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

Prepared by

Climate Prediction Center, NCEP/NOAA

July 11, 2022

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**

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

Overview

•Pacific Ocean

- La Niña condition persisted while negative Niño3.4 decreased by 0.4℃ in Jun 2022.
- The PDO has been in a negative phase since Jan 2020 with PDOI = -1.3 in Jun 2022.
- Marine Heat Waves (MHWs) persisted in the N.C. Pacific, while dissipated in the N. E. Pacific.

•Arctic Ocean

- Averaged Arctic sea ice extent for June ranked the 10th lowest in the satellite record.

•Indian Ocean

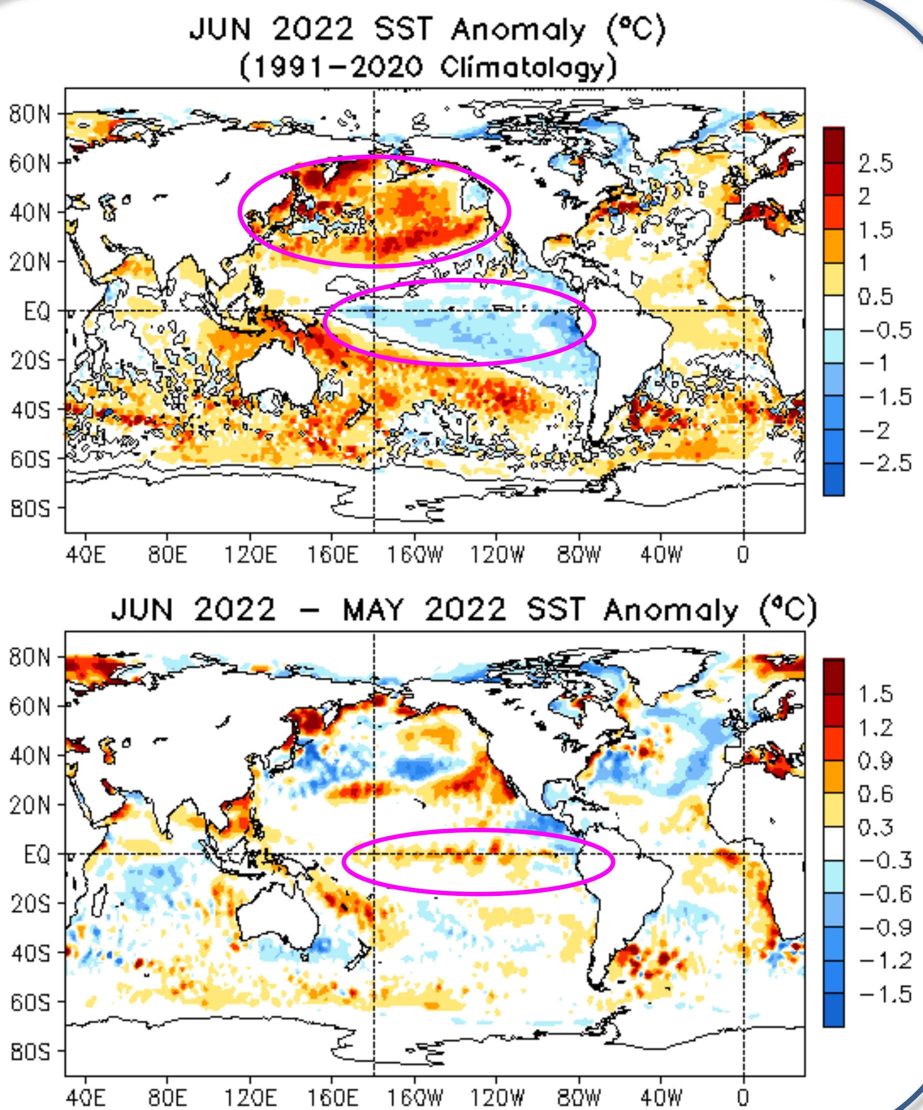
- Positive SSTA persisted in the southeastern tropical Indian Ocean in Jun 2022.
- All NMME models favor a negative IOD event during the northern hemisphere summer-fall 2022.

•Atlantic Ocean

- Positive SSTAs were observed in the equatorial Atlantic region.
- On May 24, 2022, NOAA CPC predicted above-normal 2022 Atlantic Hurricane Season.
- NMME models predicted above or nearly above average SSTs to persist in the Hurricane main development region through the whole 2022 hurricane season.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency

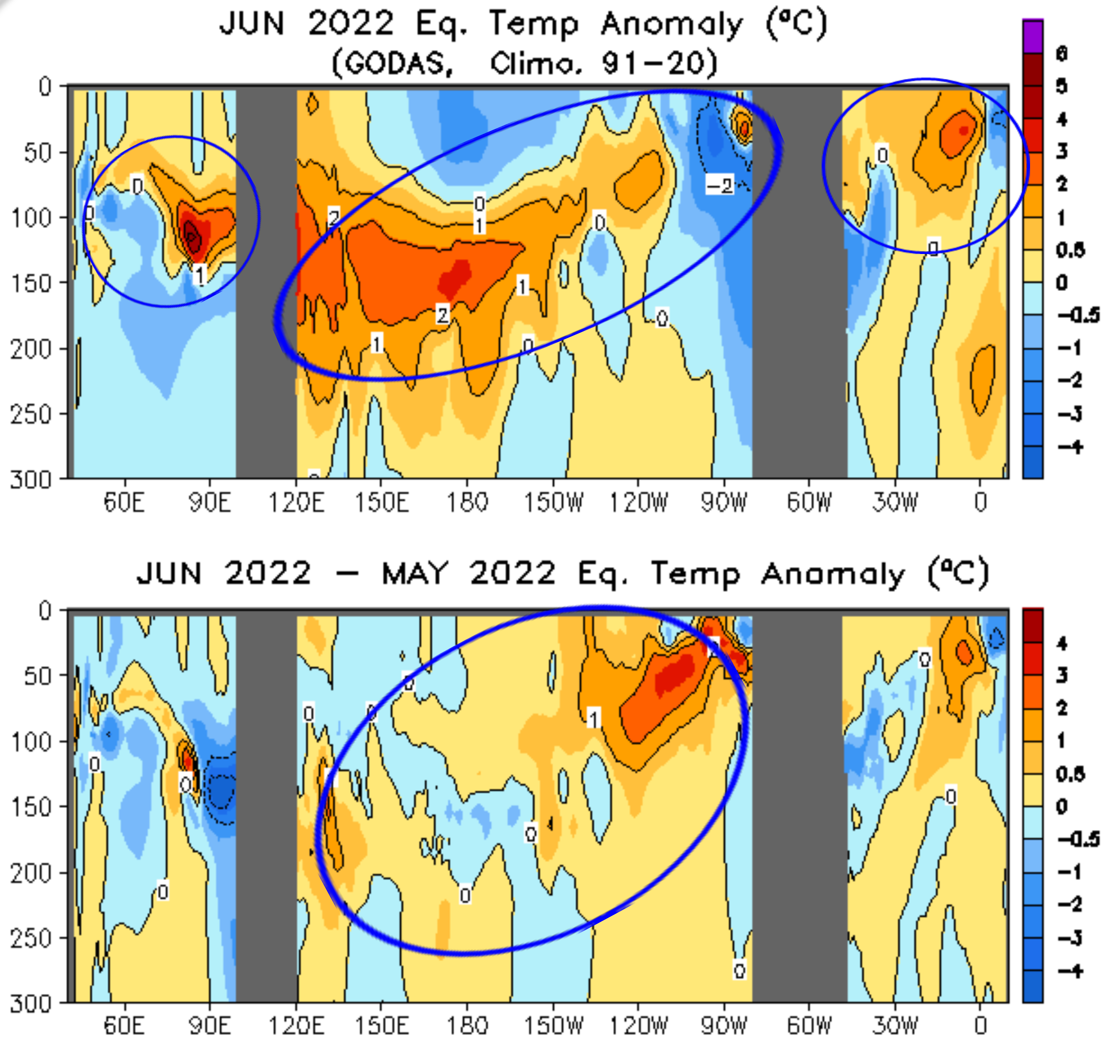


- Equatorial SSTs were below average across most of the Pacific Ocean.
- Positive SSTAs dominated the North Pacific.
- SSTs were above-average in most of the Atlantic Ocean.

- Positive SSTA tendencies were observed in the central-eastern equatorial Pacific.
- Both positive and negative SSTA tendencies were observed in the North Pacific.
- Negative SSTA tendency dominated in the northern Atlantic Ocean.
- Positive SSTA tendencies were present in the equatorial 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.

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



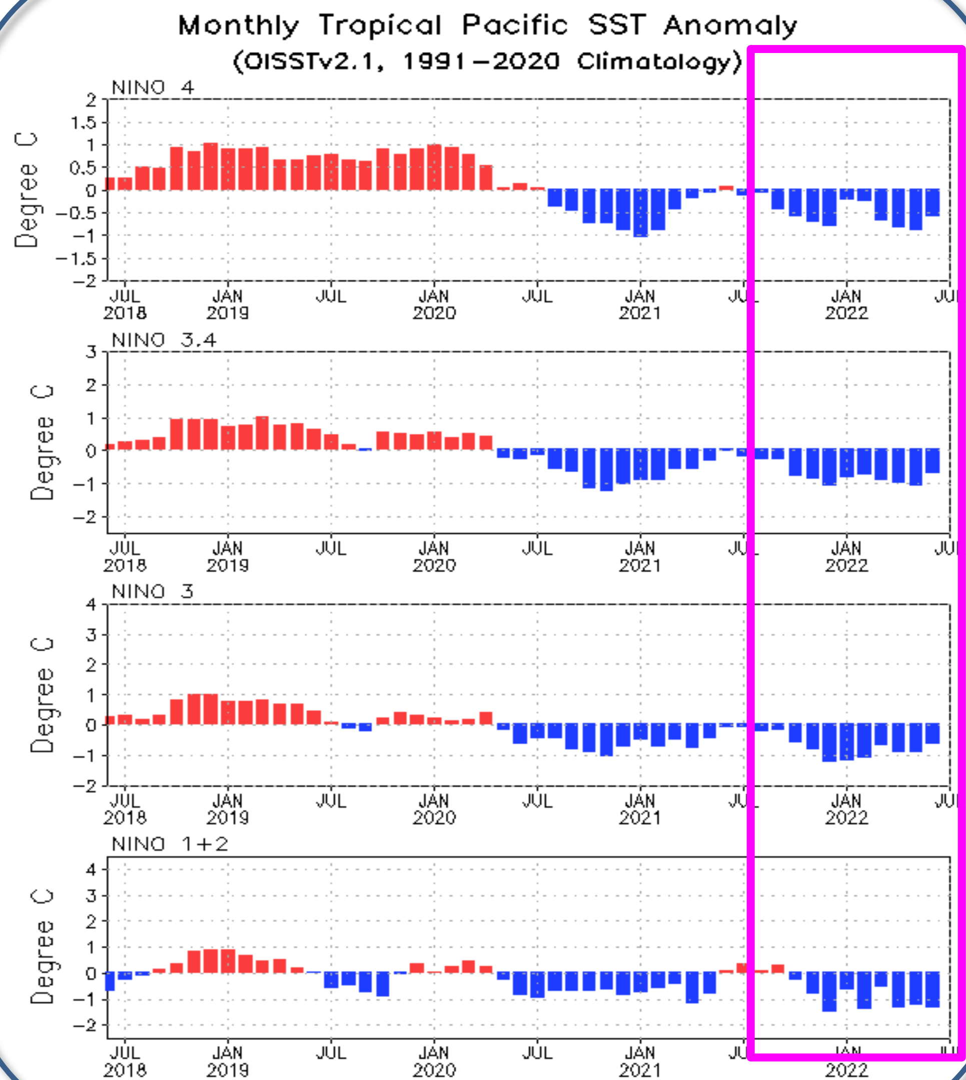
- Positive temperature anomalies were observed along most of the thermocline in the Pacific Ocean.
- Positive temperature anomalies dominated the upper 100m of equatorial Atlantic Ocean.
- Large positive temperature anomalies persisted in the eastern equatorial Indian Ocean.

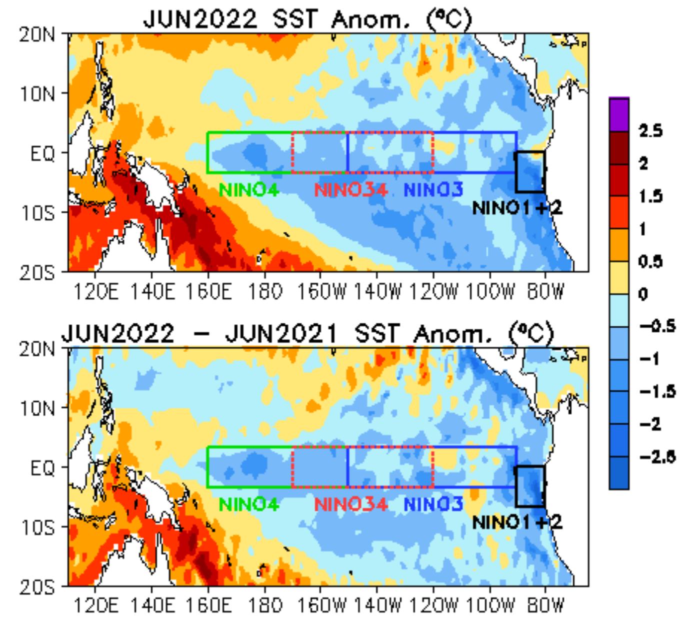
- Positive temperature anomaly tendency was observed along most of the equatorial thermocline in the Pacific Ocean.

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.

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific Niño SST Indices

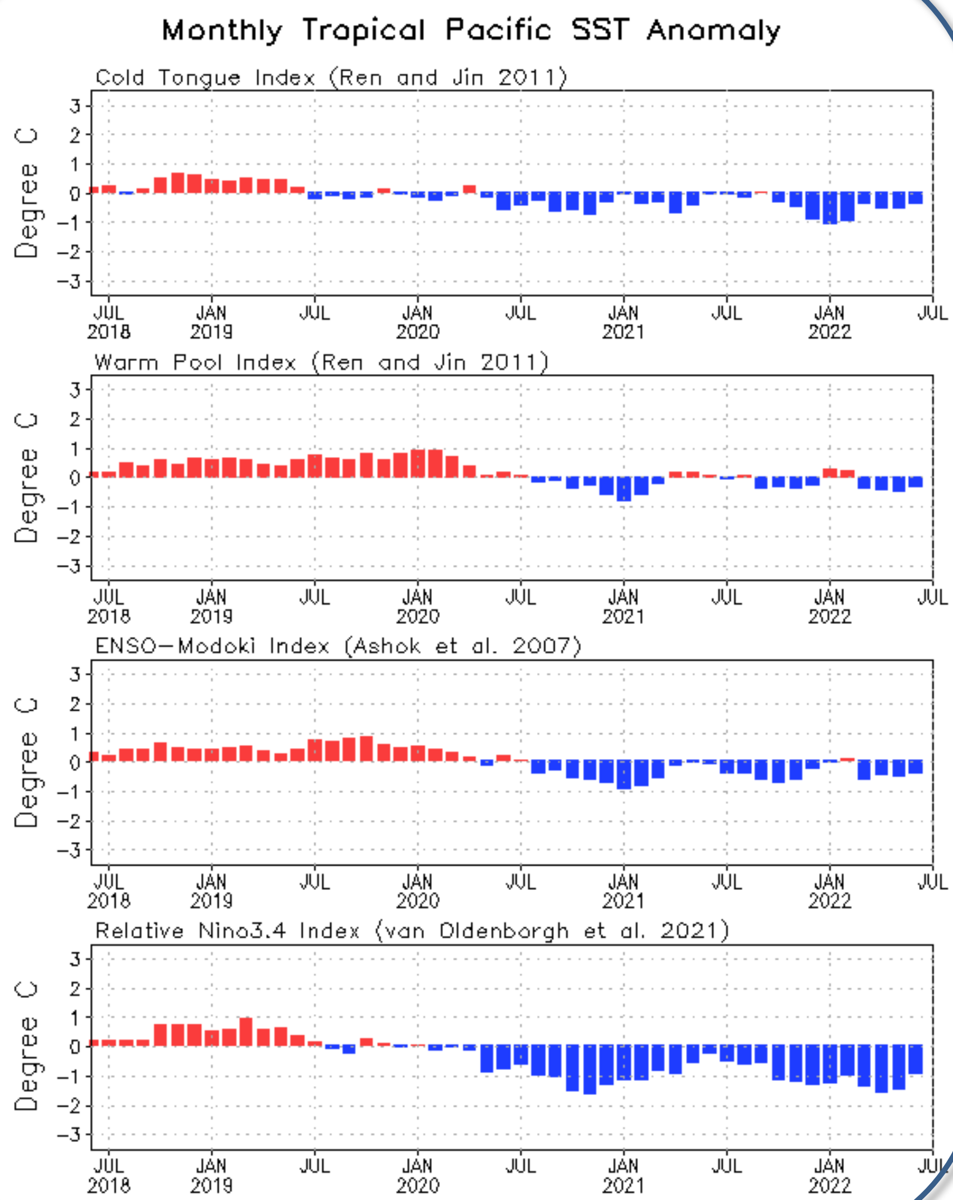


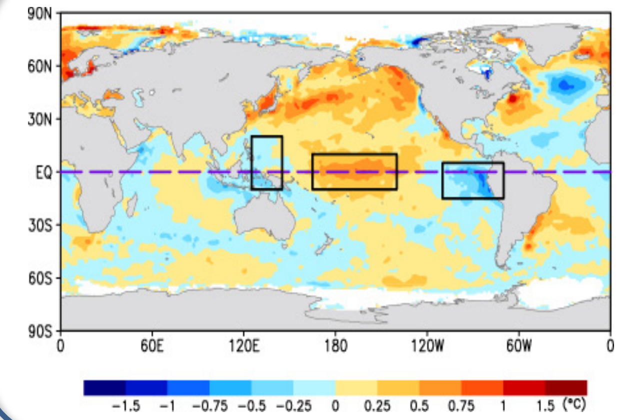


- All Niño indices stayed cold in Jun 2022.
- Negative Niño3.4 decreased substantially in June, with Niño3.4 = -0.7C.
- Compared with Jun 2021, the central-eastern and southeastern tropical Pacific was cooler in Jun 2022.
- The indices may have slight differences if based on different SST products.

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.

Evolution of Pacific Niño SST Indices



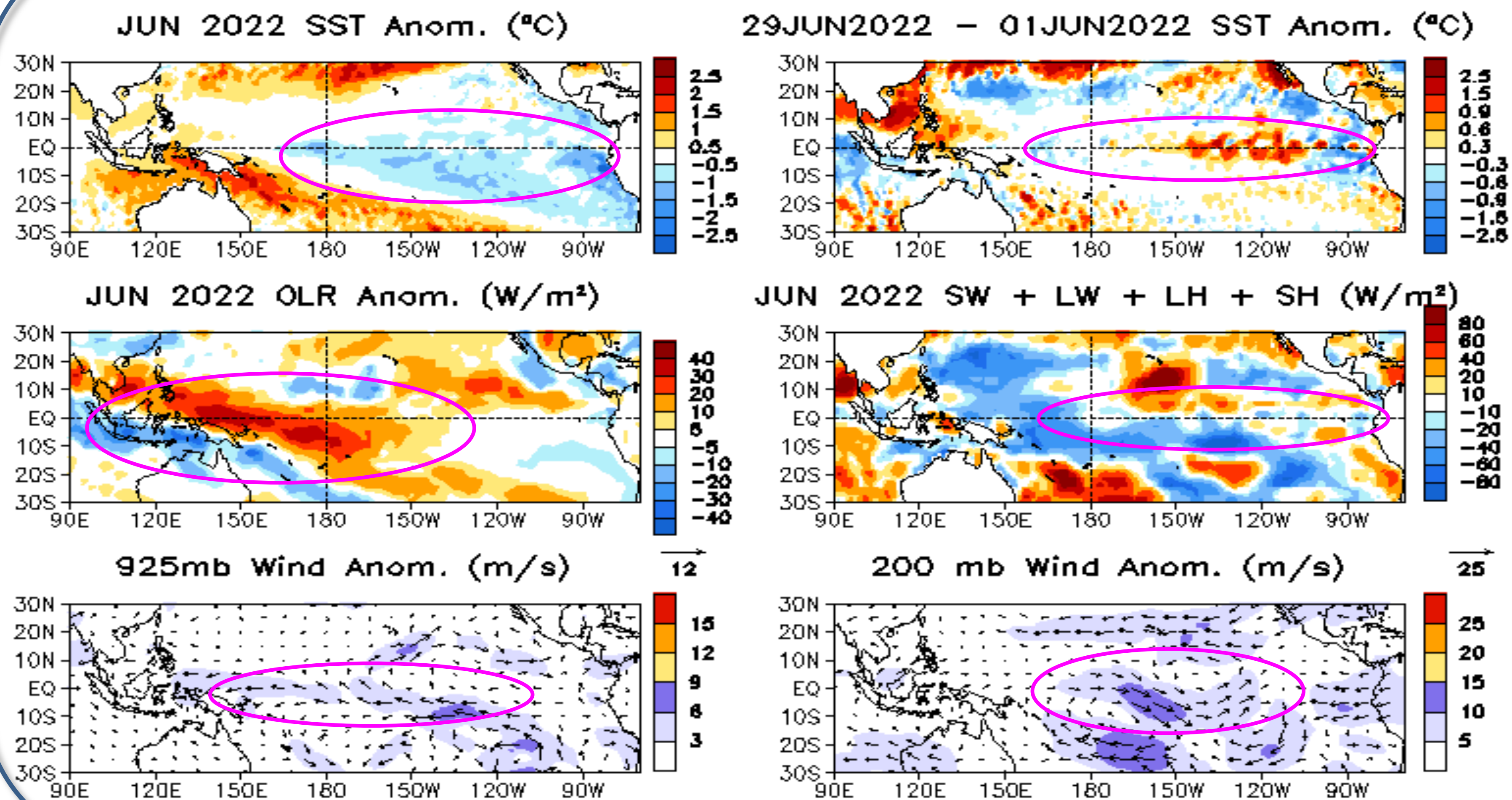


- Relative Niño3.4 index is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0º-360º, 20ºS-20ºN), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative Niño3.4 index is renormalized (van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

Relative Niño3.4 data updated monthly at:

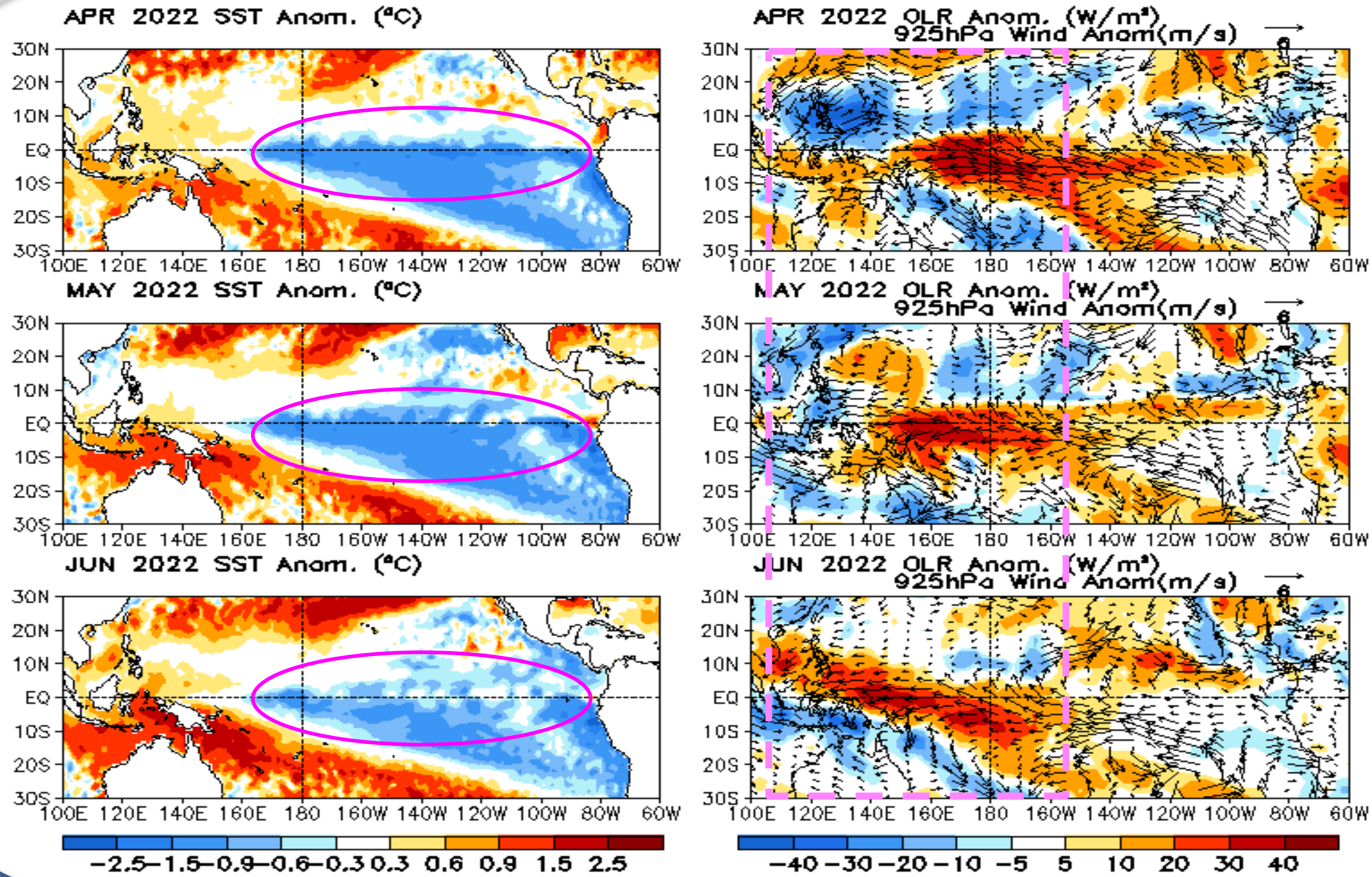
https://www.cpc.ncep.noaa.gov/data/indices/RONI.ascii.txt

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



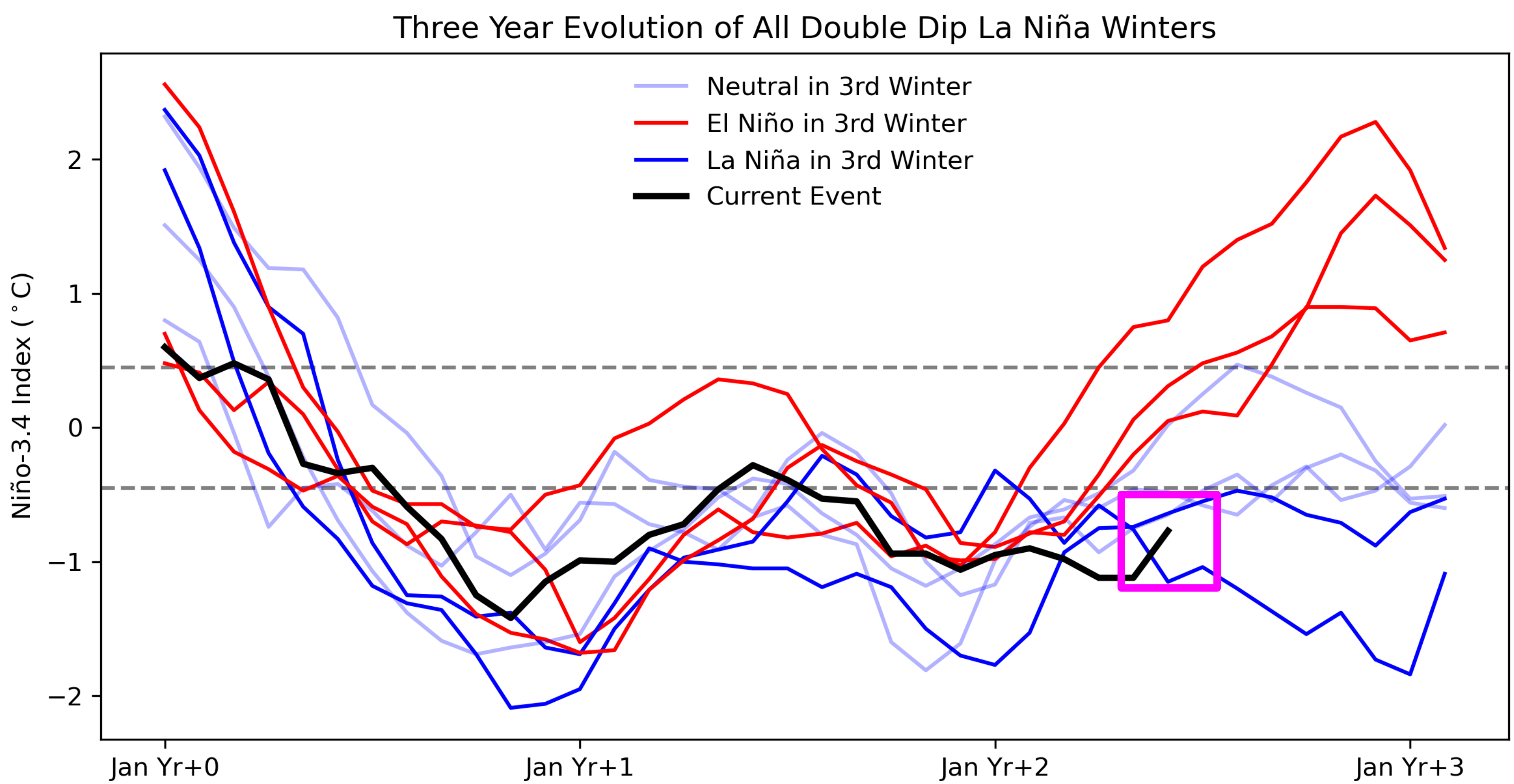
SSTAs (top-left), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly vector and its amplitude (bottom-left), 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 three months SST, OLR and uv925 anomalies



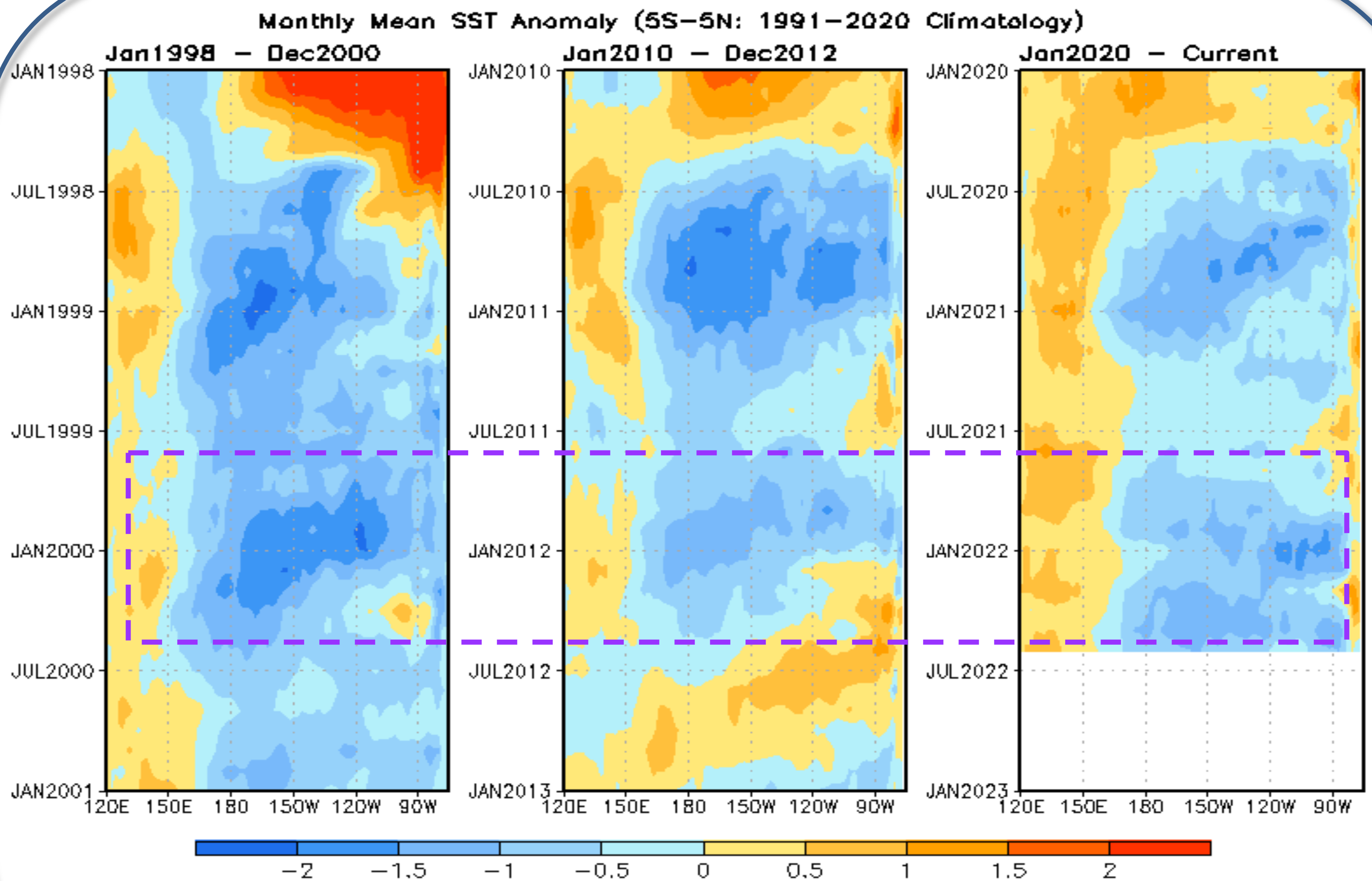
SSTAs (top-left), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly vector and its amplitude (bottom-left),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

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



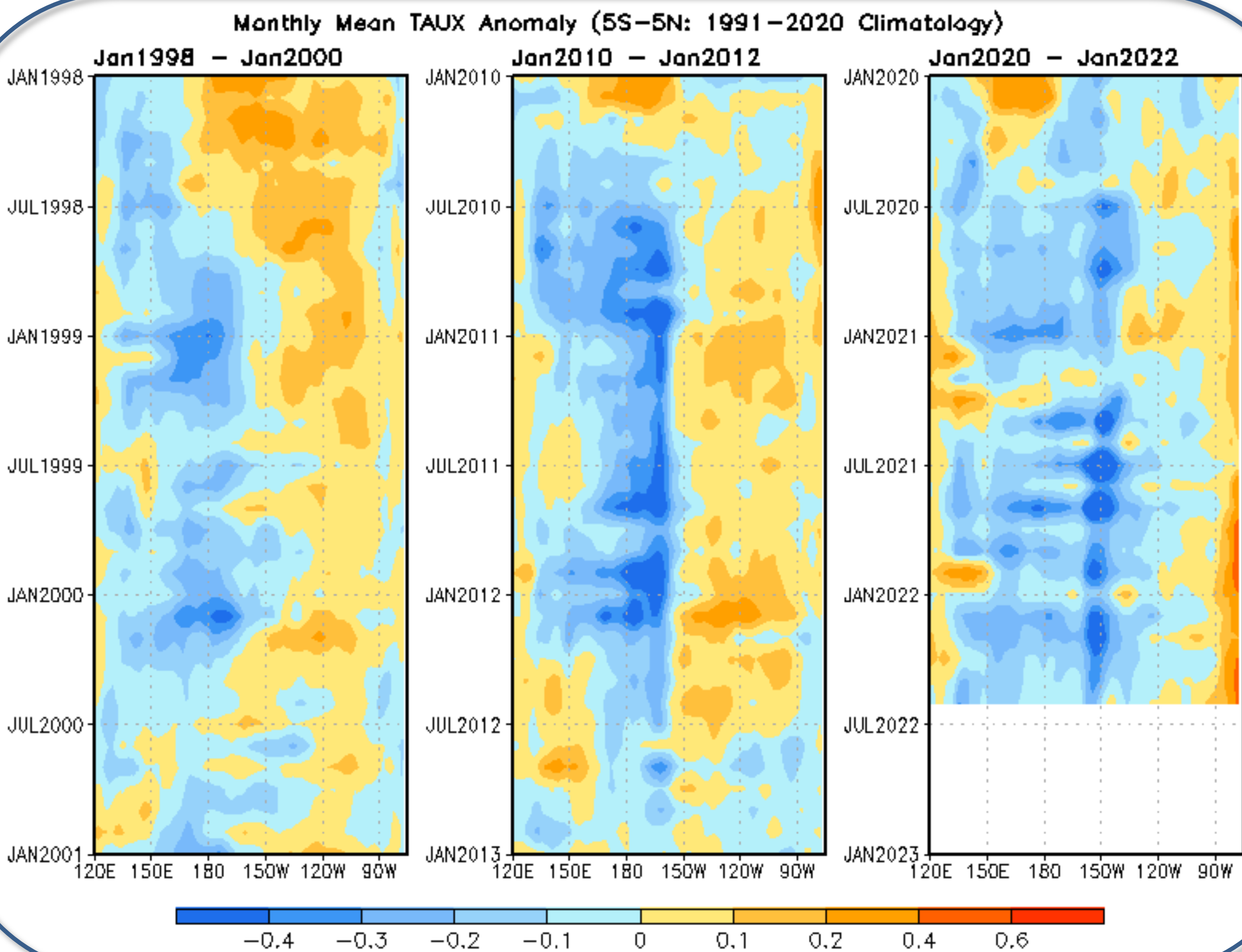
Three-year history of sea surface temperatures in the Niño-3.4 region of the tropical Pacific for 8 previous double-dip La Niña events. The color of the line indicates the state of ENSO for the third winter (red: El Niño, darker blue: La Niña, lighter blue: neutral). The black line shows the current event. Monthly Niño-3.4 index is from CPC using ERSSTv5.

