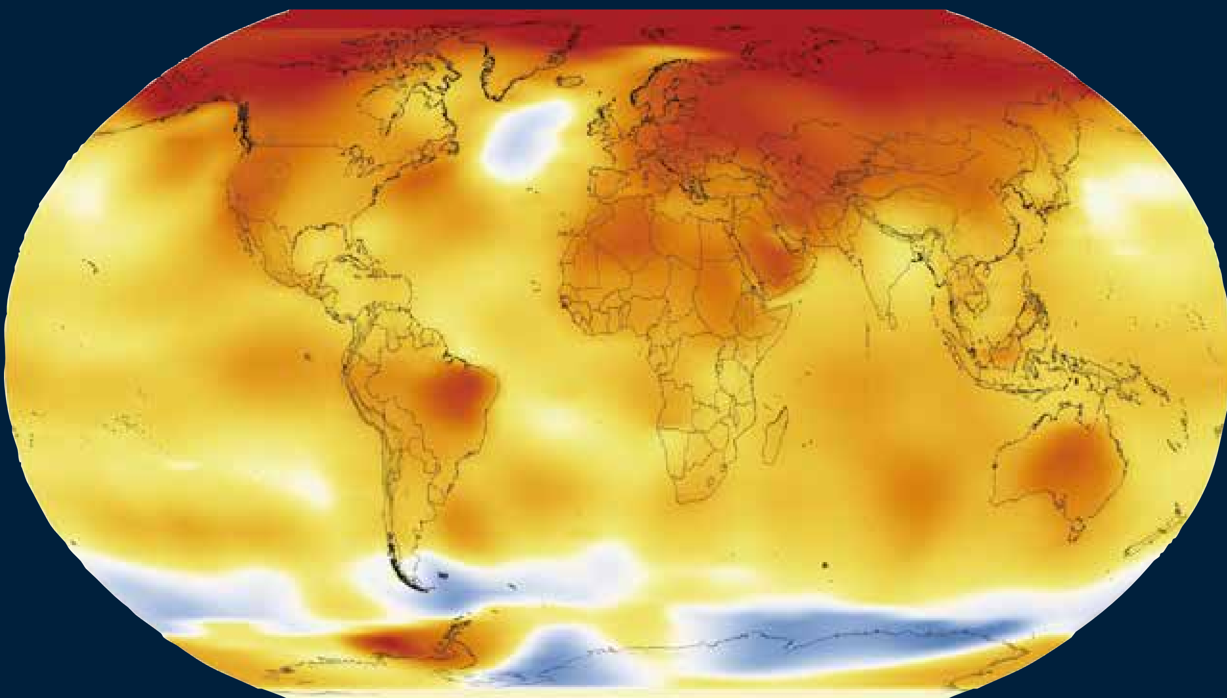
Accelerated Drying Trend in Central Asia

By Li Zhi*



An illustration of 2017 global temperatures jointly released by NASA and NOAA. (Image: By courtesy of NASA)

Over the past half century, a warming trend, the fastest seen so far, emerged in the arid and semi-arid regions in mid-latitudes of the Northern Hemisphere featuring fragile ecological systems. As predicted by scientists, the arid area will continue to expand, due to dual influence from both climate change and human activities; and about three-quarters of the drought expansion will happen in developing countries.

Meanwhile, a debate has arisen concerning whether warming leads to drying or not. Based on analysis of multiple variables, a newly published assessment of droughts in Central Asia might offer some insights for regional responses to climate change.

*Associate Professor at the Xinjiang Institute of Ecology and Geography, CAS.

Recently a group of scientists at the Xinjiang Institute of Ecology and Geography (XIEG), CAS identified and reported in *Scientific Reports* an accelerated drying trend since the early 2000s in Central Asia, against a relatively more modest drying background over the past five decades. Led by Prof. CHEN Yaning, the team has arrived at this conclusion based on their analyses of PDSI $_{\text{\_P-M}}$, a set of indices indicating the strength of drought of a certain region with variables reflecting rainfall, soil moisture, and potential evaporation. Derived from the conventional version of Palmer Drought Severity Index (PDSI) and modified with Penman-Monteith approach by the team, the new version of indices is thought to have delivered more accurate measurement of drought and offer better details in changes of overall trends.

