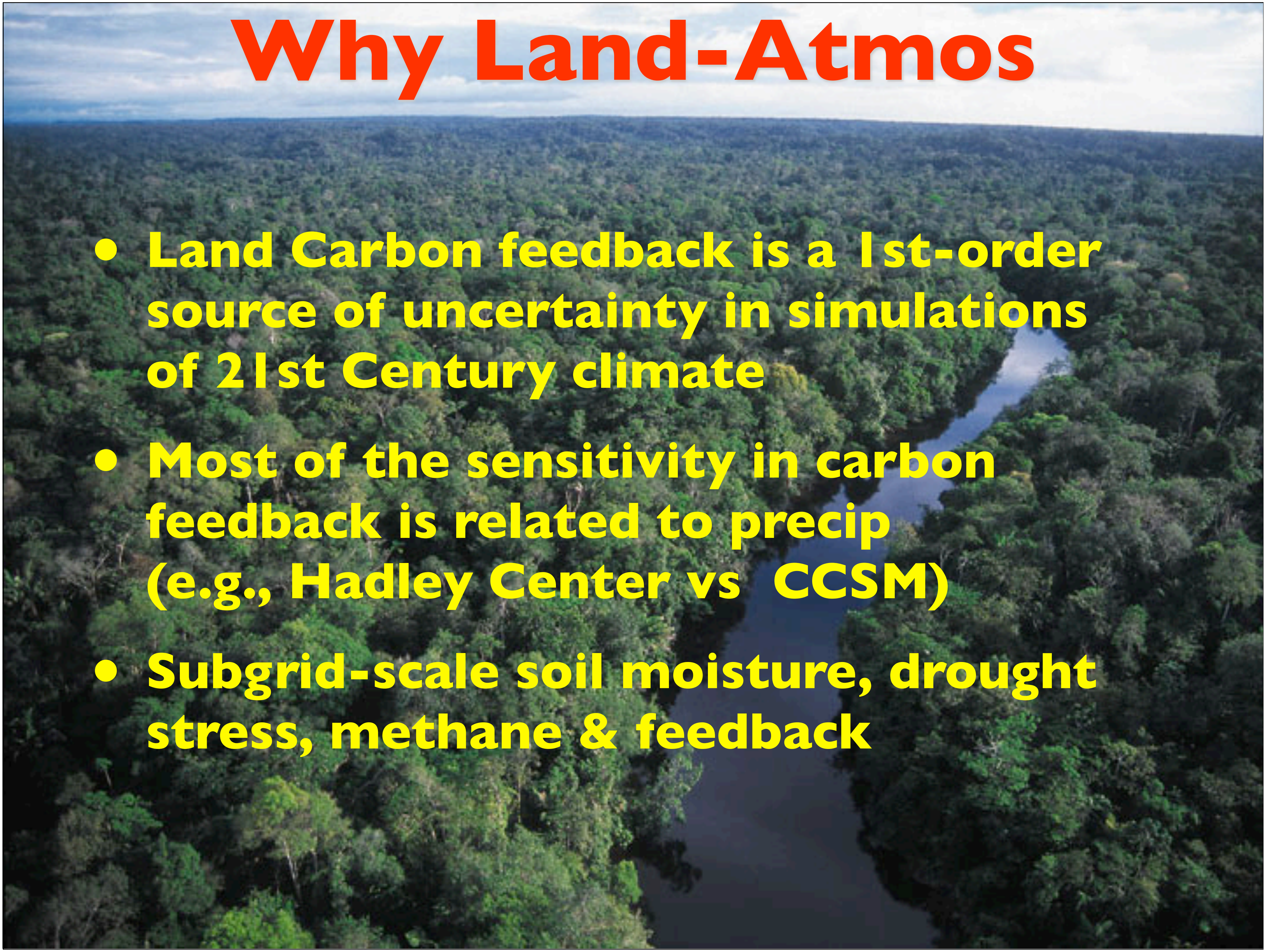
MultiScale Modeling of Land-Atmosphere Interactions

Objectives Years 6-10	Focus areas	Key Scientists/ Partner Institutions
3. Application of CMMAP models to study the multiscale processes through which the atmosphere and land-surface interact	Land-atmosphere interactions in the current climate	**Denning**, Bonan
	Changing roles of biogeochemistry and land-use change in future climates	Denning, **Bonan**

