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

Prepared by

Climate Prediction Center, NCEP/NOAA

February 10, 2023

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

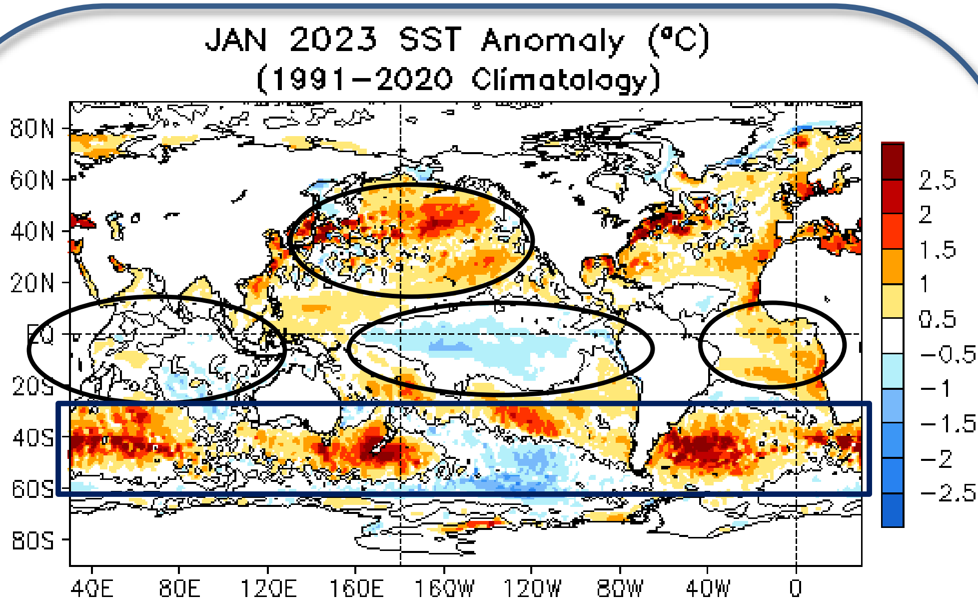
- Overview
- Recent highlights
  - Pacific/Arctic Ocean
  - Indian Ocean
  - Atlantic Ocean
- Global SSTA Predictions
- 2022 Annual Review

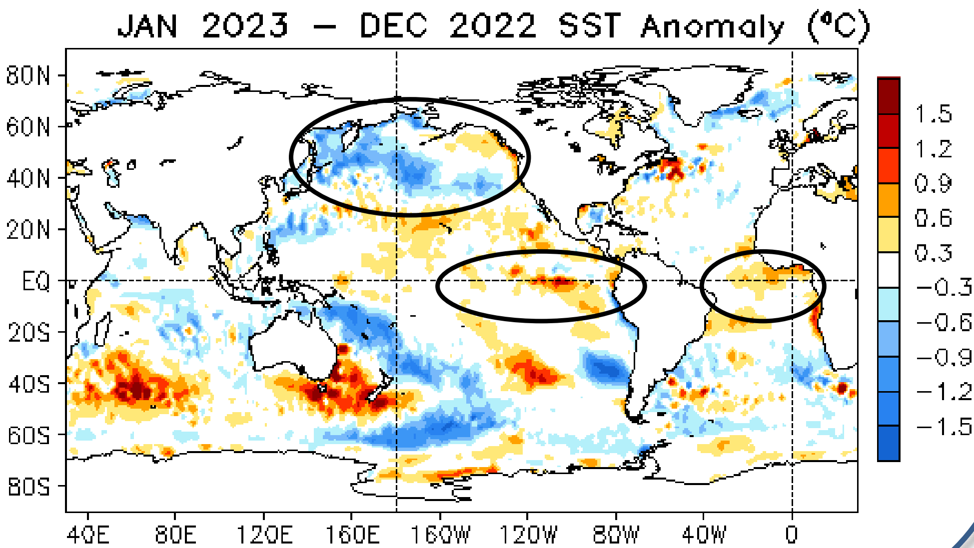
Overview

- Pacific Ocean
  - NOAA "ENSO Diagnostic Discussion" on 9 Feb 2023 stated "*ENSO-neutral conditions are expected to begin within the next couple of months, and persist through the Northern Hemisphere spring and early summer.* "
  - La Niña condition persisted, but weakened with Niño3.4 = -0.74^{o}C in Jan 2023.
  - Positive SSTAs weakened in the North Pacific in Jan 2023.
  - The PDO has been in a negative phase since Jan 2020 with PDOI = -0.96 in Jan 2023.
- Arctic Ocean
  - The Jan 2023 average Arctic sea ice extent was 13.35 million square kilometers, the third lowest Jan in the satellite record.
- Indian Ocean
  - Positive (negative) SSTAs were in the western (southeastern) tropical Indian Ocean in Jan 2023.
- Atlantic Ocean
  - NAO switched to a positive phase in Jan 2023 with NAOI= 0.95.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency



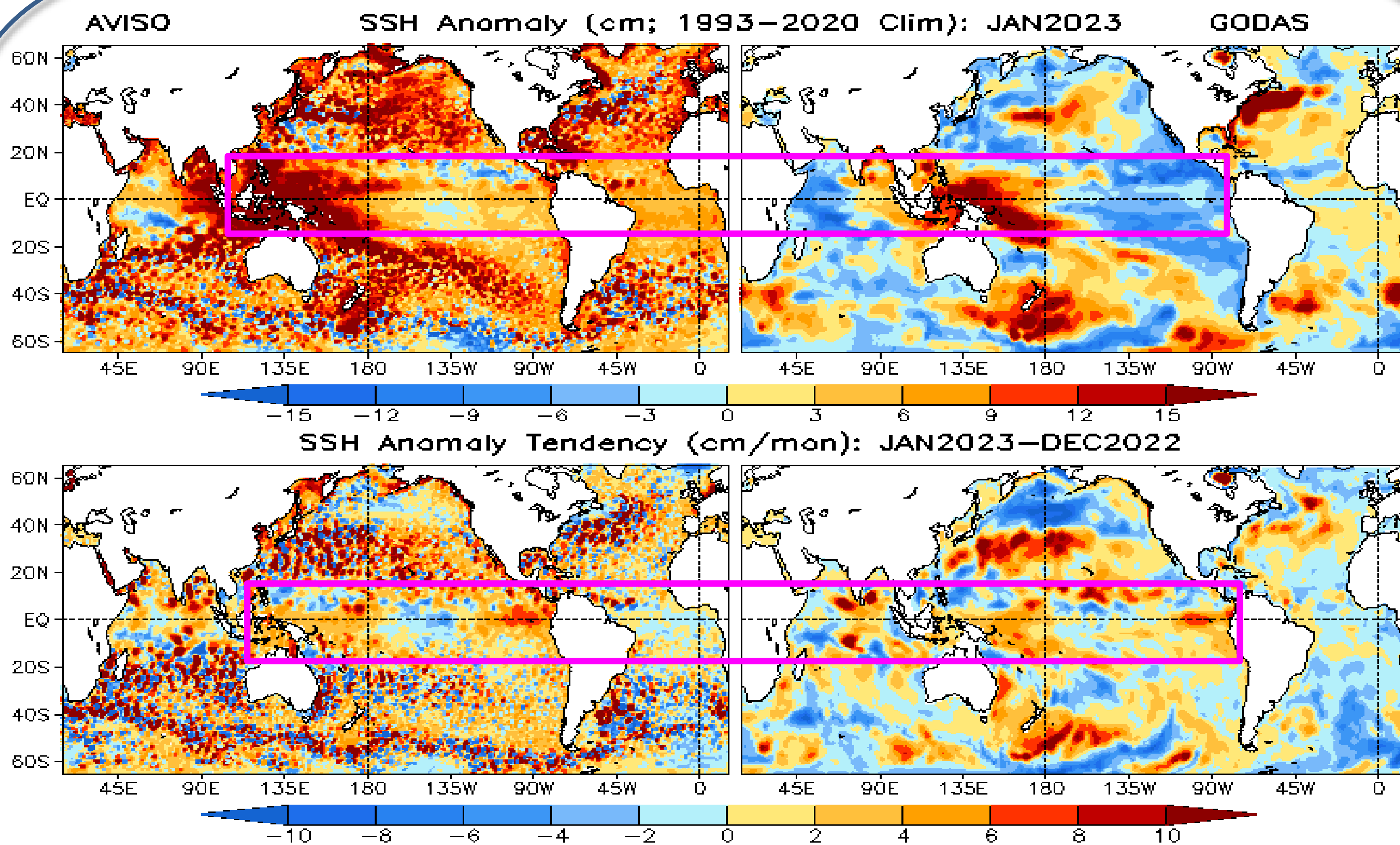


- Negative SSTAs still presented in the eastern equatorial Pacific.
- Positive SSTAs were observed in the North Pacific.
- Positive SSTAs were present in the central and eastern tropical Atlantic.
- Weak positive (negative) SSTAs were in the western (southeastern) tropical Indian Ocean.
- Appreciable positive and negative SSTAs were seen in the middle-latitudes of the Southern Hemisphere.

- Positive SSTA tendencies were observed in the eastern and west-central equatorial Pacific.
- Negative SSTA tendencies were evident in the North Pacific.
- Positive SSTA tendencies were in the eastern tropical Atlantic Ocean.

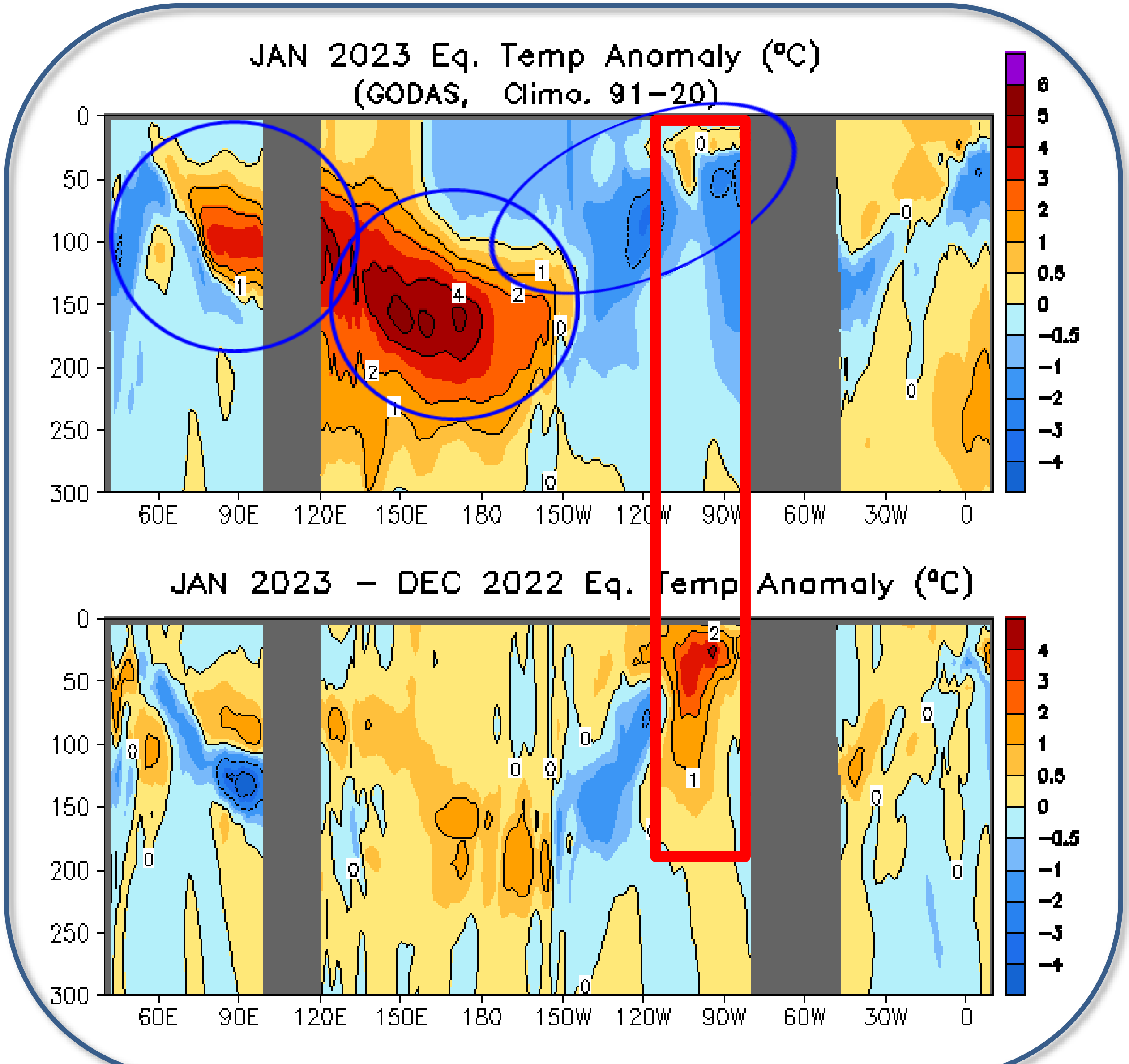
SSTAs (top) and SSTA tendency (bottom). Data are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

AVISO & GODAS SSH Anomaly (cm) and Anomaly Tendency



- SSHAs were still featured with a La Niña pattern in the tropical Pacific. However, the tendencies indicated a weakening tendency of the negative SSH anomalies in the eastern tropical Pacific.

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

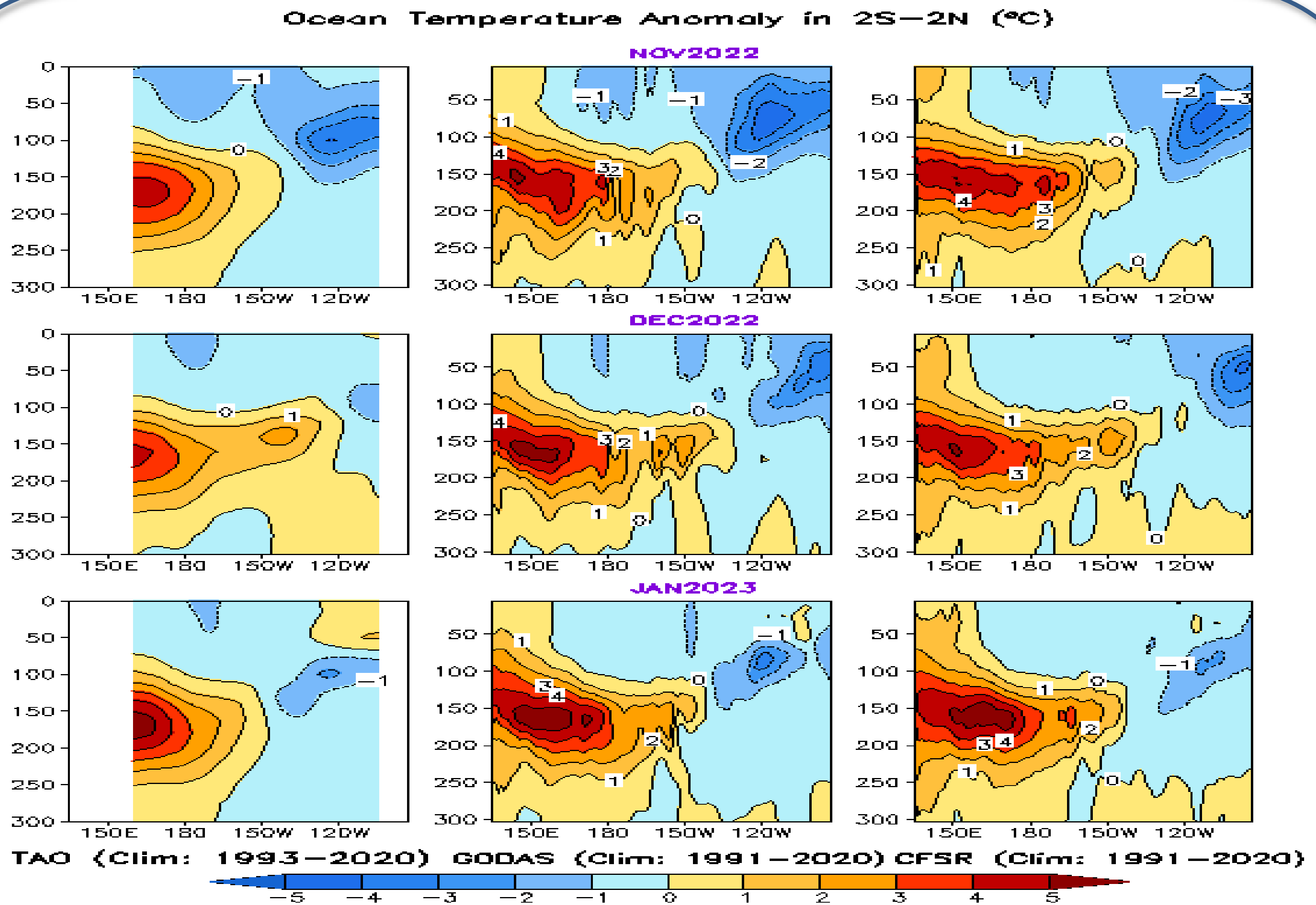


- Negative (positive) temperature anomalies presented along the thermocline in the eastern (western and central) equatorial Pacific.
- Positive (negative) temperature anomalies were observed in the eastern (western) equatorial along the thermocline in the Indian Ocean.

- Temperature anomaly tendency was positive along the thermocline in the eastern Pacific.

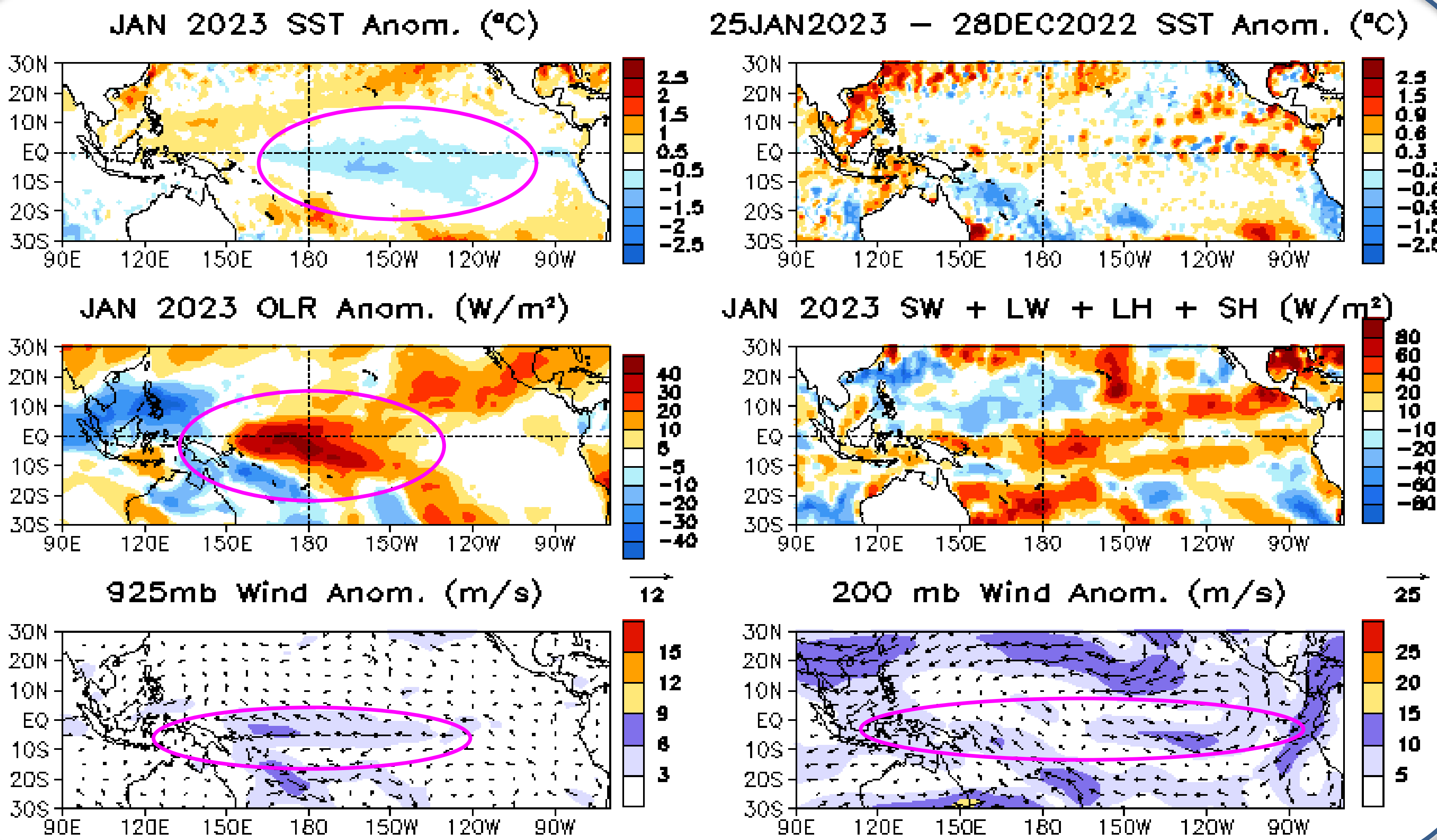
Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data is from the NCEP's GODAS. Anomalies are departures from the 1991-2020 base period means.

Monthly mean subsurface temperature anomaly along the Equator: Consistent among 3 products and a weakening tendency of the cooling



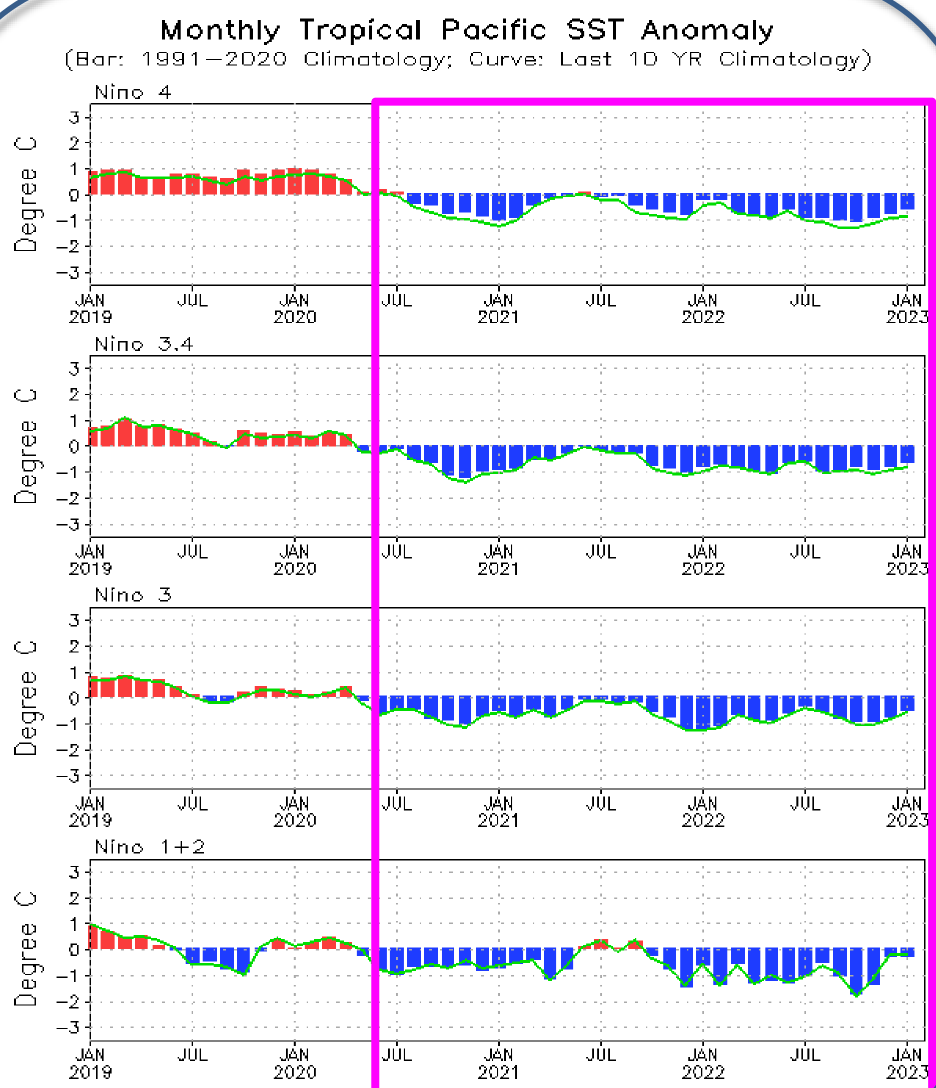
Tropical Pacific Ocean and ENSO Conditions

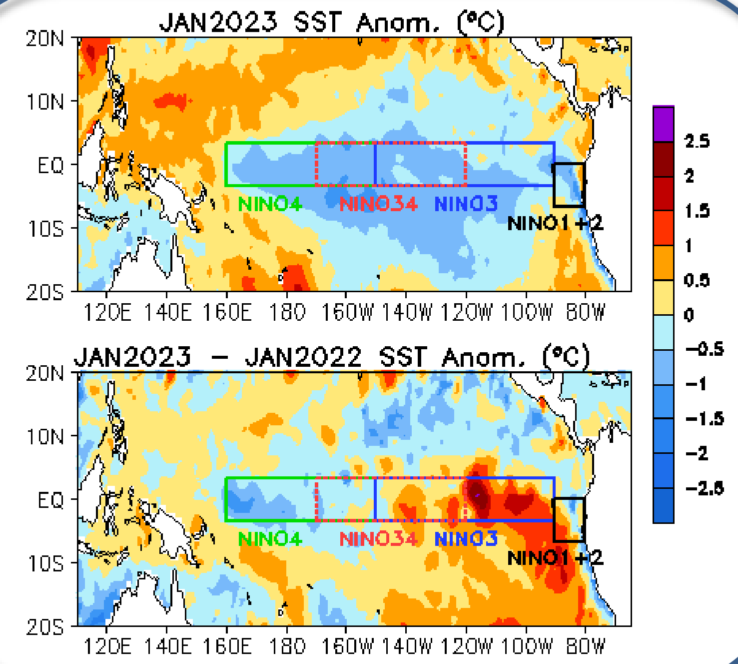
Tropical Pacific: SSTA, SSTA Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Winds



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





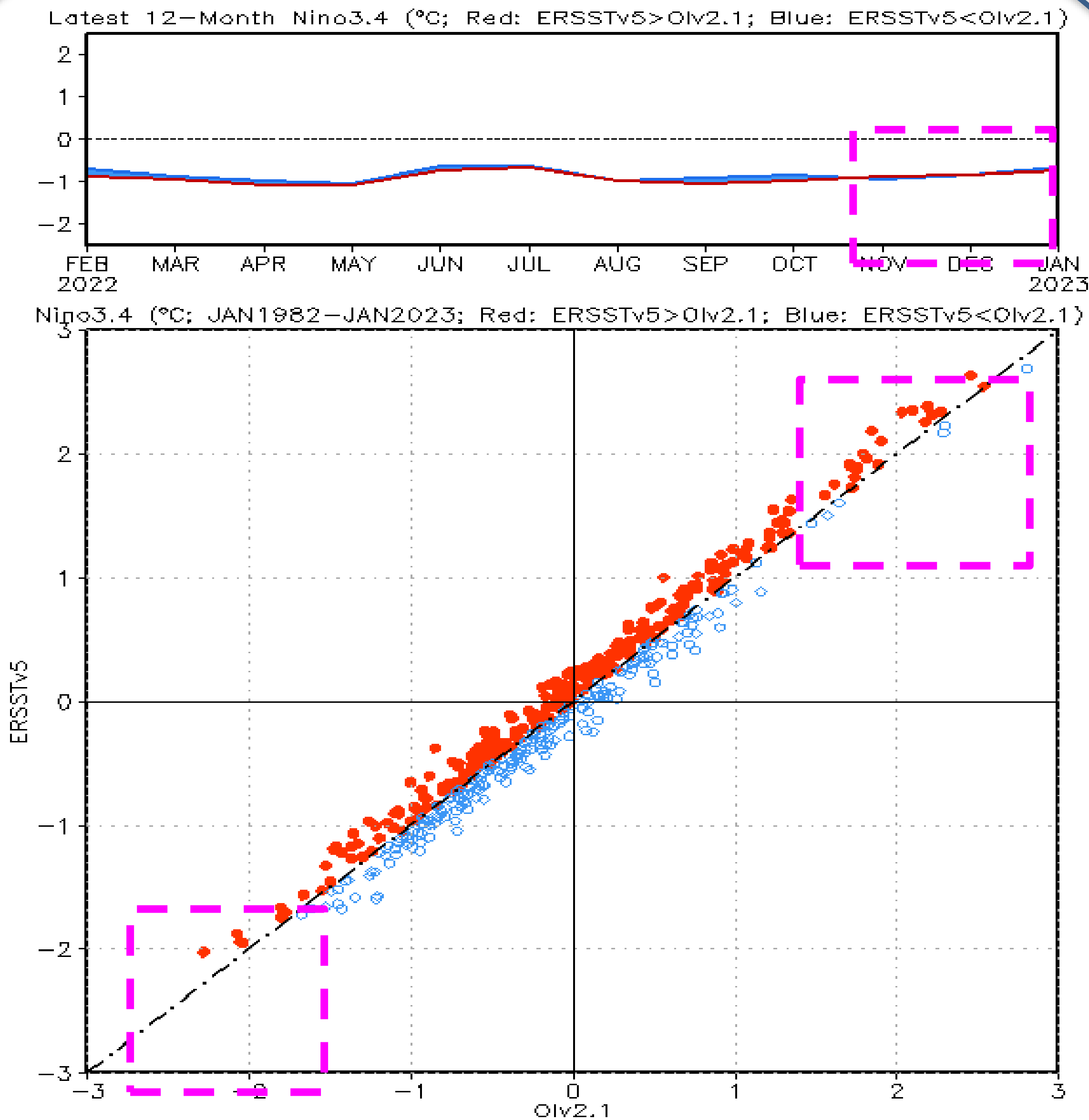
- Except for Nino1+2, all Niño indices weakened in Jan 2023, with Niño3.4 = -0.69C (OIv2.1) and -0.74C (ERSSTv5).

