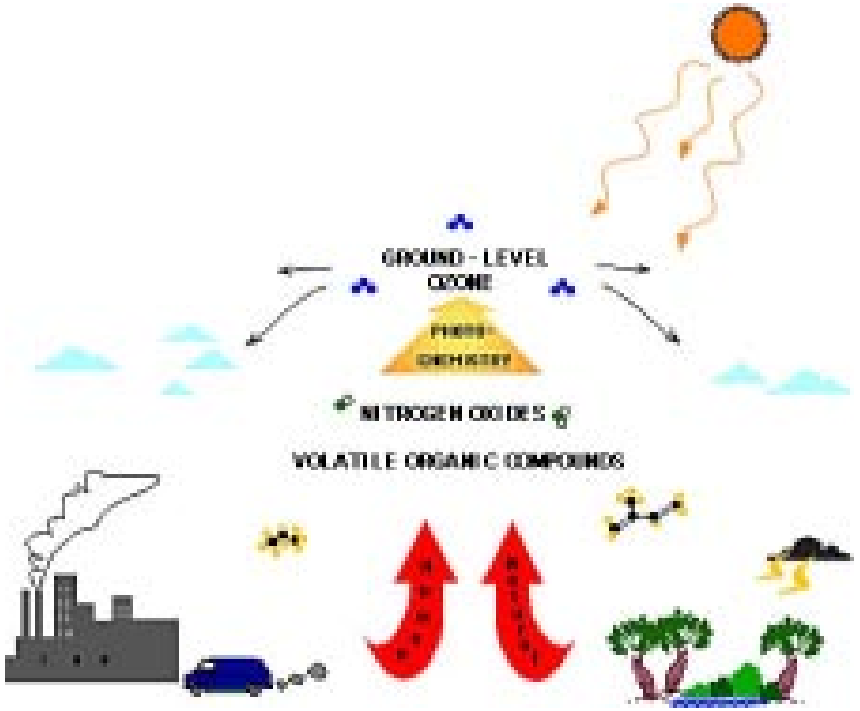
Estimating Natural Hydrocarbon Emissions

Yiwen Xu and M. L. Wesely
Environmental Research Division
Argonne National Laboratory