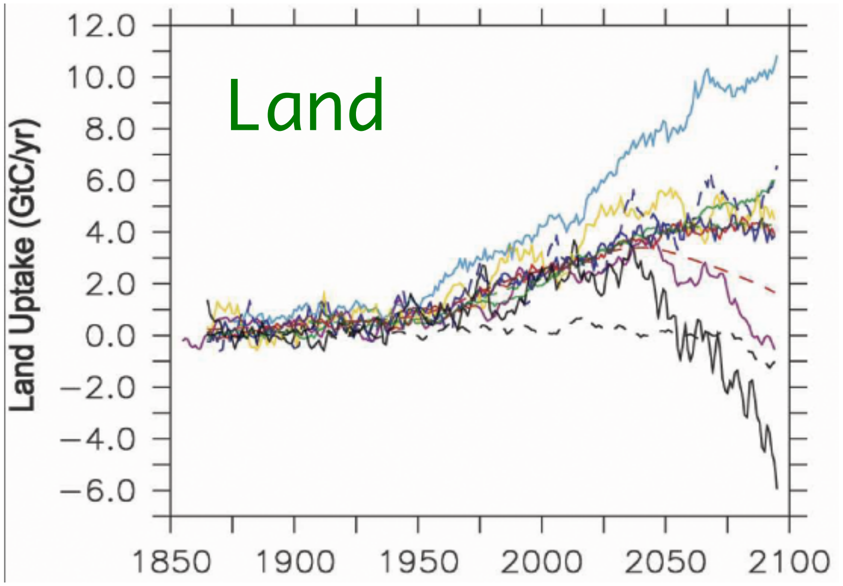


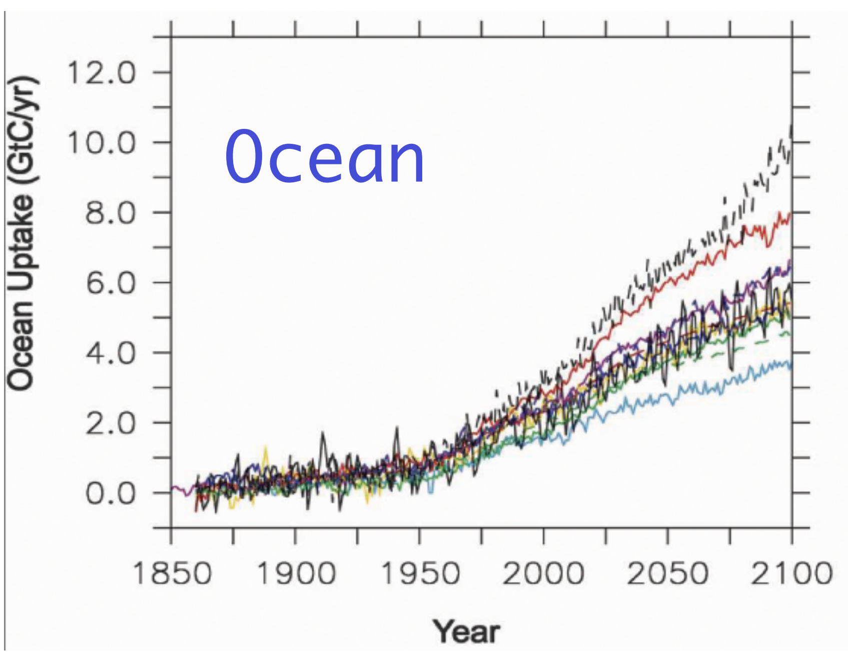
Why Land-Atmos

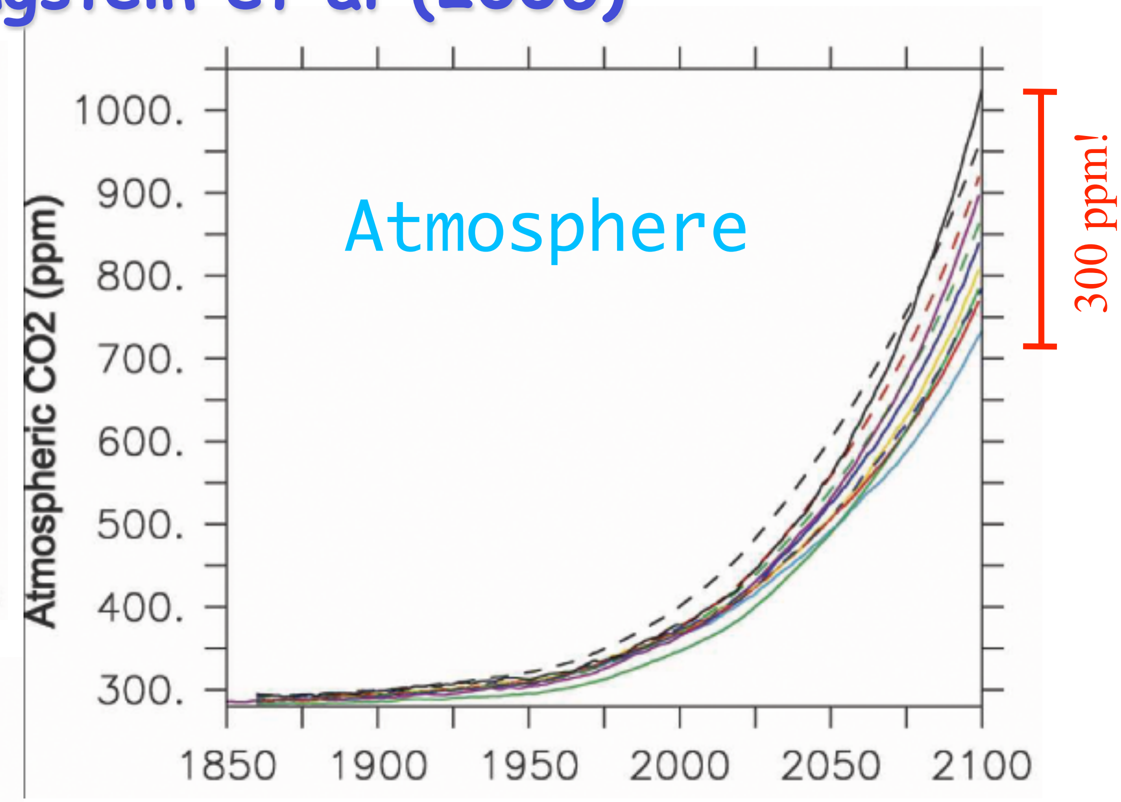
- Land Carbon feedback is a 1st-order source of uncertainty in simulations of 21st Century climate
- Most of the sensitivity in carbon feedback is related to precip (e.g., Hadley Center vs CCSM)
- Subgrid-scale soil moisture, drought stress, methane & feedback

Carbon-Climate Futures

Friedlingstein et al (2006)







- Coupled simulations of climate and the carbon cycle
- Given nearly identical human emissions, different models project dramatically different futures!

Applicatons

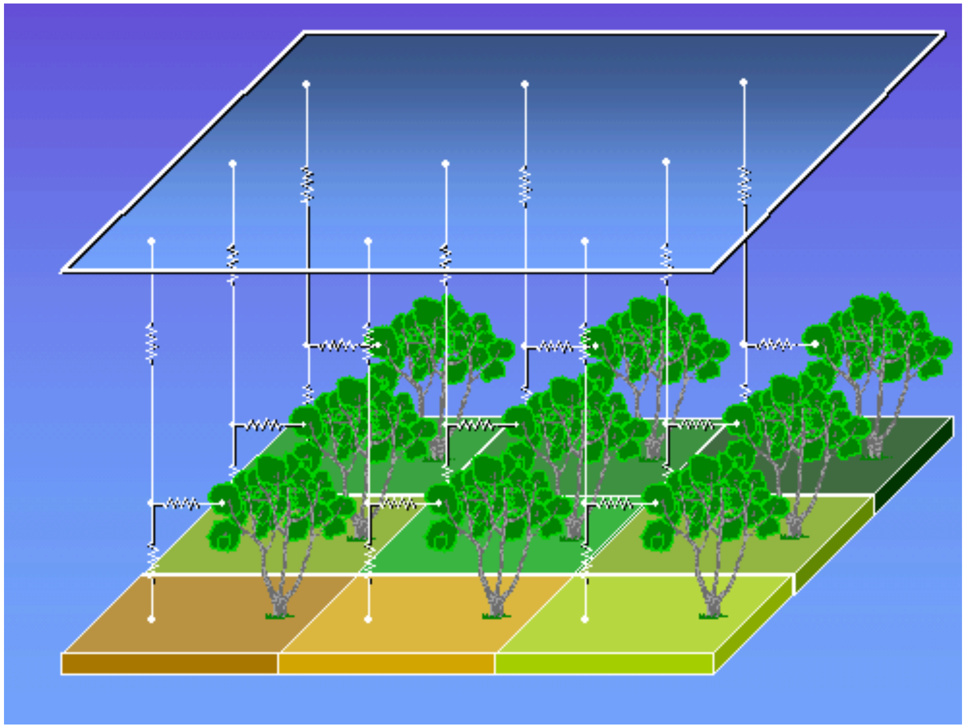
- Land-surface hydrology ... Subgrid topography, snowpack, irrigated agriculture (economically important)
- Diagnosis of contemporary carbon sinks from atmos data subject to cloud-clearsky biases
- Future climate change due to land-use and surface hydrology are subgrid-scale (e.g., development, deforestation)
- Sea-ice energy budget, clouds, radiation, dynamical coupling at fine scales is crucial for high-latitude climate feedback

Why CMMAP?

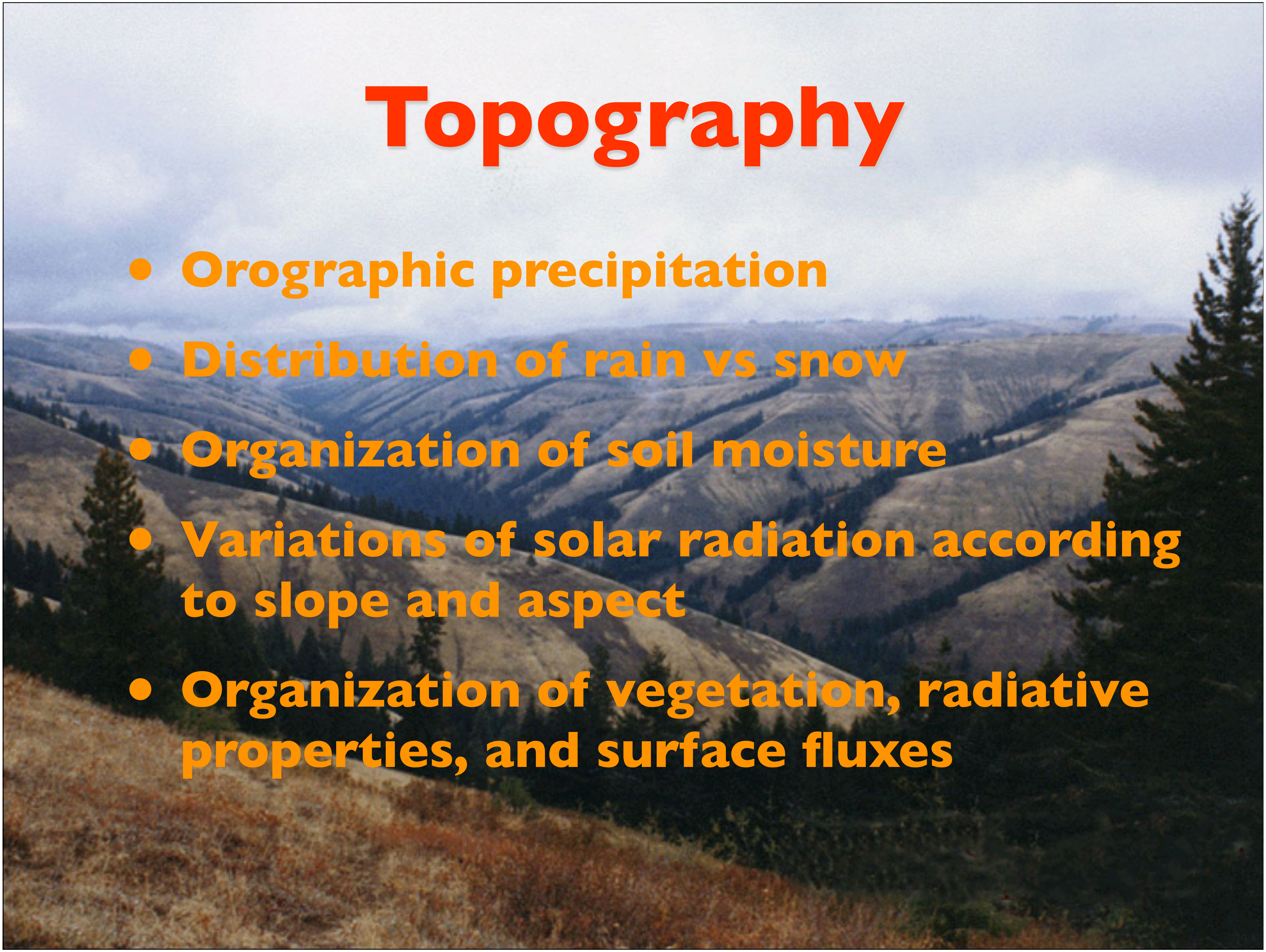
- **Realistic mechanistic coupling among clouds/radiation/precip/soil moisture/vegetation/BGC at fine spatial scales**
- **Diurnal cycle of precip & radiation is coupled to ecosystem function, much more realistic in multiscale model**
- **Limited-area models OK for study of heterogeneity, but precip requires a global domain**

Land-Surface Coupling

- Exchanges of radiation, sensible heat, water, carbon, and momentum



- Prototype model: in each GCM grid column, many cloud-resolving cells, but just one land-surface!
- Effects of heterogeneity?



