# 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

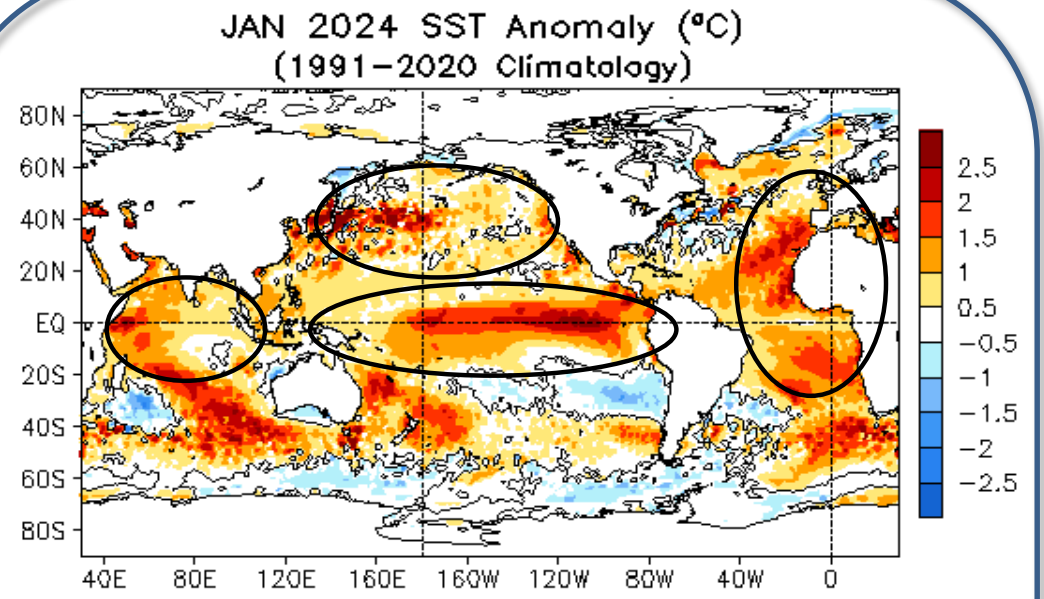
- Overview
- Recent highlights
  - Pacific
  - Arctic & Antarctic Oceans
  - Indian Ocean
  - Atlantic Ocean
- Global SSTA Predictions
- *2023 Annual Review*

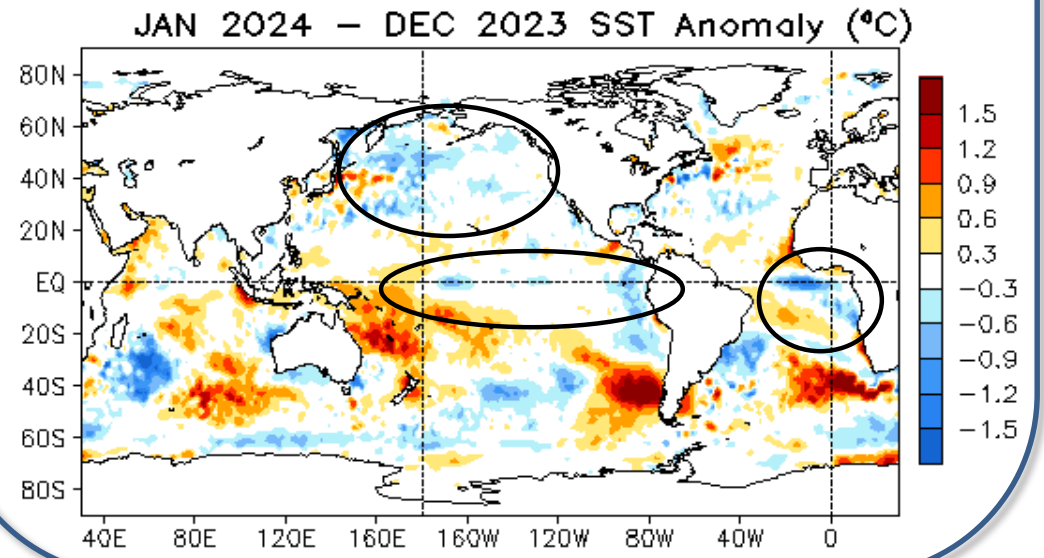
# Overview

- Pacific Ocean
  - El Niño condition weakened with Niño3.4 = 1.9$^{o}$C in Jan 2024.
  - NOAA "ENSO Diagnostic Discussion" on 9 Feb 2024 issued "*El Niño Advisory / La Niña Watch.*"
  - Positive SSTAs weakened in the North Pacific in Jan 2024.
  - The PDO has been in a negative phase since Jan 2020 with PDOI = -0.9 in Jan 2024.
- Arctic & Antarctic Oceans
  - Arctic sea ice extent was 13.92 million square kilometers in Jan 2024, 20th lowest in the 45-year satellite record in Jan. Antarctic sea ice extent was 3.96 million square kilometers in Jan 2024, tying for fourth lowest extent with 2022.
  - UFS forecasts suggest a near normal sea ice extent maximum in Mar 2024.
- Indian Ocean
  - Positive SSTAs were present in the tropical Indian Ocean with warming stronger in the west than in the east in Jan 2024.
- Atlantic Ocean
  - Positive SSTAs were observed in the tropical Atlantic with positive ATL3 index weakening in Jan 2024.
  - NAO returned to a negative phase in Jan 2024 with NAOI= -0.3.

# Global Oceans

# Global SST Anomaly (°C) and Anomaly Tendency



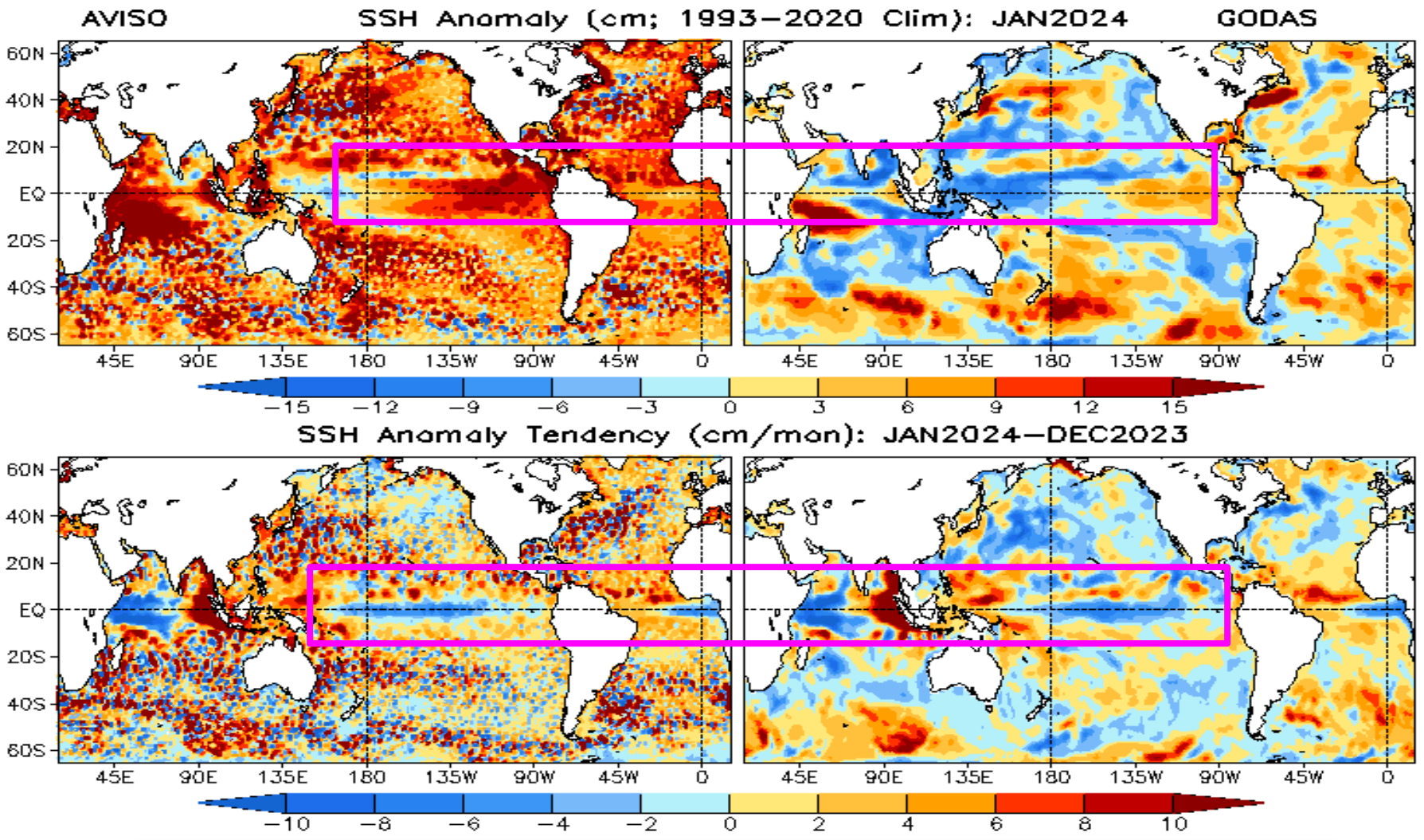




- In general, positive anomalies dominated the global oceans.
- Positive SSTAs persisted the central and eastern equatorial Pacific Ocean, however, coastal El Niño condition weakened in Jan 2024.
- Positive SSTAs were present in the North Pacific.
- Positive SSTAs dominated the eastern Atlantic Ocean.
- 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 western coast of South America and around 160°W.
- Negative SSTA tendencies were observed in the central and eastern equatorial Atlantic Ocean.
- Negative SSTA tendencies dominated the North Pacific Ocean.

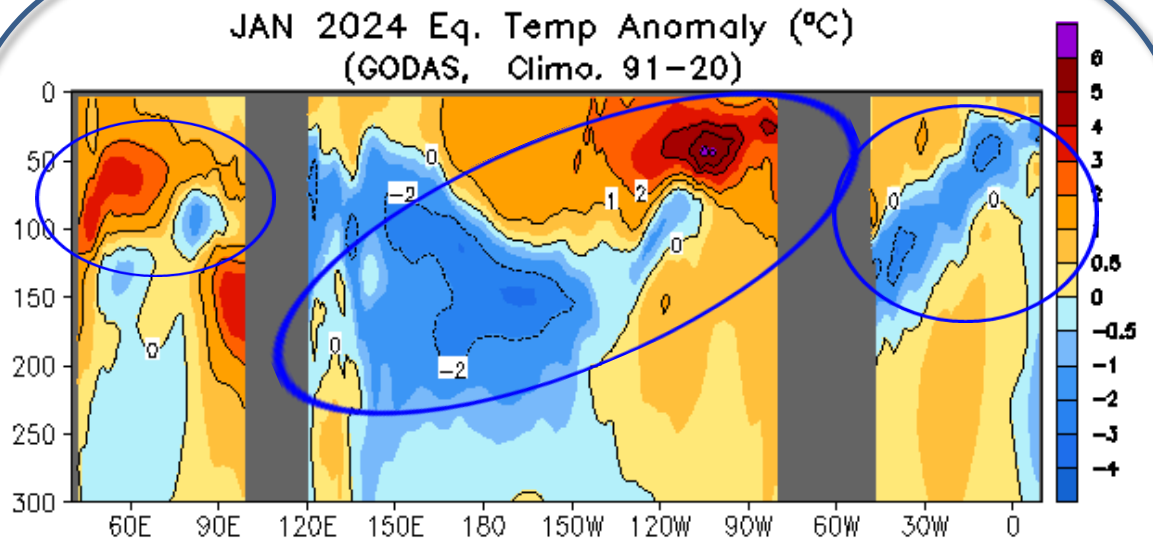
SSTAs (top) and SSTA tendency (bottom). Data are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

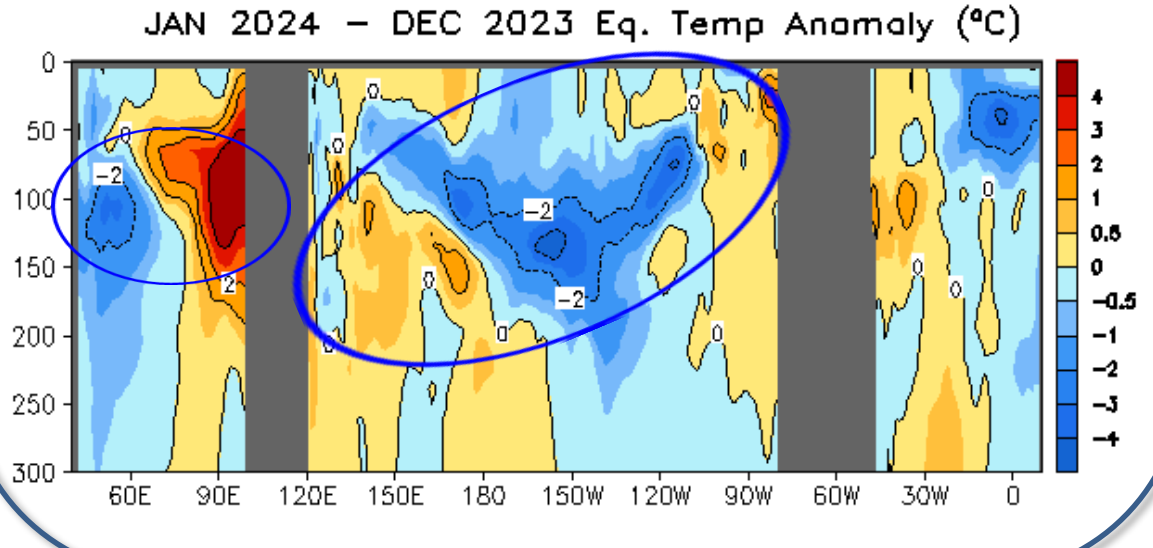
# AVISO & GODAS SSH Anomaly (cm) and Anomaly Tendency




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

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



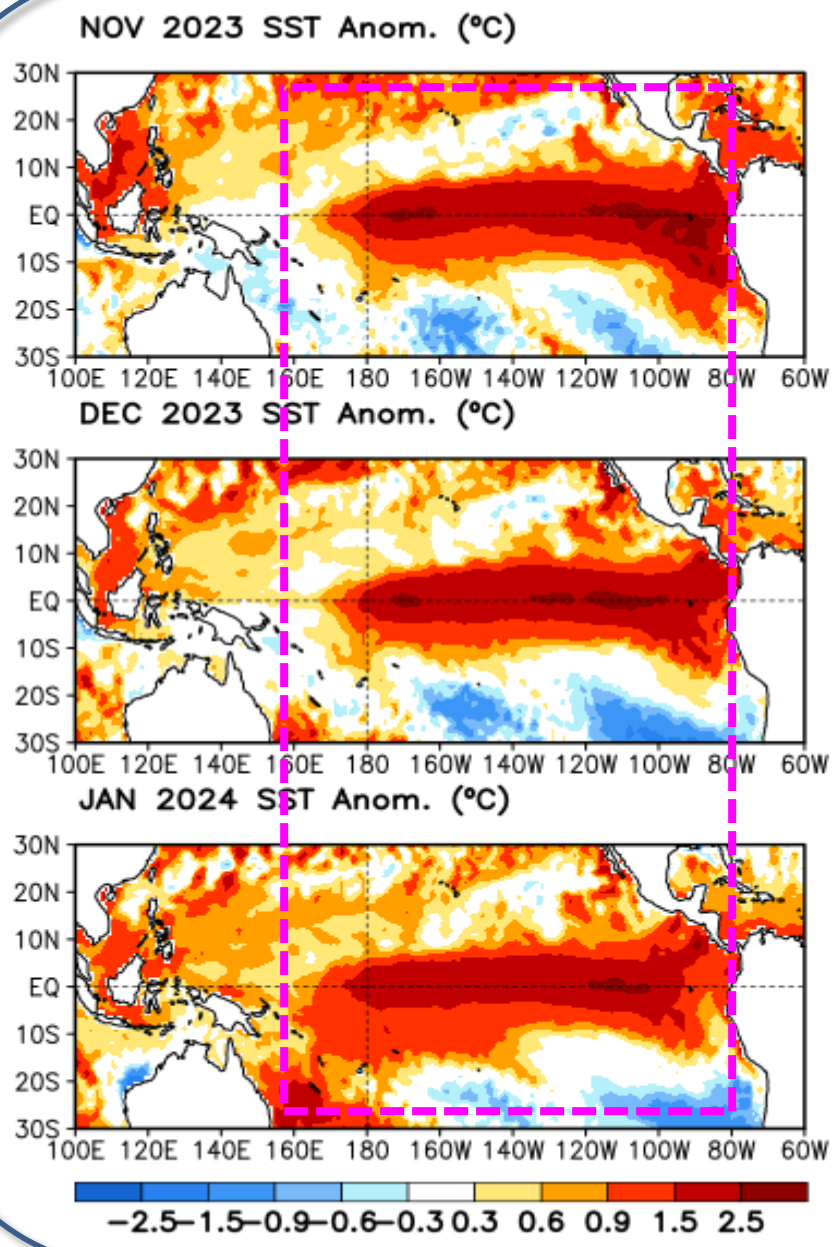

- A dipole-like pattern persisted with positive (negative) anomalies in the eastern (western) Pacific thermocline.
- Negative anomalies were observed in the Atlantic Ocean along the thermocline.
- Positive anomalies were present along the western and central Indian Ocean thermocline.

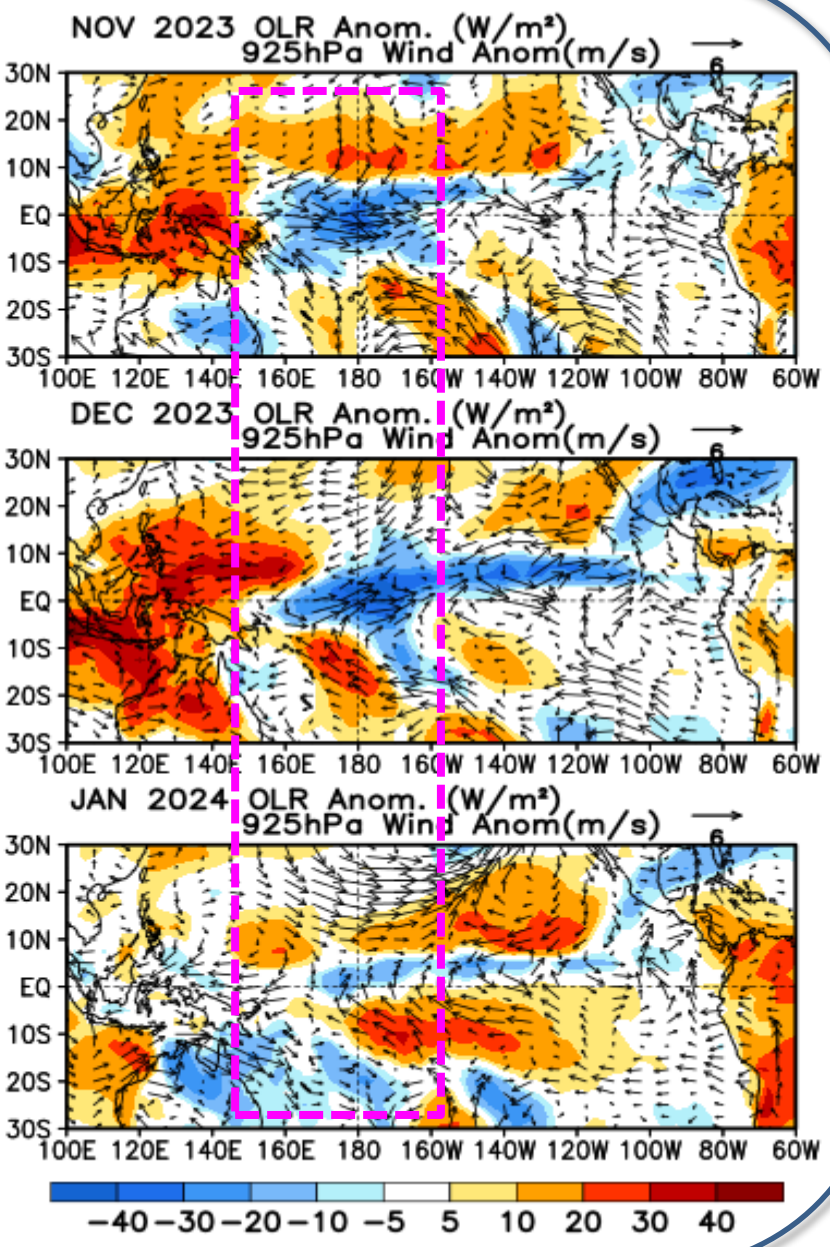
- Negative anomaly tendencies dominated along the thermocline in the Pacific.
- Positive (negative) anomaly tendencies were present in the eastern (western) Indian Ocean.

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

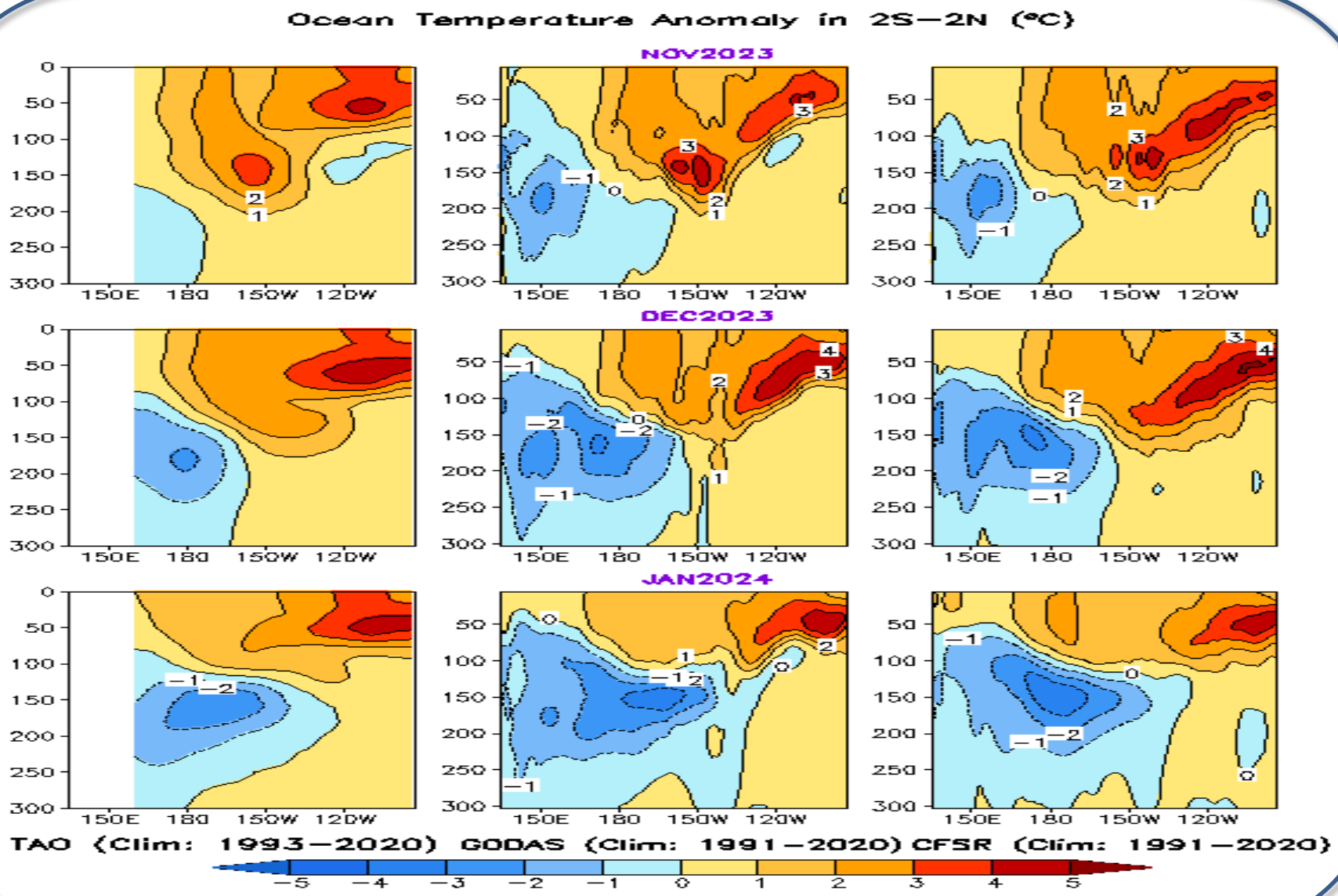
# Last 3-month Tropical Pacific Ocean SST, OLR, and uv925 Anomalies



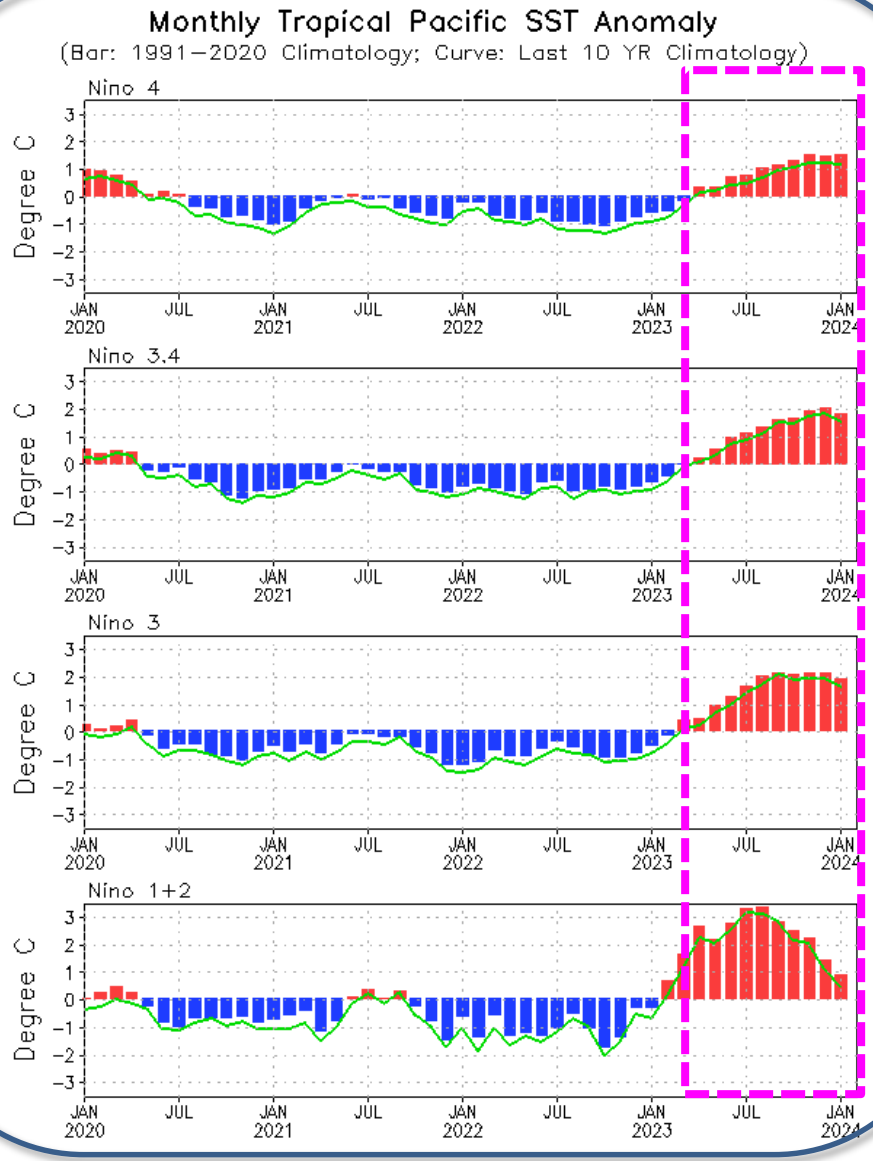



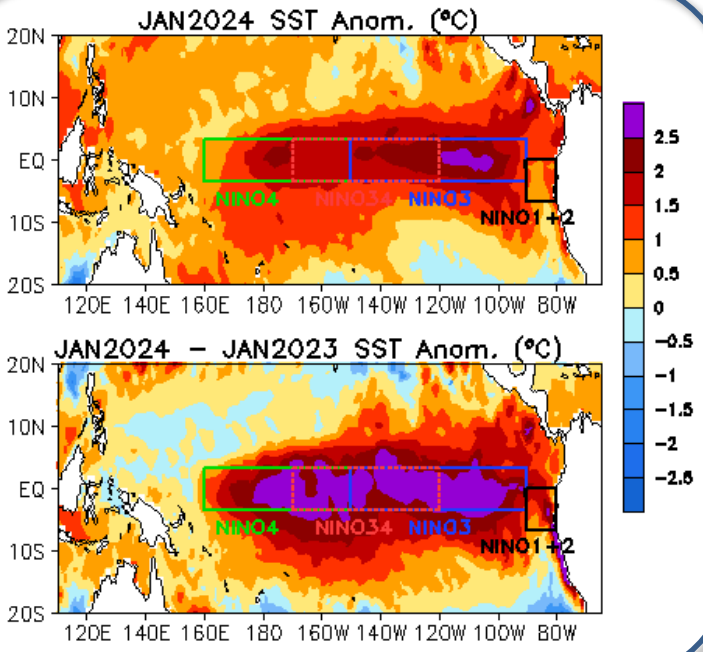
# Monthly mean subsurface temperature anomaly along the Equator:

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



# Evolution of Pacific Niño SST Indices



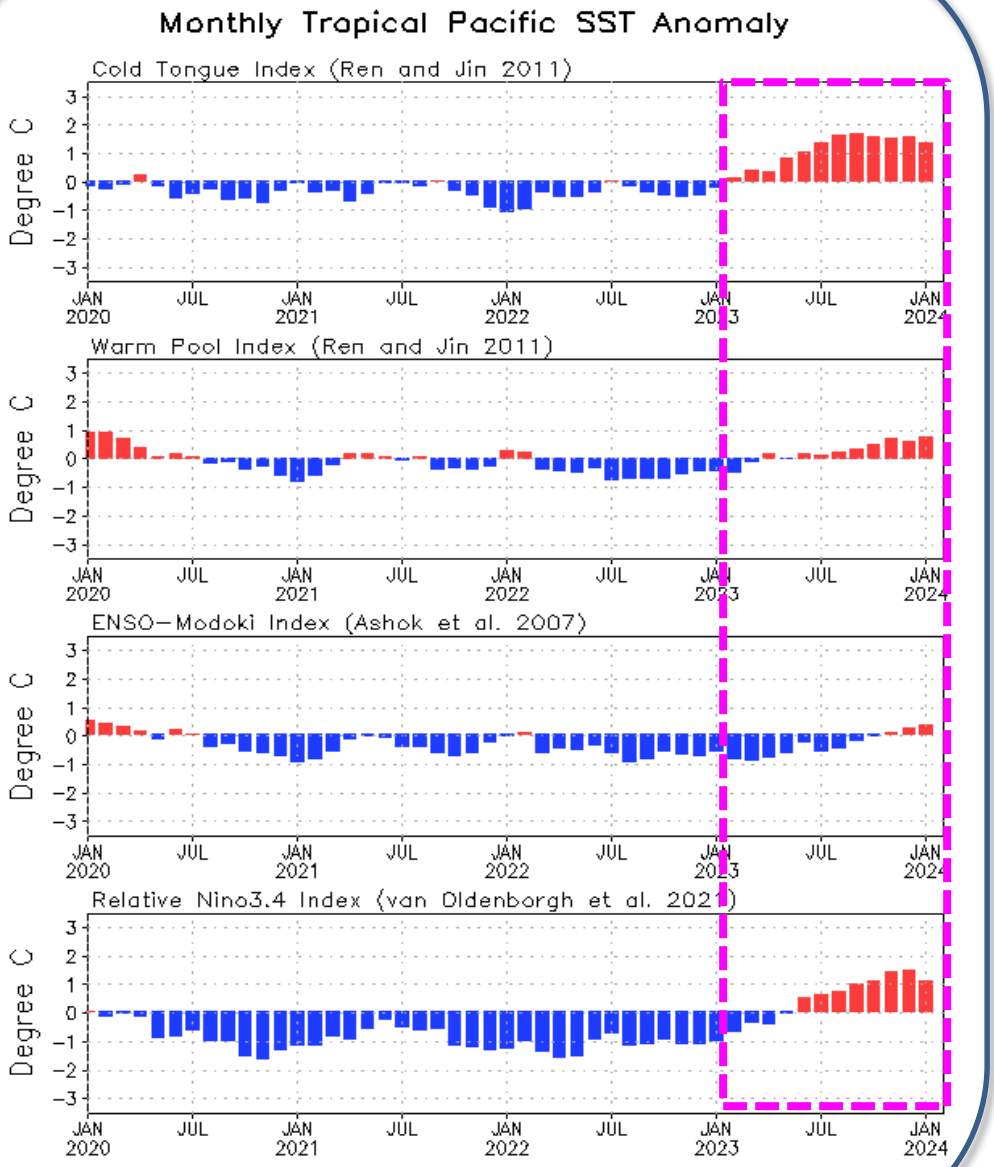

- In Jan 2024, Niño3.4 started to weaken with Niño3.4 = 1.8°C (1.9°C in ERSSTv5 data); Nino1+2 continuously weakened with Nino1+2 = 0.8°C.

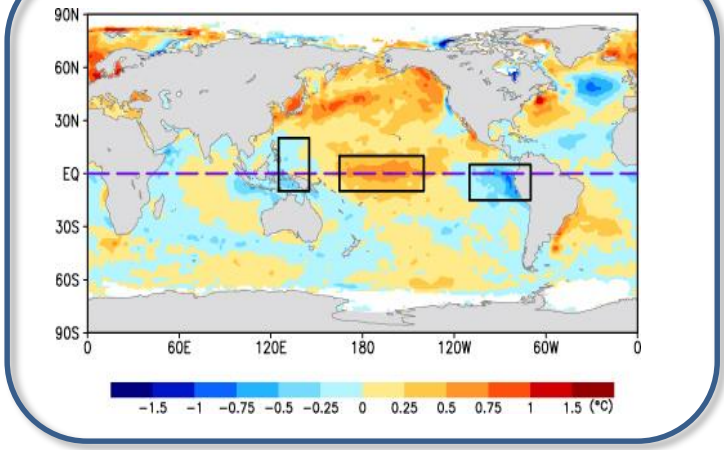
- Compared with Jan 2023, the tropical Pacific was much warmer in Jan 2024.

