Real-time Ocean Reanalyses Intercomparison for Quantifying Uncertainties in Ocean Reanalyses and Monitoring Climate Variability

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[7] JPL/NASA, USA

[8] CPO/NOAA, USA

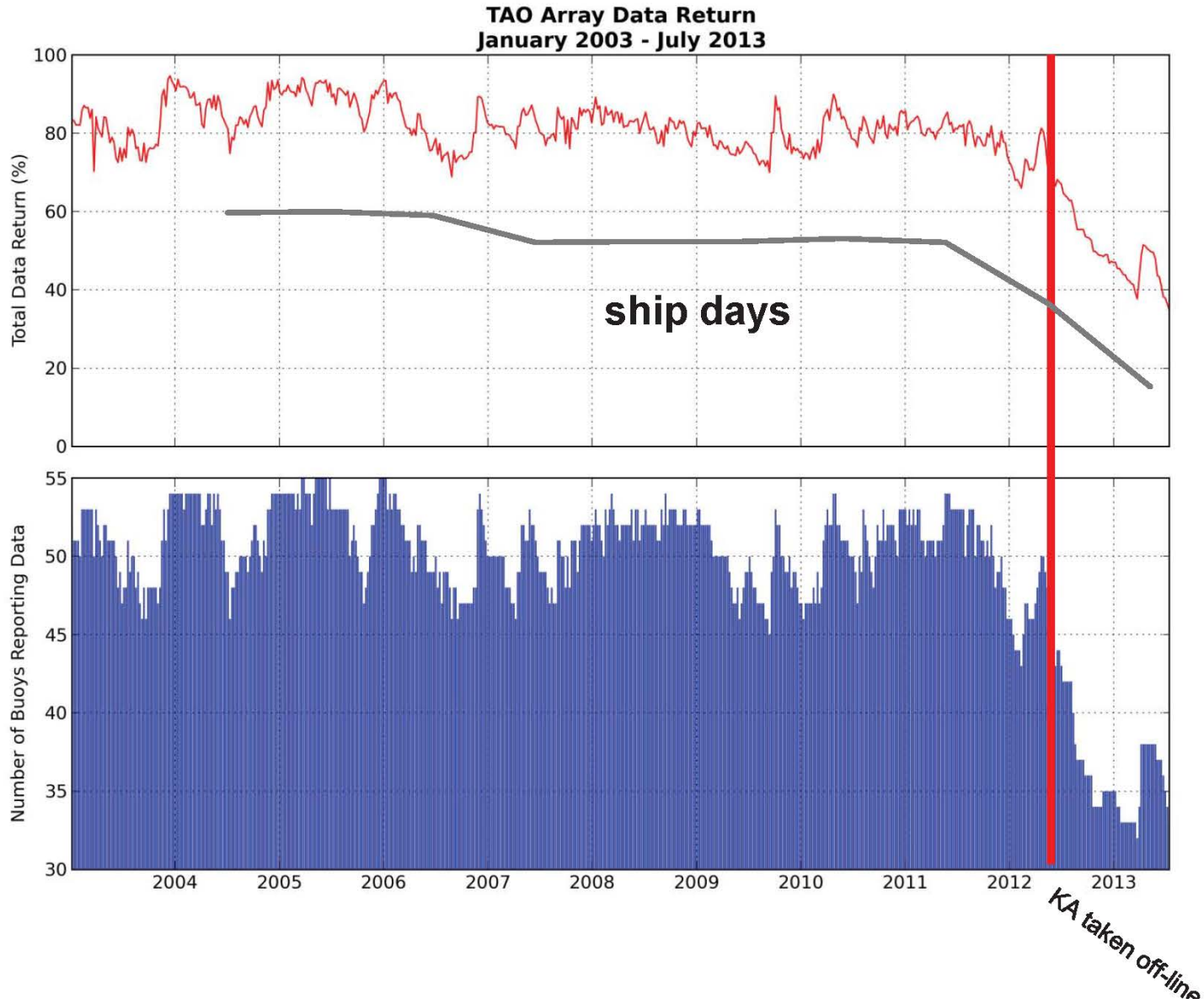
GSOP and pan-CLIVAR meeting on July 14-18, 2014, Hague, Netherlands

CLIVAR-GSOP/GODAE OceanView Ocean Reanalysis Intercomparison (ORA-IP, 2013-2014)

- **Reanalysis production is an on-going activity**
- **New vintages are produced approximately every 5 years**
  - **Improved quality controlled observations (XBT corrections, Argo corrections and black lists)**
  - **Improved and extended forcing fluxes**
  - **Improved models and methods**
- **We need to assess uncertainties among ocean reanalyses (through intercomparison and validation with independent data)**
- **We need to facilitate the use of ocean reanalyses by other communities**
- **We need to prepare for quasi-real time monitoring of the ocean**

Climate Observation Division

Historical TAO reporting + ship resourcing



Tropical Pacific Observing System (TPOS) 2020 Workshop

(January 27-30, 2014, La Jolla, CA)

- **Highlight the impacts** of the tropical Pacific observing system on information/services of societal relevance – **ENSO monitoring and prediction**
- **Evaluate existing and potential requirements** for sustained observations of ocean variables in tropical Pacific Ocean – **uncertainties in ocean estimation in tropical Pacific**
- **Evaluate the adequacy of existing observing strategies**
- **Recommend revisions and/or adjustments** to enhance resilience, efficiency, integration.
- **Evaluate logistical requirements** for implementation of the recommended Tropical Pacific Observing System.
- **Assess readiness of new technologies**, their potential impact and feasibility in addressing requirements, and/or lowering costs per observation.

Courtesy of David Legler

Operational Ocean Reanalyses

Name	Method & Forcings	In Situ Data	Altimetry Data	Resolution	Period	Vintage	Reference
EN3.v2a	Analysis Correction Scheme	No XBT corrections	No	1°x 1°, 42 Levels Monthly Temp.	1950-present	2009	Ingleby and Huddleston (2007)
NODC	Objective Analysis	No XBT corrections	No	1°x 1°, 16 Levels, 0 to 700m Seasonal Temp.	1955-present	2010	Levitus et al. (2009)
GODAS	3D-VAR	No XBT corrections	NO (Yes in real time)	1°x 1° (1/3° near Eq), 40 Levels Pentad, Monthly	1979-present	2003	Behringer and Xue (2004
ECMWF (S3)	OI	No XBT corrections	Yes	1°x1° (1/3° near Eq), 29 Levels Daily, Monthly	1959-present	2007	Balmaseda et al. (2008)
JMA	3D-VAR	No XBT corrections	Yes	1°x1° (1/3° near Eq), 50 Levels Pentad, Monthly	1979-present	2009	Usui et al. (2006)
CFSR	3D-VAR Partially coupled	No XBT corrections	No (Yes in real time)	1/2°x 1/2° (1/4° near Eq), 40 Levels Daily, Pentad, Monthly	1979-present	2010	Xue et al. (2010)
GFDL	EnKF Fully coupled	XBT corrections	Yes	1°x 1° (1/3° near Eq), 50 Levels Daily, Pentad, Monthly	1970-present	2010	Zhang et al. (2009)
GMAO	EnOI Fully coupled	XBT corrections	No	1/2°x 1/2° (1/4° near Eq), 40 Levels Daily, Monthly	1980-present	2011	Rienecker at al. (2011)
MERCATOR (PSY2G2)	KF-SEEK	No XBT corrections	Yes	2°x 2° (1/2° near Eq), 31 Levels Daily, Pentad, Monthly	1979-present	2007	Drévillon et al. (2008)
BOM (PEODAS)	EnKF	No XBT corretions	No	2°x 1.5 ° (1/2° near Eq.), 25 Levels Daily, Monthly	1980-present	2009	Yin et al. (2010)

Xue et al. 2012, J. Climate

Real-Time Ocean Renalyses Intercomparison

- **Extend CLIVAR-GSOP/GODAE OceanView Ocean Reanalyses Intercomparison Project (ORA-IP) into real time**
- **Assess uncertainties in temperature analysis of tropical Pacific in support of ENSO monitoring and prediction**
- **Explore any connections between gaps in ocean observations and spreads among ensemble ORAs**
- **Articulate needs for sustained ocean observing systems in support of TPOS2020**
- **Monitor signal-to-noise ratio in the global ocean temperature, 300m heat content, depth of 20C isotherm**

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

Real Time Multiple Ocean Reanalysis Intercomparison

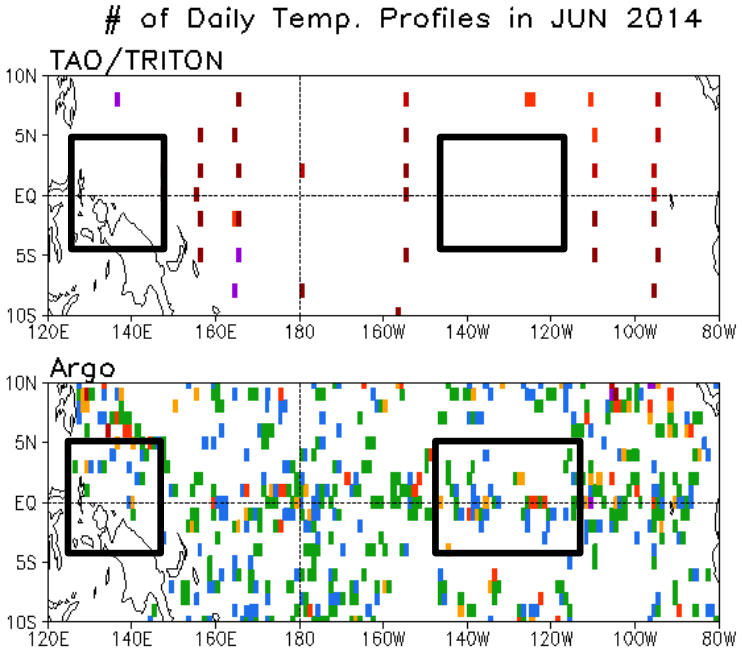
(with contributions from NCEP, ECMWF, JMA, GFDL, NASA, BOM based on 1981-2010 Climatology)

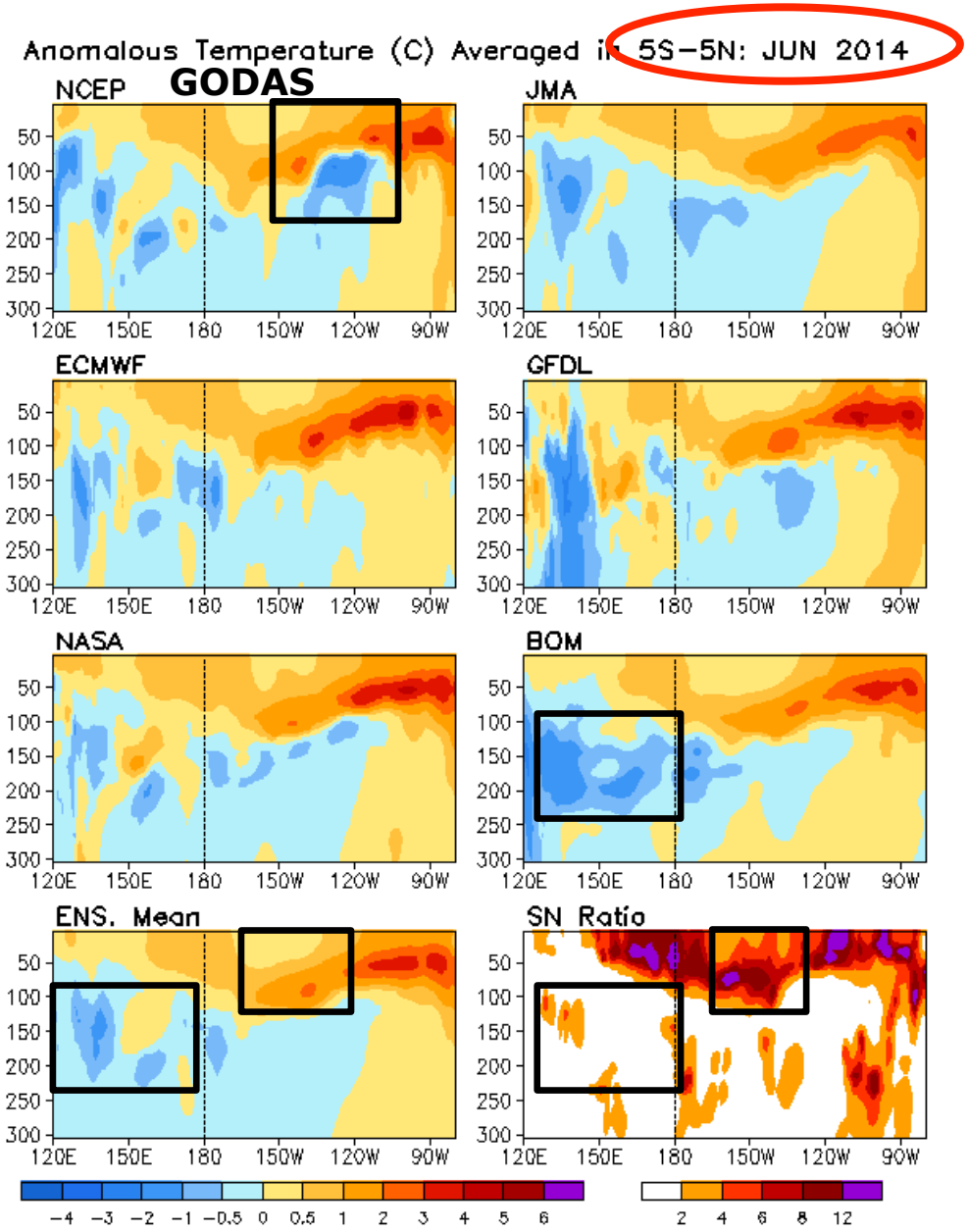
(Background Information)

