Spatial Correlation Structures in SMAP Near-Surface Soil Moisture

(How spatially correlated are the temporal variations of soil moisture at different locations? And why is this of interest?)

Randal Koster, Rolf Reichle, Sarith Mahanama, and Qing Liu
GMAO, NASA/GSFC
randal.d.koster@nasa.gov

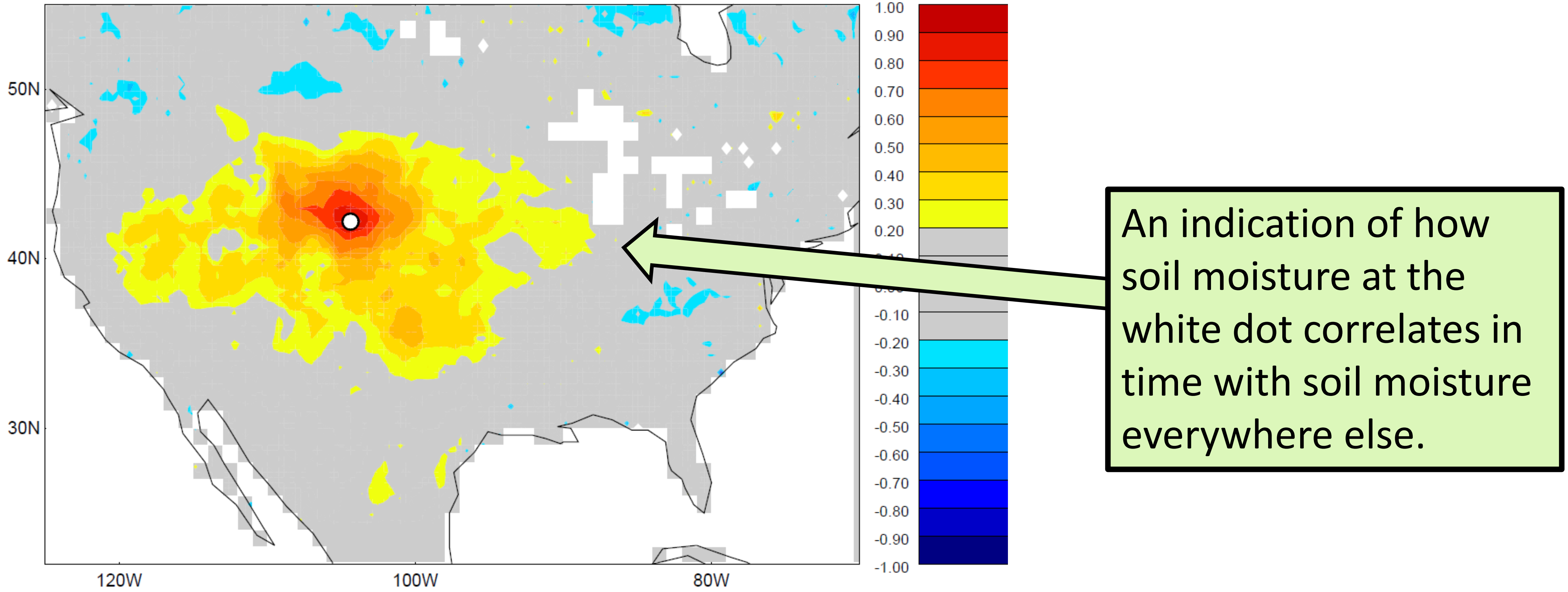
Data Examined

SMAP Level 2 soil moisture retrievals: May – September of 2015, 2016, 2017, 2018

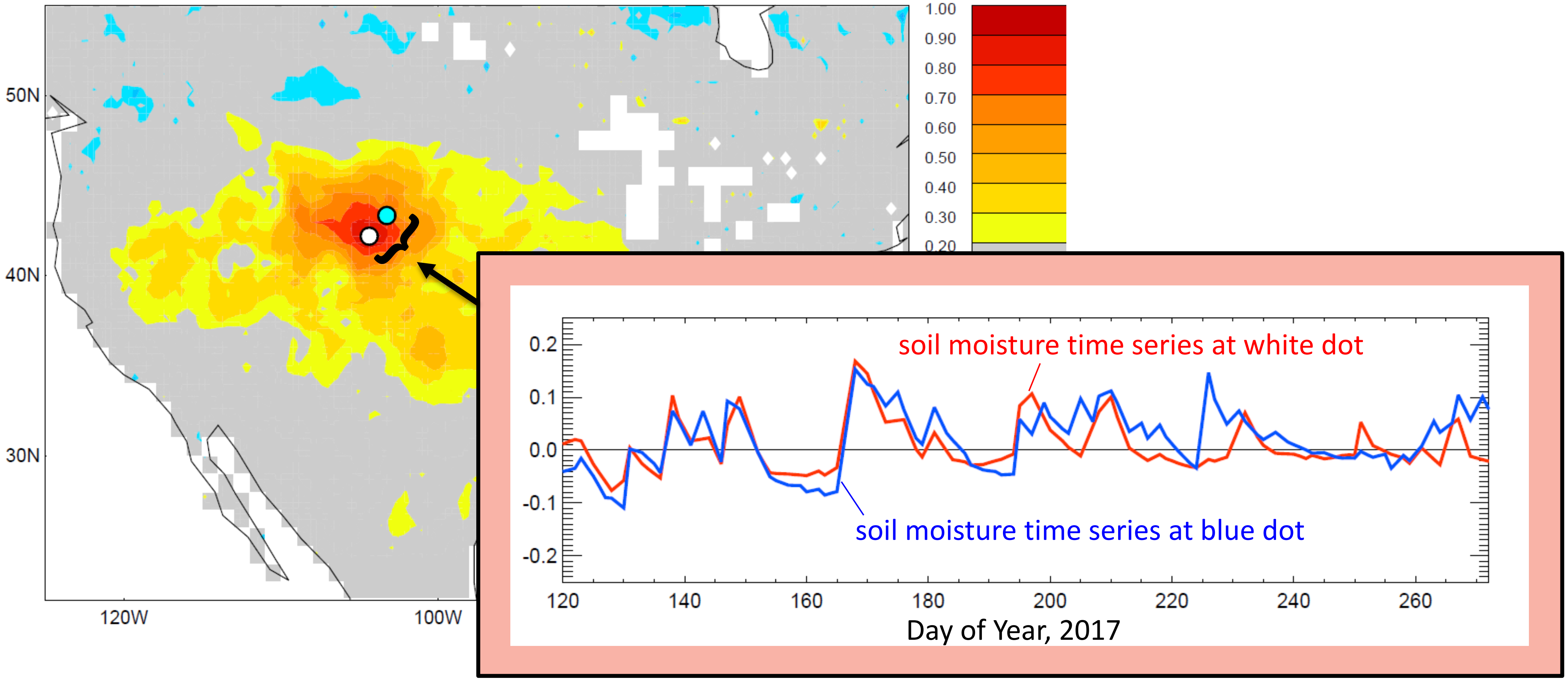
Data Processing

- Retrievals were interpolated in time ⇨ daily values at each SMAP grid cell
- Retrievals at each grid cell were converted to anomalies by subtracting an estimate of the grid cell's mean seasonal cycle (from 4 yrs of data) from each value
- Correlations were computed between different grid cells' soil moisture time series