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

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

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



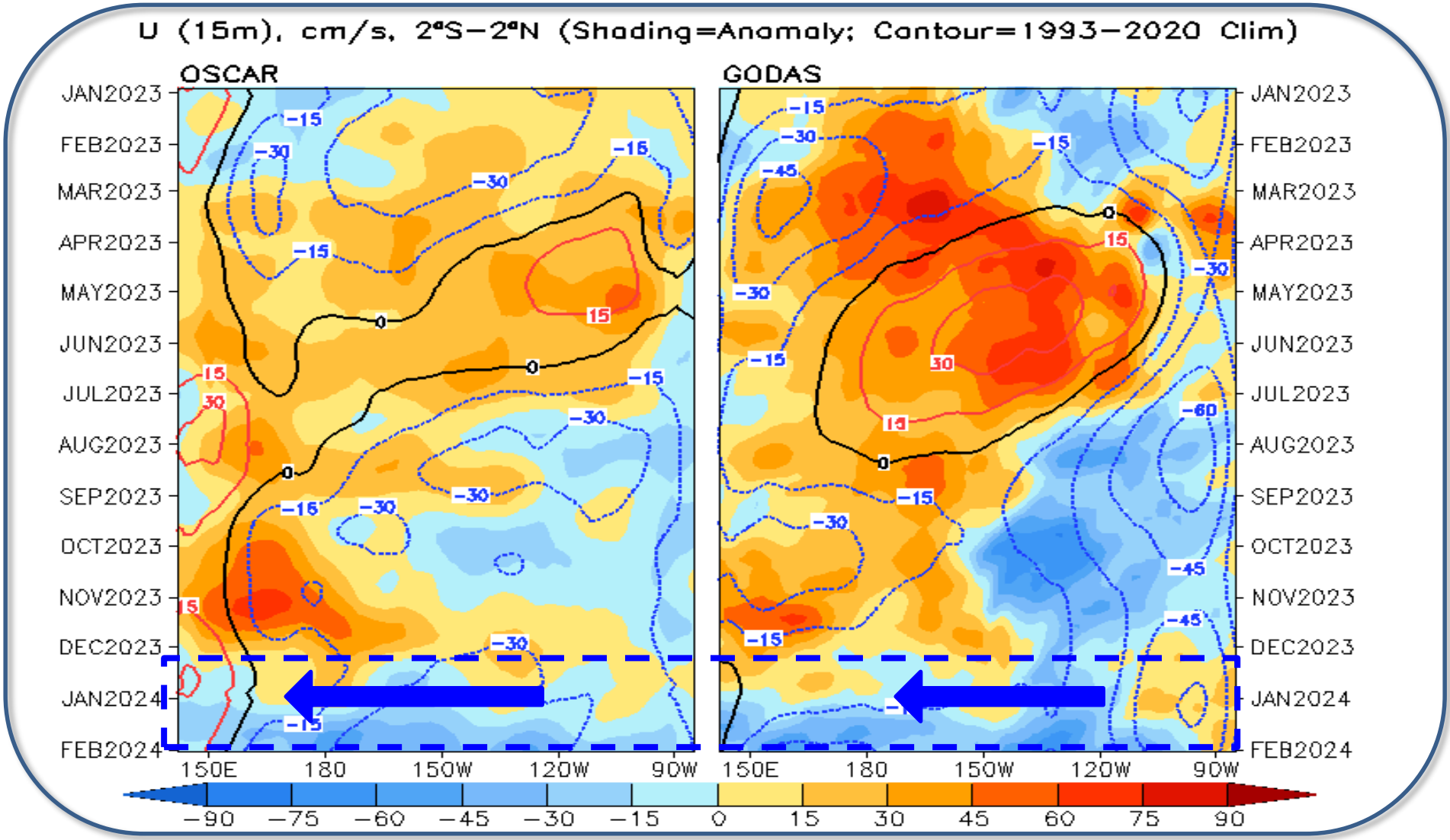




- Relative Niño3.4 index is now included in ENSO monitoring, which is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0°-360°, 20°S-20°N), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative 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:

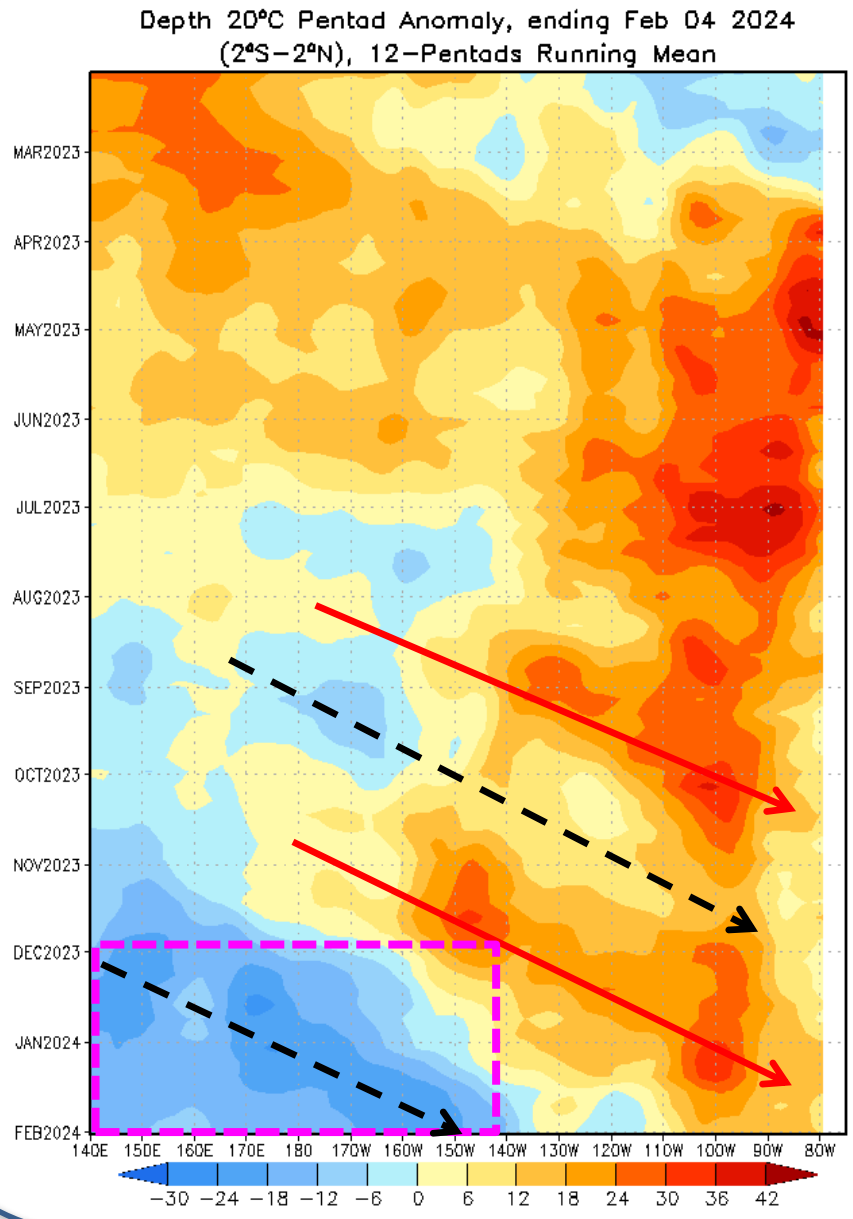
https://www.cpc.ncep.noaa.gov/data/indices/RONI.ascii.txt

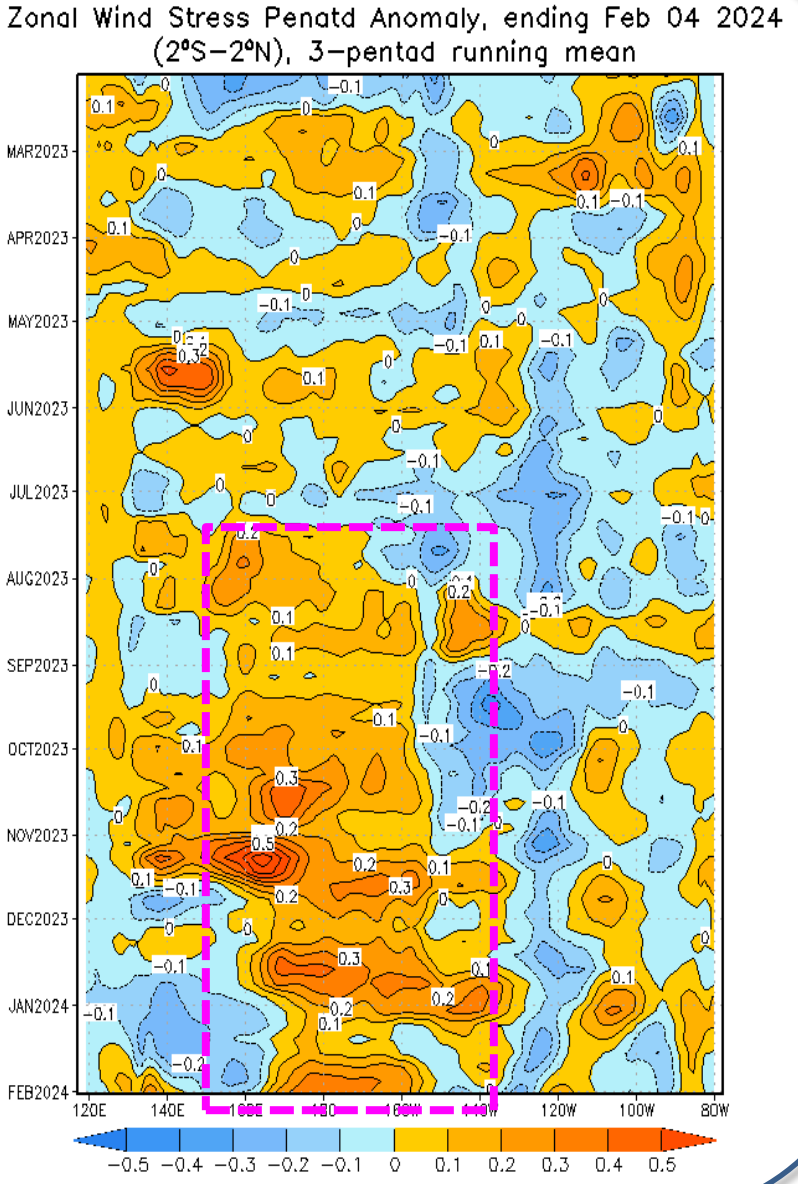
# Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



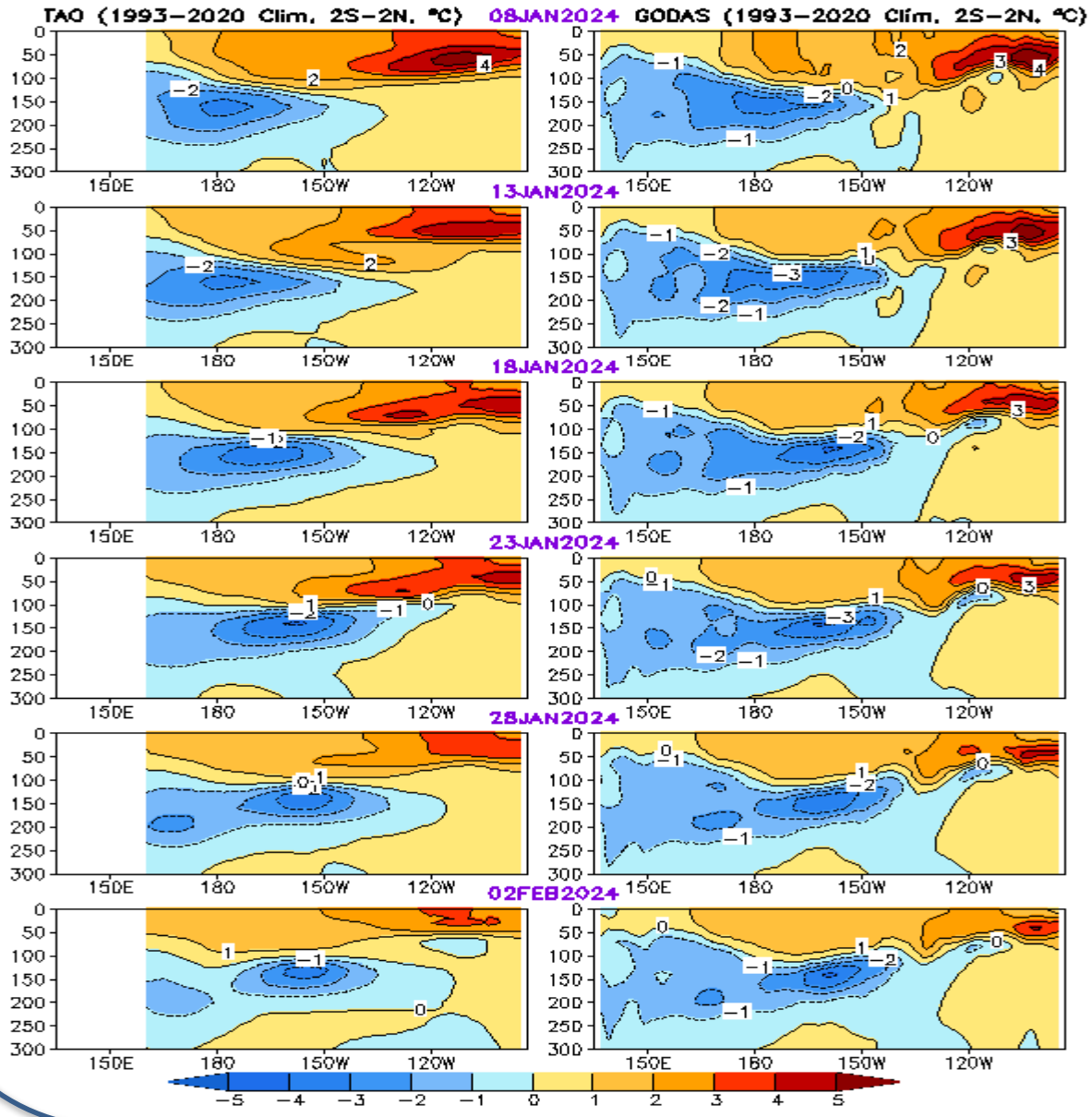

- Anomalous eastward currents were present in the equatorial Pacific in both OSCAR and GODAS during Feb-Jul 2023, which were consistent with the growth of the positive SSTA.
- Anomalous westward currents have been observed since mid-Dec 2023.

# Evolution of Pentad D20 and Taux anomalies along the equator



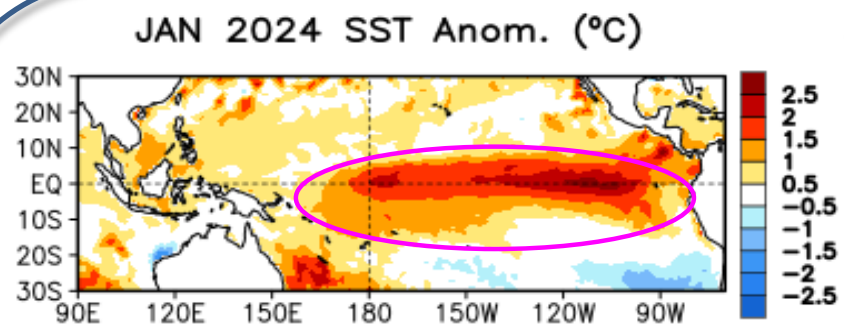



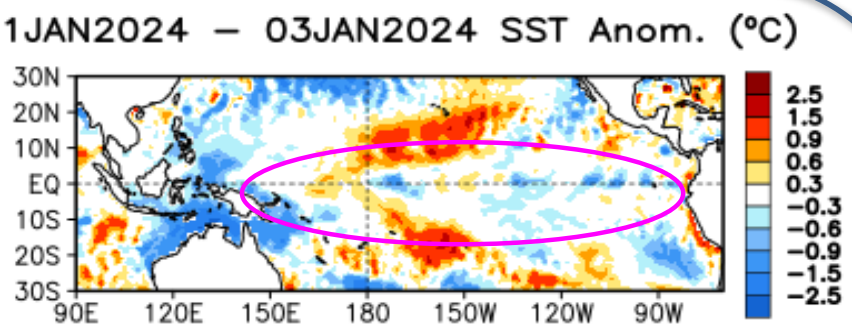
# Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

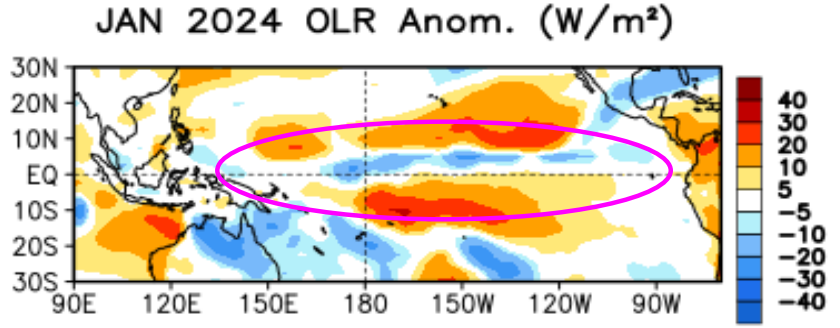


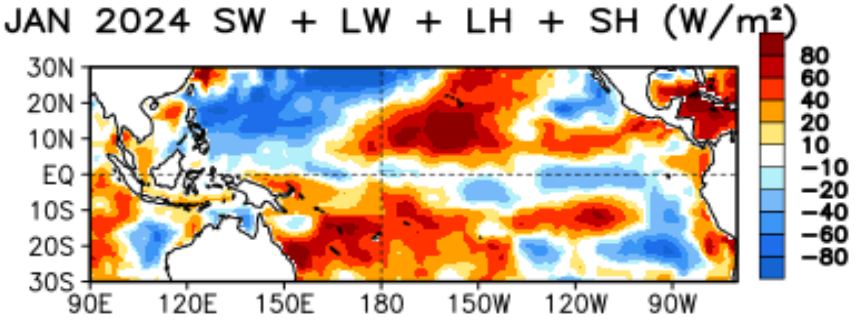

- Positive ocean temperature anomalies along the thermocline weakened in the eastern Pacific and negative anomalies in the western Pacific strengthened during the last month, featured an eastward propagation.
- The features of the ocean temperature anomalies were similar between GODAS and TAO analysis.

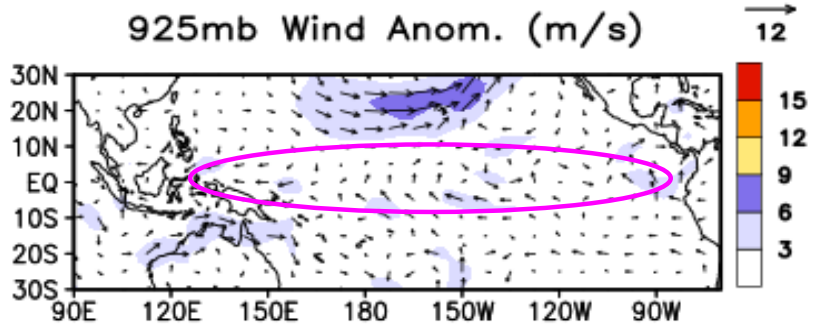
# Tropical Pacific: SSTA, SSTA Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Winds

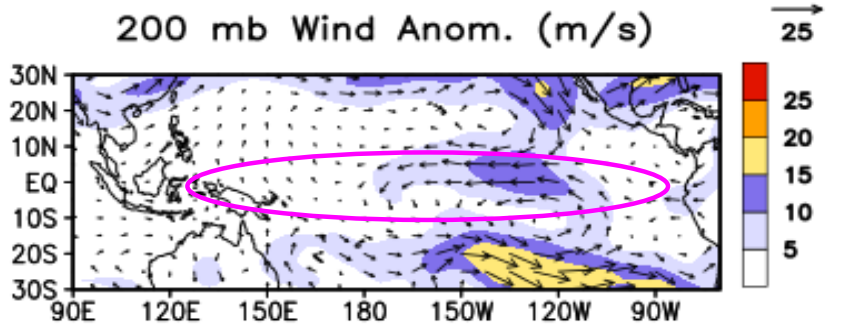


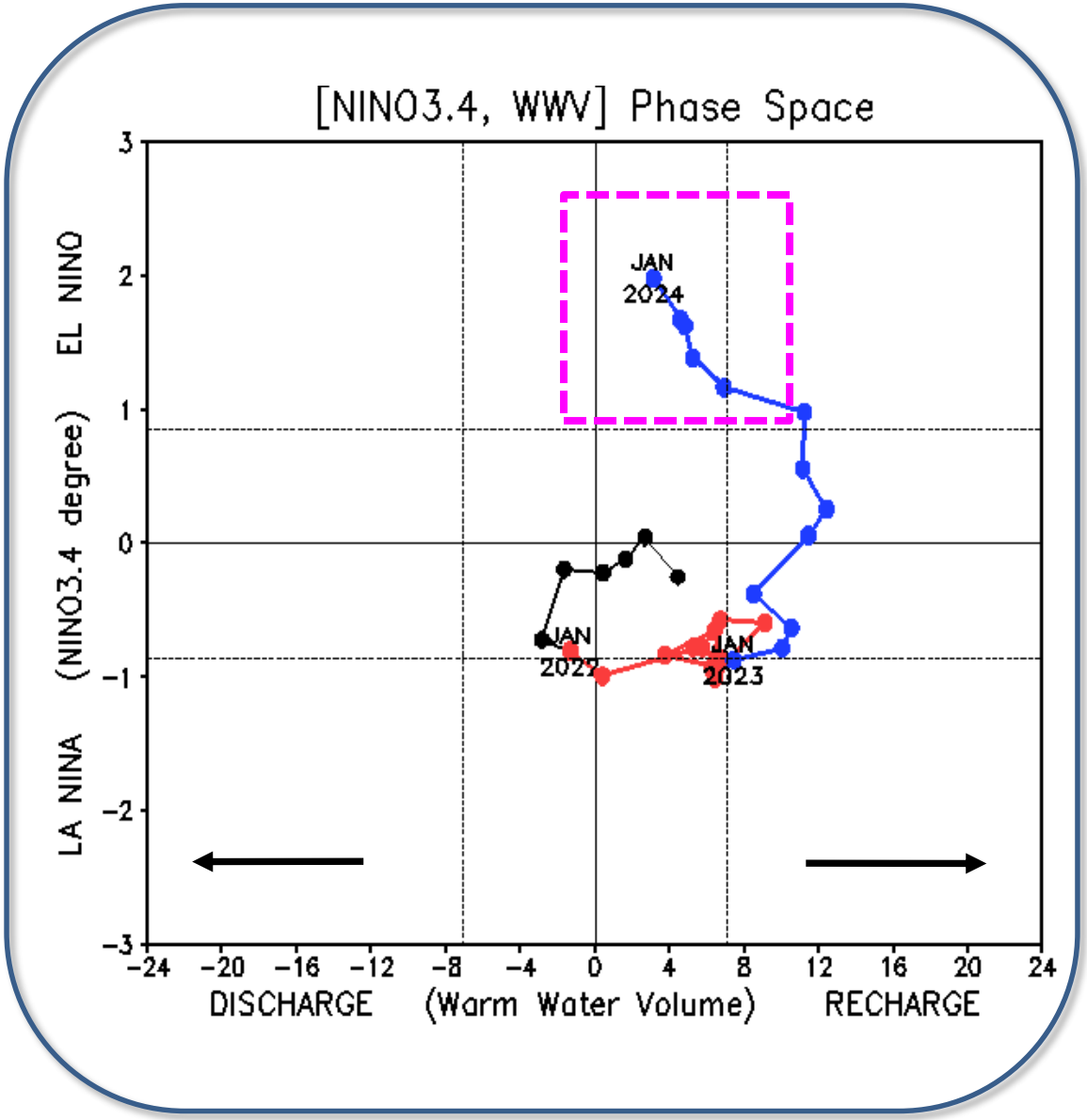




SSTAs (top-left), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly vector and its amplitude (bottom-left),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

# Warm Water Volume (WWV) and Niño3.4 Anomalies

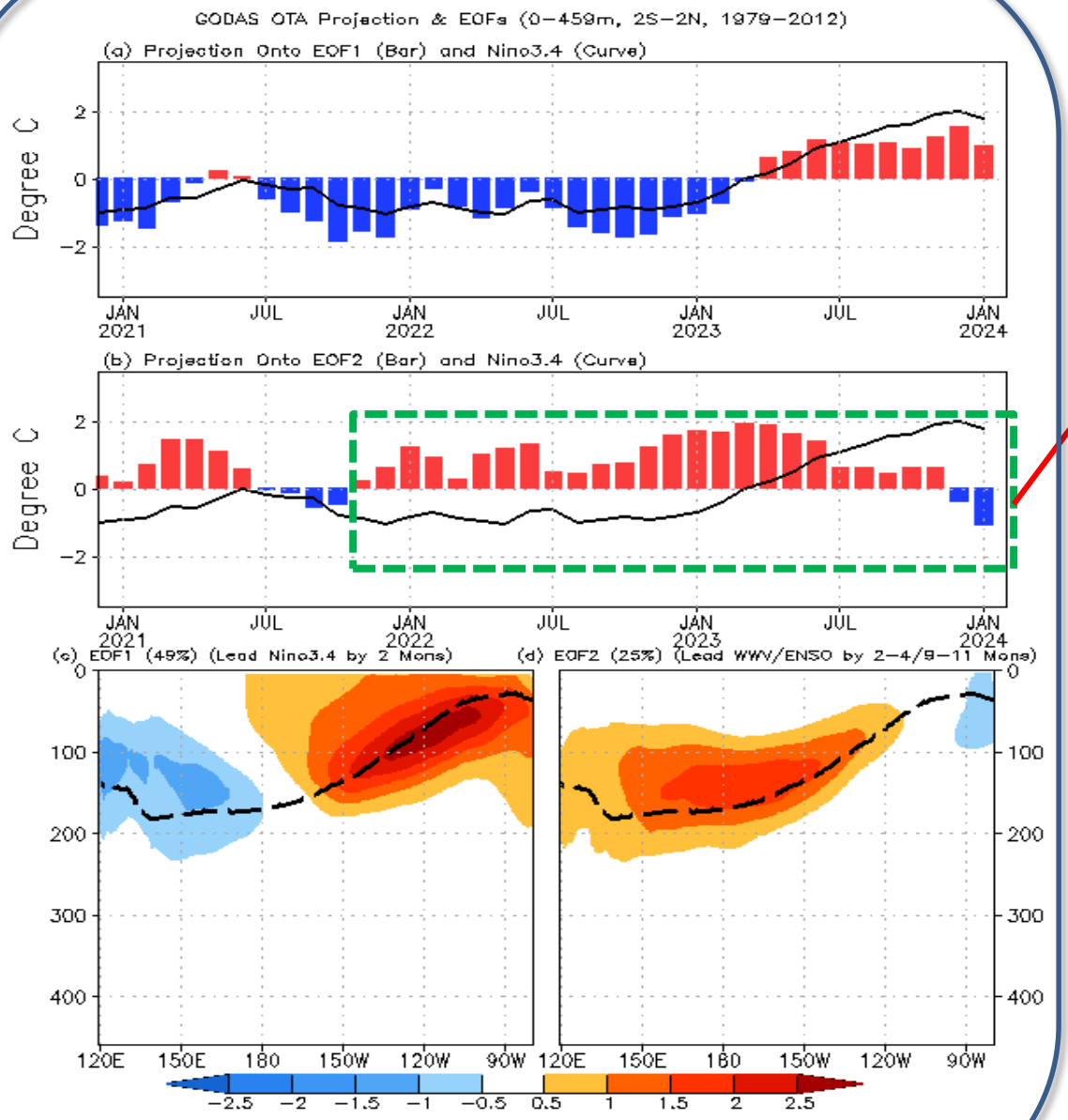
- Pacific equatorial Warm Water Volume (WWV) was still in a recharge phase, but further weakened in Jan 2024.

-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 an extended-period of recharging since Nov 2021, the equatorial Pacific has switched to a discharge phase since Dec 2023.

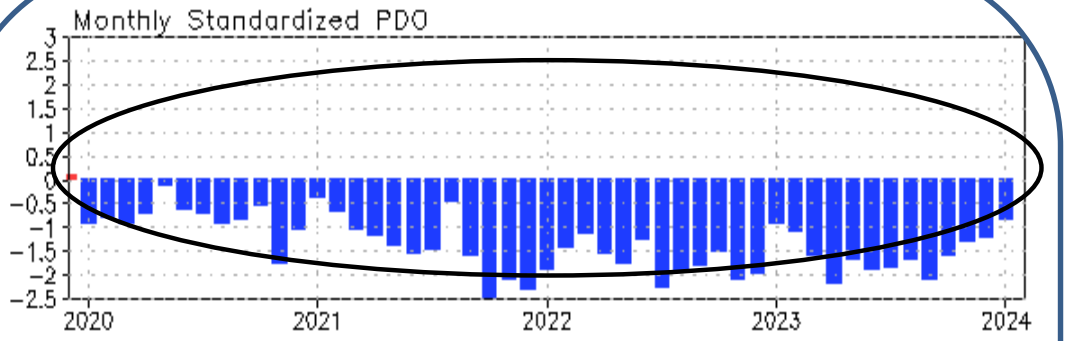
- Projection of ocean temperature anomalies onto EOF1 and EOF2; EOF1: Tilt/dipole mode (ENSO peak phase); EOF2: WWV mode.

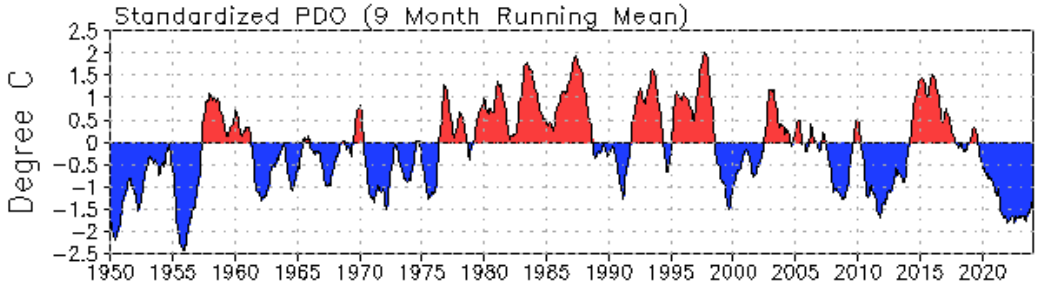
- Recharge/discharge oscillation (ENSO transition phase); Recharge process: heat transport from outside of equator to equator; Negative -> positive phase of ENSO

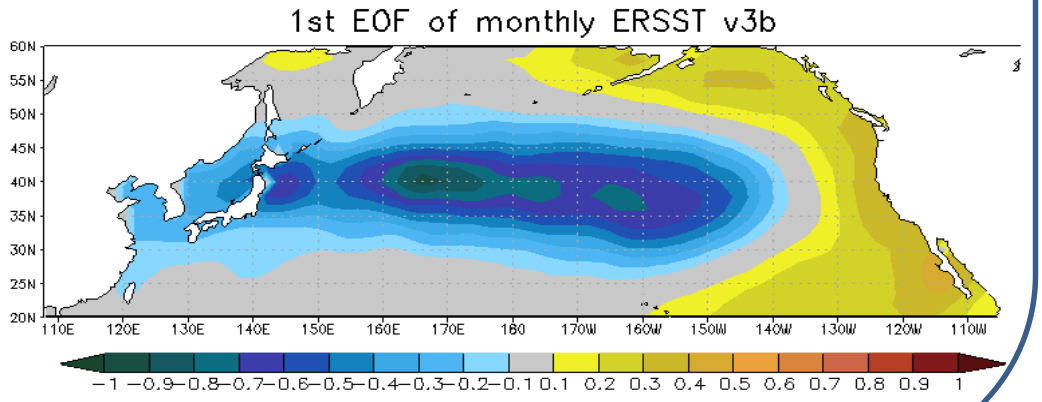
- For details, see: Kumar and Hu (2014) DOI: 10.1007/s00382-013-1721-0.