Tropical Pacific Ocean

- **Climate Indices**
  - Depth of 20C isotherm anomaly in NINO3: last 4 years last 15 years 1979-present
  - Depth of 20C isotherm anomaly in NINO4: last 4 years last 15 years 1979-present
  - Upper 300m heat content anomaly in NINO3: last 4 years last 15 years 1979-present
  - Upper 300m heat content anomaly in NINO4: last 4 years last 15 years 1979-present
  - Warm Water Volume: last 4 years last 15 years 1979-present
  - Warm Water Volume average in last two months ending in:
    Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

- **Spatial Maps**
  - Temperature anom. at z=5m (X-Y section): last month month before last month 1979-present
  - Temperature anom. at z=15m (X-Y section): last month month before last month 1979-present
  - Temperature anom. at z=35m (X-Y section): last month month before last month 1979-present
  - Temperature anom. at z=55m (X-Y section): last month month before last month 1979-present
  - Temperature anom. at z=75m (X-Y section): last month month before last month 1979-present
  - Temperature anom. at z=100m (X-Y section): last month month before last month 1979-present
  - Temperature anom. at z=150m (X-Y section): last month month before last month 1979-present
  - Temperature anom. in 1S-1N (X-Z section): last month month before last month 1979-present
  - Temperature anom. in 5N-10N (X-Z section): last month month before last month 1979-present
  - Temperature anom. in 10S-5S (X-Z section): last month month before last month 1979-present
  - Temperature anom. in 120W-90W (Y-Z section): last month month before last month 1979-present
  - Temperature anom. in 150W-120W (Y-Z section): last month month before last month 1979-present
  - Temperature anom. in 160E-150W (Y-Z section): last month month before last month 1979-present
  - Temperature anom. in 130E-160E (Y-Z section): last month month before last month 1979-present
  - Depth of 20C isotherm anomaly: last month month before last month 1979-present
  - Upper 300m heat content anomaly: last month month before last month 1979-present

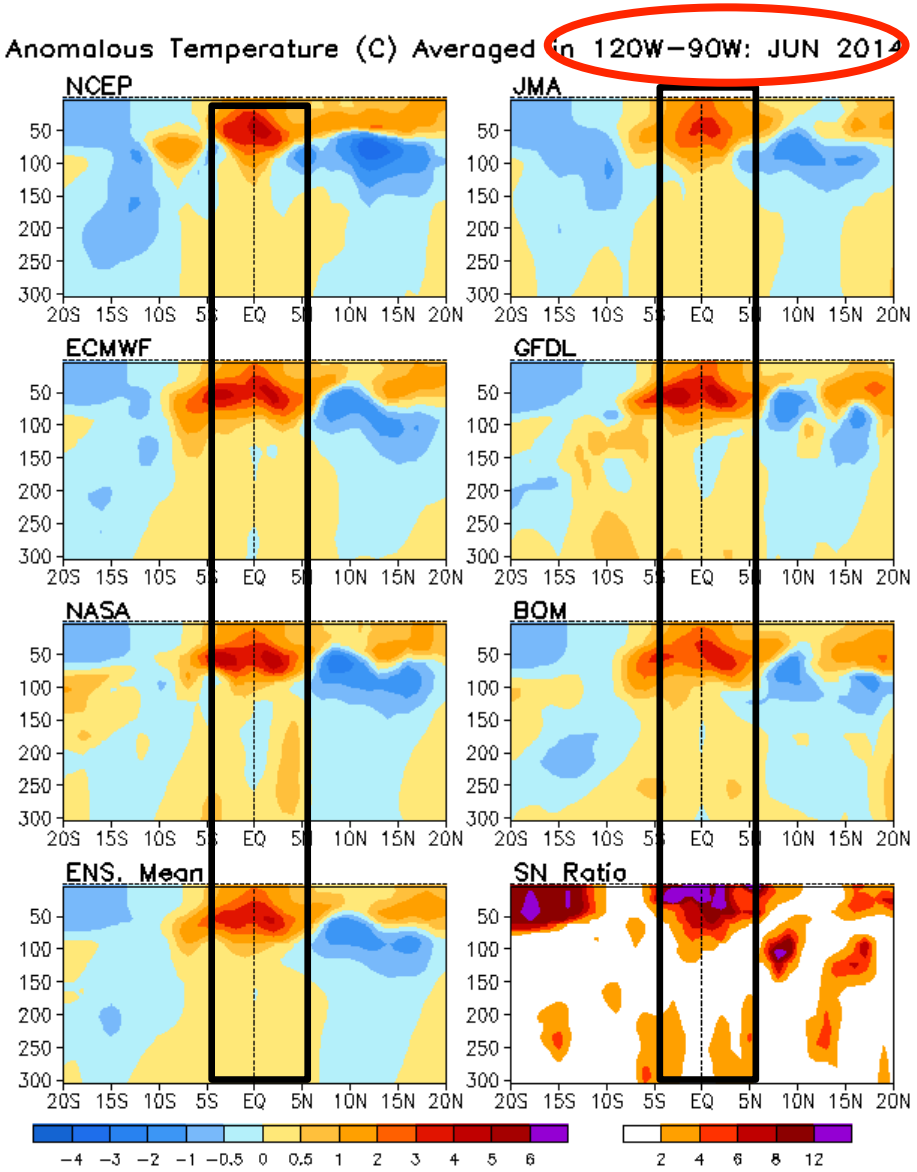


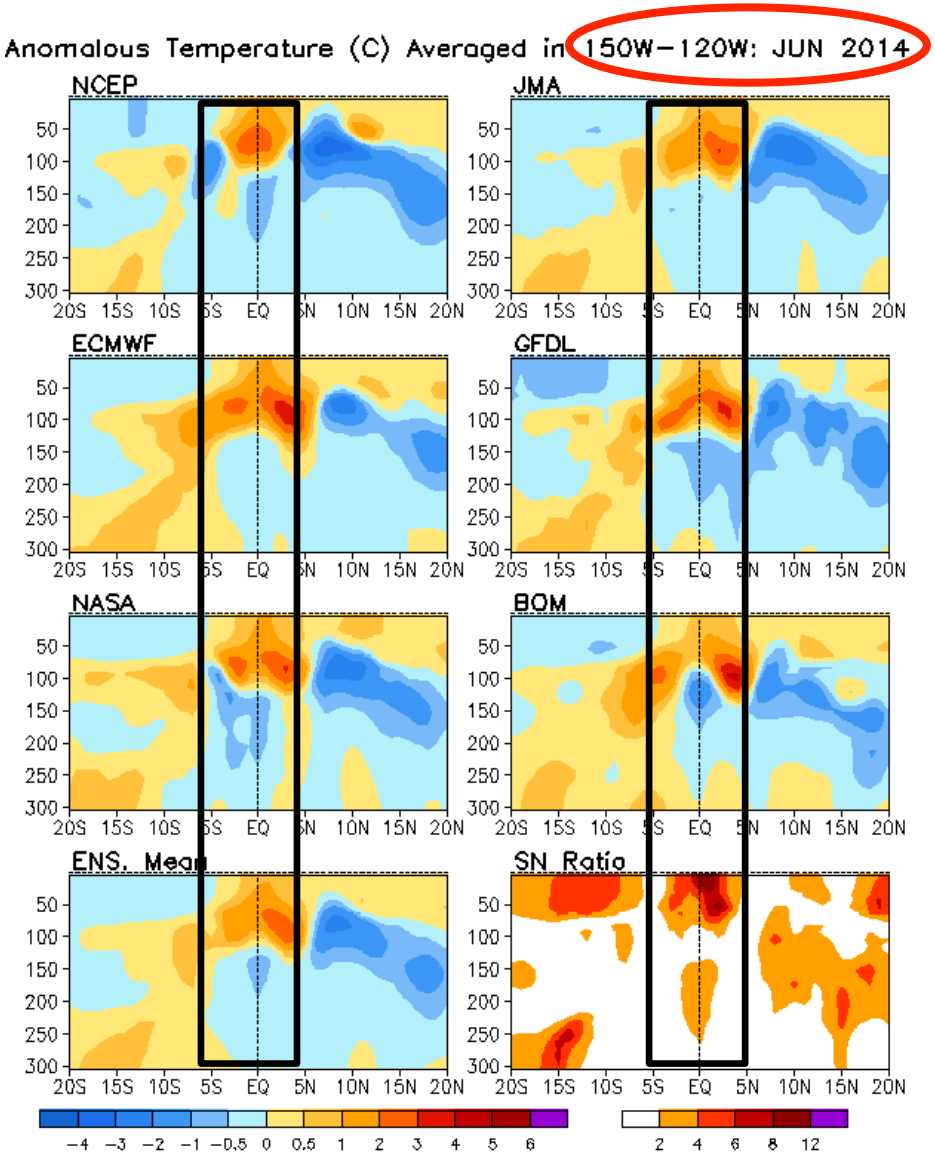


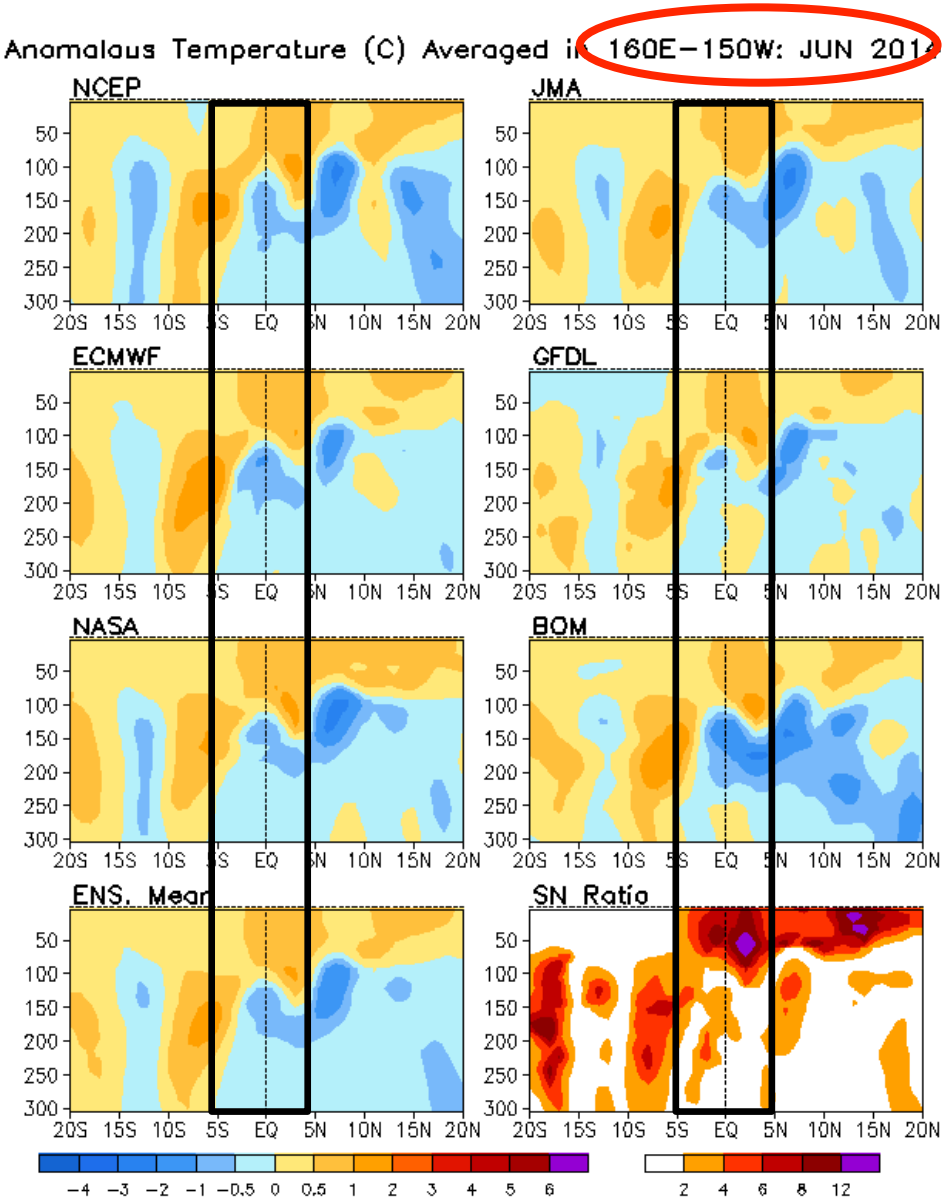
-The ensemble mean (ensemble spread) can be used to measure signal (noise).

