Enhanced Ocean Monitoring Products Using Ensemble Ocean Reanalyses: ENSO Precursors & NMME False Alarms

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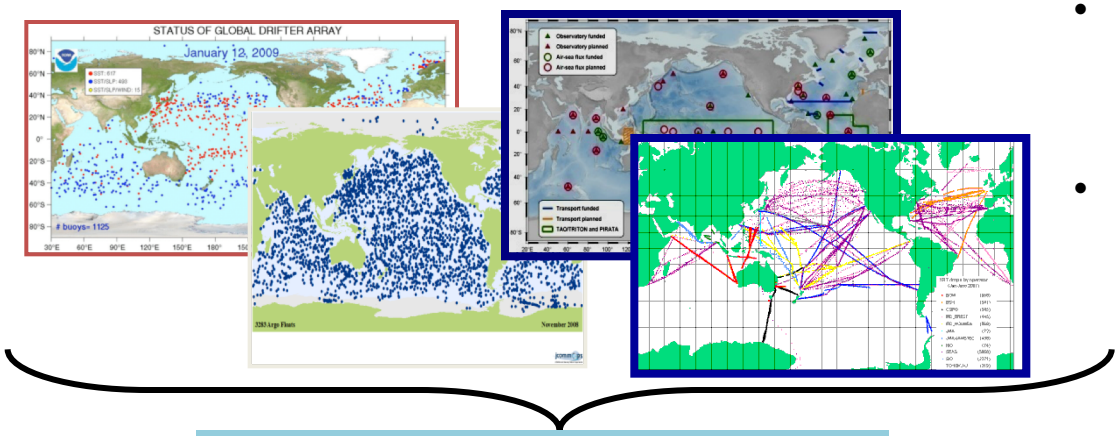
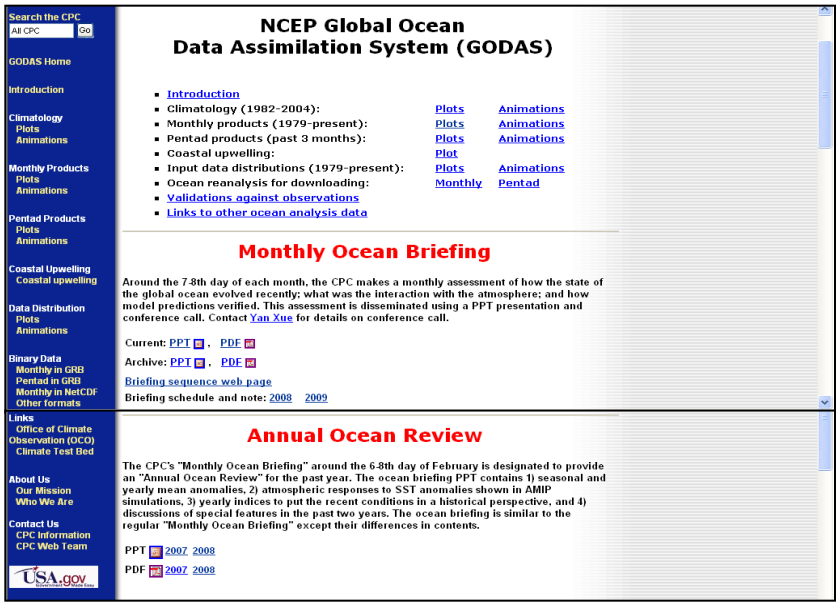
Ocean Monitoring Products at CPC

http://www.cpc.ncep.noaa.gov/products/GODAS



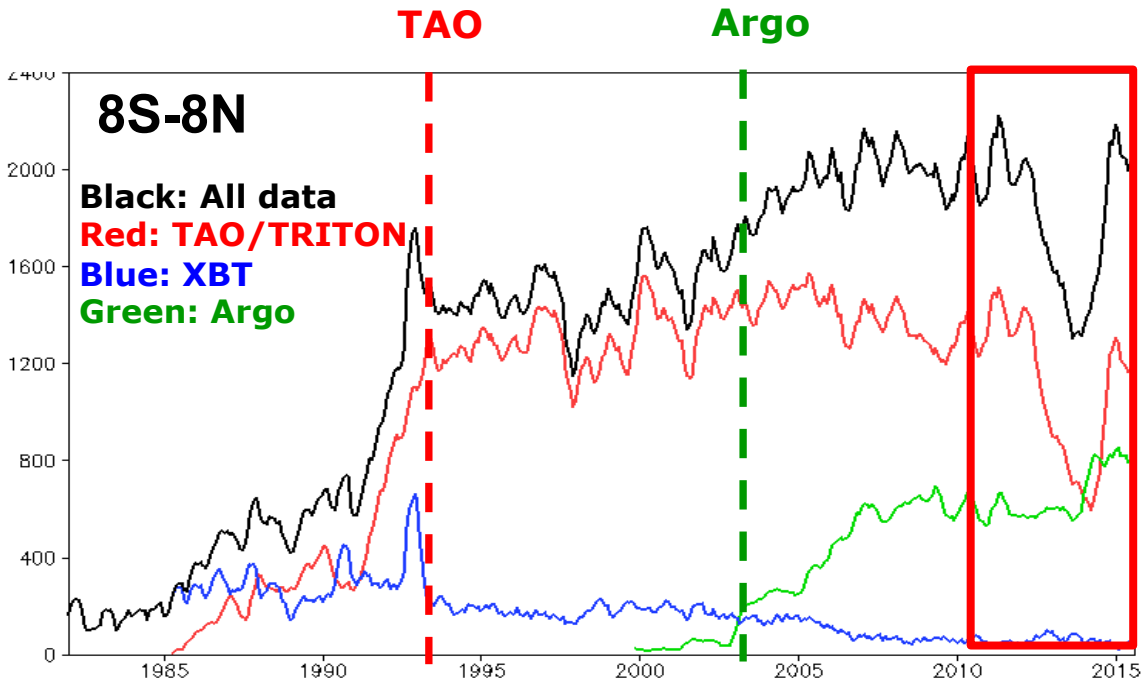
Synthesis of Ocean Observations



- **The Global Ocean Data Assimilation System (GODAS) was implemented in 2003**
- **The GODAS web site was constructed in 2005 to delivery the ocean synthesis data and ocean monitoring products to the user community and to demonstrate the benefits of NOAA's investment in global ocean observing systems for societal benefits**
- **CPC's "Monthly Ocean Briefing" was initiated in 2007 to provide the user community a monthly summary of the ocean state of climate variability associated with ENSO, PDO, IOD, TAV, AMOC, Sea Ice**

Real-Time Ocean Reanalysis Intercomparison Project

(Motived by TPOS Workshop in Jan. 2014, Coordinated by CLIVAR/GSOP and GOV)

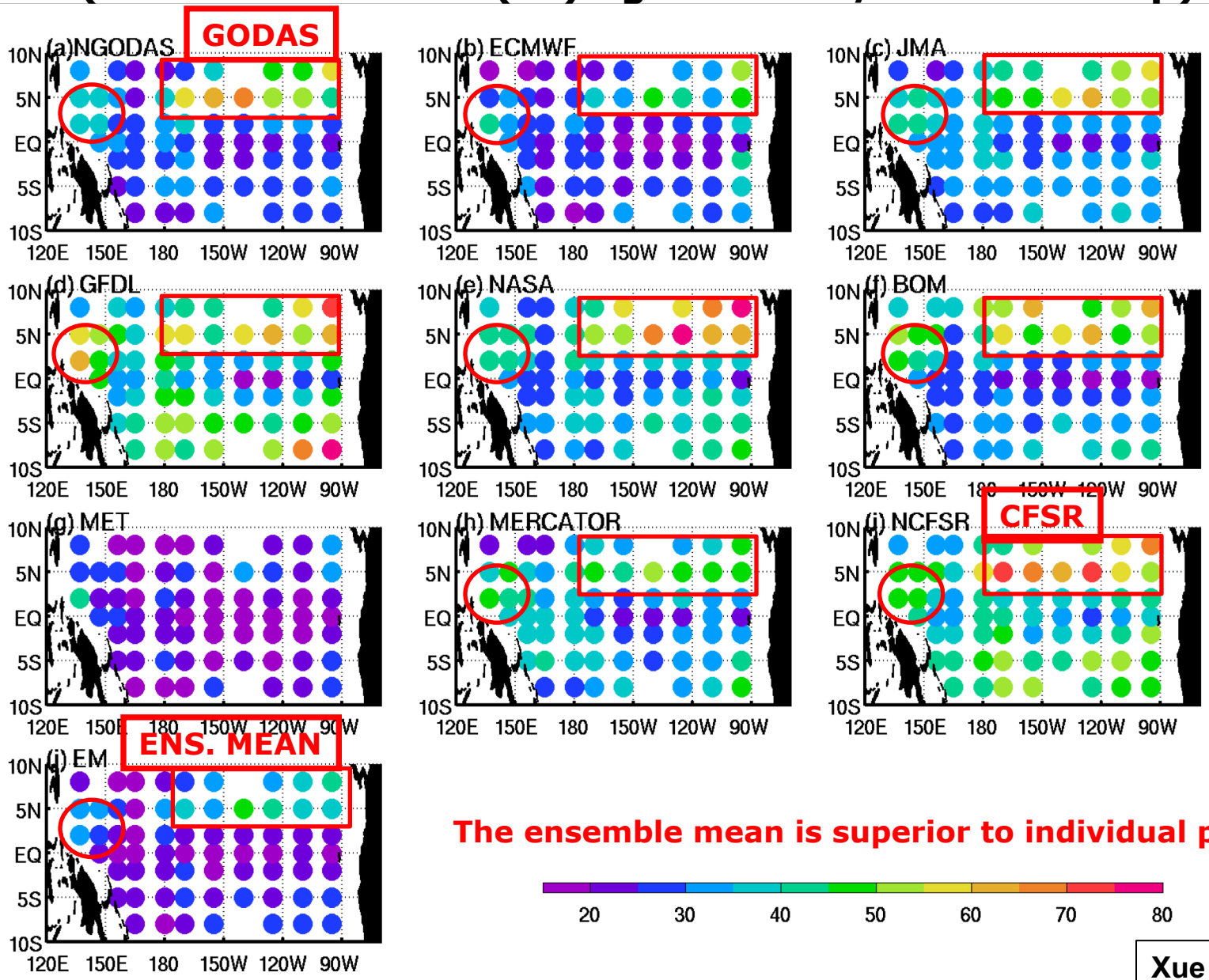


- **Extend CLIVAR-GSOP/GODAE OceanView Ocean Reanalyses Intercomparison Project (ORA-IP) into real-time**
- **Deliver ensemble ocean monitoring products with signal, noise and signal-to-noise ratio in real time**
- **Quantify uncertainties in the ocean state estimation in support of ENSO monitoring and prediction**
- **Monitor the influences of ocean observations on constraining uncertainties in ocean reanalyses**

6 products (1979-present) (http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html)
9 products (1993-present) (http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html)

Uncertainties in Ocean Reanalyses

(Normalized RMSD (%) against TAO/TRITON Temp)



