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Hydrology and Earth System Sciences Discussions

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Interactive comment

Interactive comment on "The pan-tropical response of soil moisture to El Niño" *by* Kurt C. Solander et al.

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Review #2: The manuscript "The pan-tropical response of soil moisture to El Niño" evaluates the quality of the GLDAS soil moisture dataset and uses GLDAS to investigate response of soil moisture to three recent "super El Niño" events. The study is of interest to a broad scientific community, including researchers in hydrology, ENSO dynamics, and land-atmosphere interaction. The paper is well written. But the current manuscript can be improved in both analysis and paper structure. Therefore I recommend major revisions before being considered for publication in HESS.

Author Response: We thank the reviewer for the overall positive review. We agree that the analysis and paper structure can be improved. We address each comment below.

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Discussion paper

Major suggestions: 1) On paper structure, although the title implies a scientifically oriented study, namely response in tropical soil moisture to El Niño, the paper emphasizes the technical parts, namely evaluation and bias correction of GLDAS, probably too much. I suggest keeping the title and scientific emphasis of the paper, while merging some of the discussion about data quality and bias correction into the main results/discussion. For example, it might be more convincing if you use the bias-corrected data in Figures 5-9, since you suggest the bias-corrected data is better than the original in Figure 10. You can keep the figures from original data in supplemental and briefly discuss the difference between the original data and bias-corrected data.

Author Response: We have re-done Figures 5-9 using bias-corrected soil moisture estimates (see attached Figures 1-9) and correspondingly removed the old Figure 10 from the manuscript. We have moved the old Figures 5-9 generated from the non-biased GLDAS data to the Supplemental. Also, we have moved some of the discussion about data quality and bias correction to the main results (e.g. Lines 452-455 & 472-480).

2) On analysis, you might consider an alternative or additional way of doing k-means clustering analysis. Currently, the clustering is done for each case separately. While there is advantage of doing this, the disadvantage is that the spatial distribution of clusters you get varies by each El Niño event, making the comparison of clusters between different events (Tables 3-6) a little apple-to-orange. I suggest you to repeat the k-means clustering analysis with all three events together - a multi-dimension k-means clustering analysis. In this way, you should be able to get better summary of the results, for example you can directly tell which regions have the most robust (consistent) response to all three events. Then readers can clearly see each cluster from all three events, their spatial distribution, their response sign and magnitude. I think it worths trying this way at least.

Author Response: We agree and have conducted a multi-dimensional analysis in Figure 6 by showing the overlap of existing clusters of the three major El Niño events for each season. This was achieved by determining the locations where there was a match in the cluster group over the three major El Niño events (see attached Figures 3-4) and then calculating additional statistics within Tables 3-6 (see attached Figure 10).

Minor suggestions: 1) You might consider adding the bias-corrected line to Figure 1.

Author Response: We have replaced the old GLDAS data with the bias-corrected line in Figure 1 (see attached Figure 11).

2) Add continental outlines in Figure 6.

Author Response: We have added the continental outlines in Figure 6 (see attached Figures 3-4).

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2019-535, 2019.

