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-positive differences in the western South Tropical Indian Ocean (STIO) and negative-positive-negative differences in the far eastern STIO. Representative gauges confirm that these precipitation patterns have been associated with ENSO events since 1951, and pentad 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 (Phelps et al. 2004, Chen et al. 2010). However, a "month" forecast can be more appealing to the end-user than a "seasonal" forecast for many activities.
- Gouirand and Moron (2000) 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 Agalega (Mauritius)

Atmospheric Circulation

- ✓ NCEP/NCAR Reanalysis

ENSO

- ✓ Oceanic NINO Index (ONI) – See Table 1

Years

- ✓ See Table 1

Table 1

GPCP/reanalysis El Niño	GPCP/reanalysis La Niña	Port Hedland El Niño	Port Hedland La Niña	Agalega El Niño	Agalega La Niña
1983	1985	1958	1956	1958	1956
1987	1989	1966	1971	1966	1971
1992	1996	1973	1974	1973	1974
1995	1999	1983	1975	1983	1975
1998	2000	1987	1976	1987	1976
2003	2008	1992	1985	1992	1985
		1995	1989	1995	1989
		1998	1996	1998	1996
			1999	2003	1999
			2000		2000

Acknowledgements

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Methods

- With ENSO there is normally good agreement between the seasonal precipitation anomalies and the monthly anomalies within the season (See Figures 1 and 2 for December-January-February)
- Some exceptions are noted (red circled areas)
- The monthly anomalies that make up the seasonal anomalies (hereafter El Niño minus La Niña composite, see Table 1) are defined as follows:

✓ Positive seasonal anomaly

Positive first month, positive second month, positive third month (ppp)
Positive first month, negative second month, positive third month (pnp)
Positive first month, positive second month, negative third month (ppn)
Negative first month, positive second month, positive third month (npp)

✓ Negative seasonal anomaly

Likewise: nnn, npn, nnp, pnn

- The "consistent" ppp and nnn scenarios are most likely to occur, but interestingly the "oscillation or interruption" scenario (npn, pnp) is more likely to occur than the "transition" scenario (ppn, npp, nnp, pnn) in December-January-February, when the ENSO boundary condition is strongest (see Fig. 3 below)