Topography

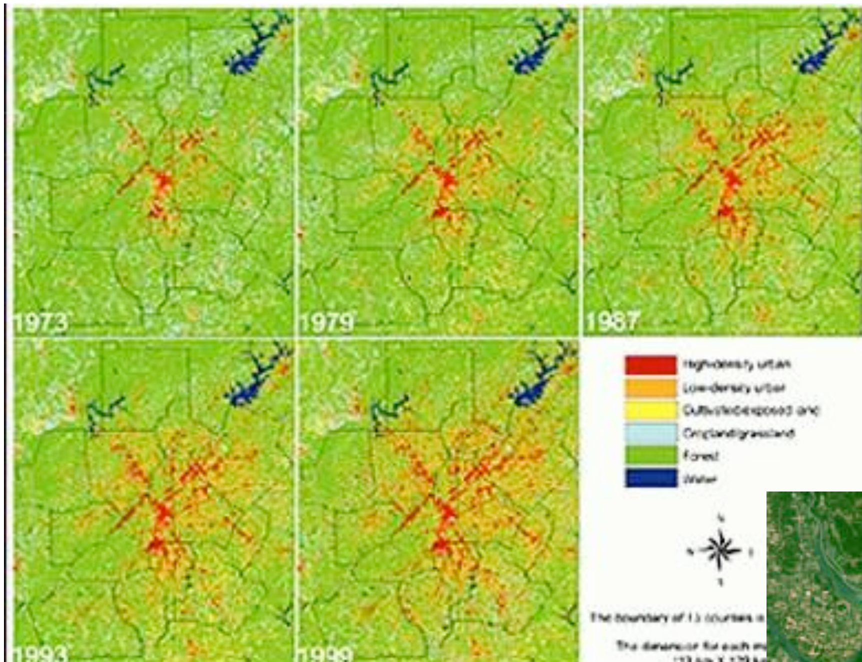
- Orographic precipitation
- Distribution of rain vs snow
- Organization of soil moisture
- Variations of solar radiation according to slope and aspect
- Organization of vegetation, radiative properties, and surface fluxes

