

Introduction

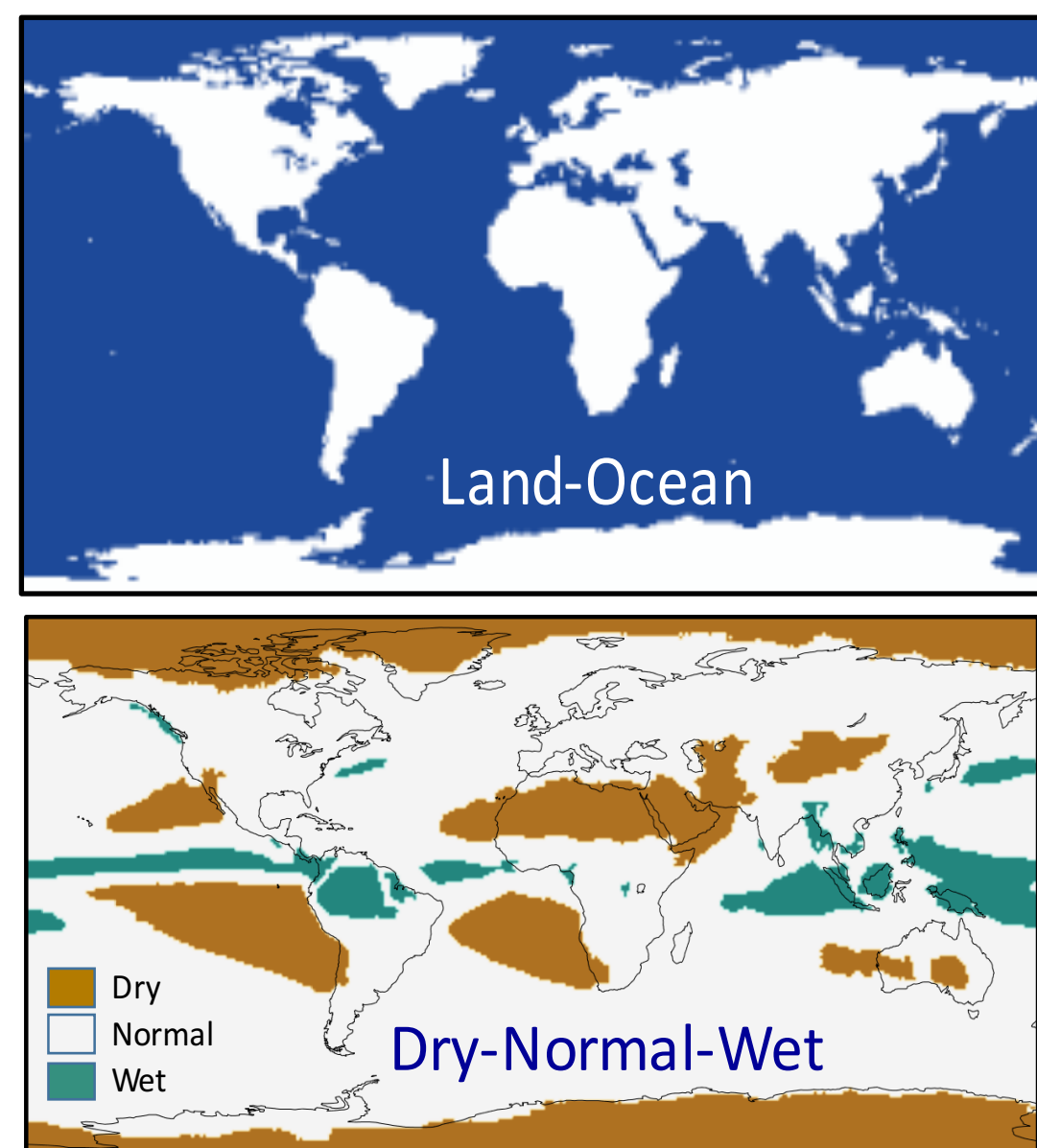
- The relationship between global monthly mean precipitation and global monthly mean surface temperature anomaly are examined using a data driven analysis method called Empirical Mode Decomposition (EMD).
- The goal is to determine if there is a relationship between precipitation and temperature in lower frequency bands that are not captured by traditional analysis.

