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

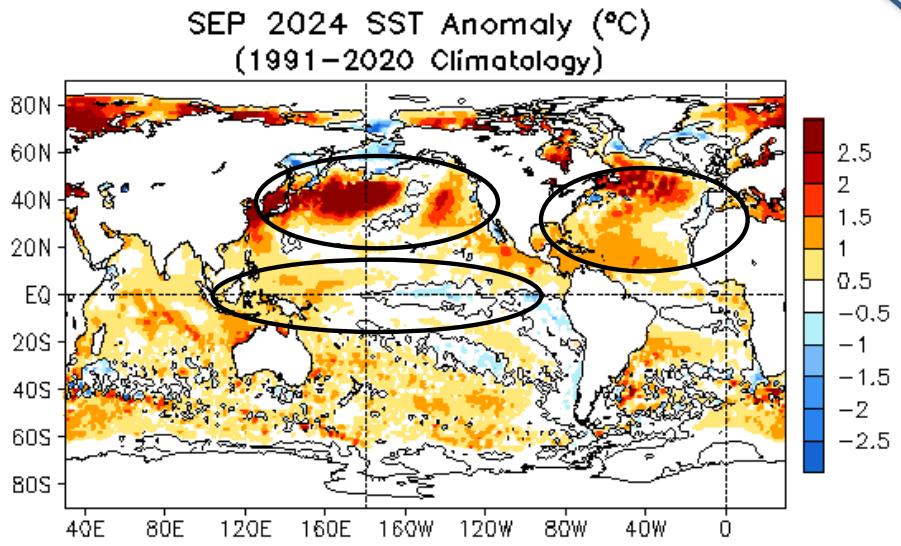
Due to storm-related disruptions affecting the systems at NOAA's National Centers for Environmental Information(NCEI) in Asheville, NC, Met Office OSTIA temporally replace NCEI OISST. BASS/CMORPH/CFSR EVAP package, Sea ice and ERSST-related slides were not updated this month.

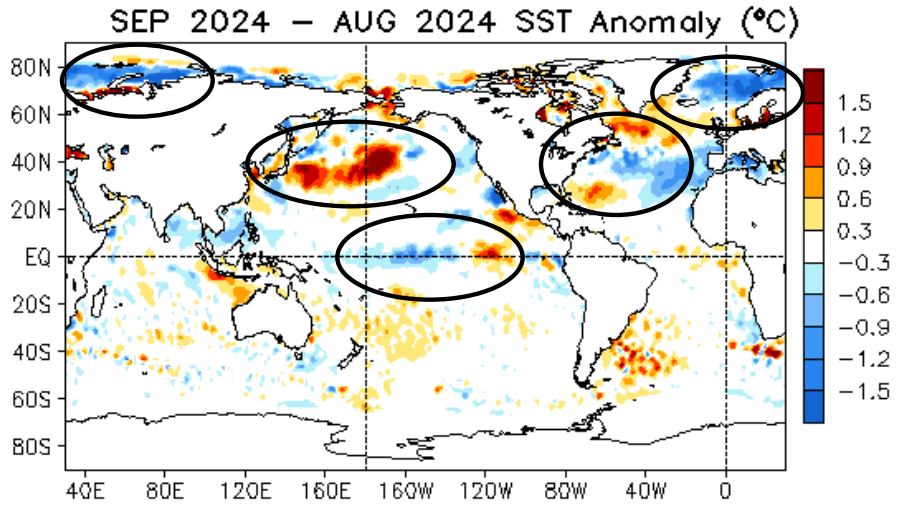
Overview

- Pacific Ocean
  - ENSO neutral conditions continued with Niño3.4 = -0.3°C (OSTIA) in Sep 2024.
  - The positive SSTA and a strong negative phase of the PDO persisted in the North Pacific.
  - Strong subsurface warming has persisted in the central North Pacific Ocean since 2020.
- Arctic & Antarctic Oceans
  - The average Arctic sea ice extent for Aug 2024 was 5.2 million km^2, ranking as the fourth lowest August since 1979.
  - Antarctic sea ice extent continues to track as the 2nd historical low August value.
  - CPC forecasts a near-normal Arctic sea ice extent maximum in Mar 2025.
- Indian Ocean
  - Positive SSTAs dominated the tropical Indian Ocean basin in Sep 2024.
  - The Indian Ocean dipole (IOD) was neutral in Sep 2024.
- Atlantic Ocean
  - Hurricane activity was very active in Sep 2024.
  - Strong Marine heat waves persisted in the north tropical Atlantic and the central extratropical Atlantic Ocean .
  - Patterns of SST, OLR and low-level wind anomalies over Jul-Sep 2024 were consistent with impact of tropical Atlantic meridional mode on local climate.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency



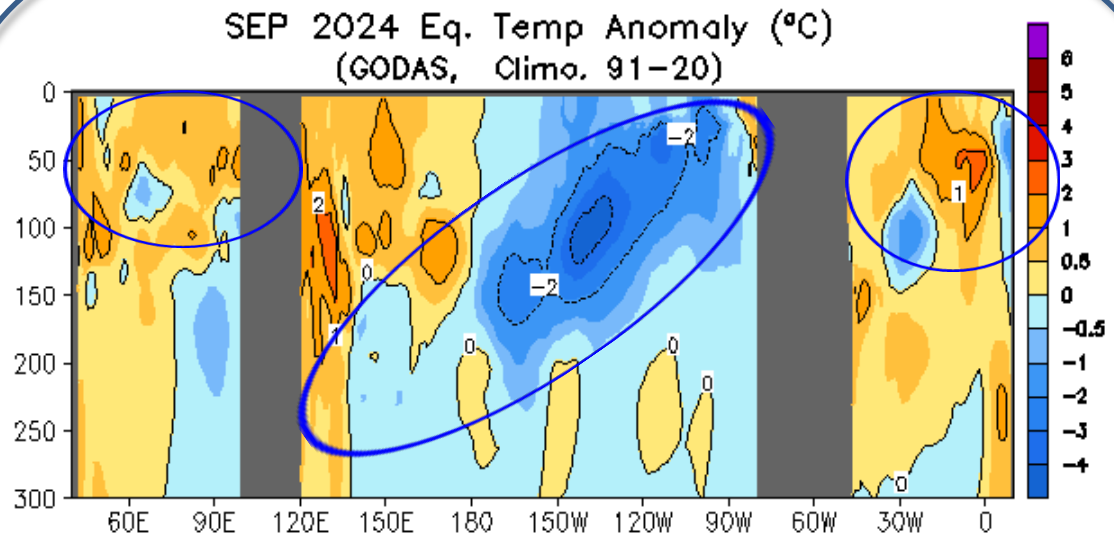


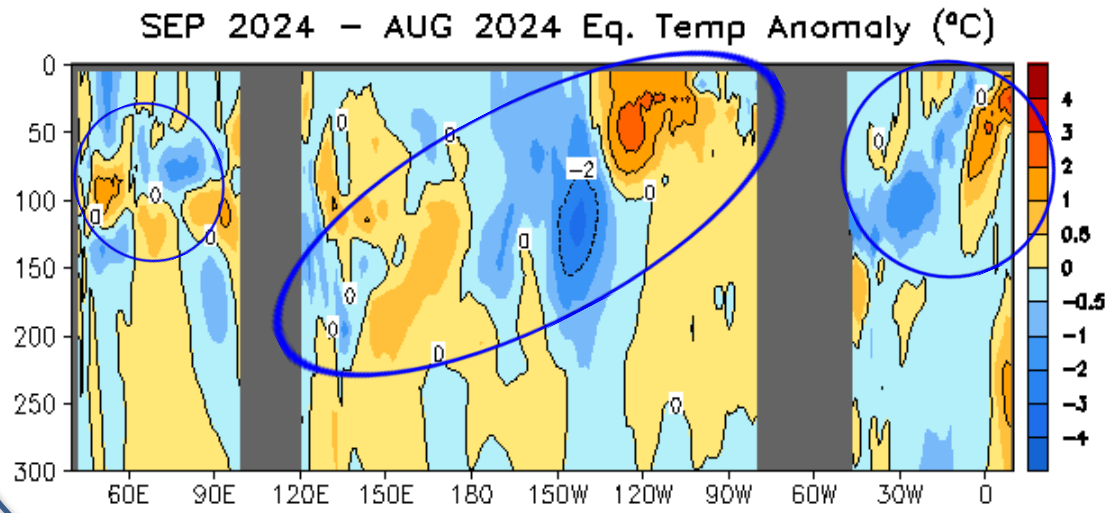
- SSTs were above average in the west-central Pacific Ocean, while near to below average SSTs were present in the eastern Pacific.
- Strong positive SSTAs continued in the mid-latitude of the North Pacific and North Atlantic Oceans.
- Positive SSTAs dominated the tropical Atlantic, Indian and Southern Oceans.

- Both positive and negative SSTA tendencies were observed in the North Pacific and Atlantic Oceans.
- Negative SSTA tendencies were present near the Barents Sea and Laptev Sea.
- Negative (positive) SSTA tendencies were present in the central-eastern (eastern) equatorial Pacific Ocean.

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

Longitude-Depth Temperature Anomaly and Anomaly Tendency in 2°S-2°N



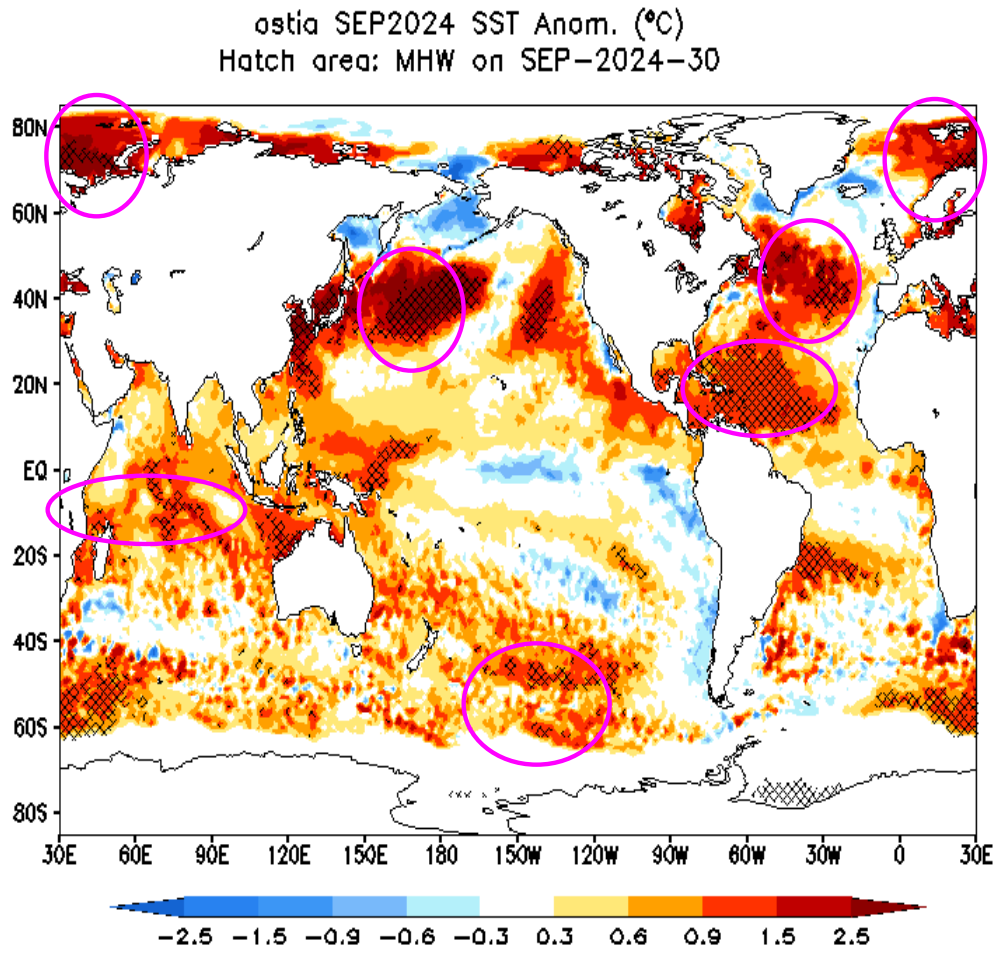


- Negative temperature anomalies persisted along the central-eastern thermocline in the Pacific, while positive temperature anomalies continued in the western Pacific.
- Positive temperature anomalies were present in the upper 150m of the Indian Ocean.
- Positive temperature anomaly dominated the upper ocean of the Atlantic.

- Both positive and negative temperature anomaly tendencies were present along the thermocline in the Pacific Ocean.

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

Global Monthly SST anomaly and Marine Heat Waves

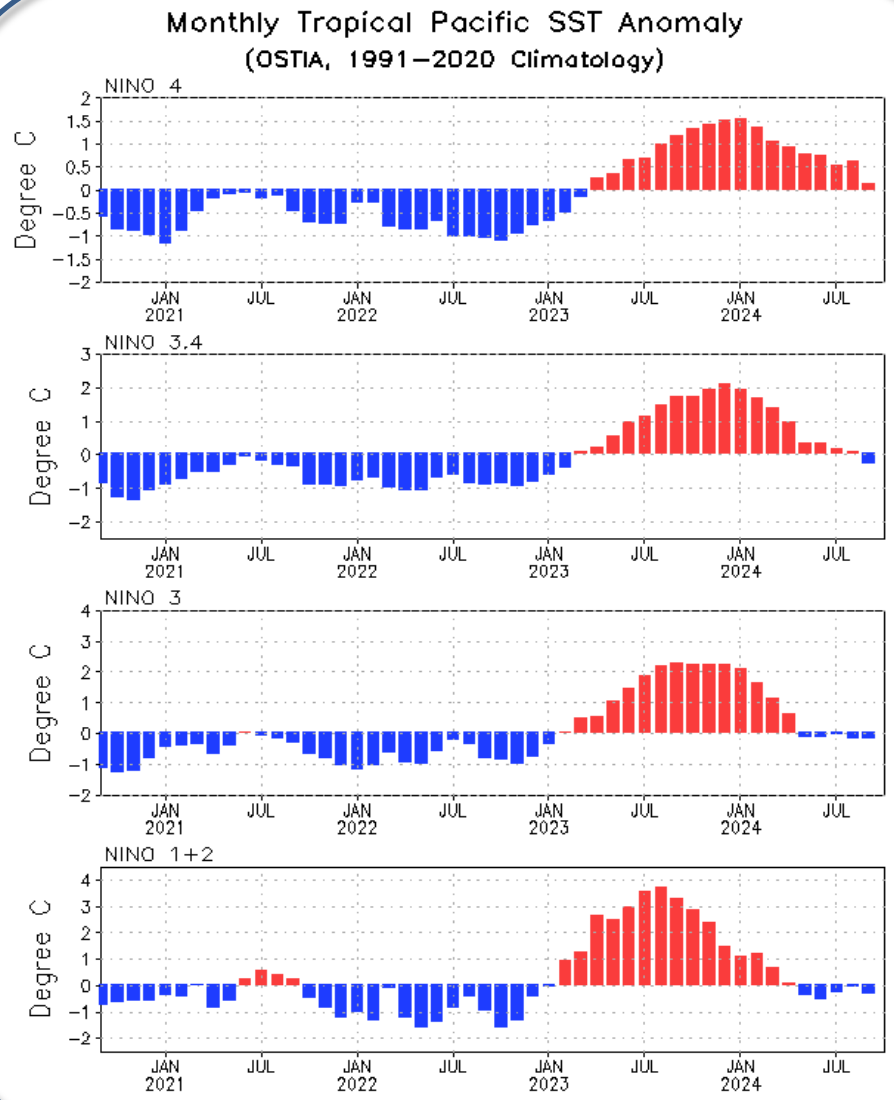


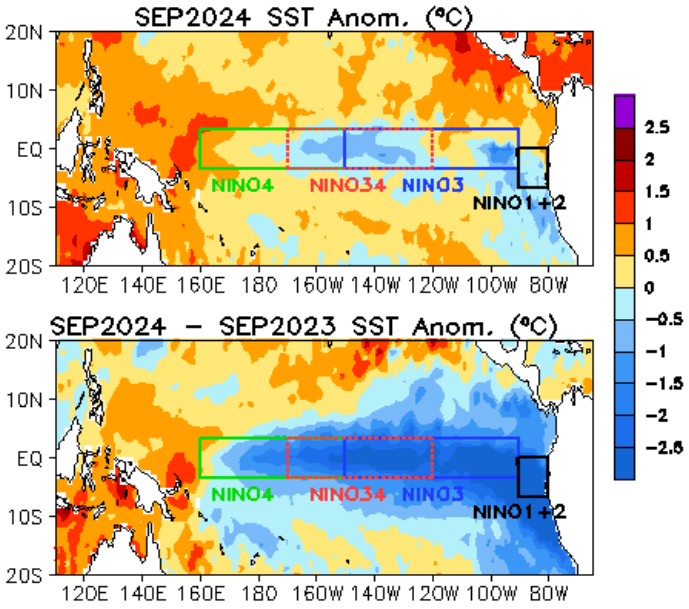
- MHWs continued in much of the central North Atlantic, tropical North Atlantic, north central - western extratropical Pacific and southern tropical Indian Oceans.
- MHW coverage area decreased in the Barents Sea and Kara Sea.

((Left panel) Monthly SST anomaly (shaded) and locations experiencing marine heat waves (hatched) by the end date labelled in the plot. Shaded area denotes the periods experiencing MHW. MHW is defined as a prolonged warming exceeding 90th percentile of daily SST for at least 14 consecutive days. Data is derived from MET office OSTIA and the reference period is 1991-2020

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific Niño SST Indices

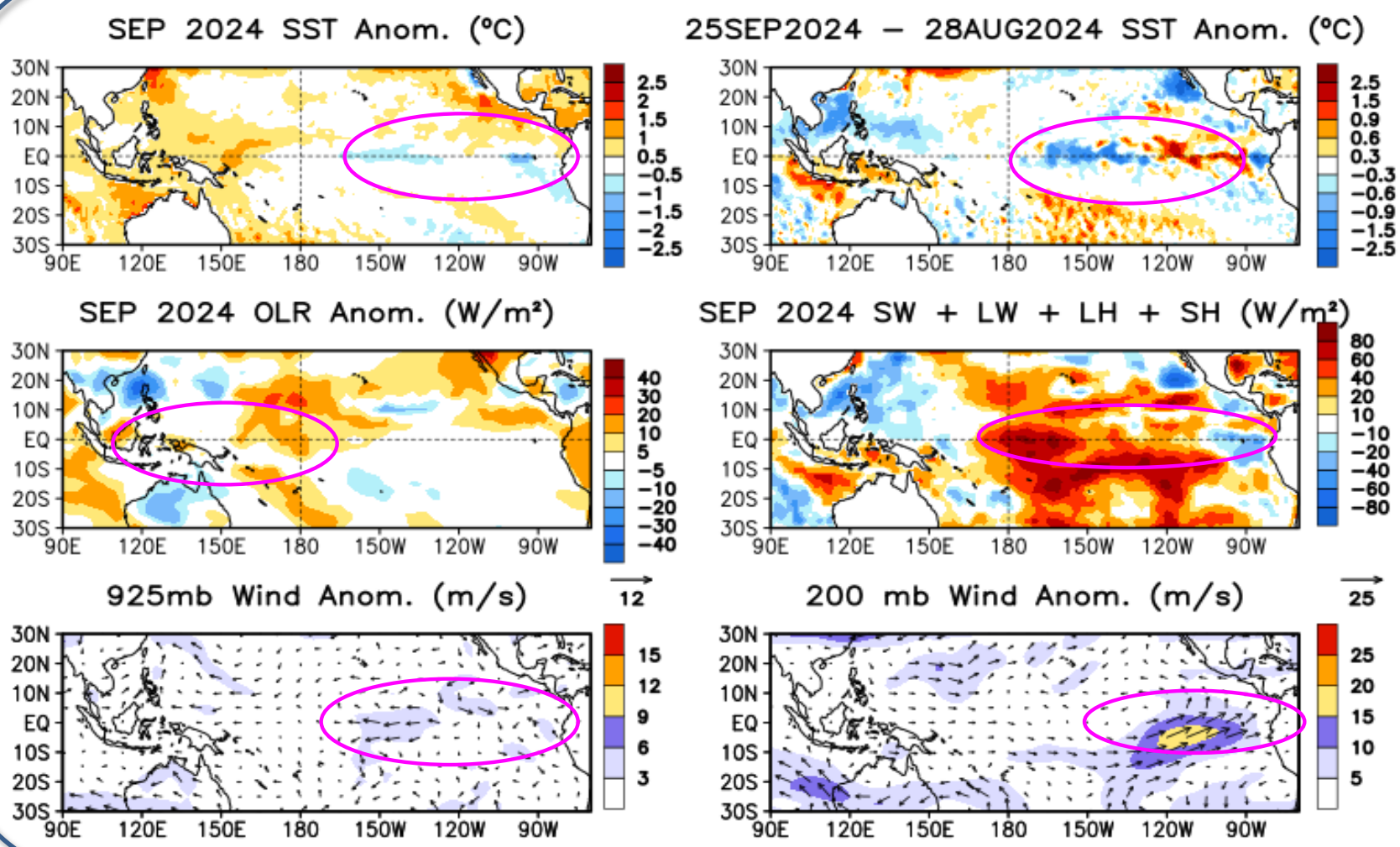




- Niño3.4 switched to negative phase in Sep 2024, with Niño3.4 = -0.3°C.
- Niño4 decreased to near normal in Sep 2024.
- Compared with Sep 2023, the tropical eastern Pacific was cooler in Sep 2024
- The indices may have differences if based on different SST products.

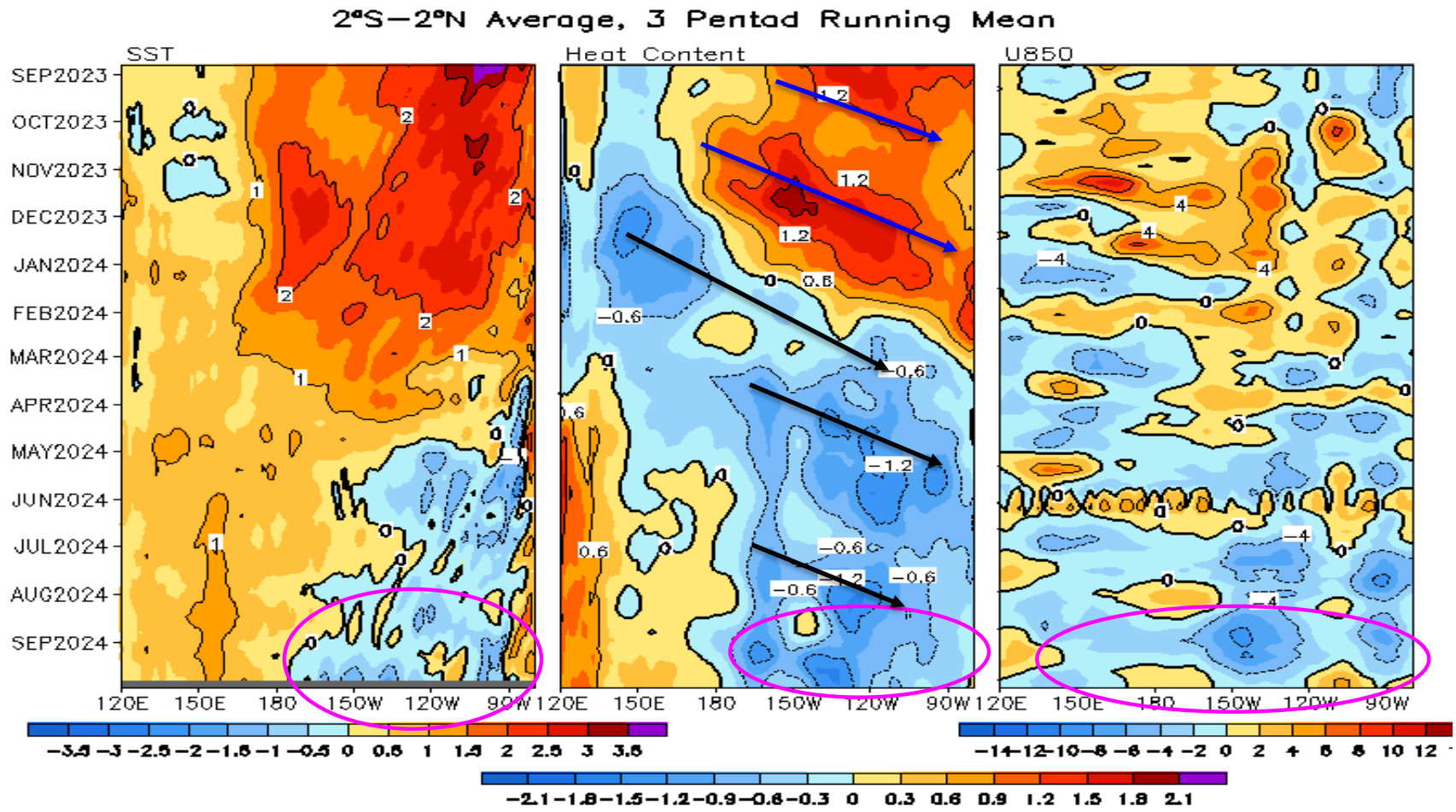
Niño region indices, calculated as the area-averaged monthly mean SSTAs (°C) for the specified region. Data are derived from the Met Office OSTIA analysis, and anomalies are departures from the 1991-2020 base period means.

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



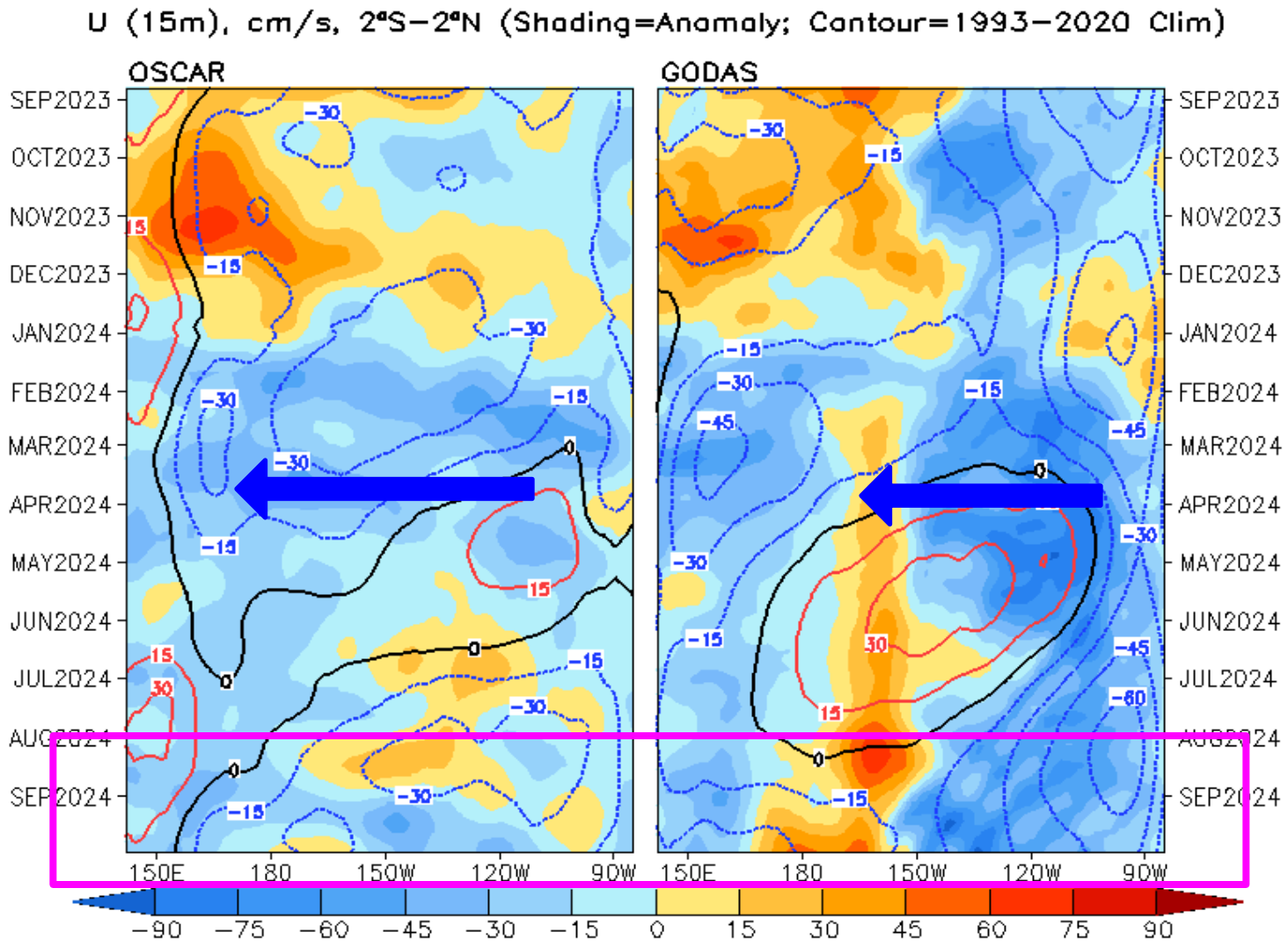
SSTAs (top-left), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the OSTIA 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.