The ensemble mean is superior to individual product

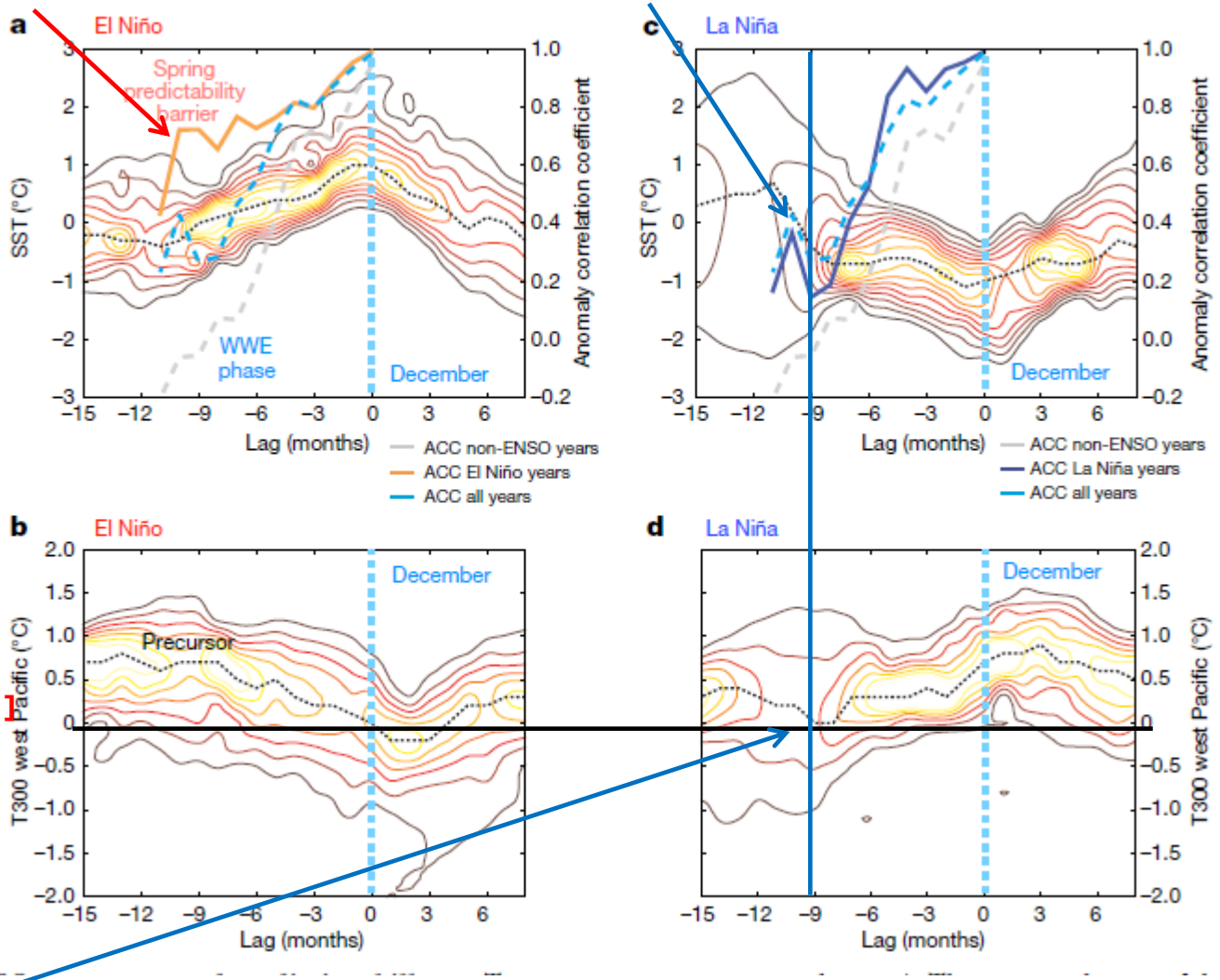
Xue et al. 2017

ENSO Forecast Skill & ENSO Precursors

Forecast Skill for El Niño

Forecast Skill for La Niña

North America Multi-Model Ensembles (NMME): 7 models and about 100 ensemble members



ENSO Precursors

HC300a [120°E-155°W, 5°S-5°N]

Poor forecast skill for La Niña is related to weak precursor

Timmermann et al. 2018, Nature

La Niña, its Precursor and Predictability

- **About 50% La Niña events last 2 years or longer (Okumura and Deser 2010 ; DiNezia and Deser 2014; Hu et al. 2014)**

- **There is a predictability of forecasting the 2 year La Niña when initialized from "strong peak El Niño" or "strong discharged state" following the peak El Niño, which indicates a strong persistence from ocean memory due to the weak instability during La Niña (Luo et al. 2010; DiNezia et al. 2017)**

- **The ocean precursors for 2 year La Niña are not well understood**

Is a strong 1st year La Niña necessary for developing a 2nd year La Niña (Hu et al. 2014)?

- The strong 1988/89 La Niña lasted only one year, while the weak 2016/17 La Niña is followed by a 2nd year La Niña

Is a strong peak El Niño needed for developing a 2 year La Niña (DiNezia et al. 2017)?

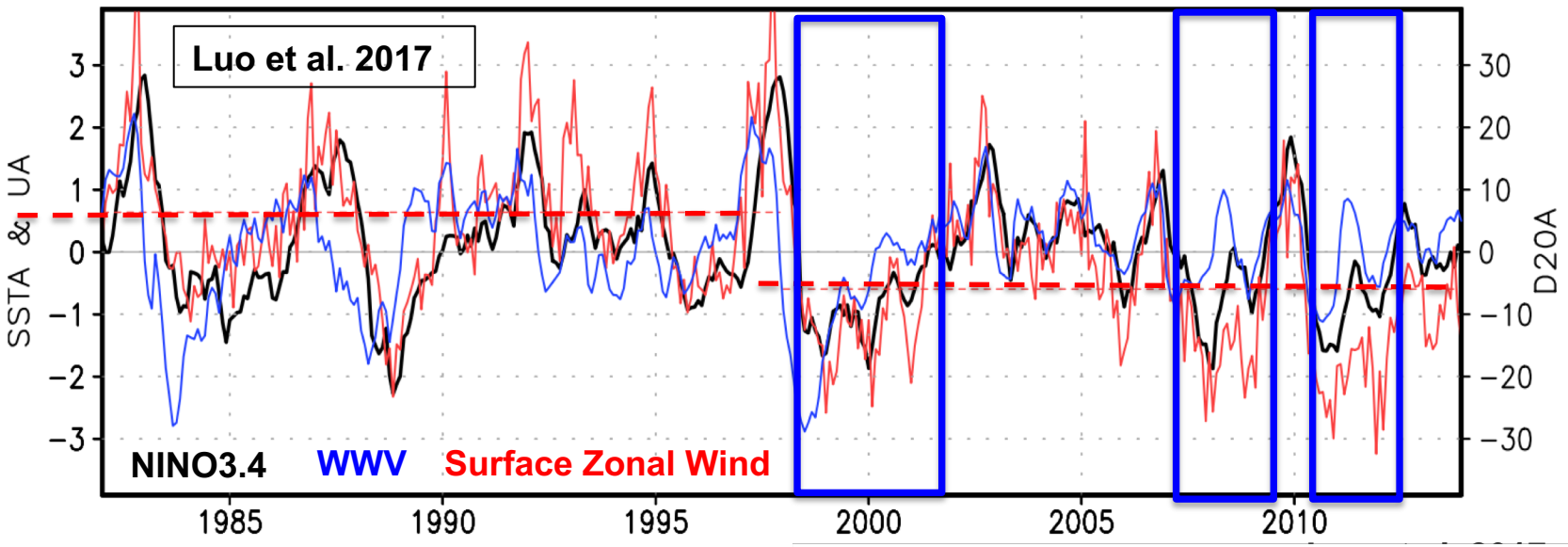
- The weak 2006/07 El Niño is followed by a 2 year La Niña

- **What are the ocean precursors for El Niño and La Niña?**

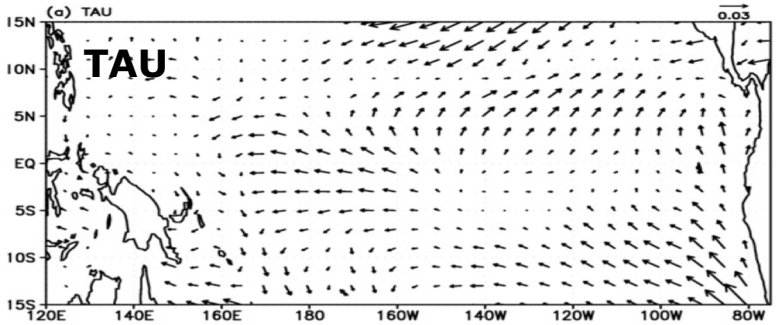
- **Can we use the ocean precursors to assist real-time ENSO prediction?**

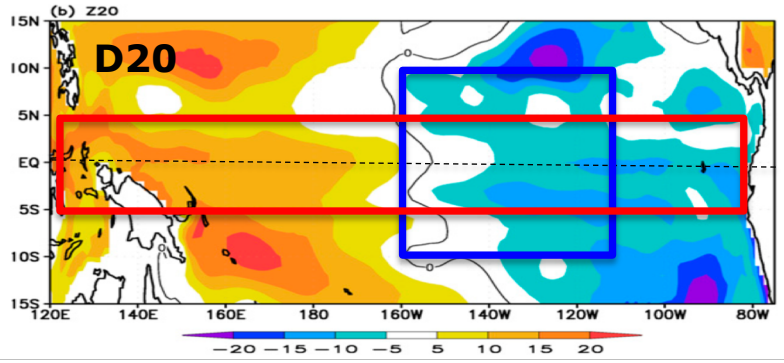
- **Are the NMME ENSO forecast false alarms related to the ocean precursors?**

Decadal Shift around 1999 and La Niña-like Conditions



Decadal Differences between 1999-2012 and 1980-1998





Two ENSO precursors were discussed (Wen et al. 2014)

Warm Water Volume Index (D20a in 120°E-80°W, 5°S-5°N)

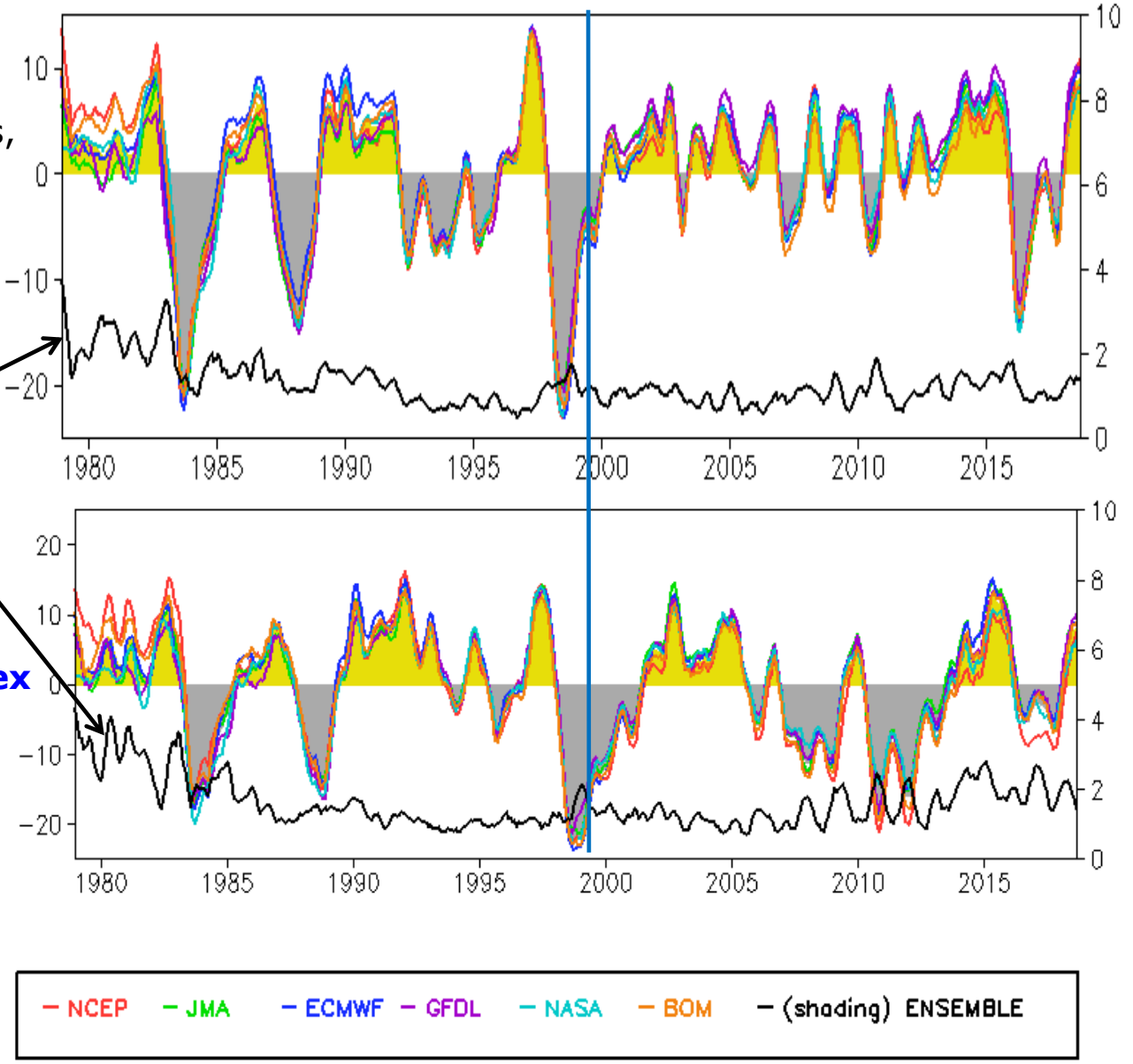
Central Tropical Pacific Index (D20a in 160°W-110°W, 10°S-10°N)

