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

Prepared by

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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 Nov 2022.
- Strong negative PDO persisted in Nov 2022, with PDOI = -2.2.
- Marine Heat Waves (MHWs) persisted in the west-central North Pacific and near the west coast of USA.

•Arctic Ocean

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

•Indian Ocean

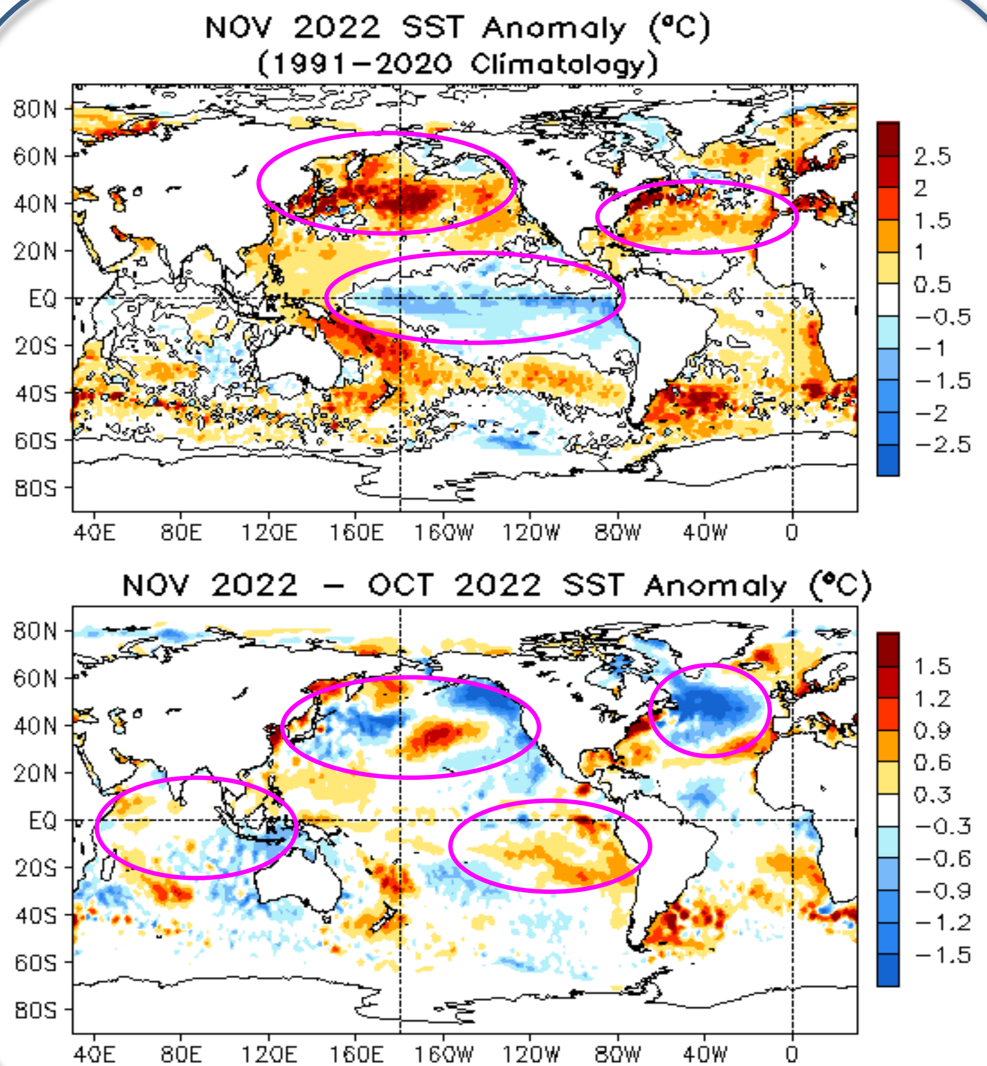
- The negative Indian dipole event returned to neutral in Nov 2022.

•Atlantic Ocean

- The 2022 hurricane season was a near-average season in terms of storm number.
- SST warming continued in the North Atlantic Ocean.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency

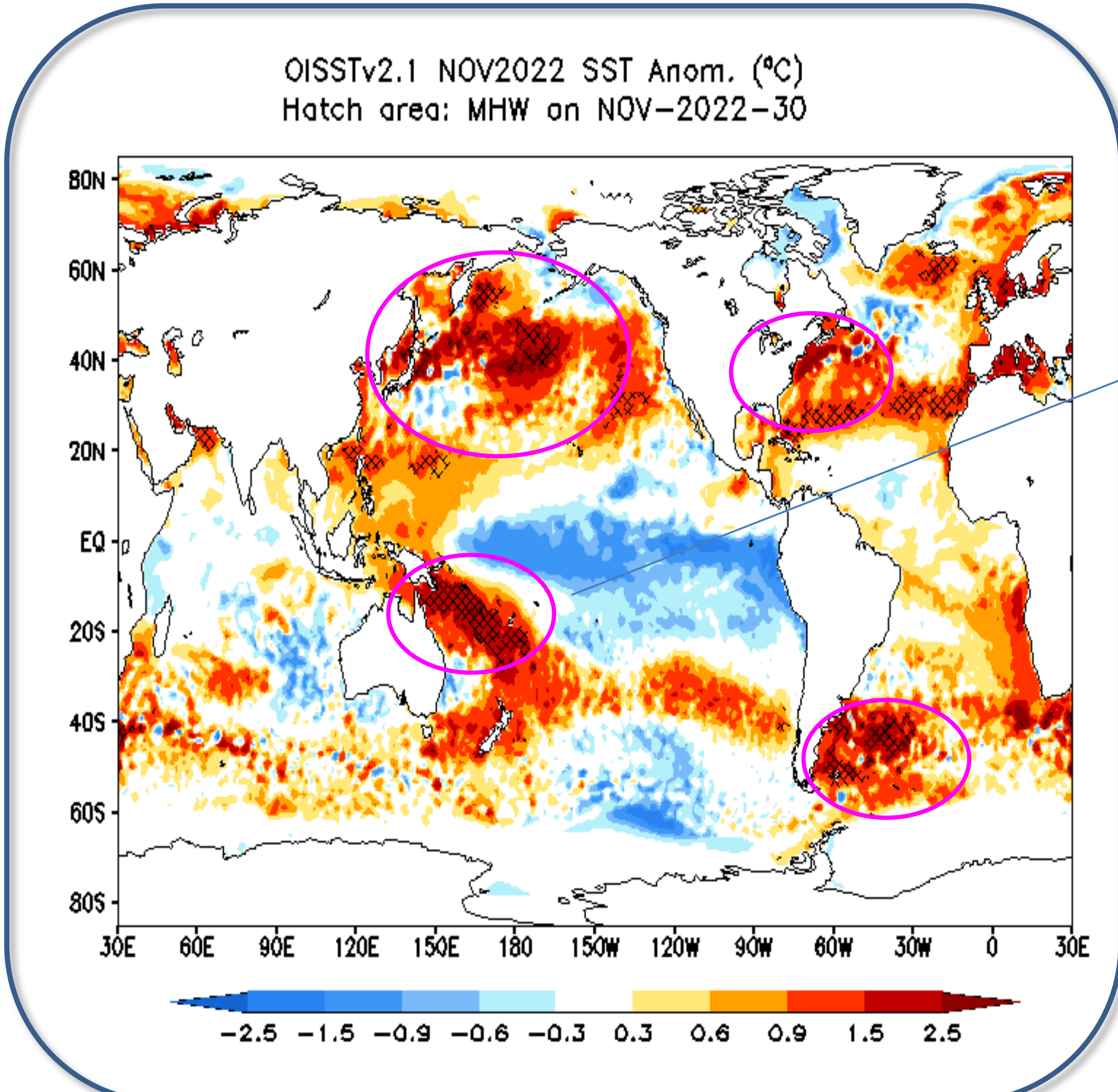


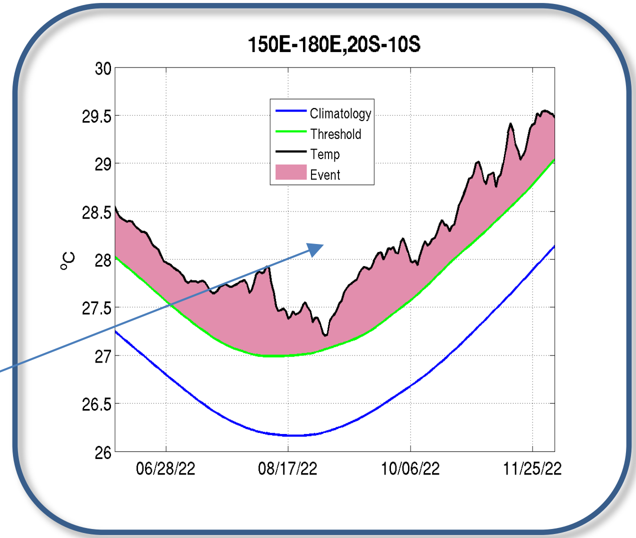
- SSTs were below average across most of the equatorial Pacific Ocean.
- Strong positive SSTAs persisted in the North Pacific and the North Atlantic Oceans.
- SST were near average in the tropical Indian and Atlantic Oceans.

- Positive SSTA tendencies were observed in the far eastern equatorial and southeastern tropical Pacific.
- Negative (positive) SSTA tendencies presented in the eastern (western) Indian Ocean.
- Both positive and negative SSTA tendencies were observed in the North Pacific.
- Large negative SSTA tendencies were observed in the subpolar North 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

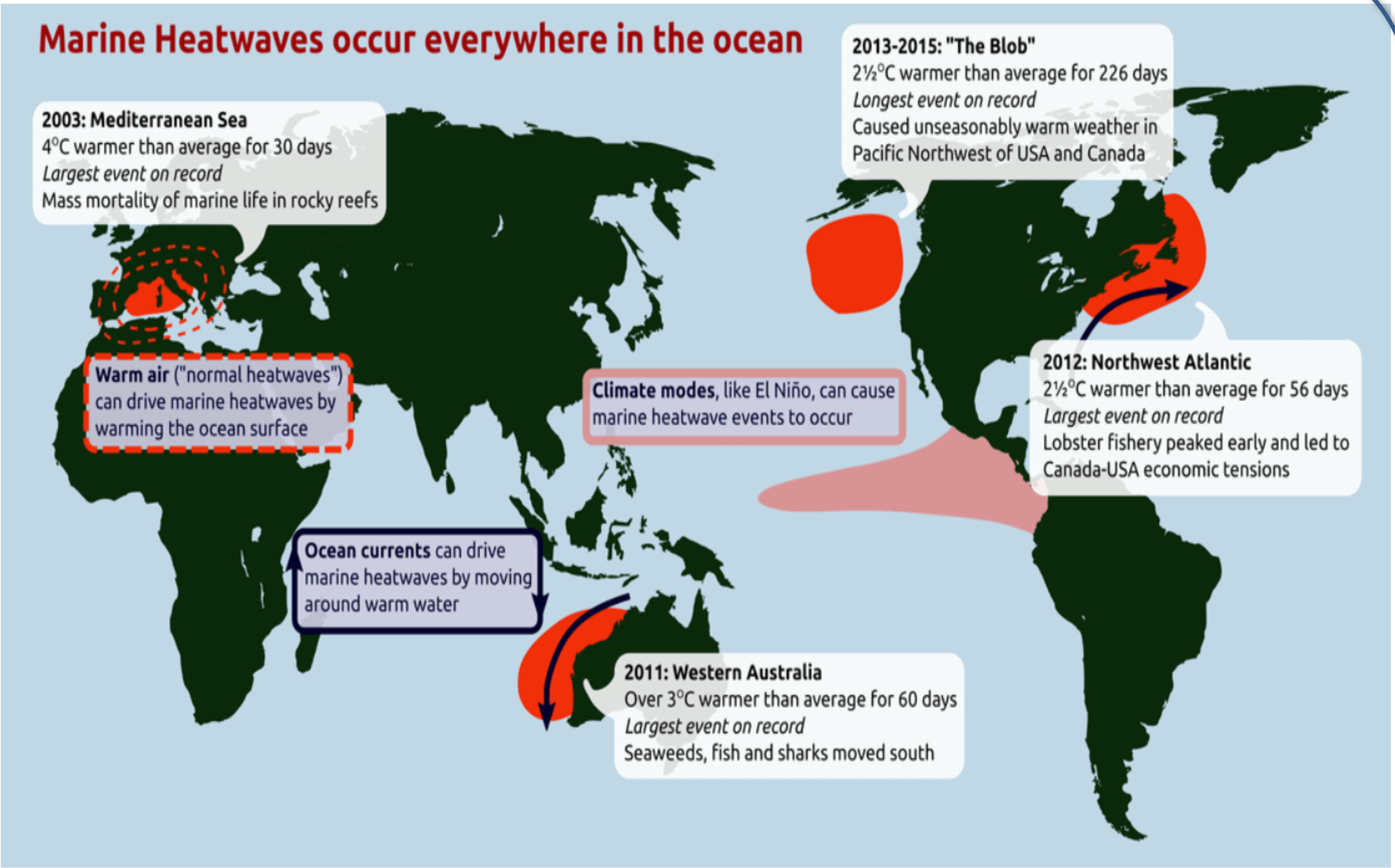




- MHWs continued in the central North Pacific, mid-latitude of north Atlantic and the Coral Sea.
- MHWs developed near the east of Argentina.

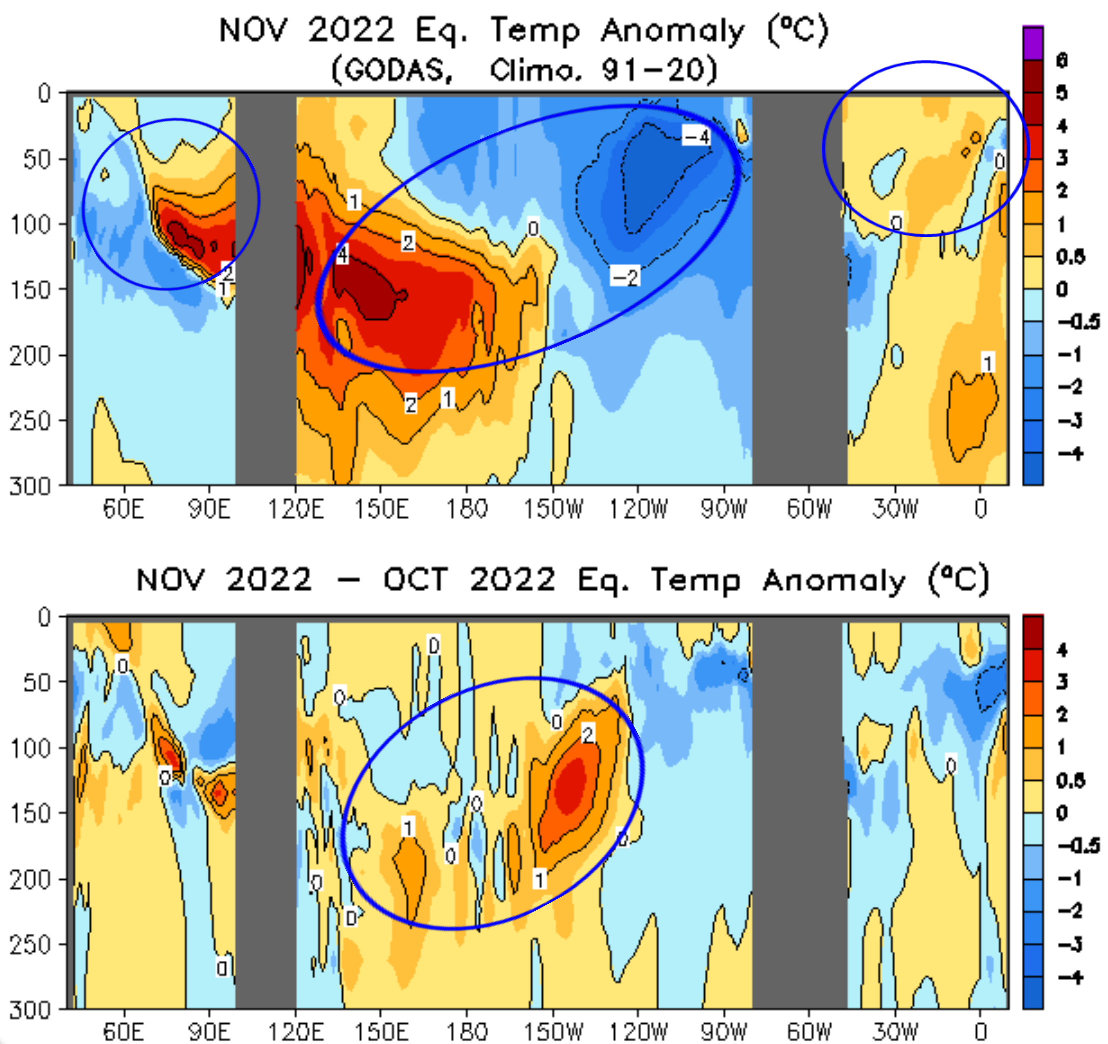
((Left panel) Monthly SST anomaly (shaded) and locations experiencing marine heat waves (hatched) by the end date labelled in the plot. (right panel) SST evolution at a specific location. Green line and blue line are the 90th percentile and daily climatology, respectively. Shaded area denotes the periods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



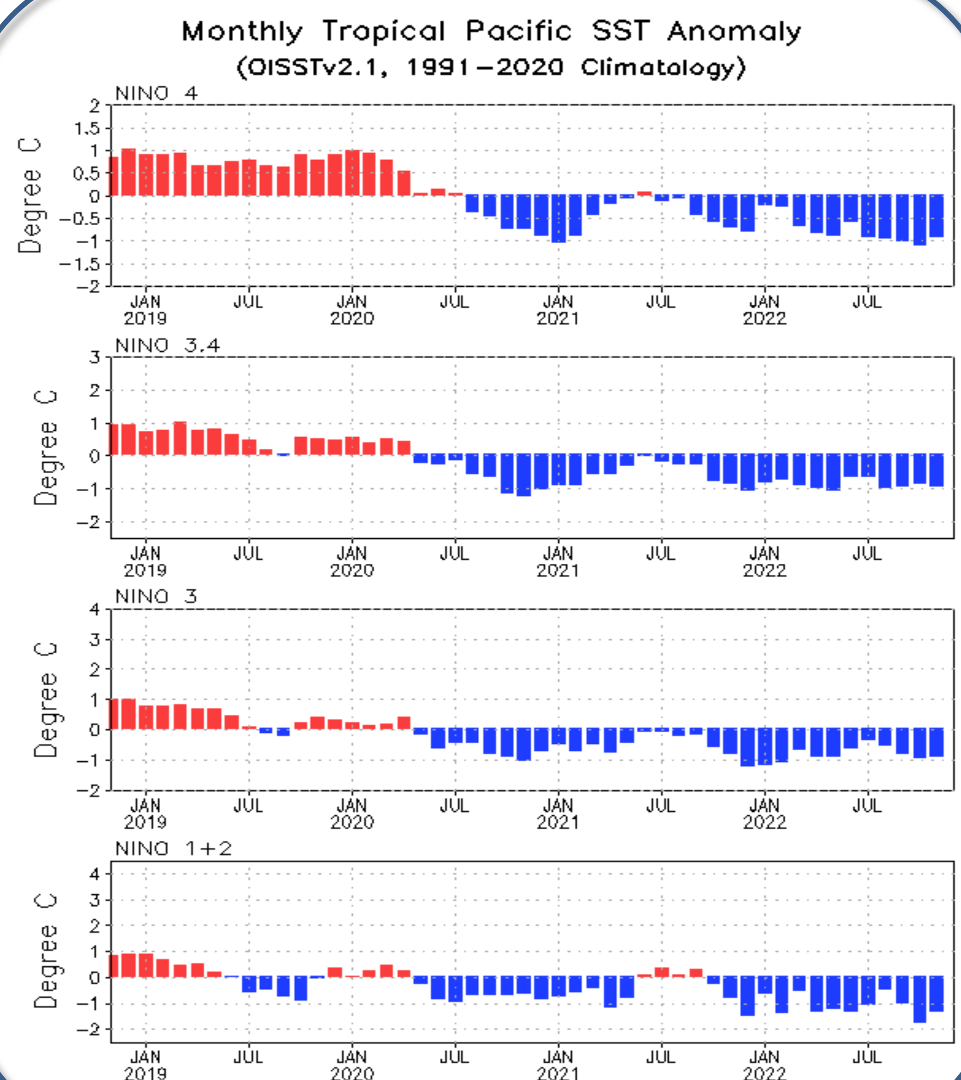
- Negative (positive) temperature anomalies persisted along the thermocline in the eastern (western) Pacific Ocean.
- Positive temperature anomalies remained in the eastern equatorial Indian Ocean.
- Positive temperature anomalies dominated the upper 100m of the equatorial Atlantic Ocean.