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



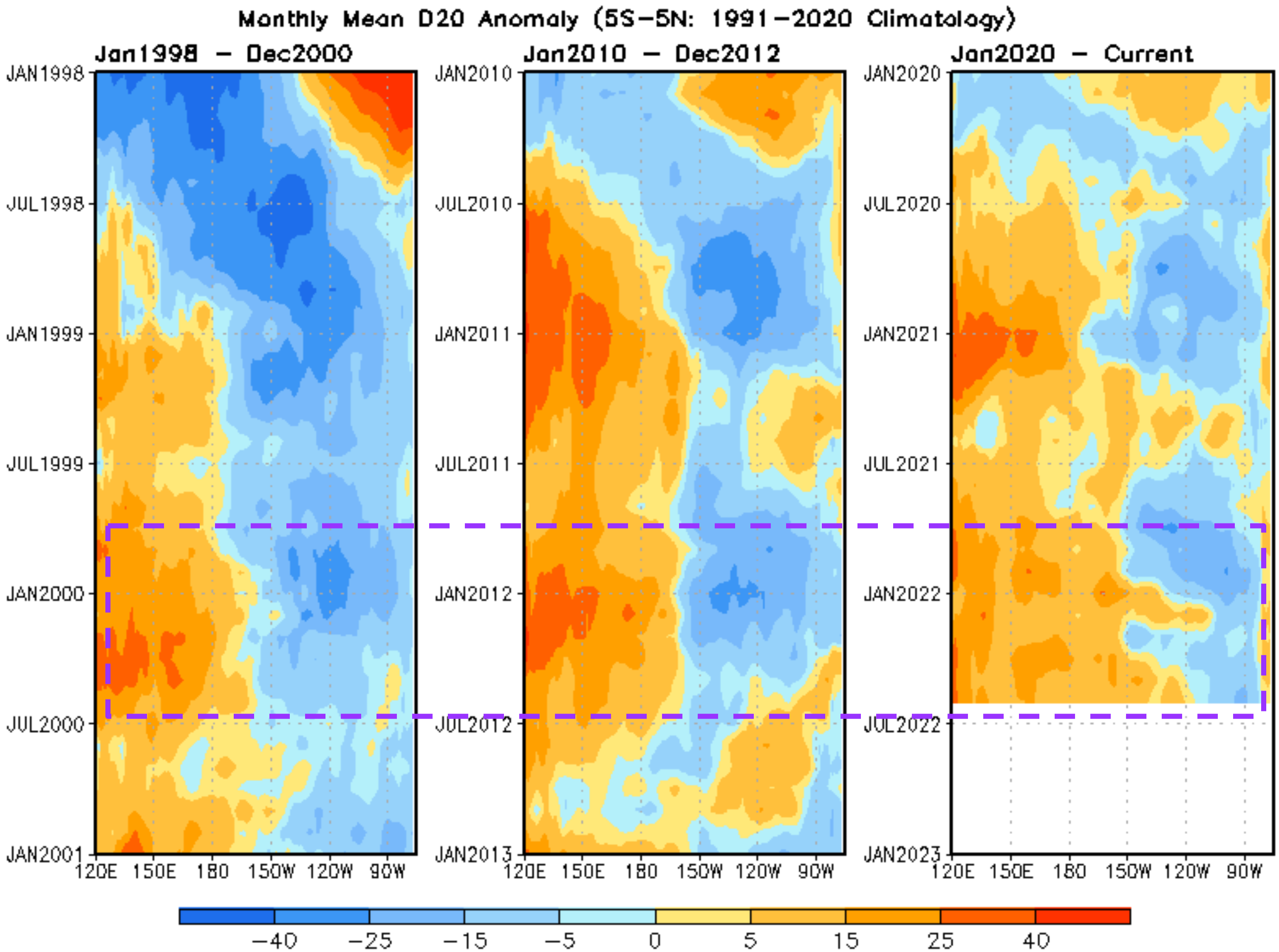
Data source: NCEP R2 reanalysis

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



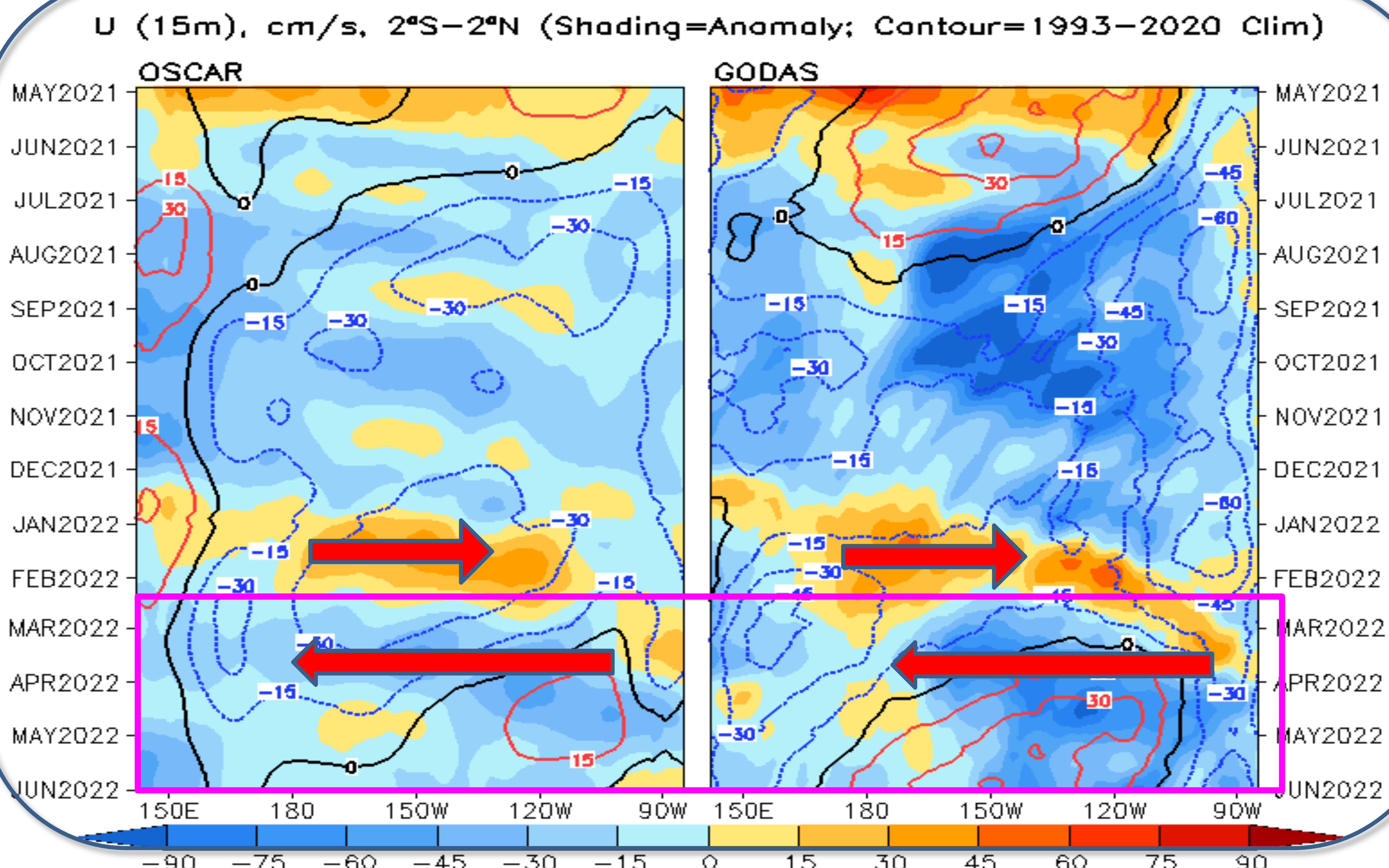
Data source: NCEP R2 reanalysis

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



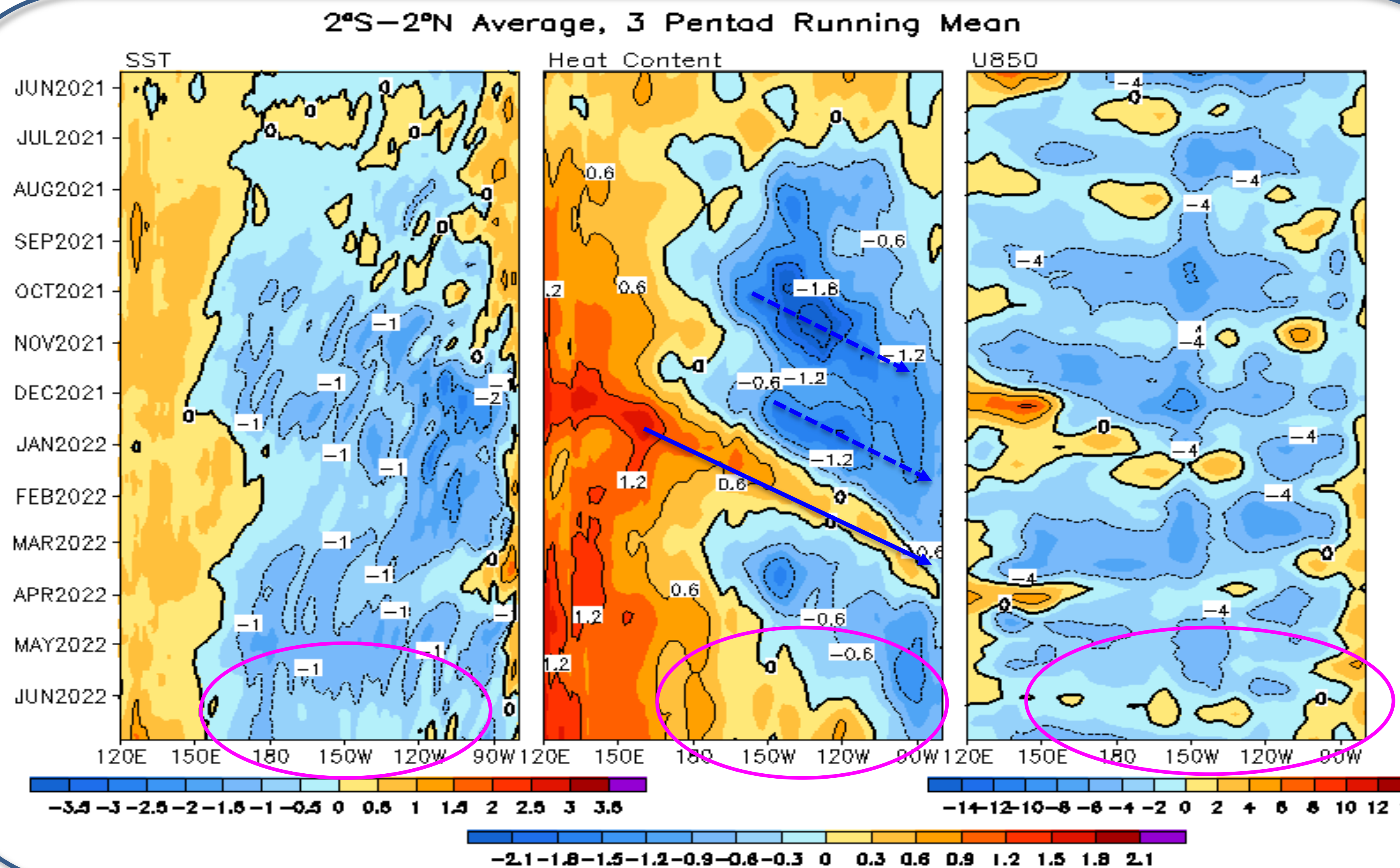
Data source: NCEP GODAS

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



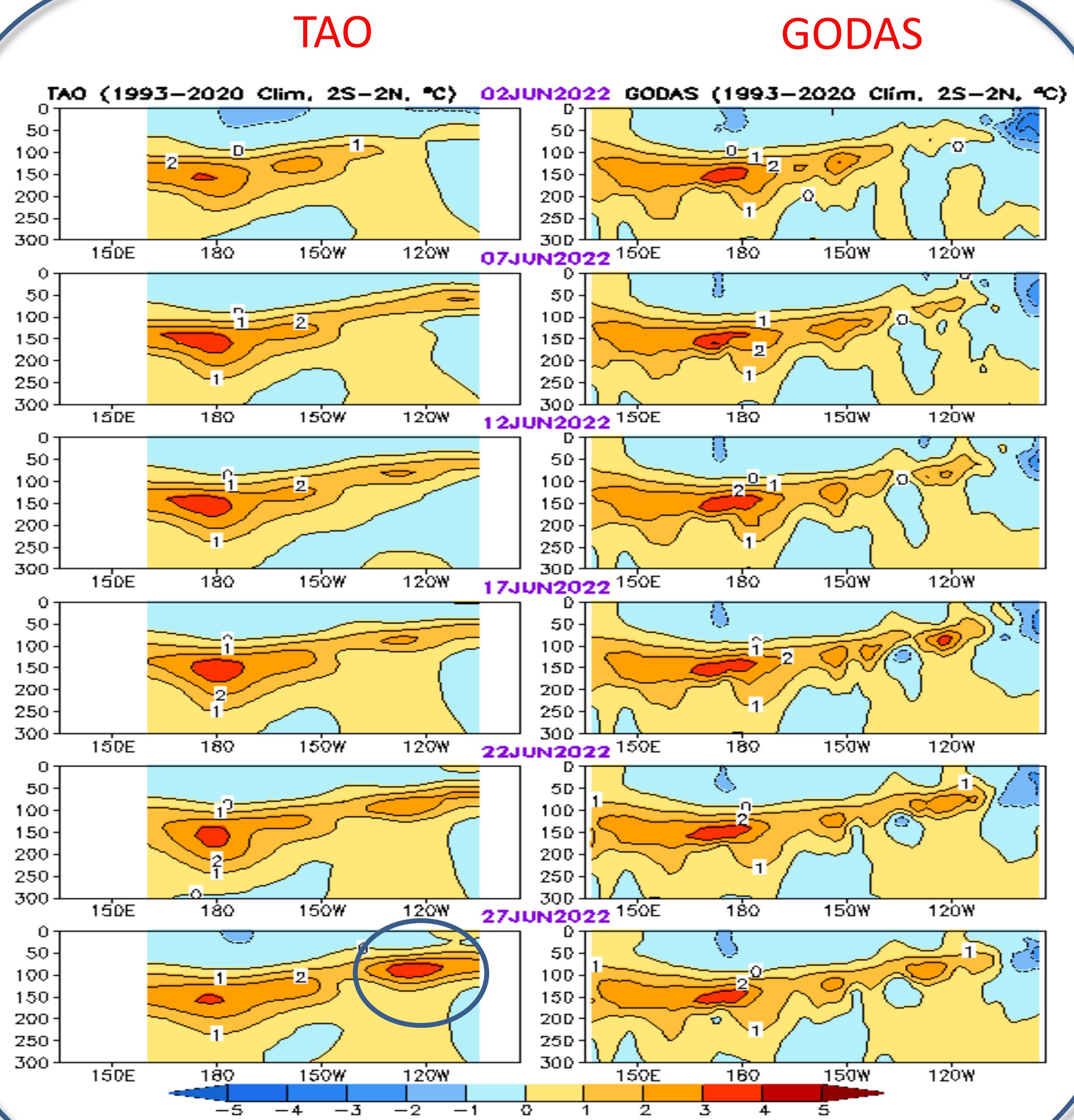
- Anomalous westward currents dominated in the equatorial Pacific both in OSCAR and GODAS since Feb 2022.

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



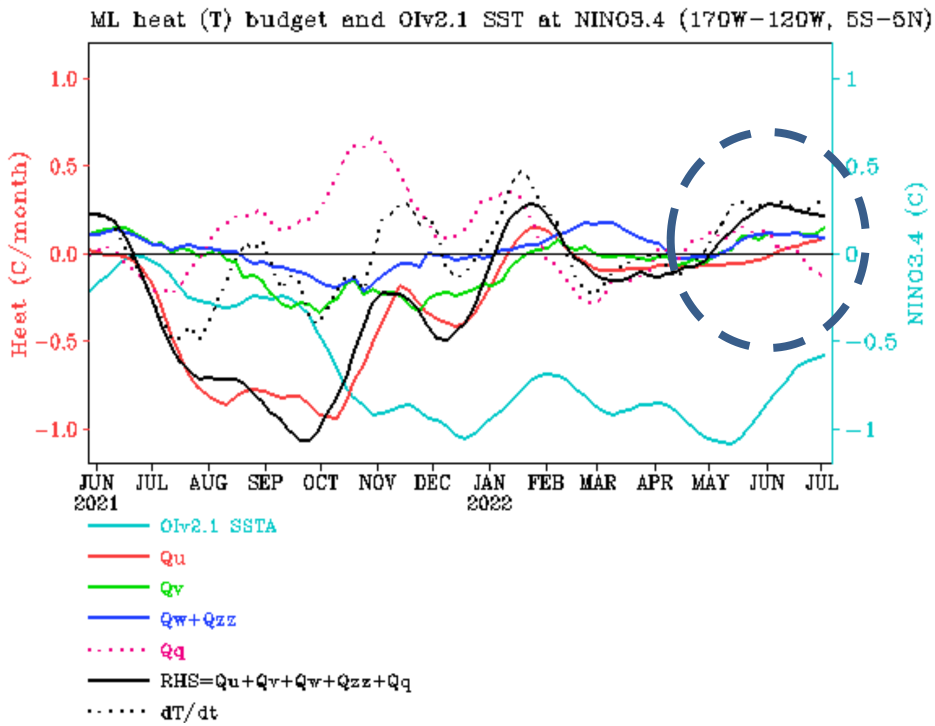
- Negative SSTA weakened in the central-eastern Pacific in Jun 2022, consistent with the eastward extension of positive subsurface temperature anomalies .
- Both easterly and westly low-level zonal wind anomalies were observed in the last couple of months.

Equatorial Pacific Ocean Temperature Pentad Mean Anomaly



- Positive ocean temperature anomalies extended eastward and reached 110ºW at the end of June.

NINO3.4 Heat Budget



Qu: Zonal advection; Qv: Meridional advection;

Qw: Vertical entrainment; Qzz: Vertical diffusion

Qq: (Qnet - Qpen + Qcorr)/ρcph;

Qnet = SW + LW + LH +SH;

Qpen: SW penetration;

Qcorr: Flux correction due to relaxation to OI SST

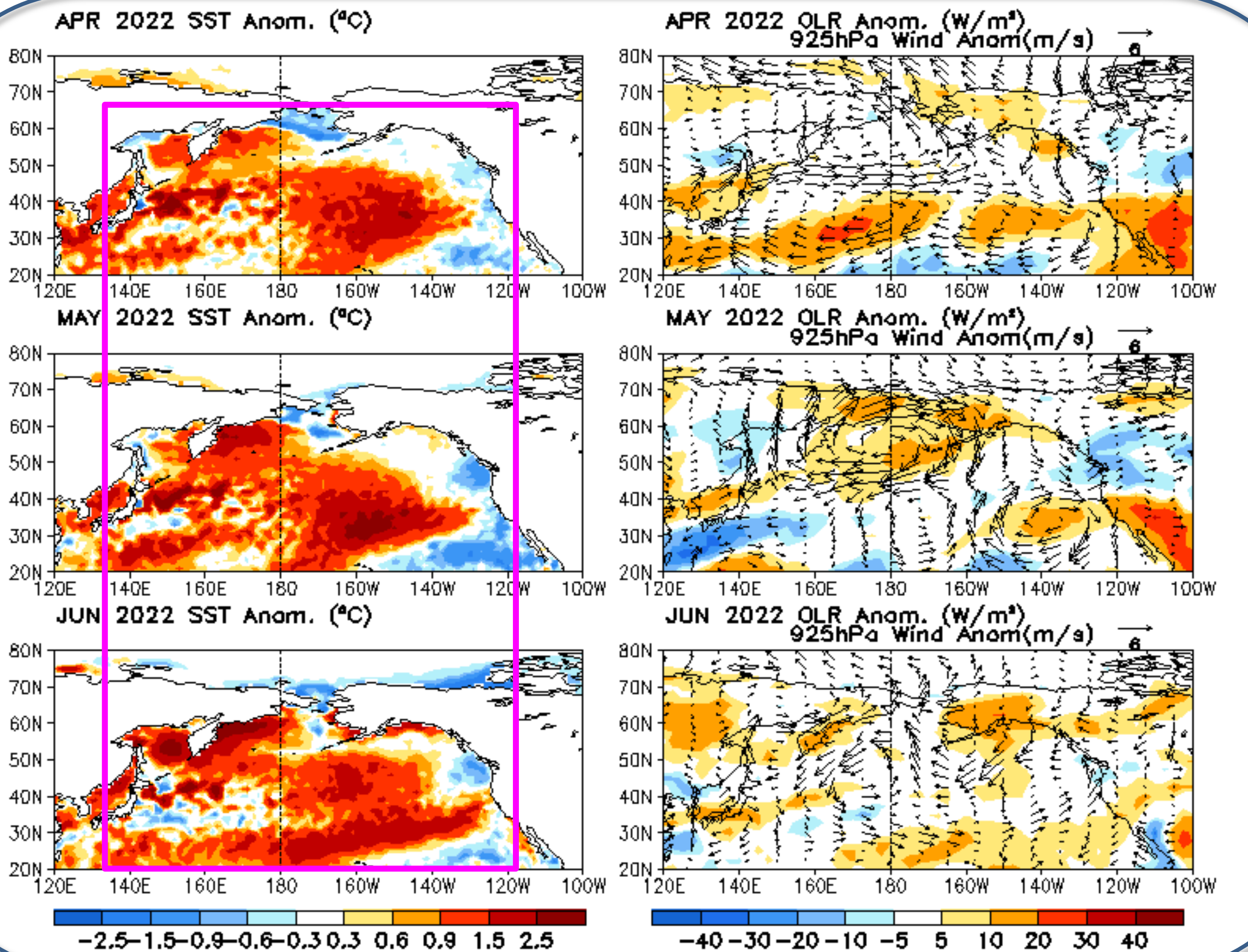
- Observed positive SSTA tendency (dT/dt) in Nino3.4 region (dotted black line) reemergent since May, 2022.

- Both vertical advection (Qw,+Qzz blue line) and meridional advection (Qv green line) terms are the two primary dynamical processes contributing to the positive tendency since May 2022.

Huang, B., Y. Xue, X. Zhang, A. Kumar, and M. J. McPhaden, 2010 : The NCEP GODAS ocean analysis of the tropical Pacific mixed layer heat budget on seasonal to interannual time scales, J. Climate., 23, 4901-4925.

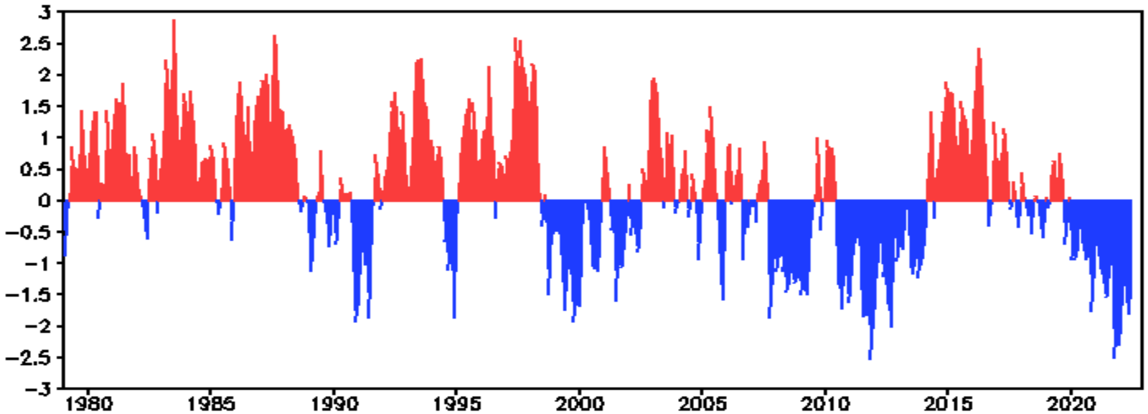
North Pacific & Arctic Oceans

Last three month North Pacific SST, OLR, and uv925 anomalies

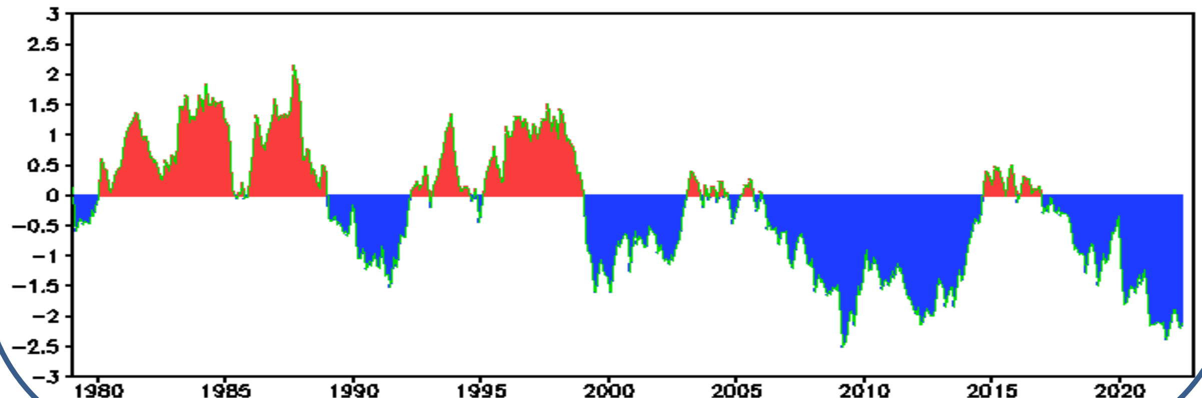


Two Oceanic PDO indices

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 = -1.3 in Jun 2022.

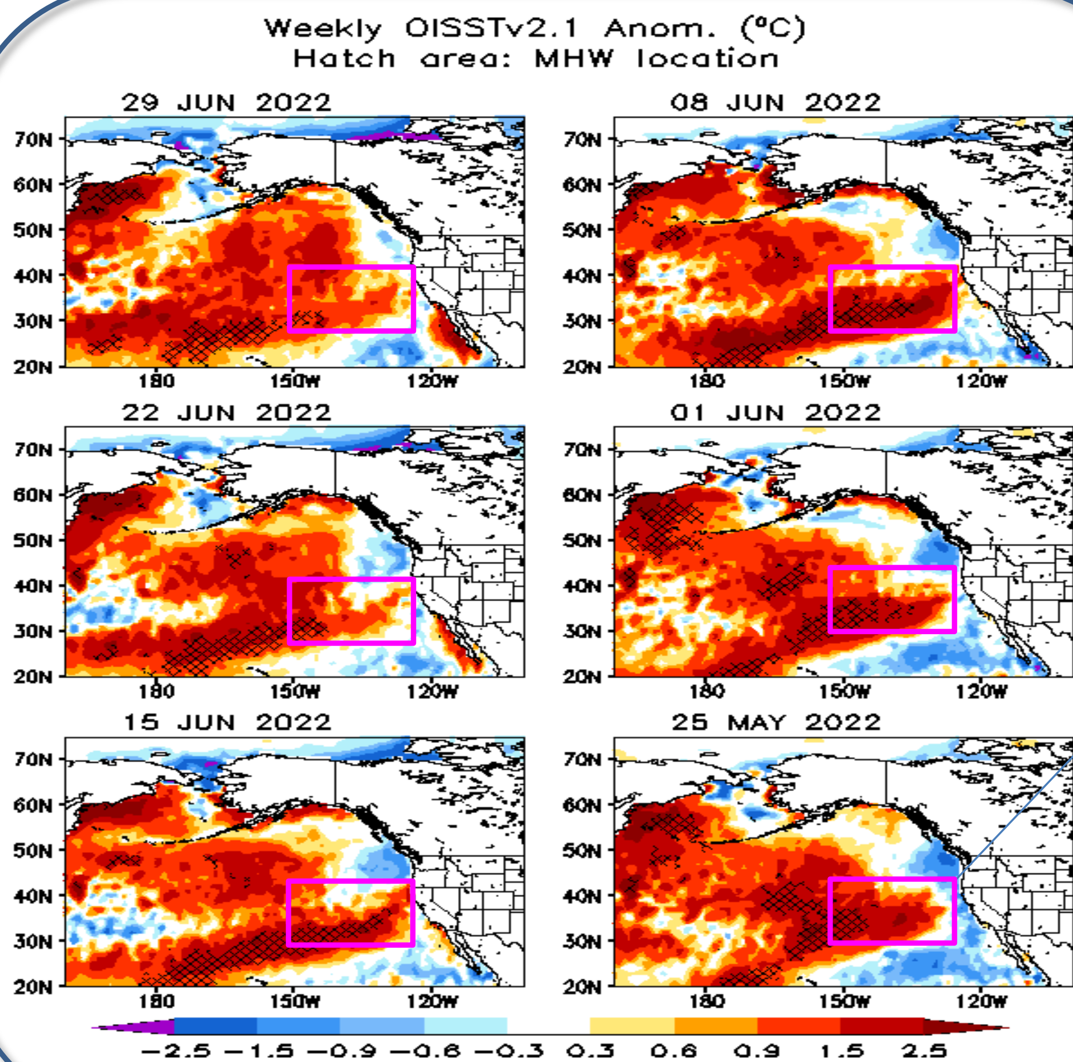
- Negative H300-based PDO index has persisted 68 months since Nov 2016, with HPDO = - 2.1 in Jun 2022.

