Land-surface processes and monsoon climate system

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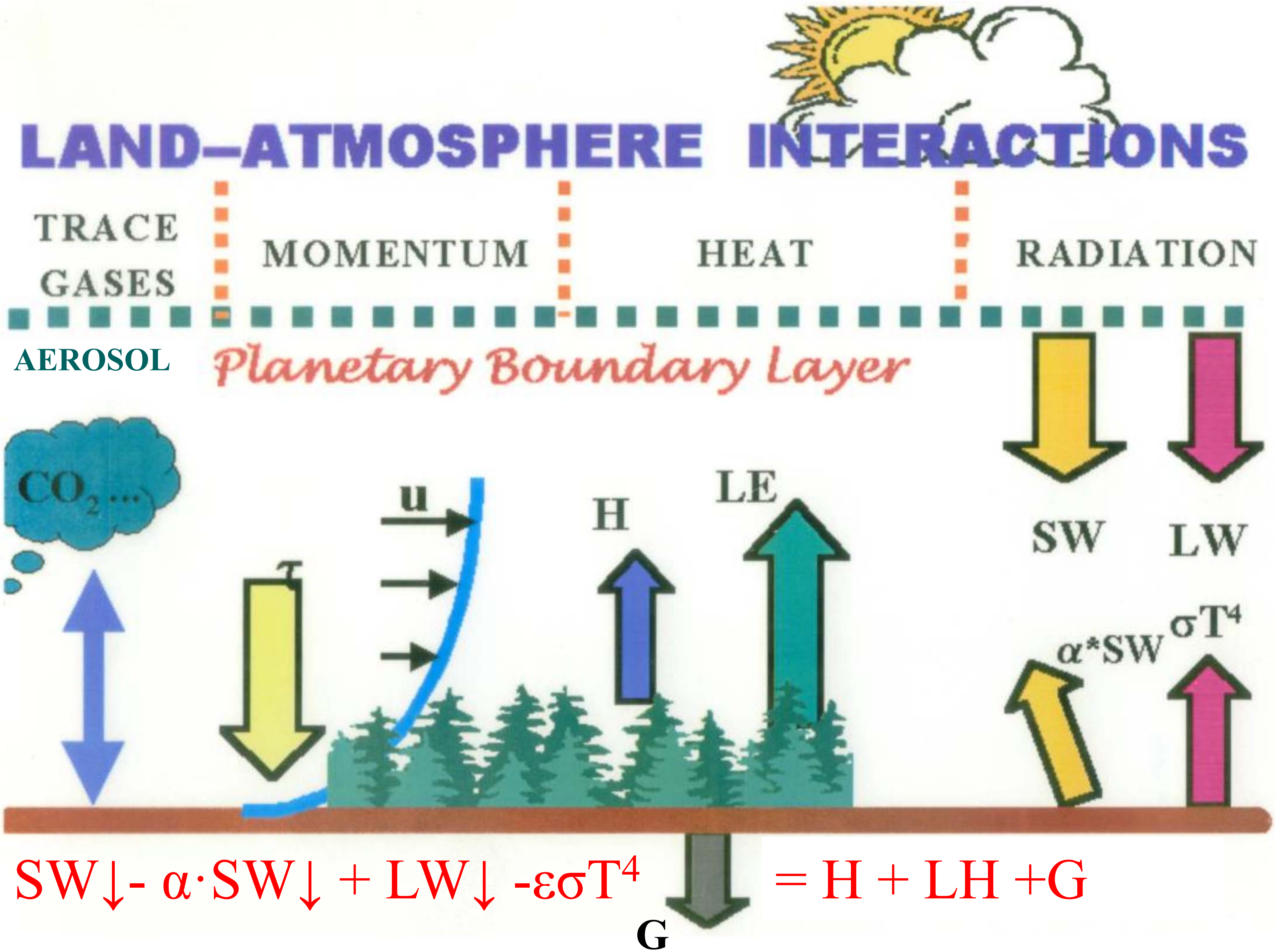
LAND–ATMOSPHERE INTERACTIONS
TRACE GASES
MOMENTUM
HEAT
RADIATION
AEROSOL
Planetary Boundary Layer
CO2 ...
u
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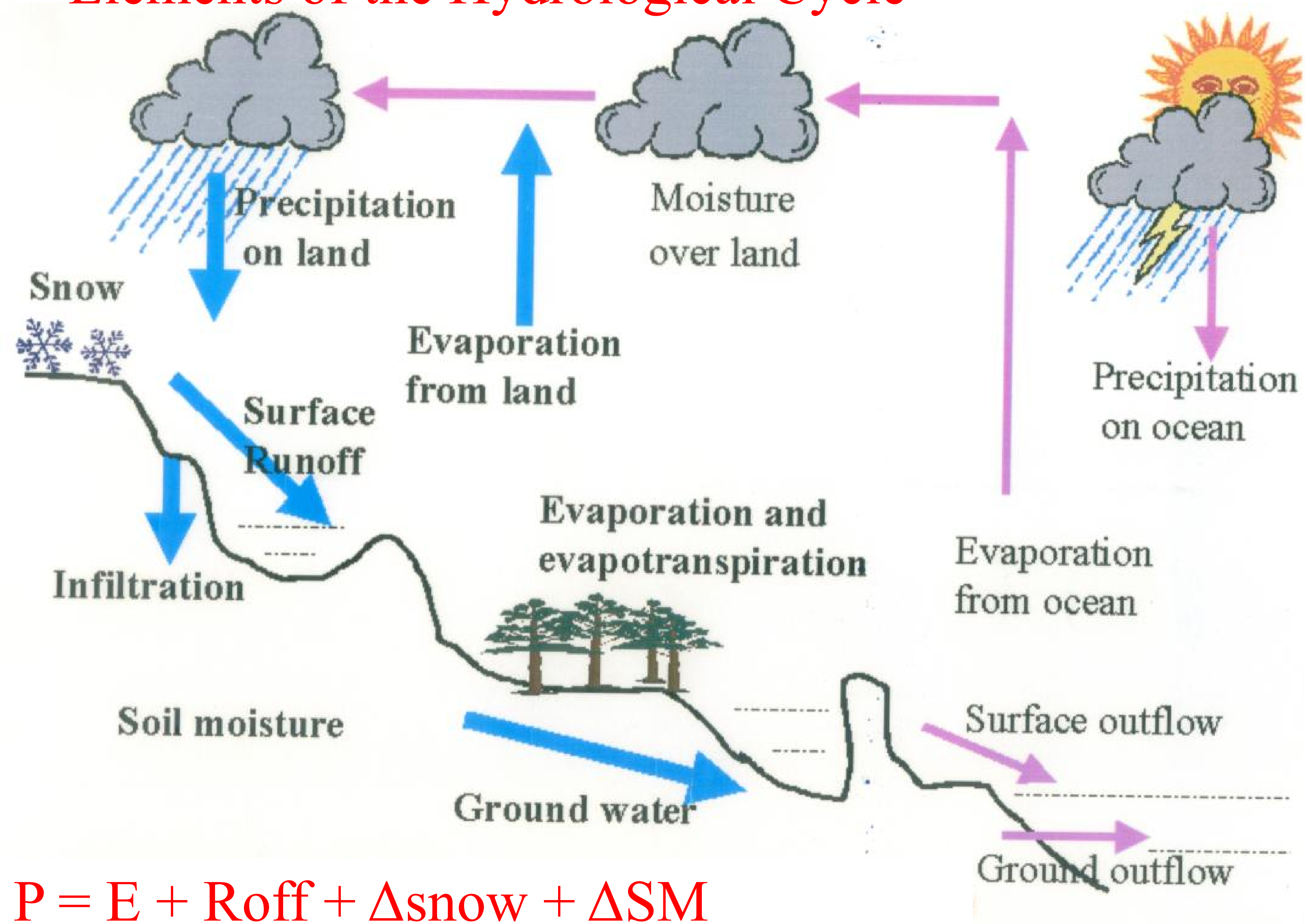
H
LE
SW
LW
α*SW
σT4
G
SW↓- α·SW↓ + LW↓ -εσT4 = H + LH +G

Elements of the Hydrological Cycle



$$P = E + Roff + \Delta snow + \Delta SM$$

Assessing land/atmosphere interaction with two modern GCM Modeling Approaches:

A). Soil Moisture Coupling Stress Approach (Koster et al., 2000, 2004, 2006; Gao & Pirmeyer, 2013)

What is soil moisture-atmosphere feedback on precipitation?