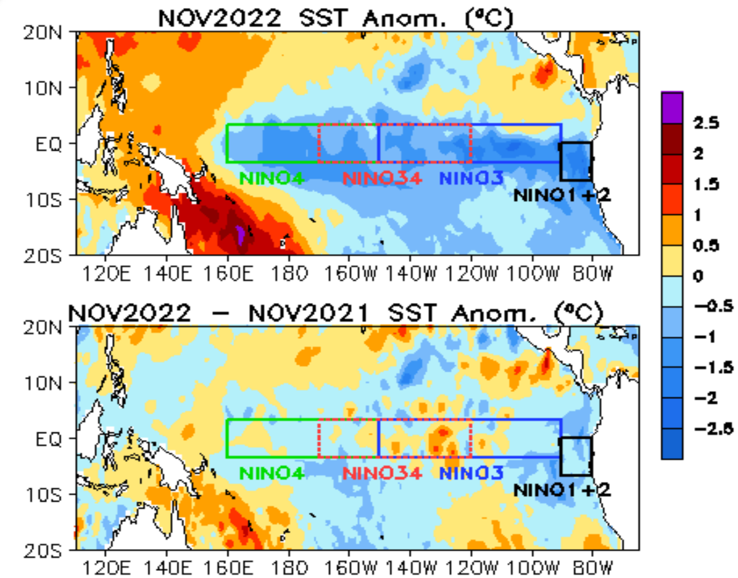
- Positive temperature anomaly tendency was observed along the thermocline in the western-central Pacific Ocean.

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.

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific Niño SST Indices





- All Niño indices were well below average in Nov 2022.

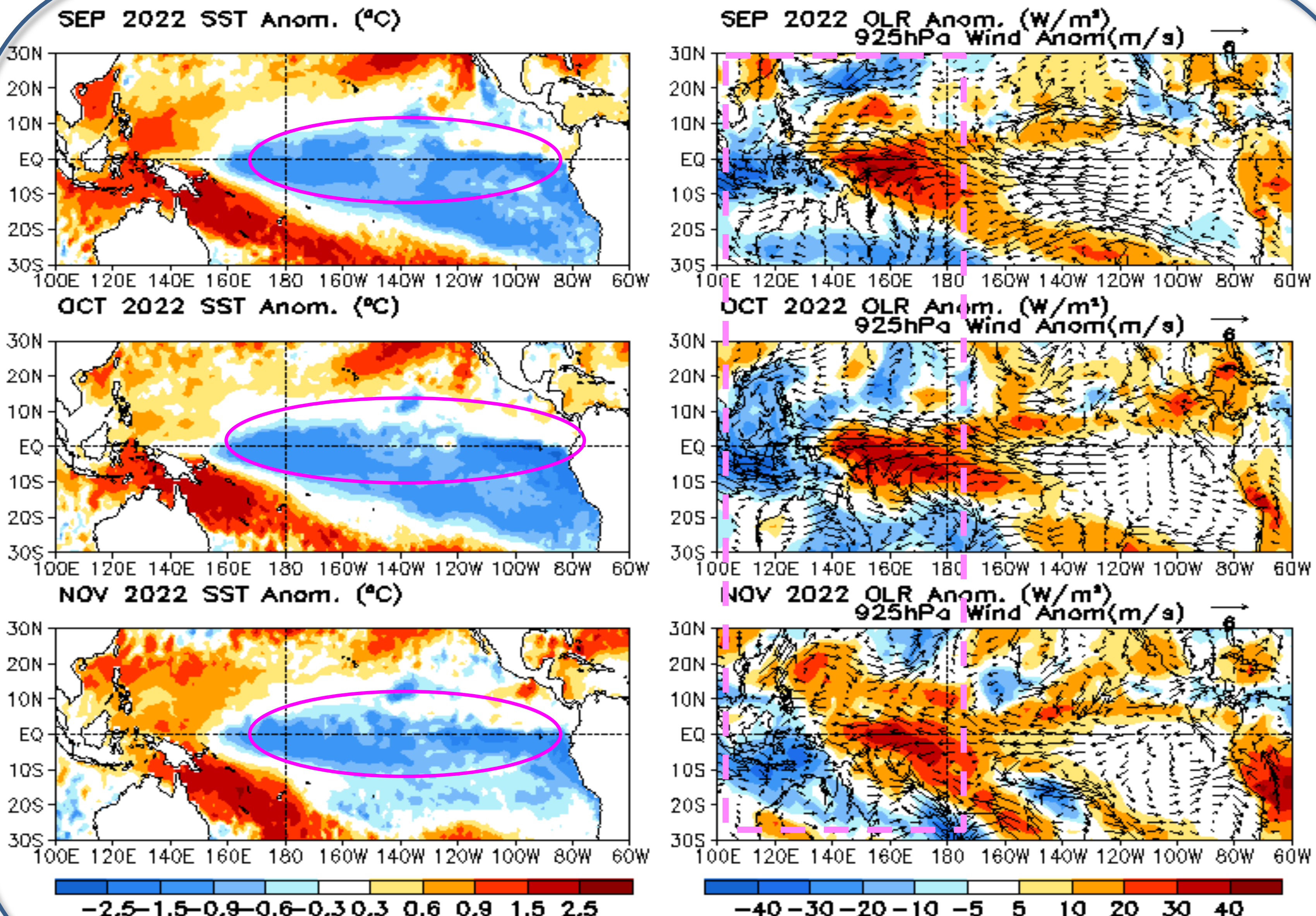
- Negative Niño3.4 enhanced slightly in Nov 2022, with Niño3.4 = -0.9C.

- Compared with Nov 2021, the eastern and southeastern tropical Pacific were cooler in Nov 2022.

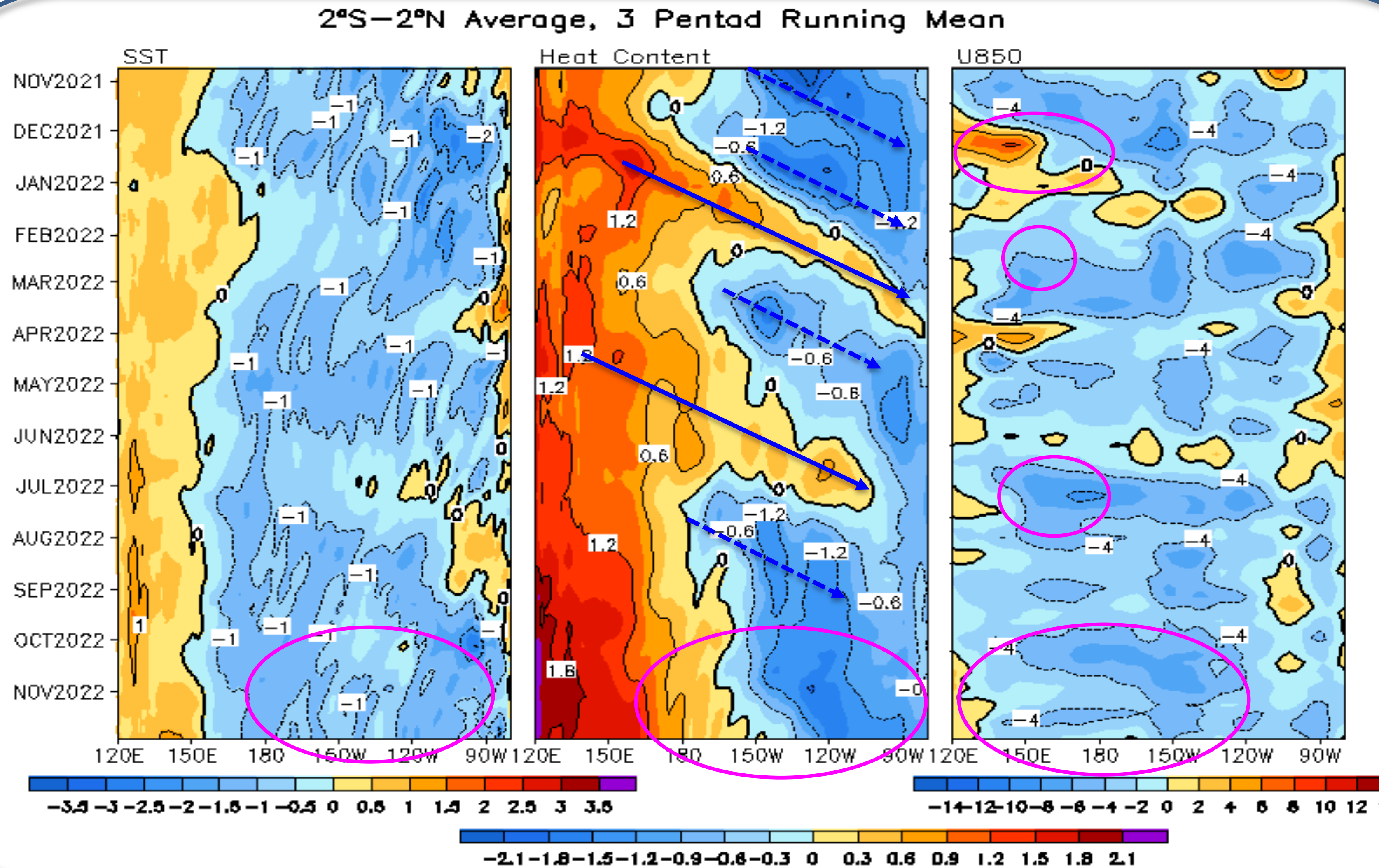
- The indices may have slight differences if based on different SST products.

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

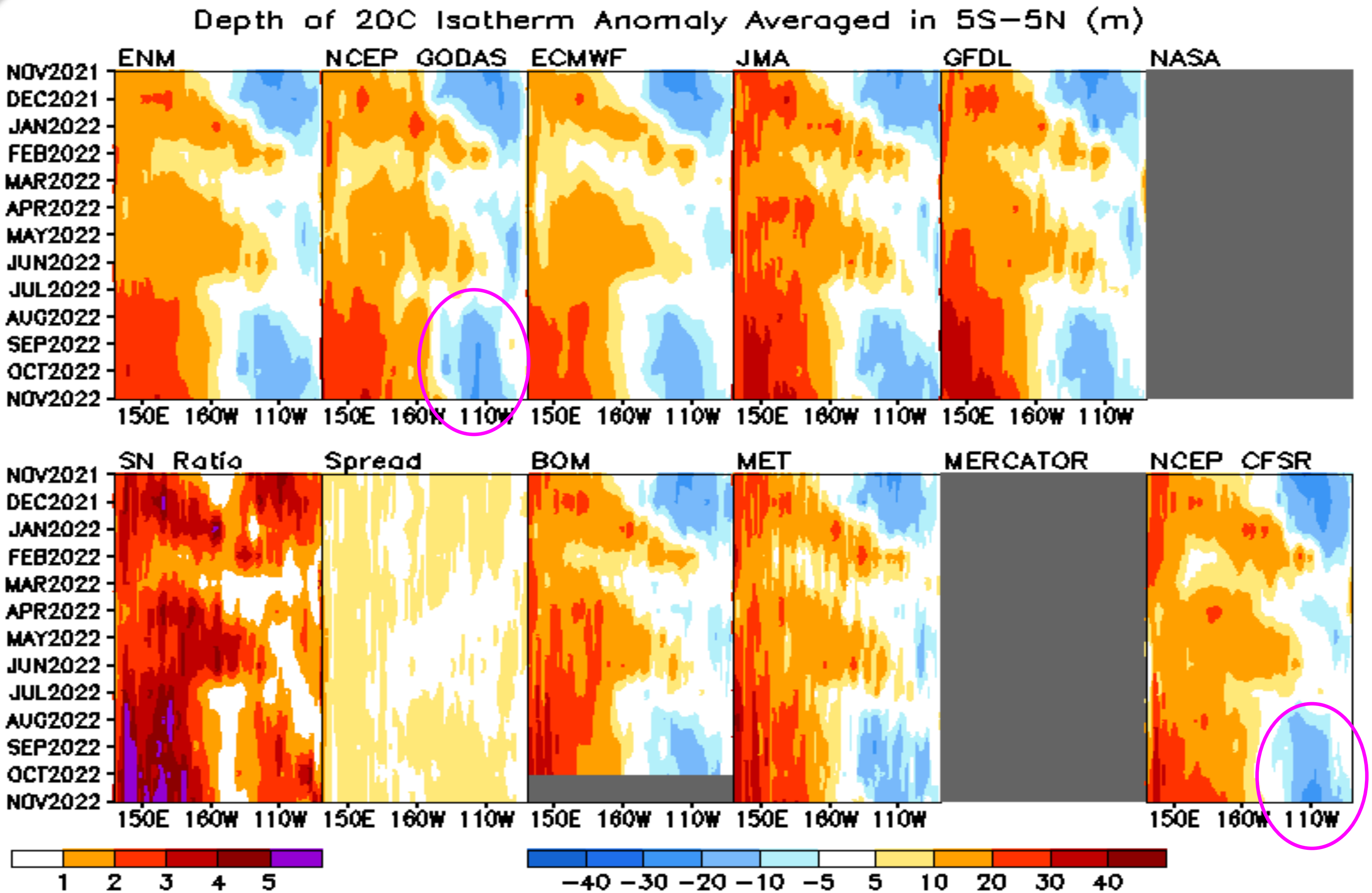


Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) Anomalies

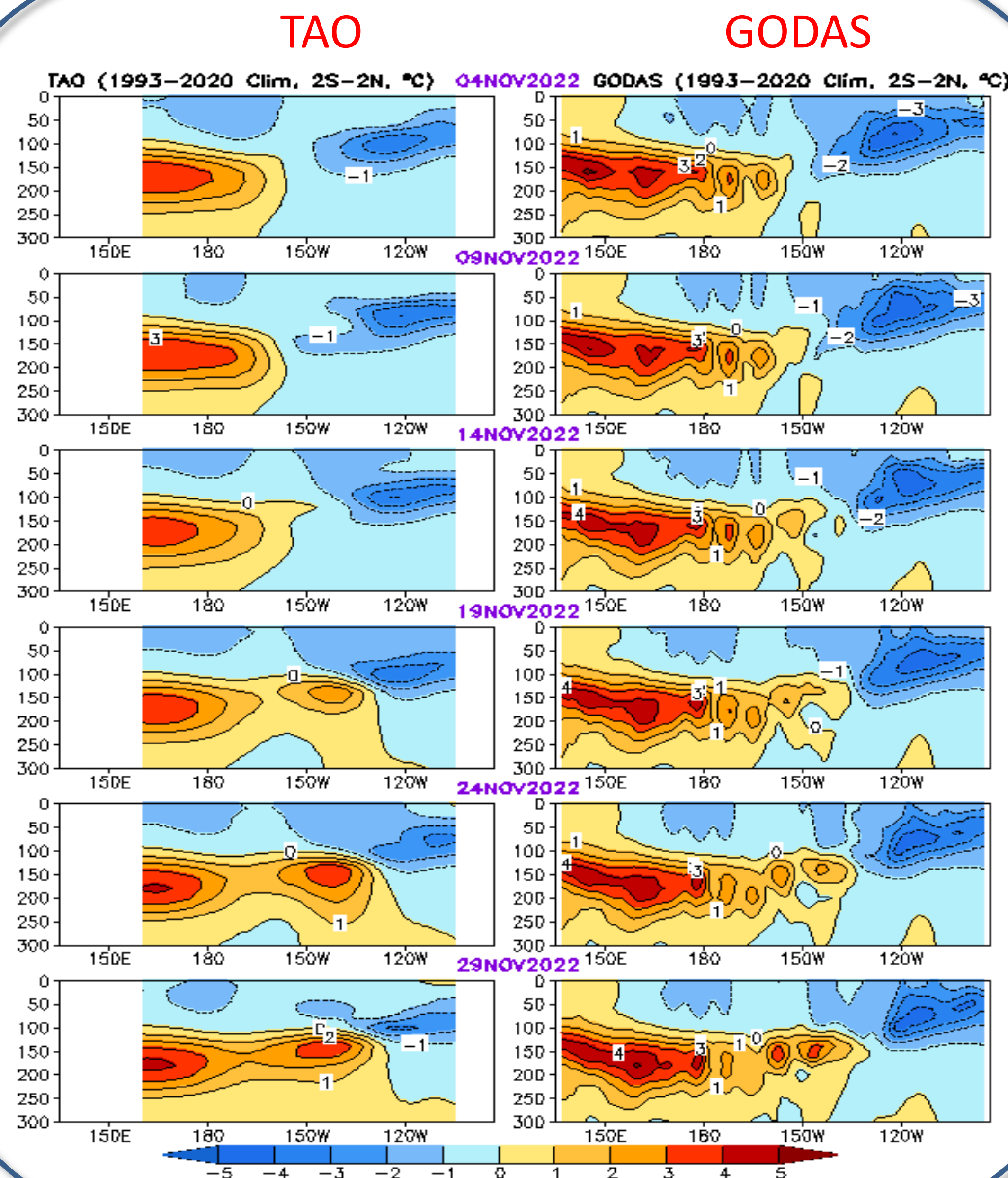


- Negative SSTA weakened in the eastern Pacific in Nov 2022.
- Easterly wind anomalies weakened over the equatorial Pacific in the middle of Nov 2022.
- Positive H300 anomaly expanded eastward and negative anomaly contracted in the eastern Pacific .

Multiple Ocean Reanalysis: Equatorial D20 Anomaly [5ºS-5ºN]

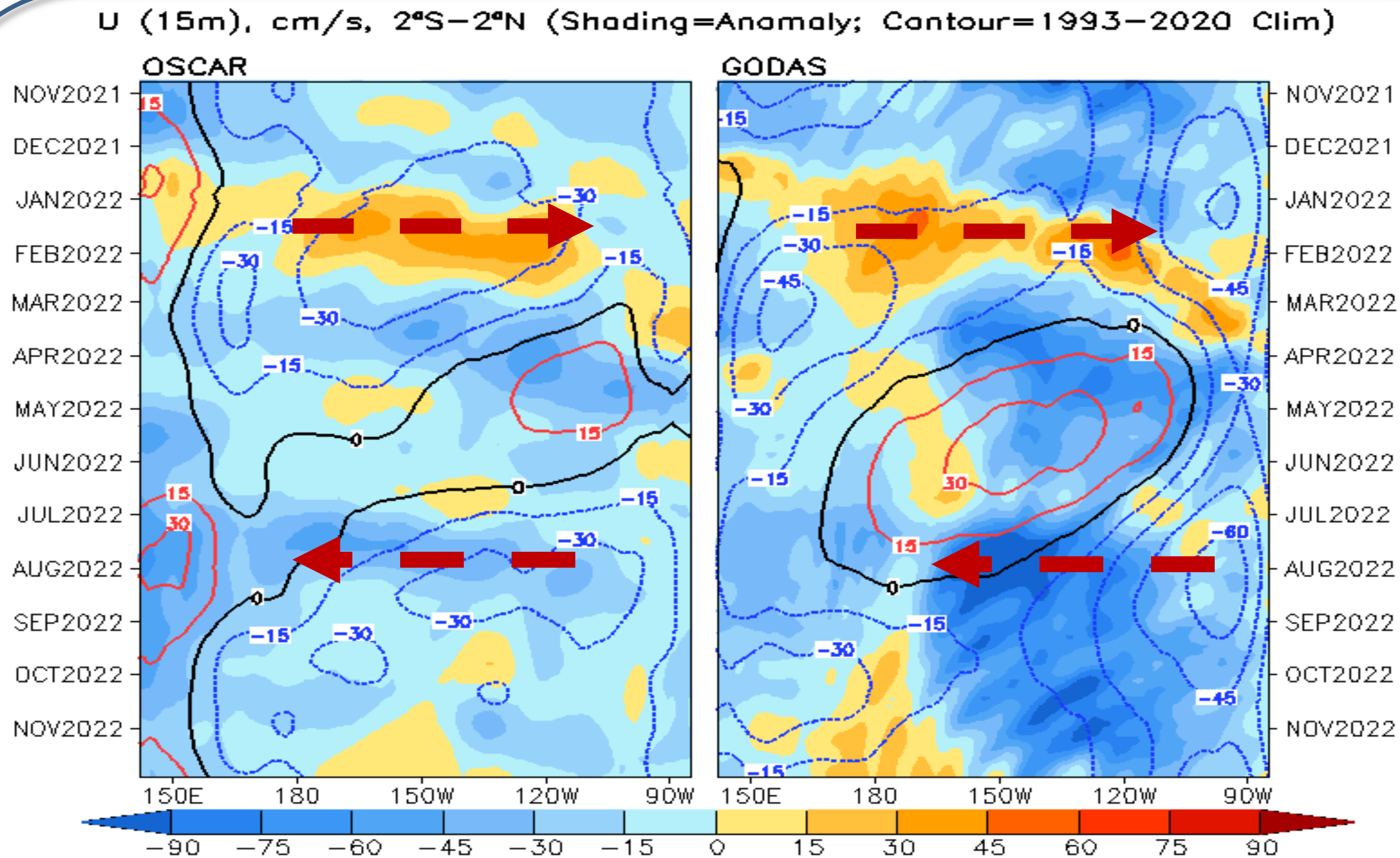


Equatorial Pacific Ocean Temperature Pentad Mean Anomaly



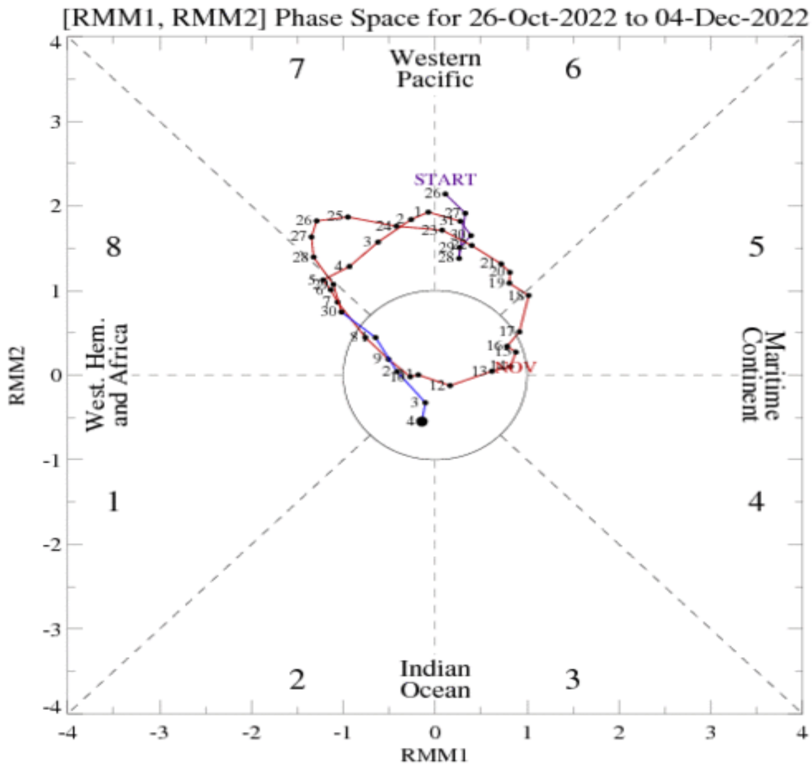
- Subsurface warm anomaly expanded into the central Pacific near the thermocline, and negative anomalies contracted in the eastern Pacific in the last three pentads.
- Subsurface cooling east of 140W in GODAS was stronger than in TAO.

