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 Ocean
  - Indian Ocean
  - Atlantic Ocean
- **Global SSTA Predictions**

Overview

•Pacific Ocean

- La Niña condition continued in Oct 2022.
- Strong negative PDO persisted in Oct 2022, with PDOI = -1.5.
- Marine Heat Waves (MHWs) persisted in the west-central North Pacific, the North-east Pacific and near the west coast of USA.

•Arctic Ocean

- Average Arctic sea ice extent for October ranked the eighth lowest in the satellite record.

•Indian Ocean

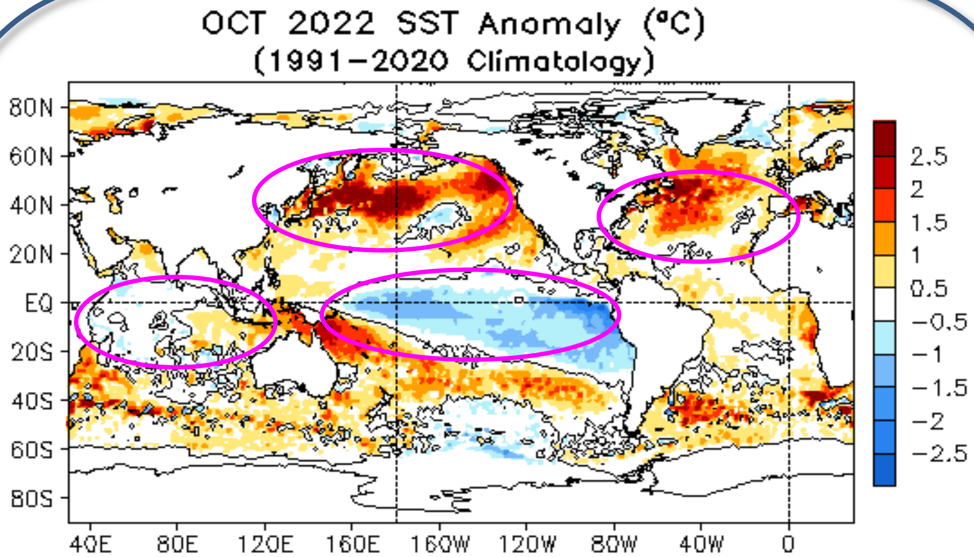
- The strength of negative Indian dipole event decreased in Oct 2022.
- All NMME models predicted the negative IOD event end in Dec 2022.

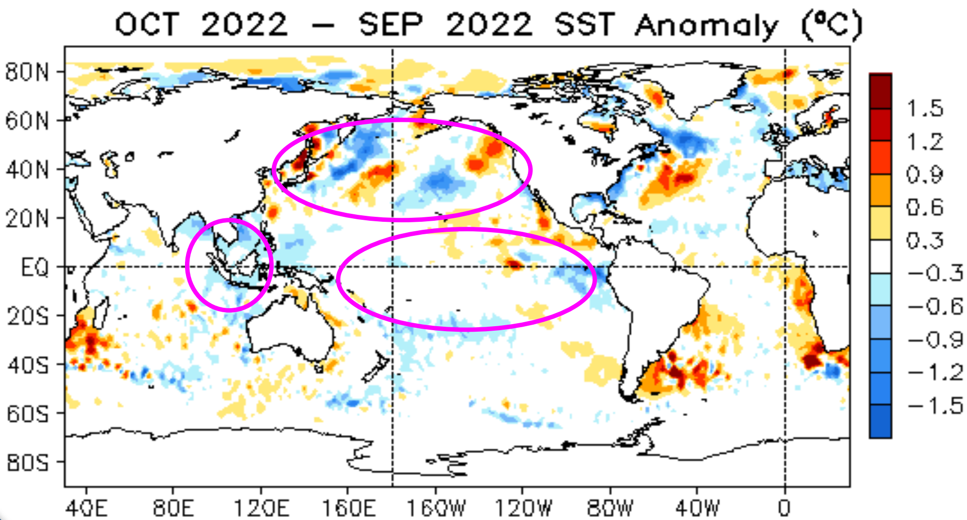
•Atlantic Ocean

- Three tropical storms formed in October, with two strengthening into hurricanes.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency



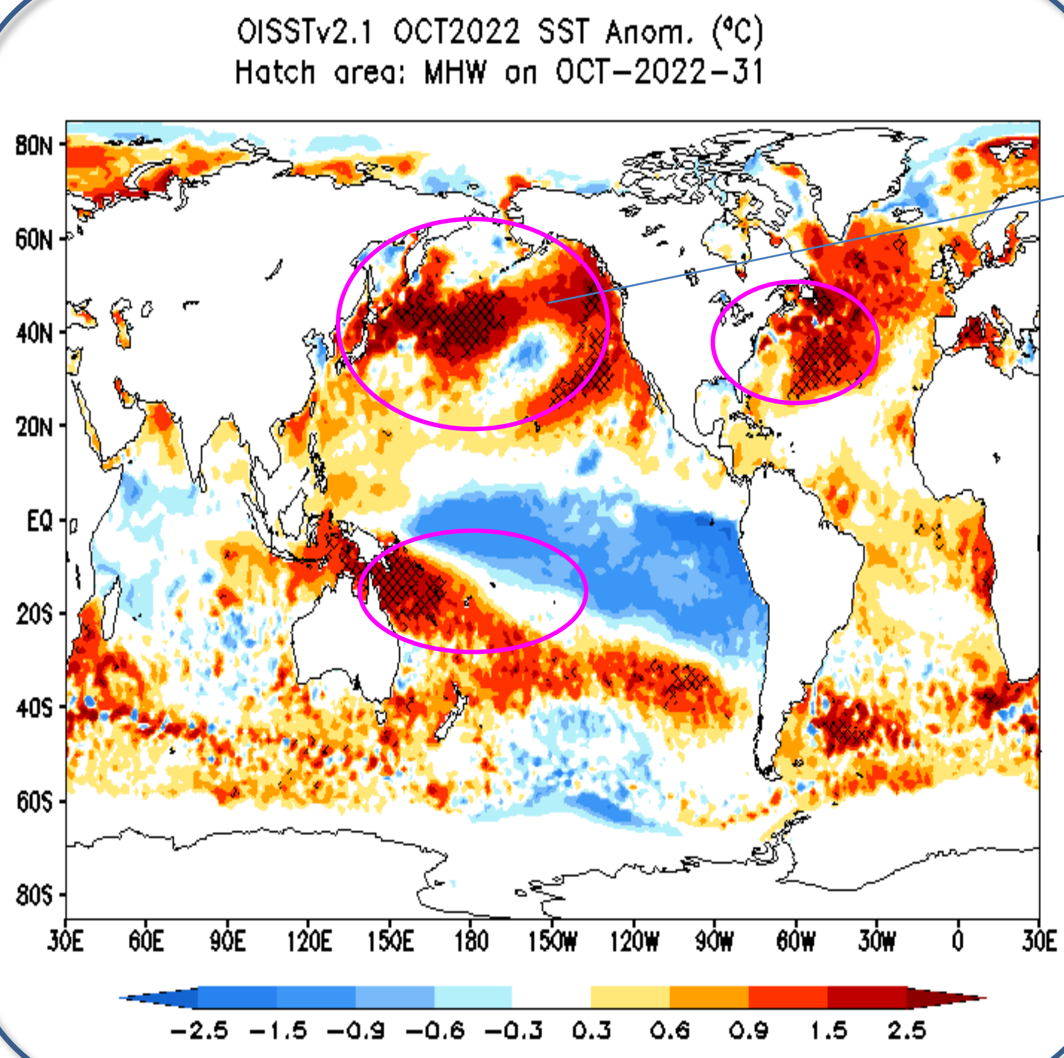


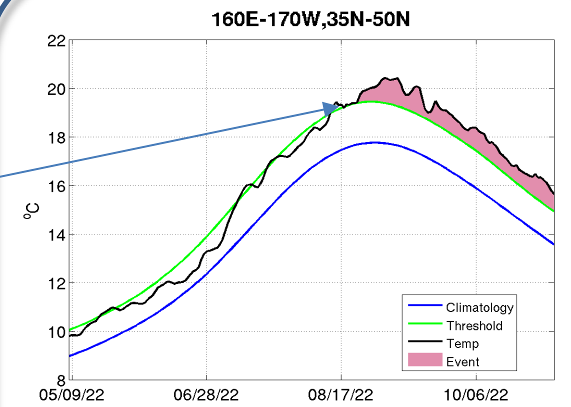
- SSTs were below average across most of the equatorial Pacific Ocean.
- Strong positive SSTAs persisted in the North Pacific and the North Atlantic Oceans.
- Positive SSTA continued in the eastern Indian Ocean.

- Negative SSTA tendencies were observed in the far eastern equatorial Pacific.
- Negative SSTA tendencies presented in the eastern Indian Ocean.
- Both positive and negative SSTA tendencies were observed in the North Pacific.
- Large positive SSTA tendencies were observed in the subpolar Atlantic Ocean.

SSTAs (top) and SSTA tendency (bottom). Data are derived from the OISSTv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

Global Monthly SST anomaly and Marine Heat Waves

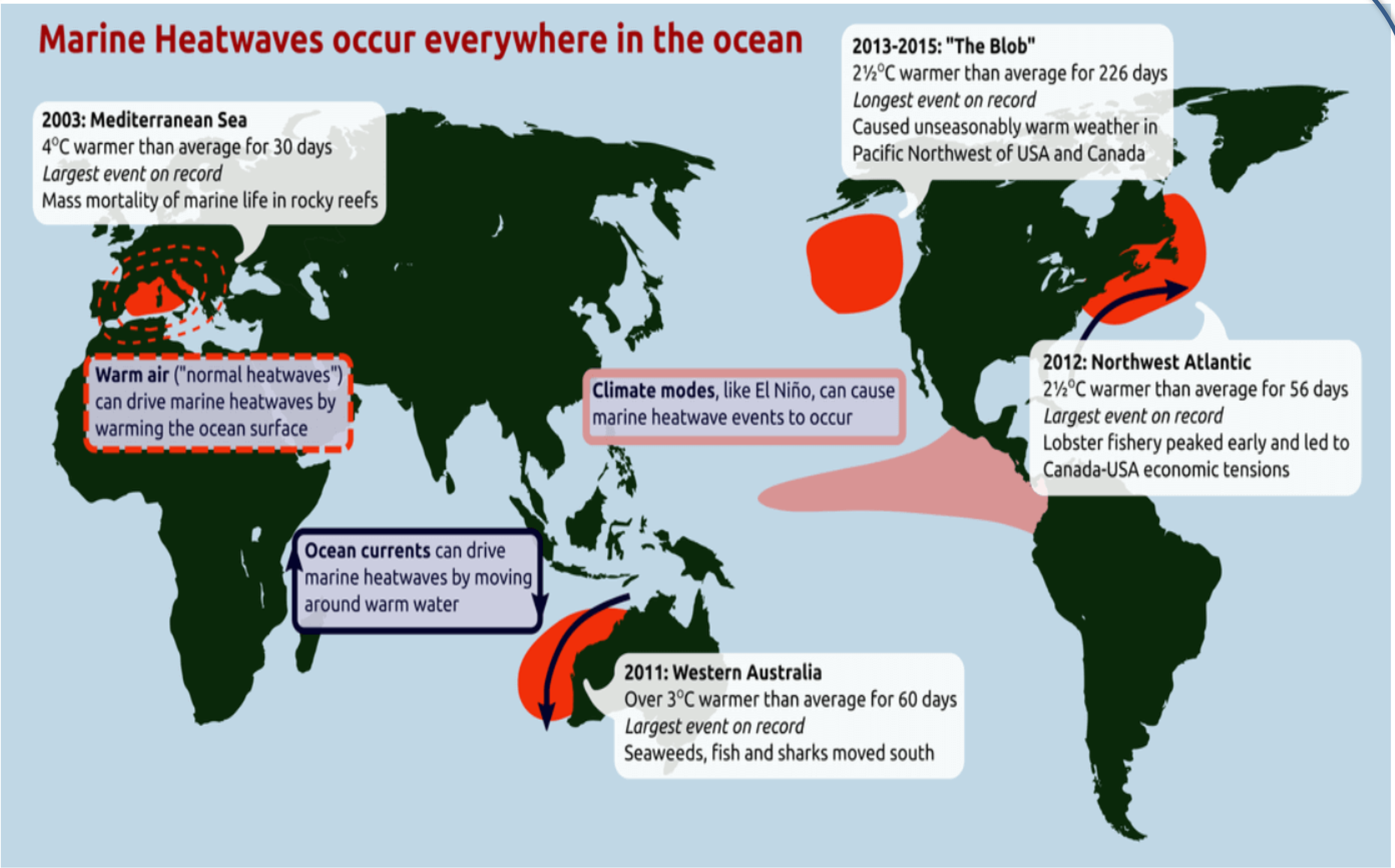




- MHWs were observed in the Northcentral, Northeast Pacific , Northwest Atlantic, and the Coral Sea.

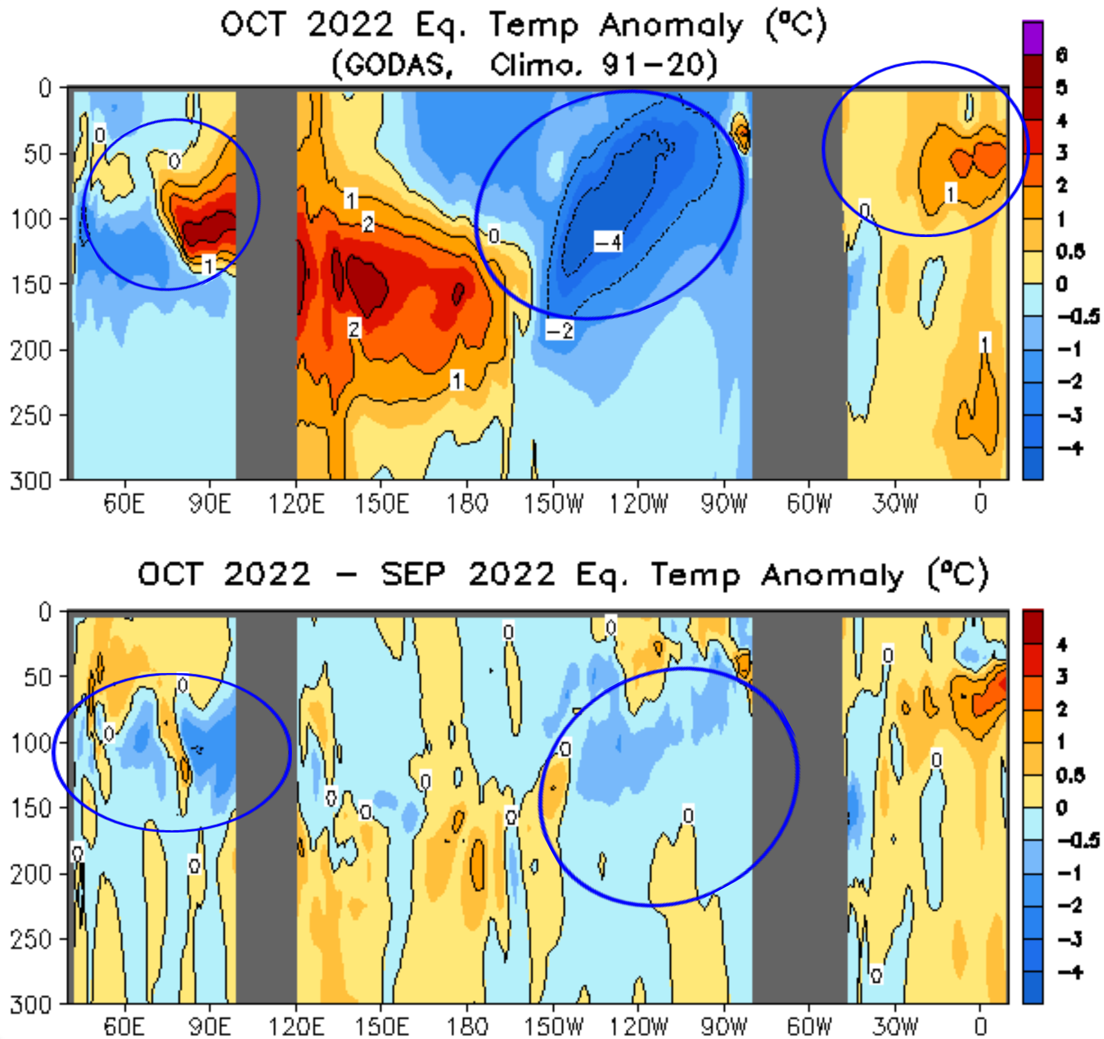
((Left panel) Monthly SST anomaly (shaded) and locations experiencing marine heat waves (hatched) by the end date labelled in the plot. (right panel) SST evolution at a specific location. Green line and blue line are the 90th percentile and daily climatology, respectively. Shaded area denotes the periods 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 NCEI OISSTv2.1 and the reference period is 1991-2020

Historical Marine Heat Wave events and impacts



https://www.severe-weather.eu/global-weather/north-pacific-ocean-anomaly-2022-usa-seasonal-influence-fa/

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



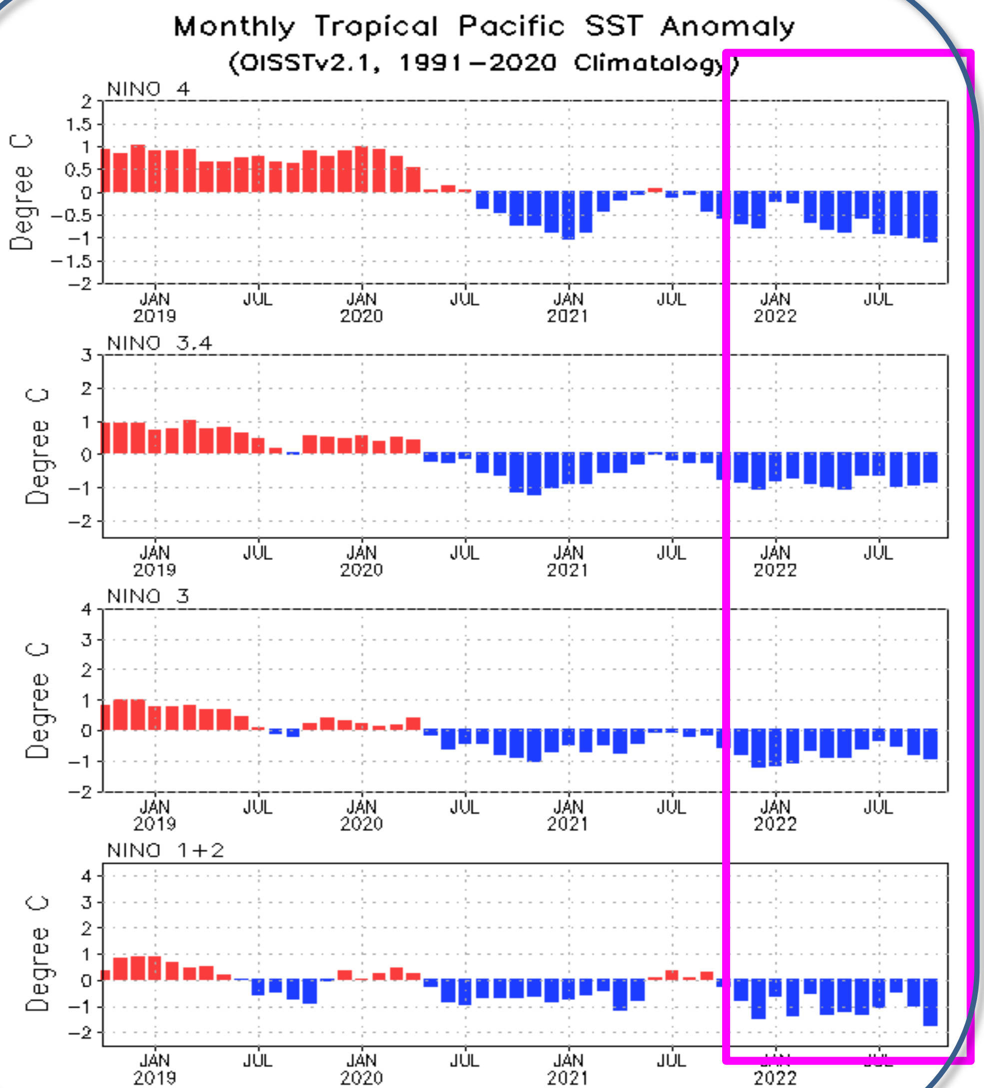
- Negative (positive) temperature anomalies persisted along the thermocline in the eastern (western) Pacific Ocean.
- Large positive temperature anomalies persisted in the eastern equatorial Indian Ocean.
- Positive temperature anomalies dominated the upper 100m of the equatorial Atlantic Ocean.

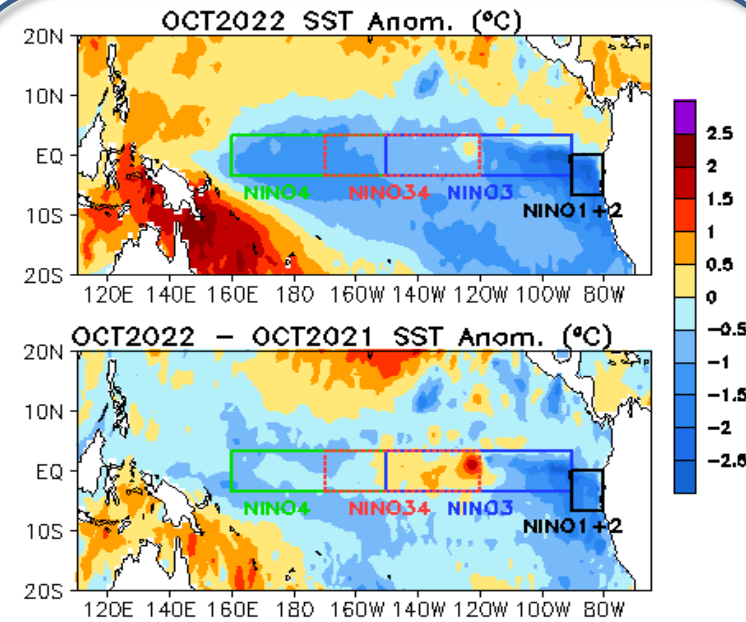
- Negative temperature anomaly tendency was observed in the upper 50-100m of Indian Ocean.