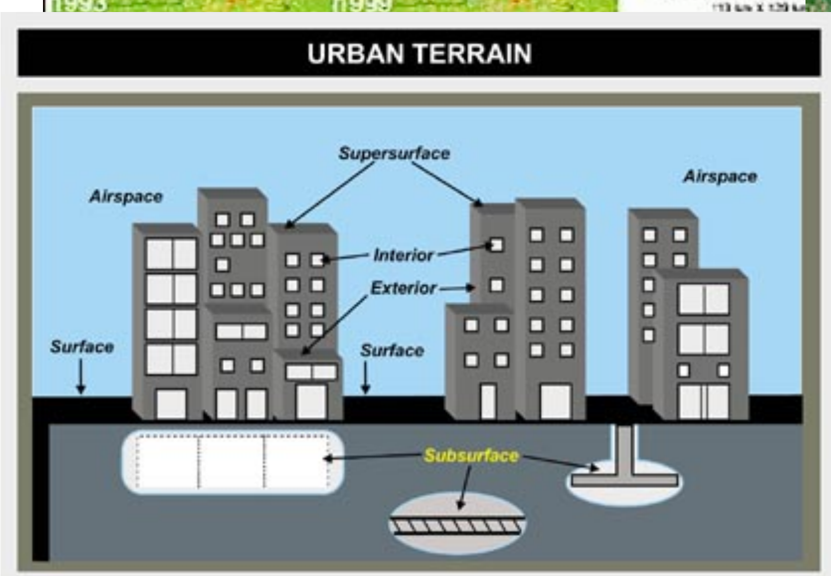
Land Management

- Agriculture
- Urban/suburban landscapes
- Commercial forest management

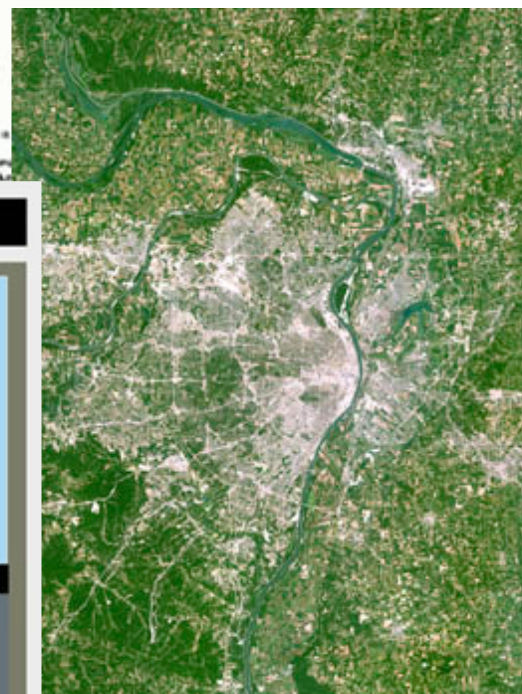
Urban/Suburban/Rural

Atlanta





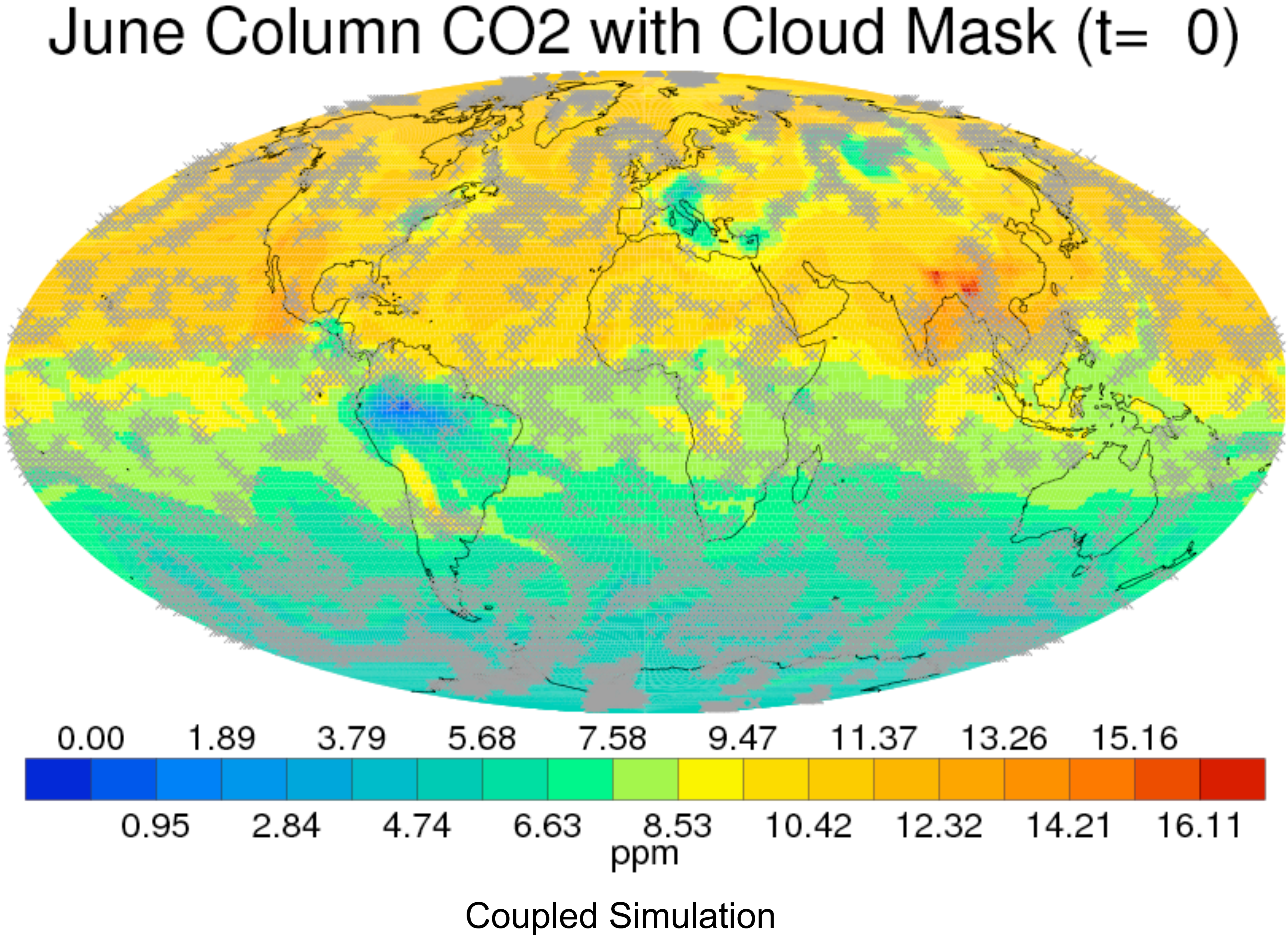
St Louis



Clouds, Radiation, and CO_2

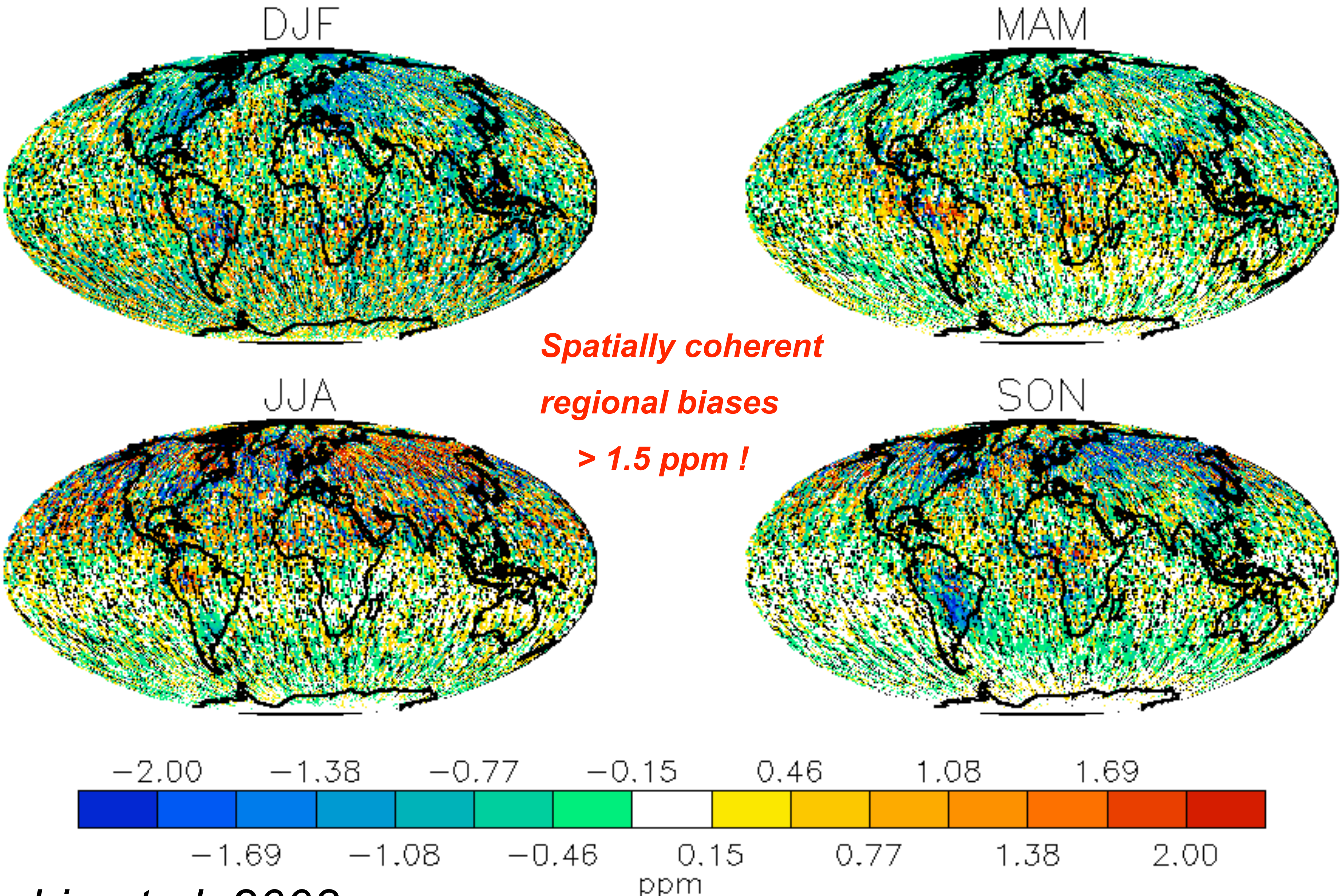
- Photosynthetic light response
  - Strong (but saturating) dependence
  - More efficient for diffuse than direct
- Covariation with precip, T, and humidity
- Cloud-scale vertical motion
- Patchy vs continuous cloud, convective vs frontal cloud systems
- Clouds might suppress photosynthesis through light response, lead to higher CO2
- Or, clouds might enhance photosynthesis due to diffuse light, lead to lower CO2

Clearsky Sampling Errors



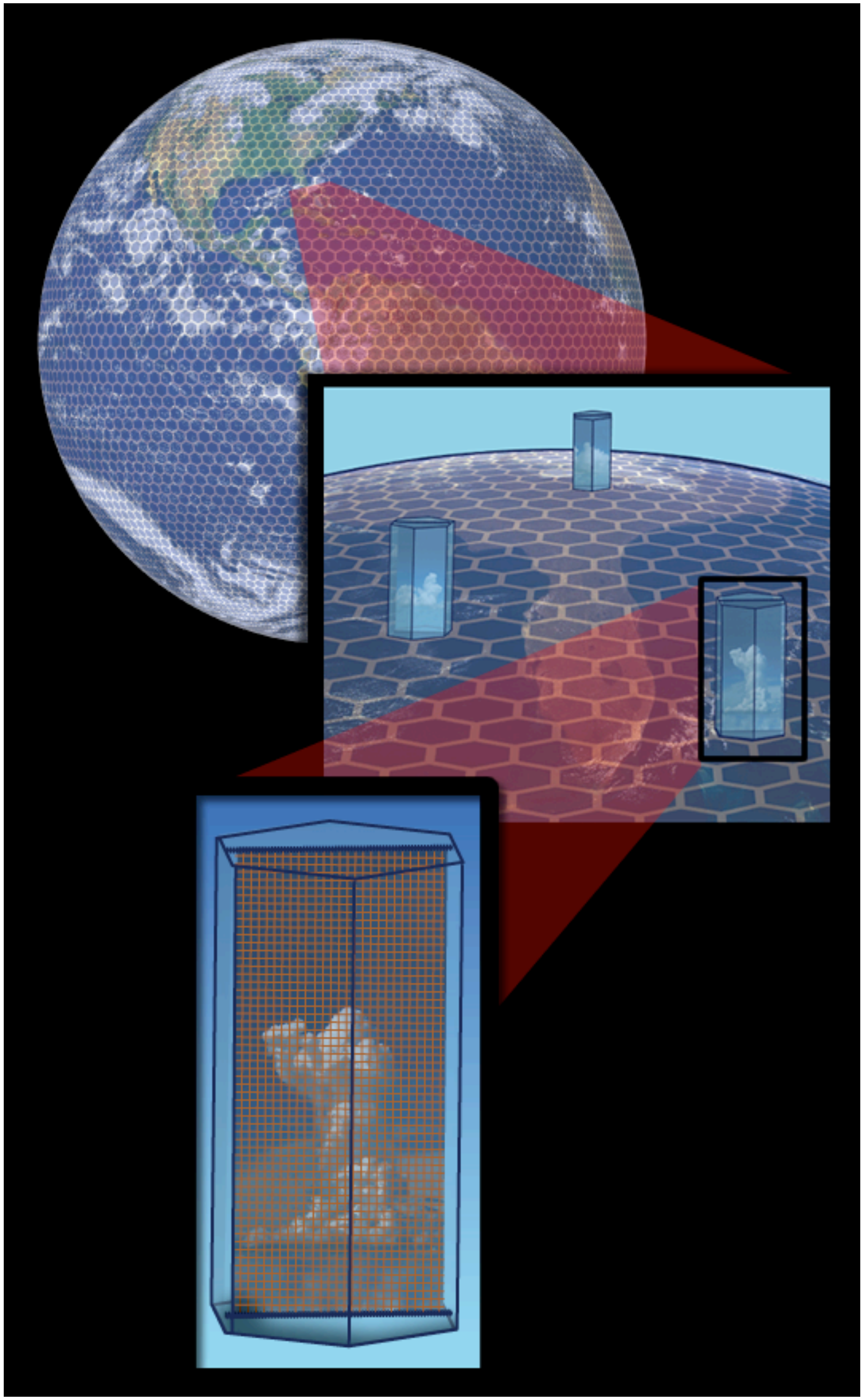
Corbin et al, 2008

Clearsky Sampling Error



Spatially coherent regional biases > 1.5 ppm !

