Impact of different land or atmospheric models on climate simulation

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1. Motivation

a. Uncertainty of land surface models
significantly different output at the same forcing (e.g., PILPS, GSWP)

b. Complexity of land-atmosphere interaction
full of nonlinear processes
uncertainties in land simulation may be brought to atmosphere

c. Sources of the signals are hard to trace in the complex system
e.g. GLACE "hotspots"

2. Models

	Models	Description	References
AGCMs	*COLA AGCM*	• T62 (1.875°×1.9°) resolution, 28 vertical layers • Relaxed Arakawa Schubert deep convection scheme • Non-local boundary layer vertical diffusion • CCM3 cloud radiation scheme	Misra et al. 2007; Kinter et al. 1997
	NCEP GFS	• T62 (1.875°×1.9°) resolution, 64 vertical layers • Simplified Arakawa–Schubert convection scheme • Explicit cloud microphysics, nonlocal vertical diffusion, and gravity wave drag	Saha et al. 2006
Land Models	*SSiB*	6 soil layers (4 in root zone), soil depth varies spatially, 12 vegetation types. State variables and fluxes are defined at the grid point level	Xue et al. 1991; Dirmeyer and Zeng 1999
	CLM3.5	• Nested subgrid hierarchy (landunit, column, PFT) • 10 soil layers, 15 PFTs (up to 4 in each column) • State variables and all fluxes are defined at the subgrid level	Oleson et al. 2004, 2008
	Noah	4 soil layers, 13 vegetation types, State variables and fluxes are defined at the grid point level	Ek et al. 2003

Each AGCM is coupled to the three land models, individually.
Totally six model configurations (combinations): **COLA-SSiB, COLA-CLM, COLA-Noah, GFS-SSiB, GFS-CLM, GFS-Noah**

3. Experiments

a. Long-term simulations
All the simulations start from April 1, 1982 and end on January 1, 2005 (close to 23 years).

b. GLACE-type simulations
Ensemble W is a set of free runs with different initial land and atmosphere conditions but forced by the same SST, and ensemble S is the same as ensemble W except that, at each time step, the soil moisture in all the soil layers is replaced by that from one member chosen from ensemble W. A diagnostic variable Ω was defined:

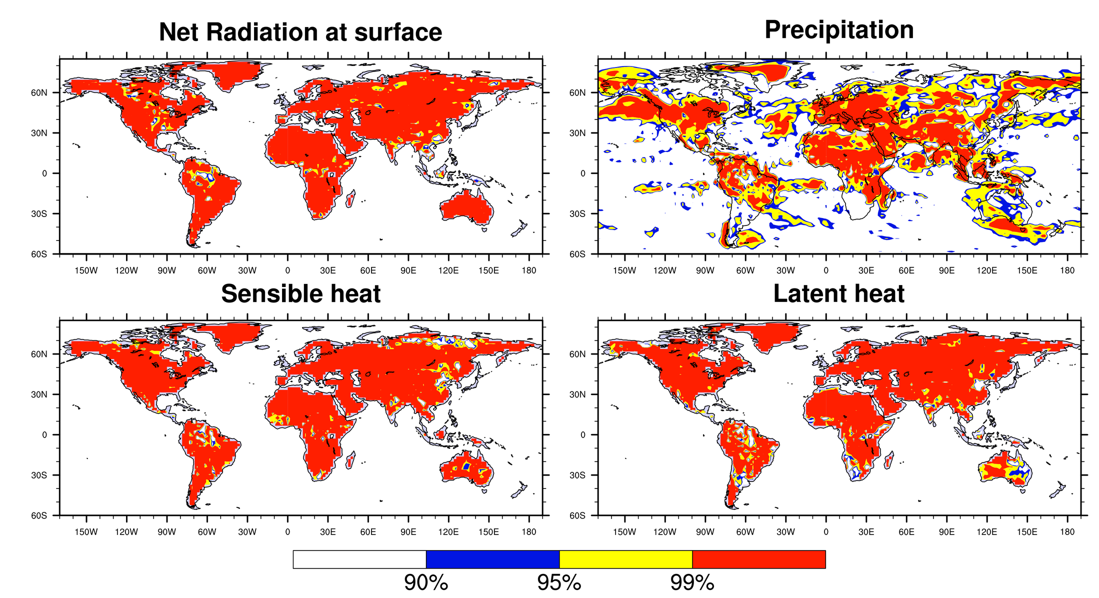
$$\Omega = \frac{16\sigma^2_{<X>} - \sigma^2_X}{15\sigma^2_X}$$

Mathematically, Ω is equivalent to the percentage of variance caused by the slowly varying boundary processes. The difference of Ω from the two ensembles, Ω(S)-Ω(W), is then equivalent to the percentage of variance caused by the prescribed soil moisture, and is a measure of land-atmosphere coupling strength in GLACE.

c. Climate change simulations (COLA AGCM only)
Same as long-term runs, but with 2xCO2 and associated SST climatology changes (from IPCC AR4).

