Coupling MM5 with ISOLSM: Development, Testing, and Application

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Outline

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Introduction

- CO₂ fluxes and other trace-gas exchanges are tightly coupled to the surface water and energy fluxes.
- Land-use change has strong impact on surface energy fluxes.
- We coupled MM5 with ISOLSM (Riley et. al 2003), which is based on LSM1 (Bonan, 1995).
- LSM1, thus ISOLSM, simulates: vegetation response to water vapor, CO₂, and radiation; soil moisture and temperature.
- ISOLSM also simulates gases and aqueous fluxes within the soil column and $^{18}$O composition of water and CO₂ exchanges between atmosphere and vegetation.
Model Integration

New interface between MM5 and ISOLSM based on the current OSULSM interface with MM5 and includes:

- partitioning shortwave radiation between diffuse and direct components
- spatially and temporally-dependent vegetation dynamics (i.e., leaf area index).

Compiler options changed to accommodate two different source code styles.

Automatic script to retrieve and process pregrid data from NCEP NNRP data.
Model Integration (cont’d)

- Import MM5 to NERSC IBM SP machine.
  - 380 compute nodes, 16 way each → 6,656 processors
  - 16 to 64 GB memory per node
  - 375 MHz per CPU → 10 Tflop/sec peak speed
  - 44 TB disk space in GPFS

- Revise MPP library and MPP object files for ISOLSM.

- Investigate optimization levels to achieve bit-for-bit MPP results with sequential runs.

- Run scripts with automatic I/O from NERSC HPSS.

- Speedup with 64 CPUs is about 36.

- Simulation time: 15 min for domain 1
  50 min for domain 2
Model Configuration

Model Initialization:
- First-guess and boundary condition interpolated from NCEP NNRP.

Model Grids:
- Outer Domain 1: Continental USA
  grid size: 54 x 68, resolution: 100 km x 100 km
- One-way nestdown
- Inner Domain 2: FIFE or ARM-CART region
  grid size: 41 x 41, resolution: 10 km x 10 km
- Vertical: 18 $\sigma$-layers between 100 mb and surface

Physics package used:
- Grell convective scheme
- Simple ice microphysics
- MRF PBL scheme
- CCM2 radiation package
Model Testing

Comparisons between:
- MM5 coupled with ISOLSM
- MM5 coupled with OSULSM (Chen and Dudhia, 2001)
- FIFE dataset: 3-year measured data (Betts and Ball 1998)
  - surface fluxes, soil moisture, soil temperature, etc.
  - spatially averaged over 225 km² area of Kansas.

ISOLSM performed comparably or better than OSULSM.
The diagram shows the comparison between measured and simulated heat flux for Julian Day 1987.

**Ground Heat (W m$^{-2}$):**
- Measured
- MM5/ISOLSM
- MM5/OSULSM

**Latent Heat (W m$^{-2}$):**
- Measured
- MM5/ISOLSM
- MM5/OSULSM

**Sensible Heat (W m$^{-2}$):**
- Measured
- MM5/ISOLSM
- MM5/OSULSM

The graphs illustrate the diurnal variation of heat flux components, indicating the model's accuracy against real-world measurements.
The graphs show the temperature at 2 m (T at 2 m (C)) and surface skin temperature (Surface Skin T (K)) over Julian Day, 1987 (d). The graphs compare measured data (red line) with simulations from MM5/ISOLSM (dashed blue line) and MM5/OSULSM (dashed green line).
Winter Wheat Harvest Simulation

MM5-ISOLSM model applied to ARM-CART region from June to July 1987.

Two scenarios:
- Early harvest: June 4, 1987 (Julian day 155)
- Late harvest: July 5, 1987 (Julian day 186)

Set harvest area with bare soil.

Four distinct time periods are evident in the simulations:
- JD 155-158: large evaporation at harvest area
- JD 158-170: reduced evaporation at harvest area
- JD 170-186: increased precipitation
- JD 186-210: two scenarios converge
ARM-CART Region
early harvest – late harvest
ARM-CART Region
early harvest - late harvest

Soil Temp.
Air Temp.
Cum. Precip.

-0.4  0.0  0.4  0.8  1.2

156 168 180 192 204
early harvest – late harvest
Conclusions

- Successfully coupled MM5 and ISOLSM.
- Built and ran the coupled model in parallel.
- Validated the coupled model against current MM5 model and FIFE dataset.
- Utilized the coupled model to study the impact of winter wheat harvest.
- Winter wheat harvest simulation indicates that harvest impacts both regional and local surface fluxes, 2 m air temperature, and soil temperature and moisture.
Observations and Future Work

The coupled model allows us to estimate surface fluxes that are consistent with ecosystem CO$_2$ exchange.

The soil advection and diffusion sub-models allow us to simulate the impacts of regional meteorology on other distributed trace-gases.

Study the impact of human-induced land-use change on regional climate and predict regionally-distributed estimates of CO$_2$ exchanges.

Investigate the practicality of estimating distributed trace-gas fluxes from atmospheric measurements.