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

Prepared by

Climate Prediction Center, NCEP/NOAA

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

This project, to deliver real-time ocean monitoring products, is implemented by CPC in cooperation with NOAA's Global Ocean Monitoring and Observing Program (GOMO)

Outline

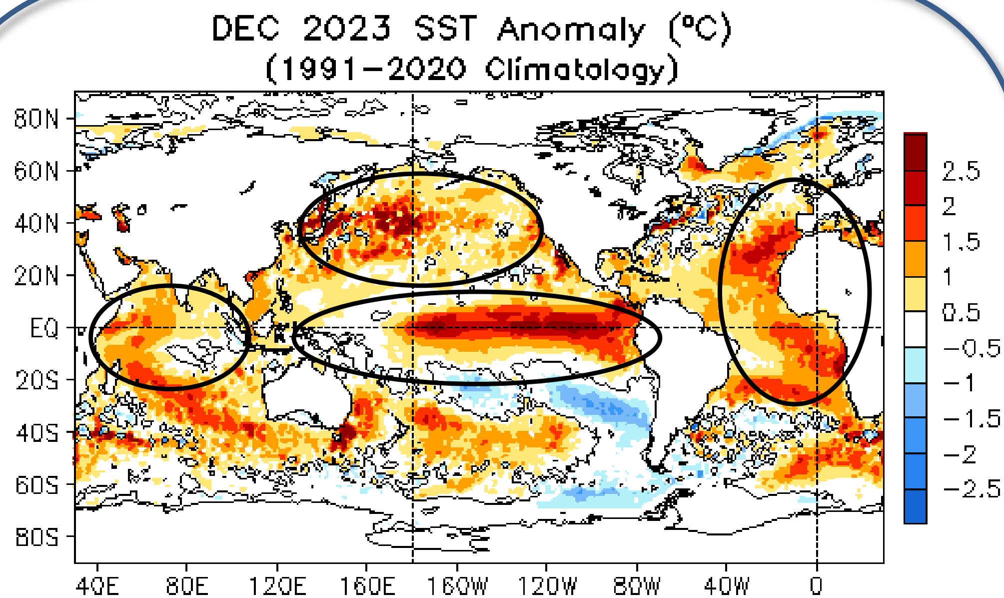
- Overview
- Recent highlights
  - Pacific Ocean
  - Arctic & Antarctic Oceans
  - Indian Ocean
  - Atlantic Ocean
- Global SSTA Predictions
- *2020-23 Triple-Dip La Nina*

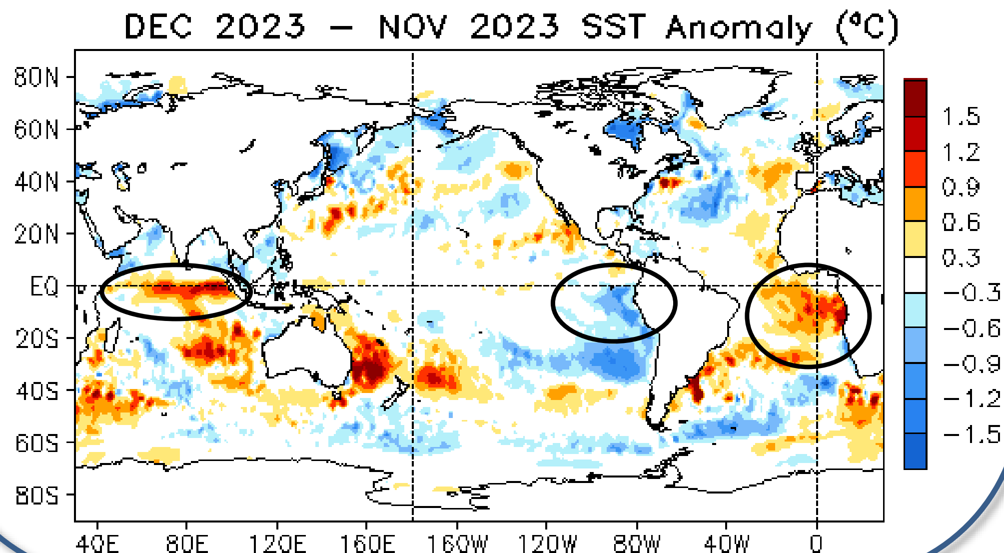
Overview

- Pacific Ocean
  - El Niño condition persisted with Niño3.4 = 2.0°C in Dec 2023.
  - NOAA "ENSO Diagnostic Discussion" on 14 Dec 2023 stated "*El Niño is expected to continue through the Northern Hemisphere winter, with a transition to ENSO-neutral favored during April-June 2024 (60% chance).*"
  - Positive SSTAs continued in the North Pacific in Dec 2023.
  - The PDO has been in a negative phase since Jan 2020 with PDOI = -1.2 in Dec 2023.
- Arctic & Antarctic Oceans
  - The Arctic sea ice extent was 12.00 million square kilometers in Dec 2023, 9th lowest in the 45-year satellite record in Dec.
  - Antarctic sea ice extent was 8.67 million square kilometers in Dec 2023, ranking the second-lowest Dec extent since 1978.
- Indian Ocean
  - SSTs were above (near) average in the western (eastern) tropical Indian Ocean in Dec 2023.
- Atlantic Ocean
  - Positive SSTAs were observed in the eastern tropical Atlantic with positive ATL3 index strengthening in Dec 2023.
  - NAO switched to a positive phase in Dec 2023 with NAOI= 1.7.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency



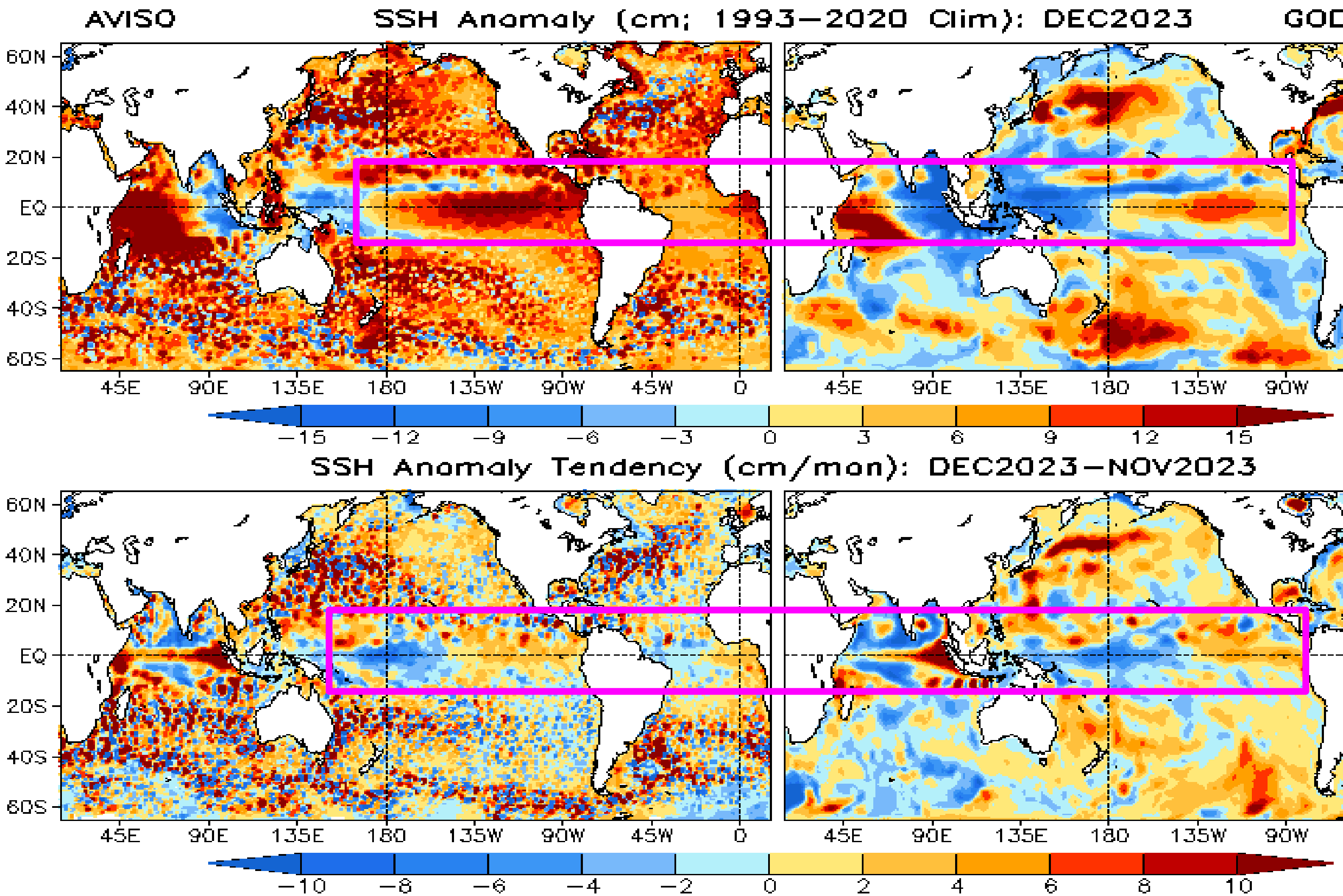


- Positive SSTAs persisted the central and eastern equatorial Pacific Ocean although coastal El Niño condition weakened in Dec 2023.
- Positive SSTAs were present in the North Pacific.
- Positive SSTAs dominated the eastern Atlantic Ocean.
- Positive SSTAs were observed in the western Indian Ocean, and the Indian dipole mode was in a positive phase.

- Negative SSTA tendencies were present along the southern American coast.
- Positive SSTA tendencies were observed in the southeastern Atlantic Ocean.
- Positive SSTA tendencies dominated the central and eastern equatorial Indian Ocean.

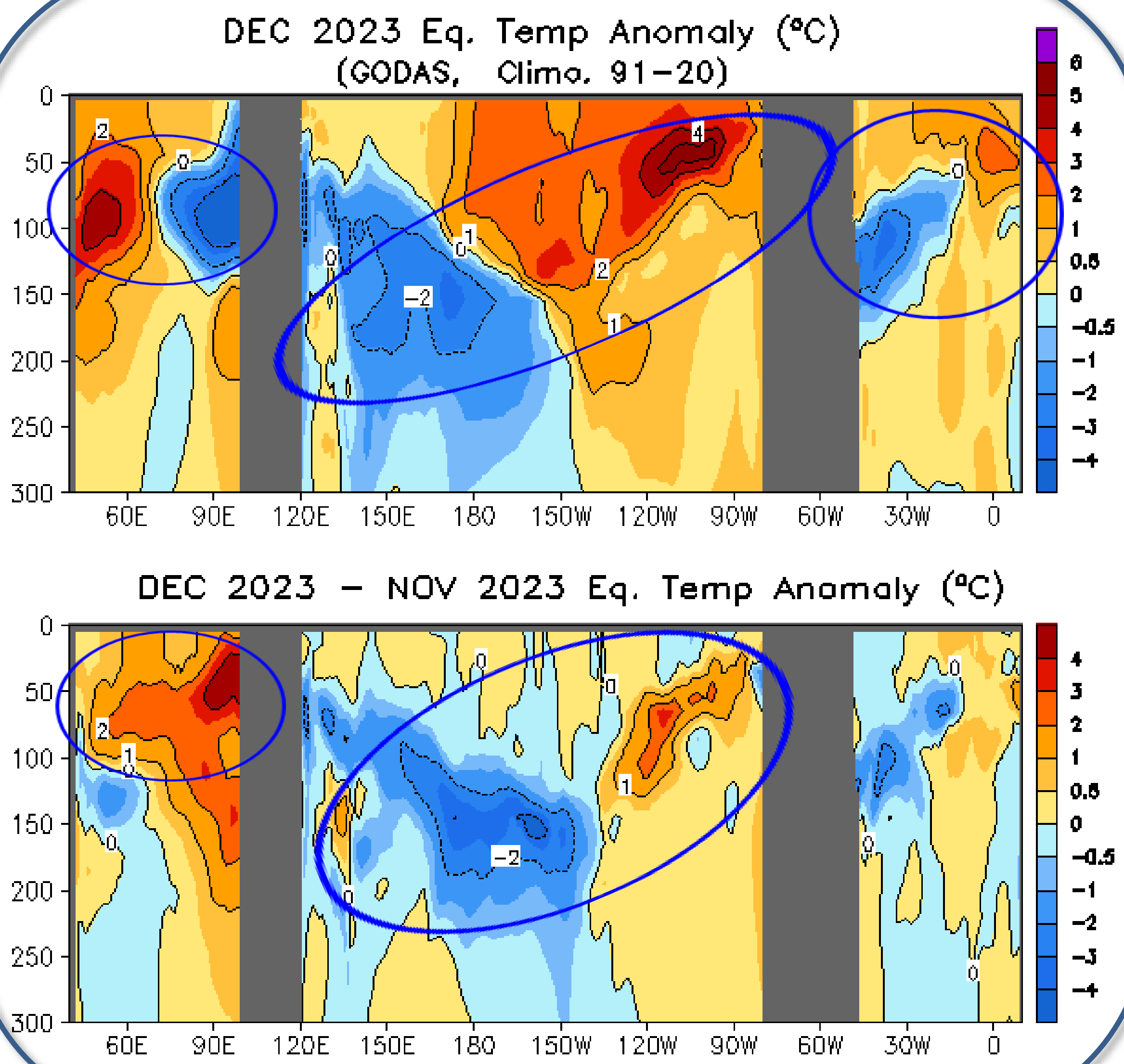
SSTAs (top) and SSTA tendency (bottom). Data are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

AVISO & GODAS SSH Anomaly (cm) and Anomaly Tendency



- SSHAs were consistent with El Niño condition in the tropical Pacific.
- However, the tendencies indicated a weakening trend of the El Niño condition in the central Pacific.

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



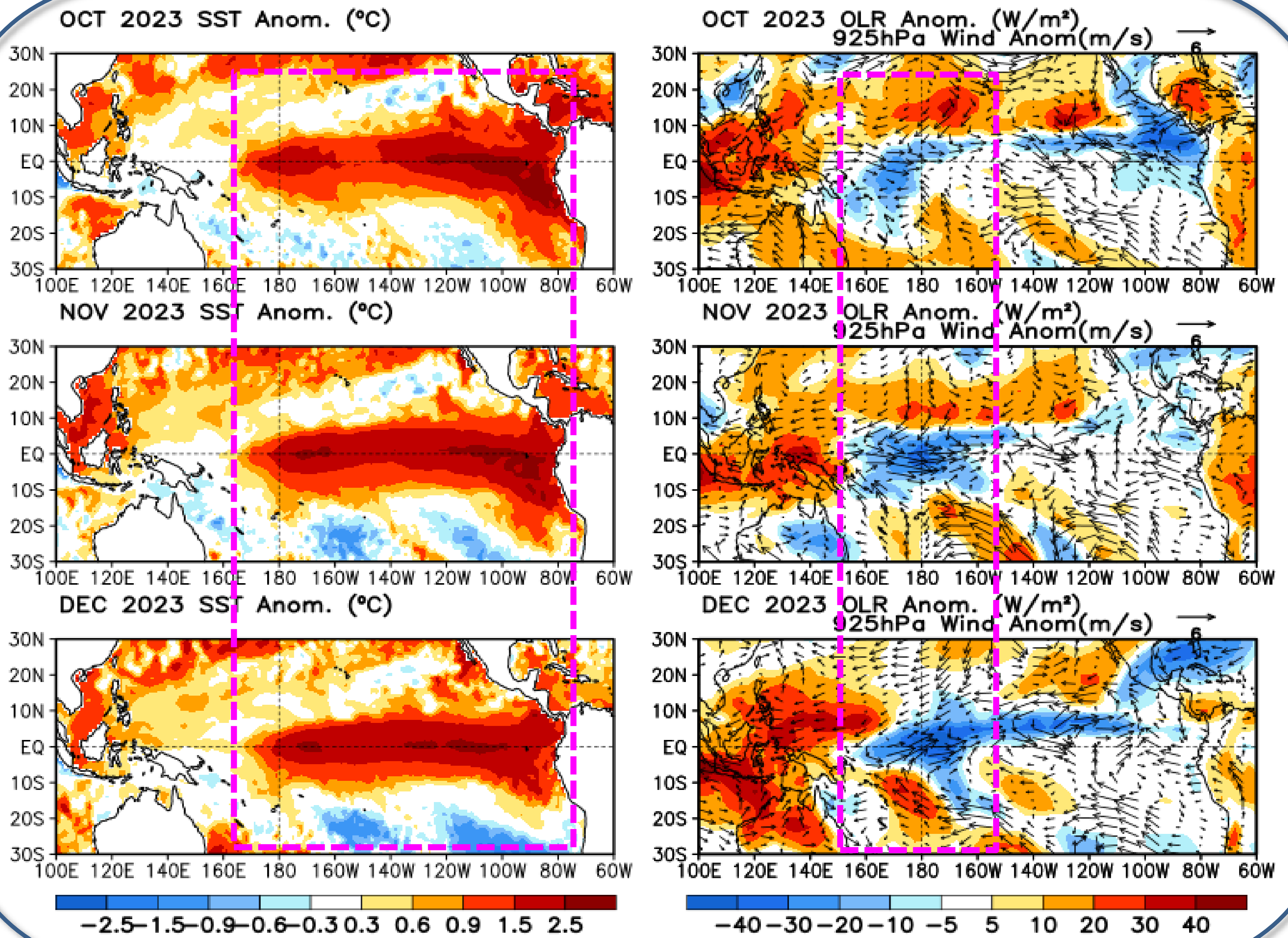
- A dipole-like pattern with positive (negative) anomalies in the eastern (western) Pacific thermocline persisted.
- Positive (negative) anomalies dominated the eastern (western) Atlantic Ocean along the thermocline.
- Positive (negative) anomalies persisted along the western (eastern) Indian Ocean thermocline, indicating a positive phase of Indian Ocean dipole.

- Negative (positive) anomaly tendencies were observed in the western and central (eastern) thermocline in the Pacific.
- Positive anomaly tendencies continued in the 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.

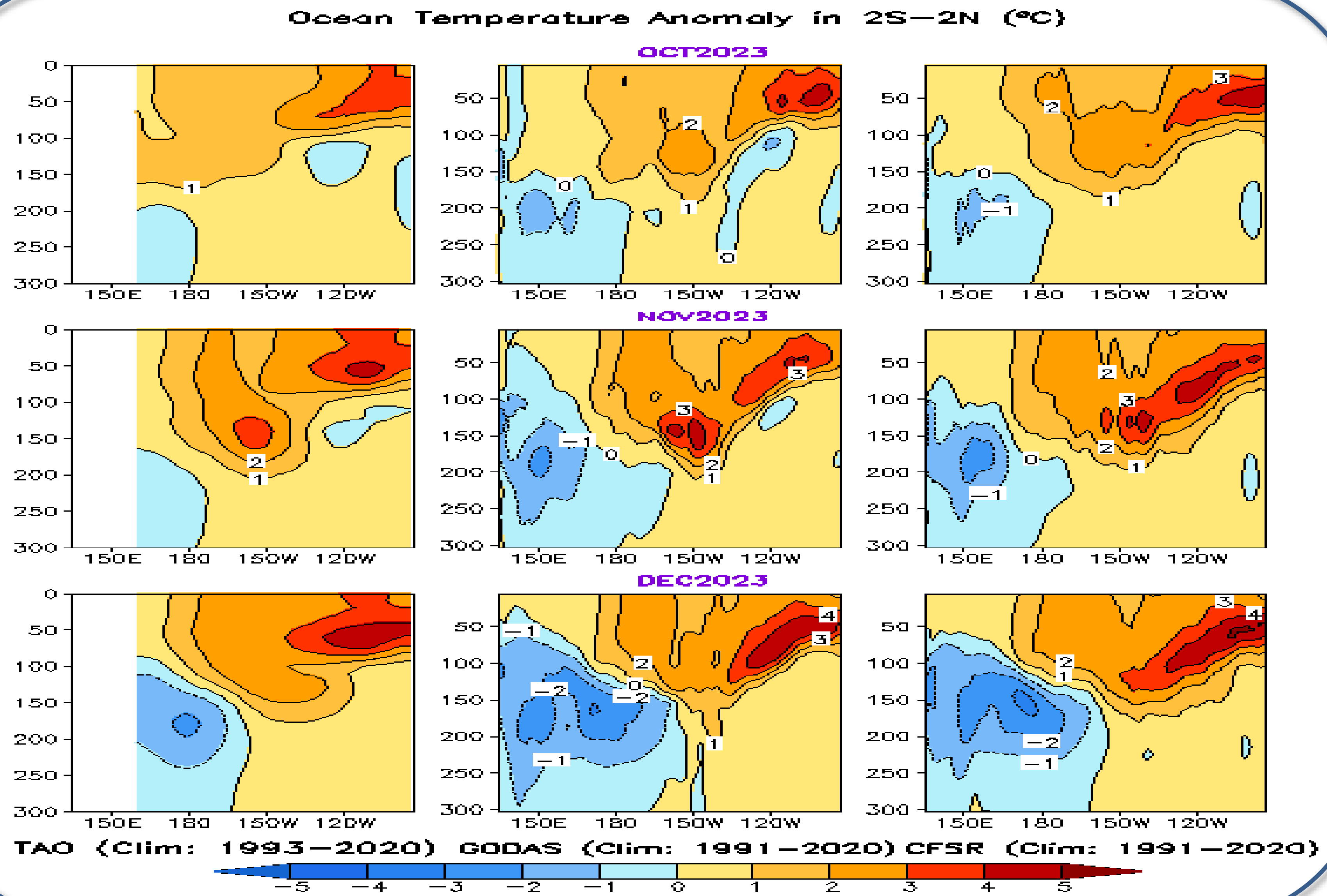
Tropical Pacific Ocean and ENSO Conditions

Last 3-month Tropical Pacific Ocean SST, OLR, and uv925 Anomalies

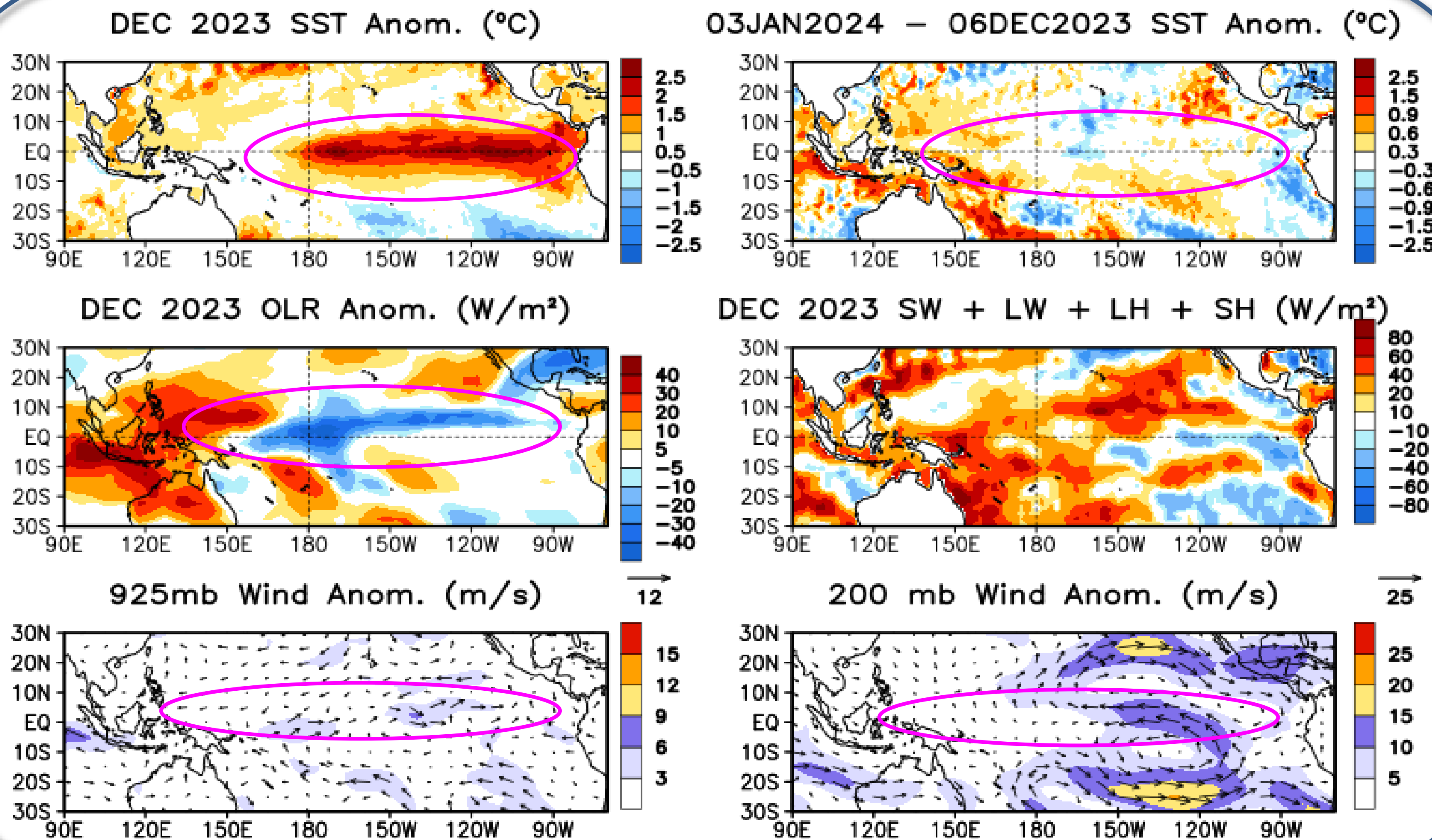


Monthly mean subsurface temperature anomaly along the Equator:

Consistent among 3 products with cooling in the western Pacific strengthening during the last 3 months

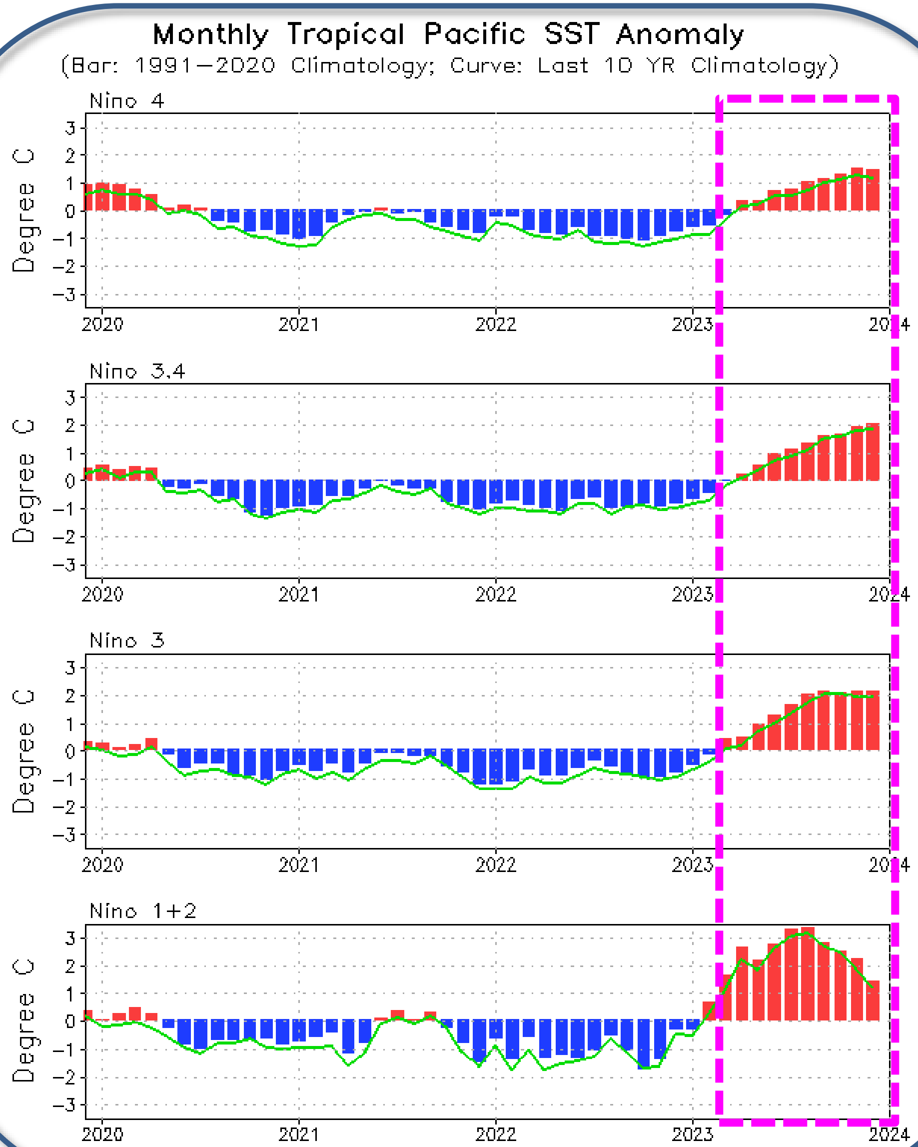


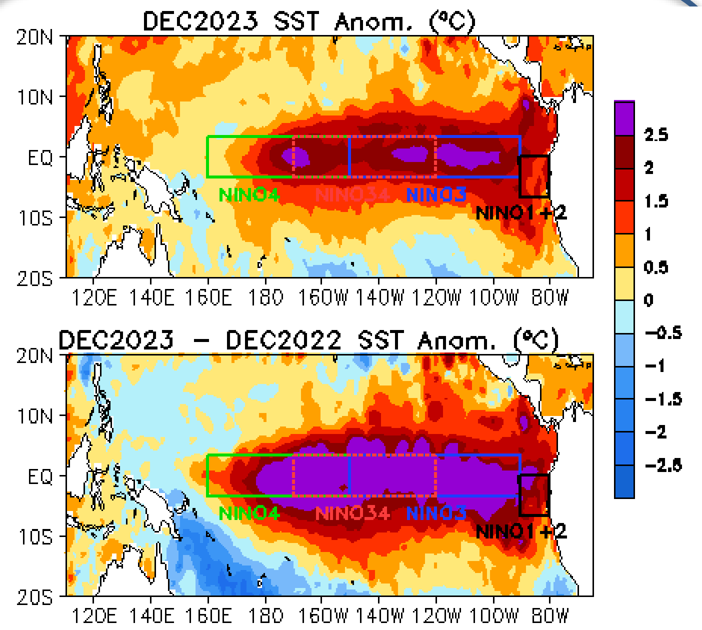
Tropical Pacific: SSTA, SSTA Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Winds



SSTAs (top-left), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the OIv2.1 SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1991-2020 base period means.

Evolution of Pacific Niño SST Indices





- Niño3.4 indices strengthened in Dec 2023, with Niño3.4 = 2.0°C (2.1°C in ERSSTv5 data).

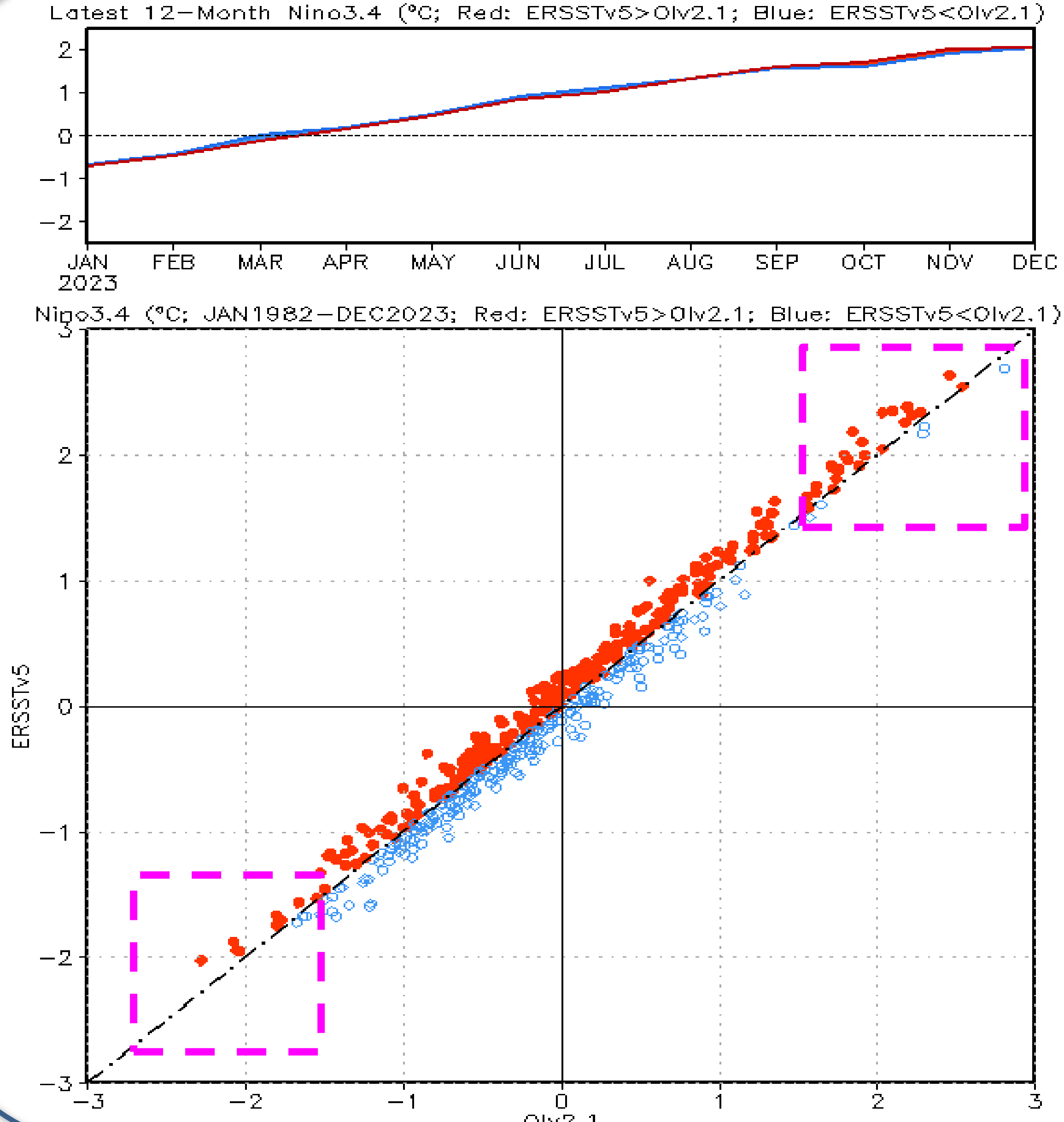
- Positive Nino1+2 continuously weakened in Dec 2023, with Nino1+2 = 1.4°C.

