# ENSO Response

## (with a focus on the GEOS-5 S2S-1.0 Model)

Taken primarily from Chen et al. 2017: ENSO Precipitation and Temperature Forecasts in the North American Multimodel Ensemble: Composite Analysis and Validation, J. Climate, http://dx.doi.org/10.1175/JCLI-D-15-0903.1

Additional figures available at http://www.cpc.ncep.noaa.gov/products/NMME/enso/

S. Schubert: 01/31/2017

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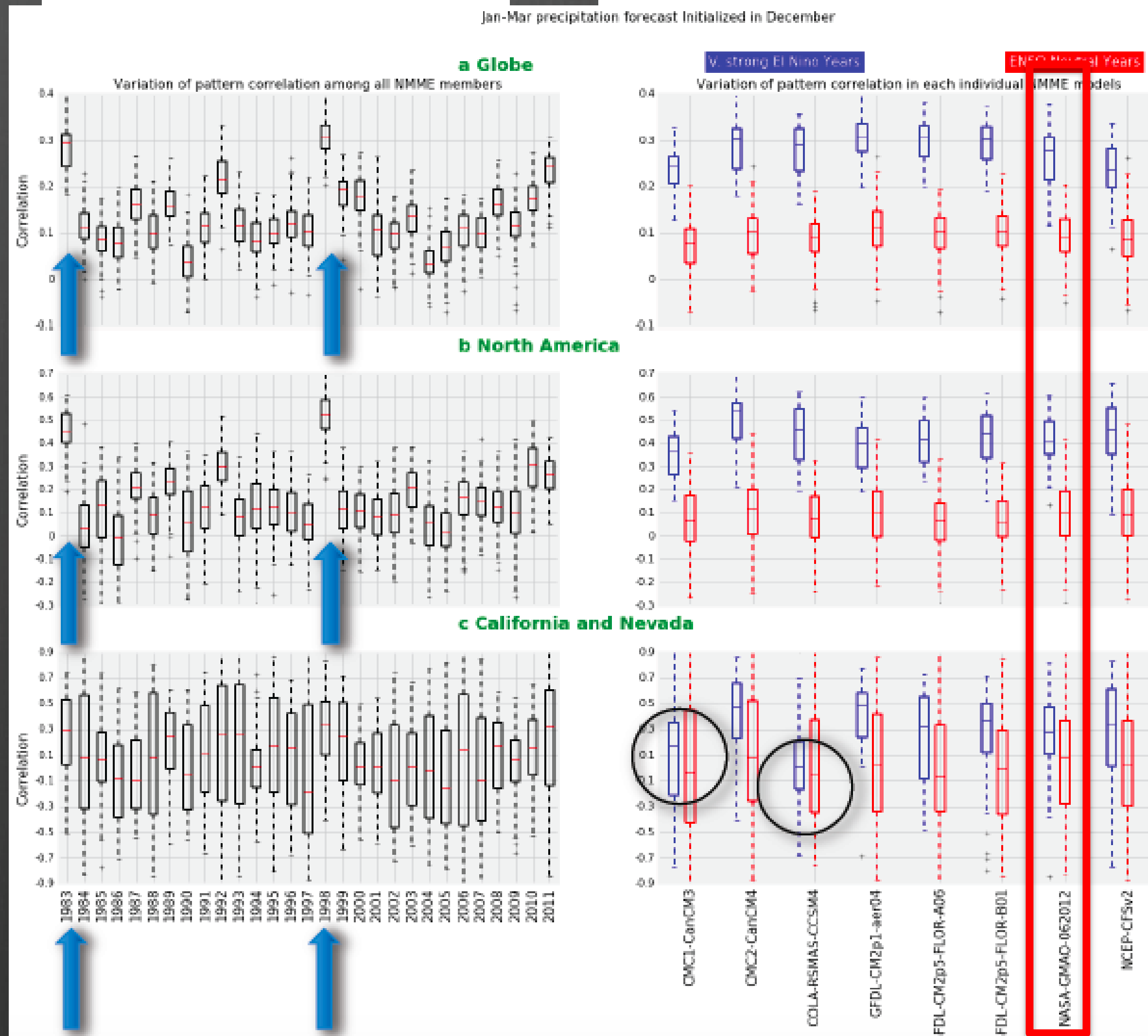
# Anomaly pattern correlation

- Both 1982-1983 and 1997-98 stand out as the years during which the pattern correlation was much higher than the rest of the period. This is true for globe and N. America.
- Over California-Nevada spread of pattern correlation is much higher and the models with the lowest median correlation during the strong El Niño events are CMC1-CanCM3 and CCSM4.

**All NMME members** | **Individual NMME models**




**Blue = Spread during strong El Nino events**

**Red = Spread during neutral ENSO events**

# ENSO Years

Seasonal Oceanic Nino Index (ONI; Kousky and Higgins 2007)
:http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

TABLE 1. Selected years used in the ENSO composite analysis. The years are chosen based on |ONI| ≥ 0.5 on average for the three consecutive months prior to the initial time of model integration. The 1982-2010 set is used for model and observed composites. The 1950-2010 set is used for observed composites only.

| IC | Oct 1 | | Nov 1 | | Dec 1 | | Jan 1 | | Feb 1 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Month | Nov | | Dec | | Jan | | Feb | | Mar | |
| ENSO | Warm | Cold | Warm | Cold | Warm | Cold | Warm | Cold | Warm | Cold |
| 1950-1981 | 1951 | 1950 | 1951 | 1954 | 1951 | 1950 | 1952 | 1951 | 1952 | 1951 |
| | 1953 | 1954 | 1953 | 1955 | 1953 | 1954 | 1954 | 1955 | 1954 | 1955 |
| | 1957 | 1955 | 1957 | 1956 | 1957 | 1955 | 1958 | 1956 | 1958 | 1956 |
| | 1963 | 1956 | 1963 | 1964 | 1963 | 1956 | 1959 | 1957 | 1959 | 1957 |
| | 1965 | 1964 | 1965 | 1970 | 1965 | 1964 | 1964 | 1965 | 1964 | 1965 |
| | 1968 | 1970 | 1968 | 1971 | 1968 | 1970 | 1966 | 1971 | 1966 | 1971 |
| | 1969 | 1971 | 1969 | 1973 | 1969 | 1971 | 1969 | 1972 | 1969 | 1972 |
| | 1972 | 1973 | 1972 | 1975 | 1972 | 1973 | 1970 | 1974 | 1970 | 1974 |
| | | 1975 | 1976 | | 1976 | 1974 | 1973 | 1975 | 1973 | 1975 |
| | | | 1977 | | 1977 | 1975 | 1977 | 1976 | 1977 | 1976 |
| | | | | | | | 1978 | | 1978 | |
| 1982-2010 | 1982 | 1985 | 1982 | 1983 | 1982 | 1983 | 1983 | 1984 | 1983 | 1984 |
| | 1986 | 1988 | 1986 | 1985 | 1986 | 1984 | 1987 | 1985 | 1987 | 1985 |
| | 1987 | 1998 | 1987 | 1988 | 1987 | 1988 | 1988 | 1989 | 1988 | 1989 |
| | 1991 | 1999 | 1991 | 1995 | 1991 | 1995 | 1992 | 1996 | 1992 | 1996 |
| | 1997 | 2000 | 1994 | 1998 | 1994 | 1998 | 1995 | 1999 | 1995 | 1999 |
| | 2002 | 2007 | 1997 | 1999 | 1997 | 1999 | 1998 | 2000 | 1998 | 2000 |
| | 2004 | 2010 | 2002 | 2000 | 2002 | 2000 | 2003 | 2001 | 2003 | 2001 |
| | 2009 | | 2004 | 2007 | 2004 | 2007 | 2005 | 2006 | 2005 | 2006 |
| | | | 2006 | 2010 | 2006 | 2010 | 2007 | 2008 | 2007 | 2008 |
| | | | 2009 | | 2009 | | 2010 | 2009 | 2010 | 2009 |
| **Total No. of events from 1982 to 2010** | **8** | **7** | **10** | **9** | **10** | **9** | **10** | **10** | **10** | **10** |
| **Total No. of events from 1950 to 2010** | **16** | **16** | **20** | **17** | **20** | **19** | **21** | **20** | **21** | **20** |