- Compared with Jan 2022, the central and eastern equatorial Pacific was warmer in Jan 2023.

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

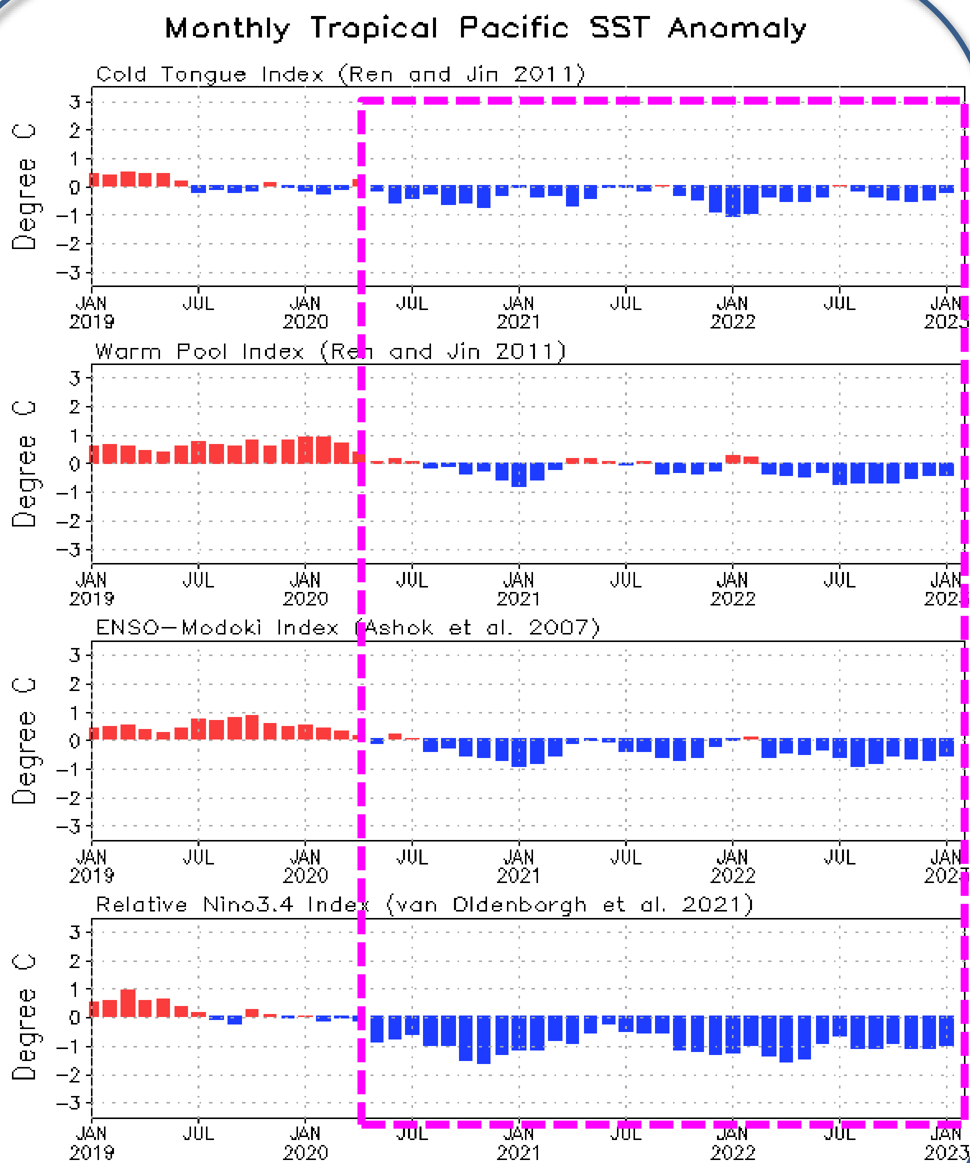
Niño region indices, calculated as the area-averaged monthly mean SSTAs (°C) for the specified region. Data are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020 base period means.

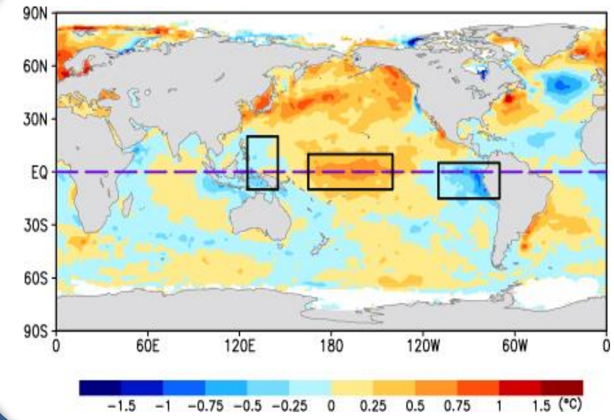
Comparison of ERSSTv5 & OIv2.1 Niño3.4 Index



- Historically, ERSSTv5 can be 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.
- During last few months, ERSSTv5 was similar to OIv2.1.

Evolution of Pacific Niño SST Indices





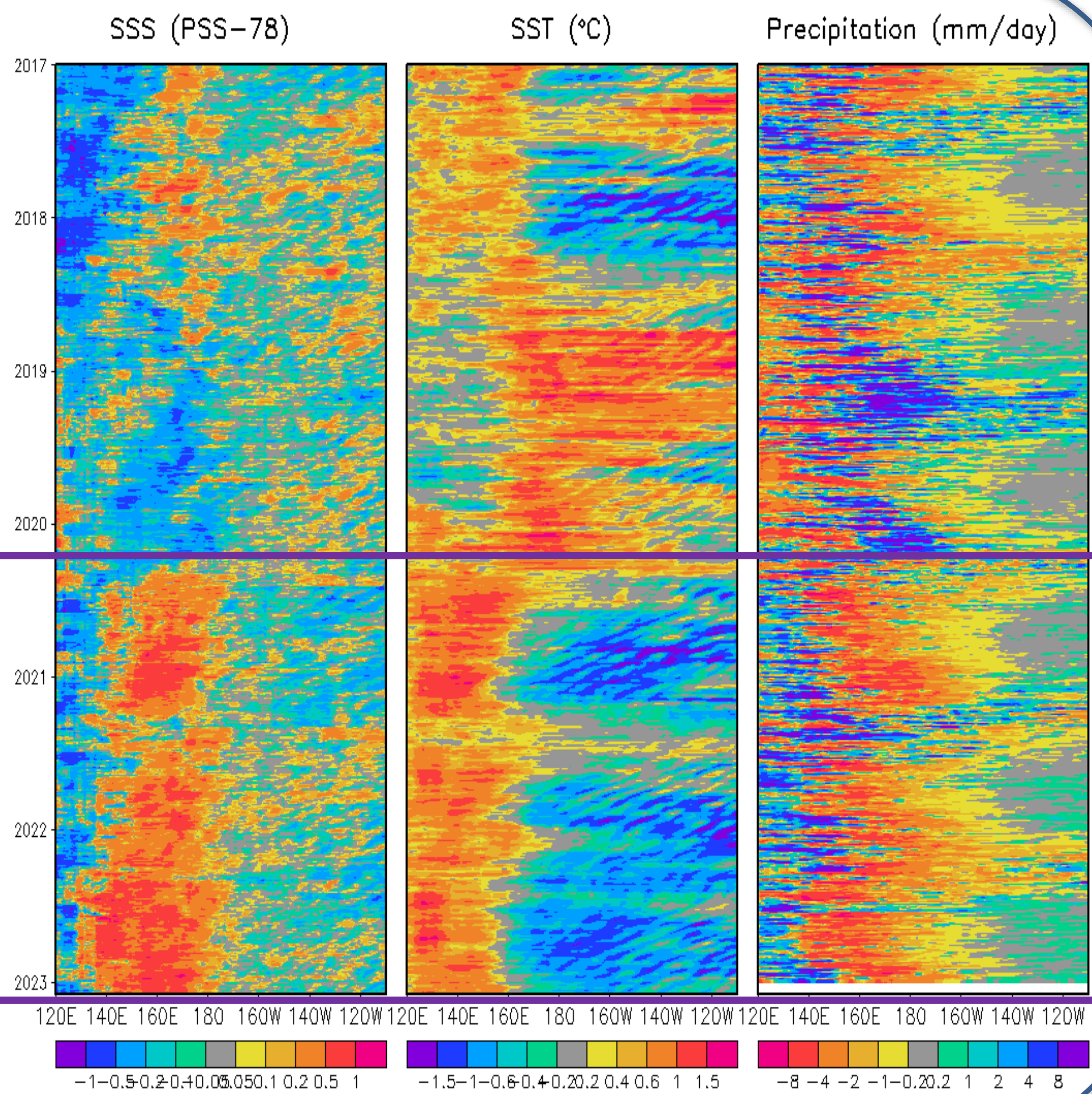
- Relative Niño3.4 index is now included in ENSO monitoring, which is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0º-360º, 20ºS-20ºN), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative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

Relative Niño3.4 data updated monthly at:

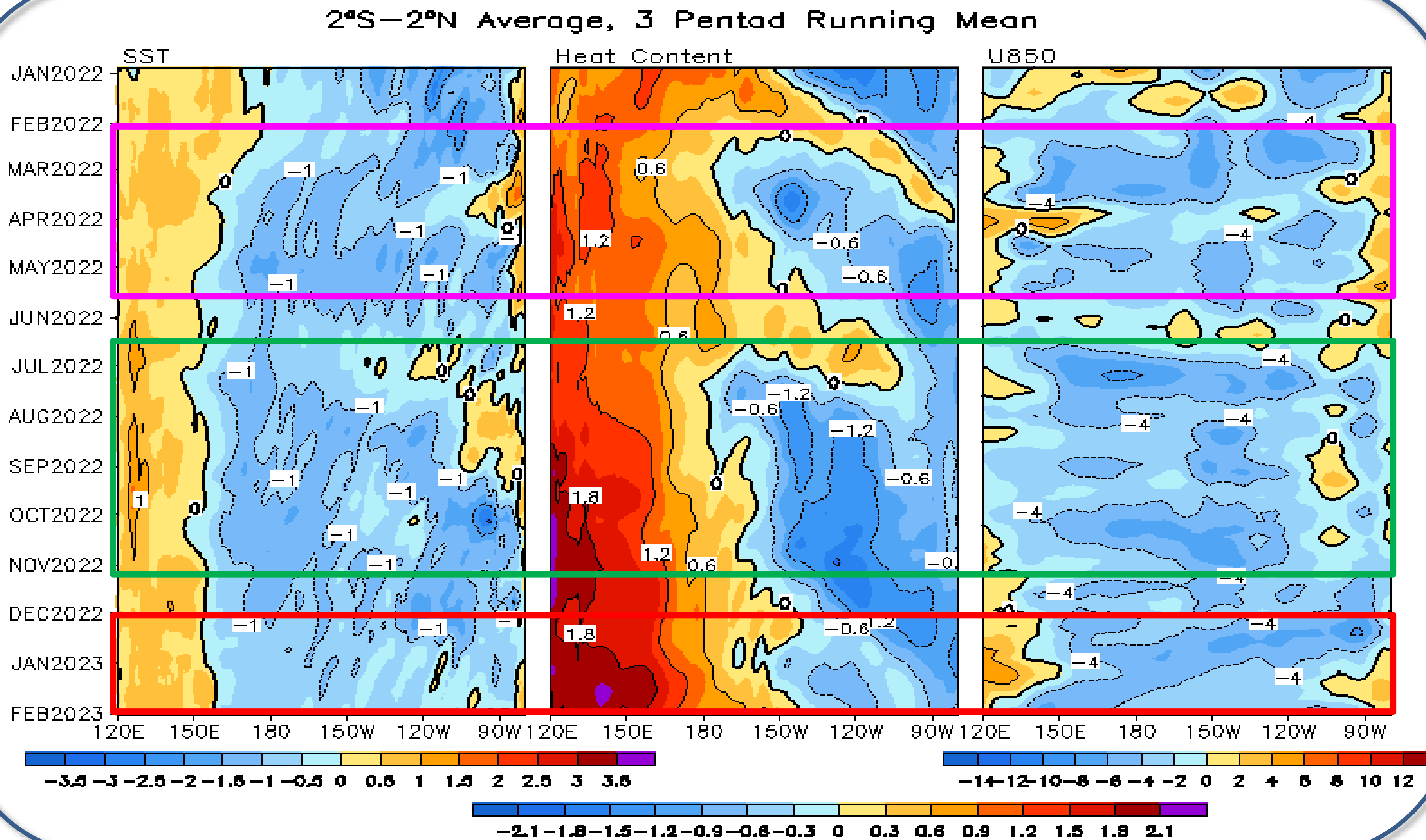
https://www.cpc.ncep.noaa.gov/data/indices/RONI.ascii.txt

Pentad SSS Anomaly Evolution over Equatorial Pacific

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

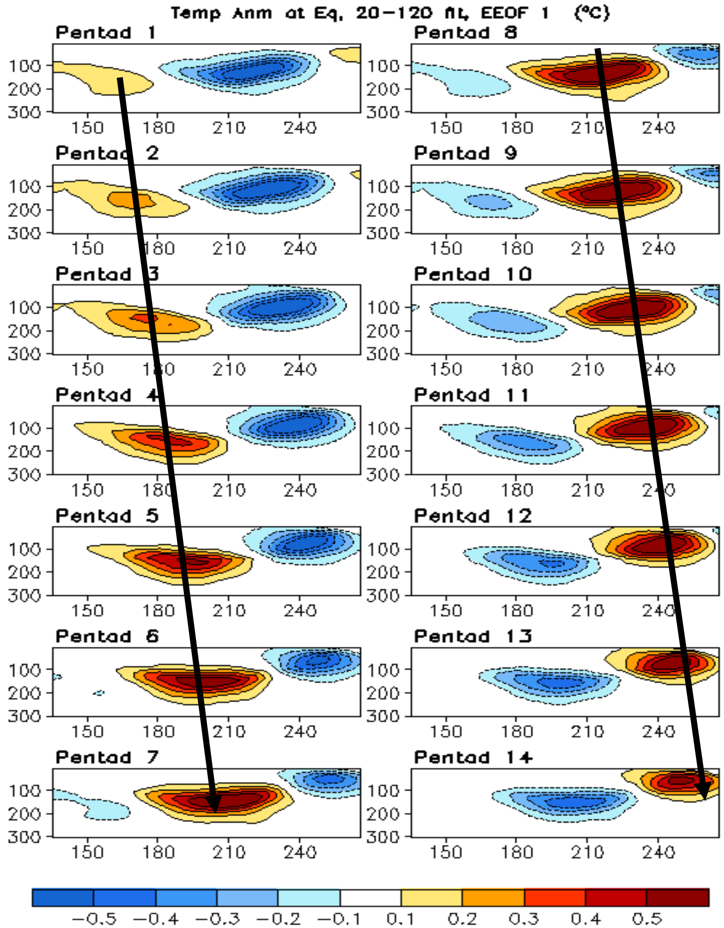


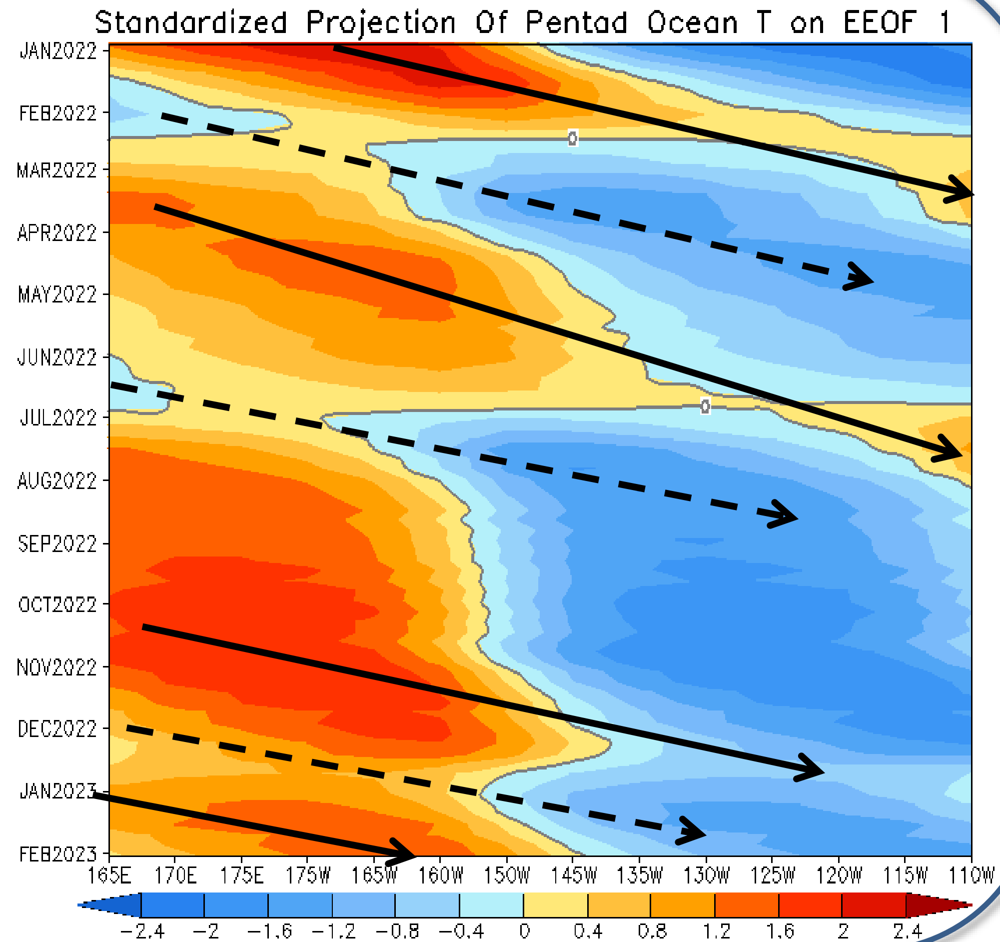
Equatorial Pacific SST (ºC), HC300 (ºC), u850 (m/s) Anomalies



- The evolution of the triple-dip La Niña SSTA in 2020-23 was linked to low-level zonal wind anomalies and Kelvin wave activities.

Oceanic Kelvin Wave (OKW) Index



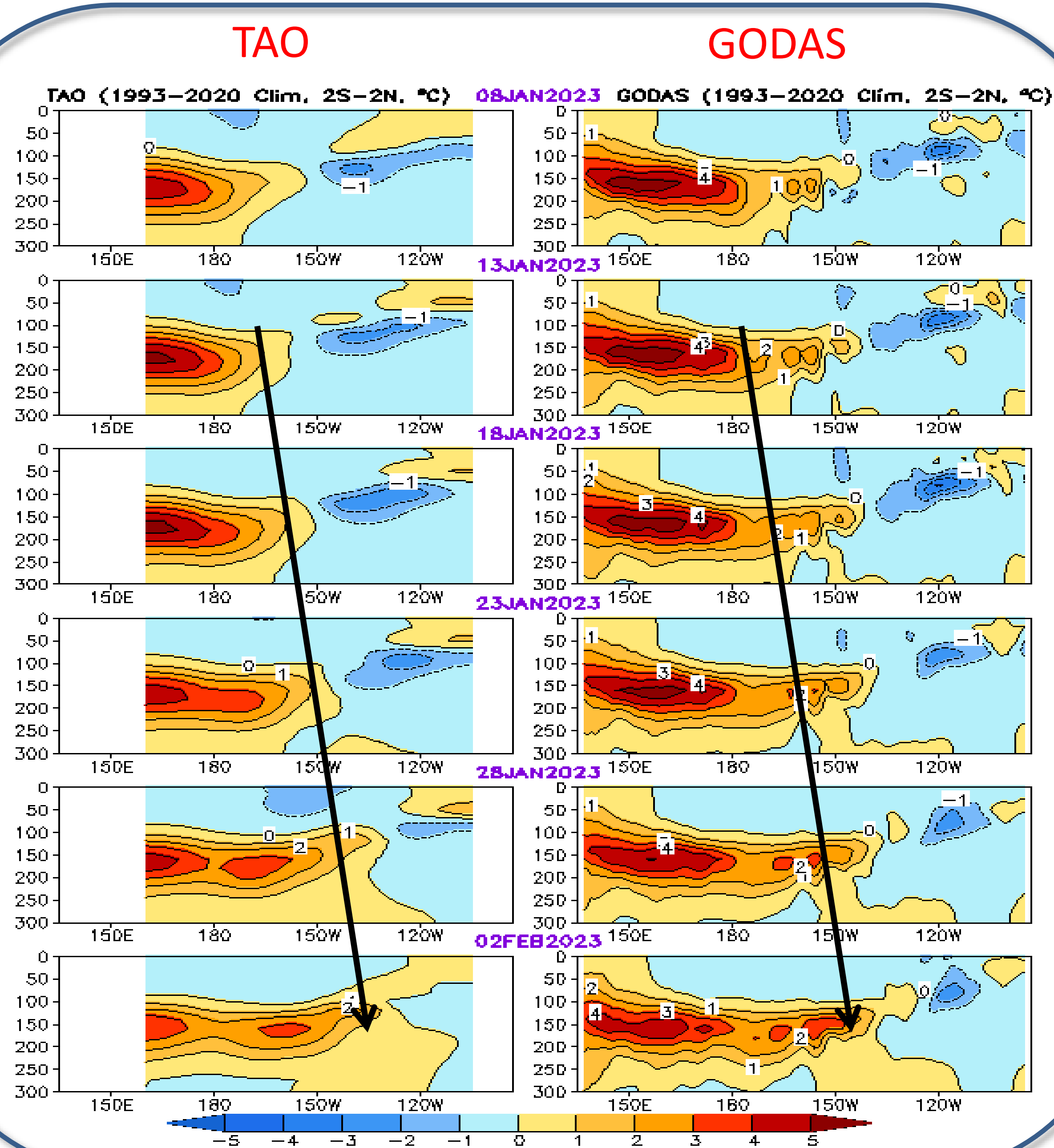


- **Multiple weak downwelling and upwelling Kelvin waves were observed in 2022, leading to the small fluctuation of SSTA in the central and eastern equatorial Pacific.**

- **A weak upwelling Kelvin wave propagated eastward since Dec 2022.**

(OKW index is defined as standardized projections of total anomalies onto the 14 patterns of Extended EOF1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).)

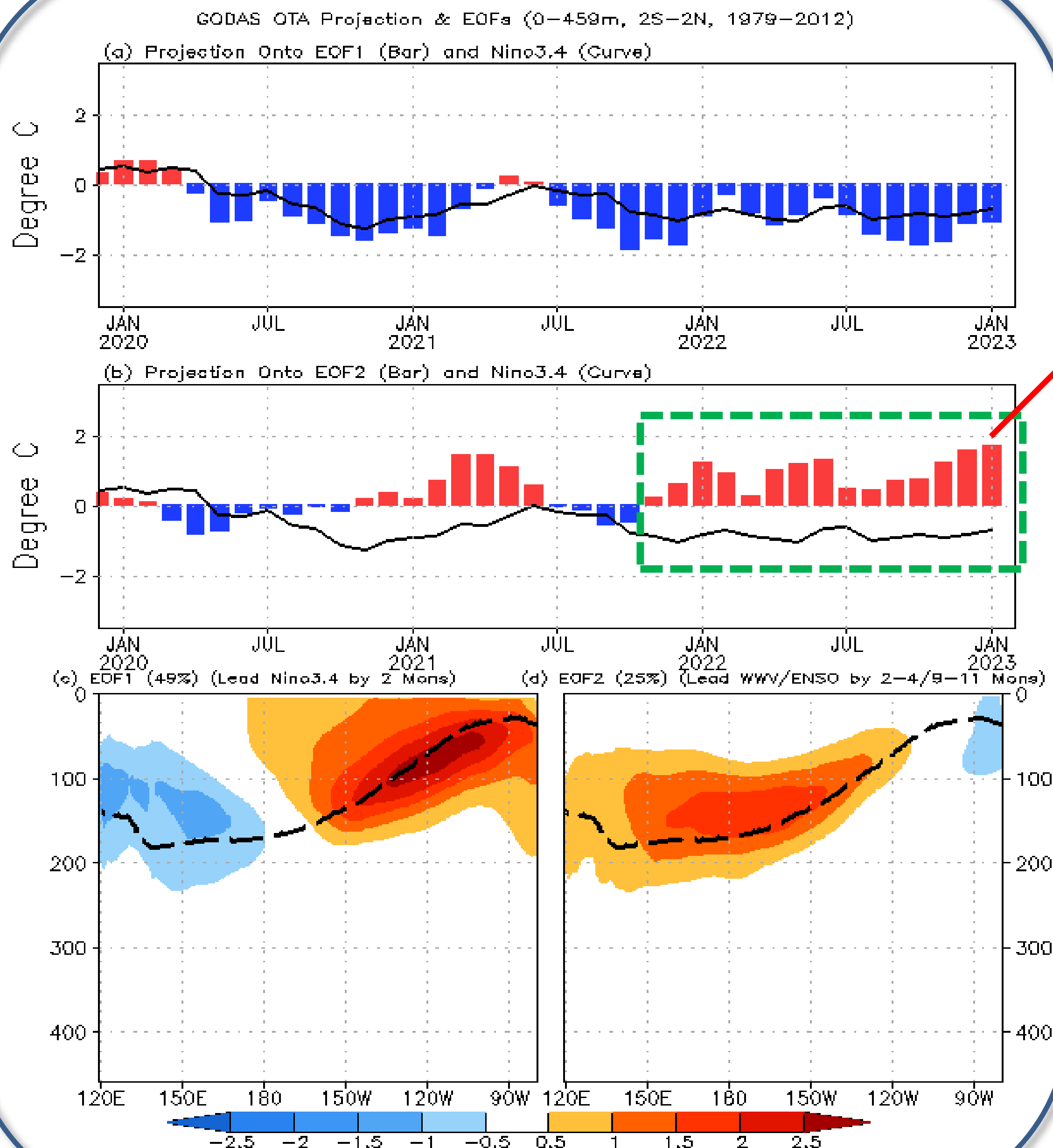
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly



- Positive ocean temperature anomalies along the thermocline in the western and central Pacific extended eastward in the last month.

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

Equatorial Sub-surface Ocean Temperature Monitoring



- The equatorial Pacific has been in a recharge phase since Nov 2021.

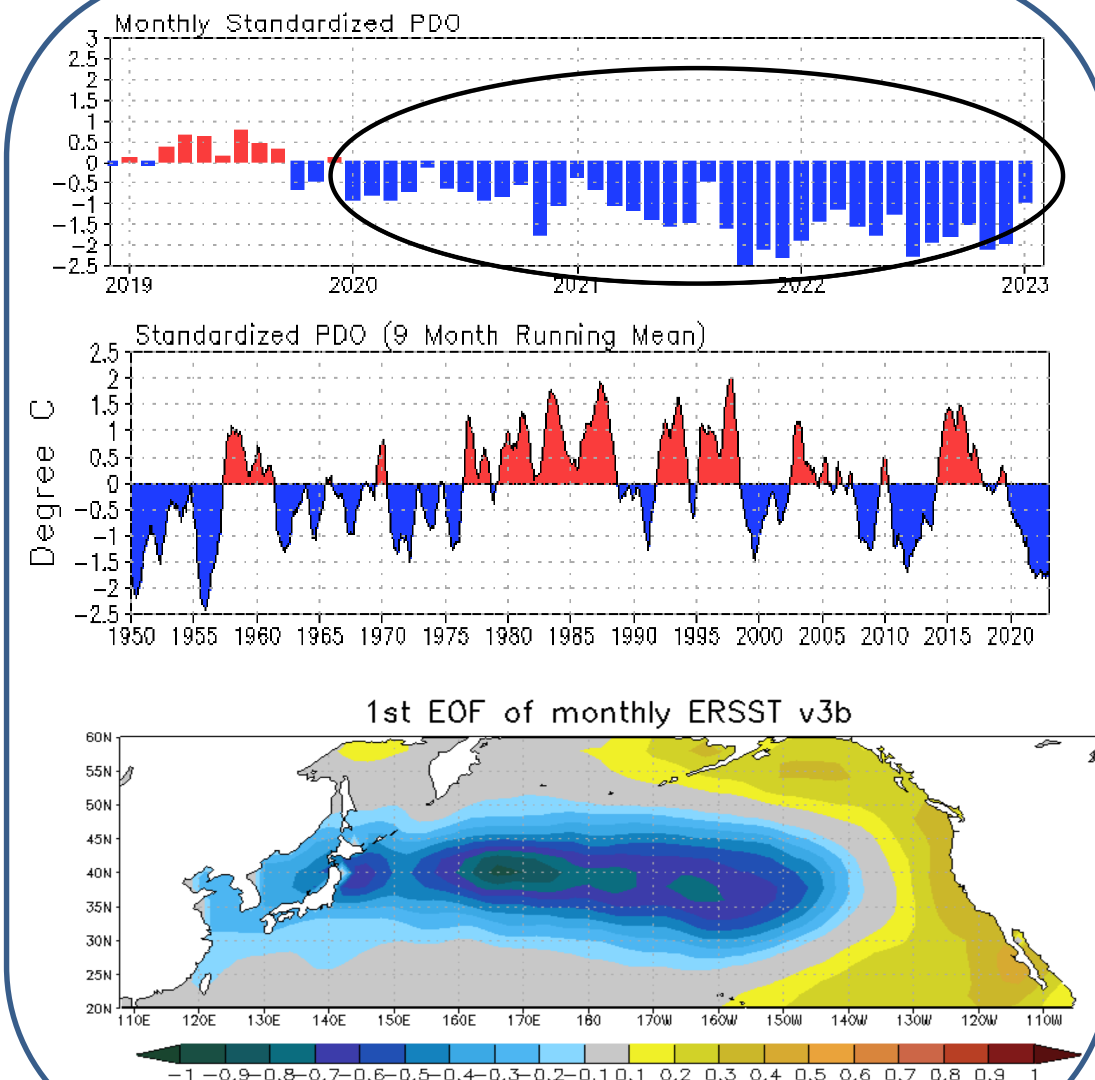
- Projection of ocean temperature anomalies onto EOF1 and EOF2; EOF1: Tilt/dipole mode (ENSO peak phase); EOF2: WWV mode.

