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

Prepared by

Climate Prediction Center, NCEP/NOAA

June 9, 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

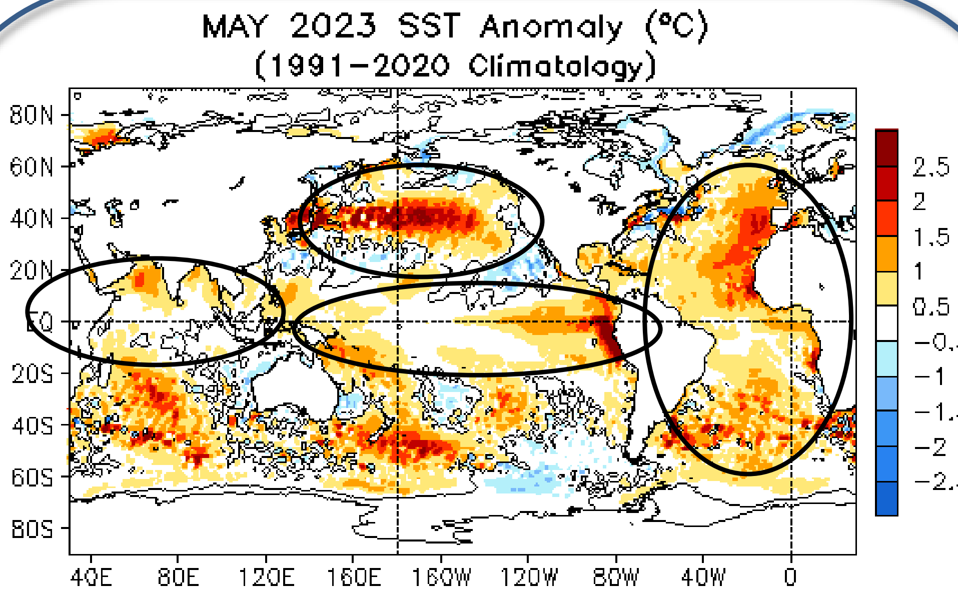
- Overview
- Recent highlights
  - Pacific Ocean (*NOAA/Physical Sciences Laboratory MHW products*)
  - Arctic & Antarctic Oceans
  - Indian Ocean
  - Atlantic Ocean (*2023 Hurricane Outlook*)
- Global SSTA Predictions

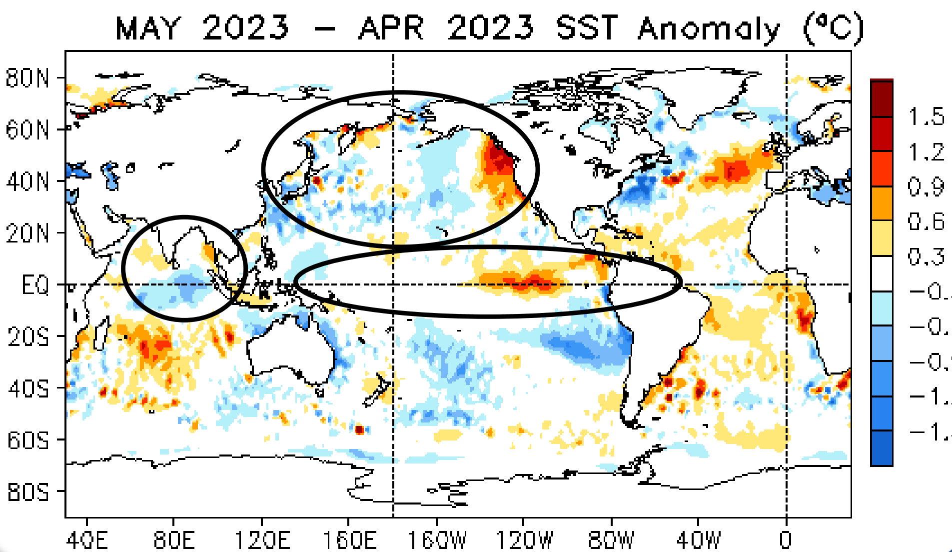
# Overview

- Pacific Ocean
  - The warming in the central and eastern equatorial Pacific increased in May 2023 with Niño3.4 = 0.47$^{o}$C (OIv2.1) and 0.39$^{o}$C (ERSSTv5).
  - A strong coastal El Niño has been observed since Feb 2023 with Niño1+2 =2.02$^{o}$C in May 2023.
  - NOAA "ENSO Diagnostic Discussion" on 8 Jun 2023 issued El Niño Advisory & stated "*El Niño conditions are present and are expected to gradually strengthen into the Northern Hemisphere winter 2023-24.*"
  - Positive SSTAs persisted in the North Pacific in May 2023. The PDO has been in a negative phase since Feb 2020 with PDOI = -1.7 in May 2023.
- Arctic and Antarctic Oceans
  - The seasonal decline in Arctic sea ice extent was moderate through much of May before picking up pace over the last few days of the month.
  - Antarctic sea ice extent remained far below previous satellite-era record lows for this time of year.
- Indian Ocean
  - SSTs were above normal in the tropical Indian Ocean in May 2023.
- Atlantic Ocean
  - NAO switched to a positive phase with NAOI= 0.4 in May 2023.

# Global Oceans

# Global SST Anomaly (°C) and Anomaly Tendency



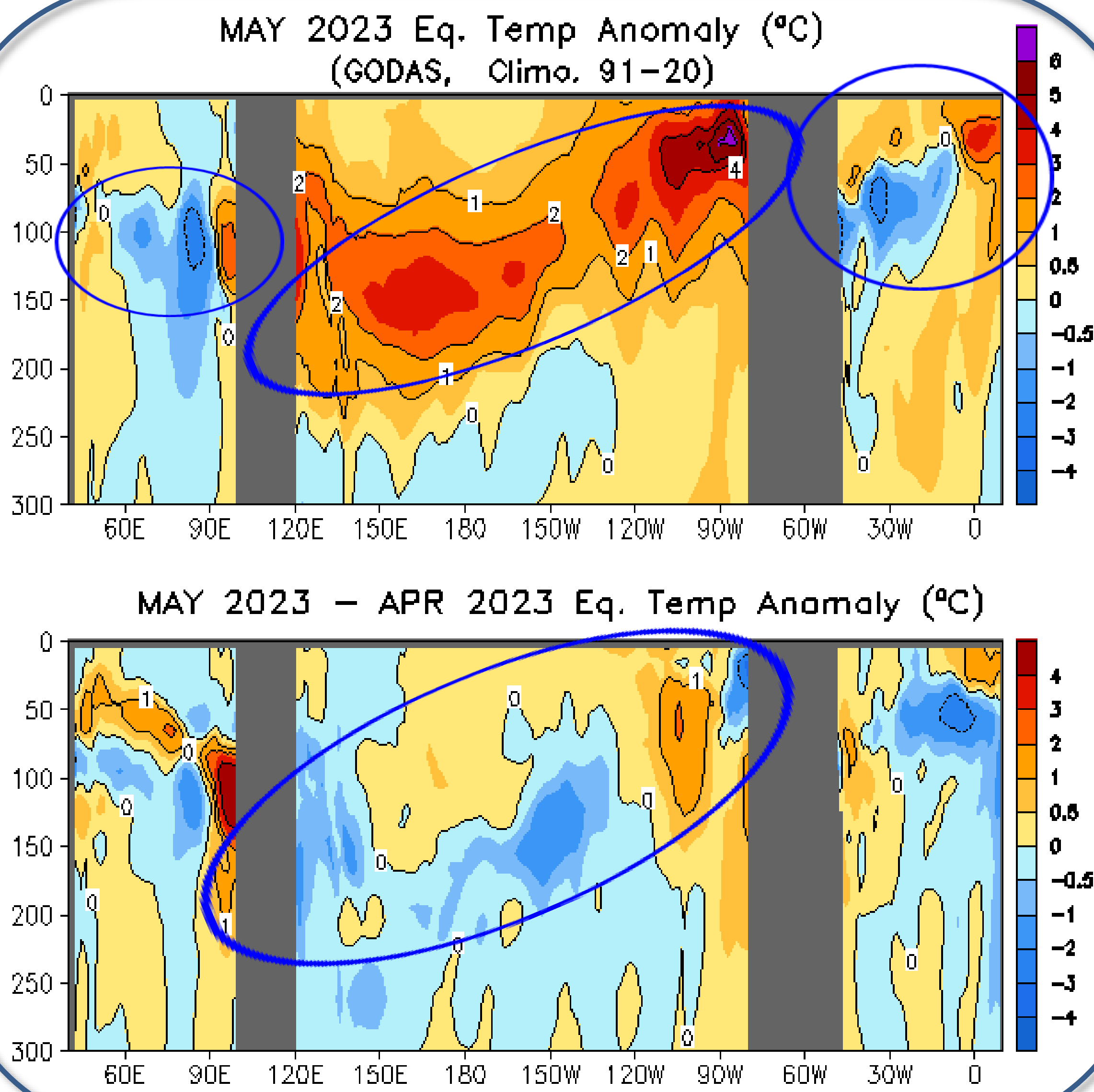




- Above (near) normal SSTs were present in the western and eastern (central) equatorial Pacific and a coastal El Nino has persisted since Feb 2023.
- Positive SSTAs were observed in the North Pacific and most of the Atlantic Ocean.
- SSTs were above normal in the tropical Indian Ocean.

- Positive (negative) SSTA tendencies were observed in the east-central (western) equatorial Pacific.
- Both positive and negative SSTA tendencies were evident in the North Pacific.
- Negative SSTA tendencies were present in the equatorial 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.

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

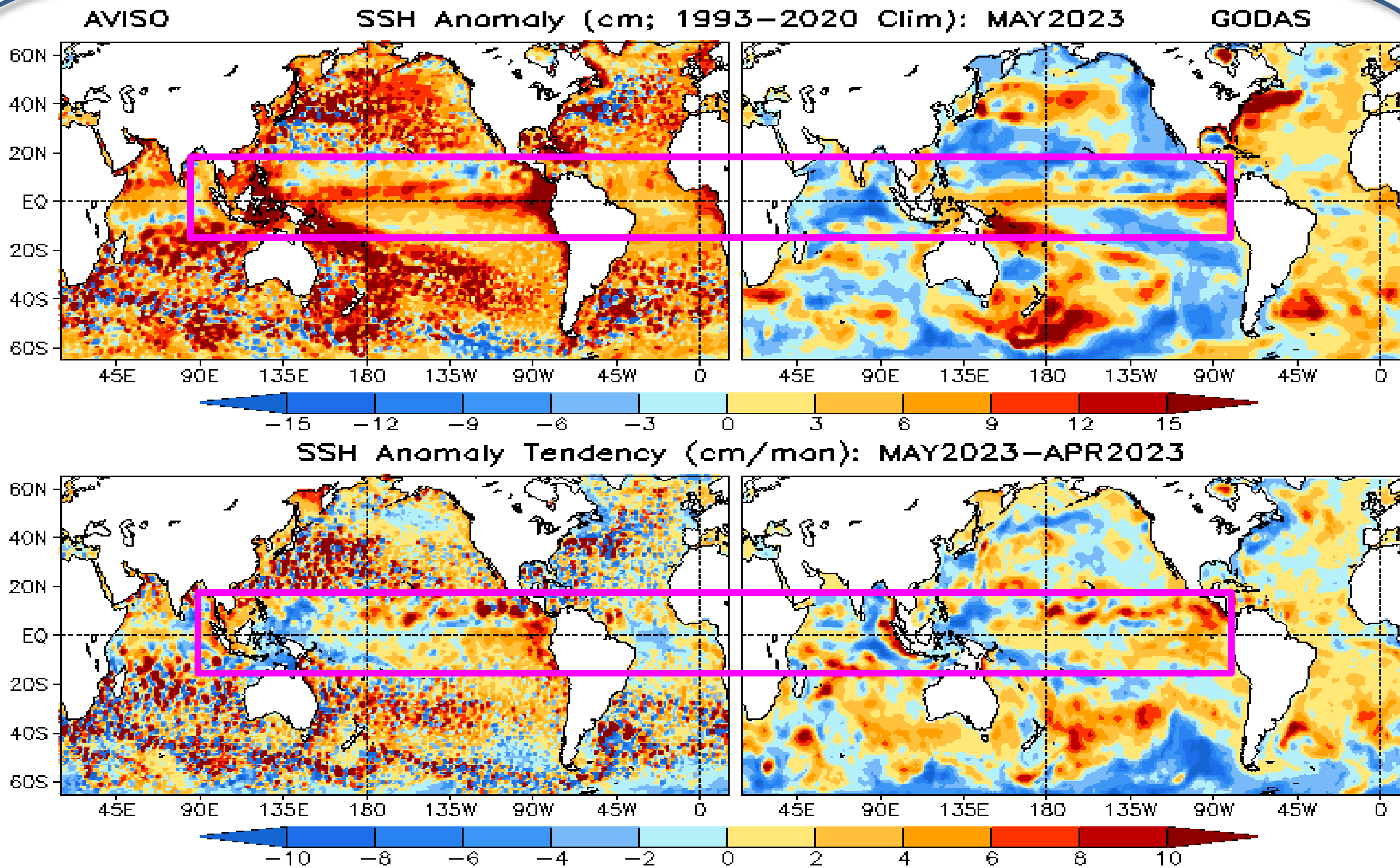



- Positive temperature anomalies were present along the thermocline in the Pacific.
- Positive (negative) temperature anomalies were observed along the thermocline in the far-eastern (central) Indian Ocean.
- The anomalies were positive (negative) along the thermocline in the eastern (western) Atlantic Ocean.

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

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.

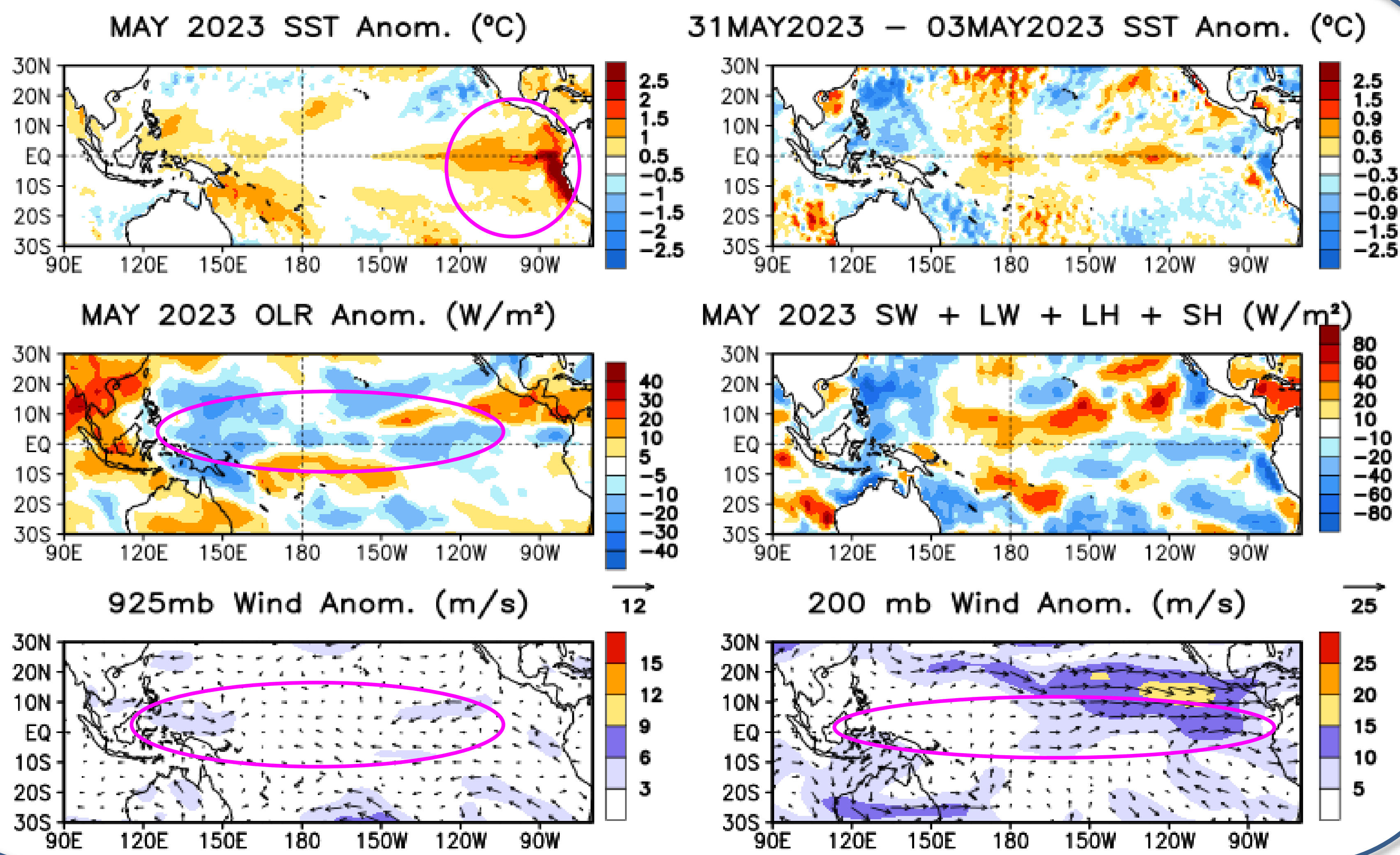
# AVISO & GODAS SSH Anomaly (cm) and Anomaly Tendency




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

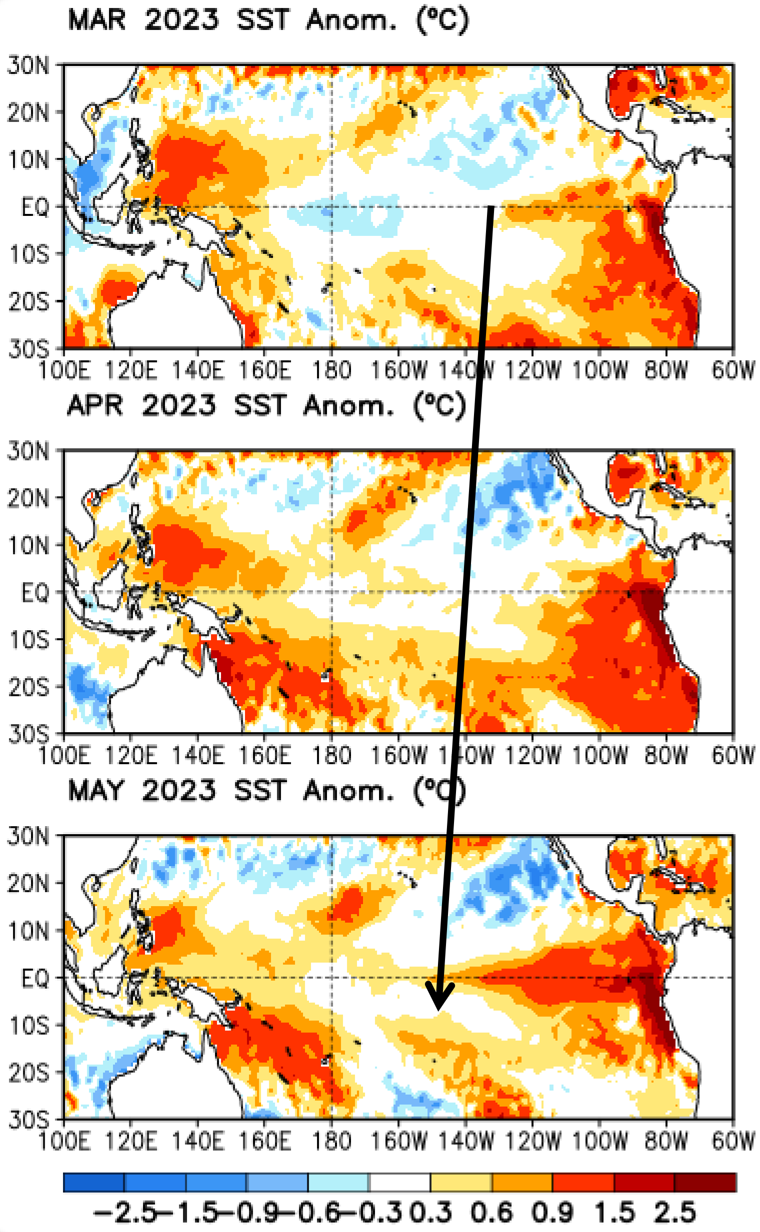
# Tropical Pacific Ocean and ENSO Conditions

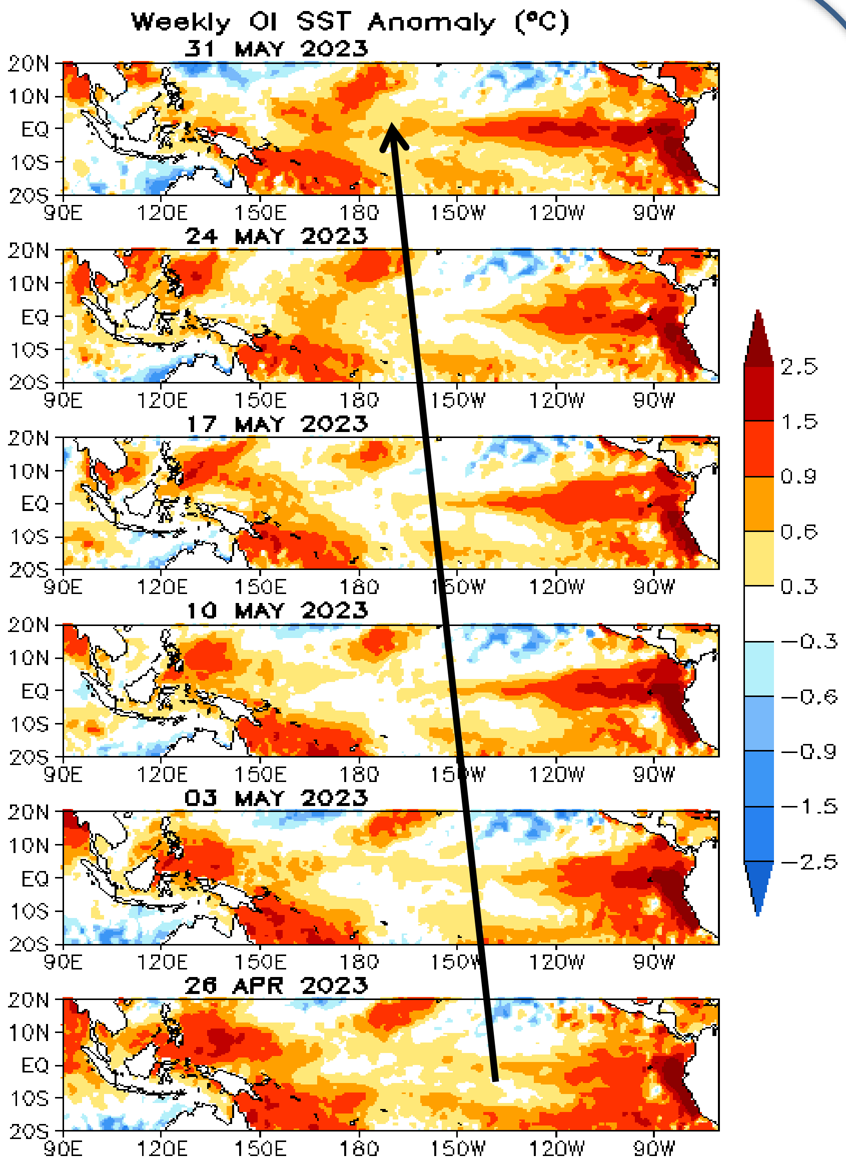
# Tropical Pacific: SSTA, SSTA Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Winds



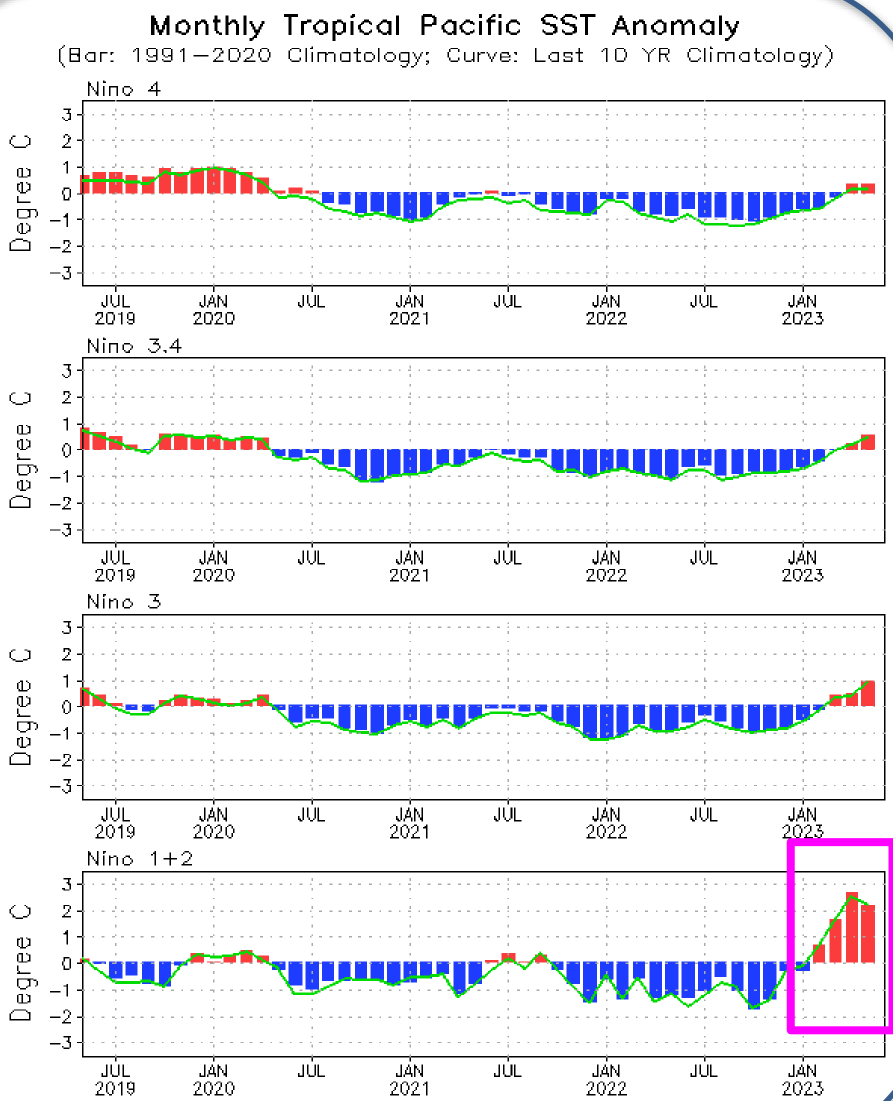

SSTAs (top-left), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly vector and its amplitude (bottom-left), 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.

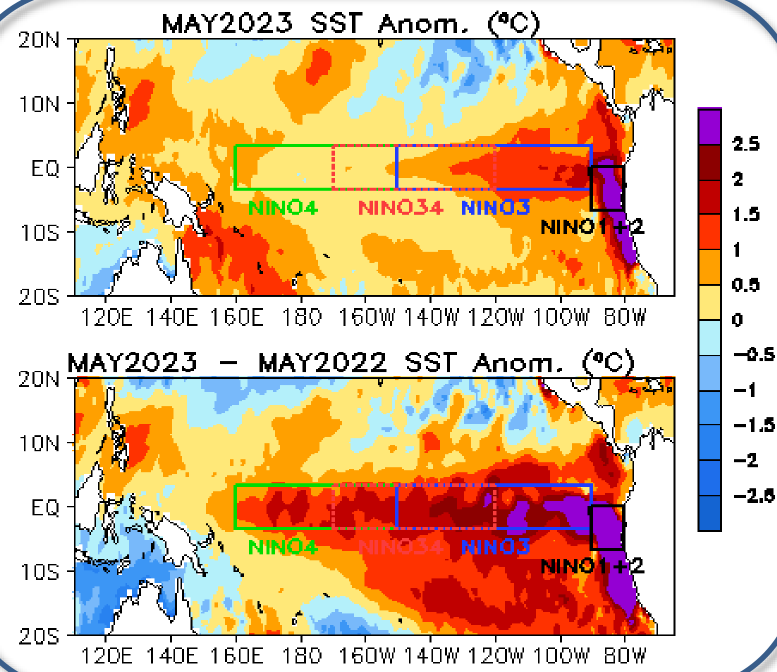
# Westward Expansion & Evolution of Coastal Niño



# Evolution of Pacific Niño SST Indices




- All Niño indices were positive in May 2023, with Niño3.4 = 0.47ºC (OIv2.1).

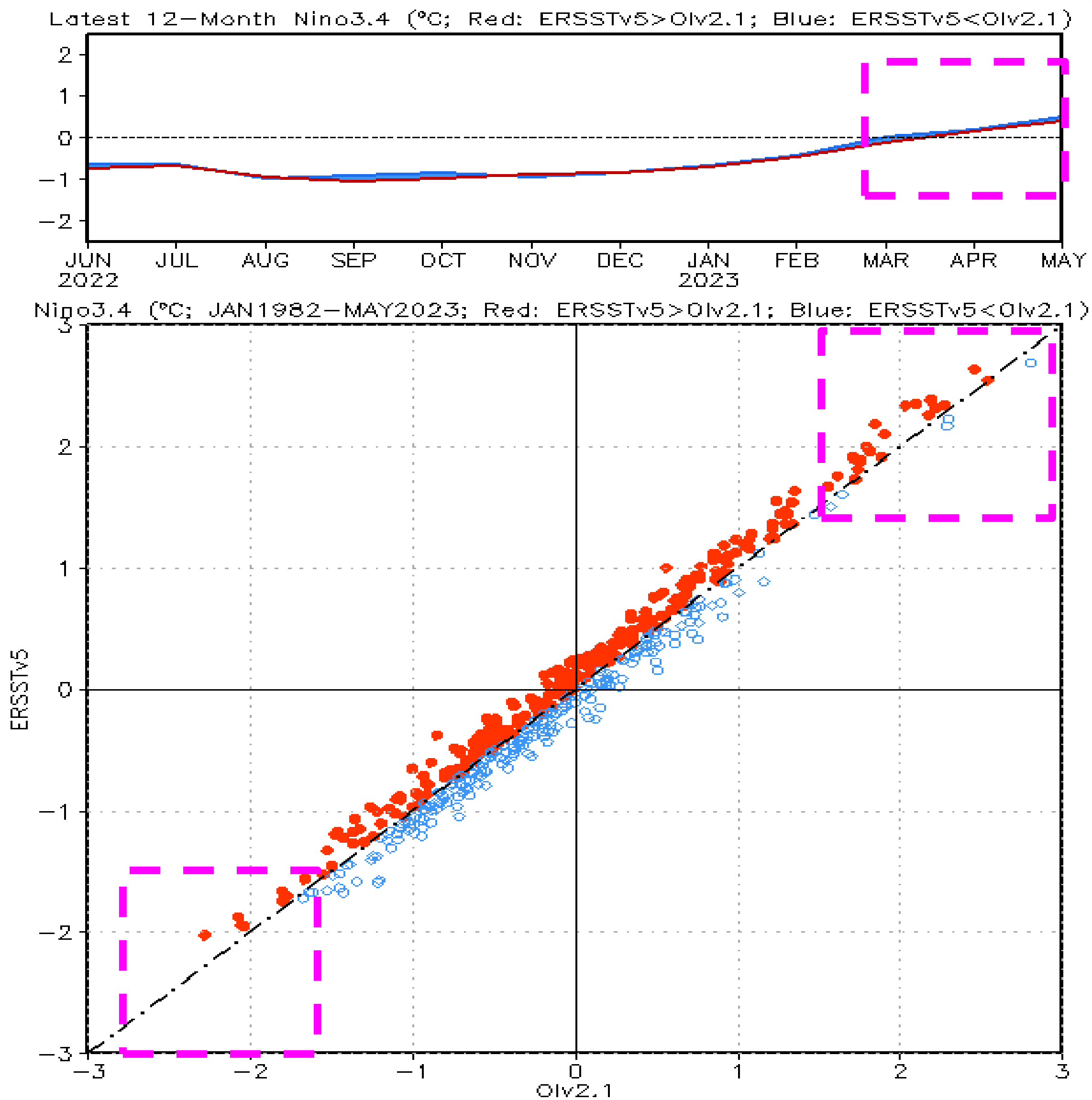
- A coastal Niño has been observed since Feb 2023 with Niño1+2= 2.02ºC(OIv2.1) in May 2023.

