Leading Tropical multidecadal (TMM) and interannual (ENSO) modes revisited 1951-2015. Major changes in recent decades?

Muthuvel Chelliah,
Climate Prediction Center, NCEP

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Tropical Multidecadal and Interannual Climate Variability in the NCEP–NCAR Reanalysis

Muthuvel Chelliah and Gerald D. Bell

Climate Prediction Center, NCEP/NWS/NOAA, Washington D.C.

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ABSTRACT

The leading tropical multidecadal mode (TMM) and tropical interannual (ENSO) mode in the 52-yr (1949–2000) NCEP–NCAR reanalysis are examined for the December–February (DJF) and June–August (JJA) seasons based on seasonal tropical convective rainfall variability and tropical surface (land + ocean) temperature variability. These combined modes are shown to capture 70%–80% of the unfiltered variance in seasonal 200-hPa velocity potential anomalies in the analysis region of 30°N–30°S. The TMM is the dominant mode overall, accounting for 50%–60% of the total unfiltered variance in both seasons, compared to the 22%–24% for ENSO.

The robustness of the tropical multidecadal mode is addressed, and the results are shown to compare favorably with observed station data and published results of decadal climate variability in the key loading regions. The temporal and spatial characteristics of this mode are found to be distinct from ENSO.

The TMM captures the global climate regimes observed during the 1950s–60s and 1980s–90s, and the 1970s transition between these regimes. It provides a global-scale perspective for many known aspects of this decadal climate variability (i.e., surface temperature, precipitation, and atmospheric circulation) and links them to coherent multidecadal variations in tropical convection and surface temperatures in four core regions: the West African monsoon region, the central tropical Pacific, the Amazon basin, and the tropical Indian Ocean.

During JJA, two distinguishing features of the tropical multidecadal mode are its link to West African monsoon variability and the pronounced zonal wavenumber-1 structure of the 200-hPa streamfunction anomalies in the subtropics of both hemispheres. During DJF a distinguishing feature is its link between anomalous tropical convection and multidecadal variations in the North Atlantic Oscillation (NAO). For the linear combination of

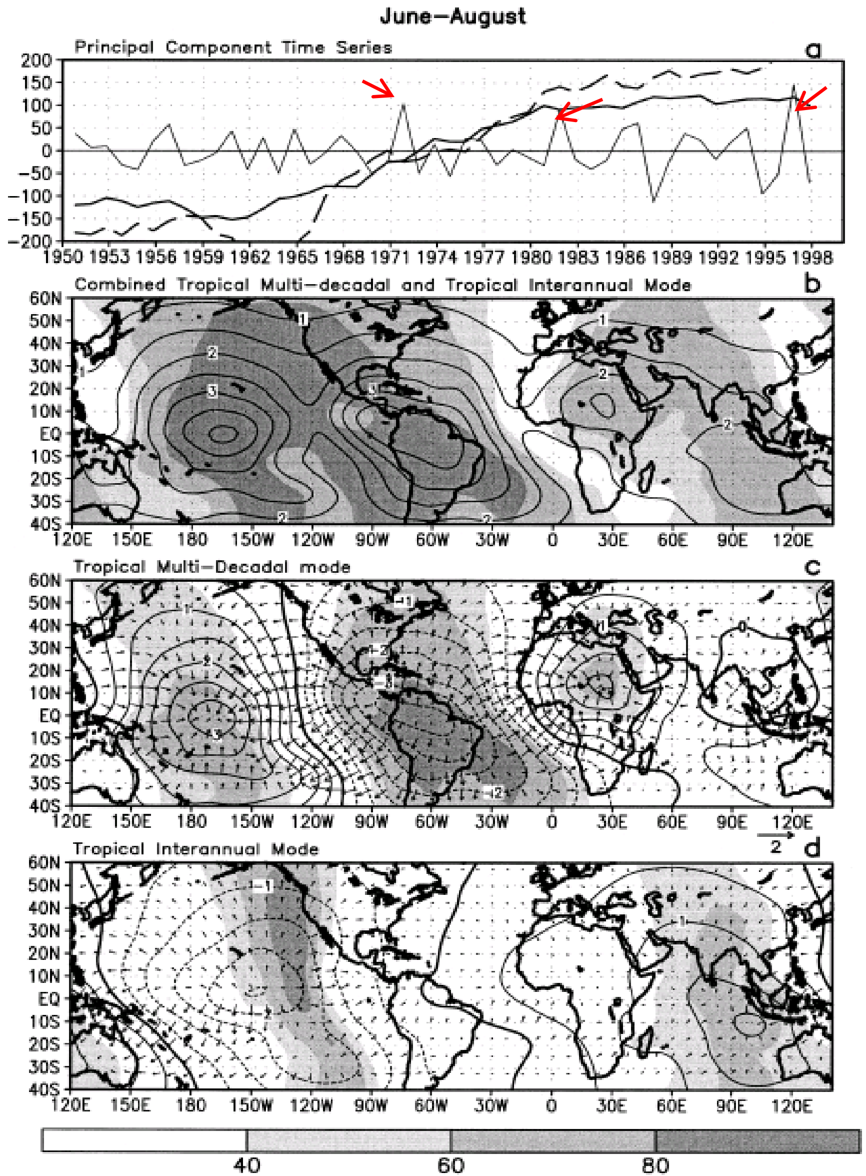

FIG. 3. JJA (a) PC time series for the TMM (thick solid), tropical interannual mode (ENSO, thin solid), and leading multidecadal EOF of seasonal surface temperature anomalies (dashed). Shading shows percent of explained variance of unfiltered seasonal 200-hPa velocity potential anomalies by the (b) combined TMM and ENSO, (c) TMM, and (d) ENSO. (b) The 1949–2000 std dev of seasonal 200-hPa velocity potential anomalies (contours, interval is 5×10^6 m^2 s^{-1}). (c), (d) The seasonal 200-hPa velocity potential loadings [contours, interval is 0.5×10^6 m^2 s^{-1} (std dev)$^{-1}$ of the TMM and ENSO, respectively]. The associated 200-hPa divergent vector wind anomalies [m s^{-1} (std dev)$^{-1}$ of the model] are also plotted, with vector scale located above (d).

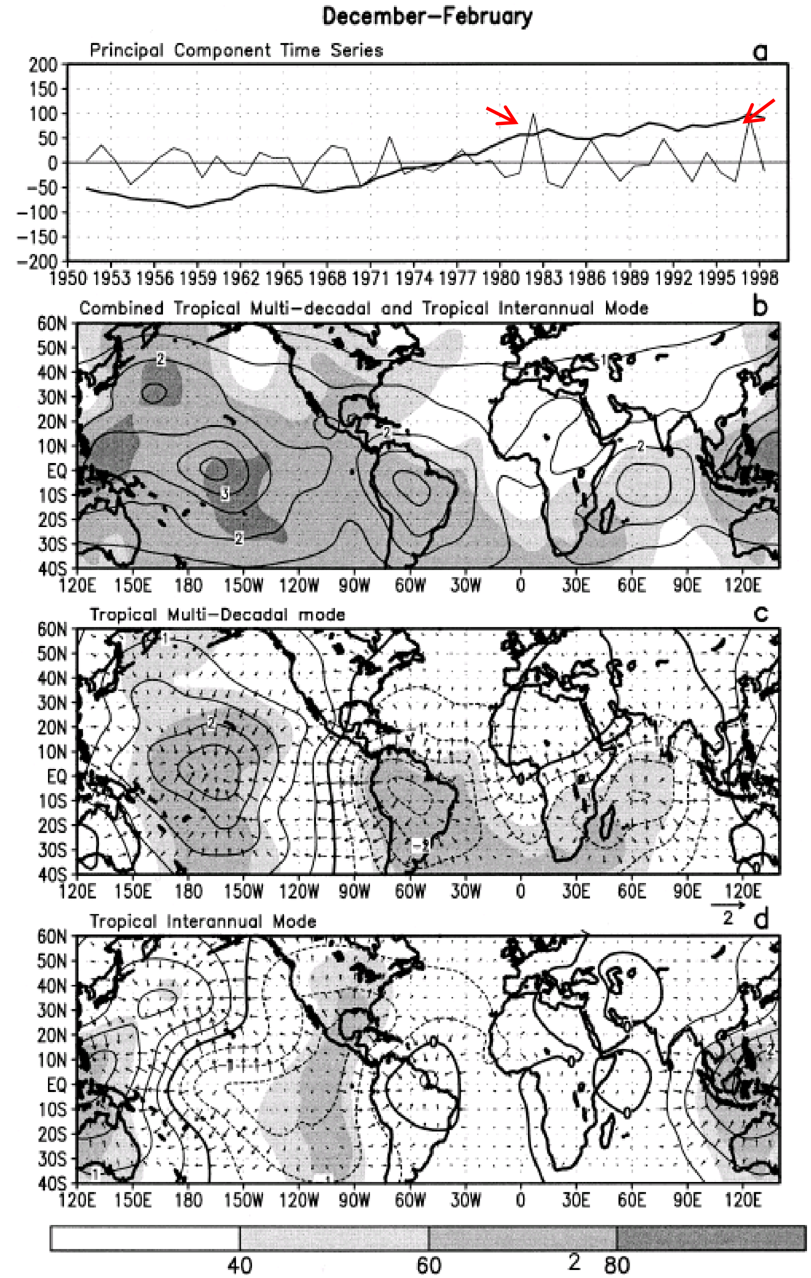

FIG. 4. As in Fig. 3, except for the DJF season.

surface temperature (land + ocean) anomalies above-average precipitation rates again over the Ama

Leading Tropical Modes Associated with Interannual and Multidecadal Fluctuations in North Atlantic Hurricane Activity

GERALD D. BELL AND MUTHUVEL CHELLIAH

Climate Prediction Center, NOAA/NWS/NCEP, Washington, D.C.

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ABSTRACT

Interannual and multidecadal extremes in Atlantic hurricane activity are shown to result from a coherent and interrelated set of atmospheric and oceanic conditions associated with three leading modes of climate variability in the Tropics. All three modes are related to fluctuations in tropical convection, with two representing the leading multidecadal modes of convective rainfall variability, and one representing the leading interannual mode (ENSO).

The tropical multidecadal modes are shown to link known fluctuations in Atlantic hurricane activity, West African monsoon rainfall, and Atlantic sea surface temperatures, to the Tropics-wide climate variability. These modes also capture an east–west seesaw in anomalous convection between the West African monsoon region and the Amazon basin, which helps to account for the interhemispheric symmetry of the 200-hPa streamfunction anomalies across the Atlantic Ocean and Africa, the 200-hPa divergent wind anomalies, and both the structure and spatial scale of the low-level tropical wind anomalies, associated with multidecadal extremes in Atlantic hurricane activity.

While there are many similarities between the 1950–69 and 1995–2004 periods of above-normal Atlantic hurricane activity, important differences in the tropical climate are also identified, which indicates that the above-normal activity since 1995 does not reflect an exact return to conditions seen during the 1950s–60s. In particular, the period 1950–69 shows a strong link to the leading tropical multidecadal mode (TMM), whereas the 1995–2002 period is associated with a sharp increase in amplitude of the second leading tropical multidecadal mode (TMM2). These differences include a very strong West African monsoon circulation and near-average sea surface temperatures across the central tropical Atlantic during 1950–69, compared with a modestly enhanced West African monsoon and exceptionally warm Atlantic sea surface temperatures

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A predictor for North Atlantic Hurricane Season ?

