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

Prepared by

Climate Prediction Center, NCEP/NOAA

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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

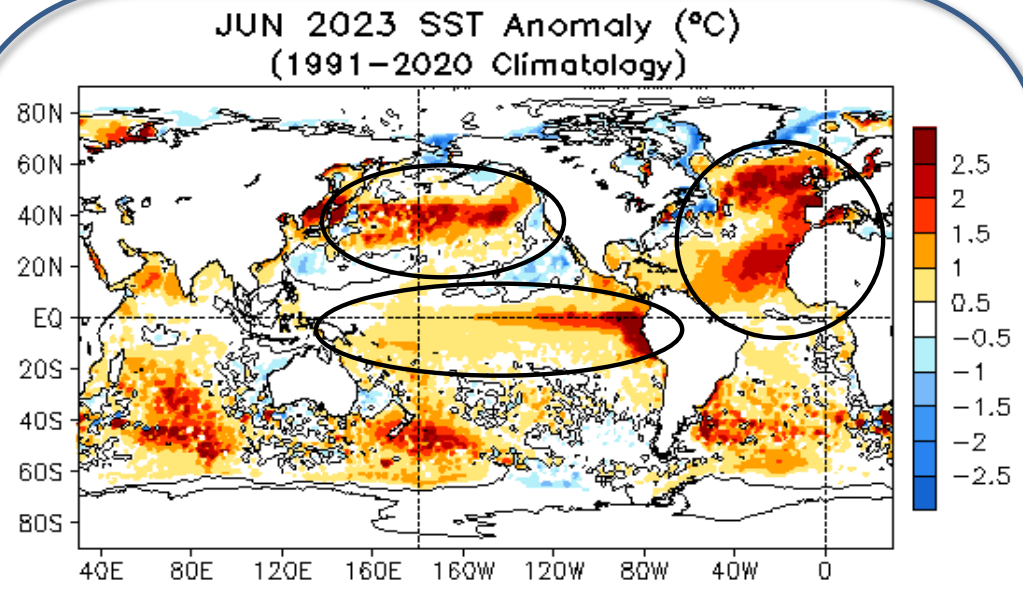
- Overview
- Recent highlights
  - Pacific Ocean
  - Arctic & Antarctic Oceans
  - Indian Ocean
  - Atlantic Ocean
- Global SSTA Predictions

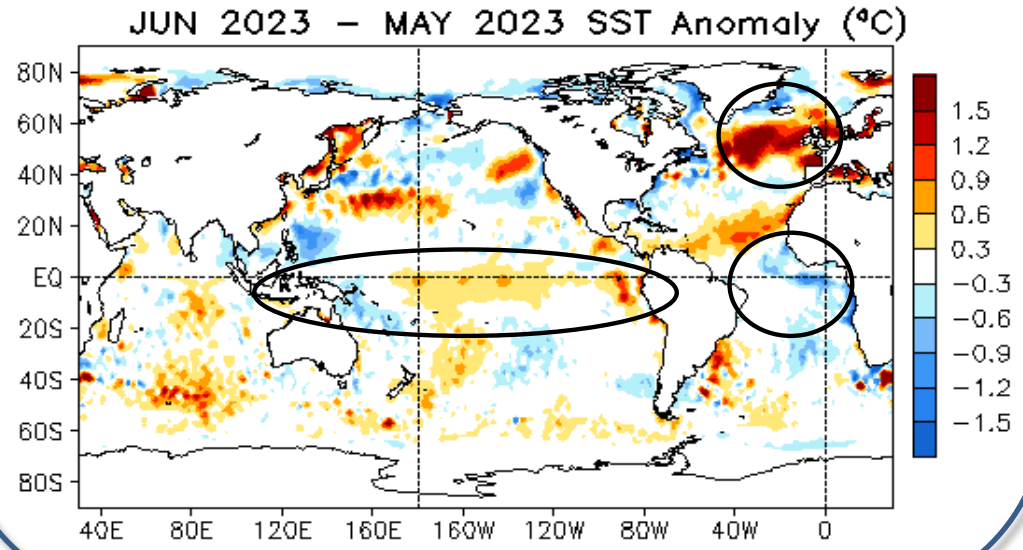
Overview

- Pacific Ocean
  - The warming in the central and eastern equatorial Pacific increased in Jun 2023 with Niño3.4 = 0.9°C
  - A strong coastal Niño has developed since Feb 2023 and continued to grow with Niño1+2= 2.6°C in Jun 2023.
  - The PDO has been in a negative phase since Jan 2020 with PDOI = -1.9 in Jun 2023.
  - Strong subsurface warming has persisted in the central north Pacific Ocean since 2020.
- Arctic and Antarctic Oceans
  - Average Arctic sea ice extent during Jun 2023 ranked the 13th lowest Jun in the satellite record.
  - Antarctic sea ice extent continues to track at historical low values.
- Indian Ocean
  - SSTs were above normal in the tropical Indian Ocean in Jun 2023.
- Atlantic Ocean
  - SST warming during May-Jun 2023 hit the historical high of the same season since 1982.
  - Strong MHWs were observed near the coast of United Kingdom and Ireland, and northeastern tropical Atlantic Ocean

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency



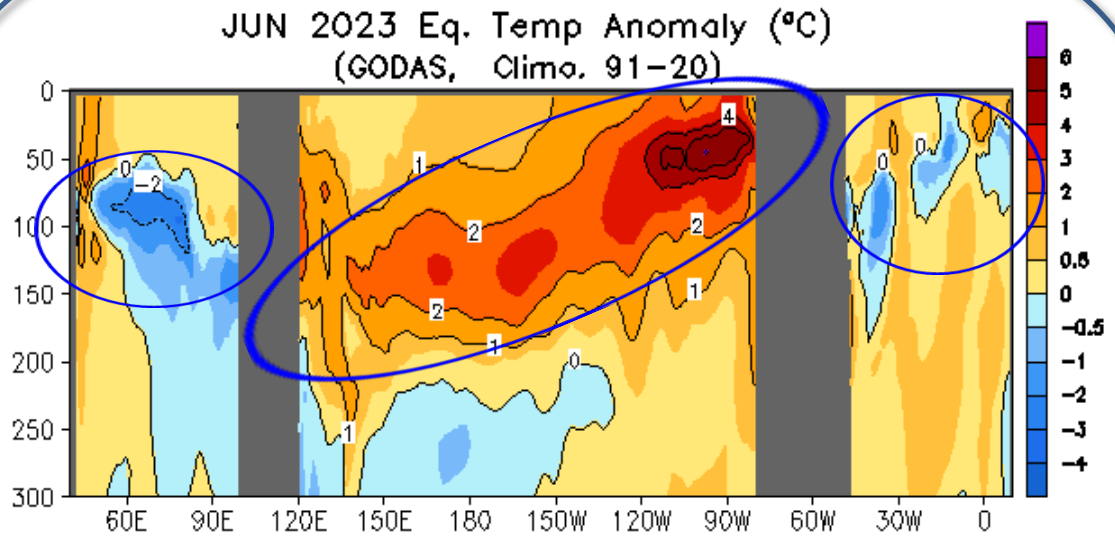


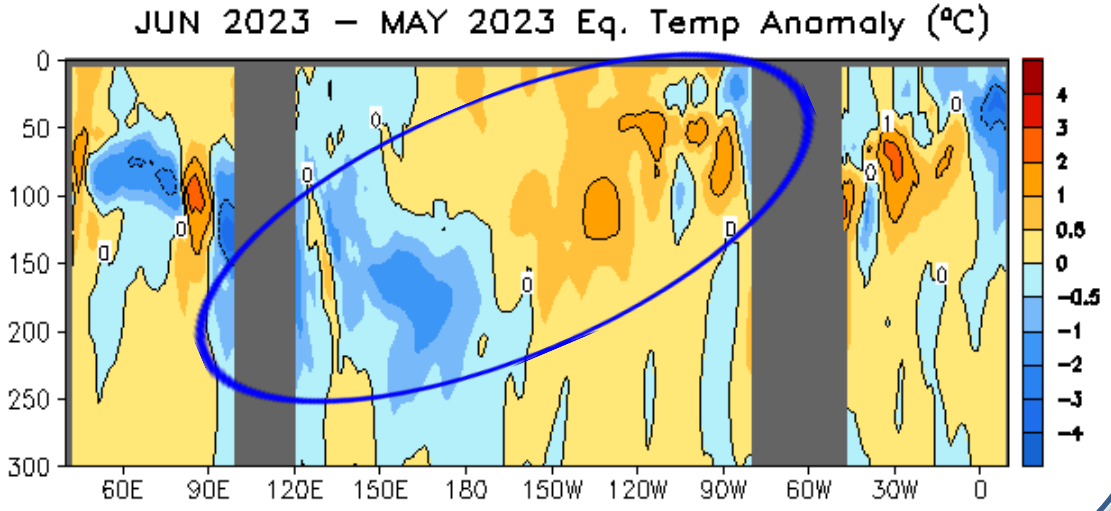
- SSTs were above average across most of the equatorial Pacific Ocean.
- The coastal El Niño continued to grow in Jun 2023.
- Strong positive SSTAs were observed in the North Pacific and the the eastern North Atlantic Ocean.

- Large SSTA tendencies were present in the high latitudes of North Atlantic Ocean.
-Positive SSTA tendencies dominated most of the equatorial Pacific.
-Negative SSTA tendencies were present in the equatorial Atlantic 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 2°S-2°N



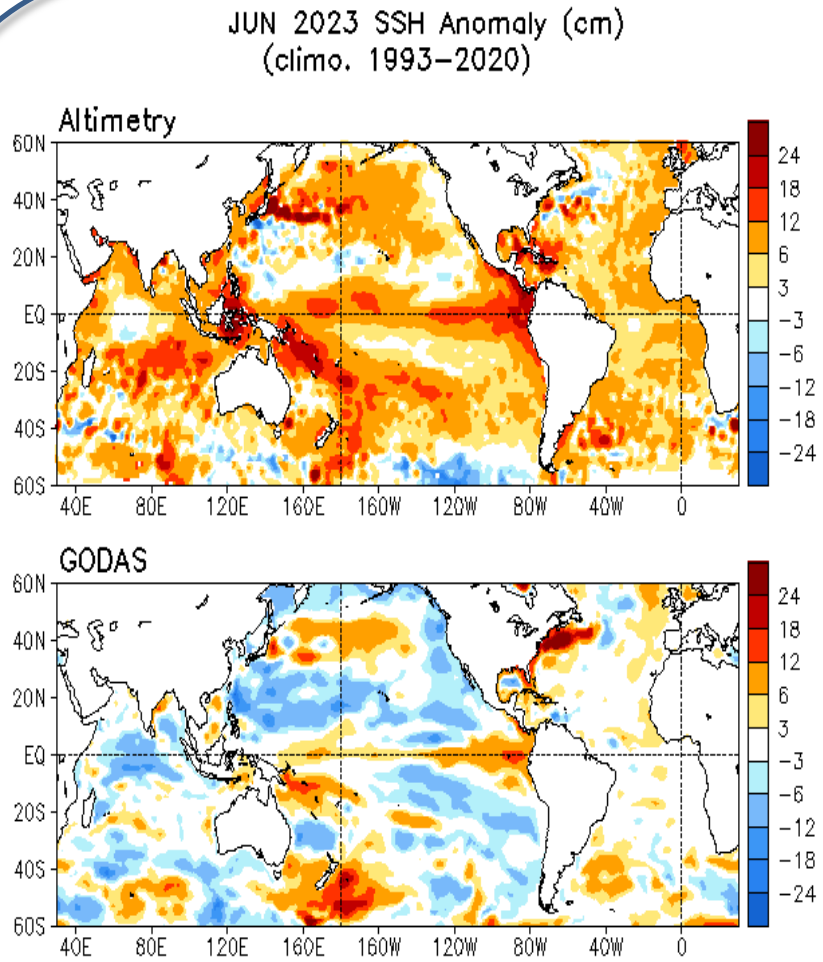


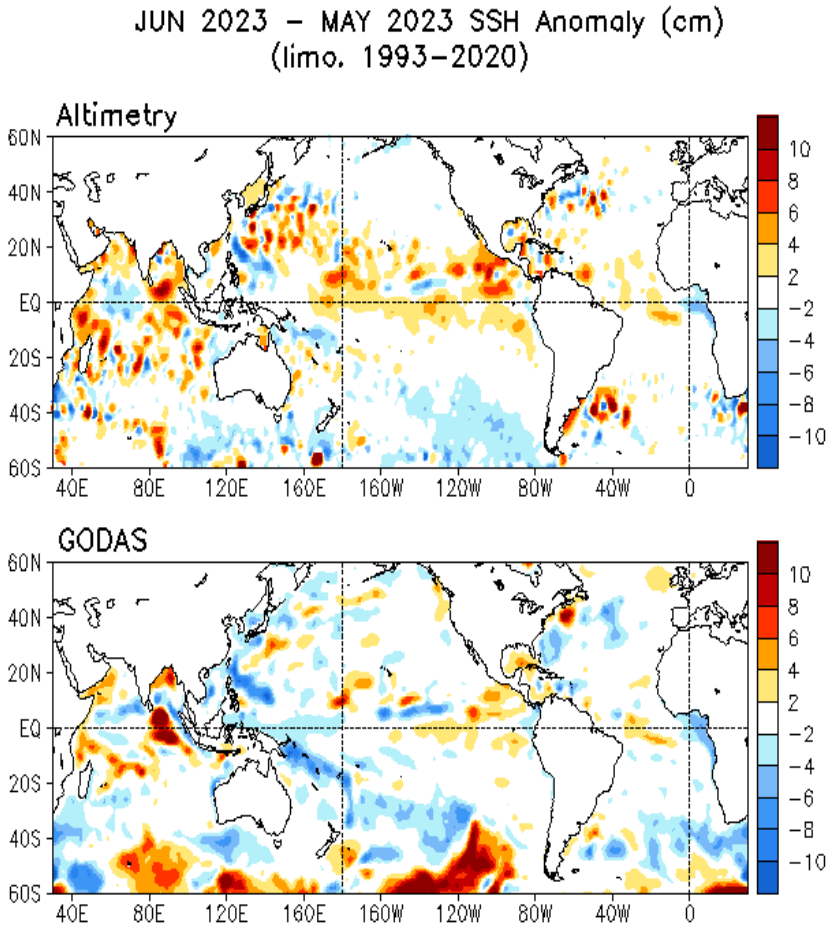
- Positive temperature anomalies were present along the thermocline in the Pacific.
- Negative temperature anomalies dominated the upper 50-150m of Indian Ocean.
- Negative temperature anomaly was present near the thermocline in the Atlantic Ocean.

- Temperature anomaly tendency was positive (negative) along the thermocline in the central-eastern (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

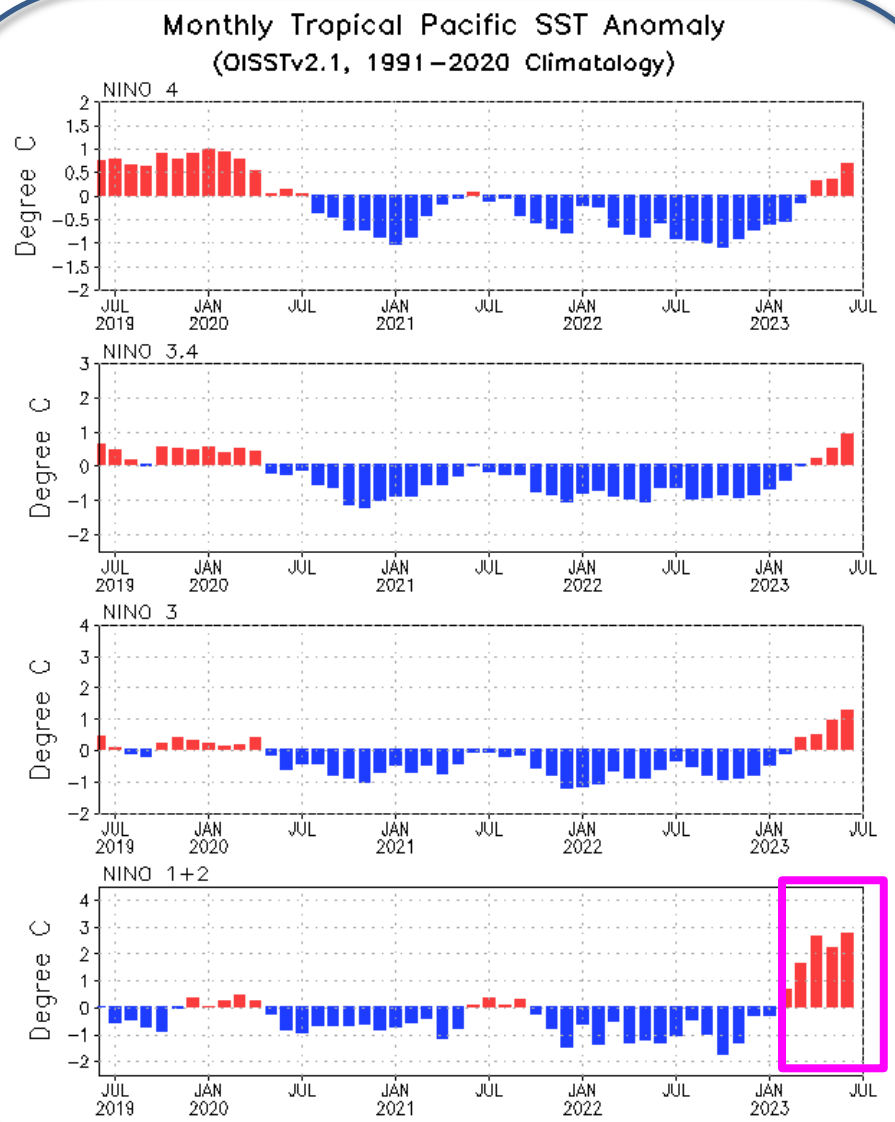


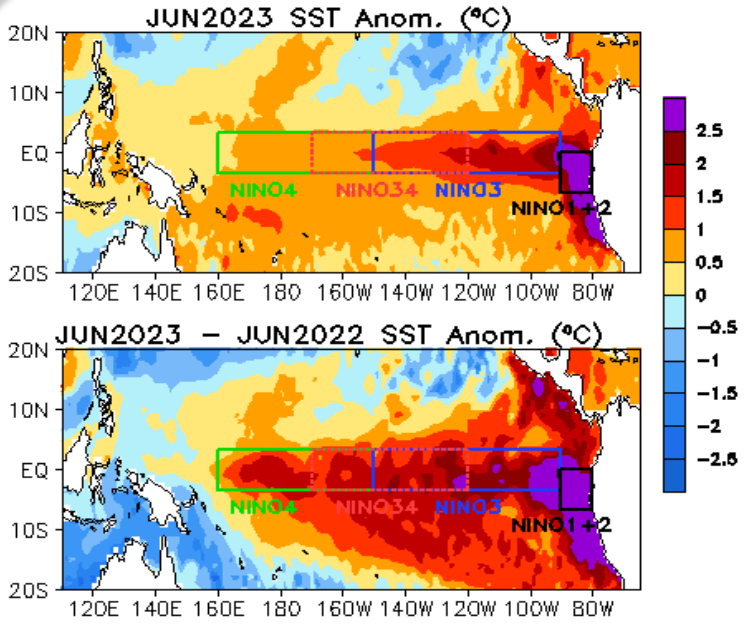


- SSHs were above normal in the equatorial Pacific in GODAS & AVISO.
- The tendencies indicated an increase (decrease) of SSH in the eastern (western) tropical Pacific.

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific Niño SST Indices





- All Niño indices strengthened in Jun 2023, with Niño3.4 = 0.9°C.

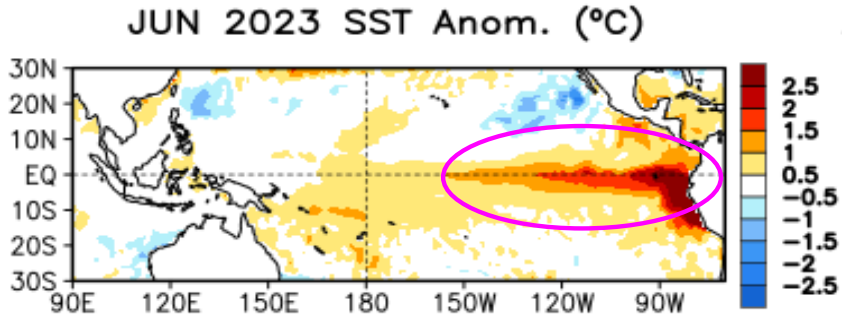
- A coastal Niño has developed since Feb 2023 and continued to grow with Niño1+2= 2.6°C in Jun 2023.

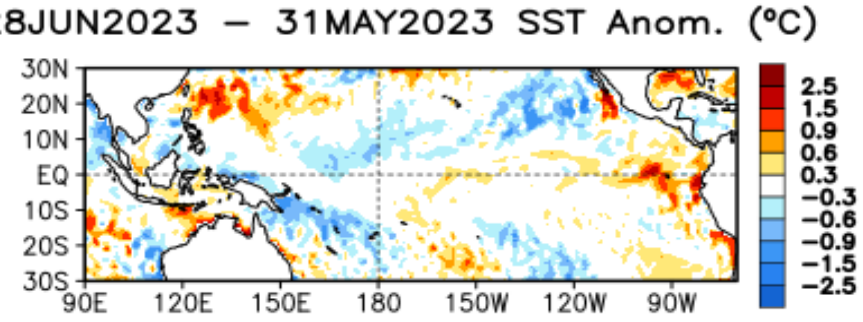
- Compared with Jun 2022, the tropical Pacific was much warmer in Jun 2023.

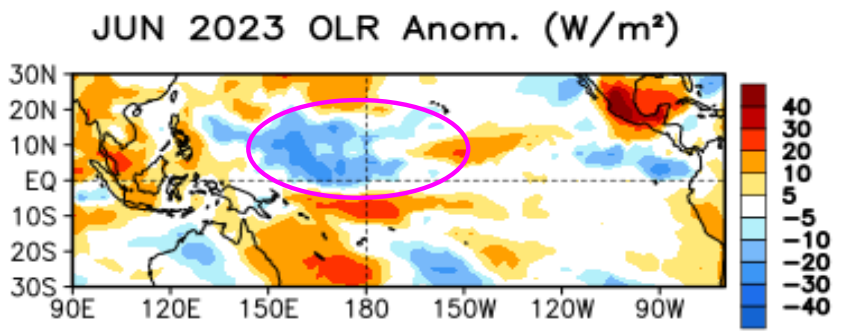
- The indices may have differences if based on different SST products.

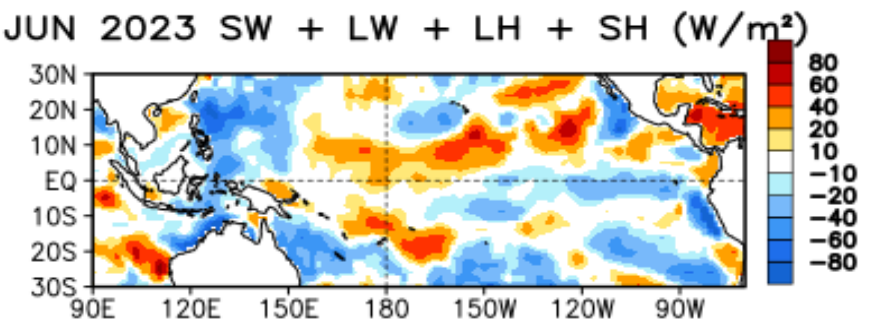
Niño region indices, calculated as the area-averaged monthly mean SSTAs (°C) for the specified region. Data are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

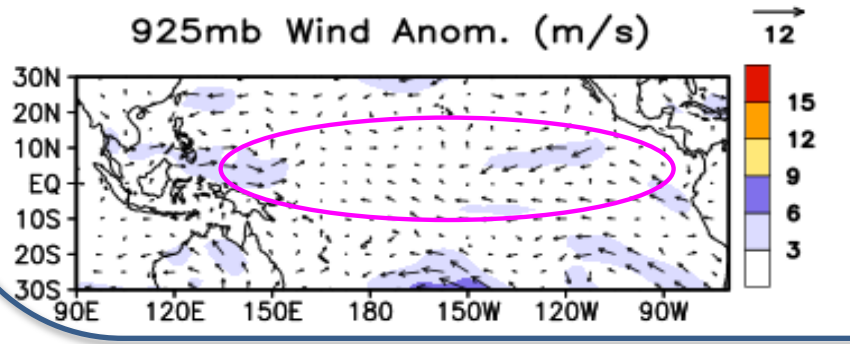
Tropical Pacific: SSTA, SSTA Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Winds