The Role of Biogenic Emission in Tropospheric Ozone Production

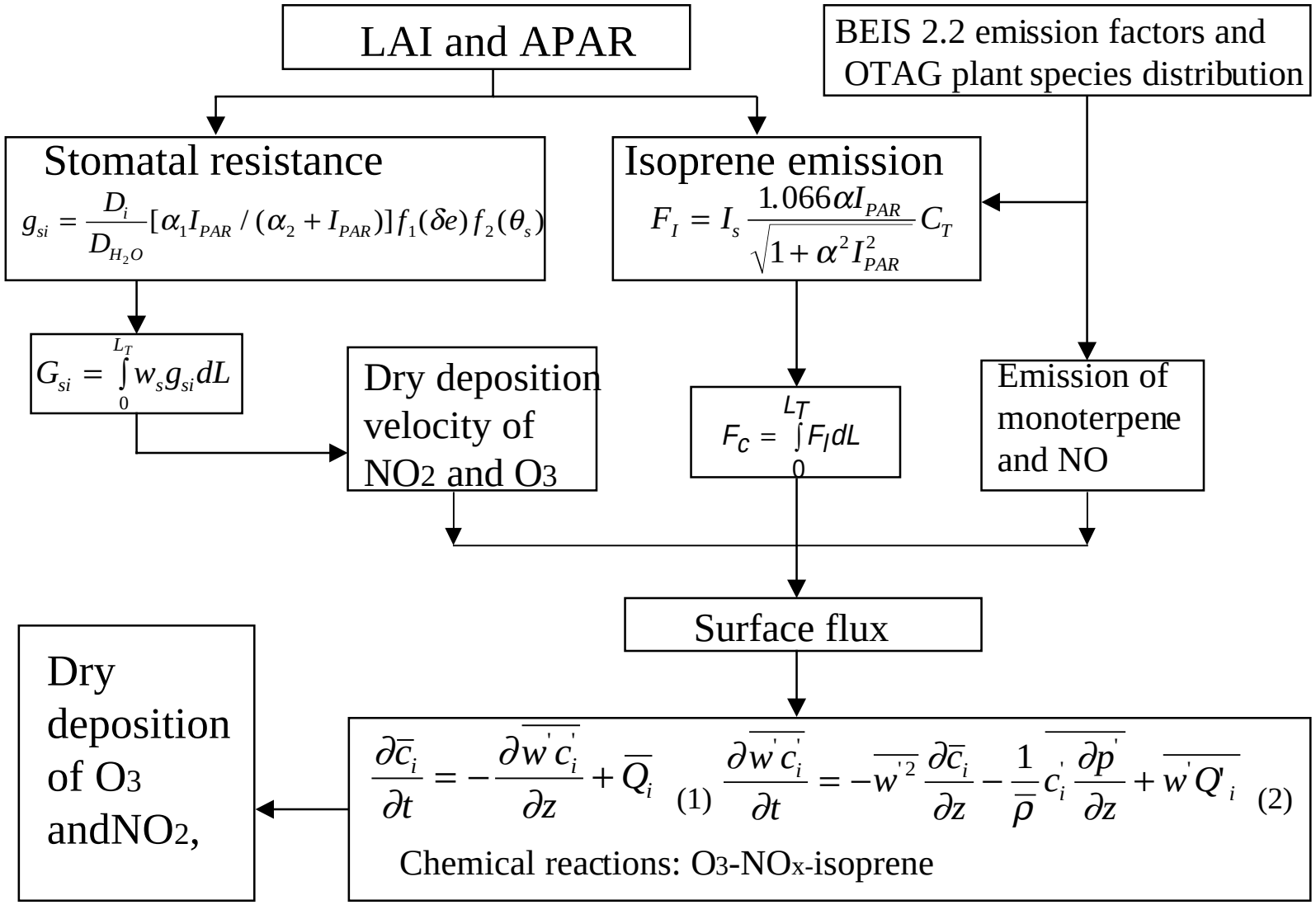
- Ozone in the stratosphere
  - protects the Earth from excessive exposure to UV radiation
- Ozone in the troposphere
  - damages the living tissue of plants and animals
  - damages materials
  - Is one of the key pollutants in “smog” over many cities
- Human activities such as fuel combustion in cars and power plants causes large increases in nitrogen oxides. These nitrogen oxides react with natural hydrocarbon/VOC /biogenic emissions and human-made VOCs, producing the unnaturally high ozone concentrations.



Biogenic Emissions

- Isoprene (2-methyl-1, 3 –butadiene, C_5H_8)
  - most abundant of BVOCs.
  - oak, pine, spruce, sweetgum, eucalyptus, and aspen are large sources
  - light and temperature dependent
  - isoprene is removed through reactions with O_3, OH, and NO_3
- Monoterpenes
  - spruce and fir are large sources
  - temperature dependent
- NO
  - emitted from soil
  - soil temperature and moisture dependent
- ORVOCs

