MJO, NAO, ENSO, and Mid-Summer Rainfall in the Caribbean

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Introduction

Much of the Caribbean experienced back-to-back extreme drought conditions during the summer of 2014 and 2015. Impacts in our study area of St. Elizabeth, Jamaica included hundreds of acres of farmland destroyed by fire, increased prices of produce, and water restrictions. June and July 2014 were particularly hard hit as indicated by our mesonet of rain gauges (Table 1) compared to a local climatology, and the GPCP v2.2 product for the grid box covering western Jamaica (Figure 1; see Figure 6a for location). Consistent with this picture, the IPCC 5th Assessment Report suggests that droughts will be more common in the future. The objective of this study is to a) present results from a multi-linear regression equation of July 2014 rainfall based on ENSO and NAO (and make a preliminary assessment for 2015), b) examine atmospheric anomalies accompanying extremely dry Julys that may help explain the connections with the climate oscillations, and c) offer a hypothesis from the literature.

Month	Mean (mm)	1951-1980 mean (mm)	Percentage
April '14	70	91	77%
May '14	112	108	104%
June '14	12	98	**12%**
July '14	28	60	47%
April '15	57	91	63%
May '15	119	108	110%
June '15	21	98	**21%**

Table 1

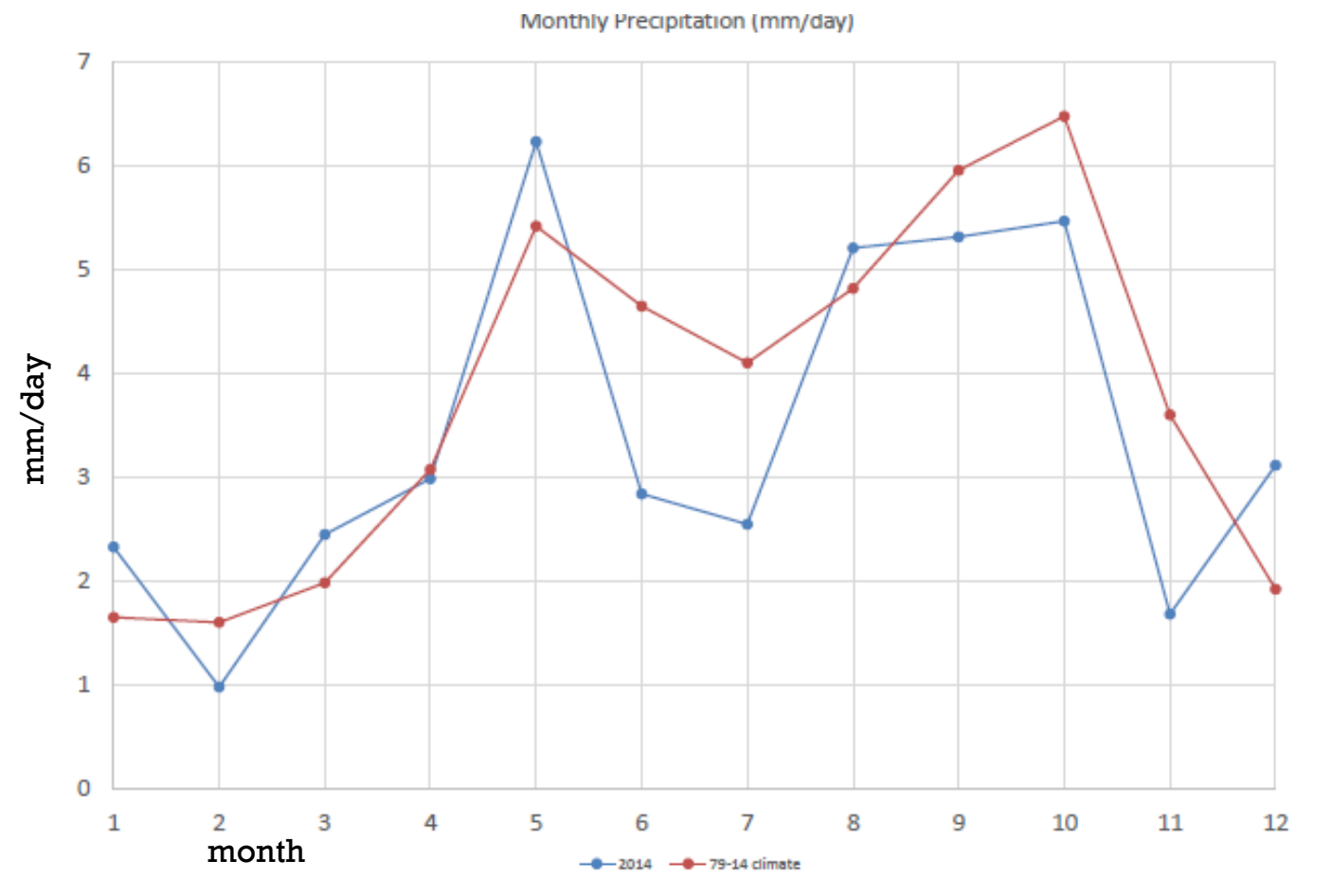

Figure 1

	March NAO	March Nino 3.4	March GPCP (mm/d)	July NAO	July Nino 3.4	July GPCP (mm/d)	Jan (+) NAO	Jan (+) Nino 3.4	Jan (+) GPCP (mm/d)
1991	-0.20	0.03	-0.65	-0.49	0.70	**-1.62**	-0.13	**1.84**	**-1.19**
1997	**1.46**	-0.19	-0.69	0.34	**1.70**	**-1.17**	0.39	**2.53**	0.23
2002	**0.69**	0.10	-0.79	**0.62**	0.76	**-1.51**	0.16	**1.19**	**1.78**
2007	**1.44**	-0.04	0.48	**-0.58**	-0.43	**-1.40**	**0.89**	**-1.86**	-0.93
2014	**0.80**	-0.22	0.46	0.18	0.18	**-1.55**	**1.79**	0.53	**-1.17**
2015	**1.45**	0.58	0.67	**-3.18**	**1.60**	**…**	**…**	…	**…**
AVG	**0.94**	0.04	-0.09	-0.52	0.75	**-1.45**	0.62	**0.85**	-0.26

Table 2

Western Jamaica precipitation related to ENSO and NAO

GPCP July precipitation in western Jamaica (18.75 N, 73.25 W; box in Fig. 6a) was found to be related to the preceding March NAO[1] value and the subsequent January Nino 3.4 value according to the following formula (Poore et al. in press) developed from 1979 to 2013:

$$\text{July rainfall (mm)} = -22.517 * \text{NAO}_{\text{March}} + -13.225 * \text{Nino3.4}_{\text{January}(+)} + 134.435$$

Accordingly, when the NAO is positive and there is a developing El Nino then rainfall is predicted to decline. Years with the five driest Julys are presented in Table 2. NAO, Nino3.4, and GPCP precipitation are given for March, July and the following year's January "January(+)". For all years except 1991, a positive NAO occurred in March. For all years except 2007, a weak to strong El Nino occurred in January(+). July 2014 (not included when generating statistical relationship) was the second driest July in the GPCP record. Given the NAO and Nino3.4 data in Table 2, the multi-linear equation above would predict a value of 109 mm (or an anomaly of -0.59 mm day^{-1}). Thus, the model underestimated the severity of the drought in July 2014. The March 2015 NAO value was comparable to 1997. Also, similar to 1997, the July 2015 Nino 3.4 anomaly was high signaling a strong El Nino event. Therefore, it is expected that GPCP rainfall in July 2015 will be low, which is consistent with real-time drought monitoring products and media reports from Jamaica and elsewhere in the Caribbean.

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[1] NAO is based on patterns of rotated Principal Component Analysis of 500 hPa height anomalies from 20N to 90N (Barnston and Livezey 1987).