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



- Negative SSTA in the eastern Pacific enhanced slightly in Sep 2024, while positive SSTA persisted west of Dateline.
- Negative H300 anomaly persisted in the eastern Pacific during Sep 2024.
- Easterly wind anomalies have mostly dominated over the central-eastern Pacific Ocean since July 2024, with some periods of westerly wind anomalies.

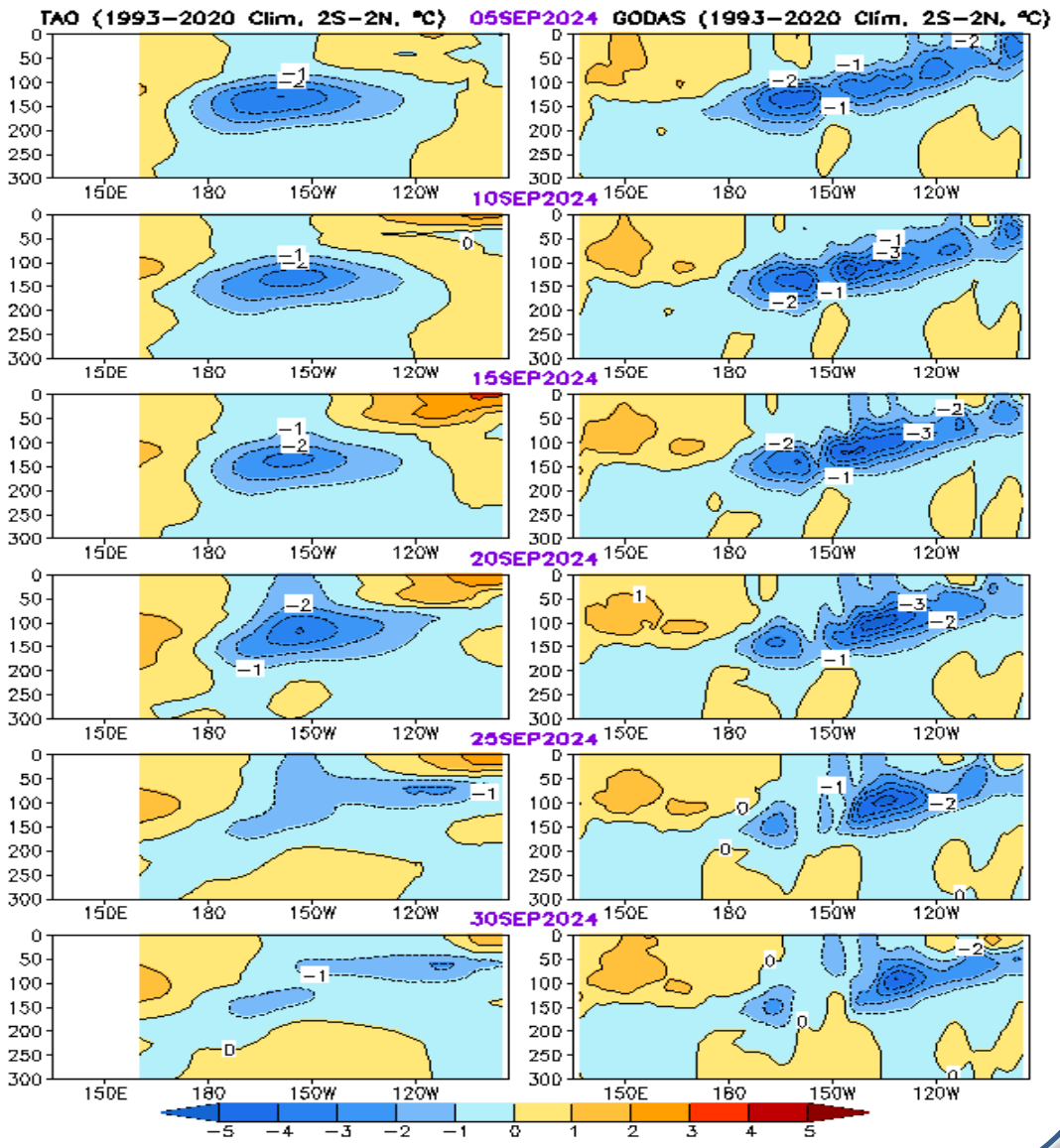
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



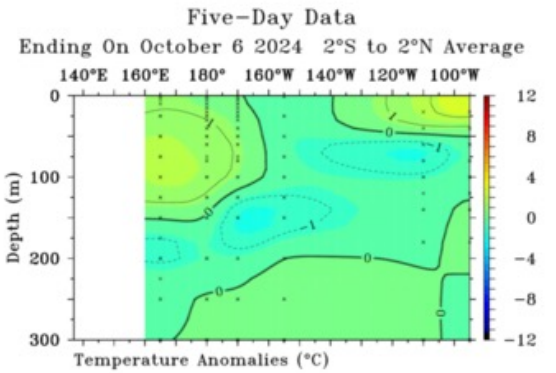
- Anomalous westward currents have been observed since mid-Dec 2023 with a weakening since May 2024.
- Anomalous westward currents were observed in the eastern Pacific both in GODAS and OSCAR during Aug 2024.

Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

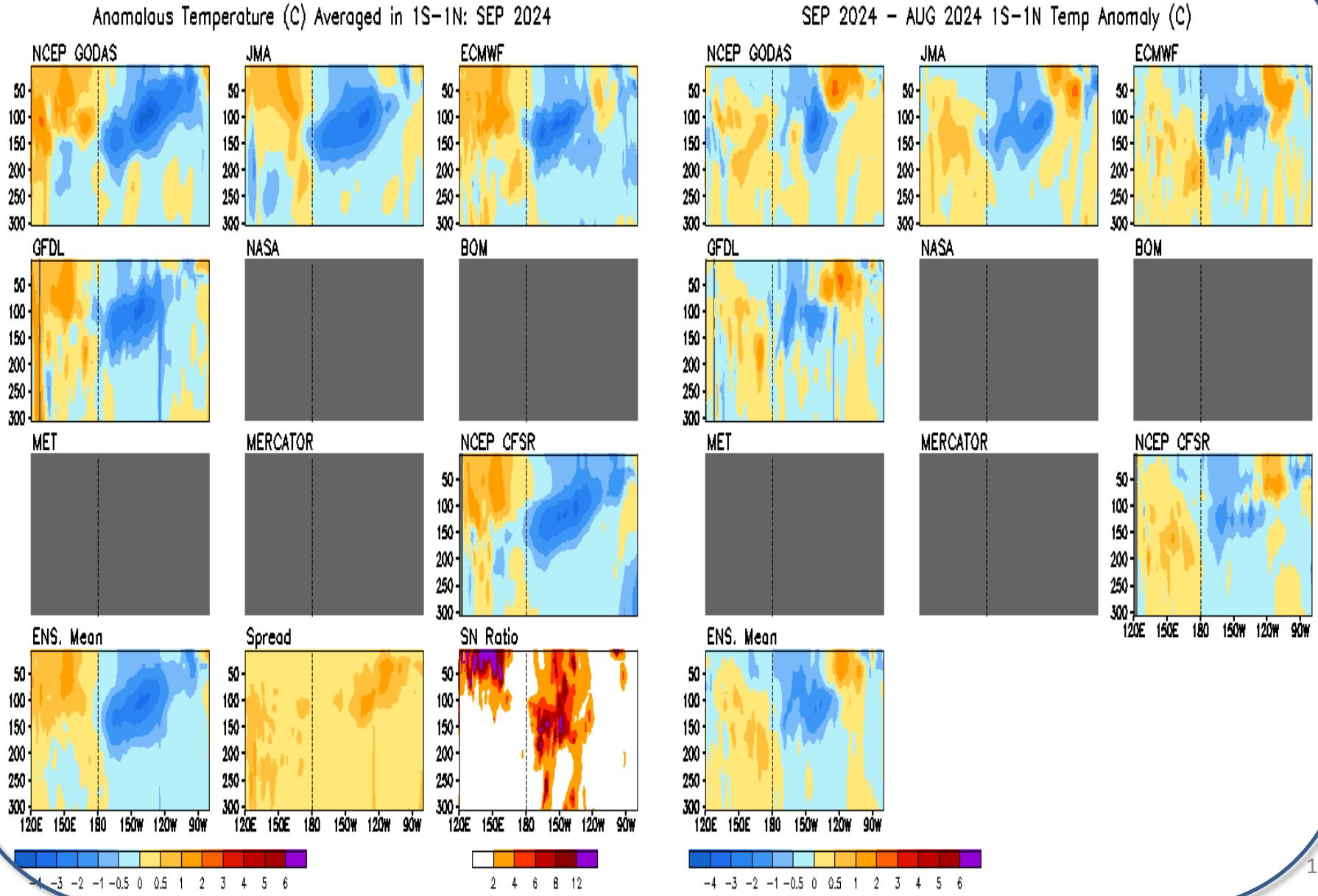
TAO GODAS



- Negative ocean temperature anomalies in the central-eastern Pacific weakened during Sep 2024.
- GODAS was much colder than TAO east of 150ºW.
- Large discrepancy between TAO and GODAS was partially due to missing data in TAO moorings in the eastern Pacific.

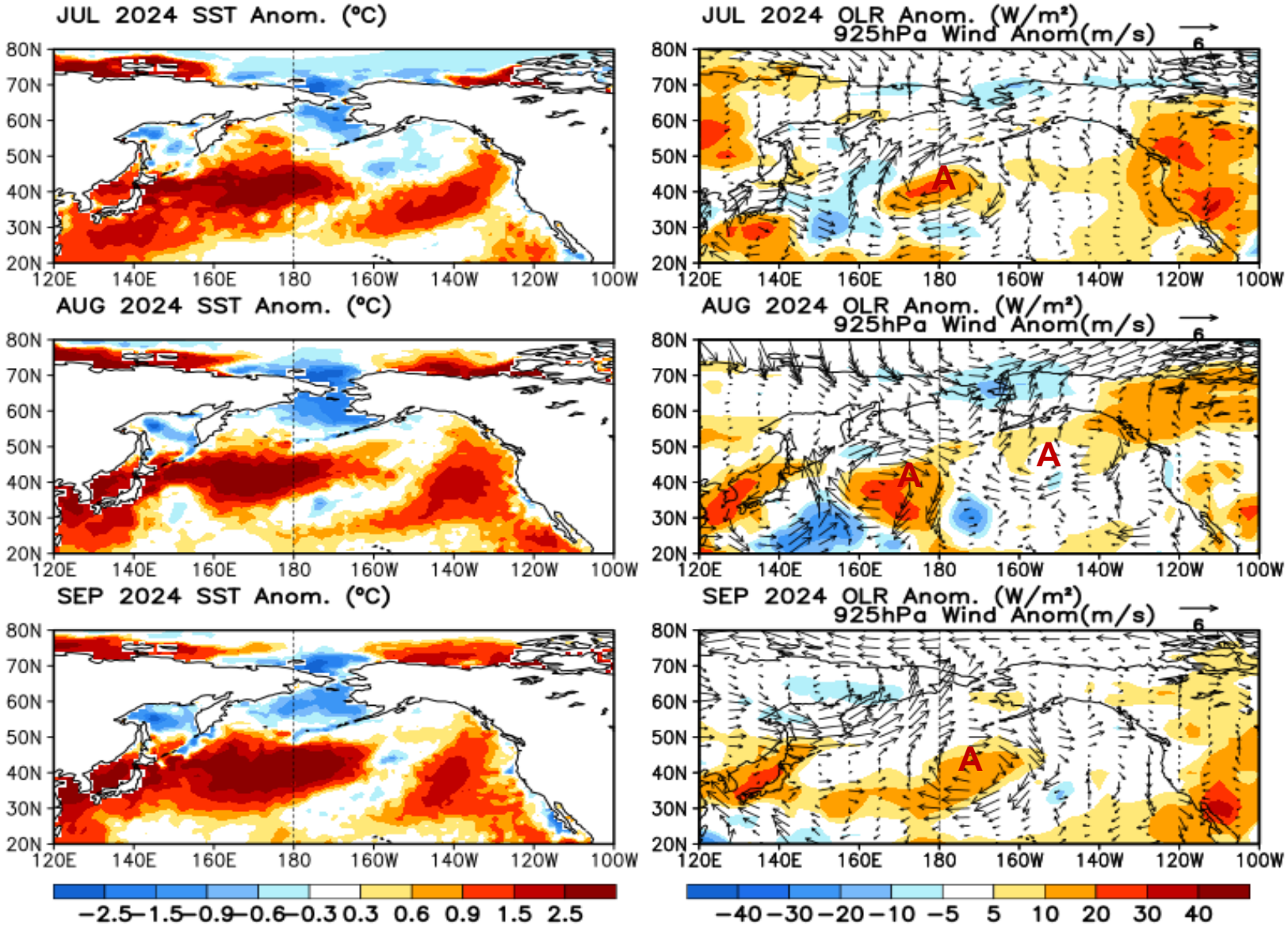


Multiple Ocean Reanalysis Intercomparison: Temperature Anomaly and Tendency at Equator

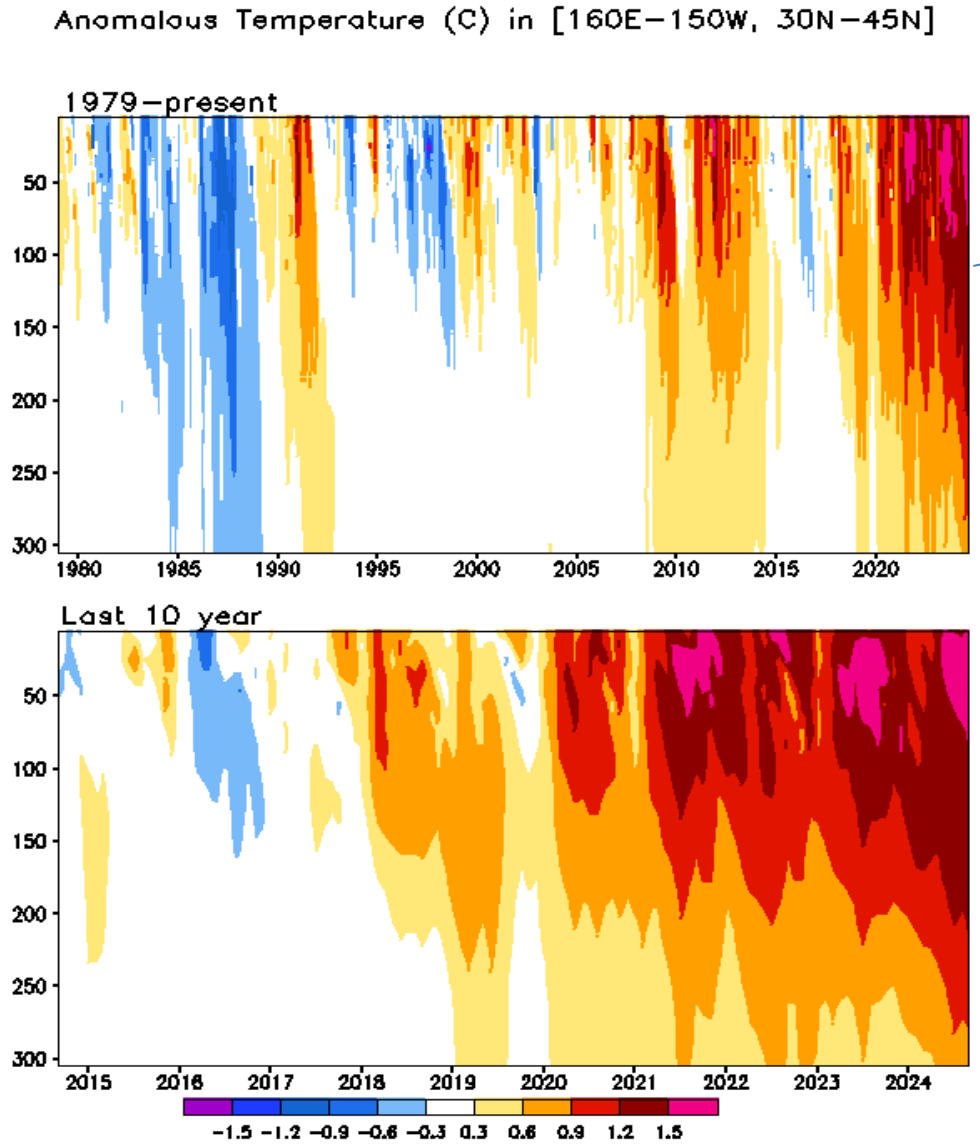


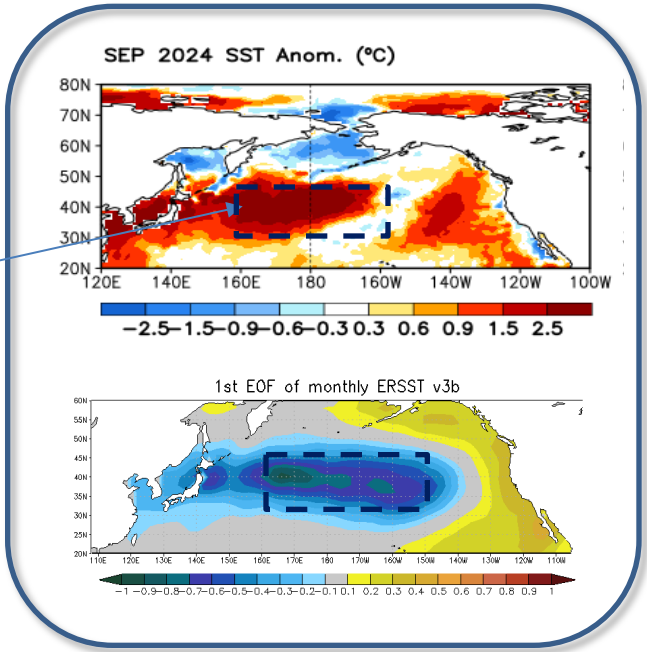
North Pacific & Arctic Oceans

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



Subsurface Temperature Anomaly in the Northcentral Pacific

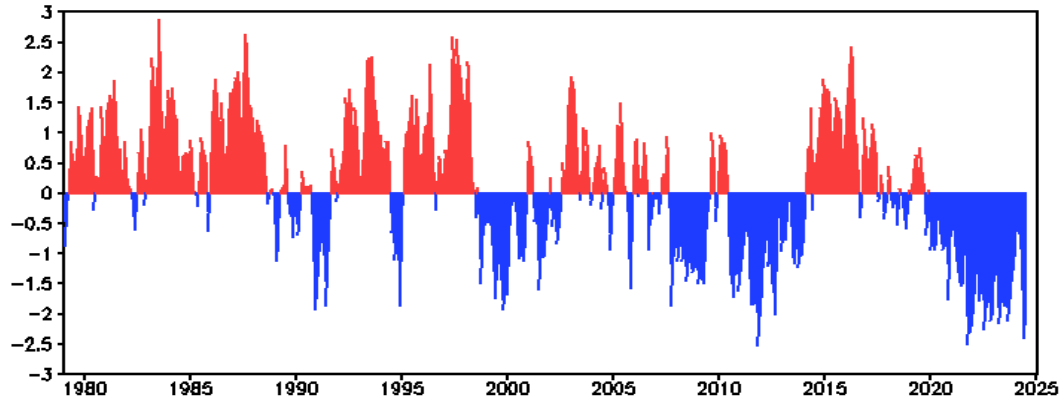




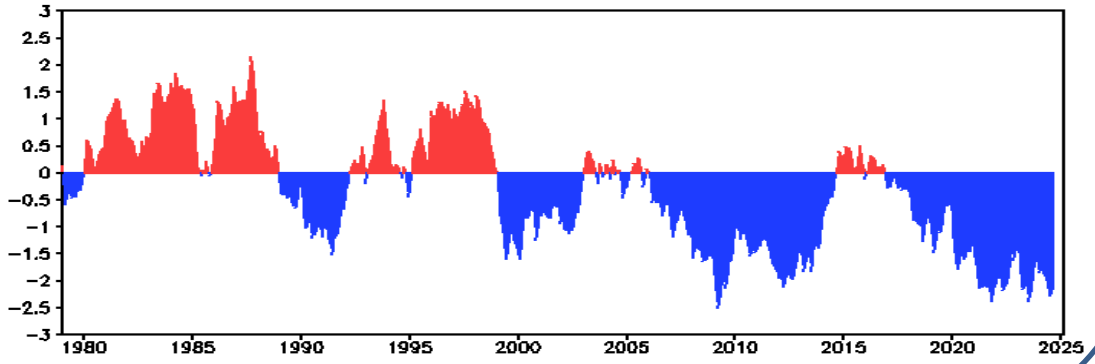
- Positive temperature anomaly (>0.9ºC) has persisted in the upper 100m since 2020, and penetrated to 300m since Jul 2024.
- Subsurface warming in the last four years is the strongest episode since 1979.

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 Aug 2024.

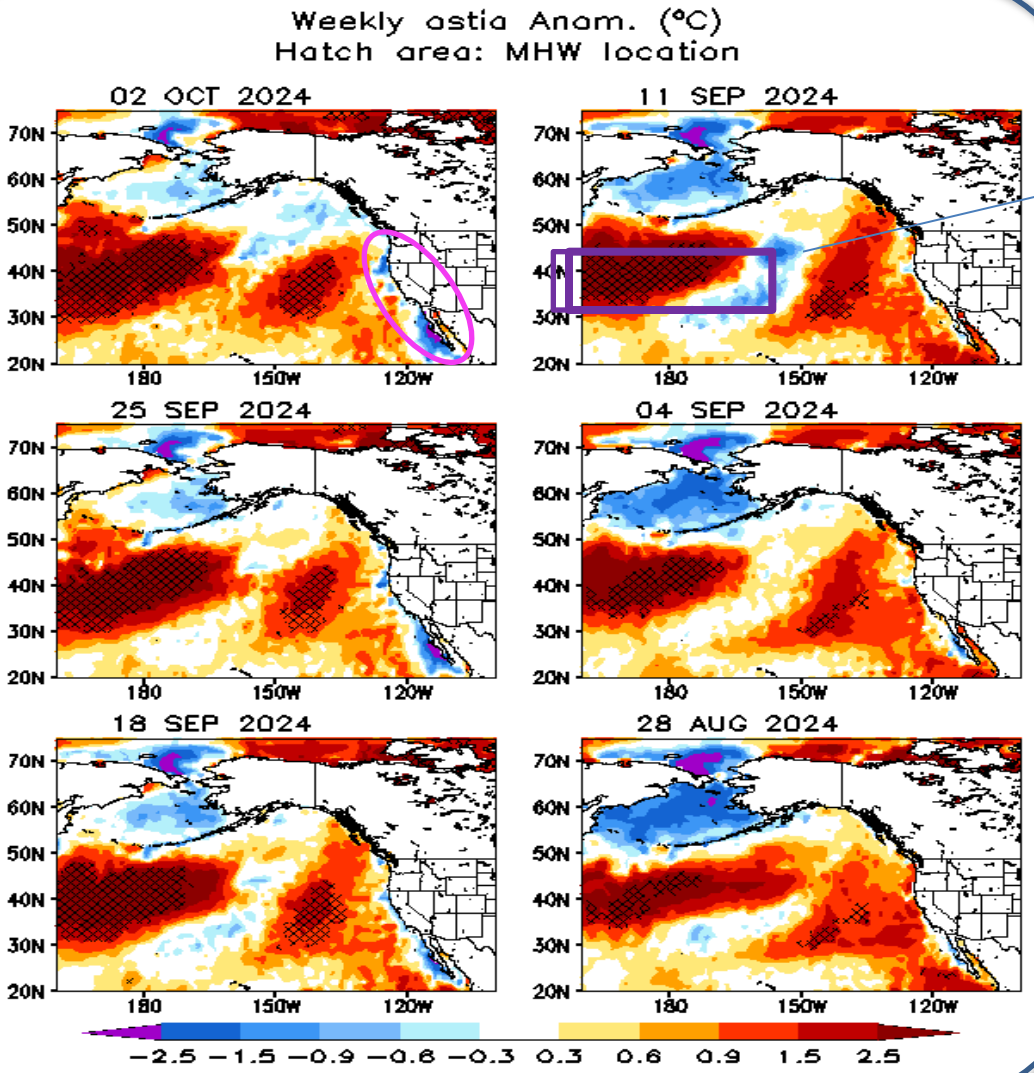
- Negative H300-based PDO index has persisted since Nov 2016, with HPDO = - 2.2 in Sep 2024.

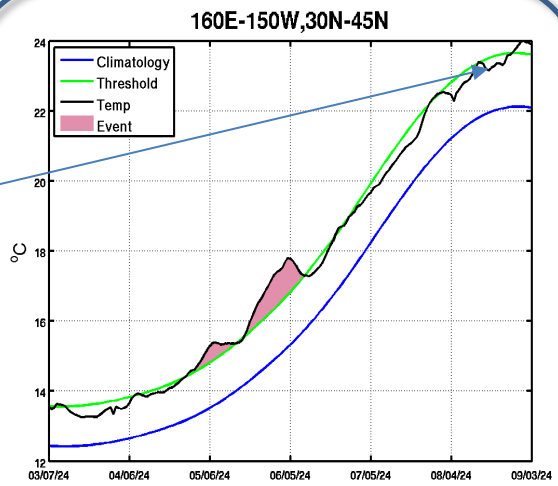
- SST-based PDO index has considerable variability both on seasonal and decadal time scales.

- 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.

