Coupling MM5 with ISOLSM: Development, Testing, and Application

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Outline

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Introduction

- CO_2 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, CO_2, and radiation; soil moisture and temperature.
- ISOLSM also simulates gases and aqueous fluxes within the soil column and ^{18}O composition of water and CO_2 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)

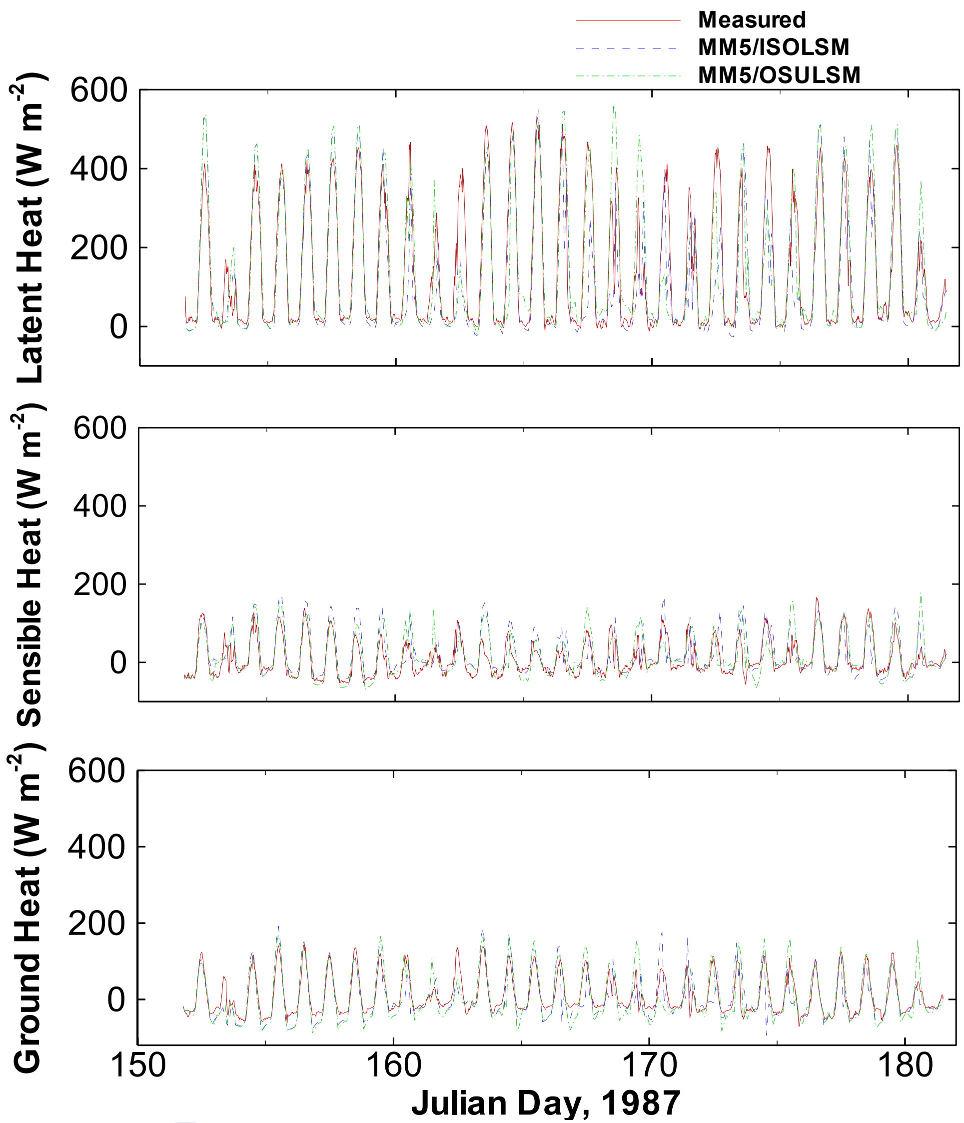
- Import MM5 to NERSC IBM SP machine.
  - 380 compute nodes, 16 way each ➔ 6,656 processors
  - 16 to 64 GB memory per node
  - 375 MHz per CPU ➔ 10 Tflop/sec peak speed
  - 44 TB disk space in GPFS
- Revise MPP library and MPP object files for ISOLSM.
- Investigate optimization levels to achieve bit-for-bit 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