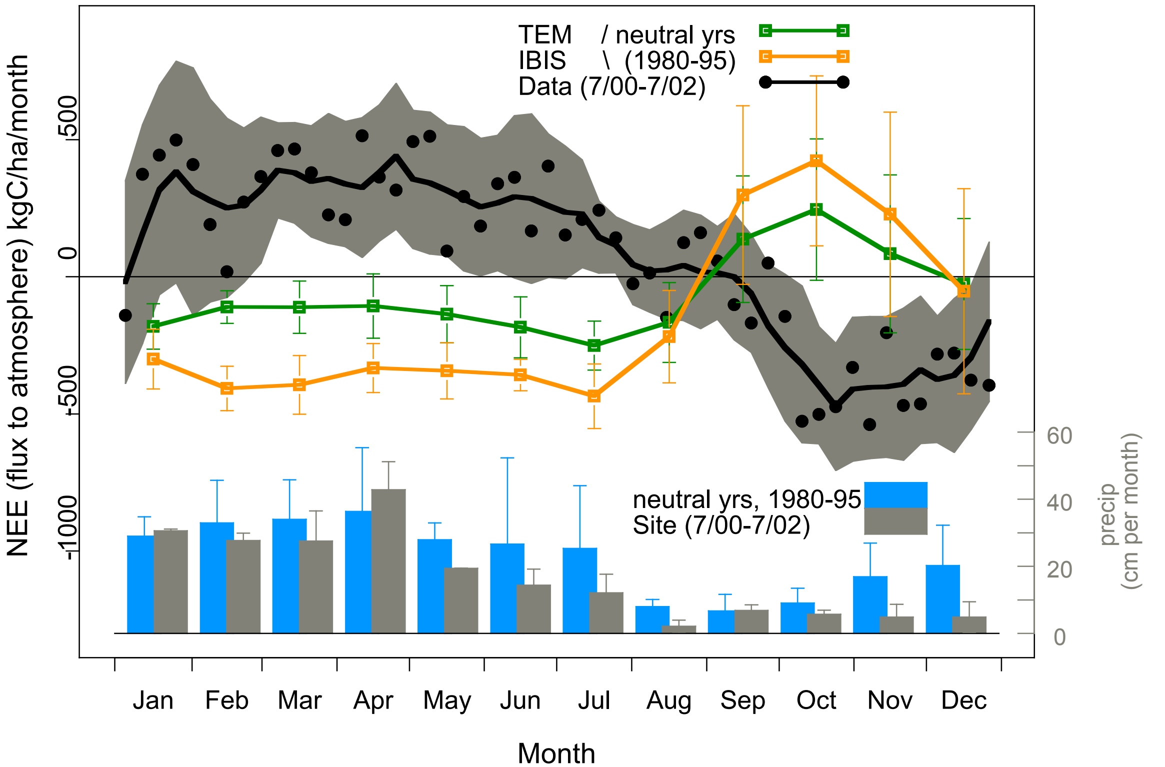
Corbin et al, 2008



Multiscale Strategy

- Understand locally (observe, experiment, & model development)
- Extrapolate to regions & evaluate (SiB-SAM)
- Implement globally and perform experiments (SiB-GCRM)
- Predict! (SiB-MMF)

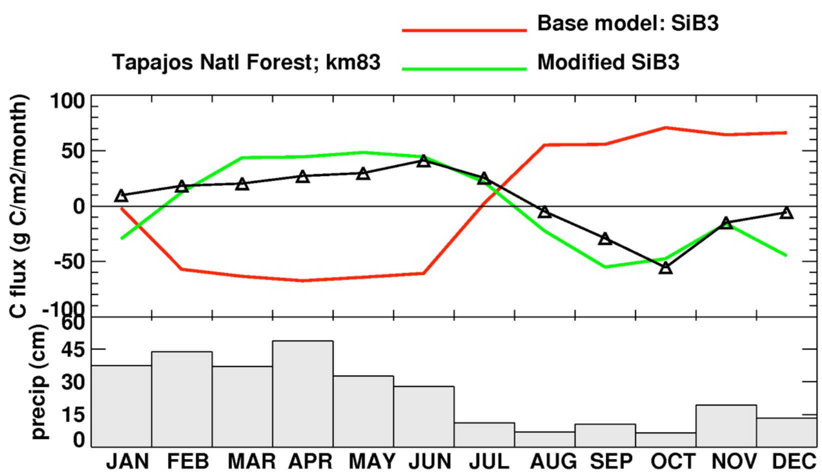
Wet-Dry Seasonality as an Analog to Climate Change

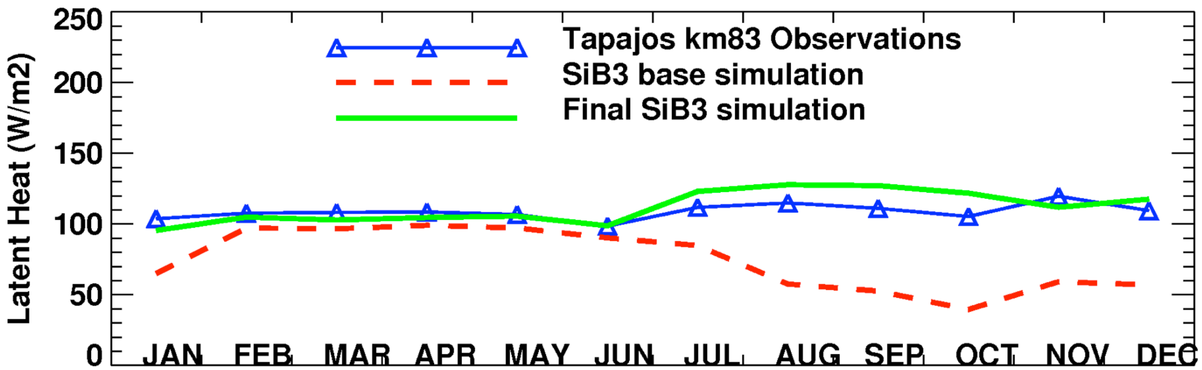


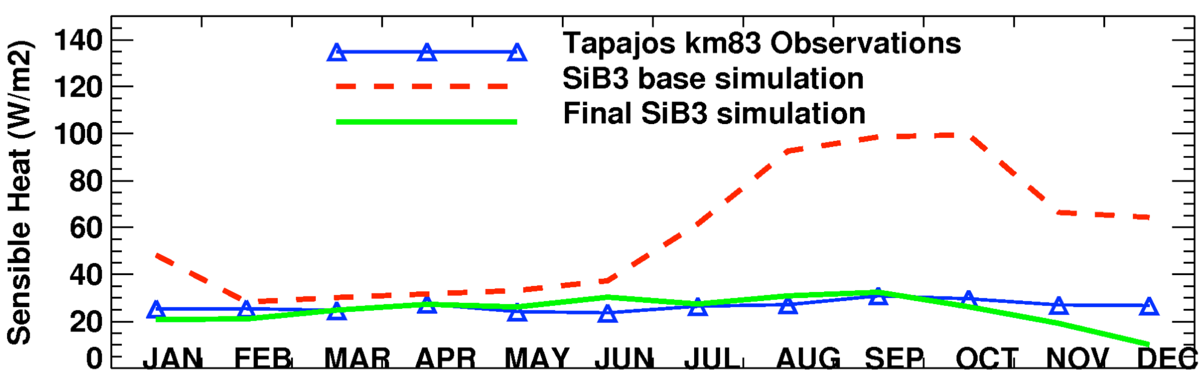
Model output is mean of 4 gridpoints: -54.5 > longitude > -55.5, -2.5 > latitude > -3.5, for neutral years 1980-81,1984-85,1990, & 1993-95.
Data is from Tapajos, km67 site (2.85 S, 55 W, from 10-Apr-01 to 08-May-02) & km83 site (3.05 S, 55 W, from 1-Jul-00 to 1-Jul-01).

Saleska *et al*, 2003, *Science*

- Models show Amazon carbon uptake in wet season, release in dry season (stress)
- Observations show exactly the opposite!