Weekly SST anomaly and MHWs in the North Pacific

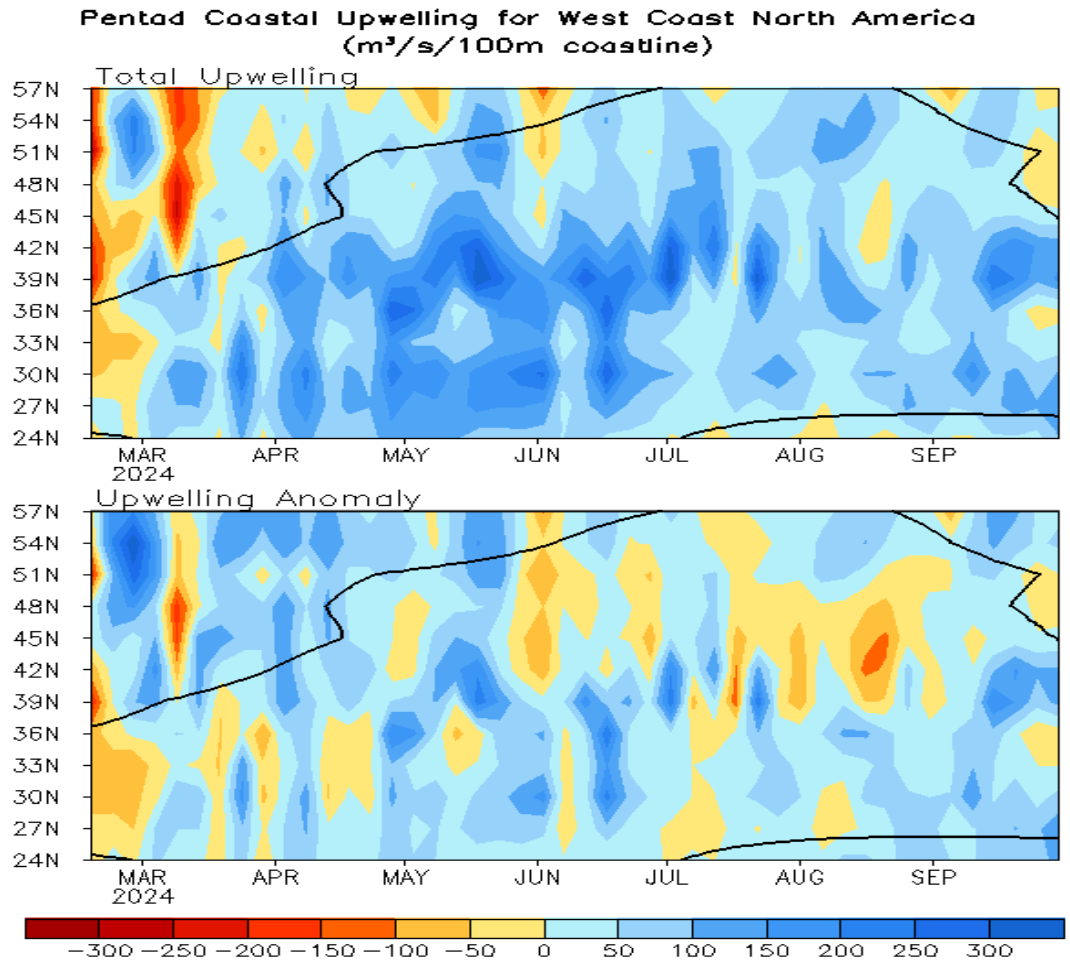


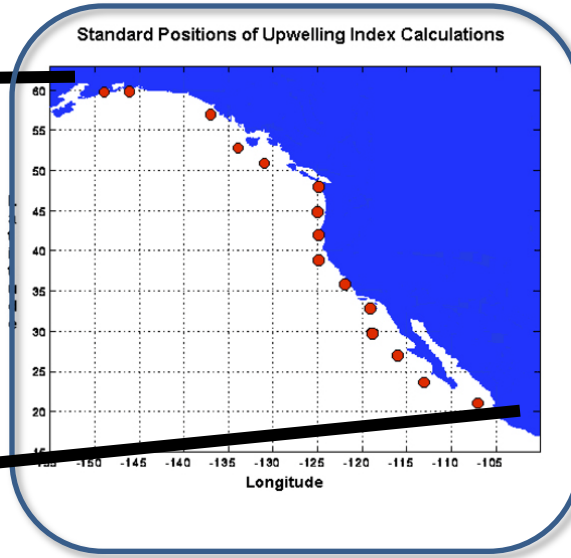


- MHWs have persisted in the central North Pacific since early May , but the coverage area varied owing to high frequency of atmosphere circulation.

(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

North America Western Coastal Upwelling

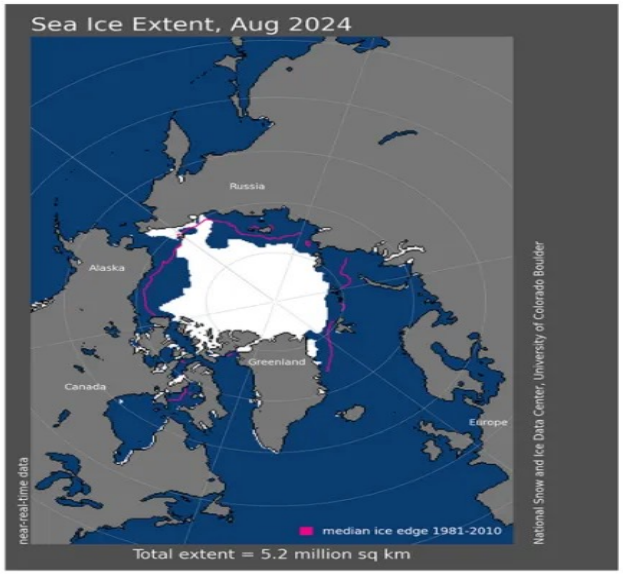


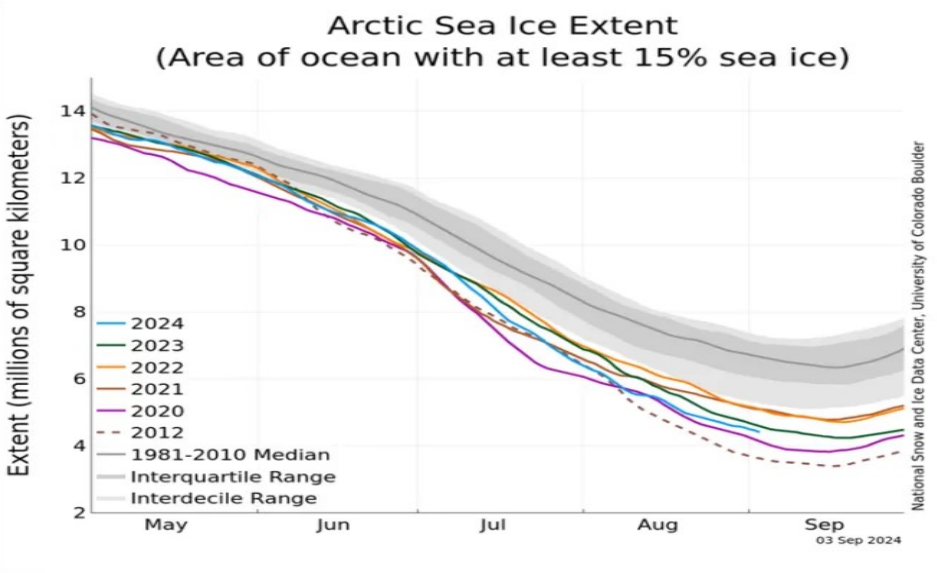


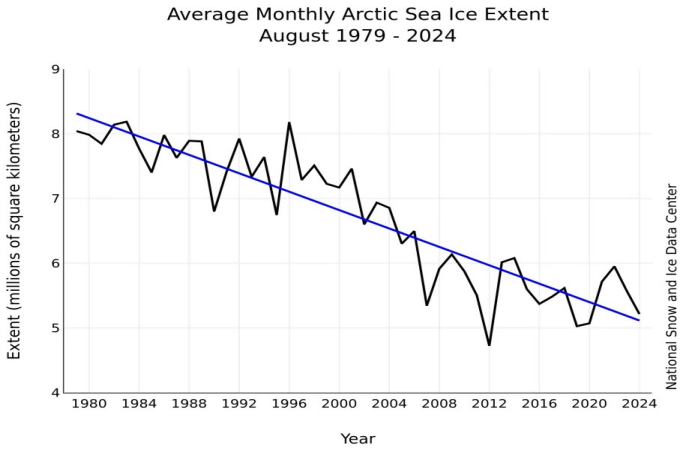
- Anomalous upwelling dominated along the western coast in Sep 2024, favoring SST cooling near the coast.

(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.

Arctic Sea Ice; NSIDC (https://nsidc.org/sea-ice-today)

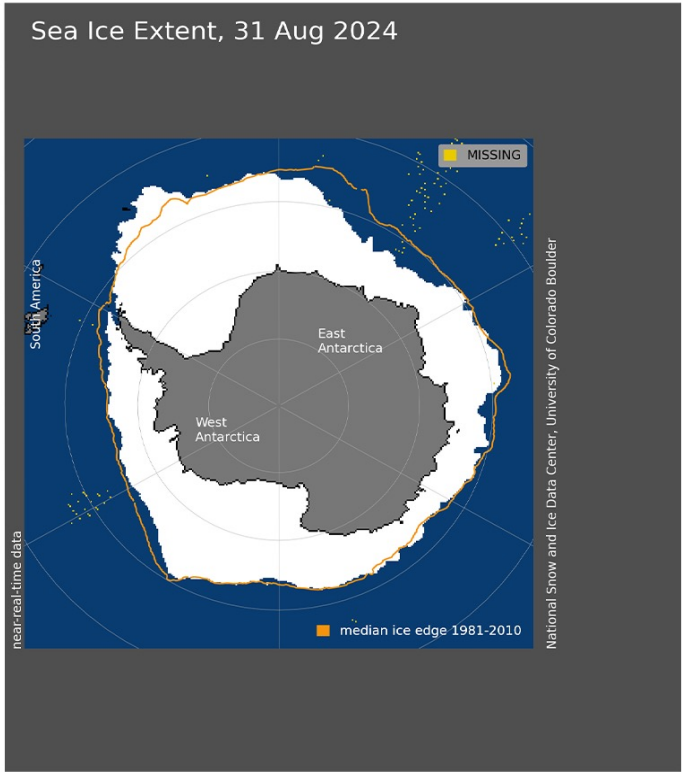


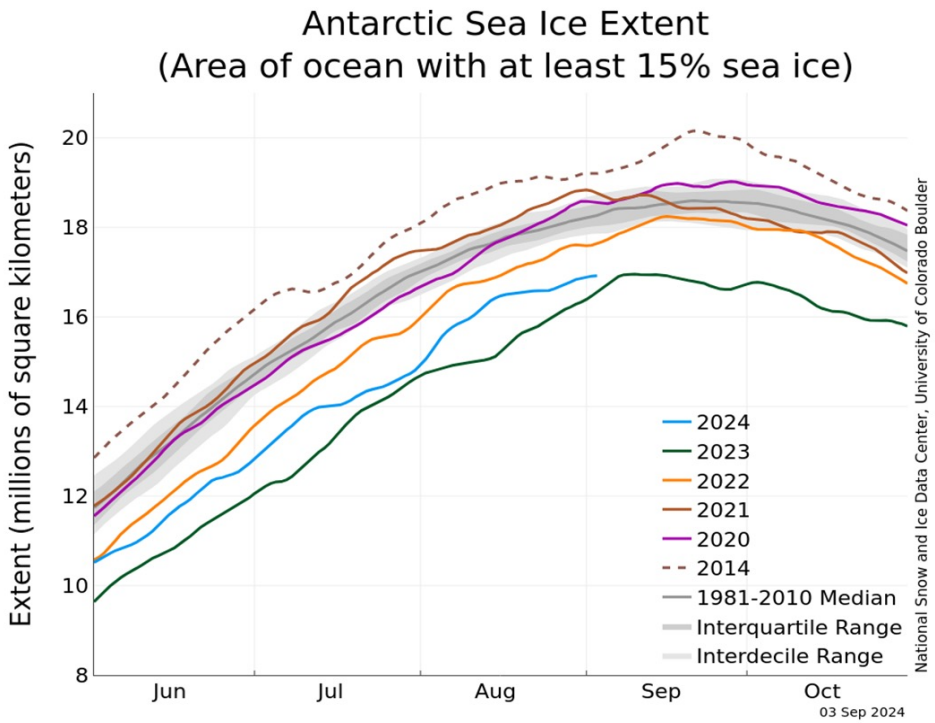




- Average Arctic sea ice extent during Aug 2024 was 5.2 million square kilometers, ranking as the fourth lowest Aug in the satellite record.

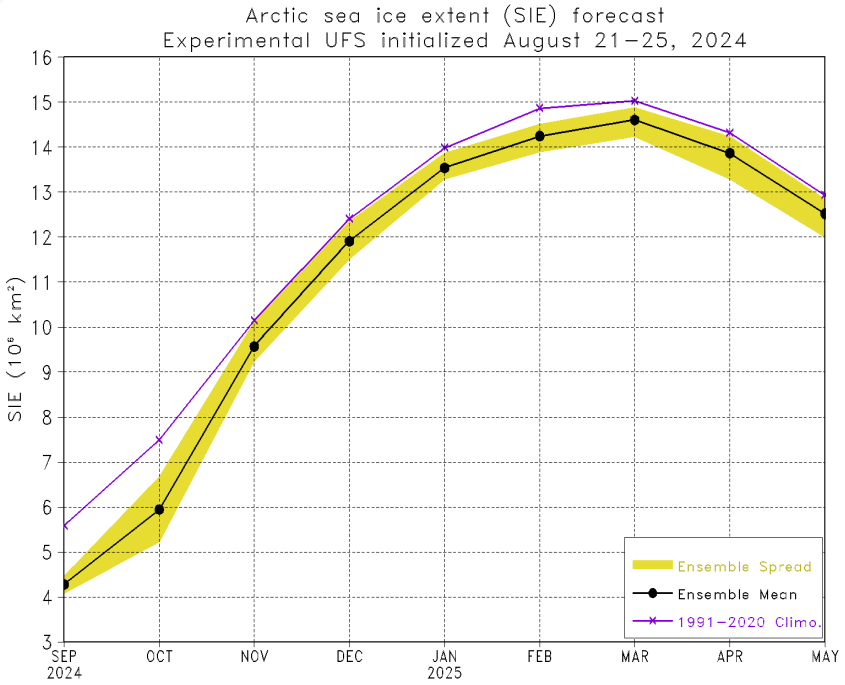
Antarctic Sea Ice; NSIDC (https://nsidc.org/sea-ice-today)

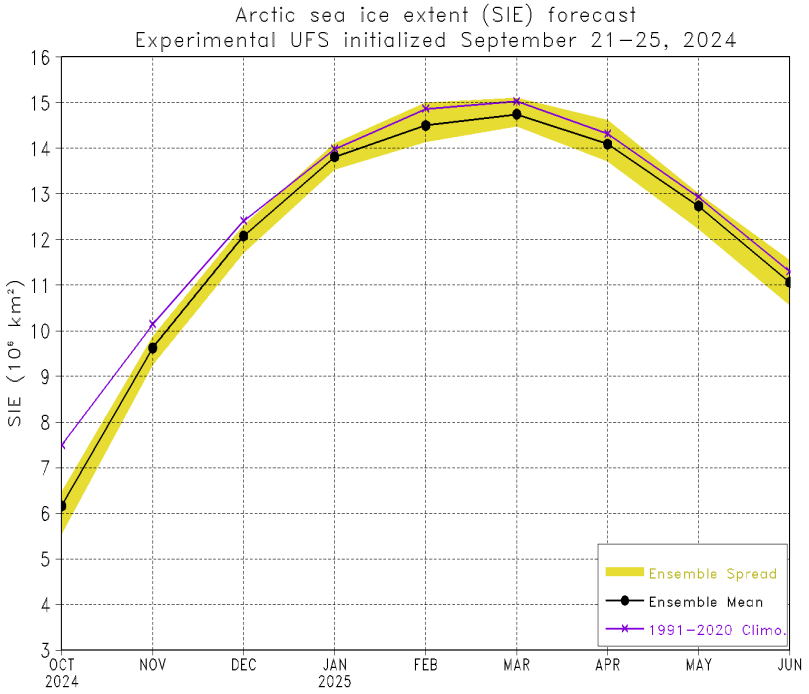




- Antarctic sea ice extent continues to track as the second lowest ice extent in the satellite data record.

NCEP/CPC Arctic Sea Ice Extent (SIE) Forecast



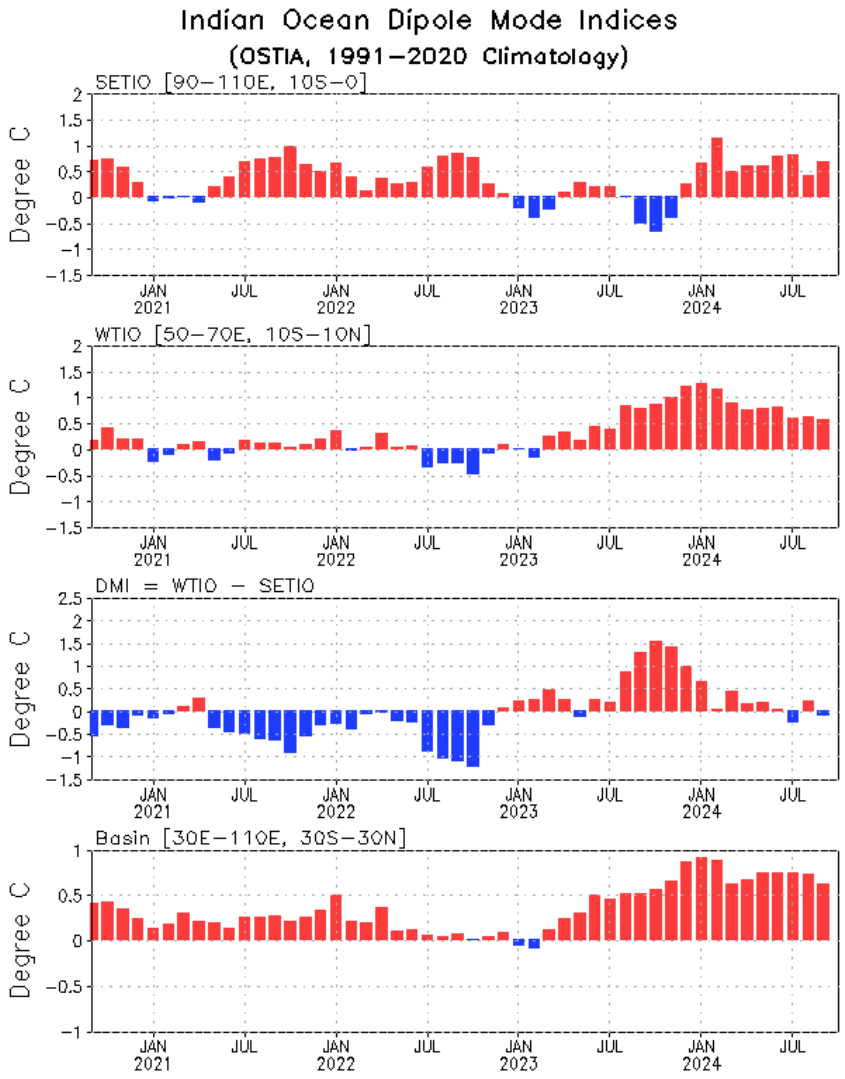


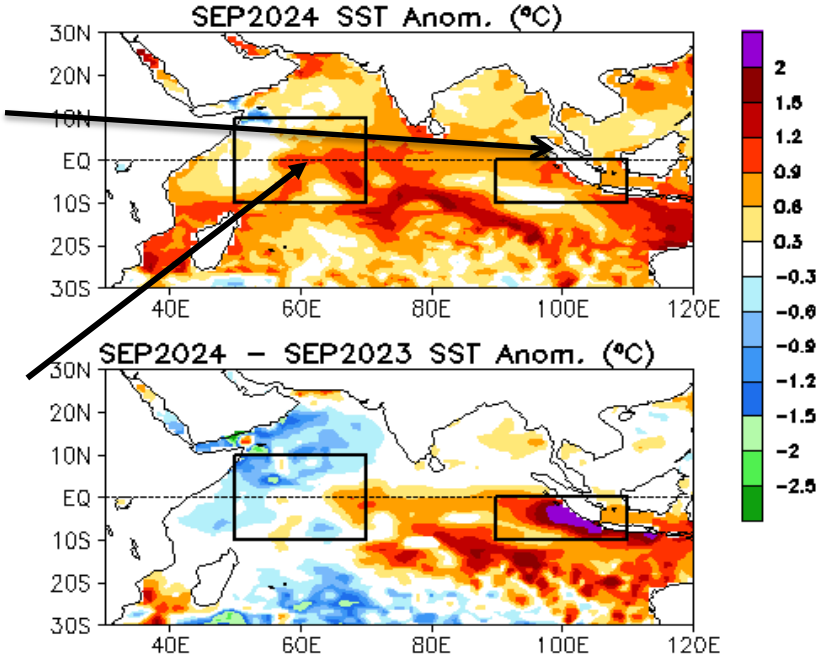
https://www.cpc.ncep.noaa.gov/products/people/jszhu/seaice_seasonal/index.html

- The latest CPC forecasts call for a near normal sea ice extent maximum in the Arctic in Mar 2025.

Indian Ocean

Evolution of Indian Ocean SST Indices

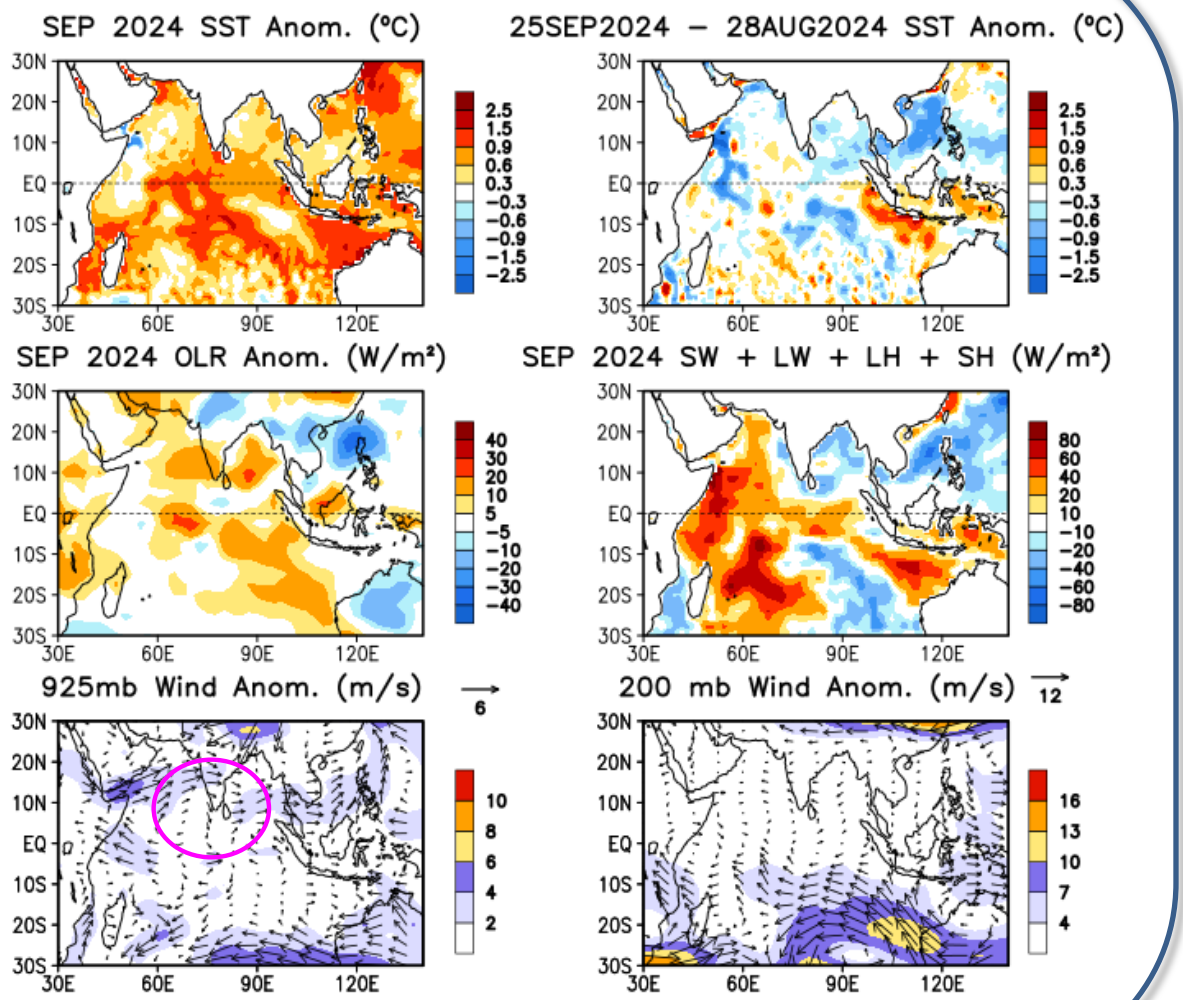




- Basin wide SST warming continued in the tropical Indian Ocean.
- Indian dipole mode was near neutral in Sep 2024.

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 Met Office OSTIA 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.



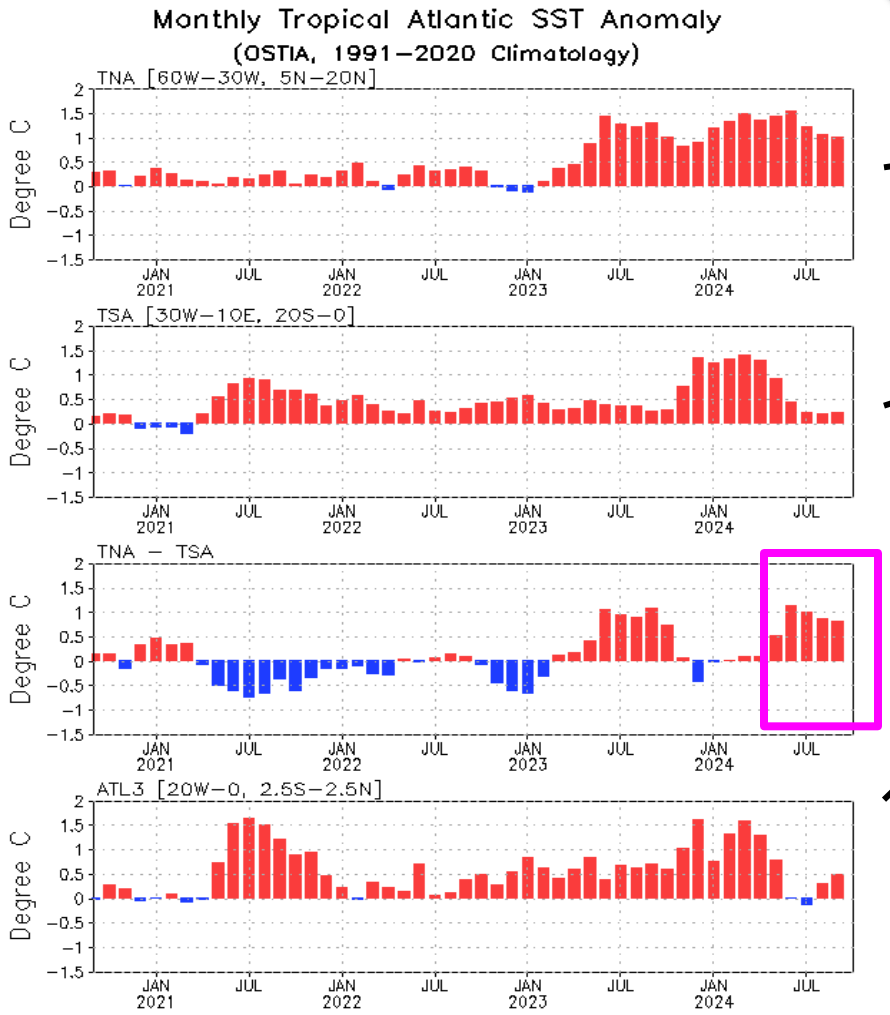
- Strong positive SSTAs were present across much of the tropical Indian Ocean.