Muthuvel Chelliah and Gerry Bell
Climate Prediction Center, NCEP, NWS, NOAA, Washington DC 20233

Based on reanalysis data beginning 1999, we at NOAA/CPC, along with NHC started issuing its first official seasonal hurricane outlooks.

1. Introduction

The hurricane activity (loosely defined here as the number of hurricanes per season) over the tropical North Atlantic ocean basin during the August-September-October (ASO) hurricane season exhibits considerable variability on both interannual and low frequency (decadal) time scales (see Figure 1, 1949-1997 data obtained from the National Hurricane Center). On interannual time scale, note for example that while 1995 hurricane season experienced nine hurricanes, 1997 hurricane season reported only one hurricane (the influence of ENSO, El Nino/La Nina events, on the ASO hurricane season will be considered in a companion study by the same authors in this report). On a much longer time scale, notice in general that there has been a general decrease in the number of hurricanes per season after 1971. In many previous studies, particularly by Dr. Bill Gray and his colleagues, a variety of regional and global factors have been considered to play a role in determining the 'level/strength' of the Atlantic Hurricane activity. In fact, forecasts for the Hurricane season are routinely issued by them and others based on those factors.

In this study, we will first demonstrate that the global scale Asian summer monsoon circulation plays a major role in determining the vertical wind shear over north Atlantic. Then we will investigate the influence of tropospheric vertical zonal wind shear (U200-U850) in the tropical Atlantic basin, on the interannual variability of north Atlantic hurricane activity. Finally, it will be shown that a meaningful 'advisory' to the ASO Atlantic Hurricane season can be issued as early as June or July based on the wind shear information alone.

2. Vertical Shear over North equatorial Atlantic and the Asian Summer Monsoon

Figure 2 shows the mean vertical zonal wind shear in the tropical Atlantic ocean basin during 10 active and 14 inactive hurricane seasons. Here, we have defined an active hurricane season as one with seven hurricanes or more per season and the inactive season as one with three hurricanes or less. It is very clear (Fig. 2a) that during an active hurricane season, over the latitudes (7.5°-15°N) where the storms/hurricanes generally form, the ASO vertical wind shear is either weak westerly or easterly. However, an inactive season (Fig. 2b) is characterized by the presence of no easterly shear, but rather strong westerly shear, which inhibits the westward passage of Atlantic storms.

In fact, the importance of easterly vertical wind shear for the westward propagating North Atlantic tropical storms and hurricanes that hit the Caribbean islands and the eastern coastal states of the U.S. are well known. But, what has not been clear from previous studies is the crucial link between the vertical shear in this Atlantic region and the Asian summer monsoon. Examination of daily or monthly mean 200 mb flow patterns during the Northern Hemisphere summer months (not shown here, for lack of space) would reveal that the north-south extent and the strength of the 200 mb easterly flow, which determines the vertical shear, over the equatorial and subtropical Atlantic is a part/resultant of the massive outflow from the large upper level anticyclone centered over India. In fact, these upper level easterlies over Atlantic is an integral part of the interhemispheric (north to south) transport of airmass that takes place during the summer monsoon season to compensate for the low level northward flow, inclusive of the east African Somali Jet, from Southern Hemisphere across the equator into the monsoon low pressure region over Indian subcontinent.

ENSO-like Interdecadal Variability: 1900–93

YUAN ZHANG, JOHN M. WALLACE, AND DAVID S. BATTISTI

Department of Atmospheric Sciences, University of Washington, Seattle, Washington

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ABSTRACT

A number of recent studies have reported an ENSO-like EOF mode in the global sea surface tempe
(SST) field, whose time variability is marked by an abrupt change toward a warmer tropical eastern Pacif
a colder extratropical central North Pacific in 1976–77. The present study compares this pattern with the str
of the interannual variability associated with the ENSO cycle and documents its time history back to 190
analysis is primarily based on the leading EOFs of the SST anomaly and "anomaly deviation" fields in v
domains and the associated expansion coefficient (or principal component) time series, which are used to co
global regression maps of SST, sea level pressure (SLP), and a number of related variables. The use of "an
deviations" (i.e., departures of local SST anomalies from the concurrent global-mean SST anomaly) re
the influence of global-mean SST trends upon the structure of the EOFs and their expansion coefficien
series. ,
surface
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field is
annual

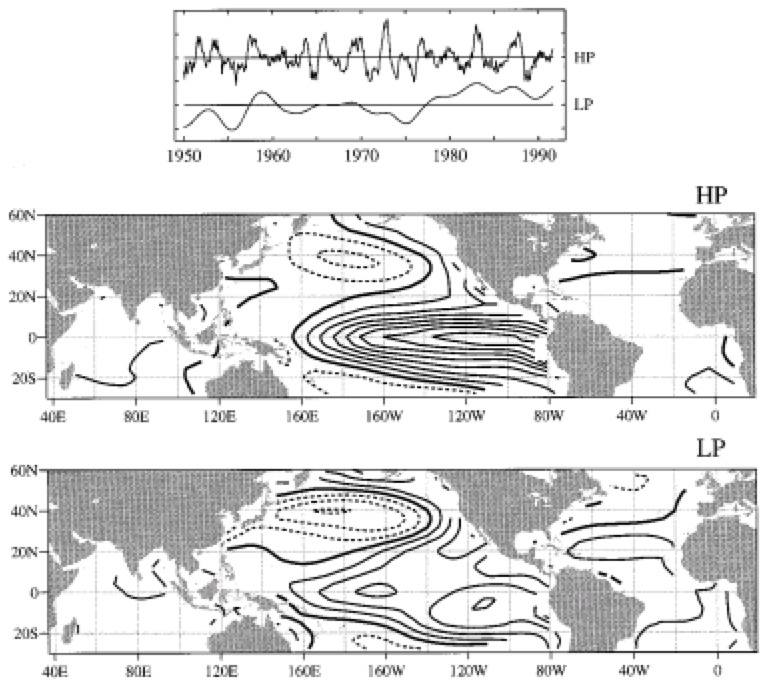

FIG. 3. The leading (normalized) PCs of 6-yr highpass- (HP) and lowpass- (LP) filtered SST over the Pacific domain shown together with the associated regression patterns for global SST. The interval between tick-marks on the vertical axis of the top panel corresponds to 1.0 standard deviation, and the spacing between the curves is arbitrary. Contour interval 0.1 K per standard deviation of the expansion coefficient time series. Negative contours are dashed; the zero contour is thickened.

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ENSO-like interdecadal variability in the Pacific Ocean as simulated in a coupled general circulation model

Seiji Yukimoto, Masahiro Endoh, Yoshiteru Kitamura, Akio Kitoh, Tatsuo Motoi, Akira Noda

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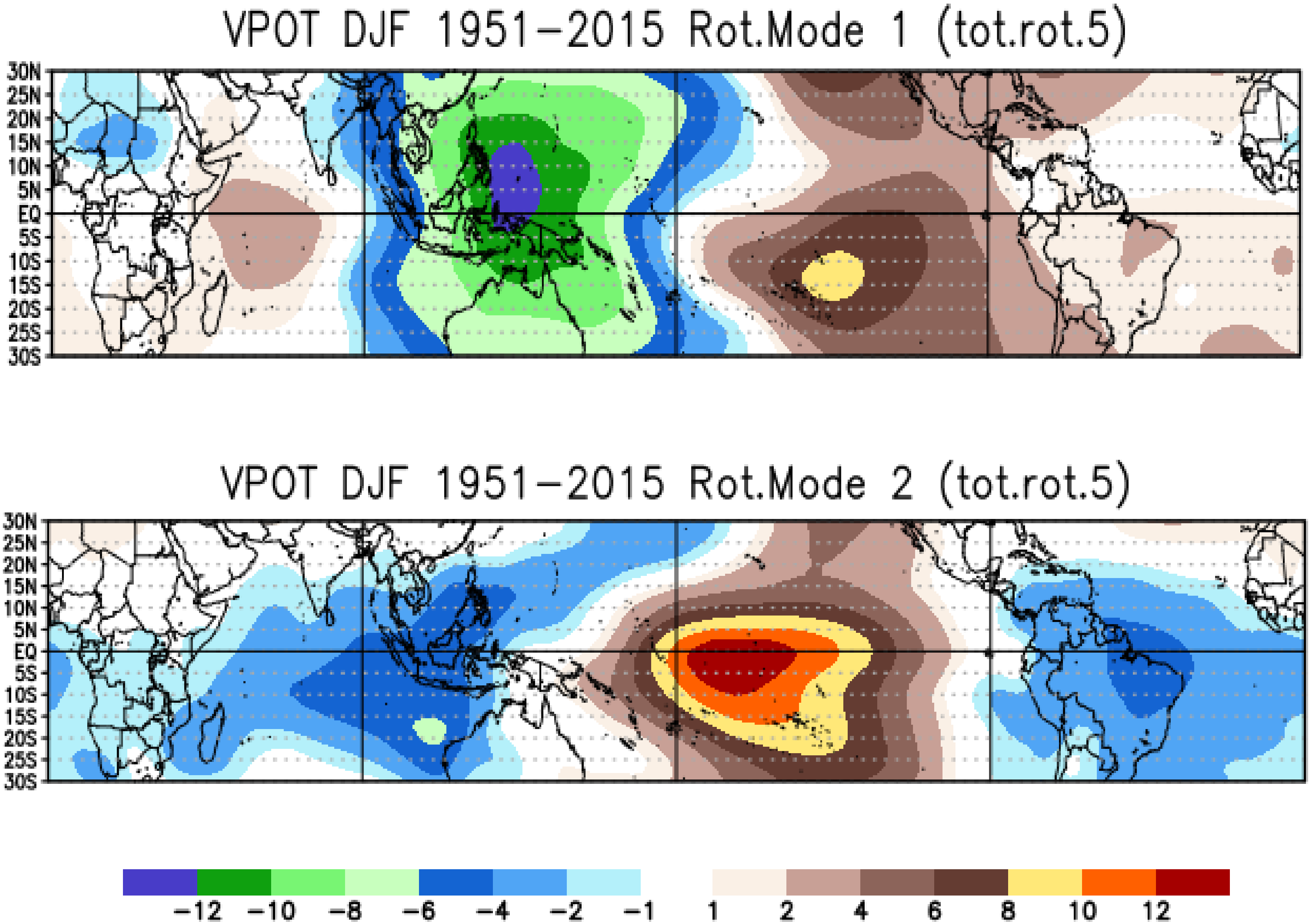
Abstract


