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Earth System Dynamics Discussions

Interactive comment on "Life time of soil moisture perturbations in a coupled land-atmosphere simulation" *by* T. Stacke and S. Hagemann

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The paper presents GCM experiments with extreme wet and dry initialization of soil moisture compared to "normal" simulations. The design of the sensitivity experiment is interesting; it is very "clean" from the standpoint of model consistency, because all states come from model climate itself. From this, soil moisture memory is assessed in the context of positive versus negative anomalies, further composited by dry, transitional and wet soil regimes. The new, unique contribution is the examination of how soil moisture memory may be extended through interactions with other state variables and deep moisture reservoirs. The work is well presented and interesting - additional description in a few places would improve clarity.

General comments:

Throughout: Correlations in particular should be accompanied with results of significance tests. For spatial correlations some estimate of the reduced numbers of degrees of freedom need to be used, based either on estimates of the spatial auto-decorrelation distance for the variable, or a count of extrema. Explained variance alone is not enough. When correlations through 9 members are discussed (e.g., Fig 10), the 2-tailed 95% confidence is at r=0.67, for 1-tailed 0.58.

A small caveat: by design the extreme perturbations in soil moisture initial conditions are synchronized everywhere (i.e., the most extreme value at each grid point at the same initial date), whereas in the free-running model (REF) and reality there would be a spatial distribution of wet, dry and normal. Thus, remote or large scale effects in INI tend away from reasonable - it's not that different than a Shukla & Mintz (1982; Science) type of simulation in this regard. This design may amplify local responses via regional-continental scale changes that would not arise in the "normal" evolution of climate. This should be noted somewhere, perhaps in Sec 6.

Couldn't it be also that there would be memory "stored" in other states as well, such as the snow cover or vegetation state, that would emerge later? Vegetation might be a negative feedback, thinking about it, as a green vegetation (say in a semi-arid zone) would transpire more, reducing memory. This could be mentioned in the discussion section.

A few small language issues are present, e.g., P1748 L7: "only few information exist" should be "little information exists". Careful proofreading would solve them.

Specific comments:

P1747 L12: say "methods" not "tools" - different methodologies yield different estimates of soil moisture memory (e.g., if daily vs. pentad or monthly data are used, lagged autocorrelations vs. variance ratios (e.g., SNR), etc.)

Sec 2: Since soil moisture is so strongly controlled by precipitation, it would be good to know about the precipitation biases in this model. Do the local features in extremes (later in Fig 4) correspond to precipitation biases, or are they believable?

Eq 1: Is this SNR calculated separately for every season, so that j=9? Thus, the sample size is quite small - is this correct?

Fig 3: Please give more details for Fig 3. Are these all of the land points or just ice-free? Every grid box goes into the distribution? All seasons together? What is meant by "seasonal ensembles"; is that from REF climatology or the wet and dry INI cases combined?

Fig 4: The mean is much different than the median soil moisture for many points in the very dry and wet regimes. Could that skewness contribute to the low apparent memory regions in Fig 4 when there are dry anomalies in dry regions, and wet anomalies in wet regions: it causes a weak signal relative to noise (which is calculated by the conventional RMSE approach in Eq 1that implicitly assumes a normal distribution)? Or asked another way, does the weak memory in those regions emerge in the tau_lag term or the tau-0 term? Do you consider this a bug or a feature of this approach, as typically memory is thought to be very high in arid regions in general (cf. Orlowsky and Seneviratne 2010; J Climate).

P1755 L5-20: It would be good here to refer to relevant previous work that describes these processes, like Koster and Suarez (2001 JHM; fig 5), or Seneviratne and Koster (2012; JHM).

Fig 7: Please put a tick for the mean and median on each red and blue side.

Fig 8: This needs more description - what exactly is shown?

P1757: Most of the discussion of correlations here should be accompanied by "not shown", or the the complete set of correlations for each season could be presented in a table.

P1759 L15-16: "...does not seem to be correlated..." - please quantify the correlations

for each.

Fig 10: tau_max is a bit of a dubious quantity to me: as a summation, it should be mainly a quadratic of the linear tau_0 term, with (usually) a little randomness added at longer time scales, no? Shouldn't tau_max >= tau_0*(tau_0+1)/2? Then how to explain the carbon panel where tau_0 is close to tau_max? Am I missing something?

P1760 L6-20: I cannot follow how this discussion comes from Fig 11. This seems to be a key result but I really cannot understand how it comes from this figure. If you are actually comparing Fig 11 to features of Figs 3 and 9, please state clearly. It may be clearer to show the differences also in another set of panels.

Fig 11: What's the difference between "extreme anomalies" vs. INI initial perturbations in the case of soil moisture? The text uses thetas and the figures do not. Please be clear and consistent. Also, what are the offset colored horizontal ticks in a few places in the panels?

P1761 L9-12: In the set of criteria, what about a minimum duration of the later periods after the anomaly rebounds? A minimum duration (much more than 1 or 2 days) might weed out some noise like that which is apparent in the example Figure 2.

P1762 L16: Regarding the "temporally hidden" memory, please see Guo et al. (2011; GRL, 2012; J Climate) for another related example of this hidden and rebounding predictability from state anomalies.

Fig 13: Place a vertical black line at 12 and 24 months so it is easy to reckon the duration of the annual cycle in all plots

Fig 14: This is not clear to me - so is there memory recurrence at every grid cell, just at different frequencies (where the CDF approaches 1)? Or is this only for a subset of points where recurrence is present? Or is the X axis "memory" and not "memory recurrence"? Please explain the figure in more detail.

Sec 6: Please state how these results fit with C. Taylor's evidence (several papers) that locally positive soil moisture-precipitation feedbacks are rare, and Guillod et al. (2015; Nature Comm) that shows there are spatial as well as temporal dimensions to the land-atmosphere feedback issue?

P1756 L18 and P1767 L7: up to 50% of the variance is not small - I think the authors are understating the impact of initial soil moisture anomalies.

L1767 P10-16: Does this model allow for organic carbon (leaf litter) to interact with soil properties and alter soil structure over time? Could that act as another delayed effect (perhaps more on decadal time scales)?

Interactive comment on Earth Syst. Dynam. Discuss., 6, 1743, 2015.