Figure 2: March 1991, 1997, 2002, 2007, and 2014 composite anomaly

a) Precipitation
b) SLP
c) .2101 sigma streamfunction

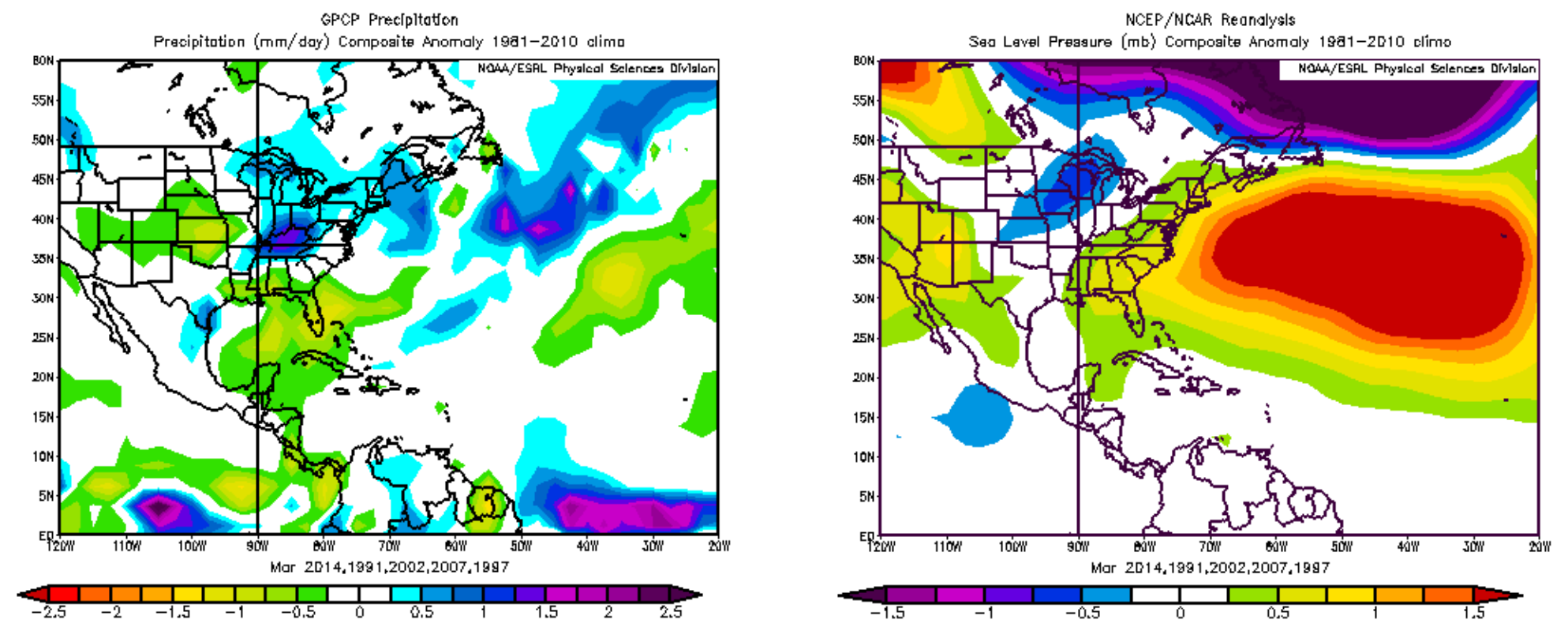


Figure 3: April 1991, 1997, 2002, 2007, and 2014 composite anomaly

a) Precipitation
b) SLP
c) .2101 sigma streamfunction

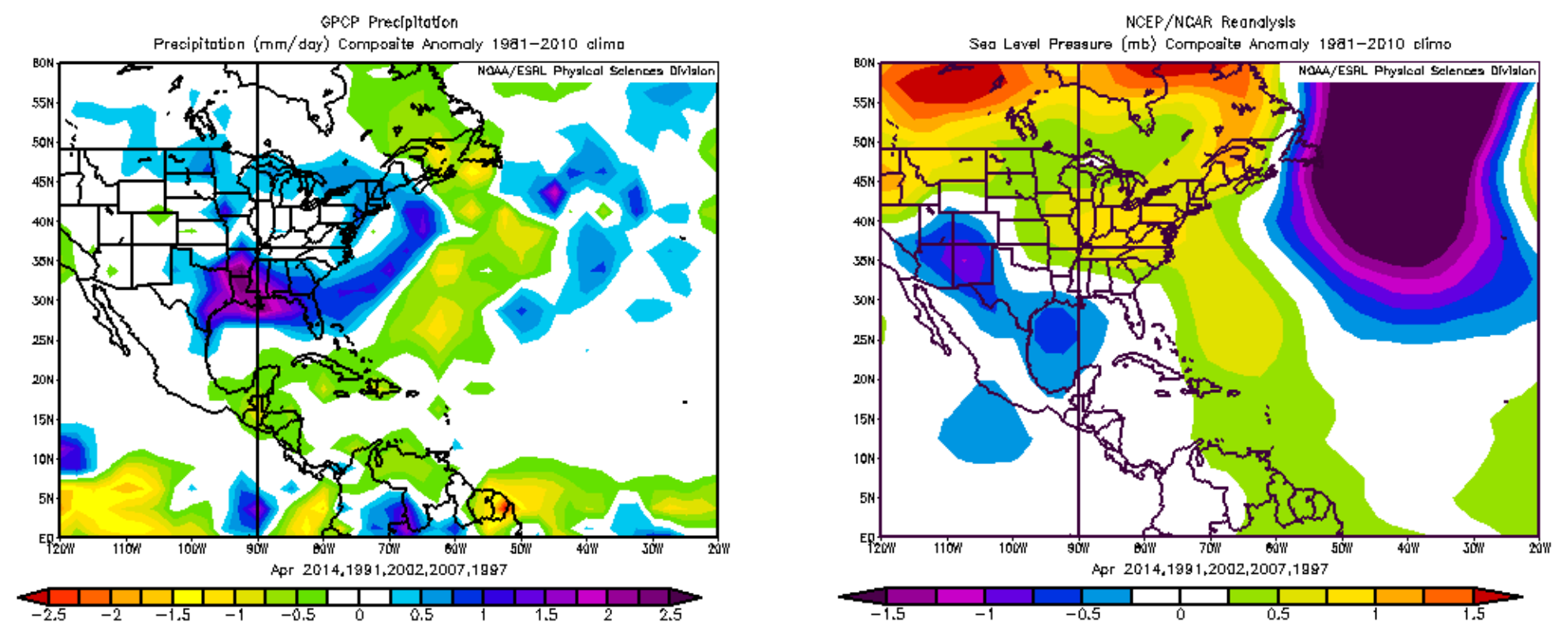


Figure 4: May 1991, 1997, 2002, 2007, and 2014 composite anomaly

a) Precipitation
b) SLP
c) .2101 sigma streamfunction

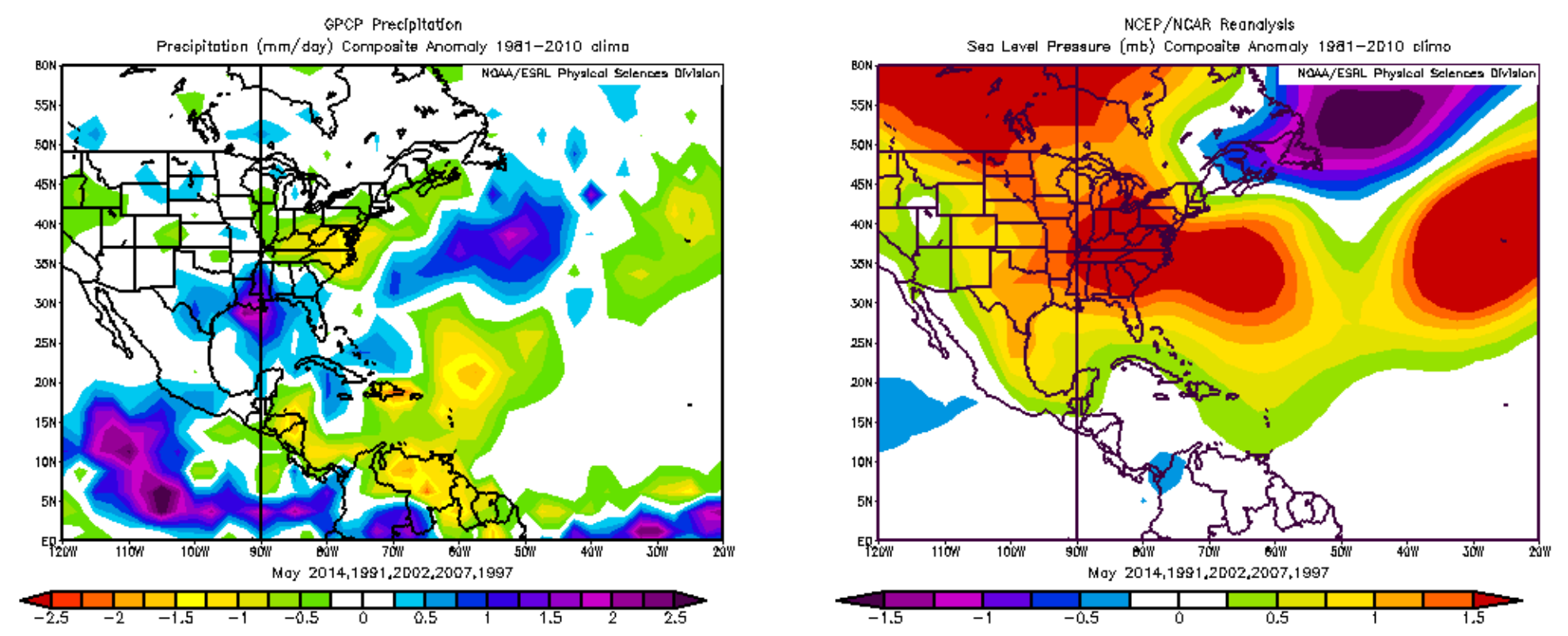


Figure 5: June 1991, 1997, 2002, 2007, and 2014 composite anomaly

a) Precipitation
b) SLP
