# Pacific and Atlantic multidecadal oscillations: relations to the ENSO and effects on the South American rainfall

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# The talk is organized in

- Introduction
- Data and methodology
- PDO & ENSO relations
- AMO & ENSO relations
- AMO/PDO backgrounds
- AMO/PDO & ENSO relations

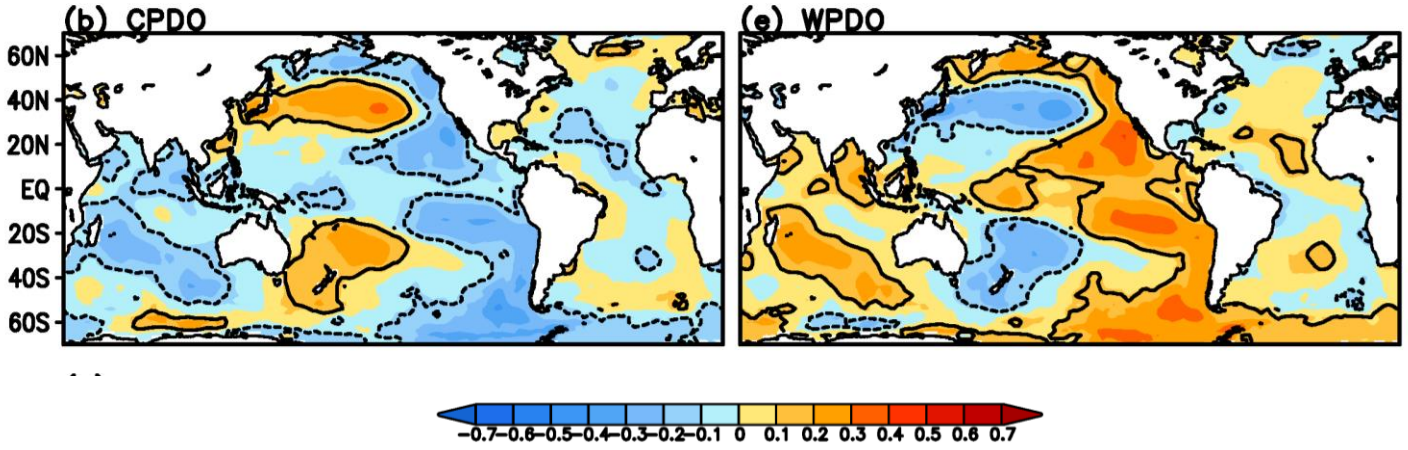
# Main question

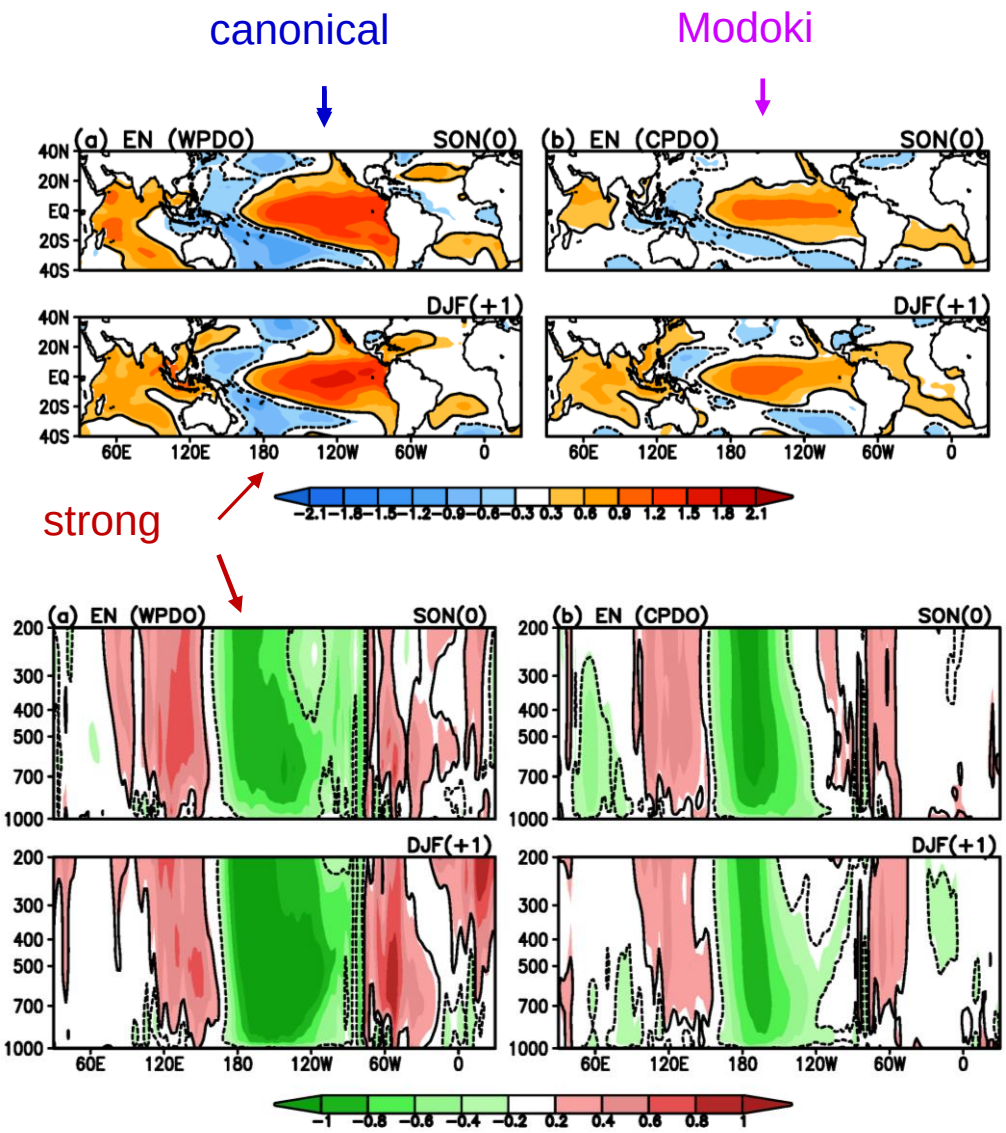
- Do the low-frequency bkgs affect the ENSO-related rainfall patterns in tropical South America?

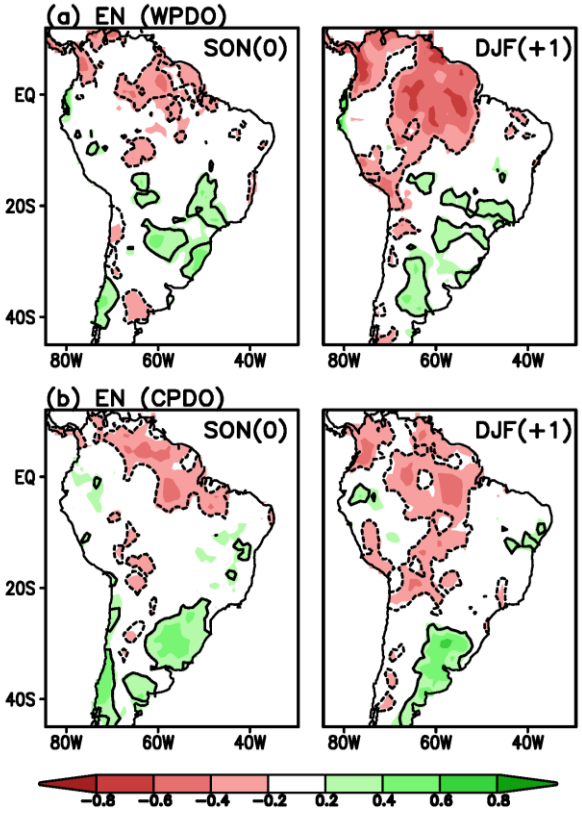
# Data and Method

- SST from NOAA/ERSST v5 (Huang et al., 2017)
- GPCC V7 (Schneider et al., 2014)
- Atmospheric circulation data from 20CR V2C (Compo et al., 2011)
- AMO and PDO indices of the 1870-2011 period
- ENSO extremes from ONI index  of the 1870-2011 period
- detrended standardized monthly anomalies of the variables for the 1901-2011 period
- Composite analysis

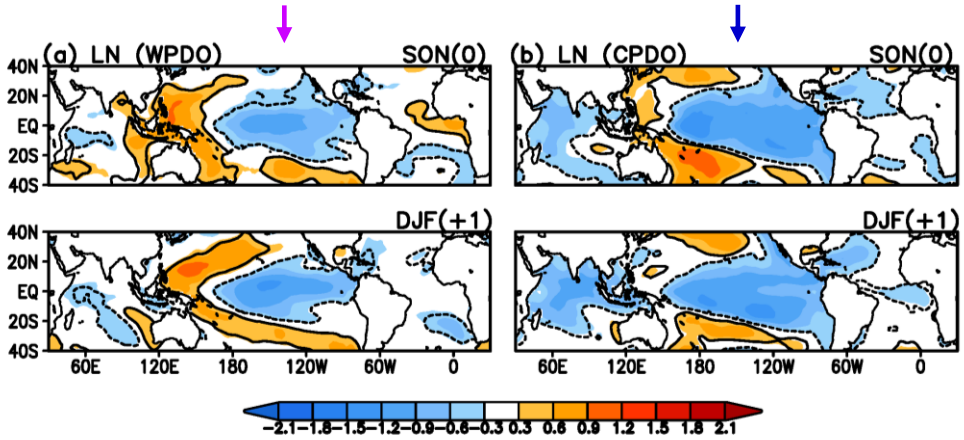
# PDO

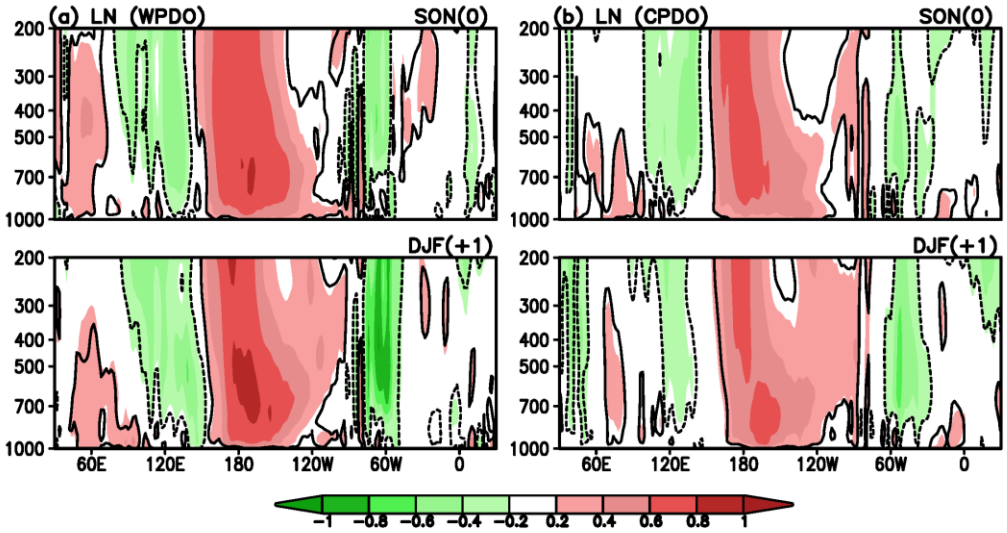

(b) CPDO
(e) WPDO
60N
40N
20N
EQ
20S
40S
60S
-0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7