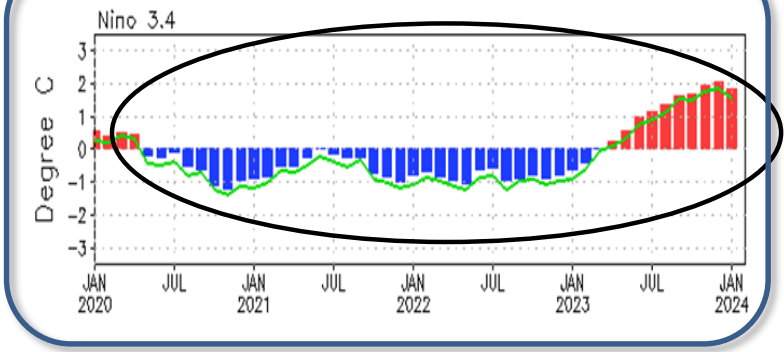
# North Pacific, Arctic, & Antarctic Oceans

# Pacific Decadal Oscillation (PDO) Index



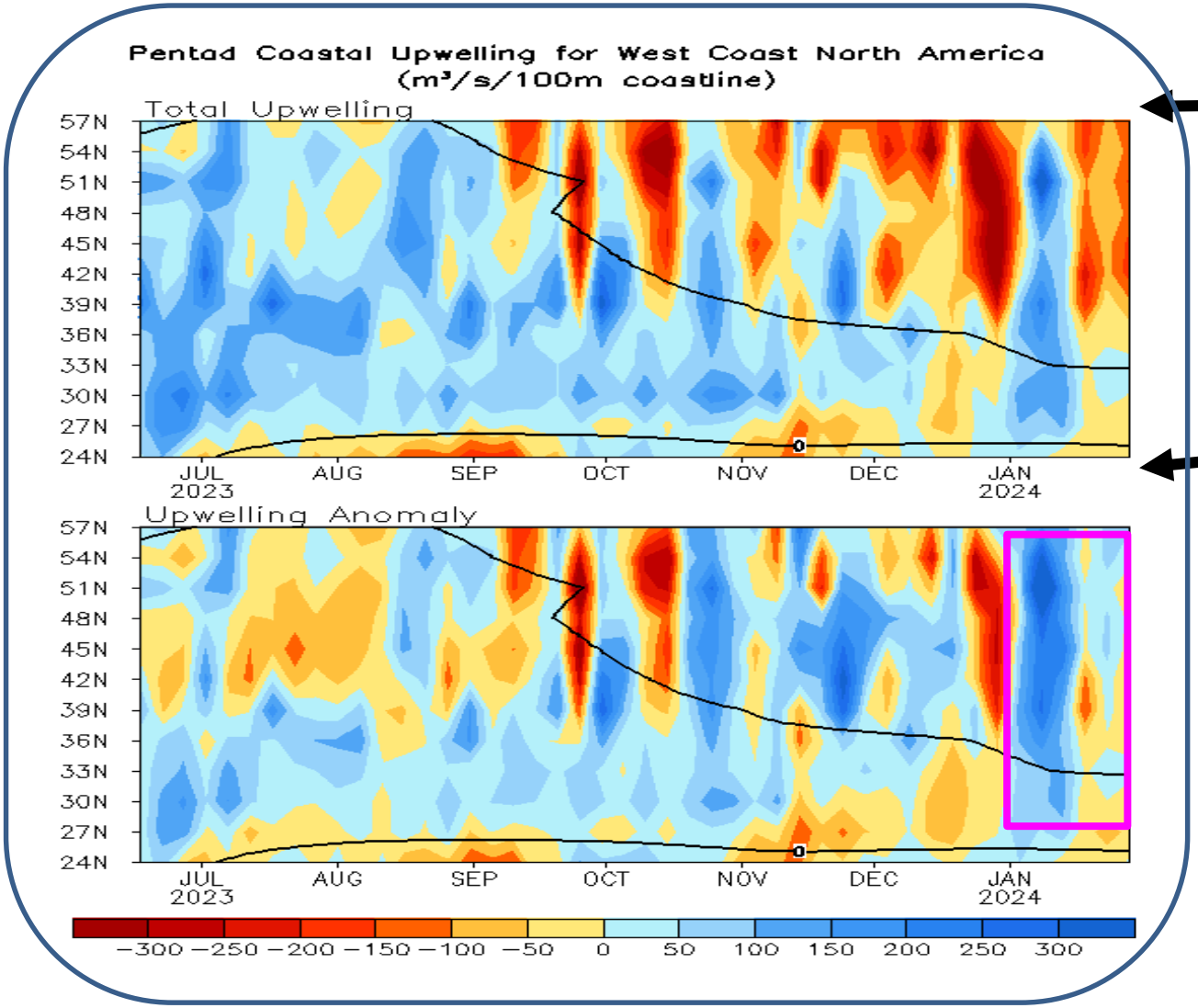



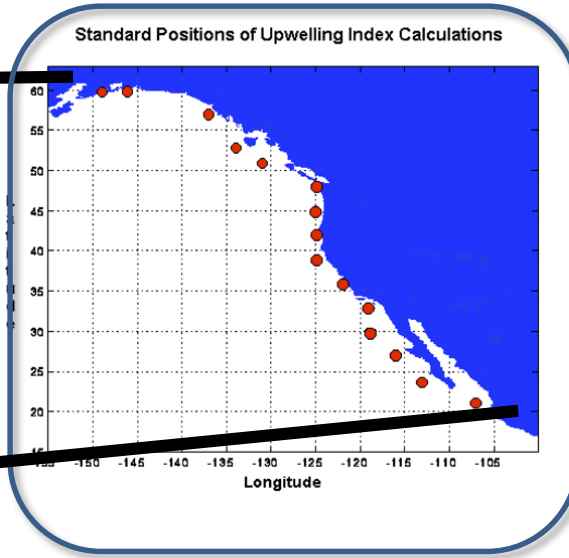




- The PDO has been in a negative phase since Jan 2020 with PDOI = -0.9 in Jan 2024.
- The negative phase of PDO since the 2nd half of 2023 is opposite to what is expected during El Niño.
- Statistically, ENSO leads PDO by 3-4 months, through teleconnection via atmospheric bridge, with El Niño (La Niña) 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

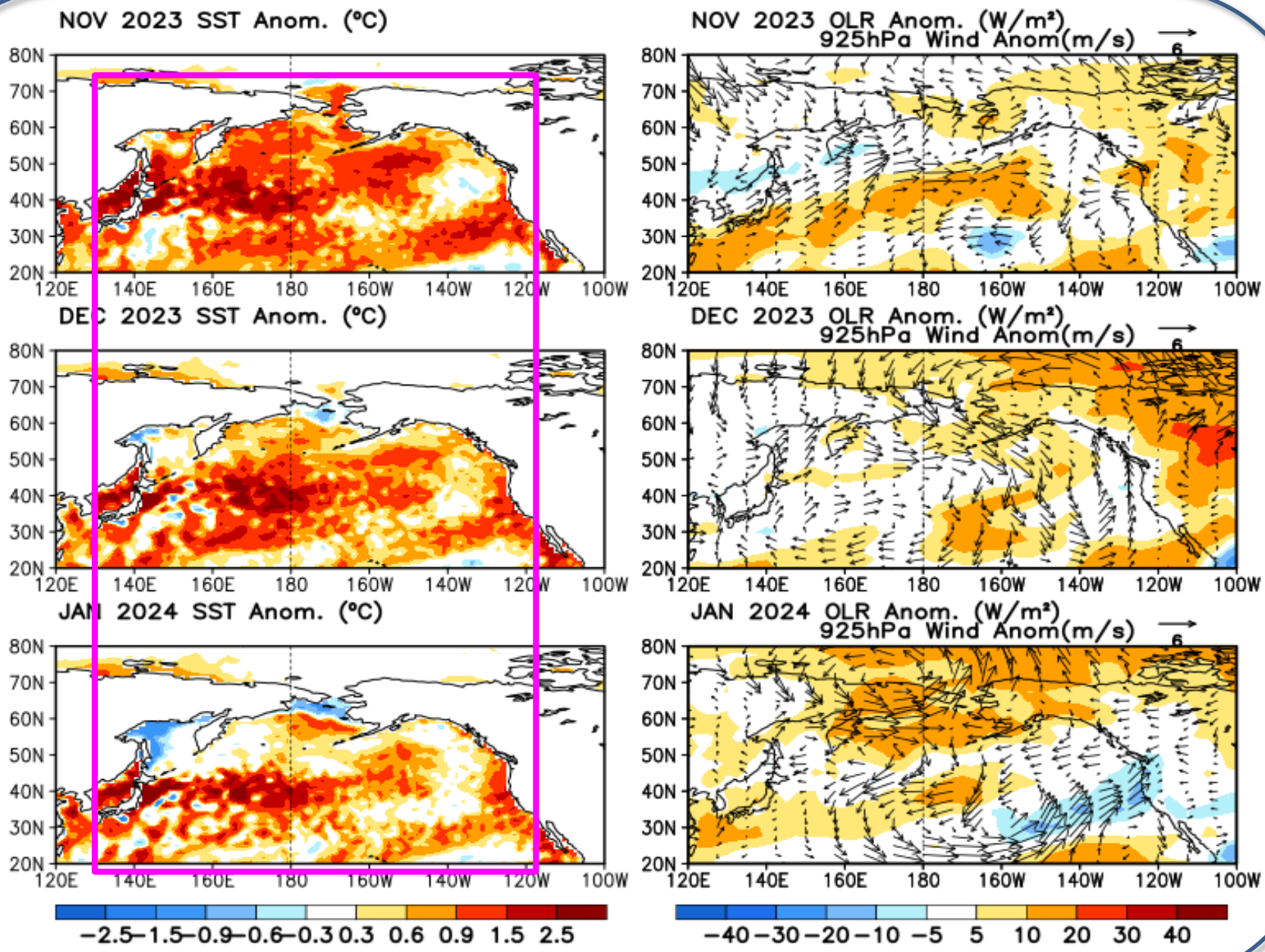


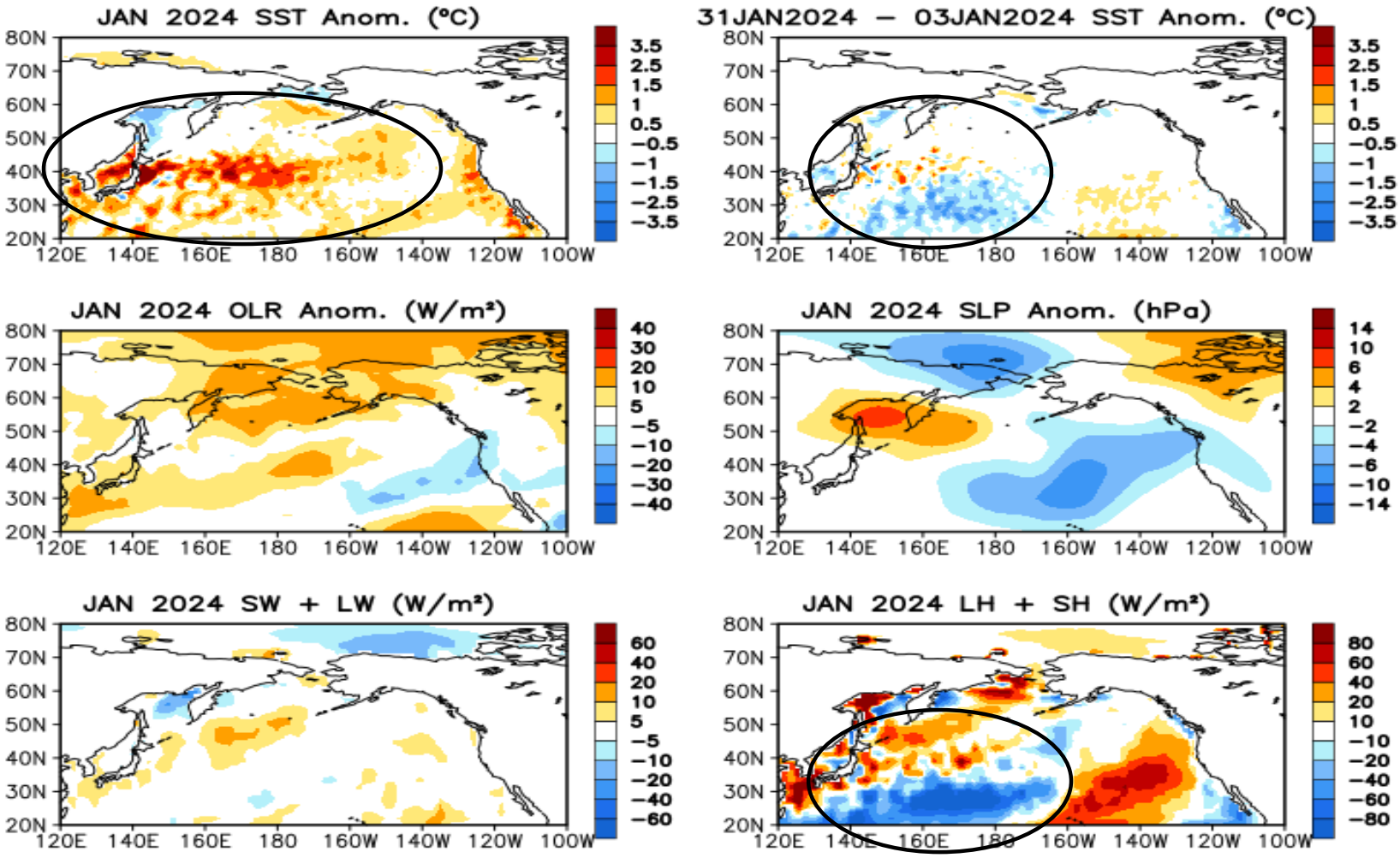

- Anomalous upwelling was present in the 1st half of Jan 2024.

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

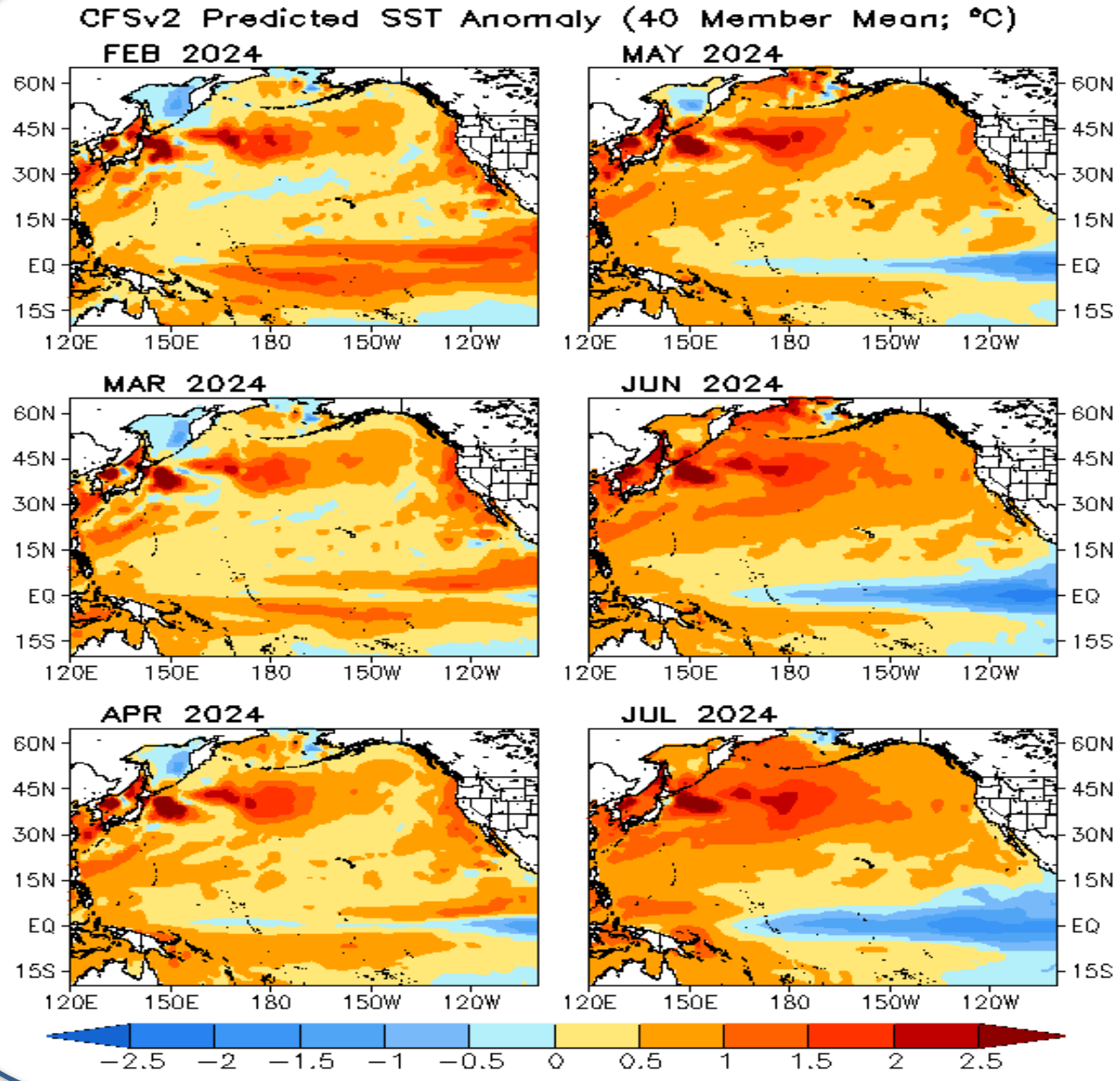


# North Pacific Ocean: SSTA, SSTA Tend., OLR, SLP, Sfc Rad, Sfc Flx Anomalies



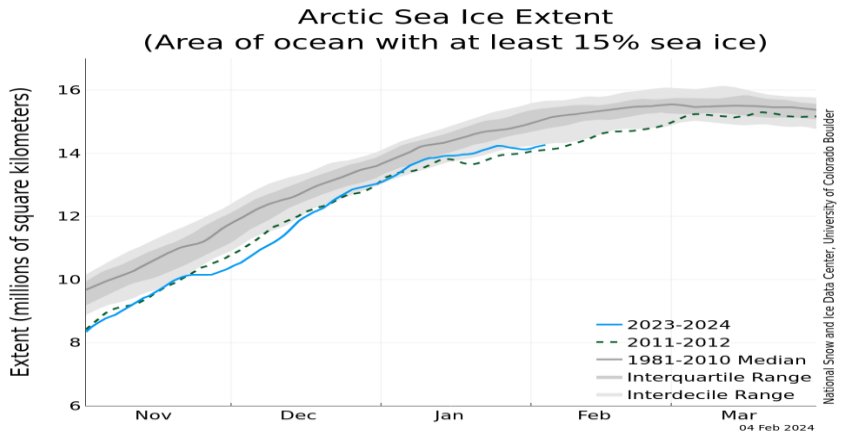

SSTA (top-left; OIv2.1 SST Analysis), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) (middle-left; NOAA 18 AVHRR IR ), sea surface pressure (middle-right; NCEP CDAS), sum of net surface short- and long-wave radiation (bottom-left; positive means heat into the ocean; NCEP CDAS), sum of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

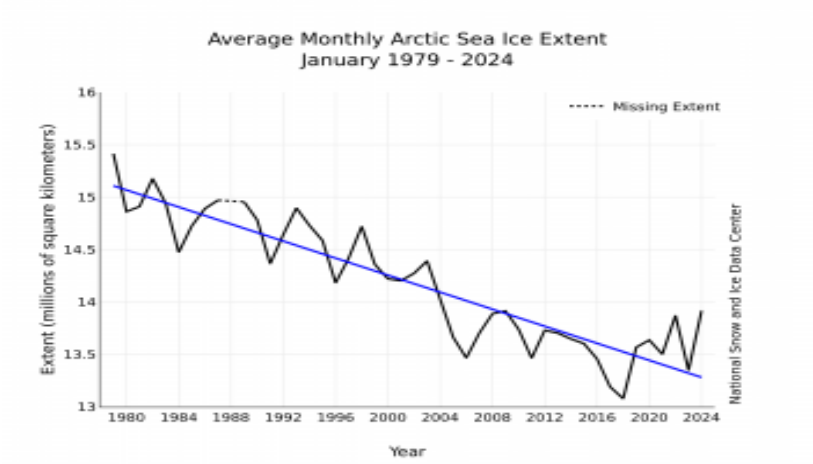
# CFSv2 NE Pacific SSTA Predictions

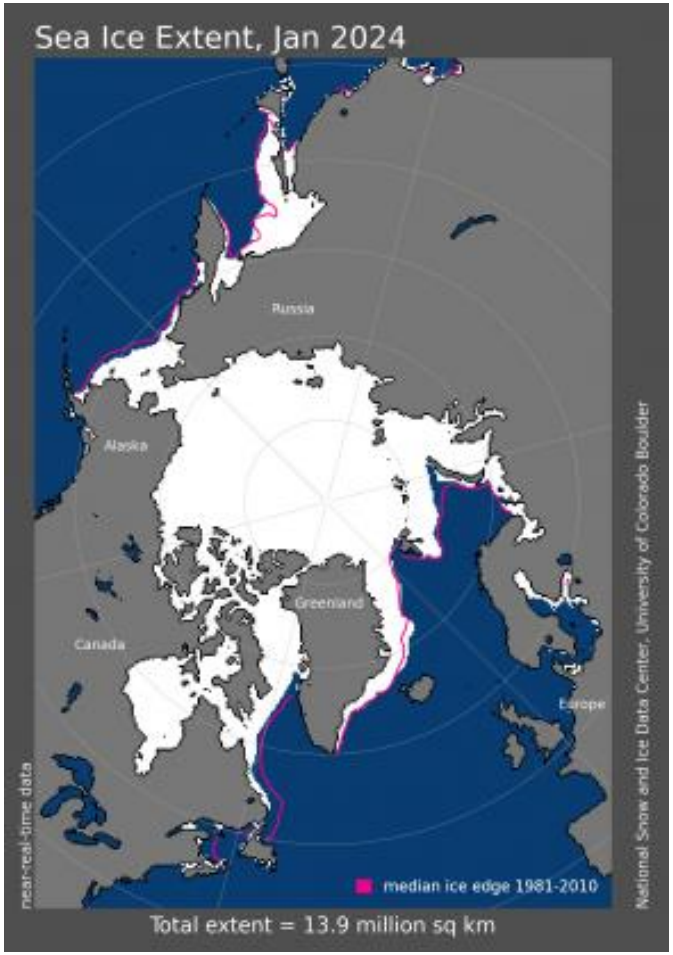



- CFSv2 predicts the current SST warm state in the North Pacific will strengthen during the summer 2024.

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

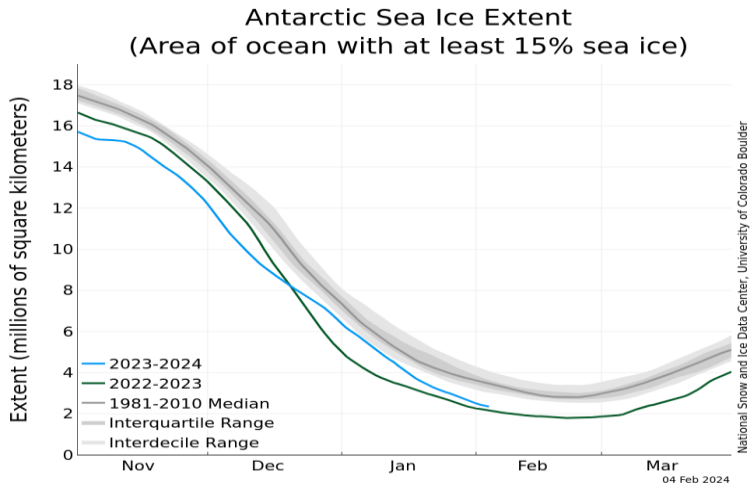


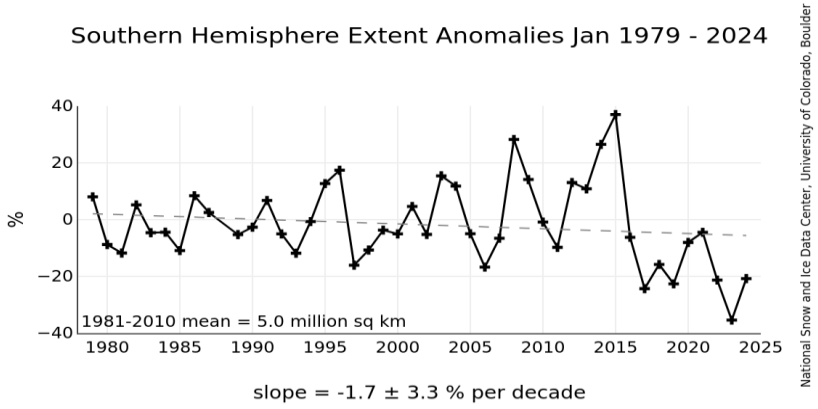



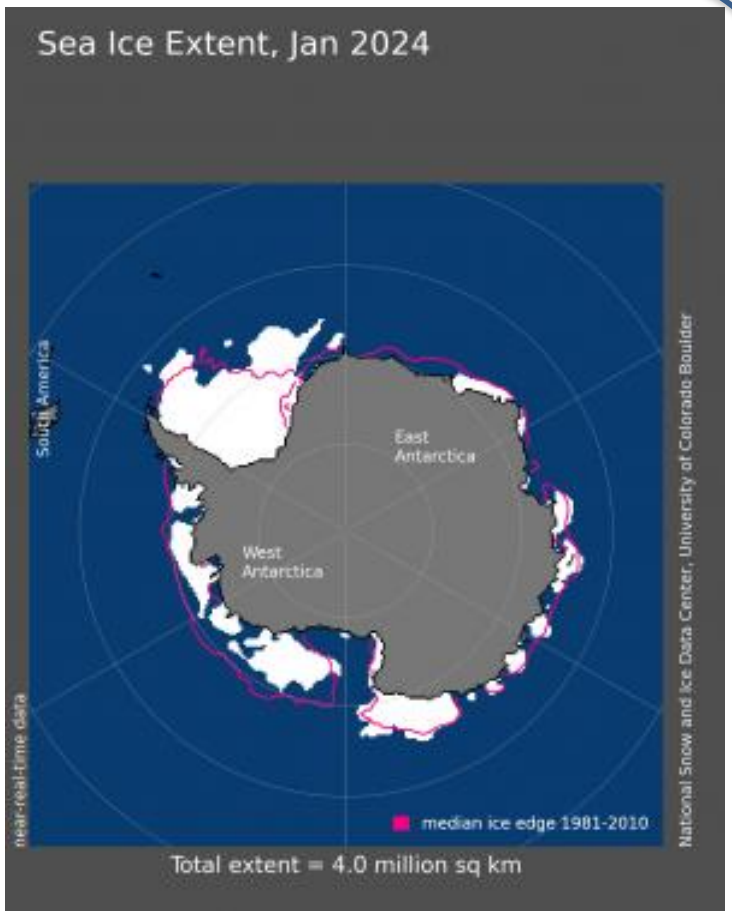




- Arctic sea ice extent was 13.92 million square kilometers in Jan 2024, 20th lowest in the 45-year satellite record in Jan.
- The downward linear trend in Arctic sea ice extent for Jan over the 45-year satellite record is 2.8% per decade relative to the 1981 to 2010 average.

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

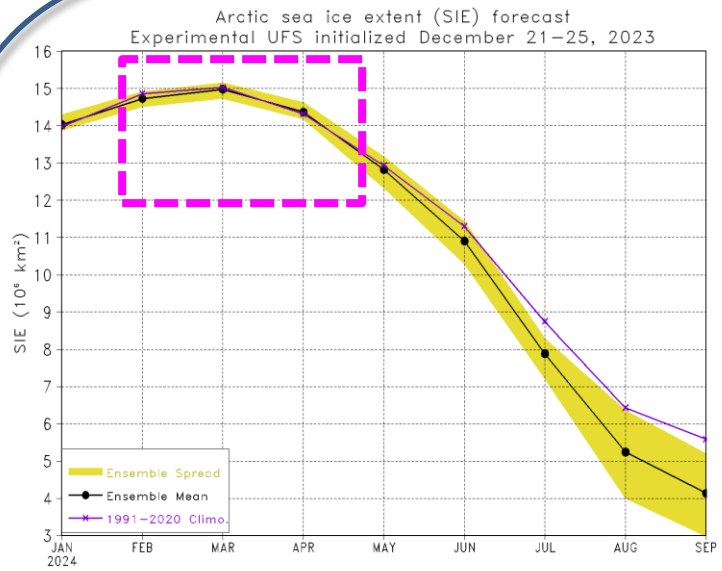


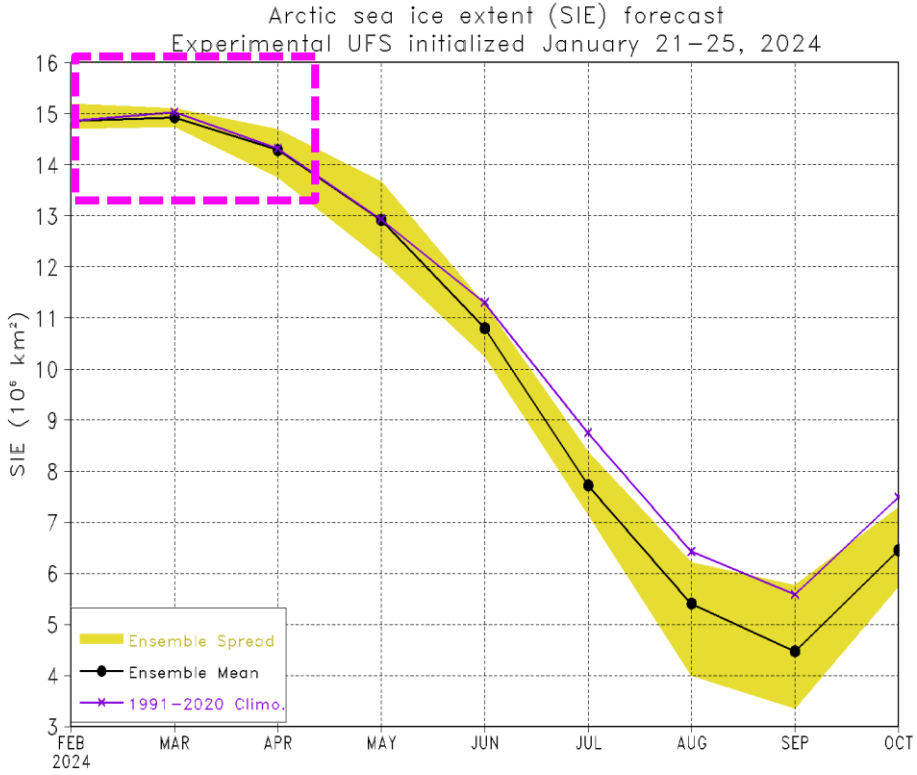




- Antarctic sea ice extent was 3.96 million square kilometers in Jan 2024, tying for fourth lowest extent with 2022.

# NCEP/CPC Arctic Sea Ice Extent (SIE) Forecast



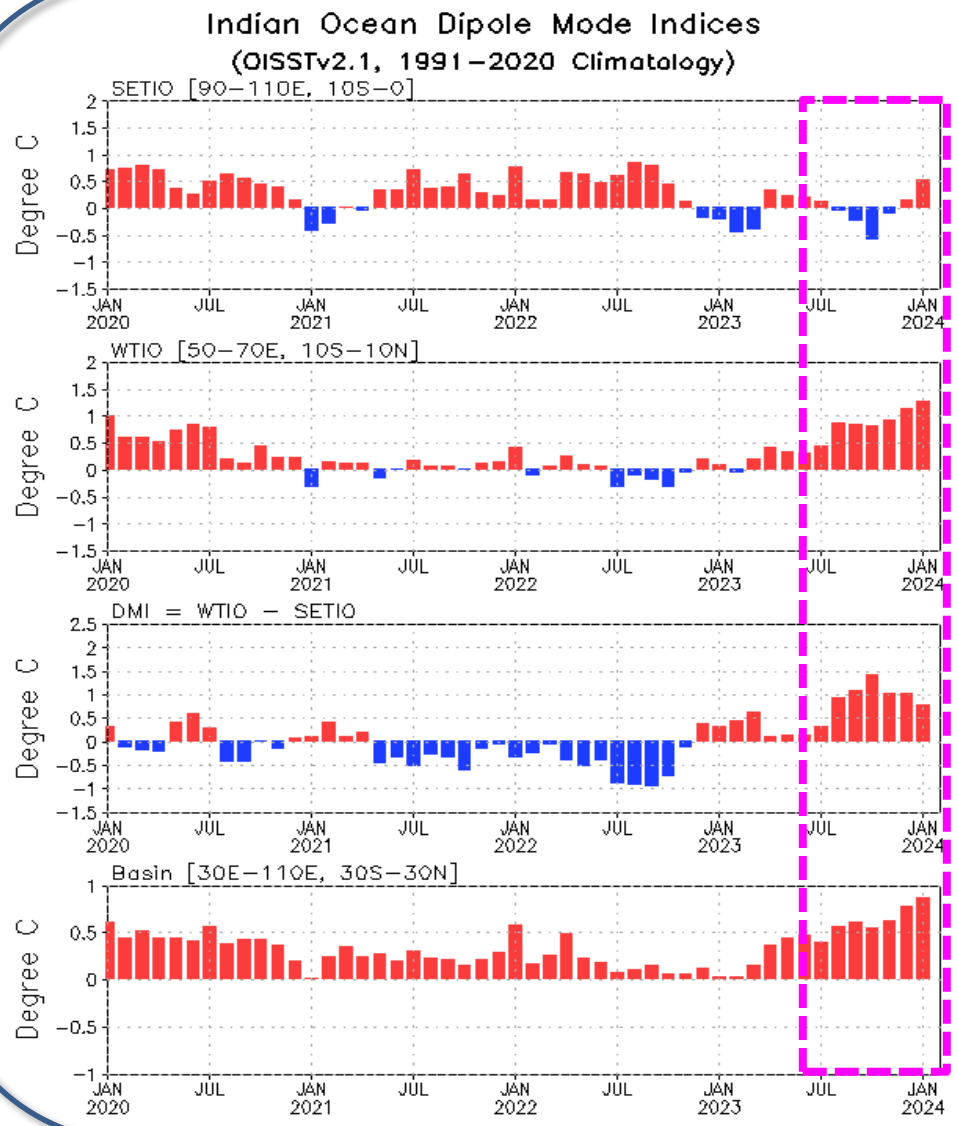

- UFS forecasts suggest a near normal sea ice extent maximum in Mar 2024, close to 1991-2020 climatology.