Spatial Correlation Map

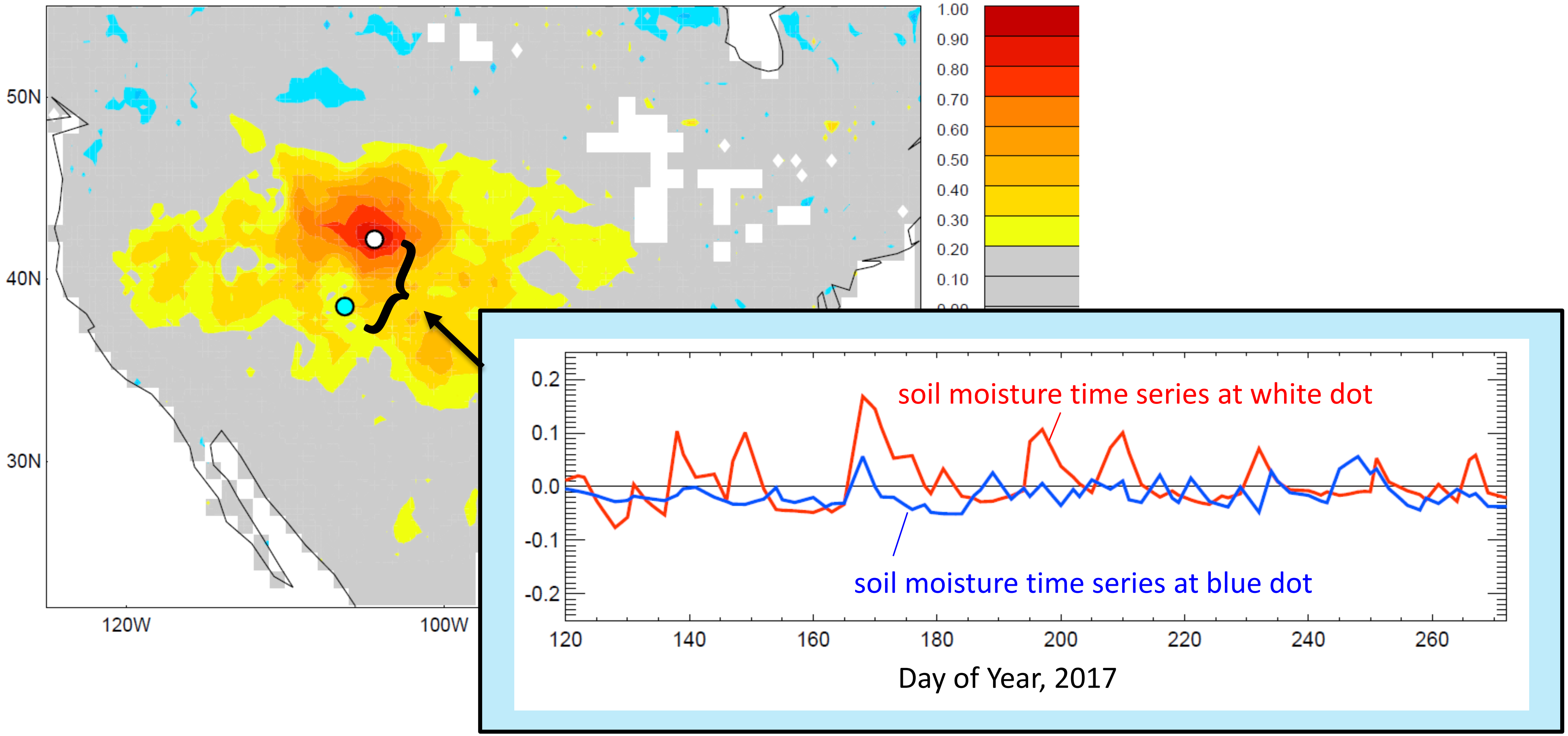


Spatial Correlation Map



estimate of mean seasonal cycle removed

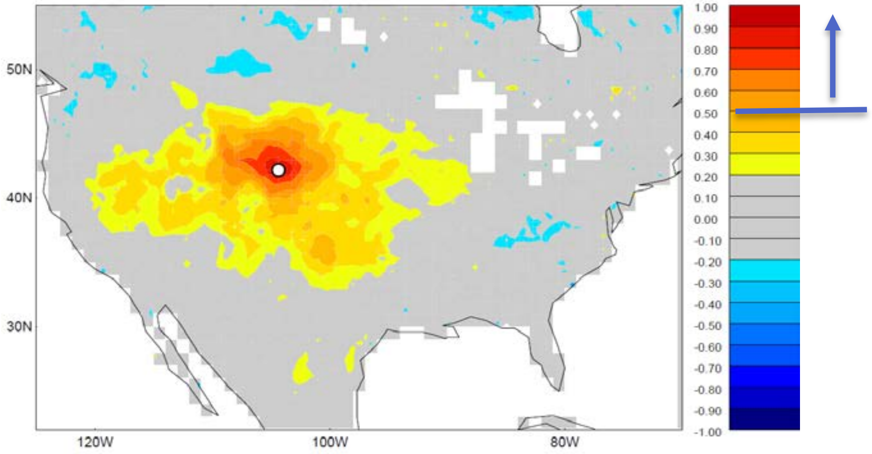
Spatial Correlation Map



Length Scale Calculation

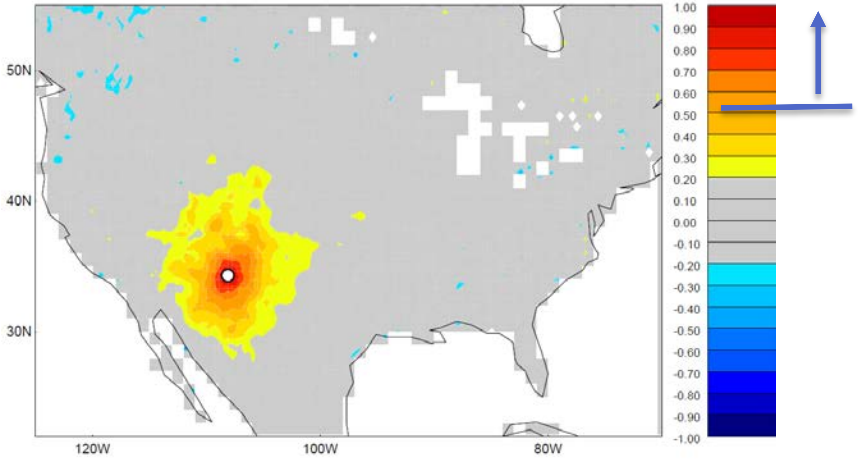
Step 1: From the map, compute the area for which spatial correlation > 0.5

Spatial Correlation Map



Area = 324,000 km^2

Spatial Correlation Map

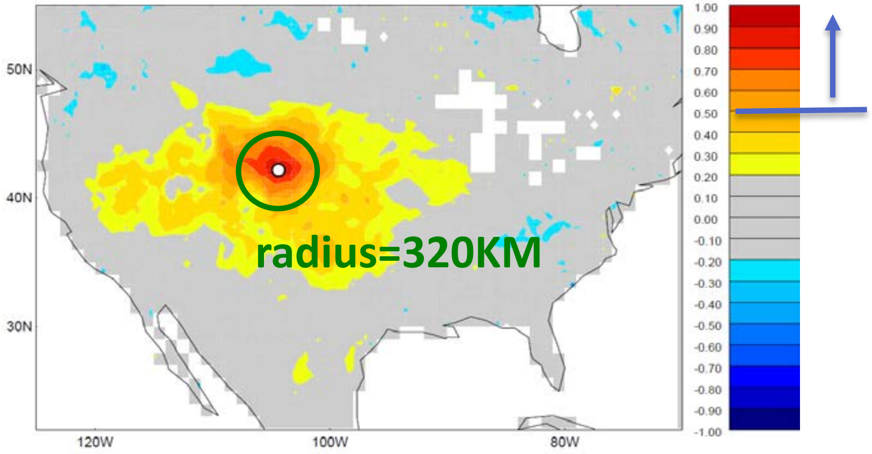


Area = 182,000 km^2

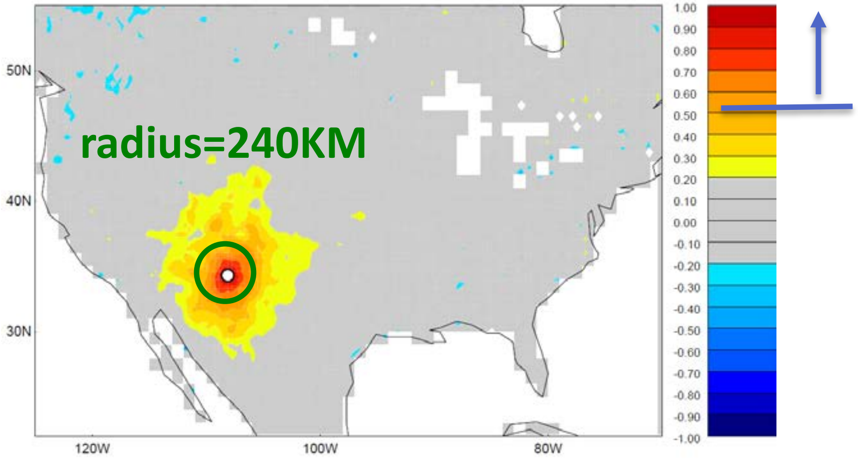
Length Scale Calculation

Step 2: Determine the circle with the same area:

