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Short Communication

Relationship between the Circumglobal Teleconnection and Silk Road Pattern over Eurasian continent

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During boreal summer, two remarkable upper-level wave trains over Eurasia were documented in literature, i.e., Circumglobal Teleconnection (CGT) and Silk Road Pattern (SRP). They are widely discussed because of their influences throughout the entire mid-latitude Eurasia. SRP was defined by 200 hPa meridional winds [1]. Enomoto et al. [2] found that the wave train influenced the climate variation over Japan when they detected the mechanism of Bonin High, and then named it as "Silk Road Pattern". SRP has 3 prominent action centers, which are located in west-central Asia, Mongolia and the Far East, respectively [3].

A circumglobal atmospheric teleconnection pattern in upper troposphere was first suggested by Branstator [4]. He used the empirical orthogonal function (EOF) analysis and indicated that the first two EOFs of the monthly mean 300 hPa meridional winds in winter season are circumglobal patterns, which extend completely around the globe. These two wave patterns are in spatial quadrature with each other, and coincide with the subtropical jet at most longitudes. Watanabe [5] suggested that the circumglobal pattern in monthly mean data can be identified in daily data as corresponding to eastward propagating wave packets, extending eastward from the North Atlantic, across Europe and South Asia, all the way to the northwest Pacific. Ding and Wang [6] defined such stationary teleconnection in summer as "Circumglobal Teleconnection", by utilizing one-point correlation analysis of 200 hPa geopotential heights. The CGT is a wave train with a global zonal wavenumber-5 structure, with 6 main activity centers over Western Europe, European Russia, west-central Asia, East Asia, North Pacific and North America, respectively.

As both SRP and CGT existing over the mid-latitude Eurasian continent, a question arising is whether these two teleconnection patterns are associated with each other or self-contained. Previous studies used the names of "CGT" and "SRP" alternatively, with the explanation that CGT and SRP were just distinct definitions that depicted an identical phenomenon [7,8]. Although some potential relationships between CGT and SRP have been mentioned, there were rare studies showing specific analyses and concrete conclusions about the linkages between these two teleconnections, or even mixed up these two concepts. On account of the confused situation about names of "CGT" and "SRP", this paper will compare these two teleconnection patterns over Eurasian continent and discuss their linkages and differences explicitly.

The dataset used in this study is the monthly reanalysis dataset from 1948 to 2013 derived by the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP/NCAR) on a 2.5° × 2.5° horizontal resolution. The summer is taken as the mean of June-July-August (JJA).

The well-defined CGT and SRP indices are picked for our study. The CGT index (CGTI) is defined as the 200 hPa geopotential height anomalies averaged over the key area (35°–40°N, 60°–70°E) [6]. The SRP index (SRPI) is the time series of leading principal component for the EOFs of the 200 hPa meridional wind anomalies over the Eurasian region (20°–60°N, 0°–150°E) [7].

The correlation map between 200 hPa geopotential height anomalies in the Northern Hemisphere and CGTI for the period of 1948–2013 (Fig. S1a online) represents the CGT pattern found by Ding and Wang [6]. An obvious wave-like structure can be seen over Eurasian continent, from Northeast Atlantic-UK to west-central Asia and East Asia, with prominent activity centers. SRP is presented by the leading EOF mode for JJA 200 hPa meridional wind anomalies over the Eurasian (20°–60°N, 0°–150°E) during 1948–2013 following Yasui and Watanabe [7] (Fig. S2a online). The leading mode accounting for 26.1% of the total variance, exhibits a

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wave-like pattern where meridional winds vary from North Europe to Far East, with positive and negative centers alternatively appearing in about every 60° of longitude.

In order to compare these two patterns more intuitively, we calculated the regressed 200 hPa geopotential heights upon SRPI and meriodional winds upon CGTI, respectively. Comparing the 200 hPa geopotential height associated with SRPI (Fig. S1b online) to CGT (Fig. S1a online), the two patterns are comprised of similar activity regions. Spatial correlation coefficients between these two anomalous patterns over Eurasian (25°–60°N, 20°W–140°E) are −0.90, indicating that CGT and SRP are nearly spatially consistent. Compared to the CGT pattern, the SRP exhibits alternative positive and negative centers more clearly. For CGT, significant centers are all positive, and negative centers are very weak. Therefore, SRP seems more notable in representing the spatial characteristics of the wave train than CGT.

The above is manifestations of the two teleconnections on the 200 hPa geopotential field. The regressed 200 hPa meridional winds against CGT (Fig. S2b online) also show the similarity of spatial structure of SPR (Fig. S2a online), with spatial correlation coefficient of −0.87 between them within the domain 25°–60°N, 20°W–140°E over Eurasia. Similar with the results on the 200 hPa geopotential field, SRP has much stronger activity centers compared to those of CGT.