Material and Methods

DATA

- Analysis Period: 1980-2015
- Precipitation Data: Global Monthly Average Precipitation Data Global Precipitation Climatology Project (Adler et al. 2018)
- Global Monthly Average Surface Temperature NASA (GISTEMP) Hansen et al. (2010)

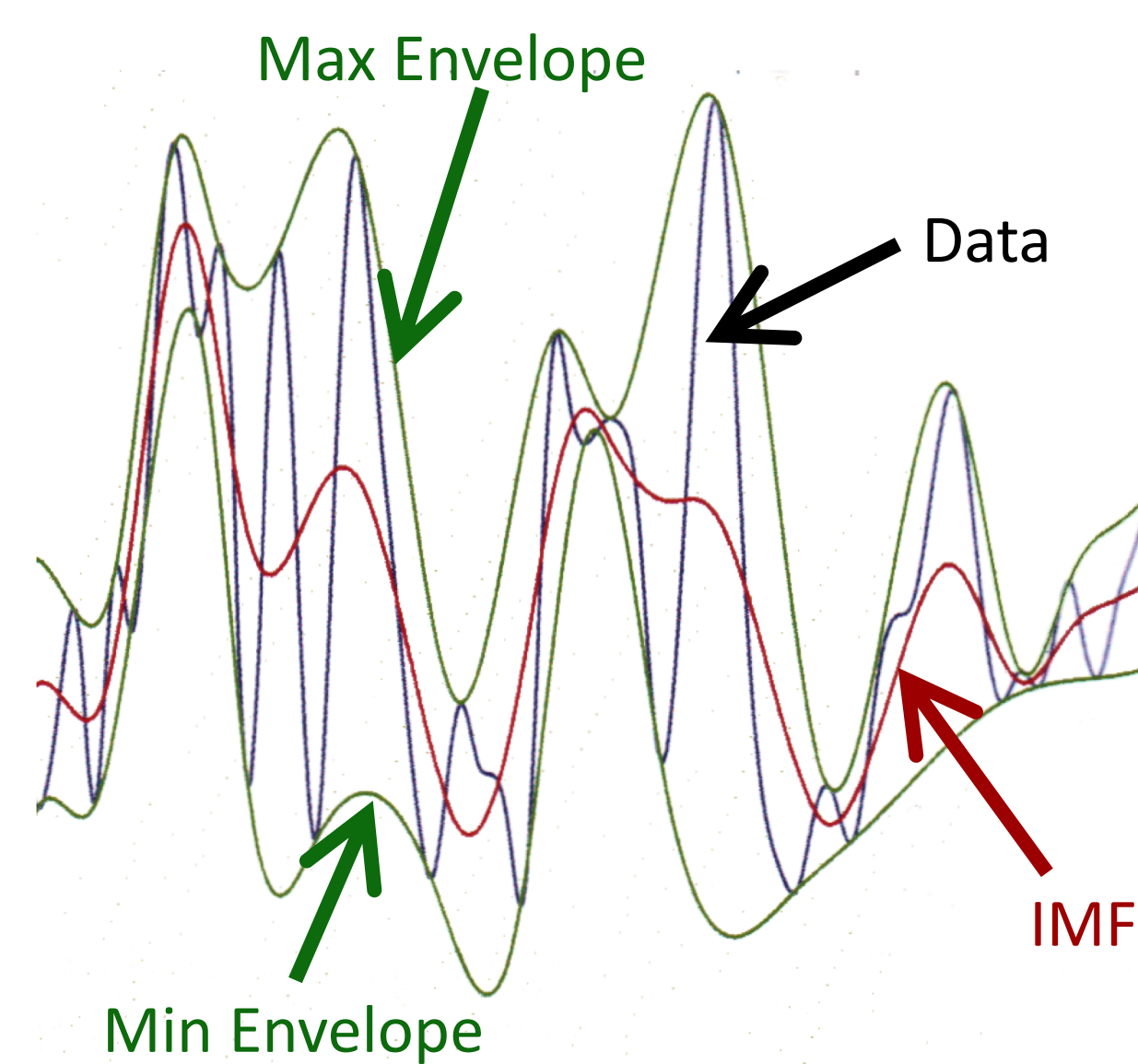
Spatial Distribution



- Six Regions include:
 - World (64800 samples),
 - Ocean (43492 samples),
 - Land (21308 samples),
- Precipitation Regimes
 - Wet regions (3425 samples) > 5 mm/day
 - Normal regions (43487 samples) 1-5 mm/day
 - Dry (17376 samples) < 1 mm/day.

