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

Prepared by

Climate Prediction Center, NCEP/NOAA

February 11, 2022

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

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

Outline

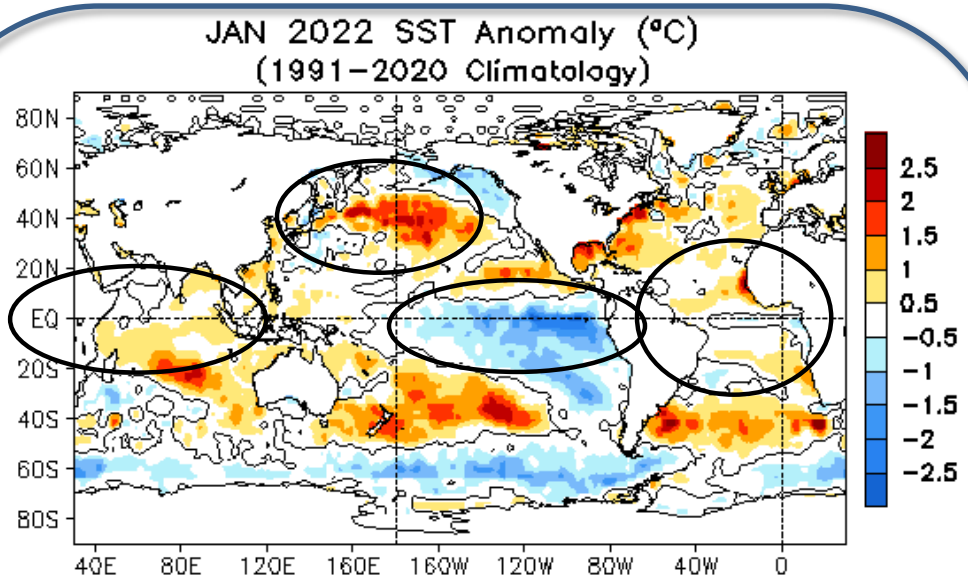
- **Overview**
- **Recent highlights**
  - Pacific/Arctic Ocean
  - Indian Ocean
  - Atlantic Ocean
- **Global SSTA Predictions**
- **2021 Annual Review**

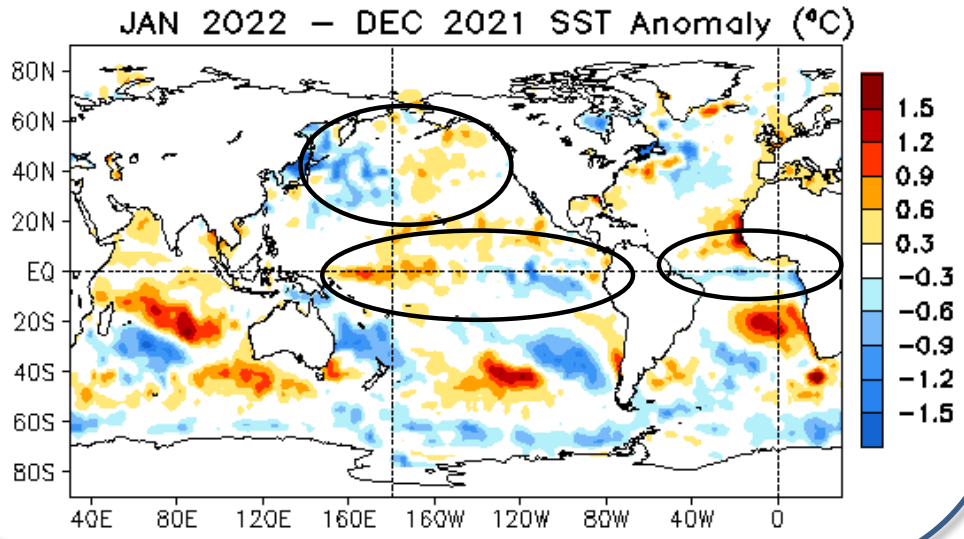
Overview

- **Pacific Ocean**
  - NOAA "ENSO Diagnostic Discussion" on 10 Feb 2022 stated *"La Niña is likely to continue into the Northern Hemisphere spring (77% chance during March-May 2022) and then transition to ENSO-neutral (56% chance during May-July 2022)."*
  - La Niña condition persisted with Niño3.4 = -0.96°C in Jan 2022.
  - Positive SSTAs continued in the North Pacific in Jan 2022.
  - The PDO has been in a negative phase since Jan 2020 with PDOI = -1.94 in Jan 2022.
- **Arctic Ocean**
  - "Arctic sea ice extent averaged for Jan 2022 was the 16th lowest in the satellite record above all years since 2009, with the exception of 2013 and 2014."
- **Indian Ocean**
  - Positive SSTAs were present in the tropics in Jan 2022.
- **Atlantic Ocean**
  - SSTAs were small in the tropics in Jan 2022.
  - NAO switched to a positive phase in Dec 2021 with NAOI= 0.74 in Jan 2022.
  - Positive SSTAs in the mid-high latitudes of the N. Atlantic have been evident since 2021.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency



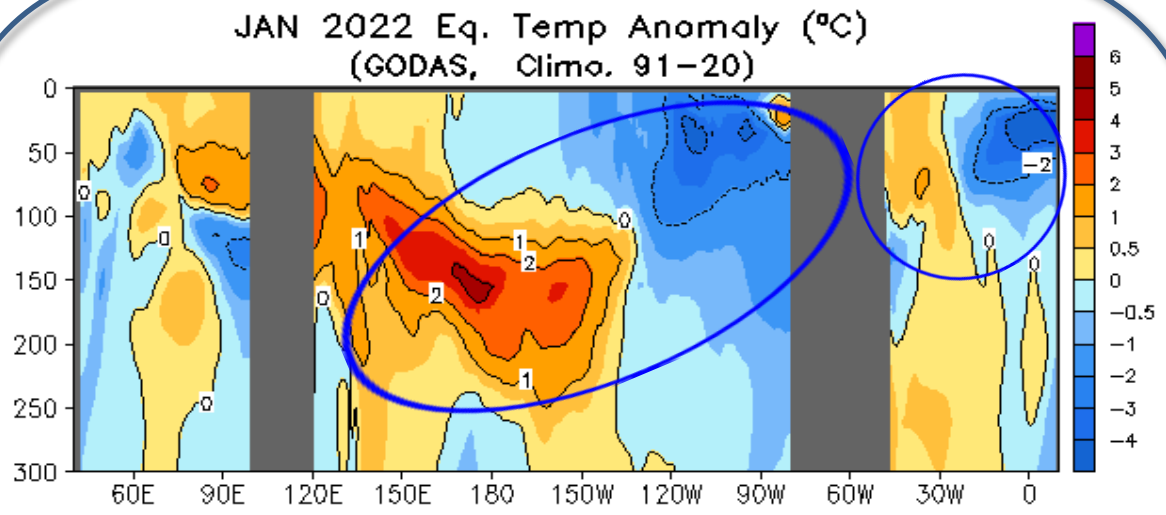


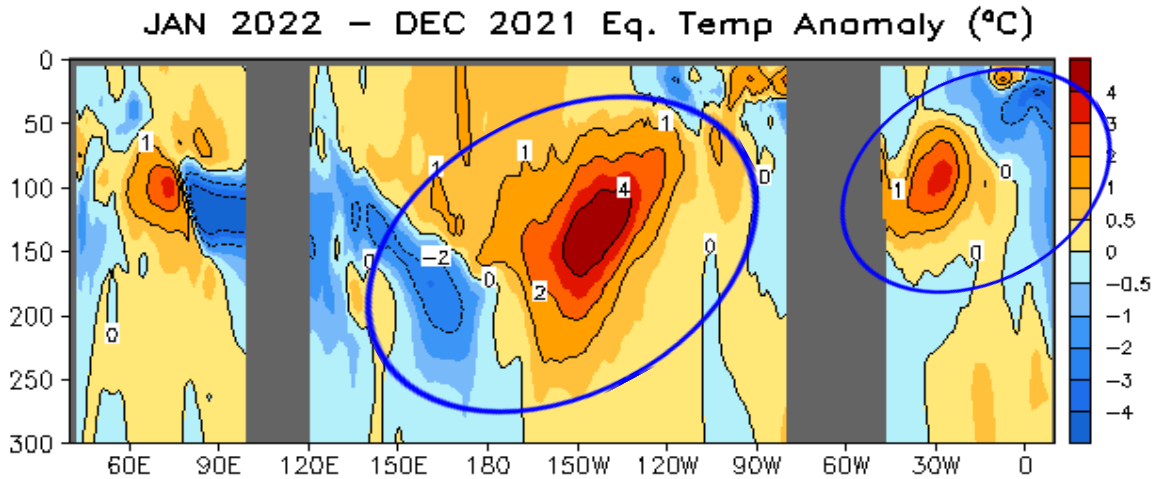
- Negative SSTAs persisted in the central and eastern equatorial Pacific.
- Positive SSTAs continued in the North Pacific.
- Weak SSTAs were evident across the tropical Atlantic.
- SSTs were slightly above average in the tropical Indian Ocean.

- Positive (negative) SSTA tendencies were observed in the central (eastern) equatorial Pacific.
- Positive (negative) SSTA tendencies were evident in the eastern (western) North Pacific.
- Negative SSTA tendencies were present in the equatorial Atlantic Ocean.

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

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



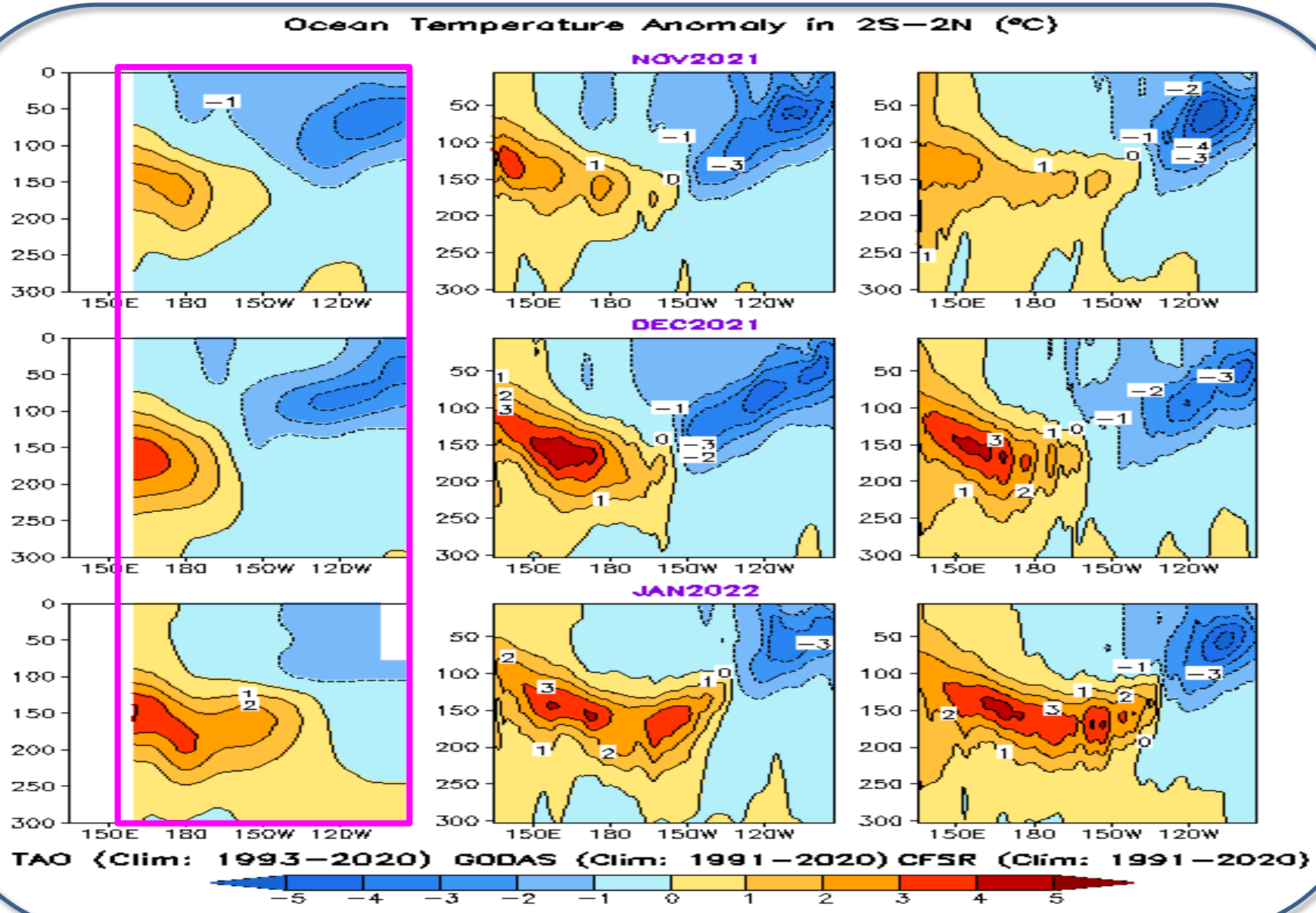


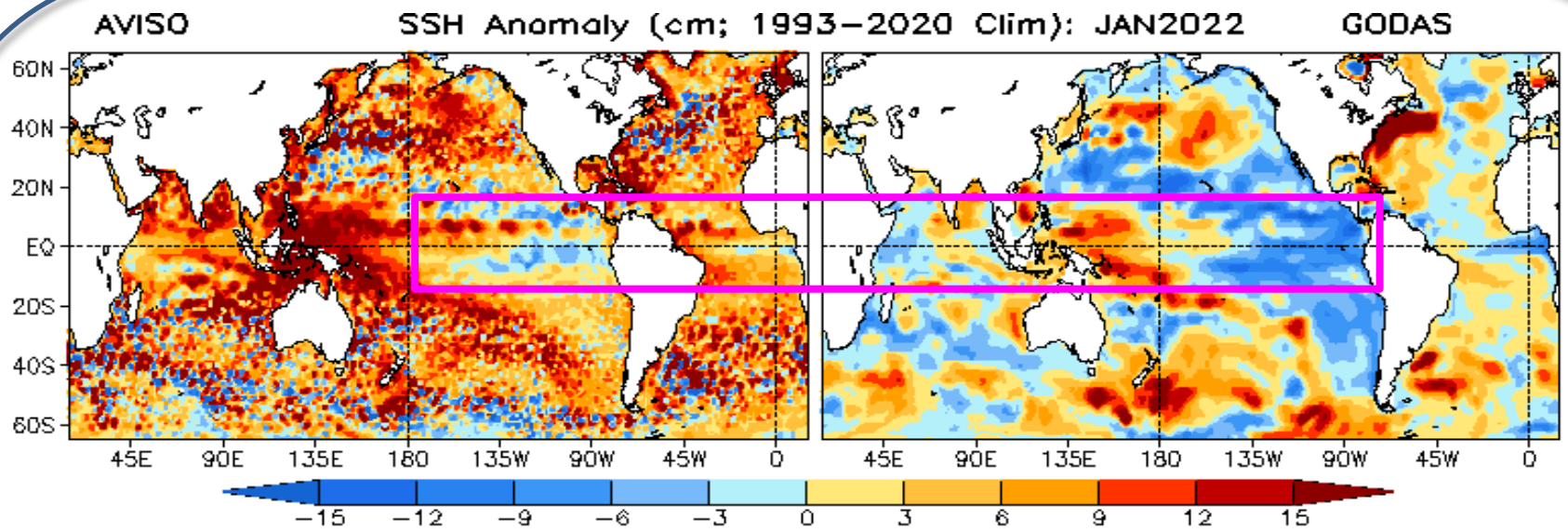
- Positive (negative) temperature anomalies were observed along the thermocline in the western and central (eastern) equatorial Pacific.
- Positive (negative) temperature anomalies were observed along the thermocline in the western (eastern) equatorial Atlantic Ocean.