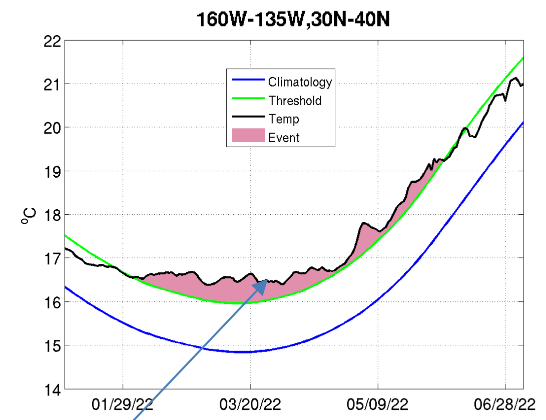
- SST-based PDO index has considerable variability both on seasonal and decadal time scales.

- 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.

Weekly SST anomaly and MHWs in the North Pacific

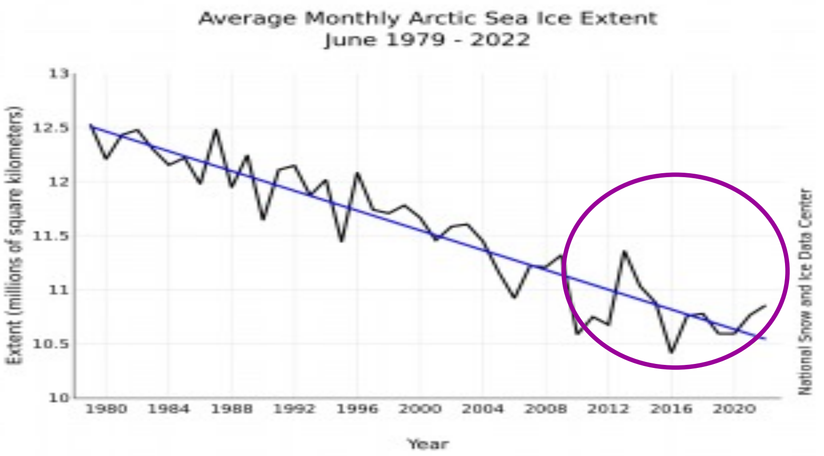


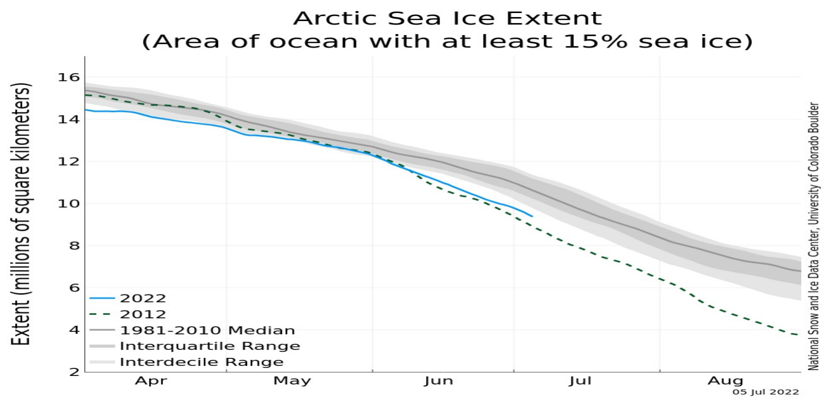


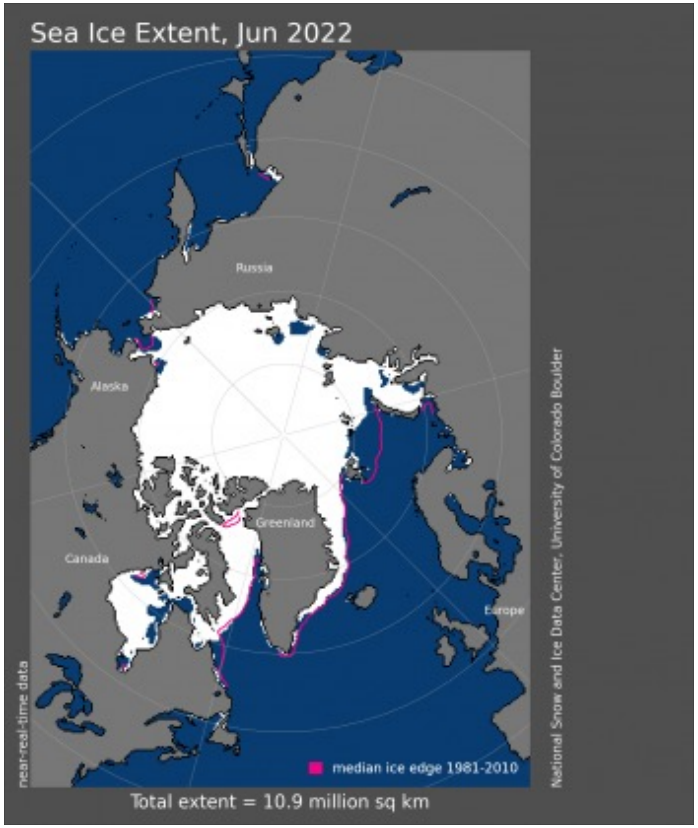
- MHWs continued in the north-central Pacific, while dissipated in north-east Pacific in the last two weeks.

(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

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

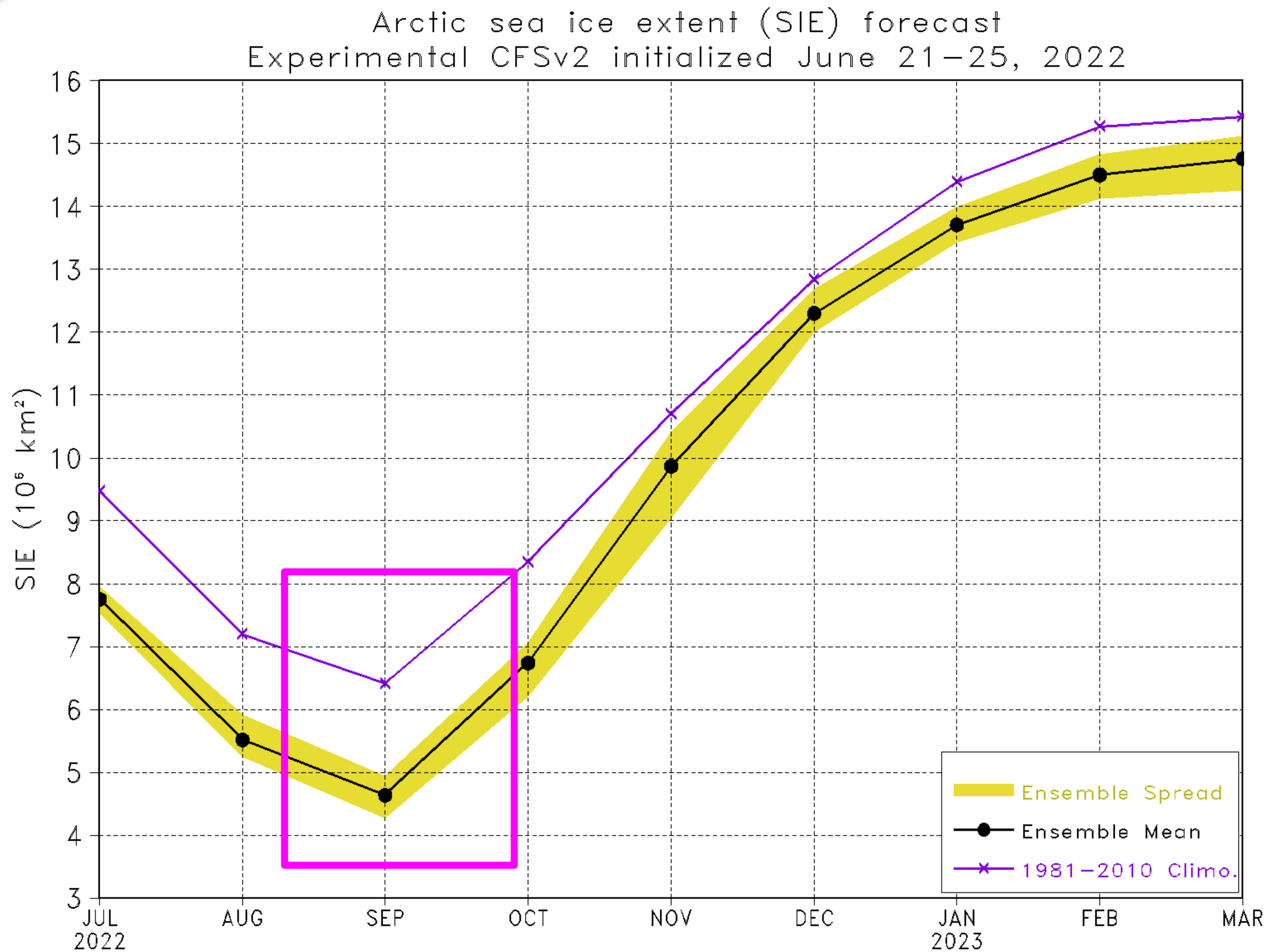






- Average Arctic sea ice extent for June 2022 was 10.86 million square kilometers, ranking tenth lowest in the satellite record.

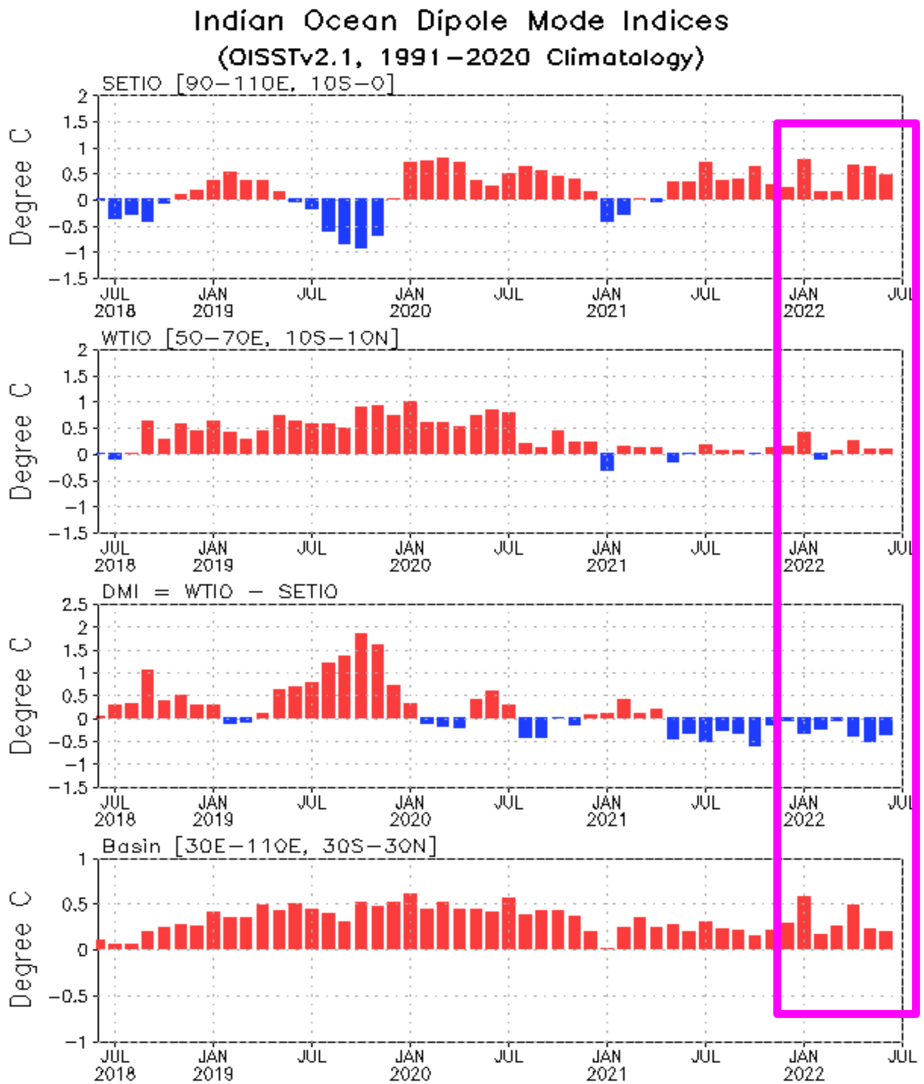
NCEP/CPC Arctic Sea Ice Extent Forecast

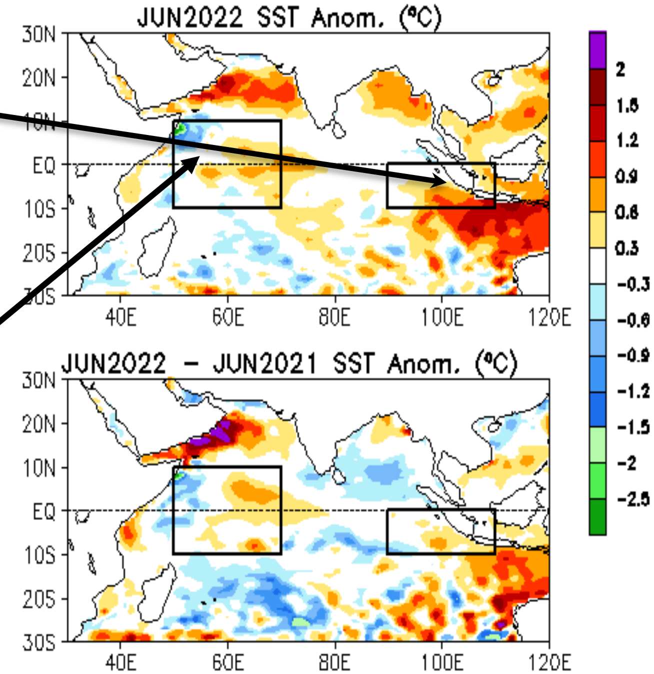


https://www.cpc.ncep.noaa.gov/products/people/wwang/seaice_seasonal/index.html

Indian Ocean

Evolution of Indian Ocean SST Indices

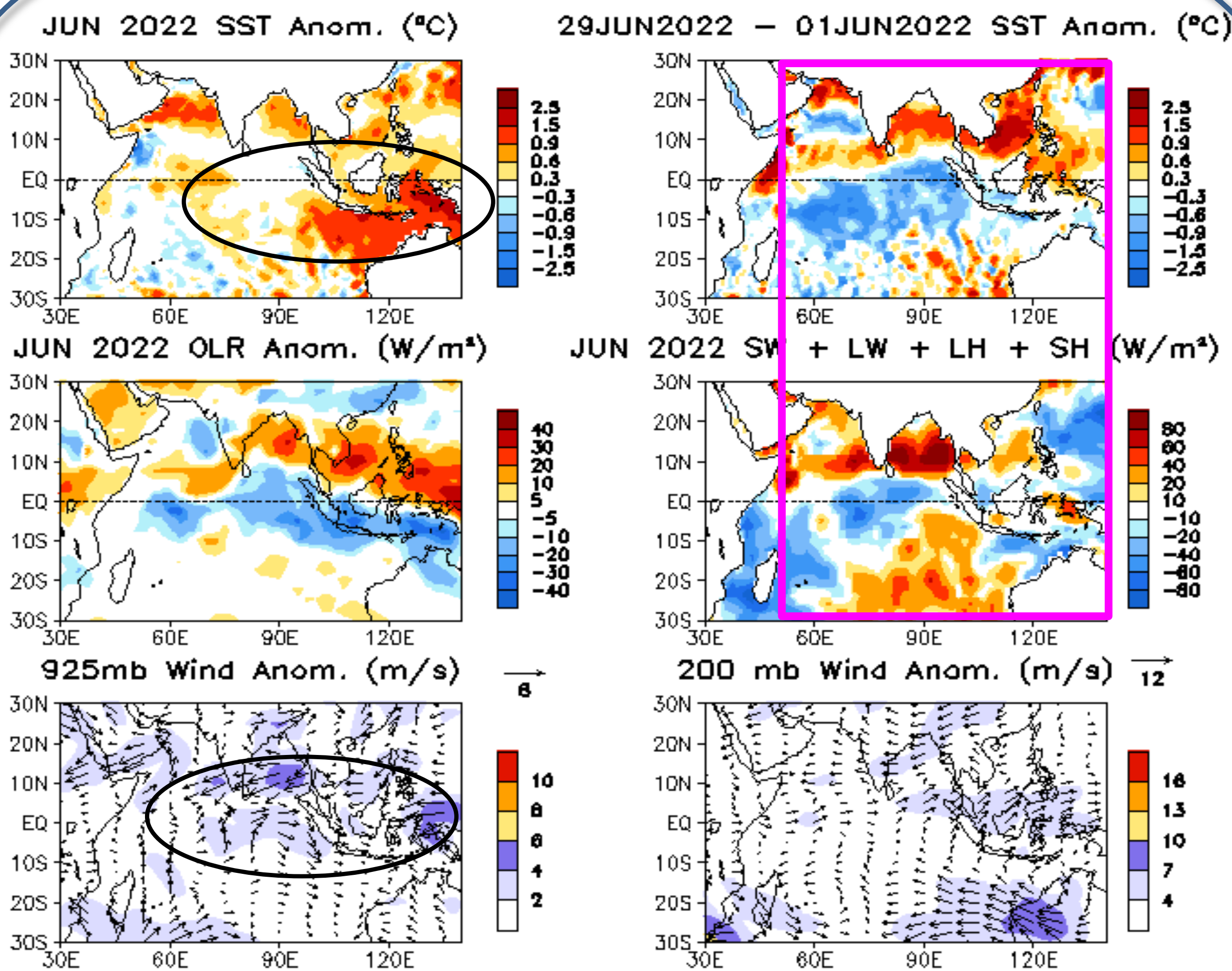




- Overall, SSTs were near or slightly above average in the tropical Indian Ocean in Jun 2022.

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.



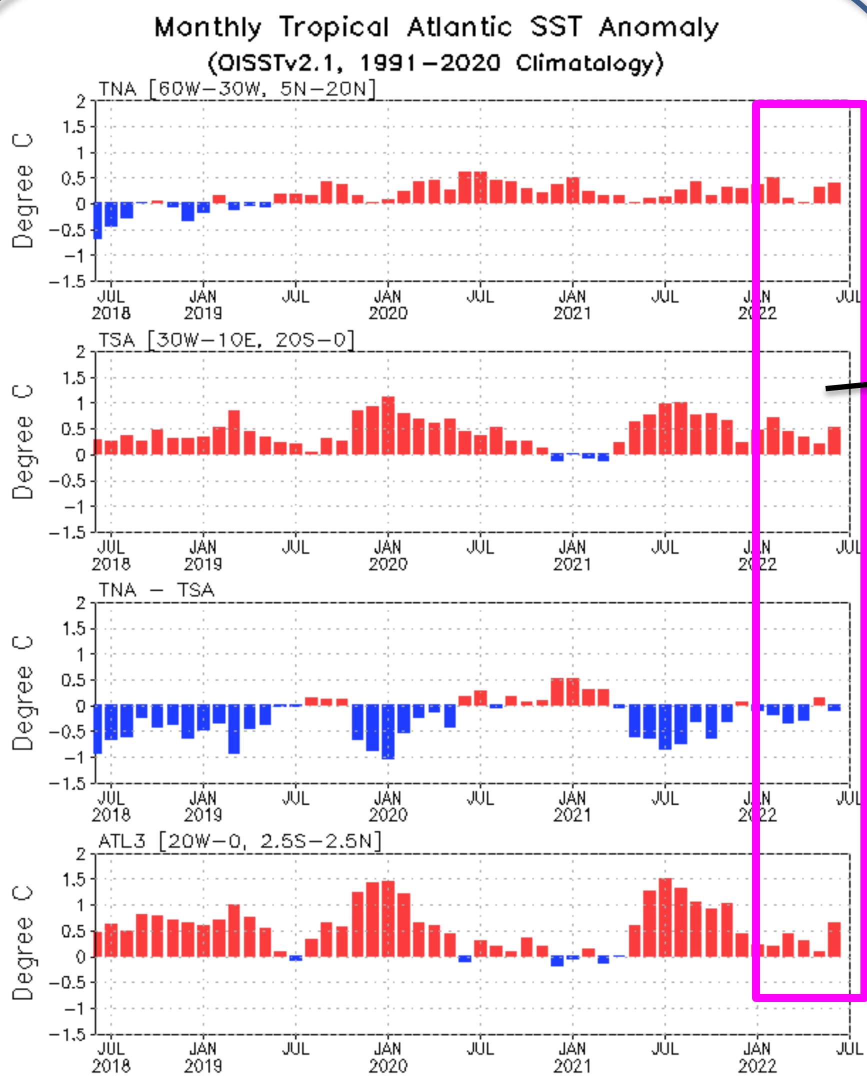
- Westerly wind anomaly prevailed over the eastern Indian Ocean, favoring further warming in the southeastern Indian Ocean.

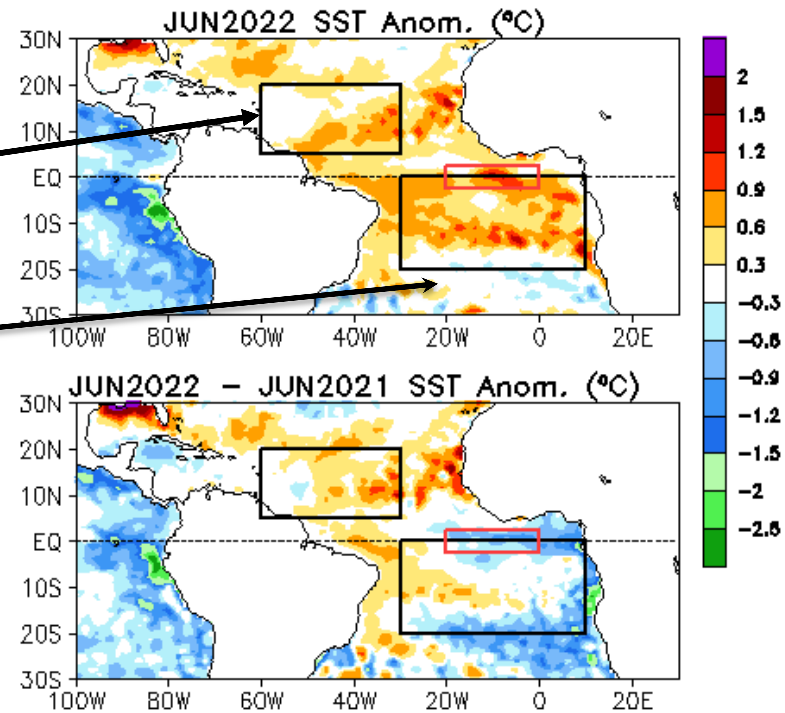
- SSTA tendencies were generally consistent with the net heat flux anomalies.

