Comparison of Land-Precipitation Coupling Strength Using Observations and Models

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1. Overview of previous work
   - (a) early 20th Century;
   - (b) isotopic tracer;
   - (c) precipitation recycling;
   - (d) water vapor tracer;
   - (e) soil water memory;
   - (f) model sensitivity;
   - (g) composite assessment
2. Our results
   - (h) initial attempt;
   - (i) new attempt
3. Conclusions

(a) Early 20th Century:

$P = E + C + d(PW)/dt$;   indicator: $\gamma = E/P$ (~ 70%)

Weakness: r (E, C);   incorrect

(b) Isotopic tracer:

Isotope of water depends on temperature and history of water; and

Condensation depletes heavy–isotope contents in P as the air moves from ocean to inland. Therefore, a small isotope gradient might indicate large contribution from land

Weakness: Quantitative linkage to coupling strength has large uncertainties

(c) Precipitation recycling:

$P = P_m + P_a \qquad \gamma = P_m / P$

Weakness: Assuming well-mixed air (i.e., Pm/P = PWm/PW)
Dynamic meaning is lacking

Strength: Relatively easy to compute

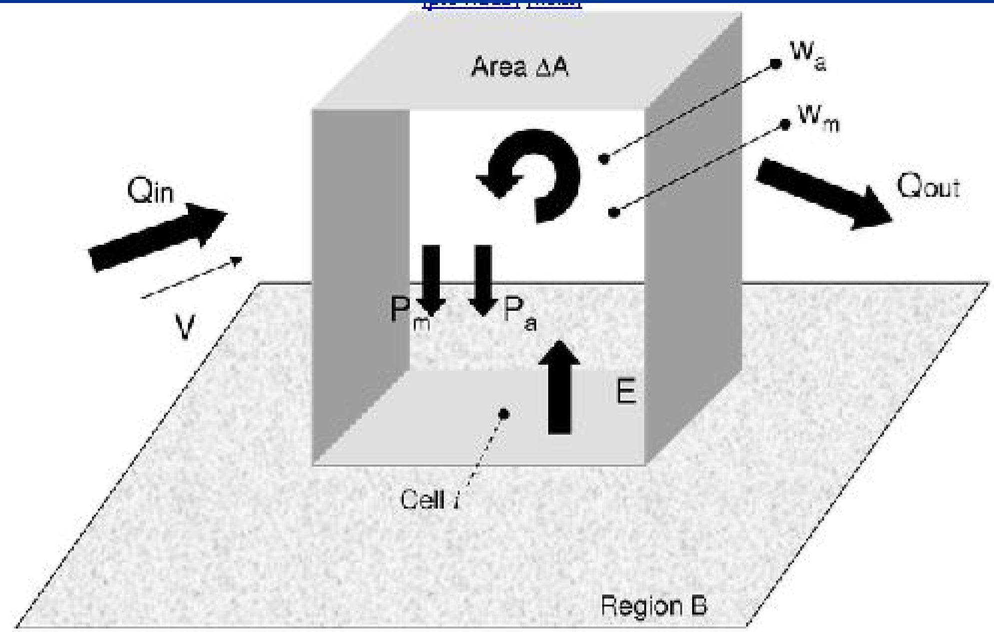


FIG. 2. Schematic representation of water vapor fluxes in an atmospheric grid box i, of area ΔA within region B. The precipitation P and precipitable water w can be divided into their recycled (m) and advective (a) components.

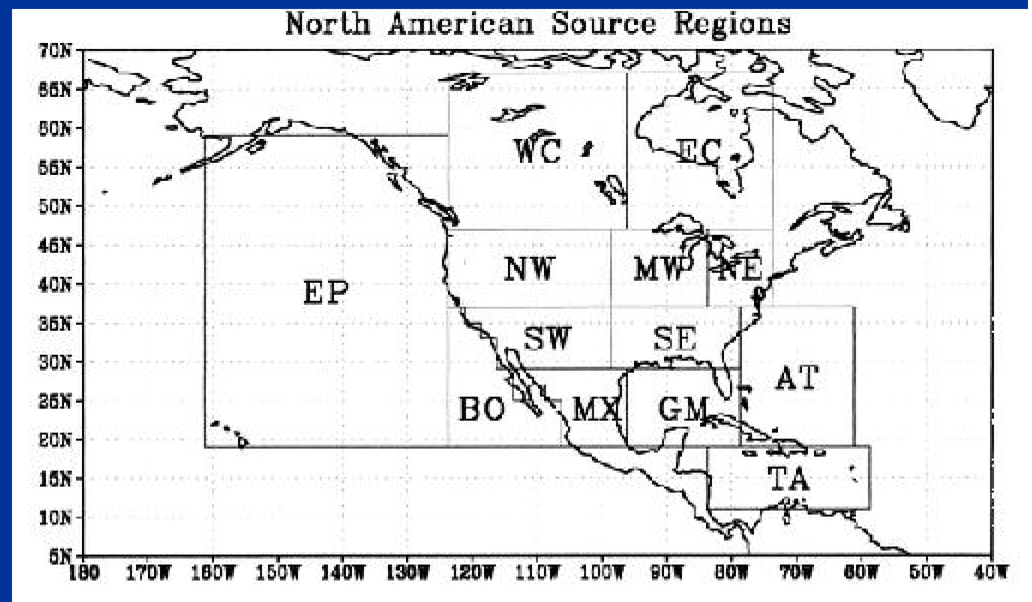
Dominguez
Et al. (2006)

(d) Water vapor tracer

$P = \Sigma P_i$ $\gamma = P_L/P$

Weakness: model-dependent
Strength: source regions

This method and precipitation recycling computations give different recycling ratios