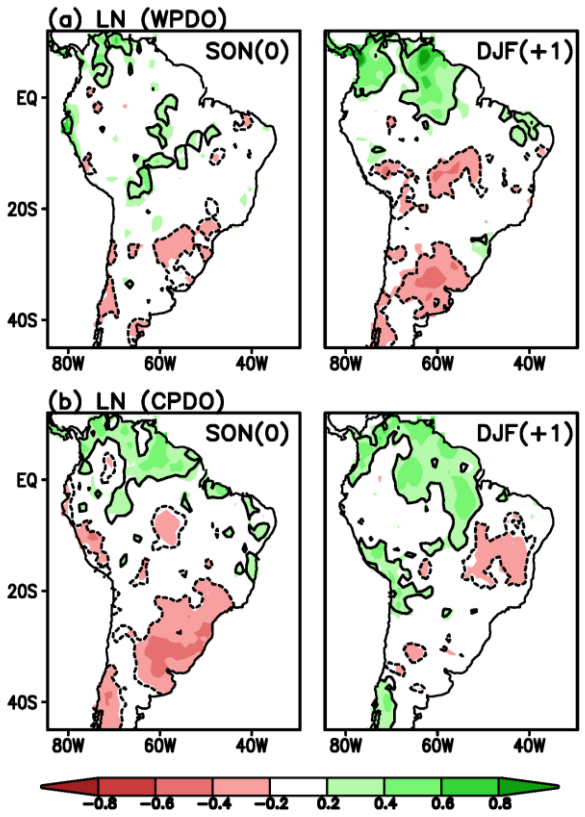

canonical
Modoki
(a) EN (WPDO)
SON(0)
(b) EN (CPDO)
SON(0)
DJF(+1)
DJF(+1)
40N
20N
EQ
20S
40S
60E
120E
180
120W
60W
0
−2.1 −1.8 −1.5 −1.2 −0.9 −0.6 −0.3 0.3 0.6 0.9 1.2 1.5 1.8 2.1
strong
200
300
400
500
700
1000
−1 −0.8 −0.6 −0.4 −0.2 0.2 0.4 0.6 0.8 1


(a) EN (WPDO)
SON(0)
DJF(+1)
EQ
20S
40S
80W
60W
40W
(b) EN (CPDO)
SON(0)
DJF(+1)
EQ
20S
40S
80W
60W
40W
−0.8
−0.6
−0.4
−0.2
0.2
0.4
0.6
0.8

Modoki canonical



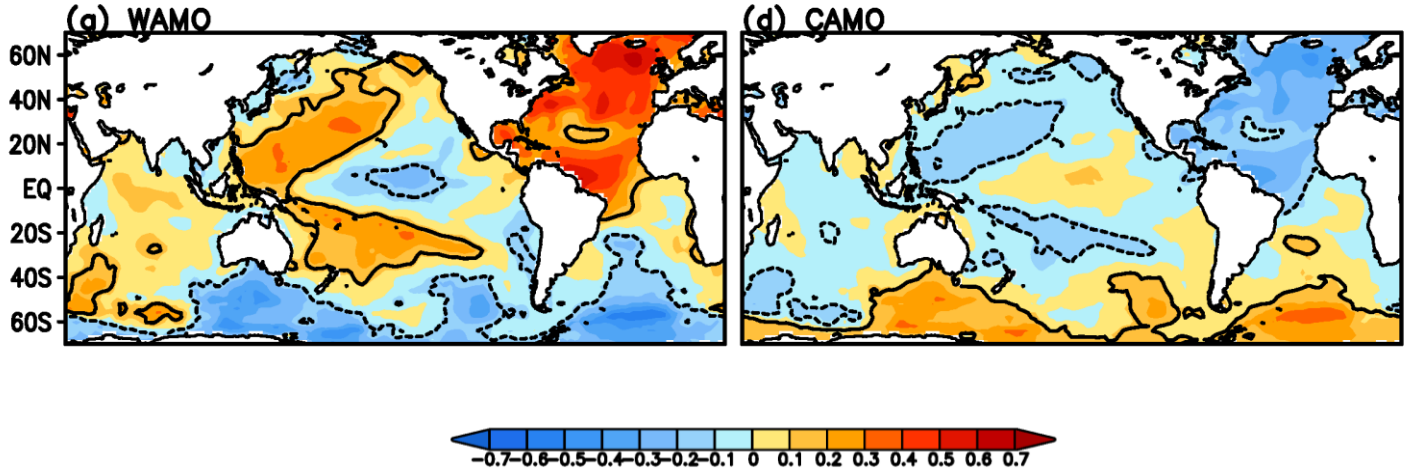

(a) LN (WPDO)
SON(0)
DJF(+1)
EQ
20S
40S
80W
60W
40W
(b) LN (CPDO)
SON(0)
DJF(+1)
EQ
20S
40S
80W
60W
40W
−0.8
−0.6
−0.4
−0.2
0.2
0.4
0.6
0.8

