1. The problem

The intensity and sign of the El Niño/Southern Oscillation (ENSO) is conventionally measured by one of several indices designed for the task. Indices provide a handy means for comparing different ENSO events, although a single index cannot differentiate among different "flavors" of ENSO. Indices are also useful for inferring the magnitude of local and remote ENSO impacts, for diagnostic and forecasting purposes. Statistics related to ENSO indices may also be used to quantify and compare ENSO performance among coupled climate models.

The National Oceanic and Atmospheric Administration (NOAA) uses three-month running-mean sea surface temperature anomalies over the Niño 3.4 region (5°N to 5°S, 120°W to 170°W) to monitor El Niño or La Niña conditions via the Oceanic Niño Index (ONI) (Lindsey 2013; Kousky and Higgins 2007). The Niño 3.4 index uses 1981-2010 as climatology to calculate the SST anomalies for index values while the ONI uses thirty-year centered averages for each five-year period (Huang et al. 2016). Other indices use different regions of the ocean (Trenberth 1997) or monitor different aspects of the coupled ocean-atmosphere system (Walker and Bliss 1932; Allan et al. 1991; Chiodi and Harrison 2010, 2013, 2015; Wolter and Timlin 1993, 2011; Williams and Patricola 2018).

Ideally, an index used for monitoring the ENSO driver of global climate impacts would have the same form in models and observations, would be robust to climate change, and would effectively identify "super" El Niño events. The ONI is suboptimal because its anomaly definition necessarily lags current climatic conditions and model studies rarely use reference periods that change every five years. Perhaps the best existing index in this regard is the ENSO Longitude Index (ELI; Williams and Patricola 2018), but this index is unfamiliar to many and doesn't have the same interpretation as ONI.

2. A proposed solution

We propose a Niño Difference Index (NDI), defined as the (raw or anomalous) difference between the sea surface temperatures in the central Tropical Pacific and sea surface temperatures elsewhere, with the premise that the temperature difference between, say, the western and central tropical Pacific drives the spatial shifts in convection that in turn drive remote ENSO responses. In principle, the NDI can possess all the desirable characteristics listed above. The research task is then to determine which two areas of sea surface temperature should define the NDI. We seek definitions which optimize the correlation with the leading EOF of regional or global precipitation, using Global Precipitation Climatology Product (GPCP) data (Adler et al. 2018).

Fig. 1 Fraction of the leading EOF of global precipitation variance explained by the difference between the average SST in the Niño 3.4 region and the average SST in a 40°x114° box centered at the specified locations. Contours highlight box locations where the difference index explains more variance than the Niño 3.4 index.
If the Niño 3.4 box is assumed to be the central Tropical Pacific area, a search over all possible box sizes and locations reveals that the greatest annual mean fraction of explained seasonal precipitation variance is obtained when the Niño 3.4 SST is subtracted from the average SST in a box 40° tall by 114° wide centered over the central Pacific. Figure 1 shows the explained variance for 40°x114° boxes centered over the Indian or Pacific Oceans. Contours (every 0.1) begin at the explained variance of Niño 3.4. Improvement in explained variance is found for boxes centered over the central or western tropical Pacific; the optimal location yields an NDI that explains 30% of the variance left unexplained by Niño 3.4.

Without the Niño 3.4 constraint, the optimal reference SST region shrinks to 6°x50°, narrower but comparable in size to the Niño 3.4 box. The ideal such box is centered on the equator in the Maritime Continent region (Fig. 2).

The optimal central Pacific box under that circumstance is centered within the Niño 3.4 region but is narrower and broader, sampling most of the equatorial Pacific Ocean (Fig. 3).

Sensitivity tests show that the largest explained variance gains are in March-May, with conversely little impact in December-February. While it is possible to specify optimal box locations for each season, consistency and simplicity dictate a constant box definition throughout the year. Using such a definition, the annual fractional explained variance of the leading precipitation EOF increases from 0.82 for Niño 3.4 to 0.88 for the NDI.

3. Summary

Using fixed box locations throughout the year, the optimal NDI definition is the mean SST in the area 3°S-3°N, 180°W-95°W minus the mean SST in the area 1°S-5°N, 120°E-170°E. Such an index can be used in either raw or anomaly form and explains substantially more of the global precipitation response than a conventional Niño 3.4 index.

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References