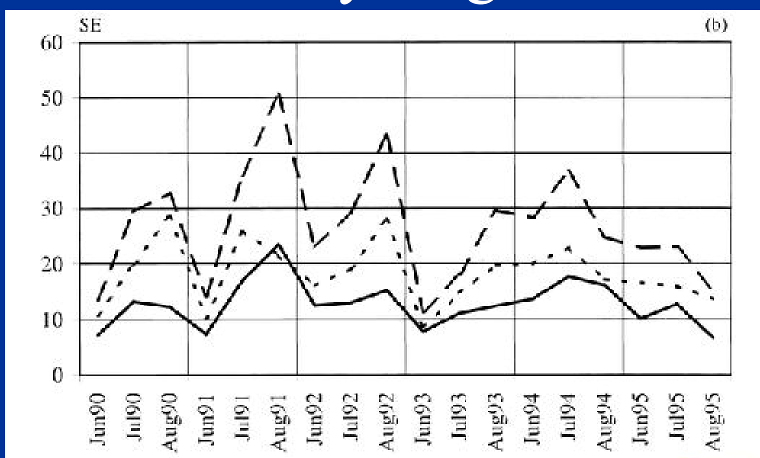
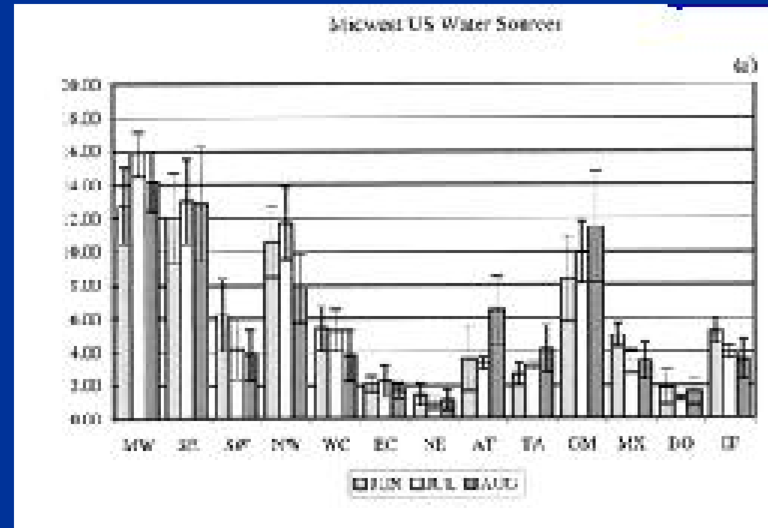


FIG. 13. Percentage of precipitation recycling for each simulated month for the WVTs (solid), Eltahir and Bras (1994; long dash), and Brubaker et al. (1993; short dash) in the (a) MW and (b) SE regions.

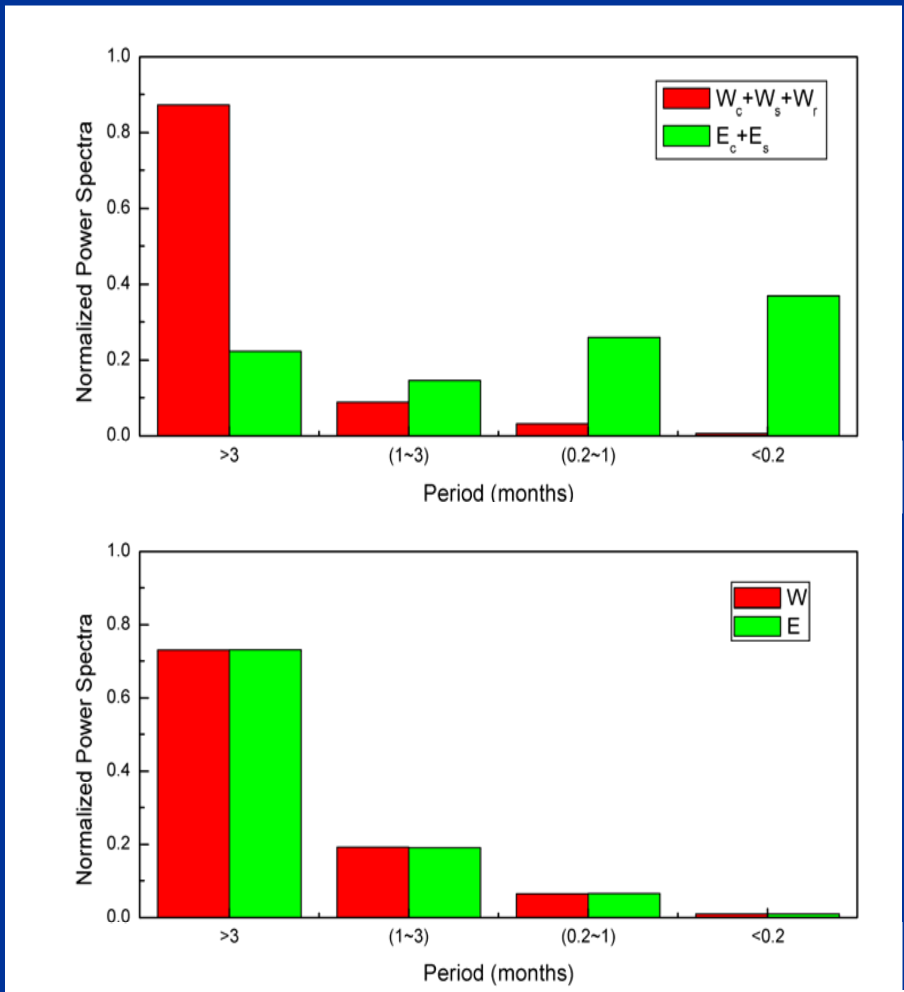


Bosilovich and Schubert (2002)

