Global Ocean Monitoring: Recent Evolution, Current Status, and Predictions

Prepared by

Climate Prediction Center, NCEP/NOAA

May 10, 2023

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

This project, to deliver real-time ocean monitoring products, is implemented

by CPC in cooperation with NOAA's Global Ocean Monitoring and Observing Program (GOMO)

Outline

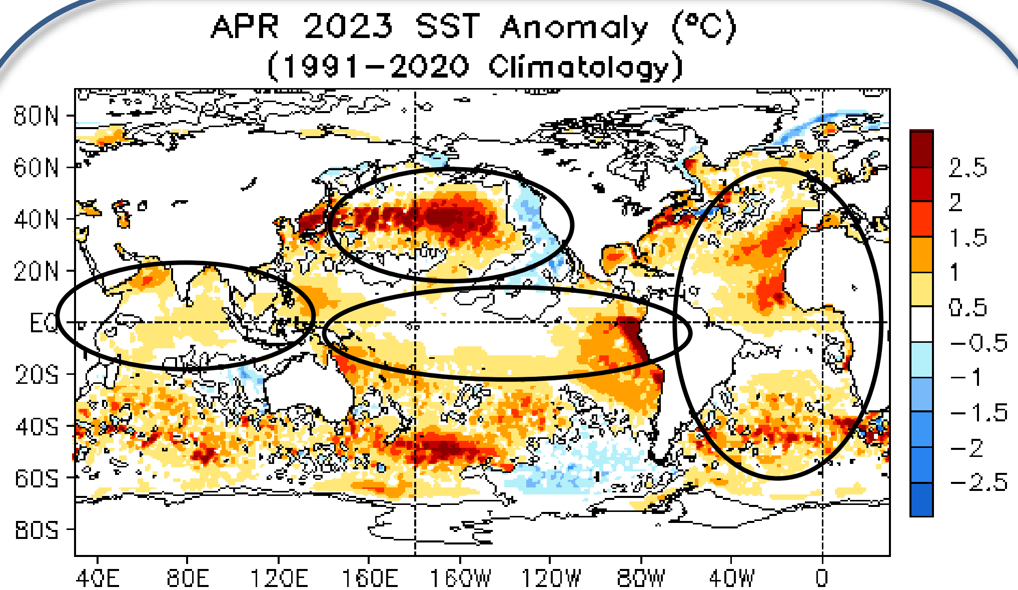
- Overview
- Recent highlights
  - Pacific Ocean
  - Arctic & Antarctic Oceans
  - Indian Ocean
  - Atlantic Ocean
- Global SSTA Predictions

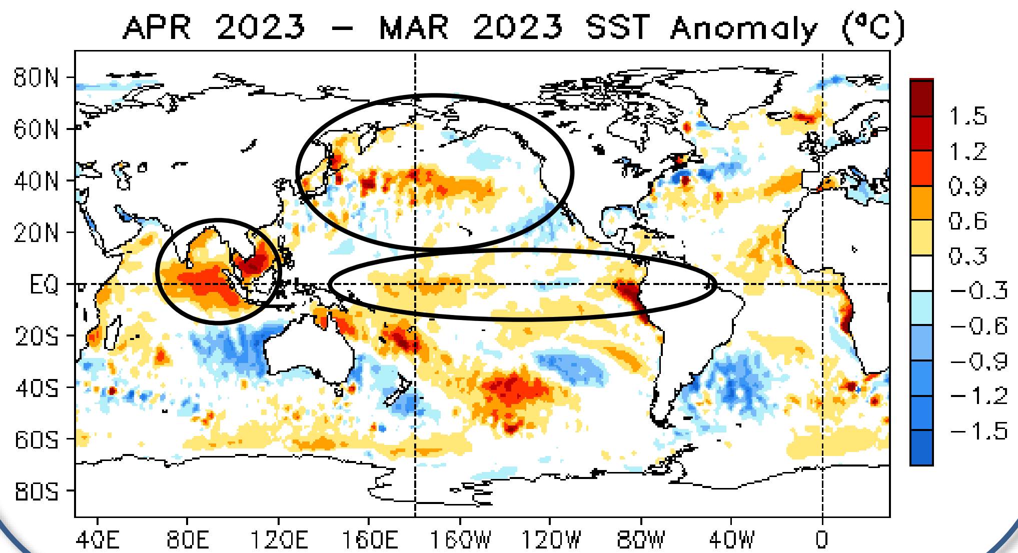
Overview

- Pacific Ocean
  - NOAA "ENSO Diagnostic Discussion" on 13 Apr 2023 issued El Niño Watch & stated "ENSO-neutral conditions are expected to continue through the Northern Hemisphere spring, followed by, with a 62% chance of El Niño forming during May-July 2023."
  - ENSO has been in neutral conditions since Mar 2023 with Niño3.4 = 0.1°C (ERSSTv5) and 0.2°C (OIv2.1) in Apr 2023.
  - A strong coastal El Niño has been observed since Feb 2023 with Niño1+2 =2.4°C in Apr 2023.
  - Positive SSTAs persisted in the North Pacific in Apr 2023. The PDO has been in a negative phase since Feb 2020 with PDOI = -2.1 in Apr 2023.
- Arctic and Antarctic Oceans
  - The Apr 2023 average Arctic sea ice extent was 13.99 million square kilometers, tied with 2004 as the tenth lowest Apr in the satellite record.
  - Antarctic sea ice extent for Apr 2023 was 5.50 million square kilometers, remained well below average.
- Indian Ocean
  - Positive SSTAs were present in the tropical Indian Ocean in Apr 2023.
- Atlantic Ocean
  - NAO switched to a negative phase in Mar 2023 with NAOI= -0.8 in Apr 2023.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency



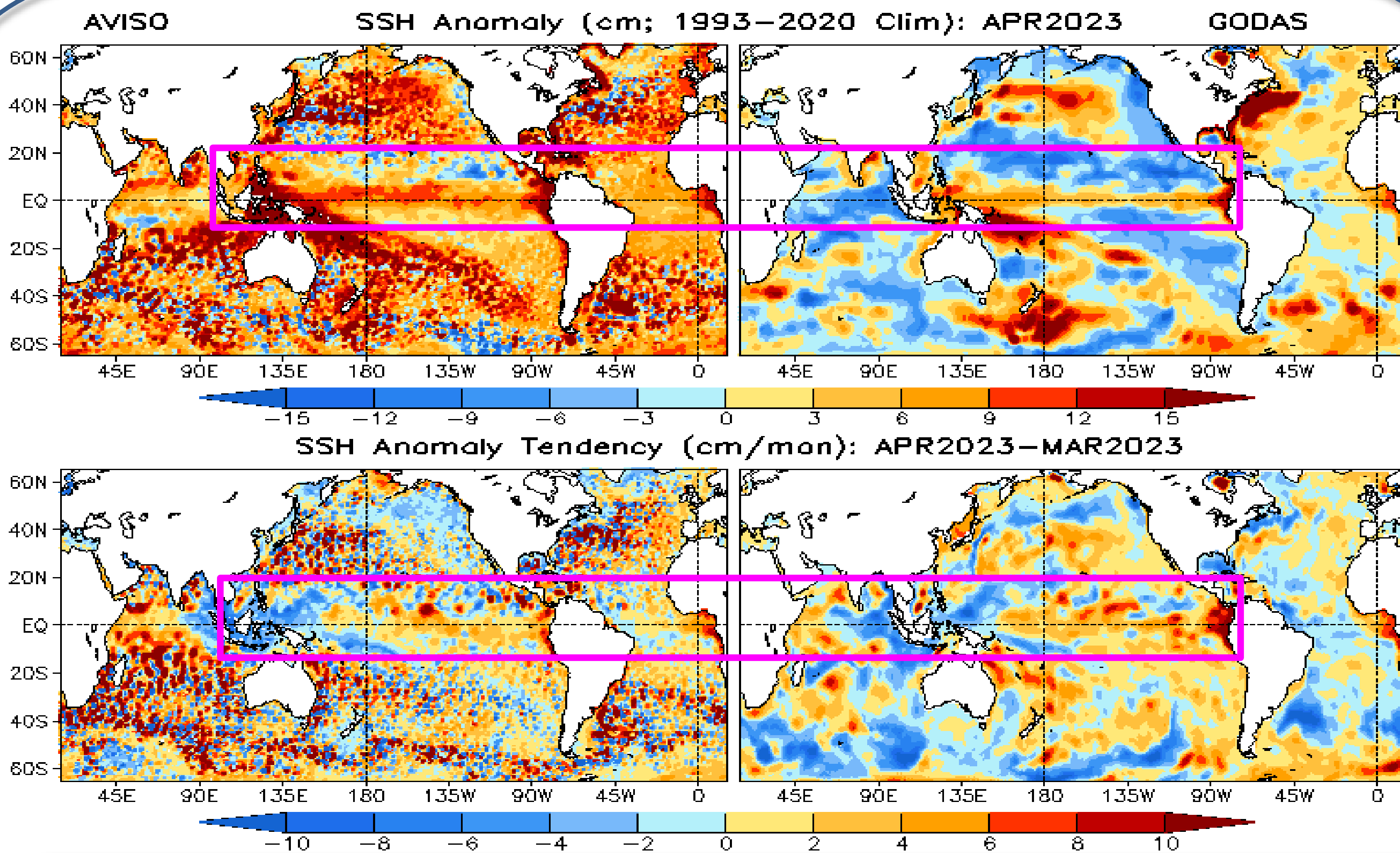


- Above (near) normal SSTs were present in the western and eastern (central) equatorial Pacific and a coastal El Nino has developed since Feb 2023.
- Positive SSTAs were observed in the North Pacific and most of the Atlantic Ocean.
- Positive SSTAs were observed in the tropical Indian Ocean.
- Both positive and negative SSTAs were seen in the middle-latitudes of the Southern Hemisphere.

- Positive (negative) SSTA tendencies were observed in the central and far-eastern (east-central) equatorial Pacific.
- Both positive and negative SSTA tendencies were evident in the North Pacific.
- Positive SSTA tendencies were located in the eastern tropical Indian Ocean.

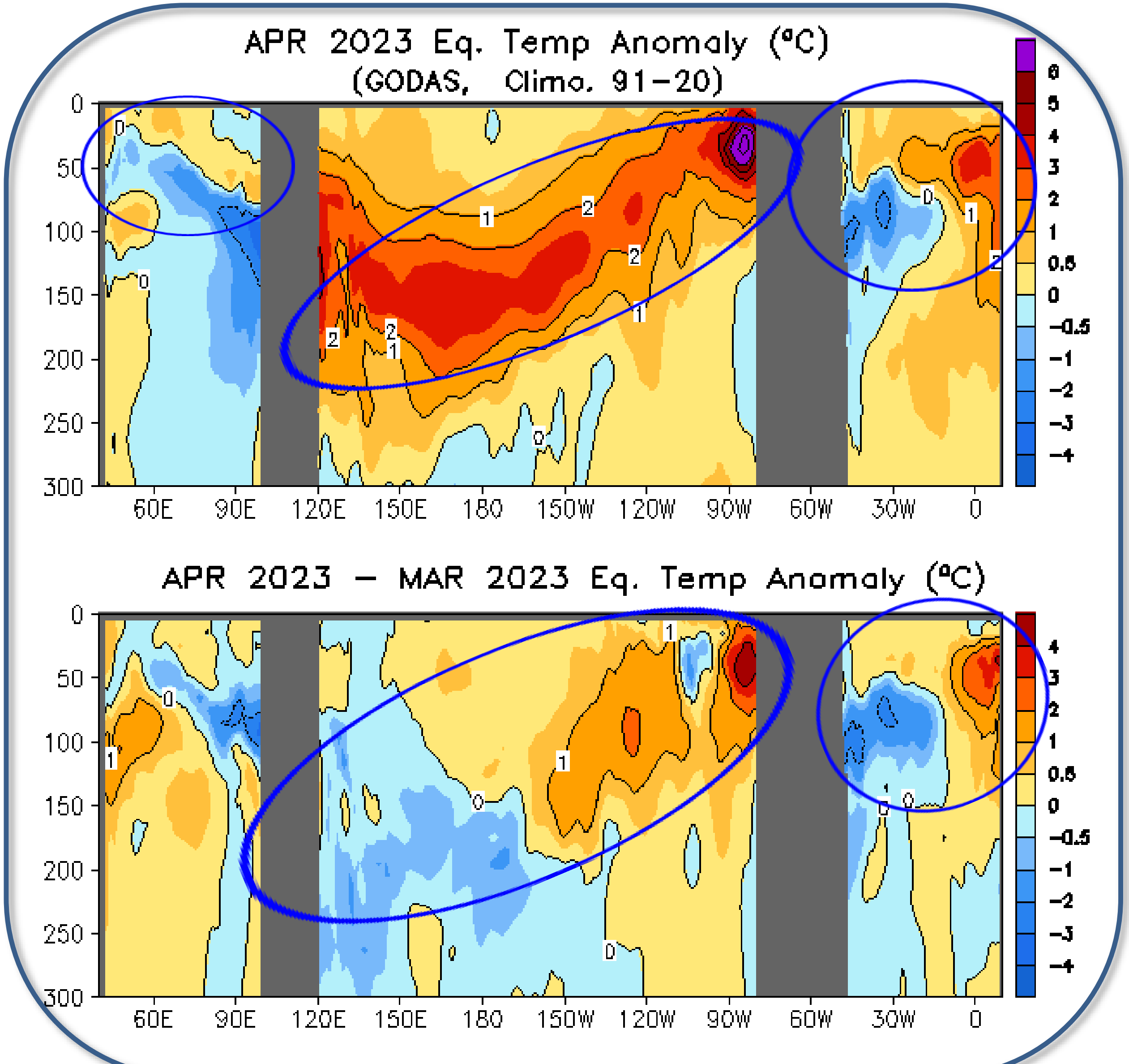
SSTAs (top) and SSTA tendency (bottom). Data are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

AVISO & GODAS SSH Anomaly (cm) and Anomaly Tendency



- SSHs were above normal along the equatorial Pacific in GODAS & AVISO.
- The tendencies indicated an increase (decrease) of SSH in the central and eastern (western) tropical Pacific.

Longitude-Depth Temperature Anomaly and Anomaly Tendency in 2ºS-2ºN



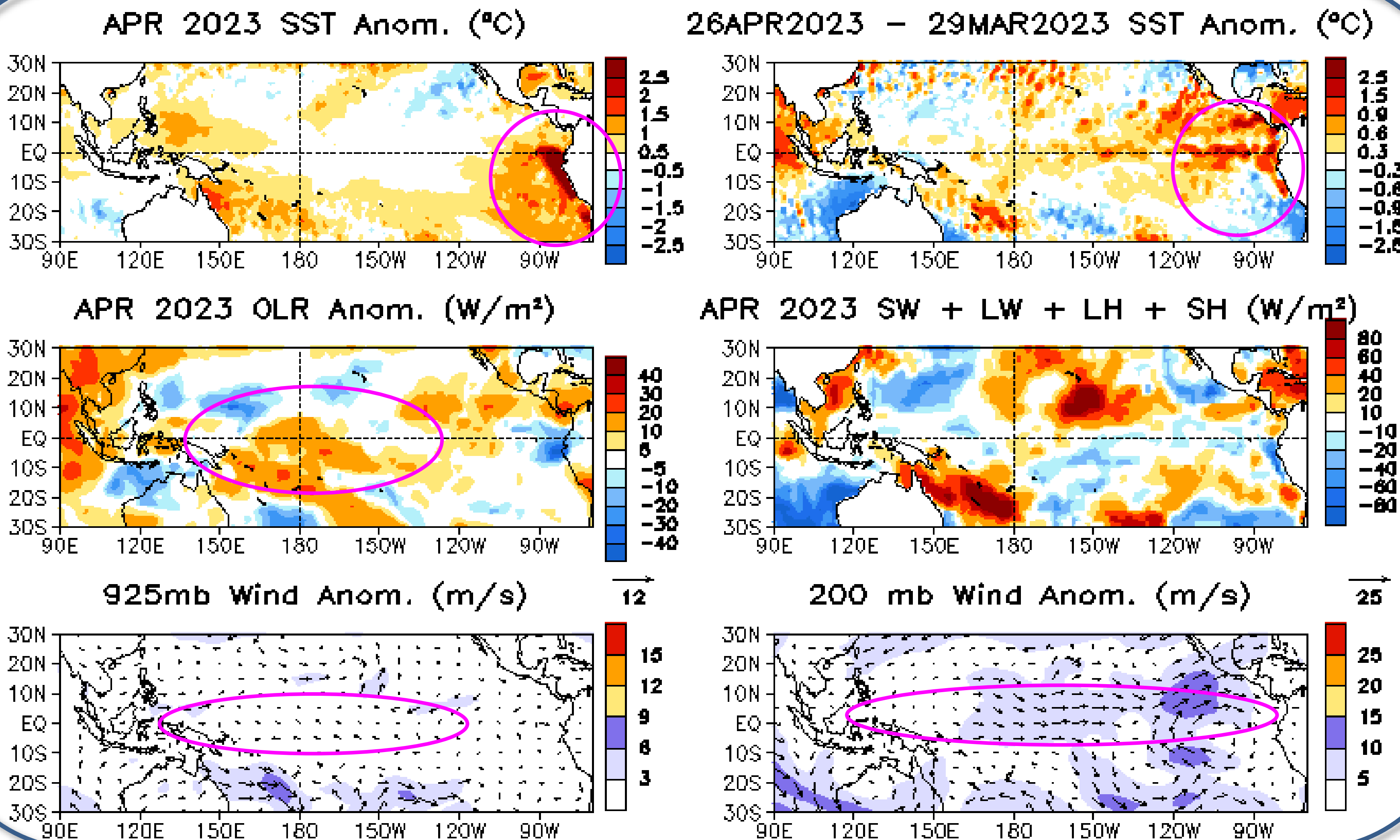
- Positive temperature anomalies were present along the thermocline in the Pacific.
- Positive (negative) temperature anomalies were observed above (below) the thermocline in the central and estern Indian Ocean.
- The anomalies were mostly positive in the Atlantic Ocean.

- Temperature anomaly tendency was positive (negative) along the thermocline in the eastern (western) Pacific.
- Temperature anomaly tendency was positive (negative) in the eastern (western) Atlantic Ocean.

Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data is from the NCEP's GODAS. Anomalies are departures from the 1991-2020 base period means.

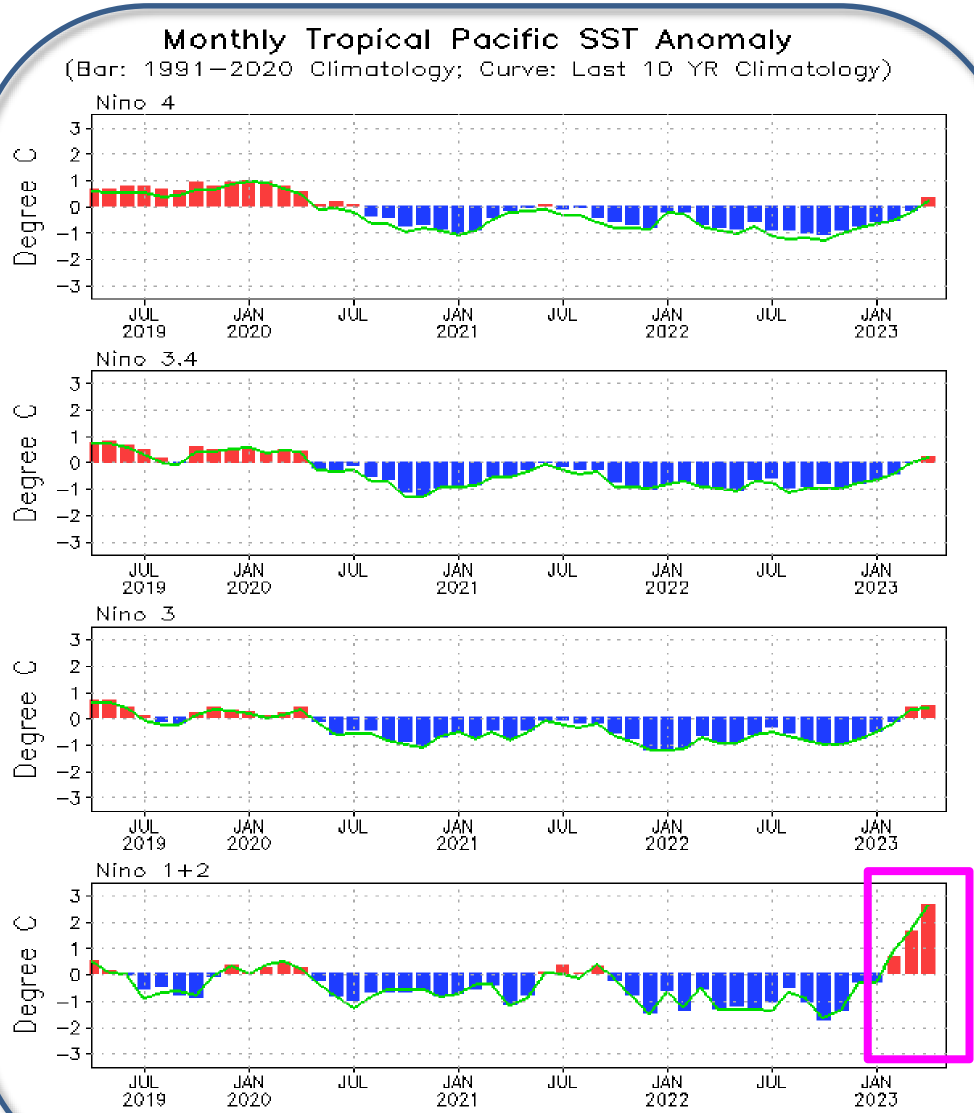
Tropical Pacific Ocean and ENSO Conditions

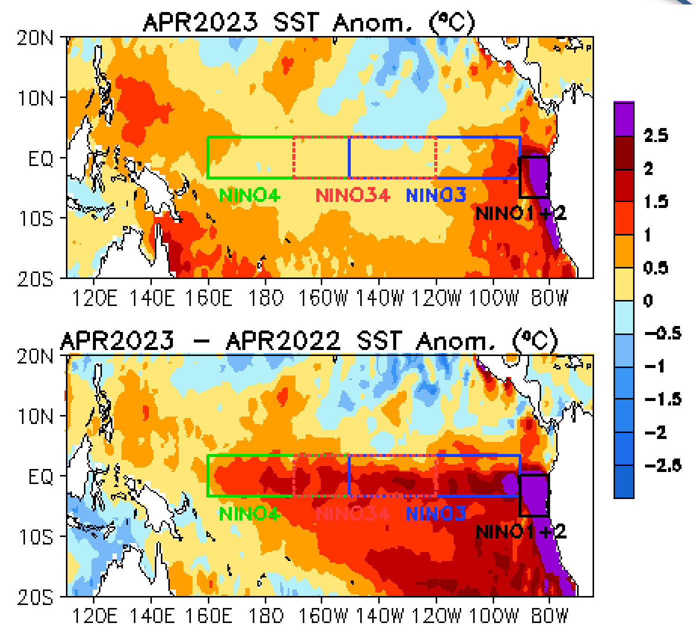
Tropical Pacific: SSTA, SSTA Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Winds



SSTAs (top-left), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the OIv2.1 SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1991-2020 base period means.

Evolution of Pacific Niño SST Indices





- All Niño indices warmed up in Apr 2023, with Niño3.4 = 0.2°C (OIv2.1).

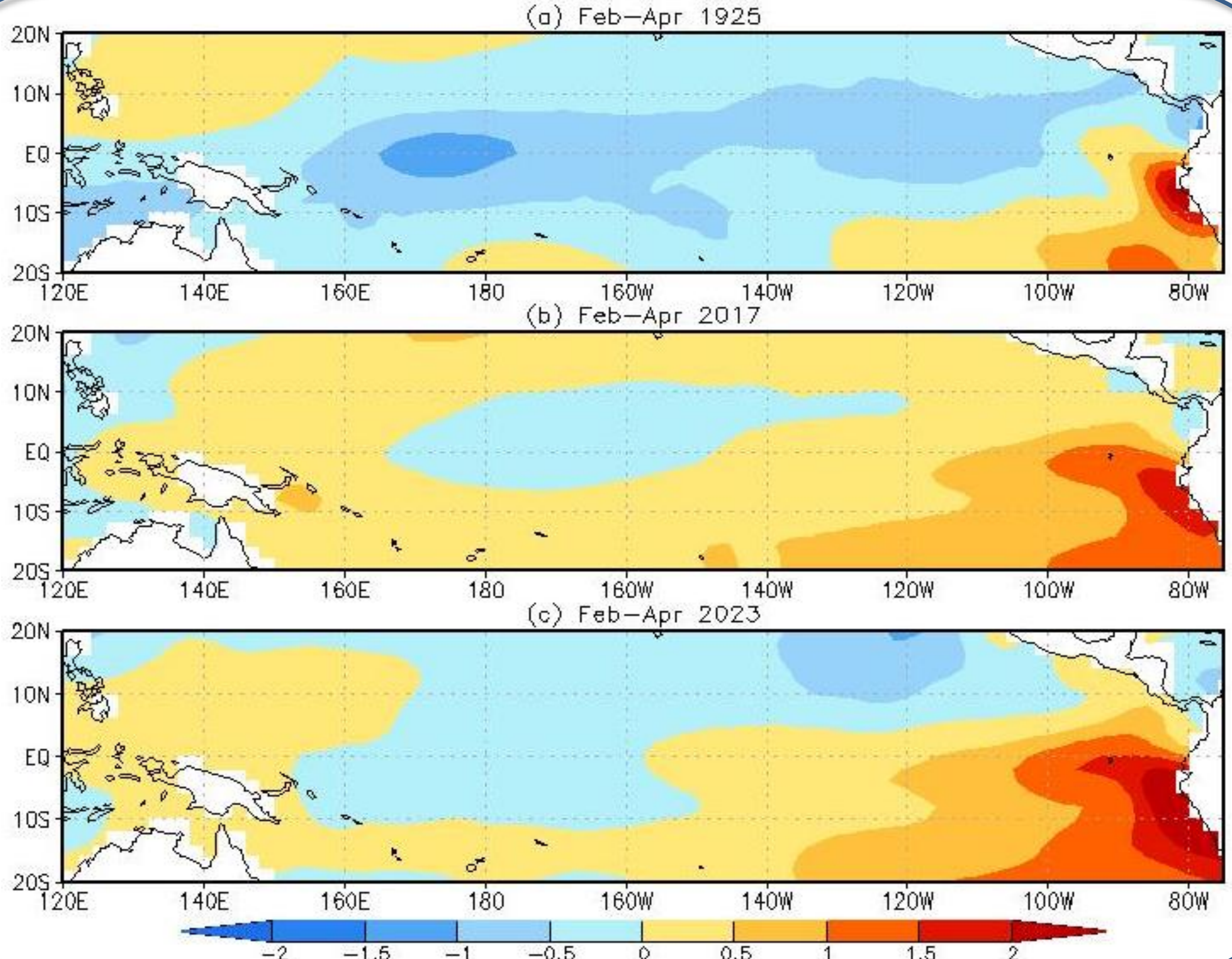
- A coastal Niño has been observed since Feb 2023 with Niño1+2= 2.4°C(OIv2.1) in Apr 2023.

- Compared with Apr 2022, the tropical Pacific was much warmer in Apr 2023.

- The indices may have differences if based on different SST products.

Niño region indices, calculated as the area-averaged monthly mean SSTAs (°C) for the specified region. Data are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

Coastal El Niños in 1925, 2017, & 2023



Definition of a coastal El Nino event in this work

- 3-month running mean Niño1+2 index ≥ one STD (0.8C; without 1982/83 & 1997/98); & ENSO-adjusted 3-month running mean Niño1+2 index ≥ one STD (0.6C; without 1982/83 & 1997/98)
- The anomaly of this magnitude persists for at least three consecutive months.

(b) 7 Coastal El Nino events since 1979:

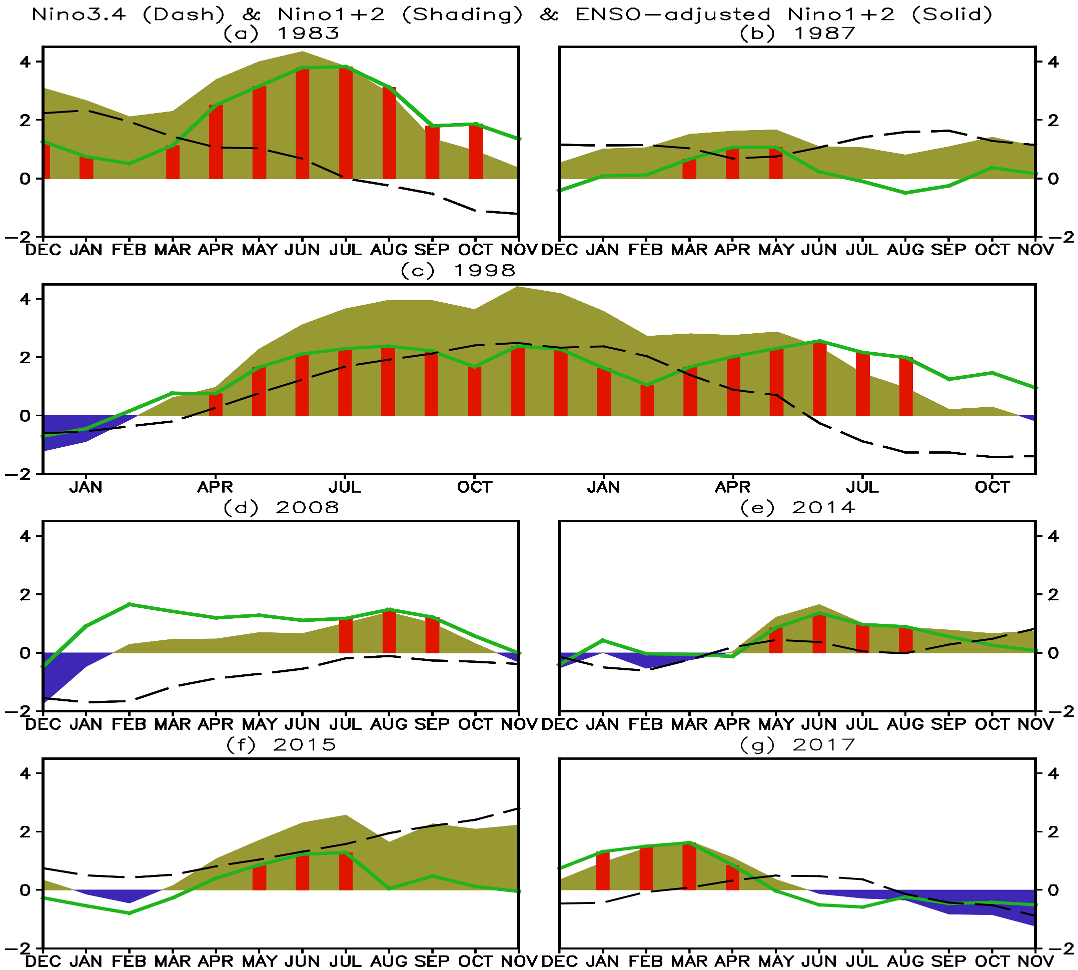
- 1983 (March-October 1983)
  1987 (March-May 1987)
  1998 (April 1997-August 1998)
  2008 (July-September 2008)
  2014 (May-August 2014)
  2015 (May-July 2015)
  2017 (January-April 2017)

- 1983, 1987, & 1997: followed by major El Nino in 1982-83, 1986-87, 97-98, & equatorward shift of ITCZ played a key role;

- 2014 & 2015: Westerly wind burst, downwelling Kelvin waves, similar to basin-scale El Nino;

- 2008 & 2017: Westerly wind anomalies, enhancement of the seasonal cycle or extended the warm phase of the seasonal cycle.

