Towards the Rebirth of the NASA GISS Land (Surface) Model: Challenges and Opportunities

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May 6, 2009
NASA GISS Lunch Seminar
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Motivation

• Coupling the Ent Dynamic Global Terrestrial Ecosystem model with the GISS Land Model

• Kevin Trenberth in Nov. 2008 @ GISS 3rd Floor: doesn’t trust the predictions of the GISS land model
  – Reduce confidence in modeling community
  – Marginalization of the GISS land model
Outline

• Introduction
• Existing GISS Land Model
  – Opportunities for improvement
• Current model development
  – Ecosystem-scale analyses
  – Global-scale analyses
• Development framework
Hydrologic Land Processes

- **Terrestrial hydrology**
  - 3-D land surface
  - Significant spatial heterogeneity in soil, vegetation, and topography
    - Surface runoff
    - Ecosystem dynamics

- **Fluvial hydrology**
Importance of land model

- Water cycle components interact with and affect:
  - Carbon (and nitrogen) cycle
  - Fire dynamics
  - Dust and trace gas emissions
  - Vegetation dynamics
- Partitions water & energy into storage reservoirs.
- Controls the release of water vapor and energy to the atmosphere.
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Current NASA GISS Land Model

- Divided into bare-soil and vegetated sections, which are conceptualized as interspersed
- A single water & energy balance for all vegetation (patches) within a grid cell
- Soil column is 3.5 m thick and 6 layers everywhere
- Explicit solution of heat & water transport in the soil column
Options for Improvement

- Continue with a one-dimensional representation (e.g. NCAR)
  - Heterogeneity (e.g. soil, topography) through statistical approaches
- Catchment-based model of GSFC (Koster et al. 2002)
- New approach to capture the heterogeneity of the land’s soil, vegetation, and topography

\[ T_{1D}, R_{1D} \]
\[ T_{GSFC} > T_{1D} \]
\[ R_{GSFC} > R_{1D} \]
\[ T_{INNOVATIVE} > T_{GSFC} \]
\[ R_{INNOVATIVE} > R_{GSFC} \]
1D example: Community Land Model


- Improved canopy integration scheme (Ent DGTEM)
- Scaling of canopy interception
- TOPMODEL-based model for surface and subsurface runoff
- Groundwater model for determining water table depth
- New frozen soil scheme
- New surface data sets and parameterizations (new land-cover maps, LAI, SAI, and soil color based on MODIS products) (Lawrence and Chase, 2007)
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Framework

- Land model must be tested offline!!
- GISS land model needed to separated from the GISS GCM
- Setup needed to test offline at 2 spatial scales
  - Ecosystem scale
  - Global scale
- FLUXNET comparisons
- Global meteorological reanalysis datasets
  - 1986-1995 data from the GSWP2
  - 50+ years data from Princeton group
Current modifications

- Poor simulation of veg. biogeography (Oleson, 2008)
  - Global-scale: forest cover is underestimated in favor of grasses due to dry soil
  - Amazon: less broadleaf evergreen & more deciduous trees

- Problems
  - Inaccurate evapotranspiration partitioning (transpiration, soil evaporation, canopy evaporation)
  - Amazon soil moisture

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Vegetation and evapotranspiration

- Poor simulation of veg. biogeography (Oleson, 2008)
  - Global-scale: forest cover is underestimated in favor of grasses due to dry soil
  - Amazon: less broadleaf evergreen & more deciduous trees
- Problems: inaccurate ET partitioning, Amazon soil moisture

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Modifications to GISS LM hydrology

• Evaporation from vegetated soil - previously none
  – canopy sheltering effects: modify atmospheric transfer coefficient based on leaf area index

• Temporal correlation in storm position (Koster and Suarez, 1996)
  – Increase precipitation throughfall
  – reduces wet canopy fraction

• Scheme to account for wet-layer effects (i.e. stomatal blocking) on water & carbon fluxes
  – Depends on plant functional type
Morgan Monroe State Forest

- Broadleaf deciduous forest in Indiana
- Temperate continental climate:
  - mean annual temp. ≈ 12.4 °C,
  - mean annual precipitation ≈ 1094 mm

• Total evapotranspiration is underestimated during growing season
• Different schemes have minimal effect on productivity
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Evapotranspiration partitioning

Original scheme
- Transpiration: 48%
- Soil Evap.: 36%
- Canopy Evap.: 16%

Modified scheme
- Transpiration: 3%
- Soil Evap.: 37%
- Canopy Evap.: 47%
Hydrologic components

**Original Scheme**

- Total ET: No Change
- Runoff: No change

**Modified Scheme**

- Total ET: No Change
- Runoff: No change
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Development Framework: 1D model

Surface Runoff (Topography-based TOPMODEL)

Vegetation Water Dynamics (e.g. more wet-layer extraction to compensate for dry layers)

Incorporate Irrigation; Infiltration Enhancement (Macropore Flow)??

Implicit solution of water and heat equation

Soil-column layering; Water table / groundwater

Canopy boundary layer; Surface boundary layer of the atmosphere

Update:
Soils data
Land-cover data (Ent)
LAI and SAI data
Return on Investment

\[
\text{ROI} = \frac{\text{Gain from Investment}}{\text{Cost of Investment}}
\]

- **Cost of Investment**
  - 1 or 2 additional researchers

- **Gain from Investment**
  - Increased recognition in the modeling community
  - Postdoctoral researchers
  - Better runoff predictions
  - Better carbon cycle
  - Better ecosystem dynamics
  - Better climate predictions
  - Potential to create a new, innovation land model
Questions ?