ENSO and non-ENSO low frequency variability from the **Modern Reanalysis Data Sets*** and Implications!

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Thanks : *Leigh Zhang, Wesley Ebisuzaki & Arun Kumar*
for producing the CoRE reanalysis data, and providing CoRE and all other reanalysis data sets.

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Motivation for this current work:

- Back about 25 years ago, in the mid-late 1990s,
  .. When after nearly the first 50 years of NCEP/NCAR reanalysis data became available, and
  .. When in 1995 almost a seismic upward shift in the North Atlantic Hurricane Activity occurred in 1995, after being for below normal for a long time, (and is kind of still in that active phase)

Then, we quickly explored if we can understand any clues for this "dramatic shift" in the behavior of seasonal North Atlantic activity from the long data record,

A predictor for North Atlantic Hurricane Season ?

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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,

Chelliah, M., and G. D. Bell, **1998**: <u>A predictor for North Atlantic Hurricane Season.</u> ***Proc. 23d Annual Climate Diagnostics Workshop***, **Miami, FL,** NOAA/Climate Prediction Center, 218–222.

Next year, in 1999, CPC/NOAA started first issuing <u>Official Seasonal Atlantic Hurricane Outlooks.</u>

CPC/NOAA also started issuing Official Seasonal <u>East Pacific Hurricane Outlooks</u> soon thereafter!

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

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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 the TMM and ENSO the strongest regressed values of the wintertime NAO index are found when their principal component (PC) time series are out of phase.

In the Tropics and subtropics the linearly combined signal for the TMM and ENSO is strongest when their PC time series are in phase and is weakest when they are out of phase. This result suggests a substantial modulation of the ENSO teleconnections by the background flow. It indicates stronger La Niña teleconnections during the 1950s–60s, compared to stronger El Niño teleconnections during the 1980s–90s. Although this study addresses the linear ENSO–TMM interference, the results also suggest that interactions between the two modes may help to explain the stronger El Niño episodes observed during the 1980s–90s compared to the 1950s–60s.

Winter (DJF) & Summer (JJA)

Analysis (EOF) of ENSO/non-ENSO modes of variability based on seasonal mean 200mv (VPOT) anomalies from NCEP/R1

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

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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 during 1995–2004.

It is shown that the ENSO teleconnections and impacts on Atlantic hurricane activity can be substantially masked or accentuated by the leading multidecadal modes. This leads to the important result that these modes provide a substantially more complete view of the climate control over Atlantic hurricane activity during individual seasons than is afforded by ENSO alone. This result applies to understanding differences in the "apparent" ENSO teleconnections not only between the above- and below-normal hurricane decades, but also between the two sets of above-normal hurricane decades.

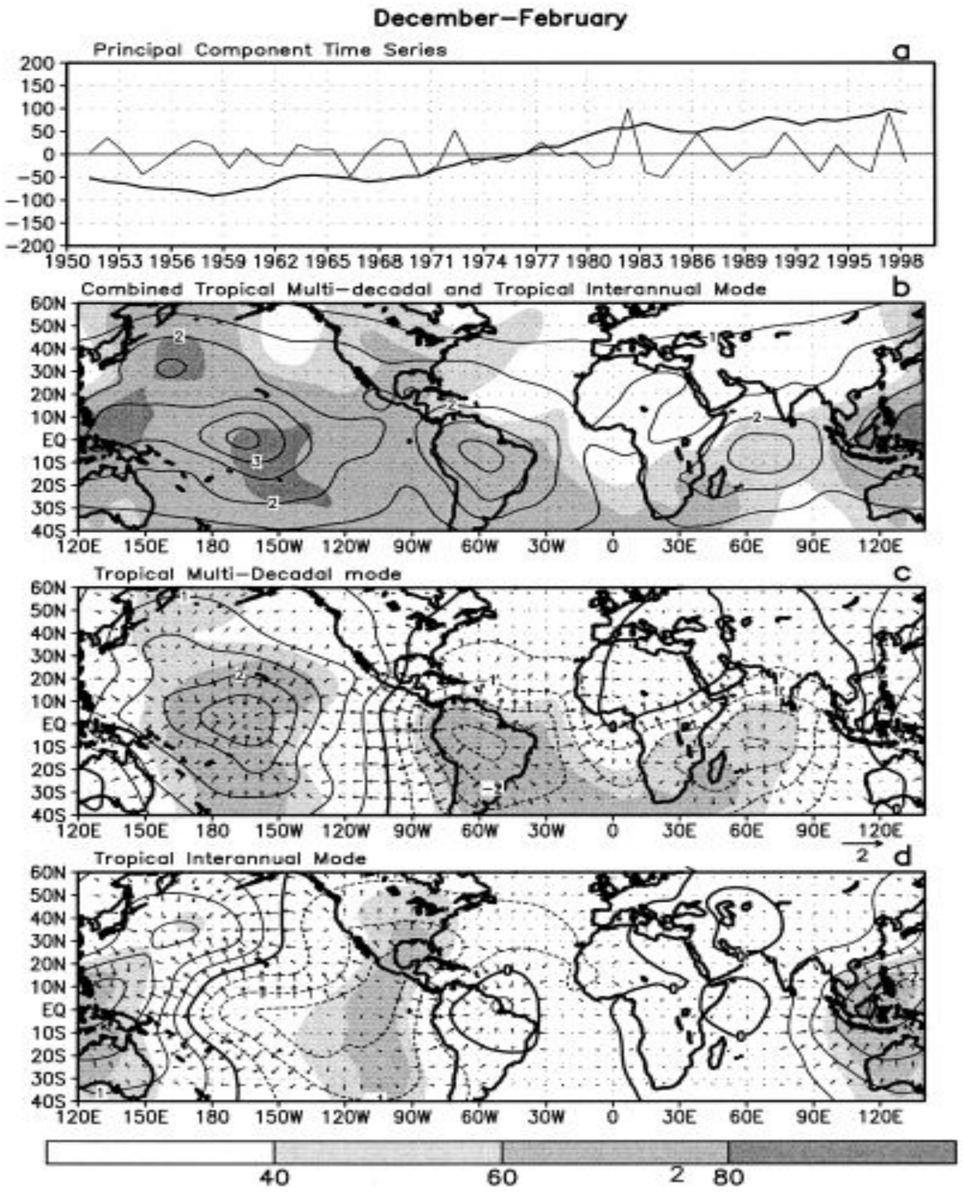


FIG. 4. As in Fig. 3, except for the DJF season.

tropical surface temperature (land + ocean) anomalies (shown for JJA, Figs. 5c, 6c), indicating that both EOF analyses are capturing similar decadal-scale climate anomalies.

During DJF the positive phase of the TMM features above-average precipitation rates again over the Amazon basin and also over the equatorial Indian Ocean (contours, Fig. 5b), with the main area of compensating subsidence shifted to the central equatorial Pacific. In its negative phase the main area of anomalous ascending

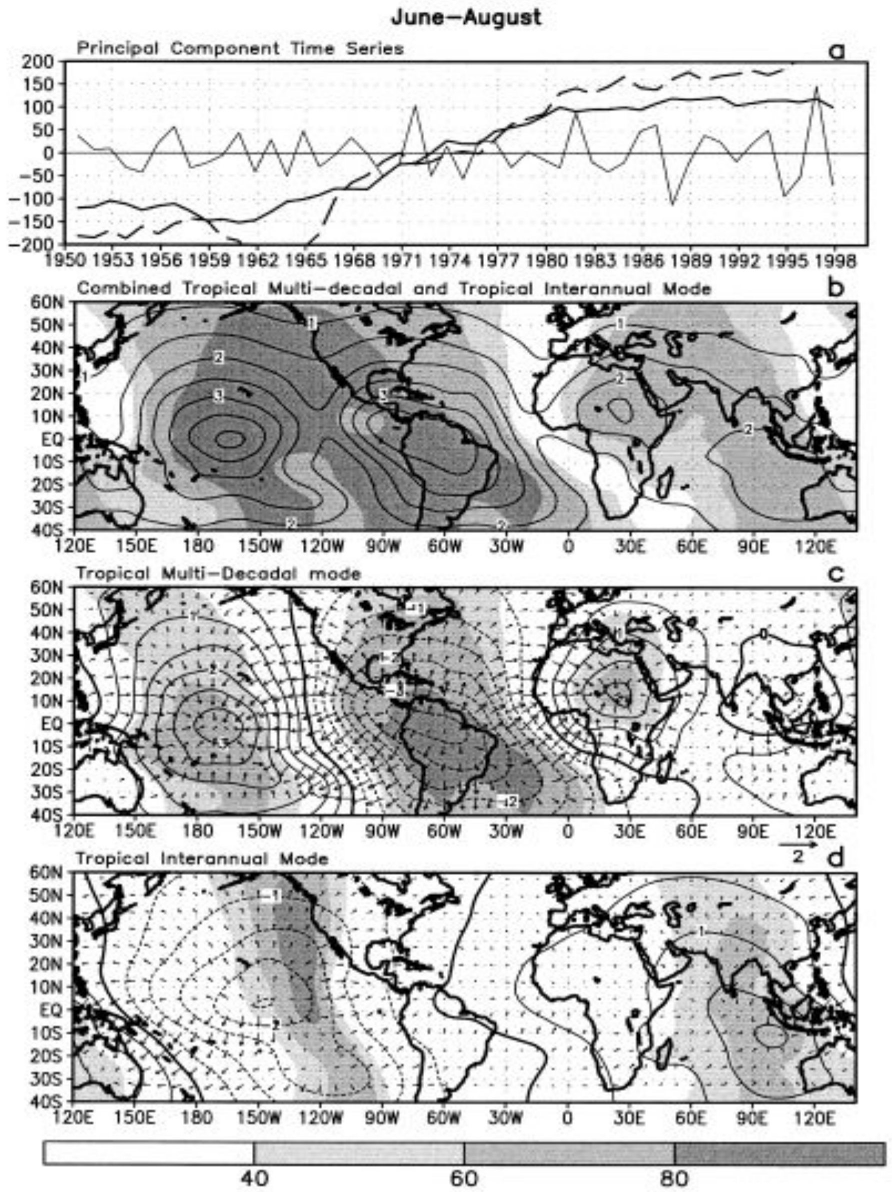


FIG. 3. JJA (a) PC time series for the TMM (thick solid), tropical interannual mode (ENSO, thin solid), and leading multidecadal EOF of seasonal surface temperature anomalies (dashed). Shading shows percent of explained variance of unfiltered seasonal 200-hPa velocity potential anomalies by the (b) combined 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).

Motivation Continued

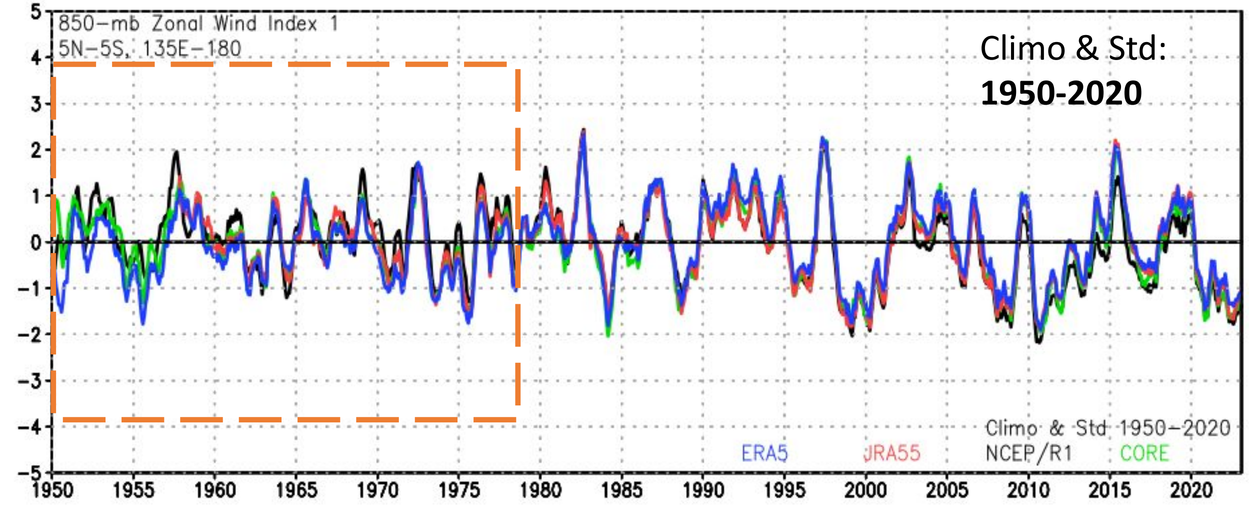
- Ever since NCEP/NCAR Reanalysis going back to 1948 and continued through real time, was produced and made freely available to the global research, academic community and operational meteorological centers, we all know that other met. Centers from around the world (ECMWF, JMA, etc.) began to follow suite and started producing their own reanalyses.

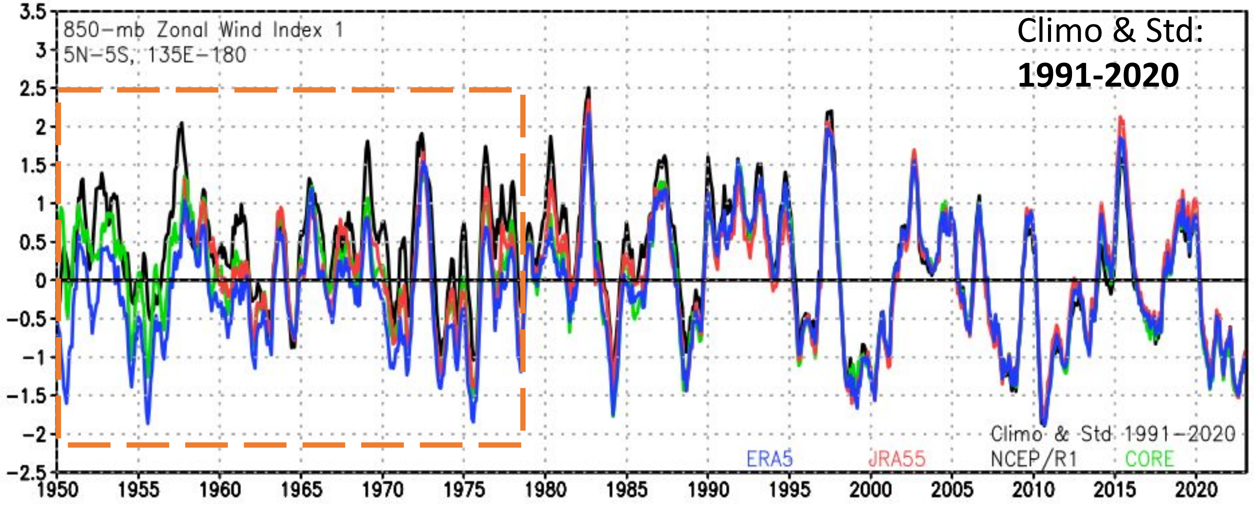
- But there have always been the nagging questions about the quality of the reanalysis data in earlier decades, the 50's and 60's. The old(?) GCM/fcst models and Global Data Assimilation Systems (GDAS) were not able to sufficiently handle this 'data poor' period.

- Recently through the availability of improved, next generation of forecast GCMs and sophisticated data assimilation systems, Modern Reanalysis data sets are becoming available.
    - CPC/NCEP's CoRE (Conventional data only, to avoid data jumps) reanalysis data based on improved ensemble data assimilation system.
    - ERA5, the fifth generation of atmospheric reanalysis produced by ECMWF.
    - JRA55, the Japanese (JMA) reanalysis data set.

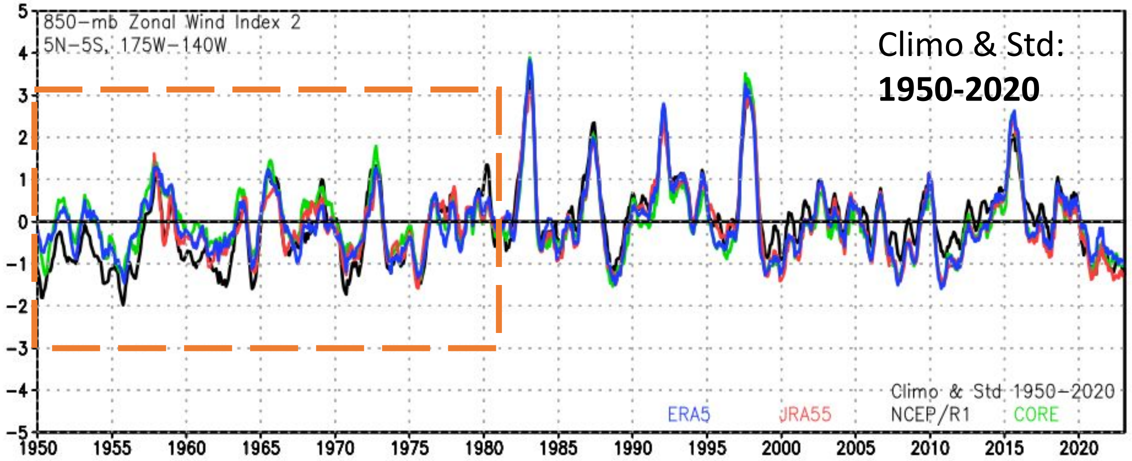
Has the modern reanalysis data quality of earlier decades improved now ?
How will a new analysis of ENSO/low frequency modes look like?

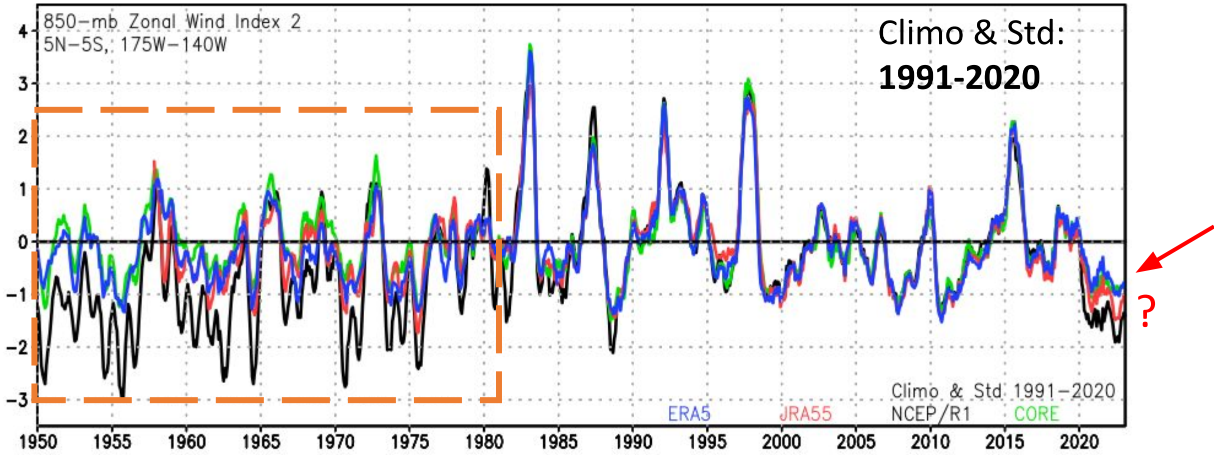
Equatorial Tropical Pacific Zonal Wind Indices (as used in CPC's Monthly Climate Diagnostic Bulletin) from 1950 as represented in **ERA5**, **JRA55**, **NCEP/R1**, and **CoRE**.





850 mb Zonal Zonal Wind Index 1 :
5 N-5 S, 135 E-180 <u>(Eq. W. Pacific, More data!)</u>

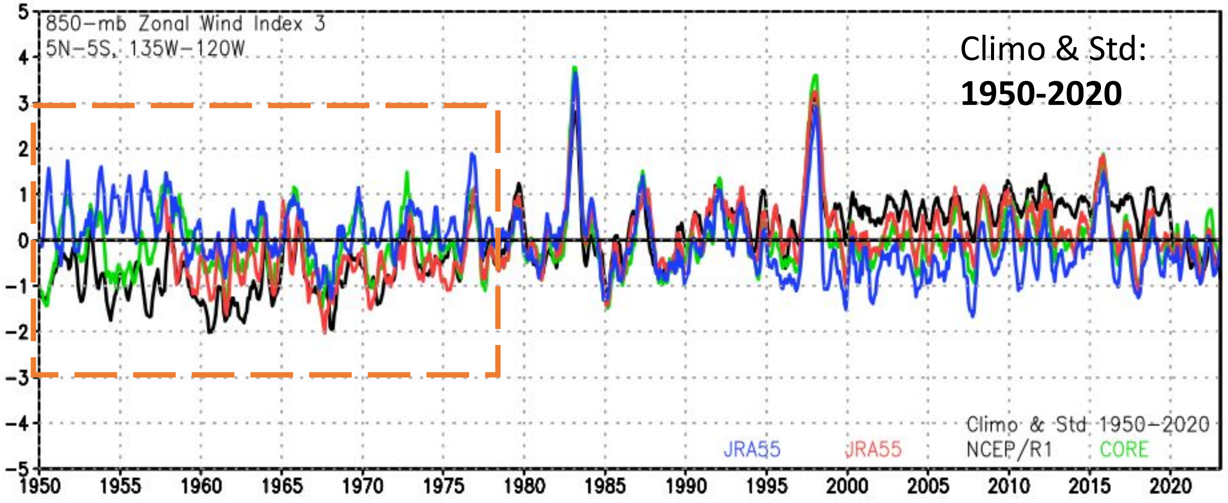


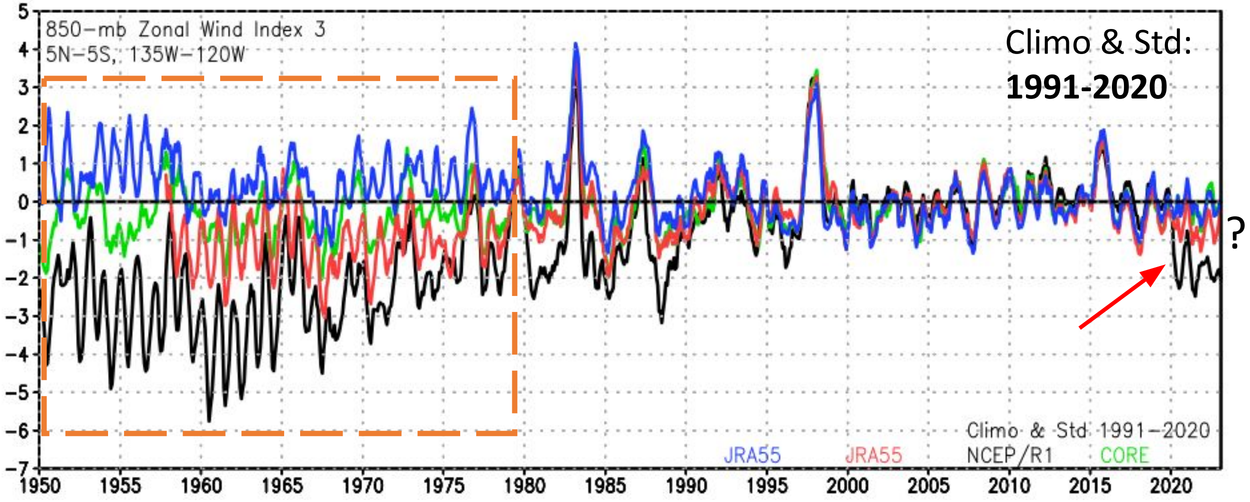


850 mb Zonal Zonal Wind Index 2 :
5 N-5 S, 175W-140W <u>(Eq. C. Pacific, less data!)</u>

- More disagreement among the 4 reanalyses in earlier decades.
- NCEP/R1 is clearly the outlier! (0bviously, it is the older reanalysis!