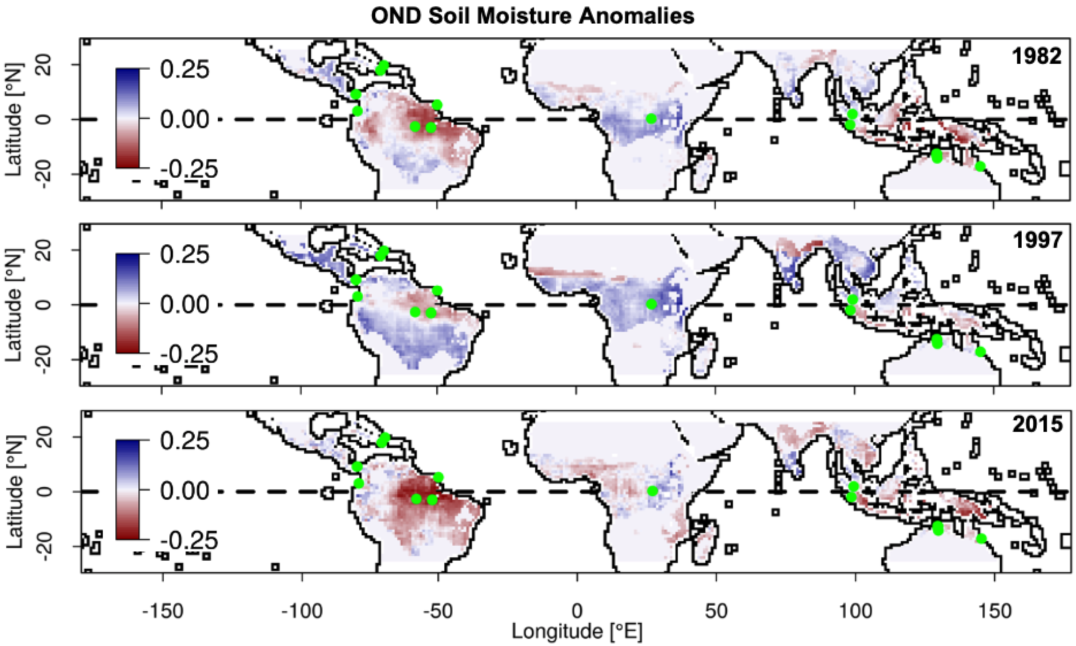

Figure 5a: October to December (OND) change in bias-corrected GLDAS soil moisture anomalies during the super El Niño years 1982 (top), 1997 (middle), and 2015 (bottom) relative to the previous years. Anomalies relative to 1979-2016 period. Green circles represent 16 in-situ data sample locations.

Fig. 1.

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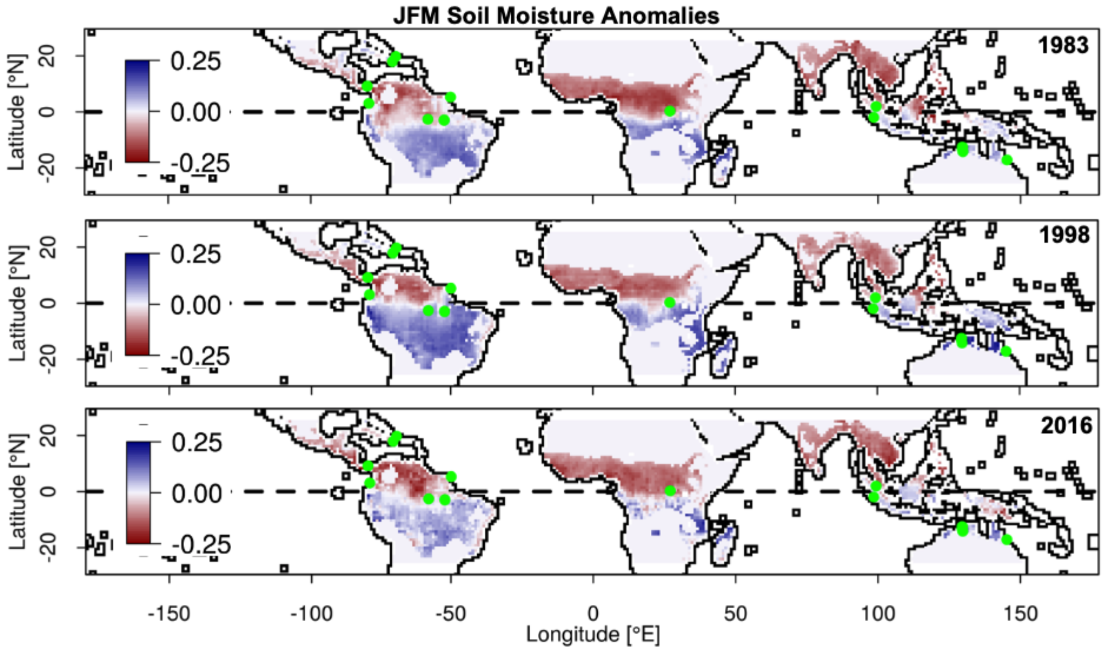

Figure 5b: Same as Figure 5a, but for January to March (JFM) in 1983 (top), 1998 (middle) and 2016 (bottom). Green circles represent 16 in-situ data sample locations.