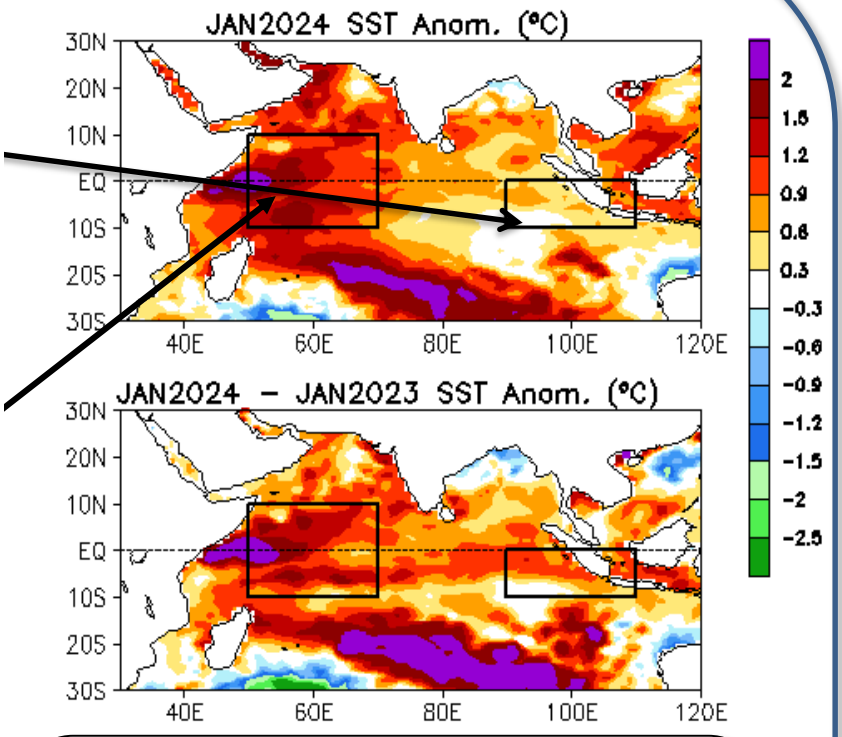



https://www.cpc.ncep.noaa.gov/products/people/jszhu/seaice_seasonal/index.html

Indian Ocean

# Evolution of Indian Ocean SST Indices

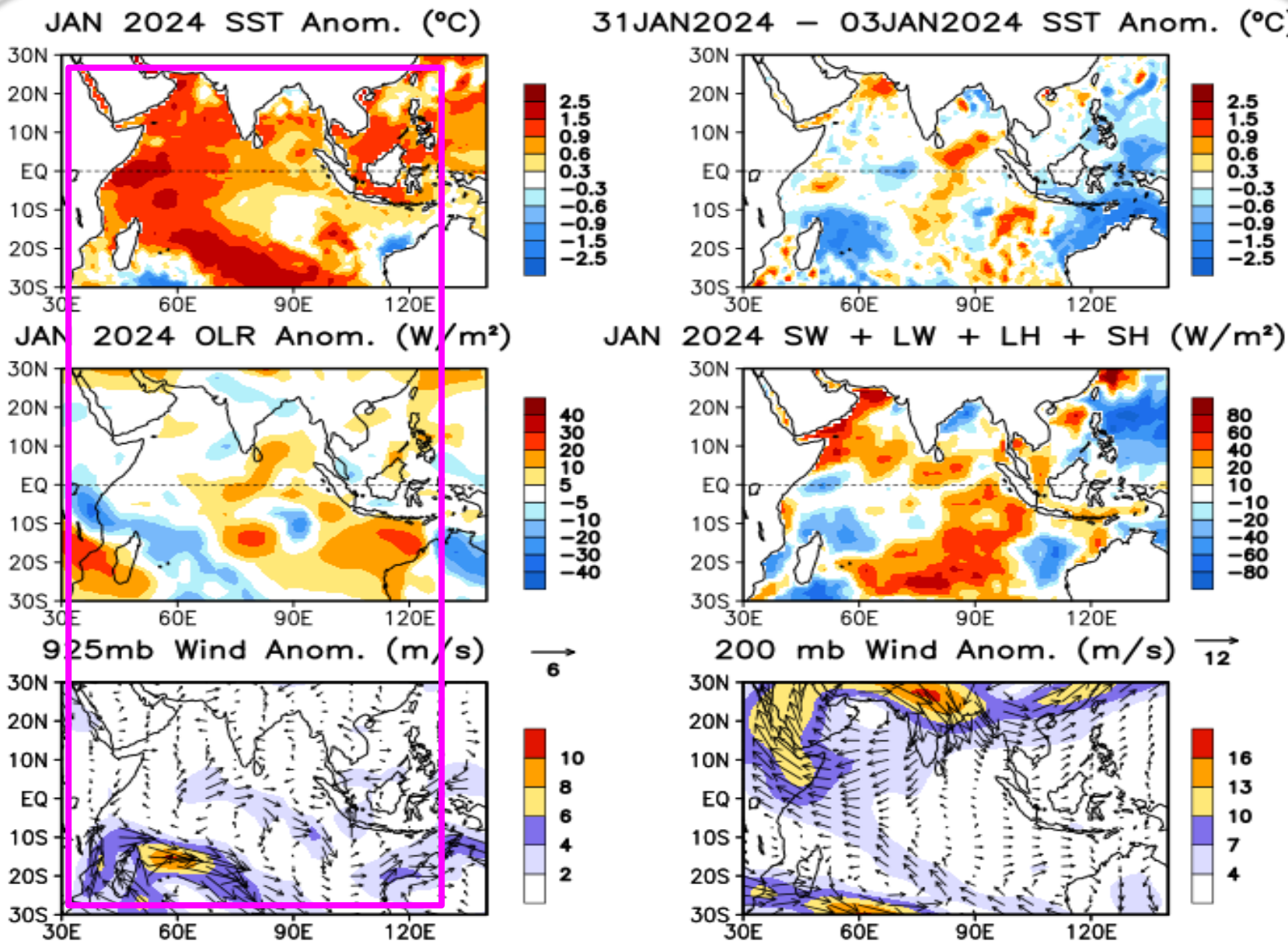



- Positive SSTAs were present in the tropical Indian Ocean with warming stronger in the west than in the east in Jan 2024, resulting in a positive phase of the IOD.

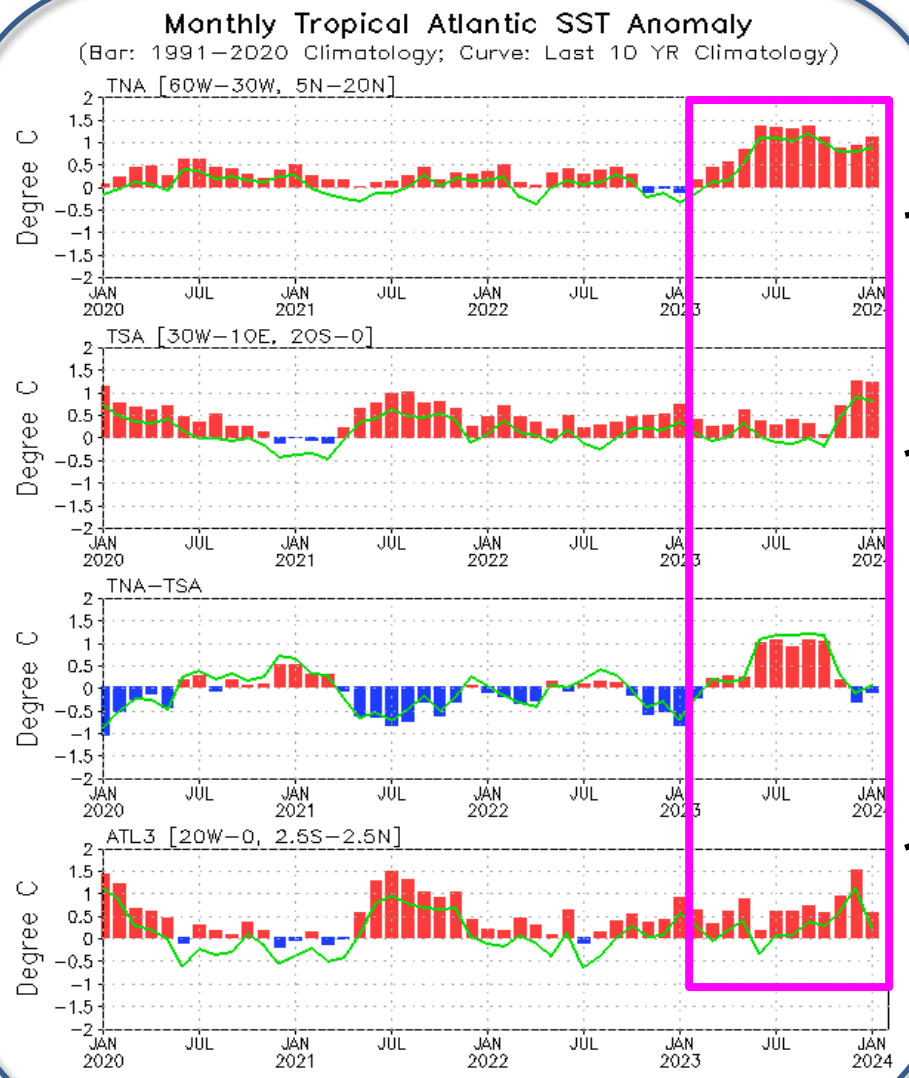
Indian Ocean region indices, calculated as the area-averaged monthly mean SSTA (OC) for the SETIO [90ºE-110ºE, 10ºS-0] and WTIO [50ºE-70ºE, 10ºS-10ºN] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the OIv2.1 SST analysis, and anomalies are departures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

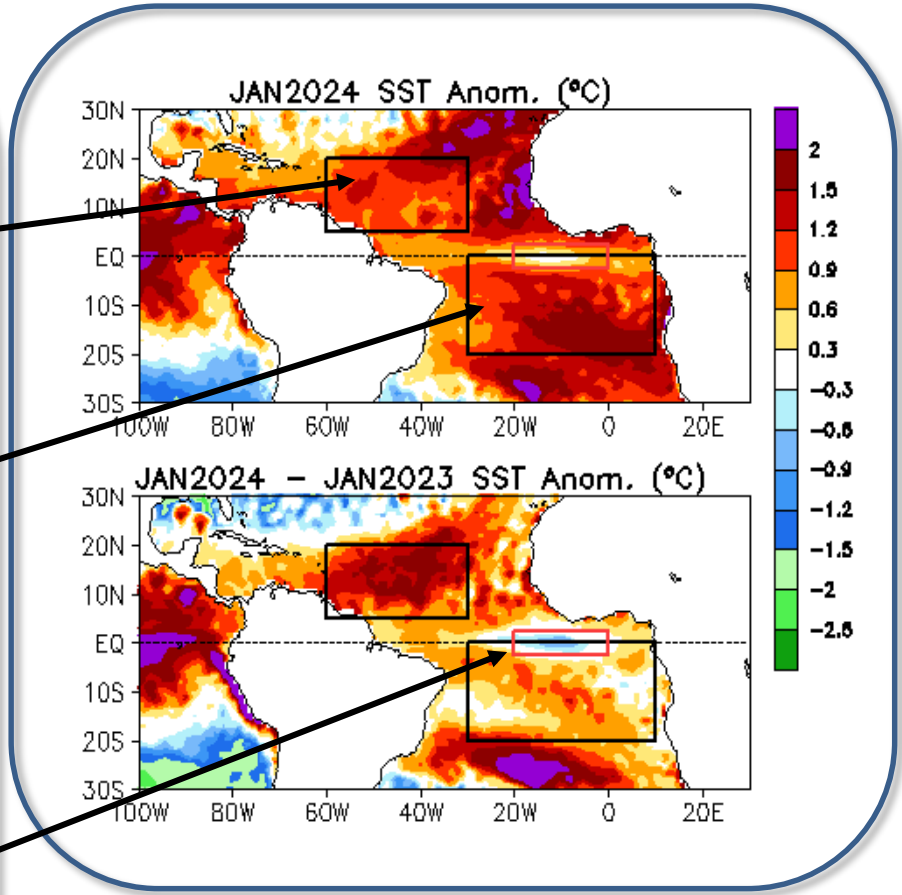
# Tropical Indian: SSTA, SSTA Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Wind Anom.



# Tropical and North Atlantic Ocean

# Evolution of Tropical Atlantic SST Indices

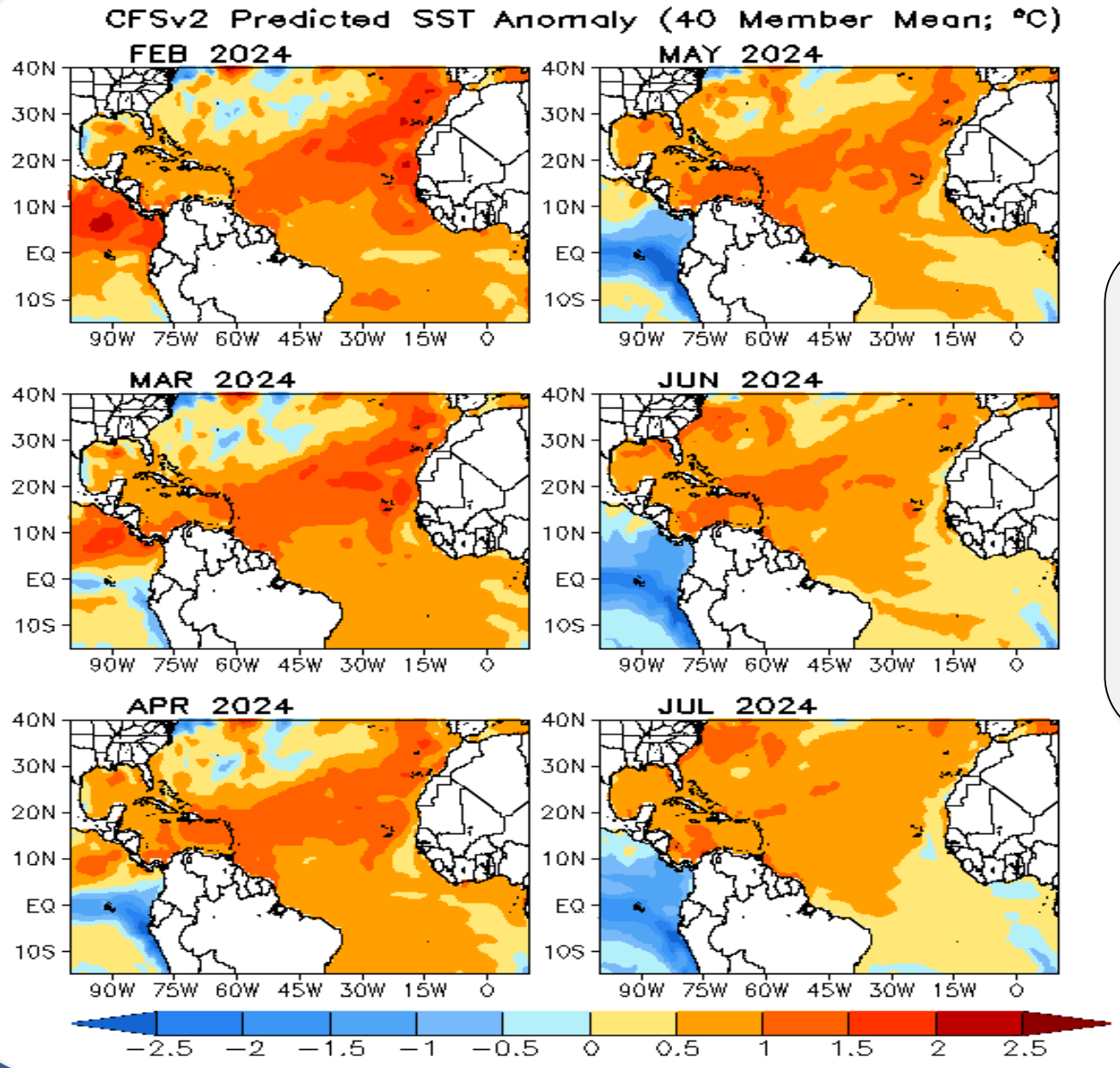



- Positive SSTAs in the tropical Atlantic were observed in Jan 2024.
- Positive ATL3 index weakened in Jan 2024.

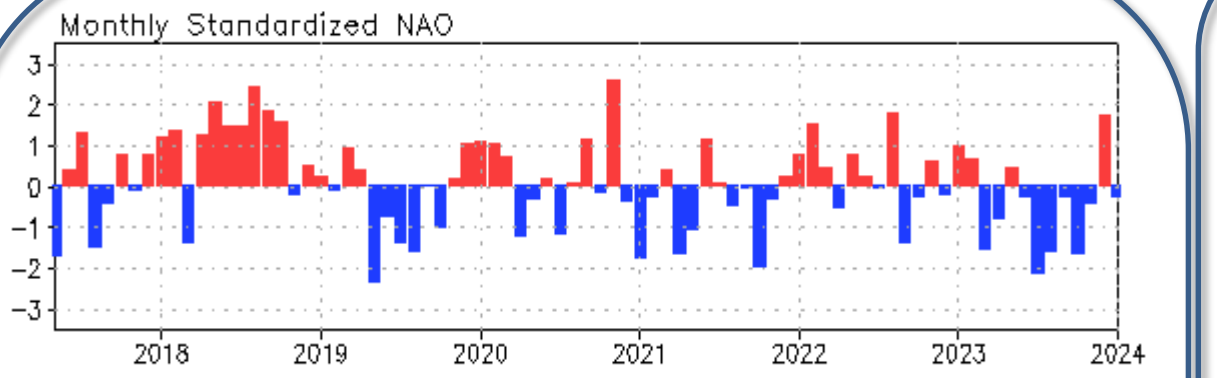
Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean SSTAs ($^{O}$C) for the TNA [60$^{O}$W-30$^{O}$W, 5ºN-20$^{O}$N], TSA [30$^{O}$W-10$^{O}$E, 20$^{O}$S-0] and ATL3 [20$^{O}$W-0, 2.5$^{O}$S-2.5$^{O}$N] regions, and Meridional Gradient Index, defined as differences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

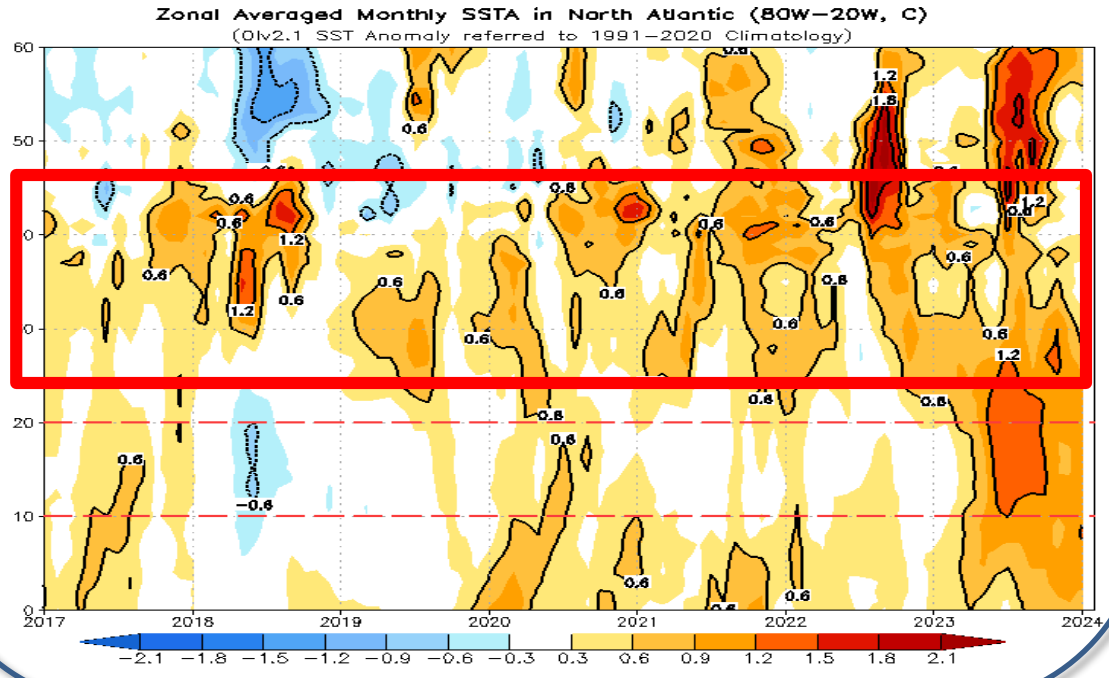
# CFSv2 Atlantic SSTA Predictions

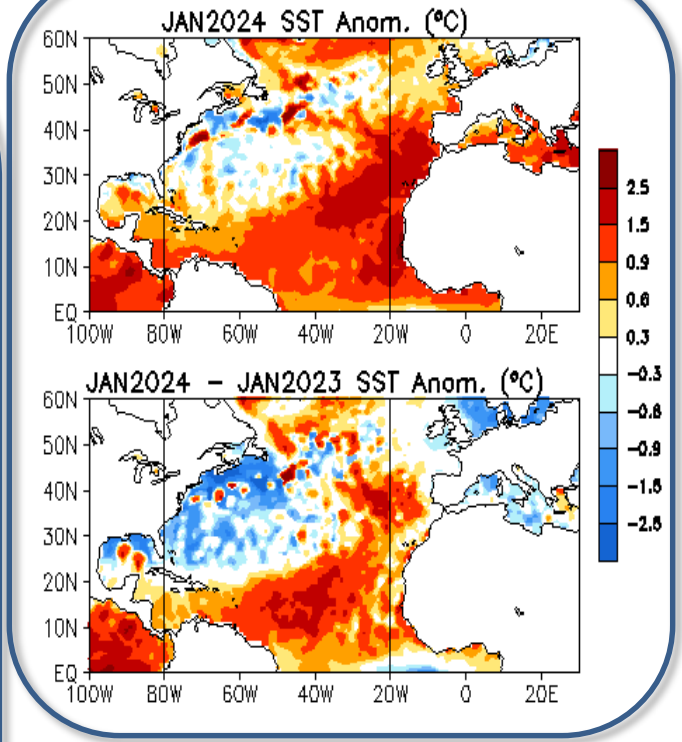



- Latest CFSv2 predictions call above-normal SST in the middle-latitudes of the North Atlantic in the next 6 months.

# NAO and SST Anomaly in North Atlantic



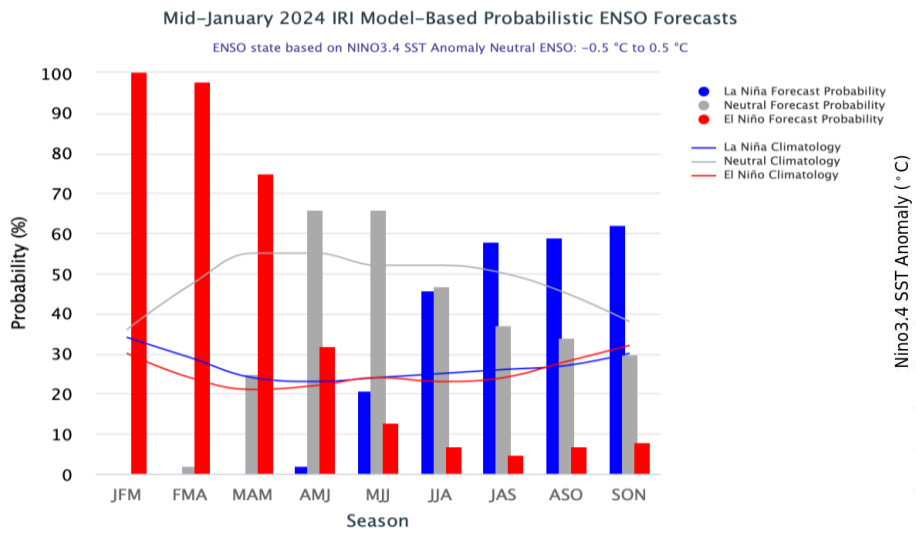



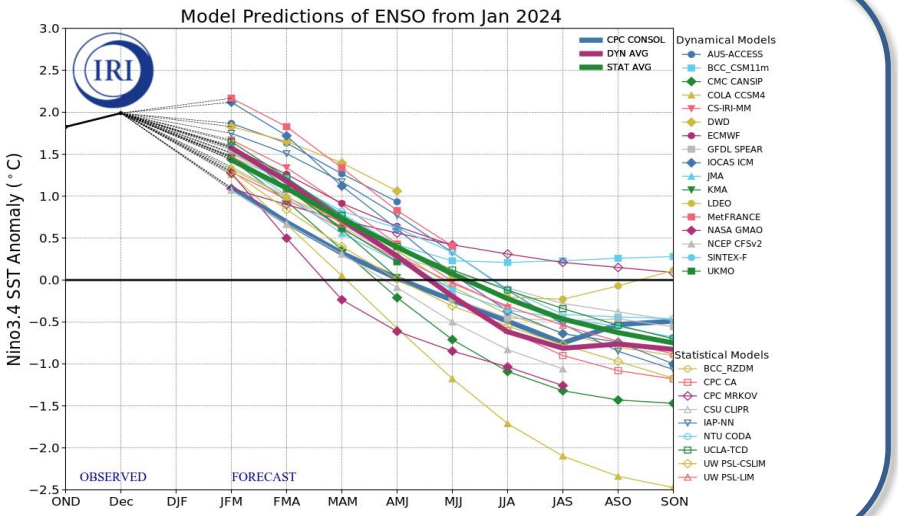

- NAO retuned to a negative phase in Jan 2024 with NAOI= -0.3.
- The prolonged positive SSTAs in the middle latitudes were evident during the last 5-6 years.

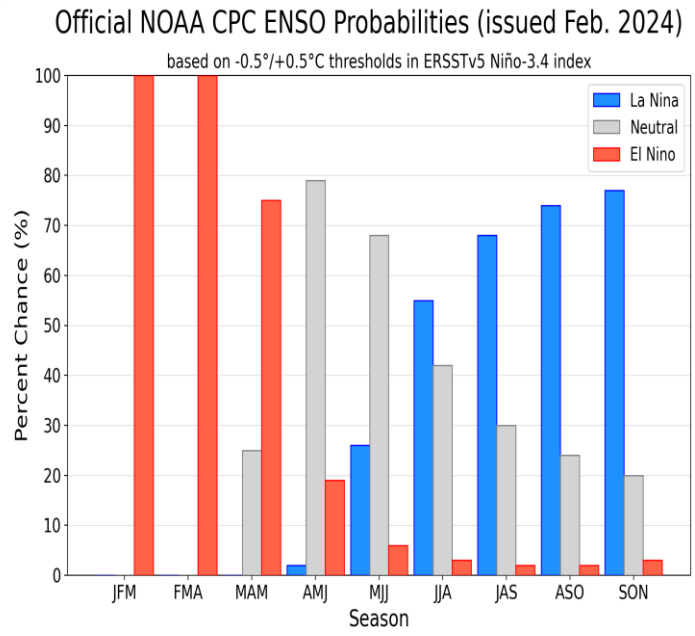
Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20$^{O}$N-90$^{O}$N. Time-latitude section of SSTAs averaged between 80ºW and 20ºW (bottom). SST are derived from the OIv2.1 SST analysis, and anomalies are departures from the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

# ENSO and Global SST Predictions

# CPC & IRI Niño3.4 Forecast



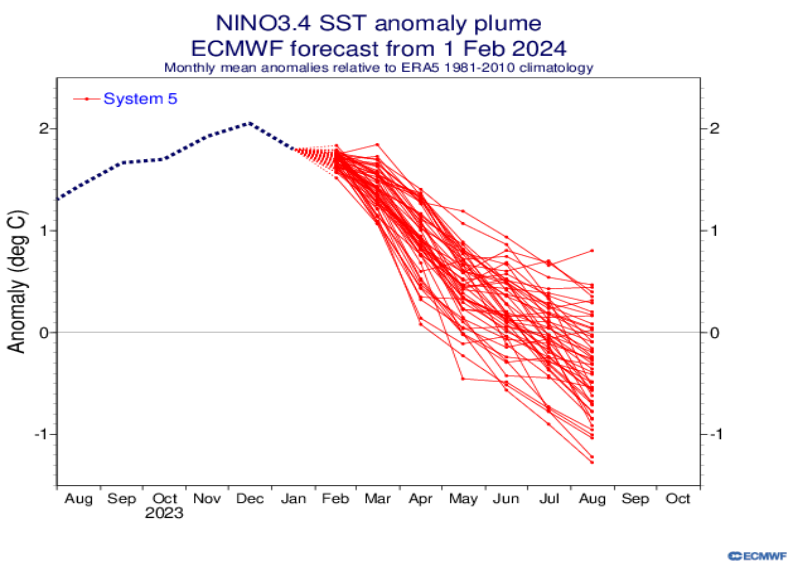



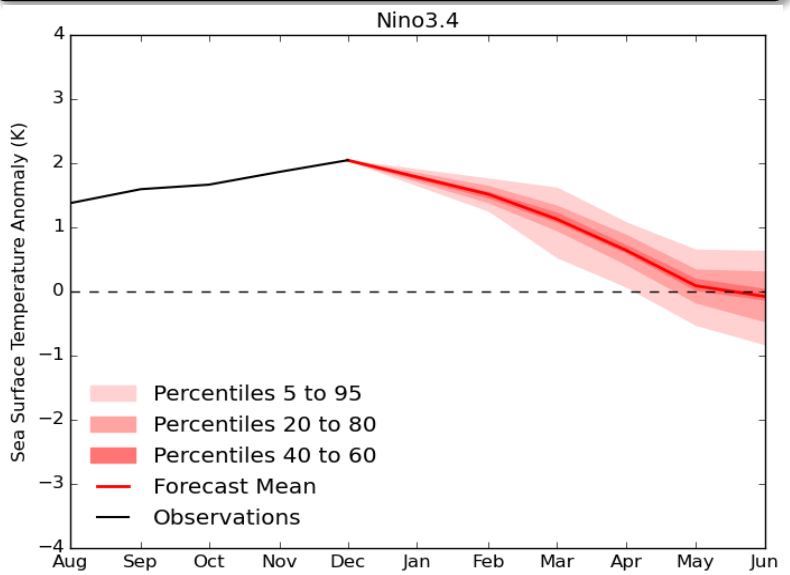

- Model ensemble mean predicts a neutral condition from Apr-Jun to Jun-Aug 2024.
- **On 9 Feb 2024, CPC issued: El Niño Advisory / La Niña Watch.**
- Synopsis: "*A transition from El Niño to ENSO-neutral is likely by April-June 2024 (79% chance), with increasing odds of La Niña developing in June-August 2024 (55% chance).*"

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

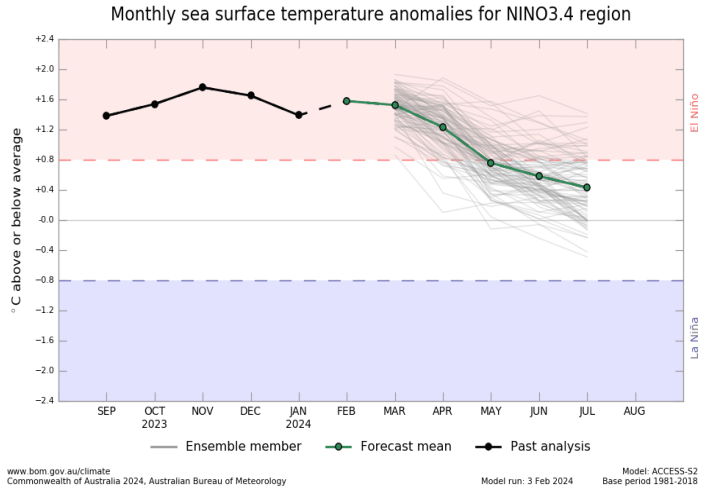
## EC: Niño3.4, IC= 1 Feb 2024



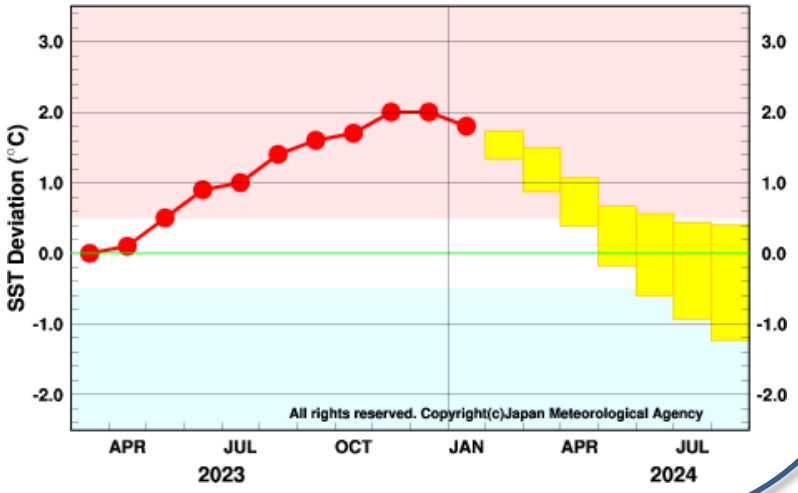

## UKMO: Niño3.4, Updated 11 Jan 2024



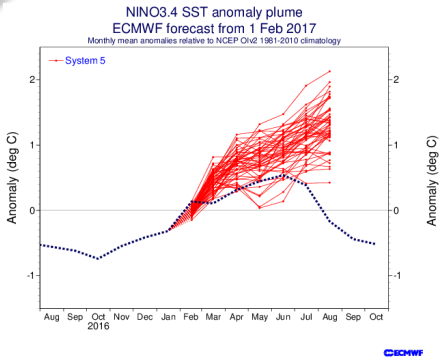

## BOM: Niño3.4, Updated 3 Feb 2024

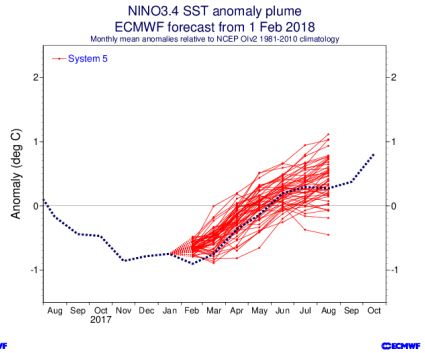


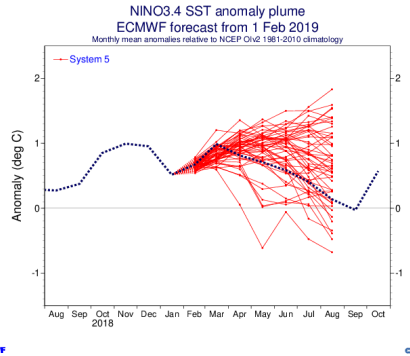

## JMA: Niño3.4, Updated 9 Feb 2024

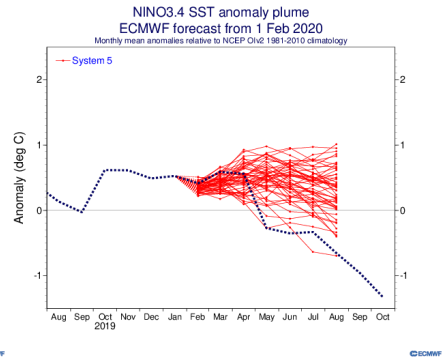


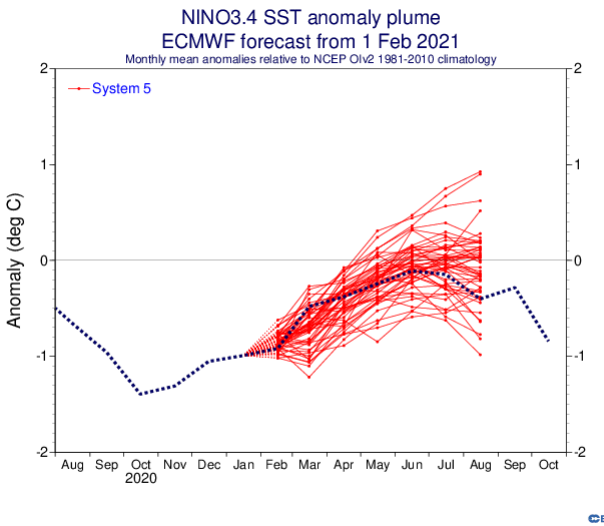
# ECMWF Forecasts with IC in Feb since 2017