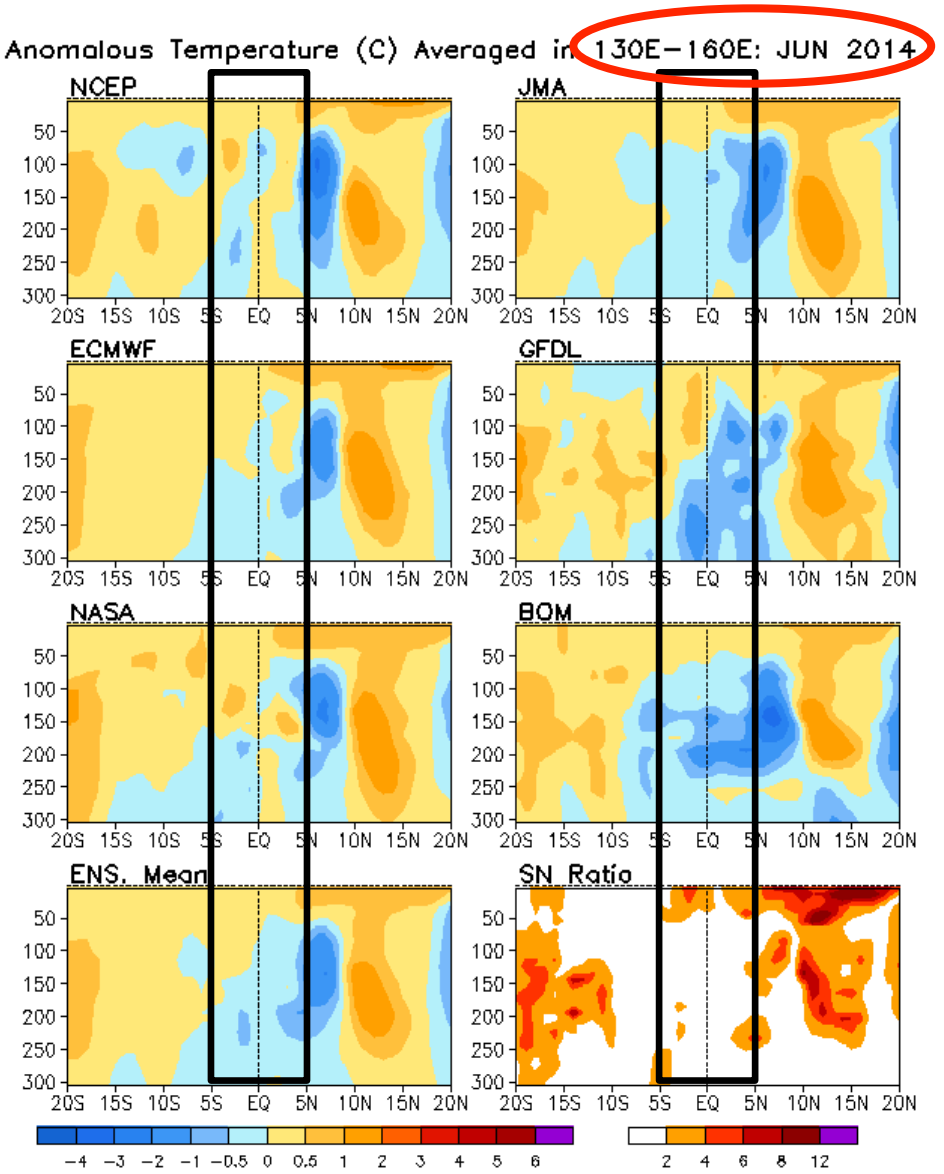
- The signal-to-noise (SN) ratio is relatively low in the western (central-eastern) Pacific where negative (positive) anomalies presented.

- The low signal-to-noise ratio may be partially attributed to the sparse observations in those regions.


Anomalous Temperature (C) Averaged in 120W–90W: JUN 2014
NCEP
JMA
ECMWF
GFDL
NASA
BOM
ENS. Mean
SN Ratio
50
100
150
200
250
300
20S 15S 10S 5S EQ 5N 10N 15N 20N
−4 −3 −2 −1 −0.5 0 0.5 1 2 3 4 5 6
2 4 6 8 12

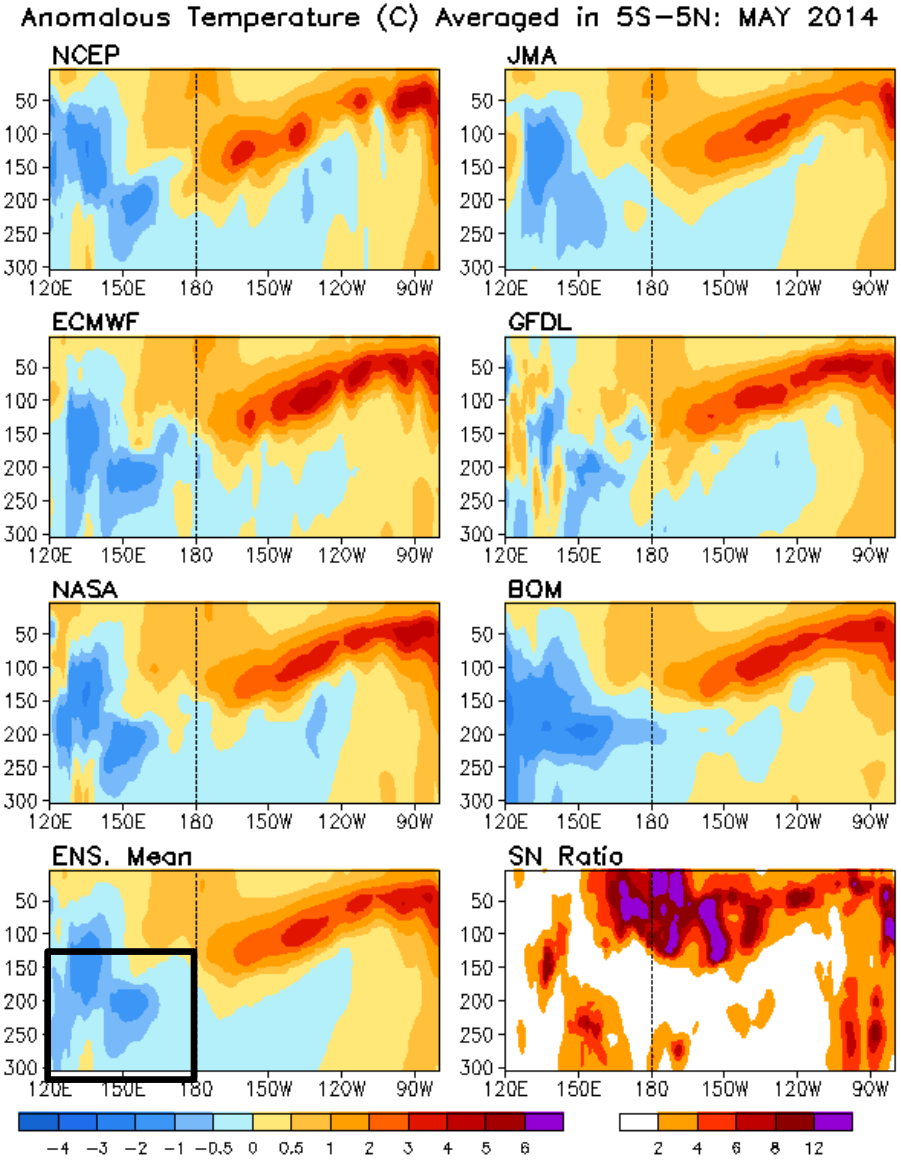

Anomalous Temperature (C) Averaged in 150W–120W: JUN 2014
NCEP
JMA
ECMWF
GFDL
NASA
BOM
ENS. Mean
SN Ratio
50
100
150
200
250
300
20S 15S 10S 5S EQ 5N 10N 15N 20N
−4 −3 −2 −1 −0.5 0 0.5 1 2 3 4 5 6
2 4 6 8 12


Anomalous Temperature (C) Averaged in 160E−150W: JUN 2014
NCEP
JMA
ECMWF
GFDL
NASA
BOM
ENS. Mean
SN Ratio
50
100
150
200
250
300
20S 15S 10S 5S EQ 5N 10N 15N 20N
−4 −3 −2 −1 −0.5 0 0.5 1 2 3 4 5 6
2 4 6 8 12

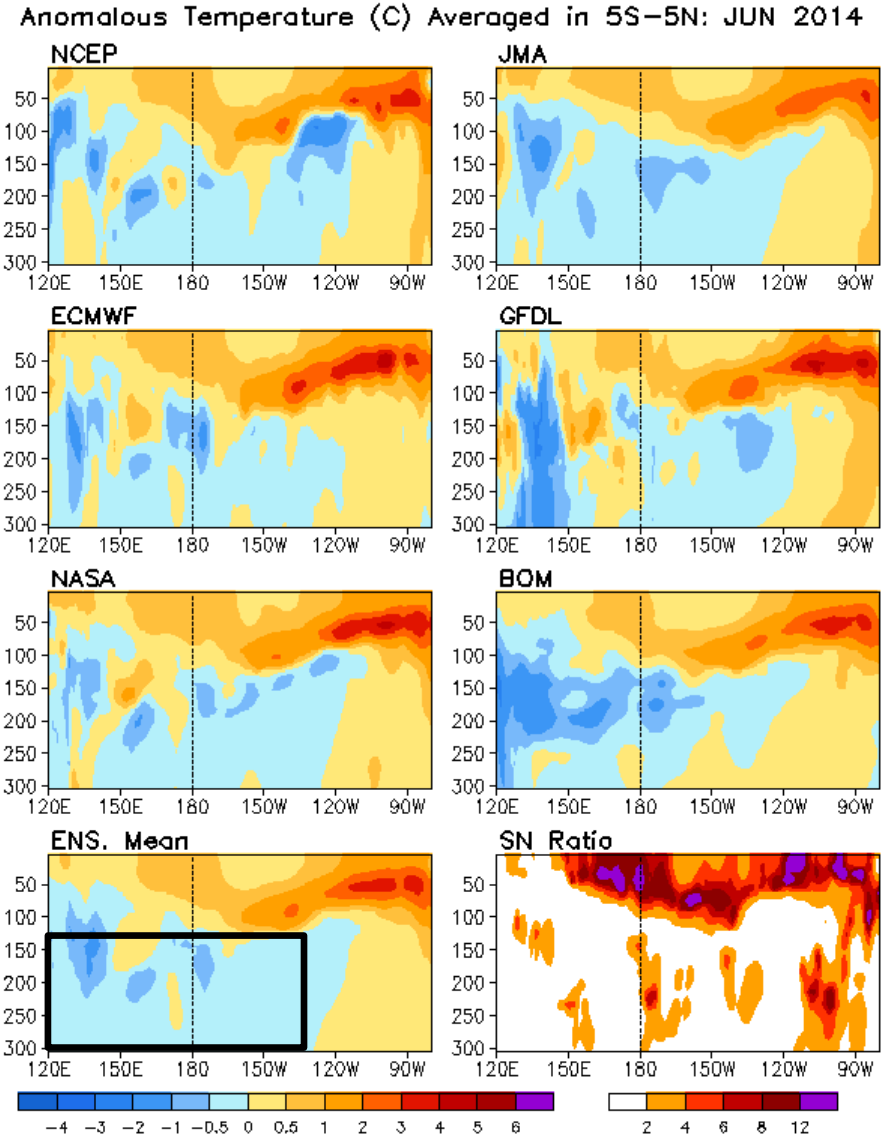

Anomalous Temperature (C) Averaged in 130E−160E: JUN 2014
NCEP
JMA
ECMWF
GFDL
NASA
BOM
ENS. Mean
SN Ratio
50
100
150
200
250
300
20S 15S 10S 5S EQ 5N 10N 15N 20N
−4 −3 −2 −1 −0.5 0 0.5 1 2 3 4 5 6
2 4 6 8 12