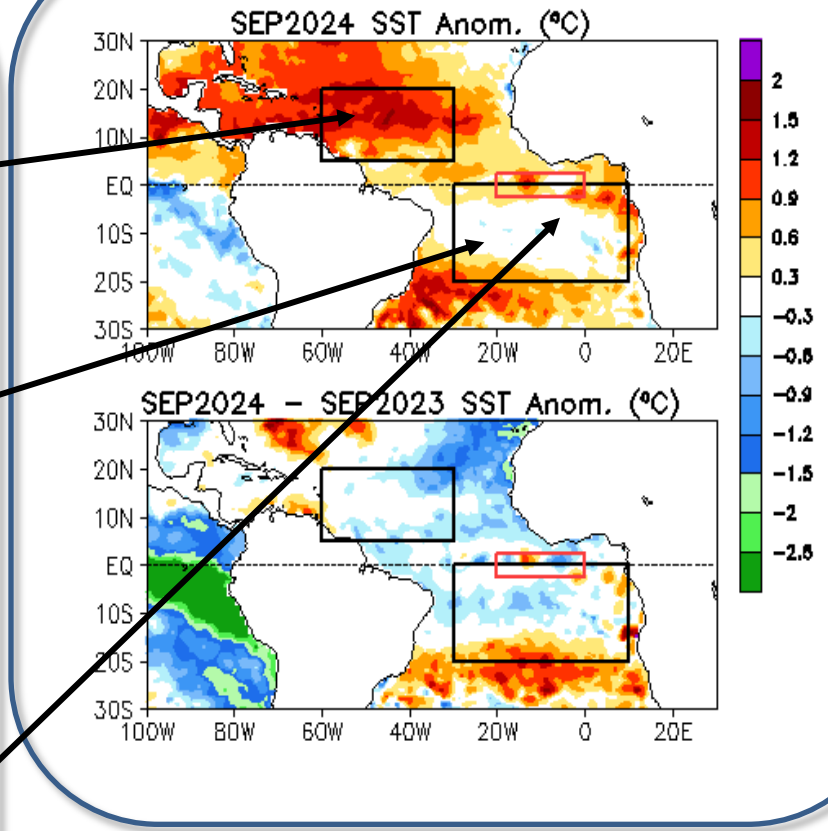
- Southwesterly wind anomaly contributed to an above-normal Indian summer monsoon rainfall.

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 OSTIA 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

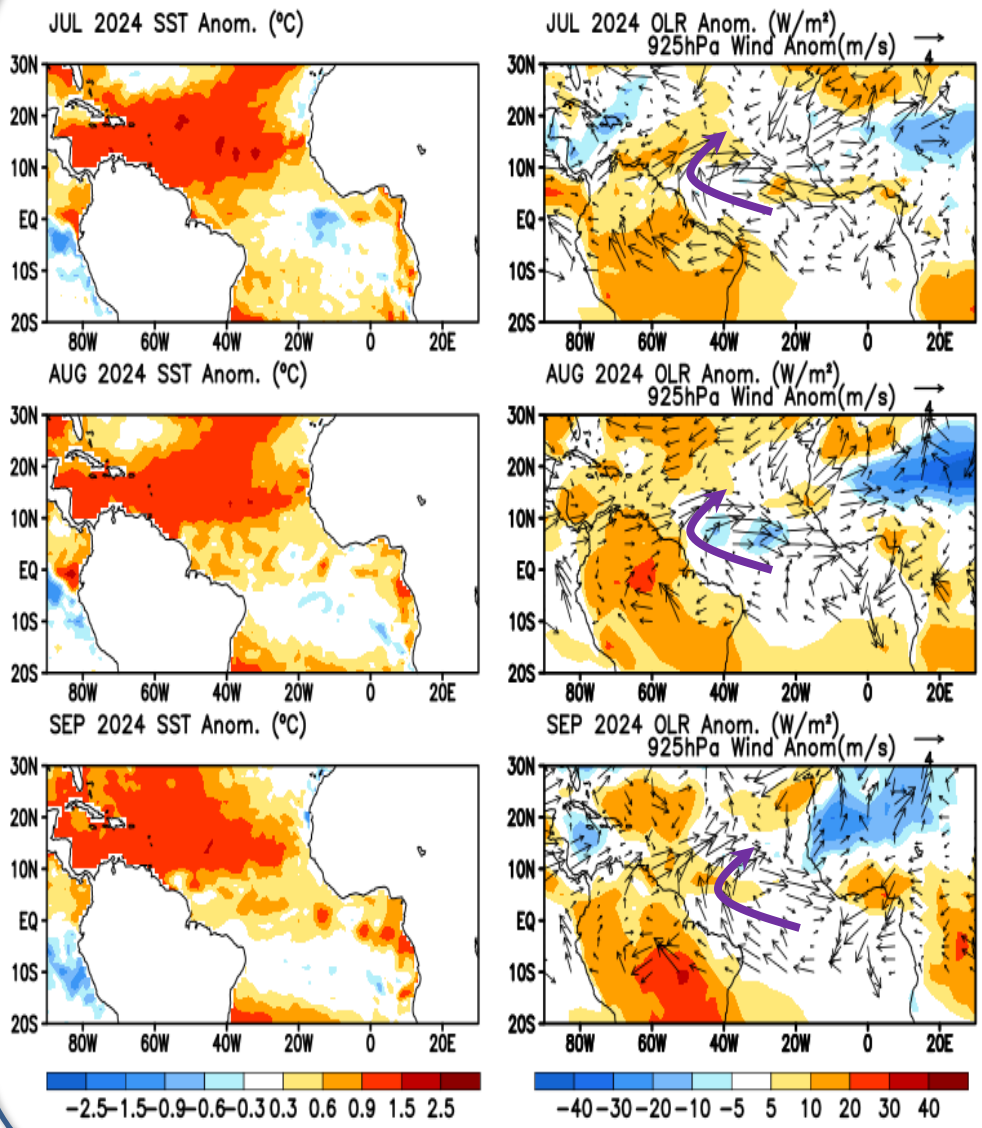


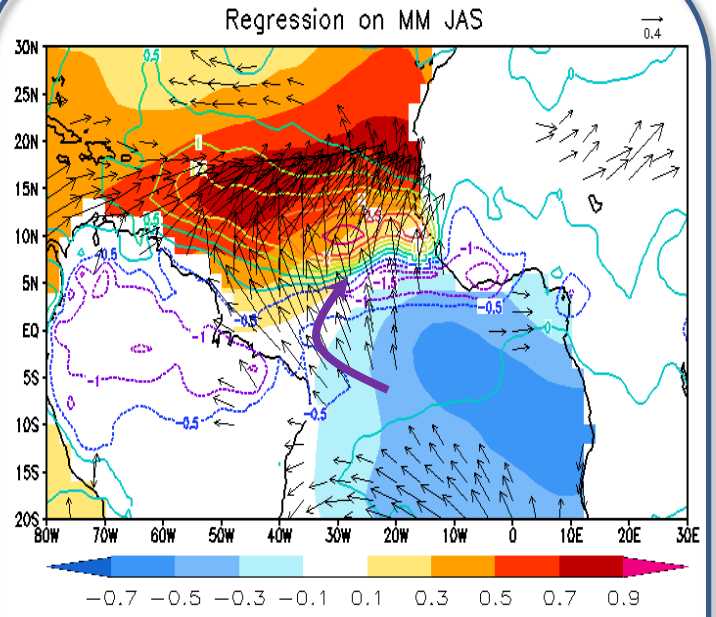


- Meridional gradient mode index remained well above average since Jun 2024, indicating the presence of a strong positive meridional mode phase.
- ATL3 index increased to 0.5°C in Sep 2024.

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

Impact of Atlantic Meridional Mode (MM) on African climate

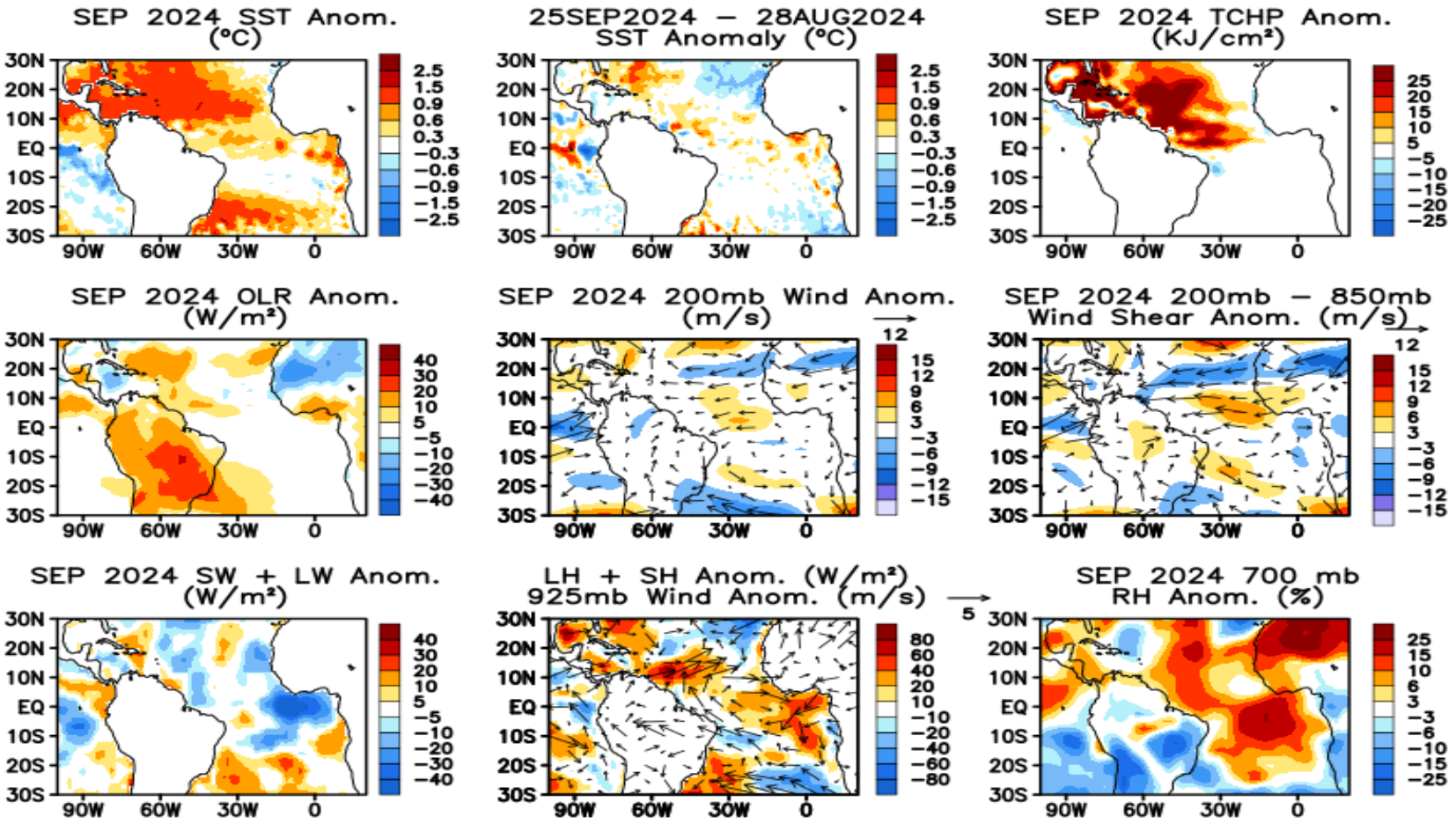




Shaded: SSTA Vector: 10m wind, Contour: precipitation

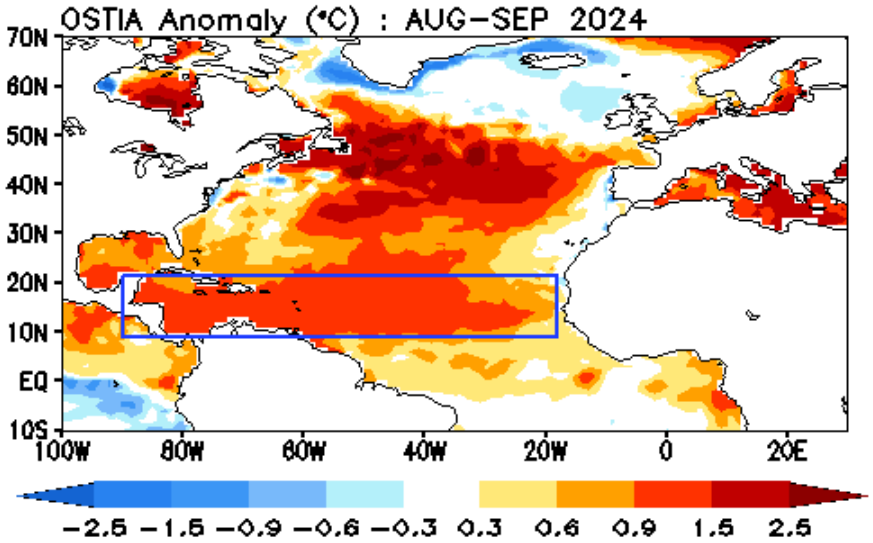
- Patterns of SSTA, wind anomaly and OLR anomalies over the past three months are consistent with the impact of positive MM on the African and South American climate.

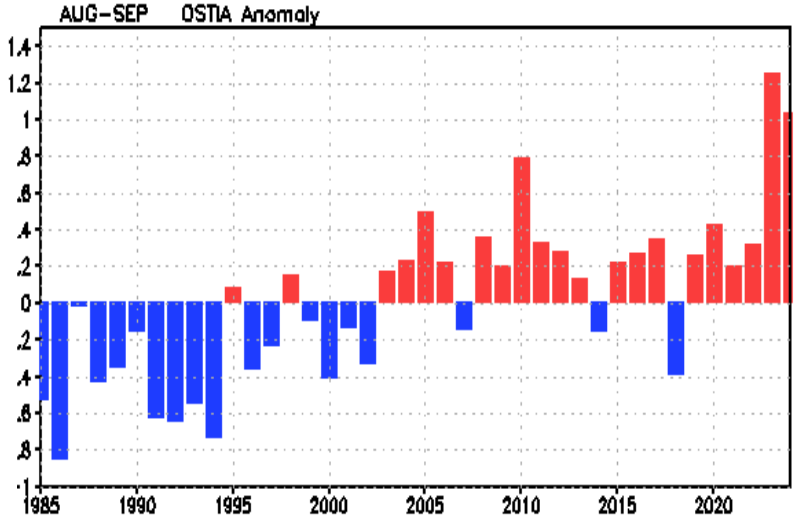
Tropical Atlantic: SST, SST tend., TCHP, OLR, 200 hPa wind, wind share, heat flex, & RH anom.



Top Row: SSTA (left; OSTIA), 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.

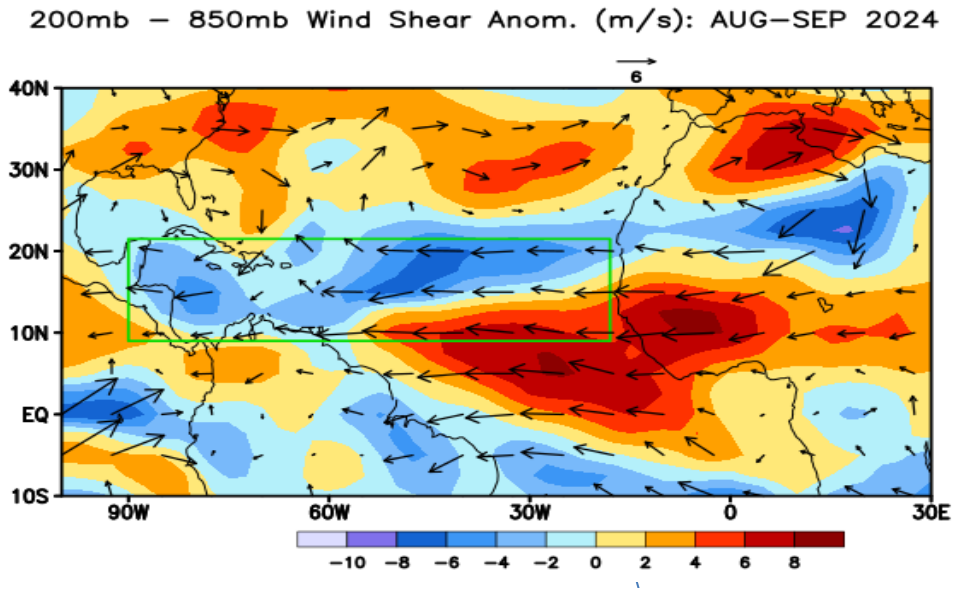
Evolution of SST anomaly in the North Atlantic

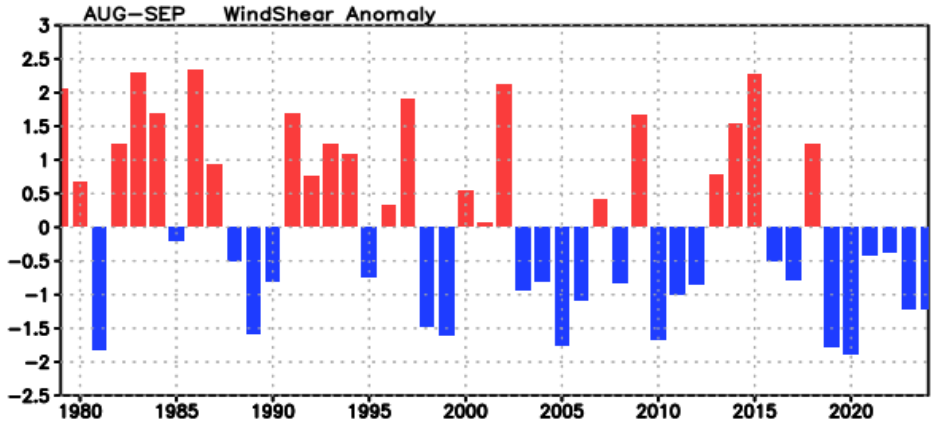




- SST warming in the hurricane main development region ranked the 2nd warmest Aug-Sep since 1982, nearly matching the record high set in 2023.

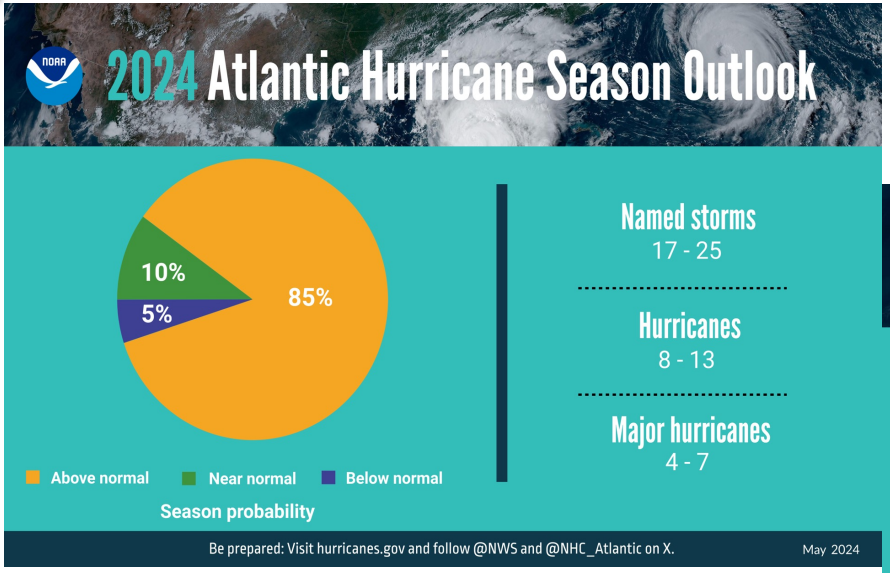
Evolution of 200mb-850mb Wind Shear Anomaly

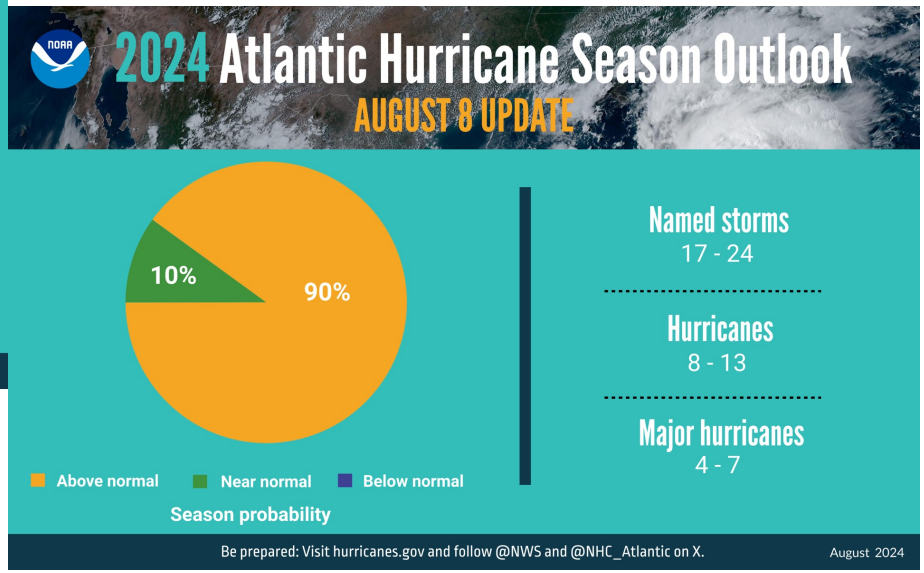




- Statistically, wind shear tends to enhance (weaken) over the Hurricane Main Development region (MDR, green box) during El Niño (La Niña) events.
- Negative wind shear anomalies dominated in the MDR during Aug-Sep 2024, favouring tropical storm development.

2024 Atlantic Hurricane Season Outlook Update



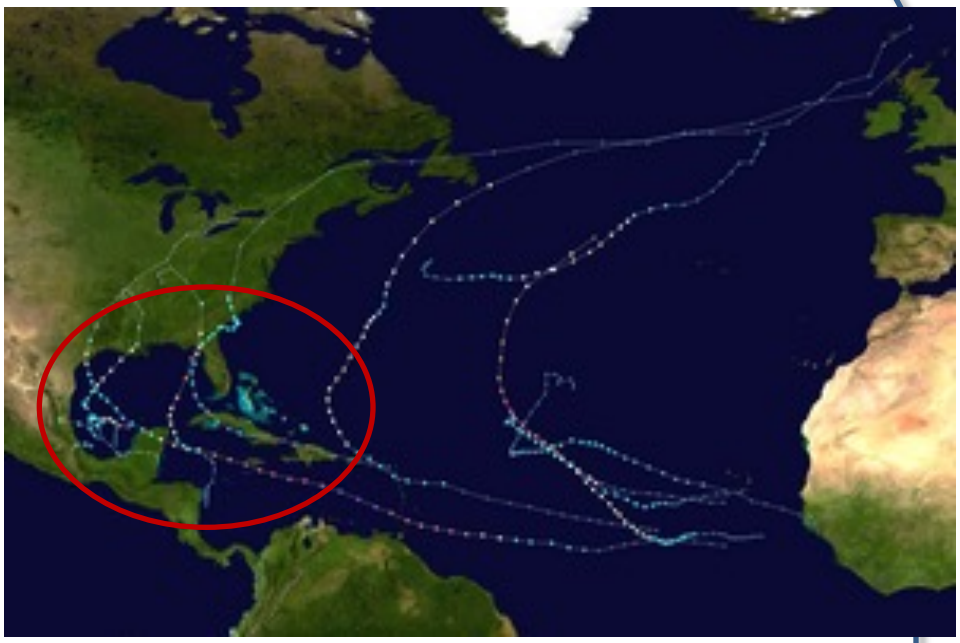


- NOAA forecasters have increased the likelihood of an above-normal Atlantic hurricane season from 85%in outlook issued in May to 90% in August outlook update.
- Main climate factors expected to influence the 2024 Atlantic hurricane activity are :

Continuous of warm phase of AMO
Near historical high record of SST over the MDR
Below normal 200-850hPa wind shear
Enhanced west African monsoon
High chance of La Nina development during peak of the hurricane season

(https://www.cpc.ncep.noaa.gov/products/outlooks/hurricane.shtml)

2024 Atlantic Hurricane Season Activities

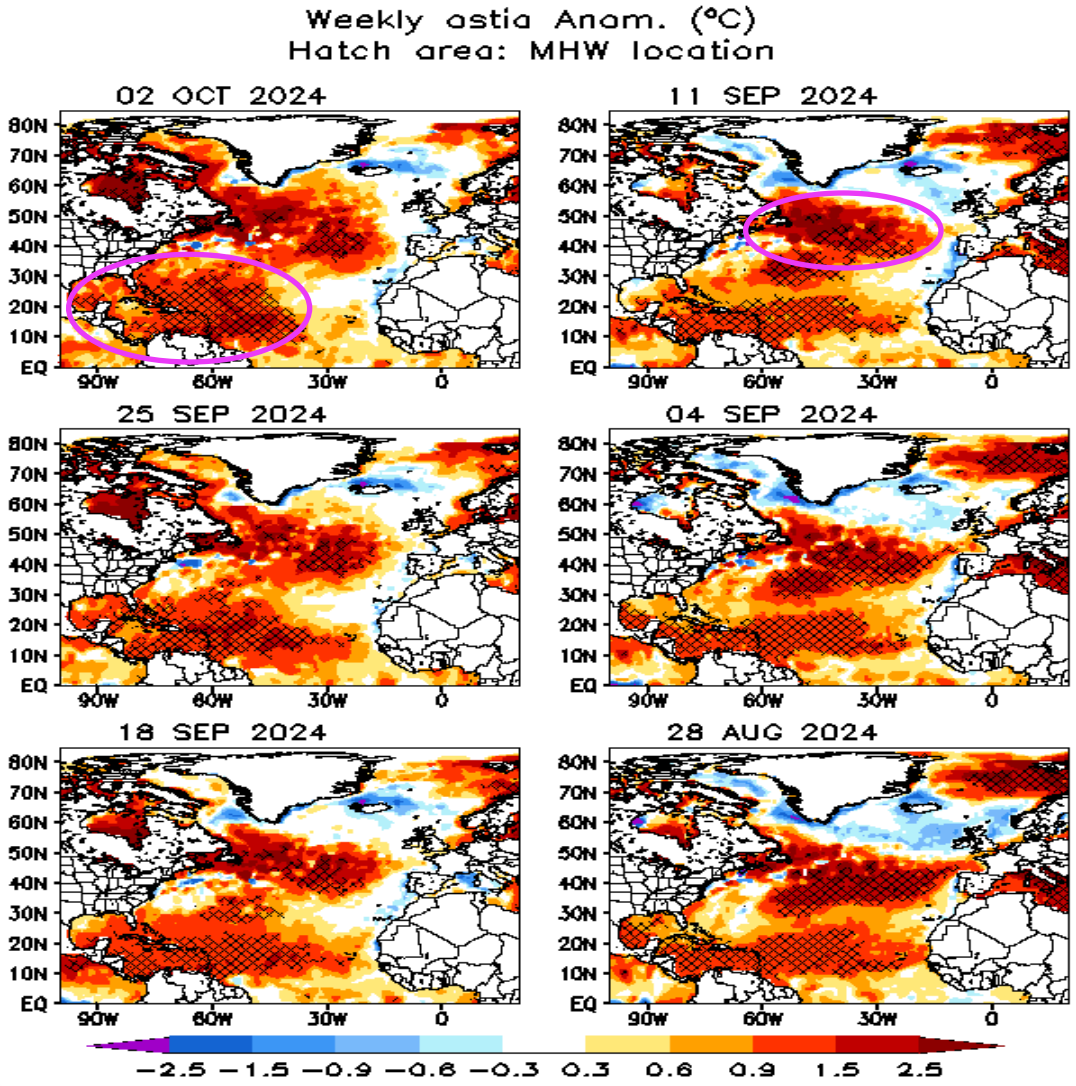


https://en.wikipedia.org/wiki/2024_Atlantic_hurricane_season

- Six tropical storms formed in Sep 2024, with four into hurricanes.
- By Oct 7 2024, thirteen tropical storms formed, with four developing into major hurricane and nine into hurricanes.