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.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

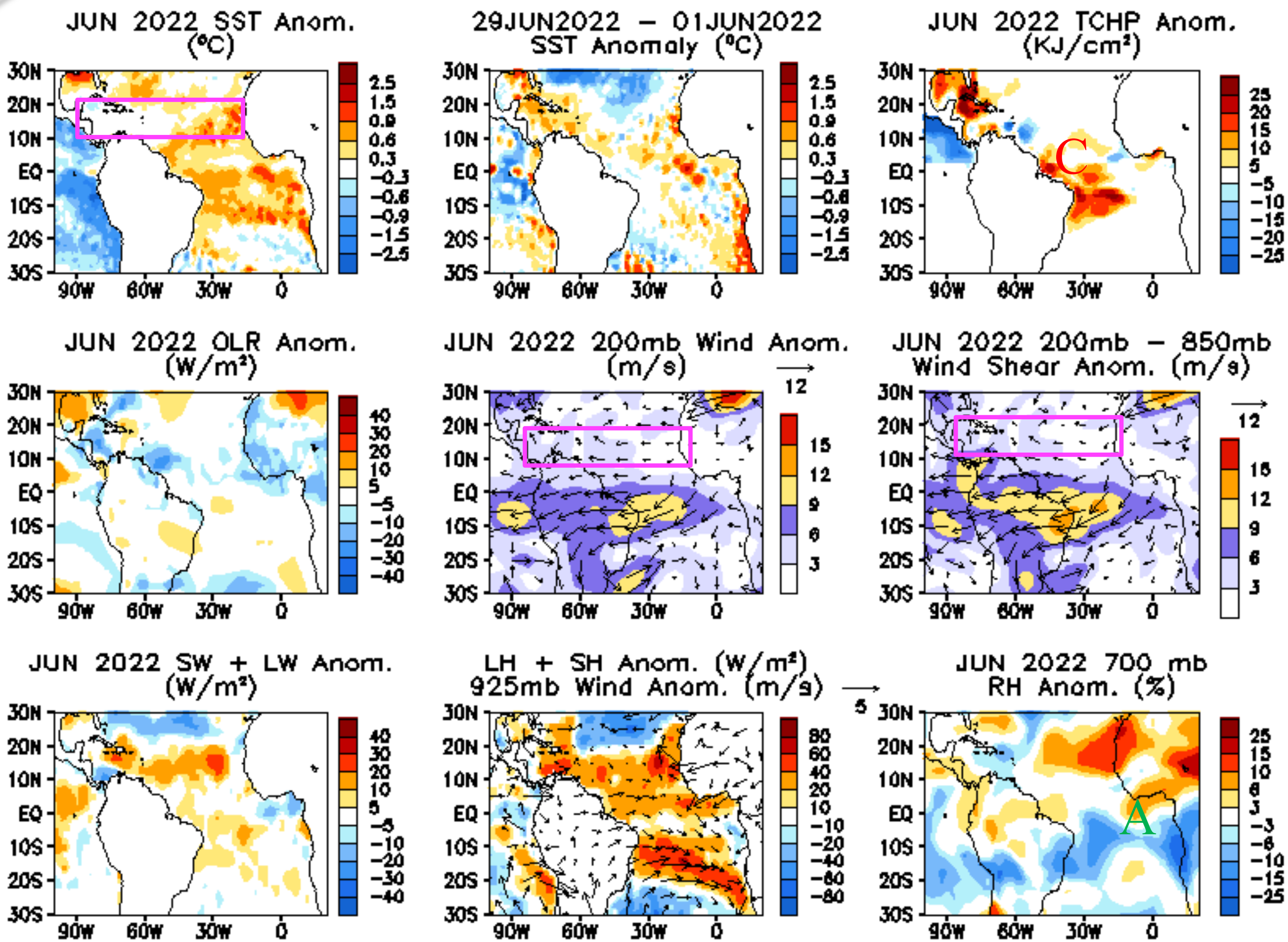




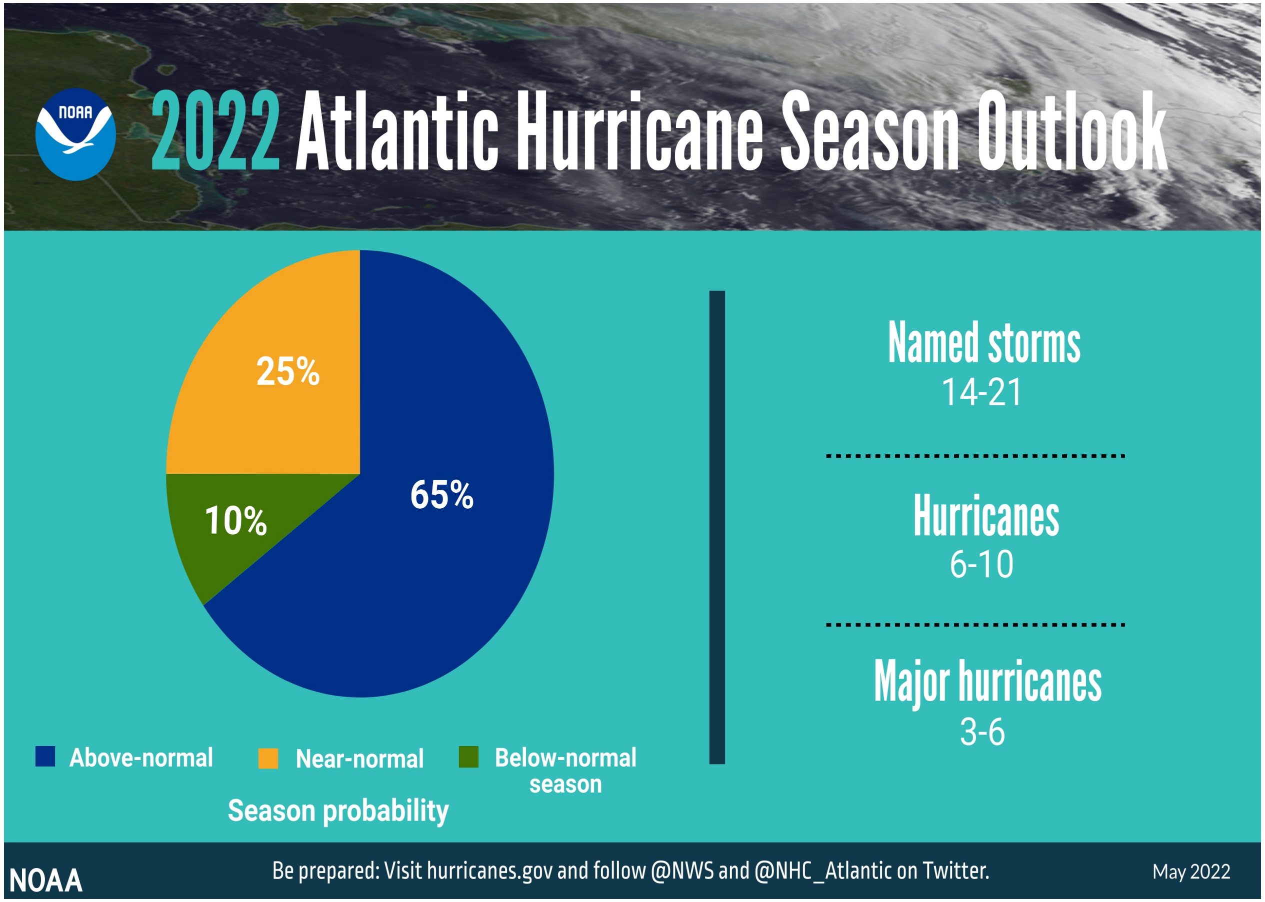
- SSTs were above-average in the tropical Atlantic Ocean in Jun 2022.
- Positive ATL3 index increased substantially in Jun 2022, with ATL3 = 0.6º C

Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean SSTAs (ºC) for the TNA [60ºW-30ºW, 5ºN-20ºN], TSA [30ºW-10ºE, 20ºS-0] and ATL3 [20ºW-0, 2.5ºS-2.5ºN] 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, and Heat Flux Anomalies



2022 Atlantic Hurricane Season Outlook

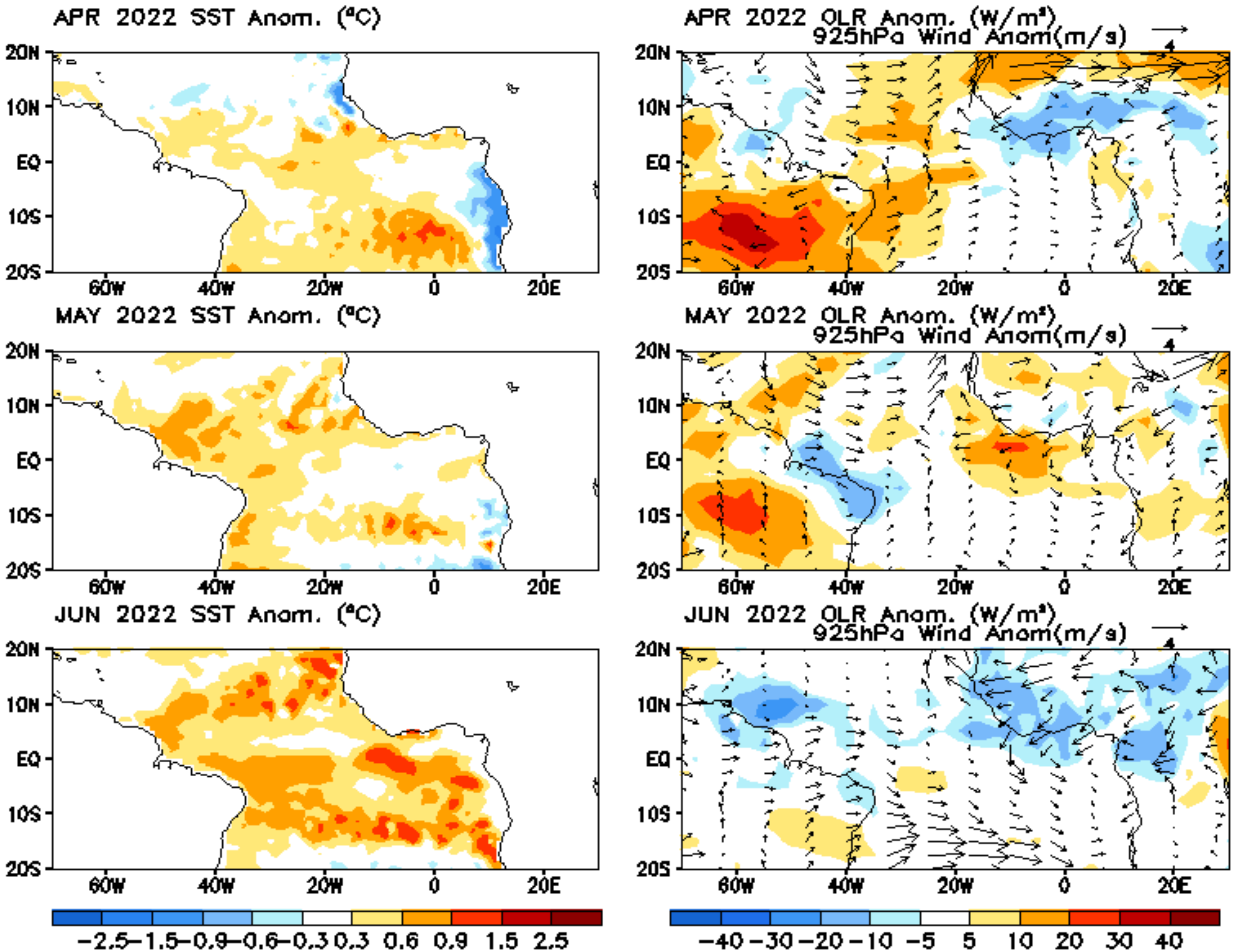


- May 24, 2022: NOAA CPC predicted above-normal 2022 Atlantic Hurricane Season with a 65% chance of an above-normal season, a 25% chance of a near-normal season and a 10% chance of a below-normal season.

- "The increased activity anticipated this hurricane season is attributed to several climate factors, including the ongoing La Niña that is likely to persist throughout the hurricane season, warmer-than-average sea surface temperatures in the Atlantic Ocean and Caribbean Sea, weaker tropical Atlantic trade winds and an enhanced west African monsoon."

-*(https://www.noaa.gov/news-release/noaa-predicts-above-normal-2022-atlantic-hurricane-season)*

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



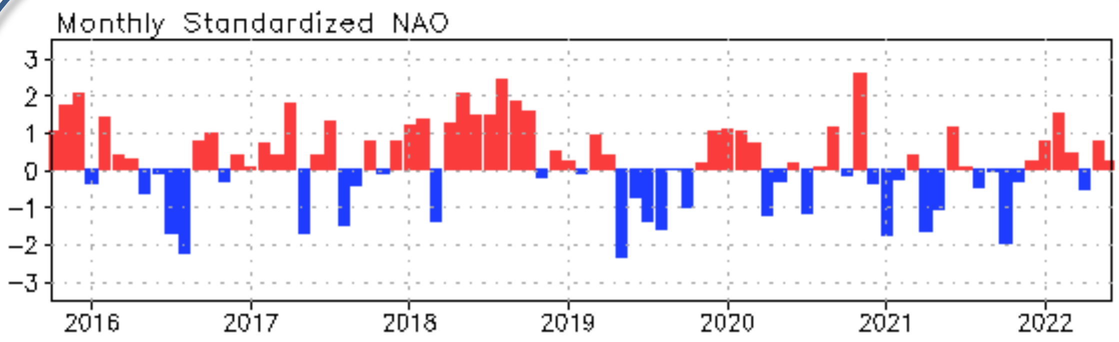
2022 Atlantic Hurricane Season Activities

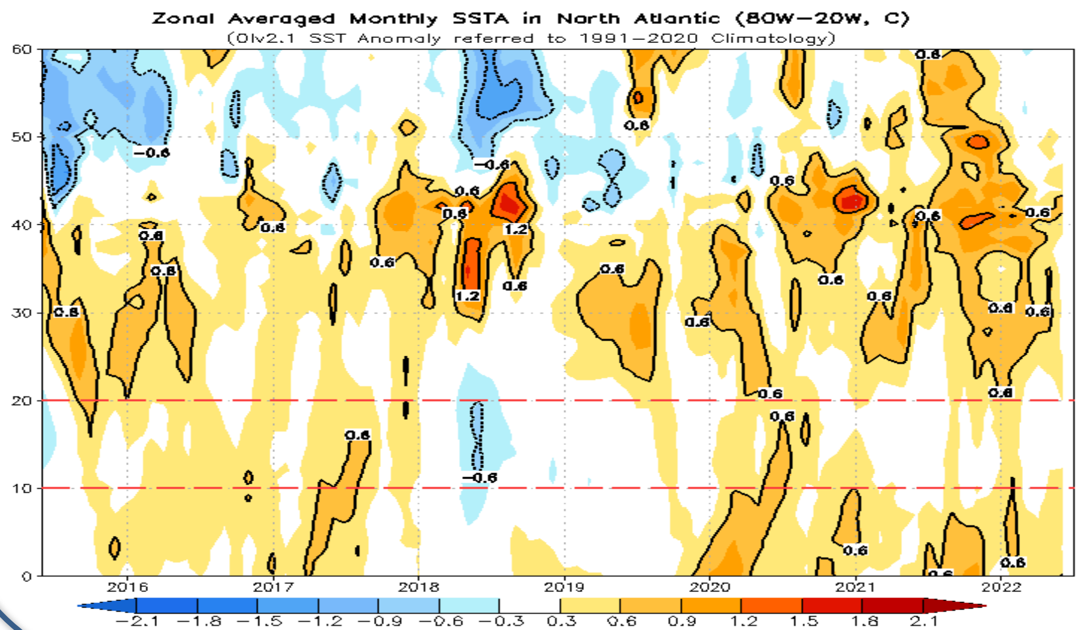
https://en.wikipedia.org/wiki/2022_Atlantic_hurricane_season

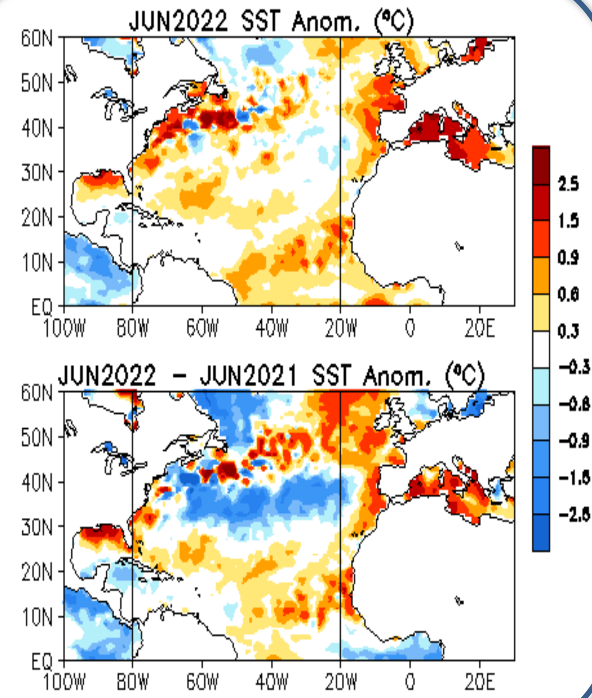
- By Jul 10 2022, three tropical storms formed.

Atlantic	Observations (By Jul 10)	Outlook (May 24) 60% above-normal	(1991-2020)
Total storms	3	14-21	14
Hurricanes	0	6-10	7
Major hurricanes	0	3-6	3

NAO and SST Anomaly in North Atlantic





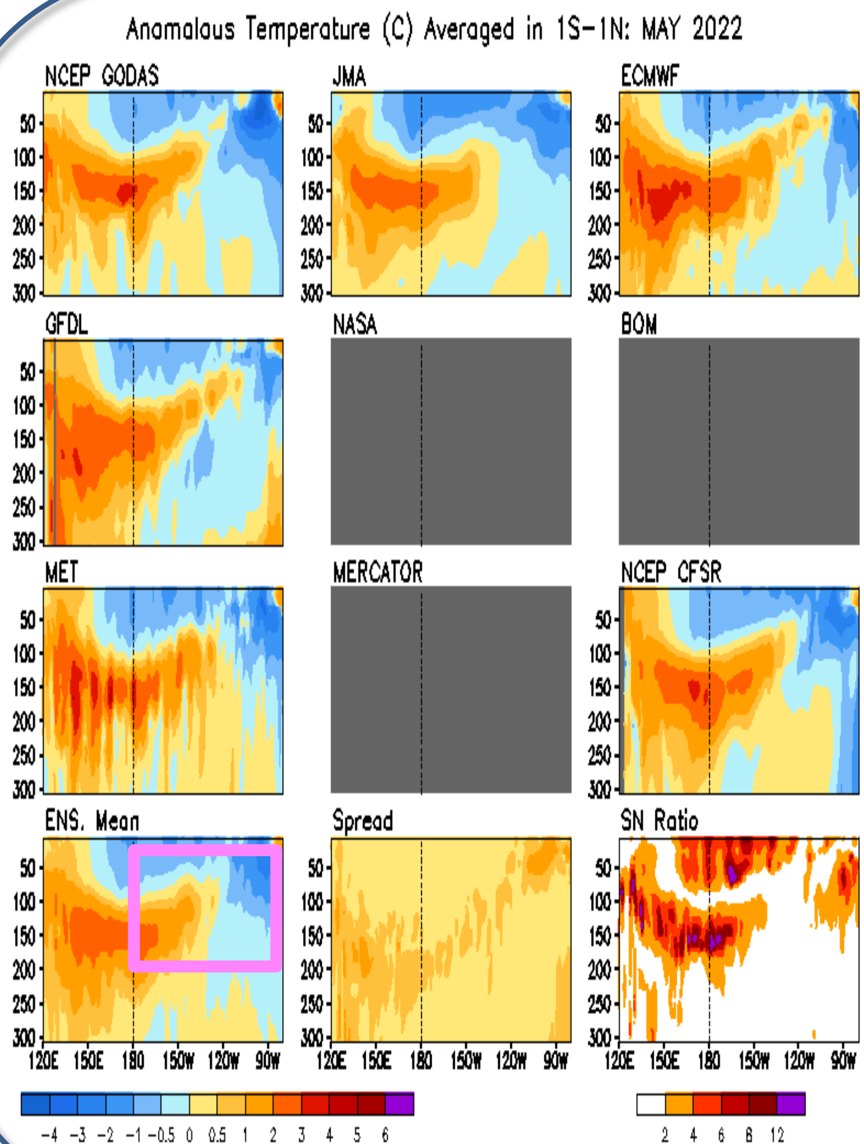


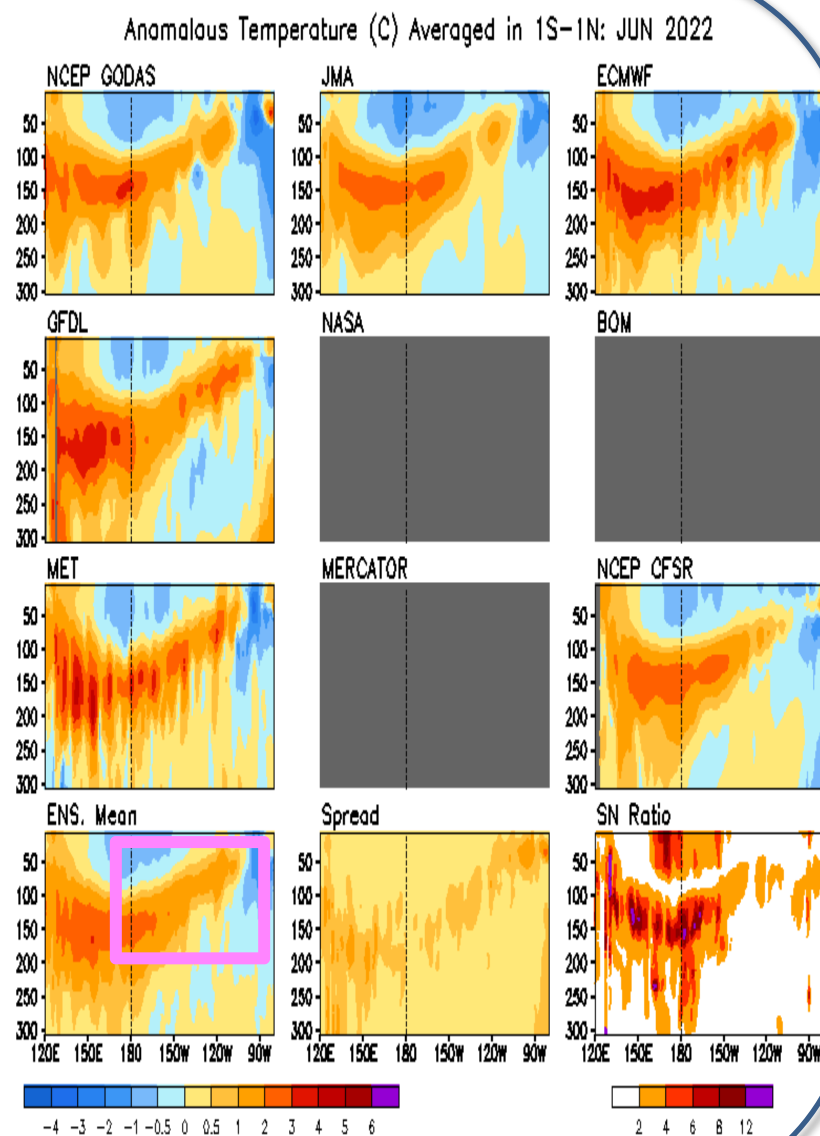
- Positive NAO decreased in Jun 2022 with NAOI= 0.2.
- The positive SSTAs in the mid-high latitudes of the North Atlantic Ocean were evident since 2021.