The accelerated drying trend, as proposed by researchers, could be mostly attributed to the dramatic increase in air temperature. However, intuitive as it might look, warming does not necessarily go with drying; nor is drought so easy to measure and understand.

Warming Means Drying?

Concerning the impact of global warming on drought, a debate has emerged in the literature published over the past decade. Some earlier work concluded that "warmer is more arid," arguing that increase in air temperature leads to intensified drying. Paradoxically, other evidence has led the geoscience community to conclude that "warmer is less arid."

The debate hinges on the mathematical model used to assess drought, namely PDSI. The studies supporting the theory "warmer is more arid" were essentially based on the classical version of the model, as proposed by Thornthwaite, assuming that the change in potential evaporation is solely determined by the change in air temperature. This might not be the case, as the team revealed in their published work.

The team analyzed different aspects of drought since the early 2000s: meteorological drought as represented by rainfall, agro-ecological drought represented by soil moisture and vegetation dynamics, and hydrological drought by runoff. The variabilities of meteorological and agro-ecological droughts, they discovered, were broadly comparable to various PDSI drought indices given by previous studies. Interestingly, the hydrological drought was not completely comparable to former results. For example, the catchment of the Issky-Kul River, which is originated from the western part of the Tienshan Mountains, and the one of the Tarim River originated from the Tienshan Mountains, fall in the regions stricken by the drying trend but showed a wetting trend with their runoff. This, they suggest, indicates that not all the runoff in arid and semi-arid regions was generated primarily from precipitation. Instead, fraction of glacierized areas in catchments caused large variations in the observed runoff changes, due to varied contributions from glacier melt water.

This difference proved to play an overlooked role in climatic modeling, and the journey from here arrives at an unexpected vision that might inspire the long-going debate about the consequence of warming on drought.

It is now recognized that the PDSI model needs to be revised with physically based approaches, with potential evaporation calculated as a function of radiation, temperature, humidity, and wind speed. Meanwhile, it is still challenging to reveal the mechanism of drought formation and quantify the sensitivity of the drought to climate change.

Aridity in Central Asia

Central Asia, which consists of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan and the arid region of Northwest China, is located in the hinterland of the Eurasian continent. It is one of the most arid areas in the world, with limited and unequal spatial distribution of water resources, and responds sensitively to climate change. It has attracted increased international attention, not only for its location on China's renowned Silk Road Economic Belt, but also for its unique landscape that features expansive and fragile ecosystems, *e.g.* the sharply shrinking Aral Sea. The temperature in Central Asia experienced a sharp increase in 1997, and since then the region has been in a state of high volatility, making the last decade its warmest period on record. The resulting drought caught high attention.

Various drought indices and metrics that comprehensively assess and quantitatively interpret recent changes in droughts have not been adequately factored into the equation of PDSI. As a result, from the very same equation, very different, even opposite trends in droughts could be derived if the potential evaporation was estimated in two different methods, *i.e.*, the widely used Thornthwaite