Hu, Z.-Z., B. Huang, J. Zhu, A. Kumar, and M. J. McPhaden: 2019: On the variety of coastal El Niño events. Climate Dyn., 52 (12), 7537-7552. DOI: 10.1007/s00382-018-4290-4.

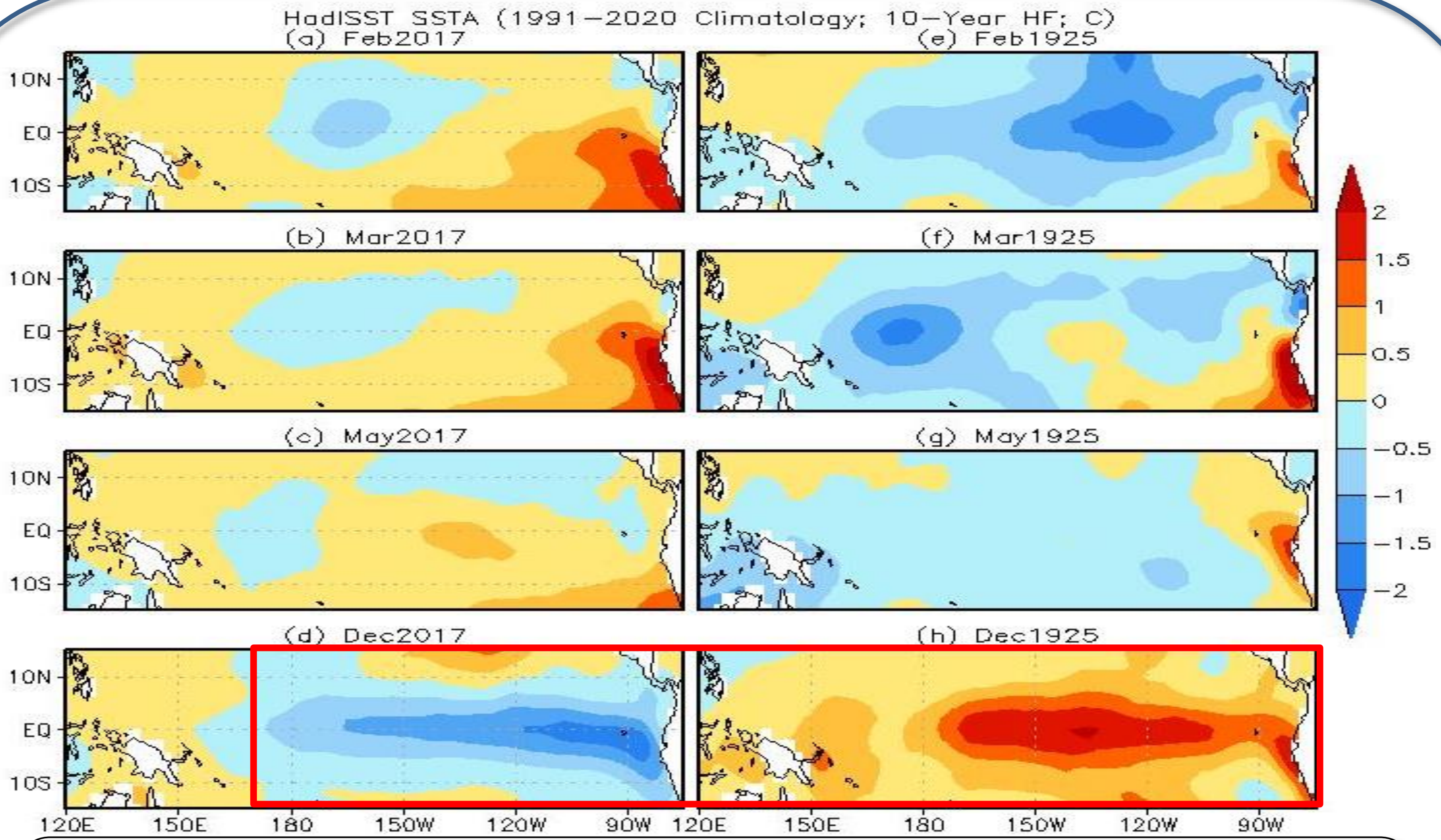


- **Coastal El Nino normally peaks in spring or summer;**
- **The durations of the seven coastal El Niños range from 3 months (1987, 2008, 2015) to 17 months (1998).**

Evolution of 3-month running mean Niño1+2 (shading), ENSO-adjusted Niño1+2 (green solid line), and Niño3.4 (dashed line) indices in the seven coastal Niño events. The bars represent the months that both the Niño1+2 index is equal to or larger than one STD (0.8°C) and the ENSO-adjusted Niño1+2 index is equal to or larger than one STD (0.6°C). The unit is °C.

Hu, Z.-Z., B. Huang, J. Zhu, A. Kumar, and M. J. McPhaden: 2019: On the variety of coastal El Niño events. Climate Dyn., 52 (12), 7537-7552. DOI: 10.1007/s00382-018-4290-4.

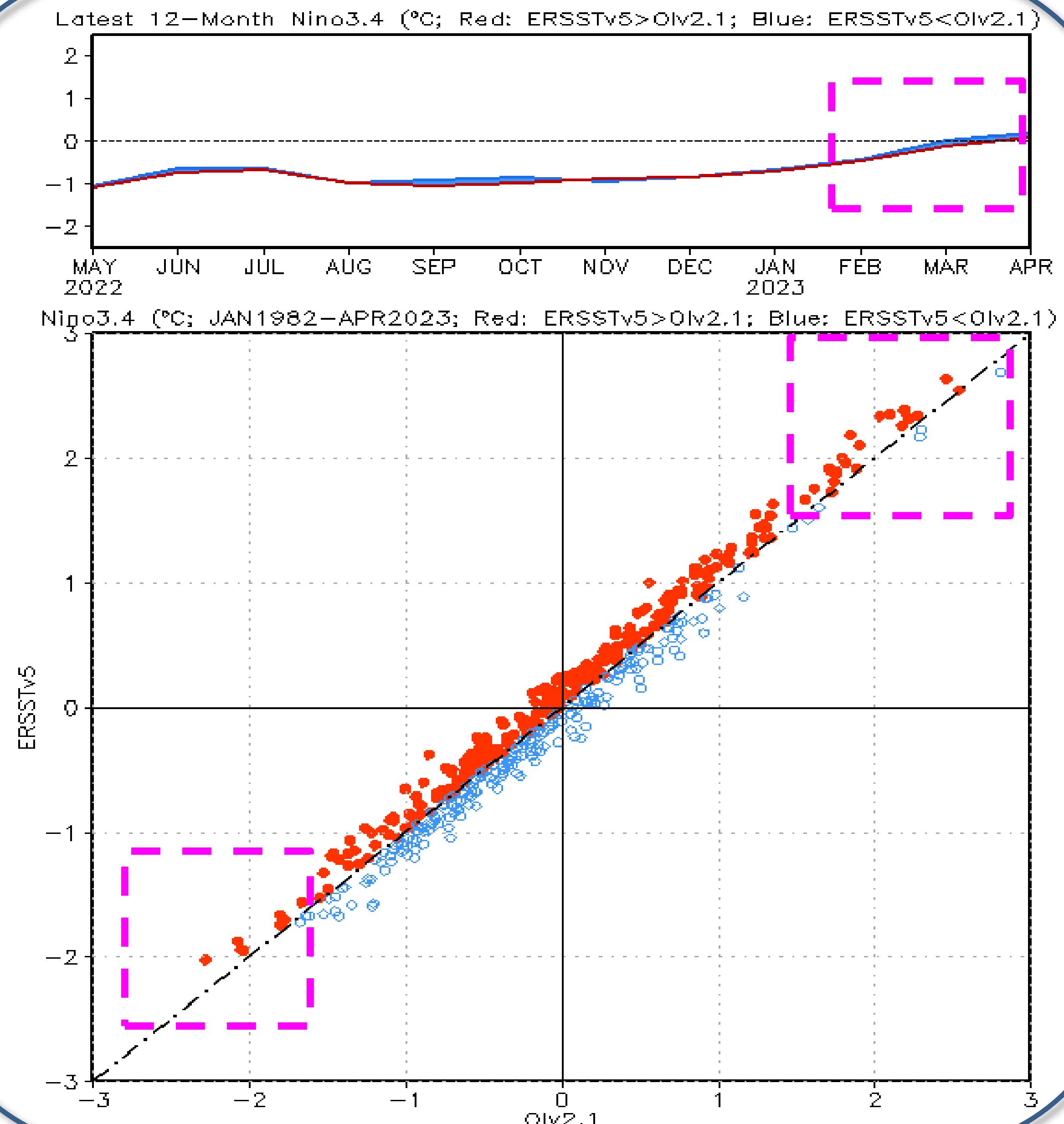
El Niño & Coastal El Niño



- Coastal El Niño in spring 2017 was followed by a La Niña, while coastal El Niño in spring 1925 was followed by a canonical El Niño.

Hu, Z.-Z., B. Huang, J. Zhu, A. Kumar, and M. J. McPhaden: 2019: On the variety of coastal El Niño events. Climate Dyn., 52 (12), 7537-7552. DOI: 10.1007/s00382-018-4290-4.

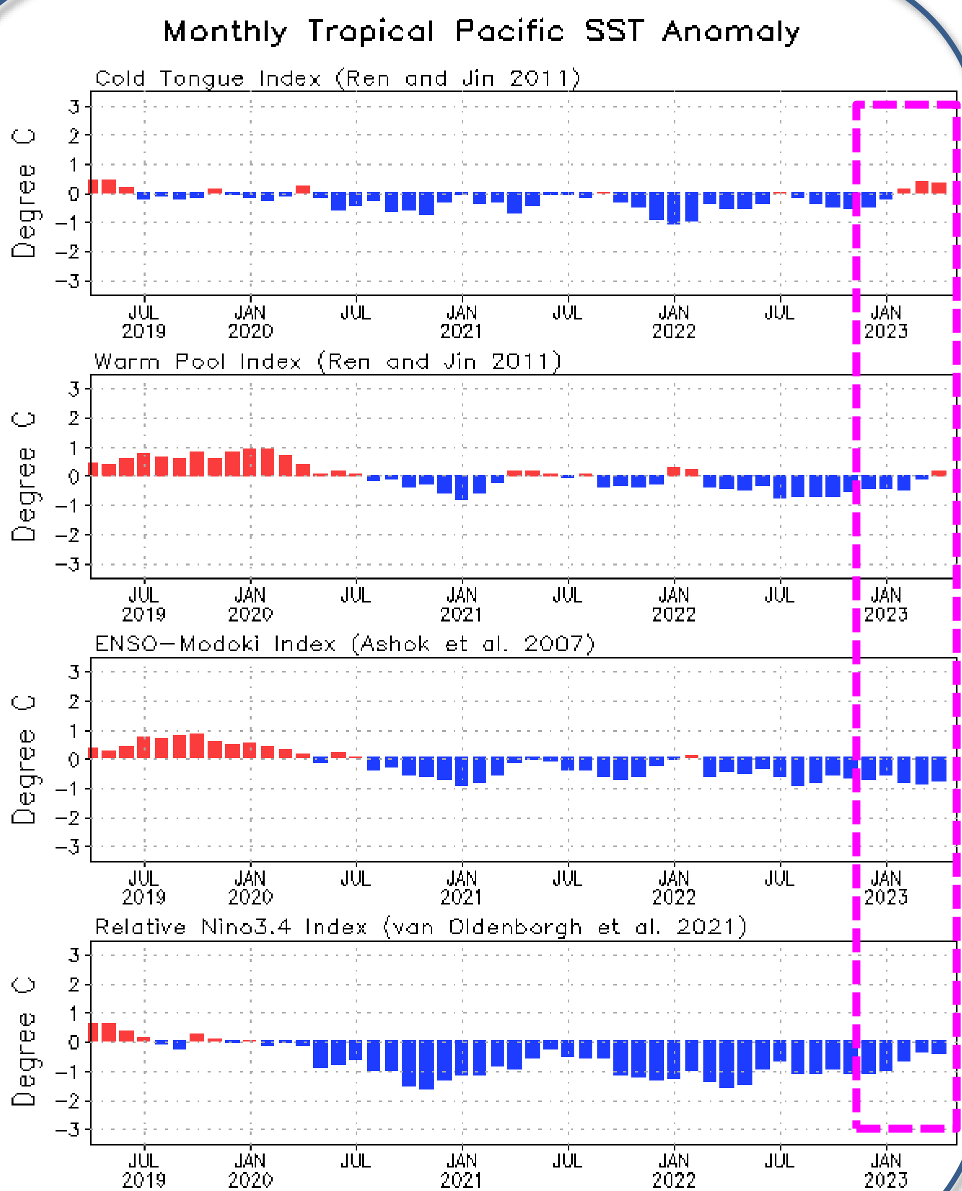
Comparison of ERSSTv5 & OIv2.1 Niño3.4 Index

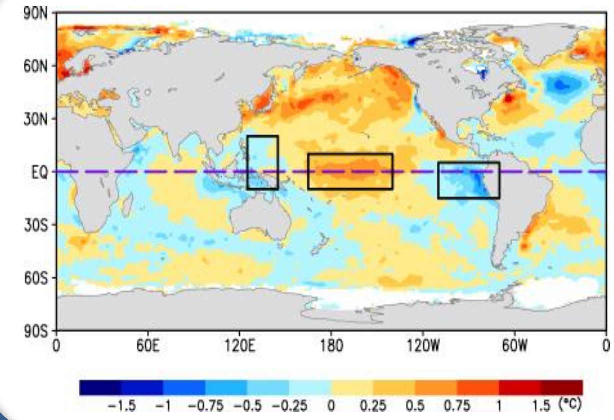


- Recently, ERSSTv5 is cooler than OIv2.1: 0.2C (OIv2.1) & 0.1C (ERSSTv5).

- Historically, ERSSTv5 can be either warmer or cooler than OIv2.1.
- For both the extreme positive and negative (>1.5ºC or <-1.5ºC) Niño3.4, ERSSTv5 is mostly warmer than OIv2.1.
- During last few months, ERSSTv5 was similar to OIv2.1.

Evolution of Pacific Niño SST Indices



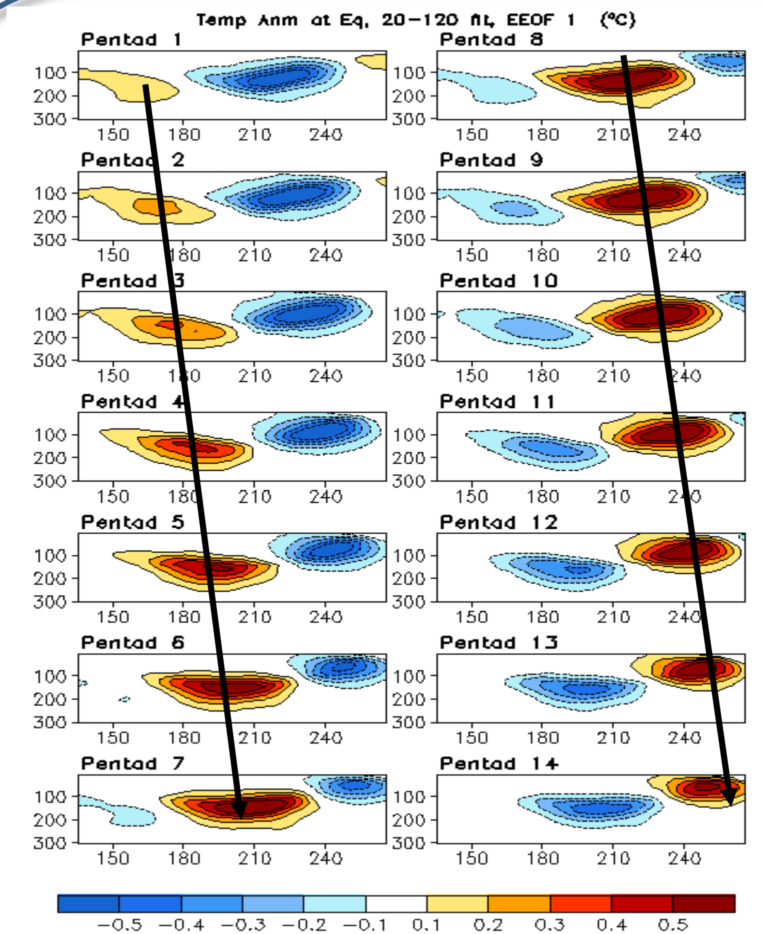


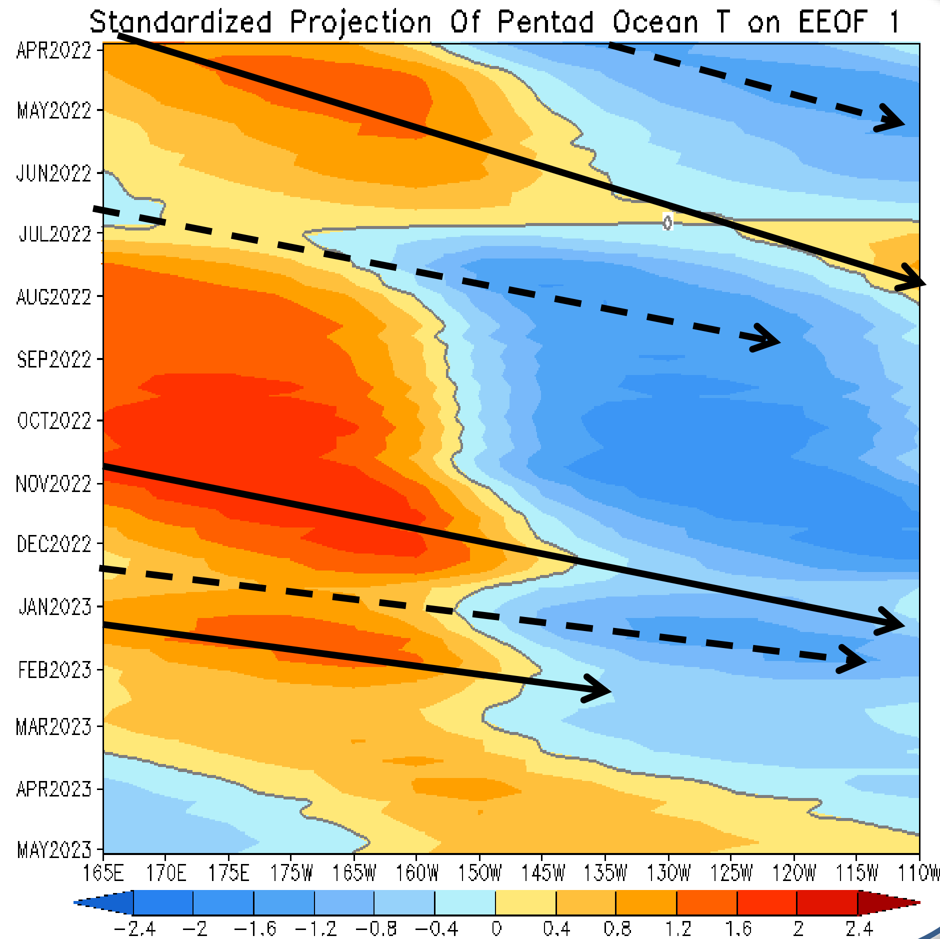
- Relative Niño3.4 index is now included in ENSO monitoring, which is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0º-360º, 20ºS-20ºN), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative Niño3.4 index is renormalized (van Oldenborgh et al. 2021: ERL, 10.1088/1748-9326/abe9ed).

Relative Niño3.4 data updated monthly at:

https://www.cpc.ncep.noaa.gov/data/indices/RONI.ascii.txt

Oceanic Kelvin Wave (OKW) Index



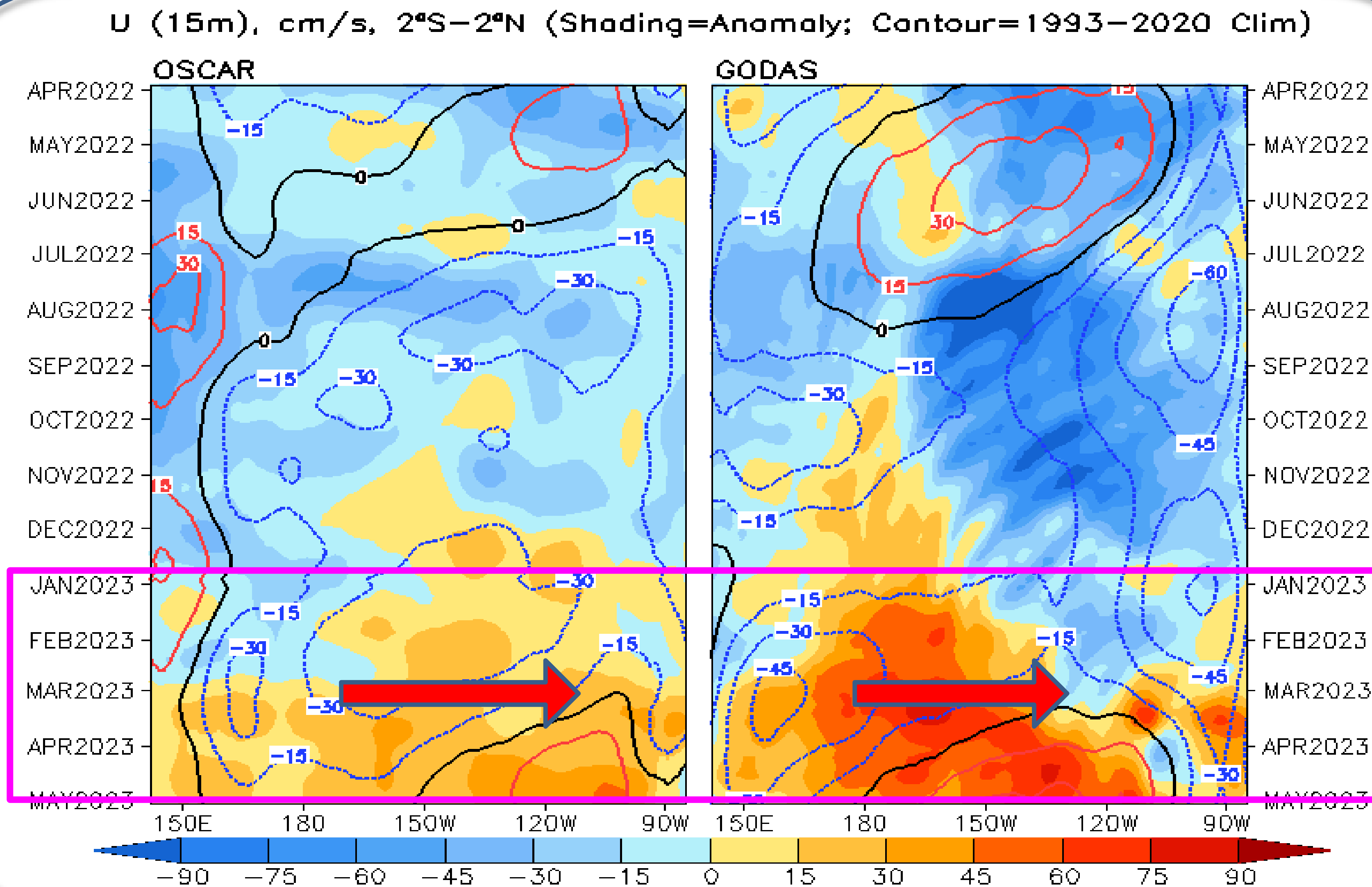


- **Multiple weak downwelling and upwelling Kelvin waves were observed in 2022, leading to the small fluctuation of SSTA in the central and eastern equatorial Pacific.**

- **A weak downwelling Kelvin wave propagated eastward since Jan 2023.**

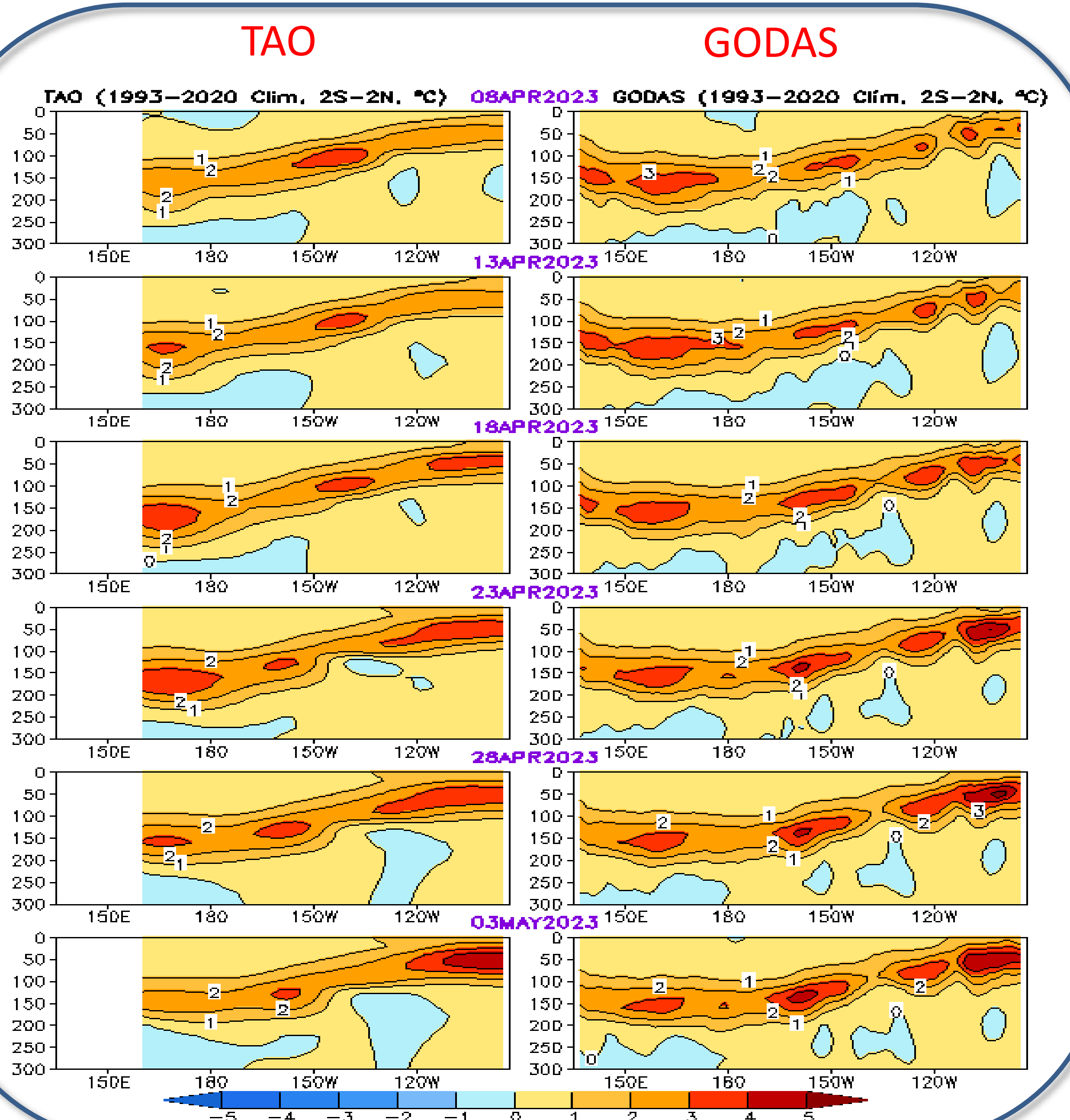
(OKW index is defined as standardized projections of total anomalies onto the 14 patterns of Extended EOF1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).)

Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- Anomalous eastward currents were present along the equatorial Pacific in both OSCAR and GODAS since Mar 2023, which were consistent with the growth of the positive SSTA.