Temperature Anomaly Averaged in 5S-5N

May

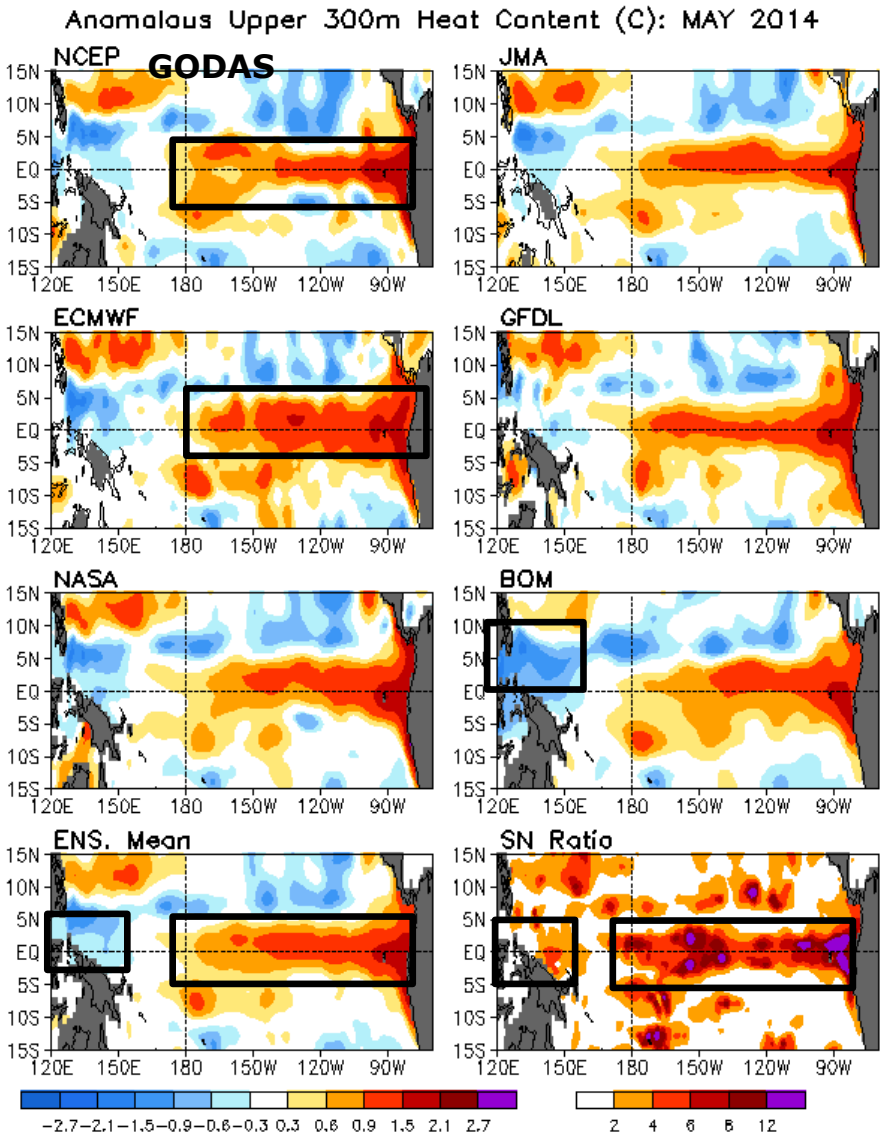


June

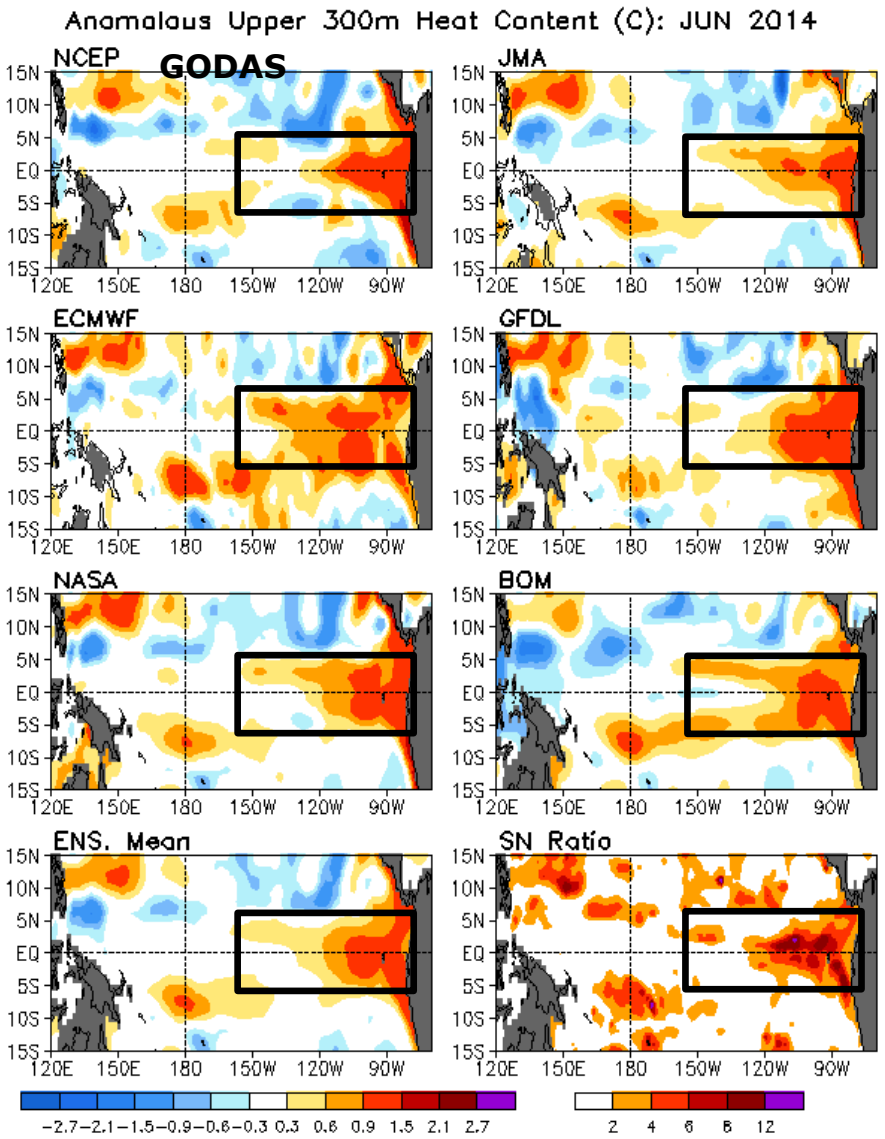


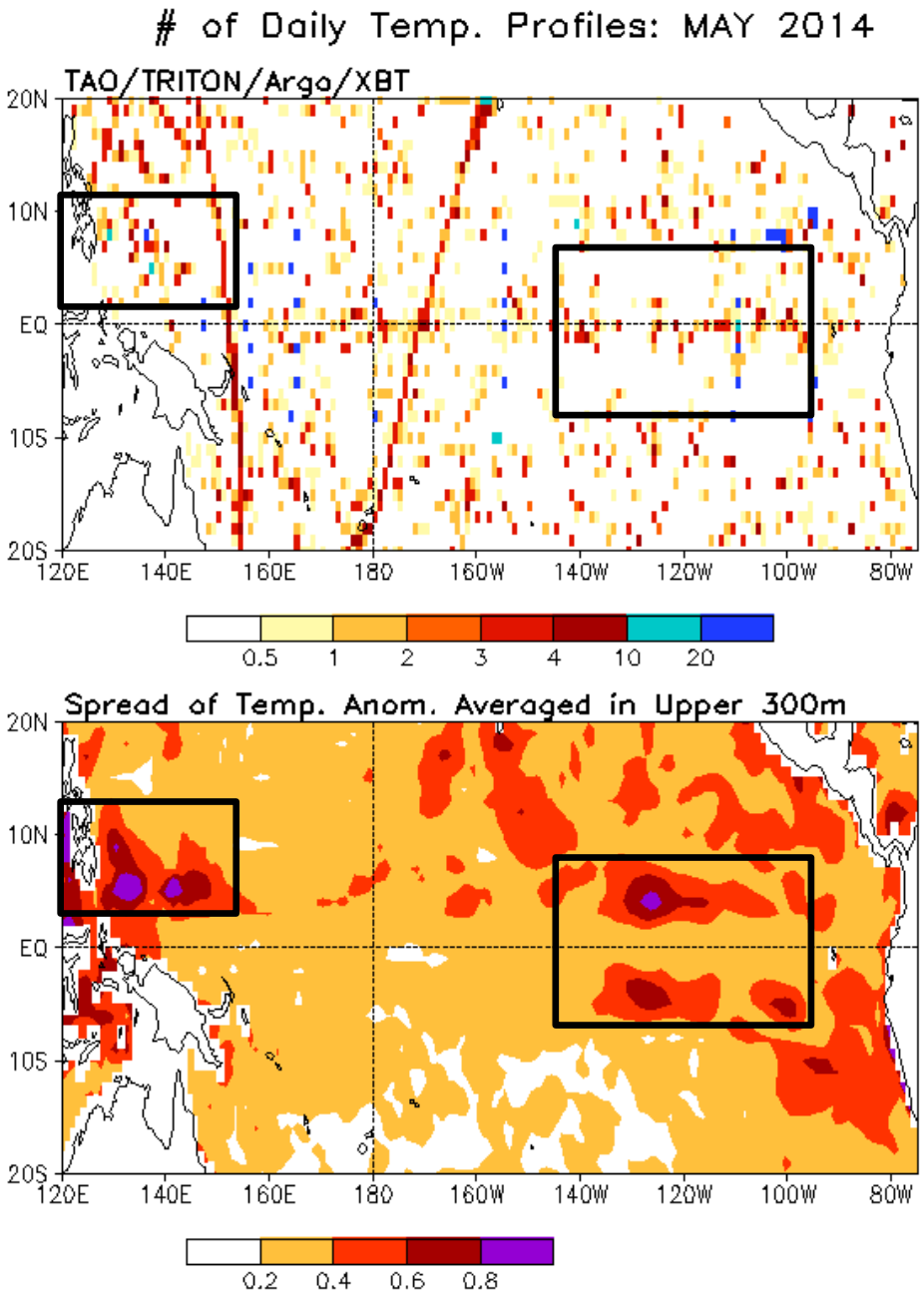
Upper 300m Heat Content Anomaly

May

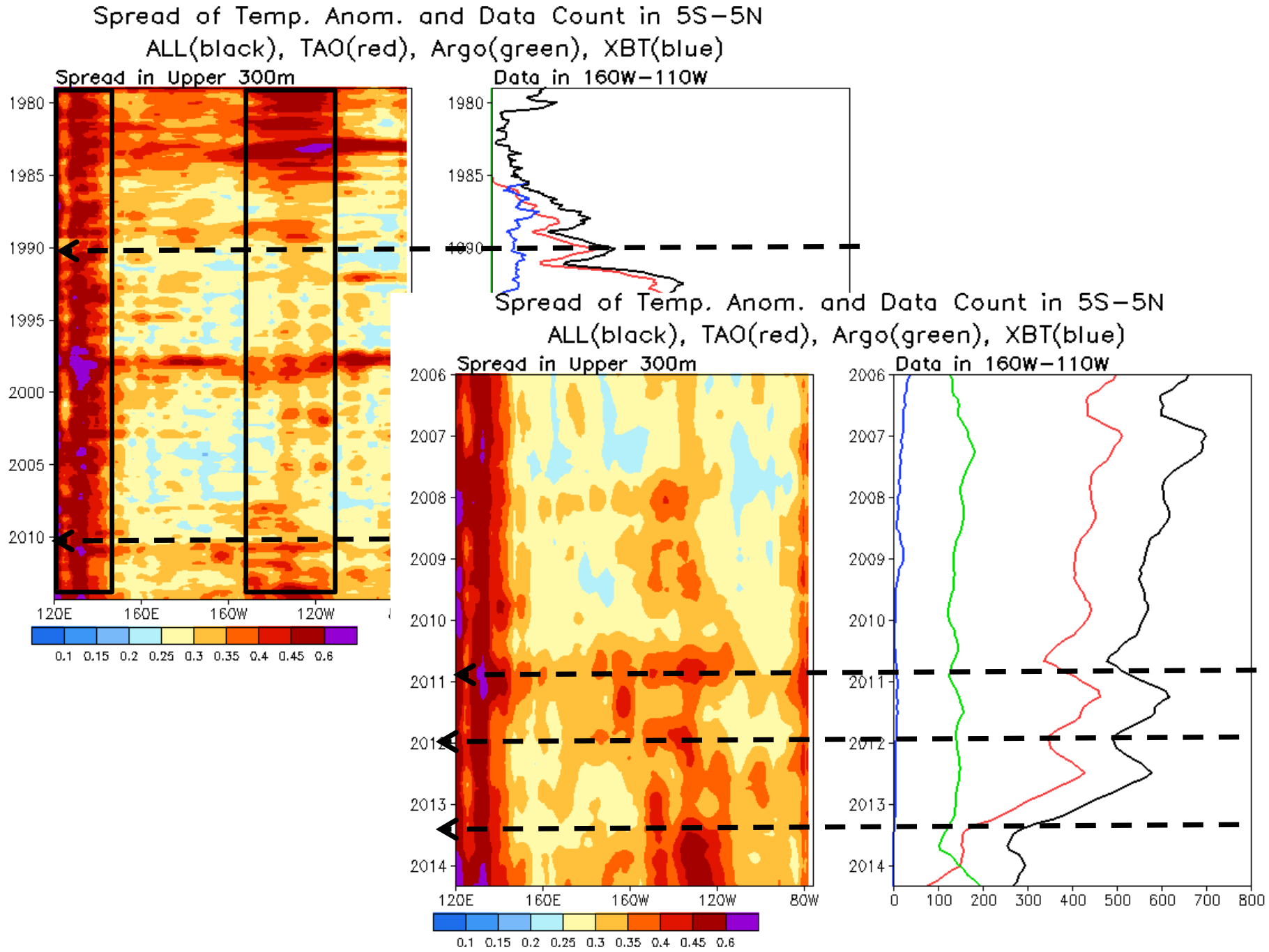


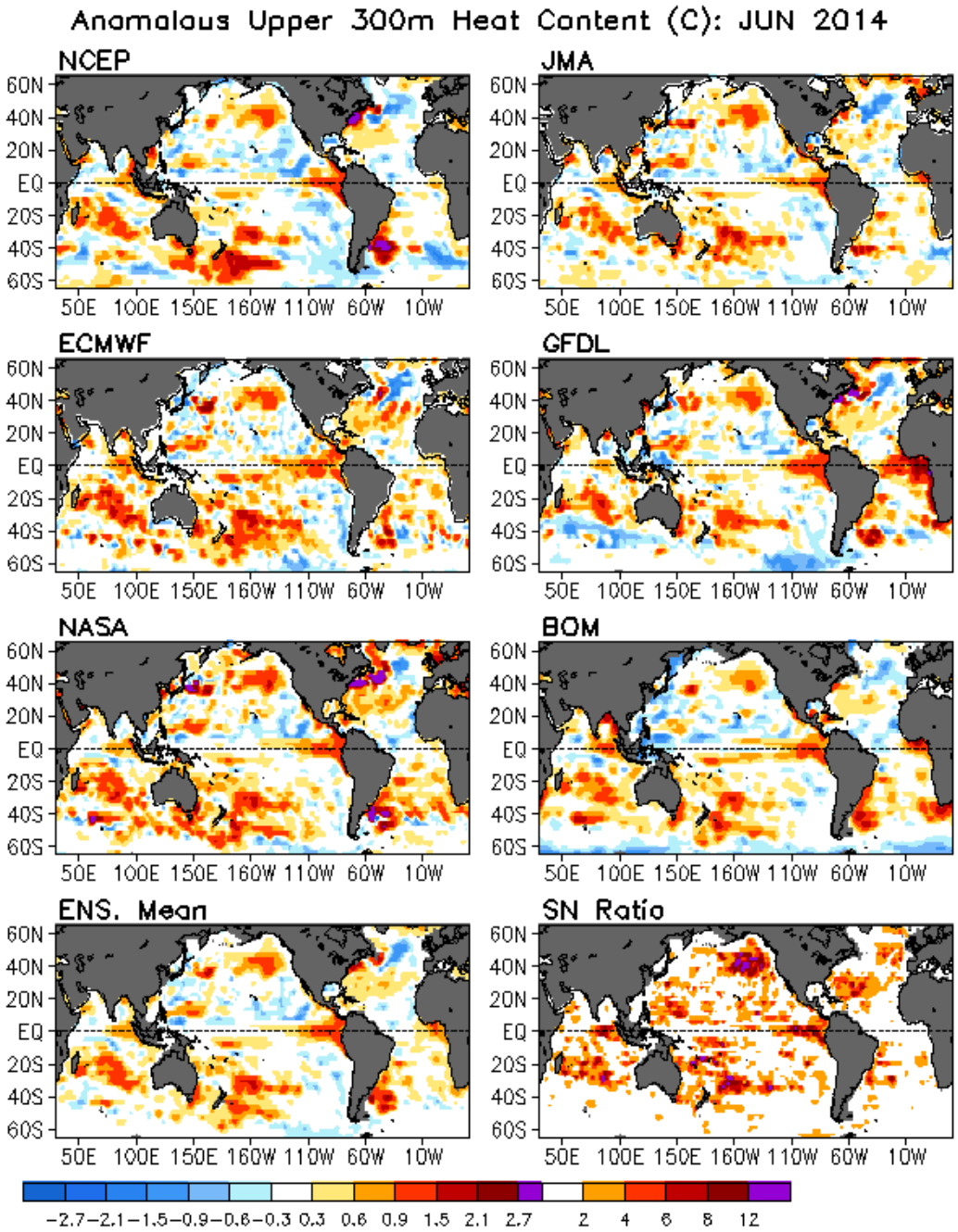
June



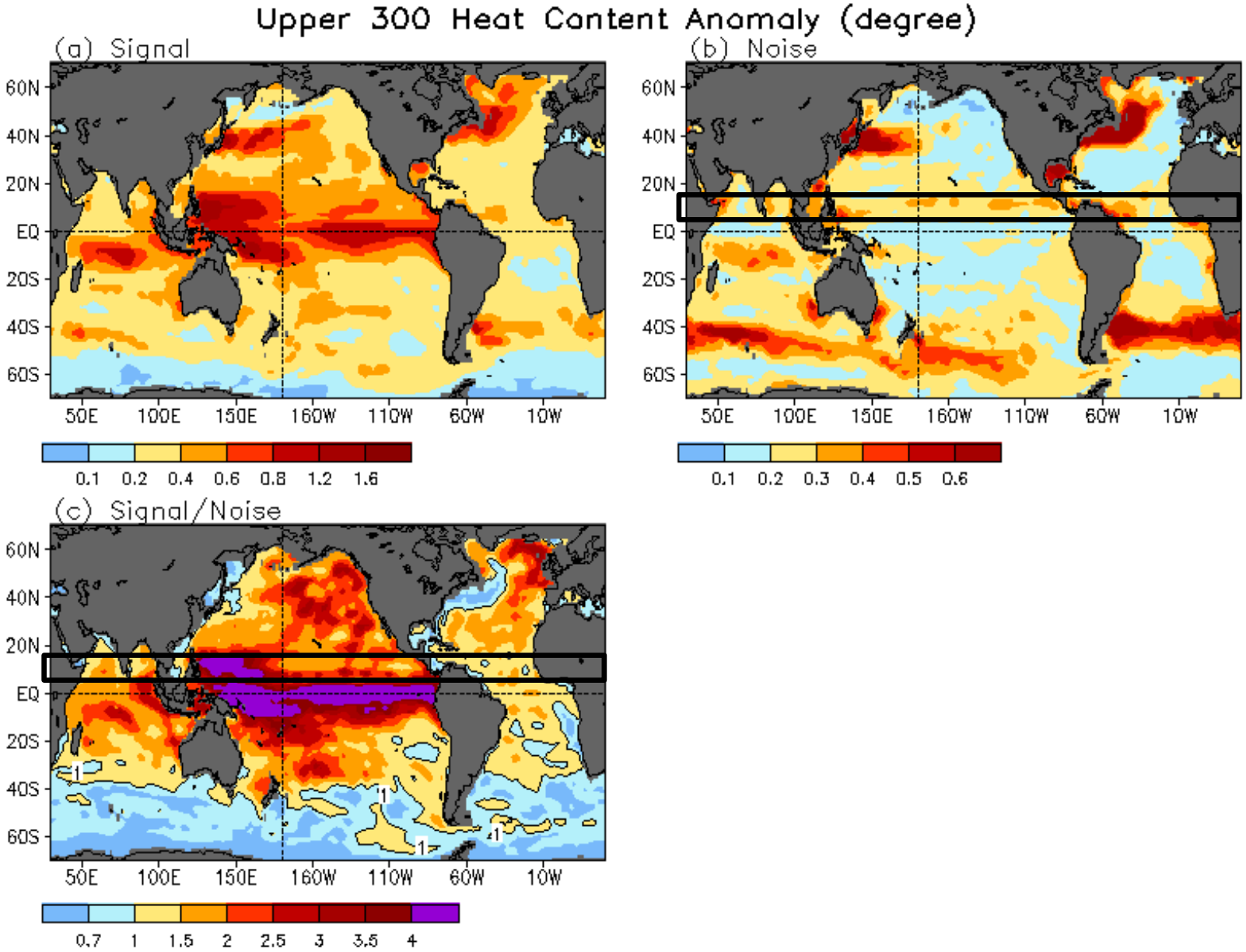


Influences of ocean observations on spread among ocean reanalyses

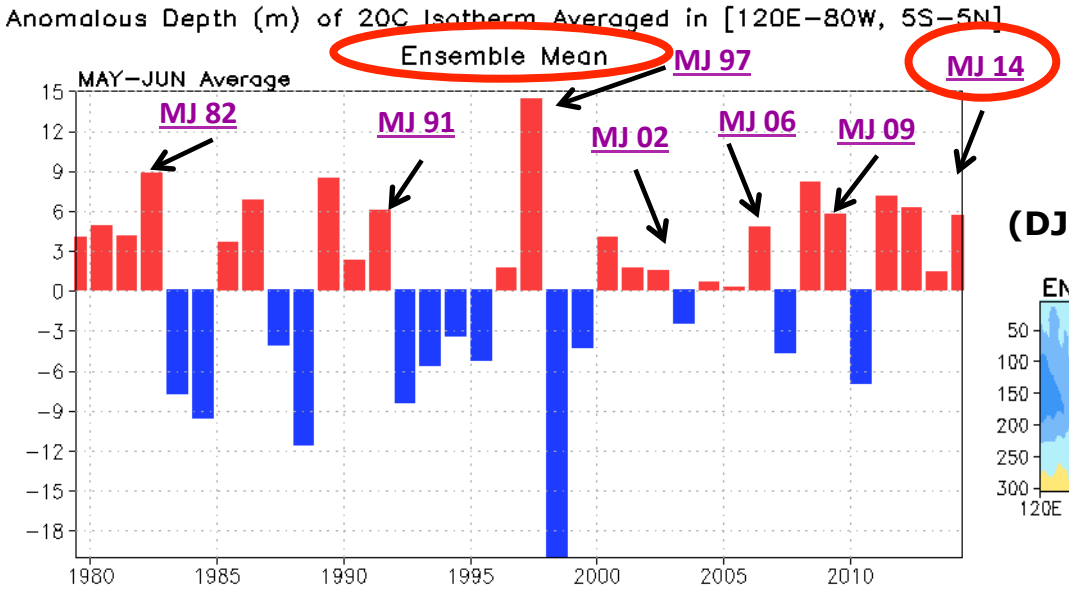

Spread of Temp. Anom. and Data Count in 5S-5N
ALL(black), TAO(red), Argo(green), XBT(blue)
Spread in Upper 300m
Data in 160W-110W
1980
1985
1990
1995
2000
2005
2010
120E
160E
160W
120W
0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.6
Spread of Temp. Anom. and Data Count in 5S-5N
ALL(black), TAO(red), Argo(green), XBT(blue)
Spread in Upper 300m
Data in 160W-110W
2006
2007
2008
2009
2010
2011
2012
2013
2014
120E
160E
160W
120W
80W
0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.6
0
100
200
300
400
500
600
700
800


Anomalous Upper 300m Heat Content (C): JUN 2014
NCEP
JMA
ECMWF
GFDL
NASA