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

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific Niño SST Indices

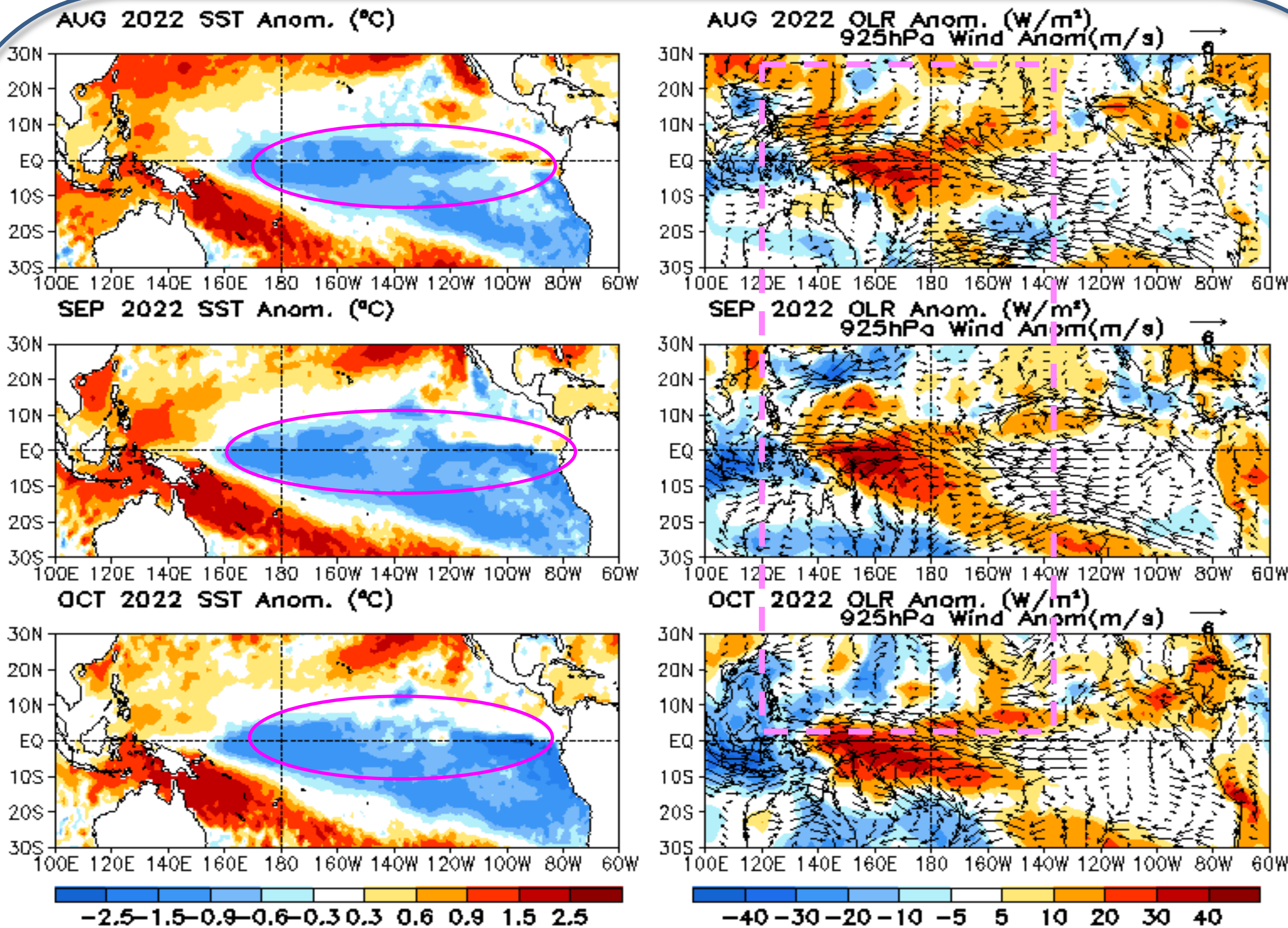




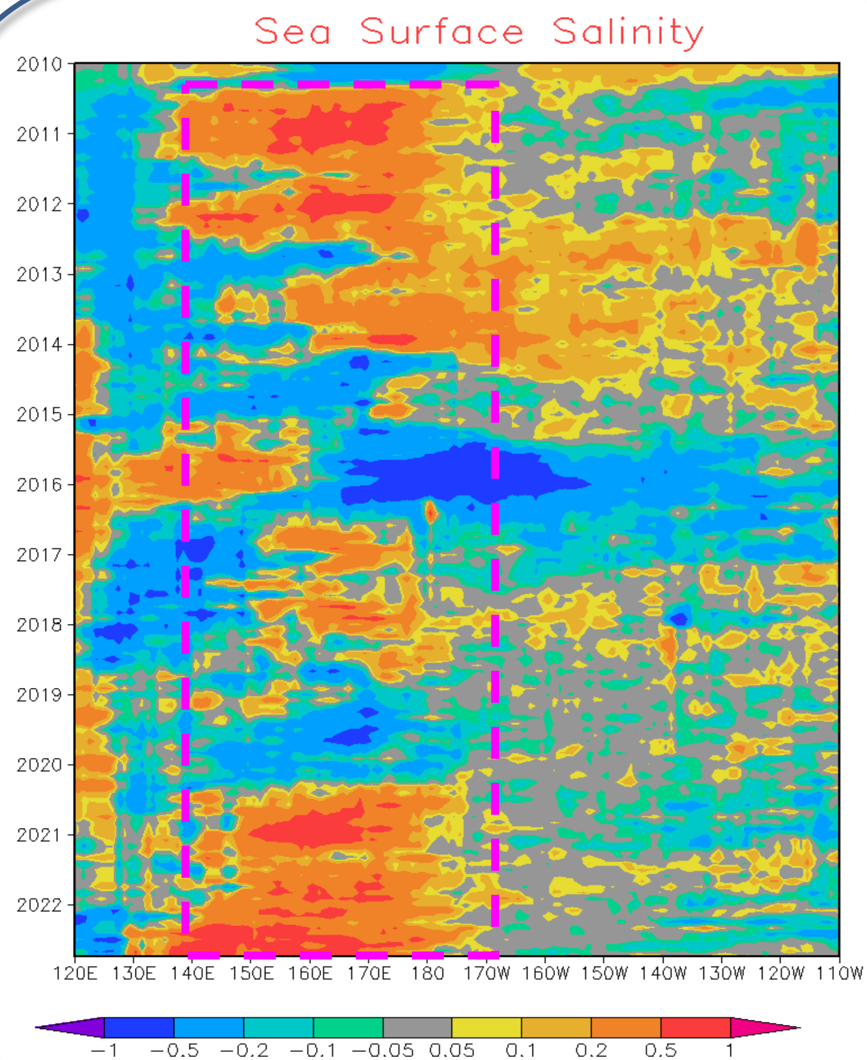
- Except for Niño 34, the other three Niño indices cooled in Oct 2022.
- Negative Niño3.4 weakened slightly in Oct 2022, with Niño3.4 = -0.9C.
- Compared with Oct 2021, the eastern and southeastern tropical Pacific were cooler in Oct 2022.
- The indices may have slight differences if based on different SST products.

Niño region indices, calculated as the area-averaged monthly mean SSTAs (°C) for the specified region. Data are derived from the OISSTv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

Last three months SST, OLR and uv925 anomalies



Equatorial Pacific Sea Surface Salinity(SSS) Anomaly

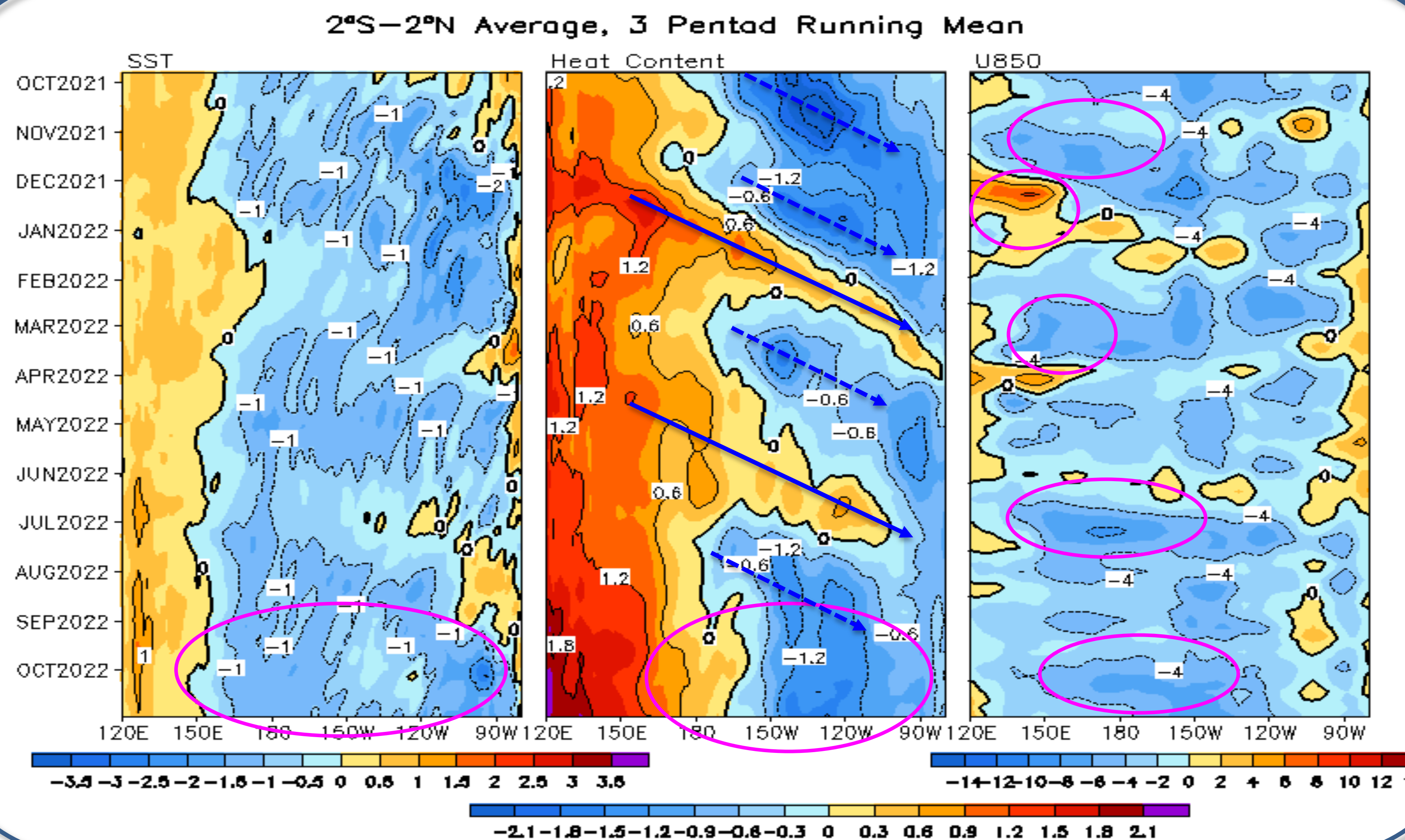


- Positive (negative) SSS anomaly presented east (west) of 140E during 2010, 2011, 2016, 2017, 2020, 2021 La Nina events.

- Positive SSS anomaly continued and enhanced in the western-central equatorial Pacific in Oct 2022.

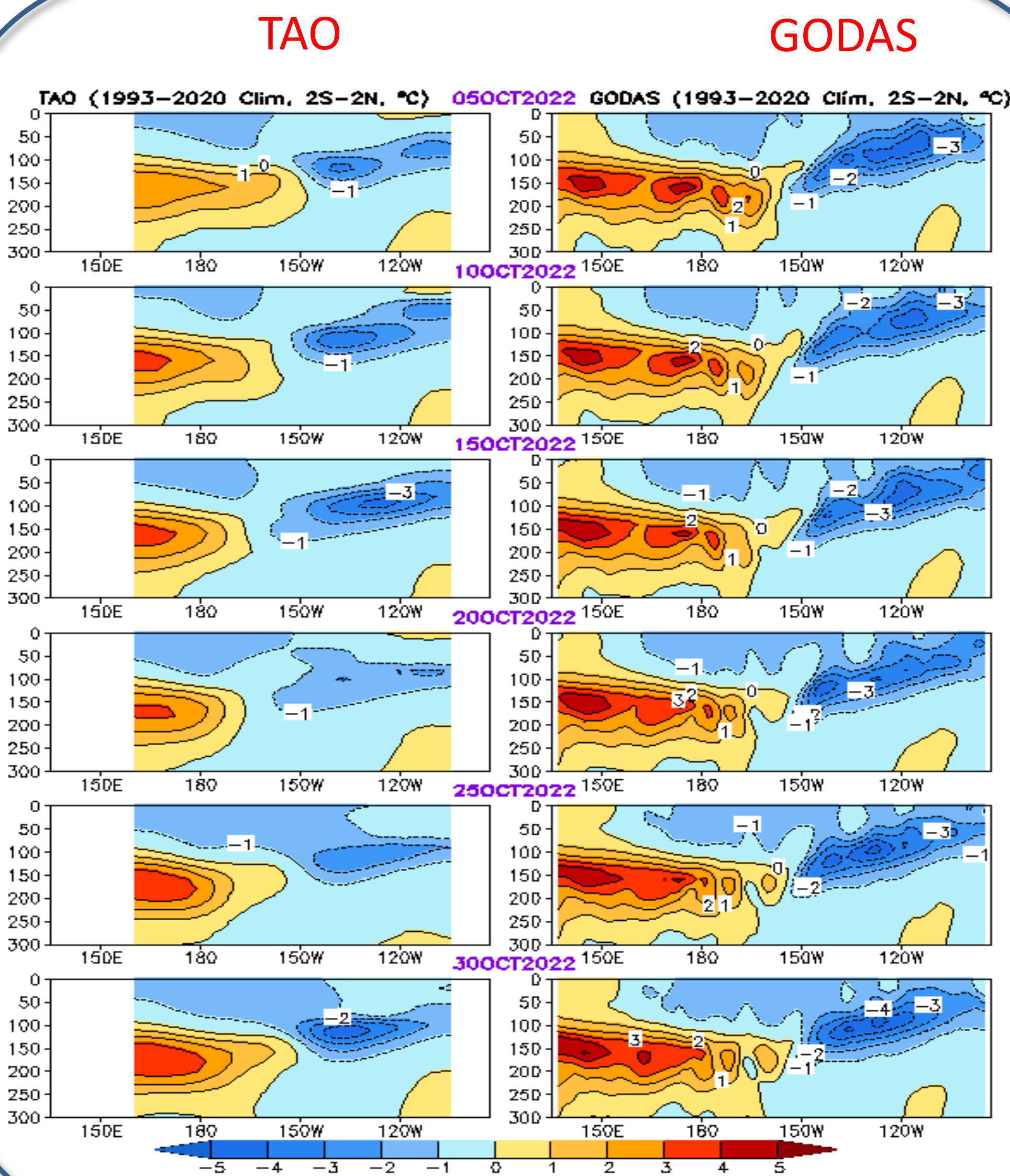
Sea surface salinity (SSS) anomalies are derived from Blended Analysis of Surface Salinity (BASS) V0.Z (Xie et al. 2014). Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015,The BASS SSS is from in situ, SMOS and Aquarius. Data is available at ftp.cpc.ncep.noaa.gov/precip/BAS.

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



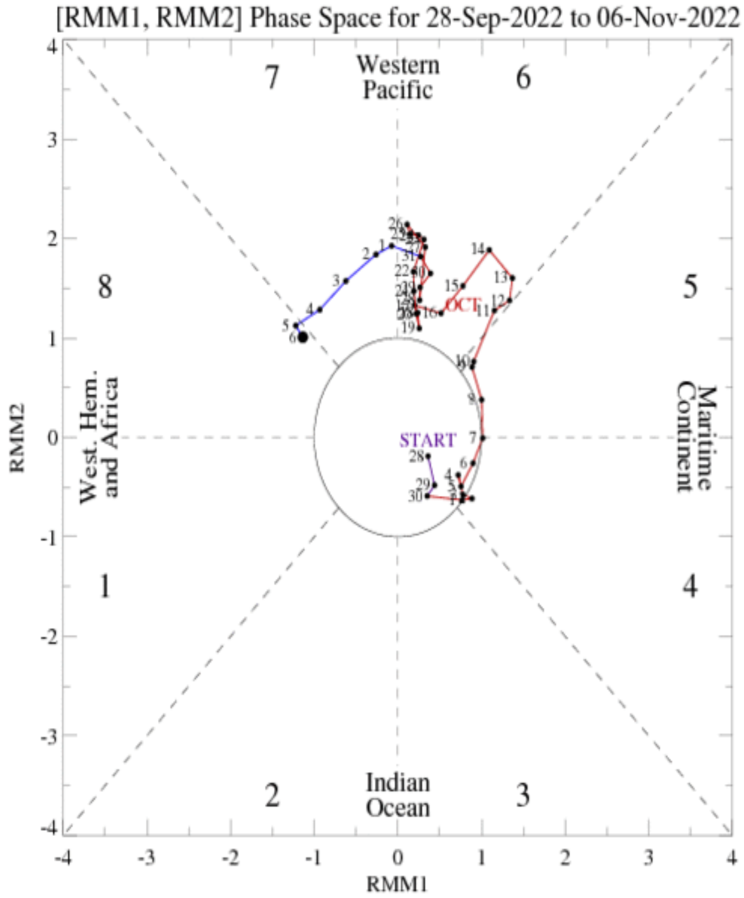
- Negative SSTA enhanced in the western-central and the eastern Pacific in Oct 2022.
- Easterly wind anomalies prevailed over the equatorial Pacific in Oct 2022.
- West-east dipole pattern was stationary in the last couple of months.

Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

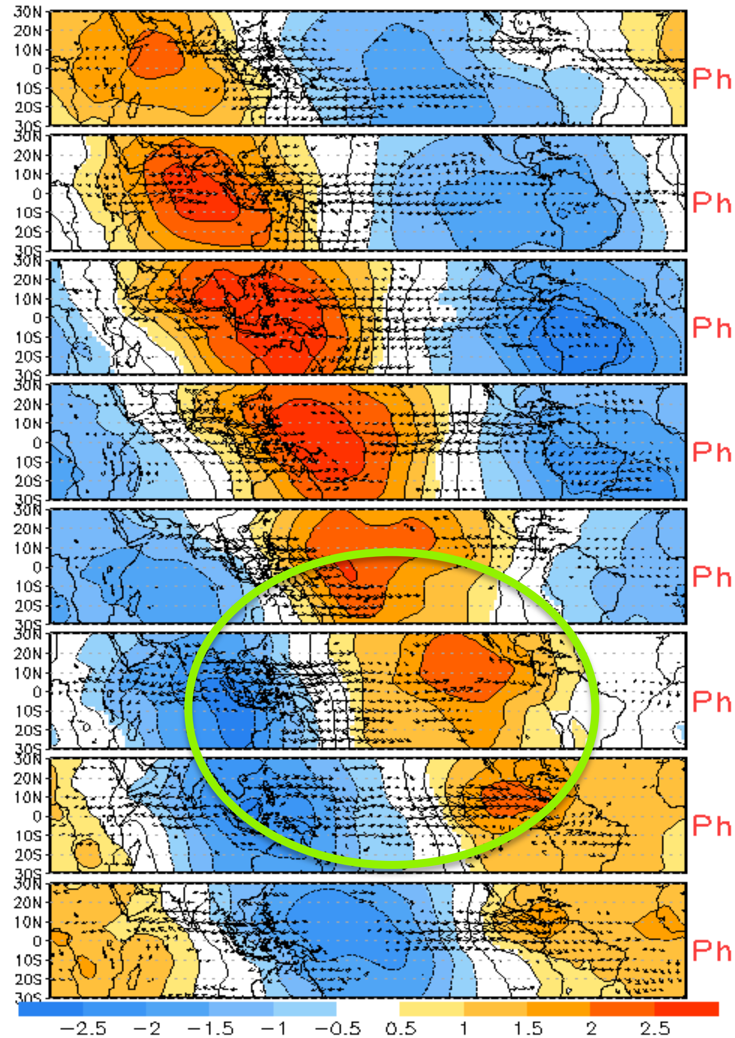


- Negative temperature anomaly in the eastern Pacific entered the mixed layer, in favoring of further SST cooling in the eastern Pacific.
- West-east dipole pattern was stationary in the last six pentads.