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

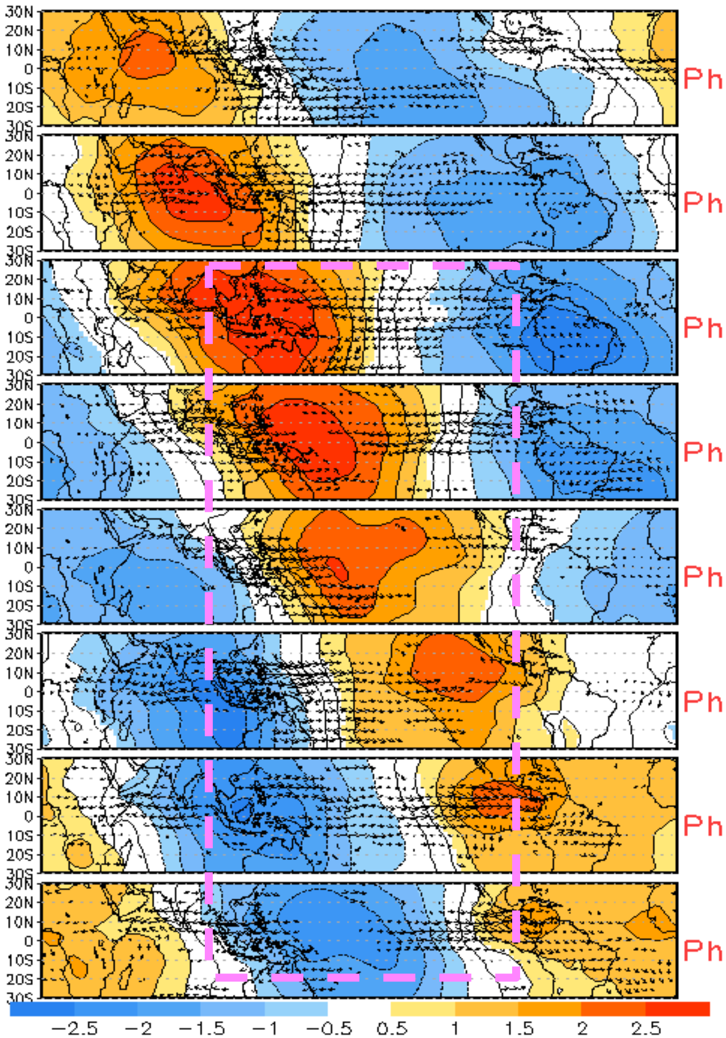


- Anomalous eastward currents emerged in the western-central Pacific both in OSCAR and GODAS in Nov 2022.

MJO Activities

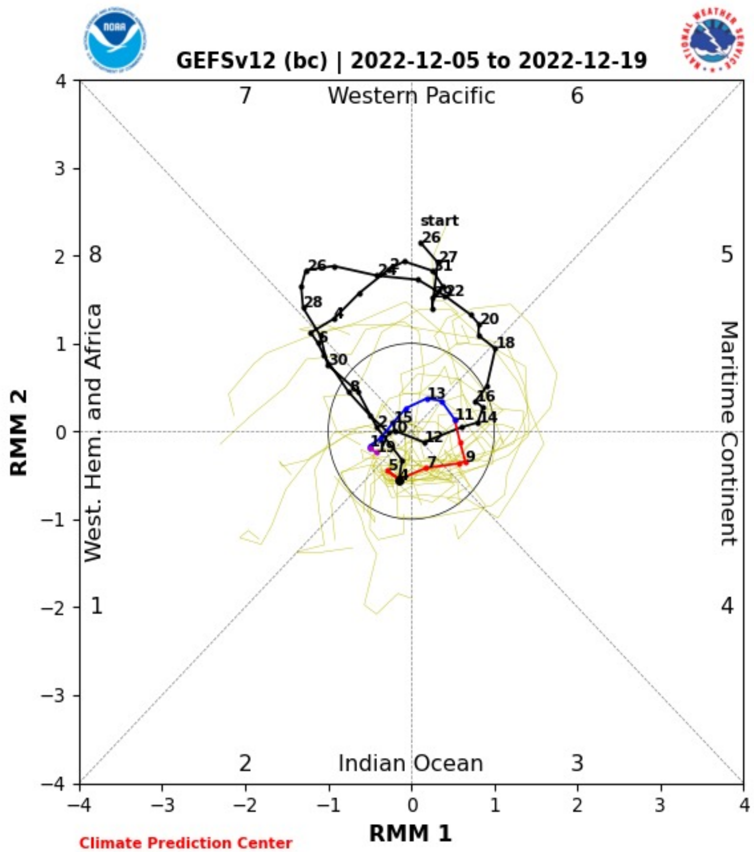


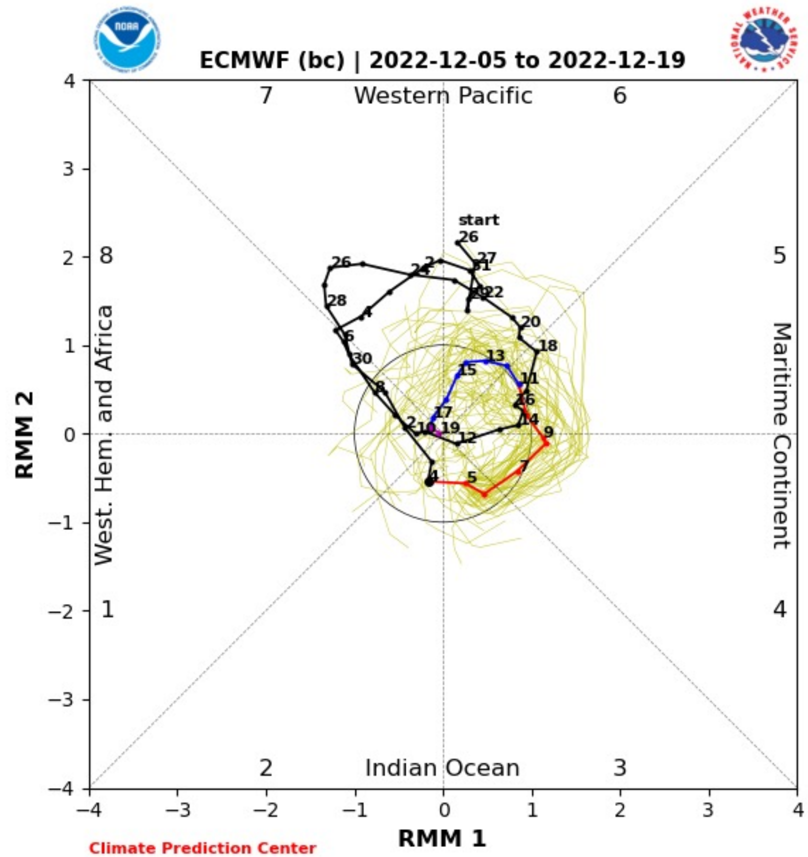
850-hPa Velocity Potential and Wind Anomalies



- RMM observation indicated a steady eastward propagation of MJO in Nov 2022.

MJO Index: Forecasts



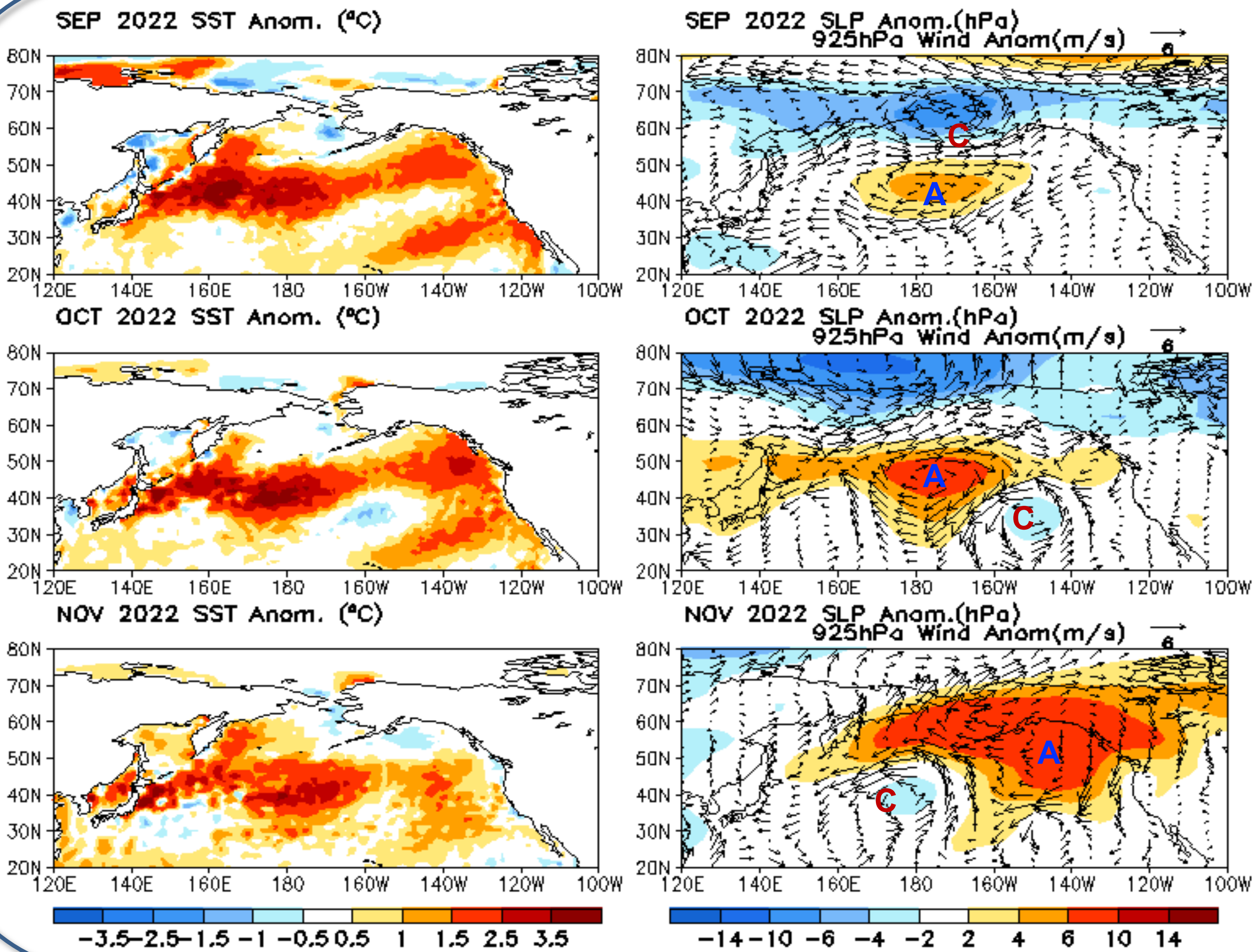


https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml#forecast

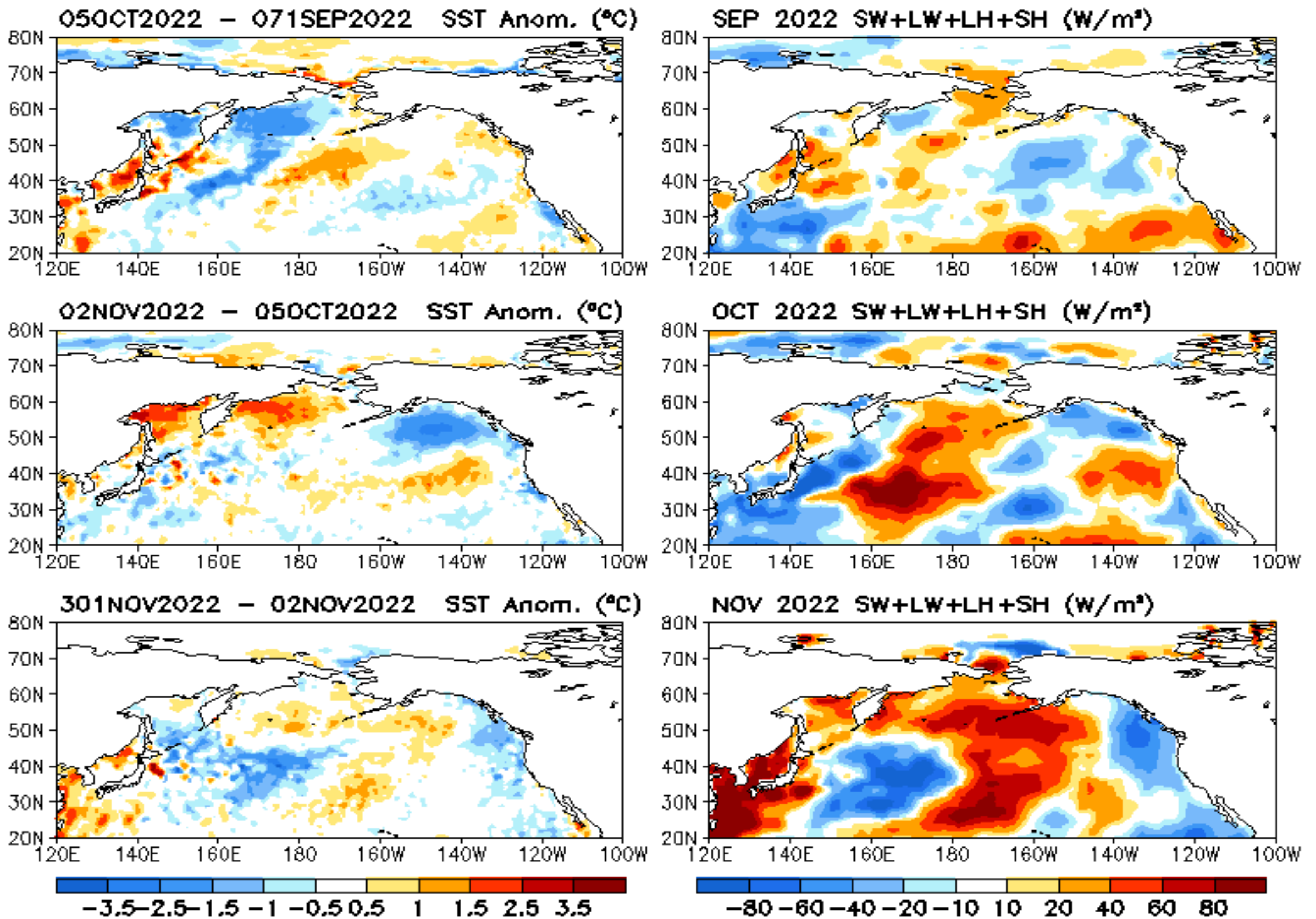
- Both GEFS and ECMWF ensembles forecast MJO-signal remained weak in the next two weeks.
- A number of ensemble members predicted a continuous eastward propagation into the Maritime continent, in favor of re-enhanced easterly wind anomaly over the central Pacific.

North Pacific & Arctic Oceans

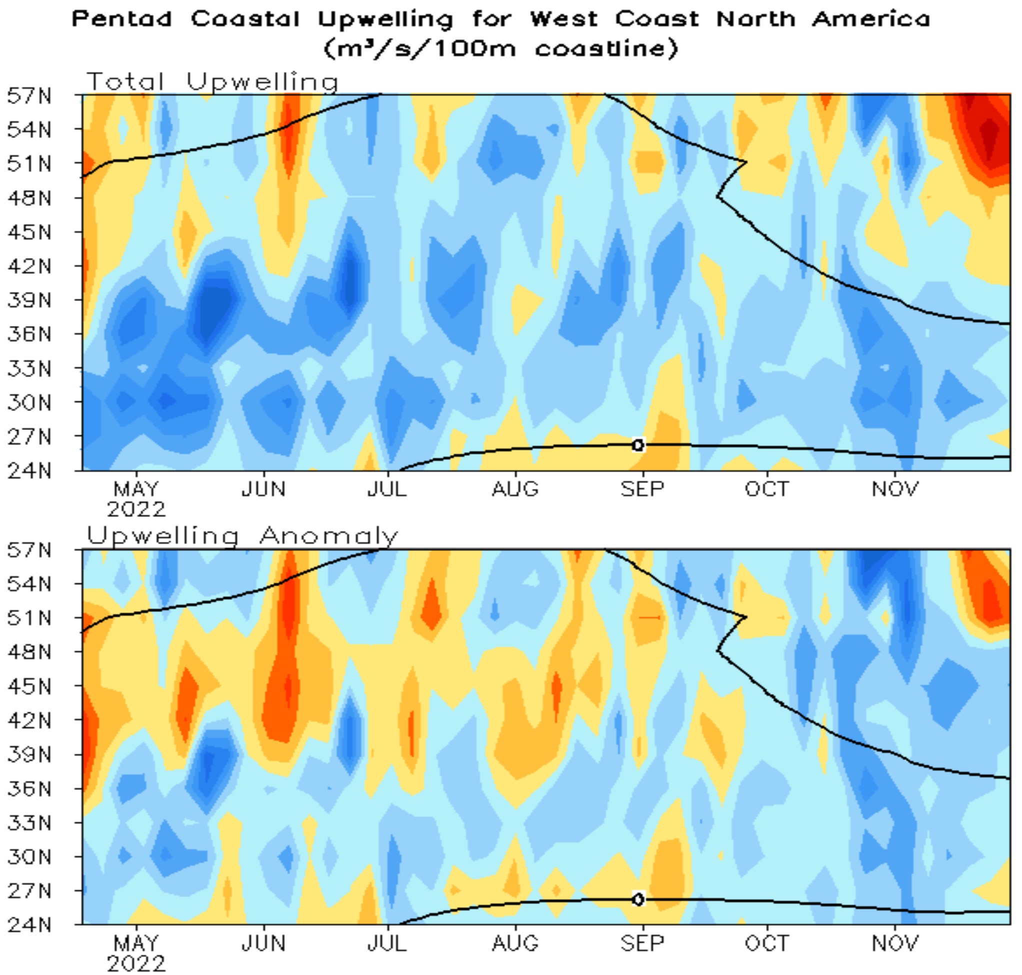
Last 3- month North Pacific SST, SLP, and uv925 anomalies

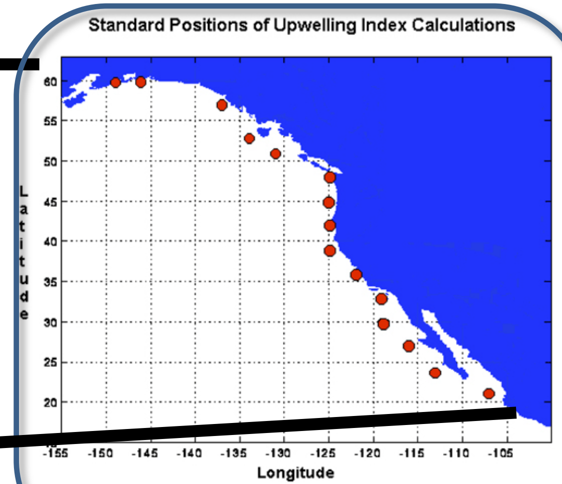


Last 3- month North Pacific SSTA tendency and Surface Heat Flux anomalies



North America Western Coastal Upwelling



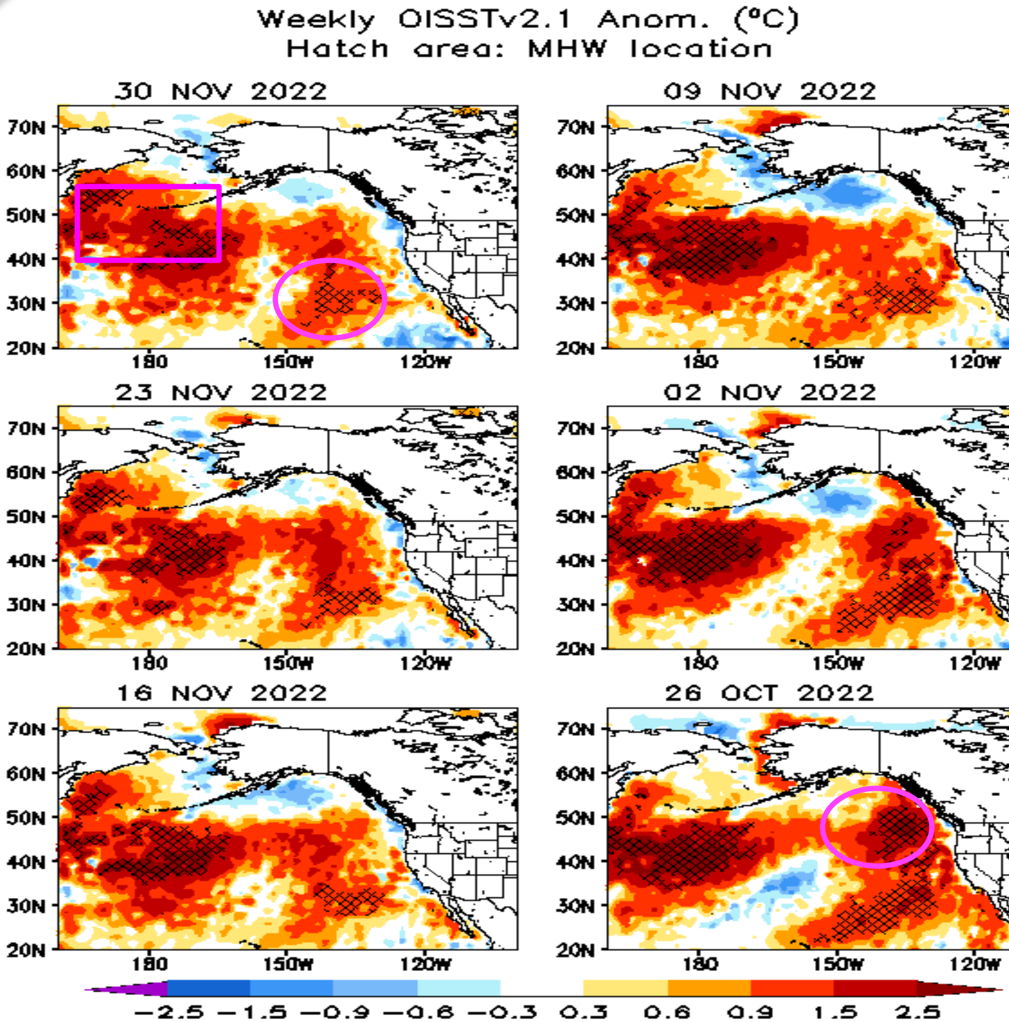


- Anomalous upwelling dominated along the coastline south of 51°N, contributing to the SST cooling in Nov 2022.