Methodology

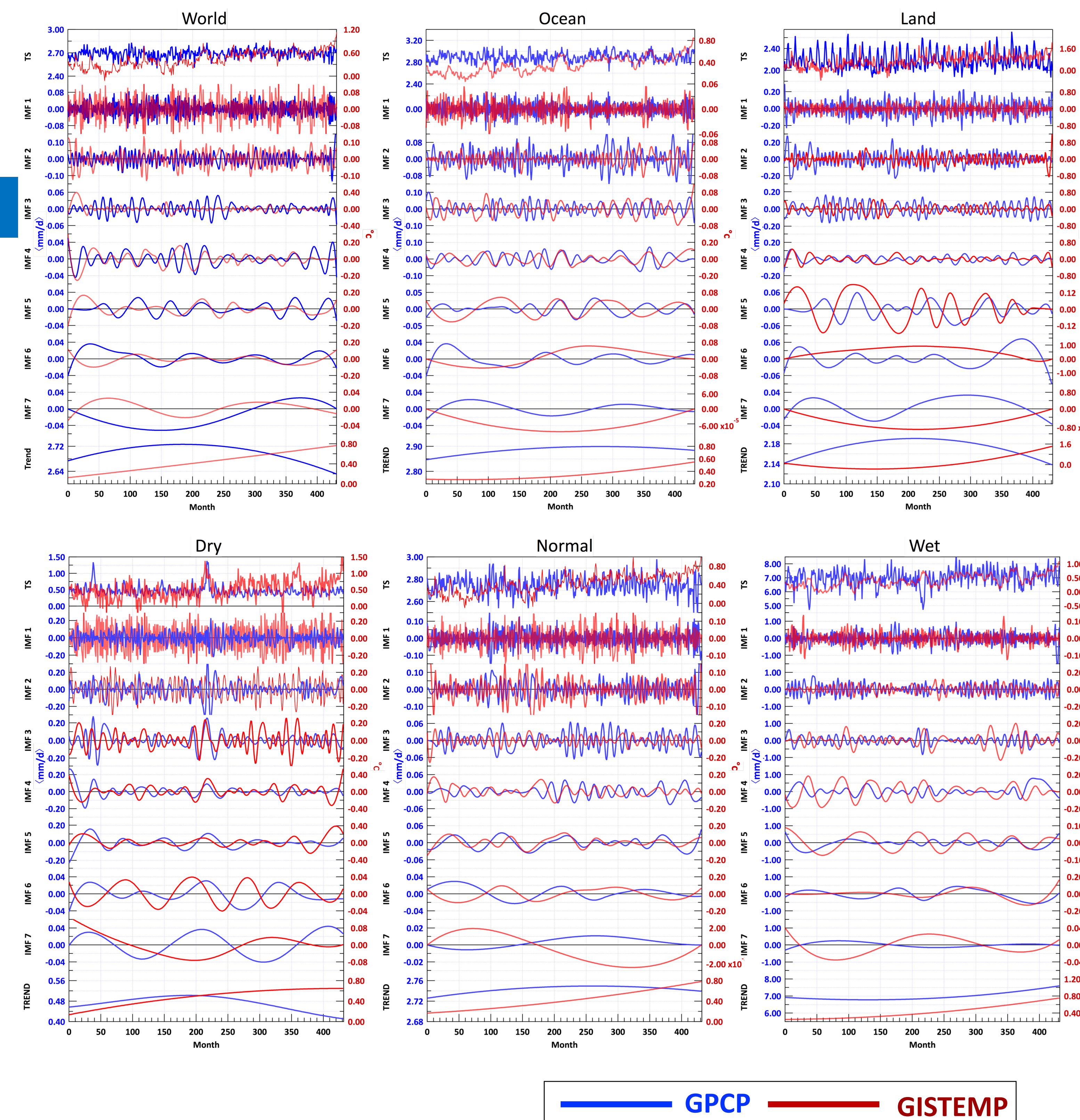
- GISTEMP and GPCP time series were deconstructed using an extended version of EMD known as Ensemble Empirical Mode Decomposition (EEMD)
- EEMD reduces a nonstationary, nonlinear time series into a set of derived oscillating time series (*Intrinsic Mode Functions-IMF*) of decreasing frequency until a non-oscillating trend is reached. This achieved by taking the mean of the extrema envelope of the initial data and subtracting it from the original time series then repeated until no additional extreme envelopes and only a final trend remains.