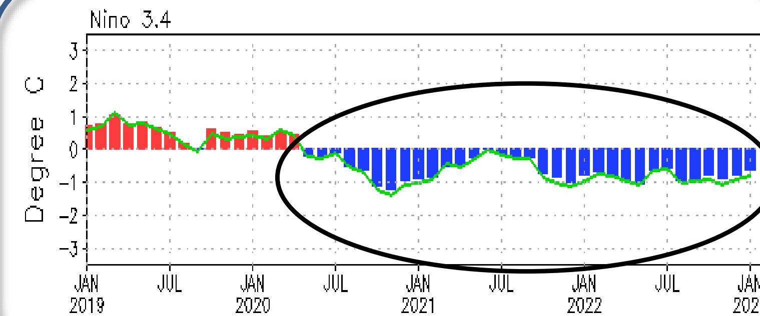
- Recharge/discharge oscillation (ENSO transition phase); Recharge process: heat transport from outside of equator to equator; Negative -> positive phase of ENSO

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

North Pacific & Arctic Oceans

Pacific Decadal Oscillation (PDO) Index



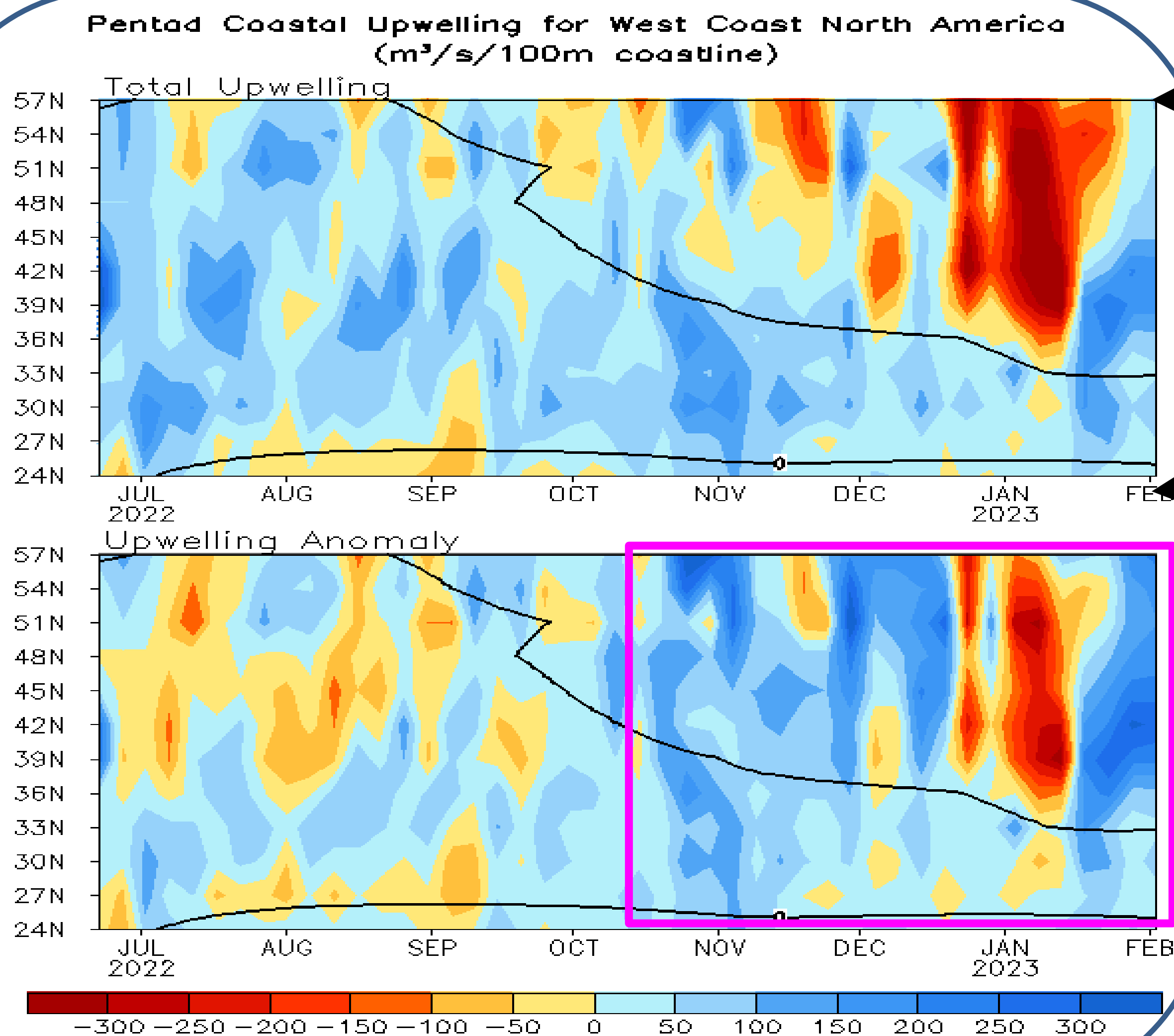


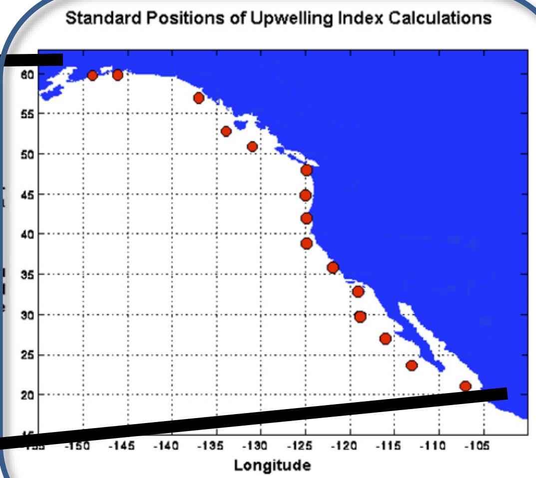
- The PDO has been in a negative phase since Jan 2020 with PDOI = -0.96 in Jan 2023.

- 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

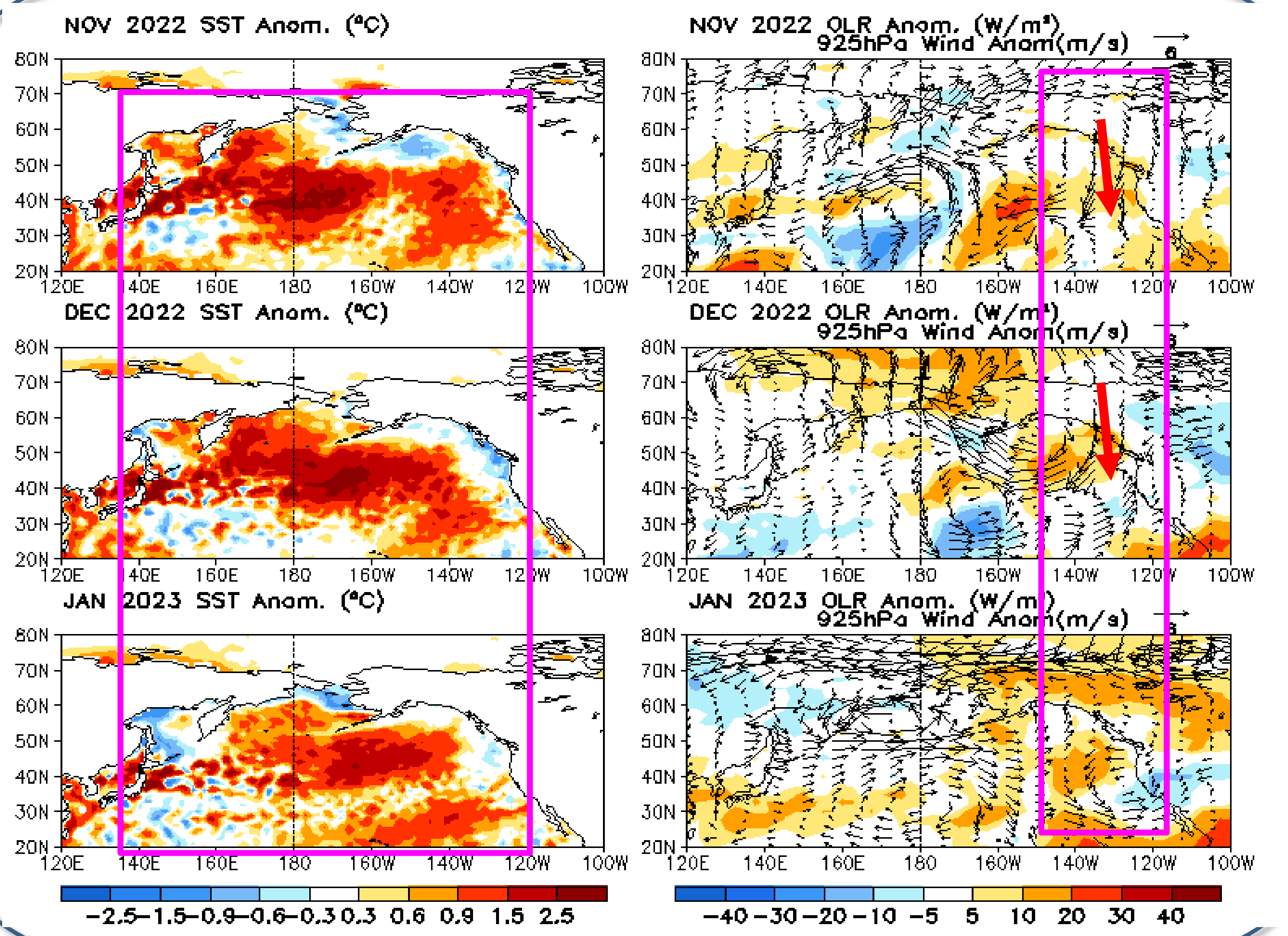




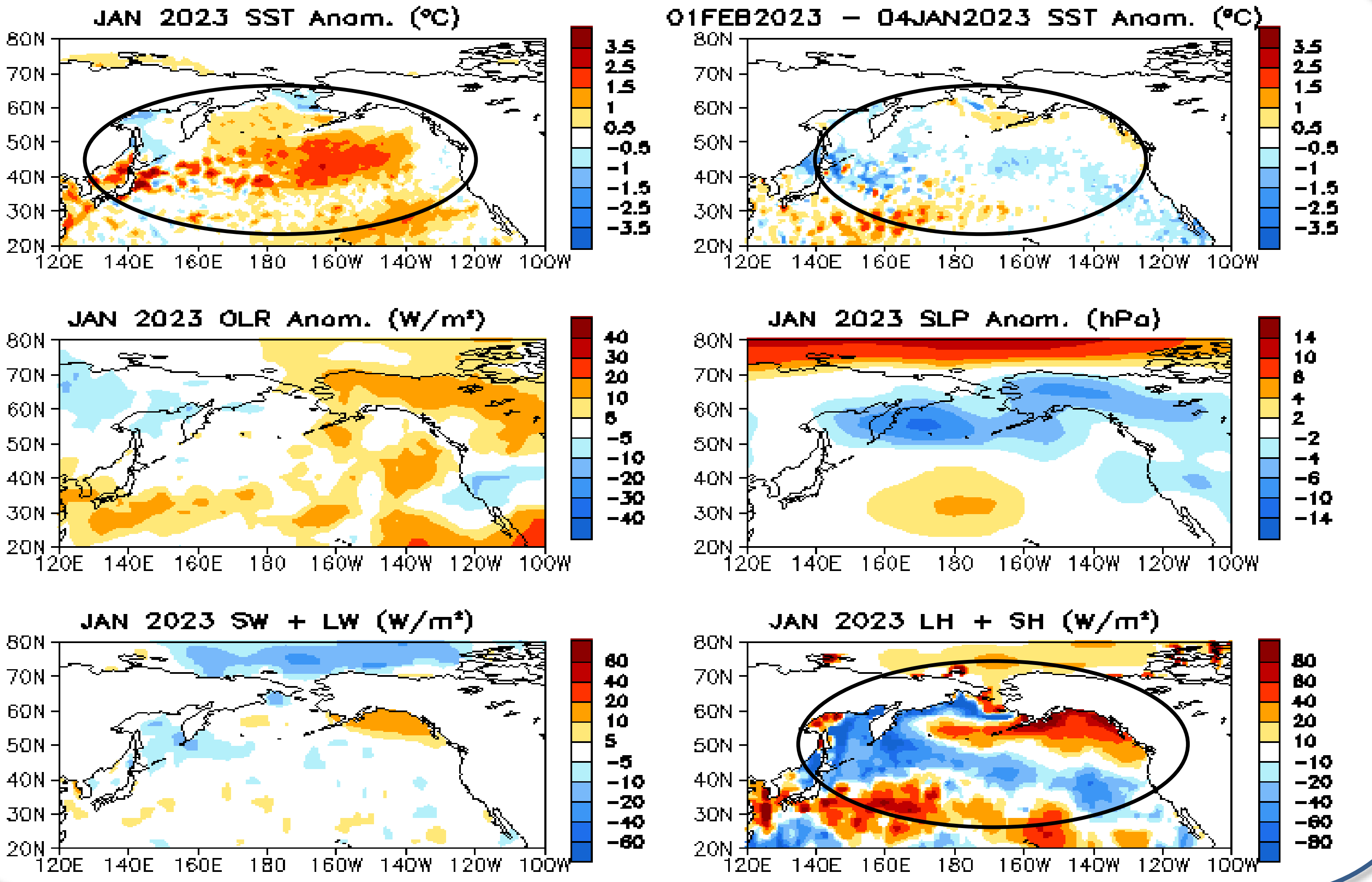
- Coastal anomalous downwelling turned to anomalous upwelling in mid-Jan 2023.

(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.

North Pacific SST, OLR, and uv925 anomalies

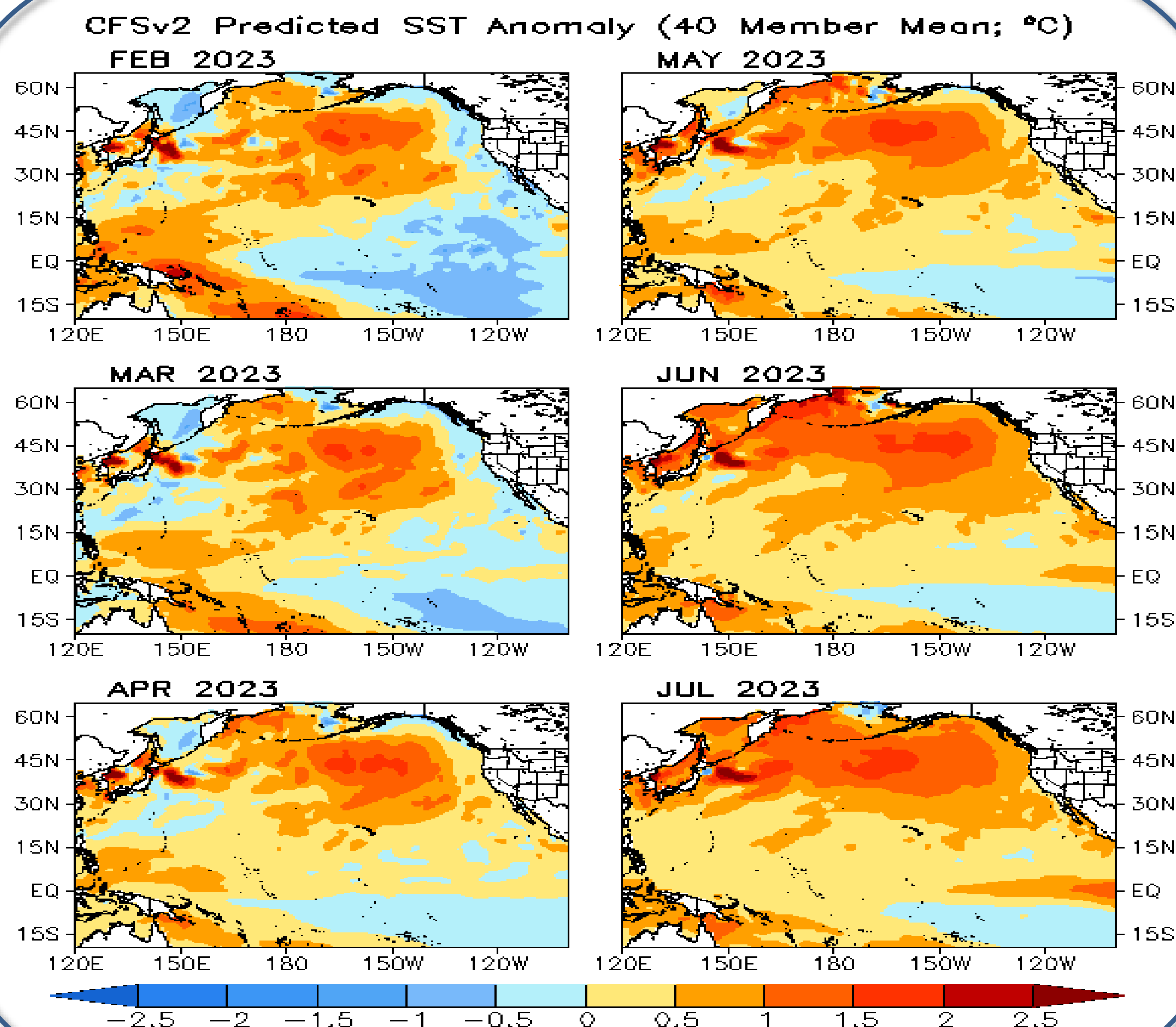


North Pacific & Arctic Ocean: SSTA, SSTA Tend., OLR, SLP, Sfc Rad, Sfc Flx Anomalies



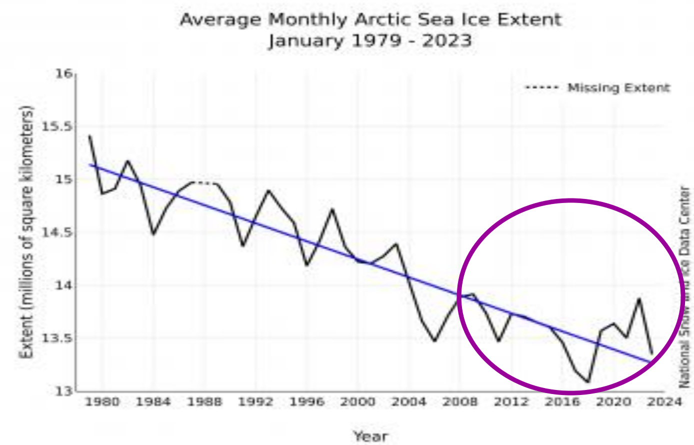
SSTA (top-left; OIv2.1 SST Analysis), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) (middle-left; NOAA 18 AVHRR IR), sea surface pressure (middle-right; NCEP CDAS), sum of net surface short- and long-wave radiation (bottom-left; positive means heat into the ocean; NCEP CDAS), sum of latent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

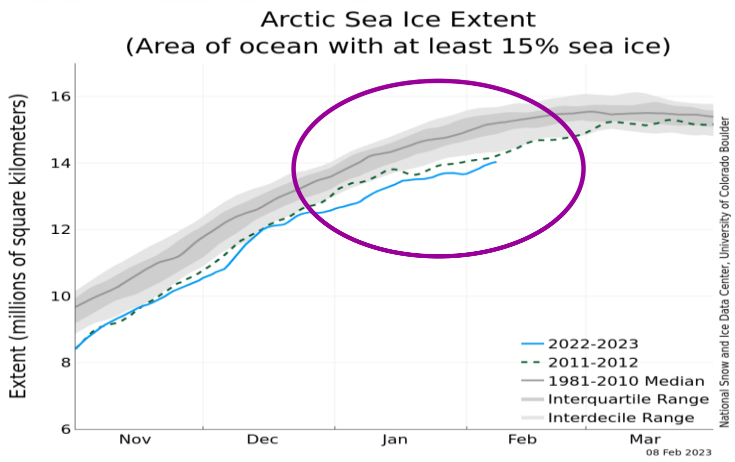
CFSv2 NE Pacific SSTA Predictions

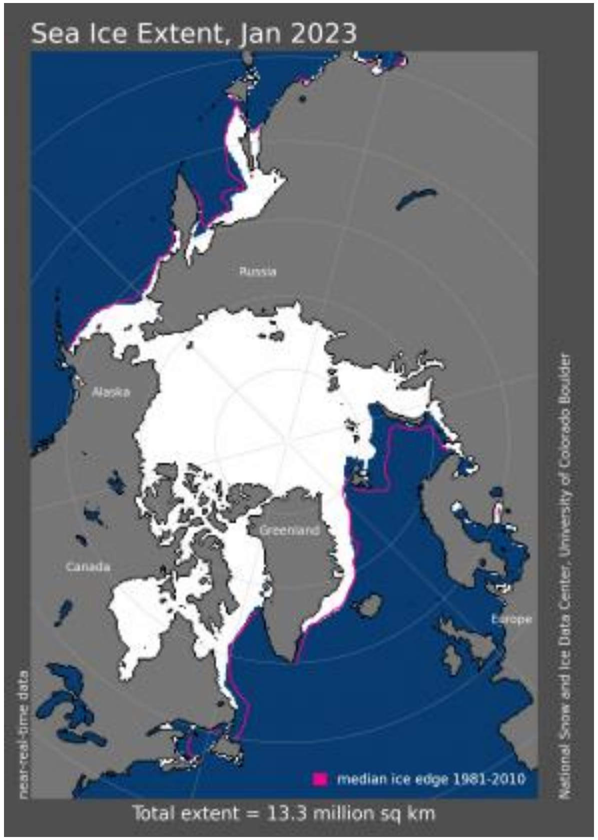


- The CFSv2 predicts the current SST warm state in the N Pacific will continue into the summer 2023.

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

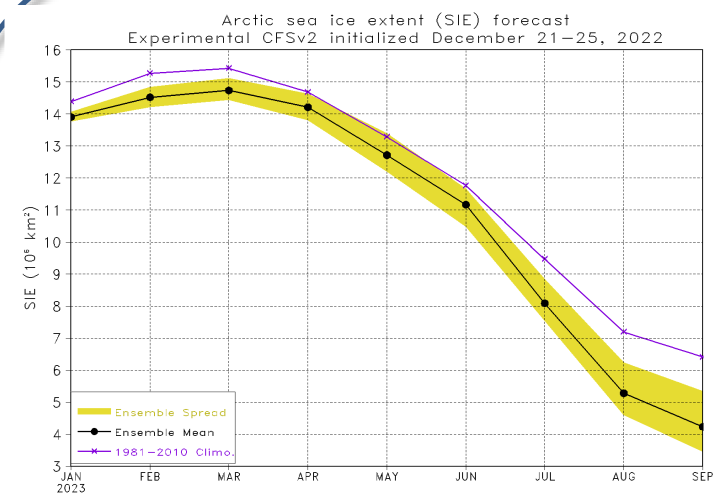


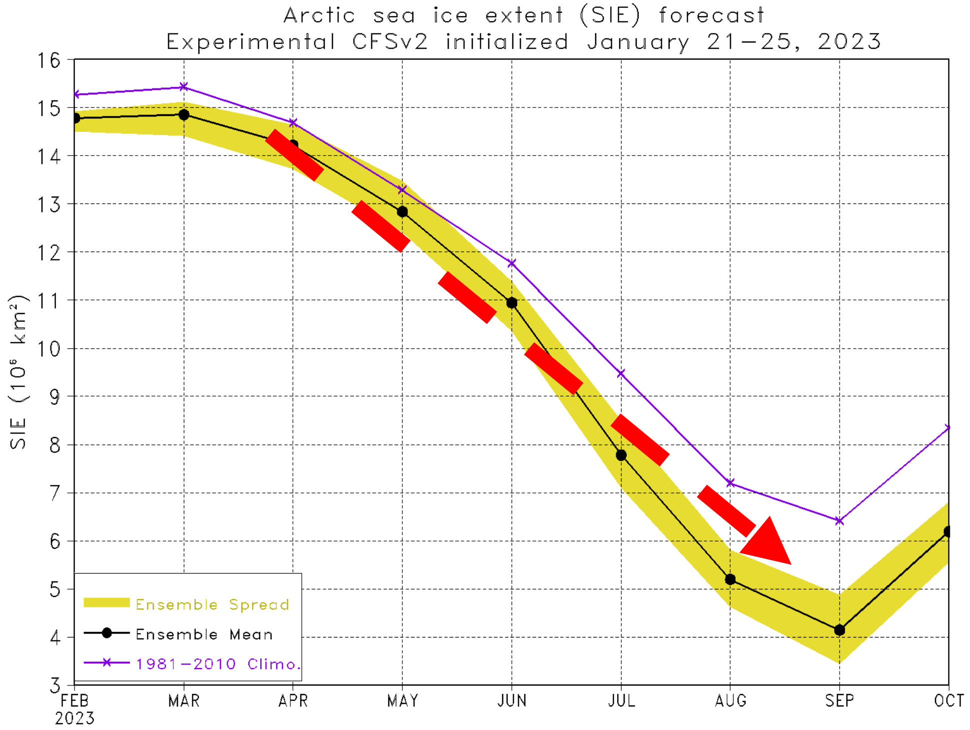




- The Jan 2023 average Arctic sea ice extent was 13.35 million square kilometers, the third lowest Jan in the satellite record.
- The downward linear trend in Jan sea ice extent over the 44-year satellite record is 3.0% per decade relative to the 1981 to 2010 average.