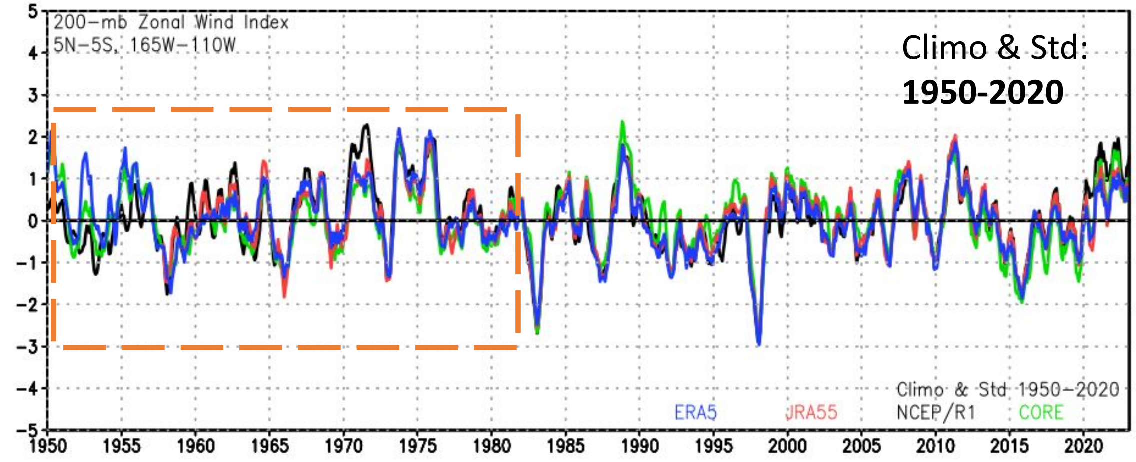
Equatorial Tropical Pacific Zonal Wind Indices (as used in CPC's Monthly Climate Diagnostic Bulletin) from 1950 from **ERA5**, **JRA55**, **NCEP/R1**, and **CoRE**.

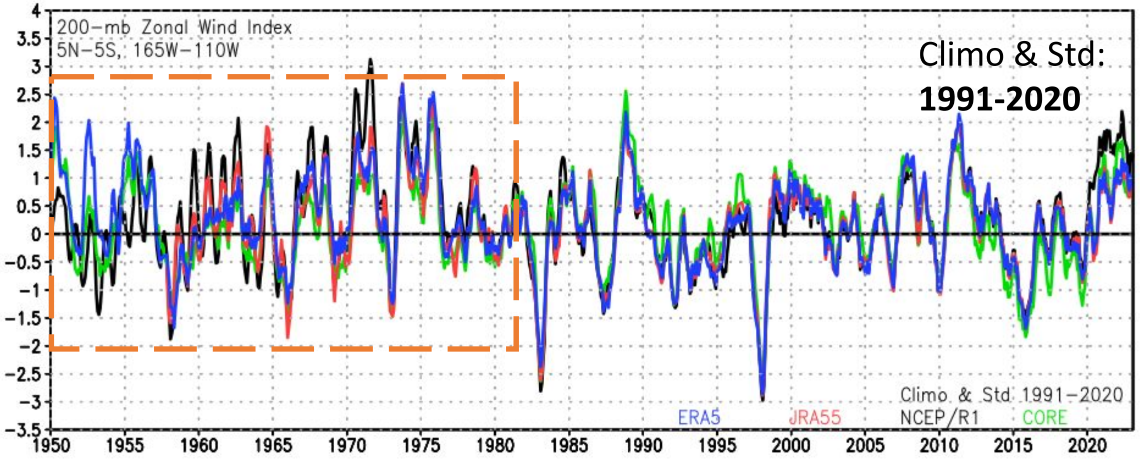




850 mb Zonal Zonal Wind Index 3 :

5 N-5 S, 135 W-120 W <u>(Eq. E. Pacific, data poor!)</u>



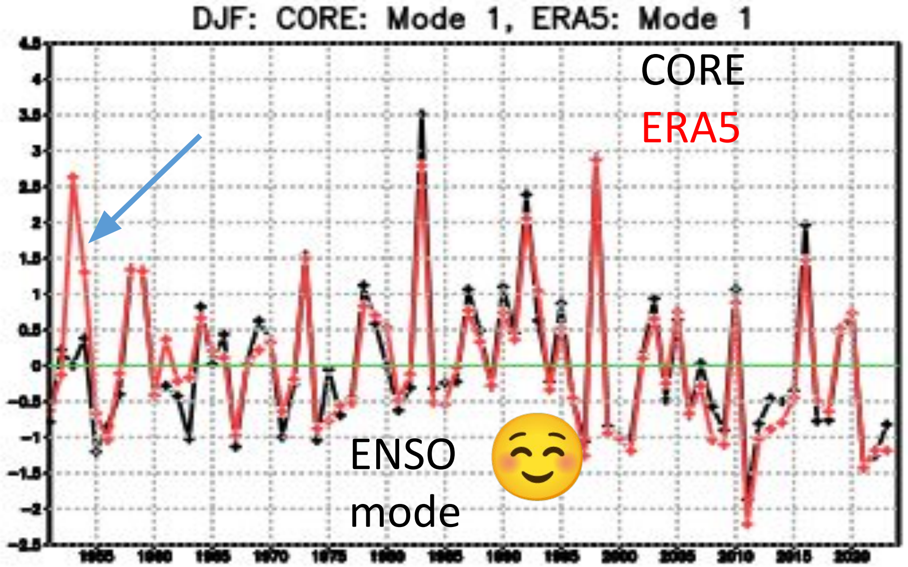


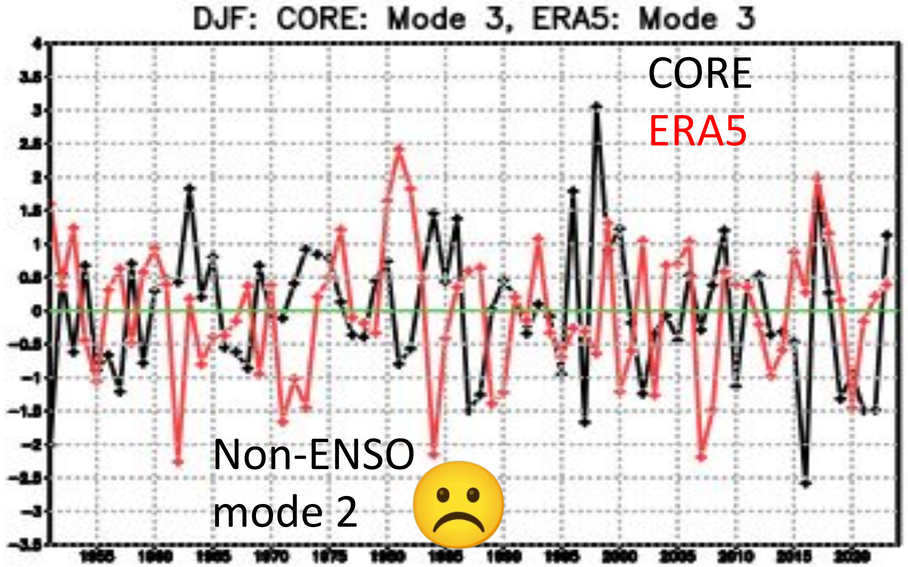
200 mb Zonal Zonal Wind Index :

5 N-5 S, 165 W-110 W (Eq. Pacific.)

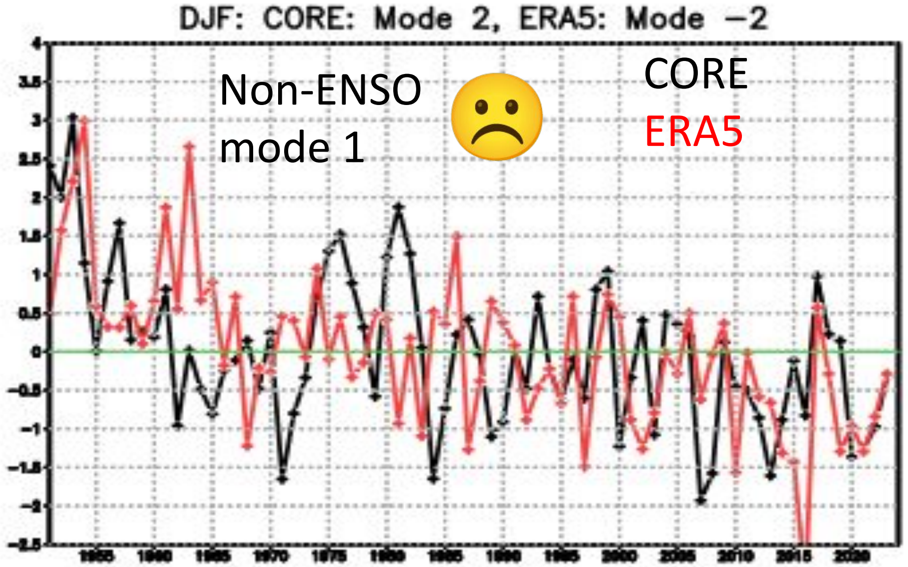
- More disagreement among the 4 reanalyses in earlier decades.
- NCEP/R1 is clearly the outlier! (0bviously, it is the 1st/older reanalysis!
- More disagreement in the data poor central/Eastern Pacific!!!!

So, will not use NCEP/R1 further in this



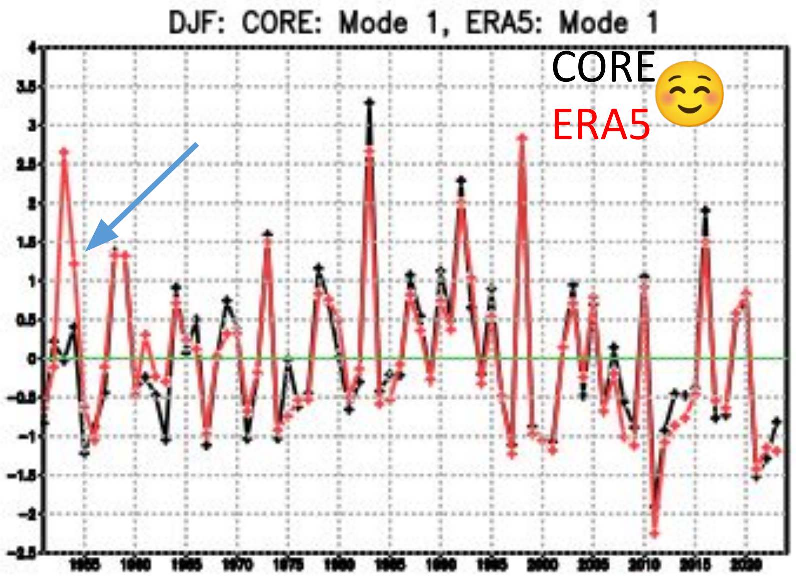


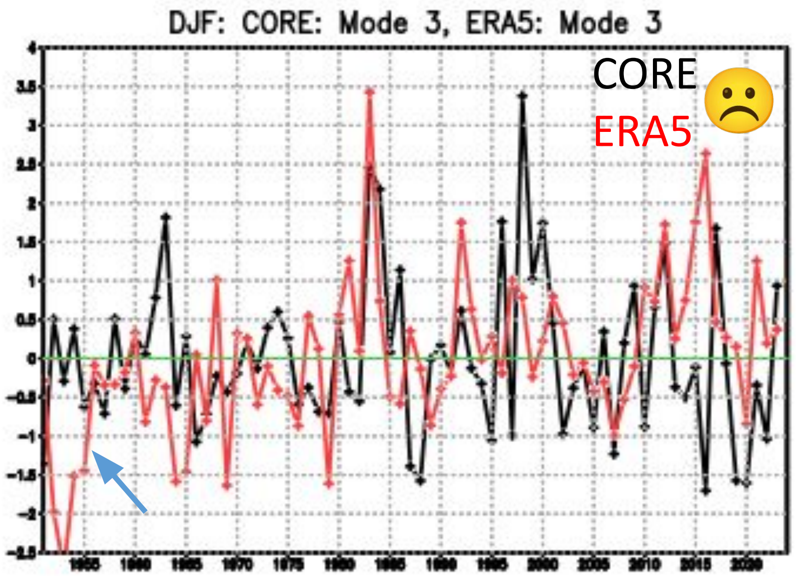
DJF: 1951 - 2023

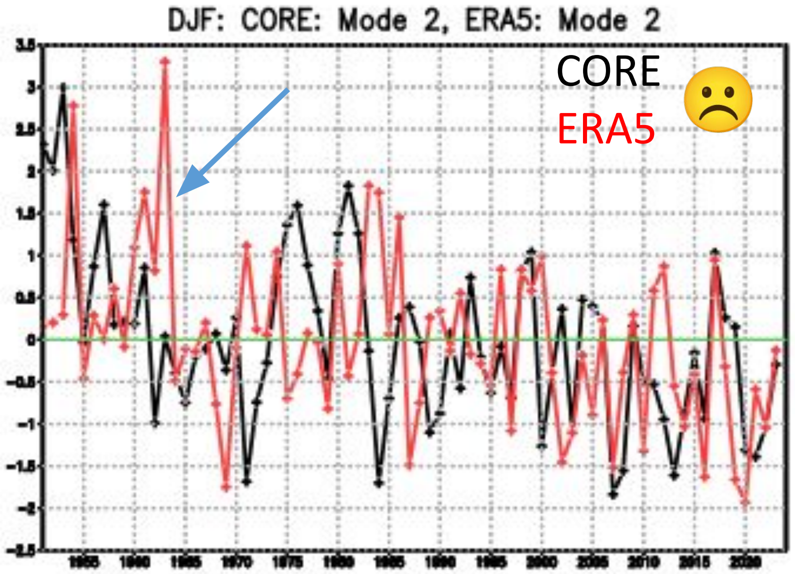


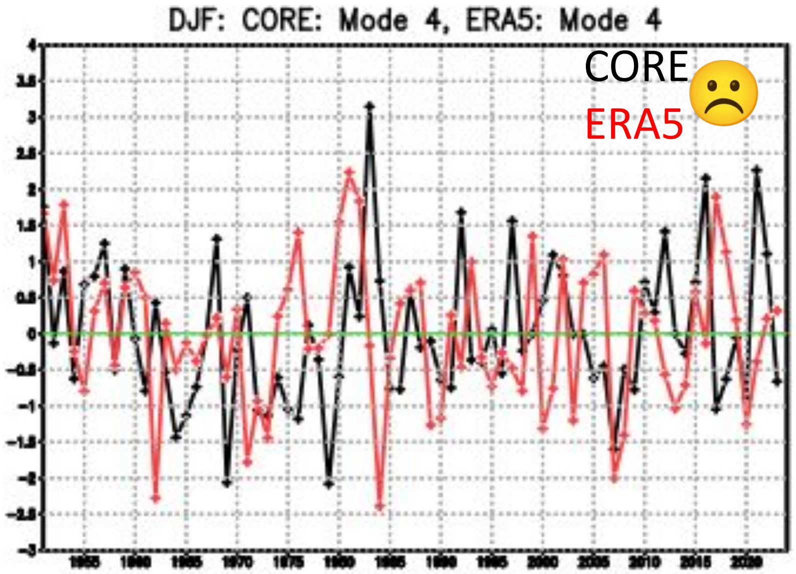
- For the full period from **1951 onwards**, I cannot do/repeat the analysis with JMA, as that reanalysis data does not go back that far.
- I can only do analysis with ERA5 & CoRE.
- This slide shows the major **3-rotated** modes from both CoRE and ERA (after rotation, which hopefully makes the modes more physical and meaningful!).
- **Only in mode 1 (ENSO) – there is a good resemblance between CoRE and ERA5.**
- **No matter what I do, I cannot get the same resemblance (as mode 1) for modes 2 and 3.**

- **The uncertainty and dubious strong amplitude in the earlier decade(s) /years (1951-64 !) with poor data quality, is possibly contaminating the later years and modes!!**



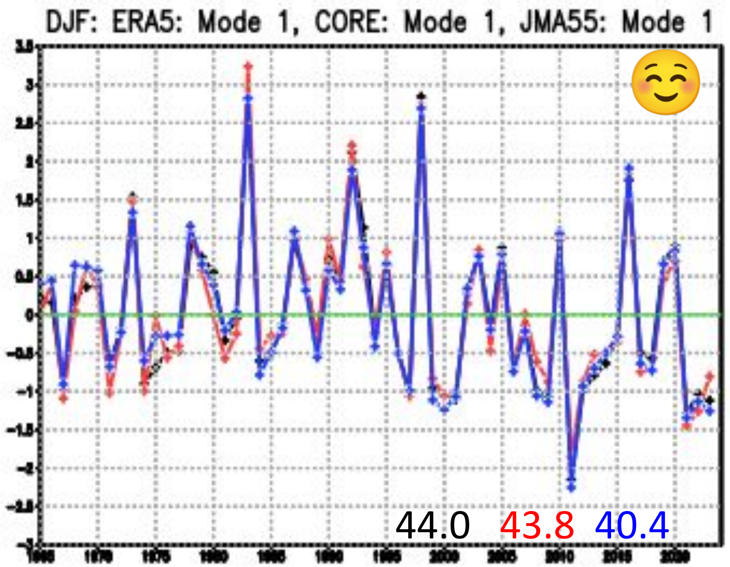


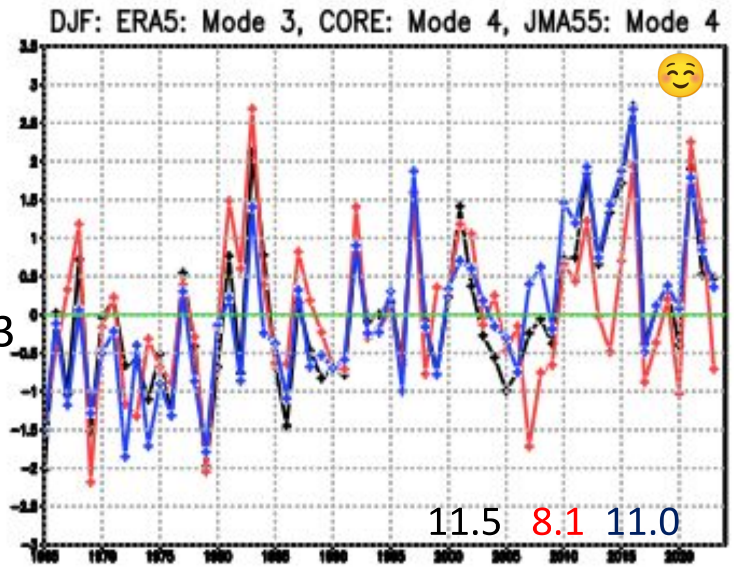




- Same as Prev. slide, but now with **4-rotated** modes from both CoRE and ERA (after rotation, which hopefully makes the modes more physical and meaningful!).
- Again, Only in mode 1 (ENSO) – there is a good resemblance between CoRE and ERA5.
- No matter what I do, I cannot get the same resemblance/agreement for modes 2, 3 and 4.
- **The uncertainty and dubious strong amplitude in the earlier decade(s) /years (1951-64 !) with poor data quality, is possibly contaminating the later years and modes!!**

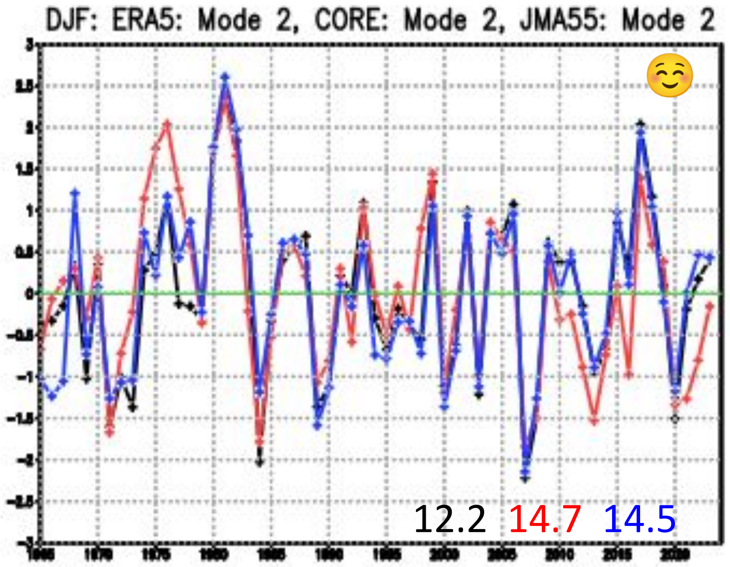
(Skip slide!)

