How much do different land models matter for climate simulation: results from an AGCM coupled to three land models

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Motivation

- Uncertainty of land surface schemes (LSSs)
- Complexity of land-atmosphere interaction
- Sources of the signals are hard to trace
- Different behaviors of offline and coupled simulations
Different behaviors of LSSs in offline and coupled simulations

Offline

Forcing

LSS1 (dry)

AGCM

Coupled

Forcing

LSS2 (wet)

AGCM

LSS1 (wet)

LSS2 (dry)
Method

- To understand the role of the components of coupled land-atmosphere models in climate variability, we tile multiple LSSs into a single AGCM.
- Each LSS will see the same atmospheric boundary condition and calculate its response fluxes, which are averaged across LSSs in a mosaic tiling approach and passed back to the AGCM.
- Running any individual LSS coupled to the AGCM is just a special case of the multi-model coupling.
- With this approach, we can have a better understanding of the mechanisms for land-atmosphere coupling and its dependence on the water and energy characteristics of the component models.
Experiments

Exp I:

AGCM

SSiB

AGCM

CLM

AGCM

Noah

Exp C:

AGCM

SSiB  CLM  Noah
## Models

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<th>Models</th>
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<td><strong>AGCM</strong></td>
<td>COLA AGCM*&lt;br&gt;- T62 (1.875°×1.9°) resolution, 28 vertical layers&lt;br&gt;- Relaxed Arakawa Schubert deep convection scheme&lt;br&gt;- Non-local boundary layer vertical diffusion&lt;br&gt;- CCM3 cloud radiation scheme</td>
<td>Misra et al. 2007; Kinter et al. 1997</td>
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<td><strong>Land Models</strong></td>
<td>SSiB&lt;br&gt;- 6 soil layers (4 in root zone), soil depth varies spatially, 12 vegetation types. Surface state variables and fluxes are defined at the grid point level</td>
<td>Xue et al. 1991; Dirmeyer and Zeng 1999</td>
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<td>CLM3.5&lt;br&gt;- Nested subgrid hierarchy (landunit, column, PFT)&lt;br&gt;- 10 soil layers, 15 PFTs (up to 4 in each column)&lt;br&gt;- Vegetation state variables and all fluxes are defined at the PFT level&lt;br&gt;- Soil and snow properties are defined at the column level</td>
<td>Oleson et al. 2004, 2008</td>
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<td>Noah&lt;br&gt;- 4 soil layers, 13 vegetation types, Surface state variables and fluxes are defined at the grid point level</td>
<td>Ek et al. 2003</td>
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* The multi-model coupling with NOAA GFS is also underway.
Precipitation climatology
Precipitation seasonal cycle

Amazon (10S-0,290-310E)

Great Plains (35-45N,260-270E)
Significance of inter-model differences in JJA

\[ t_{1,2} = \frac{|\bar{x}_1 - \bar{x}_2|}{\left(\frac{s_1^2}{n} + \frac{s_2^2}{n}\right)^{1/2}} \]

\[ \bar{t} = \left( t_{SSiB, CLM} + t_{SSiB, Noah} + t_{Noah, CLM} \right) / 3 \]
Significance of inter-model differences in JJA
Inter-model variances of JJA climatology

Var(I)  Var(C)  Var(C)/Var(I)

Sensible heat

Latent heat
**Atmosphere control:** the same humidity of atmosphere cause the LH of LSSs to diverge more in C

**Land surface control:** the same precipitation (similar soil wetness) cause the LH of LSSs to converge more in C
Summary

- The models can generally simulate the spatial patterns and seasonal cycles of precipitation, but system errors exist in both AGCM and LSSs.
- The results from combined coupling generally fall within the range of individually coupled simulations.
- The coupling of different LSSs to the same AGCM does have significant influence on the simulated climate over most land area.
- Coupling the LSSs to an AGCM can increase or decrease the inter-model divergences of fluxes, depending on the evaporation regime of the models in different regions.