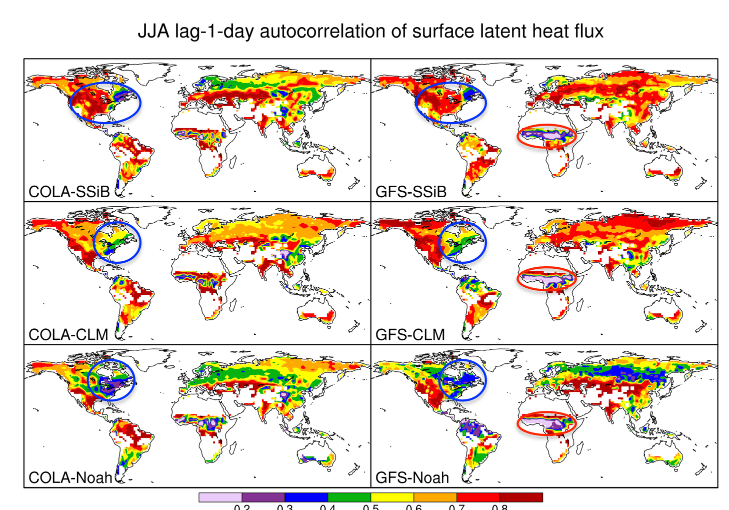
4. Results

a. Climatology

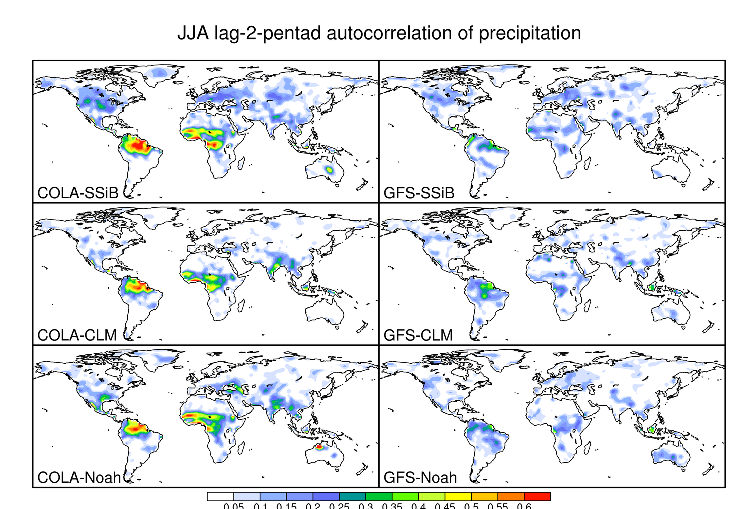


Average confidence level of inter-model difference in JJA climatology between COLA-SSiB, COLA-CLM, and COLA-Noah.
(*Wei et al. 2010c*)