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.

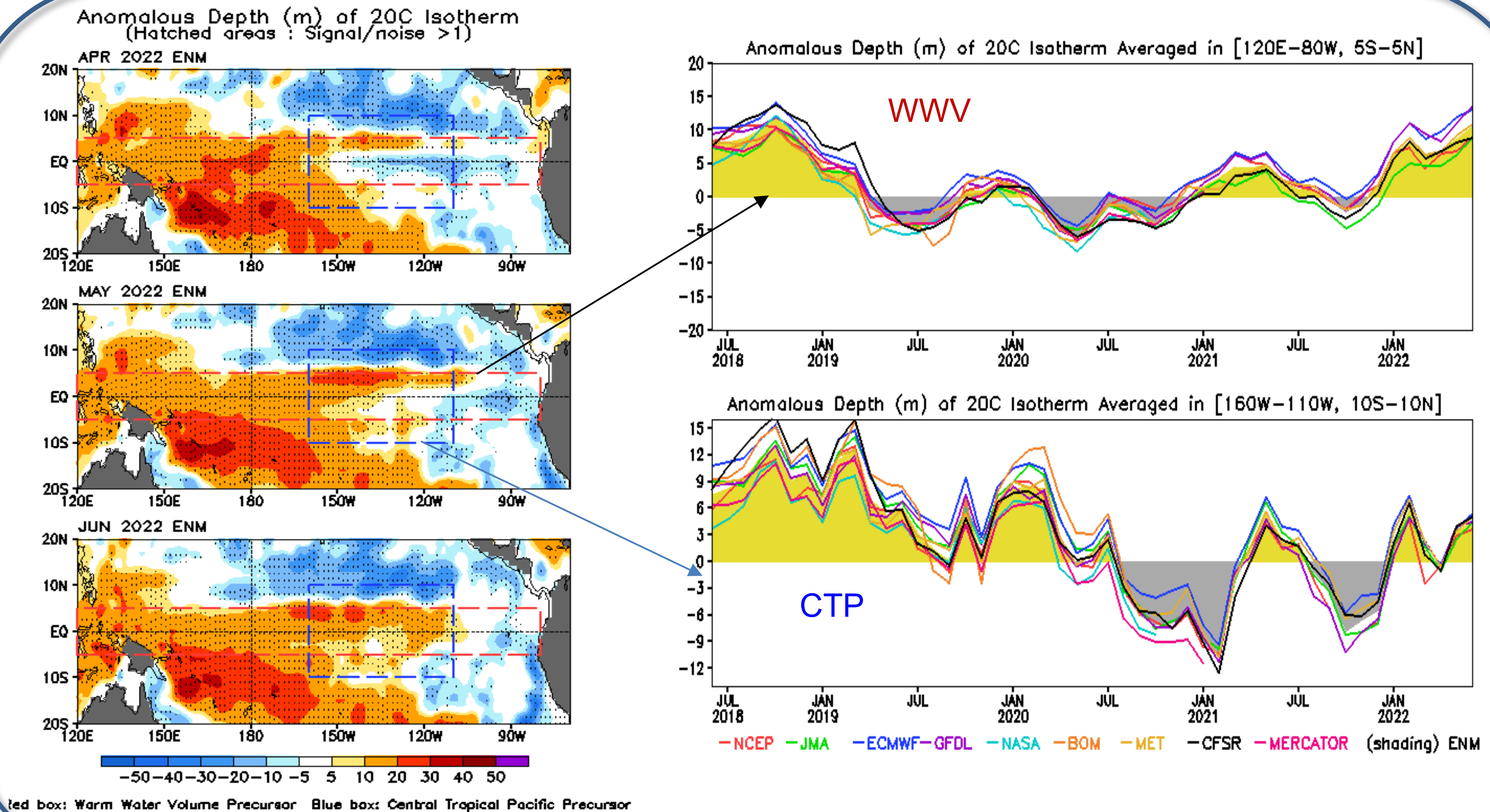
ENSO and Global SST Predictions

Multiple Ocean Reanalysis: Temperature anomaly at Equator



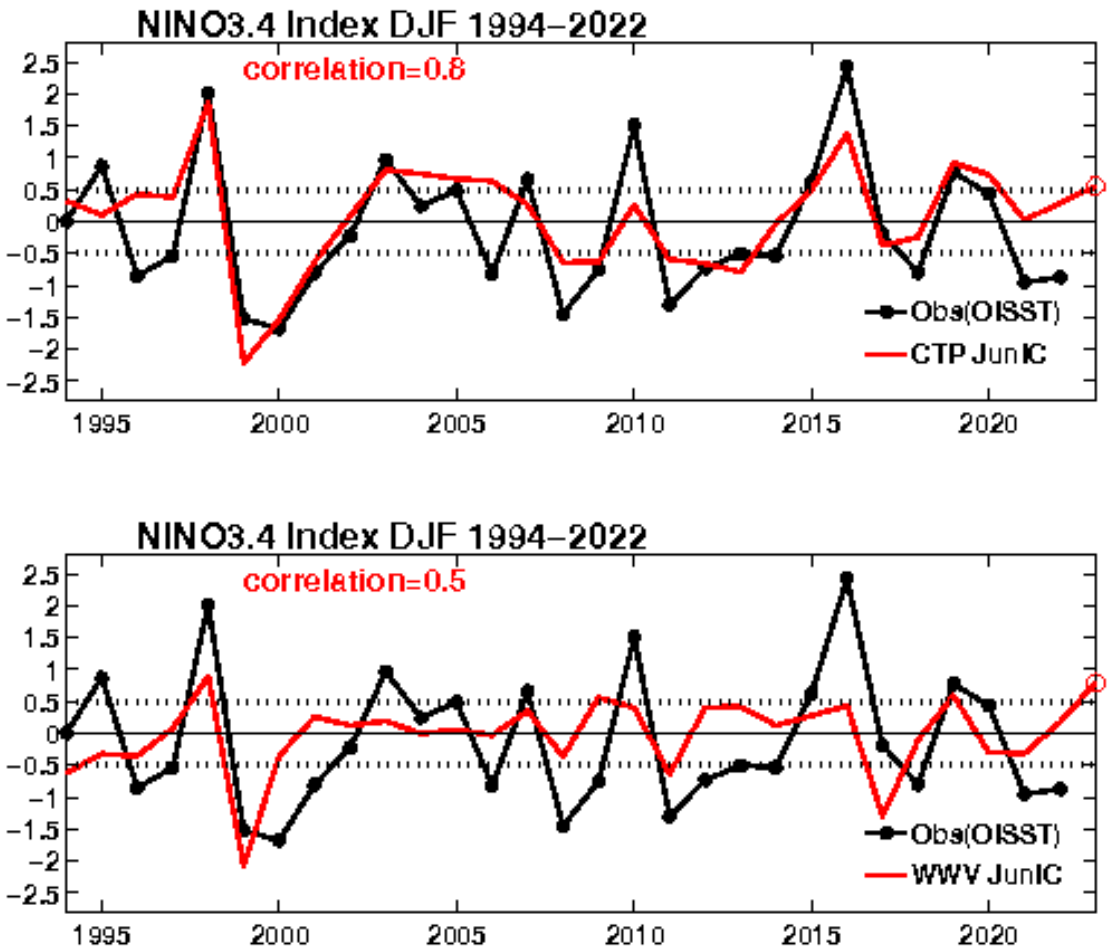


Oceanic ENSO Presursors: WWV & CTP



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

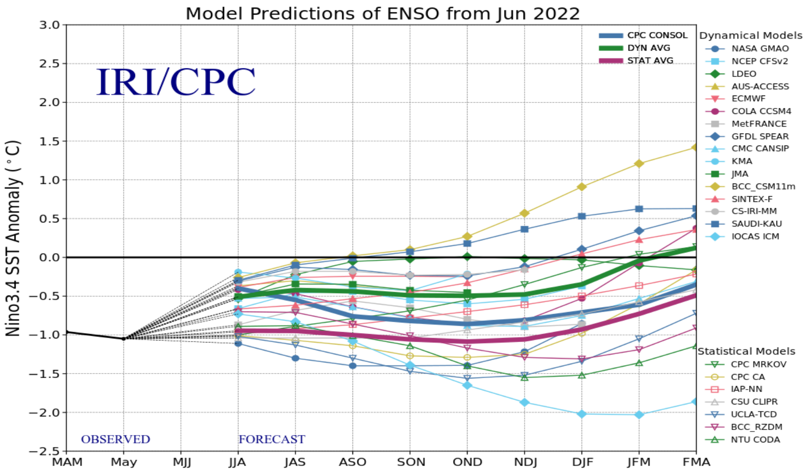
DJF Nino34 predictions based on ENSO precursors

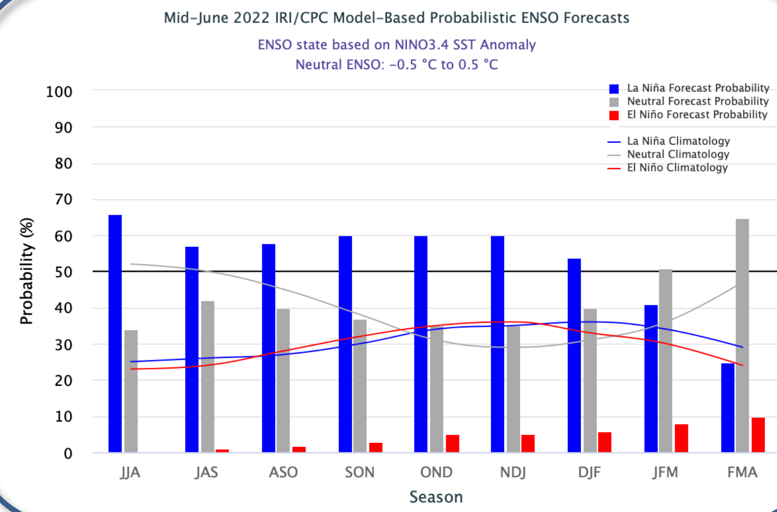


- Both WWV and CTP in June predict El Nino condition in DJF 2022.

Prediction models are constructed using leave-one-year-out cross validation over the full period by iteratively recomputing the coefficients with the target prediction year removed. For details Wen et al. (2021) DOI: https://doi.org/10.1175/JCLI-D-20-0648.1

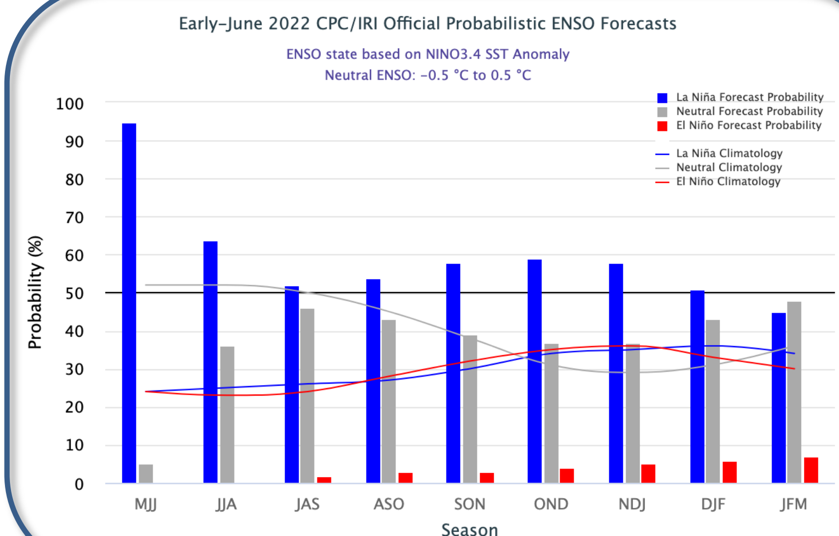
IRI/CPC Niño3.4 Forecast : June 2022





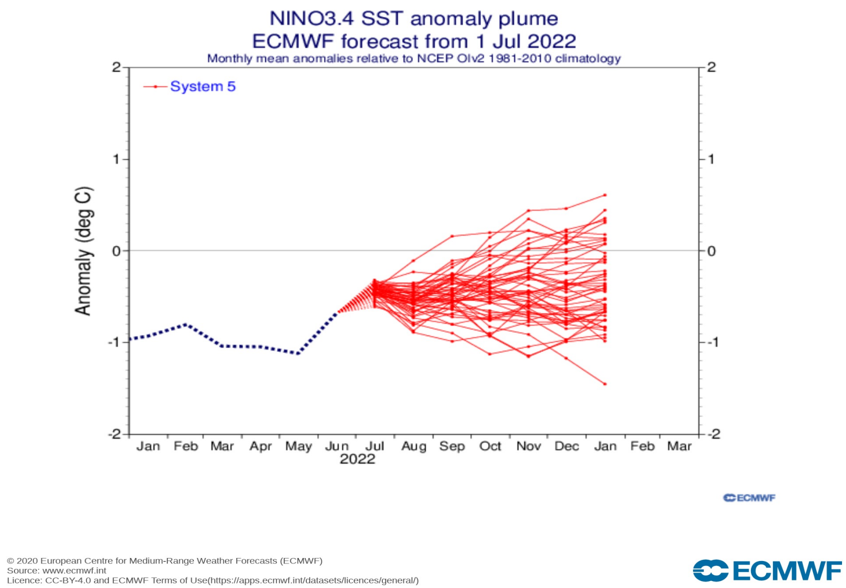
- A majority of models predict SSTs to remain below-normal at the level of a weak La Niña through the Northern Hemisphere summer and into early winter 2022-23.

- NOAA "ENSO Diagnostics Discussion" on June 9 stated that "Though La Niña is favored to continue through the end of the year, the odds for La Niña decrease into the Northern Hemisphere late summer (52% chance in July-September 2022) before slightly increasing through the Northern Hemisphere fall and early winter 2022 (58-59% chance).".