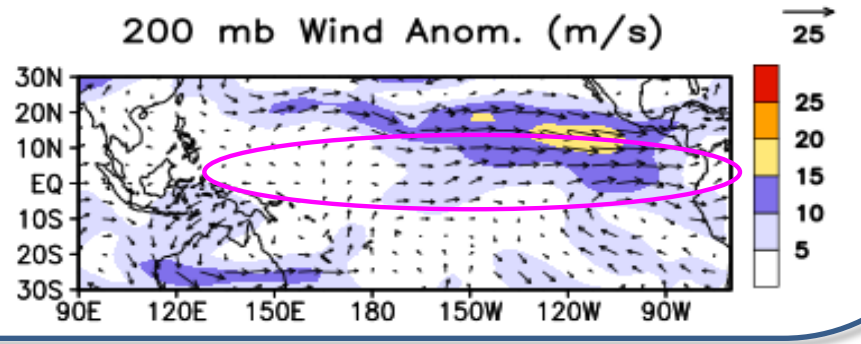






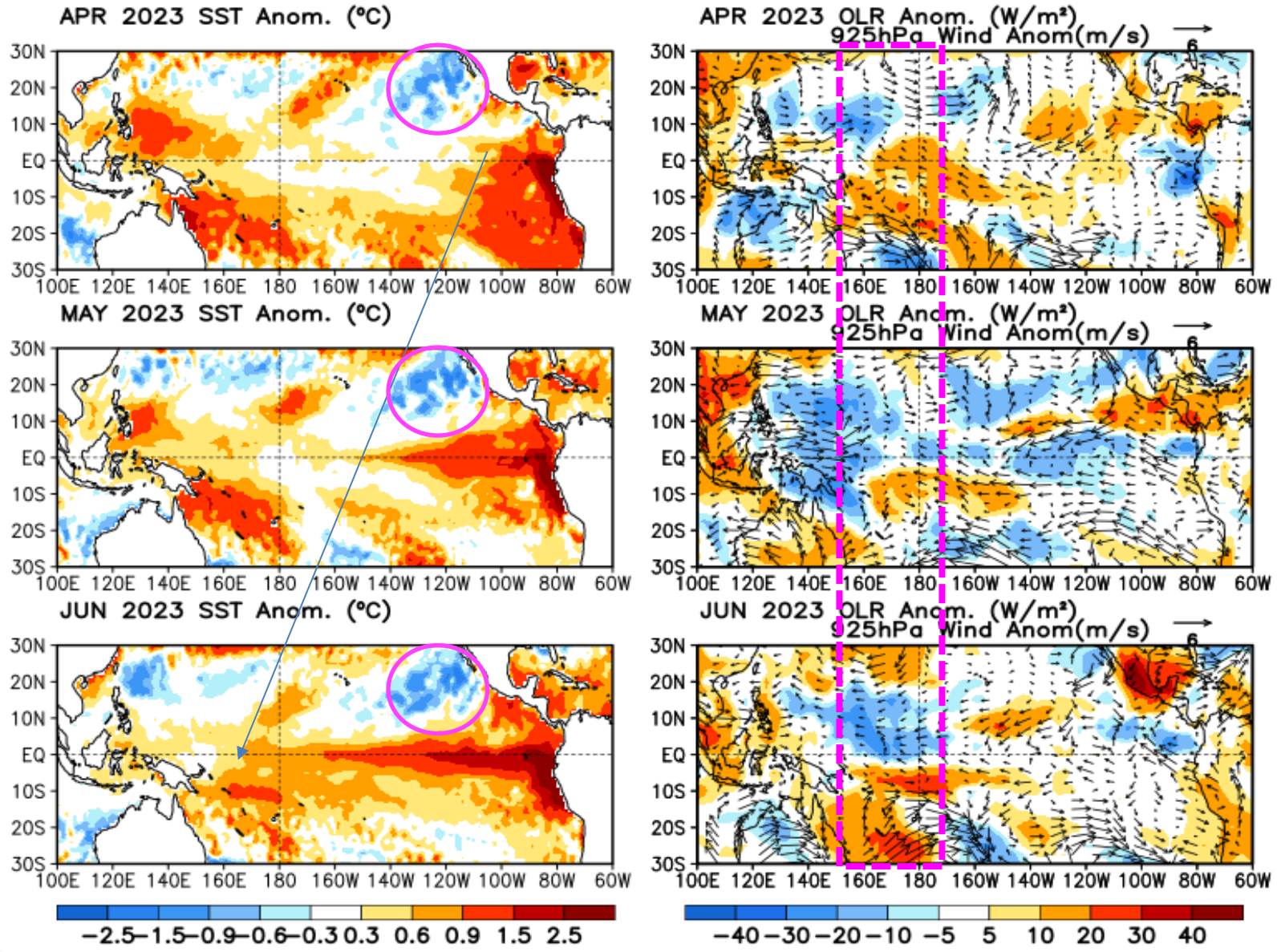




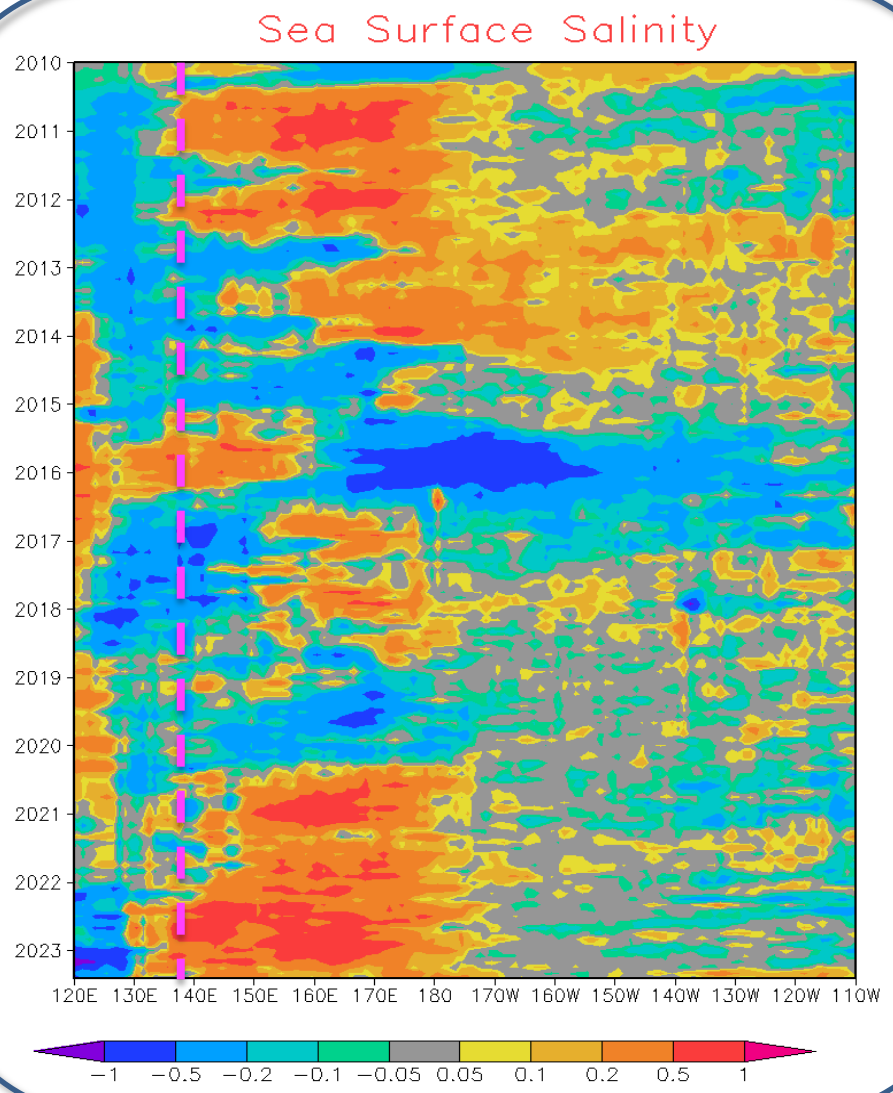


SSTAs (top-left), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly vector and its amplitude (bottom-left),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



Equatorial Pacific Sea Surface Salinity(SSS) Anomaly

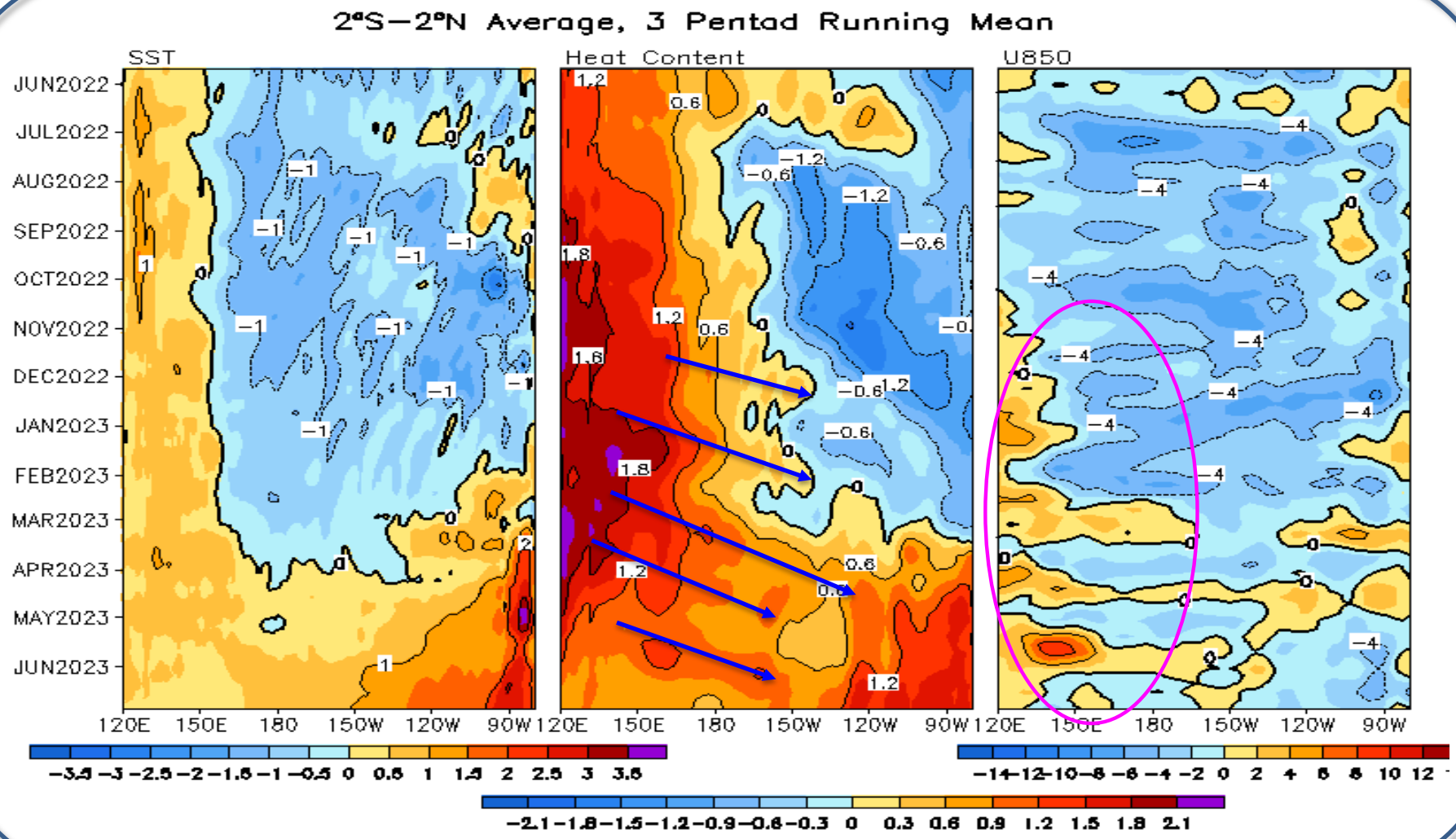


- Positive (negative) SSS anomaly presented east (west) of 140E during 2010, 2011, 2016-17, 2020-22 La Nina events.

- Positive SSS anomaly weakened in the western-central equatorial Pacific in Jun 2023.

Sea surface salinity (SSS) anomalies are derived from Blended Analysis of Surface Salinity (BASS) V0.Z (Xie et al. 2014). 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. Data is available at ftp.cpc.ncep.noaa.gov/precip/BAS.

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

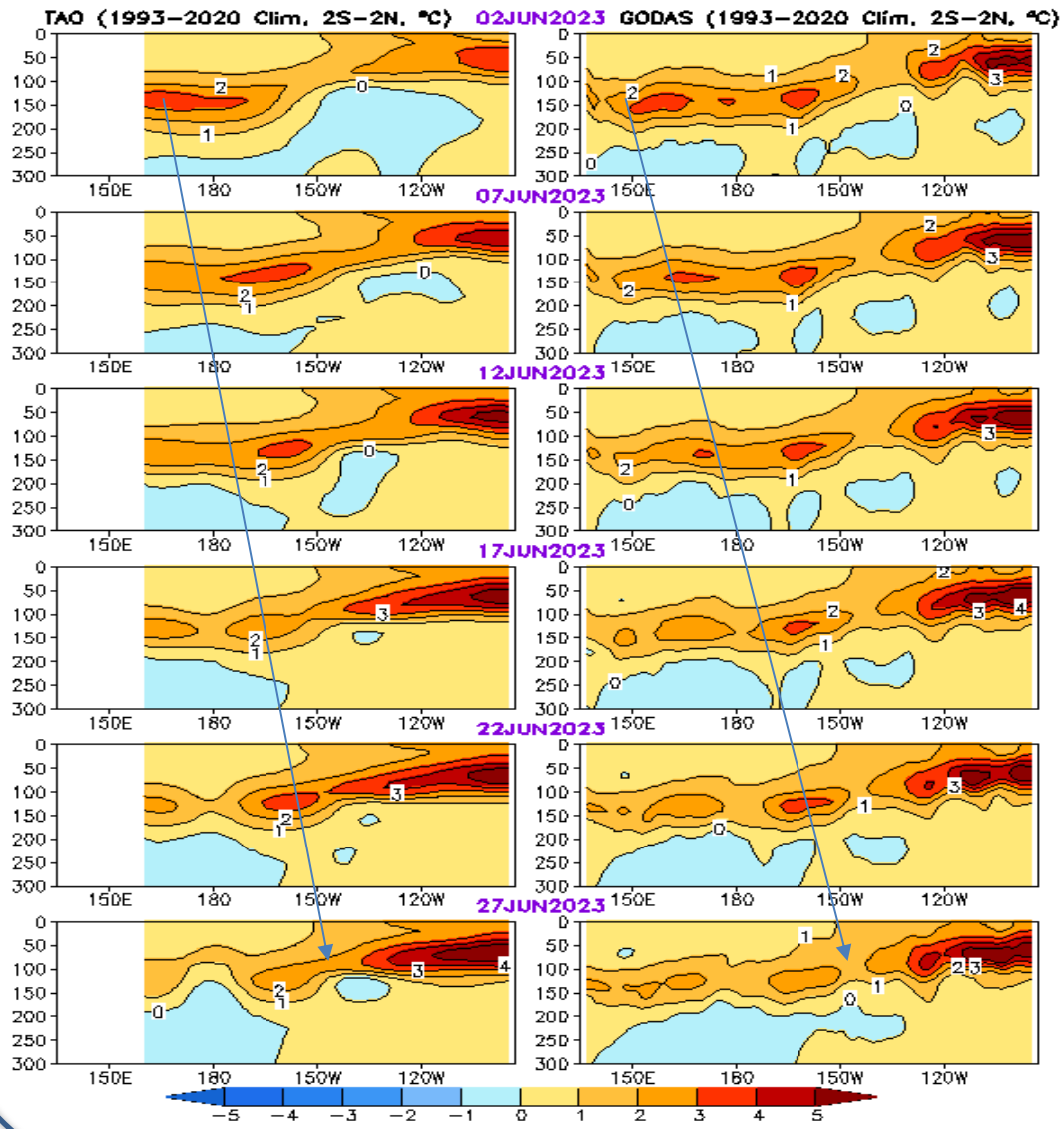


-Since Feb 2023, a set of westerly wind surges triggered downwelling Kelvin waves, helping to reinforce the subsurface warming in the central-eastern Pacific.

- Positive SST anomalies continued to strengthen and expanded westward.

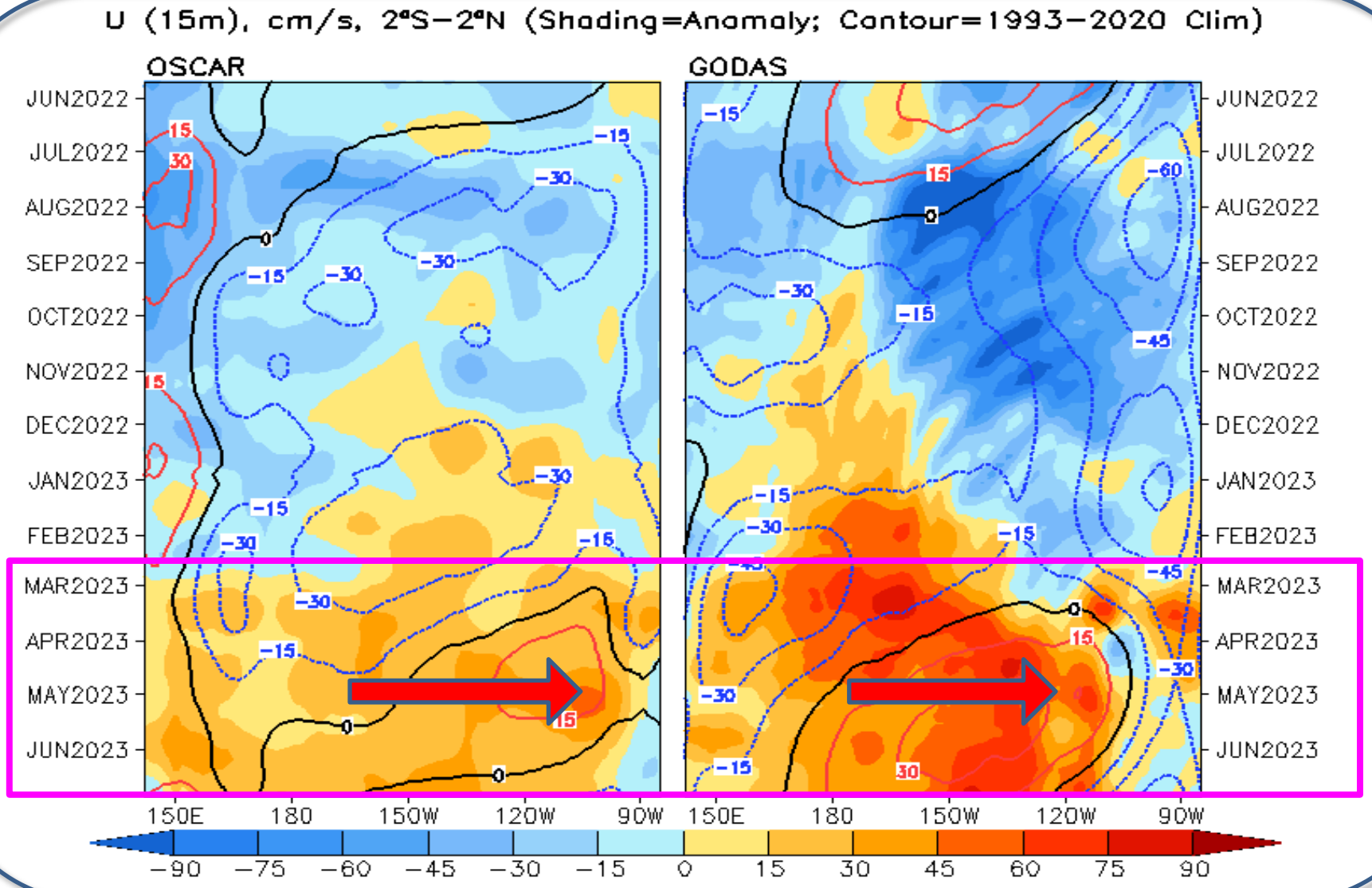
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

TAO GODAS



- Positive ocean temperature anomalies propagated eastward along the thermocline, consistent with H300 anomaly evolution (previous slide).
- Subsurface temperature anomaly in the far eastern Pacific strengthened .
- The features of the ocean temperature anomalies were similar between GODAS (model based) and TAO (objective) analysis.

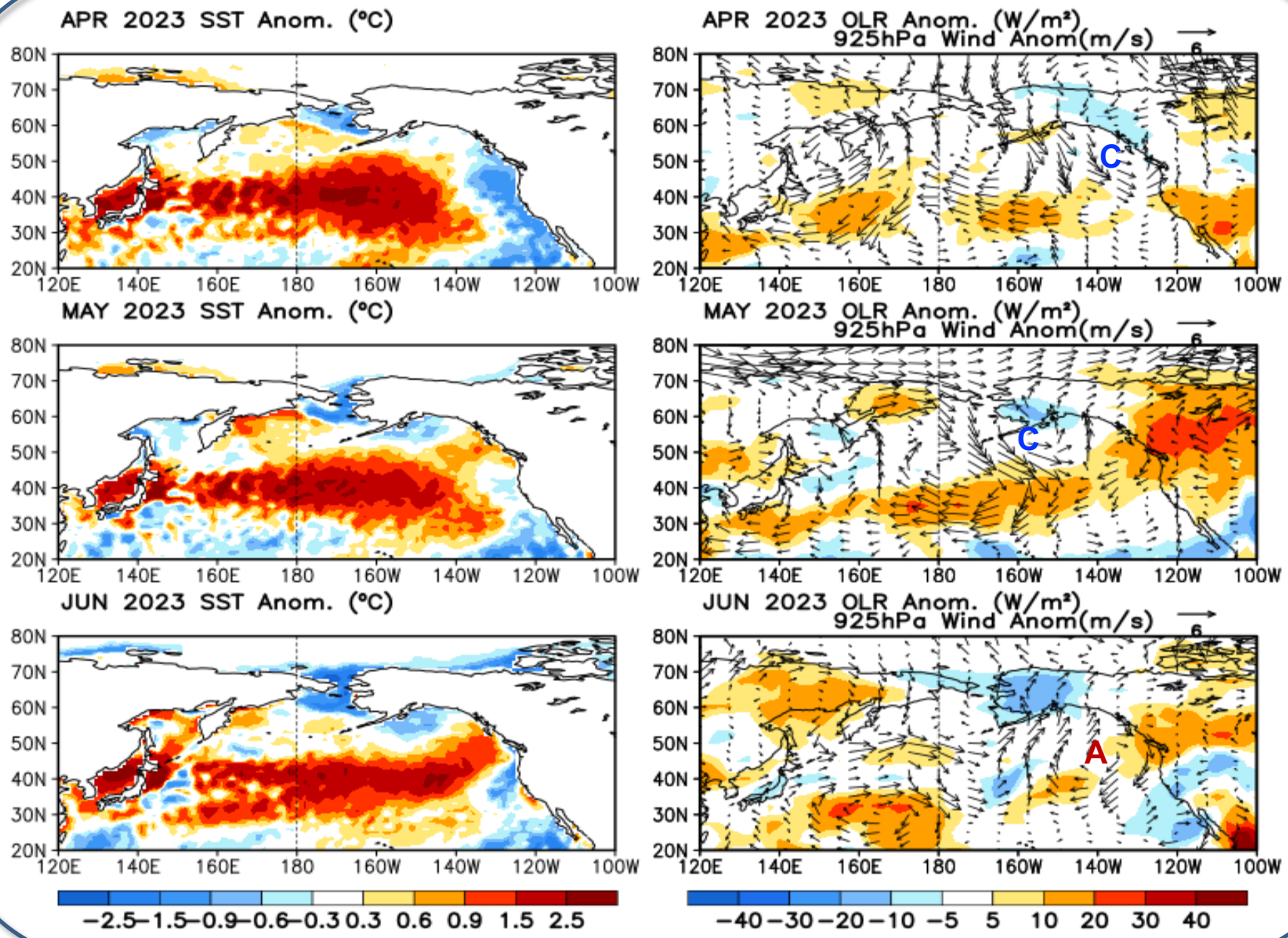
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



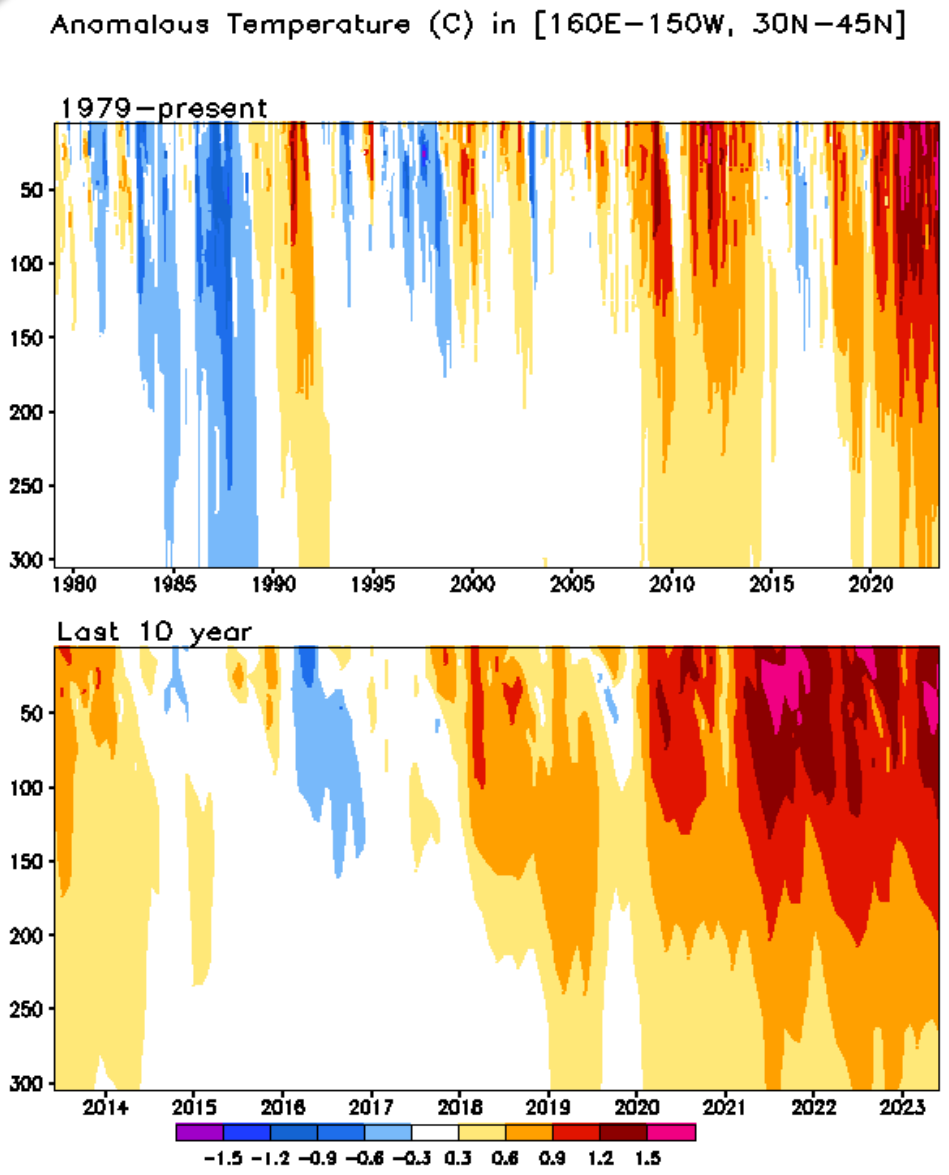
- Anomalous eastward currents were present in the equatorial Pacific in both OSCAR and GODAS since Mar 2023, which were consistent with the growth of the positive SSTA.