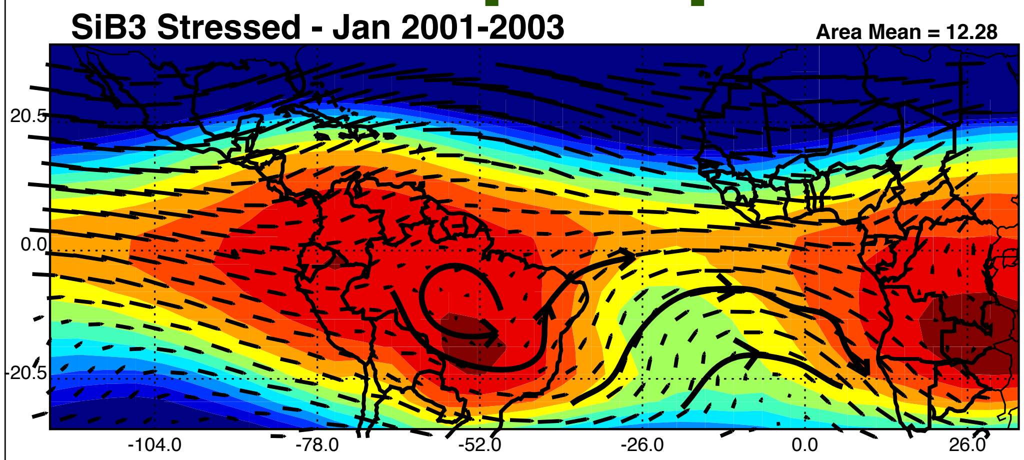




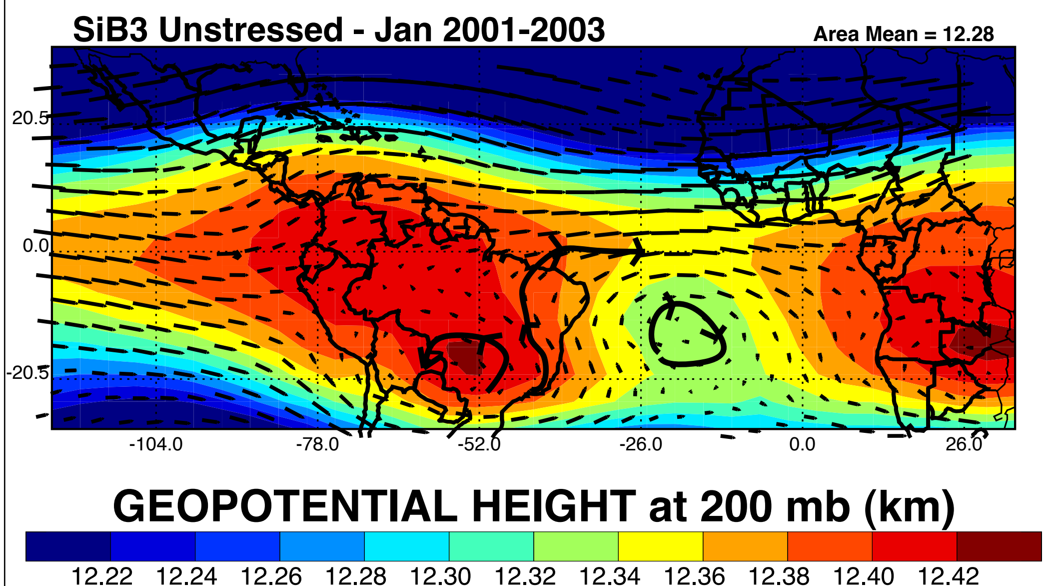


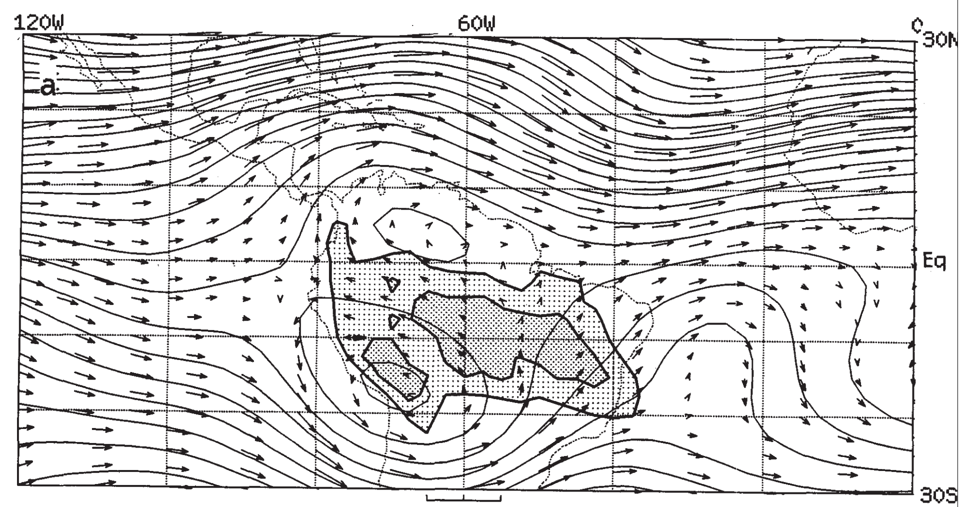
Impact of improved treatment of tropical root-zone physiology

Impact of roots on Upper Tropospheric Circulation



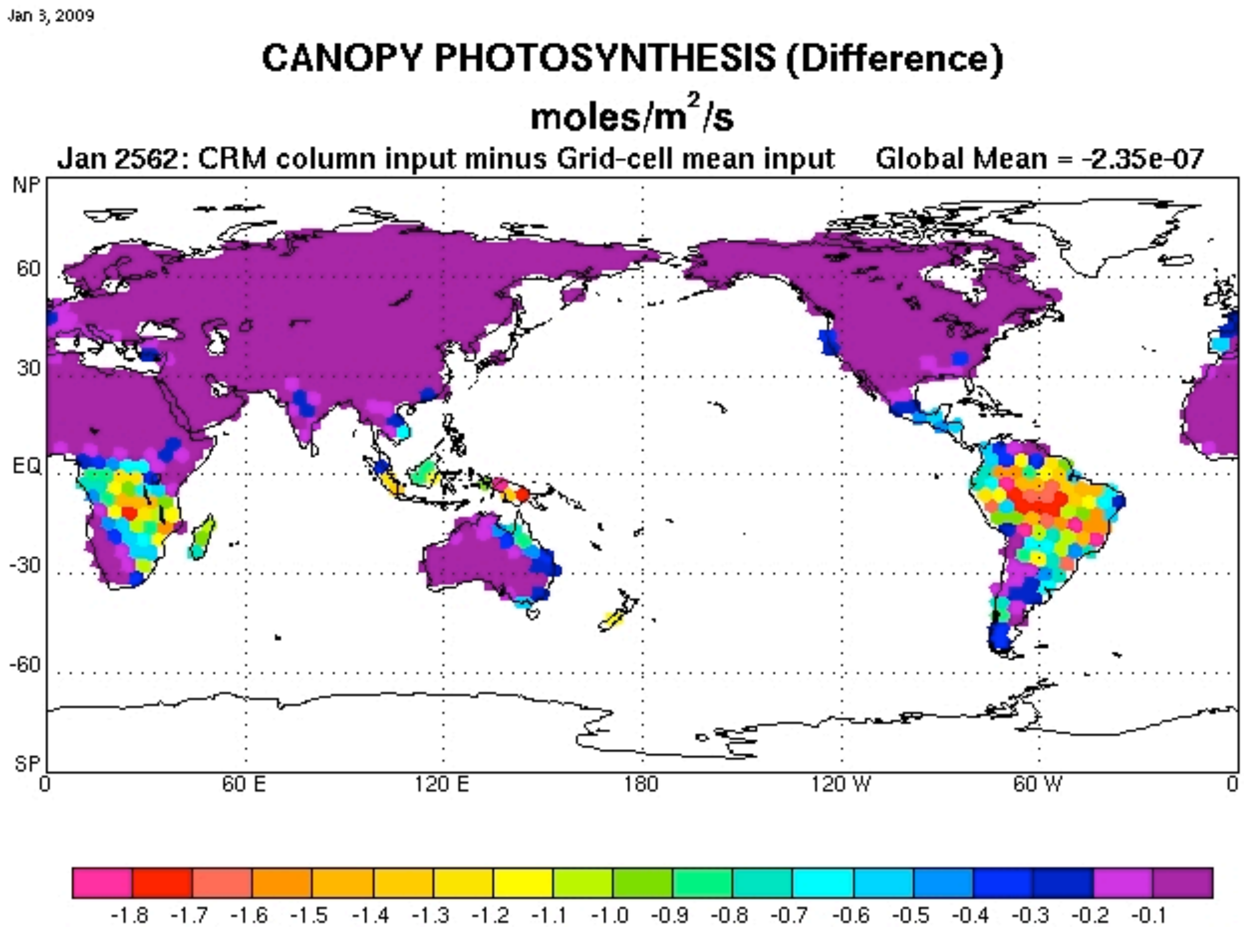
Improved simulation of Bolivian High and Nordeste Low





