El Niño/Southern Oscillation Induced Monthly Oscillations of Precipitation: The Unique Case of the South Tropical Indian Ocean

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Abstract

Seasonal (three-month average) climate forecasts have advanced due in large part to improved modeling of the ENSO phenomenon. Long-range monthly forecasts are more problematic because of internal atmospheric variability. Further, it is often assumed that monthly precipitation anomalies are representative of the overall seasonal anomaly. This is not always the case as, according to the Global Precipitation Climatology Project Version 2.1 data set, up to 20% of areas demonstrating some significant teleconnection to ENSO show El Niño minus La Niña differences of one sign in the middle month and the opposite sign in the adjacent months. Most interestingly, this maximum percentage occurs in December-January-February (DJF), a time when the ENSO boundary forcing is strongest. These oscillatory DJF seasons also cluster in space - with significant positive-negative differences in the western South Tropical Indian Ocean (STIO) and negative-positive differences in the far eastern STIO. Representative gauges confirm that these precipitation patterns have been associated with ENSO events since 1951, and pentadal precipitation data confirm that they are confined to DJF and evolve at the monthly scale. The abrupt end of the Indian Ocean Dipole mode in January, an increase in the importance of local SST anomalies in February, and an ENSO-induced mid-latitude Rossby wave during austral summer combine to generate the cross-basin precipitation gradient around 15°S.

Introduction

• An ongoing climate challenge is the prediction of seasonal precipitation variability with enough accuracy and lead time for useful societal preparations.
• Improved skill of seasonal forecasts is in a large part due to our understanding of the El Niño/Southern Oscillation phenomenon (Zebiak 2003).
• Monthly forecasts based on ENSO have not been produced routinely, because internal atmospheric variability reduces the signal-to-noise ratio (Philips et al. 2004, Chen et al. 2010). However, a “monthly” forecast can be more appealing to the end-user than a “seasonal” forecast for many activities.
• Gouriard and Monon (2006) note that the practice of combining months into seasons can miss genuine ENSO teleconnections.

Data

Precipitation
Global Precipitation Climatology Project (GPCP) Version 2.1 Monthly Data Set (Huffman et al. 2009).
Global Surface Network Long-Term Rain Gauge Network: Port Hedland AMO (Australia) and Agulega (Mauritius).

Atmospheric Circulation
NCEP/NCAR Reanalysis

Table 1

| ENSO | Oceanic Niño Index (ONI) | DJF | 3M | MAM | JJA | SON | 12M | ONI |
|------|-------------------------|-----|----|-----|-----|-----|-----|-----|------|
| 0.50 | 0.40  | 0.30  | 0.20 | 0.10 | 0.00 | -0.10| -0.20| -0.30| -0.40|
| 0.40 | 0.30  | 0.20  | 0.10 | 0.00 | -0.10| -0.20| -0.30| -0.40|
| 0.30 | 0.20  | 0.10  | 0.00 | -0.10| -0.20| -0.30| -0.40|
| 0.20 | 0.10  | 0.00  | -0.10| -0.20| -0.30| -0.40|
| 0.10 | 0.00  | -0.10| -0.20| -0.30| -0.40|
| 0.00 | -0.10| -0.20| -0.30| -0.40|
| -0.10| -0.20| -0.30| -0.40|
| -0.20| -0.30| -0.40|
| -0.30| -0.40|

Years

See Table 1

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References


* Based on the Climate Dynamics paper with the same title:


Results

• El Niño minus La Niña differences were computed for only those GPCP grid boxes where the December and February anomalies were of opposite sign (pnp or npn cases). Significant differences at the 90% level are contoured (Fig. 4). The only area that exhibits a strong significant oscillatory signal appears in the South Tropical Indian Ocean (STIO, Fig. 5). This is also true over a longer record (Table 3) for representative gauges: Agulega (Fig. 6a) and Port Hedland (Fig. 6b).

Discussion

• In December the Indian Ocean Dipole (IOD) is strong, and the dipole of precipitation anomalies reaches as far south as the vicinity of Agulega and Port Hedland (Fig. 1b). At the same time the IOD has generated a Rossby wave in the mid-latitudes, extending down to 50S (Fig. 7). These tropical and extra-tropical phenomena are linked together through anomalously low pressure in the western STIO (Fig. 7). Figure 10 represents a schematic diagram of the processes involved.

• An elongated northwest-southeast oriented band of positive SST anomalies and a similar band of negative SST anomalies to the south (Fig. 1a solid and dashed ellipses respectively) has been described as the Indian Ocean Subtropical Dipole (IODS) mode, the strongest interannual signal of ocean temperature in the Indian Ocean (Huanga and Shukla 2008). The anomalous pressure gradient set up by the Rossby wave strengthens the IODS and advects the SST anomalies to the southeast into January (Fig. 10b).

• Also by January the Rossby wave has propagated so that now a center of anomalously high pressure connects to the tropics where high pressure anomalies prevail in the western STIO (Fig. 8), which becomes dry. The eastern STIO is influenced by a Rossby center of low pressure anomalies (Fig. 8b) and is wet during El Niño.

• Finally, in February, the Rossby wave has decayed (Fig. 9) and local thermodynamic feedbacks result in positive vorticity and convection anomalies in the west and negative vorticity and convection anomalies in the east (Fig. 10c).