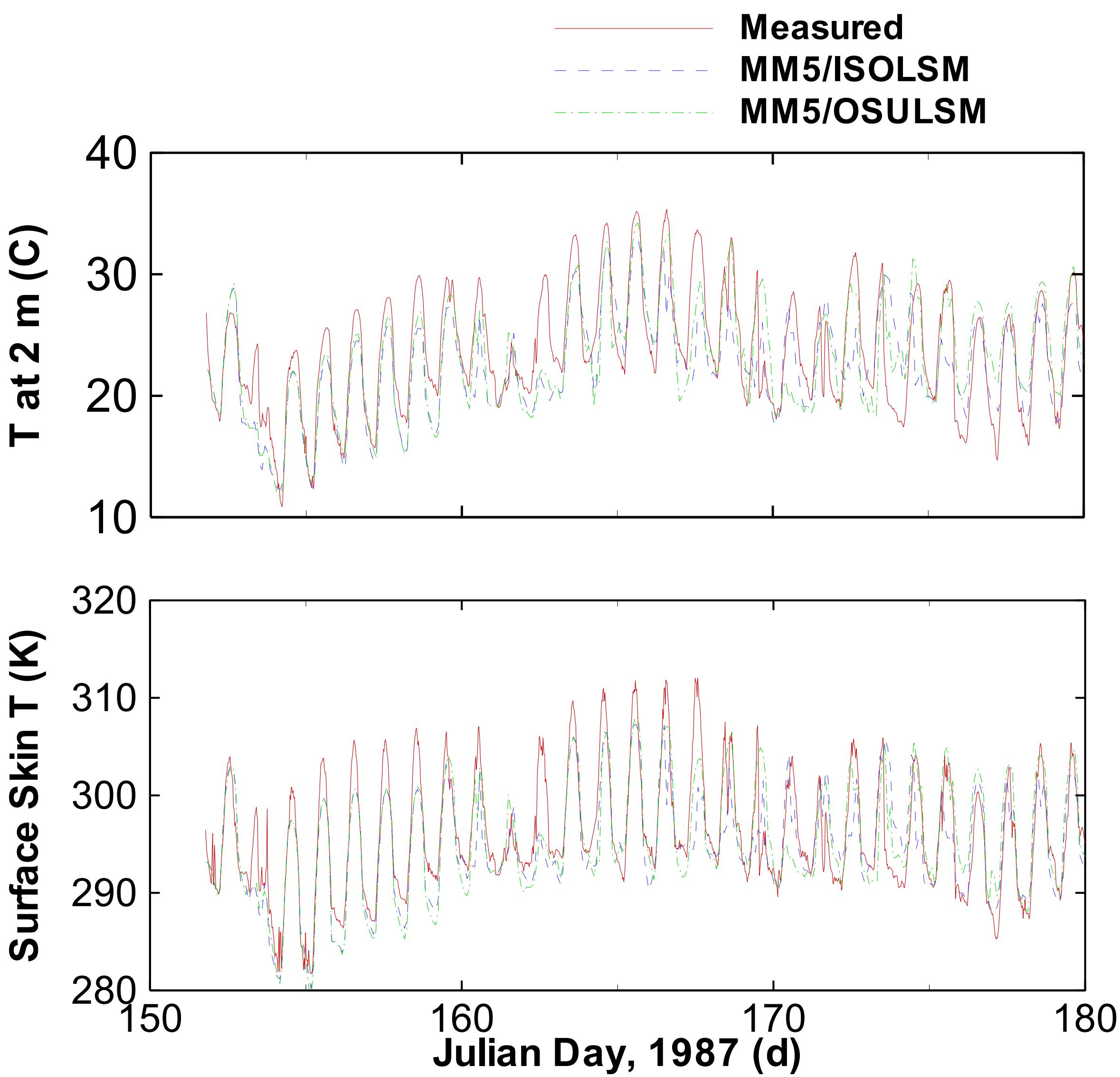
Model Configuration

- 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 σ-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 km^2 area of Kansas.
    - June, July, August of 1987-1989.
- ISOLSM performed comparably or better than OSULSM.