(e) Soil moisture memory

Strength: clear interpretation

Weakness: interpretation of land-P coupling is lacking



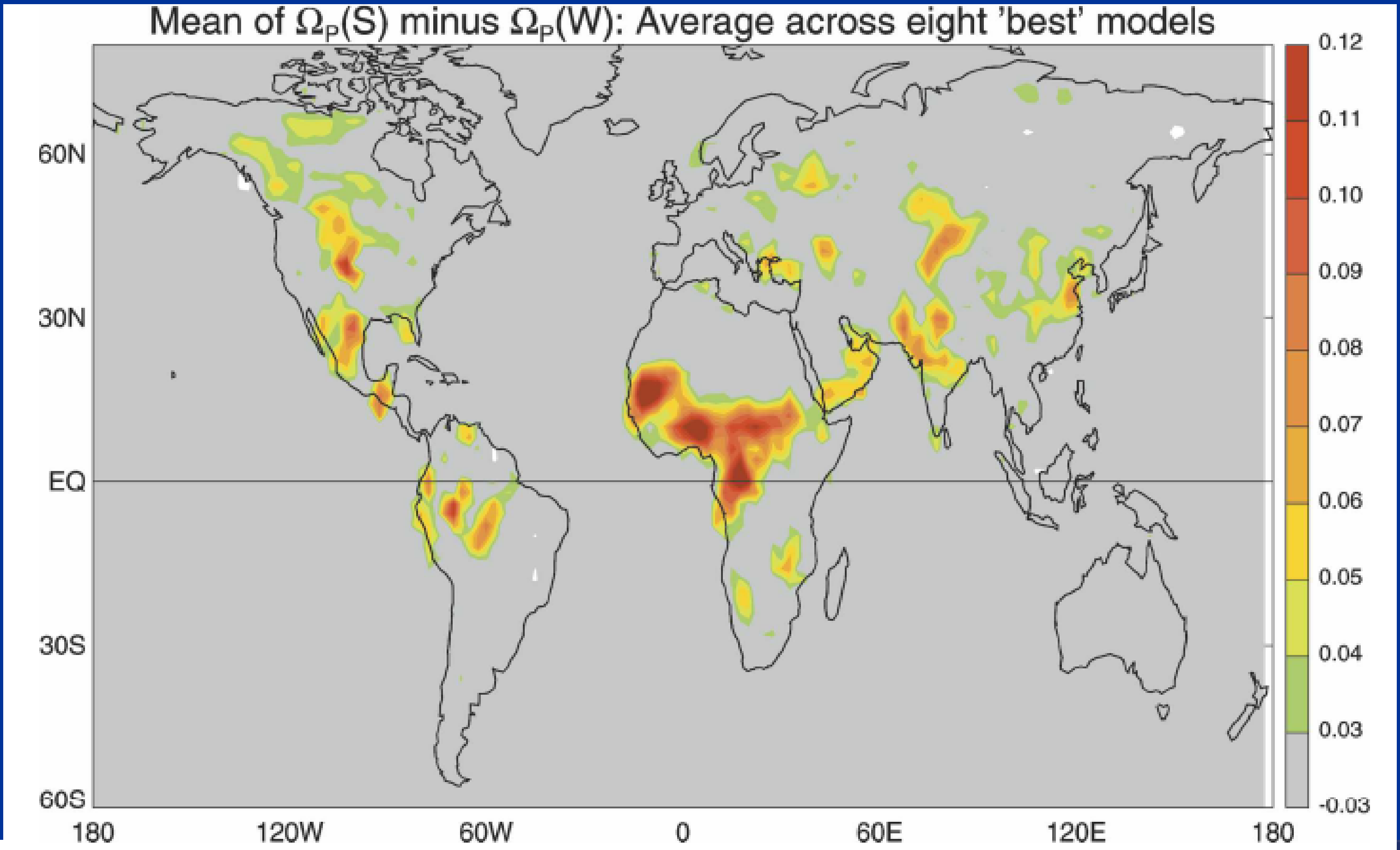
Wang et al. (2006): Extending the theoretical analysis of 1-layer bucket model to 3 layers

(f) Model sensitivity: Hot Spots

Weakness: model-dependent; expensive computationally

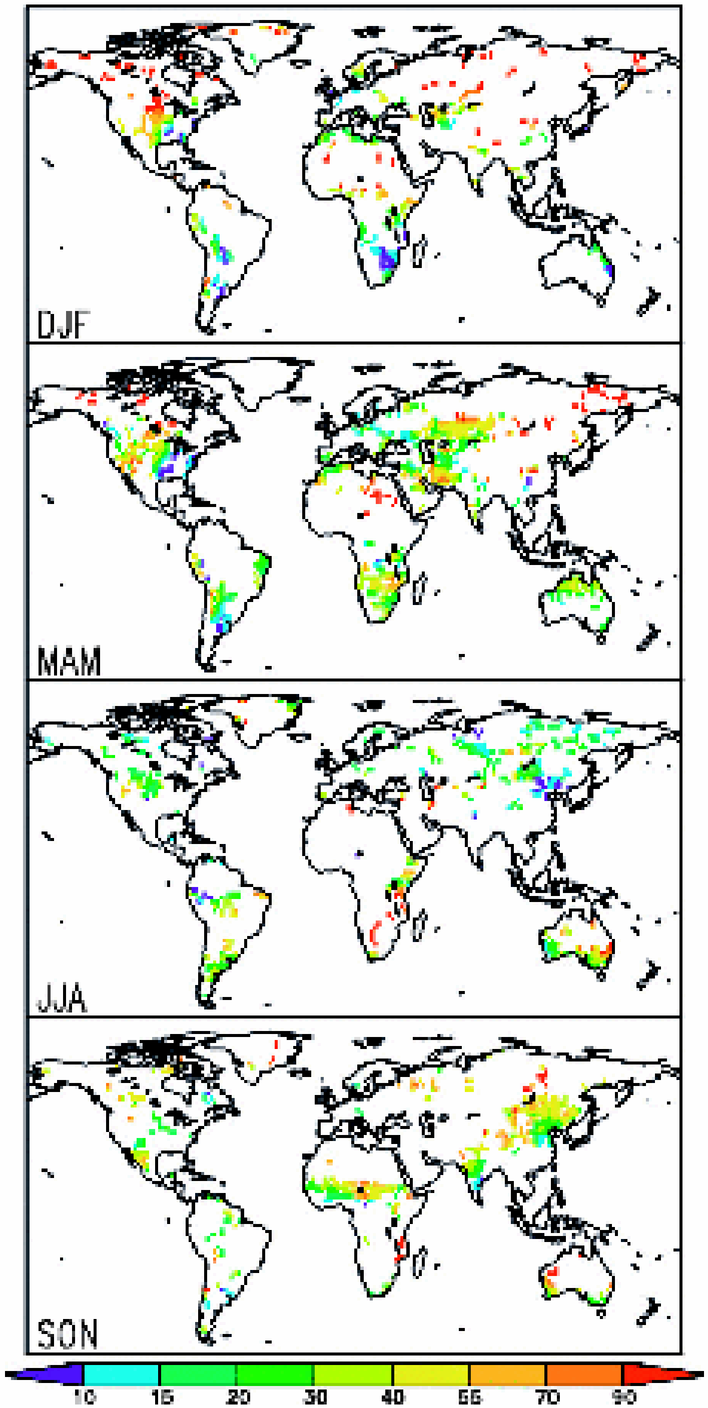
Strength: interpretation is straightforward