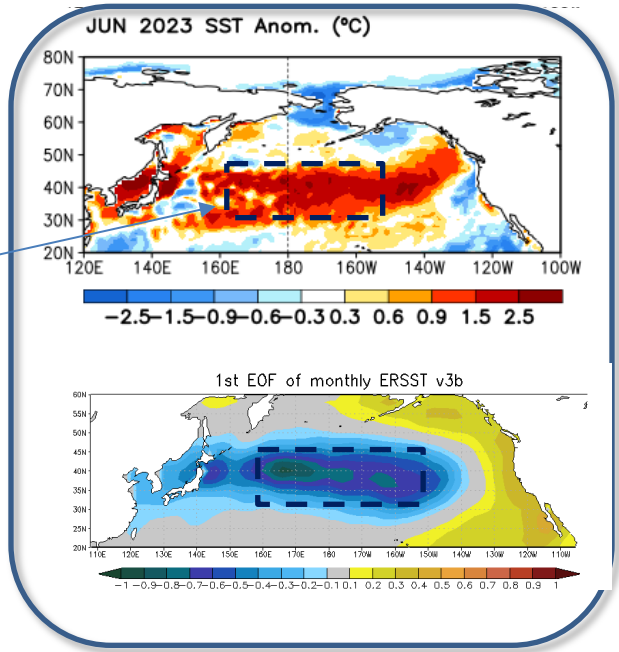
North Pacific & Arctic Oceans

Last 3- month North Pacific SST, SLP, and uv925 anomalies



Subsurface Temperature Anomaly in the Northcentral Pacific

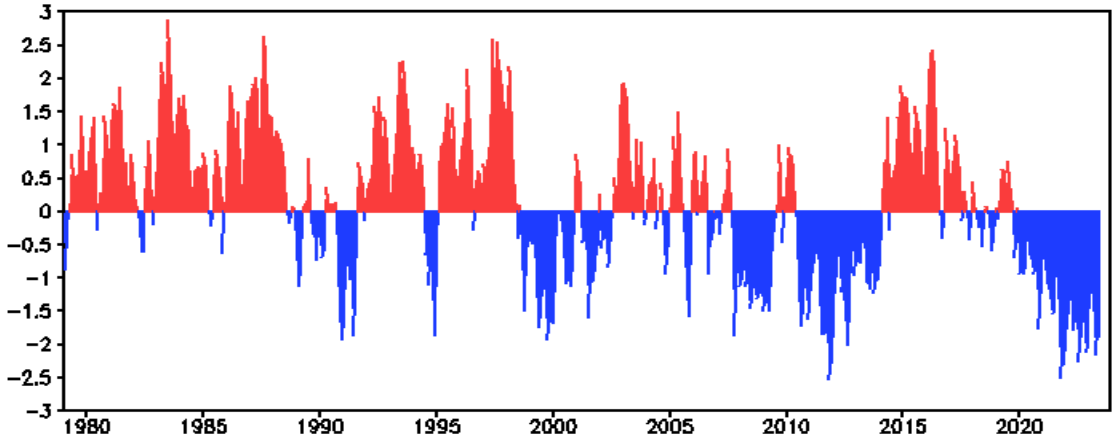




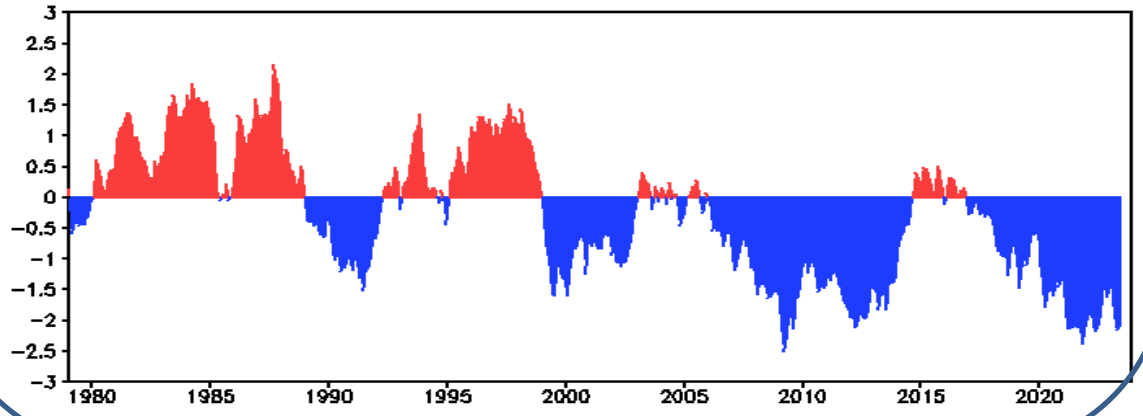
- Positive temperature anomaly (>0.9ºC) penetrated to 100m and persisted since 2020.
- Subsurface warming in the last three years is the strongest event since 1979.

Two Oceanic PDO indices

SST-based PDO (Wen et al. 2014: GRL)



H300-based PDO (Arun and Wen 2016:Mon.Wea.Rev.)



- The negative phase of PDO has persisted since Jan 2020 with PDOI = -1.9. in Jun 2023.

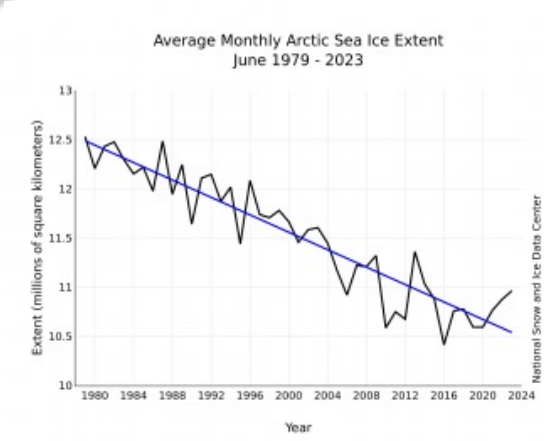
- Negative H300-based PDO index has persisted since Nov 2016, with HPDO = - 2.1 in Jun 2023.

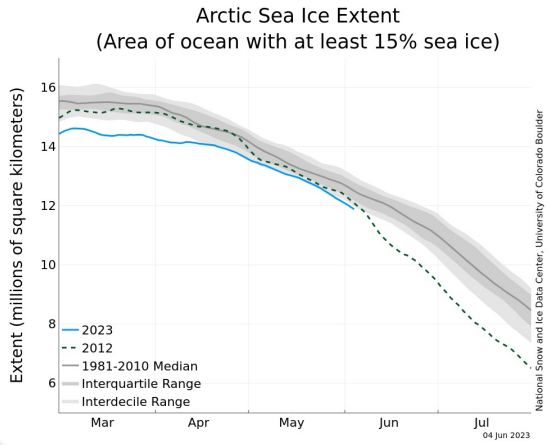
- SST-based PDO index has considerable variability both on seasonal and decadal time scales.

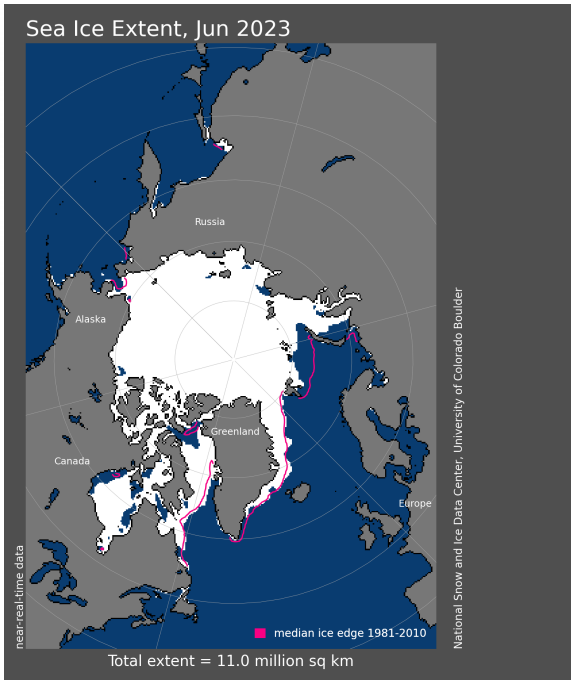
- H300-based PDO index highlights the slower variability and encapsulates an integrated view of temperature variability in the upper ocean.

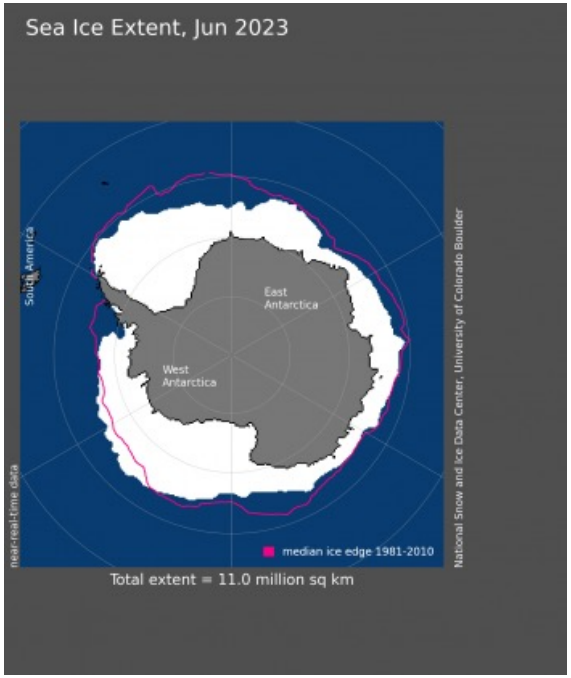
SST-based PDO is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly ERSSTv5 SST anomalies onto the 1st EOF pattern. H300-based Pacific Decadal Oscillation is defined as the projection of monthly mean H300 anomalies from NCEP GODAS onto their first EOF vector in the North Pacific. PDO indices are downloadable from https://www.cpc.ncep.noaa.gov/products/GODAS/ocean_briefing.shtml.

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





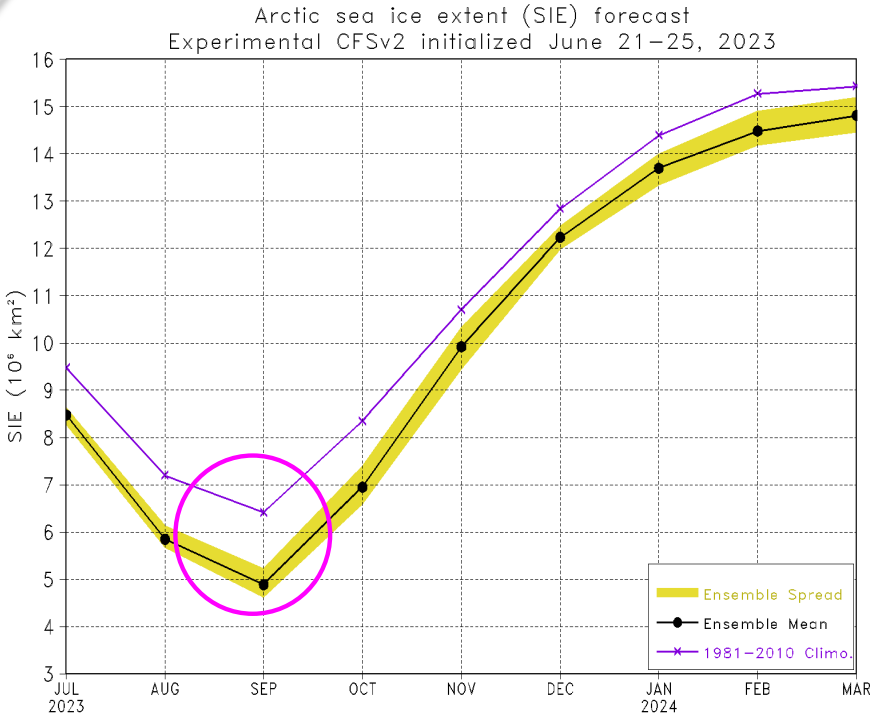




- Average Arctic sea ice extent during Jun 2023 was 10.96 million square kilometers, the 13th lowest Jun in the satellite record.
- Antarctic sea ice extent is continuing to track at extreme record low levels at record low levels since 1979.

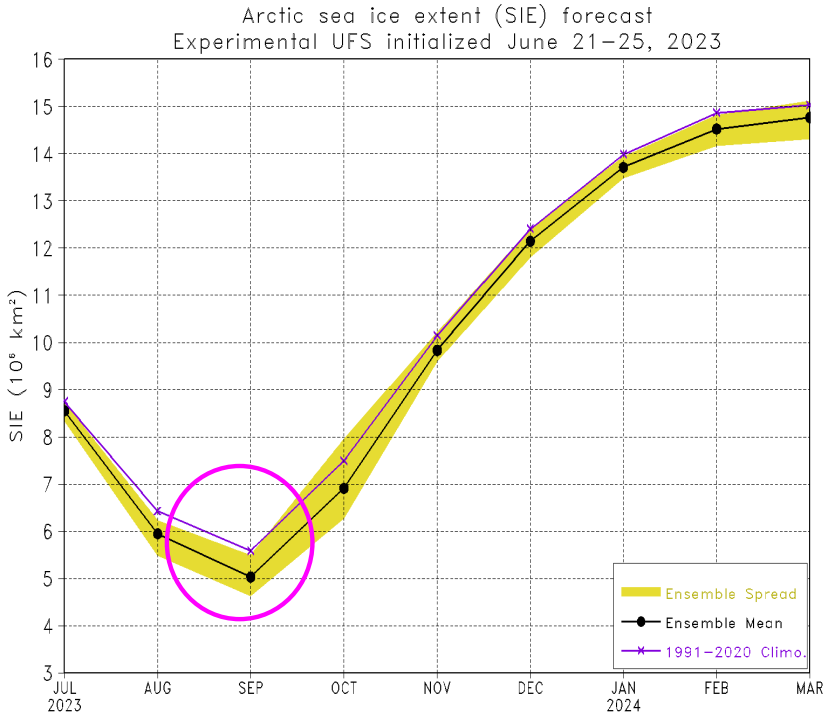
NCEP/CPC Arctic Sea Ice Extent (SIE) Forecast

CFSm5



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

UFS

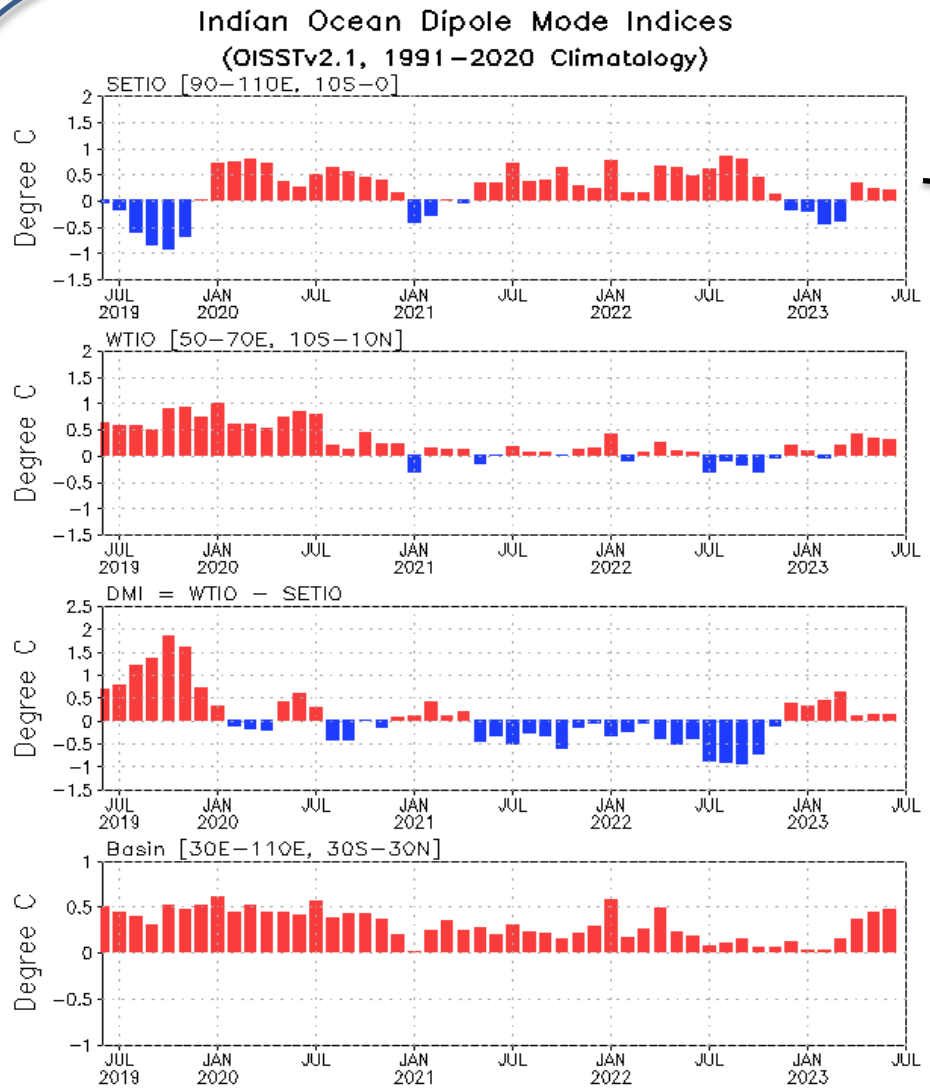


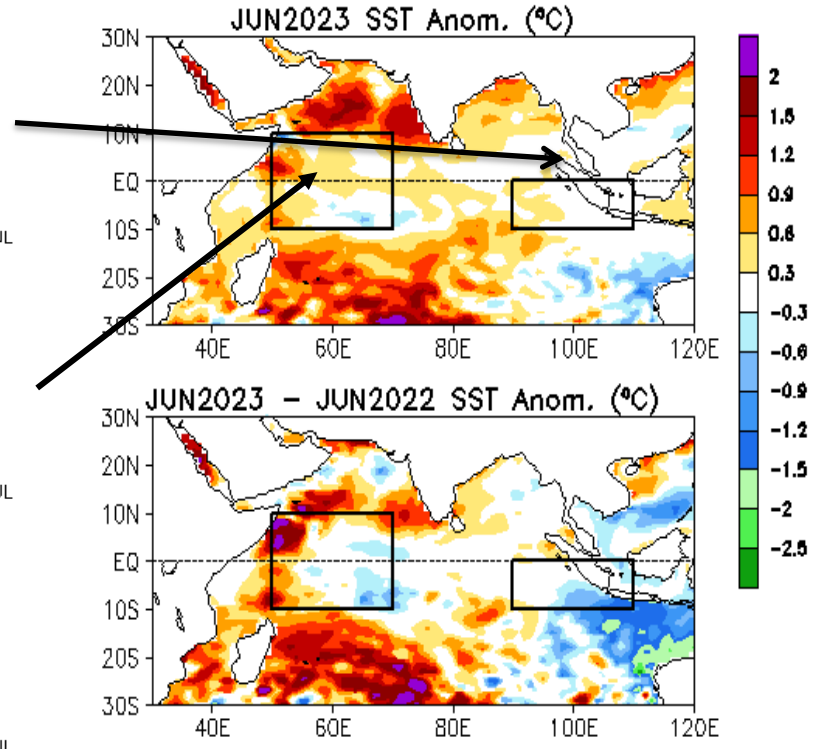
https://www.cpc.ncep.noaa.gov/products/people/jszhu/seaice_seasonal/index.html

- Both CFSm5 and UFS produced forecasts suggest SIE will be around 5 million square kilometers in Sep 2023.

Indian Ocean

Evolution of Indian Ocean SST Indices

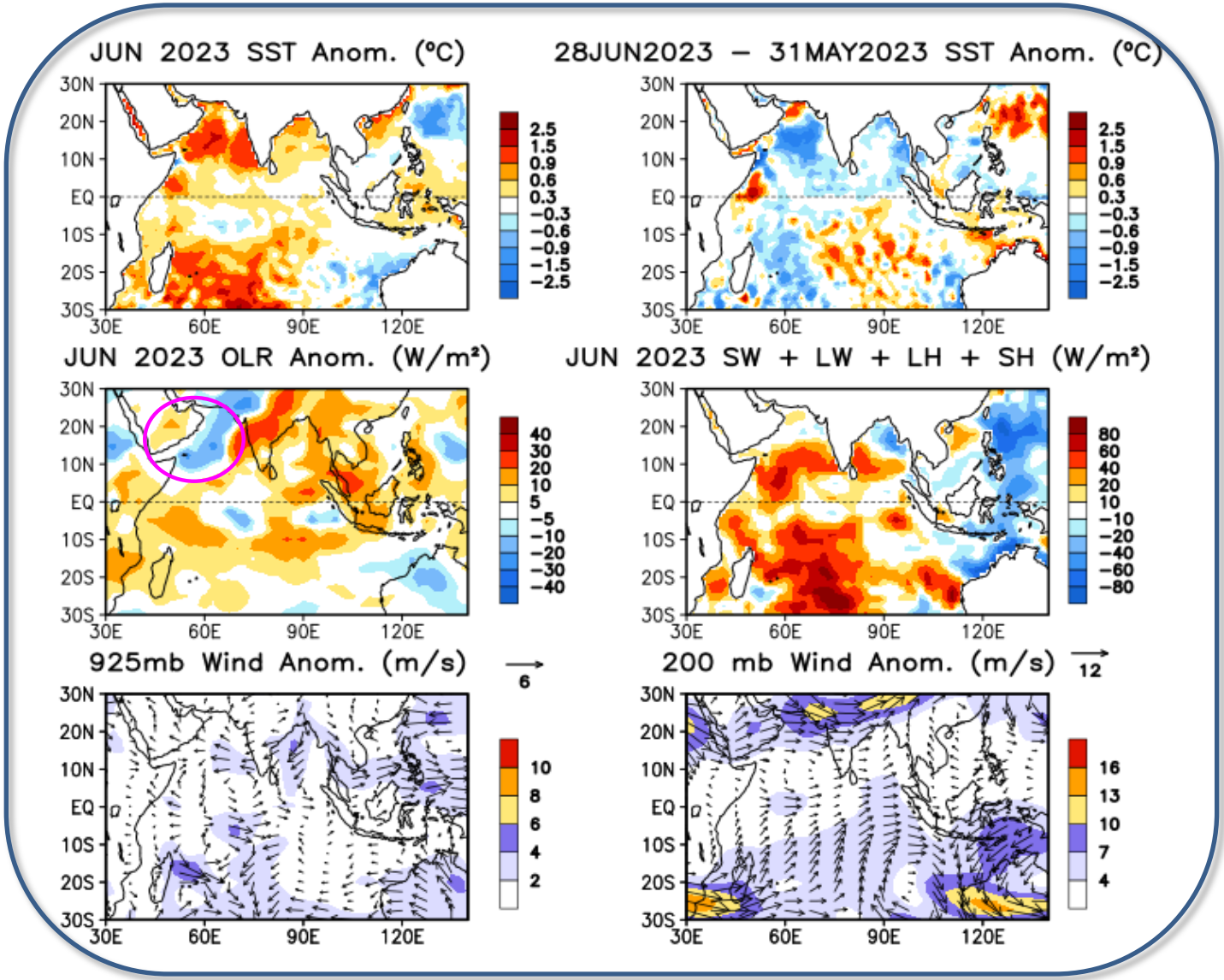




- Positive SSTAs dominated the tropical Indian Ocean basin in Jun 2023.

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

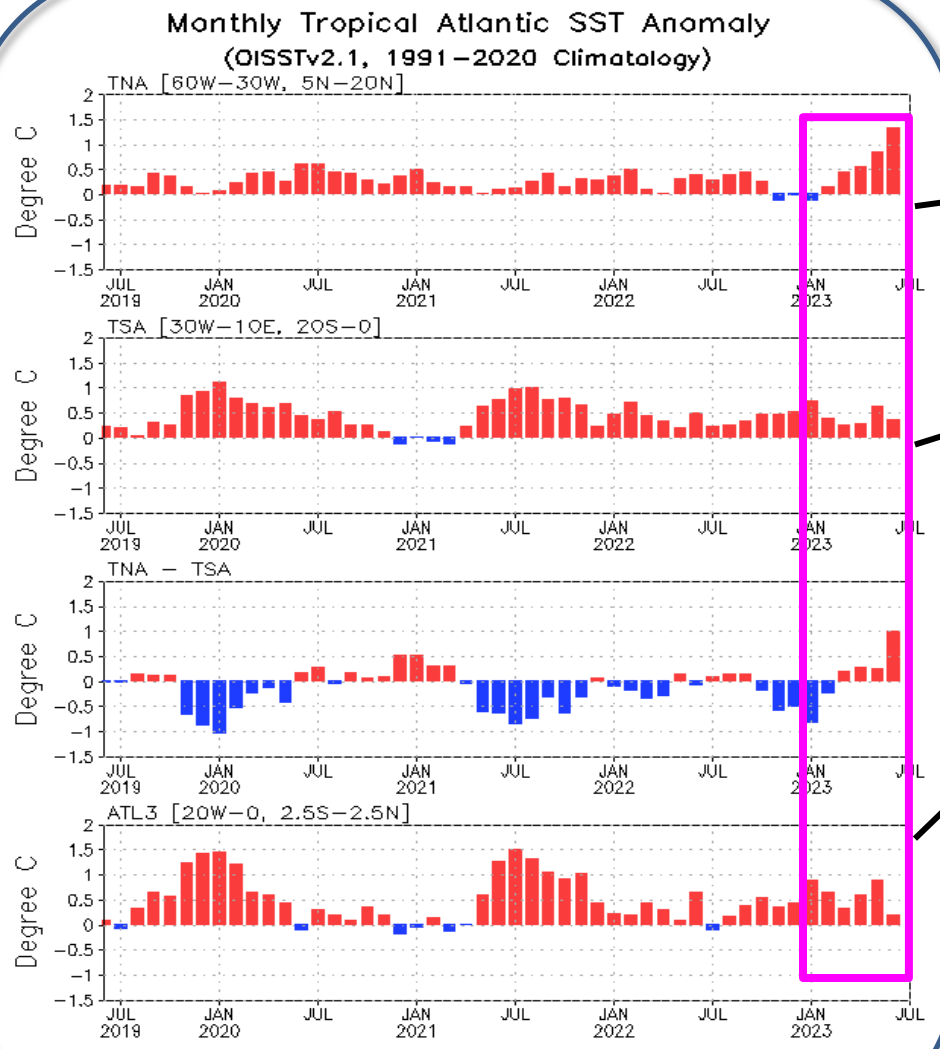


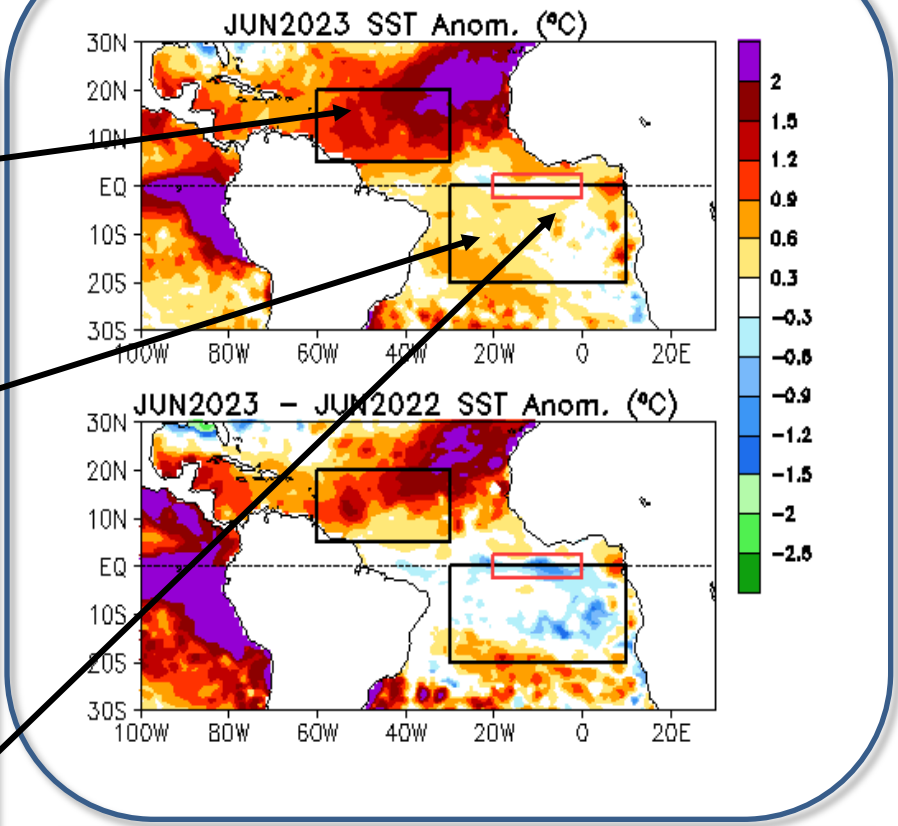
- Convection was enhanced near the Arabian Sea.