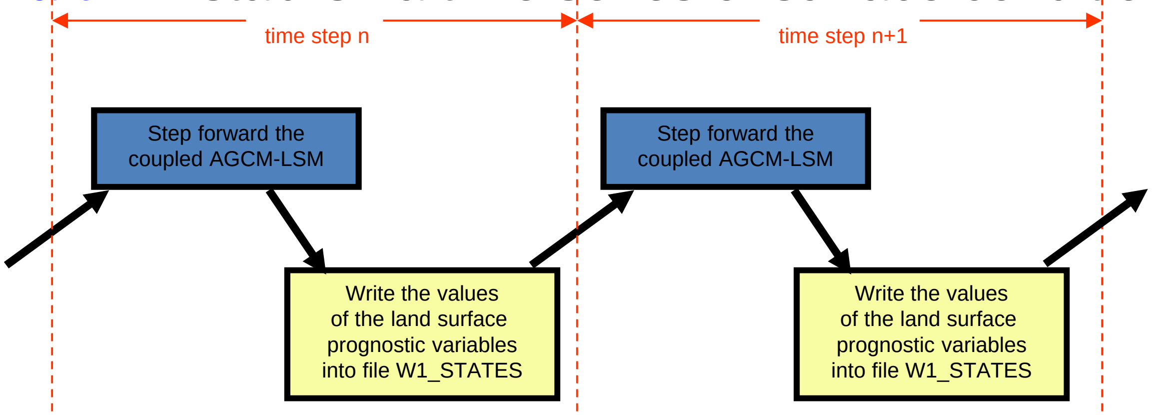
For soil moisture to contribute to precipitation predictability, two things must happen:

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

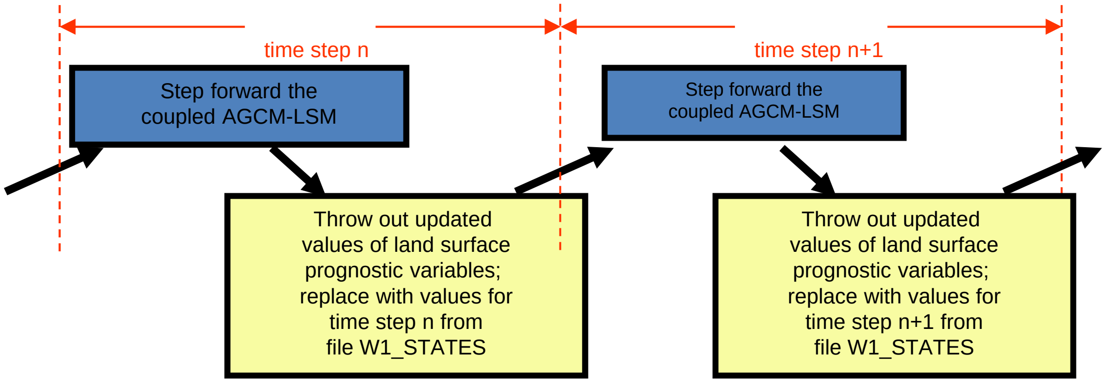
2. The atmosphere must respond in a predictable way to the remembered soil moisture anomalies.

The GLACE Experiment

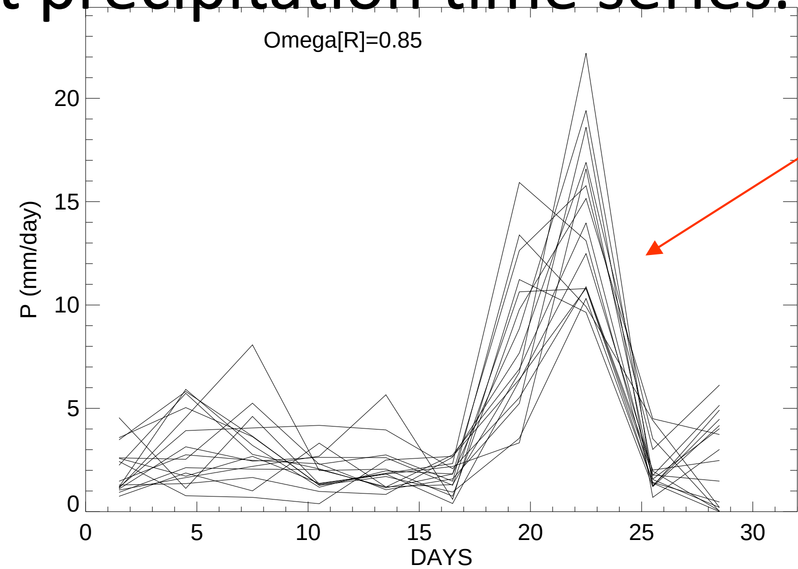
Part 1: Establish a time series of surface conditions (Simulation W1-W16)



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

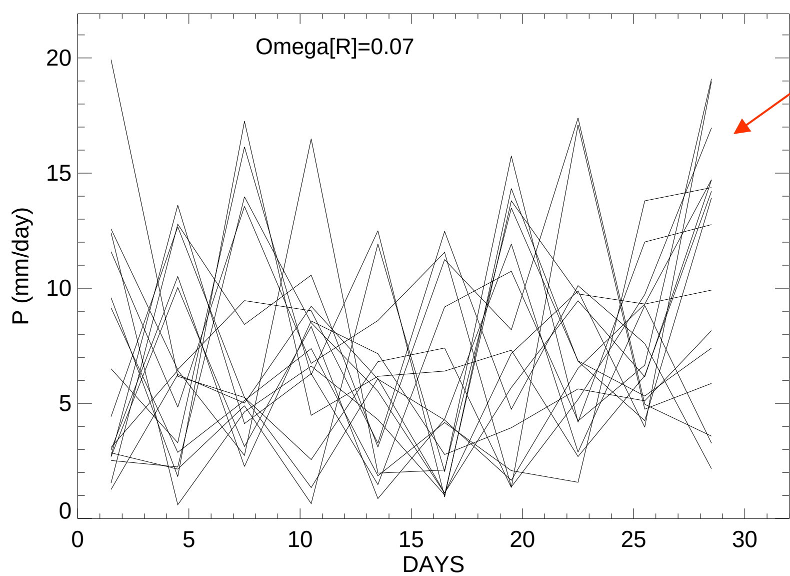


A variable Ω is defined that describes the coherence between the different precipitation time series.



All simulations in ensemble respond to the land surface boundary condition in the same way

→ Ω is high

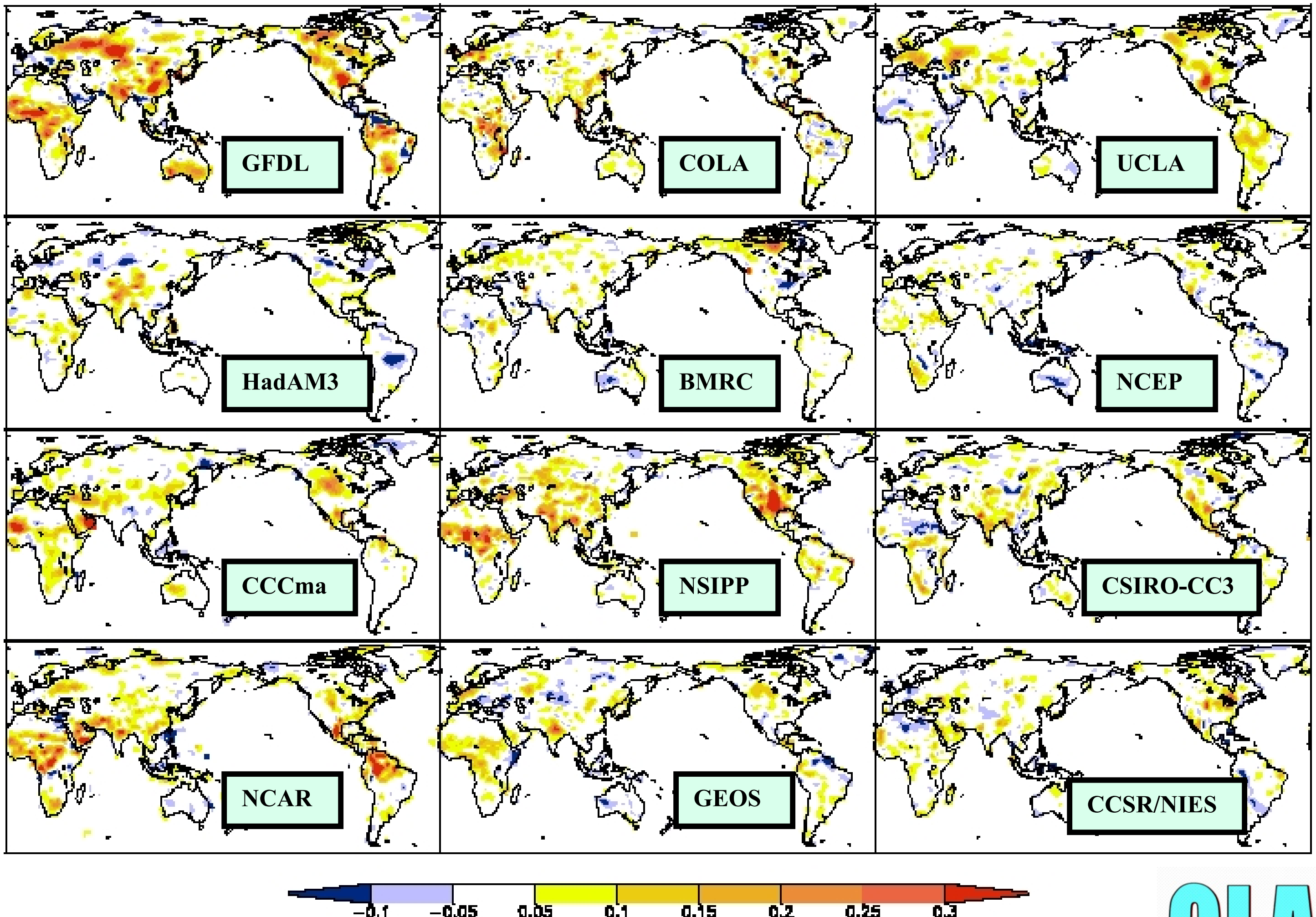


Simulations in ensemble have no coherent response to the land surface boundary condition