Koster et al. (2006): GLACE; Also Wang et al. (2007)'s ΔΦ index



(g) Composite assessment based on θ persistence, θ control of E, and P recycling (Dirmeyer et al. 2009)

Weakness: Some of the hot spots are difficult to understand (e.g.,
DJF over central U.S.,
JJA over Sahel,
JJA over Australia)
Strength: Good consideration of the physical processes

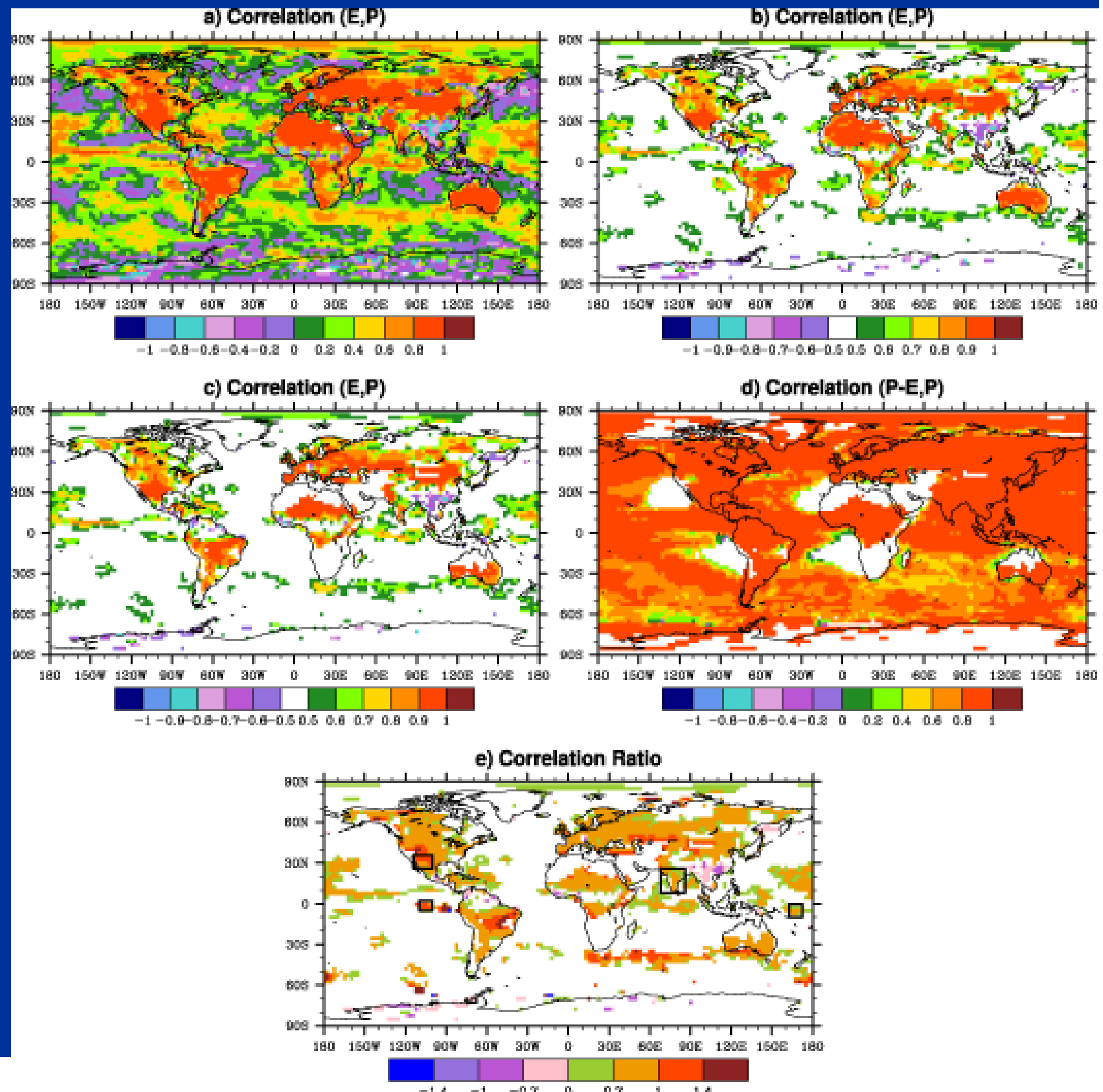


(h) Our initial attempt (Wink et al. 2003; unpublished):

$P' = E' + (P - E)'$ $\gamma = r(P', E')/r[P', (P\text{-}E)']$

Main criticism:

Difficult to interpret γ quantitatively (e.g., > 1.4 over a few regions)