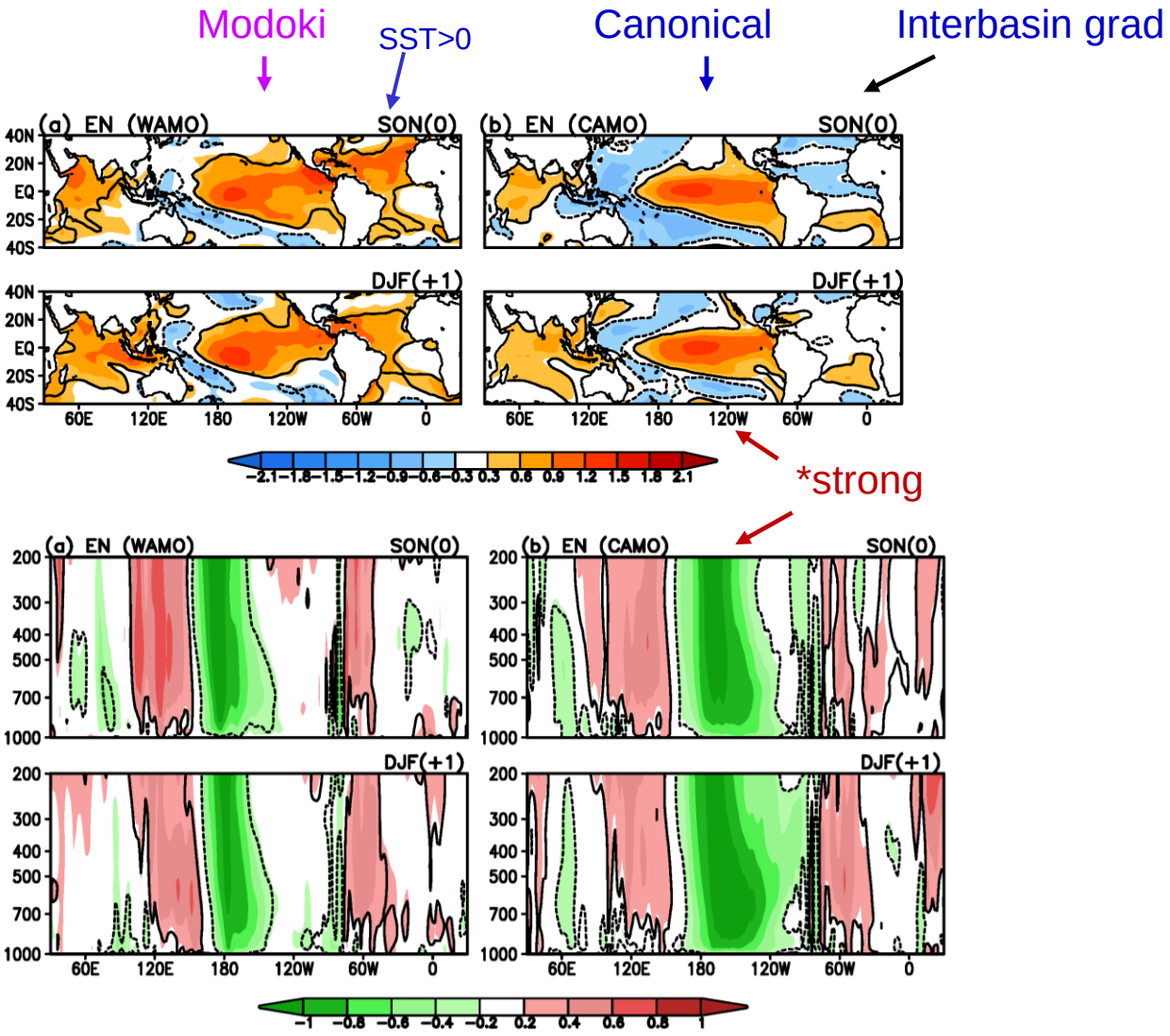
# PDO & ENSO

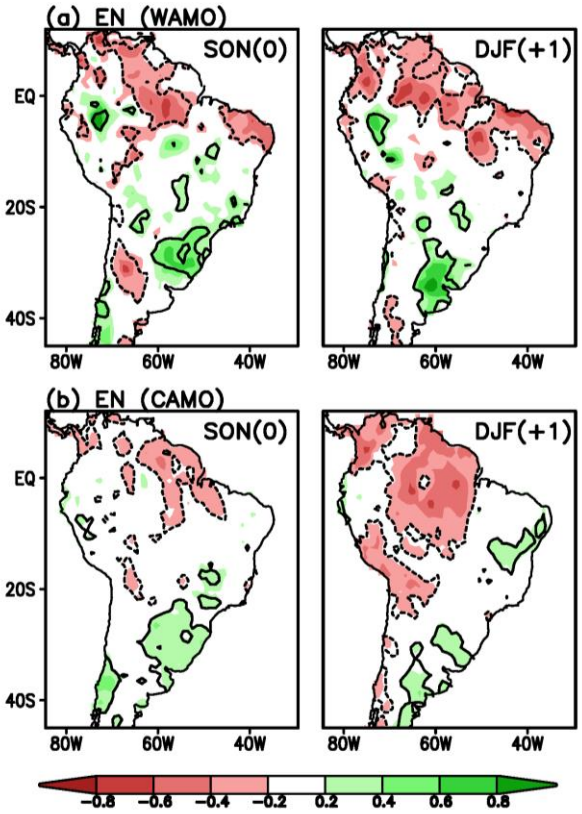
- WPDO: Strong canonical EN ; Modoki LN
- CPDO: Canonical LN; Modoki EN
- PDO modulates the ENSO intensities and types

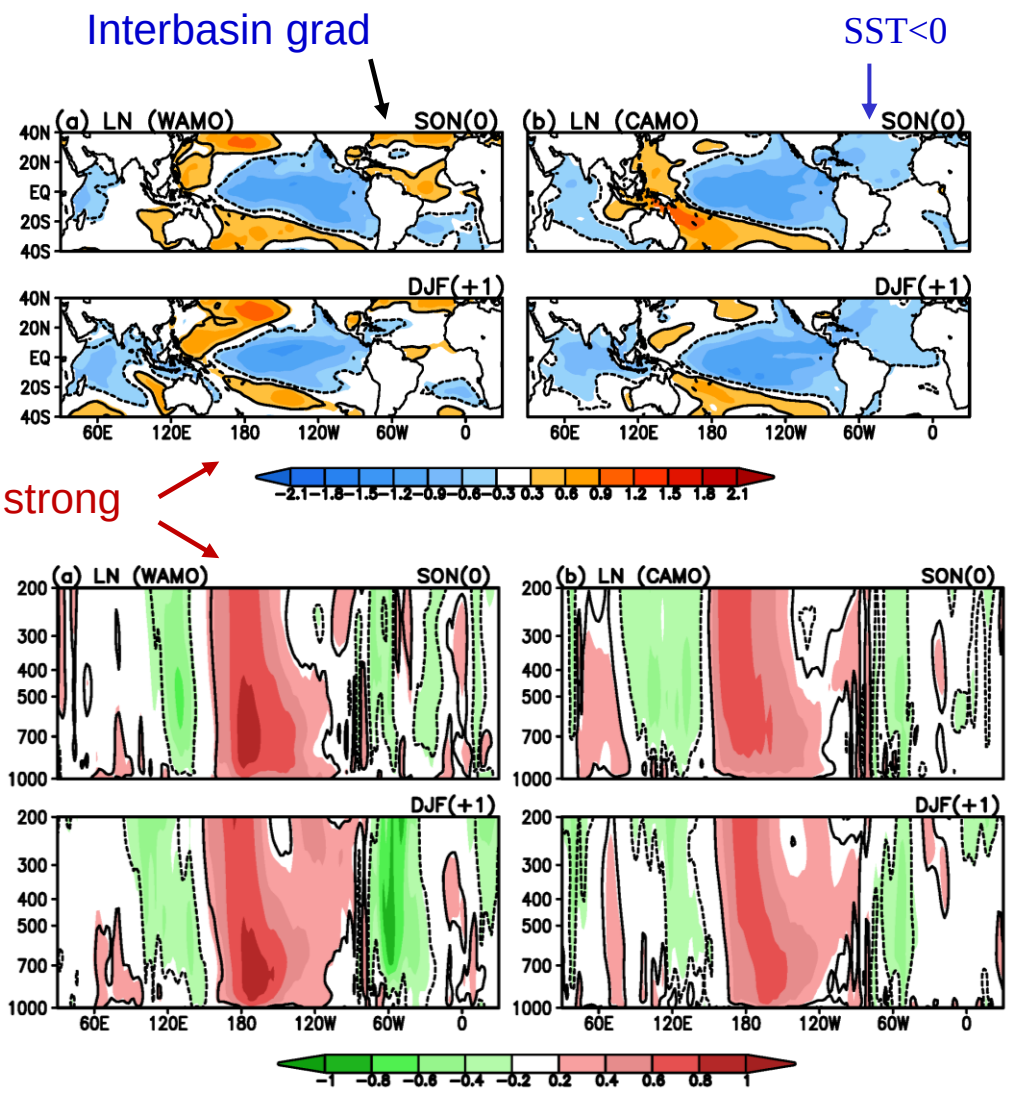
- WPDO: stronger EN-related summer dryness occurs in northern/northwestern S.A.
- CPDO: spatially more organized LN-related wetness in northern/northwestern S.A. during summer
- PDO modulates the ENSO-related SST and circulation anomaly patterns and the S.A. rainfall anomalies
- PDO contributes to the SAMS interanual variability

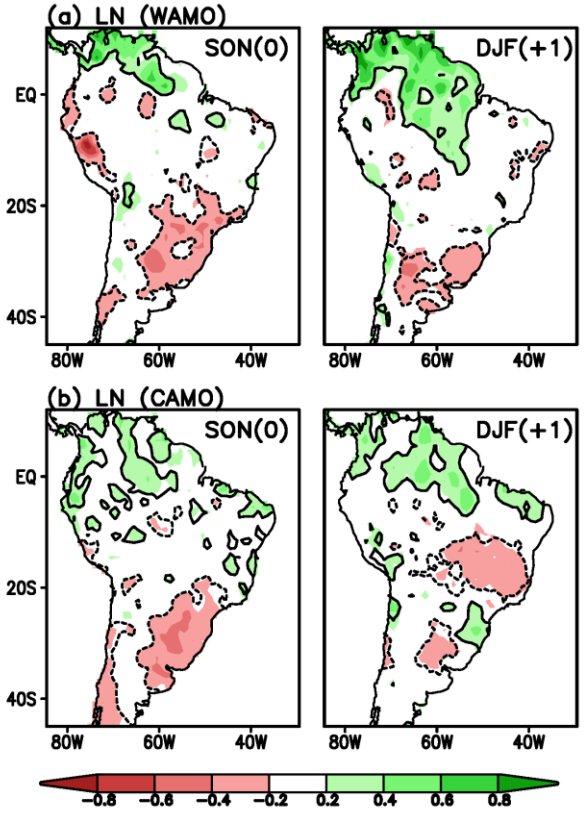
# AMO


(a) WAMO
(d) CAMO
60N
40N
20N
EQ
20S
40S
60S
−0.7 −0.6 −0.5 −0.4 −0.3 −0.2 −0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7


Modoki
SST>0
Canonical
Interbasin grad
(a) EN (WAMO)
SON(0)
(b) EN (CAMO)
SON(0)
DJF(+1)
DJF(+1)
40N
20N
EQ
20S
40S
60E
120E
180
120W
60W
0
−2.1 −1.8 −1.5 −1.2 −0.9 −0.6 −0.3 0.3 0.6 0.9 1.2 1.5 1.8 2.1
*strong
200
300
400
500
700
1000
−1 −0.8 −0.6 −0.4 −0.2 0.2 0.4 0.6 0.8 1


(a) EN (WAMO)
SON(0)
DJF(+1)
EQ
20S
40S
80W
60W
40W
(b) EN (CAMO)
SON(0)
DJF(+1)
EQ
20S
40S
80W
60W
40W
−0.8
−0.6
−0.4
−0.2
0.2
0.4
0.6
0.8


Interbasin grad
SST<0
(a) LN (WAMO)
SON(0)
(b) LN (CAMO)
SON(0)
DJF(+1)
DJF(+1)
40N
20N
EQ
20S
40S
60E
120E
180
120W
60W
0
−2.1 −1.8 −1.5 −1.2 −0.9 −0.6 −0.3 0.3 0.6 0.9 1.2 1.5 1.8 2.1
strong
(a) LN (WAMO)
SON(0)
(b) LN (CAMO)
SON(0)
DJF(+1)
DJF(+1)
200
300
400
500
700
1000
−1 −0.8 −0.6 −0.4 −0.2 0.2 0.4 0.6 0.8 1


(a) LN (WAMO)
SON(0)
DJF(+1)
EQ
20S
40S
80W
60W
40W
(b) LN (CAMO)
SON(0)
DJF(+1)
EQ
20S
40S
80W
60W
40W
−0.8
−0.6
−0.4
−0.2
0.2
0.4
0.6
0.8

# AMO & ENSO

- CAMO: *Strong EN ; negative interbasin SST grad
- WAMO: Strong LN ; positive interbasin SST grad
- AMO modulates the Atlantic/Pacific interbasin grad