→ Ω is low

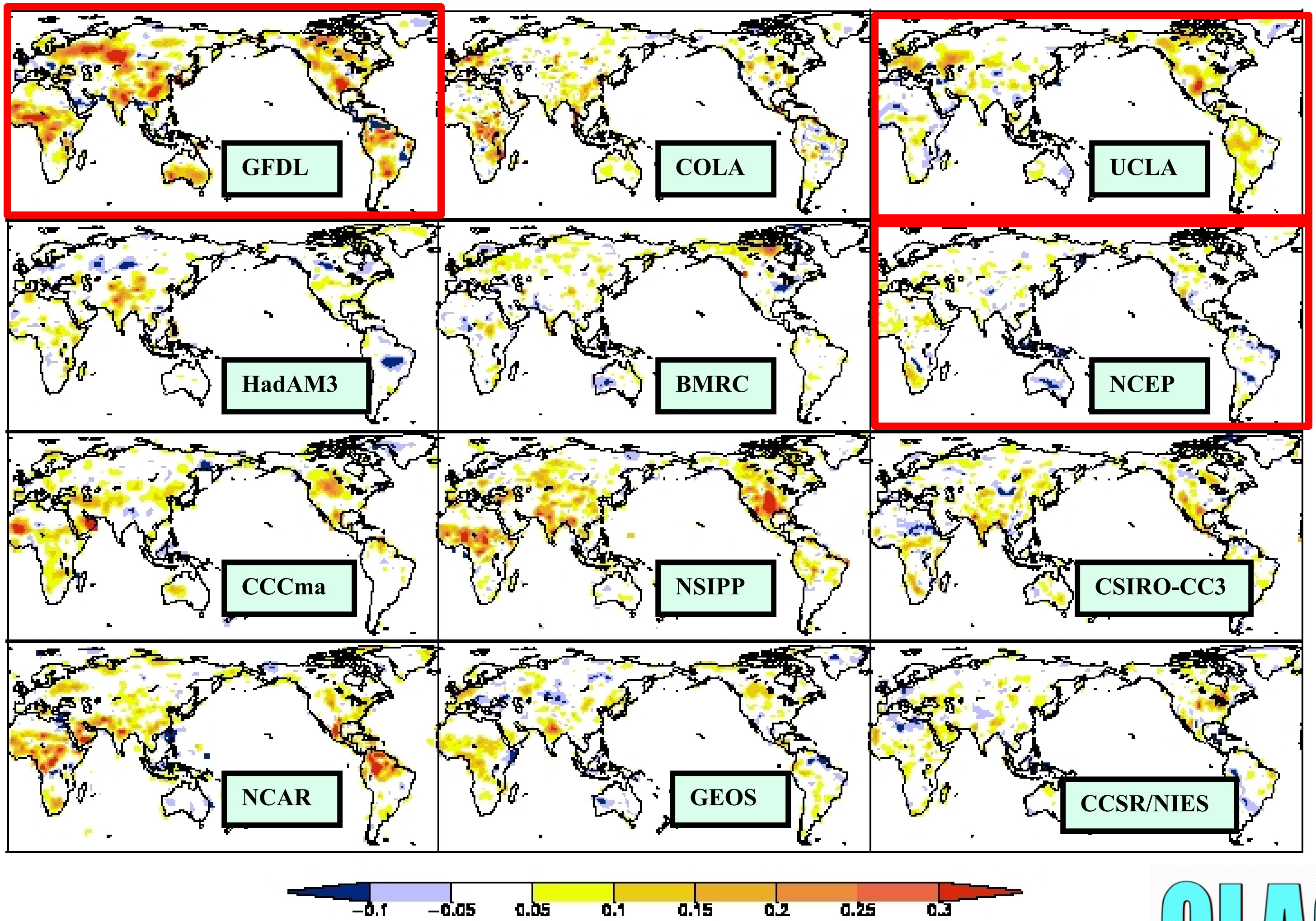
6-day averages used in GLACE

Ω_p (R -W): Impact of sub-surface soil moisture on precipitation



GLACE

Ω_p (R -W): Impact of sub-surface soil moisture on precipitation



Soil Moisture JJA coupling strength

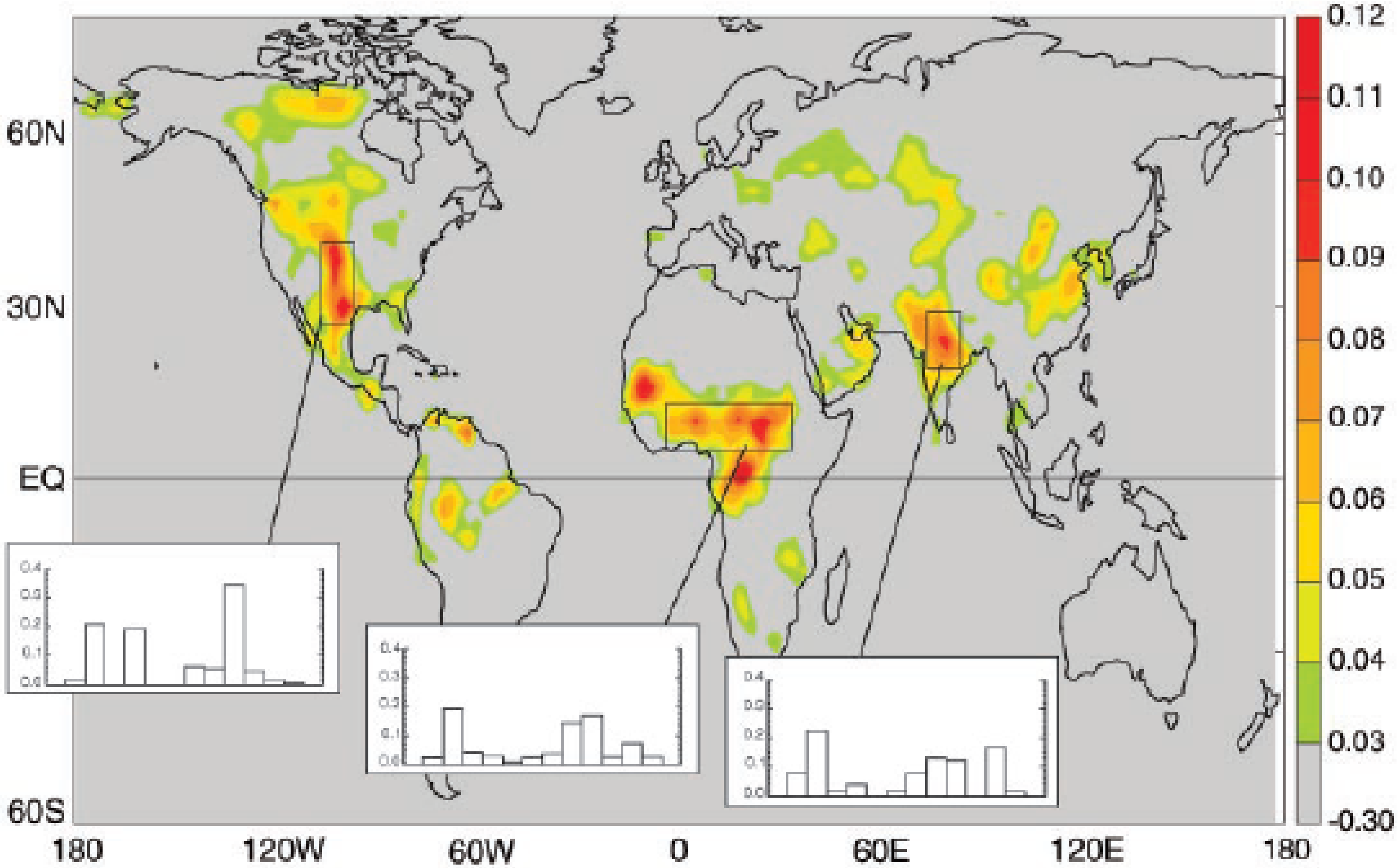
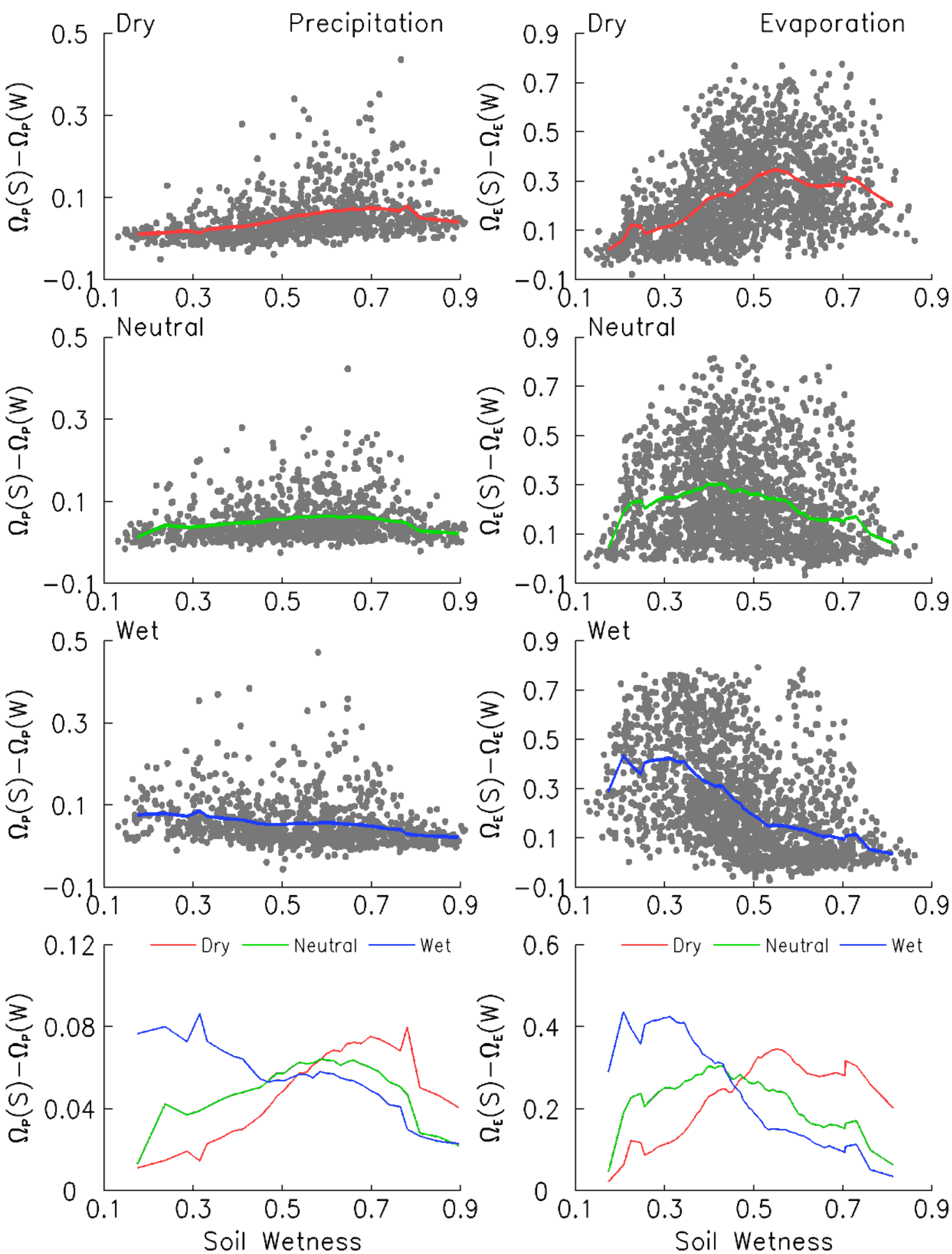