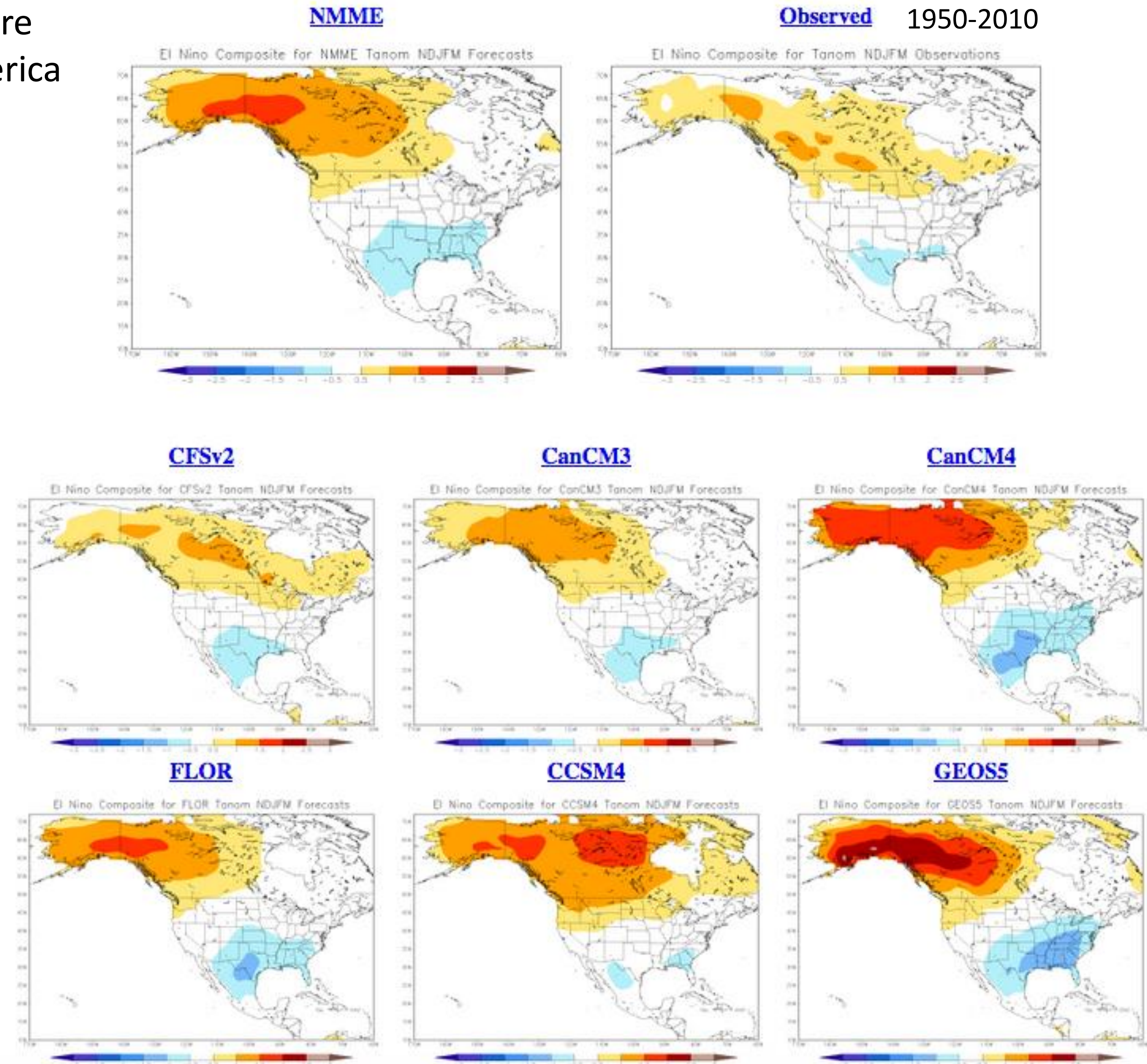
Composites for Observations (1950-2010)

Composites for Hindcasts (1982-2010)

Focus on lead 1-month composites for Nov, Dec, Jan, Feb, Mar

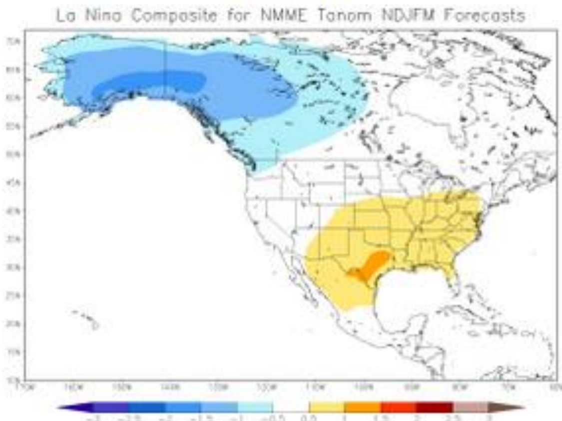
(NDJFM is the average of the four 1-month lead composites)