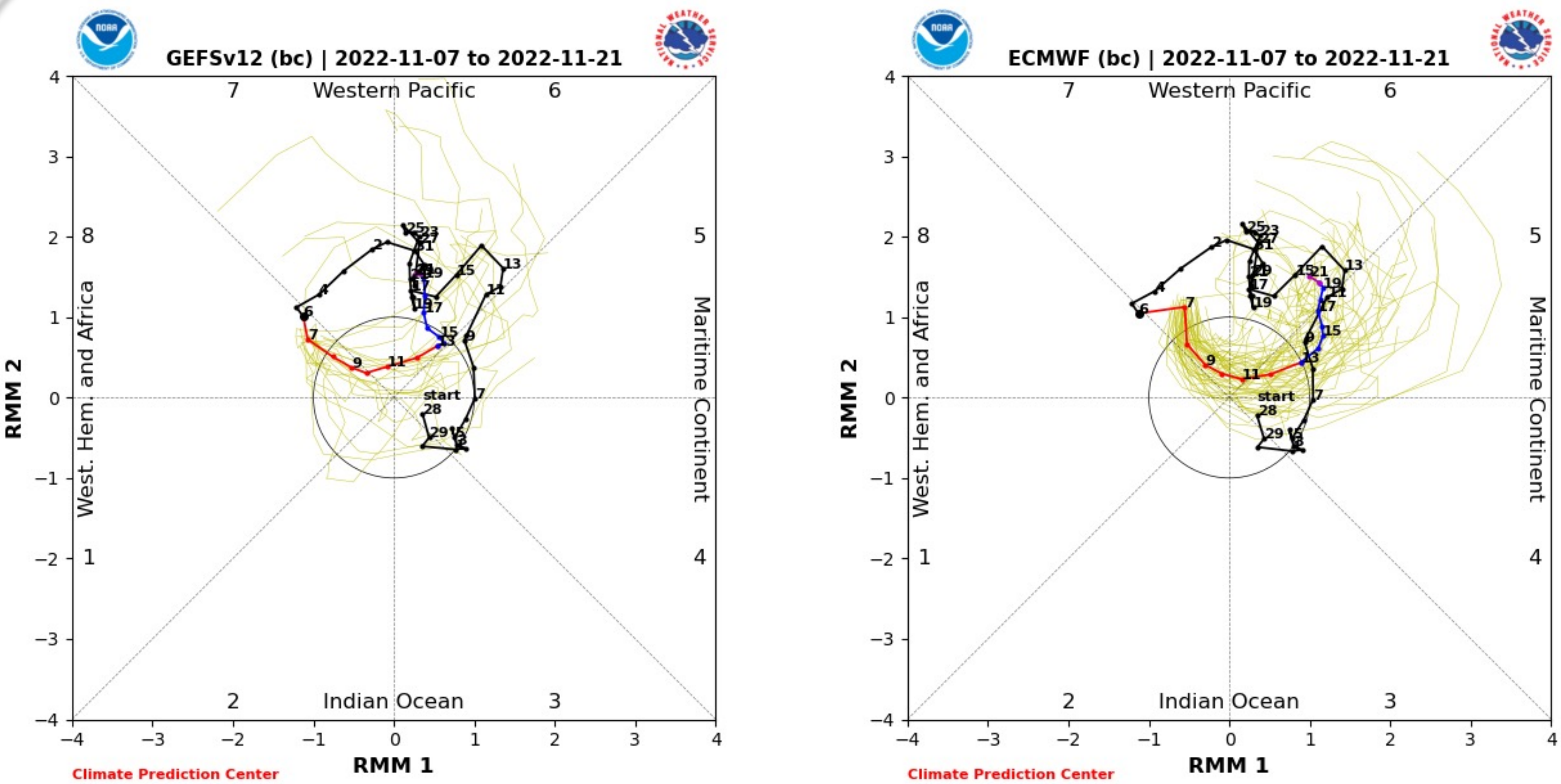
MJO Activities



850-hPa Velocity Potential and Wind Anomalies



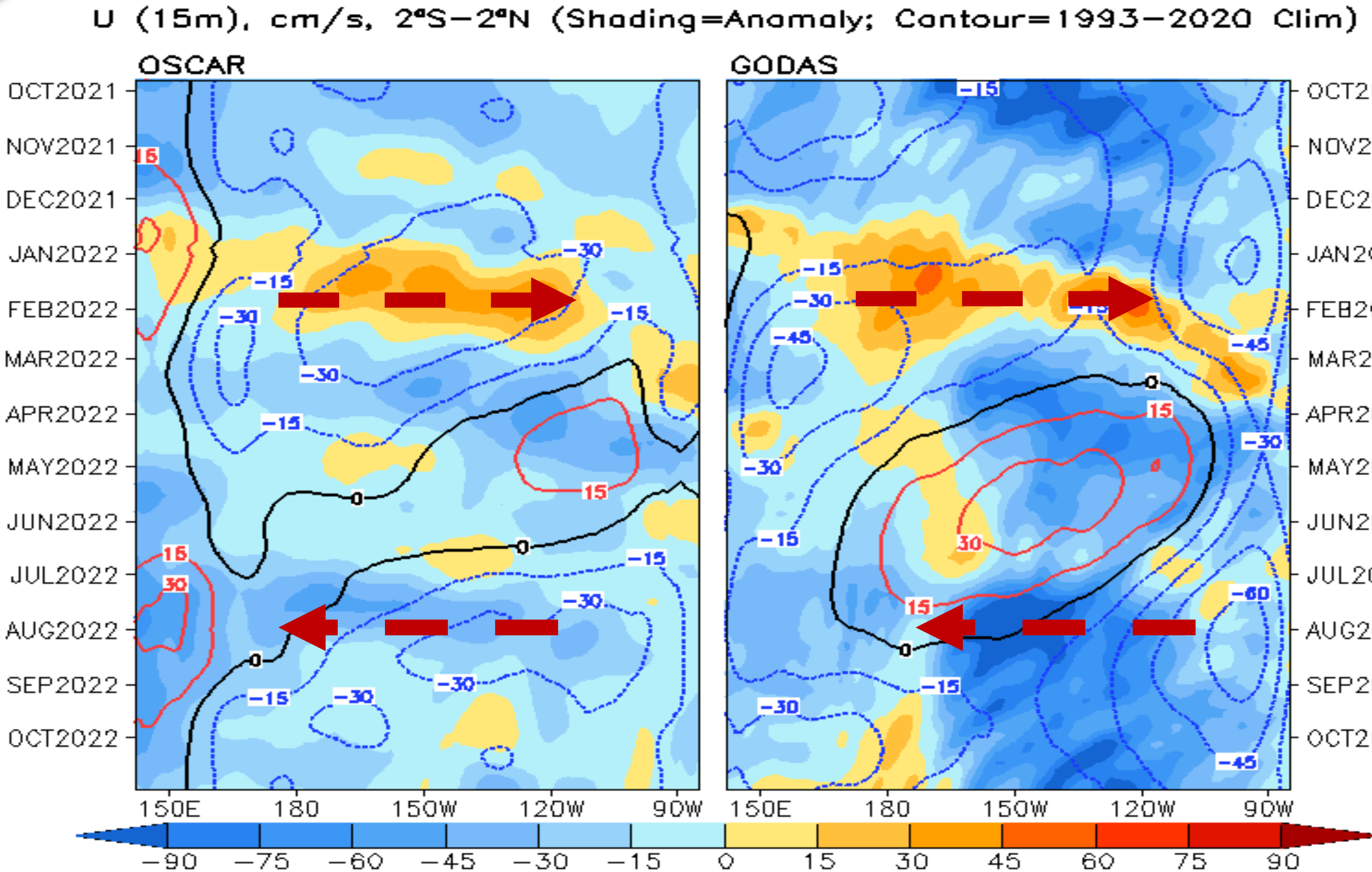
MJO Index: Forecasts



https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml#forecast

- Both GEFS and ECMWF ensembles forecast MJO-signal re-emerge across the Maritime Continent by week-2.

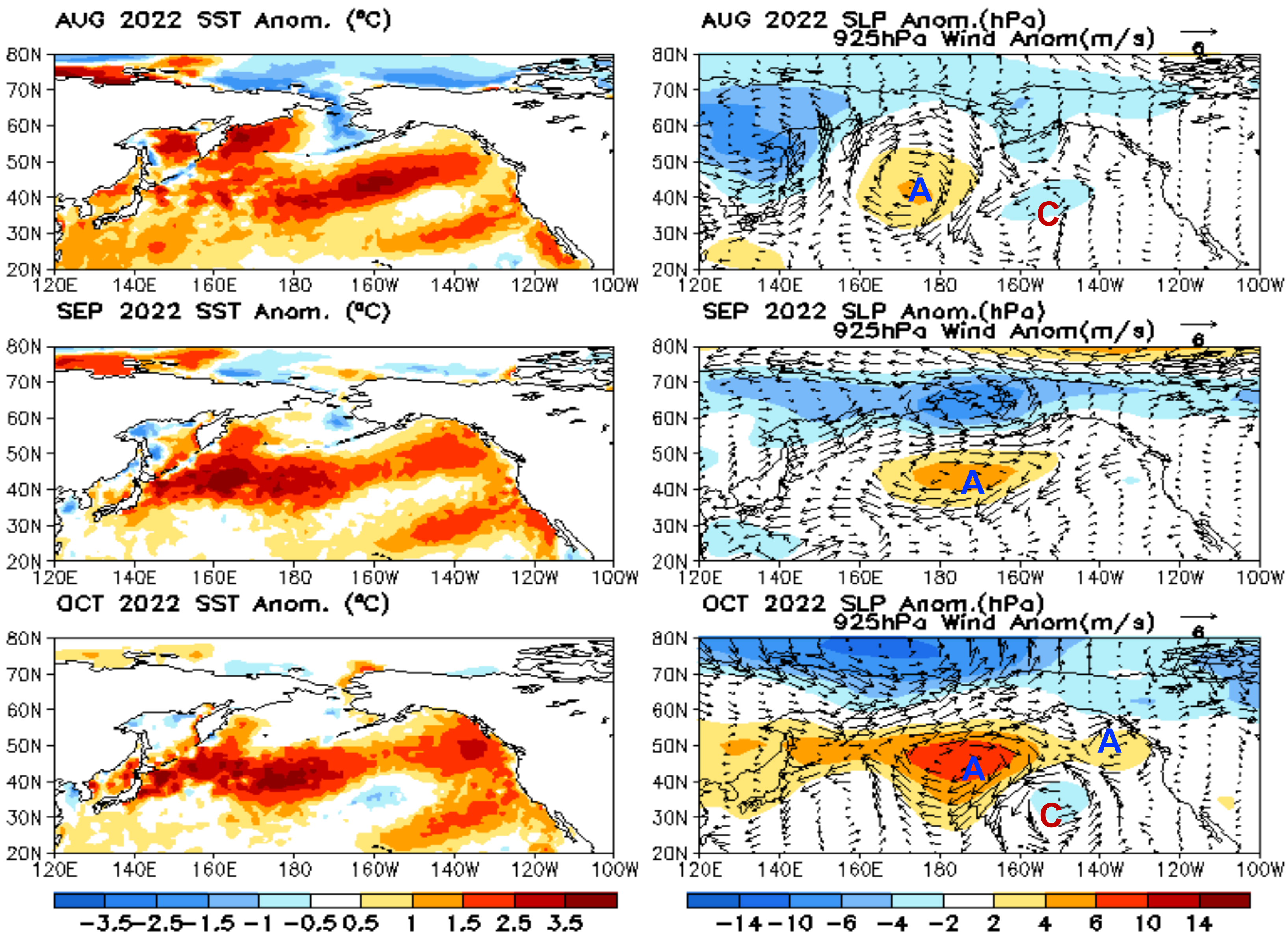
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



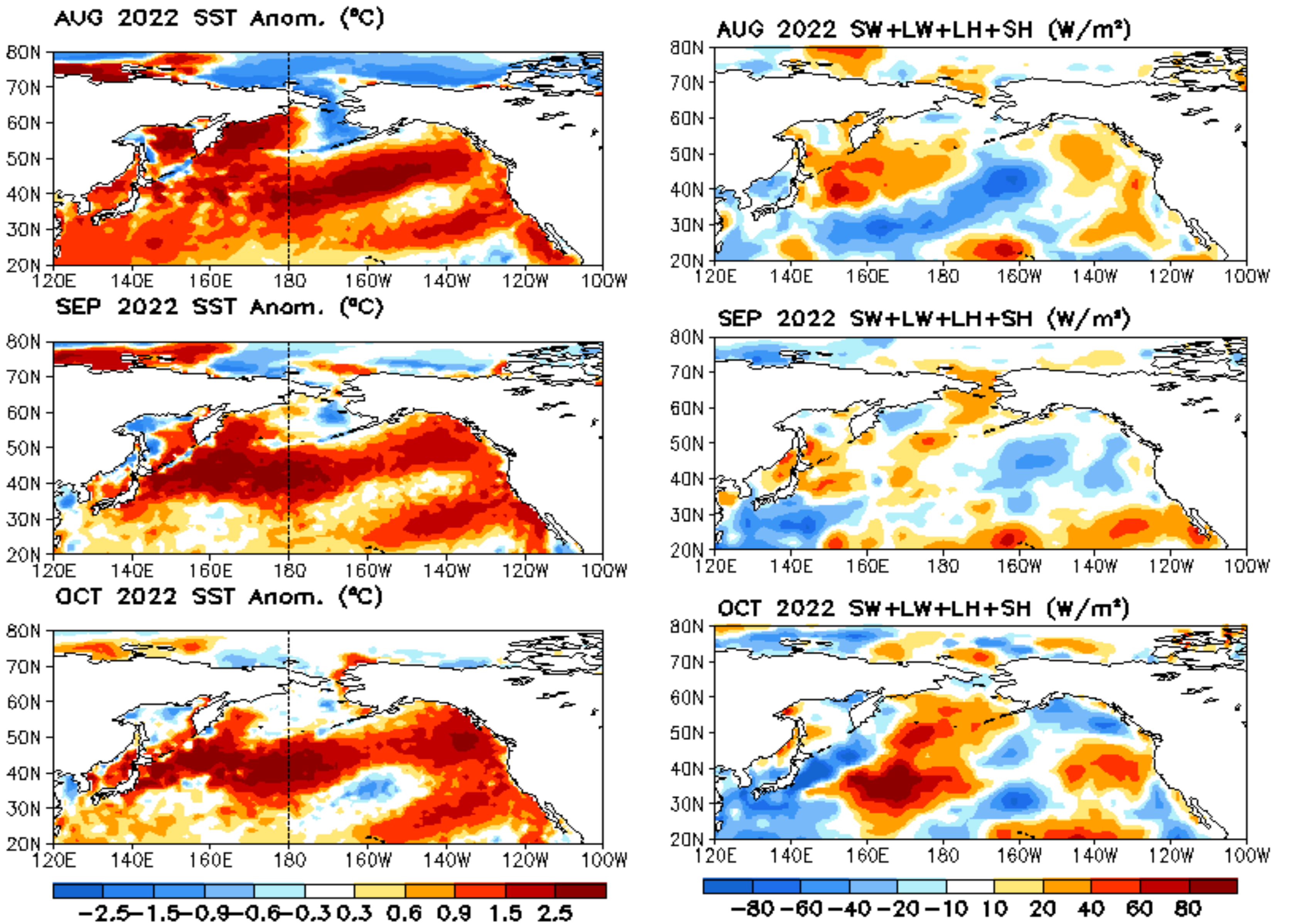
- Anomalous westward currents were present in the eastern equatorial Pacific both in OSCAR and GODAS since Feb 2022.

North Pacific & Arctic Oceans

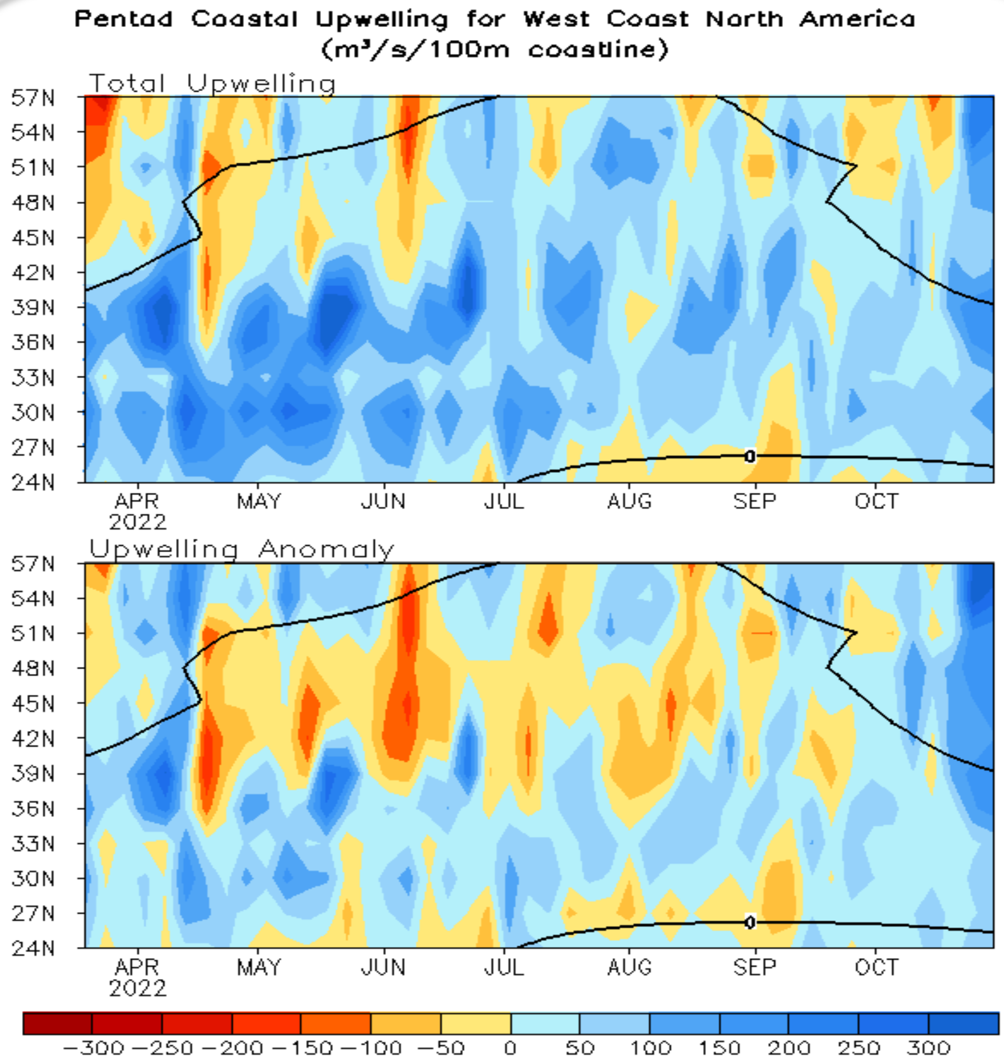
Last 3- month North Pacific SST, SLP, and uv925 anomalies

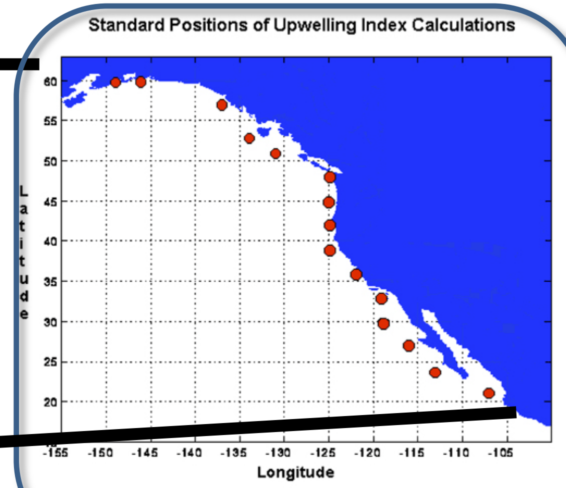


Last 3- month North Pacific SST and Surface Heat Flux anomalies



North America Western Coastal Upwelling



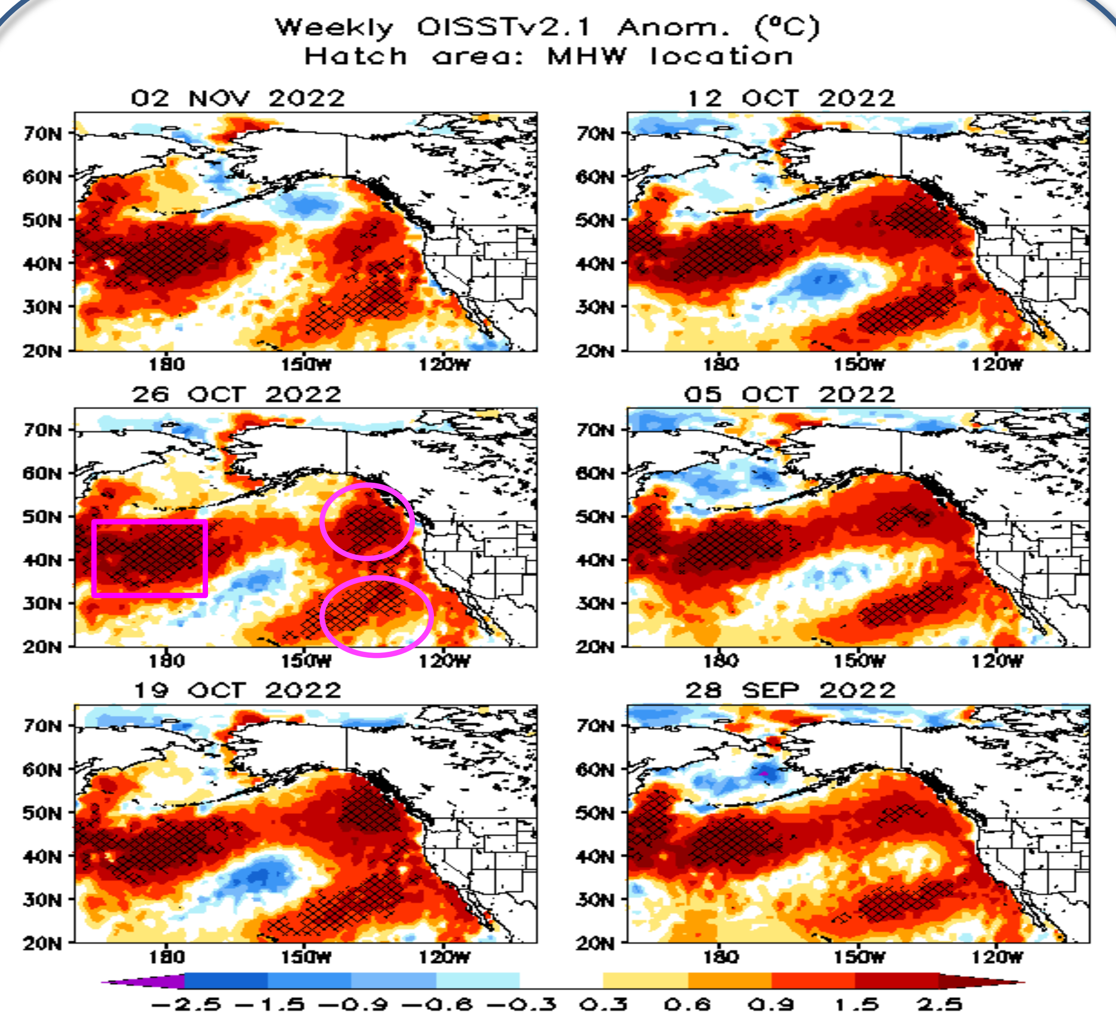


- Anomalous upwelling dominated along the coastline in Oct 2022.

(top) Total and (bottom) anomalous upwelling indices at the 15 standard locations for the western coast of North America. Derived from the vertical velocity of the NCEP's GODAS and are calculated as integrated vertical volume transport at 50-meter depth from each location to its nearest coast point ($m^3/s/100m$ coastline). Anomalies are departures from the 1991-2020 base period pentad means.

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

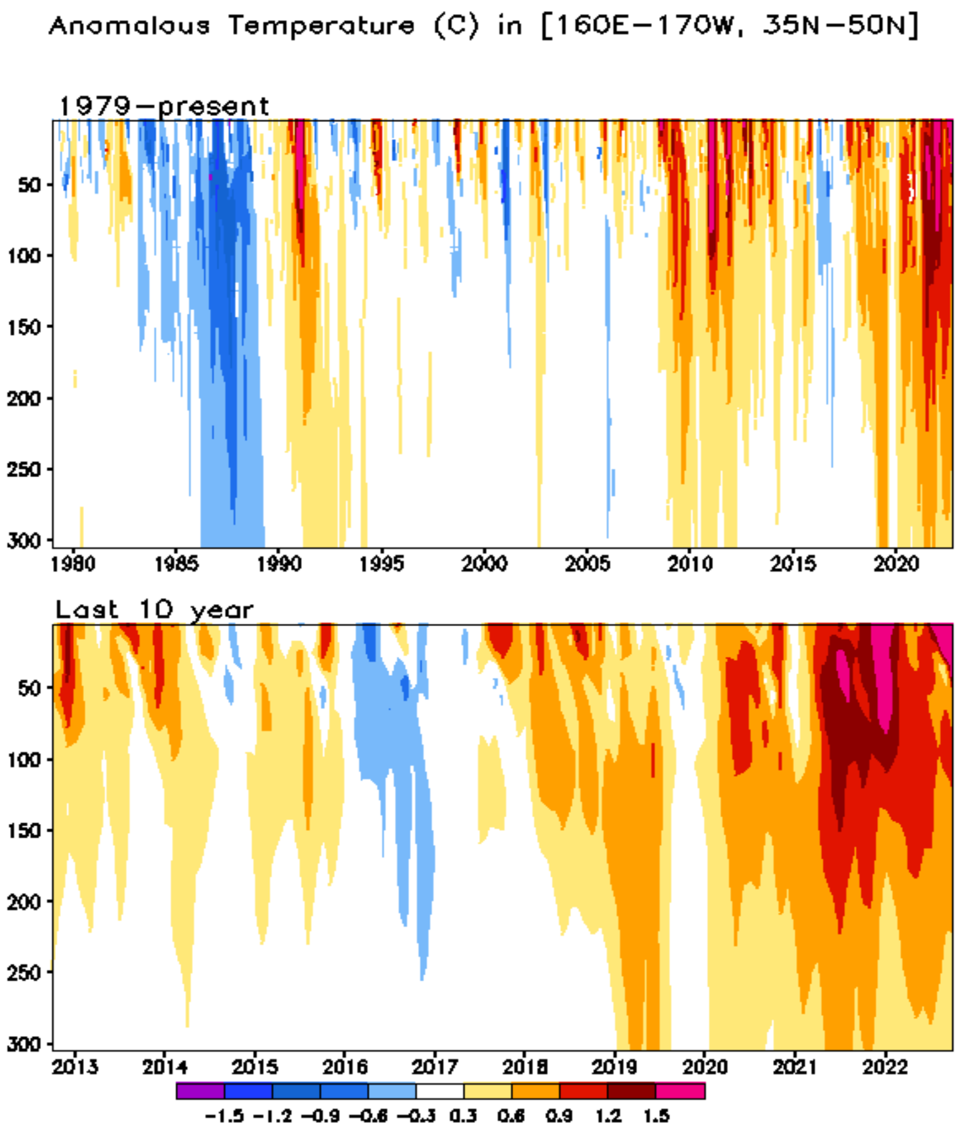
Weekly SST anomaly and MHWs in the North Pacific

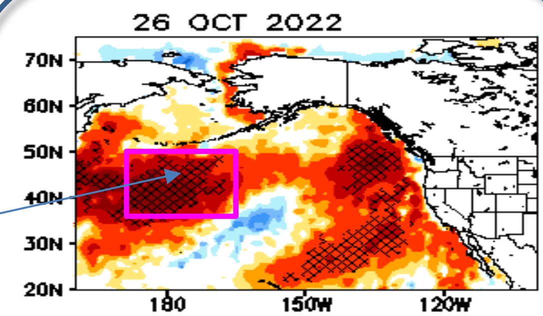


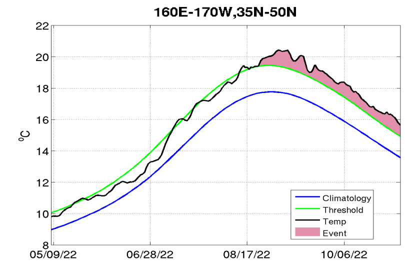
-MHWs persisted in the western-central Pacific, northeast Pacific (Pacific Blob) and near the west coast of USA in Oct 2022.