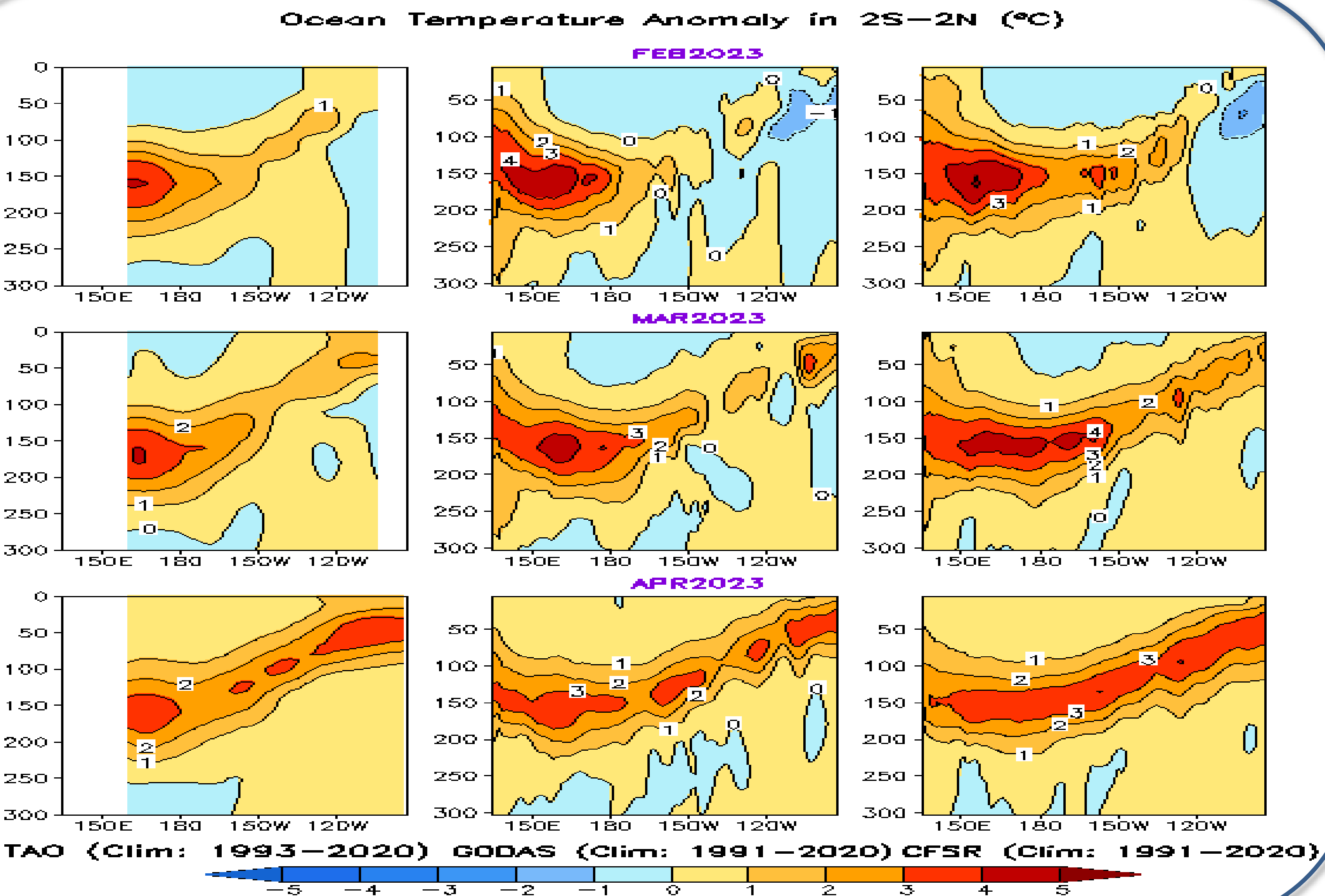
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly



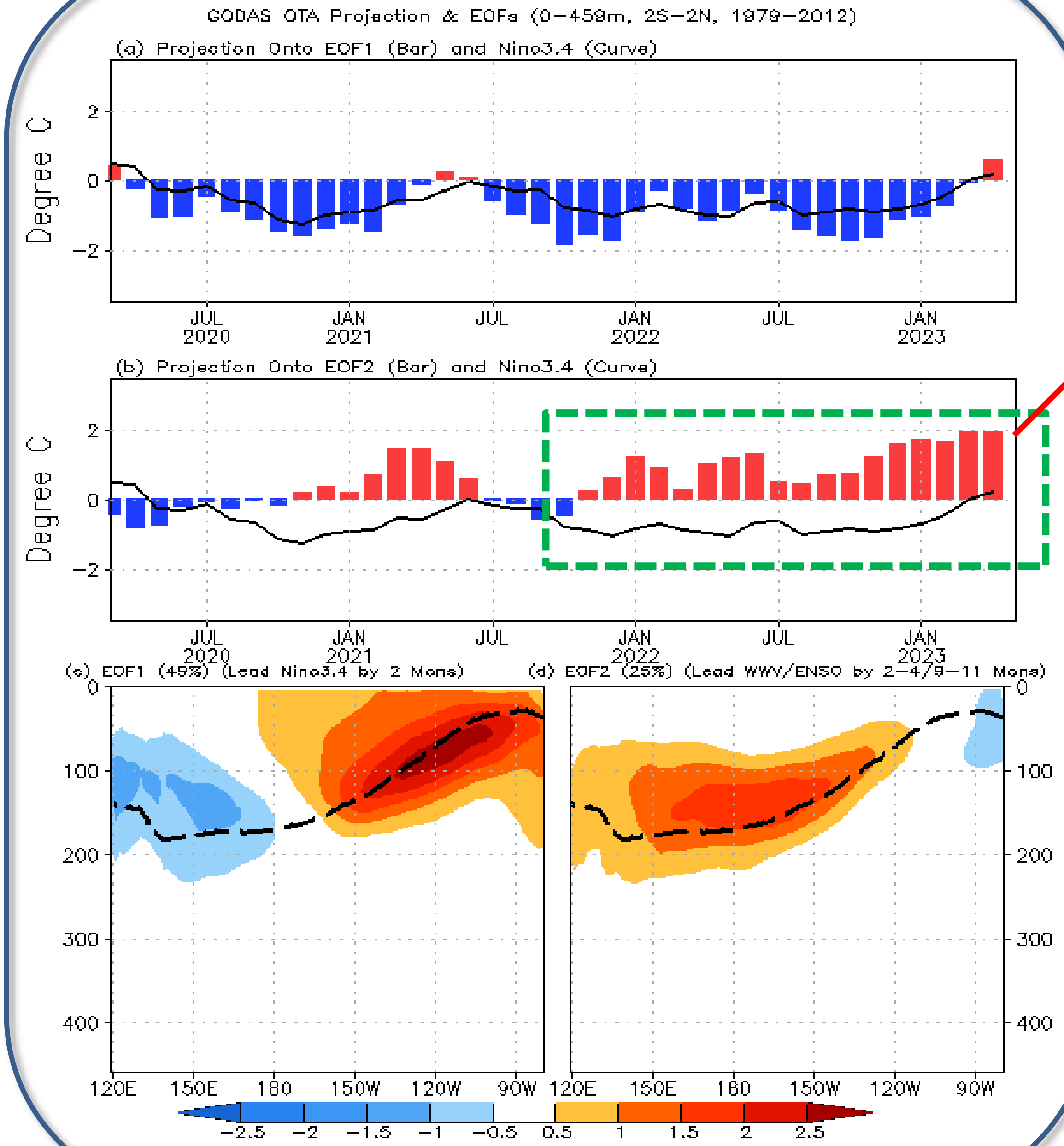
- Positive ocean temperature anomalies were dominated along the thermocline in the last month.

- The features of the ocean temperature anomalies were similar between GODAS and TAO analysis.

Monthly mean subsurface temperature anomaly along the Equator:
A consistent eastward expansion of the warm anomalies



Equatorial Sub-surface Ocean Temperature Monitoring



- The equatorial Pacific has been in a recharge phase since Nov 2021.

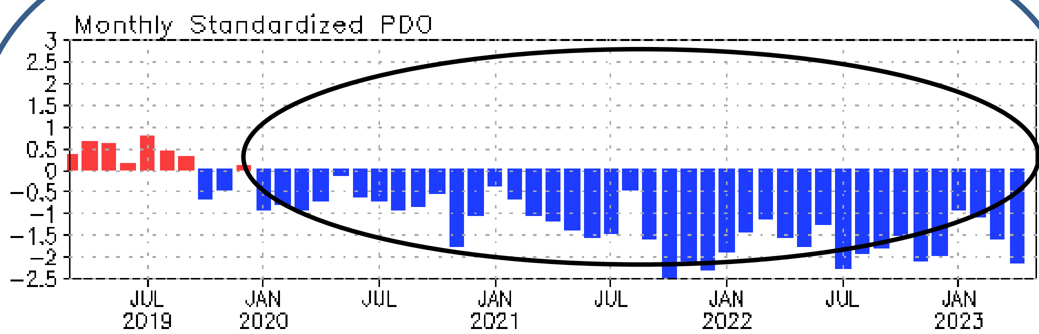
- Projection of ocean temperature anomalies onto EOF1 and EOF2; EOF1: Tilt/dipole mode (ENSO peak phase); EOF2: WWV mode.

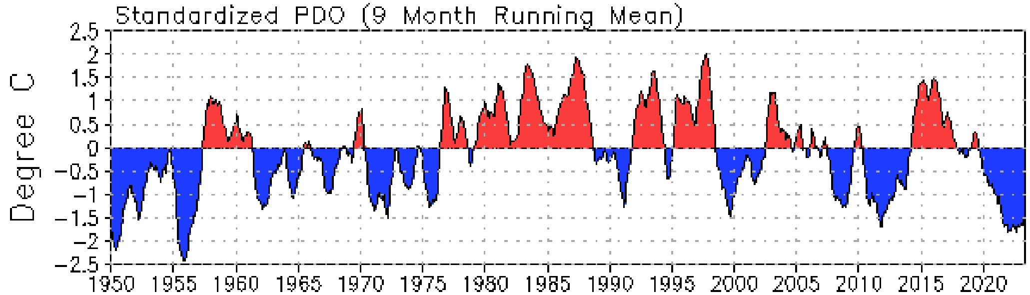
- Recharge/discharge oscillation (ENSO transition phase); Recharge process: heat transport from outside of equator to equator; Negative -> positive phase of ENSO

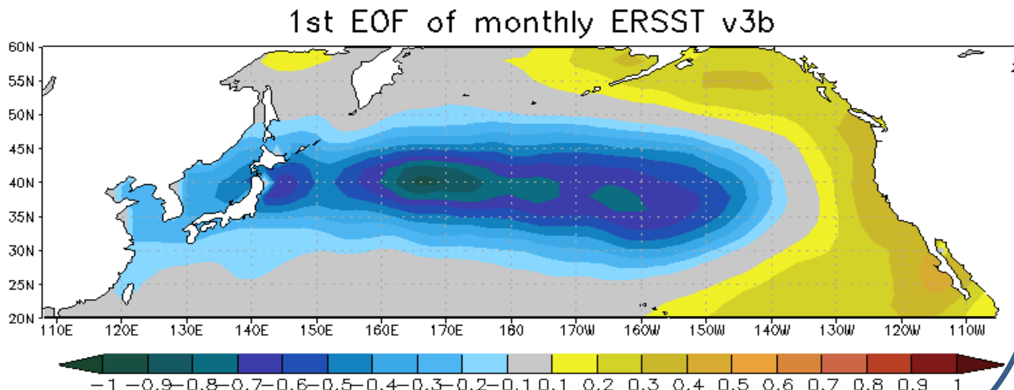
- For details, see: Kumar and Hu (2014) DOI: 10.1007/s00382-013-1721-0.

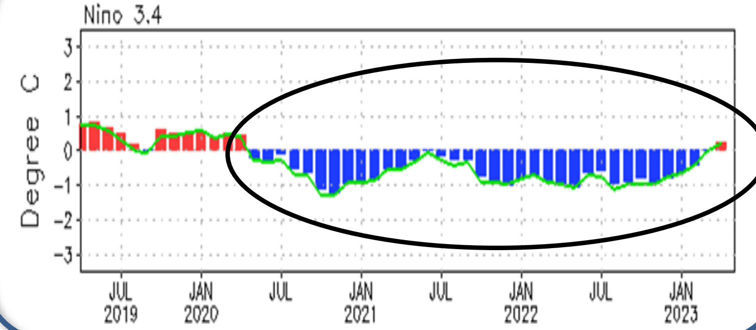
North Pacific & Arctic Oceans

Pacific Decadal Oscillation (PDO) Index







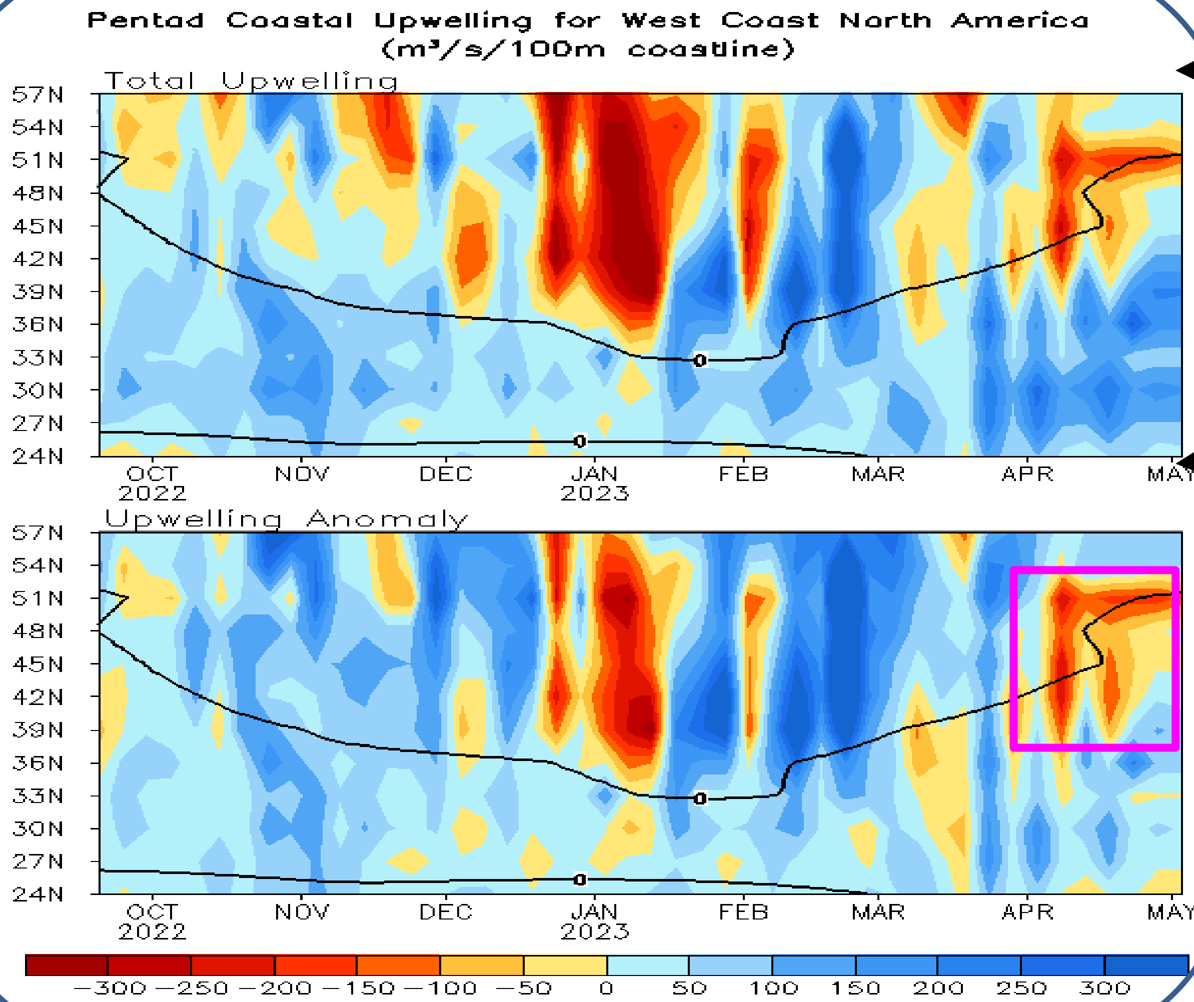


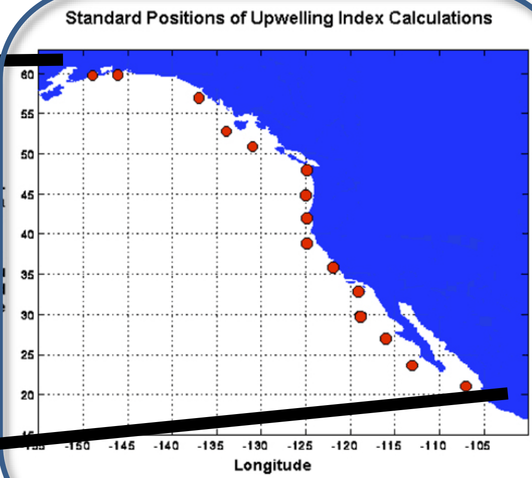
- The PDO has been in a negative phase since Feb 2020 with PDOI = -2.1 in Apr 2023.

- Statistically, ENSO leads PDO by 3-4 months, through teleconnection via atmospheric bridge, with El Niño (La Niña) associated with positive (negative) PDO Index.

• PDO is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.

North America Western Coastal Upwelling

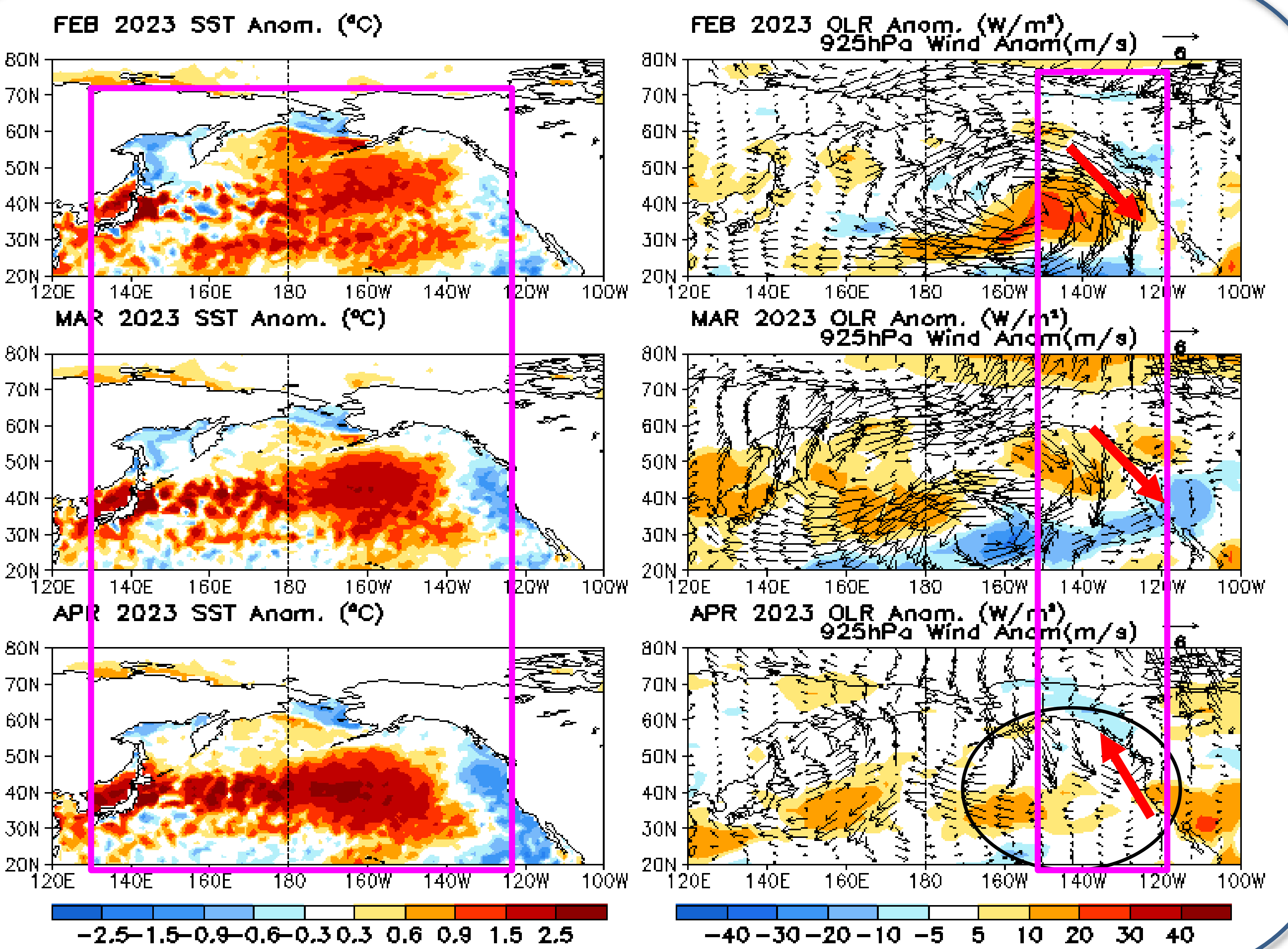




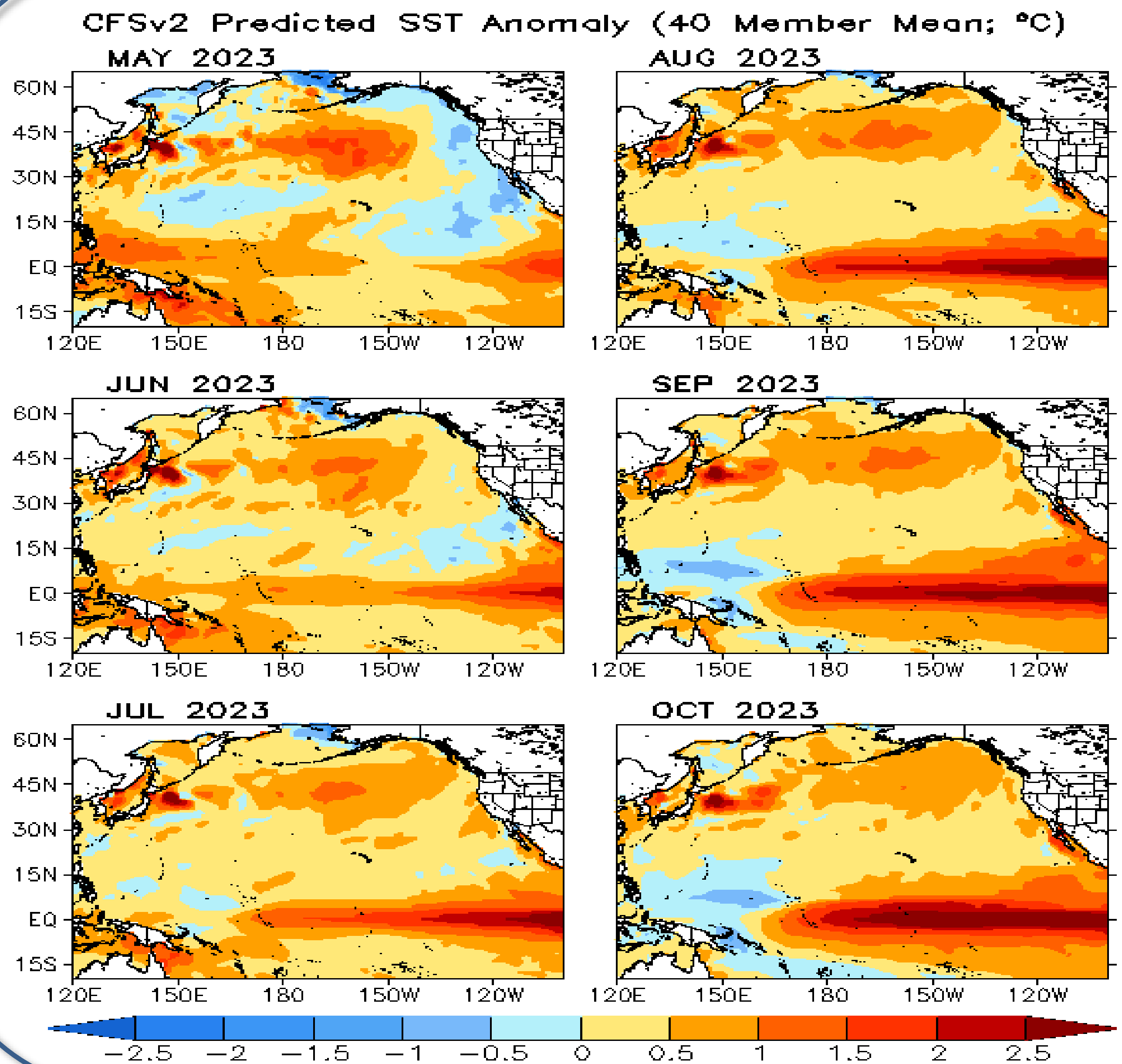
- Coastal (39º-54ºN) anomalous downwelling was observed in Apr 2023.

(top) Total and (bottom) anomalous upwelling indices at the 15 standard locations for the western coast of North America. Derived from the vertical velocity of the NCEP's GODAS and are calculated as integrated vertical volume transport at 50-meter depth from each location to its nearest coast point ($m^3/s/100m$ coastline). Anomalies are departures from the 1991-2020 base period pentad means.
- Area below (above) black line indicates climatological upwelling (downwelling) season.
- Climatologically upwelling season progresses from March to July along the west coast of North America from 36ºN to 57ºN.

North Pacific SST, OLR, and uv925 anomalies

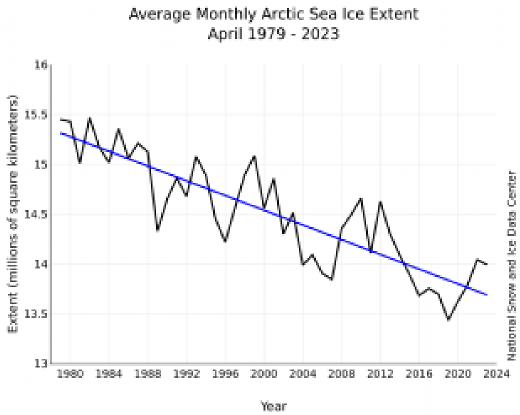


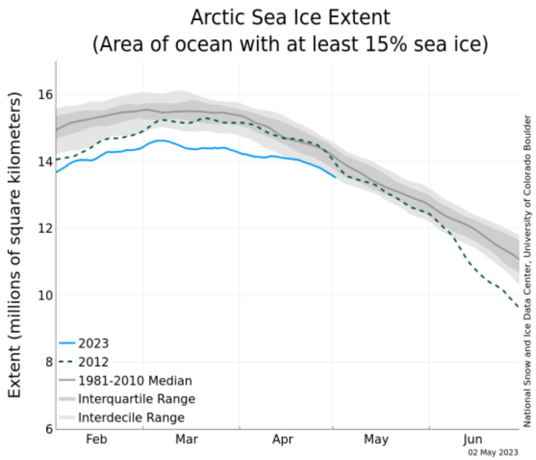
CFSv2 NE Pacific SSTA Predictions

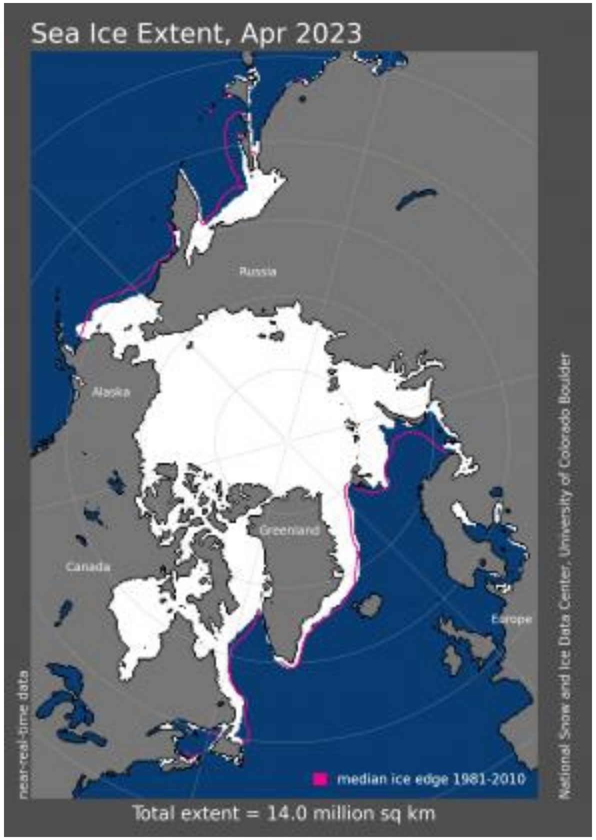


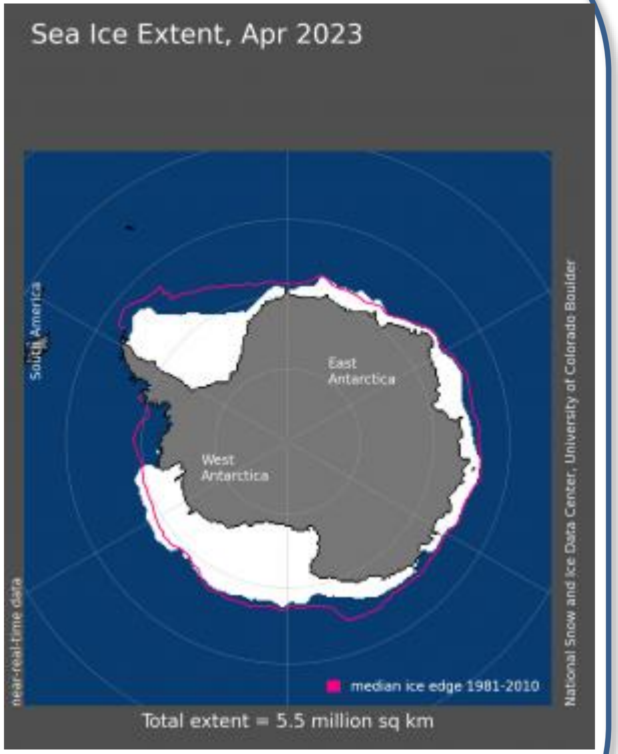
- The CFSv2 predicts above normal SSTs in the N. Pacific during spring – autumn 2023.

Sea Ice; NSIDC (http://nsidc.org/arcticseaicenews/index.html)







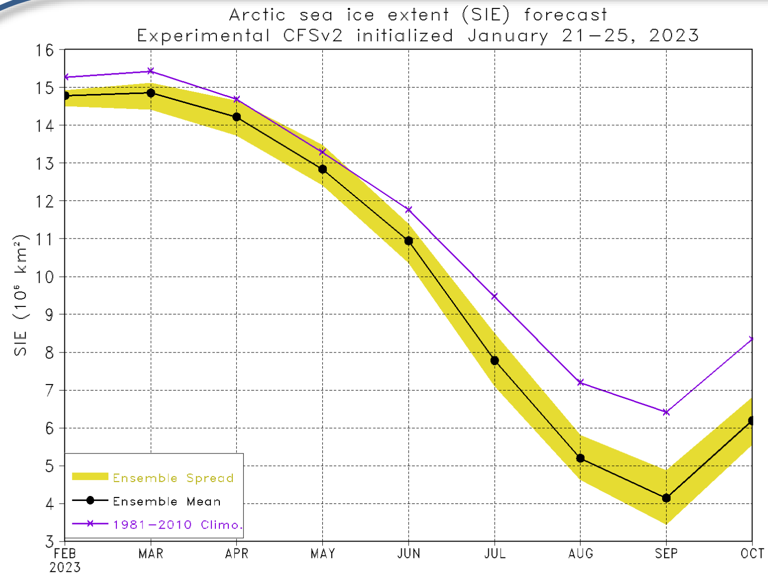


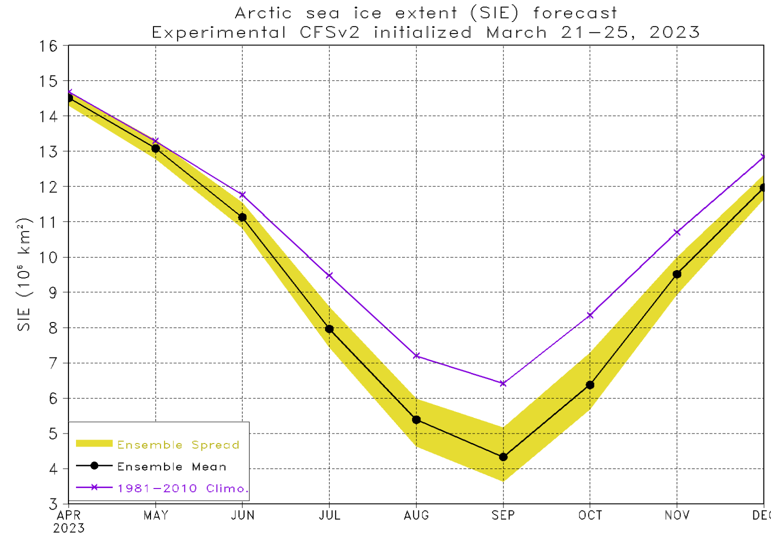
- The rate of Arctic ice loss for Apr 2023 was slow, owing to cool conditions across the ice-covered Arctic Ocean and below-average to near-average temperatures near the ice edge.

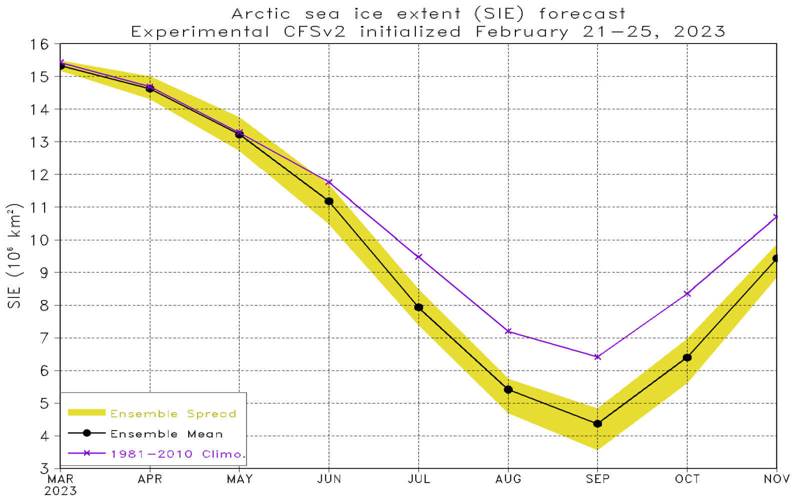
-The Apr 2023 average Arctic sea ice extent was 13.99 million square kilometers, tied with 2004 as the tenth lowest Apr in the satellite record.