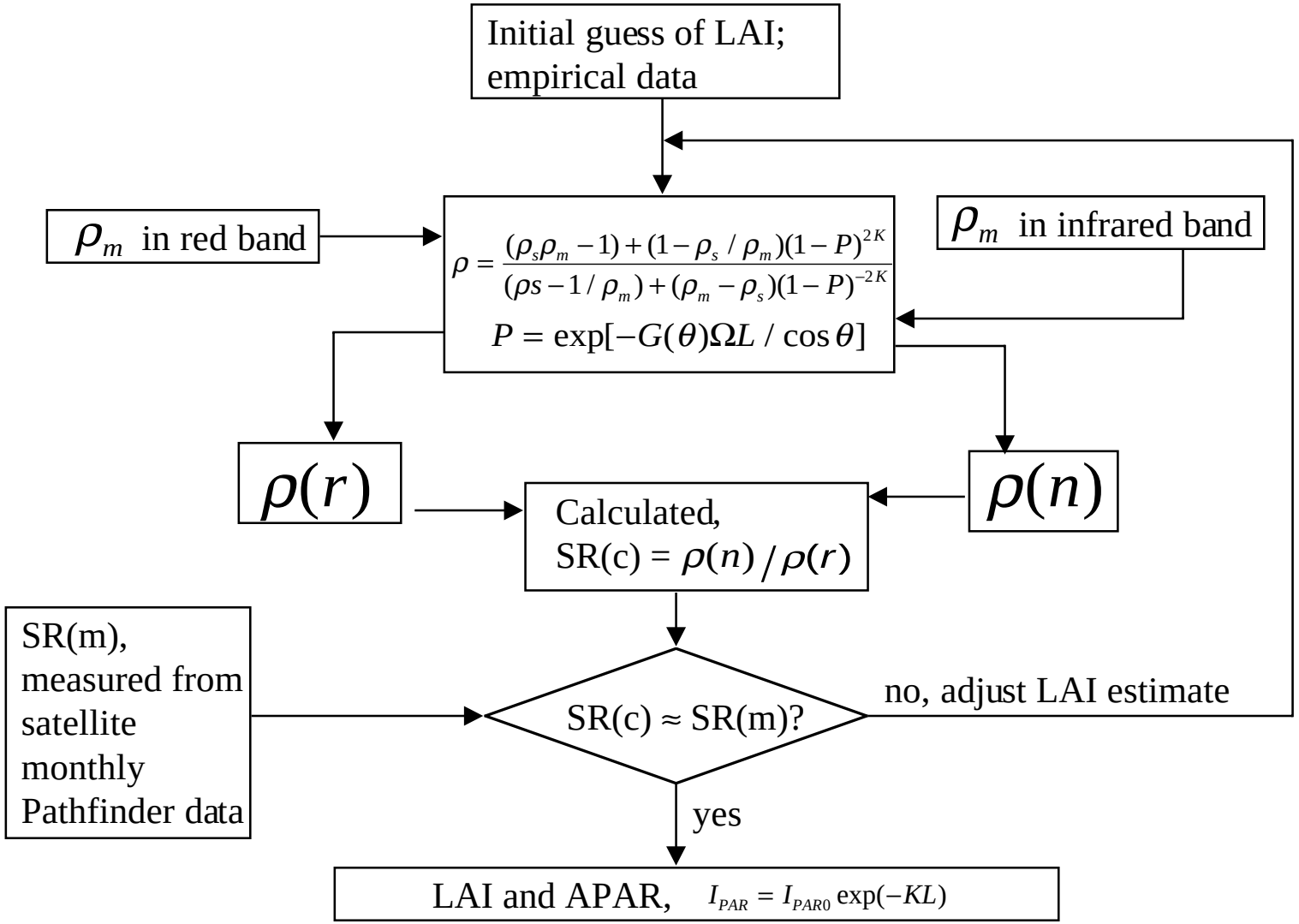
Dry Deposition and Emission Module



LAI and APAR

- Leaf Area Index:
  - is the total leaf area per unit of ground area.
  - influences the rate of exchange through leaf stomata for the bulk canopy
- Absorbed Photosynthetic Active Radiation
  - influences photosynthetic activity
  - influences stomatal opening size