# El Nino NDJF Temperature North America



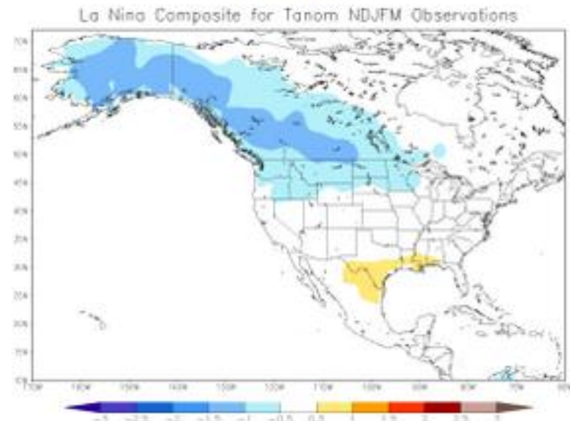
La Nina NDJF
Temperature
North America

NMME

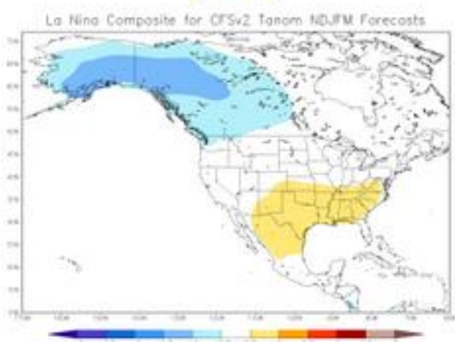



Observed

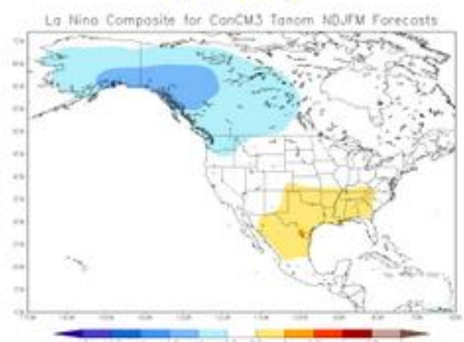
1950-2010



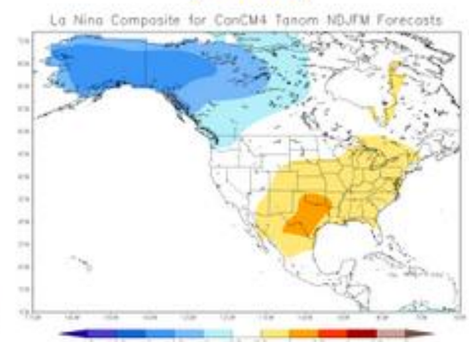

CFSv2



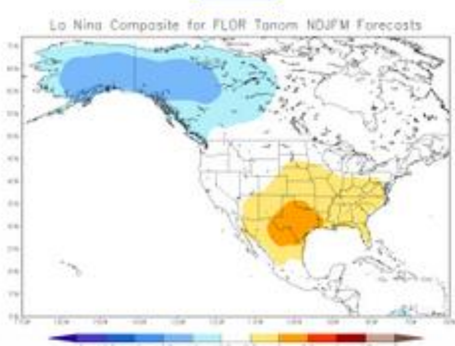

CanCM3



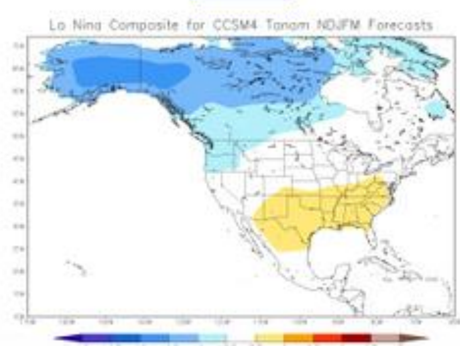

CanCM4



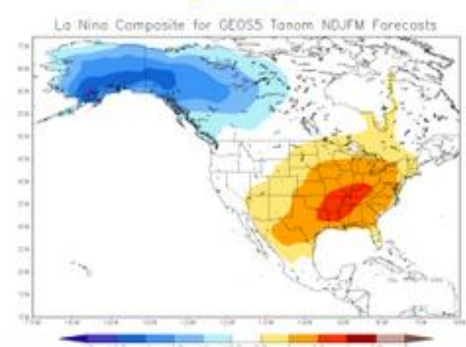

FLOR




CCSM4

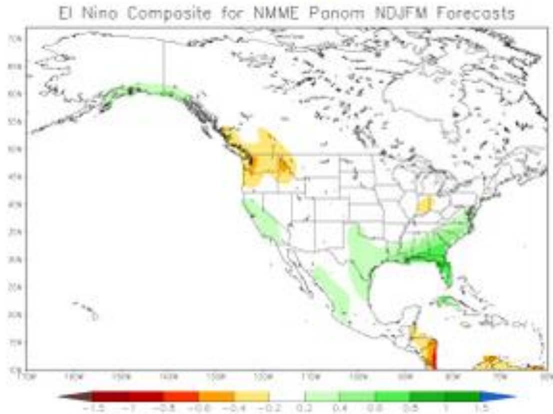



GEOS5

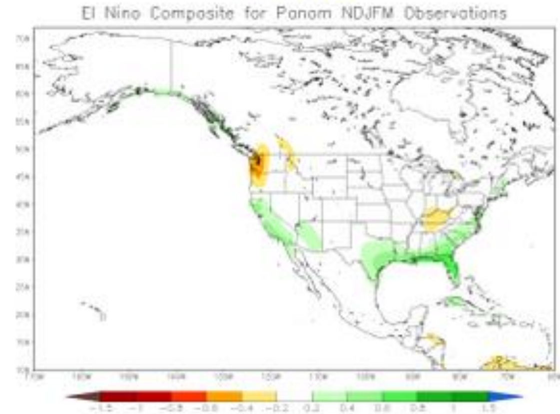


El Nino NDJF
Precipitation
North America

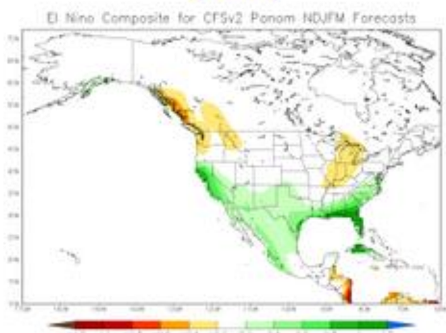
**NMME**



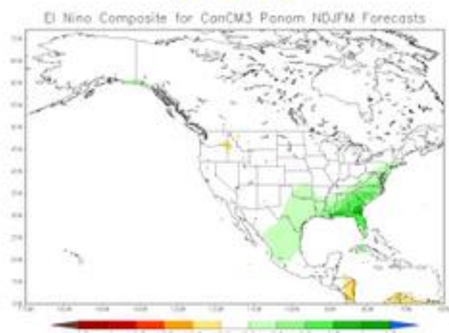

**Observed** 1950-2010



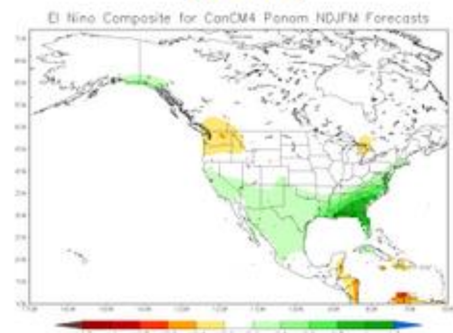

**CFSv2**



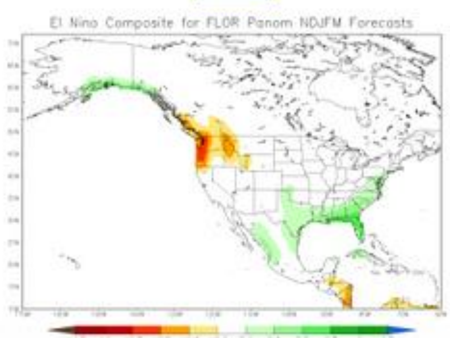

**CanCM3**



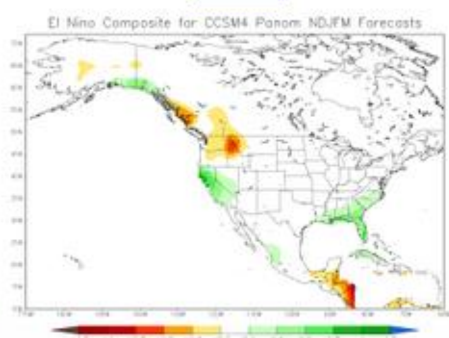

**CanCM4**



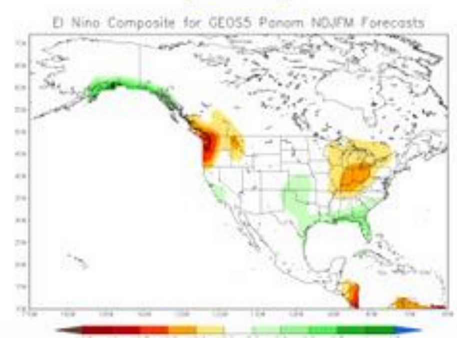

**FLOR**




**CCSM4**

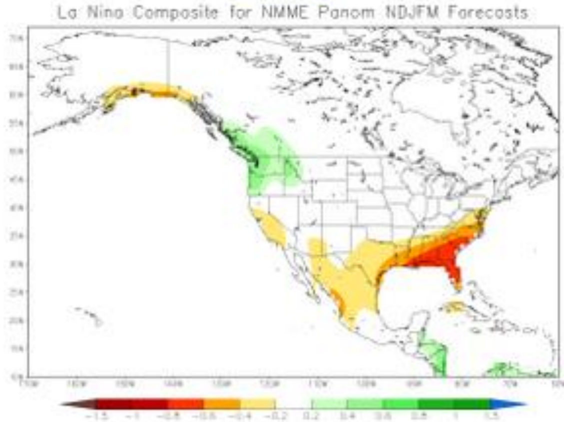



**GEOS5**

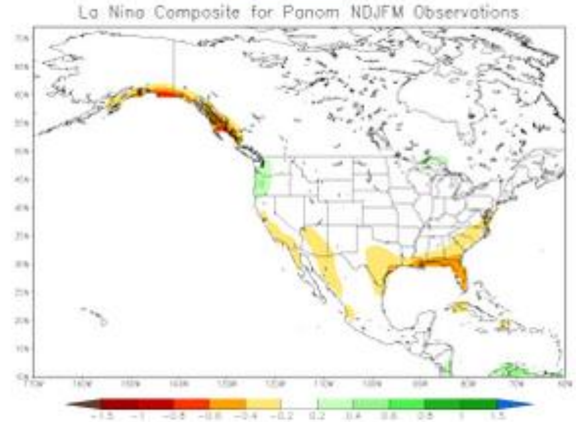


La Nina NDJF Precipitation North America

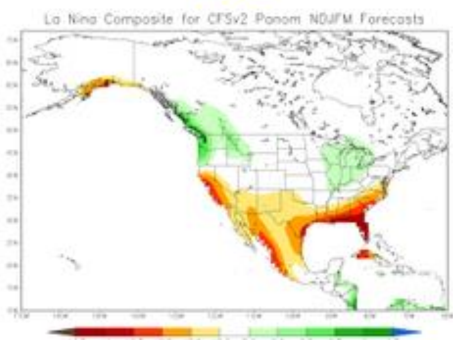
NMME



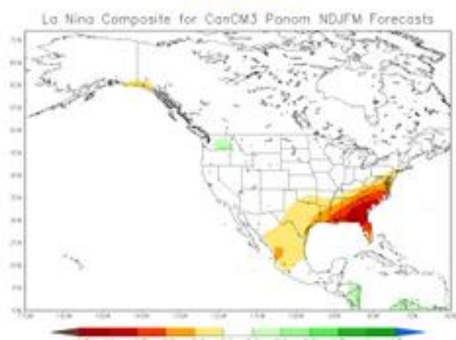