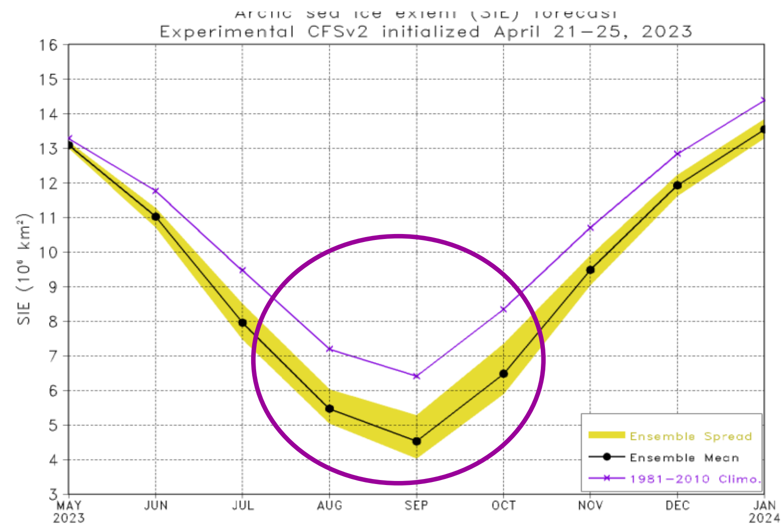
-Antarctic sea ice extent for Apr 2023 was 5.50 million square kilometers, remained well below average.

NCEP/CPC Arctic Sea Ice Extent Forecast









https://www.cpc.ncep.noaa.gov/products/people/wwang/seaice_seasonal/index.html

Seasonal sea ice forecast with UFS

Seasonal hindcasts

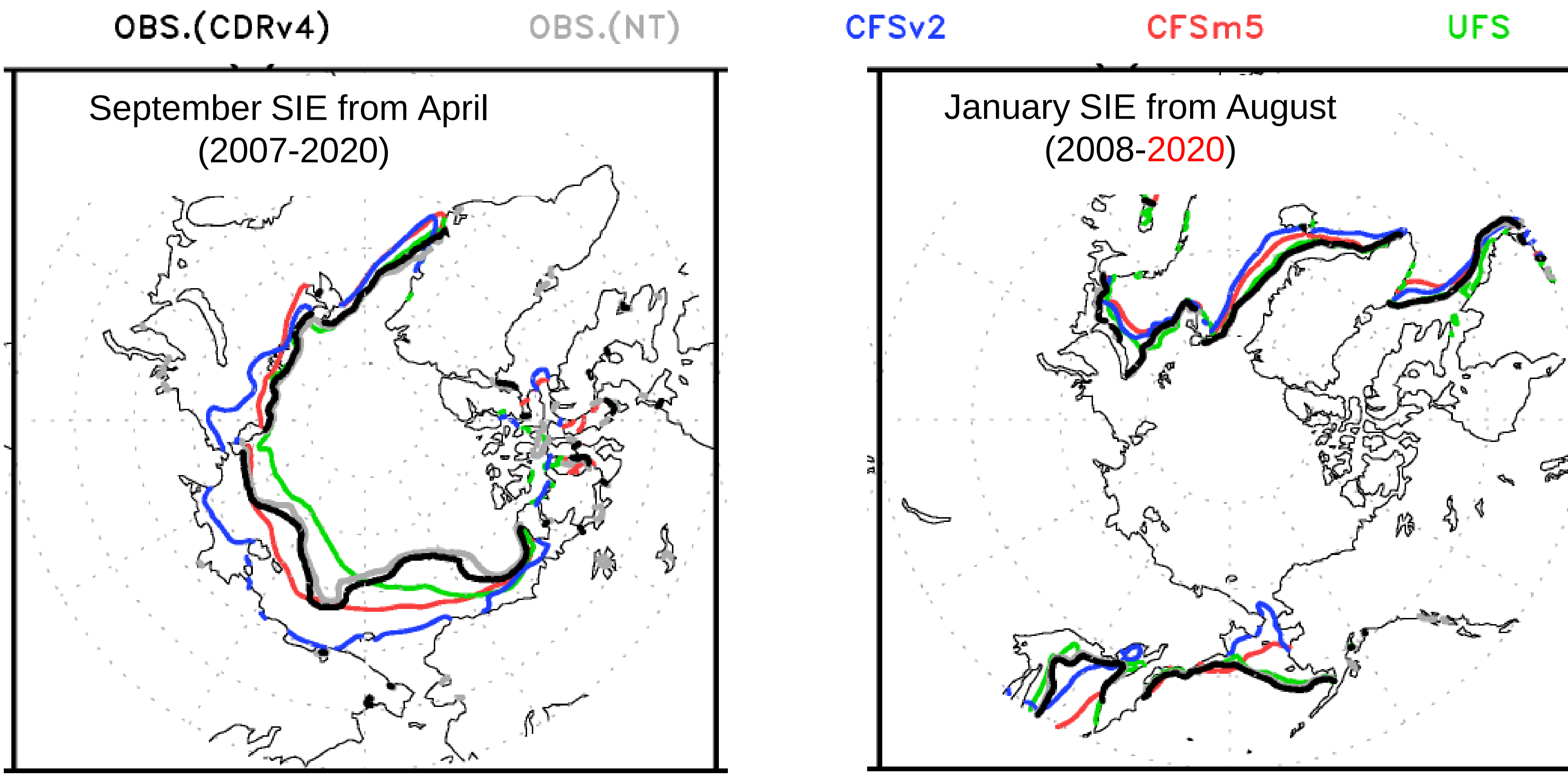
- Model: UFS P5 C20b
- ICs: CFSR OCN/ATM + CSIS ICE
- Period: Jan.-Dec. IC (21-25), 2007-2020
- Validation SIC: NOAA/NSIDC CDR v4

Prior hindcasts: CFS5m (5 members)+CFSv2 (10 members)

Zhu, J., Wang, W., Liu, Y., Kumar, A., & DeWitt, D. (2023). Advances in seasonal predictions of Arctic sea ice with NOAA UFS. GRL, 50, e2022GL102392. https://doi.org/10.1029/2022GL102392R

Seasonal sea ice forecast with UFS

Hindcast evaluations: Climatological sea ice coverage



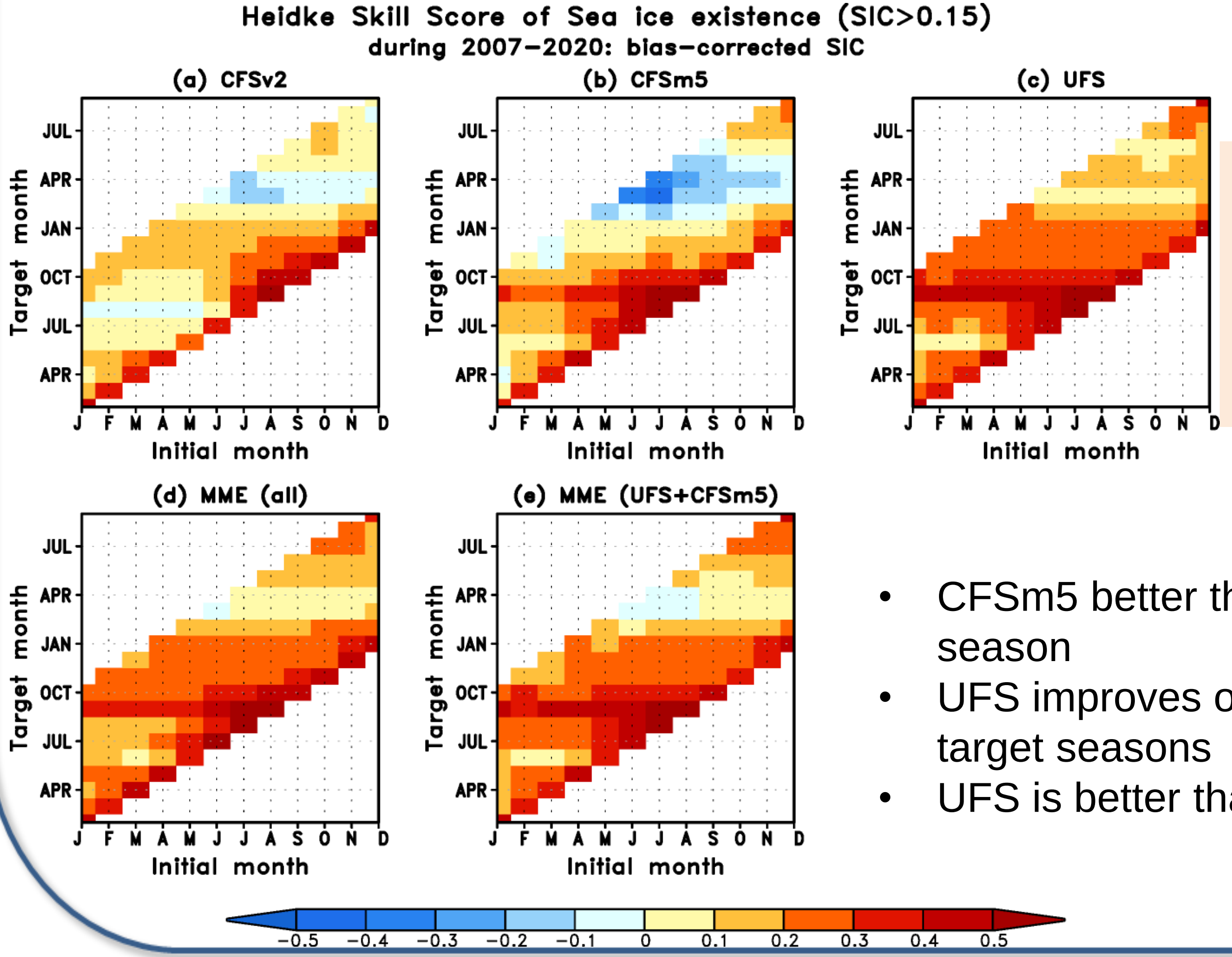
- CFSv2 > OBS
- UFS & CFSm5 erros comparable in magnitude, better than CFSv2

- Improvements in Atlantic and Bering Strait. UFS better than CFSm5 and CFS

Zhu et al. (2023)

Seasonal sea ice forecast with UFS

Hindcast evaluations: Heidke Skill Score for sea ice existence



$$HSS = \frac{AC - AC_e}{AT - AC_e}$$

***AC*:** Area of correct forecast of sea ice existence
***AC$_e$*:** Area of expected correct forecast of sea ice existence (using climatological SIC during 1991-2020 here)
***AT*:** Area of total forecast grid boxes
Sea ice existence: SIC > 0.15

Model SICs are bias-corrected by removing lead time-dependent climatologies;

- CFSm5 better than CFSv2 for summer target season
- UFS improves over CFSm5 and CFSv2 for all target seasons
- UFS is better than or comparable to MMEs

Zhu et al. (2023)

Seasonal sea ice forecast with UFS

Real-time forecasts: website dissemination

https://www.cpc.ncep.noaa.gov/products/people/jszhu/seaice_seasonal/index.html

cpc.ncep.noaa.gov/products/people/jszhu/seaice_seasonal/index.html

Update

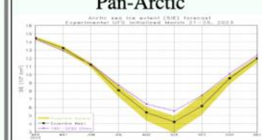
Climate Prediction Center seasonal sea ice prediction

Apr 2023 to Dec 2023 (Updated: Thu Mar 30 10:50:18 EDT 2023)

This page displays Climate Prediction Center (CPC) experimental sea ice forecasts for the next 9 months. The forecasts are initialized from CPC sea ice initialization system (CSIS) and produced with Unified Forecast System (UFS). The forecast ensemble includes 20 members. Mean bias correction is made based on the average differences between retrospecitve forecasts and observations for 2007-2022. The forecasts are initialized from 21-25Mar2023 with four forecast members from each day. Sea ice extent (SIE) is the area sum of grid boxes where sea ice concentration is greater than 15%. Sea ice probability (SIP) is defined as the fraction of ensemble members in an ensemble forecast with September ice concentration in excess of 15%. Sea ice melt date (IMD) for each grid box is determined as the first day of the first 15 day period of sea ice concentration below 15% after 1 April. Sea ice freeze date (IFD) is determined by working backwards from the last day of the forecast and finding the first 15 day period of sea ice concentration below 15% and defining IFD as the day after this period.

Sea ice extent

Pan-Arctic



Spatial maps

Monthly mean sea ice concentration	Ensemble mean	Ensemble spread
Monthly sea ice probability	SIP	
IMD	Global	Alaska

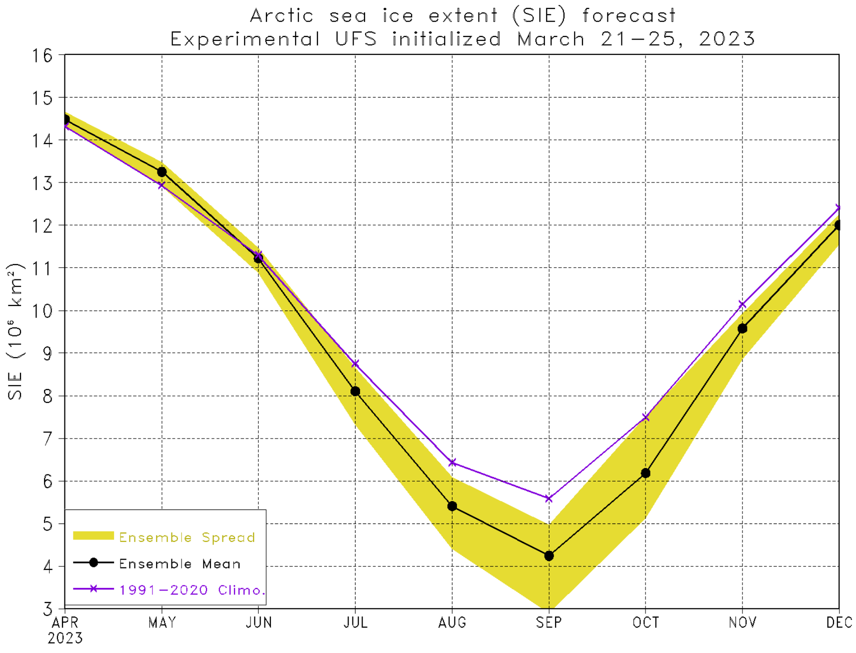
Forecast data can be downloaded here.
The performance of seasonal sea ice prediction with UFS was evaluated in Zhu et al. (2023).

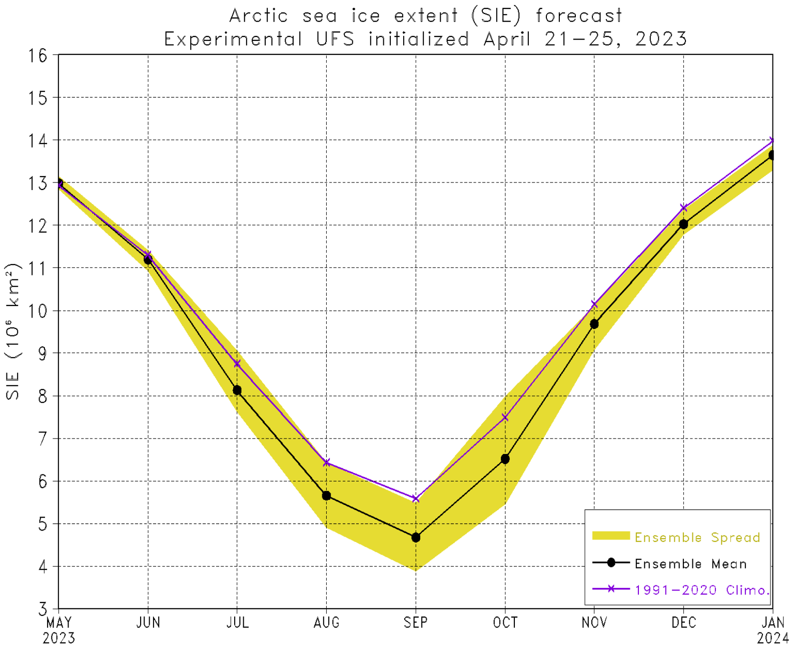
Send your comments to: Jieshun Zhu and Wanqiu Wang

Seasonal sea ice forecast with UFS

Real-time forecasts: website dissemination

https://www.cpc.ncep.noaa.gov/products/people/jszhu/seaice_seasonal/index.html

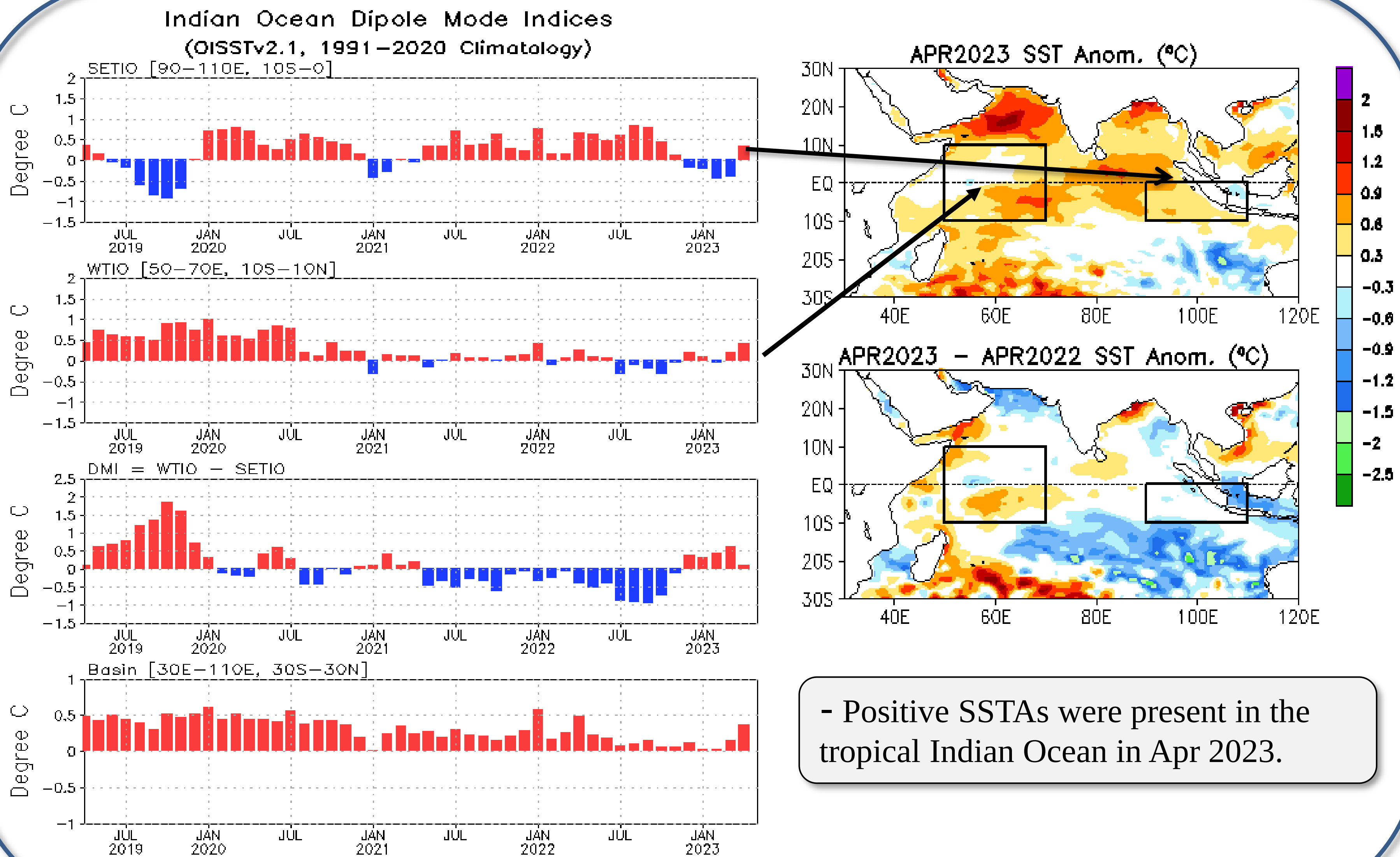




UFS forecasts suggested that the Sep sea ice extent will be below the 1991-2020 climatology.

Indian Ocean

Evolution of Indian Ocean SST Indices

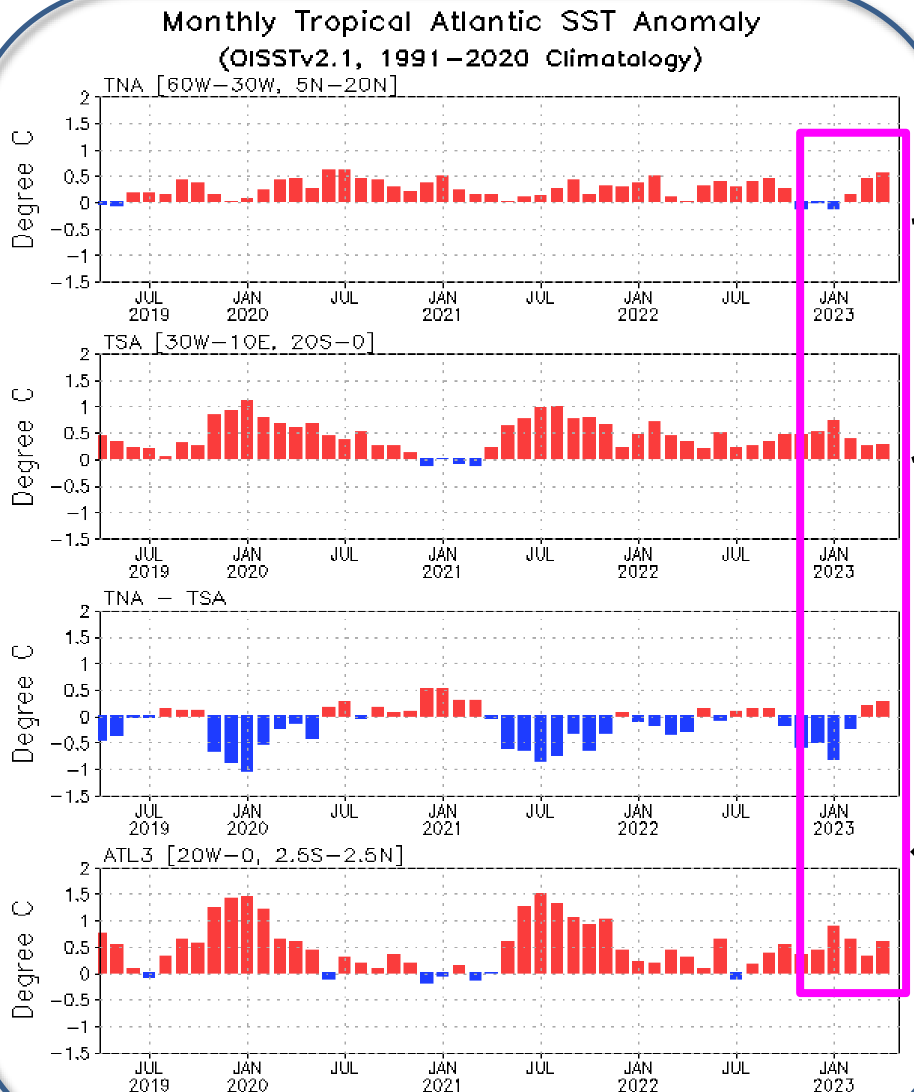


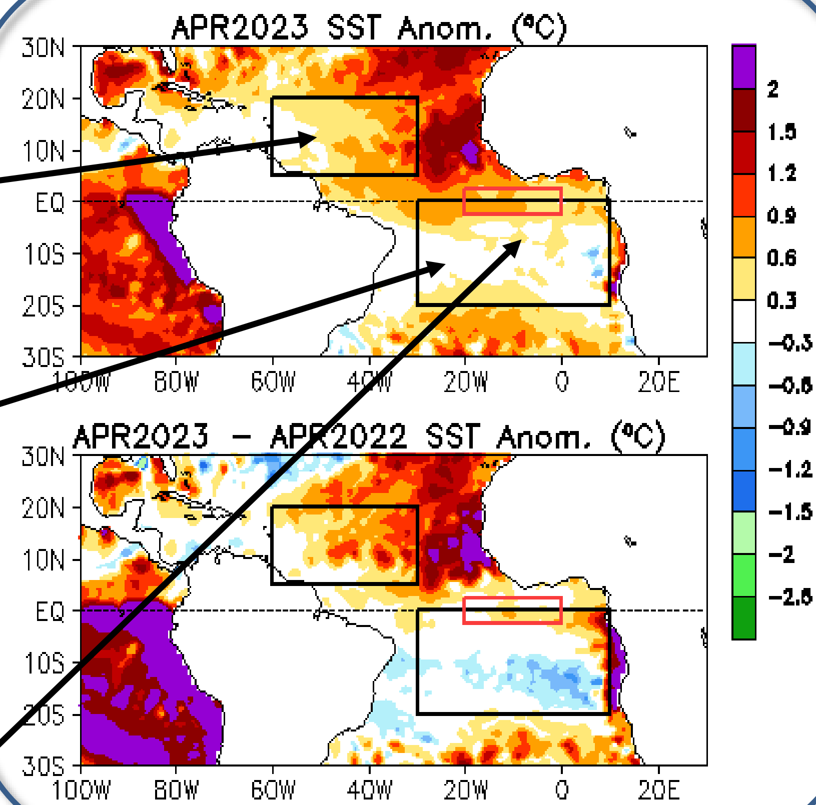
- Positive SSTAs were present in the tropical Indian Ocean in Apr 2023.

Indian Ocean region indices, calculated as the area-averaged monthly mean SSTA (OC) for the SETIO [90ºE-110ºE, 10ºS-0] and WTIO [50ºE-70ºE, 10ºS-10ºN] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

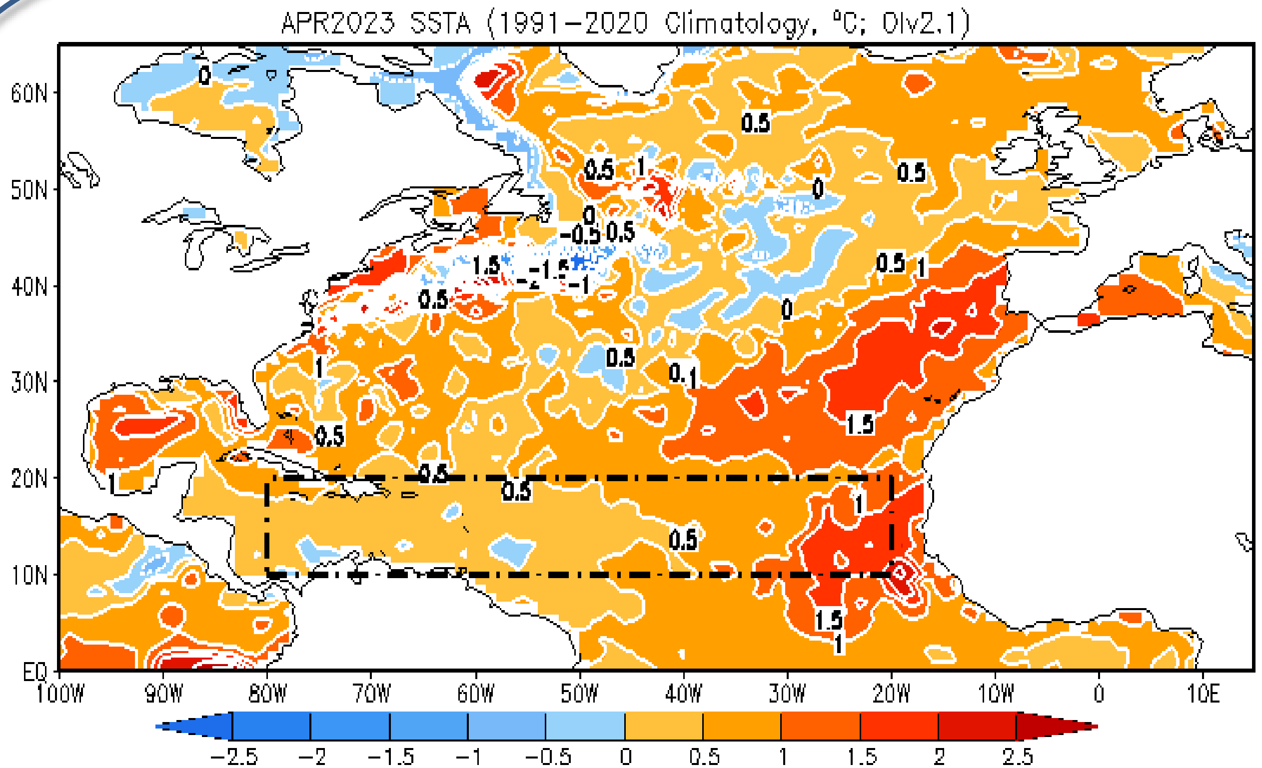


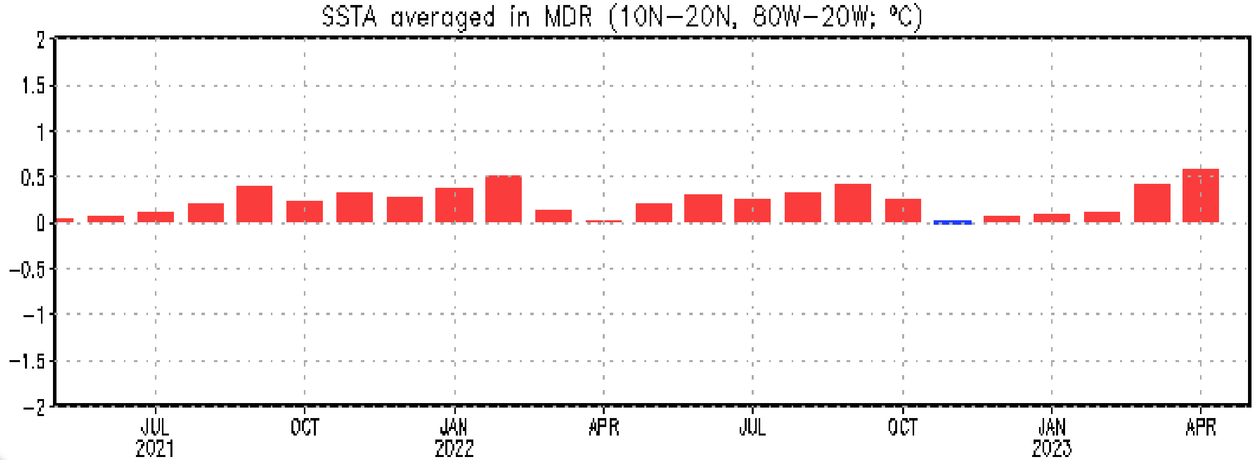


- Positive SSTAs were observed in the tropical South and North Atlantic with strong warming in the eastern North Atlantic.
- Positive ATL3 index increased in Apr 2023.

Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean SSTAs (^{O}C) for the TNA [60^{O}W-30^{O}W, 5ºN-20^{O}N], TSA [30^{O}W-10^{O}E, 20^{O}S-0] and ATL3 [20^{O}W-0, 2.5^{O}S-2.5^{O}N] regions, and Meridional Gradient Index, defined as differences between TNA and TSA. Data are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

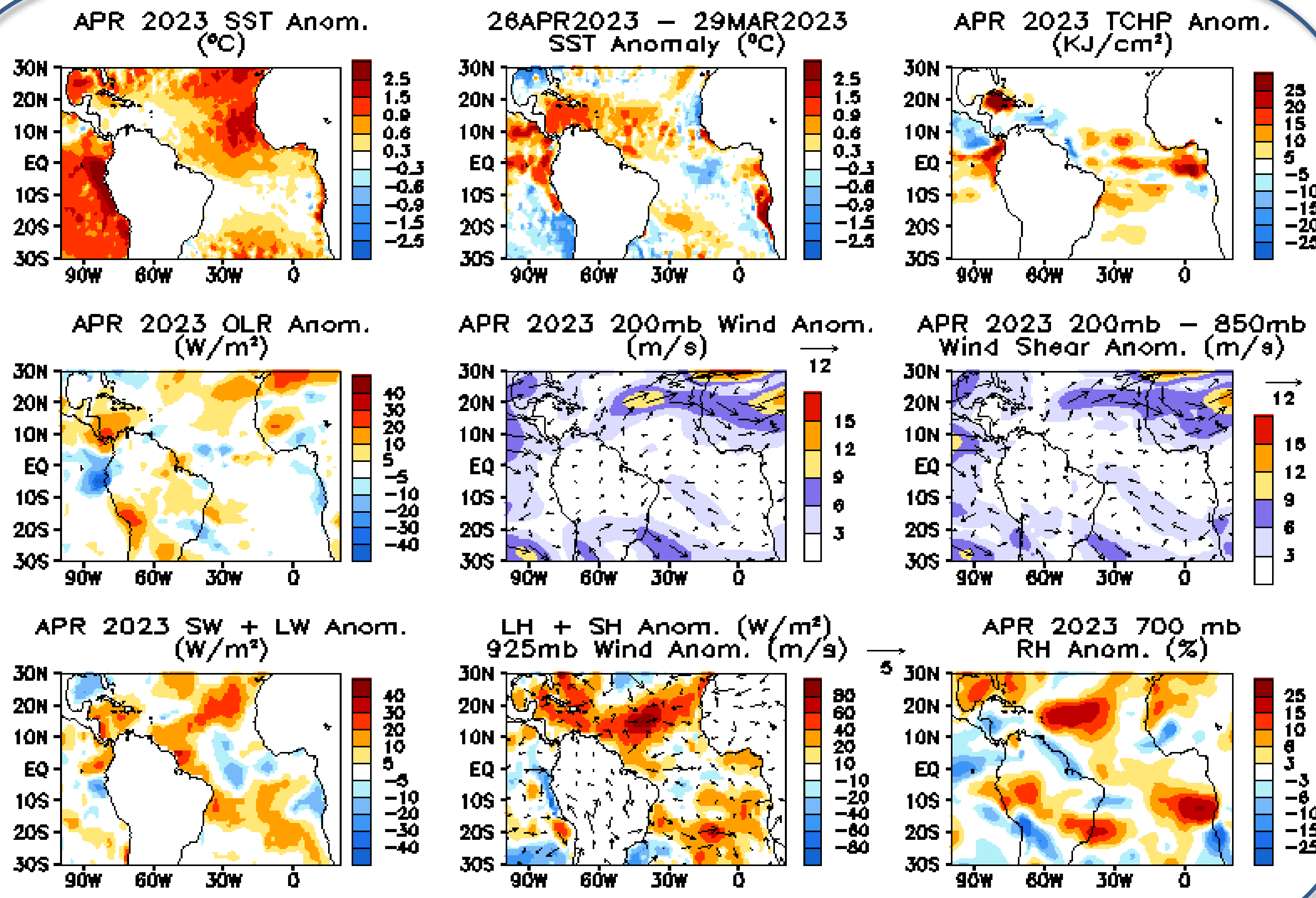
SSTAs in the North Atlantic & MDR



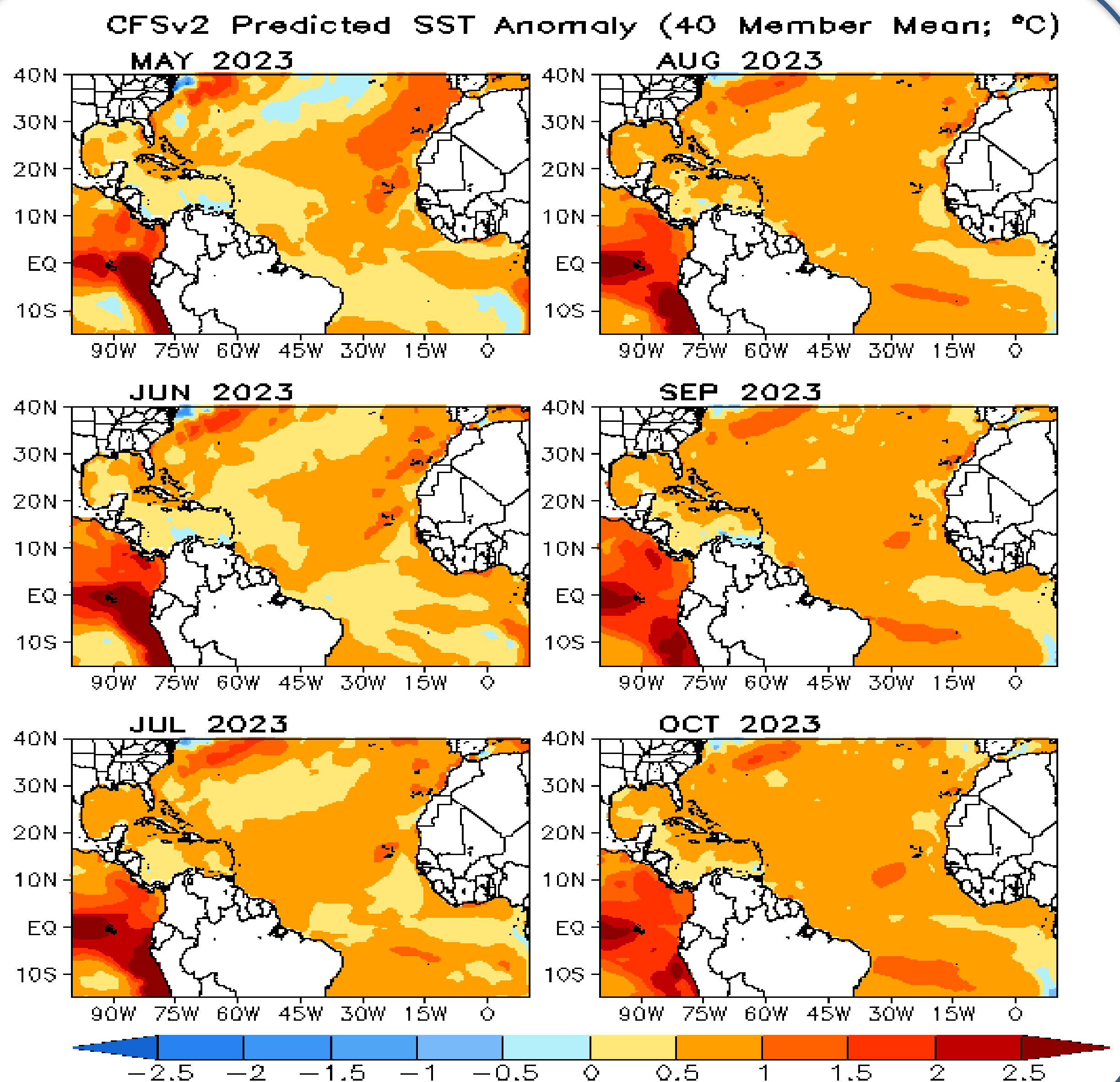


- SST in MDR was above average in Apr 2023.

Tropical Atlantic: SST, SST tend., TCHP, OLR, 200 hPa wind, wind share, heat flex, & RH anom.

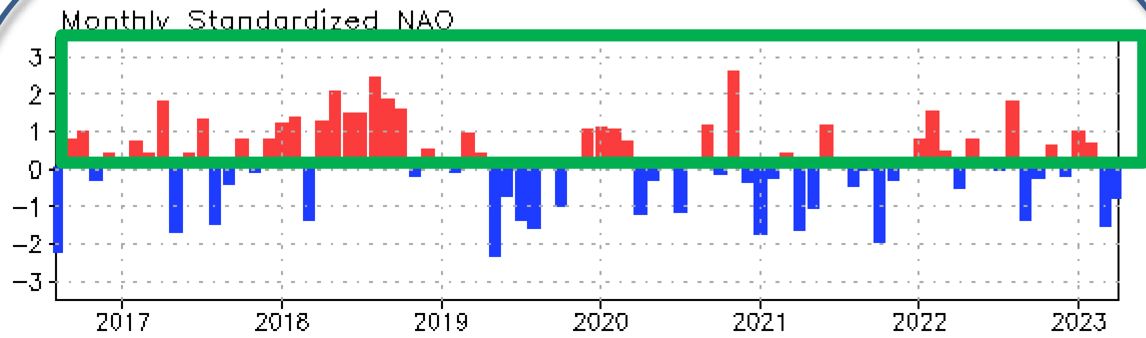


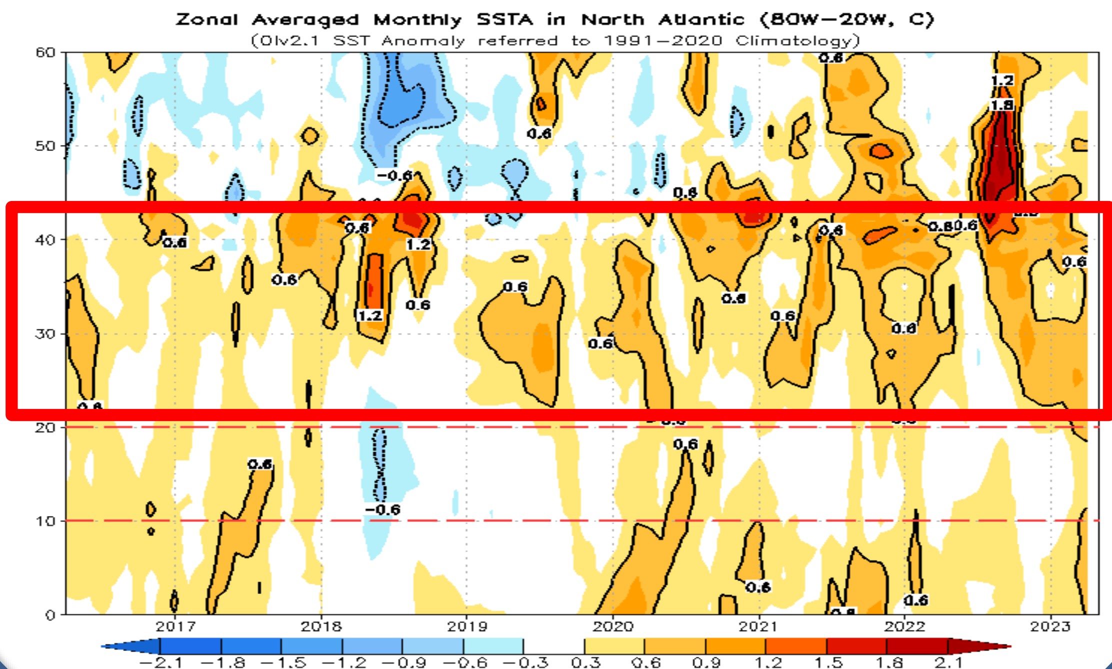
CFSv2 Atlantic SSTA Predictions

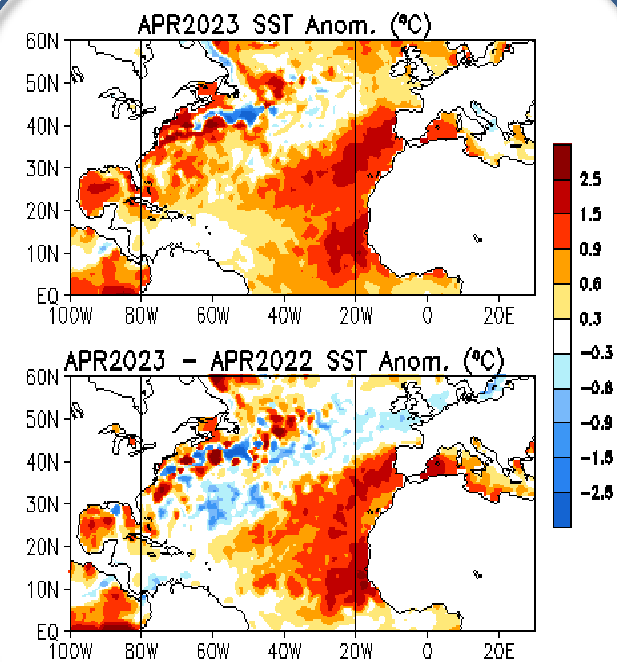


- The latest CFSv2 predictions call for above-normal SST in the tropical and N. Atlantic in the next 6 months.

NAO and SST Anomaly in North Atlantic





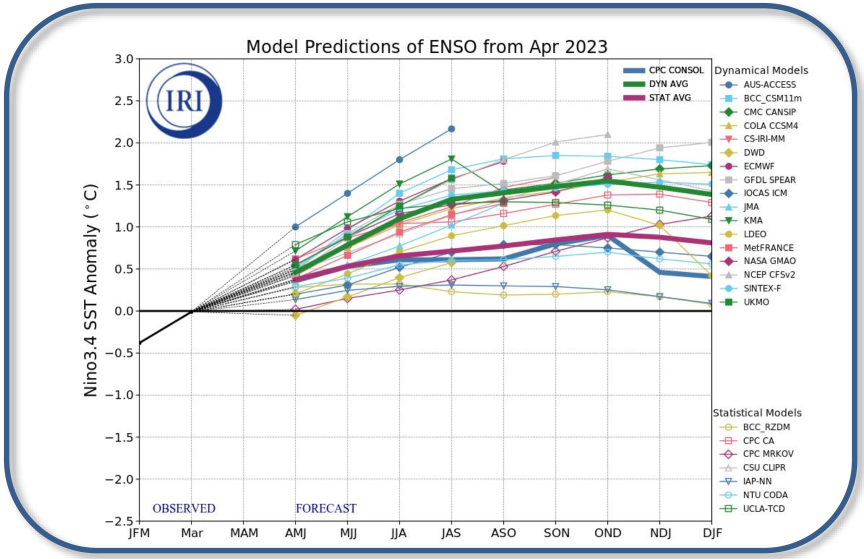


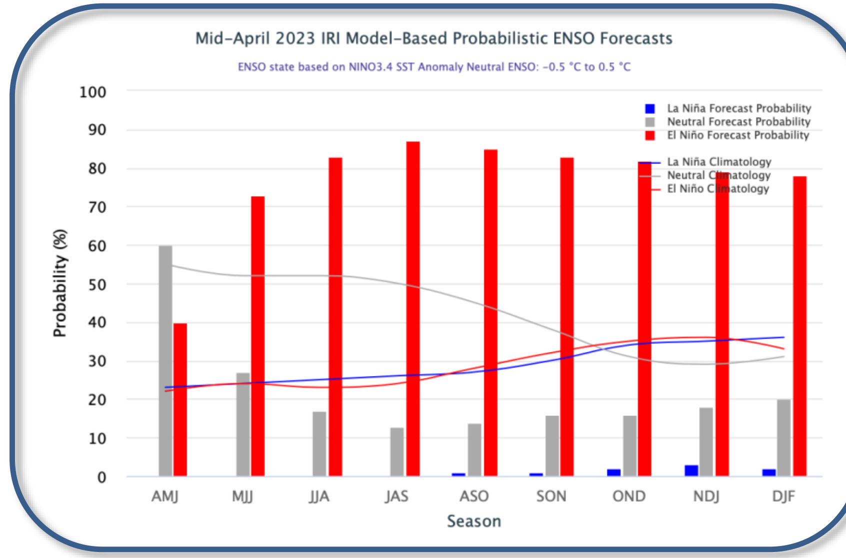
- NAO switched to a negative phase in Mar 2023 with NAOI= -0.8 in Apr 2023.
- Strong warming was in the eastern North Atlantic
- The prolonged positive SSTAs in the middle latitudes were evident, due to dominance of the positive phase of NAO during the last 5-6 years.

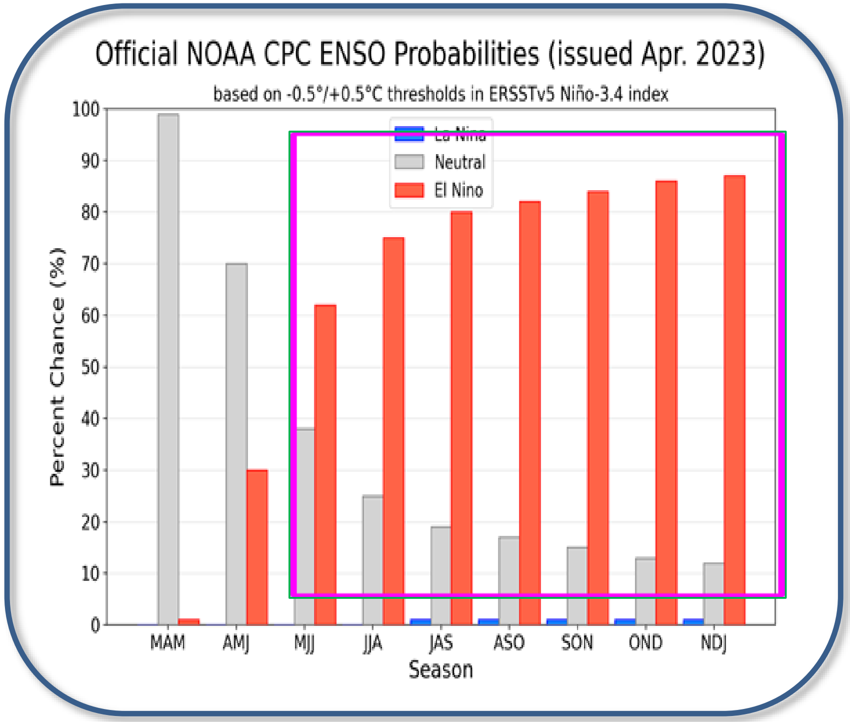
Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20^{O}N-90^{O}N. Time-latitude section of SSTAs averaged between 80ºW and 20ºW (bottom). SST are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

ENSO and Global SST Predictions

IRI/CPC Niño3.4 Forecast



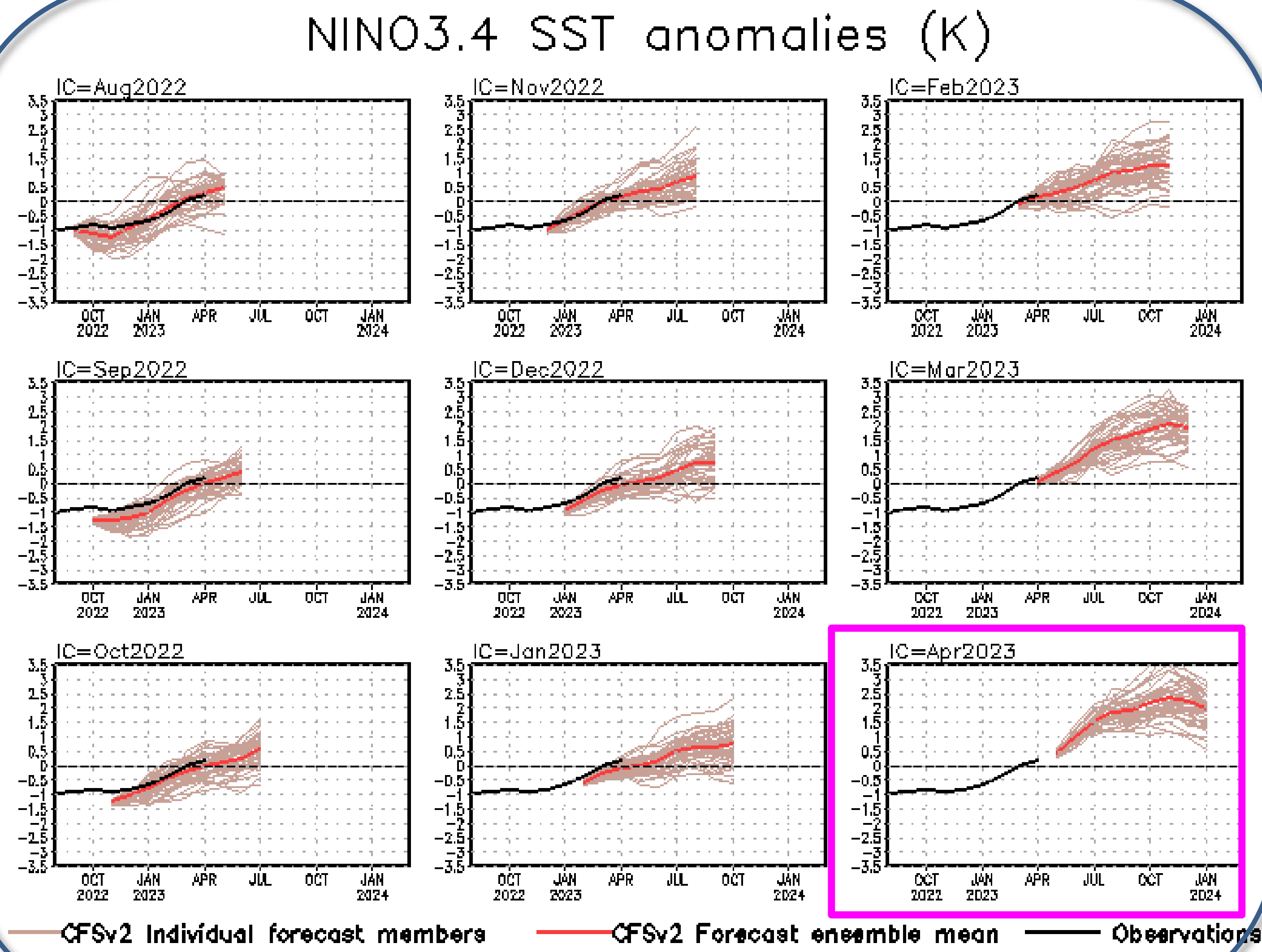




- ENSO Alert System Status issued on 13 Apr 2023: El Niño Watch

- <u>Synopsis:</u> *"ENSO-neutral conditions are expected to continue through the Northern Hemisphere spring, followed by, with a 62% chance of El Niño forming during May-July 2023."*

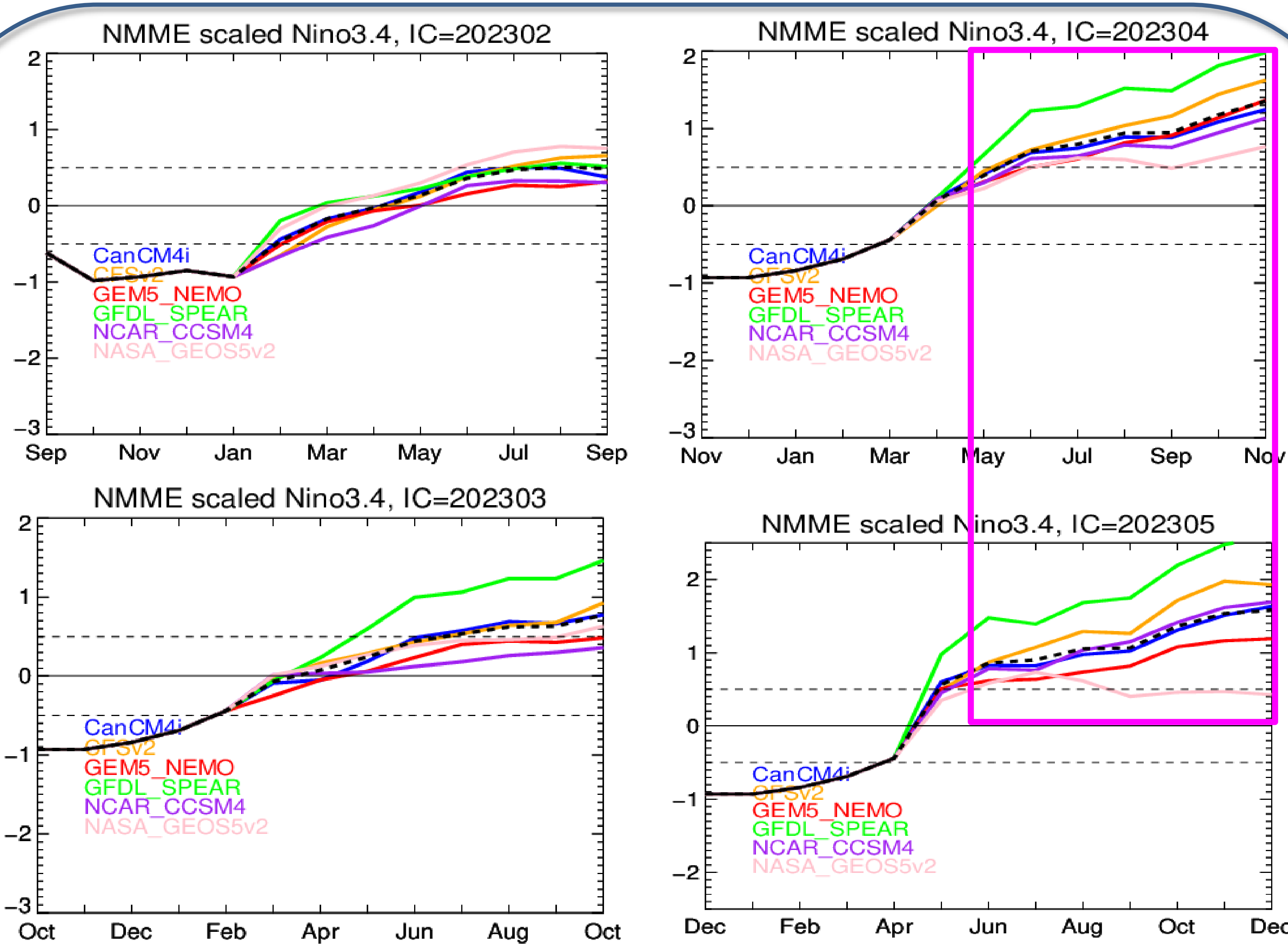
CFS Niño3.4 SST Predictions from Different Initial Months



- The latest CFSv2 forecasts call for an El Niño in the second half of 2023.

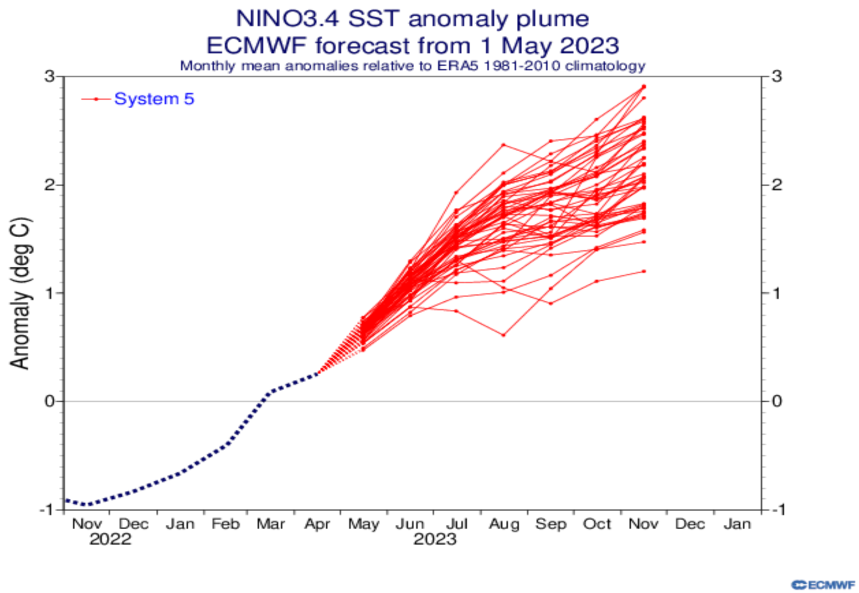
CFS Niño3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1991-2020 base period means.