(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

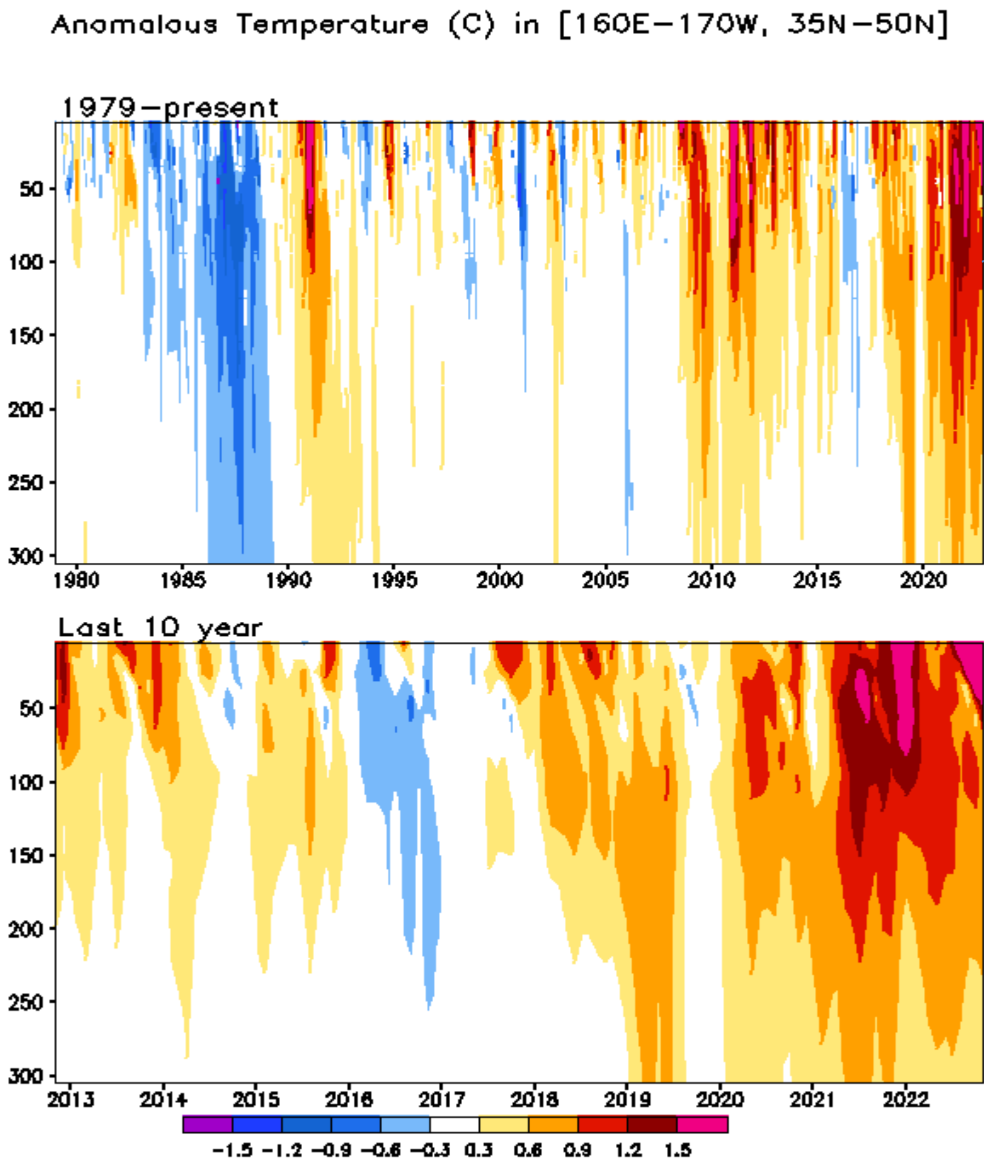


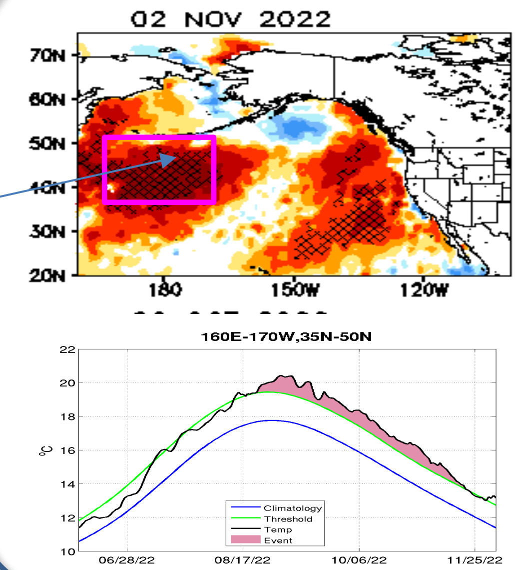
- MHWs persisted in the western-central Pacific and near the west coast of USA in Nov 2022.

- MHWs decayed in the northeastern Pacific in early Nov 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





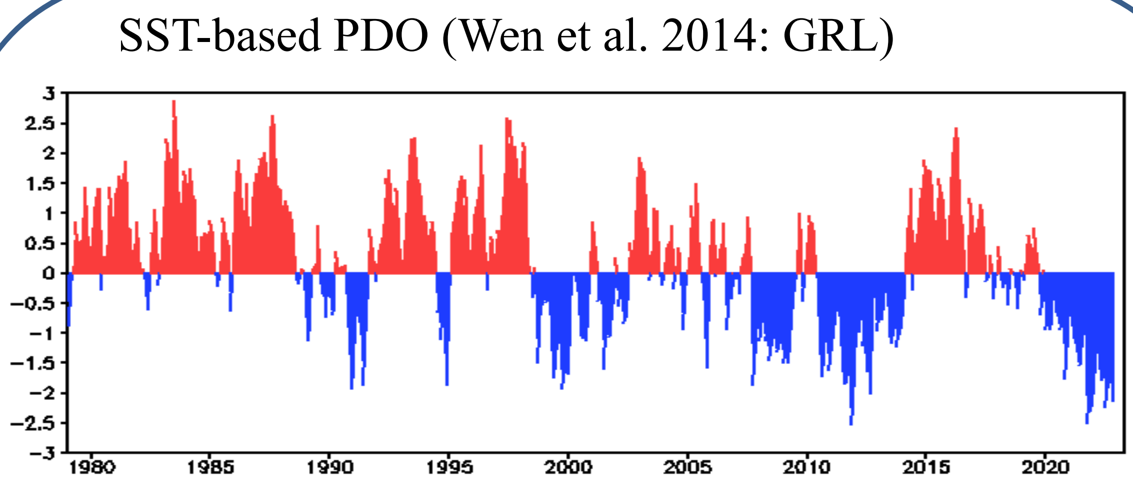
- MHWs has persisted since Aug 2022.

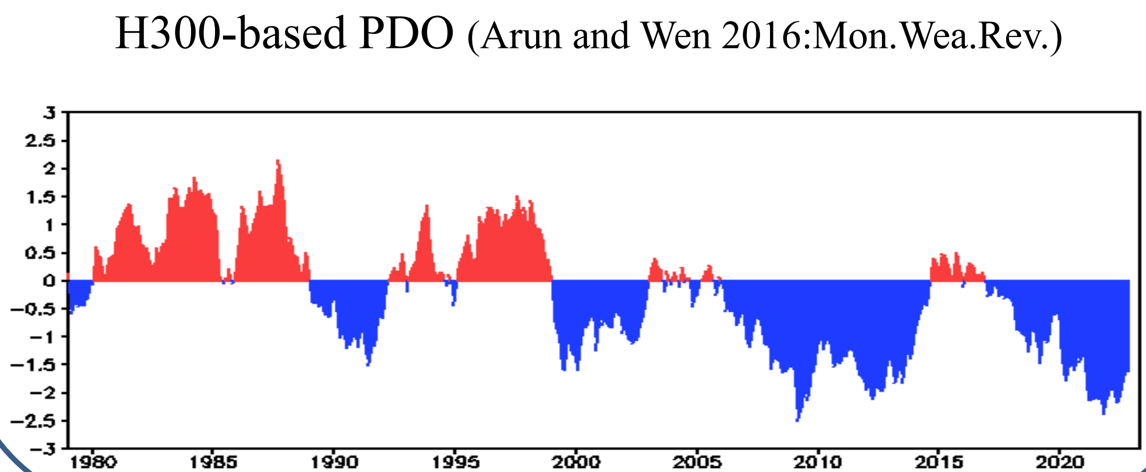
-Positive subsurface temperature anomaly in the North central Pacific has persisted since 2020.

- 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.

Two Oceanic PDO indices





- The negative phase of PDO has persisted since Jan 2020 with PDOI = -2.2. in Nov 2022.

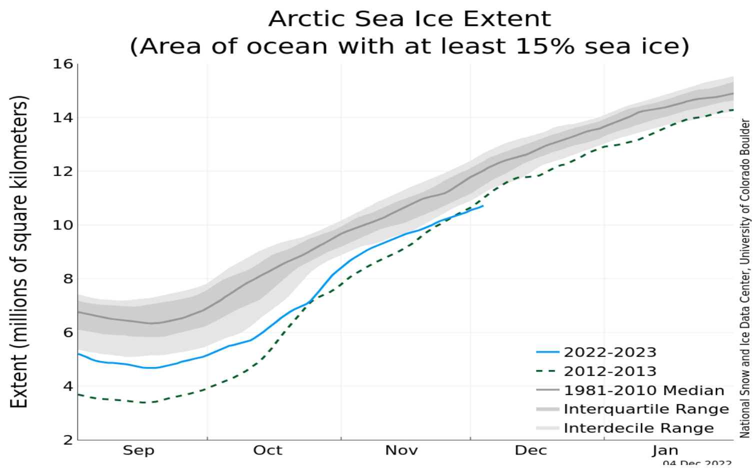
- Negative H300-based PDO index has persisted 75 months since Nov 2016, with HPDO = - 1.6 in Nov 2022.

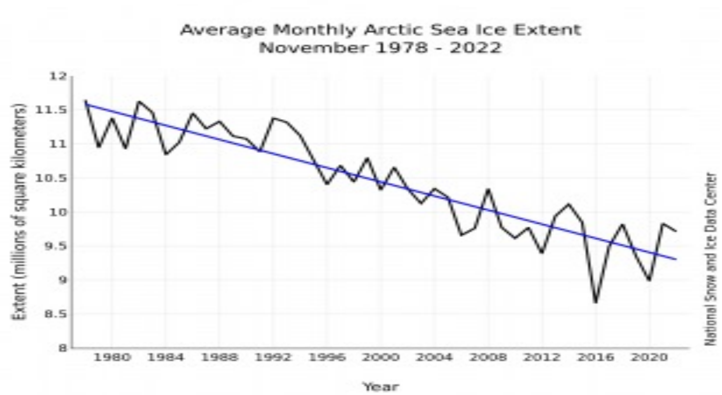
- SST-based PDO index has considerable variability both on seasonal and decadal time scales.

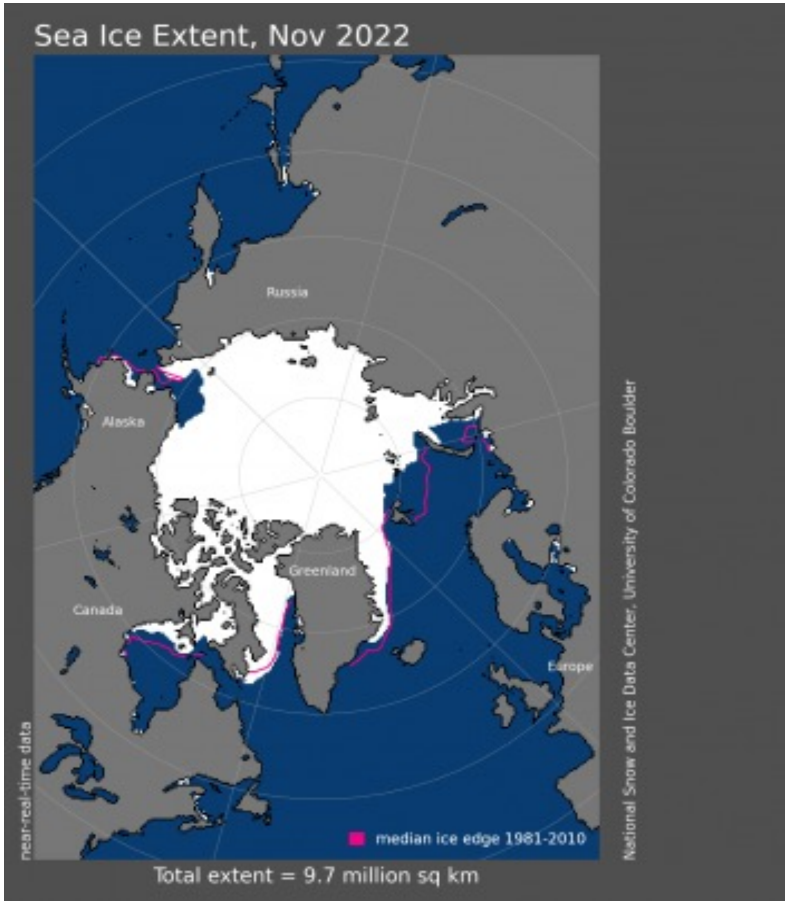
- H300-based PDO index highlights the slower variability and encapsulates an integrated view of temperature variability in the upper ocean.

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)

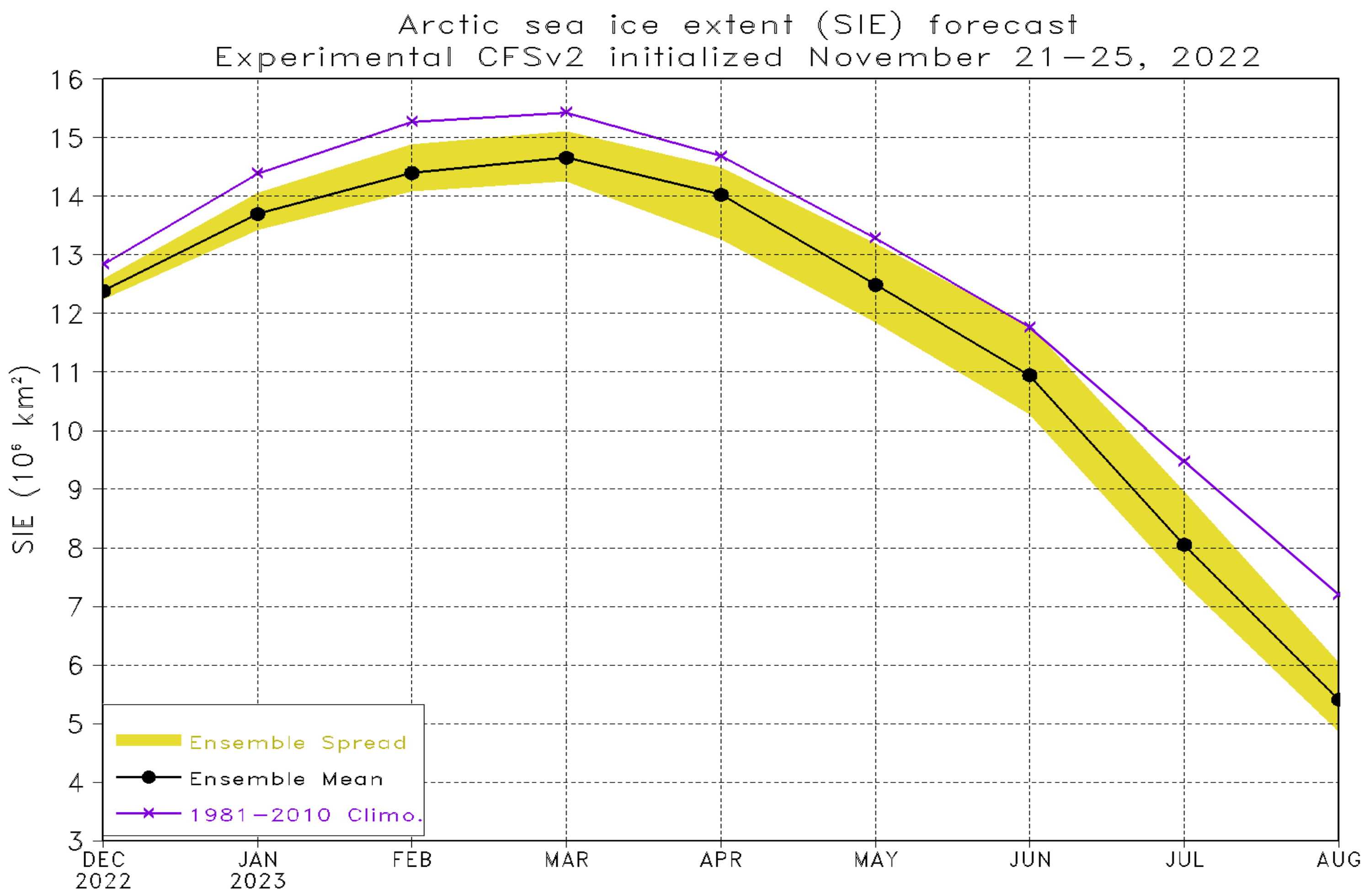






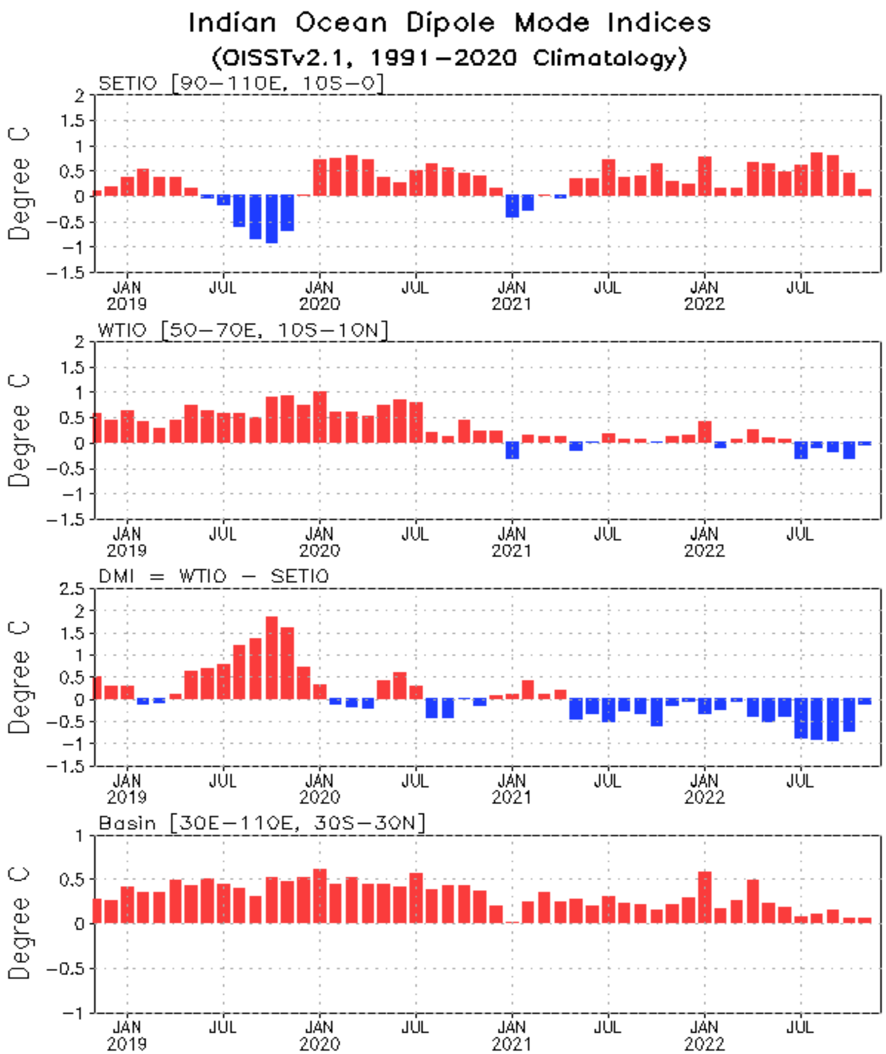
- Average Arctic sea ice extent for November 2022 was 9.71million square kilometers, ranking the eighth lowest in the satellite record.