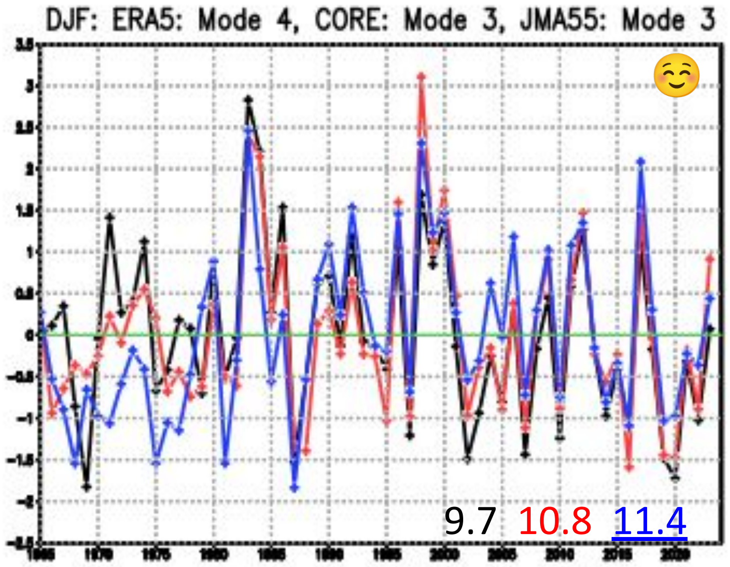




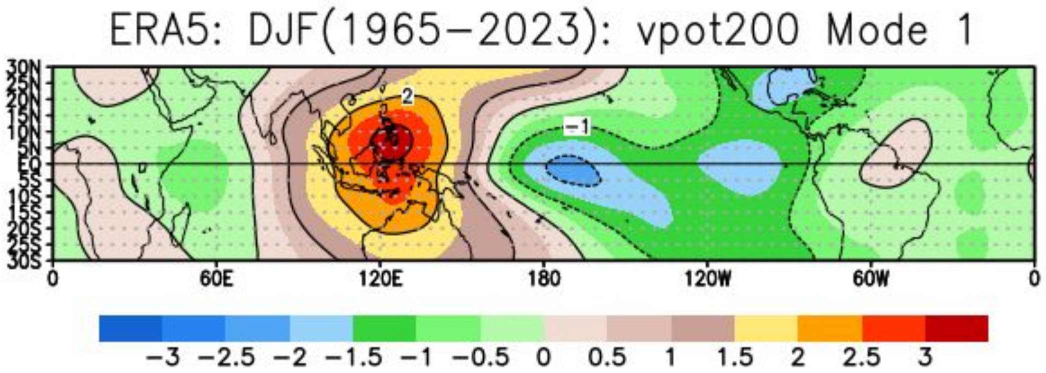
1965
-2023

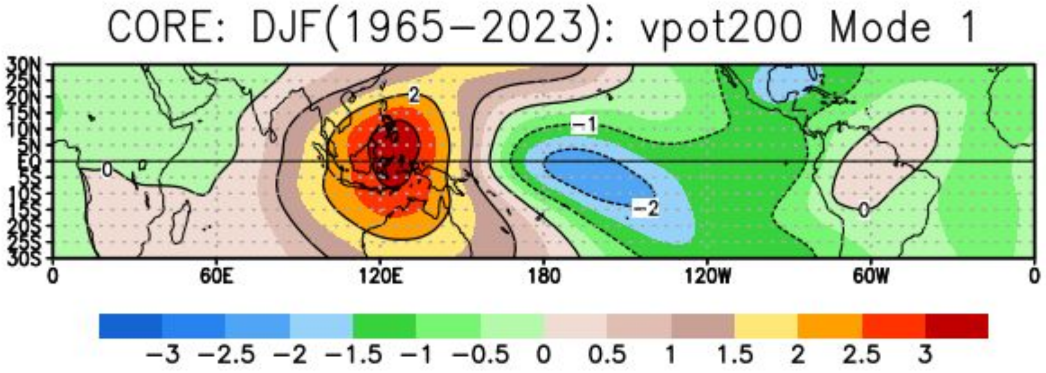
ERA5(black), CoRE(red) & JMA55(blue).

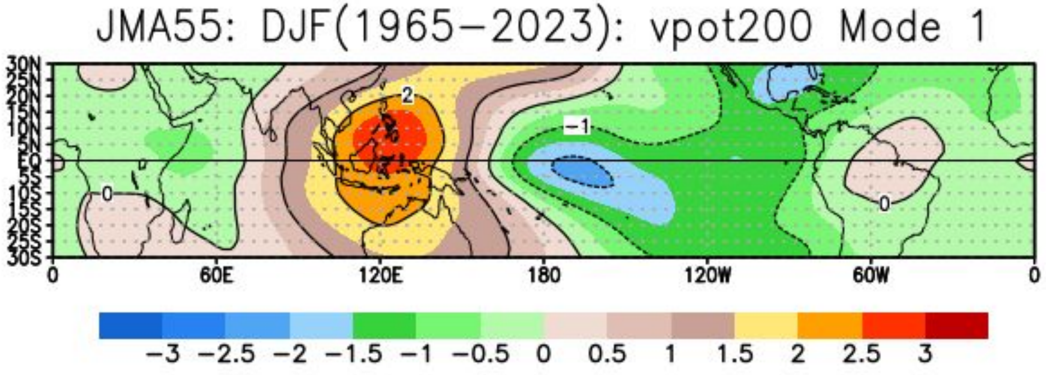




- The analysis is now repeated, leaving out the earlier decade(s)/years 1951-64, **but only for period 1965-2023.**
- For all three major reanlayses, ERA5(black), CoRE(red) & JMA55(blue). The number of modes rotated are 4!
- Now notice that, the agreement/ resemblance is not just in the 1st ENSO mode, but slightly better in subsequent non-ENSO modes 2-4.
- The agreement is best for the leading ENSO mode 1, with maximum explained variance and better/good for modes 2-4, with smaller/decreasing explained variances.
- All leading modes 1-4 are numbered the same in both CoRE and JMA55.
- But in ERA5, modes 3 and 4 are switched.







Modes

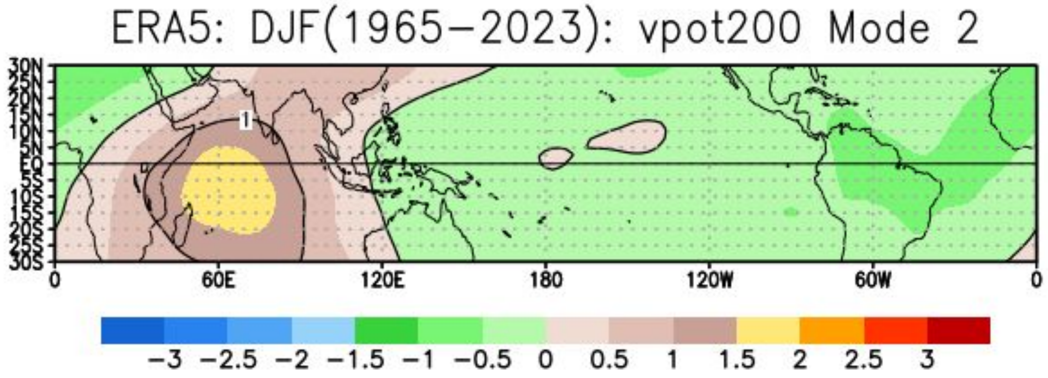
1

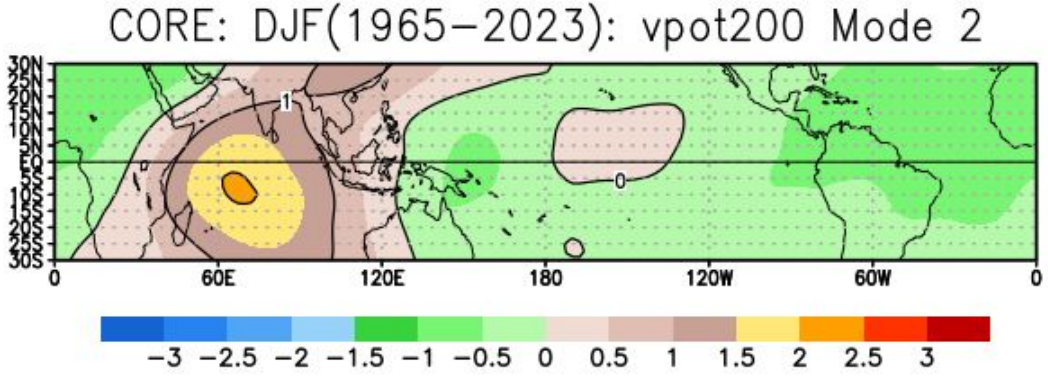
(ENSO)

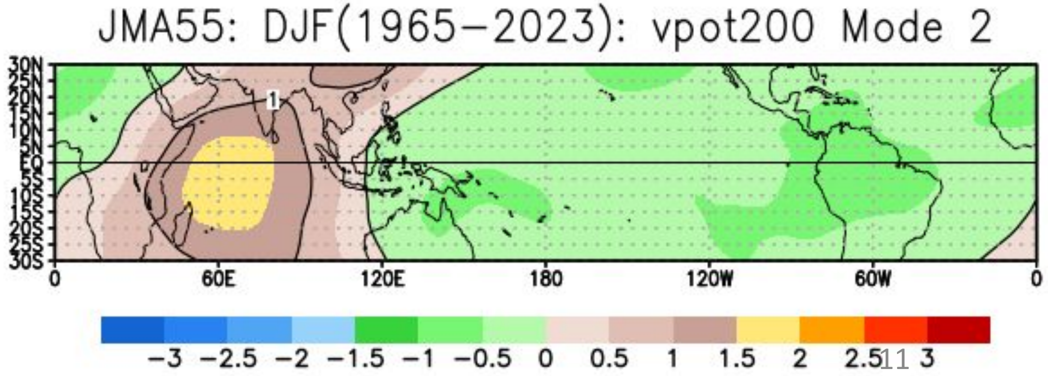
&

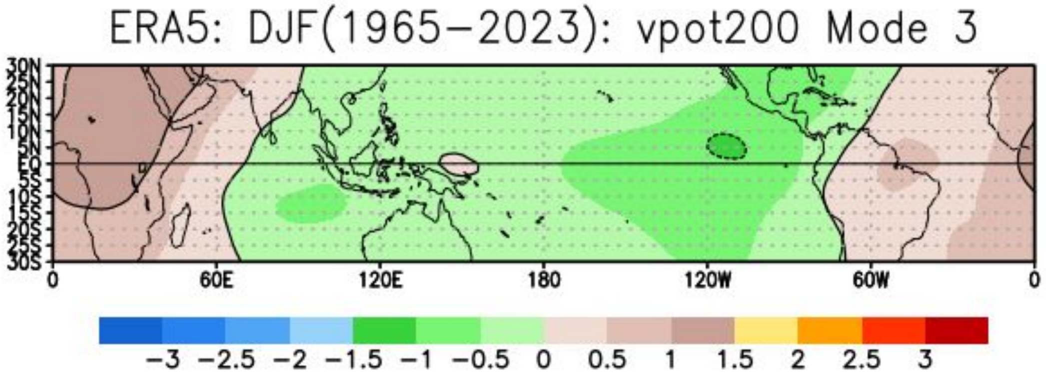
2

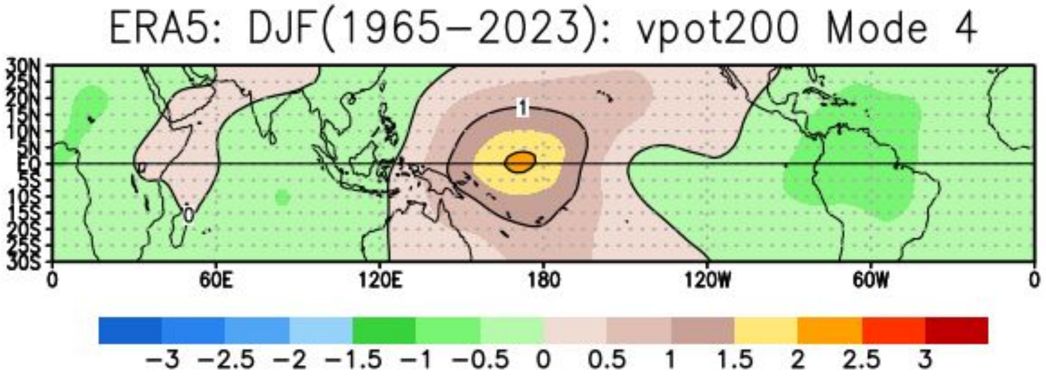
(Indian Ocn!)

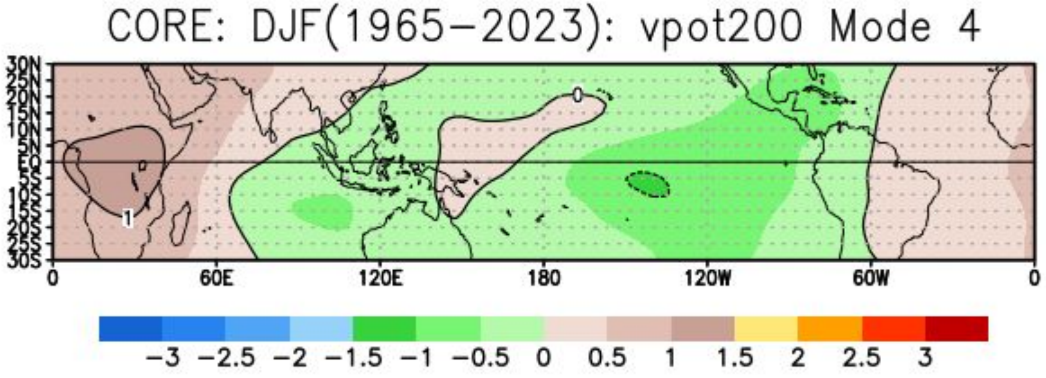


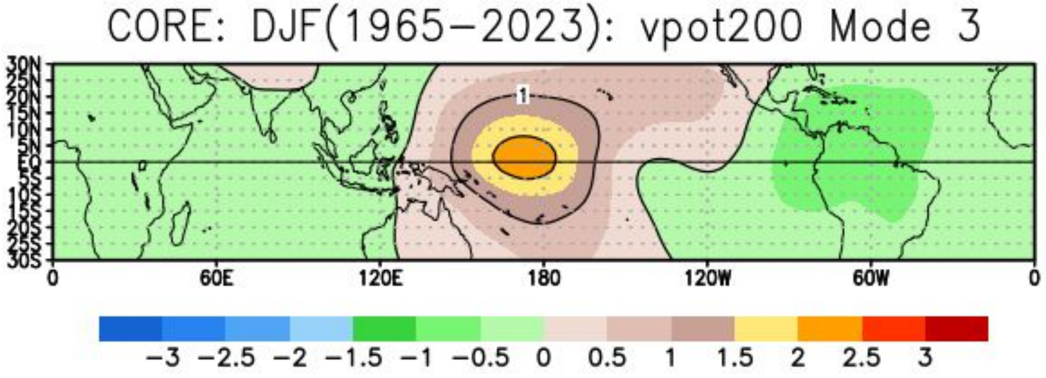


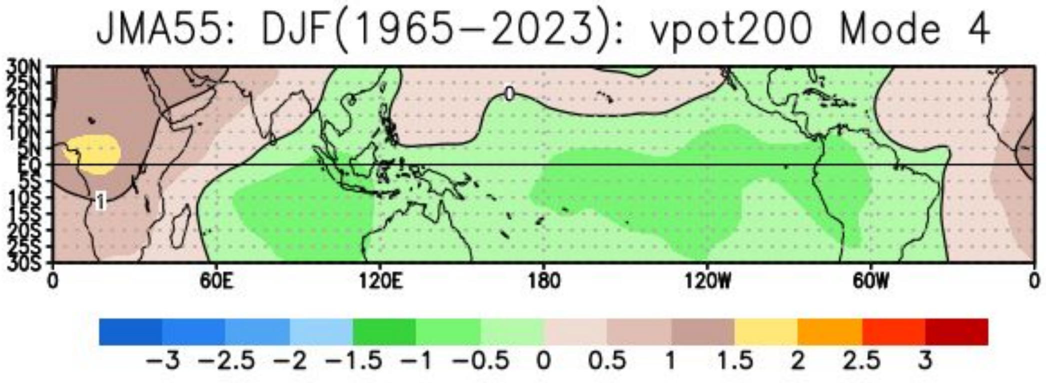


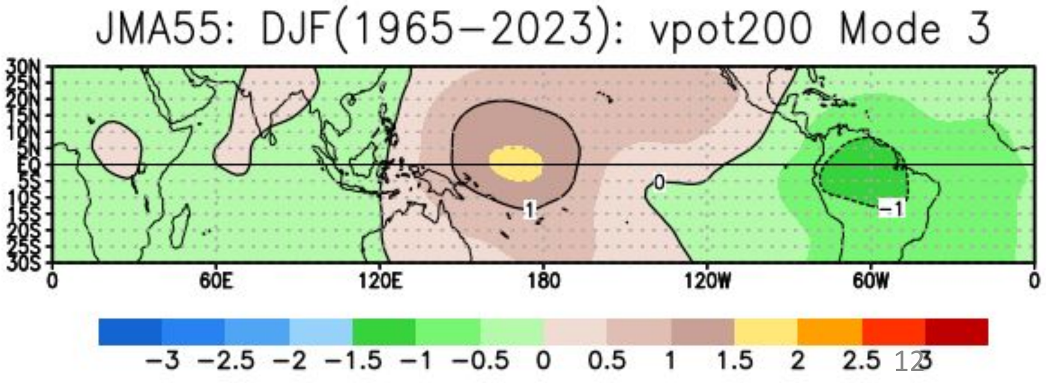












Modes

3

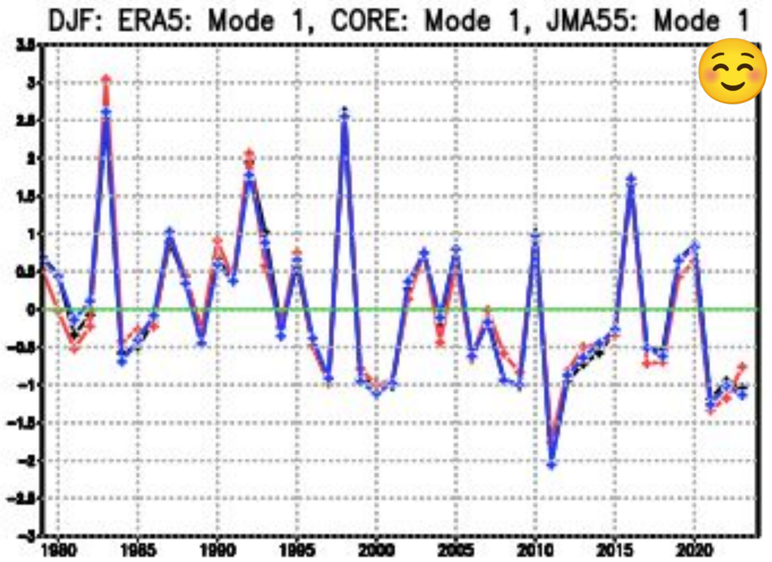
&

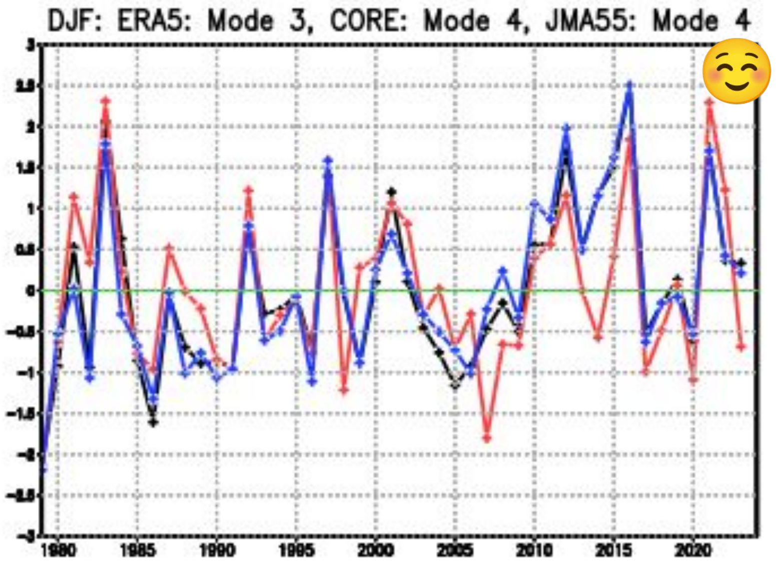
4

(mixed!)