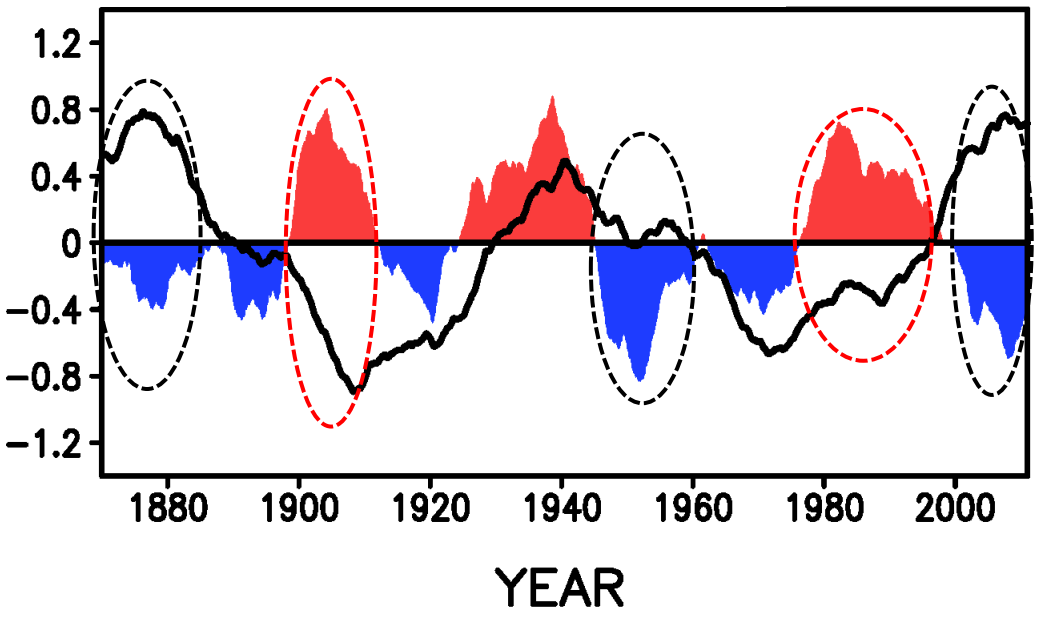
- canonical EN during CAMO and Modoki EN during WAMO

- Under interbasin SST grad: more intense and horizontally better organized ENSO-related precip anomalies over S.A.

- AMO modulates the ENSO-related SST and circulation anomaly patterns and the ENSO effects on the S.A. rainfall anomalies

- AMO contributes to the SAMS interanual variability

PDO and AMO indices




WAMO/WPDO: 1931-1944 (14)

CAMO/CPDO : 1892-1897; 1963-1976; 1913-1923 (31)

WAMO/CPDO : 1870-1889; 1946-1958; 2001-2011 (44)

CAMO/WPDO : 1892-1911; 1925-1929; 1977-1996 (45)

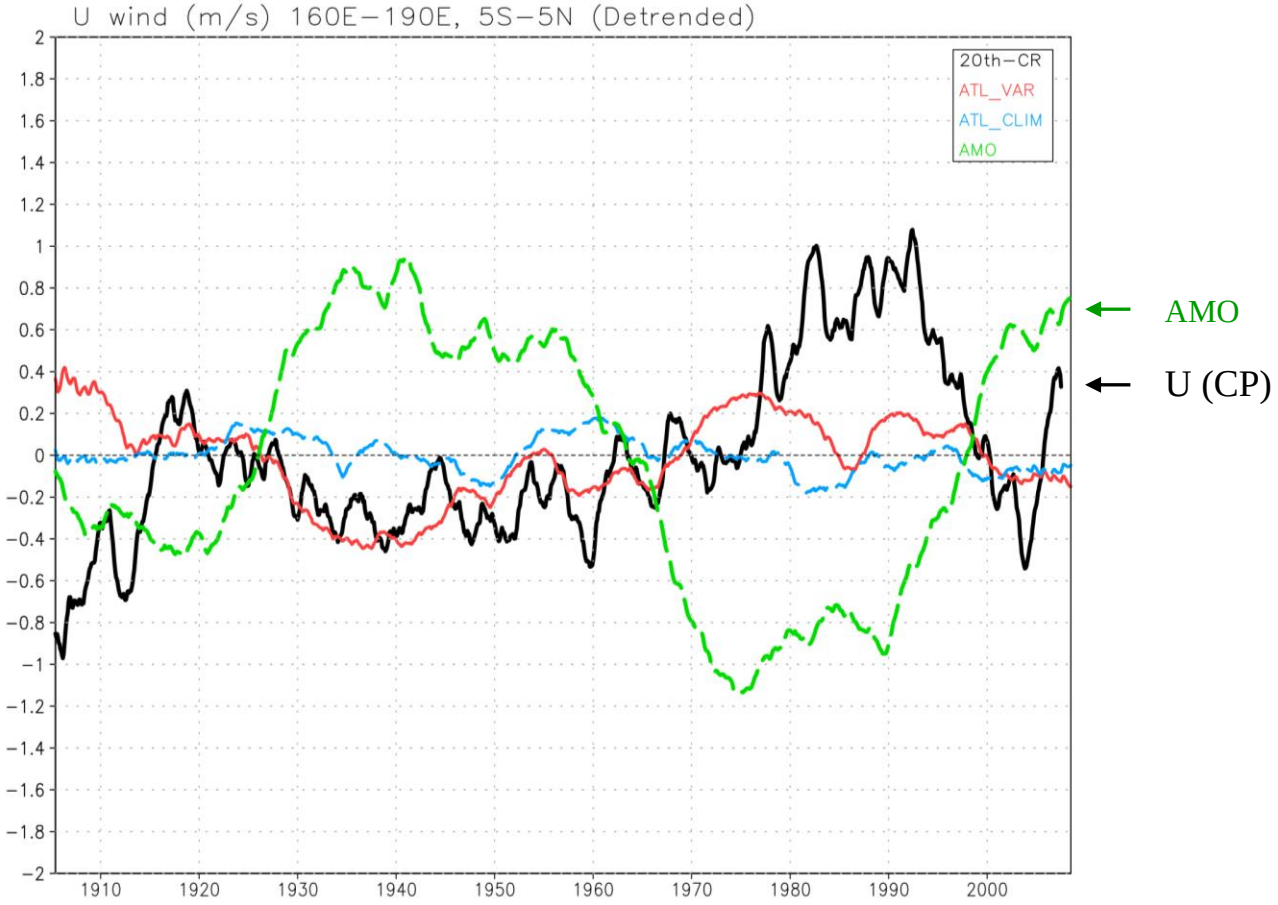



**Fig. 4** Central equatorial zonal near surface wind anomaly index (CPWI; averaged over area 160°E−190°E, 5°S–5°N). The anomaly time series have been filtered by a 10-year running mean. Shown are observations (*black line*), ATL_VAR ensemble mean (*red line*). The ATL_CLIM ensemble mean (*dashed blue line*). The AMO index is also plotted in the figure, multiplied by 4 as *green dashed line*. Units are m/s for all wind indexes, and K for the AMO index

Kucharski et al. (2016)

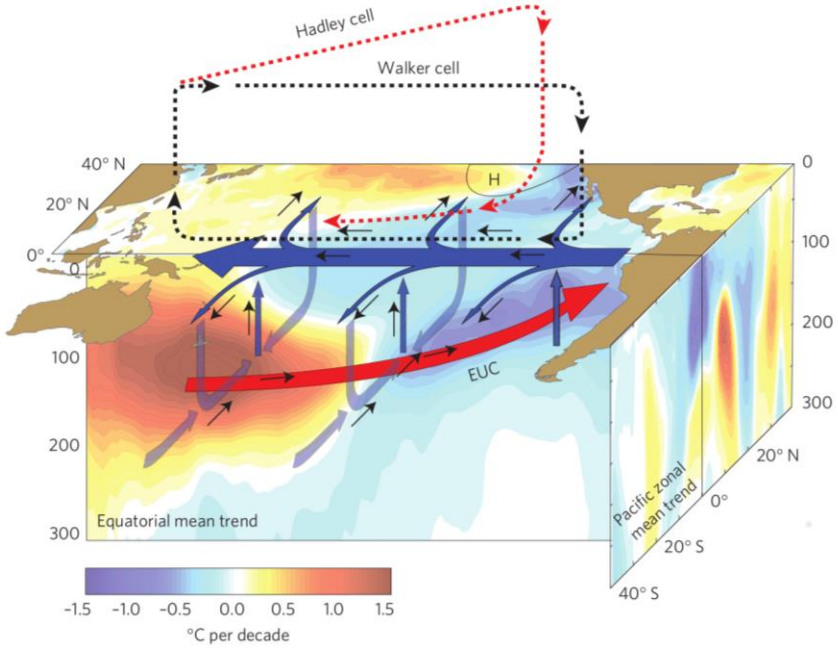



**Figure 3 | Schematic of the trends in temperature and ocean–atmosphere circulation in the Pacific over the past two decades.** Colour shading shows observed temperature trends (°C per decade) during 1992–2011 at the sea surface (Northern Hemisphere only), zonally averaged in the latitude-depth sense (as per Supplementary Fig. 6) and along the equatorial Pacific in the longitude-depth plane (averaged between 5° N–5° S). Peak warming in the western Pacific thermocline is 2.0 °C per decade in the reanalysis data and 2.2 °C per decade in the model. The mean and anomalous circulation in the Pacific Ocean is shown by bold and thin arrows, respectively, indicating an overall acceleration of the Pacific Ocean shallow overturning cells, the equatorial surface currents and the Equatorial Undercurrent (EUC). The accelerated atmospheric circulation in the Pacific is indicated by the dashed arrows; including the Walker cell (black dashed) and the Hadley cell (red dashed; Northern Hemisphere only). Anomalously high SLP in the North Pacific is indicated by the symbol 'H'. An equivalent accelerated Hadley cell in the Southern Hemisphere is omitted for clarity.