Observed 1950-2010



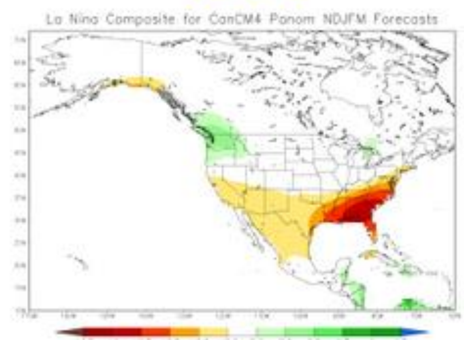

CFSv2



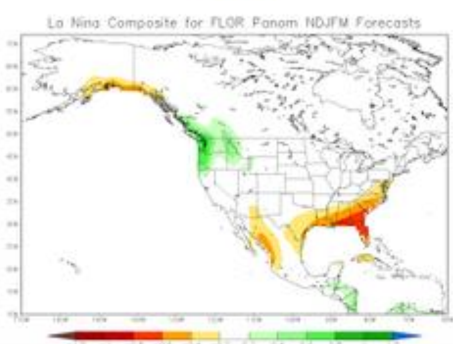

CanCM3



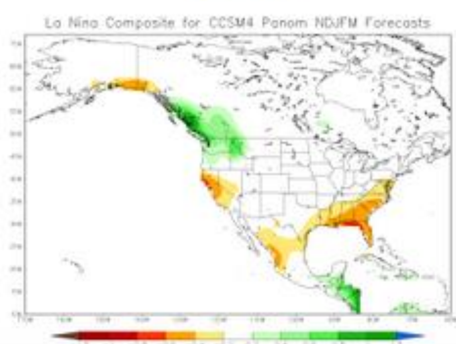

CanCM4



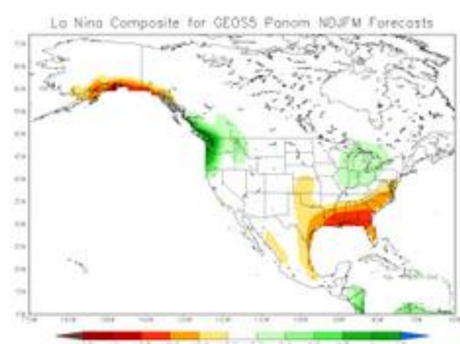

FLOR




CCSM4




GEOS5



North America
Anomaly Correlation
Coefficient

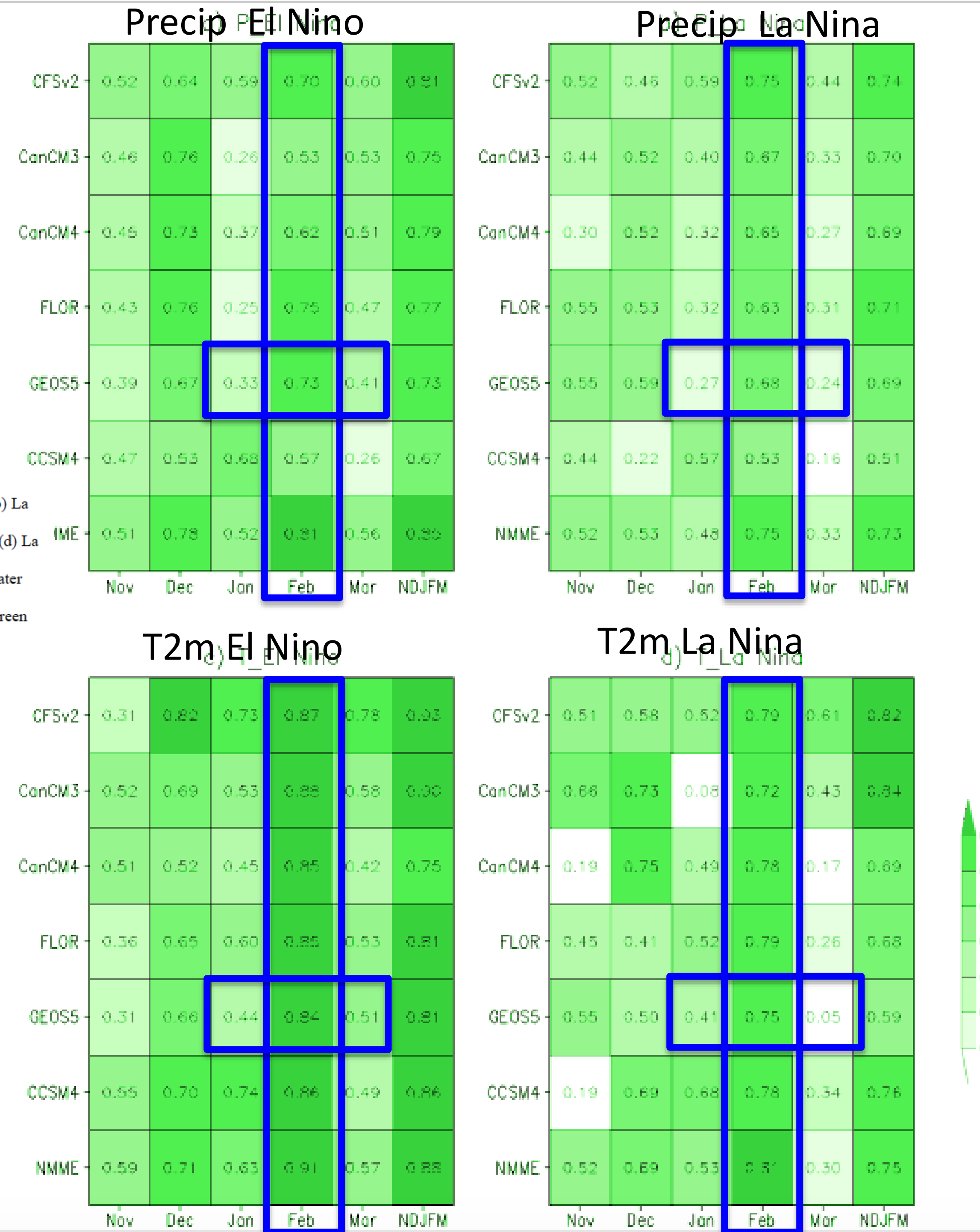
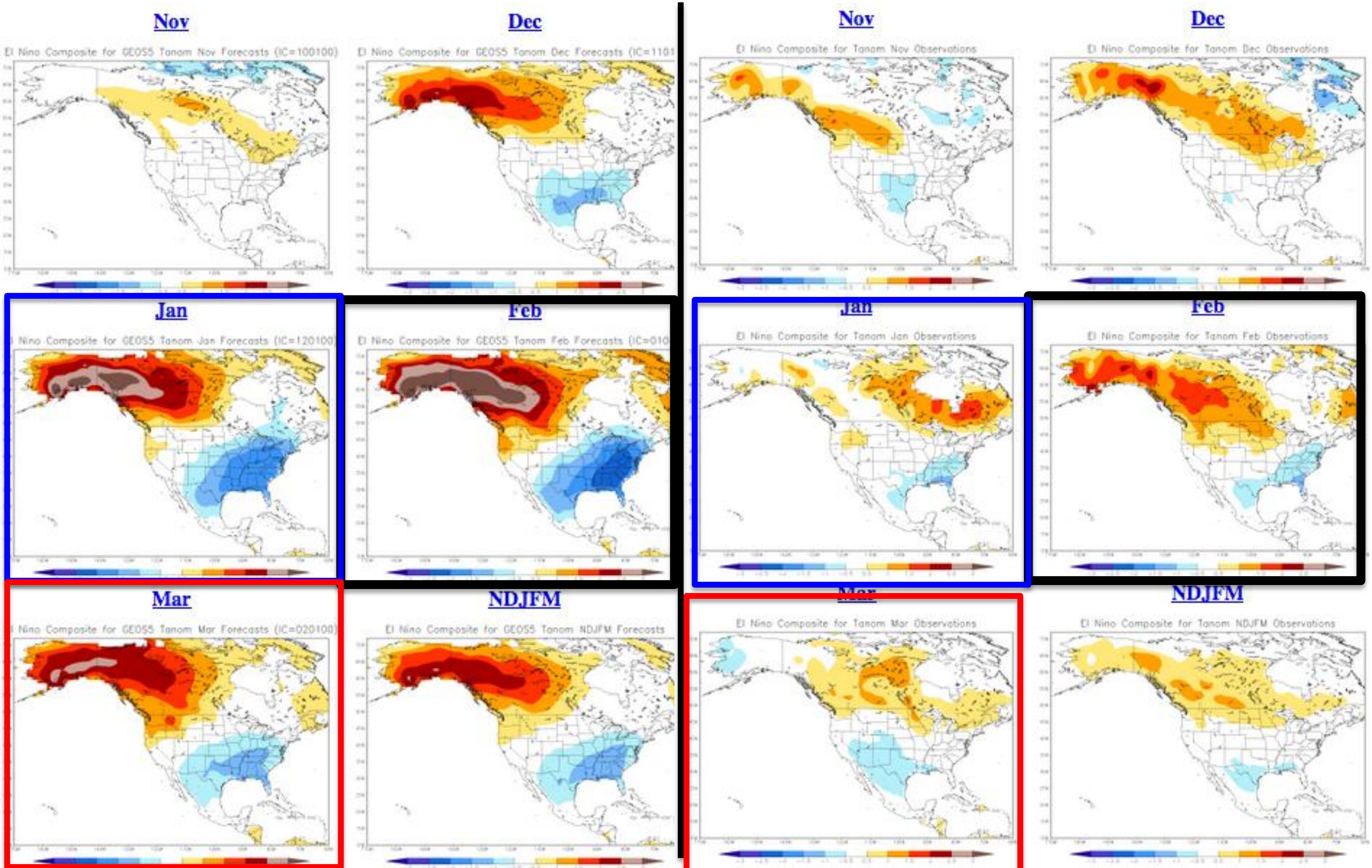



FIG. 5. ACC of all models and months for (a) El Nino precipitation anomaly composites, (b) La Nina precipitation anomaly composites, (c) El Nino temperature anomaly composites, and (d) La Nina temperature anomaly composites, validated with 1950-2010 observations. Values greater than 0.2 are significant at the 90% confidence level based on student's t test. The level of green shading corresponds to the range of ACC values indicated by the color bar.

# El Nino Temperature

GEOS-5 | Observations



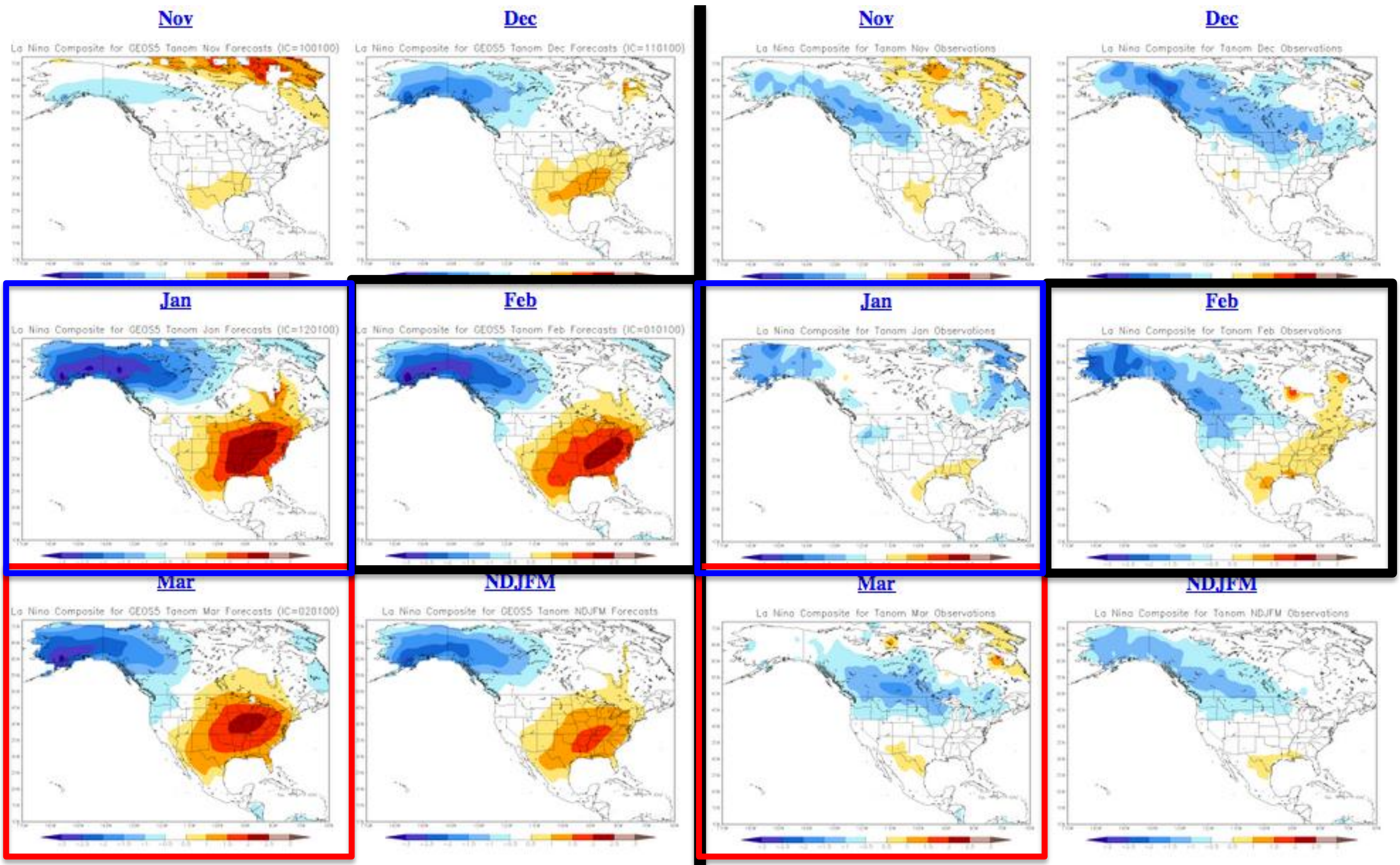

GEOS-5 El Nino T2m anomaly composites (1982-2010) for Lead-1 forecasts with initial conditions of (a) October 1, (b) November 1, (c) December 1, (d) January 1, and (e) February 1, and for (f) five-month (NDJFM) aggregates. The anomaly unit is mm/day.