Spatial Correlation Map

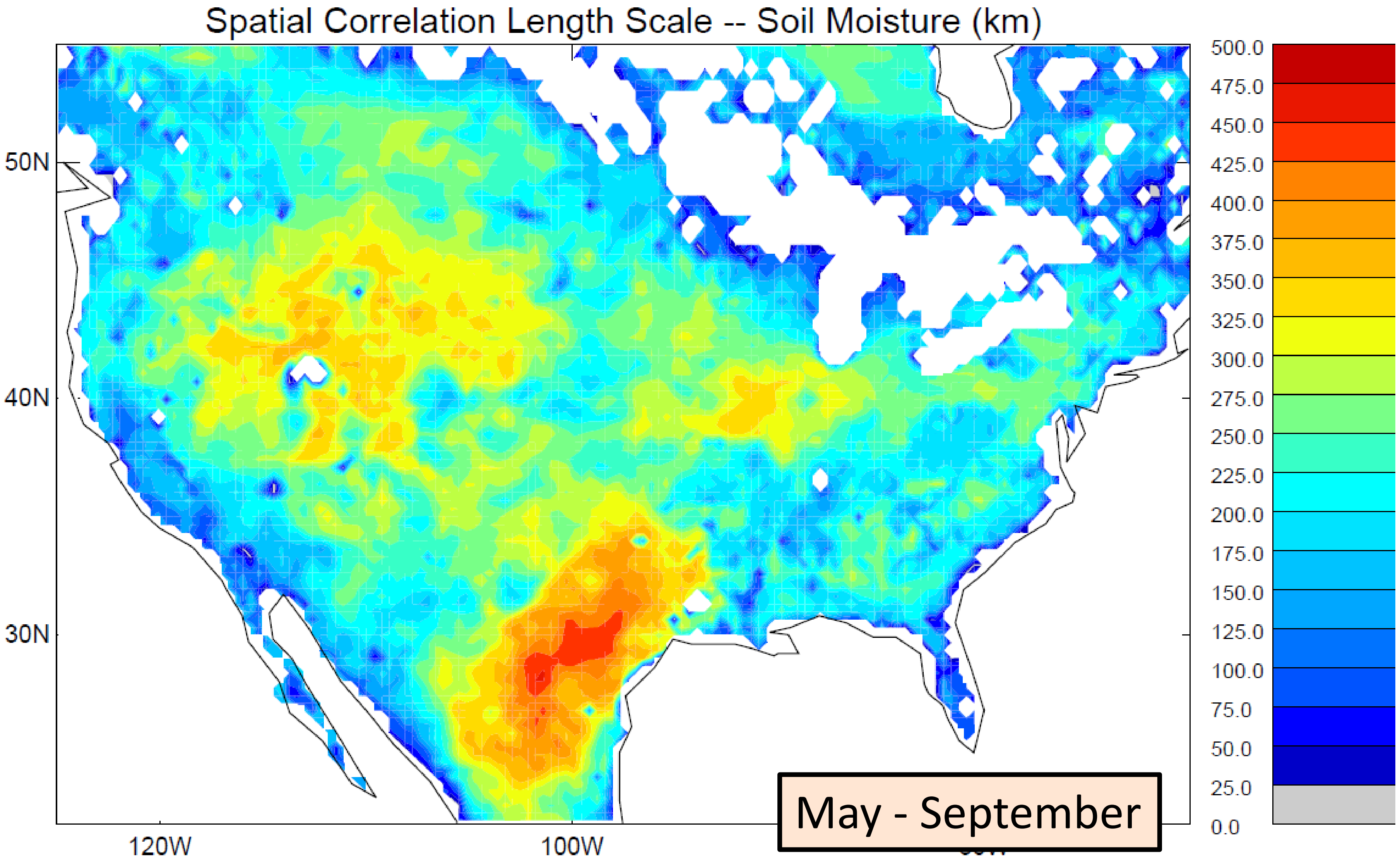


Spatial Correlation Map



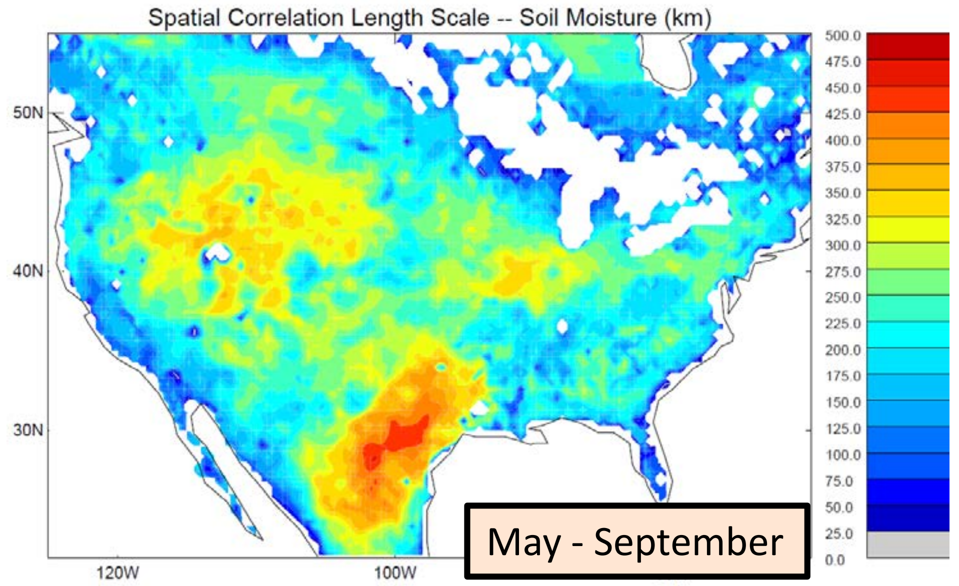
Step 3: Plot the radius of that circle at that point.

Results:


Spatial Correlation Length Scale -- Soil Moisture (km)
50N
40N
30N
120W
100W
500.0
475.0
450.0
425.0
400.0
375.0
350.0
325.0
300.0
275.0
250.0
225.0
200.0
175.0
150.0
125.0
100.0
75.0
50.0
25.0
0.0
May - September

You might guess that this pattern reflects the corresponding pattern for precipitation.

Length Scale:
Soil Moisture



Perform complementary precipitation analysis:

- Process gauge-based precipitation data (CPCU) into 5-day running means
- Compute anomalies from an approximated mean seasonal cycle
- Repeat correlation analysis to compute length scales for precipitation

→ ?

You might guess that this pattern largely reflects the corresponding pattern for precipitation.

Perform complementary precipitation analysis:

- Process gauge-based precipitation data (CPCU) into 5-day running means
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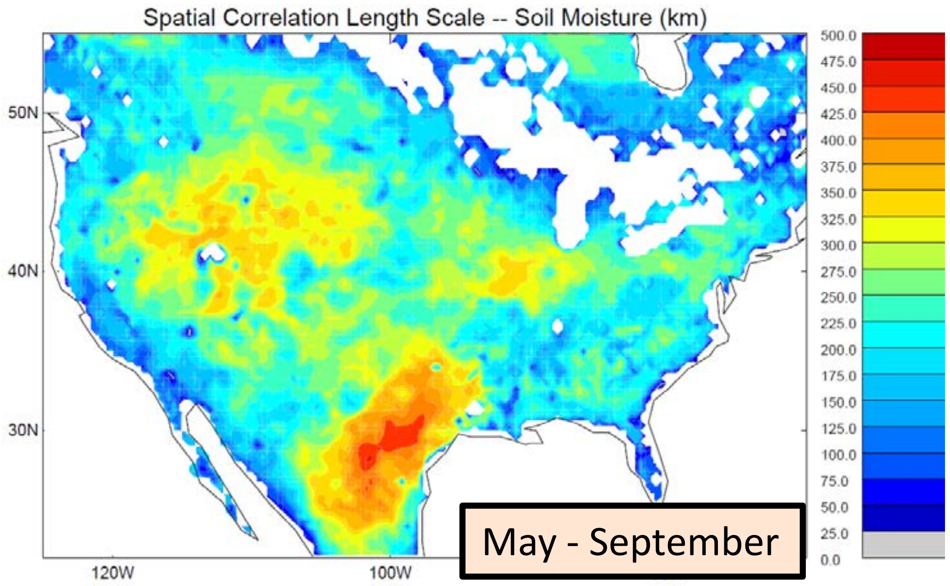
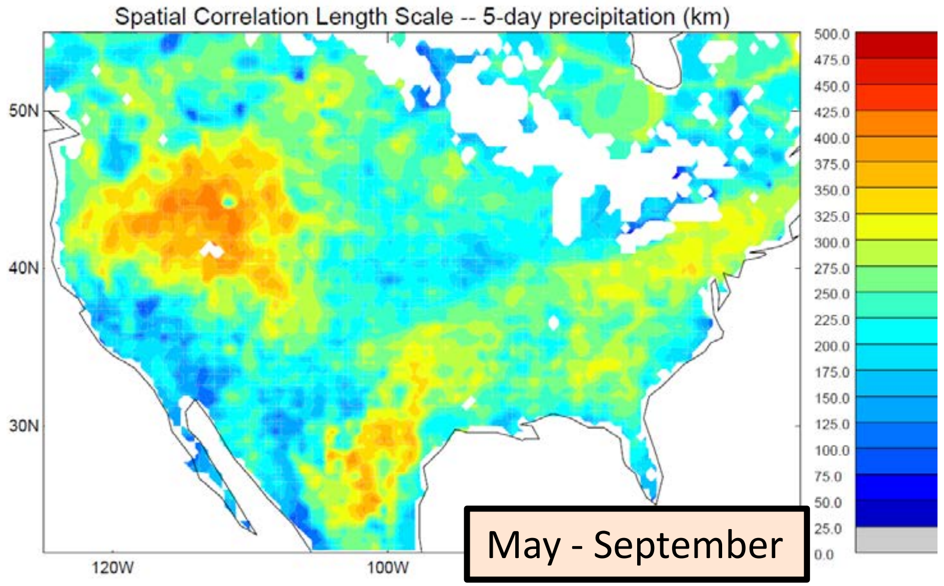
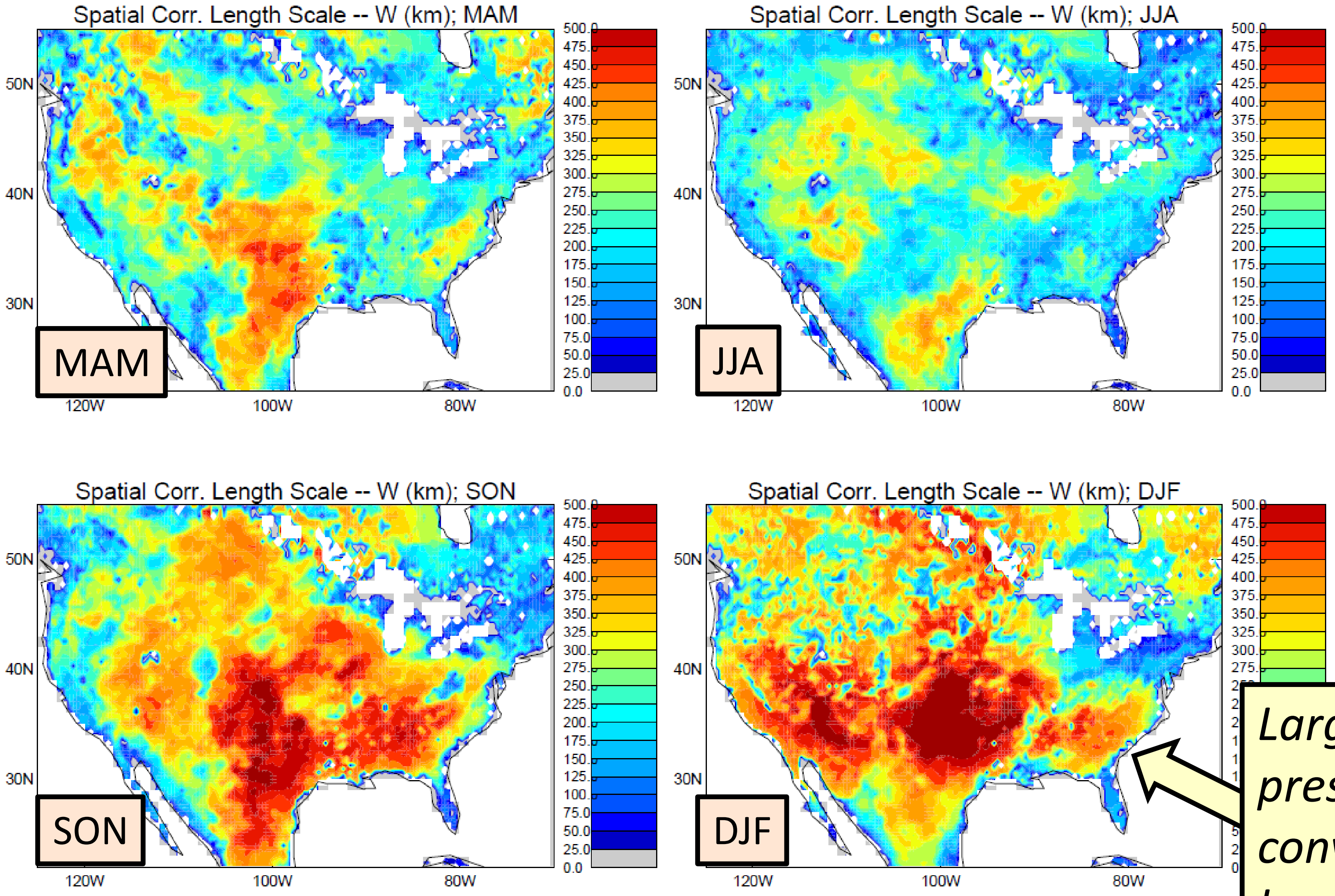
Length Scale: Soil Moisture



