Assessment of MERRA-2 Land Surface Energy Flux Estimates

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Outline

- In MERRA-2, observed precipitation is inserted in place of model-generated precipitation at the land surface [1,2].
- The use of observed precipitation was originally developed for MERRA-Land (a land-only replay of MERRA with model-generated precipitation replaced with observations)
- Previously shown that the land hydrology in MERRA-2 and MERRA-Land is better than MERRA [3].
- We test whether the improved land surface hydrology in MERRA-2 leads to the expected improvements in the land surface energy fluxes and 2 m air temperatures (T^{2m}).

Sensitivity to observed precip. in MERRA-2

1. Sensitivity of Latent Heat (LH) to soil moisture

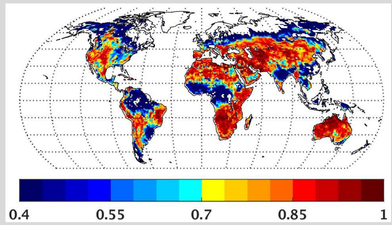
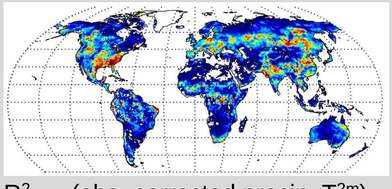


Fig 1: MERRA-2 JJA R^2_{anom}(soil moisture, LH).

- High values (red): LH is moisture-limited (sensitive to soil moisture). This is where LH responds most to the improved precipitation.
- Low values: LH is energy-limited.

2. Sensitivity of daily max. T^{2m} to precipitation

R^2_{anom}(model-generated precip, T^{2m})



R^2_{anom}(obs.-corrected precip, T^{2m})

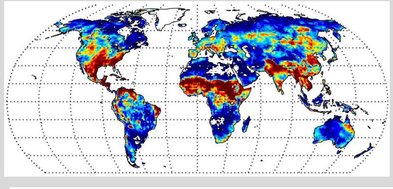


Fig 2: MERRA-2 JJA R^2_{anom}(antecedent precip., T^{2m}) for model-generated and obs.-corrected precip. See [4] for details.

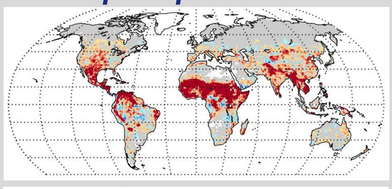


Fig 3: Difference: left lower – left upper plots.

- Above is the difference in the T^{2m} variance explained by the obs.-corrected precip (seen by the land) over that explained by the model-generated precip.
- This is the sensitivity of the MERRA-2 T^{2m} to the observed precipitation.

LH anomaly correlations (R_{anom})

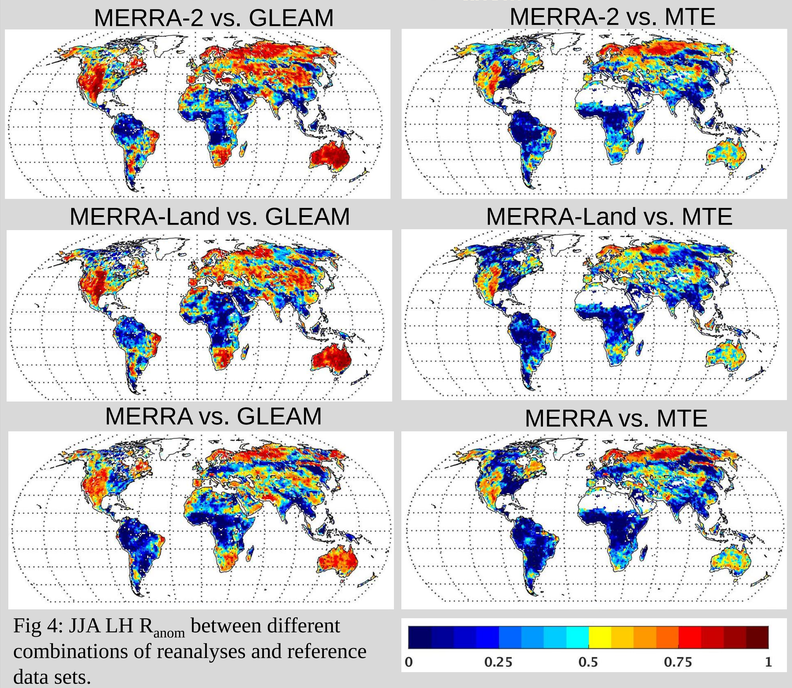


Fig 4: JJA LH R_{anom} between different combinations of reanalyses and reference data sets.

- Broad similarity of R_{anom} spatial patterns vs. GLEAM (left) and MTE (right), with GLEAM showing stronger agreement.
- The R_{anom} are low, likely due to errors in the reanalyses and reference data.
- Agreement is generally better where LH is moisture-limited.