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

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

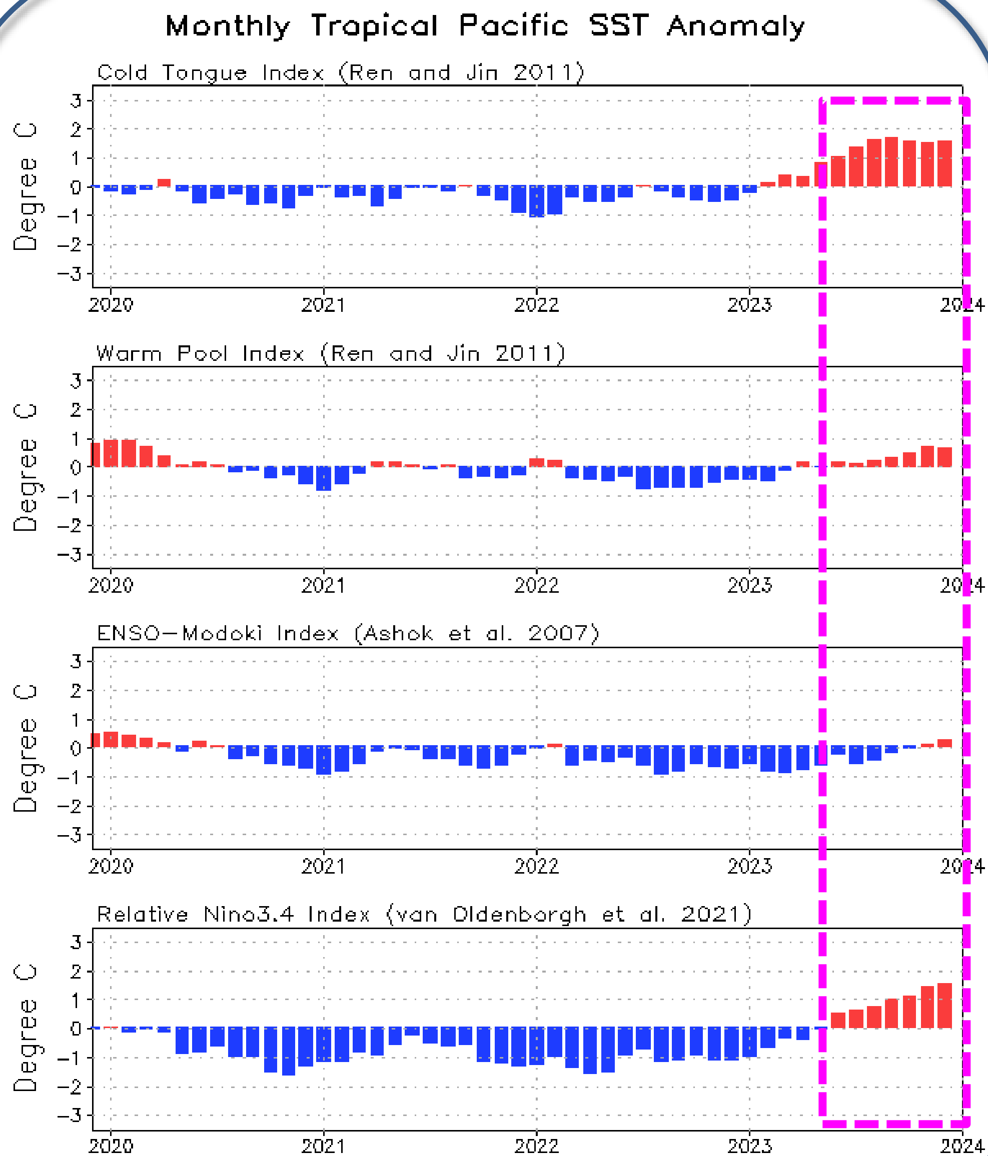
Niño region indices, calculated as the area-averaged monthly mean SSTAs (°C) for the specified region. Data are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

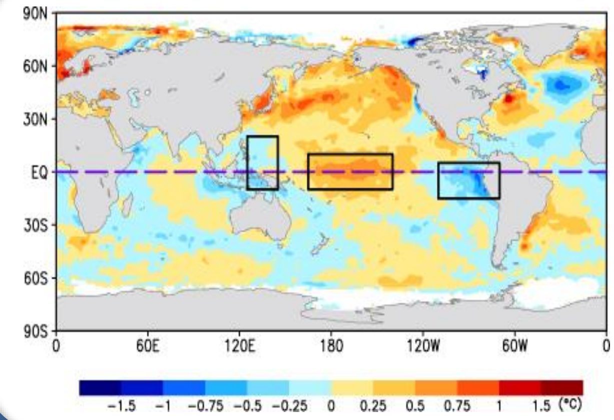
Comparison of ERSSTv5 & OIv2.1 Niño3.4 Index



- During the last year, ERSSTv5 was close to OIv2.1.
- Sometimes, ERSSTv5 is either warmer or cooler than OIv2.1.
- For both the extreme positive and negative (>1.5°C or <-1.5°C) Niño3.4, ERSSTv5 is mostly warmer than OIv2.1.

Evolution of Pacific Niño SST Indices: Warming mainly in the cold tongue



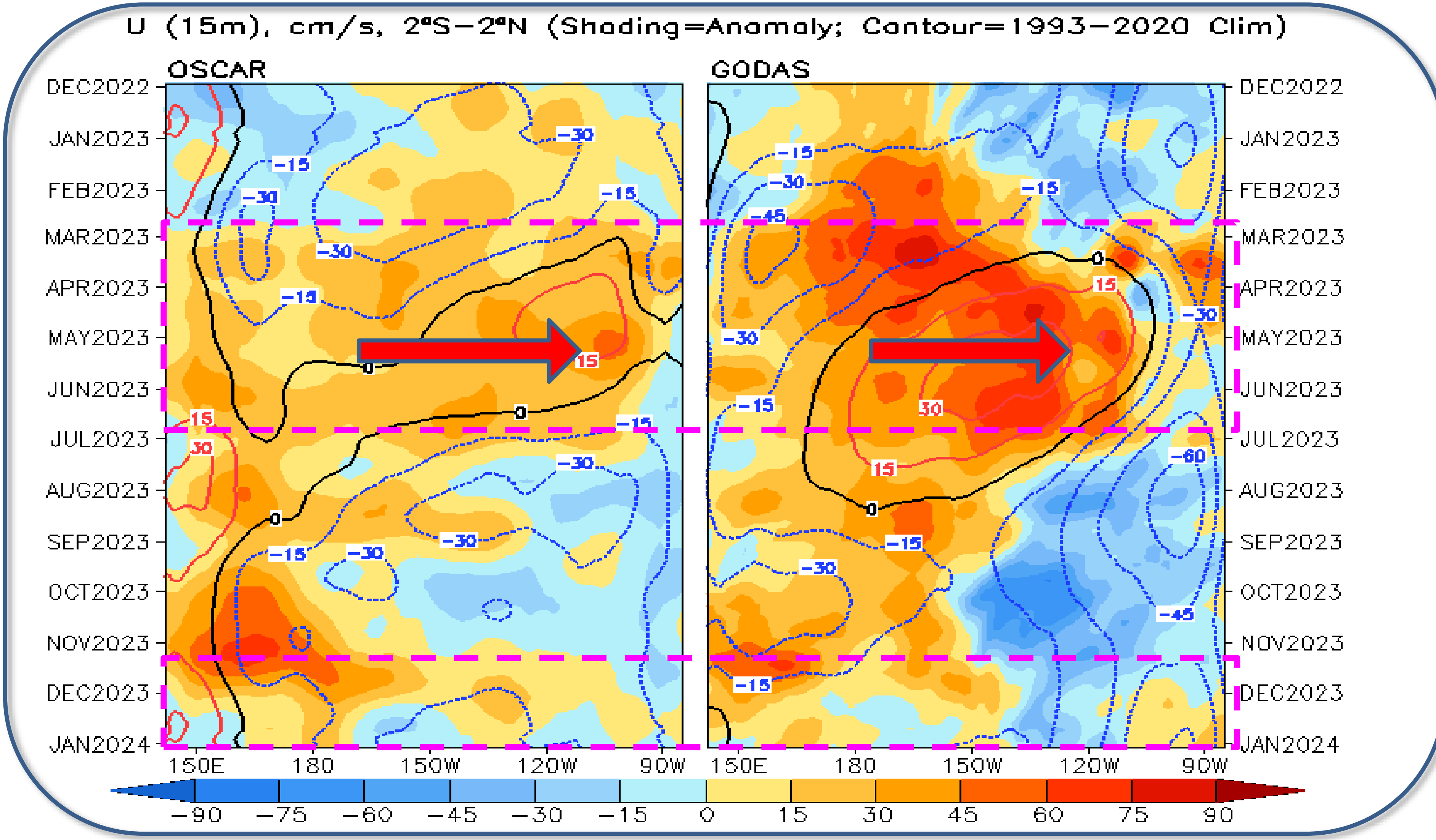


- Relative Niño3.4 index is now included in ENSO monitoring, which is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0º-360º, 20ºS-20ºN), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative Niño3.4 index is renormalized (van Oldenborgh et al. 2021: ERL, 10.1088/1748-9326/abe9ed; L'Heureux, et al. 2024: J. Climate, 10.1175/JCLI-D-23-0406.1).

Relative Niño3.4 data updated monthly at:

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

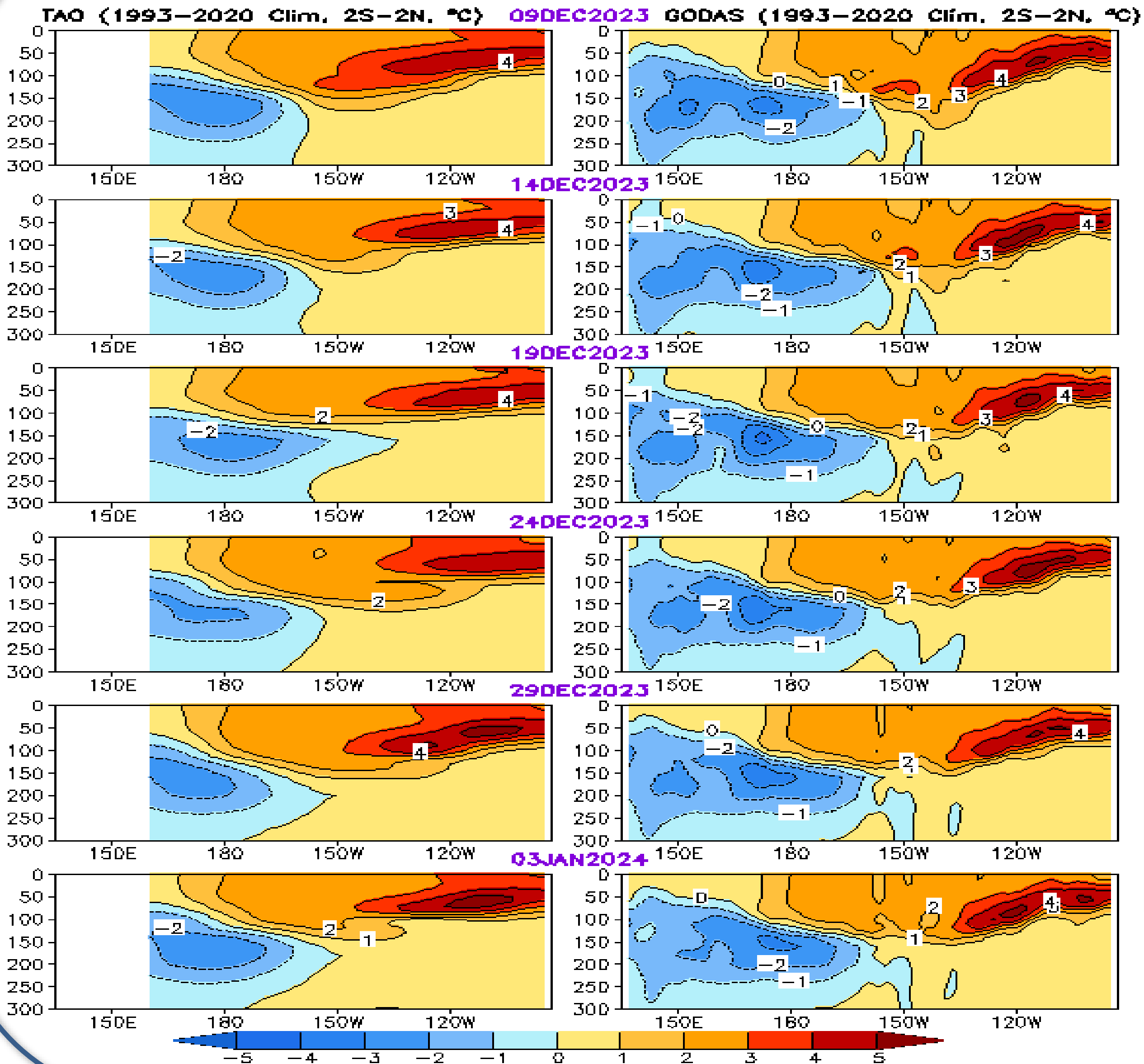
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- Anomalous eastward currents were present in the equatorial Pacific in both OSCAR and GODAS during Feb-Jul 2023, which were consistent with the growth of the positive SSTA.
- Anomalous currents were weak in Dec 2023.

Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

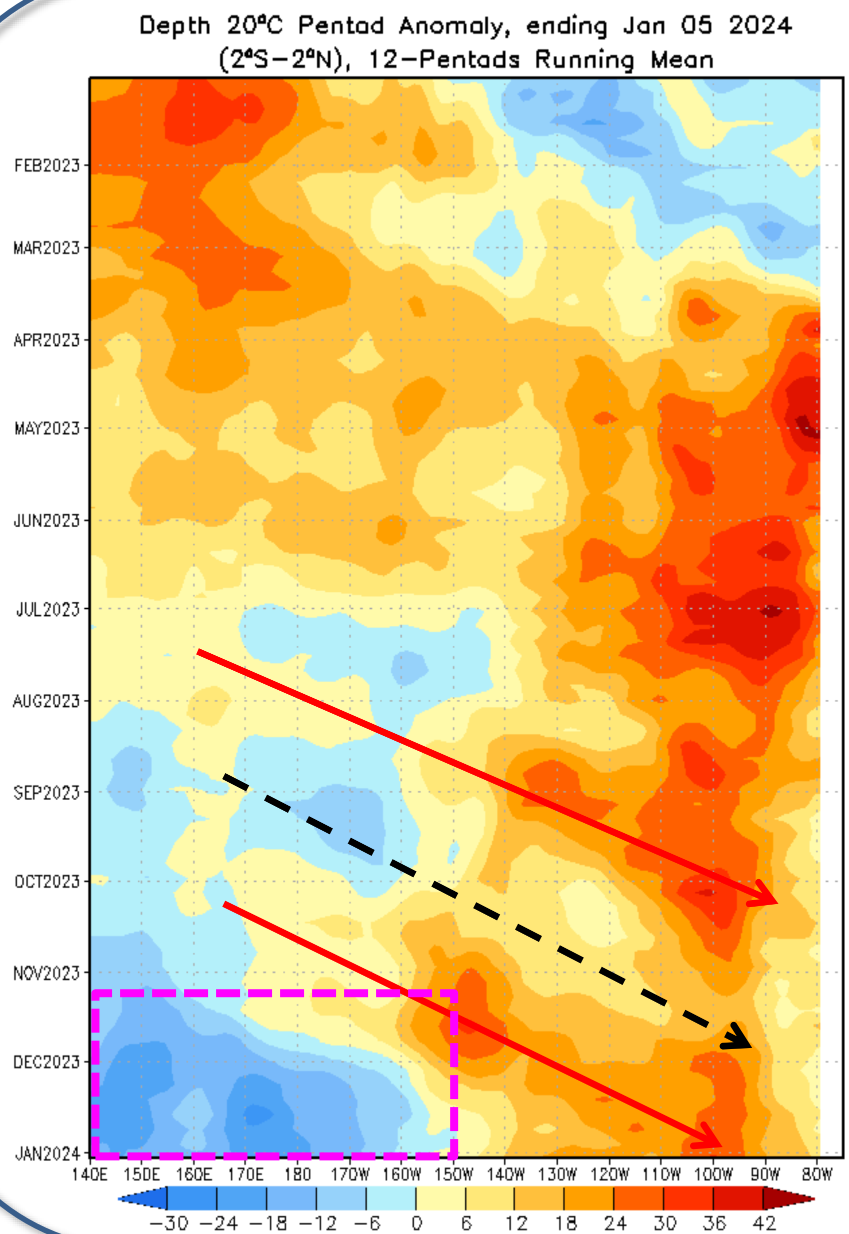
TAO GODAS

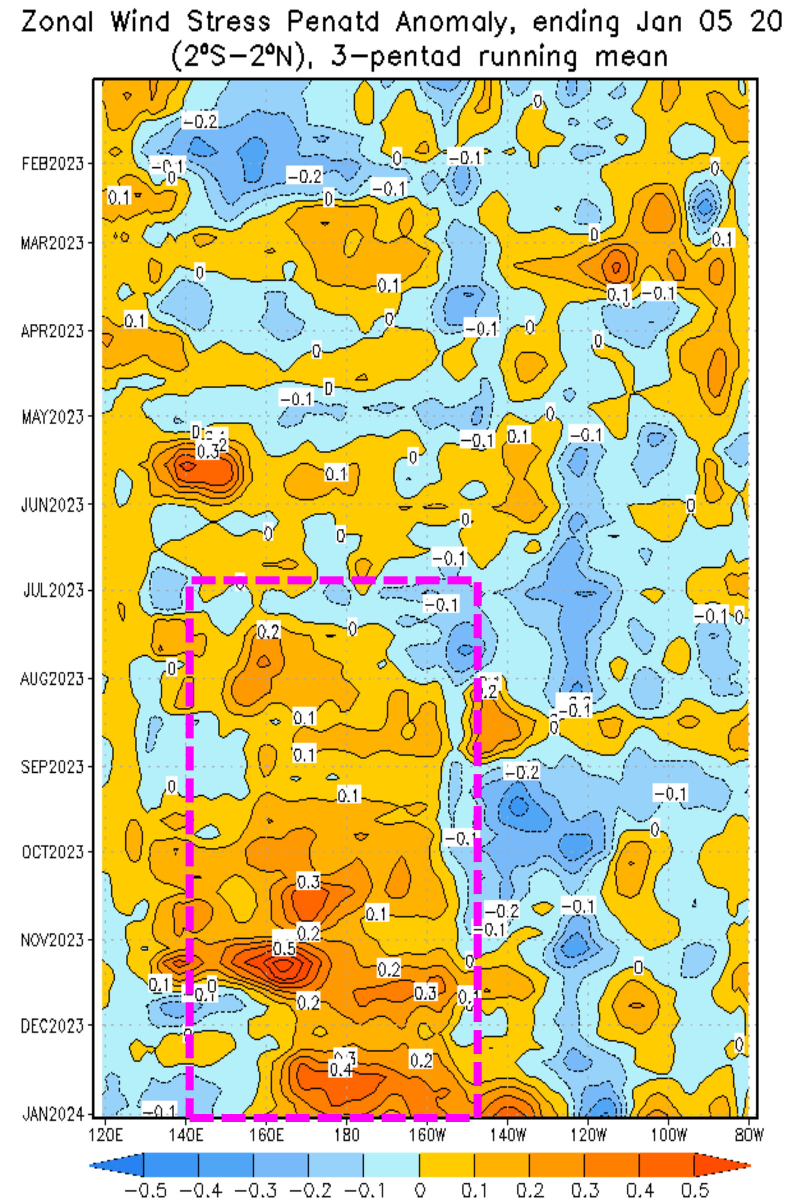


- Positive ocean temperature anomalies along the thermocline in the eastern Pacific and negative anomalies in the western Pacific were persistent in the last month.

- The features of the ocean temperature anomalies were similar between GODAS and TAO analysis.

Evolution of Pentad D20 and Taux anomalies along the equator

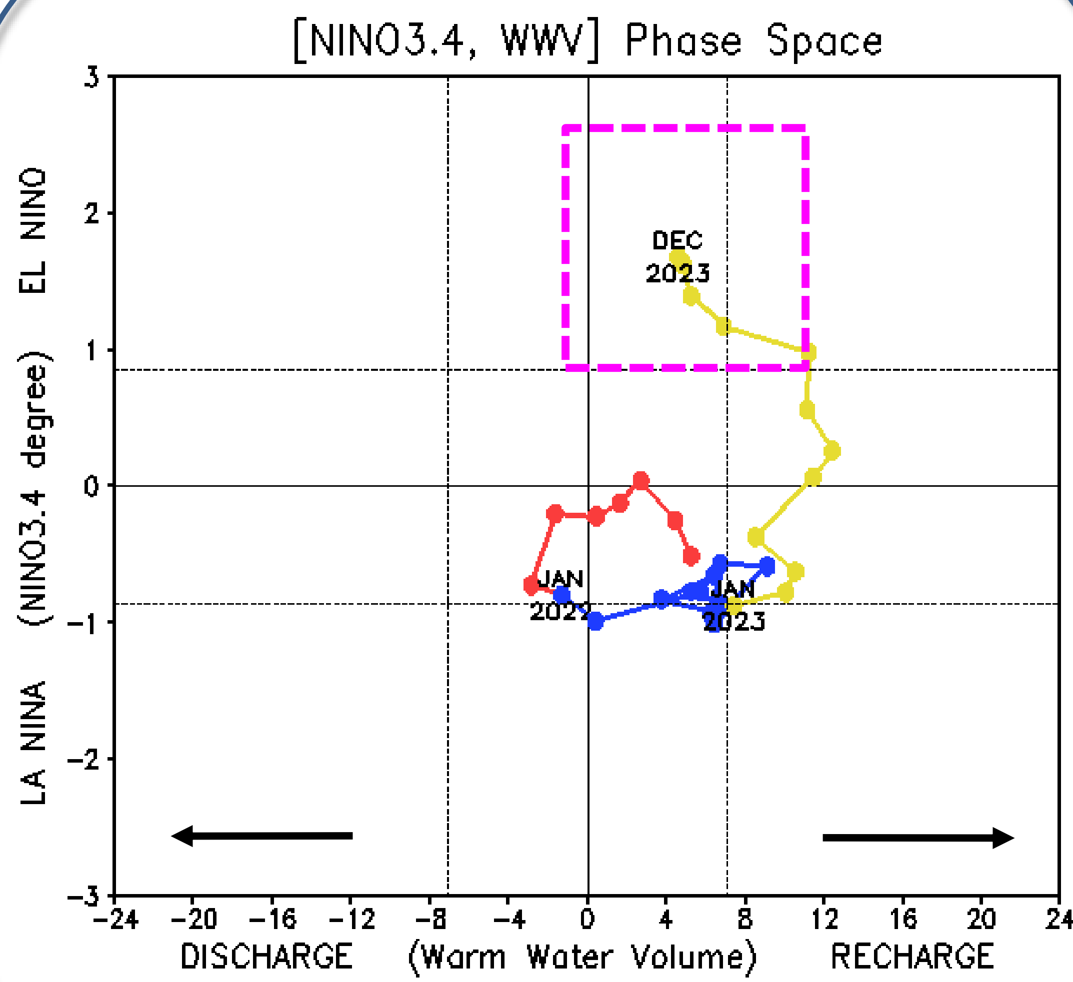




Warm Water Volume (WWV) and Niño3.4 Anomalies

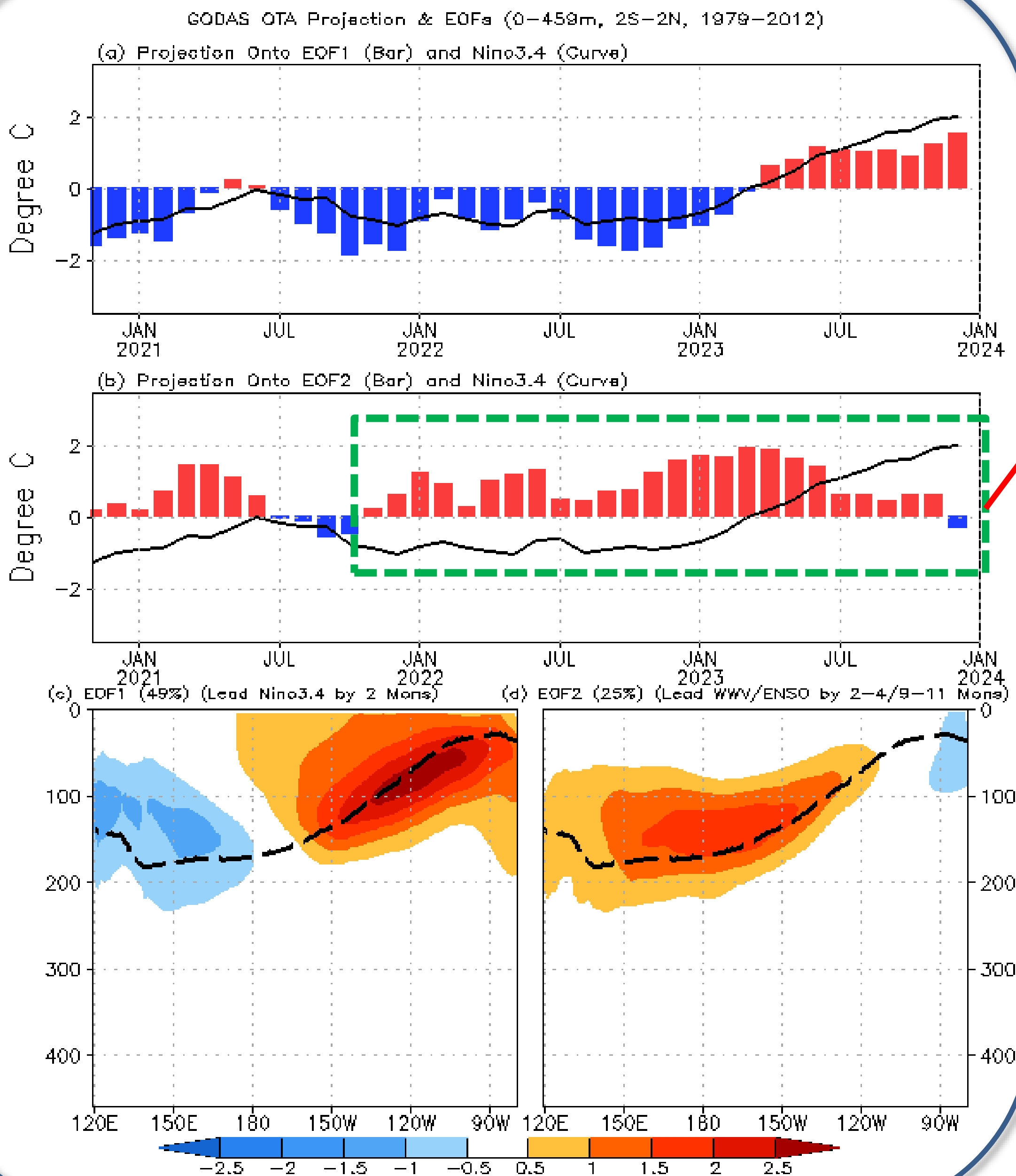
- Pacific equatorial Warm Water Volume (WWV) was still in a recharge phase, but weakened in Dec 2023.

-As WWV is intimately linked to ENSO variability (Wyrtki 1985; Jin 1997), it is useful to monitor ENSO in a phase space of WWV and Niño3.4 (Kessler 2002).
- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.



Phase diagram of Warm Water Volume (WWV) and Niño3.4 indices. WWV is the average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN] calculated with the NCEP's GODAS. Anomalies are departures from the 1991-2020 base period means.

Equatorial Sub-surface Ocean Temperature Monitoring



- After a long-period recharging since Nov 2021, the equatorial Pacific switched to a discharge phase in Dec 2023.

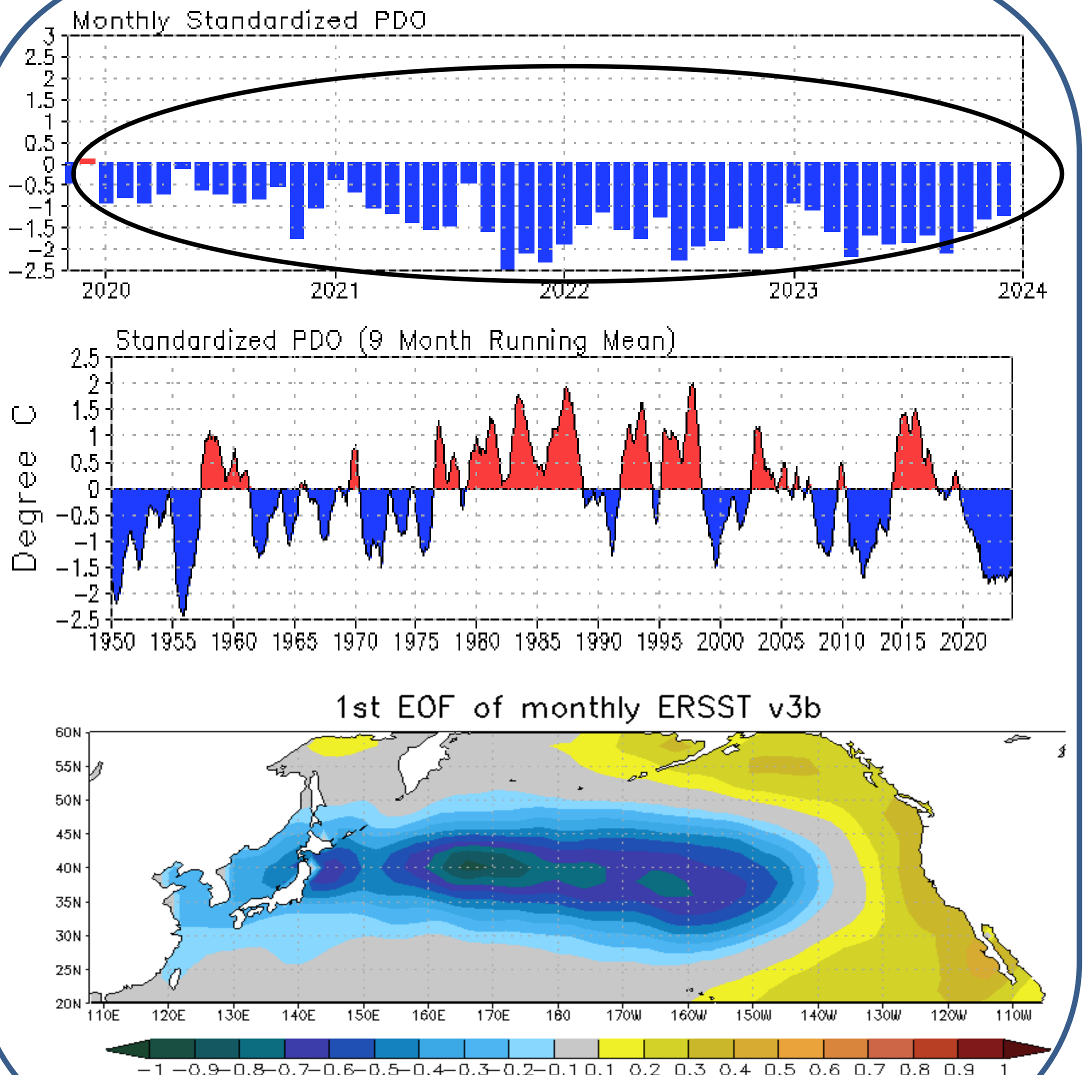
- Projection of ocean temperature anomalies onto EOF1 and EOF2; EOF1: Tilt/dipole mode (ENSO peak phase); EOF2: WWV mode.

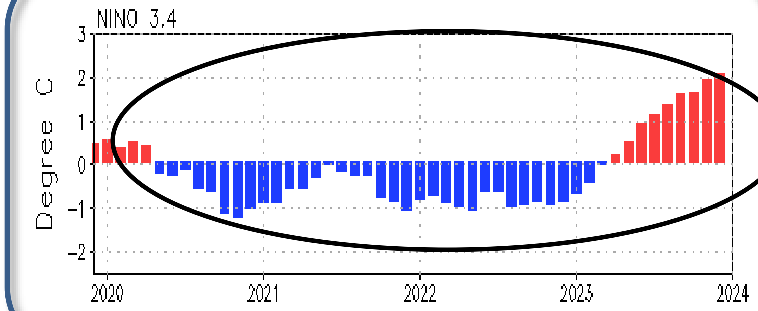
- Recharge/discharge oscillation (ENSO transition phase); Recharge process: heat transport from outside of equator to equator; Negative -> positive phase of ENSO

- For details, see: Kumar and Hu (2014) DOI: 10.1007/s00382-013-1721-0.