Atlantic	Observations (By Oct 7)	Updated Outlook (Aug) 90% above-normal	Outlook (May 23) 85% above-normal	(1991-2020)
Total storms	13	17-24	17-25	14
Hurricanes	9	8-13	8-13	7
Major hurricanes	4	4-7	4-7	3

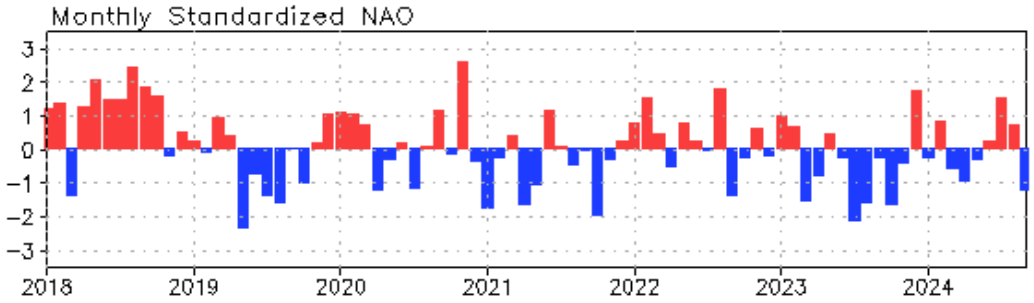
Weekly SST anomaly and MHWs in the North Atlantic

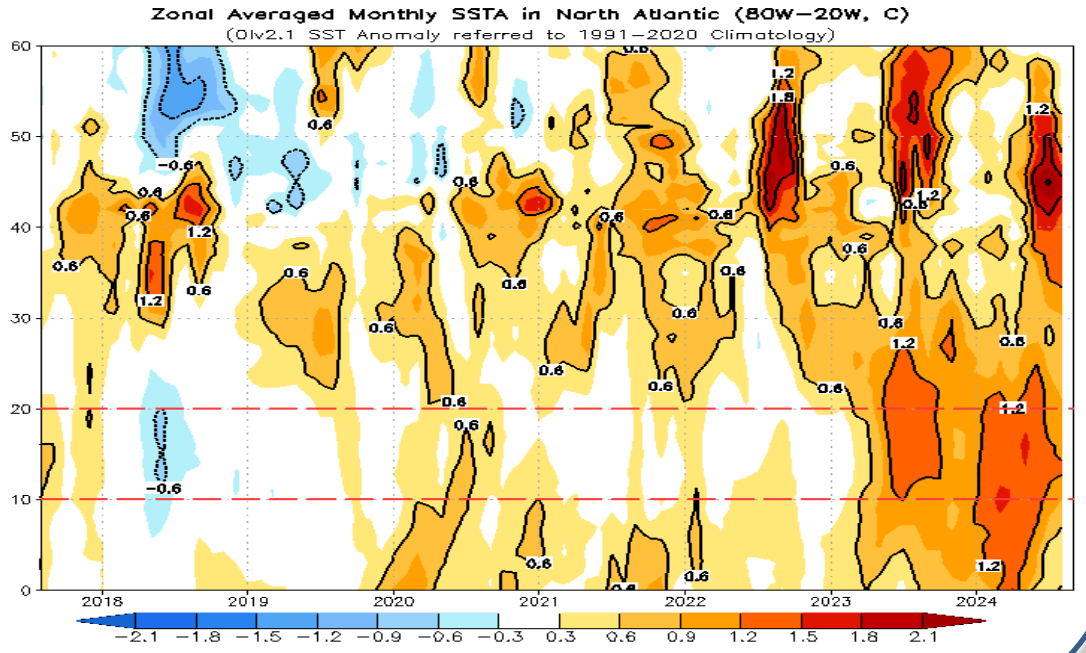


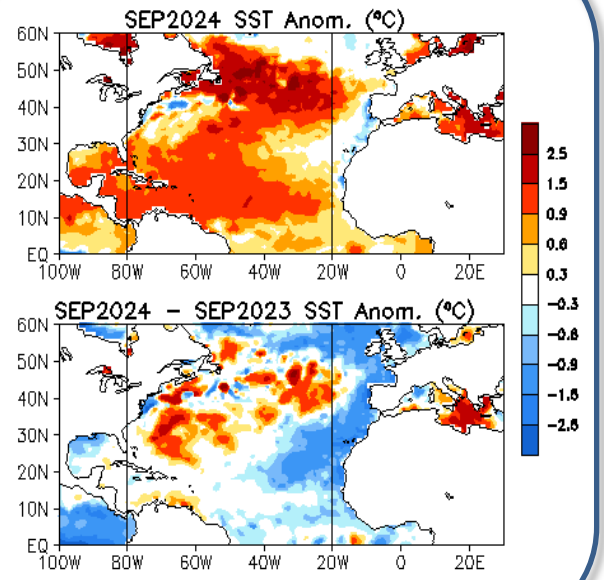
- Strong MHWs persisted in the Caribbean Sea and Gulf of Mexico region, and the central extratropical Atlantic Ocean.

Weekly SST anomaly (shaded) and locations experience Marine heat waves (hatched) by the date labelled in the plot. MHW is defined as a discrete prolonged warmer than 90th percentile of daily SST for at least 14 days. Data is derived from MET Office OSTIA and the climatology reference period is 1991-2020.

NAO and SST Anomaly in North Atlantic





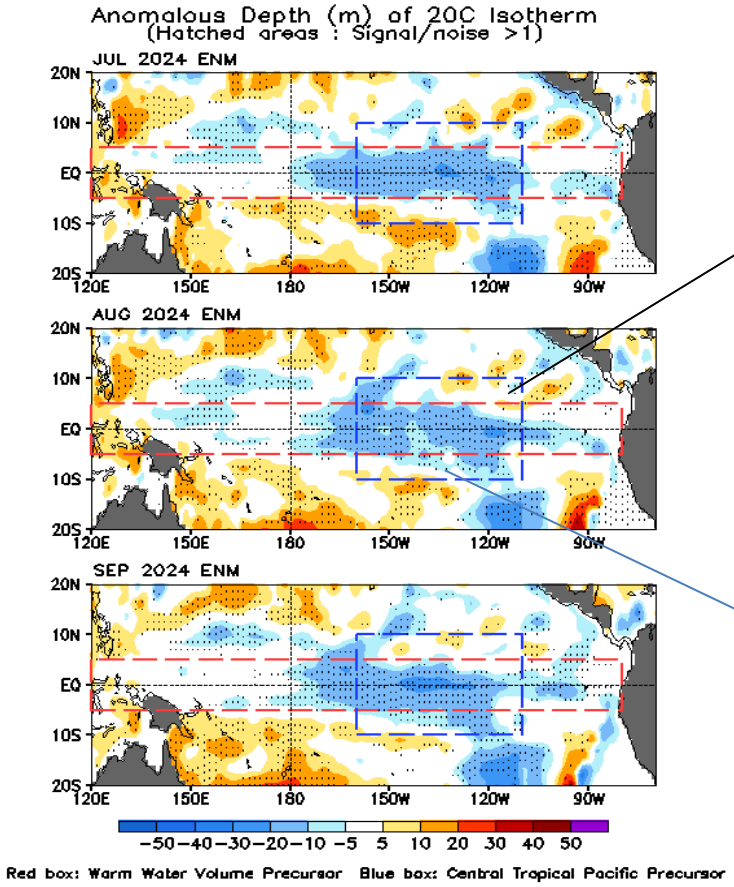


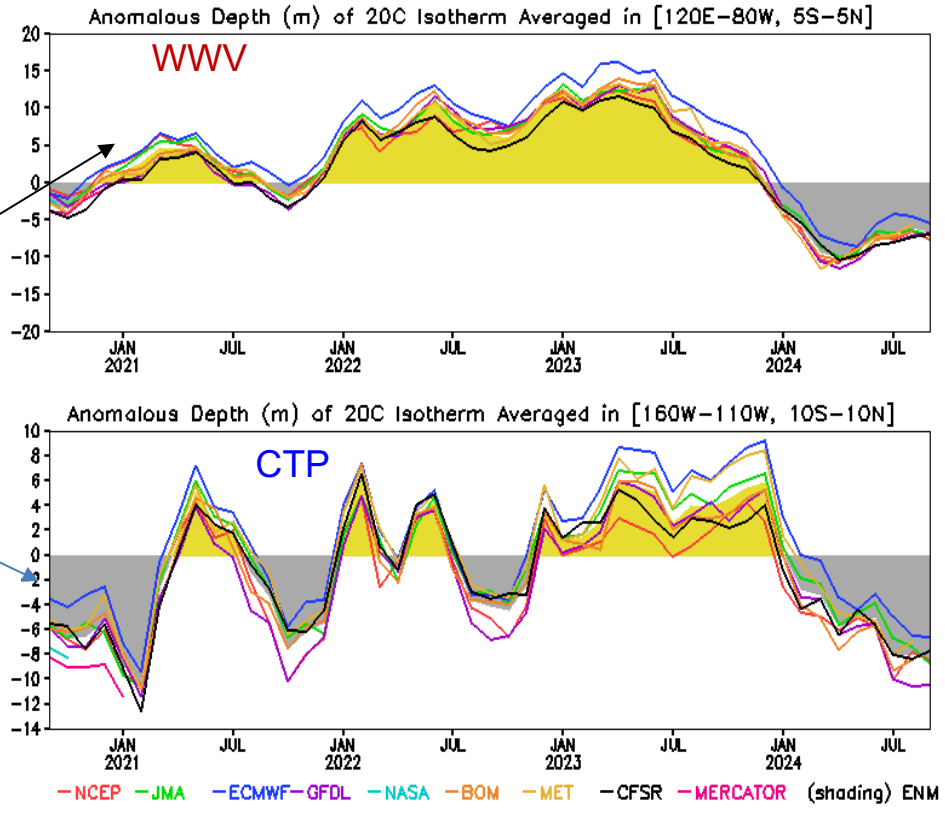
- Positive NAO switched to a negative phase in Sep 2024, with NAO index=-1.3.
- Strong warming continued in the eastern North Atlantic Ocean.
- The prolonged positive SSTAs in the middle latitudes were evident, due to dominance of the positive phase of NAO during the last 5-6 years.

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

Oceanic ENSO Precursors: WWV & CTP



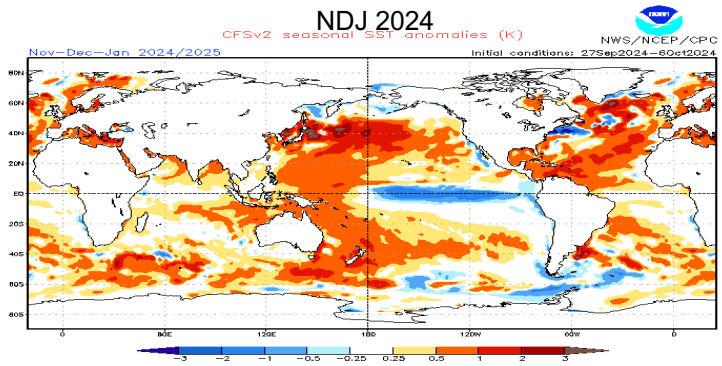


Warm water volume (WWV) is defined as an average of D20 anomaly across the equatorial Pacific (120° E – 80° W, 5° S-5° N) (Meinen and McPhaden 2000). Central tropical Pacific (CTP) index is calculated as the averaged D20 anomaly in the central tropical Pacific (160° W-110° W, 10° S-10° N) (Wen et al. 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).

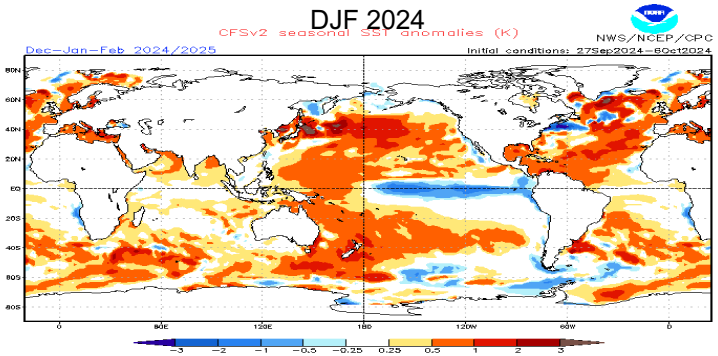
CFSv2 and NMME SST predictions : October Initial Conditions

CFSv2

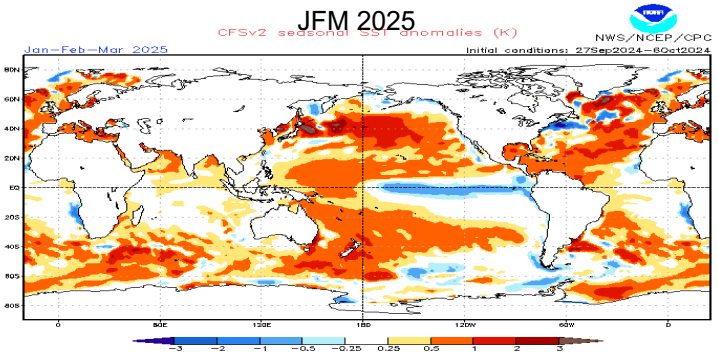
NDJ 2024



DJF 2024



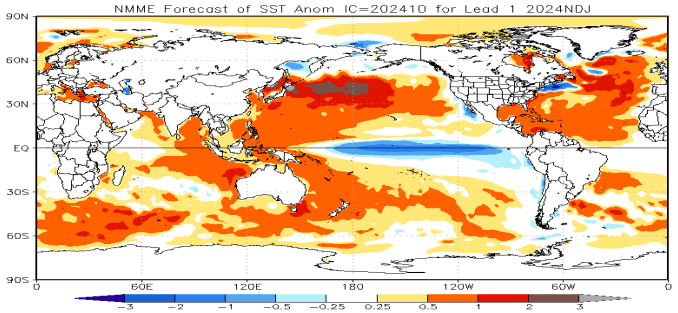
JFM 2025



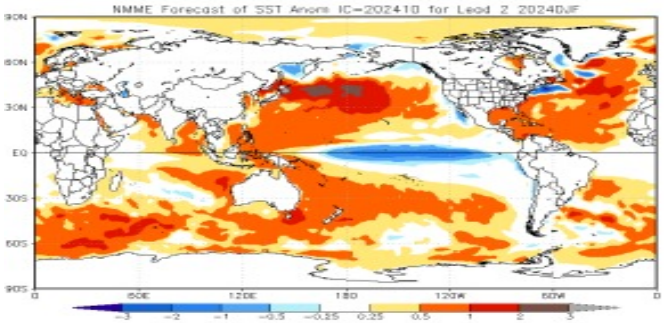
https://www.cpc.ncep.noaa.gov/products/CFSv2/CFSv2seasonal.shtml

NMME

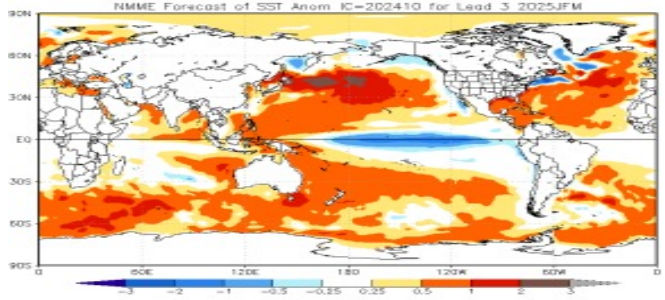
NDJ 2024



DJF 2024

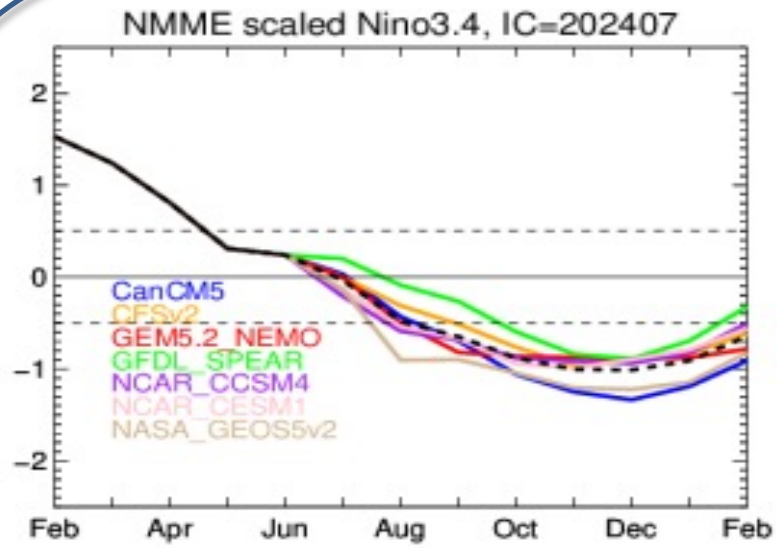


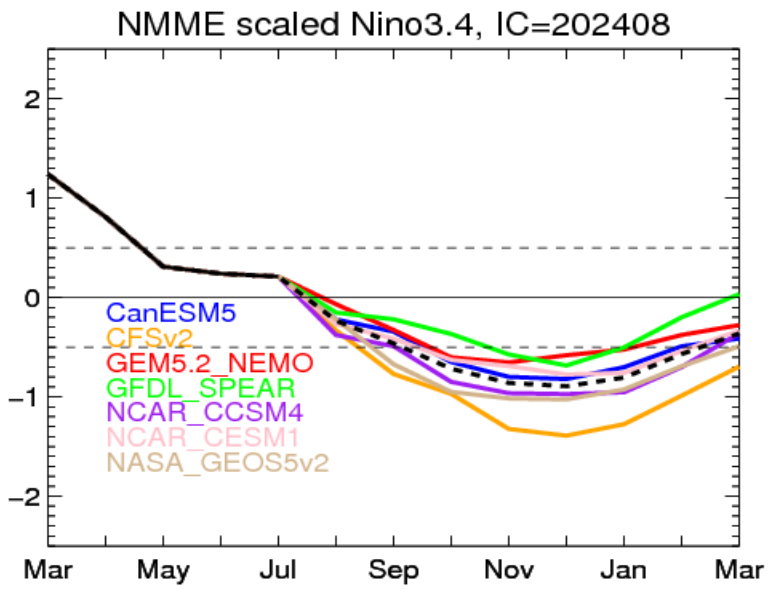
JFM 2025

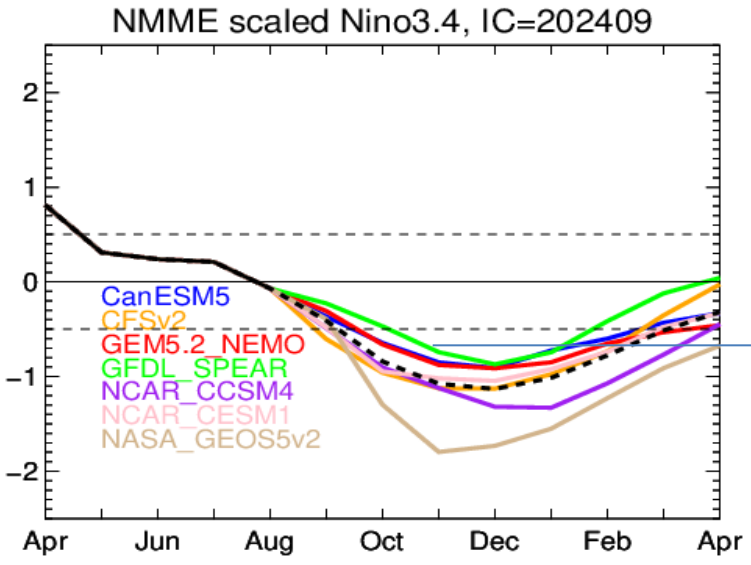


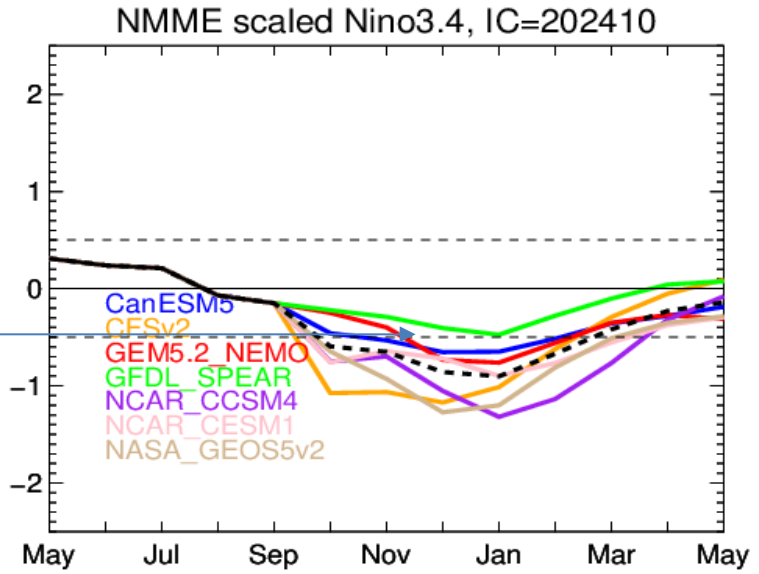
https://www.cpc.ncep.noaa.gov/products/NMME/

NMME forecasts from different initial conditions



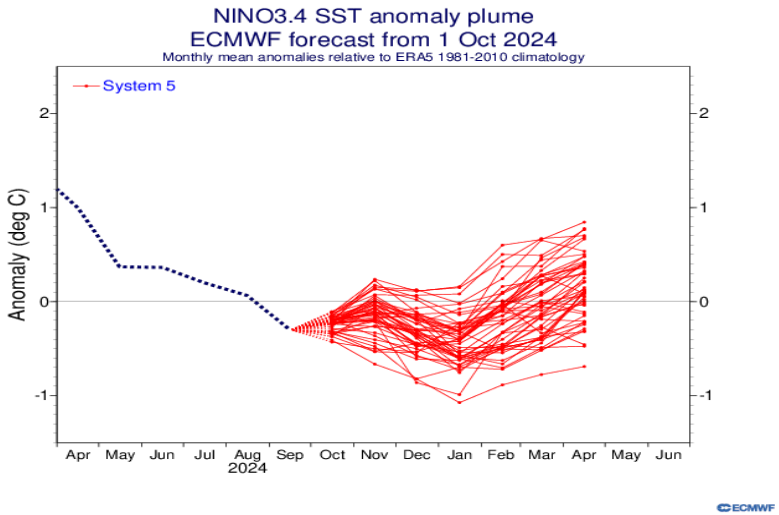




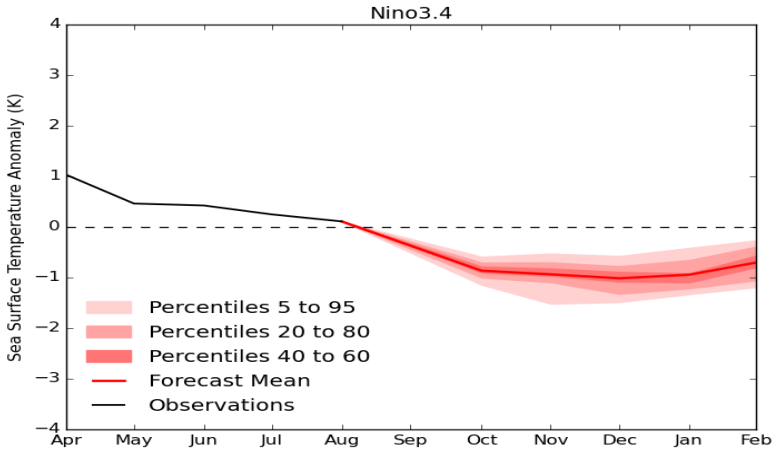


Individual Model Forecasts: El Niño transitions to neutral or La Niña in Autumn-Winter 2024