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

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

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

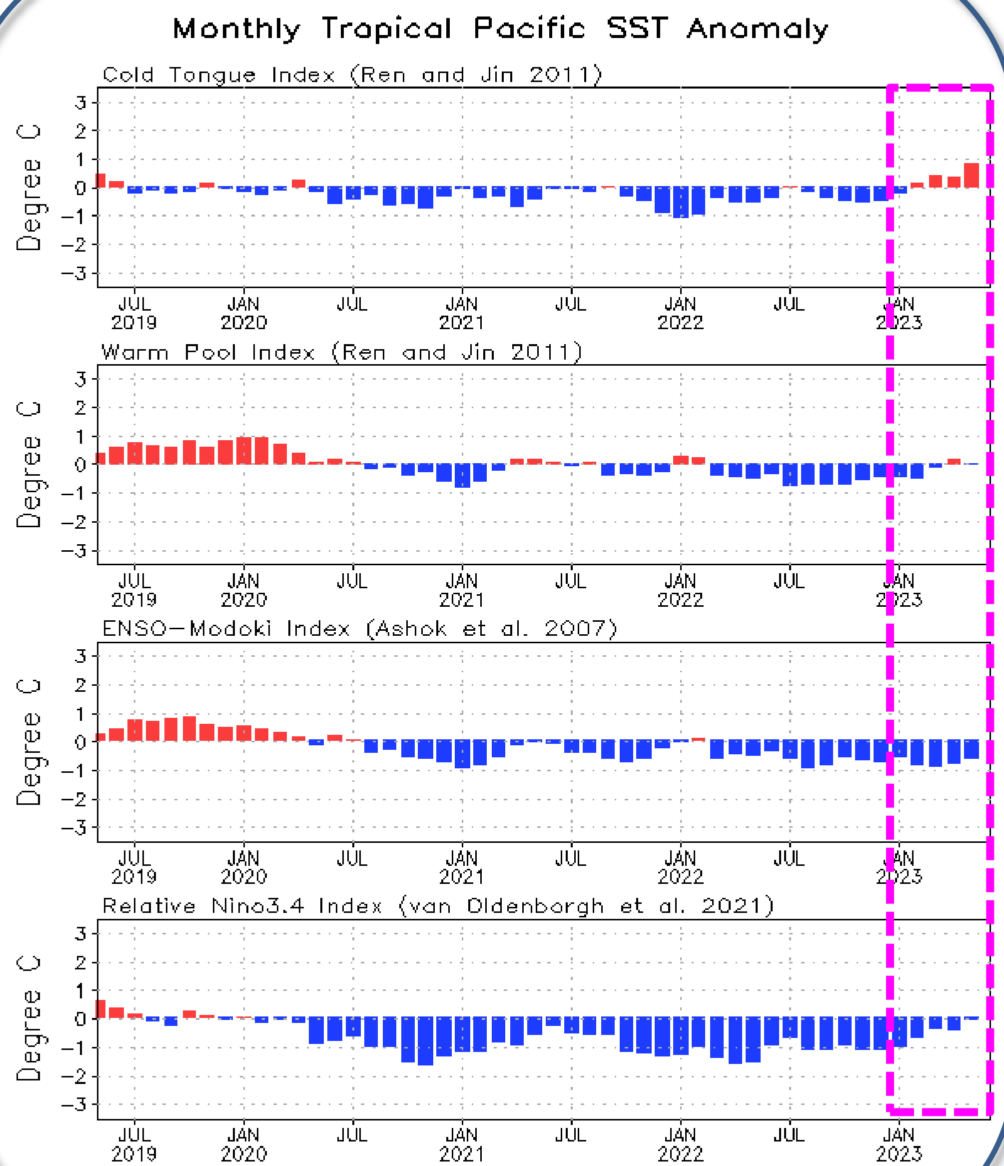
# Comparison of ERSSTv5 & OIv2.1 Niño3.4 Index

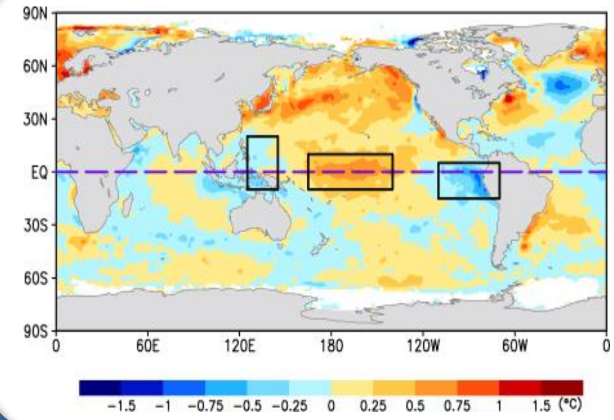



- Recently, ERSSTv5 is cooler than OIv2.1: 0.47C (OIv2.1) & 0.39C (ERSSTv5).

- Historically, ERSSTv5 can be either warmer or cooler than OIv2.1.
- For both the extreme positive and negative (>1.5°C or <-1.5°C) 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



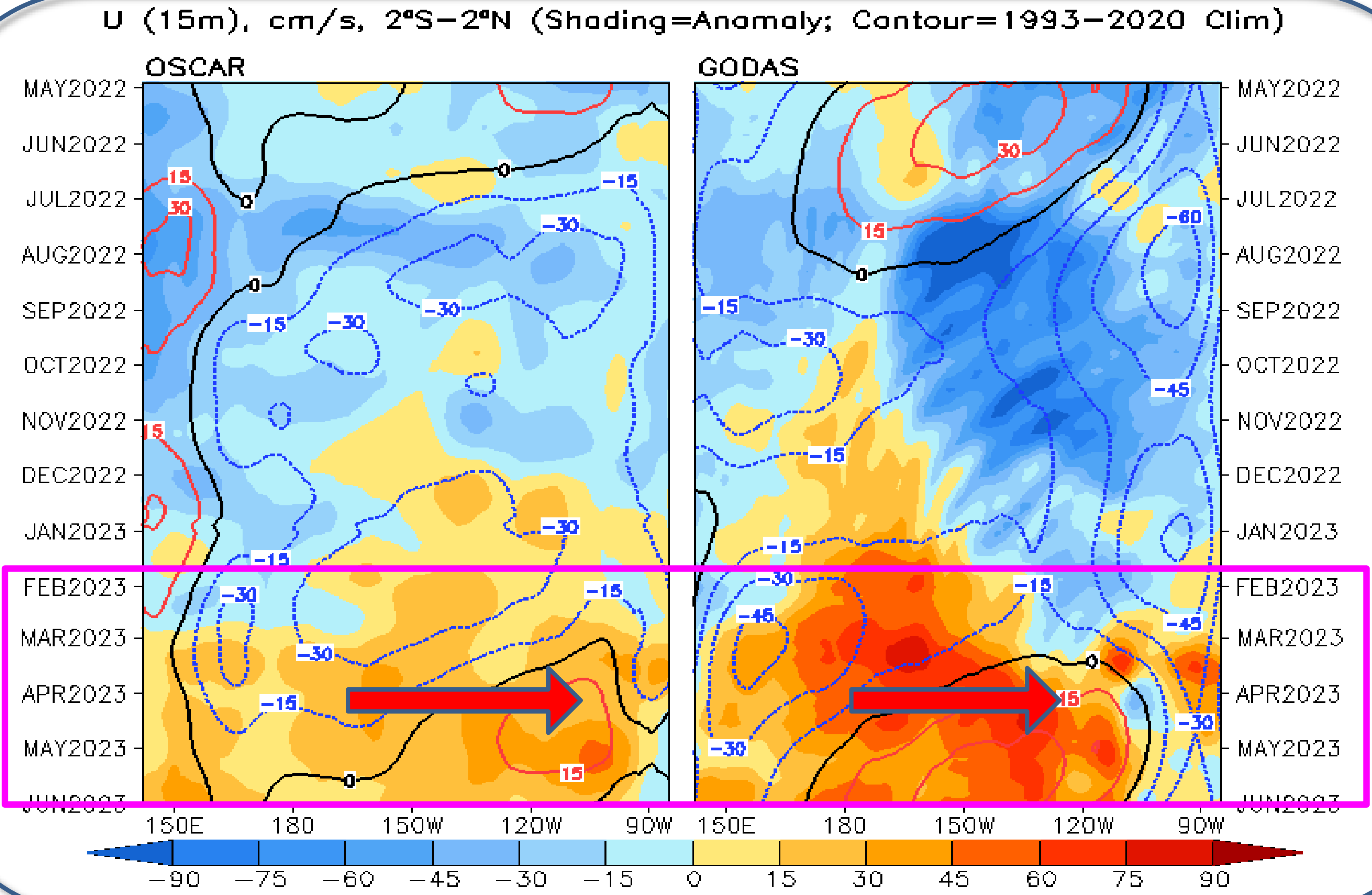




- Relative Niño3.4 index is now included in ENSO monitoring, which is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0º-360º, 20ºS-20ºN), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative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

Relative Niño3.4 data updated monthly at:

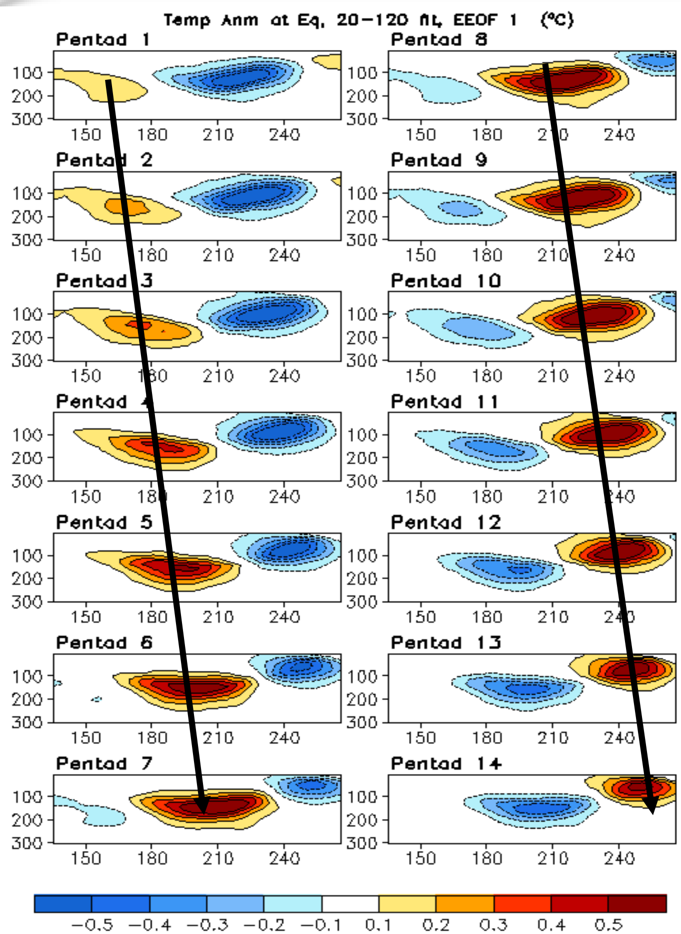
https://www.cpc.ncep.noaa.gov/data/indices/RONI.ascii.txt

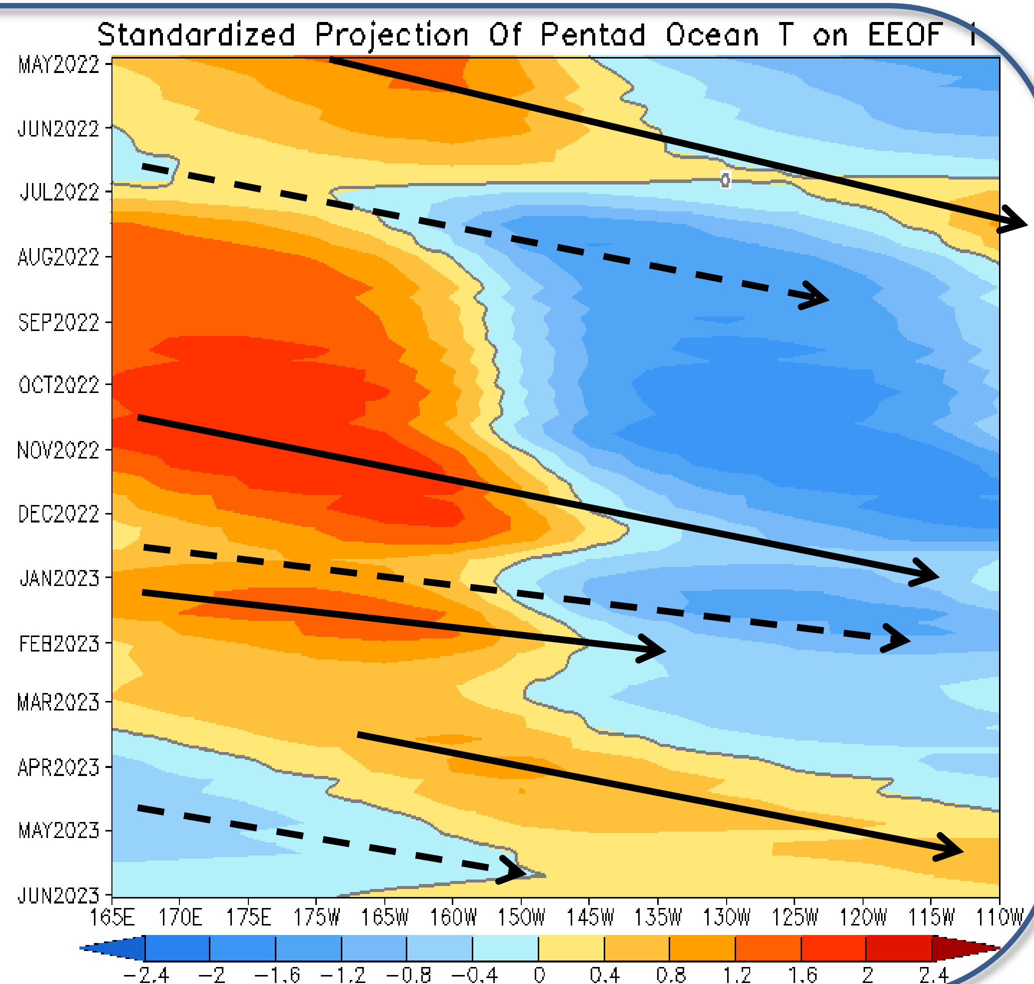
# Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)




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

# Oceanic Kelvin Wave (OKW) Index

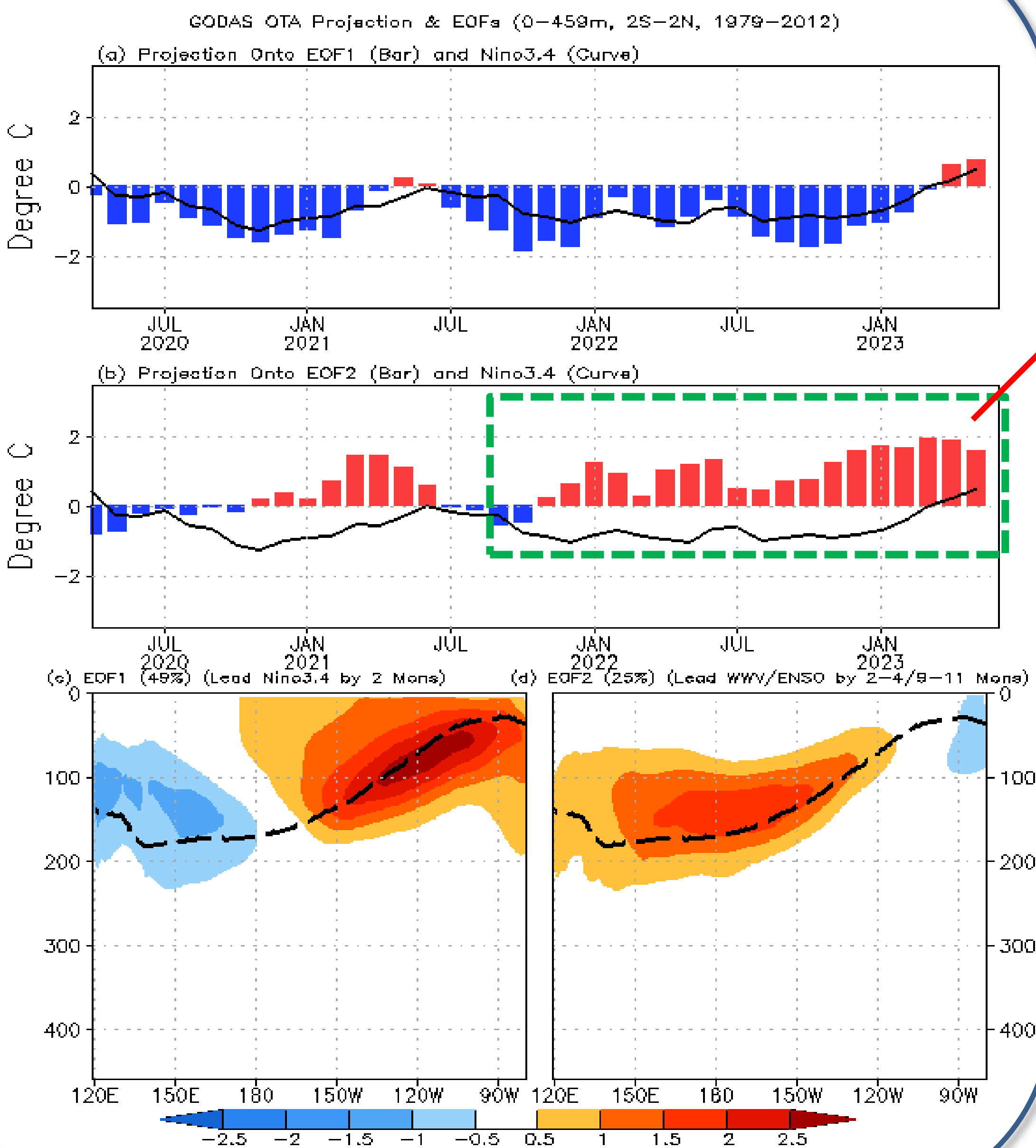



- **Multiple weak downwelling and upwelling Kelvin waves were observed in 2022, leading to the small fluctuation of SSTA in the central and eastern equatorial Pacific.**
- **A weak downwelling Kelvin wave propagated eastward since Jan 2023 and a weak upwelling Kevin wave emerged since Apr 2023.**

*(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).)*

# Equatorial Sub-surface Ocean Temperature Monitoring




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

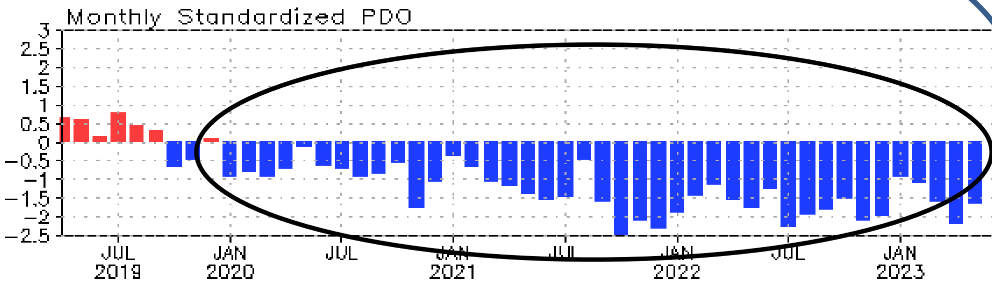
- Projection of ocean temperature anomalies onto EOF1 and EOF2; EOF1: Tilt/dipole mode (ENSO peak phase); EOF2: WWV mode.

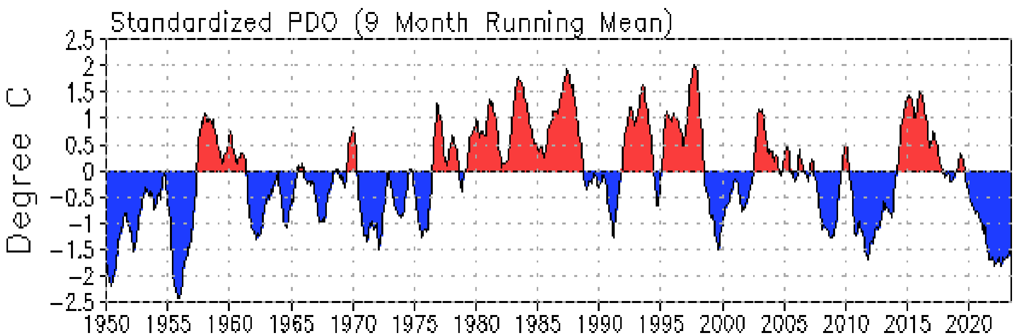
- Recharge/discharge oscillation (ENSO transition phase); Recharge process: heat transport from outside of equator to equator; Negative -> positive phase of ENSO

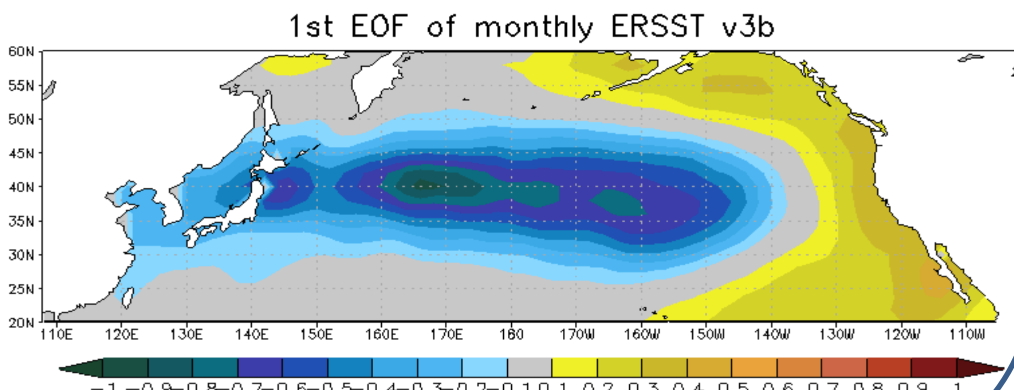
- For details, see: Kumar and Hu (2014) DOI: 10.1007/s00382-013-1721-0.

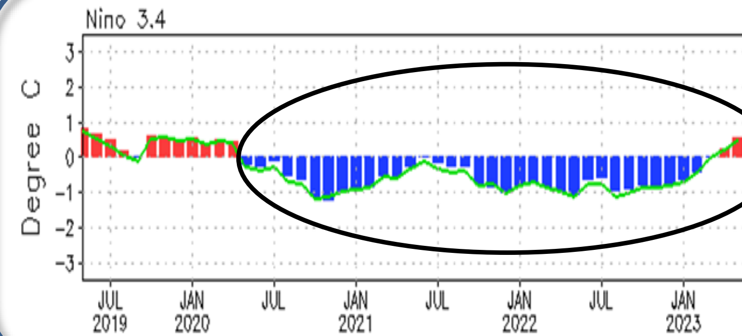
# North Pacific & Arctic Oceans

# Pacific Decadal Oscillation (PDO) Index



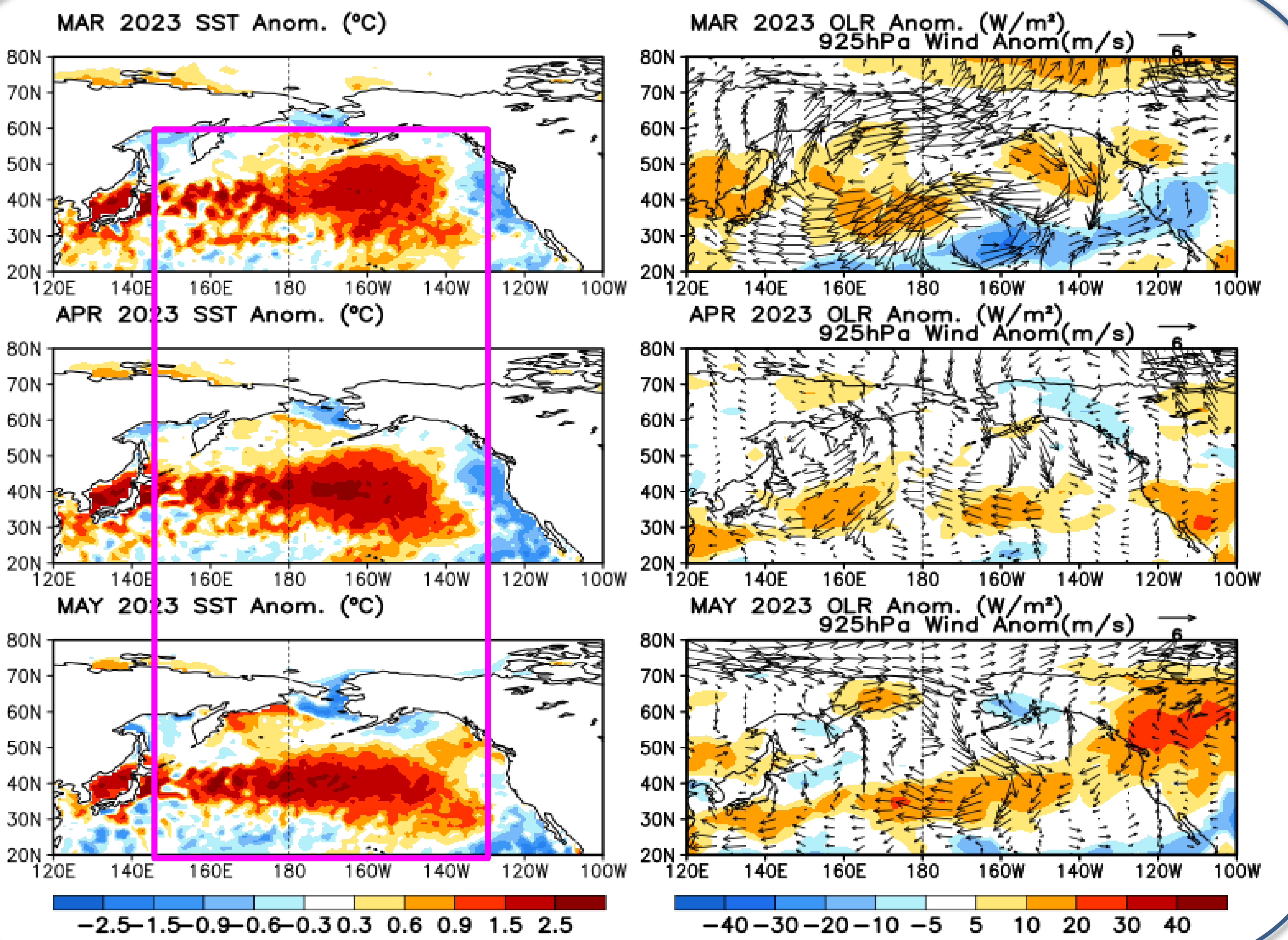




- The PDO has been in a negative phase since Feb 2020 with PDOI = -1.7 in May 2023.

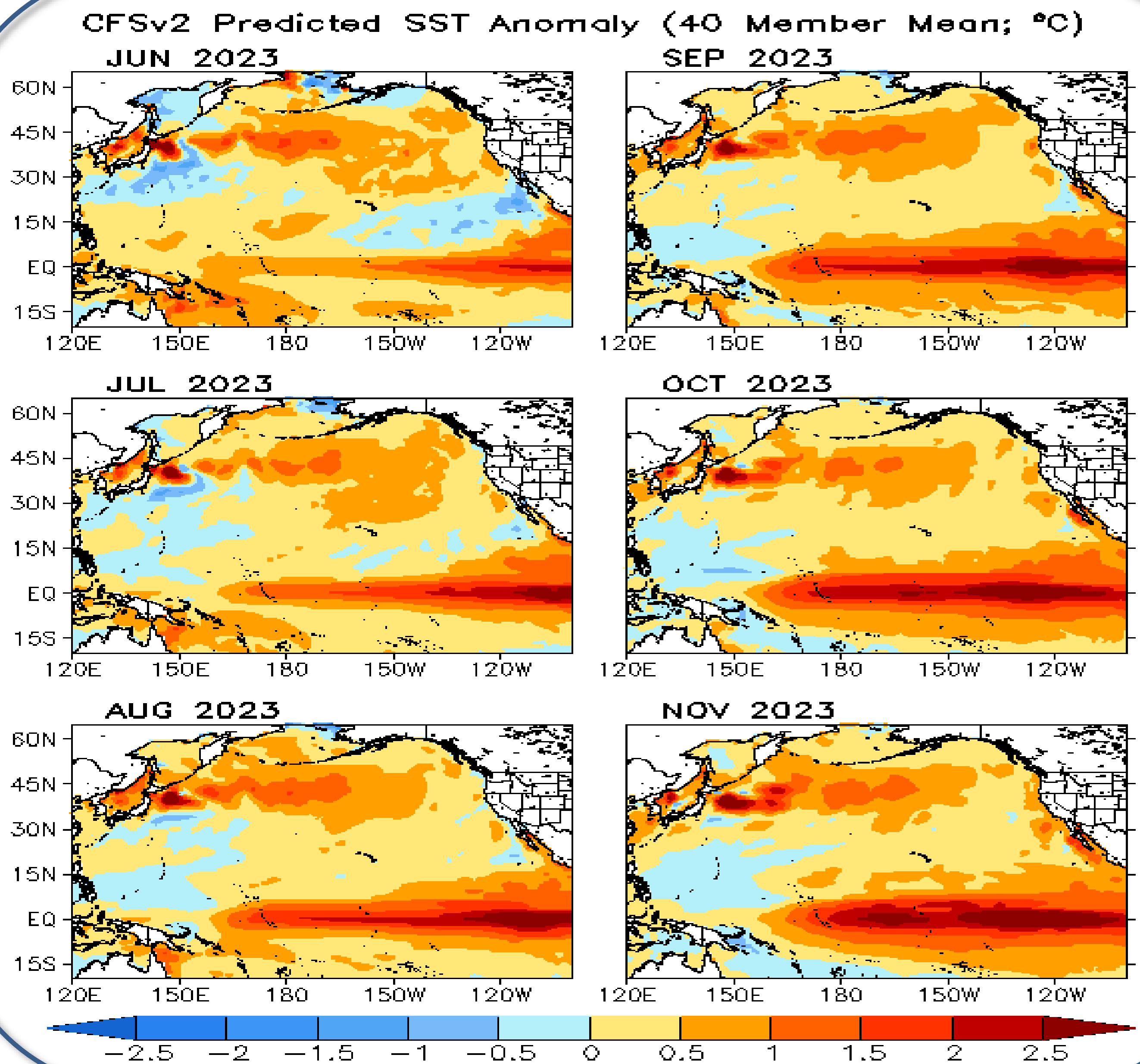
- Statistically, ENSO leads PDO by 3-4 months, through teleconnection via atmospheric bridge, with El Niño (La Niña) associated with positive (negative) PDO Index.

• 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.

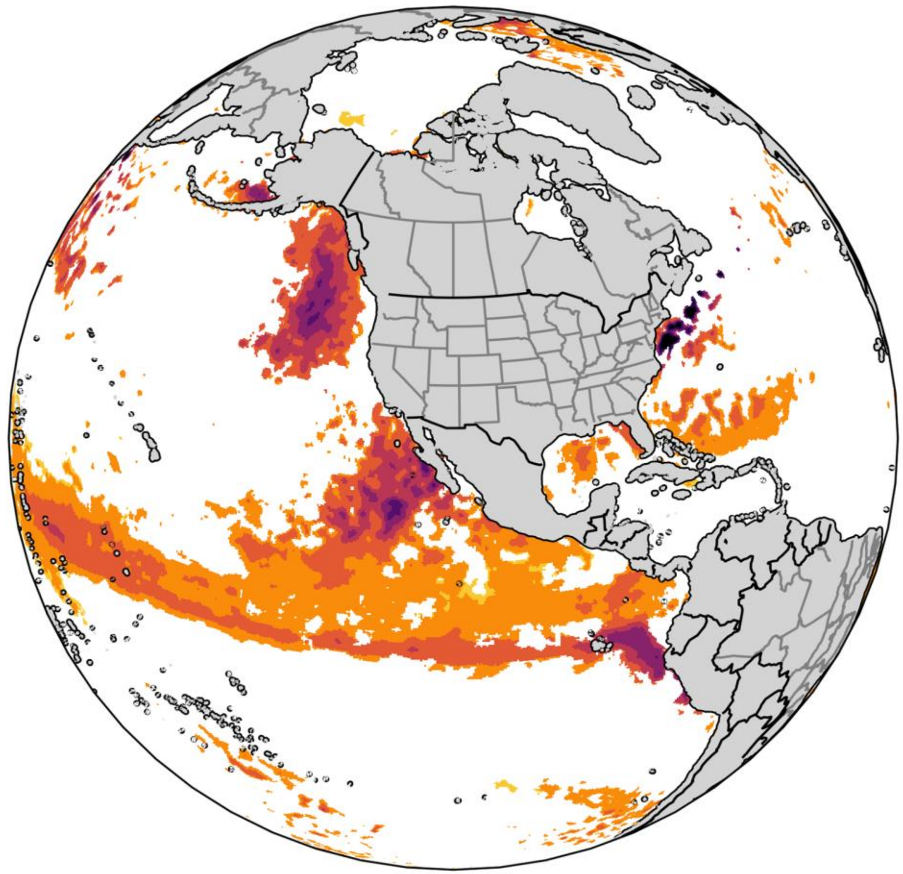
# North Pacific SST, OLR, and uv925 anomalies



# CFSv2 NE Pacific SSTA Predictions




- The CFSv2 predicts above-normal SSTs in the N. Pacific through fall 2023.