VPOT DJF 1951–2015 Rot.Mode 1 (tot.rot.5)
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
VPOT DJF 1951–2015 Rot.Mode 2 (tot.rot.5)
30N
25N
20N
15N
10N
5N
EQ
5S
10S
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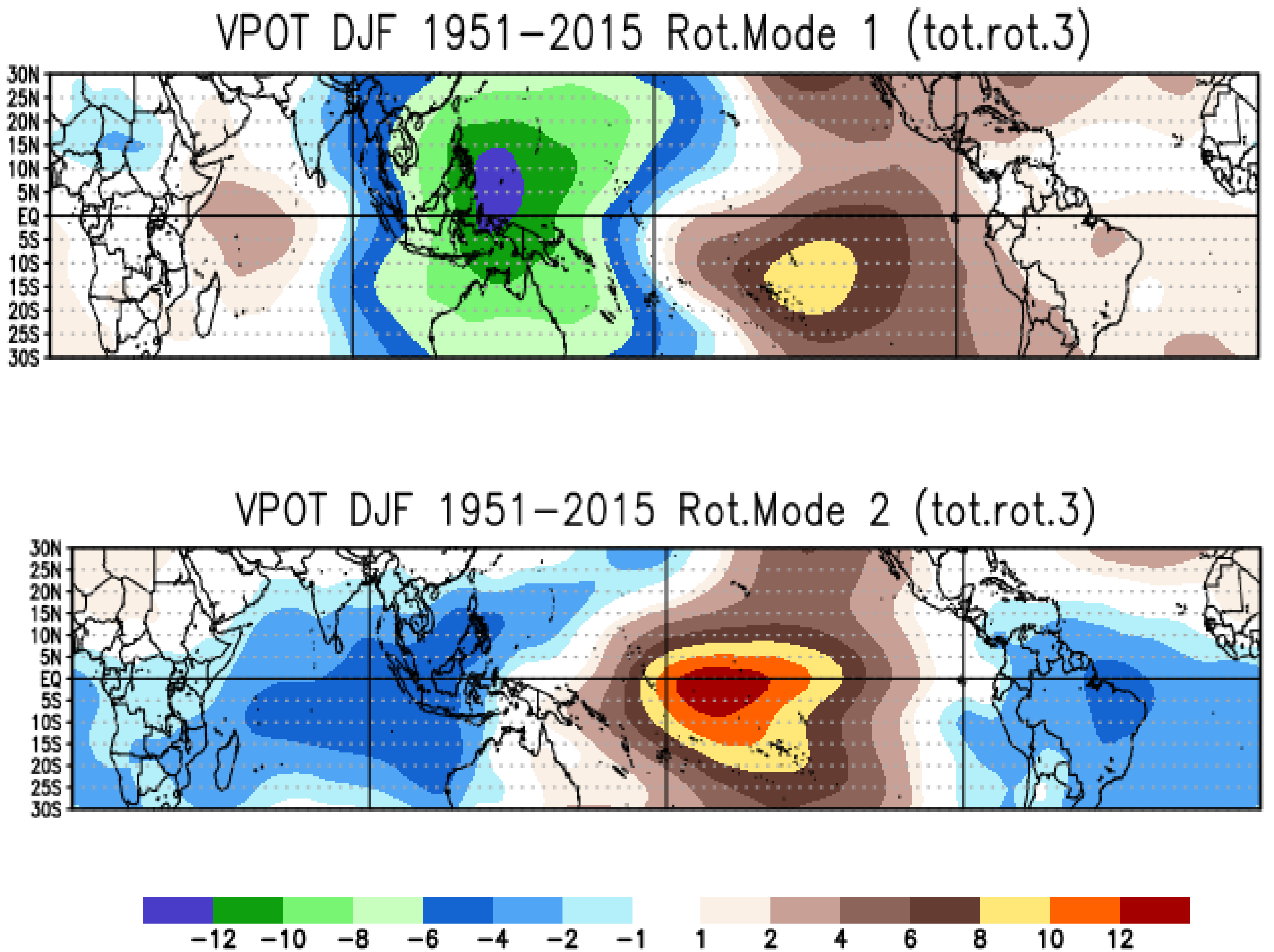
20S
25S
30S
−12 −10 −8 −6 −4 −2 −1 1 2 4 6 8 10 12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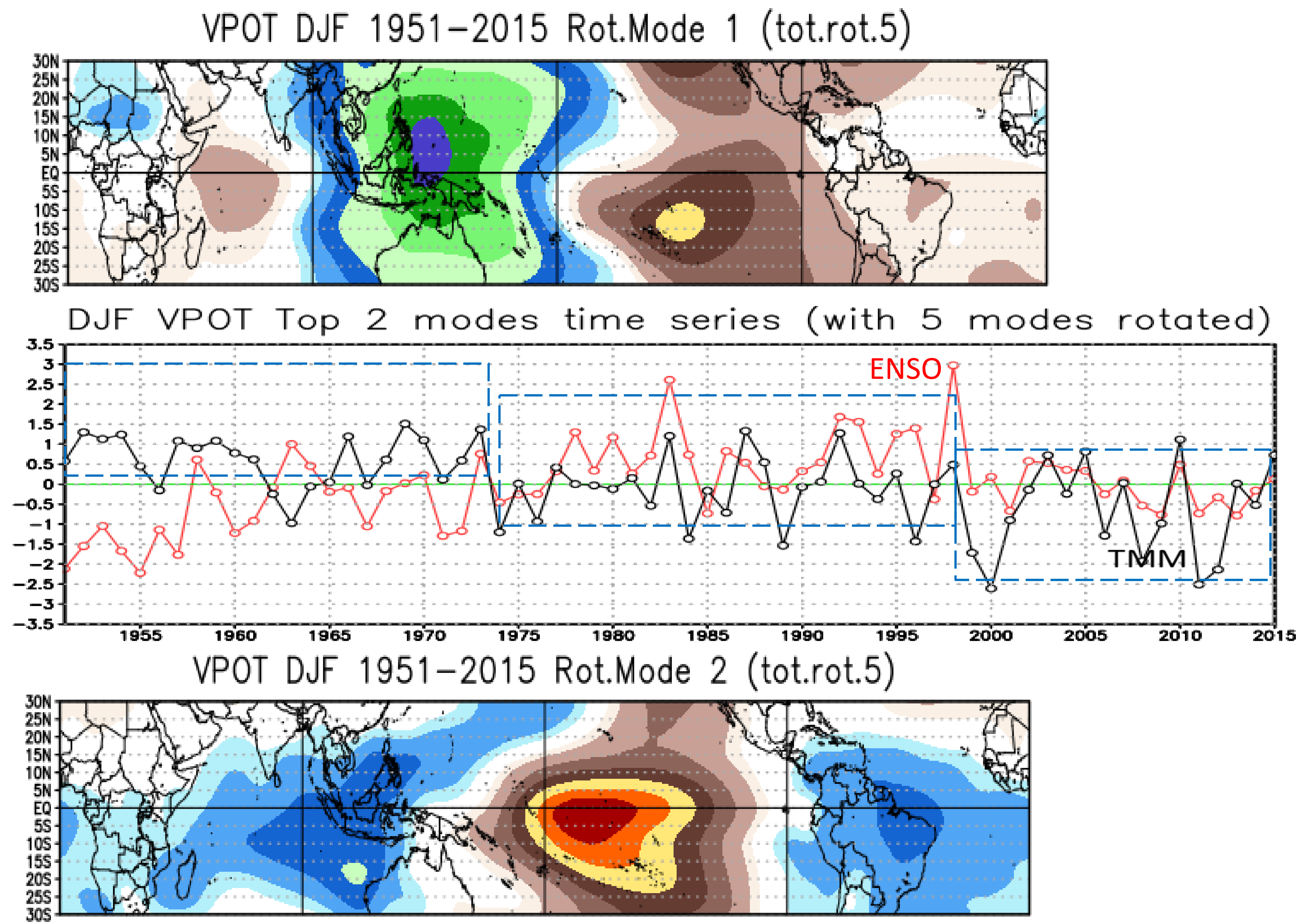
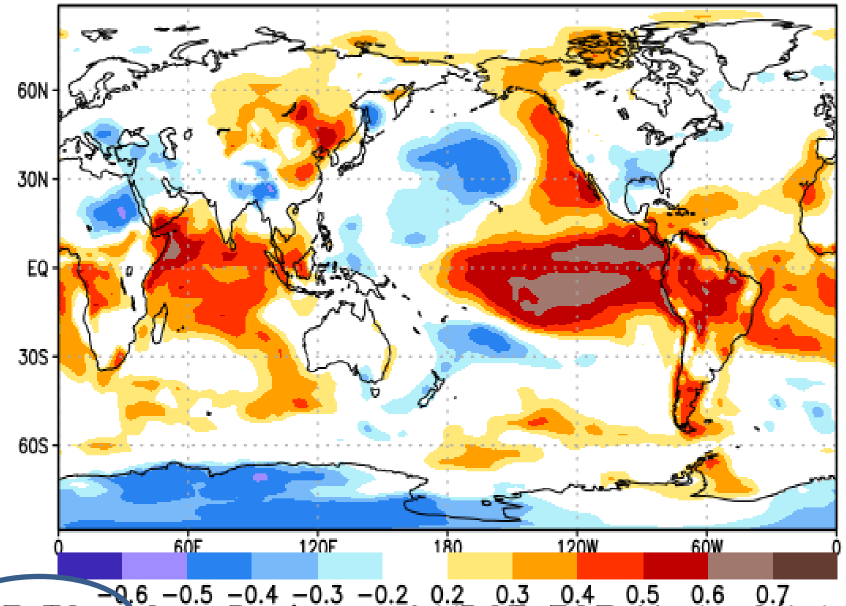
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
VPOT DJF 1951–2015 Rot.Mode 2 (tot.rot.3)
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
−12 −10 −8 −6 −4 −2 −1 1 2 4 6 8 10 12

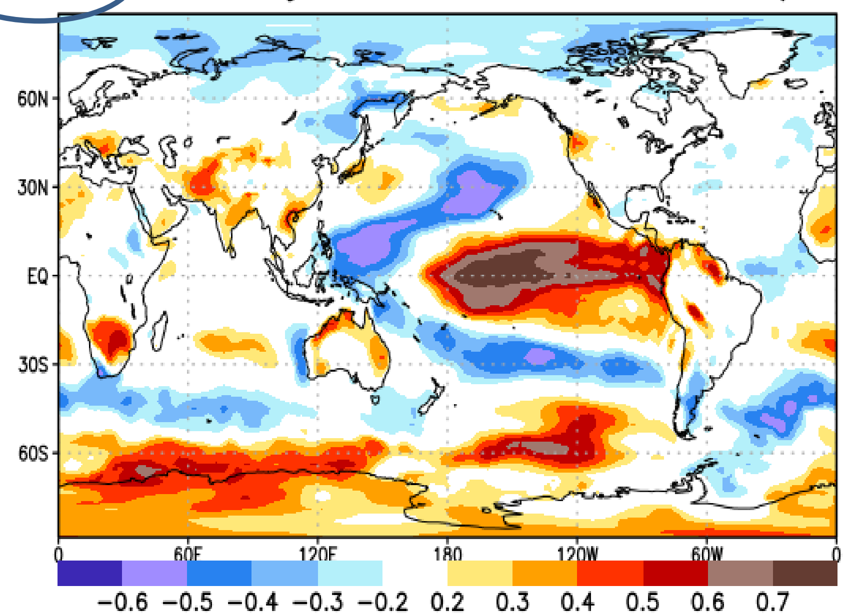


VPOT DJF 1951–2015 Rot.Mode 1 (tot.rot.5)
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
DJF VPOT Top 2 modes time series (with 5 modes rotated)
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
−3.5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
ENSO
TMM
VPOT DJF 1951–2015 Rot.Mode 2 (tot.rot.5)
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S

DJF T2m Corr:Projexn of VPOT EOF Mode 1(ENSO)



DJF T2m Corr:Projexn of VPOT EOF Mode 2(Int.Dec.)