(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

Subsurface Temperature Anomaly in the Northcentral Pacific







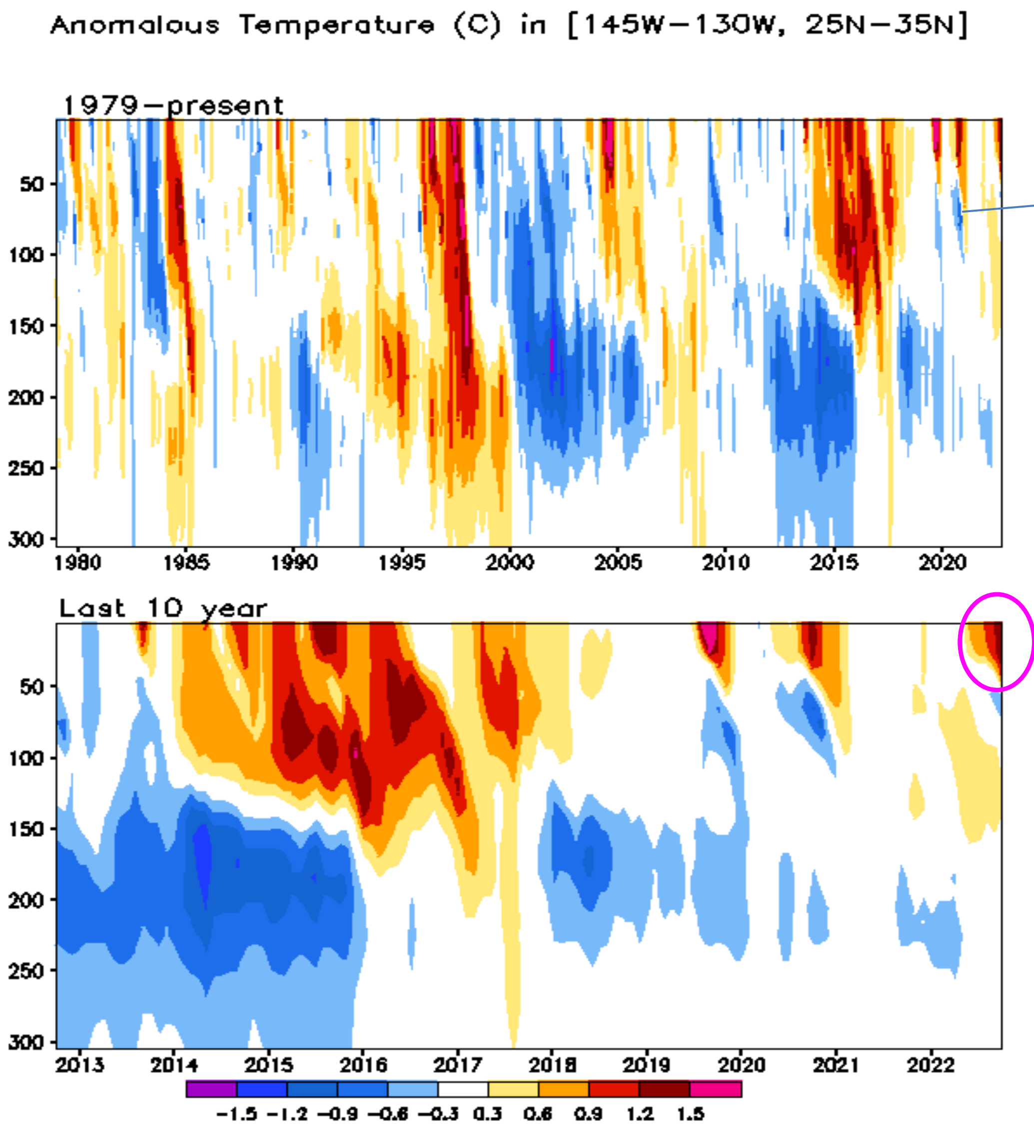
- MHWs has persisted since Aug 2022.

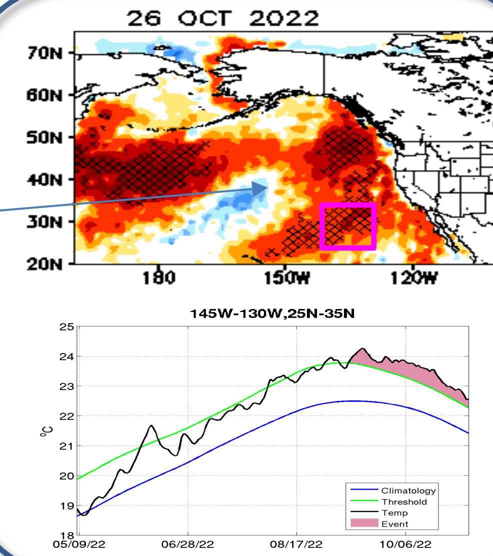
-Positive subsurface temperature anomaly in the North central Pacific has persisted since 2020.

- Subsurface warming in the last couple of years is the strongest event since 1979.

- Positive temperature anomaly (>0.9ºC) penetrated to 200m in recent months.

Subsurface Temperature Anomaly near the west coast of USA



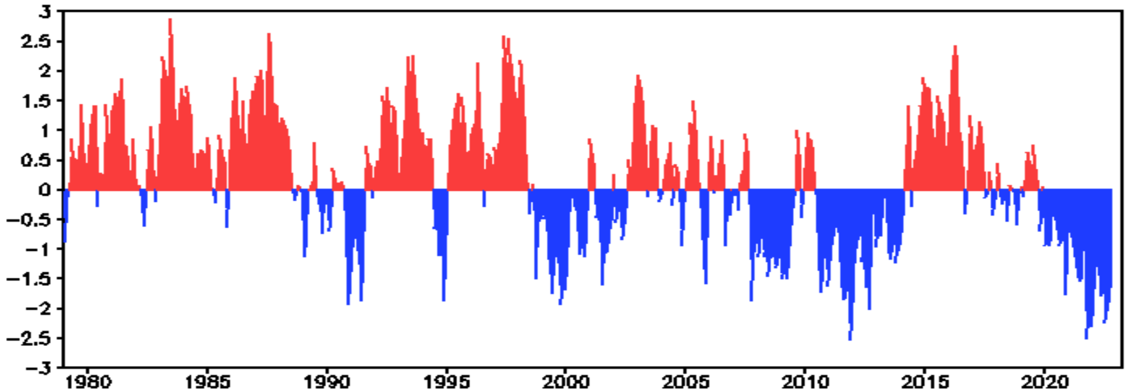


- MHWs has persisted since Sep 2022.

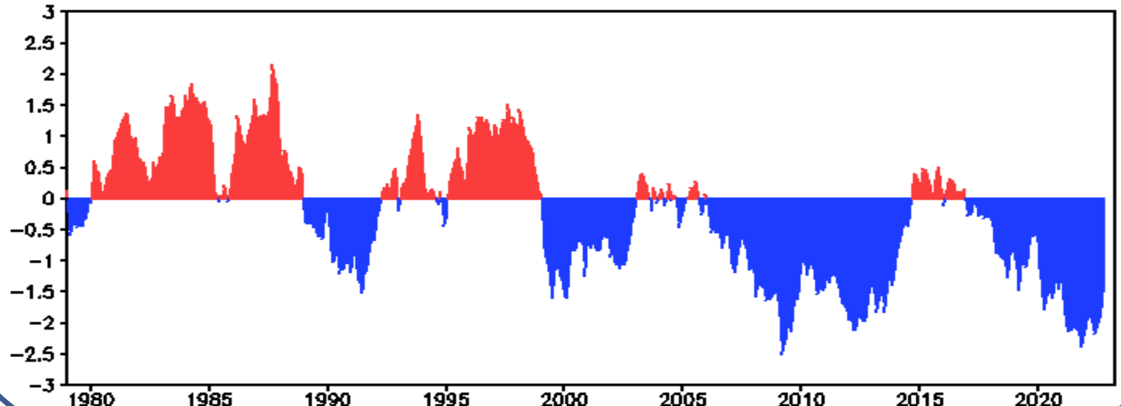
-Positive subsurface temperature anomaly (>0.9ºC) was confined in the upper 50m in Oct 2022.

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 = -1.5. in Oct 2022.

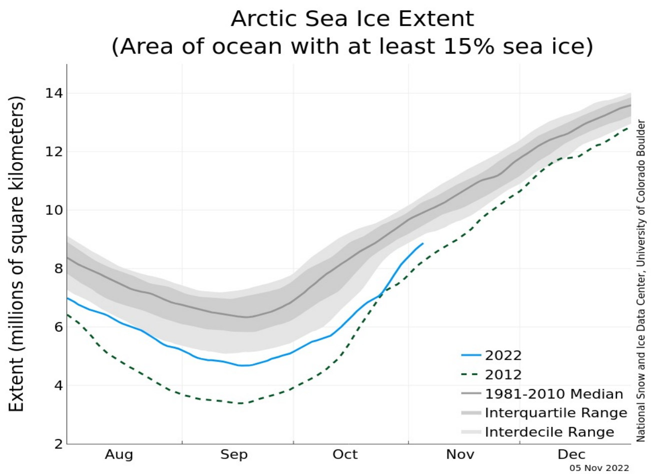
- Negative H300-based PDO index has persisted 72 months since Nov 2016, with HPDO = - 1.4 in Oct 2022.

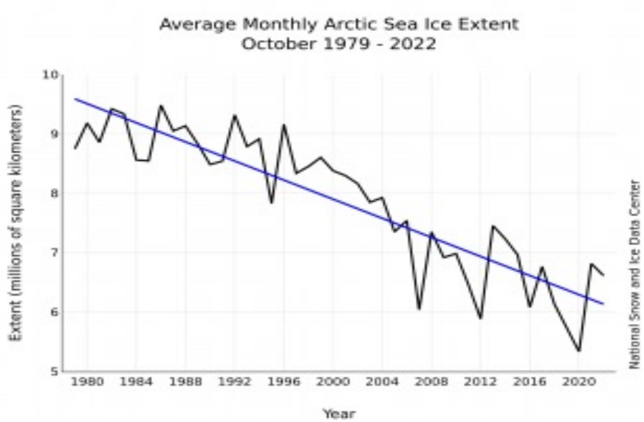
- SST-based PDO index has considerable variability both on seasonal and decadal time scales.

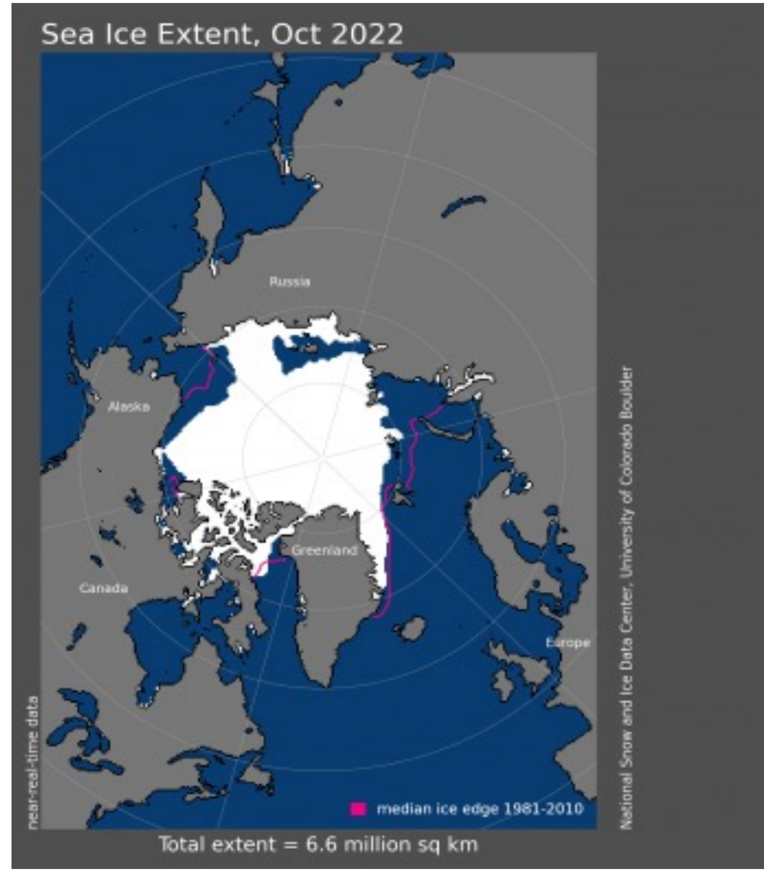
- H300-based PDO index highlights the slower variability and encapsulates an integrated view of temperature variability in the upper ocean.

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.

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

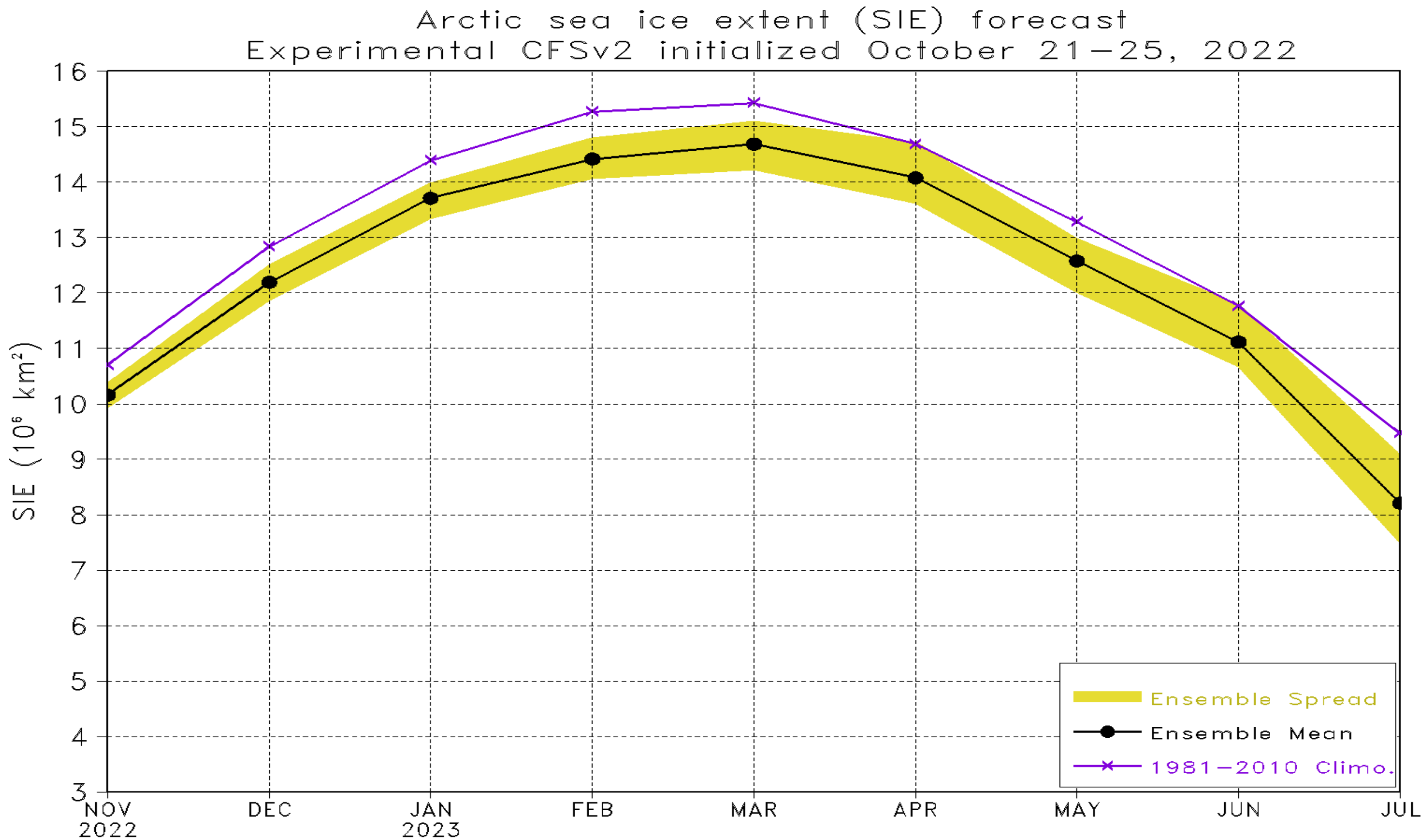






- Average Arctic sea ice extent for October 2022 was 6.61million square kilometers, ranking the eighth lowest in the satellite record.