BOM
ENS. Mean
SN Ratio
60N
40N
20N
EQ
20S
40S
60S
50E 100E 150E 160W 110W 60W 10W
-2.7 -2.1 -1.5 -0.9 -0.6 -0.3 0.3 0.6 0.9 1.5 2.1 2.7 2 4 6 8 12

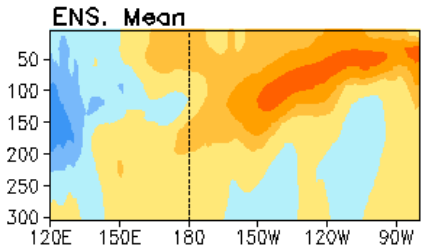
Signal, Noise and Signal-to-Noise Ratio (1985-2013)



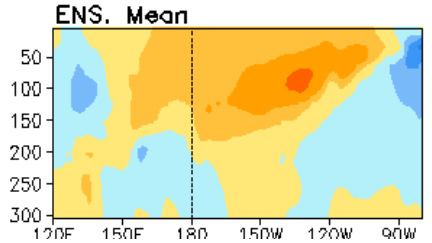
Warm Water Volume Index Derived From Ensemble Mean of Ocean Reanalyses



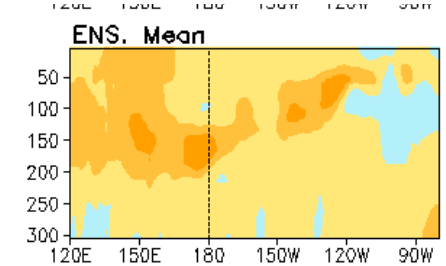
Jun 1991 (DJF NINO3.4=+1.6)



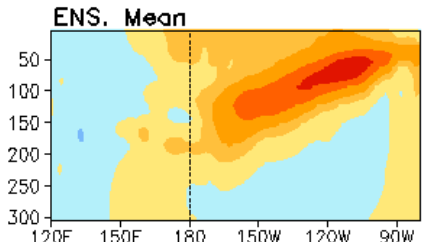
Jun 2002 (DJF NINO3.4=+1.1)



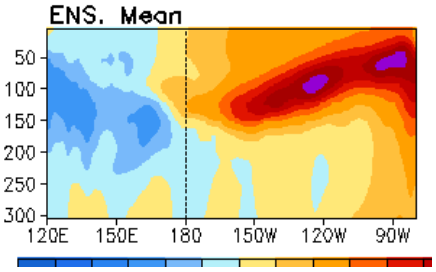
Jun 2006 (DJF NINO3.4=+0.7)



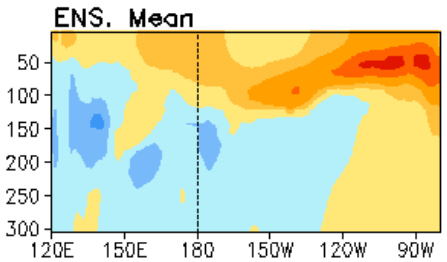
Jun 1982 (DJF NINO3.4=+2.2)



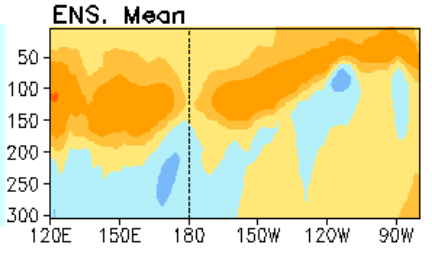
Jun 1997 (DJF NINO3.4=+2.2)



Jun 2014



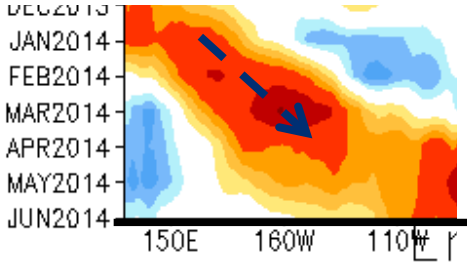
Jun 2009 (DJF NINO3.4=+1.6)



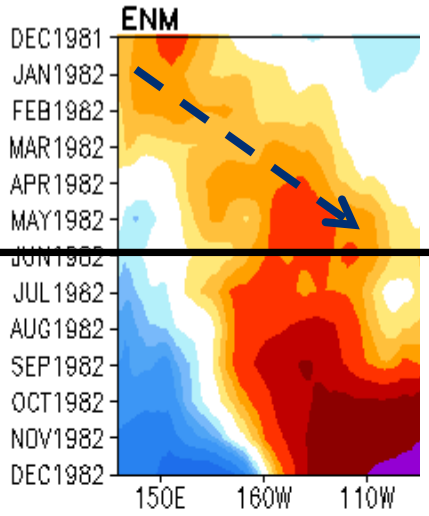
- Warm Water Volume averaged in May-June 2014 is similar to that in May-June of 2009, 2006 and 1991. However, the pattern of subsurface temperature anomaly averaged in 5S-5N in Jun 2014 is mostly similar to Jun 1991.

