El Niño Related Tropical Land Surface Water and Energy Response in MERRA-2

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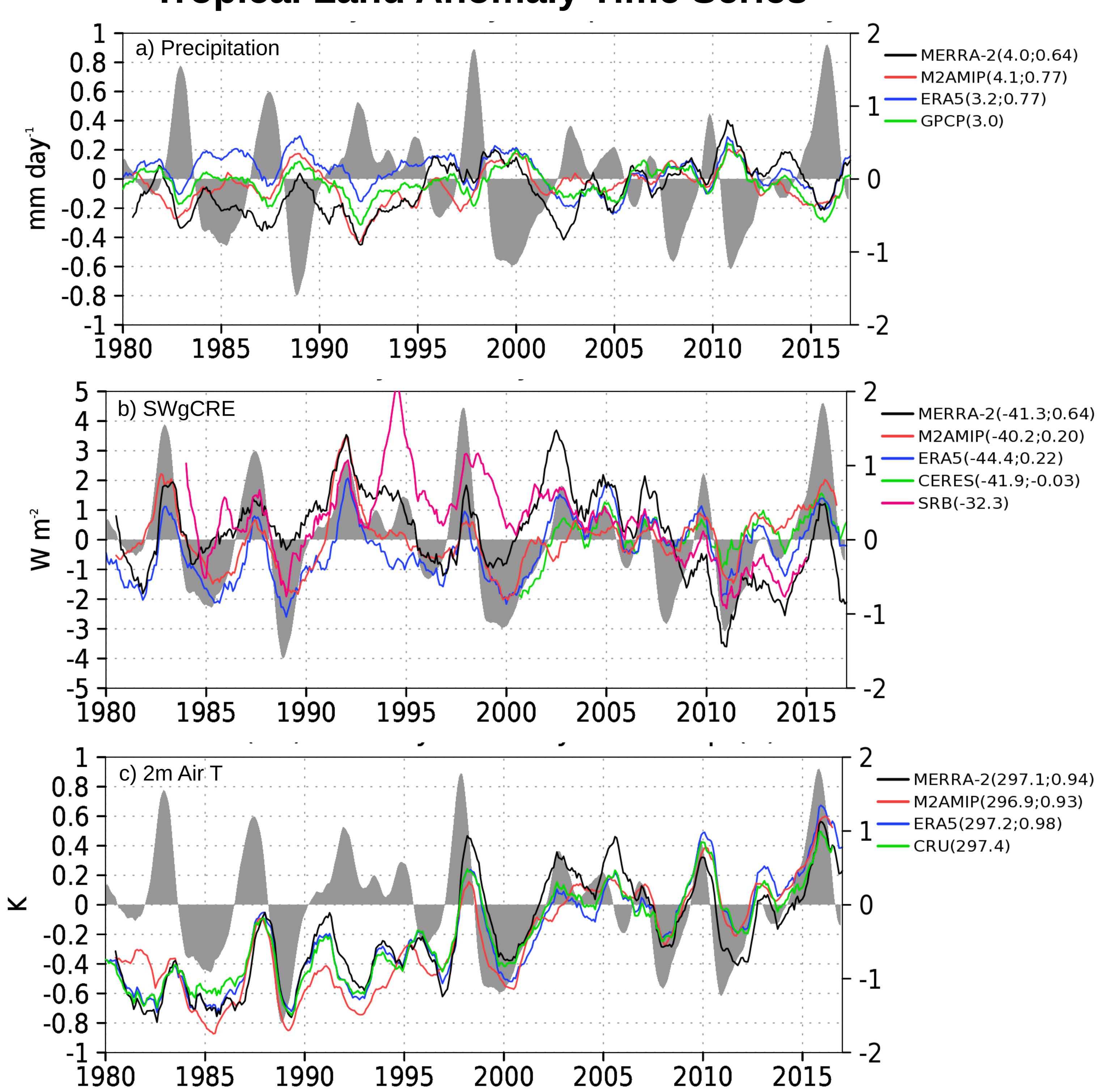
Using MERRA-2 and M2AMIP to characterize the energy links between El Niño SST and tropical land drought