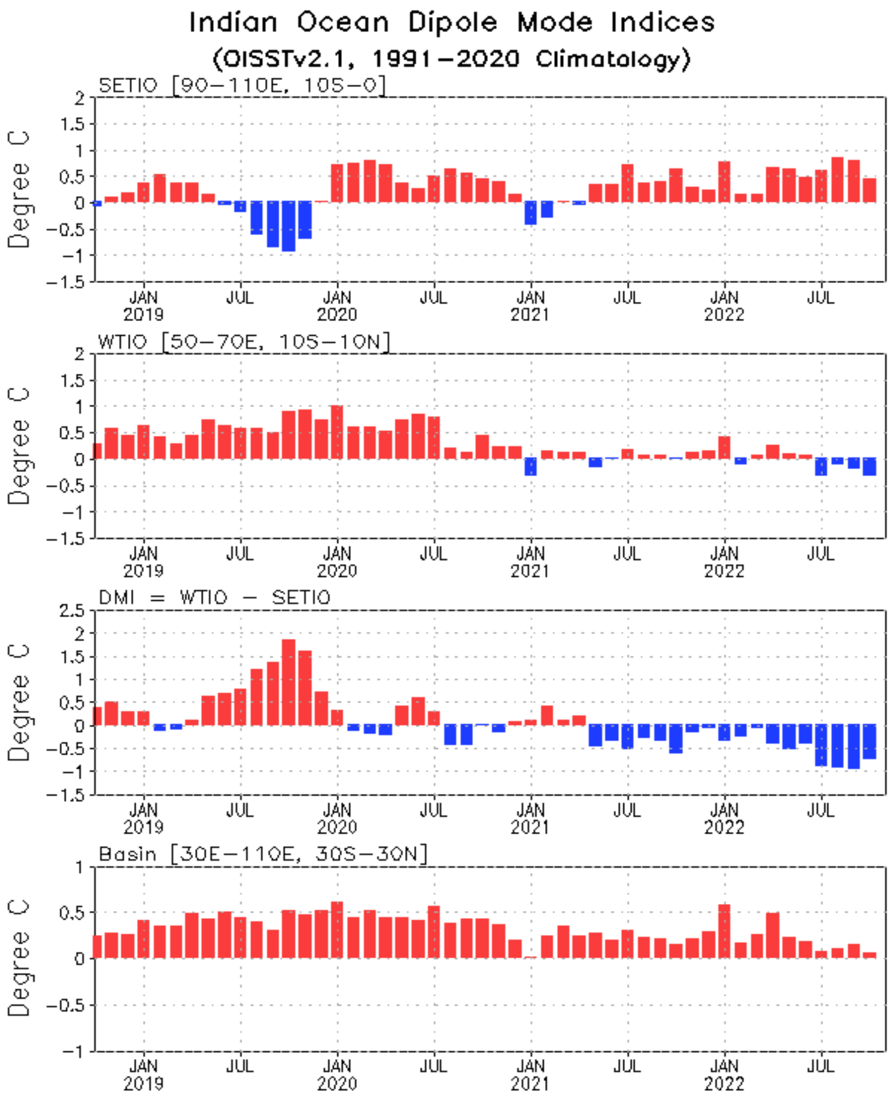
NCEP/CPC Arctic Sea Ice Extent Forecast

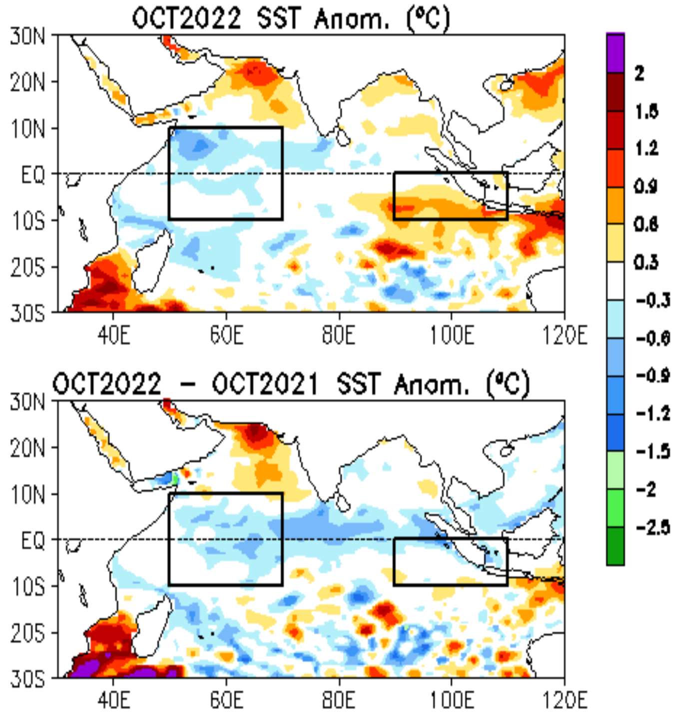


https://www.cpc.ncep.noaa.gov/products/people/wwang/seaice_seasonal/index.html

Indian Ocean

Evolution of Indian Ocean SST Indices

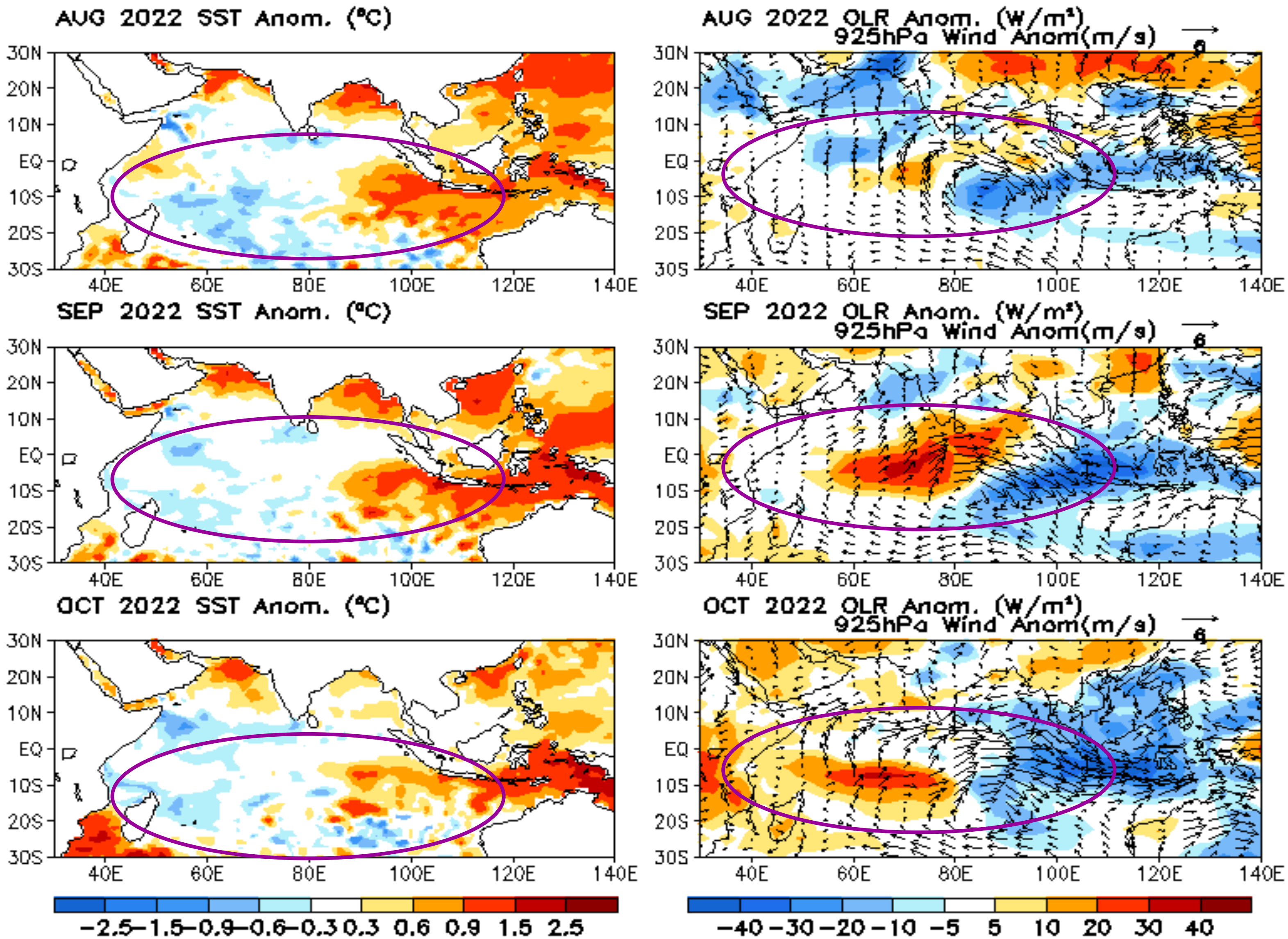




- Negative Indian Ocean Dipole event weakened in Oct 2022, with DMI= -0.8 °C.

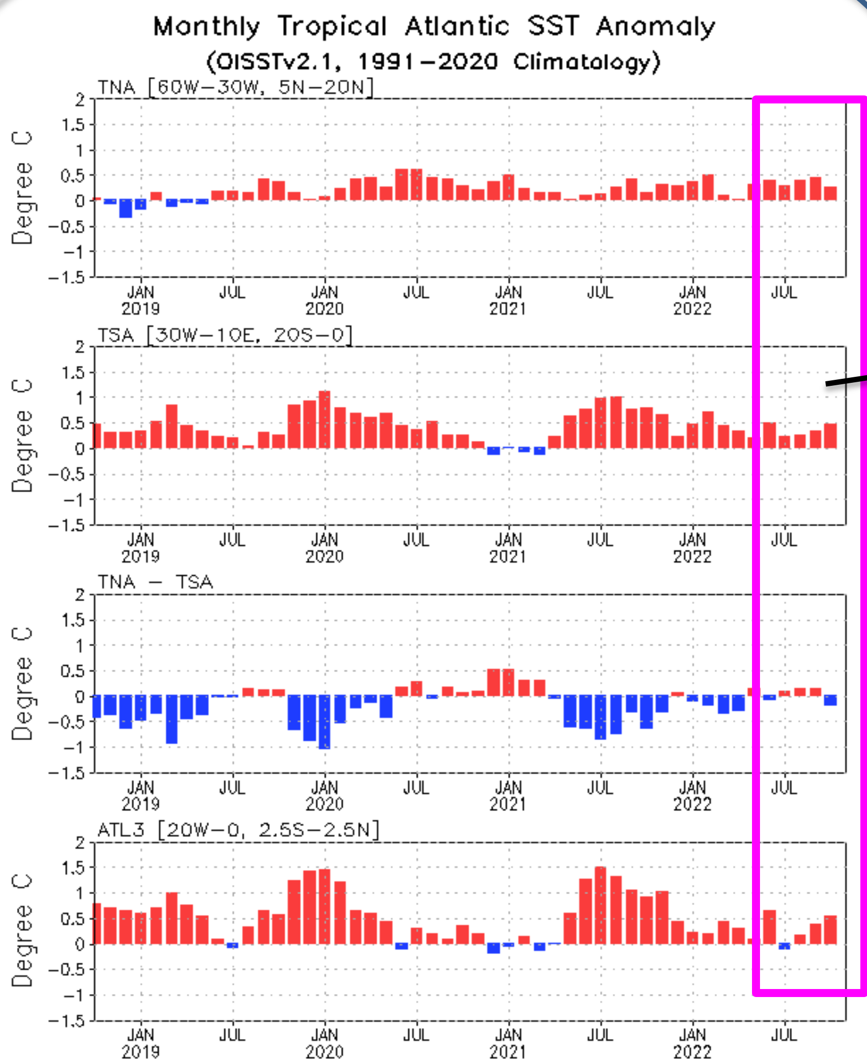
Indian Ocean region indices, calculated as the area-averaged monthly mean SSTA (OC) for the SETIO [90ºE-110ºE, 10ºS-0] and WTIO [50ºE-70ºE, 10ºS-10ºN] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the OIv2.1 SST analysis, and anomalies are departures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

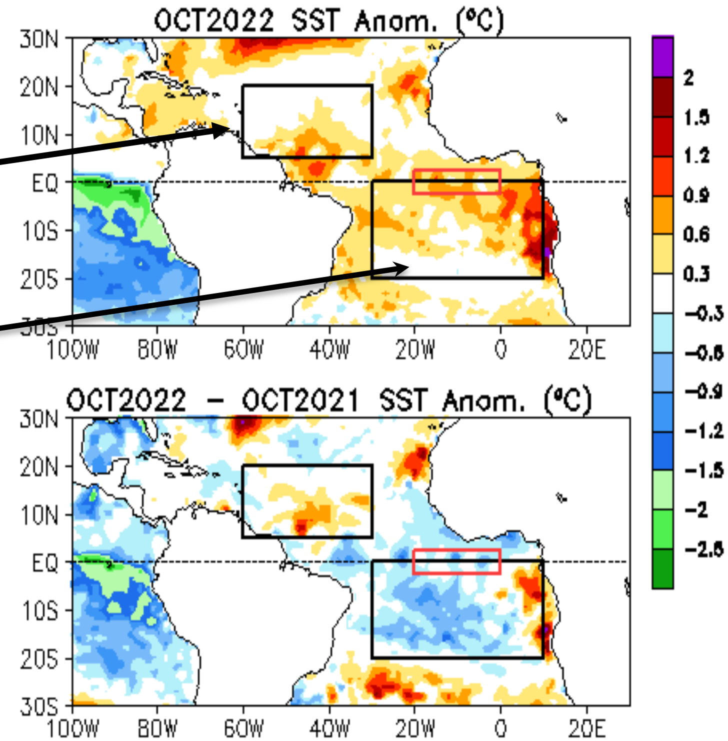
Last 3-month Tropical Indian SST , OLR & uv925 anomalies



Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

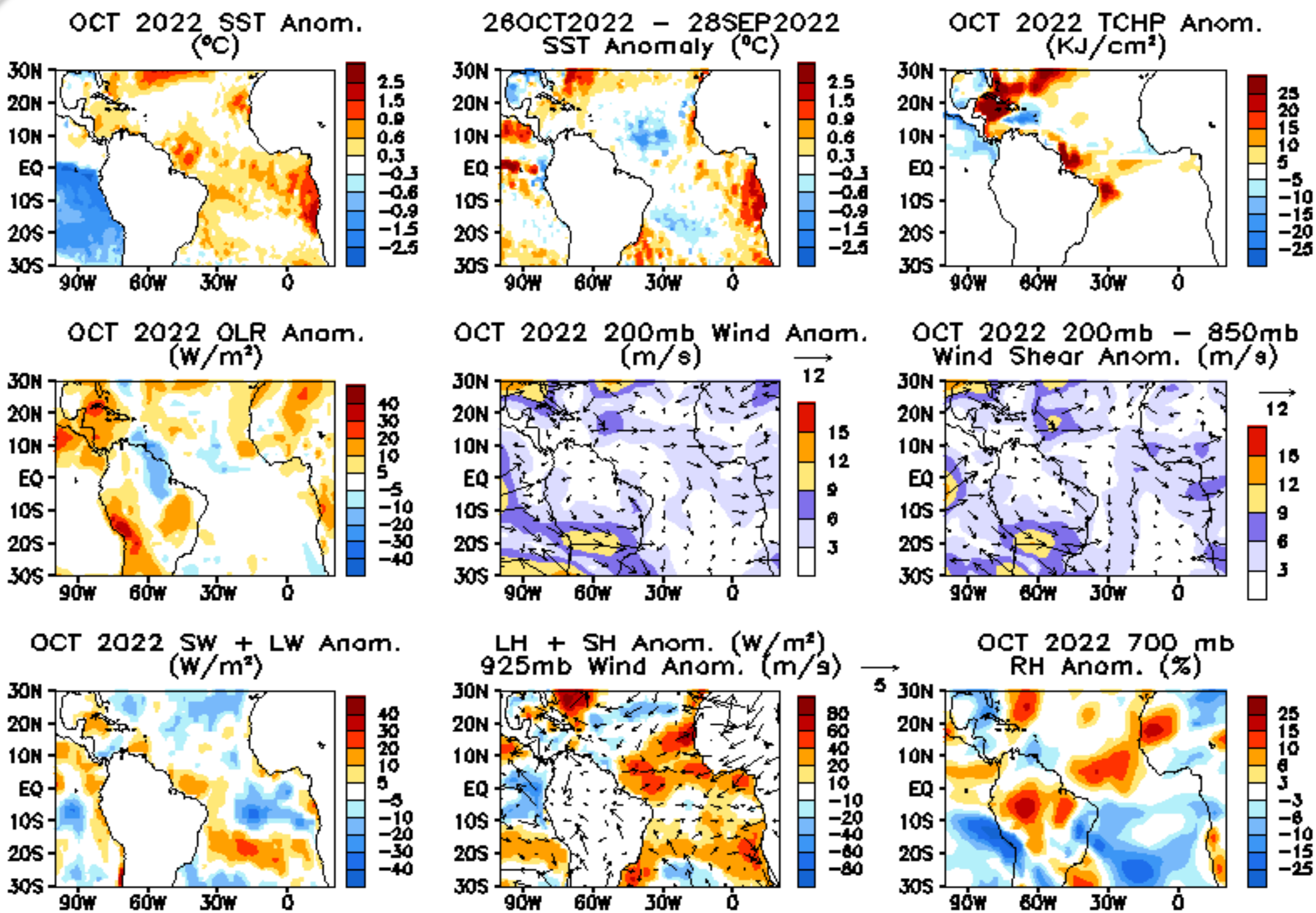




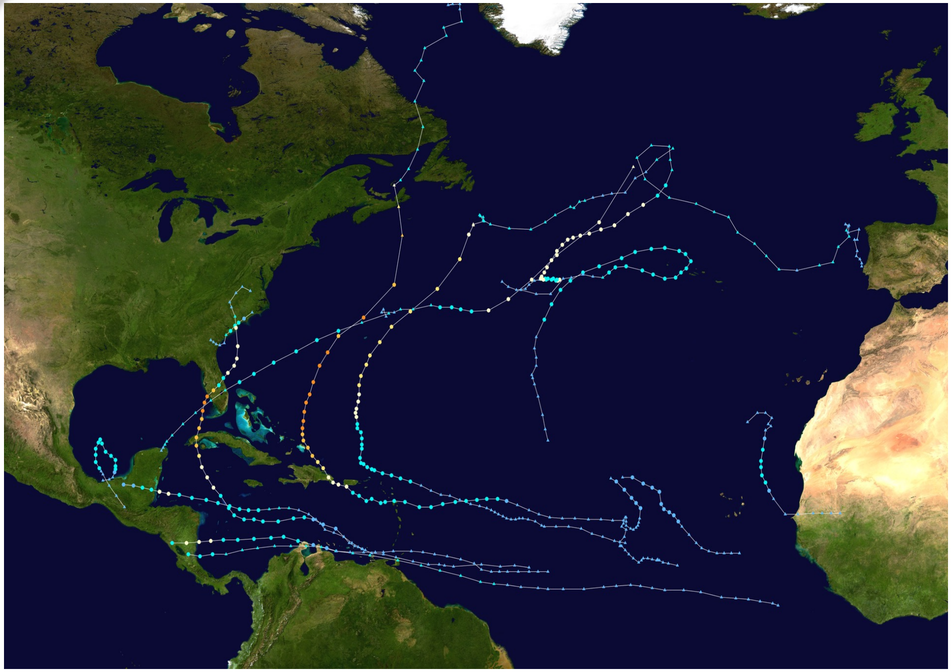
- Positive ATL3 index increased in Oct 2022, with ATL3=0.54°C.

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 OISSTv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

Tropical Atlantic Ocean: SSTA, SSTA Trend, TCHP,OLR,UV200,UV200-UV850, Heat Flux and RH Anomalies



2022 Atlantic Hurricane Season Activities



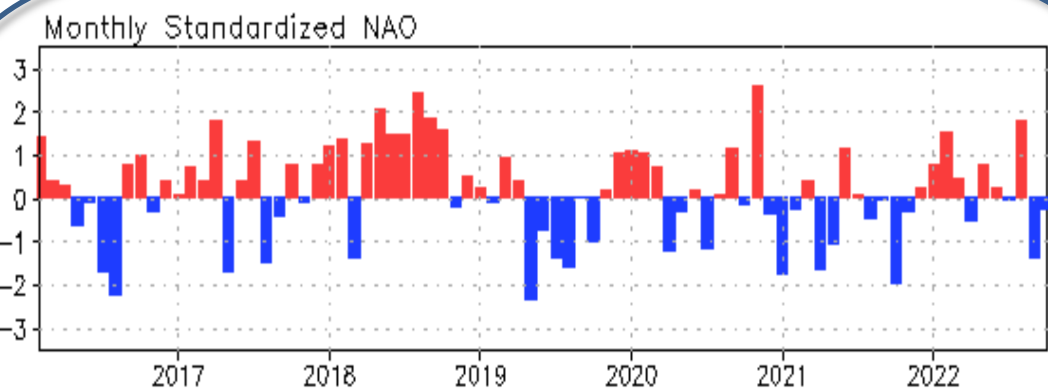
https://en.wikipedia.org/wiki/2022_Atlantic_hurricane_season

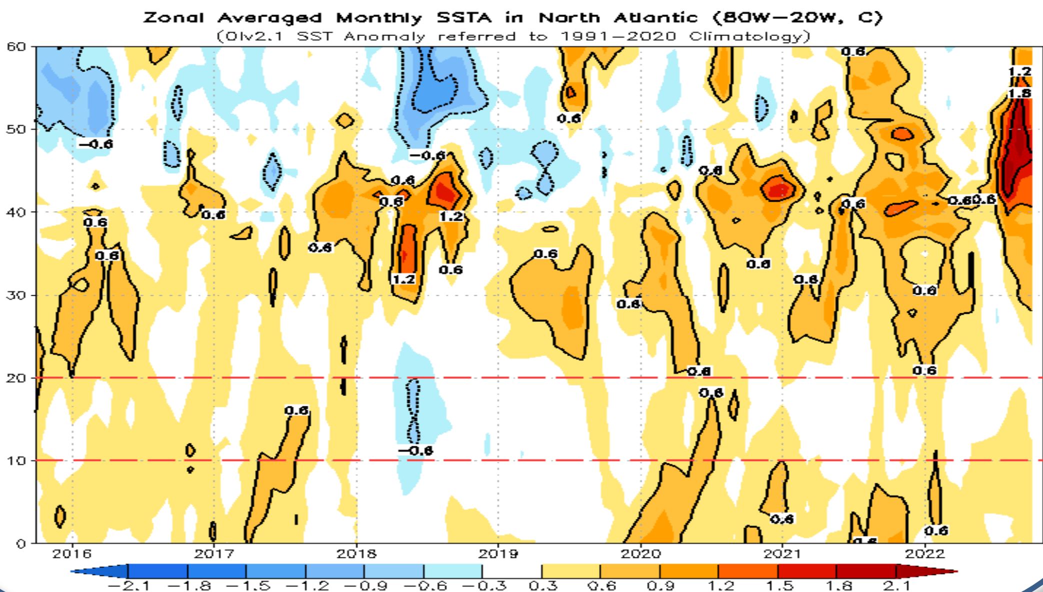
- Three tropical storms formed in Oct, with two strengthening into hurricanes.

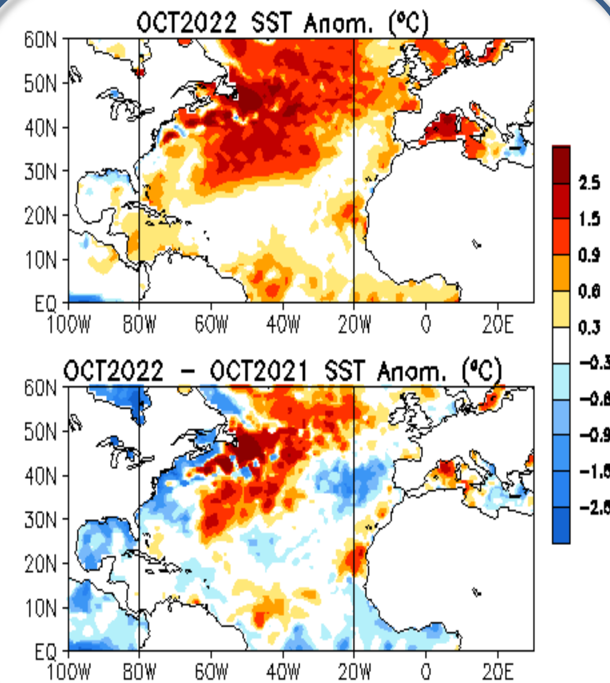
- By Nov 8 2022, fourteen tropical storms formed, with seven developing to hurricanes, and two developing to major hurricanes.

Atlantic	Observations (By Nov 8)	Updated Outlook (Aug) 60% above-normal	Outlook (May) 65% above-normal	(1991-2020)
Total storms	14	14-20	14-21	14
Hurricanes	7	6-10	6-10	7
Major hurricanes	2	3-5	3-6	3

NAO and SST Anomaly in North Atlantic







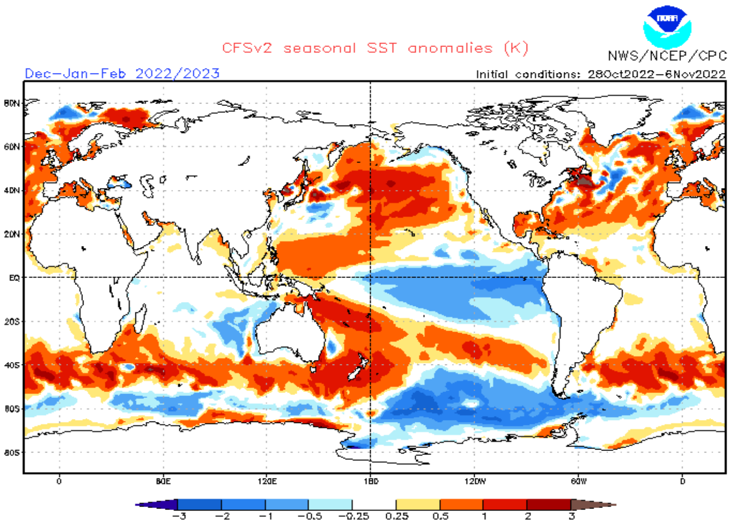
- Negative NAO decreased substantially in Oct 2022, with NAO=-0.3.
- The positive SSTAs in the mid-high latitudes of the North Atlantic Ocean were evident since 2021.

Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20ºN-90ºN. 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.