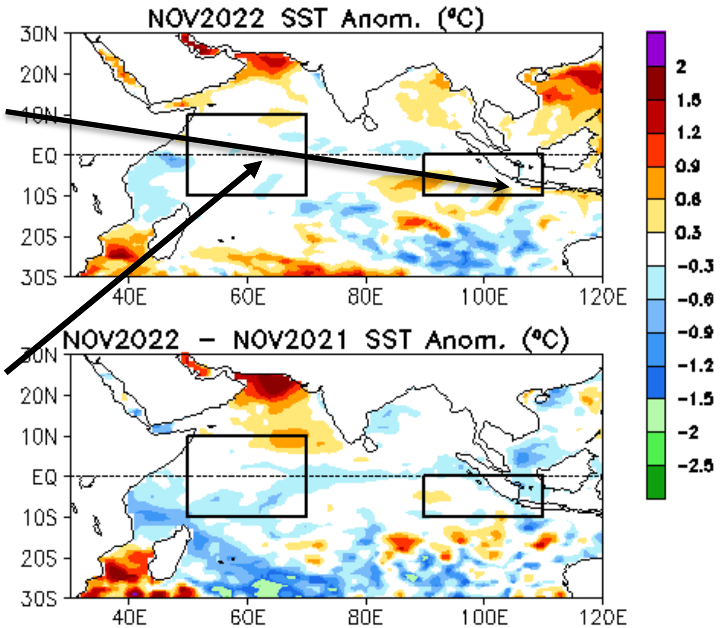
NCEP/CPC Arctic Sea Ice Extent Forecast



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

Indian Ocean

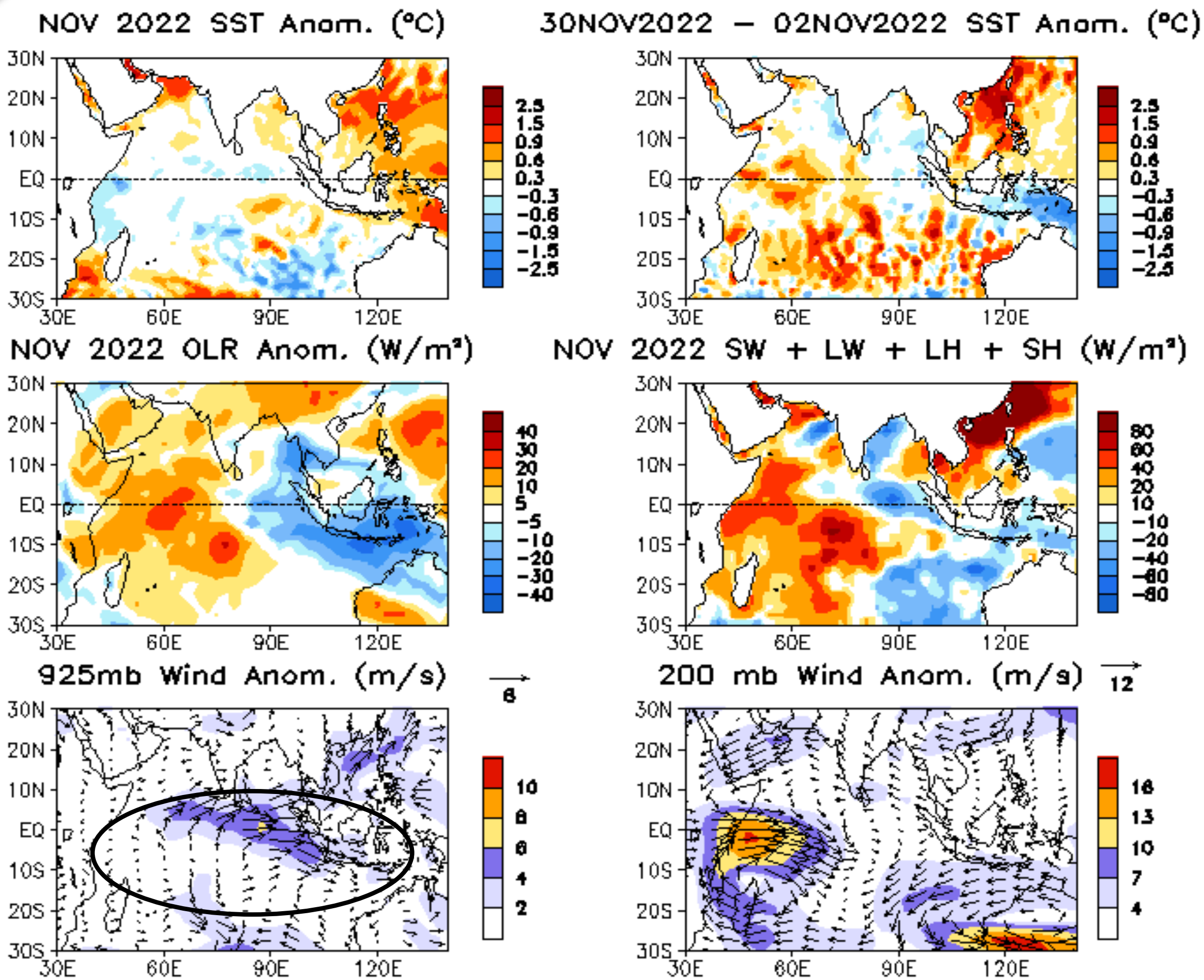




- The negative Indian Ocean Dipole event returned to neutral in Nov 2022.

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.



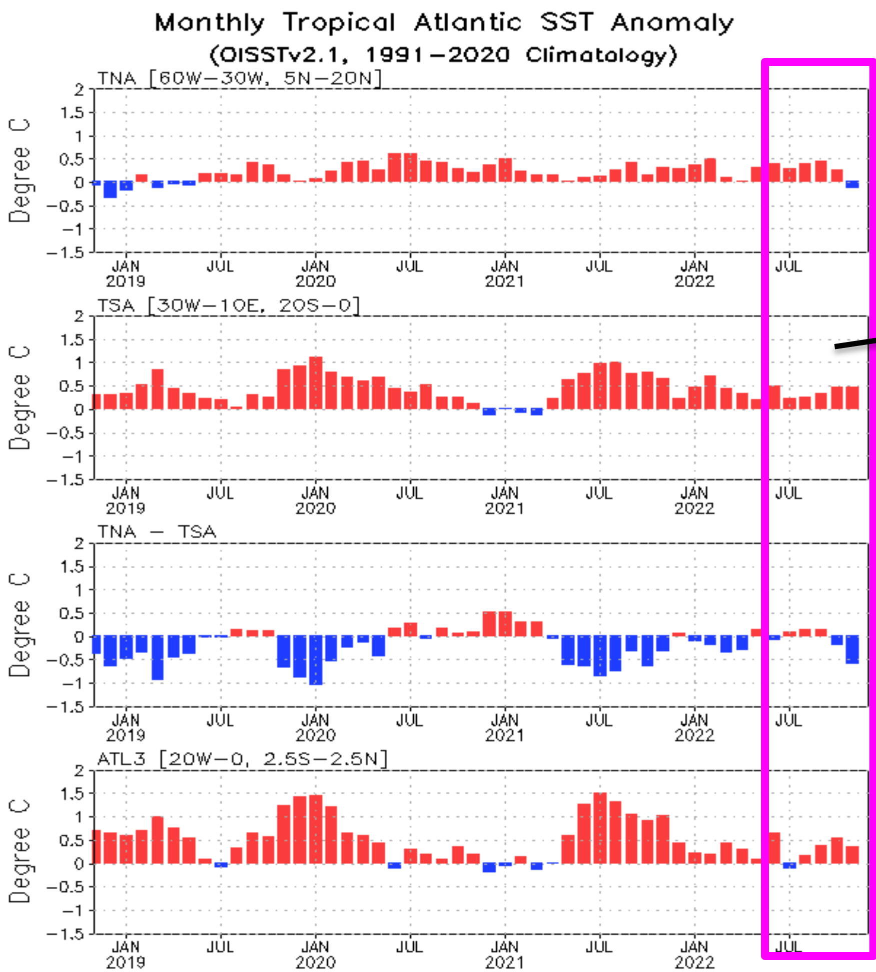
-Westerly wind anomaly weakened over the eastern Indian Ocean.

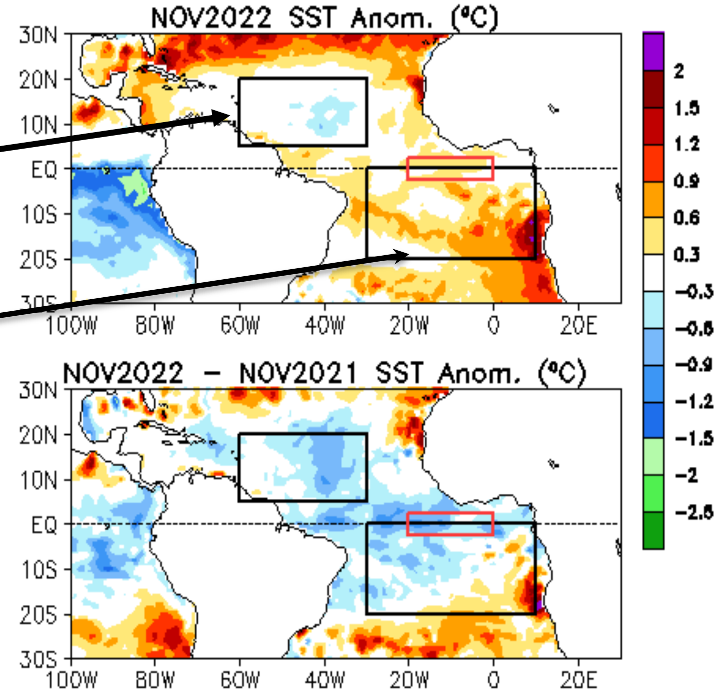
- SSTs were near average across most of the tropical Indian Ocean, indicate the ending of 2022 negative Indian dipole event.

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.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

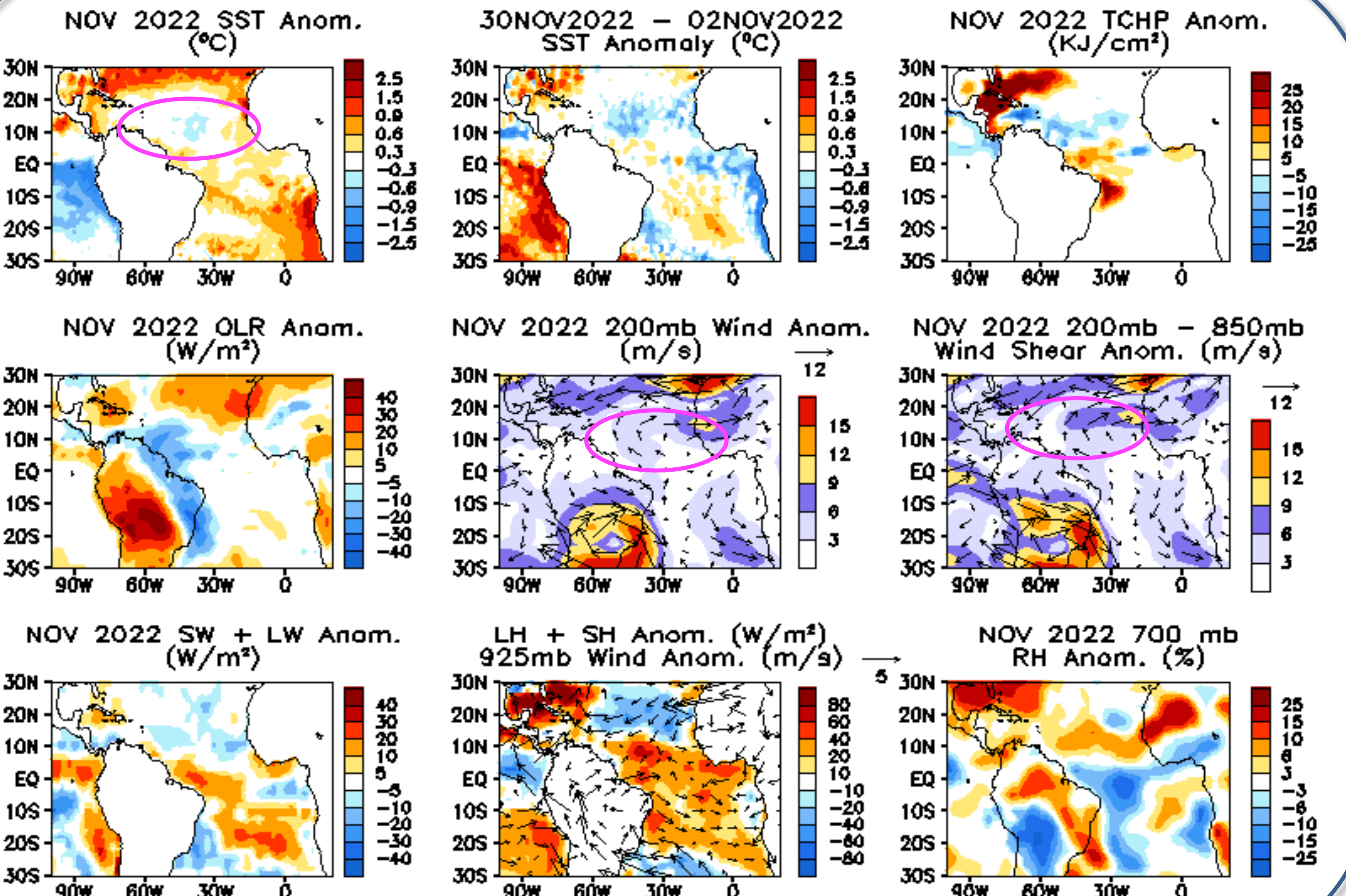




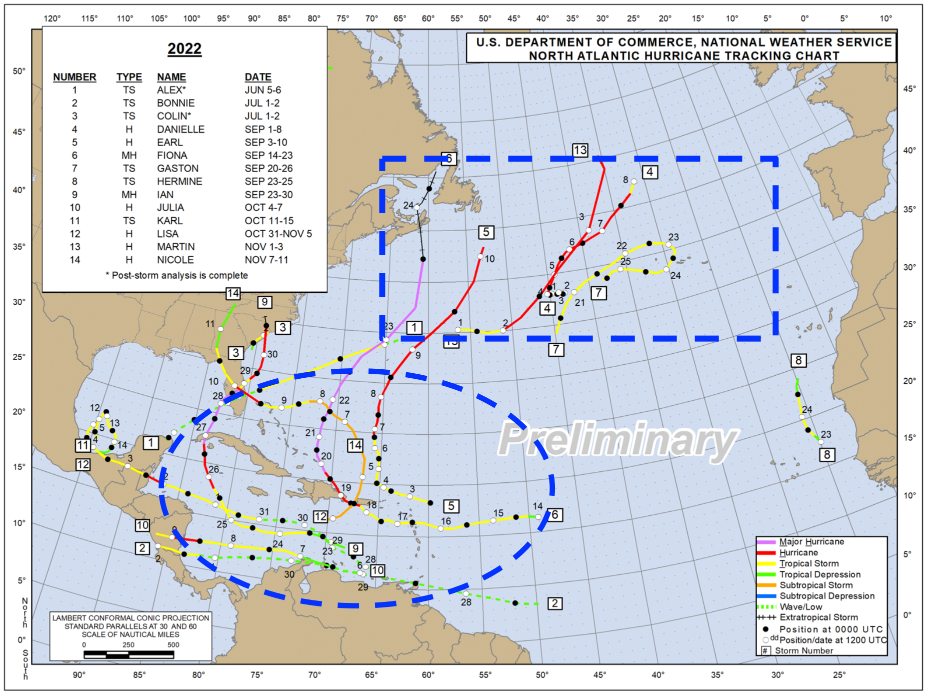
-Tropical North Atlantic index switched to negative in Nov 2022.

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

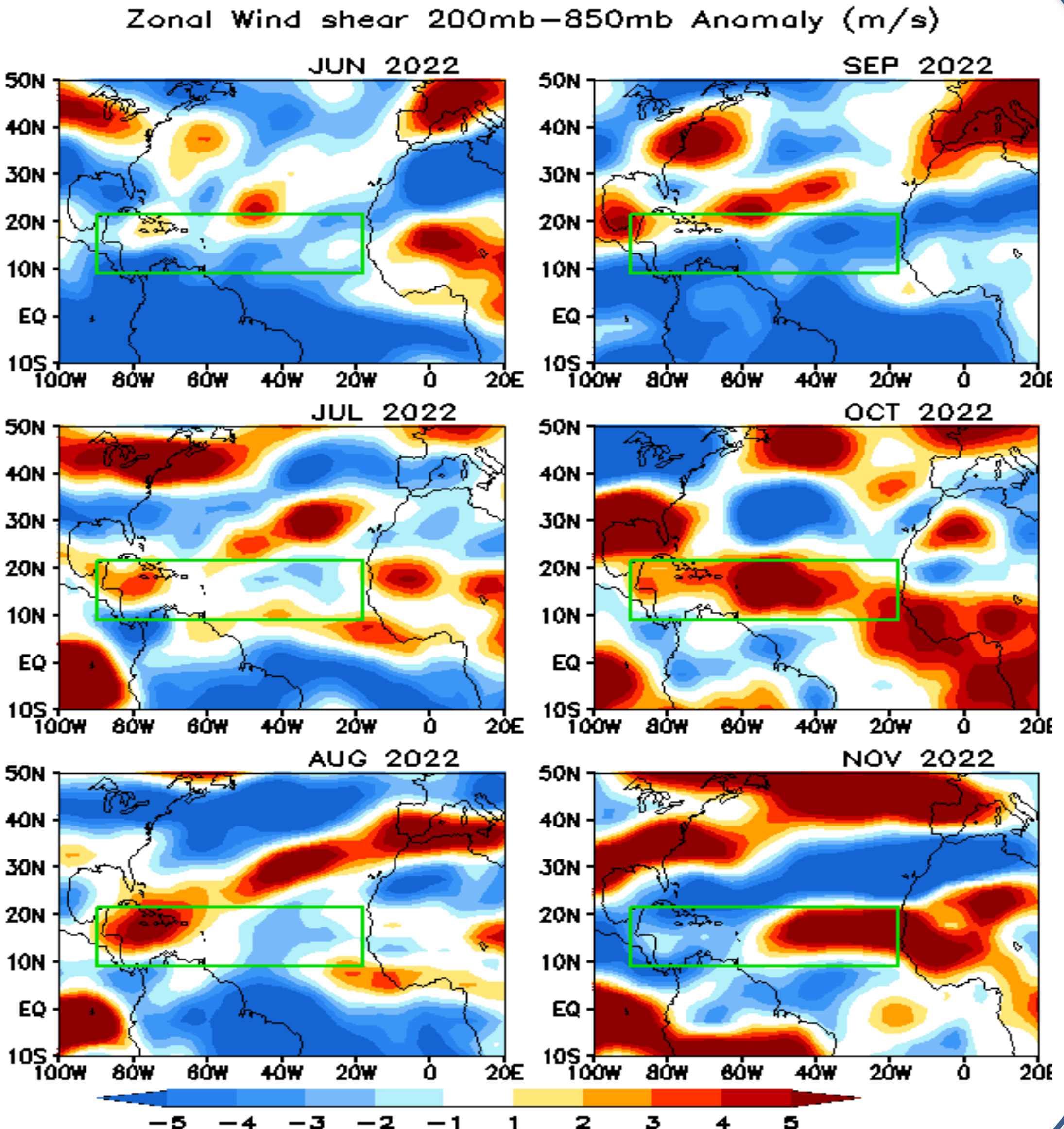


https://www.nhc.noaa.gov/data/tcr/

- Three hurricanes developed in Nov 2022.
- Fourteen named storms formed, with eight developing to hurricanes, and two developing to major hurricanes during the 2022 Atlantic hurricane season.
- Most storms developed in the western hurricane main development region and mid-latitude of north Atlantic Ocean.