Two ENSO Precursors Based on Ensemble Ocean Reanalyses

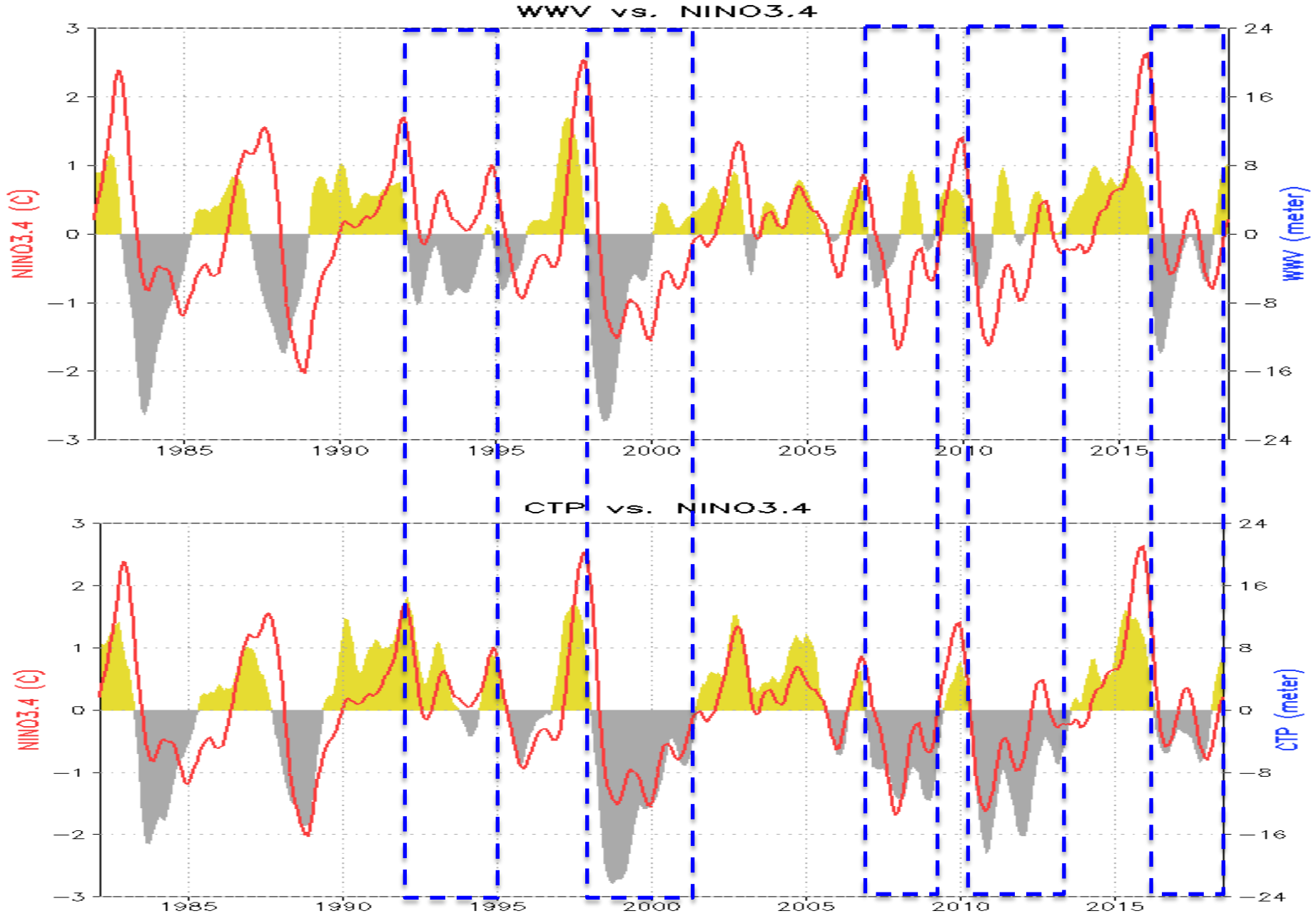
Warm Water Volume
(leads NINO3.4 by 6-9 months,
Meinen and McPhaden 2000)

Ensemble Spread

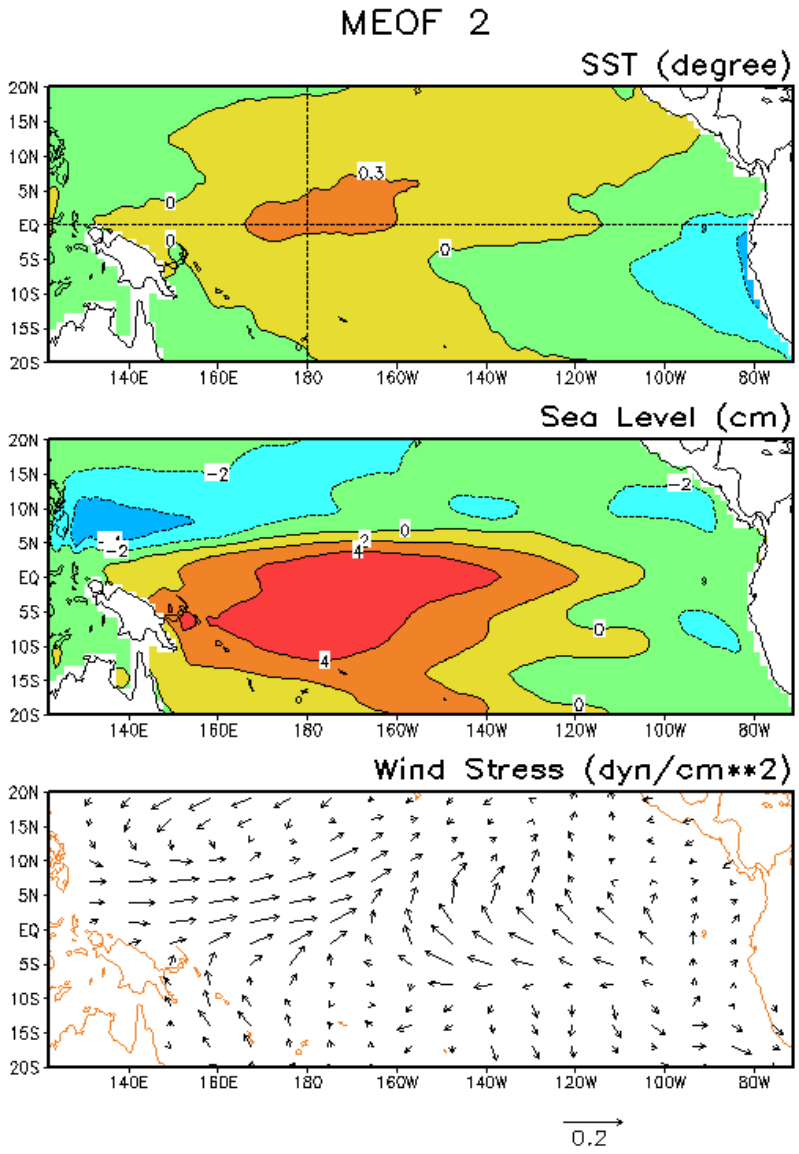
Central Tropical Pacific Index

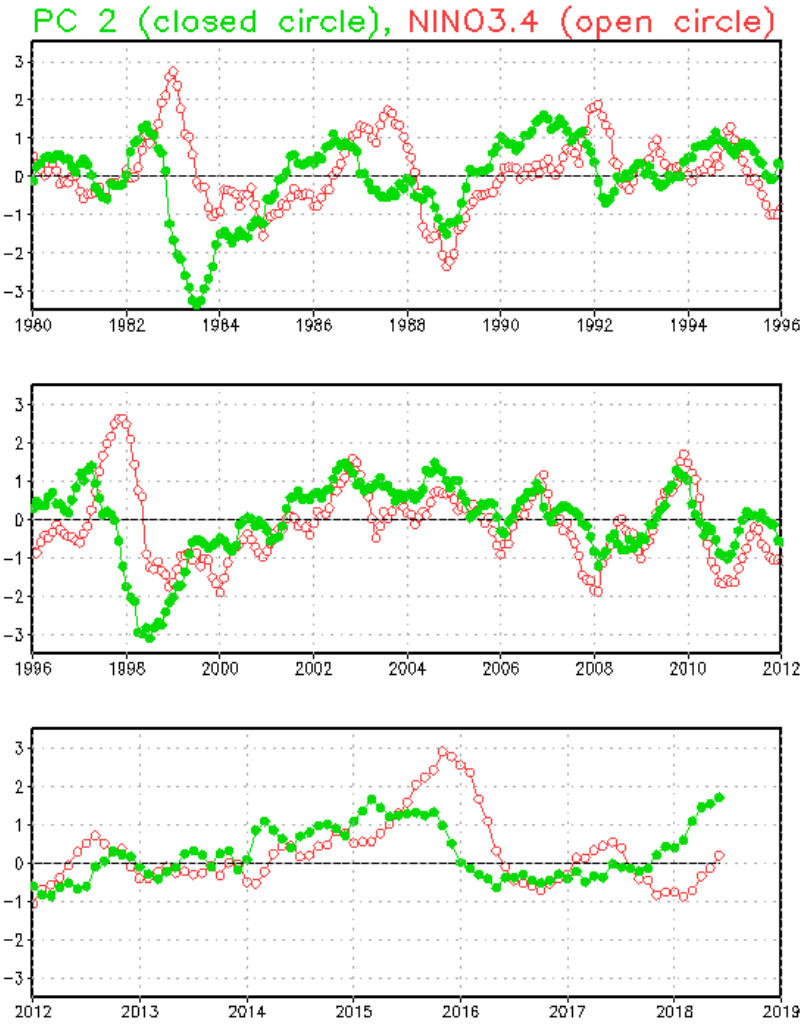


ENSO Precursors vs. NINO3.4



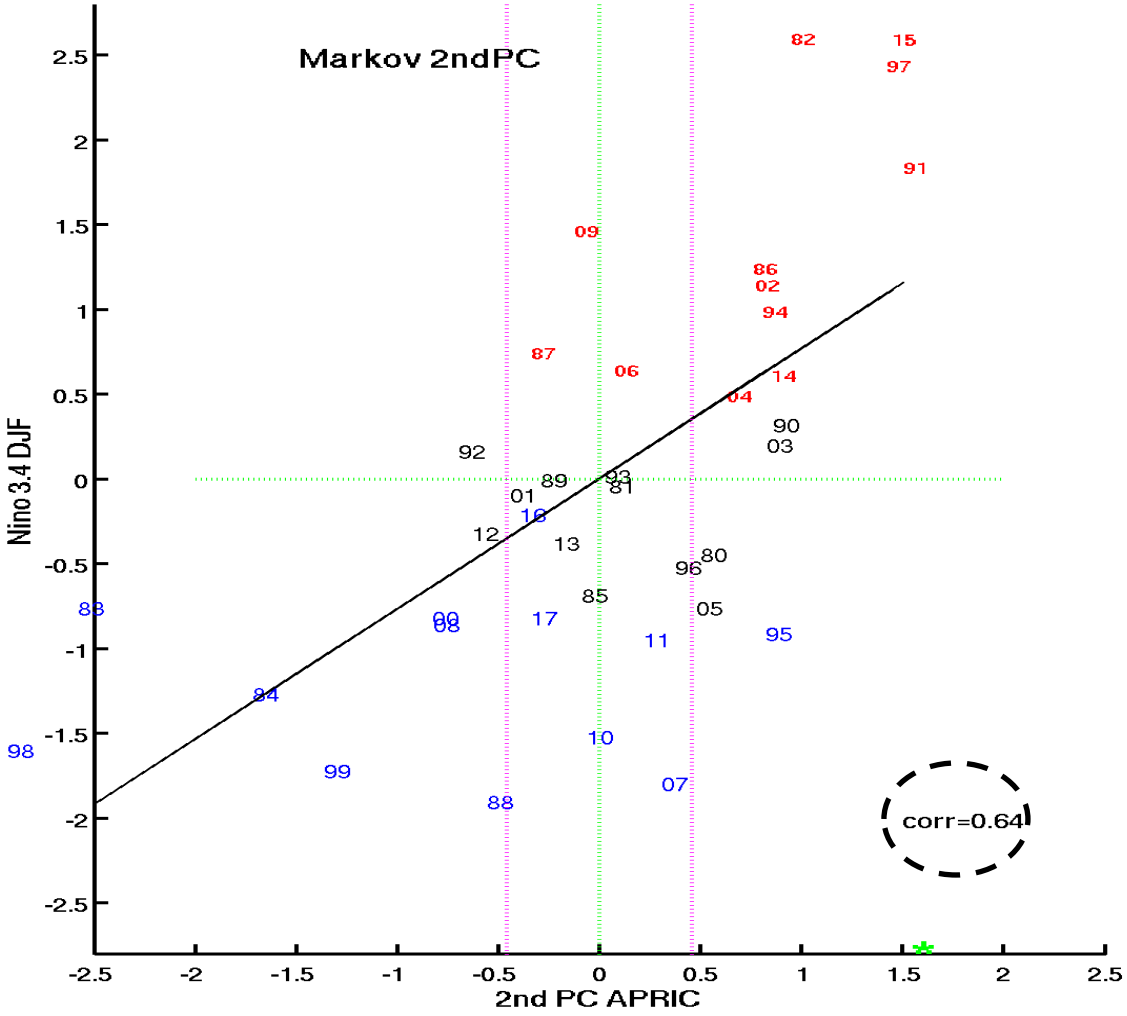
Markov PC2 vs. Nino3.4 (DJF)