b. Variability



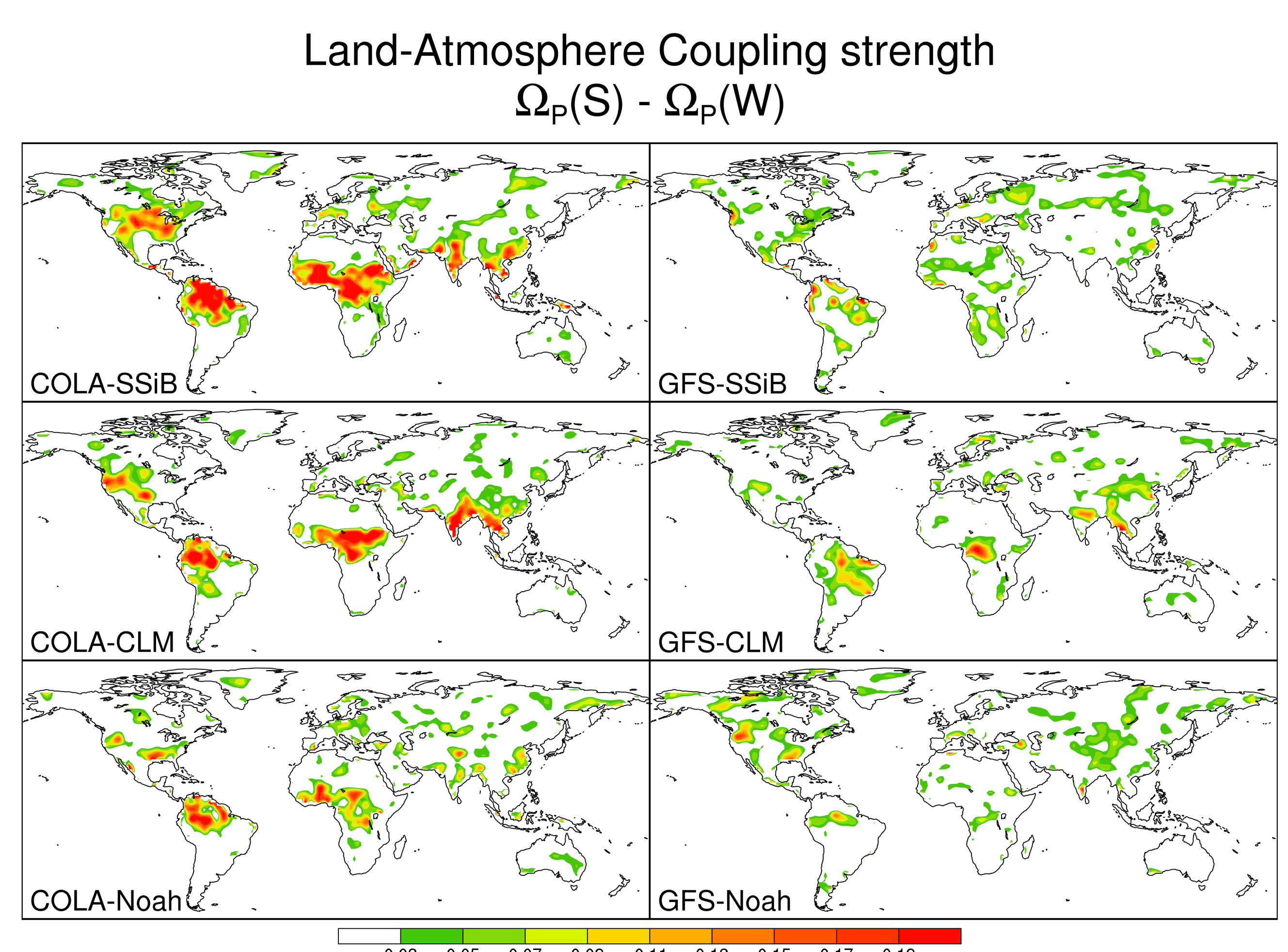
• Blue circles show the dominant impact of the land models when coupled to different AGCMs.
• Red circles show the dominant impact of the AGCM (GFS) when coupled to different land models.



The precipitation variability is mainly determined by the AGCM.

(*Wei et al. 2010b, c, Wei and Dirmeyer 2010*)

c. Land-atmosphere coupling



The strength of land-atmosphere coupling seems to be mainly determined by the AGCM, although the land model has regional impacts.
(*Wei and Dirmeyer 2010; Wei et al. 2010b*)