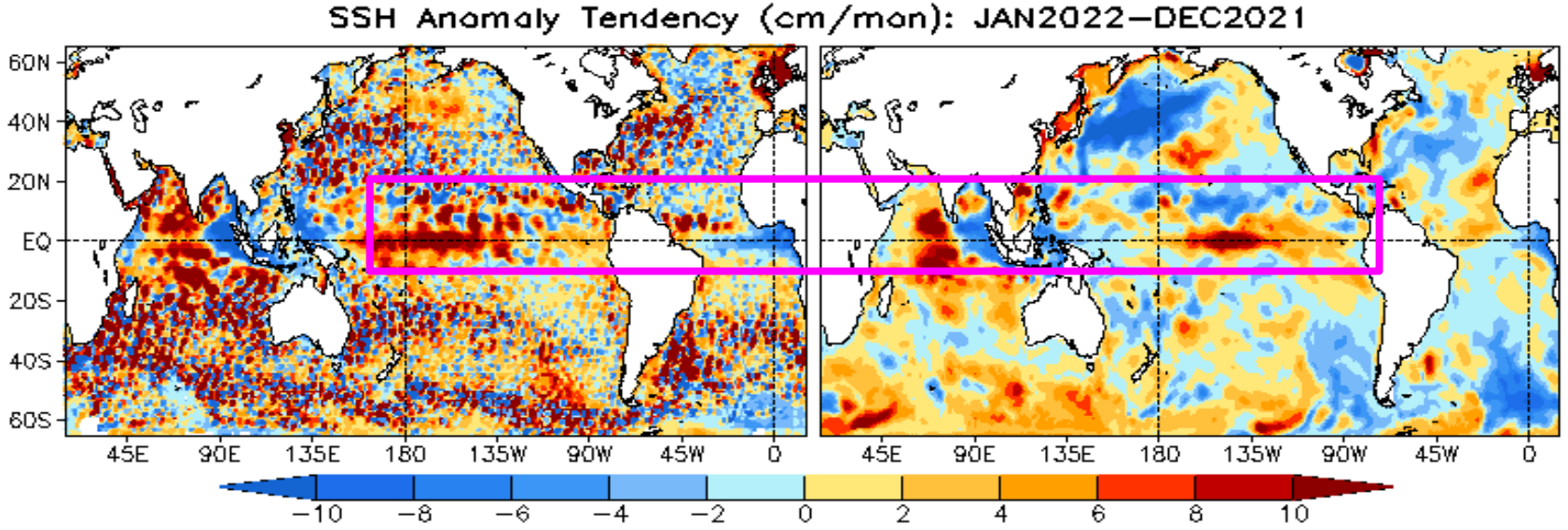
- Temperature anomaly tendency was positive (negative) along the thermocline in the east-central (western) Pacific.
- Positive (negative) temperature anomaly tendency was evident in the western (eastern) Atlantic Ocean.

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.

TAO, GODAS, & CFSR monthly mean subsurface temperature anomalies along the Equator during the last 3 months



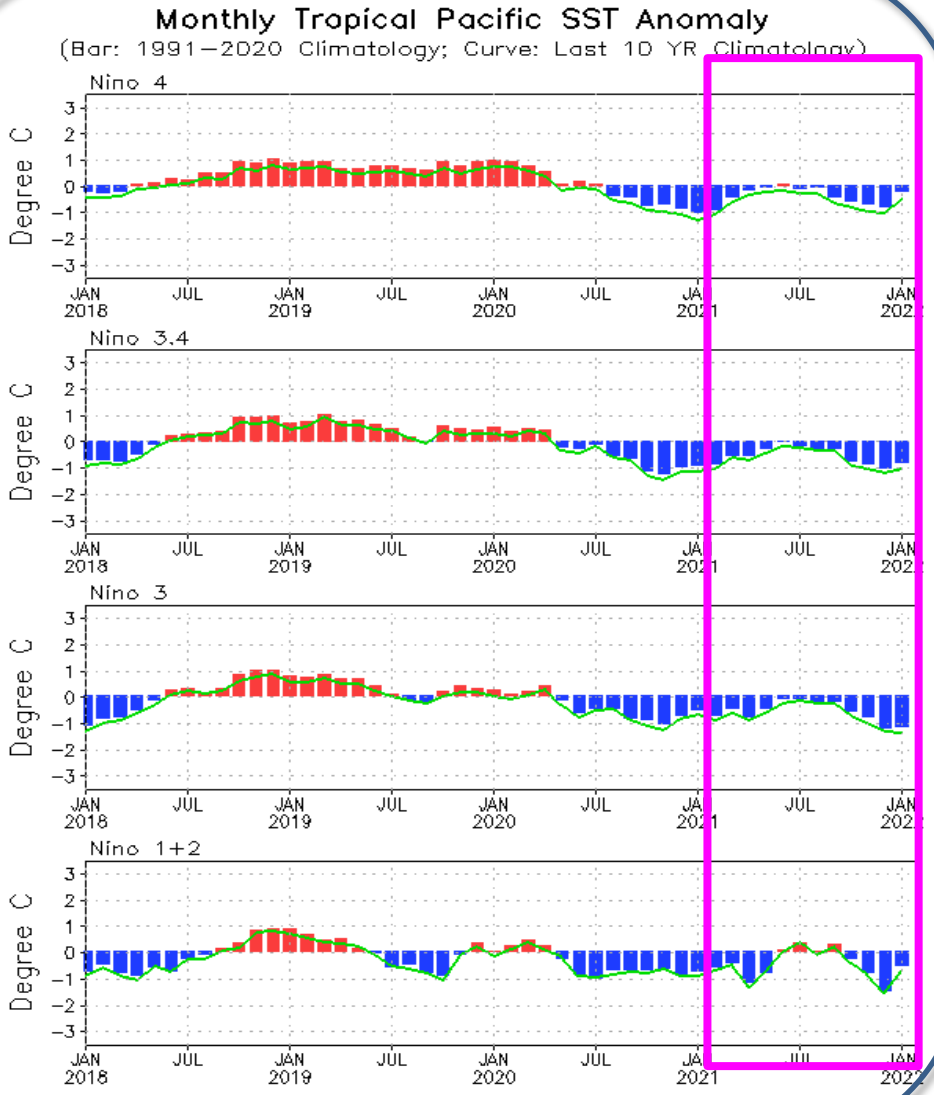


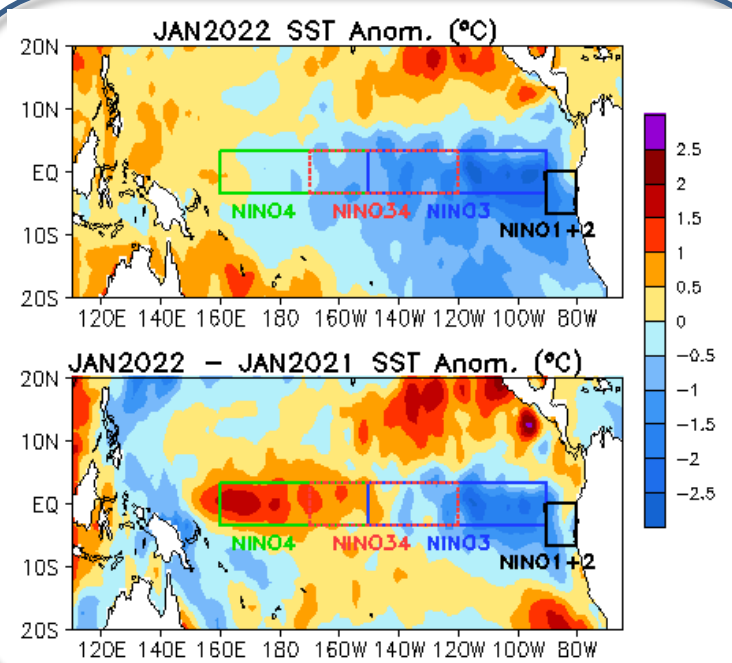


- Basic features in the tropical Pacific associated La Nina evolution are consistent between AVISO and GOSA.
- There are some differences in details between AVISO & GODAS with a lot of small-scale variabilities in AVISO.

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific Niño SST Indices

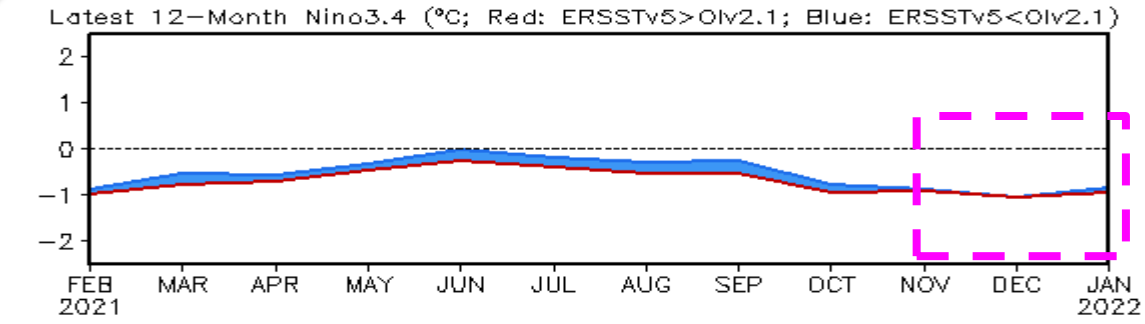


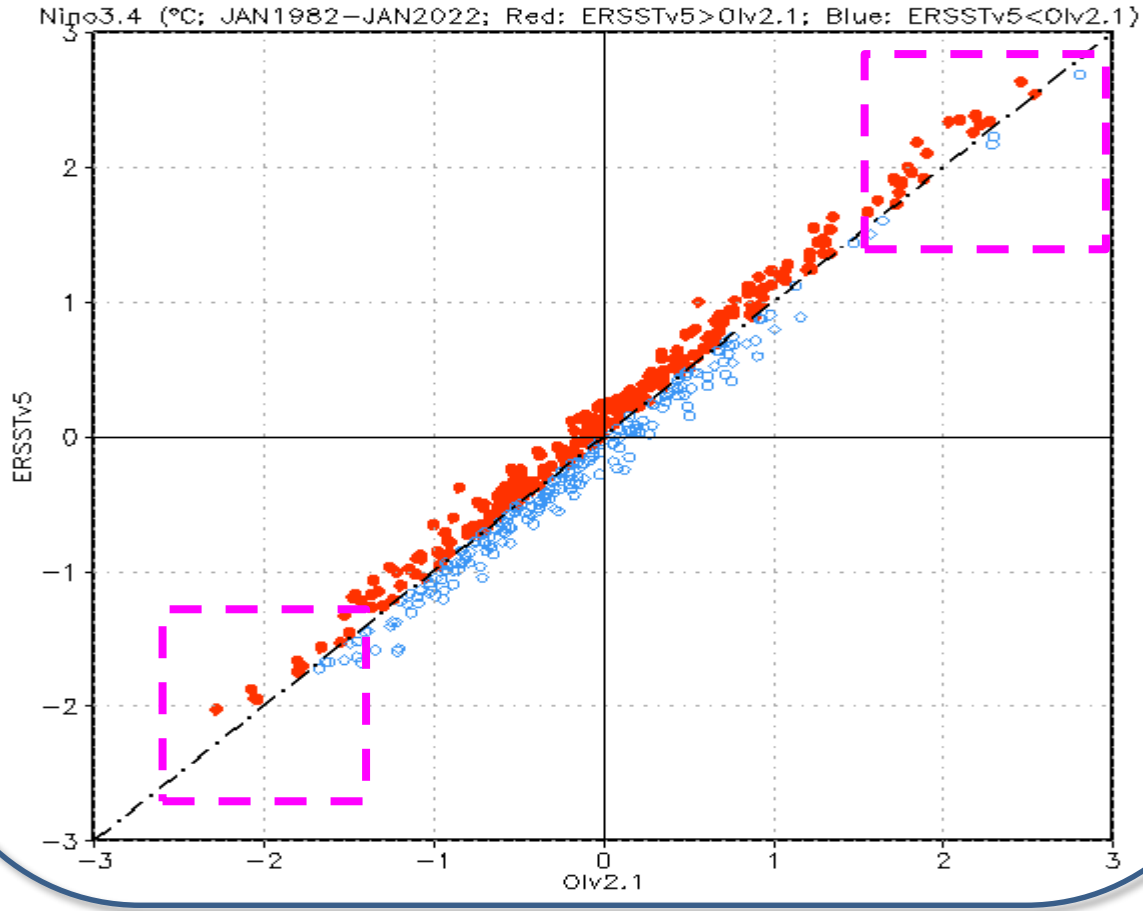


- All Niño indices weakened in Jan 2022, with Niño3.4 = -0.96C.
- Compared with Jan 2021, the central (eastern) equatorial Pacific was warmer (cooler) in Jan 2022.
- The indices may have slight differences if based on different SST products.

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

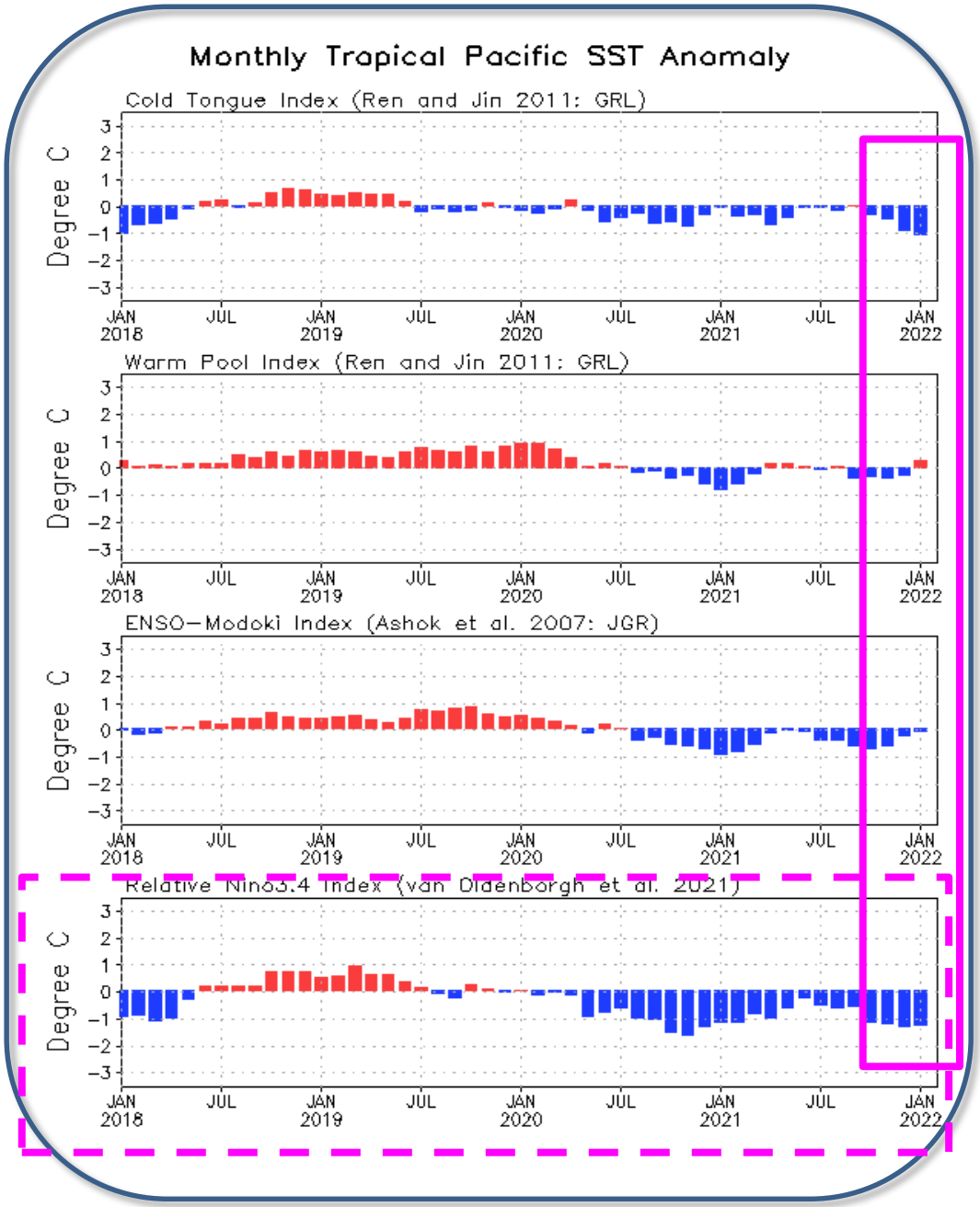
Comparison of ERSSTv5 & OIv2.1 Niño3.4 Index

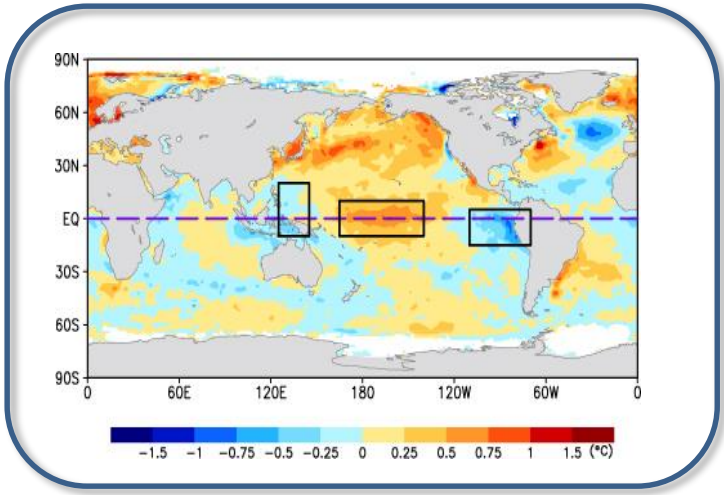




- Sometimes, ERSSTv5 is warmer (cooler) than OIv2.1.
- For both the extreme positive (negative; ±1.5°C) Niño3.4, ERSSTv5 is mostly warmer than OIv2.1.
- During last a few months, ERSSTv5 was close to OIv2.1.