# NOAA/Physical Sciences Laboratory: Marine Heatwave Portal

Creators : Chia-Wei Hsu, Michael Alexander, Catherine Smith, Michael Jacox, & Chris Kreutzer

Physical Sciences Laboratory

About | People | Research | Data | Products | News | Events | Learn

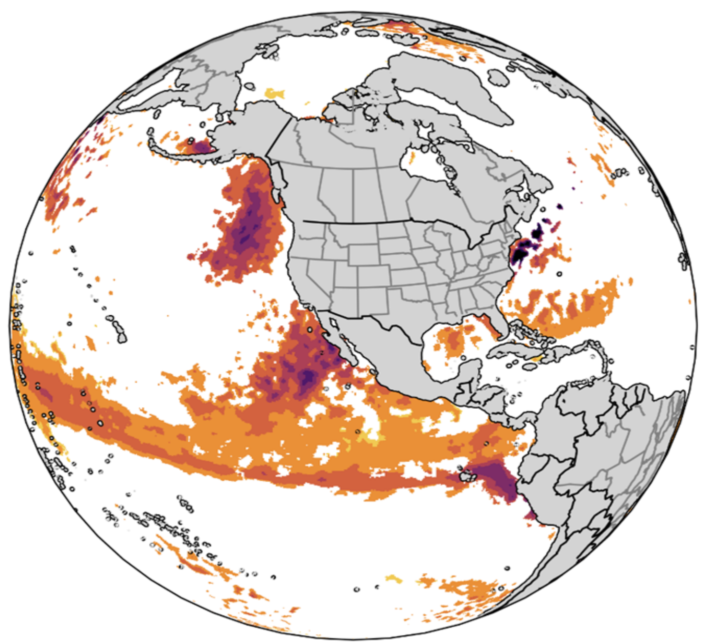
Home » Research » Marine Heatwaves

# Marine Heatwaves

Overview | Observation | Forecasts | Large Marine Ecosystems | Explore | PSL Papers | Data | News | Links

## Overview

Marine heatwaves are periods of persistent anomalously warm ocean temperatures, which can have significant impacts on marine life as well as coastal communities and economies. Scientists at PSL are working to characterize marine heatwaves, understand how they form and dissipate, and predict them in advance. On this page, we will provide current ocean maps, forecasts of heatwaves, interactive tools for users to explore ocean heatwaves themselves, links to research results and to webpages at other institutions.

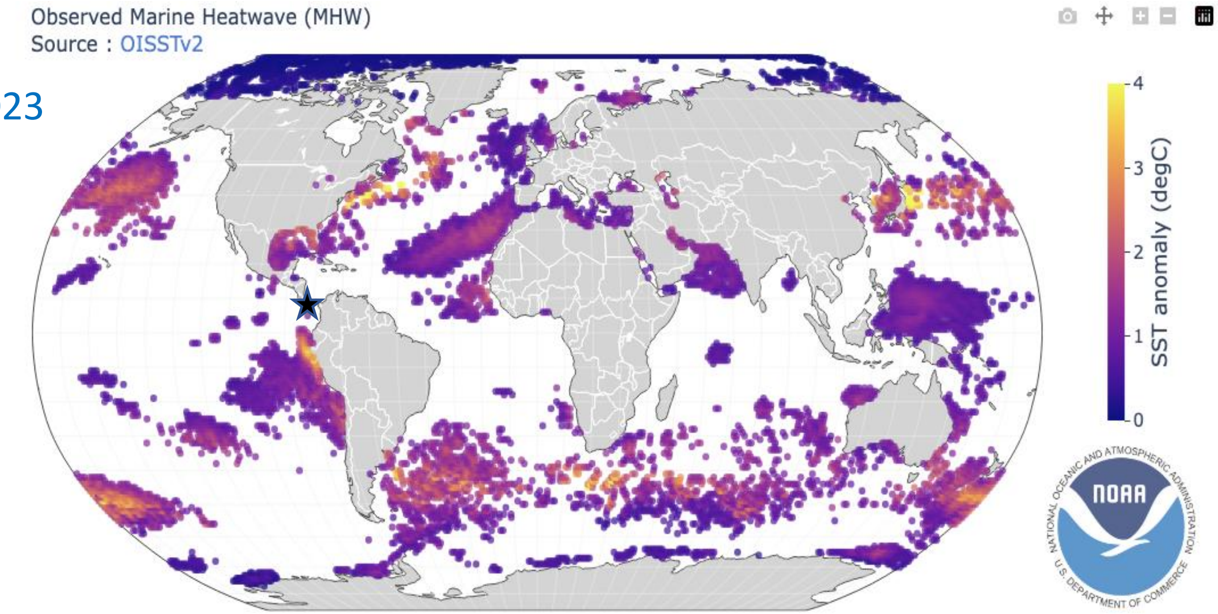


https://psl.noaa.gov/marine-heatwaves/

# Observed MHWs (monthly)

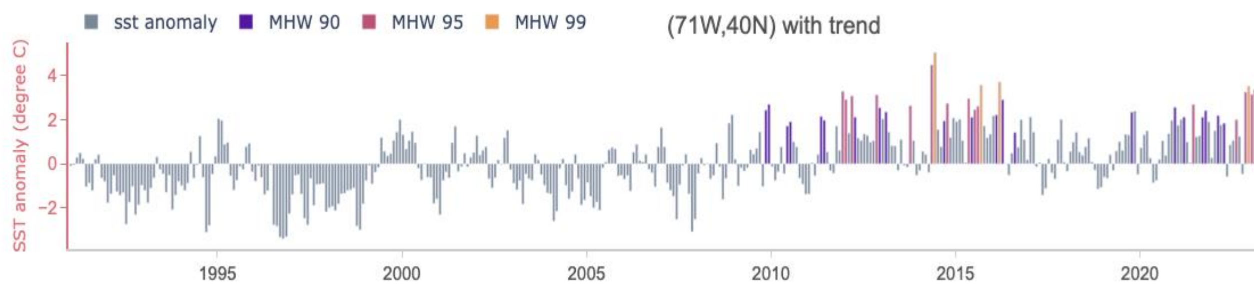
March 2023

90th %

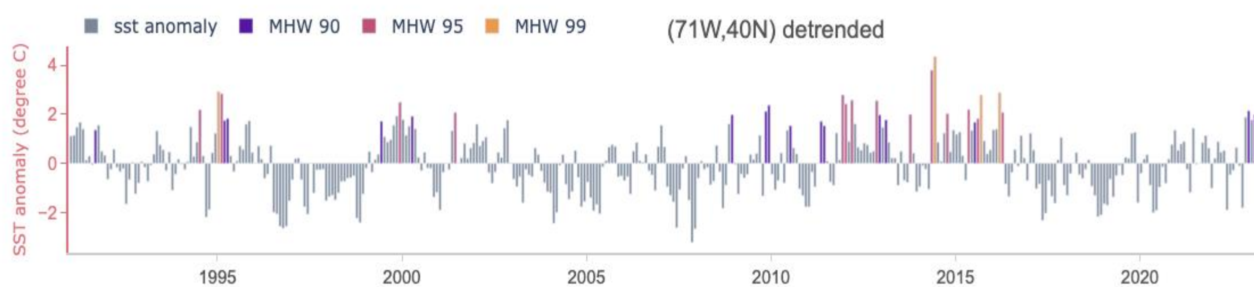


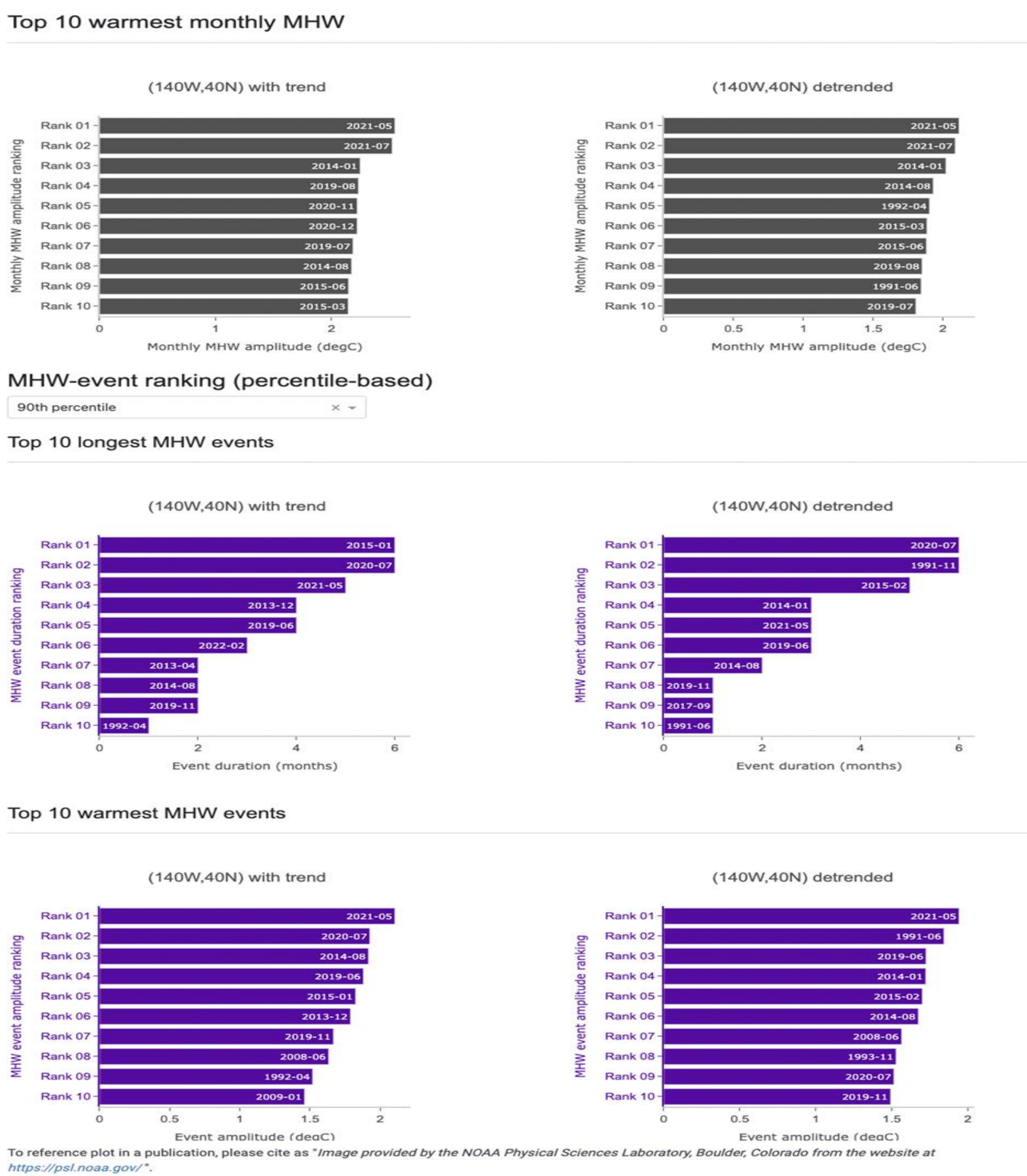

Point selected off
The NEUS coast

SST Anomaly



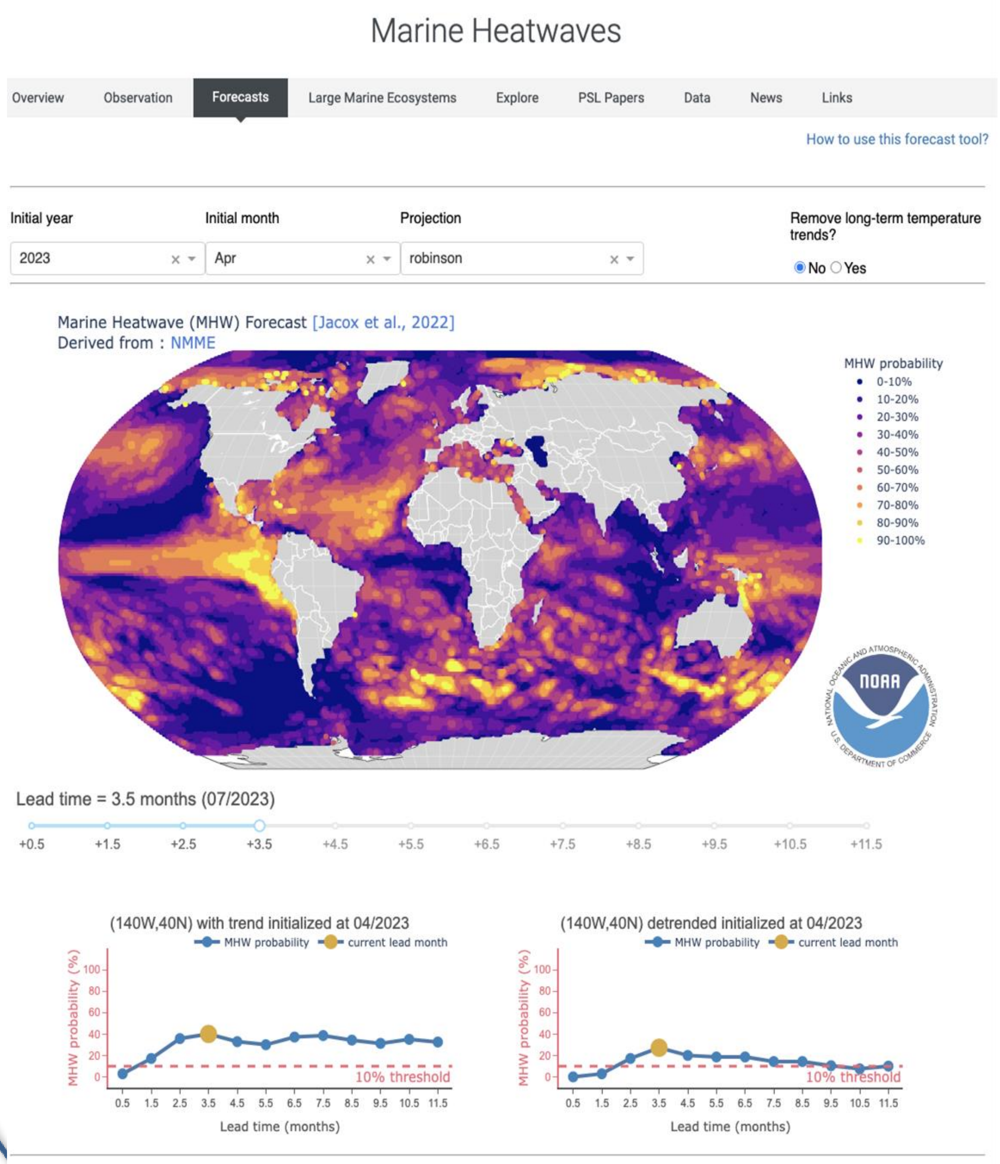

SST Anomaly Detrended



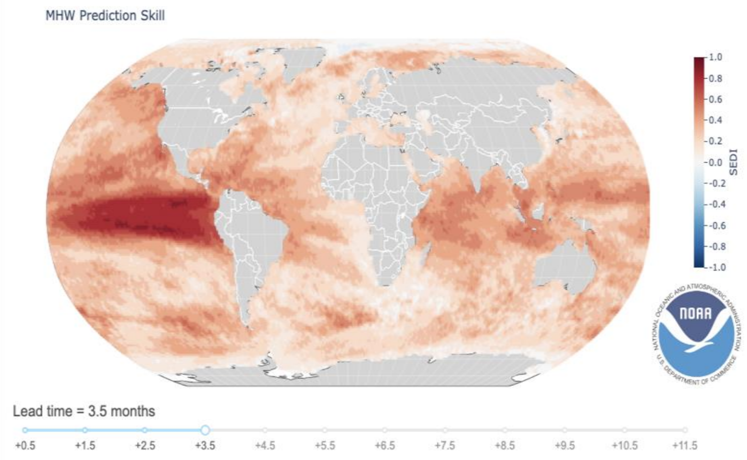



Monthly SST anomaly ranking (top 10) based on monthly value/MHW event

# NMME: MHW Seasonal Forecasts & Skills

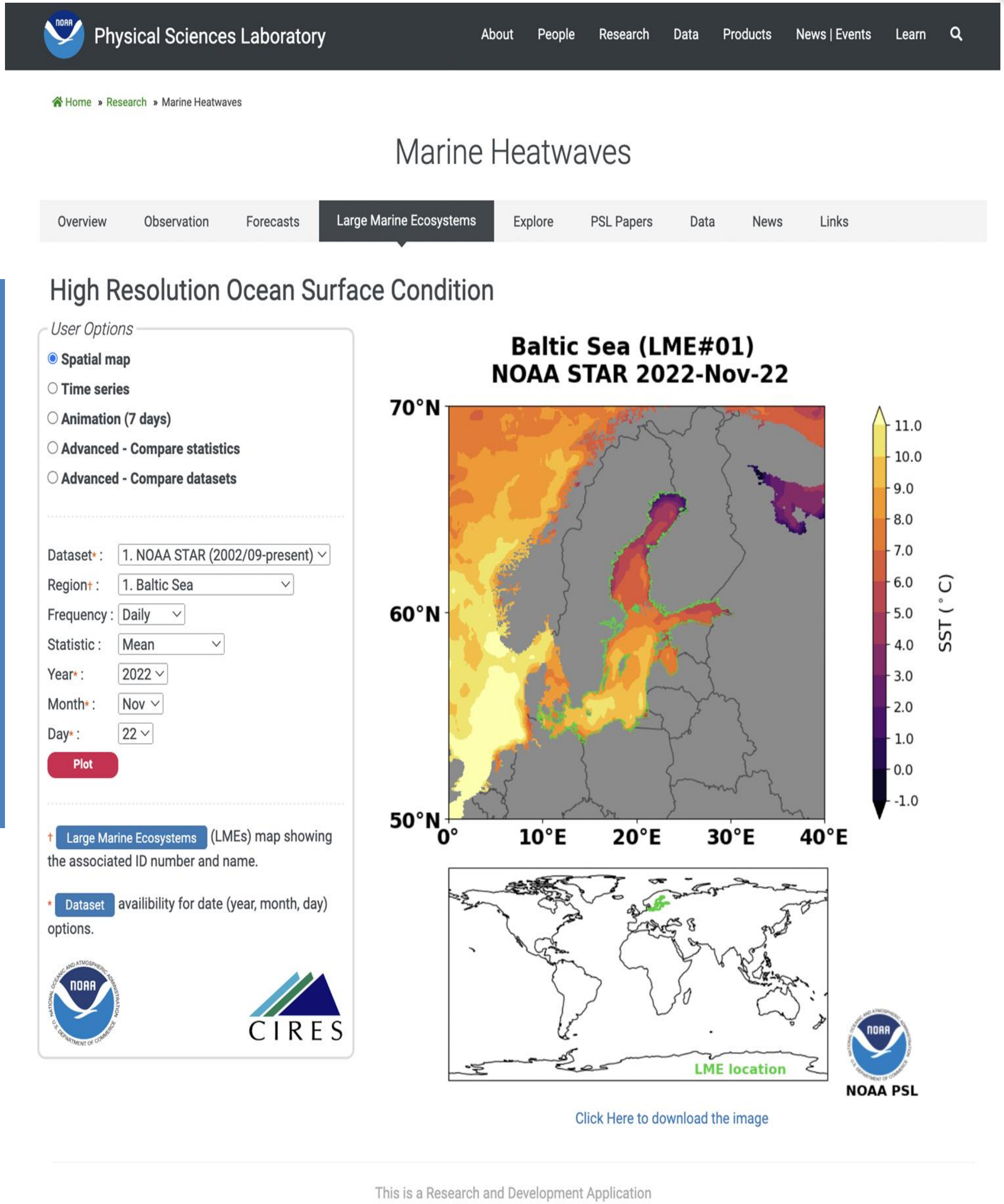



Prediction Skill (SEDI >0)




Jacox, et al. 2022: Global seasonal forecasts of marine heatwaves, Nature, 604, 486-490, doi:10.1038/s41586-022-04573-9

**High temporal and spatial SST observations over all 65 large marine ecosystems (LMEs) around the globe.**



# Resources & Suggestions

**Resources:**

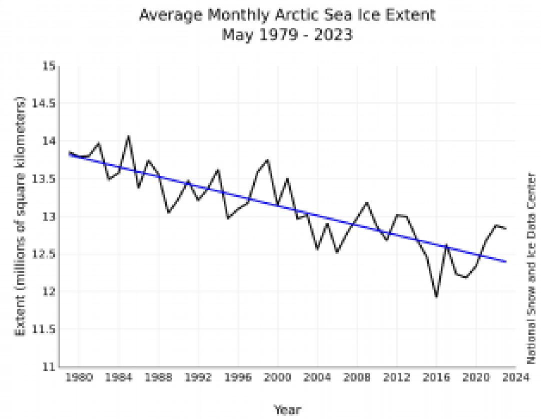
- Marine Heat wave Webpage: https://psl.noaa.gov/marine-heatwaves/

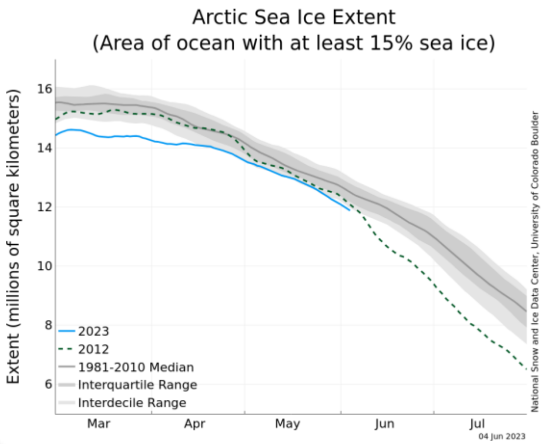
***Suggestions for improving & new web pages***

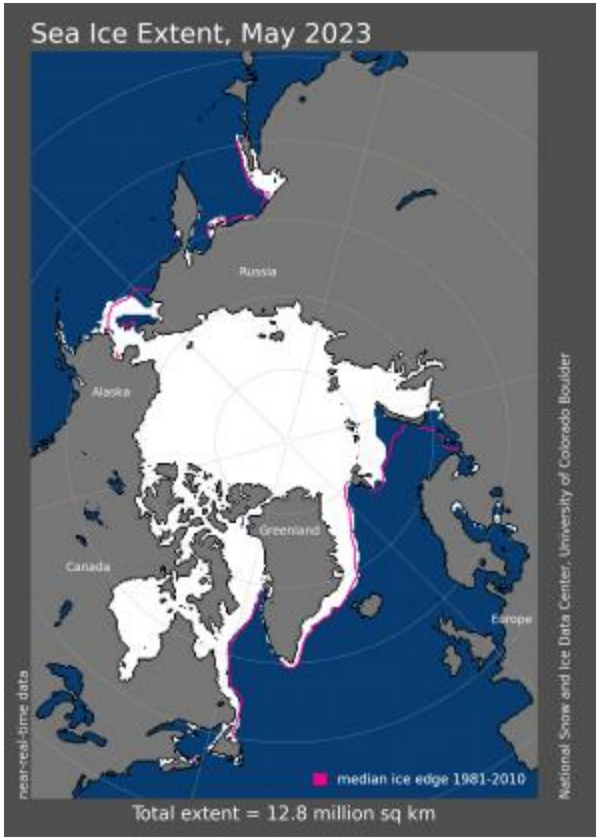
***Contacts:***

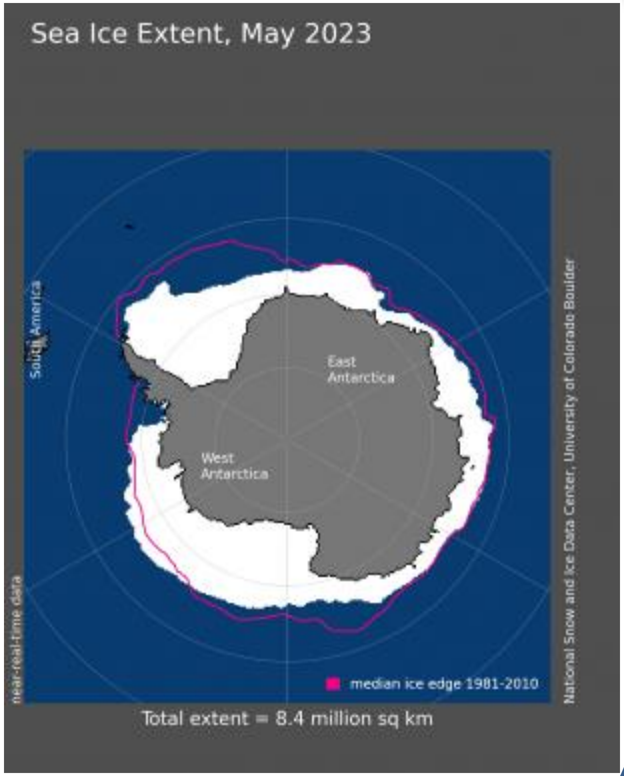
- Michael Alexander (michael.alexander@noaa.gov)
- Cathy Smith (cathy.smith@noaa.gov)
- Chia-Wei Hsu (chia-wei.hsu@noaa.gov)

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



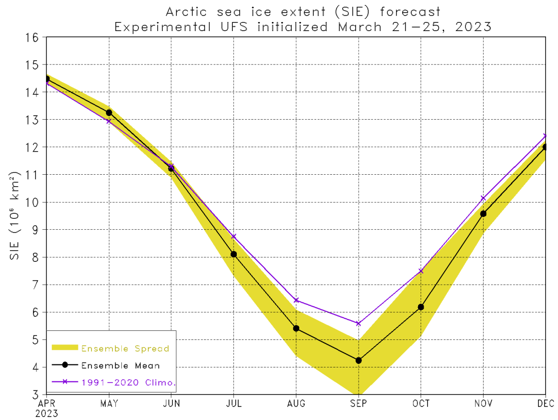



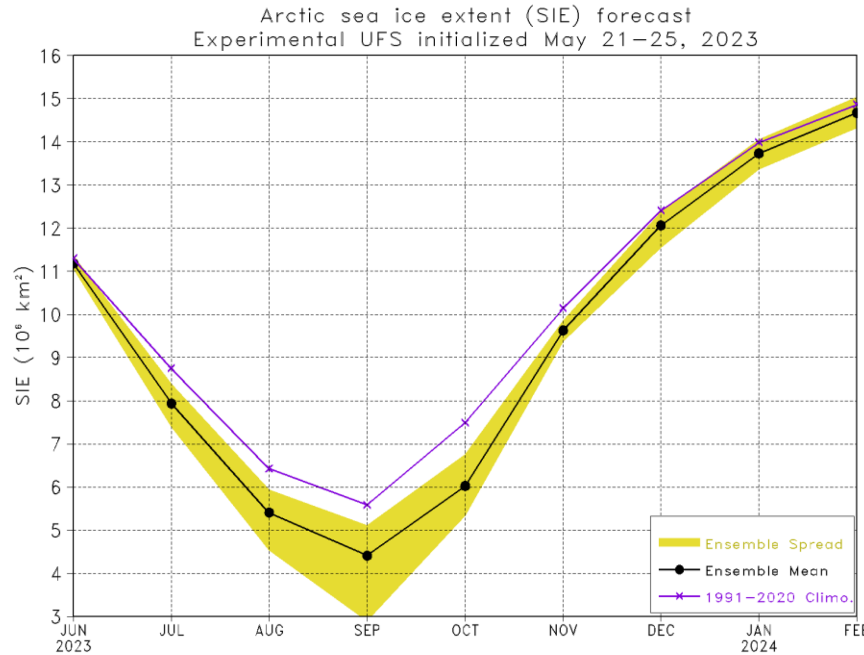



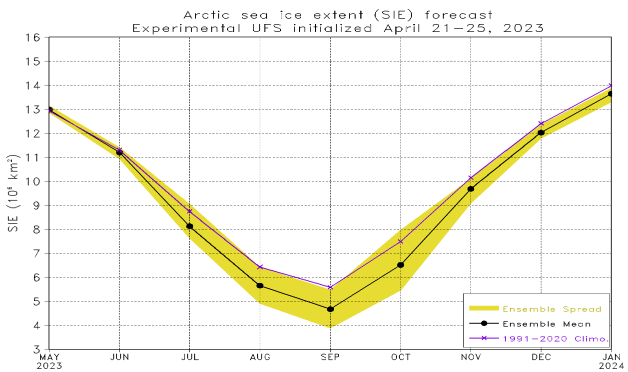

- Average Arctic sea ice extent during May 2023 was 12.83 million square kilometers, the 13th lowest May in the satellite record.
- Based on the linear trend, May has lost 1.42 million square kilometers of ice since 1979. This is roughly equivalent to four times the size of Germany.
- Antarctic sea ice extent is at record low levels as assessed over the satellite record since 1978.

# Seasonal sea ice forecast with UFS

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



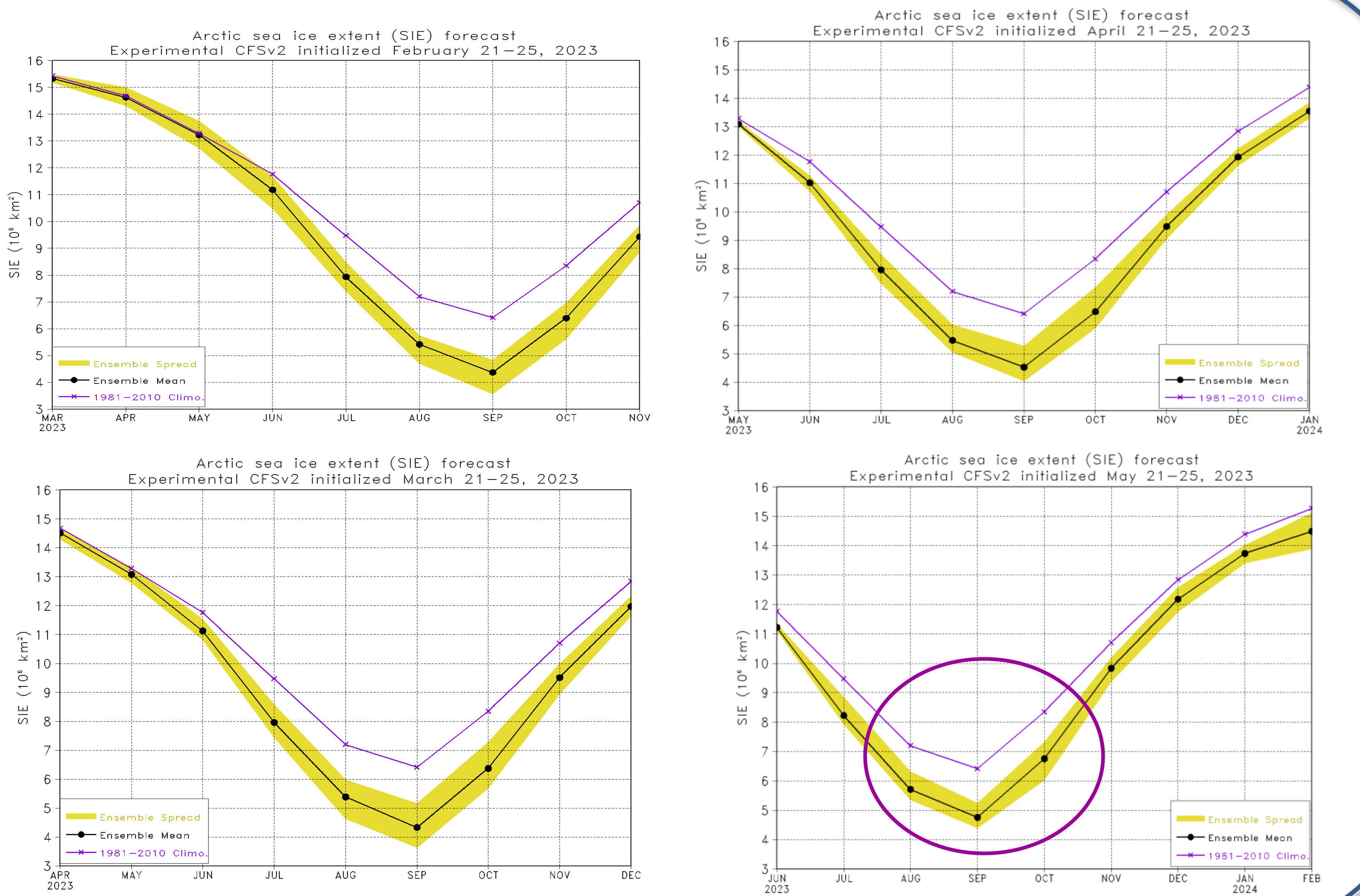




UFS forecasts suggested that the Sep sea ice extent will be below the 1991-2020 climatology.