Fig. 2.

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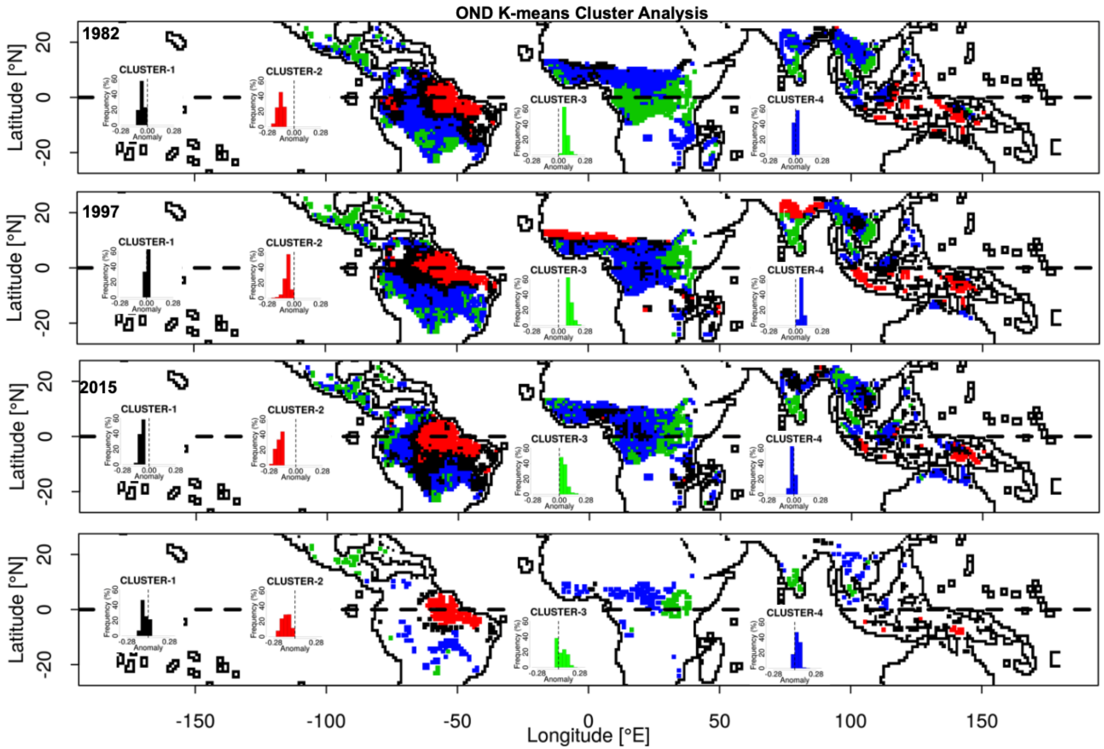

Figure 6a: K-means cluster analysis results for October to December (OND) for 1982, 1997, 2015 and the overlap of the 3-years (top to bottom). Corresponding histograms of soil moisture anomalies for each of the four clusters also shown. Anomalies relative to 1979-2016 period.

Fig. 3.