Upper 300m Heat Content Anomaly Averaged in 5S-5N

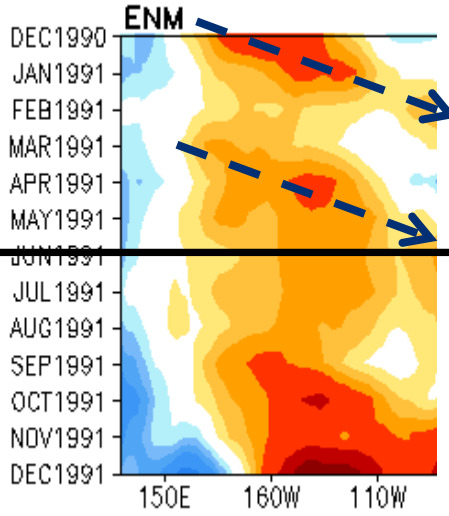
14/15



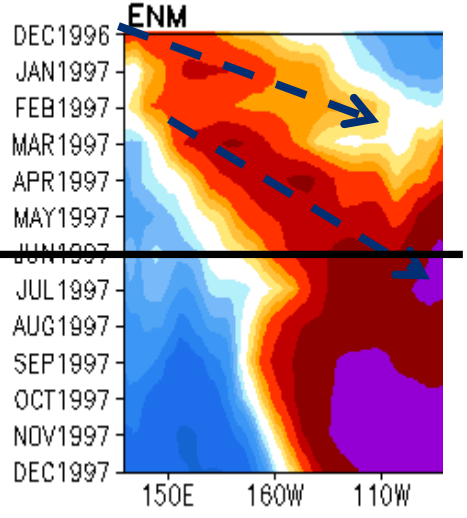
82/83



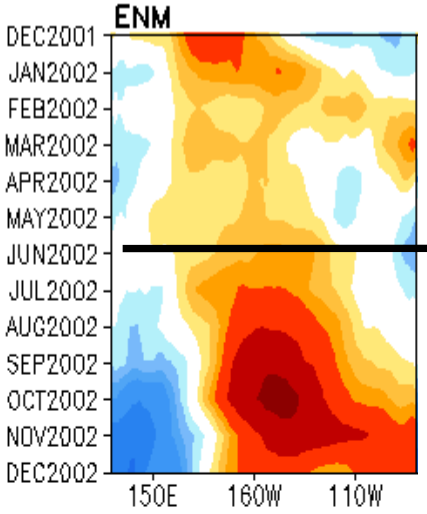
91/92



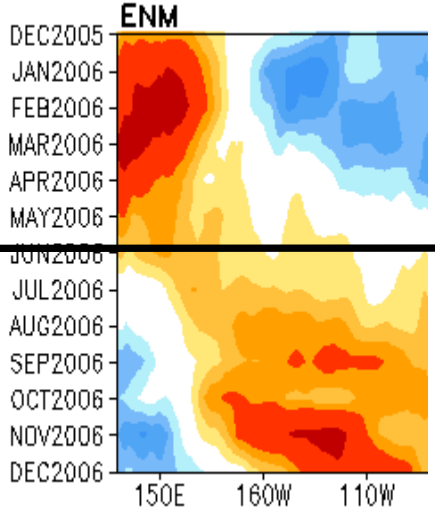
97/98



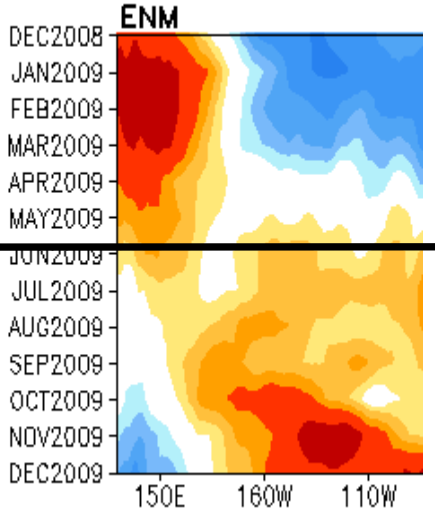
02/03



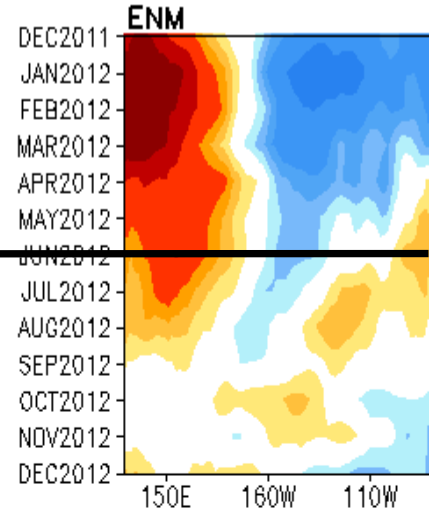
06/07



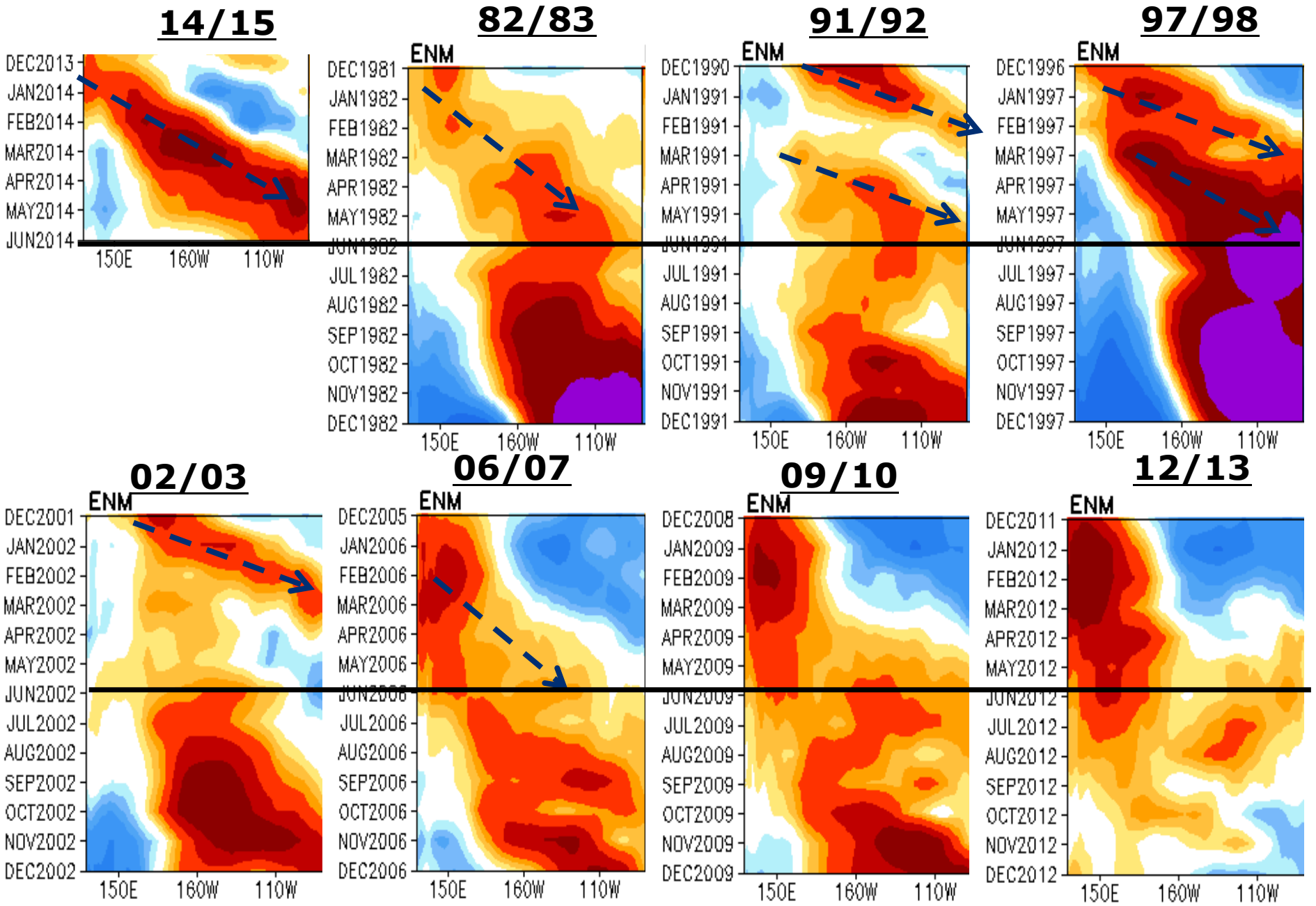
09/10



12/13

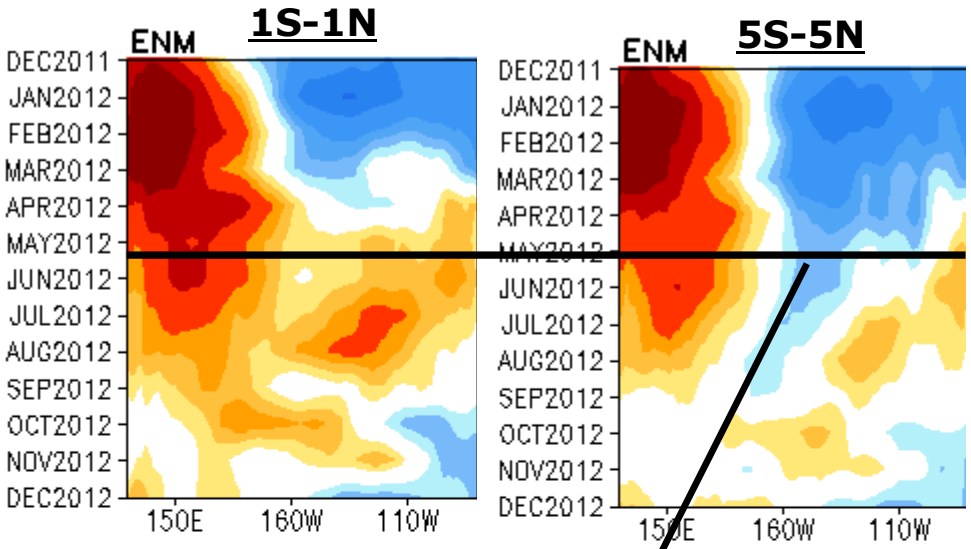


Upper 300m Heat Content Anomaly Averaged in 1S-1N

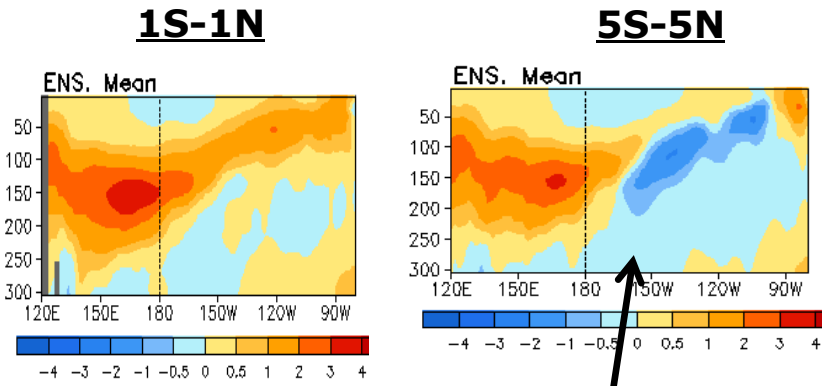


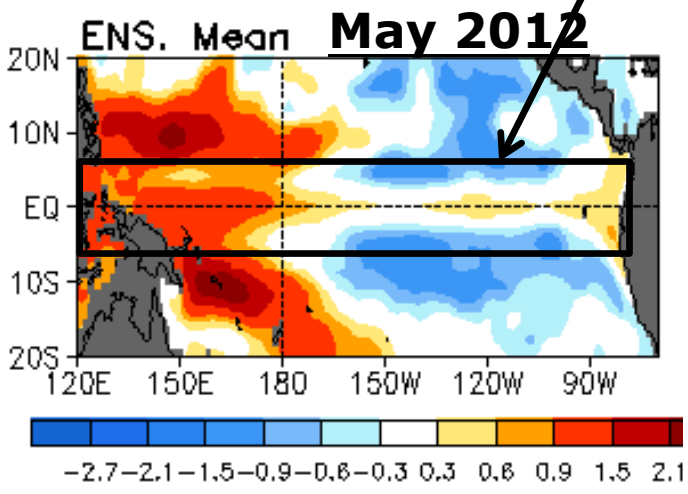
2012

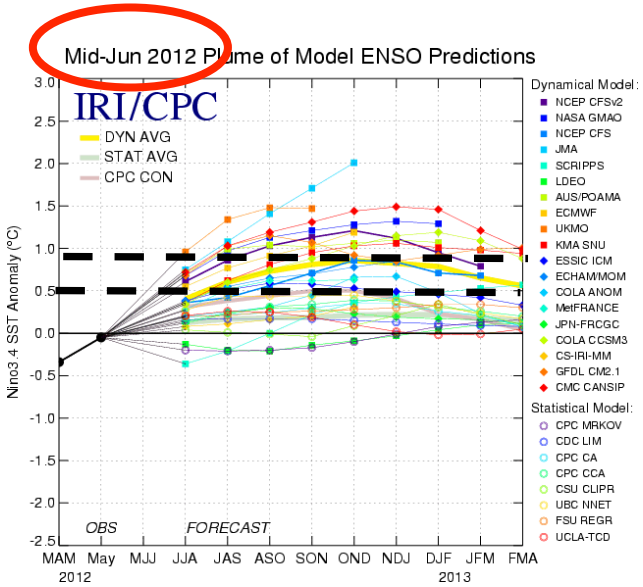
Heat Content Anomaly

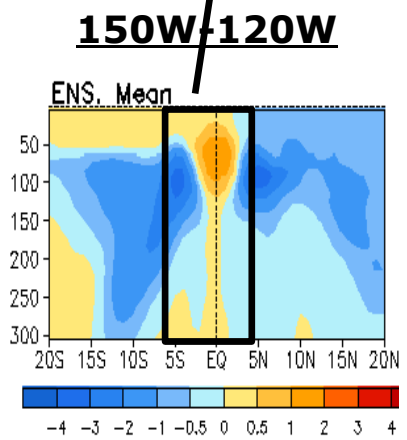


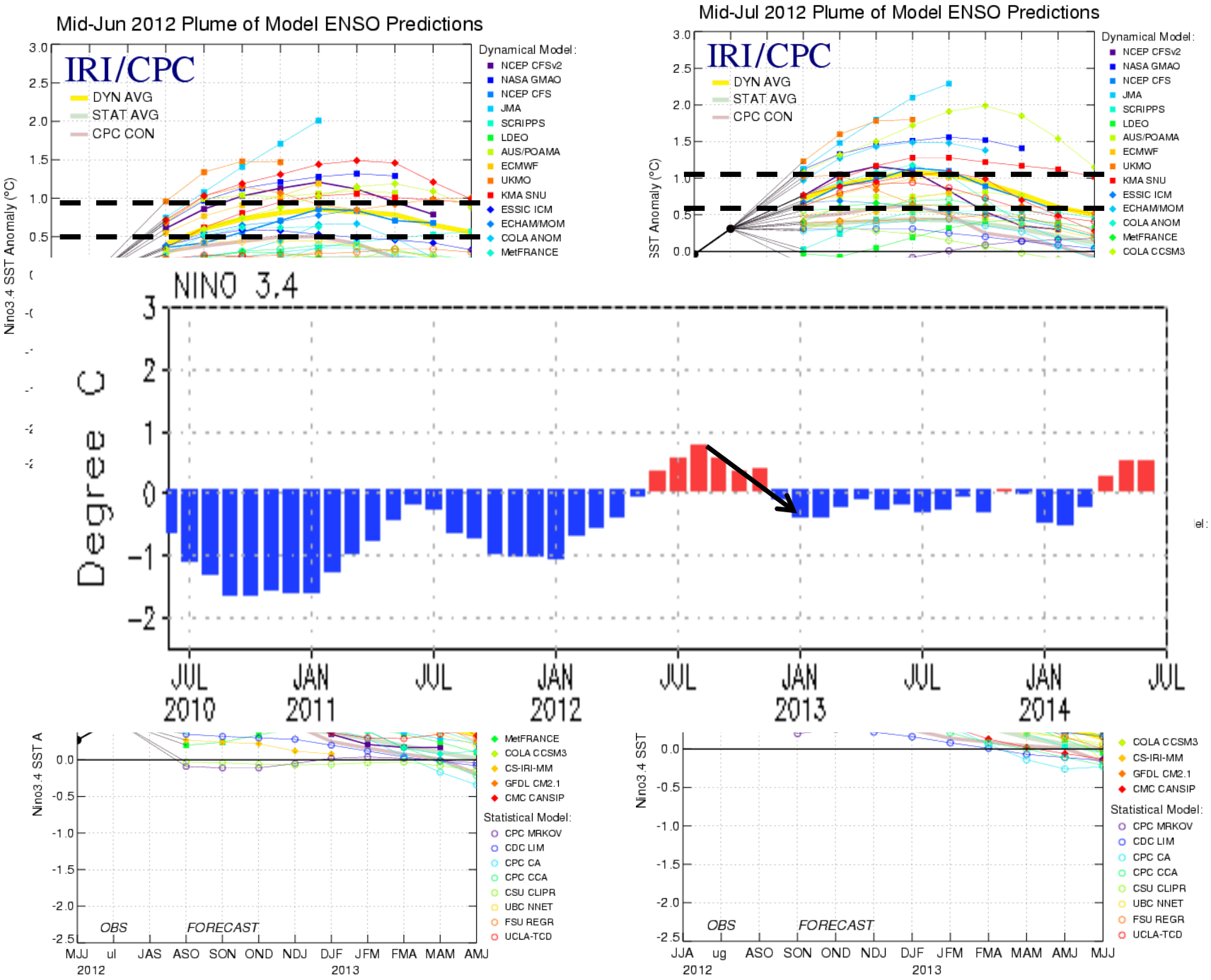
Temperature Anomaly May 2012










Mid-Jun 2012 Plume of Model ENSO Predictions
IRI/CPC
DYN AVG
STAT AVG
CPC CON
Nino3.4 SST Anomaly (°C)
Dynamical Model:
NCEP CFSv2
NASA GMAO
NCEP CFS
JMA
SCRIPPS
LDEO
AUS/POAMA
ECMWF
UKMO
KMA SNU
ESSIC ICM
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MetFRANCE
COLA CCSM3
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JUL 2010
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JAN 2013
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Nino3.4 SST A
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COLA CCSM3
CS-IRI-MM
GFDL CM2.1
CMC CANSIP
Statistical Model:
CPC MRKOV
CDC LIM
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CSU CLIPR
UBC NNET
FSU REGR
UCLA-TCD
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FORECAST
MJJ ul JAS ASO SON OND NDJ DJF JFM FMA MAM AMJ
2012
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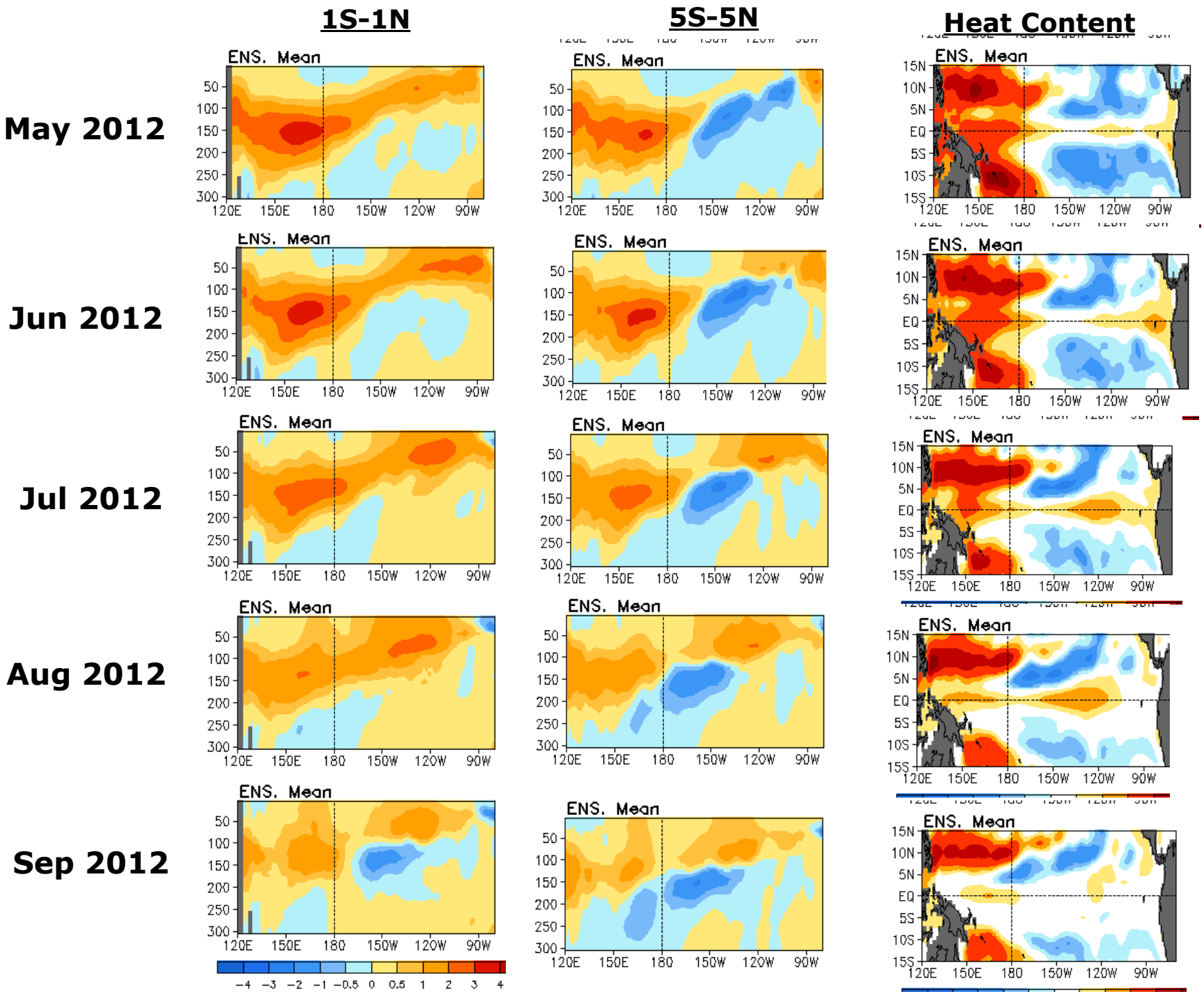
2012
2013


1S-1N
5S-5N
Heat Content
May 2012