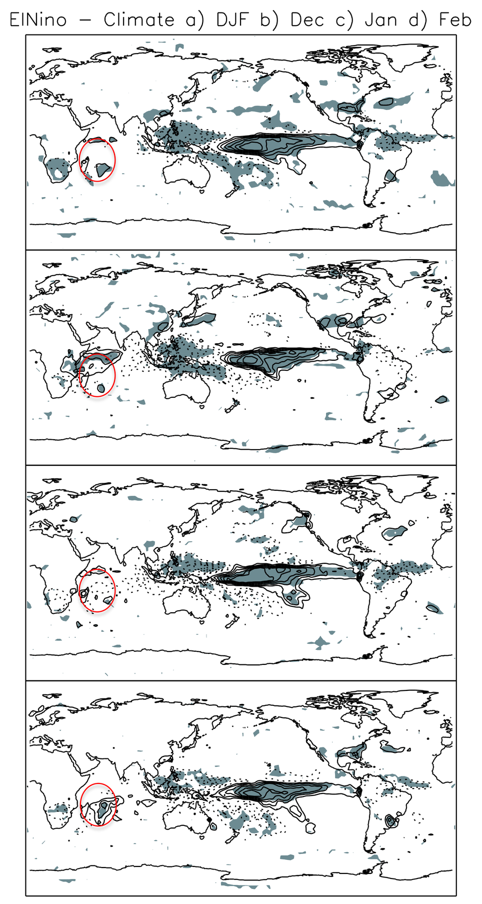

Figure 1

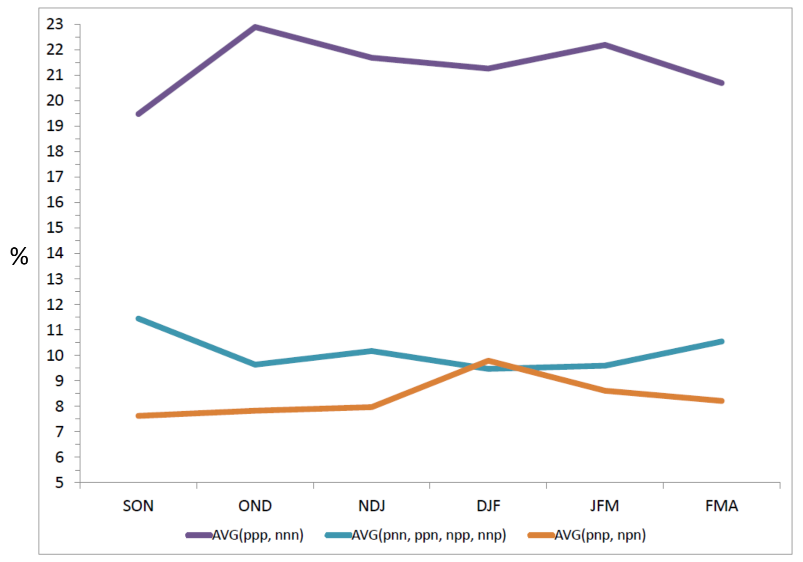

Figure 3

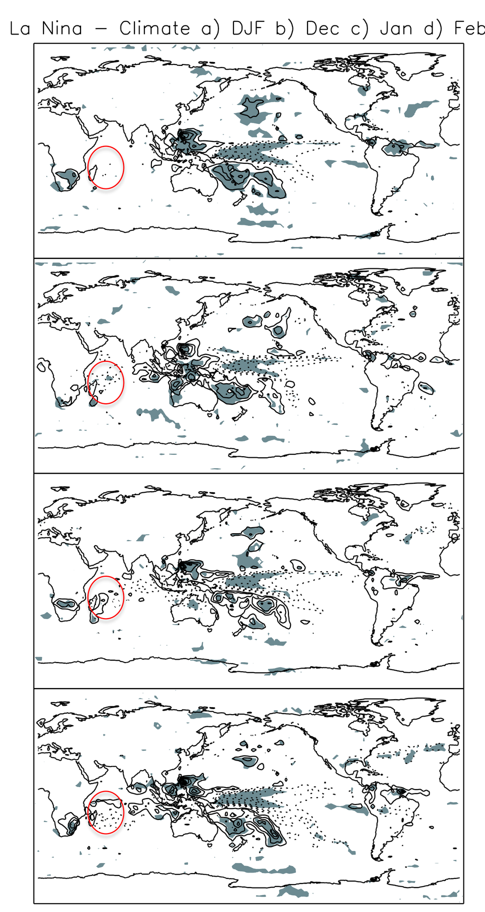

Figure 2

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Huffman GJ, Adler RF, Bolvin DT, Gu G (2009) Improving the global precipitation record: GPCP Version 2.1. Geophys Res Lett 36:L17808. doi:10.1029/2009GL040000 Phelps

Zebiak SE (2003) Research potential for improvements in climate prediction. Bull Am Meteor Soc 84:1692–1696

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 1) for representative gauges: Agalega (Fig. 6a) and Port Hedland (Fig. 6b)

