remote sensing

MDPI

Supplementary Information for

Annual and seasonal trends of vegetation responses and feedback to temperature on the Tibetan Plateau since the 1980s

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S1. Detailed procedures of SQMK test

Referring to [59,60], the SQMK test is calculated as follows:
For a time series of n samples, $x_1, x_2, x_3, \ldots x_n$,

$$s_k = \sum_{i=1}^{k} r_i, k = 2, 3, \ldots, n \tag{1}$$

where S_k represents the test statistic; r_i represents the number of time $x_i > x_j$; x_i and x_j are the sequential values in a series and can be expressed as:

$$r_i = \begin{Bmatrix} 1, x_i > x_j \\ 0, x_i \le x_j \end{Bmatrix} j = 1, 2, \ldots, i \tag{2}$$

The statistics UF_k is calculated by Eq. (3):

$$UF_k = \frac{[s_k - E(s_k)]}{\sqrt{\mathrm{var}(s_k)}}, k = 2, 3 \cdots, n \tag{3}$$

The mean and variance of S_k are $E(S_k)$ and var(S_k), respectively; and can be calculated by Eq. (4):

$$\begin{cases} E(s_k) = \dfrac{k(k-1)}{4}, \\ \mathrm{var}(s_k) = \dfrac{k(k-1)(2k+5)}{72} \end{cases} k = 2, 3, \cdots n \tag{4}$$

$$UB_k = \frac{[s'_k - E(s'_k)]}{\sqrt{\mathrm{var}(s'_k)}}, k = 2, 3 \cdots, n \tag{5}$$

where S'_k, $E(S'_k)$, and var(S'_k) are calculated using the same equations for UF_k.

The curves of UF_k and UB_k are plotted between the confidence lines once they are estimated. If the two curves intersect within the specific threshold value of ±1.96 or ±2.58 (significance level of 0.05 or 0.01), their intersection point is the time of abrupt change (Here we set the α value as 0.05, i.e., the confidence level is 95%).

As recommended by the World Meteorological Organization, the nonparametric Mann–Kendall (MK) test was used to calculate the significance level in NDVI, LST, and Albedo trends [43,44]. It is robust to outliers and missing data, and does not require samples to follow a certain distribution. The statistic S can be defined as follows in Eq. (6):

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i) \tag{6}$$

where n is the number of samples and x_i and x_j are the value in time series *i* and *j*, respectively.

$$\operatorname{sgn}(x_j - x_i) = \begin{cases} 1, x_j - x_i > 0 \\ 0, x_j - x_i = 0 \\ -1, x_j - x_i < 0 \end{cases} \tag{7}$$

Where $\operatorname{sgn}(x_i - x_j)$ refers to the sign function.

The formula for calculating the standard normal distribution variable Z constructed is as follows:

$$Z = \begin{Bmatrix} \dfrac{S-1}{\sqrt{\operatorname{var}(S)}}, S > 0 \\ 0, S = 0 \\ \dfrac{S+1}{\sqrt{\operatorname{var}(S)}}, .S < 0 \end{Bmatrix} \tag{8}$$

The variance is computed as

$$\operatorname{var}(S) = \frac{[n(n-1)(2n+5)] - \sum_{i=1}^{m} t_i (t_i - 1)(2t_i + 5)}{18} \tag{9}$$

where *n* is the number of data points, *m* is the number of tied groups, and t_i denotes the number of ties of extent *i*. A tied group is a set of sample data with the same value.

The statistics Z, was used to determine significant variation. The null hypothesis of no trend is rejected if $|Z| \geq Z_{1-\frac{\alpha}{2}}$, which means a significant trend exists in the time series, where α is the statistical significance level concerned.

S2. Detailed procedures of Sen's slope

The mathematical equation for calculating slope is defined in Eq. (10):

$$SS = Median[(X_j - X_i) / (j - i)] \tag{10}$$

Where X_j and X_i are the values in the j_{th} and i_{th} years, respectively. A positive value of *SS* indicates an increasing trend while a negative value indicates a decreasing trend.

S3. Overall trends of NDVI, LST, and albedo over the Tibetan Plateau

We analyzed how key surface parameters changed on the TP from 2000 to 2021 at a finer scale by using MODIS products. The NDVI showed an increasing trend at all time-scales, with the most significant increase noted to have occurred during the spring (Figure S1a). The LST showed an increasing trend in summer and autumn, and on annual scales, but a decreasing trend in spring and winter (Figure S1b). Finally, albedo showed an increasing trend in the spring and winter, and on annual scale, but a decreasing trend in the summer and autumn (Figure S1c).

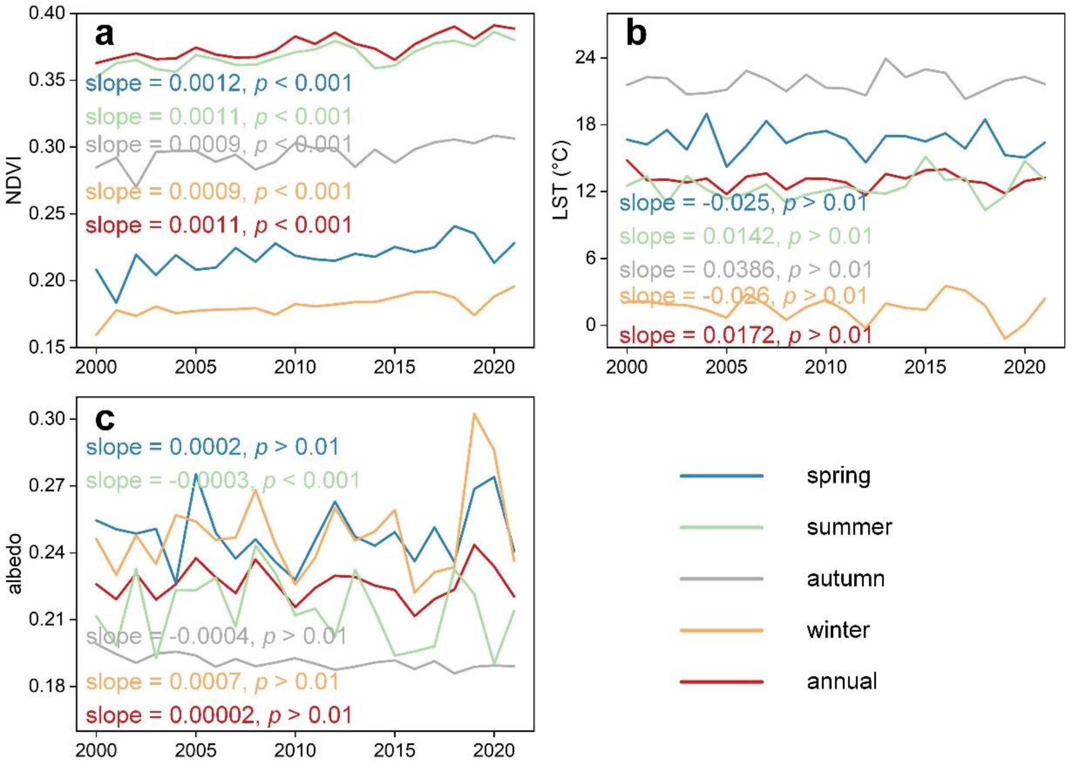

Figure S1. MODIS-based NDVI, LST, and albedo trends over the Tibetan Plateau at annual and seasonal scales during 2000–2021.

References

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