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

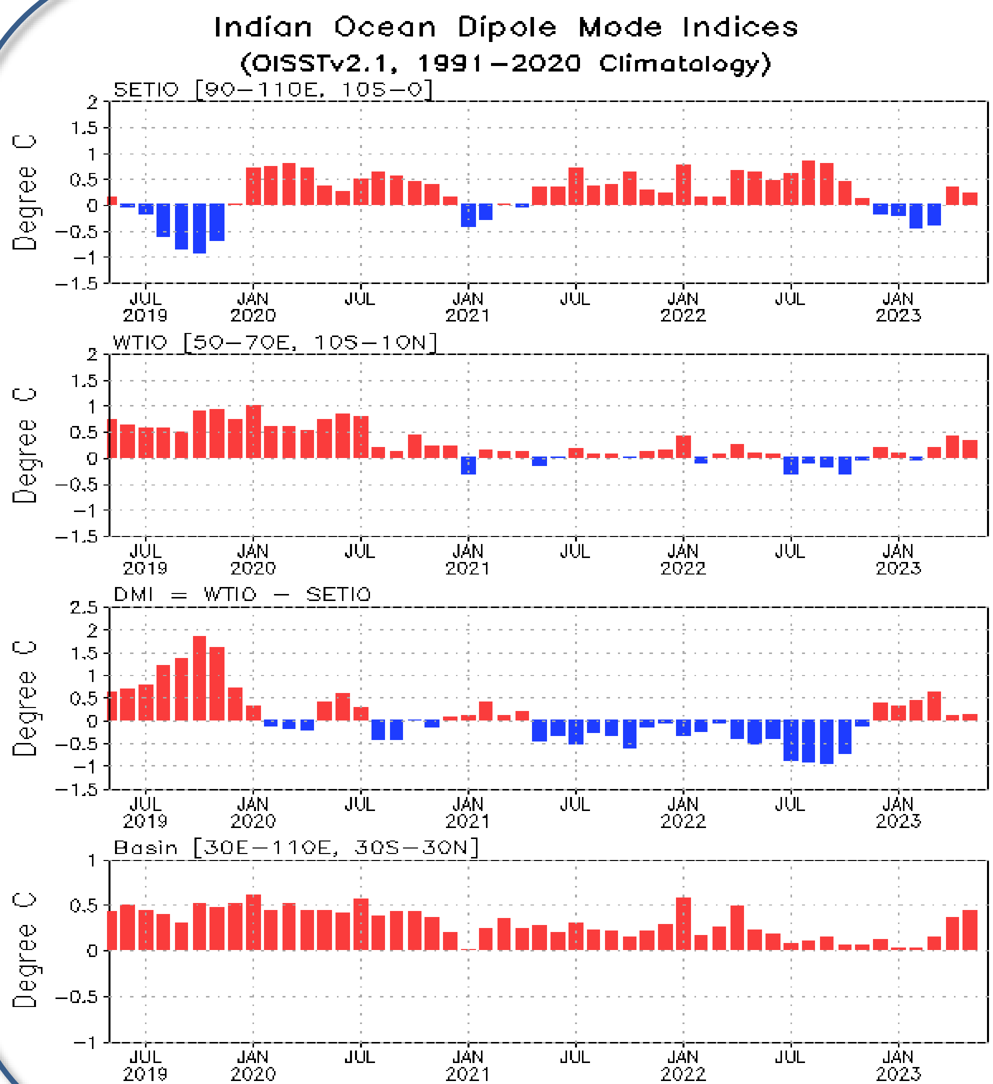
# NCEP/CPC Arctic Sea Ice Extent Forecast

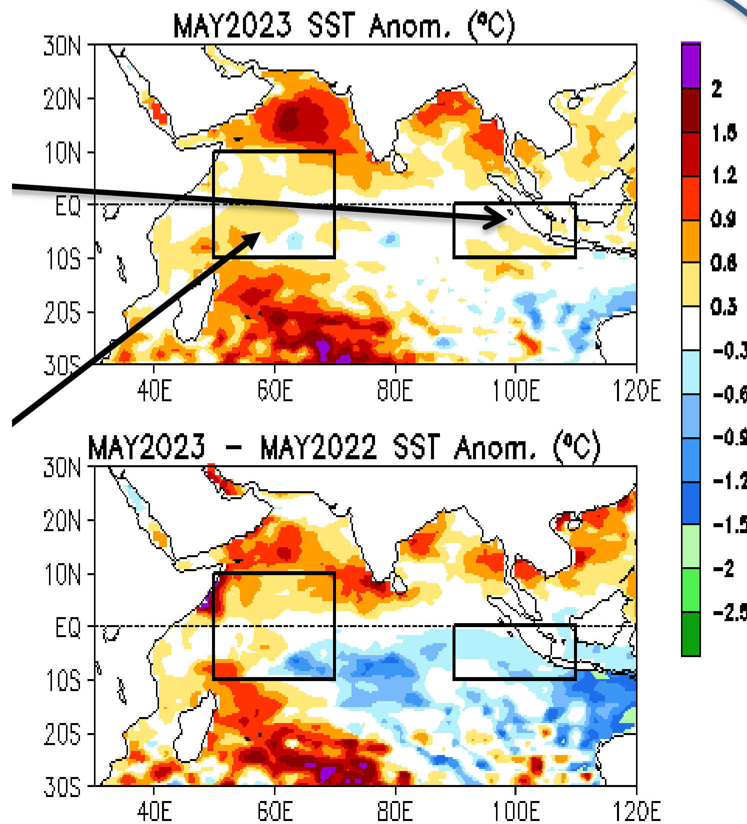



https://www.cpc.ncep.noaa.gov/products/people/wwang/seaice_seasonal/index.html

# Indian Ocean

# Evolution of Indian Ocean SST Indices



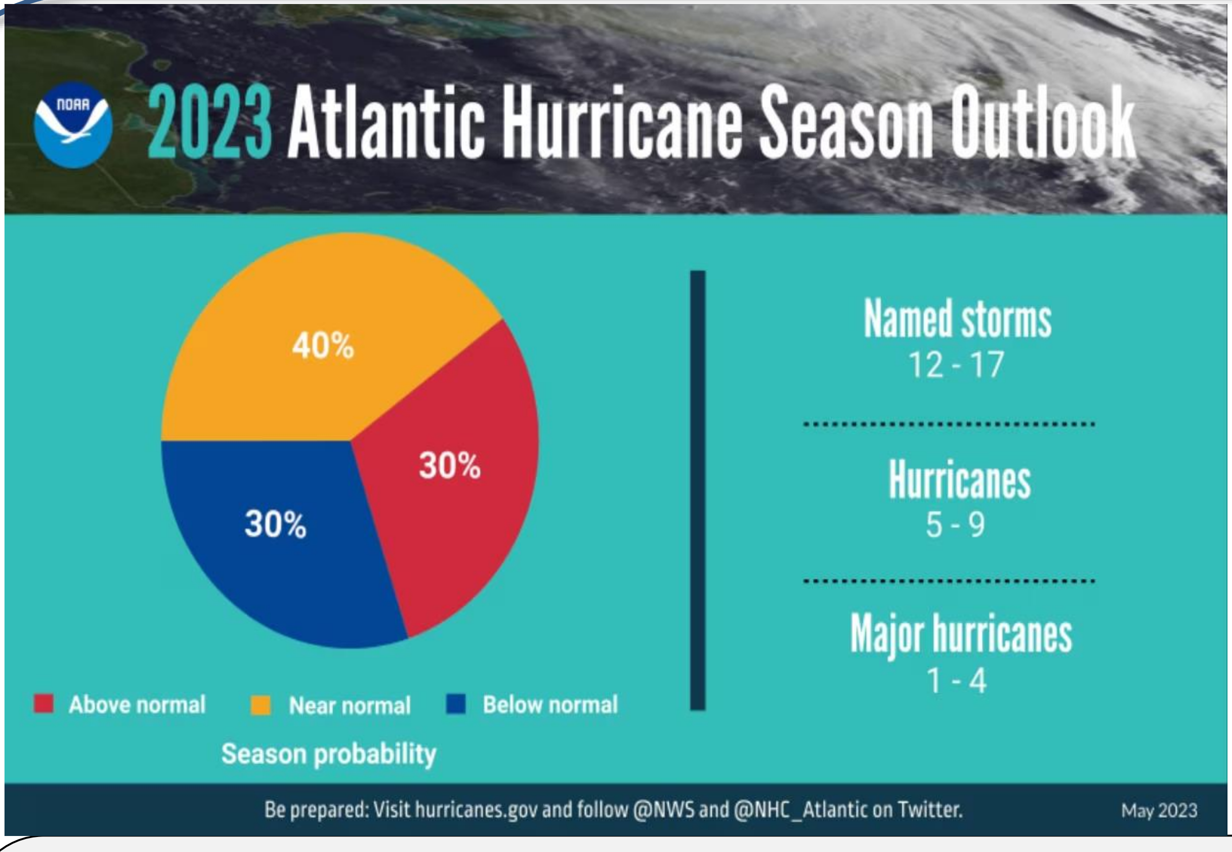




- Positive SSTAs were present in the tropical Indian Ocean in May 2023.

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

# 2023 Atlantic Hurricane Season Outlook



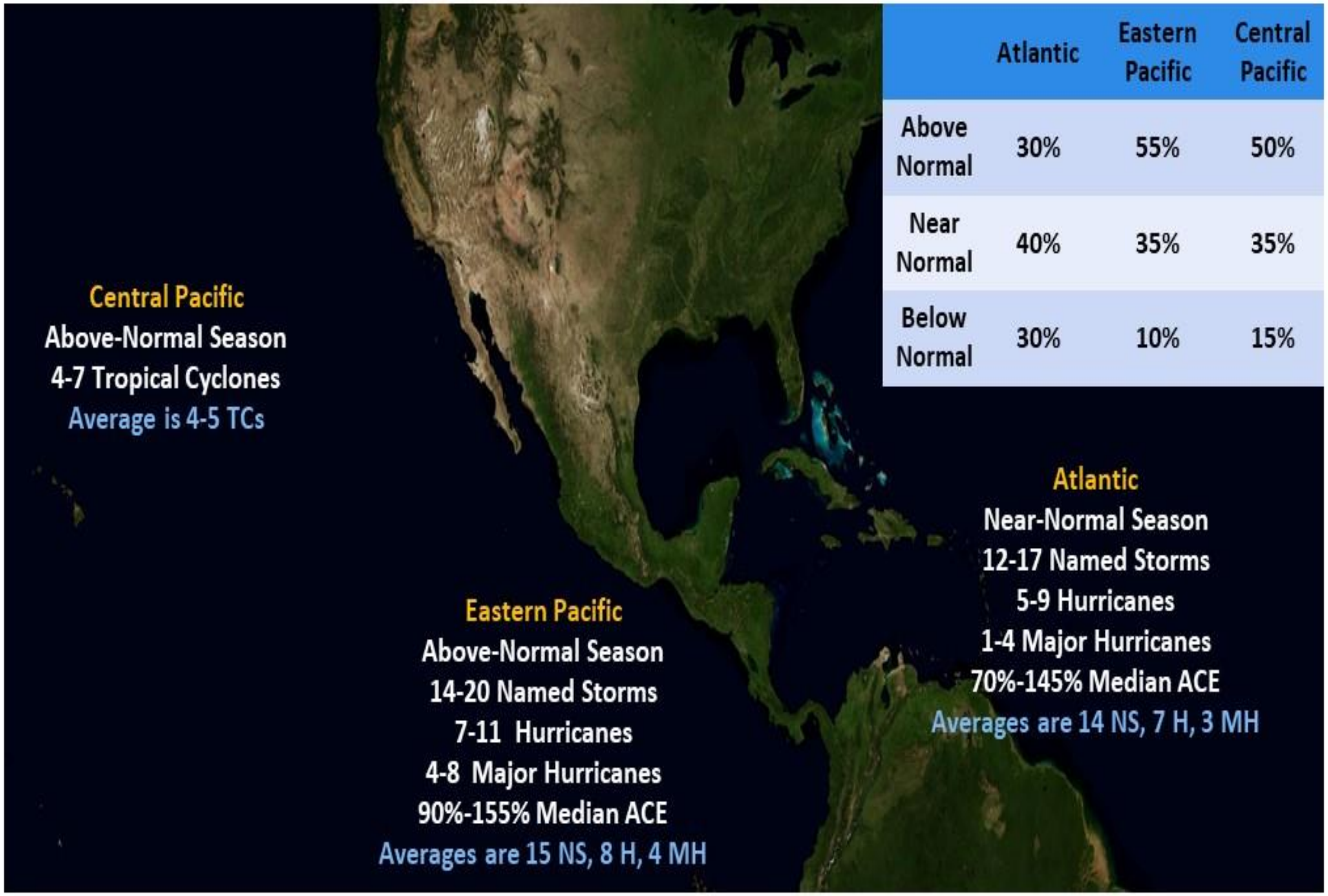

- May 25, 2023: NOAA CPC forecast a range of 12 to 17 total named storms. Of those, 5 to 9 could become hurricanes, including 1 to 4 major hurricanes (category 3, 4 or 5). NOAA has a 70% confidence in these ranges.

"…. NOAA scientists predict a high potential for El Nino to develop this summer, which can suppress Atlantic hurricane activity. El Nino's potential influence on storm development could be offset by favorable conditions local to the tropical Atlantic Basin. Those conditions include the potential for an above-normal west African monsoon, which produces African easterly waves and seeds some of the stronger and longer-lived Atlantic storms, and warmer-than-normal sea surface temperatures in the tropical Atlantic Ocean and Caribbean Sea which creates more energy to fuel storm development. These factors are part of the longer term variability in Atlantic atmospheric and oceanic conditions that are conducive to hurricane development — known as the high-activity era for Atlantic hurricanes — which have been producing more active Atlantic hurricane seasons since 1995. …."*(https://www.noaa.gov/news-release/2023-atlantic-hurricane-season-outlook)*

# 2023 Hurricane Season Outlook

## NOAA's 2023 Hurricane Season Outlooks

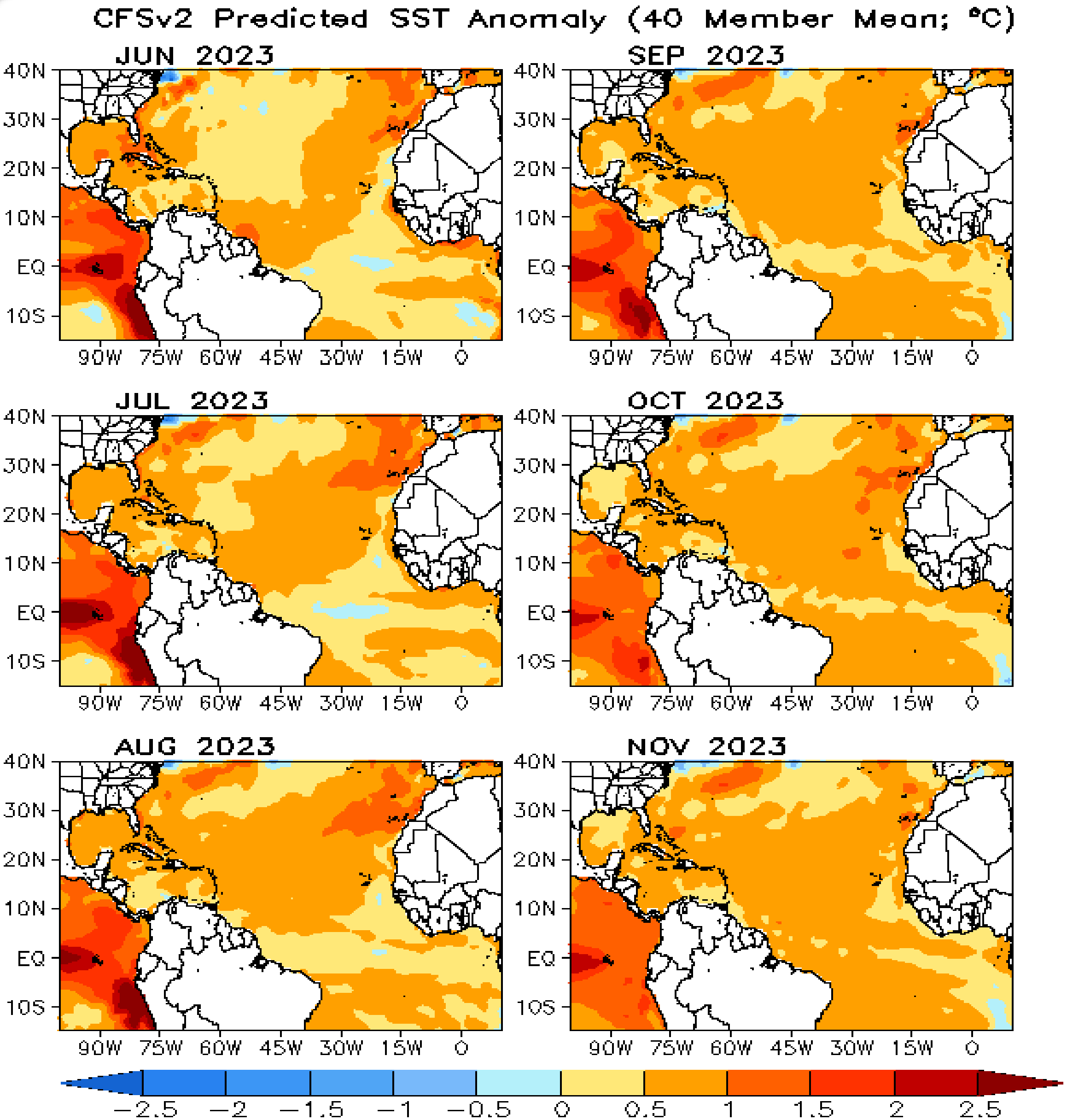
| | Atlantic | Eastern Pacific | Central Pacific |
|---|---|---|---|
| Above Normal | 30% | 55% | 50% |
| Near Normal | 40% | 35% | 35% |
| Below Normal | 30% | 10% | 15% |




For the Atlantic hurricane region, the outlooks indicate a 40% chance of a near-normal season, a 30% chance of an above-normal season, and a 30% chance of an below-normal season.

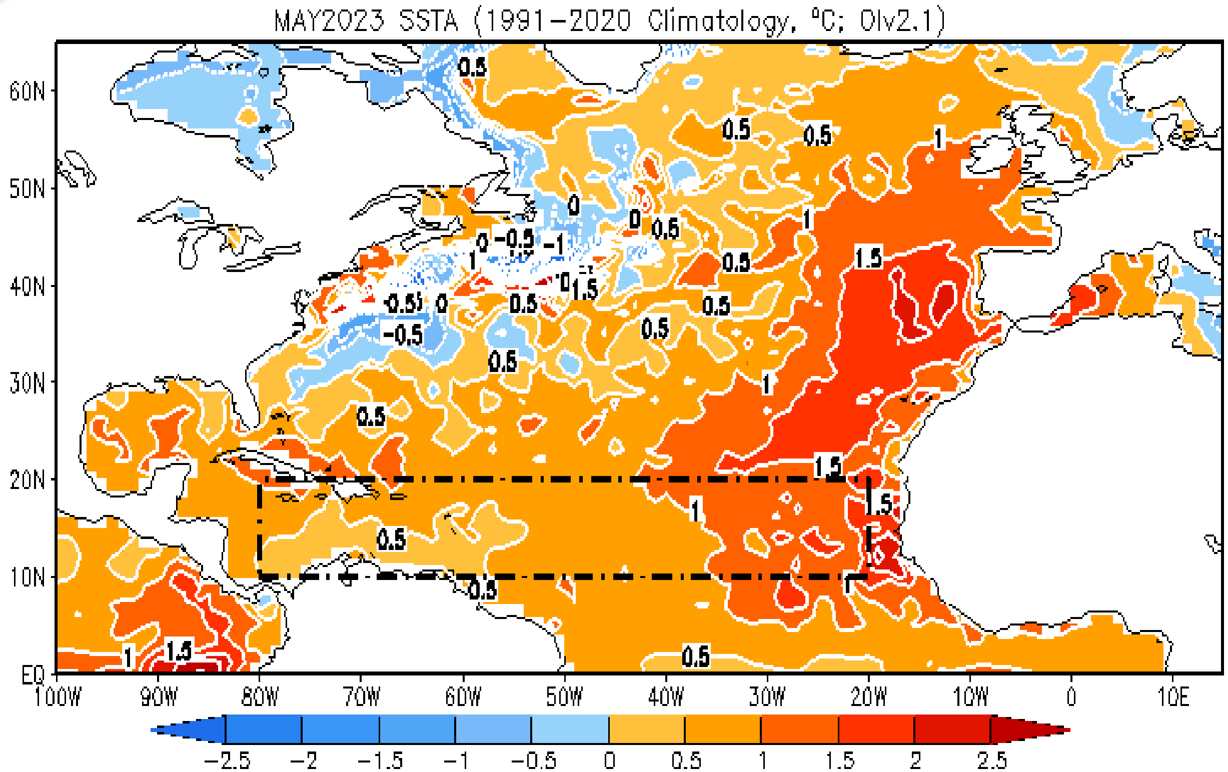
These outlooks are for the overall seasonal activity. They are not a hurricane landfall forecast.

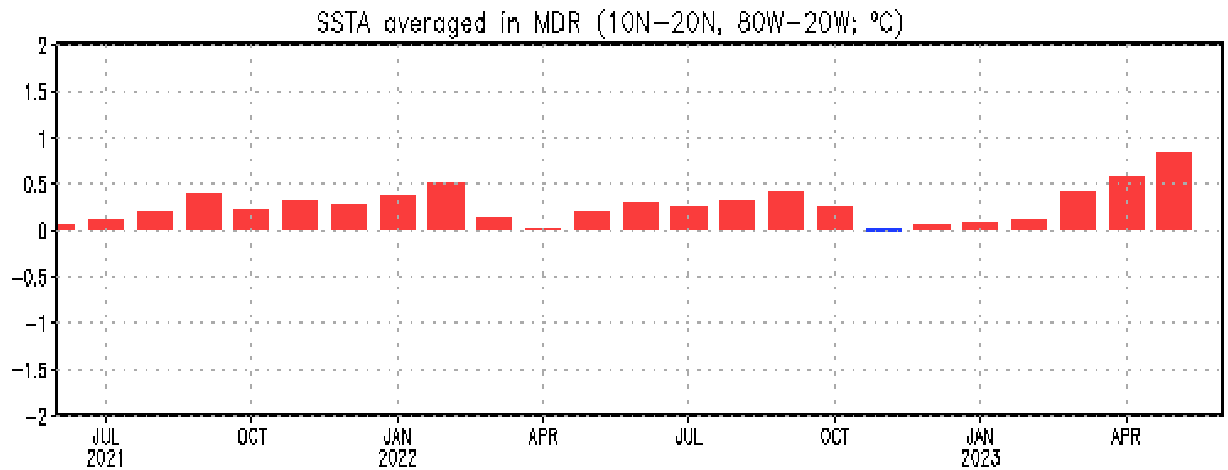
# CFSv2 Atlantic SSTA Predictions




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

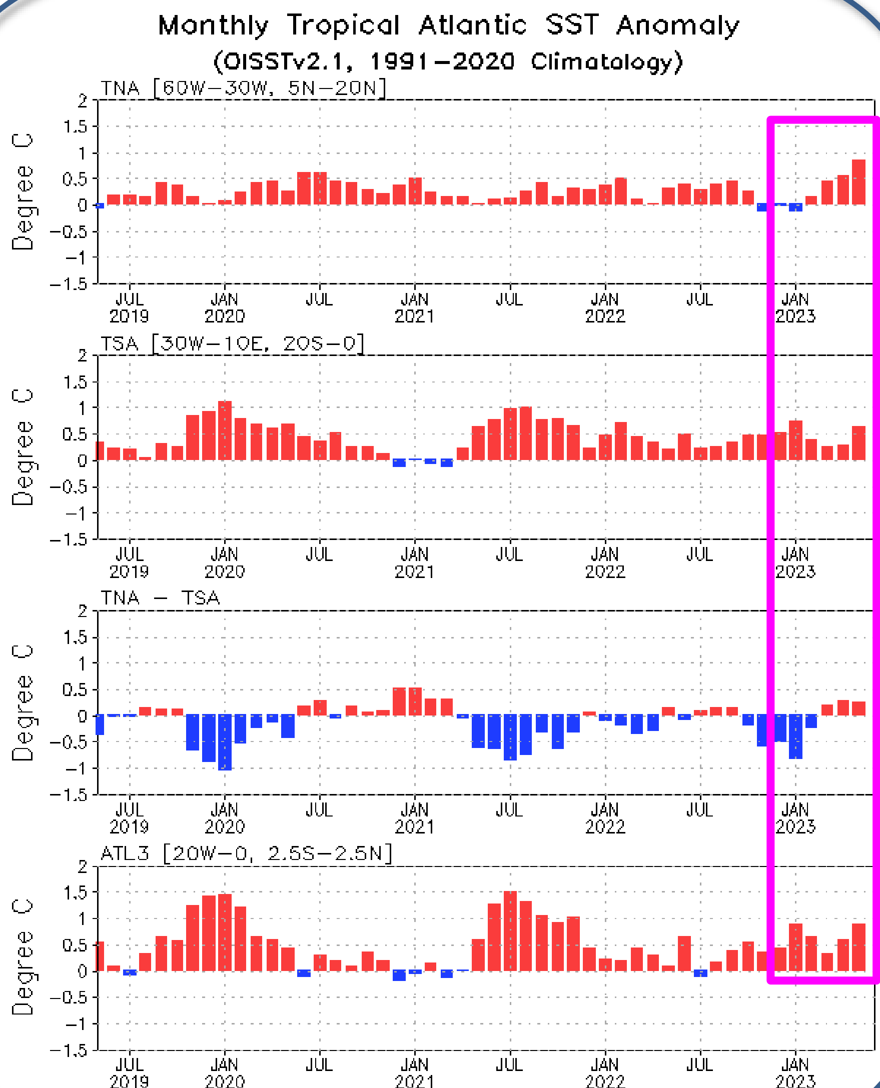
# SSTAs in the North Atlantic & MDR

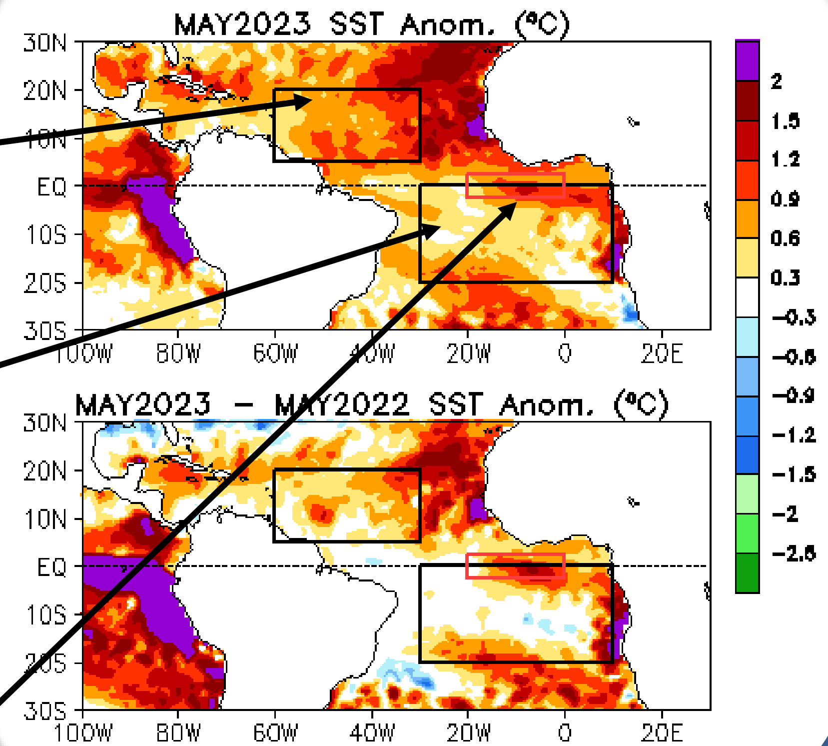



- SST in MDR was above average in May 2023.