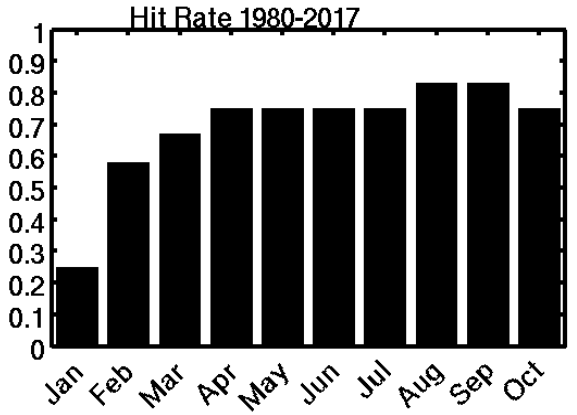


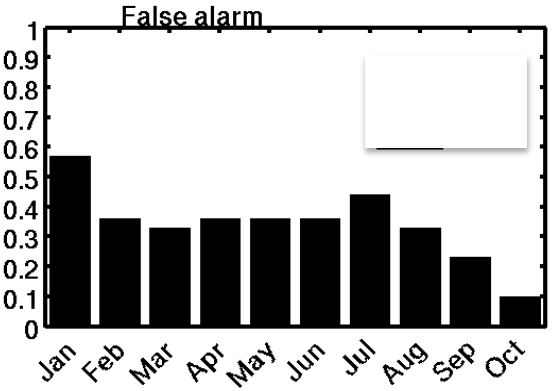
http://www.cpc.ncep.noaa.gov/products/people/yxue/ENSO_forecast_clim81-10_godas.html

Markov PC2 in Apr vs. Nino3.4 in DJF

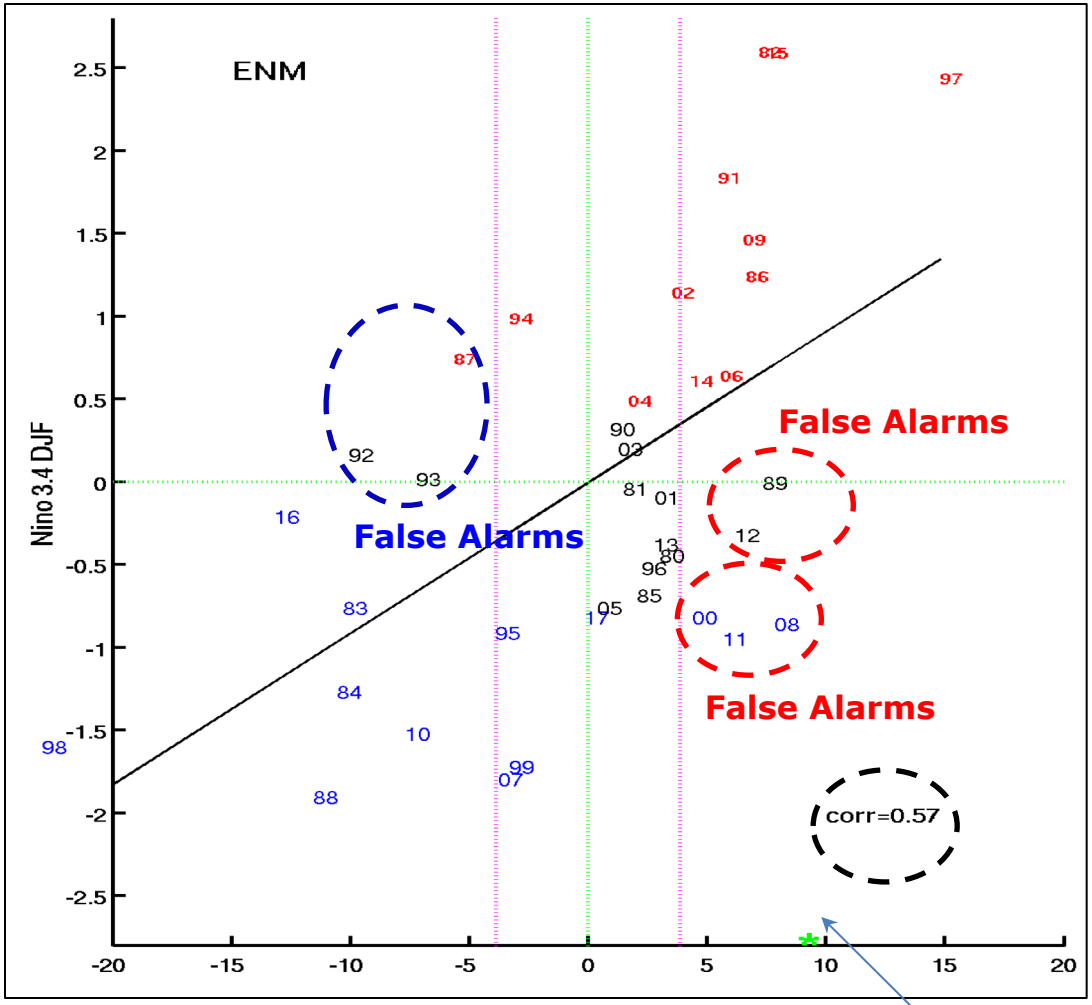


2x2 contingency table El Niño (1980-2017)	Apr Criterion: 0.5 = 0.5 STD
Percent correct rate	0.8 (30/38)
Hit rate	0.75 (9/12)
False alarm rate	0.36 (5/14)





Warm Water Volume in June vs. NINO3.4 in DJF



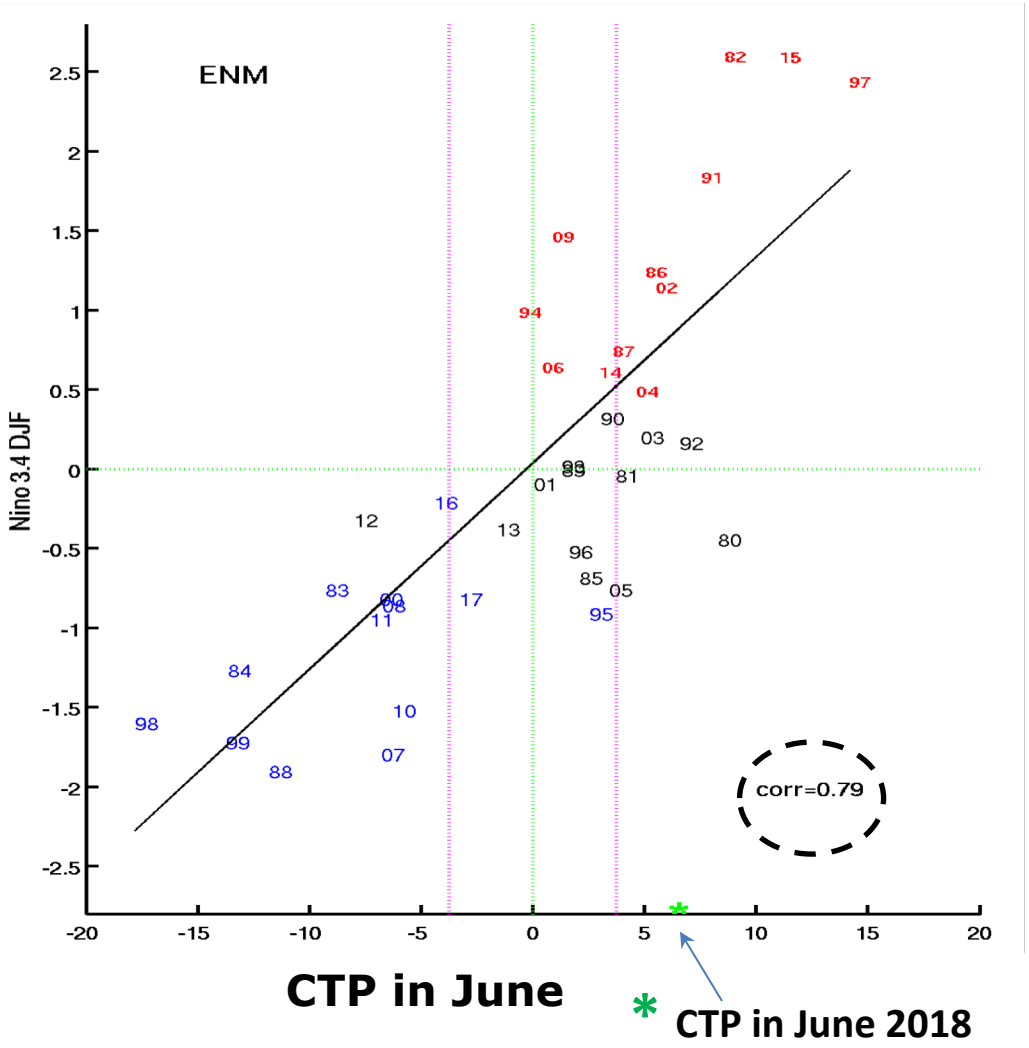
WWV in June * **WWV in June 2018**

2x2 contingency table El Niño (1980-2017)	June Criterion: 3.9 = 0.5 STD
Percent correct rate	0.76 (29/38)
Hit rate	0.67 (8/12)
False alarm rate	0.4 (5/13)

2x2 contingency table La Niña (1980-2017)	June Criterion: -3.9 = -0.5 STD
Percent correct rate	0.76 (29/38)
Hit rate	0.54 (7/13)
False alarm rate	0.3 (5/10)

Data downloadable from http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

Central Tropical Pacific in June vs. NINO3.4 in DJF



2x2 contingency table El Niño (1980-2017)	June Criterion: 3.8 = 0.5 STD
Percent correct rate	0.8 (30/38)
Hit rate	0.6 (7/12)
False alarm rate	0.3 (3/10)

2x2 contingency table La Niña (1980-2017)	June Criterion: -3.8 = -0.5 STD
Percent correct rate	0.92 (35/38)
Hit rate	0.85 (11/13)
False alarm rate	0.08 (1/12)

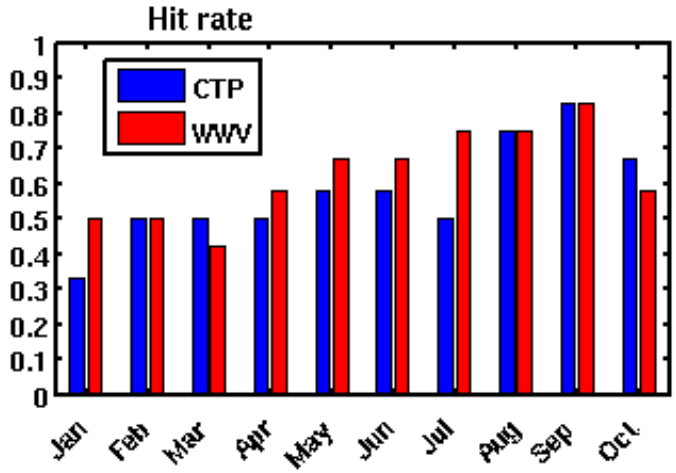
CTP is the best precursor for forecasting La Niña

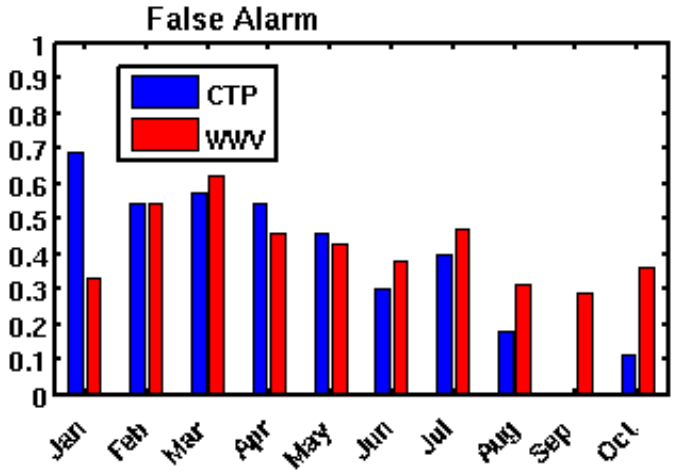
Data downloadable from http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