(i) Our new effort

$$\Sigma P'P' = \Sigma P'E' + \Sigma P'C'; \quad C = F_{in} - F_{out} - dW/dt + \alpha$$

$$\Gamma = \Sigma P'E' / \Sigma P'P'$$

E', P' are monthly deviations from climatology

$$\gamma = \Gamma / (1 - \Gamma) \; \sigma_C / \sigma_E$$

in general $\gamma > \Gamma$

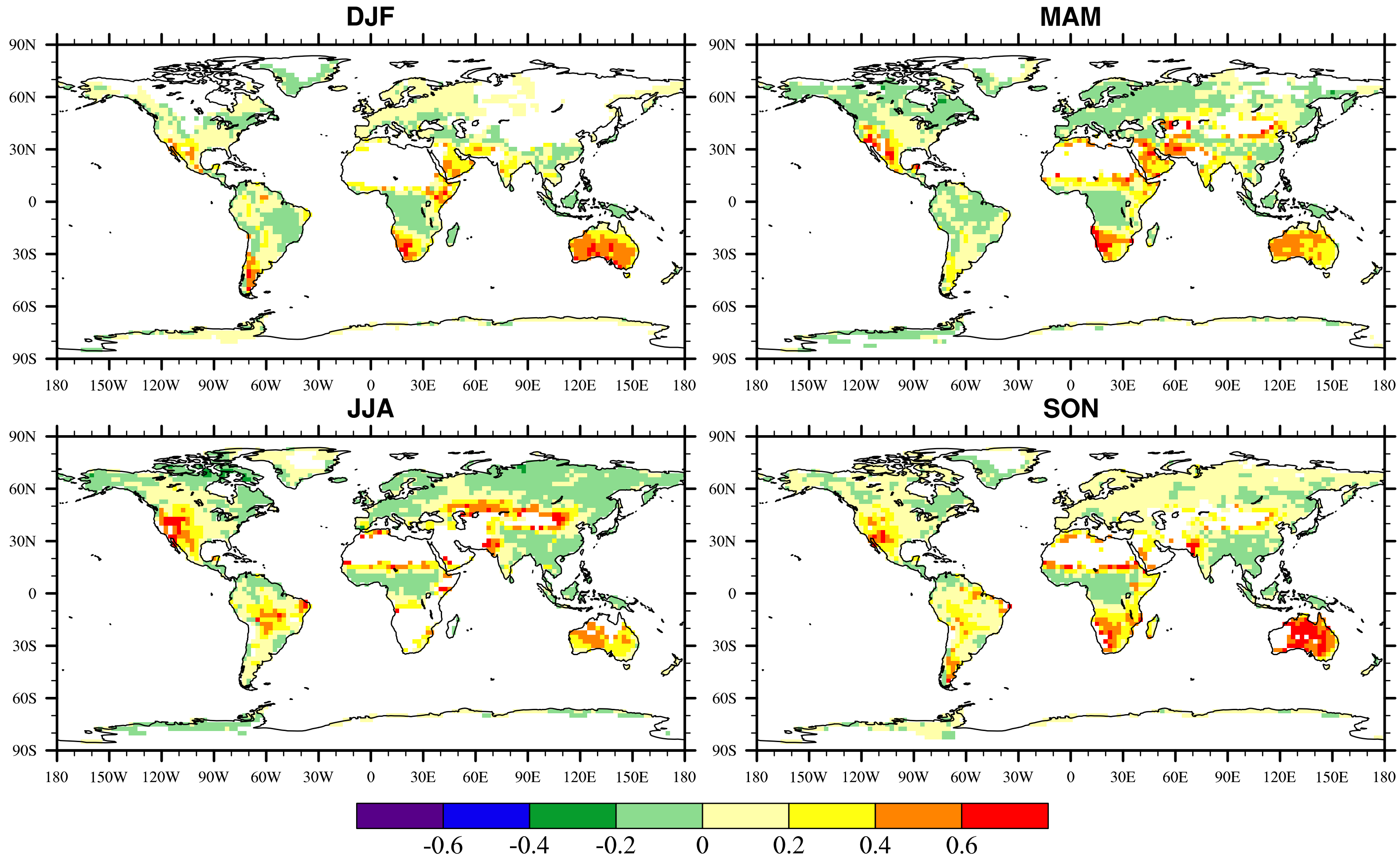
Strength: derived rigorously; easy to interpret physically
easy to compute from data or model output
Weakness: just a necessary condition for land-P coupling;
does not provide causality

Data: Monthly P and E data from various sources

Why not time-delayed covariance $\Sigma P_i' E_{i-1}'$
a) it does not provide causality either (Wei et al. 2008)
b) $\Sigma P_i' E_{i-1}' / \Sigma P'P'$ does not have a clear meaning any more

P not assimilated; σ_p < 0.2 mm/day masked

ECMWF 45yr Reanalysis

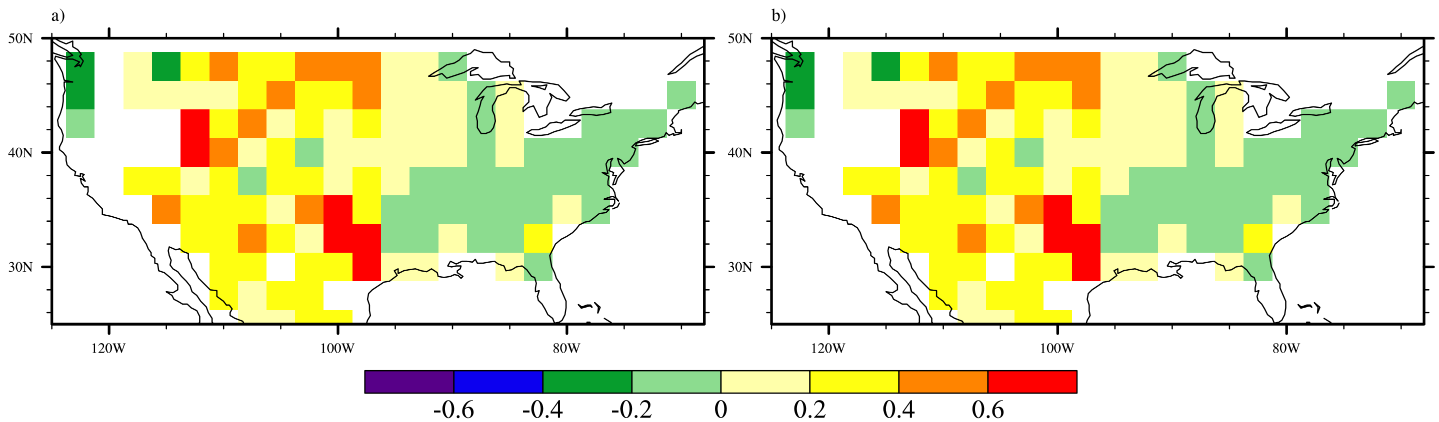


P assimilated

Our results are insensitive to scales (32 km vs 2.5 deg);