Observed composites (1950-2010)

# La Nina Temperature

## GEOS-5

## Observations

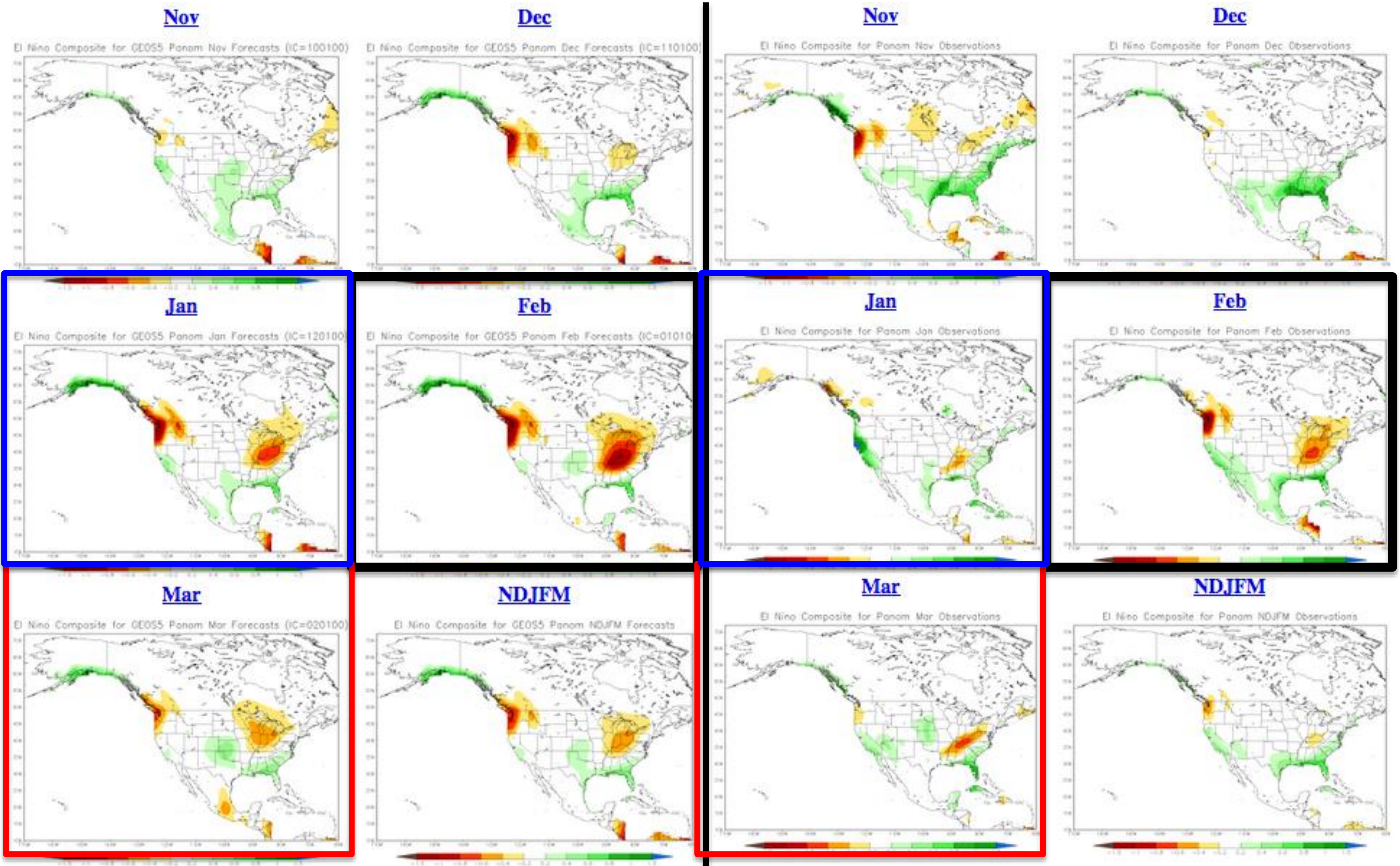



GEOS-5 La Nina T2m anomaly composites (1982-2010) for Lead-1 forecasts with initial conditions of (a) October 1, (b) November 1, (c) December 1, (d) January 1, and (e) February 1, and for (f) five-month (NDJFM) aggregates. The anomaly unit is °C.

Observed composites (1950-2010)

# El Nino Precipitation

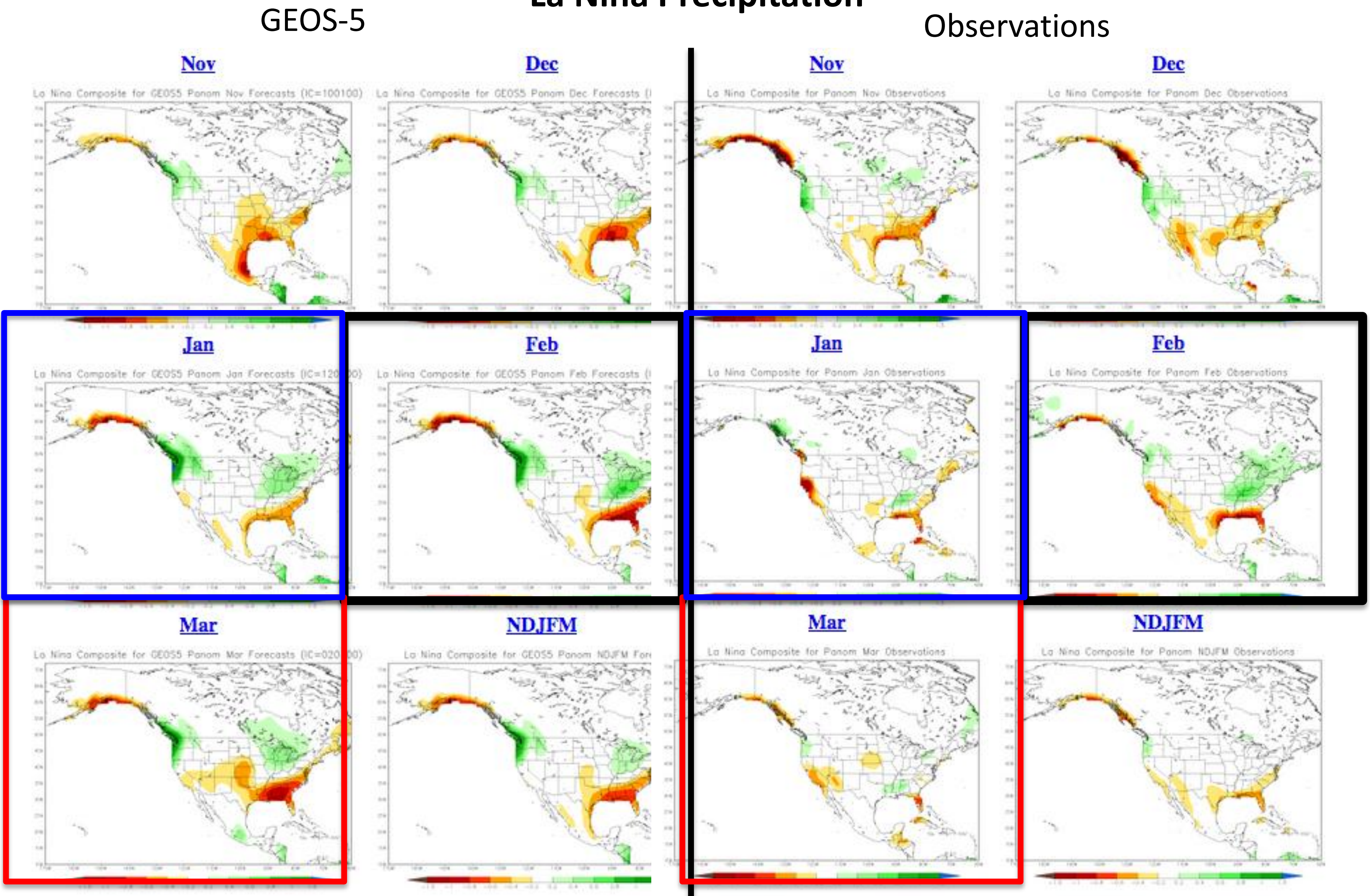
GEOS-5 | Observations




GEOS-5 El Nino precipitation anomaly composites (1982-2010) for Lead-1 forecasts with initial conditions of (a) October 1, (b) November 1, (c) December 1, (d) January 1, and (e) February 1, and for (f) five-month (NDJFM) aggregates. The anomaly unit is mm/day.