NMME forecasts from different initial conditions

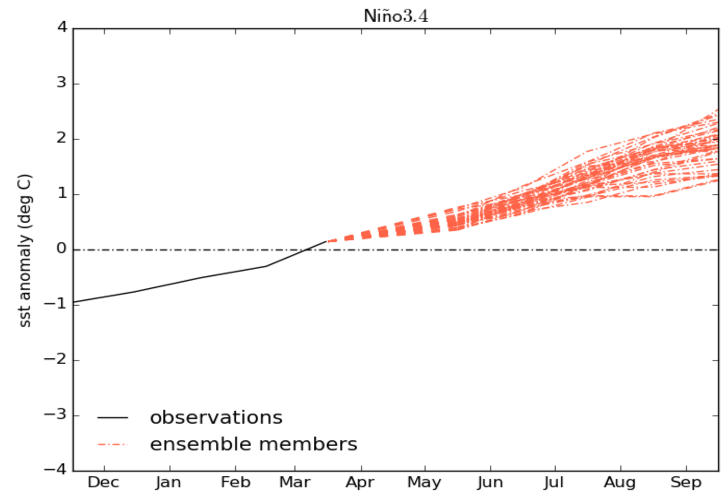


Individual Model Forecasts: La Niña will return to neutral in spring

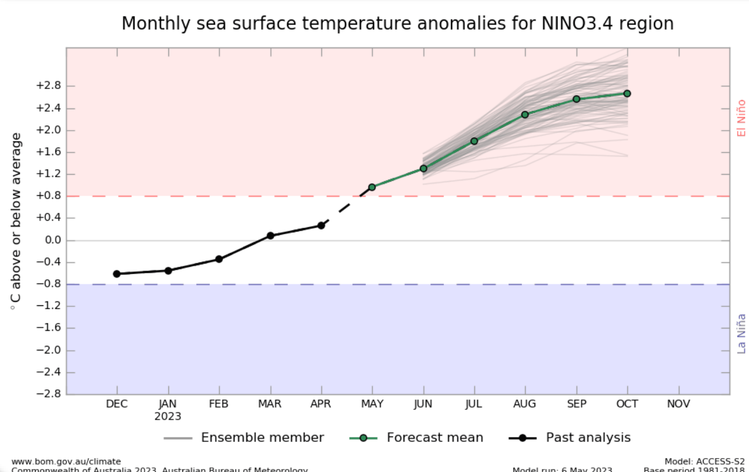
EC: Niño3.4, IC= 1 May 2023



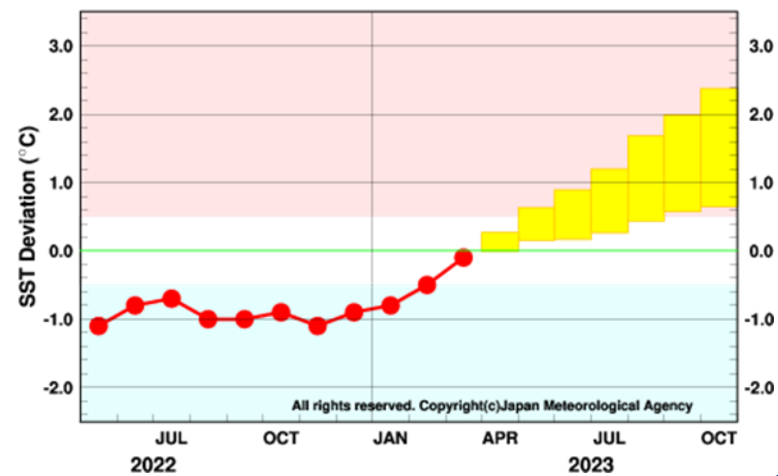
UKMO: Niño3.4, Updated 11 Apr 2023



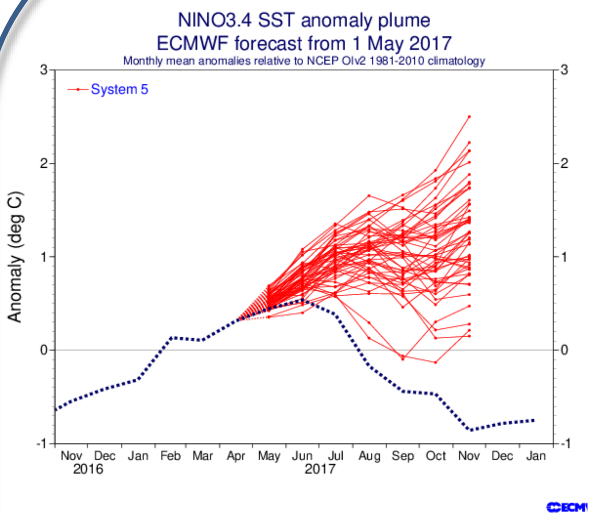
BOM: Niño3.4, Updated 6 May 2023

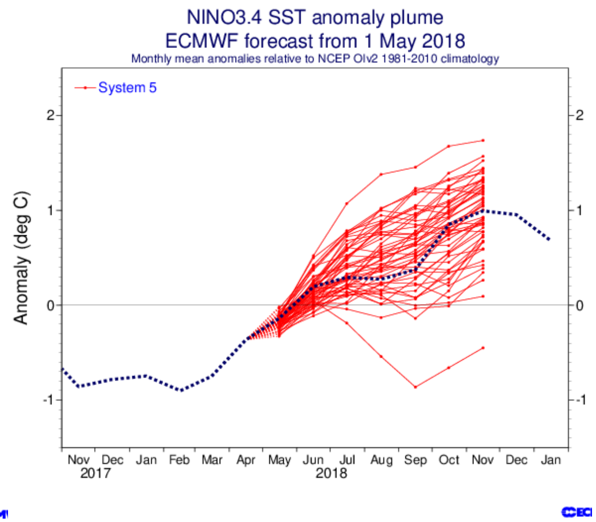


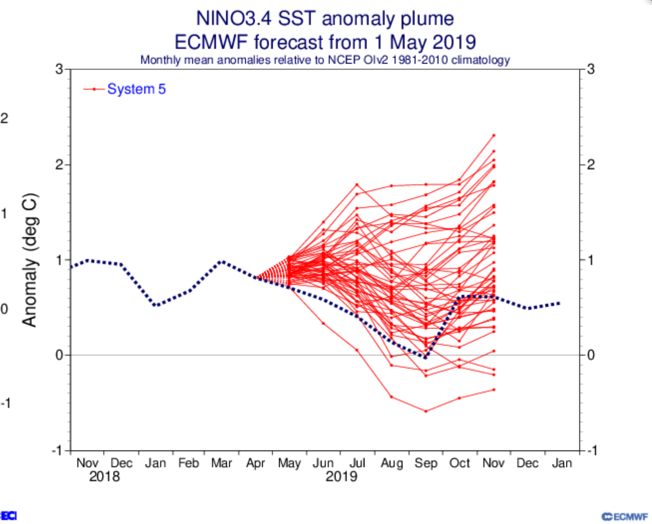
JMA: Niño3.4, Updated 10 Apr 2023

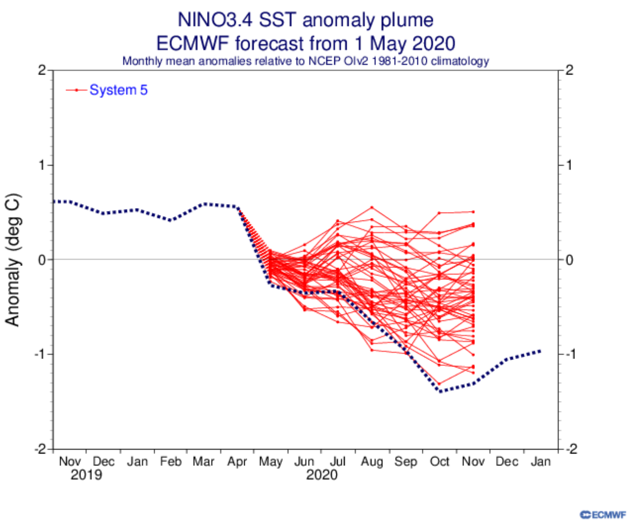


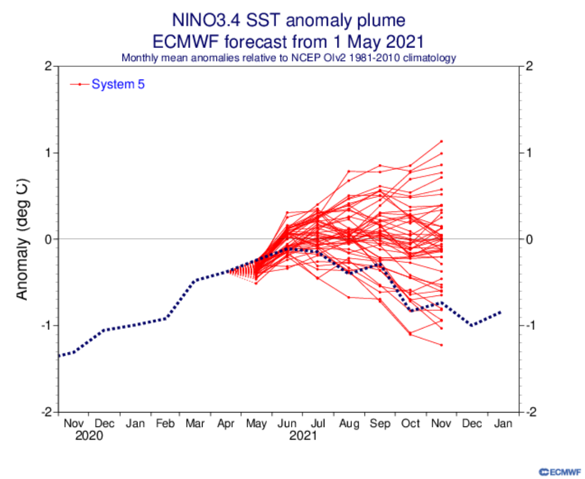
ECMWF Forecasts: warm bias in May IC runs since 2017

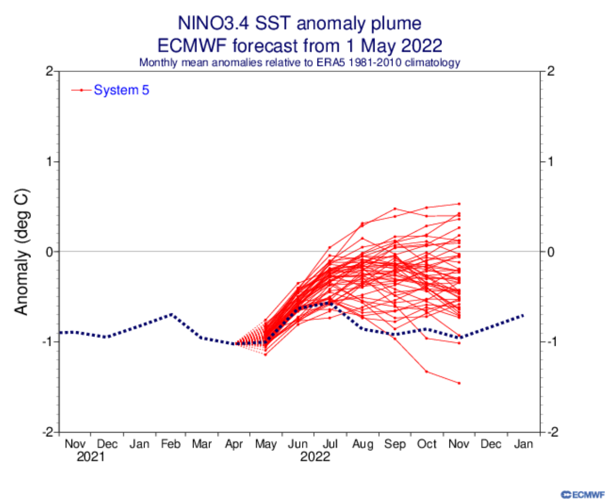




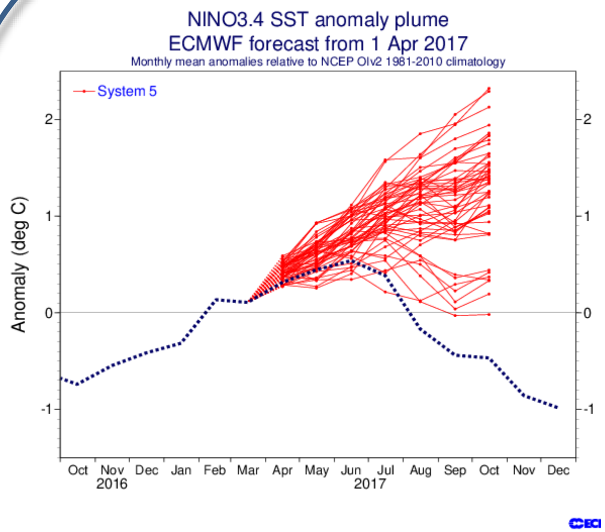


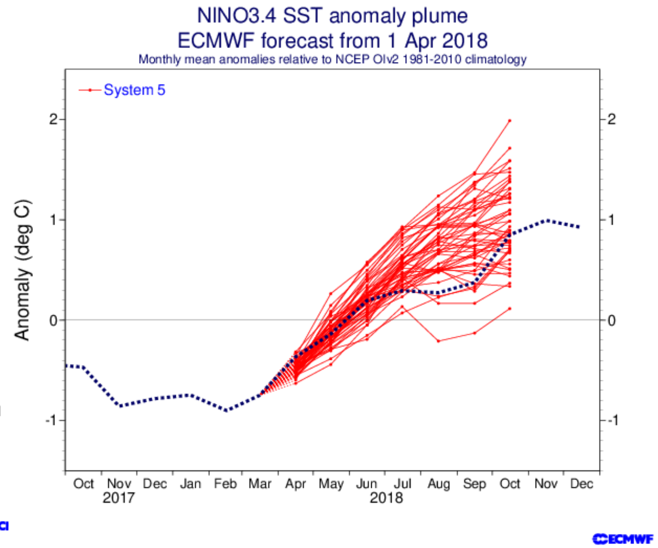


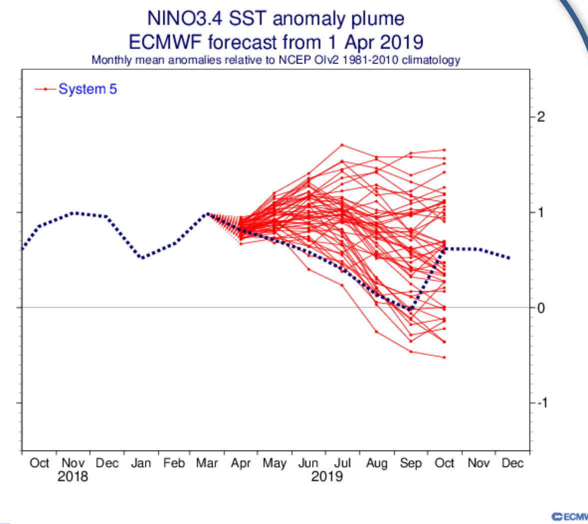


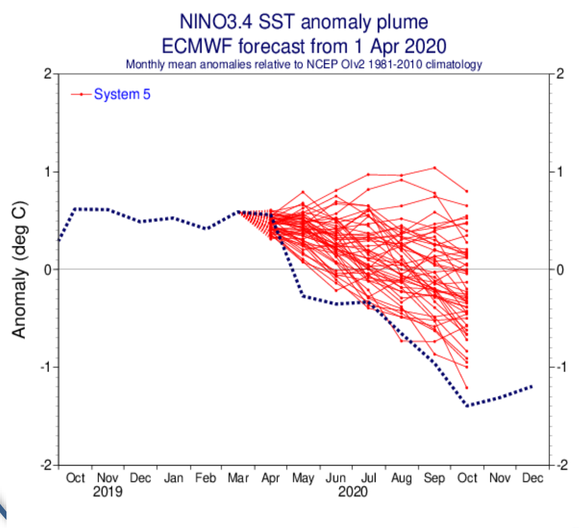


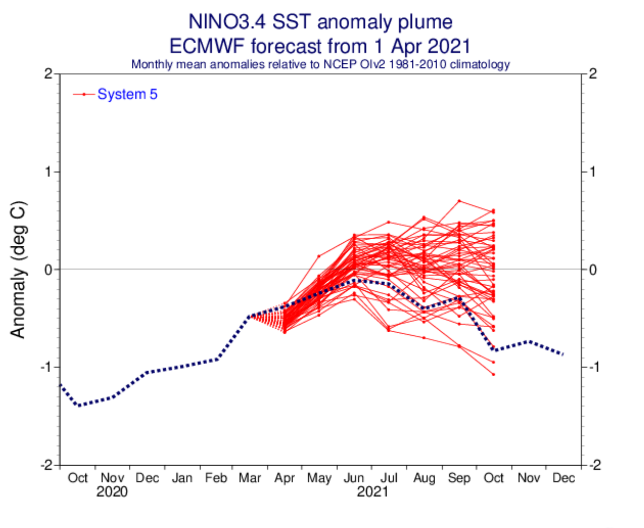
ECMWF Forecasts: warm bias in Apr IC runs since 2017

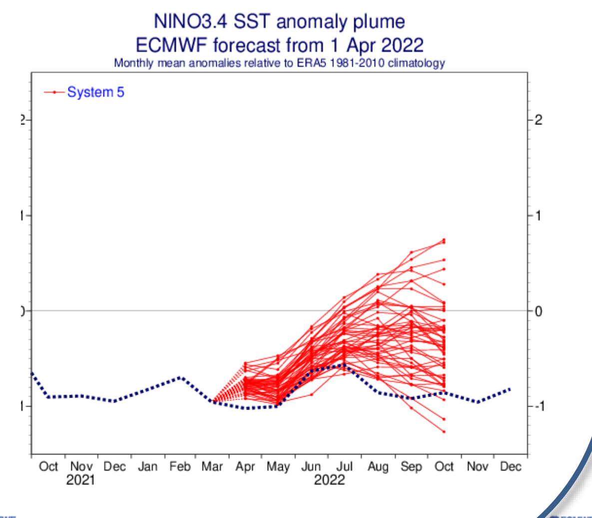




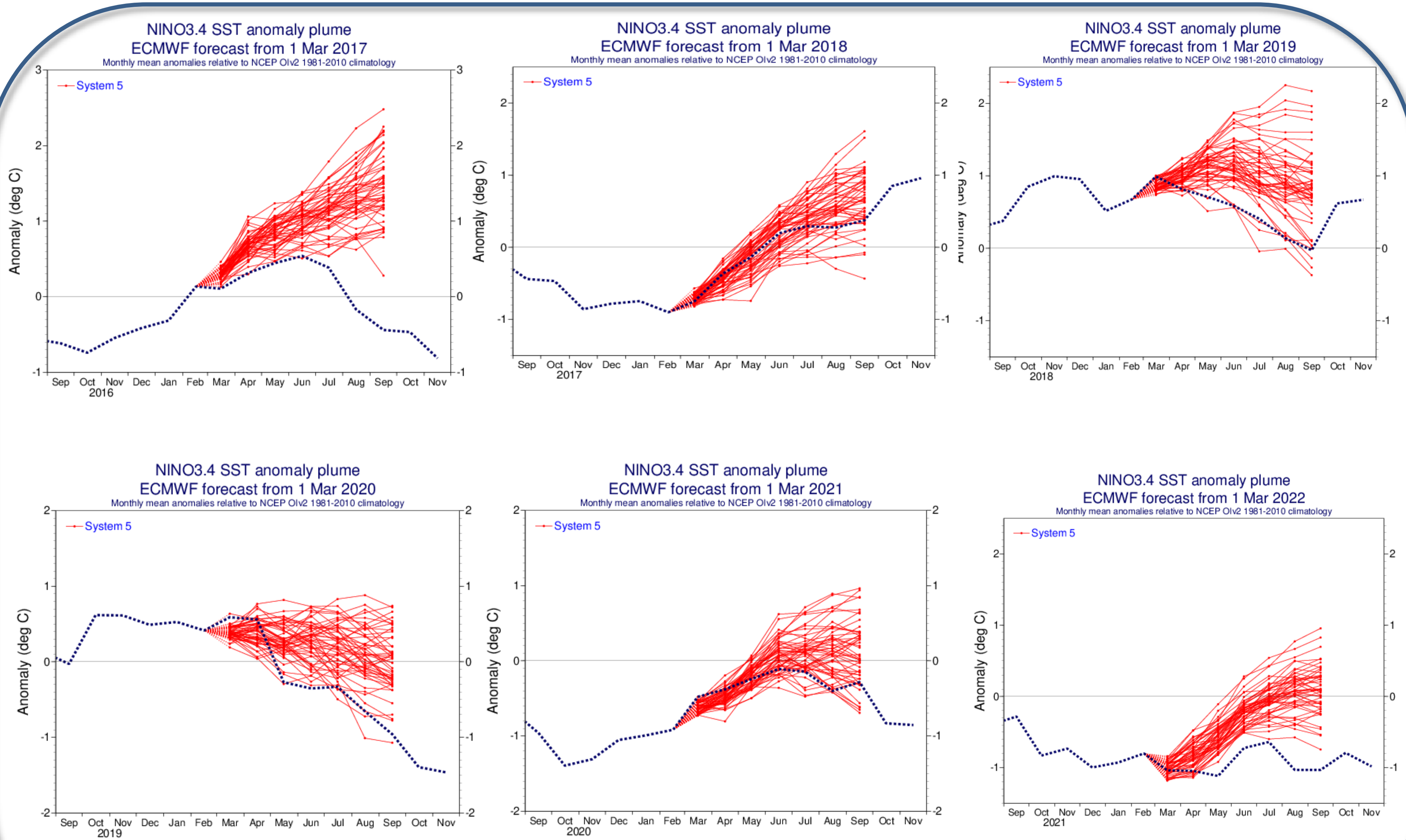




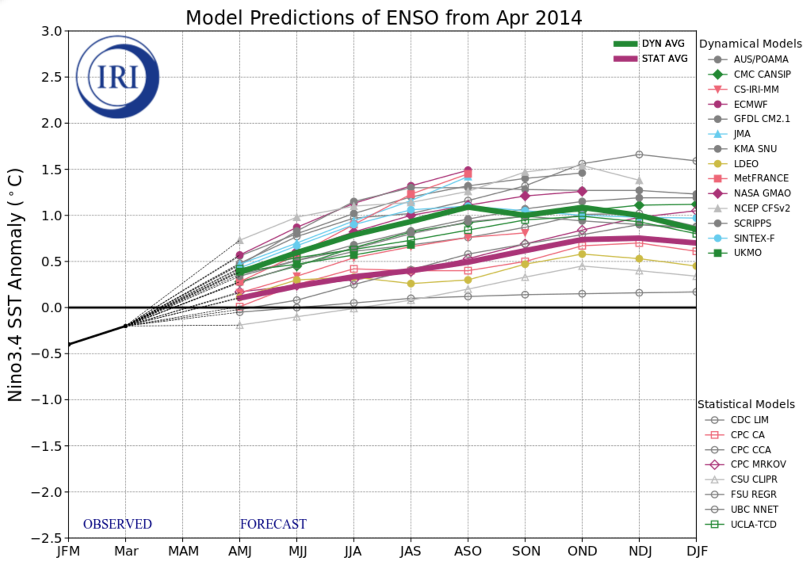


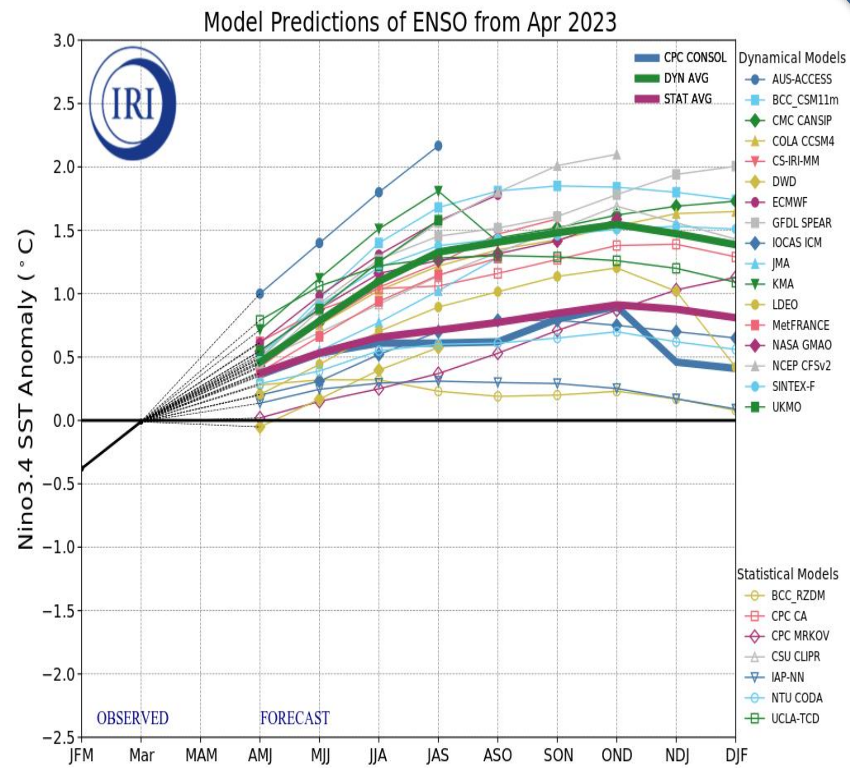


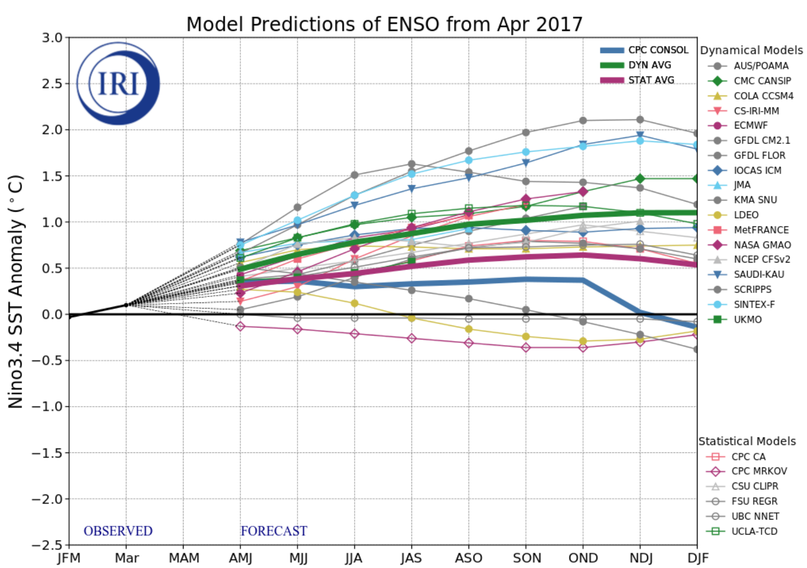
ECMWF Forecasts: warm bias in March IC runs since 2017