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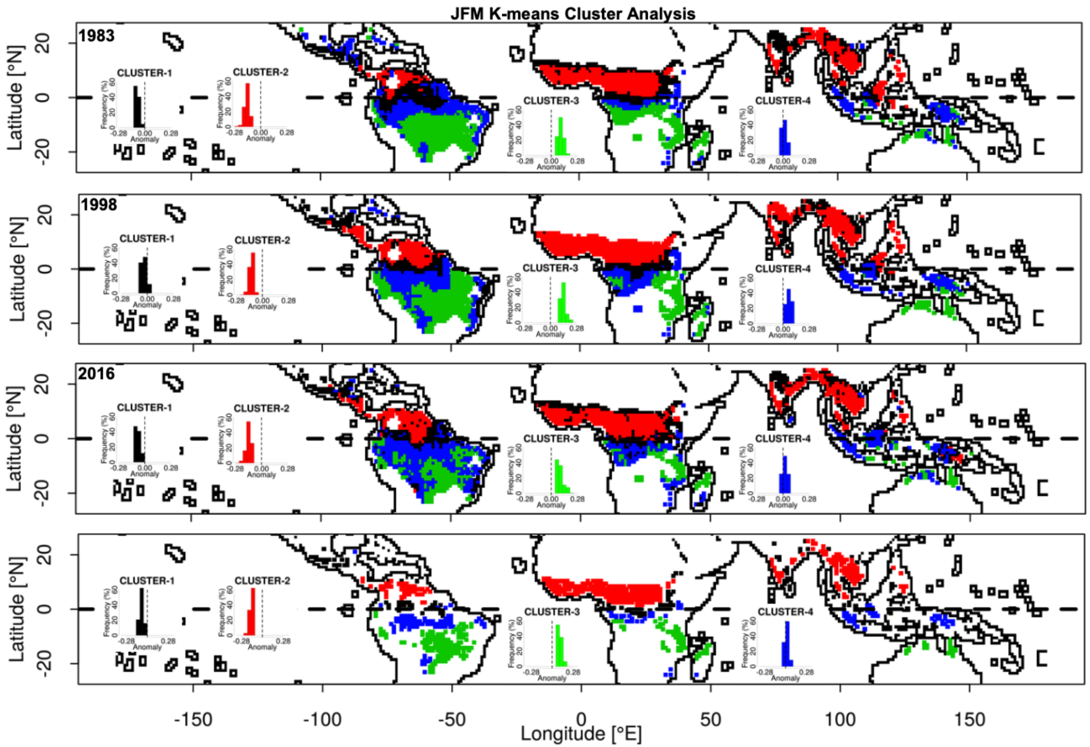

Figure 6b: Same as Figure 6a, but for January to March (JFM) in 1983, 1998, 2016 and the overlap of the 3-years (top to bottom).

Fig. 4.