c) .2101 sigma streamfunction

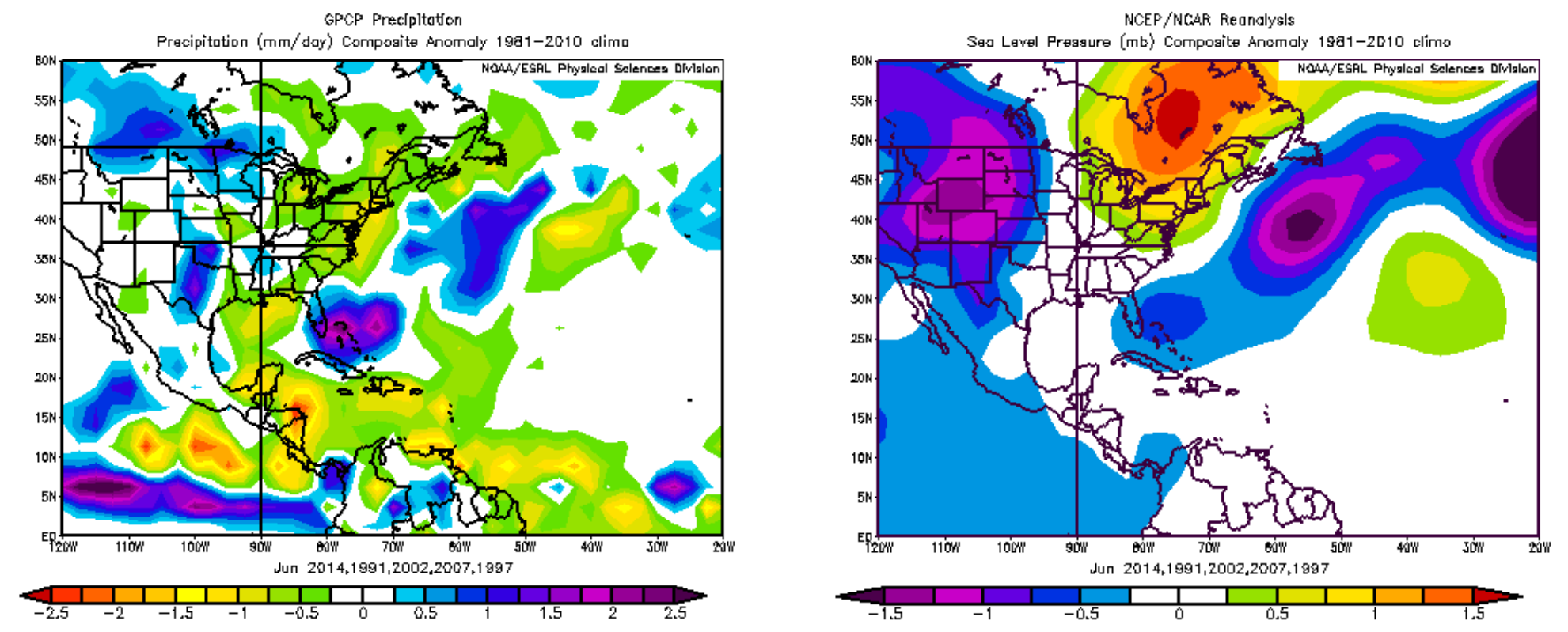
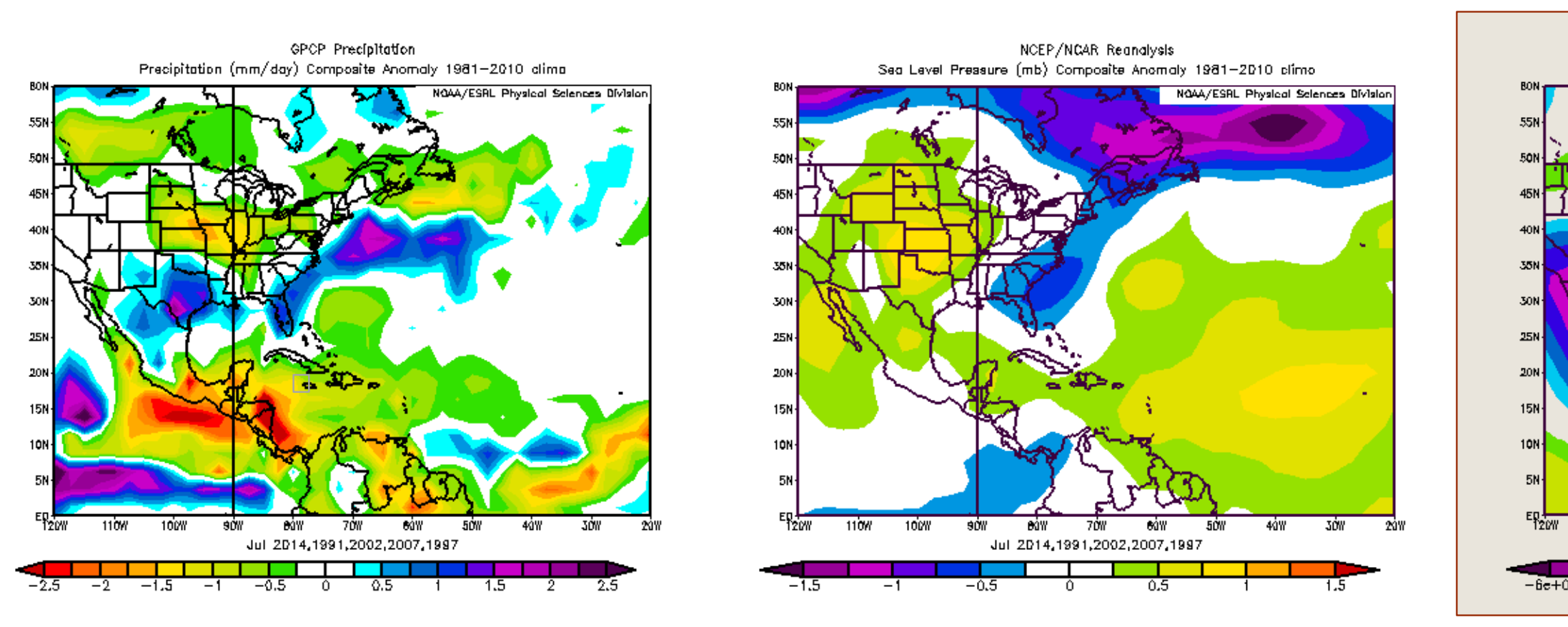


Figure 6: July 1991, 1997, 2002, 2007, and 2014 composite anomaly

a) Precipitation
b) SLP
c) .2101 sigma streamfunction



Atmospheric Patterns Leading to Extreme Dryness in July

GPCP precipitation and NCEP/NCAR reanalysis data were averaged for March (Figure 2) to July (Figure 6) of the years with the five driest Julys (see Table 2), including 2014.

- The composite maps suggests that for these years, the drying began in June
- The positive phase of the NAO is clearly seen in March with a southward extension of the low pressure anomaly into April. A wave-train pattern emerges in June and July
- A negative upper-tropospheric streamfunction anomaly establishes itself in the Caribbean in May and strengthens in the western basin into July. Streamfunction is related to vorticity, except the sign is reversed (negative = cyclonic motion) and the field is spatially smoother
- The lower-tropospheric streamfunction anomaly is of opposite sign in the Caribbean (not shown)
- Centers of anomalous anticyclonic rotation in the lower-troposphere and cyclonic rotation in the upper-troposphere over the western Caribbean are found, with the strongest subsidence at the axis point (see Fig. 7), coincident with the GPCP grid box location

Hypothesis

Lin et al. (2009) and Frederiksen and Lin (2013) using theory and observations show that the MJO excites an atmospheric wave train as the MJO crosses through the Maritime Continent. As shown below, it begins as a Pacific-North American-like pattern in 300hPa streamfunction followed by an NAO-like pattern. Note the similarities between Frederiksen and Lin's Figure 10c and our Figure 4c.