Source: England et al. 2014

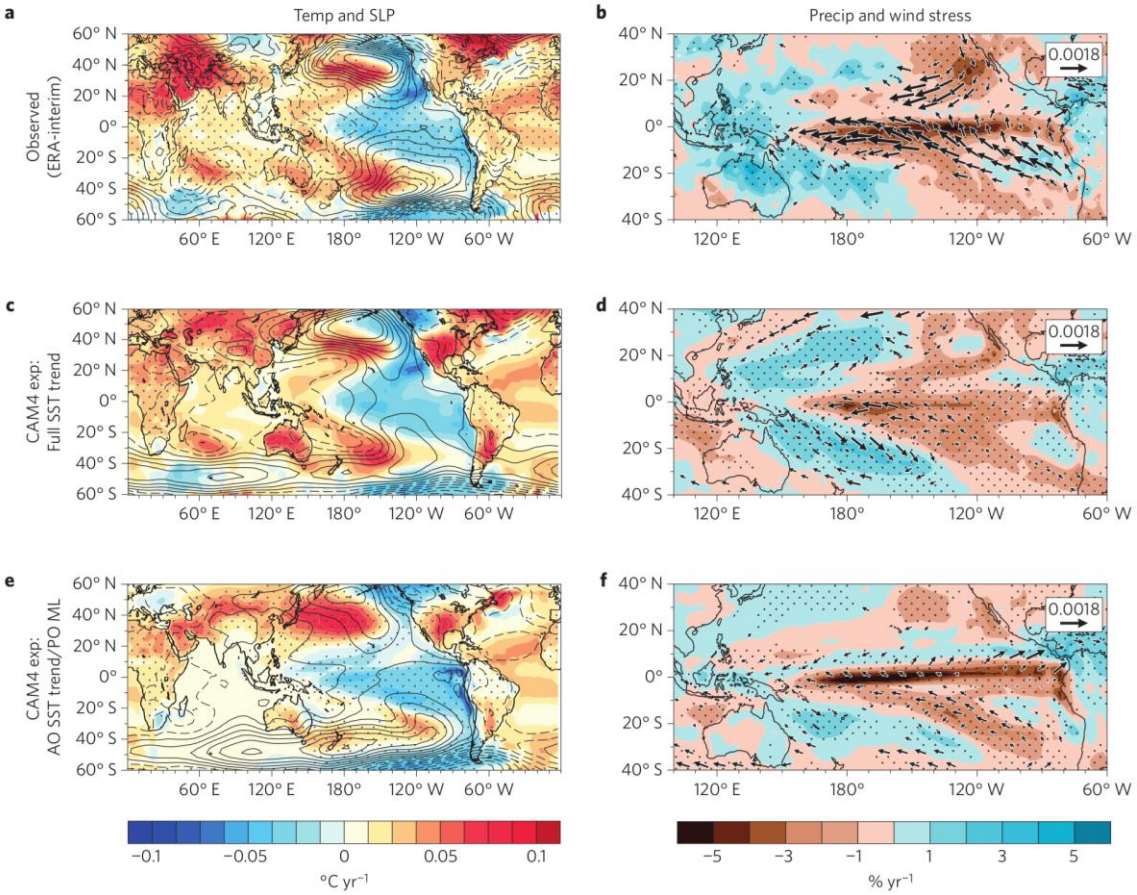
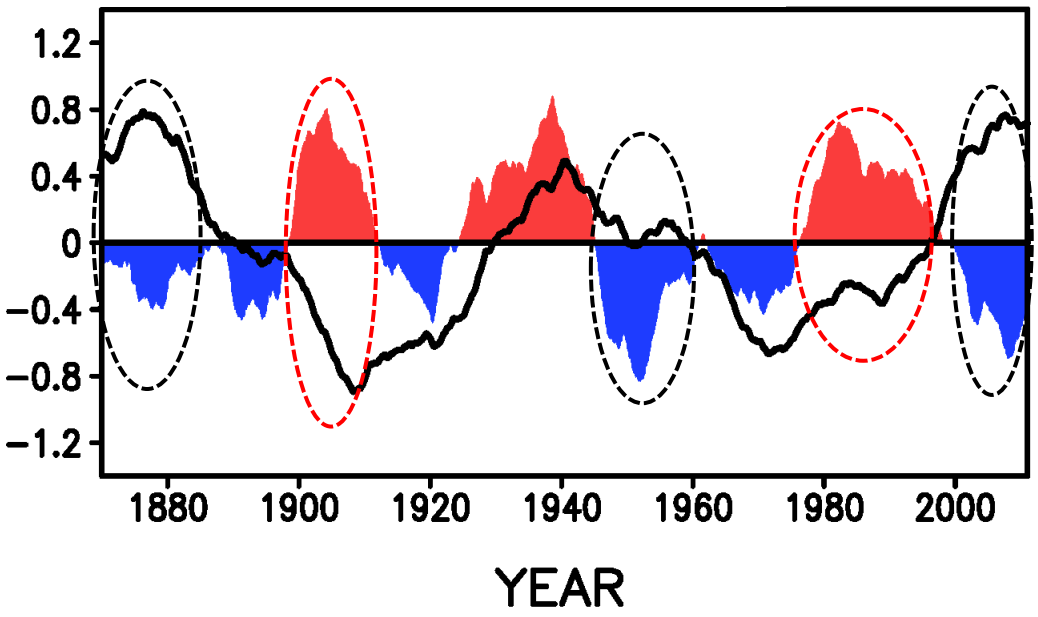



**Figure 1 | Trends (1992–2011) of SST, SLP, wind stress and relative precipitation. a**, Observed surface temperature[29] (colour scale) and SLP (ref. 30) (contours; Pa $yr^{-1}$); SLP trend contours range from −14 Pa to 14 Pa with a contour level of 4 Pa; negative contours are dashed. **b**, Observed relative precipitation trends (colour scale) and significant wind stress trends[30] (N $m^{-2}$ $yr^{-1}$) significant above the 95% level (vector). In all panels stippling indicates that the changes in the underlying shaded plots are significant above the 95% level. SLP significance levels in **a**,**c**,**e** are represented as stippling in Supplementary Fig. 4. **c**,**d**, As in **a** and **b**, but for the CAM4 experiment forced with the global observed SST trend (shading). **e**,**f**, As in **a** and **b**, but for the CAM4 experiment forced with the Atlantic SST trend and a Pacific mixed layer.

Source:McGregor et al. 2014

Global warming hiatus

PDO and AMO indices




WAMO/WPDO: 1931-1944 (14)

CAMO/CPDO : 1892-1897; 1963-1976; 1913-1923 (31)

