Development of a Parameterization Scheme of Mesoscale Convective Systems

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The goal of this research is to develop a parameterization scheme of mesoscale convective systems (MCS) including diabatic heating, moisture and momentum transports, cloud formation, and precipitation.

The approach is

- Perform explicit cloud-resolving simulation of MCSs.
- Perform statistical analyses (conditional sampling, ensemble averages, term analyses along trajectories) of simulated MCSs to assist in fabricating a parameterization, calibrating coefficients, etc.
- Test the parameterization scheme against independent field data [e.g., Cloud and Radiation Testbed (CART) measurements and in numerical weather prediction (NWP) models emulating general circulation model (GCM) grid resolution].

Thus far we have formulated, calibrated, implemented and tested a deep convective engine against explicit Florida sea breeze convection and in coarse-grid regional simulations of mid-latitude and tropical MCSs.

A "fossil" MCS parameterization scheme has been fabricated (based on a prognostic vertical velocity variance scheme) and is now being generalized, calibrated, and tested.

Several explicit simulations of MCSs have been completed, and several others are in progress. Analysis code is being written and run on the explicitly simulated data. The cases selected are discussed below.

The 10-11 June 1985 squall line that occurred during the PRESTORM field project has been simulated using standard available data to initialize the model. By using the interactive nesting capability of the Regional Atmospheric Modeling System (RAMS), we were able to nest from a coarse grid of 80 km down to the finest 2.22 km grid, thus explicitly capturing the system as it transitioned from a convective line only to a system with convective and stratiform regions.

This simulation serves us in two ways. First, it acts as further verification for the Level 2.5w convective scheme (the "convective engine" for the MCS parameterization). Second, diagnostic analyses guide us in the parameterization of the mesoscale circulations which comprise the fast (and perhaps some slow) manifold processes of an MCS. The diagnostics include conditional sampling of various quantities as well as some Lagrangian tracer analysis to help identify coherent flow branches within the system. These diagnostics provide further guidance in the fabrication of a parameterization.

Two tropical mesoscale systems are being simulated with RAMS. One of the simulated systems is EMEX 9, so named because it was probed during the ninth aircraft mission of the Equatorial Mesoscale Experiment (2-3 February 1987). The prevailing synoptic feature at the time of EMEX 9 was a deep westerly monsoon trough extending from northern Australia across into New Guinea. The monsoon trough provided a primary lifting mechanism for the EMEX 9 cluster. Currently, 80-km and 20-km grid spacing runs have been completed. The simulation results support the suspicion that EMEX 9 was originally forced along a land breeze convergence line just north of Australia's Top End peninsula. Explicit cloud-resolving grids will be activated shortly.

Another tropical MCS being simulated is the 5 December 1989 system observed during the Down Under Doppler and Electricity Experiment (DUNDEE). Although, like the EMEX 9 case, the 5 December MCS contains a northward propagating east-west oriented convective line, the similarities end there. First, the 5 December system occurs during a break in the westerly monsoon rather than during the monsoon. Second, the system appears to be forced by a sea breeze circulation impinging on the higher terrain just south of Darwin, Australia, rather than being forced by a land breeze over the ocean. Third, the system is quite small in geographic area compared with EMEX 9. Fourth, the lifetime of the system is only about 6 hours, compared with 12 hours for EMEX 9. Although we have successfully simulated this case in two dimensions, the three-dimensional simulation has yet to meet the same measure of success that EMEX 9 has.

A weakly sheared, extra-tropical MCS observed during PRESTORM has been the most challenging case. The simulations have been performed with nested grids from 80-km down to 2.2-km grid spacing. While the runs with the Weissbluth scheme produce an MCS that superficially resembles the observed system, the MCS does not contain the observed organization of the wind fields in the system. Moreover, the explicitly cloud-resolving grids are unable to trigger an MCS without imposing some heat bubbles in the grid. Nonetheless the latest explicit runs are encouraging.

Overall, an MCS parameterization scheme has been proposed which consist of the following components:

1. a deep convective engine (the Weissbluth scheme)
2. a fast manifold (unbalanced) mesoscale response consisting of slantwise ascending and descending branches—A modified Moncrieff archetypal approach and a new parcel model for specified flow branches derived from model output statistics are being considered.
3. a slow manifold (balanced) mesoscale response—Currently we are exploring the possibility of using potential vorticity (PV) as a basis for describing the slow manifold processes of MCSs. The beauty of PV is that it contains information on both flow and mass fields; hence, the dynamics and thermodynamics can be traced by predicting one variable. The flow and mass fields themselves can be retrieved by use of the appropriate invertibility principle. Idealized model studies indicate that PV is modified by diabatic heating from MCSs. Other studies imply that a preexisting upper-level PV anomaly destabilizes the atmosphere below and may be a factor in triggering an MCS. We believe that PV may a useful tool to identify the communication between a GCM and the sub-grid mesoscale.
4. A "fossil" MCS component consisting of radiative-convective cloud responses and precipitation from middle and high clouds (cirrus) remaining after the decay of the active MCS—This component is under development using the Weissbluth small-scale turbulence component of the convective parameterization scheme.