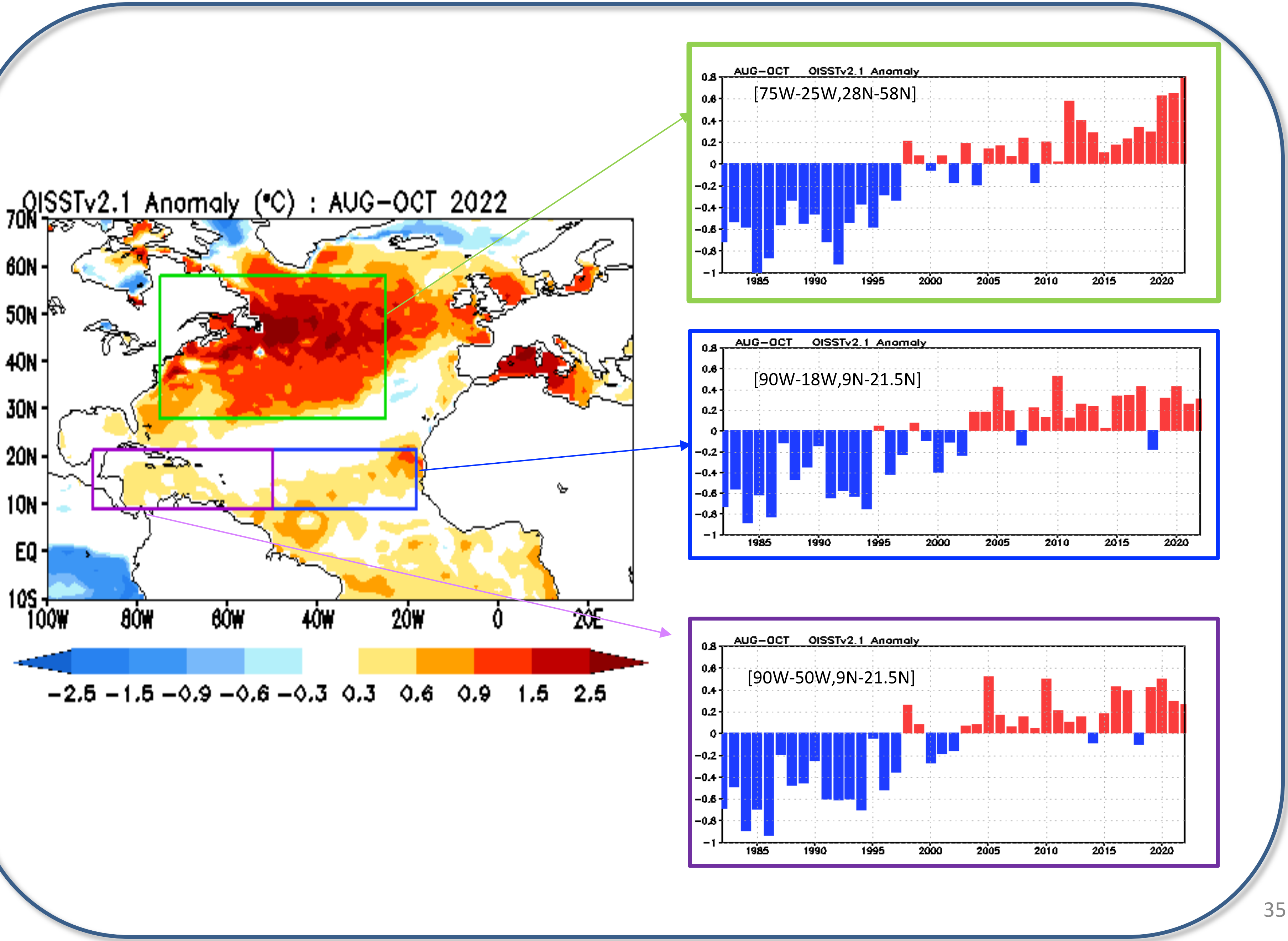
Atlantic	Observations (By Dec 5)	Updated Outlook (Aug) 60% above-normal	Outlook (May) 65% above-normal	(1991-2020)
Total storms	14	14-20	14-21	14
Hurricanes	8	6-10	6-10	7
Major hurricanes	2	3-5	3-6	3

Last 6-month of North Atlantic zonal wind shear anomaly

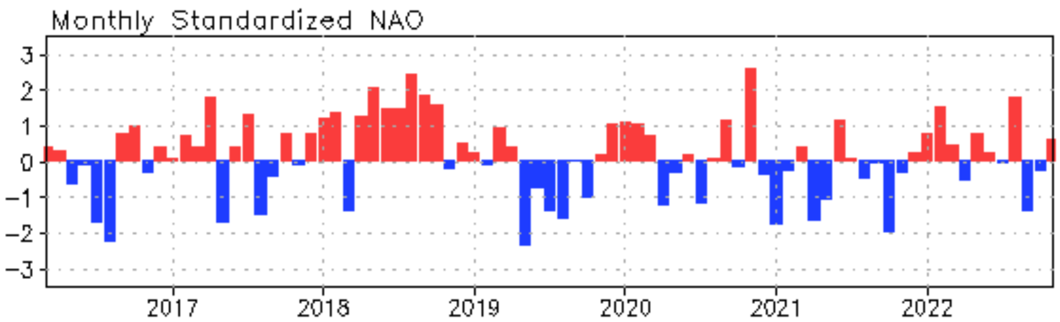


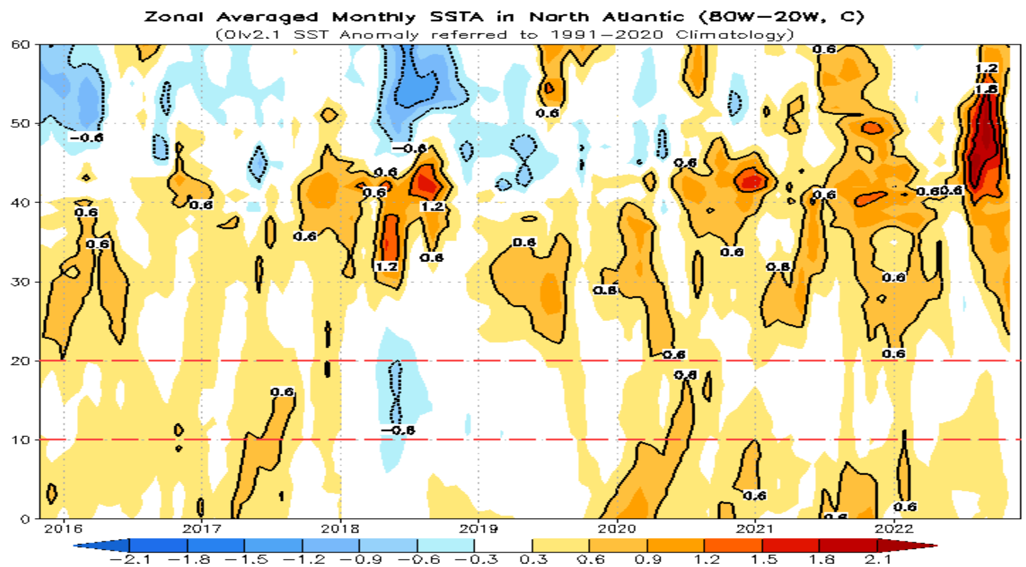
- Strong negative zonal wind shear anomalies dominated in the whole hurricane main developing region (MDR, green box) in Sep, coincided with the most active month this season.

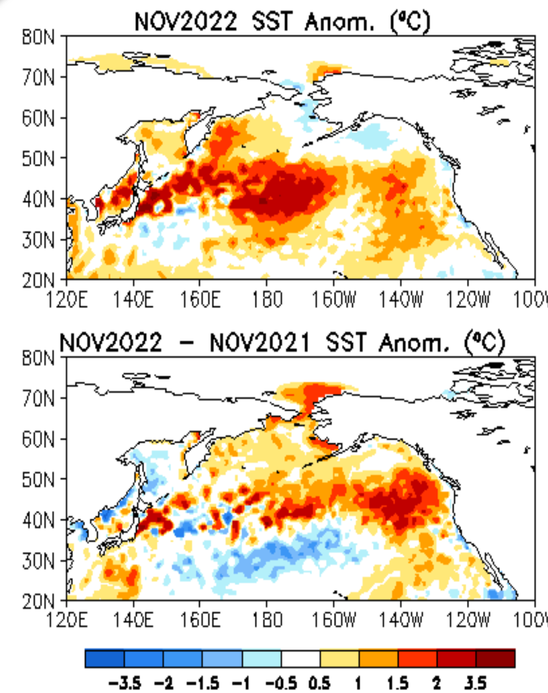
August-October SST anomaly in the North Atlantic



NAO and SST Anomaly in North Atlantic







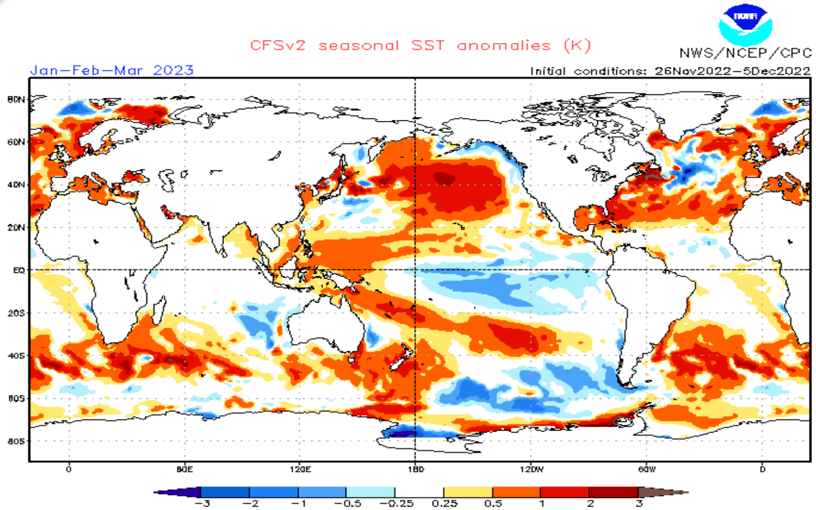
- Negative NAO switched to positive in Nov 2022, with NAO=0.6.
- The positive SSTAs in the mid-high latitudes of the North Atlantic Ocean were evident since 2021.

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

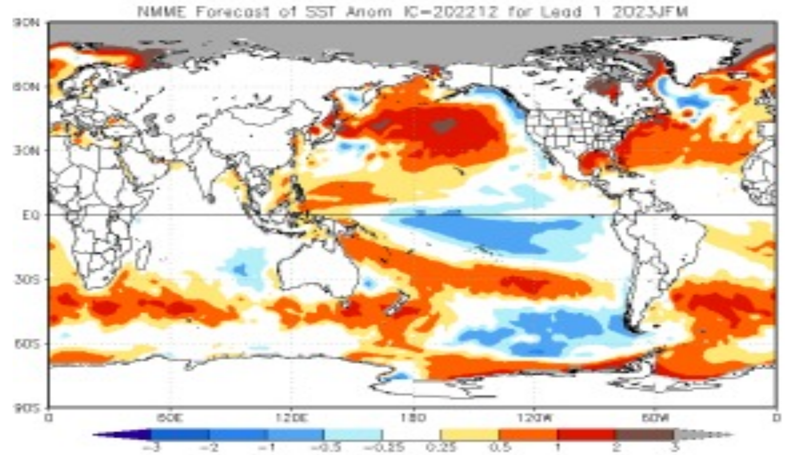
ENSO and Global SST Predictions

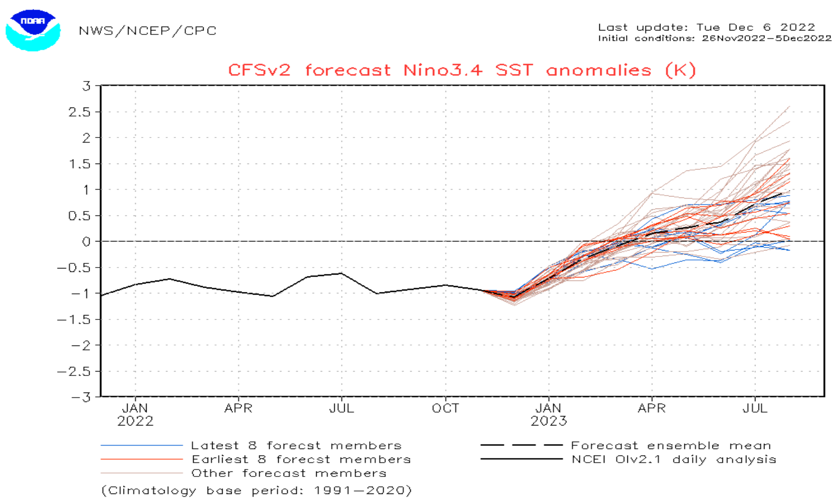
CFSv2 and NMME SST predictions

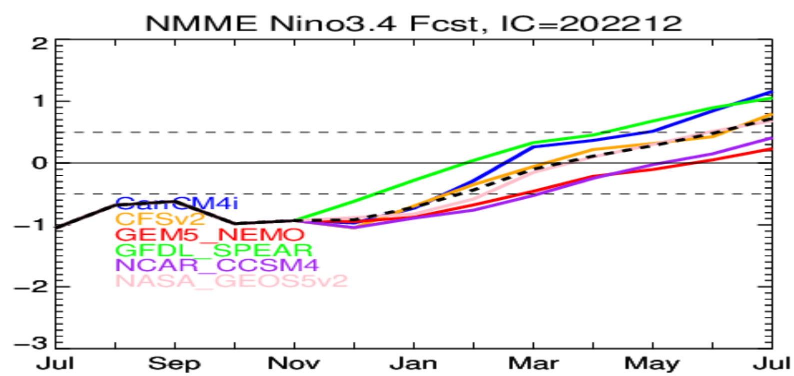
CFSv2 IC:Nov for 2022 JFM



NMME IC:Nov for 2022 JFM



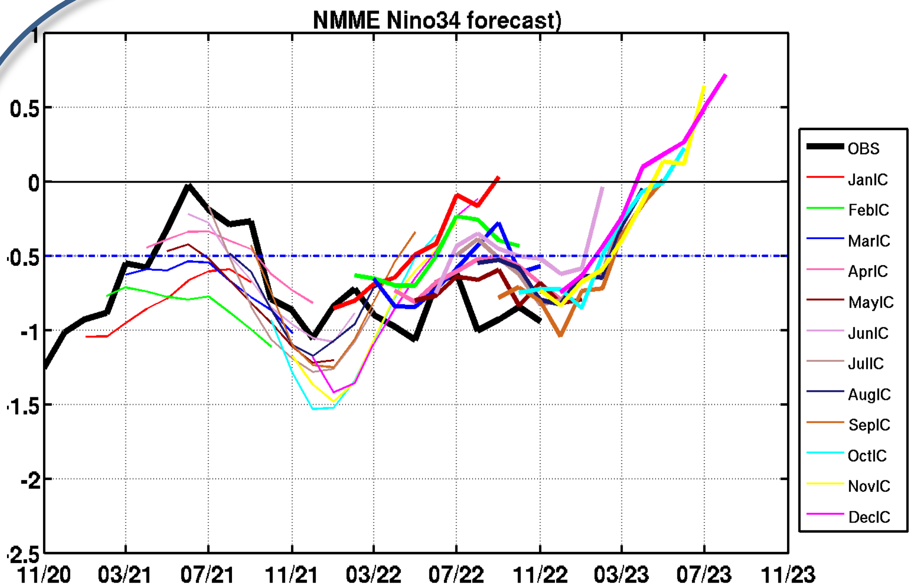


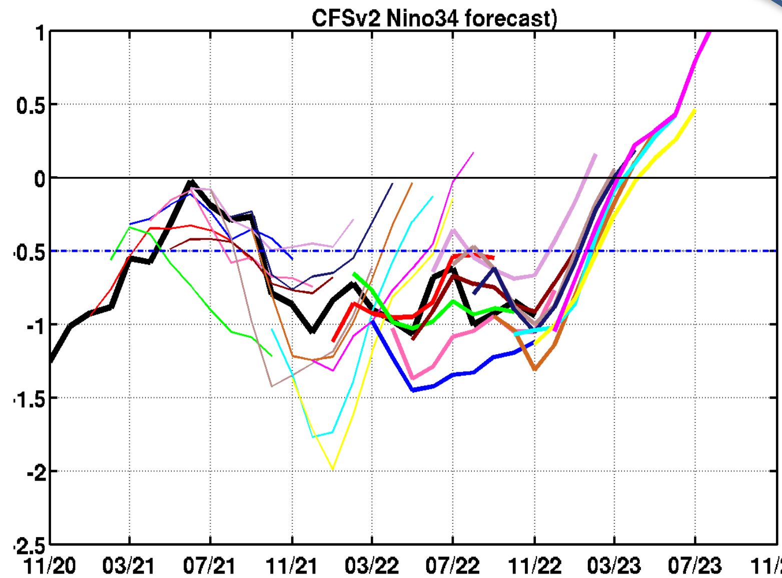


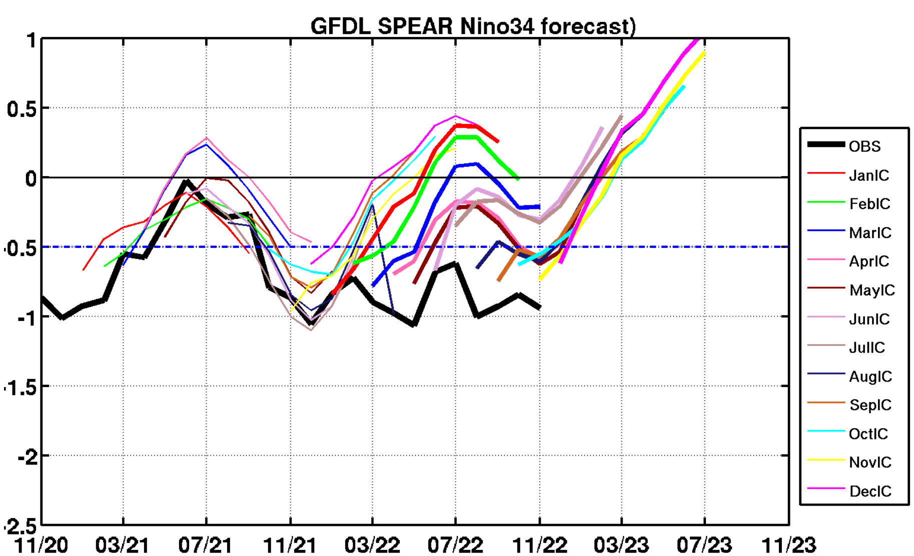
https://www.cpc.ncep.noaa.gov/products/CFSv2/CFSv2seasonal.shtml

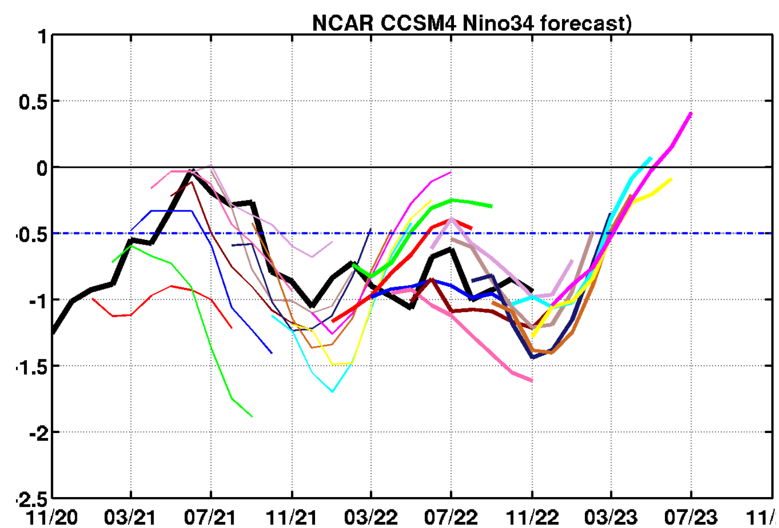
https://www.cpc.ncep.noaa.gov/products/NMME/