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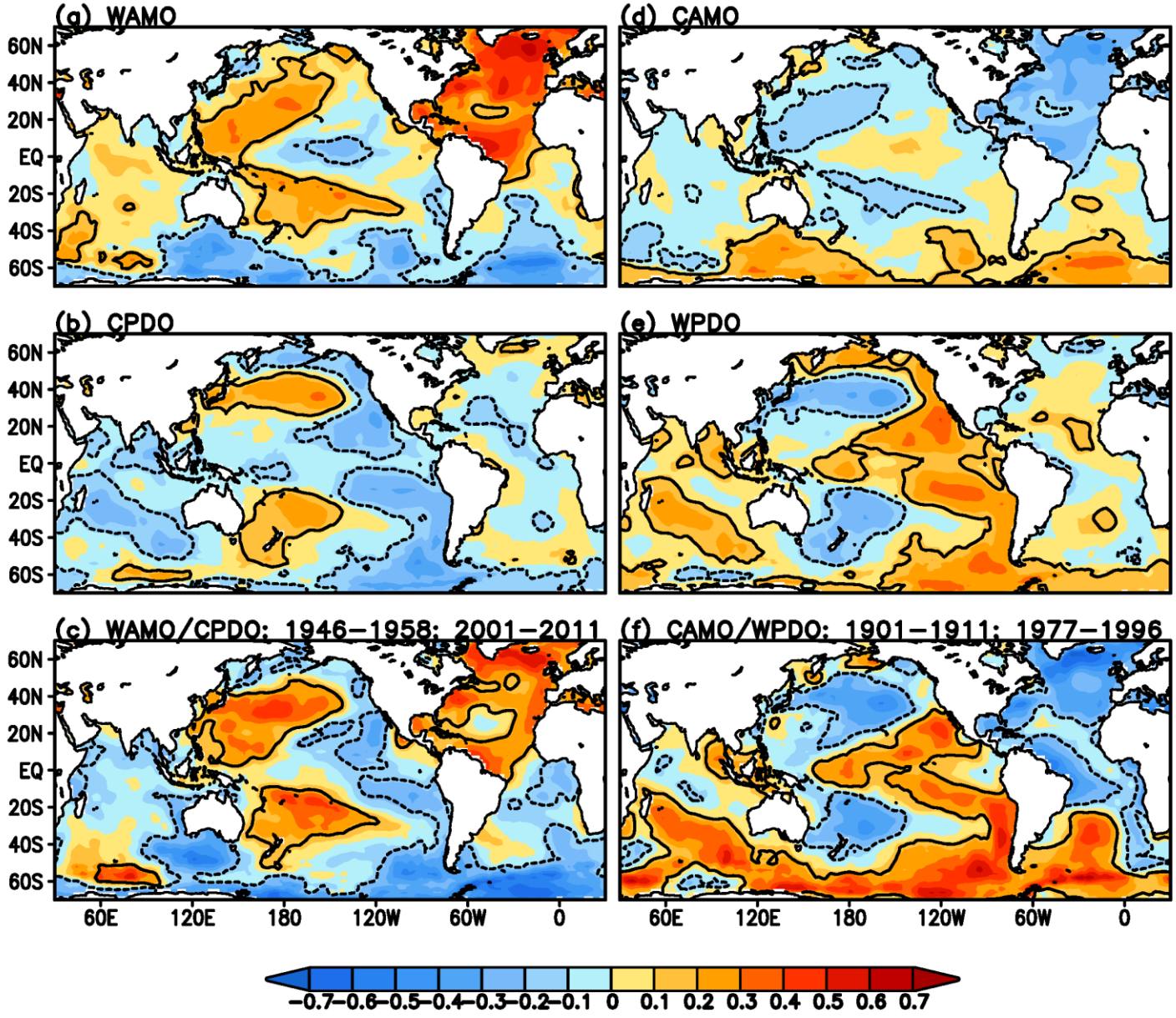
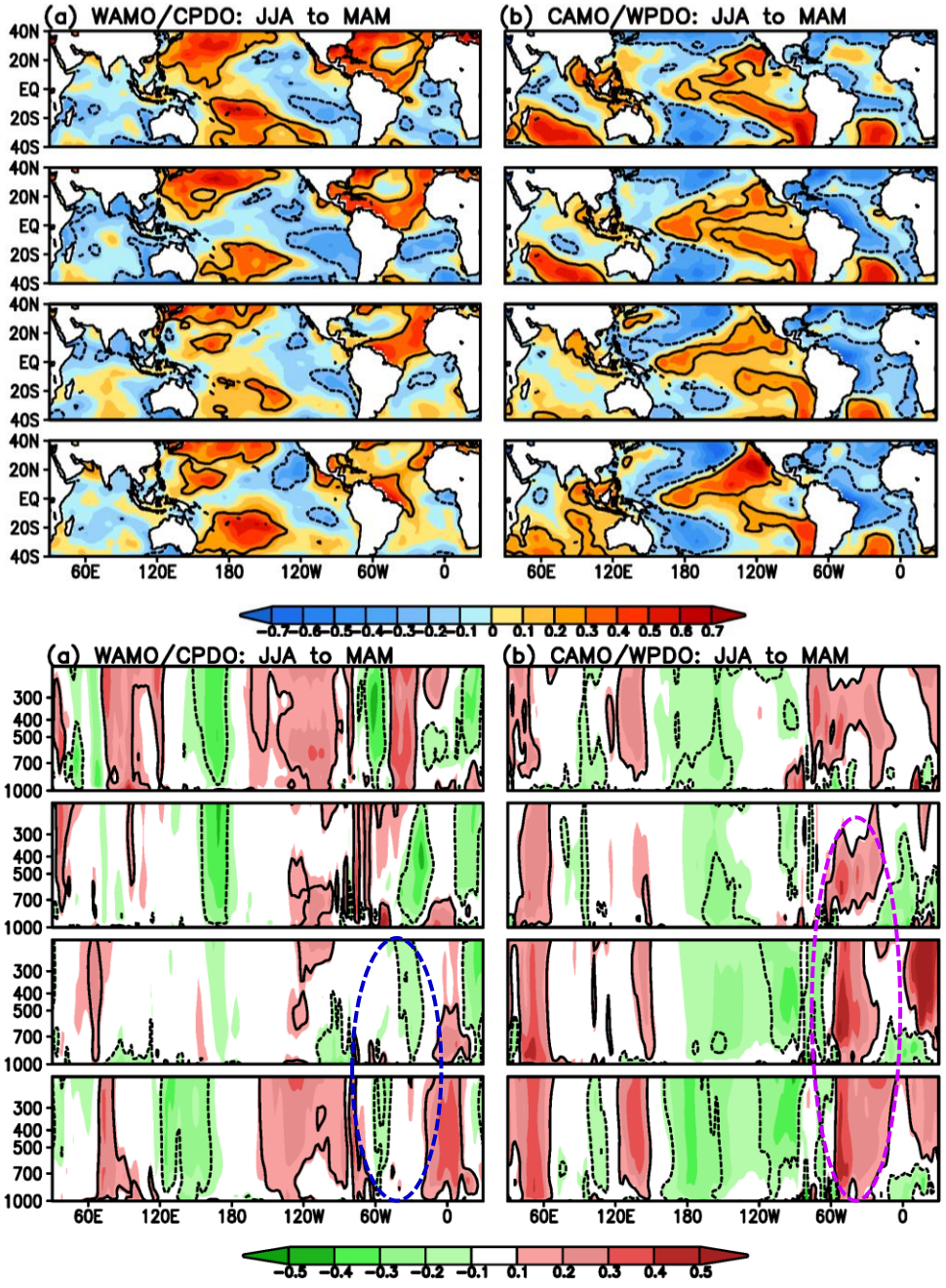
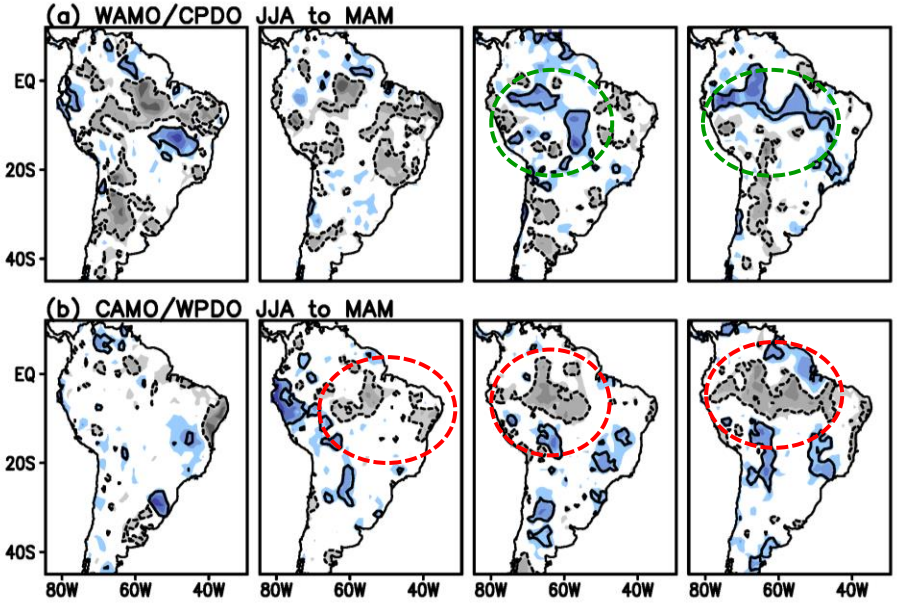

(a) WAMO
(d) CAMO
(b) CPDO
(e) WPDO
(c) WAMO/CPDO: 1946–1958; 2001–2011
(f) CAMO/WPDO: 1901–1911; 1977–1996
60N
40N
20N
EQ
20S
40S
60S
60E
120E
180
120W
60W
0
−0.7 −0.6 −0.5 −0.4 −0.3 −0.2 −0.1 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7




interbasin
SST grad

Walker cell
intensification


(a) WAMO/CPDO JJA to MAM
EQ
20S
40S
(b) CAMO/WPDO JJA to MAM
EQ
20S
40S
80W
60W
40W
80W
60W
40W
80W
60W
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80W
60W
40W

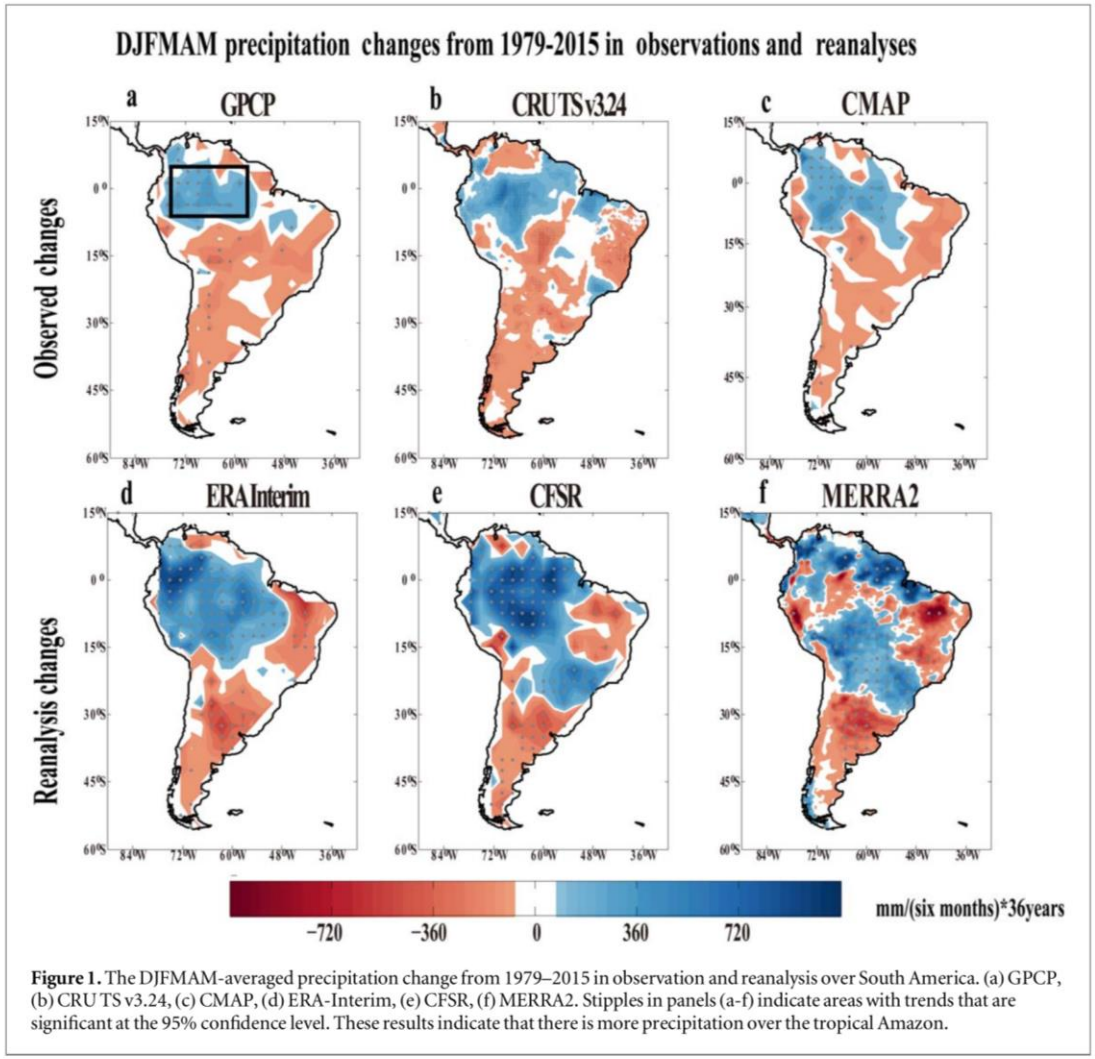



**Figure 1.** The DJFMAM-averaged precipitation change from 1979–2015 in observation and reanalysis over South America. (a) GPCP, (b) CRU TS v3.24, (c) CMAP, (d) ERA-Interim, (e) CFSR, (f) MERRA2. Stipples in panels (a-f) indicate areas with trends that are significant at the 95% confidence level. These results indicate that there is more precipitation over the tropical Amazon.