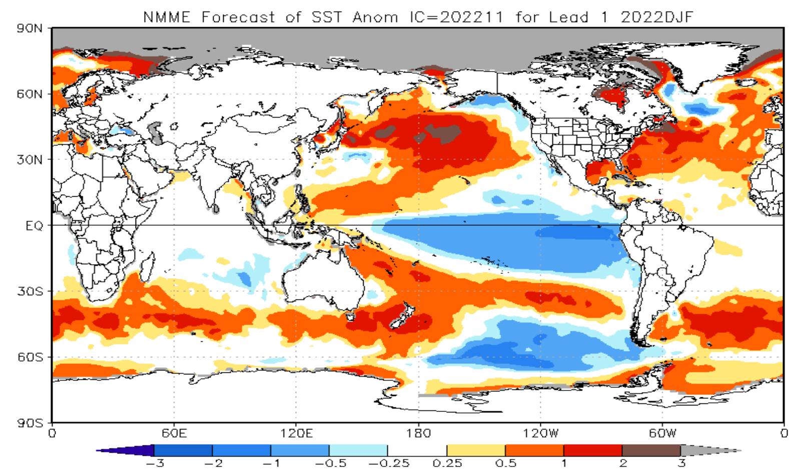
ENSO and Global SST Predictions

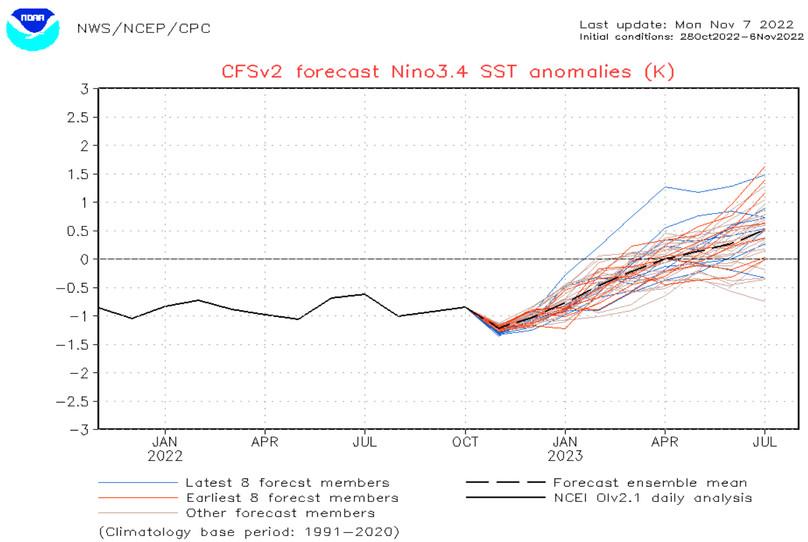
CFSv2 and NMME SST predictions

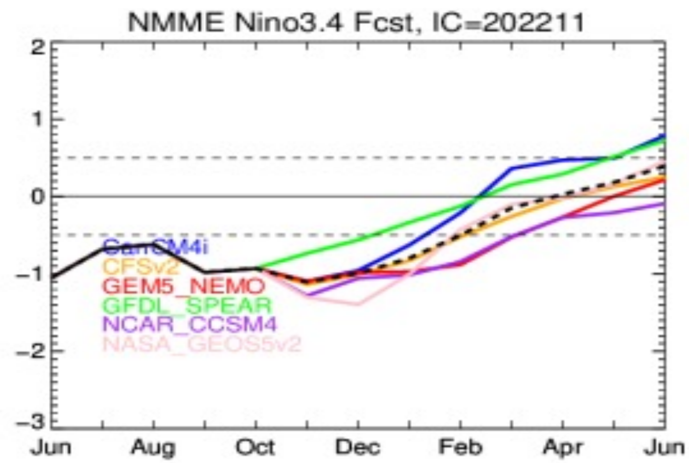
CFSv2 IC:Nov for 2022 DJF



NMME IC:Nov for 2022 DJF



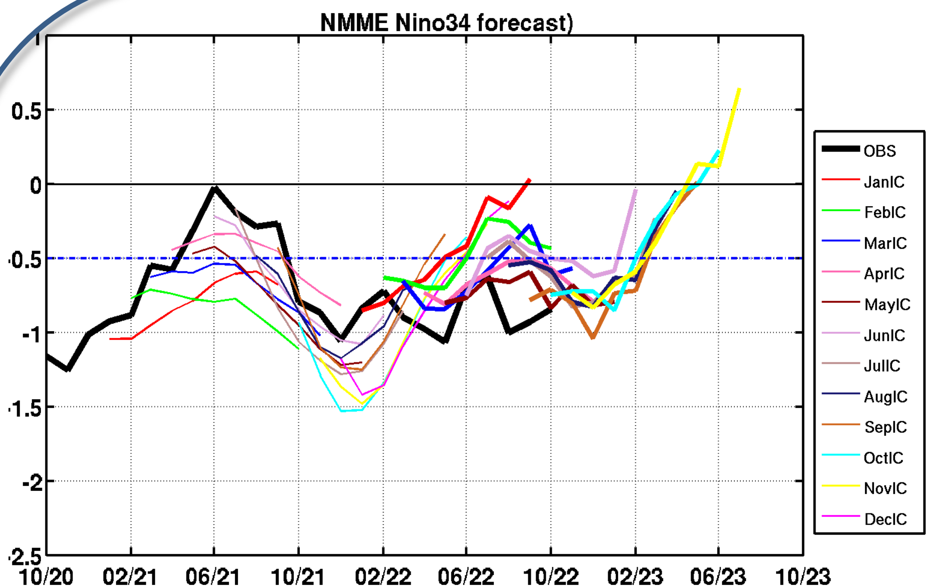


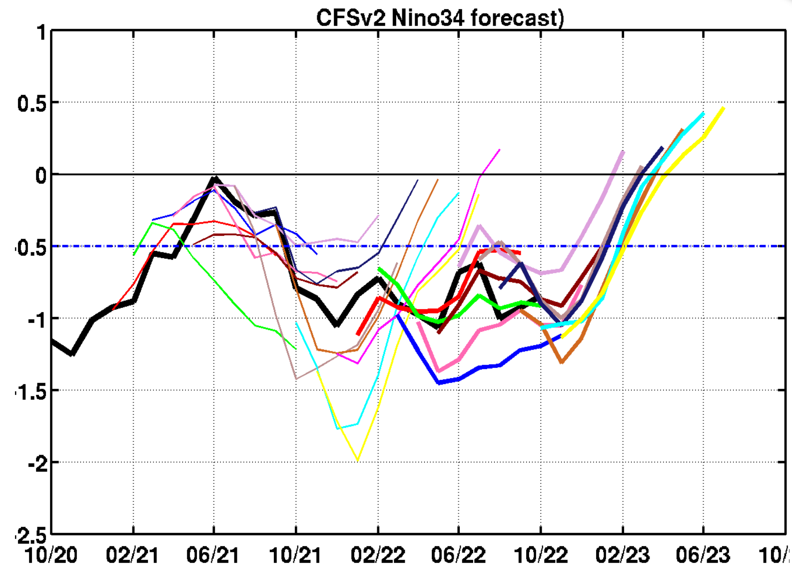


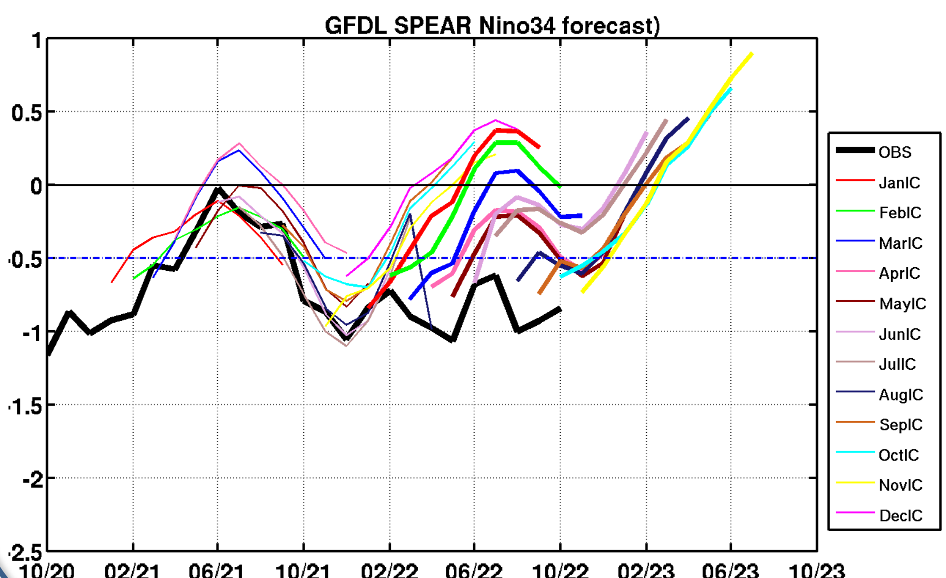
https://www.cpc.ncep.noaa.gov/products/CFSv2/CFSv2seasonal.shtml

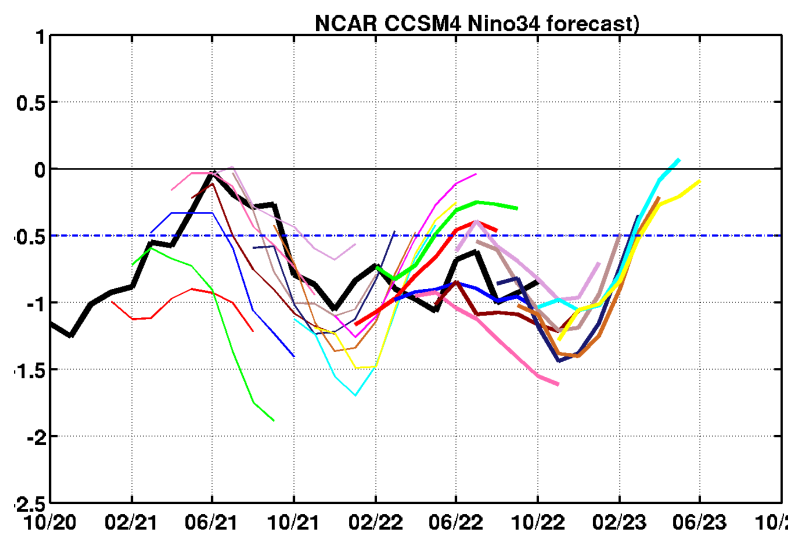
https://www.cpc.ncep.noaa.gov/products/NMME/

NMME Nino34 predictions

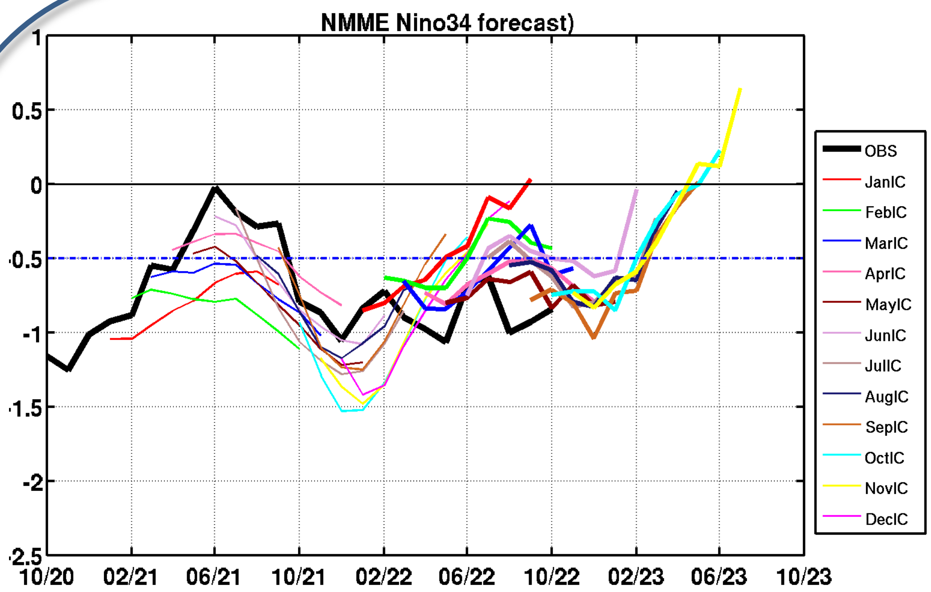


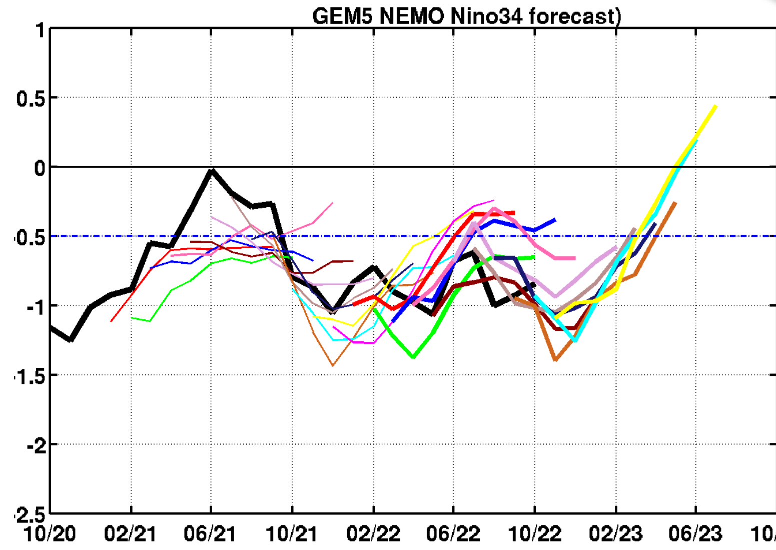


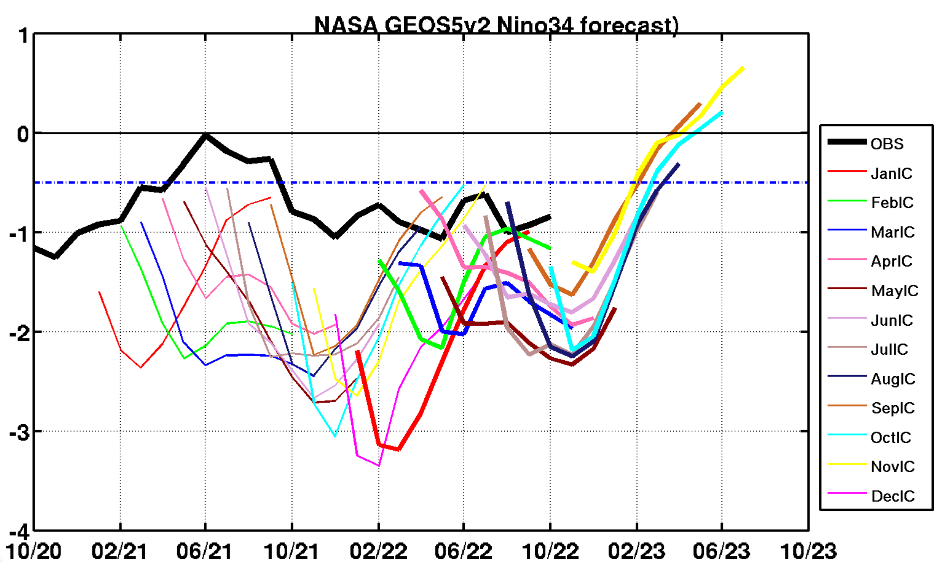


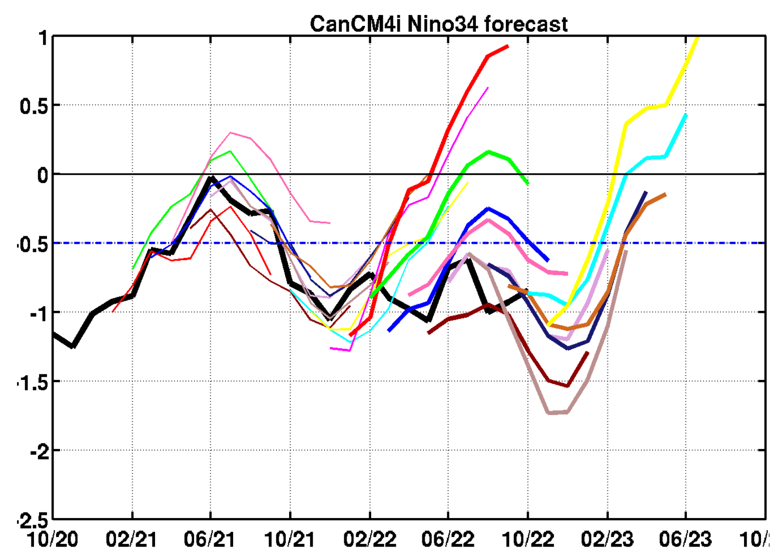


NMME Nino34 predictions

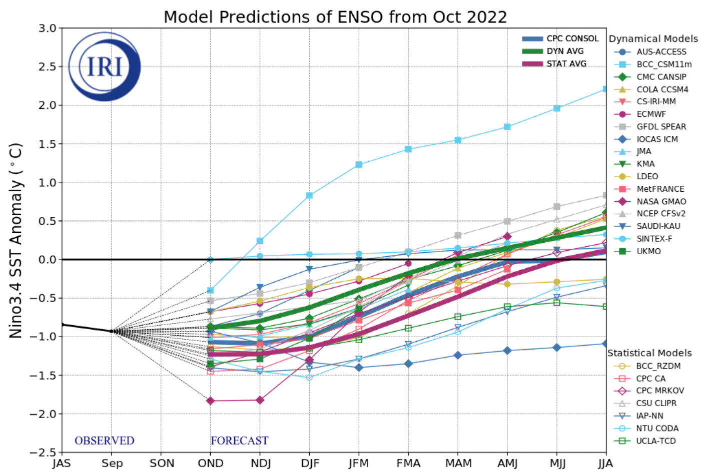


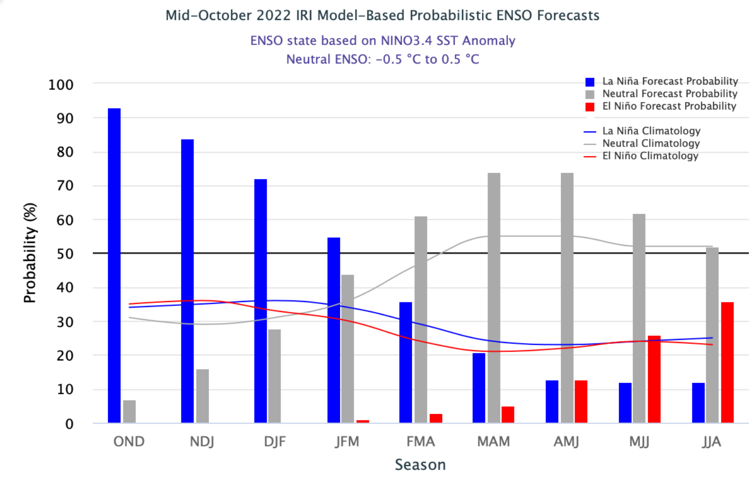






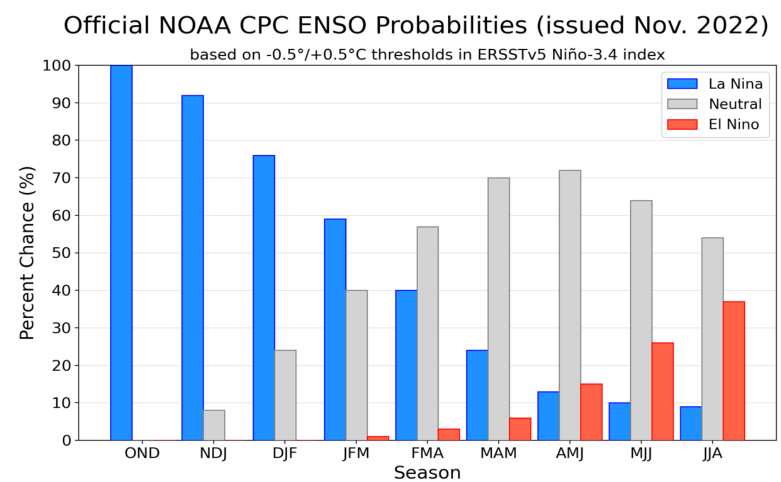
IRI/CPC Niño3.4 Forecast : July 2022



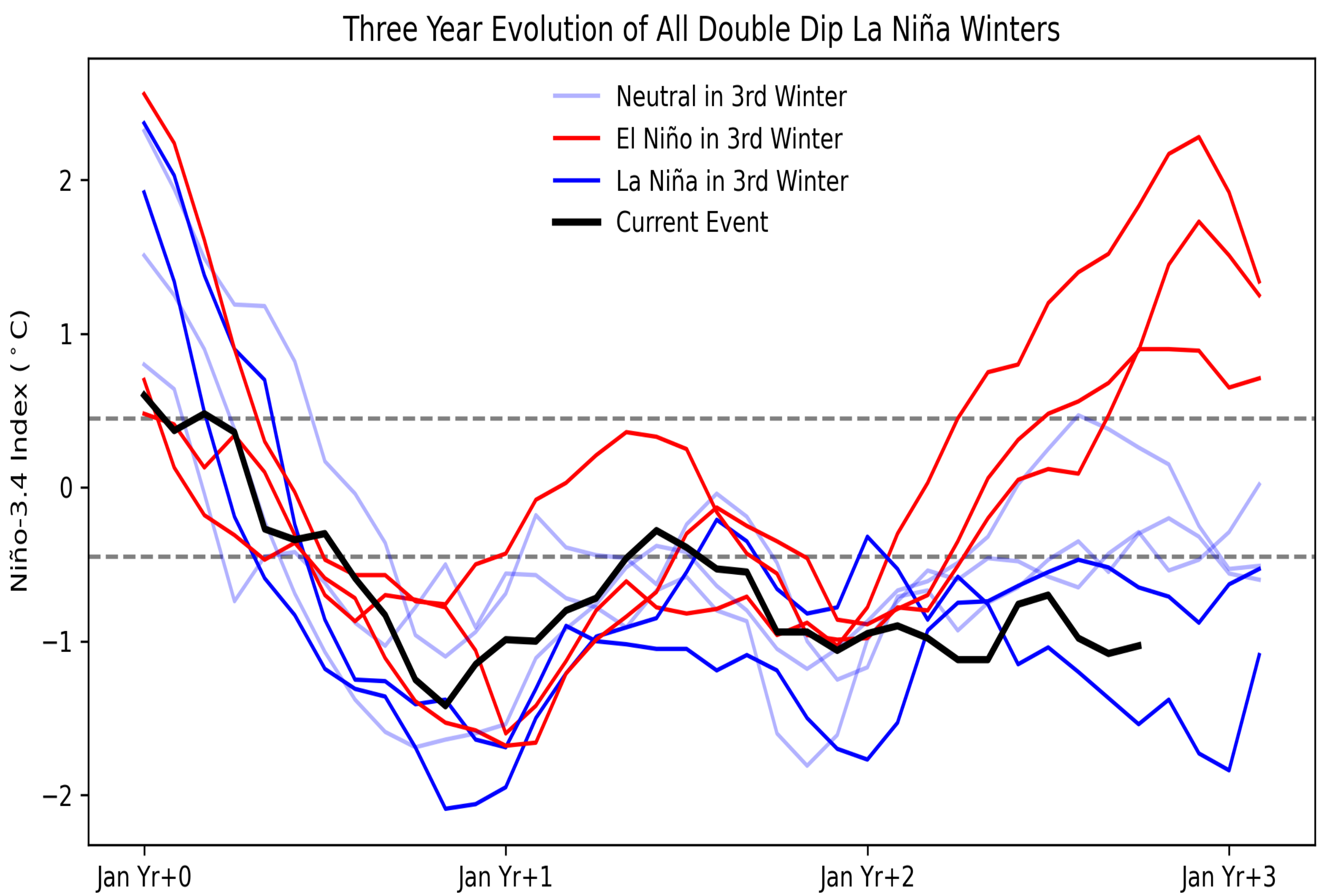


- A majority of models predict SSTs to remain below-normal at the level of a La Niña until Jan-Mar 2023 with a 55% chance.