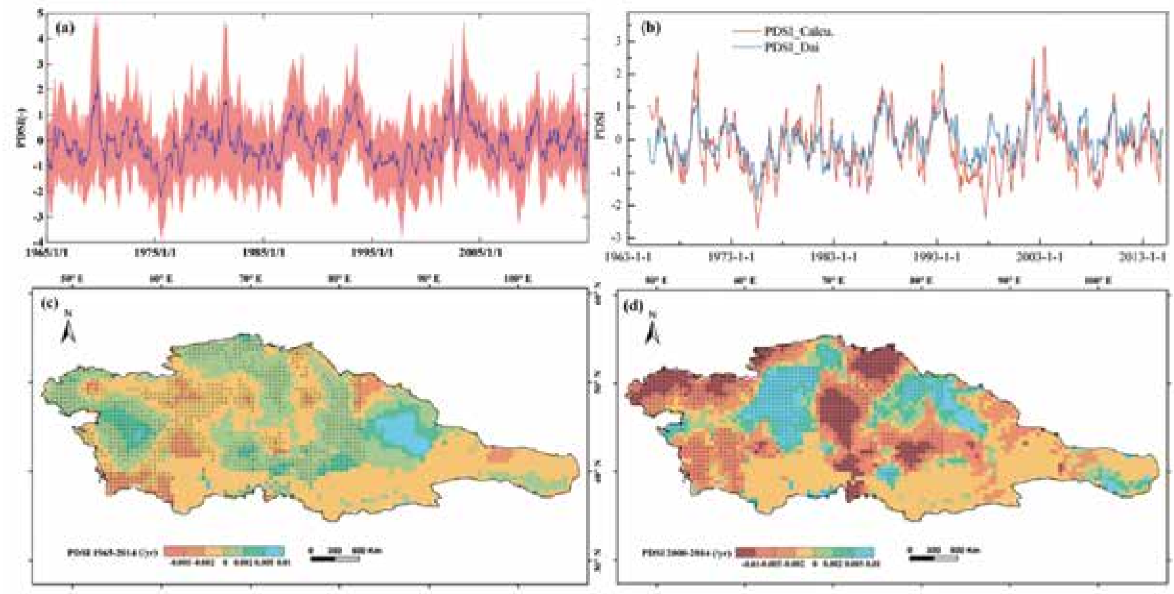


Figure 1: Spatio-temporal changes in the recent droughts over Central Asia during the period from 1965 to 2014.

approach and the Penman-Monteith approach.

The research team led by Prof. CHEN Yaning at XIEG modified the PDSI model to suit it to the estimation of drought in Central Asia. Being closer to standard meteorological and agro-ecological drought indices, the revised version of PDSI, in which potential evaporation is calculated as a function of radiation, temperature, humidity, and wind speed, is a better set of indices to assess the regional drought.

Using the revised PDSI, they analyzed data of the period from 1965 to 2014 and found that drought of this period remained at a normal level, showing a near-zero drying (0.0036 per year). Despite the weaker overall trend indicated by PDSI, a switch emerged in the early 2000s, and an accelerated drying went on over the past decade (-0.023 per year), with 65% of the land area more or less drying up, especially in western and eastern Kazakhstan, Turkmenistan, and Kyrghyzstan. The Tarim River basin in China also indicates obvious declining (drying) trends (Figure 1).

Tracking the Causes of Drought

Accurate attribution of the drought requires revelation of contributions of the involved natural variables in the equation to the resulting trends and quantifying the sensitivity of drought to different variables. To this end, the team designed numerical experiments to understand how the drying trend responds to climatic factors. To dissect impacts from different factors, they detrended certain factors from the model to eliminate the influence from them and investigate the impact of the components of interest on the overall trend, in an attempt to form a new "detrended" time series to avoid setbacks of the traditional correlation analysis, which is weak in establishing causing relationships. As a result, they found that drying trend strongly responded to the dramatic increase in air temperature. As it turns out, the probability density function (PDF) of the PDSI is broadened when the trend resulting from precipitation is included, which is slightly wetting but very small compared with the large variation (Figure 2).

Outlook

Even though the revised PDSI model has now been brought closer to key water balance components, there remain some setbacks. The current model needs further modification to accommodate a couple of correlations, including those between 1) precipitation and meteorological drought, 2) soil moisture deficits and

