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Title: *Validation of coupled land-atmosphere behavior in global weather and climate models*

For decades, land surface models have been coupled to atmospheric models to provide lower boundary conditions over continents and to close the surface energy and water budgets in weather and climate forecasts and simulations. Although the coupling has typically been performed based on sound physical and numerical principles, the coupled behavior has not been validated except in a few very limited cases. Usually the coupled behavior is considered acceptable based on the character of errors in related states, such as near-surface air temperature, which can be affected by many factors in addition to the land-atmosphere coupling. Often the land surface becomes the tuning mechanism to reduce errors in widely measured meteorological terms like temperature and precipitation, generating undiagnosed compensating errors in other terms such as surface heat and moisture fluxes.

This is a critical problem because the land surface is a potential source of predictability for weather and climate on a range of time scales. In particular, soil moisture, as a relatively slowly varying land surface state (compared to atmospheric states) can provide predictability on scales from days to months, particularly over the critical range between deterministic weather (ca. 1 week) and probabilistic climate (seasonal and longer) processes. However, this predictability only exists where the coupled behavior of land and atmosphere permits significant feedbacks, and for models which adequately capture the character and variability of the coupling.

The growth of FLUXNET and the compilation of the synthesis data set enable for the first time the type of global observationally-based assessment of coupled land-atmosphere behavior, and the validation of coupled land-atmosphere models. Specifically, recent work in several projects of the Global Land-Atmosphere System Study (GLASS) an effort within the Global Energy and Water Exchanges (GEWEX) project with the World Climate Research Programme (WCRP) has led to the development of metrics of coupled land-atmosphere behavior and feedbacks that are quantifiable from field measurements and applicable to model validation. These will be applied in this study to four global models: NASA/GSFC [GEOS5+Catchment], NOAA/NCEP [GFS+Noah], NCAR [CAM+CLM] and ECMWF [IFS+HTESSEL] in three configurations: offline (land surface model only); coupled (atmosphere+land) and reanalysis (atmosphere+land with data assimilation).

Specific objectives:

- Quantify and compare the day-to-day variance and persistence (lagged auto-correlation) of land surface states, surface fluxes (latent and sensible heat) and near-surface meteorology between FLUXNET sites and corresponding model grid boxes.
- Quantify the correlation between land surface states (namely soil moisture at the surface and subsurface layers) and surface fluxes (namely latent and sensible heat flux) with data at daily intervals. A positive (negative) correlation between soil moisture and

latent (sensible) heat flux is indicative of a situation where the land surface state controls the fluxes and a feedback pathway from land to atmosphere via the energy and water cycles exists. The opposite correlation indicates a thermal/radiatively controlled domain where fluxes control soil moisture and no feedback pathway exists (Dirmeyer et al. 2013).

- Quantify the correlation between surface fluxes and atmospheric boundary layer growth (using lifted condensation level calculated from 2m temperature and humidity as a proxy) for FLUXNET sites and models.
- Estimate terrestrial and atmospheric coupling indices as the product of the correlations described above and the standard deviations of the downstream or responding quantity (Guo et al. 2006, Dirmeyer 2011). For instance, for the terrestrial component, the correlation between soil moisture and latent heat flux times the standard deviation of latent heat flux gives the coupling index through the water cycle.
- Estimate terms of mixing diagrams and LCL deficit (Santanello et al. 2011) as well as other metrics (e.g., Betts 2004).

Both terrestrial and atmospheric legs of the feedback pathway must be in place and strong, and the memory of land-surface anomalies (lagged autocorrelation of soil moisture) sufficiently long for the land to be a controlling factor in local-regional climate. Many modeling studies suggest these factors vary spatially seasonally, and even from year to year. FLUXNET data can be used to verify these findings and potentially improve model behavior to more accurately capture observed relationships.

Sites to use:

Along with Fair-Use and Open-access sites, we would like to use La Thuile sites that have sufficient data for statistically stable estimates of correlations with daily data – generally at least 90-100 sets of contemporaneous soil moisture, flux and meteorological measurements – more than 1 year for seasonal estimates, at least 3 years for month-by-month estimates. The more sites included, the more spatially complete the assessment can be.

Authorship:

The rules as proposed in the disclaimer for the FLUXNET synthesis will be applied.

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