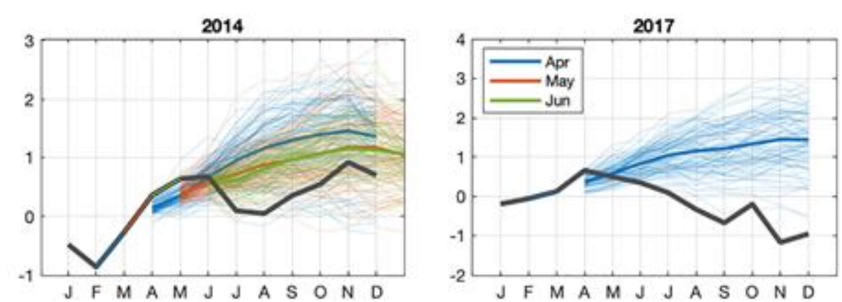


2023 ENSO Forecast, 2014 & 2017 El Niño False Alarm

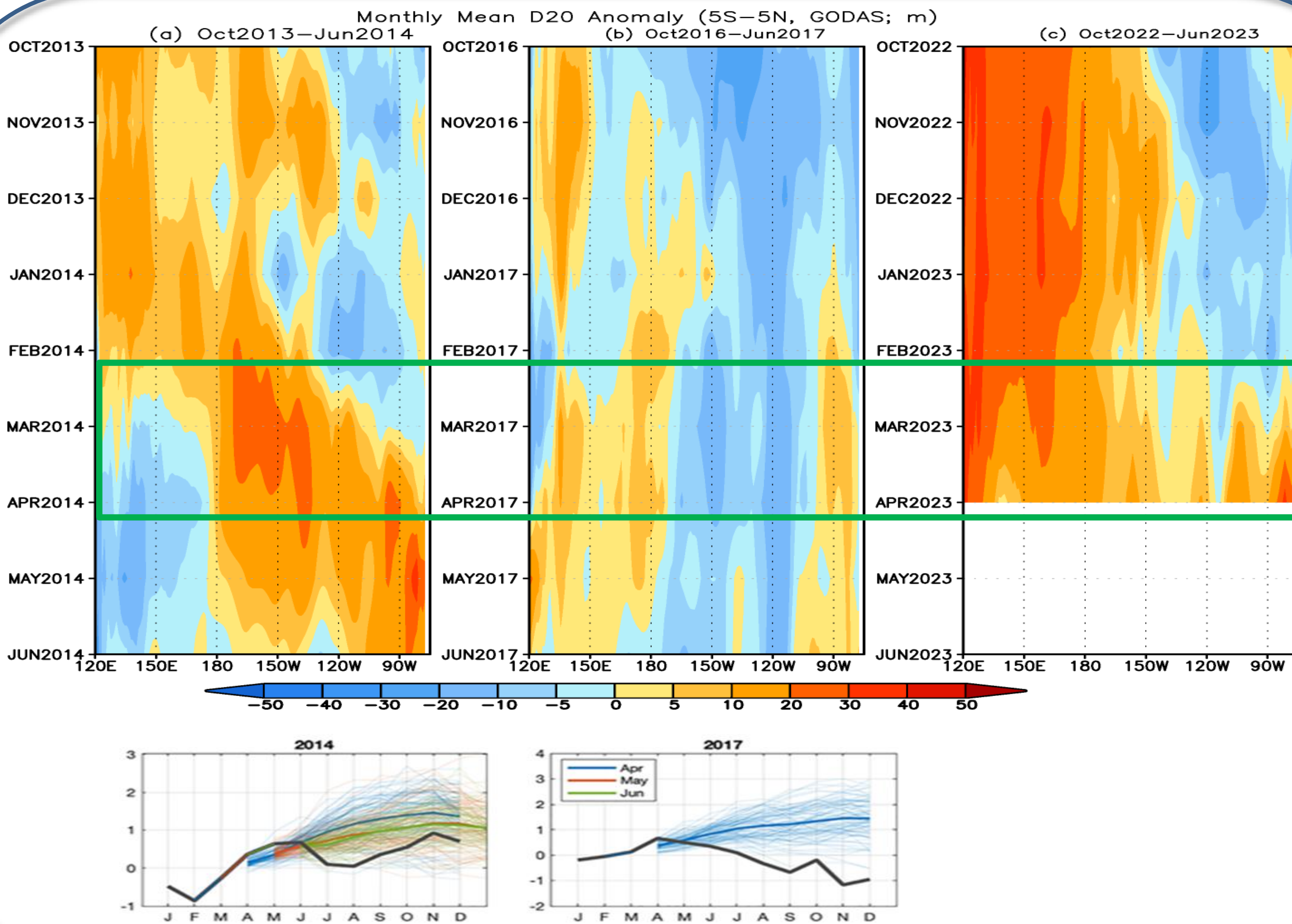




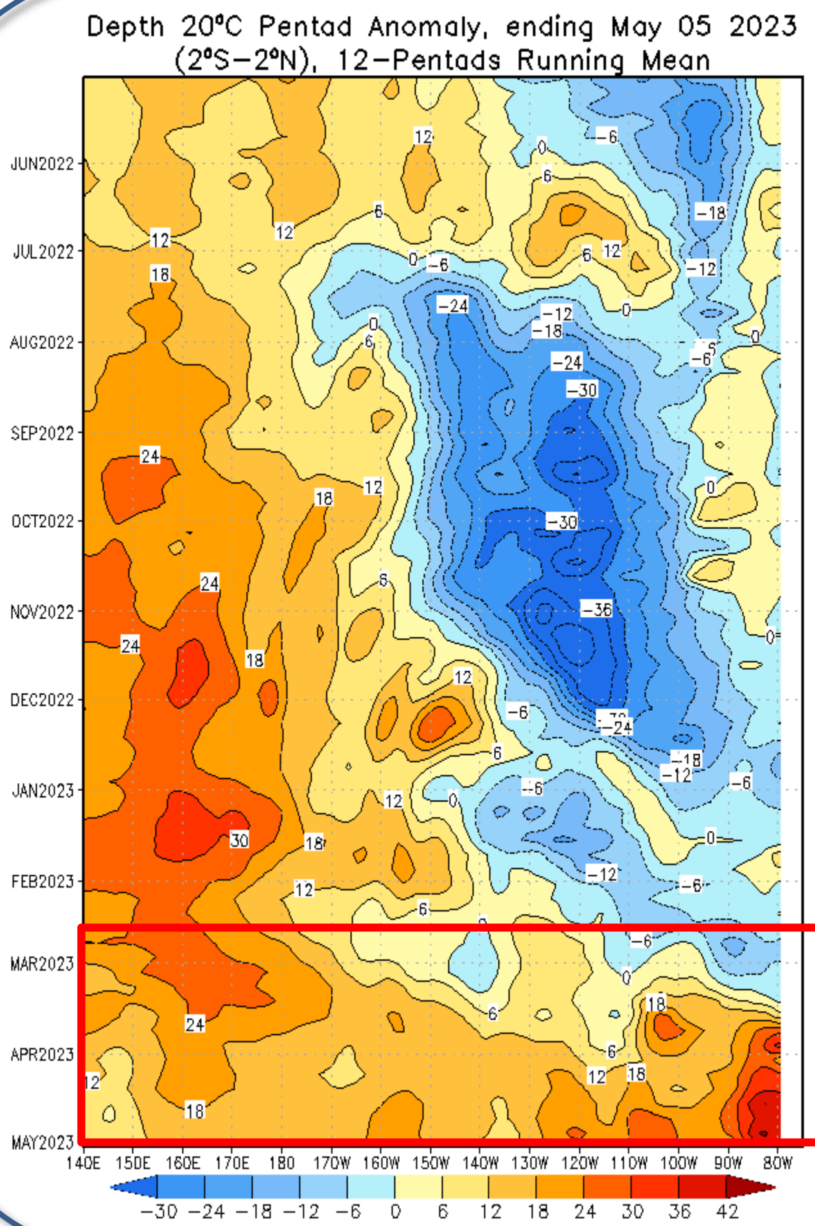


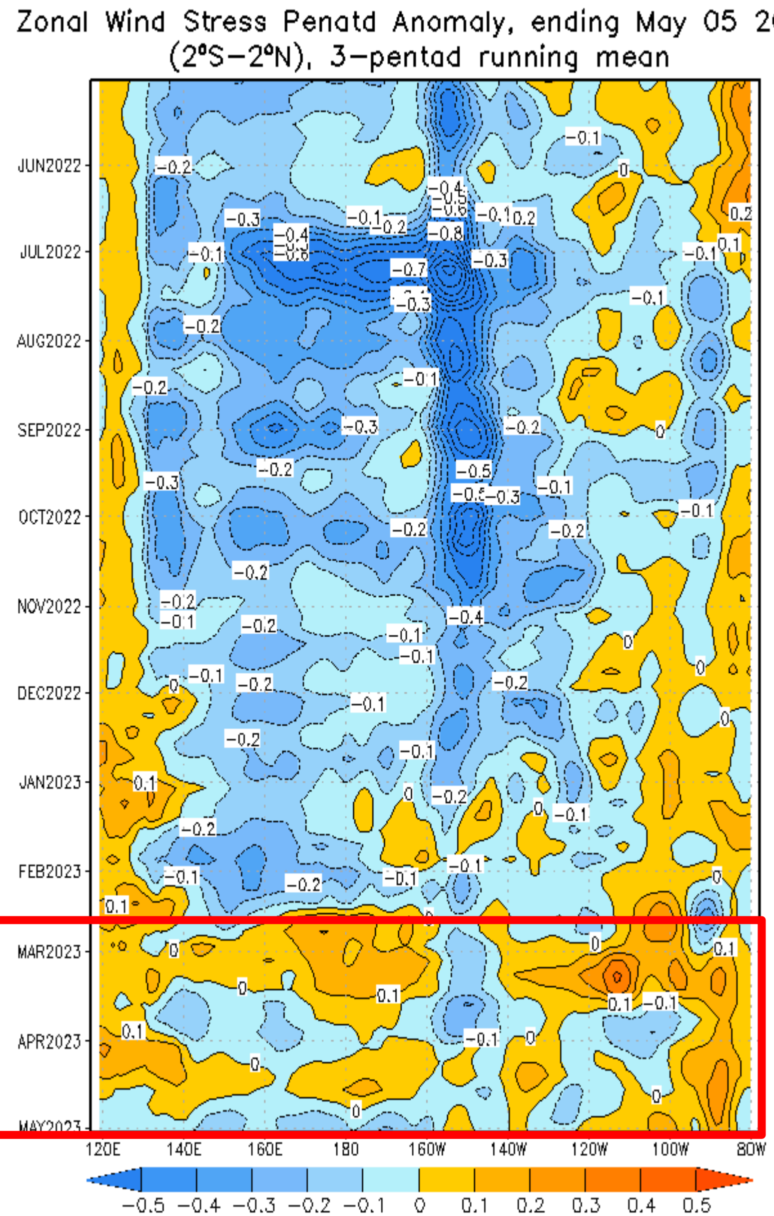


Equatorial D20 anomalous evolution in 2013/14, 2016/17 & 2022/23

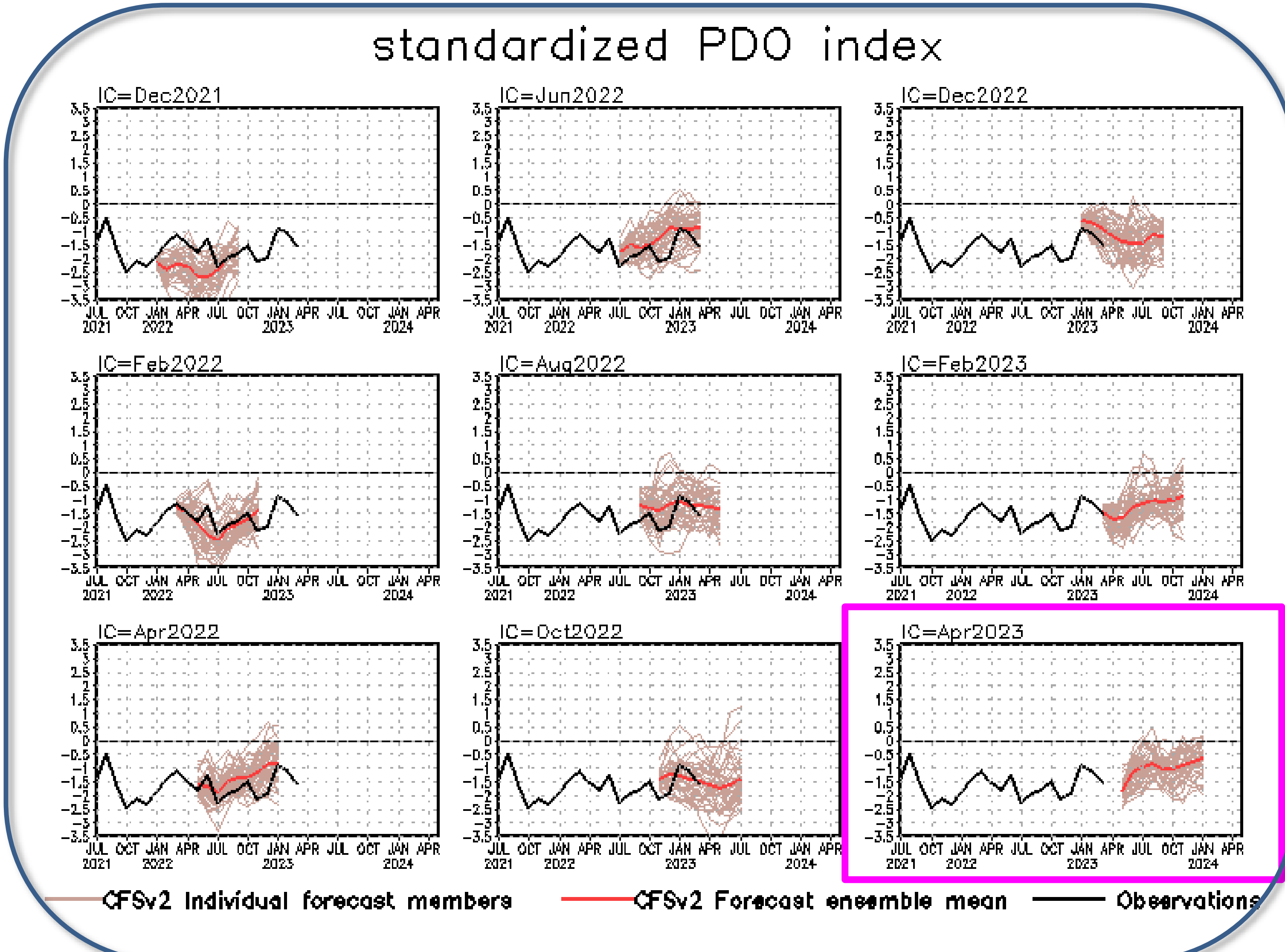


Monthly mean subsurface temperature anomaly along the Equator





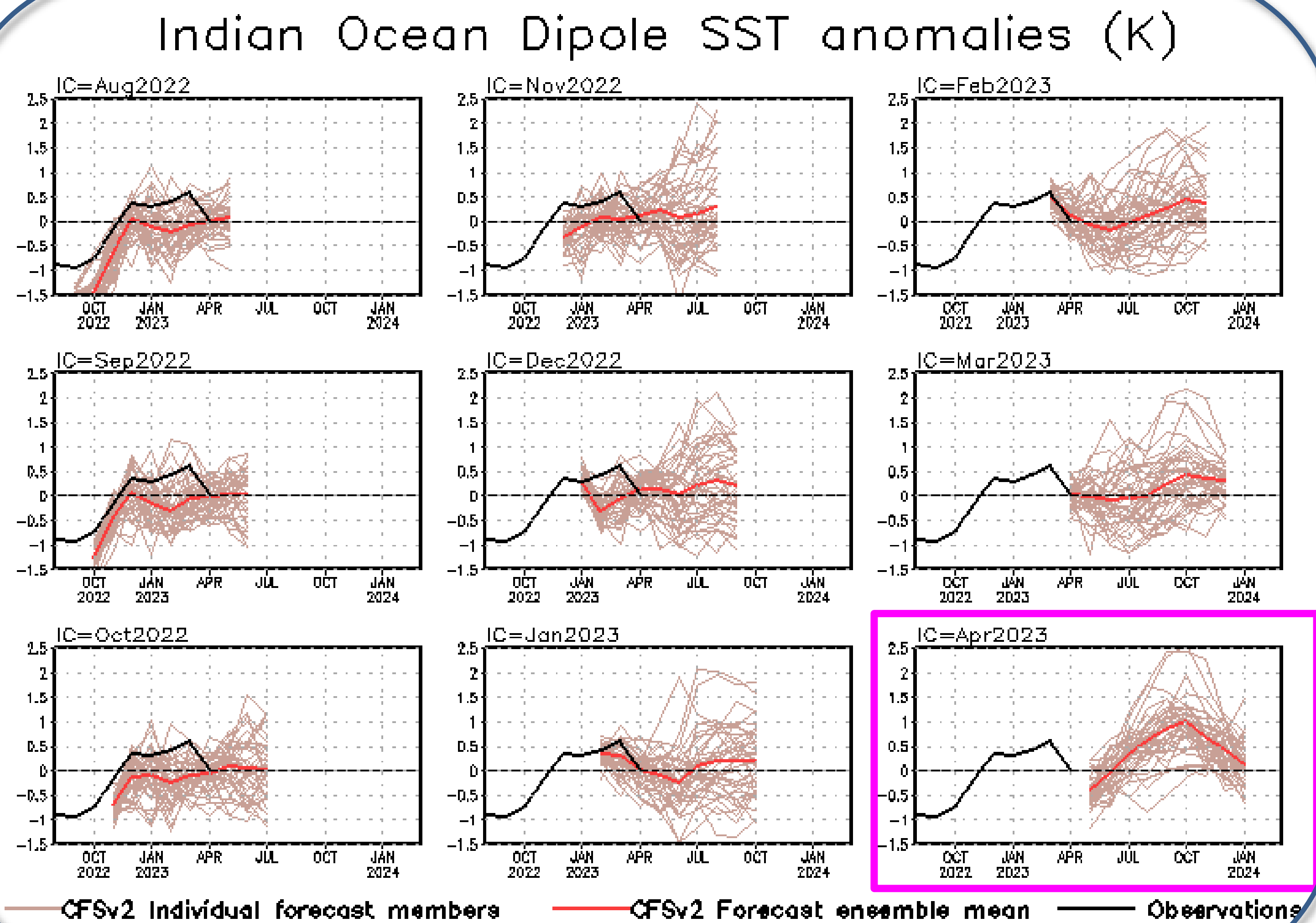
CFS Pacific Decadal Oscillation (PDO) Index Predictions from Different Initial Months



- CFSv2 predicts a persistent negative phase of PDO through autumn 2023.

CFS Pacific Decadal Oscillation (PDO) index predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1991-2020 base period means. PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N]. CFS PDO index is the standardized projection of CFS SST forecast anomalies onto the PDO EOF pattern.

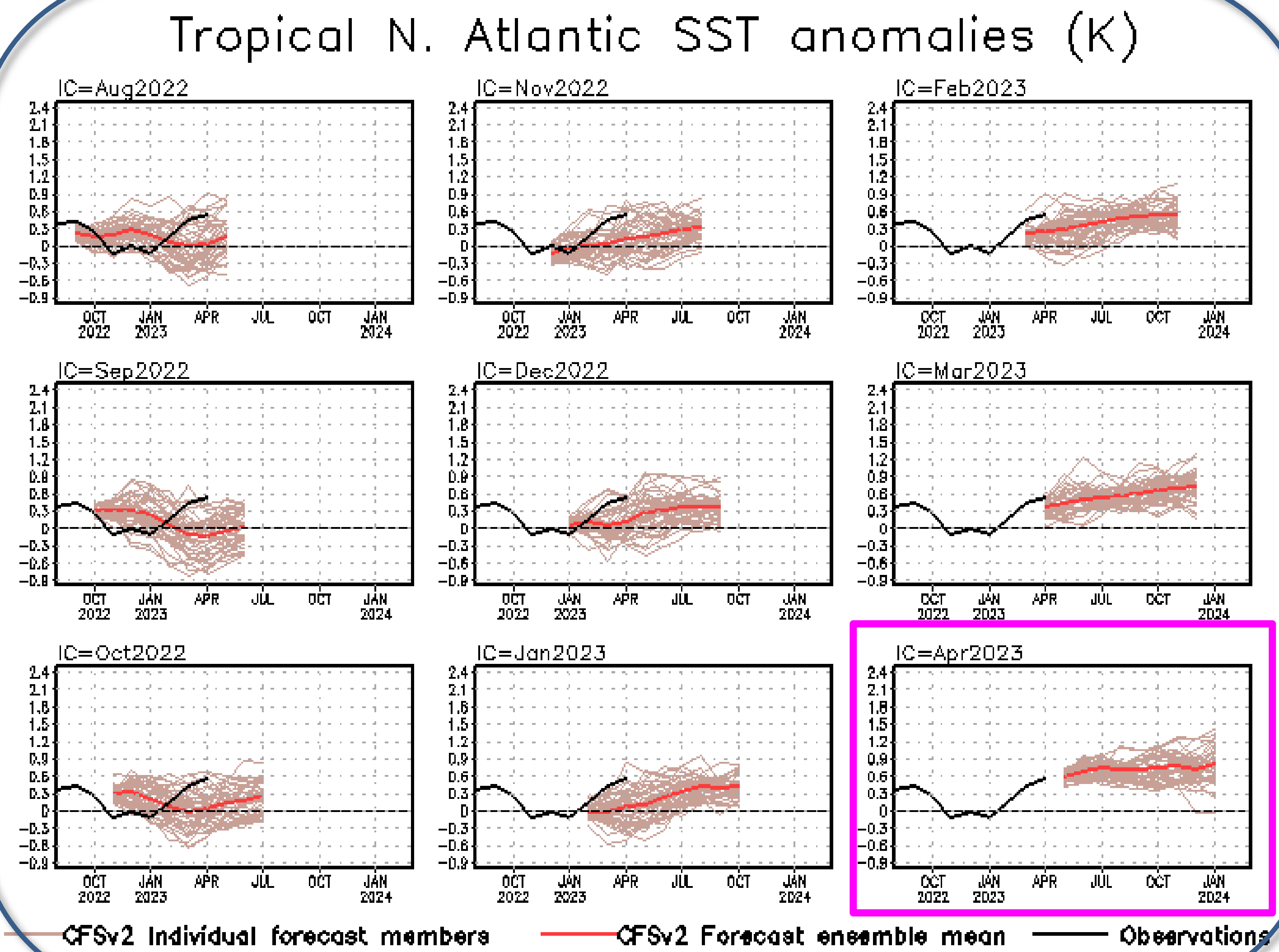
NCEP CFS DMI SST Predictions from Different Initial Months



- CFSv2 predicts a positive phase of IOD in the 2nd half of 2023.

CFS Dipole Model Index (DMI) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1991-2020 base period means.

CFS Tropical North Atlantic (TNA) SST Predictions from Different Initial Months



- Latest CFSv2 predictions call for above-normal SST in the tropical North Atlantic.

CFS Tropical North Atlantic (TNA) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1991-2020 base period means. TNA is the SST anomaly averaged in the region of [60oW-30oW, 5oN-20oN].

Acknowledgement

- Drs. Jieshun Zhu, Caihong Wen, and Arun Kumar: reviewed PPT, and provide insightful suggestions and comments
- Dr. Pingping Xie provided the BASS/CMORPH/CFSR EVAP package
- Dr. Wanqiu Wang maintains the CFSv2 forecast archive
- Drs. Jieshun Zhu and Wanqiu Wang provided the upgraded sea ice forecasts

Please send your comments and suggestions to:

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Zeng-Zhen.Hu@noaa.gov

Data Sources (climatology is for 1991-2020)

- **NCEP/CPC Ocean Monitoring & Briefing Operation (Hu et al., 2022, BAMS)**
- **Weekly Optimal Interpolation SST (OIv2.1 SST; Huang et al. 2021)**
- **Extended Reconstructed SST (ERSST) v5 (Huang et al. 2017)**
- **Blended Analysis of Surface Salinity (BASS) (Xie et al. 2014)**
- **CMORPH precipitation (Xie et al. 2017)**
- **CFSR evaporation adjusted to OAFlux (Xie and Ren 2018)**
- **NCEP CDAS winds, surface radiation and heat fluxes (Kalnay et al. 1996)**
- **NESDIS Outgoing Long-wave Radiation (Liebmann and Smith 1996)**
- **NCEP's GODAS temperature, heat content, currents (Behringer and Xue 2004)**
- **Aviso altimetry sea surface height from CMEMS**
- **Ocean Surface Current Analyses – Realtime (OSCAR)**
- **In situ data objective analyses (IPRC, Scripps, EN4.2.1, PMEL TAO)**
- **Operational Ocean Reanalysis Intercomparison Project**
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html

BAMS Article

Global Ocean Monitoring and Prediction at NOAA Climate Prediction Center

15 Years of Operations

Zeng-Zhen Hu, Yan Xue, Boyin Huang, Arun Kumar, Caihong Wen, Pingping Xie, Jieshun Zhu, Philip J. Pegion, Li Ren, and Wanqiu Wang

ABSTRACT: Climate variability on subseasonal to interannual time scales has significant impacts on our economy, society, and Earth's environment. Predictability for these time scales is largely due to the influence of the slowly varying climate anomalies in the oceans. The importance of the global oceans in governing climate variability demonstrates the need to monitor and forecast the global oceans in addition to El Niño–Southern Oscillation in the tropical Pacific. To meet this need, the Climate Prediction Center (CPC) of the National Centers for Environmental Prediction (NCEP) initiated real-time global ocean monitoring and a monthly briefing in 2007. The monitoring covers observations as well as forecasts for each ocean basin. In this paper, we introduce the monitoring and forecast products. CPC's efforts bridge the gap between the ocean observing system and the delivery of the analyzed products to the community. We also discuss the challenges involved in ocean monitoring and forecasting, as well as the future directions for these efforts.

KEYWORDS: Ocean; Atmosphere-ocean interaction; ENSO; Climate prediction; Oceanic variability; Climate services

https://doi.org/10.1175/BAMS-D-22-0056.1

Corresponding author: Zeng-Zhen Hu, zeng-zhen.hu@noaa.gov

In final form 15 August 2022

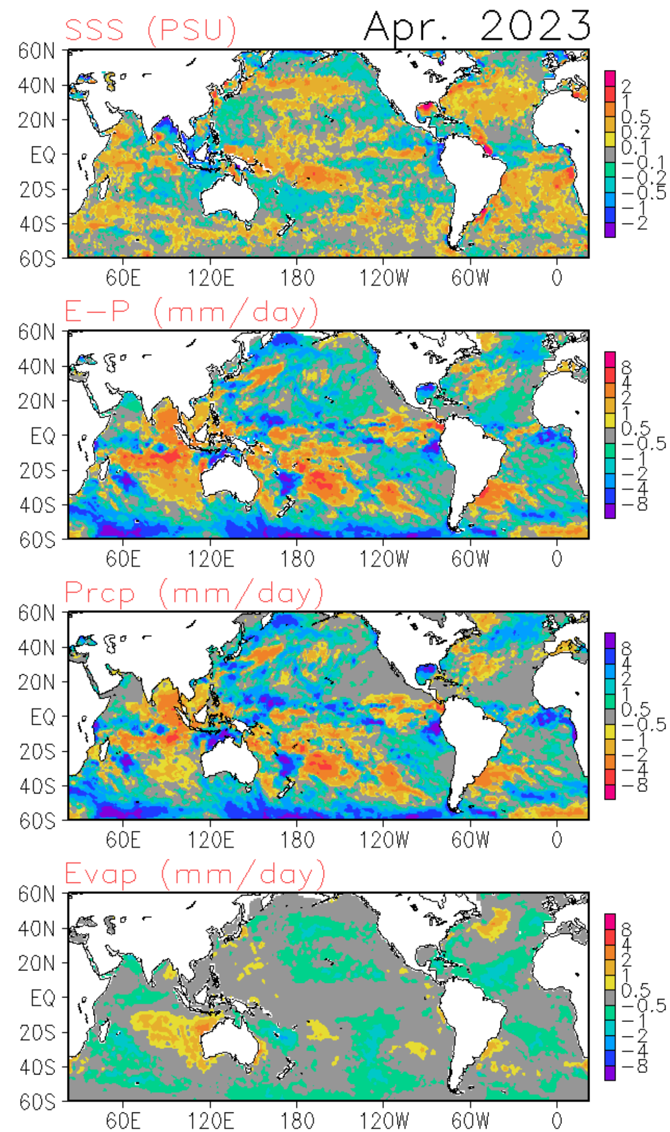
Hu, Z.-Z., Y. Xue, B. Huang, A. Kumar, C. Wen, P. Xie, J. Zhu, P. Pegion, L. Ren, and W. Wang, 2022: Global ocean monitoring and forecast at NOAA Climate Prediction Center: 15 Years of Operations. *Bull. Amer. Meteor. Soc.*, **103 (12),** E2701–E2718. DOI: 10.1175/BAMS-D-22-0056.1.

Backup Slides

Global Sea Surface Salinity (SSS): Anomaly for April 2023

New Update: The NCEI SST data used in the quality control procedure has been updated to version 2.1 since May 2020;

Over the tropical Pacific and tropical Atlantic Ocean, large-scale salinity anomalies are still largely influenced by variations of fresh water flux especially precipitation. In particular, the double ITCZ structure over the east equatorial Pacific has caused zonally-oriented positive and negative SSS anomaly belts over the region. SSS anomaly patterns over the Bay of Bengal and the Gulf of Mexico appear out of phase with those of precipitation, suggesting dominant contributions by the oceanic processes there.



SSS : Blended Analysis of Surface Salinity (BASS) V0.Z

(a CPC-NESDIS/NODC-NESDIS/STAR joint effort)

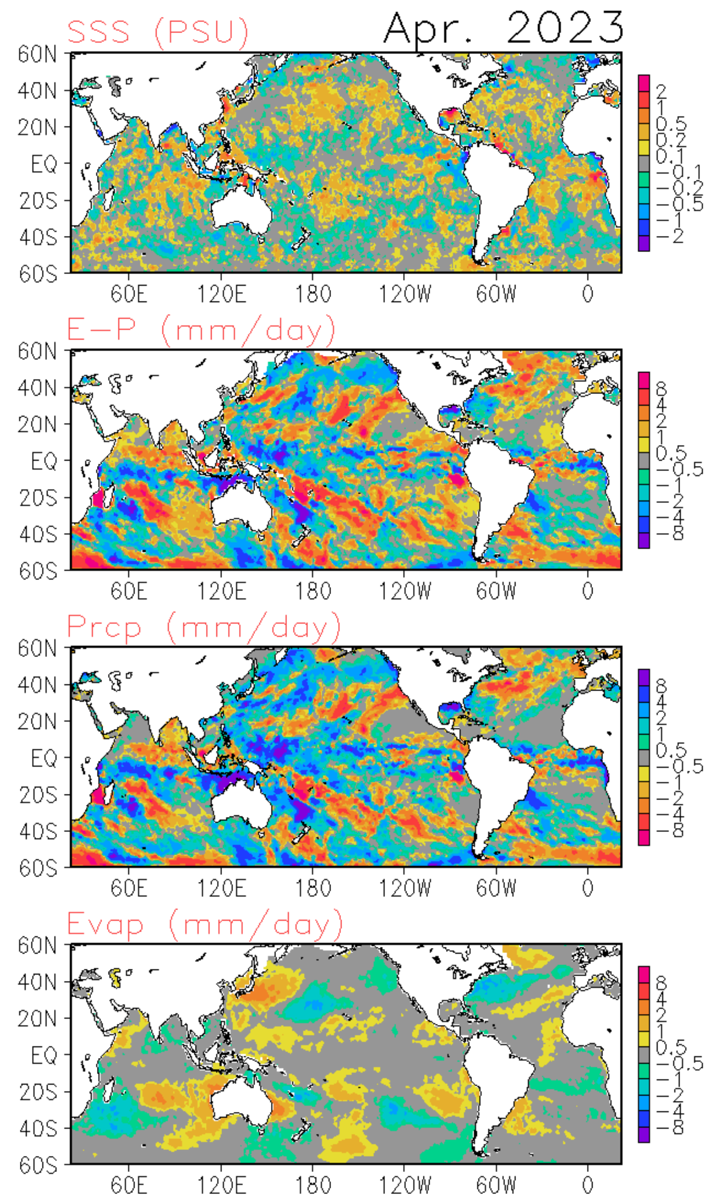
ftp.cpc.ncep.noaa.gov/precip/BASS

Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: Adjusted CFS Reanalysis

Global Sea Surface Salinity (SSS): Tendency for April 2023

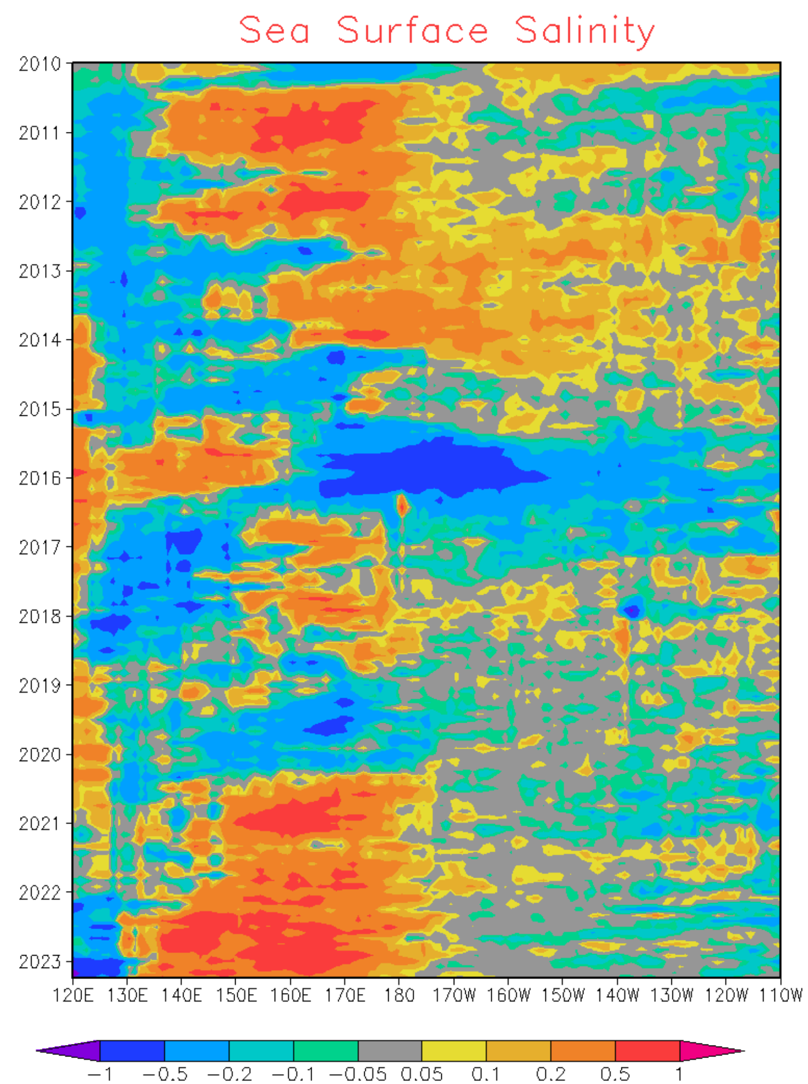
Freshening SSS tendency is observed over the western and central equatorial Pacific and over the western south pacific off the eastern Austria attributable to the enhanced fresh water flux into the ocean. Freshening / saltier SSS tendency appears over the Bay of Bengal / Gulf of Mexico during this process. SSS tendency over the regions are generally in opposite signs with that is the fresh water flux, suggesting contributions from the oceanic processes.



Monthly SSS Anomaly Evolution over Equatorial Pacific

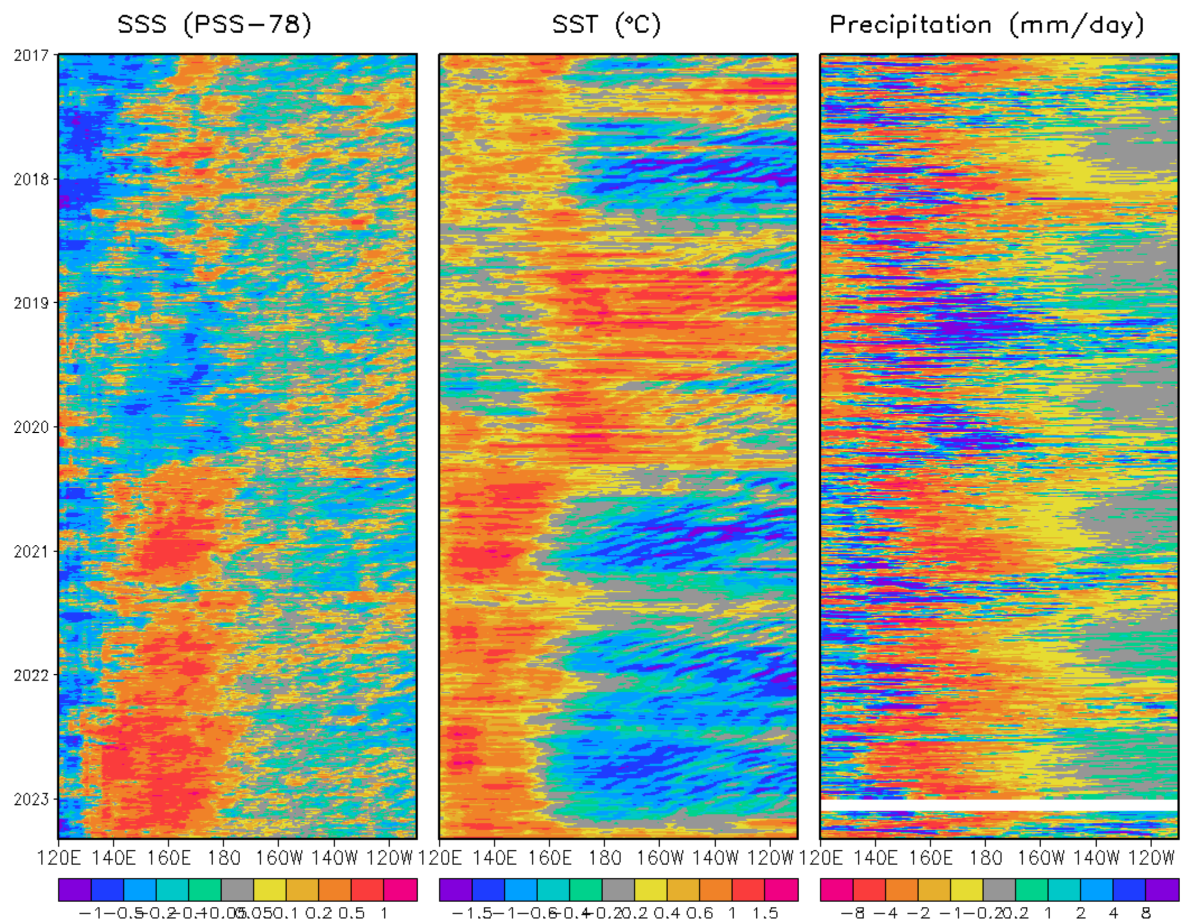
NOTE: Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015,The BASS SSS is from in situ, SMOS and Aquarius.

- Hovermoller diagram for equatorial SSS anomaly **(5° S-5° N);**
- Positive SSS anomalies continued over the western and central equatorial Pacific (130°E-180°). The intensity of the saltier anomaly over the central equatorial (155°E-170°E) as a result of the enhanced ITCZ precipitation anomalies there.