North Pacific, Arctic, & Antarctic Oceans

Pacific Decadal Oscillation (PDO) Index

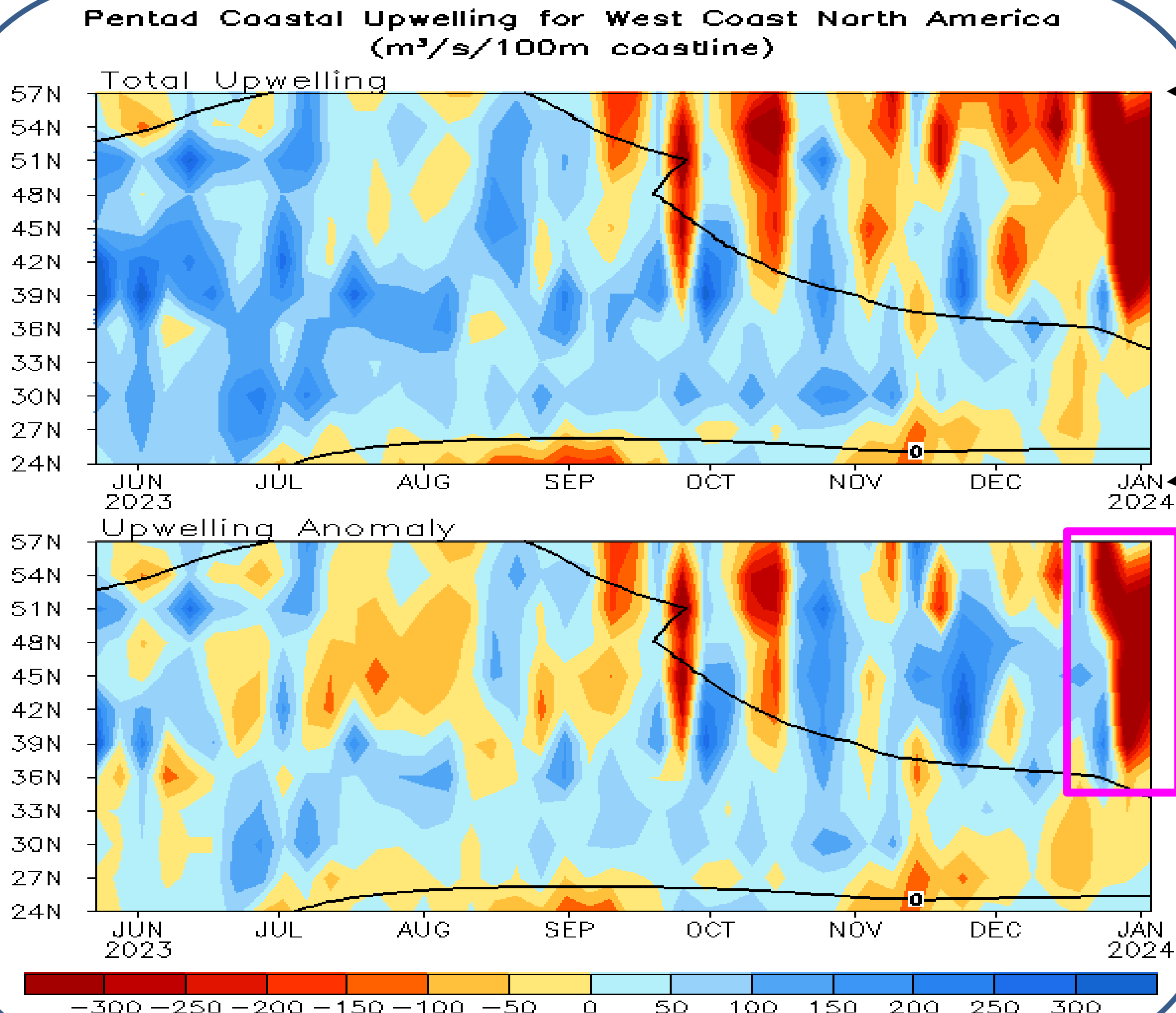


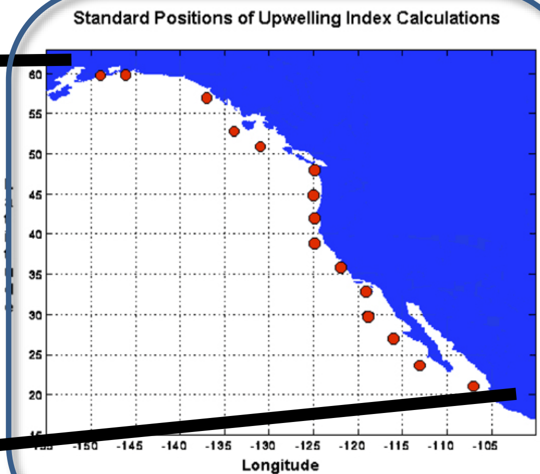


- The PDO has been in a negative phase since Jan 2020 with PDOI = -1.2 in Dec 2023.
- Statistically, ENSO leads PDO by 3-4 months, through teleconnection via atmospheric bridge, with El Niño (La Niña) associated with positive (negative) PDO Index.

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

North America Western Coastal Upwelling



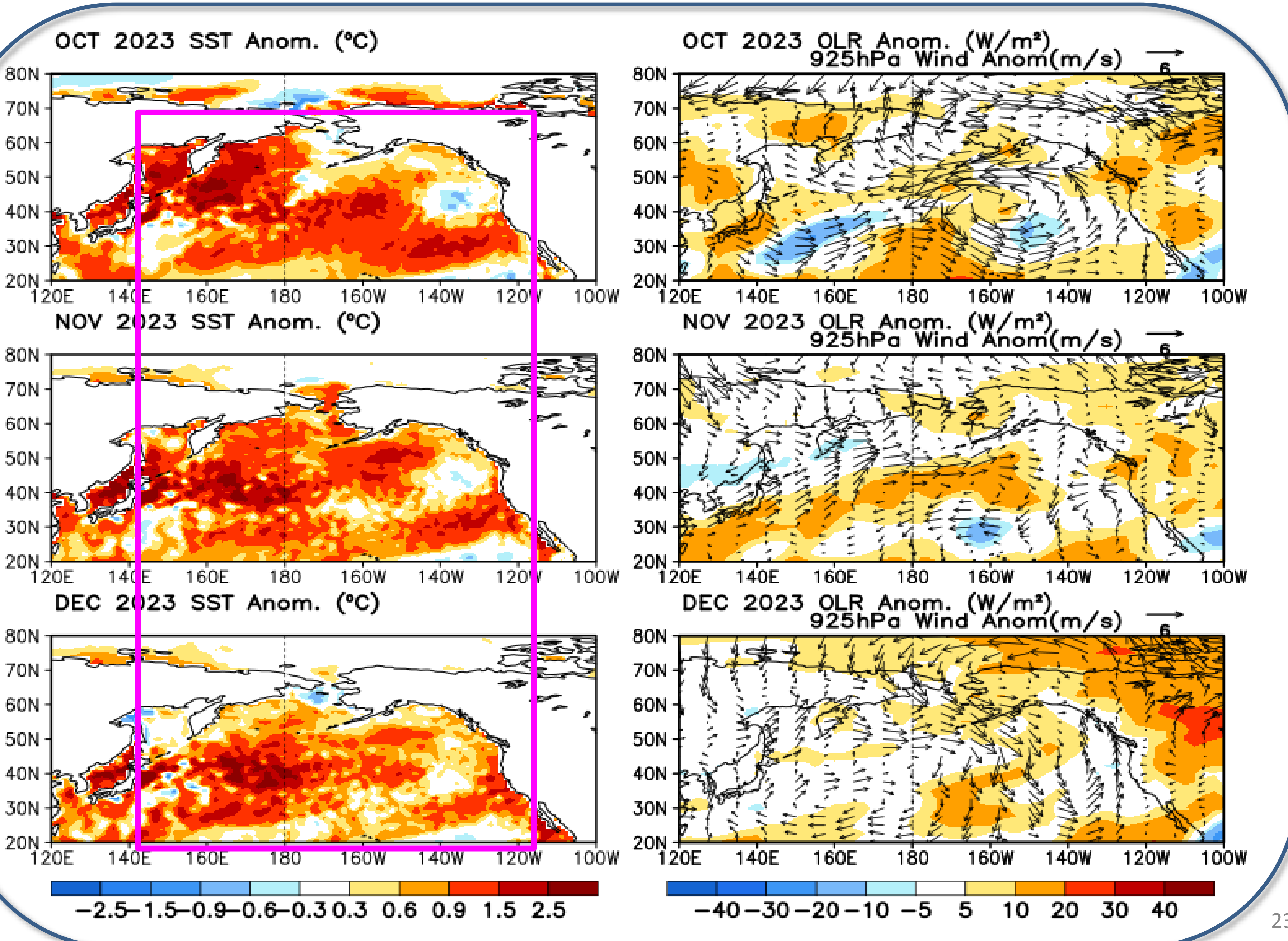


- Strong anomalous downwelling was present since late-Dec 2023.

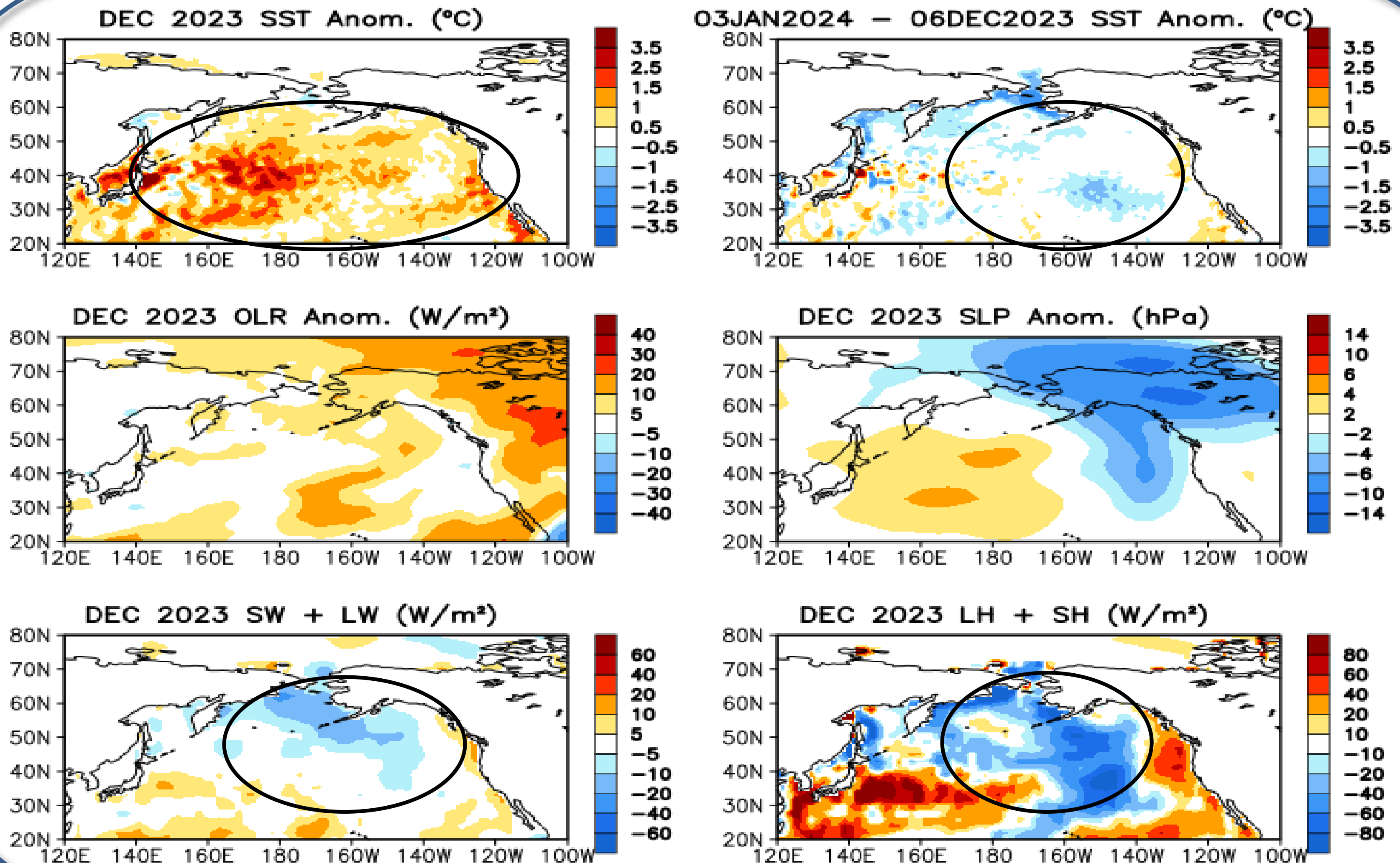
(top) Total and (bottom) anomalous upwelling indices at the 15 standard locations for the western coast of North America. Derived from the vertical velocity of the NCEP's GODAS and are calculated as integrated vertical volume transport at 50-meter depth from each location to its nearest coast point ($m^3/s/100m$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

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

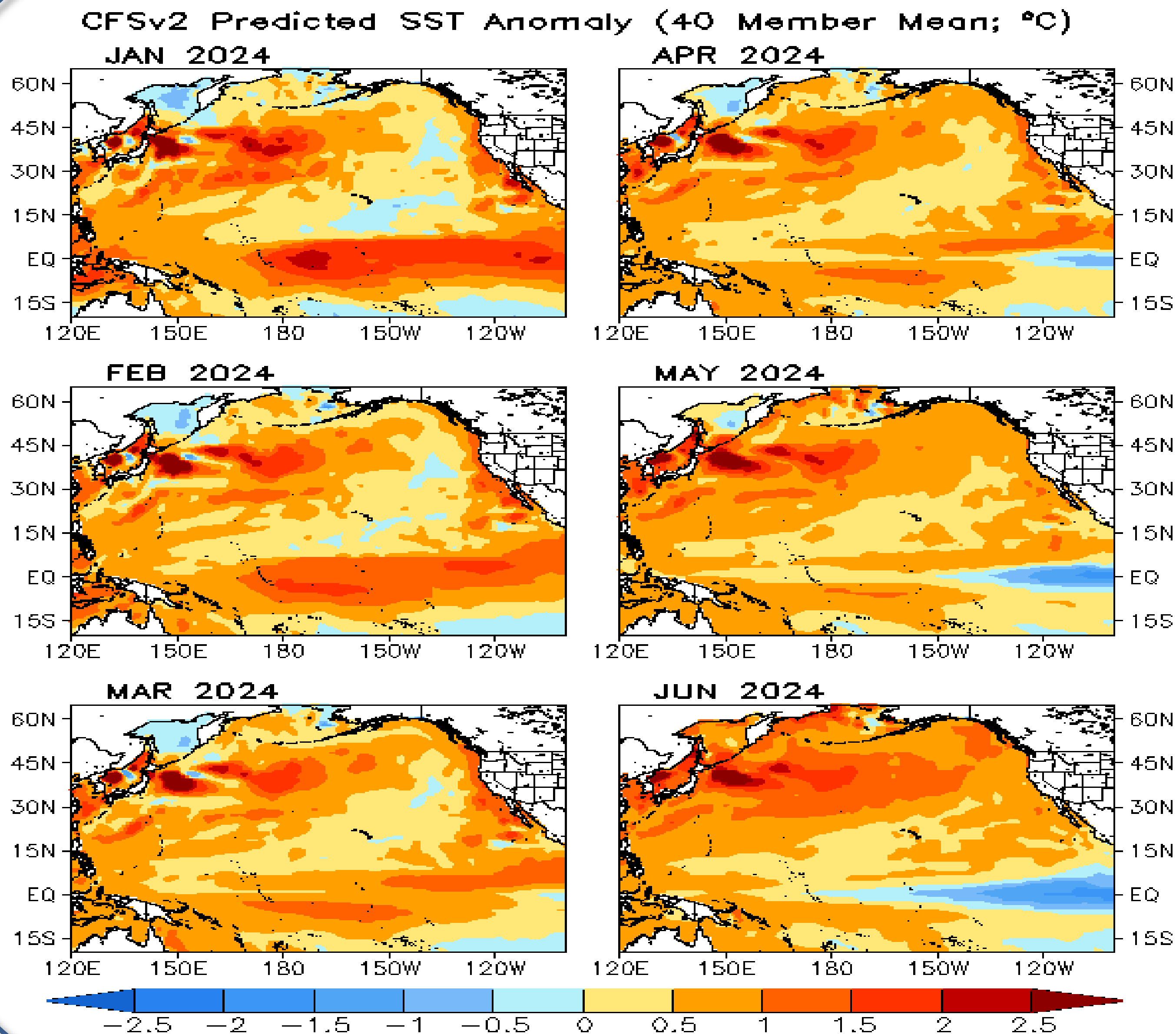


North Pacific Ocean: SSTA, SSTA Tend., OLR, SLP, Sfc Rad, Sfc Flx Anomalies



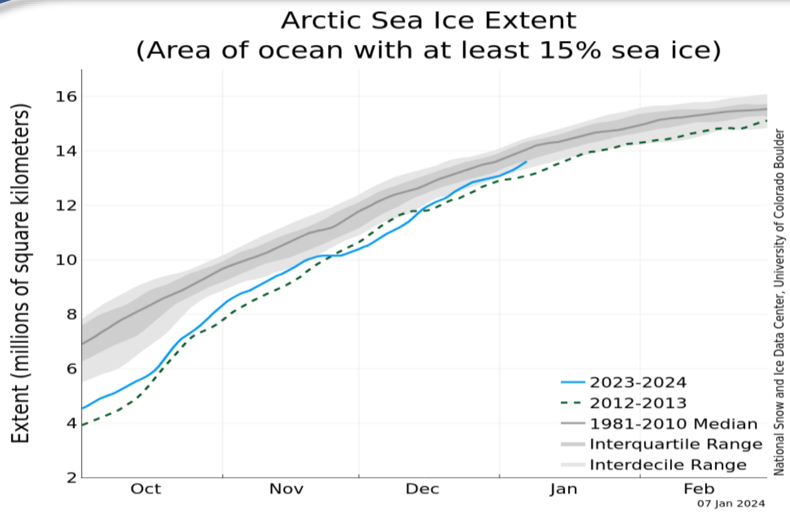
SSTA (top-left; OIv2.1 SST Analysis), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) (middle-left; NOAA 18 AVHRR IR), sea surface pressure (middle-right; NCEP CDAS), sum of net surface short- and long-wave radiation (bottom-left; positive means heat into the ocean; NCEP CDAS), sum of latent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

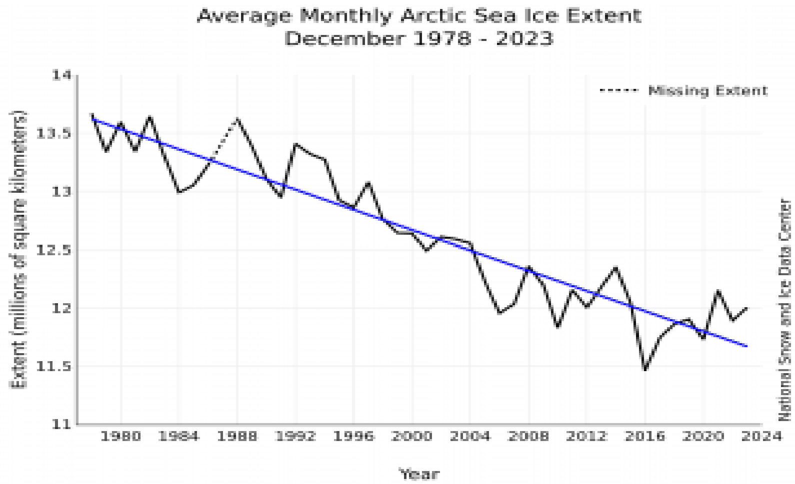
CFSv2 NE Pacific SSTA Predictions

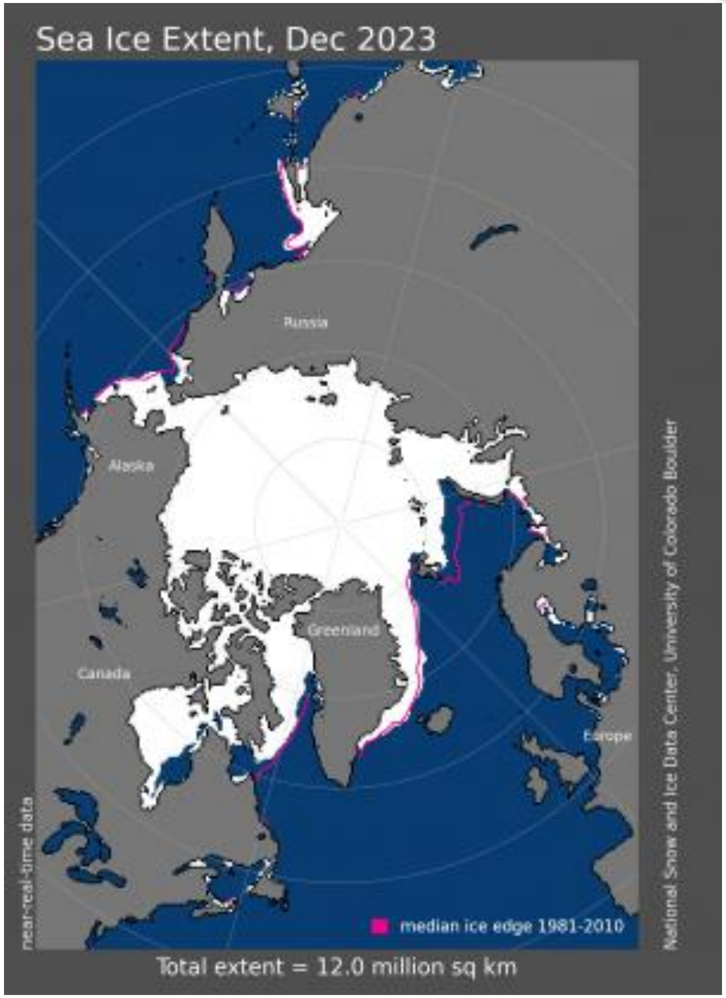


- CFSv2 predicts the current SST warm state in the North Pacific will continue into the summer 2024.

Arctic Sea Ice; NSIDC (https://nsidc.org/arcticseaicenews/)

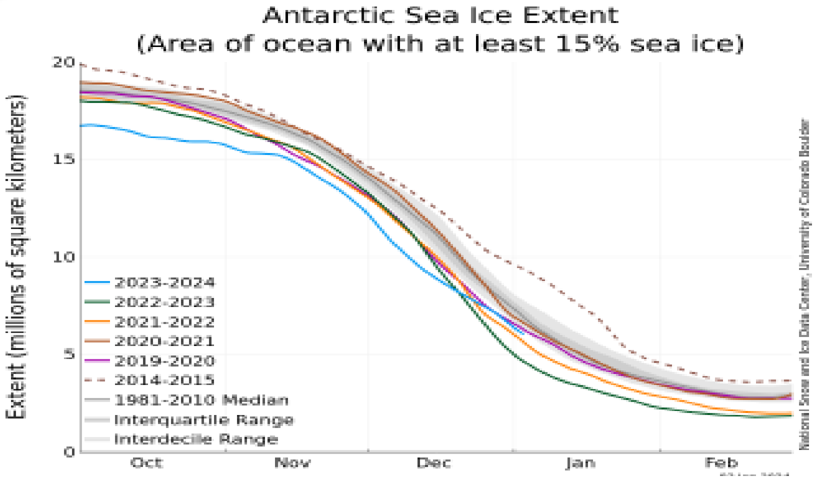


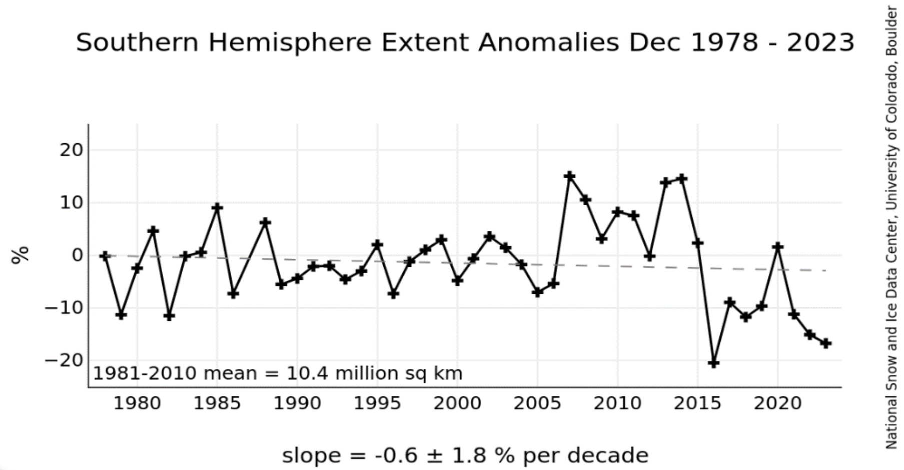


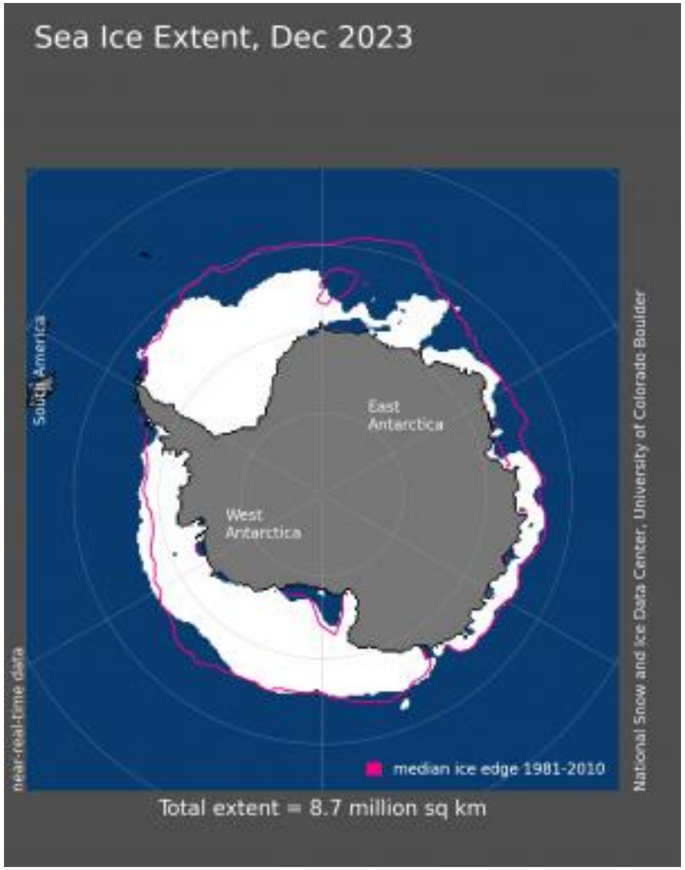


- Arctic sea ice extent was 12.00 million square kilometers in Dec 2023, 9th lowest in the 45-year satellite record in Dec.
- The downward linear trend in Arctic sea ice extent for Dec over the 45-year satellite record is 3.4% per decade relative to the 1981 to 2010 average.

Antarctic Sea Ice; NSIDC (https://nsidc.org/arcticseaicenews/)

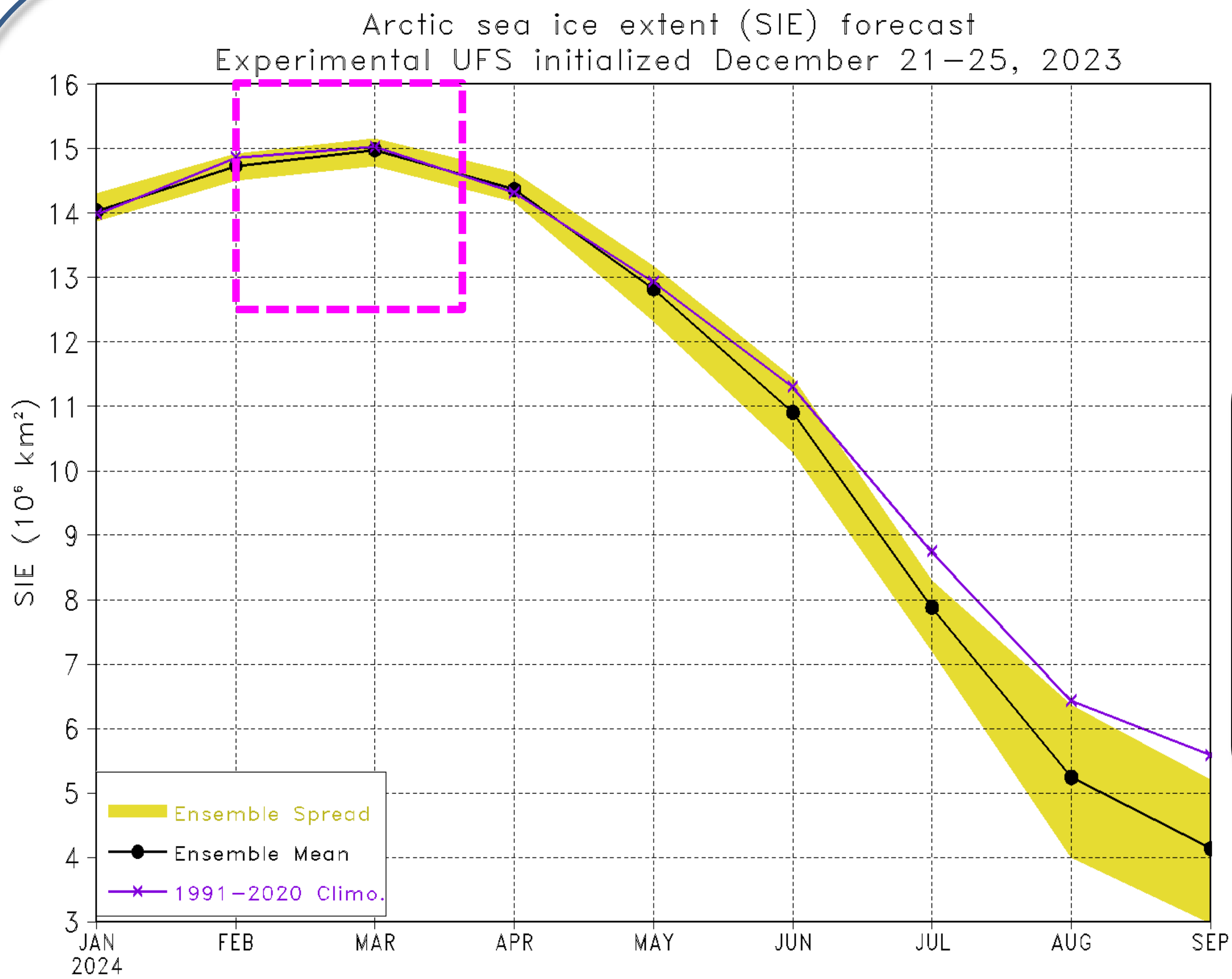






- Antarctic sea ice extent was 8.67 million square kilometers in Dec 2023, ranking the second-lowest Dec extent since 1978.