Cold & Warm Episodes by Season

Link to Previous Version of ONI (ERSST.v3b)

Notice: Because of the high frequency filter applied to the ERSSTv4 data (Huang et al. 2015, J.Climate), ONI values may change up to two months after the initial "real time" value is posted. Therefore, the most recent ONI values should be considered an estimate.

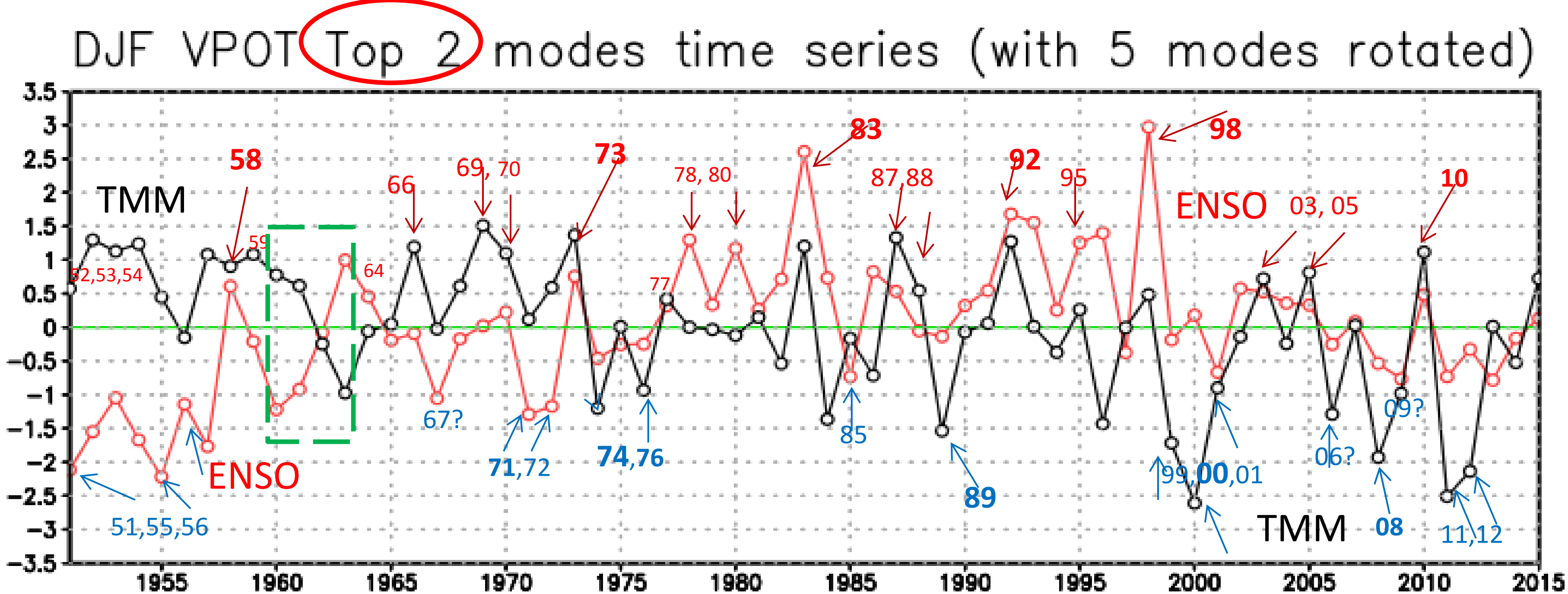
DESCRIPTION: Warm (red) and cold (blue) periods based on a threshold of +/- 0.5°C for the Oceanic Niño Index (ONI) [3 month running mean of ERSST.v4 SST anomalies in the Niño 3.4 region (5°N-5°S, 120°-170°W)], based on centered 30-year base periods updated every 5 years.

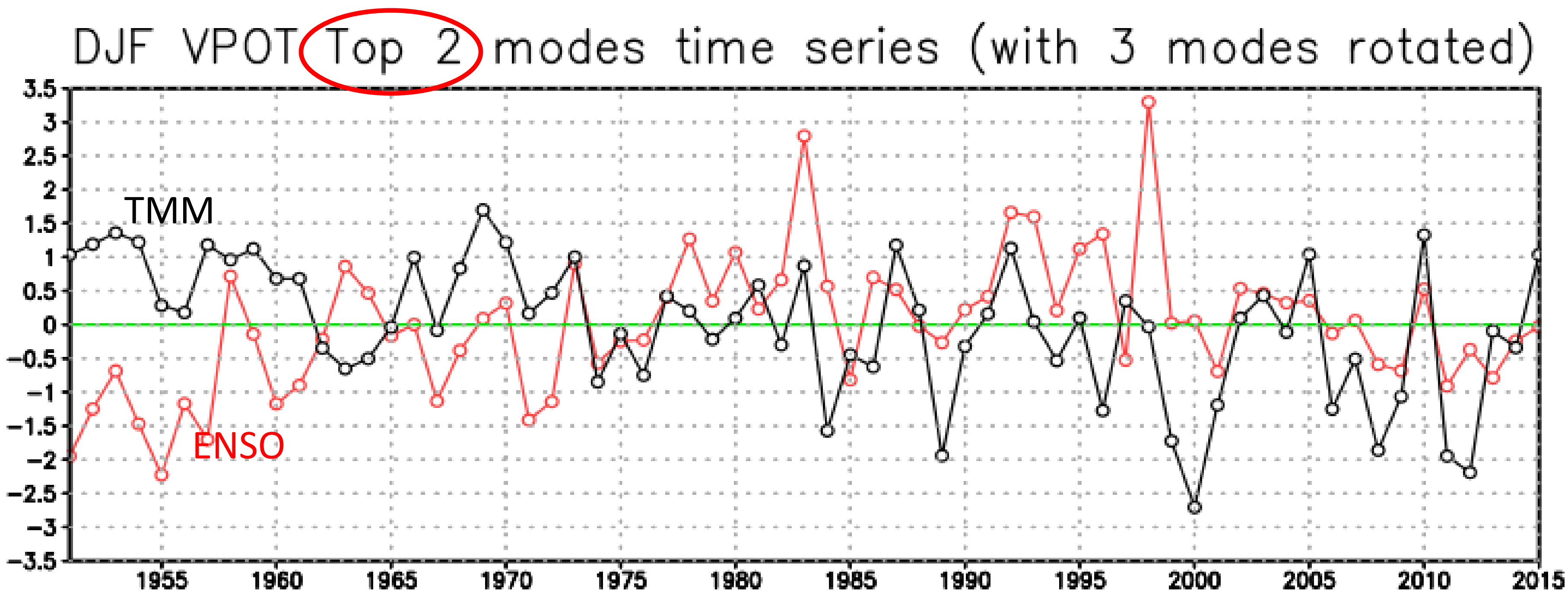
For historical purposes, periods of below and above normal SSTs are colored in blue and red when the threshold is met for a minimum of 5 consecutive overlapping seasons. The ONI is one measure of the El Niño-Southern Oscillation, and other indices can confirm whether features consistent with a coupled ocean-atmosphere phenomenon accompanied these periods.

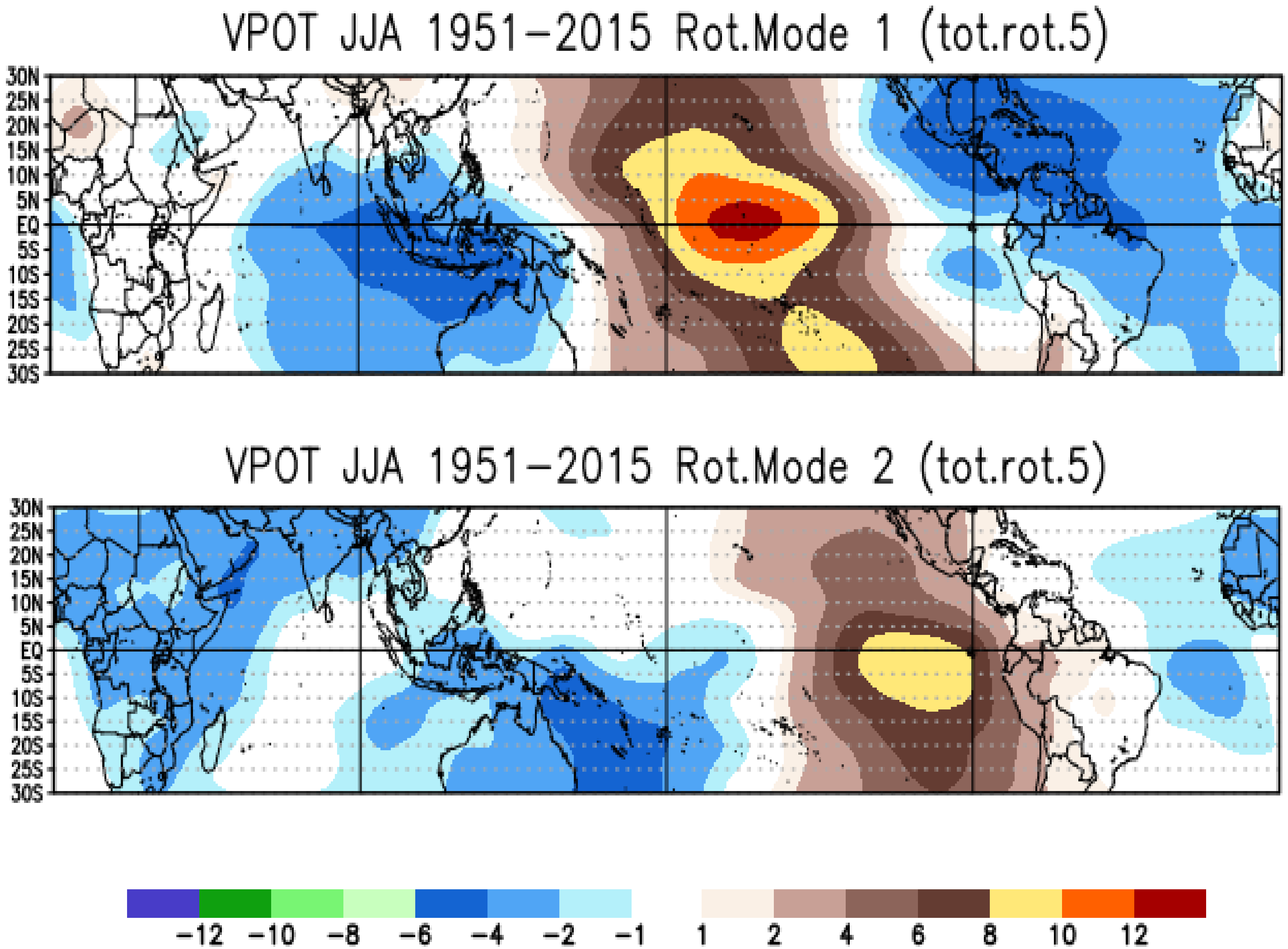
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1950	-1.4	-1.2	-1.1	-1.2	-1.1	-0.9	-0.6	-0.6	-0.5	-0.6	-0.7	-0.8
1951	-0.8	-0.6	-0.2	0.2	0.2	0.4	0.5	0.7	0.8	0.9	0.7	0.6
1952	0.5	0.4	0.4	0.4	0.4	0.2	0	0.1	0.2	0.2	0.2	0.3
1953	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.7
1954	0.7	0.4	0	-0.4	-0.5	-0.5	-0.5	-0.7	-0.7	-0.6	-0.5	-0.5
1955	-0.6	-0.6	-0.7	-0.7	-0.7	-0.6	-0.6	-0.6	-1.0	-1.4	-1.6	-1.4
1956	-0.9	-0.6	-0.6	-0.5	-0.5	-0.4	-0.5	-0.5	-0.4	-0.4	-0.5	-0.4
1957	-0.3	0	0.3	0.6	0.7	0.9	1.0	1.2	1.1	1.2	1.3	1.6
1958	1.7	1.5	1.2	0.8	0.7	0.6	0.5	0.4	0.4	0.5	0.6	0.6
1959	0.6	0.5	0.4	0.2	0.1	-0.2	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1
1960	-0.1	-0.2	-0.1	0	-0.1	-0.2	0	0.1	0.2	0.1	0	0