# Evolution of Tropical Atlantic SST Indices

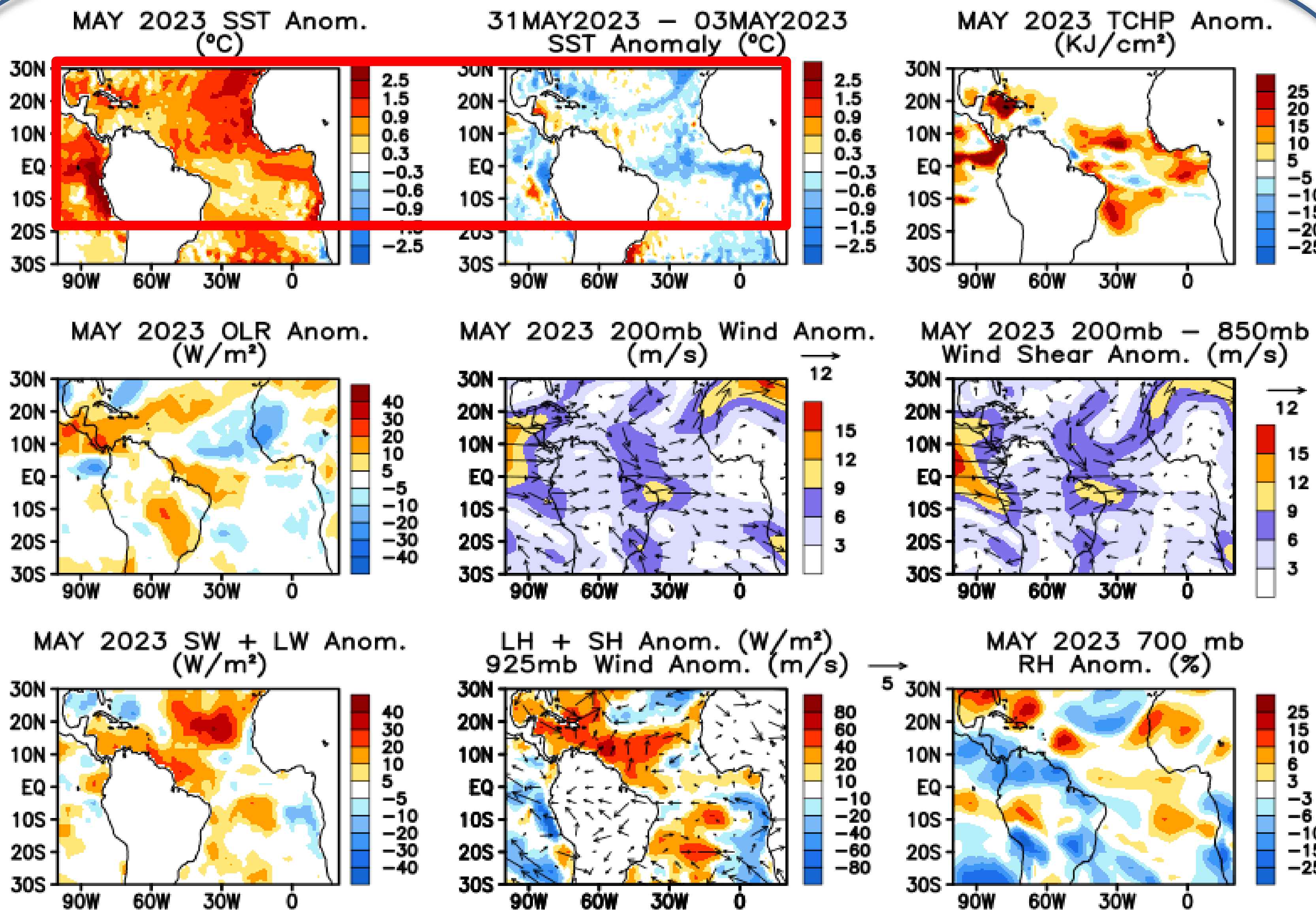


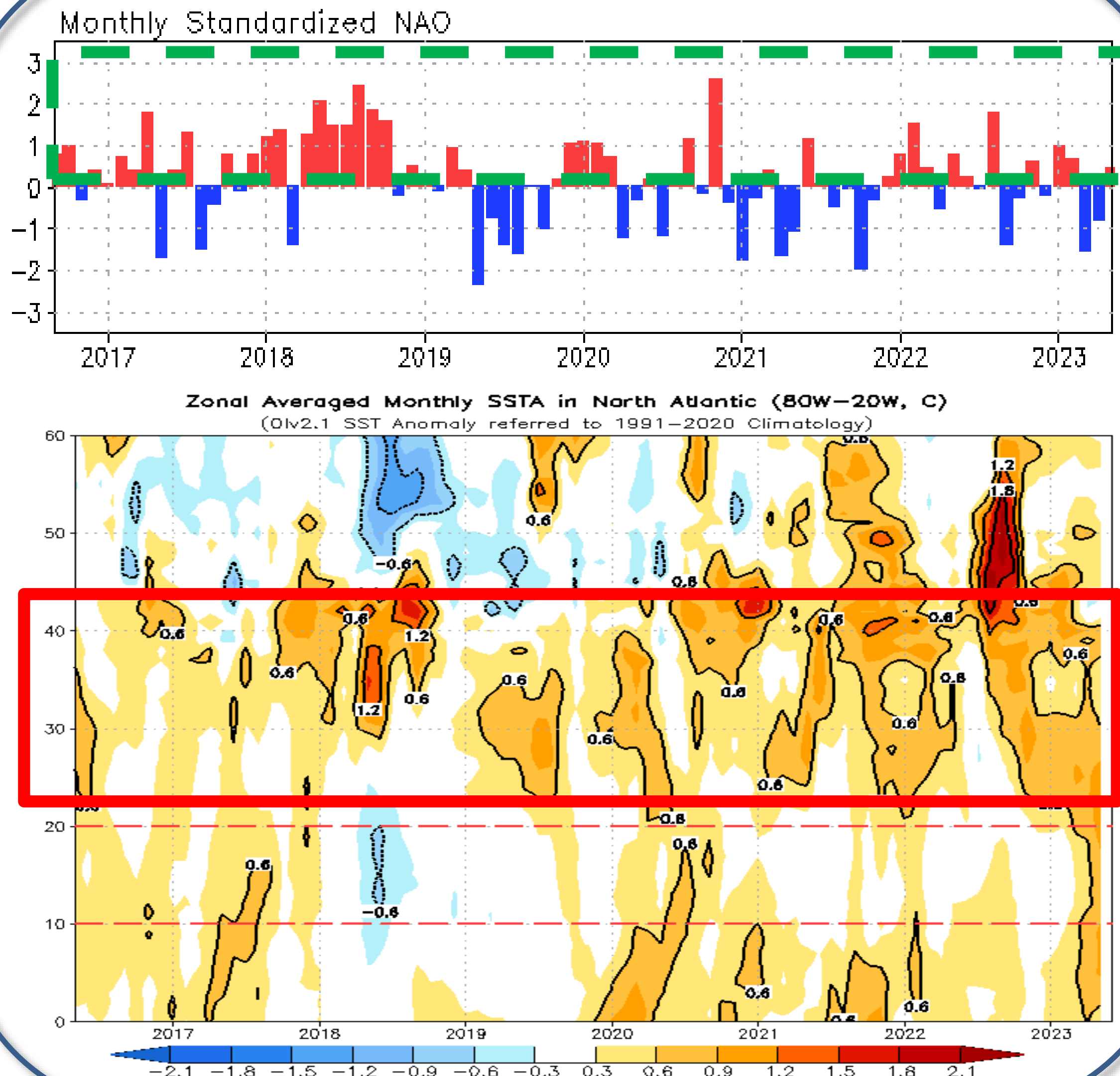

- Positive SSTAs were observed in the tropical South and North Atlantic with strong warming in the eastern North Atlantic.
- Positive ATL3 index increased in May 2023.

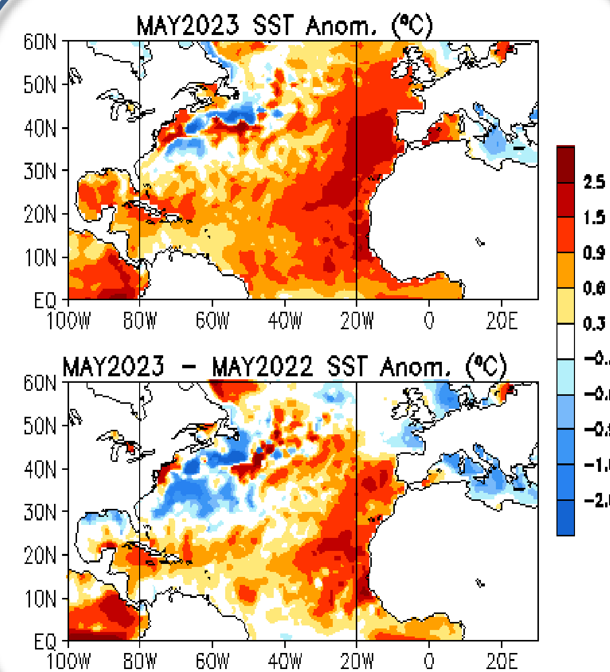
Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean SSTAs ($^{O}$C) for the TNA [60$^{O}$W-30$^{O}$W, 5ºN-20$^{O}$N], TSA [30$^{O}$W-10$^{O}$E, 20$^{O}$S-0] and ATL3 [20$^{O}$W-0, 2.5$^{O}$S-2.5$^{O}$N] regions, and Meridional Gradient Index, defined as differences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

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



# NAO and SST Anomaly in North Atlantic



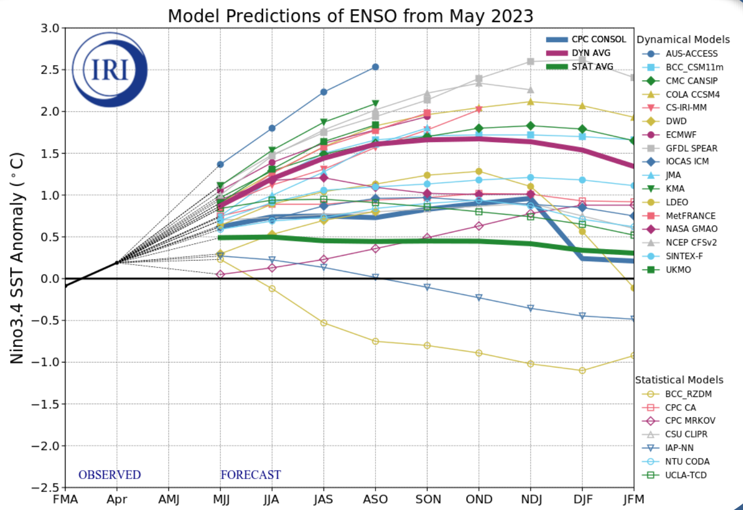



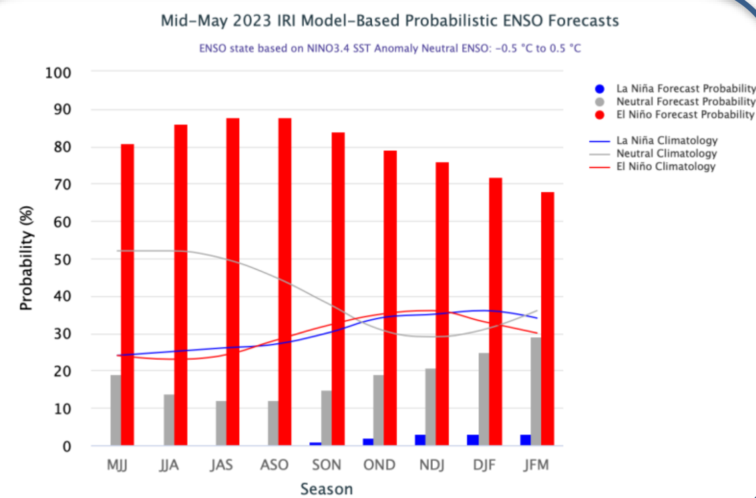

- NAO switched to a positive phase with NAOI= 0.4 in May 2023.
- Strong warming was in the eastern North Atlantic
- The prolonged positive SSTAs in the middle latitudes were evident, due to dominance of the positive phase of NAO during the last 5-6 years.

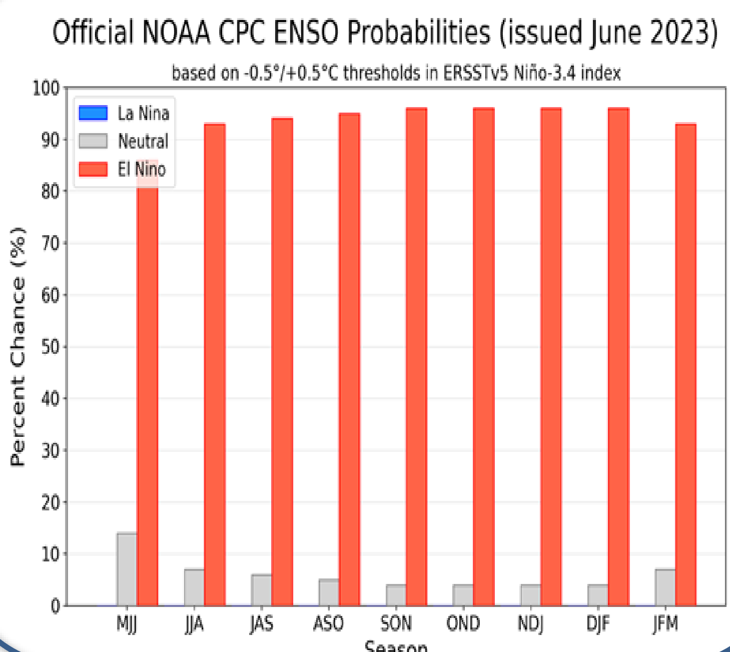
Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20$^{O}$N-90$^{O}$N. Time-latitude section of SSTAs averaged between 80ºW and 20ºW (bottom). SST are derived from the OIv2.1 SST analysis, and anomalies are departures from the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

# ENSO and Global SST Predictions

# IRI/CPC Niño3.4 Forecast



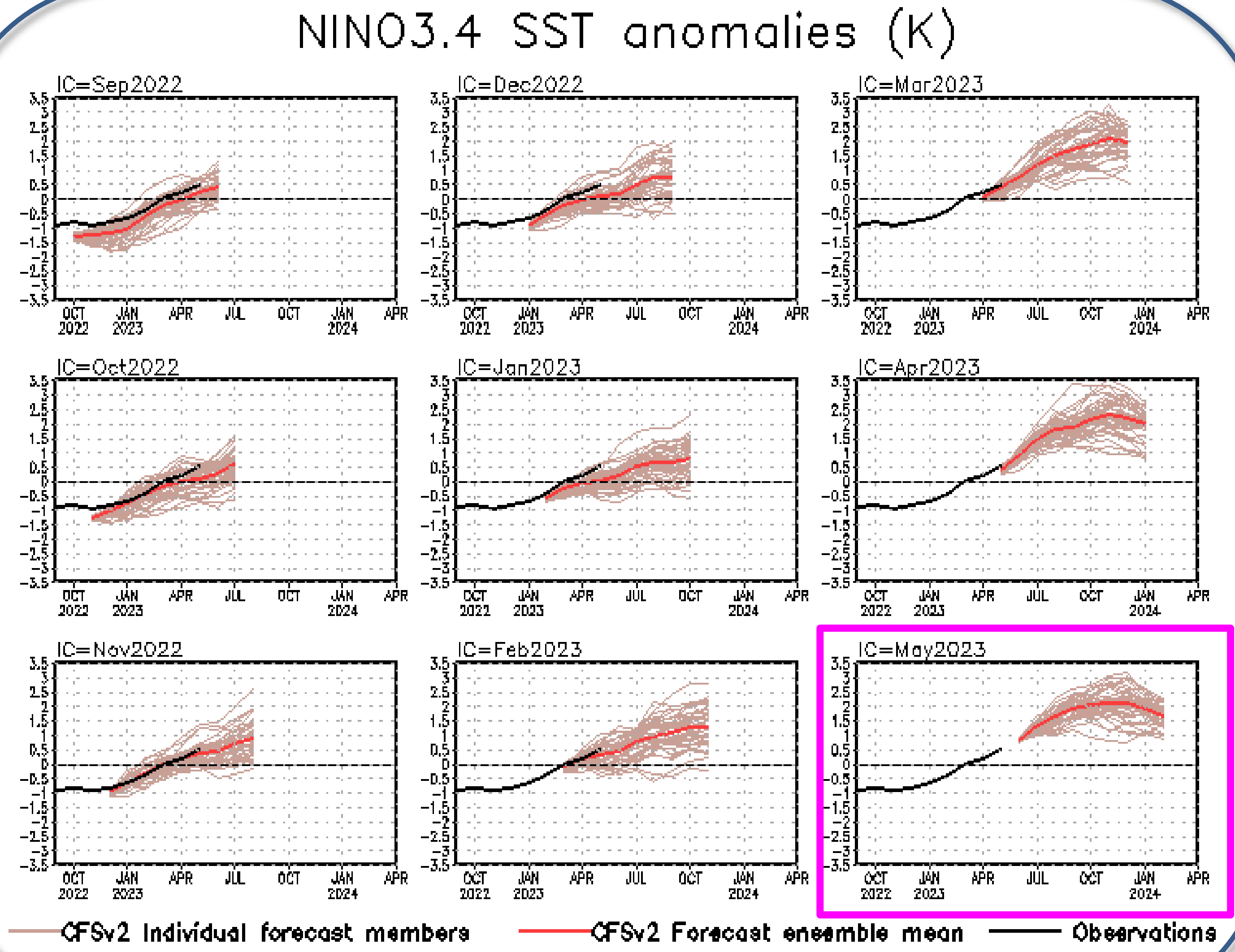




**- ENSO Alert System Status issued on 8 June 2023: El Niño Advisory**

- Synopsis: *"El Niño conditions are present and are expected to gradually strengthen into the Northern Hemisphere winter 2023-24."*

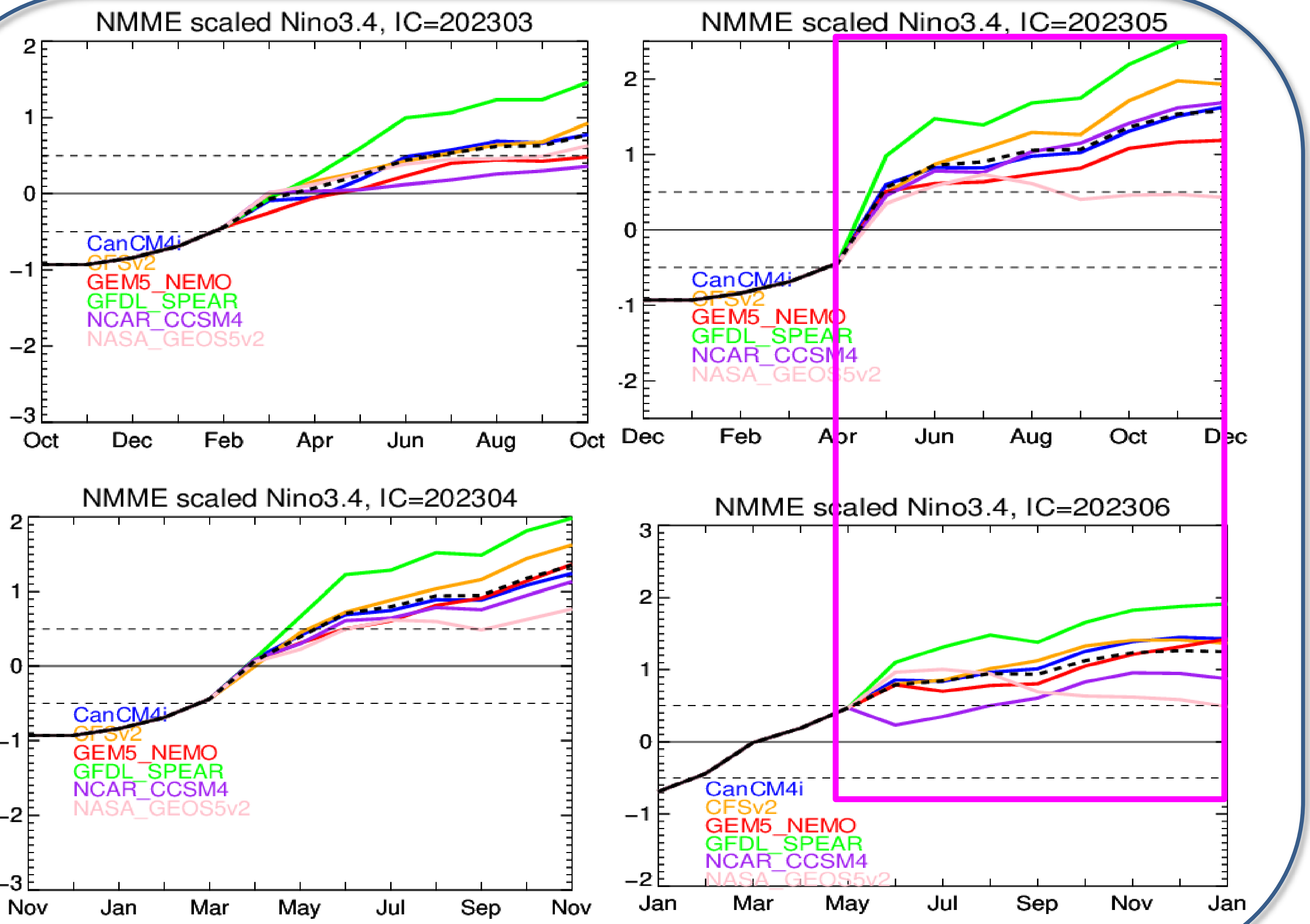
# CFS Niño3.4 SST Predictions from Different Initial Months




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

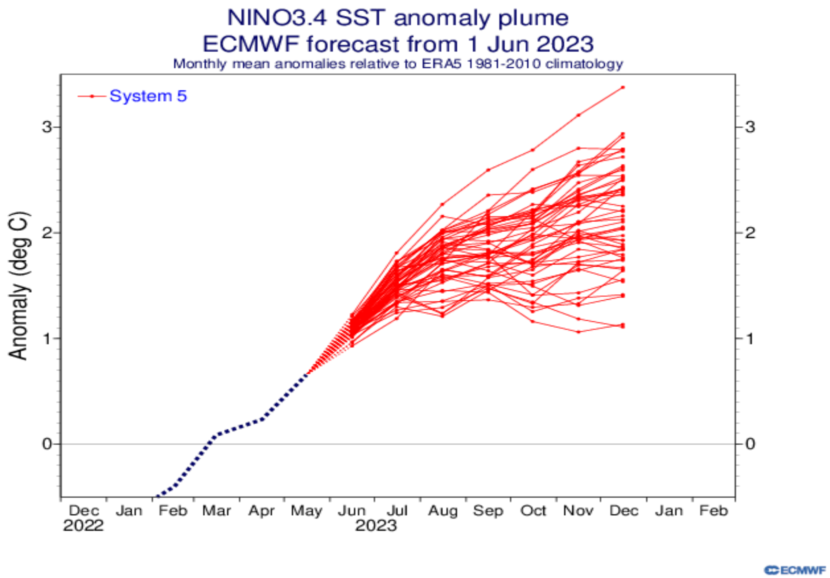
CFS Niño3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect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

# NMME forecasts from different initial conditions

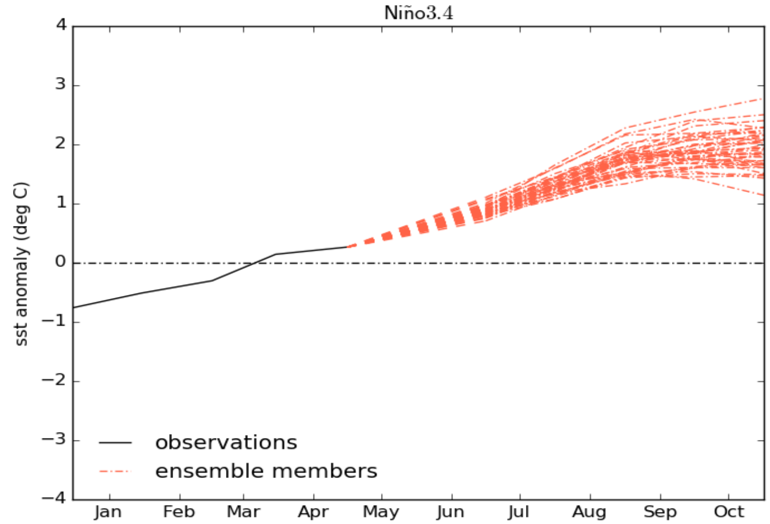


# Individual Model Forecasts: A strong El Niño in 2023

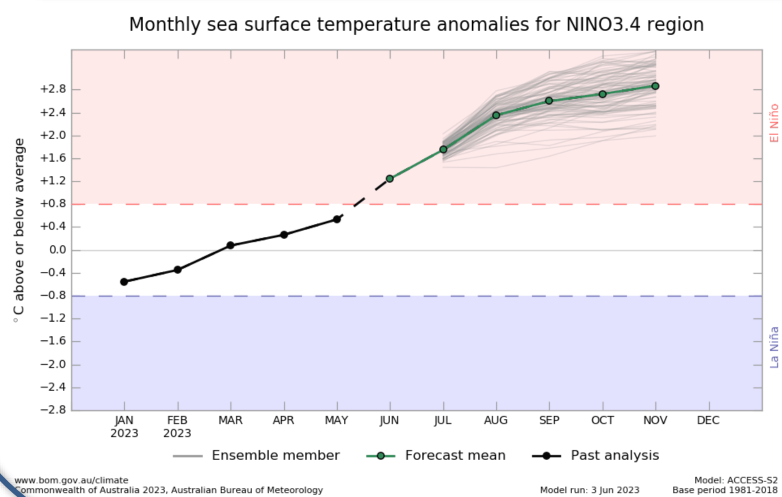
## EC: Niño3.4, IC= 1 June 2023



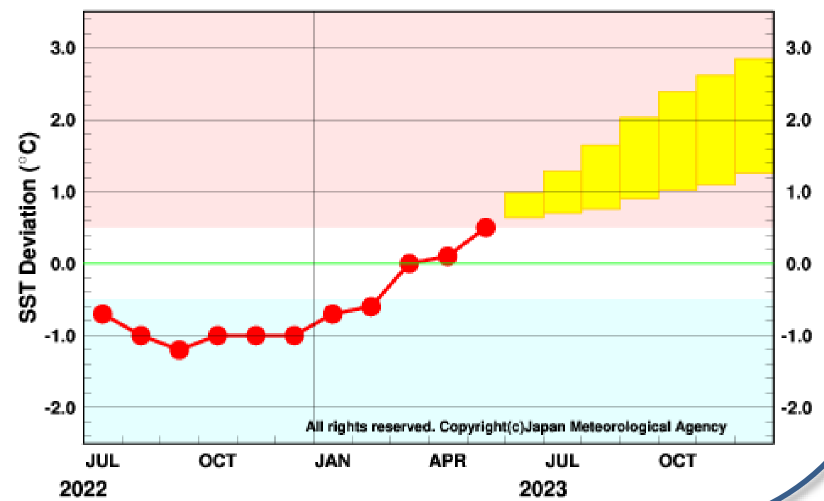

## UKMO: Niño3.4, Updated 11 May 2023



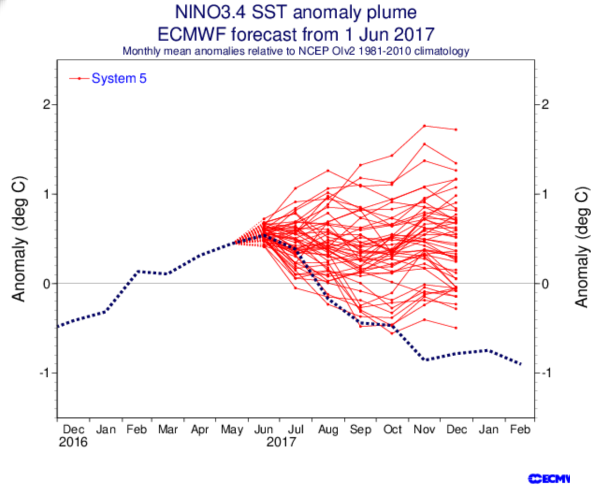

## BOM: Niño3.4, Updated 3 June 2023

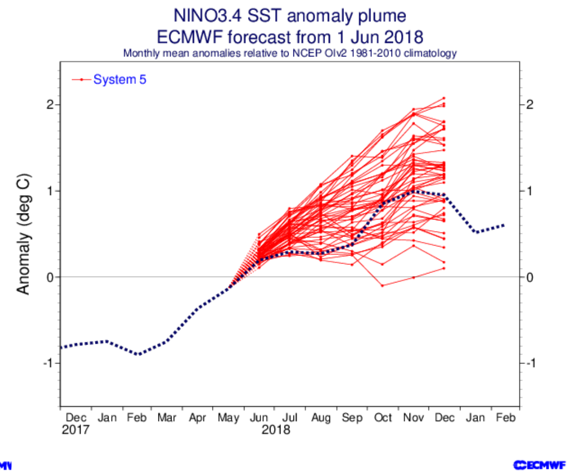


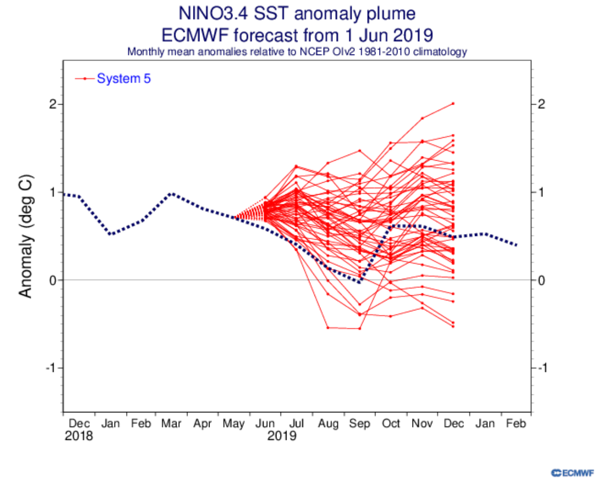

## JMA: Niño3.4, Updated 9 June 2023

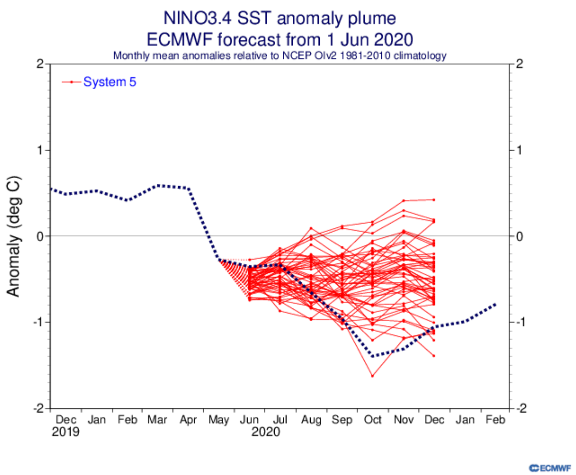


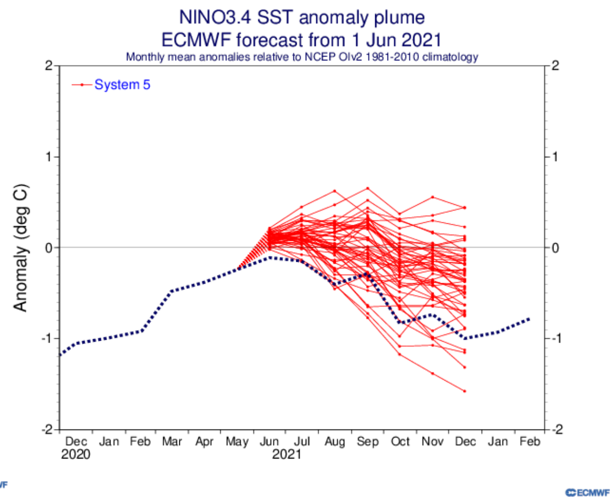
# ECMWF Forecasts: warm bias in June IC runs since 2017