Evolution of Pacific Niño SST Indices



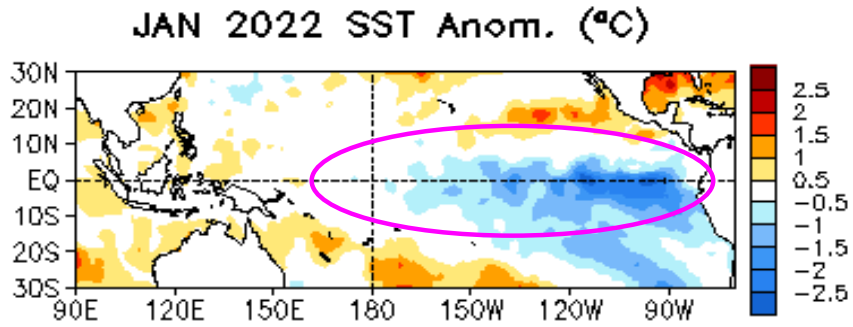


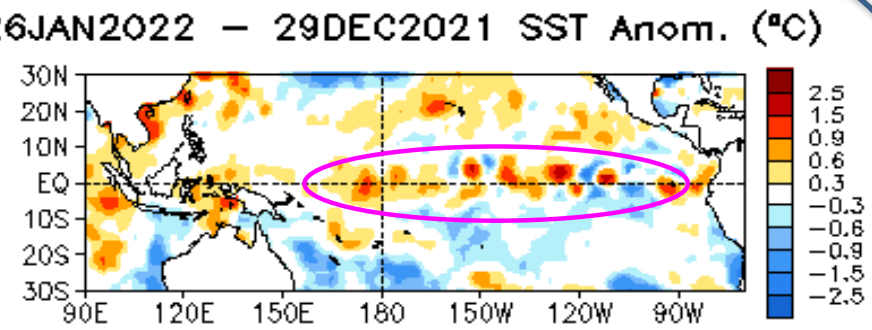
- Relative Niño3.4 index is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0°-360°, 20°S-20°N), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative Niño3.4 index is renormalized (van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

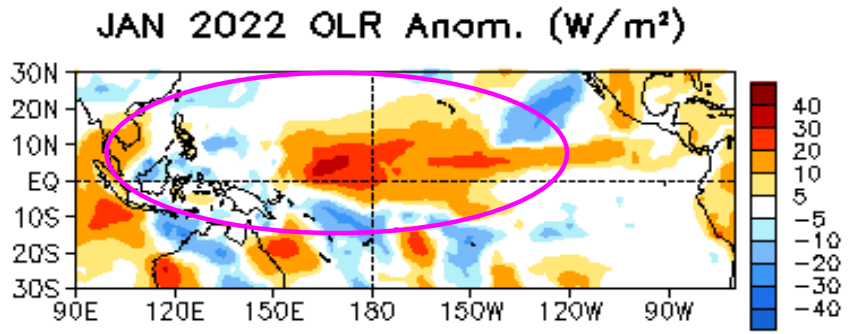
Relative Niño3.4 data updated monthly at:

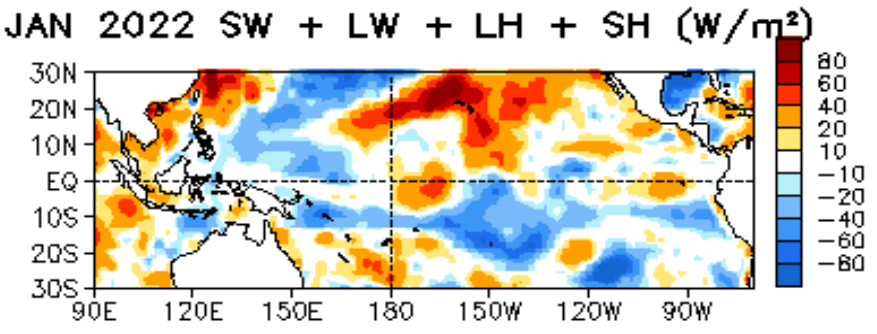
https://www.cpc.ncep.noaa.gov/data/indices/RONI.ascii.txt

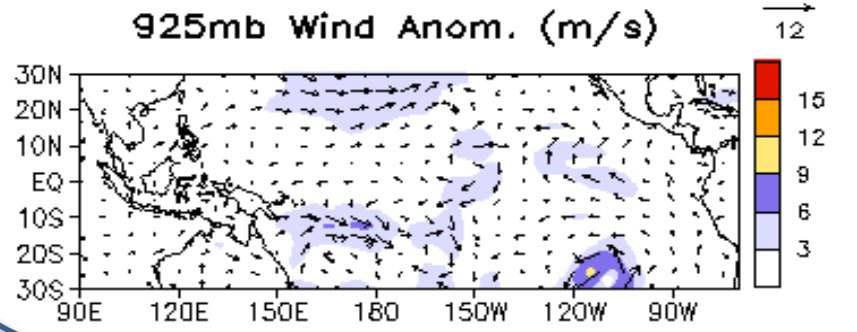
Tropical Pacific: SSTA, SSTA Tend., OLR, Sfc Rad, Sfc Flx, 925-mb & 200-mb Winds

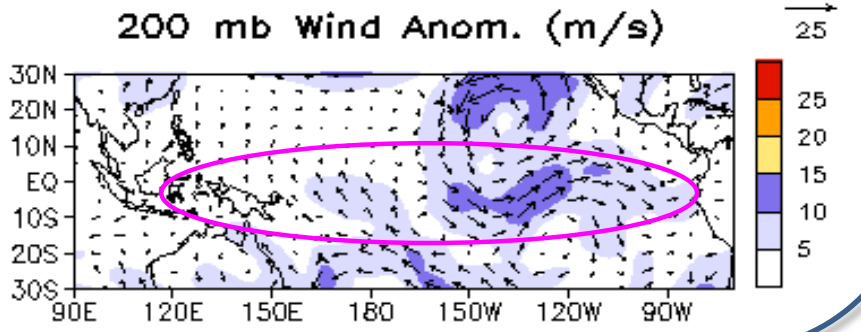






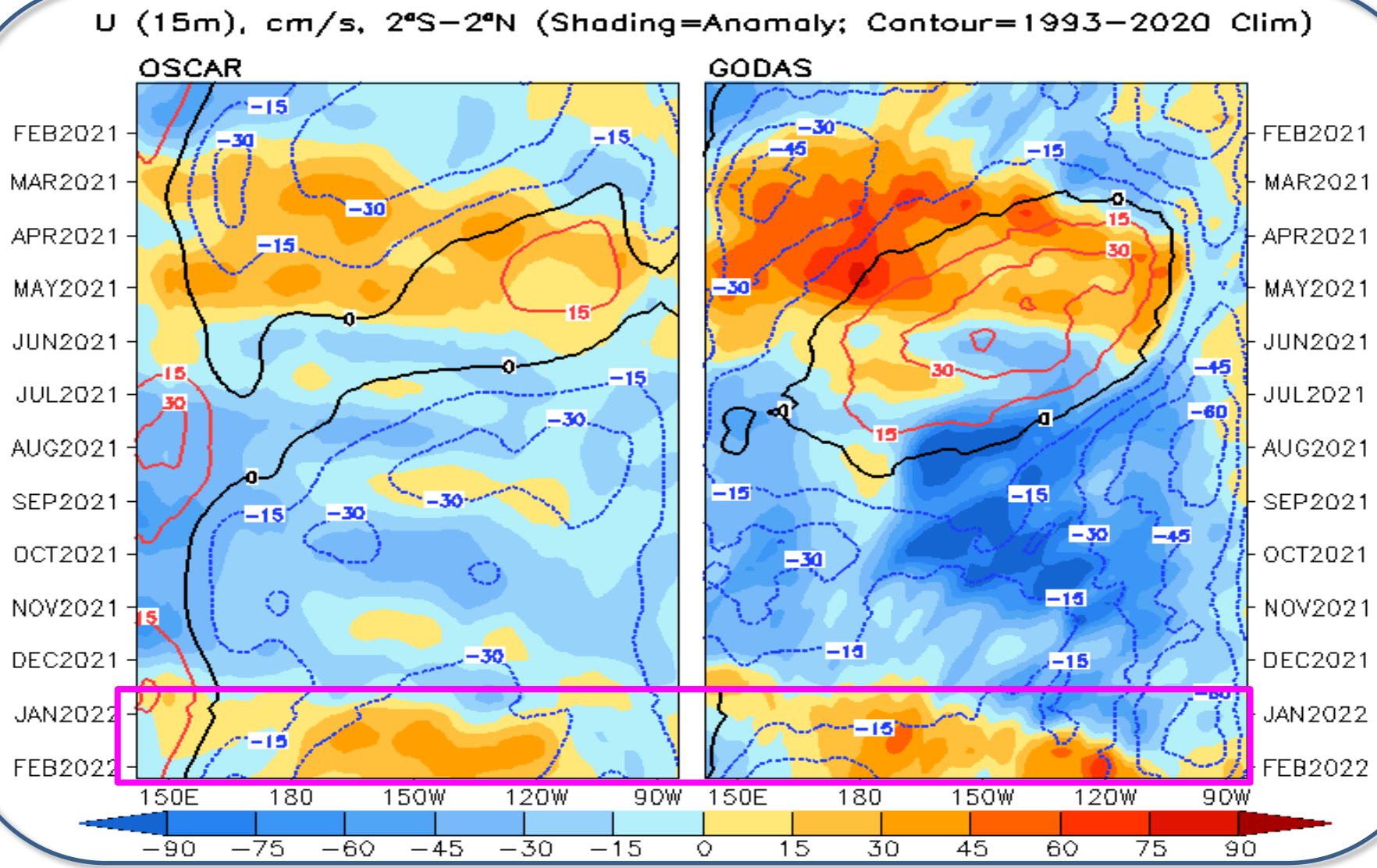






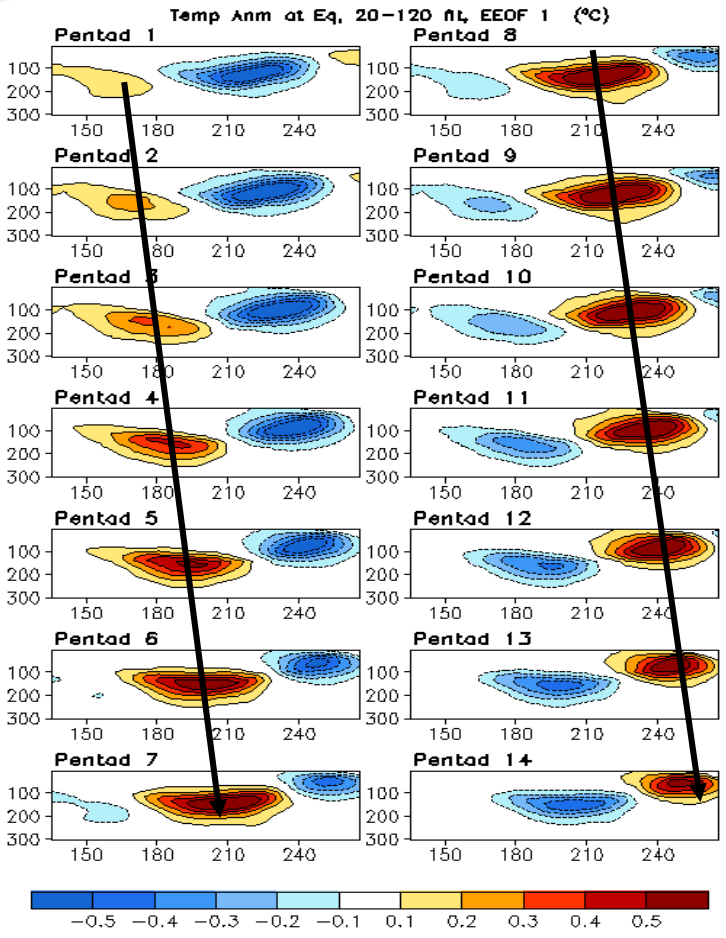
SSTAs (top-left), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly vector and its amplitude (bottom-left),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

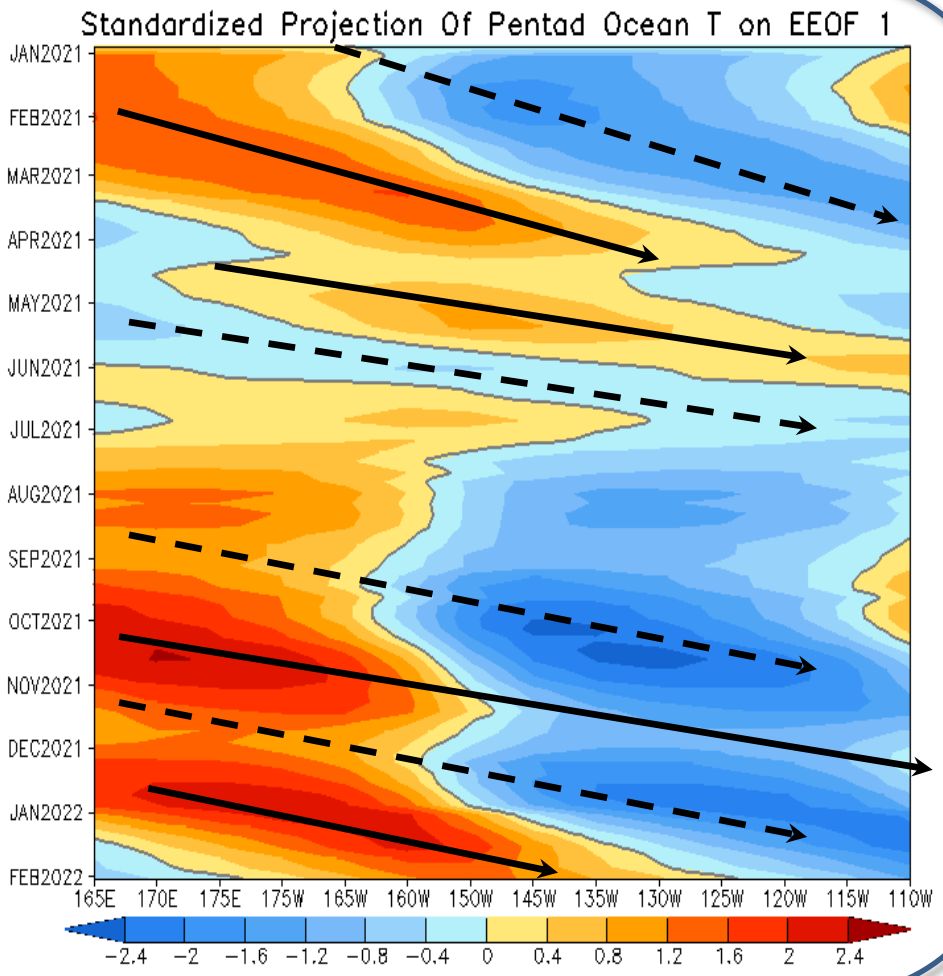
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- Anomalous eastward currents were observed in the equatorial Pacific in both OSCAR and GODAS in Jan 2022. That may be a factor leading to the weakening of the negative SSTAs in the central and eastern equatorial Pacific.