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.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

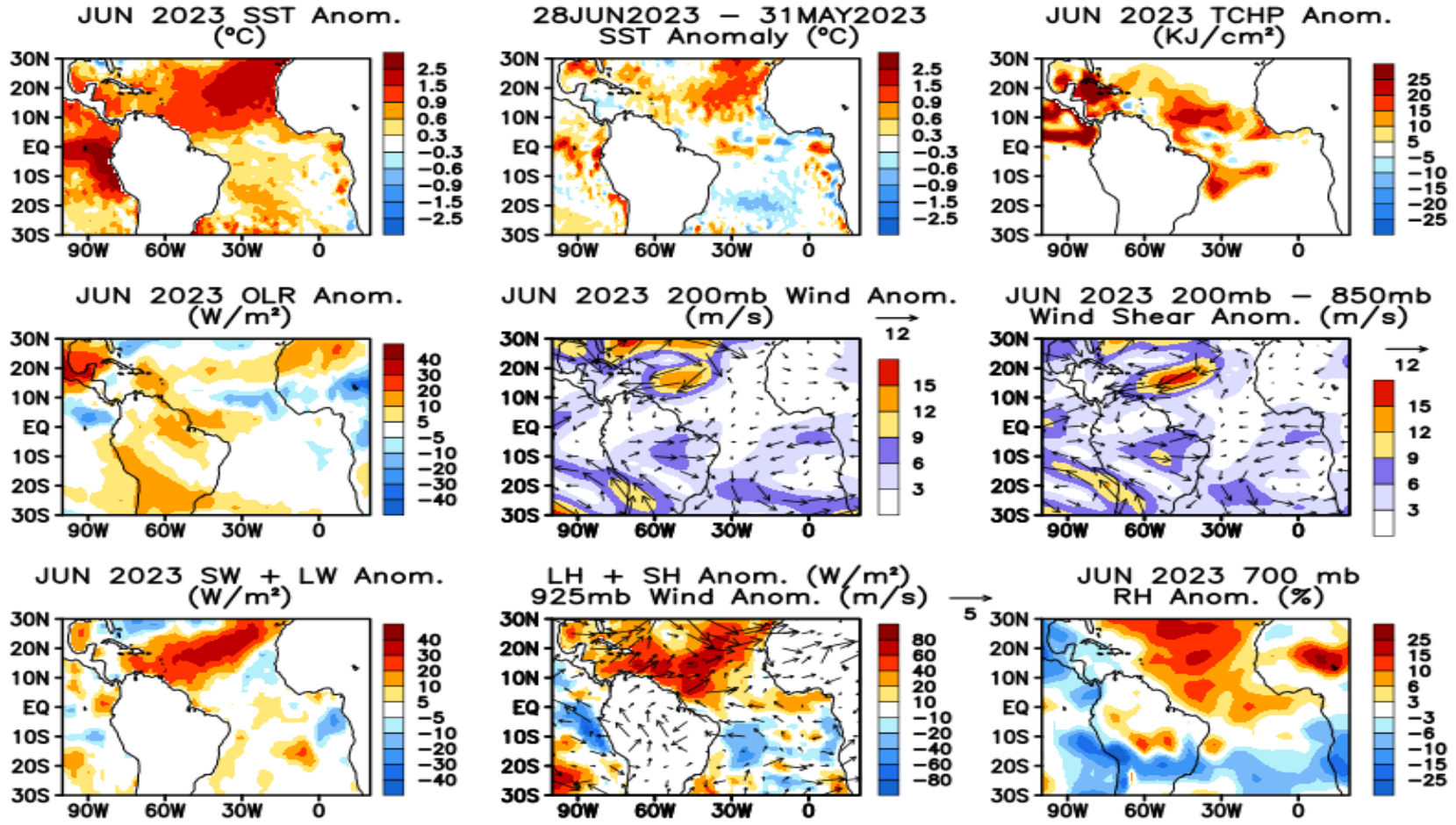




- Positive SSTA in the tropical north Atlantic increased rapidly in Jun 2023, contributing to the substantial increase in the Meridional mode index.
- Positive ATL3 index decreased by 0.7 ^{O}C in Jun 2023.

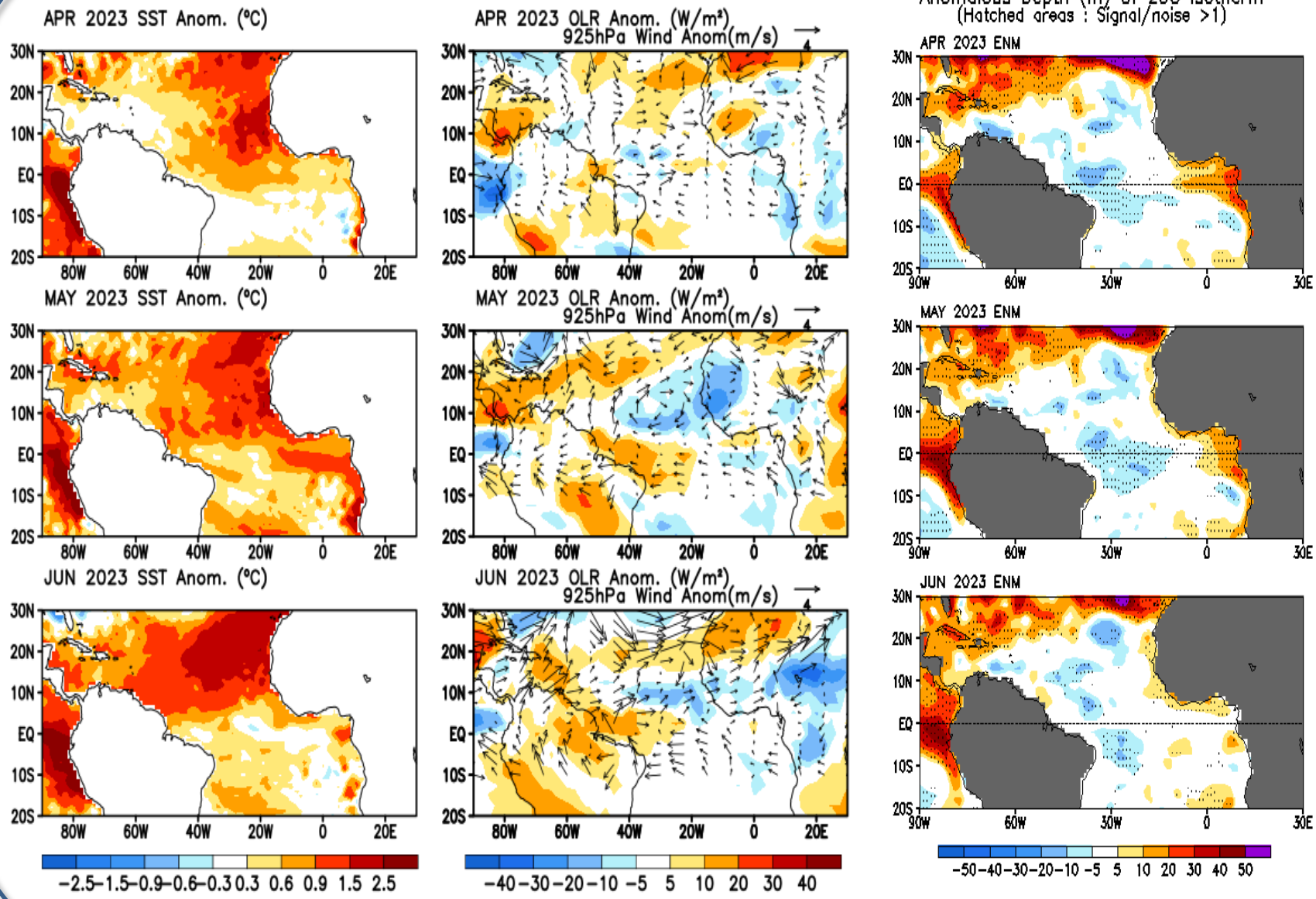
Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean SSTAs (^{O}C) for the TNA [60^{O}W-30^{O}W, 5ºN-20^{O}N], TSA [30^{O}W-10^{O}E, 20^{O}S-0] and ATL3 [20^{O}W-0, 2.5^{O}S-2.5^{O}N] regions, and Meridional Gradient Index, defined as differences between TNA and 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.

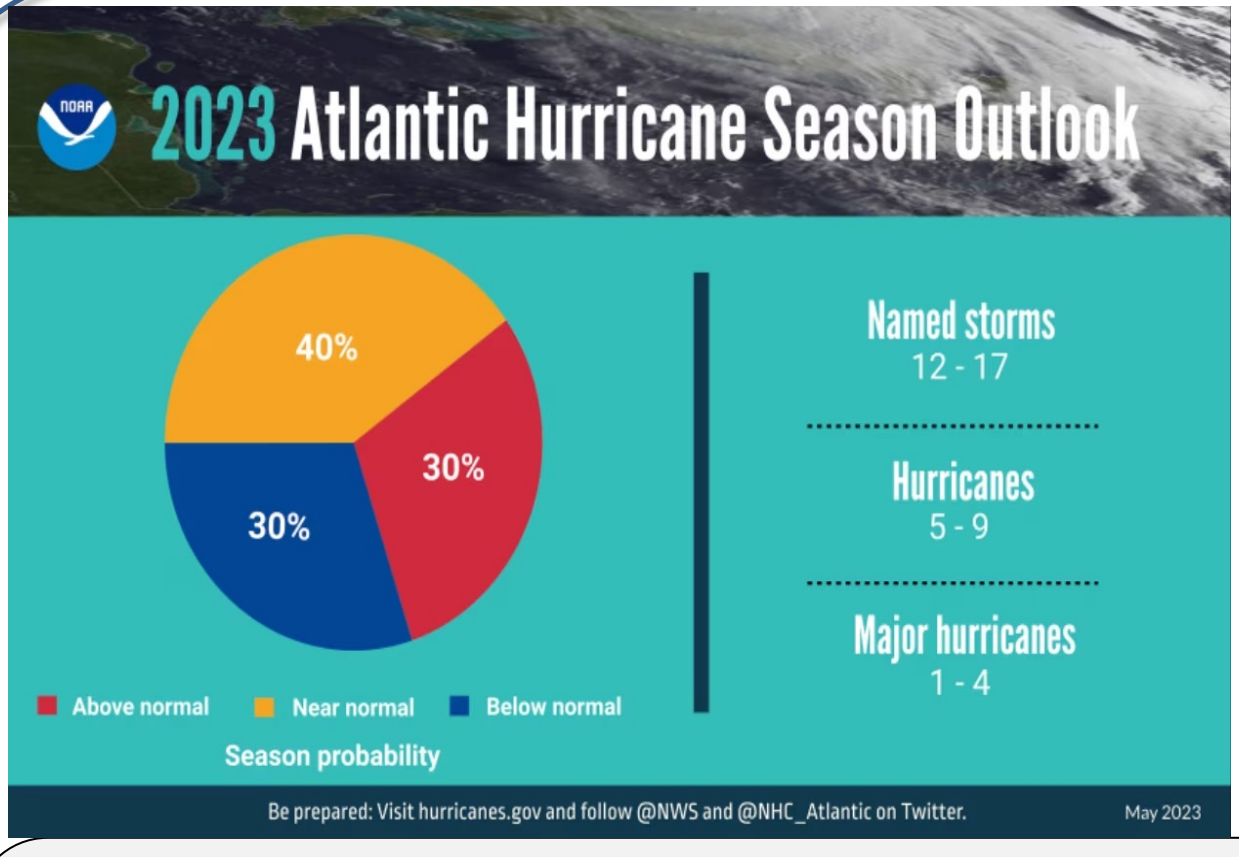


Top Row: SSTA (left; OI SST), SSTA tendency (central), Tropical Cyclone Heat Potential anomaly (right; GODAS).
Middle row: OLR (left; NOAA 18 AVHRR IR), UV200 (central; NCEP CDAS), UV200-UV850 (right; NCEP CDAS) anomalies.
Bottom row: SW+LW (left), LH+SH (central), Relative humidity at 700 hPa (right; NCEP CDAS) anomalies.
Anomalies are departures from the 1991-2020 base period means.

Last 3-month Atlantic SST , OLR & uv925 and D20 anomalies



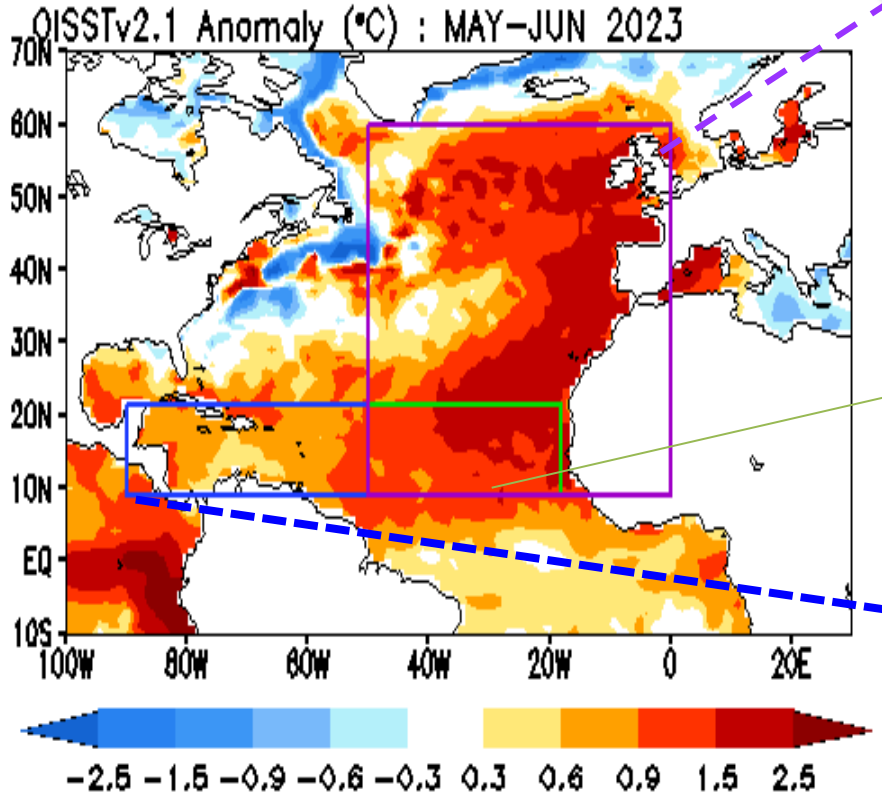
2023 Atlantic Hurricane Season Outlook

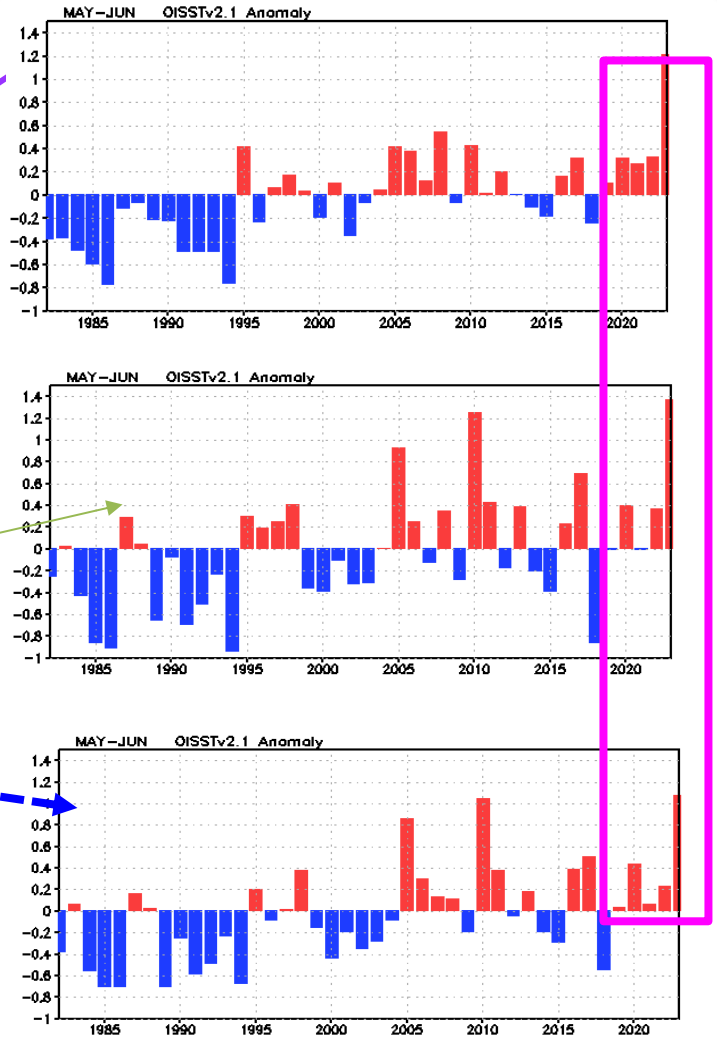


- May 25, 2023: NOAA CPC forecast a range of 12 to 17 total named storms. Of those, 5 to 9 could become hurricanes, including 1 to 4 major hurricanes (category 3, 4 or 5). NOAA has a 70% confidence in these ranges.

"…. 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)*

Evolution of SST anomaly in the North Atlantic





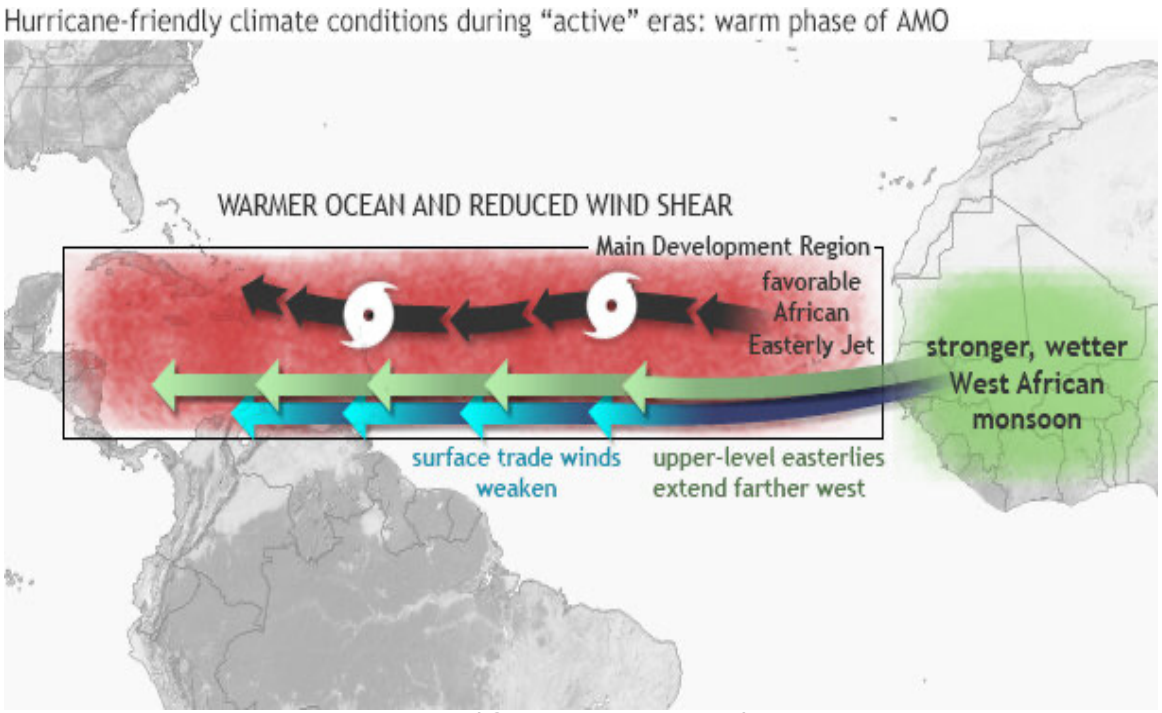
2023 Atlantic Hurricane Season Activities

https://en.wikipedia.org/wiki/2023_Atlantic_hurricane_season

- By Jul 10 2023, four tropical storms formed.

Atlantic	Observations (By Jul 10)	Outlook (May 25) 40% near-normal	(1991-2020)
Total storms	4	12-17	14
Hurricanes	0	5-9	7
Major hurricanes	0	1-4	3

Hurricane-friendly Climate Conditions



(Gerry Bell,2014)

https://www.climate.gov/news-features/blogs/enso/impacts-el-ni%C3%B1o-and-la-ni%C3%B1a-hurricane-season

Established theories:

- Warm phase of Atlantic Multi-decadal Oscillation (AMO)
- Warmer SSTs across the Atlantic hurricane main development region
- Reduced wind shear (i.e ENSO impact
- Stronger West African monsoon

A potential predictor for seasonal outlook: Atlantic Niño

(Courtesy of Dongmin Kim)

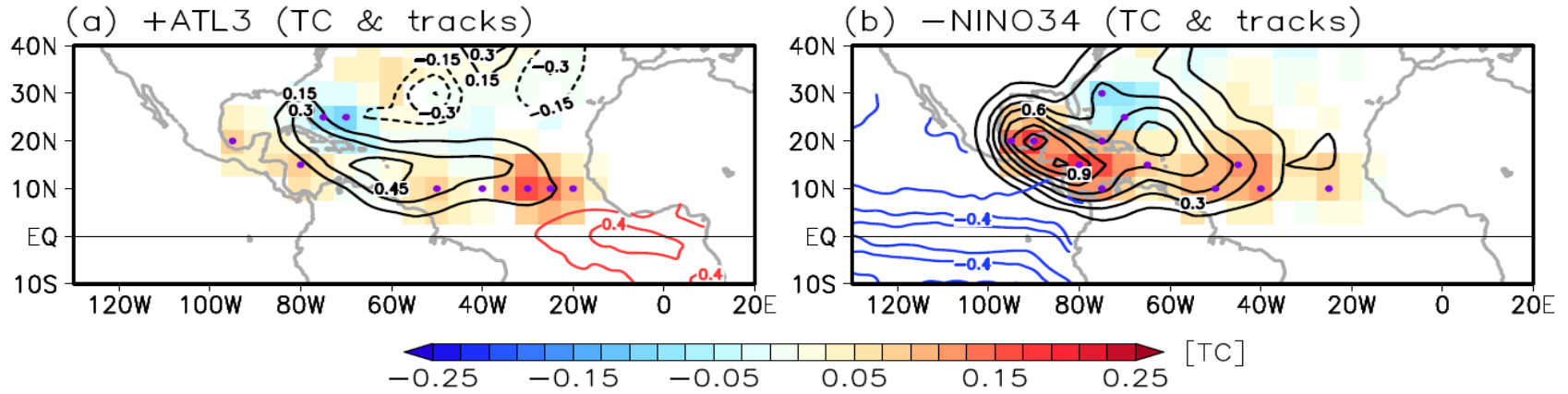
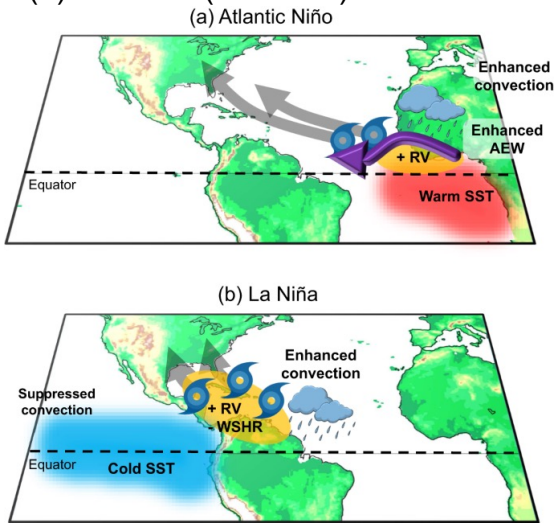


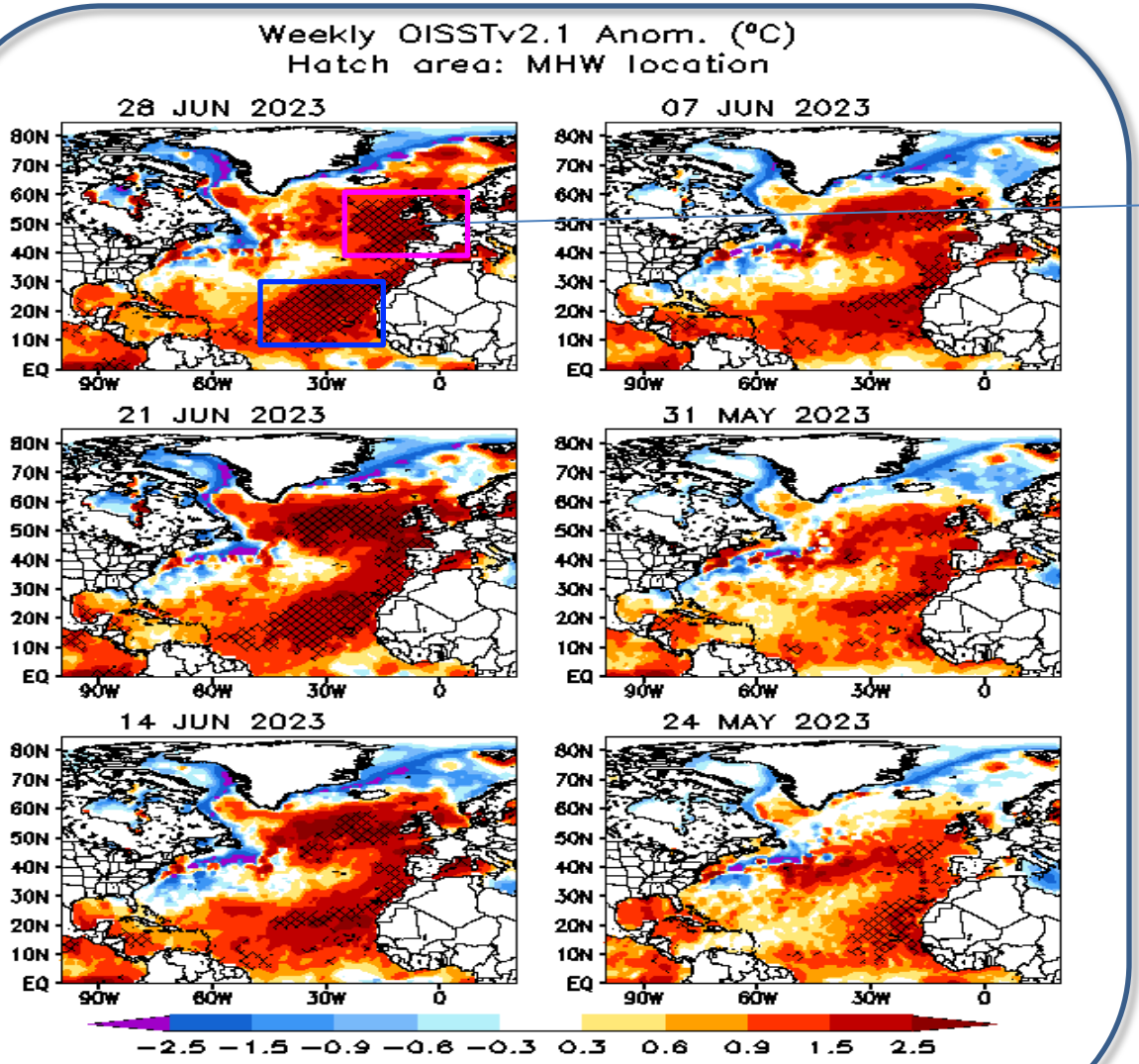
Fig. Partial regressions of tropical cyclone genesis (shaded), track density (black contours), and sea surface temperature anomalies (red and blue contours, interval is 0.2 K) onto (a) Atlantic Niño (ATL3) and (b) Niño 3.4 (NINO3.4) indices