Fig. 1. The land-atmosphere coupling strength diagnostic for boreal summer (the Ω difference, dimensionless, describing the impact of soil moisture on precipitation), averaged across the 12 models participating in GLACE. **(Insets)** Areally averaged coupling strengths for the 12 individual models over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



the Ω 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:

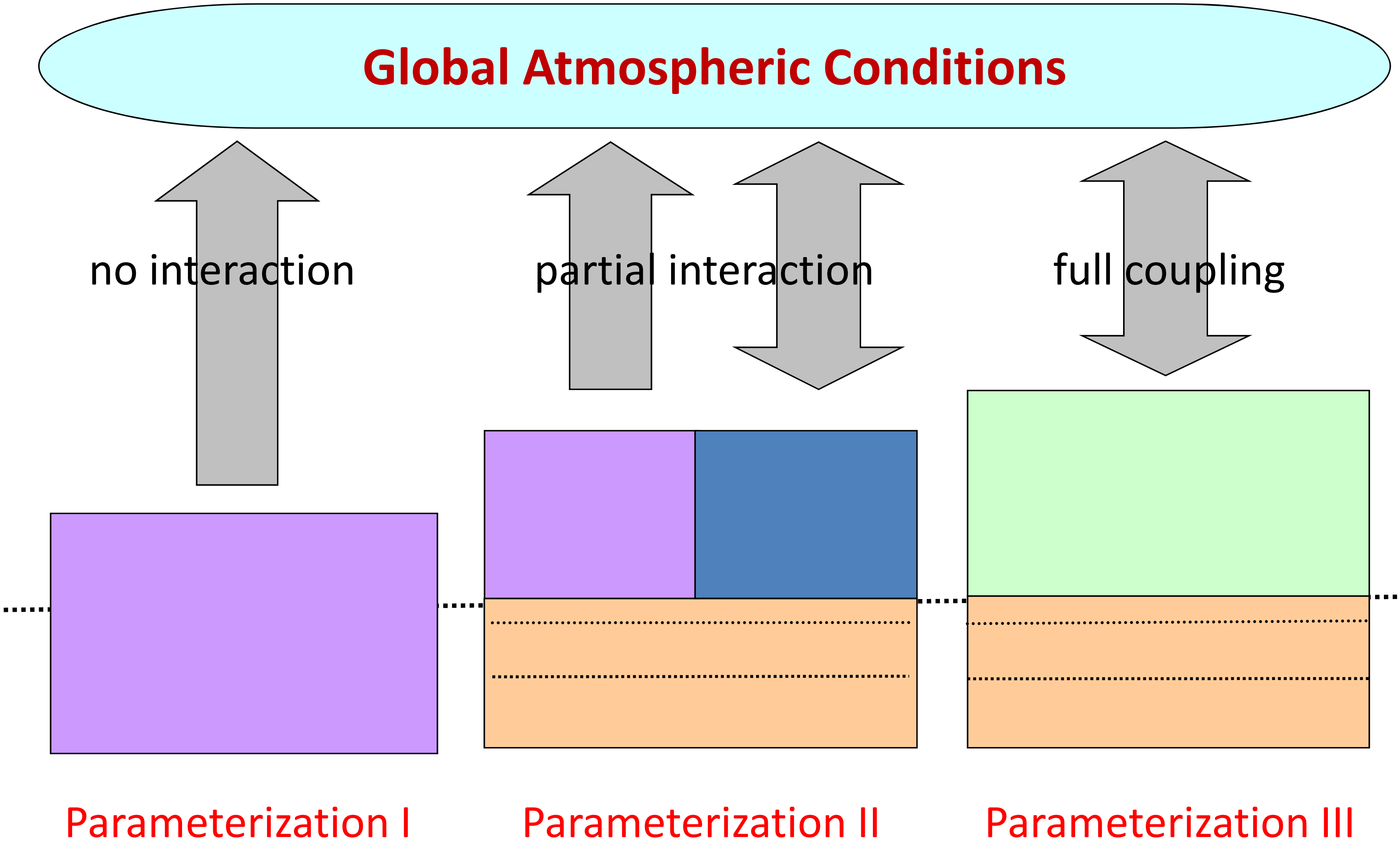
A). Vegetation Biophysical Process (VBP) Approach (Xue et al., 2004, 2005, 2006, 2010, Ma et al., 2013)

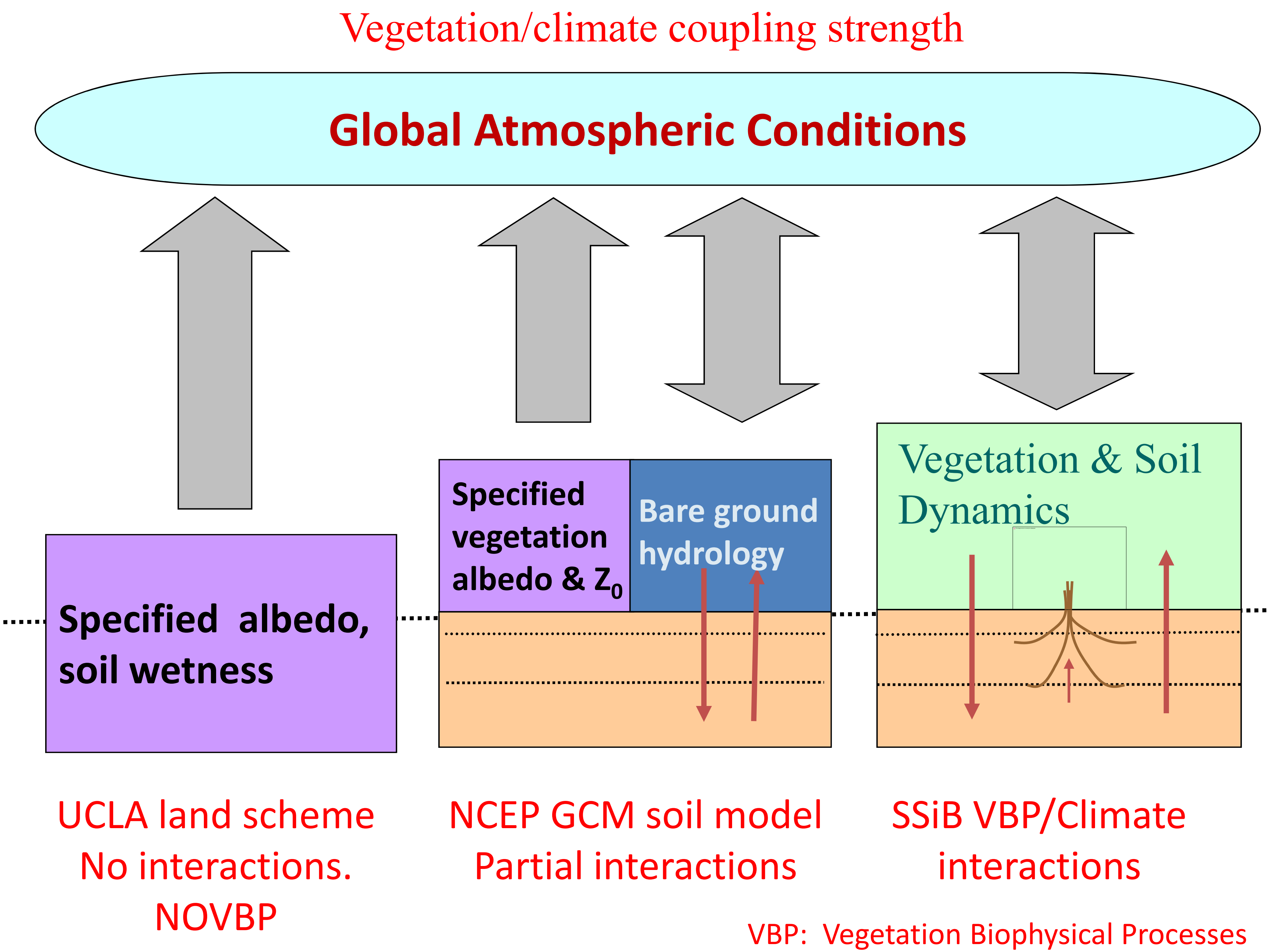
Criteria

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.