Length Scale: Precipitation





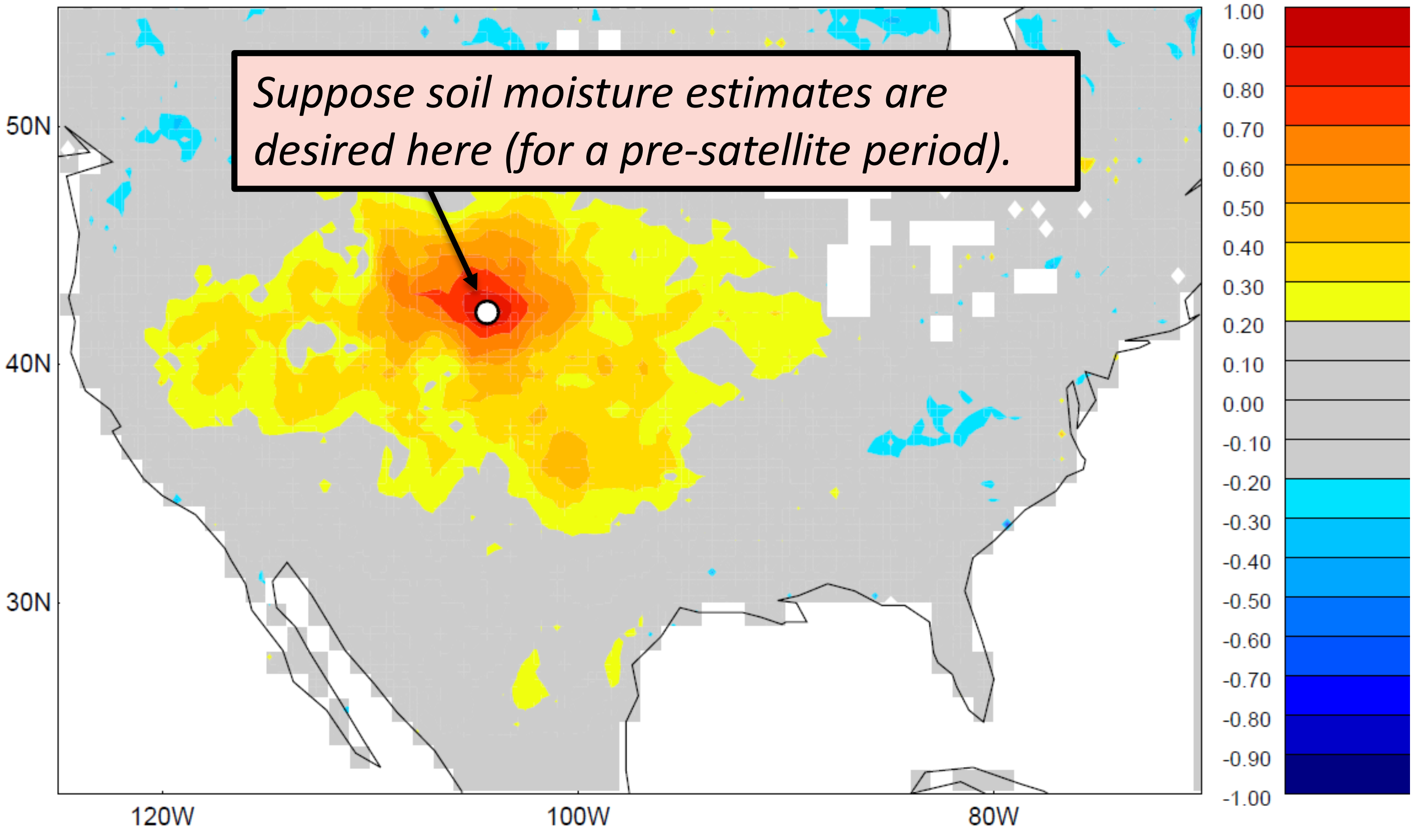
The connection between soil moisture and precipitation length scales is especially clear when considering different seasons.

Redo soil moisture analysis for MAM, JJA, SON, and DJF separately

Larger length scales presumably due to less convection / more large-scale rainfall

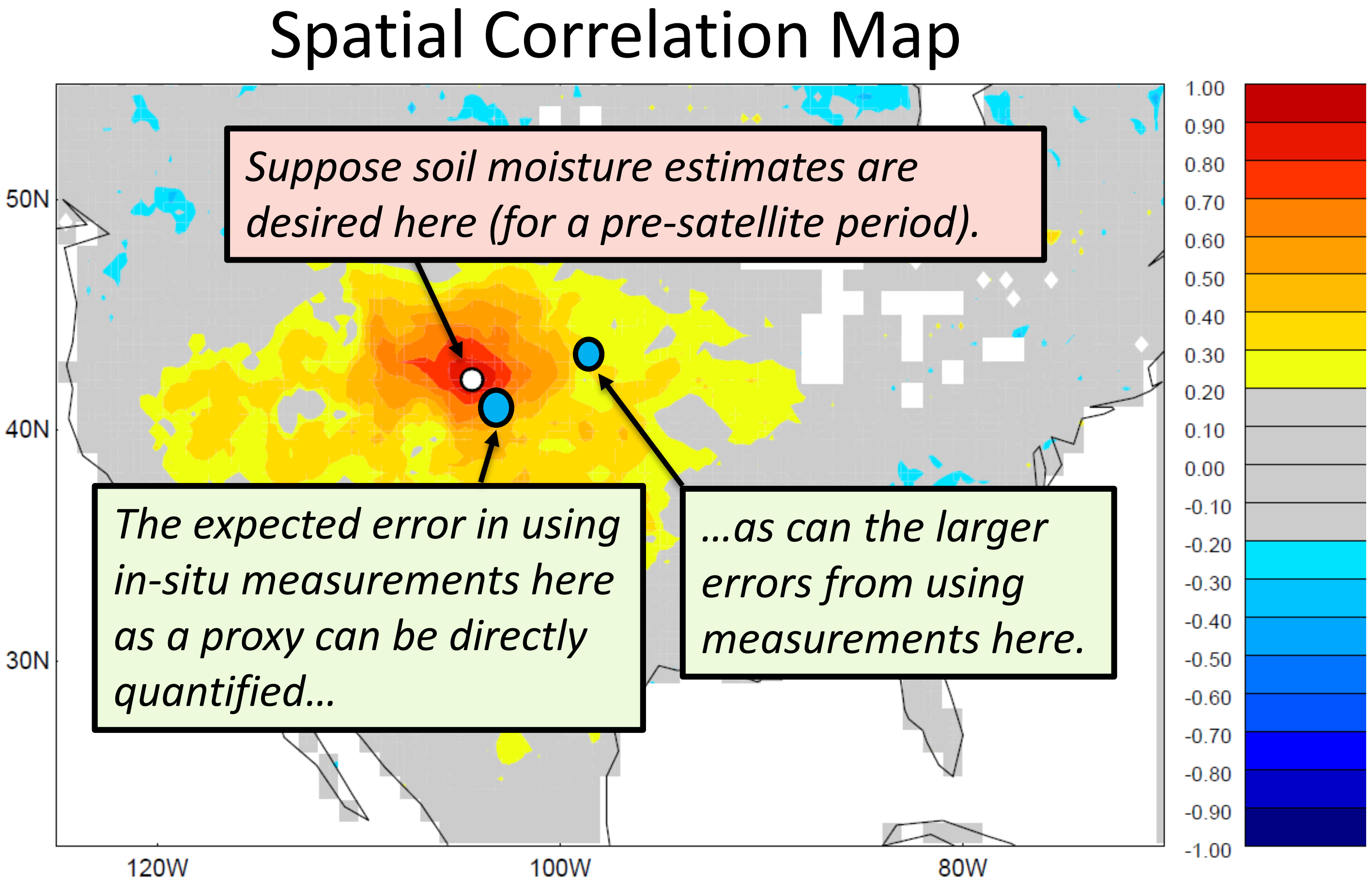
Why are these spatial correlations important hydrologically?

Spatial Correlation Map



One reason: they can help guide reconstructions of historical soil moisture data from neighboring measurements – and can provide uncertainty estimates for such reconstructions.

