Vegetation response to extreme climate events on the Mongolian plateau from 2000-2010

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Introduction

Extreme climatic events on the Mongolian Plateau have lead to severe summer droughts as well as extreme winters in the last decade. The objectives of this study are to quantify spatio-temporal changes in vegetation greenness anomalies using long term earth observation data records and possibly explain the climate drivers of these anomalies using meteorological data trends.

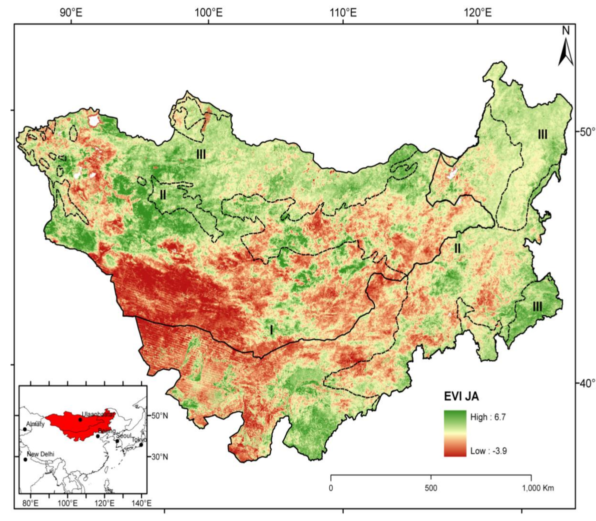

Figure 1

Our research questions are: What are the vegetation responses to these climate extremes, over space and time in the last decade as compared to long term means on the plateau?
Were there any significant differences between the biomes, especially during the extreme summer drought of 2000-02 & 2009 and winter *dzud* of 2010?

Methods

We evaluated standardized anomalies (*sa*) of satellite based data, expressed as

$$sa = \frac{x - \bar{x}}{\sigma}$$

- where, *x* is the standardized anomaly of a biophysical variable for the dry season mean of a specific year (2000-2010) as compared to the long term growing season mean, and standard deviation, σ, over the past decade.
- MODIS monthly composites of vegetation greenness (EVI, from MOD13A3), land surface temperature (LST, MOD11A2) and shortwave White Sky albedo (MCD43B3) with a spatial resolution of 1km were used. We also tested EVI2 from Vegetation Index and Phenology(VIP) MEaSUREs product and the monthly TRMM 3B43v.7 product to validate the VI anomalies
- We used the highest quality pixels for our MODIS and VIP products, with pixel reliability flag = 0 to exclude cloud and/or aerosol contaminated pixels using quality control (QC) bit masks.
- We stratified the heterogeneous Mongolian plateau into its constituent biomes (desert, grassland and forest) and major political divisions (Inner Mongolia & Outer Mongolia) to enable the comparison of vegetation between biomes and to avoid confounding effects in interannual comparisons of anomaly trends.
- We plotted frequency histograms of the anomalies to track the temporal variation over the decade and then binned the data using MATLAB® software to quantify negative large anomalies (< -1 σ) as percentage of vegetated area.

Figure 1: Standardized anomalies (July-August 2010) of MODIS-derived EVI, (MOD13A3), on the Mongolian Plateau, as compared to decadal mean, overlaid with terrestrial ecoregion (WWF) biome boundaries, desert (I), grassland (II), forest (III).

Figure 2: Standardized anomalies of EVI2, White sky albedo and EVI in 2001 (a,c,e) and 2009 (b,d,f) summer drought. Negative VI anomalies correlate with positive albedo anomalies (a & e correlate with c). VI anomalies are also validated by TRMM 2001 & 2009 July-August anomalies (g & h) respectively. January- February LST anomalies in 2001 and 2010 (i & j).