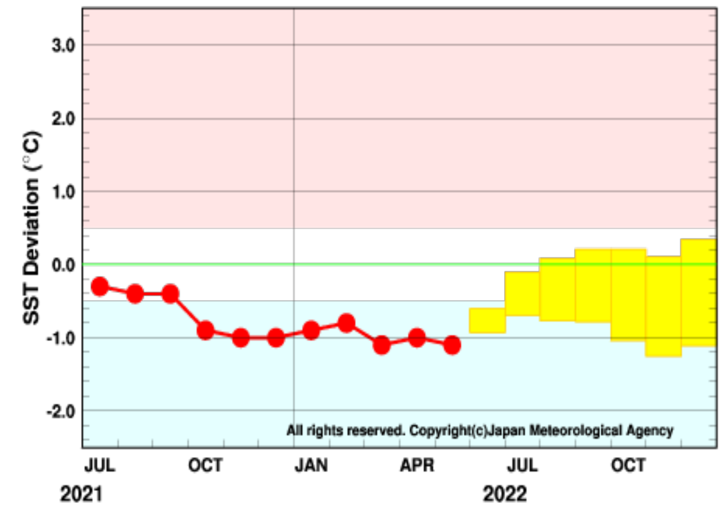


Individual Model Forecasts: ENSO neutral or borderline La Nina

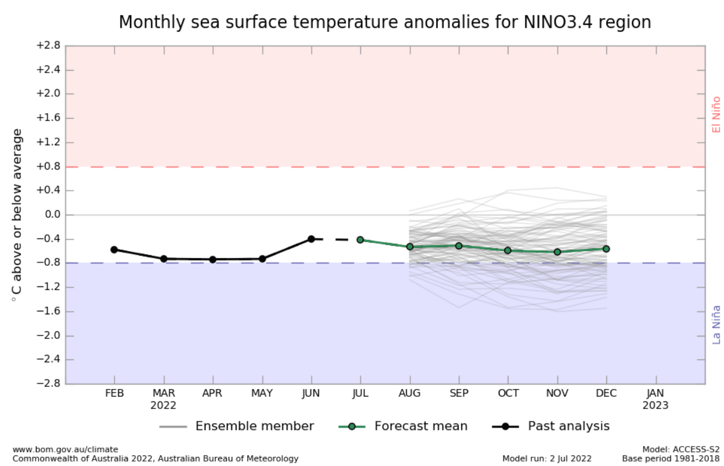
EC: IC= 1 July 2022



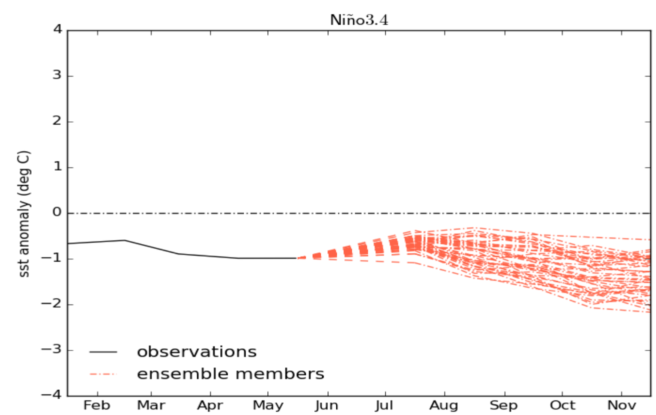
JMA: Updated 10 Jun 2022



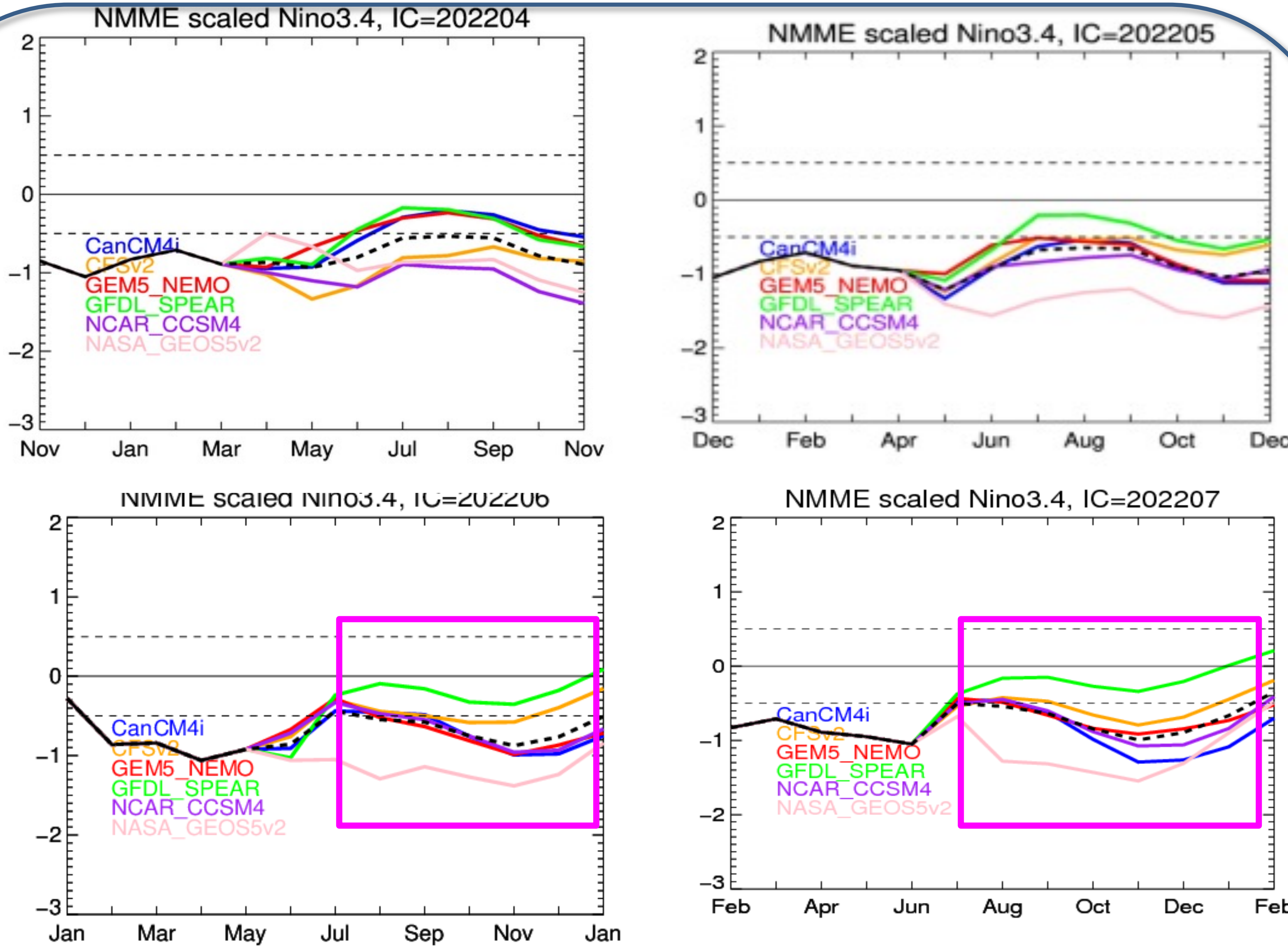
Australian BOM: Updated 2 Jul 2022



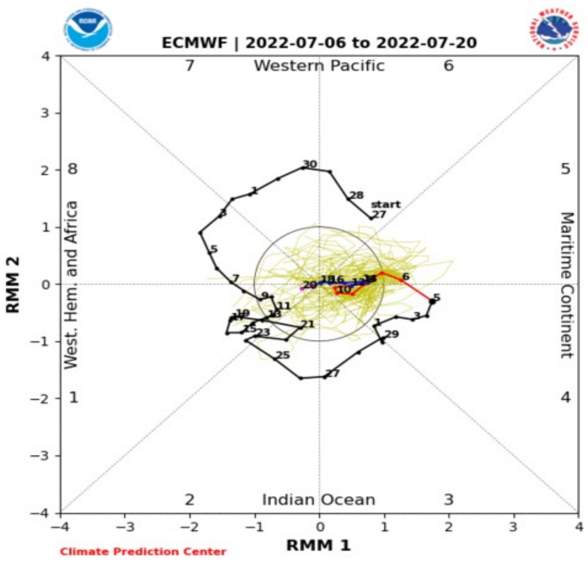
UKMO: Updated 11 Jun 2022

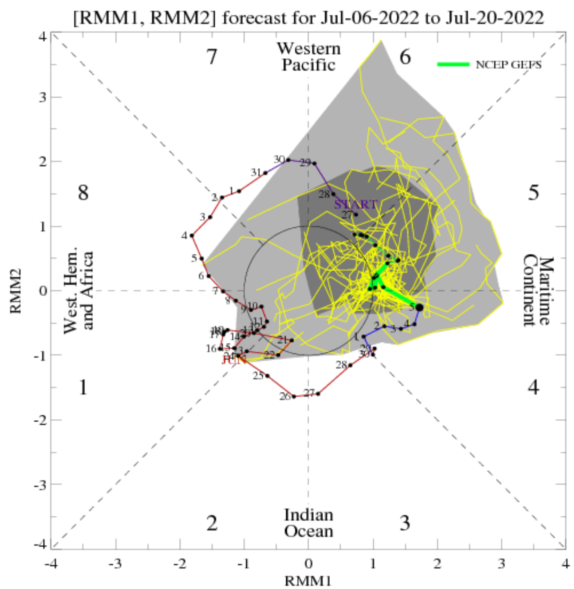


NMME forecasts from different initial conditions

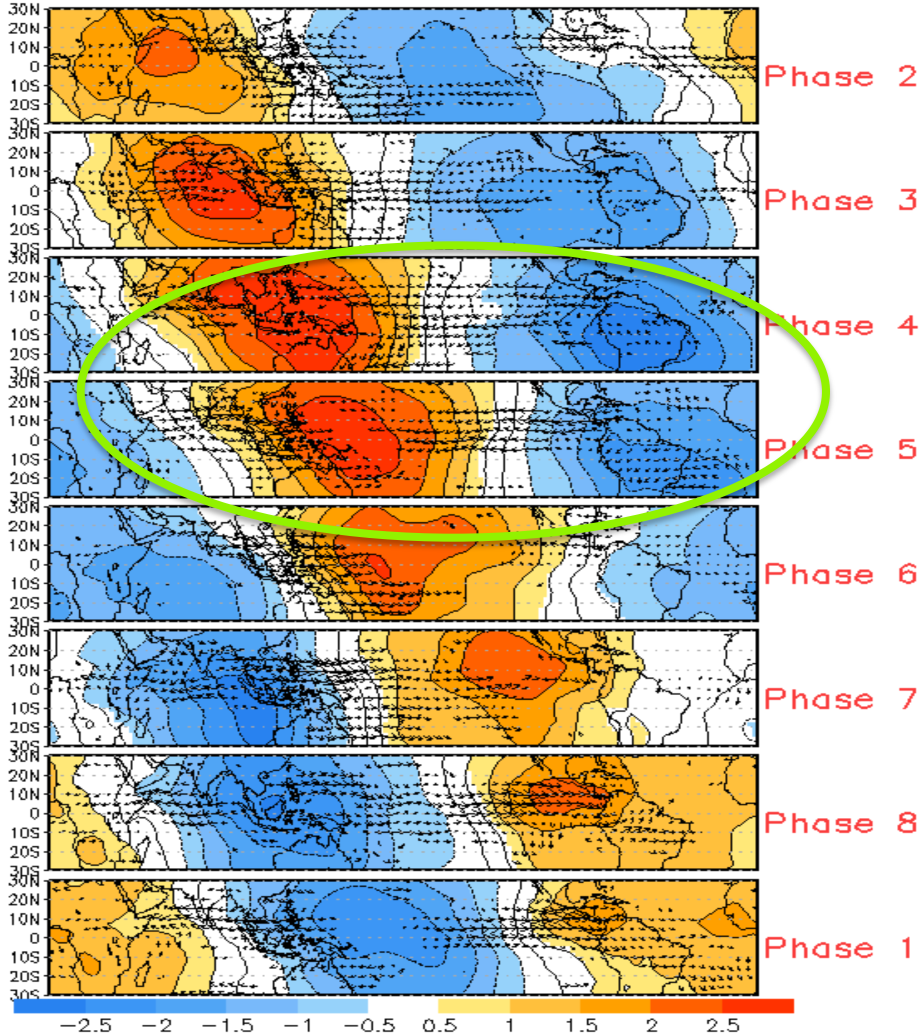


MJO Forecasts

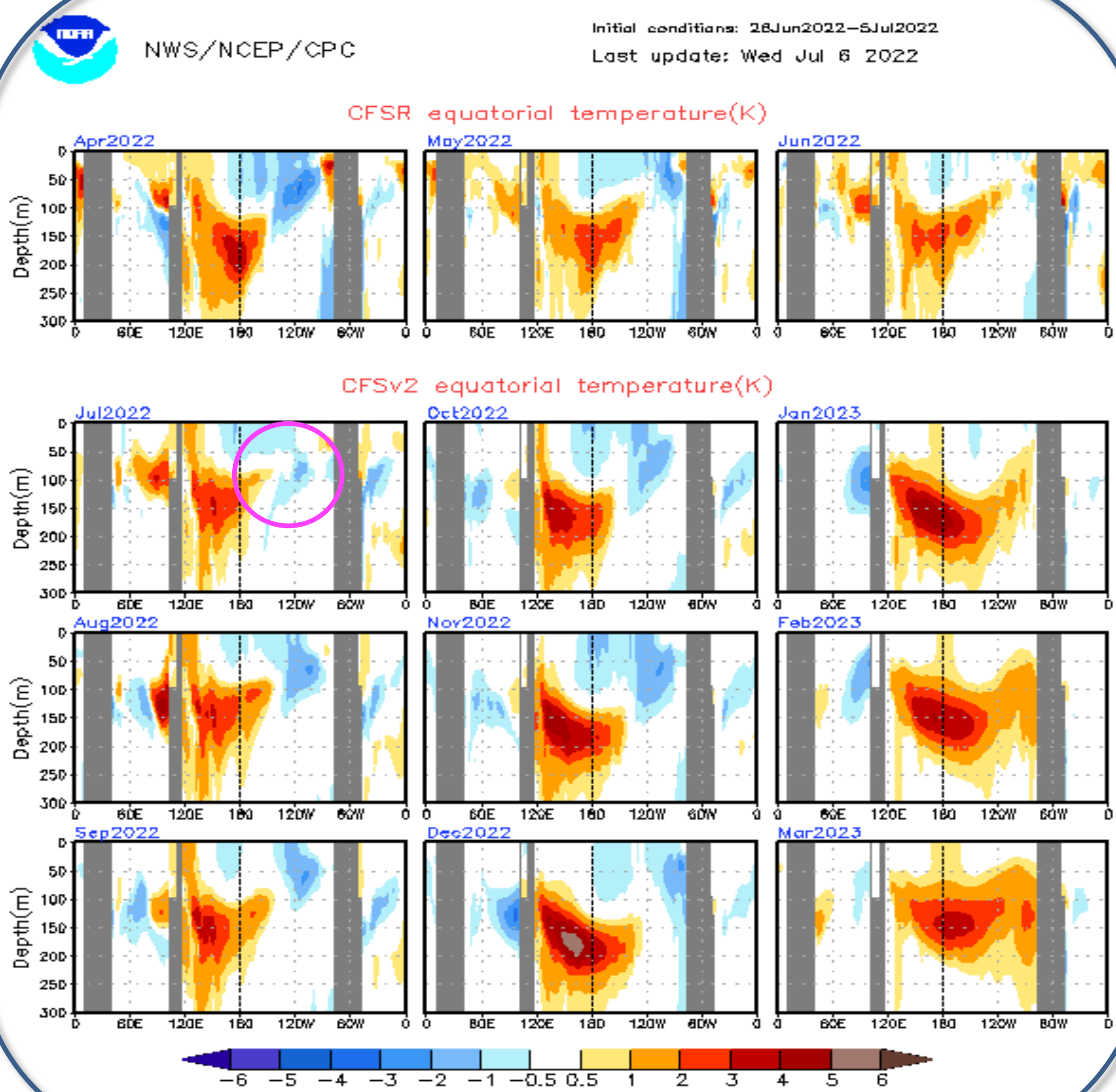




850-hPa Velocity Potential and Wind Anomalies

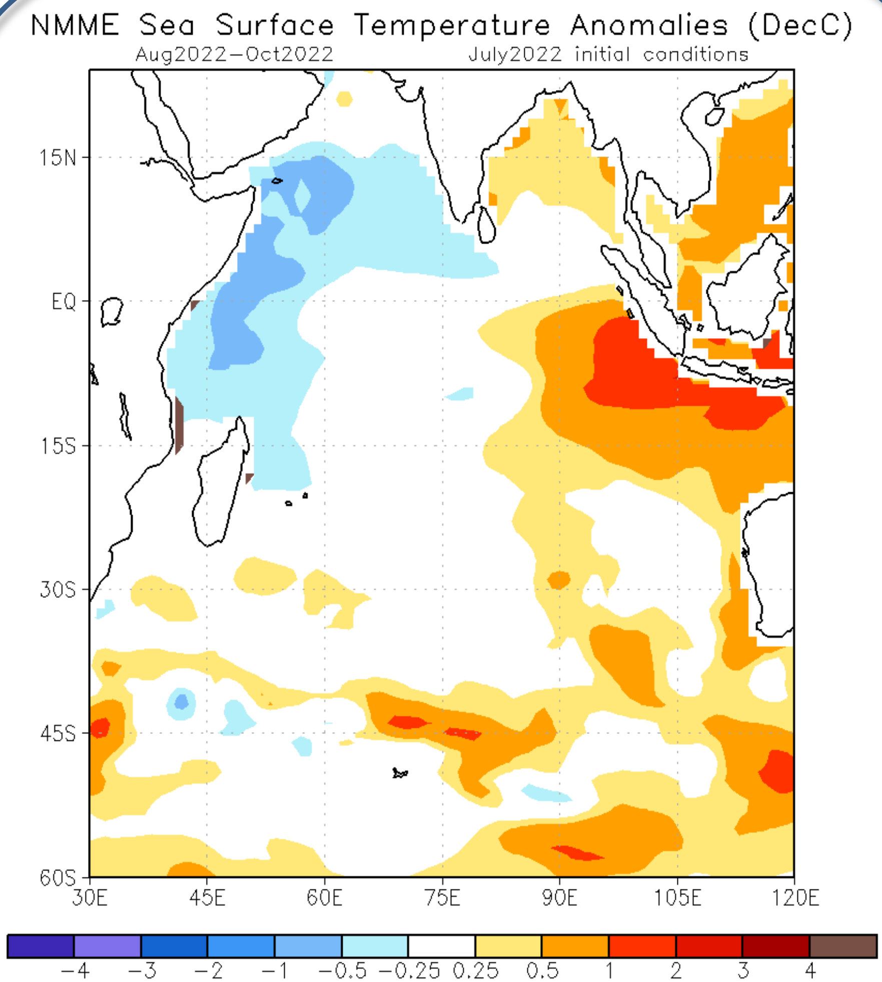


CFSv2 equatorial temperature forecasts

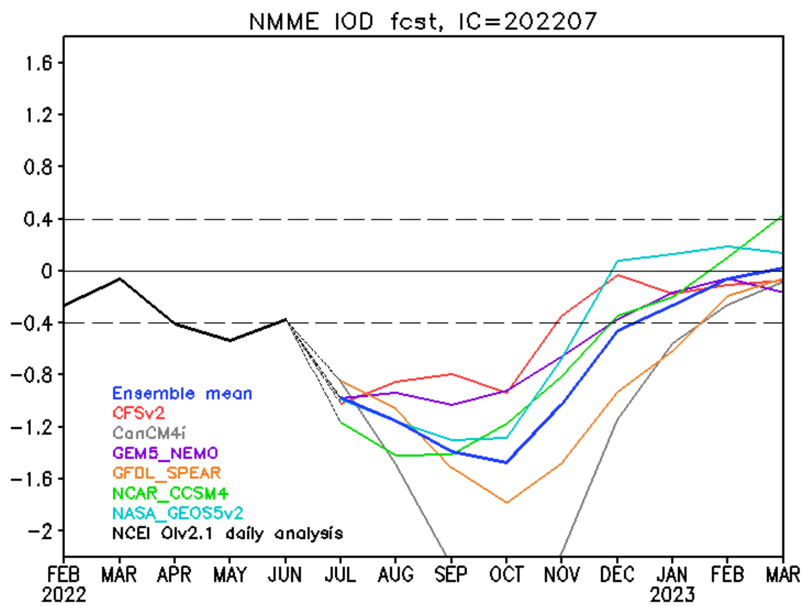


- Latest CFSv2 predicted negative temperature anomalies re-emerge in the eastern Pacific in July.

NMME Forecasts in the Indian Ocean

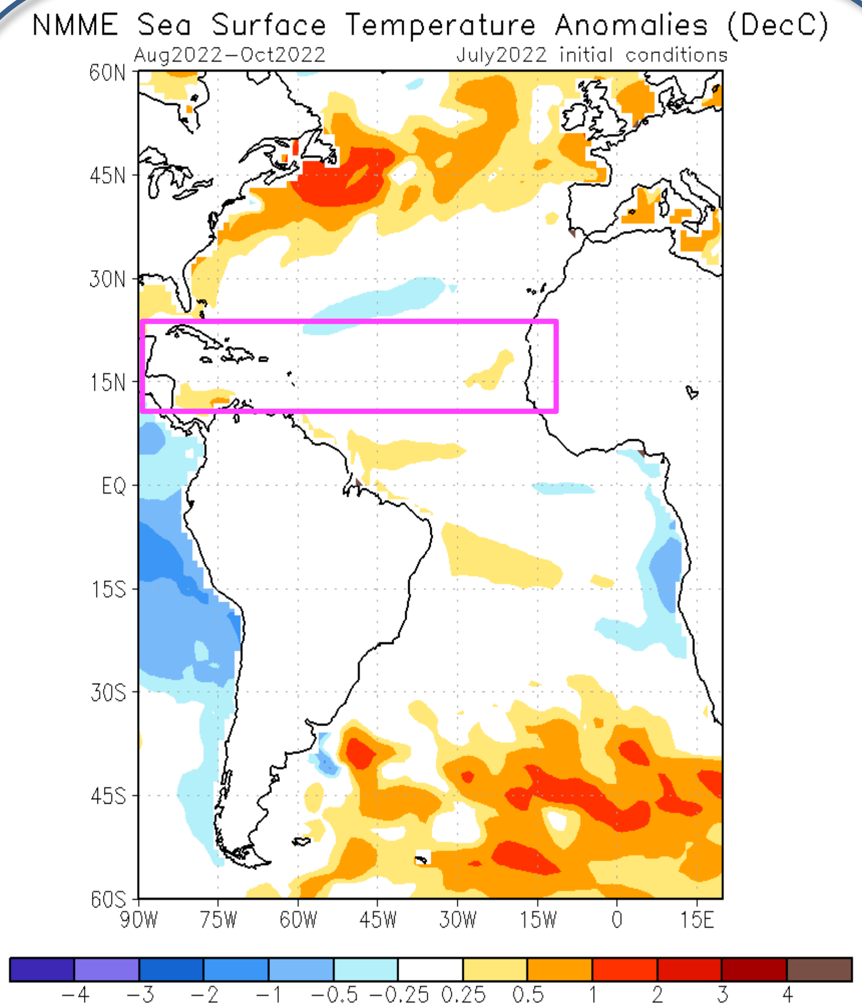


https://www.cpc.ncep.noaa.gov/products/international/index.shtml

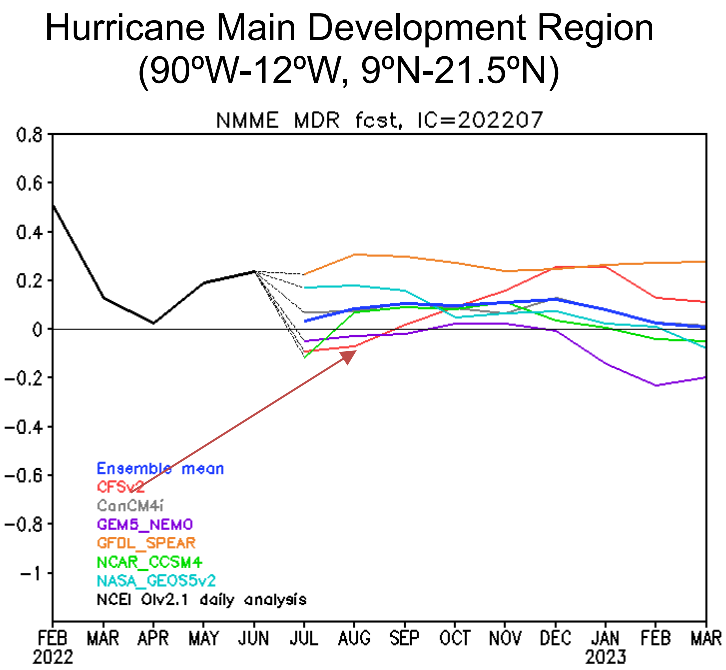


- All NMME models favor a negative IOD event during Jul-Oct 2022.

NMME Forecasts in the Atlantic Ocean

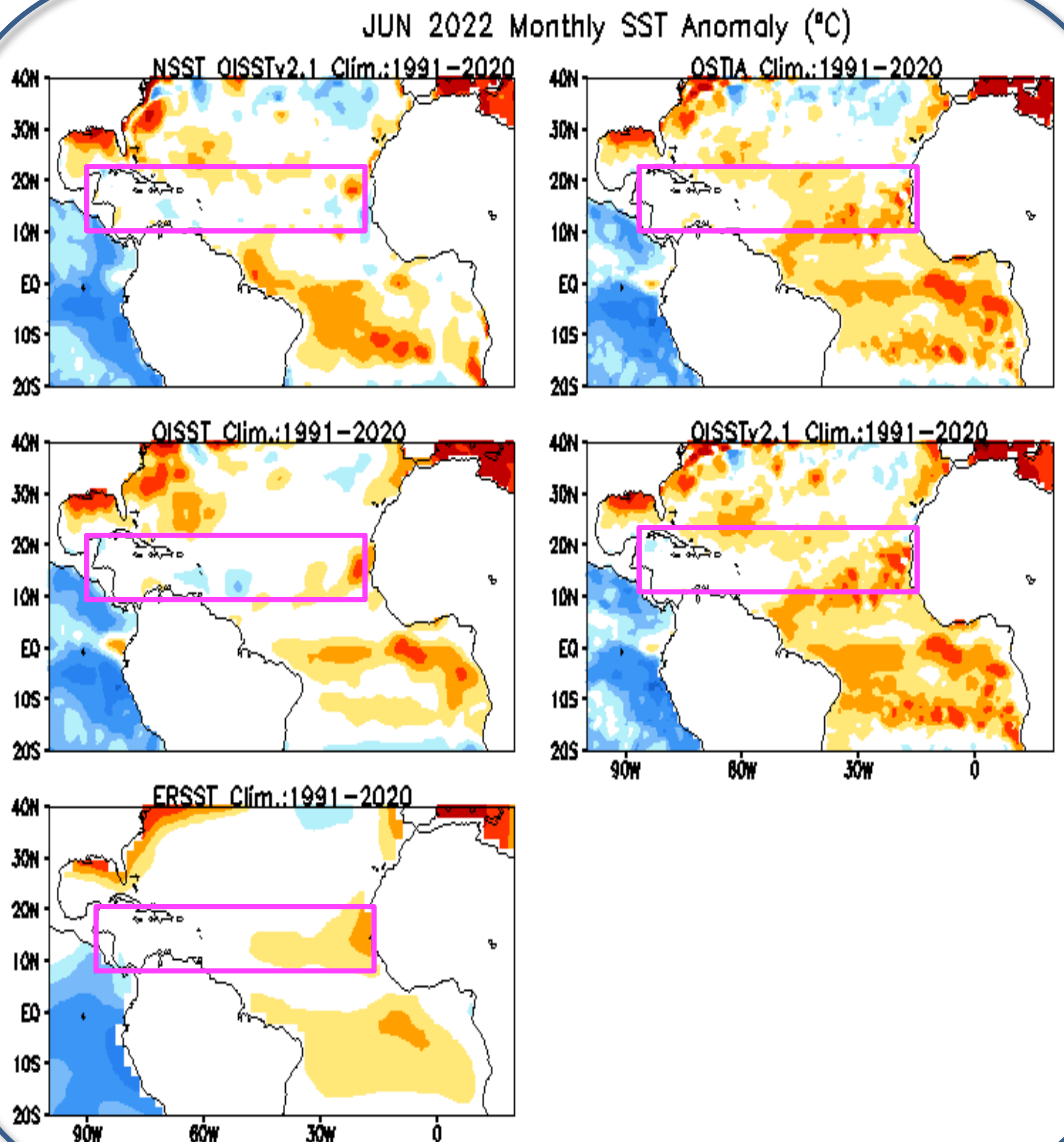


https://www.cpc.ncep.noaa.gov/products/international/index.shtml



- NMME models predicted above or nearly above average SSTs persist in the hurricane main development region through the whole 2022 hurricane season.