Observed composites (1950-2010)

# La Nina Precipitation




GEOS-5 La Nina Precipitation anomaly composites (1982-2010) for Lead-1 forecasts with initial conditions of (a) October 1, (b) November 1, (c) December 1, (d) January 1, and (e) February 1, and for (f) five-month (NDJFM) aggregates. The anomaly unit is mm/day

Observed composites (1950-2010)

**Some of Chen et al. conclusions:**

- GEOS-5, CanCM4 and FLOR have difficulty in producing ENSO-temperature relations (both in magnitude and spatial patterns)

- February tends to have higher scores than other winter months for all models

- Most models perform slightly better in predicting El Nino patterns than La Nina patterns

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- A closer look indicates that the GEOS-5 model has a too strong tendency to produce a canonical (PNA-like) response to ENSO SST

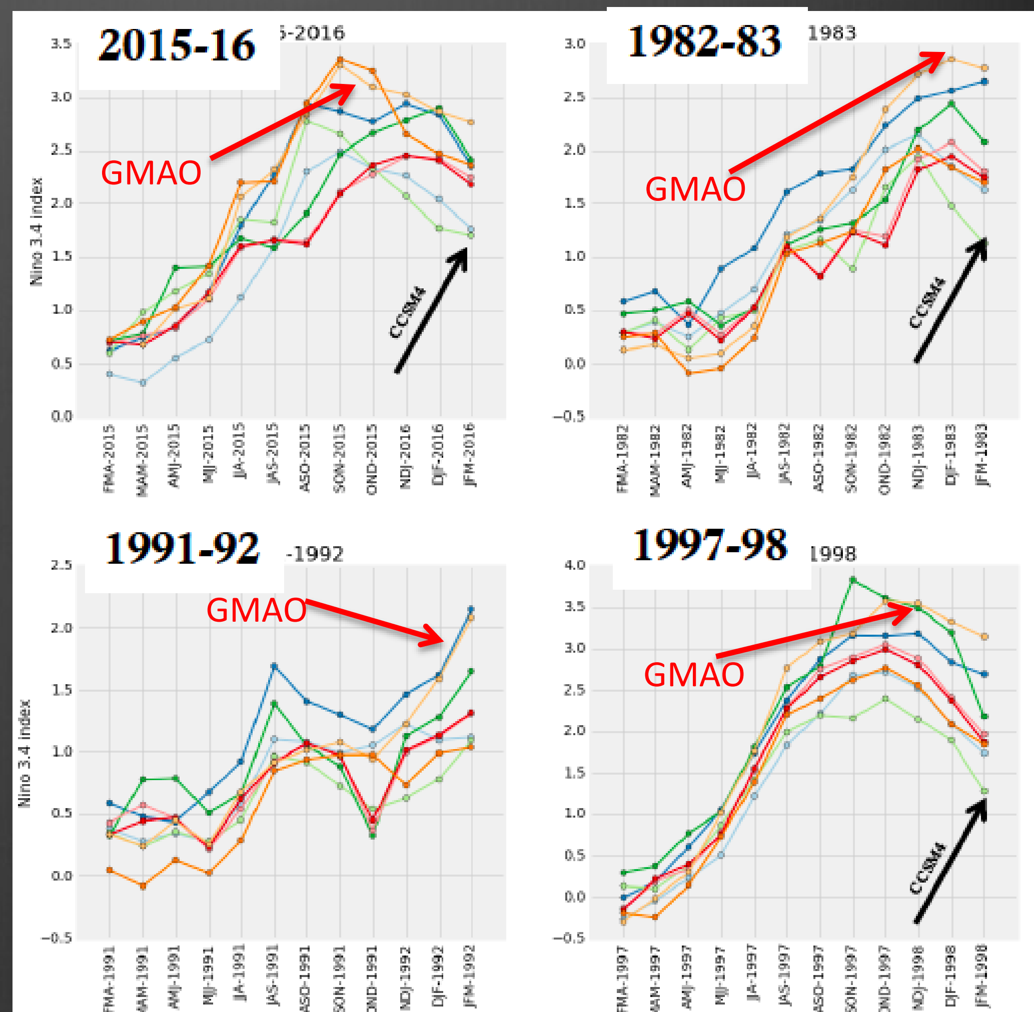
- **Why?**
  - *Perhaps an incorrect sensitivity of the atmospheric response to equatorial Pacific SST*

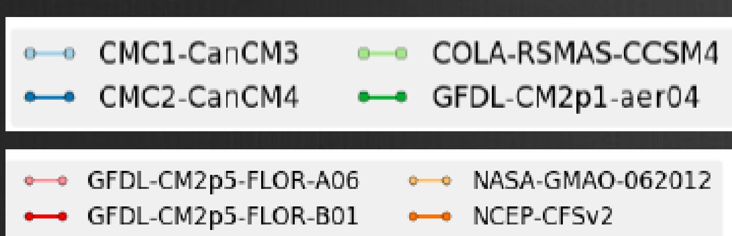
  - *Perhaps due to too-strong ENSO SST anomalies that extend too far*

Shraddhanand Shukla; CNAP a NOAA RISA team

# Evolution of Niño 3.4 during past strong El Niño events

- In general CCSM4 forecasted weakest El Niño and in JFM forecasts for each events CCSM4 and CMC1-CanCM3 SST forecast anomalies were the weakest (and NASA-GMAO SST anomalies were the strongest).
- The differences in the evolution and intensity of El Niño are slightly less pronounced in the lead-0 forecasts (not shown).