- Now all analyses repeated with more recent period, (1979-2023)when supposedly the data quality is much better! Limiting to DJF season. With/for all 3 major modern reanalyses (ERA,CoRE,JMA55).

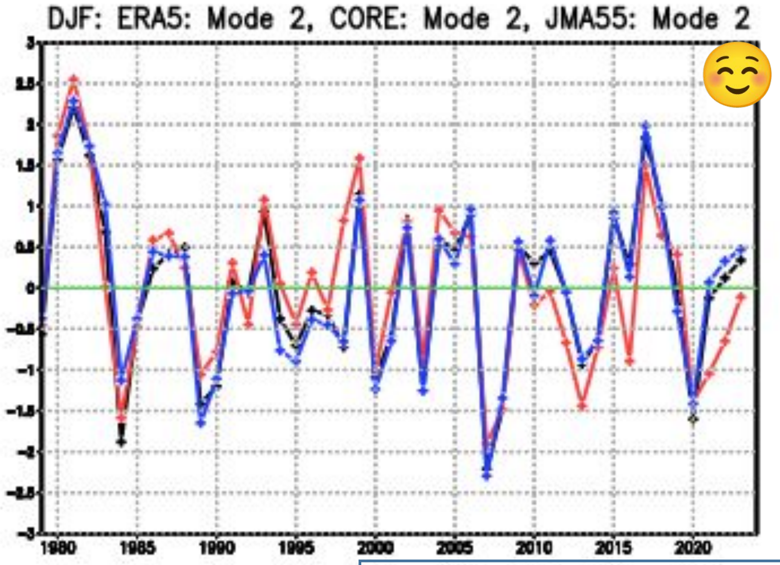
- Earlier we did from 1965- onwards (for all three major modern reanalyses), which sharpened the results
  from even much earlier
  analyses wit h 1951-onwads, the results from which suggested that the later/recent anomalies were contaminated by the earlier low-quality/uncertain reanalyses data.

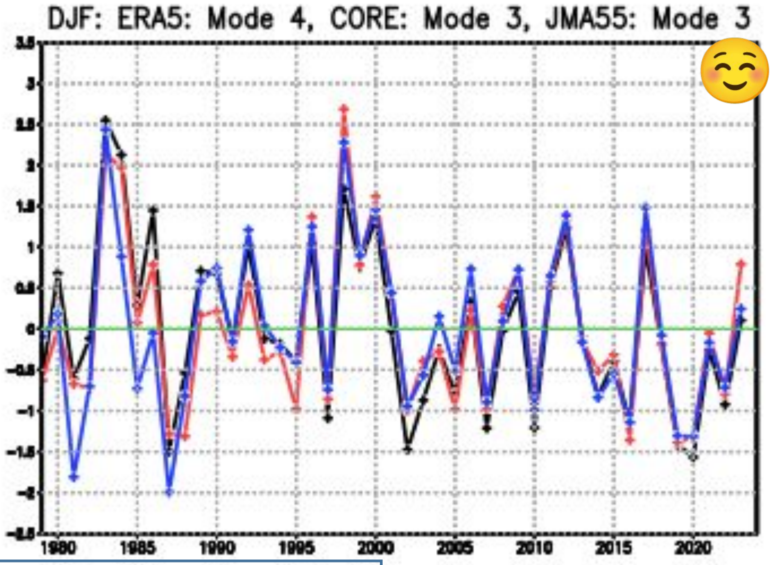




ERA5
CoRE
JMA55

Period: 1979 - 2023 DJF





* slight problem/inconsistency with CoRE in more recent years???, Need to redo this period? Some possible error?, Or it because of only using Conventional data ????

The DJF winter season 200mb VPOT EOF analysis (1979-2023) is characterized by 4 major/leading modes, and these are the time series.

- **With analysis confined to more recent periods, <u>the time series of higher modes seem to agree more and more with each other</u>., as can be seen by the time series.**
- **<u>AMAZING Consistency!</u>**

- **The expl. variances are also interestingly highly similar to each other.**

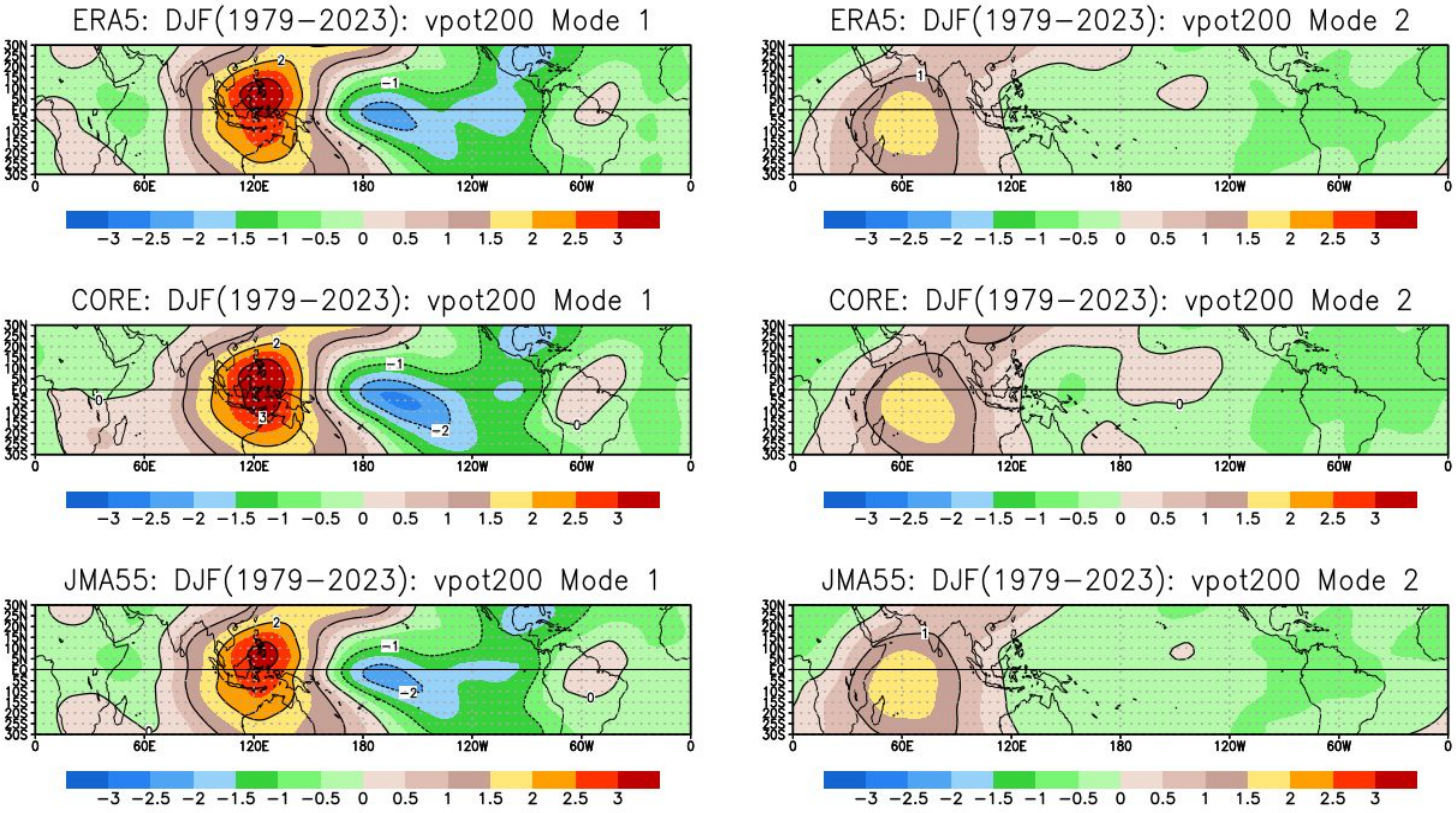
<u>% Exp. Variances of 4 modes & **Total**</u>

ERA5:	48, 13, 11, 10	**~82**
CoRE:	47, 13, 12, 8	**~80**
JMA55:	45, 14, 12, 10	**~81**

-The leading 4 modes of the 3 reanalyses are the same.
-only for ERA5, modes 3 & 4 were switched as compared with CoRE,JMA55.
-The first mode is always ENSO.
-The second mode is always Indian Ocn.

Interestingly, for all three modern reanalyses, the largest and most explained variance related changes is happening in The western Pacific Ocean and Indian Ocean regions!! – Kind of easy to understand why and reconcile.. !!

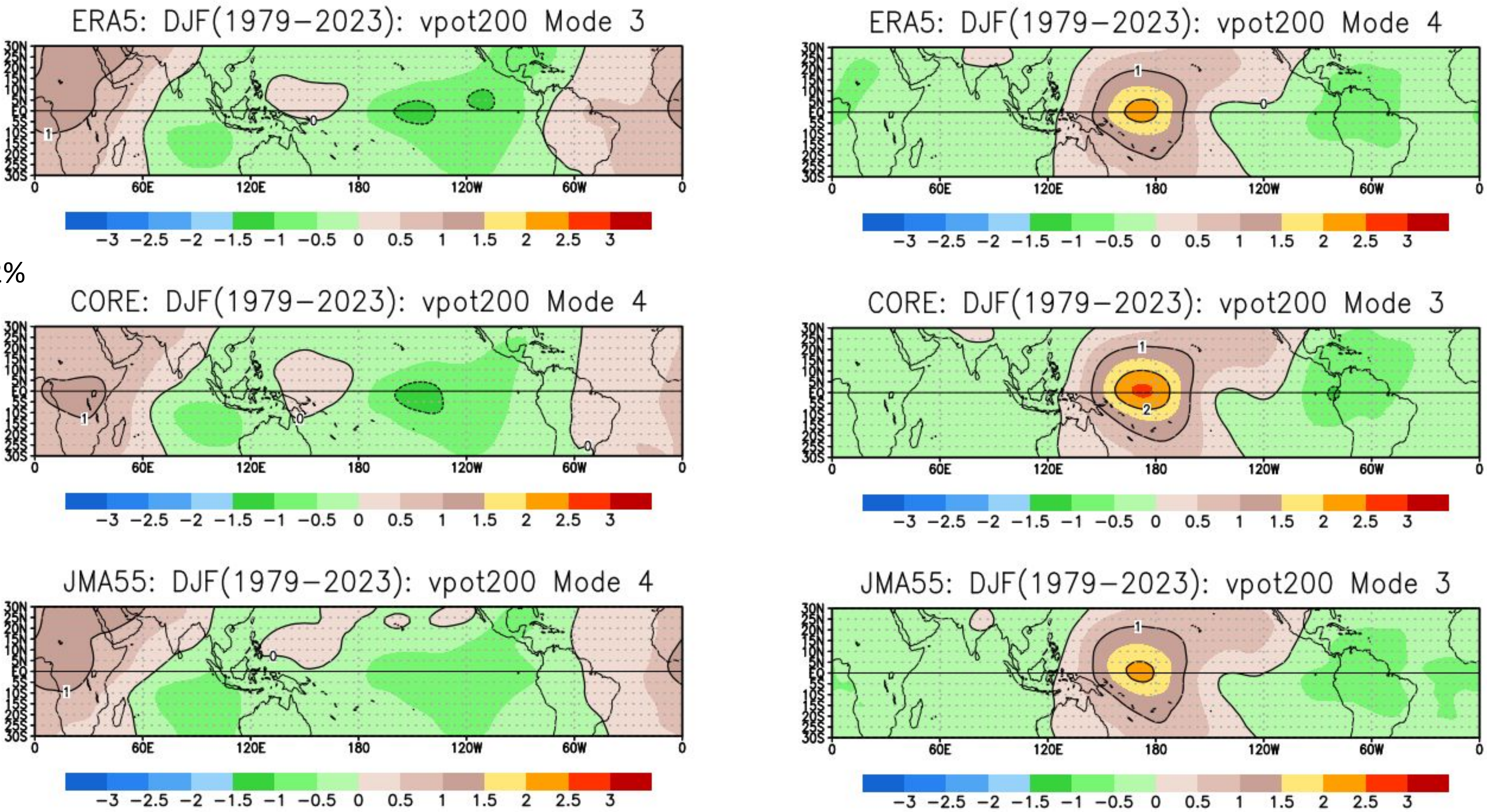
~47%

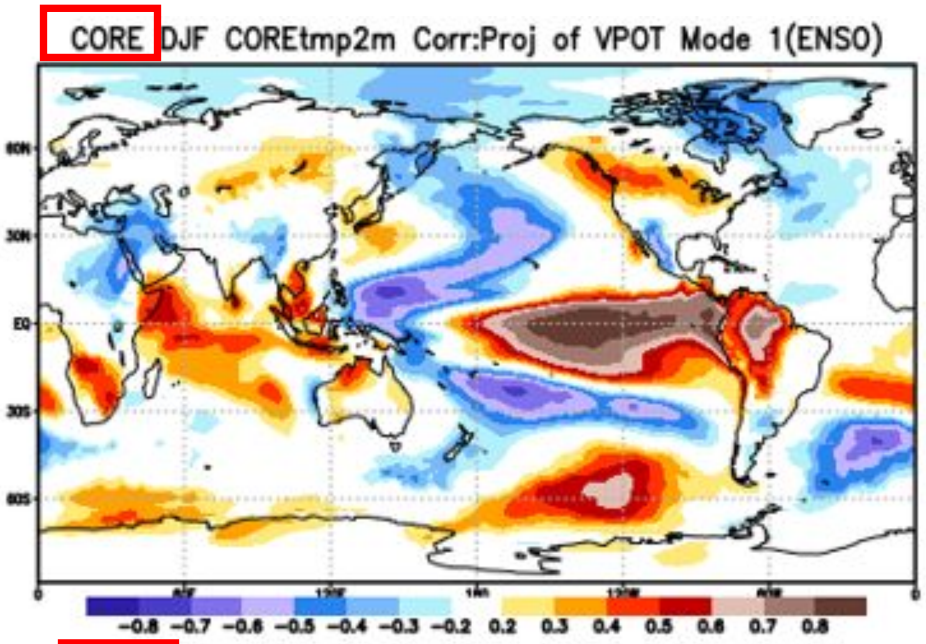


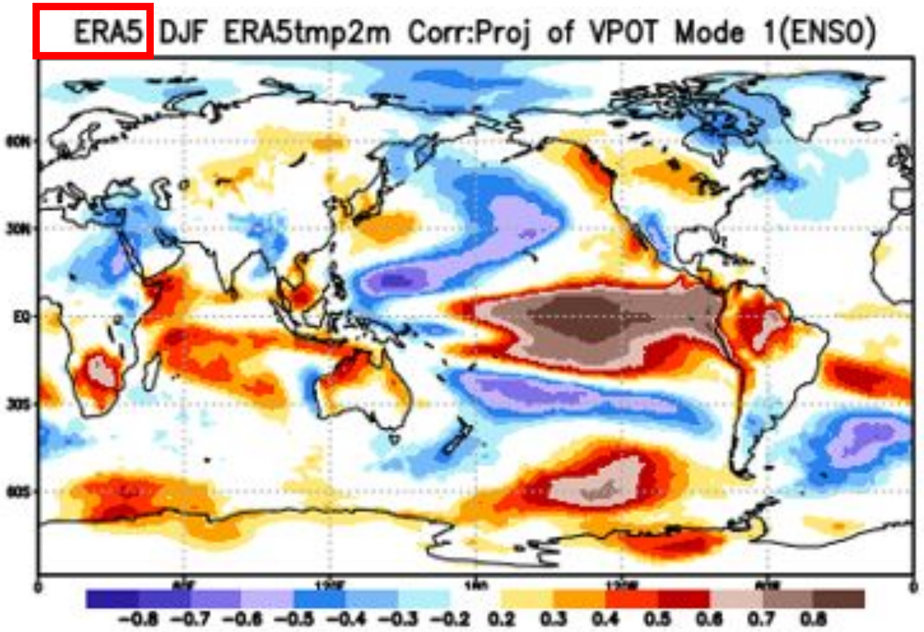
~13%

~12%

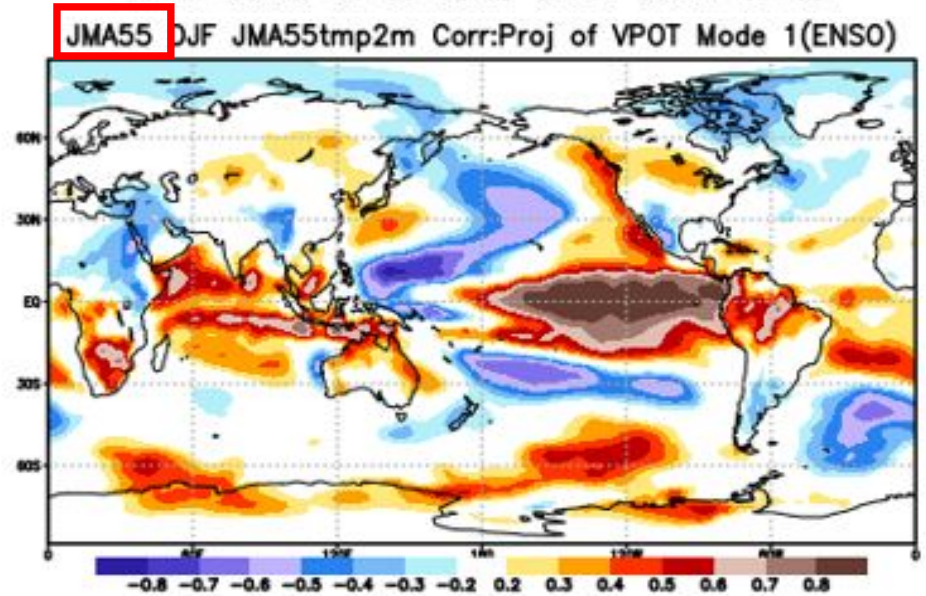
~10%

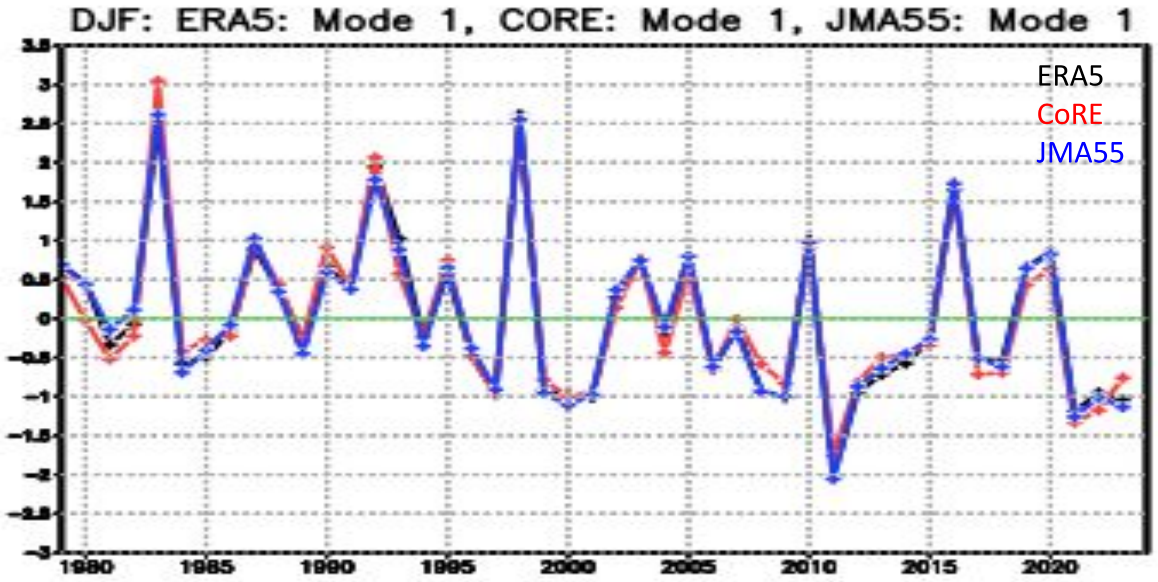

ERA5: DJF(1979–2023): vpot200 Mode 3
ERA5: DJF(1979–2023): vpot200 Mode 4
CORE: DJF(1979–2023): vpot200 Mode 4
CORE: DJF(1979–2023): vpot200 Mode 3
JMA55: DJF(1979–2023): vpot200 Mode 4
JMA55: DJF(1979–2023): vpot200 Mode 3
30N 25N 20N 15N 10N 5N EQ 5S 10S 15S 20S 25S 30S
0 60E 120E 180 120W 60W 0
−3 −2.5 −2 −1.5 −1 −0.5 0 0.5 1 1.5 2 2.5 3