Deriving LAI and APAR



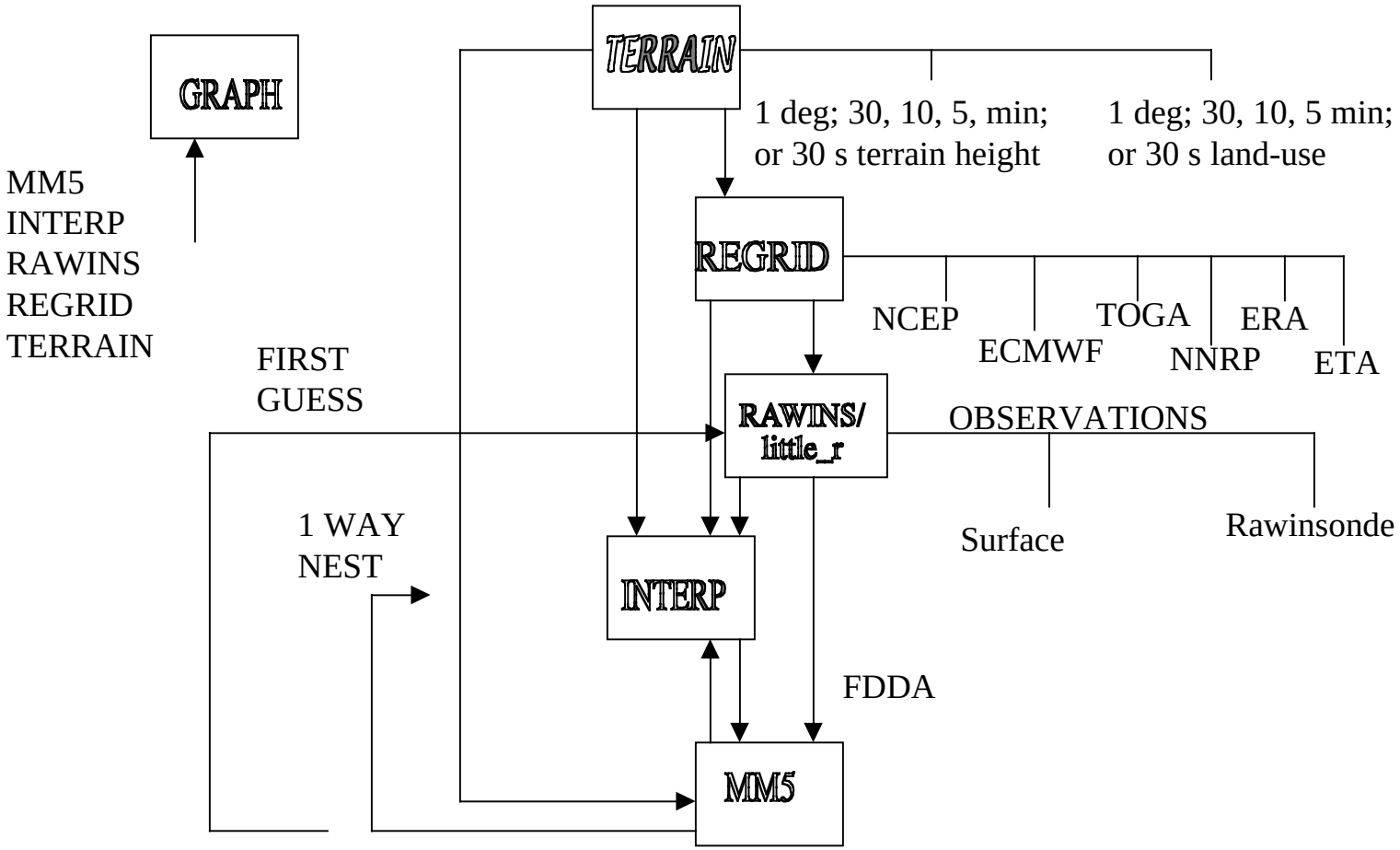
Model Application

- Biogenic emission model can be coupled with
  - meteorological model to obtain meteorological inputs, e.g., MM5 (Mesoscale Meteorological Model) developed by Penn State/NCAR
  - photochemistry model to estimate concentrations of photochemical species, e.g., UAM (Urban Air Shield Model)
  - dry deposition model/acid deposition model to estimate dry and wet deposition or flux, e.g., Argonne's Dry Deposition and Emission Model