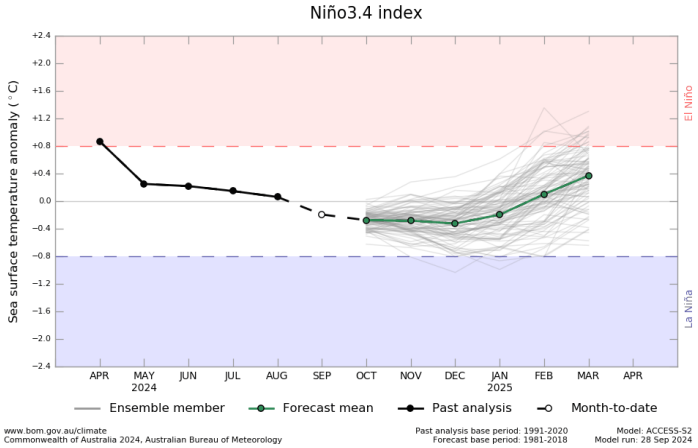
EC: Niño3.4, IC= 1 Oct 2024



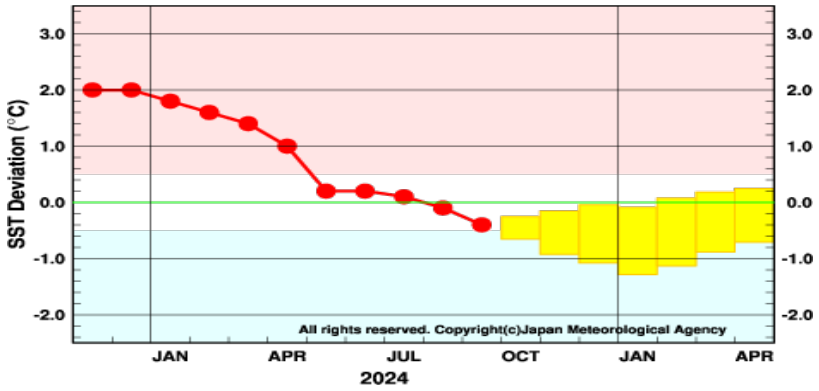
UKMO: Niño3.4, Updated 11 Sep 2024



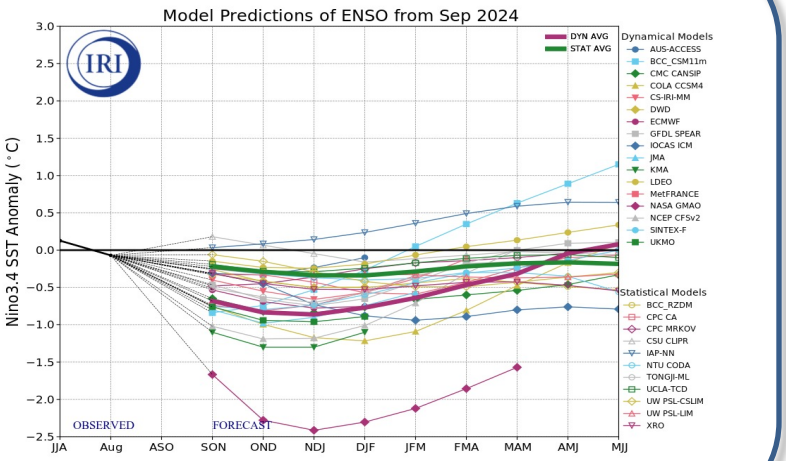
BOM: Niño3.4, Updated 28 Sep 2024

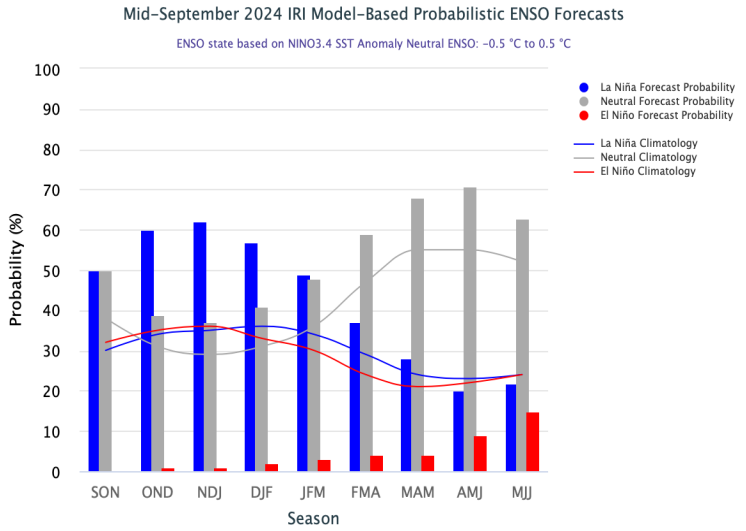


JMA: Niño3.4, Updated 10 Oct 2024



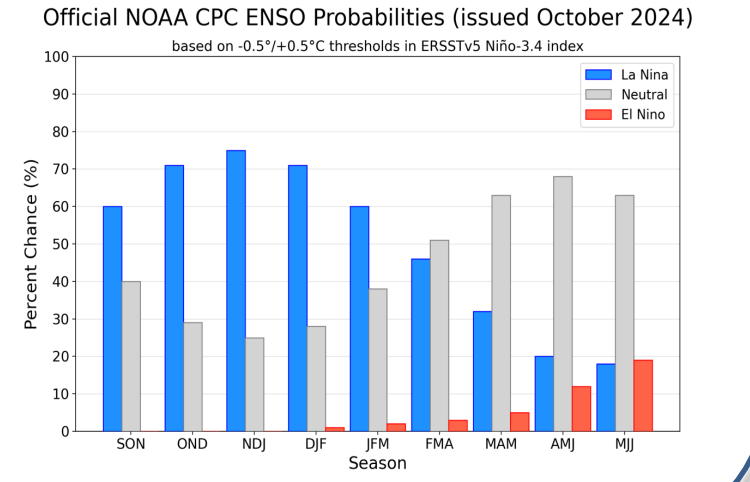
IRI/CPC Niño3.4 Forecast



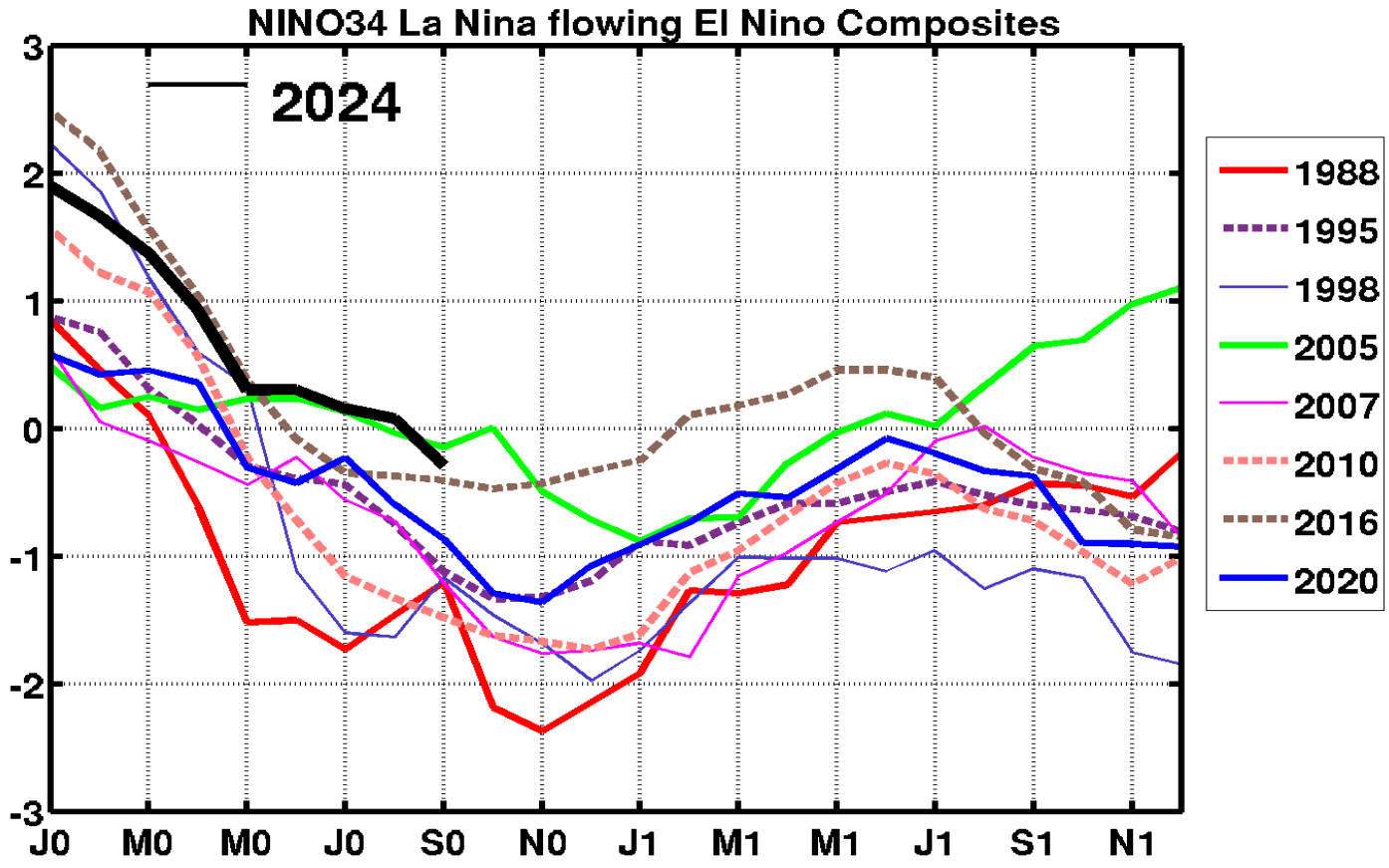


- Most of models predict ENSO neutral condition through Sep-Nov, with borderline La Niña conditions developing during Oct-Dec 2024, followed by a transition to neutral conditions during JFM 2025.

- On 10 Oct 2024, CPC maintained a "***La Niña Watch***".
- Synopsis: "***La Niña is favored to emerge in September-November (60% chance) and is expected to persist through January-March 2025.*** "

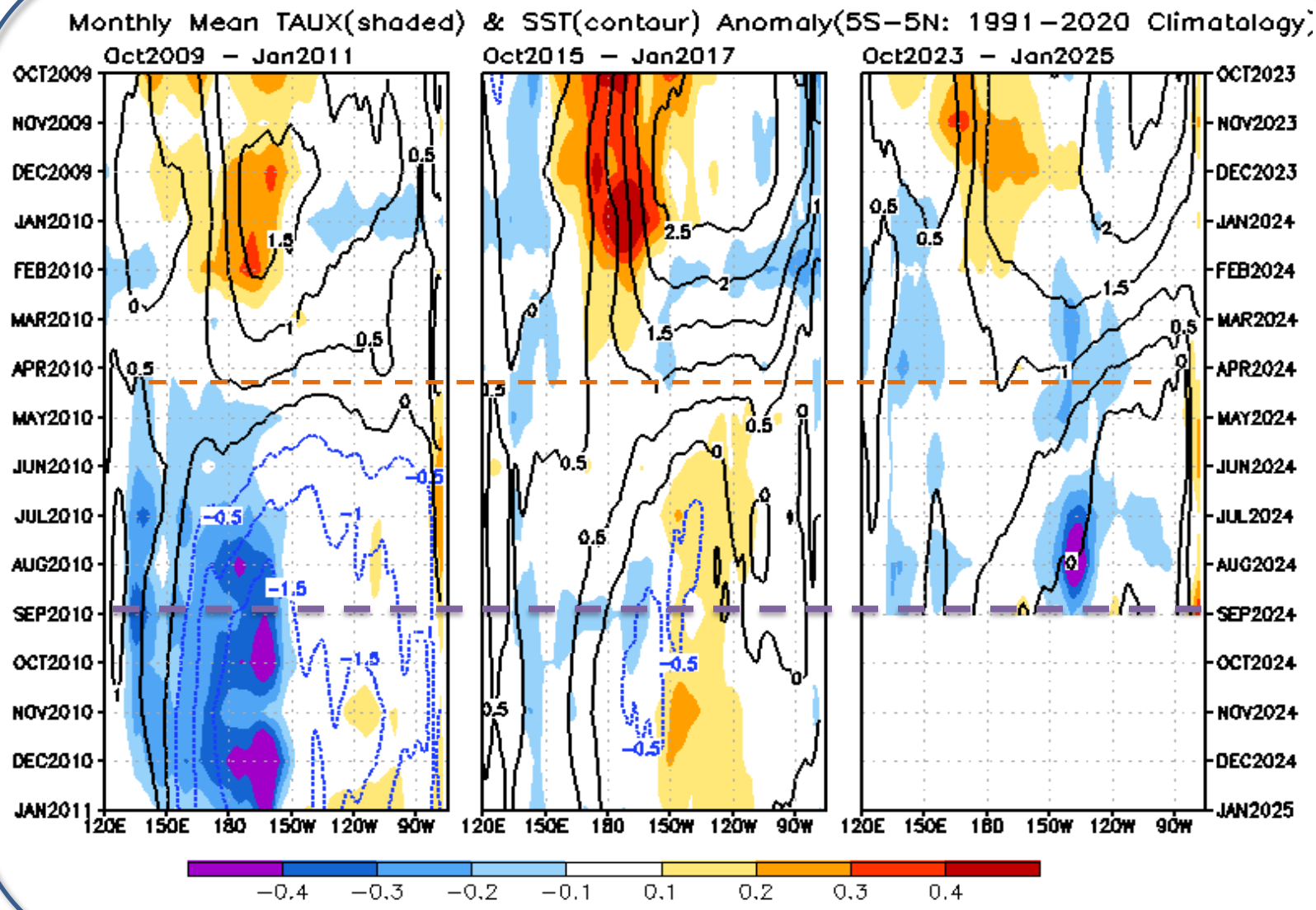


NINO34 in La Nina Years following El Nino conditions



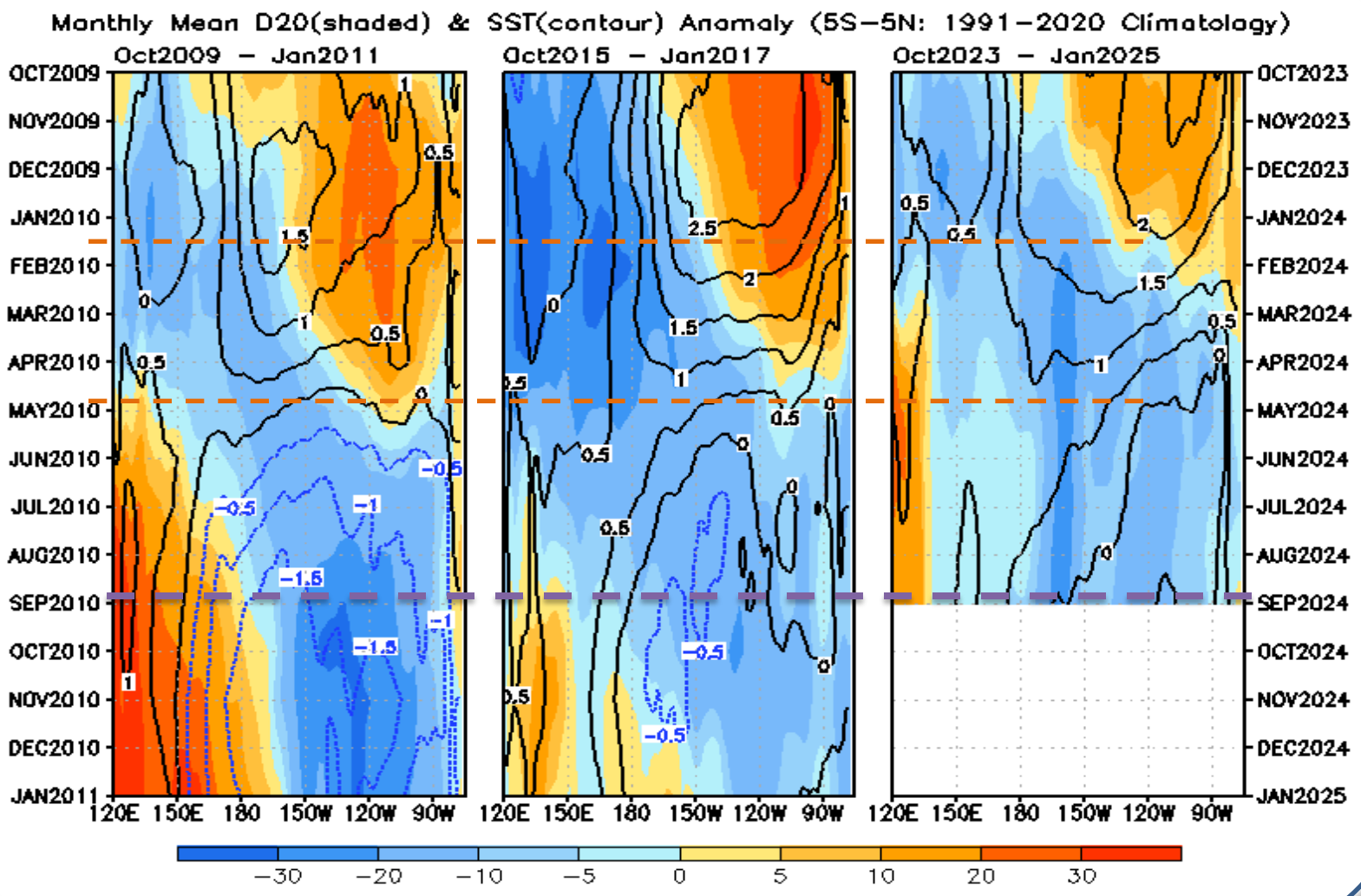
Following strong El Nino events: 1983, 1998,2016
Following moderate El Nino events: 1988, 2007, 2010
Following weak El Nino events: 1995, 2005, 2020

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



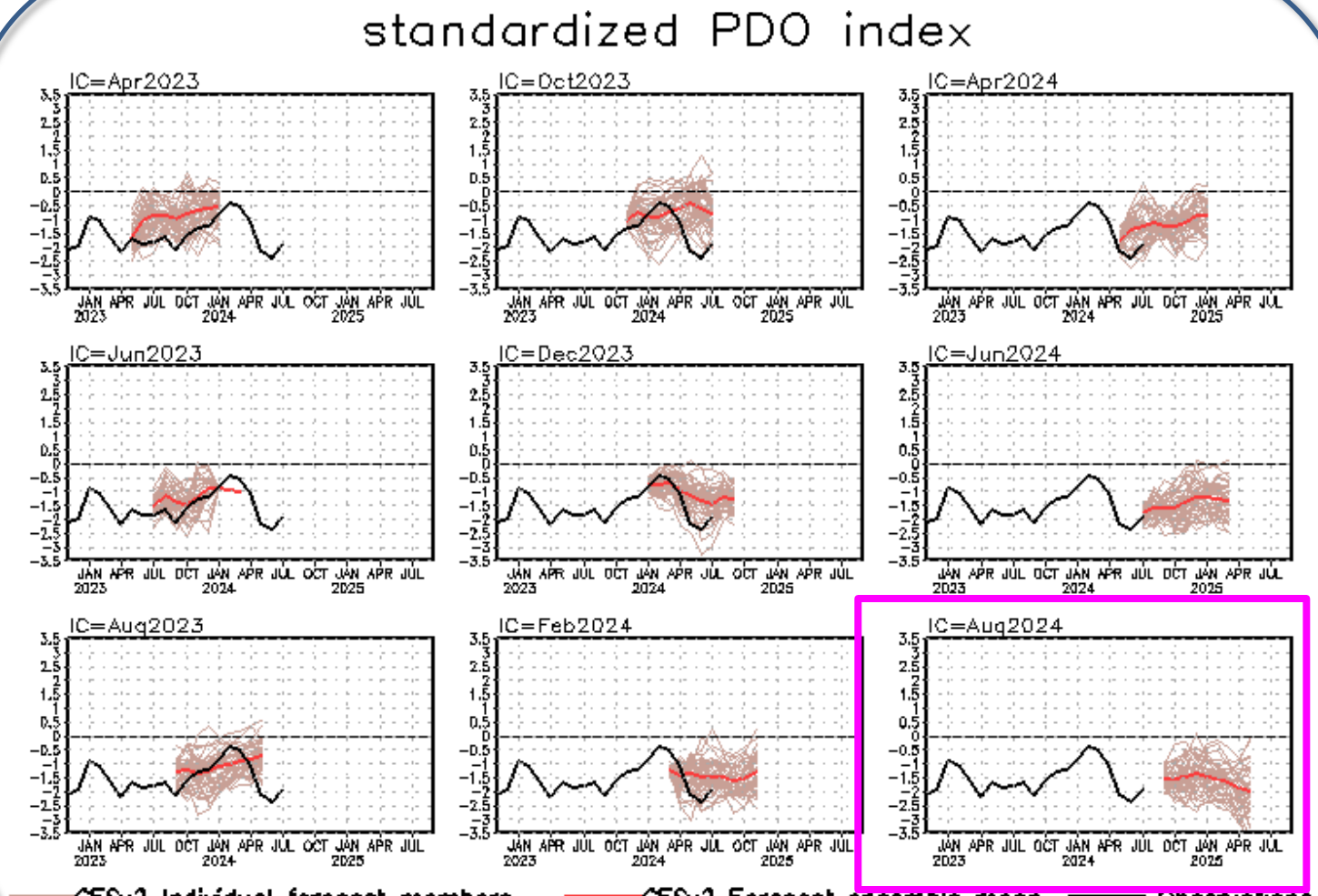
Data source: NCEP R2 reanalysis and OSTIA SST

Evolution of Monthly Mean D20 Anomaly across [5S-5N]



Data source: NCEP GODAS and OSTIA SST

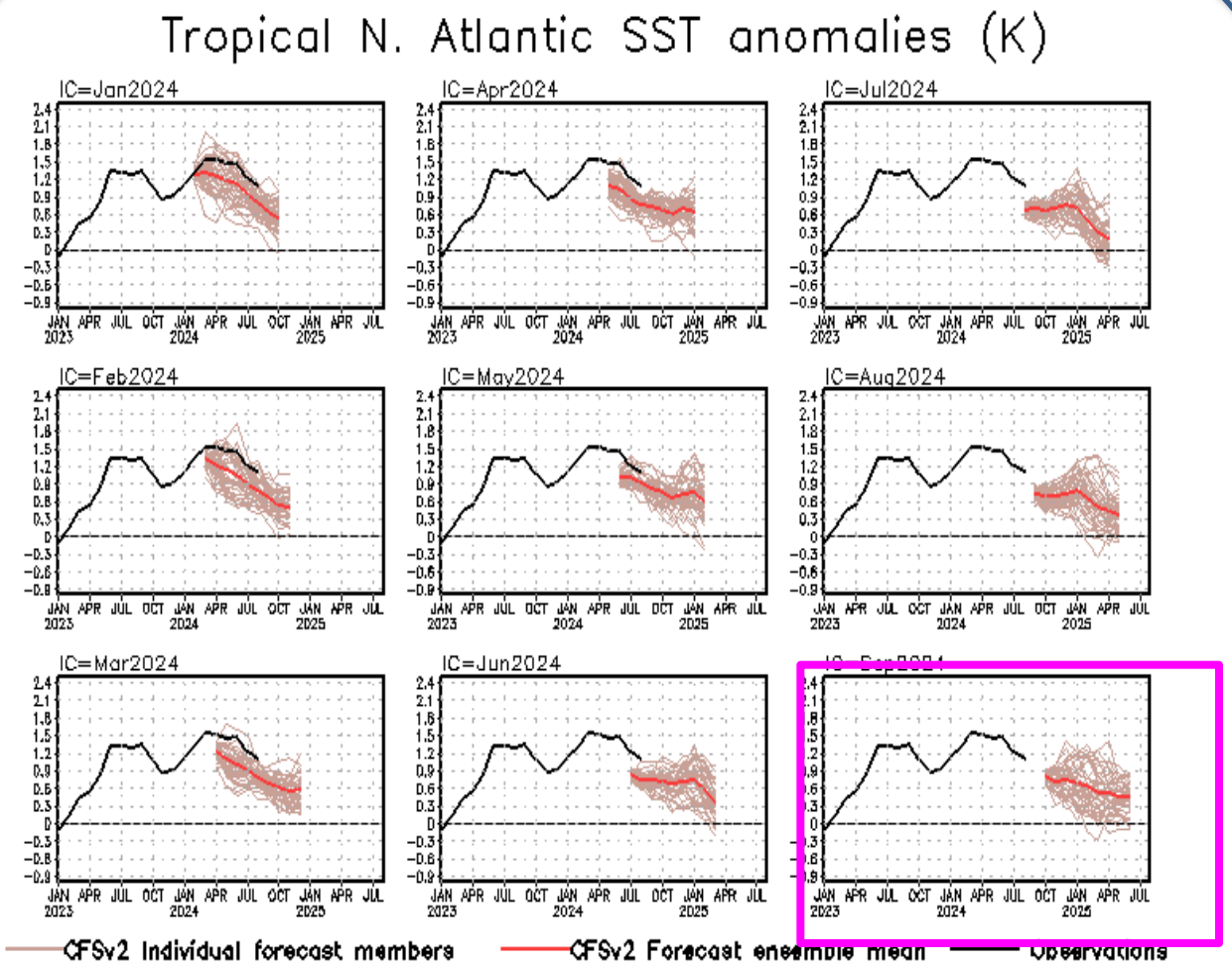
CFS Pacific Decadal Oscillation (PDO) Index Predictions from Different Initial Months



- CFSv2 predicts the negative phase of PDO will continue through winter 2024.

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.

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



- Latest CFSv2 predictions call for above-normal SST in the tropical North Atlantic.
- CFSv2 has large cold bias at 0-month lead since Feb 2024.

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

Acknowledgement

- Drs. Arun Kumar, Zeng-Zhen Hu and Jieshun Zhu: reviewed PPT, and gave insightful suggestions and comments
- Drs. Yanjuan Guo and Pingping Xie provided the BASS/CMORPH/CFSR EVAP package
- Drs. Jieshun Zhu & Wanqiu Wang maintained the sea ice forecasts

Please send your comments and suggestions to:

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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

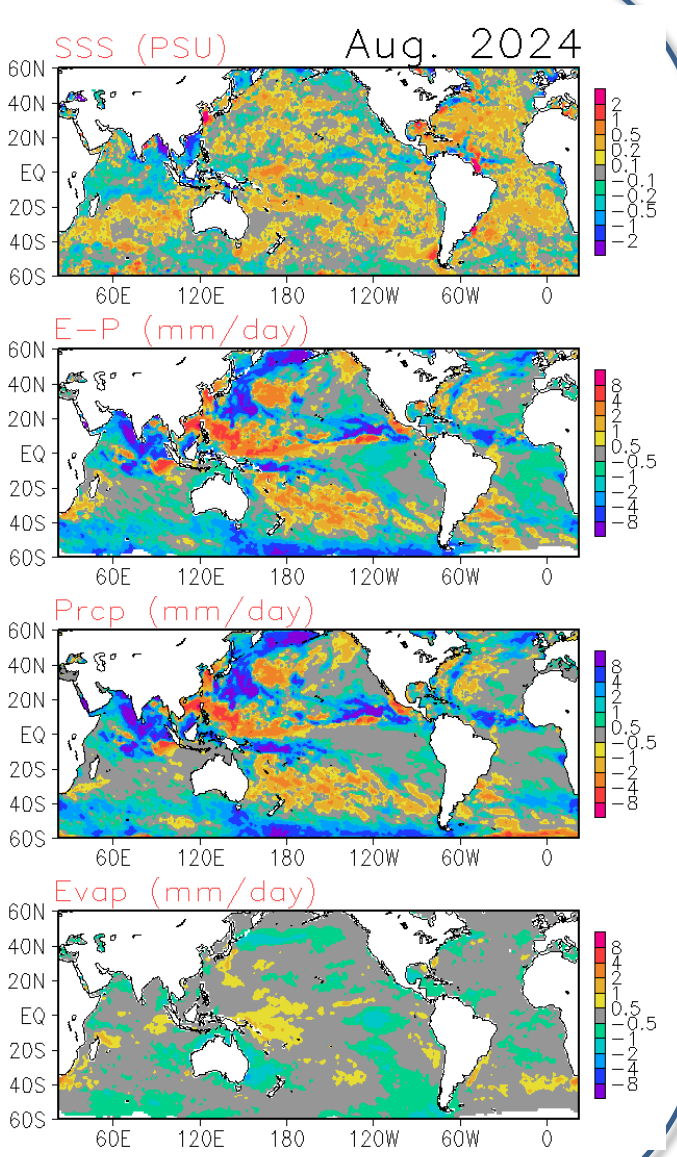
http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html

Backup Slides

Global Sea Surface Salinity (SSS): Anomaly for August 2024

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

Strong positive SSS anomalies are found over certain mid-latitude regions of the Pacific and Atlantic oceans, while strong negative anomalies in some higher latitudes of Pacific and Atlantic as well as northern Indian ocean. The SSS anomaly patterns are overall consistent with the E-P flux anomaly patterns over the Pacific and Indian Oceans, which is more dominated by the precipitation anomalies over these regions. In the meantime, the consistency between the SSS and E-P flux in the southern Atlantic and Indian Oceans is less obvious.