Contingency Tables for ENSO Prediction in 1980-2016

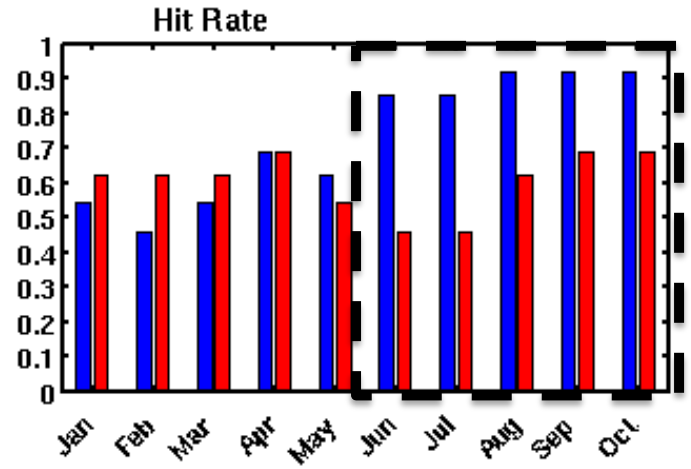
NINO3.4 Target Season: DJF

EL NINO

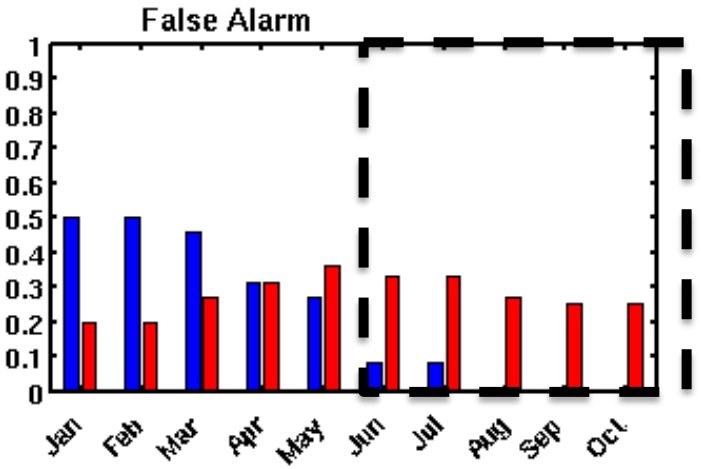




LA NINA



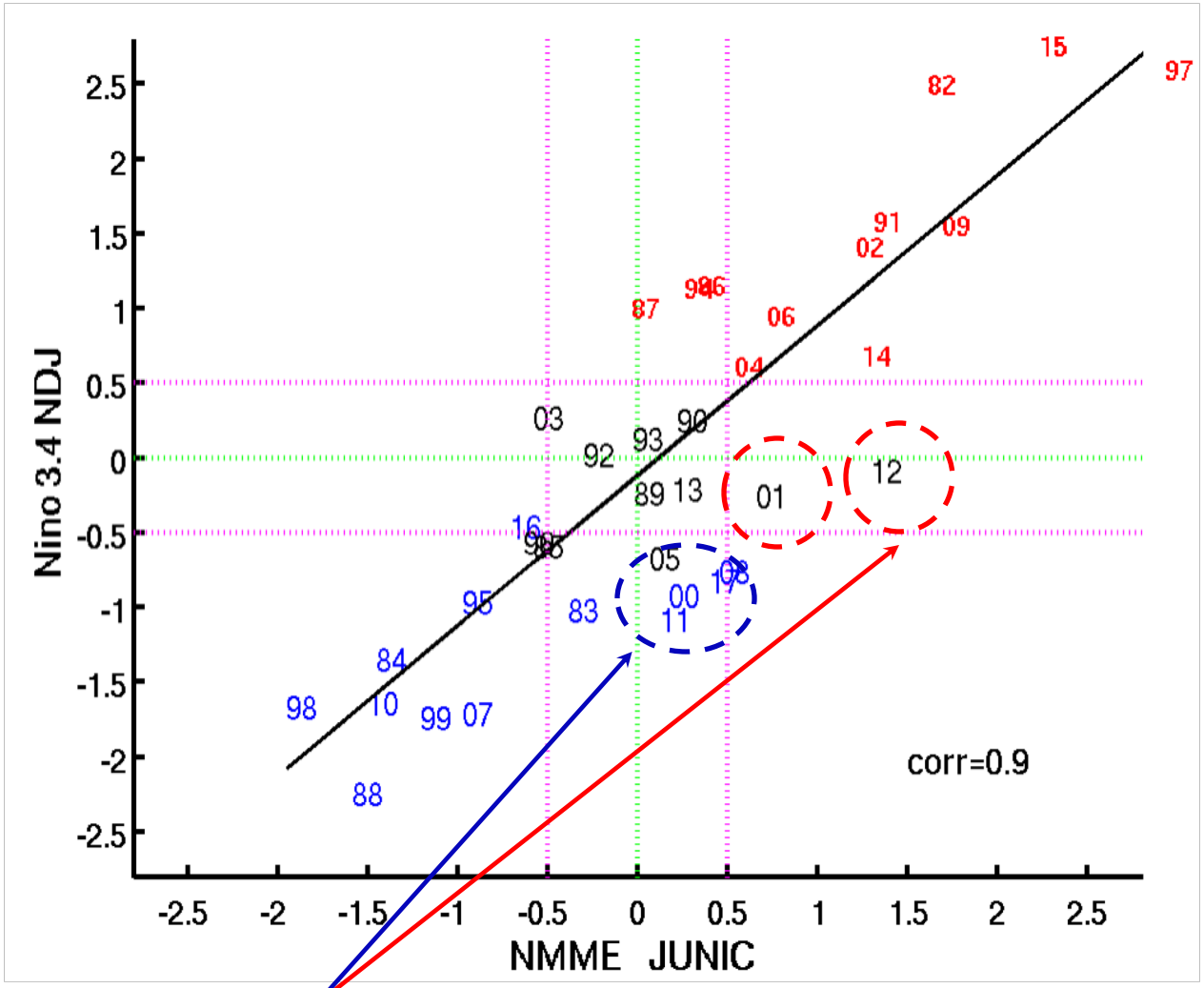
IC month



IC month

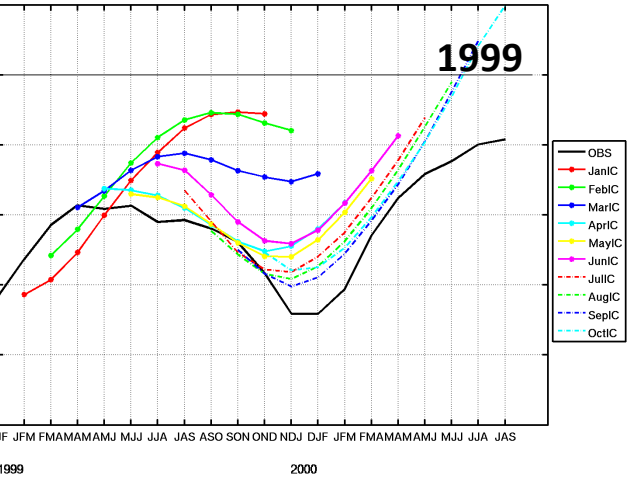
NMME NINO3.4 vs. Observed NINO3.4

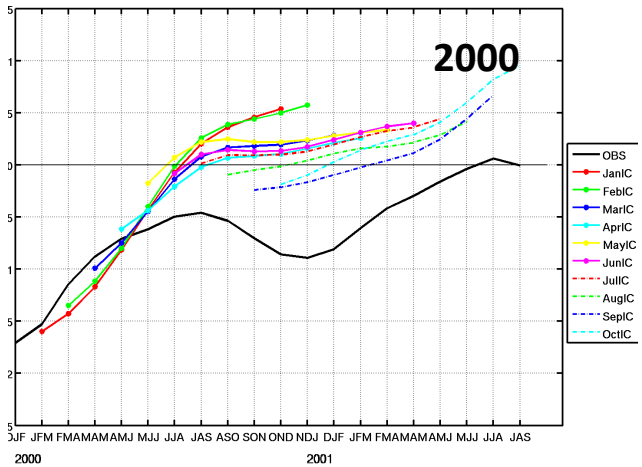
Obs NINO3.4 in NDJ

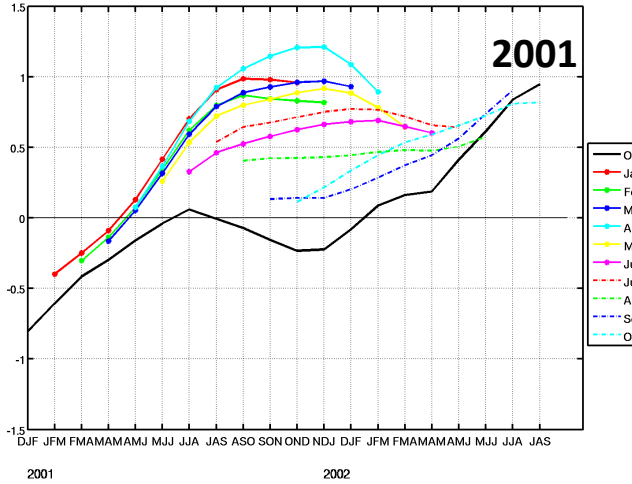


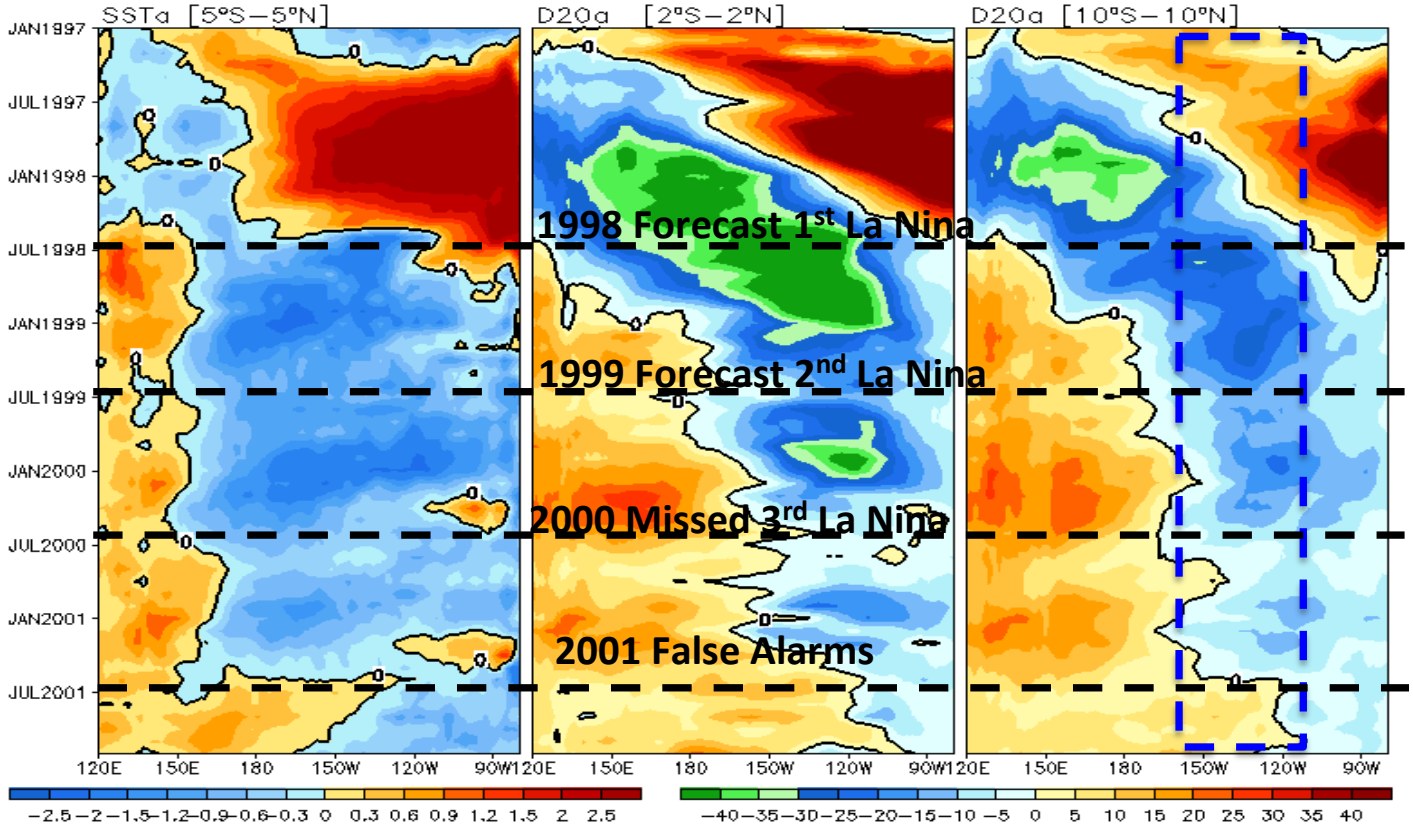
NMME Forecast from Jun 1

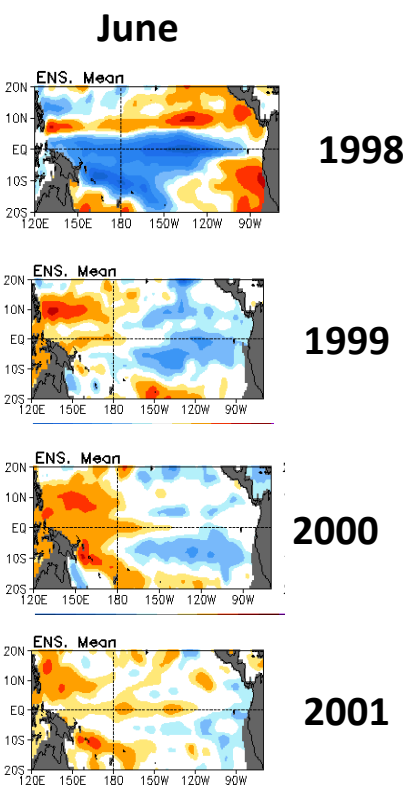
False alarms in 00, 08, 11, 17 (2nd La Niña years)→ CTP is negative
False alarms in 01, 12 (neutral years following 2nd, 3rd La Niña years) → CTP is negative