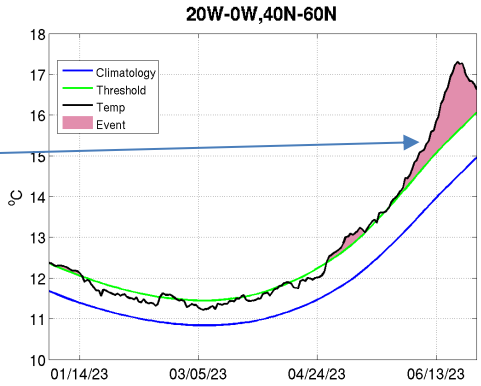
- Atlantic Niño/Niña is a dominant climate mode during Atlantic hurricane season (June–November).
- Atlantic Niño, by strengthening the Atlantic inter-tropical convergence zone rainband, enhances African easterly wave activity and low-level cyclonic vorticity across the deep tropical eastern North Atlantic. These conditions increase the likelihood of hurricanes developing in the deep tropics near the Cape Verde islands
- Atlantic Niño/Niña may serve as an additional predictor to improve seasonal Atlantic hurricane outlooks, especially when ENSO and AMM are in near-neutral phases



Kim, D. et al. (2023): Increase in Cape Verde hurricanes during Atlantic Niño. *Nat Commun* **14**, 3704 https://doi.org/10.1038/s41467-023-39467-5

Weekly SST anomaly and MHWs in the North Atlantic

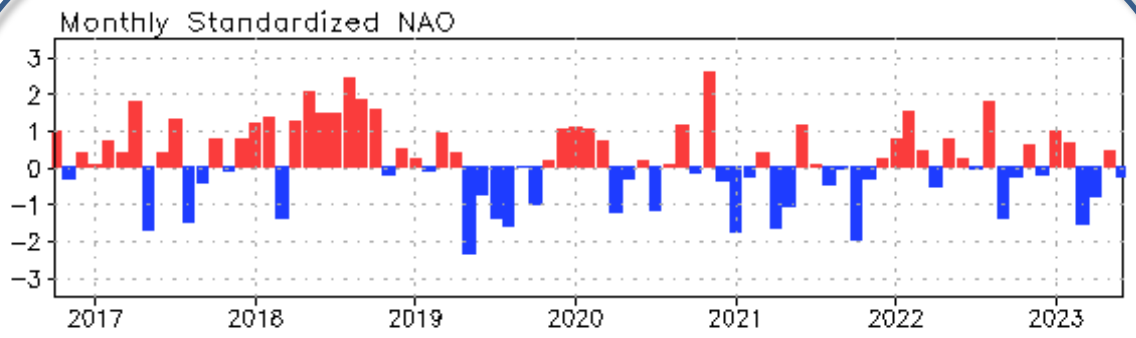


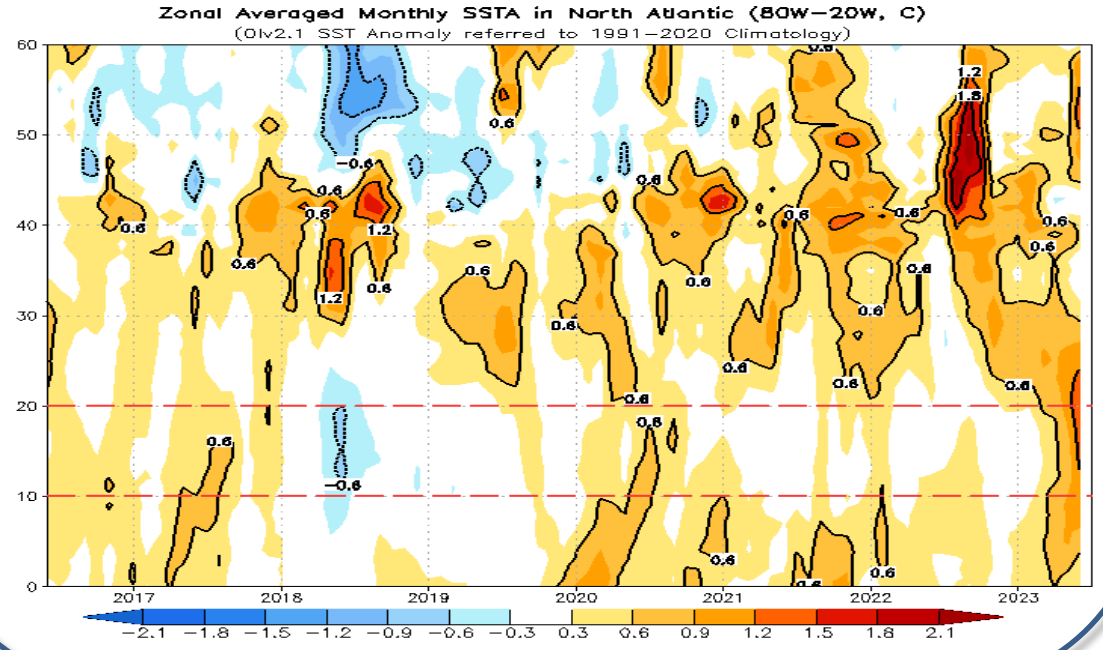


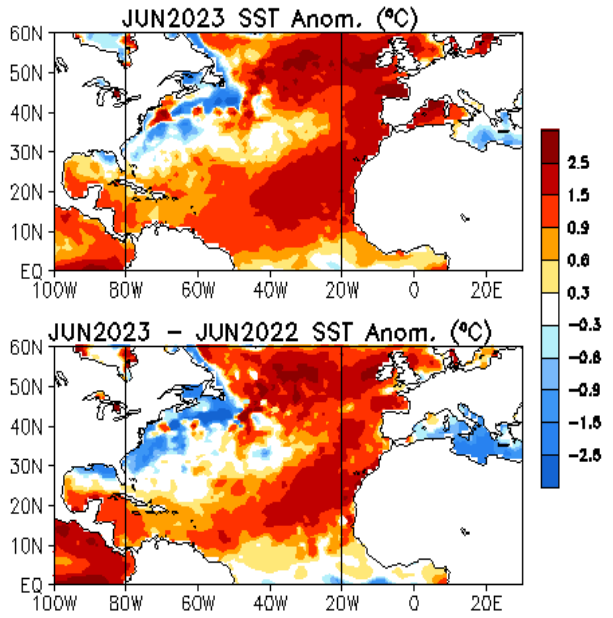
- Strong MHWs were observed near the coast of United Kingdom and Ireland, and northeastern tropical Atlantic Ocean.

(Left panel) Weekly SST anomaly (shaded) and locations experience Marine heat waves (hatched) by the date labelled in the plot. (right panel) SST evolution at a specific location. Green line and blue line denote the seasonal 90th percentile and daily climatology, respectively. Shaded area denotes the periods experiencing MHW. MHW is defined as a discrete prolonged warmer than 90th percentile of daily SST for at least 14 days. Data is derived from NCEI OISSTv2.1 and the climatology reference period is 1991-2020

NAO and SST Anomaly in North Atlantic





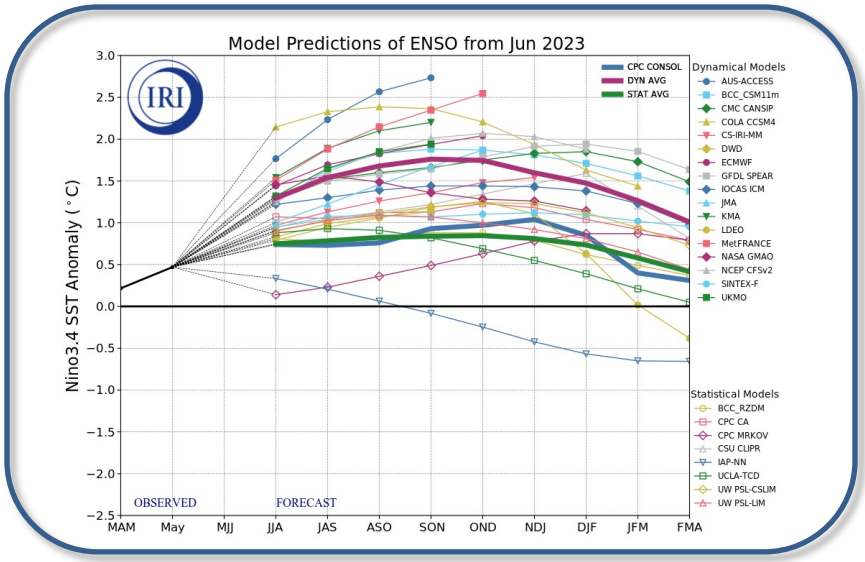


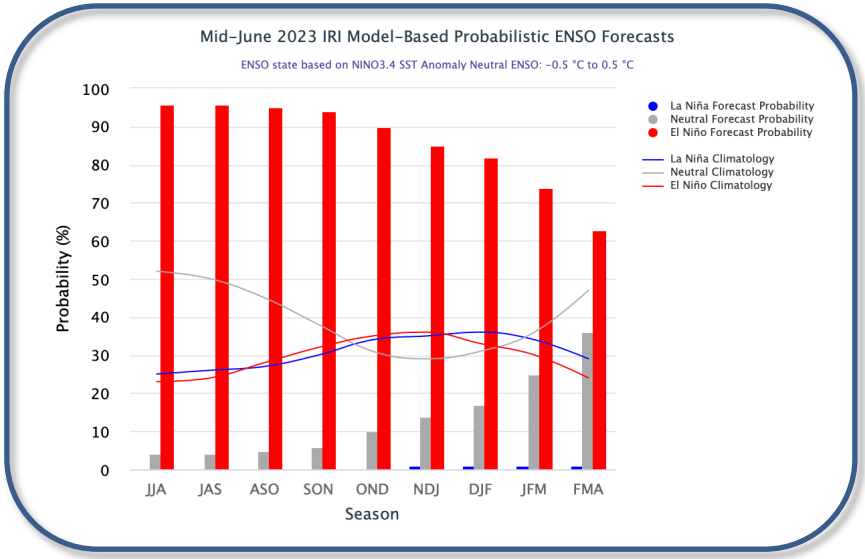
- NAO was near-normal in Jun 2023.
- Strong warming continued in the eastern North Atlantic Ocean.
- The prolonged positive SSTAs in the middle latitudes were evident, due to dominance of the positive phase of NAO during the last 5-6 years.

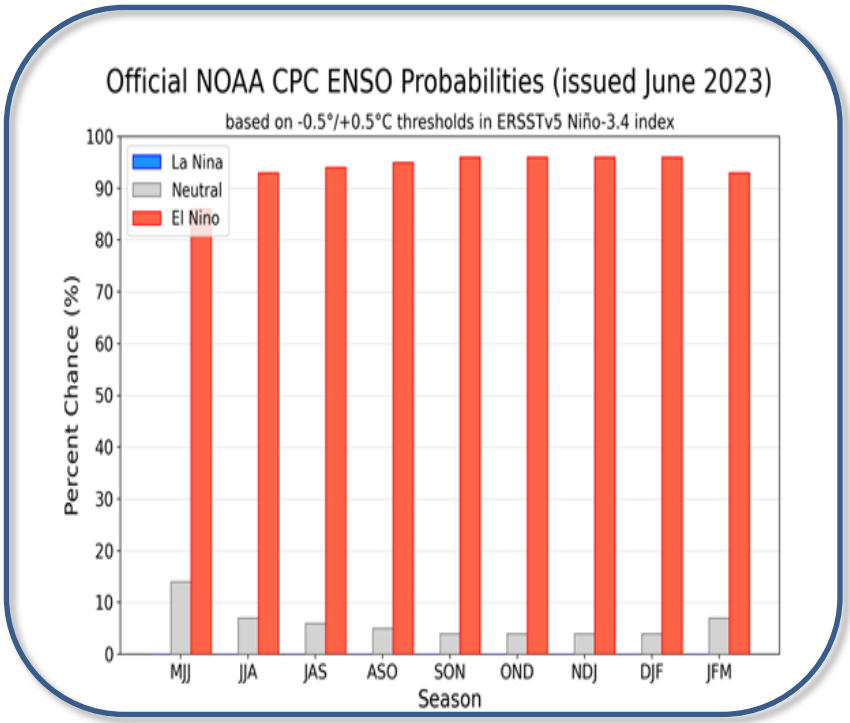
Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N. Time-latitude section of SSTAs averaged between 80ºW and 20ºW (bottom). SST are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020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

ENSO and Global SST Predictions

IRI/CPC Niño3.4 Forecast

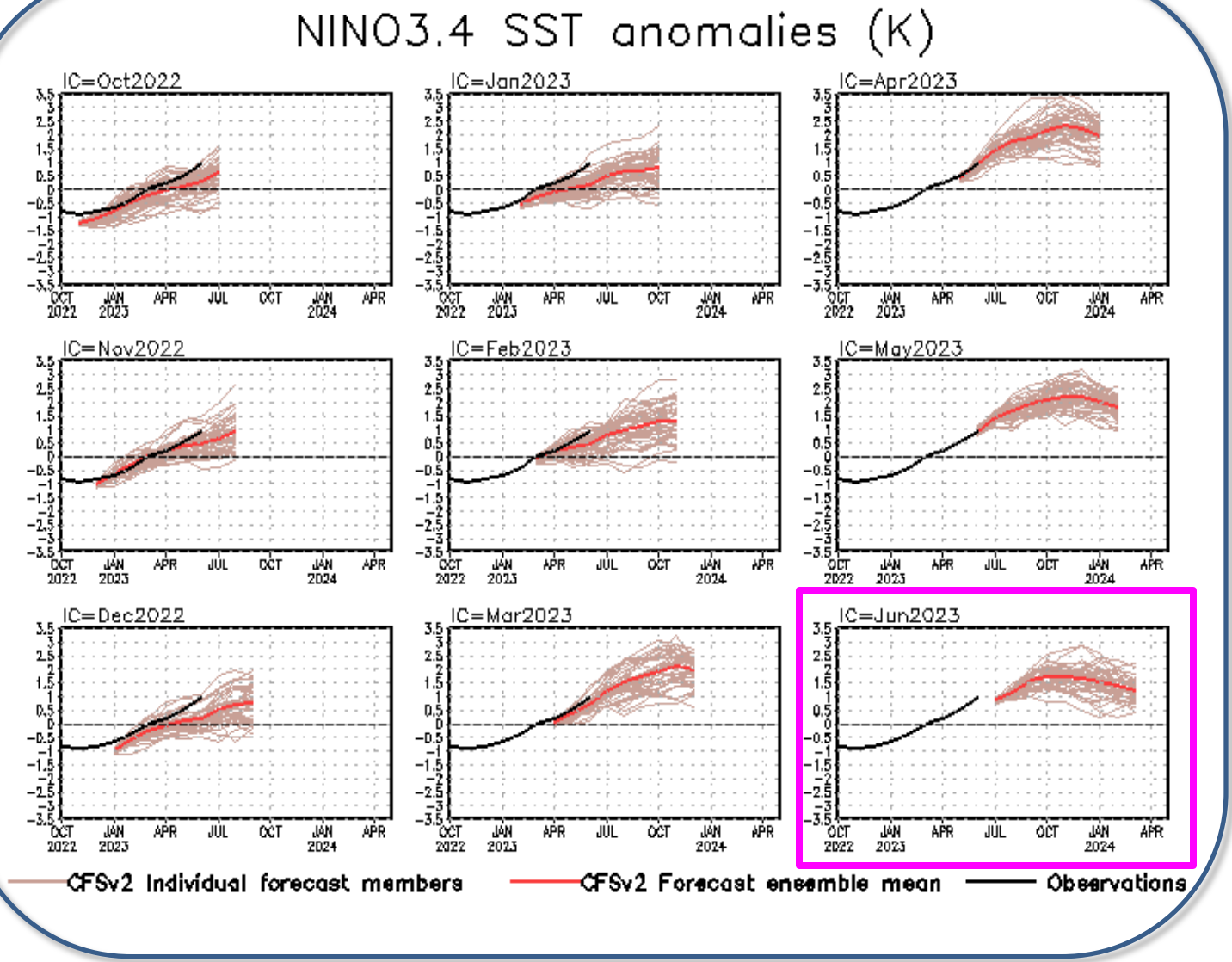






- Most of models forecasted that El Niño conditions will continue through the Northern Hemisphere winter 2023-24.
- **ENSO Alert System Status issued on 8 June 2023: El Niño Advisory**
- Synopsis: *"El Niño conditions are present and are expected to gradually strengthen into the Northern Hemisphere winter 2023-24."*

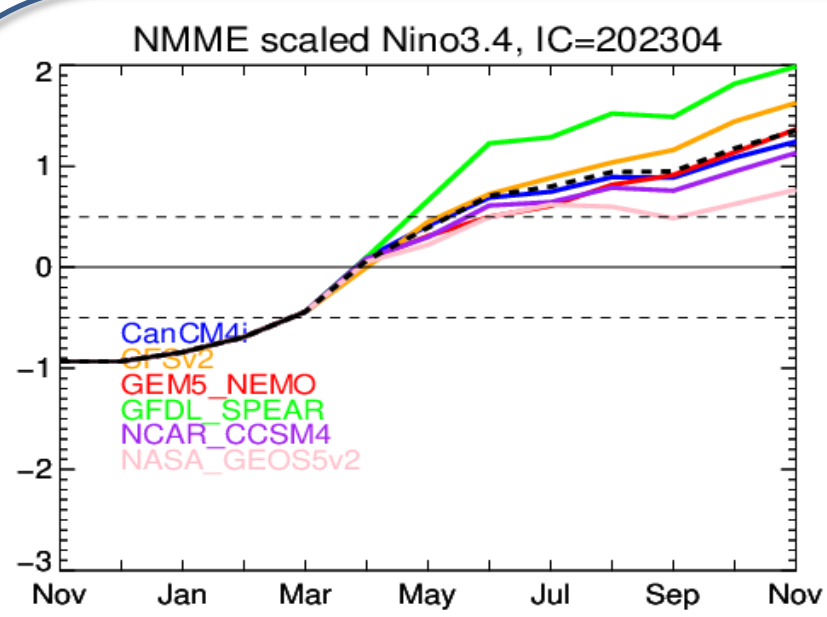
CFS Niño3.4 SST Predictions from Different Initial Months

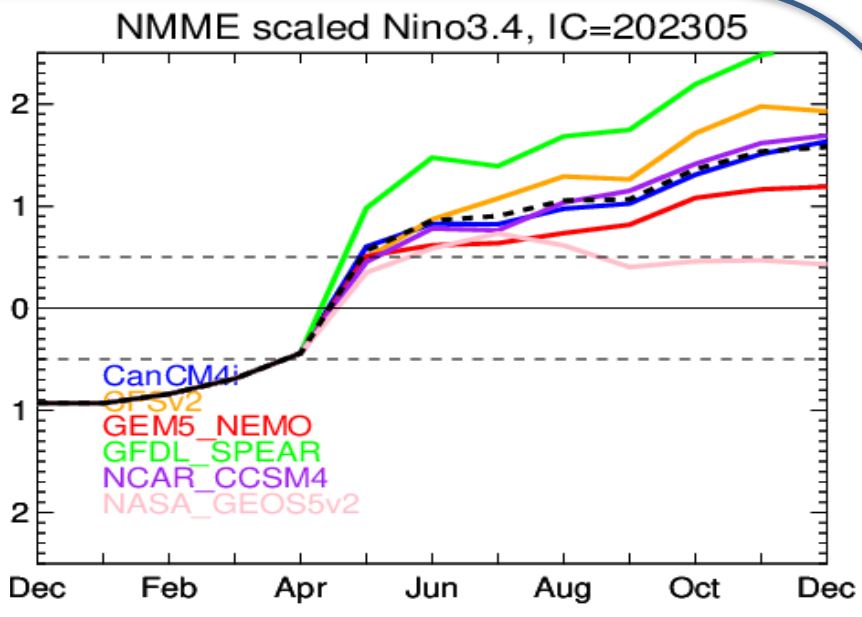


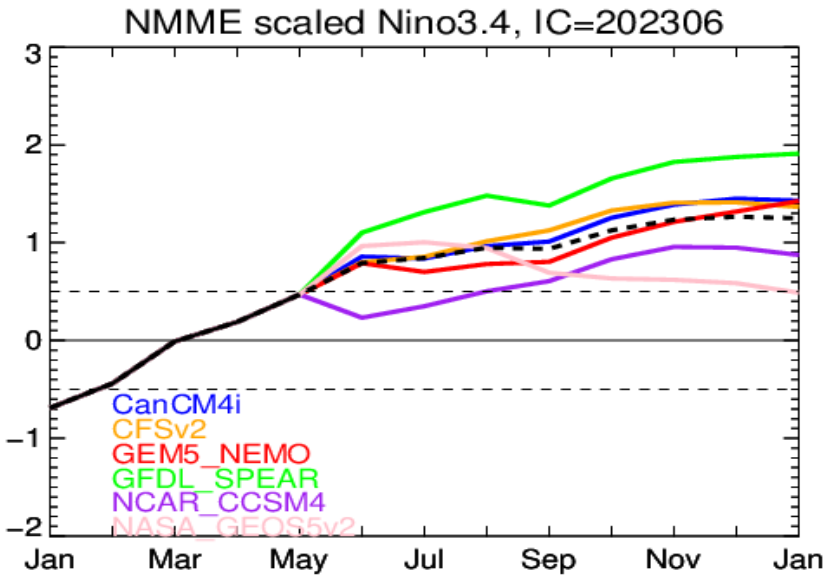
- The latest CFSv2 forecasts call for an El Niño in the second half of 2023.

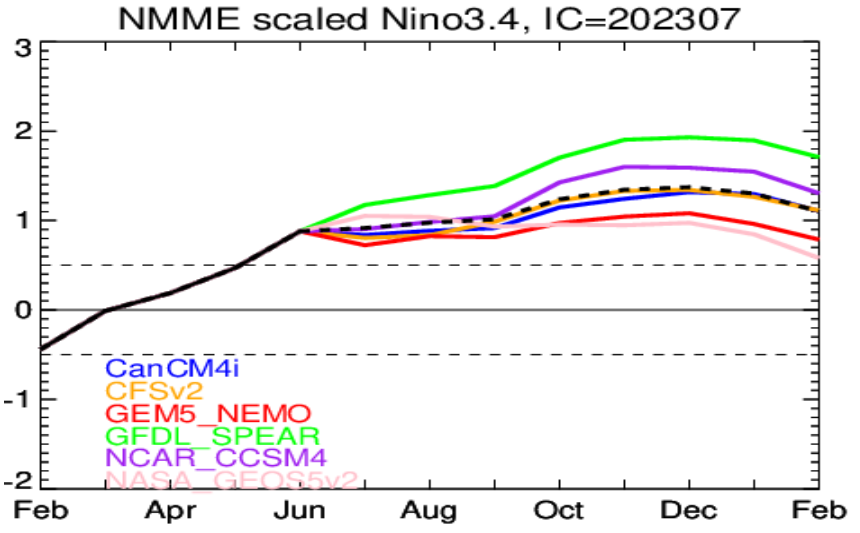
CFS Niño3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect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