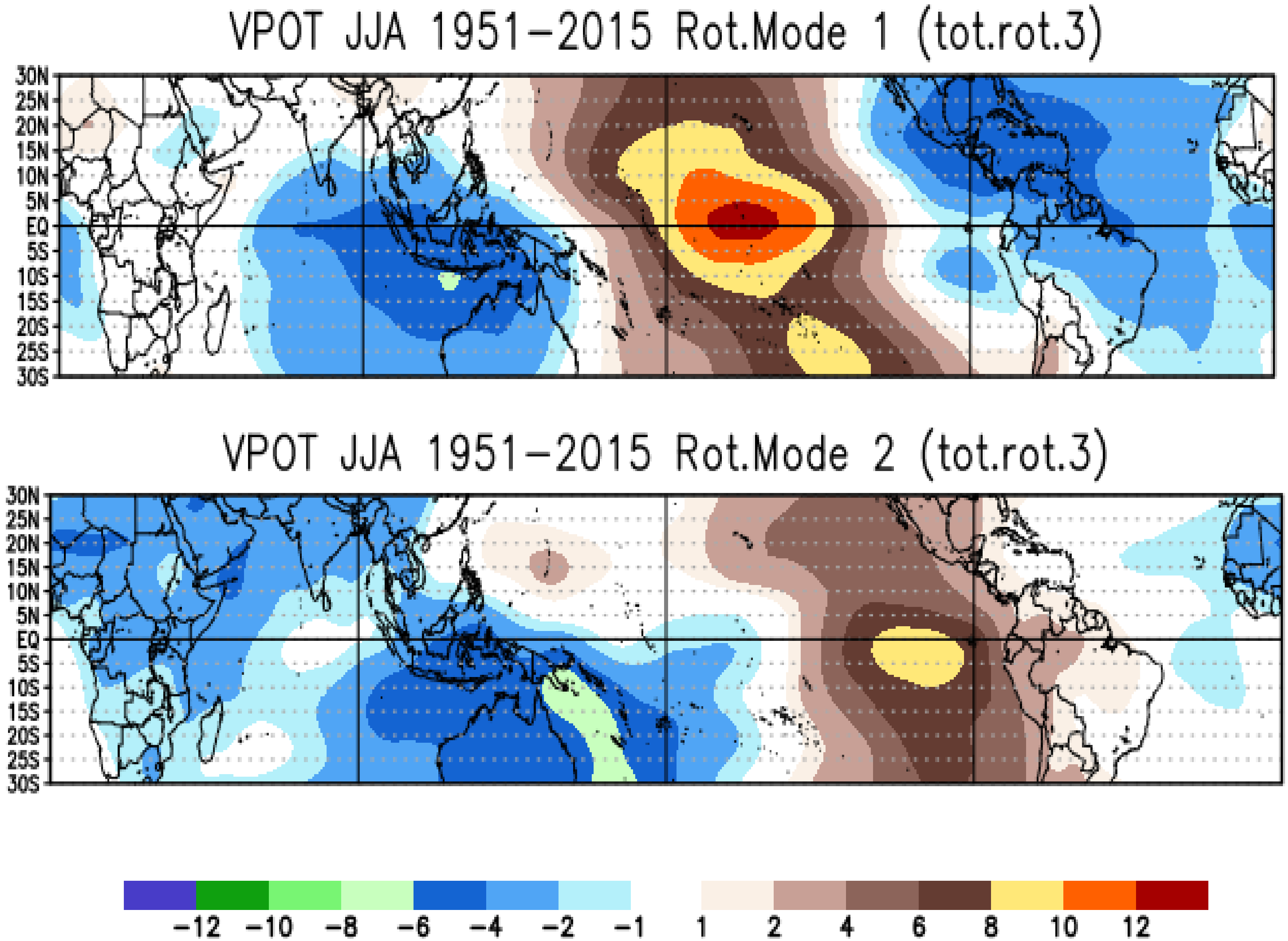
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1950	-1.4	-1.2	-1.1	-1.2	-1.1	-0.9	-0.6	-0.6	-0.5	-0.6	-0.7	-0.8
1951	-0.8	-0.6	-0.2	0.2	0.2	0.4	0.5	0.7	0.8	0.9	0.7	0.6
1952	0.5	0.4	0.4	0.4	0.4	0.2	0	0.1	0.2	0.2	0.2	0.3
1953	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.7
1954	0.7	0.4	0	-0.4	-0.5	-0.5	-0.5	-0.7	-0.7	-0.6	-0.5	-0.5
1955	-0.6	-0.6	-0.7	-0.7	-0.7	-0.6	-0.6	-0.6	-1.0	-1.4	-1.6	-1.4
1956	-0.9	-0.6	-0.6	-0.5	-0.5	-0.4	-0.5	-0.5	-0.4	-0.4	-0.5	-0.4
1957	-0.3	0	0.3	0.6	0.7	0.9	1.0	1.2	1.1	1.2	1.3	1.6
1958	1.7	1.5	1.2	0.8	0.7	0.6	0.5	0.4	0.4	0.5	0.6	0.6
1959	0.6	0.5	0.4	0.2	0.1	-0.2	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1
1960	-0.1	-0.2	-0.1	0	-0.1	-0.2	0	0.1	0.2	0.1	0	0
1961	0	0	-0.1	0	0.1	0.2	0.1	-0.1	-0.3	-0.3	-0.2	-0.2
1962	-0.2	-0.2	-0.2	-0.3	-0.3	-0.2	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4
1963	-0.4	-0.2	0.1	0.2	0.2	0.4	0.7	1.0	1.1	1.2	1.2	1.1
1964	1.0	0.6	0.1	-0.3	-0.6	-0.6	-0.7	-0.7	-0.8	-0.8	-0.8	-0.8
1965	-0.5	-0.3	-0.1	0.1	0.4	0.7	1.0	1.3	1.6	1.7	1.8	1.5
1966	1.3	1.0	0.9	0.6	0.3	0.2	0.2	0.1	0	-0.1	-0.1	-0.3
1967	-0.4	-0.5	-0.5	-0.5	-0.2	0	0	-0.2	-0.3	-0.4	-0.4	-0.5
1968	-0.7	-0.8	-0.7	-0.5	-0.1	0.2	0.5	0.4	0.3	0.4	0.6	0.8
1969	0.9	1.0	0.9	0.7	0.6	0.5	0.4	0.5	0.8	0.8	0.8	0.7
1970	0.6	0.4	0.4	0.3	0.1	-0.3	-0.6	-0.8	-0.8	-0.8	-0.9	-1.2
1971	-1.3	-1.3	-1.1	-0.9	-0.8	-0.7	-0.8	-0.7	-0.8	-0.8	-0.9	-0.8
1972	-0.7	-0.4	0	0.3	0.6	0.8	1.1	1.3	1.5	1.8	2.0	1.9
1973	1.7	1.2	0.6	0	-0.4	-0.8	-1.0	-1.2	-1.4	-1.7	-1.9	-1.9
1974	-1.7	-1.5	-1.2	-1.0	-0.9	-0.8	-0.6	-0.4	-0.4	-0.6	-0.7	-0.6
1975	-0.5	-0.5	-0.6	-0.6	-0.7	-0.8	-1.0	-1.1	-1.3	-1.4	-1.5	-1.6
1976	-1.5	-1.1	-0.7	-0.4	-0.3	-0.1	0.1	0.3	0.5	0.7	0.8	0.8
1977	0.7	0.6	0.4	0.3	0.3	0.4	0.4	0.4	0.5	0.6	0.8	0.8
1978	0.7	0.4	0.1	-0.2	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.1	0
1979	0	0.1	0.2	0.3	0.3	0.1	0.1	0.2	0.3	0.5	0.5	0.6
1980	0.6	0.5	0.3	0.4	0.5	0.5	0.3	0.2	0	0.1	0.1	0
1981	-0.2	-0.4	-0.4	-0.3	-0.2	-0.3	-0.3	-0.3	-0.2	-0.1	-0.1	0
1982	0	0.1	0.2	0.5	0.6	0.7	0.8	1.0	1.5	1.9	2.1	2.1
1983	2.1	1.8	1.5	1.2	1.0	0.7	0.3	0	-0.3	-0.6	-0.8	-0.8
1984	-0.5	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.2	-0.3	-0.6	-0.9	-1.1
1985	-0.9	-0.7	-0.7	-0.7	-0.7	-0.6	-0.4	-0.4	-0.4	-0.3	-0.2	-0.3