NCEP/CPC Arctic Sea Ice Extent Forecast

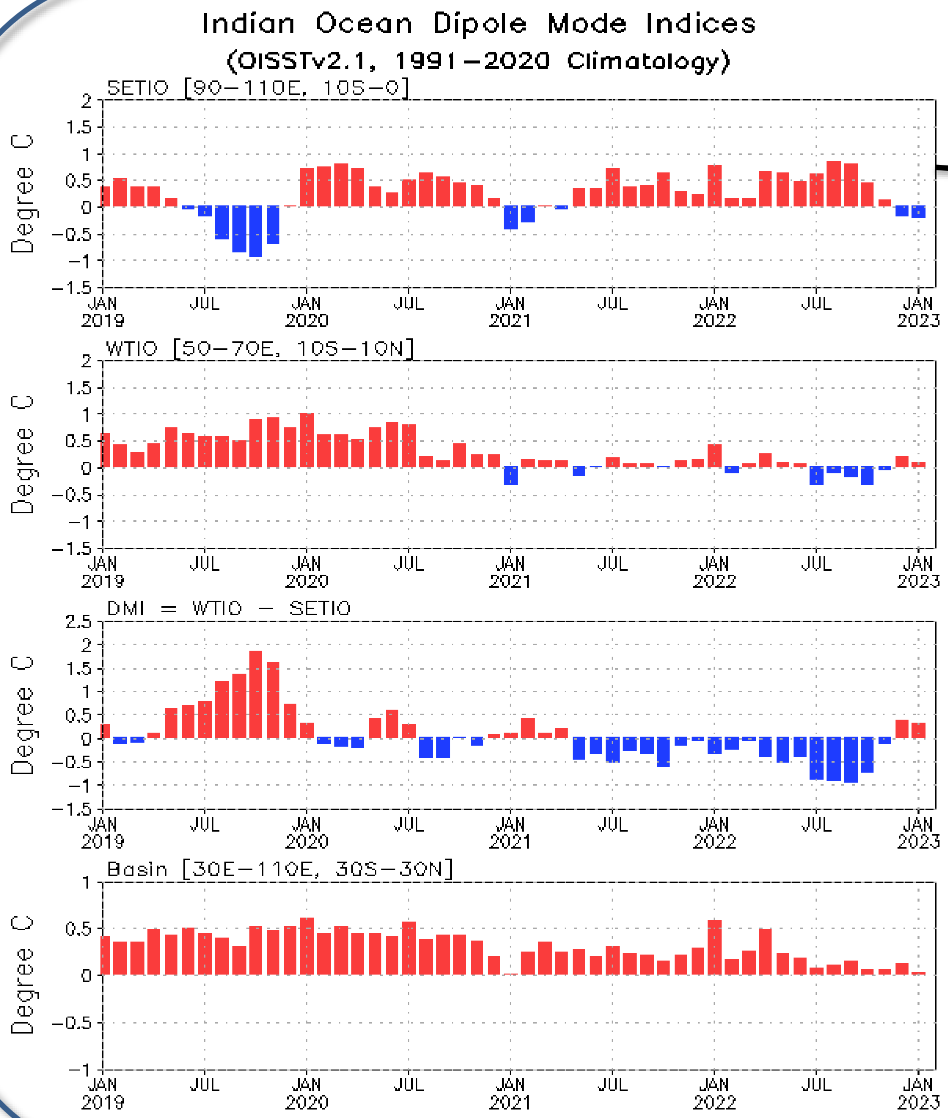


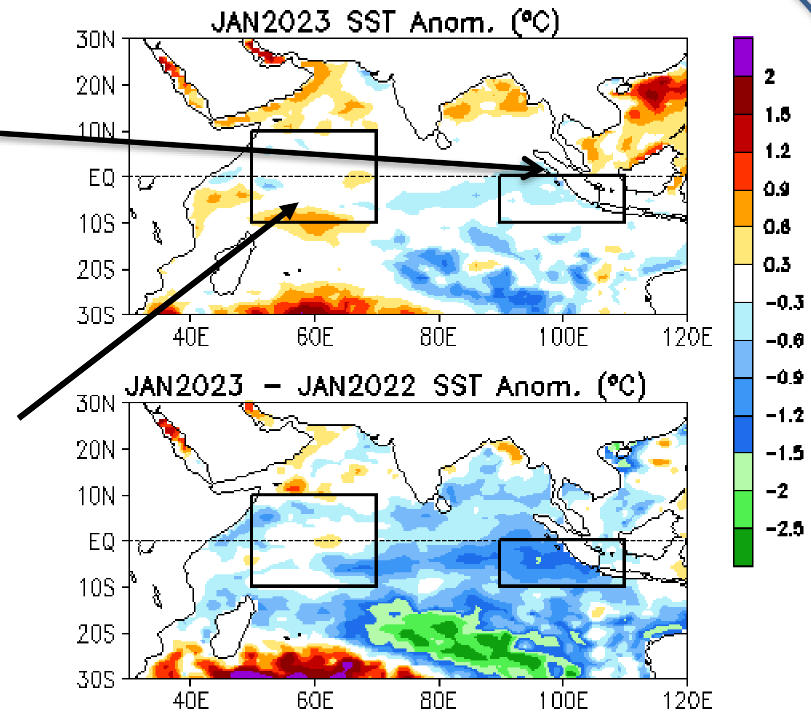


https://www.cpc.ncep.noaa.gov/products/people/wwang/seaice_seasonal/index.html

Indian Ocean

Evolution of Indian Ocean SST Indices



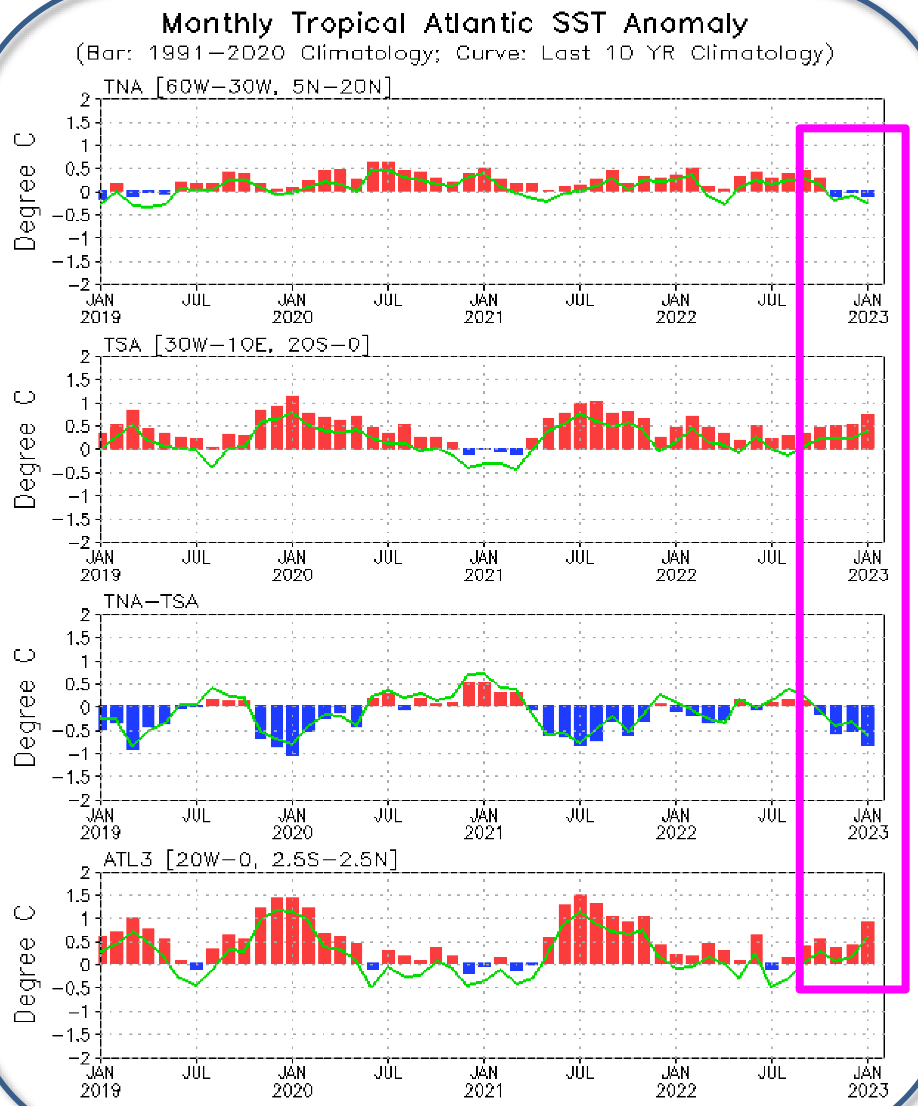


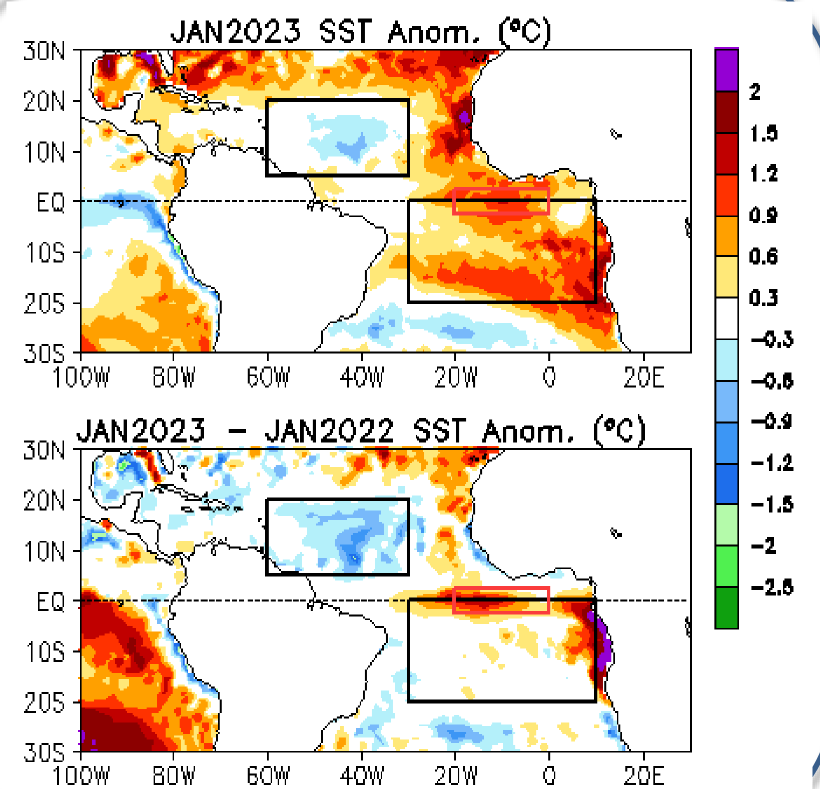
- Positive (negative) SSTAs were in the western (southeastern) tropical Indian Ocean in Jan 2023, featuring a positive phase of IOD.

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 and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

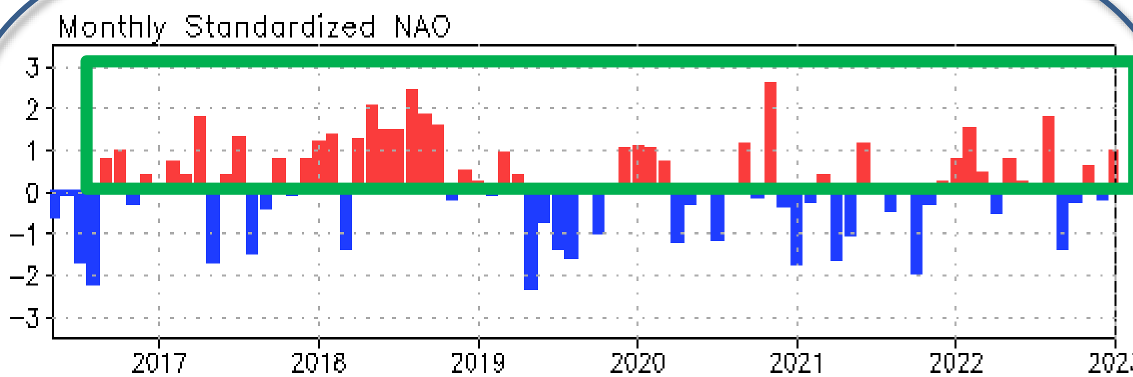


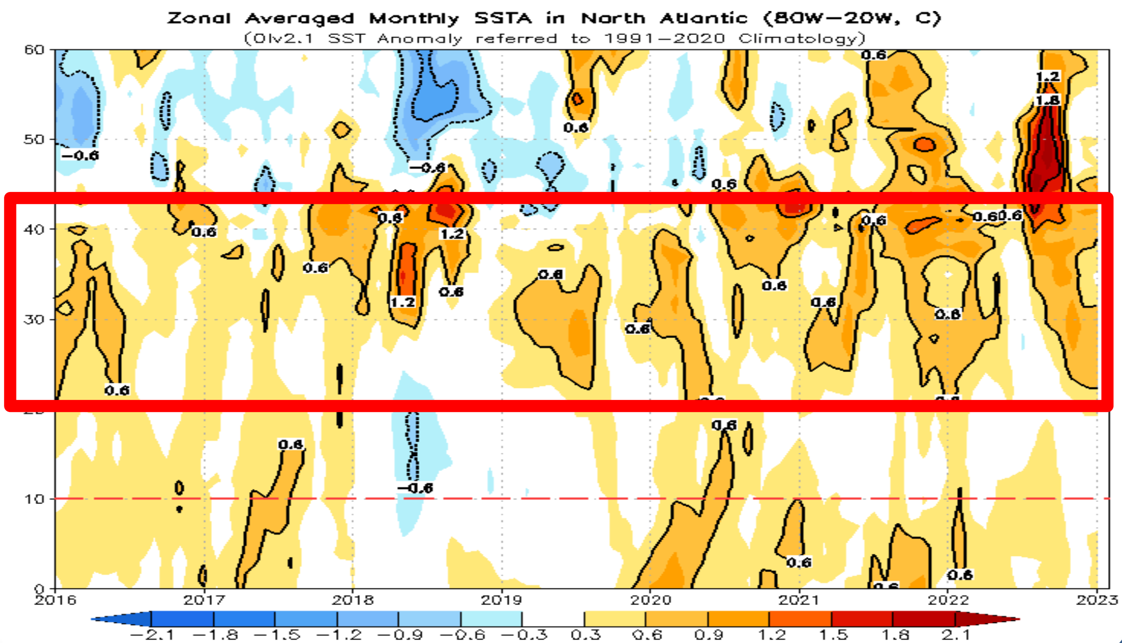


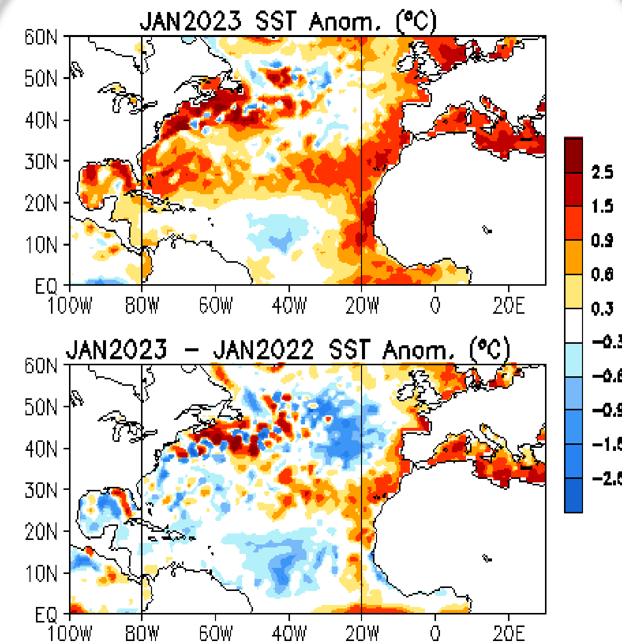
- Positive (negative) SSTAs in the tropical South (North) Atlantic feature a negative phase of the Atlantic meridional dipole mode during the last few months.
- Positive ATL3 index strengthened in Jan 2023.

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.

NAO and SST Anomaly in North Atlantic





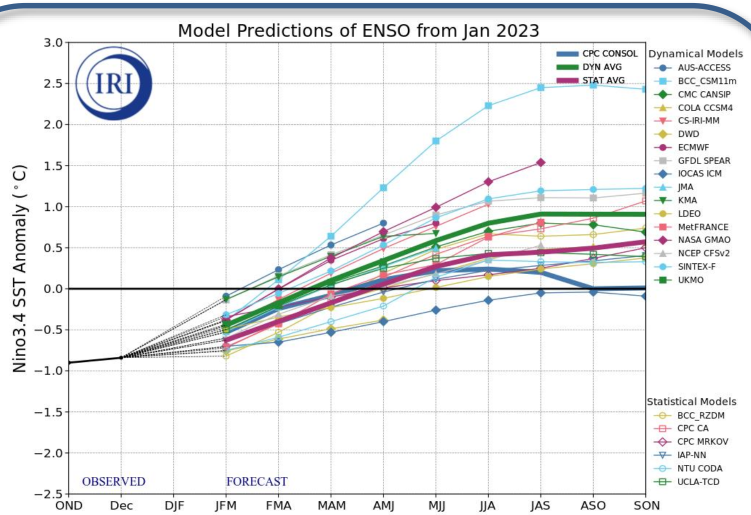


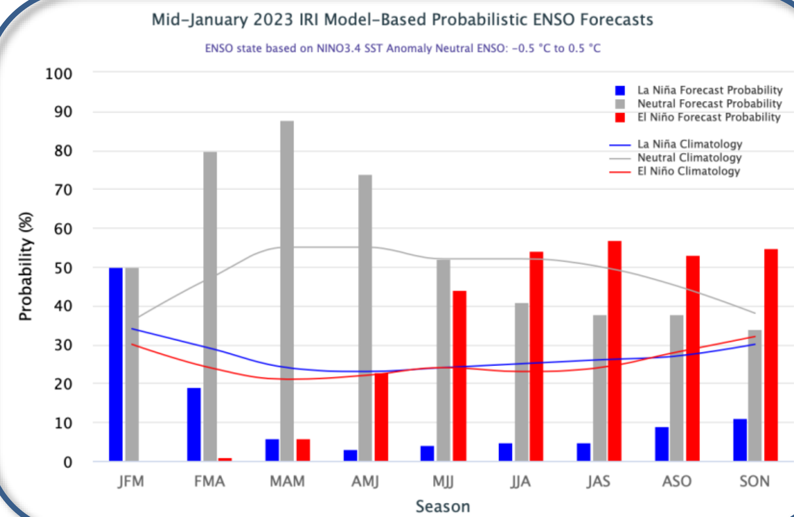
- NAO switched to a positive phase in Jan 2023 with NAOI= 0.95.
- The prolonged positive SSTAs in the middle latitudes were evident, due to the domination of the positive phase of NAO during the last 5-6 years.

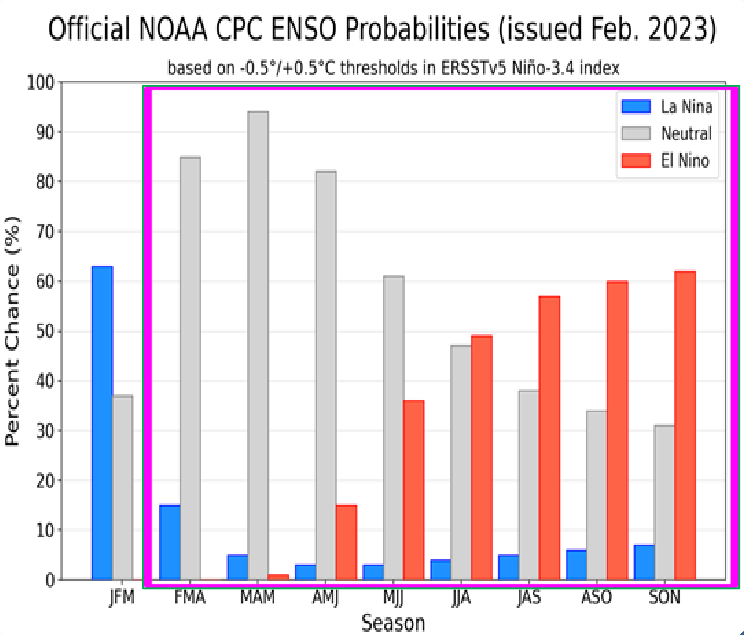
Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20ºN-90ºN. Time-latitude section of SSTAs averaged between 80ºW and 20ºW (bottom). SST are derived from the OIv2.1 SST analysis, and anomalies are departures from the 1991-2020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

ENSO and Global SST Predictions

IRI/CPC Niño3.4 Forecast: Jan 2023





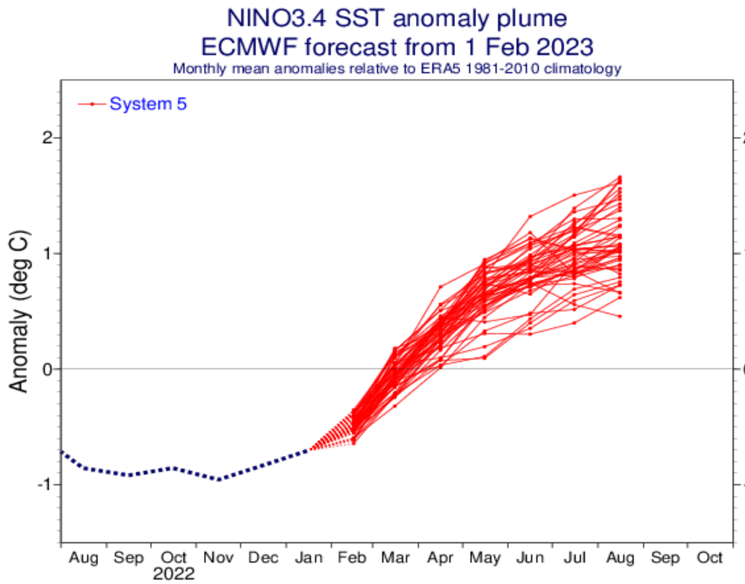


- ENSO Alert System Status: La Niña Advisory

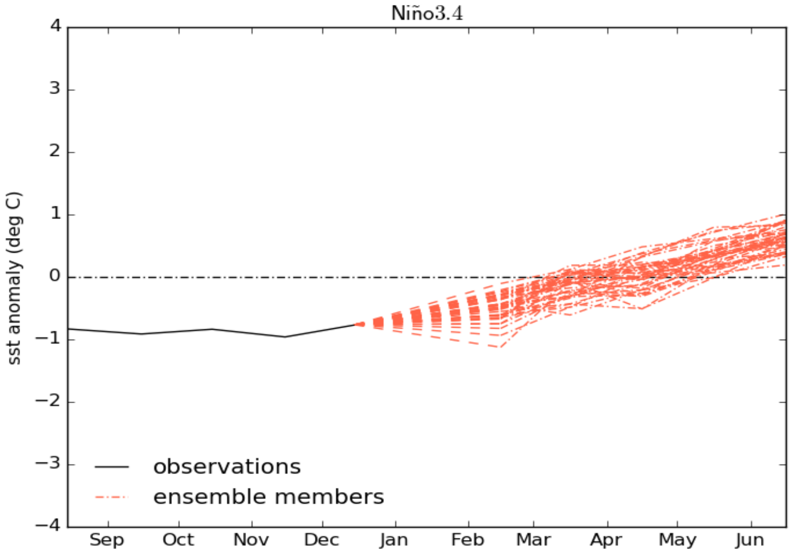
- <u>Synopsis:</u> *"ENSO-neutral conditions are expected to begin within the next couple of months, and persist through the Northern Hemisphere spring and early summer."*

Individual Model Forecasts: Moderate La Niña will return to neutral in spring

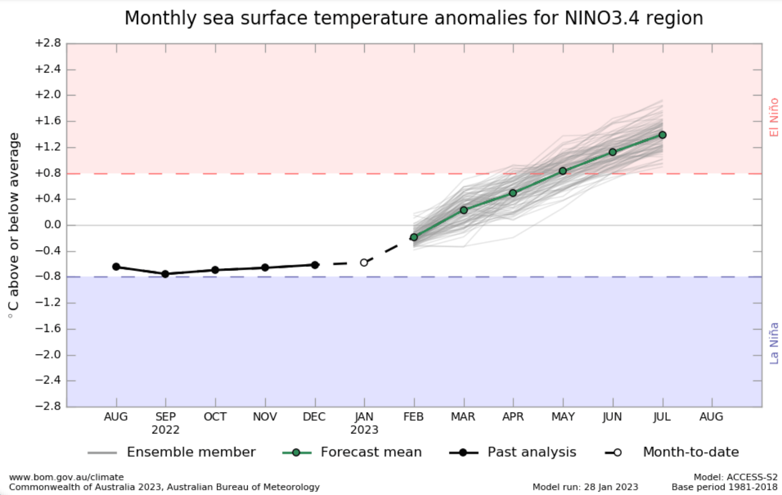
EC: Niño3.4, IC= 1 Feb 2023



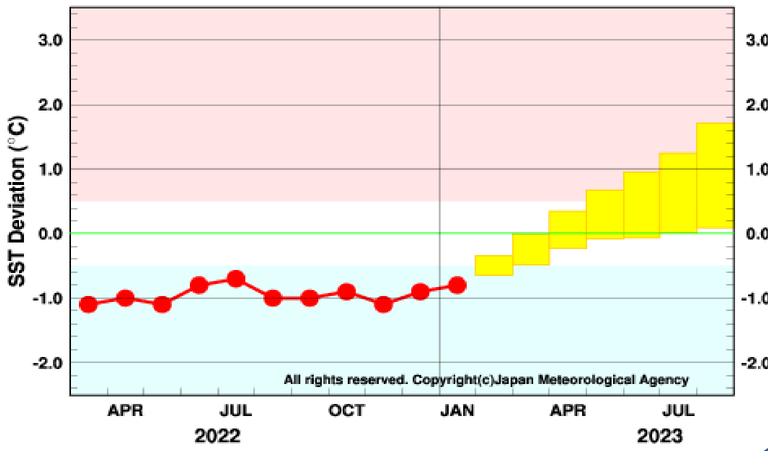
UKMO: Niño3.4, Updated 11 Jan 2023



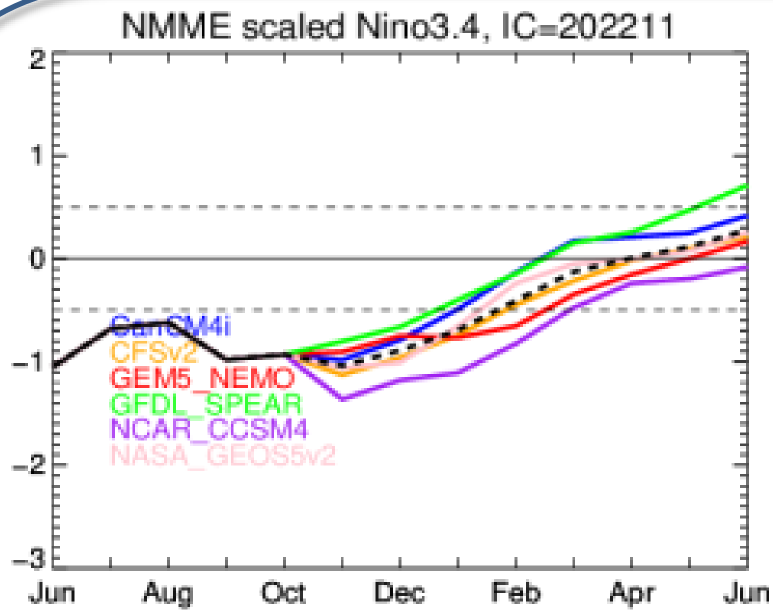
Australian BOM: Niño3.4, Updated 28 Jan2023