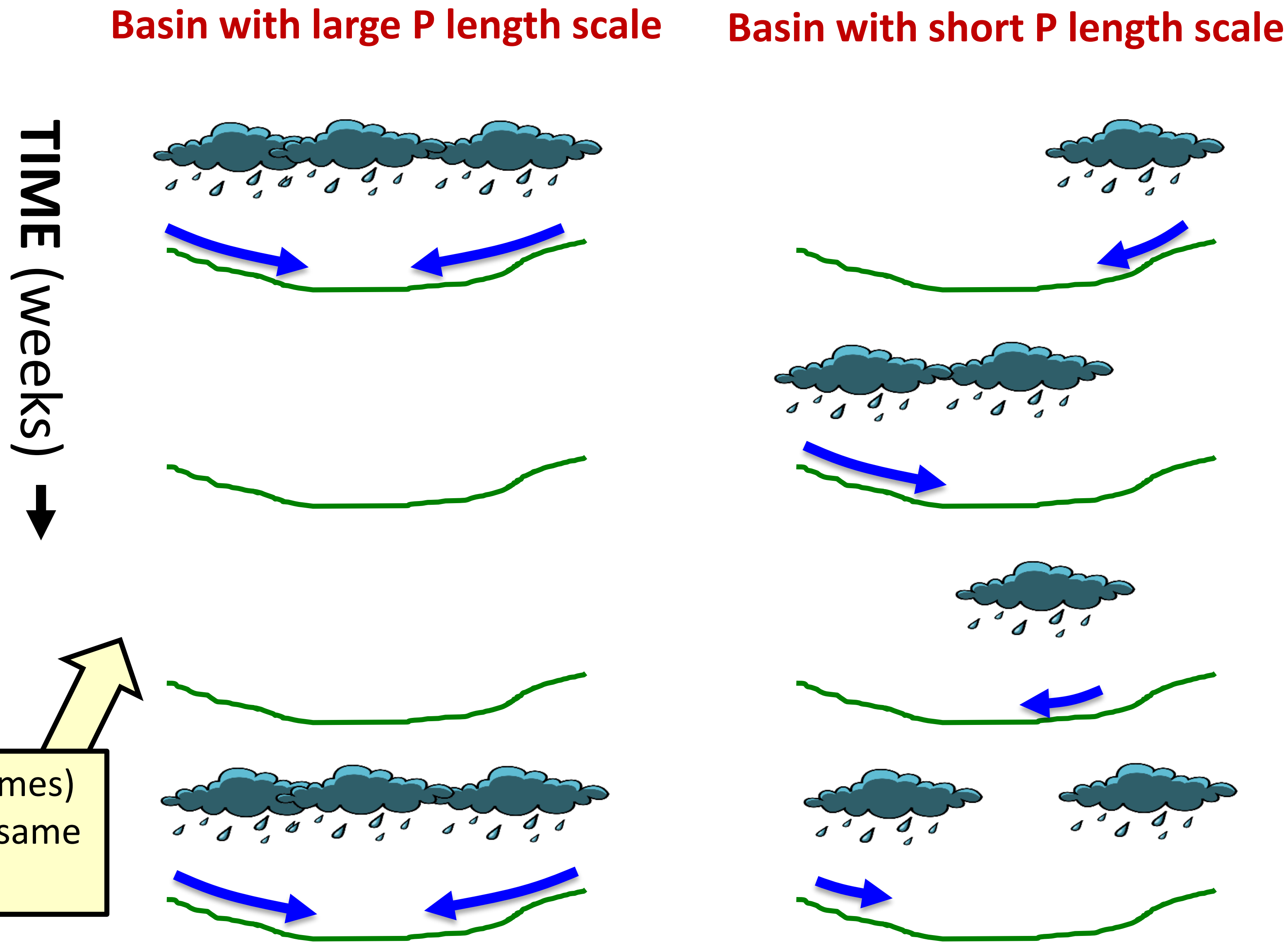
Why are these spatial correlations important hydrologically?



One reason: they can help guide reconstructions of historical soil moisture data from neighboring measurements – and can provide uncertainty estimates for such reconstructions.

Another reason why spatial correlations are important:

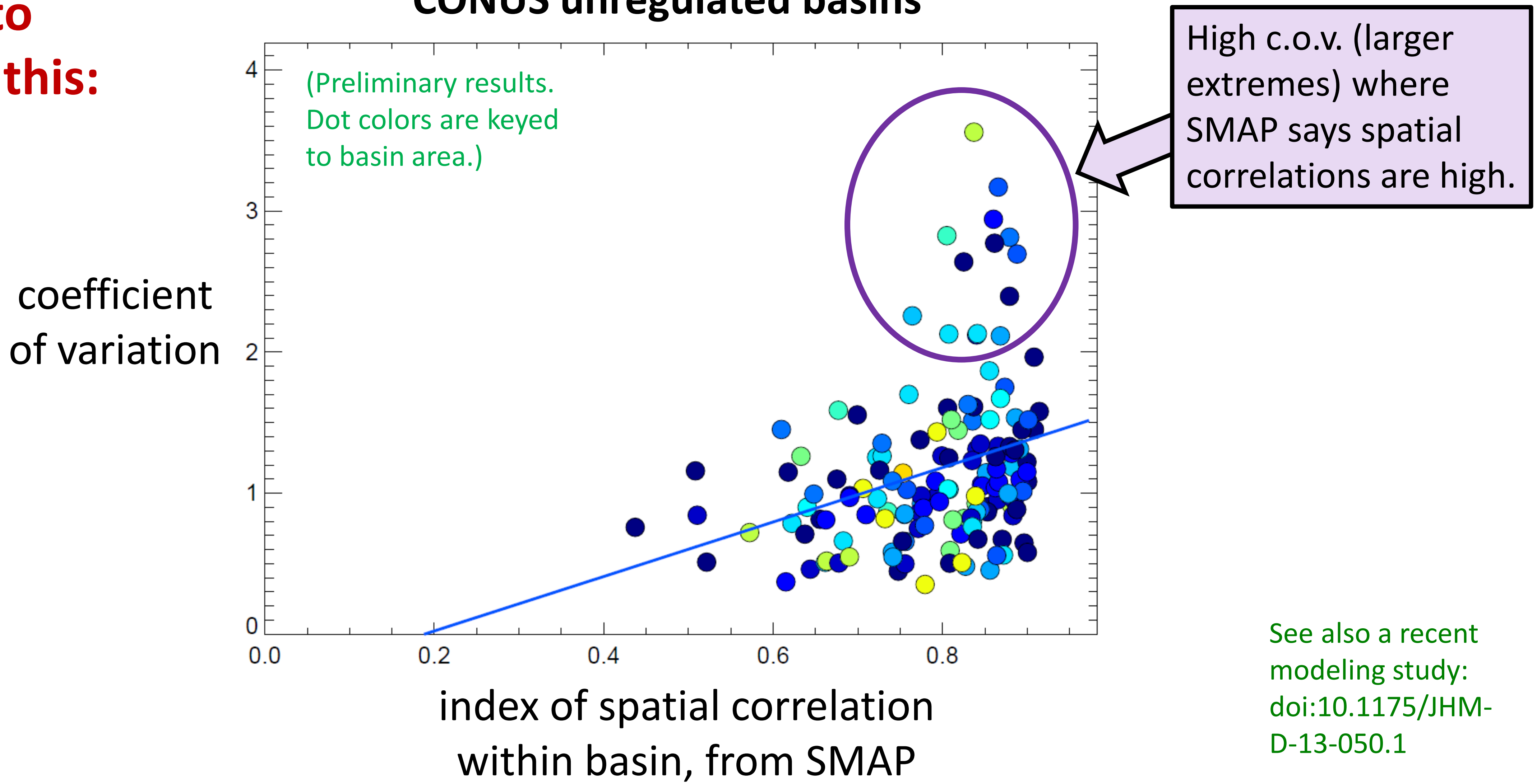
Large-scale hydrological basins respond differently to different levels of spatial correlation.



More variation (& higher extremes) in weekly total streamflow for same total rainfall

Observations appear to support this:

Variability of 10-day streamflow in CONUS unregulated basins



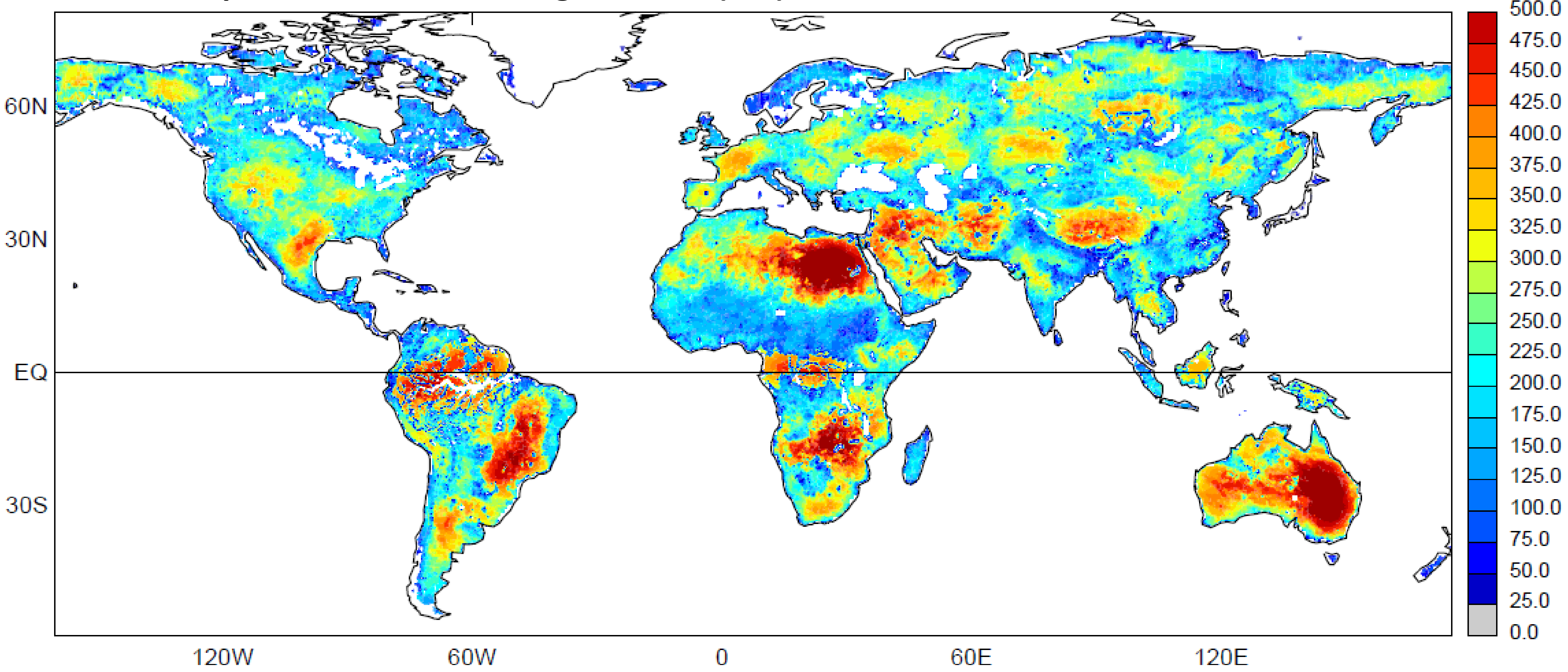
See also a recent modeling study: doi:10.1175/JHM-D-13-050.1

The ability of SMAP to capture this facet of hydrological behavior (stemming from precipitation behavior) is important:

Outside of well-gauged areas, we cannot glean this information accurately from precipitation datasets.