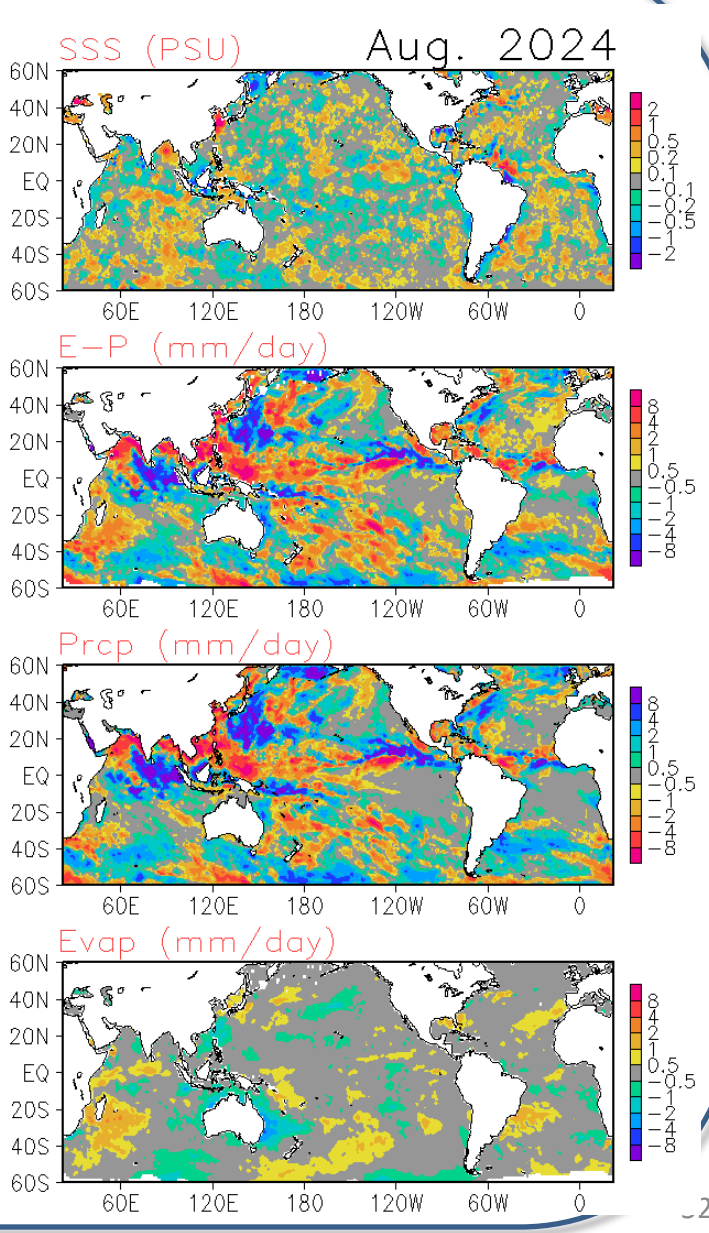
SSS : Blended Analysis of Surface Salinity (BASS) V0.Z
(a CPC-NESDIS/NODC-NESDIS/STAR joint effort)
ftp.cpc.ncep.noaa.gov/precip/BASS

Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: Adjusted CFS Reanalysis

Global Sea Surface Salinity (SSS): Tendency for August 2024

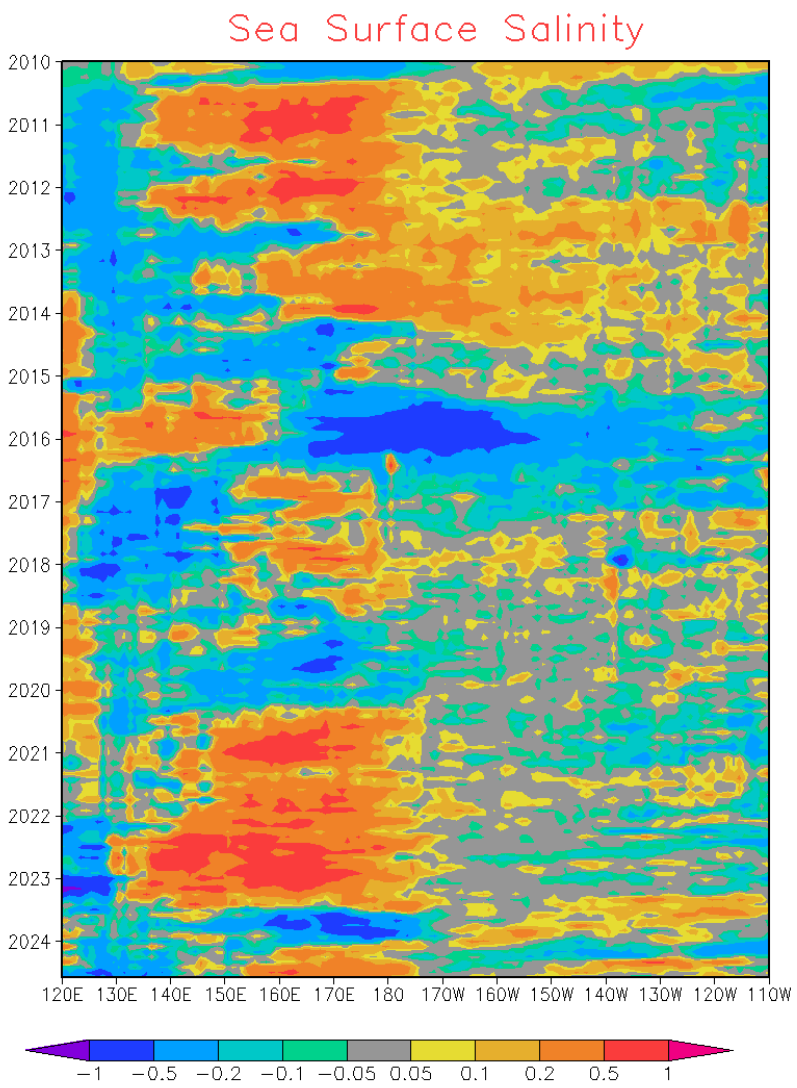
The global SSS tendency in August 2024 is overall weak and with mixed signs. The Precipitation are generally decreasing along the equator but enhancing off equator in the Pacific, whereas strong precipitation increase is found in the equatorial Indian ocean but decrease north of the equator. The E-P flux patterns seem to be more dominated by the precipitation patters. Overall, the SSS trend doesn't show pronounced large scale pattern for this month.



Monthly SSS Anomaly Evolution over Equatorial Pacific

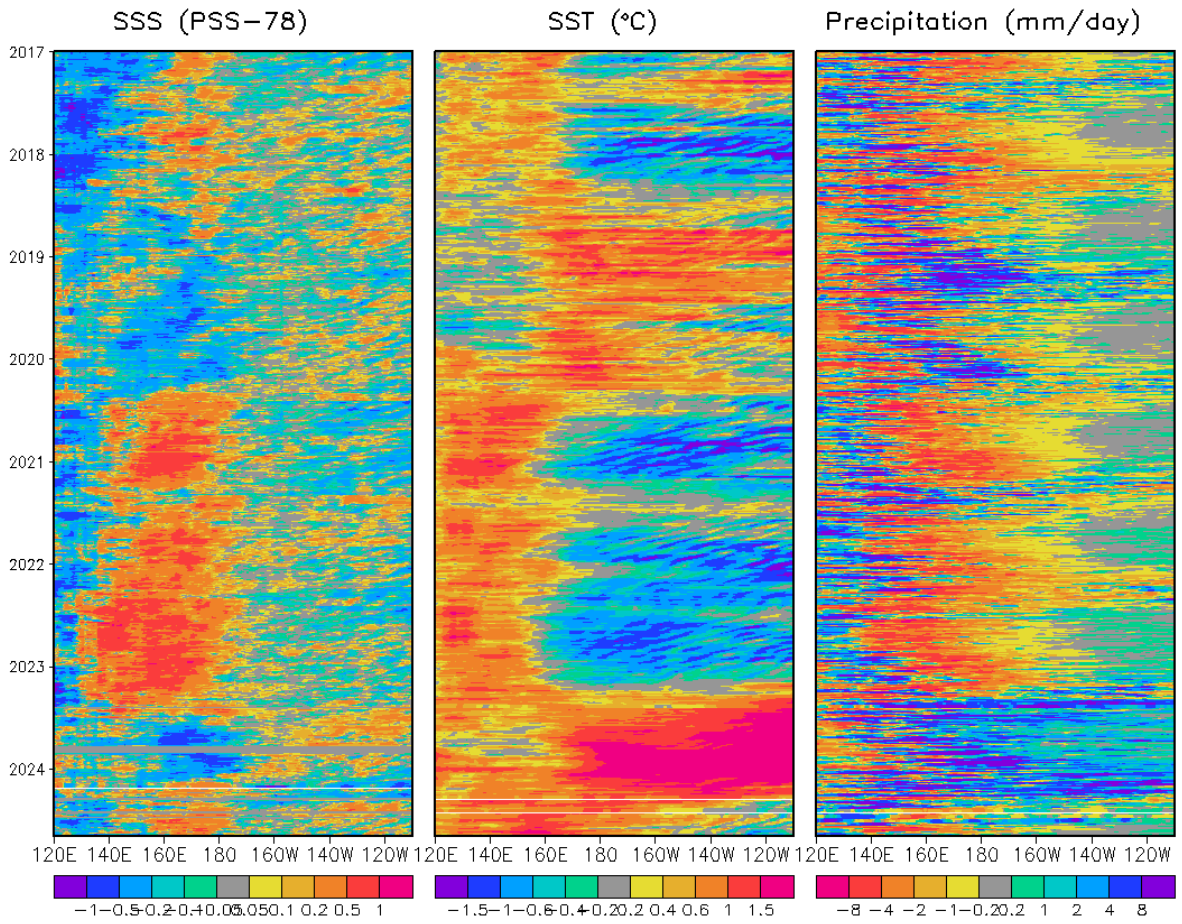
NOTE: Since August 2015, the BASS SSS is from in situ, SMOS and SMAP; before August 2015,The BASS SSS is from in situ, SMOS and Aquarius.

- Hovermoller diagram for equatorial SSS anomaly **(5S-5˚N);**
- Decreased SSS is found over the warm pool region, but increased over the central Pacific. SSS increasing is also found over the equatorial eastern Pacific.

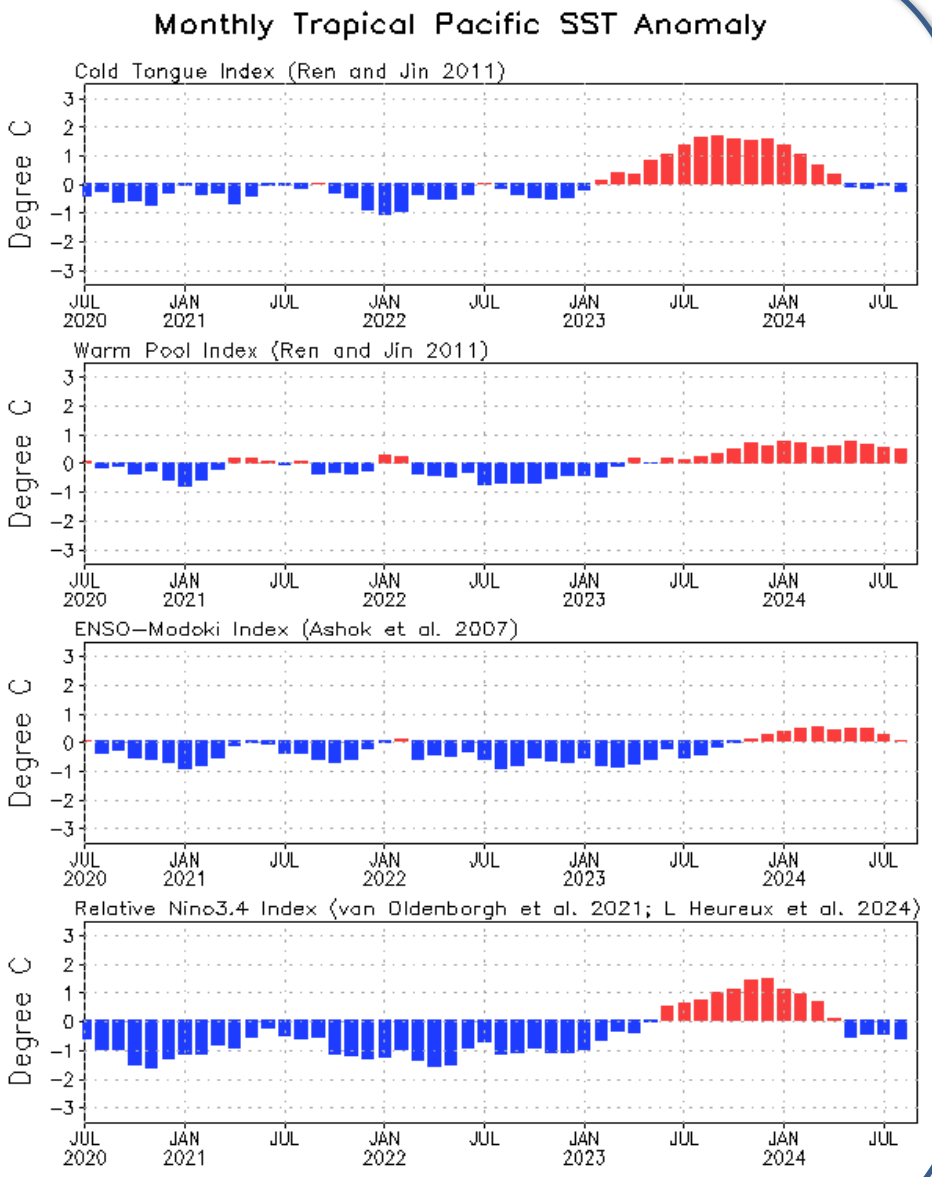


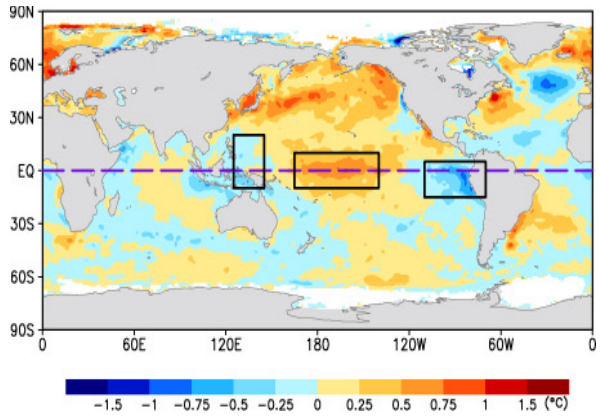
Pentad SSS Anomaly Evolution over Equatorial Pacific

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



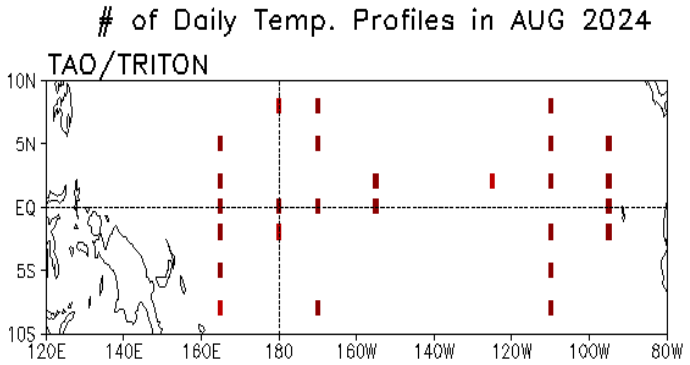


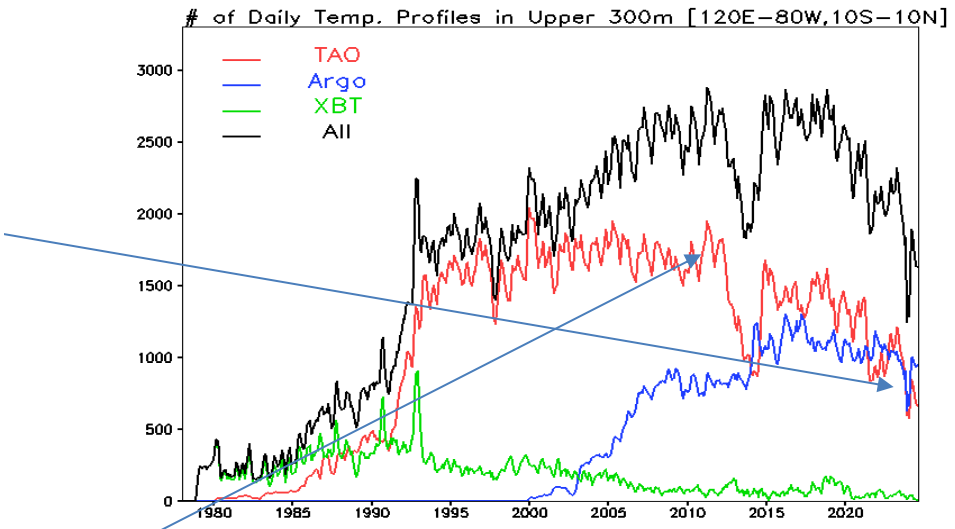
- Relative Niño3.4 index is now included in ENSO monitoring, which is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0º-360º, 20ºS-20ºN), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative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

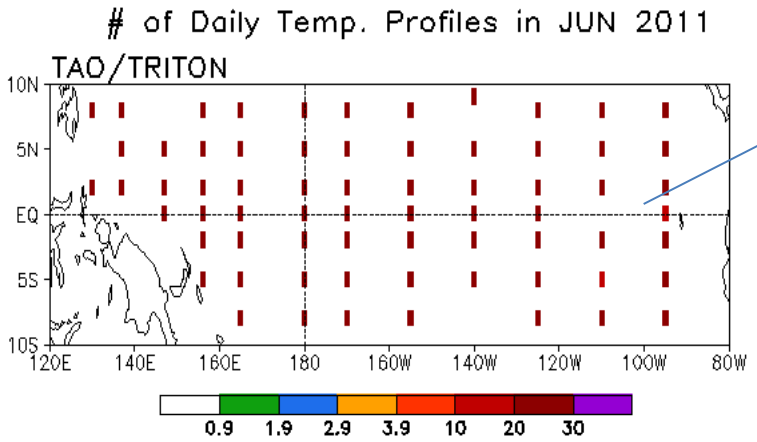
Relative Niño3.4 data updated monthly at:

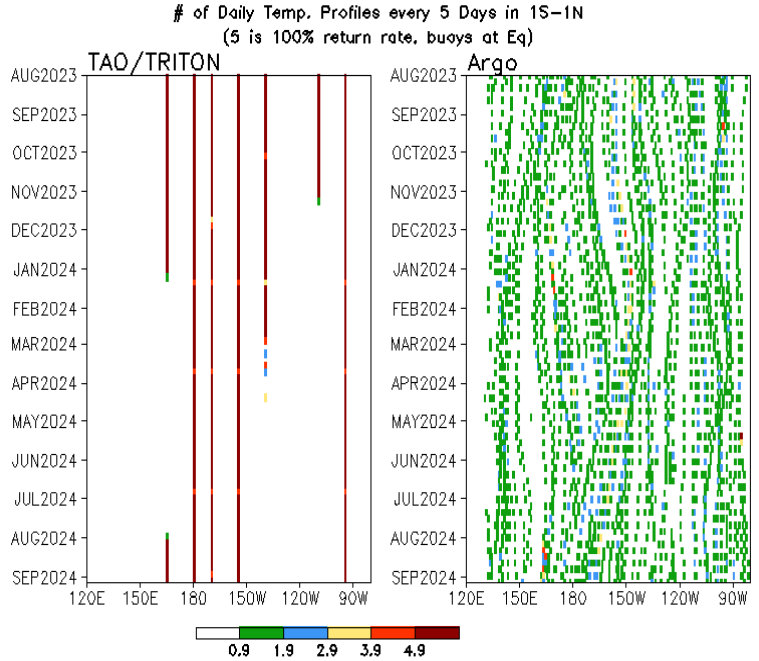
https://www.cpc.ncep.noaa.gov/data/indices/RONI.ascii.txt

Potential Impact of Missing TAO DATA on GODAS



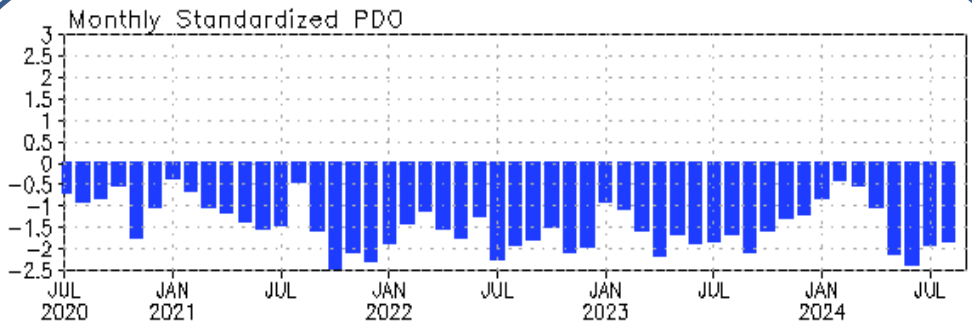


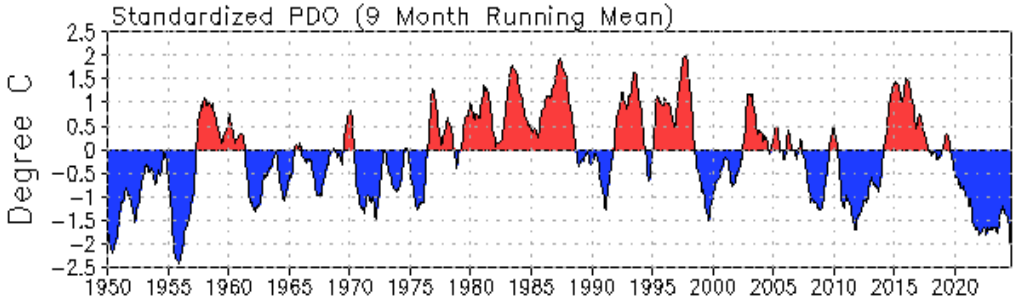


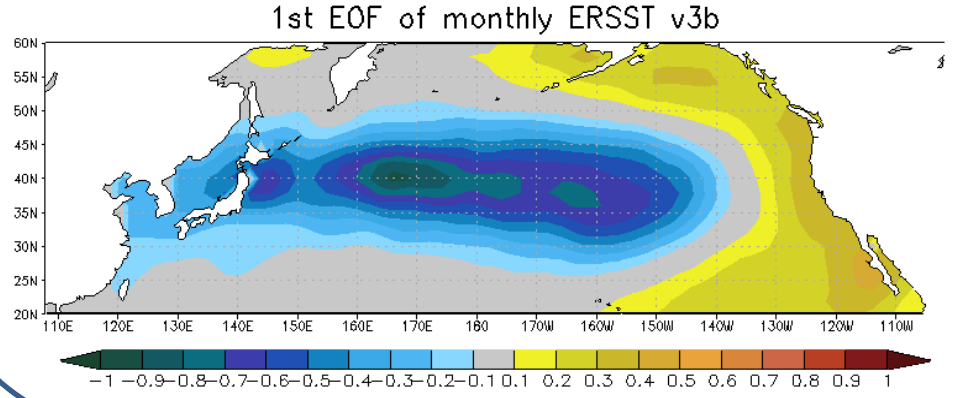


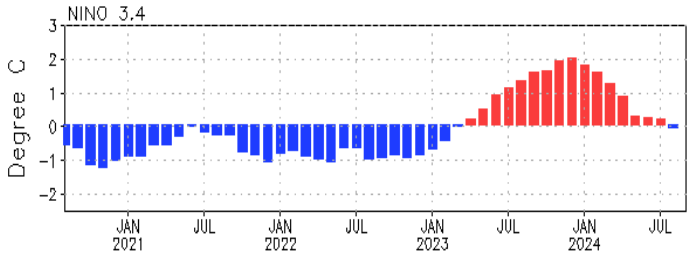
- There are fewer moorings reporting in the eastern Pacific since Nov 2023.
- TAO mooring profiles number in Aug 2024 is close to the historical low since 1993.

Pacific Decadal Oscillation (PDO) Index





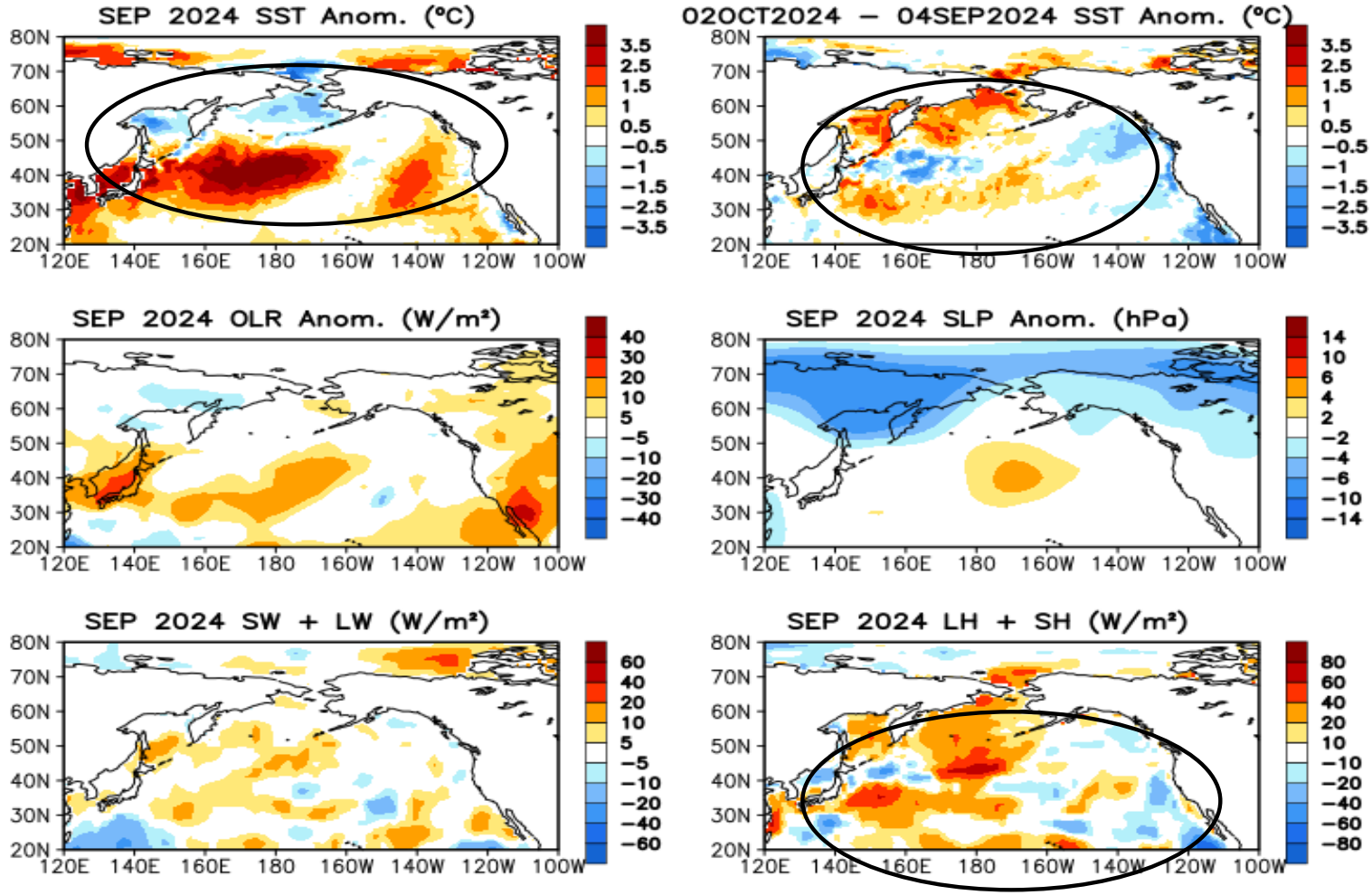




- The PDO has been in a negative phase since Jan 2020 and weakened slightly with PDOI = -1.9 in Aug 2024.
- Statistically, ENSO leads PDO by 3-4 months, through teleconnection via atmospheric bridge, with El Niño (La Niña) associated with positive (negative) PDO Index, but this relationship has weakened in recent years.