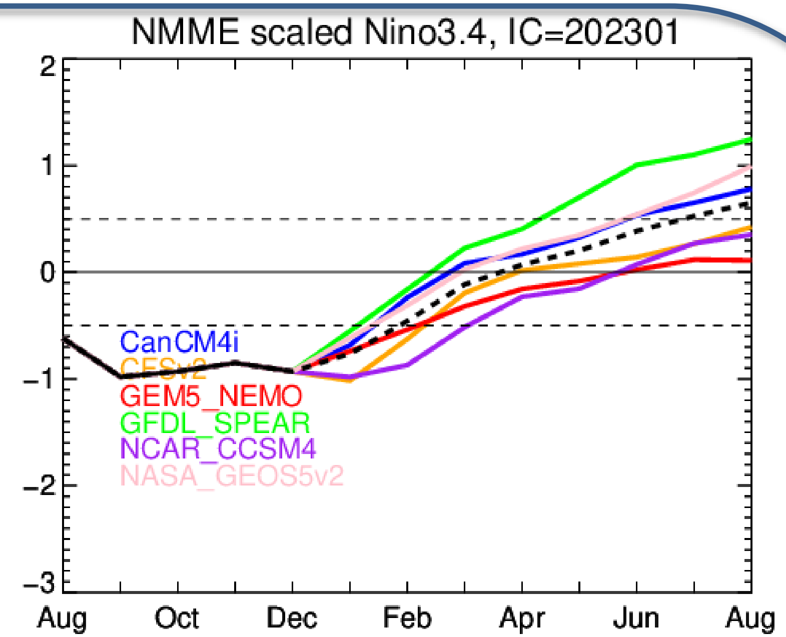


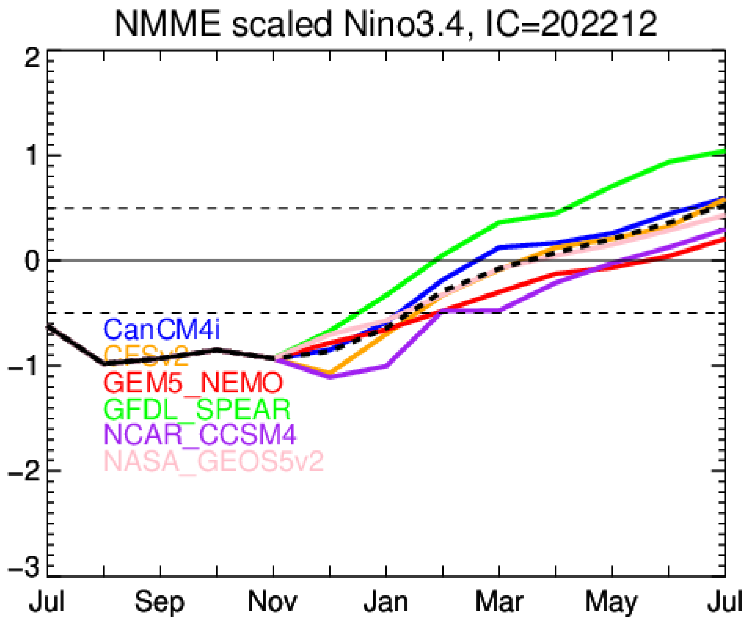
JMA: Niño3.4, Updated 10 Feb 2023

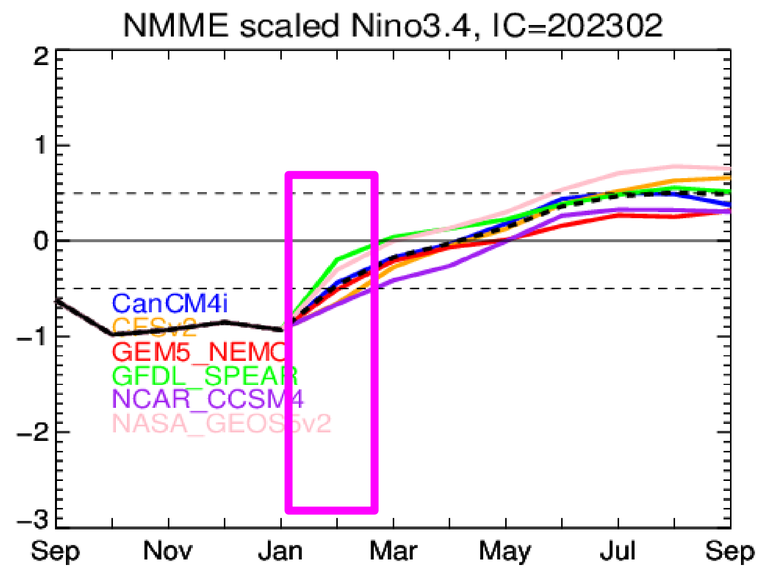


NMME forecasts from different initial conditions

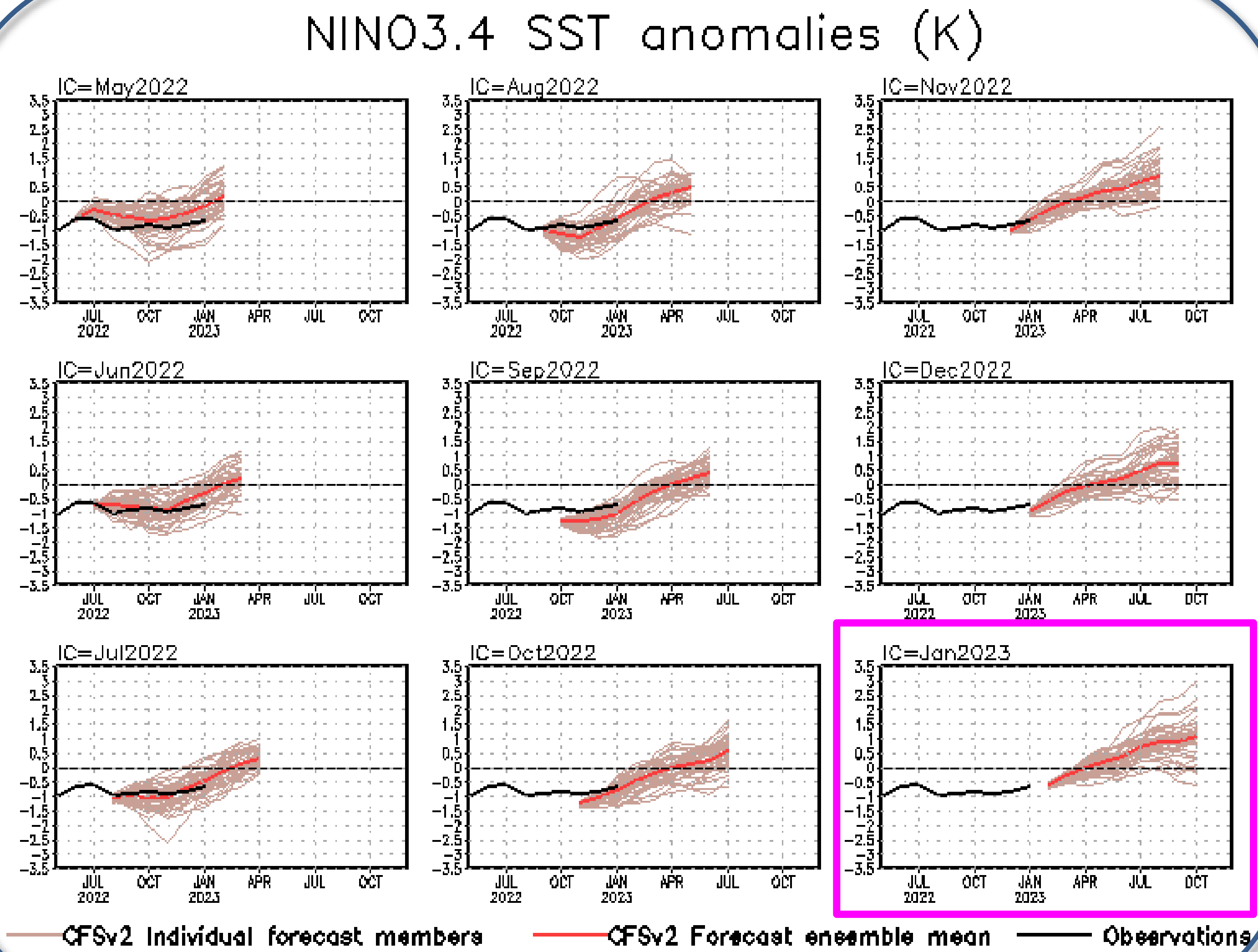








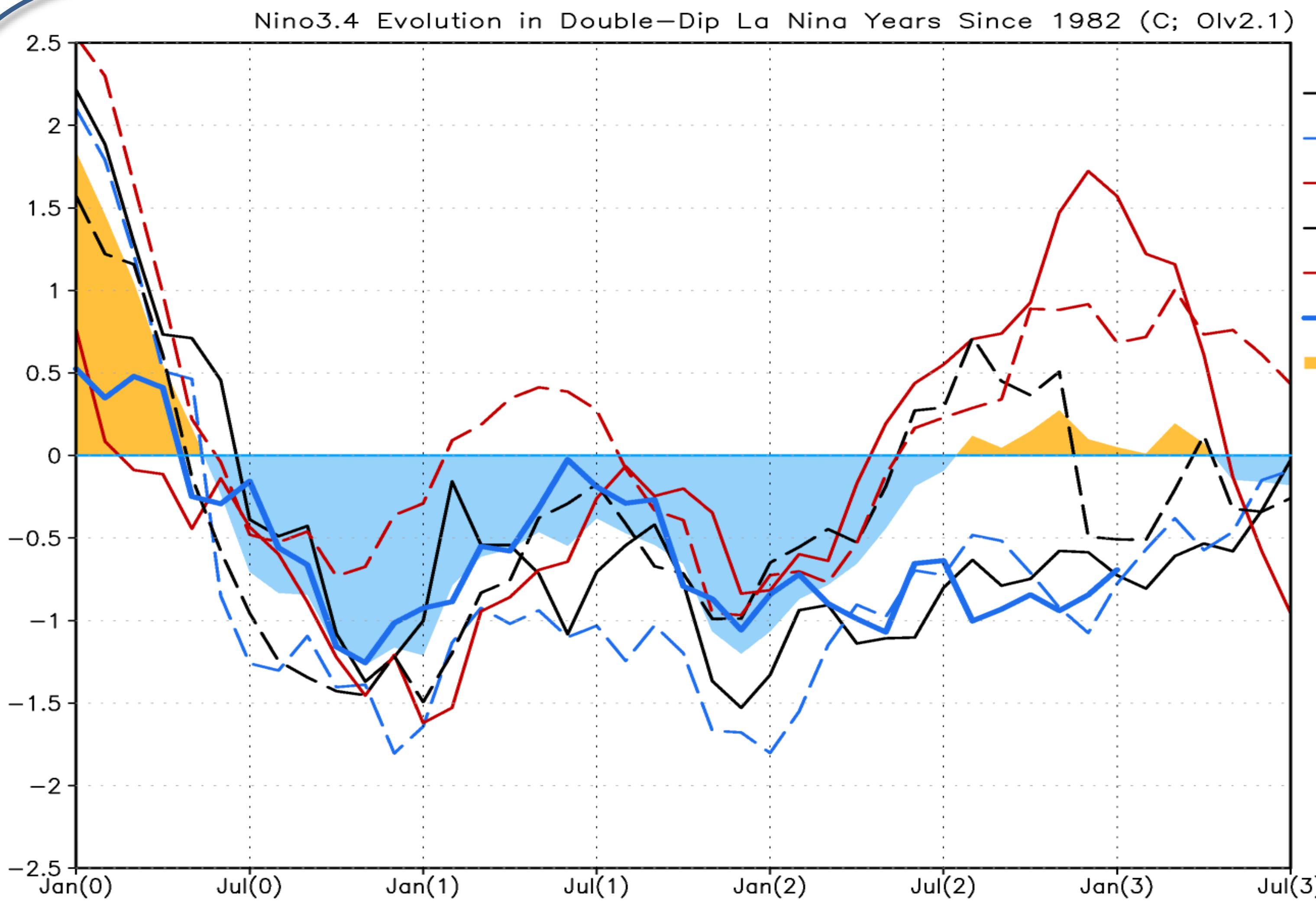
CFS Niño3.4 SST Predictions from Different Initial Months



- The latest CFSv2 forecasts the La Niña will return to a neutral condition in spring 2023.

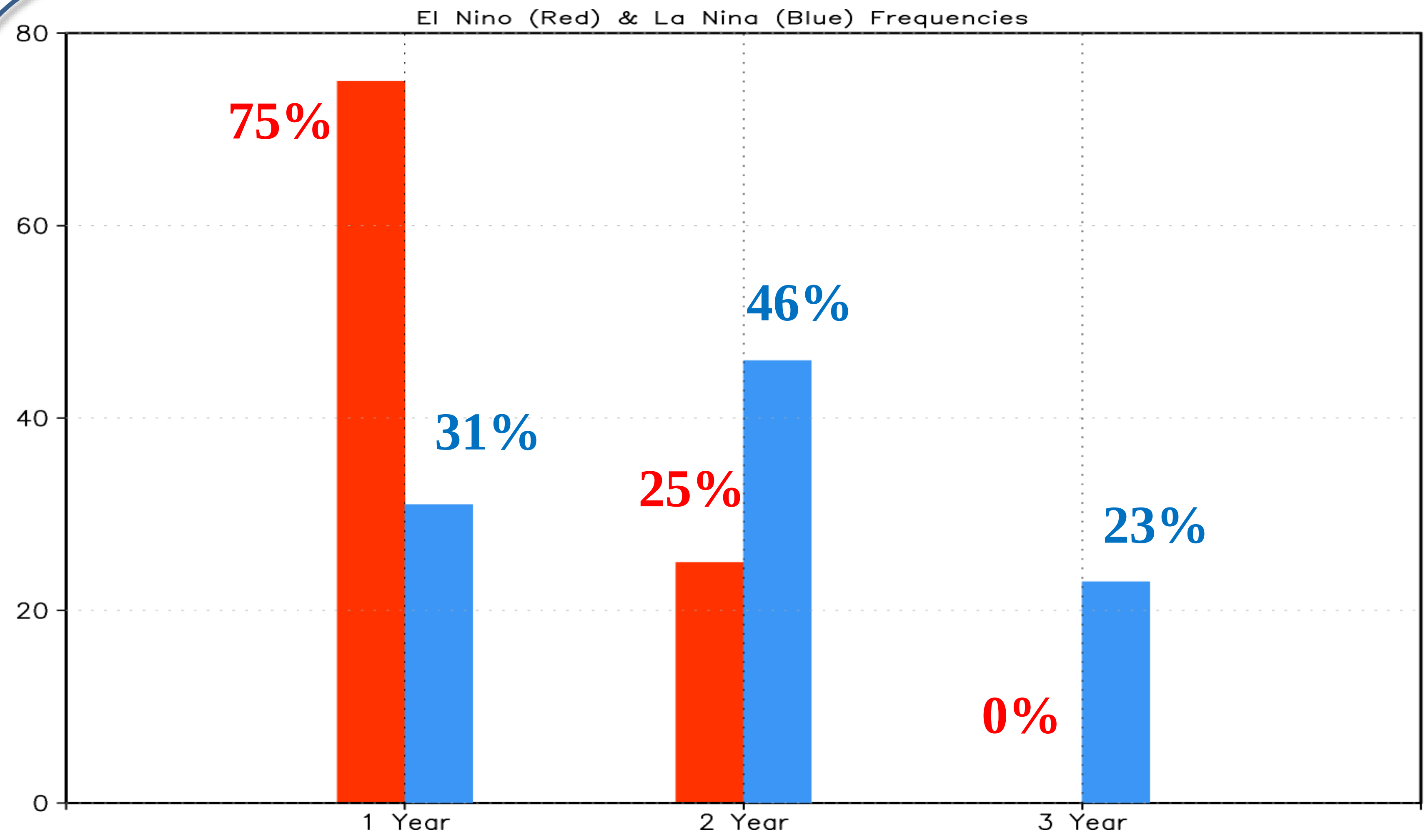
CFS Niño3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect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

Niño3.4 Evolution in Double & Triple dip La Niña Years Since 1982 (OIv2.1; C)



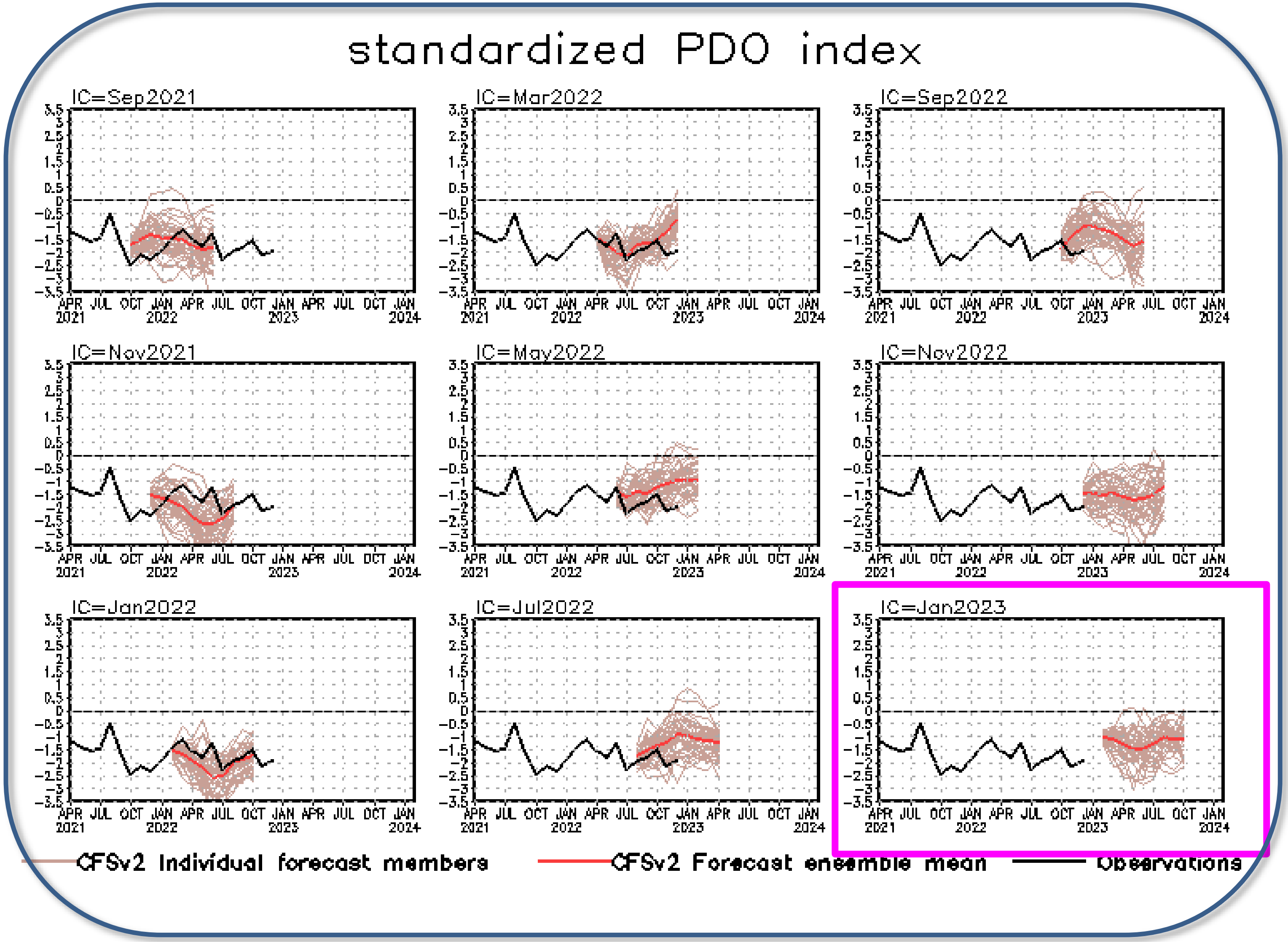
During 1982-2022, among 6 double-dip La Niñas, 2 (2007-09 & 2016-18) were followed by El Niño; 2 (1998-00; 2020-22) by a 3rd-year La Niña, & 2 (1983-85 & 2010-12) by neutral.

Percentages (%) of single-, double-, and triple-year El Niños (red bars) and La Niñas (blue bars) during 1951-2022



Gao, Z., et al., 2023: Single-Year and Double-Year El Niños. Climate Dyn. DOI: 10.1007/s00382-022-06425-8.

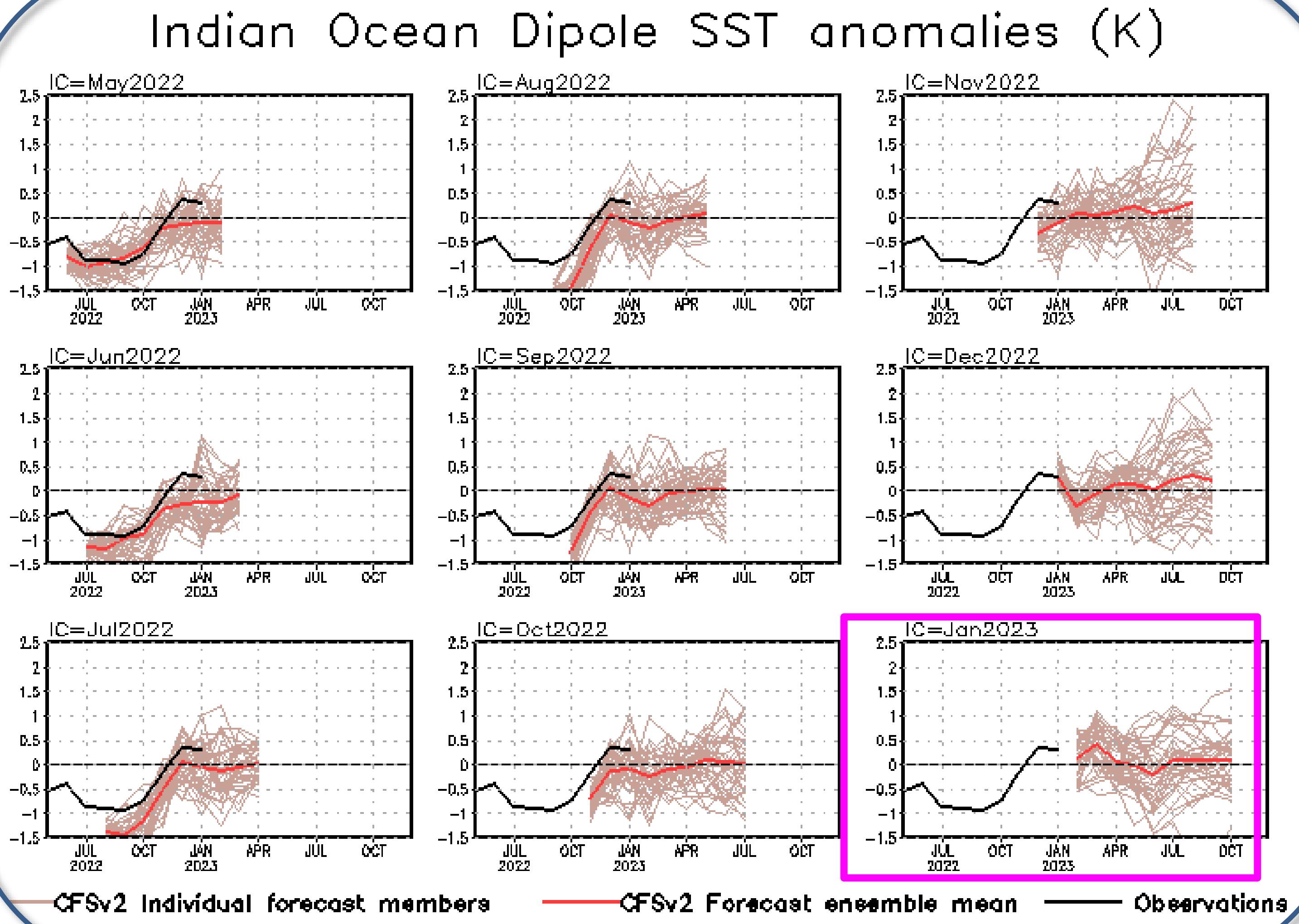
CFS Pacific Decadal Oscillation (PDO) Index Predictions from Different Initial Months



- CFSv2 predicts a persistent negative phase of PDO through autumn 2023.

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

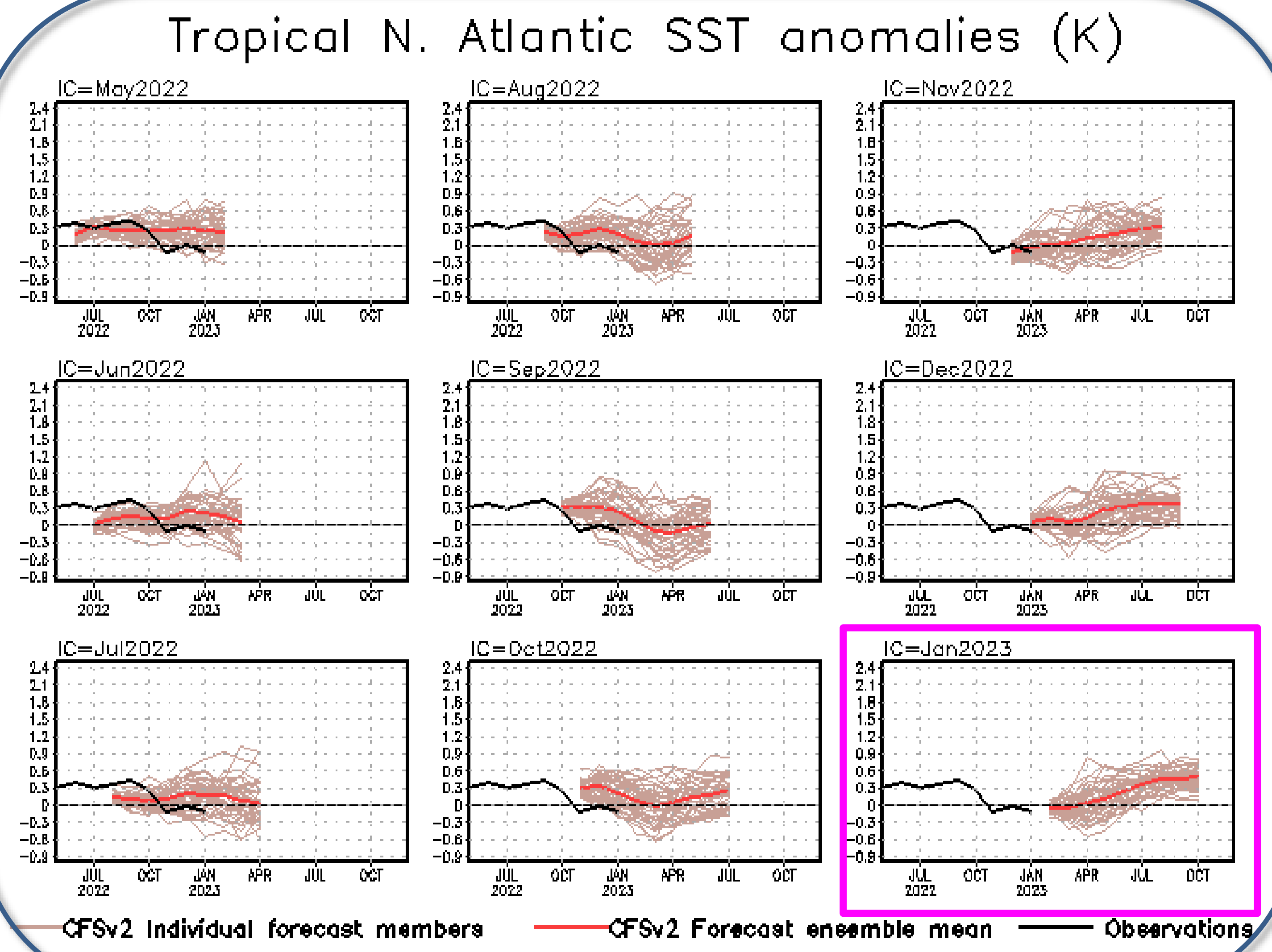
NCEP CFS DMI SST Predictions from Different Initial Months



- CFSv2 predicts a near-normal IOD through autumn 2023.

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.

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

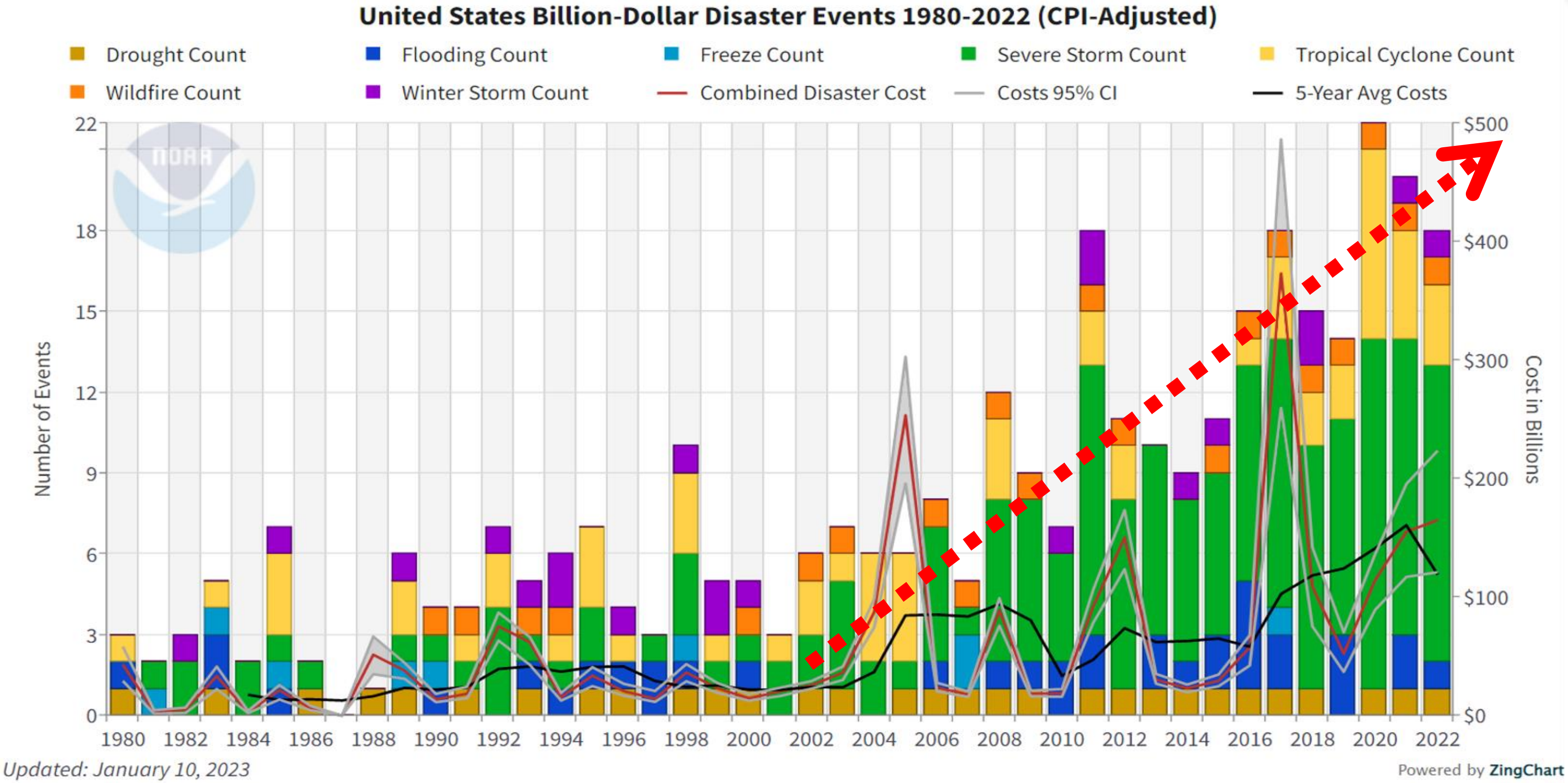


- Latest CFSv2 predictions call for above-normal SSTA in the tropical North Atlantic.

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].