First: a quick look at SMAP-based length scales across the globe…

Spatial Correlation Length Scales (km), as Determined from SMAP Data



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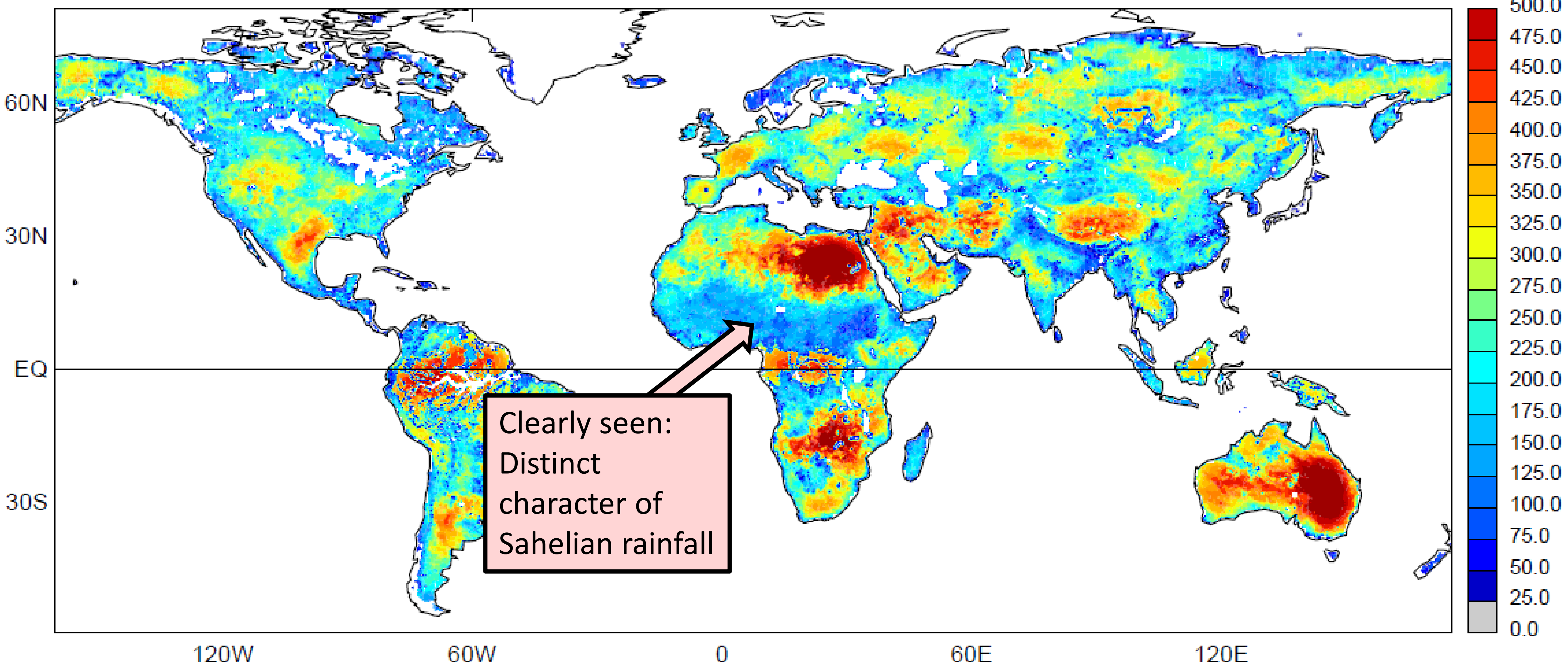

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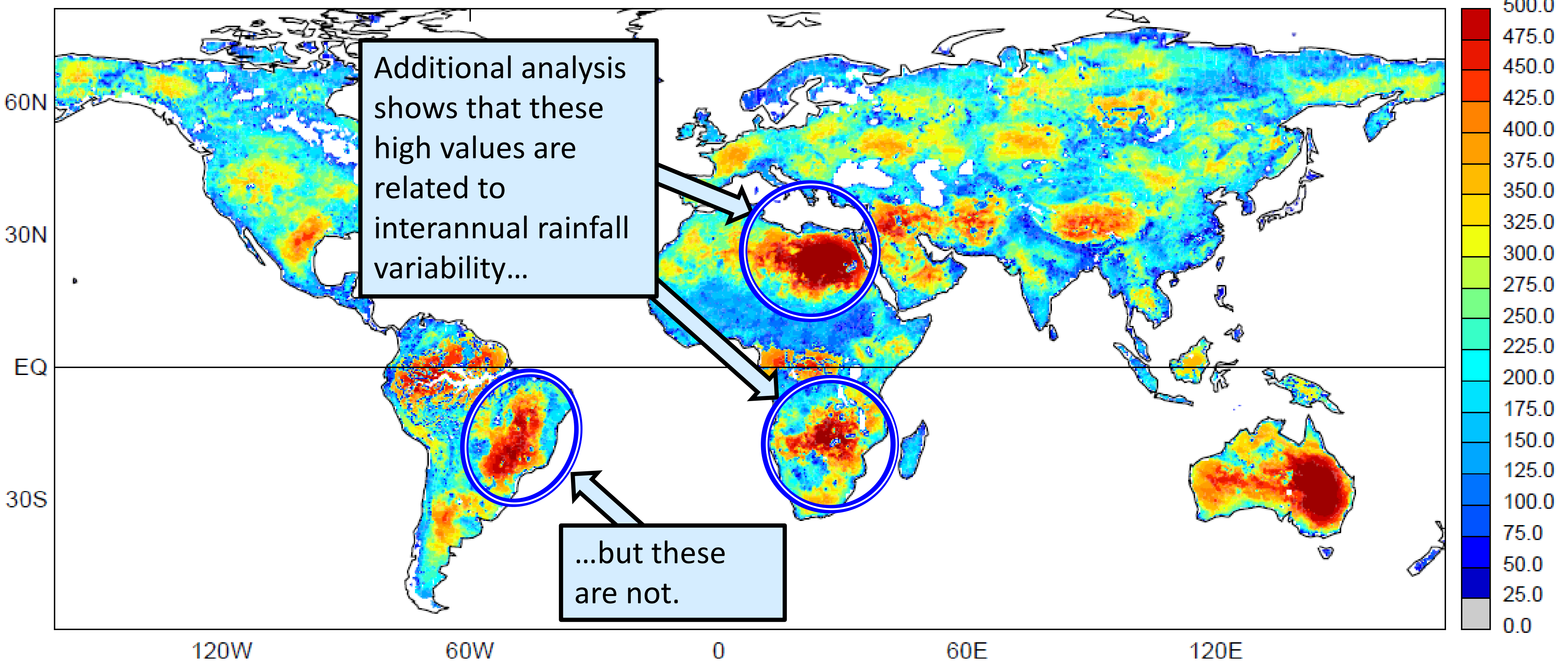
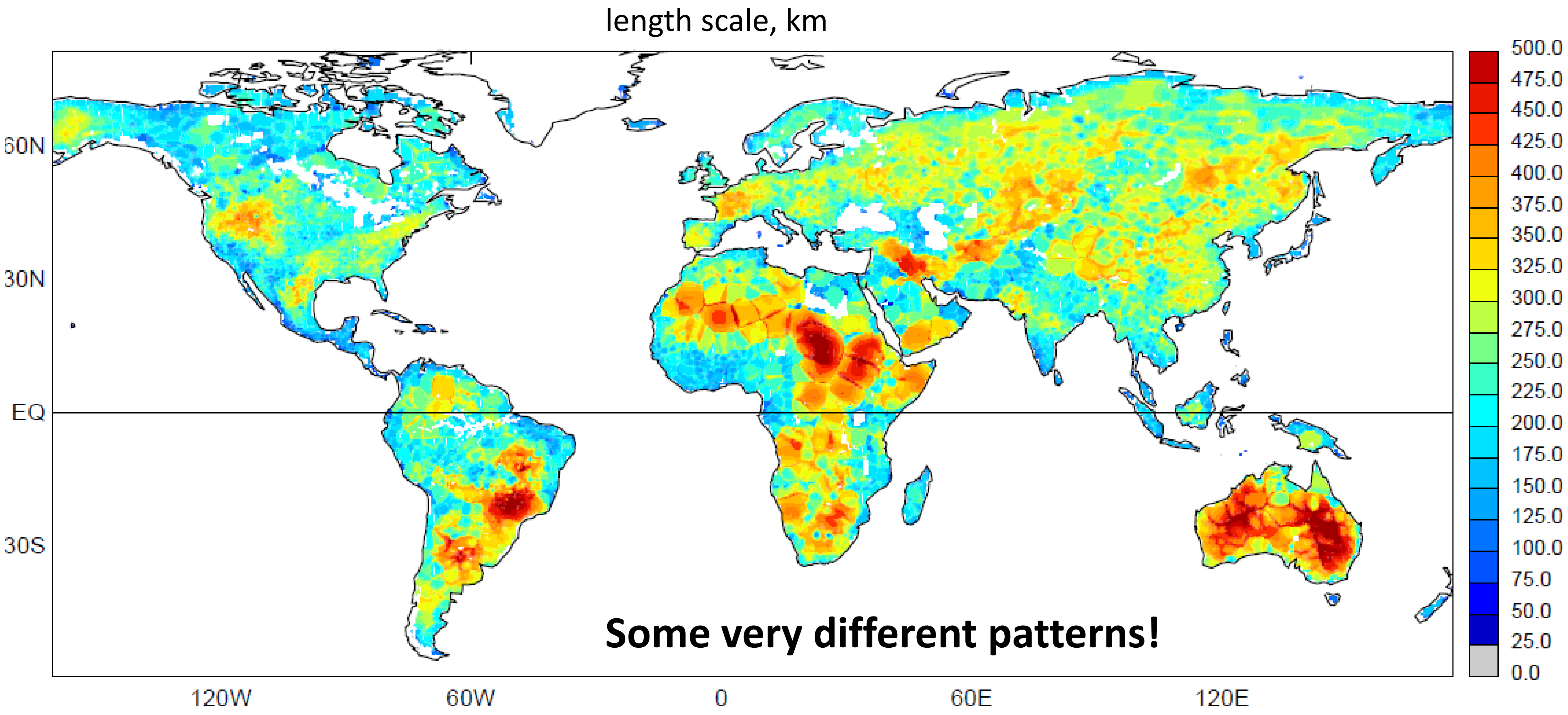
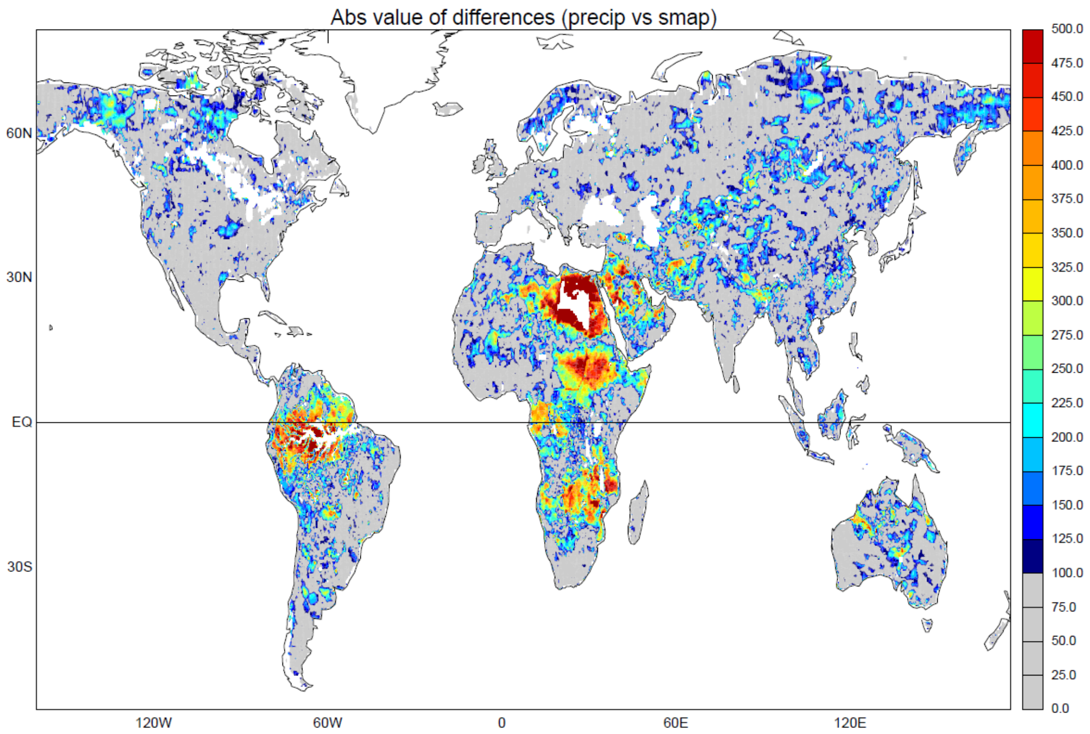