NMME forecasts from different initial conditions



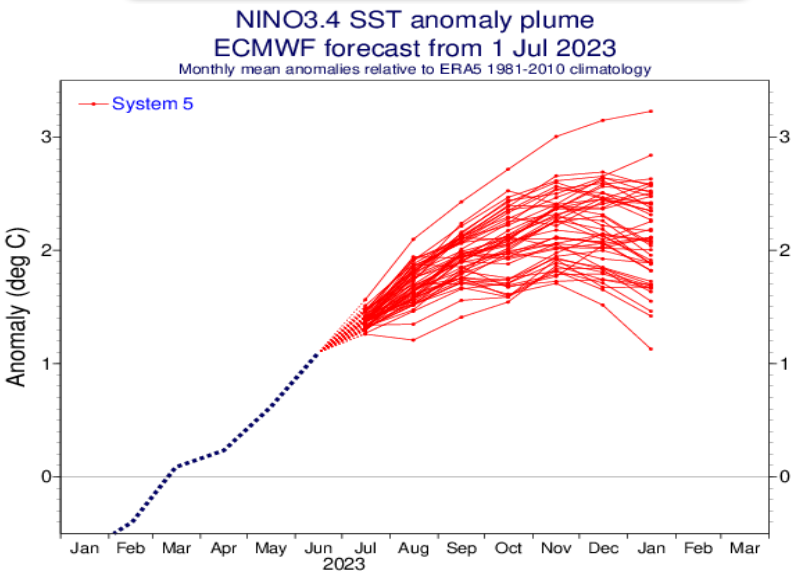




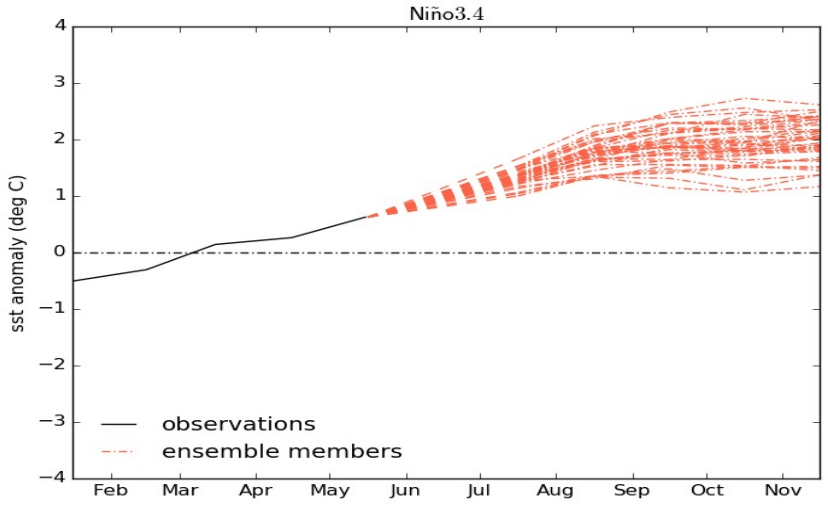


Individual Model Forecasts: A strong El Niño in 2023

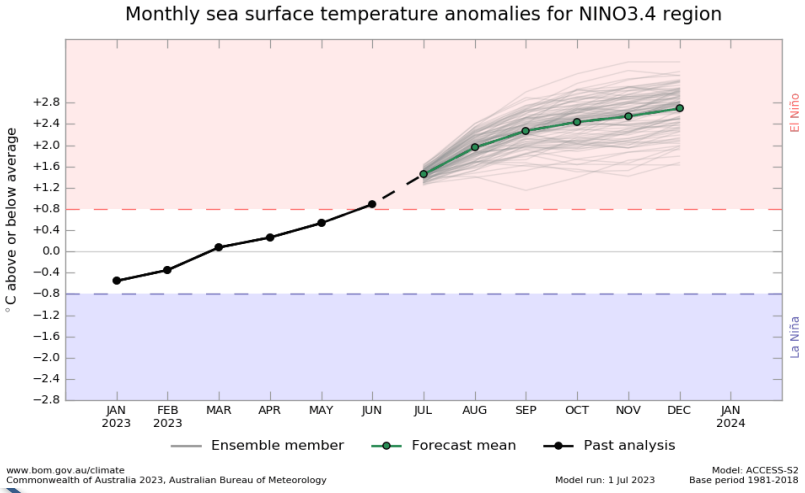
EC: Niño3.4, IC= 1 July 2023



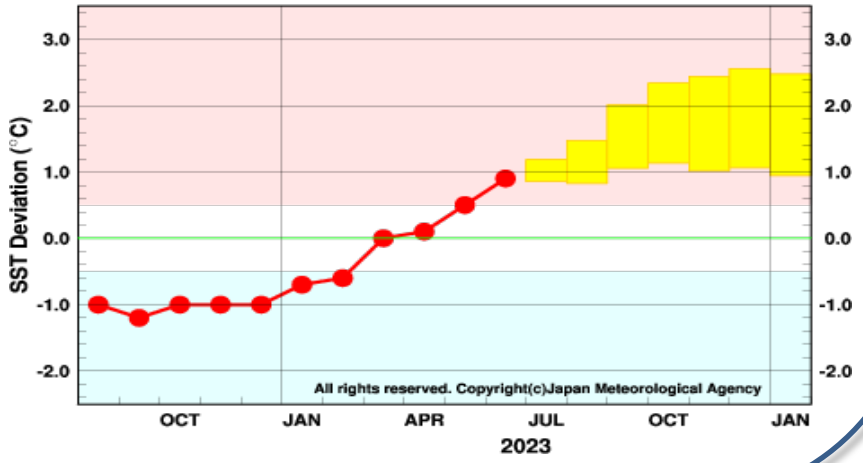
UKMO: Niño3.4, Updated 16 Jun 2023



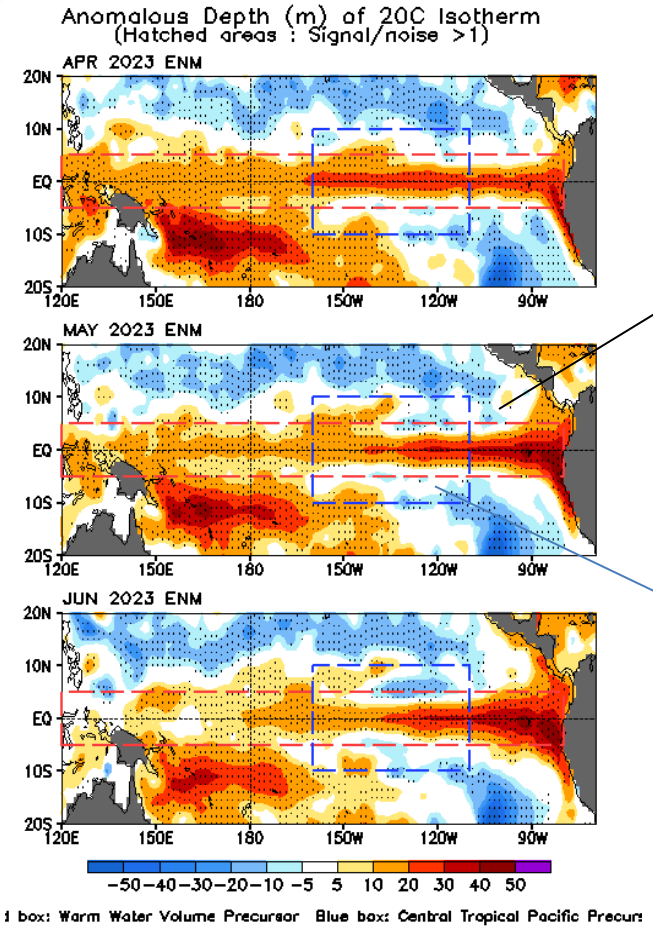
BOM: Niño3.4, Updated 1 July 2023

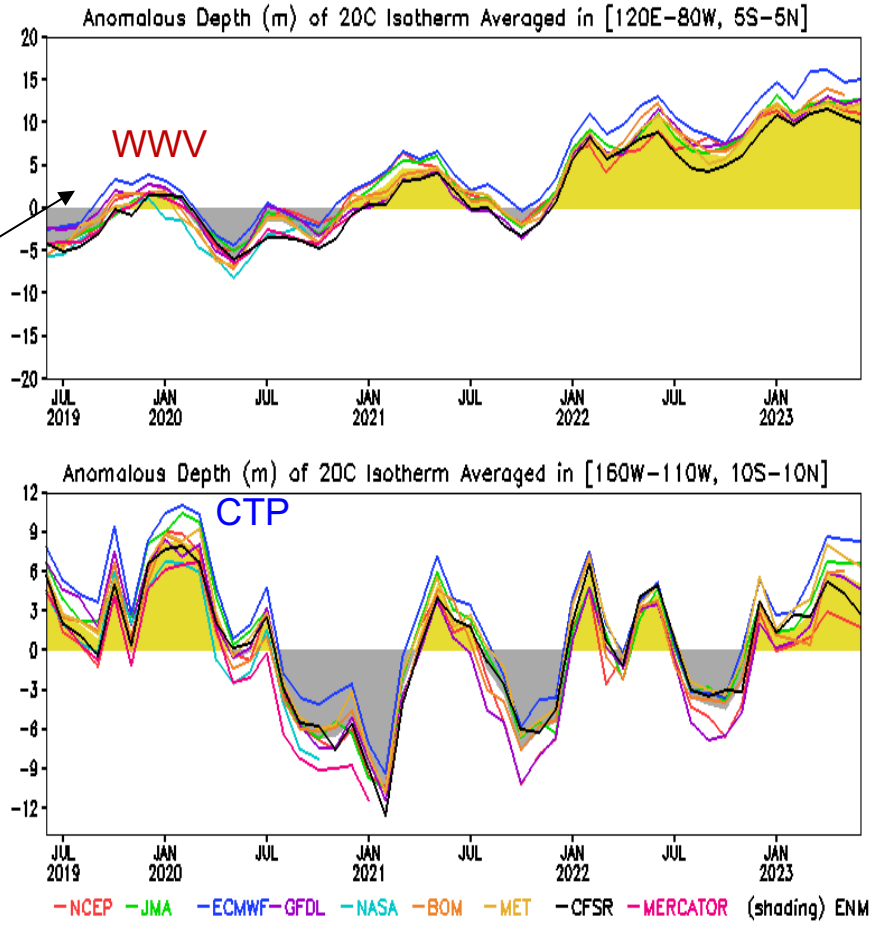


JMA: Niño3.4, Updated 9 June 2023



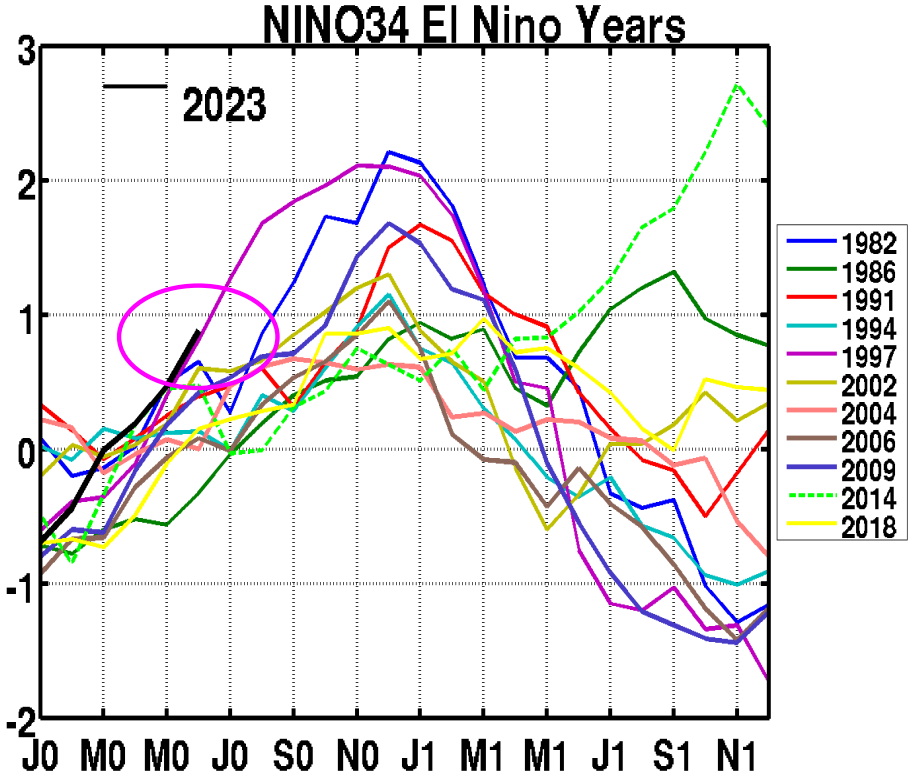
Oceanic ENSO Precursors: WWV & CTP

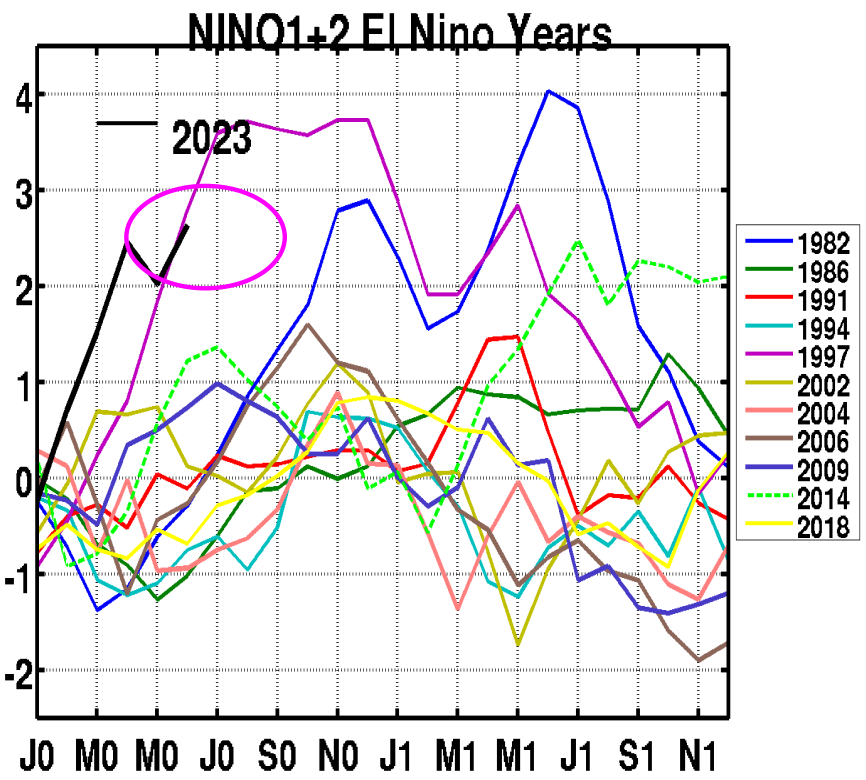




Warm water volume (WWV) is defined as an average of D20 anomaly across the equatorial Pacific (120° E – 80° W, 5° S-5° N) (Meinen and McPhaden 2000). Central tropical Pacific (CTP) index is calculated as the averaged D20 anomaly in the central tropical Pacific (160° W-110° W, 10° S-10° N) (Wen et al. 2014). The monthly D20 data is obtained from the Real-time Ocean Reanalysis Intercomparison Project(https://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html).

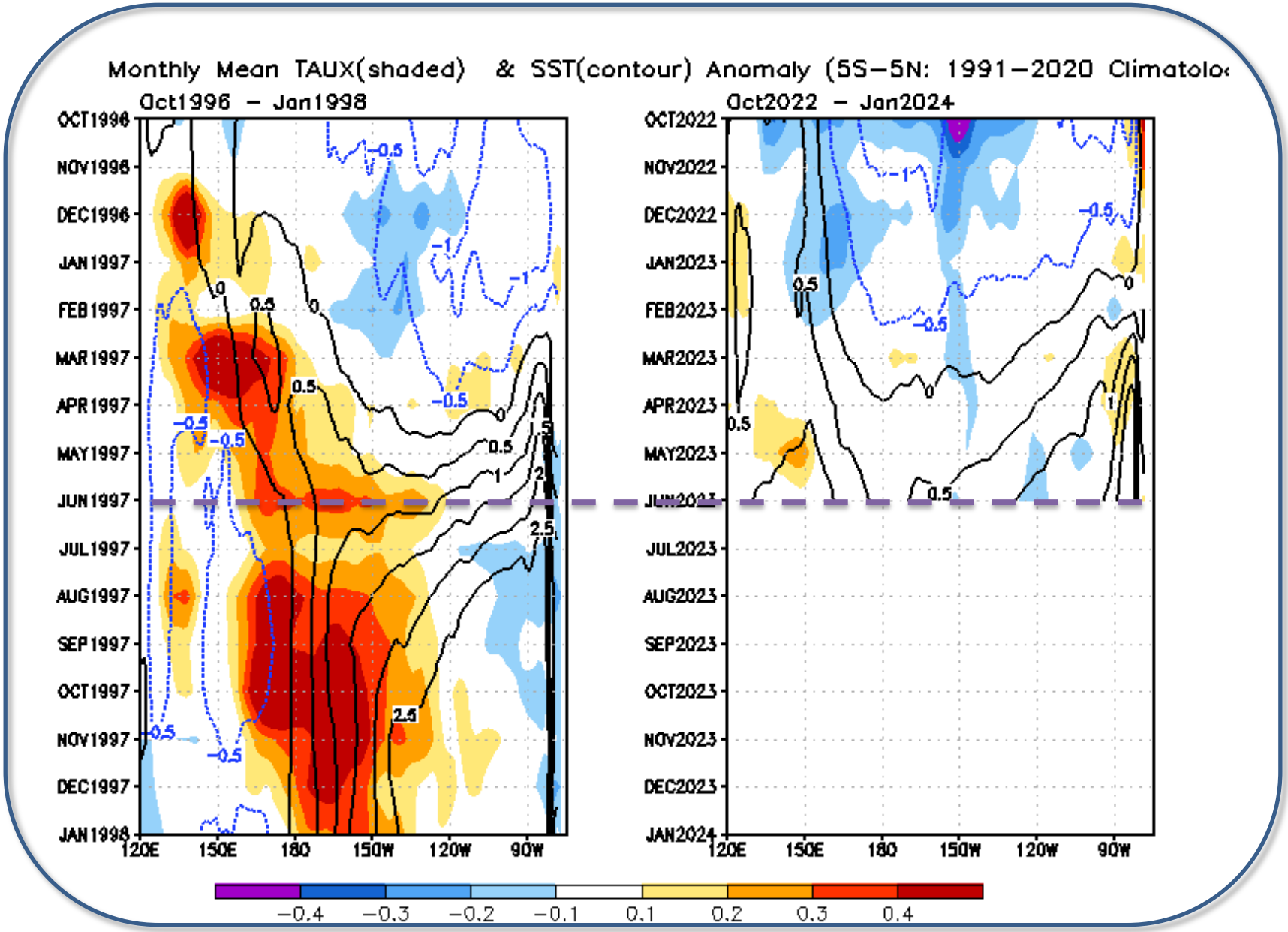
Evolution of NINO34 & NINO1+2 in El Niño Years





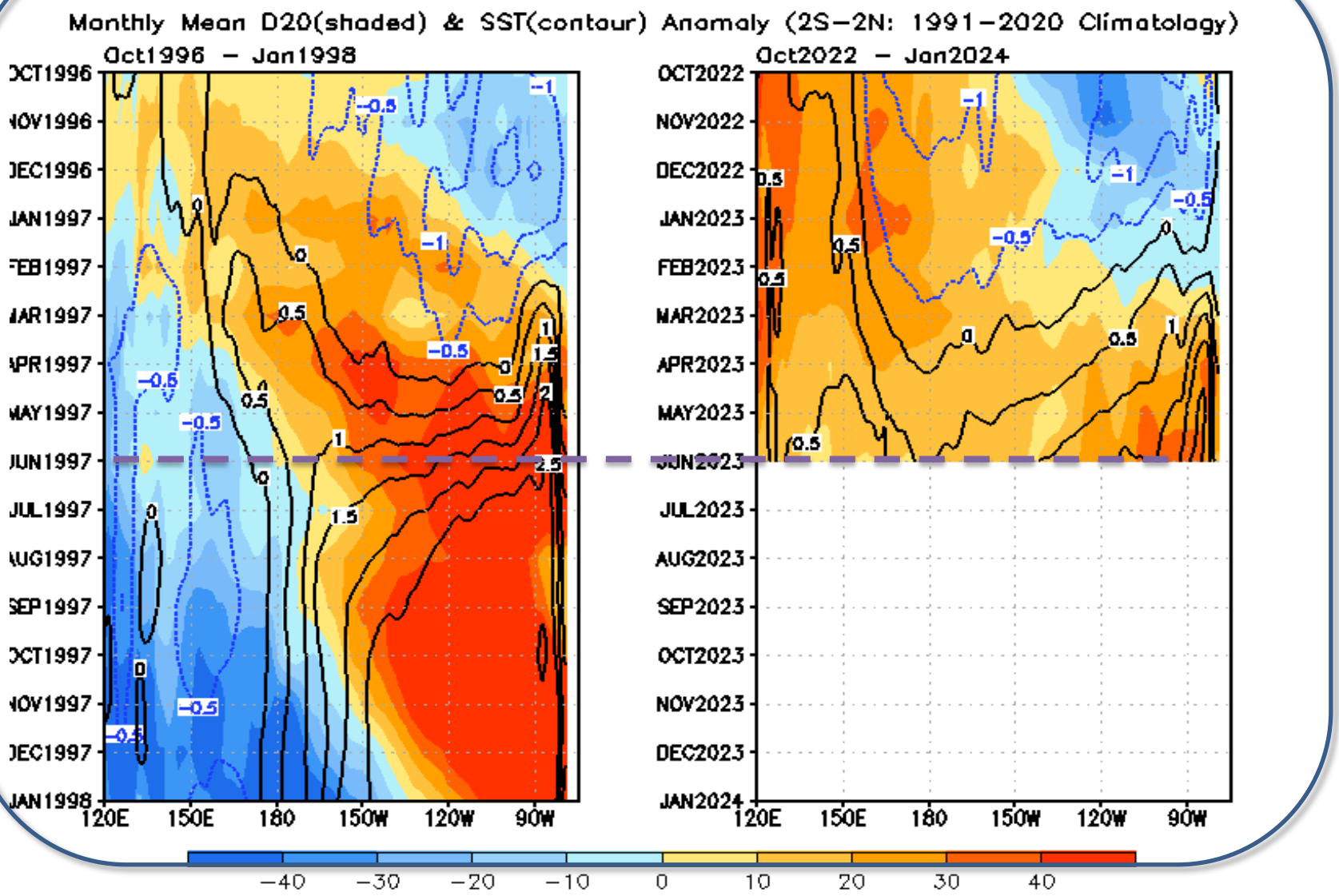
Nino 34 iand NINO1+2ndex is derived from the NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means

Evolution of Monthly Mean Zonal Wind Stress Anomaly across [5S-5N]



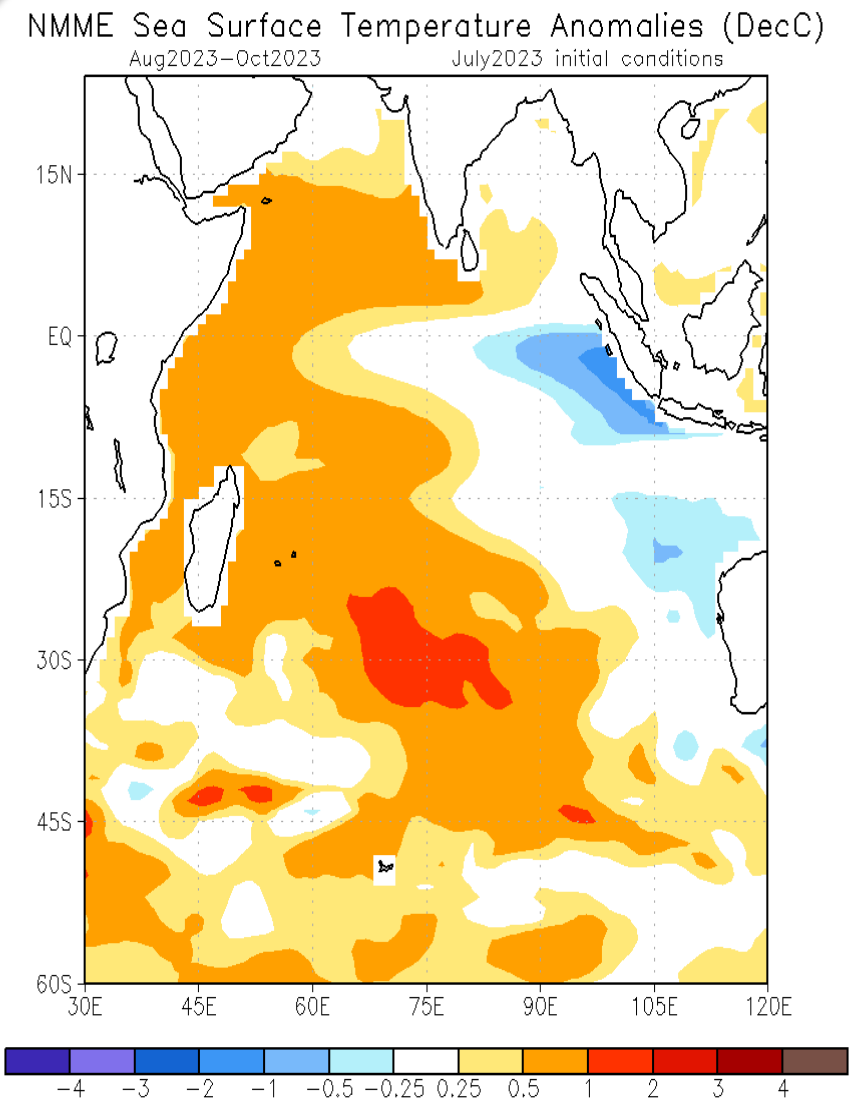
Data source: NCEP R2 reanalysis

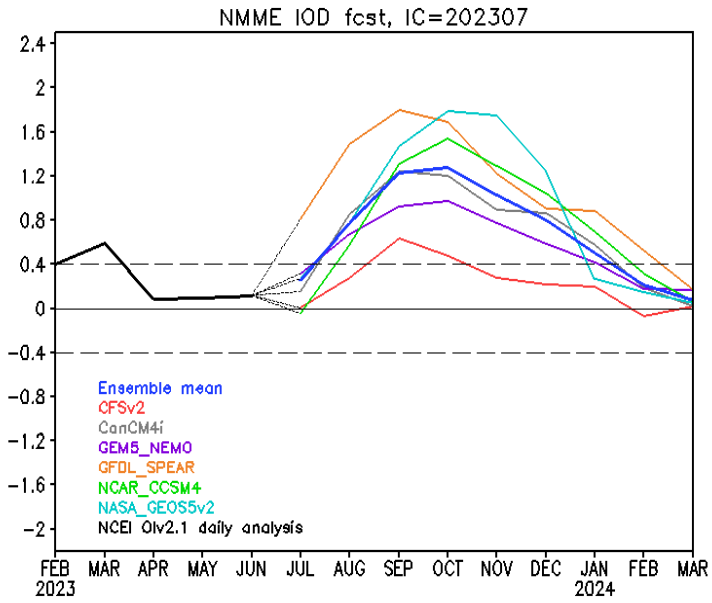
Evolution of Monthly Mean D20 Anomaly across [2S-2N]



Data source: NCEP GODAS

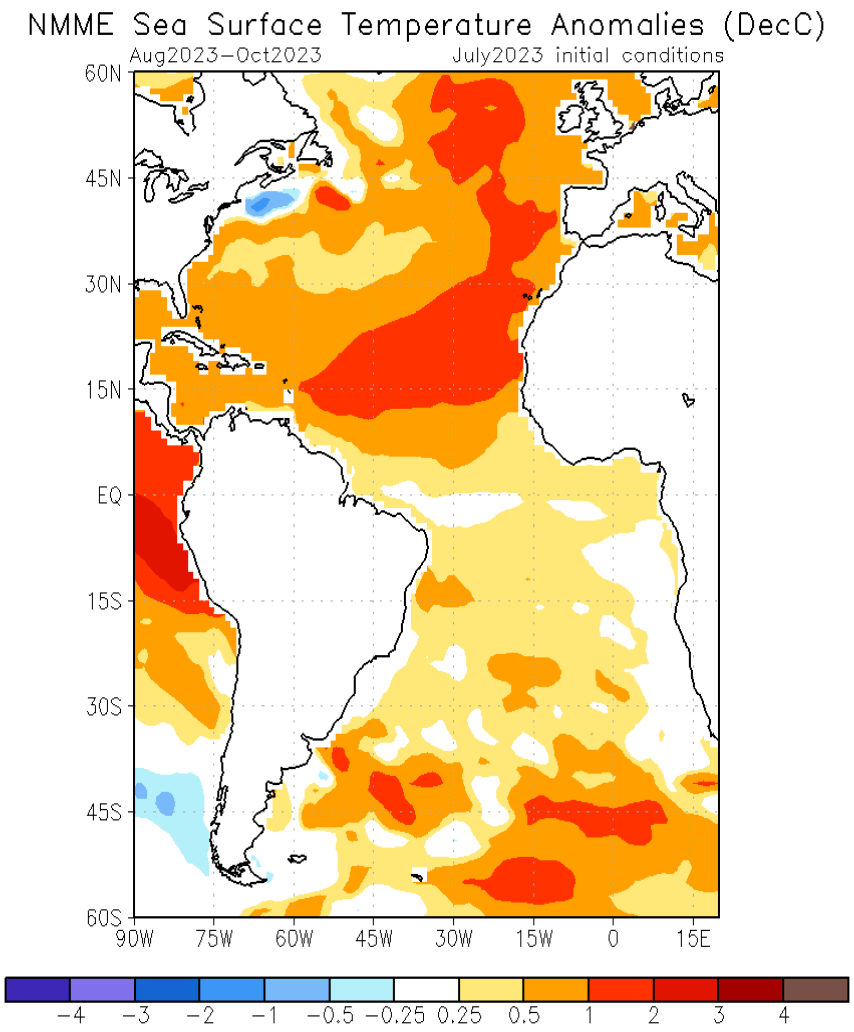
NMME Forecasts in the Indian Ocean

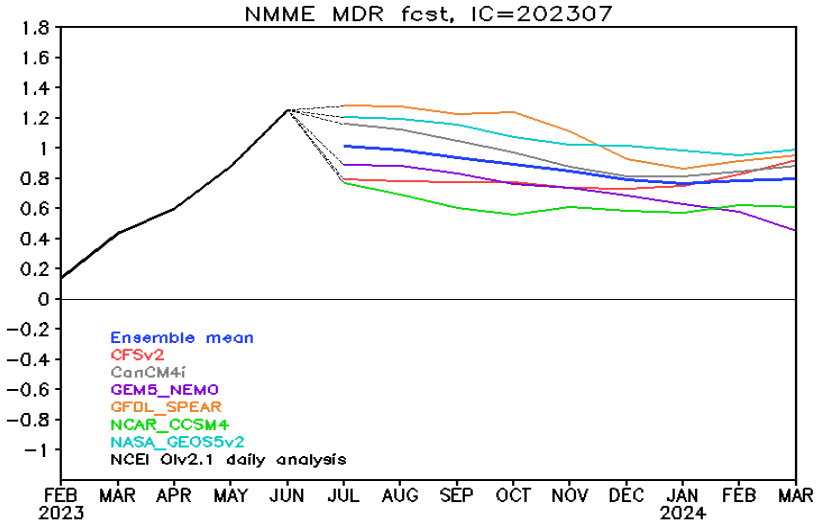


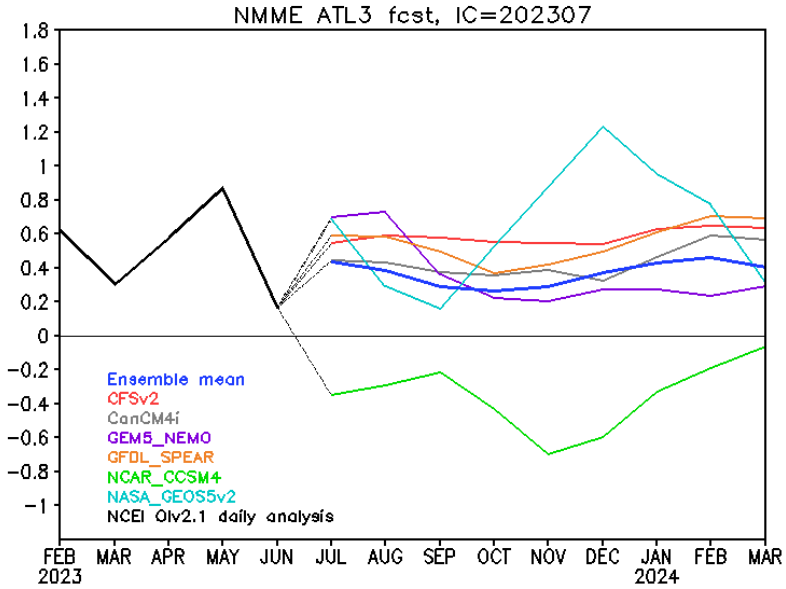


- Most of NMME members predict a positive IOD event will develop in summer and last through winter.