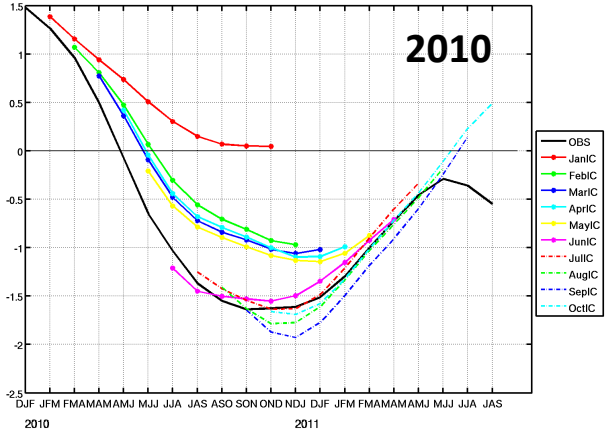

1999
OBS
JanIC
FebIC
MarIC
AprIC
MayIC
JunIC
JulIC
AugIC
SepIC
OctIC
JJA JAS ASO SON OND NDJ DJF JFM FMAMAMAMJ MJJ JJA JAS
1999
2000

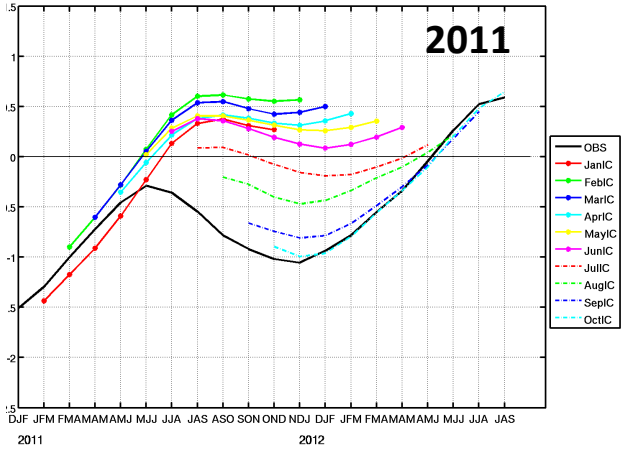

2000
OBS
JanIC
FebIC
MarIC
AprIC
MayIC
JunIC
JulIC
AugIC
SepIC
OctIC
DJF JFM FMAMAMAMJ MJJ JJA JAS ASO SON OND NDJ DJF JFM FMAMAMAMJ MJJ JJA JAS
2000
2001

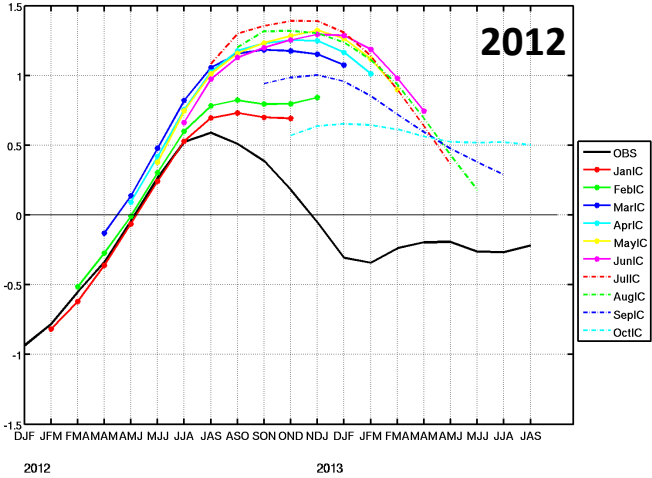

2001
DJF JFM FMAMAMAMJ MJJ JJA JAS ASO SON OND NDJ DJF JFM FMAMAMAMJ MJJ JJA JAS
2001
2002

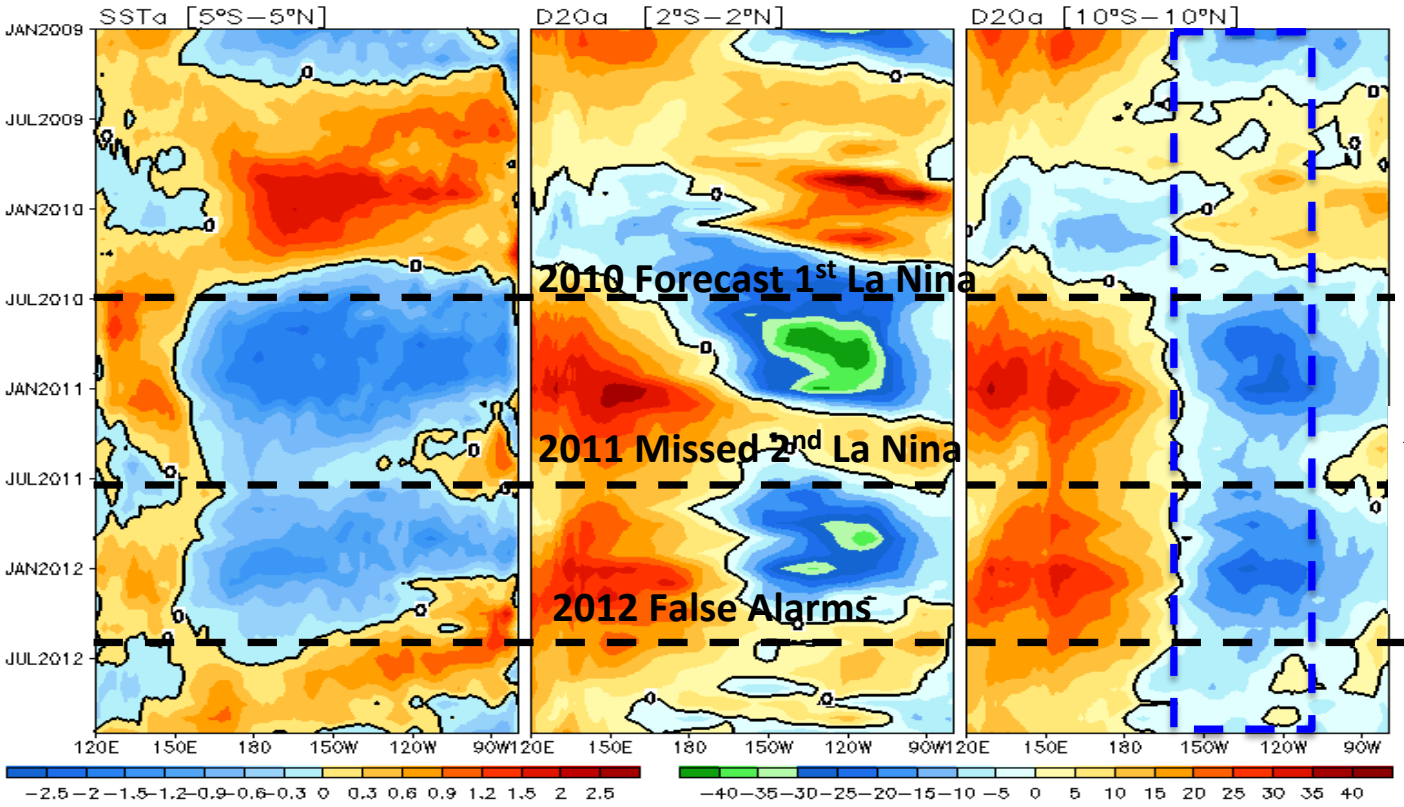

SSTa [5°S–5°N]
D20a [2°S–2°N]
D20a [10°S–10°N]
JAN1997
JUL1997
JAN1998
JUL1998
JAN1999
JUL1999
JAN2000
JUL2000
JAN2001
JUL2001
1998 Forecast 1st La Nina
1999 Forecast 2nd La Nina
2000 Missed 3rd La Nina
2001 False Alarms
120E 150E 180 150W 120W 90W
−2.5 −2 −1.5 −1.2 −0.9 −0.6 −0.3 0 0.3 0.6 0.9 1.2 1.5 2 2.5
−40 −35 −30 −25 −20 −15 −10 −5 0 5 10 15 20 25 30 35 40


June
ENS. Mean
20N
10N
EQ
10S
20S
120E 150E 180 150W 120W 90W
1998
1999
2000
2001


2010
OBS
JanIC
FebIC
MarIC
AprIC
MayIC
JunIC
JulIC
AugIC
SepIC
OctIC


2011
OBS
JanIC
FebIC
MarIC
AprIC
MayIC
JunIC
JulIC
AugIC
SepIC
OctIC


2012
OBS
JanIC
FebIC
MarIC
AprIC
MayIC
JunIC
JulIC
AugIC
SepIC
OctIC


SSTa [5°S–5°N]
D20a [2°S–2°N]
D20a [10°S–10°N]
JAN2009
JUL2009
JAN2010
JUL2010
JAN2011
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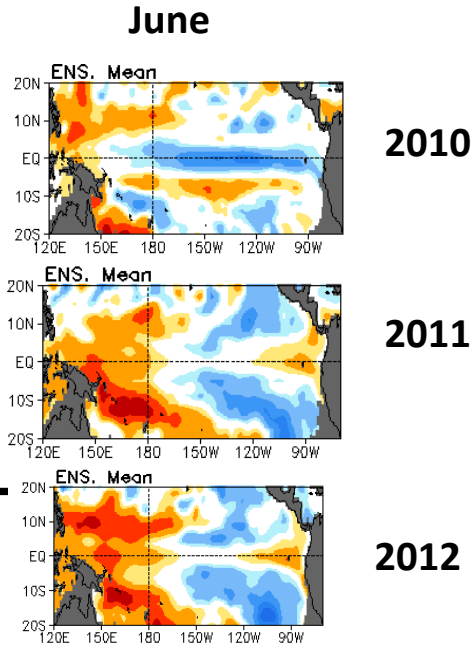
JAN2012
JUL2012
2010 Forecast 1st La Nina
2011 Missed 2nd La Nina
2012 False Alarms
120E 150E 180 150W 120W 90W
−2.5 −2 −1.5 −1.2 −0.9 −0.6 −0.3 0 0.3 0.6 0.9 1.2 1.5 2 2.5
−40 −35 −30 −25 −20 −15 −10 −5 0 5 10 15 20 25 30 35 40


June
ENS. Mean
20N
10N
EQ
10S
20S
120E 150E 180 150W 120W 90W
2010
2011
2012

Summary

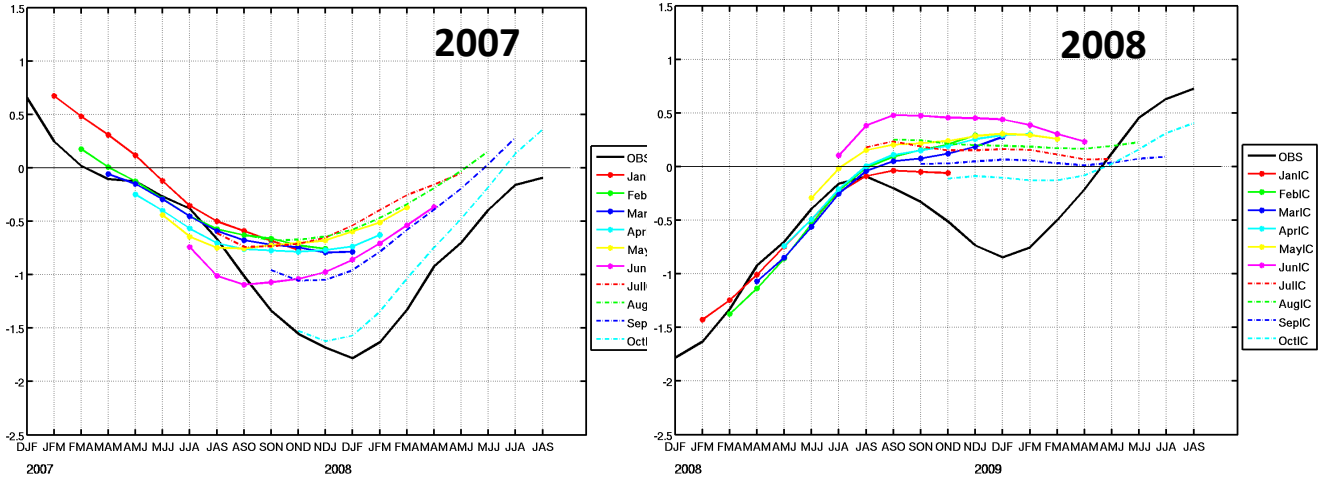
- Three ENSO precursors have been developed based on ensemble ocean reanalyses from Real-time Ocean Reanalysis Intercomparison Project
- The Markov PC2 is the best precursor for El Niño since it contains signals of both equatorial Warm Water Volume (WWV) and North Pacific Meridional Mode
- The Central Tropical Pacific (CTP) is the best precursor for La Niña since it contains both equatorial and off-equatorial thermocline variations
- The CTP has been used in identifying the false alarms in the NMME ensemble forecast, which are most prominent in forecasting 2nd year La Niña and neutral years following 2nd and 3rd year La Niña and are common across models
- We need to study the mechanism on how the off-equatorial D20 anom. contributes to the emergence of the 2nd and 3nd year La Niña, which can be used to understand the causes of the NMME forecast false alarms
- Those false alarm cases can be used in evaluating the next generation of seasonal forecast systems