NCEP/CPC Arctic Sea Ice Extent (SIE) Forecast

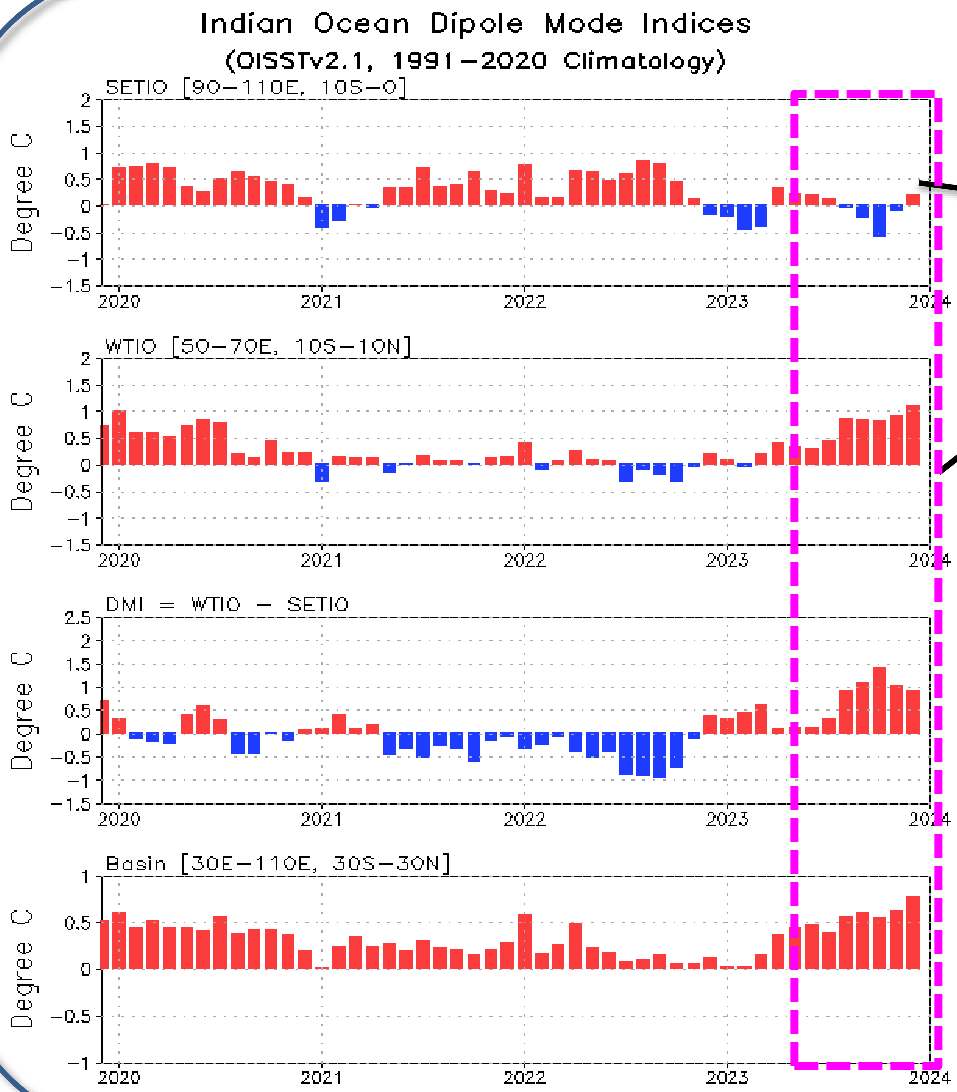


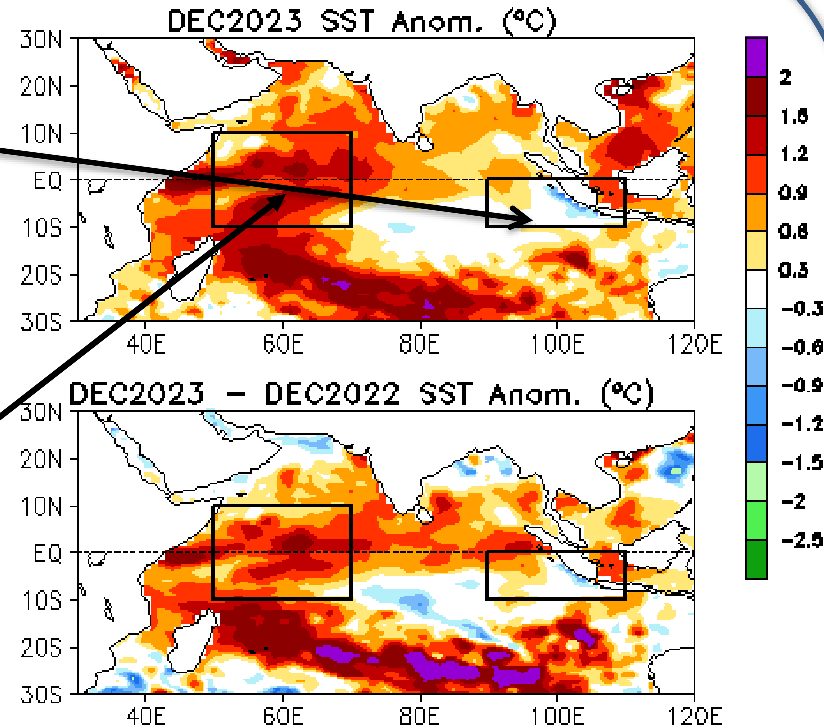
- UFS forecasts suggest sea ice extent maximum in Mar 2024, close to 1991-2020 climatology.

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

Indian Ocean

Evolution of Indian Ocean SST Indices

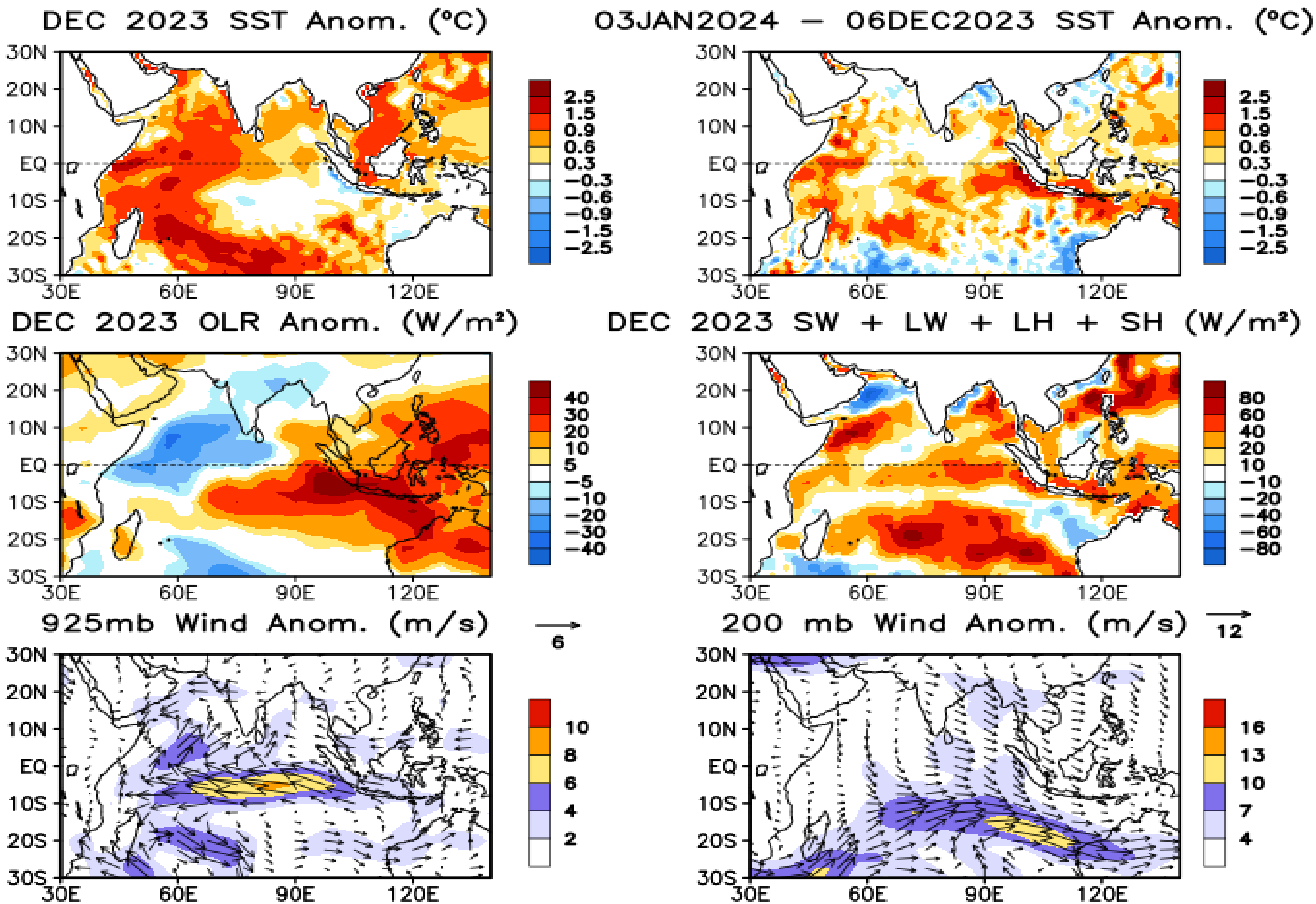




- SSTs were above (near) average in the western (eastern) tropical Indian Ocean in Dec 2023, featuring a positive phase of the dipole mode.

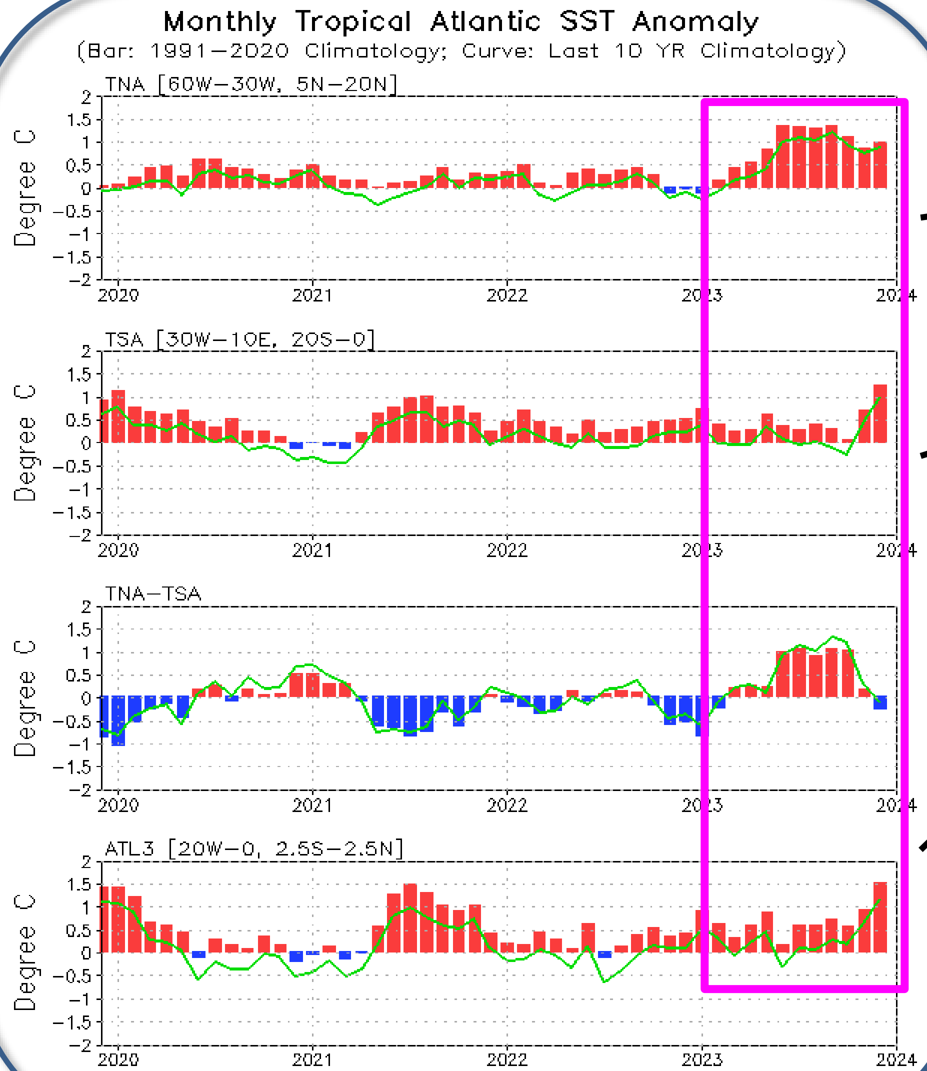
Indian Ocean region indices, calculated as the area-averaged monthly mean SSTA (OC) for the SETIO [90ºE-110ºE, 10ºS-0] and WTIO [50ºE-70ºE, 10ºS-10ºN] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the OIv2.1 SST analysis, and anomalies are departures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

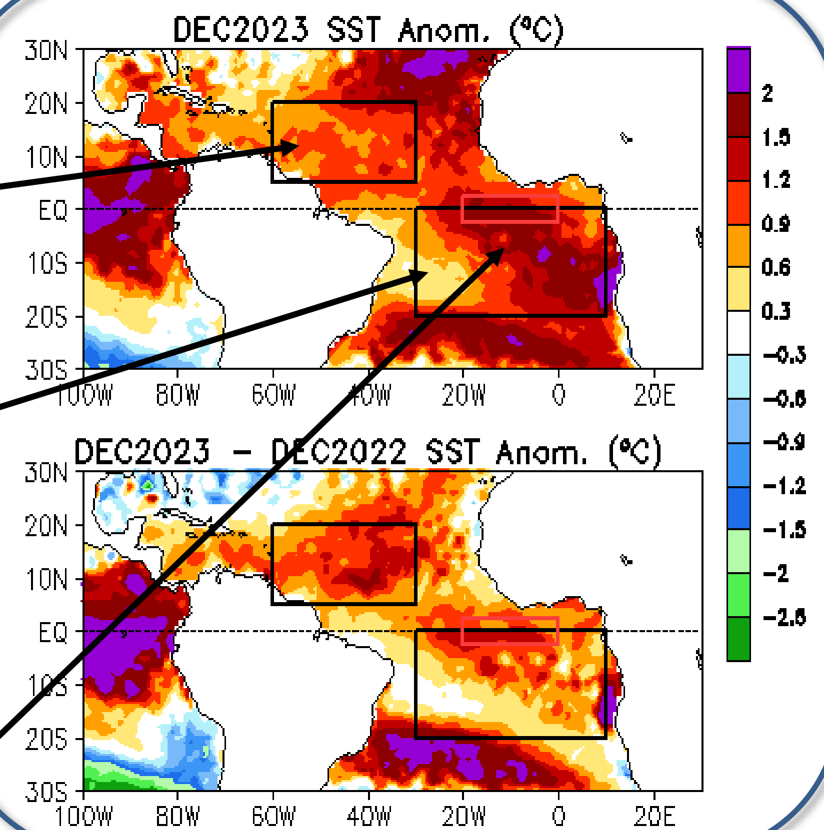
Tropical Indian: SSTA, SSTA Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Wind Anom.



Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

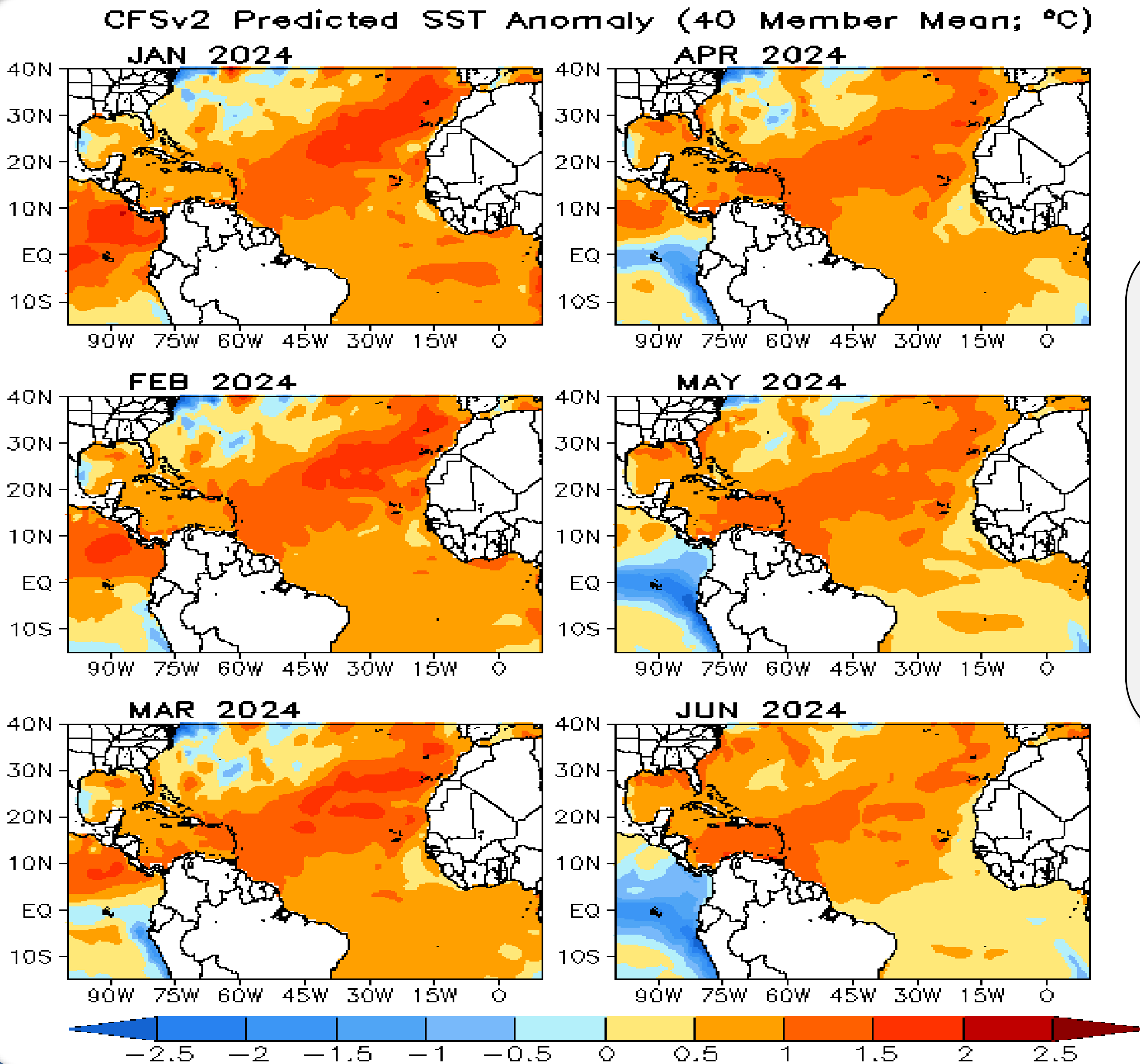




- Positive SSTAs in the tropical Atlantic were observed in Dec 2023.
- Positive ATL3 index strengthened in Dec 2023.

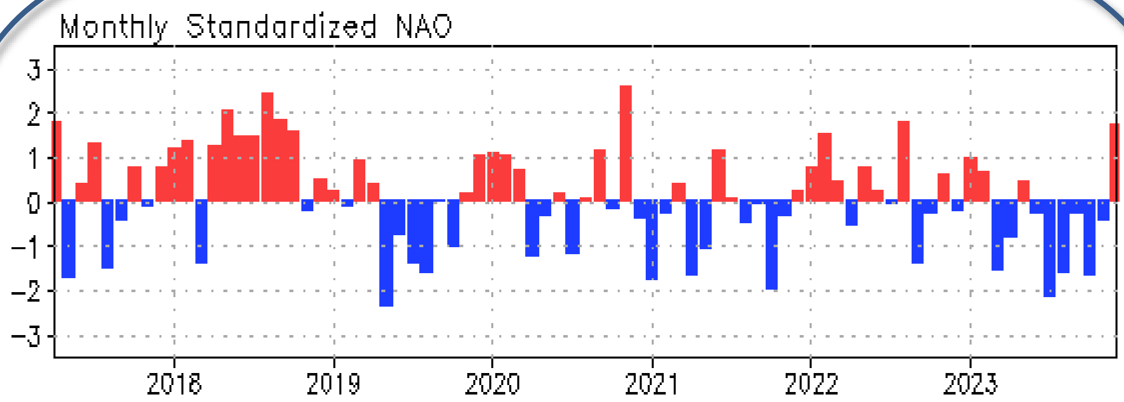
Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean SSTAs (^{O}C) for the TNA [60^{O}W-30^{O}W, 5ºN-20^{O}N], TSA [30^{O}W-10^{O}E, 20^{O}S-0] and ATL3 [20^{O}W-0, 2.5^{O}S-2.5^{O}N] regions, and Meridional Gradient Index, defined as differences between TNA and TSA. Data are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

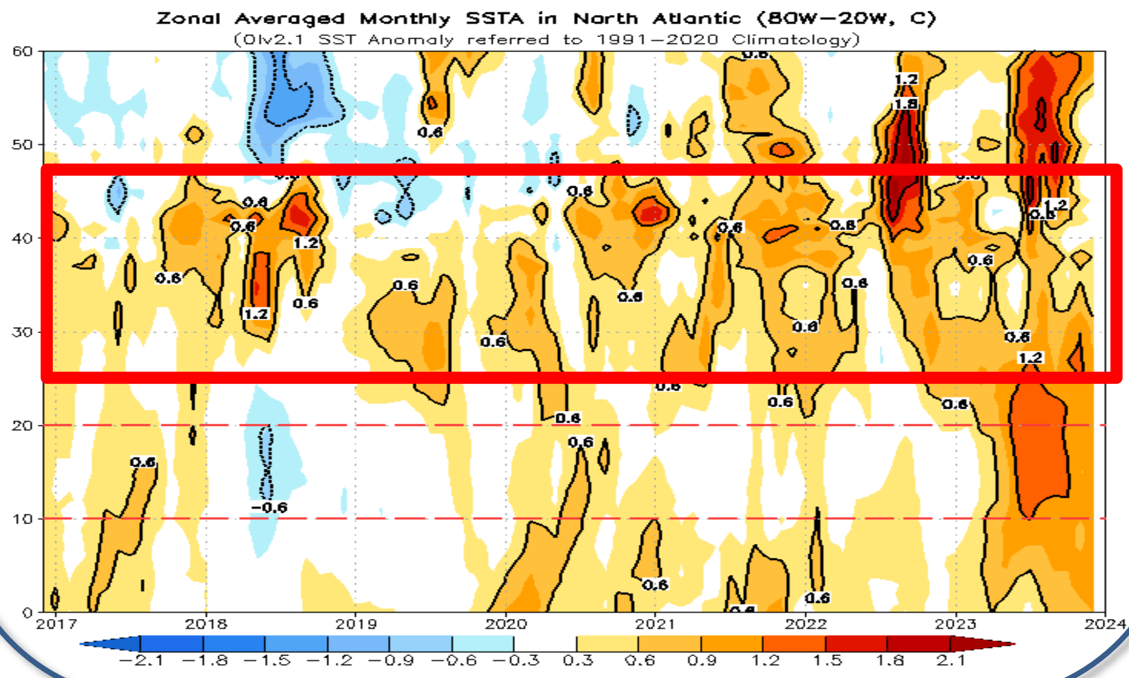
CFSv2 Atlantic SSTA Predictions

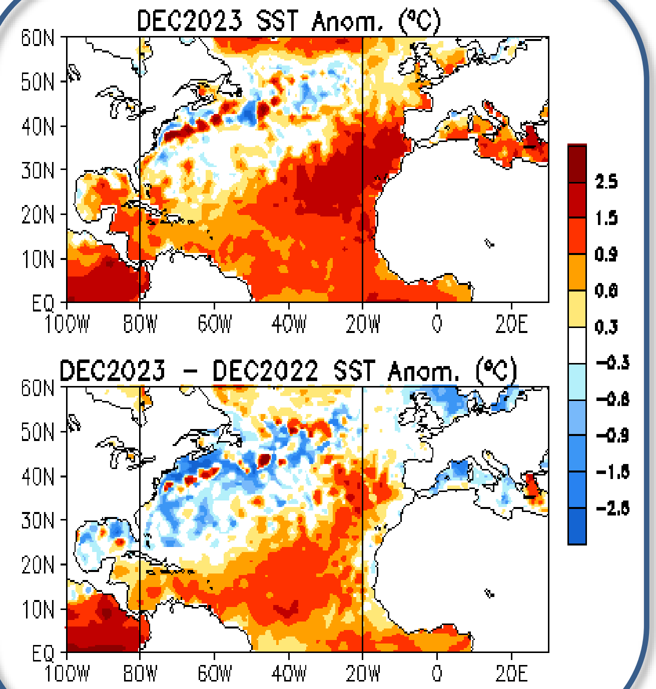


- Latest CFSv2 predictions call above-normal SST in the middle-latitudes of the North Atlantic in the next 6 months.

NAO and SST Anomaly in North Atlantic





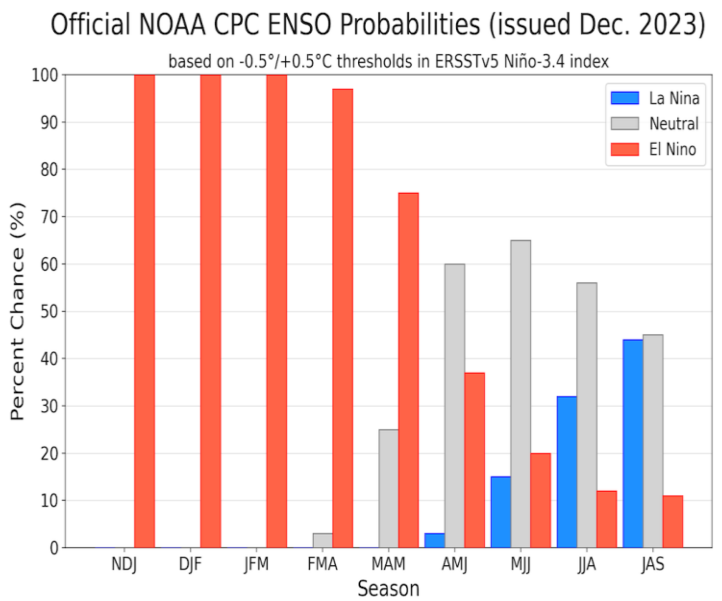


- NAO switched to a positive phase in Dec 2023 with NAOI= 1.7.
- The prolonged positive SSTAs in the middle latitudes were evident during the last 5-6 years.

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

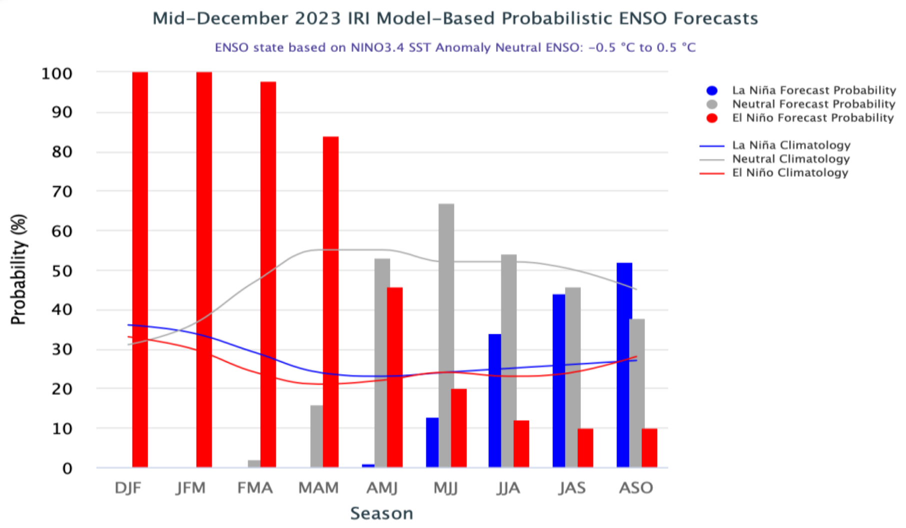
CPC & IRI Niño3.4 Forecast

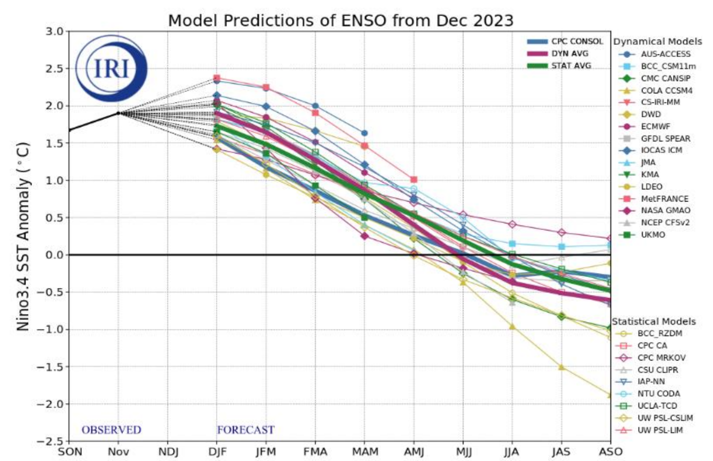


- Model ensemble mean predicts a neutral condition from Apr-Jun to Jul-Sep 2024.

-ENSO Alert System Status issued on 14 Dec 2023: El Niño Advisory

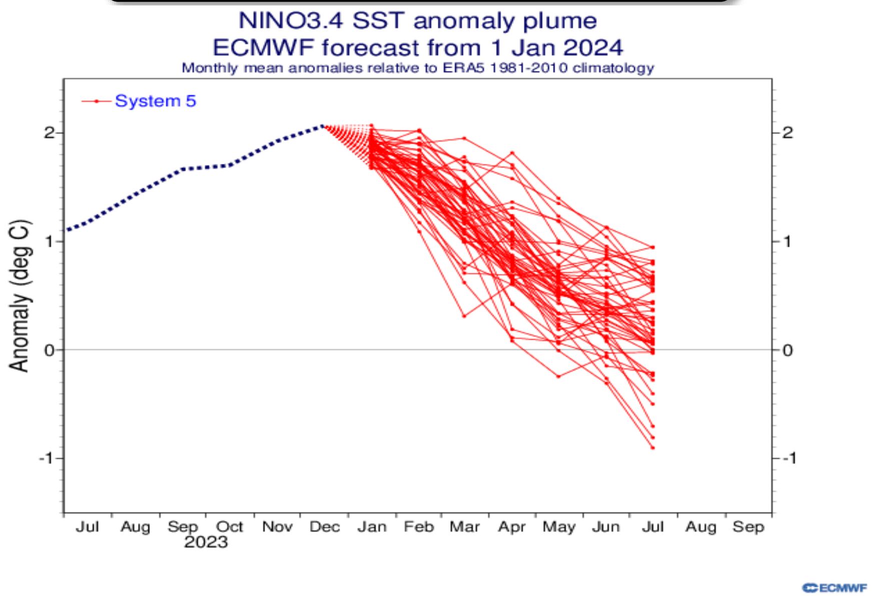
- Synopsis: "*El Niño is expected to continue through the Northern Hemisphere winter, with a transition to ENSO-neutral favored during April-June 2024 (60% chance).*"



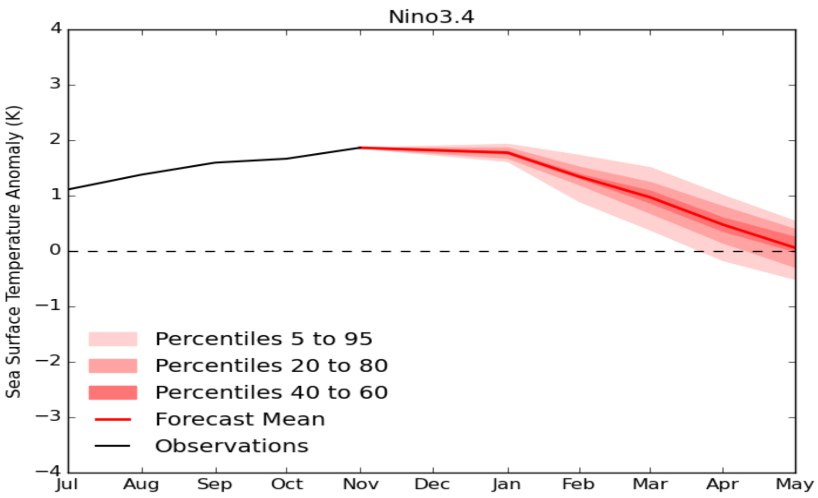


Individual Model Forecasts: El Niño transitions to neutral or La Niña in 2024

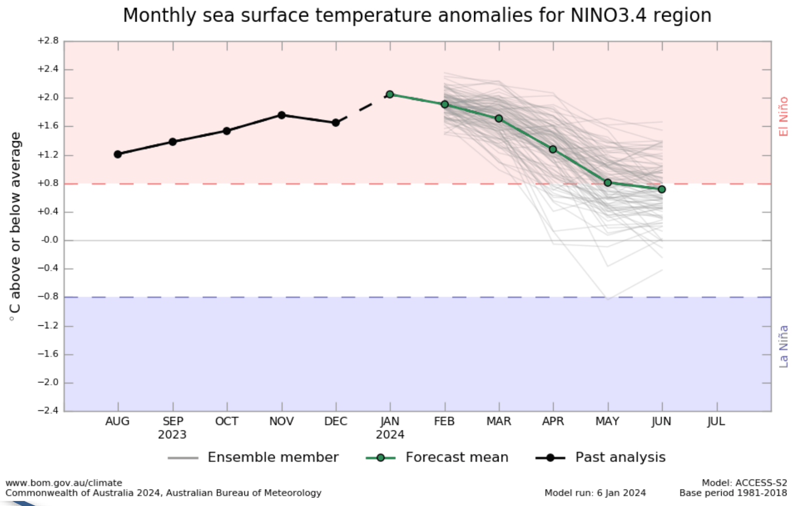
EC: Niño3.4, IC= 1 Jan 2024



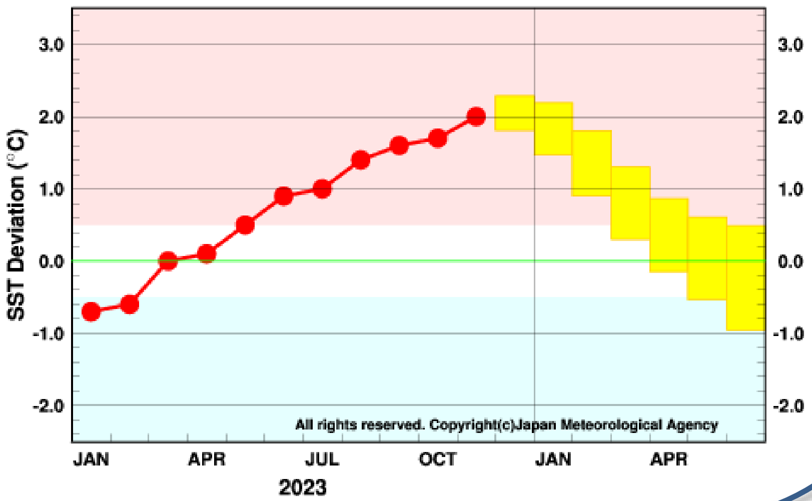
UKMO: Niño3.4, Updated 11 Dec 2023



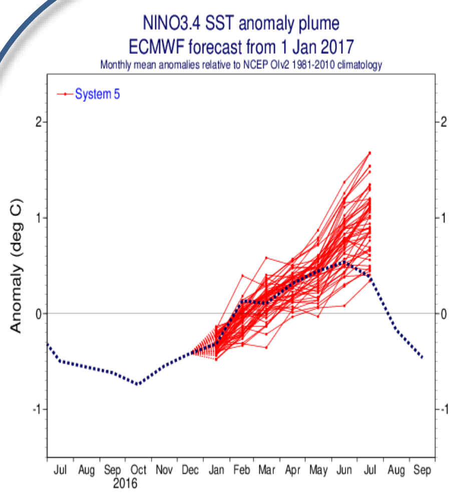
BOM: Niño3.4, Updated 6 Jan 2024

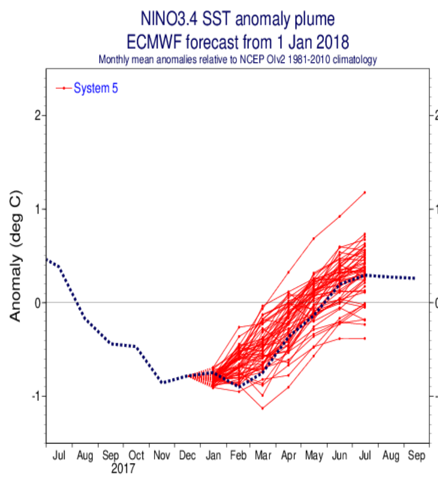


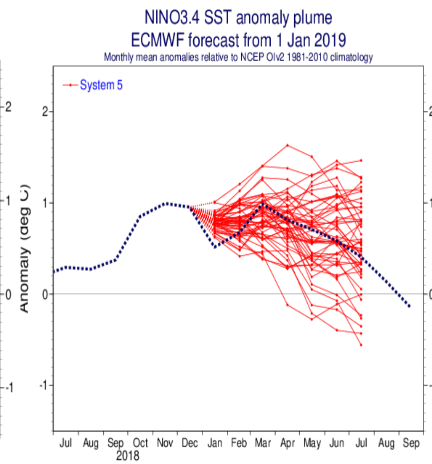
JMA: Niño3.4, Updated 11 Dec 2023

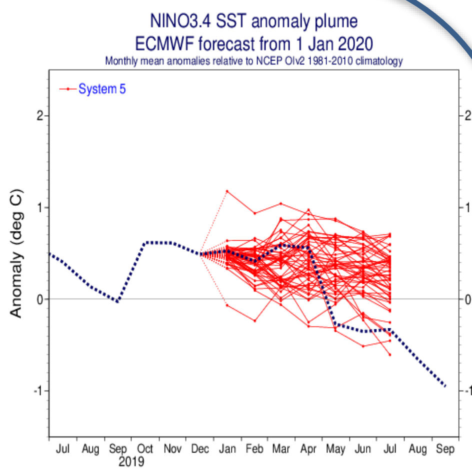


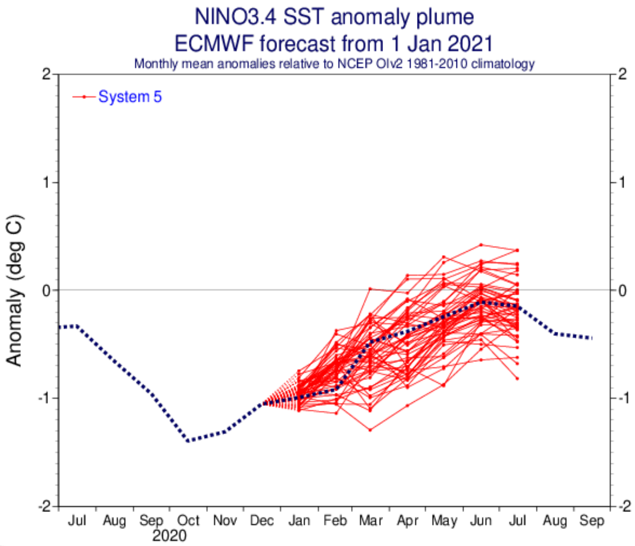
ECMWF Forecasts with IC in Jan since 2017