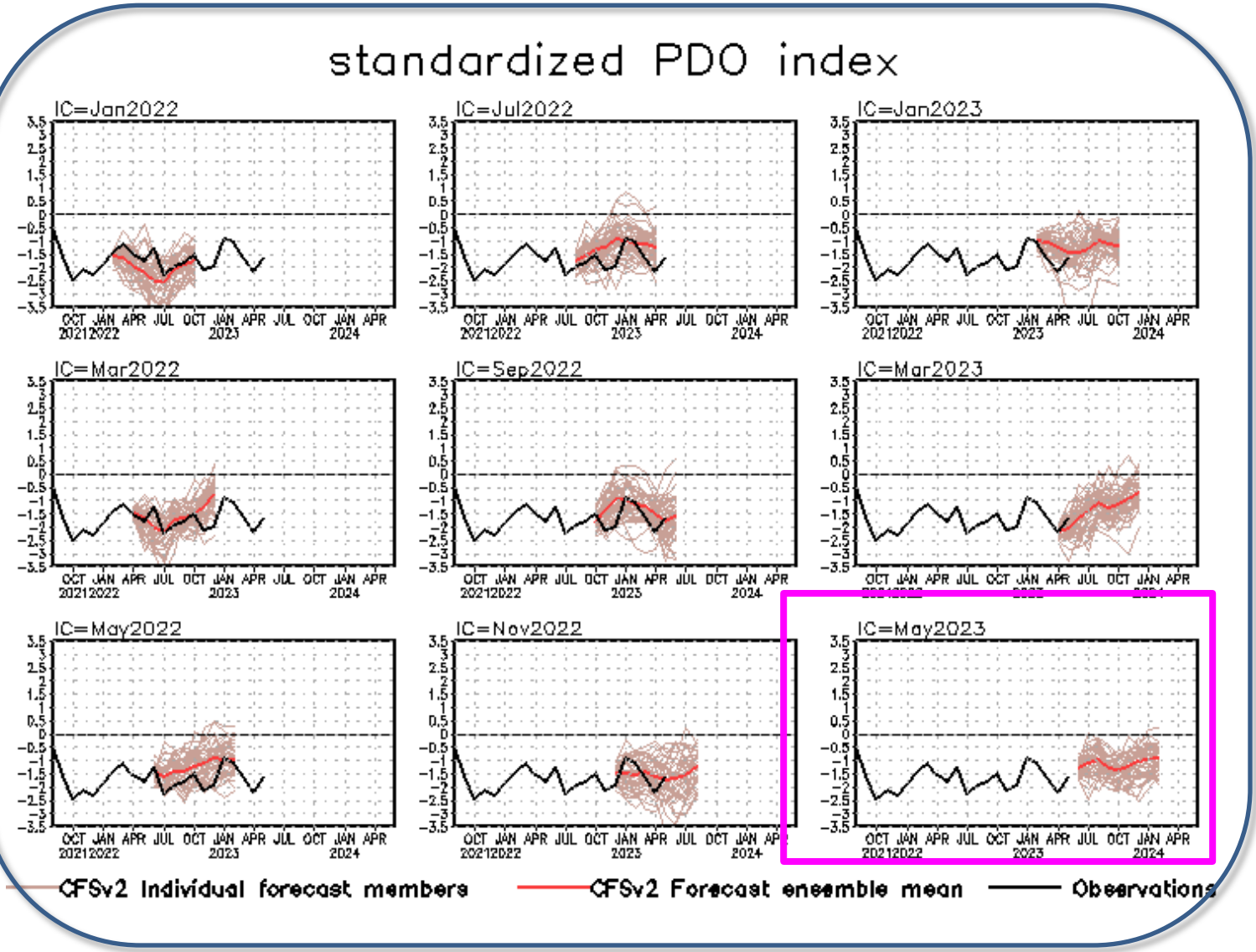
NMME Forecasts in the Atlantic Ocean







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



- CFSv2 predicts the negative phase of PDO will continue through winter 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.

Acknowledgement

- Drs. Jieshun Zhu reviewed PPT, and provide insightful suggestions and comments
- Dr Dongmin Kim provided the slide of Atlantic Nino impact on the Atlantic Hurricane.
- Dr. Pingping Xie provided the BASS/CMORPH/CFSR EVAP package
- Drs. Jieshun Zhu and Wanqiu Wang provided the upgraded sea ice forecasts

Please send your comments and suggestions to:

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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

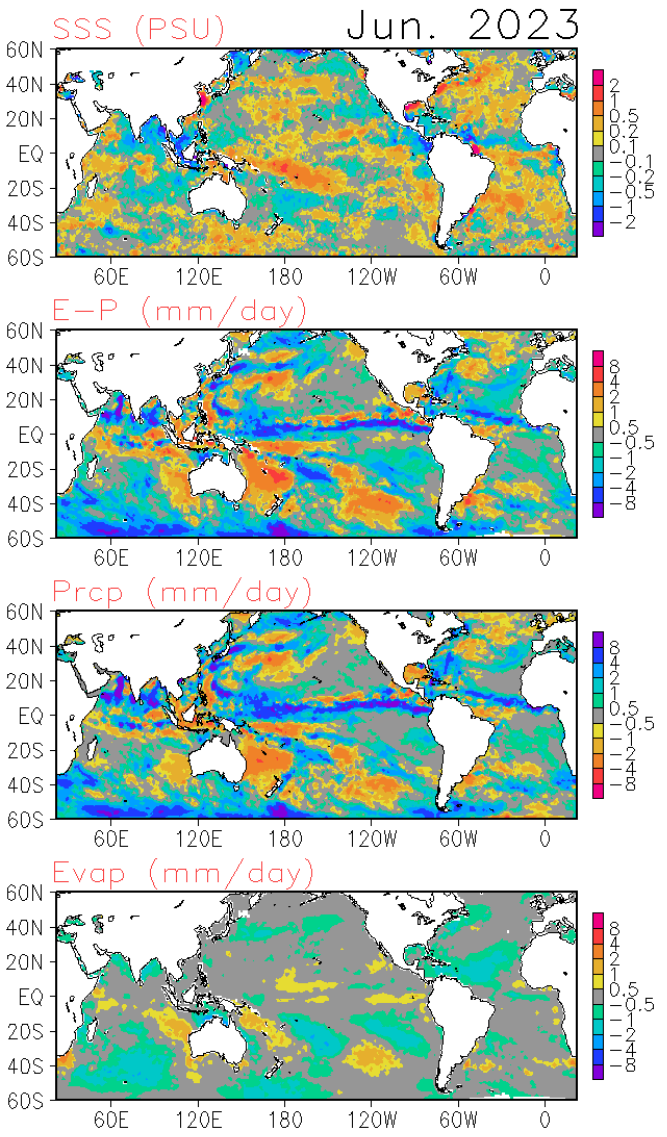
http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html

Backup Slides

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

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

ITCZ is enhanced over most of the equatorial sections across all three oceans, and shifted slightly southwardly over the central and eastern equatorial Pacific, freshening the salinity over the ocean there, Soldier SSS anomalies remain over part of the western equatorial Pacific as a result of extended soldier SSS over the past years. Small regions of positive SSS anomalies are also observed off the mouths of the Yangtze river over the northwestern Pacific and the Amazon river over western Atlantic, probably attributable to the shortfall of river runoffs from the two rivers.



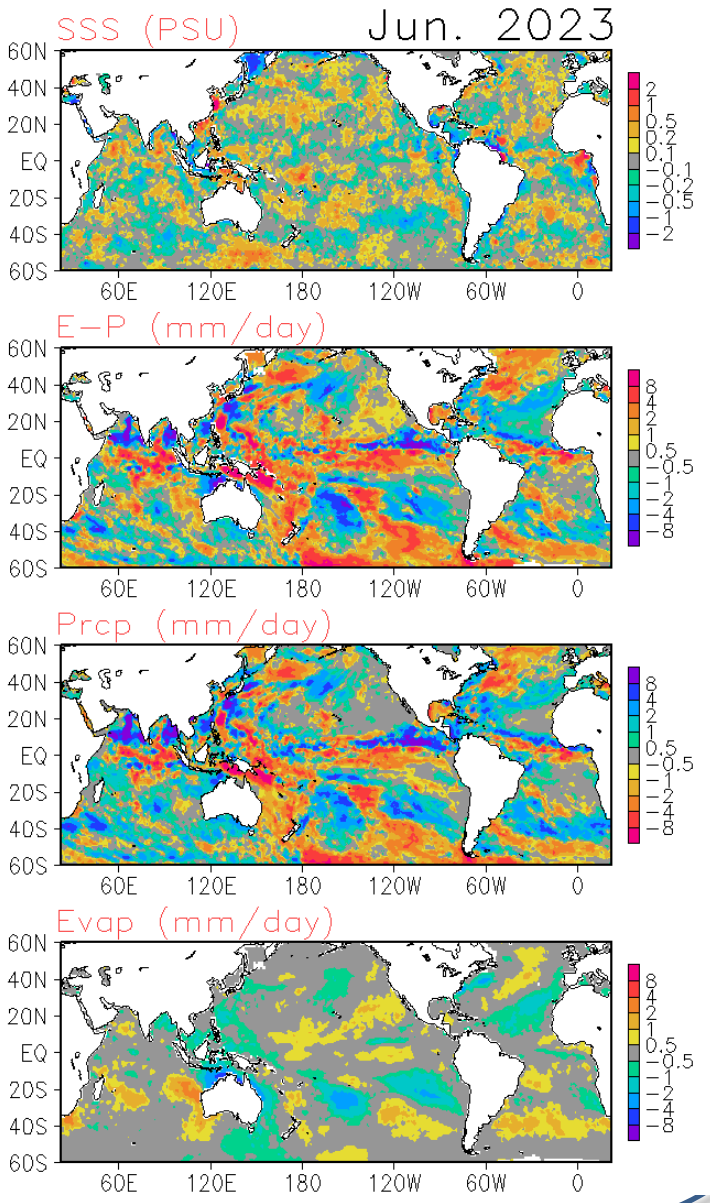
SSS : Blended Analysis of Surface Salinity (BASS) V0.Z
(a CPC-NESDIS/NODC-NESDIS/STAR joint effort)
ftp.cpc.ncep.noaa.gov/precip/BASS

Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: Adjusted CFS Reanalysis

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

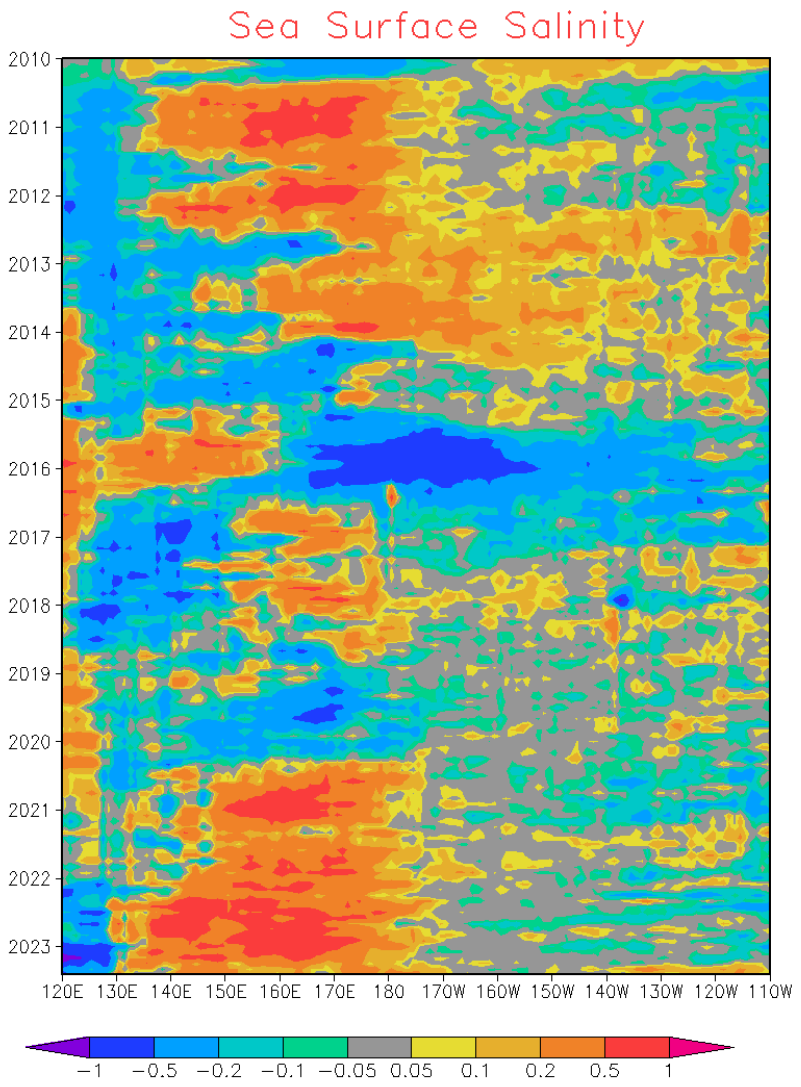
Enhanced ITCZ precipitation (convection) tendency is observed across the equatorial oceans especially over the central and eastern Pacific, causing freshening SSS tendency over the regions. Positive precipitation tendency also appears over northern Indian ocean, resulting negative SSS tendency there. A belt of soldier SSS tendency is observed along the east coast of mainland China.



Monthly SSS Anomaly Evolution over Equatorial Pacific

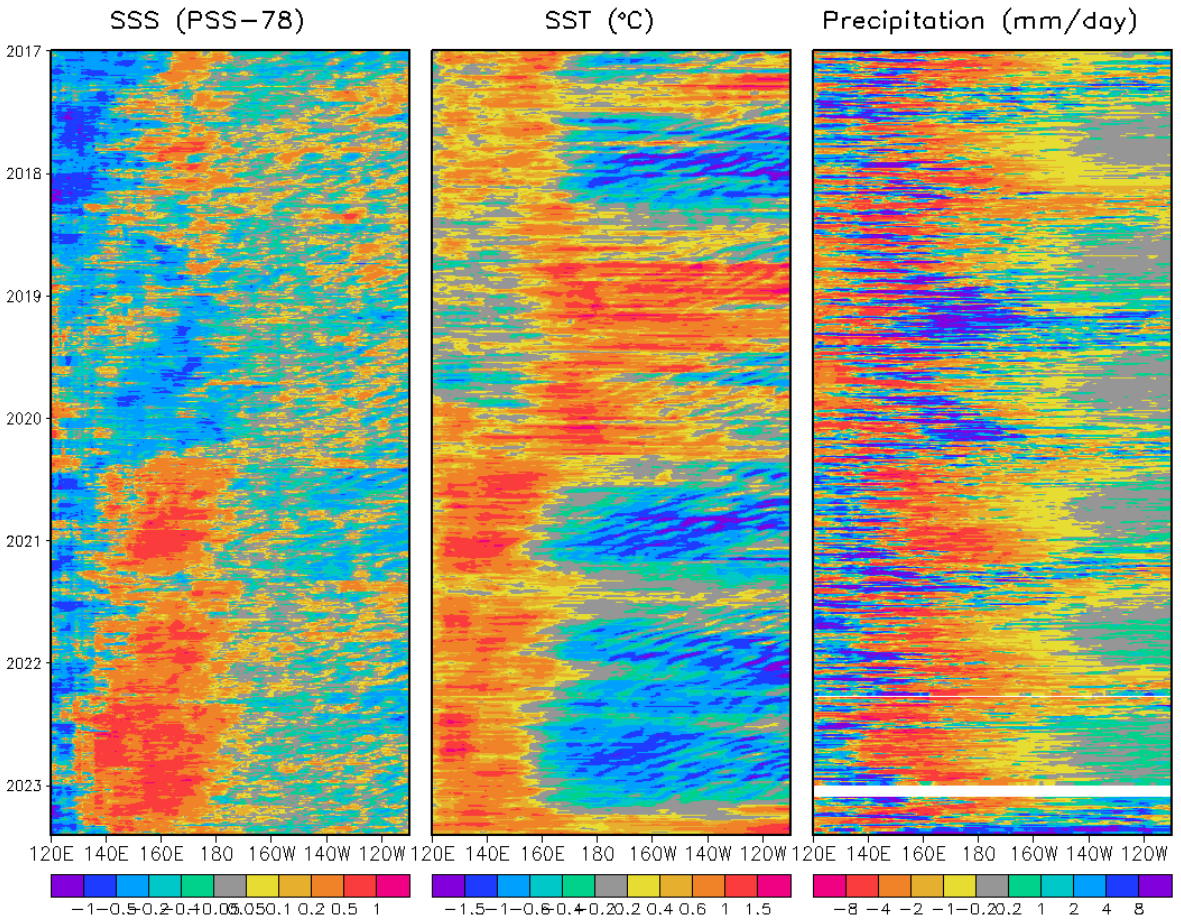
NOTE: Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015,The BASS SSS is from in situ, SMOS and Aquarius.

- Hovermoller diagram for equatorial SSS anomaly **(5˚S-5˚N);**
- Positive SSS anomalies still remain over the western and central equatorial Pacific (130°E-180°). The intensity of the saltier anomaly over the central equatorial (155°E-170°E), however, has been weakened substantially over the past month.



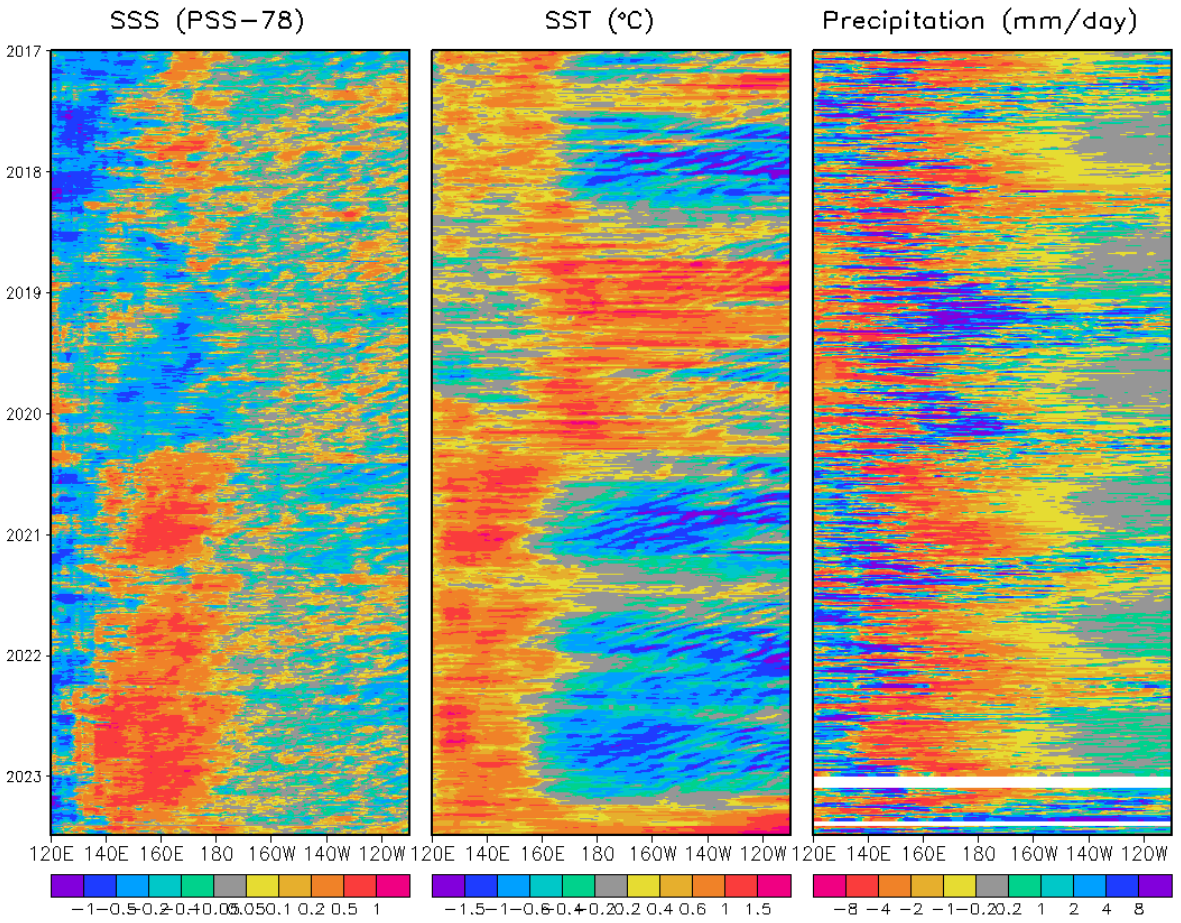
Pentad SSS Anomaly Evolution over Equatorial Pacific

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.

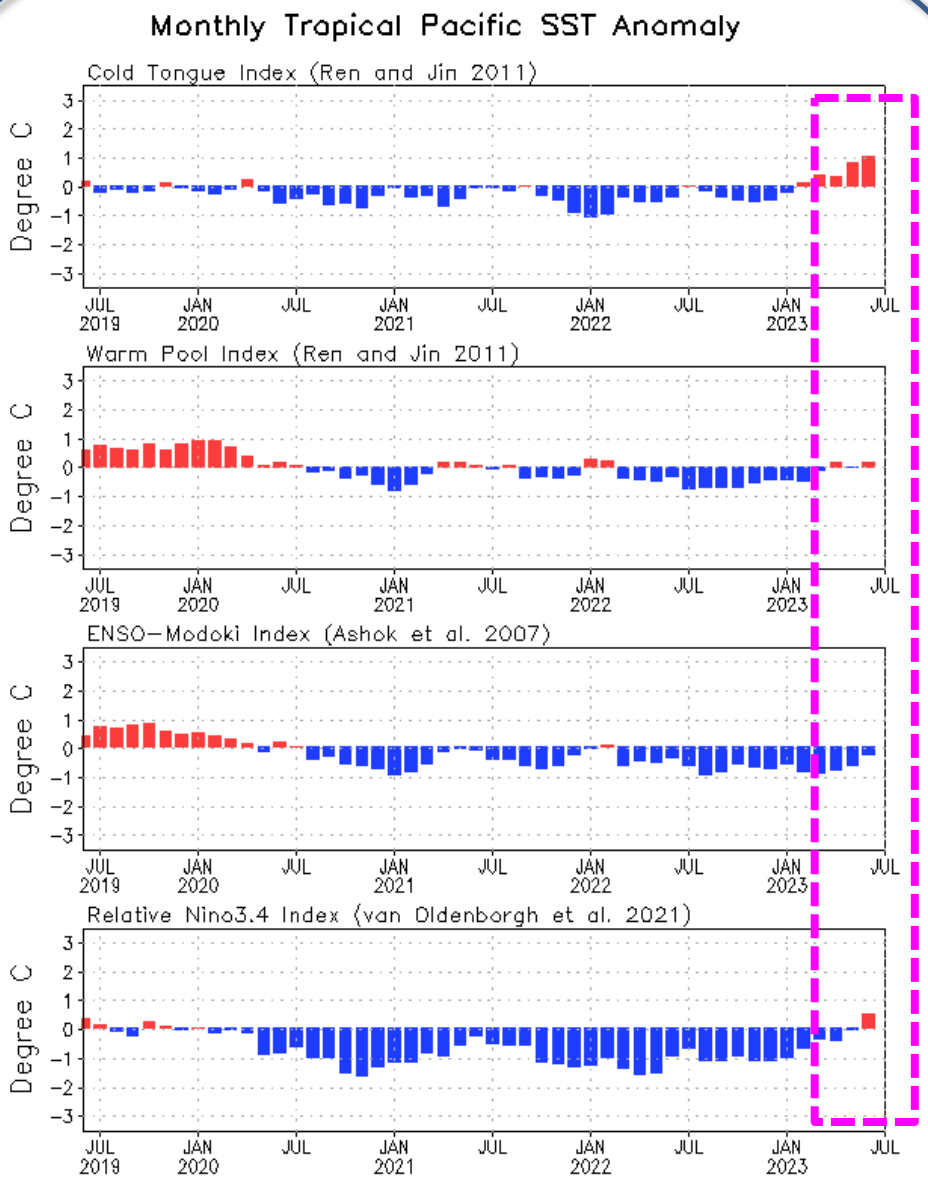


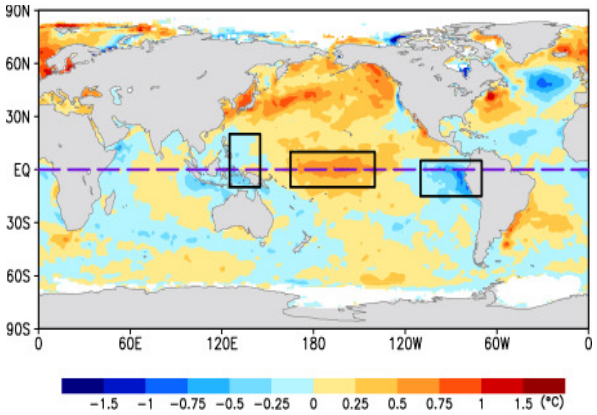
Pentad SSS Anomaly Evolution over Equatorial Pacific

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.