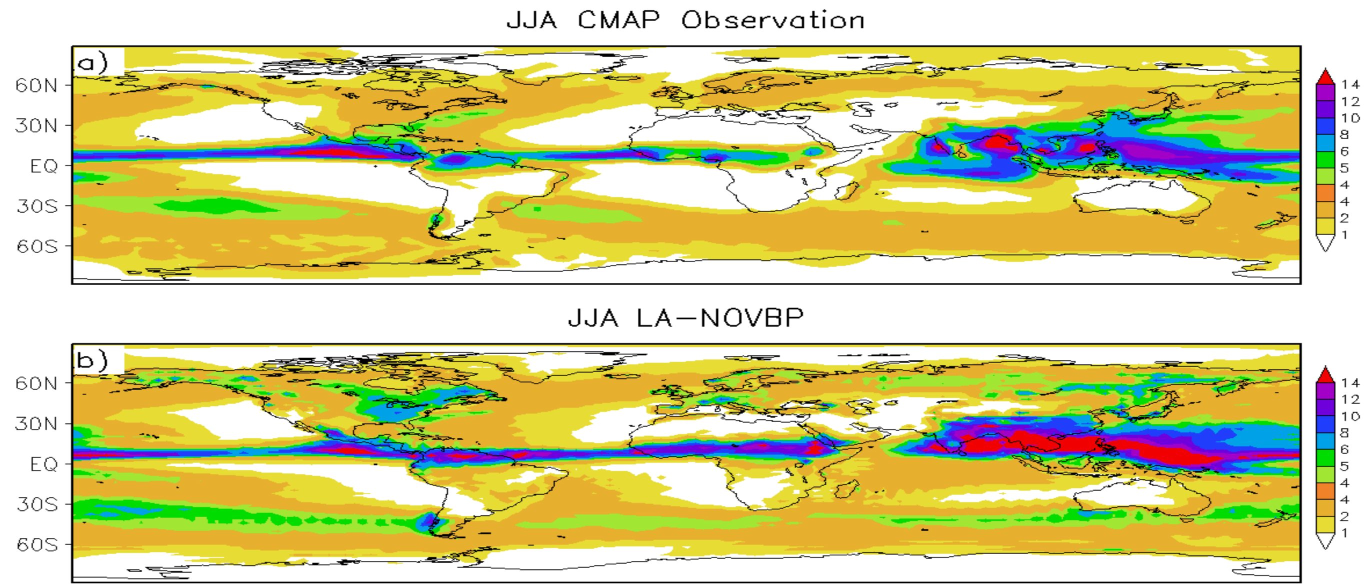
Observational data as a reference is necessary.

Vegetation/climate Interactions

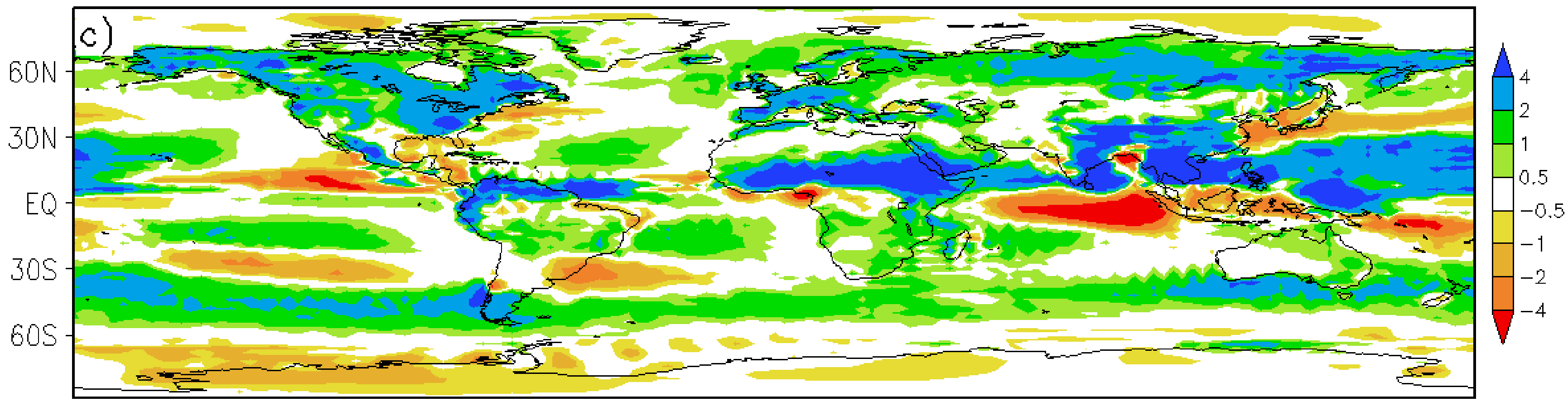



Vegetation/climate coupling strength
Global Atmospheric Conditions
Specified albedo, soil wetness
Specified vegetation albedo & Z_0
Bare ground hydrology
Vegetation & Soil Dynamics
UCLA land scheme
No interactions.
NOVBP
NCEP GCM soil model
Partial interactions
SSiB VBP/Climate
interactions
VBP: Vegetation Biophysical Processes

Observed and the simulated JJA precipitation (mm day^{-1})

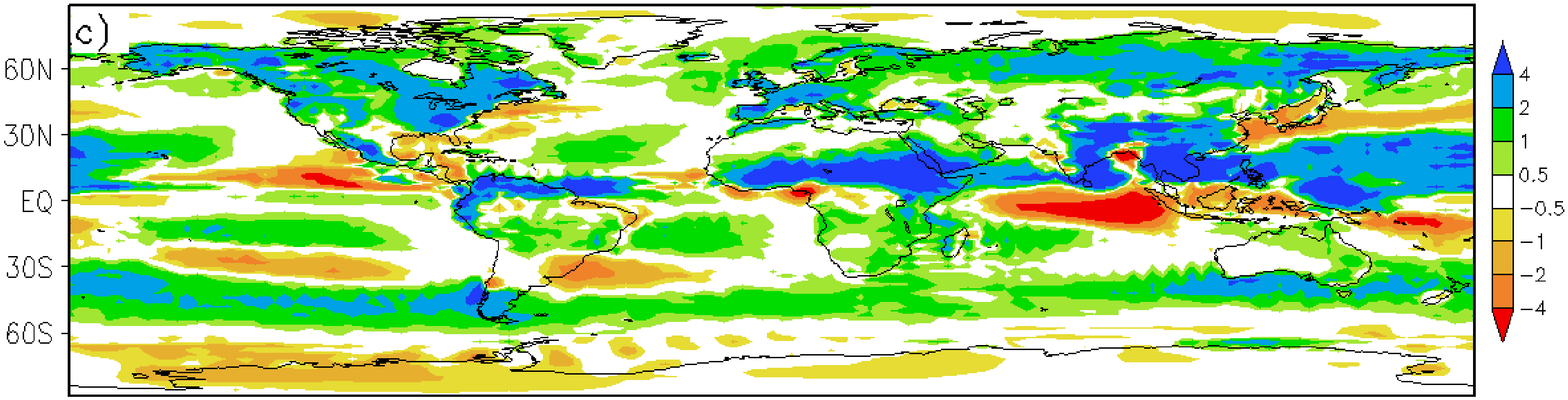


Bias due to not considering vegetation biophysical processes (NOVBP)

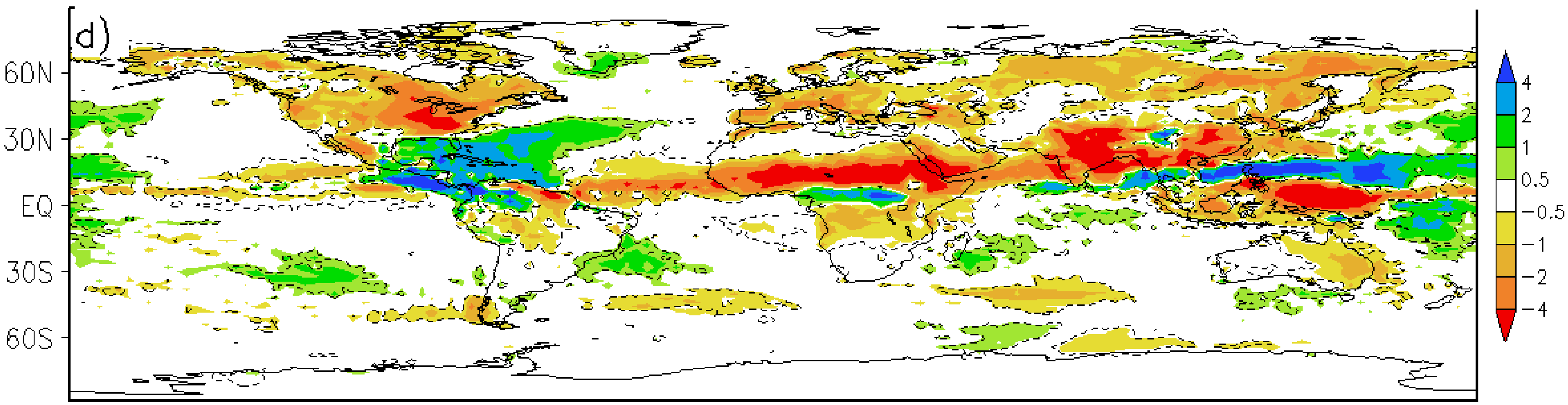


Vegetation impacts on JJA precipitation (mm day^{-1})