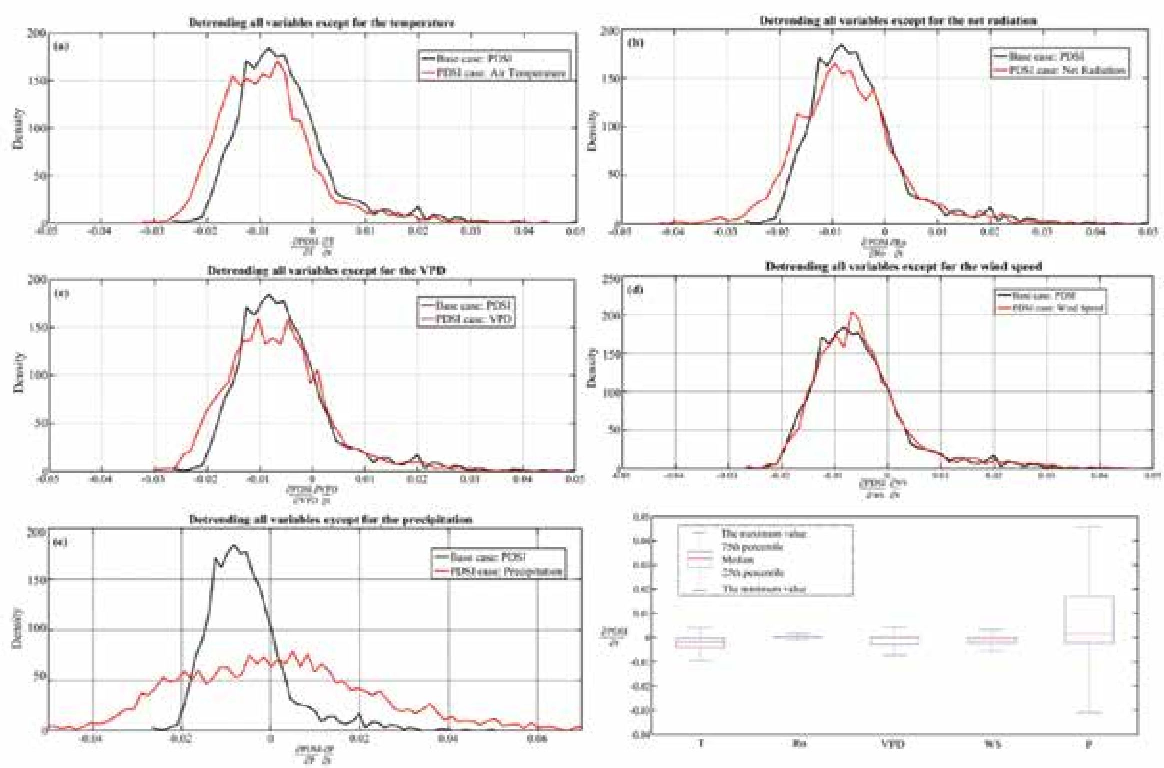


Figure 2: Quantifying the sensitivity of the changes in droughts over Central Asia using a series of numerical experiments. (a) the temperature case (detrending all variables except for the temperature): the probability density function (PDF) of the trends in the PDSI; (b) the net radiation case; (c) the vapour pressure deficiency case, (d) the wind speed case; (e) the precipitation case; (f) the summary of the contributions from different meteorological variables to the PDSI droughts.

agro-ecological drought, and 3) runoff and hydrological drought, to understand the roles of precipitation, evapotranspiration and runoff in climate-induced drought. As it is noted that the three types of droughts are not consistent with each other at the same time in Central Asia, a more comprehensive discussion is needed to deal with the complex mechanism of drought. River runoff responds in a complex way to changes in climate and the cryosphere in arid and semi-arid regions. It should be pointed out that under the impact of global warming, the vulnerability of water systems and uncertainty of water resources are increasing.

This study is part of a program funded by the State Key Program of National Natural Science Foundation of China (41630859) focused on the effects of climate change on "water tower" changes in Central Asia. The discovery, published in *Scientific Reports*, is expected to shed some light on the understanding of regional drought and wet changes against the context of climate change. This understanding will then lay a scientific basis for the water resources management in Central Asia and Silk Road Economic Belt construction.

For more information please refer to:

Zhi Li, Yaning Chen, Gonghuan Fang & Yupeng Li. (2017) Multivariate assessment and attribution of droughts in Central Asia, *Scientific Reports*, 7: 1316. (DOI:10.1038/s41598-017-01473-1)