Evolution of Pacific Niño SST Indices



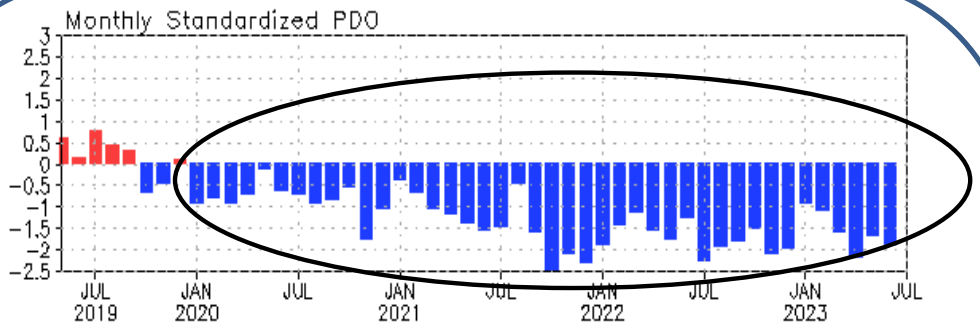


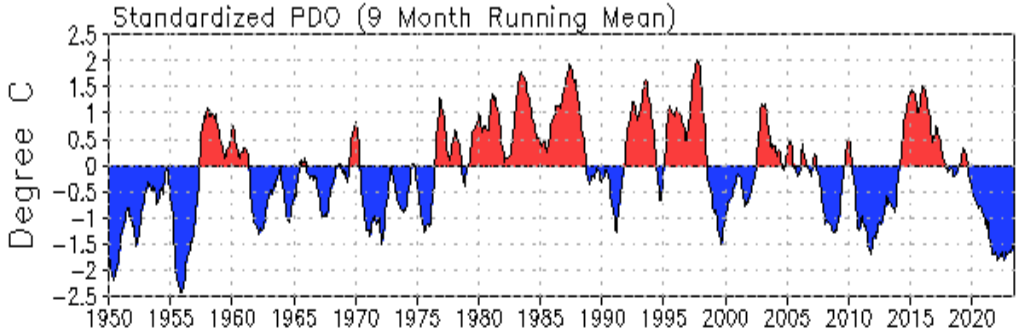
- Relative Niño3.4 index is now included in ENSO monitoring, which is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0º-360º, 20ºS-20ºN), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative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

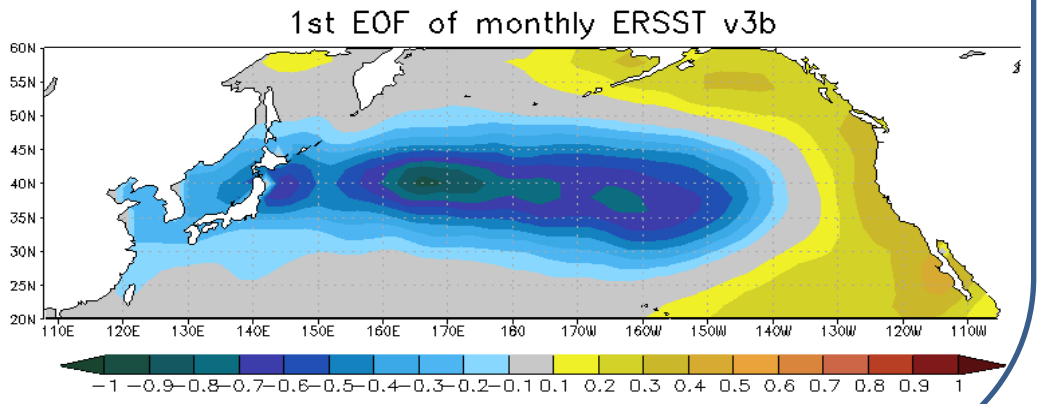
Relative Niño3.4 data updated monthly at:

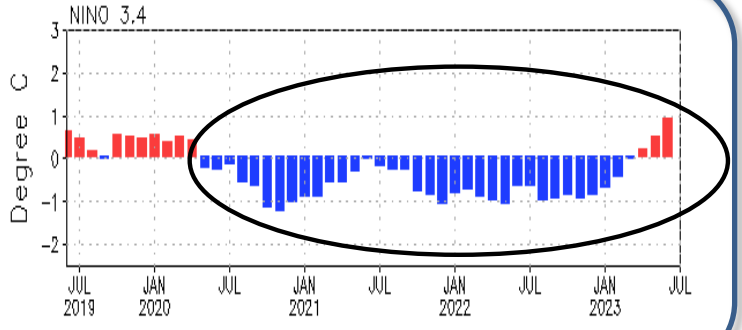
https://www.cpc.ncep.noaa.gov/data/indices/RONI.ascii.txt

Pacific Decadal Oscillation (PDO) Index







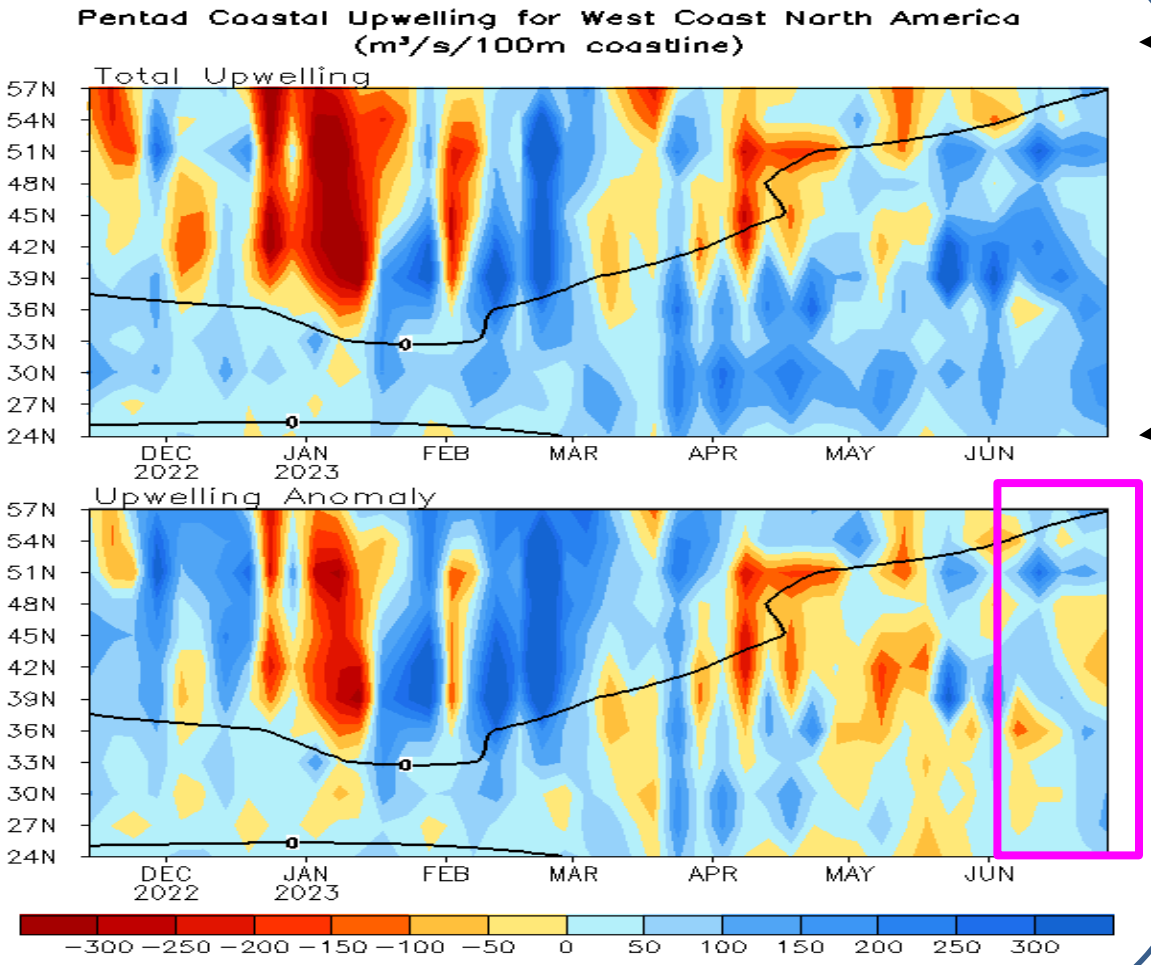


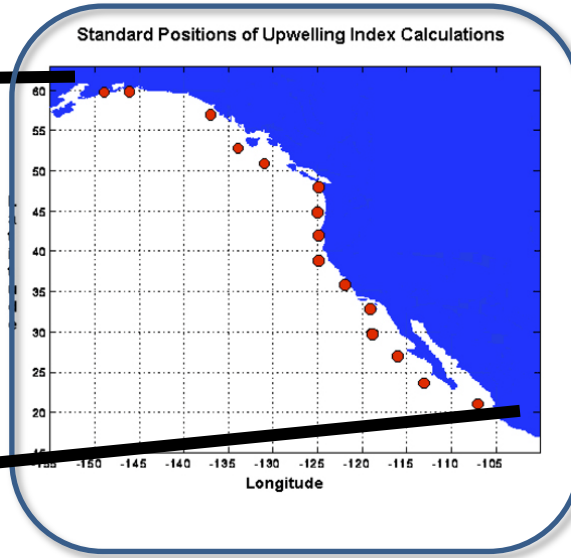
- The PDO has been in a negative phase since Jan 2020 with PDOI = -1.9 in Jun 2023.

- 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

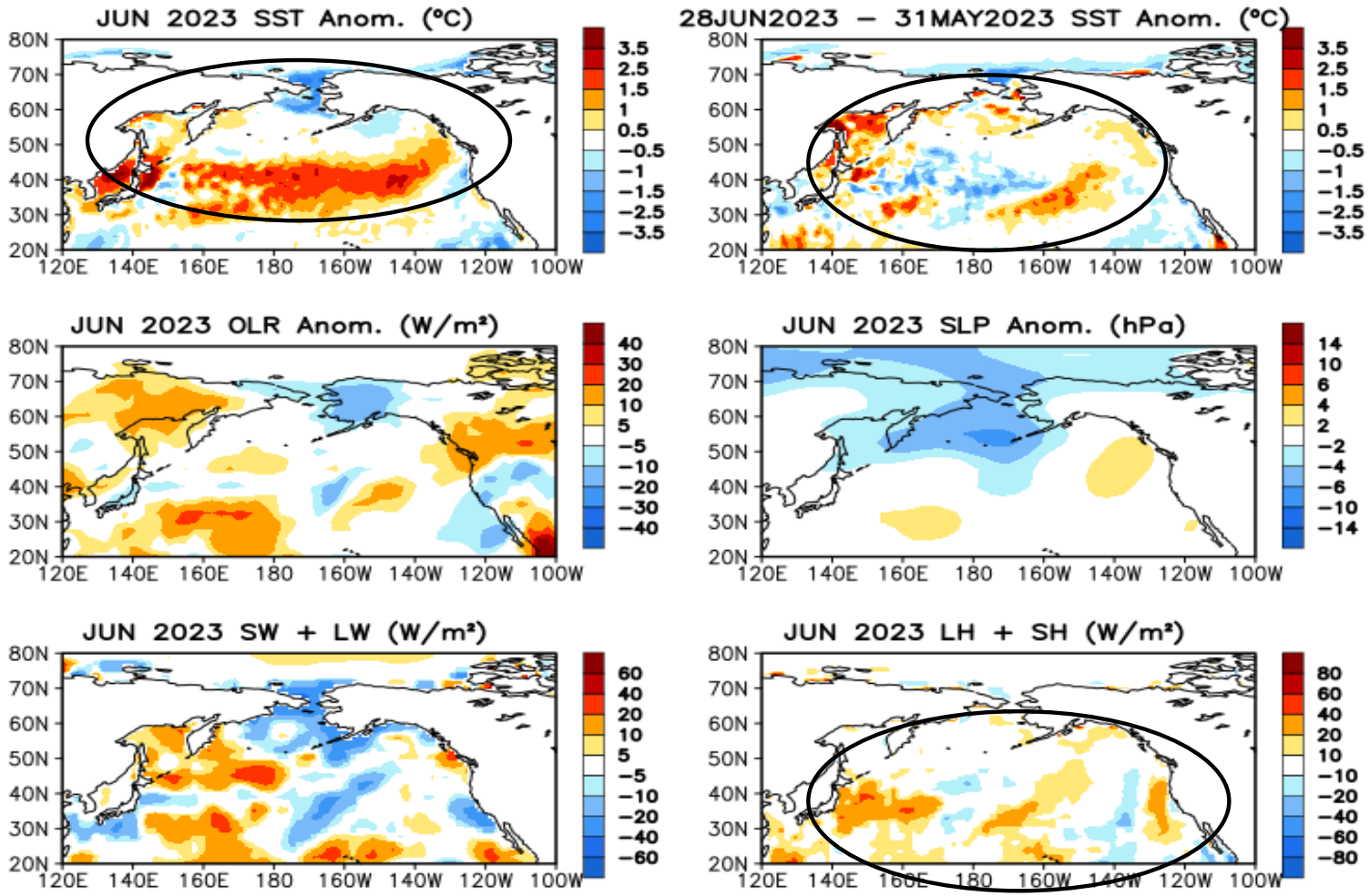




- Weak coastal (39º-54ºN) anomalous downwelling and upwelling were observed in Jun 2023.

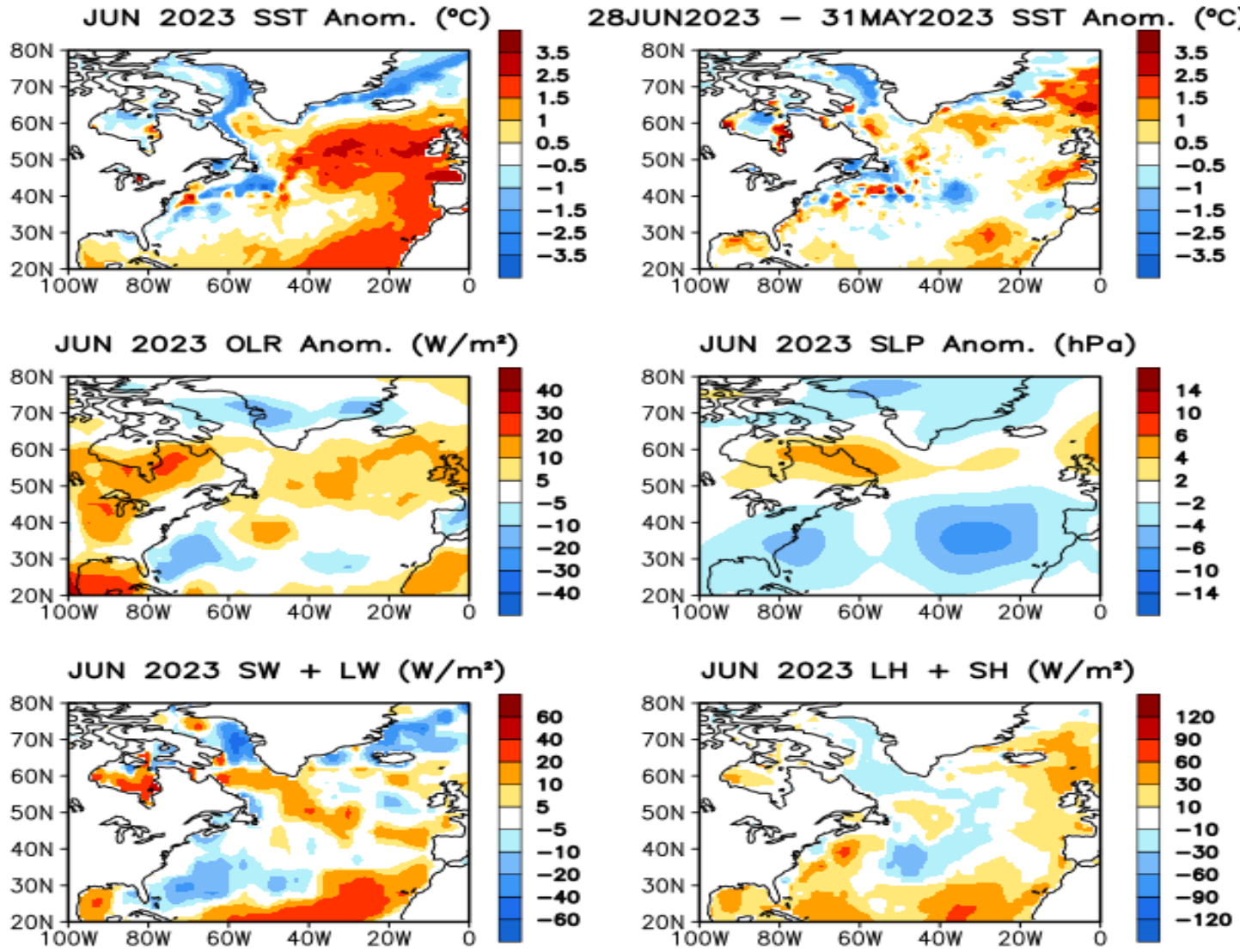
(top) Total and (bottom) anomalous upwelling indices at the 15 standard locations for the western coast of North America. Derived from the vertical velocity of the NCEP's GODAS and are calculated as integrated vertical volume transport at 50-meter depth from each location to its nearest coast point (m³/s/100m 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 & Arctic Ocean: SSTA, SSTA Tend., OLR, SLP, Sfc Rad, Sfc Flx Anomalies

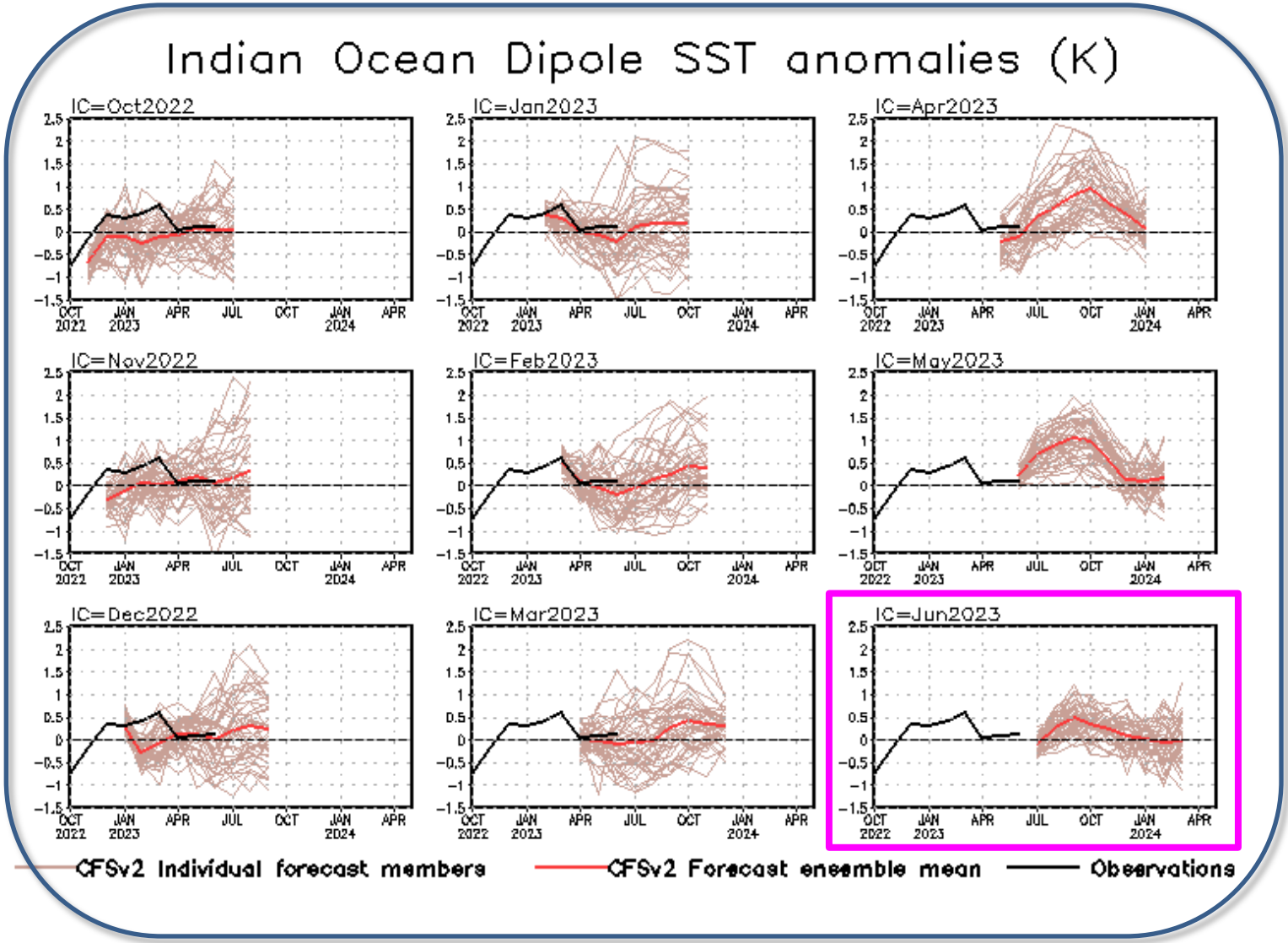


SSTA (top-left; OIv2.1 SST Analysis), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) (middle-left; NOAA 18 AVHRR IR), sea surface pressure (middle-right; NCEP CDAS), sum of net surface short- and long-wave radiation (bottom-left; positive means heat into the ocean; NCEP CDAS), sum of latent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

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



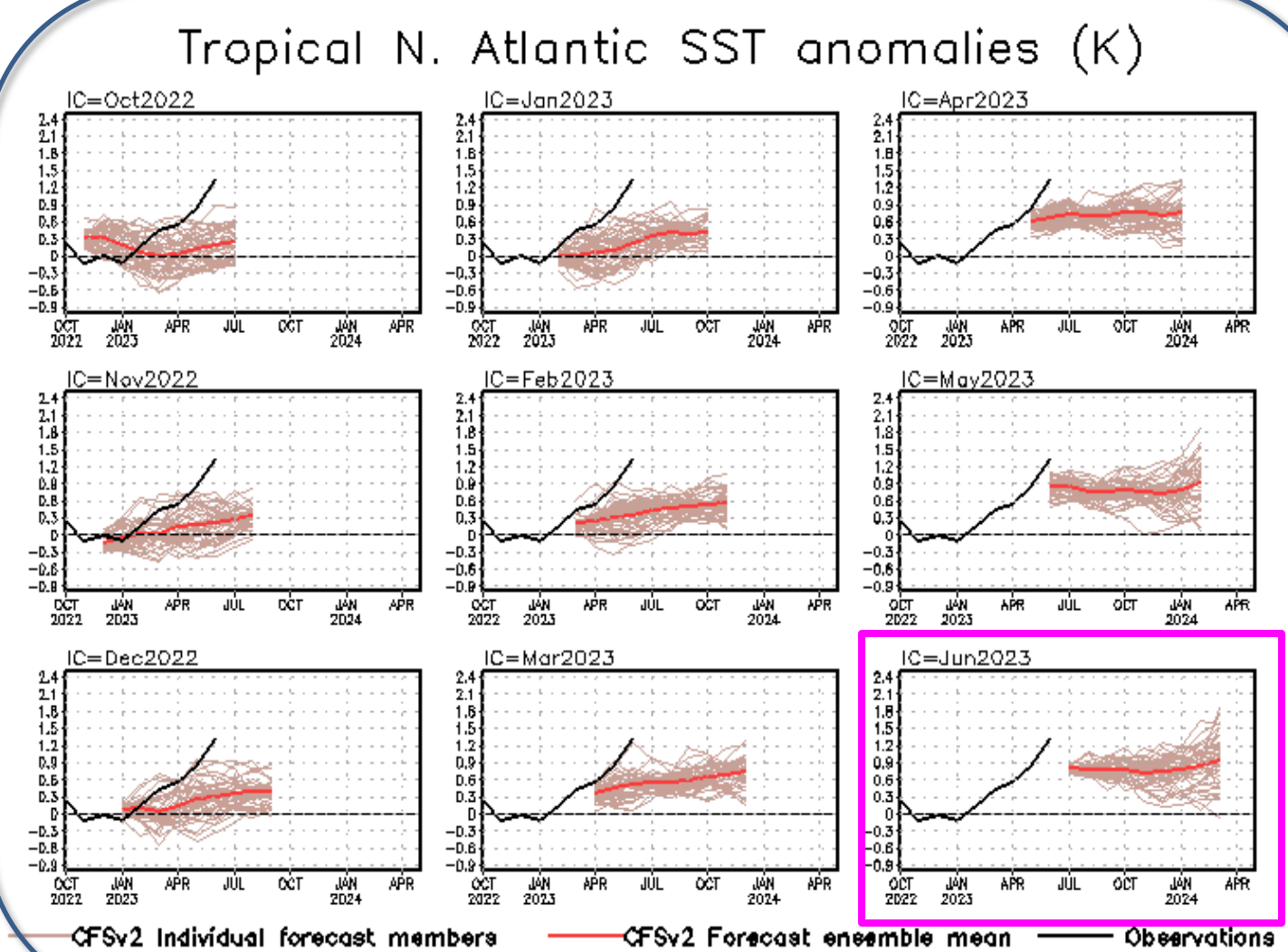
NCEP CFS DMI SST Predictions from Different Initial Months



- 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].