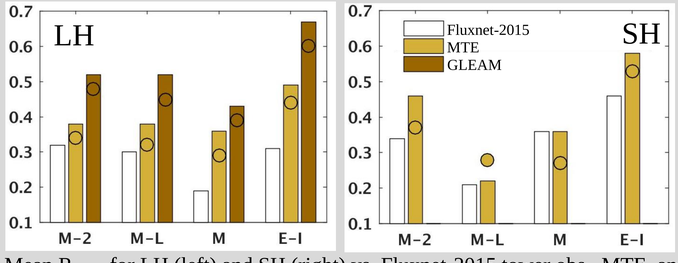


Fig 5: Mean R_{anom} for LH (left) and SH (right) vs. Fluxnet-2015 tower obs., MTE, and GLEAM, averaged across 20 Fluxnet-2015 sites (bars), and averaged globally (circles).

- Similar results from each reference data set: MERRA-2 and MERRA-Land higher than MERRA, ERA-Interim is highest.
- MERRA-Land SH R_{anom} is lower than for MERRA.

GLEAM: Global Land Evaporation Amsterdam Model [5]
MTE: Fluxnet-Model Tree Ensembles [6]
Fluxnet-2015 (http://fluxnet.fluxdata.org/data/fluxnet2015-dataset/)
CRU: Climatic Research Unit [7]

LH biases

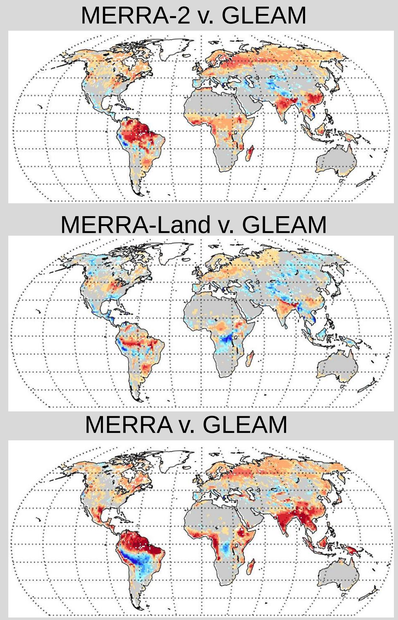


Fig 7: Bias between reanalyses and GLEAM LH (W/m^2).

- Comparison of LH biases vs. GLEAM (Fig 8.) and vs. MTE (not shown) suggest similar patterns of bias.
- MERRA-2 has large positive biases (> 20 W/m^2) where LH is energy-limited (hence relatively insensitive to soil moisture/antecedent precip). MERRA shows similar results.
- Biases are reduced in MERRA-Land almost everywhere

Daily max. T^{2m} R_{anom}

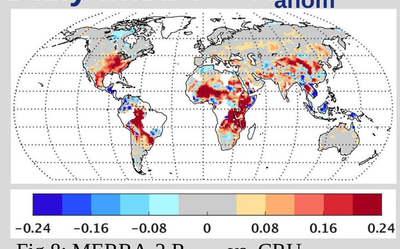


Fig 8: MERRA-2 R_{anom} vs. CRU – MERRA R_{anom} vs. CRU.

- T^{2m} R_{anom} overall increased.
- Compare to Fig 3: where T^{2m} is most sensitive to observed precip. the change in T^{2m} R_{anom} is often large (but not always positive).
- Also large improvements in many insensitive regions: likely due to other system upgrades.

Conclusions

- It is difficult to evaluate surface energy fluxes, as there is no globally recognized truth
- Comparison to multiple reference data sets (globally: GLEAM, MTE, locally: Fluxnet-2015) suggests the same conclusions: MERRA-2 has improved LH and SH (bias and R_{anom}) compared to MERRA, while MERRA-Land has improved LH, but degraded SH (is replacing precipitation in an offline system generating an inconsistency?)
- However, the greatest uncertainties in LH occur in energy-limited regions, where LH is much less sensitive to soil moisture/precipitation.

References:

[1] Gelaro et al. (2017), MERRA-2, J. Climate, doi:10.1175/JCLI-D-16-0758.1.
[2] Reichle et al. (2017b), Land surface precipitation in MERRA-2, J. Climate, doi:10.1175/JCLI-D-16-0570.1.
[3] Reichle et al. (2017a), Assessment of MERRA-2 land surface hydrology estimates, J. Climate, doi:10.1175/JCLI-D-16-0720.1.
[4] Draper et al. (2017), Assessment of MERRA-2 Land Surface Energy Flux Estimates, *J. Climate*, doi:10.1175/JCLI-D-17-0121.1.
[5] Martens et al. (2017), GLEAMv3, *Geosci. Model Dev.*, doi:10.1175/JCLI-D-14-00556.1
[6] Jung et al. (2009), Towards global empirical upscaling of FLUXNET eddy covariance observations, *Biogeosciences*, doi:10.5194/bg-6-2001-2009.
[7] Harris et al. (2014), Updated high-resolution grids of monthly climatic observations - the CRU TS3.10 Dataset, *Int. J. Climatol.*, doi:10.1002/joc.3711.

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