Oceanic Kelvin Wave (OKW) Index



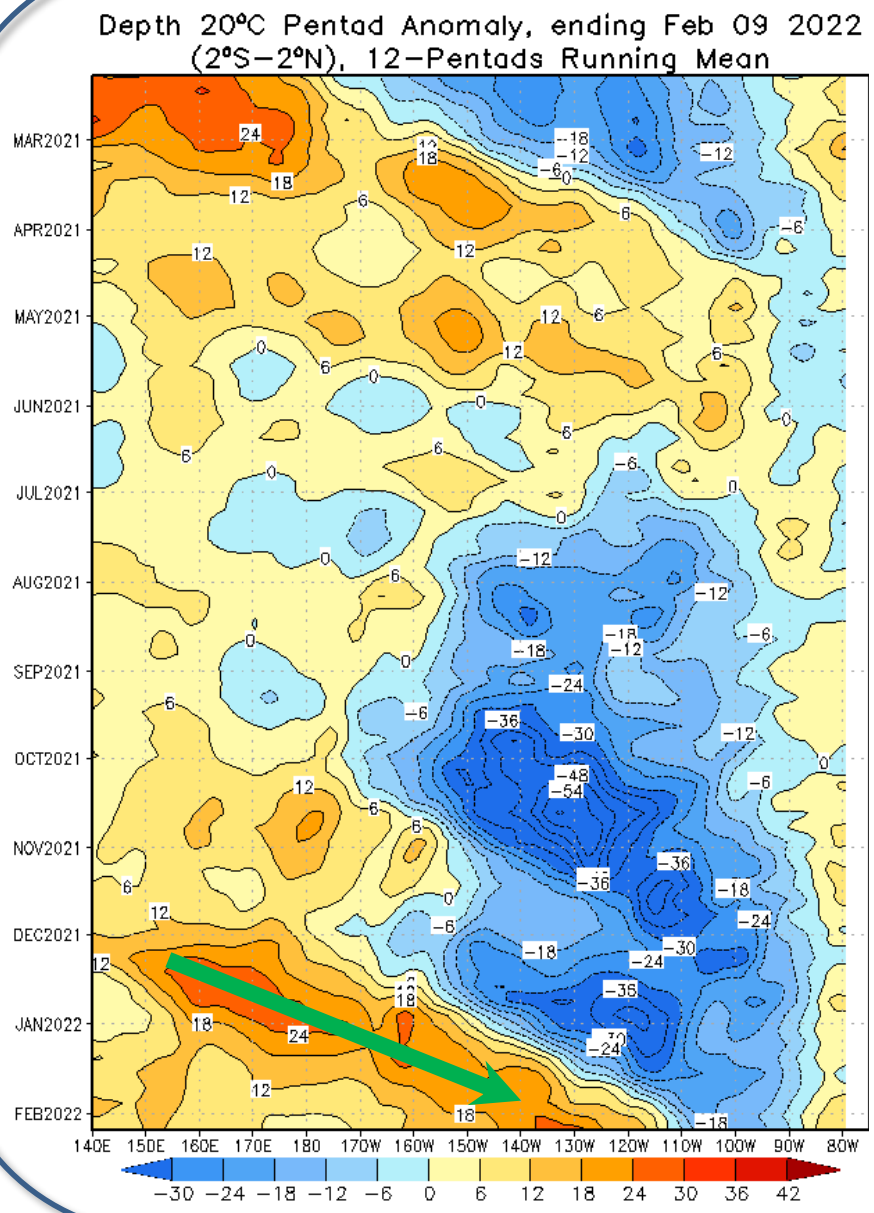


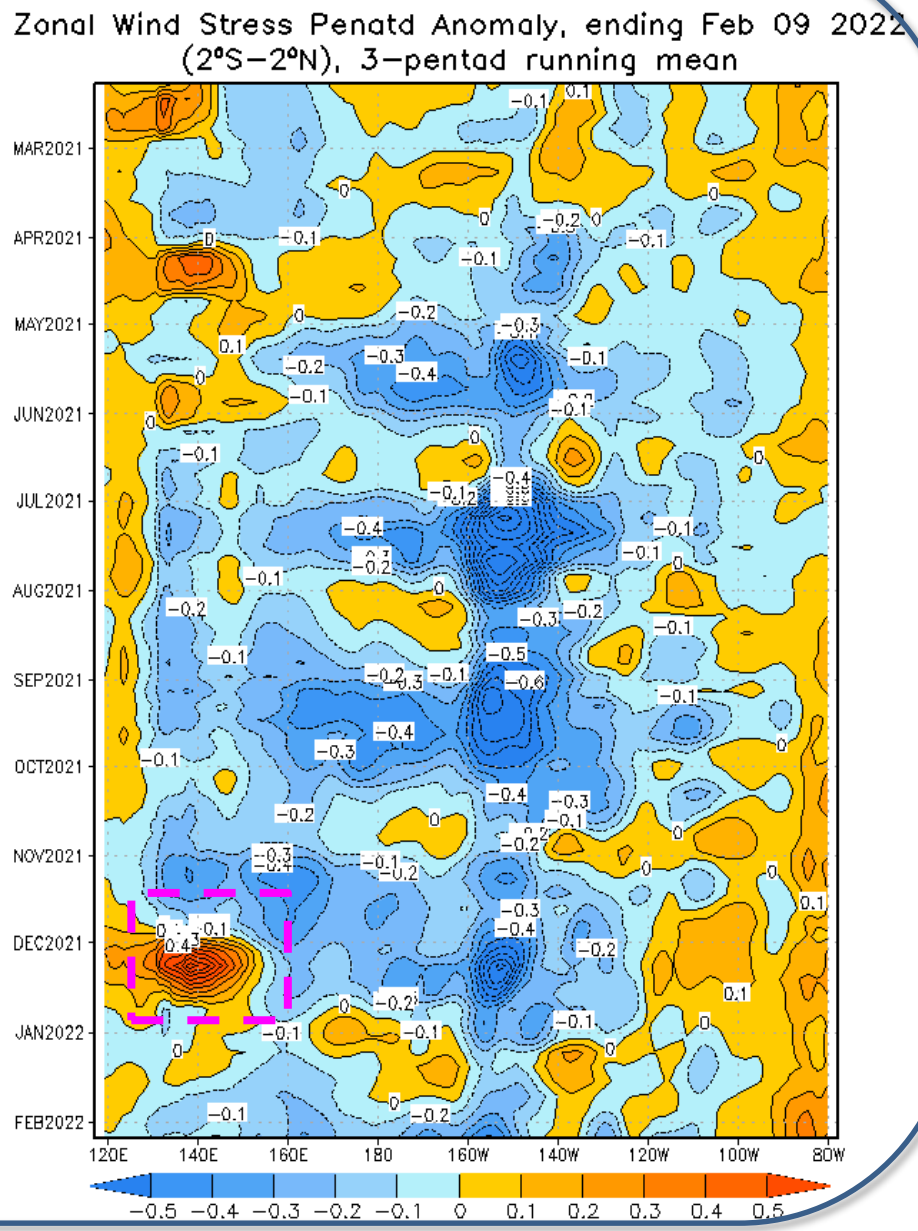
- **Upwelling Kelvin waves were initiated in May, Aug, & Nov 2021, leading to the subsurface cooling in the eastern equatorial Pacific and the development of the 2021/22 La Niña.**

- **Downwelling Kelvin wave initiated in Dec 2021 led to the weakening of 2021/22 La Niña.**

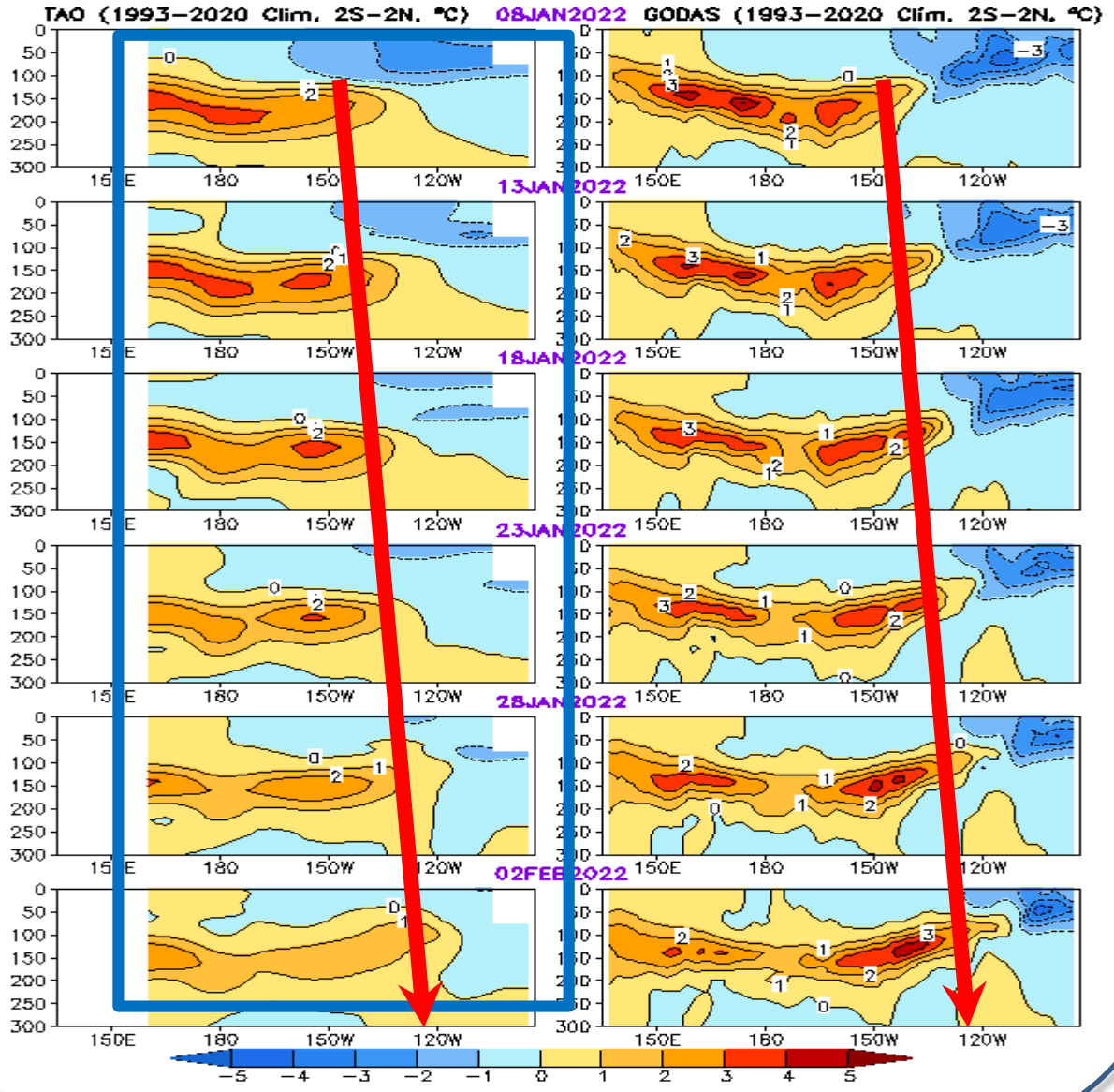
(OKW index is defined as standardized projections of total anomalies onto the 14 patterns of Extended EOF1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).)

Evolution of Pentad D20 and Taux anomalies along the equator



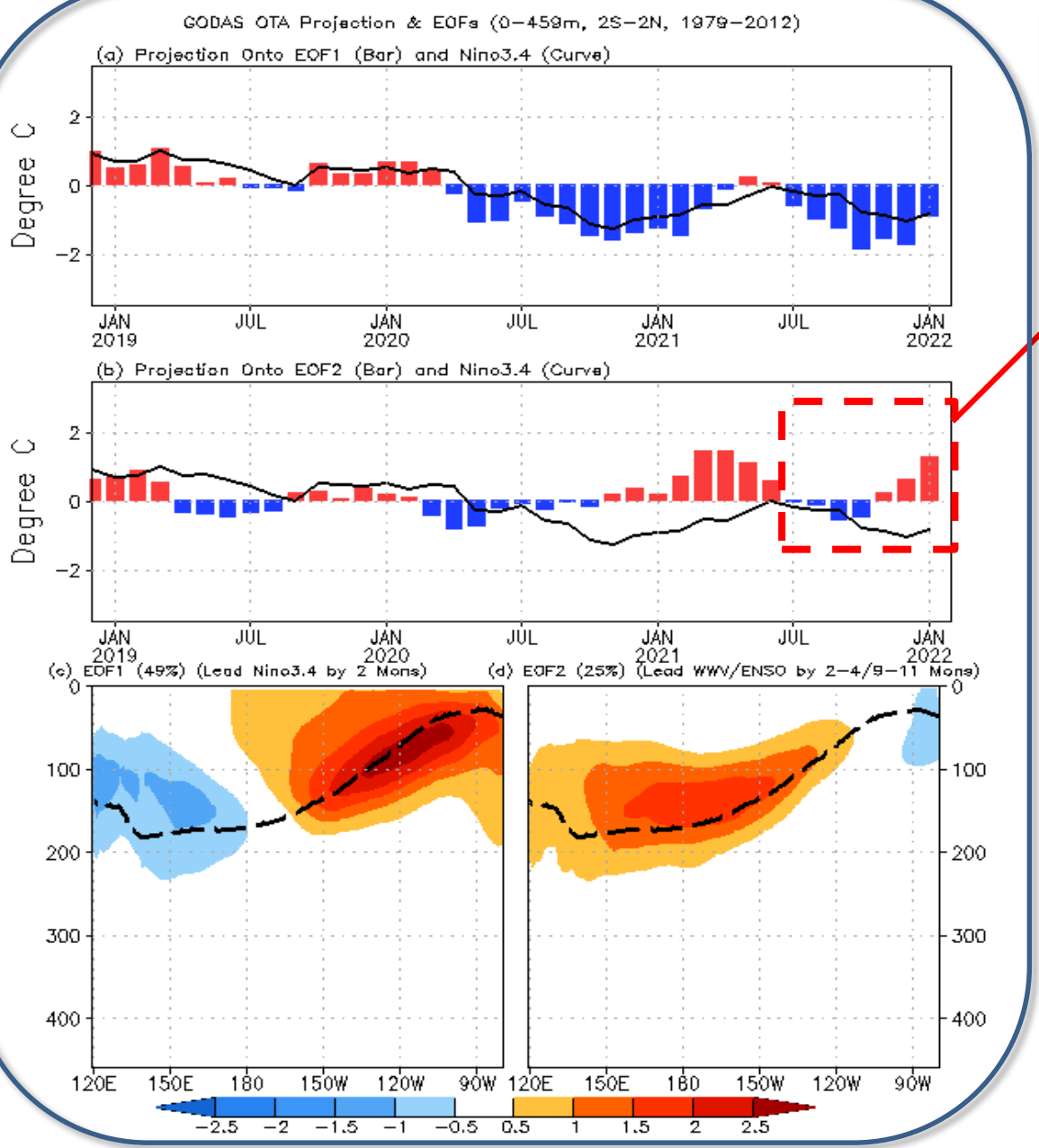


Equatorial Pacific Ocean Temperature Pentad Mean Anomaly



- Positive ocean temperature anomalies weakened and propagated eastward along the thermocline.
- The negative anomalies in the eastern Pacific weakened.