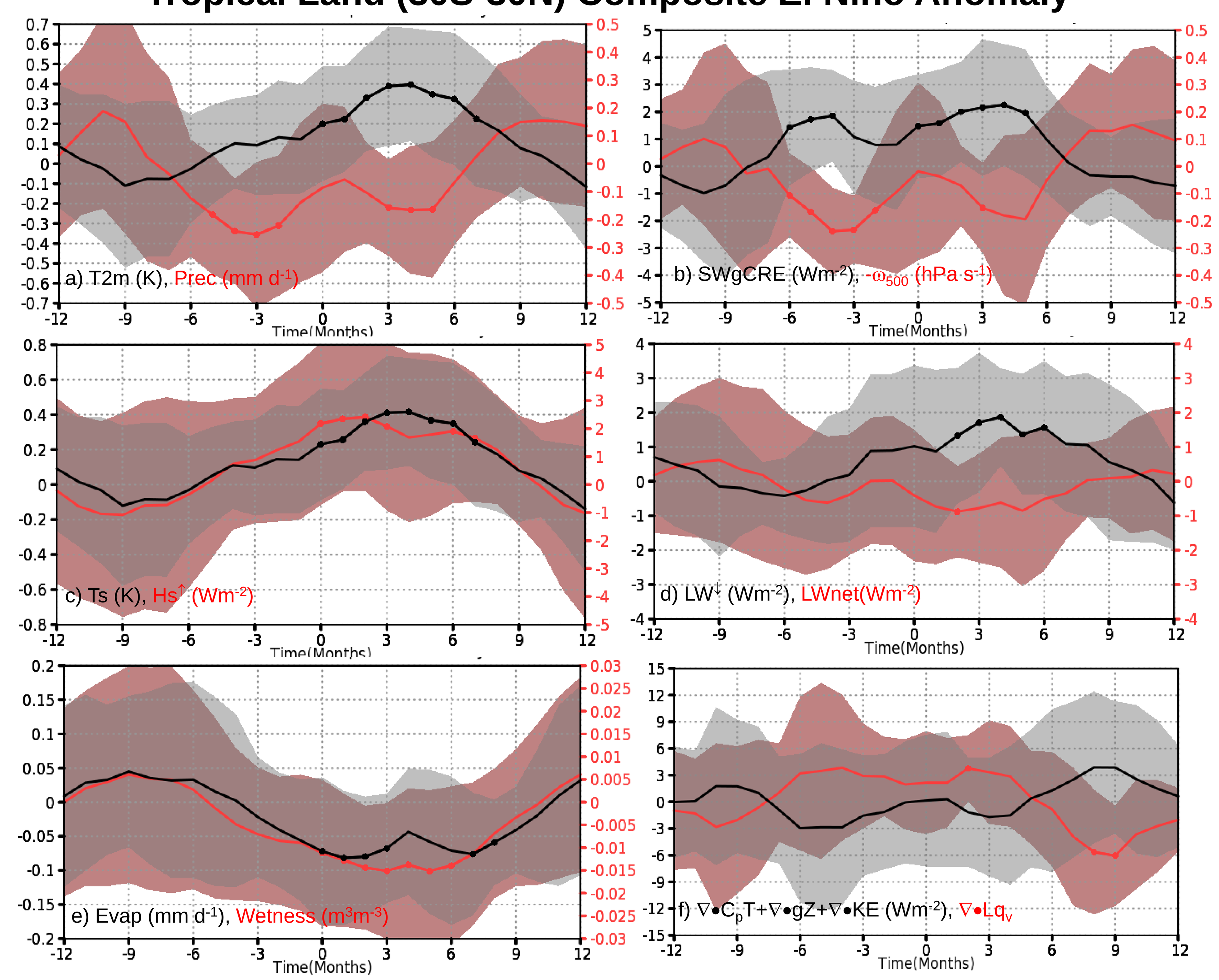
The El Niño Southern Oscillation (ENSO) is a coupled Earth system circulation phenomena that reaches all around the globe. The heat added to the atmosphere by increased precipitation produces circulation changes that have global reach and, over time, warms the entire tropical band, and much of the Earth. Many studies have noted that El Niño causes warm and dry (and sometimes drought) conditions over tropical land masses. We develop a composite analysis of El Niño to identify the predominate features of tropical land response. This analysis shows that the land's lagged response is related to a reduction clouds that leads to increase surface shortwave radiation that increases the surface temperature. The precipitation lag is somewhat longer, and then leads to a reduction in soil water and, in concert with increased SW induced surface warming, leads to increased sensible heating of the atmosphere above. The M2AMIP simulation generally captures these features, but the response is strongest with increased temporal and spatial proximity to the El Niño peak warming. The regionality of these features is also discussed, and it is noted that even the strongest individual El Niño events can vary from this composite mechanistic paradigm.