2022 Ocean Annual Review

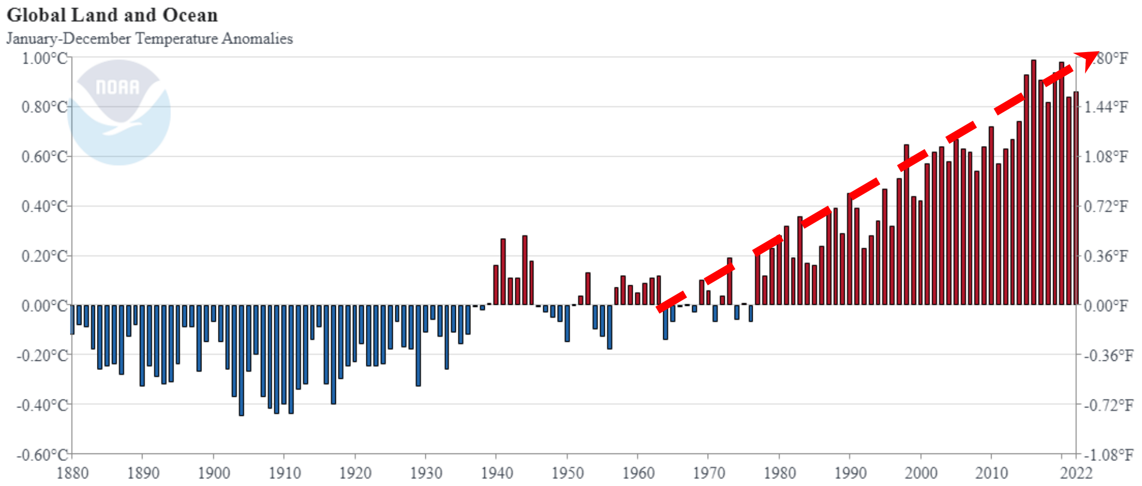
United States Billion-Dollar Disaster Events

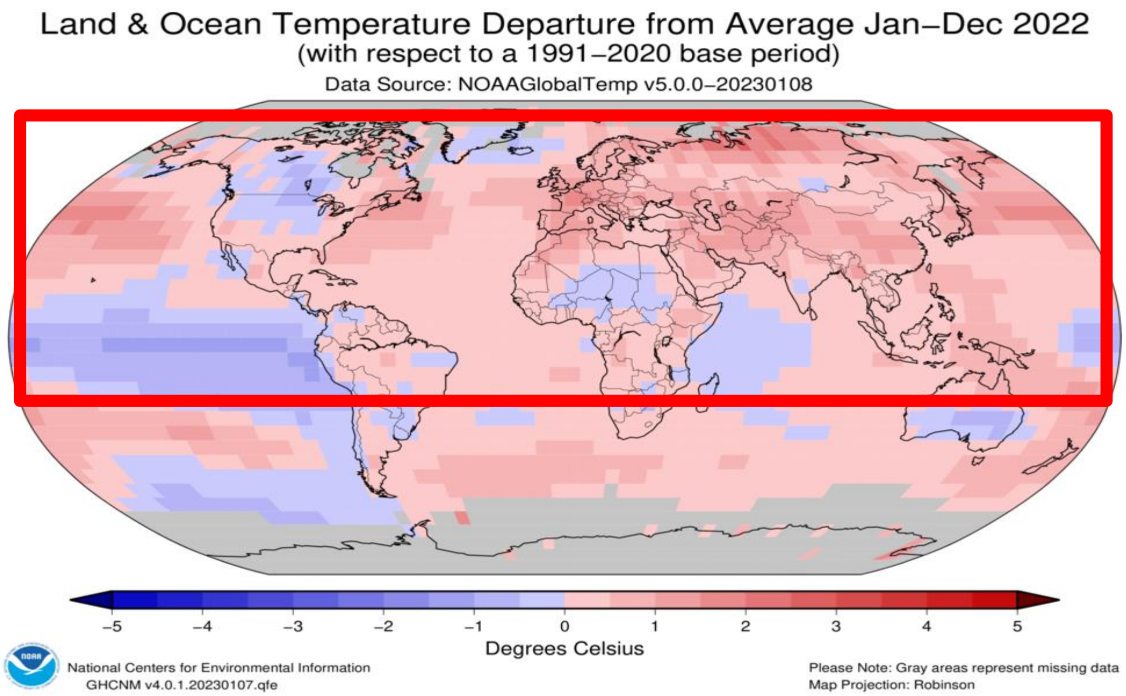


- **2020** was a **record-shattering year** of billion-dollar events; 4th highest annual costs (**$95.0 billion**)
- 1980–2020: 41-yr annual cost average $45.7 billion (inflation-adjusted) → 7.0 events / year
- 2011–2020: 10-yr annual cost average $89.0 billion (inflation-adjusted) → 13.5 events / year
- 2016–2020: 5-yr annual cost average $121.3 billion (inflation-adjusted) → 16.2 events / year

Global Land + Ocean Temperature Anomalies

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



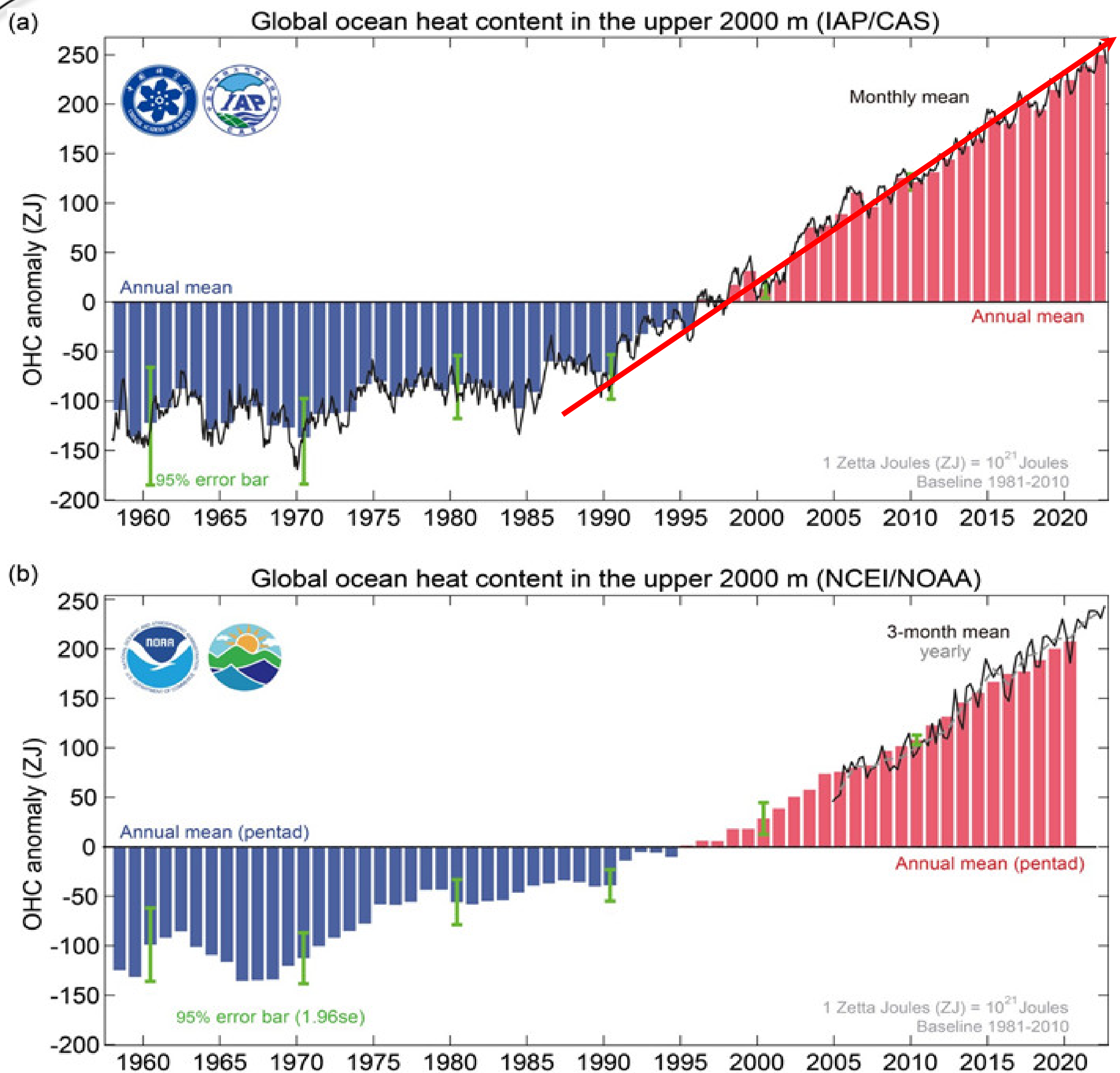


- “The year 2022 was the 6th warmest year since global records began in 1880 at 0.86°C above the 20th century average of 13.9°C.”

- **“The 2022 NH surface temperature was also the 6th highest on record at +1.10°C.**

- **Meanwhile, the SH had its 7th-warmest year on record, with a temperature that was 0.61°C above the 20th century average.”**

Global Ocean Heat Content (HC2000) since 1958



Global upper 2000 m OHC from 1958 through 2022 according to (a) IAP/CAS and (b) NCEI/NOAA data. 1 ZJ = 1021 Joules. 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., 2023: Another year of record heat for the oceans. Adv. Atmos. Sci., https://doi.org/10.1007/s00376-023-2385-2

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

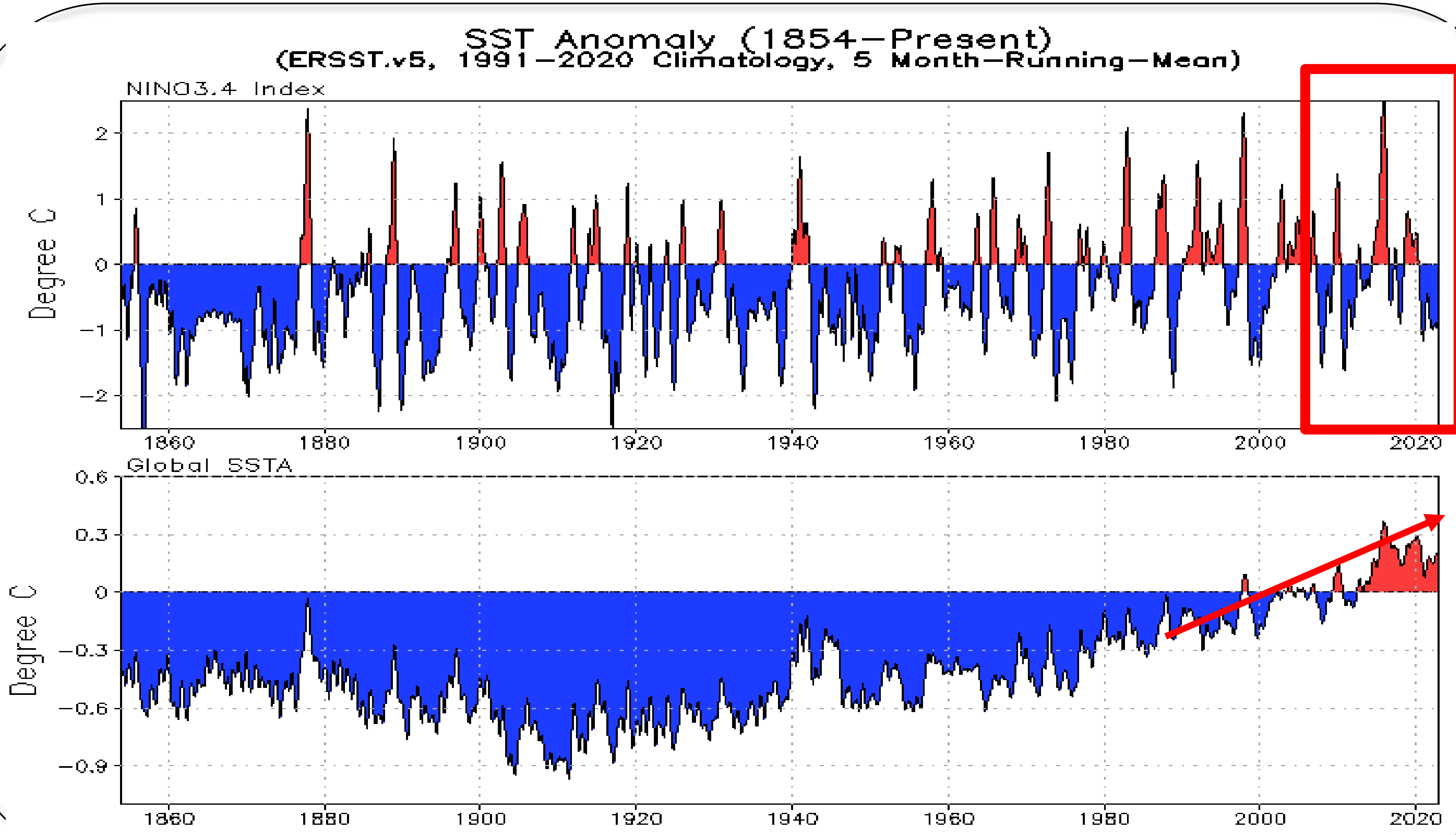
Table 1. Ranked order of the five hottest years of the world's oceans since 1955. The OHC values are anomalies for the upper 2000 m in units of ZJ relative to the 1981–2010 average.

Rank	Year	IAP/CAS	NCEI/NOAA
1	2022	245	238
2	2021	234	229
3	2020	221	211
4	2019	214	210
5	2017	202	189

"In 2022, the world's oceans, as given by OHC, were again the hottest in the historical record and exceeded the previous 2021 record maximum. …since the 1950s."

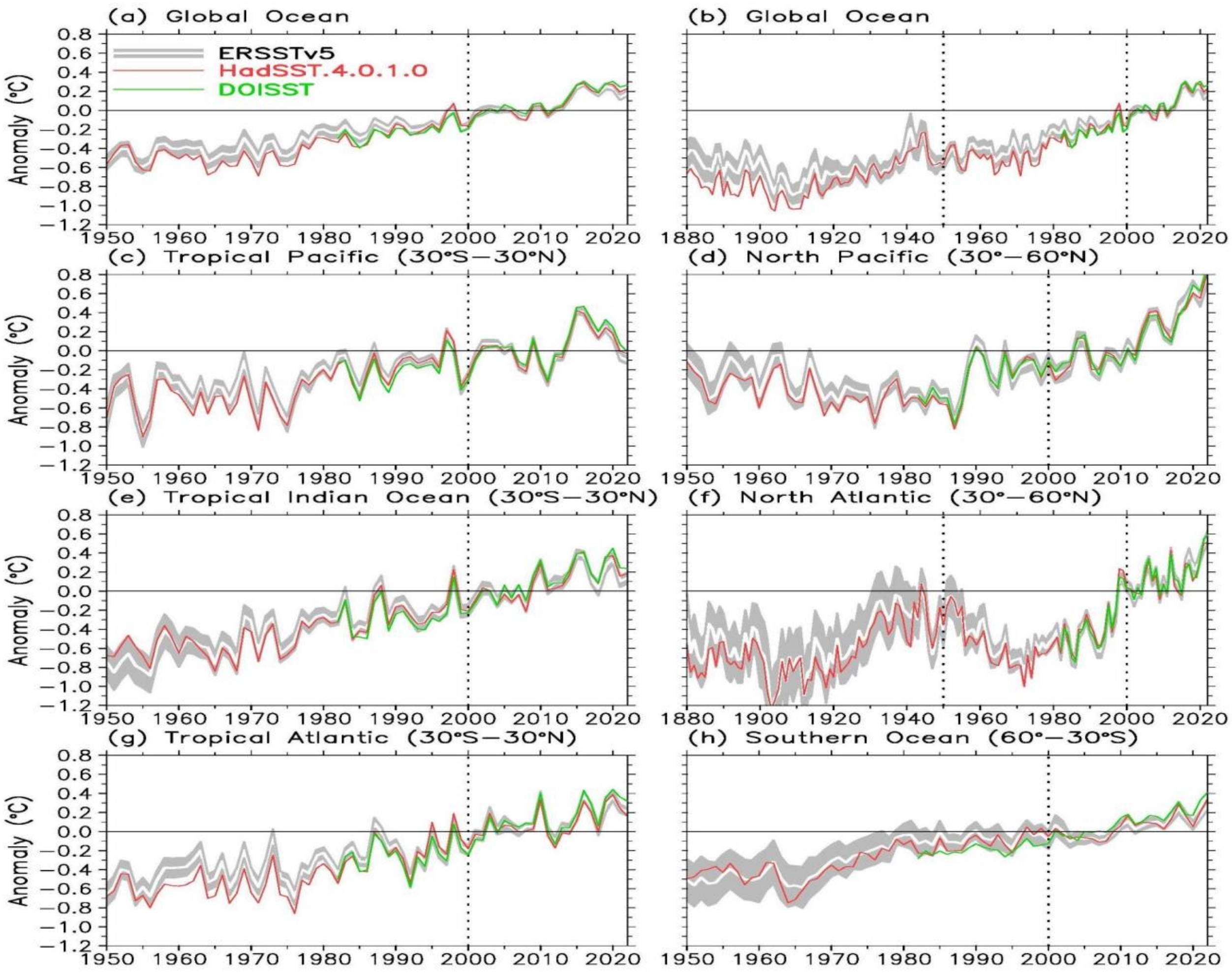
Cheng, et al., 2023: Another year of record heat for the oceans. Adv. Atmos. Sci., https://doi.org/10.1007/s00376-023-2385-2

Nino3.4 Index and Global SSTA since 1854



- Strong warming tendency was observed for global SST; but 2022 wasn't 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 SSTAs in 2022 0.33±0.01°C which is higher than in 2021 (0.29±0.01°C), but lower than in 2019 (0.41±0.02°C) and 2020 (0.39±0.01°C).

- Despite the influence from the La Niña, 2022 global SST still ranks as the 6th hottest year on record since 1854, tied with 2018.

- 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 1950–2022 except for (b). (a) Global, (b) Global in 1880–2022, (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 2022 by *Yin, X., B. Huang, Z.-Z. Hu, N. A. Rayner, D. Chan, and H.-M. Zhang, 2023: Sea Surface Temperatures. [In "State of the Climate in 2022"]. Bull. Amer. Meteor. Soc.*

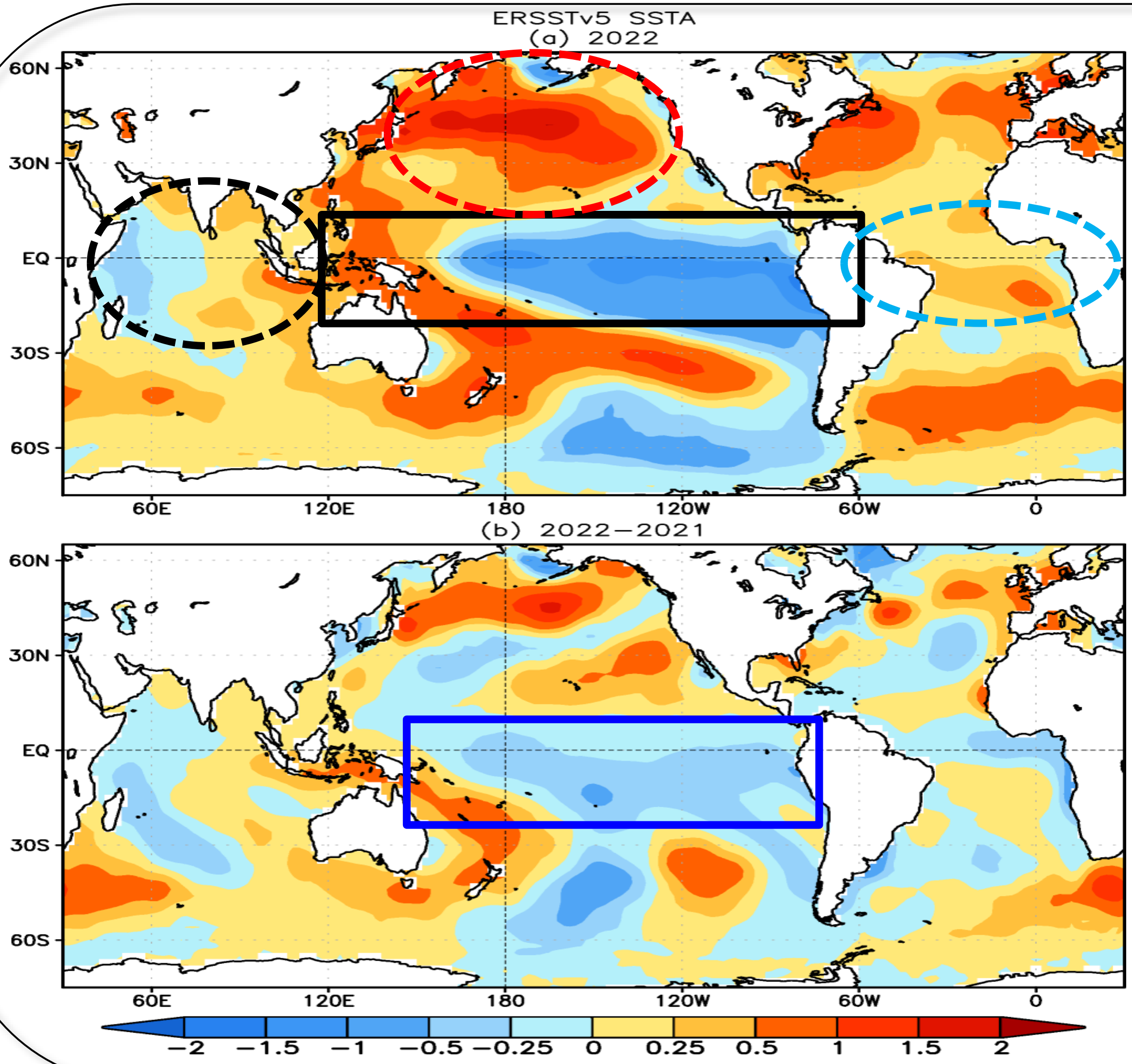
Linear Trend Values

Product	Region	*2000–2022*	1950–2022
HadSST.4.0.1.0	Global	*0.171±0.063*	0.118±0.018
DOISST	Global	*0.186±0.054*	N/A
ERSSTv5	Global	*0.150±0.062*	0.102±0.012
ERSSTv5	Tropical Pacific (30°S–30°N)	*0.109±0.160*	0.096±0.026
ERSSTv5	North Pacific (30°–60°N)	*0.397±0.123*	0.094±0.042
ERSSTv5	Tropical Indian Ocean (30°S–30°N)	*0.166±0.083*	0.140±0.017
ERSSTv5	North Atlantic (30°–60°N)	*0.184±0.092*	0.119±0.045
ERSSTv5	Tropical Atlantic (30°S–30°N)	*0.143±0.077*	0.112±0.019
ERSSTv5	Southern Ocean (30°–60°S)	*0.130±0.050*	0.099±0.015

- Overall, the warming trends of the global & individual oceans since the 1950s persisted.
- Based on ERSSTv5, the linear trends of globally annually averaged SSTAs were 0.102°±0.012°C/decade over 1950–2022.
- The warming trend was the largest in the tropical Indian Ocean **(0.14±0.017°C/decade)** & the smallest in the North Pacific **(0.094±0.042°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 2022 by** *Yin, X., B. Huang, Z.-Z. Hu, N. A. Rayner, D. Chan, and H.-M. Zhang, 2023: Sea Surface Temperatures. [In "State of the Climate in 2022"]. Bull. Amer. Meteor. Soc.*

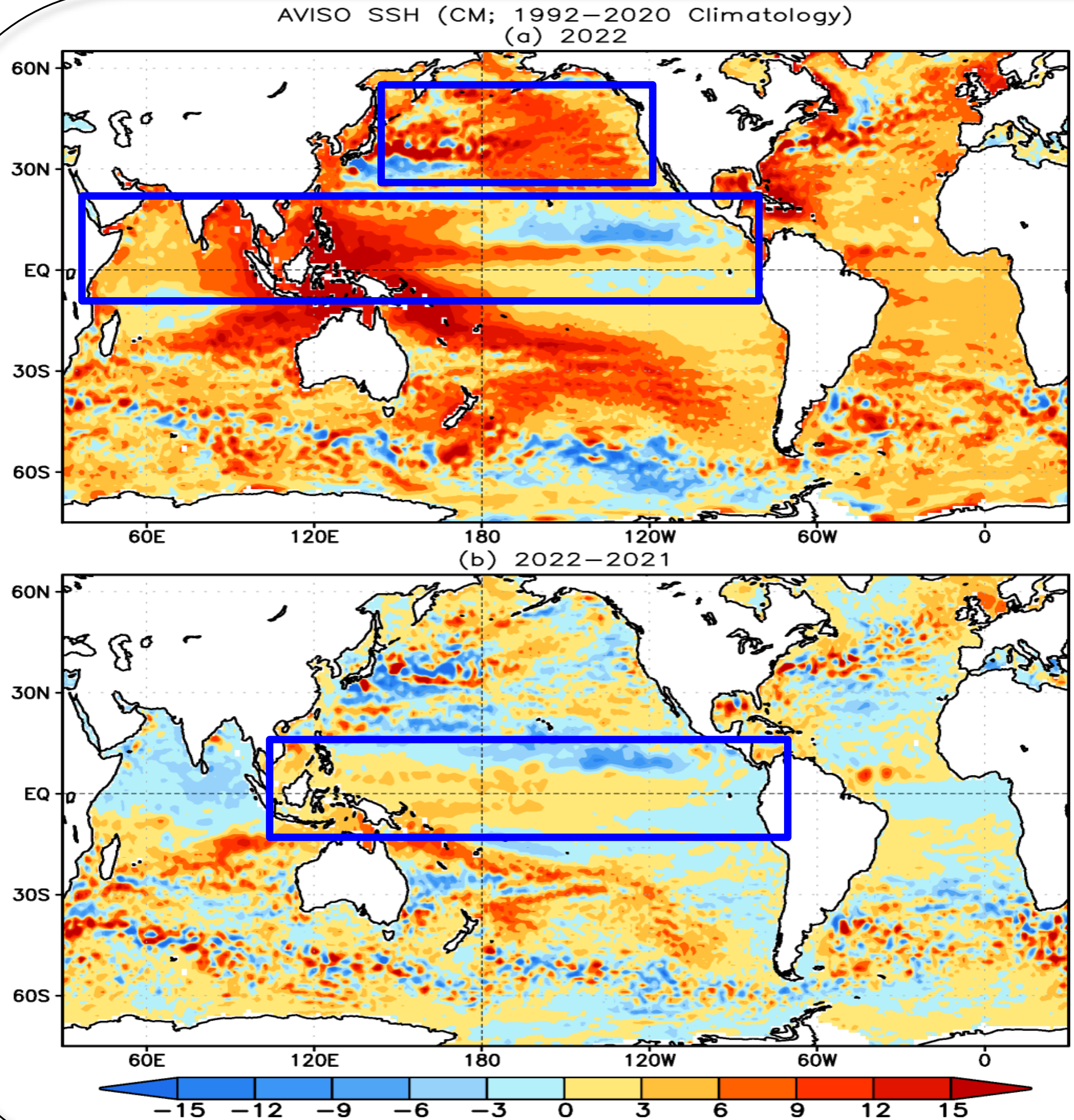
2022 Yearly Mean ERSSTv5 SSTA & Tendency



- The cooling (warming) in the eastern (western) tropical Pacific, associated with the La Niña in 2022.
- Warming in the North Pacific was consistent with the negative phase of PDO in 2022.
- Above-normal SST was observed in the tropical Atlantic Ocean.
- It was a dipole-like pattern with warming (cooling) in the eastern (western) tropical Indian Ocean in 2022.
- Cooling in the tropical Pacific was stronger in 2022 than in 2021.

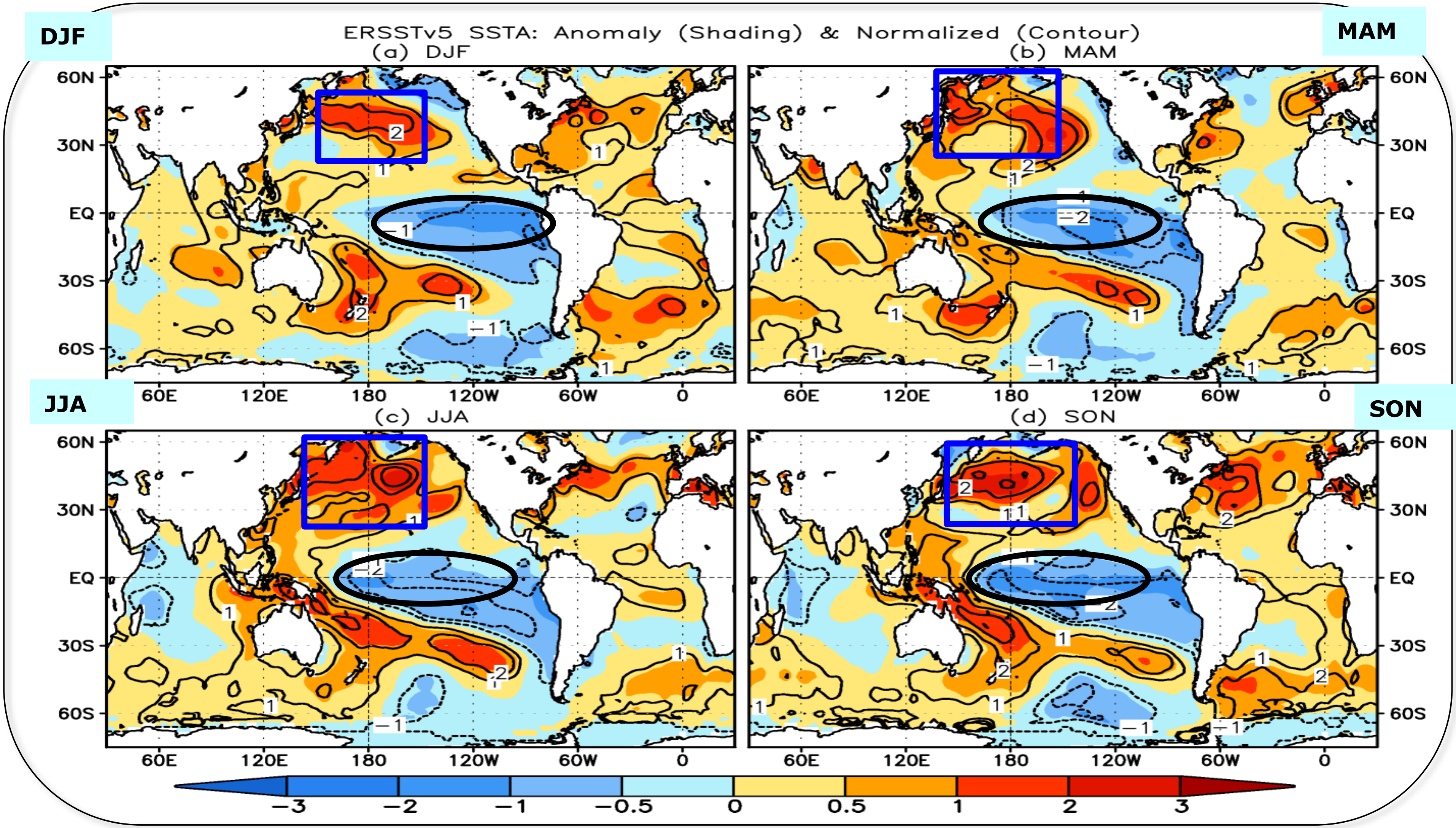
- Fig. 3.1. (a) Annually-averaged SSTAs in 2022 and (b) difference of annually-averaged SSTAs between 2022 and 2021. Values are relative to 1991–2020 climatology and the SSTA difference in is significant at 95% level in stippled areas.
- **BAMS State of the Climate in 2022 by** *Yin, X., B. Huang, Z.-Z. Hu, N. A. Rayner, D. Chan, and H.-M. Zhang, 2023: Sea Surface Temperatures. [In "State of the Climate in 2022"]. Bull. Amer. Meteor. Soc.*

2022 Yearly Mean AVISO SSH Anomalies & Tendency



- **Pronounced positive SSH anomalies were present in the eastern tropical Indian Ocean and western tropical Pacific, consisting with the La Niña condition in 2022.**
- **Positive SSH anomalies were observed in the North Pacific.**
- **The east-west contrast across the tropical Pacific was larger in 2022 than in 2021.**

Seasonal Mean ERSSTv5 SSTA in 2022



- Fig 3.2. Seasonally-averaged SSTAs of ERSSTv5 (°C; shading) for (a) Dec 2021 to Feb 2022, (b) Mar to May 2022, (c) Jun to Aug 2022, and (d) Sep to Nov 2022. The normalized seasonal mean SSTAs based on seasonal mean standard deviation 1 std. dev. 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 2022 by** *Yin, X., B. Huang, Z.-Z. Hu, N. A. Rayner, D. Chan, and H.-M. Zhang, 2023: Sea Surface Temperatures. [In "State of the Climate in 2022"]. Bull. Amer. Meteor. Soc.*

2022 Annual Review

- The year 2022 was the 6th warmest year since global (ocean + land) records began in 1880 at 0.86°C above the 20th century average of 13.9°C, according to NOAA NCEI.
- 2022 global ocean (HC2000) was the warmest since 1955.
- Based on ERSSTv5, the global averaged SSTAs in 2022 0.33°C which is higher than in 2021 (0.29°C), but lower than in 2019 (0.41°C) and 2020 (0.39°C). 2022 SST ranks as the 6th hottest year on record since 1854, tied with 2018.
- Overall, the warming trends of the global oceans since the 1950s persisted with the linear trends of globally annually averaged SSTAs of 0.102°C decade^{-1} over 1950–2022.
- The warming trend was the largest in the tropical Indian Ocean and the smallest in the North Pacific since 1950.

(Yin, X., B. Huang, Z.-Z. Hu, N. A. Rayner, D. Chan, and H.-M. Zhang, 2023: Sea Surface Temperatures. [In "State of the Climate in 2022"]. Bull. Amer. Meteor. Soc.)