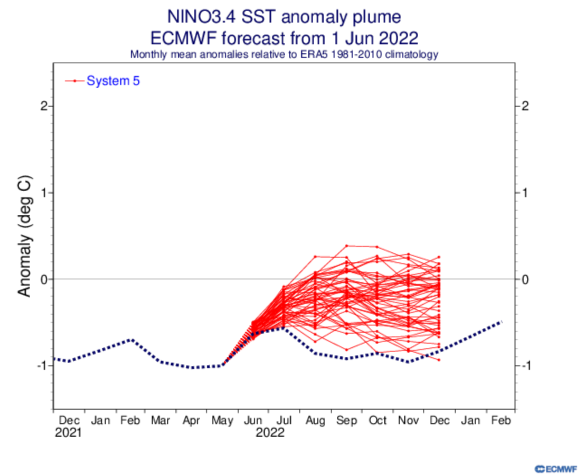


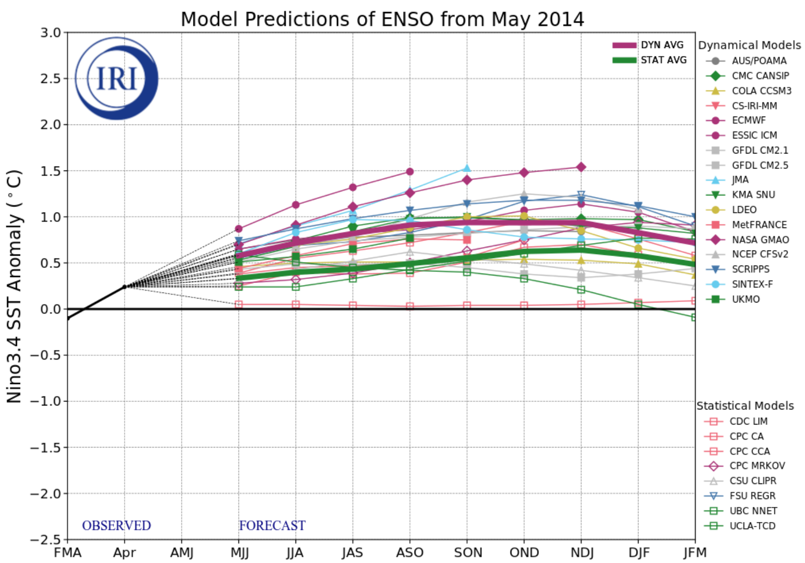



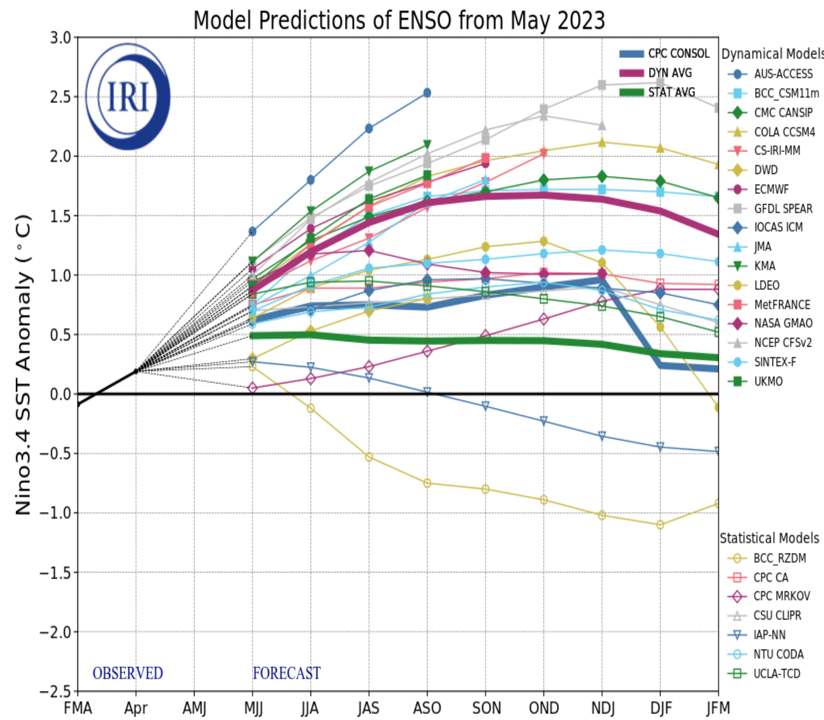



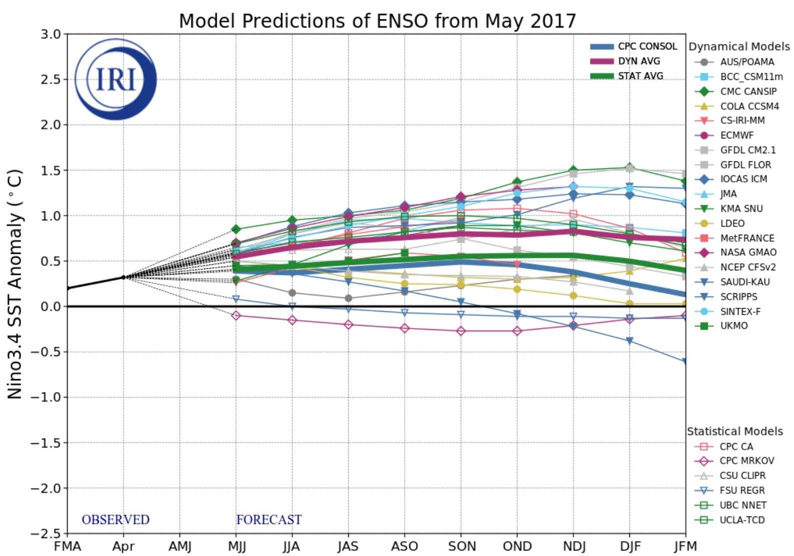



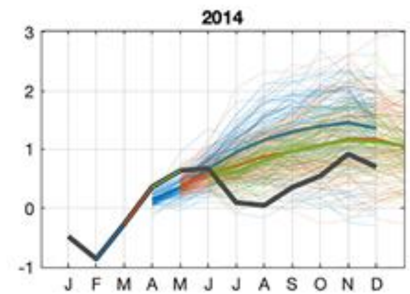



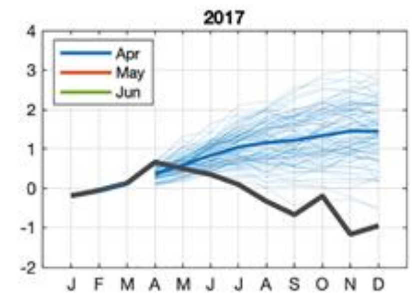
# 2023 ENSO Forecast, 2014 & 2017 El Niño False Alarm



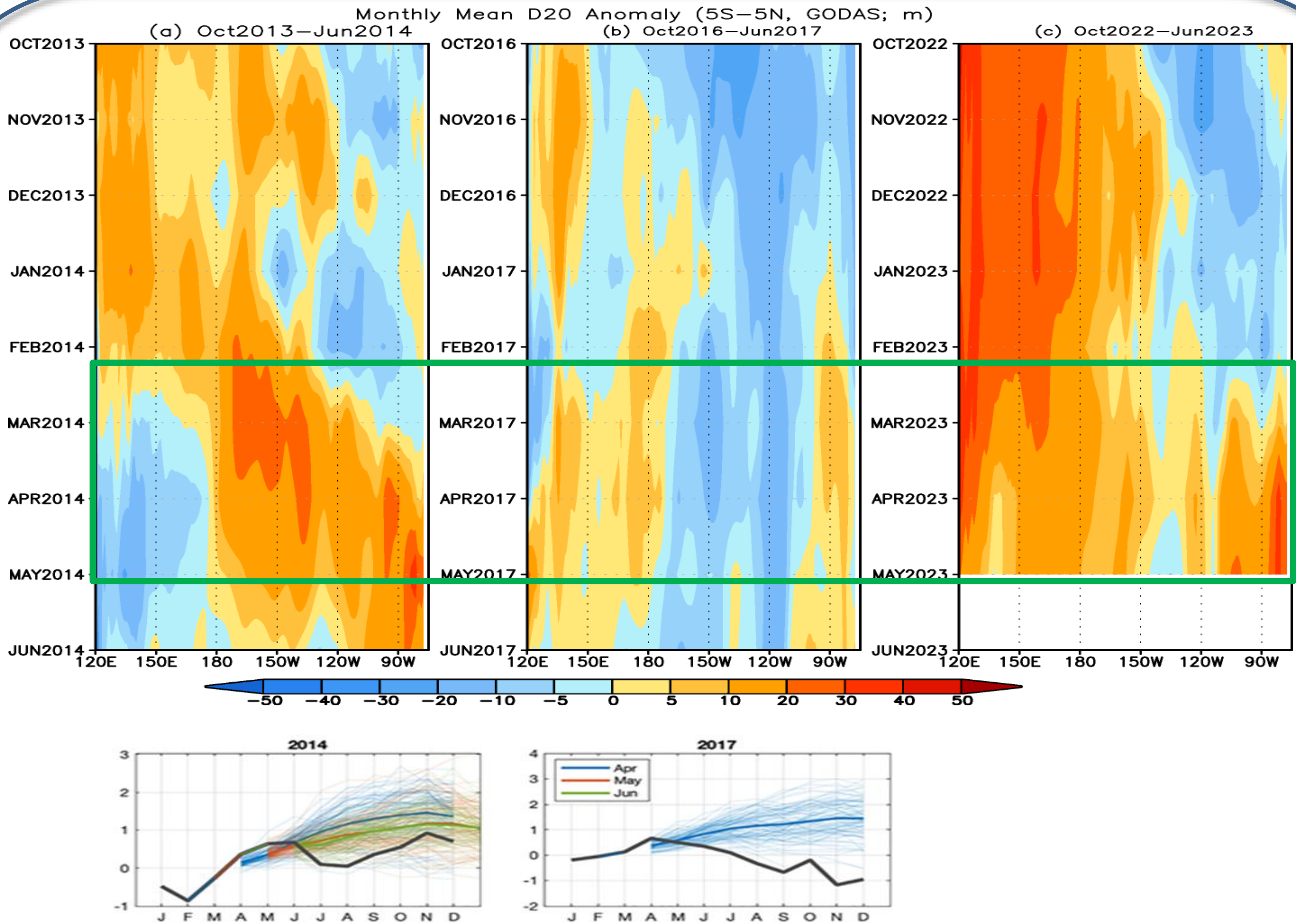



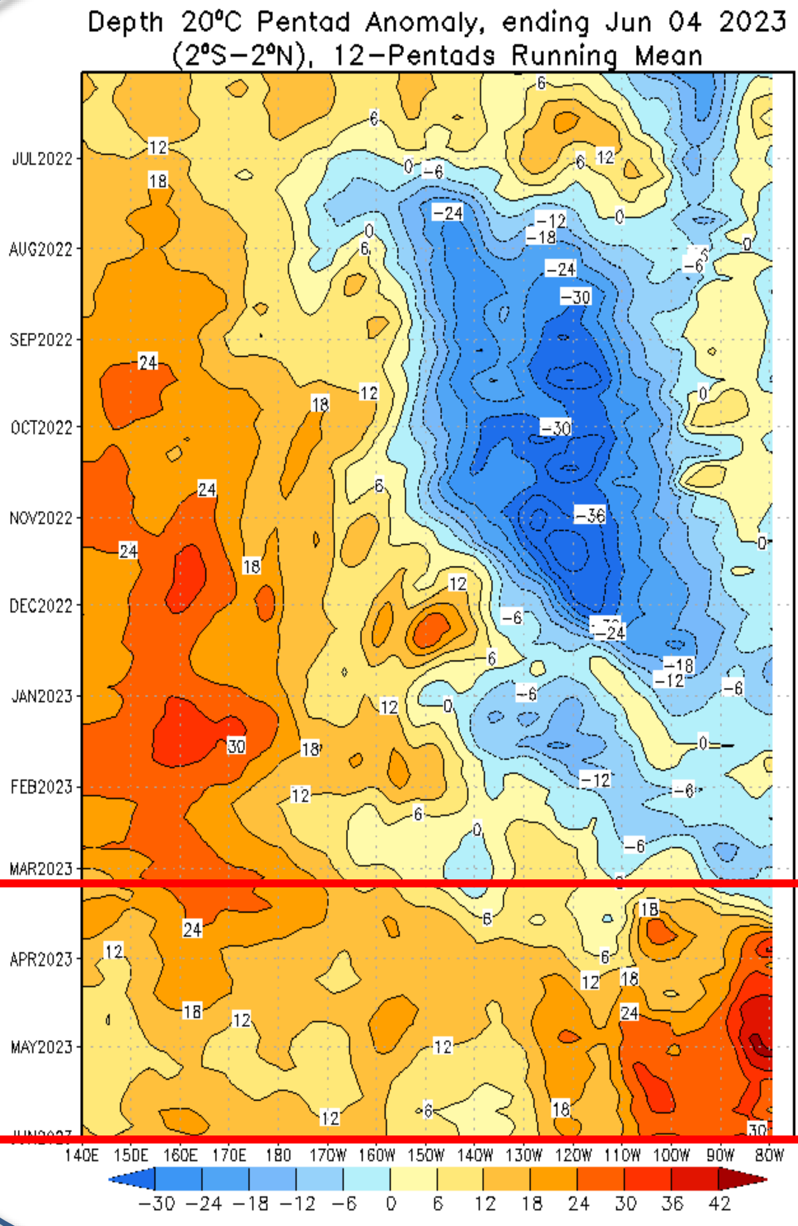



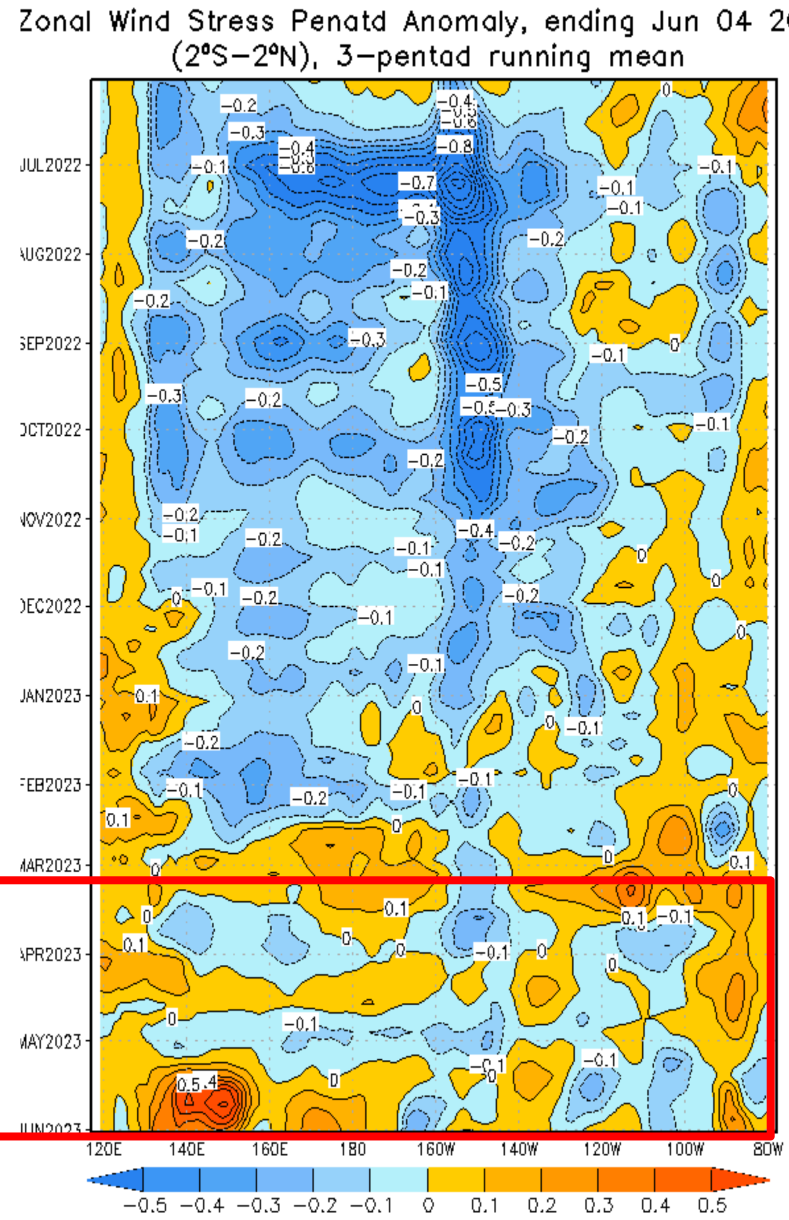



# Equatorial D20 anomalous evolution in 2013/14, 2016/17 & 2022/23

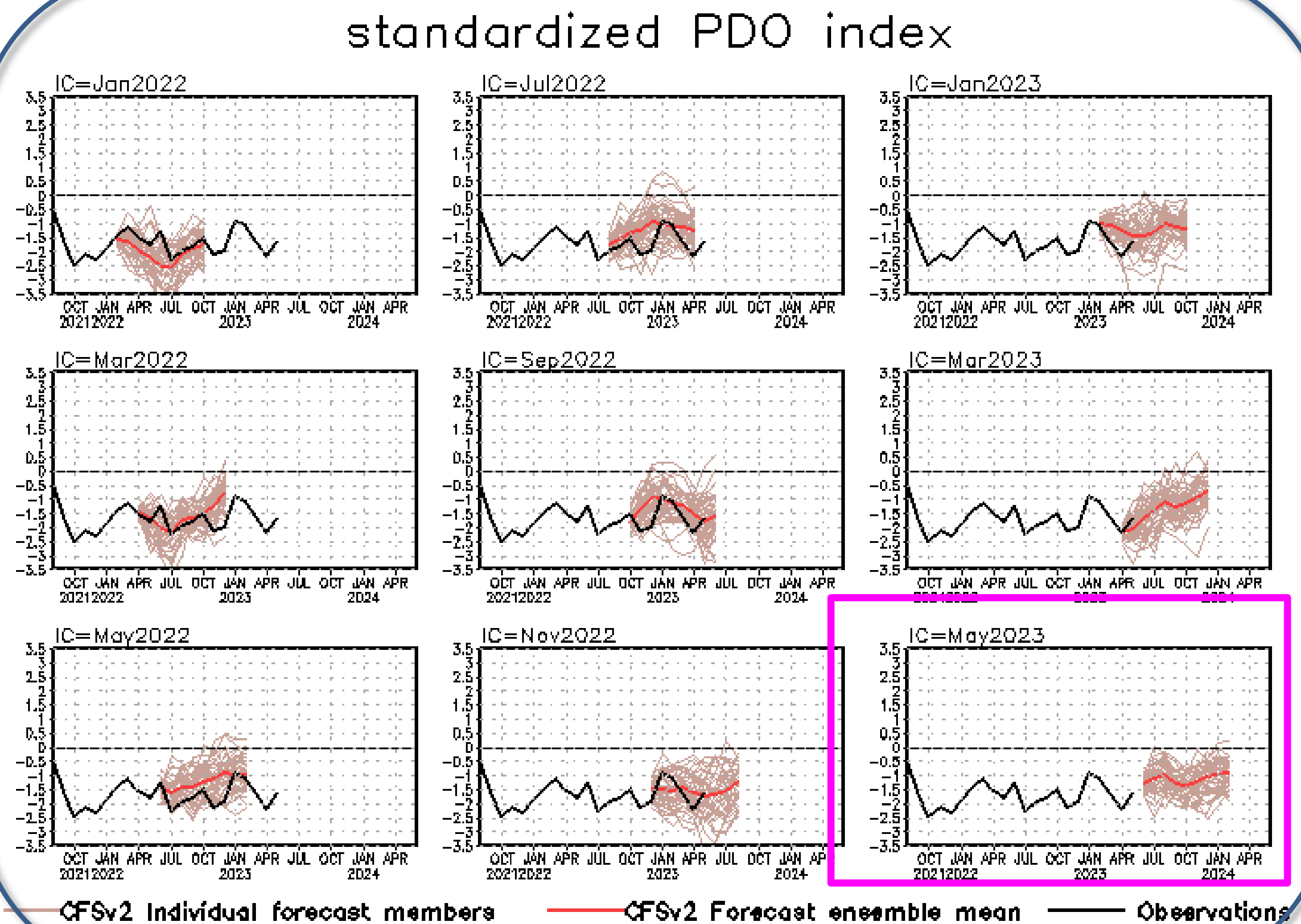


# Monthly mean subsurface temperature anomaly along the Equator



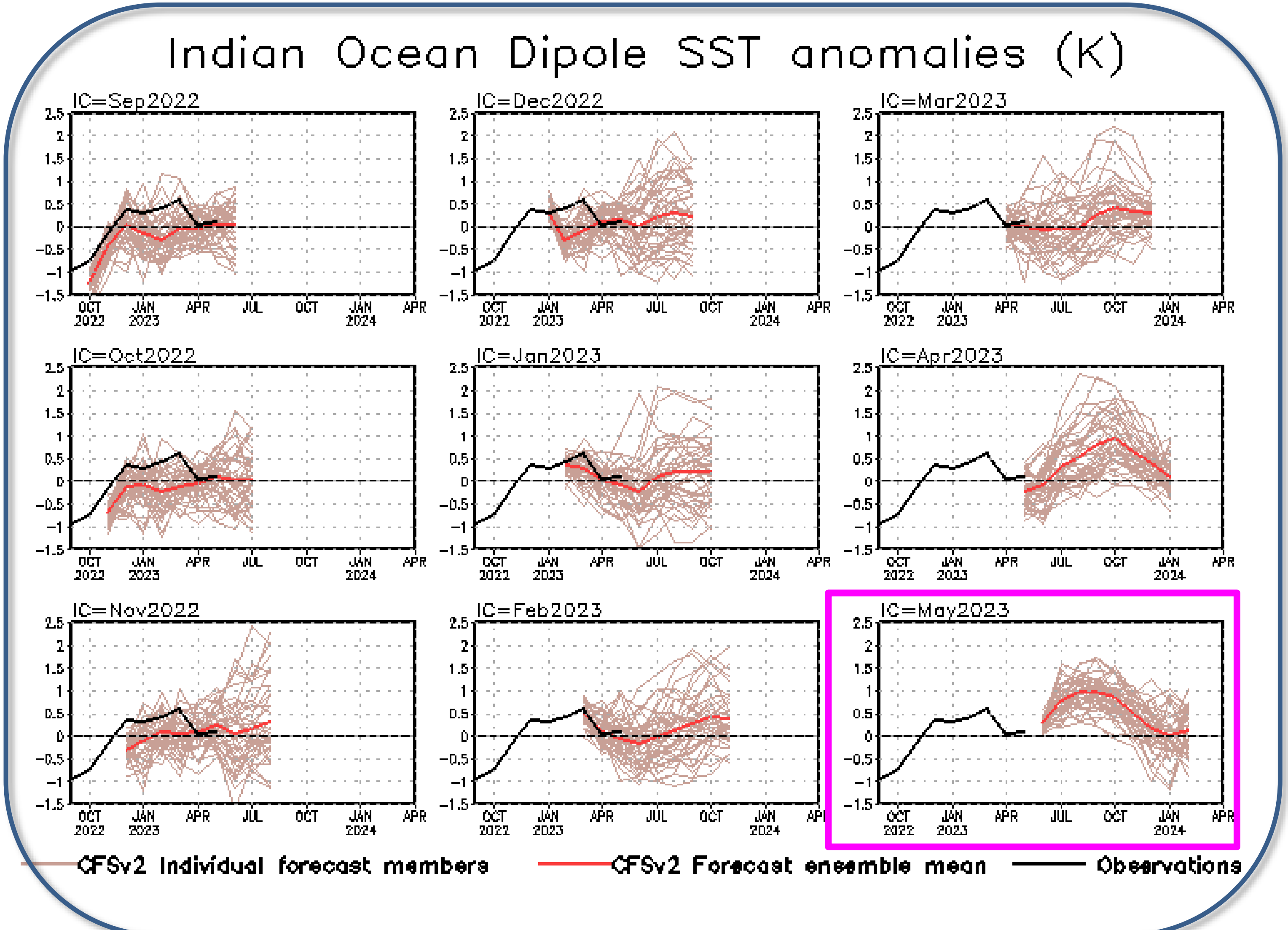
# CFS Pacific Decadal Oscillation (PDO) Index Predictions from Different Initial Months




- CFSv2 predicts a negative phase of PDO through 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 [110ºE-100ºW, 20ºN-60ºN]. CFS PDO index is the standardized projection of CFS SST forecast anomalies onto the PDO EOF pattern.

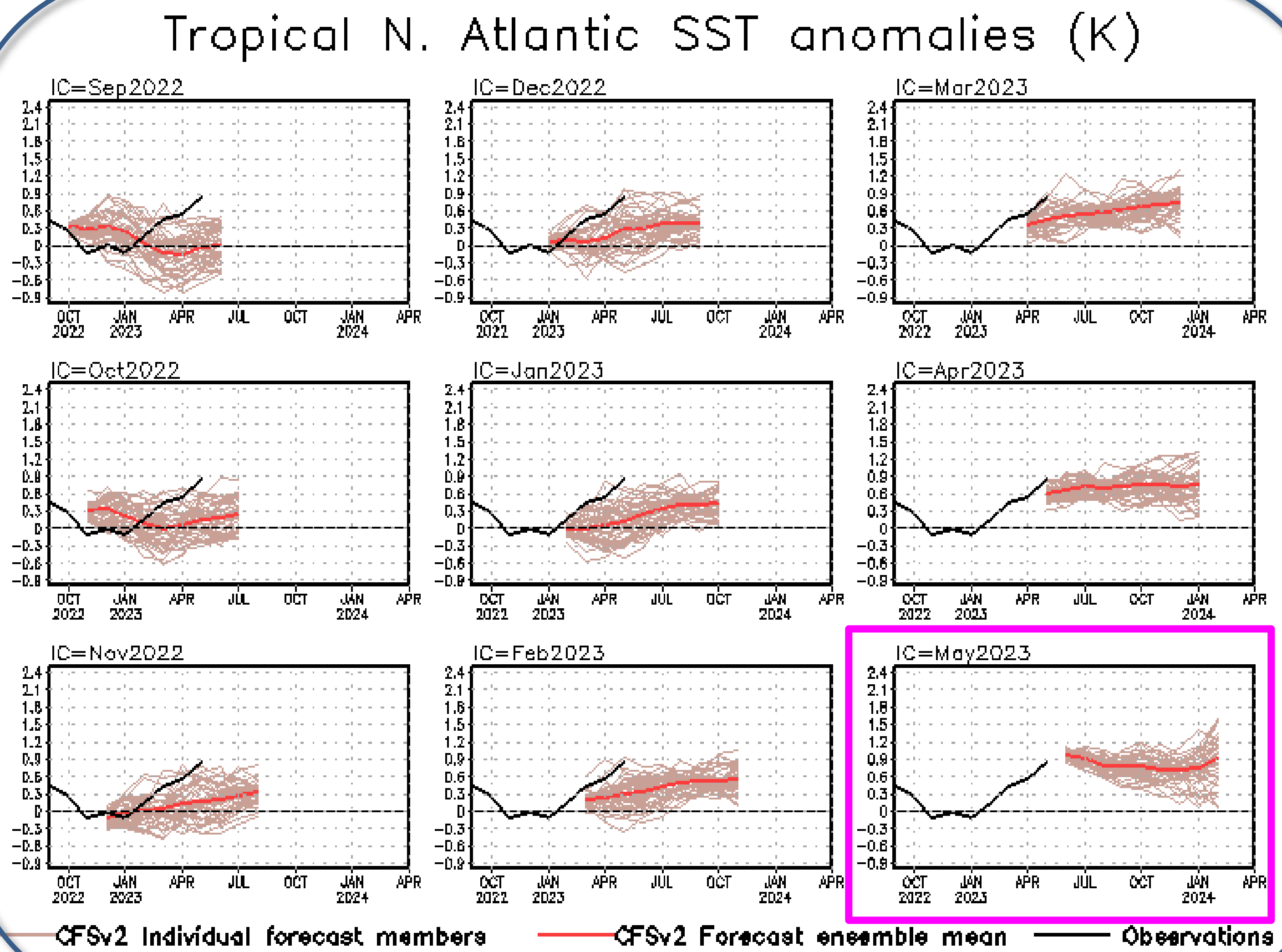
# NCEP CFS DMI SST Predictions from Different Initial Months




- 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


- PSL Team (Michael Alexander; Cathy Smith; Chia-Wei Hsu) provided the MHW slides
- 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:**


**Arun.Kumar@noaa.gov**
**Caihong.Wen@noaa.gov**
**Jieshun.Zhu@noaa.gov**
**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





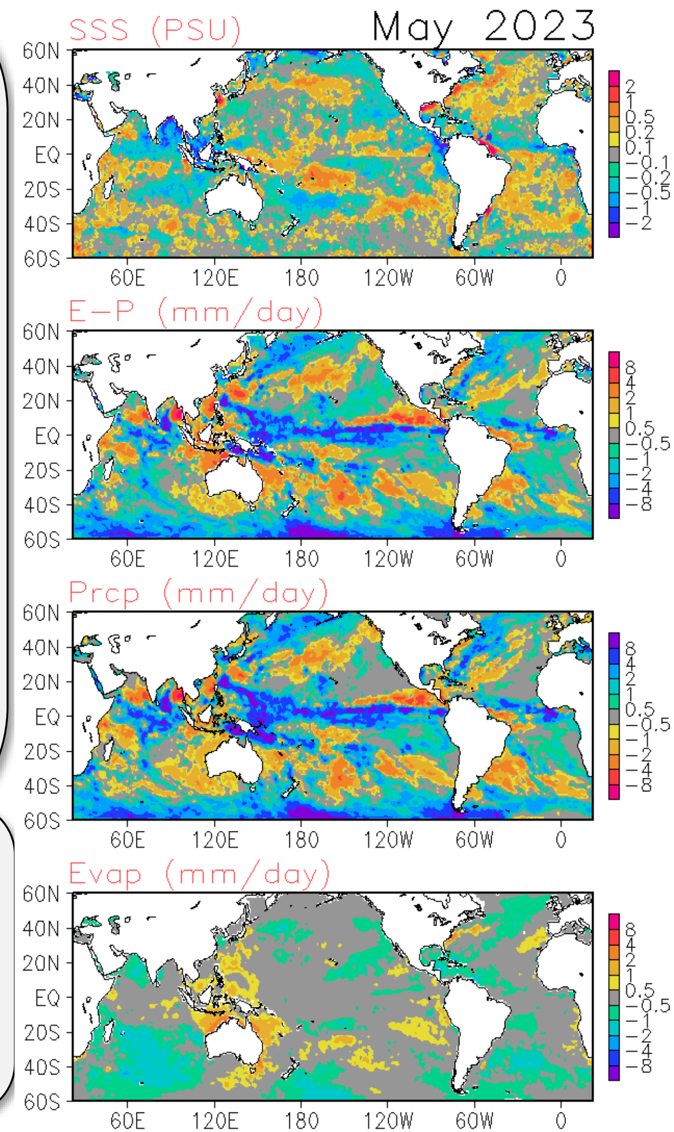
Hu, Z.-Z., Y. Xue, B. Huang, A. Kumar, C. Wen, P. Xie, J. Zhu, P. Pegion, L. Ren, and W. Wang, 2022: Global ocean monitoring and forecast at NOAA Climate Prediction Center: 15 Years of Operations. *Bull. Amer. Meteor. Soc.*, **103 (12),** E2701–E2718. DOI: 10.1175/BAMS-D-22-0056.1.

# Backup Slides

# Global Sea Surface Salinity (SSS): Anomaly for May 2023

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

**Over most of the tropical Atlantic and majority of the equatorial Pacific, large-scale salinity anomalies are dominated by the variation of fresh water flux (primarily precipitation) over the regions. SSS anomalies, however, receive substantial influences from other processes (circulations, oceanic processes, and river runoffs) as well, presenting anomaly patterns that are very different from those of fresh water fluxes over the northwestern Pacific off the west coasts of the North America continent, tropical Indian oceans and the Golf of Mexico and the Bay of Bangel.**




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

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

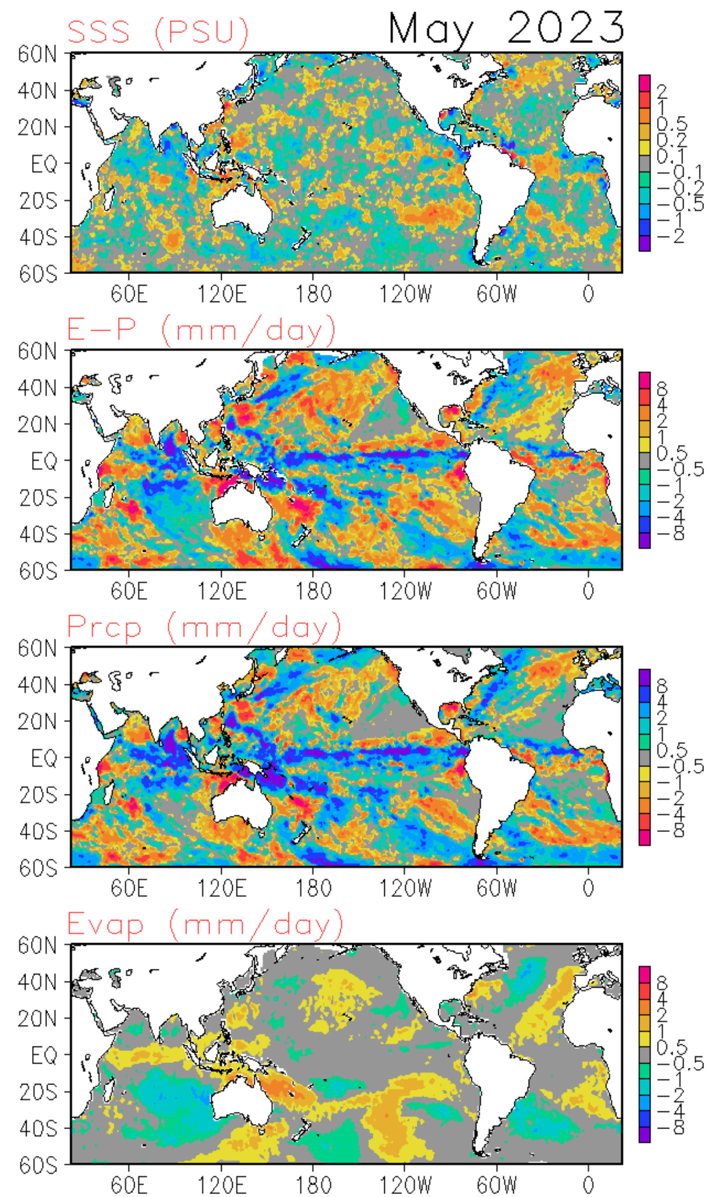
[ftp.cpc.ncep.noaa.gov/precip/BASS](ftp.cpc.ncep.noaa.gov/precip/BASS)

**Precipitation: CMORPH adjusted satellite precipitation estimates**

**Evaporation: Adjusted CFS Reanalysis**

# Global Sea Surface Salinity (SSS): Tendency for May 2023

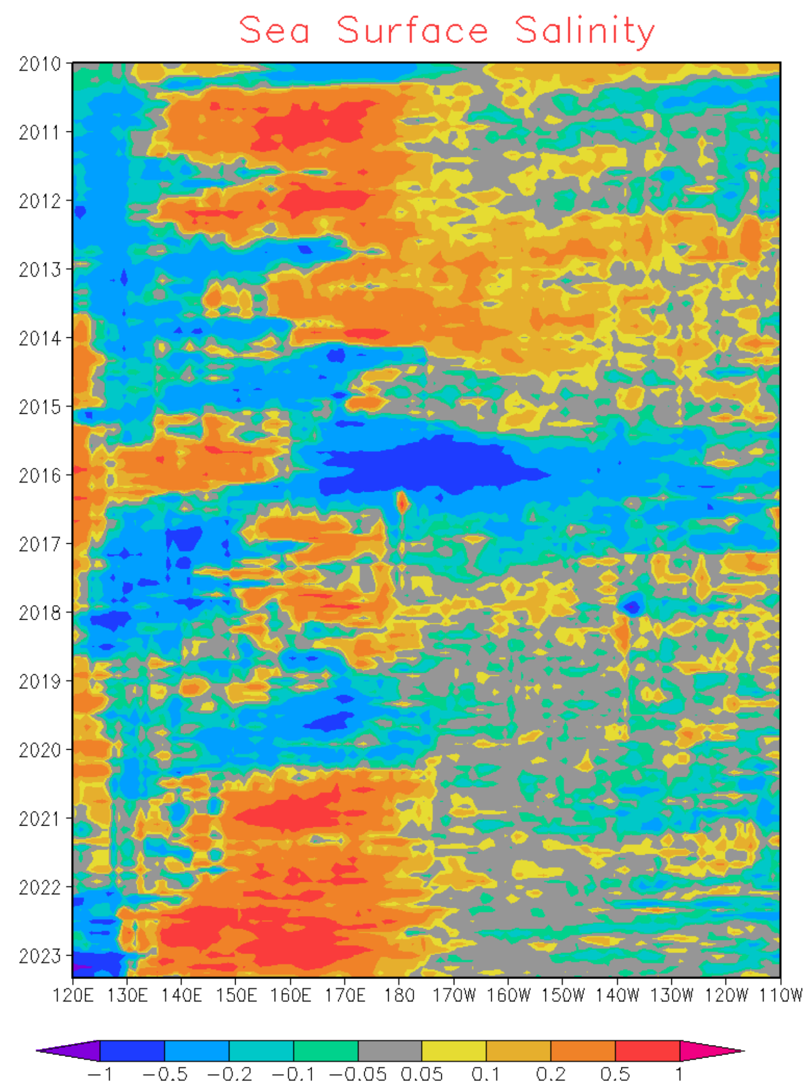
Freshening SSS tendency continues over the western and central equatorial Pacific and over the central south Pacific, attributable to the fresh water flux (mainly precipitation) into the ocean. Freshening tendency is also observed over majority of the northern Indian ocean, a reflection of the enhanced precipitation tendency. Saltier SSS tendency appears over the Gulf of Mexico and the river mouth of the Amazon off the South America continent, likely caused by the reduced river runoffs there.