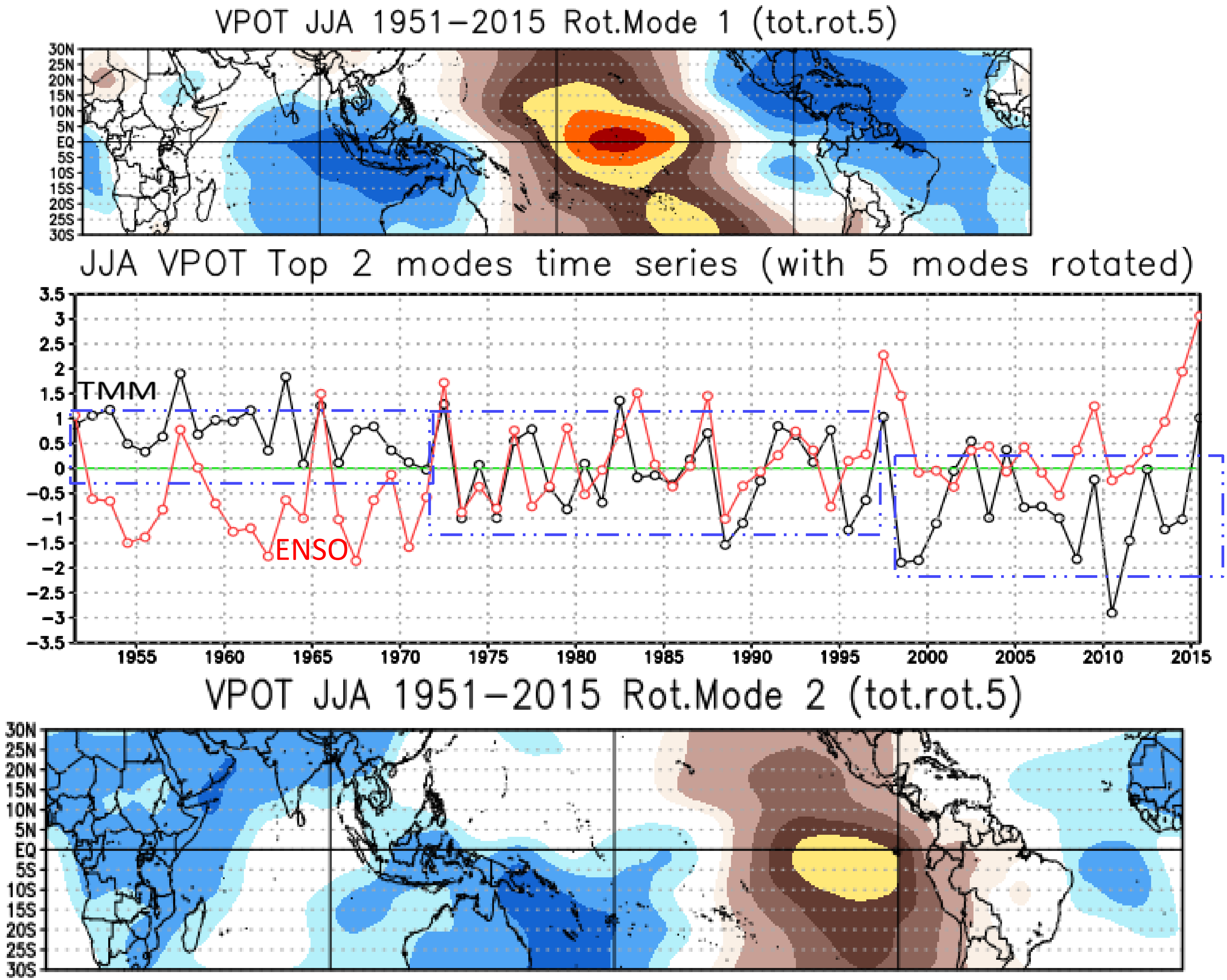
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1981	-0.2	-0.4	-0.4	-0.3	-0.2	-0.3	-0.3	-0.3	-0.2	-0.1	-0.1	0
1982	0	0.1	0.2	0.5	0.6	0.7	0.8	1.0	1.5	1.9	2.1	2.1
1983	2.1	1.8	1.5	1.2	1.0	0.7	0.3	0	-0.3	-0.6	-0.8	-0.8
1984	-0.5	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.2	-0.3	-0.6	-0.9	-1.1
1985	-0.9	-0.7	-0.7	-0.7	-0.7	-0.6	-0.4	-0.4	-0.4	-0.3	-0.2	-0.3
1986	-0.4	-0.4	-0.3	-0.2	-0.1	0	0.2	0.4	0.7	0.9	1.0	1.1
1987	1.1	1.2	1.1	1.0	0.9	1.1	1.4	1.6	1.6	1.4	1.2	1.1
1988	0.8	0.5	0.1	-0.3	-0.8	-1.2	-1.2	-1.1	-1.2	-1.4	-1.7	-1.8
1989	-1.6	-1.4	-1.1	-0.9	-0.6	-0.4	-0.3	-0.3	-0.3	-0.3	-0.2	-0.1
1990	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.3	0.4	0.4
1991	0.4	0.3	0.2	0.2	0.4	0.6	0.7	0.7	0.7	0.8	1.2	1.4
1992	1.6	1.5	1.4	1.2	1.0	0.8	0.5	0.2	0	-0.1	-0.1	0
1993	0.2	0.3	0.5	0.7	0.8	0.6	0.3	0.2	0.2	0.2	0.1	0.1
1994	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.6	0.9	1.0
1995	0.9	0.7	0.5	0.3	0.2	0	-0.2	-0.5	-0.7	-0.9	-1.0	-0.9
1996	-0.9	-0.7	-0.6	-0.4	-0.2	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4	-0.5
1997	-0.5	-0.4	-0.2	0.1	0.6	1.0	1.4	1.7	2.0	2.2	2.3	2.3
1998	2.1	1.8	1.4	1.0	0.5	-0.1	-0.7	-1.0	-1.2	-1.2	-1.3	-1.4
1999	-1.4	-1.2	-1.0	-0.9	-0.9	-1.0	-1.0	-1.0	-1.1	-1.2	-1.4	-1.6
2000	-1.6	-1.4	-1.1	-0.9	-0.7	-0.7	-0.6	-0.5	-0.6	-0.7	-0.8	-0.8
2001	-0.7	-0.6	-0.5	-0.3	-0.2	-0.1	0	-0.1	-0.1	-0.2	-0.3	-0.3
2002	-0.2	-0.1	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.2	1.3	1.1
2003	0.9	0.6	0.4	0	-0.2	-0.1	0.1	0.2	0.3	0.4	0.4	0.4
2004	0.3	0.2	0.1	0.1	0.2	0.3	0.5	0.7	0.7	0.7	0.7	0.7
2005	0.6	0.6	0.5	0.5	0.4	0.2	0.1	0	0	-0.1	-0.4	-0.7
2006	-0.7	-0.6	-0.4	-0.2	0.0	0.1	0.2	0.3	0.5	0.8	0.9	1.0
2007	0.7	0.3	0	-0.1	-0.2	-0.2	-0.3	-0.6	-0.8	-1.1	-1.2	-1.3
2008	-1.4	-1.3	-1.1	-0.9	-0.7	-0.5	-0.3	-0.2	-0.2	-0.3	-0.5	-0.7
2009	-0.8	-0.7	-0.4	-0.1	0.2	0.4	0.5	0.6	0.7	1.0	1.2	1.3
2010	1.3	1.1	0.8	0.5	0	-0.4	-0.8	-1.1	-1.3	-1.4	-1.3	-1.4
2011	-1.3	-1.1	-0.8	-0.6	-0.3	-0.2	-0.3	-0.5	-0.7	-0.9	-0.9	-0.8
2012	-0.7	-0.6	-0.5	-0.4	-0.3	-0.1	0.1	0.3	0.4	0.4	0.2	-0.2
2013	-0.4	-0.5	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.3
2014	-0.5	-0.6	-0.4	-0.2	0	0	0	0	0.2	0.4	0.6	0.6
2015	0.5	0.4	0.5	0.7	0.9	1.0	1.2	1.5				?
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ

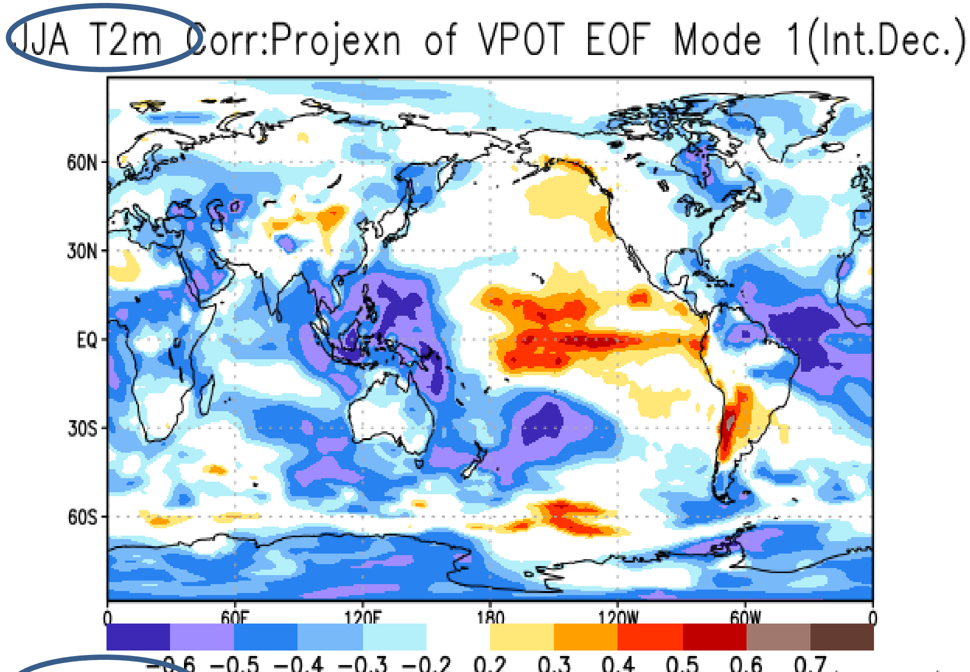

DJF VPOT Top 2 modes time series (with 5 modes rotated)
TMM
ENSO
58
66
69, 70
73
78, 80
83
87,88
92
95
98
03, 05
10
59
52,53,54
64
77
51,55,56
67?
71,72
74,76
85
89
99,00,01
06?
08
09?
11,12
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
−3.5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

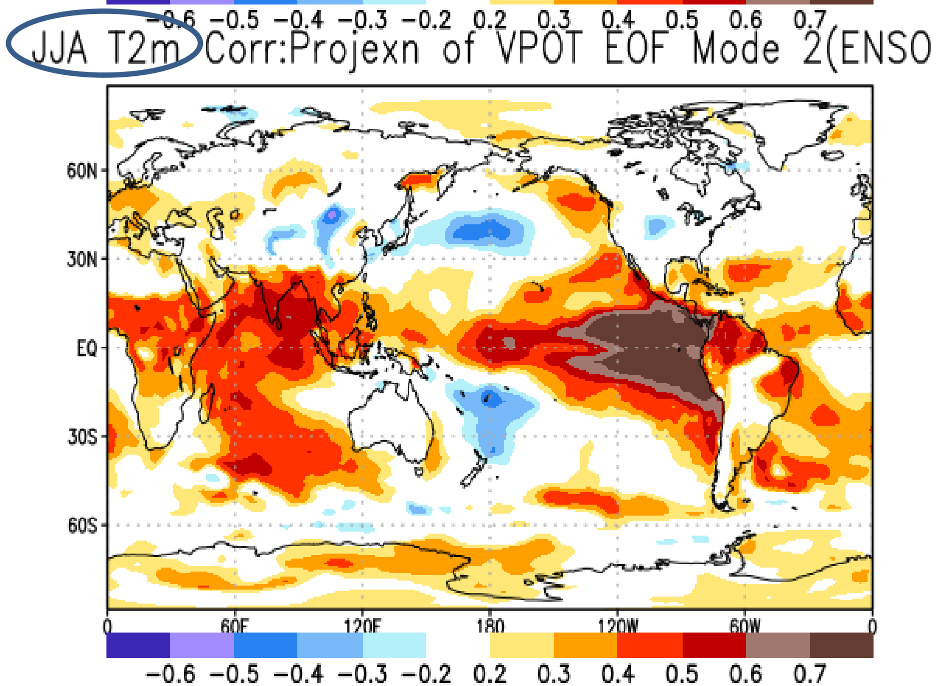

DJF VPOT Top 2 modes time series (with 3 modes rotated)
TMM
ENSO
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
−3.5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