Source: Wang et al. 2018

# AMO & PDO combined bkg

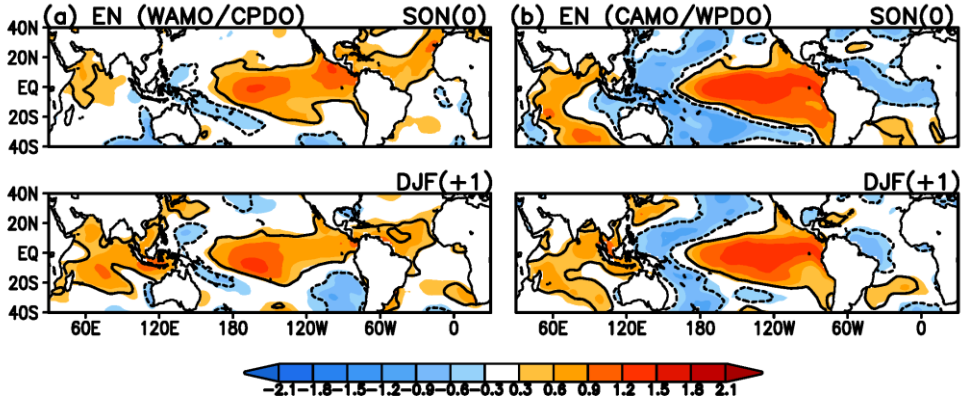
- WAMO/CPDO and CAMO/WPDO longer than other mean states due to the negative SST relation between Atlantic and Pacific which affects the equatorial easterlies (Bjerknes process)

- the Walker cell: strengthened during the WAMO/CPDO;
  weakened during CAMO/WPDO. (McGregor et al. 2014)

- Atlantic-Pacific east-west inter-basin grad modulates tropical S.A. precip

- Low-frequency precip patterns over tropical S.A.: in part, define the precip anomaly patterns

- Amazonian rainfall increase over 1979-2015 (Wang *et al*., 2018) and the flooding extreme intensification over 1903-2015 (Barichivich *et al*., 2018): related to the change from CAMO/WPDO (1977-1996) to WAMO/CPDO (2001-2011).


(a) EN (WAMO/CPDO)
SON(0)
(b) EN (CAMO/WPDO)
SON(0)
DJF(+1)
DJF(+1)
40N
20N
EQ
20S
40S
60E
120E
180
120W
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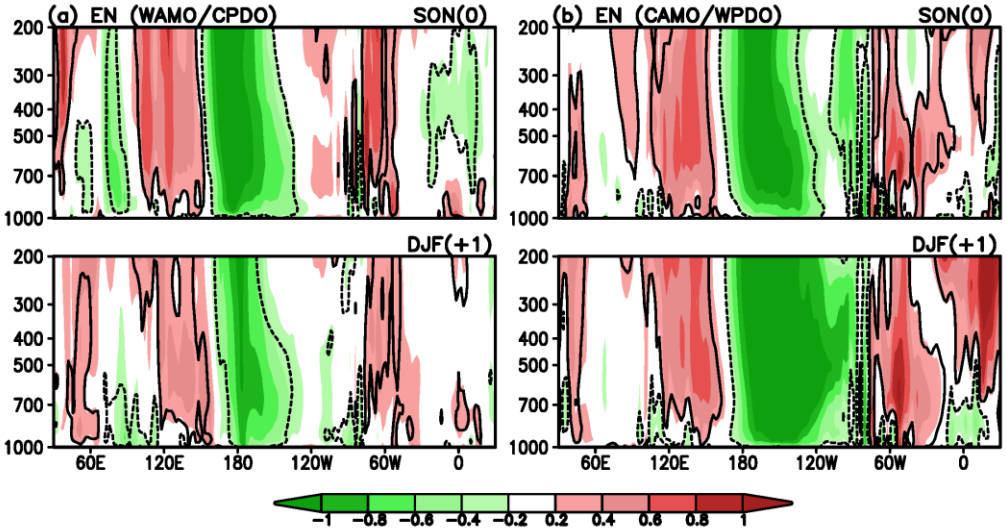
0
-2.1 -1.8 -1.5 -1.2 -0.9 -0.6 -0.3 0.3 0.6 0.9 1.2 1.5 1.8 2.1


(a) EN (WAMO/CPDO)
SON(0)
(b) EN (CAMO/WPDO)
SON(0)
DJF(+1)
DJF(+1)
200
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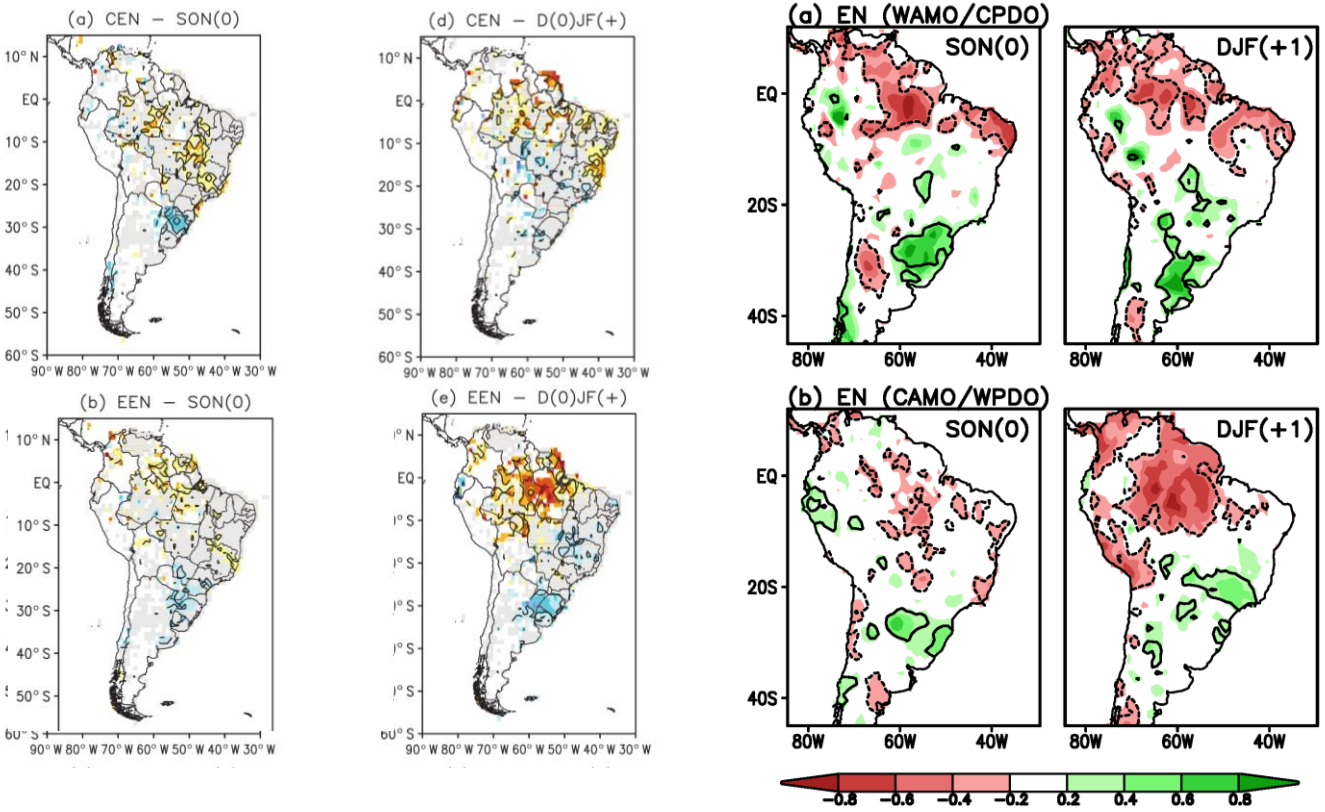
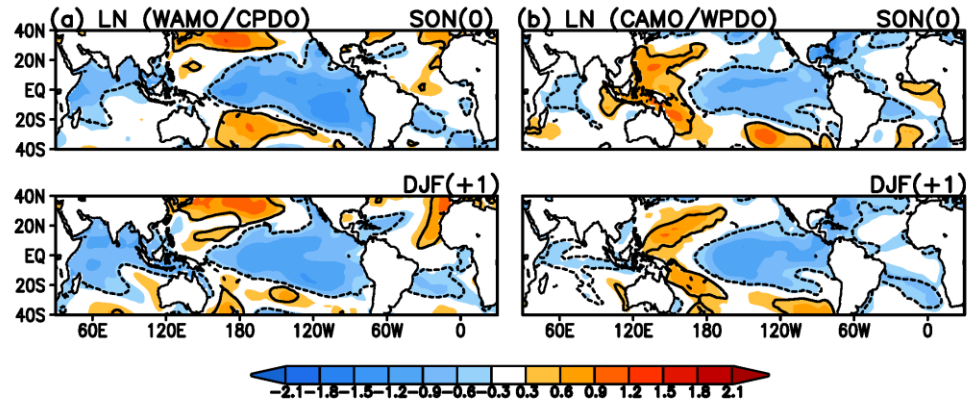
-1 -0.8 -0.6 -0.4 -0.2 0.2 0.4 0.6 0.8 1




Source:Tedeschi et al. (2015)