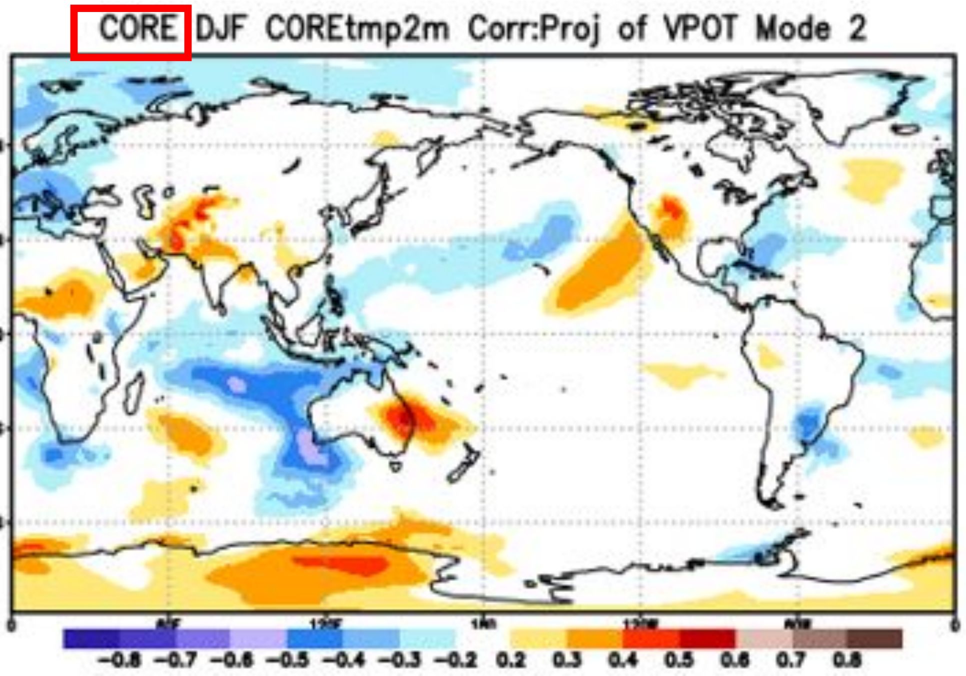


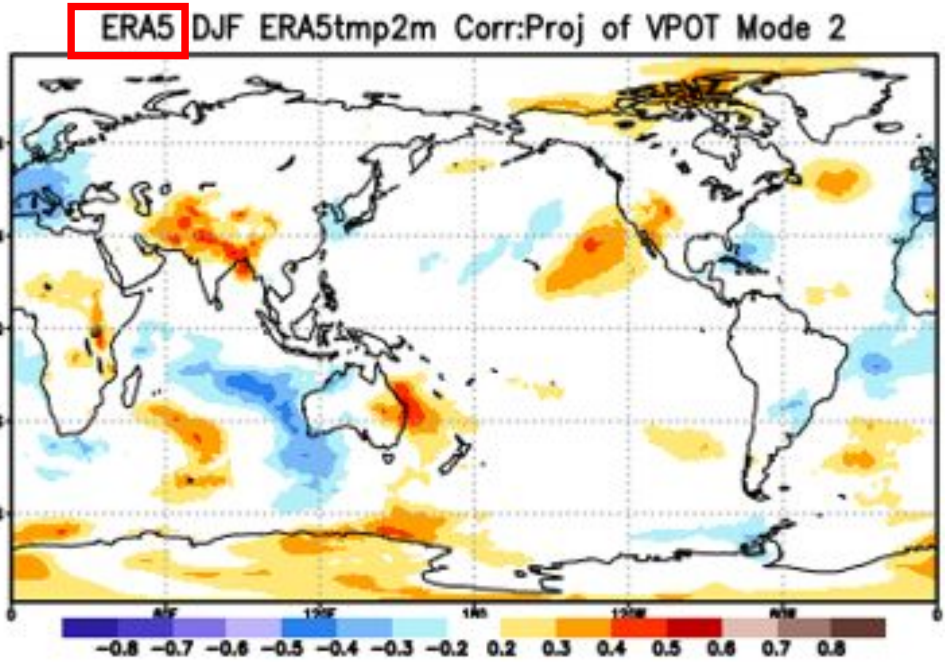


Projection of Mode 1 (ENSO mode) onto **T2m**



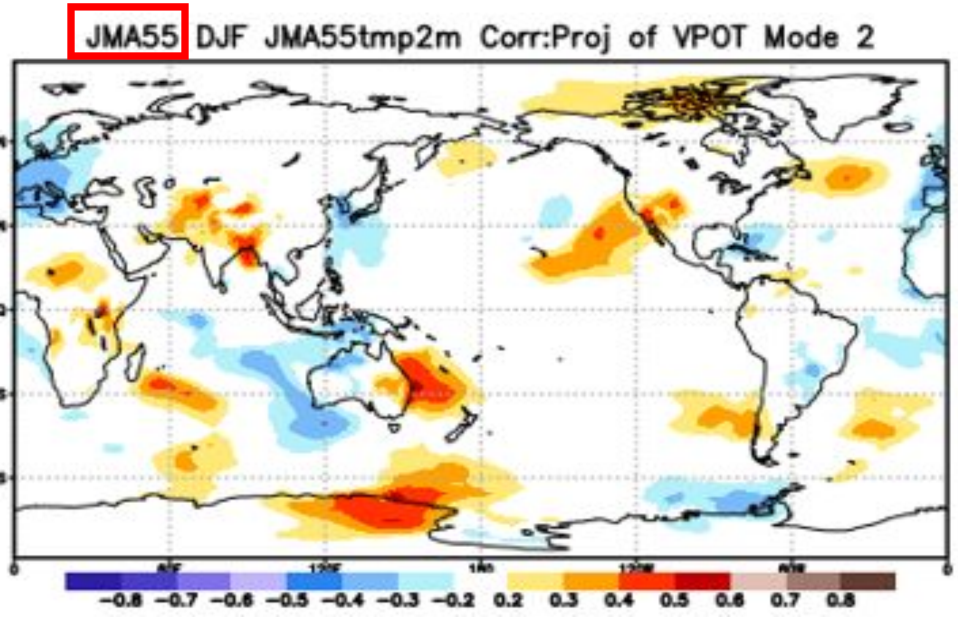


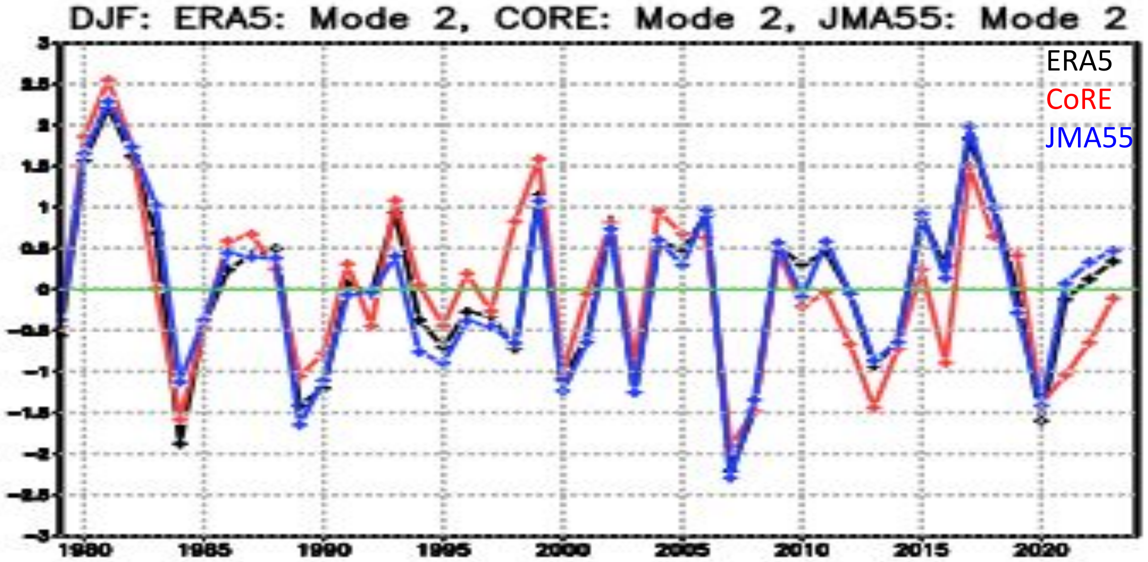


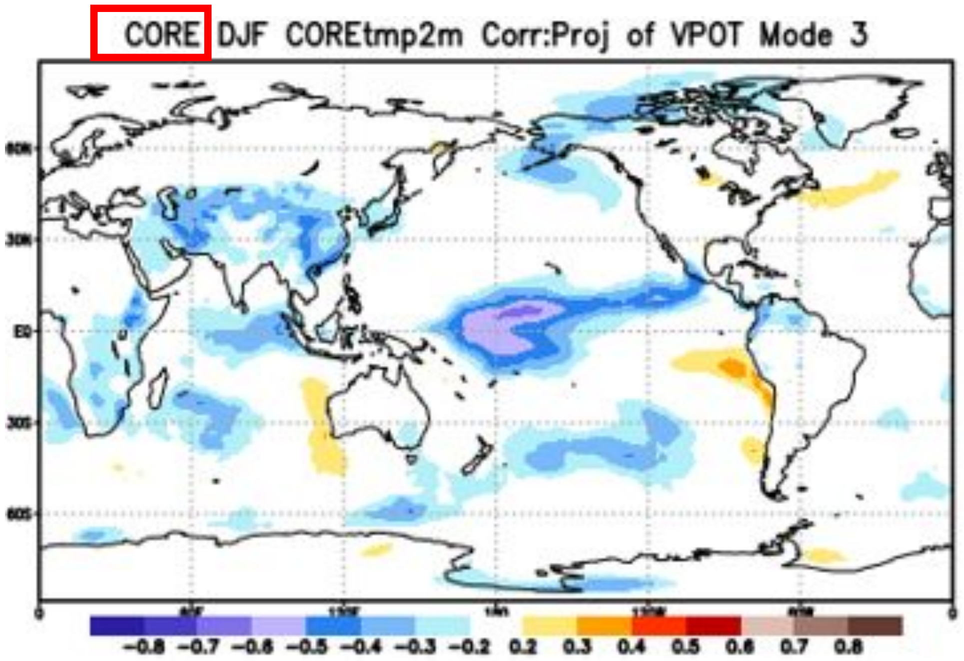


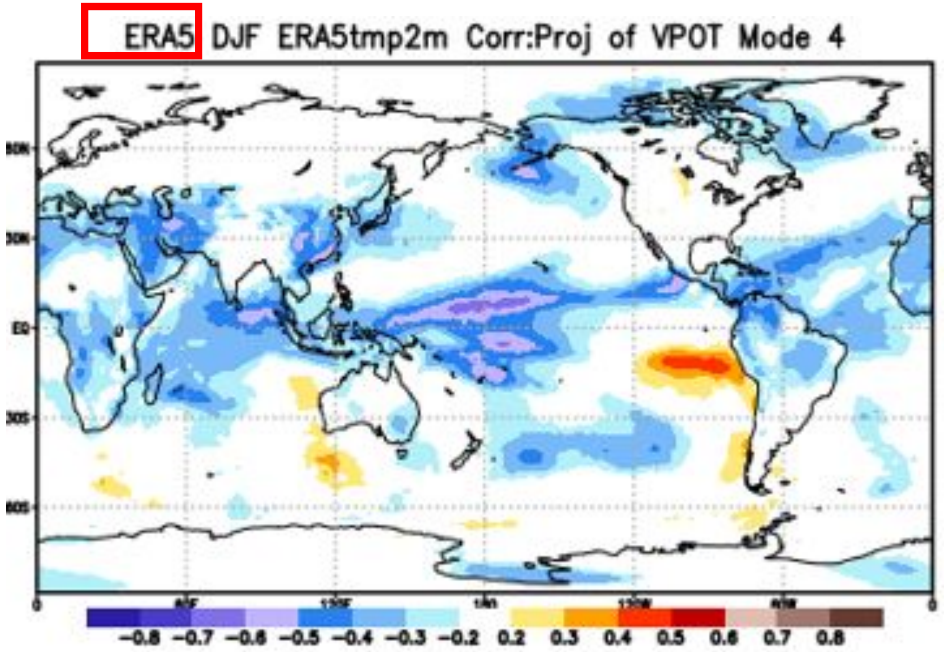
Projection of Mode 2 (non-ENSO, Indian Ocn mode) onto **T2m**

Recall. VPOT loadings earlier!