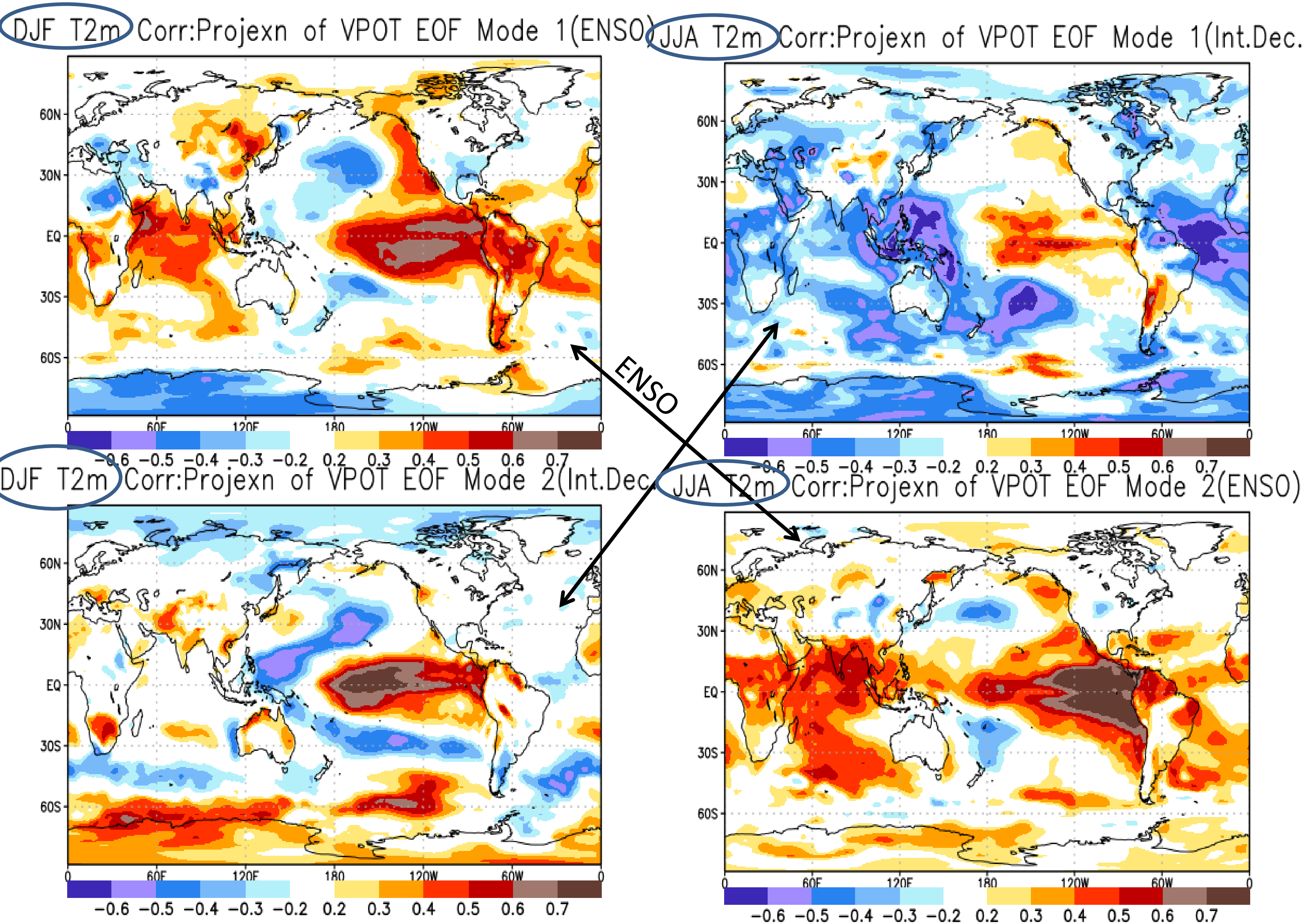

VPOT JJA 1951–2015 Rot.Mode 1 (tot.rot.5)
VPOT JJA 1951–2015 Rot.Mode 2 (tot.rot.5)
30N 25N 20N 15N 10N 5N EQ 5S 10S 15S 20S 25S 30S
−12 −10 −8 −6 −4 −2 −1 1 2 4 6 8 10 12


VPOT JJA 1951–2015 Rot.Mode 1 (tot.rot.3)
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
VPOT JJA 1951–2015 Rot.Mode 2 (tot.rot.3)
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
−12
−10
−8
−6
−4
−2
−1
1
2
4
6
8
10
12


VPOT JJA 1951–2015 Rot.Mode 1 (tot.rot.5)
30N 25N 20N 15N 10N 5N EQ 5S 10S 15S 20S 25S 30S
JJA VPOT Top 2 modes time series (with 5 modes rotated)
3.5 3 2.5 2 1.5 1 0.5 0 −0.5 −1 −1.5 −2 −2.5 −3 −3.5
TMM
ENSO
1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
VPOT JJA 1951–2015 Rot.Mode 2 (tot.rot.5)
30N 25N 20N 15N 10N 5N EQ 5S 10S 15S 20S 25S 30S

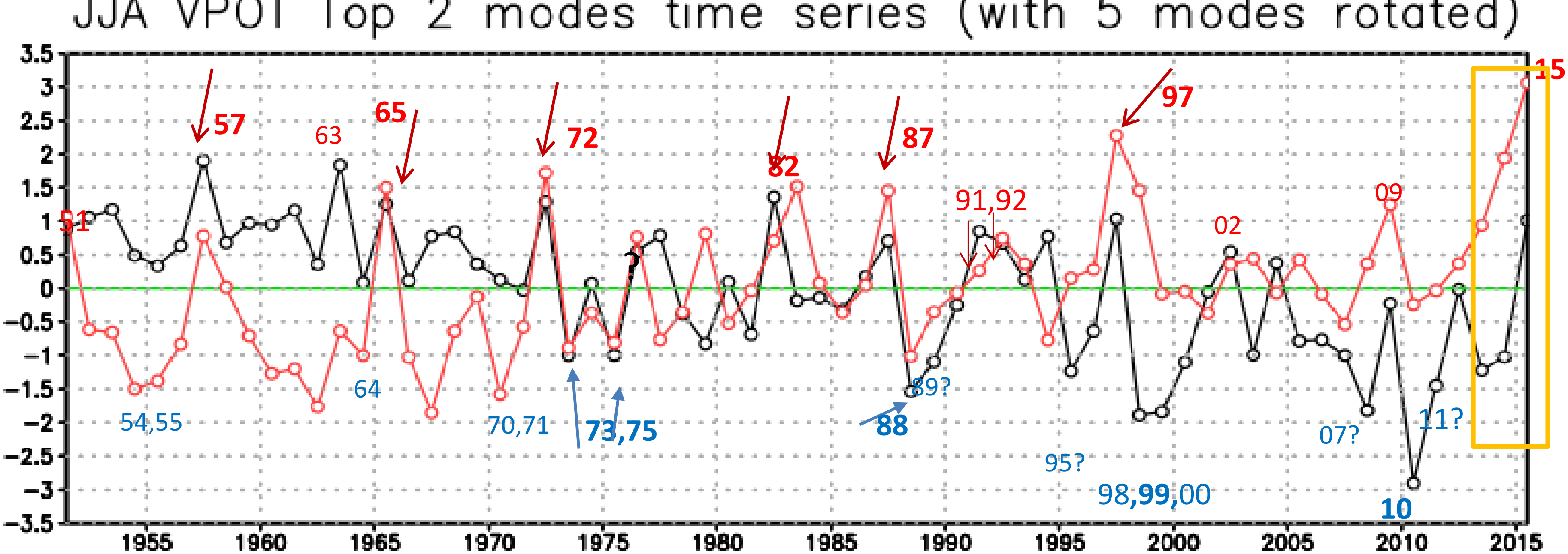

JJA T2m Corr:Projexn of VPOT EOF Mode 1(Int.Dec.)
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
−0.6 −0.5 −0.4 −0.3 −0.2 0.2 0.3 0.4 0.5 0.6 0.7

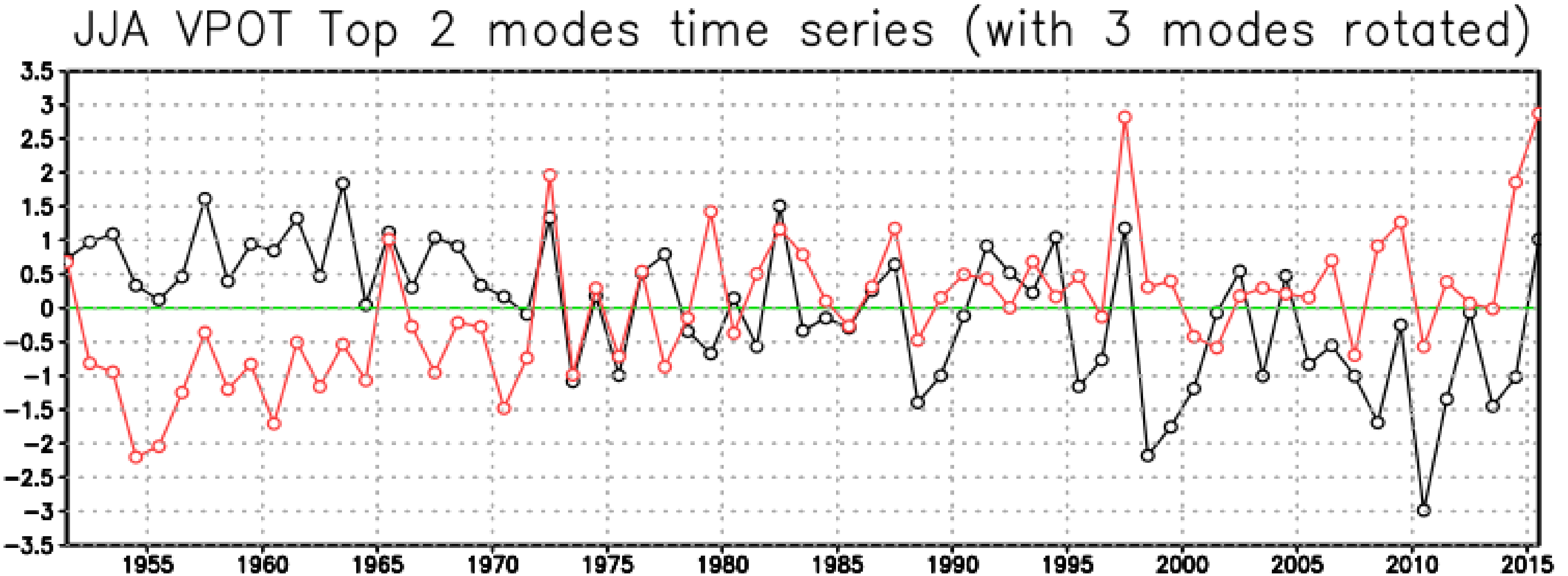

JJA T2m Corr:Projexn of VPOT EOF Mode 2(ENSO)
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
−0.6 −0.5 −0.4 −0.3 −0.2 0.2 0.3 0.4 0.5 0.6 0.7


DJF T2m Corr:Projexn of VPOT EOF Mode 1(ENSO)
JJA T2m Corr:Projexn of VPOT EOF Mode 1(Int.Dec.)
DJF T2m Corr:Projexn of VPOT EOF Mode 2(Int.Dec.)
JJA T2m Corr:Projexn of VPOT EOF Mode 2(ENSO)
ENSO
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
−0.6 −0.5 −0.4 −0.3 −0.2 0.2 0.3 0.4 0.5 0.6 0.7