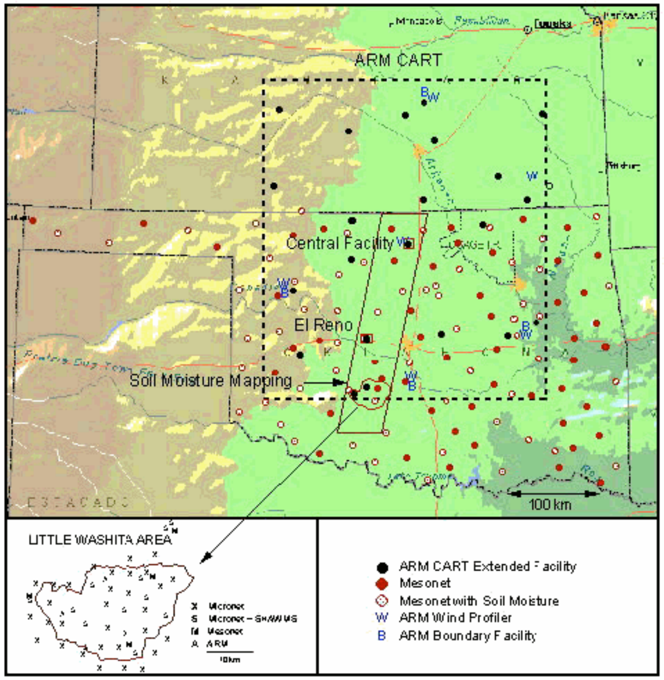
Obs from Horel et al. 1989: Jan 1-5, 1980-1987. 200mb geopotential height, wind vectors, & OLR

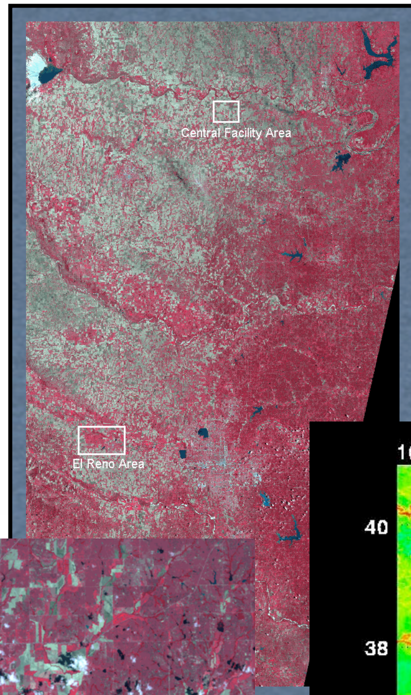
Surface Heterogeneity Impact on Carbon Cycle

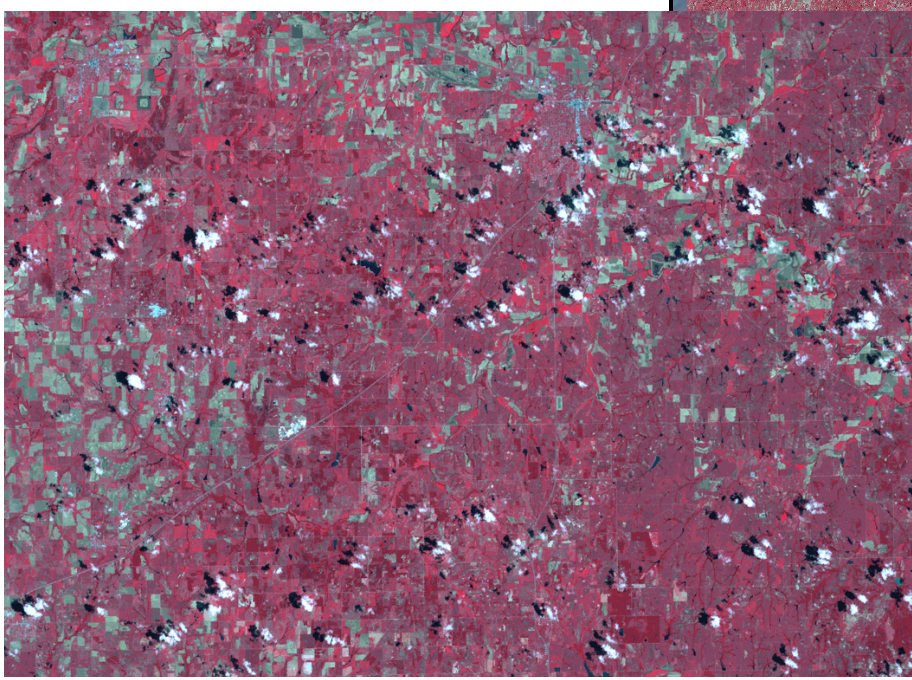


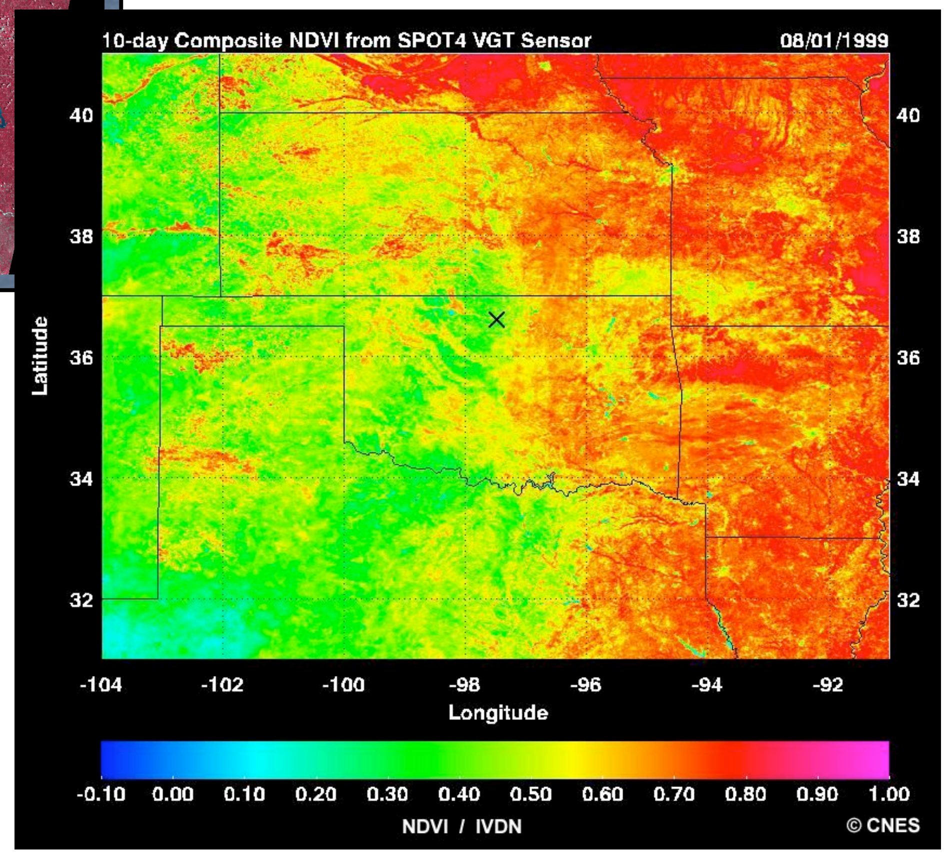
- Latent/Sensible Heat Fluxes Relatively Unchanged
- Reduction in Photosynthesis (mean; 12%)

ARM

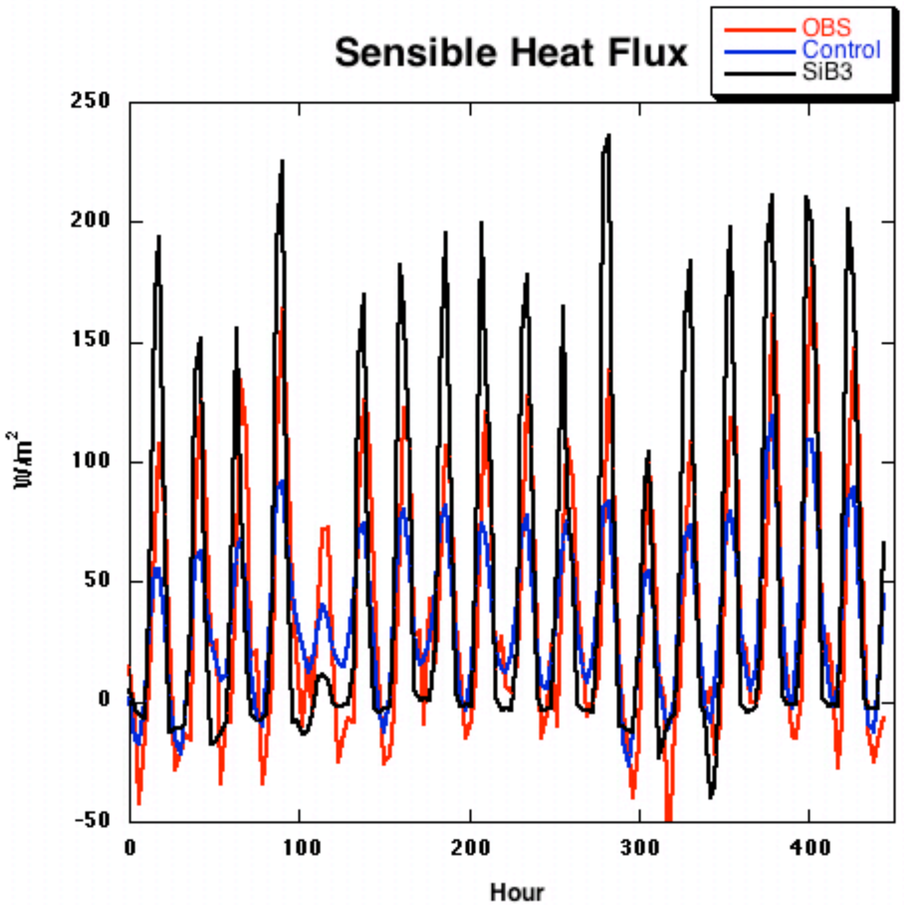

ARM CART
Central Facility
El Reno
Soil Moisture Mapping
100 km
LITTLE WASHITA AREA
ARM CART Extended Facility
Mesonet
Mesonet with Soil Moisture
ARM Wind Profiler
ARM Boundary Facility