P recycling computation is sensitive to scales

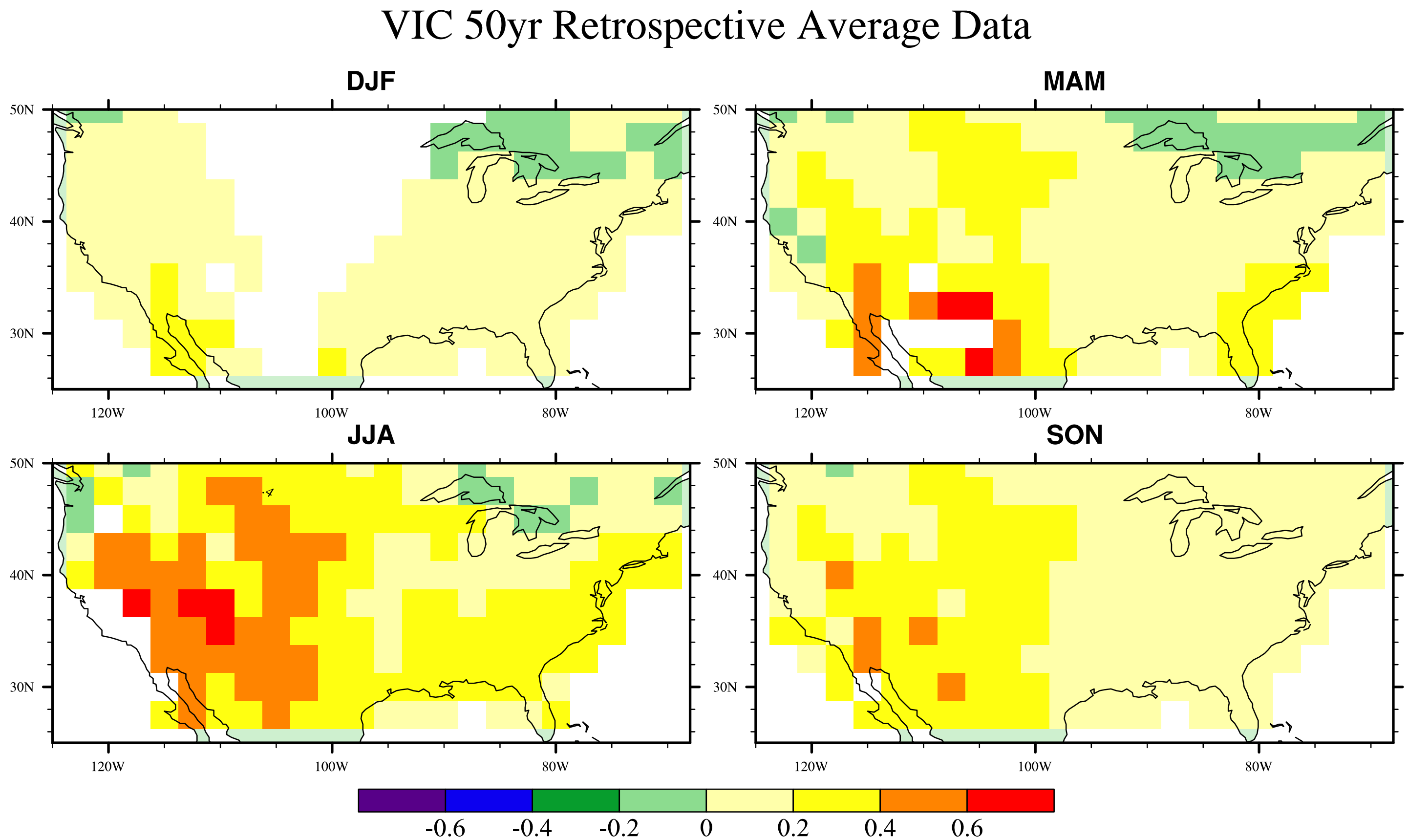
NARR



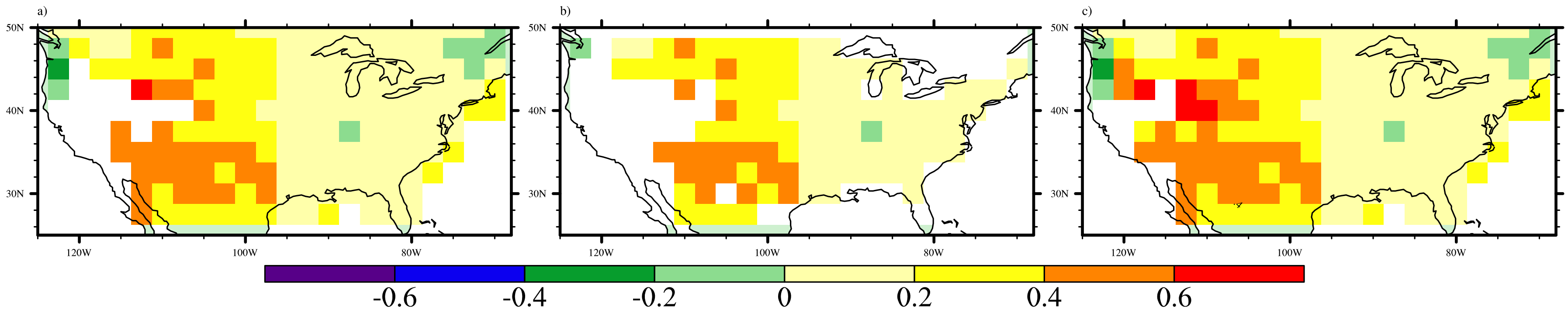
Γ is computed using 2.5 deg data