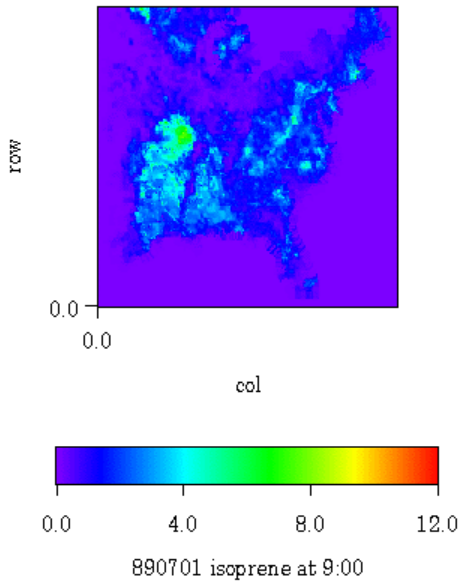
MM5

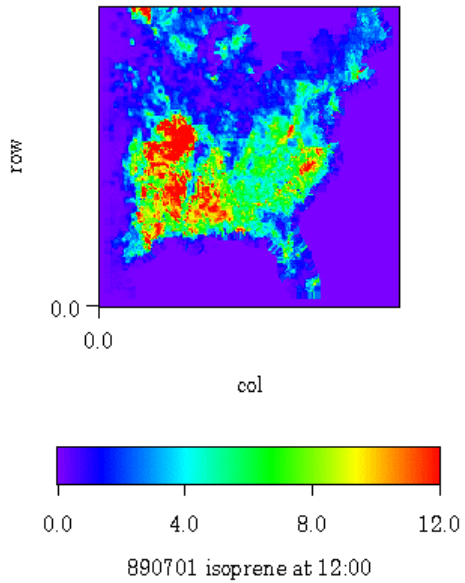
- weather forecast model, used in EPA Models 3 system
- terrain following vertical coordinate system
- multiple-nest capability
- non-hydrostatic Eulerian model
- physical options for cloud formation, PBL, precipitation formation, long and short wave radiation, and ground and soil temperature
- four-dimensional data assimilation (FDDA) available for initialization, dynamic analysis, and boundary conditions