- Correlation analysis was performed on the decomposed GISTEMP and GPCP time series segments.

Results

Intrinsic Mode Functions



Correlation Analysis

	TS	IMF 1	IMF 2	IMF 3	IMF 4	IMF 5	IMF 6	IMF 7	Trend
World	0.118	-0.002	0.097	-0.118	0.324	0.150	-0.312	0.250	-5.090
Ocean	0.155	-0.113	-0.043	-0.015	0.267	0.108	0.022	0.183	0.500
Land	-0.112	-0.048	-0.049	-0.286	0.358	-0.053	-0.383	-0.155	-0.668
Dry	0.079	-0.840	0.026	0.088	-0.011	0.302	0.652	-0.963	0.940
Wet	0.181	-0.013	0.029	-0.071	0.045	-0.585	-0.508	-0.877	0.524
Normal	0.052	0.058	0.012	0.244	0.339	0.232	-0.289	-0.134	-0.353

N=432 Significant Values at the 5% level are indicated in bold

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Interpretation

- The EMD Process generated eight Intrinsic Mode Functions.
- Each mode represents a unique frequency band with increasing mode number representing lower frequency components of the original signal.
- Results reveal the following:
 - The EMD process reveals both linear and non-linear trends.
 - Correlations within regions increase with IMF mode number,
 - Each IMF mode corresponds to a unique frequency band
 - Mode 1 captures the monthly to seasonal variability.
 - Mode 2 captures the semi-annual variability
 - Mode 3 captures the annual variability.
 - Mode 4 Biennial variability
 - Mode 5 Pentadal variability
 - Mode 6 Decadal variability
 - Mode 7 20-30 year climate cycle
 - Mode 8 Trend

Conclusion

- All components show a strong correlation.
 - World, Land and Dry regions show negative relationships COD values ranging from 10 to 40%.
 - Positive correlations are exhibited by the Ocean, Wet and Normal regions with the wet region showing the strongest correlations ($r = 0.94$).
- Apparent wave-wave interactions between high and low frequency components appear to be observed in the IMF 1 and 2.
 - The low frequency component in these modes appears as distorted amplitude-frequency modulations that emerge in about a 10-year cycle.
 - Distortions appear to correspond to the troughs and peaks in the decadal cycle captured in IMF 6.
- EMD appears to be a uniquely valuable analysis tool for deconstructing signals from climate time series and comparing responses.
- EMD appears to capture relationships with physical meaning that are not captured by other analysis methods such as Empirical Orthogonal Functions and Fourier analysis

References

- Hansen, J., R. Ruedy, M. Sato, and K. Lo, 2010: Global surface temperature change, Rev. Geophys., 48, RG4004, doi:10.1029/2010RG000345
- Adler, R. F., M. Sapiiano, G. J. Huffman, J.-J. Wang, G. Gu, D. Bolvin, L. Chiu, U. Schneider, A. Becker, E. Nelkin, P. Xie, R. Ferraro, and D.-B. Shin. 2018. The Global Precipitation Climatology Project (GPCP) Monthly Analysis (New Version 2.3) and a Review of 2017 Global Precipitation. Atmosphere, 9(4), 138, doi:10.3390/atmos9040138.

Data Sources

- GPCP Dataset accessed 2018-02-01 http://eagle1.umd.edu/GPCP_ICDR/GPCP_Monthly.html
- GISTEMP Team, 2018: GISS Surface Temperature Analysis (GISTEMP). NASA Goddard Institute for Space Studies. Dataset accessed 2018-02-01 at <https://data.giss.nasa.gov/gistemp/>.