# Monthly SSS Anomaly Evolution over Equatorial Pacific

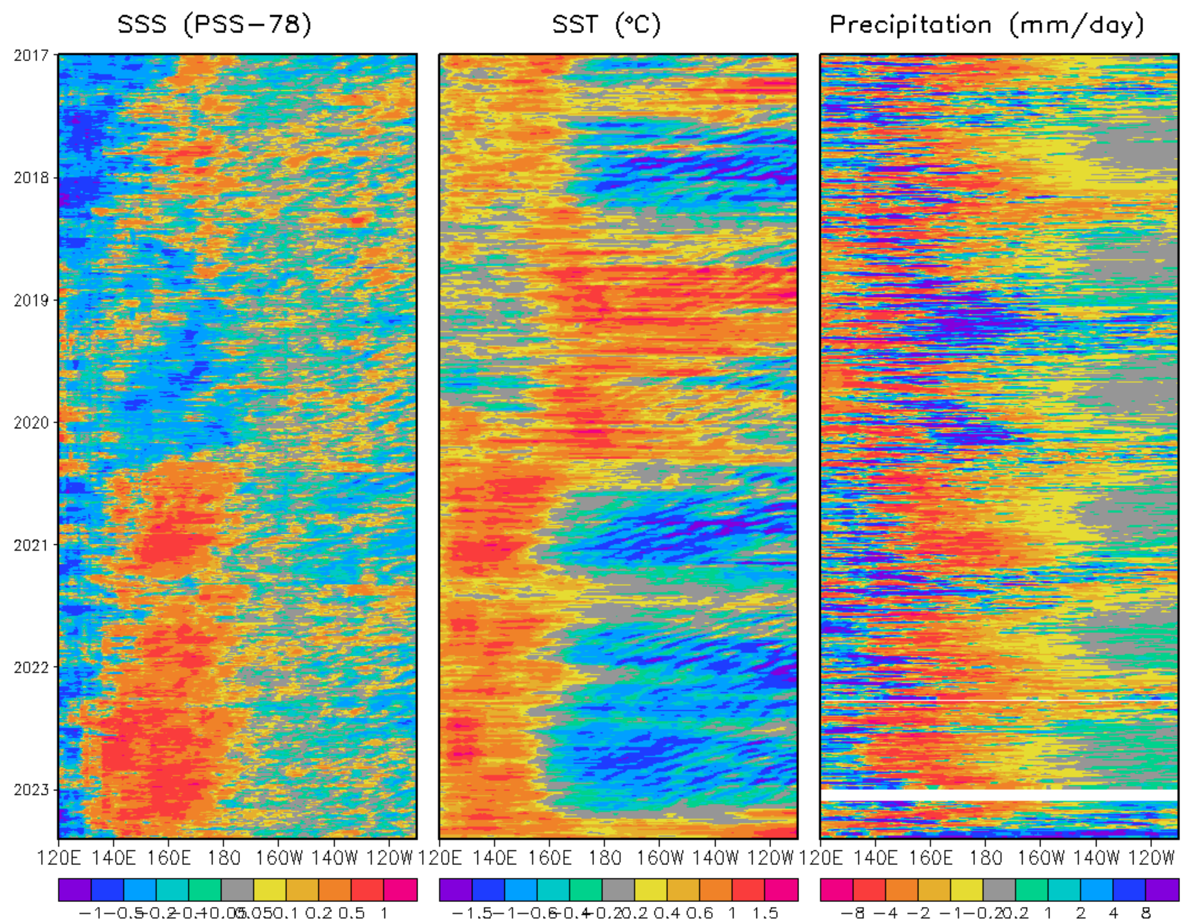
**NOTE: Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015,The BASS SSS is from in situ, SMOS and Aquarius.**

- 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) is weakening slightly compared to that over the past months.



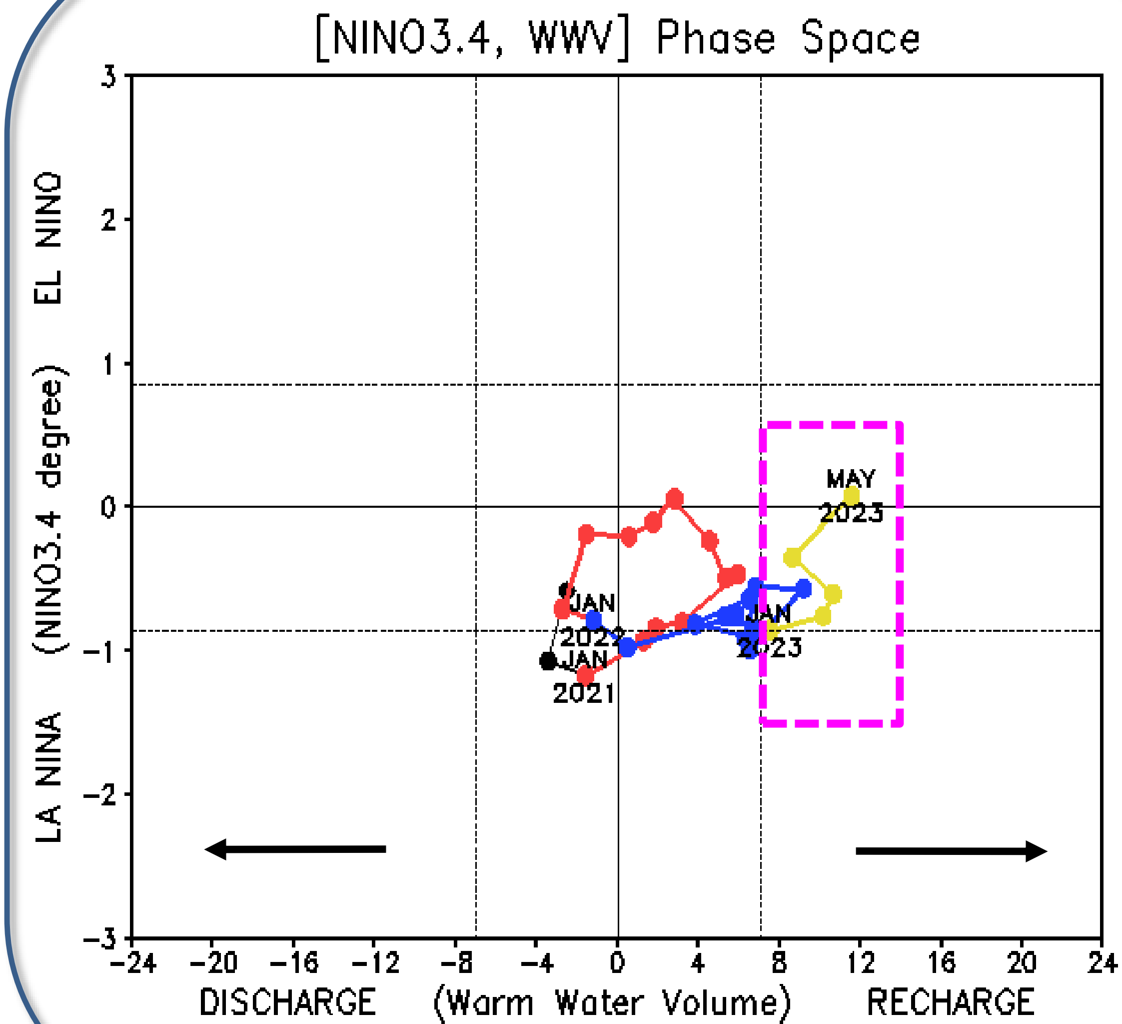
# Pentad SSS Anomaly Evolution over Equatorial Pacific

**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 May 2023.

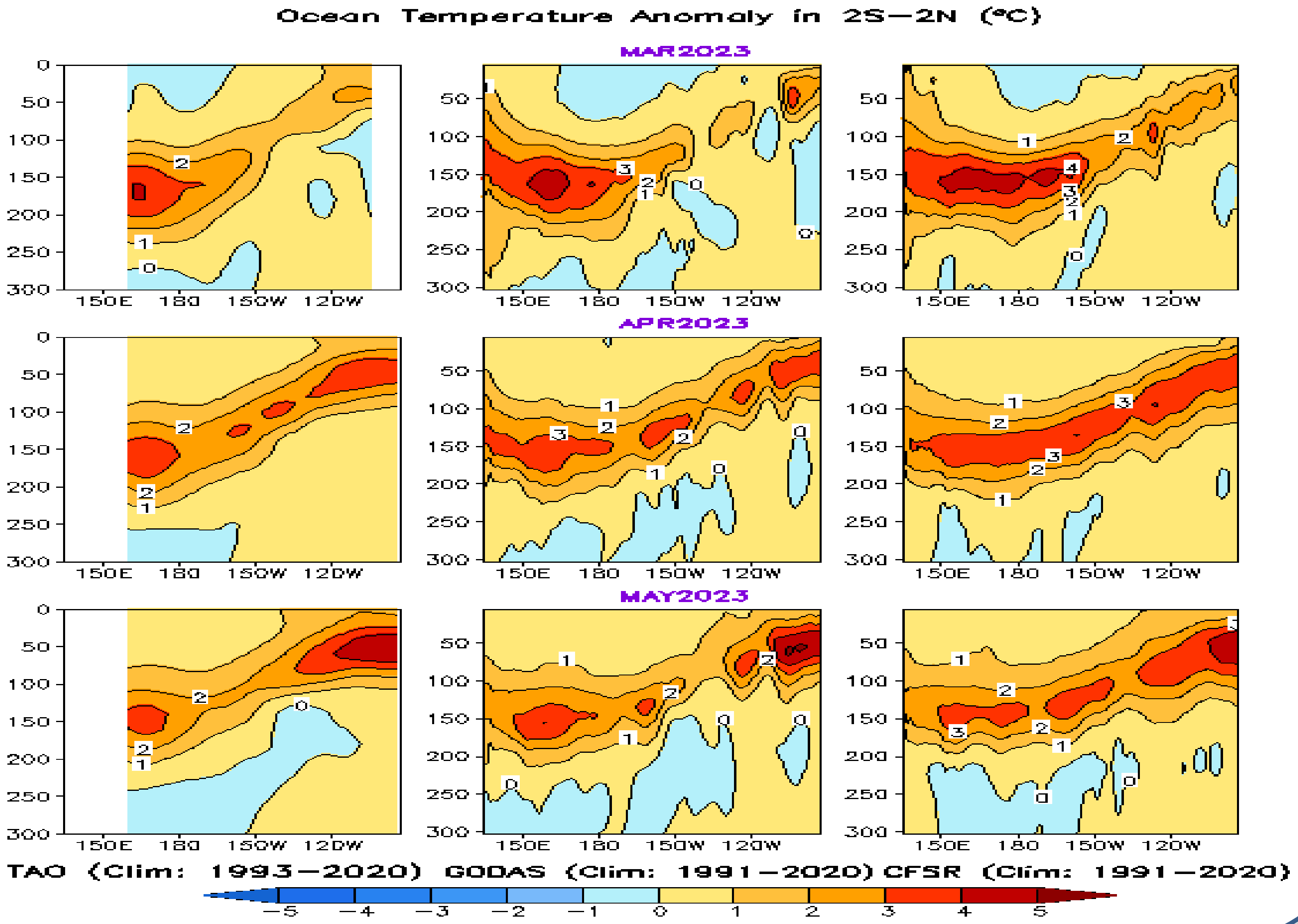



-As WWV is intimately linked to ENSO variability (Wyrtki 1985; Jin 1997), it is useful to monitor ENSO in a phase space of WWV and Niño3.4 (Kessler 2002).

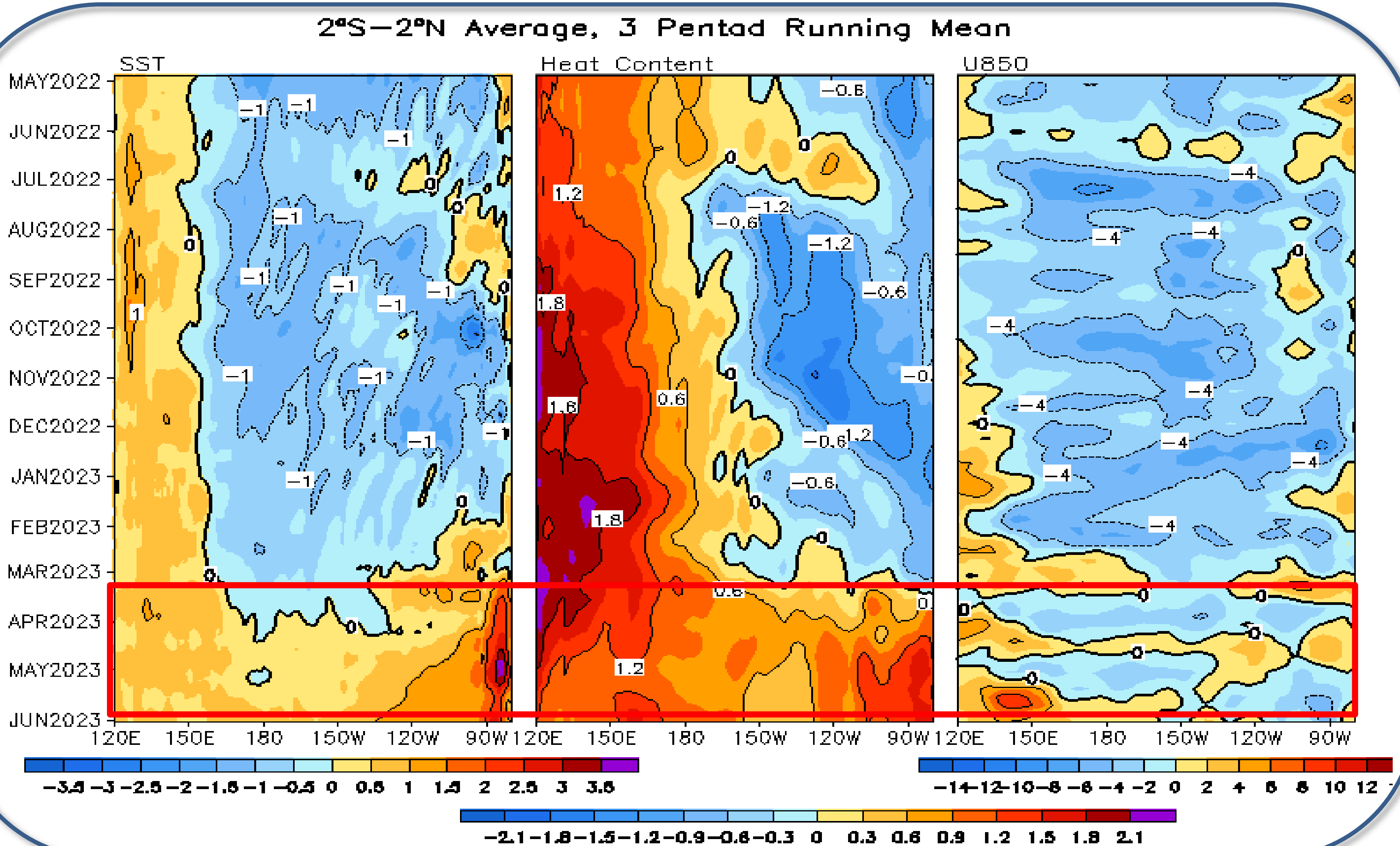
- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.

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.

# Monthly mean subsurface temperature anomaly along the Equator:
## Strengthening of the warm anomalies along the coast

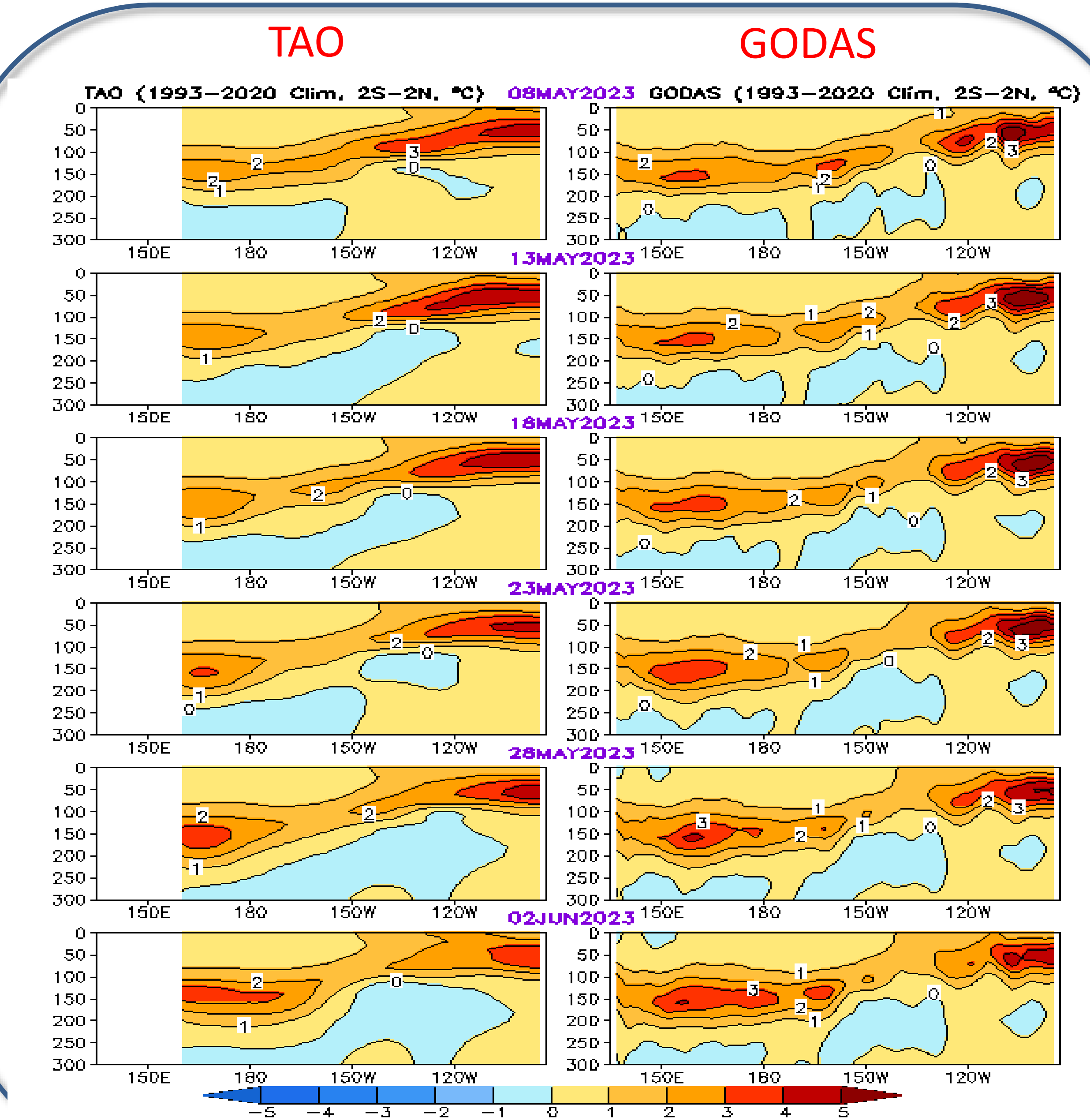


# Equatorial Pacific SST (ºC), HC300 (ºC), u850 (m/s) Anomalies




- 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 positive SSTA were observed.

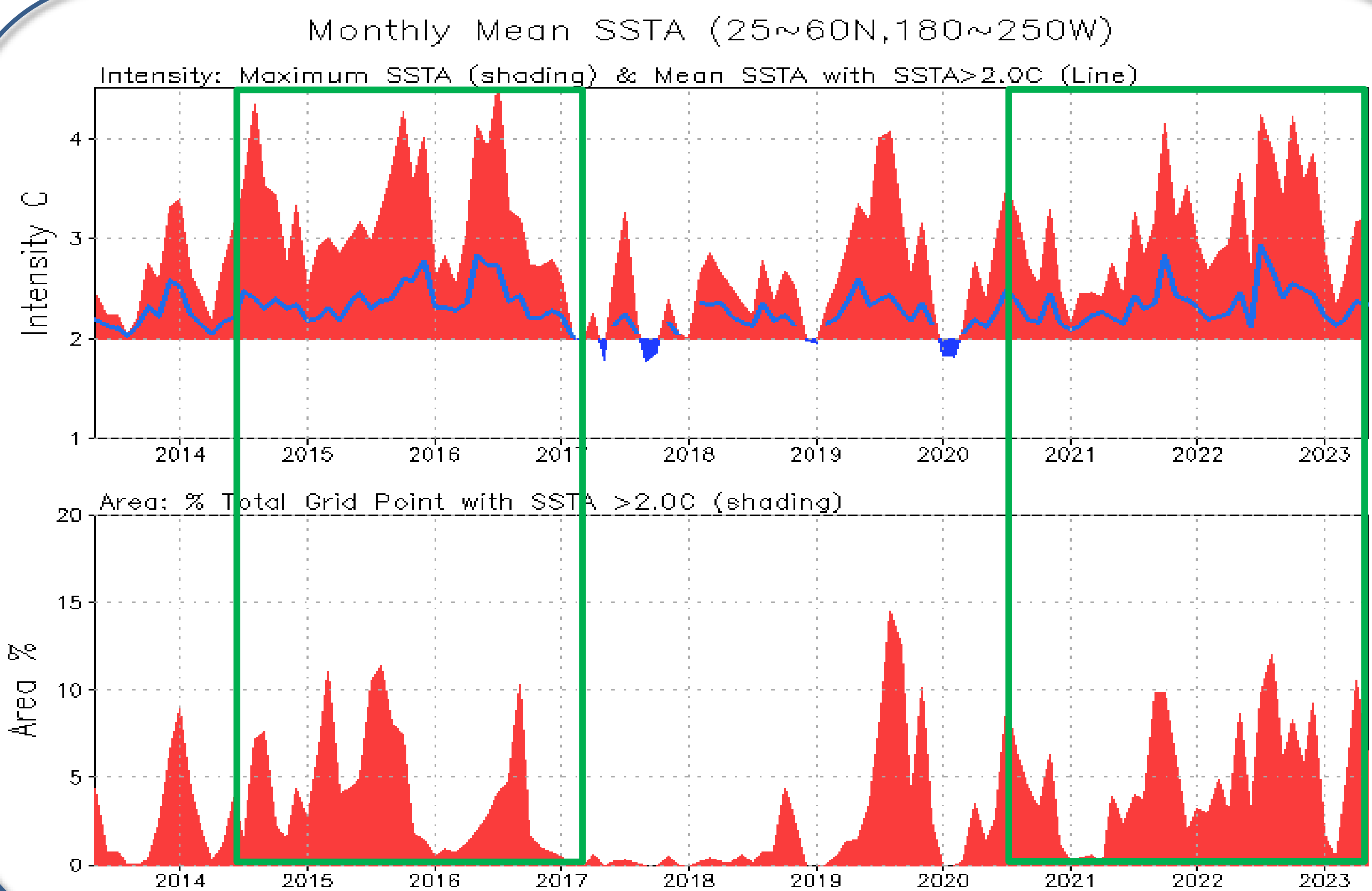
# Equatorial Pacific Ocean Temperature Pentad Mean Anomaly




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

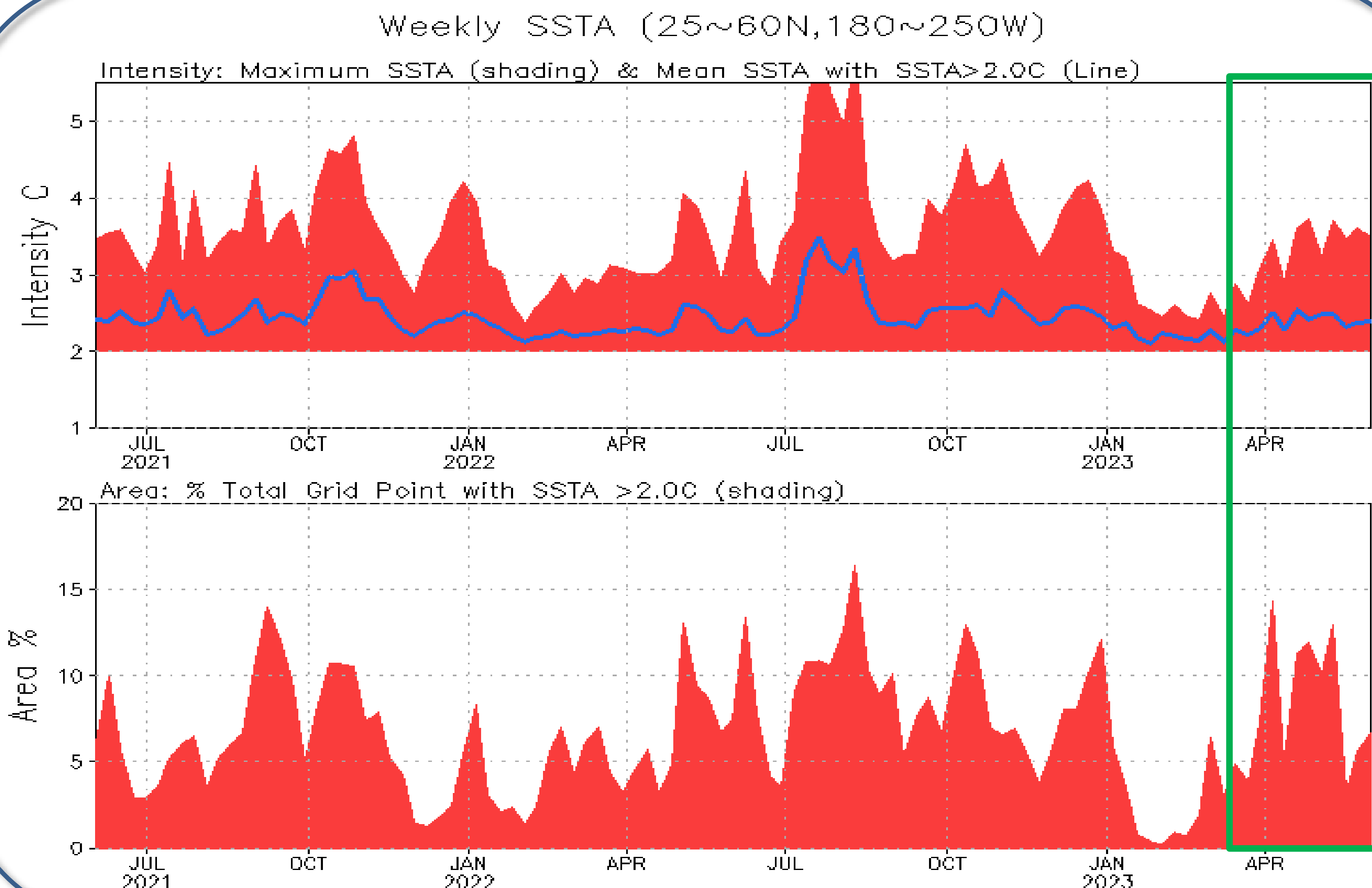
- The features of the ocean temperature anomalies were similar between GODAS and TAO analysis.