Repeat length scale calculation using CPCU gauge precipitation data



Absolute Value of Differences:

Length scale from CPCU precipitation minus length scale from SMAP



Absolute Value of Differences:

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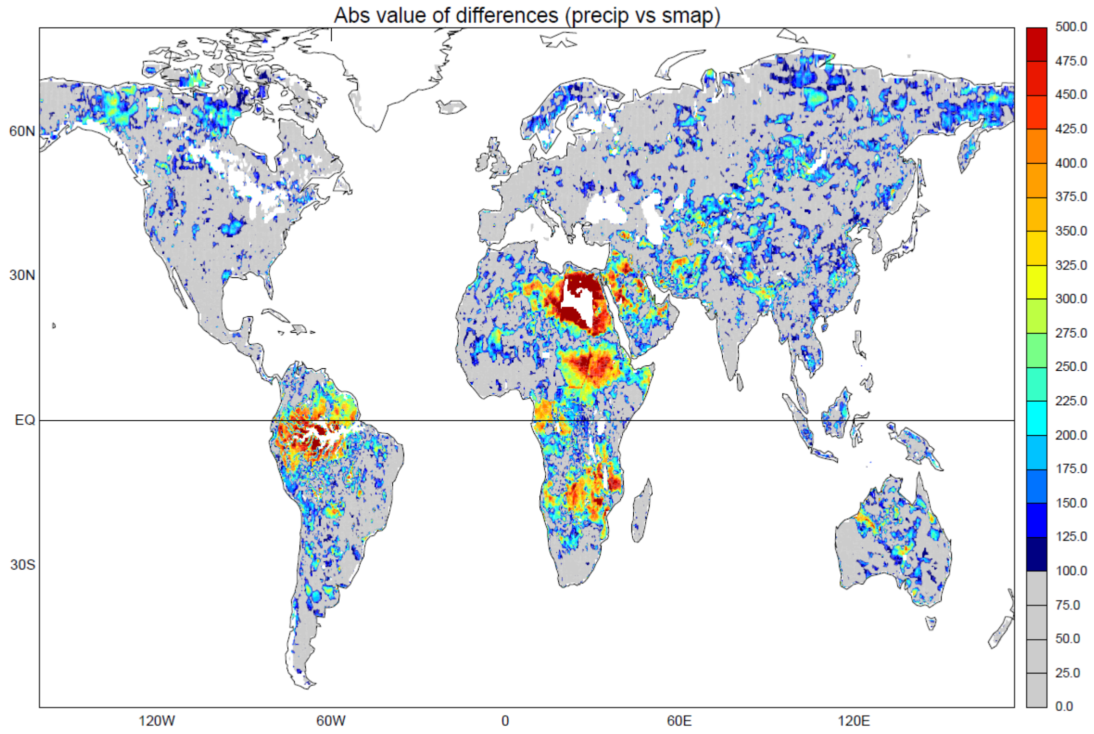
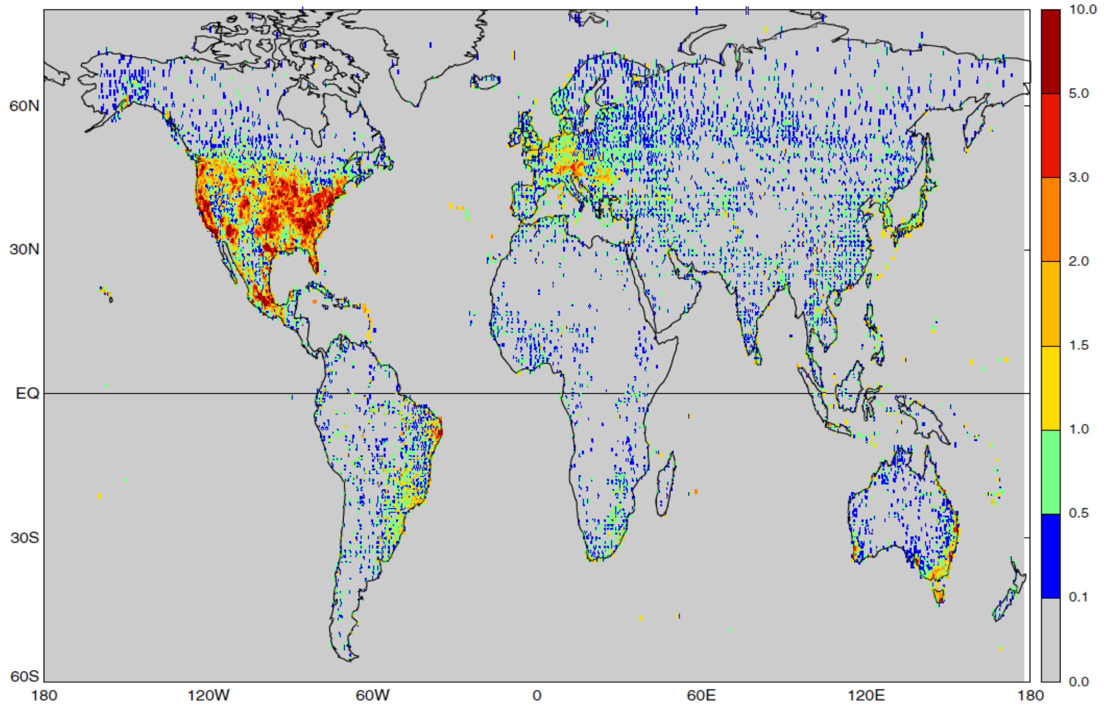