Barsugli and Sardeshmukh 2002

**PNA most sensitive to SST in this region (Nino4)**

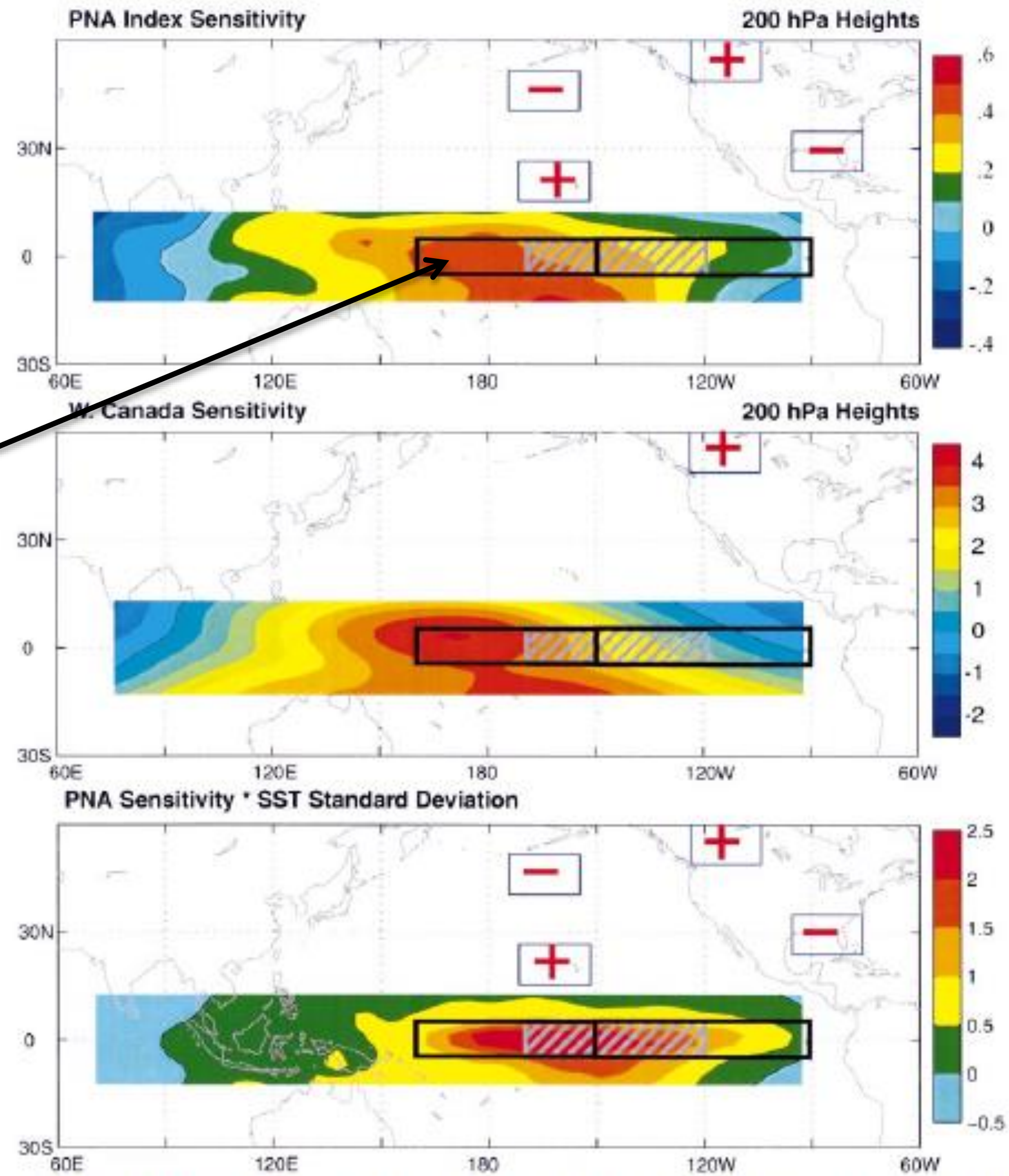
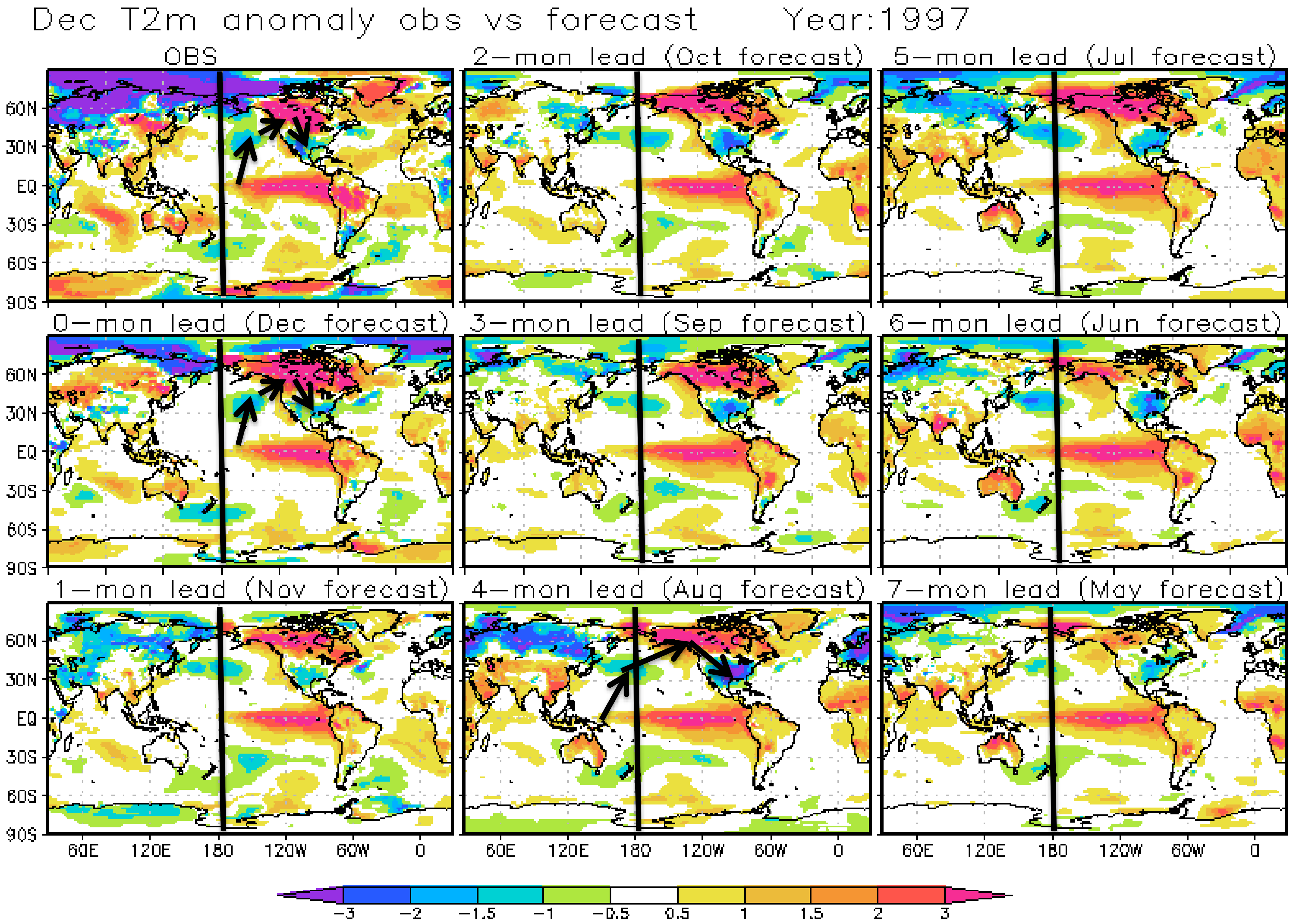
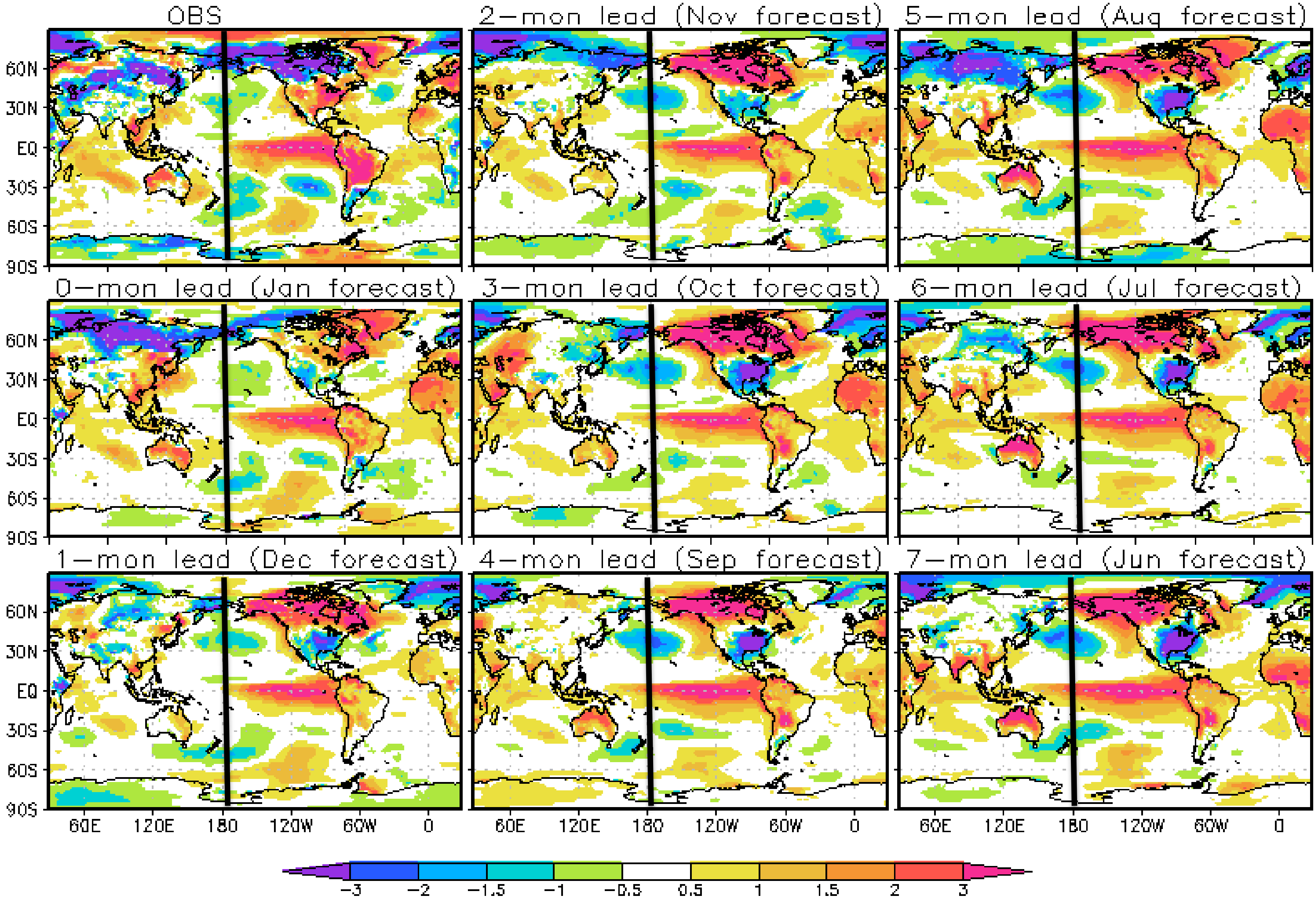



FIG. 7. (a) Sensitivity of the PNA index defined from 200-mb heights (contour interval is 0.1 $SSTU^{-1}$). Target regions that were used to define the PNA pattern and the signs of their contributions to the index are indicated. The Niño-4 and Niño-3 regions are depicted by black rectangles on the equator; the Niño-3.4 region by a gray hatched rectangle. (b) Sensitivity of the center over western Canada (0.5 m $SSTU^{-1}$). (c) PNA sensitivity multiplied by the standard deviation of Jan SSTs ($0.5 \times 10^{-6}$ $km^{-2}$). SSTs have been interpolated through land points.



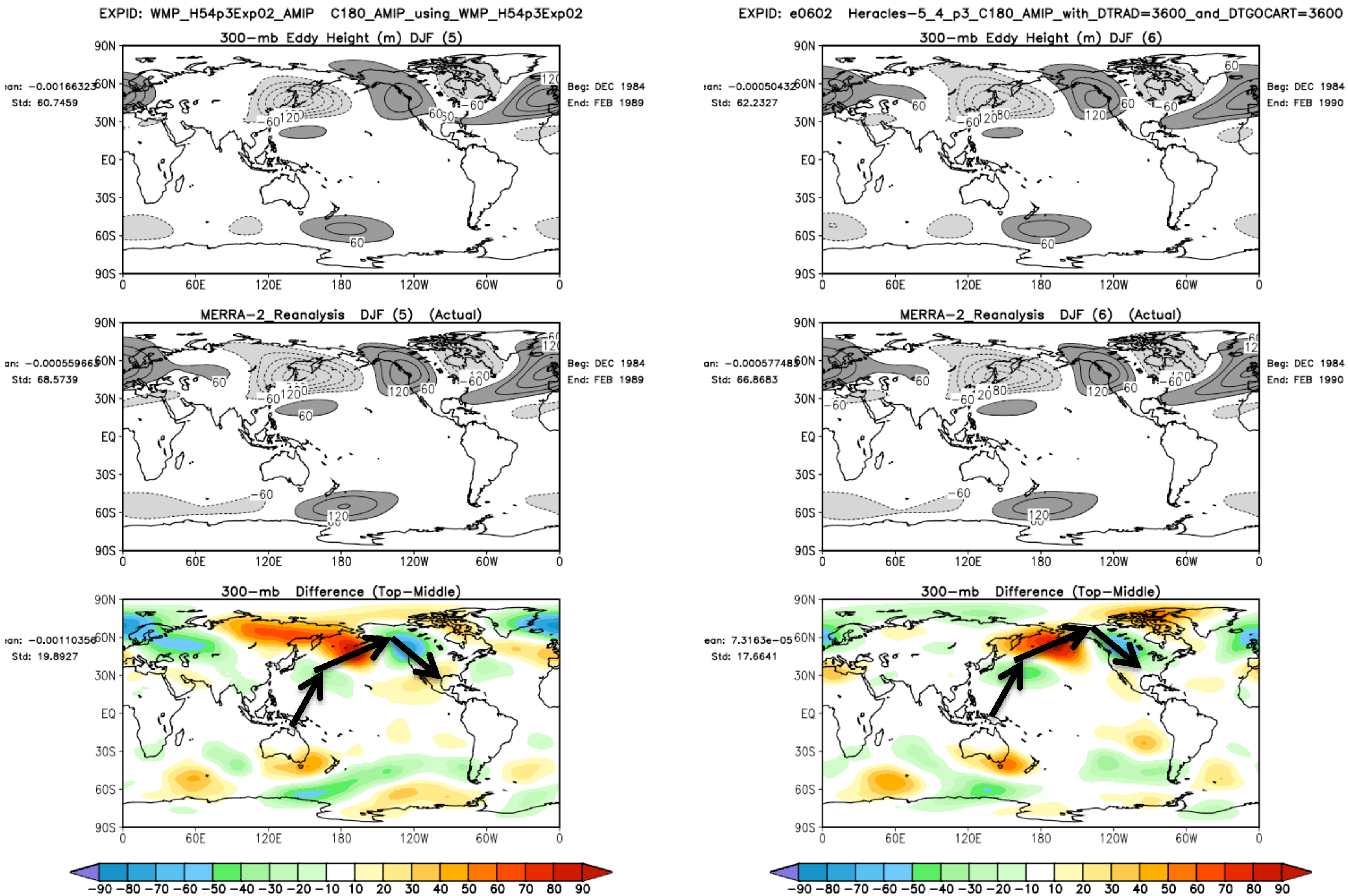

https://gmao.gsfc.nasa.gov/cgi-bin/products/climateforecasts/GEOS5/ATMOS/index_hind_anom_lnd.cgi?year=1998&month=3&var=t2m&reg=global