# N. Pacific Marine Heat Wave



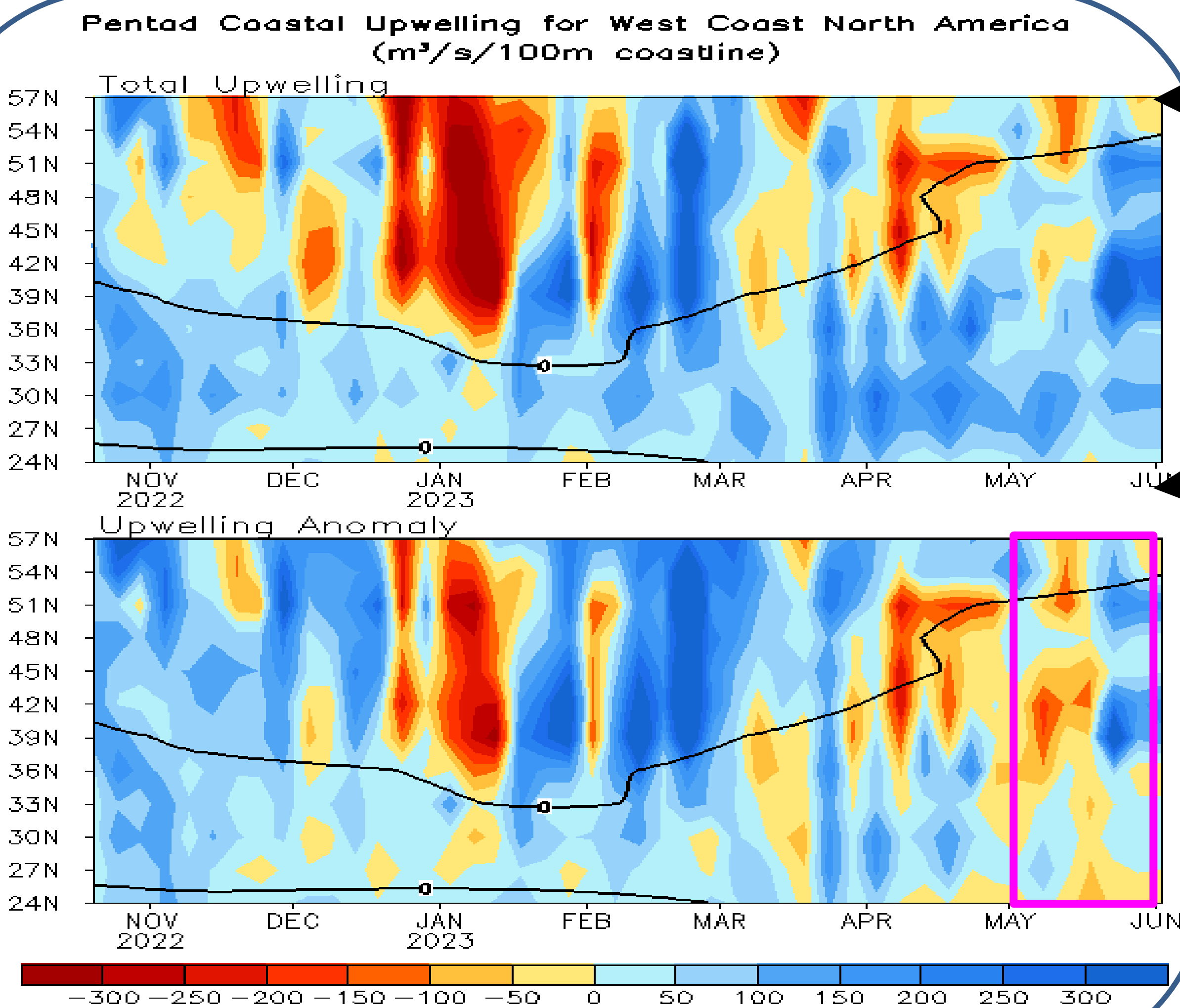

https://origin.cpc.ncep.noaa.gov/products/GODAS/MarineHeatWave.html

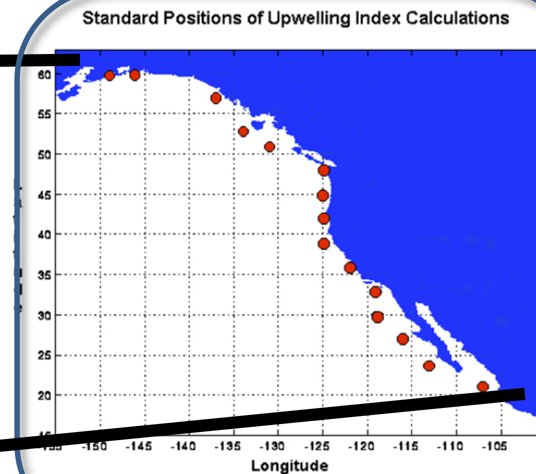
# N. Pacific Marine Heat Wave




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

# North America Western Coastal Upwelling



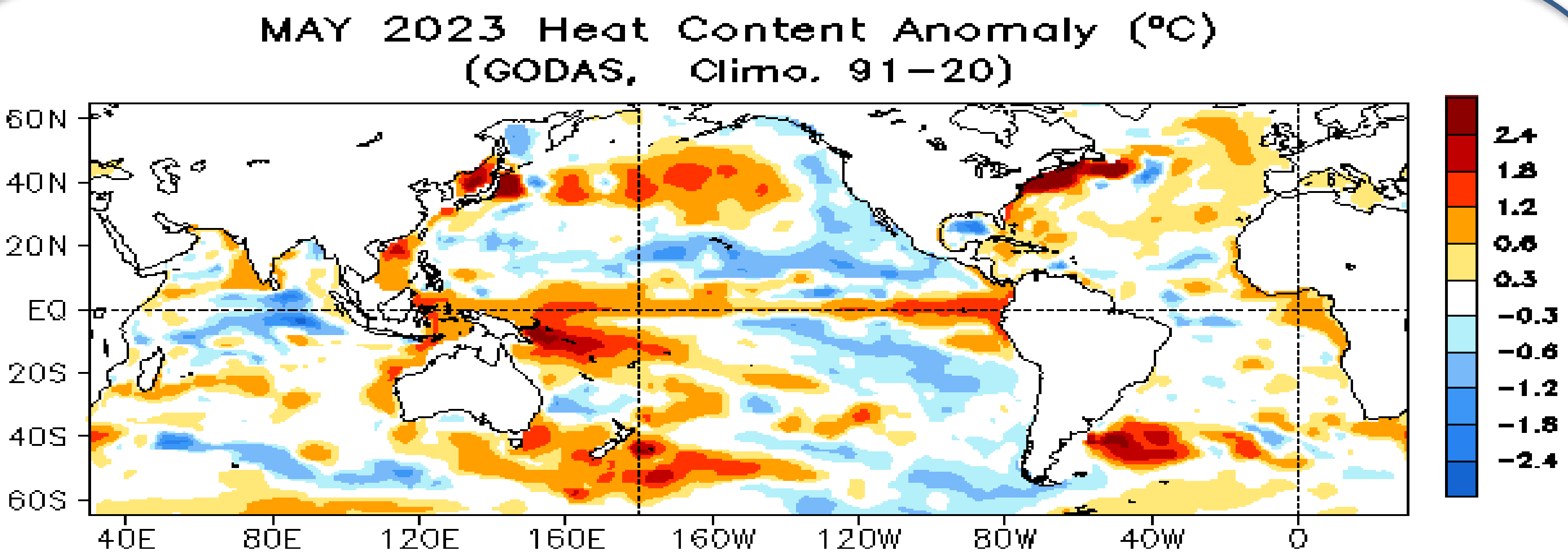



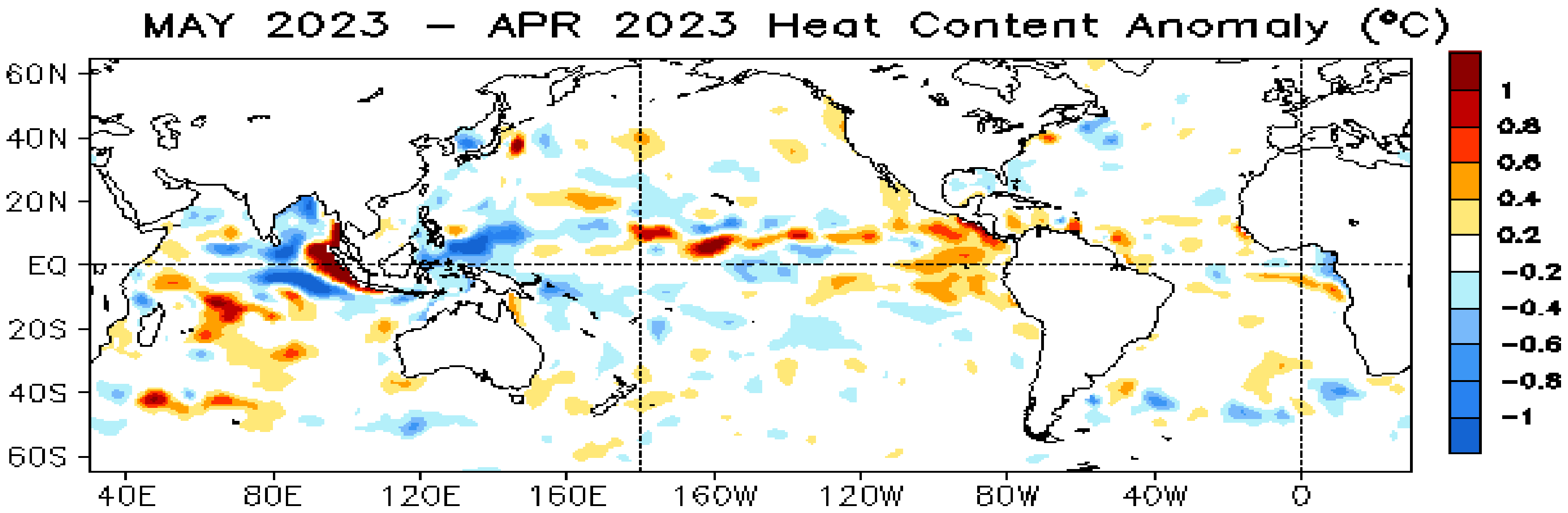

- Weak coastal (39º-54ºN) anomalous downwelling and upwelling were observed in May 2023.

(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.

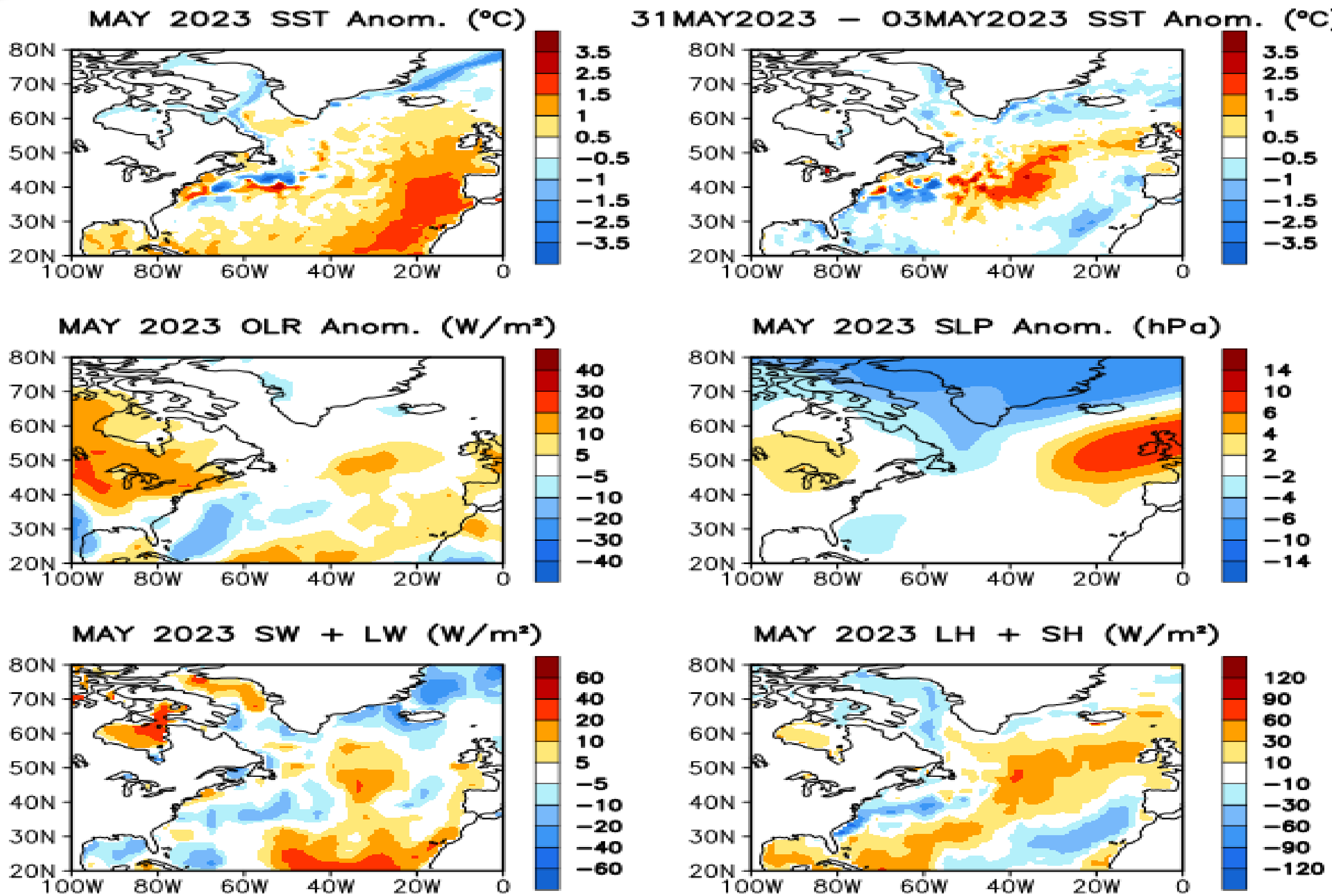
- Area below (above) black line indicates climatological upwelling (downwelling) season.
- Climatologically upwelling season progresses from March to July along the west coast of North America from 36ºN to 57ºN.

# Global HC300 Anomaly & Anomaly Tendency



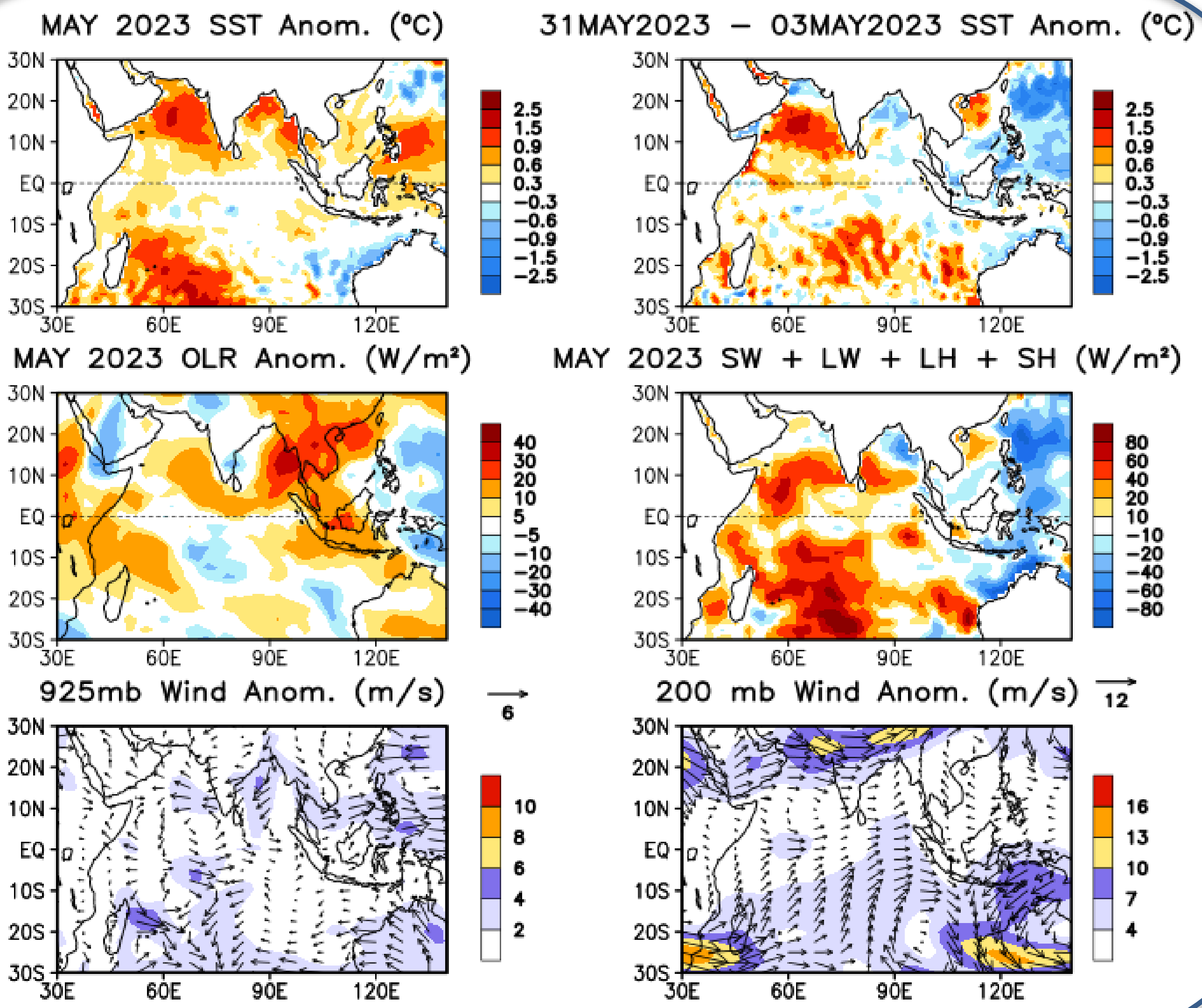



# North Pacific & Arctic Ocean: SSTA, SSTA Tend., OLR, SLP, Sfc Rad, Sfc Flx Anomalies




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.

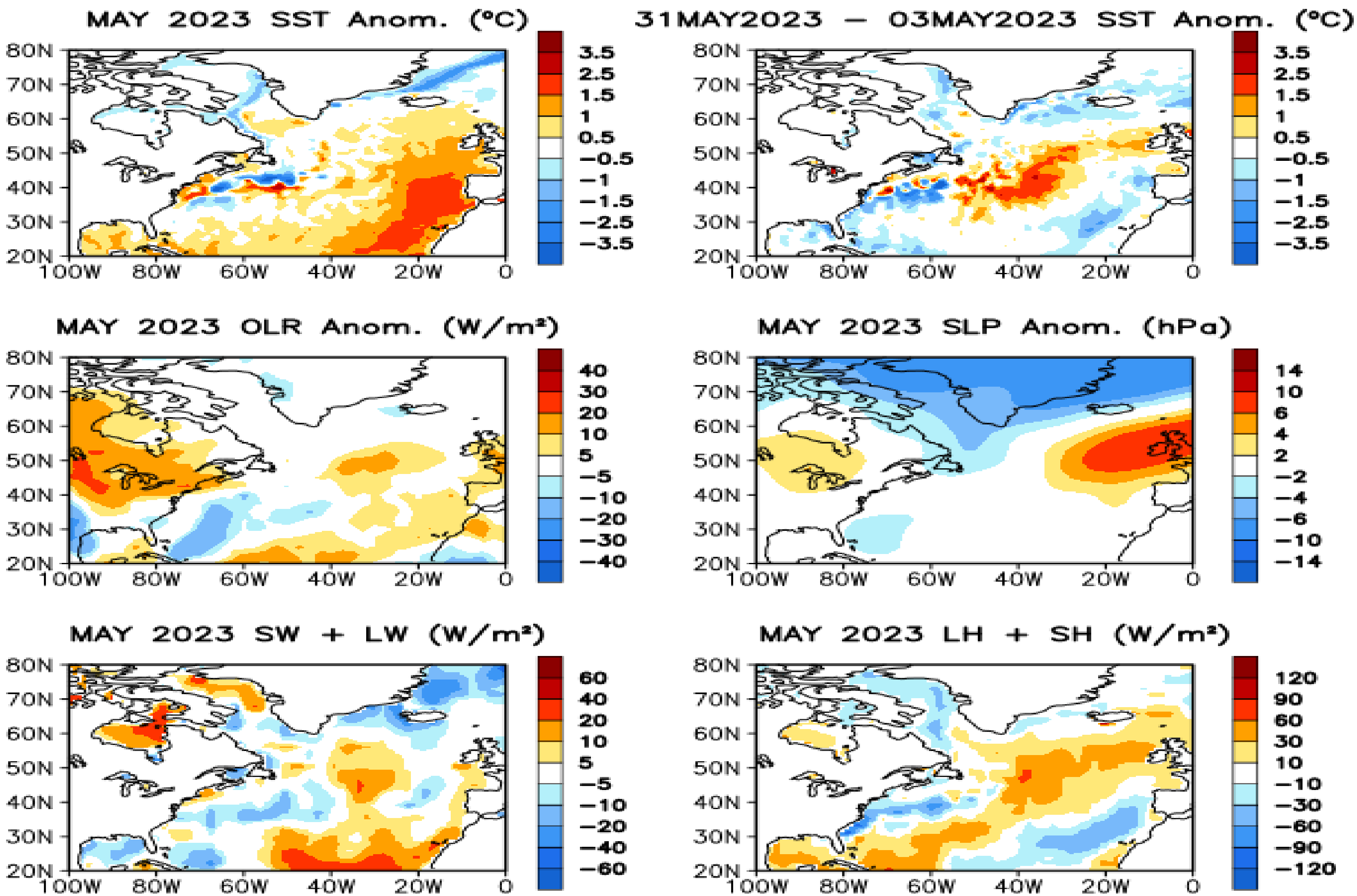
# Tropical Indian: SSTA, SSTA Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Wind Anom.



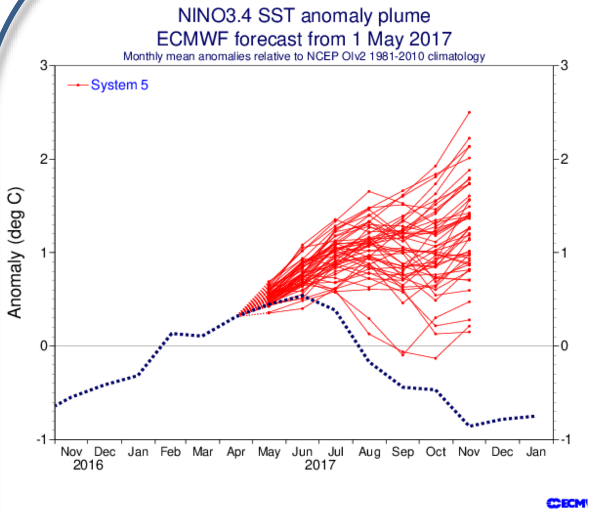

Convection was enhanced (suppressed) over the northern (southern) tropical Indian Ocean.

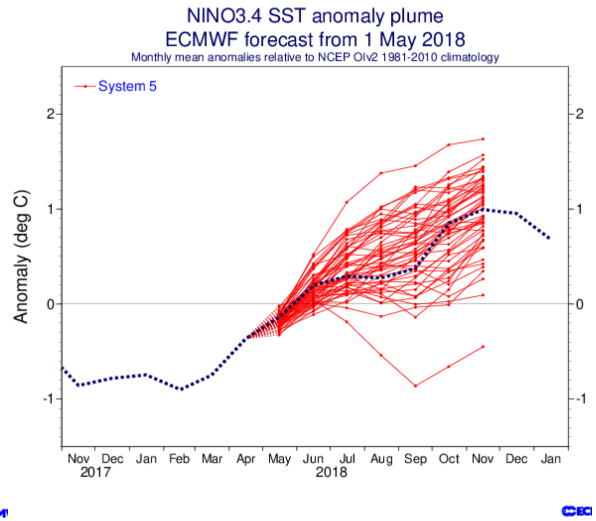
SSTAs (top-left), SSTA tendency (top-right), OLR anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). 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.

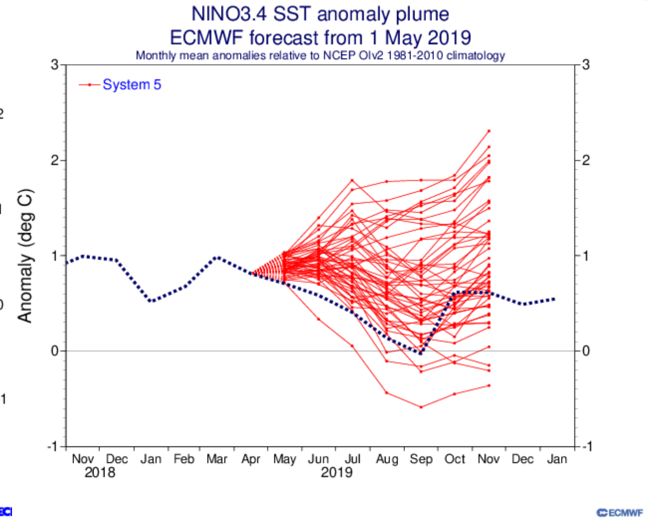
# N. Atlantic: SST, SST tend., OLR, SLP, & heat flex anom.

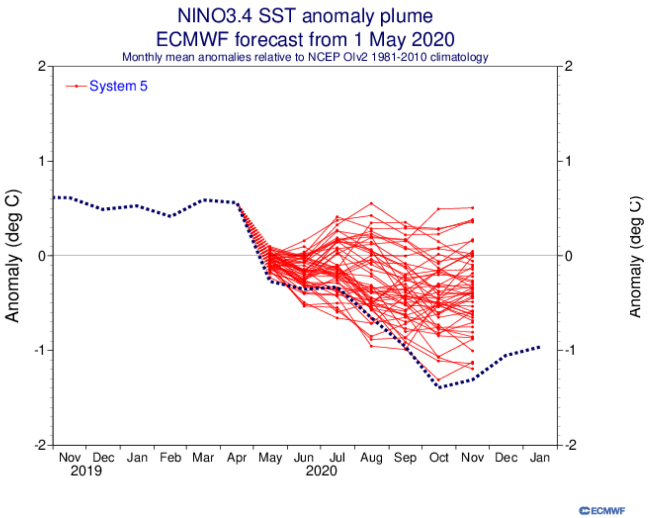


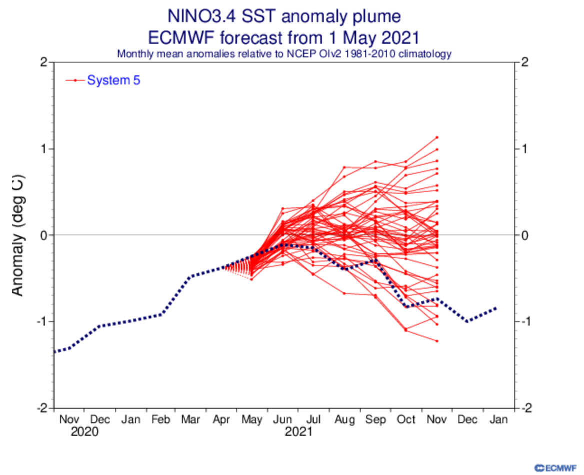
# ECMWF Forecasts: warm bias in May IC runs since 2017

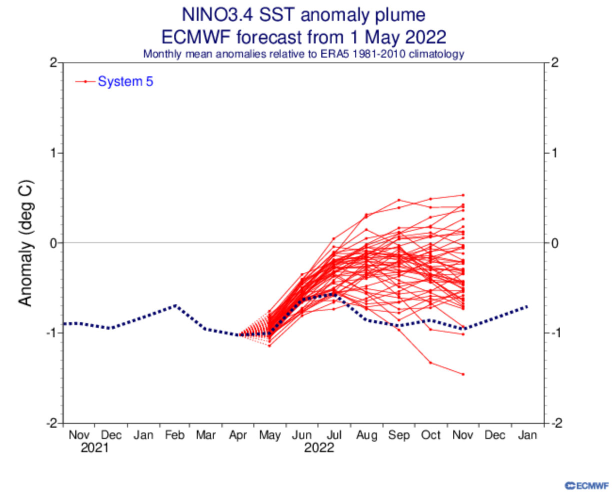


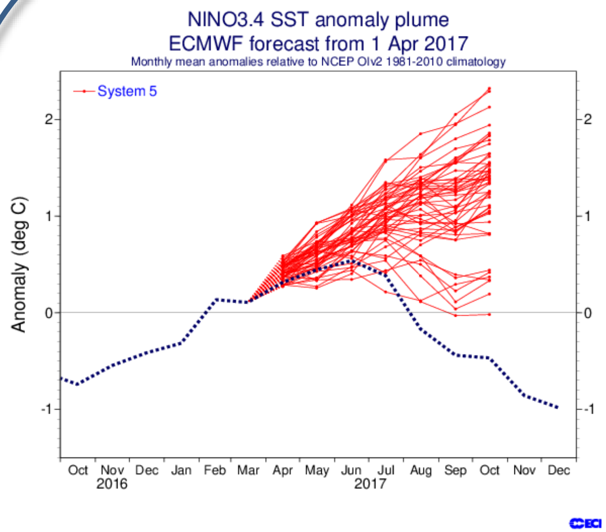



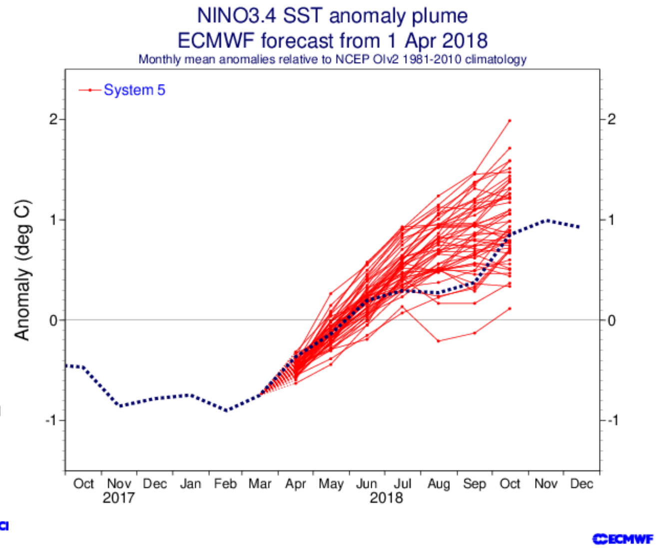



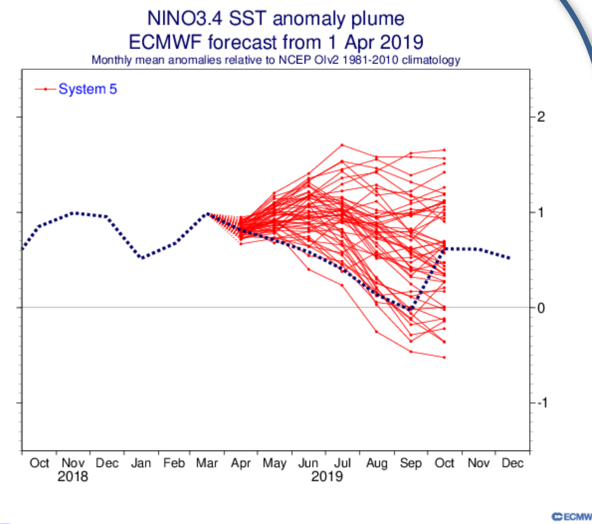



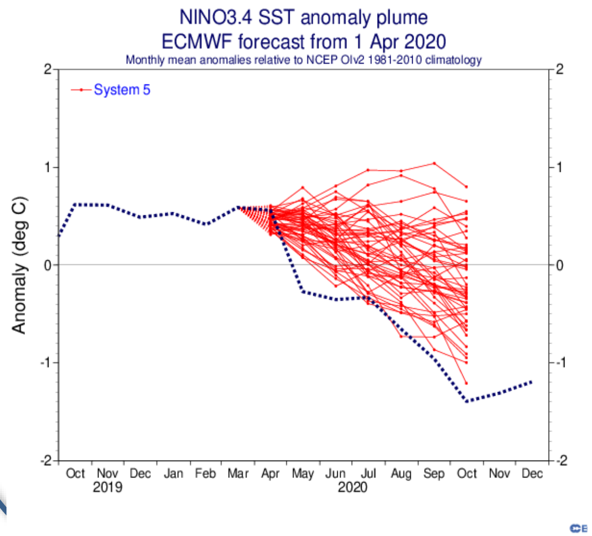



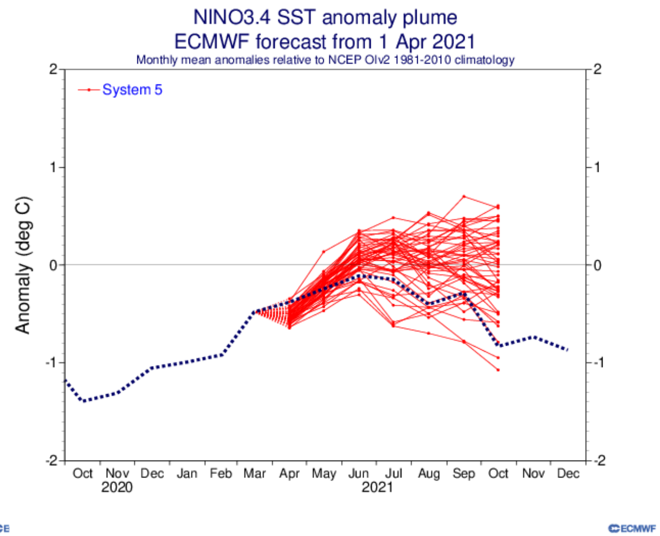
# ECMWF Forecasts: warm bias in Apr IC runs since 2017

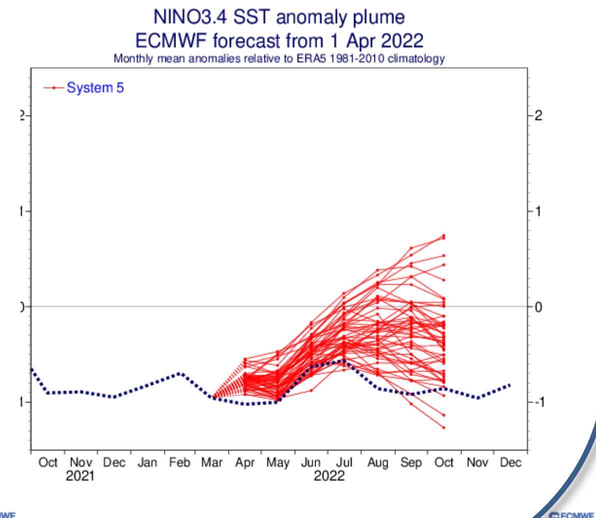


# ECMWF Forecasts: warm bias in March IC runs since 2017