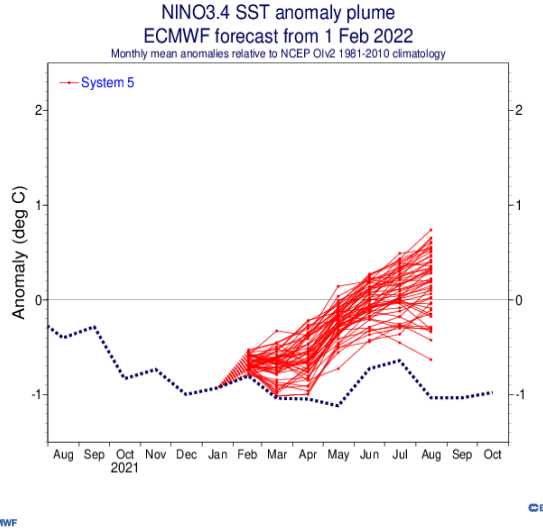


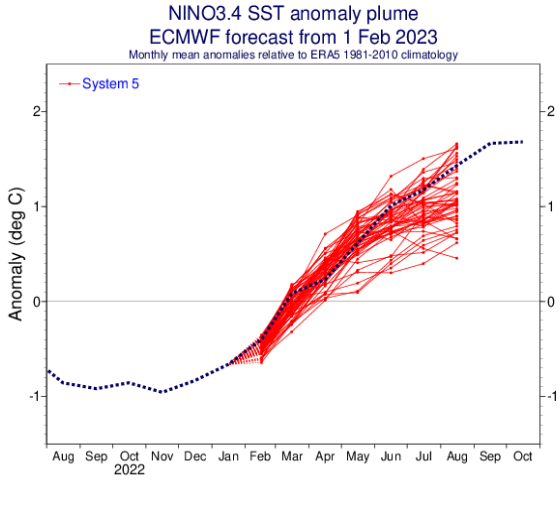



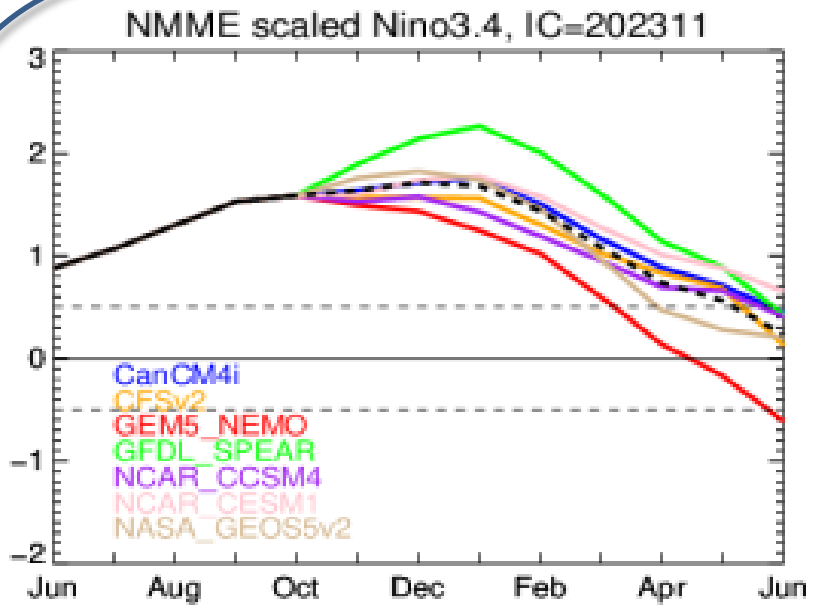



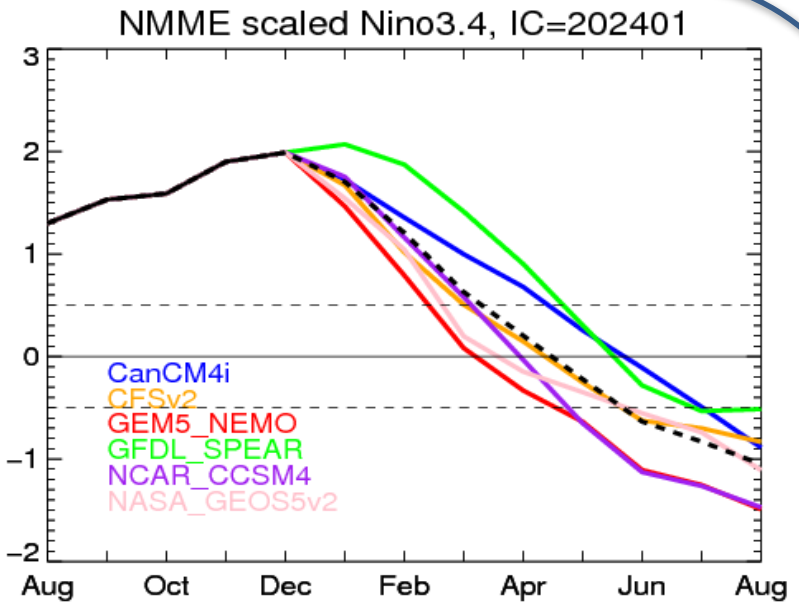



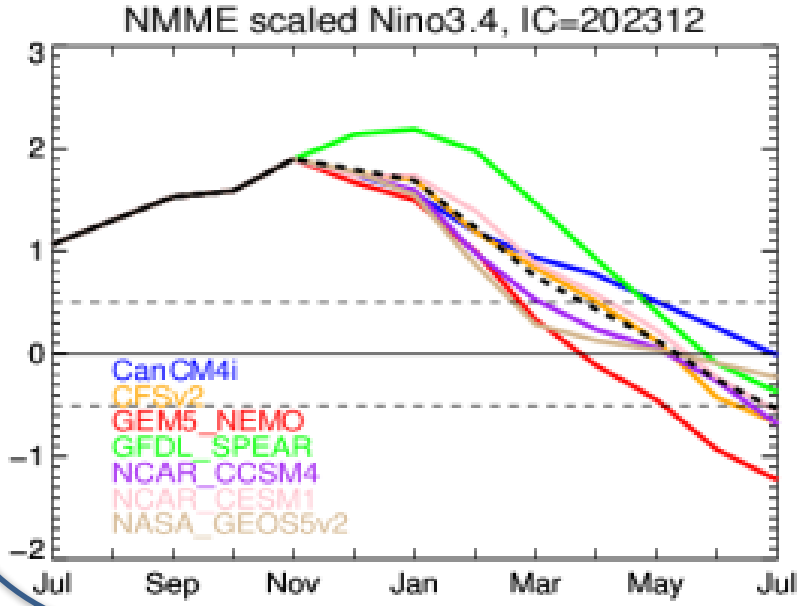



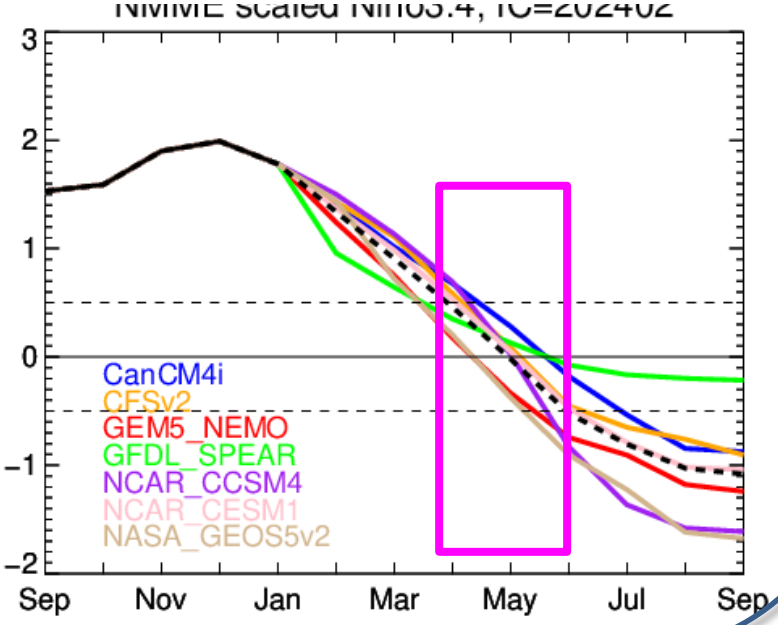



# NMME forecasts from different initial conditions

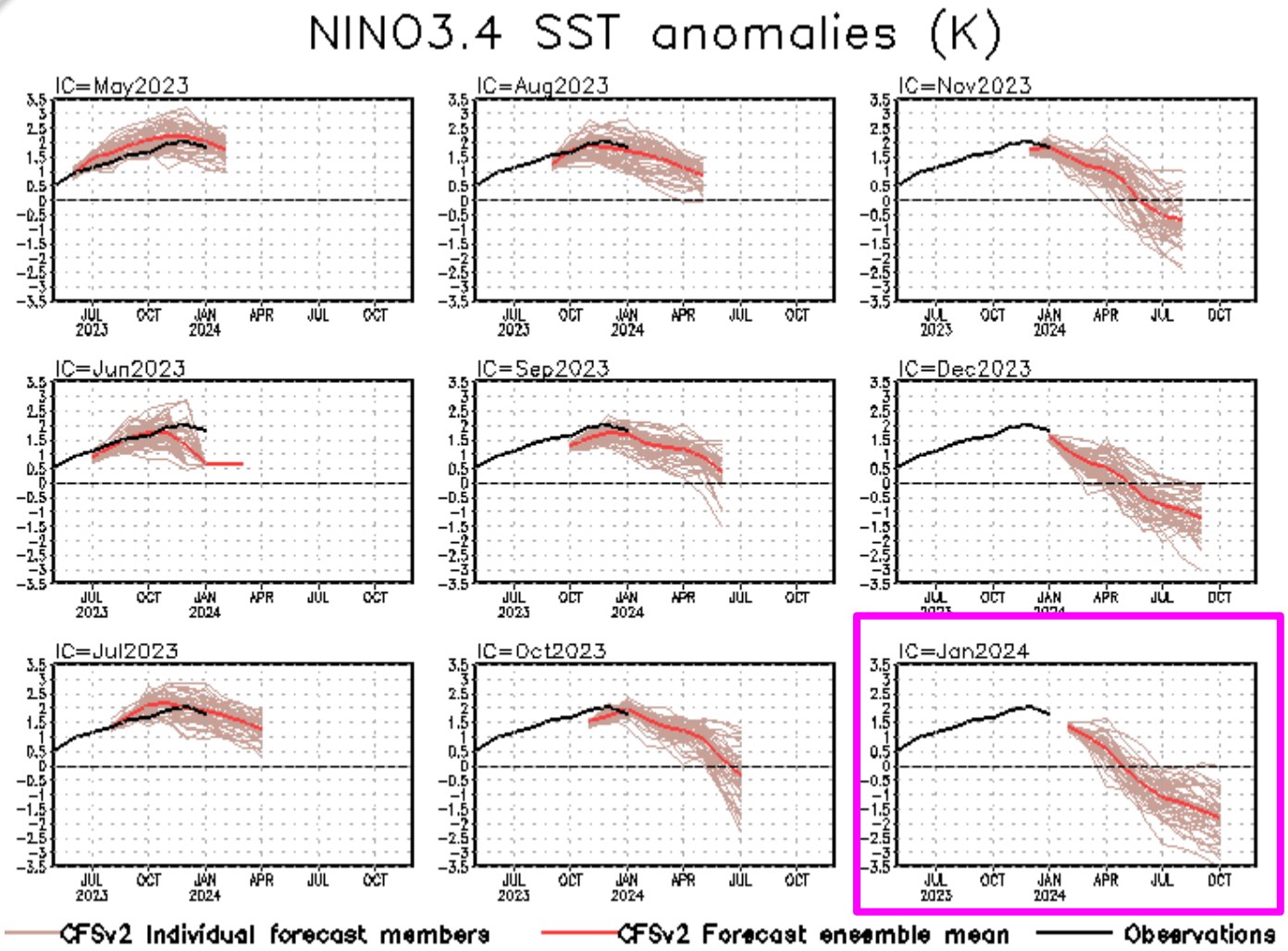


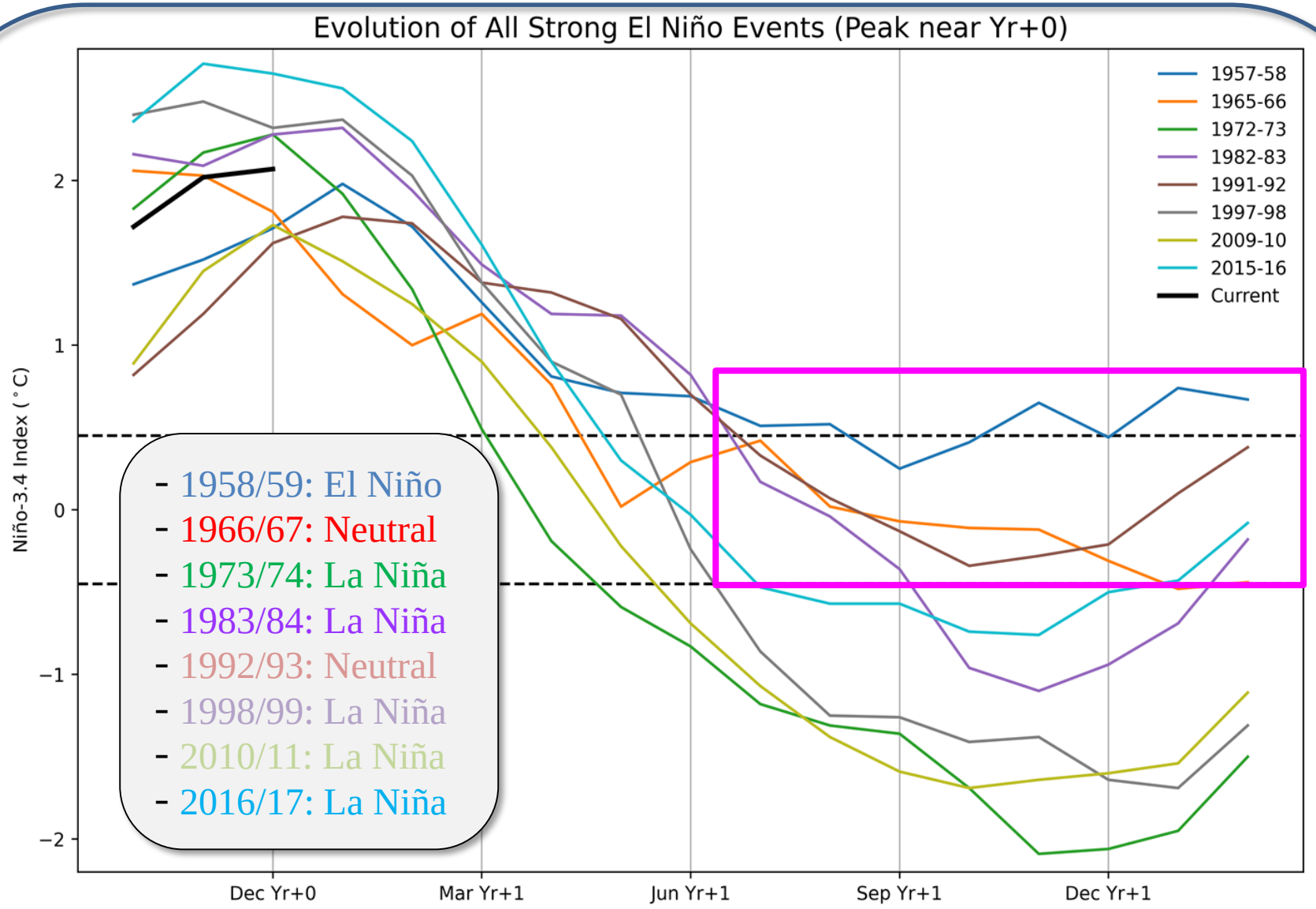
# CFS Niño3.4 SST Predictions from Different Initial Months




- The latest CFSv2 forecasts call for a neutral condition in spring 2024 and La Niña in the 2nd half of 2024.

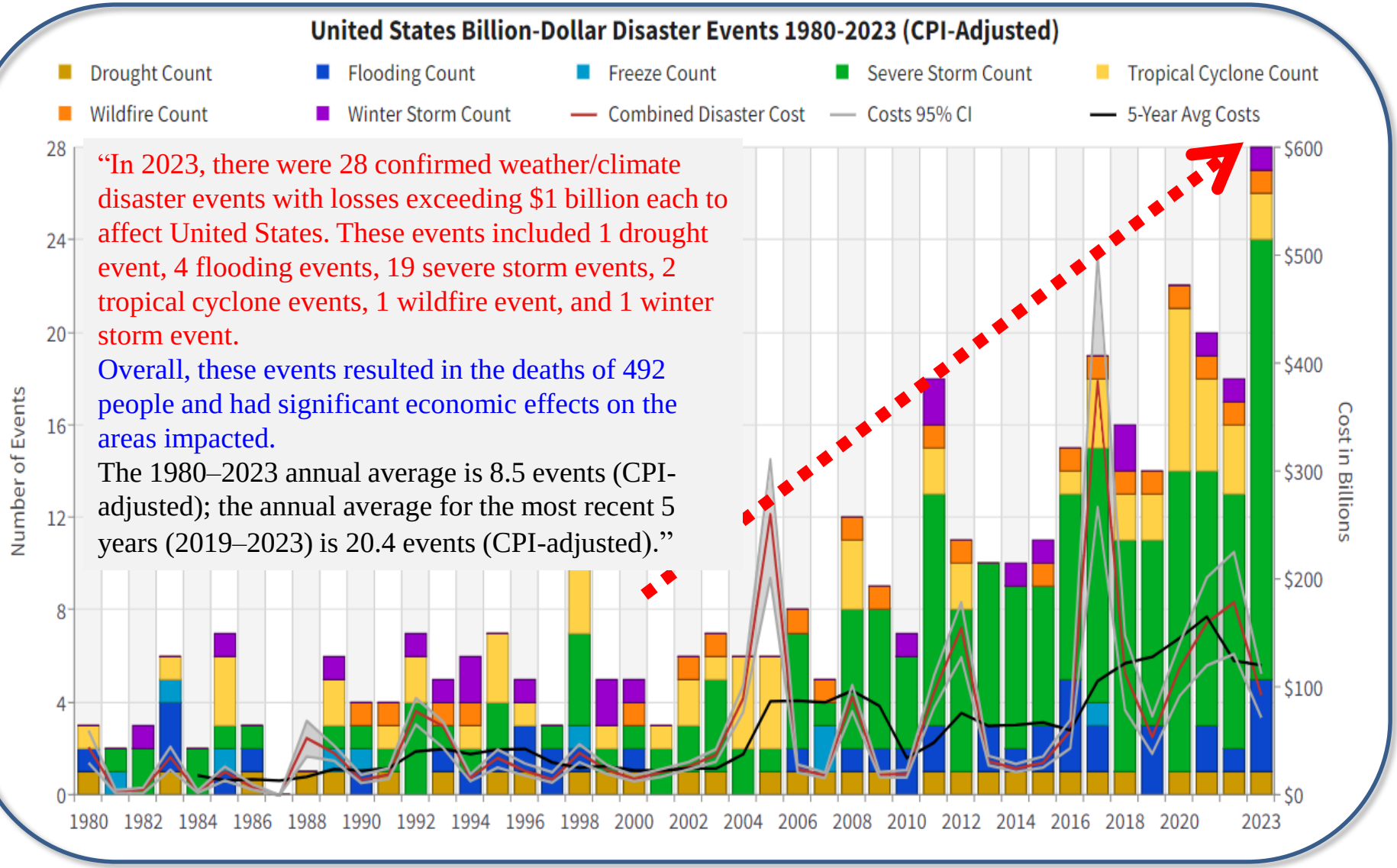
CFS Niño3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect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

# Strong El Niños (since 1950) and their evolution for the following year (Michelle L'Heureux )



# 2023 Ocean Annual Review

# United States Billion-Dollar Disaster Events (https://www.ncei.noaa.gov/access/billions/)

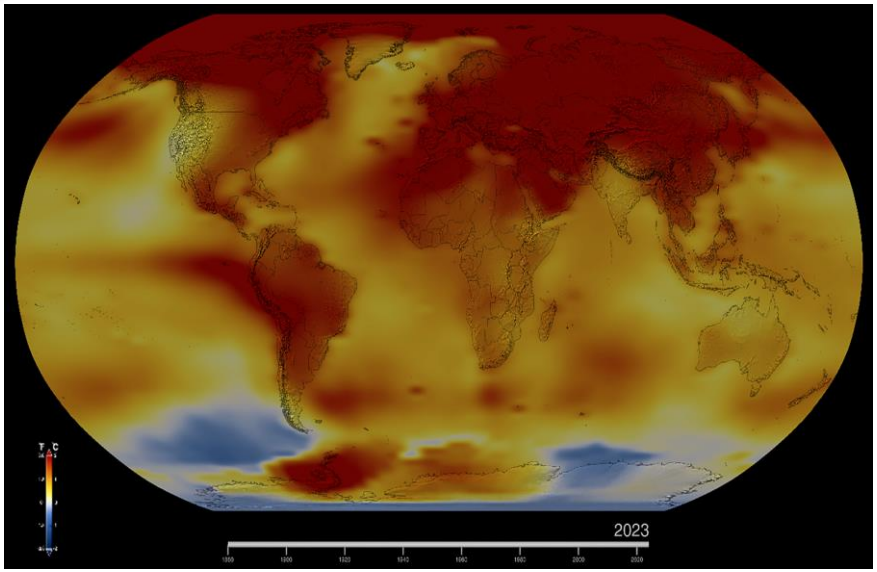


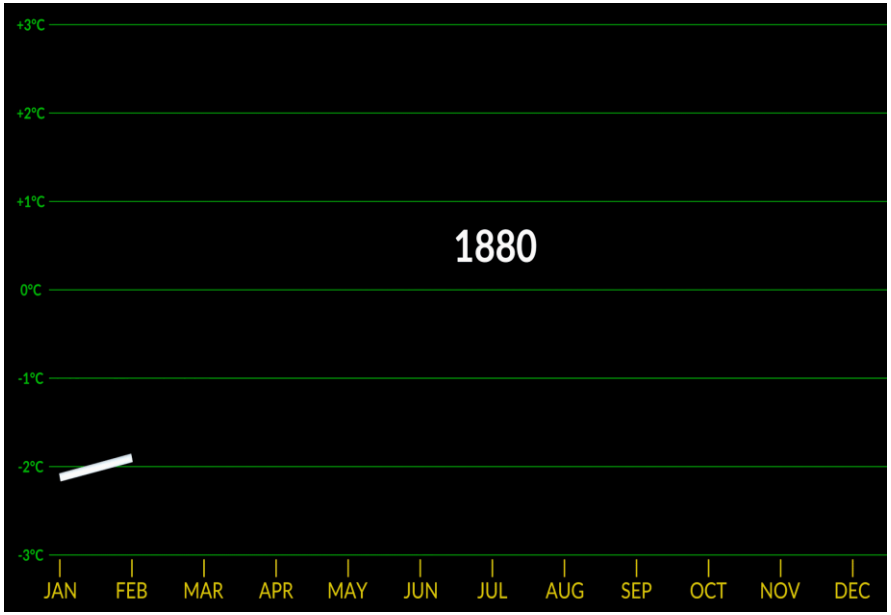

- 1980–2020: 41-yr annual cost average $45.7 billion (inflation-adjusted) → 7.0 events / year
- 2011–2020: 10-yr annual cost average $89.0 billion (inflation-adjusted) → 13.5 events / year
- 2016–2020: 5-yr annual cost average $121.3 billion (inflation-adjusted) → 16.2 events / year

# WMO & NASA GISS Global Land + Ocean Temperature Anomalies

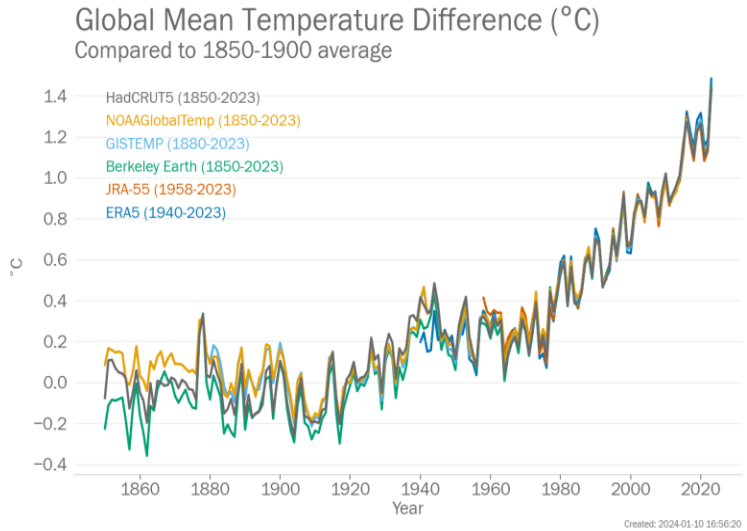
https://www.nasa.gov/news-release/nasa-analysis-confirms-2023-as-warmest-year-on-record/

https://www.meteorologicaltechnologyinternational.com/news/world-meteorological-organization/wmo-confirms-that-2023-smashed-global-temperature-record.html



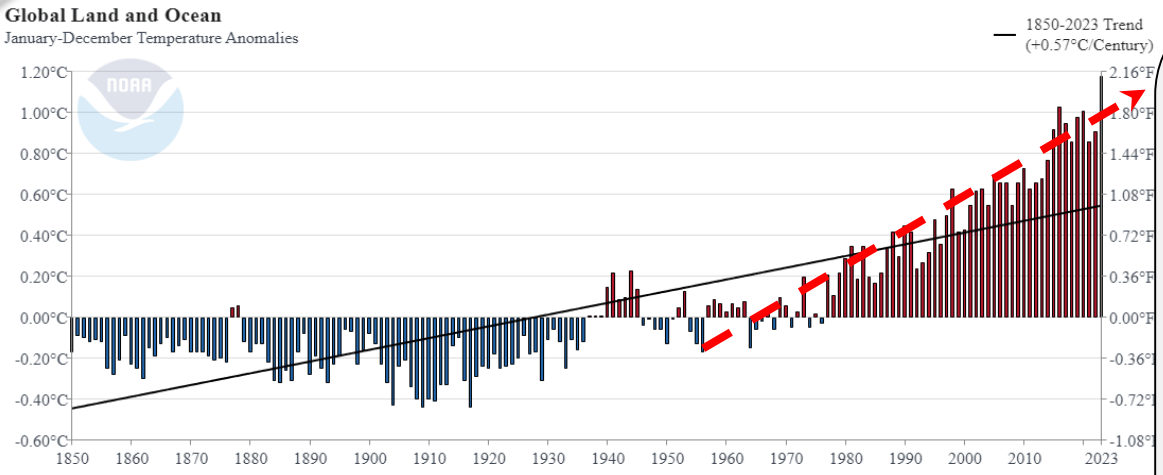




- "Earth's average surface temperature in 2023 was the warmest on record, according to an analysis by NASA. Global temperatures last year were around1.2°C above the average for NASA's baseline period (1951-1980)….
- and each month from June through December set a global record for the respective month. July was the hottest month ever recorded. "

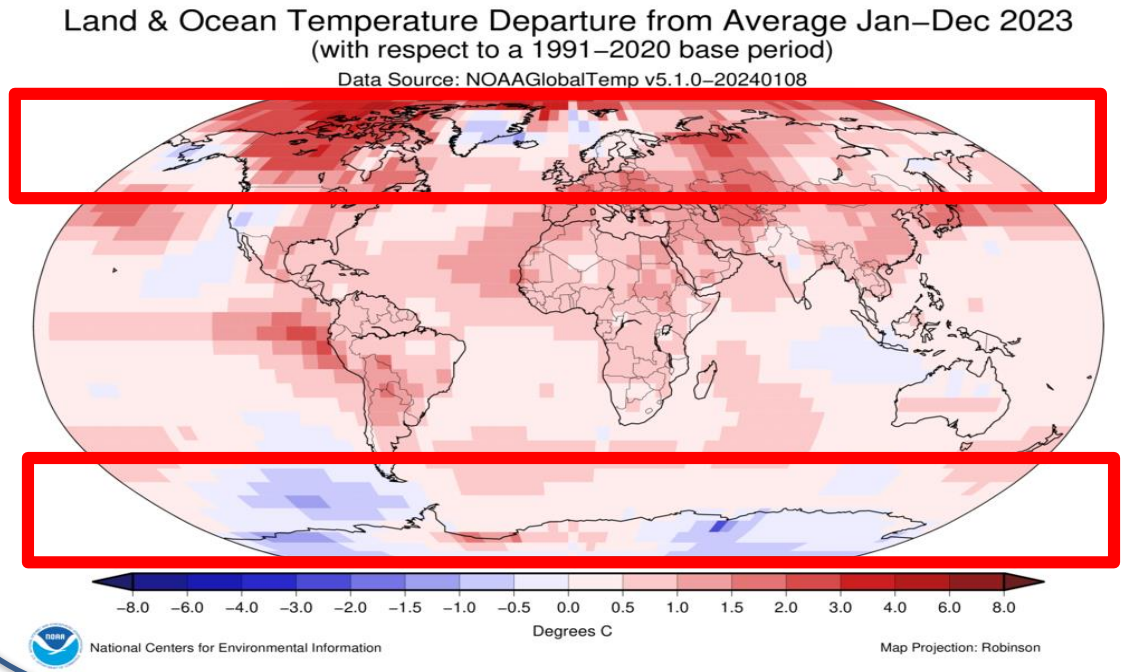


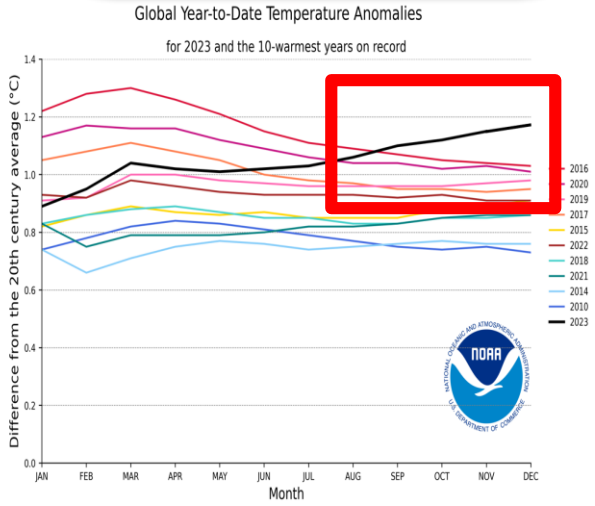
# NOAA NCEI: Global Land + Ocean Temperature Anomalies

https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/

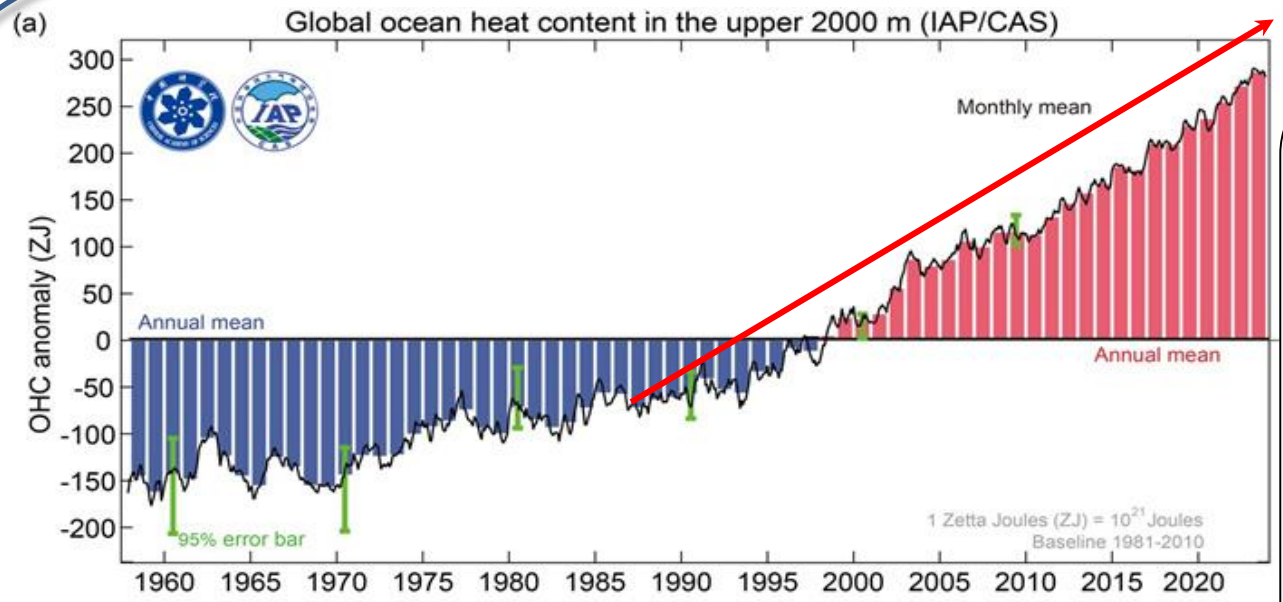


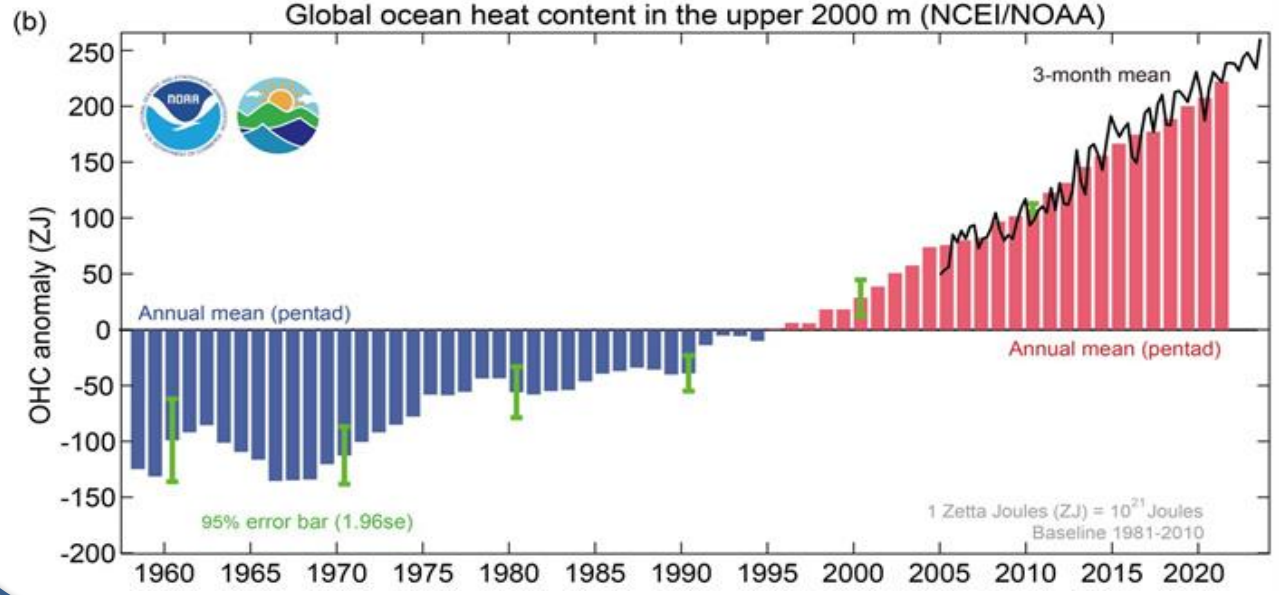

➢ "The average global land and ocean surface temperature for Jan–Dec 2023 was 1.18°C above the 20th century average of 13.9°C—the highest global land and ocean temperature for Jan–Dec in the 1850–2023 record."