NMME Nino34 predictions

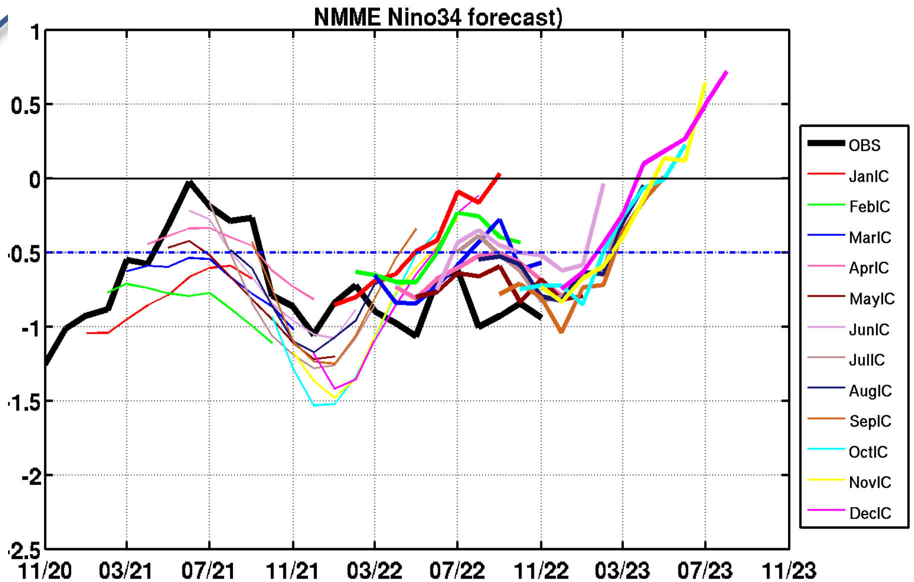


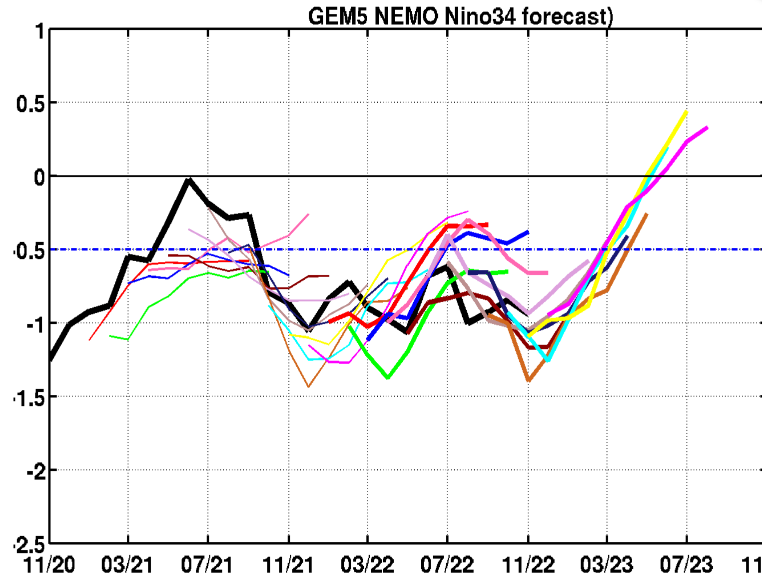


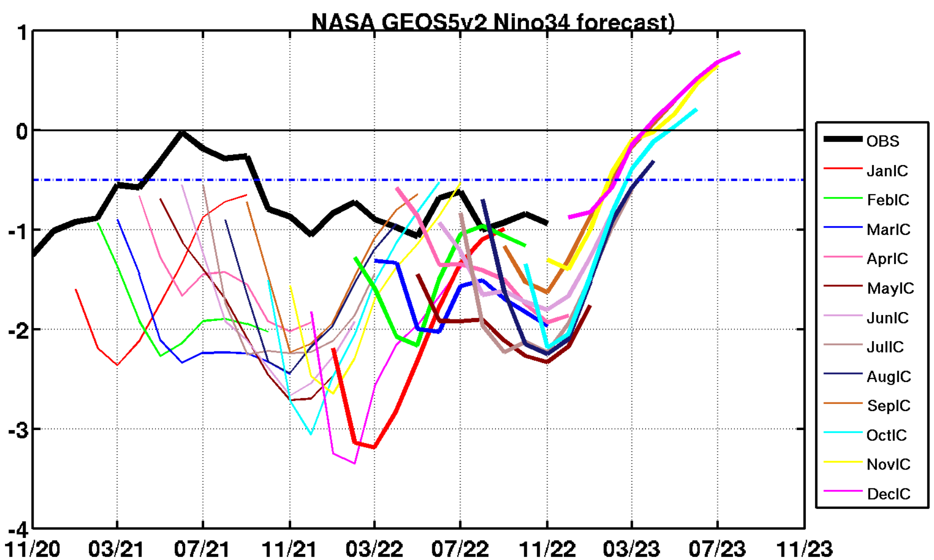


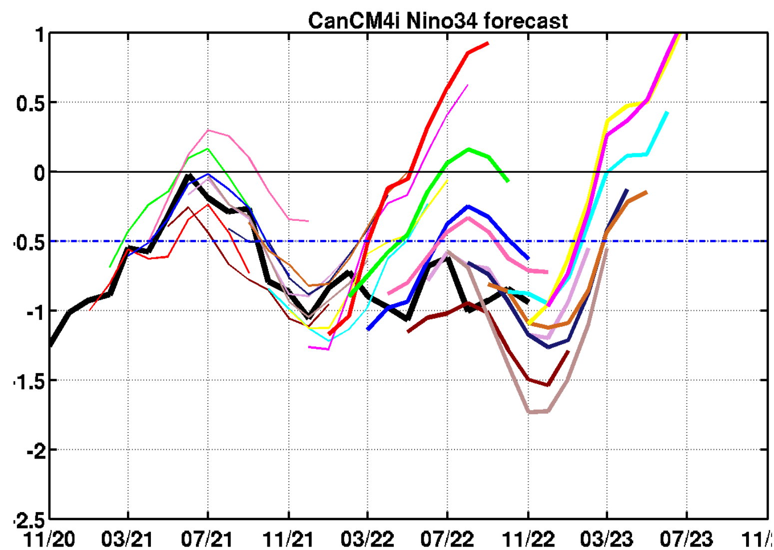


NMME Nino34 predictions

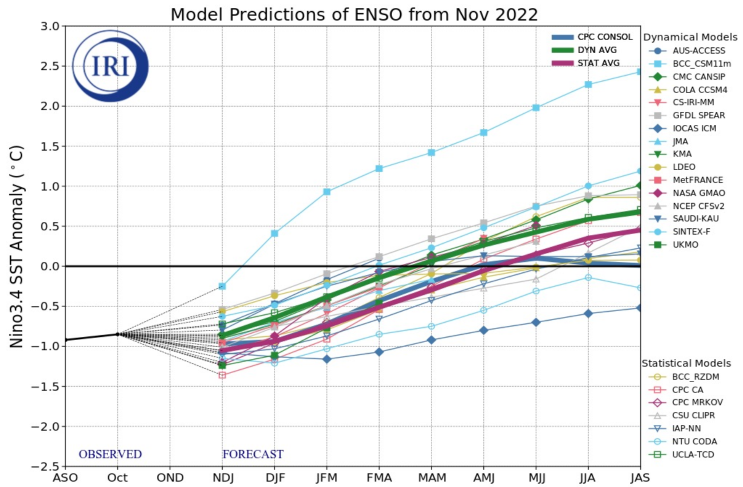


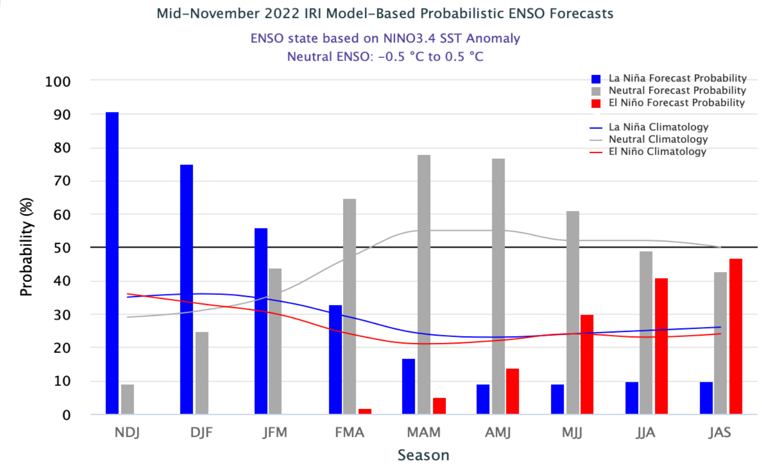






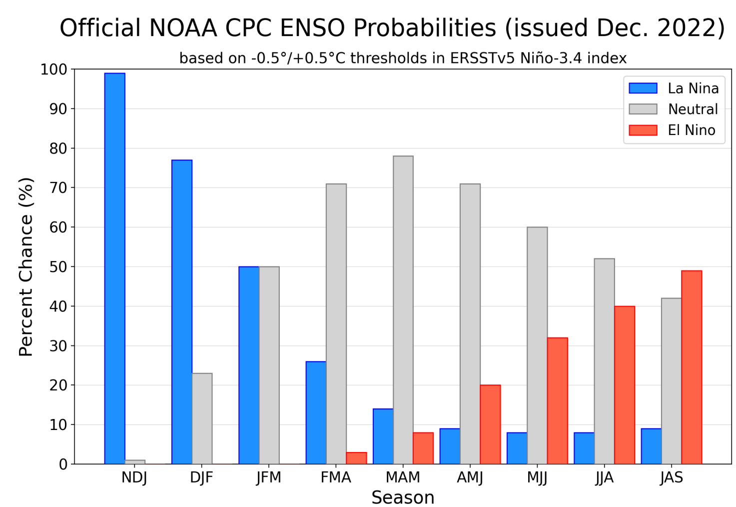
IRI/CPC Niño3.4 Forecast : Dec 2022



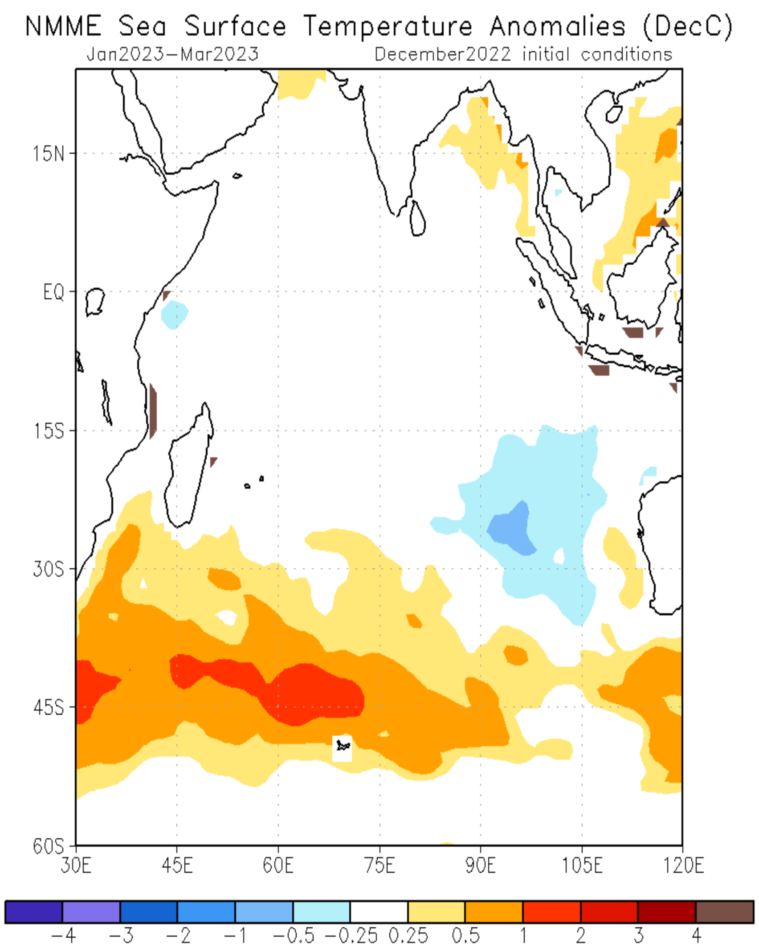


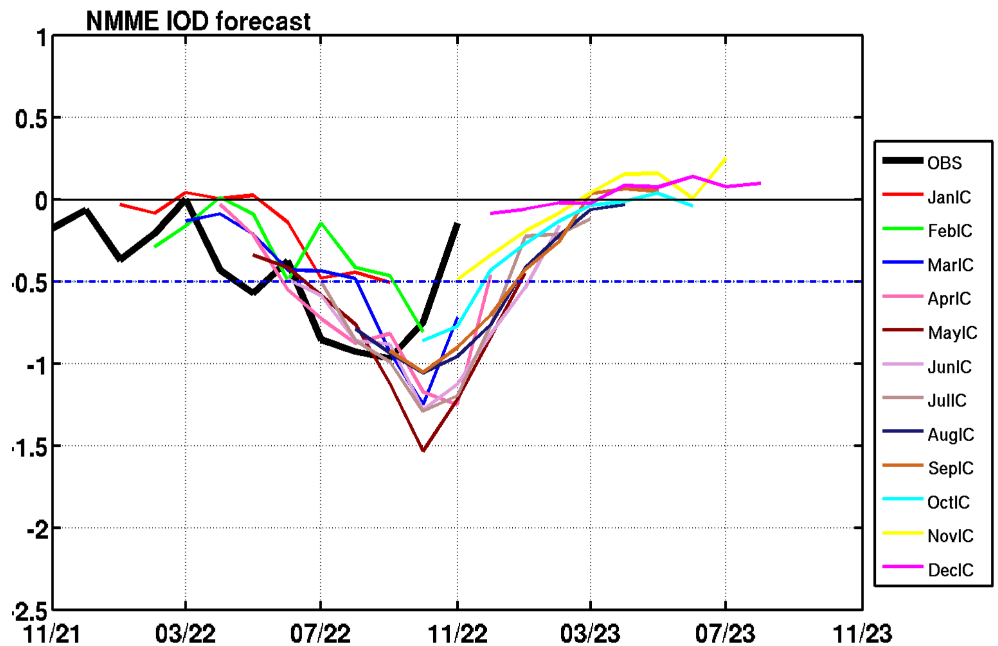
- A majority of models predict SSTs to remain below-normal at the level of a La Niña until Jan-Mar 2023 with a 56% chance.

- NOAA “ENSO Diagnostics Discussion” on 8 December stated that “La Niña is expected to continue into the winter, with equal chances of La Niña and ENSO-neutral during January-March 2023. In February-April 2023, there is a 71% chance of ENSO-neutral ”.



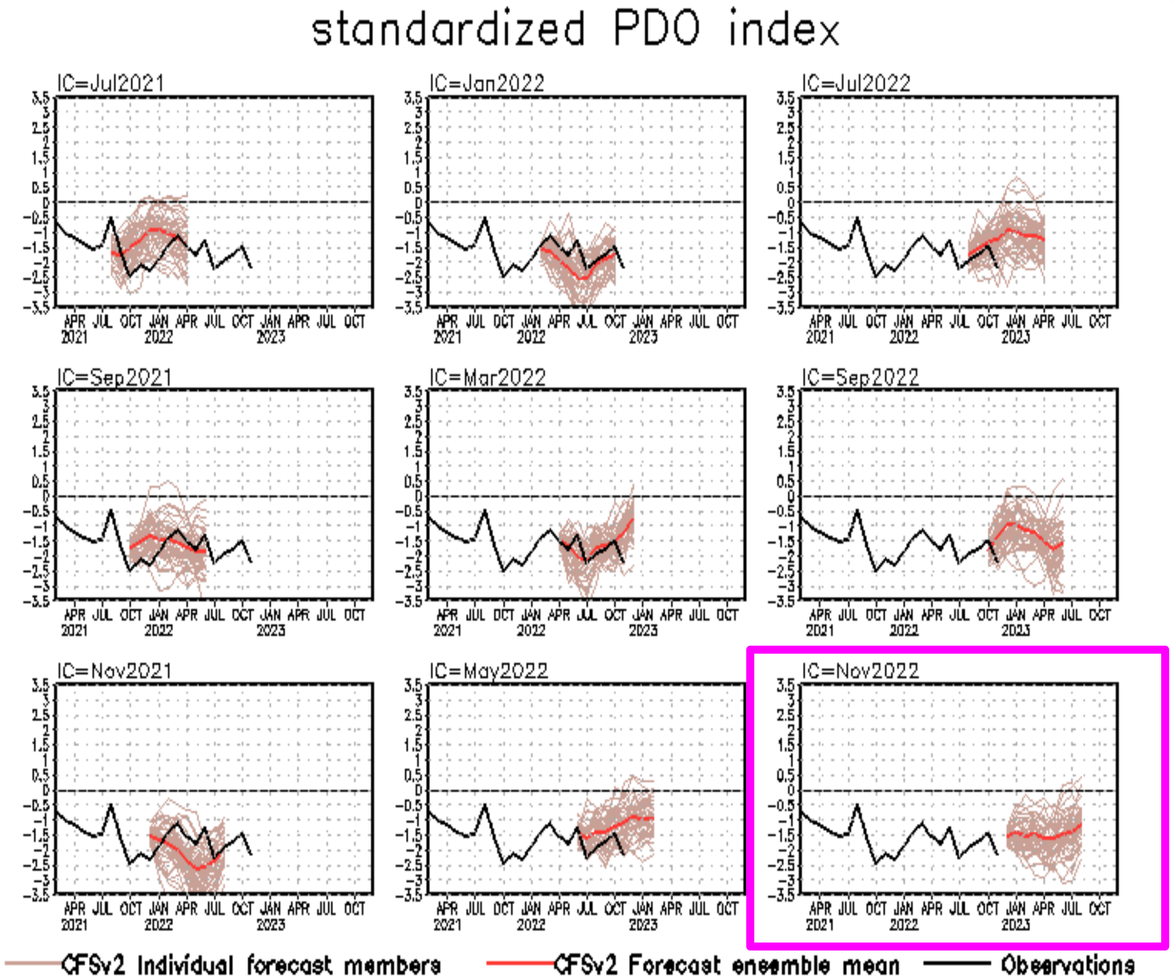
NMME Forecasts in the Indian Ocean





- NMME ensemble mean predict IOD will remain neutral through early summer 2023.

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



- Latest CFSv2 predicts the negative phase of PDO will continue through July 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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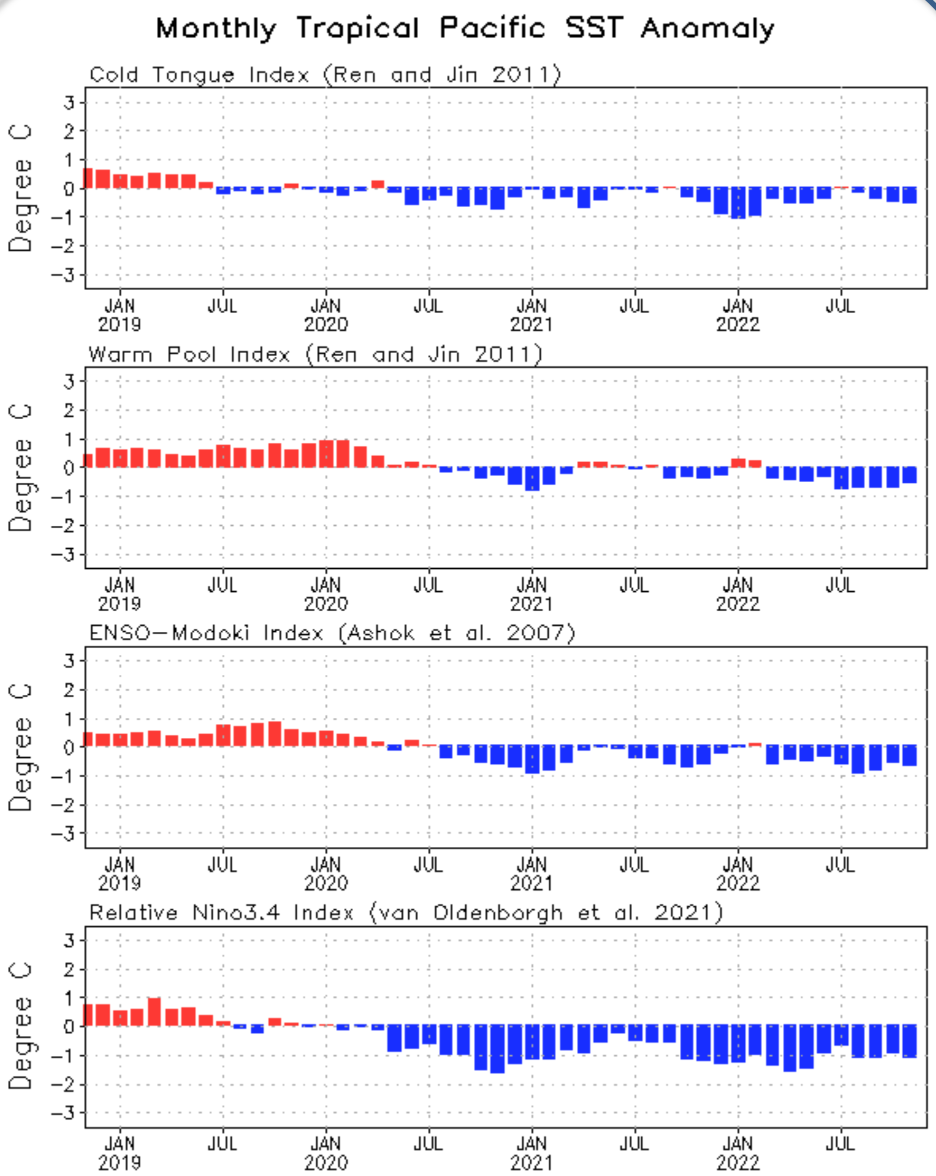
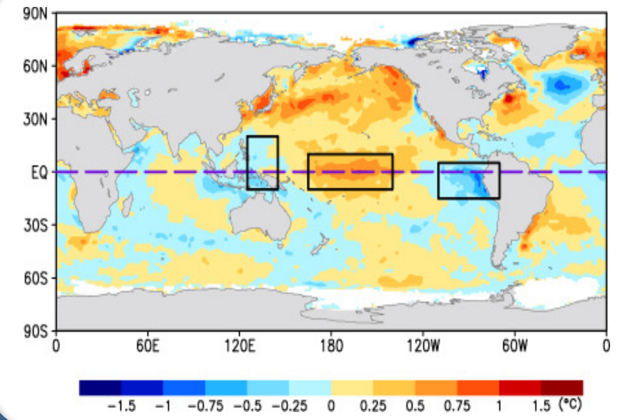
Zeng-Zhen.Hu@noaa.gov