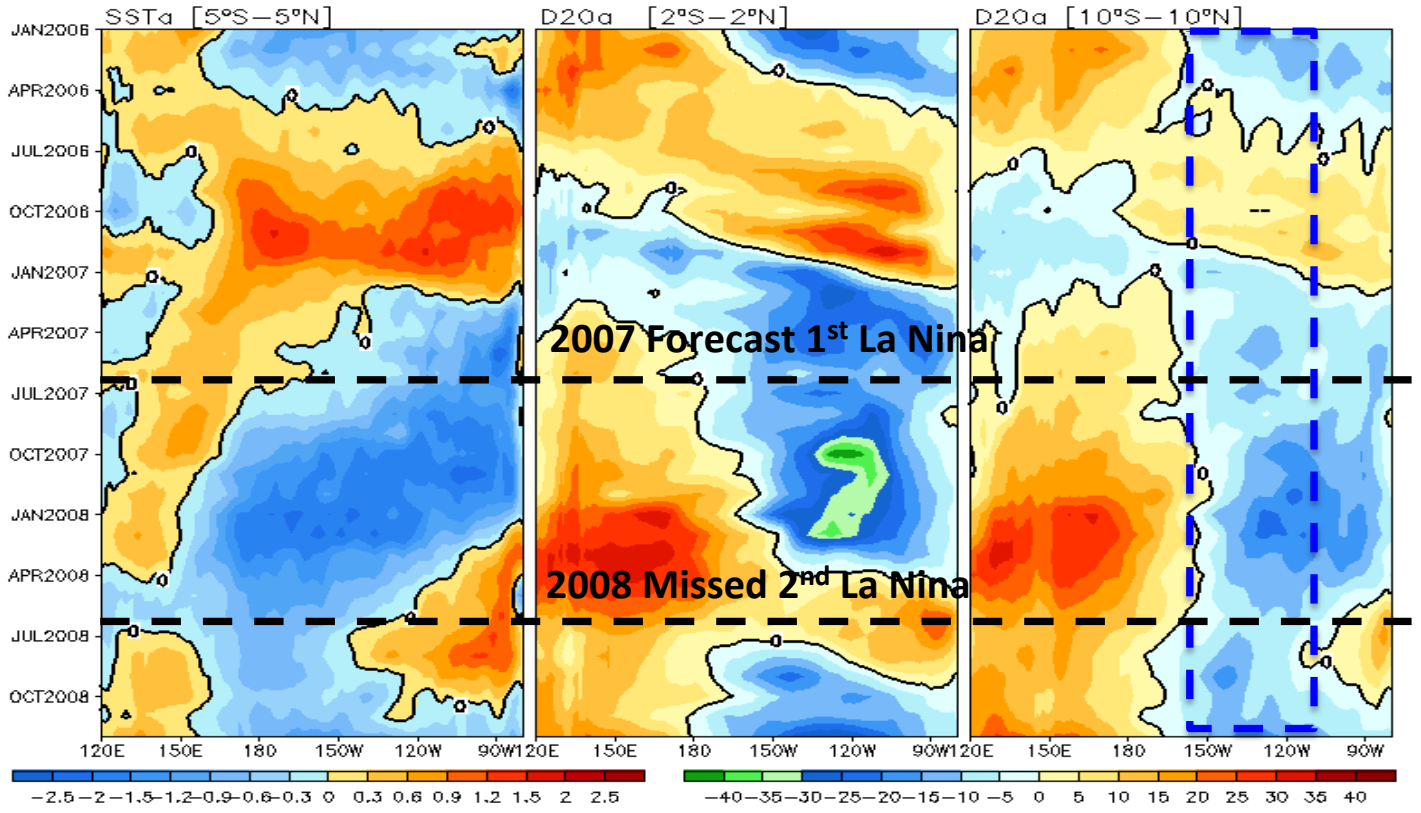
		Event Observed	
		YES	NO
Event Forecasts	YES	A (hits)	B (false alarms)
	NO	C (misses)	D (correct rejection)

Percent correct rate = (A+D)/(A+B+C+D)

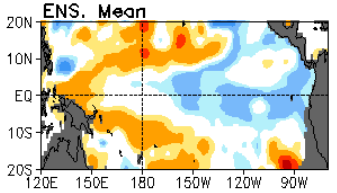
Hit rate = A/(A+C)

False alarm rate = B/(A+B)