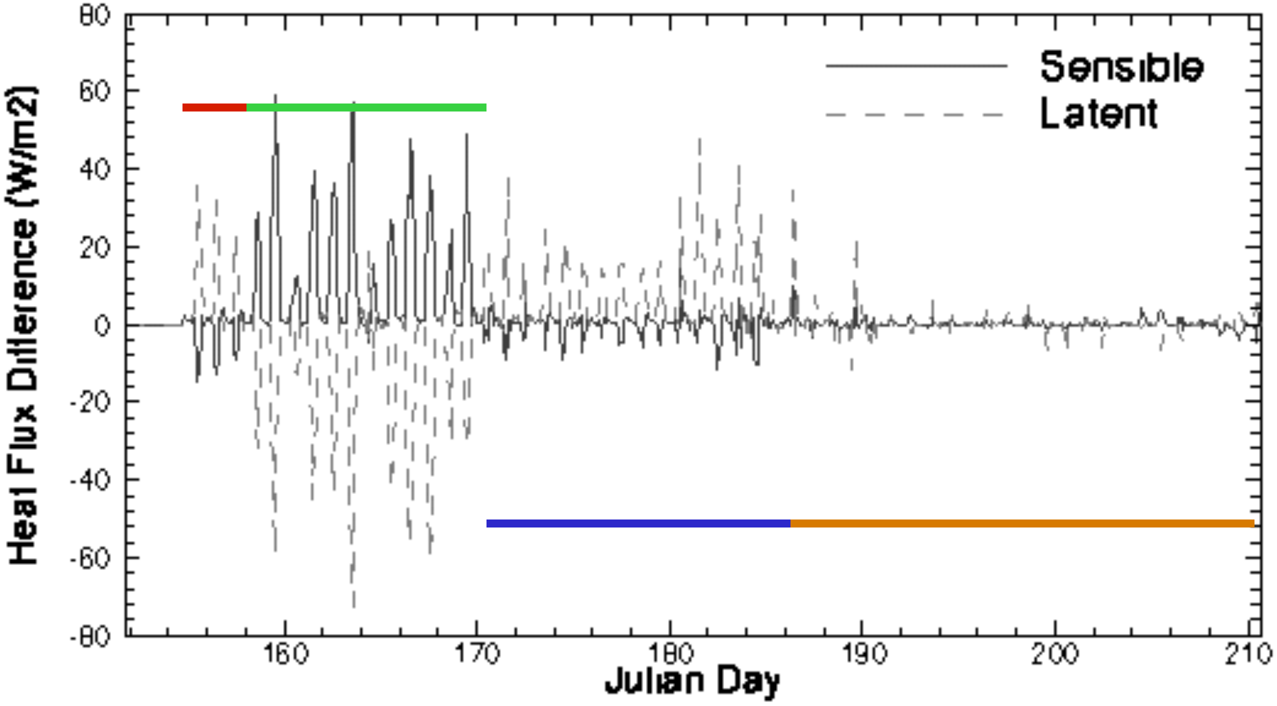

Measured
MM5/ISOLSM
MM5/OSULSM
Latent Heat (W m^{-2})
Sensible Heat (W m^{-2})
Ground Heat (W m^{-2})
600
400
200
0
150
160
170
180
Julian Day, 1987


Measured
MM5/ISOLSM
MM5/OSULSM
T at 2 m (C)
40
30
20
10
Surface Skin T (K)
320
310
300
290
280
150
160
170
180
Julian Day, 1987 (d)