Tropical Land Anomaly Time Series



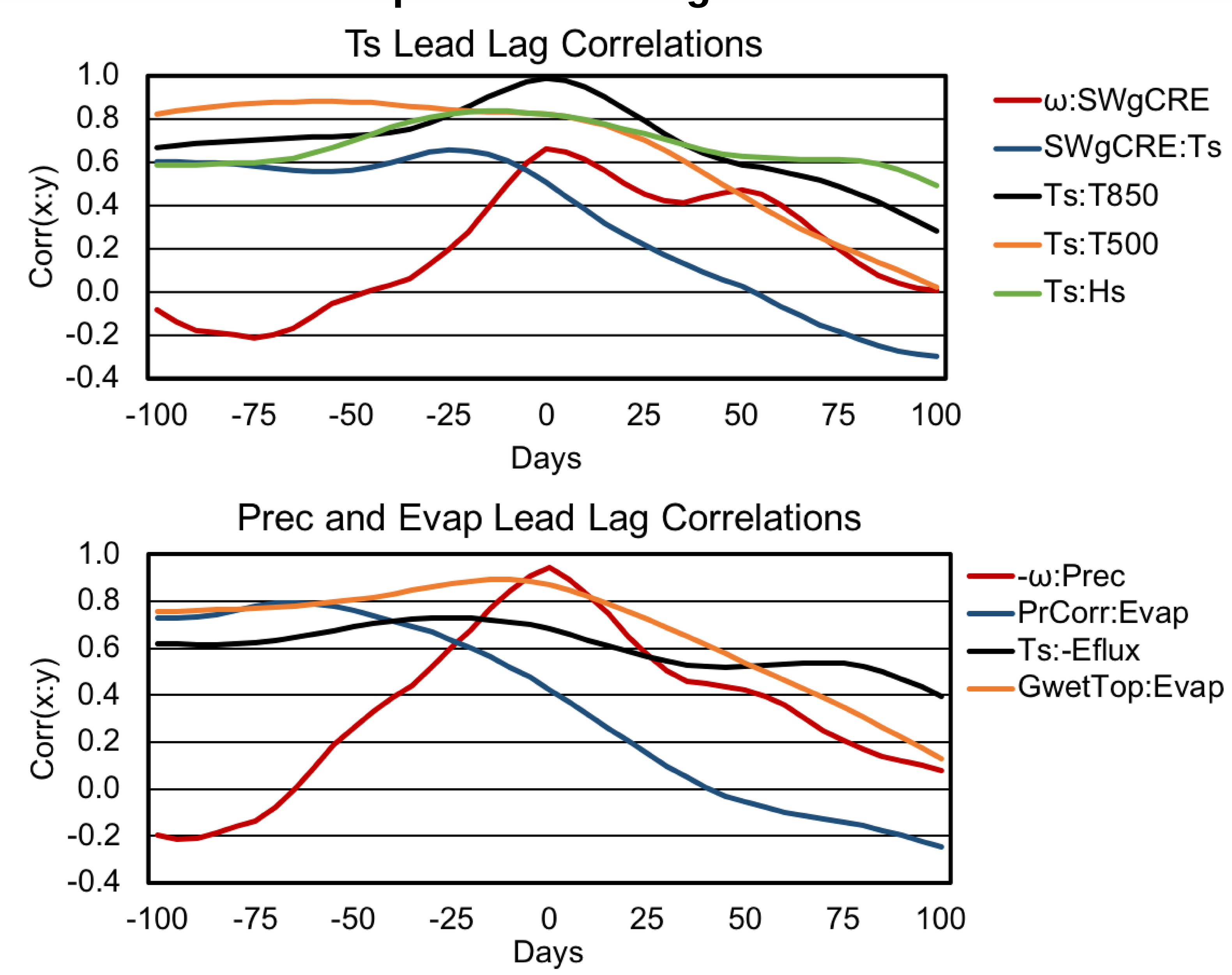
Comparison of anomalies of tropical (a) precipitation, (b) surface shortwave cloud radiative effect (SWCRE), and (c) near surface air temperature over land (30S-30N) regions for MERRA-2, M2AMIP, and ERA5 data with observations from CERES/SRB, GPCP and CRU, respectively. The anomalies remove the common mean annual cycle period (2000-2014), and have a 12-month running mean applied. The time averaged mean of the data is reported in the legend. Niño 3.4 SST anomalies (K) are grey shaded with the scale on the right axis (anomalies are 12-month running means). Mean values and correlations coefficients to the reference observations are shown in the legend. .

Tropical Land (30S-30N) Composite El Niño Anomaly



Tropical global monsoon land areas (30S-30N) composite El Niño anomaly time series for MERRA-2 (left) and M2AMIP (right) for several key quantities listed on the figure. The solid line indicates the composite average and shading indicates ± 1 standard deviation of the composite mean. Scales are color coded for each line. Dots indicate anomalies significantly different from zero (at 90% confidence). The variables are near surface air temperature (T2m), precipitation, SWgCRE, vertical velocity ($-\omega_{500}$, directed positive for upward motion, at the 500hPa level), surface temperature (Ts), sensible heat flux (Hs), downward longwave radiation ($LW^{\downarrow}$) and net surface longwave radiation (LWnet, directed downward positive), dry static energy (DSE) divergence ($\nabla \bullet C_pT+\nabla \bullet gZ+ \nabla \bullet KE$), heating due to water vapor divergence ($\nabla \bullet Lq_v$), surface evaporation (Evap) and surface soil wetness. DSE and water vapor divergence are computed from the model output fluxes of q_v, C_pT and gZ, and do not include mass corrections to the wind.

Pentad Composite Lead/Lag Correlations



Tropical land global monsoon region lead lag correlations for a) surface temperature variables and b) water cycle variables. The correlations are developed by from the MERRA-2 pentad time series, with leading correlations as negative days and lag correlations are positive days for pairs of variables x:y, where the first variable (x) is computed as leading or lagging the second variable (y). Correlation units are dimensionless, and the values are computed over 101 data points (8 months of pentads) and values of 0.26 are significant at 99% confidence. Here, 0 days refers to contemporaneous correlation of pentads, not the M=0 El Niño peak.

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