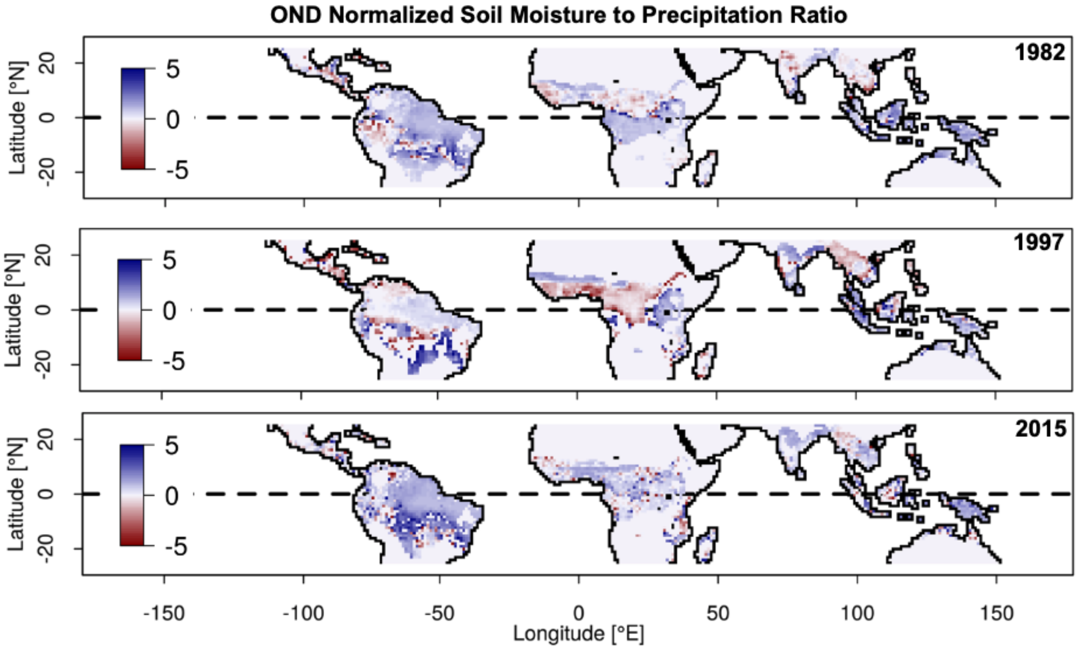

Figure 7a: Ratio of bias-corrected GLDAS soil moisture to precipitation change computed using October to December (OND) anomalies during El Niño years 1982-83, 1997-98, and 2015-16 relative to previous years. Anomalies normalized by the mean relative to 1979-2016 period.

Fig. 5.

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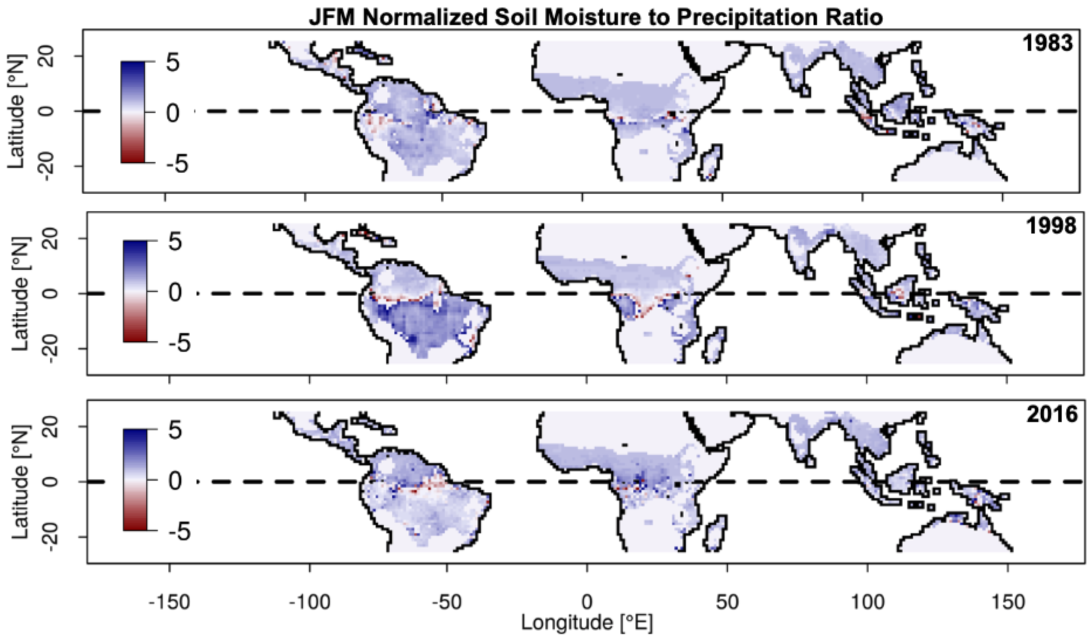

Figure 7b: Same as Figure 7a but for January to March in 1983 (top), 1998 (middle) and 2016 (bottom).

Fig. 6.