Bias due to not considering vegetation biophysical processes (NOVBP)



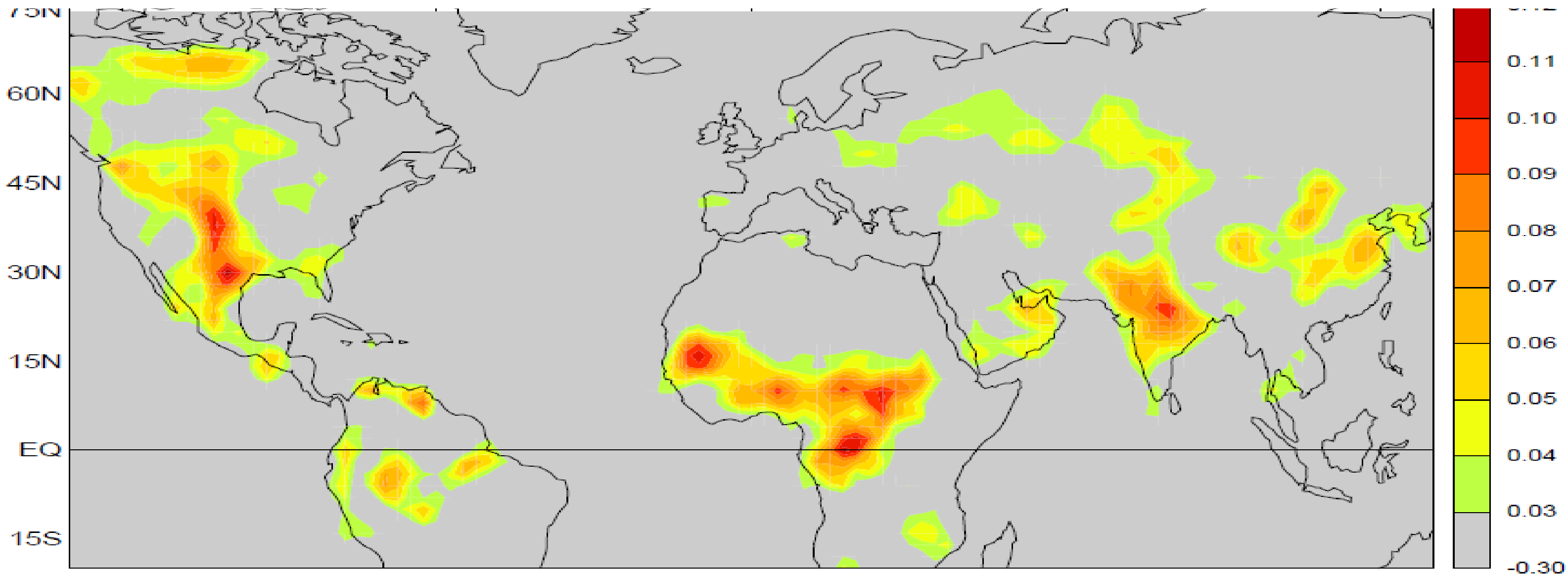
Difference in precipitation between VBP and NOVBP



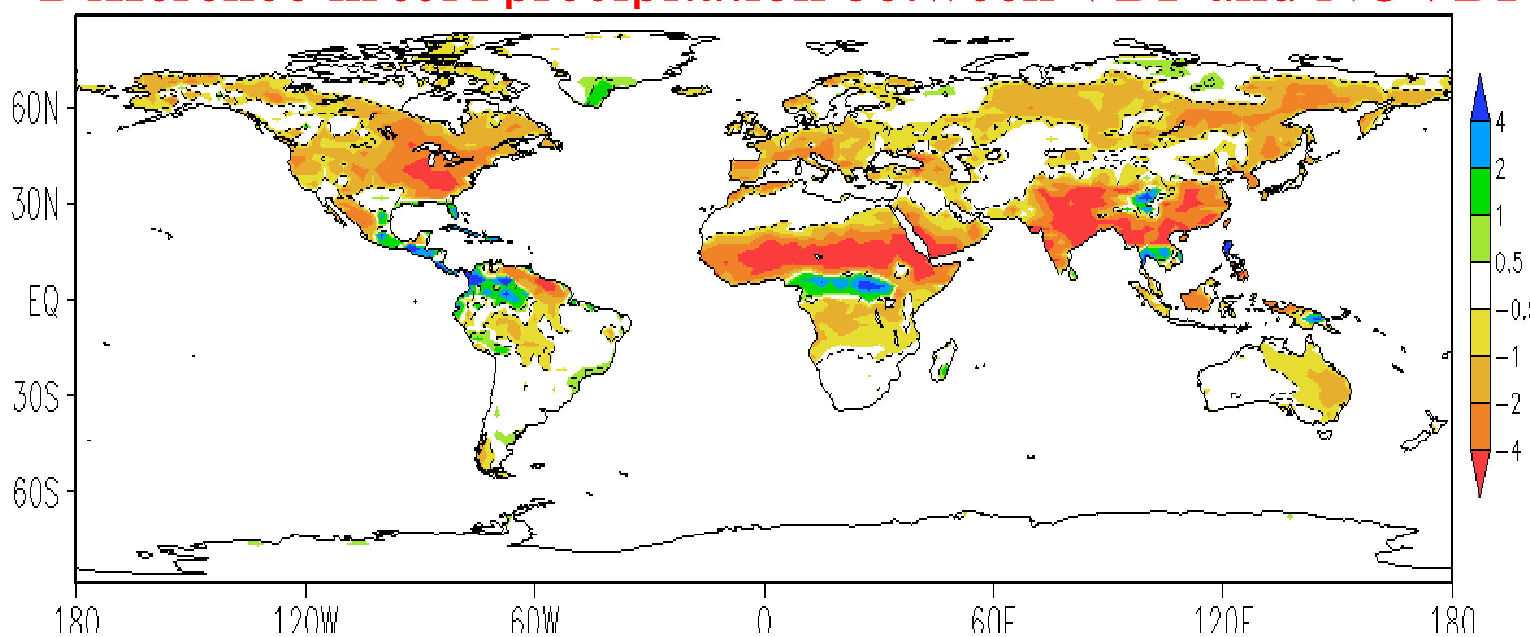
Compared with NOVEG, VBP reduced RMSE by 42% over land and 18% over global

Comparison between VBP and Soil Moisture approache

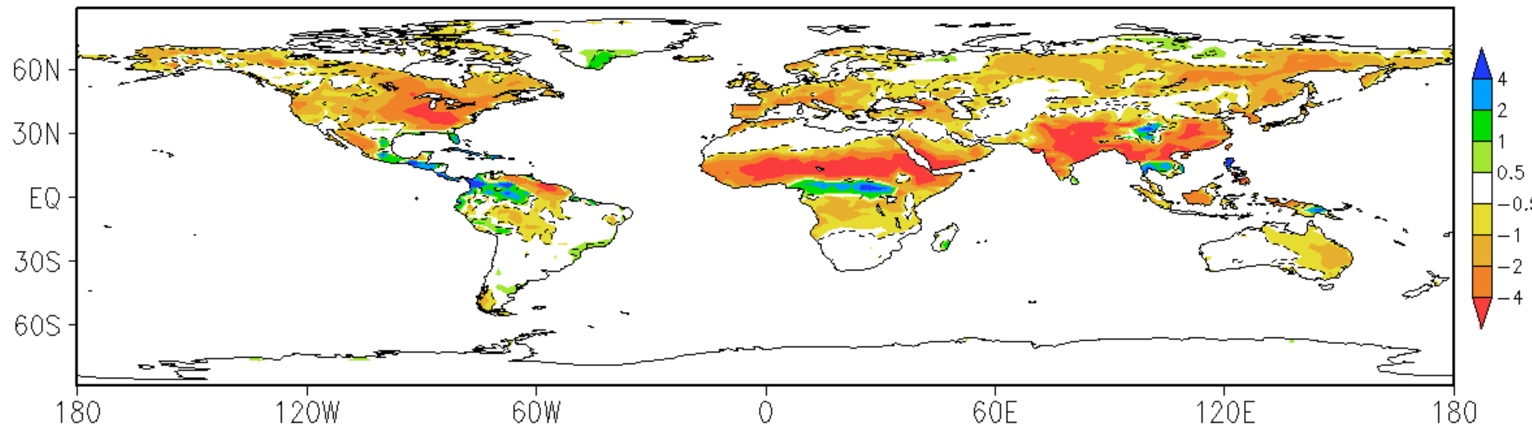
Soil Moisture JJA coupling strength



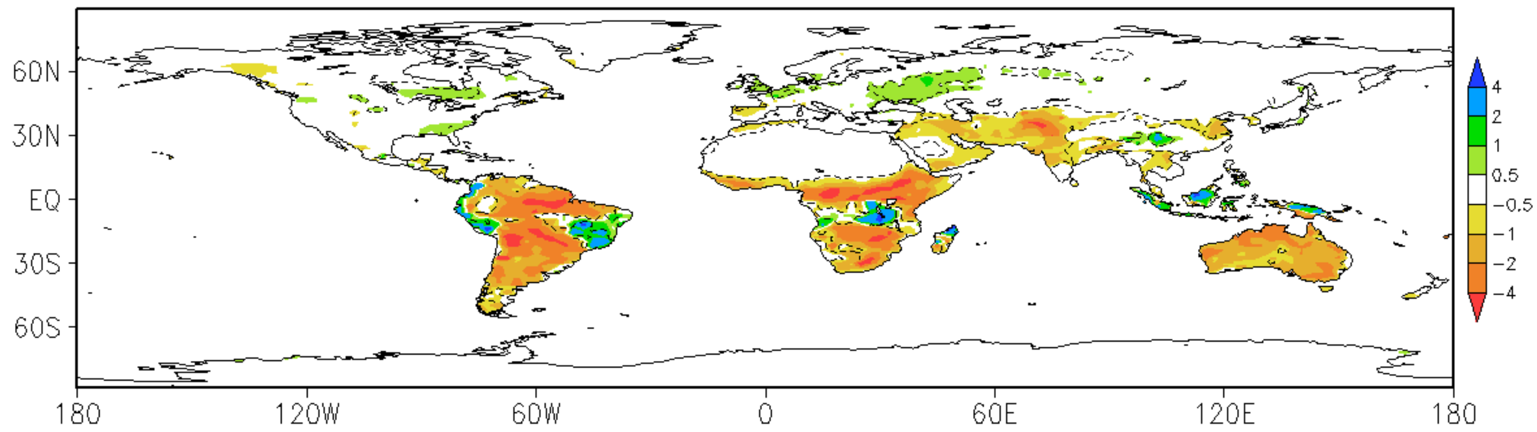
Difference in JJA precipitation between VBP and NOVBP