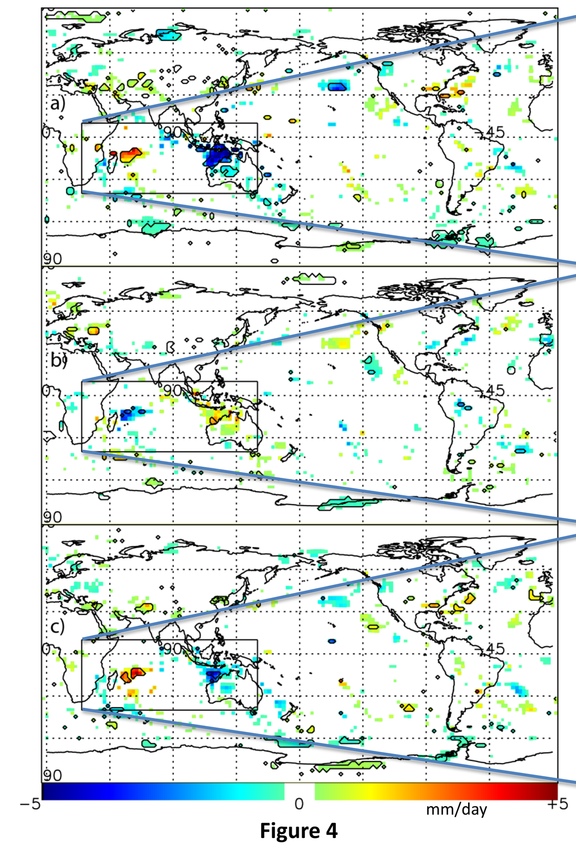

Figure 4

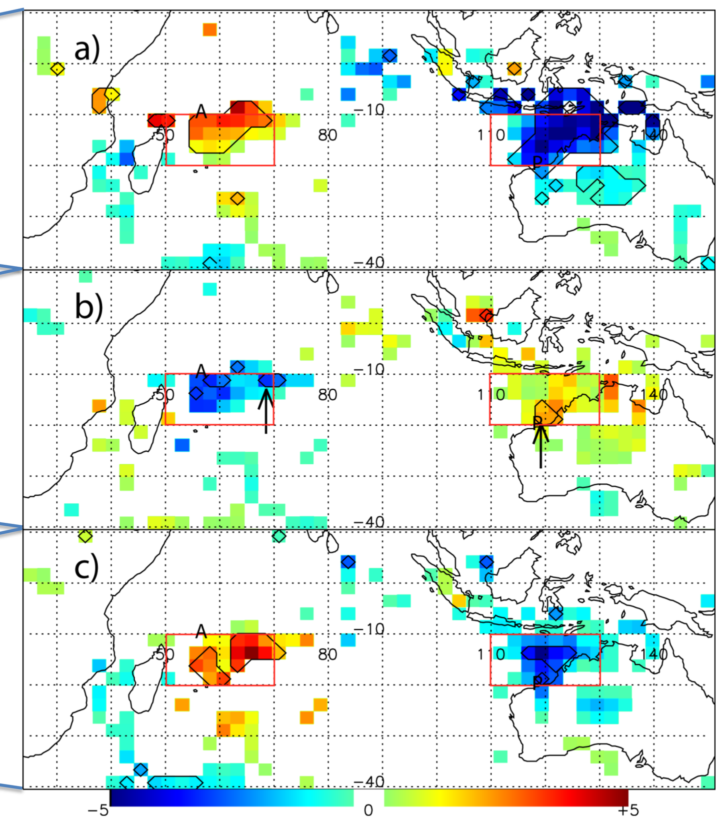

Figure 5

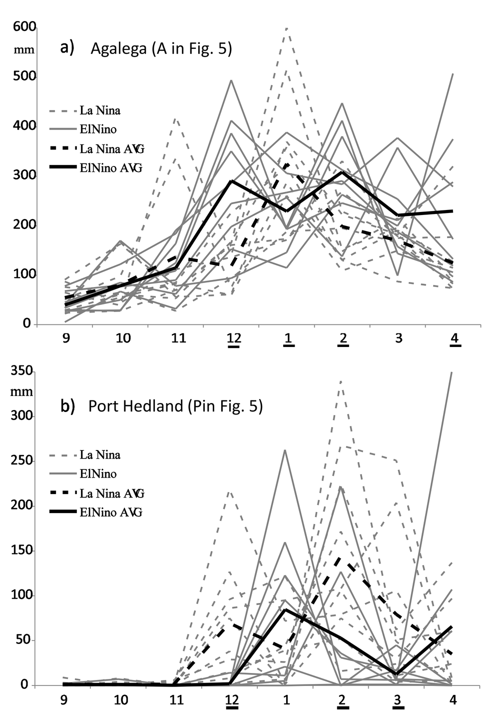

Figure 6

Discussion

- In December the Indian Ocean Dipole (IOD) is strong, and the dipole of precipitation anomalies reaches as far south as the vicinity of Agalega and Port Hedland (Fig. 1b). At the same time the IOD has generated a Rossby wave in the mid-latitudes, extending down to 925 hPa (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. 10a solid and dashed ellipses respectively) has been described as the Indian Ocean Subtropical Dipole (IOSD) mode, the strongest interannual signal of ocean temperature in the Indian Ocean (Huang and Shukla 2008). The anomalous pressure gradient set up by the Rossby wave strengthens the IOSD and advects the SST anomalies to the southeast into January (Fig. 10b).
- Also by January the Rossby wave has propogated 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. 8) 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).