Equatorial Sub-surface Ocean Temperature Monitoring



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

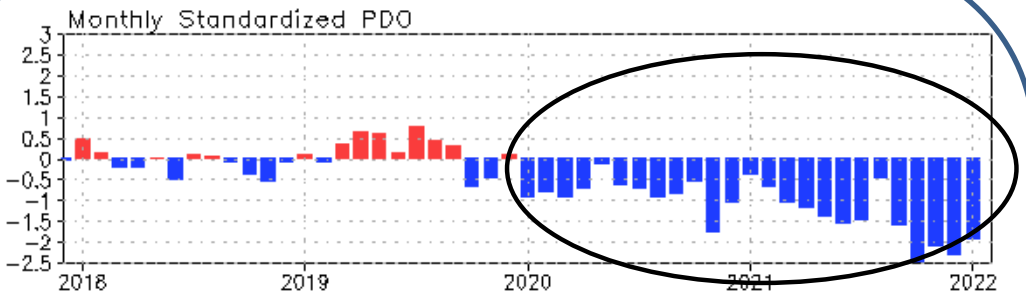
- Projection of ocean temperature anomalies onto EOF1 and EOF2; EOF1: Tilt/dipole mode (ENSO peak phase); EOF2: WWV mode.

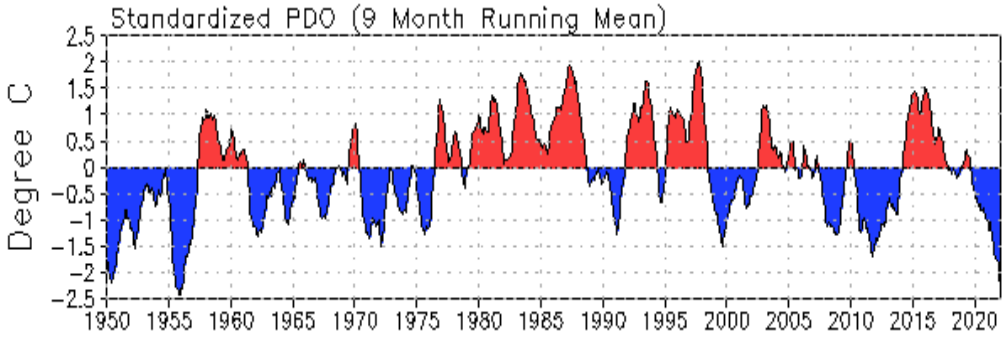
- Recharge/discharge oscillation (ENSO transition phase); Recharge process: heat transport from outside of equator to equator; Negative -> positive phase of ENSO

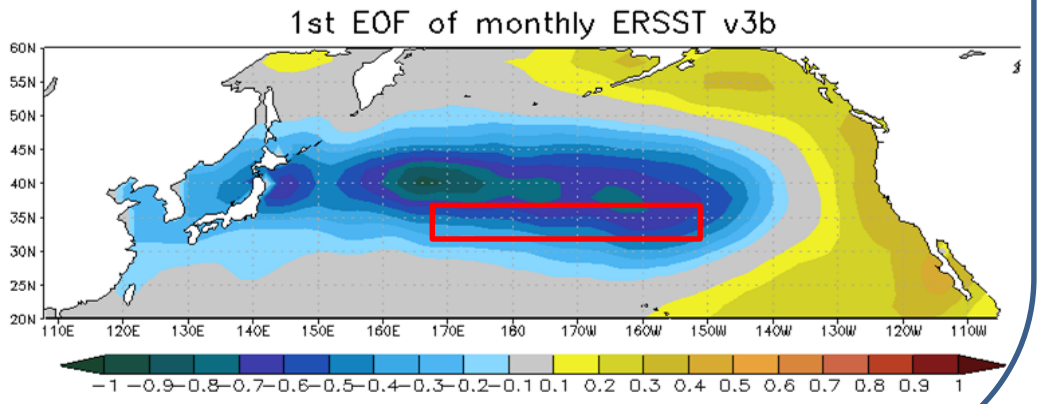
- For details, see: Kumar A, Z-Z Hu (2014) DOI: 10.1007/s00382-013-1721-0.

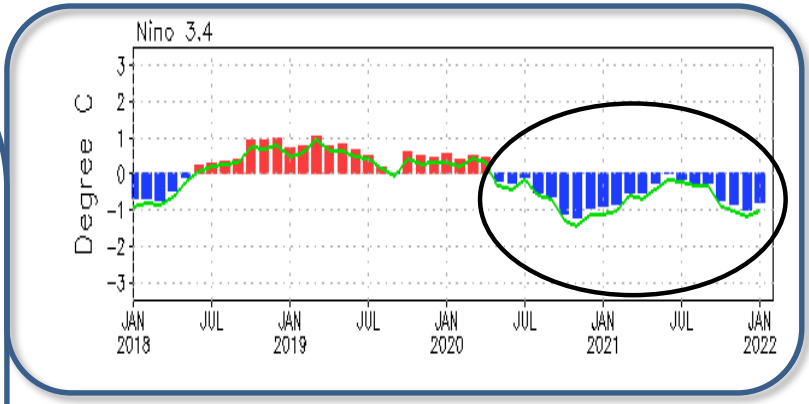
North Pacific & Arctic Oceans

Pacific Decadal Oscillation (PDO) Index







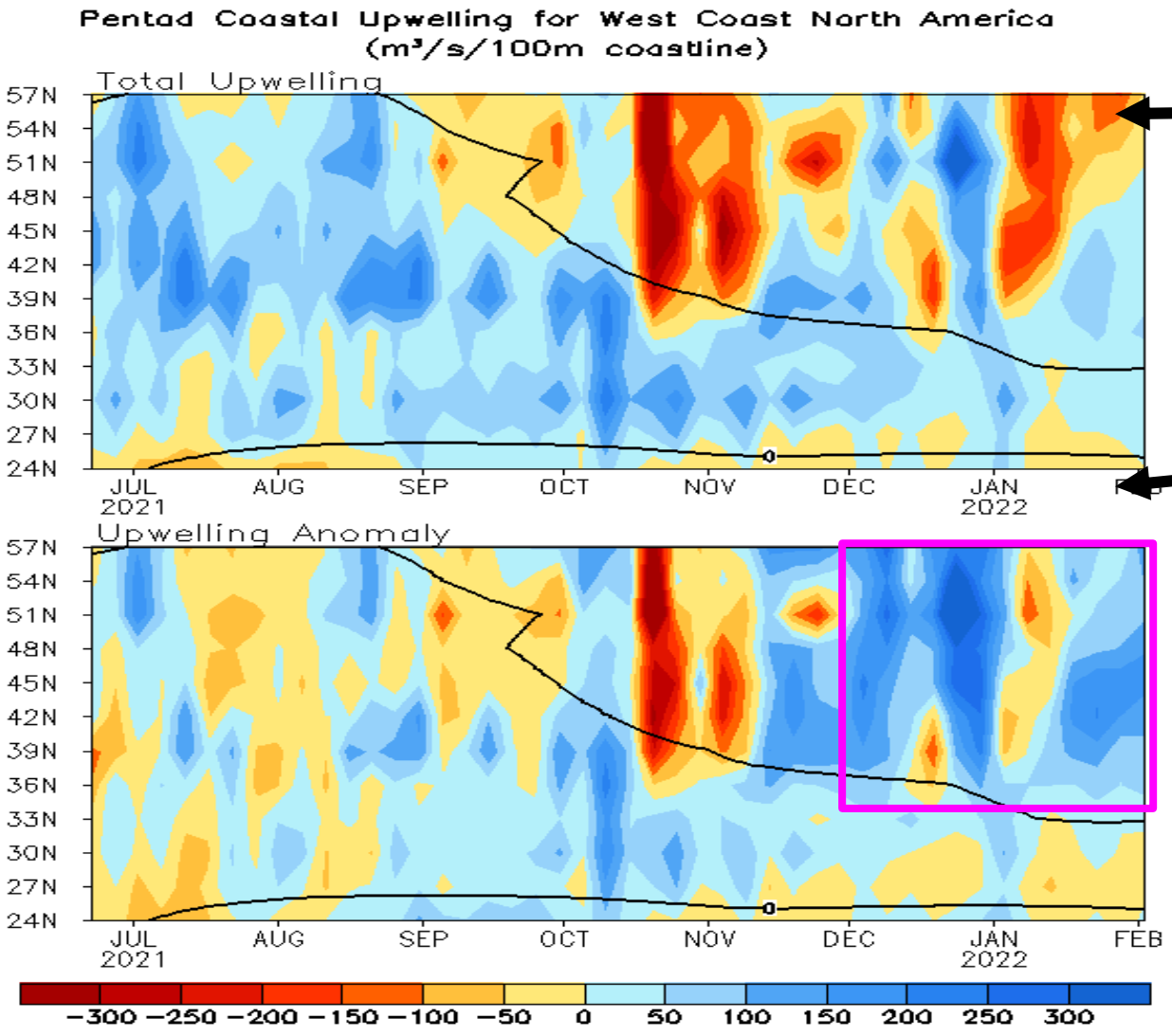


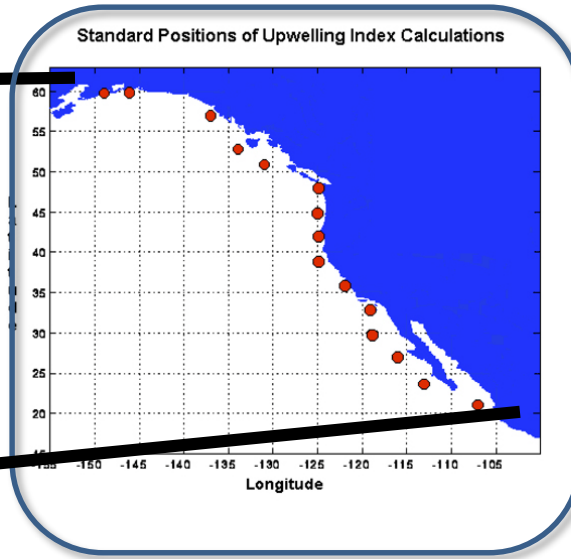
- The PDO has been in a negative phase since Jan 2020 with PDOI = -1.94 in Jan 2022.

- Statistically, ENSO leads PDO by 3-4 months, through teleconnection via atmospheric bridge, with El Niñno (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

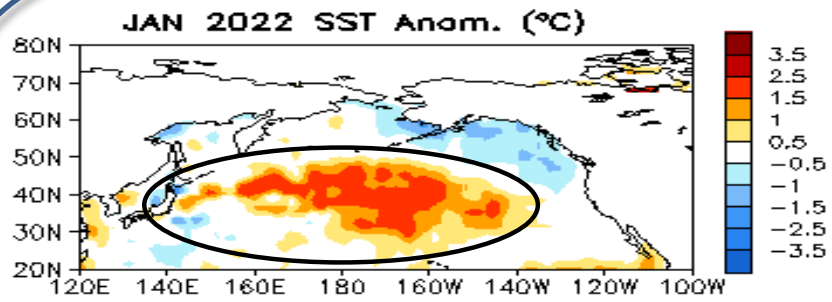


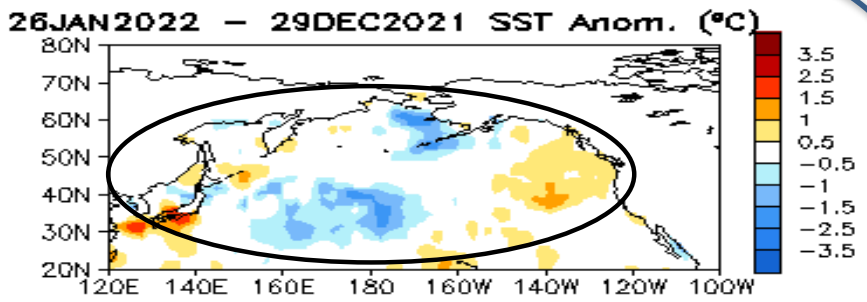


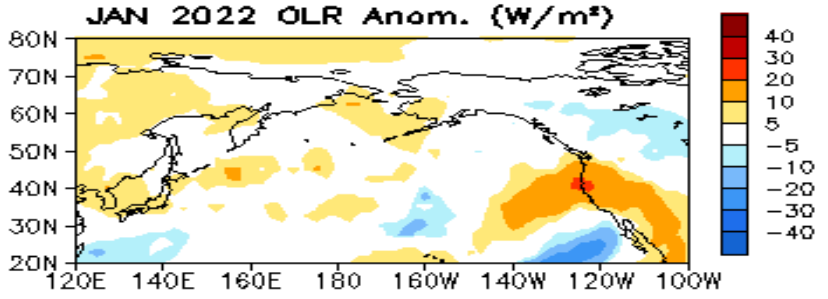
- Anomalous coastal upwelling was present in the north of 35ºN in Dec 2021 and Jan 2022.

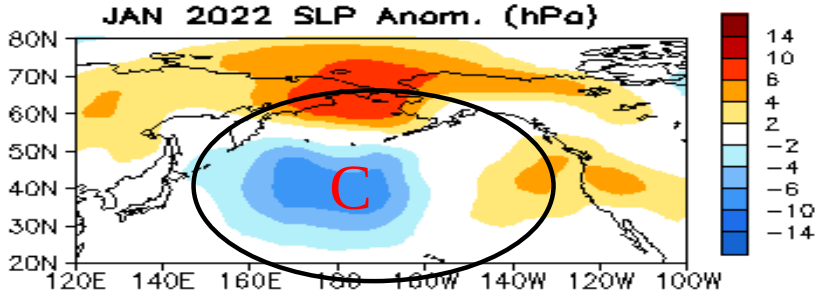
(top) Total and (bottom) anomalous upwelling indices at the 15 standard locations for the western coast of North America. Derived from the vertical velocity of the NCEP's GODAS and are calculated as integrated vertical volume transport at 50-meter depth from each location to its nearest coast point ($m^3/s/100m$ coastline). Anomalies are departures from the 1991-2020 base period pentad means.
- Area below (above) black line indicates climatological upwelling (downwelling) season.
- Climatologically upwelling season progresses from March to July along the west coast of North America from 36ºN to 57ºN.