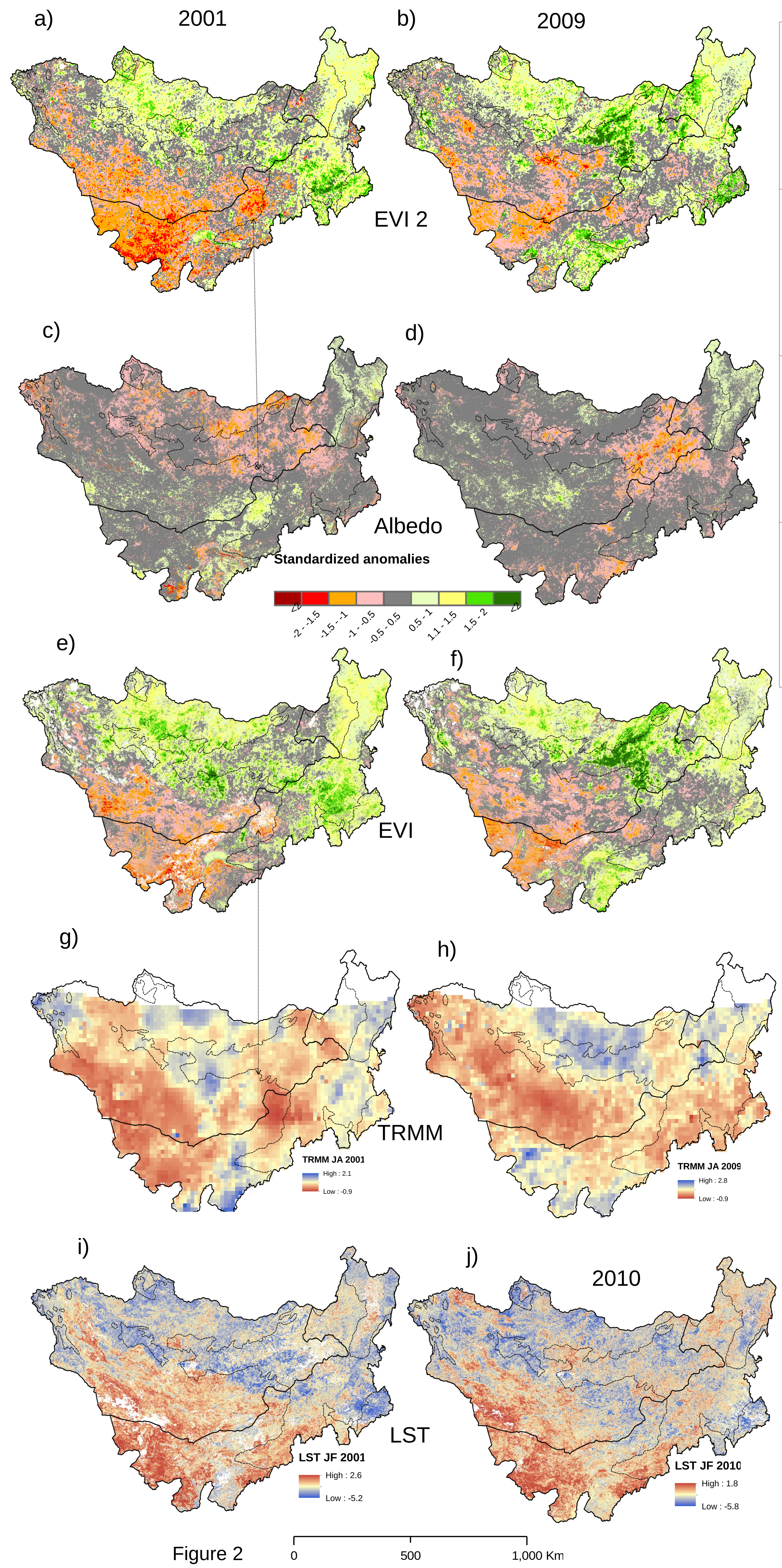

Figure 2

Results

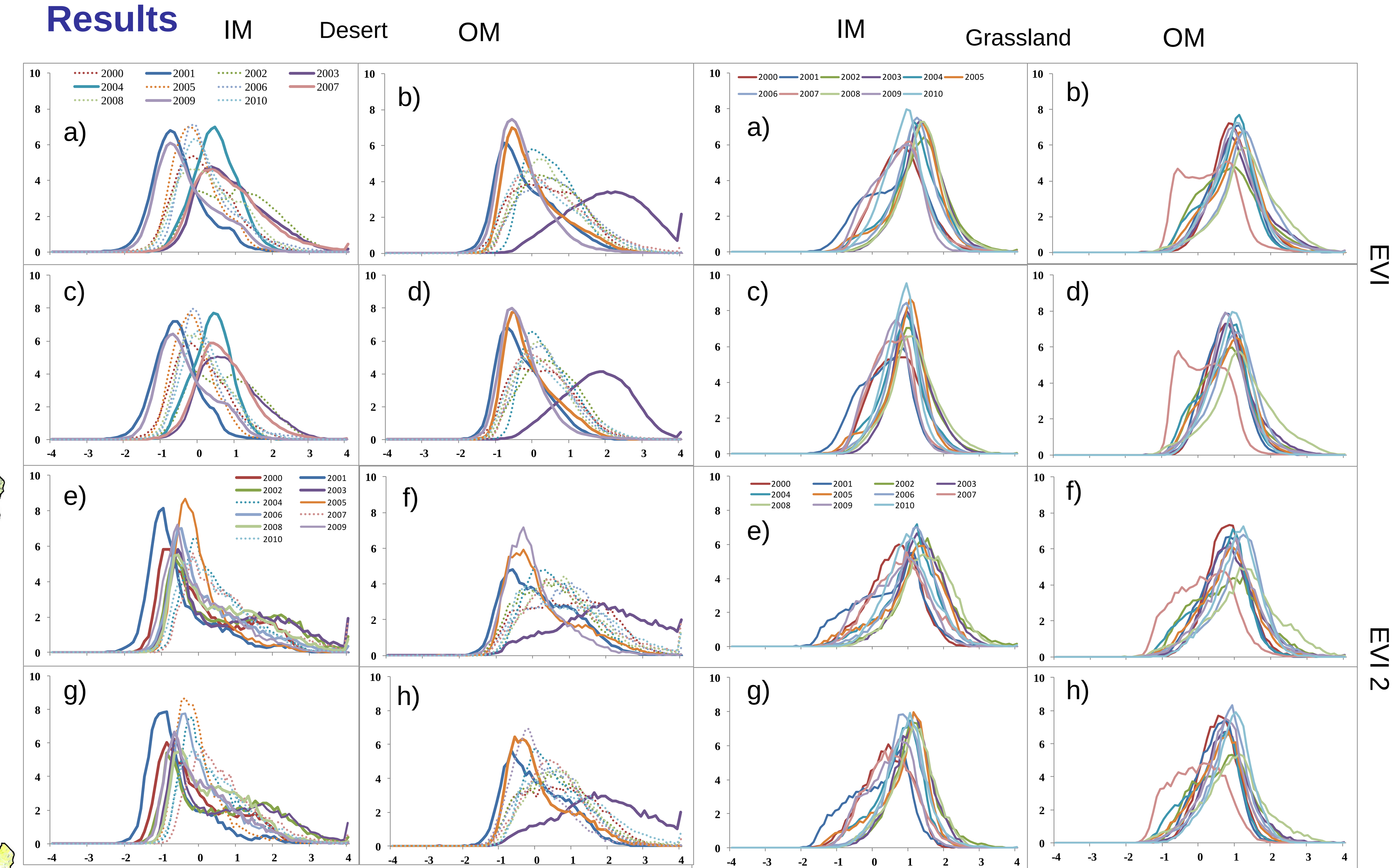

Figure 3: Frequency distributions of standardized MODIS EVI & VIP EVI2 July-August (a, b, e, f) and June-July-August (c, d, g, h) anomalies in the desert biome (2000-2010) for Inner Mongolia (IM) and Outer Mongolia (OM).

- Positively skewed drought years in the desert biome (severe droughts 2001, 2005, 2009) are characterized by the majority of negative anomalies (< -1 σ) with peak values between -1.5 and -0.5 std. and are statistically different ($p < 0.001$) from relatively wet years (2003, 2004 & 2007). VIP EVI2 is based on a longer term mean (1981-2010) than MODIS EVI.
- The distributions of dry years are not statistically different ($p < 0.001$) from relatively wet years in the grassland biome as compared to the desert biome suggesting that the grasslands ecosystems are more stable than deserts.
- Areas under negative VI anomalies in both desert and grassland biomes (> -1) were correlated with positive albedo anomalies (<1) .