Rain Gauge Density



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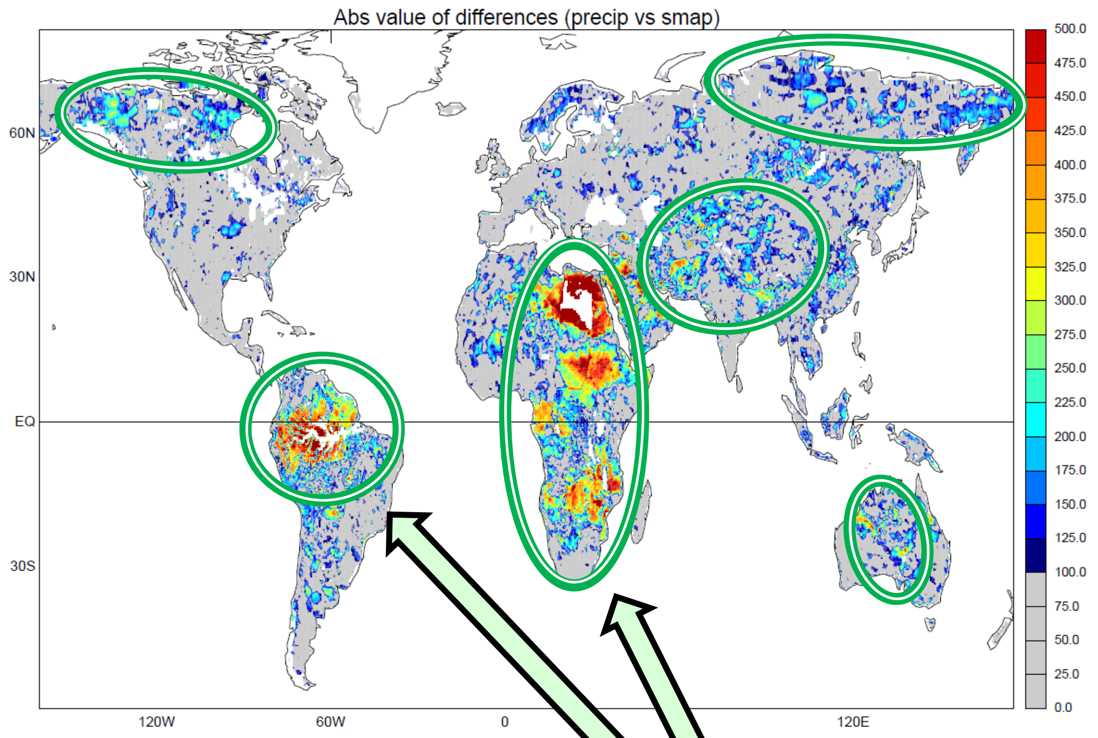
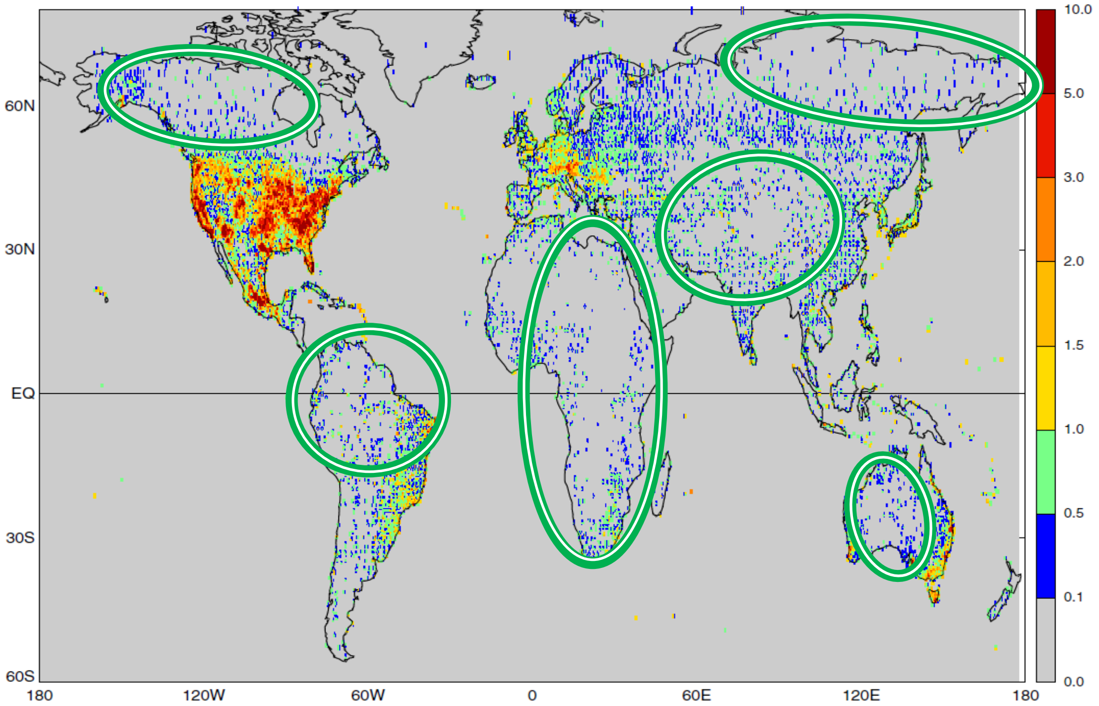


Rain Gauge Density



Differences are largest where gauge density is smallest ⇨ rainfall data are ineffective at providing length scales in such areas

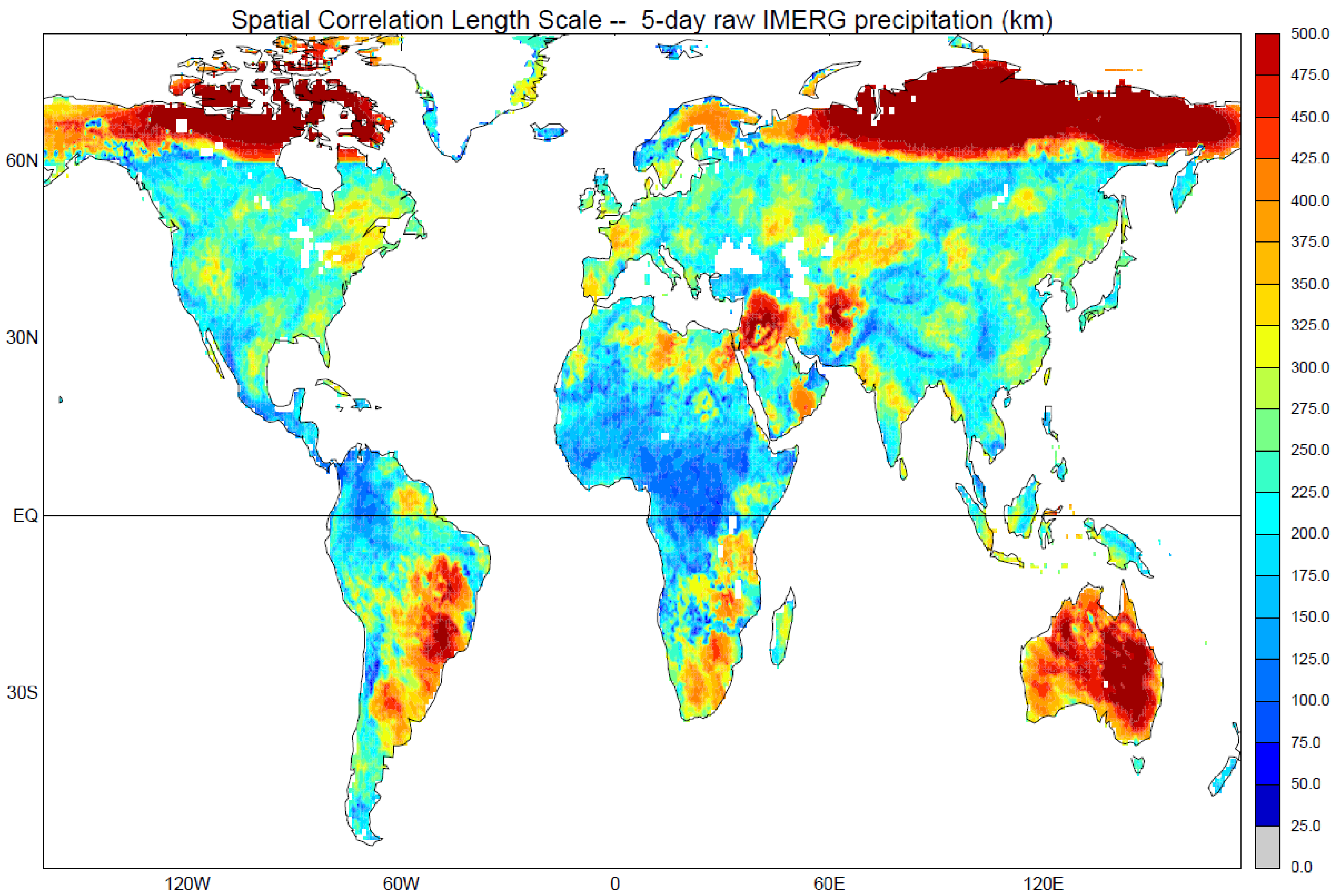
Summary

- SMAP Level 2 data can be processed to produce length scales of soil moisture correlation.

- These length scales are strongly related to precipitation length scales and, accordingly, have significant hydrological relevance (e.g., to characterize the propensity for extreme streamflows in a hydrological basin).

- SMAP may be the only reliable data source for extracting these length scales in areas where precipitation gauge coverage is poor. (Note: we also performed an analysis, not shown here, of a satellite-based precipitation product. The estimated length scales appear better – but not much better – than those derived from the rain gauge product.)

Extra Slides


Spatial Correlation Length Scale -- 5-day raw IMERG precipitation (km)
60N
30N
EQ
30S
120W
60W
0
60E
120E
500.0
475.0
450.0
425.0
400.0
375.0
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