Acknowledgement

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

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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

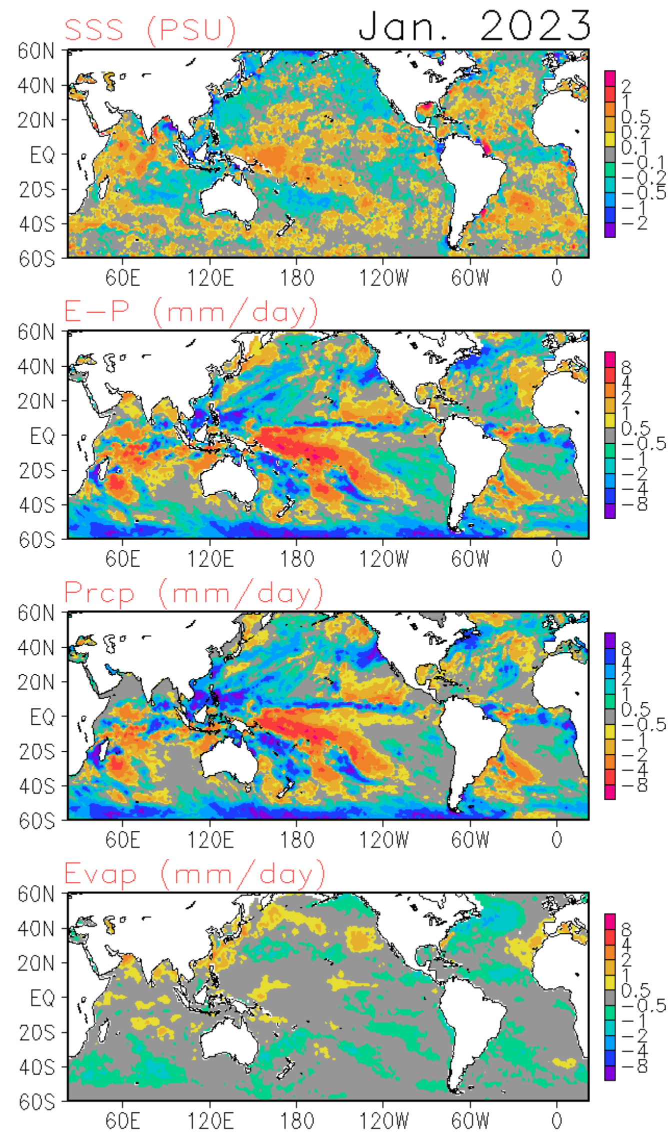
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html

Backup Slides

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

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

Over the tropical oceans, large-scale SSS anomalies correspond well with those of fresh water flux, which in turn are dominated by the precipitation anomalies. Soldier SSS is observed over the mouths of the Amazon Mississippi and Ganges, likely attributable to the deficit runoffs from the three rivers. Freshen SSS anomalies appear over the NW Pacific caused by enhanced precipitation there.



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

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

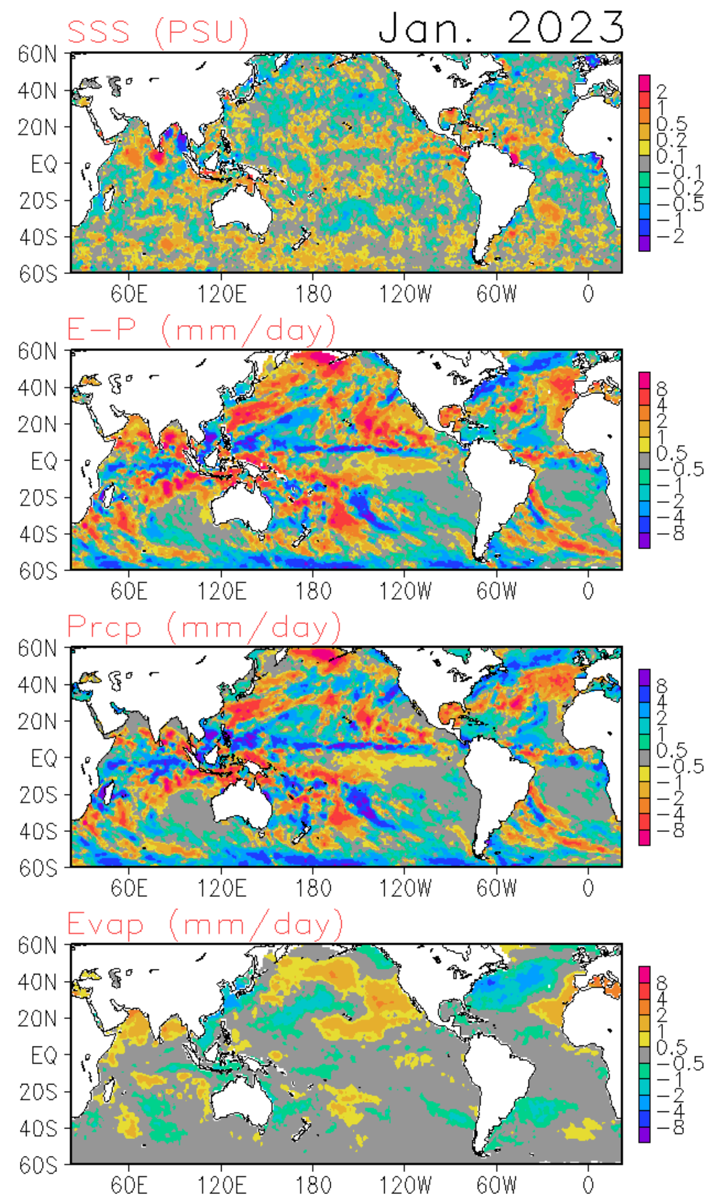
ftp.cpc.ncep.noaa.gov/precip/BASS

Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: Adjusted CFS Reanalysis

Global Sea Surface Salinity (SSS): Tendency for January 2023

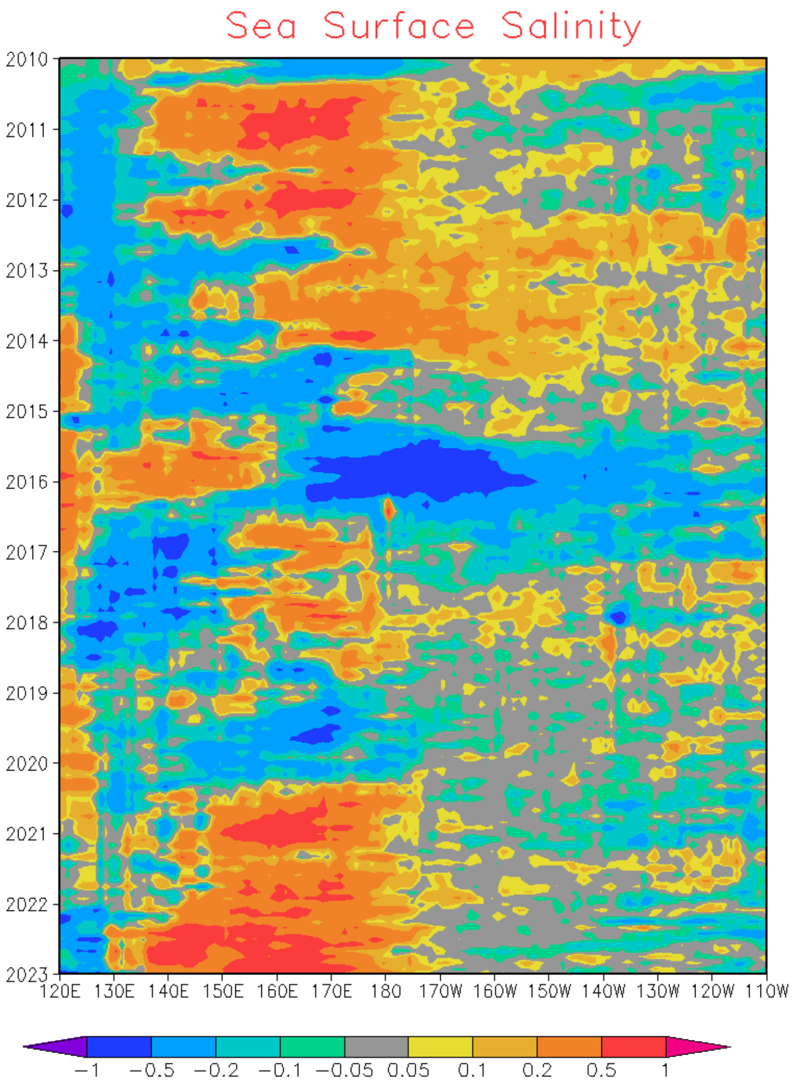
Meridional shift of the ITCZ over all three oceans and the intensification of the ITCZ over the Pacific and the Indian ocean characterized the large-scale precipitation tendency patterns over the tropical oceans, causing changes in the fresh water flux (E-P) and thereby in the SSS. Eastward shift of the SPCZ and the north ward shift of the NW Atlantic storm track activities also create large-scale tendency patterns in the precipitation, freshwater flux and the SSS.



Monthly SSS Anomaly Evolution over Equatorial Pacific

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

- Hovmoller diagram for equatorial SSS anomaly **(5˚S-5˚N);**
- Positive SSS anomalies continued and enhanced over the Central Equatorial Pacific between 140ºE and 170ºW.



BAMS
Article

Global Ocean Monitoring and Prediction at NOAA Climate Prediction Center

15 Years of Operations

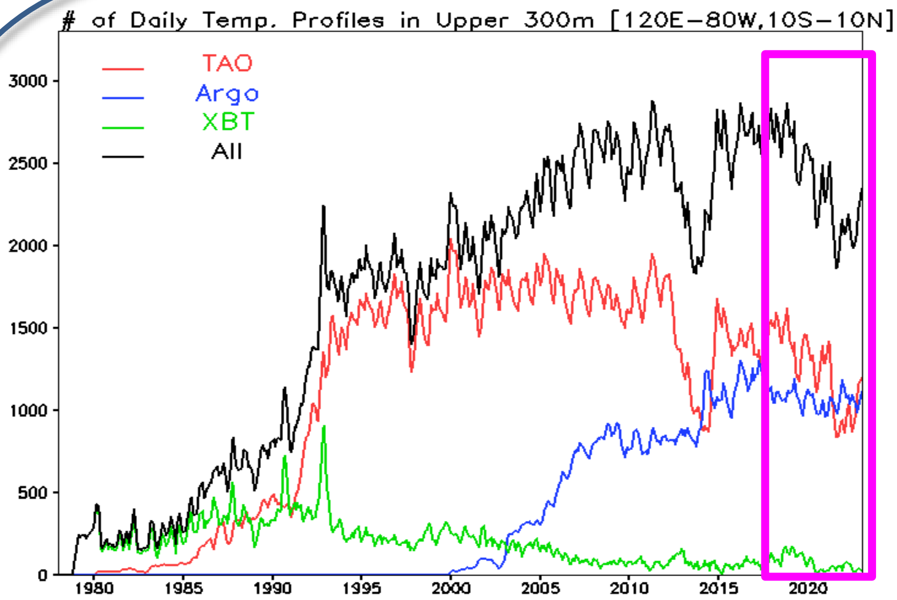
Zeng-Zhen Hu, Yan Xue, Boyin Huang, Arun Kumar, Caihong Wen, Pingping Xie, Jieshun Zhu, Philip J. Pegion, Li Ren, and Wanqiu Wang

ABSTRACT: Climate variability on subseasonal to interannual time scales has significant impacts on our economy, society, and Earth's environment. Predictability for these time scales is largely due to the influence of the slowly varying climate anomalies in the oceans. The importance of the global oceans in governing climate variability demonstrates the need to monitor and forecast the global oceans in addition to El Niño–Southern Oscillation in the tropical Pacific. To meet this need, the Climate Prediction Center (CPC) of the National Centers for Environmental Prediction (NCEP) initiated real-time global ocean monitoring and a monthly briefing in 2007. The monitoring covers observations as well as forecasts for each ocean basin. In this paper, we introduce the monitoring and forecast products. CPC's efforts bridge the gap between the ocean observing system and the delivery of the analyzed products to the community. We also discuss the challenges involved in ocean monitoring and forecasting, as well as the future directions for these efforts.

KEYWORDS: Ocean; Atmosphere-ocean interaction; ENSO; Climate prediction; Oceanic variability; Climate services

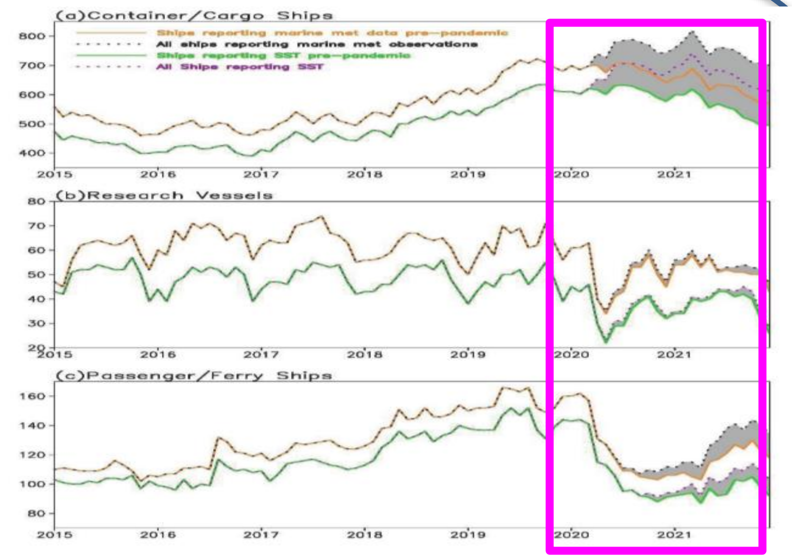
https://doi.org/10.1175/BAMS-D-22-0056.1
Corresponding author: Zeng-Zhen Hu, zeng-zhen.hu@noaa.gov
In final form 15 August 2022

Hu, Z.-Z., Y. Xue, B. Huang, A. Kumar, C. Wen, P. Xie, J. Zhu, P. Pegion, L. Ren, and W. Wang, 2022: Global ocean monitoring and forecast at NOAA Climate Prediction Center: 15 Years of Operations. *Bull. Amer. Meteor. Soc.*, **103 (12),** E2701–E2718. DOI: 10.1175/BAMS-D-22-0056.1.



Hu et al. 2022: Fig. 9: Time series of the number of daily ocean temperature profiles per month accumulated in the tropical Pacific from the Tropical Atmosphere Ocean/Triangle Trans-Ocean Buoy Network (TAO/TRITON; red line), Argo (blue line), the Expendable Bathythermograph (XBT; green line), and TAO/TRITON/Argo/XBT together (black line) since January 1979.

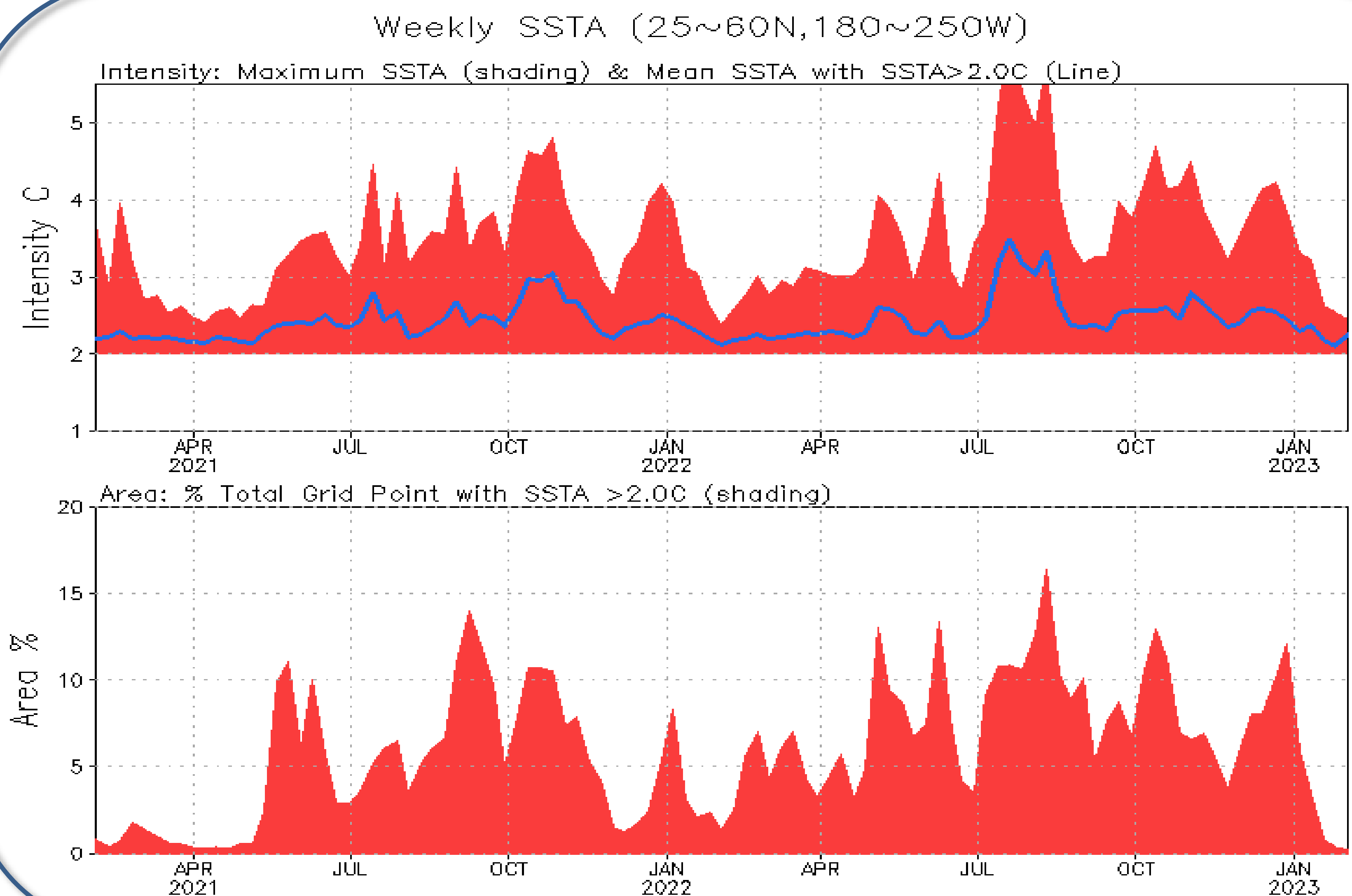
… the pandemic caused critical loss to longer-term (years to decades) observations…



Boyer et al. 2023: Fig. 2. Number of ships with independent WMO call sign numbers since 2015 in the ICOADS R3.0.2 near real-time collection. Top panel (a) is for the container/cargo ships, middle panel (b) for the research vessels/ships, and bottom panel (c) for passenger/ferry ships. The Orange and Black lines are for all ships, compared to the Green and Purple lines which are for subsets of ships reporting SST measurements. The solid lines are for the number of ships that were reporting data pre-pandemic (defined as March 2020) and have continued since then, while the dashed lines are the total number of ships reporting data during the pandemic.

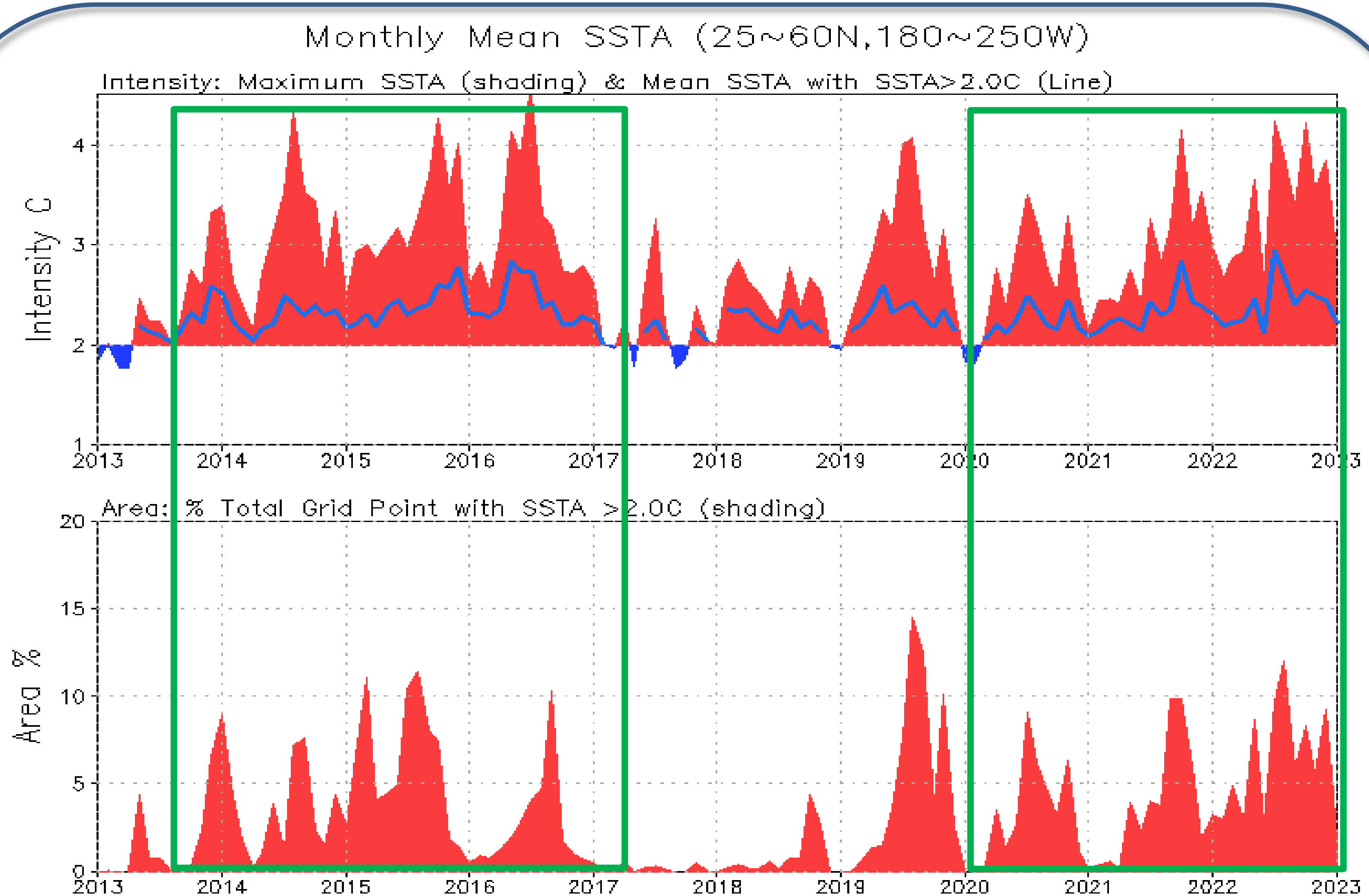
Boyer, T., Zhang, H., O'Brien, K., Reagan, J., Diggs, S., Freeman, E., Garcia, H., Heslop, E., Hogan, P., Huang, B., Jiang, L., Kozyr, A., Liu, C., Locarnini, R., Mishonov, A. V., Paver, C., Wang, Z., Zweng, M., Alin, S., Barbero, L., Barth, J. A., Belbeoch, M., Cebrian, J., Connell, K., Cowley, R., Dukhovskoy, D., Galbraith, N. R., Goni, G., Katz, F., Kramp, M., Kumar, A., Legler, D., Lumpkin, R., McMahon, C. R., Pierrot, D., Plueddemann, A. J., Smith, E. A., Sutton, A., Turpin, V., Jiang, L., Suneel, V., Wanninkhof, R., Weller, R. A., & Wong, A. P. (2023). Effects of the Pandemic on Observing the Global Ocean, BAMS. BAMS-D-21-0210.1/BAMS-D-21-0210.1.xml

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

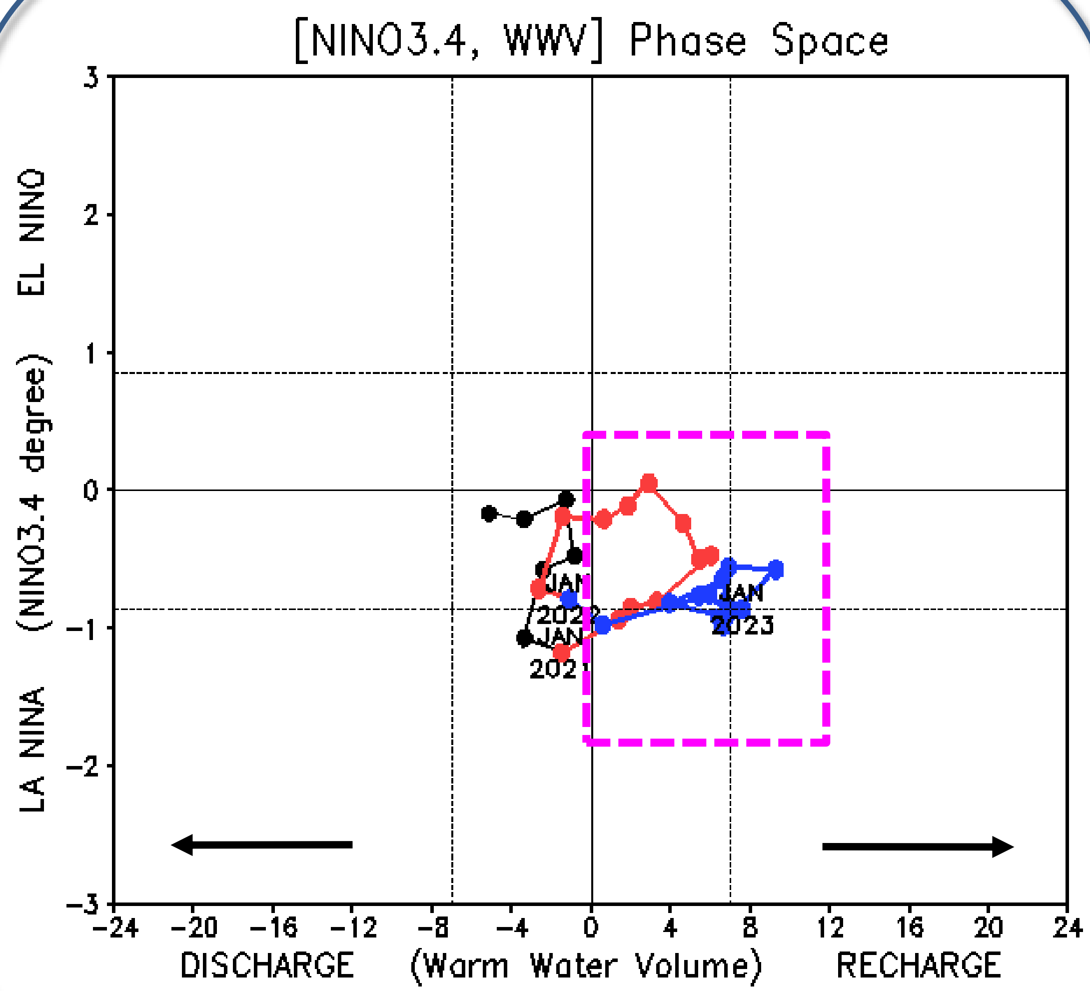
https://www.cpc.ncep.noaa.gov/products/GODAS/MarineHeatWave.html

Warm Water Volume (WWV) and Niño3.4 Anomalies

- Equatorial Warm Water Volume (WWV) was in a recharge phase in Jan 2023.

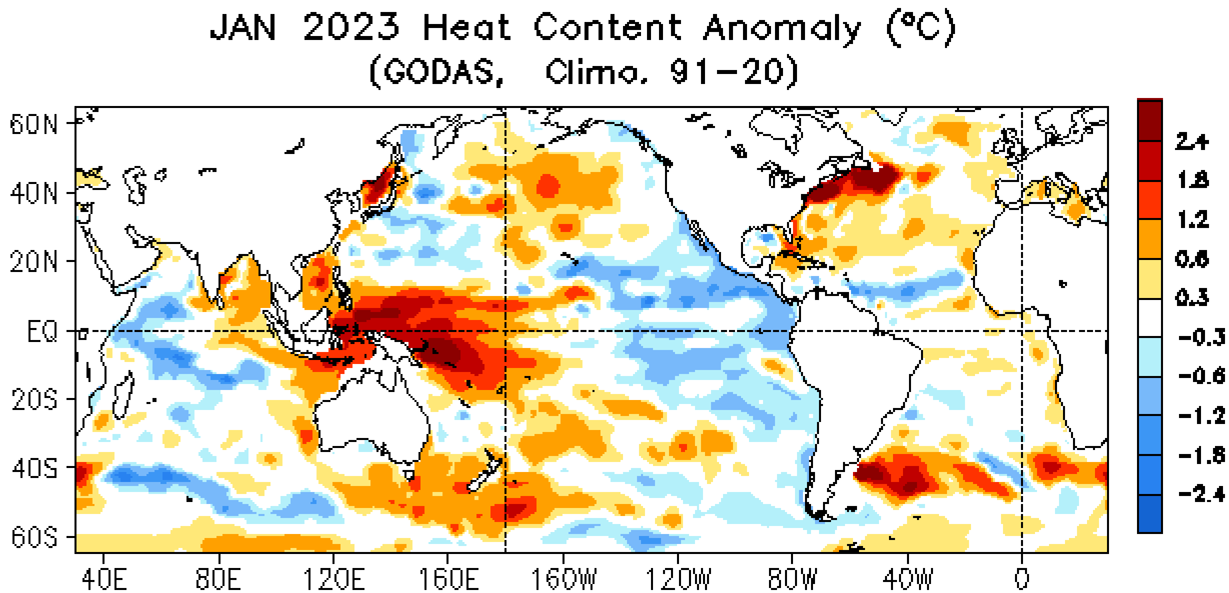
-As WWV is intimately linked to ENSO variability (Wyrtki 1985; Jin 1997), it is useful to monitor ENSO in a phase space of WWV and Niño3.4 (Kessler 2002).