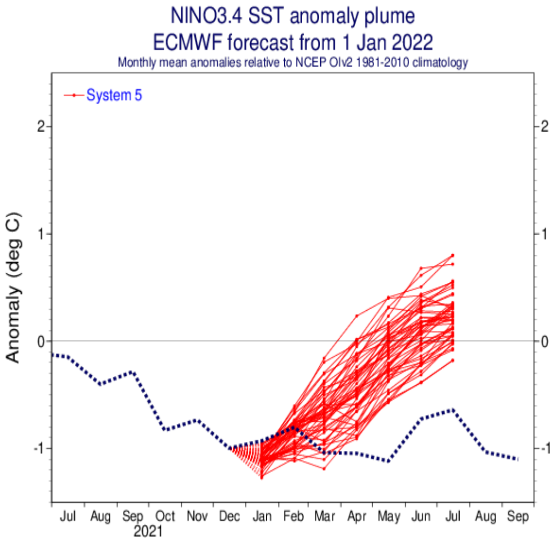


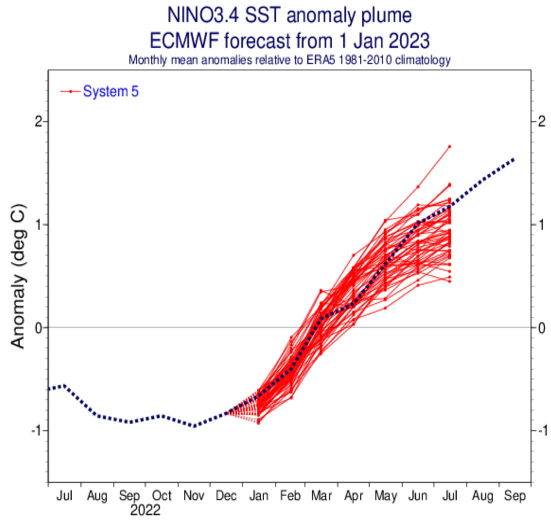




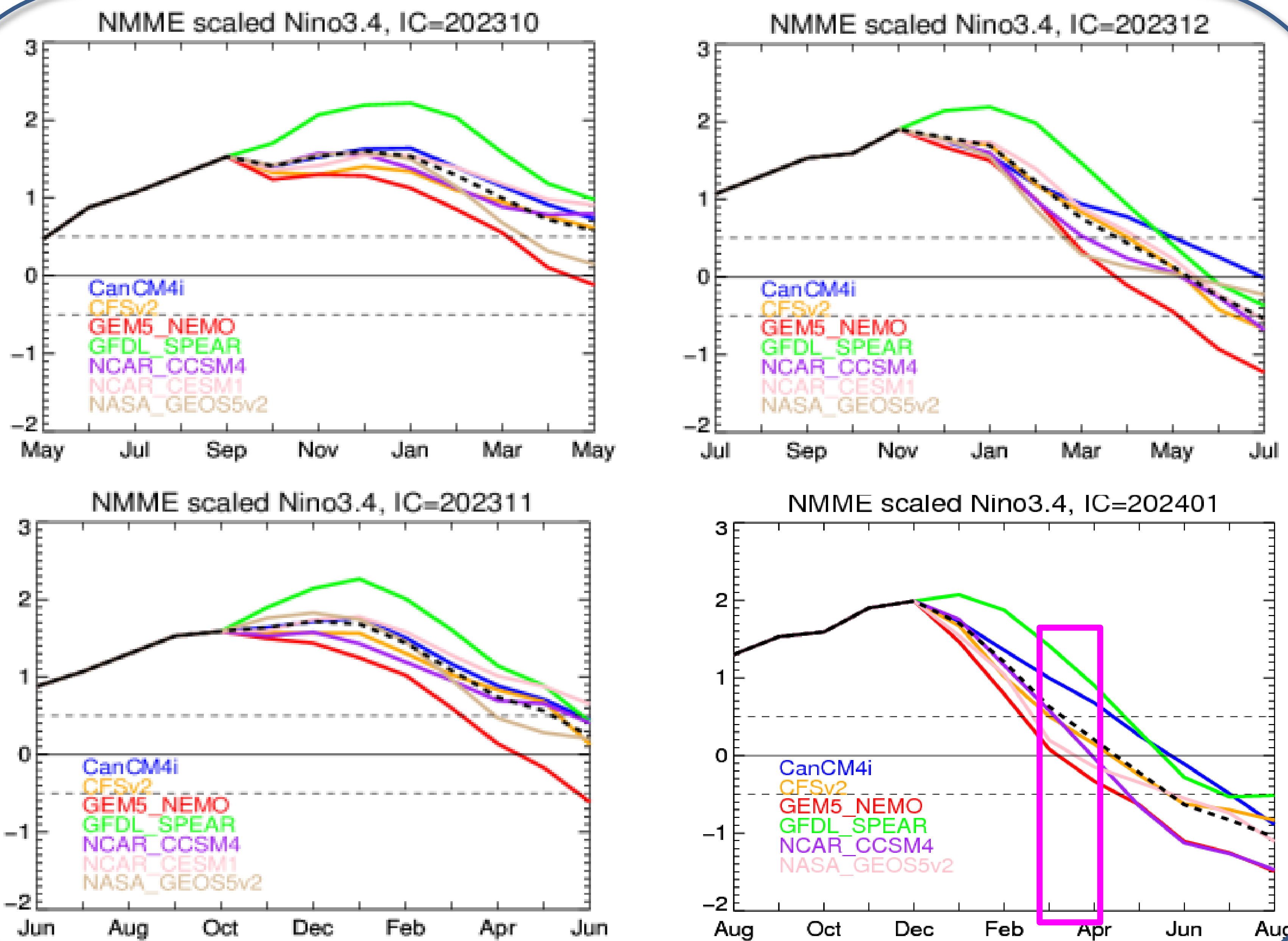




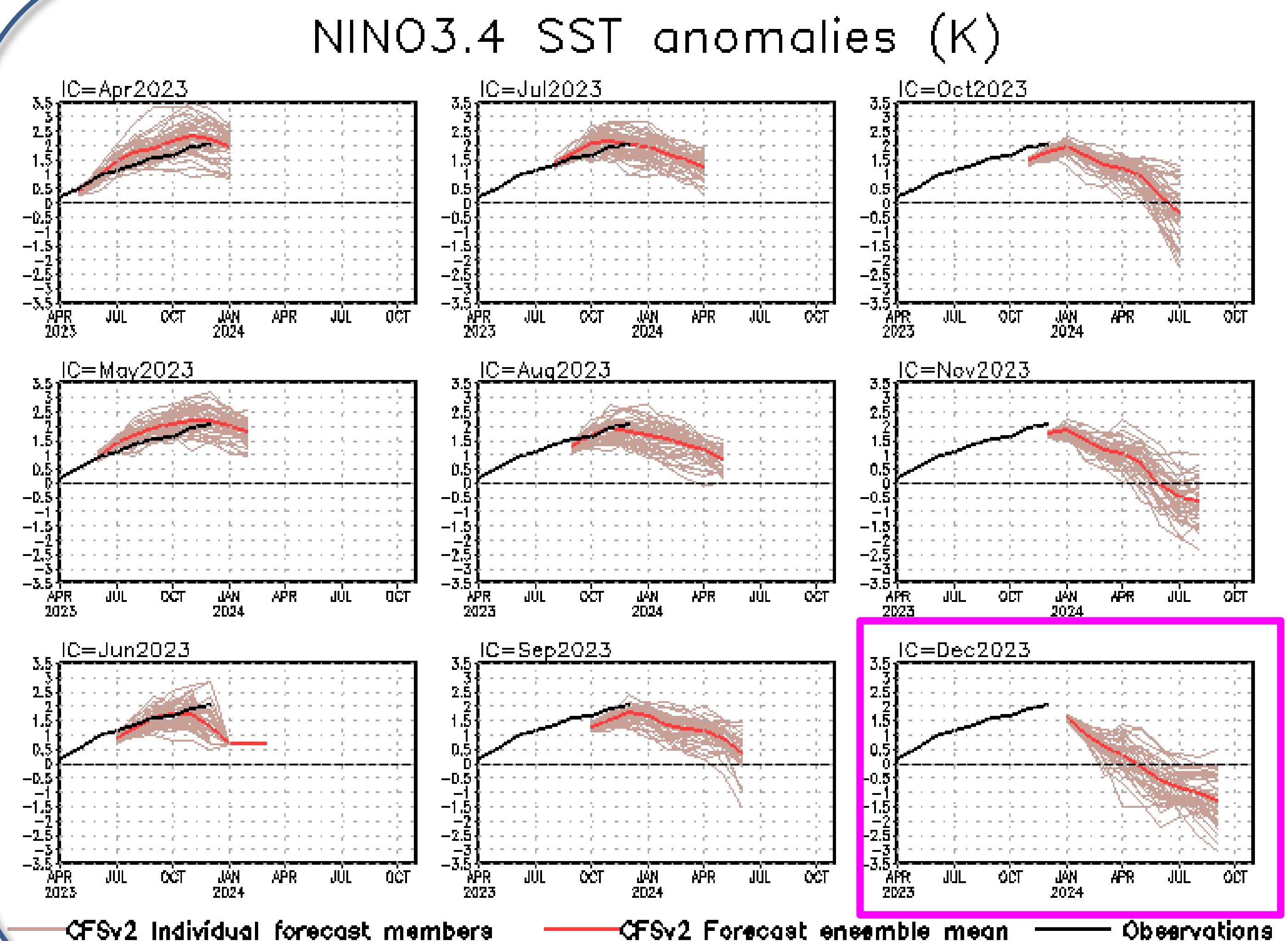




NMME forecasts from different initial conditions



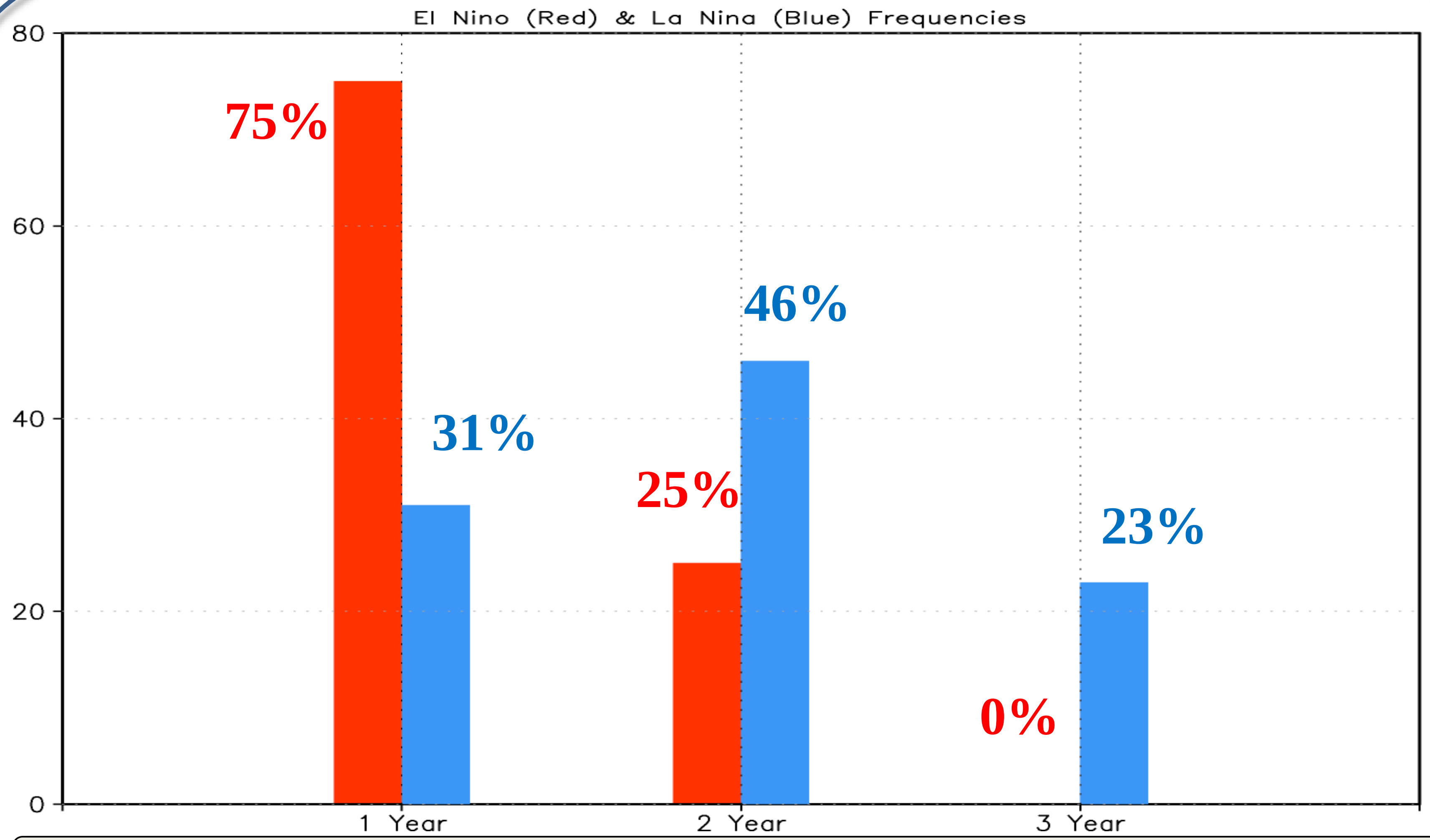
CFS Niño3.4 SST Predictions from Different Initial Months



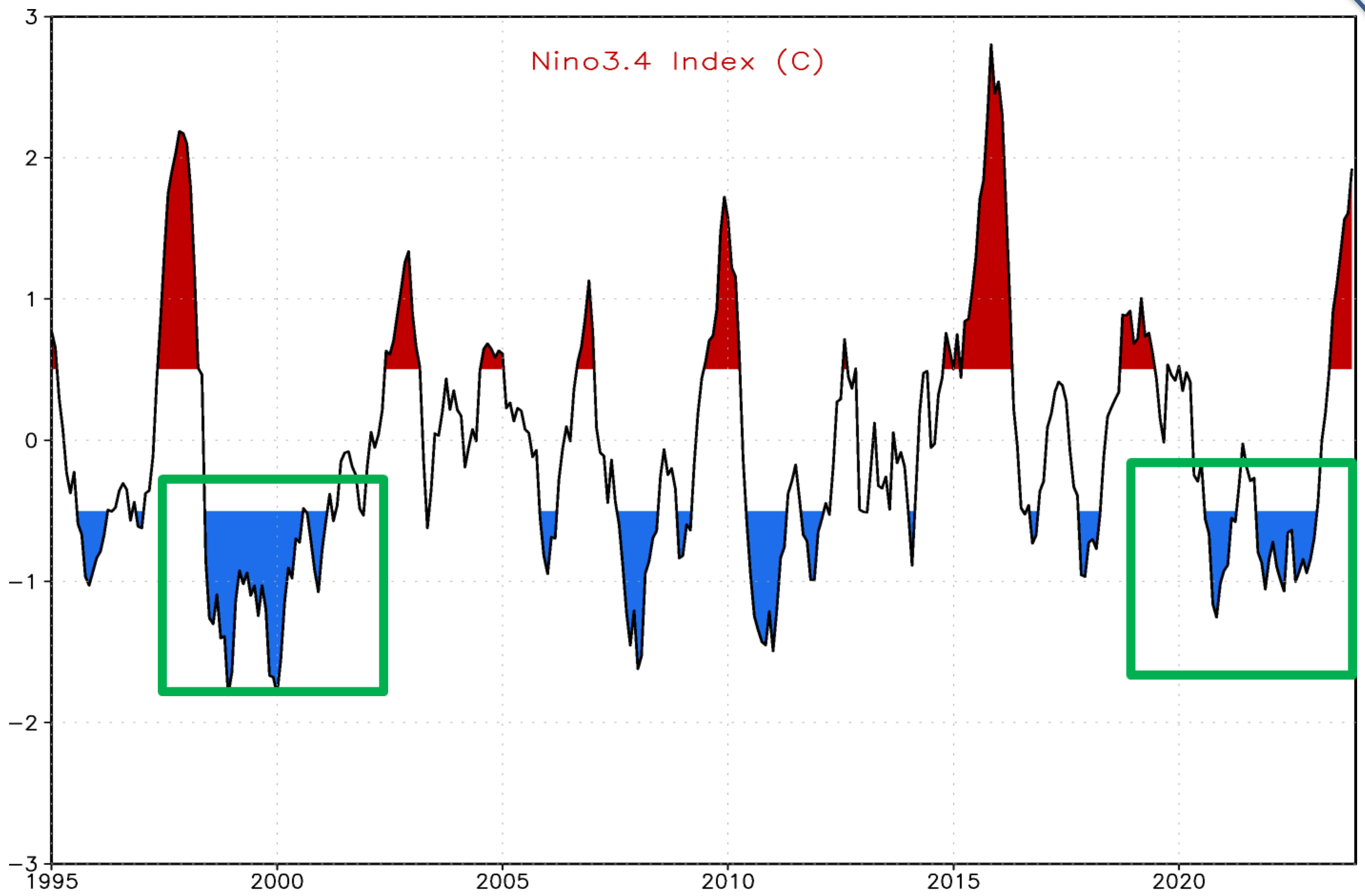
- The latest CFSv2 forecasts call for a neutral condition in spring 2024.

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

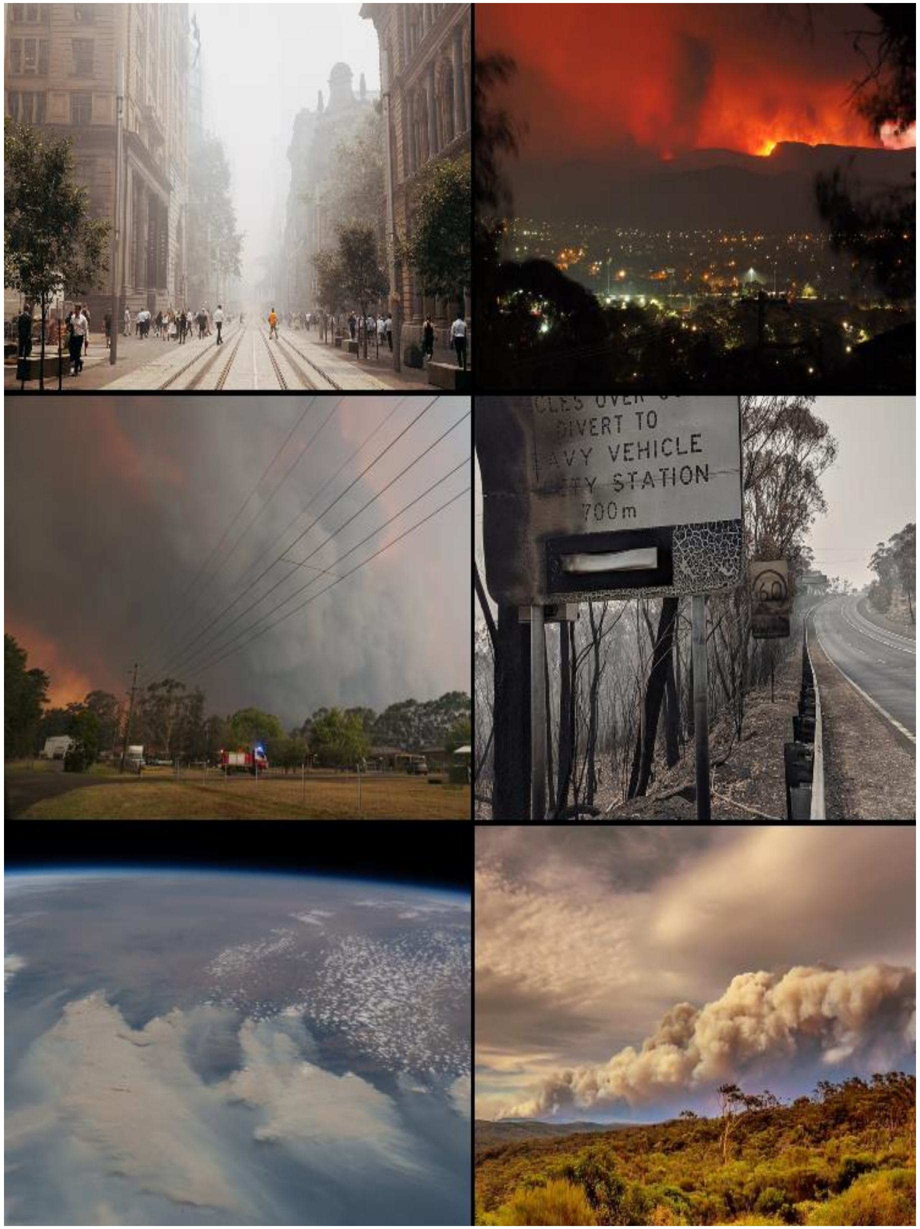
Percentages (%) of single-, double-, and triple-year El Niños (red bars) and La Niñas (blue bars) during 1951-2023



Gao, et al. 2023: Single-Year and Double-Year El Niños. Clim Dyn 60 (7-8), 2235–2243. 10.1007/s00382-022-06425-8.



Nino3.4 Index (C)
3
2
1
0
−1
−2
−3
1995
2000
2005
2010
2015
2020



- The 2019–20 Australian bushfire season or Black Summer was one of the most intense fire seasons on record in Australia.

(https://en.wikipedia.org/wiki/2019%E2%80%9320_Australian_bushfire_season)

Clockwise from top left: Sydney's George Street blanketed by smoke in Dec 2019; Orroral Valley fire seen from Tuggeranong; damaged road sign along Bells Line of Road; Gospers Mountain bushfire; smoke plume viewed from the International Space Station; uncontained bushfire in South West Sydney.

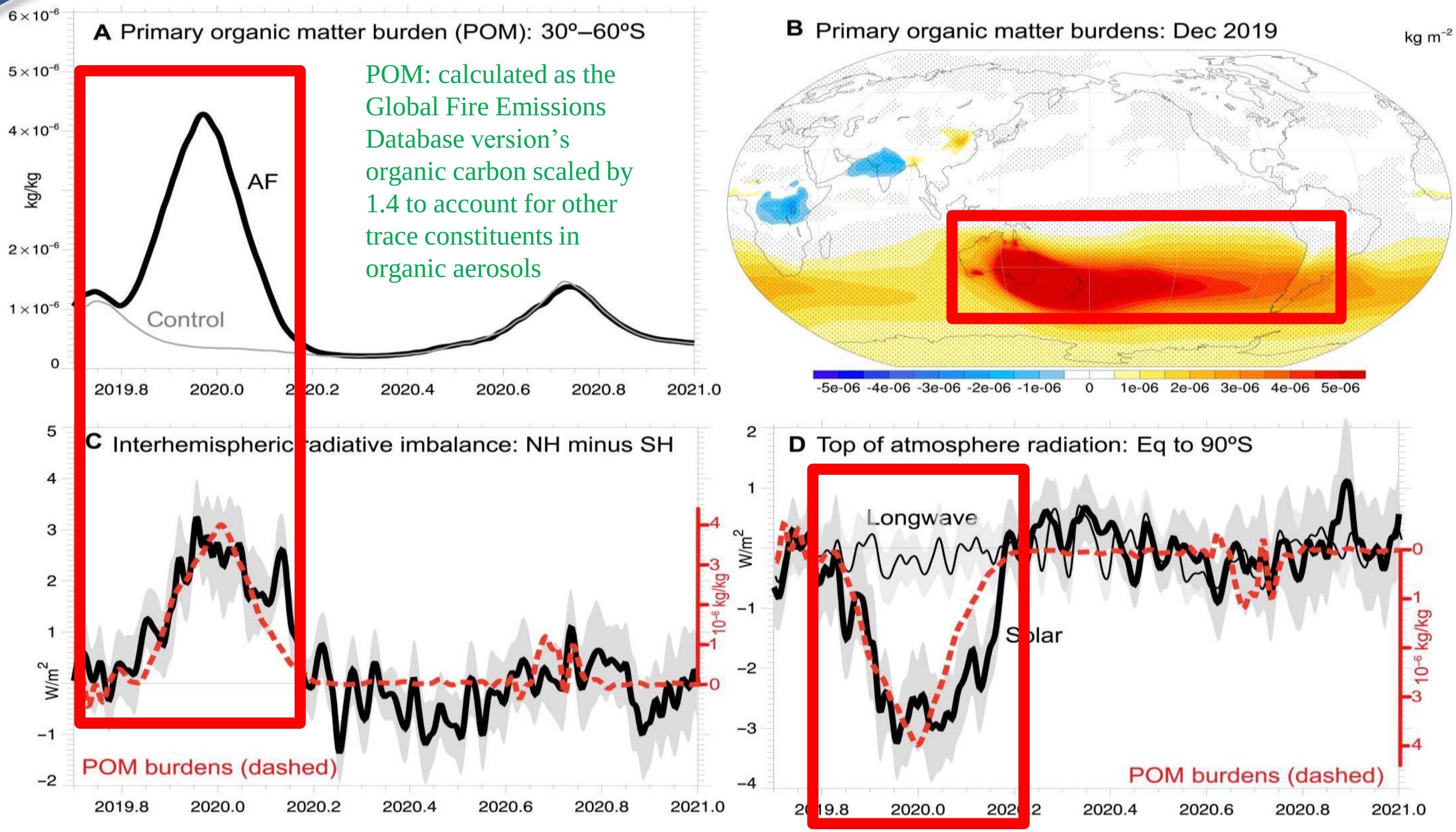
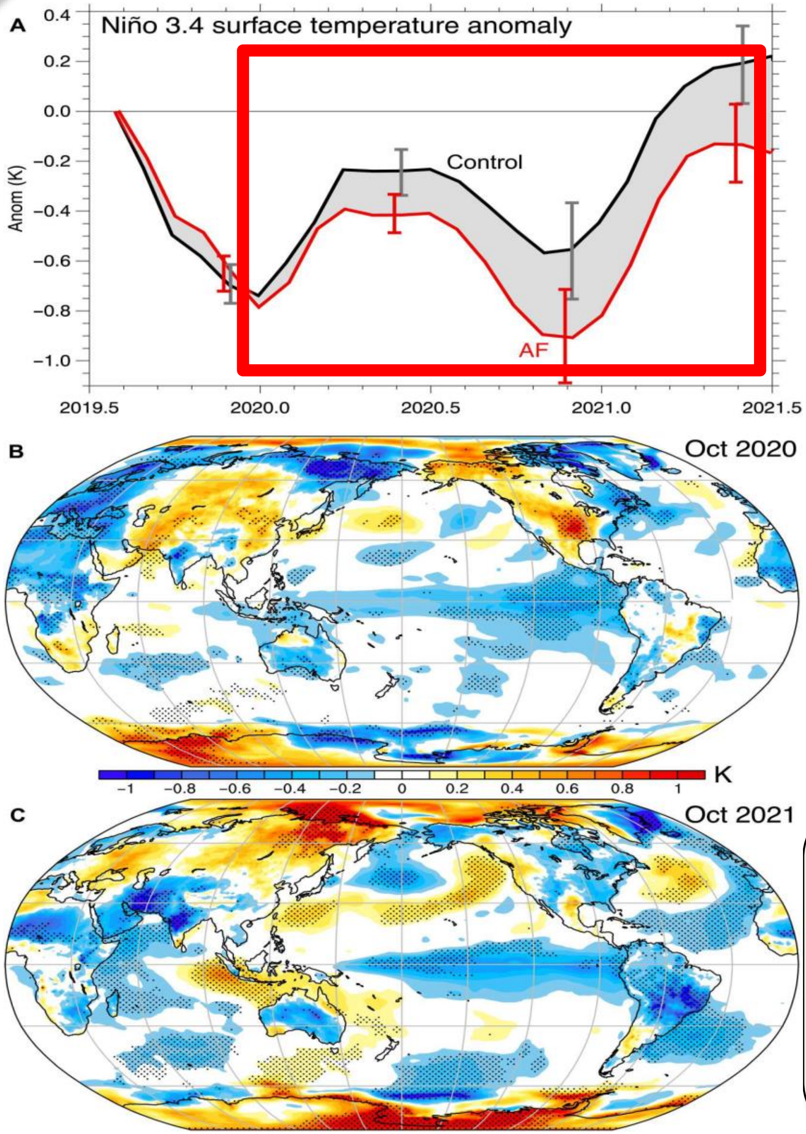


Fig. 1. Large-scale climate responses. The ensemble mean evolution of Primary organic matter (POM) burdens from 30° S to 60° S (A) in control and AF (gray) and the spatial distribution of their differences in December 2019 (B). Associated responses in the interhemispheric radiative imbalance anomaly (C) and southern hemisphere (SH) top of atmosphere radiation (D) (solar, thick; longwave, thin) are also shown. Responses in POM burdens (dashed), defined as the difference between lines in (A), are scaled to match the target data and overlain in (C) and (D) to illustrate their in-phase relationship. Shading corresponds to twice the ensemble standard error. Stippling is shown in (B) where anomalies exceed twice the ensemble standard error.

Fasullo et al., 2023: A multiyear tropical Pacific cooling response to recent Australian wildfires in CESM2. Sci. Adv. 9,eadg1213. DOI:10.1126/sciadv.adg1213.