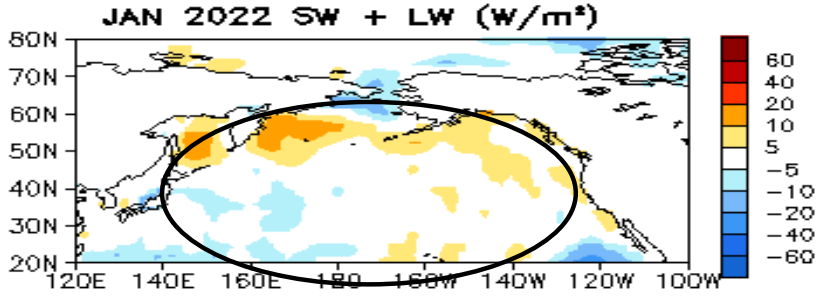
North Pacific & Arctic Ocean: SSTA, SSTA Tend., OLR, SLP, Sfc Rad, Sfc Flx Anomalies

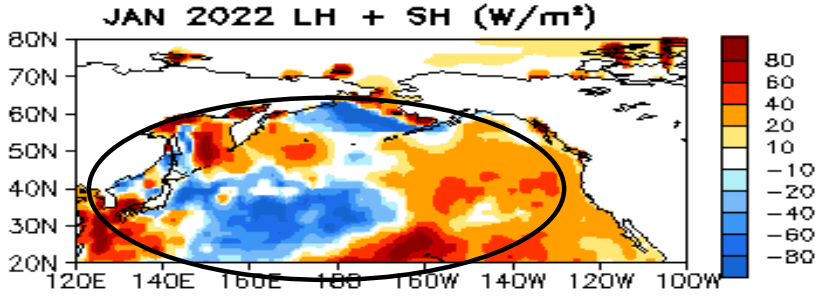






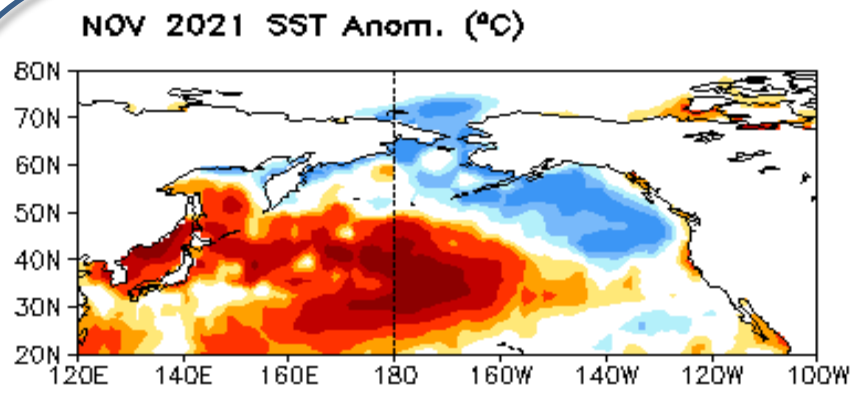


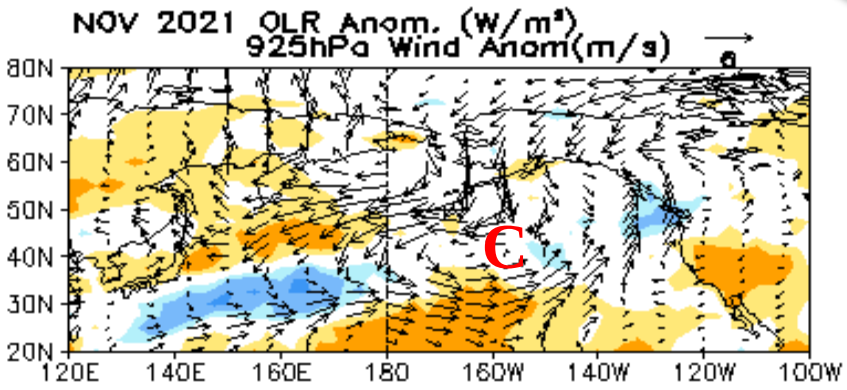


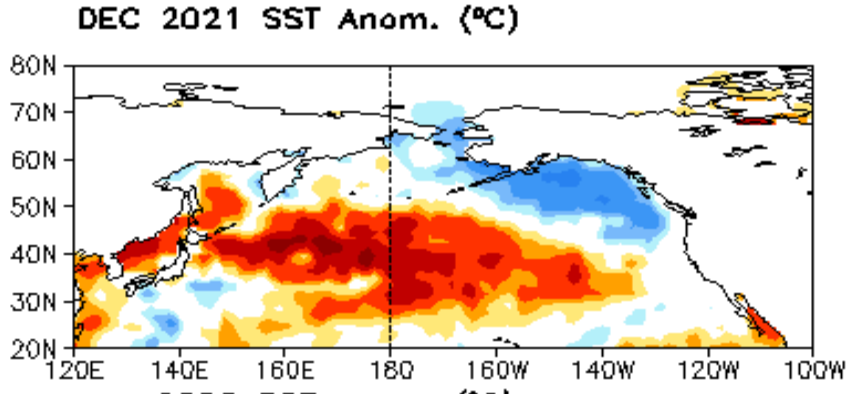


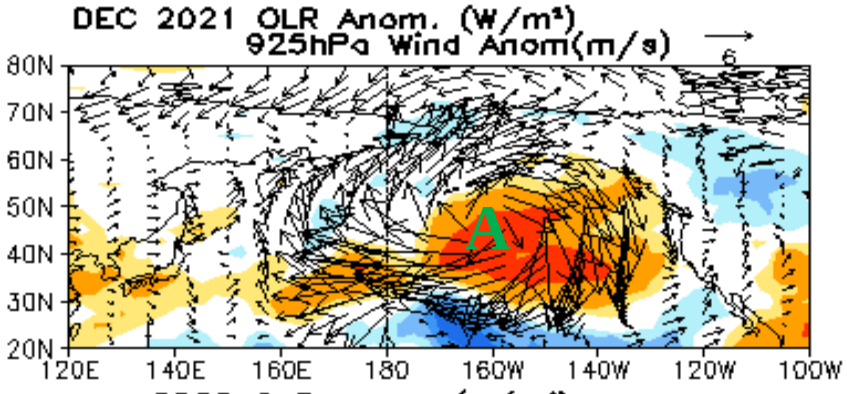
SSTA (top-left; OI SST Analysis), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) (middle-left; NOAA 18 AVHRR IR), sea surface pressure (middle-right; NCEP CDAS), sum of net surface short- and long-wave radiation (bottom-left; positive means heat into the ocean; NCEP CDAS), sum of latent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

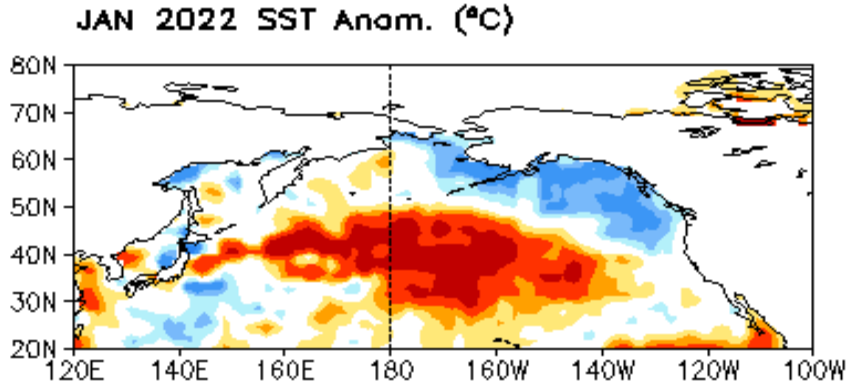
North Pacific SST, OLR, and uv925 anomalies

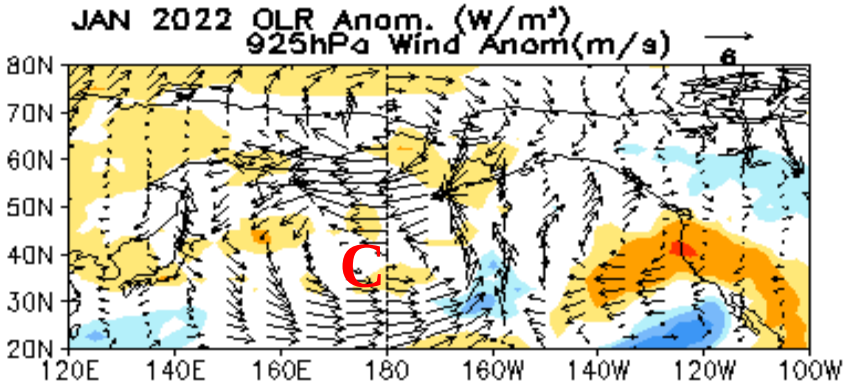


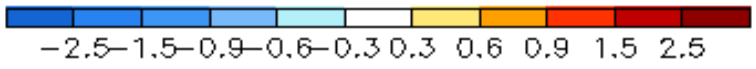


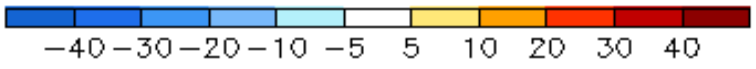




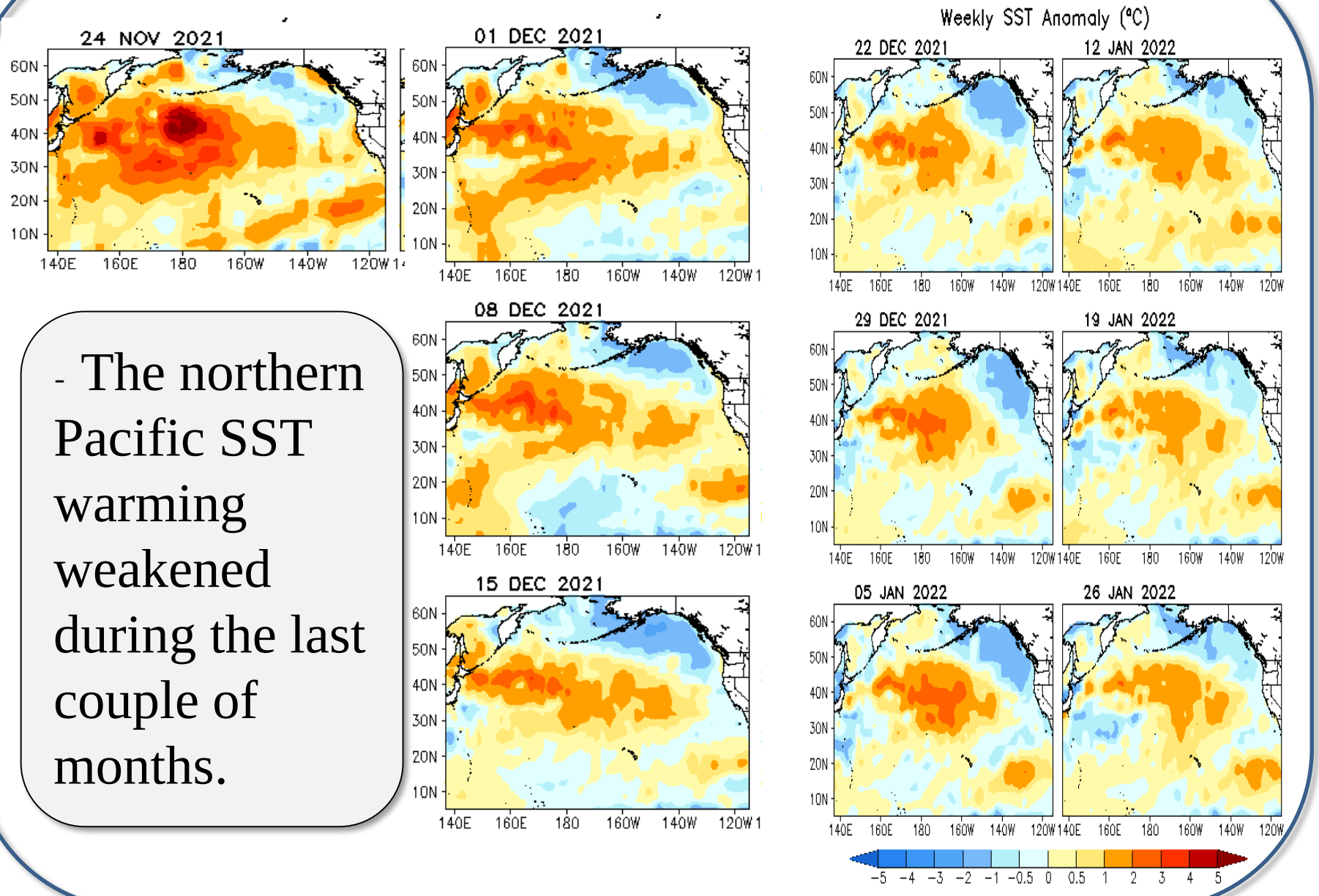






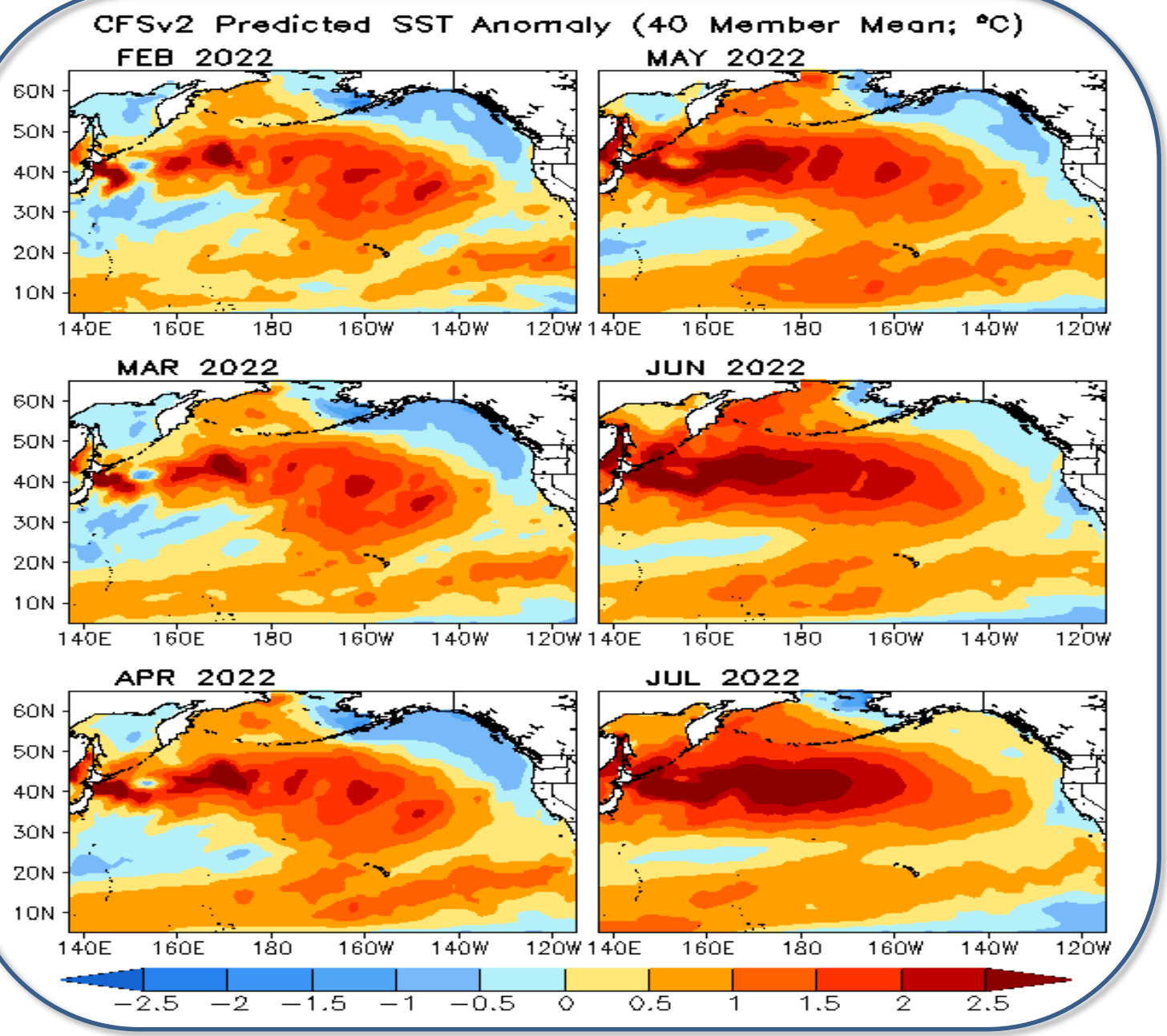


Weekly SSTA evolutions in the NE Pacific



- The northern Pacific SST warming weakened during the last couple of months.

CFSv2 North Pacific SSTA Predictions



- The CFSv2 predicts that the current SST warm state will continue.