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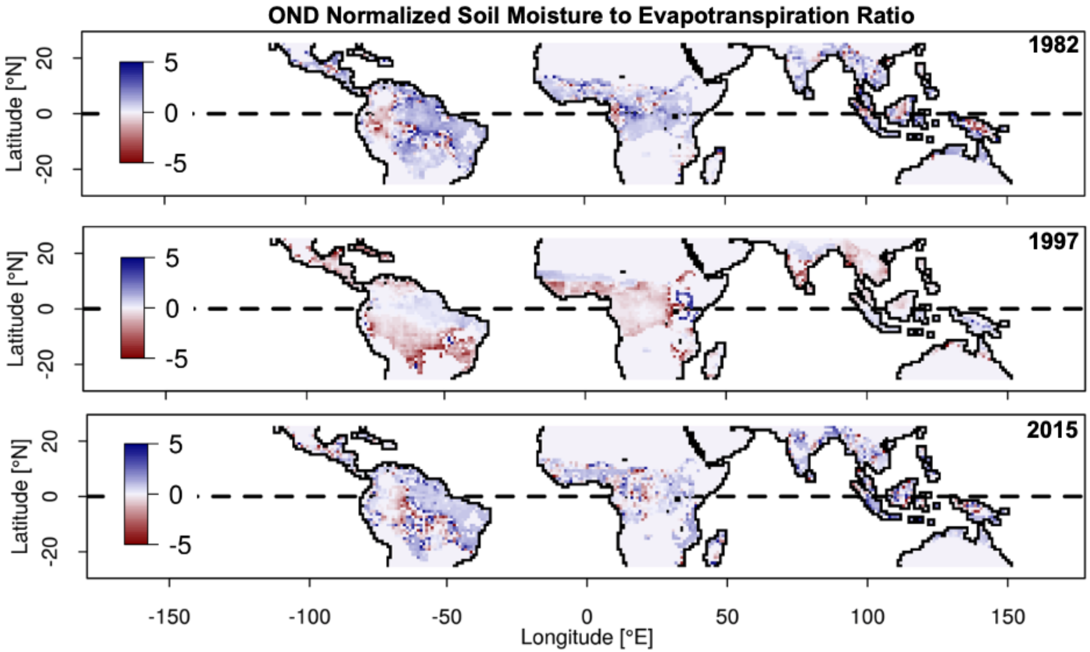

Figure 8a: Ratio of bias-corrected GLDAS soil moisture to evapotranspiration change computed using October to December (OND) anomalies during El Niño years 1982-83, 1997-98, and 2015-16 relative to previous years. Anomalies normalized by the mean relative to 1979-2016 period.

Fig. 7.

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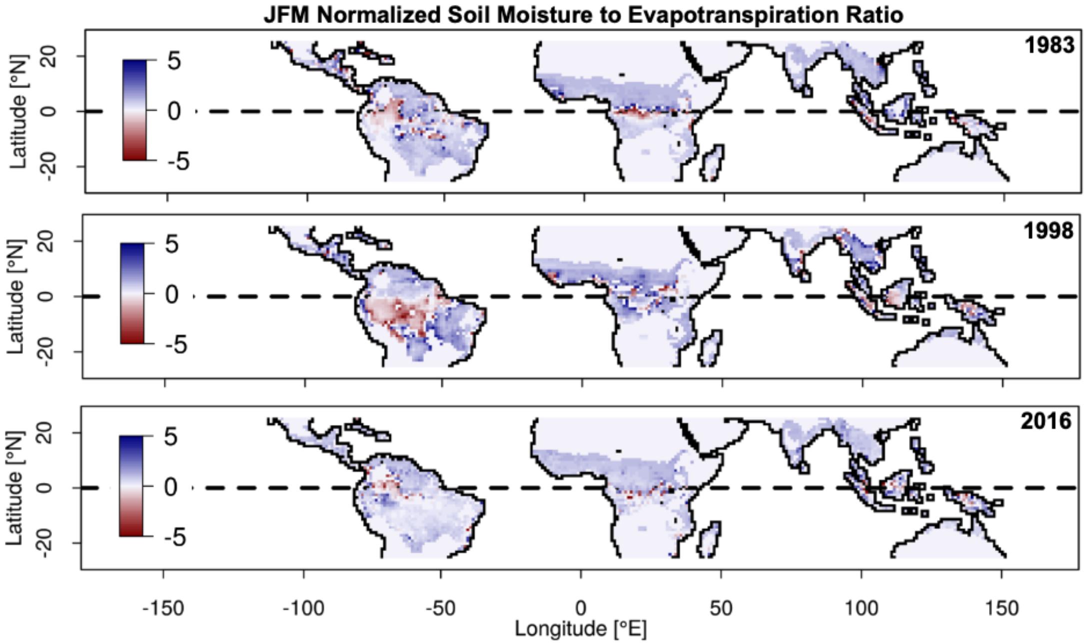