Frederiksen and Lin (2013)

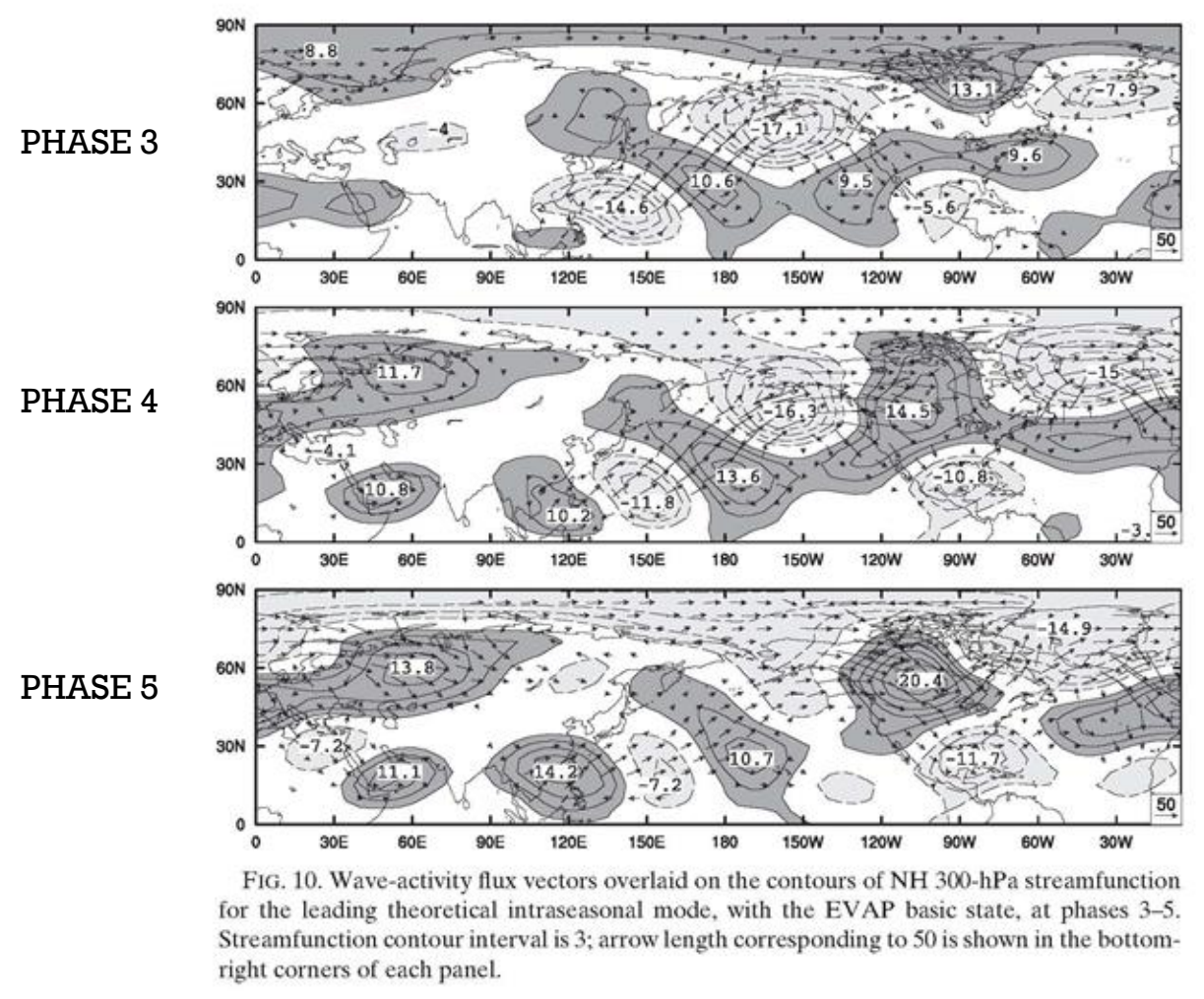
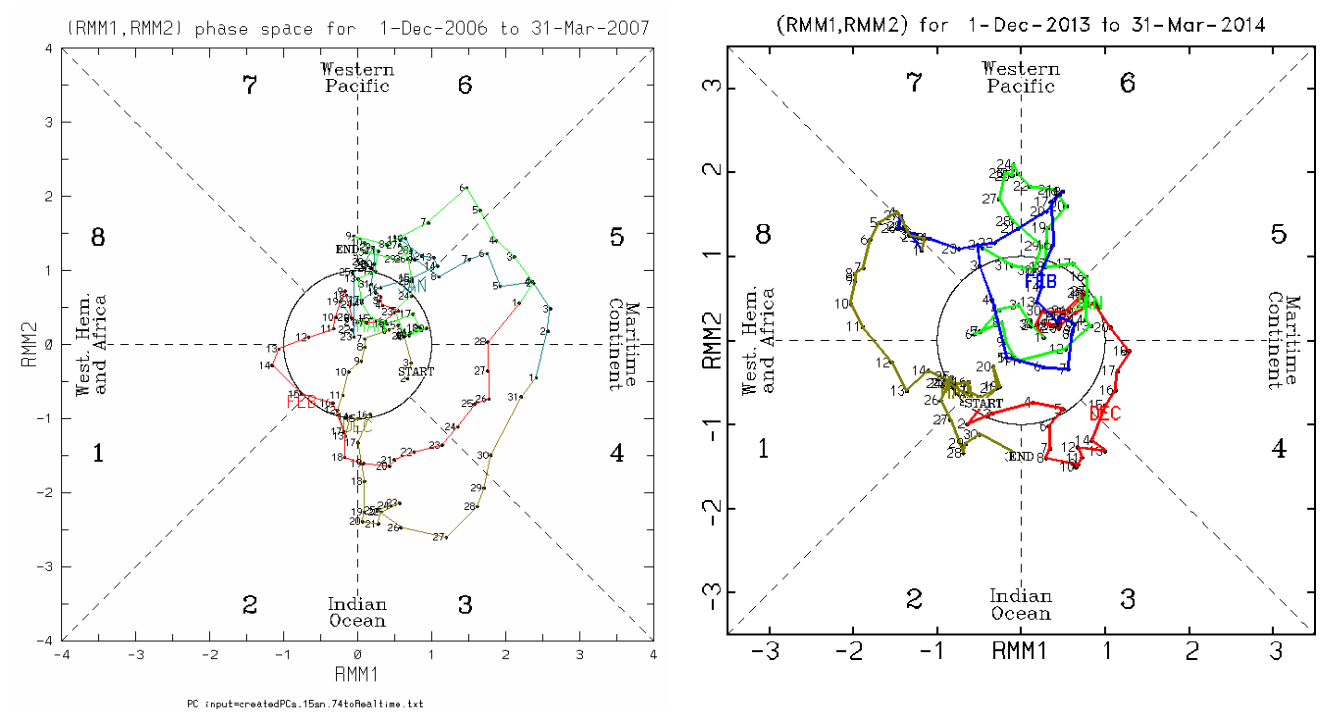
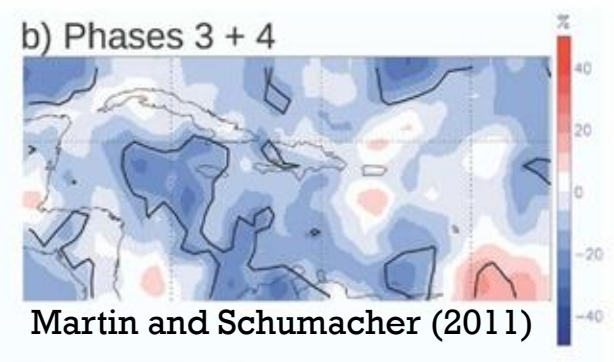