CFSv2 North Pacific SSTA Prediction Skill: Mainly from ENSO Influence

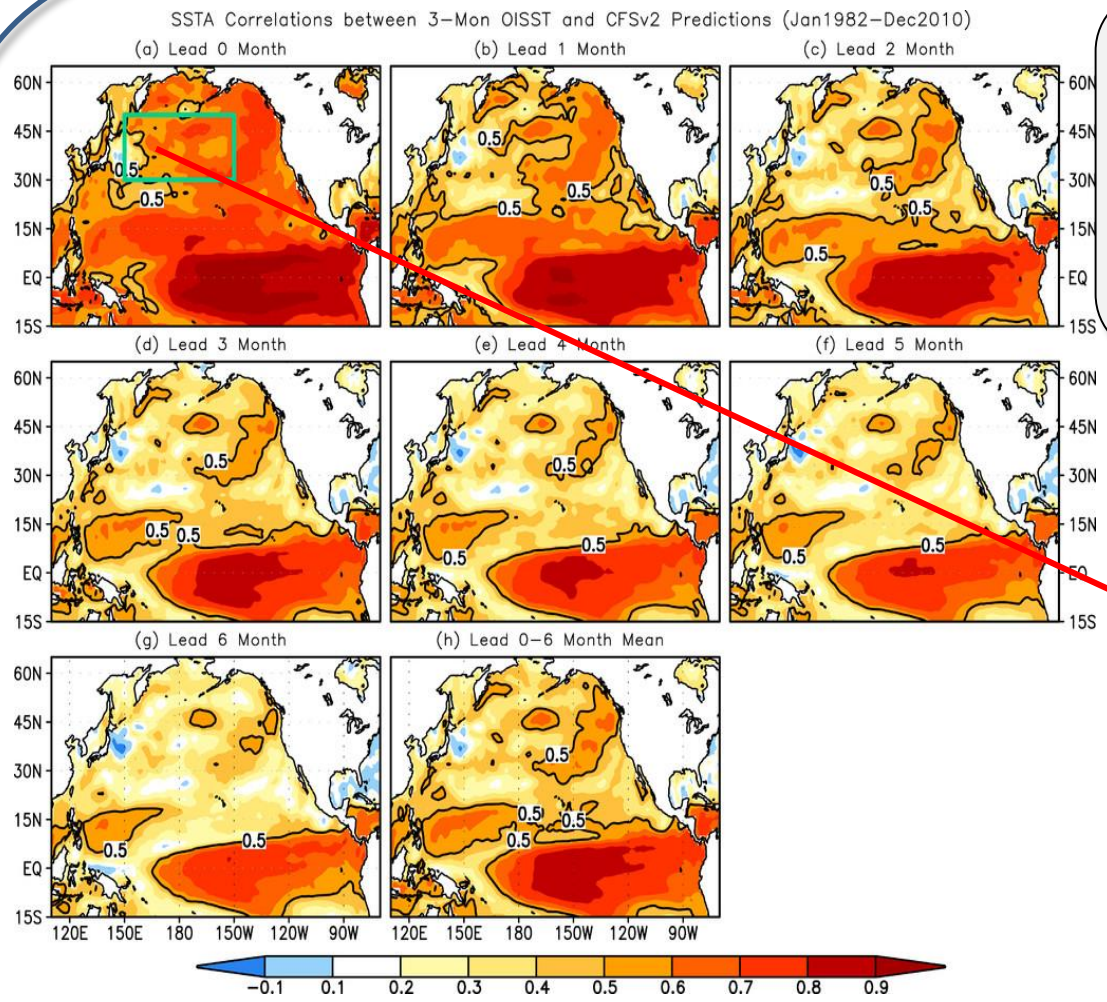


Fig. 1: (a)–(g) Correlations between OISSTv2 analyzed and CFSv2 predicted ensemble mean SSTA in the tropical and North Pacific for 0–6-month lead with IC in January 1982–December 2010. (h) The average of the correlations in (a)–(g). Only the 0.5 contour is plotted. The green rectangle in (a) represents region of 30°–50°N, 150°E–150°W used to define NPV index.

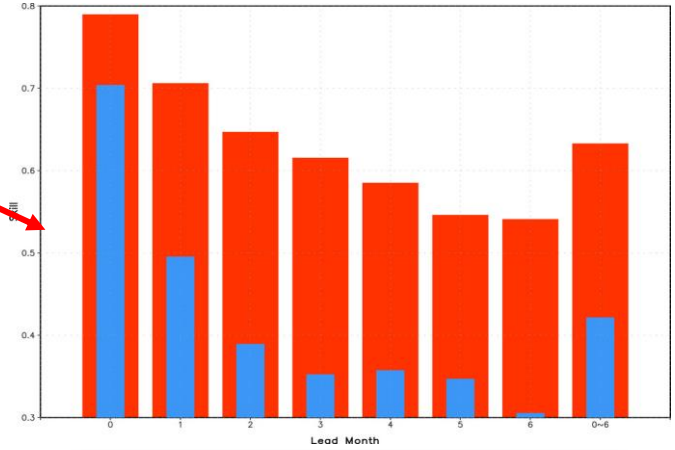
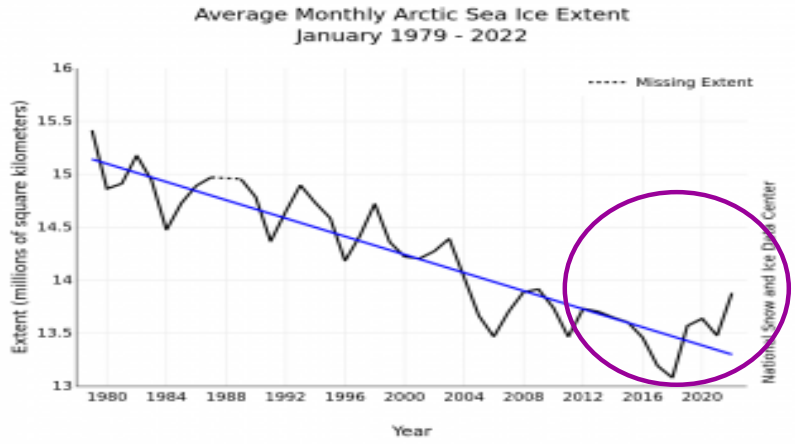
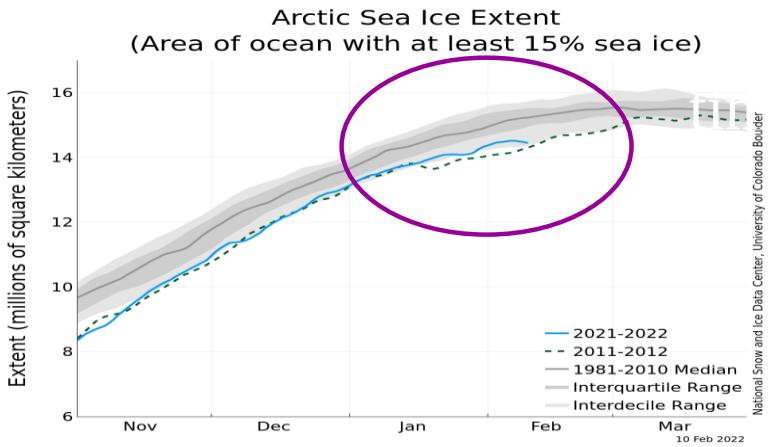


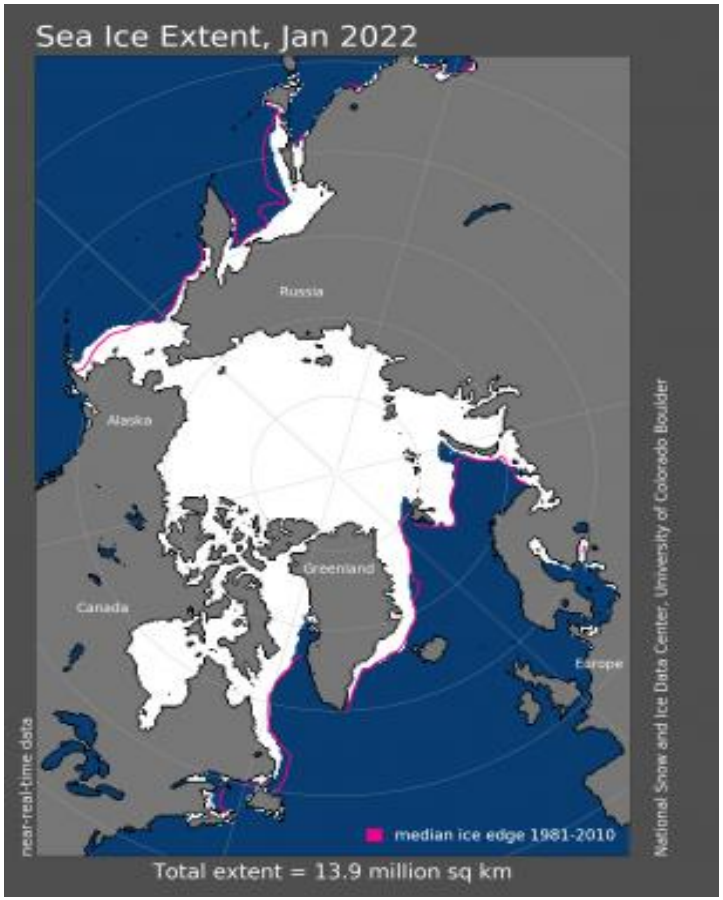
Fig. 2: Dependence of prediction skills of CFSv2 predicted NPV index with IC in January 1982–December 2010 on lead time and phase relationship between Niño-3.4 and NPV indices. Red (blue) bars represent the prediction skills of NPV index for in-phase (out of phase) variations between Niño-3.4 and NPV indices at IC. The rightmost bar is the average of the skill for 0–6 month lead.

Hu, Z.-Z., A. Kumar, B. Huang, J. Zhu, and Y. Guan, 2014: Prediction skill of North Pacific variability in NCEP Climate Forecast System Version 2: Impact of ENSO and beyond. J. Climate, 27 (11), 4263-4272. DOI: 10.1175/JCLI-D-13-00633.1

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

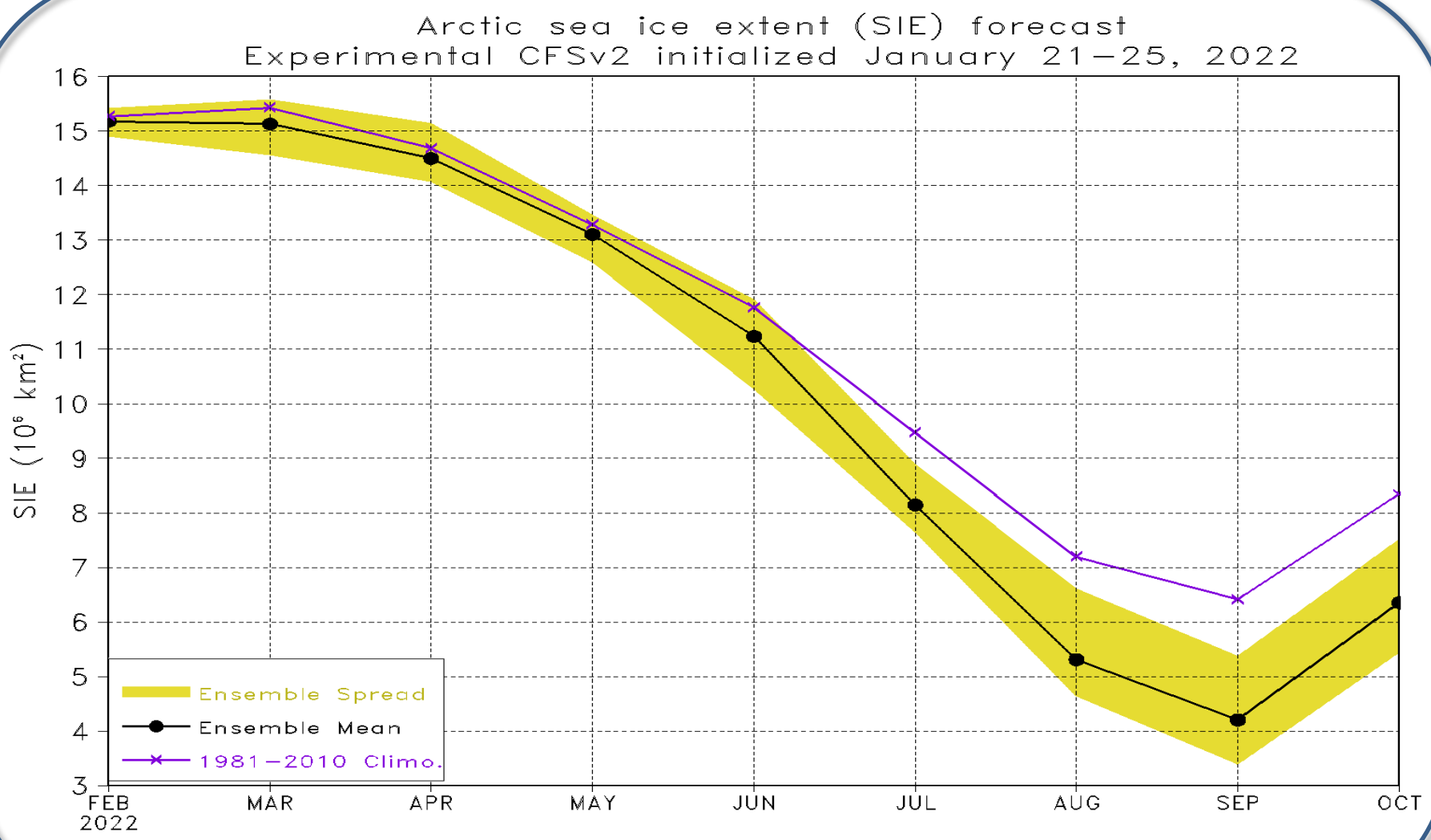






- "Arctic sea ice extent averaged for Jan 2022 was the 16th lowest in the satellite record above all years since 2009, with the exception of 2013 and 2014. This illustrates the large natural variability in sea ice conditions."
- The downward linear trend in January sea ice extent over the 44-year satellite record is 3.0% per decade relative to the 1981 to 2010 average.

