N94-24395

4.3 Session on coupled land surface/hydrological/atmospheric models

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a. *Assessment of current abilities and approaches*

The current model capabilities in the context of land surface interactions with the atmosphere include only one-dimensional characterizations of vegetation and soil surface heat, moisture, momentum, and selected other trace gas fluxes (e.g., CO_2) The influence of spatially coherent fluxes that result from landscape heterogeneity have not been included.

Valuable representations of several aspects of the landscape pattern currently exist. These include digital elevation data and measures of the leaf area index (i.e., NDVI from AVHRR data). A major deficiency, however, is the lack of an ability to sample spatially representative shallow and (especially) deep soil moisture. Numerous mesoscale modeling and observational studies have demonstrated the sensitivity of planetary boundary layer structure and deep convection to the magnitude of the surface moisture flux.

b. *Most critical unknowns*

The unknowns include specific meteorological parameters as well as physical processes. The unknown physical processes include the following:

- What is the role of subsurface hydrology (vertical and horizontal transport) in determining surface heat and moisture fluxes?
- How important are biospheric/chemical processes in affecting surface fluxes?
- How does the boundary layer modulate the interactions of the surface with clouds?
- How have human influences on land use altered convection and the hydrologic cycle (this question is also important as a linkage to global change)?
- What are the nature and causes of temporal and spatial variability of rainfall?
- How do surface characteristics affect "predictability"?
- What scale of surface data is the most critical to develop the surface forced mesoscale circulations which may help trigger MCS's? The critical scale may help us determine how fine our surface data must be for future operational and research needs. Is there a scale beyond which there is little mesoscale return?
- How do PBL dynamics and structure affect this critical land-surface data scale?

The CME needs to consider the following in defining measurement requirements:

- Borrow heavily from FIFE and BOREAS experiment plans.
- Required for scaling up ("aggregating") from the land surface to the MCS scale: latent heat, sensible heat and net radiative fluxes are needed at enough sites to characterize means and variability.
- Incorporate satellite remote sensing technologies, especially the FIRE results, into the CME project design and operation to support model initialization/validation.
- Start with high-resolution observing system simulation experiments (OSSE) then gradually degrade the resolution of the simulated data to examine sensitivity to the quality, distribution, and sampling of various land surface and vegetation parameters.
- The importance of high-resolution measurements near surface landscape boundaries needs further exploration.

The needed spatial and temporal resolution of these data need to be determined using existing observational and modeling studies. The evidence available at present suggests that averaged values of land surface parameters over (1 km)^2 footprint areas may be sufficient.

c. *Recommendations for the improvement of coupled multiscale models*

There is a need to permit two-way interactions between the atmosphere, and biophysical and hydrologic processes. This feedback is essential in order to properly represent the control on transpiration of water into the boundary layer environment. In addition, since stomatal conductance of water is directly related to carbon dioxide fluxes, these models must also influence dry deposition of other chemical species, particularly hydroscopic aerosols and gases. These interactions point to the necessity for interdisciplinary activities in the CME. Involvement by the hydrology community would be mutually beneficial. The meteorological models require knowledge of soil hydraulic properties for input to surface layer parameterizations. Correspondingly, an accurate characterization of precipitation, evapotranspiration, and landscape structure is necessary for input to hydrology models. A similar relationship exists with the ecological modeling community. Atmospheric models are strongly affected by vegetation processes, while the ecological community needs atmospheric information to properly simulate soil and vegetation biophysics (e.g., the soil carbon budget).

Specific improvements for coupled multiscale models include:

- Continue work to minimize further the reflection and refraction of wave energy as it is transmitted through the lateral boundaries of meteorological nested grids.

- Develop physically and computationally consistent treatment of cumulus convection and boundary layer turbulence in nested grid models.

- Introduce procedures to aggregate subgrid terrain and landscape variations into the variable grid increment sizes that exist in nested multi-scale models.

- Apply techniques to assimilate synoptic and asynoptic observational data on nested grid domains.

- The value of adaptive multiscale models as contrasted with a nested grid modelling framework needs to be quantitatively investigated.

- The theoretical time limits of predictability as a function of spatial scale needs to be investigated using sets of coupled multi-scale model simulations.

- The level of physical completeness in hydrologic and ecological models, which are to be coupled to atmospheric models, needs to be described. A critical question is the level of detail needed in these models so as to accurately represent the meteorological response.

- The required accuracy in the simulation of winds, turbulence, and radiative fluxes for use in atmospheric chemistry models needs to be defined. Since these chemical models require concentration fields, it is essential that the differential advection and diffusion of chemical species be correctly represented.

d. Observations needed to initialize and verify these models

Specific measurements that we need include the following:

- Vegetation cover, soil characteristics, terrain slope on scales <1 km

- Recording/archiving of *all* WSR-88D data: e.g., base scan reflectivity (for rainfall rate validation), gate-to-gate velocity/reflectivity (morphology of storm)

- Soil moisture profiles by neutron probe (needs to be automated)

- Dual ground based Doppler lidar to characterize boundaries (dryline, irrigated areas)

- Ground based radiometric profilers with RASS

- Mobile CLASS soundings

- Aircraft: King-Air class for PBL; NASA downward-looking DIAL lidar (especially near boundaries); Eldora-2; and NOAA P-3 airborne doppler

- New types of measurement platforms (e.g., new types of measurement platforms for economical boundary layer measurements such as instrumented radio-controlled aircraft)

- Data archival and distribution (CD-ROM? Distributed archive?)

The specific data needed to characterize the landscape structure include AVHRR NDVI data at 1 km pixel scales for at least a weekly sampling period, digital elevation data sampling scales of ~50 m, and use of microwave data to estimate antecedent rainfall. The

CME planning committee should incorporate satellite remote sensing technologies, especially FIFE results, into the project design and operation. Existing observational opportunities should be exploited, such as WSR-88D, the Oklahoma mesonet, and the profiler network. In addition, CME should establish a linkage with other programs (ARM-CART, GCIP, USWRP, etc.) and disciplines (hydrology, chemistry, ecology), and also leverage existing technologies and data sources (EROS, etc.).

N94-24396

4.4 Joint sessions on modeling of boundary layer and radiative transfer processes

4.4.1 Session on modeling of boundary layer processes

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The following topics were addressed in the PBL session of the Workshop: (1) current PBL parameterizations used in mesoscale models, (2) critical issues in improving PBL parameterizations for mesoscale models, (3) suggestions for future modeling efforts, and (4) suggestions for observing system strategies.

a. Current PBL Parameterizations Used in Atmospheric Models

Current general circulation and mesoscale models employ either a bulk or multi-layer PBL scheme. The former includes mixed-layer modeling while the latter encompasses Richardson number-dependent K models, Mellor--Yamada one-equation models, transilient theory, and the Blackadar model. A common advantage of all parameterizations is that they are simple and computationally economical for mesoscale and climate models. The shortcomings of these models are the following:

- These models were developed for horizontally homogeneous PBL flows. They also were meant to account solely for turbulent fluxes (because the closures in the models were determined based on turbulent flows and turbulence theories)
- Some of the models, viz., mixed-layer and Blackadar models, are appropriate for convective PBLs only
- Interactions between cumulus clouds and the PBL are absent in most models
- PBL stratus-type clouds are usually neglected

b. Critical Issues for Improving PBL Parameterizations for Mesoscale Models

C-2