Jun 2012
Jul 2012
Aug 2012
Sep 2012
ENS. Mean
50
100
150
200
250
300
120E
150E
180
150W
120W
90W
15N
10N
5N
EQ
5S
10S
15S
−4
−3
−2
−1
−0.5
0
0.5
1
2
3
4

Summary

- **An ensemble of six operational ORAs has been collected to assess signal (ensemble mean) and noise (ensemble spread) in upper ocean temperature analysis in near real-time**

- **Uncertainties in ocean reanalyses seem partially attributed to the declining TAO array:**

  - **The spread of ensemble ORAs decreased abruptly in early 1990s when the TAO array was fully implemented.**

  - **The spread started to increase since 2010 and reached a peak value in 2013 when the TAO array return rate drops to 40%**

- **Although there are uncertainties in ocean reanalysis products, the ensemble mean of multiple ocean reanalyses likely provides the best estimation of the state of ocean and can be used to derive climate indicators. The ensemble spread provides uncertainties in our estimation.**

- **The ensemble mean of temperature analyses from multiple ORA products has been used in monitoring and prediction for current ENSO conditions.**

Future Plan

- **Review the experimental web site**
  - **Are all the plots useful?**
  - **Are there any new plots need to be developed?**
  - **Should some of the plots be displayed in a more prominent web site, e.g. OOPC?**

- **Further explore the linkage between spread and data distribution**

- **Understand why spread is large in certain areas and what are implications for designing ocean observing systems**

- **Develop plots for other oceans, how?**

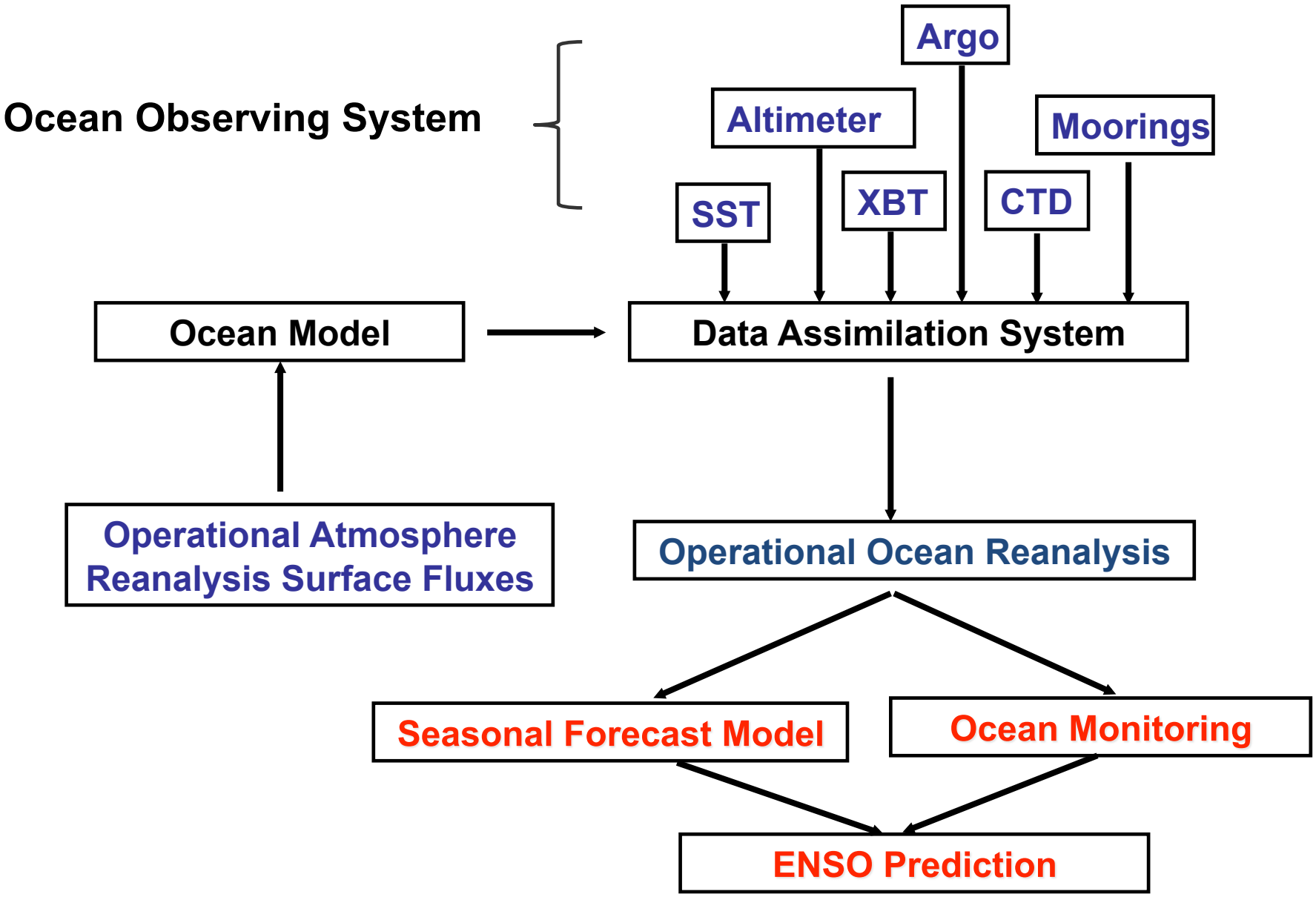
- **Support TPOS2020?**

- **Support Climate Indicator Task Team?**

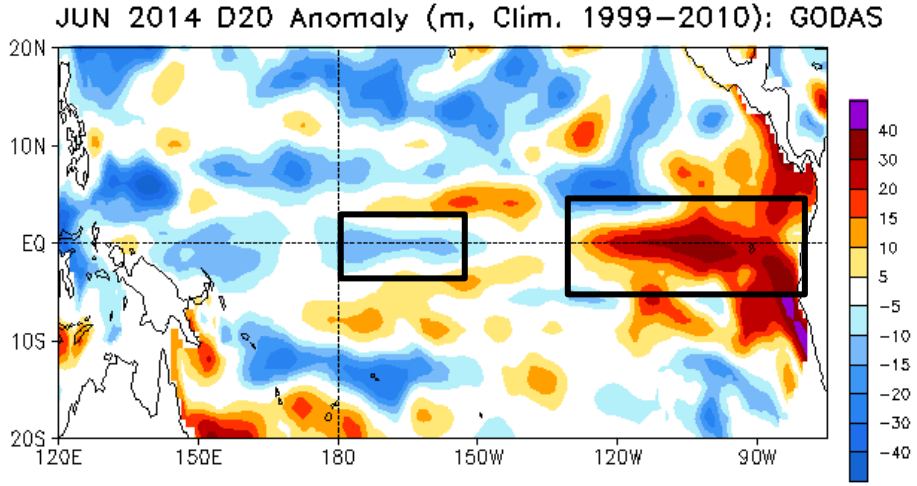
Thanks!