Γ values at 32 km are averaged to 2.5 deg

observed P;
offline model-derived ET



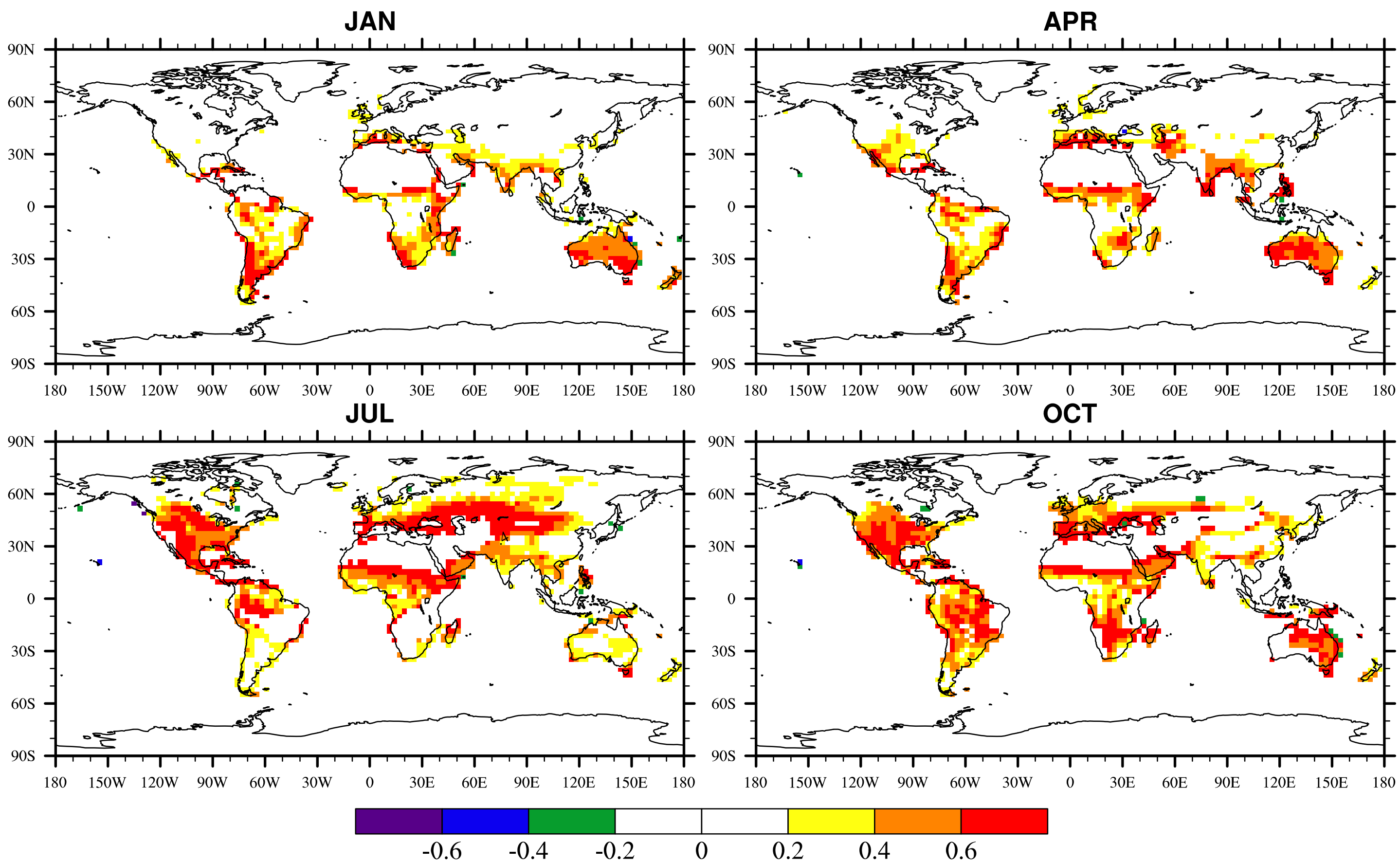
Combination of ECMWF and NCEP reanalyses, NARR regional reanalysis, and VIC data