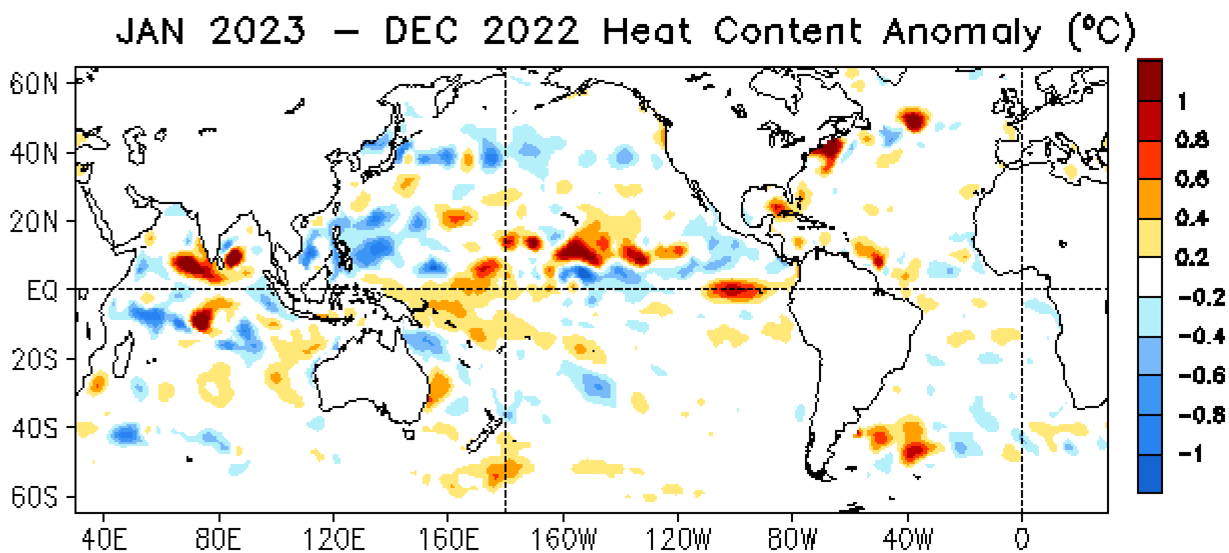
- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.



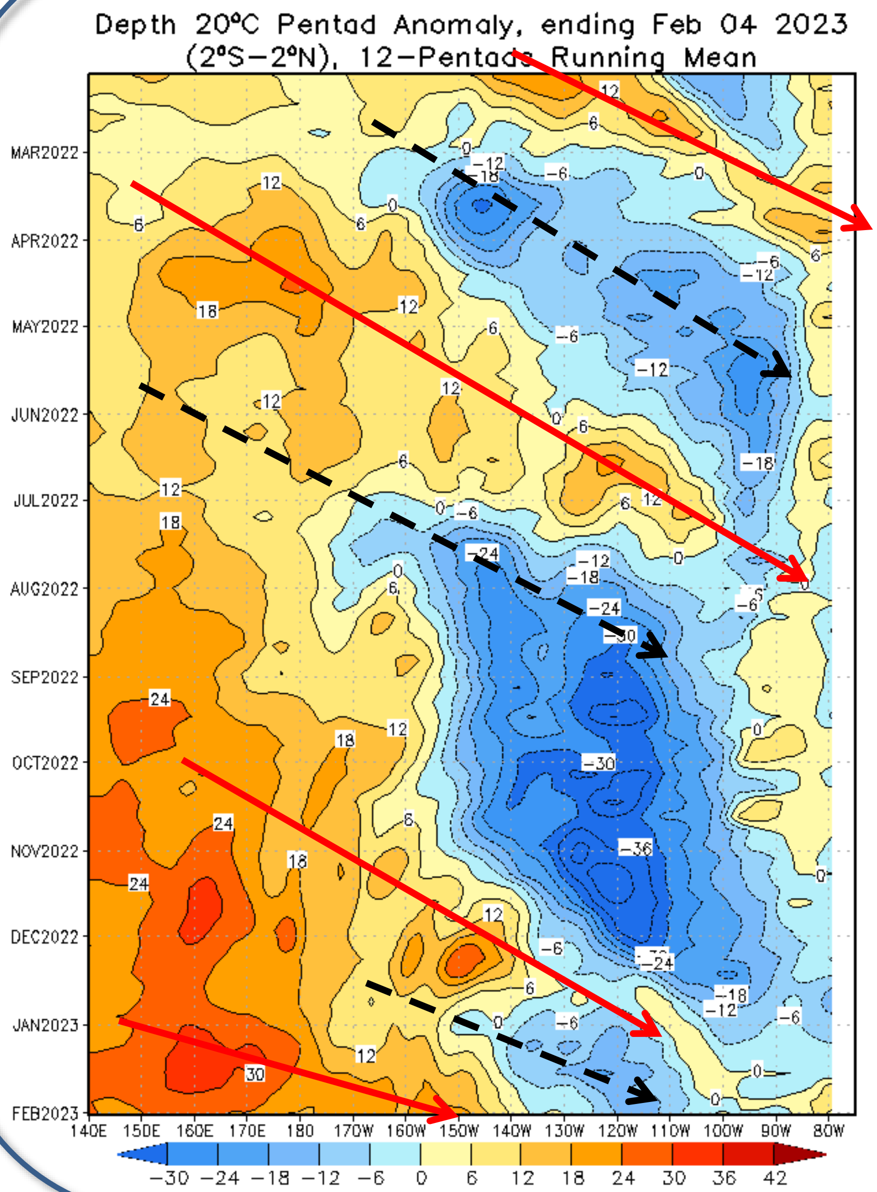
Phase diagram of Warm Water Volume (WWV) and Niño3.4 indices. WWV is the average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN] calculated with the NCEP's GODAS. Anomalies are departures from the 1991-2020 base period means.

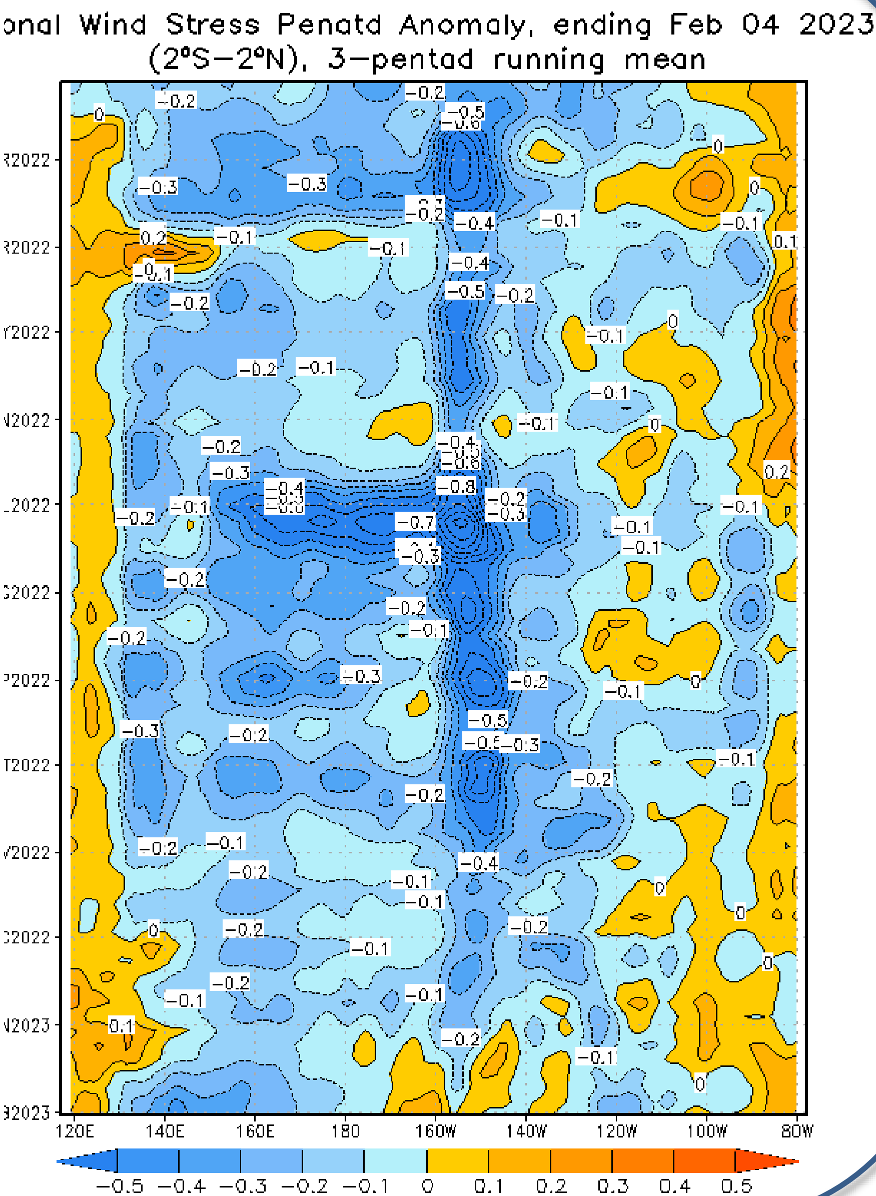
Global HC300 Anomaly & Anomaly Tendency



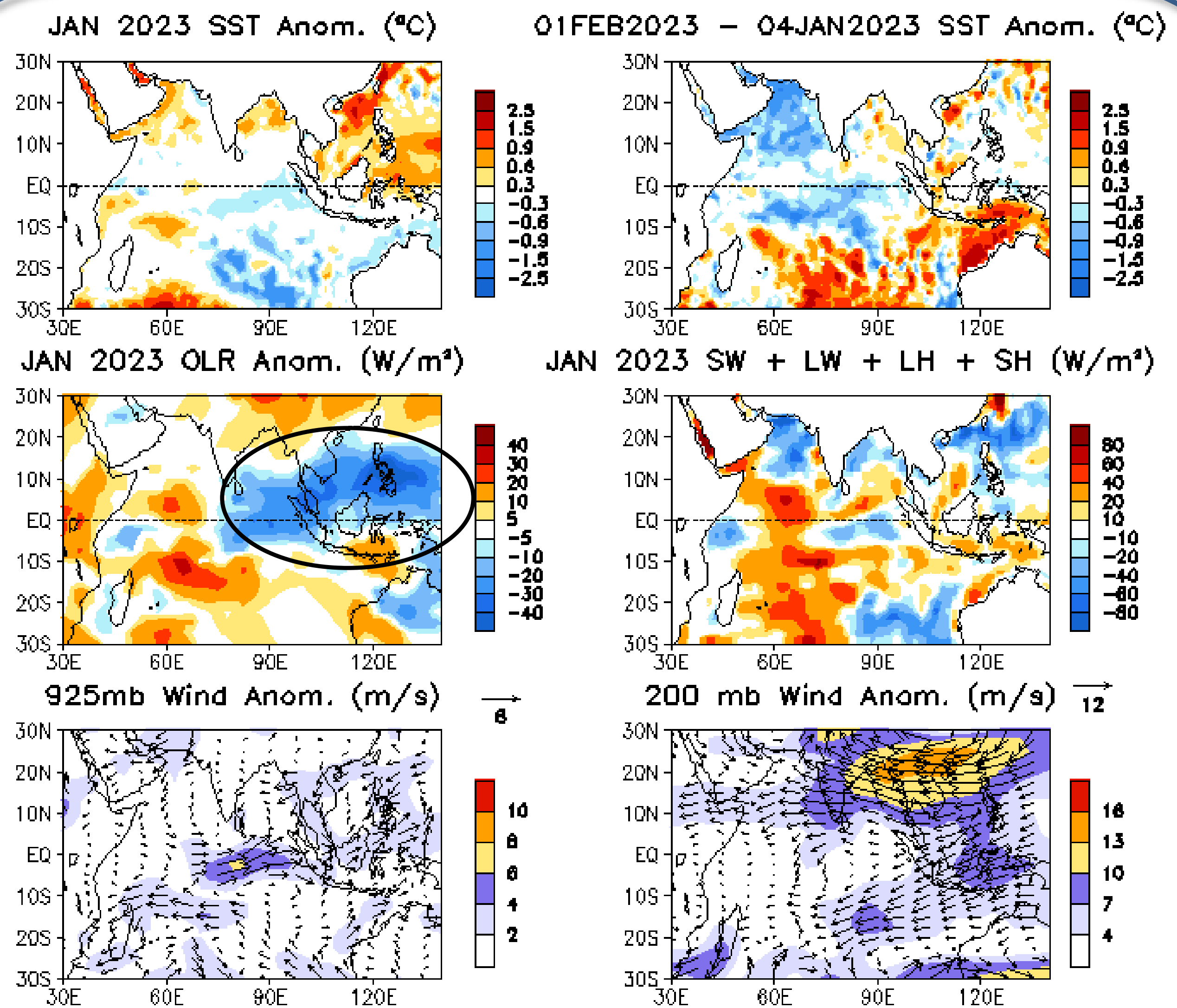


Evolution of Pentad D20 and Taux anomalies along the equator





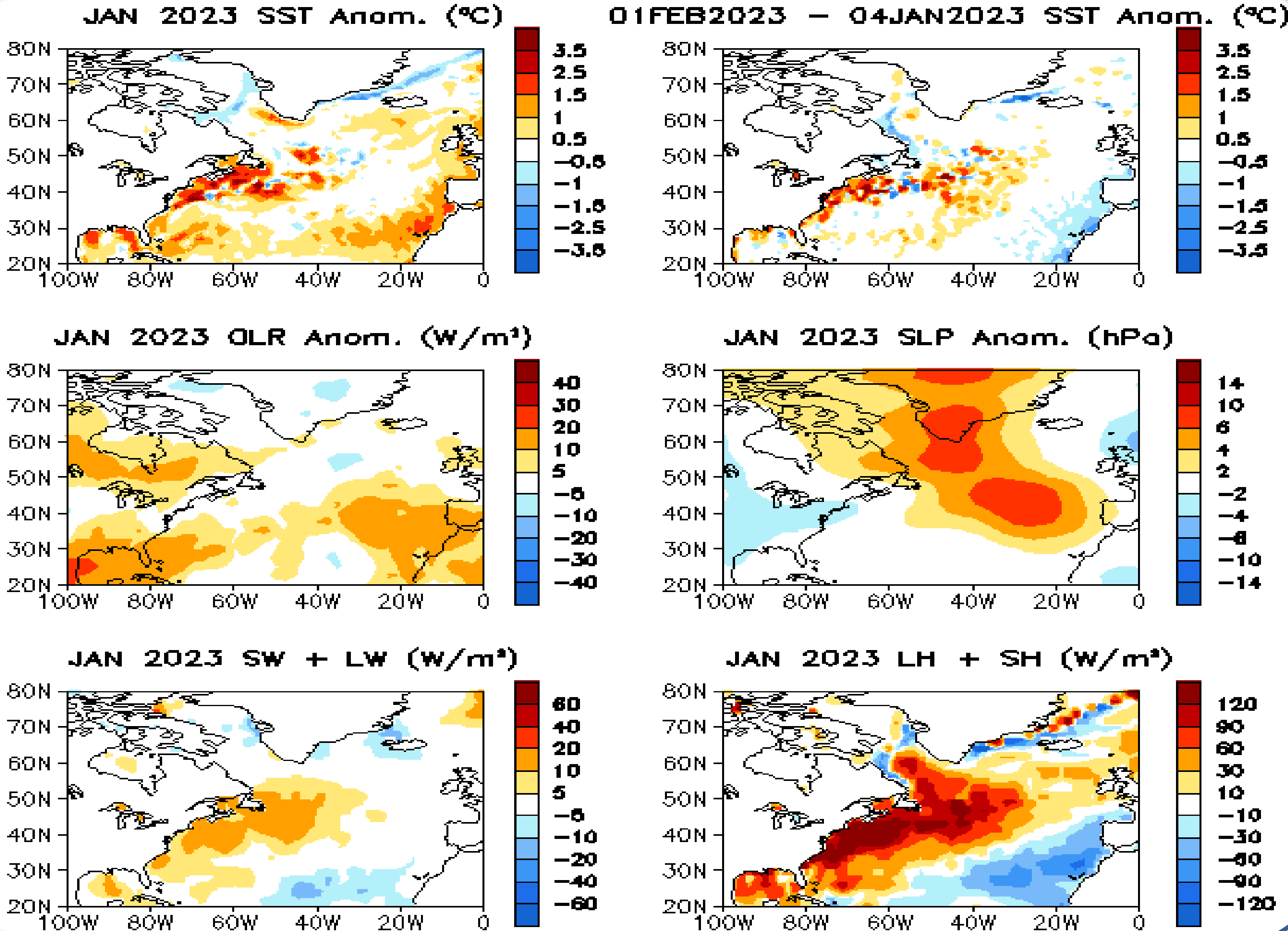
Tropical Indian: SSTA, SSTA Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Wind Anom.



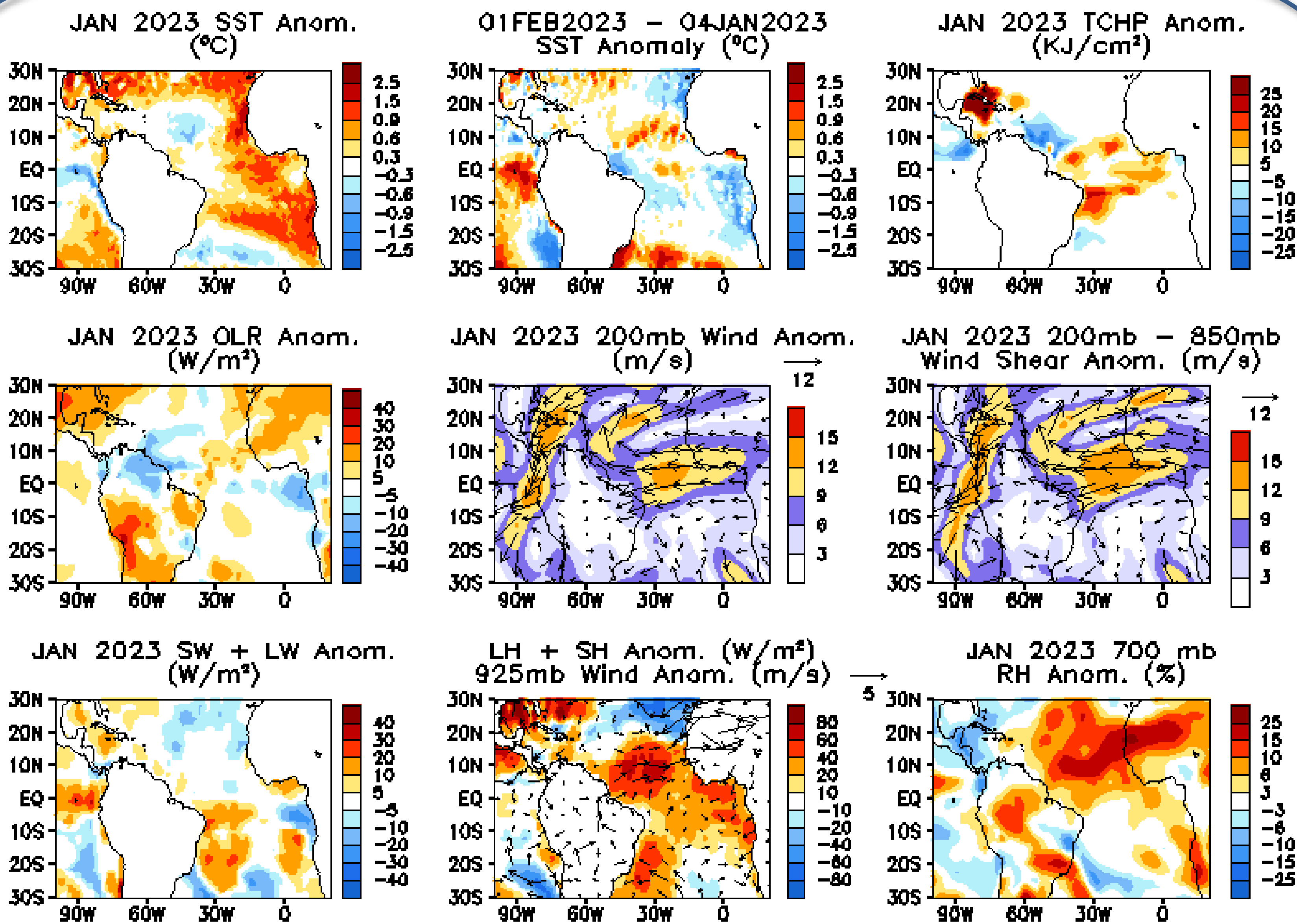
Convection was enhanced (suppressed) over the eastern (western) Indian Ocean.

SSTAs (top-left), SSTA tendency (top-right), OLR anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the 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.

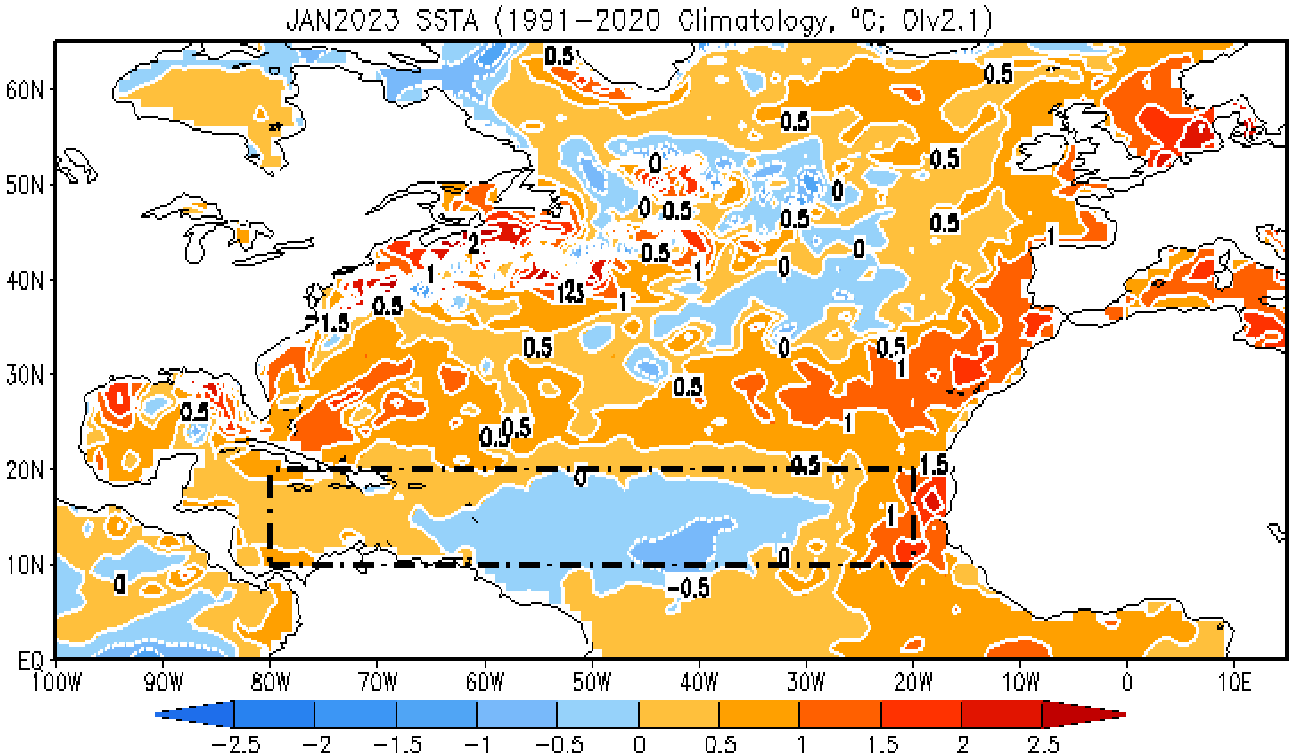
N. Atlantic: SST, SST tend., OLR, SLP, & heat flex anom.

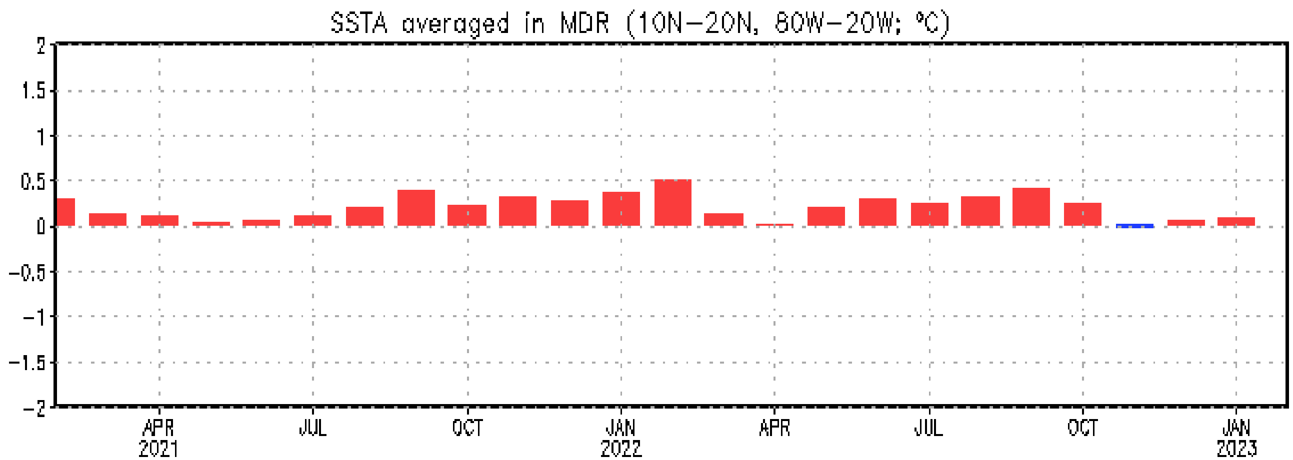


Tropical Atlantic: SST, SST tend., TCHP, OLR, 200 hPa wind, wind share, heat flex, & RH anom.



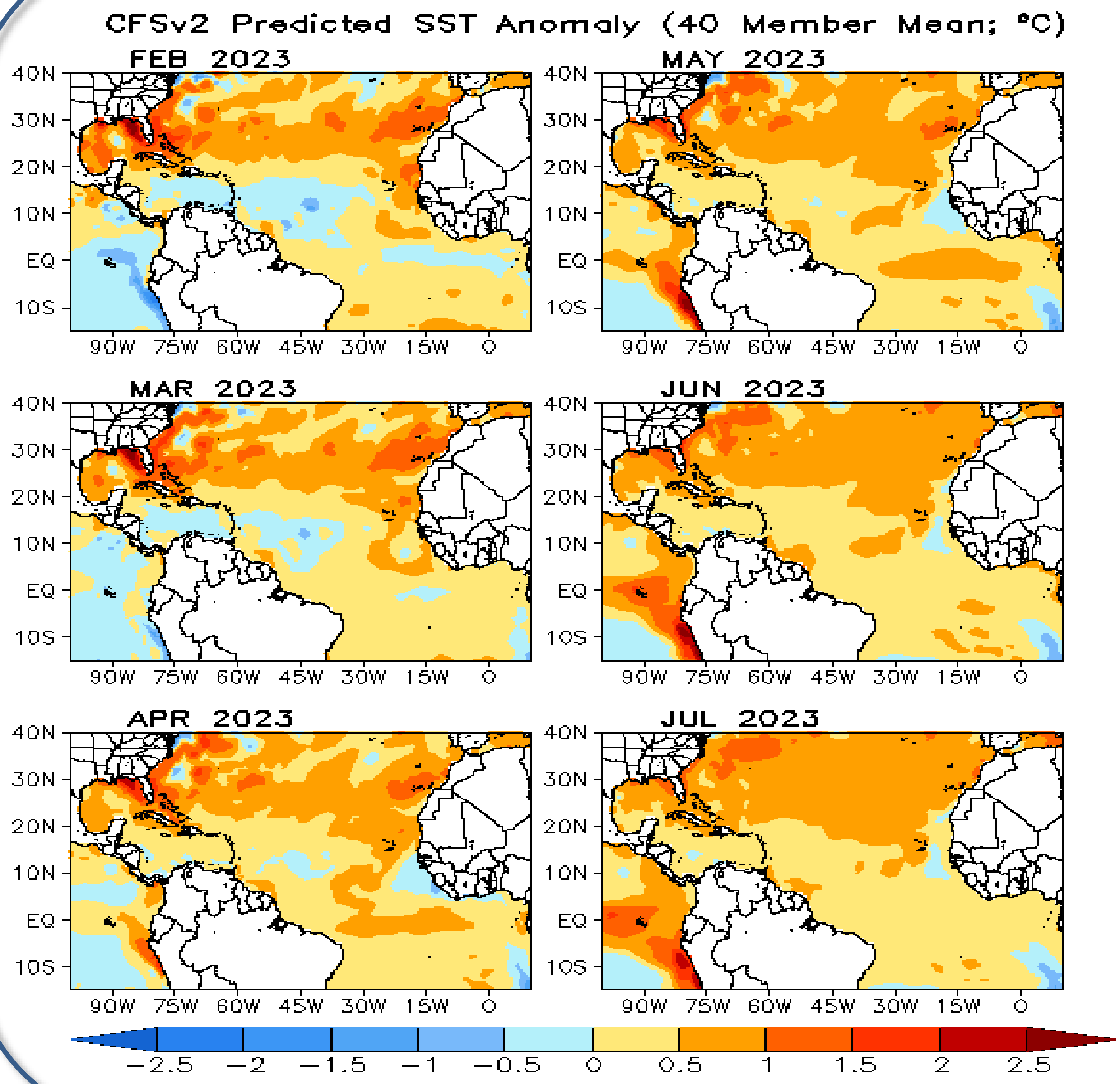
SSTAs in the North Atlantic & MDR





- SST in MDR was above (blow) average in the eastern (central) portion in Jan 2023.

CFSv2 Atlantic SSTA Predictions



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