# Global Ocean Heat Content (HC2000) since 1958:
# Upper 2000 m ocean heat content (OHC) reached record highs in 2023




Global upper 2000 m OHC from 1958 through 2023 according to (a) IAP/CAS and (b) NCEI/NOAA (1 ZJ = 1021 J). The line shows (a) monthly and (b) seasonal values, and the histogram presents (a) annual and (b) pentad anomalies relative to a 1981–2010 baseline..

*Cheng, et al., 2024: New record ocean temperatures and related climate indicators in 2023, Adv. Atmos. Sci., https://doi.org/10.1007/s00376-024-3378-5*

# Top 5- Hottest Years of Global Ocean Heat Content since 1958

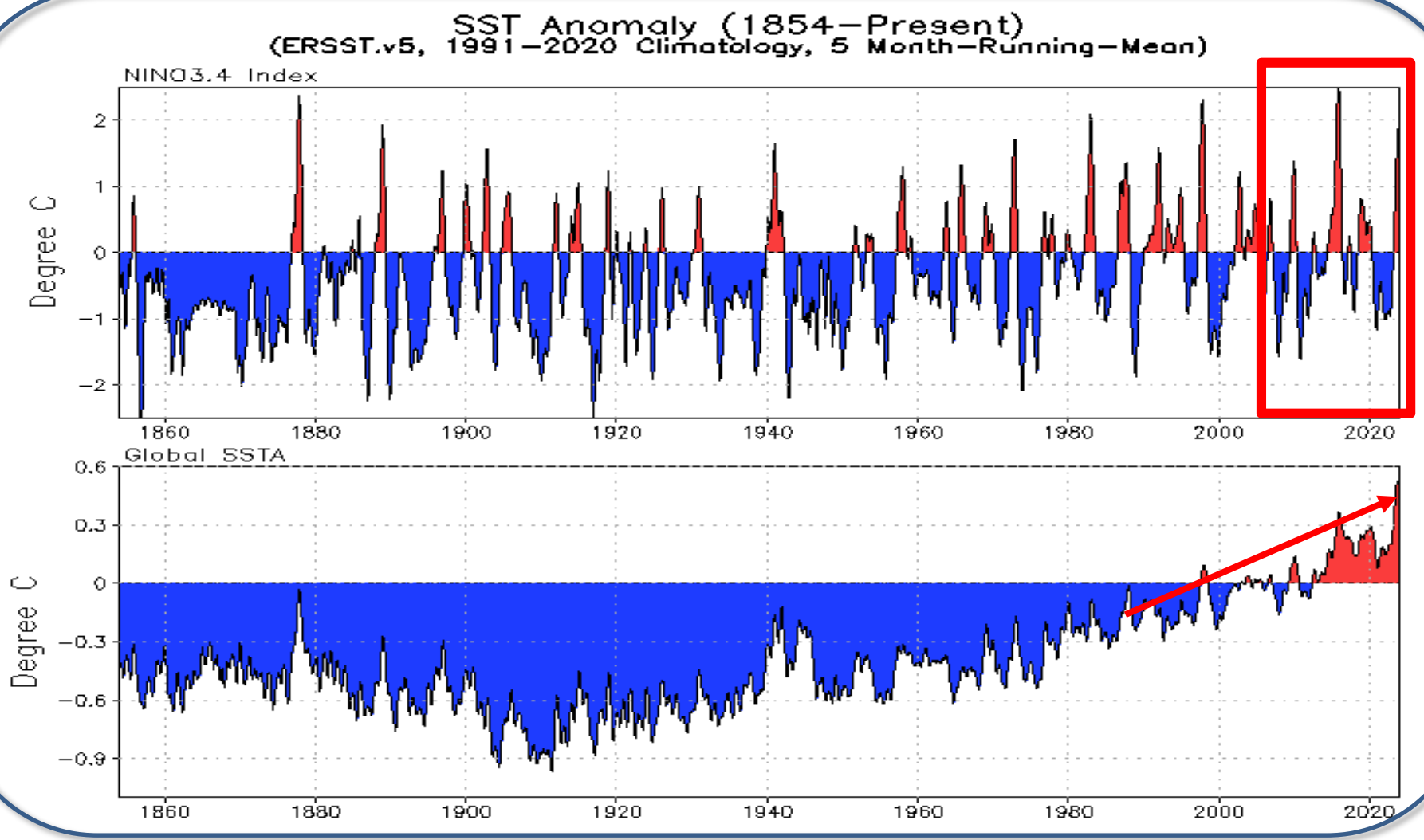
**Table 1.** Ranked order of the five hottest years of the world's ocean since 1955. The OHC values are for the upper 2000 m in units of ZJ. The SST values are in °C. Both OHC and SST anomalies are relative to the 1981–2010 average. Note the IAP/CAS values are collectively higher (~20 ZJ) than the previous release (Cheng et al., 2023) because of the update of the IAP/CAS dataset that led to higher OHC anomalies relative to the 1981–2010 baseline.

| Rank | Year | OHC (IAP/CAS) (units: ZJ) | OHC (NCEI/NOAA) (units: ZJ) | SST anomaly (IAP/CAS) (units: °C) |
|---|---|---|---|---|
| 1 | 2023 | 286 | 247 | 0.54 |
| 2 | 2022 | 271 | 238 | 0.51 |
| 3 | 2021 | 254 | 229 | 0.28 |
| 4 | 2020 | 237 | 211 | 0.38 |
| 5 | 2019 | 228 | 210 | 0.40 |

"In 2023, OHC was at the highest level ever recorded in the world's ocean, and the El Niño effects may not yet be fully evident."

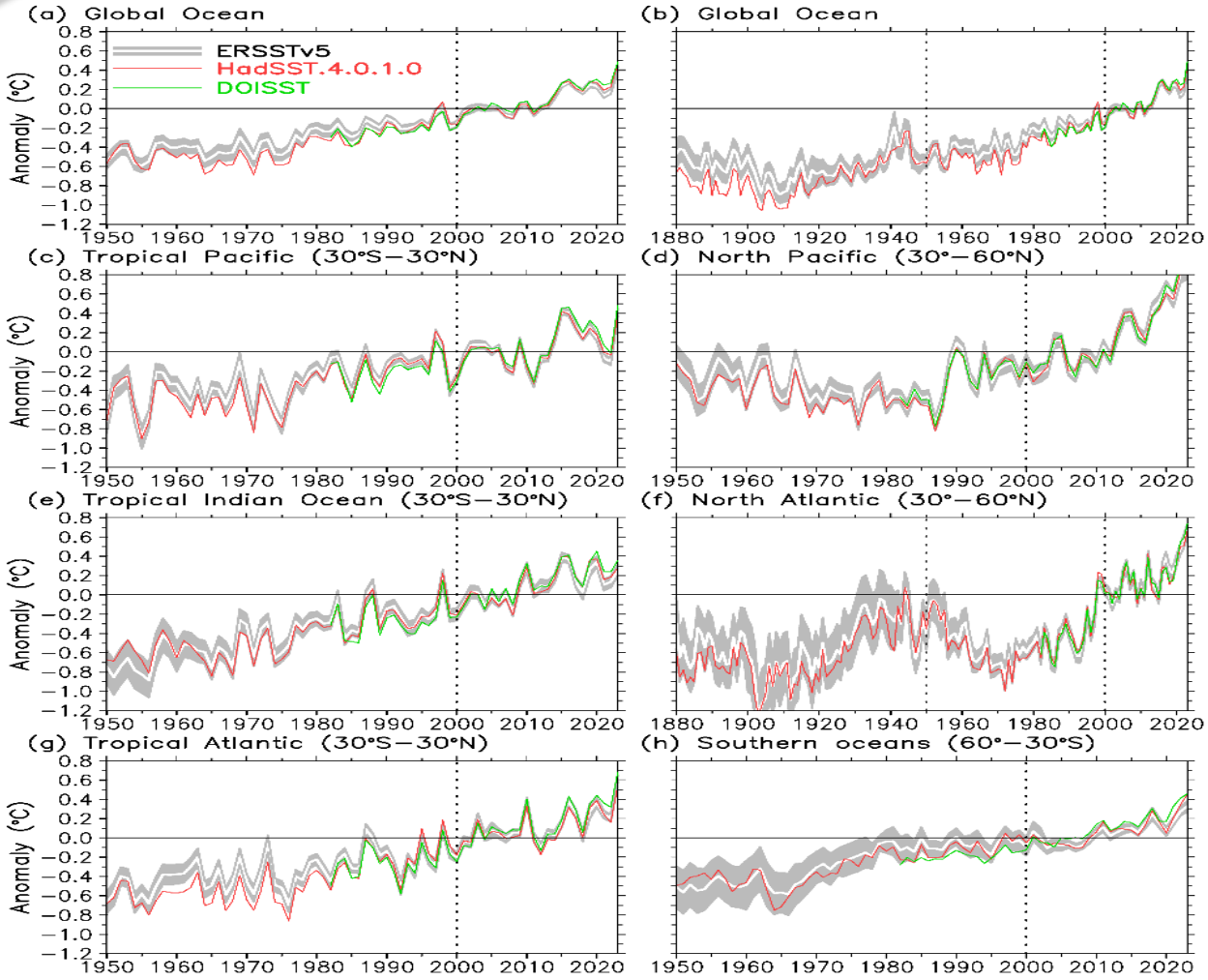
*Cheng, et al., 2024: New record ocean temperatures and related climate indicators in 2023, Adv. Atmos. Sci., https://doi.org/10.1007/s00376-024-3378-5*

# Nino3.4 Index and Global SSTA since 1854




- Strong warming tendency was observed for global SST.
- 2023 was the warmest year based on global averaged ERSSTv5.
- Warming tendency was ambiguous in the Niño3.4 region.

# Yearly Mean SSTA Indices




- Based on ERSSTv5, the global averaged SSTA in 2023 was 0.41°C, exceeding the second warmest year 2016 (0.28°C) by a large margin.

- Despite the influence from the La Niña in the early of 2023, 2023 global averaged SST was the highest on record since 1854.

Fig. 3.3. Annually-averaged SSTAs of ERSSTv5 (solid white) and 2 std. dev. (grey shading) of ERSSTv5, SSTAs of HadSST.4.0.1.04 (solid red), and SSTAs of DOISST (solid green), in 1950–2023 except for (b). (a) Global, (b) Global in 1880–2023, (c) Tropical Pacific, (d) Tropical Indian, (e) Tropical Atlantic, (f) North Pacific, (g) North Atlantic, and (h) Southern Oceans. The 2 std. dev. envelope was derived from a 500-member ensemble analysis based on ERSSTv5 (Huang et al. 2020) and centered to SSTAs of ERSSTv5. The year 2000 is indicated by a vertical black dotted line.
**BAMS State of the Climate in 2023 by** *Yin, et al., 2024: Sea Surface Temperatures. Bull. Amer. Meteor. Soc.*

# Linear Trends

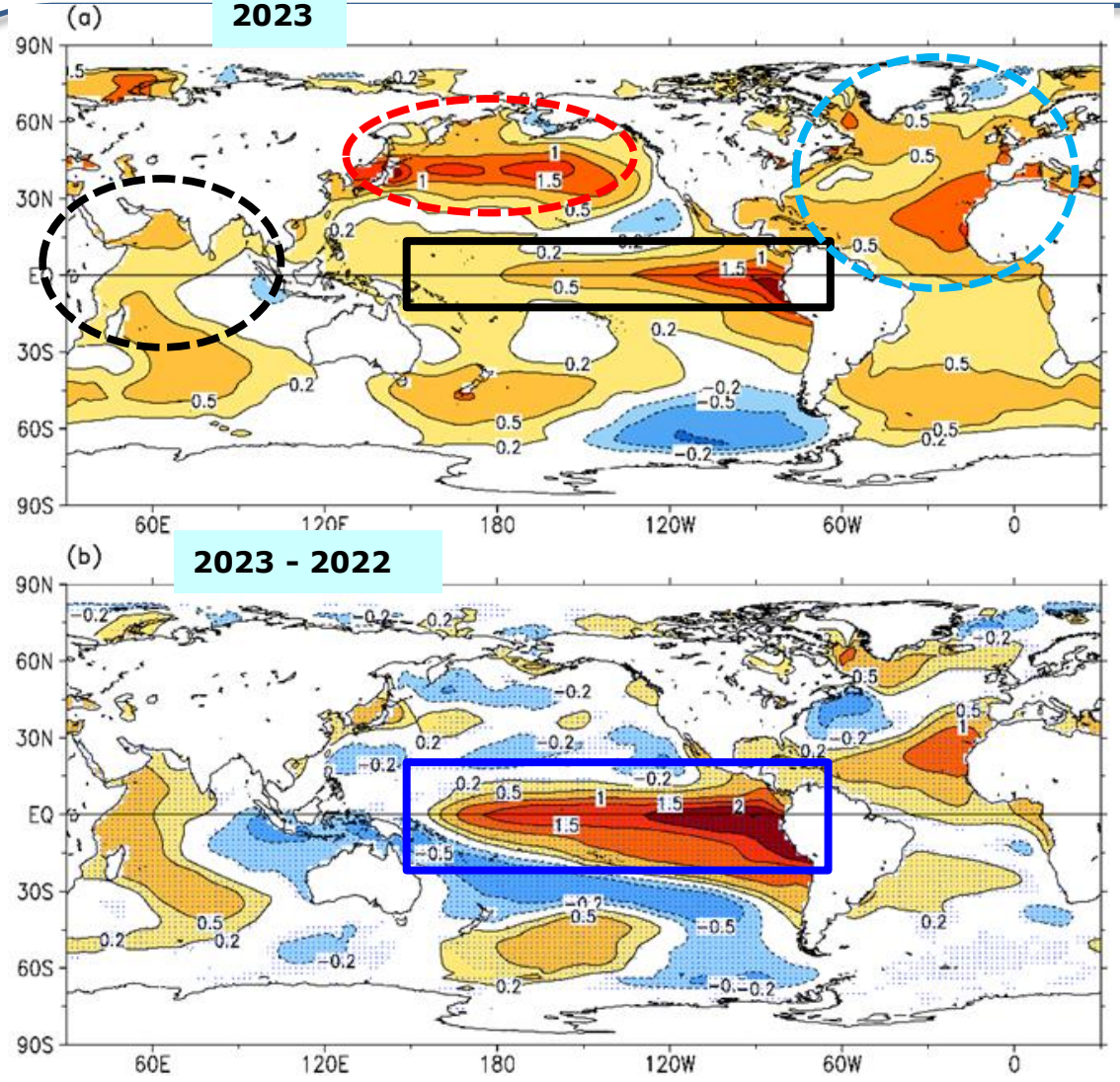
| Product | Region | 1950–2023 | 2000-2023 |
|---|---|---|---|
| HadSST.4.0.1.0 | Global | 0.12±0.02 | 0.19±0.06 |
| DOISSTv2.1 | Global | N/A | 0.20±0.05 |
| ERSSTv5 | Global | 0.11±0.01 | 0.17±0.06 |
| | Tropical Pacific (30°S–30°N) | 0.10±0.03 | 0.14±0.14 |
| | North Pacific (30°–60°N) | 0.10±0.04 | 0.42±0.13 |
| | Tropical Indian Ocean (30°S–30°N) | 0.140±0.02 | 0.16±0.08 |
| | North Atlantic (30°–60°N) | 0.13±0.05 | 0.21±0.10 |
| | Tropical Atlantic (30°S–30°N) | 0.12±0.02 | 0.18±0.08 |
| | Southern oceans (30°–60°S) | 0.10±0.02 | 0.14±0.05 |

- Based on ERSSTv5, the linear trends of globally annually averaged SSTAs were 0.11°C/decade since 1950 & 0.17°C/decade since 2000.
- Among the individual ocean basins, the warming trend in the North Pacific was the smallest during 1950-2023 (0.10°C/decade) & the largest during 2000-2023 (0.42°C/decade).

- Table 3.1. Linear trends (°C/ decade) of annually and regionally averaged SSTAs from ERSSTv5, HadSST4, and DOISST. The uncertainties at 95% confidence level are estimated by accounting for the effective sampling number quantified by lag-1 auto correlation on the degrees of freedom of annually-averaged SST series.

**BAMS State of the Climate in 2023 by** *Yin, et al., 2024: Sea Surface Temperatures. Bull. Amer. Meteor. Soc.*

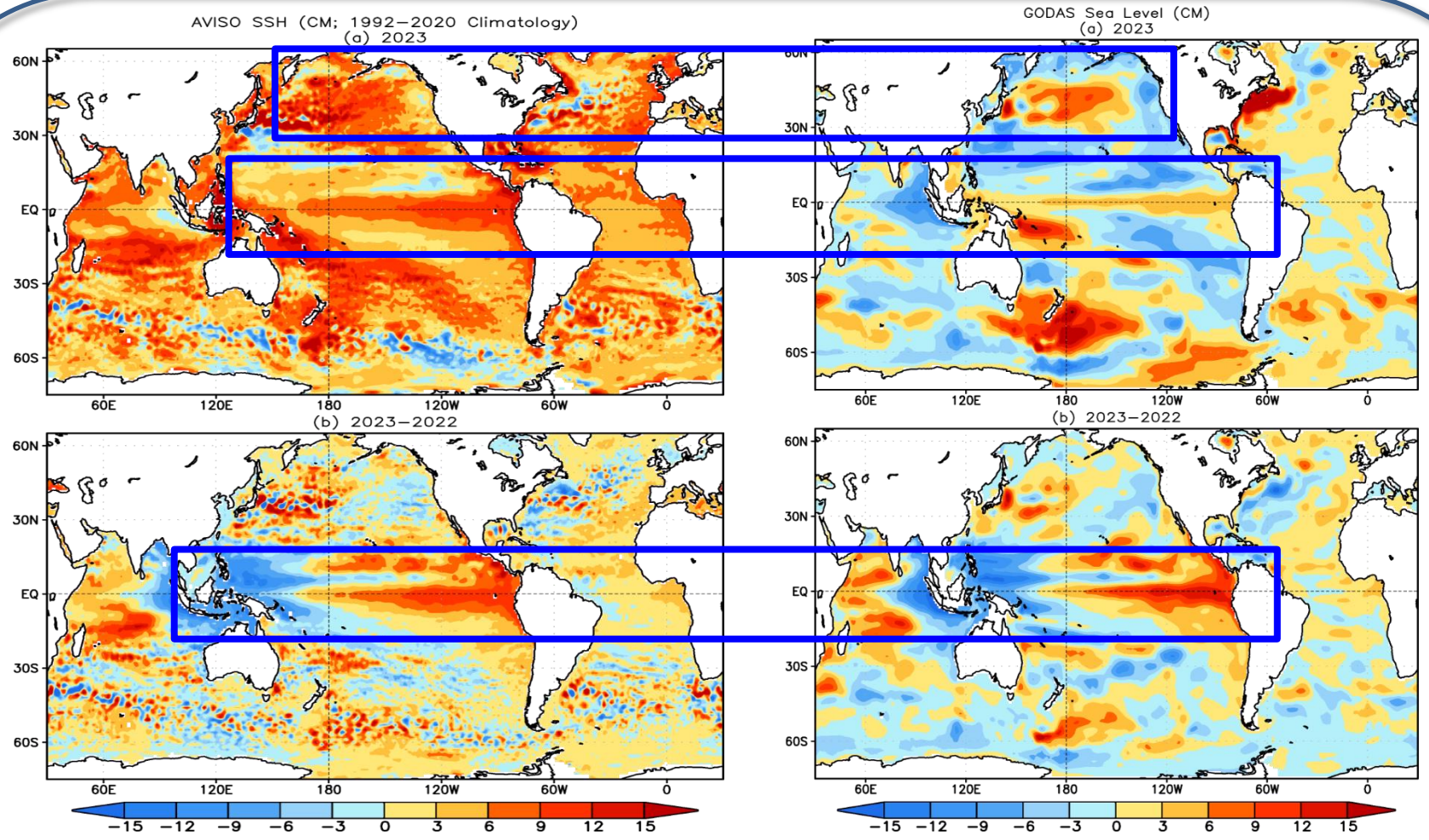
# 2023 Yearly Mean ERSSTv5 SSTA & Tendency




- **The warming in the central & eastern tropical Pacific was associated with the El Niño in the second half 2023.**
- **Warming in the North Pacific was consistent with the negative phase of PDO in 2023.**
- **Above-normal SST was observed in the North Atlantic Ocean.**
- **It was a dipole-like pattern with warming (cooling) in the western (eastern) tropical Indian Ocean in 2023.**
- **The tropical Pacific was warmer in 2023 than in 2022.**

Fig. 3.1. (a) Annually averaged SSTAs in 2023 (°C) and (b) difference of annually averaged SSTAs from the previous year (2023 minus 2022; °C). Values are relative to 1991–2020 climatology and the SSTA difference is significant at a 95% confidence level in stippled areas.
**BAMS State of the Climate in 2023 by** *Yin, et al., 2024: Sea Surface Temperatures. Bull. Amer. Meteor. Soc.*

# 2023 Yearly Mean AVISO SSH Anomalies & Tendency




- **Pronounced positive SSH anomalies were present in the central & eastern tropical Pacific, consisting with the El Niño condition in the second half of 2023.**
- **Positive SSH anomalies were observed in the North Pacific.**
- **The east-west contrast across the tropical Pacific was weaker in 2023 than in 2022.**

# Seasonal Mean ERSSTv5 SSTA in 2023

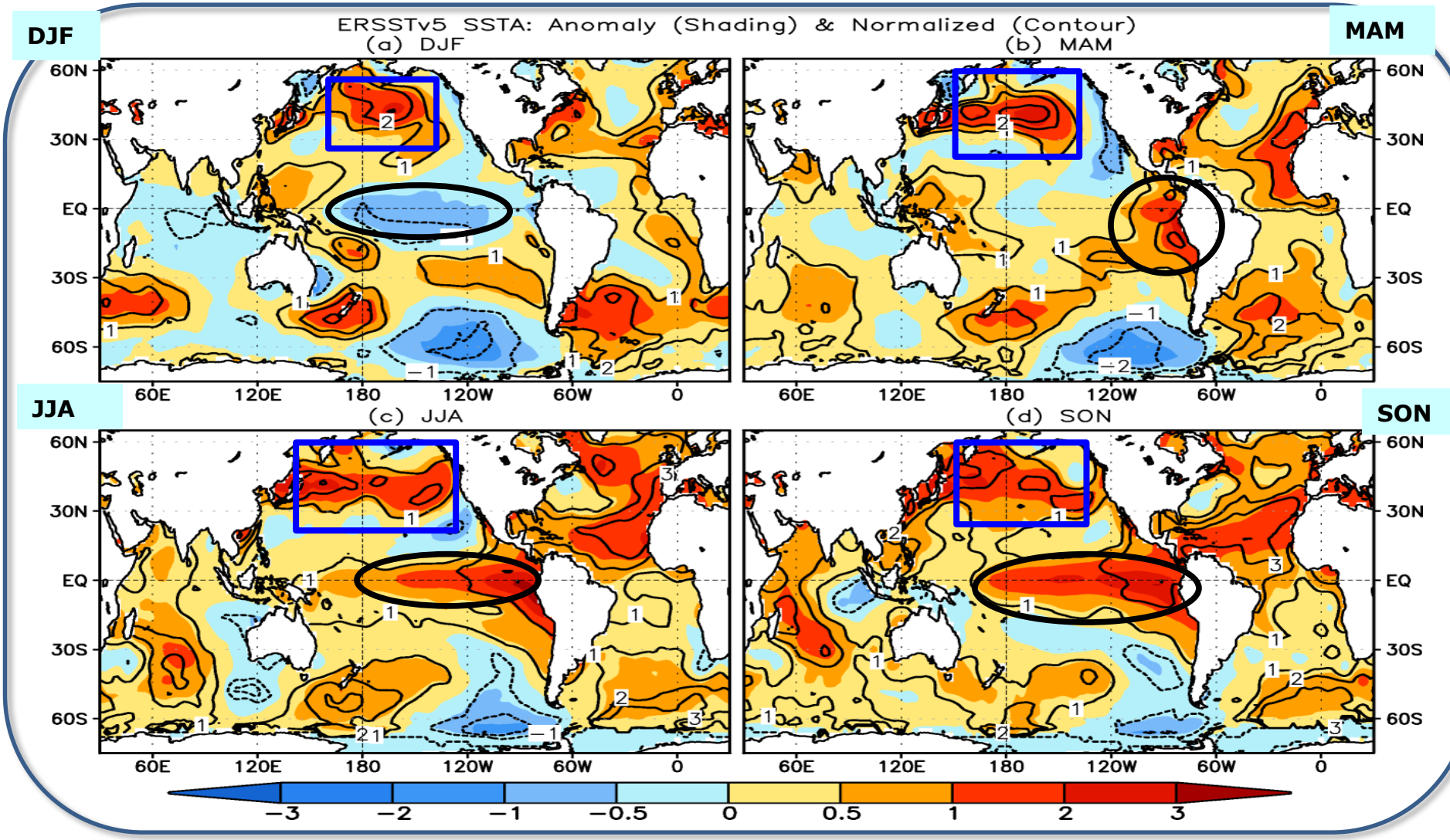
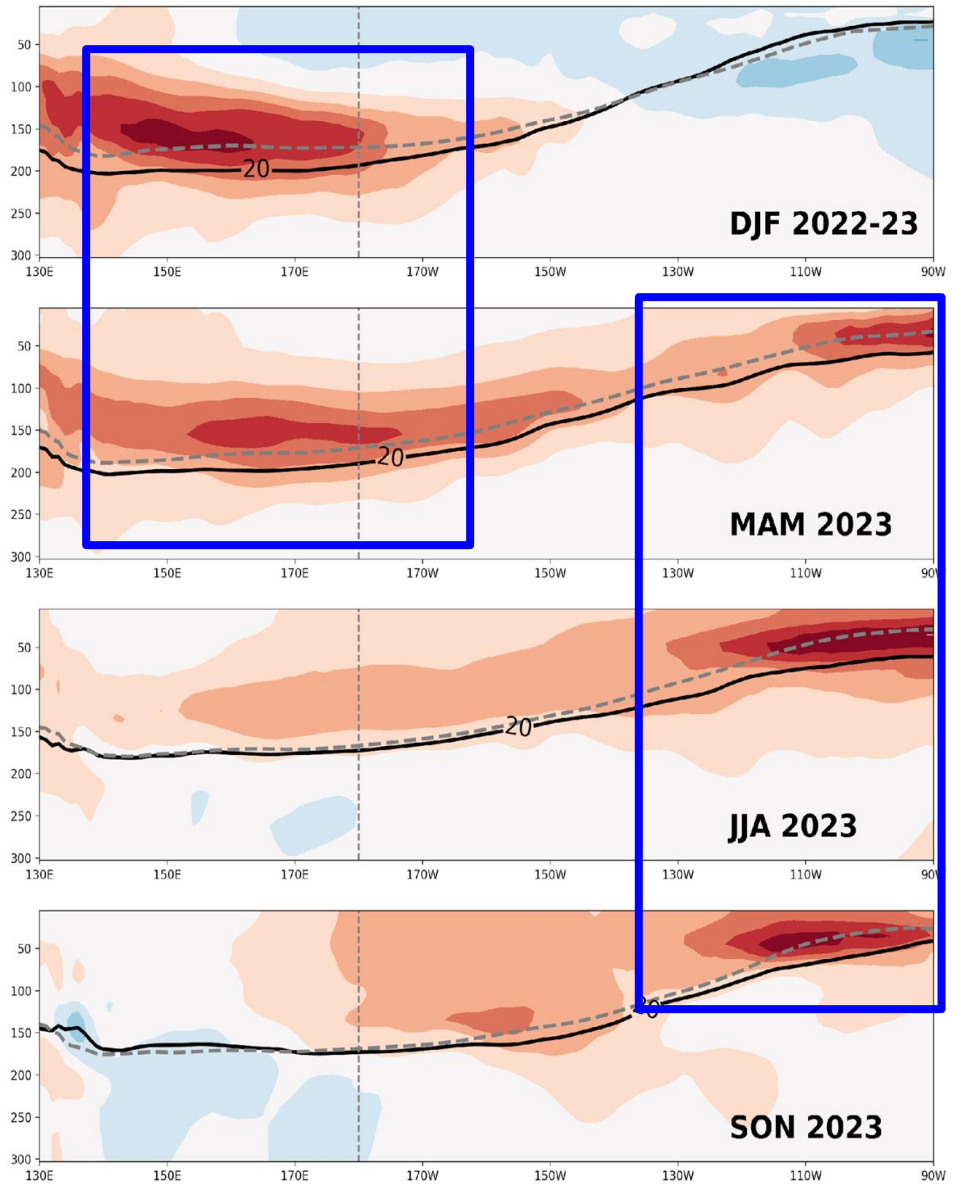
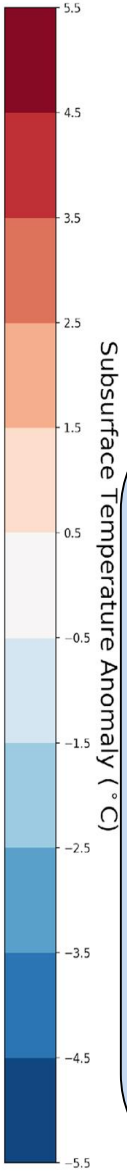



Fig. 3.2. Seasonally averaged SSTAs of ERSSTv5 (°C; shading) for (a) Dec 2022–Feb 2023, (b) Mar–May 2023, (c) Jun–Aug 2023, and (d) Sep–Nov 2023. The normalized seasonal mean SSTAs based on the seasonal mean standard deviation (1 SD) over 1991–2020 are indicated by contours of −2 (dashed white), −1 (dashed black), 1 (solid black), and 2 (solid white).

**BAMS State of the Climate in 2023 by** *Yin, et al.: Sea Surface Temperatures. Bull. Amer. Meteor. Soc.*

# Seasonal Mean Subsurface T Anomalies Along equator in 2023



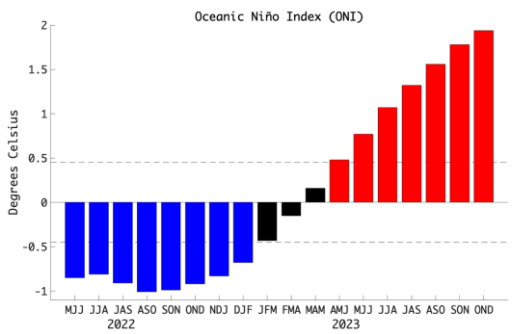




Fig 3. Equatorial depth-longitude section of Pacific Ocean temperature anomalies (°C) averaged between 5°N and 5°S during (a) DJF 2022–23, (b) MAM 2023, (c) JJA 2023, and (d) SON 2023. The 20°C isotherm (thick solid line) approximates the center of the oceanic thermocline. The grey, dashed line shows the climatology of the 20°C isotherm based on 1991-2020. The data are derived from a reanalysis system that assimilates oceanic observations into an oceanic general circulation model (Behringer 2007). Anomalies are departures from the 1991-2020 period monthly means.

**BAMS State of the Climate in 2023 by** *Becker, et al.: ENSO and the Tropical Pacific. Bull. Amer. Meteor. Soc.*

# 2023 Annual Review

- In 2023, there were 28 confirmed weather/climate disaster events with losses exceeding $1 billion each to affect United States, which is the maximum in the record.
- Earth's average surface temperature in 2023 was the warmest on record, according to an analysis by NASA & NOAA. Global temperatures were around1.2$^{o}$C above the average for NASA's baseline period (1951-1980).
- Upper 2000 m ocean heat content (OHC) in 2023 reached record high since 1955. Based on ERSSTv5, the global averaged SSTA in 2023 was 0.41$^{o}$C, the highest on record since 1854.
- Overall, the warming trends of the global oceans since the 1950s persisted with the linear trends of globally annually averaged SSTAs of 0.11$^{o}$C decade$^{-1}$ over 1950–2023. Among the individual ocean basins, the warming trend in the North Pacific was the smallest during 1950-2023 (0.10$^{o}$C/decade) & the largest during 2000-2023 (0.42$^{o}$C/decade).