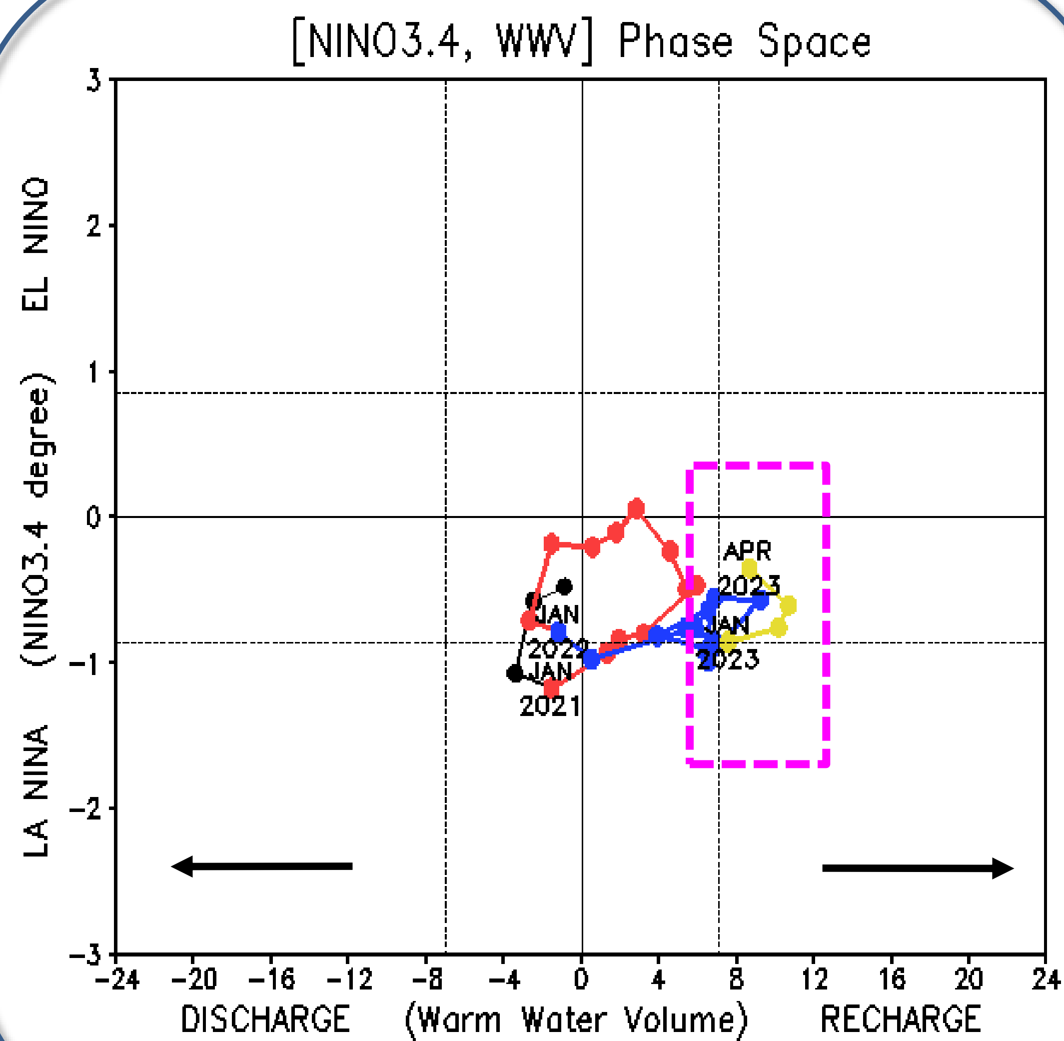
Pentad SSS Anomaly Evolution over Equatorial Pacific

Figure caption: Hovermoller diagram for equatorial (5° S-5° N) 5-day mean SSS, SST and precipitation anomalies. The climatology for SSS is Levitus 1994 climatology. The SST data used here is the OISST V2 AVHRR only daily dataset with its climatology being calculated from 1985 to 2010. The precipitation data used here is the adjusted CMORPH dataset with its climatology being calculated from 1999 to 2013.



Warm Water Volume (WWV) and Niño3.4 Anomalies

- Equatorial Warm Water Volume (WWV) was in a recharge phase in Apr 2023.

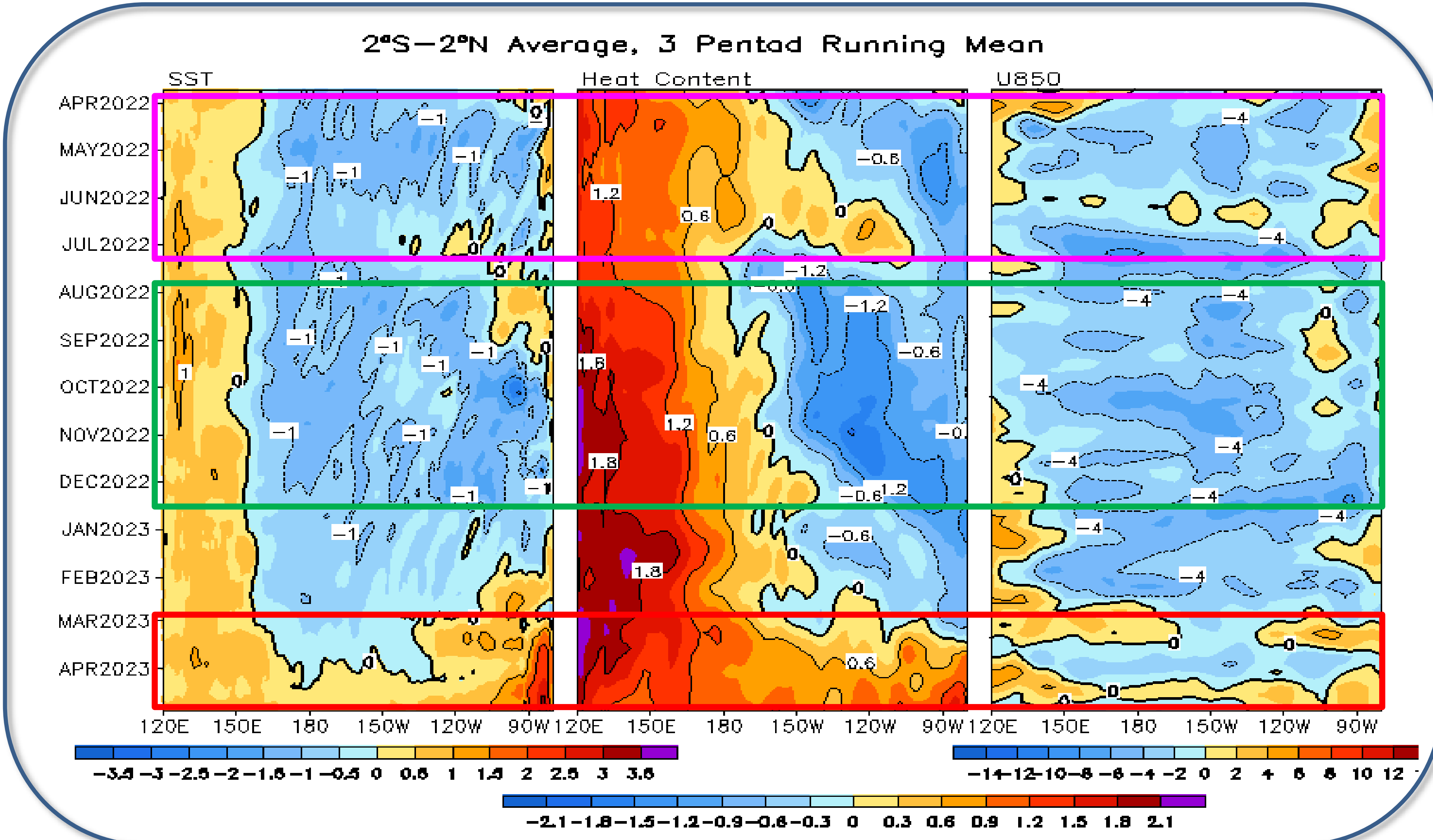


-As WWV is intimately linked to ENSO variability (Wyrtki 1985; Jin 1997), it is useful to monitor ENSO in a phase space of WWV and Niño3.4 (Kessler 2002).

- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.

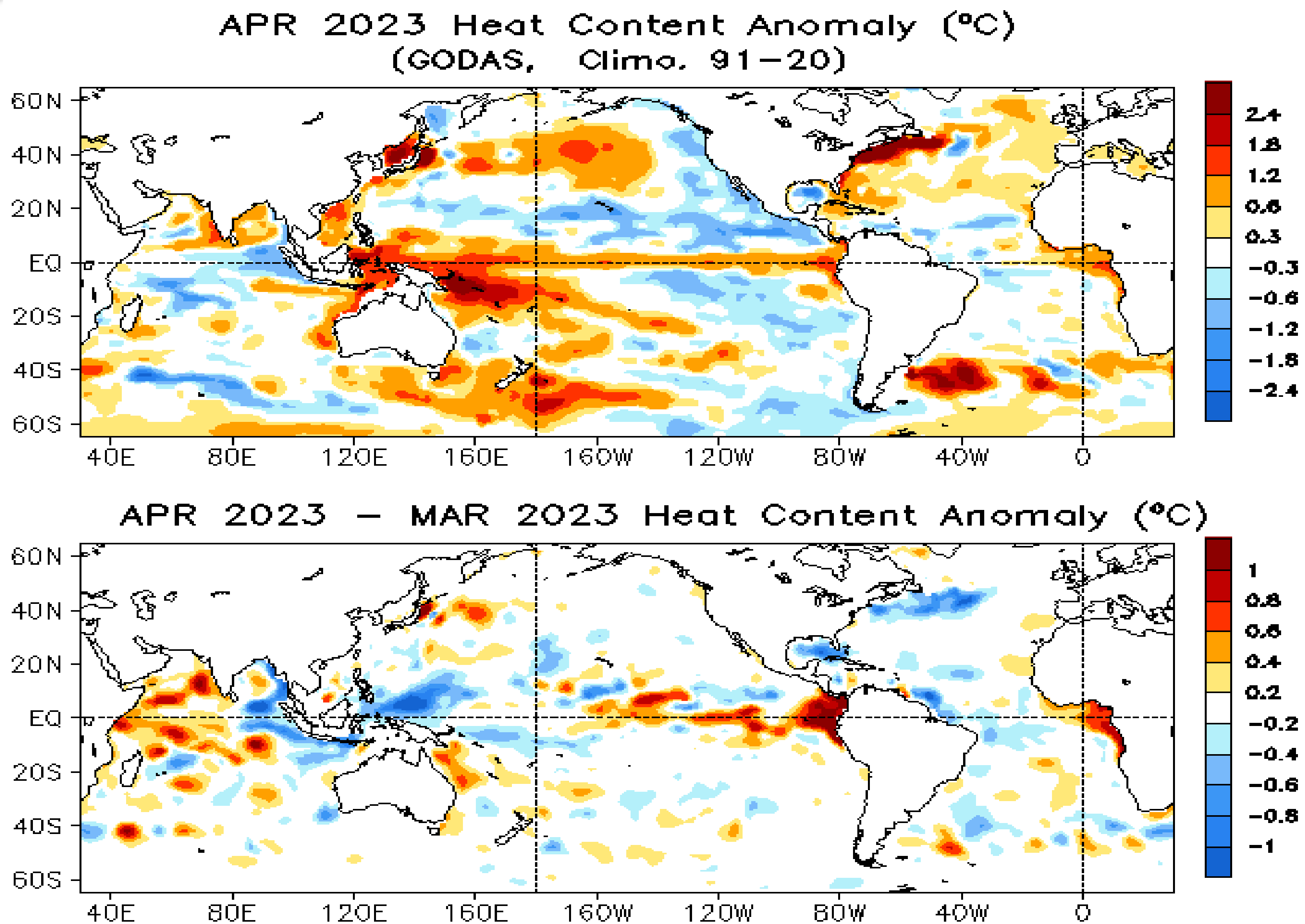
Phase diagram of Warm Water Volume (WWV) and Niño3.4 indices. WWV is the average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN] calculated with the NCEP's GODAS. Anomalies are departures from the 1991-2020 base period means.

Equatorial Pacific SST (ºC), HC300 (ºC), u850 (m/s) Anomalies

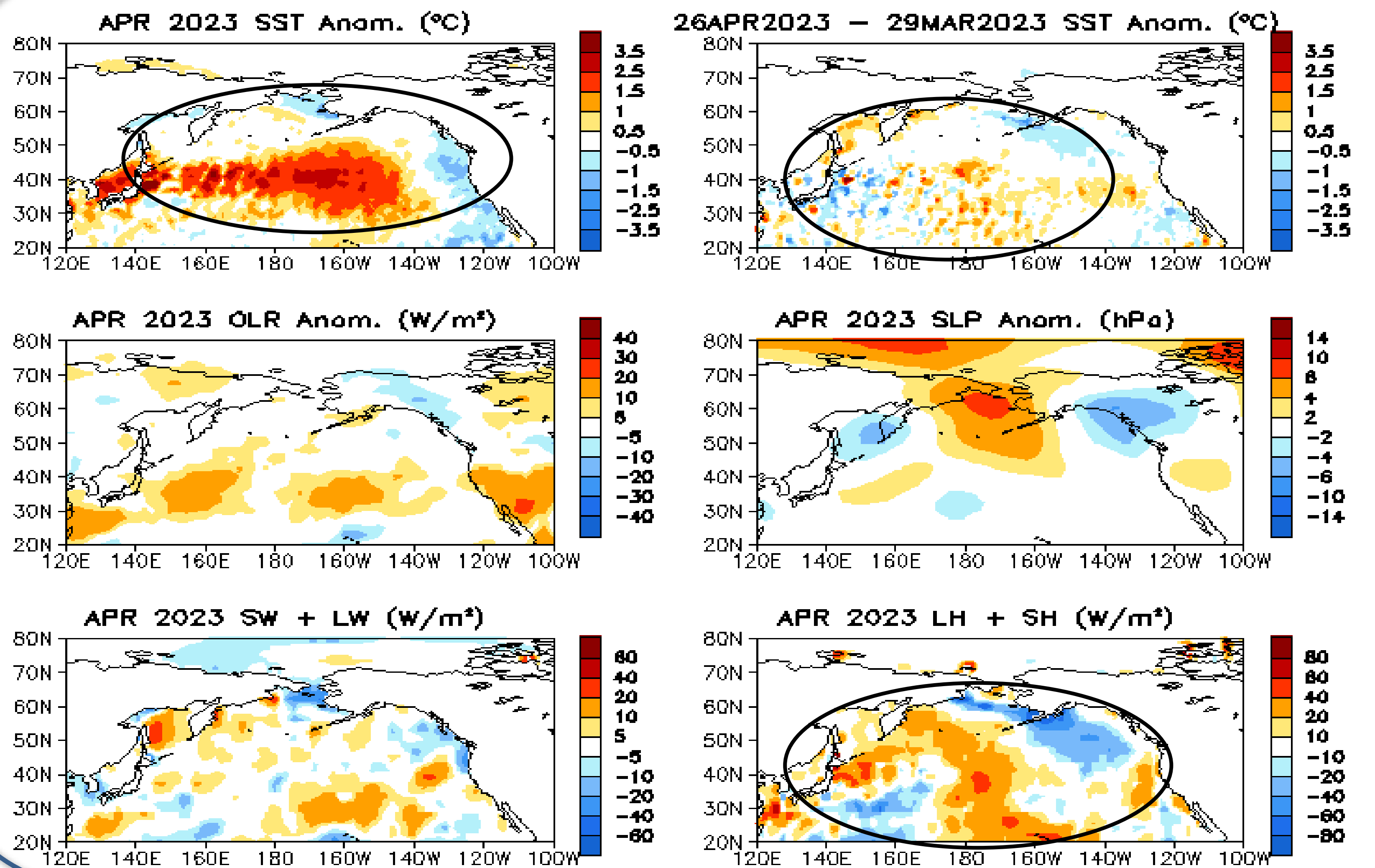


- The evolution of the triple-dip La Niña SSTA in 2020-23 was linked to low-level zonal wind anomalies and Kelvin wave activities.
- Since Feb 2023, positive HC300 anomaly extended eastward while westerly wind anomalies and positive SSTA were observed.

Global HC300 Anomaly & Anomaly Tendency

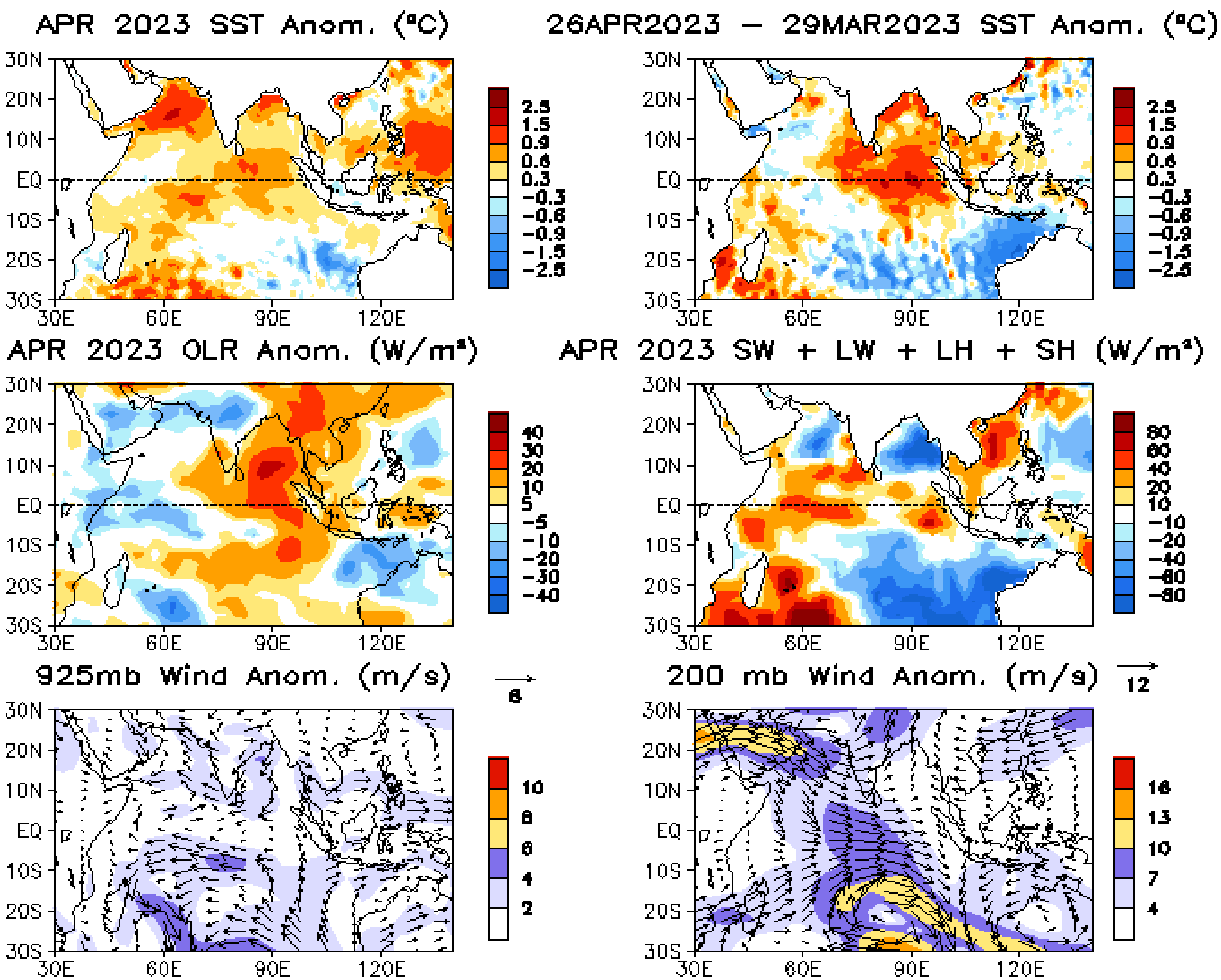


North Pacific & Arctic Ocean: SSTA, SSTA Tend., OLR, SLP, Sfc Rad, Sfc Flx Anomalies



SSTA (top-left; OIv2.1 SST Analysis), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) (middle-left; NOAA 18 AVHRR IR), sea surface pressure (middle-right; NCEP CDAS), sum of net surface short- and long-wave radiation (bottom-left; positive means heat into the ocean; NCEP CDAS), sum of latent and sensible heat flux (bottom-right; positive means heat into the ocean; NCEP CDAS). Anomalies are departures from the 1991-2020 base period means.

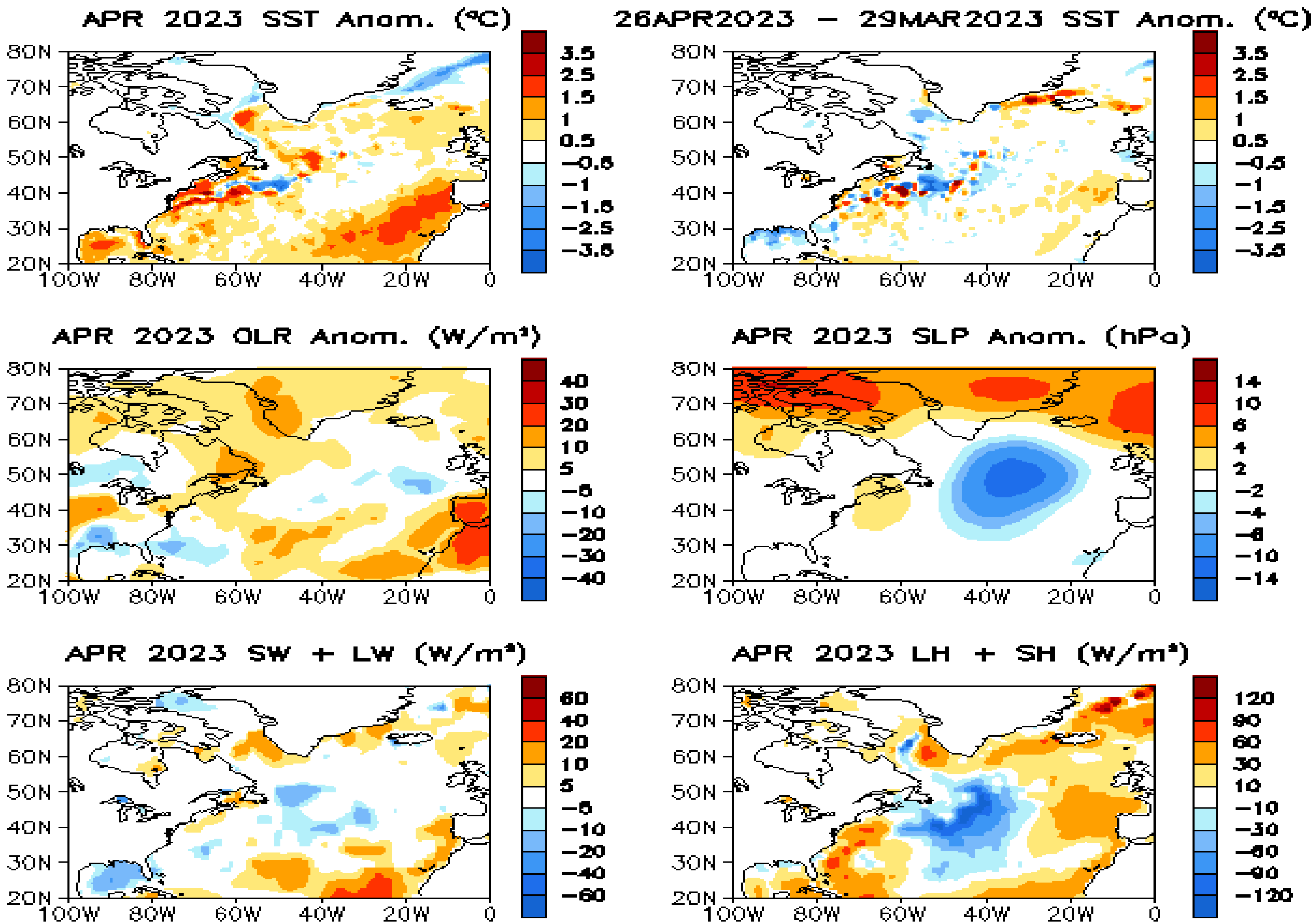
Tropical Indian: SSTA, SSTA Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Wind Anom.



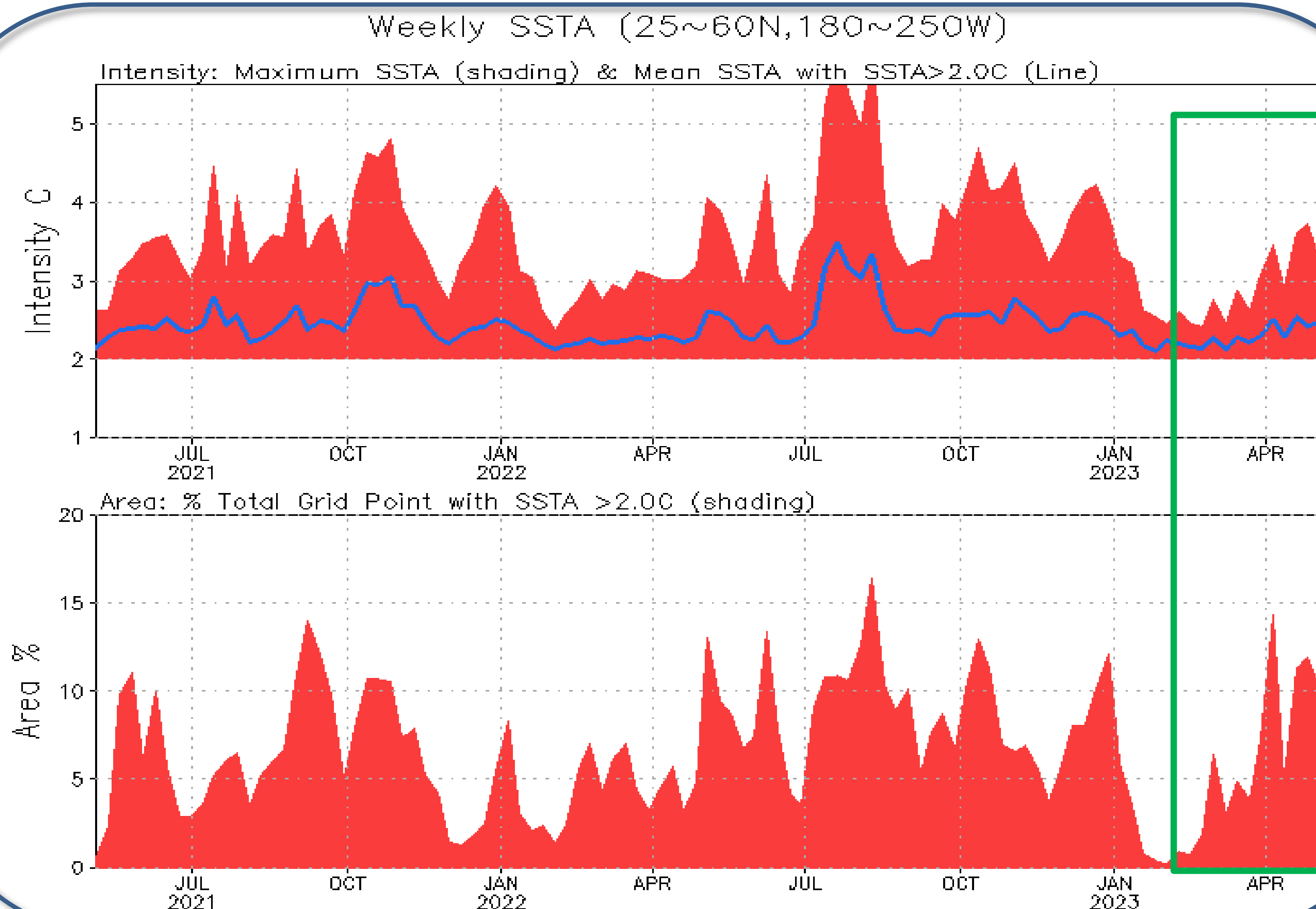
Convection was enhanced (suppressed) over the northern (southern) tropical Indian Ocean.

SSTAs (top-left), SSTA tendency (top-right), OLR anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the OIv2.1 SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1991-2020 base period means.

N. Atlantic: SST, SST tend., OLR, SLP, & heat flex anom.

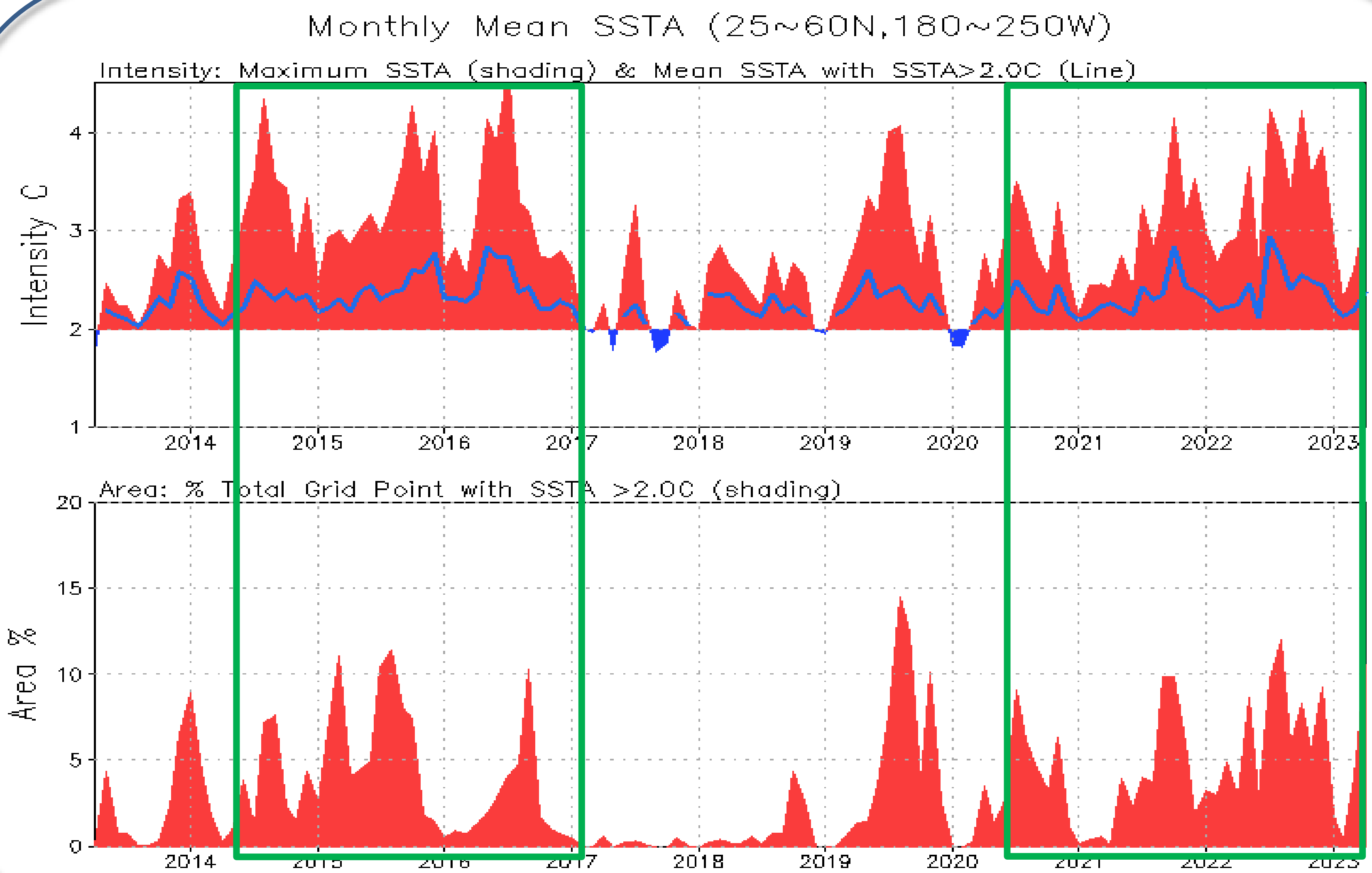


N. Pacific Marine Heat Wave



https://origin.cpc.ncep.noaa.gov/products/GODAS/MarineHeatWave.html

N. Pacific Marine Heat Wave



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