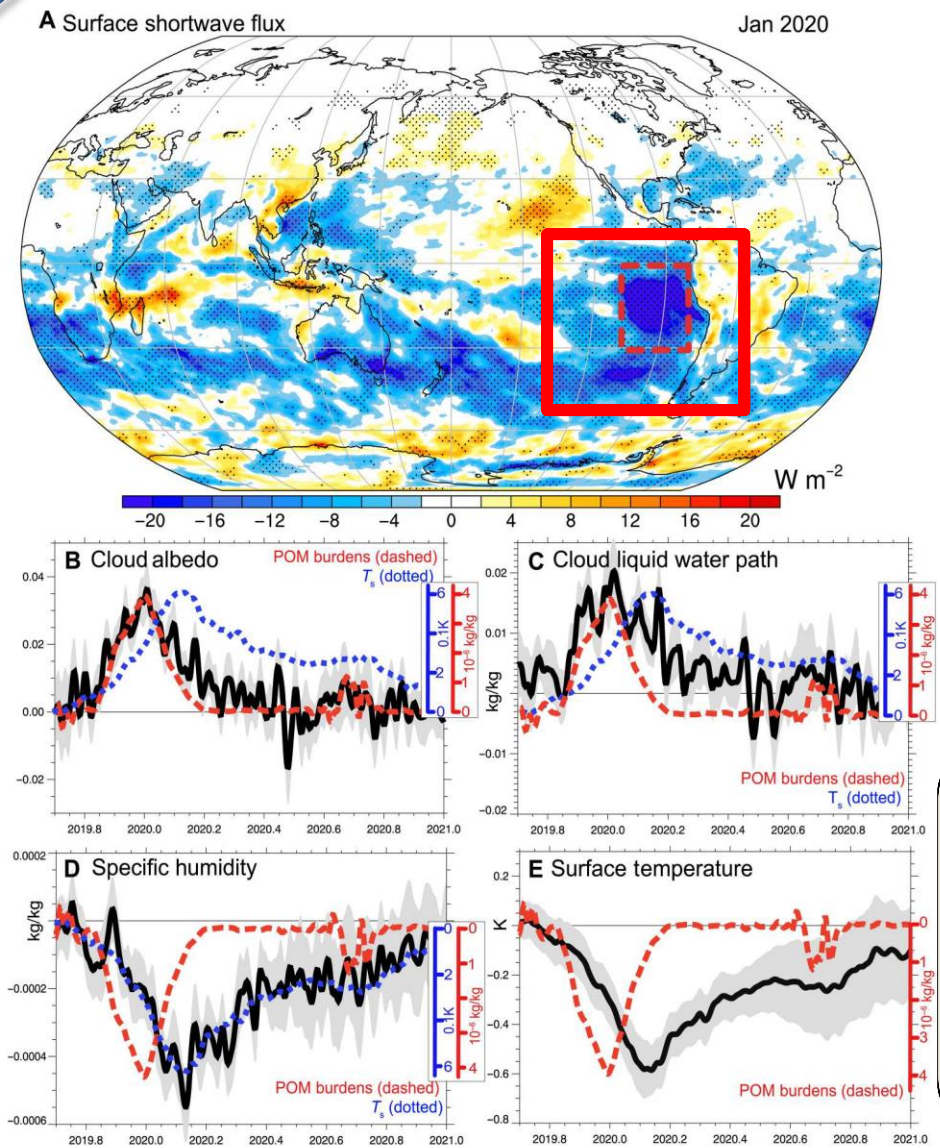


Question & Comment:

- ➢ From Fig. 2a, it seems that the impact of the wildfire on ENSO keeps increasing until at least May 2021. But POM returned to normal since Feb 2020 (Fig.1a).

Fig. 2. Responses in the tropical Pacific Ocean. (A) The ensemble mean control (black) and AF (red) projections are shown for SST anomalies in the Niño3.4 region over the period for which drift correction is available (see Materials and Methods). Maps of the spatial structure of differences in surface temperature are also shown for (B) October 2020 and (C) October 2021, illustrating the persistent cooling of the tropical Pacific in the AF ensemble relative to the control ensemble. Regions where ensemble differences exceed twice the ensemble standard error are stippled.

Fasullo et al., 2023: A multiyear tropical Pacific cooling response to recent Australian wildfires in CESM2. Sci. Adv. 9,eadg1213. DOI:10.1126/sciadv.adg1213.

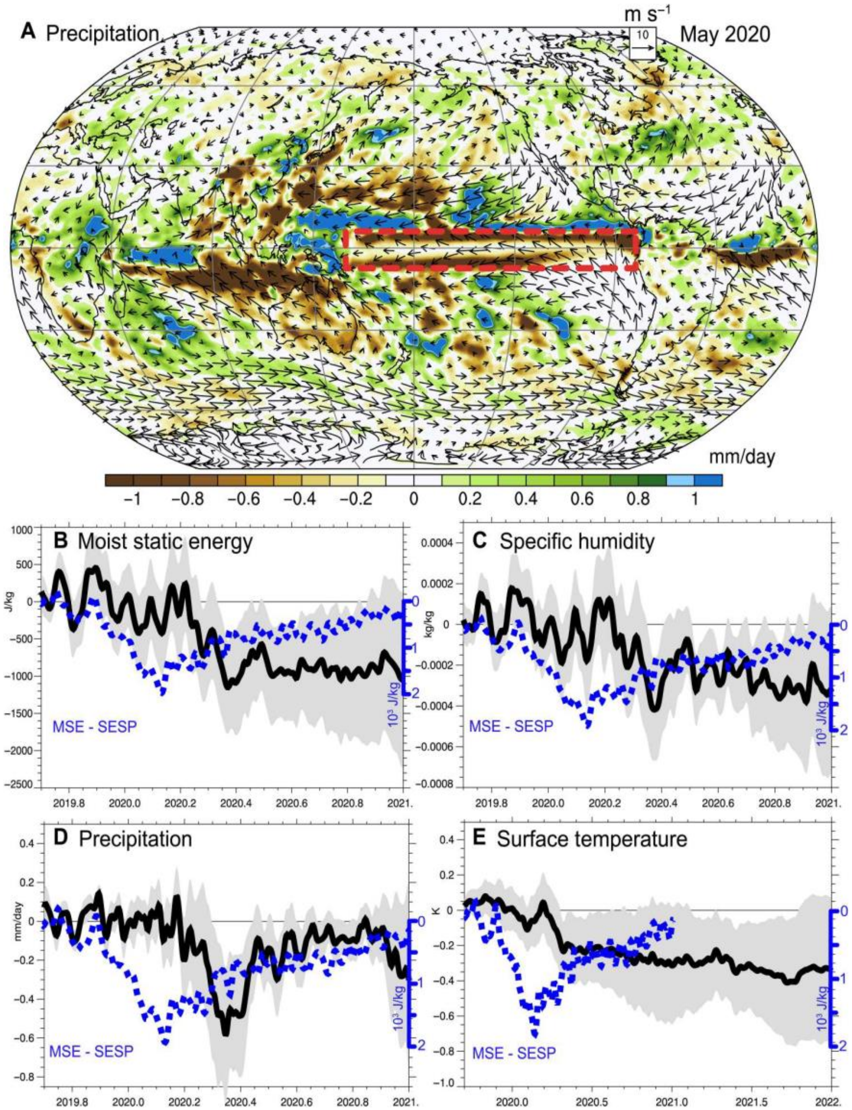


Question & Comment:

- The cooling caused by the Australian wildfire is mainly in SH (Figs. 1B, 3A, S3).

Fig. 3. Responses in the SESP Ocean. (A) Ensemble mean difference in surface downwelling shortwave radiation between the AF and control ensembles, stippled where differences exceed twice the ensemble standard error. The SESP region is outlined [red dashed lines in (A)]. The response in the SESP region of cloud albedo (B), cloud liquid water path (C), 2-m specific humidity (D), and SST (E) is also shown. Responses in POM burdens (Fig. 1, red dashed) and surface temperature (TS) in the SESP region (E) are scaled to match the target data and overlain to illustrate their relative phase.

Fasullo et al., 2023: A multiyear tropical Pacific cooling response to recent Australian wildfires in CESM2. Sci. Adv. 9,eadg1213. DOI:10.1126/sciadv.adg1213.



➢ **The increase in albedo due to the wildfire emission acts to cool the surface, dry the boundary layer, and reduce the moist static energy of the advected low-level flow into the deep tropics, leading to La Niña.**

Fig. 4. Evolution of responses in the equatorial Pacific Ocean. (A) Response in precipitation in May 2020. The mean near-surface wind field in the AF ensemble is also shown (vectors, m s−1) to illustrate advection from the SESP region to the equatorial Pacific Ocean. The temporal evolutions of 2-m MSE (B), 2-m specific humidity (C), precipitation (D), and SST (E) in the equatorial Pacific [red dashed region in (A)] are also shown. The evolution of MSE in the SESP region is rescaled and overlain to illustrate its leading character (blue dashed line). Note that the abscissa in (E) extends through the end of 2021 to illustrate the multiyear persistence of the cooling response.

Fasullo et al., 2023: A multiyear tropical Pacific cooling response to recent Australian wildfires in CESM2. Sci. Adv. 9,eadg1213. DOI:10.1126/sciadv.adg1213.

Key Points:

- Through model experiments, the authors discussed the possible impact of the 2019 Australian wildfire on the tropical climate and 2020/21 La Niña.
- They argued that the increase in albedo due to the wildfire emission acts to cool the surface, dry the boundary layer, and reduce the moist static energy of the advected low-level flow into the deep tropics.
- Consequently, the ITCZ migrated northward and the Niño3.4 region SST cooled, suggesting an important contribution to the 2020/21 La Niña event.

Triple-dip La Niña in 2020-23:

(1) Influence of Australian wildfires:

Fasullo, et al., 2023: A multiyear tropical Pacific cooling response to recent Australian wildfires in CESM2.Sci. Adv.9,eadg1213.DOI:10.1126/sciadv.adg1213.

(2) Effect of the Indian Ocean:

Hasan, et al., 2022: The influence of tropical basin interactions on the 2020-2022 double-dip La Niña. Frontiers in Climate, 4. DOI: 10.3389/fclim.2022.1001174.

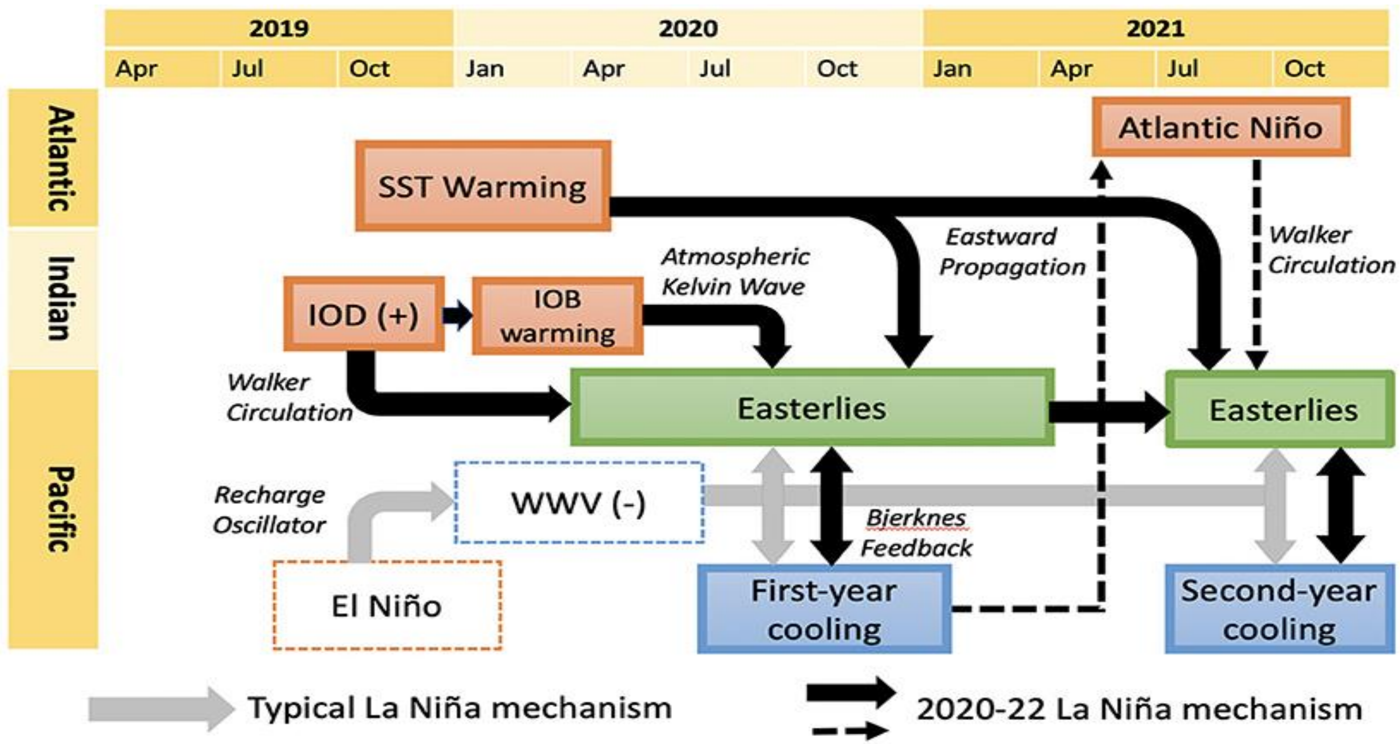
(3) Role of Mean State Change:

Li, et al., 2023: Triple-Dip La Niñas in 1998-2001 and 2020-2023: Impact of Mean State Changes. JGR, 128 (17), e2023JD038843. DOI: 10.1029/2023JD038843.

(4) Extratropical contributions:

Shi, et al. 2023: Extratropical impacts on the 2020–2023 Triple-Dip La Niña event, Atmospheric Research, 294, 106937, 10.1016/j.atmosres.2023.106937.

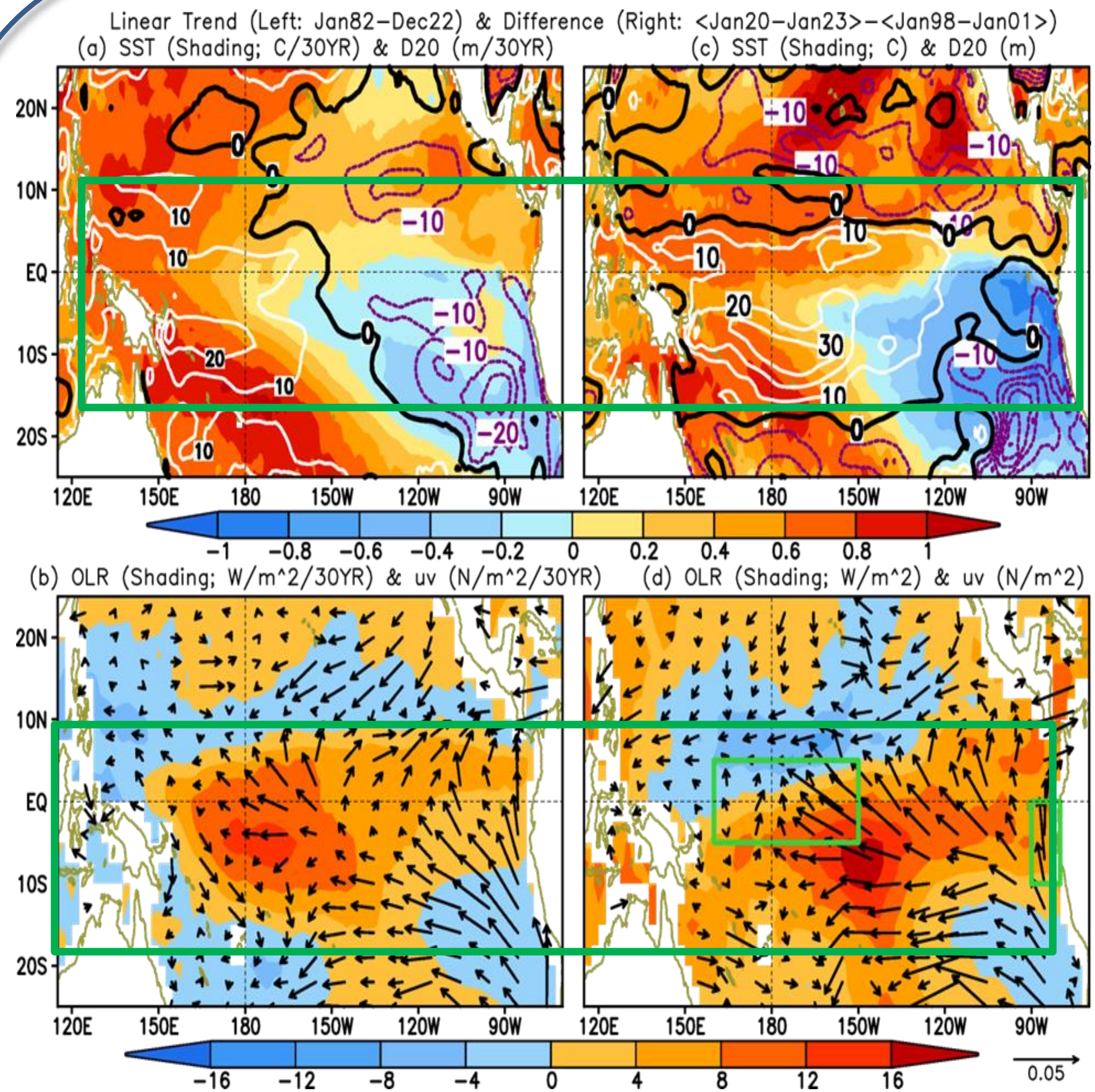
Iwakiri, et al. 2023: Triple-dip La Niña in 2020–23: North Pacific atmosphere drives 2nd year La Niña. GRL, 50, e2023GL105763. https://doi.org/10.1029/2023GL105763.



- **A strong positive IOD during the boreal fall of 2019 that gave way to basin-scale warming in the Indian Ocean in early 2020 & a strong Atlantic Niño developed in the boreal summer of 2021.**
- **The unusual sequence of events in 2019–2021 in the Indian and Atlantic Oceans may have energized and sustained the 2020–2022 La Niña event without any significant WWV preconditioning within the tropical Pacific.**

Fig 6. Schematic representation of the energizing and persistent processes of 2020–2022 La Niña in comparison to typical double-dip La Niña events. Solid grey arrow represents typical La Niña mechanism whereas the solid and dashed black arrow represent 2020–2022 La Niña mechanism.

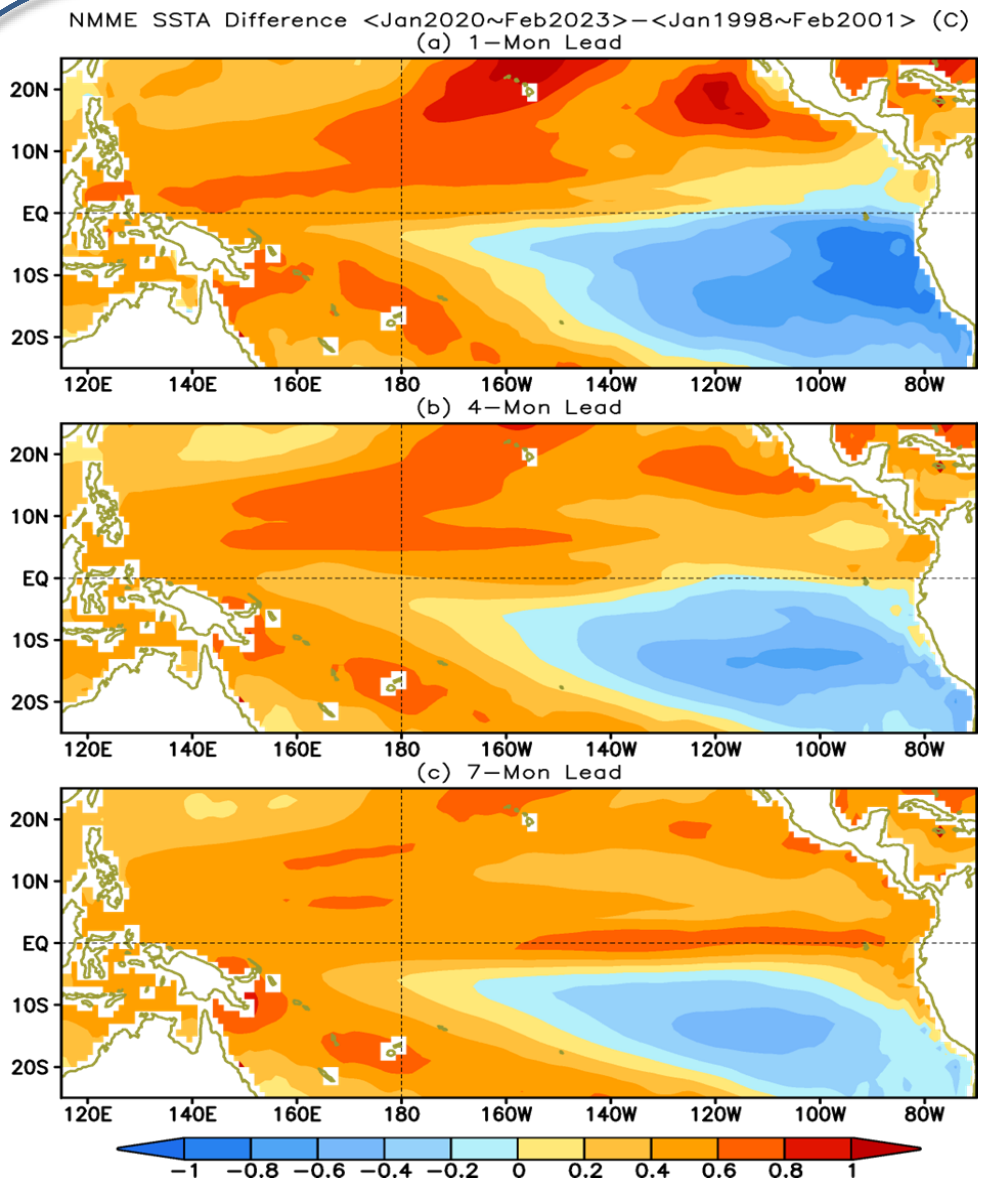
Hasan, et al., 2022: The influence of tropical basin interactions on the 2020-2022 double-dip La Niña. Frontiers in Climate, 4. DOI: 10.3389/fclim.2022.1001174



- **Linear trends contributed to the evolution of the 2020-2023 La Niña.**

Fig. 4: Anomalous linear trends of monthly means of (a) SST (shading; °C/30 years) and D20 (contours; m/30 years), and (b) OLR (shading; W/m²/30 years) and surface wind stress (vectors; N/m²/30 years) over land during January 1982-December 2022. Anomalous differences between the monthly means in January 2020-January 2023 and January 1998-January 2001 for (c) SST (shading; °C) and D20 (contours; m), and (d) OLR (shading; W/m²) and surface wind stress (vectors; N/m²). The contours in white, black, and purple in (a, c) represent positive, zero, and negative values, respectively. The green rectangles in (d) represent the Niño4 and Niño1+2 regions, respectively.

Li, et al., 2023: Triple-Dip La Niñas in 1998-2001 and 2020-2023: Impact of Mean State Changes. JGR, 128 (17), e2023JD038843. DOI: 10.1029/2023JD038843



- **Linear trends contributed to the predictability of the 2020-2023 La Niña.**

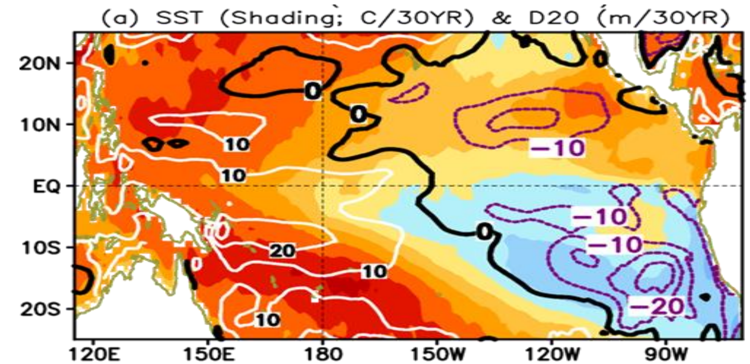
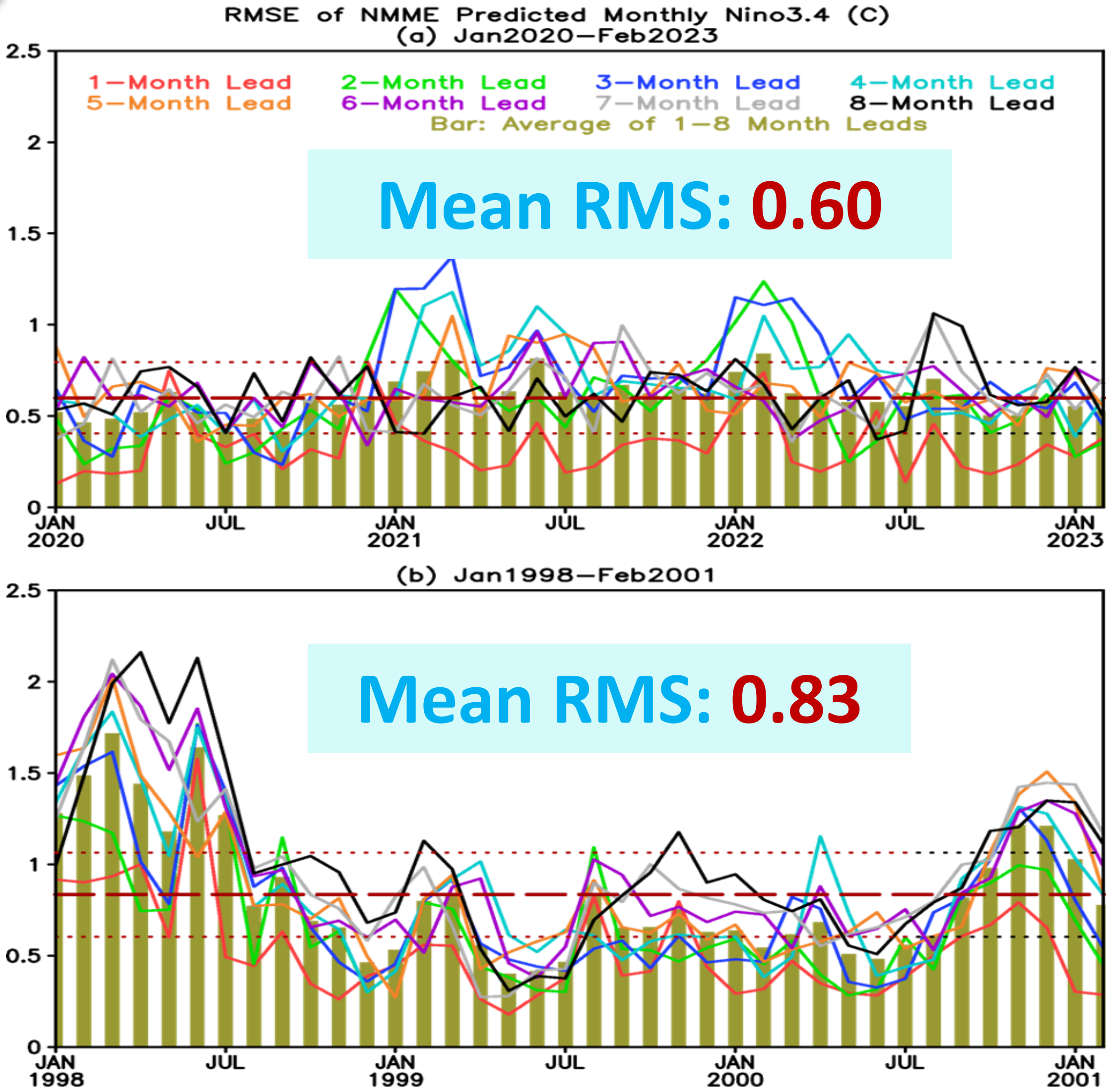


Fig. 8: NMME averaged SSTA differences between the means in Jan 202019-Feb 2023 and Jan 1998-Feb 2001 in (a) 1, (b) 4, and (c) 7-month leads. The unit is ^{o}C.

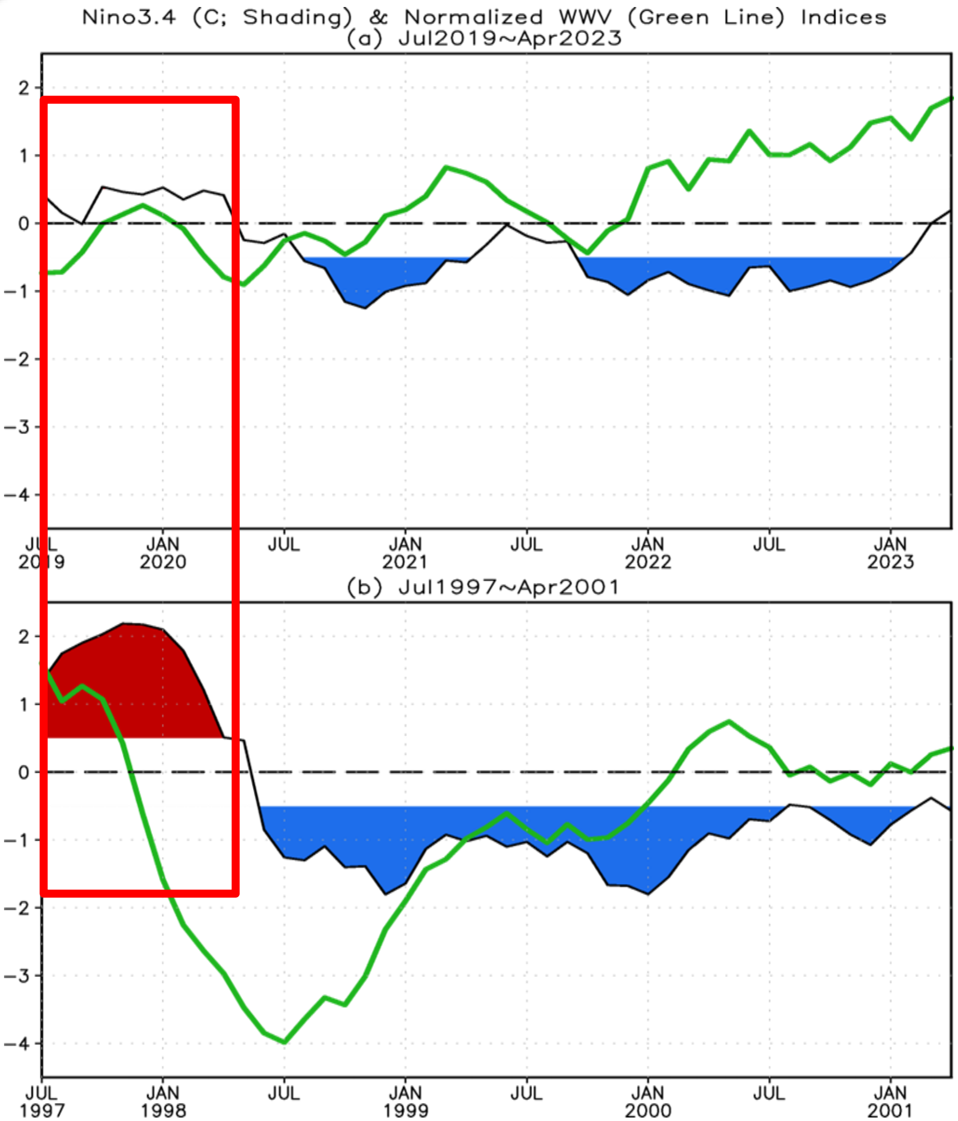
Li, et al., 2023: Triple-Dip La Niñas in 1998-2001 and 2020-2023: Impact of Mean State Changes. JGR, 128 (17), e2023JD038843. DOI: 10.1029/2023JD038843



- **Due to the contribution & predictability of the linear trends, prediction biases are smaller in the 2020-2023 La Niña than in 1998-2001 La Niña.**

Fig. 9: Root-Mean-Square-Errors (RMSE) of six models predicted monthly mean Niño3.4 index in (a) Jan 2020-Feb 2023 and (b) Jan 1998-Feb 2001 in 1-8 month leads. The bars are the average for 1-8 month leads. The unit is °C. Horizontal red dashed and dotted lines represent the mean RMSE of 1-8 leads and ± one standard deviation over the 3 years of each prediction ensemble, respectively.

