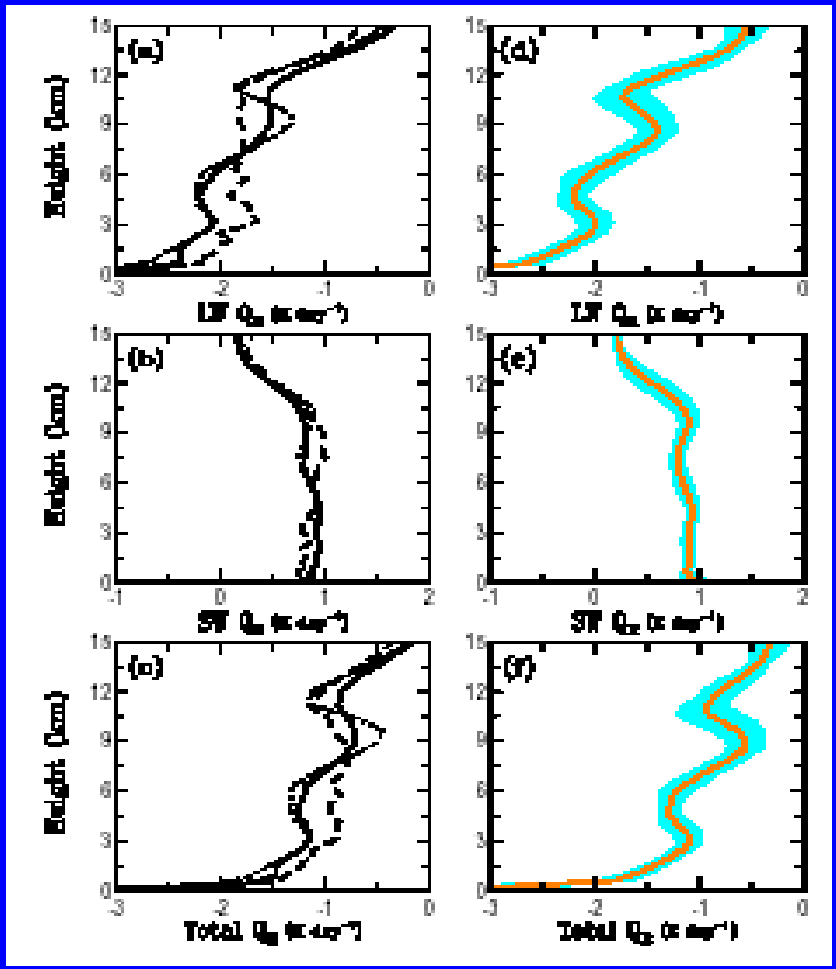
CRM Dz=160m



LES Dz=40m

Cloud Microphysics and Radiation

- How sophisticated cloud microphysics is needed?
- How to improve ice-phase microphysics? (hail process over land; graupel process over ocean with single-moment bulk parameter.)
- How to interact aerosols with cloud microphysics?
- How to interact radiation with cloud microphysics?
- What are the major deficiencies in radiation when applied in CSRMs?



[plots from Xu (2004); sensitivity of diagnosed radiative heating rates to overlap and homogeneous hydrometeor (left panels); and consensus of ten CRMs and the standard deviation from the ensemble mean (right panels)]

Aerosols/Chemical Transport/Land Surface processes

- Interaction of Aerosols with cloud microphysics (at cloud scales)?
- Embed a land-surface model in a CSRM or Use the statistics of precipitation (intensity and area coverage) as key inputs for the land-surface model in GCM grids?
- Use the cloud draft statistics as inputs for the chemical transport model in GCM grids or embed a CTM in a CSRM?

Offline Testing of CSRMs

- Field experiments for deep convective situations
- Field experiments for boundary-layer clouds
- LES results for boundary-layer clouds
- Large ensemble testing against “cloud object” data
- Testing of individual components of the CSRM against available observations
- “Big brother” experiments: testing of the Quasi-3D framework against fully 3-D simulations over a few climatically significant regions