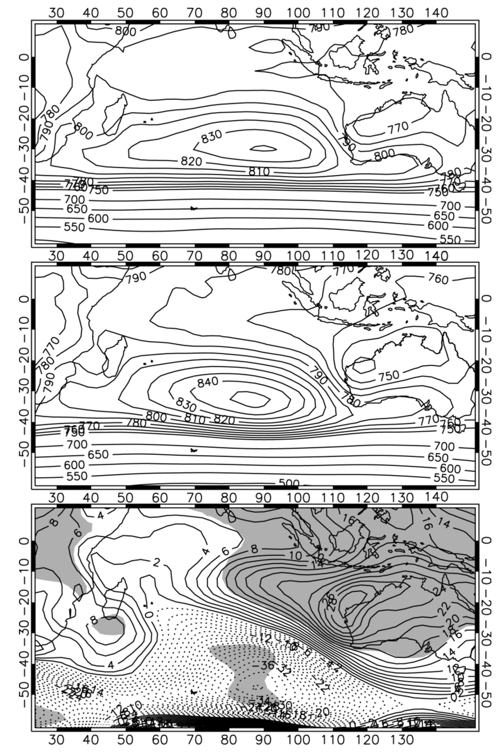

Figure 7: December 925hPa ϕ

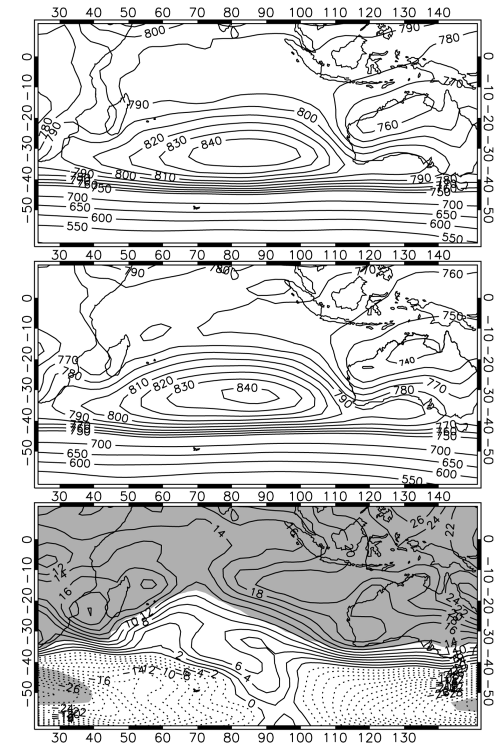

Figure 8: January 925hPa ϕ

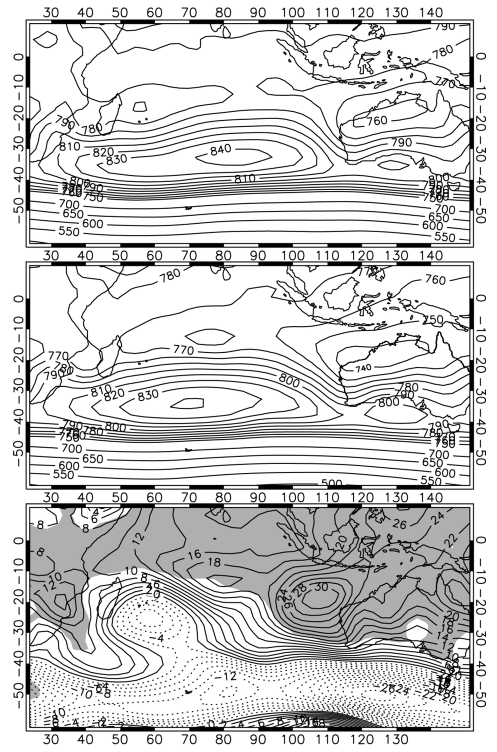

Figure 9: February 925hPa ϕ

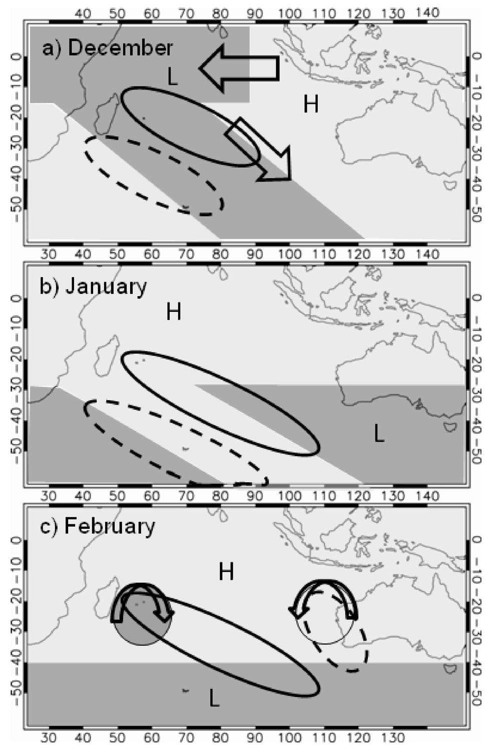

Figure 10: schematic