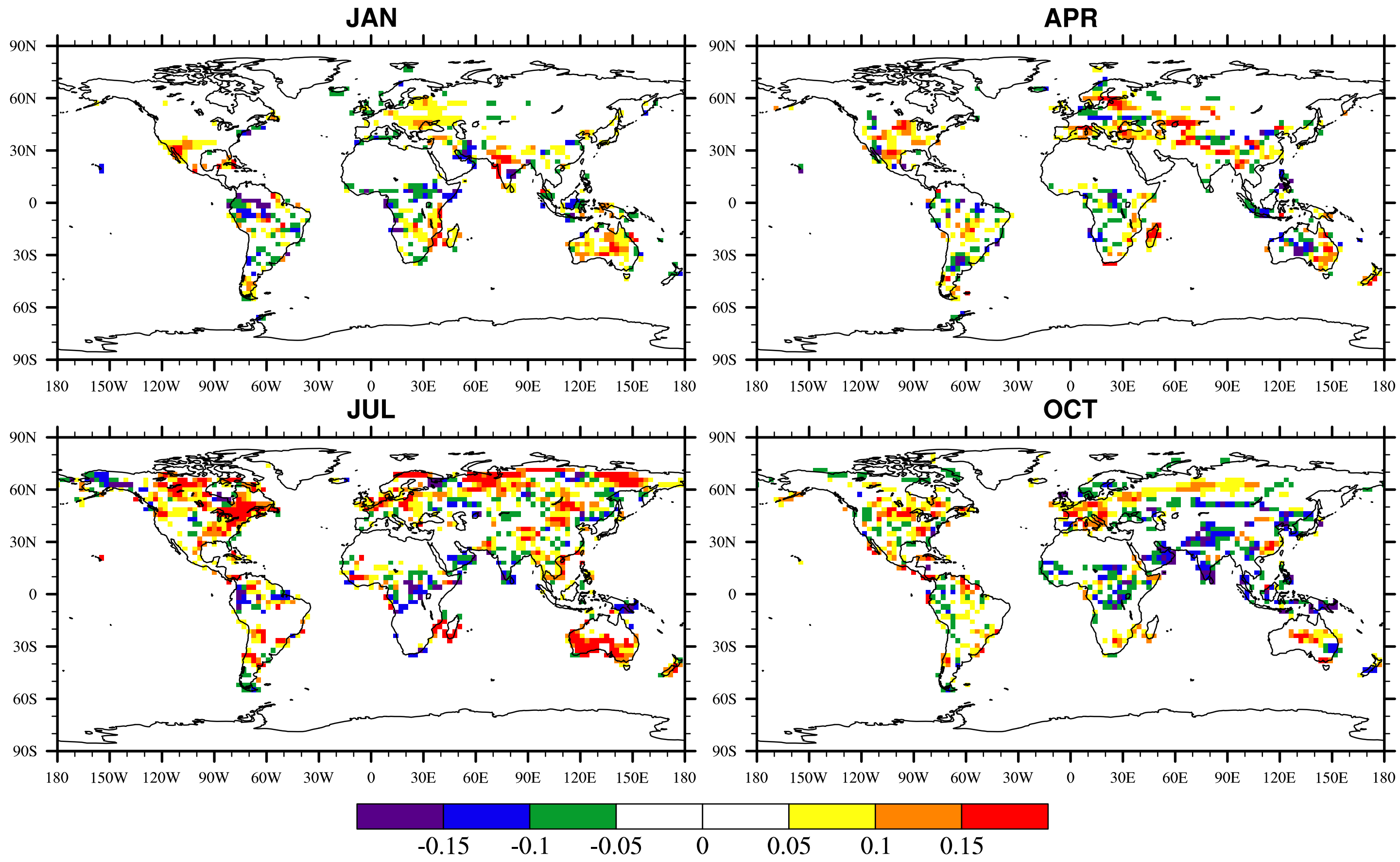
July

Γ provides a simple indicator to characterize a GCM's coupling strength

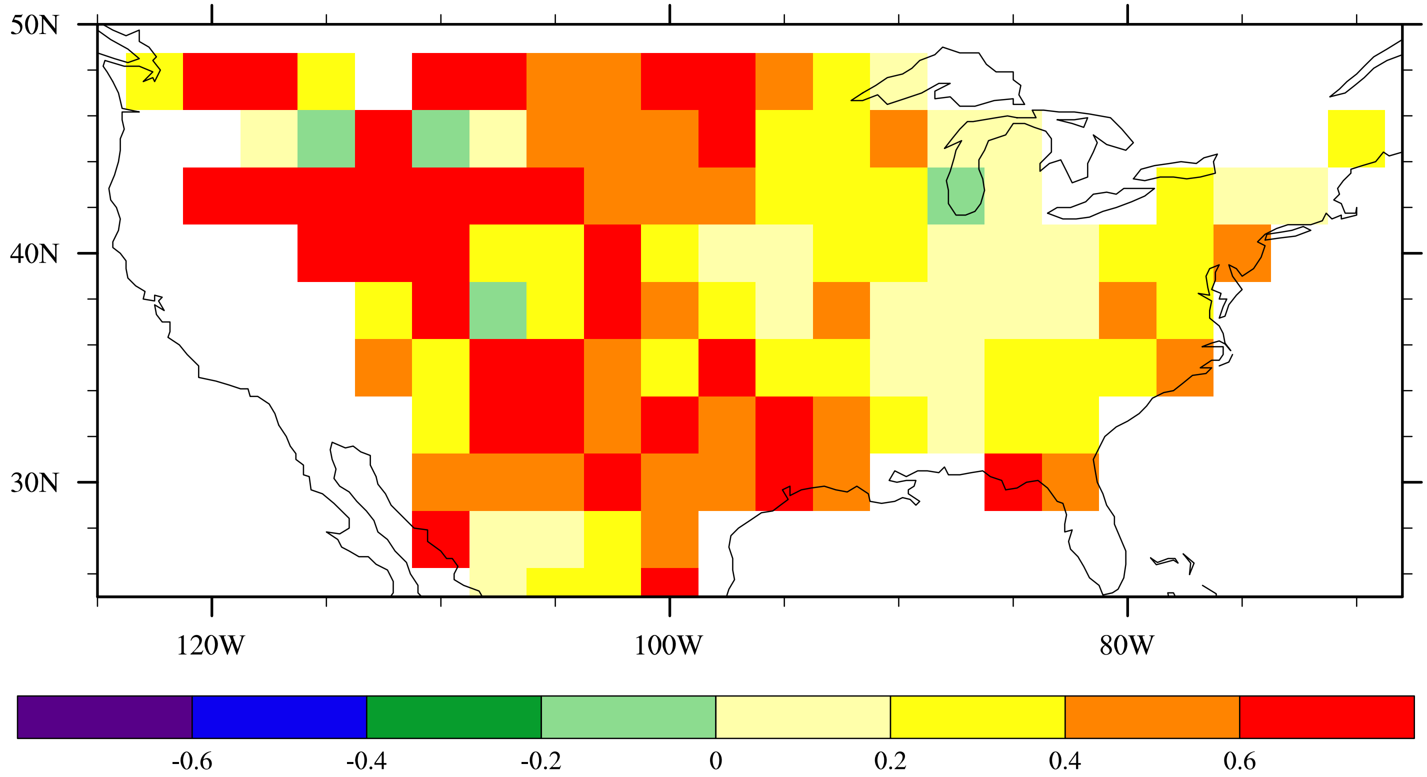
CCSM3 50yr Control Run



CCSM3 50yr 2X CO2 - Control



RAMS July



Conclusions

1. Develop a new indicator to characterize the land-precipitation coupling: $\Gamma = \Sigma P'E' / \Sigma P'P'$

Strength: derived rigorously; easy to interpret physically;
easy to compute from data or model output;
insensitive to horizontal scales

Weakness: just a necessary condition for land-P coupling;
does not provide causality

2. CCSM land-P coupling strength is too strong;
RAMS is not as strong but it is still stronger than indicated by the data analysis

3. Doubling of CO_2 change little the overall coupling strength of CCSM