Backup Slides

Evolution of Pacific Niño SST Indices



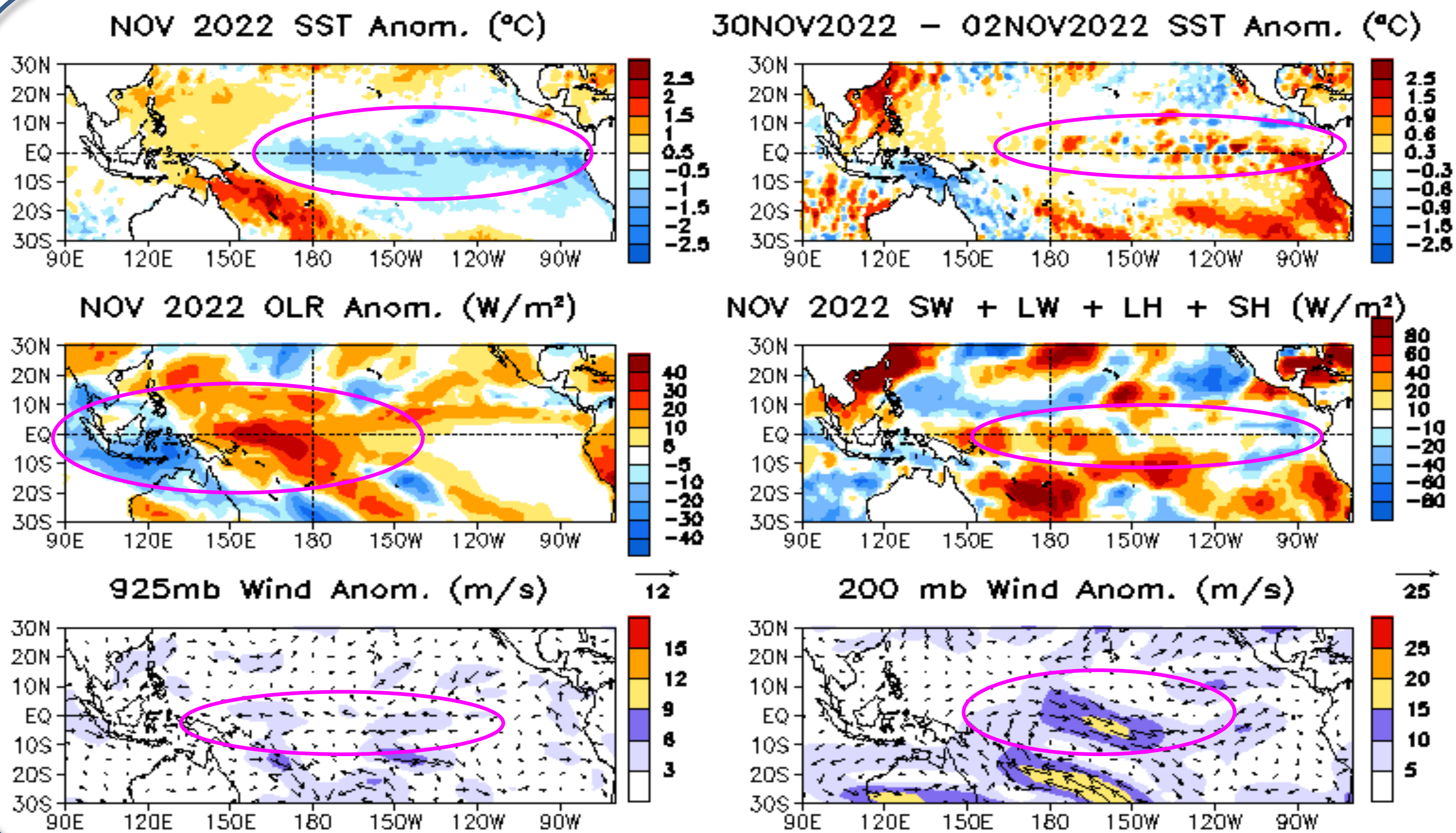


- Relative Niño3.4 index is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0º-360º, 20ºS-20ºN), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative Niño3.4 index is renormalized (van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

Relative Niño3.4 data updated monthly at:

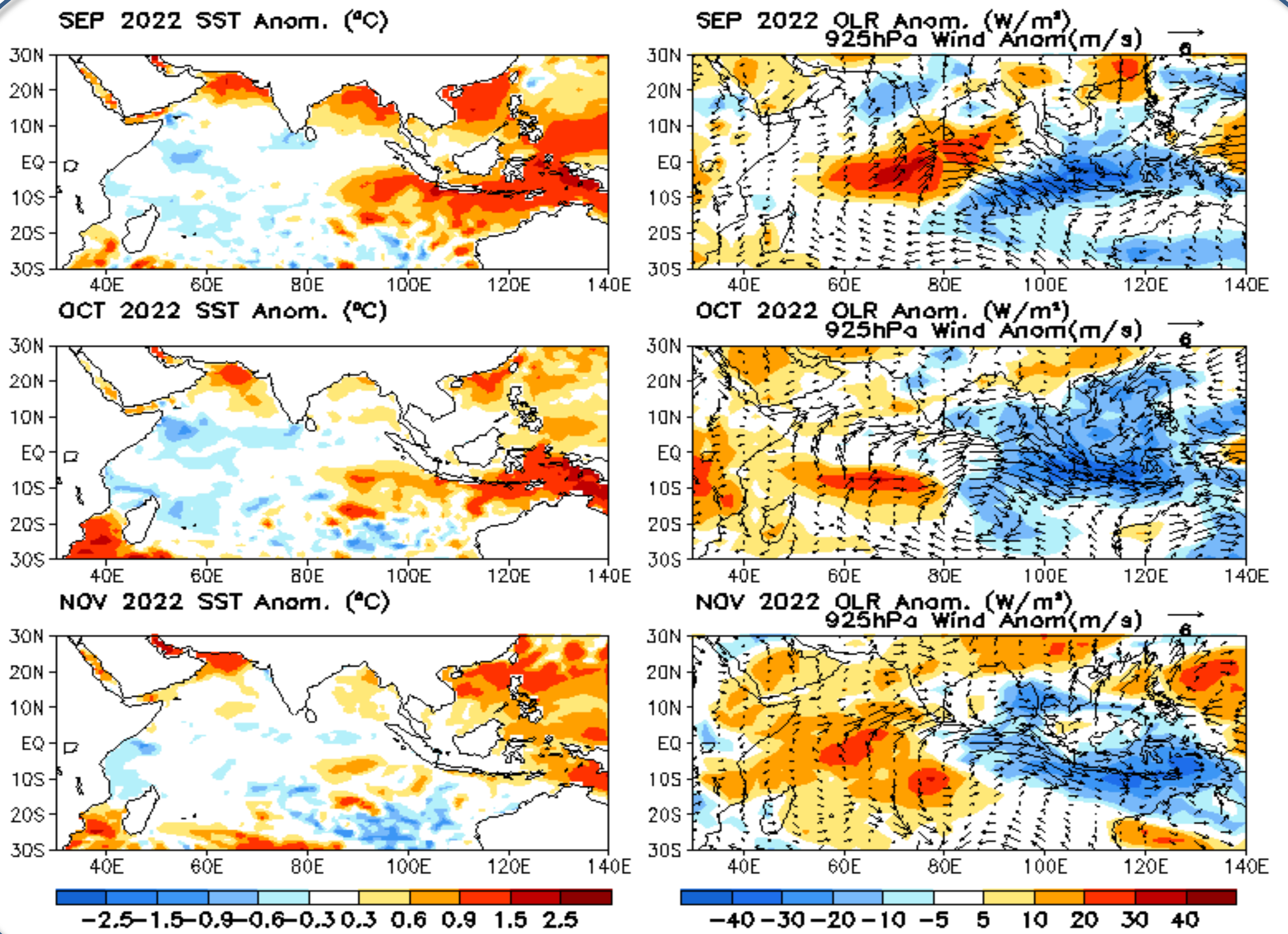
https://www.cpc.ncep.noaa.gov/data/indices/RONI.ascii.txt

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

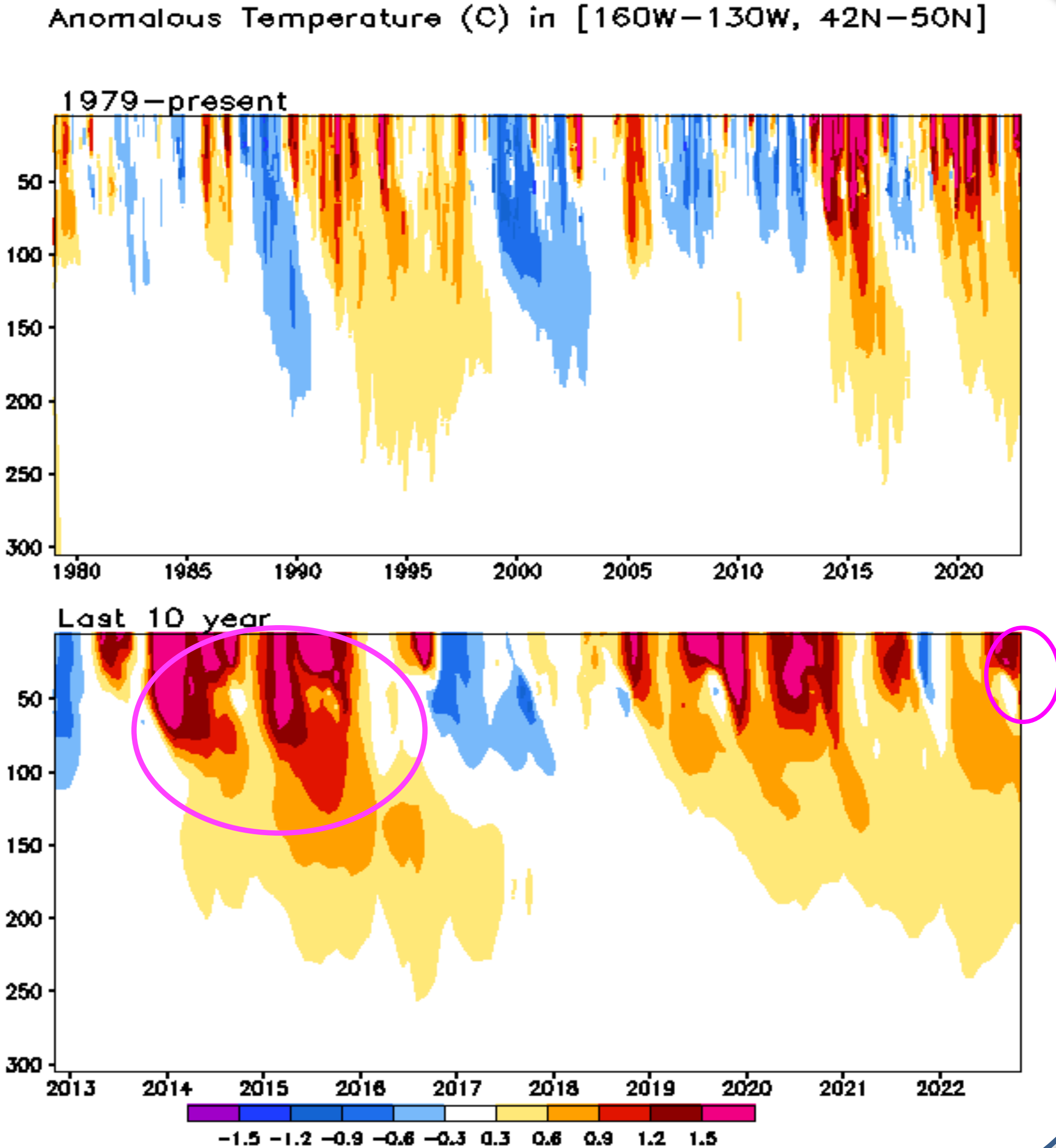


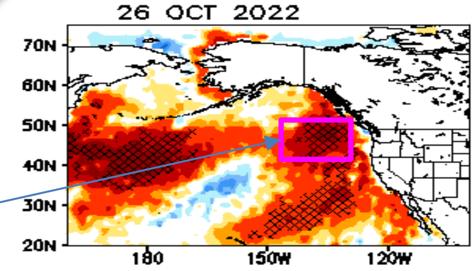
SSTAs (top-left), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly vector and its amplitude (bottom-left),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

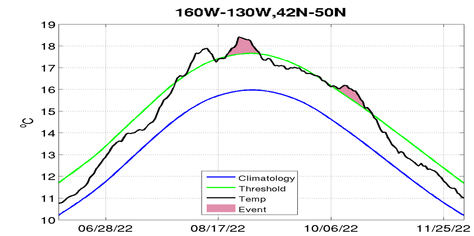
Last 3-month Tropical Indian SST , OLR & uv925 anomalies



Subsurface Temperature Anomaly in the Northeast Pacific (Pacific Blob)





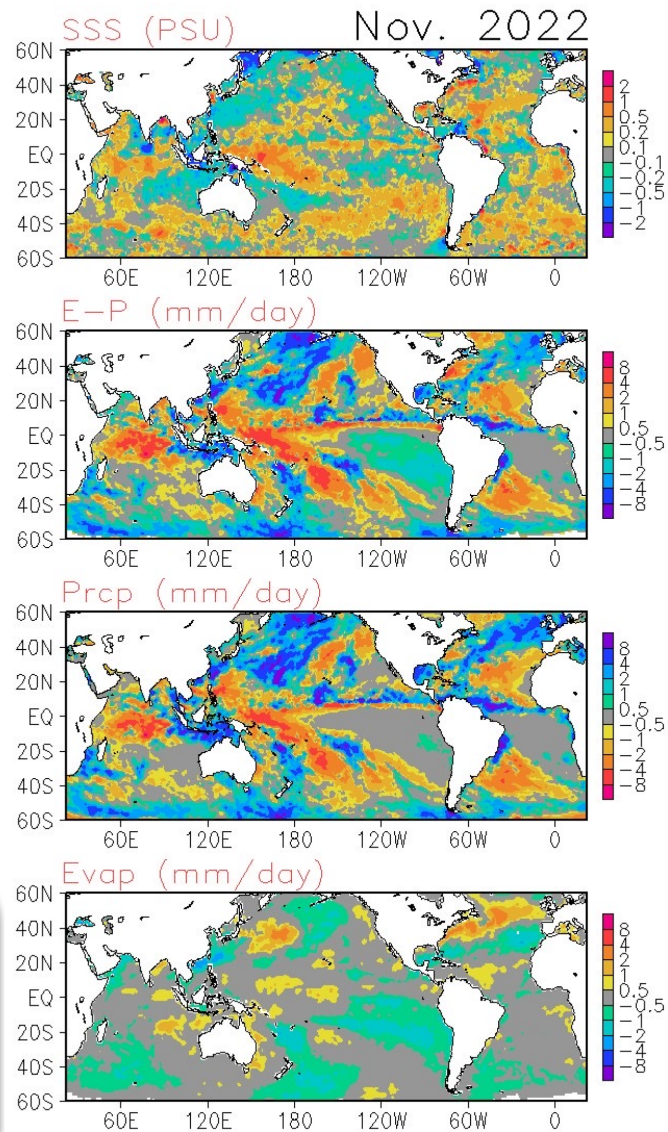


- Positive subsurface temperature anomaly (>0.9ºC) was confined in the upper 50m in Nov 2022.
- Subsurface warming was strongest during 2014-2016 (Pacific Blob).

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

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

The negative precipitation anomalies contribute to the anomalously positive oceanic freshwater flux (E-P) over the Central and West Indian Ocean, resulting in an anomalously salty ocean in that region. Enhanced evaporation occurs over the Mid-Atlantic Bight, which is likely contributing to a saltier ocean in that area. The negative precipitation anomalies over major portions of the Central and West Equatorial Pacific Ocean are a major contributor to the anomalously positive freshwater flux, resulting in a saltier ocean in that region.



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

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

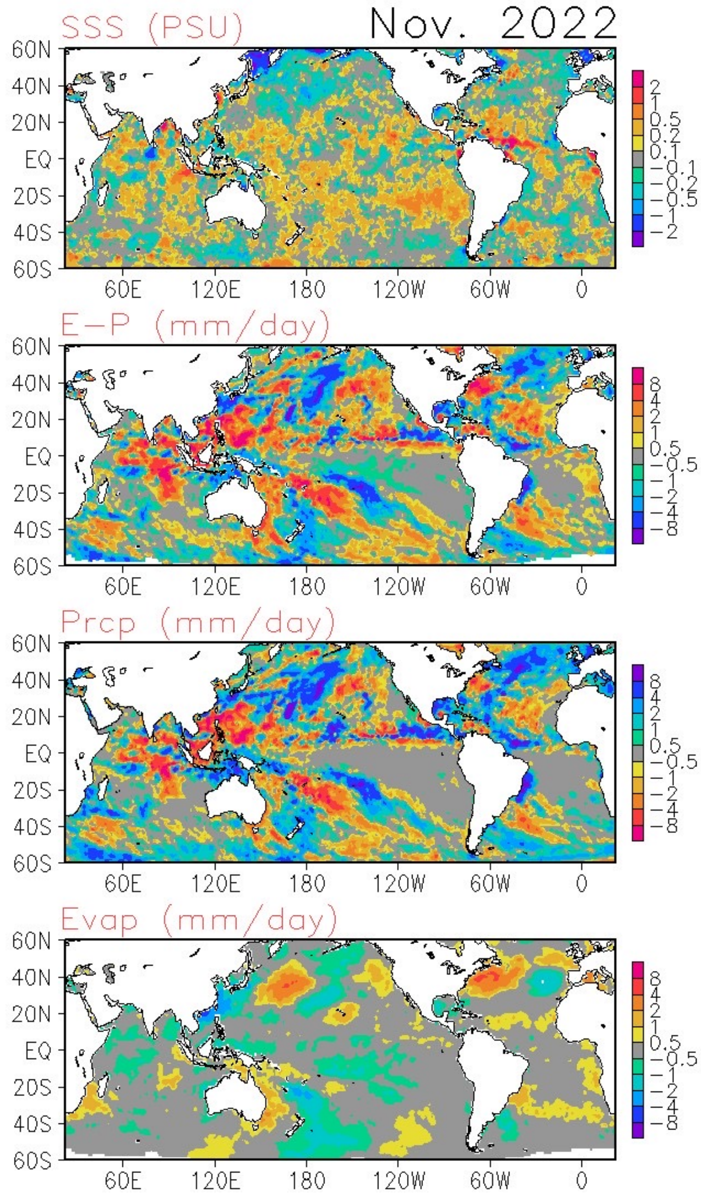
ftp.cpc.ncep.noaa.gov/precip/BASS

Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: Adjusted CFS Reanalysis

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

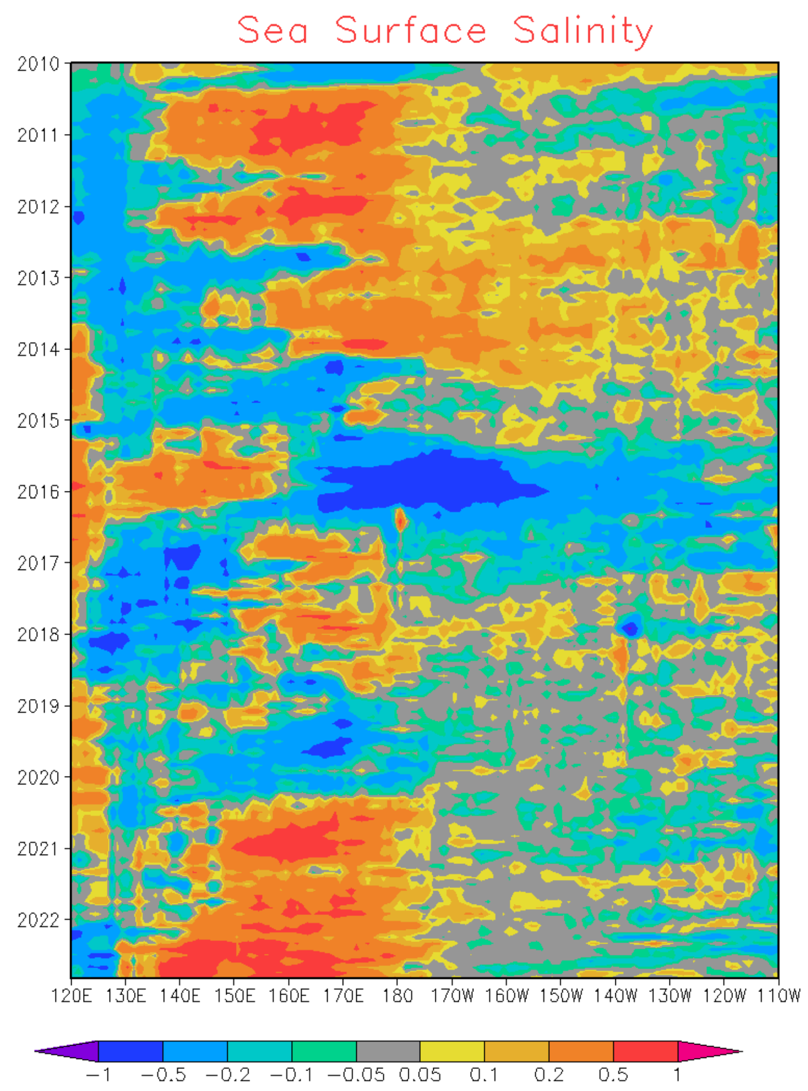
Large-scale SSS tendencies are not well organized compared to the corresponding monthly anomalies. A fresher SSS tendency can be observed over the Sea of Okhotsk, while a saltier SSS tendency can be observed over many parts of the equatorial Atlantic Ocean. The Mid-Atlantic Bight is experiencing a positive oceanic freshwater flux tendency, which is because of the enhanced evaporation and negative precipitation tendencies in that region.



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.

- Hovmoller diagram for equatorial SSS anomaly **(5˚S-5˚N);**
- Positive SSS anomalies continued and enhanced over the Central and Western Equatorial Pacific between 140ºE and 170ºW. Weak positive SSS anomalies emerged over parts of the East Pacific between 125ºW and 155ºW.



Pentad SSS Anomaly Evolution over Equatorial Pacific

Figure caption: Hovmoller 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.