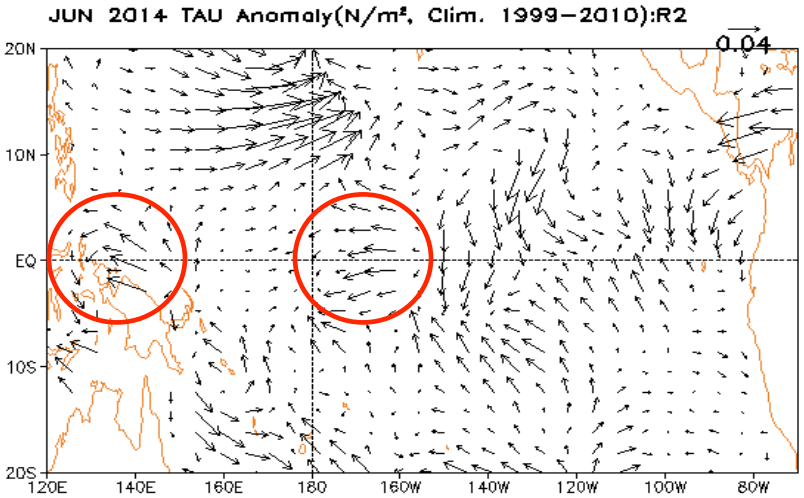
Comments and Suggestions?

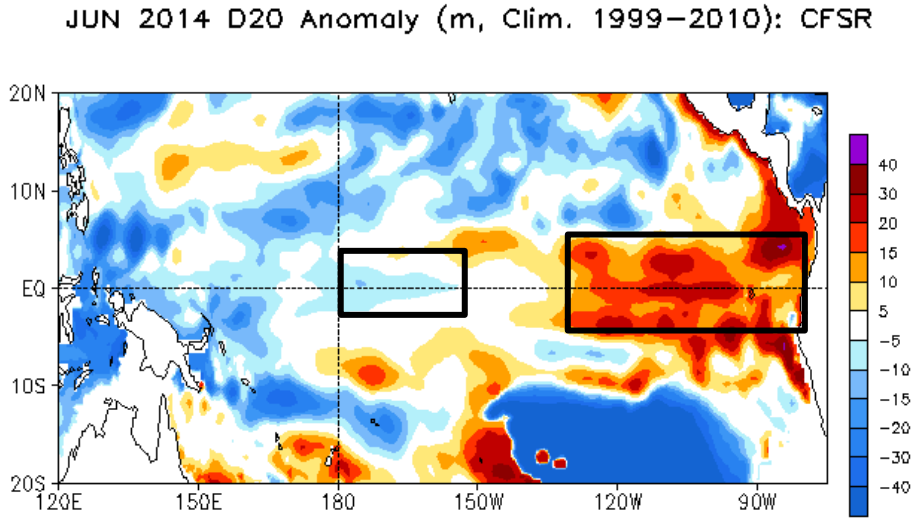
Operational Ocean Reanalysis

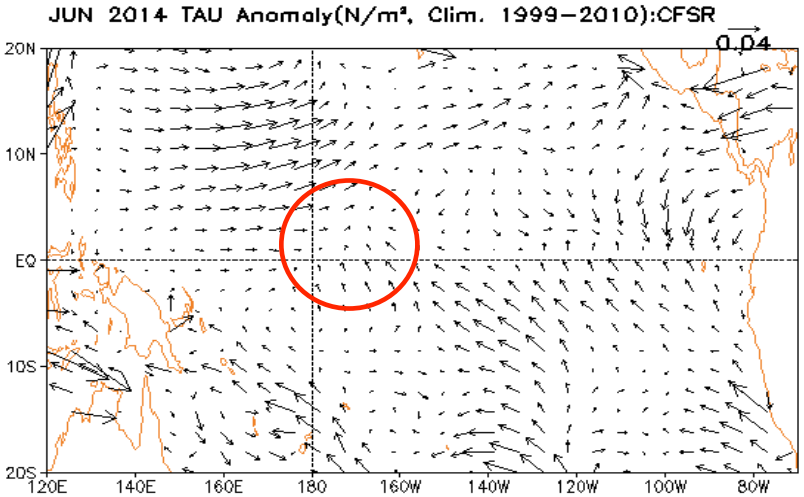


Difference between GODAS and CFSR (1999-2010 Clim.)





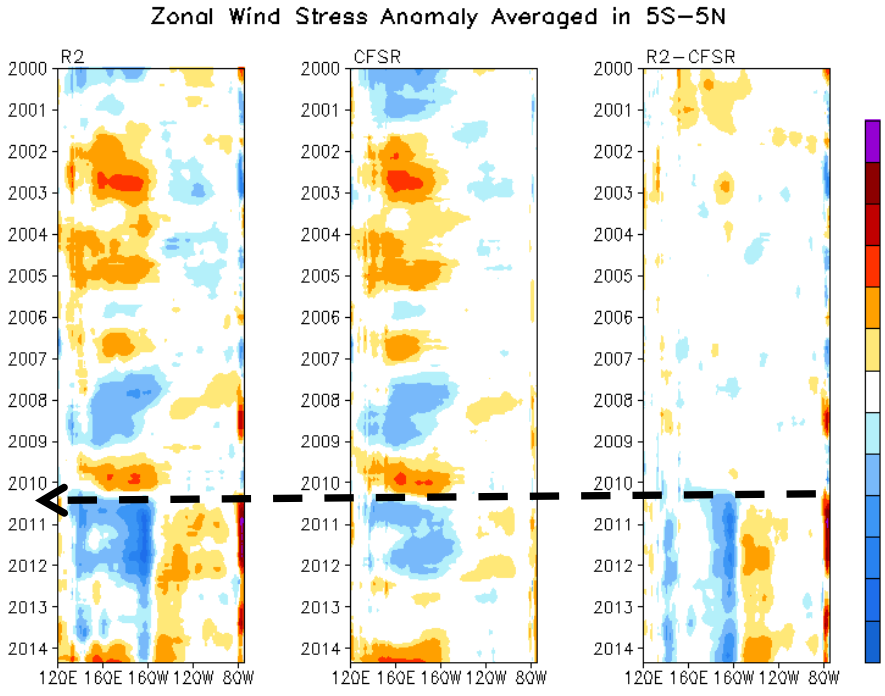




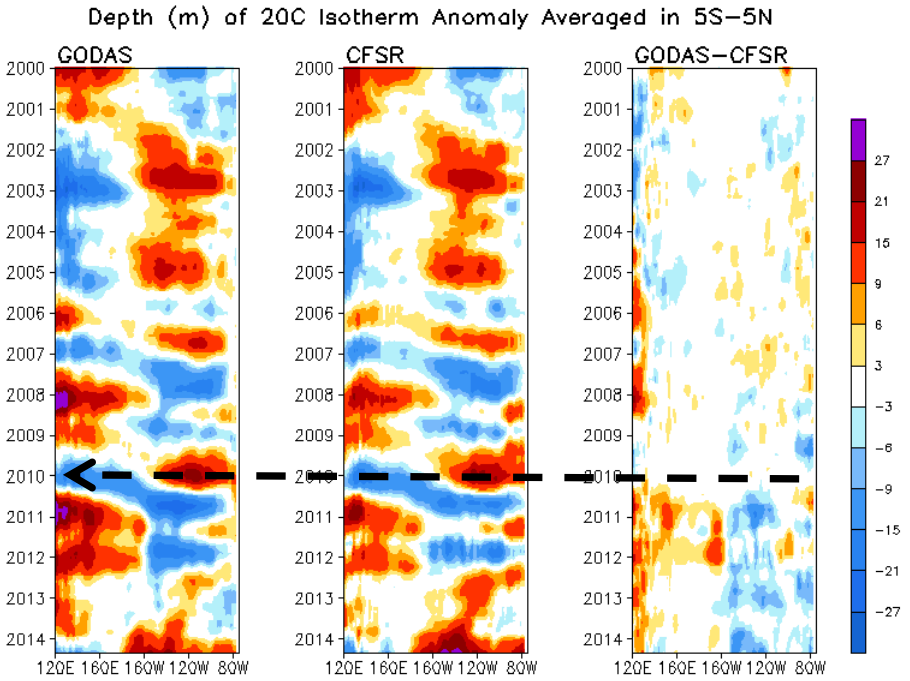
- **Positive D20 anomaly in GODAS has much narrower meridional extend than CFSR between 130W-100W, and negative D20 anomaly near Dateline was stronger than that in CFSR.**
- **Easterly wind anomaly was stronger in R2 than that in CFSR.**

Difference between GODAS and CFSR

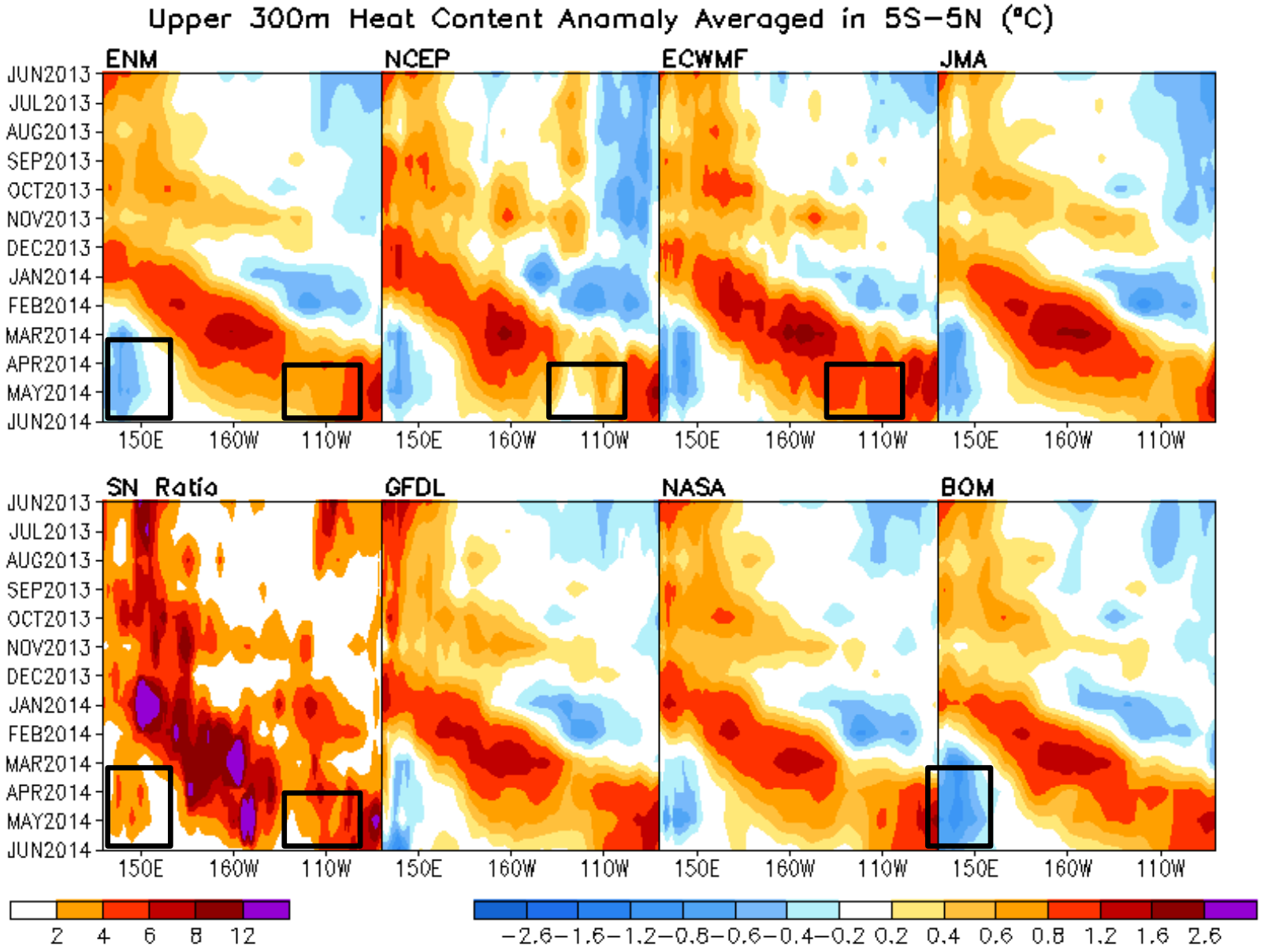
Zonal Wind Stress Anomaly



Depth of 20C Isotherm Anomaly



- **Trade winds in R2 are much stronger than those in CFSR near 170W since 2010.**

- **Consistent to the stronger trade winds in R2, D20 anomaly in GODAS is about 3-6m lower than that in CFSR east of 150W since 2010.**

Recent Evolution of Ocean Heat Content Anomaly