*(a) Yin, X., B. Huang, D. Chan, G. Graham, Z.-Z. Hu, and H.-M. Zhang, 2024: Sea Surface Temperatures. [In "State of the Climate in 2023"]. Bull. Amer. Meteor. Soc.*

*(b) Becker, E., M. L'Heureux, A. Kumar, and Z.-Z. Hu, 2024: ENSO and the tropical Pacific. [In "State of the Climate in 2023"]. Bull. Amer. Meteor. Soc.*

# 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 provided the sea ice forecasts
- Drs. XunGang Yin & Boyin Huang provided some annual review results


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

# Data Sources (climatology is for 1991-2020)

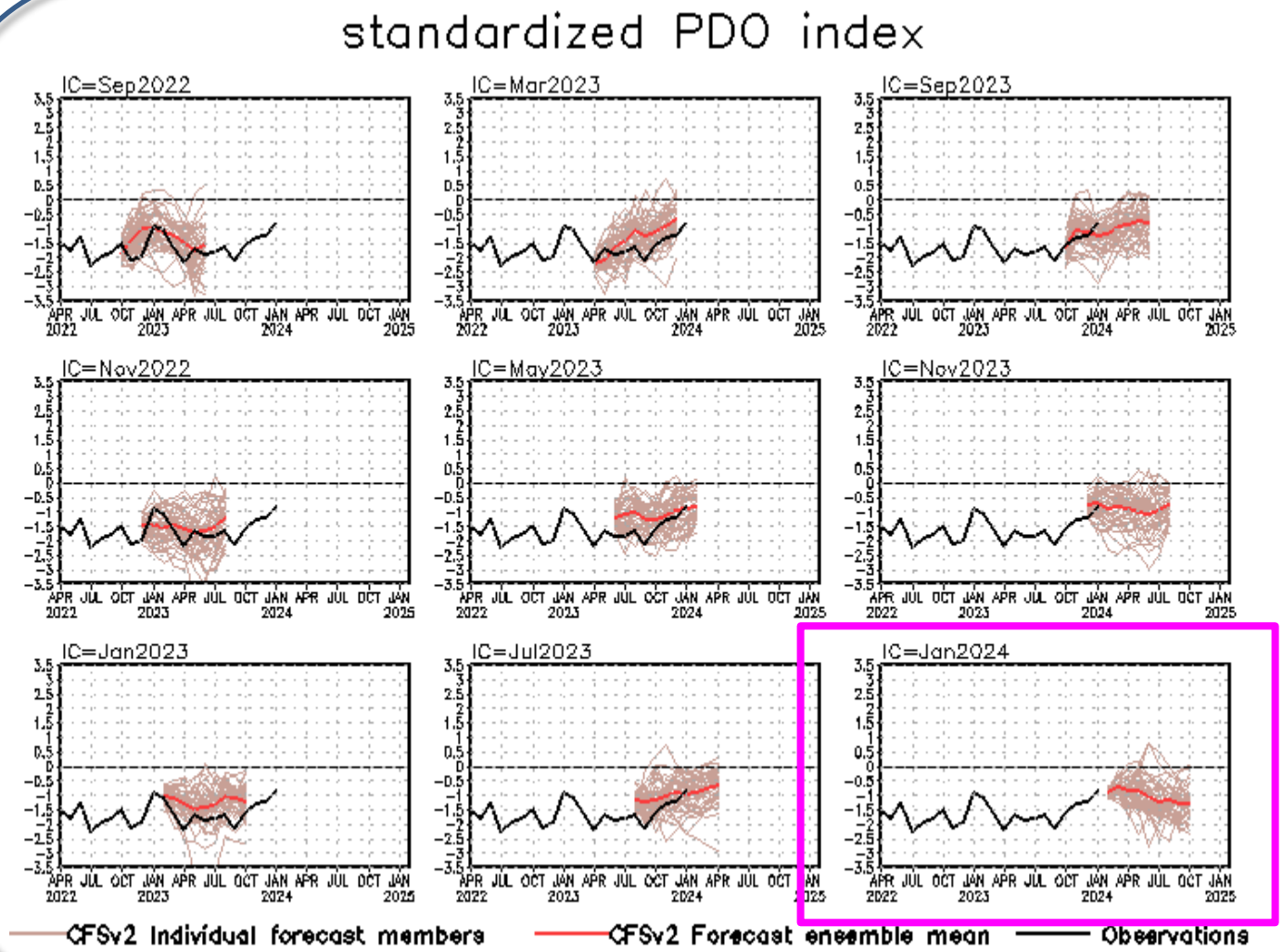
- **NCEP/CPC Ocean Monitoring & Briefing Operation (Hu et al., 2022, BAMS)**
- **Weekly Optimal Interpolation SST (OIv2.1 SST; Huang et al. 2021)**
- **Extended Reconstructed SST (ERSST) v5 (Huang et al. 2017)**
- **Blended Analysis of Surface Salinity (BASS) (Xie et al. 2014)**
- **CMORPH precipitation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

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

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

# Backup Slides

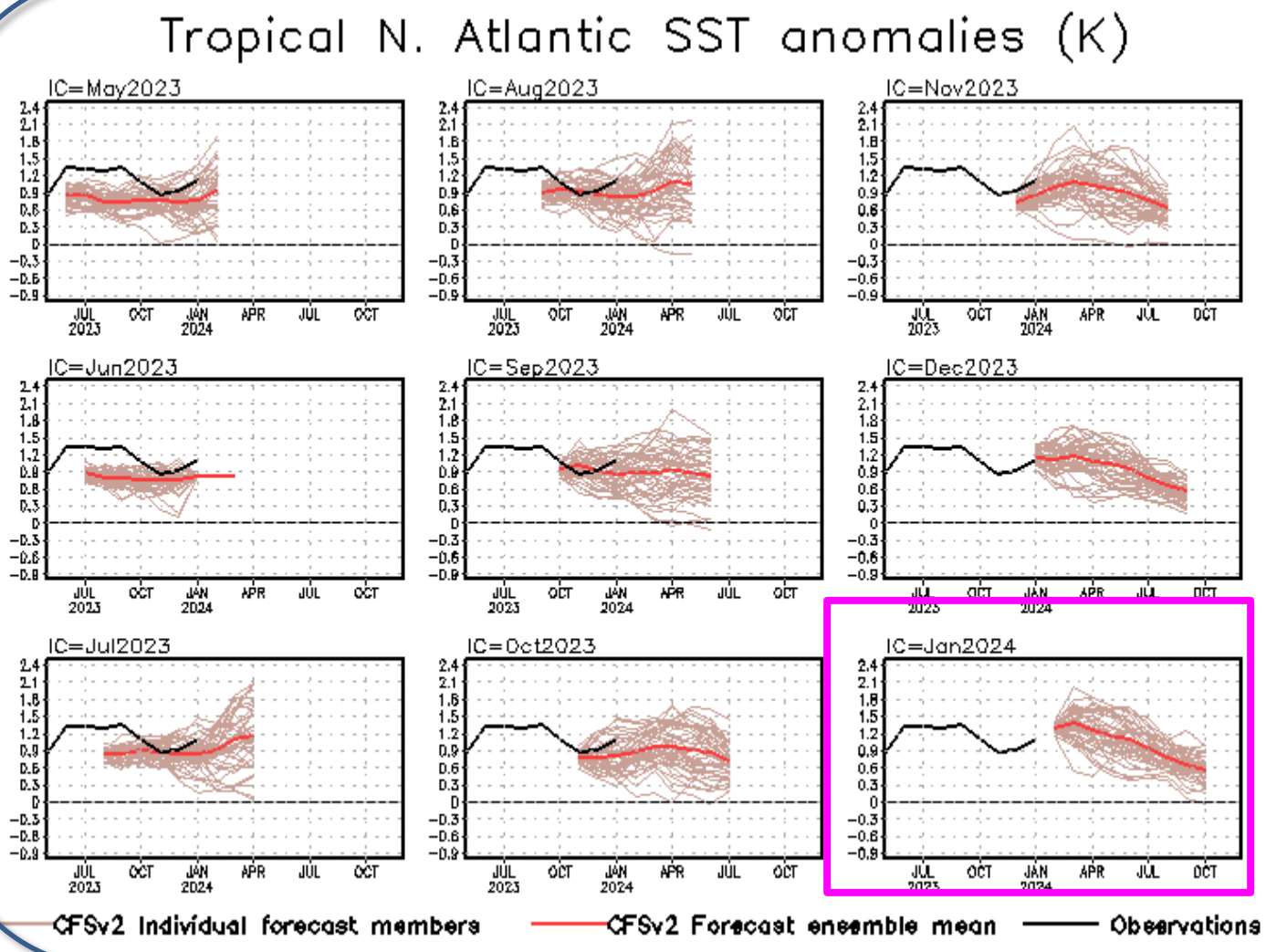
# NCEP CFSv2 PDO Index Predictions from Different Initial Months




- 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.

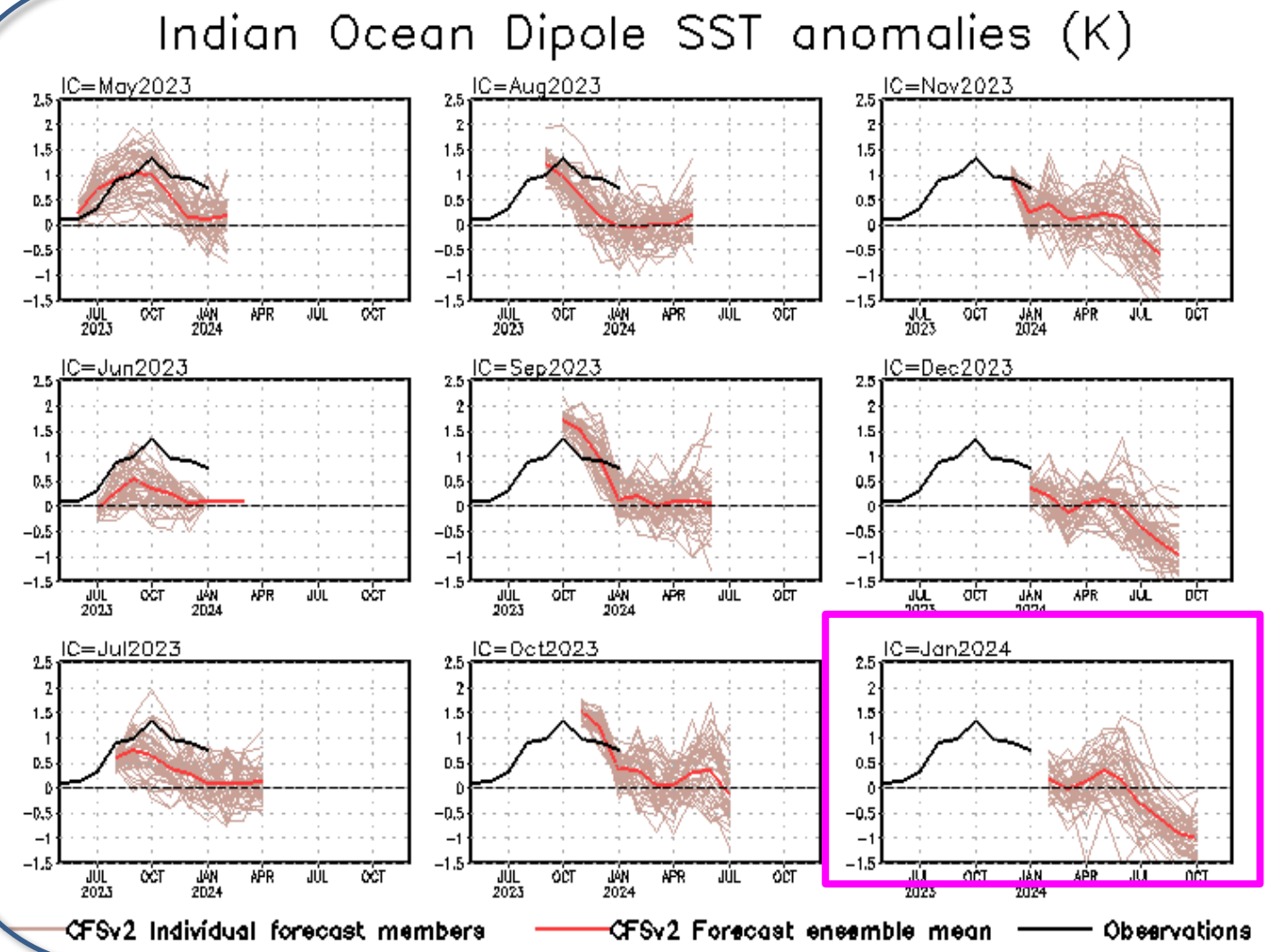
# NCEP CFSv2 Tropical North Atlantic (TNA) SST Predictions from Different Initial Months




- 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].

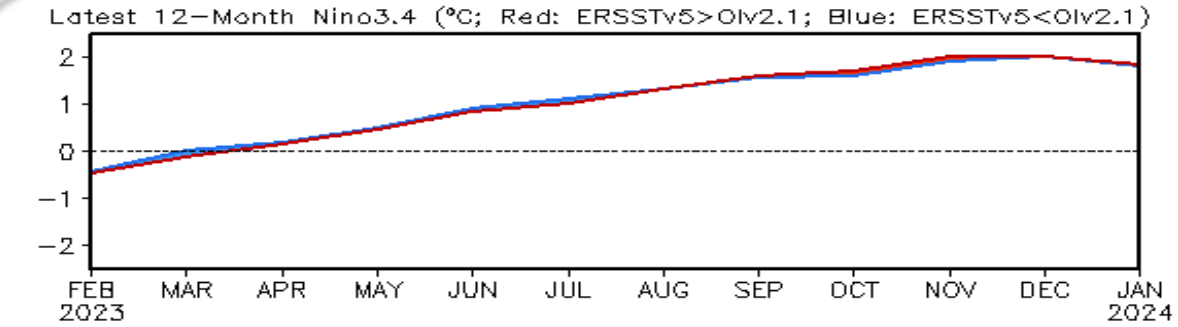
# NCEP CFSv2 DMI SST Predictions from Different Initial Months

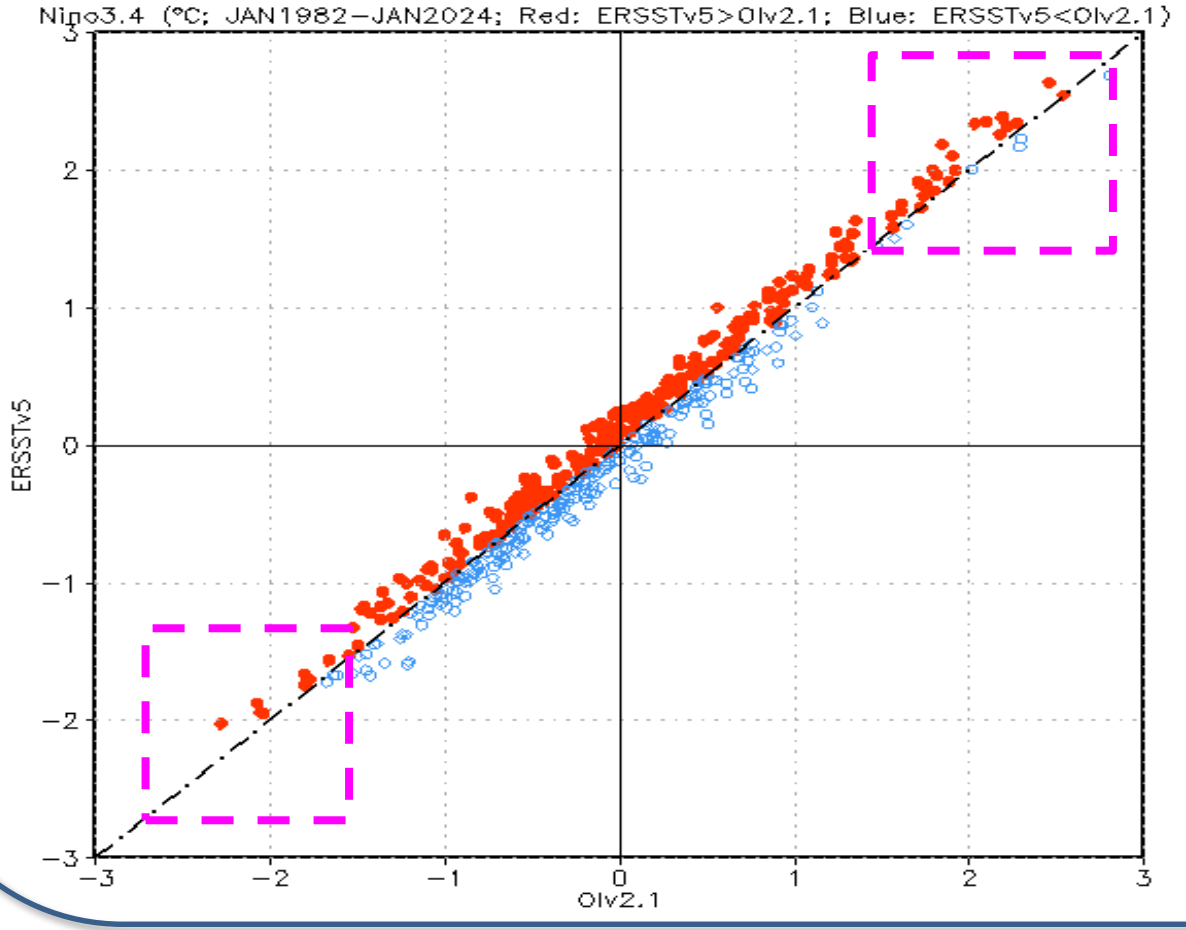



- CFSv2 predicts a negative phase of IOD since the summer of 2024.

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.

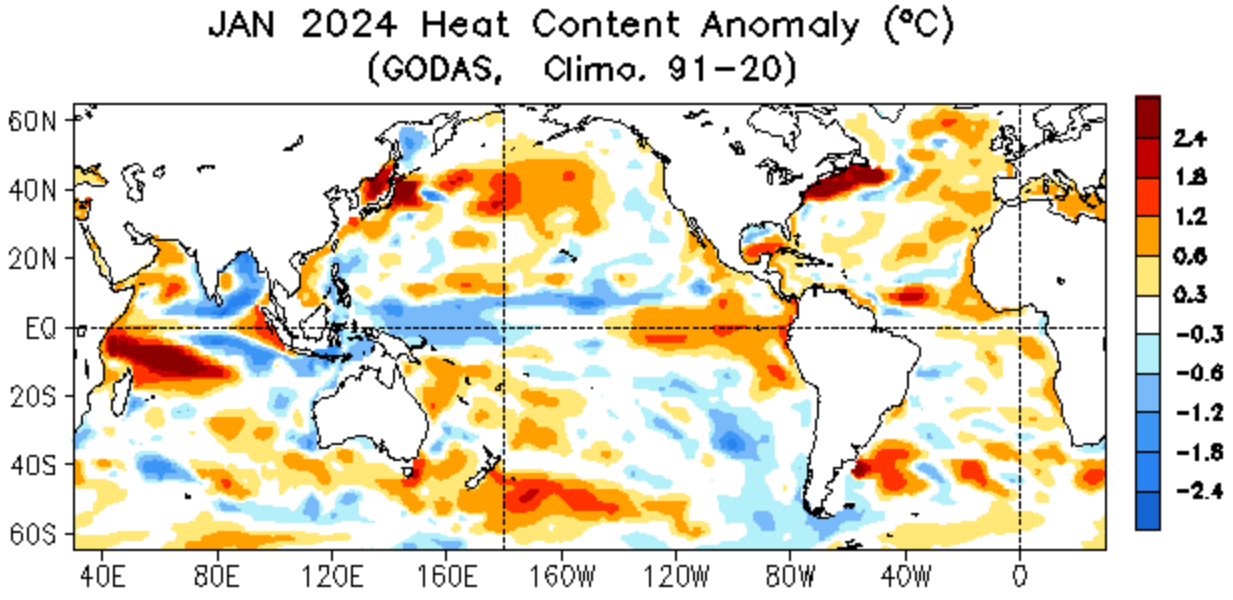
# Comparison of ERSSTv5 & OIv2.1 Niño3.4 Index

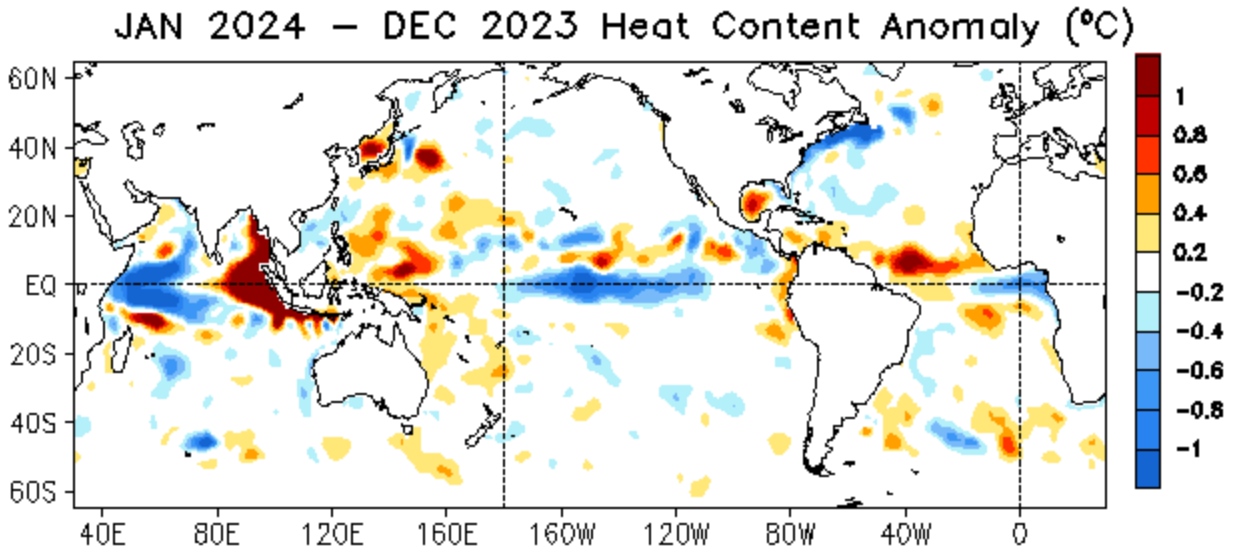


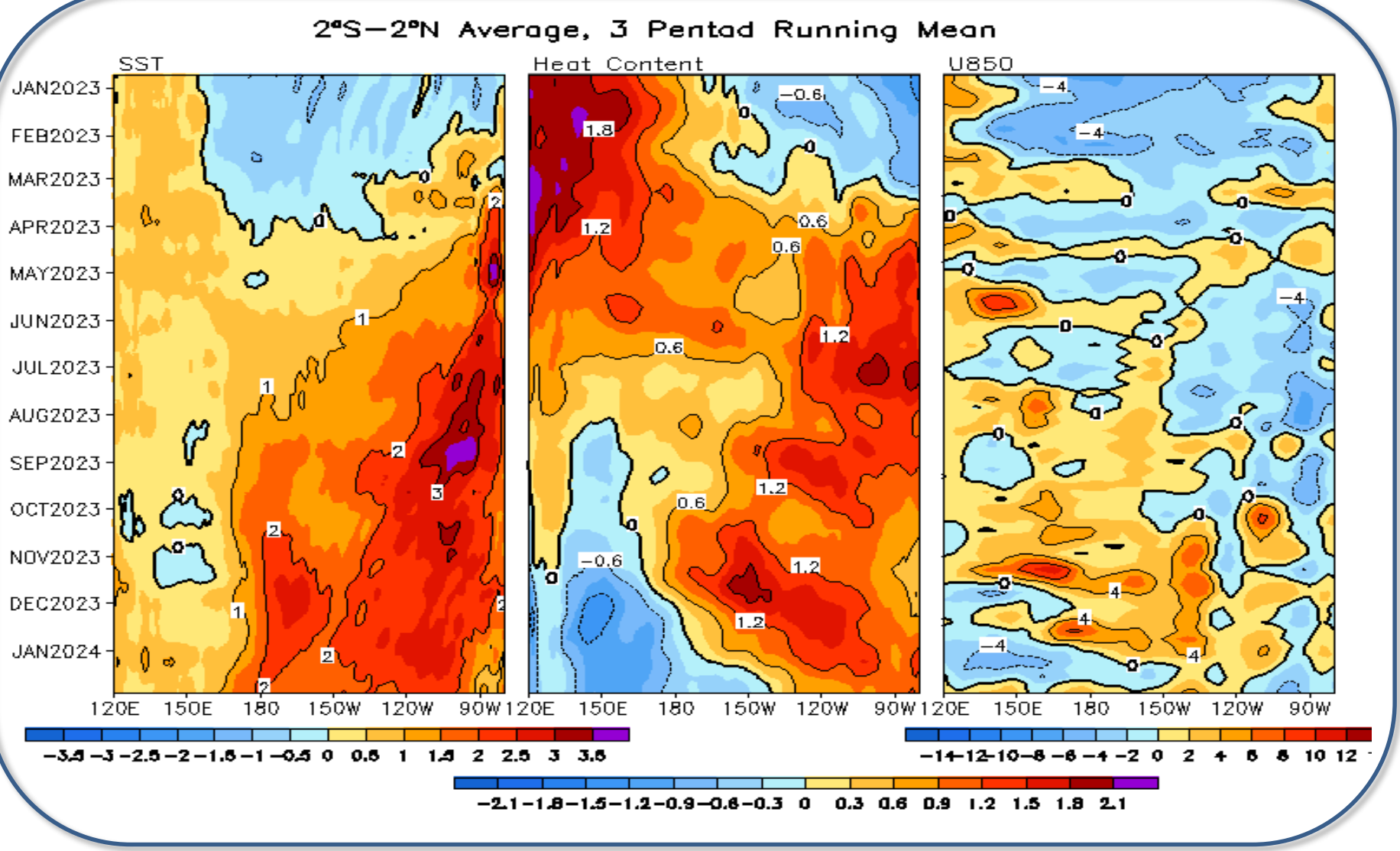

- During the last year, ERSSTv5 was close to OIv2.1.
- Sometimes, ERSSTv5 is either warmer or cooler than OIv2.1.
- For both the extreme positive and negative (>1.5°C or <-1.5°C) Niño3.4, ERSSTv5 is mostly warmer than OIv2.1.

# Global HC300 Anomaly & Anomaly Tendency



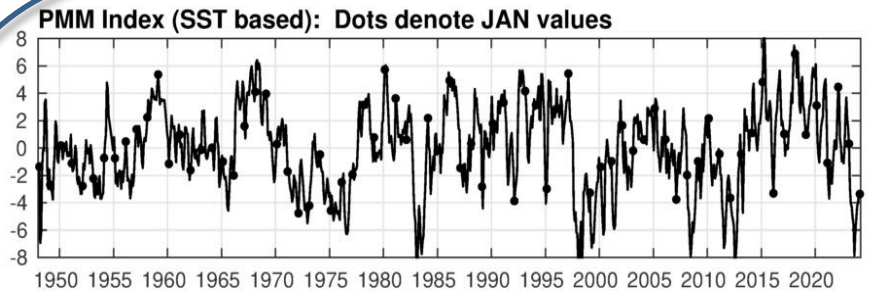



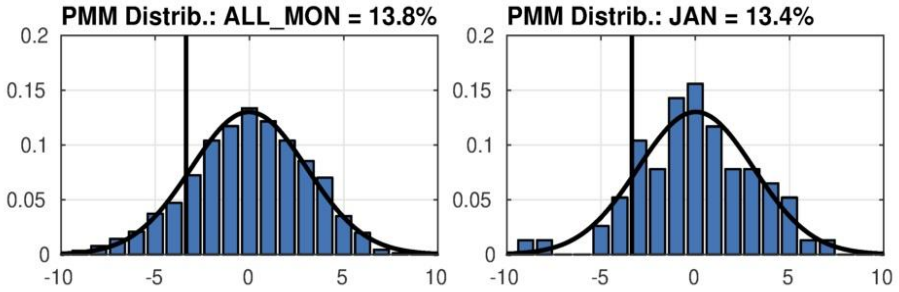
# Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) Anomalies

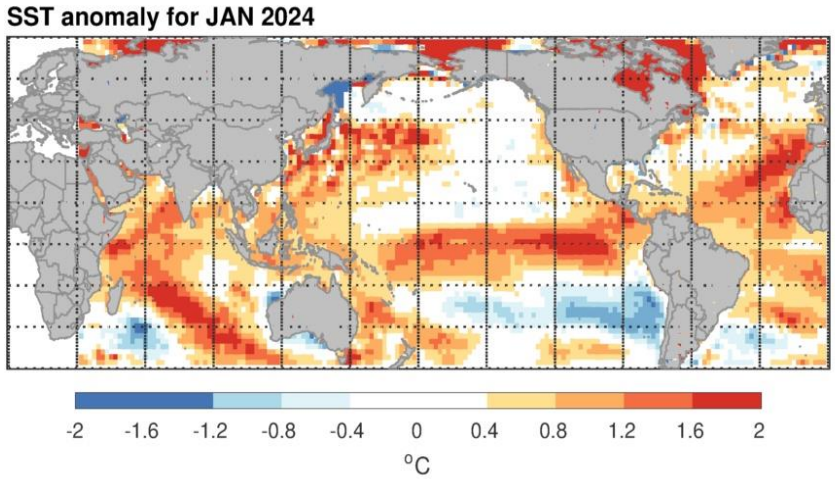



- Since Feb 2023, a set of westerly wind surges triggered downwelling Kelvin waves, reinforcing the subsurface warming in the central and eastern Pacific.

# Current Status of the Pacific Meridional Mode (PMM)

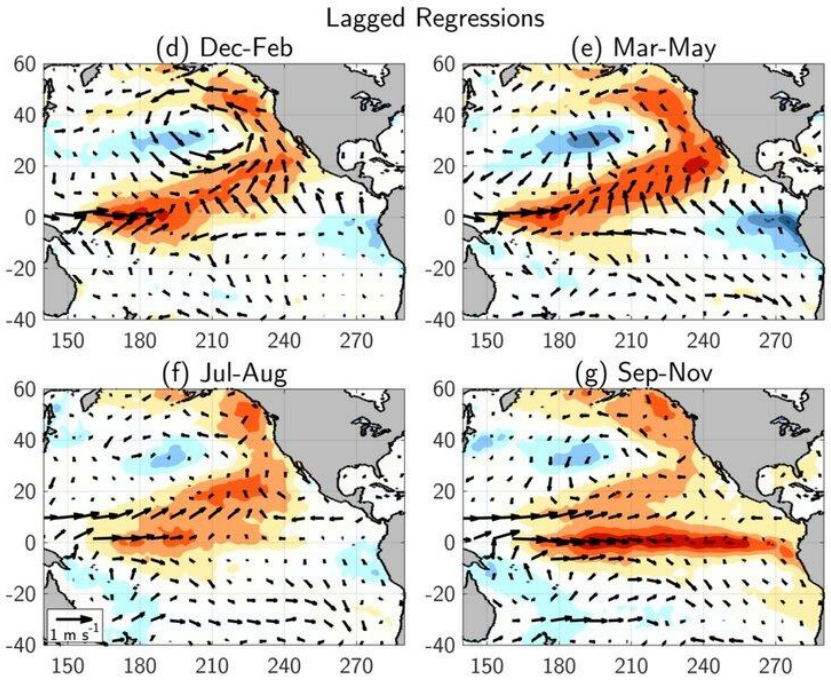


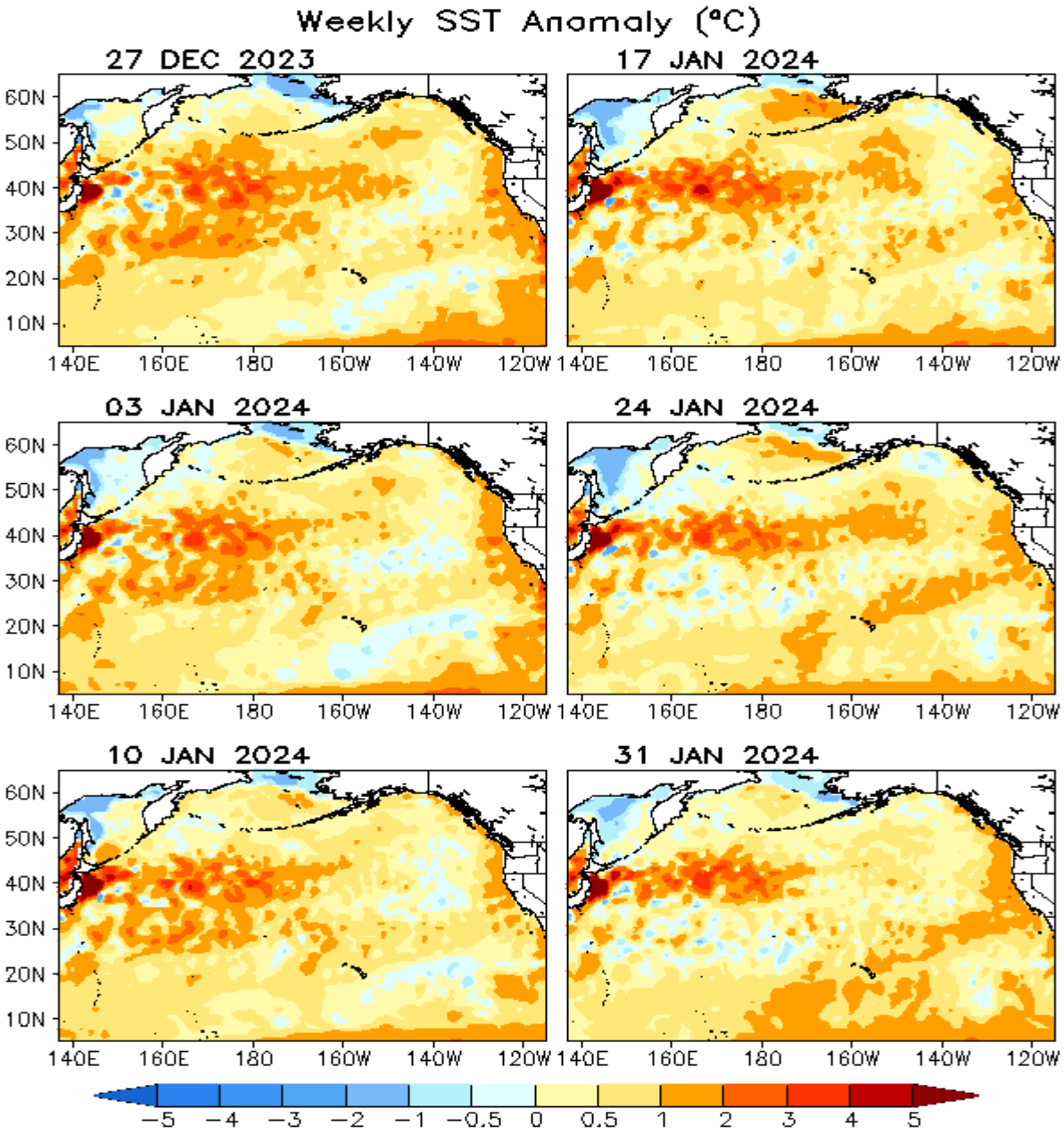

*https://www.aos.wisc.edu/~dvimont/MModes/PMM.html*

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



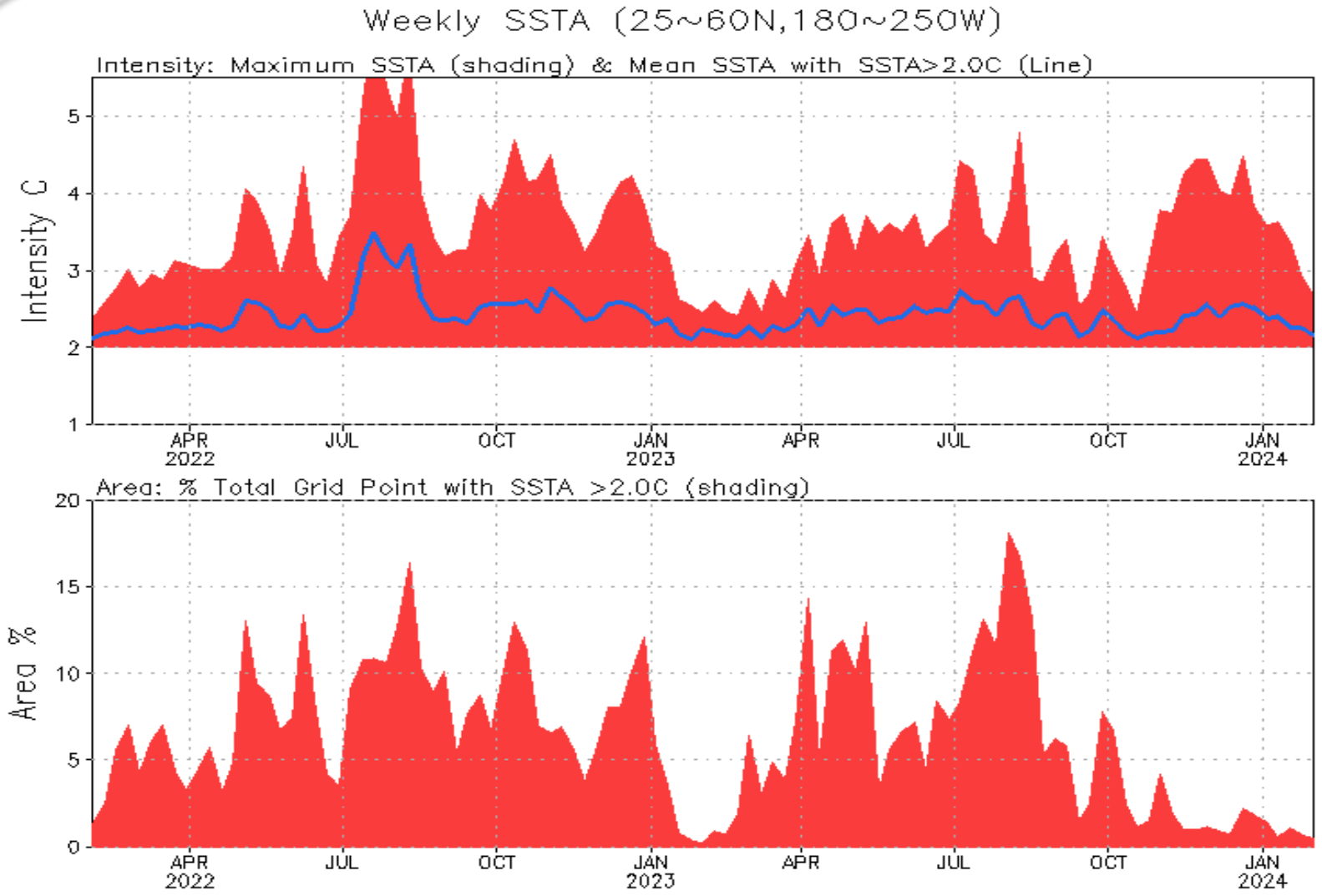

*Amaya, D. J., 2019: The Pacific meridional mode and ENSO: A review. Curr. Climate Change Rep., 5, 296–307, 10.1007/s40641-019-00142-x.*