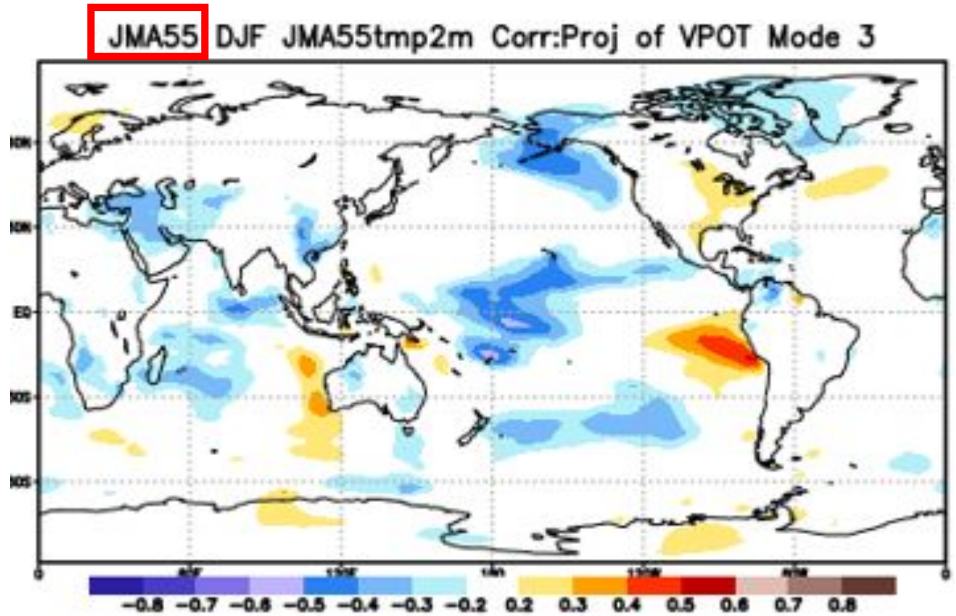


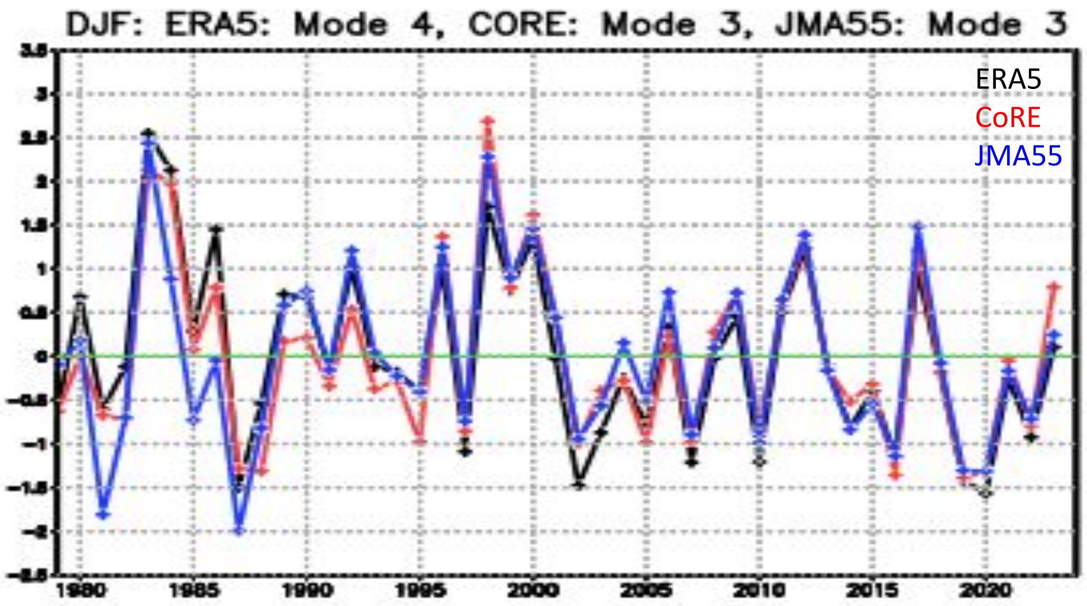


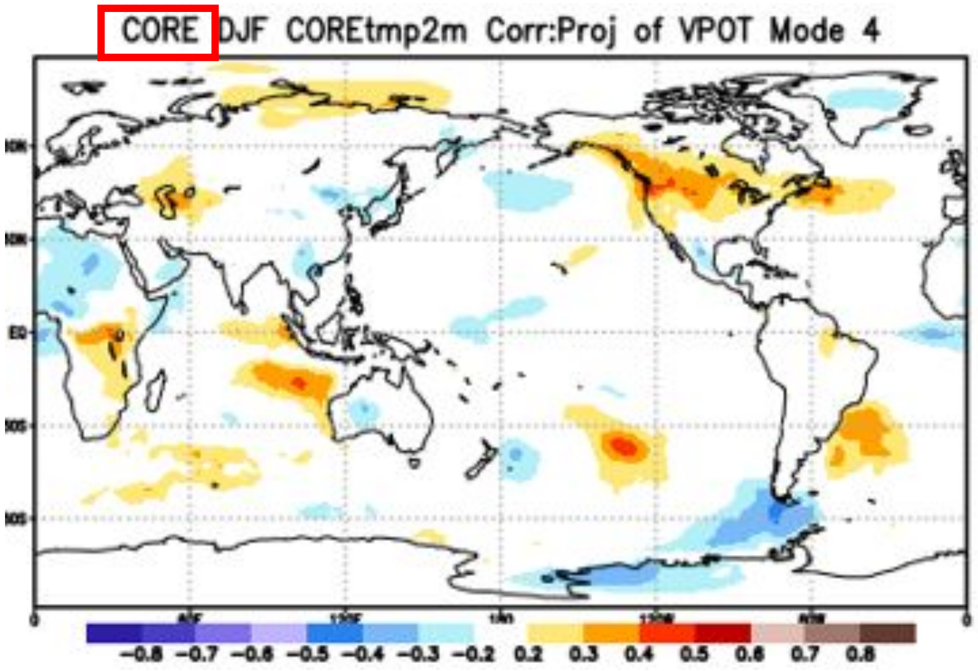


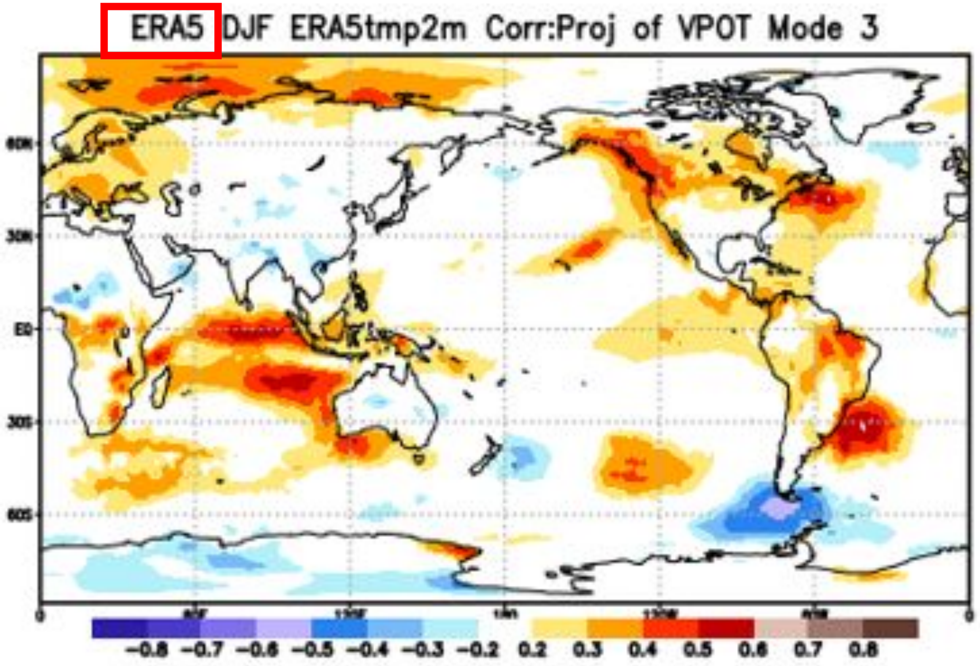


Projection of Mode 3 onto **T2m**

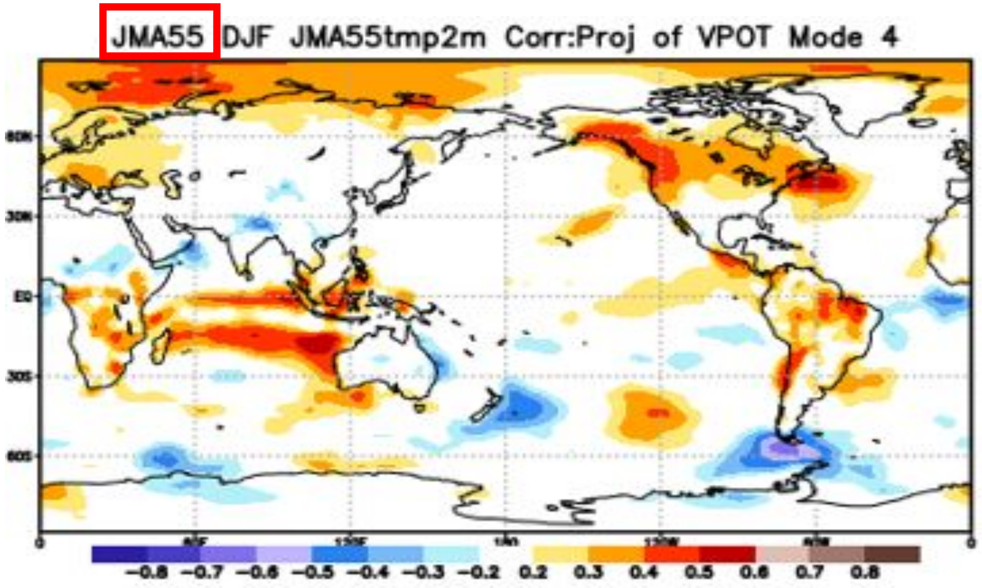


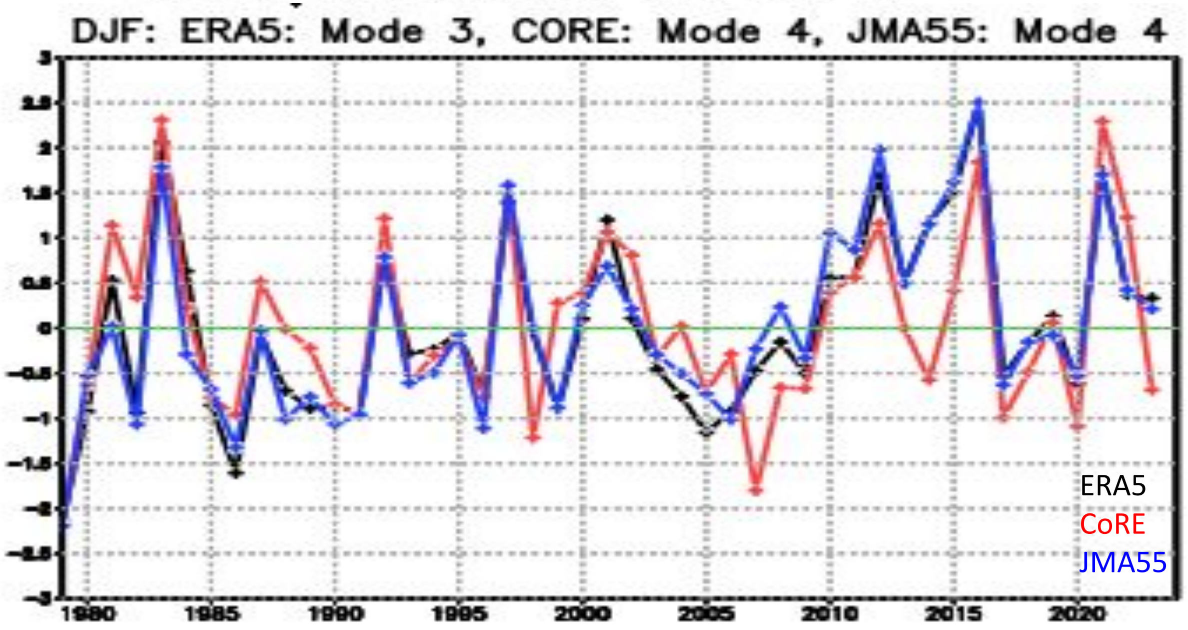


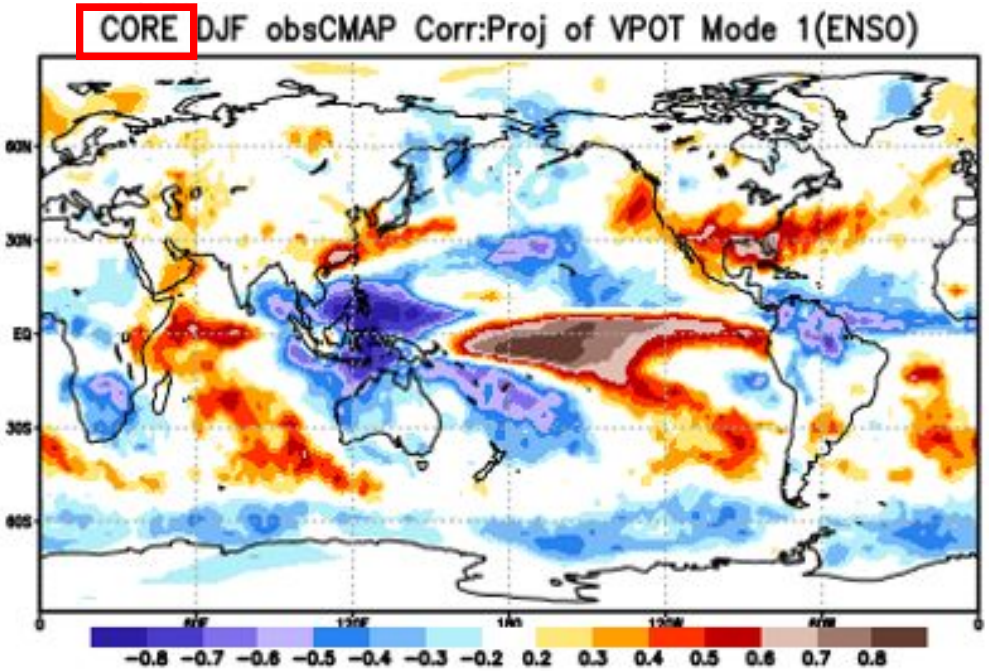


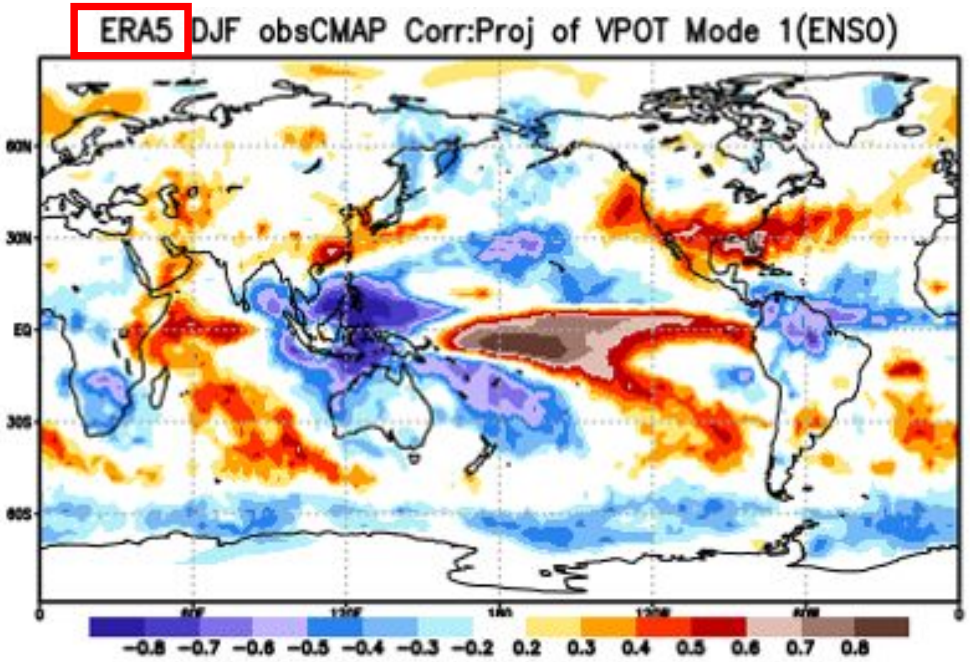


Projection of Mode 4 onto **T2m**

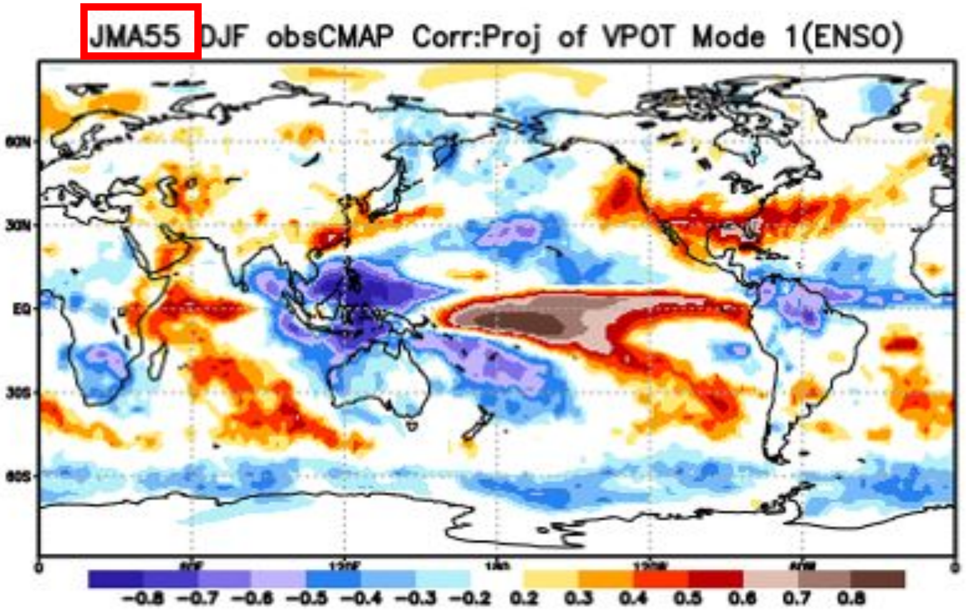


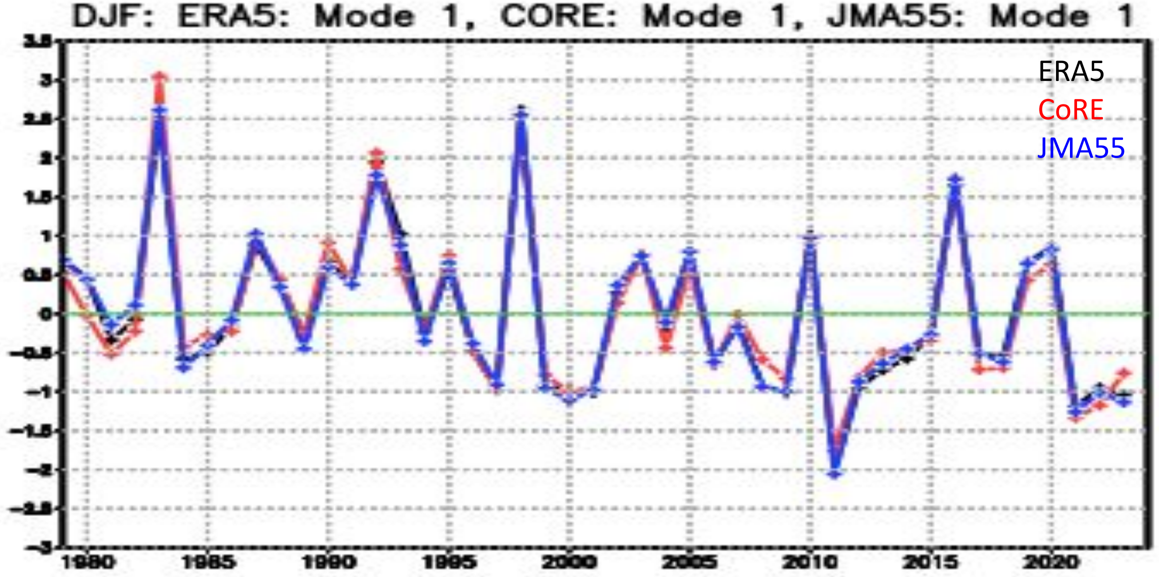


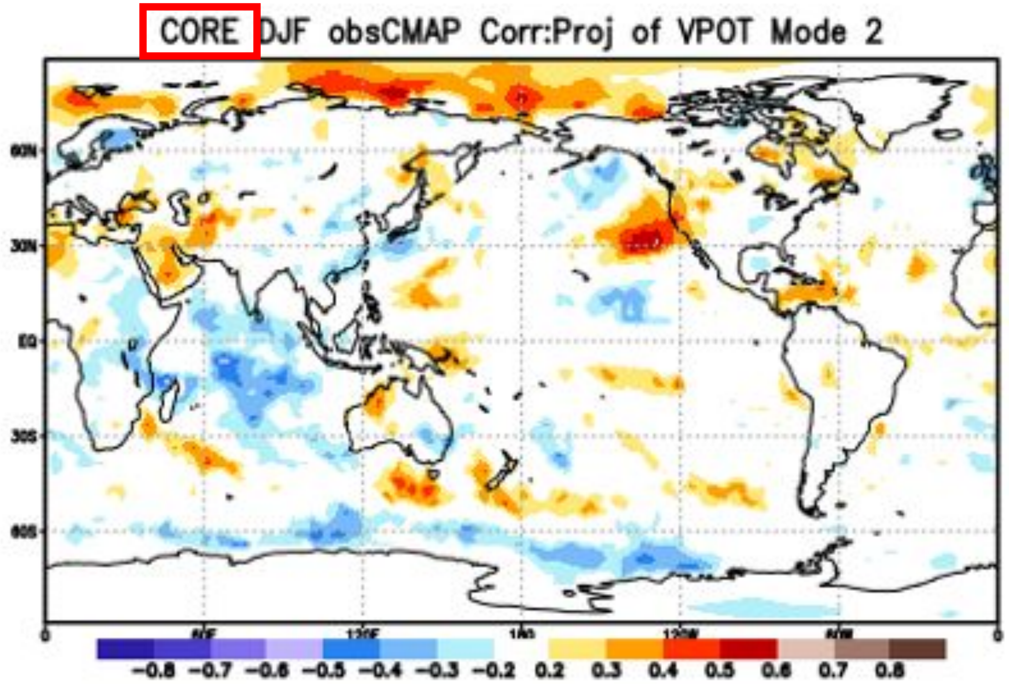


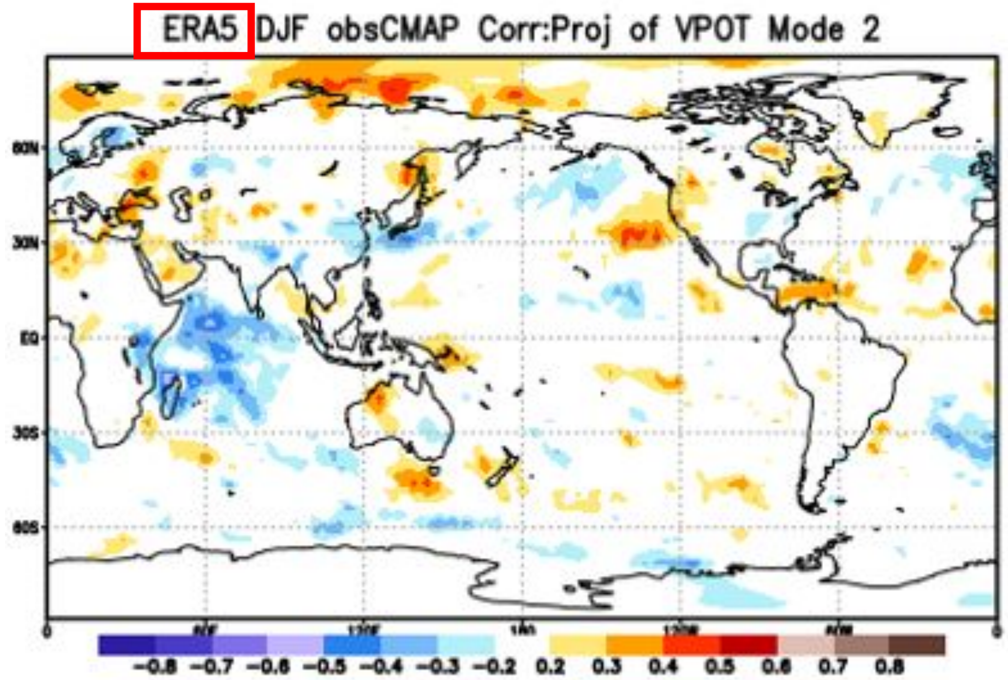


Projection of Mode 1 (ENSO mode) onto **CMAP Precip**

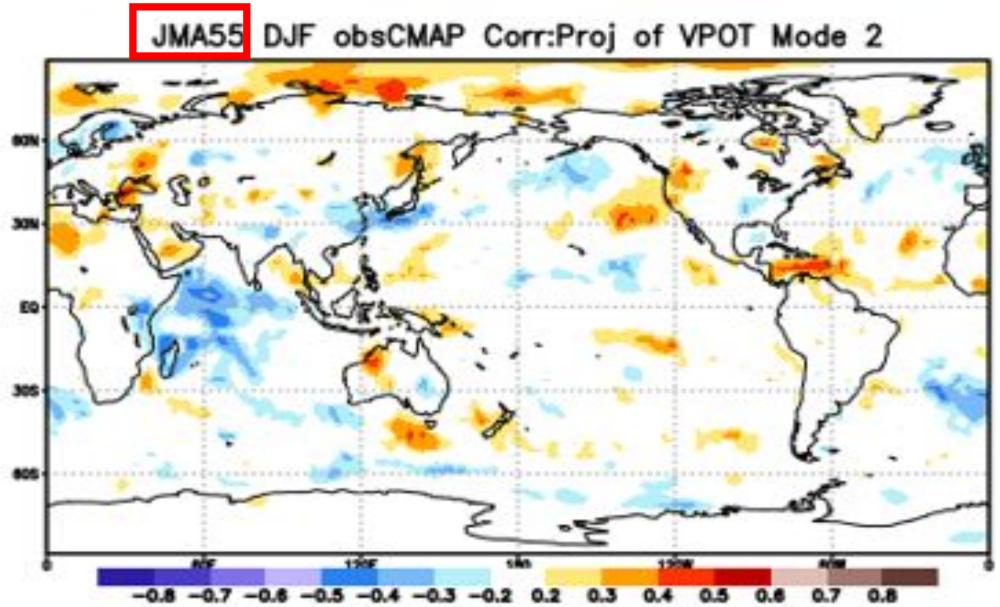


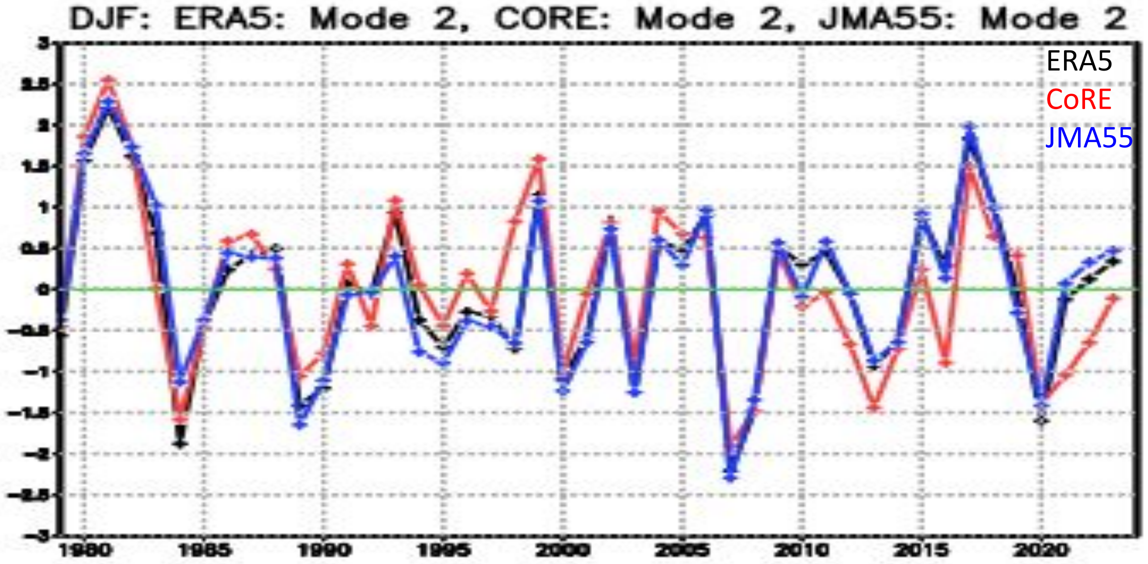


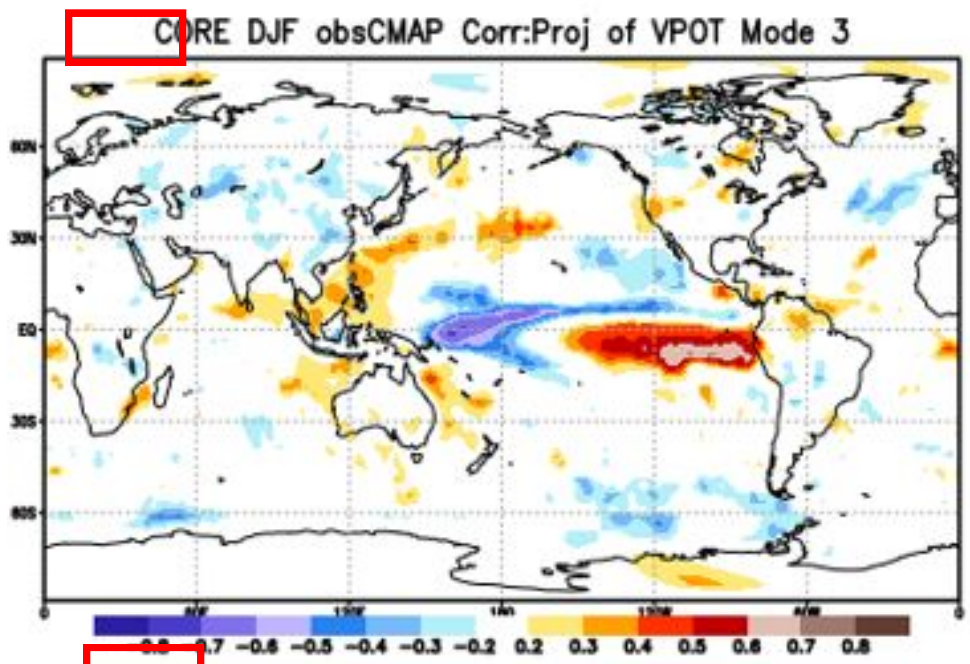


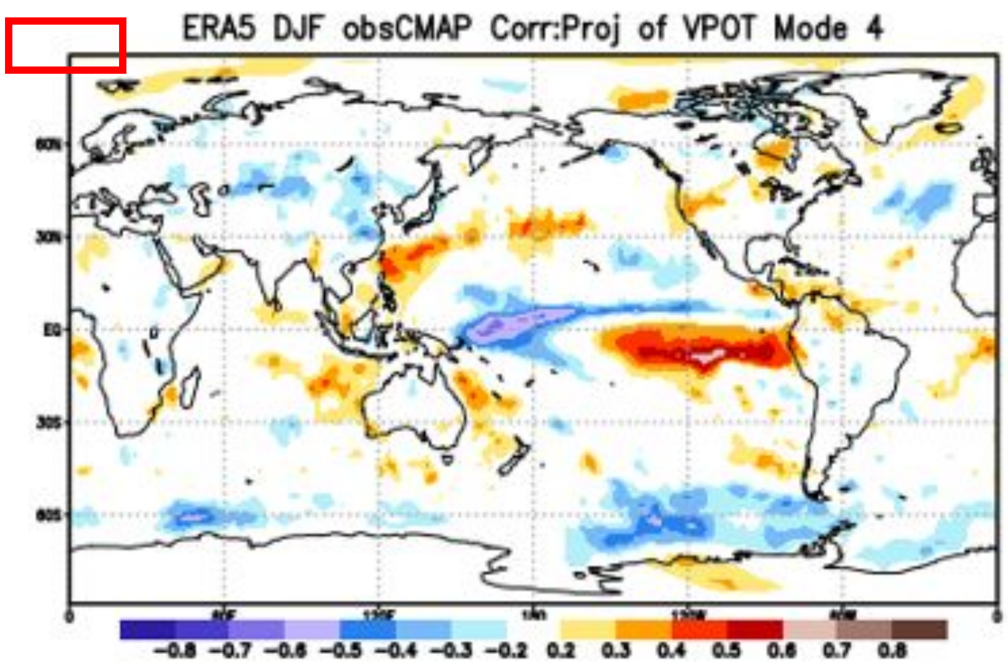


Projection of Mode 2 (Ind. Ocn. Mode) onto **CMAP Precip.**

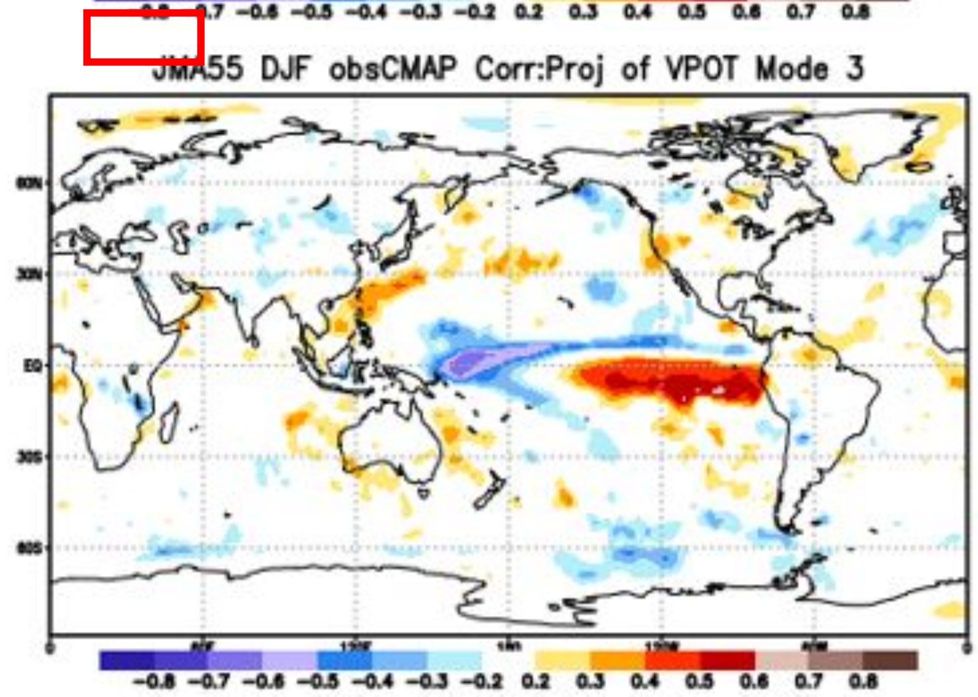


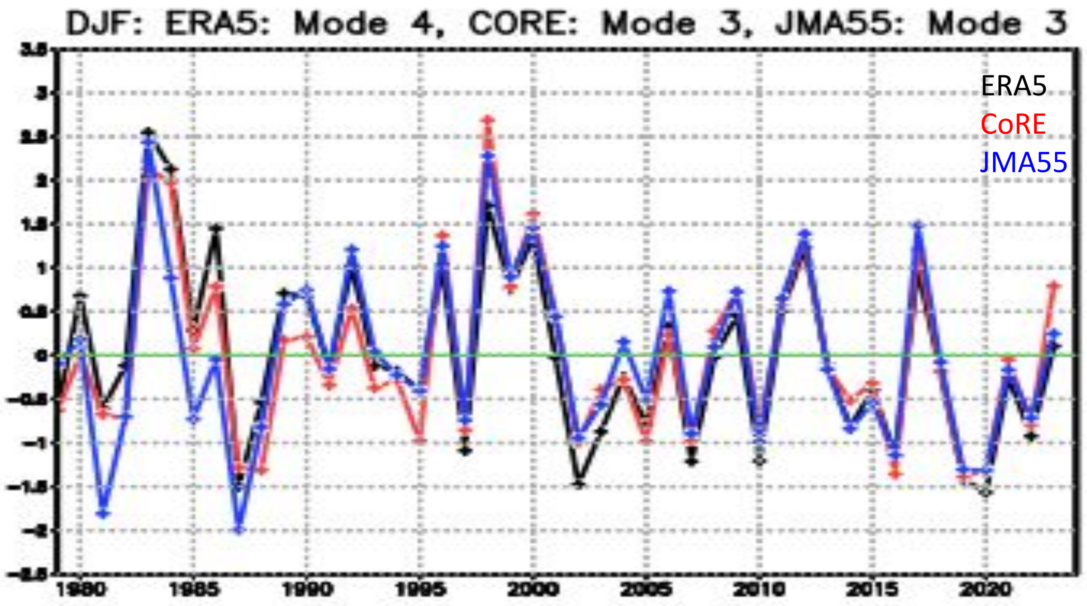


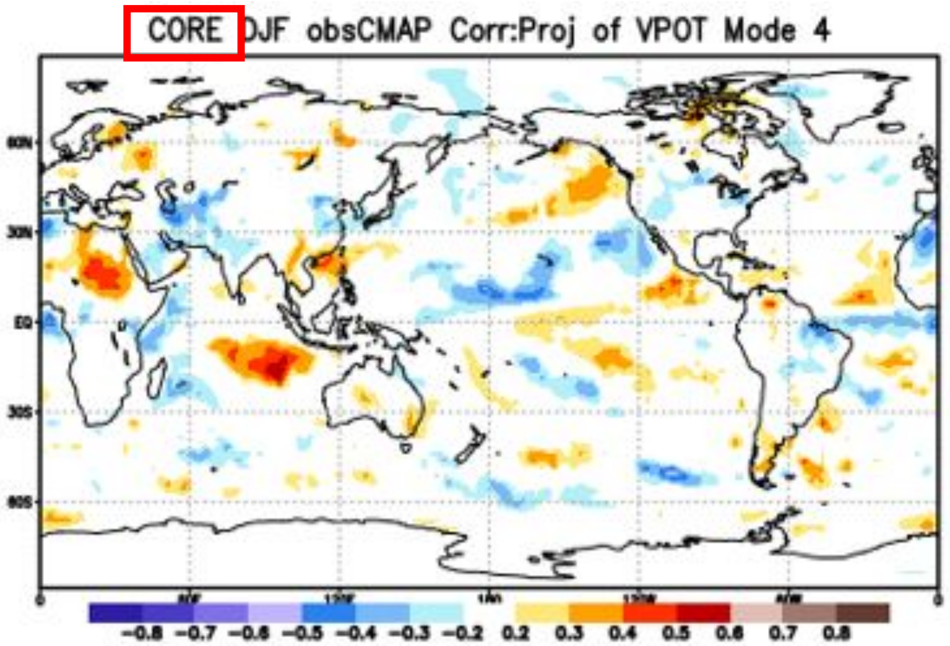


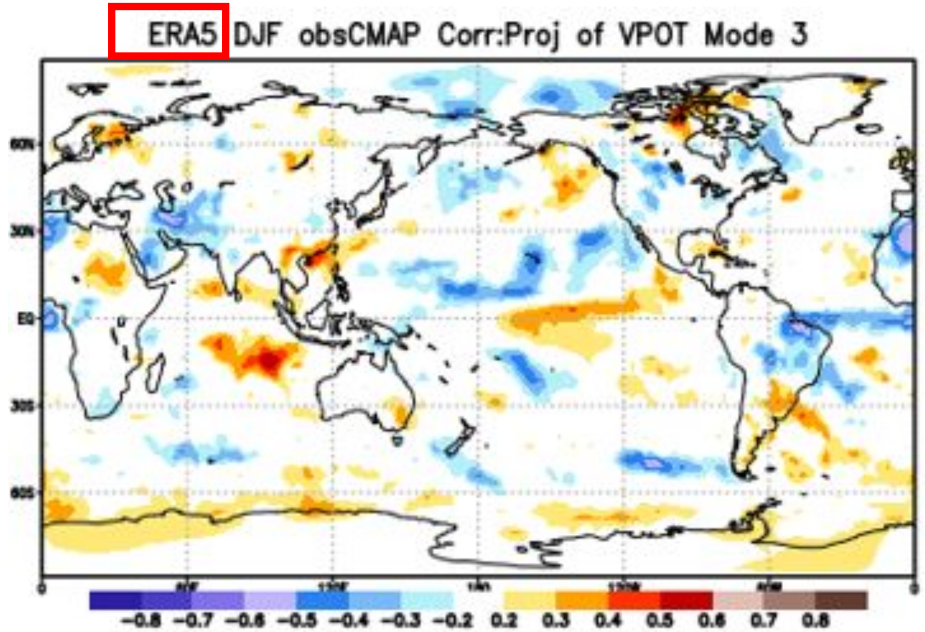


Projection of Mode 4 onto **CMAP Precip.**

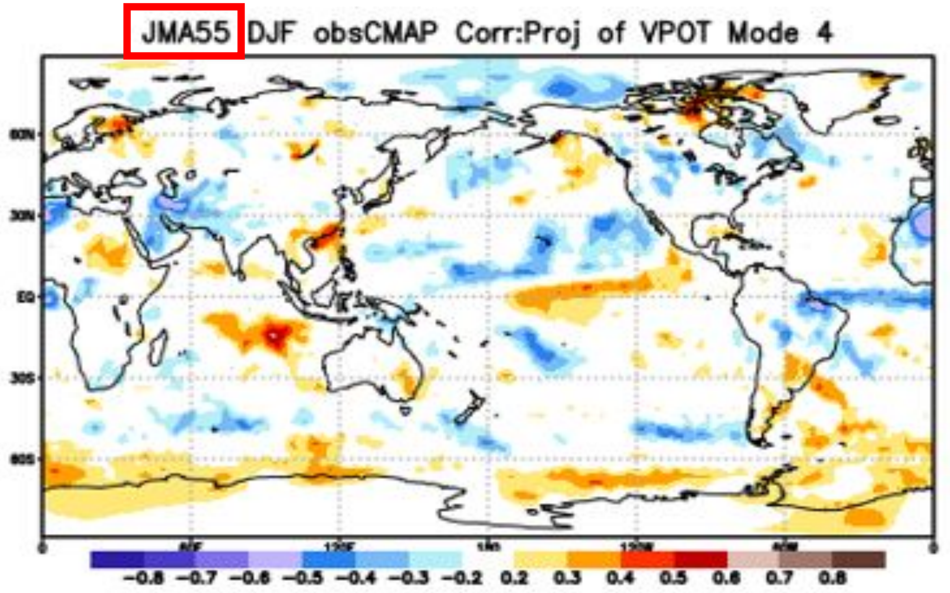


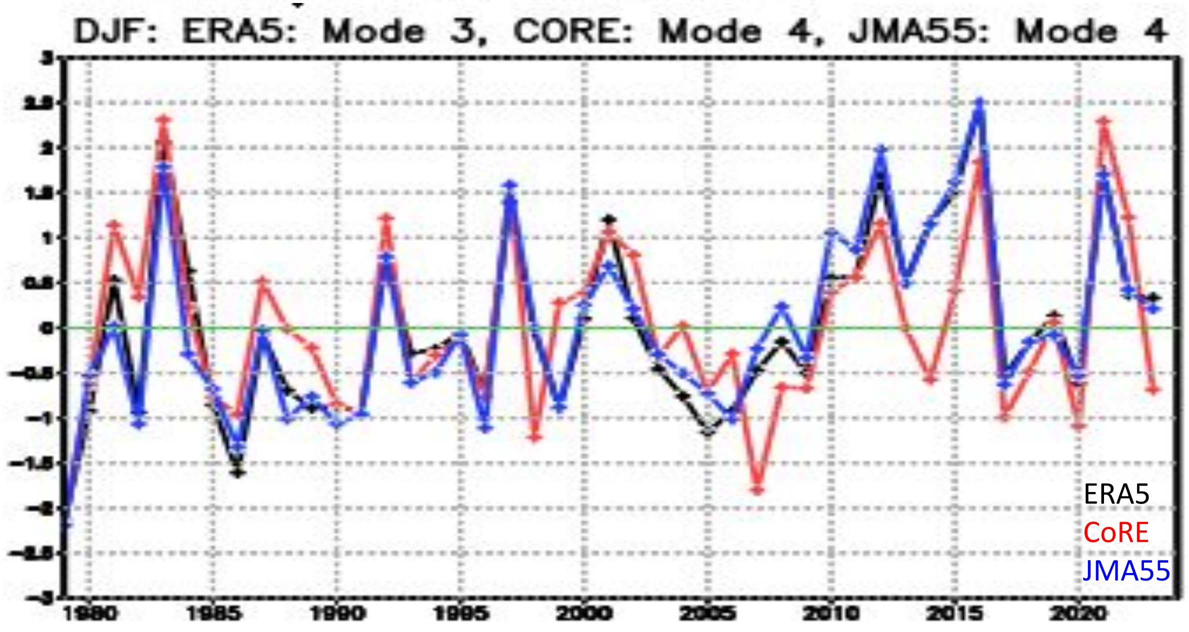






Projection of
Mode 4 (ENSO mode)
onto **CMAP Precip.**





In Summary:

- It's about time to replace the original, one and only, NCEP/NCAR Reanalysis R1 (early 1990's based model and GDAS), for operational global climate monitoring with a modern reanalysis.

- Modern Reanalyses include CoRE(CPC/NCEP), ERA5 (ECMWF), JRA55(JMA), etc. based on new and improved forecast GCM's with sophisticated data assimilation systems, including ensemble data assimilation, which are now almost available for ~ 75 years period and extending in near real time.