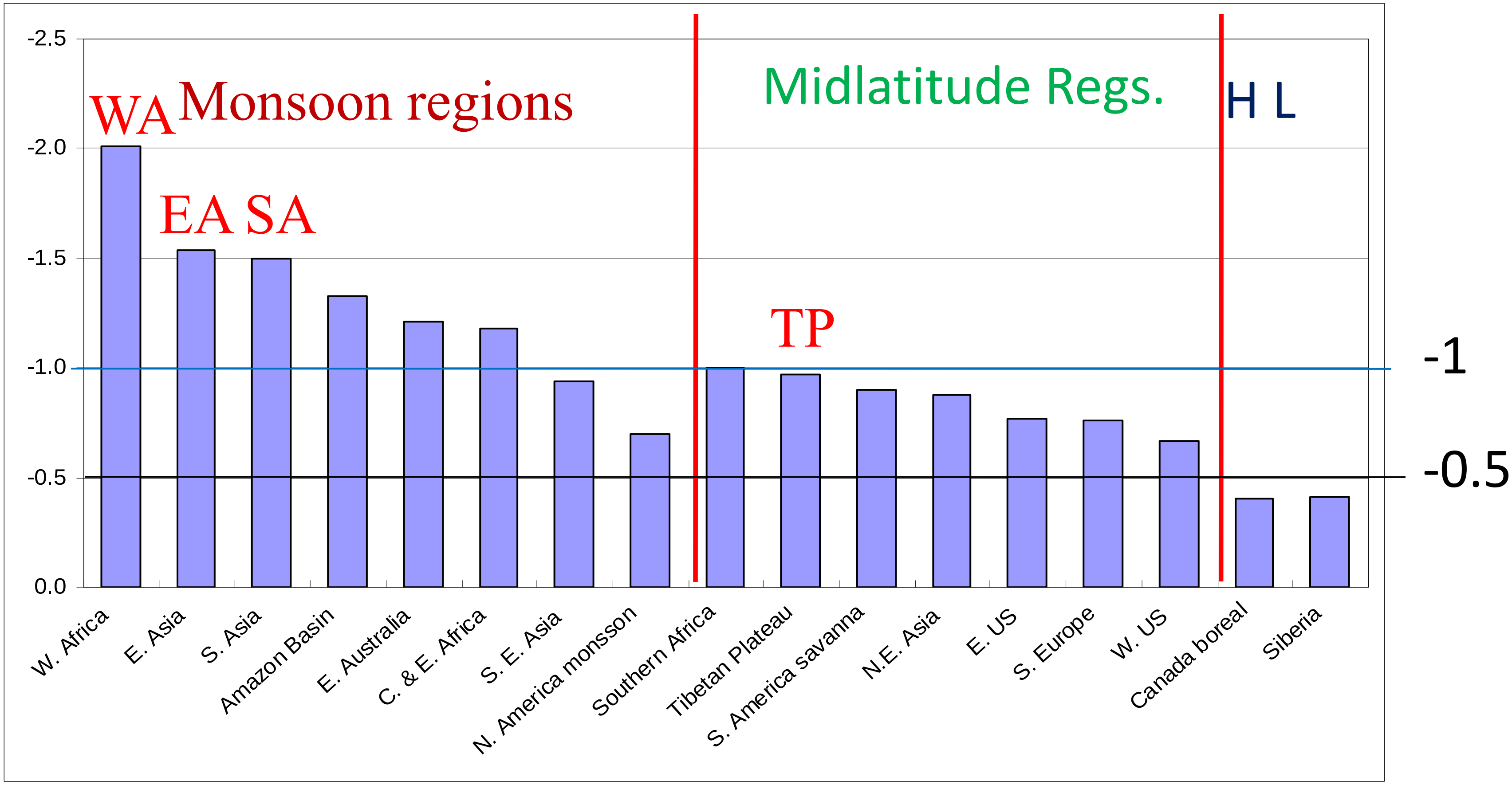
Difference in JJA precipitation between VBP and NOVBP



Difference in DJF precipitation between VBP and NOVBP



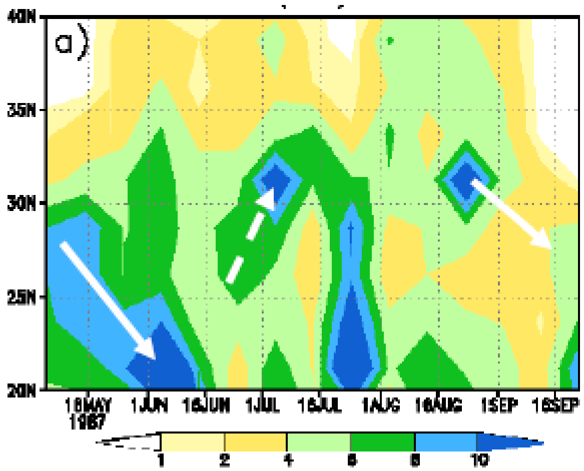
Impact of vegetation biophysical processes on precipitation RMSE Reduction



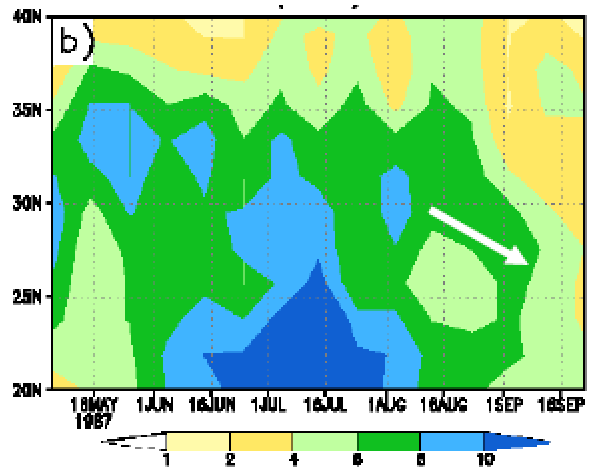
HL: High latitudes; EA: East Asia; SA: South Asia; WA: West Africa; TP: Tibet Plateau

East Asian Monsoon Intraseasonal Evolution (105E – 120E)