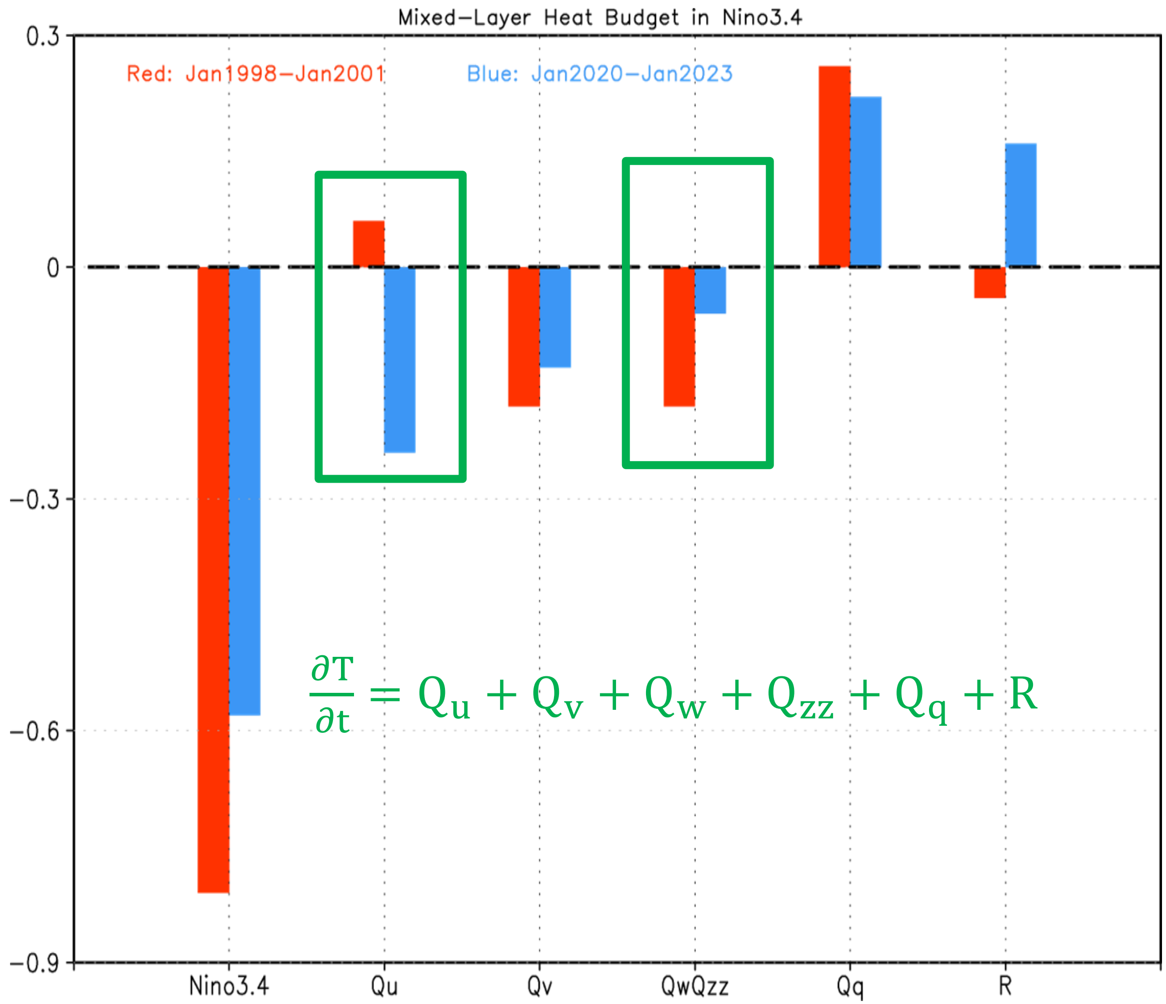
Li, et al., 2023: Triple-Dip La Niñas in 1998-2001 and 2020-2023: Impact of Mean State Changes. JGR,128 (17), e2023JD038843. DOI: 10.1029/2023JD038843



- **Ocean heat content as a precursor was more important for the predictability of the 1998-2001 La Niña than the 2020-2023 La Niña.**

Fig. 1: Monthly mean of the Niño3.4 (black line; °C) and normalized WWV (green line) indices during (a) July 2019-April 2023 and (b) July 1997-April 2001. WWV is normalized by its standard deviation over January 1991-December 2020, which is 6.4 m. The Niño3.4 index is shaded with a value larger than 0.5 °C or smaller than -0.5 °C.

Li, et al., 2023: Triple-Dip La Niñas in 1998-2001 and 2020-2023: Impact of Mean State Changes. JGR, 128 (17), e2023JD038843. DOI: 10.1029/2023JD038843



- **In the Niño3.4 region (Fig. 6), ocean vertical entrainment and diffusion (Q_w and Q_zz) were stronger during 1998-2001 than during 2020-2023;**
- **While zonal advection was large and negative during 2020-2023 but positive during 1998-2001.**

Fig. 6: Niño3.4 region averaged pentad mean SST (°C), Qu, Qv, Qw+Qzz, Qq, and R (°C/month) during Jan 1998-Jan 2001 (red bars) and Jan 2020-Jan2023 (blue bars). The anomalies are referred to a 1991-2020 climatology.

Li, et al., 2023: Triple-Dip La Niñas in 1998-2001 and 2020-2023: Impact of Mean State Changes. JGR, 128 (17), e2023JD038843. DOI: 10.1029/2023JD038843

Acknowledgement

- Drs. Jieshun Zhu, Caihong Wen, and Arun Kumar: reviewed PPT, and provide insightful suggestions and comments
- Dr. Pingping Xie provided the BASS/CMORPH/CFSR EVAP package
- Drs. Jieshun Zhu & Wanqiu Wang provides the sea ice forecasts

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Jieshun.Zhu@noaa.gov
Zeng-Zhen.Hu@noaa.gov

Data Sources (climatology is for 1991-2020)

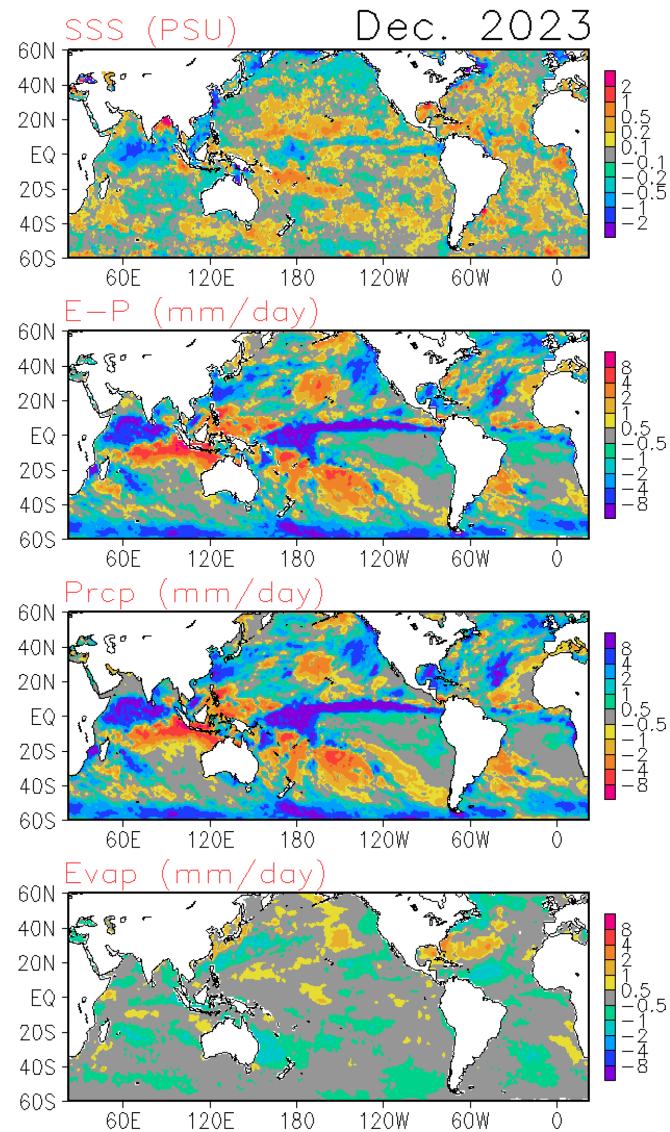
- **NCEP/CPC Ocean Monitoring & Briefing Operation (Hu et al., 2022, BAMS)**
- **Weekly Optimal Interpolation SST (OIv2.1 SST; Huang et al. 2021)**
- **Extended Reconstructed SST (ERSST) v5 (Huang et al. 2017)**
- **Blended Analysis of Surface Salinity (BASS) (Xie et al. 2014)**
- **CMORPH precipitation (Xie et al. 2017)**
- **CFSR evaporation adjusted to OAFlux (Xie and Ren 2018)**
- **NCEP CDAS winds, surface radiation and heat fluxes (Kalnay et al. 1996)**
- **NESDIS Outgoing Long-wave Radiation (Liebmann and Smith 1996)**
- **NCEP's GODAS temperature, heat content, currents (Behringer and Xue 2004)**
- **Aviso altimetry sea surface height from CMEMS**
- **Ocean Surface Current Analyses – Realtime (OSCAR)**
- **In situ data objective analyses (IPRC, Scripps, EN4.2.1, PMEL TAO)**
- **Operational Ocean Reanalysis Intercomparison Project**
  - **http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html**
  - **http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html**

Backup Slides

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

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

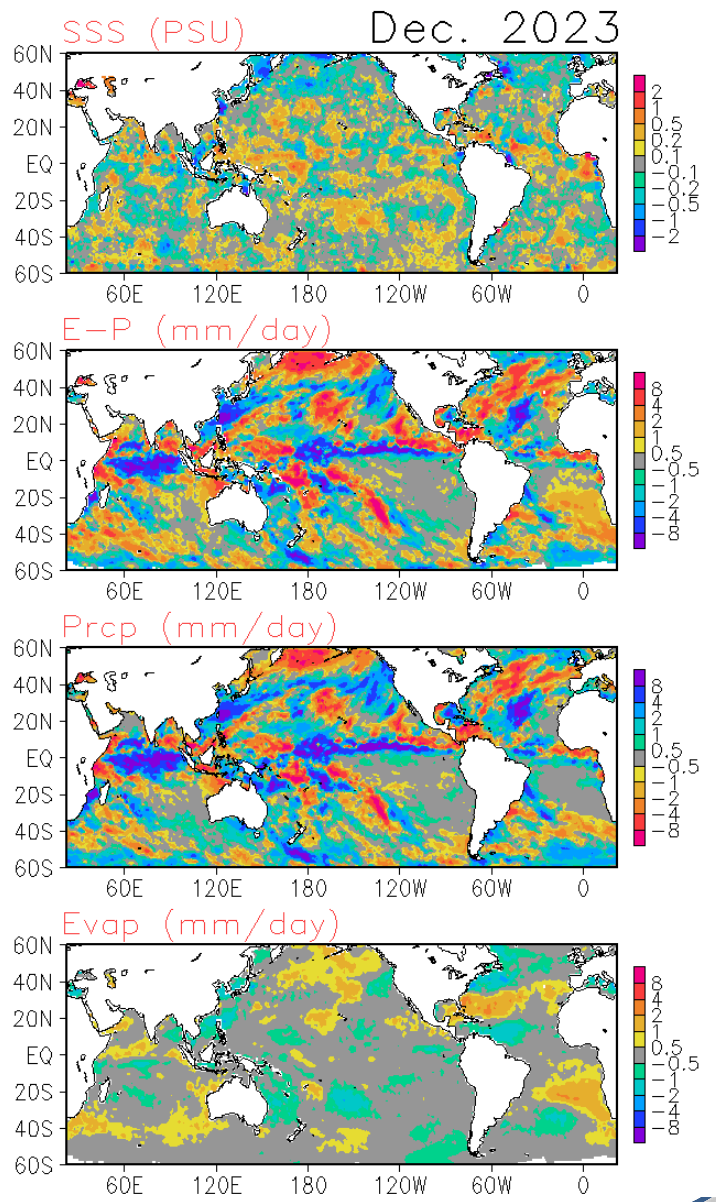
Positive precipitation (Enhanced fresh water flux) is observed across the equatorial Pacific from the American coasts to ~160oW, and over the northern portion of equatorial Indian ocean. Dry precipitation (saltier SSS) anomalies, meanwhile, are visible around the Maritime continent. Freshened SSS anomalies also appear over the NW Pacific off the coast of East Asia, attributable to the enhanced precipitation there.



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 December 2023

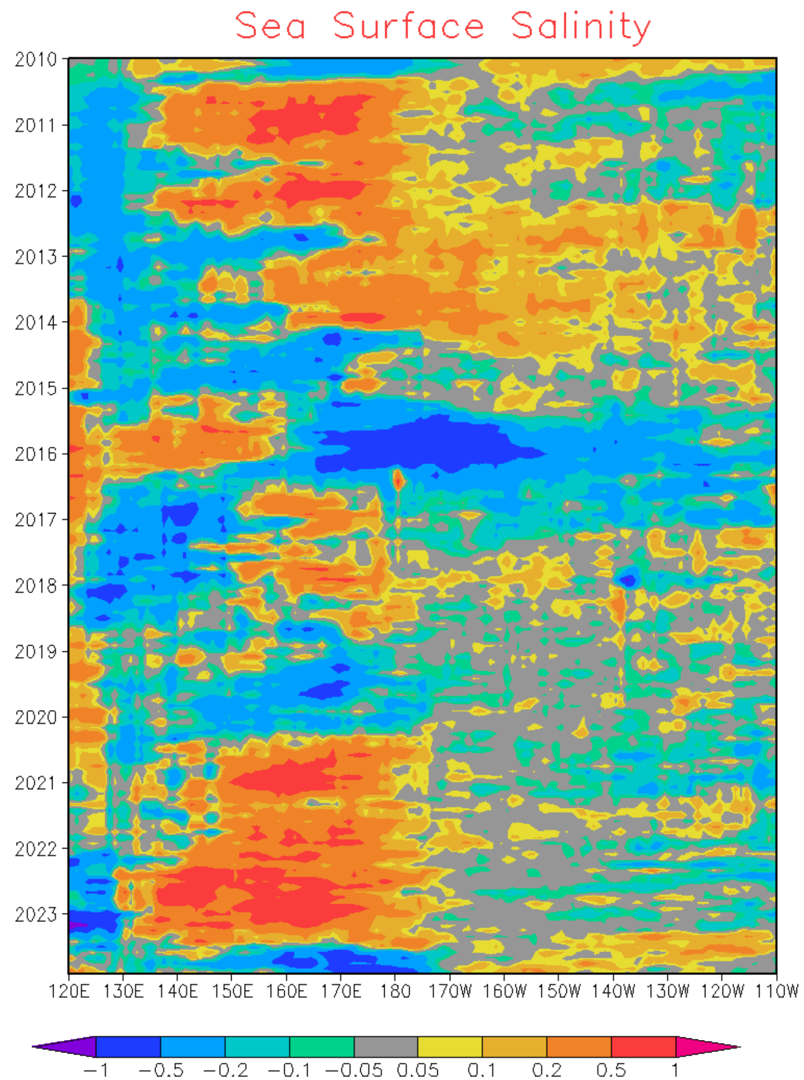
Precipitation anomalies are enhanced over an extensive portion of the equatorial Pacific from the dateline to ~100ºW. To the west of the region, a drier precipitation tendency is visible, causing the saltier SSS tendency there. Over the eastern Pacific, positive and negative precipitation tendencies are noticed over the southern and northern equatorial Pacific, respectively., resulting a mixed pattern of freshened and saltier SSS tendencies there.



Monthly SSS Anomaly Evolution over Equatorial Pacific

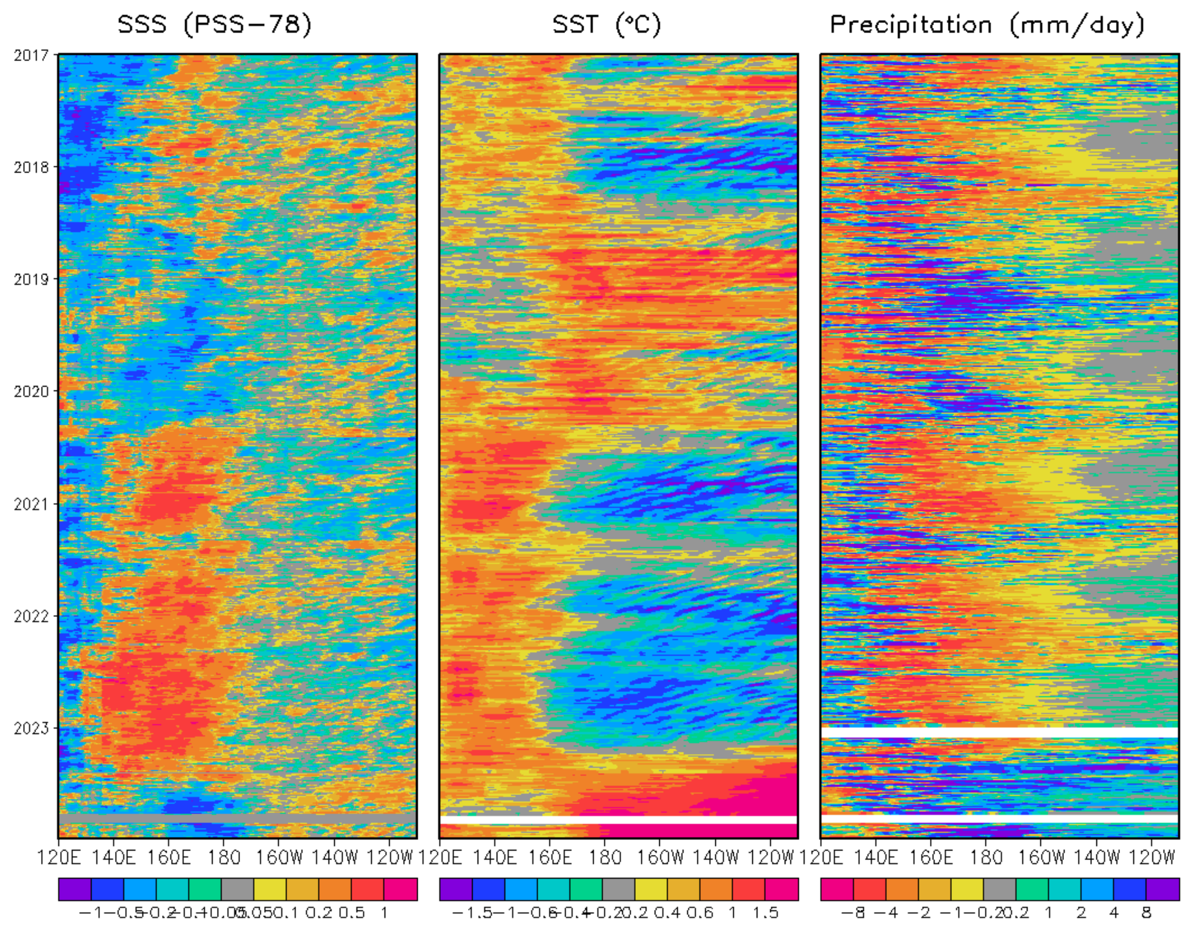
NOTE: Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015,The BASS SSS is from in situ, SMOS and Aquarius.

- Hovermoller diagram for equatorial SSS anomaly **(5° S-5° N);**
- Strong freshened SSS anomalies continued over the central equatorial Pacific (160ºE-170ºW) during December 2023. SSS anomalies over the western equatorial Pacific are still negative (freshened) but weak. Saltier SSS anomalies over the eastern equatorial Pacific are largely dissipated.

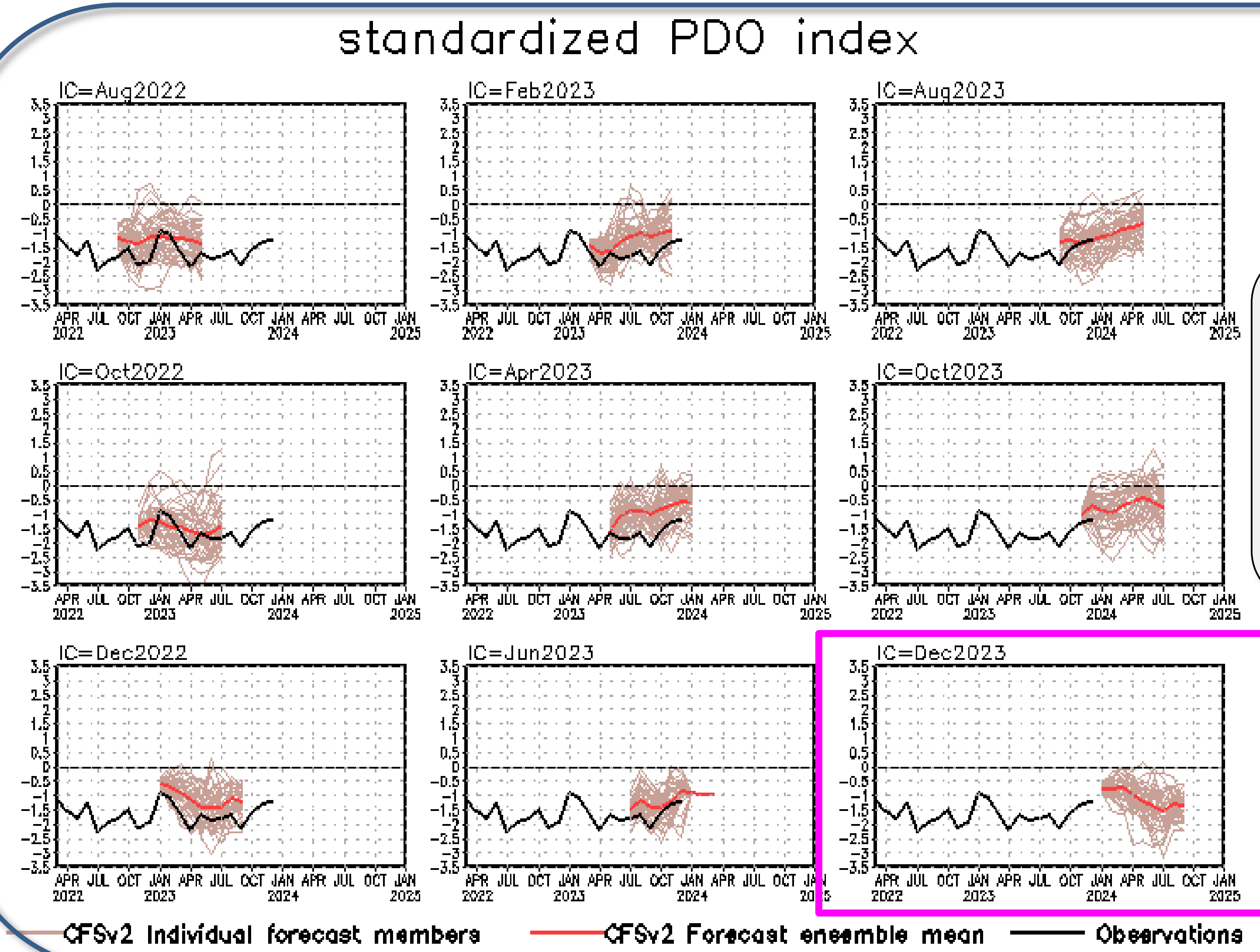


Pentad SSS Anomaly Evolution over Equatorial Pacific

Figure caption: Hovermoller diagram for equatorial (5° S-5° N) 5-day mean SSS, SST and precipitation anomalies. The climatology for SSS is Levitus 1994 climatology. The SST data used here is the OISST V2 AVHRR only daily dataset with its climatology being calculated from 1985 to 2010. The precipitation data used here is the adjusted CMORPH dataset with its climatology being calculated from 1999 to 2013.



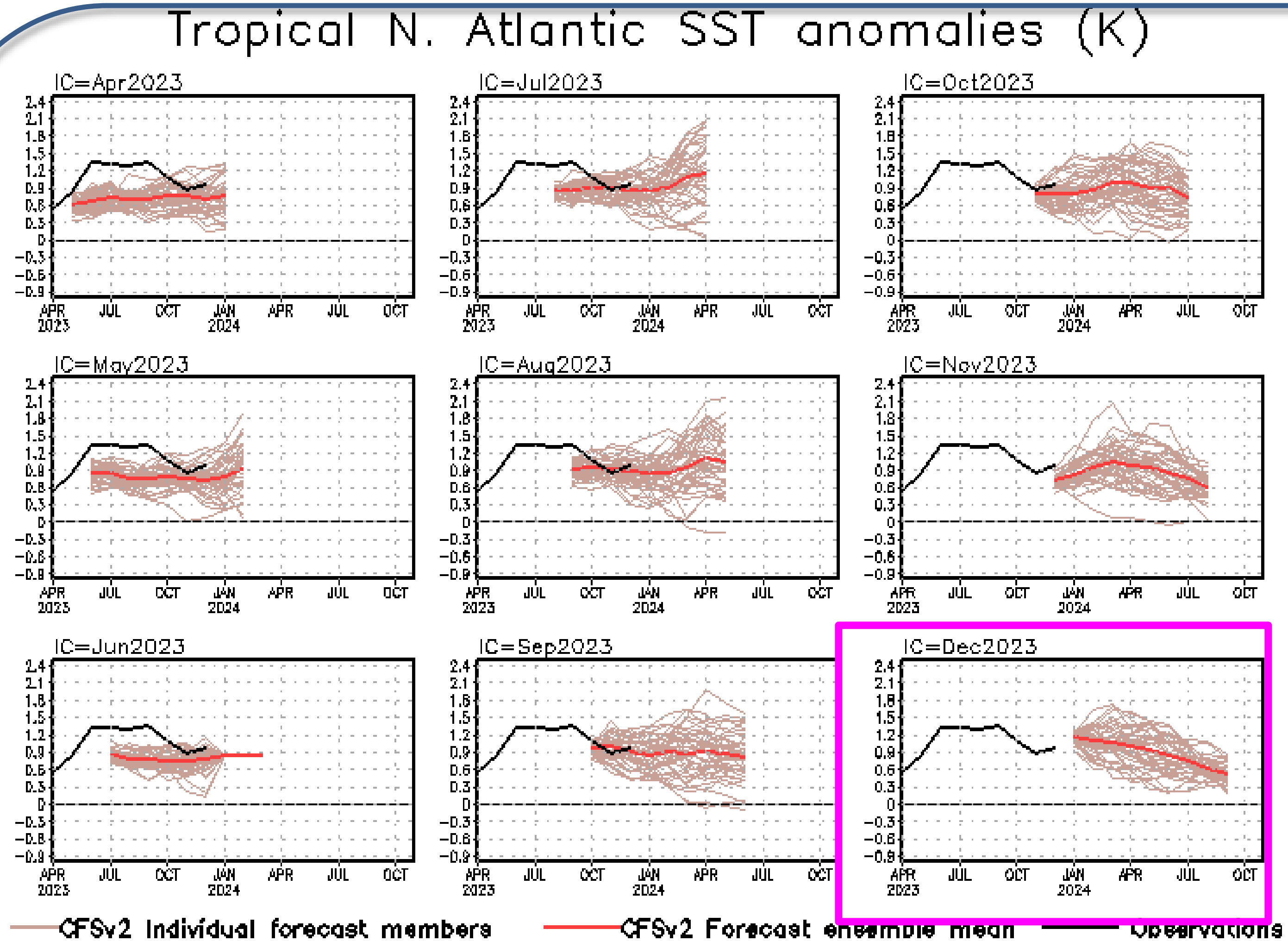
NCEP CFSv2 PDO Index Predictions from Different Initial Months



- CFSv2 predicts a persistent negative phase of PDO in 2024.

CFS Pacific Decadal Oscillation (PDO) index predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1991-2020 base period means. PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N]. CFS PDO index is the standardized projection of CFS SST forecast anomalies onto the PDO EOF pattern.

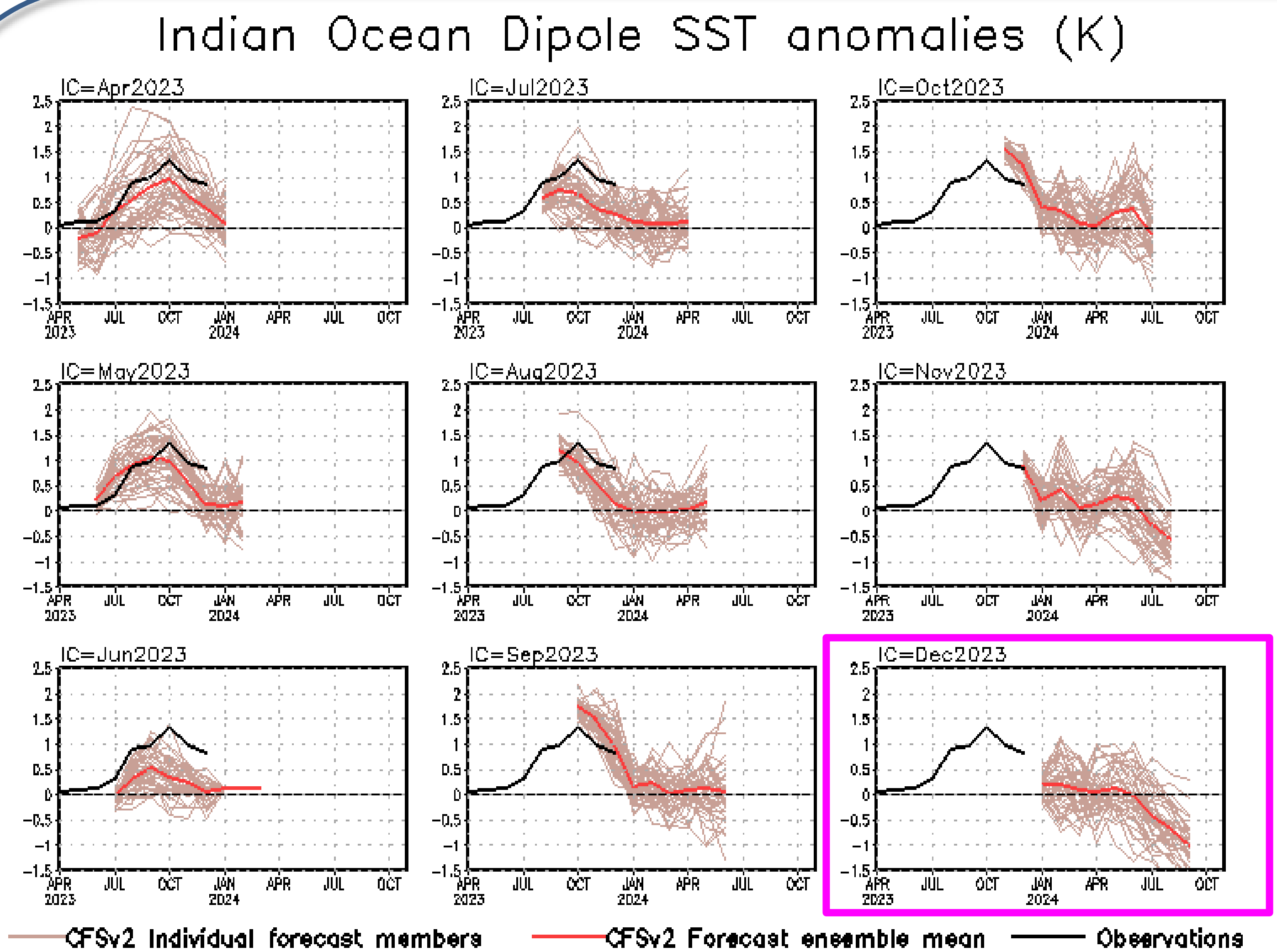
NCEP CFSv2 Tropical North Atlantic (TNA) SST Predictions from Different Initial Months



- Latest CFSv2 predictions call for above-normal SSTA in the tropical North Atlantic.

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

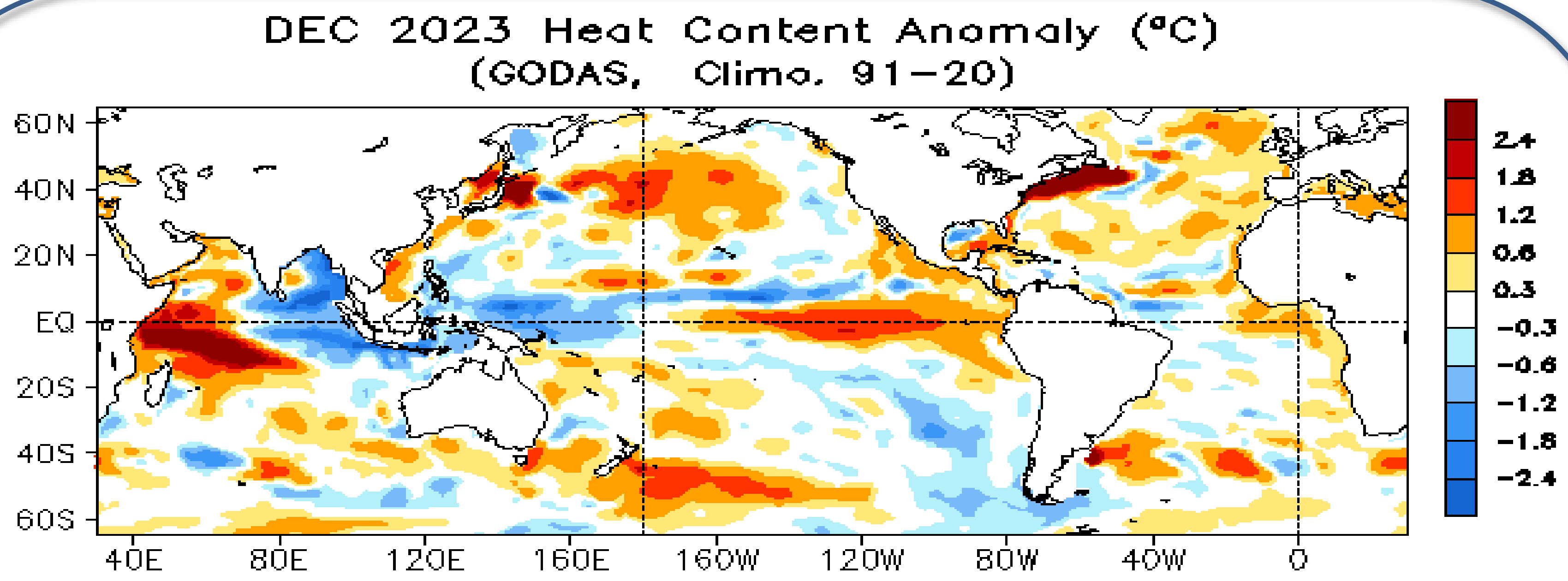
NCEP CFSv2 DMI SST Predictions from Different Initial Months

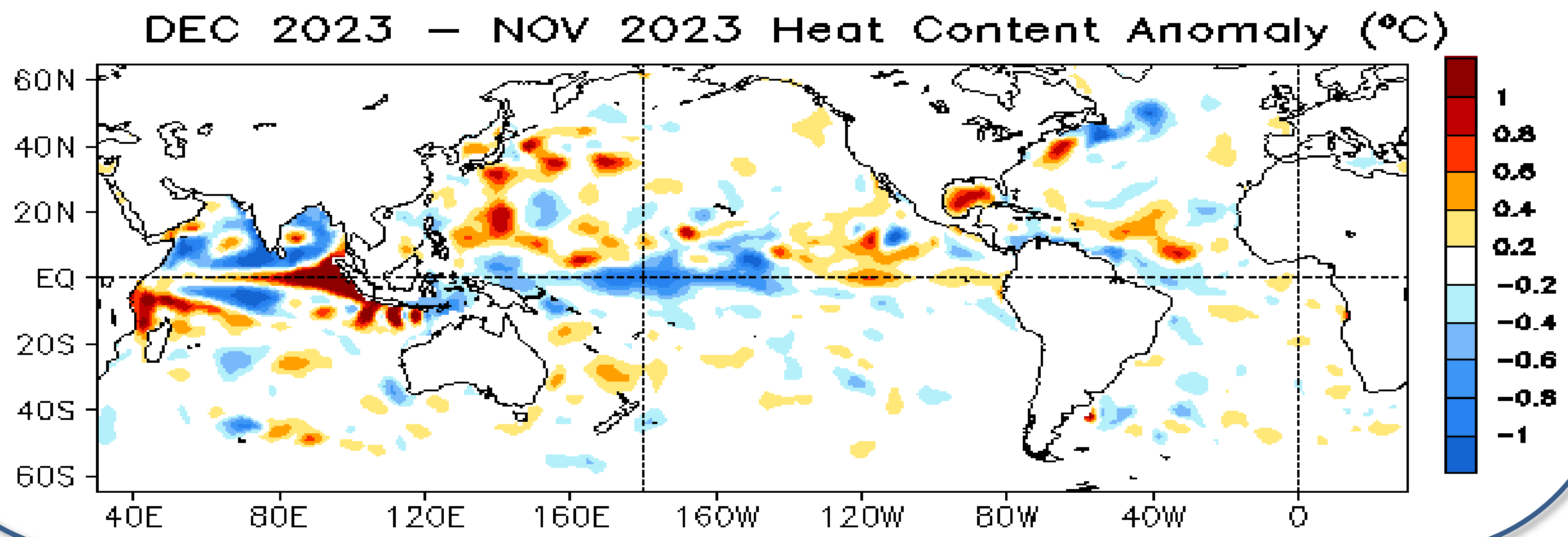


- CFSv2 predicts a negative phase of IOD since the summer of 2024.