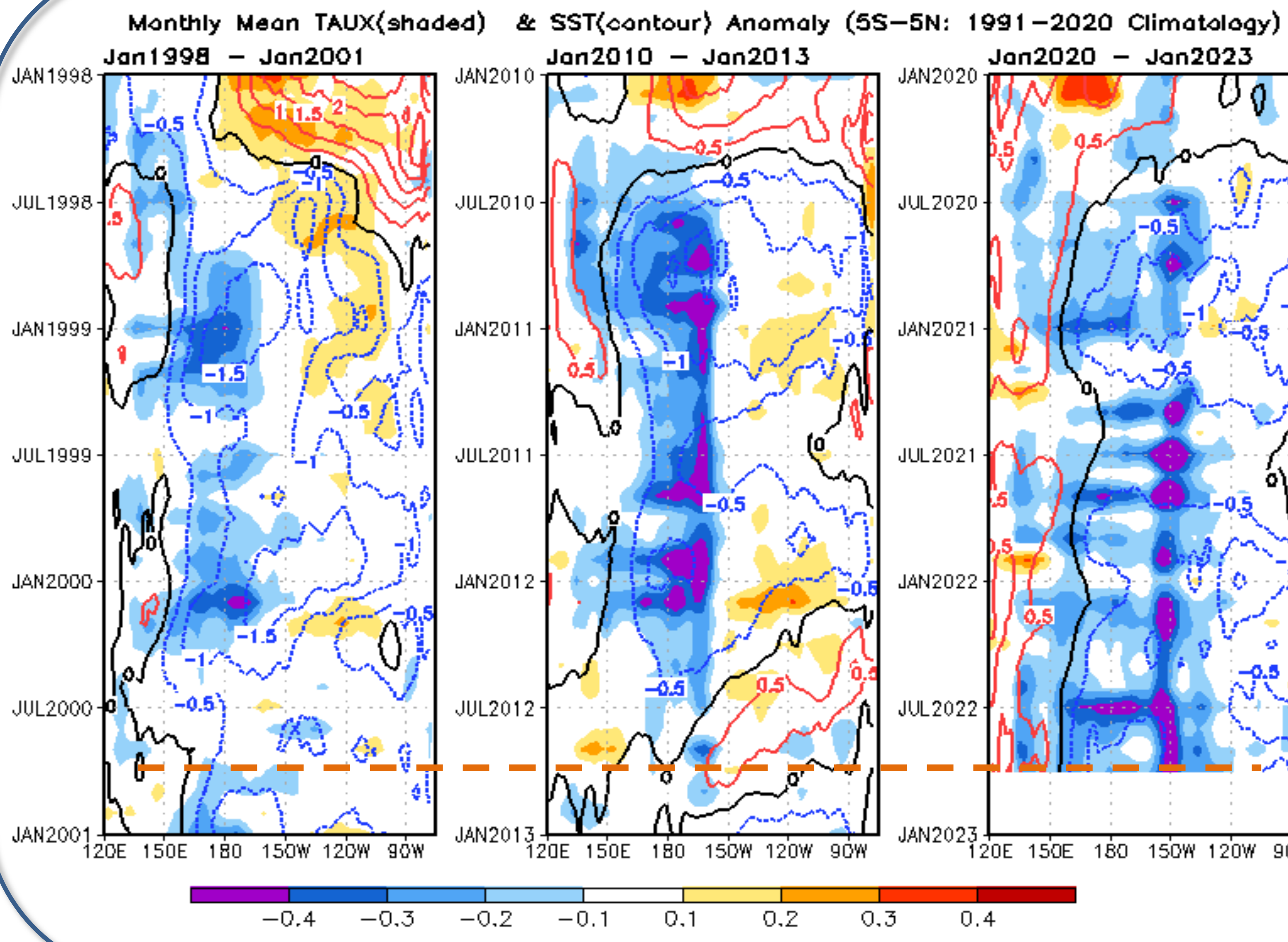
- NOAA "ENSO Diagnostics Discussion" on 10 November stated that "There is a 76% chance of La Niña during the Northern Hemisphere winter (December--February) 2022-23, with a transition to ENSO-neutral favored in February-April 2023 (57% chance)".



Nino3.4 Index Evolution in two-year La Ninas since 1950 (MICHELLE L'HEUREUX)

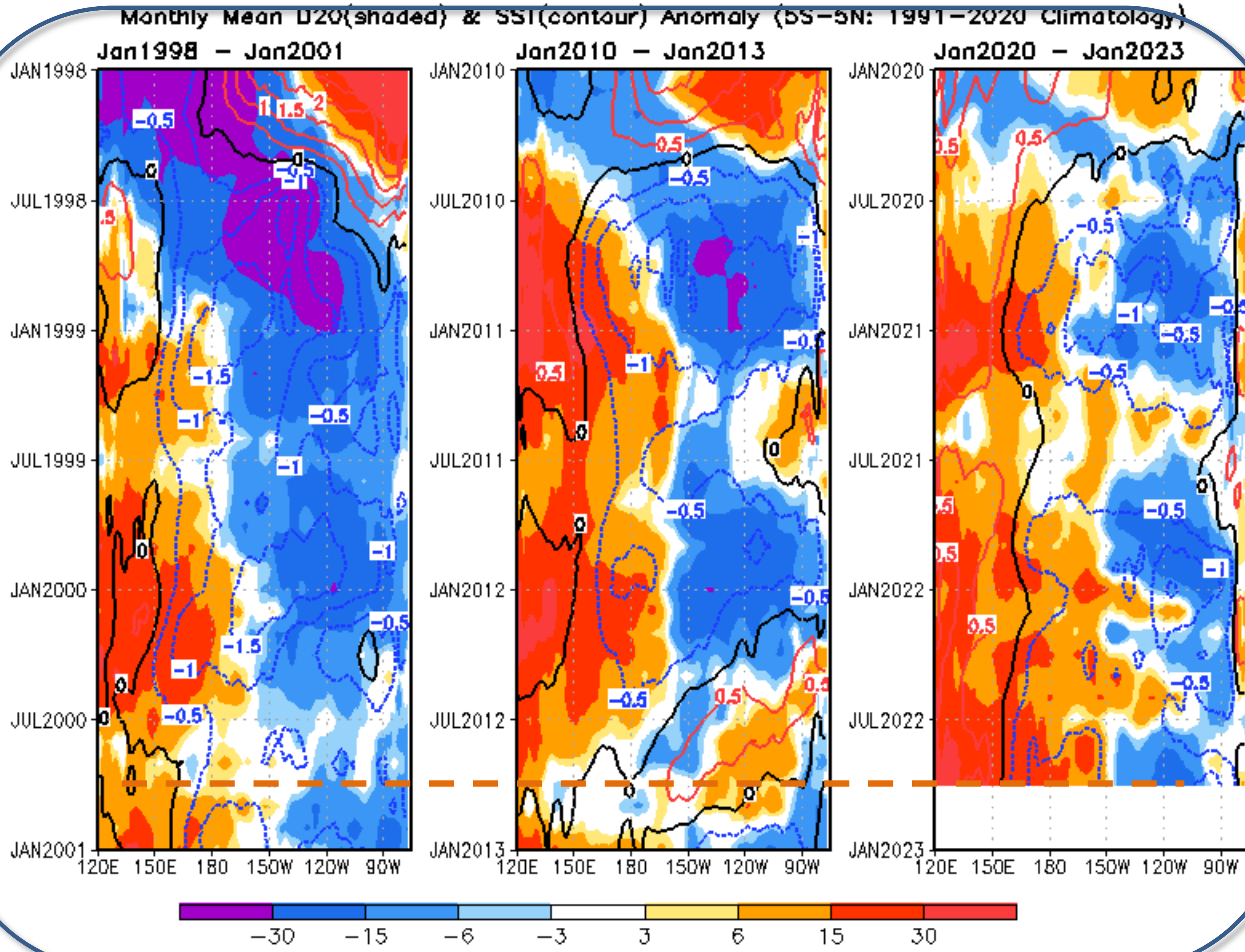


Evolution of Monthly Mean TAUX & SST Anomaly across [5S-5N]



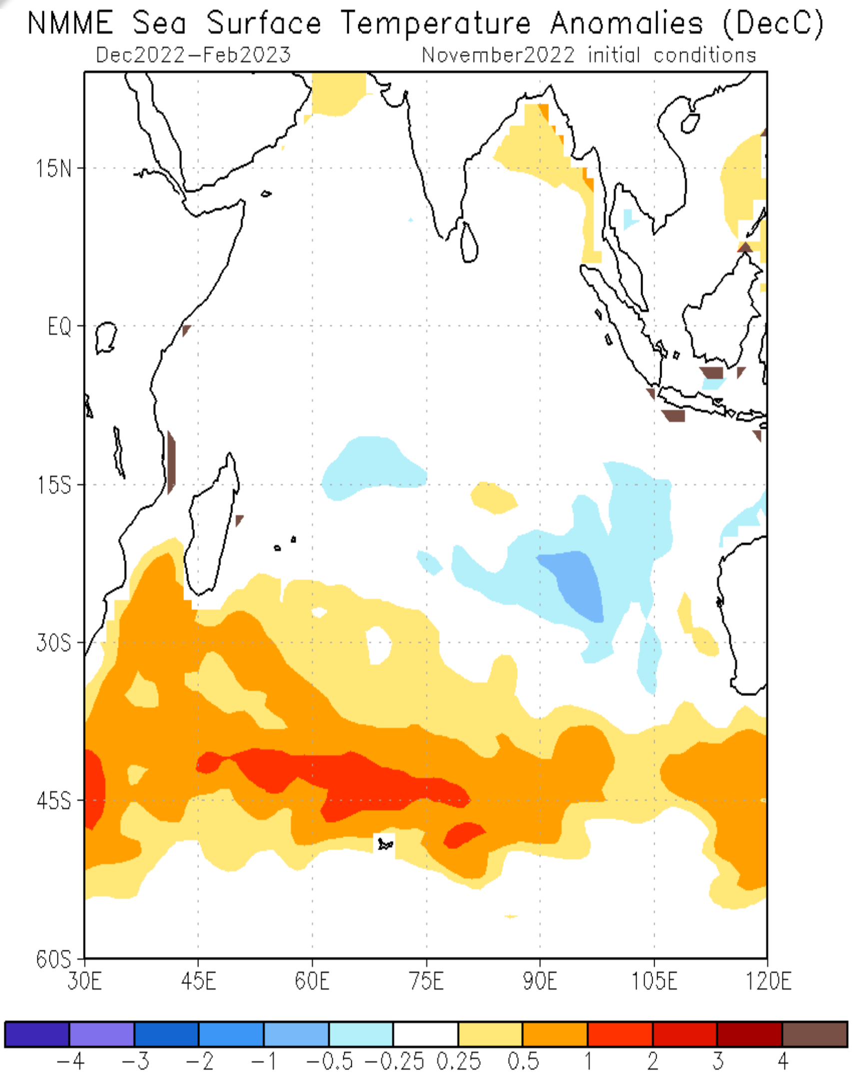
Data source: NCEP R2 reanalysis

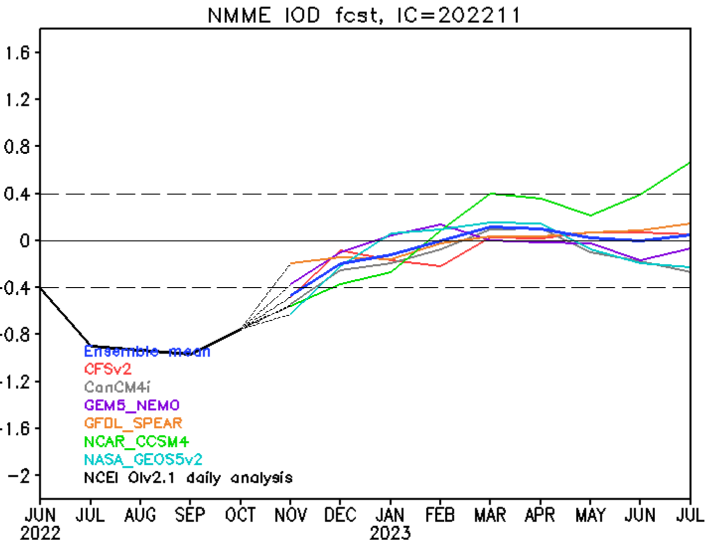
Evolution of Monthly Mean TAUX & SST Anomaly across [5S-5N]



Data source: NCEP R2 reanalysis

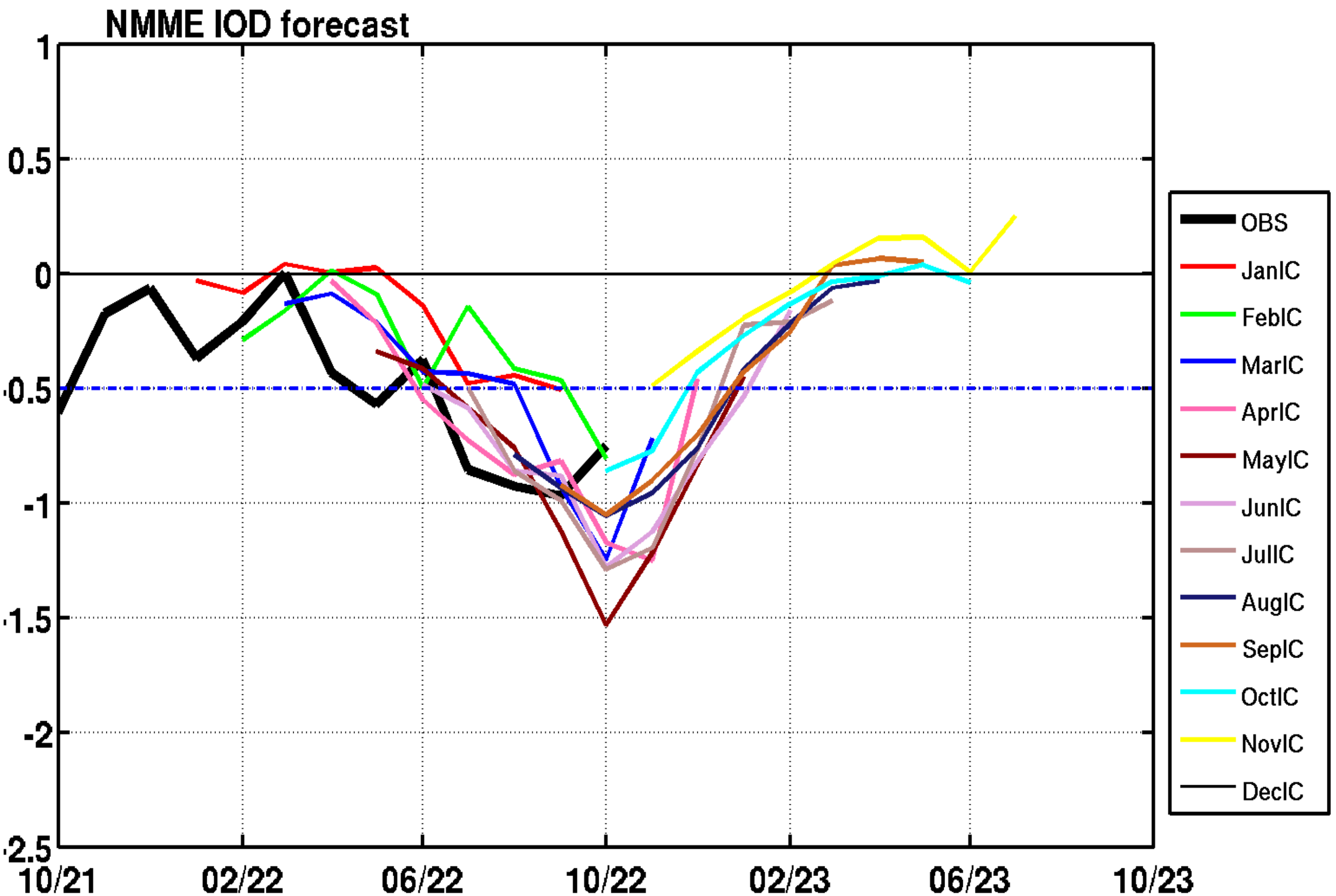
NMME Forecasts in the Indian Ocean



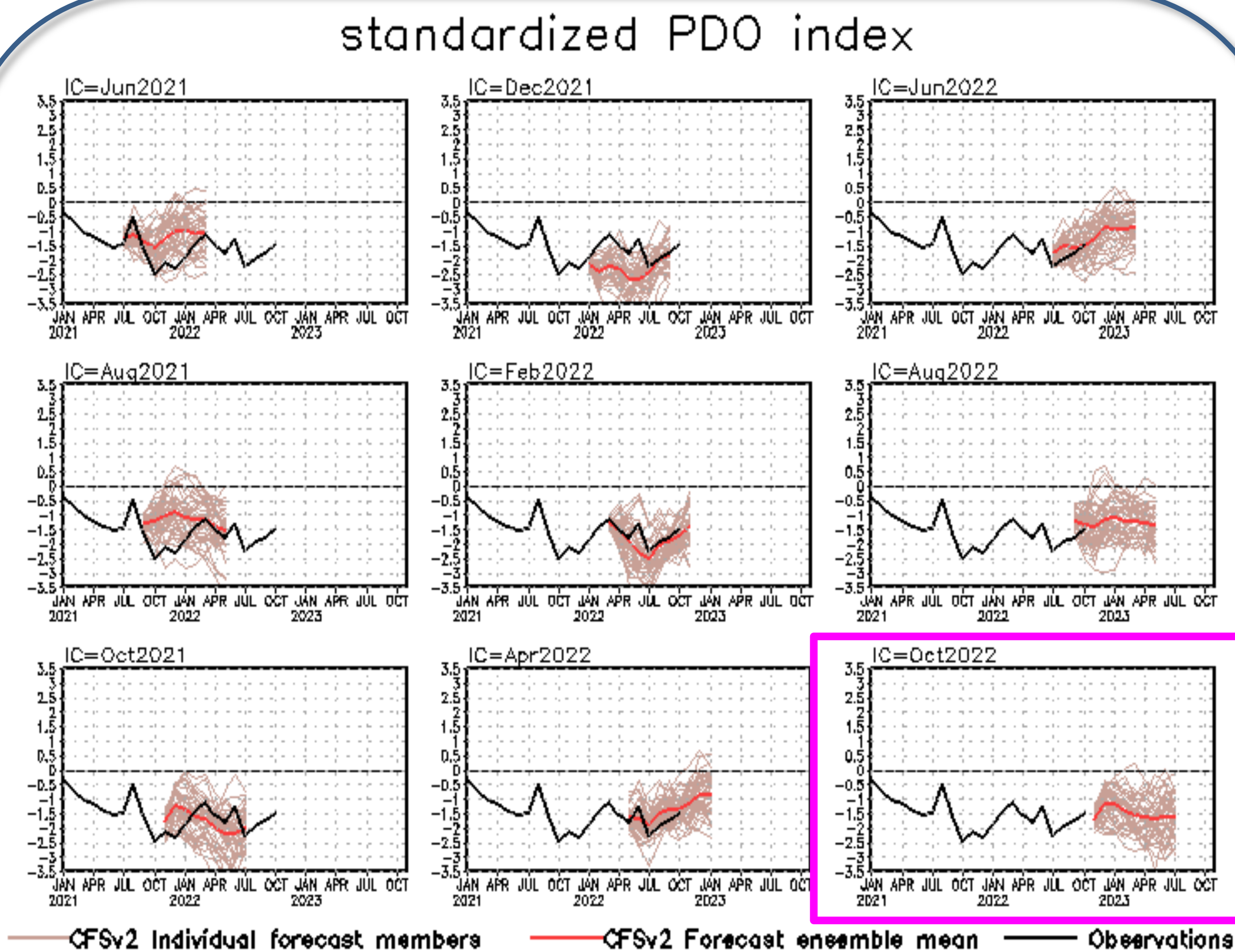


- All NMME models predict the negative IOD condition will transit to neutral in Dec 2022.

NMME IOD predictions



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



- Latest CFSv2 predicts the negative phase of PDO will continue through northern hemisphere Spring 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.

Data Sources (climatology is for 1991-2020)

- NCEP Weekly Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002, historical Monthly Ocean Briefing achieves ,Ocean briefing and GODAS web pages prior July 2022)
- Staring July 2022, NCEI Daily OISSTv2.1(Huang et al. 2021) replaced NCEP Weekly OISST data in the Monthly Ocean Briefing PPT , Ocean Briefing and GODAS web pages)
- 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)
- NCDP/DOE Reanalysis II (R2) winds and heat fluxes (Kanamitsu et al. 2002)
- 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

Acknowledgement

❖ Drs. Arun Kumar, Zeng-Zhen Hu and Jieshun Zhu : reviewed PPT, and provide insightful suggestions and comments

❖ Dr. Pingping Xie provided the BASS/CMORPH/CFSR EVAP package

❖ Dr. Wanqiu Wang provides the sea ice forecasts and maintains the CFSv2 forecast archive

Please send your comments and suggestions to:

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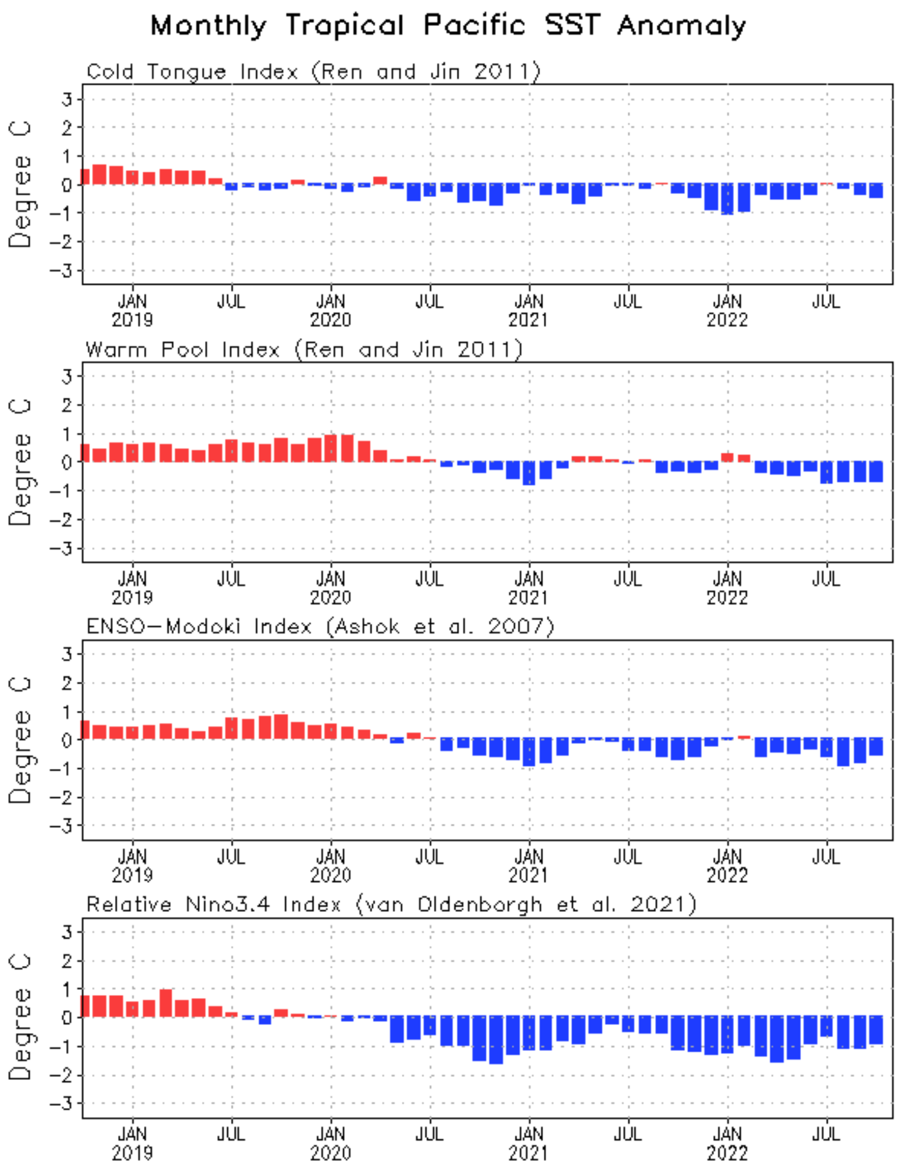
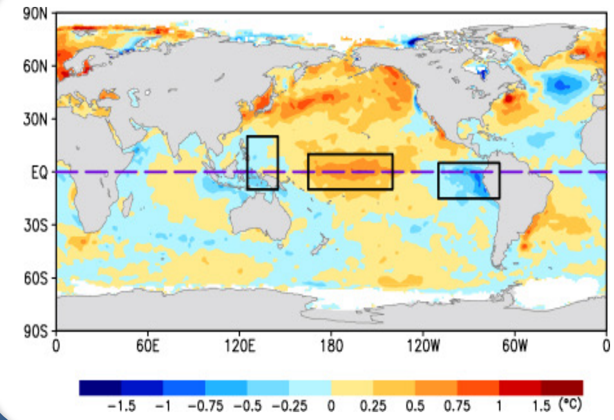
Caihong.Wen@noaa.gov
Zeng-Zhen.Hu@noaa.gov