FIG. 10. Wave-activity flux vectors overlaid on the contours of NH 300-hPa streamfunction for the leading theoretical intraseasonal mode, with the EVAP basic state, at phases 3–5. Streamfunction contour interval is 3; arrow length corresponding to 50 is shown in the bottom-right corners of each panel.

Below are two phase space plots of the MJO noting location and strength from December to March 2006-07 (left) and 2013-14 (right). In these and the other three dry years (Table 2) the MJO was located in the Maritime Continent (phases 3-5) during December and January. Martin and Schumacher (2011) also note that the annual mean precipitation decreases when the MJO is in phases 3 and 4 and they attribute it to an increase in the low-level jet.





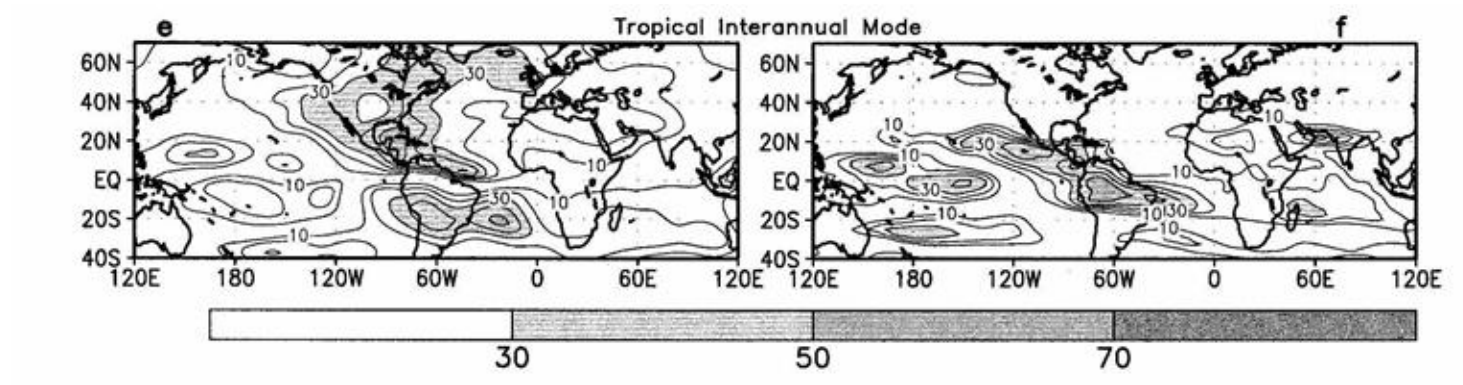
Martin and Schumacher (2011)

Thus, MJO activity over the Maritime Continent in the winter season prior to drought in the western Caribbean may encompass (and be stronger than and earlier than) the separate NAO and ENSO predictors. In addition to the MJO-NAO relationship described here, it has been shown that MJO activity can lead to the development of El Nino, but not always, as was the case in 2007-2008. Future work will include examining the MJO-drought relationship directly.