# Weekly SSTA evolutions in the NE Pacific



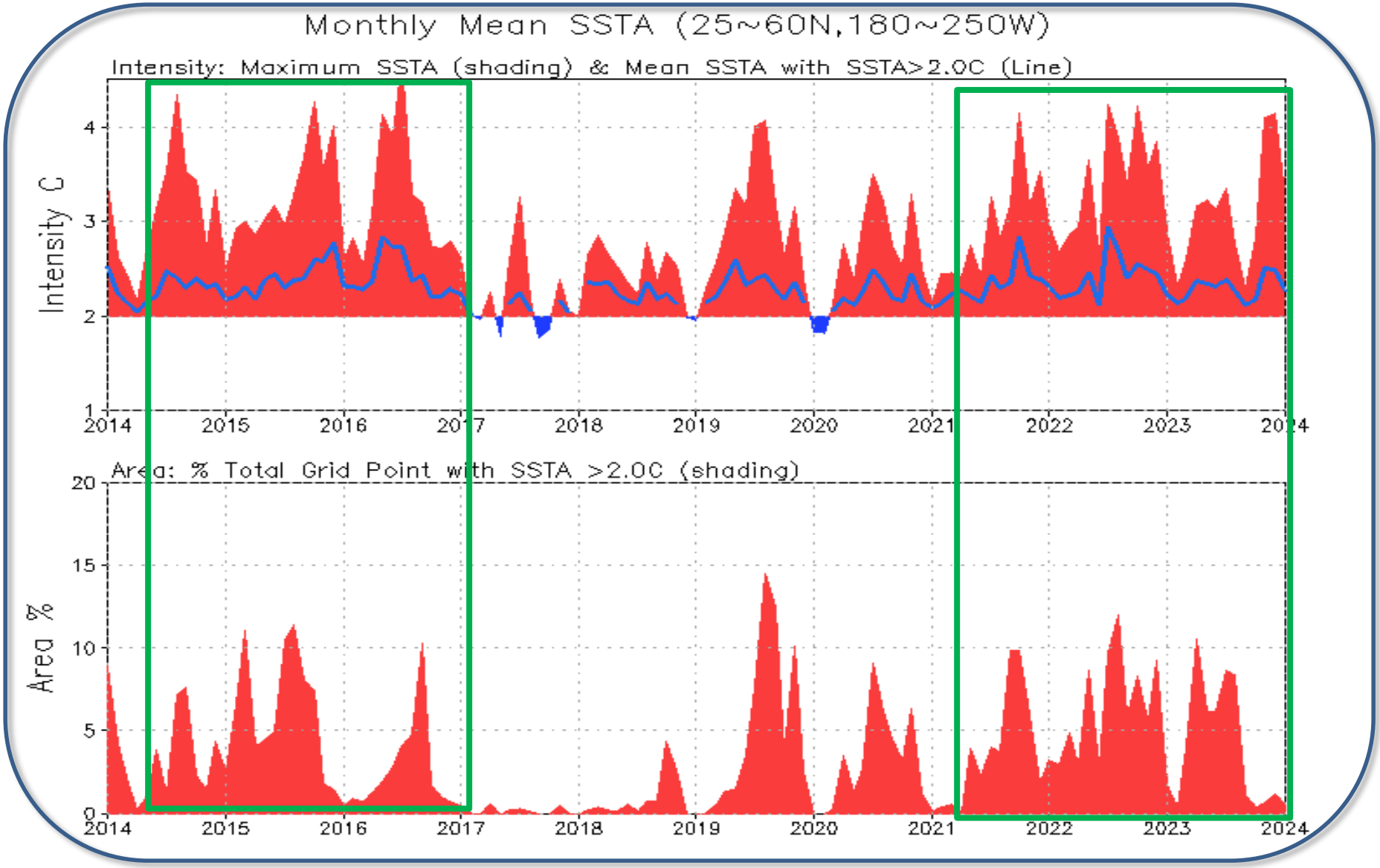

- Positive SST anomalies were persistent in the northern Pacific during the last six weeks.

# 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

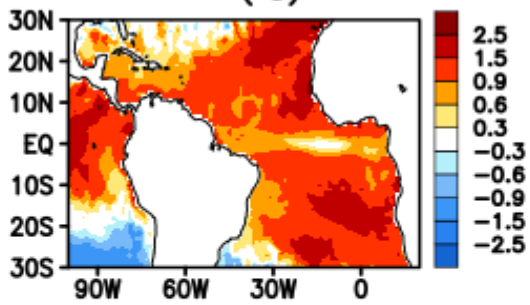
### Marine Heatwave Monitoring and Forecast

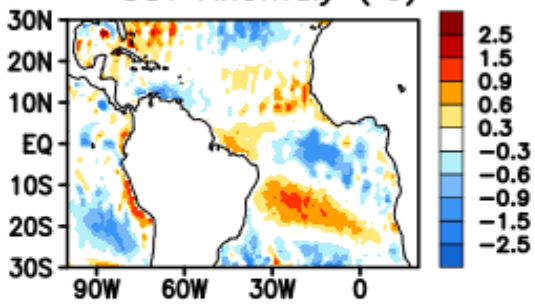
- **Indices & Time Series**
  - N. Pacific MHW Intensity & Area Indices: Weekly Monthly
  - Regional Mean SST: Global Monthly & Nino3.4 Since 1854 N. Pacific Weekly Gulf of Alaska & Subtropical Coast Weekly

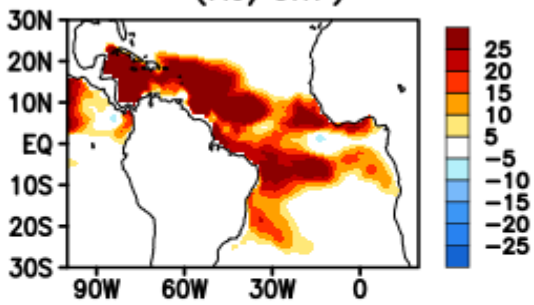
- **Spatial Distribution**
  - Global Monthly Anomaly
    - SST
  - N. Pacific Anomaly
    - Pentad Subsurface Ocean Temperature: 5m 55m 105m 155m
    - Weekly SST Weekly SST2
    - Pentad 300m Ocean Heat Content Pentad Ocean Surface Heigh Pentad Surface Heat Flux
    - 3-month SST, SLP, & UV925 SST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

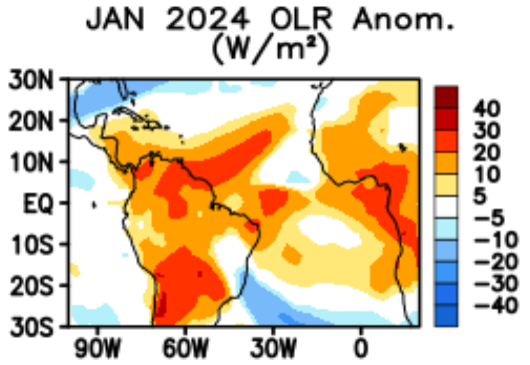
- **NMME & CFSv2 Forecasts**
  - Tropical N. Atlantic SSTA: NMME CFSv2
  - N. Pacific SSTA: NMME CFSv2
  - CFSv2: N. Pacific Sea Surface Height Anomaly
  - CFSv2 SSTA Index: Last month Last 9 months

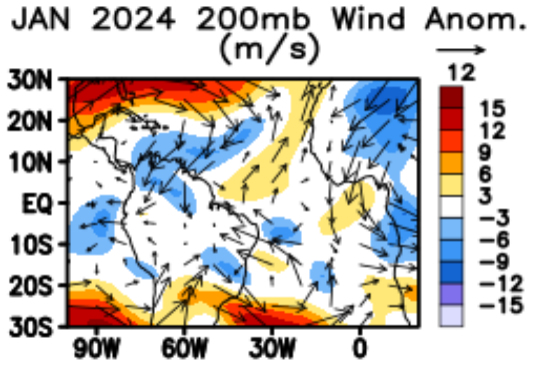
# Tropical Atlantic: SST, SST tend., TCHP, OLR, 200 hPa wind, wind share, heat flex, & RH anom.

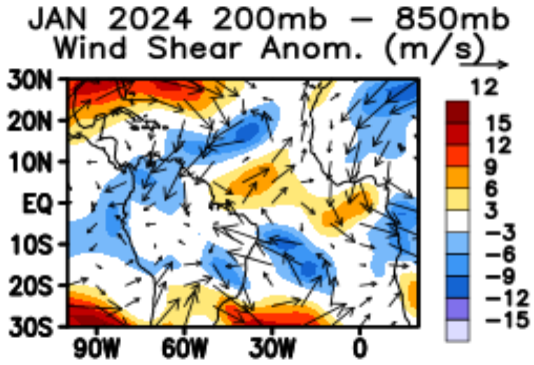


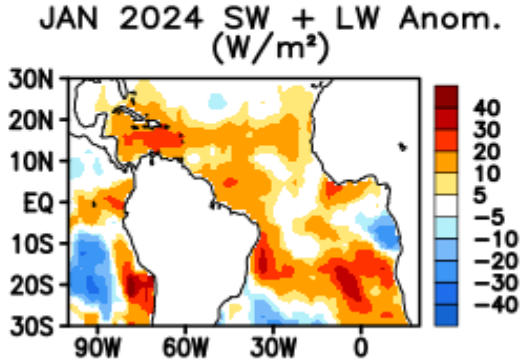



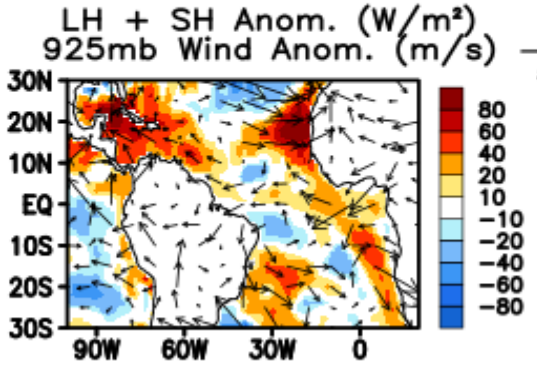



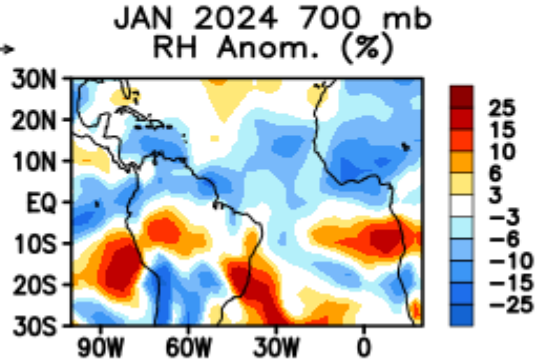



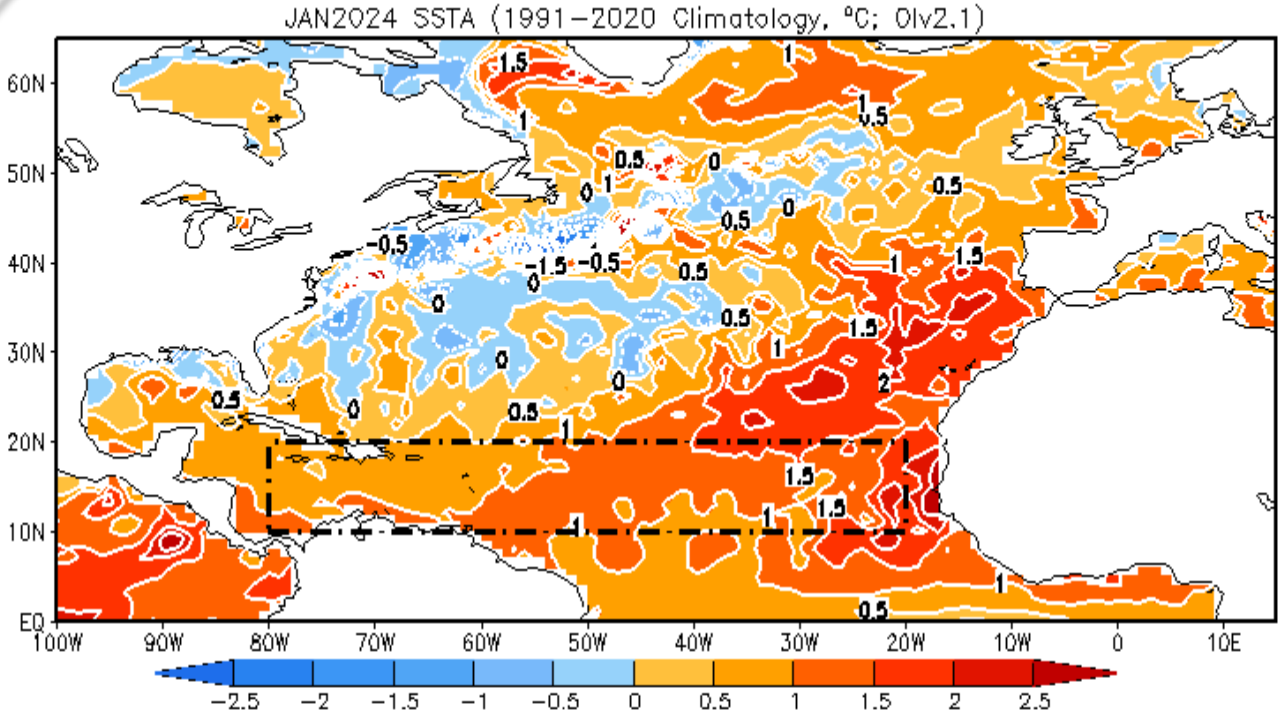



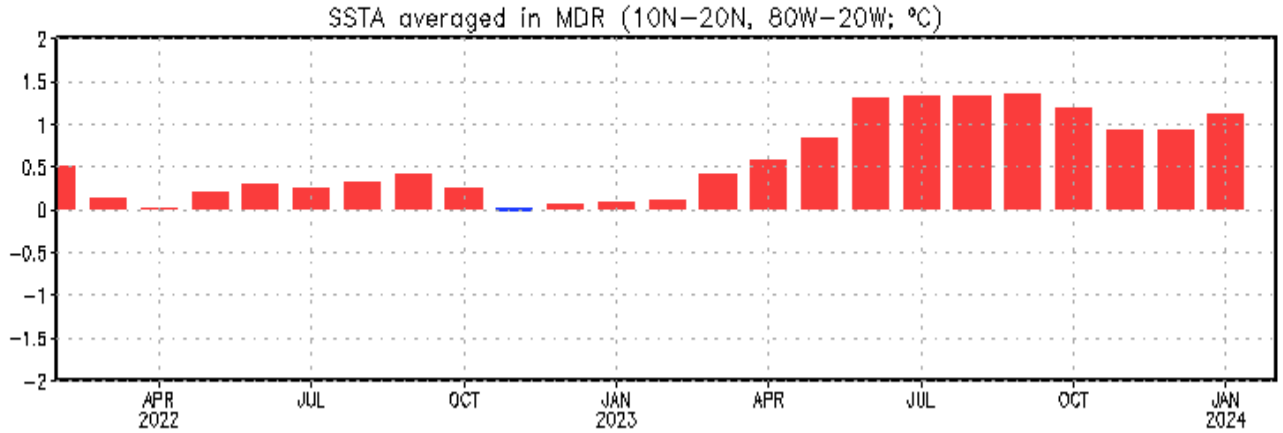



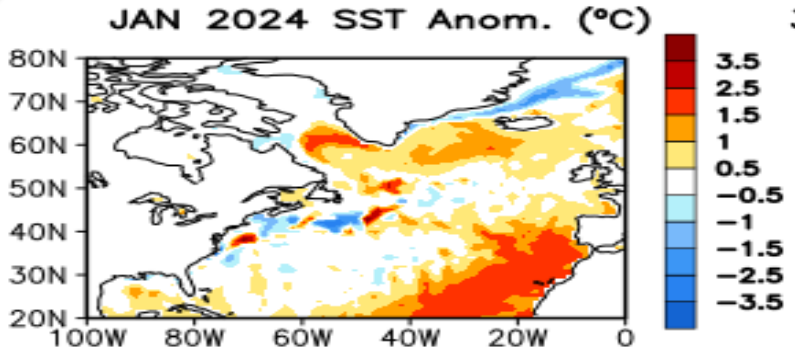
# SSTAs in the North Atlantic & MDR

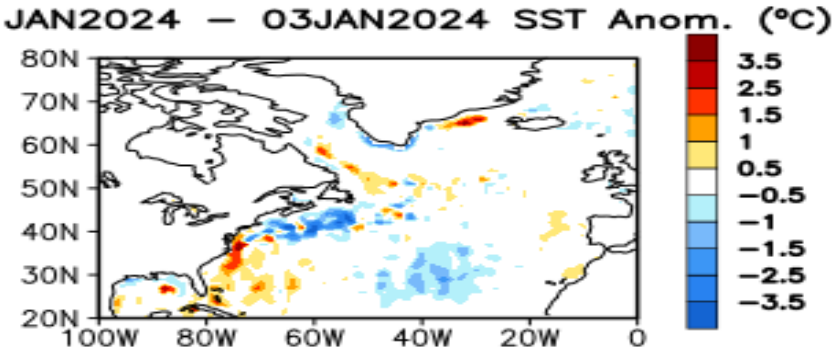


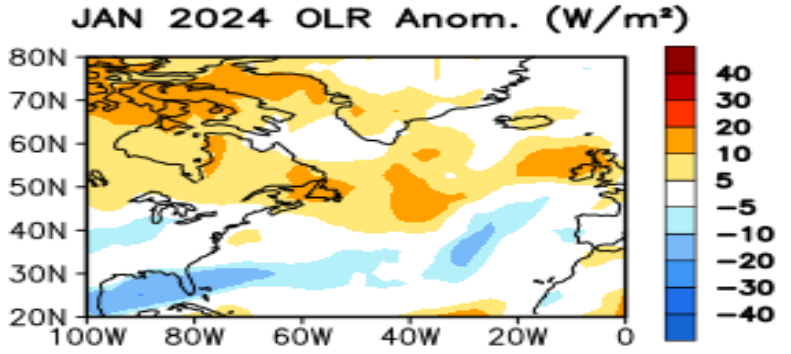



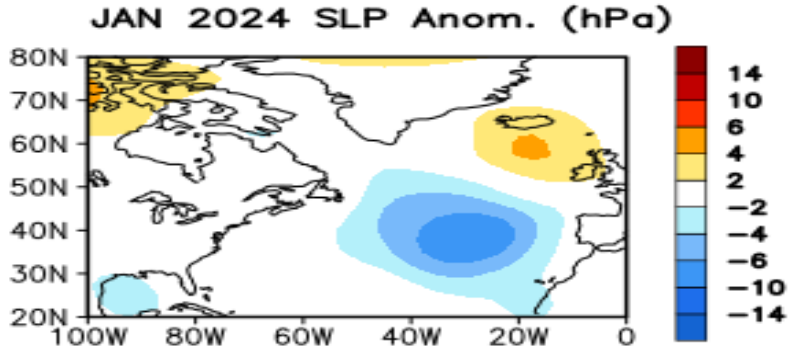

- SST in MDR was above average during the last 14 months.

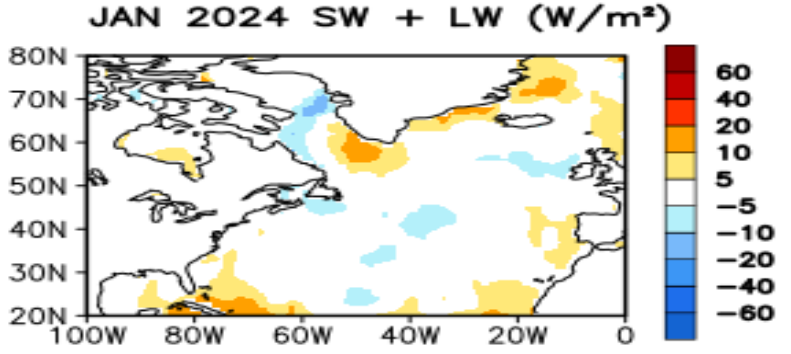
# N. Atlantic: SST, SST tend., OLR, SLP, & heat flex anom.

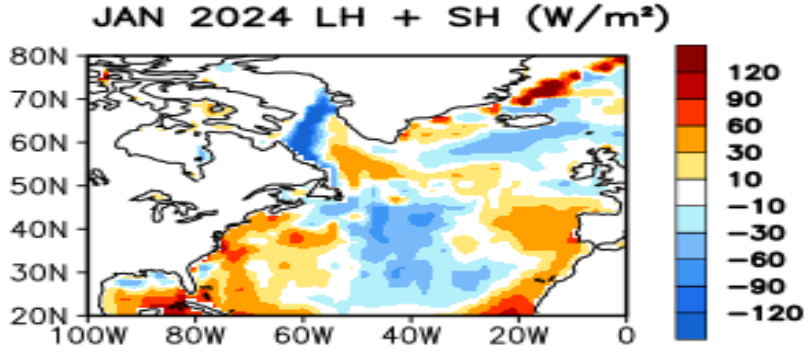


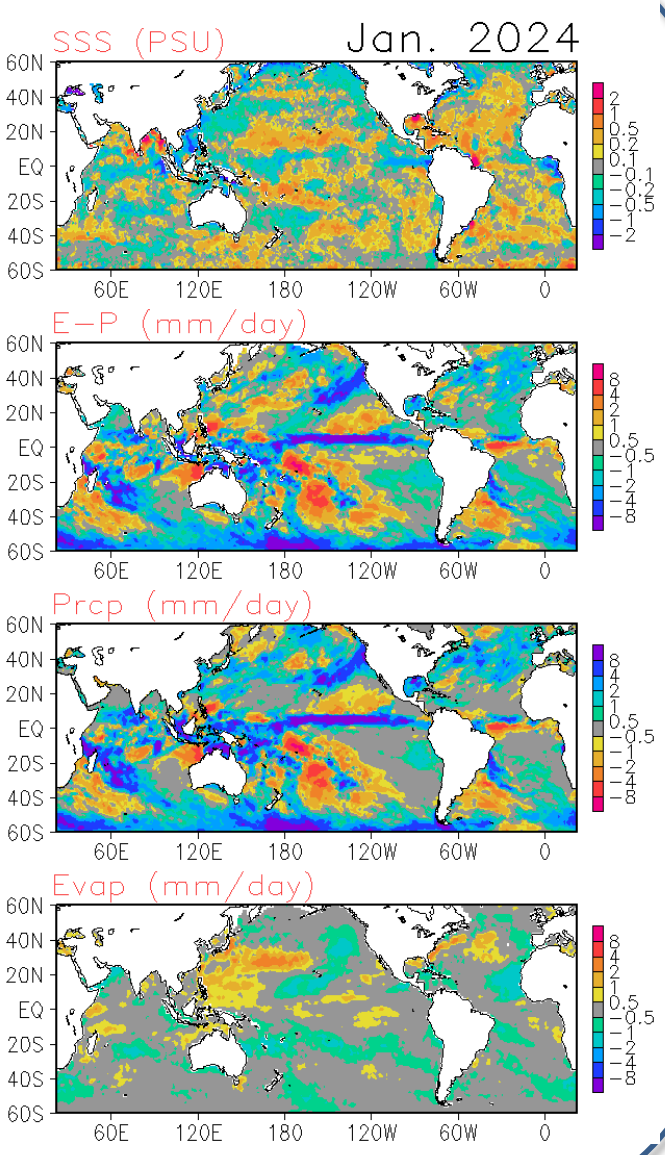



# Global Sea Surface Salinity (SSS): Anomaly for January 2024

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

**Enhanced precipitation anomalies (negative E-P anomalies) appear across the tropical Pacific. Over the tropical Atlantic, ITCZ is shifted northward from its climatological position. SSS anomalies are present over the region, largely influenced by the fresh water flux there, partially contributing to the SSS anomalies there. In the same time, saltier SSS anomalies exhibit over the Golf of Mexico and the Bay of Bengal, likely results of multiple factors including river run-off, precipitation and oceanic processes.**



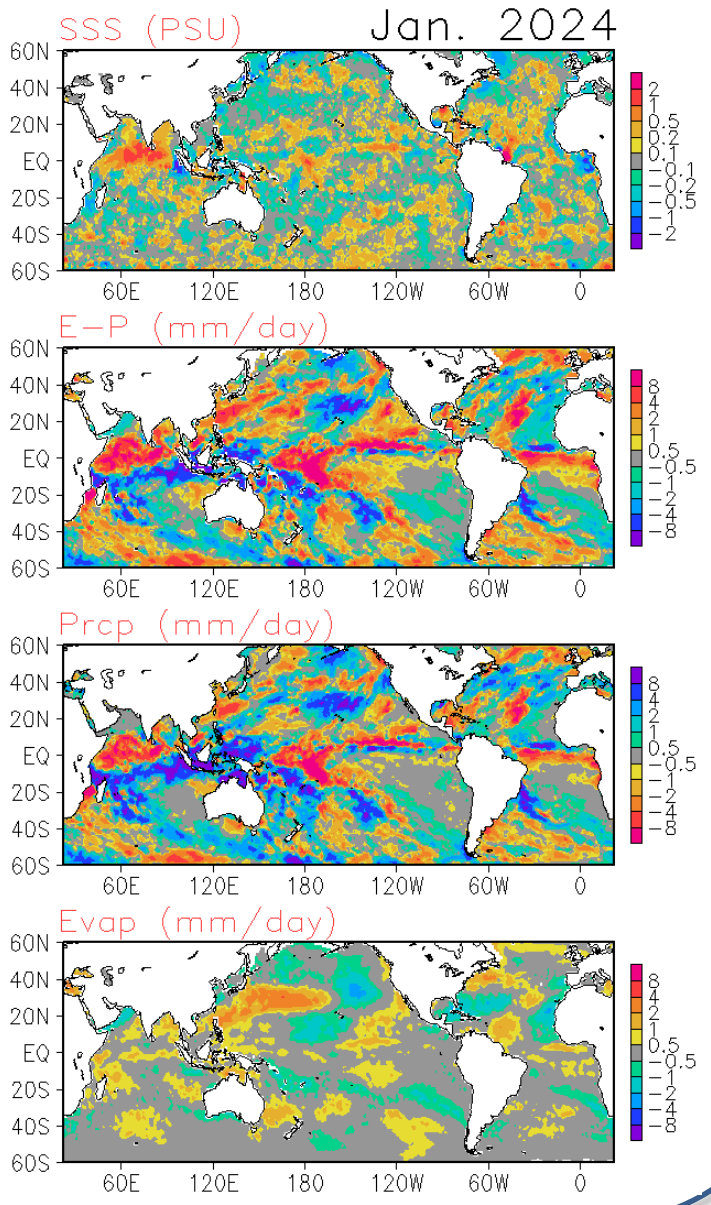

**SSS : Blended Analysis of Surface Salinity (BASS) V0.Z**
**(a CPC-NESDIS/NODC-NESDIS/STAR joint effort)**
**ftp.cpc.ncep.noaa.gov/precip/BASS**

**Precipitation: CMORPH adjusted satellite precipitation estimates**

**Evaporation: Adjusted CFS Reanalysis**

# Global Sea Surface Salinity (SSS): Tendency for January 2024

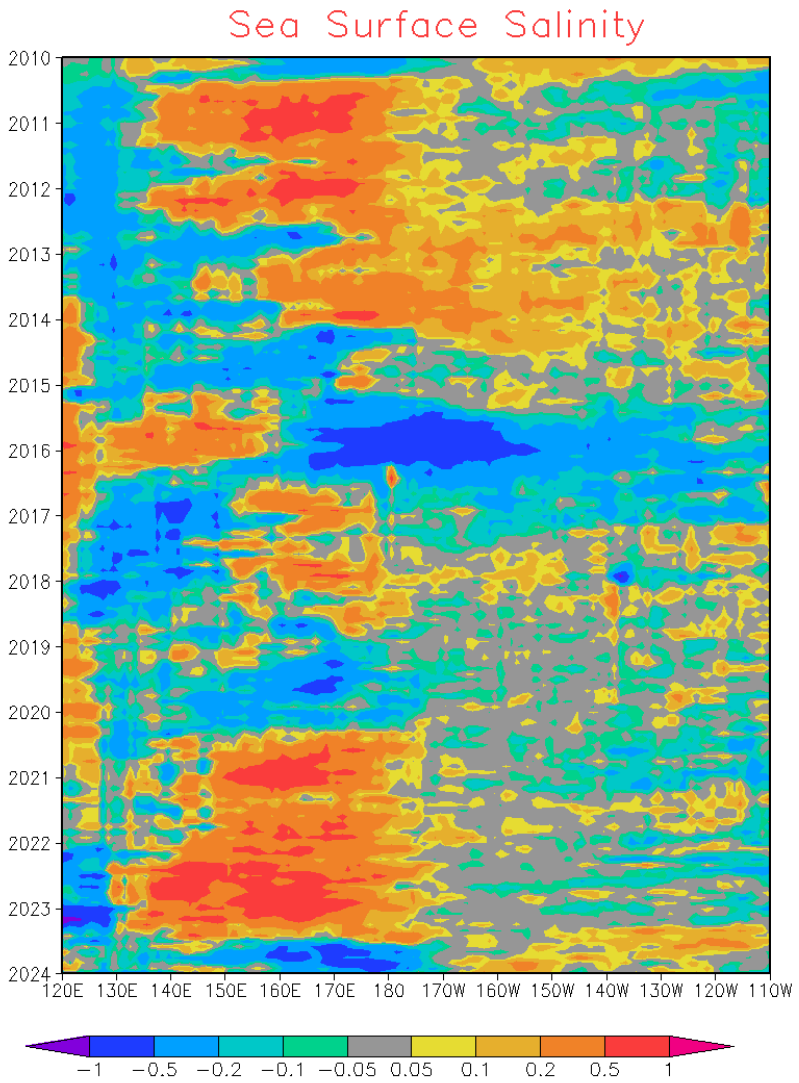
Precipitation (and freshwater flux) anomalies are enhanced over the Maritime Continent but weakened over the equatorial central Pacific. Over the eastern Pacific, positive precipitation anomalies shifted slightly southward to a position closer to the equator. Over the equatorial Atlantic, the ITCZ moved northward, producing zonally oriented parallel lines of positive / negative precipitation tendencies there. Over the Indian ocean, a dry precipitation tendency is observed. Tendencies of SSS anomalies can be seen over these regions as a response to the above mentioned precipitation (freshwater flux) tendencies.



# 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);**
- Freshened SSS anomalies are weakened over the western and central Pacific during January 2024. SSS anomalies over the equatorial eastern Pacific present mixed signs and are not very strong in general.



# 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.