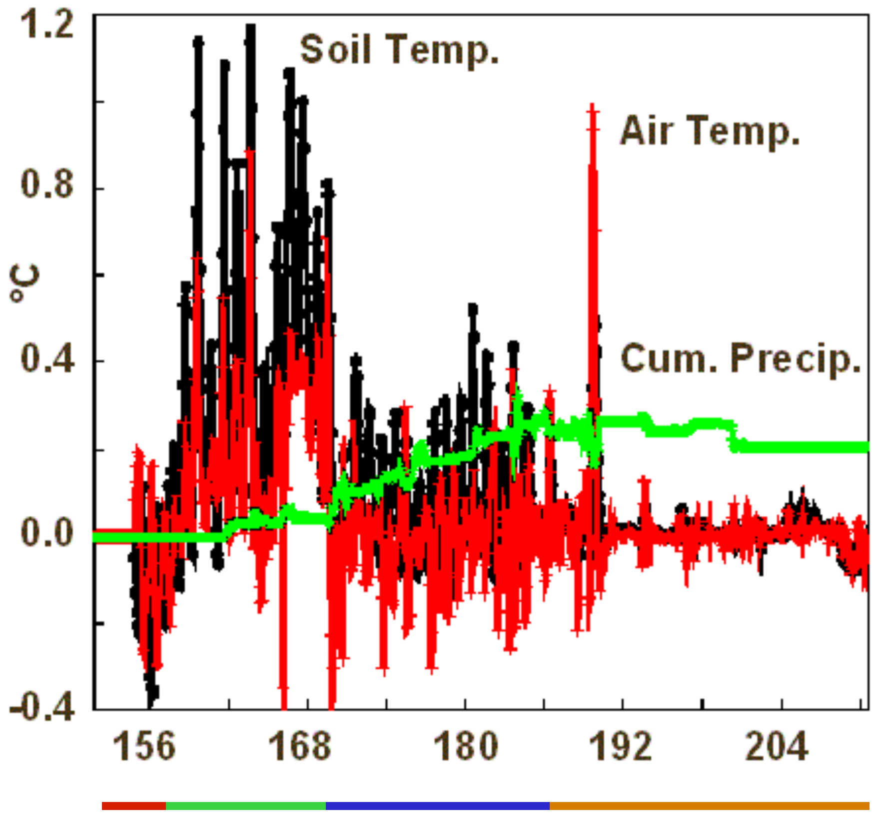
Winter Wheat Harvest Simulation

- 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

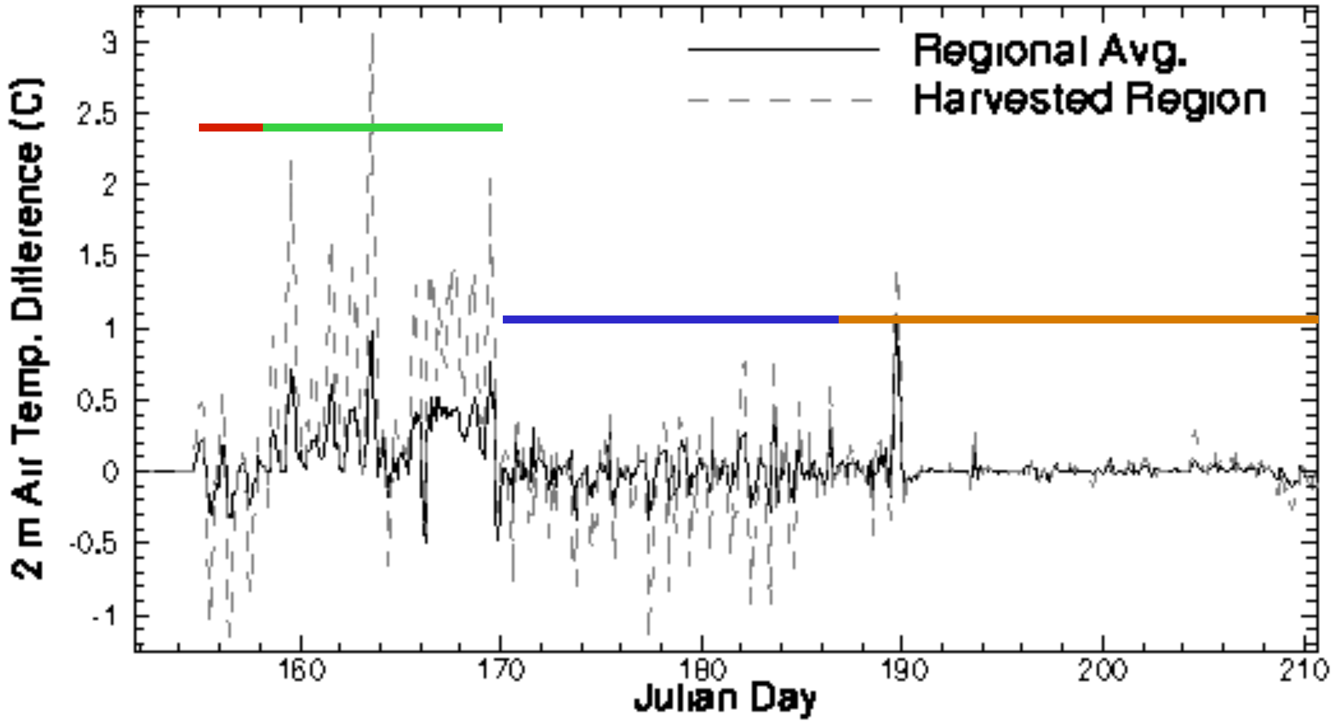
ARM-CART Region
early harvest – late harvest



ARM-CART Region
early harvest - late harvest



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.