By the summer season, the streamfunction anomaly over the Caribbean may be explained by interannual variability. The patterns in July (Fig. 6c and 7a) are very similar to the percent of explained variance of the JJA 200 hPa streamfunction and zonal wind, respectively, associated with the interannual (ENSO) EOF of 200 hPa velocity potential (Chelliah and Bell 2004).

Chelliah and Bell (2004)

200hPa STREAMFUNCTION

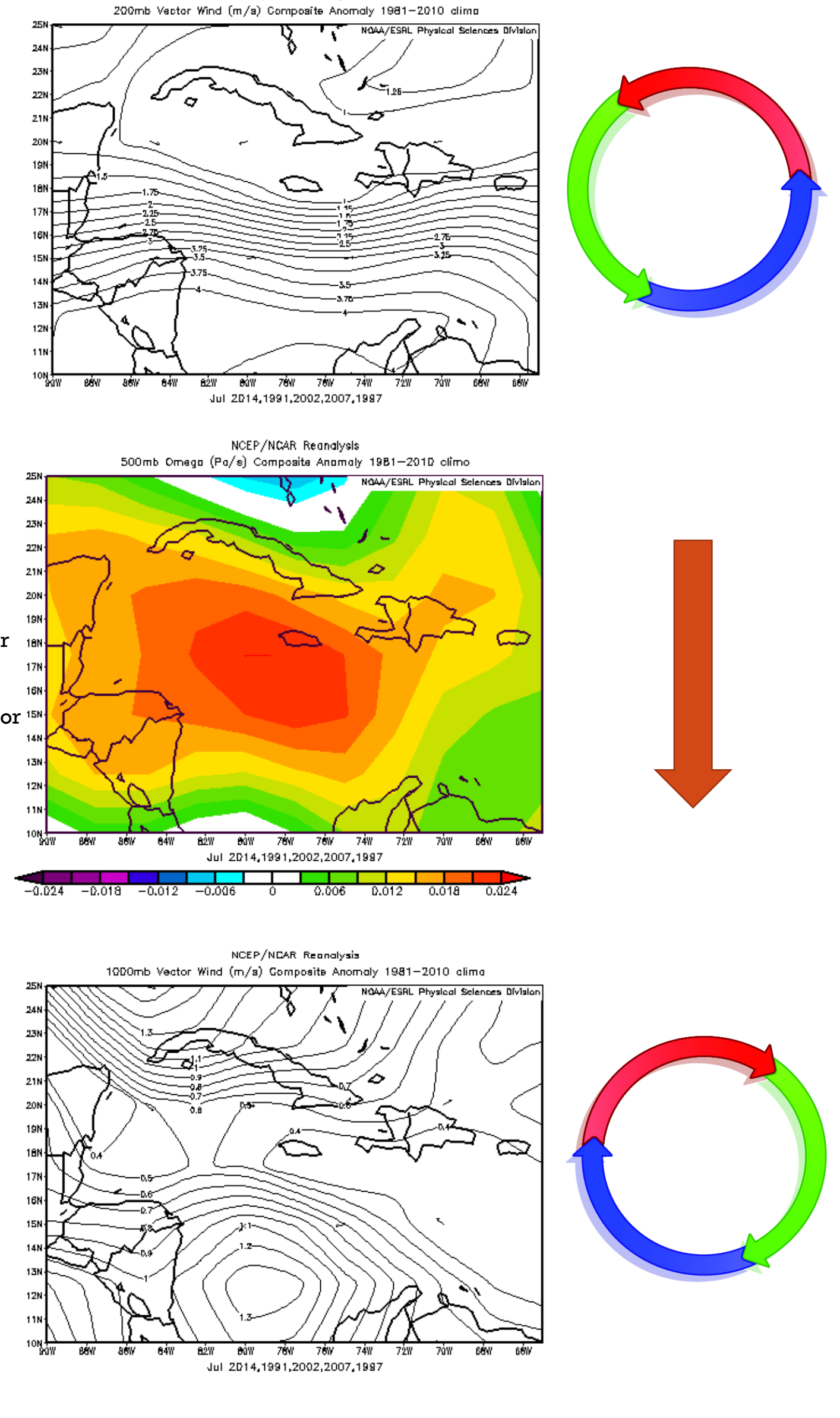


200hPa ZONAL WIND

FIG. 13. 200 hPa: JJA percent of explained variance of the (left) unfiltered seasonal streamfunction and (right) zonal wind anomalies associated with (a), (b) the combined tropical multidecadal mode (TMM) and ENSO; (c), (d) the TMM; and (e), (f) ENSO.

Figure 7: July 1991, 1997, 2002, 2007, and 2014

a) 200 hPa wind vector and speed
b) 500 hPa omega
c) 1000 hPa wind vector and speed



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