In addition to the spatial structure, the two teleconnections are strongly related on their time evolutions. The time series of CGTI and SRPI are obviously out of phase (Fig. S3 online). Correlation coefficient is −0.68 between CGTI and SRPI, which is statistically significant exceeding the 95% significance level. Above analyses reflect the great conformity of CGT and SRP on both spatial structure and temporal variation, and SRP shows more noticeable spatial pattern.

In the aforementioned work, CGT and SRP have shown great linkages in either spatial pattern or temporal variation. In the following, the independence of these two teleconnections will be investigated, based on the method of partial correlation by which the signal of one pattern can be deleted from another.

By utilizing the 200 hPa meridional winds, in Fig. 1a we present the CGT pattern after removing the influence of SRP. Compare to the original distribution (Fig. S2b online), it manifests great alteration. The wave-like structure nearly disappears in the mid-latitudes. However, if the CGT signal is removed from the SRP pattern, SRP still remains well over Eurasian area (Fig. 1b). The structure of mid-latitude wave train nearly keeps intact. Therefore, over Eurasia, SRP is self-maintained whether CGT exists or not.

Here we can see that when SRP signal is deleted, no CGT leaves; but after subtracting CGT, SRP remains, which means SRP is an intrinsic wave train over Eurasia during boreal summer, while CGT seems relying on SRP for existence, acting as a part of SRP.

Here we discussed the association between CGT and SRP over Eurasian continent in summer, by using 200 hPa geopotential heights and 200 hPa meridional winds, respectively. The results suggest high spatial similarity and great temporal dependency between these two teleconnections.

Using partial correlation method, we found that when the influence of SRP is removed, the wave train pattern of CGT disappears; while that of CGT is removed, SRP still remains. It is indicated that SRP is the internal inherent mode in summer in upper troposphere over Eurasia, and CGT can be regarded as a section of SRP.

In fact, the SRP can be well explained by the waveguide effect of the upper-tropospheric Asian westerly jet according to the wave ray theory suggested by Hoskins and Ambrizzi [9]. This may also provide extra support for the conclusion of this study that SRP is an internal inherent mode in upper troposphere over Eurasia in summer. Previous studies held the opinion that CGT should be more circumglobal [6], whereas SRP mainly occurred over the Eurasia [1]. Reason of this disagreement is worthy of further intensive study. In addition, previous study [10] pointed out that both Indian and East Asian summer monsoon rainfall has major impact on the circulations in upper troposphere over Eurasian continent. How CGT and SRP are influenced by the monsoons is another important topic for future investigation.

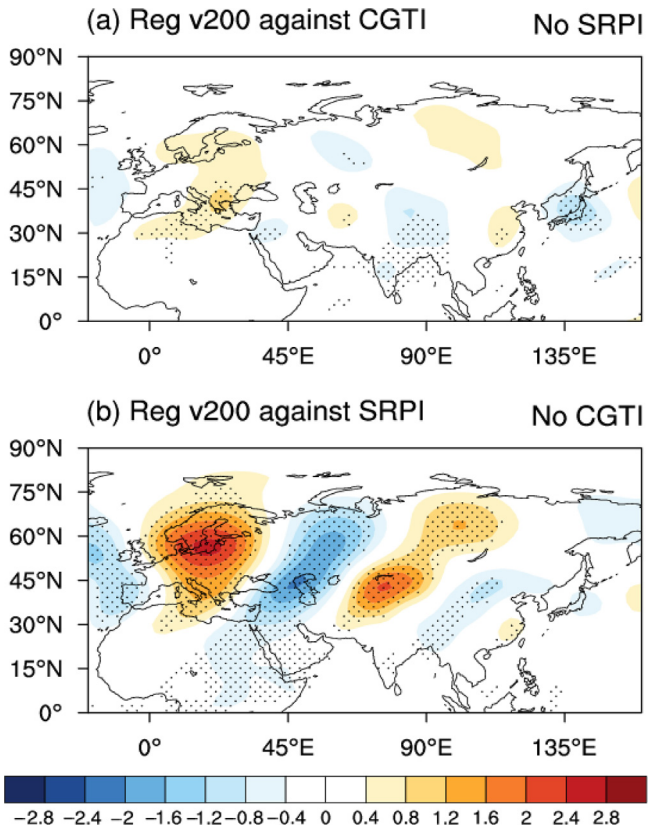

Fig. 1. Regression of JJA 200 hPa meridional wind velocity (shadings; units: m s^{-1}) against (a) CGTI after removing SRP, and (b) SRPI after removing CGT for 1948–2013. The black dots indicate the statistical significance exceeding 95% confidence levels based on the student's *t* test.

Conflict of interest

The authors declare that they have no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scib.2019.02.014.

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