Jan T2m anomaly obs vs forecast Year:1998



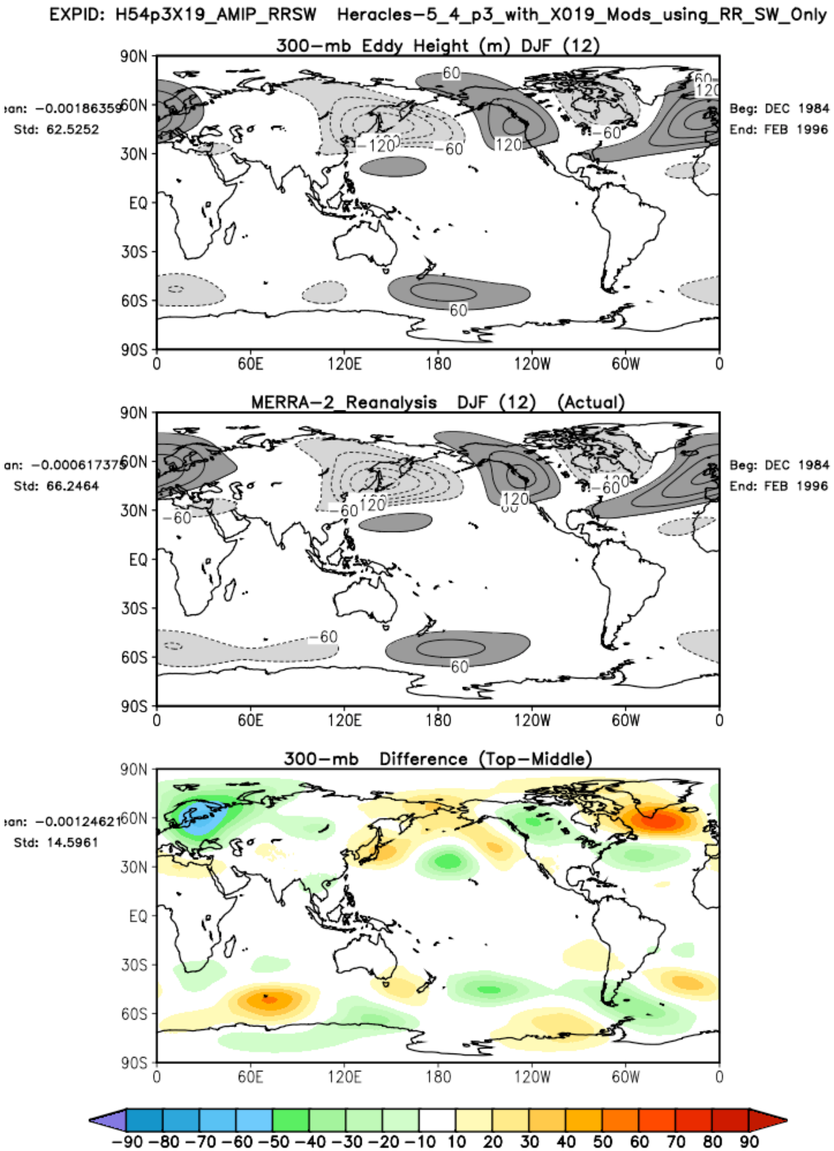

https://gmao.gsfc.nasa.gov/cgi-bin/products/climateforecasts/GEOS5/ATMOS/index_hind_anom_lnd.cgi?year=1998&month=3&var=t2m&reg=global

# AMIP runs: Some examples showing PNA-like model bias (300mb eddy height for DJF)

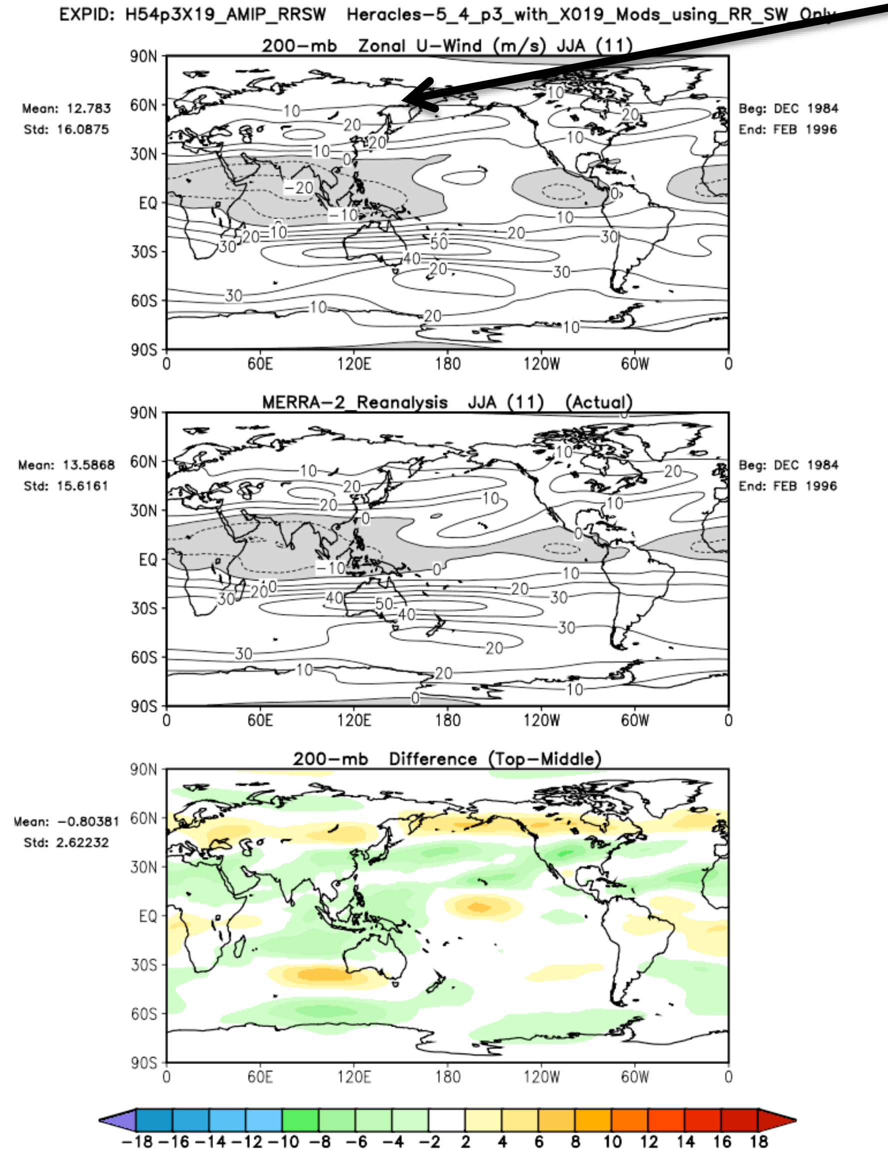


# AMIP runs: This version seems to get it about right (also very nice JJA jets)

## DJF 300mb eddy heights




## JJA 200mb zonal wind




Best I've ever seen!

# Conclusions

- Previous slides suggest that a key problem with the GEOS-5 coupled model response to ENSO is that the forecast SST anomalies extend too far to the west (in the 1997/98 example, the PNA-like response appears to develop after a lead time of a few months as the forecast SST anomalies erroneously spread west of the dateline)

- However, it is also likely that the atmospheric model's extra-tropical response to SST in the Pacific warm pool region has systematic errors (often resembling the PNA)

- The key point is that the Pacific warm pool region (just west of the dateline) is critical to get the extratropical boreal winter response right (likely impacted by both SST forecast bias and an incorrect response by the atmospheric model to SST in that region)

# Some Comments

- For the coupled model: A priority should be placed on improving the equatorial Pacific SST especially the cold tongue (extent and strength, SST gradients) and annual cycle. The SSTs at the eastern edge of the warm pool appear to be critical to getting the extratropical wave response correct.

- For the AGCM: Getting the correct atmospheric response to the SST in that region (Pacific warm pool) is critical for getting good forecasts over North America (impacts the steering of storms, etc). I suspect that is even true for short term (weather) forecasts. Need to look at summer as well.

- It would be helpful to develop an in-house capability to do ENSO composites from any set of hindcasts and AMIP-style runs (on-line, with flexibility to look at any quantity for an lead and start month (monthly and seasonal) – suggest following compositing convention of Chen et al.

- It would be very useful to produce an estimate of the AGCM's Green's function linking SST to the atmospheric response (a diagnostic tool that would allow us to produce SST sensitivity maps for an arbitrary atmospheric quantity)

# References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