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1950	-1.4	-1.2	-1.1	-1.2	-1.1	-0.9	-0.6	-0.6	-0.5	-0.6	-0.7	-0.8
1951	-0.8	-0.6	-0.2	0.2	0.2	0.4	0.5	0.7	0.8	0.9	0.7	0.6
1952	0.5	0.4	0.4	0.4	0.4	0.2	0	0.1	0.2	0.2	0.2	0.3
1953	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.7
1954	0.7	0.4	0	-0.4	-0.5	-0.5	-0.5	-0.7	-0.7	-0.6	-0.5	-0.5
1955	-0.6	-0.6	-0.7	-0.7	-0.7	-0.6	-0.6	-0.6	-1.0	-1.4	-1.6	-1.4
1956	-0.9	-0.6	-0.6	-0.5	-0.5	-0.4	-0.5	-0.5	-0.4	-0.4	-0.5	-0.4
1957	-0.3	0	0.3	0.6	0.7	0.9	1.0	1.2	1.1	1.2	1.3	1.6
1958	1.7	1.5	1.2	0.8	0.7	0.6	0.5	0.4	0.4	0.5	0.6	0.6
1959	0.6	0.5	0.4	0.2	0.1	-0.2	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1
1960	-0.1	-0.2	-0.1	0	-0.1	-0.2	0	0.1	0.2	0.1	0	0
1961	0	0	-0.1	0	0.1	0.2	0.1	-0.1	-0.3	-0.3	-0.2	-0.2
1962	-0.2	-0.2	-0.2	-0.3	-0.3	-0.2	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4
1963	-0.4	-0.2	0.1	0.2	0.2	0.4	0.7	1.0	1.1	1.2	1.2	1.1
1964	1.0	0.6	0.1	-0.3	-0.6	-0.6	-0.7	-0.7	-0.8	-0.8	-0.8	-0.8
1965	-0.5	-0.3	-0.1	0.1	0.4	0.7	1.0	1.3	1.6	1.7	1.8	1.5
1966	1.3	1.0	0.9	0.6	0.3	0.2	0.2	0.1	0	-0.1	-0.1	-0.3
1967	-0.4	-0.5	-0.5	-0.5	-0.2	0	0	-0.2	-0.3	-0.4	-0.4	-0.5
1968	-0.7	-0.8	-0.7	-0.5	-0.1	0.2	0.5	0.4	0.3	0.4	0.6	0.8
1969	0.9	1.0	0.9	0.7	0.6	0.5	0.4	0.5	0.8	0.8	0.8	0.7
1970	0.6	0.4	0.4	0.3	0.1	-0.3	-0.6	-0.8	-0.8	-0.8	-0.9	-1.2
1971	-1.3	-1.3	-1.1	-0.9	-0.8	-0.7	-0.8	-0.7	-0.8	-0.8	-0.9	-0.8
1972	-0.7	-0.4	0	0.3	0.6	0.8	1.1	1.3	1.5	1.8	2.0	1.9
1973	1.7	1.2	0.6	0	-0.4	-0.8	-1.0	-1.2	-1.4	-1.7	-1.9	-1.9
1974	-1.7	-1.5	-1.2	-1.0	-0.9	-0.8	-0.6	-0.4	-0.4	-0.6	-0.7	-0.6
1975	-0.5	-0.5	-0.6	-0.6	-0.7	-0.8	-1.0	-1.1	-1.3	-1.4	-1.5	-1.6
1976	-1.5	-1.1	-0.7	-0.4	-0.3	-0.1	0.1	0.3	0.5	0.7	0.8	0.8
1977	0.7	0.6	0.4	0.3	0.3	0.4	0.4	0.4	0.5	0.6	0.8	0.8
1978	0.7	0.4	0.1	-0.2	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.1	0
1979	0	0.1	0.2	0.3	0.3	0.1	0.1	0.2	0.3	0.5	0.5	0.6
1980	0.6	0.5	0.3	0.4	0.5	0.5	0.3	0.2	0	0.1	0.1	0
1981	-0.2	-0.4	-0.4	-0.3	-0.2	-0.3	-0.3	-0.3	-0.2	-0.1	-0.1	0
1982	0	0.1	0.2	0.5	0.6	0.7	0.8	1.0	1.5	1.9	2.1	2.1
1983	2.1	1.8	1.5	1.2	1.0	0.7	0.3	0	-0.3	-0.6	-0.8	-0.8
1984	-0.5	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.2	-0.3	-0.6	-0.9	-1.1
1985	-0.9	-0.7	-0.7	-0.7	-0.7	-0.6	-0.4	-0.4	-0.4	-0.3	-0.2	-0.3

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1981	-0.2	-0.4	-0.4	-0.3	-0.2	-0.3	-0.3	-0.3	-0.2	-0.1	-0.1	0
1982	0	0.1	0.2	0.5	0.6	0.7	0.8	1.0	1.5	1.9	2.1	2.1
1983	2.1	1.8	1.5	1.2	1.0	0.7	0.3	0	-0.3	-0.6	-0.8	-0.8
1984	-0.5	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.2	-0.3	-0.6	-0.9	-1.1
1985	-0.9	-0.7	-0.7	-0.7	-0.7	-0.6	-0.4	-0.4	-0.4	-0.3	-0.2	-0.3
1986	-0.4	-0.4	-0.3	-0.2	-0.1	0	0.2	0.4	0.7	0.9	1.0	1.1
1987	1.1	1.2	1.1	1.0	0.9	1.1	1.4	1.6	1.6	1.4	1.2	1.1
1988	0.8	0.5	0.1	-0.3	-0.8	-1.2	-1.2	-1.1	-1.2	-1.4	-1.7	-1.8
1989	-1.6	-1.4	-1.1	-0.9	-0.6	-0.4	-0.3	-0.3	-0.3	-0.3	-0.2	-0.1
1990	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.3	0.4	0.4
1991	0.4	0.3	0.2	0.2	0.4	0.6	0.7	0.7	0.7	0.8	1.2	1.4
1992	1.6	1.5	1.4	1.2	1.0	0.8	0.5	0.2	0	-0.1	-0.1	0
1993	0.2	0.3	0.5	0.7	0.8	0.6	0.3	0.2	0.2	0.2	0.1	0.1
1994	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.6	0.9	1.0
1995	0.9	0.7	0.5	0.3	0.2	0	-0.2	-0.5	-0.7	-0.9	-1.0	-0.9
1996	-0.9	-0.7	-0.6	-0.4	-0.2	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4	-0.5
1997	-0.5	-0.4	-0.2	0.1	0.6	1.0	1.4	1.7	2.0	2.2	2.3	2.3
1998	2.1	1.8	1.4	1.0	0.5	-0.1	-0.7	-1.0	-1.2	-1.2	-1.3	-1.4
1999	-1.4	-1.2	-1.0	-0.9	-0.9	-1.0	-1.0	-1.0	-1.1	-1.2	-1.4	-1.6
2000	-1.6	-1.4	-1.1	-0.9	-0.7	-0.7	-0.6	-0.5	-0.6	-0.7	-0.8	-0.8
2001	-0.7	-0.6	-0.5	-0.3	-0.2	-0.1	0	-0.1	-0.1	-0.2	-0.3	-0.3
2002	-0.2	-0.1	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.2	1.3	1.1
2003	0.9	0.6	0.4	0	-0.2	-0.1	0.1	0.2	0.3	0.4	0.4	0.4
2004	0.3	0.2	0.1	0.1	0.2	0.3	0.5	0.7	0.7	0.7	0.7	0.7
2005	0.6	0.6	0.5	0.5	0.4	0.2	0.1	0	0	-0.1	-0.4	-0.7
2006	-0.7	-0.6	-0.4	-0.2	0.0	0.1	0.2	0.3	0.5	0.8	0.9	1.0
2007	0.7	0.3	0	-0.1	-0.2	-0.2	-0.3	-0.6	-0.8	-1.1	-1.2	-1.3
2008	-1.4	-1.3	-1.1	-0.9	-0.7	-0.5	-0.3	-0.2	-0.2	-0.3	-0.5	-0.7
2009	-0.8	-0.7	-0.4	-0.1	0.2	0.4	0.5	0.6	0.7	1.0	1.2	1.3
2010	1.3	1.1	0.8	0.5	0	-0.4	-0.8	-1.1	-1.3	-1.4	-1.3	-1.4
2011	-1.3	-1.1	-0.8	-0.6	-0.3	-0.2	-0.3	-0.5	-0.7	-0.9	-0.9	-0.8
2012	-0.7	-0.6	-0.5	-0.4	-0.3	-0.1	0.1	0.3	0.4	0.4	0.2	-0.2
2013	-0.4	-0.5	-0.3	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.3
2014	-0.5	-0.6	-0.4	-0.2	0	0	0	0	0.2	0.4	0.6	0.6
2015	0.5	0.4	0.5	0.7	0.9	1.0	1.2	1.5				?
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ


JJA VPOT Top 2 modes time series (with 5 modes rotated)
51
57
63
65
72
82
87
91,92
97
02
09
15
54,55
64
70,71
73,75
88
89?
95?
98,99,00
07?
10
11?
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
−3.5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015


JJA VPOT Top 2 modes time series (with 3 modes rotated)
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
−3.5
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

Summary/Key Findings:

- The two major modes of variability in the global tropics identified in Chelliah and Bell, 2004 during both DJF/JJA seasons, viz., the Tropical Interdecadal/Multidecadal (TMM) and the ElNino Southern Oscillation (ENSO) modes, are revisited with more recent data up to 2015 (1951-2015).

- The analysis has identified when and under what circumstances a weak ENSO (El Nino or La Nina) event tends to strengthen to a moderate or strong event, and when it is not not.

- In the analysis period considered, 1951-2015:
  - a) when both modes are positive and in phase, moderate/strong El Ninos (1958, 1973, 1983, 1992, 1998 2010) occurred. (El Nino fizzled in 2014 because TMM was out of phase with ENSO, but it turned favorably in 2015 for a strong El Nino. 2016?)
  - b) when both modes are negative and are in phase, moderate/strong La Nina events occurred.
  - c) When both modes are of approximately equal amplitude, but of opposite phases, no ENSO events occurred.
  - d) When both modes are of opposite phases, and of uneven amplitudes in strength, the stronger amplitude mode decided the ENSO event.
  - e) 90-95% of all (weak, moderate and strong) ENSO events, and neutral years, can be accounted for by the above phasing/out-of-phasing of the two dominant tropical modes.

- Coincident with the 1972/73 strong ElNino event, and the change in phase (from –ve to +ve) of the TMM mode, the tendency for El Nino events to become stronger (and conversely for the relative absence of strong La Ninas) has enhanced. It appears that a shift is highly likely in the phase of the low frequency TMM mode, and the phase change may already be underway coincident with the current ongoing major 2015/16 El Nino event. (Note: This change of phase is a process/slow-adjustment that takes place over the course of a few years!)

Ongoing/addnl.work:

- Extend/Obtain the modes pair for the earlier period (before 1951)–(How if using VPOT from NCEP/R1?)
- Do analyses for the other two seasons SON/MAM as well to get the full annual cycle evolution!!
- Explore the predictability issue!!

Thank you very much
for listening !!