- Even a simple comparison of NCEP1 R1 with CoRE, ERA5,and JRA55 in such quantities as equatorial zonal wind indices in the tropical Pacific to monitor ENSO suggests that NCEP R1 is clearly the outlier (hence the 1st point above!)

- In spite of the vast improvements in GCMS's and global data assimilation systems, the three major modern reanalysis data sets still differ even in such basic quantities such as eq. area mean wind indices to monitor ENSO in the early 1950s, 1960's decades. However, the overall agreement and consistency between the modern reanalyses slowly and markedly improved with time in the following decades.

- A low frequency (ENSO and non-ENSO) EOF analysis, including the earlier decades of the wintertime (DJF) 30N-30S 200 mb VPOT anomalies, and its signature/projection on to global surface T & P , showed that the uncertainty and inconsistency of the 'data poor' 1950s and 60s, is corrupting the overall spatial structure and time series of the leading modes even in recent decades.

- The above same analysis with only the recent ~45 years (1979-2023) period revealed amazingly consistent similar behavior in all the leading 4 leading modes (total ~80% EV) in all the 3 modern reanalyses . Besides the leading ENSO mode, the Indian Ocean mode with possible teleconnections to anomalous (not canonical) US west coast rainfall during ENSO winters needs to be further explored.

- In the last 45 years, ERA5 & JRA55 reanalysis agreed more closer with each other than CoRE, possibly due to us of only conv. data. ***

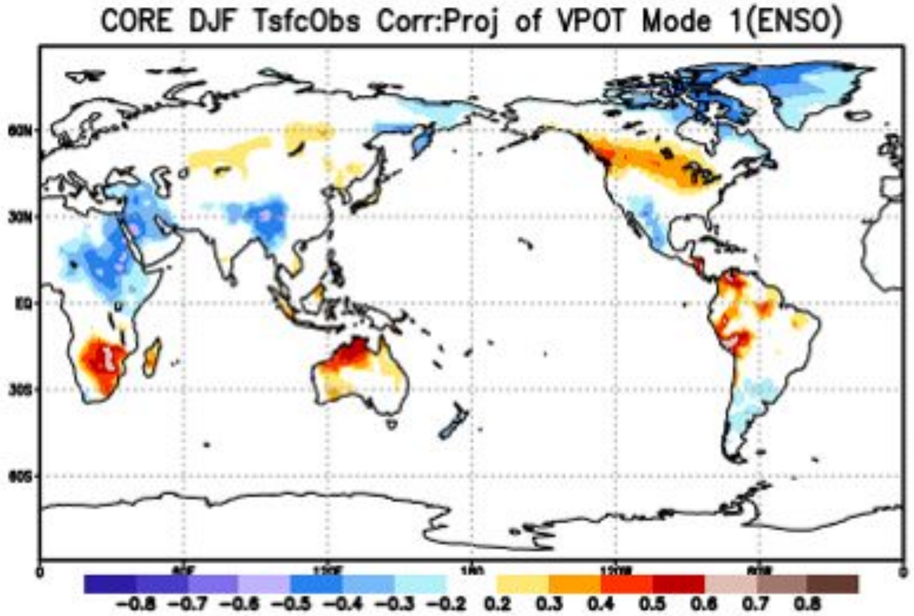
END!

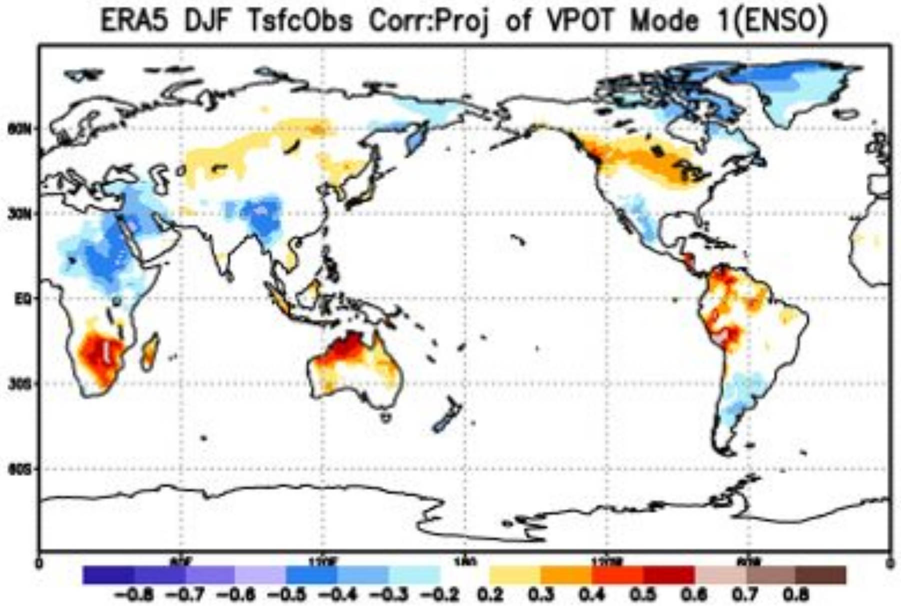
Thanks very much!!