Figure 8b: Same as Figure 8a but for January to March in 1983 (top), 1998 (middle) and 2016 (bottom). Anomalies normalized by the mean relative to 1979-2016 period.

Fig. 8.

Table 3: Mean and standard deviation of October to December (OND) and January to March (JFM) change in the soil moisture for clustered regions in the humid tropics. Statistics computed using OND and JFM bias-corrected GLDAS soil moisture anomalies during El Niño years 1982-83, 1997-98, 2015-16 and all three years relative to the 1979-2016 mean.

Region	Season	1982-83, 1997-98, 2015-16, All Years Mean Change ± Standard Deviation
Cluster-1	OND	-0.06 ±0.02, 0.01 ±0.02, -0.08 ±0.02, -0.04 ±0.04
Cluster-2	OND	-0.14 ±0.03, -0.07 ±0.03, -0.17 ±0.03, -0.12 ±0.05
Cluster-3	OND	0.07 ±0.03, 0.12 ±0.02, 0.05±0.03, 0.04 ±0.06
Cluster-4	OND	0.01 ±0.02, 0.06 ±0.01, -0.01 ±0.02, 0.04 ±0.03
Cluster-1	JFM	-0.08 ±0.02, -0.04 ±0.03, -0.07 ±0.02, -0.08 ±0.02
Cluster-2	JFM	-0.15 ±0.02, -0.12 ±0.02, -0.14 ±0.03, -0.14 ±0.02
Cluster-3	JFM	0.10 ±0.03, 0.14 ±0.03, 0.10 ±0.03, 0.10 ±0.03
Cluster-4	JFM	0.01 ±0.03, 0.06 ±0.02, 0.02 ±0.02, 0.01 ±0.03

Table 4: Mean and standard deviation of October to December (OND) and January to March (JFM) change in soil moisture to precipitation ratio for the same regions shown in Table 3. Statistics computed using OND and JFM bias-corrected GLDAS soil moisture anomalies during El Niño years 1982-83, 1997-98, 2015-16 and all three years relative to the 1979-2016 mean.

Region	Season	1982-83, 1997-98, 2015-16, All Years Mean Change ± Standard Deviation
Cluster-1	OND	1.57 ±16.41, -0.01 ±3.11, 4.72 ±53.07, 0.31 ±7.06
Cluster-2	OND	0.77 ±3.76, 0.47 ±12.16, 1.40 ±0.53, -0.14 ±7.11
Cluster-3	OND	0.39 ±8.72, 3.33 ±47.90, 0.26 ±6.40, 0.60 ±6.96
Cluster-4	OND	-0.34 ±20.35, 12.35 ±284.91, -1.62 ±130.82, 0.26 ±7.30
Cluster-1	JFM	1.38 ±4.26, 0.55 ±0.73, 29.67 ±1042.43, 0.98 ±1.39
Cluster-2	JFM	1.10 ±0.20, 0.99 ±0.21, 1.33 ±0.86, 1.00 ±1.16
Cluster-3	JFM	1.18 ±1.28, 1.84 ±2.37, 0.92 ±0.37, 0.98 ±1.45
Cluster-4	JFM	0.64 ±22.22, -2.41 ±80.07, 0.72 ±7.77, 0.97 ±1.50

Table 5: Mean and standard deviation of October to December (OND) and January to March (JFM) change in soil moisture to evapotranspiration ratio for the same regions shown in Table 3. Statistics computed using OND and JFM bias-corrected GLDAS soil moisture anomalies during El Niño years 1982-83, 1997-98, 2015-16 and all three years relative to the 1979-2016 mean.