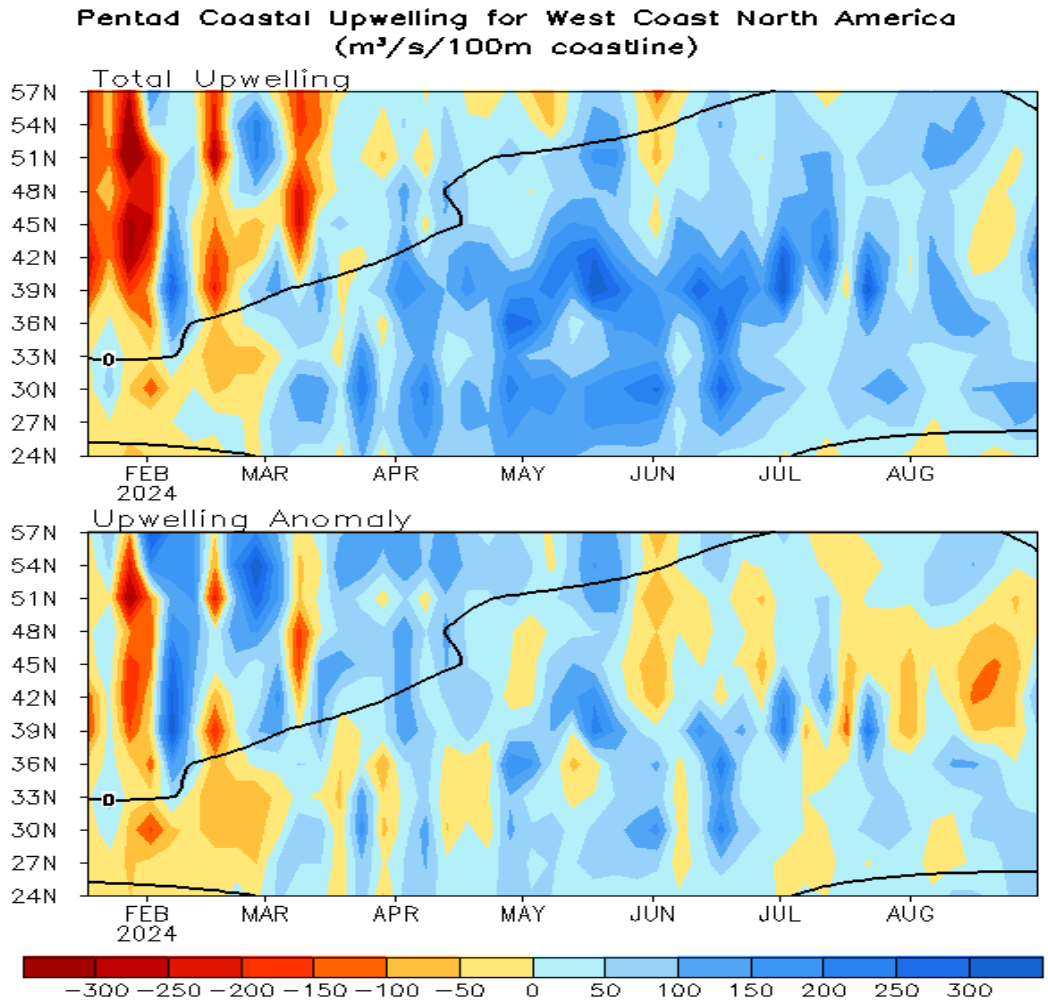
• PDO is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.

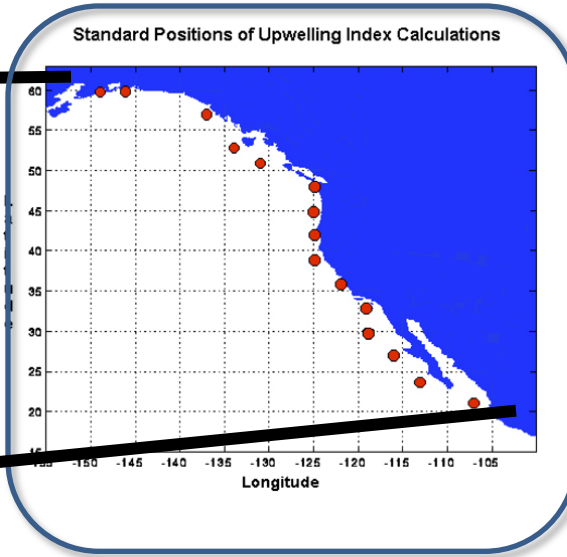
North Pacific & Arctic Ocean: SSTA, SSTA Tend., OLR, SLP, Sfc Rad, Sfc Flx Anomalies



SSTA (top-left; OSTIA 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.

North America Western Coastal Upwelling



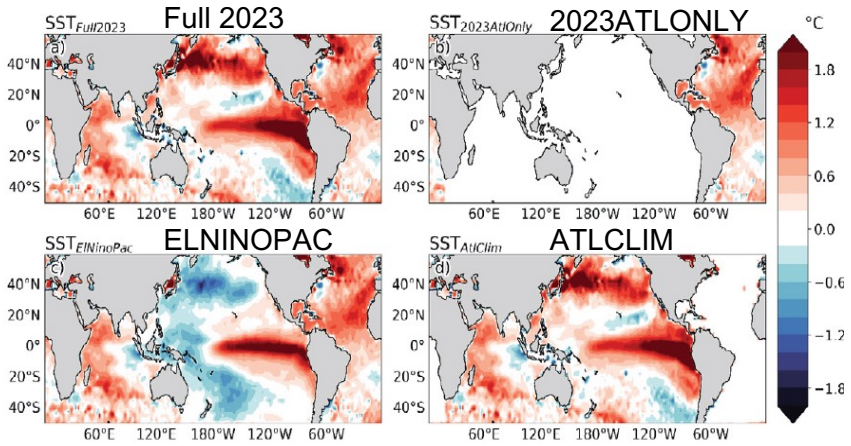


- Both **a**nomalous upwelling and downwelling were observed in Aug 2024.

(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.

Impact of Extremely Warm Atlantic on 2023 Hurricane Activity

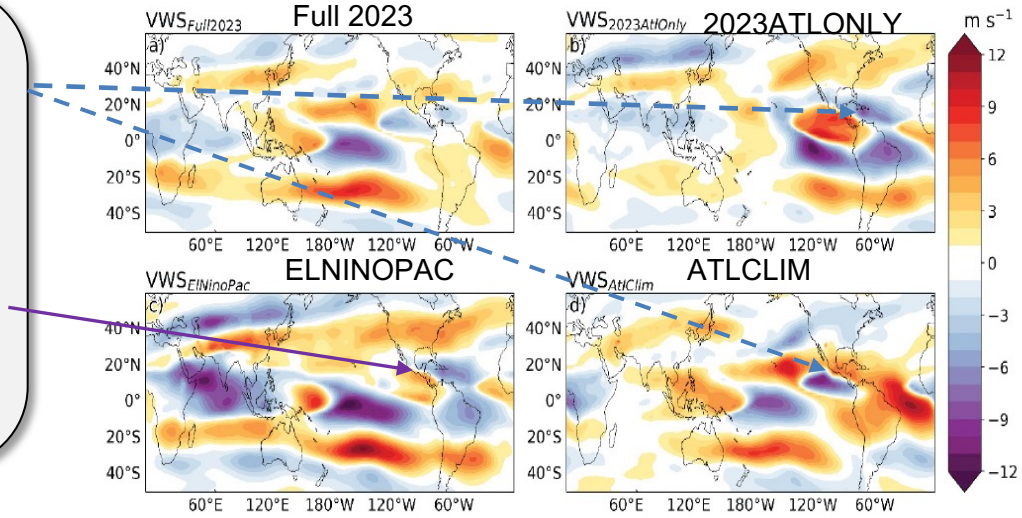
SST Configurations



- **Full2023**: 2023 Jan-Nov SST forcing
- **2023ATLONLY**: 2023 Atlantic SSTS only and climatology elsewhere
- **ELNINOPAC**: 2023 SSTs with Pacific SSTs swapped for El Nino composite (1982,1987,9997,20022125)
- **ATLCLIM**: Atlantic SSTs set to climatology with 2023 SSTs elsewhere

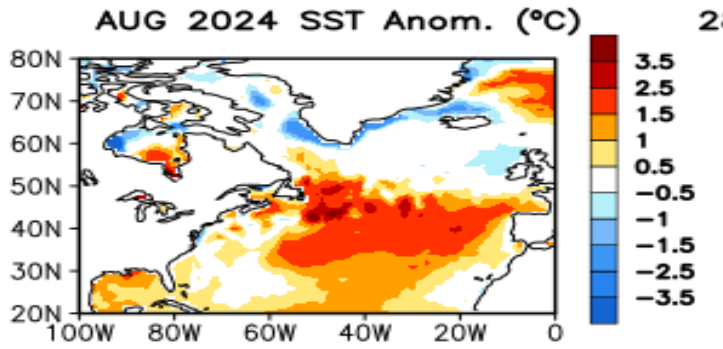
- Extremely warm Atlantic was the primary driver of the reduced vertical wind shear over the hurricane main development region.
- The unique spatial pattern of 2023 El Niño contributes to increased levels of vertical wind shear than historical moderate/strong El Niño composite.

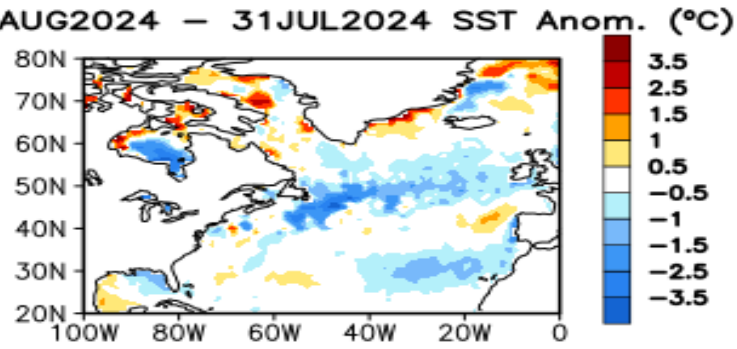
ASO Vertical Wind Shear Anomalies

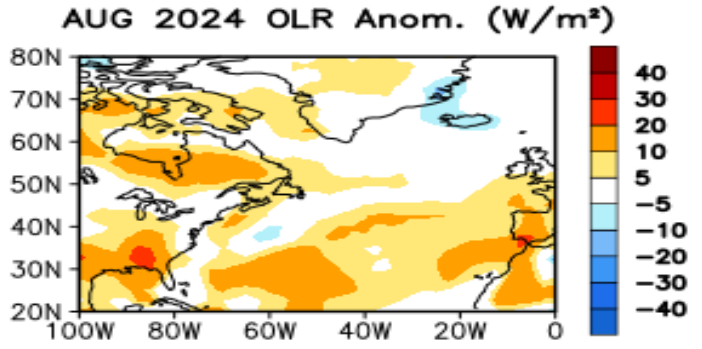


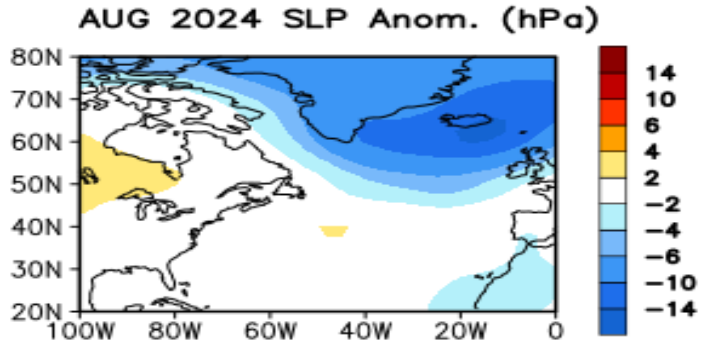
Klotzbach et al, 2024: The 2023 Atlantic Hurricane Season: An Above-Normal Season Despite Strong El Niño Conditions Bull. Amer. Meteor. Soc. https://doi.org/10.1175/BAMS-D-23-0305.1

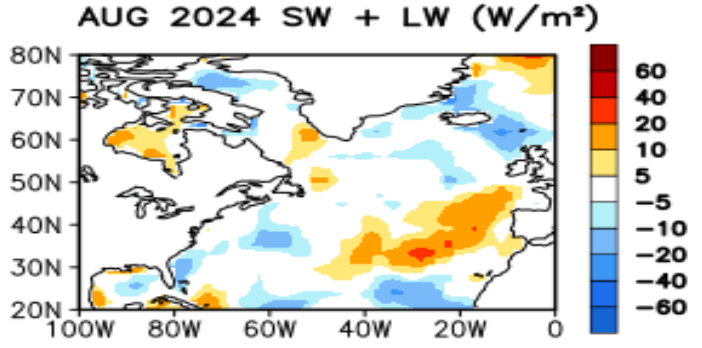
North Atlantic Ocean: SSTA, SSTA Tend., OLR, SLP, Sfc Rad, Sfc Flx Anomalies

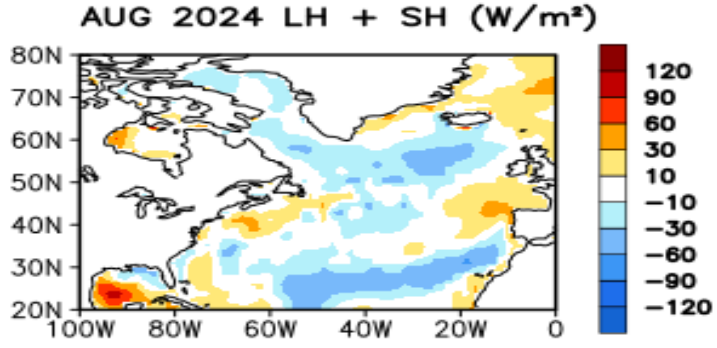




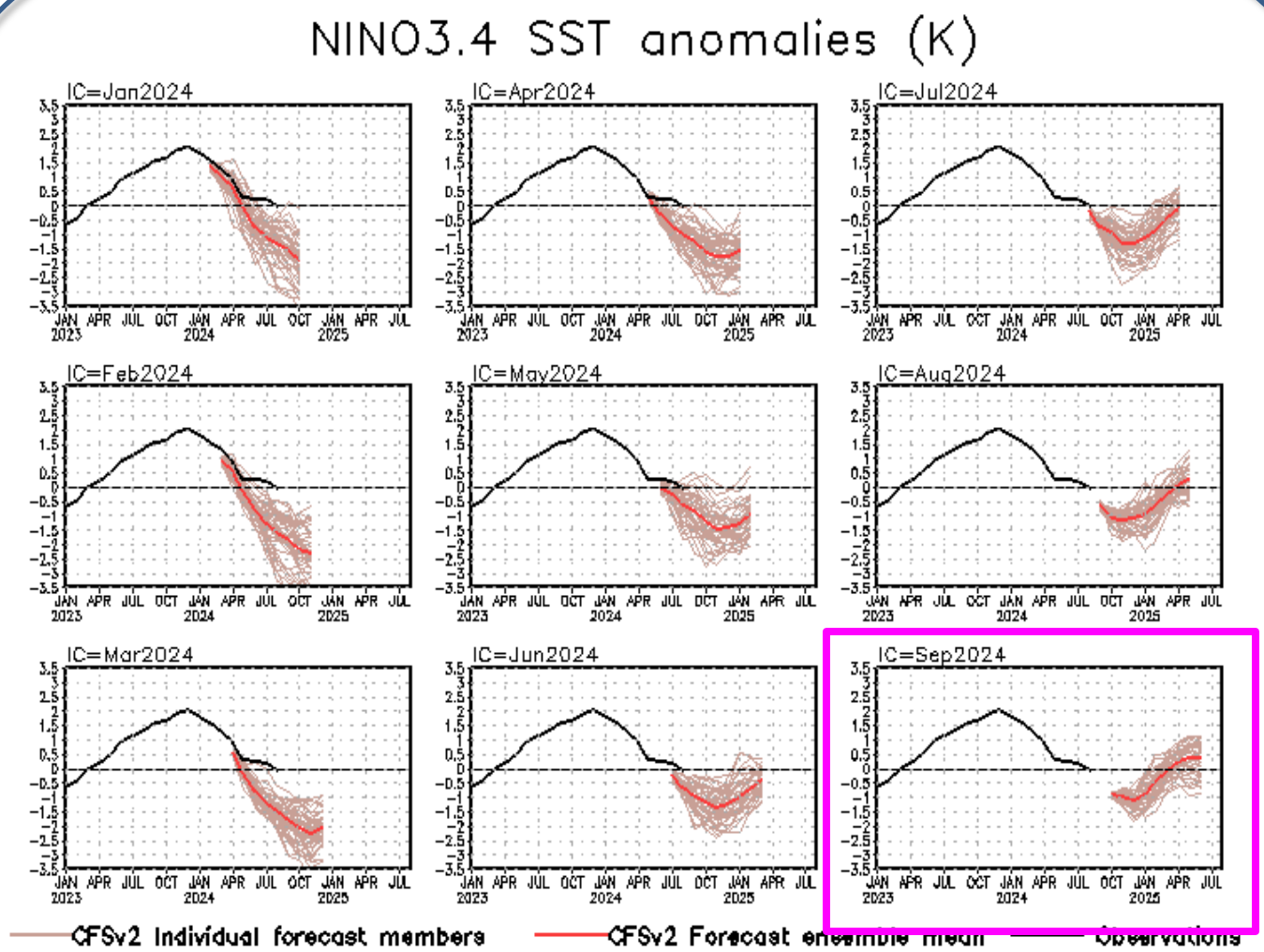








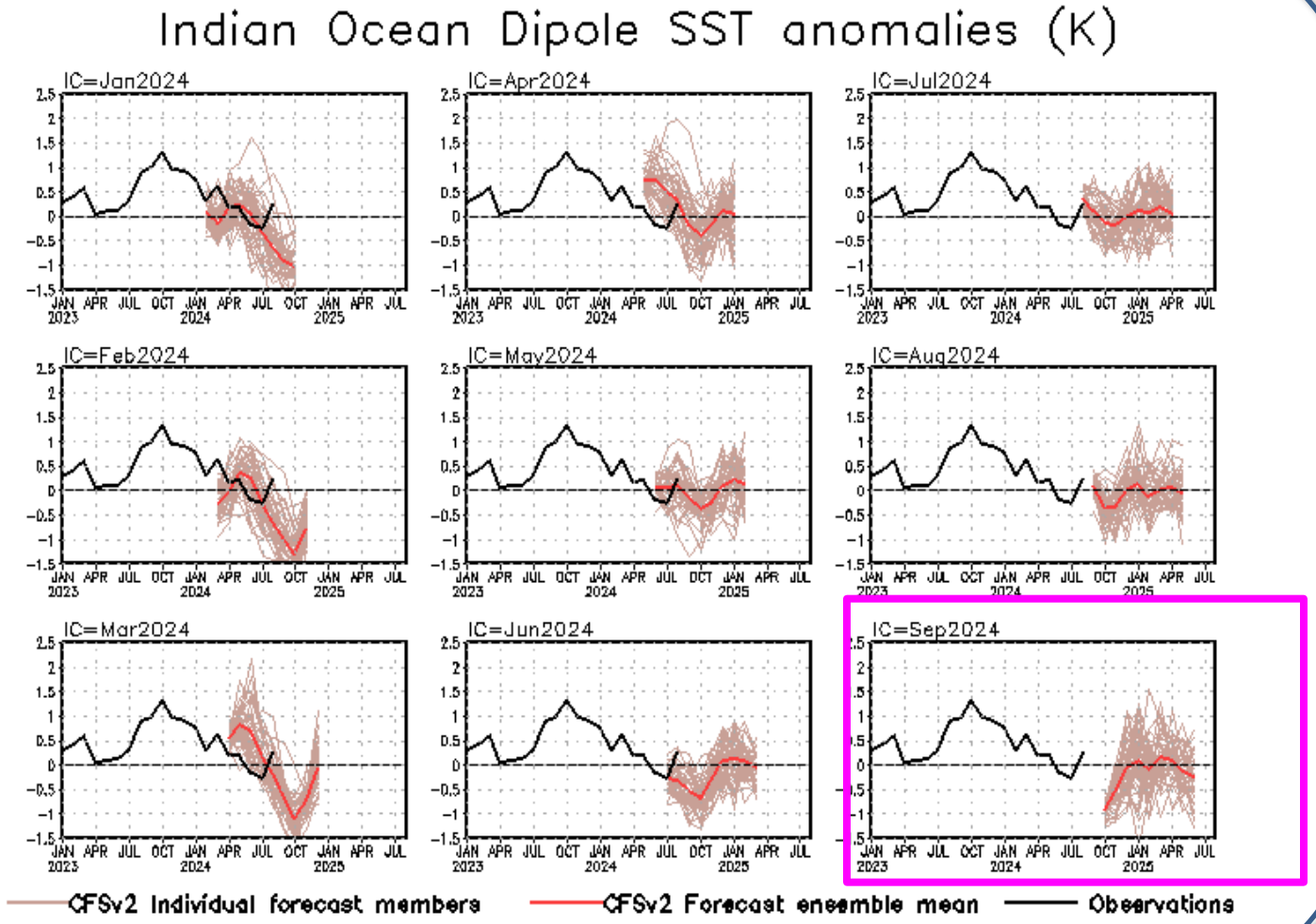
CFS Niño3.4 SST Predictions from Different Initial Months



- The latest CFSv2 forecasts an La Niña will develop in Oct 2024.

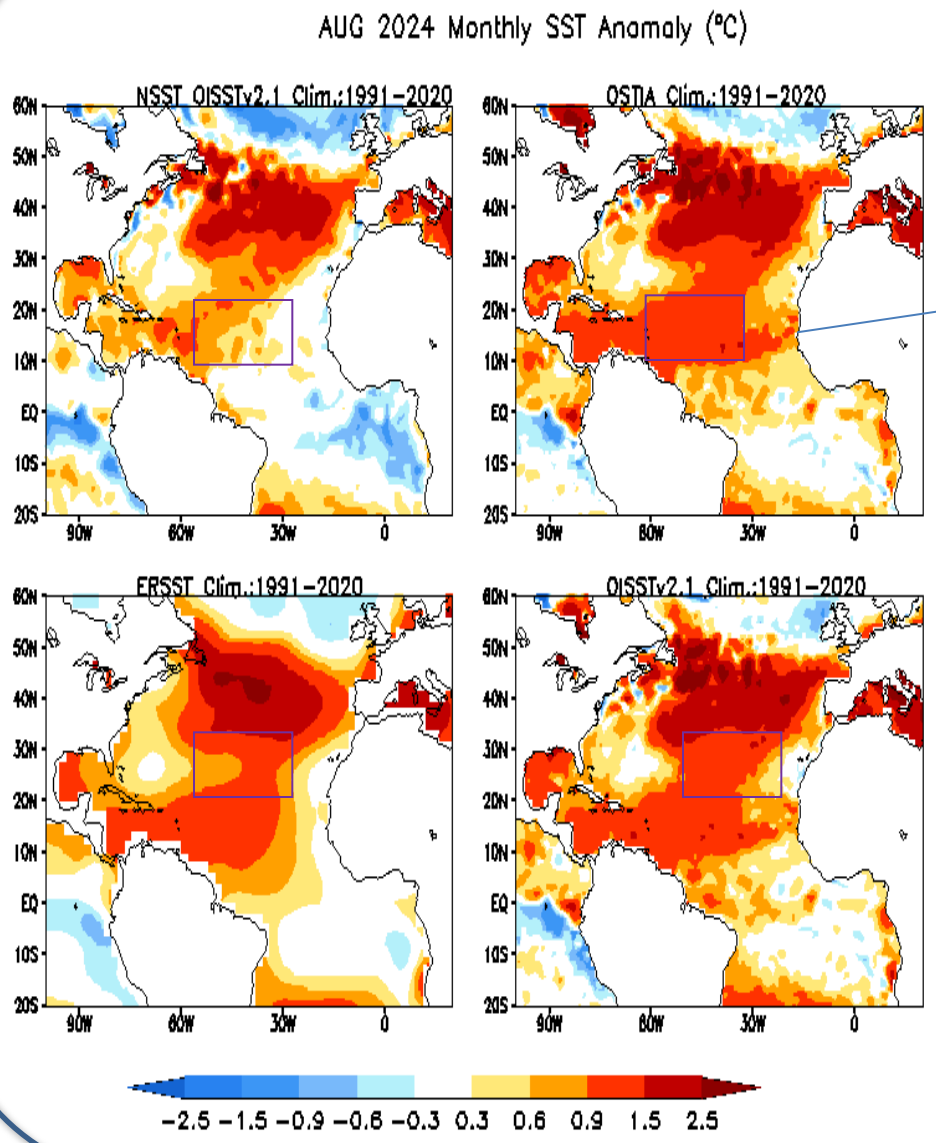
CFS Niño3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect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

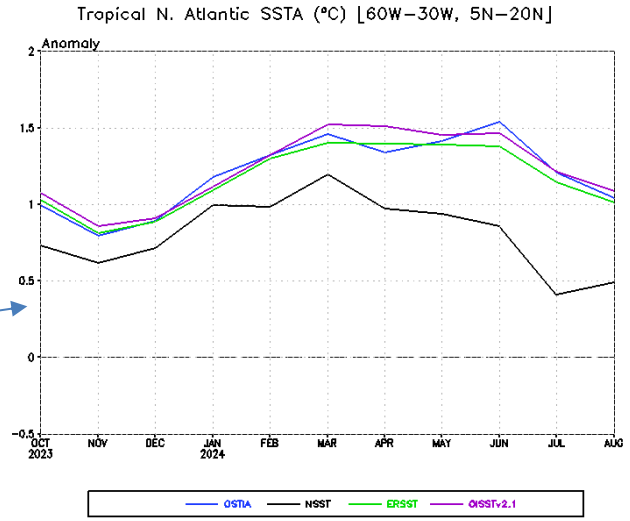
NCEP CFS DMI SST Predictions from Different Initial Months



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.

Monthly SST Anomaly in the Atlantic Ocean





- NSST provide SST nudging source for CFSR.
- NSST was cooler than other SST analysis in most of tropical Atlantic Ocean.
- NSST anomaly in the northern tropical Atlantic Ocean region was colder than OISST v2.1 anomaly by 0.5C in Aug 2024.
- NSST cold bias at least partially contributed to cold bias in CFSv2 short-lead forecasts.