Land-surface processes and monsoon climate system

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SW↓ - α·SW↓ + LW↓ -εσT^4 = H + LH + G
Elements of the Hydrological Cycle

\[ P = E + \text{Roff} + \Delta \text{snow} + \Delta \text{SM} \]
Assessing land/atmosphere interaction with two modern GCM Modeling Approaches:

What is soil moisture-atmosphere feedback on precipitation?

For soil moisture to contribute to precipitation predictability, two things must happen:

1. A soil moisture anomaly must be “remembered” into the forecast period.

2. The atmosphere must respond in a predictable way to the remembered soil moisture anomalies.
The GLACE Experiment

Part 1: Establish a time series of surface conditions (Simulation W1-W16)

Step forward the coupled AGCM-LSM

Write the values of the land surface prognostic variables into file W1_STATES

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Part 2: Run a 16-member ensemble, with each member forced to maintain the same time series of surface prognostic variables (Simulations R1 – R16)

Step forward the coupled AGCM-LSM

Throw out updated values of land surface prognostic variables; replace with values for time step n from file W1_STATES

Step forward the coupled AGCM-LSM

Throw out updated values of land surface prognostic variables; replace with values for time step n+1 from file W1_STATES
A variable $\Omega$ is defined that describes the coherence between the different precipitation time series.

All simulations in ensemble respond to the land surface boundary condition in the same way $\Omega$ is high.

Simulations in ensemble have no coherent response to the land surface boundary condition $\Omega$ is low.

6-day averages used in GLACE.
$\Omega_p (R - W)$: Impact of sub-surface soil moisture on precipitation
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Soil Moisture JJA coupling strength

Fig. 1. The land-atmosphere coupling strength diagnostic for boreal summer (the $\Omega$ difference, dimensionless, describing the impact of soil moisture on precipitation), averaged across the 12 models participating in GLACE. (Insets) Areally averaged coupling strengths for the 12 individual models over the outlined, representative hotspot regions. No signal appears in southern South America or at the southern tip of Africa.
the $\Omega$ diagnostic difference for precipitation and evaporation partitioned according to the hydrological conditions

Guo and Dirmeyer, 2013
Advantage:
1). Easy to design
2). No observational data required
3). Can explore the land surface process mechanisms

Issues:
1). Need multi-model to verify
2). How to explore the dynamic process
3). How to make quantitative assessment (except coupling stress)
4). How to extend beyond soil moisture or other
Assessing land/atmosphere interaction with two modern GCM Modeling Approaches:

Criteria

Should VBP is important in a real climate system and the VBP model properly presents the VBP process, the simulations should be improved. VBP effect is identified by the statistically significant reduction of errors or improvement in simulations.

Observational data as a reference is necessary.
Vegetation/climate Interactions

Global Atmospheric Conditions

Parameterization I

Parameterization II

Parameterization III

no interaction

partial interaction

full coupling
Vegetation/climate coupling strength

Global Atmospheric Conditions

Specified albedo, soil wetness

UCLA land scheme
No interactions.
NOVBP

Specified vegetation albedo & $Z_0$
Bare ground hydrology

NCEP GCM soil model
Partial interactions

Vegetation & Soil Dynamics

SSiB VBP/Climate interactions

VBP: Vegetation Biophysical Processes
Observed and the simulated JJA precipitation (mm day$^{-1}$)
Bias due to not considering vegetation biophysical processes (NOVBP)
Vegetation impacts on JJA precipitation (mm day$^{-1}$)

Bias due to not considering vegetation biophysical processes (NOVBP)

Compared with NOVEG, VBP reduced RMSE by 42% over land and 18% over global
Comparison between VBP and Soil Moisture approaches

Soil Moisture JJA coupling strength

Difference in JJA precipitation between VBP and NOVBP
Difference in JJA precipitation between VBP and NOVBP

Difference in DJF precipitation between VBP and NOVBP
Impact of vegetation biophysical processes on precipitation RMSE Reduction

WA Monsoon regions

Midlatitude Regs.

HL: High latitudes; EA: East Asia; SA: South Asia; WA: West Africa; TP: Tibet Plateau
East Asian Monsoon Intraseasonal Evolution (105E – 120E)

VBP Produces the monsoon jump in June
South American intraseasonal monsoon Evolution (60W-45W)
Vegetation-induced heating helps the circulation turning in early monsoon.
Difference in precipitation between VBP and NOVBP in AGCM and AOGCM simulations

Over land, the AOGCM and AGCM produces consistent results

Ma et al., 2013
Advantage:
1). Quantitatively assess the role in global hydrological cycle based on observational data
2). Analyze dynamic mechanisms

Issues:
1). Require observational data
2). Require reasonable coupled land models/AO or AGCMs
Regional Climate Model’s Dynamic Downscaling Ability in Seasonal Simulation/Prediction and Major Factors that Affect this Ability – A review

Yongkang Xue, Zavisa Jajnic, Jim Dudhia, Ratko Vasic, Fernando De Sales
References


