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:

\[ P = E + C + \frac{d(PW)}{dt}; \quad \text{indicator: } \gamma = \frac{E}{P} \approx 70\% \]

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:
\[ P = P_m + P_a \quad \gamma = \frac{P_m}{P} \]

Weakness: Assuming well-mixed air (i.e., \( P_m/P = P_{Wm}/P_W \))
Dynamic meaning is lacking
Strength: Relatively easy to compute

Dominguez et al. (2006)
(d) Water vapor tracer
\[ P = \sum P_i \quad \gamma = \frac{P_L}{P} \]

Weakness: model-dependent
Strength: source regions

This method and precipitation recycling computations give different recycling ratios

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 $\Delta \Phi$ index
(g) Composite assessment based on $\theta$ persistence, $\theta$ 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(h) Our initial attempt (Wink et al. 2003; unpublished):

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

Main criticism:

Difficult to interpret \( \gamma \) quantitatively (e.g., > 1.4 over a few regions)
(i) Our new effort

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

\[ \Gamma = \Sigma \Delta P' \Delta E' / \Sigma \Delta P' \Delta P' \]

\[ \gamma = \Gamma / (1 - \Gamma) \quad \sigma_C / \sigma_E \]

E’, P’ are monthly deviations from climatology

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; $\sigma_p < 0.2$ 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

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

VIC 50yr Retrospective Average Data
Combination of ECMWF and NCEP reanalyses, NARR regional reanalysis, and VIC data

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Γ provides a simple indicator to characterize a GCM’s coupling strength
CCSM3 50yr 2X CO2 - Control
Conclusions

1. Develop a new indicator to characterize the land-precipitation coupling:
   \[ \Gamma = \frac{\Sigma P'E'}{\Sigma P'P'} \]
   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 CO2 change little the overall coupling strength of CCSM