Backup Slides

Evolution of Pacific Niño SST Indices



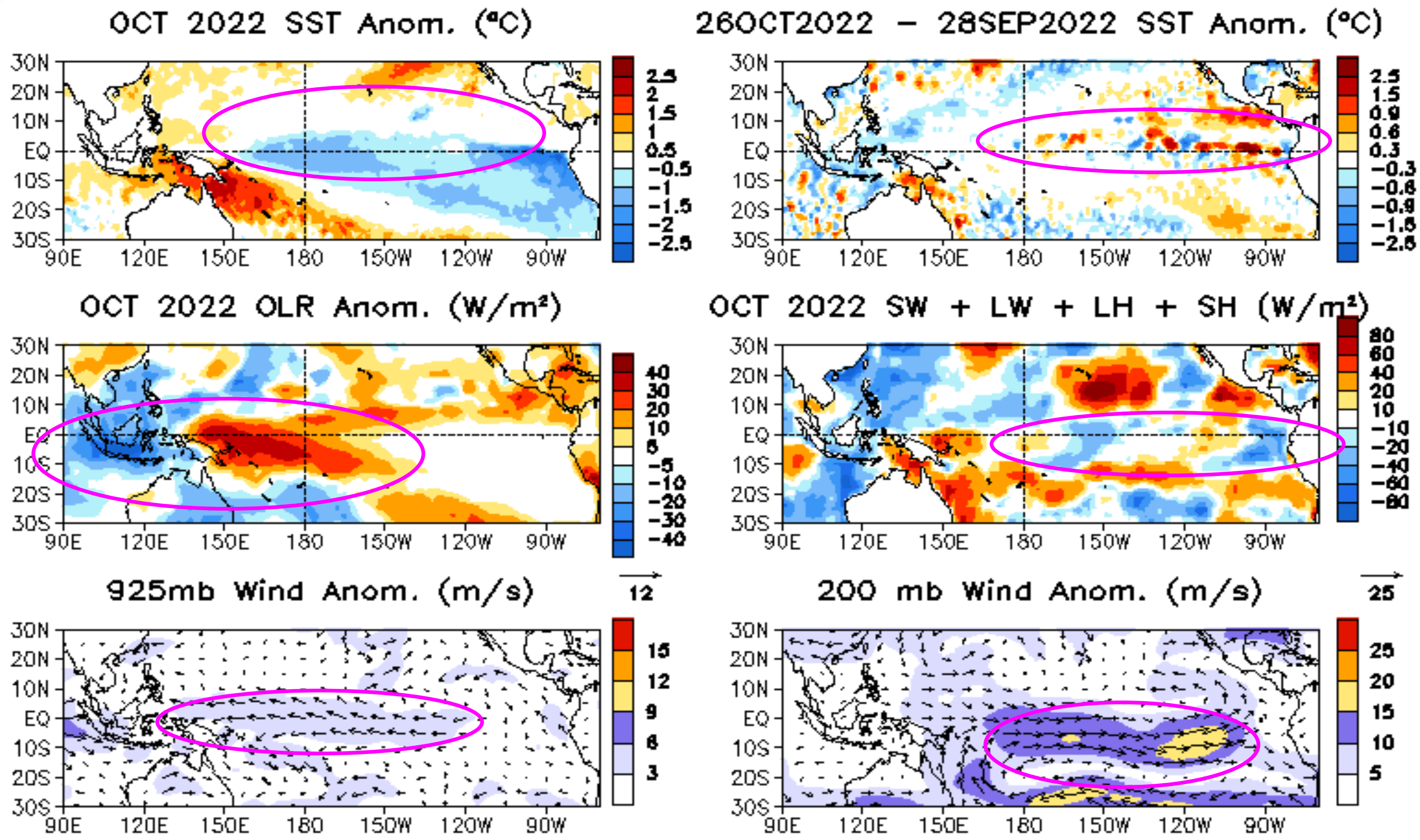


- Relative Niño3.4 index is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0º-360º, 20ºS-20ºN), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative Niño3.4 index is renormalized (van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

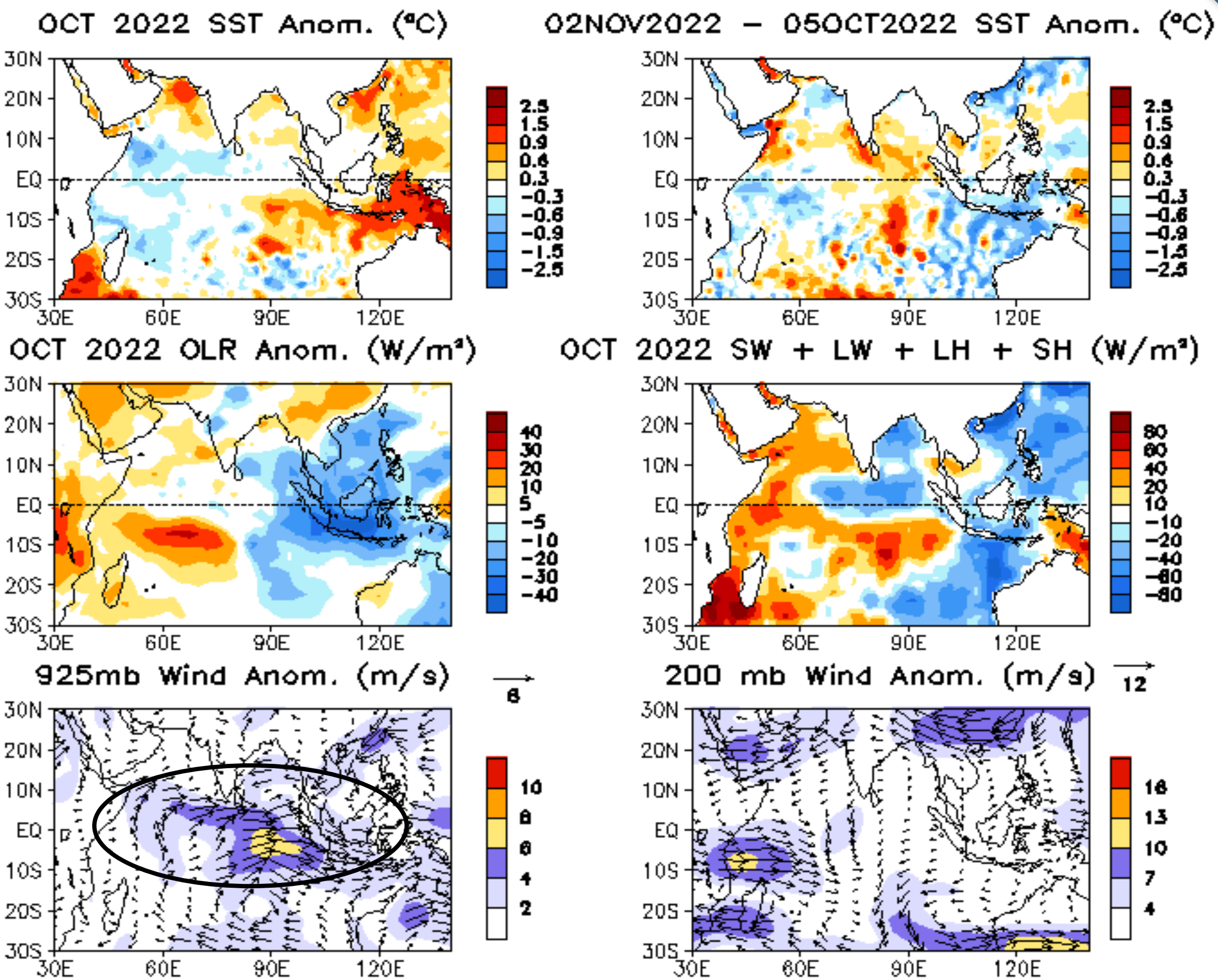
Relative Niño3.4 data updated monthly at:

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

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 OISSTv2.1 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.

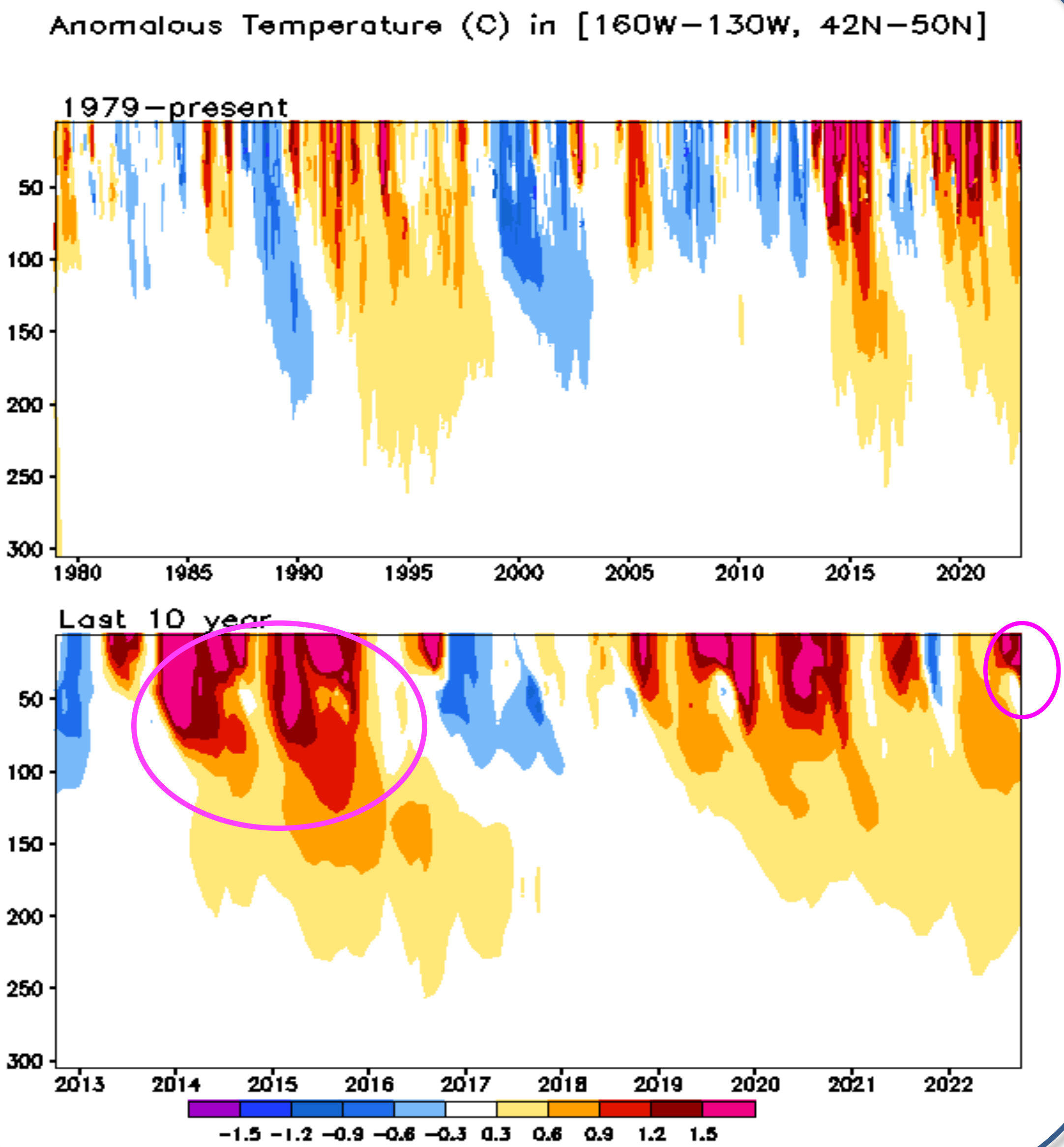


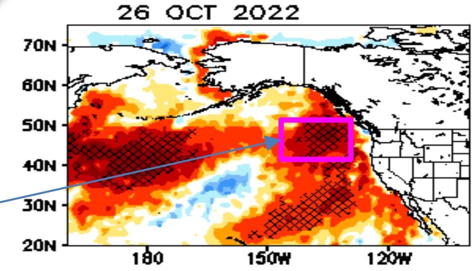
-Westerly wind anomaly prevailed over the eastern Indian Ocean, favoring further warming in the southeastern Indian Ocean.

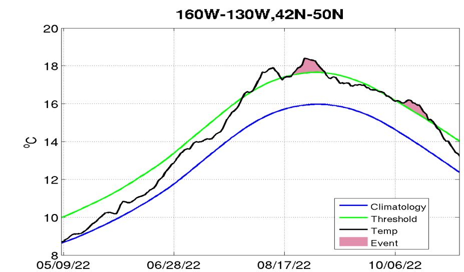
- SSTA tendencies were generally consistent with the net heat flux anomalies.

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 OISSTv2.1 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.

Subsurface Temperature Anomaly in the Northeast Pacific (Pacific Blob)







- Positive subsurface temperature anomaly (>0.9ºC) was confined in the upper 50m in Oct 2022.
- Subsurface warming was strongest during 2014-2016 (Pacific Blob).

Global Sea Surface Salinity (SSS): Anomaly for October 2022

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

Deficit precipitation, combined with enhanced evaporation over the central / western Pacific and the western Indian ocean contribute greatly to the extensive saltier SSS anomalies over the regions. At the same time, fresher SSS anomalies are observed over the oceanic areas around the Maritime continent and the northwestern Pacific, largely influenced by the wetter precipitation there. Negative SSS anomalies also appear over the equatorial Atlantic and the Caribbean areas where active hurricane activities are noticeable during the month.

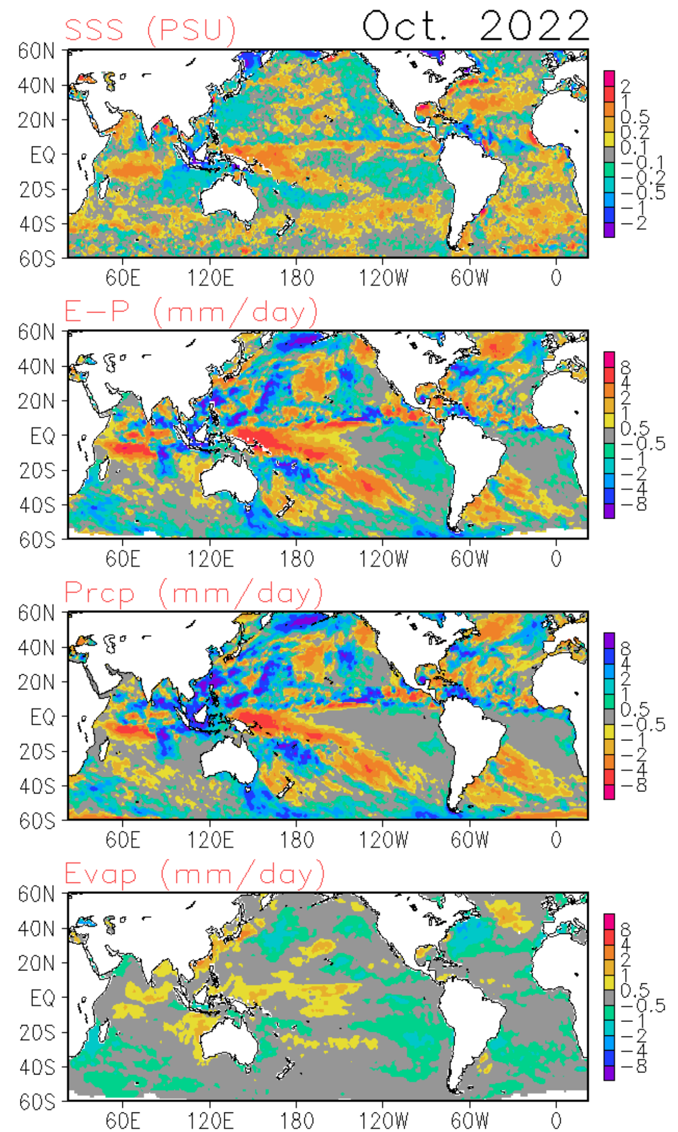
SSS : Blended Analysis of Surface Salinity (BASS) V0.Z

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

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

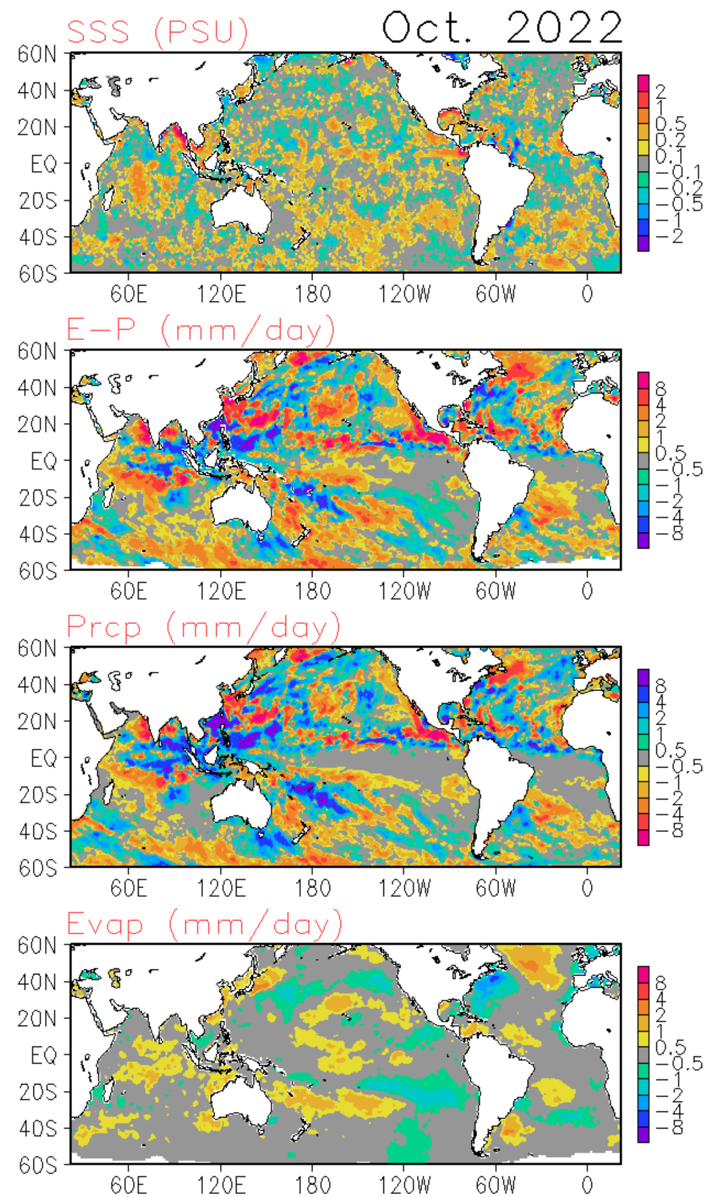
Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: Adjusted CFS Reanalysis



Global Sea Surface Salinity (SSS): Tendency for October 2022

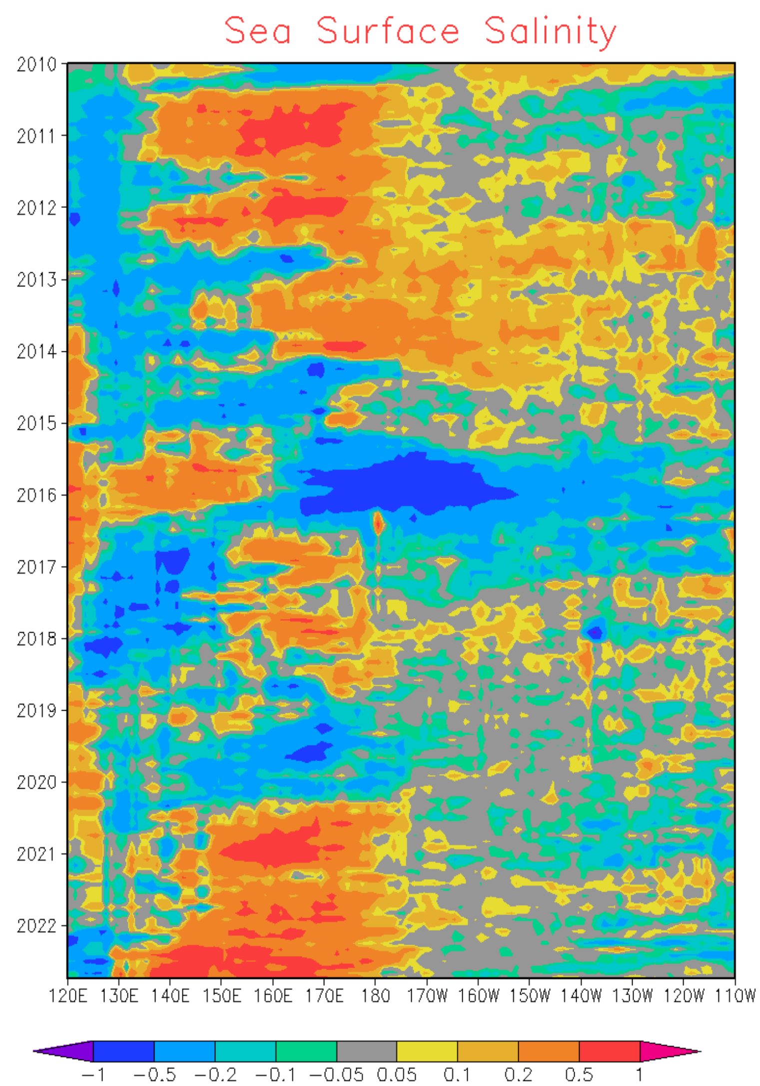
Tendency of the fresh water flux, especially that of the precipitation, appears quite organized in association with the intensity variations and merional shift of the ITCZ across all the three oceans. The tendency for the SSS, however, is more complicated. Over the equatorial eastern Pacific, a saltier SSS tendency is observed over regions of dry fresh water flux, while over the Bay of Bengal and the Gulf of Mexico, saltier SSS tendency presents over regions of enhanced fresh water flux, suggesting influences of other geophysical processes (e.g. river run offs, oceanic circulations, mixed layer processes).



Monthly SSS Anomaly Evolution over Equatorial Pacific

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

- Hovemoller diagram for equatorial SSS anomaly **(5˚S-5˚N);**
- Positive SSS anomaly continues and enhanced over the central / western equatorial Pacific between 140°E and 170°W. Negative SSS anomalies is weakening over the eastern Pacific and even disappeared over the far east end of the equatorial Pacific.



Pentad SSS Anomaly Evolution over Equatorial Pacific

Figure caption:
Hovemoller 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.