(a) LN (WAMO/CPDO)
SON(0)
(b) LN (CAMO/WPDO)
SON(0)
DJF(+1)
DJF(+1)
40N
20N
EQ
20S
40S
60E
120E
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120W
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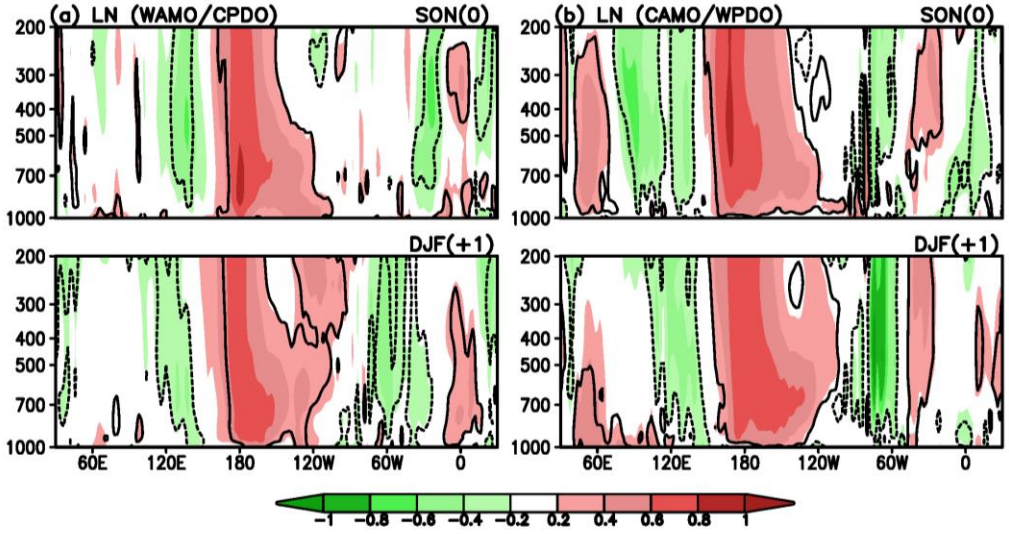
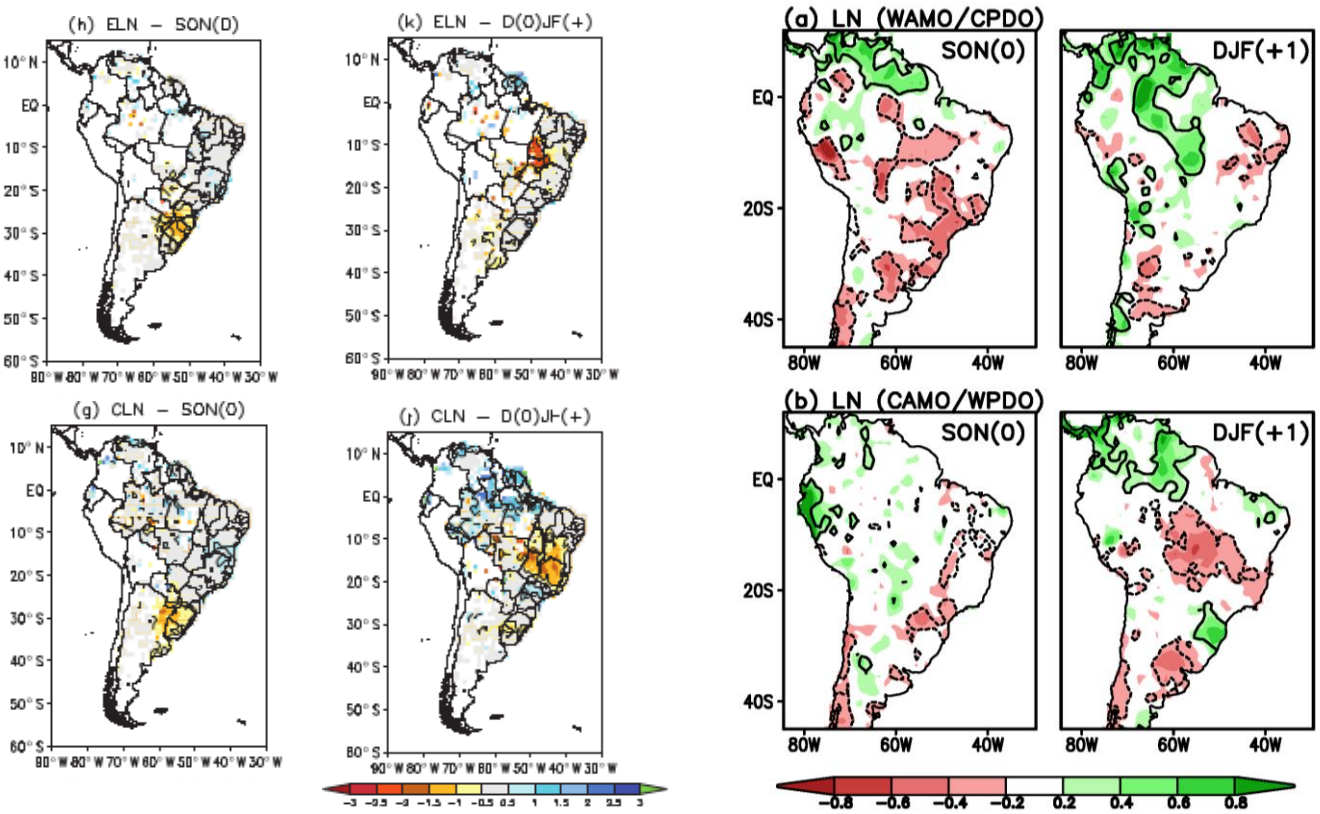
0
-2.1 -1.8 -1.5 -1.2 -0.9 -0.6 -0.3 0.3 0.6 0.9 1.2 1.5 1.8 2.1

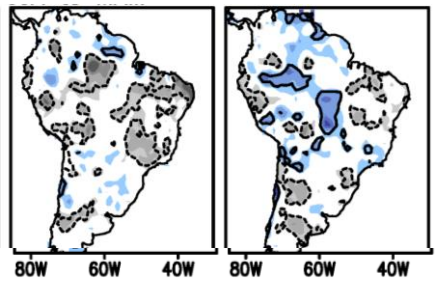

(a) LN (WAMO/CPDO)
SON(0)
(b) LN (CAMO/WPDO)
SON(0)
DJF(+1)
DJF(+1)
200
300
400
500
700
1000
60E
120E
180
120W
60W
0
-1 -0.8 -0.6 -0.4 -0.2 0.2 0.4 0.6 0.8 1

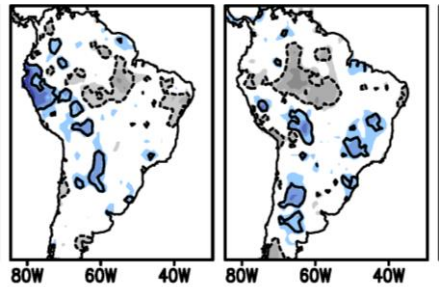


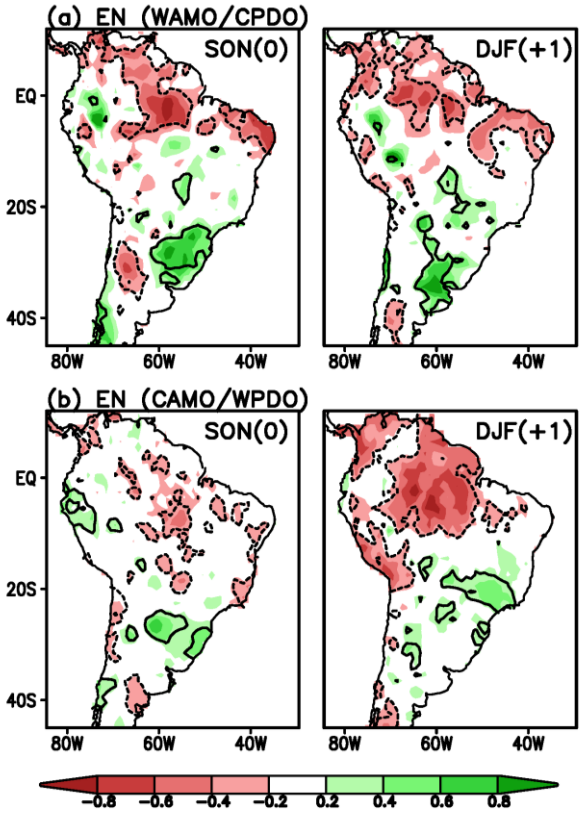

Source:Tedeschi et al. (2015)

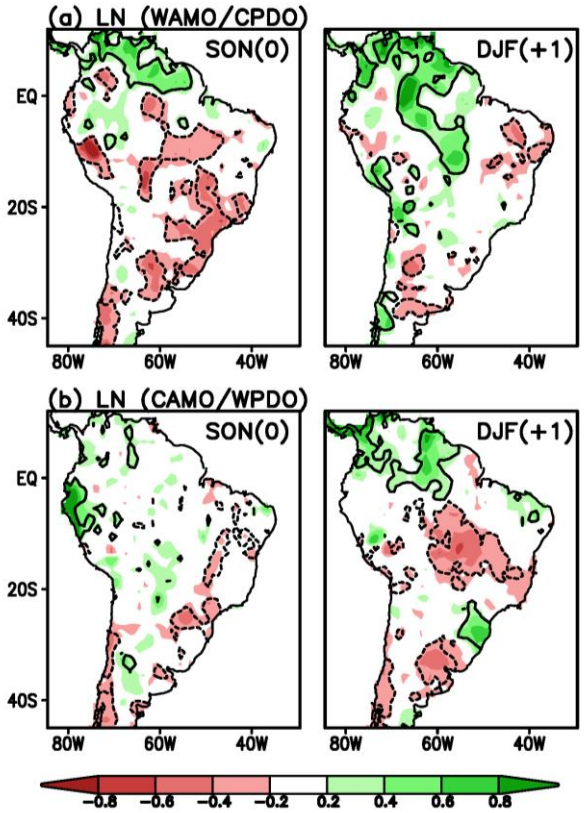
WAMO/CPDO: SON ; DJF

CAMO/WPDO: SON; DJF



# Conclusions and Remarks

- Both PDO and AMO contribute to the SAMS interanual variability
- AMO modulates the Atlantic/Pacific interbasin grad, which in turn modulates the ENSO-related precip in S.A.
- AMO and PDO are connected through an east-west cell which drives the Bjerkens feedback
- AMO/PDO bkgs contribute to define the ENSO types
- The low-frequency precip patterns define in part the precip anomaly pattern over tropical S.A. during ENSO and non-ENSO years

- Since AMO and PDO bkgs are connected through an east-west cell, they should not be interpreted separately, in particular concerning the SAMS

- A similar analysis for the NAMS should bring relevant results
- Paleoclimate studies should consider the AMO/PDO bkgs.
- AMO/PDO bkgs might affect higher frequency variability modes (MJO, SACZ, etc)

Thank you!!

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