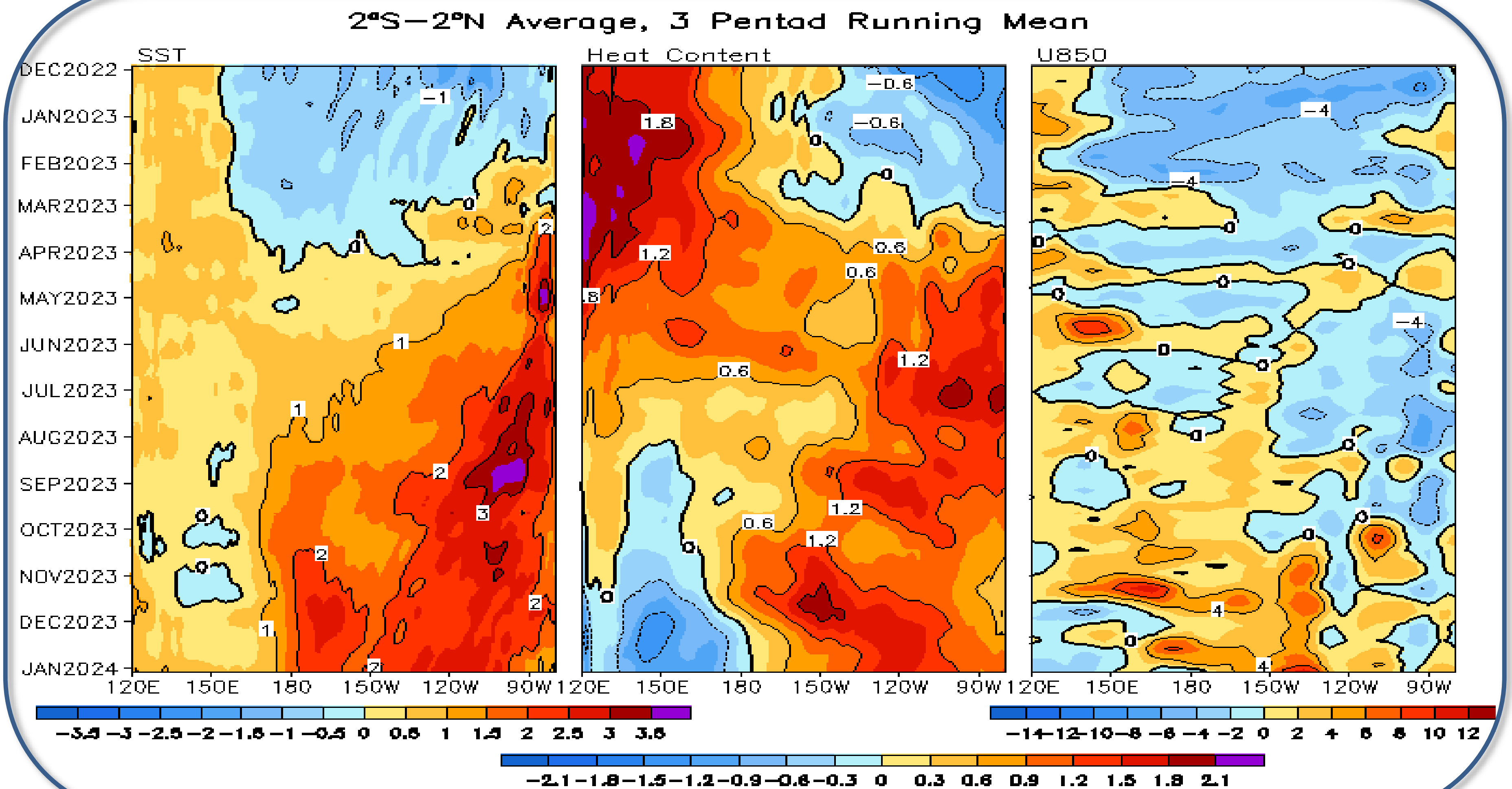
CFS Dipole Model Index (DMI) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1991-2020 base period means.

Global HC300 Anomaly & Anomaly Tendency



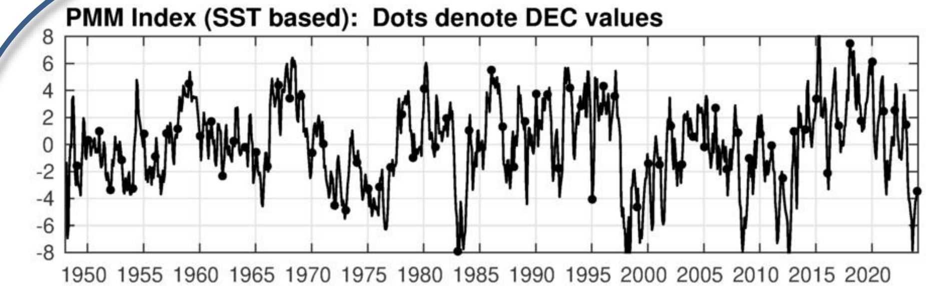


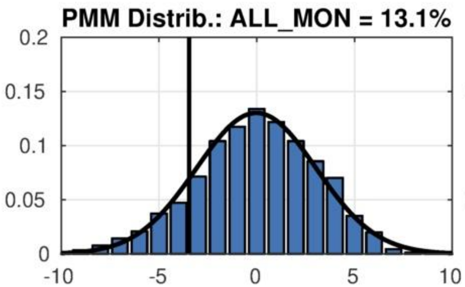
Equatorial Pacific SST (ºC), HC300 (ºC), u850 (m/s) Anomalies

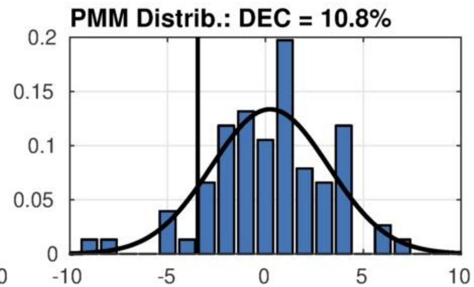


- Since Feb 2023, a set of westerly wind surges triggered downwelling Kelvin waves, reinforcing the subsurface warming in the central and eastern Pacific.
- Westerly wind anomalies prevailed over most of equatorial Pacific Ocean since Oct 2023.
- Positive SST anomalies persisted in the central Pacific in Dec 2023.

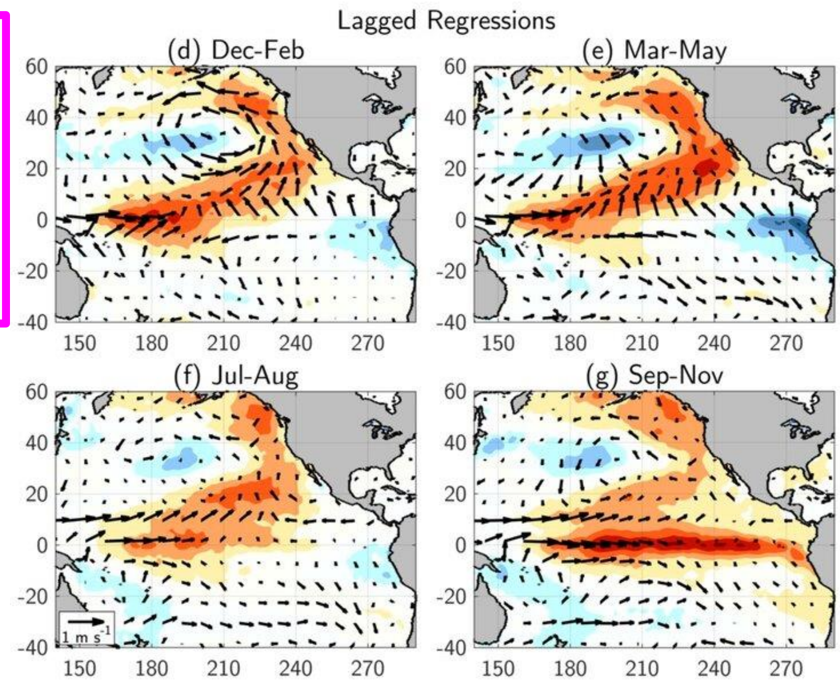
Current Status of the Pacific Meridional Mode (PMM)

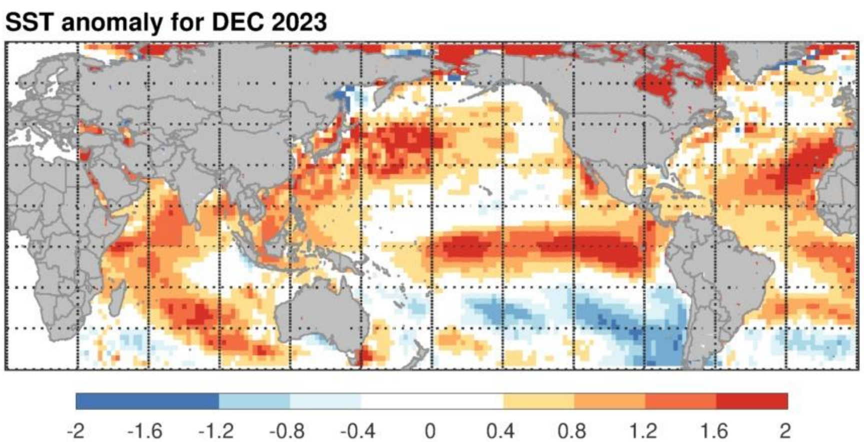






Lagged regressions of seasonally averaged SST and surface wind anomalies on NPMM SST time series calculated from a Maximum Covariance Analysis.

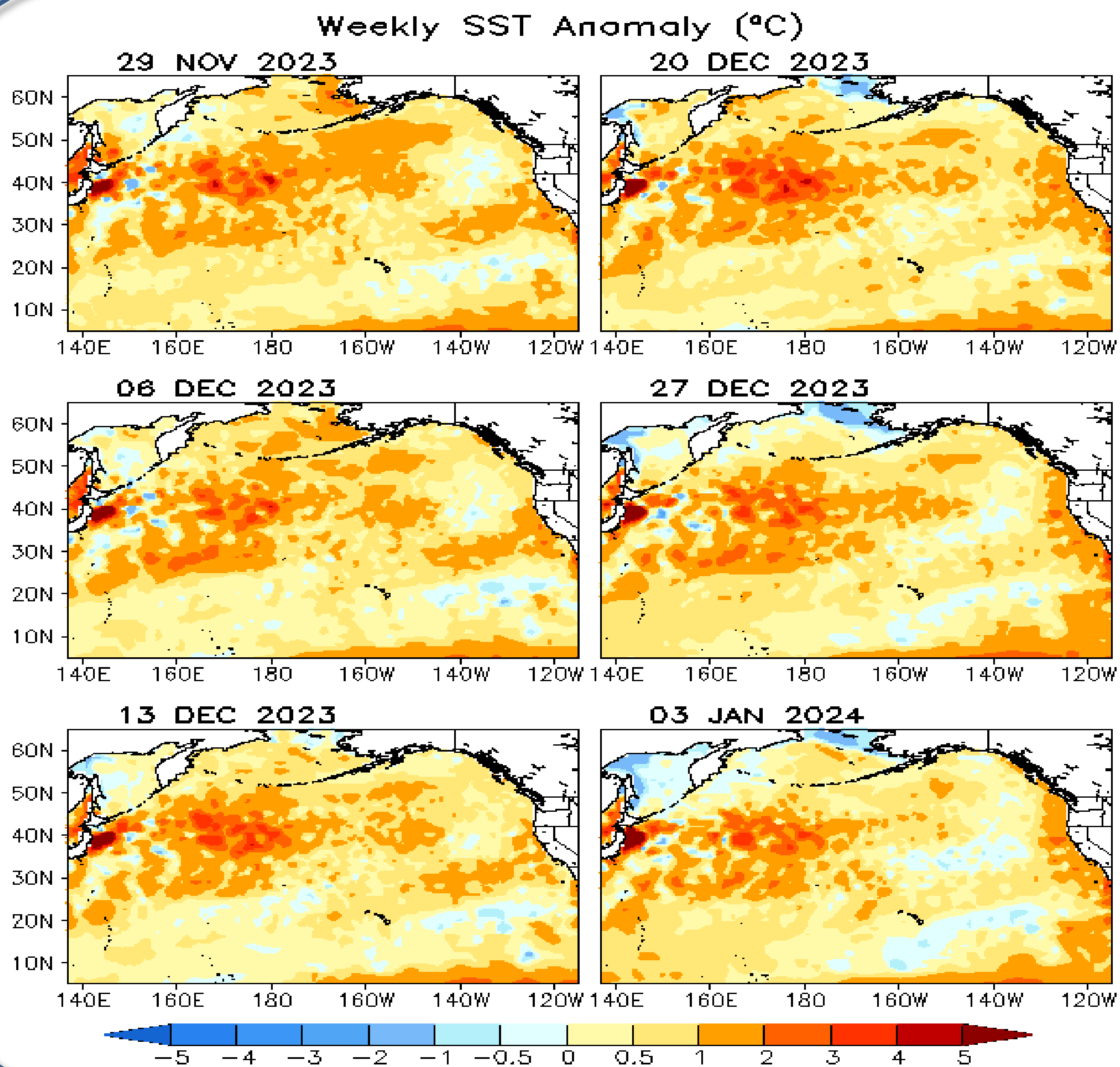




https://www.aos.wisc.edu/~dvimont/MModes/PMM.html

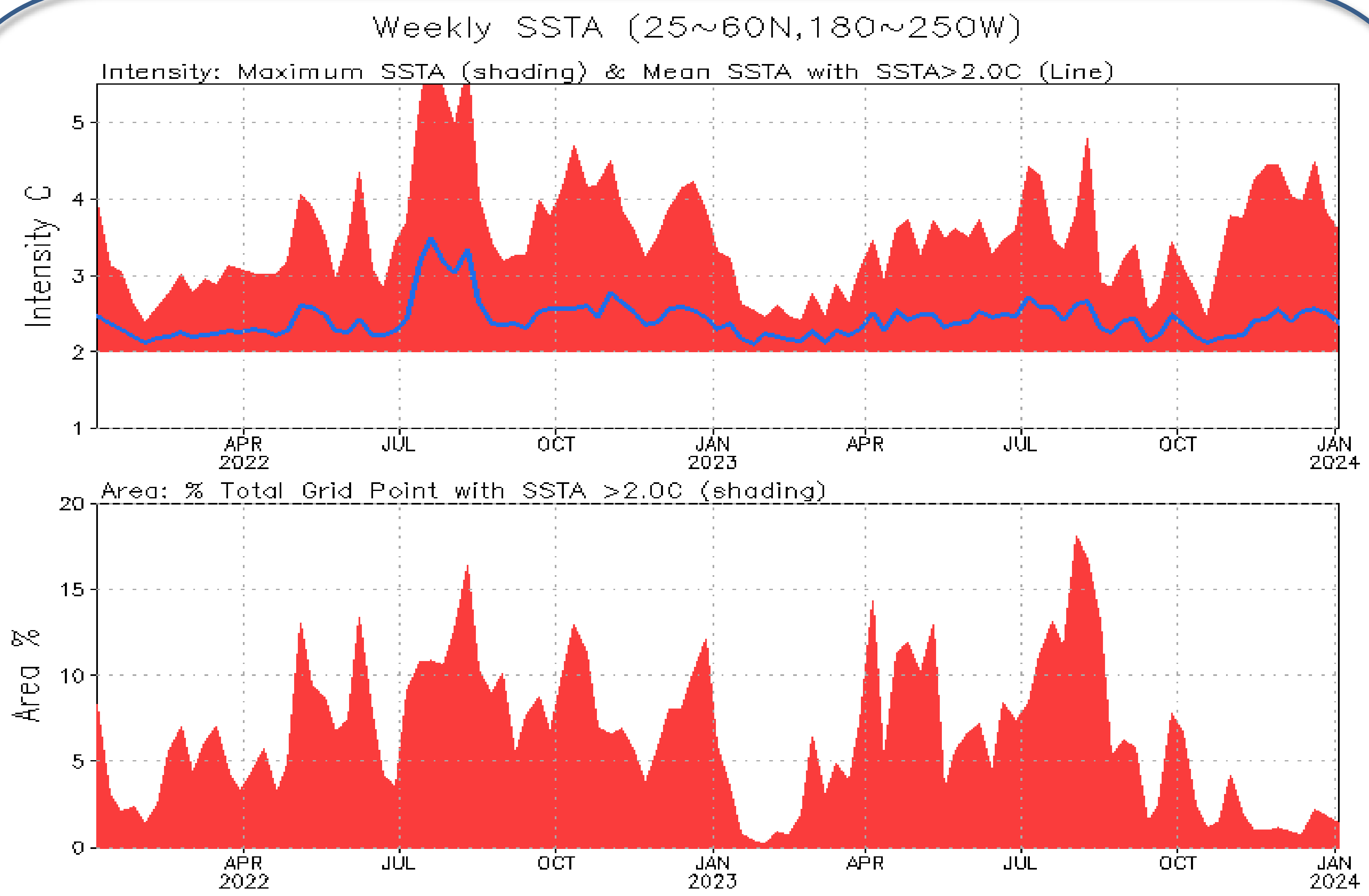
Amaya, D. J., 2019: The Pacific meridional mode and ENSO: A review. Curr. Climate Change Rep., 5, 296–307, 10.1007/s40641-019-00142-x.

Weekly SSTA evolutions in the NE Pacific



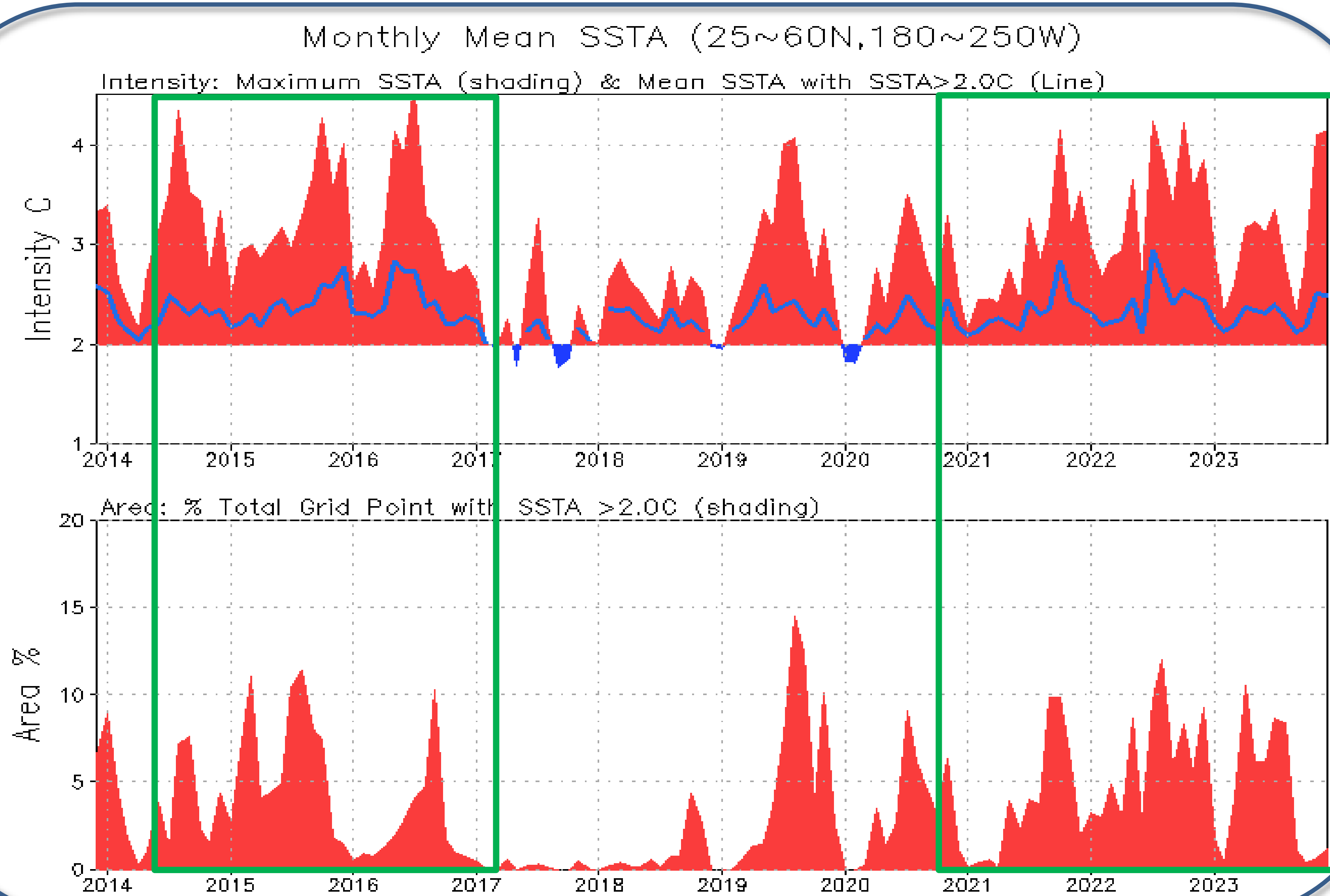
- Positive SST anomalies were persistent in the northern Pacific during the last six weeks.

N. Pacific Marine Heat Wave



https://origin.cpc.ncep.noaa.gov/products/GODAS/MarineHeatWave.html

N. Pacific Marine Heat Wave



https://origin.cpc.ncep.noaa.gov/products/GODAS/MarineHeatWave.html

NOAA/NWS/NCEP CPC Marine Heat Wave Webpage

https://www.cpc.ncep.noaa.gov/products/GODAS/MarineHeatWave.html

NOAA/NCEP Climate Prediction Center

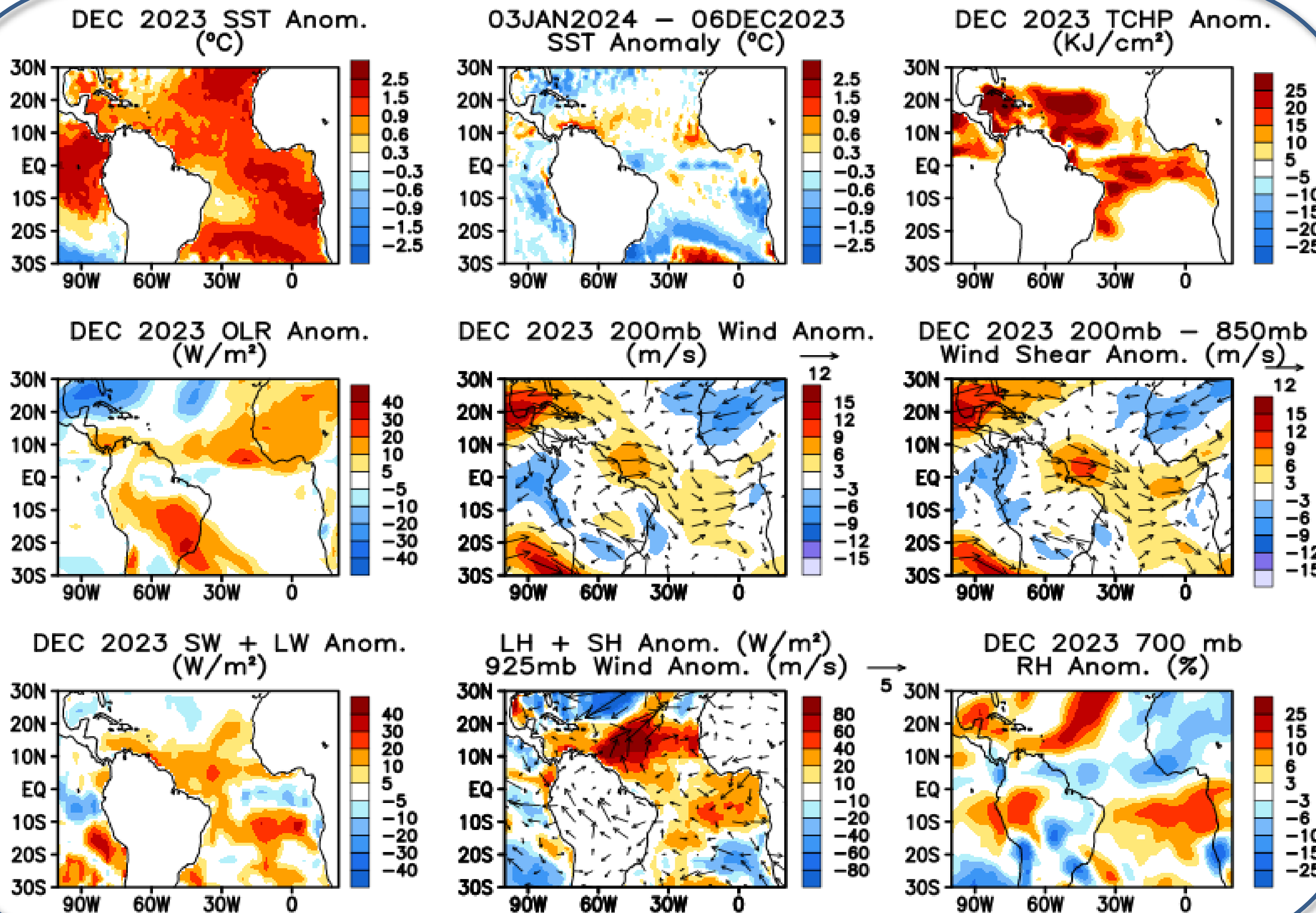
Marine Heatwave Monitoring and Forecast

- **Indices & Time Series**
  - N. Pacific MHW Intensity & Area Indices: Weekly Monthly
  - Regional Mean SST: Global Monthly & Nino3.4 Since 1854 N. Pacific Weekly Gulf of Alaska & Subtropical Coast Weekly

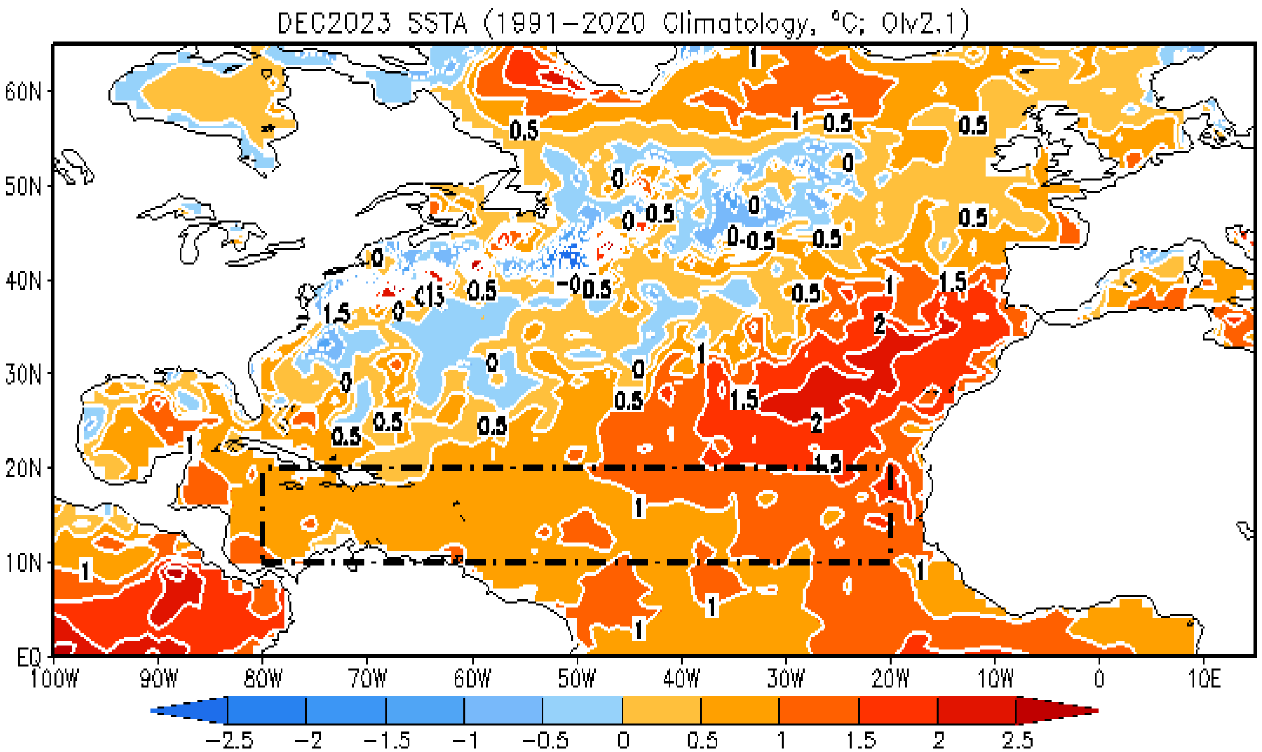
- **Spatial Distribution**
  - Global Monthly Anomaly
  - SST
  - N. Pacific Anomaly
  - Pentad Subsurface Ocean Temperature: 5m 55m 105m 155m
  - Weekly SST Weekly SST2
  - Pentad 300m Ocean Heat Content Pentad Ocean Surface Heigh Pentad Surface Heat Flux
  - 3-month SST, SLP, & UV925 SST Tendency & 3-Month Heat Flux
  - Ocean Temperature Profile GODAS Ocean Temperature Profile
  - N. Atlantic Anomaly
  - Weekly SSTA Monthly MDR SSTA
  - 3-month SST, SLP, & UV925 SST Tendency & 3-Month Heat Flux

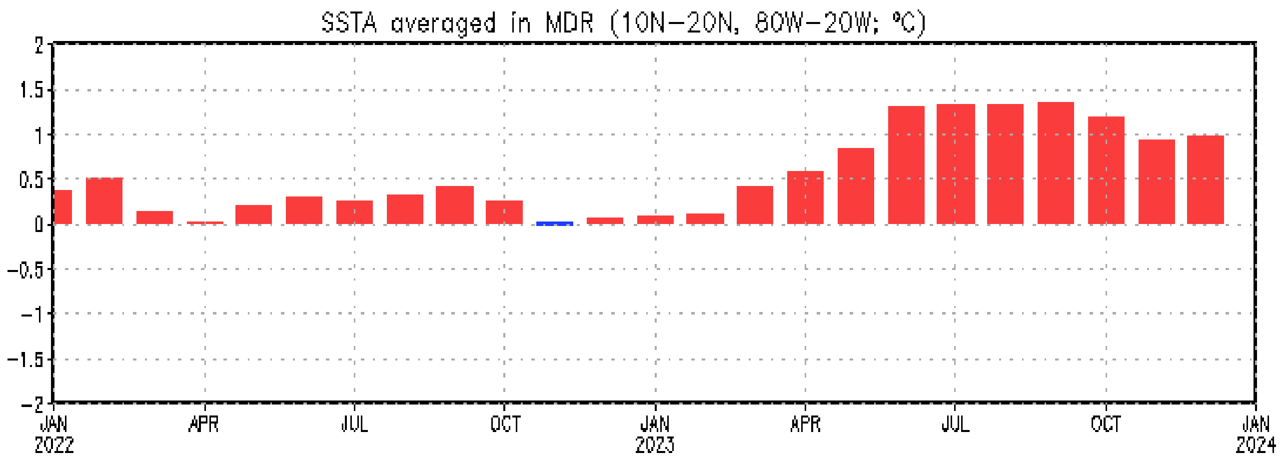
- **NMME & CFSv2 Forecasts**
  - Tropical N. Atlantic SSTA: NMME CFSv2
  - N. Pacific SSTA: NMME CFSv2
  - CFSv2: N. Pacific Sea Surface Height Anomaly
  - CFSv2 SSTA Index: Last month Last 9 months

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



SSTAs in the North Atlantic & MDR





- SST in MDR was above average during the last two months.

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