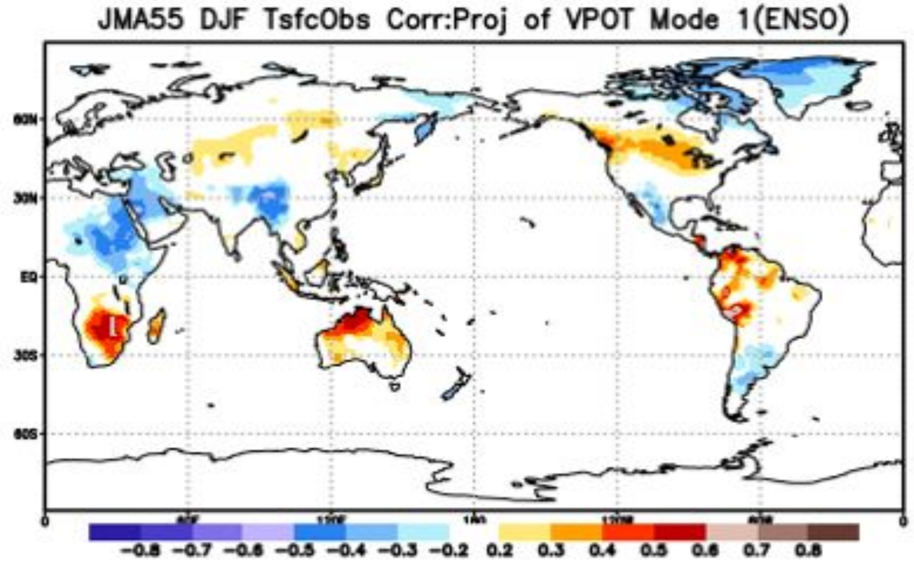
Some additional slides……

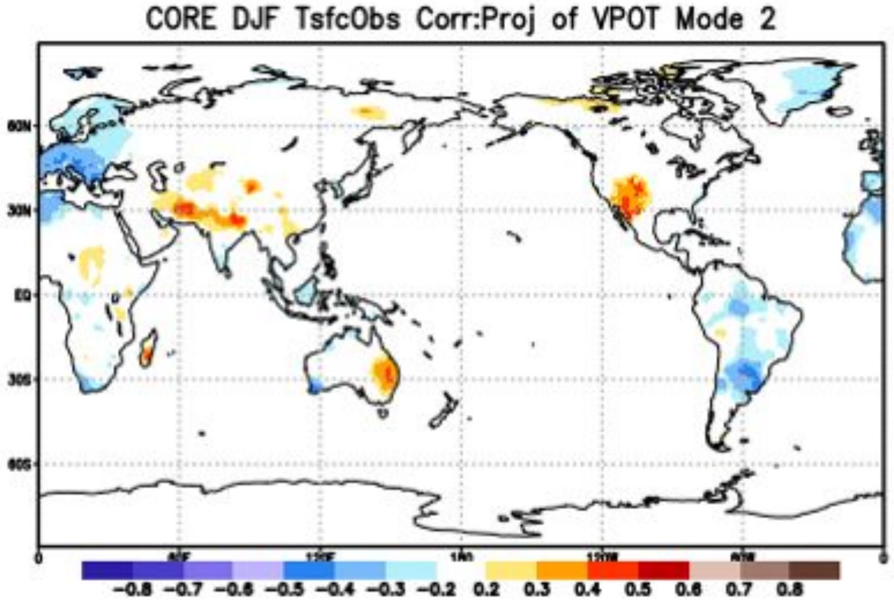
1978	0.7	0.4	0.1	-0.2	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.1	0.0
1979	0.0	0.1	0.2	0.3	0.2	0.0	0.0	0.2	0.3	0.5	0.5	0.6
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1980	0.6	0.5	0.3	0.4	0.5	0.5	0.3	0.0	-0.1	0.0	0.1	0.0
1981	-0.3	-0.5	-0.5	-0.4	-0.3	-0.3	-0.3	-0.2	-0.2	-0.1	-0.2	-0.1
1982	0.0	0.1	0.2	0.5	0.7	0.7	0.8	1.1	1.6	2.0	2.2	2.2
1983	2.2	1.9	1.5	1.3	1.1	0.7	0.3	-0.1	-0.5	-0.8	-1.0	-0.9
1984	-0.6	-0.4	-0.3	-0.4	-0.5	-0.4	-0.3	-0.2	-0.2	-0.6	-0.9	-1.1
1985	-1.0	-0.8	-0.8	-0.8	-0.8	-0.6	-0.5	-0.5	-0.4	-0.3	-0.3	-0.4
1986	-0.5	-0.5	-0.3	-0.2	-0.1	0.0	0.2	0.4	0.7	0.9	1.1	1.2
1987	1.2	1.2	1.1	0.9	1.0	1.2	1.5	1.7	1.6	1.5	1.3	1.1
1988	0.8	0.5	0.1	-0.3	-0.9	-1.3	-1.3	-1.1	-1.2	-1.5	-1.8	-1.8
1989	-1.7	-1.4	-1.1	-0.8	-0.6	-0.4	-0.3	-0.3	-0.2	-0.2	-0.2	-0.1
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1990	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.4	0.4
1991	0.4	0.3	0.2	0.3	0.5	0.6	0.7	0.6	0.6	0.8	1.2	1.5
1992	1.7	1.6	1.5	1.3	1.1	0.7	0.4	0.1	-0.1	-0.2	-0.3	-0.1
1993	0.1	0.3	0.5	0.7	0.7	0.6	0.3	0.3	0.2	0.1	0.0	0.1
1994	0.1	0.1	0.2	0.3	0.4	0.4	0.4	0.4	0.6	0.7	1.0	1.1
1995	1.0	0.7	0.5	0.3	0.1	0.0	-0.2	-0.5	-0.8	-1.0	-1.0	-1.0
1996	-0.9	-0.8	-0.6	-0.4	-0.3	-0.3	-0.3	-0.3	-0.4	-0.4	-0.4	-0.5
1997	-0.5	-0.4	-0.1	0.3	0.8	1.2	1.6	1.9	2.1	2.3	2.4	2.4
1998	2.2	1.9	1.4	1.0	0.5	-0.1	-0.8	-1.1	-1.3	-1.4	-1.5	-1.6
1999	-1.5	-1.3	-1.1	-1.0	-1.0	-1.0	-1.1	-1.1	-1.2	-1.3	-1.5	-1.7
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2000	-1.7	-1.4	-1.1	-0.8	-0.7	-0.6	-0.6	-0.5	-0.5	-0.6	-0.7	-0.7

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2000	-1.7	-1.4	-1.1	-0.8	-0.7	-0.6	-0.6	-0.5	-0.5	-0.6	-0.7	-0.7
2001	-0.7	-0.5	-0.4	-0.3	-0.3	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.3
2002	-0.1	0.0	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	-0.3	-0.2	0.1	0.2	0.3	0.3	0.4	0.4
2004	0.4	0.3	0.2	0.2	0.2	0.3	0.5	0.6	0.7	0.7	0.7	0.7
2005	0.6	0.6	0.4	0.4	0.3	0.1	-0.1	-0.1	-0.1	-0.3	-0.6	-0.8
2006	-0.9	-0.8	-0.6	-0.4	-0.1	0.0	0.1	0.3	0.5	0.8	0.9	0.9
2007	0.7	0.2	-0.1	-0.3	-0.4	-0.5	-0.6	-0.8	-1.1	-1.3	-1.5	-1.6
2008	-1.6	-1.5	-1.3	-1.0	-0.8	-0.6	-0.4	-0.2	-0.2	-0.4	-0.6	-0.7
2009	-0.8	-0.8	-0.6	-0.3	0.0	0.3	0.5	0.6	0.7	1.0	1.4	1.6
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2010	1.5	1.2	0.8	0.4	-0.2	-0.7	-1.0	-1.3	-1.6	-1.6	-1.6	-1.6
2011	-1.4	-1.2	-0.9	-0.7	-0.6	-0.4	-0.5	-0.6	-0.8	-1.0	-1.1	-1.0
2012	-0.9	-0.7	-0.6	-0.5	-0.3	0.0	0.2	0.4	0.4	0.3	0.1	-0.2
2013	-0.4	-0.4	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.3	-0.2	-0.2	-0.3
2014	-0.4	-0.5	-0.3	0.0	0.2	0.2	0.0	0.1	0.2	0.5	0.6	0.7
2015	0.5	0.5	0.5	0.7	0.9	1.2	1.5	1.9	2.2	2.4	2.6	2.6
2016	2.5	2.1	1.6	0.9	0.4	-0.1	-0.4	-0.5	-0.6	-0.7	-0.7	-0.6
2017	-0.3	-0.2	0.1	0.2	0.3	0.3	0.1	-0.1	-0.4	-0.7	-0.8	-1.0
2018	-0.9	-0.9	-0.7	-0.5	-0.2	0.0	0.1	0.2	0.5	0.8	0.9	0.8
2019	0.7	0.7	0.7	0.7	0.5	0.5	0.3	0.1	0.2	0.3	0.5	0.5
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2020	0.5	0.5	0.4	0.2	-0.1	-0.3	-0.4	-0.6	-0.9	-1.2	-1.3	-1.2
2021	-1.0	-0.9	-0.8	-0.7	-0.5	-0.4	-0.4	-0.5	-0.7	-0.8	-1.0	-1.0
2022	-1.0	-0.9	-1.0	-1.1	-1.0	-0.9	-0.8	-0.9	-1.0	-1.0	-0.9	-0.8
2023	-0.7	-0.4	-0.1	0.2	0.5	0.8	1.1	1.3	1.6	1.8	1.9	2.0
2024	1.8											


CORE DJF TsfcObs Corr:Proj of VPOT Mode 1(ENSO)
-0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 0.2 0.3 0.4 0.5 0.6 0.7 0.8


ERA5 DJF TsfcObs Corr:Proj of VPOT Mode 1(ENSO)
-0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 0.2 0.3 0.4 0.5 0.6 0.7 0.8


JMA55 DJF TsfcObs Corr:Proj of VPOT Mode 1(ENSO)
-0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 0.2 0.3 0.4 0.5 0.6 0.7 0.8


CORE DJF TsfcObs Corr:Proj of VPOT Mode 2
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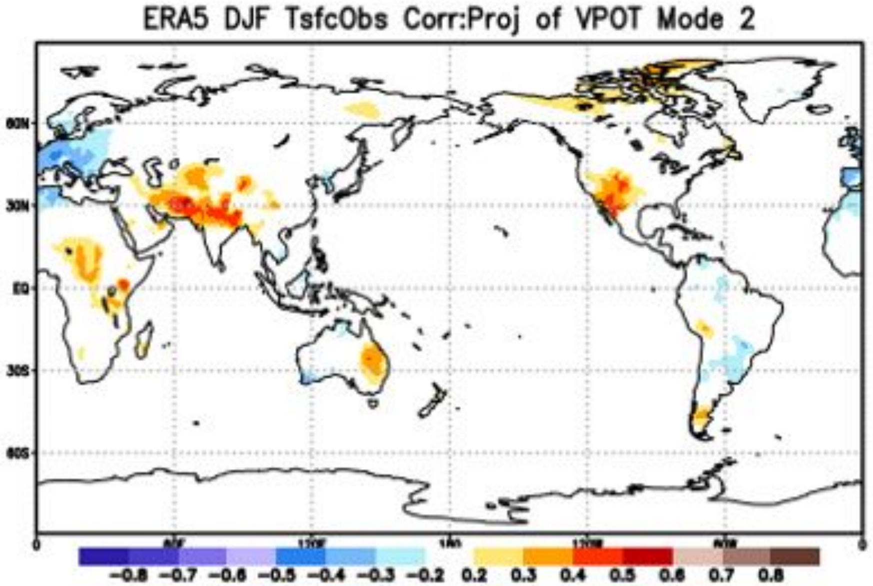
ERA5 DJF TsfcObs Corr:Proj of VPOT Mode 2
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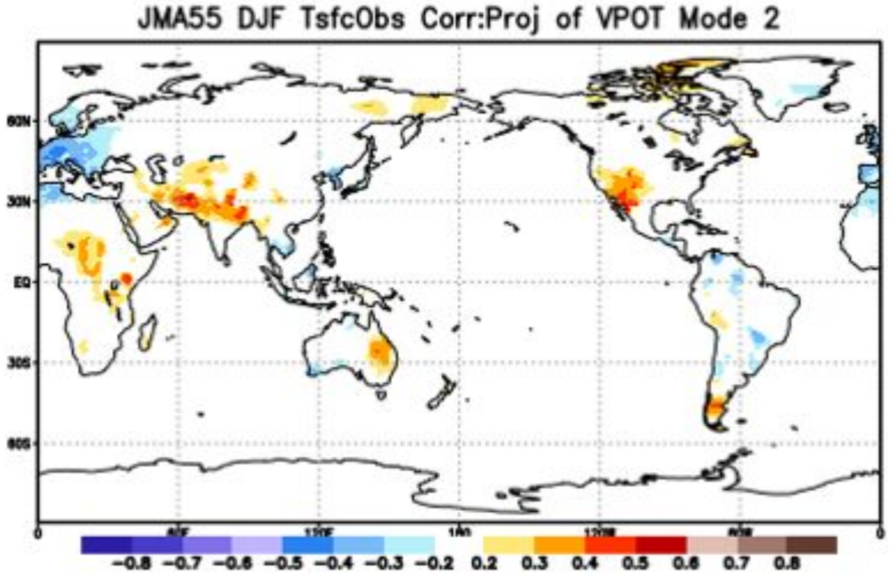
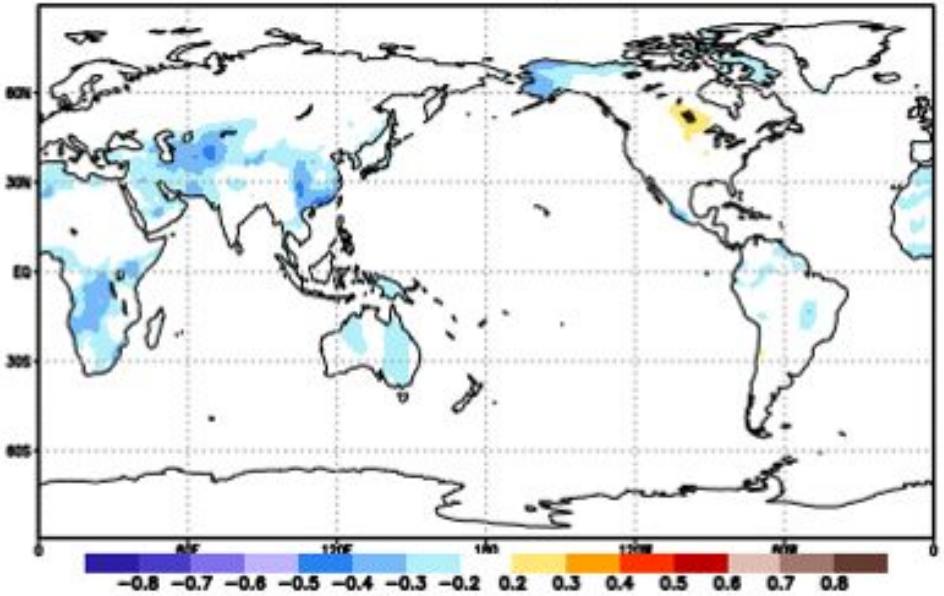
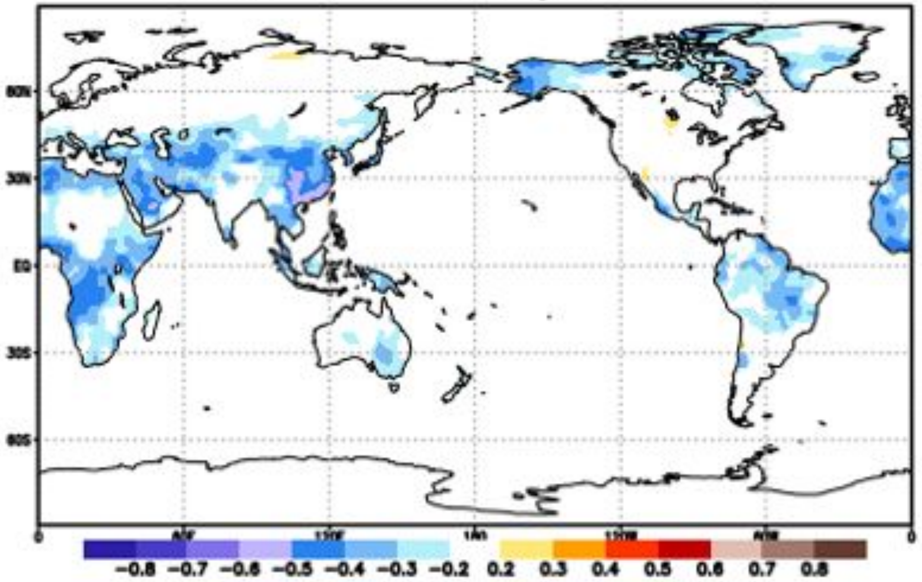

JMA55 DJF TsfcObs Corr:Proj of VPOT Mode 2
−0.8 −0.7 −0.6 −0.5 −0.4 −0.3 −0.2 0.2 0.3 0.4 0.5 0.6 0.7 0.8

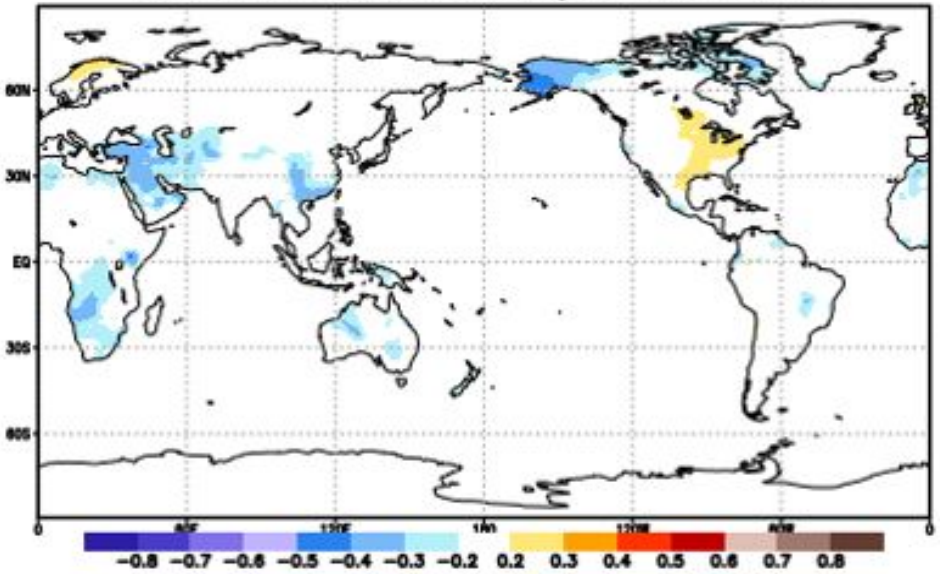
CORE DJF TsfcObs Corr:Proj of VPOT Mode 3



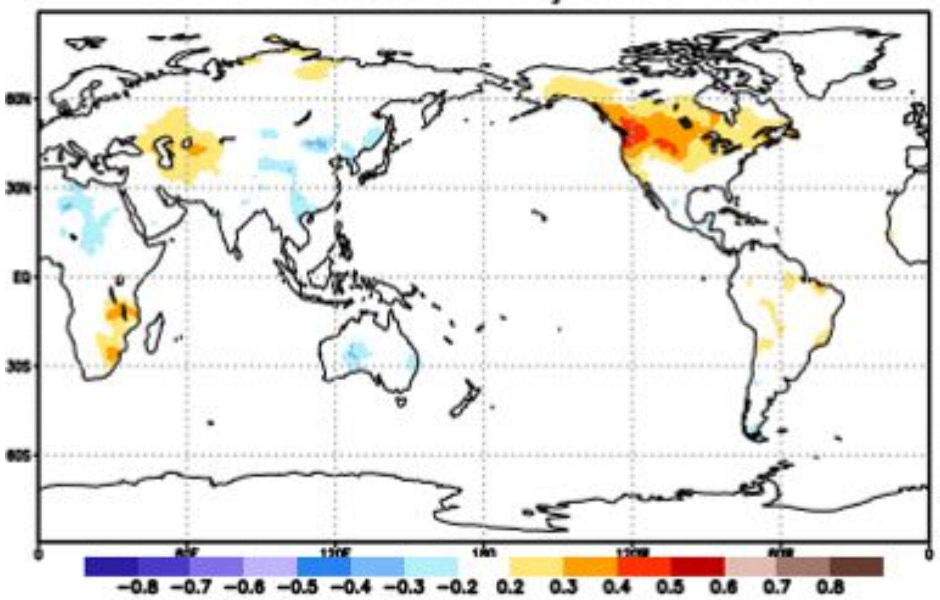
ERA5 DJF TsfcObs Corr:Proj of VPOT Mode 4



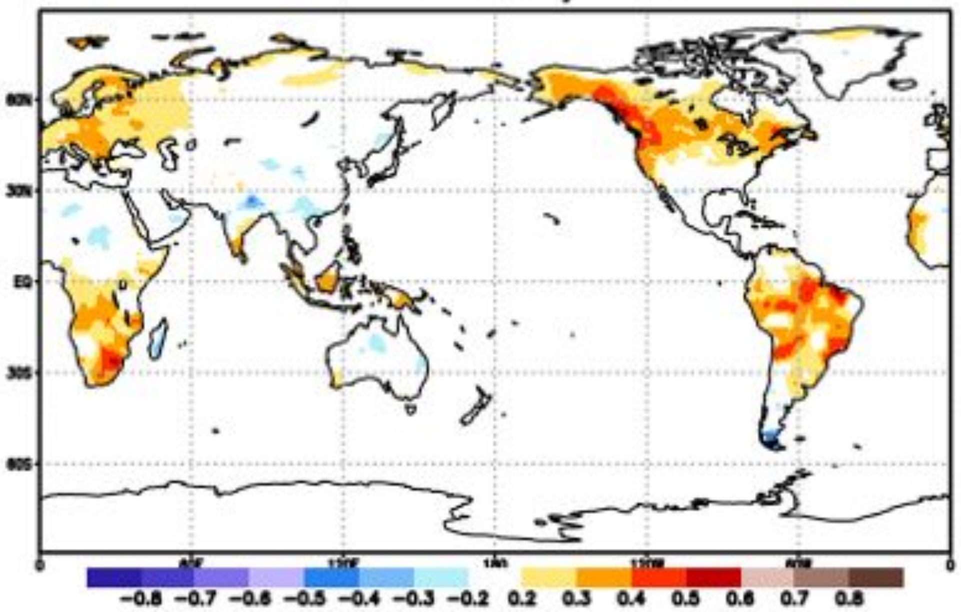
JMA55 DJF TsfcObs Corr:Proj of VPOT Mode 3



CORE DJF TsfcObs Corr:Proj of VPOT Mode 4



ERA5 DJF TsfcObs Corr:Proj of VPOT Mode 3



JMA55 DJF TsfcObs Corr:Proj of VPOT Mode 4