Region	Season	1982-83, 1997-98, 2015-16, All Years Mean Change ± Standard Deviation
Cluster-1	OND	3.03 ±45.24, -0.21 ±1.12, 1.98 ±24.52, 6.21 ±69.04
Cluster-2	OND	1.76 ±6.31, 0.47 ±1.86, 0.42±5.76, 3.73 ±54.78
Cluster-3	OND	3.46 ±58.48, 0.54 ±23.03, 0.53 ±15.53, 1.18 ±5.79
Cluster-4	OND	-2.46 ±57.10, -1.13 ±5.46, -4.88 ±135.52, 1.95 ±13.07
Cluster-1	JFM	0.63 ±7.48, -0.72 ±24.22, 1.82 ±28.88, 0.43 ±15.80
Cluster-2	JFM	0.34 ±16.37, 0.98±7.30, 1.87 ±22.99, 0.67 ±13.15
Cluster-3	JFM	0.72 ±2.86, 19.11 ±387.74, 0.67 ±1.89,0.36 ±16.53
Cluster-4	JFM	-0.74 ±8.60, -5.97 ±135.48, 0.34 ±3.39, 0.30 ±17.05

Fig. 9.

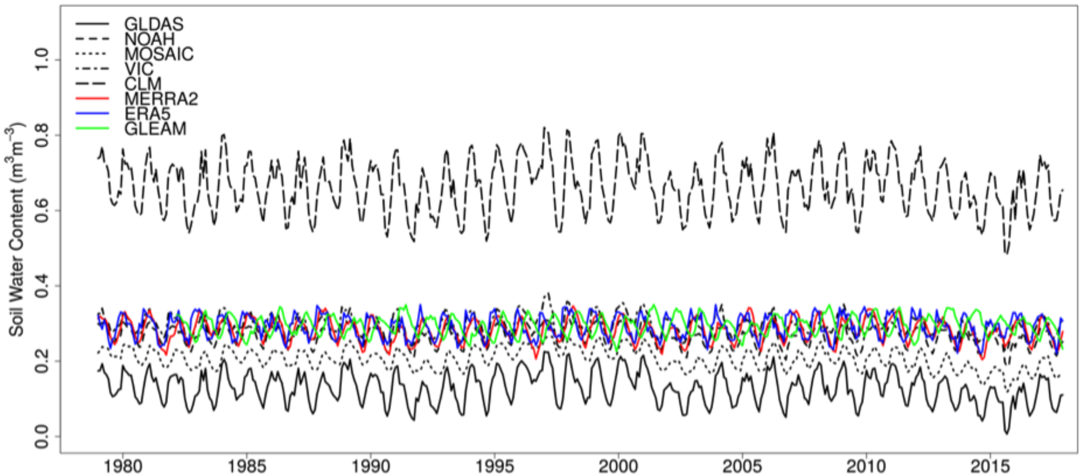

Figure 1: 1979-2017 monthly time series of mean soil moisture across all in-situ data locations shown in Table 1 for multiple data products including the bias-corrected GLDAS multi-model mean (black, solid), MERRA2 (red, solid), ERA5 (blue, solid), and GLEAM (green, solid), as well as the individual land surface models that make up GLDAS NOAH (black, short dash), MOSAIC (black, dot), VIC (black, dash dot) and CLM (black, long dash). Note that the GLEAM time series starts from 1982.

Fig. 10.

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