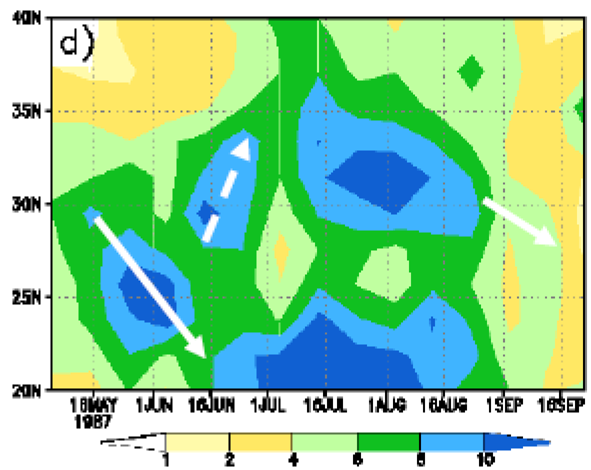
CMAP



NOVBP

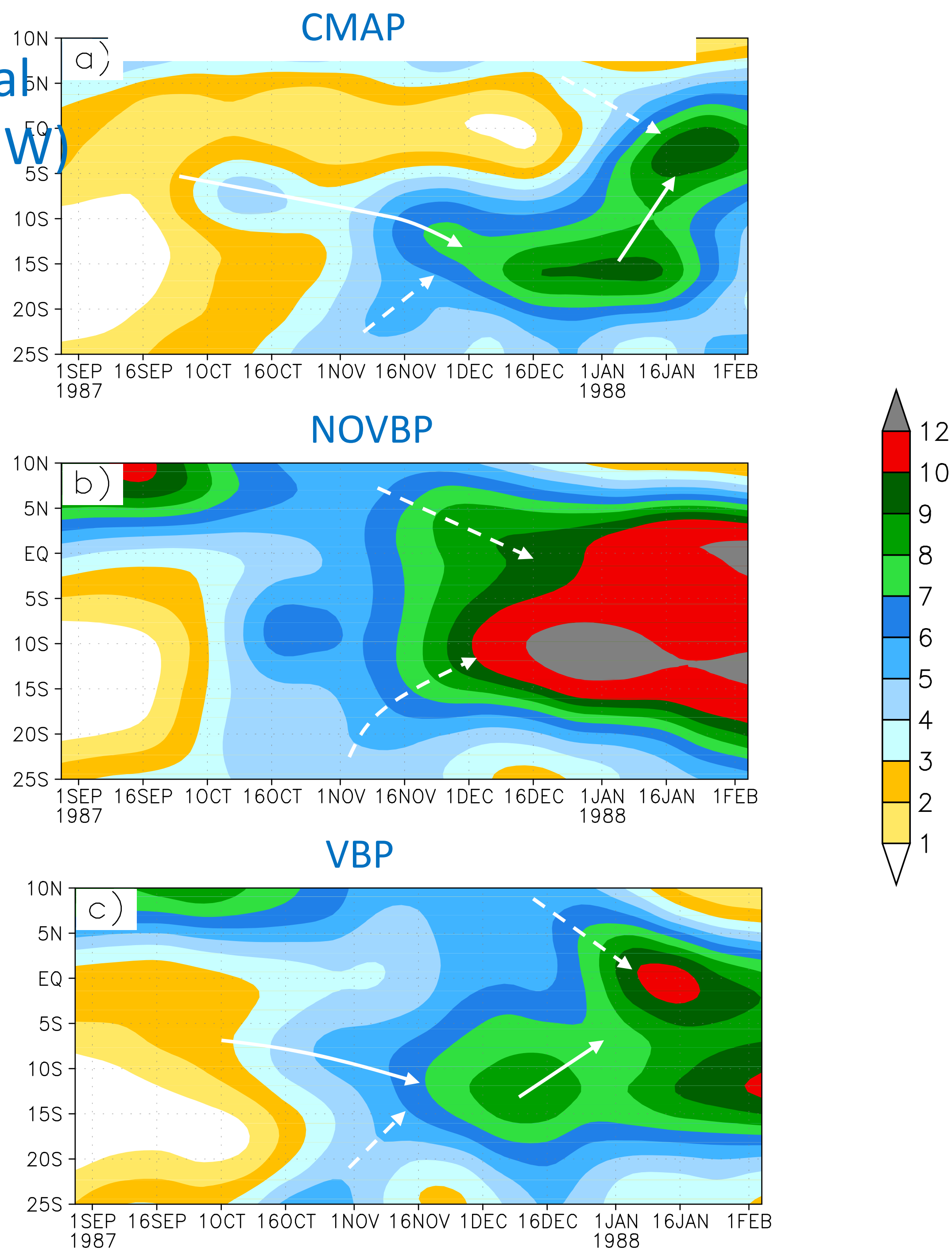


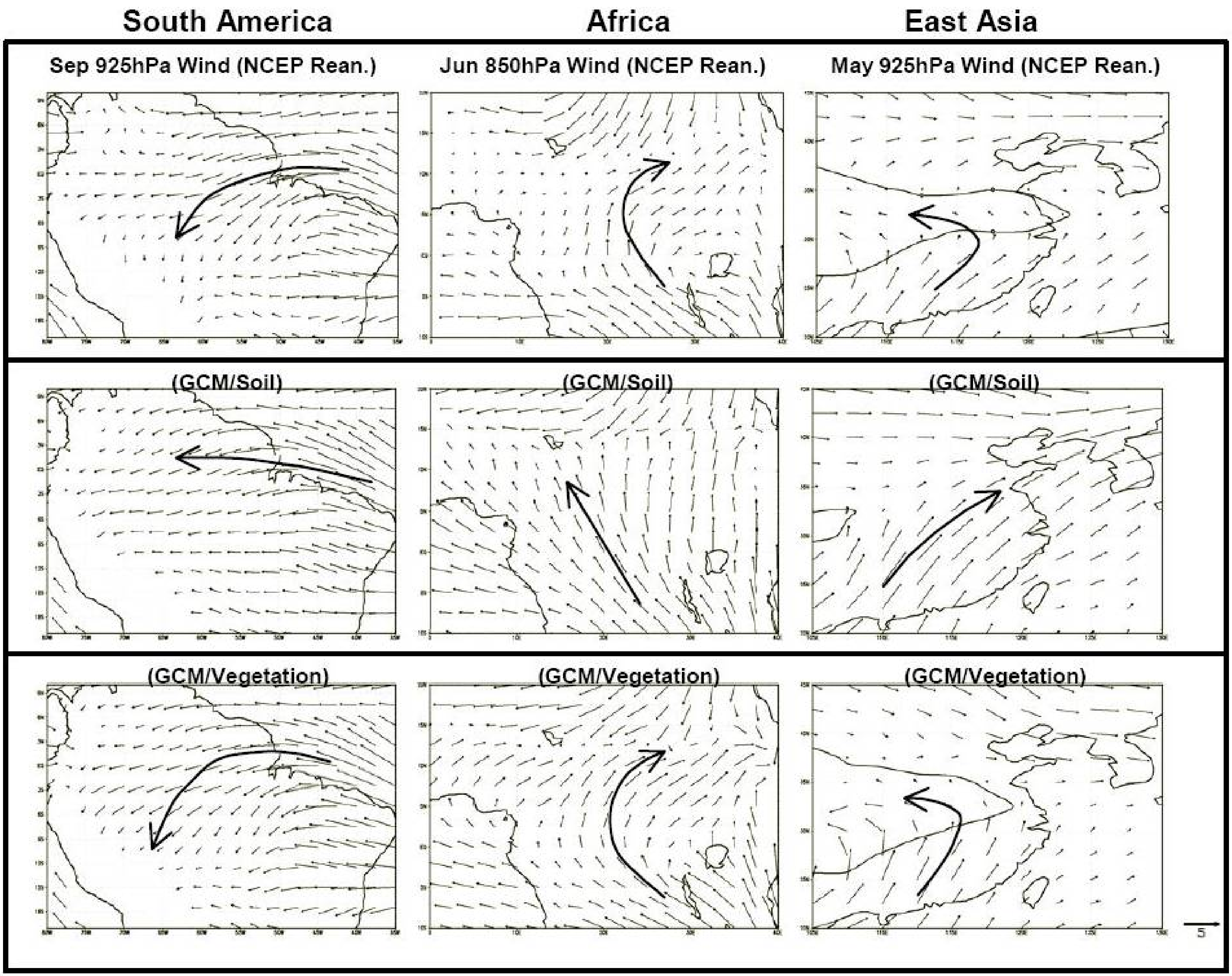
VBP



VBP Produces the monsoon jump in June

South American intraseasonal monsoon Evolution (60W-45W)

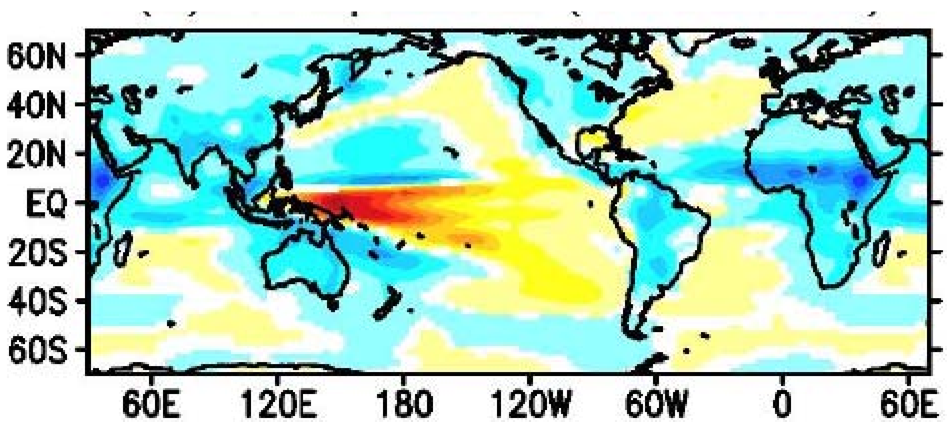




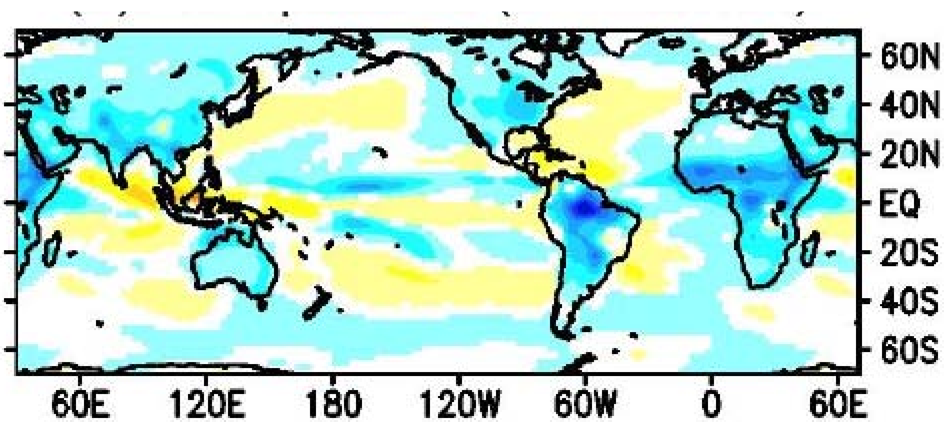
Vegetation-induced heating helps the circulation turning in early monsoon

Difference in precipitation between VBP and NOVBP in AGCM and AOGCM simulations

AOGCM



AGCM



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

ELSEVIER

ATMOSPHERIC RESEARCH

Clouds - Precipitation - Aerosols - Radiation - Weather Modification

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