- Conversely, areas under positive VI anomalies (<1), correlated with negative albedo anomalies (> -1), were explained in part by irrigated agriculture in IM and cropland expansion in north central OM, suggesting that the vegetation anomalies were not false positives caused by clouds and/or aerosol contaminated pixels.

Table 1: Proportion of vegetated area < = -1 Standardized anomaly

	IM					OM				
DESERT										
	01	05	08	09	10	01	05	08	09	10
EVI JA	30.4	5.4	4.8	23.2	3.4	15.8	5	2.6	11.5	4.5
EVI JJA	28.2	5.1	2.4	20.6	2.2	15.1	5	2.6	10	3.4
EVI2 JA	46.1	5.7	1.2	7.1	1.0	19.4	9.7	2.7	11.8	1.5
EVI2JJA	50.5	5.4	0.8	4.9	0.2	21.5	11	3.7	10.9	1.2
LST JF	20.2	47	65	24.5	43	31.5	70	49	30	62
GRASSLAND										
	01	05	08	09	10	01	05	08	09	10
EVI JA	3.3	0.6	0	0.3	0.1	0	0.1	0.6	0.1	0
EVI JJA	3.7	0.7	0.1	0.2	0.1	0.1	0.1	0.8	0.2	0
EVI2 JA	5.7	1.6	0	0.9	0.4	0.3	1.0	2.0	1.3	0.3
EVI2JJA	6.8	1.6	0.1	0.6	0.4	0.3	1.5	2.0	1.6	0.3
LST JF	52	79	52	42	69	72	77	60	42	83

Future work

We will validate these vegetation anomalies with TRMM rainfall anomalies and < -1 PDSI

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