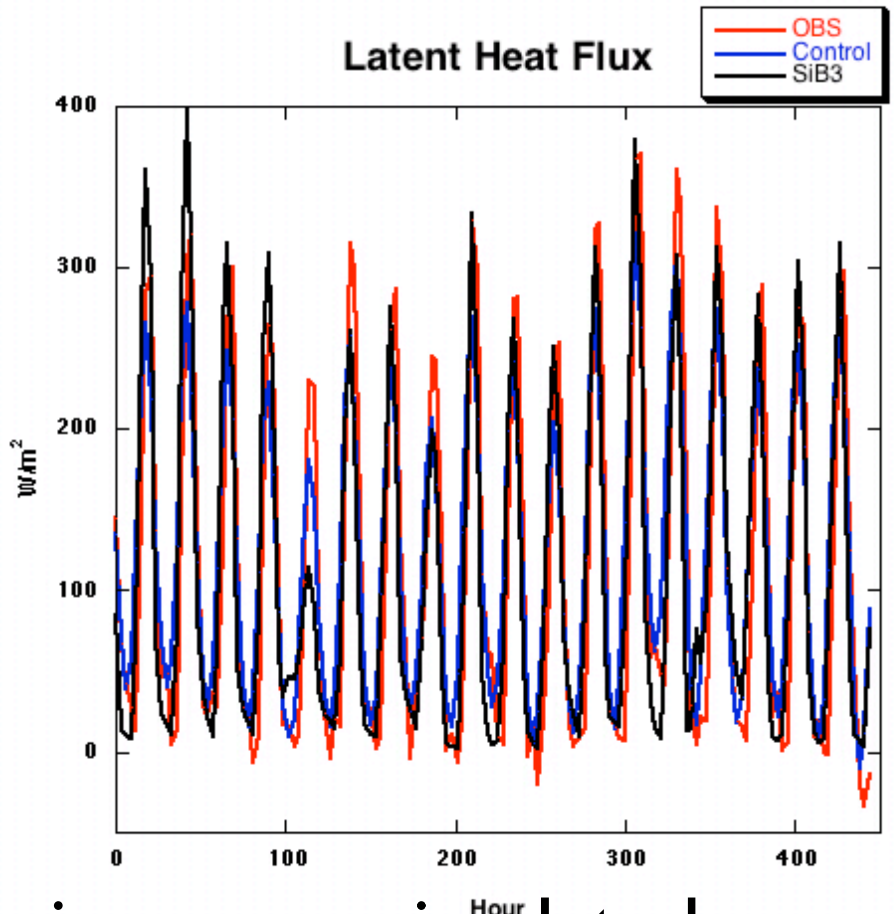

Central Facility Area
El Reno Area




10-day Composite NDVI from SPOT4 VGT Sensor
08/01/1999
Latitude
Longitude
-104 -102 -100 -98 -96 -94 -92
32 34 36 38 40
-0.10 0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
NDVI / IVDN
© CNES

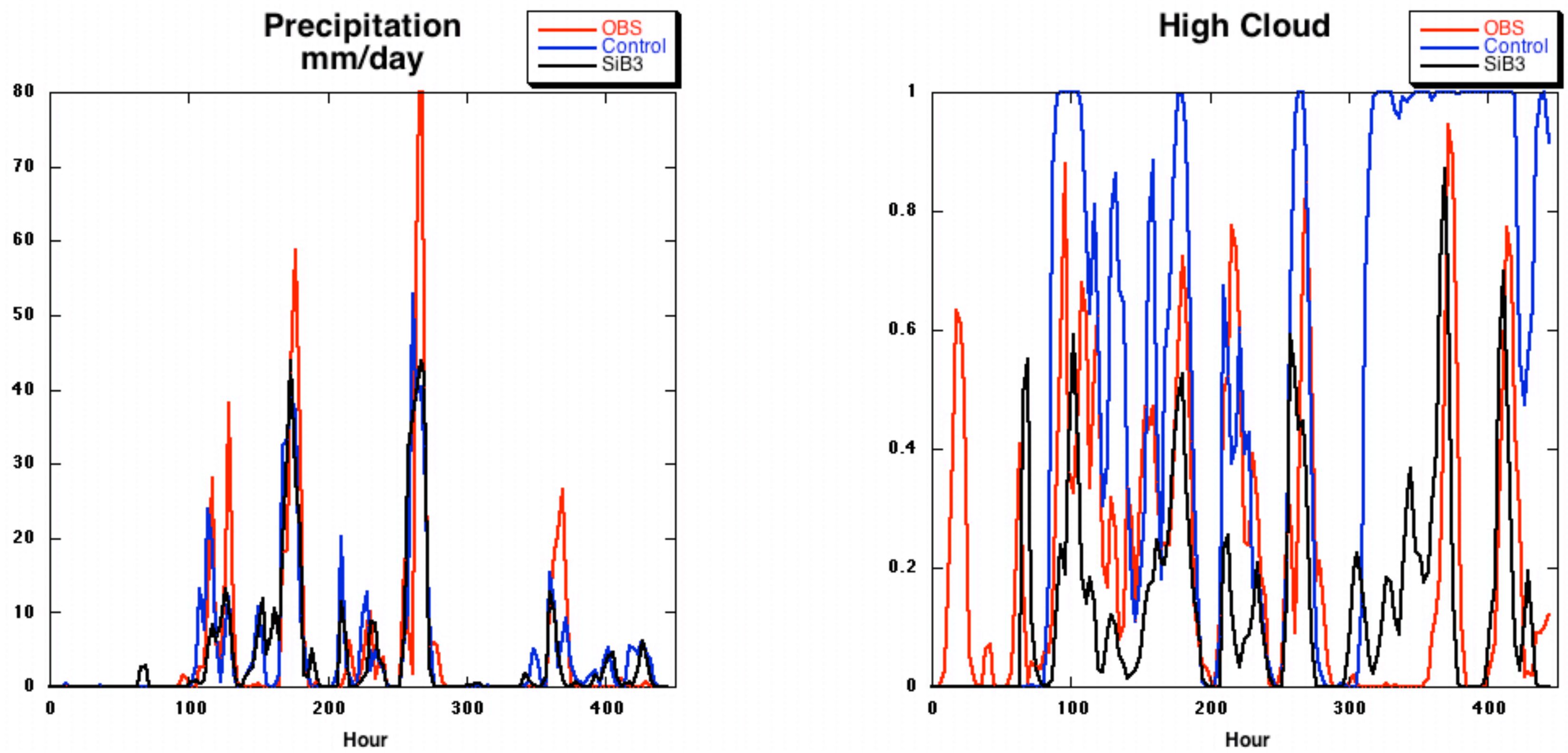
Coupled Simulations in a Cloud-Resolving Model





- Land-surface heterogeneity improves simulated surface fluxes of energy and water

Coupled Simulations in a Cloud-Resolving Model



- Land-surface heterogeneity improves simulated precipitation and clouds!

Current Climate

- Coupled SiB-LES experiments
- Regional SiB-SAM experiments

  1. continental US (emphasis on topographic control, mesoscale organization, and CO2)
  2. monsoon climates (emphasizing coupled onset and proagation)
  3. Amazon (emphasizing fine-scale deforestation)

- SiB-GCRM experiments

Future Climate

- coupled land-atmosphere MMF to study the effects of land-use change and biogeochemistry in simulations of future climates.
- These simulations will use land-use change scenarios being developed using the IMAGE model.
- Hostorical and projected future land-use change scenarios are currently available on a 0.5 deegree grid. These will be downscaled using topographic controls and run in the coupled MMF and CCSM