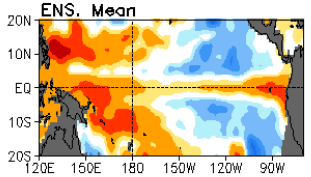




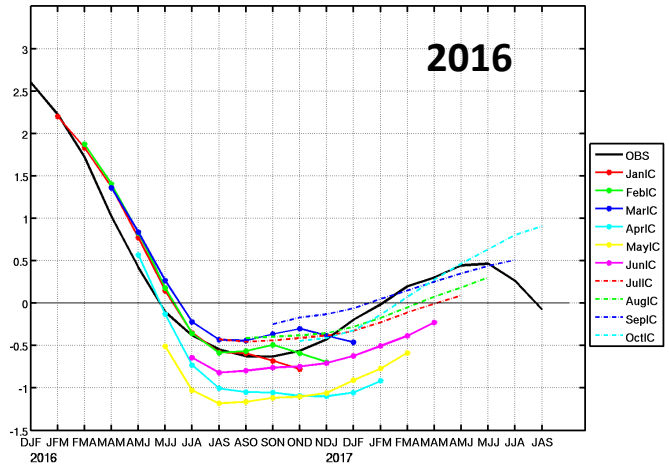
June

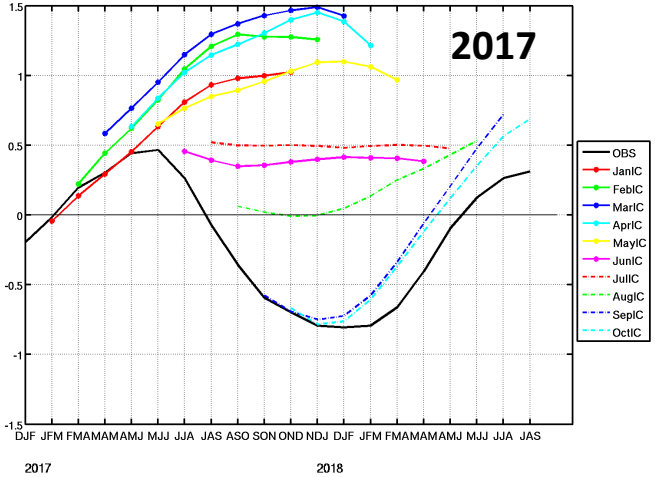


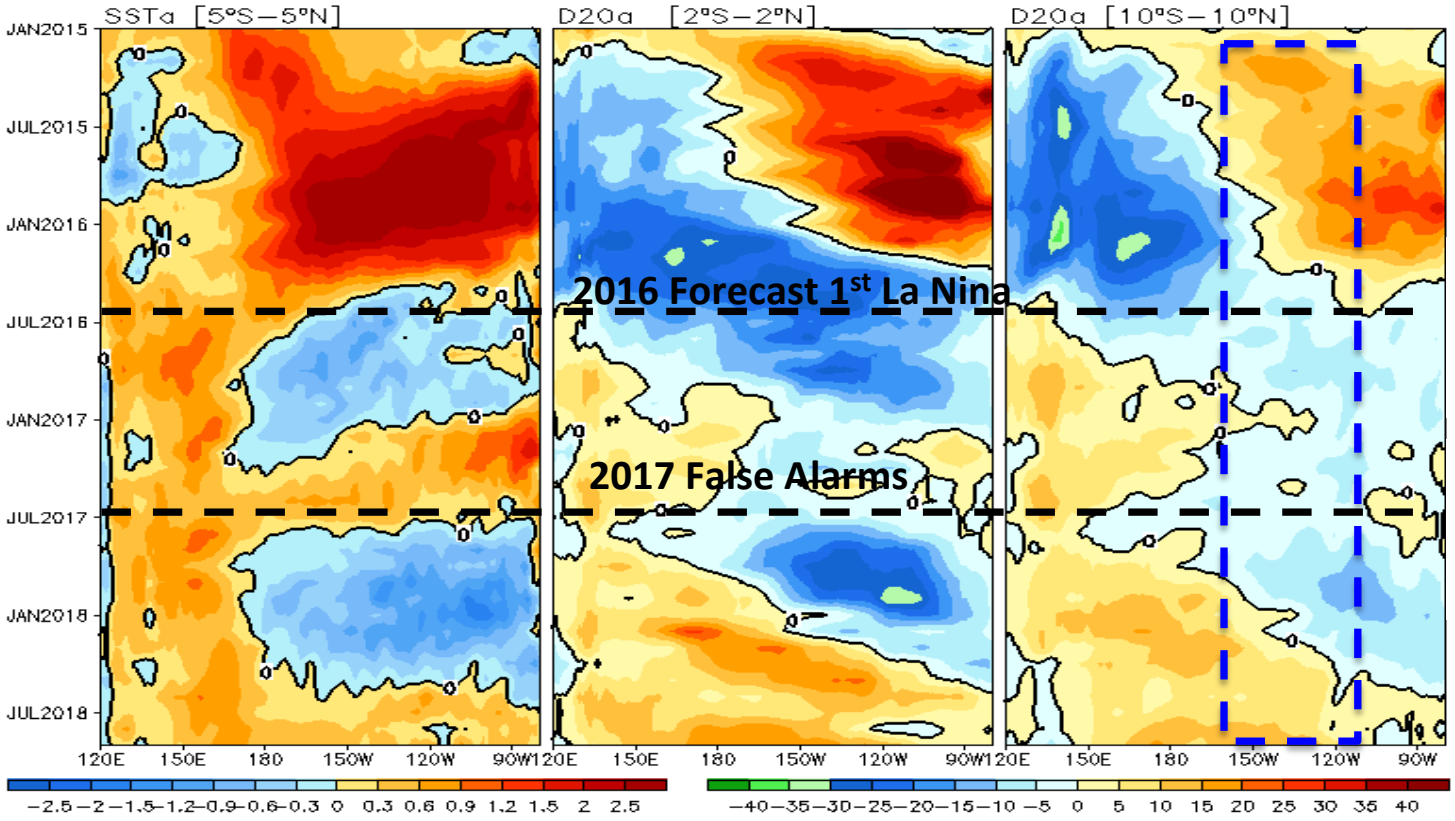
2007



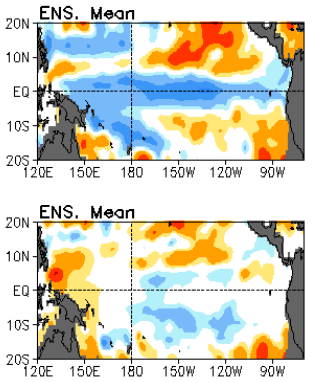
2008





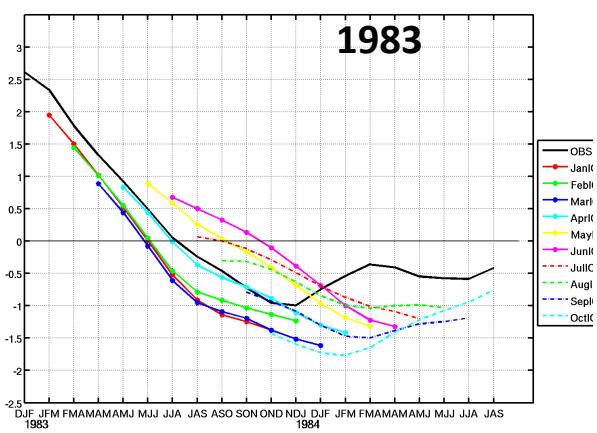


June



2016

2017


1983
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MarIC
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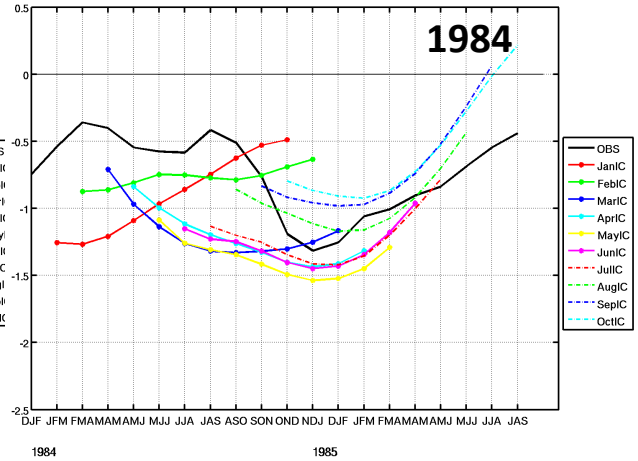
1983
1984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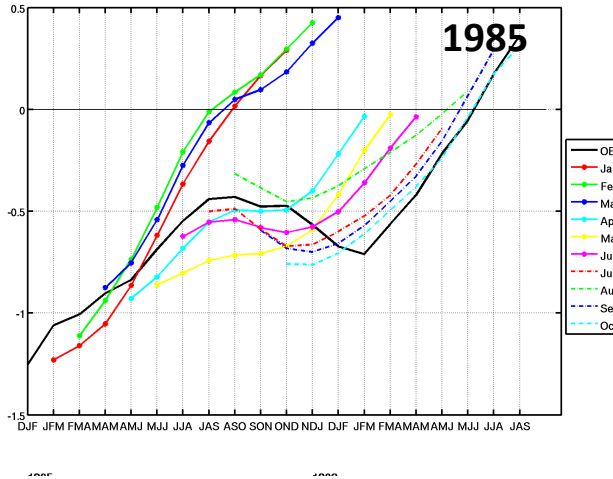
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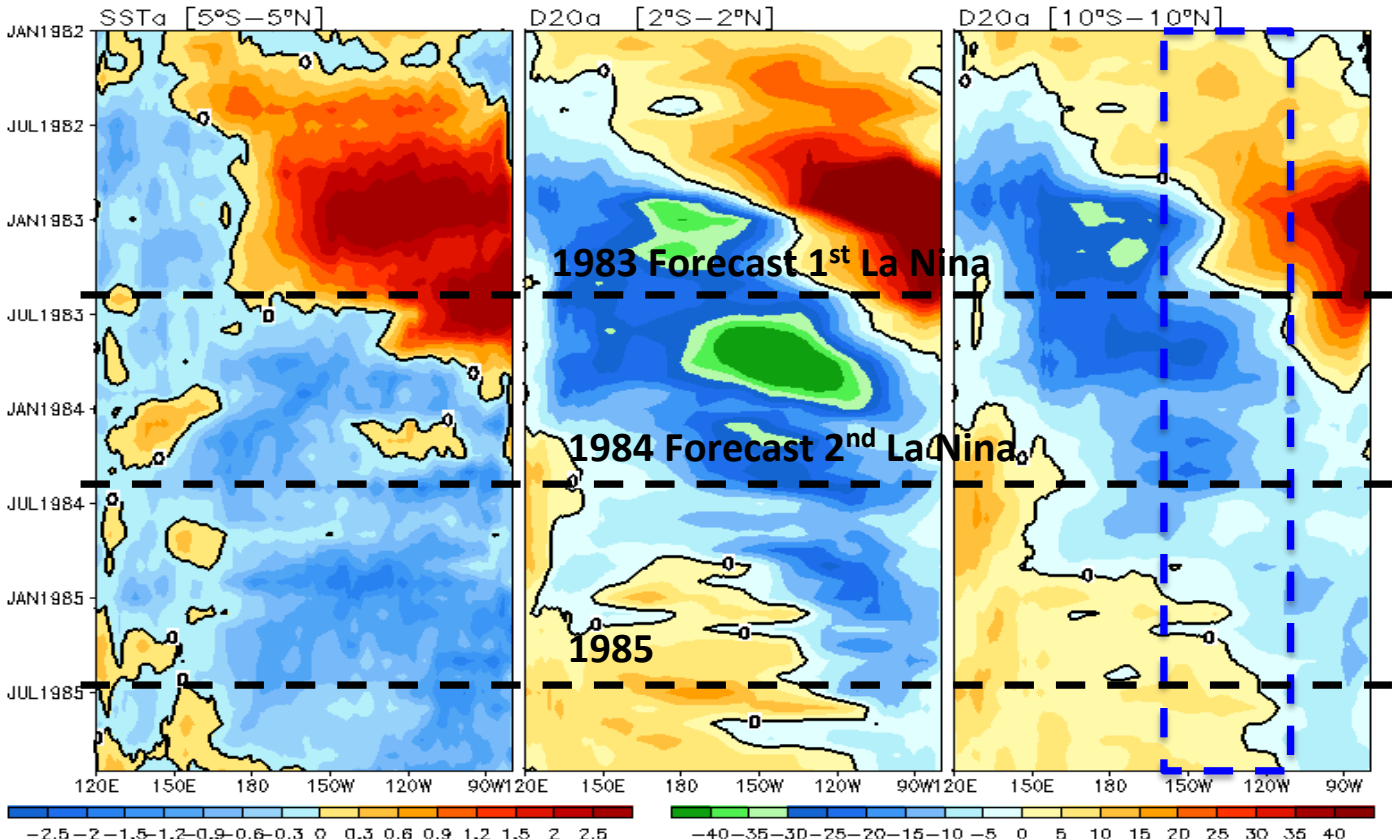
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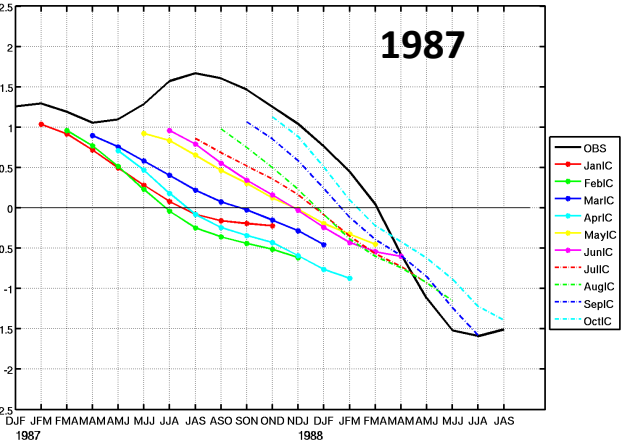
D20a [2°S–2°N]
D20a [10°S–10°N]
JAN1982
JUL1982
JAN1983
JUL1983
JAN1984
JUL1984
JAN1985
JUL1985
1983 Forecast 1st La Nina
1984 Forecast 2nd La Nina
1985
120E 150E 180 150W 120W 90W
−2.5 −2 −1.5 −1.2 −0.9 −0.6 −0.3 0 0.3 0.6 0.9 1.2 1.5 2 2.5
−40 −35 −30 −25 −20 −15 −10 −5 0 5 10 15 20 25 30 35 40

June

1983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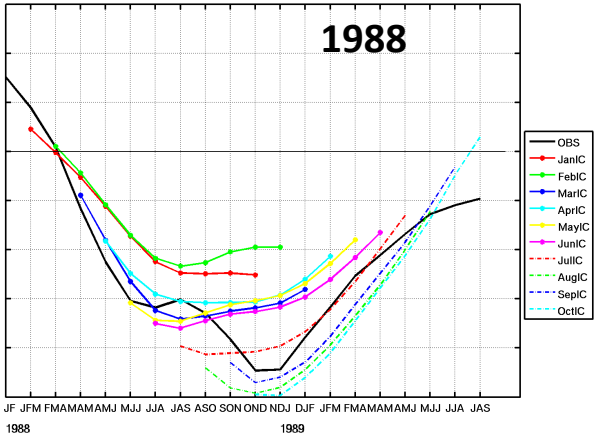
DJF JFM FMAMAMJ MJJ JJA JAS ASO SON OND NDJ DJF JFM FMAMAMJ MJJ JJA JAS
1987
1988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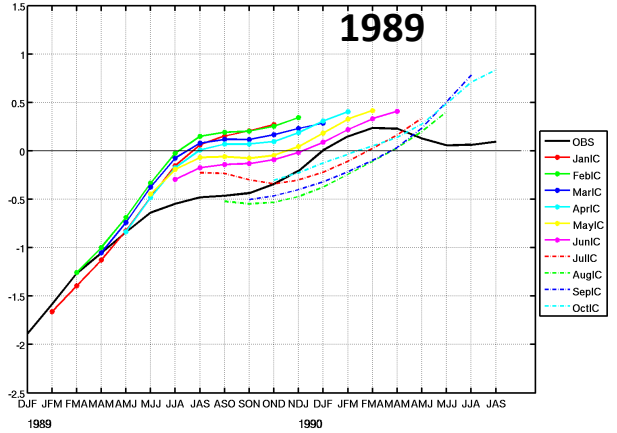
1988
1989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OBS
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MarIC
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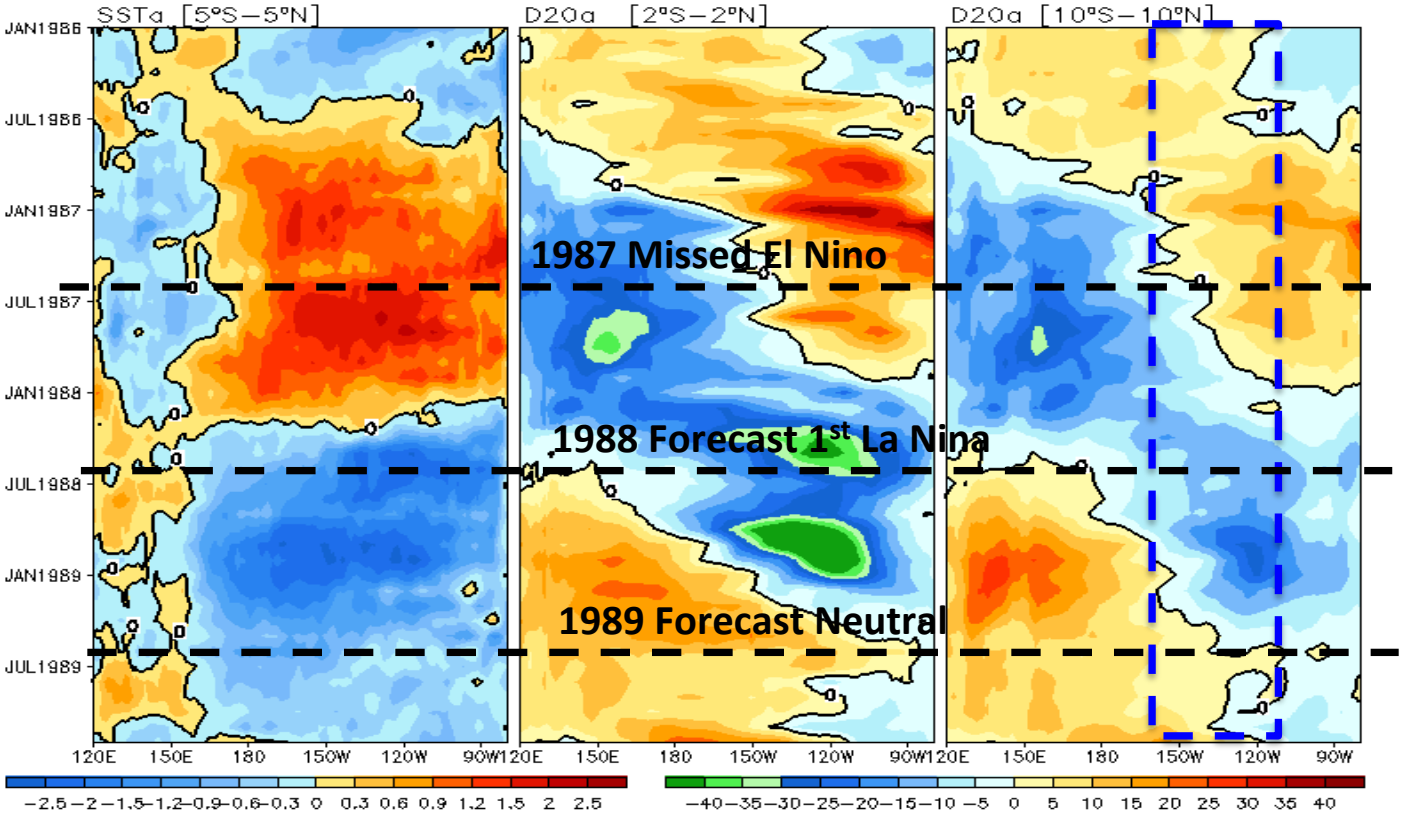
DJF JFM FMAMAMJ MJJ JJA JAS ASO SON OND NDJ DJF JFM FMAMAMJ MJJ JJA JAS
1989
1990


SSTa [5°S–5°N]
D20a [2°S–2°N]
D20a [10°S–10°N]
JAN1986
JUL1986
JAN1987
JUL1987
JAN1988
JUL1988
JAN1989
JUL1989
1987 Missed El Nino
1988 Forecast 1st La Nina
1989 Forecast Neutral
120E 150E 180 150W 120W 90W
−2.5 −2 −1.5 −1.2 −0.9 −0.6 −0.3 0 0.3 0.6 0.9 1.2 1.5 2 2.5
−40 −35 −30 −25 −20 −15 −10 −5 0 5 10 15 20 25 30 35 40

June

1987