LETTERS

Drought in Central and Southwest Asia: La Niña, the Warm Pool, and Indian Ocean Precipitation

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ABSTRACT

Severe drought over the past three years (1998–2001), in combination with the effects of protracted socio-political disruption, has led to widespread famine affecting over 60 million people in central and southwest (CSW) Asia. Here both a regional and a large-scale mode of climate variability are documented that, together, suggest a possible forcing mechanism for the drought. During the boreal cold season, an inverse relationship exists between precipitation anomalies in the eastern Indian Ocean and CSW Asia. Suppression of precipitation over CSW Asia is consistent with interaction between local synoptic storms and wave energy generated by enhanced tropical rainfall in the eastern Indian Ocean. This regional out-of-phase precipitation relationship is related to large-scale climate variability through a subset of El Niño–Southern Oscillation (ENSO) events characterized by an enhanced signal in the warm pool region of the western Pacific Ocean. Both the prolonged duration of the 1998–2001 cold phase ENSO (La Niña) event and unusually warm ocean waters in the western Pacific appear to contribute to the severity of the drought.

1. CSW Asia and ongoing drought

Most of central and southwest (CSW) Asia is semiarid steppe receiving little precipitation with, nonetheless, much of the population directly reliant on agriculture. Precipitation occurs primarily during late winter and early spring, due to orographic capture of eastward-propagating midlatitude cyclones from the Atlantic Ocean and Mediterranean Sea (Martyn 1992). This year (2001) marks the third consecutive year of drought for a broad region centered on Iran, Afghanistan, and Pakistan (see time series in Fig. 1), with wet season (November–April) precipitation since 1998/99 at less than 55% of the long-term average.

2. Monitoring: Synchronous large-scale and regional anomalies

The recent drought period, 1998–2001, has also featured coherent patterns of large spatial scale in November–April anomalies of precipitation, sea surface temperatures (SST), and wind (Fig. 2), including a prolonged cold-phase El Niño–Southern Oscillation (ENSO) event. The general aspects of the recent western and central Pacific climate anomalies are similar to the typical November–April ENSO signature in SSTs (Rasmusson and Carpenter 1982; Ropelewski and Halpert 1989), precipitation (Ropelewski and Halpert 1987), and upper-level winds (Horel and Wallace 1981).

However, other regional features during this period are not generally noted as being La Niña–related, particularly the Indian Ocean precipitation extension (IPX region; see box in Fig. 2a) of the positive anomalies in the west Pacific, the drought in CSW Asia, and the exceptionally warm SSTs in the western Pacific (Hoerling et al. 2001).

3. Potential mechanism for drought

a. Regional: Indian Ocean Precipitation Extension (IPX) and tropical forcing

The time series for the IPX index is shown as the line in Fig. 1, revealing an out-of-phase relationship with CSW Asia not only during the recent drought period but throughout the record. The spatial pattern of precipitation correlated to the IPX index (Fig. 3a) shows that this general inverse relationship, while modest in
magnitude, also has considerable similarity in position and extent to the recent drought period anomalies (Fig. 2a). The SST correlation (not shown) to the IPX index resembles an ENSO pattern with an enhanced signal in the warm pool region, as in the recent three winters. The covariance between the IPX and upper-level atmospheric circulation (Fig. 3a), consists primarily of two westward-extended anticyclones poleward of the heating, favoring the winter hemisphere, again with considerable similarity to the drought period (Fig. 2a).

In the linear Gill–Matsuno model of tropical dynamics (Matsuno 1966; Gill 1980), the deep tropical latent heat release associated with the IPX precipitation would produce two baroclinic Rossby wave packets, symmetric about the equator, to the west of the heating. At upper levels these Rossby wave packets would be realized in the wind field as anticyclonic circulations. To illustrate...
b. Large-scale: ENSO and the warm pool

Although the IPX–CSW Asia precipitation relationship is not typically noted as part of the ENSO signal, there has also been an enhanced signal in the warm pool (red box in Fig. 2b) for both the recent La Niña and the SST correlations to the IPX. To test a possible relationship between the warm pool and changes in the ENSO signal, we calculated standard correlations to the Niño-3.4 SST index of ENSO for both precipitation and SSTs, but with the monthly contributions to the correlations sorted into two equal-sized groups, based on the strength of the SST anomalies in the warm pool. That is, we stratified the ENSO relationships into two cases: a strong warm pool case, where the ENSO events occurred in conjunction with vigorous SST anomalies in the west Pacific; and a weak warm pool case, where the ENSO events occurred in conjunction with weak SST anomalies in the west Pacific. The results are shown in Fig. 4, with the signs reversed for comparison to La Niña. The recent drought period was not included in the calculations, to avoid bias by a single event.

The subset of ENSOs with a strong warm pool signal are associated with a vigorous extension of positive precipitation anomalies into the Indian Ocean (the IPX region) and negative anomalies over CSW Asia (Fig. 4b). The similarity between this rainfall pattern and the drought period rainfall (Fig. 2a) is striking. Although the magnitude of the pattern is modest, the difference in precipitation between the two cases for the Indian
Ocean–CSW Asia region (see red box in Fig. 4b) has high statistical significance: the probability that a random stratification of the ENSO correlation would result in as large a difference is less than 0.005 (using monthly data as with original calculation, therefore 108 samples over 18 yr). We have also stratified the correlations to the warm pool SST anomalies with respect to ENSO strength; the warm pool–IPX–CSW Asia relationship appears to be only present during active ENSO periods. Additionally, we have verified the warm pool–IPX relationship prior to the mid-1970s (the advent of satellite data and estimates of oceanic precipitation), by examining the warm pool stratification of ENSO correlation to upper-level winds for 1949–78.

4. Discussion and implications

The similarity between the enhanced warm pool–La Niña composite and the climate anomalies of 1998–2001, in both regional and large-scale aspects, suggests that the prolonged, westward-concentrated La Niña during this period was a major factor in the CSW Asia drought. As the diagnosed linkages have been present throughout the available period of data, whereas the drought has been exceptionally harsh, we speculate that the severity of the drought is related to a combination of the prolonged duration of the recent La Niña and the unusually warm SSTs in the west Pacific, which may have enhanced the regional dynamics of the warm pool. Given the demise of the La Niña in early 2001, conditions may be favorable for a return toward normal in CSW Asia.

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REFERENCES