Monthly SST Anomaly in the Atlantic Ocean



- NSST was cooler than OISST v2.1 in the northern tropical Atlantic Ocean.
- NSST provides SST boundary source for CFSR, which provides oceanic initial conditions for CFSv2 and NCAR-CCSM4.

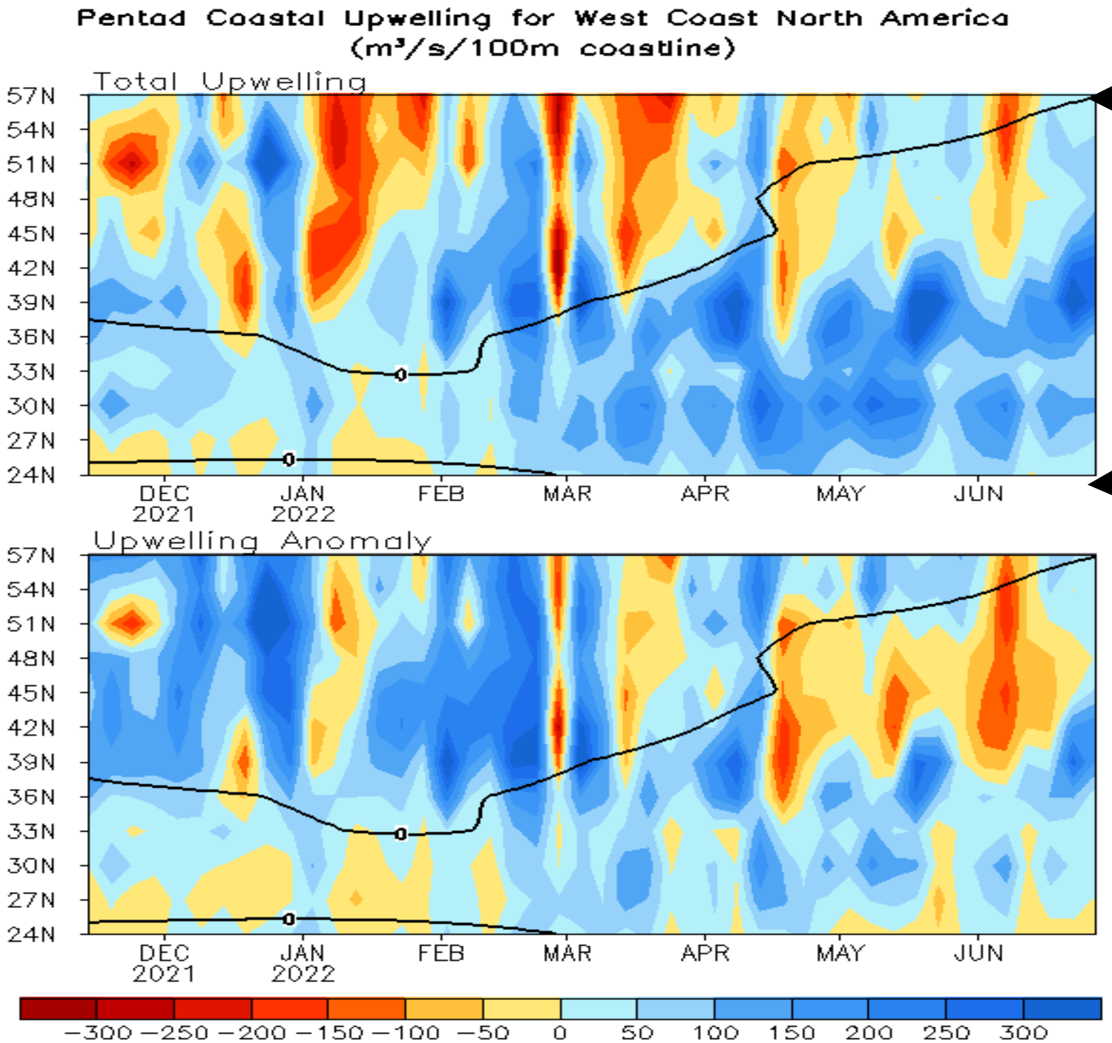
Acknowledgement

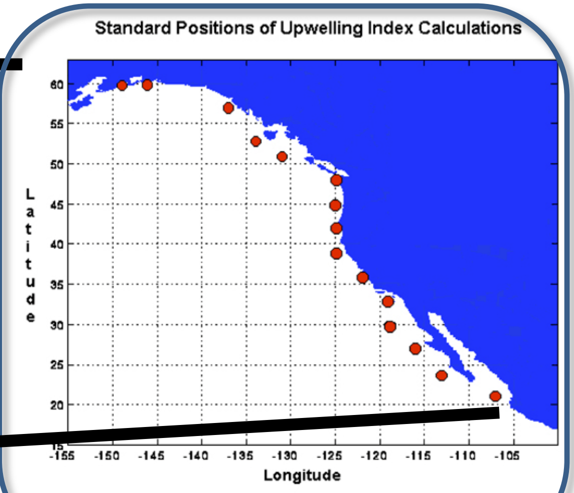
- ❖ Drs. Arun Kumar, Zeng-Zhen Hu and Jieshun Zhu : reviewed PPT, and provide insightful suggestions and comments
- ❖ Dr. Pingping Xie provided the BASS/CMORPH/CFSR EVAP package
- ❖ Dr. Wanqiu Wang provides the sea ice forecasts and maintains the CFSv2 forecast archive

Please send your comments and suggestions to:
Arun.Kumar@noaa.gov
Jieshun.Zhu@noaa.gov
Caihong.Wen@noaa.gov
Zeng-Zhen.Hu@noaa.gov

Backup Slides

North America Western Coastal Upwelling



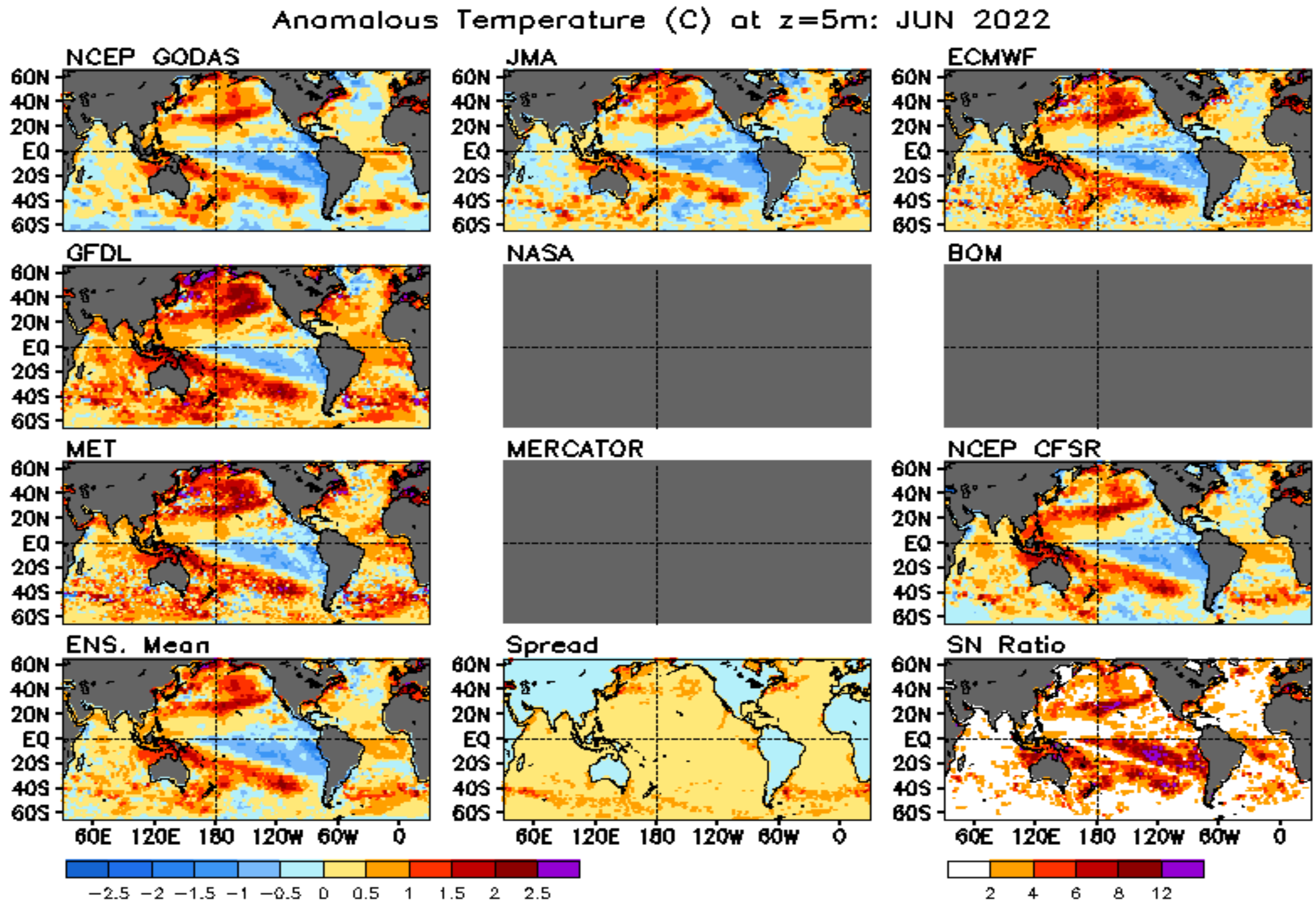


- Both anomalous coastal downwelling and upwelling were observed since mid-Apr 2022.

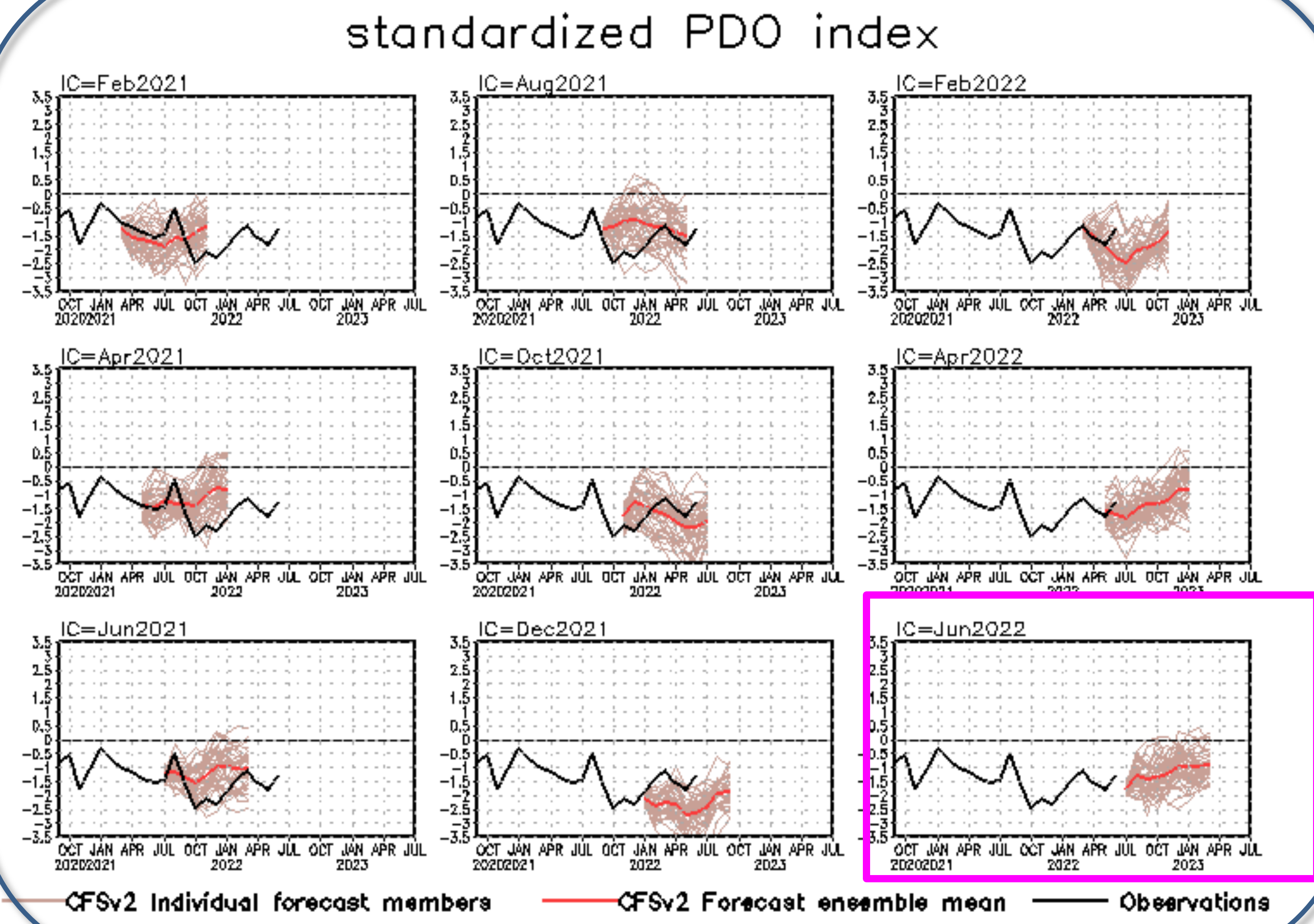
(top) Total and (bottom) anomalous upwelling indices at the 15 standard locations for the western coast of North America. Derived from the vertical velocity of the NCEP's GODAS and are calculated as integrated vertical volume transport at 50-meter depth from each location to its nearest coast point (m^3/s/100m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

Multiple Ocean Reanalysis: SST Anomaly



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



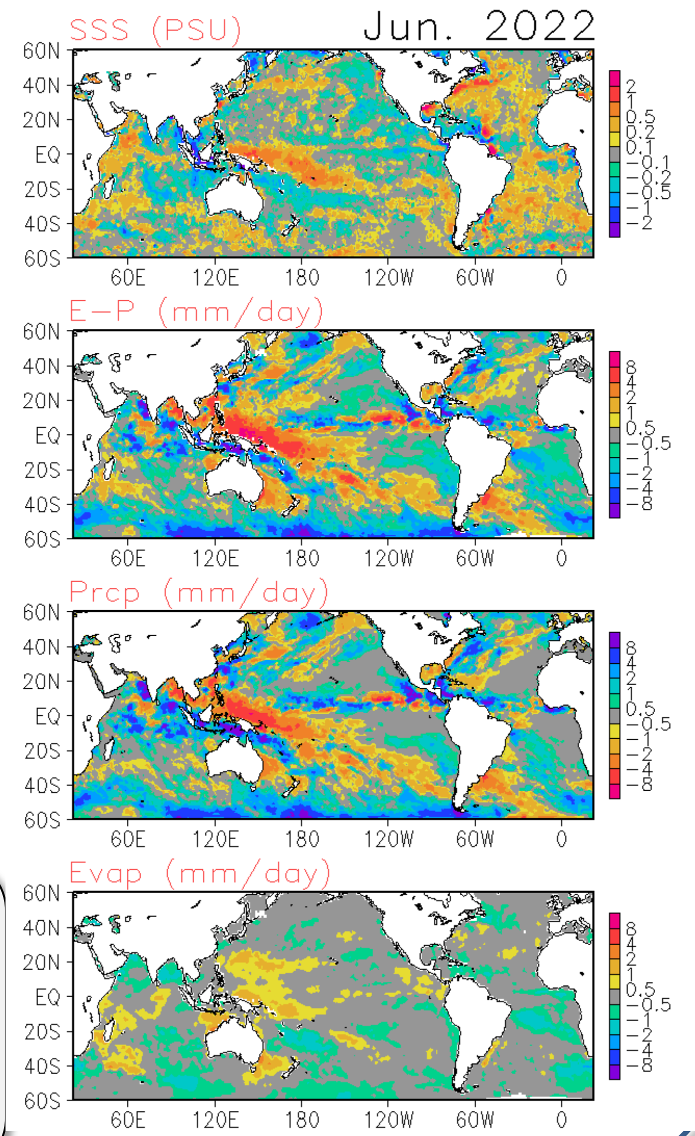
- CFSv2 predicts a negative phase of PDO in 2022.

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.

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

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

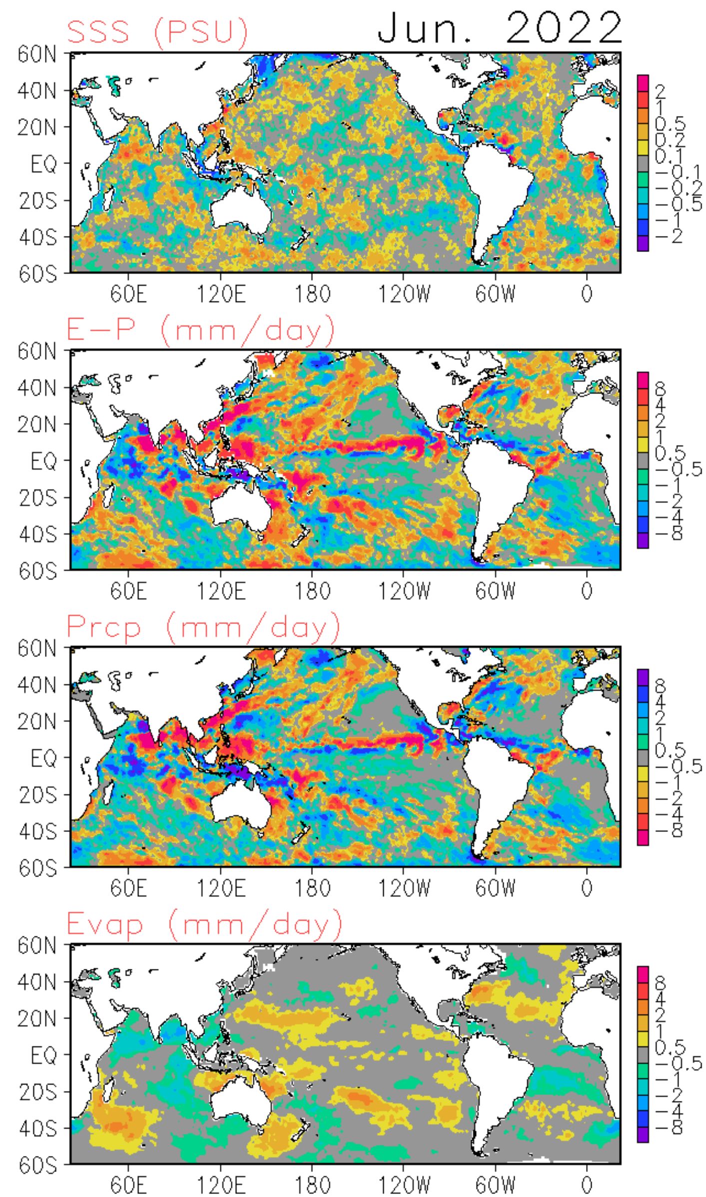
Overall, large-scale SSS anomaly patterns remains very close to those in the previous months, characterized by the positive SSS anomalies over the western equatorial Pacific Ocean and over the NE side of the SPCZ regions, as well as the negative anomalies over the SW side of the SPCZ and over the majority of the northern Pacific and southern tropical Indian ocean between the EQ and 30ºS. Negative SSS anomalies are also observed over the Bay of Bengal shows, consistent with the negative E-P over the 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 June 2022

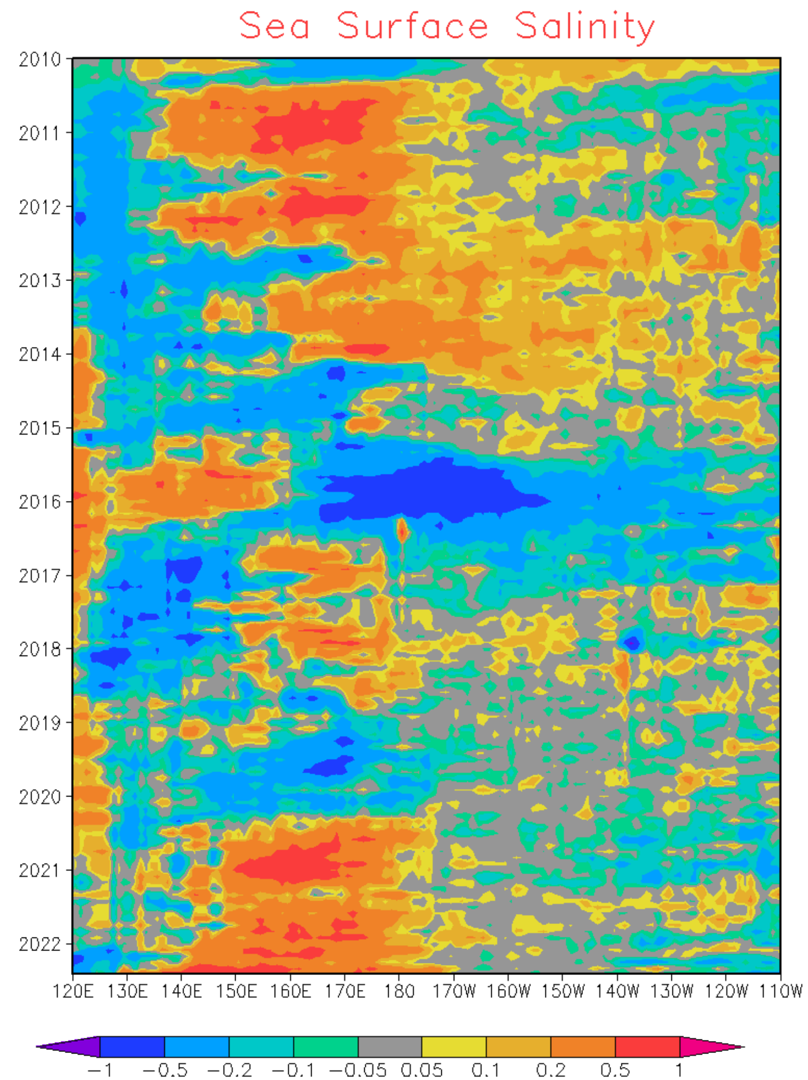
Pacific ITCZ is weakening and moved slightly southwardly, creating a pair of not-so-clear but visible west-east bands of saltier and freshened SSS over the region. Precipitation intensified significantly over the southern GOM and the Caribbean Sea, causing negative SSS anomalies. Also noticeable are the enhanced precipitation (freshened SSS) over large portions of the SE Pacific



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 over the central / western equatorial Pacific between 140ºE and 170ºW, spread slightly towards both east and west. Negative SSS anomaly over the western equatorial Pacific retrieved westward compared to the previous month.



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.