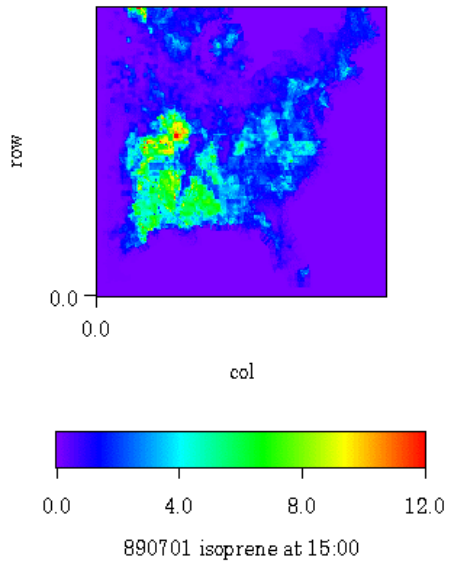
MM5 Modeling System Flow Chart

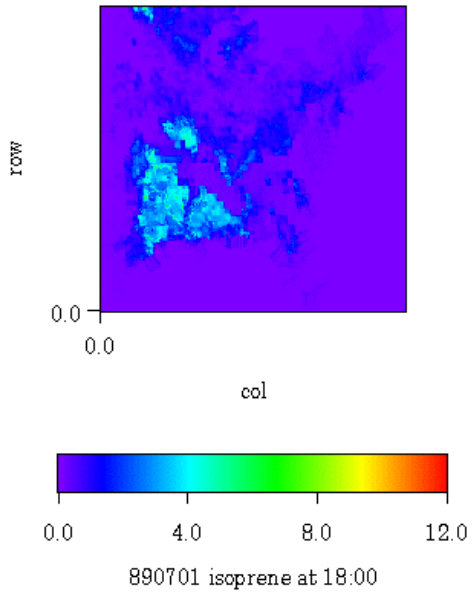


Simulated Isoprene Emission over Eastern U.S

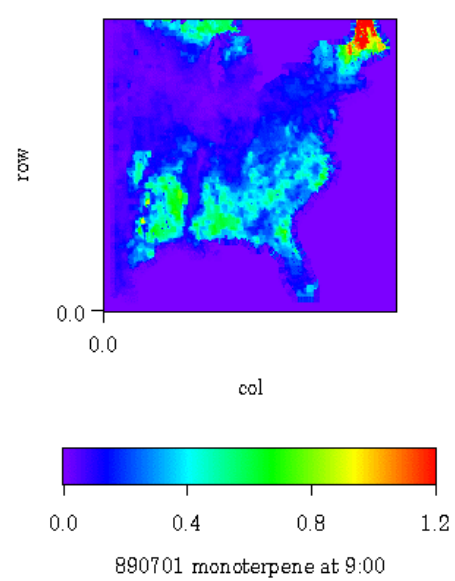


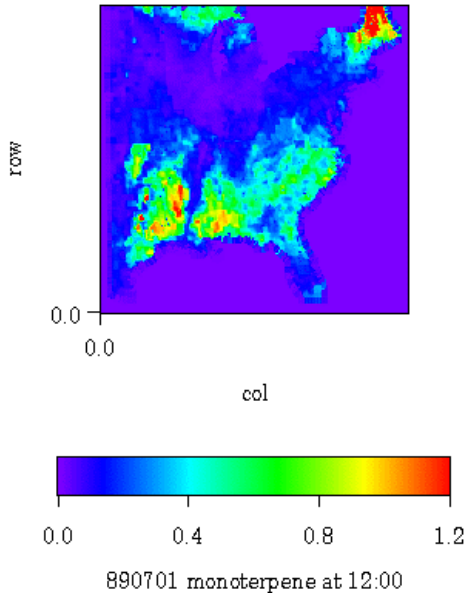


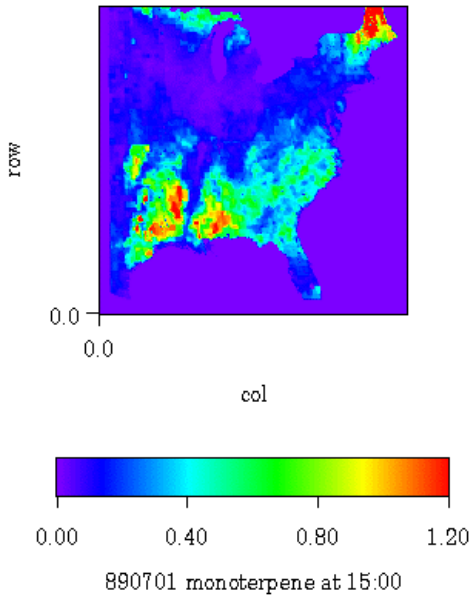


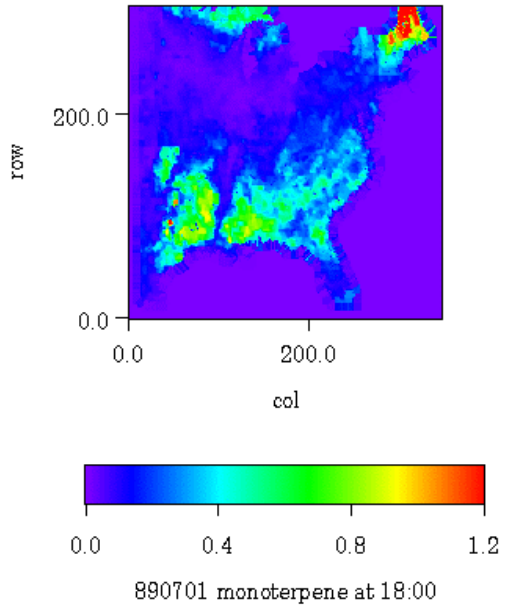


Simulated Monoterpene Emission over Eastern U.S

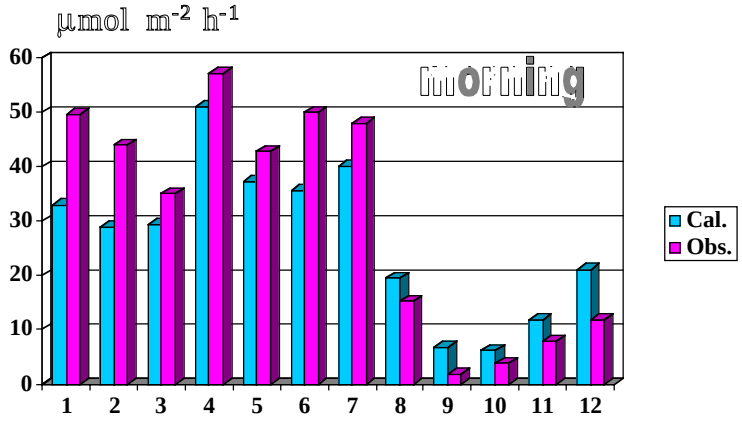


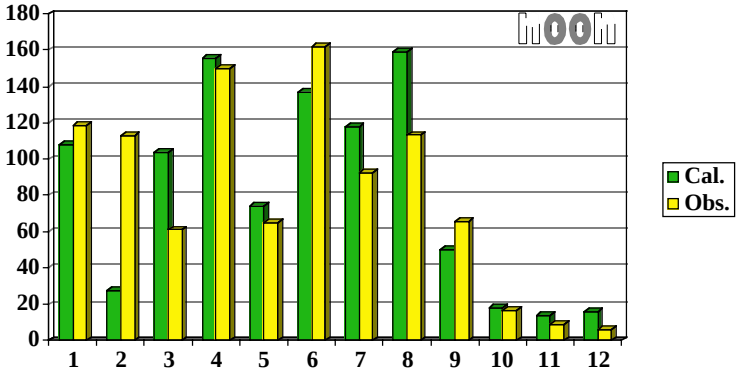


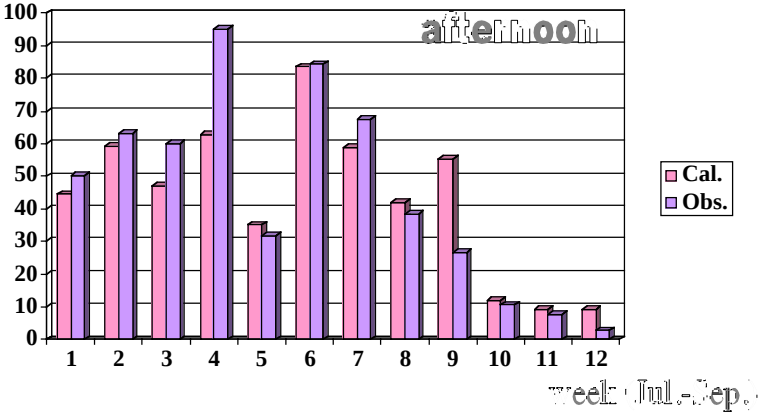




Comparison with Measurements of Isoprene Emission at Harvard Forest







- 50 to 70 years old deciduous forest, with leaf area index of 3.4
- tree species are oak (mostly red), red maple, red pine, hemlock, birch, white pine, and cherry
- 45-min-averaged measurements of isoprene emission for May to October and hourly meteorological data

Conclusions

- The modeled results matches up well with the Harvard Forest weekly data for the full leaf period. The maximum isoprene emission rate occurs at noon and early afternoon during hot summer days.
- Simulations for the eastern U.S. successfully capture the diurnal circle of isoprene emission rates, which are largest at noon and nearly zero at night. Large emission rates occur in and near the Ozark region due to the high density of oak and gum trees. The use of NDVI data derived from satellite data reveals considerable detail, and coupling with MM5 produces more realistic results.
- Isoprene emission rates are overestimated for late summer at Harvard Forest, which might be caused by the effects of leaf senescence and a reduction of the green leaf area index.
- Measurements at a forest near Oak Ridge, Tennessee, in July 1992 show the mean flux of isoprene ranges from 4.8 to 5.9 µmol m^{-2} in strong sunlight (~1000 µmol m^{-2} h^{-1}) and moderate temperatures (~25ºC). The modeled values at noon are close to the measurement values.
- The simulated monoterpene emission rates over the eastern U.S. change diurnally as expected, with relative small rates during morning and evening. High emission rates are seen over the southeastern U.S and over northern spruce-fir-pine forests.

Possible Future Work

- Use fine resolution plant species distribution data and more detailed plant species classification
- Use parallel system for MM5 to do longer time period and finer resolution calculation
- Search more measurements data for direct comparison and couple emission model with photo-chemistry model for indirect comparison
- Model leaf temperature by using energy balance