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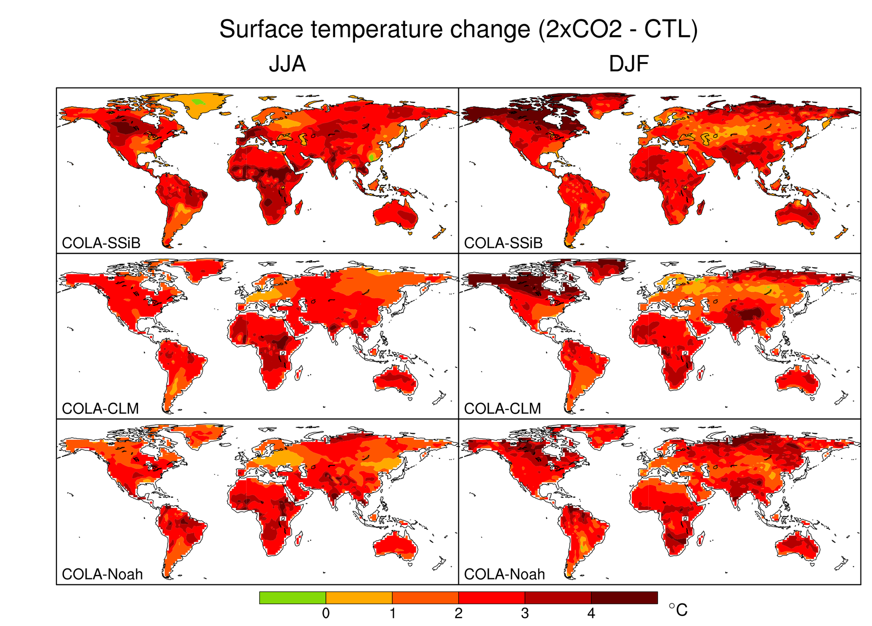
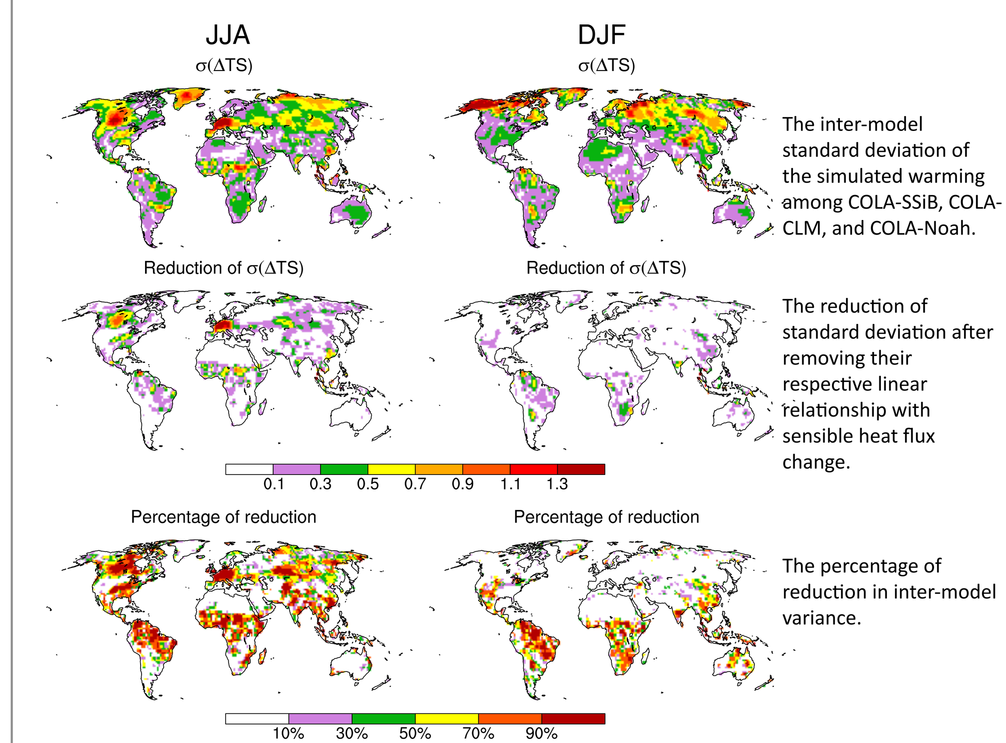
d. Climate change



Different land models can greatly impact the spatial distribution and amplitude of the simulated warming over land, but the annual global-average land surface warmings are very close.



In warm regions, the different descriptions of local land processes and their associated feedbacks are responsible for about half of the inter-model spread. In cold regions, almost all of the spread is caused by the circulation differences triggered by land model differences, and the local land processes have little direct impact.
(*Wei et al. 2010a*)

5. Conclusions

a. When coupled to the same AGCM, the three land models produces significantly different downward and upward water and energy fluxes over most of the land.

b. For the six model configurations, the choice of AGCMs is the main reason for the substantially different precipitation variability, and land-atmosphere coupling strength among the configurations. The impact of different land models is secondary, although they show dominant impacts on surface fluxes over some regions.

c. The different land models have strong regional impact on the simulated surface warming, especially over warm regions, but has little impact on projections of annual global-average temperature change.

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