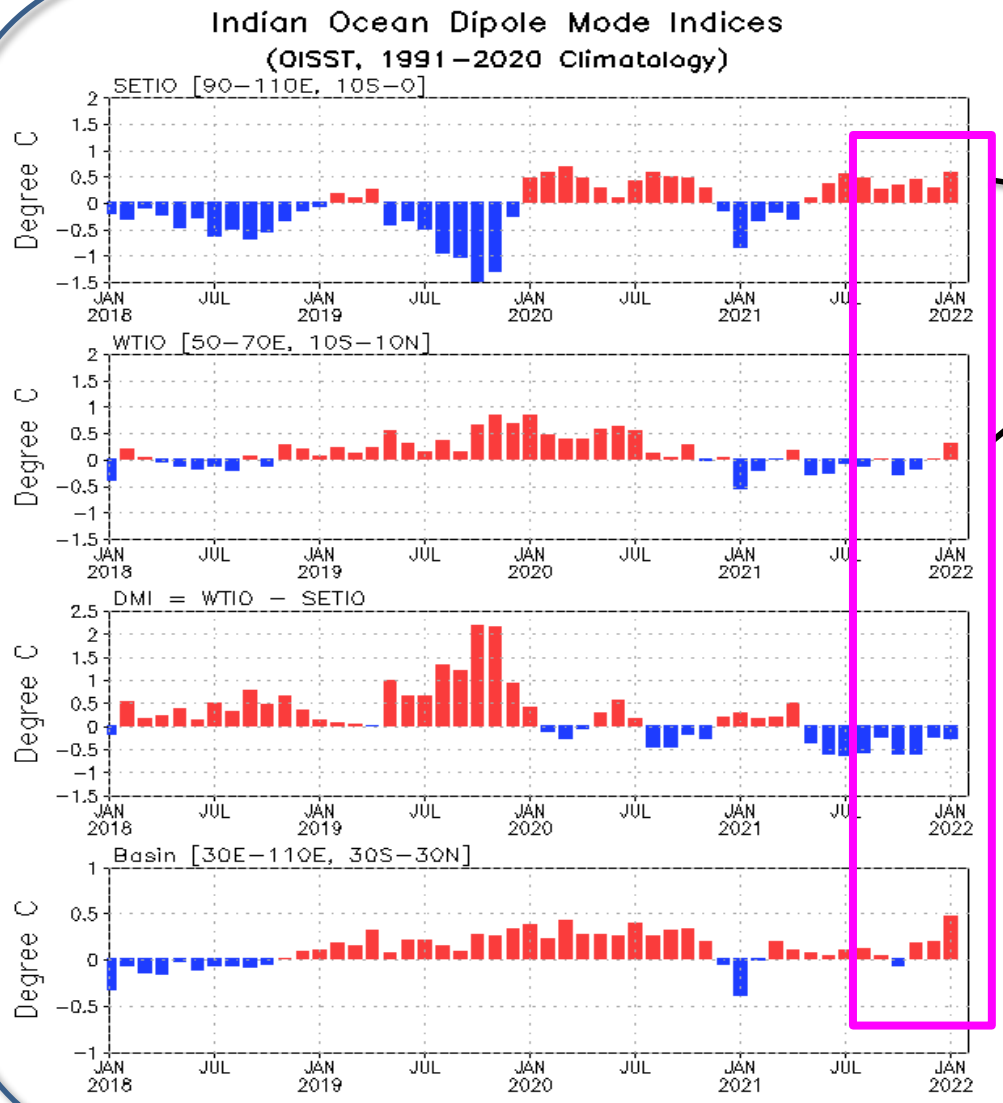
NCEP/CPC Arctic Sea Ice Extent Forecast

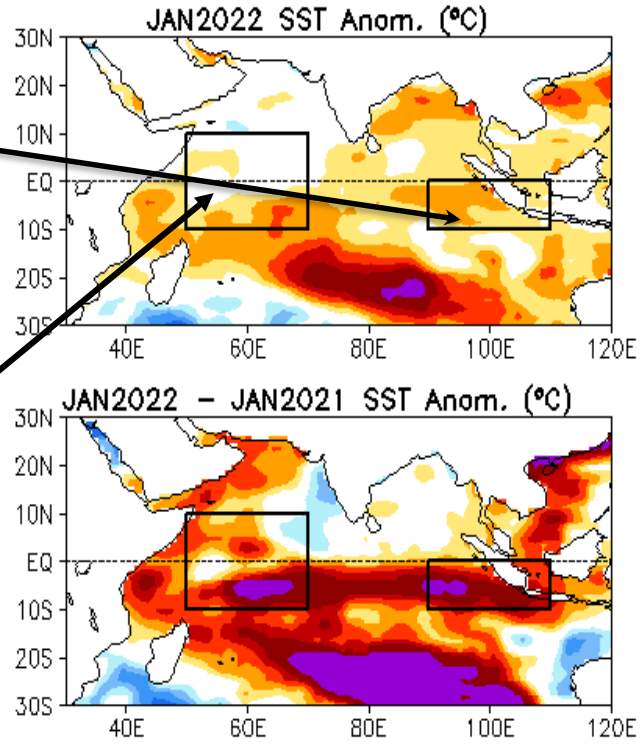


https://www.cpc.ncep.noaa.gov/products/people/wwang/seaice_seasonal/index.html

Indian Ocean

Evolution of Indian Ocean SST Indices

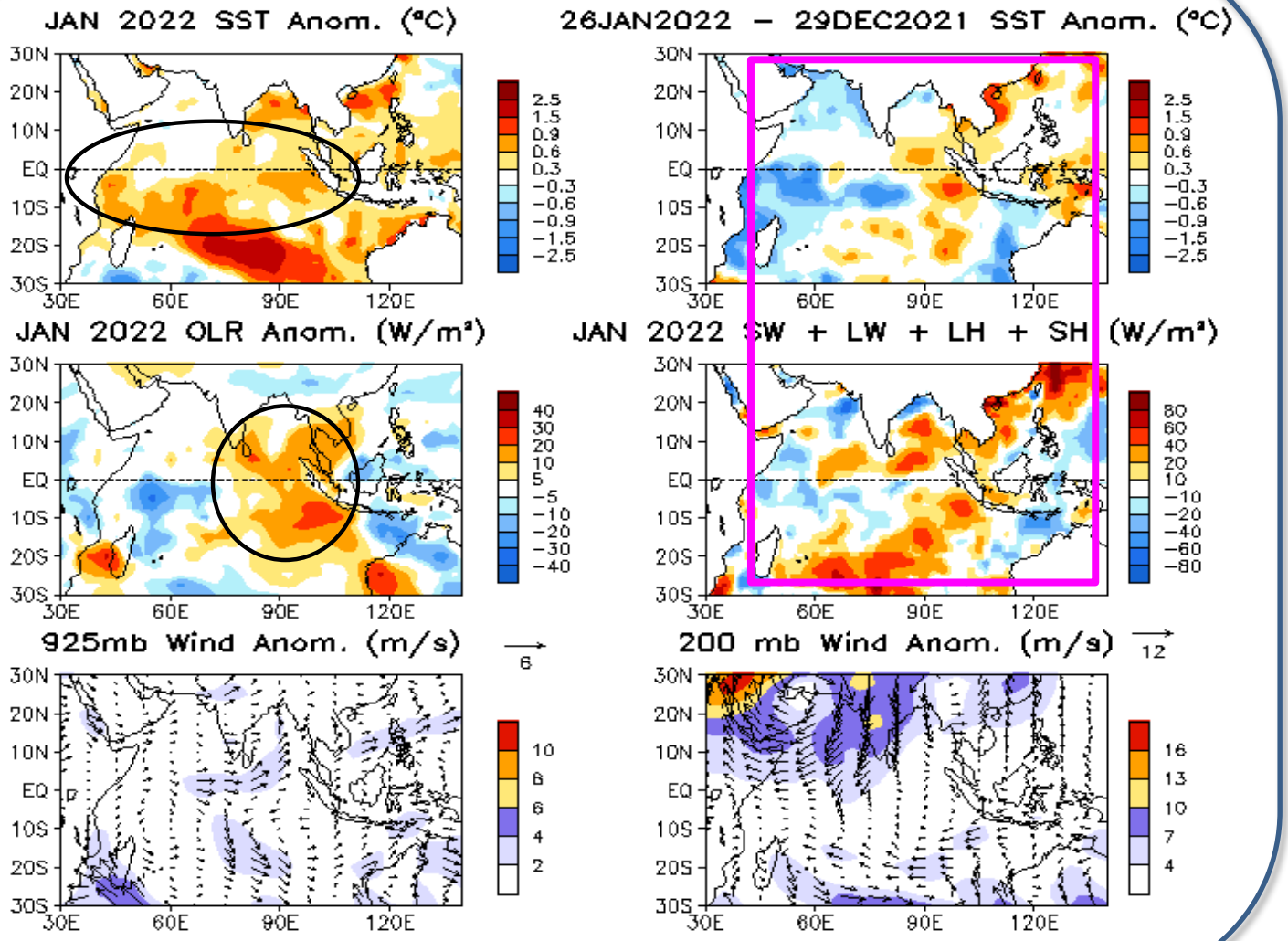




- Overall, positive SSTAs were observed in the tropical Indian Ocean in Jan 2022.

Indian Ocean region indices, calculated as the area-averaged monthly mean SSTA (OC) for the SETIO [90ºE-110ºE, 10ºS-0] and WTIO [50ºE-70ºE, 10ºS-10ºN] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the OI 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.



- SSTAs were overall positive in the tropical Indian Ocean.

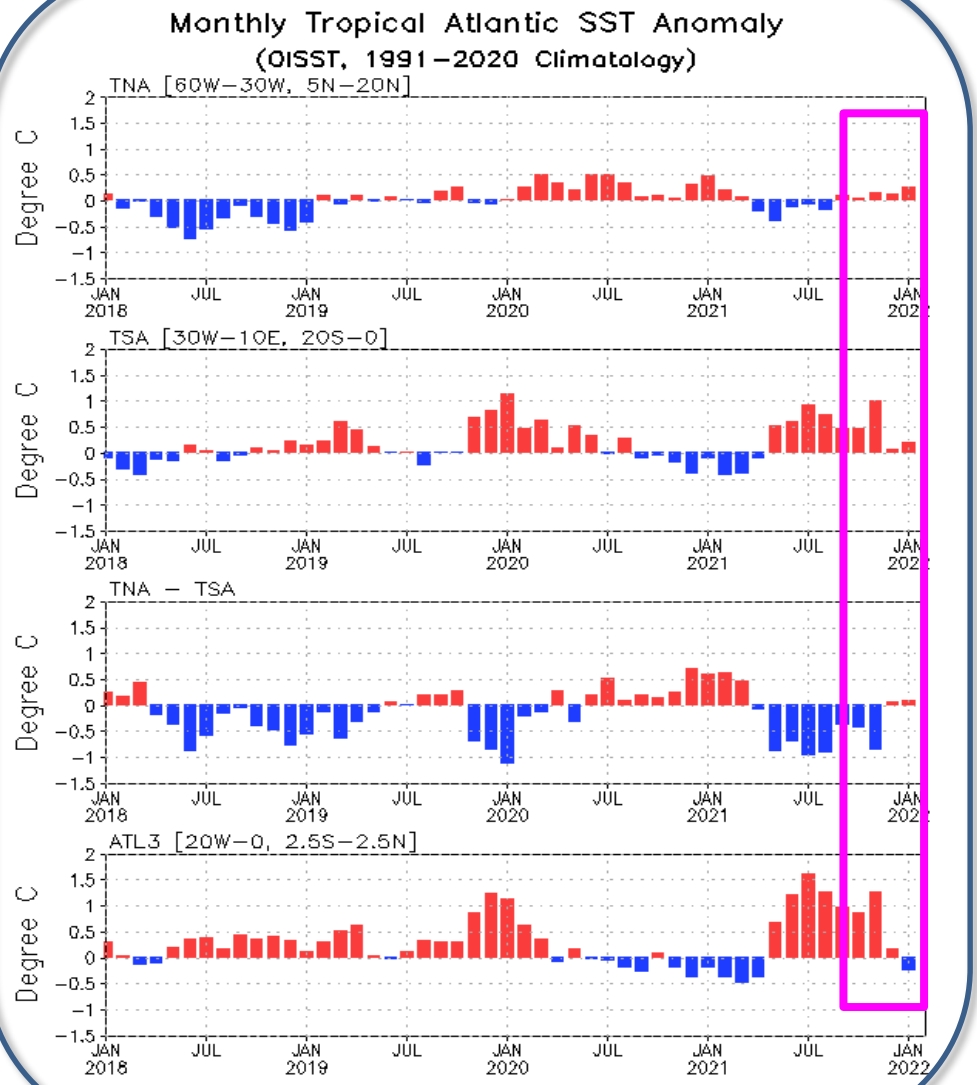
- Convection was suppressed over the tropical eastern Indian Ocean.

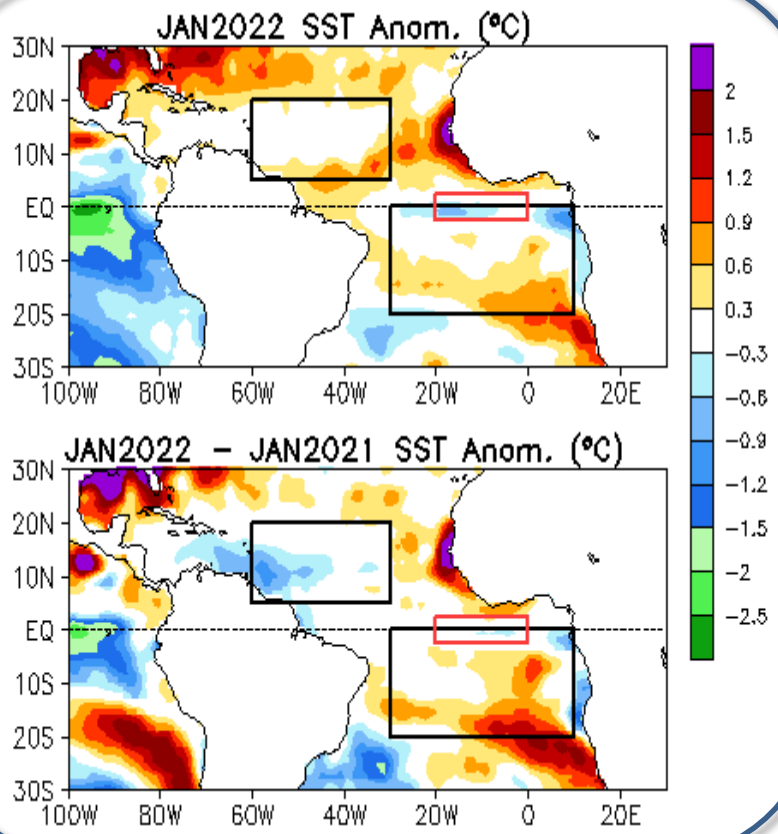
- SSTA tendencies are generally consistent with heat flux anomalies

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

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

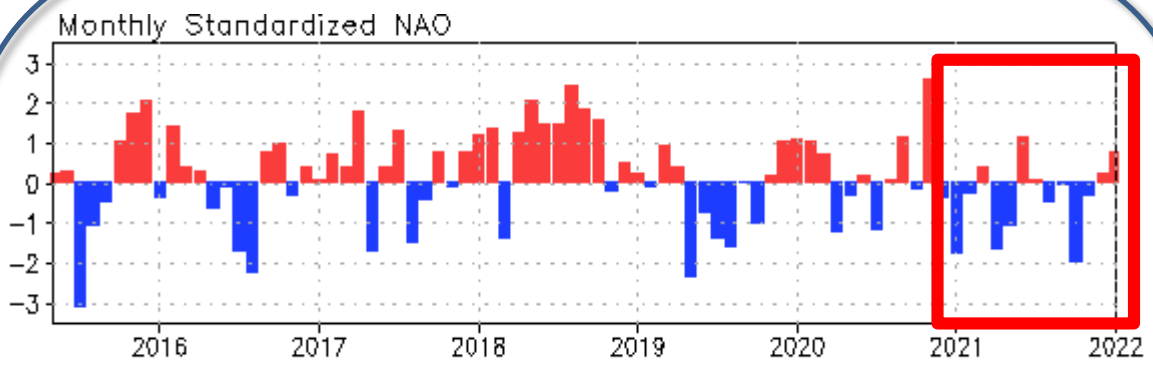


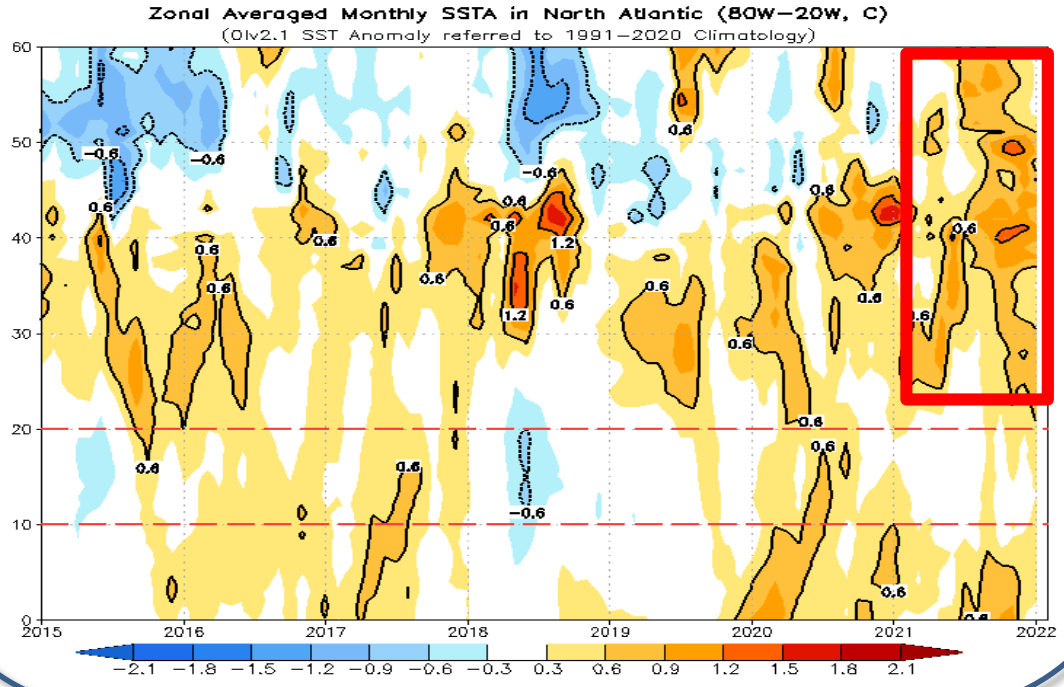


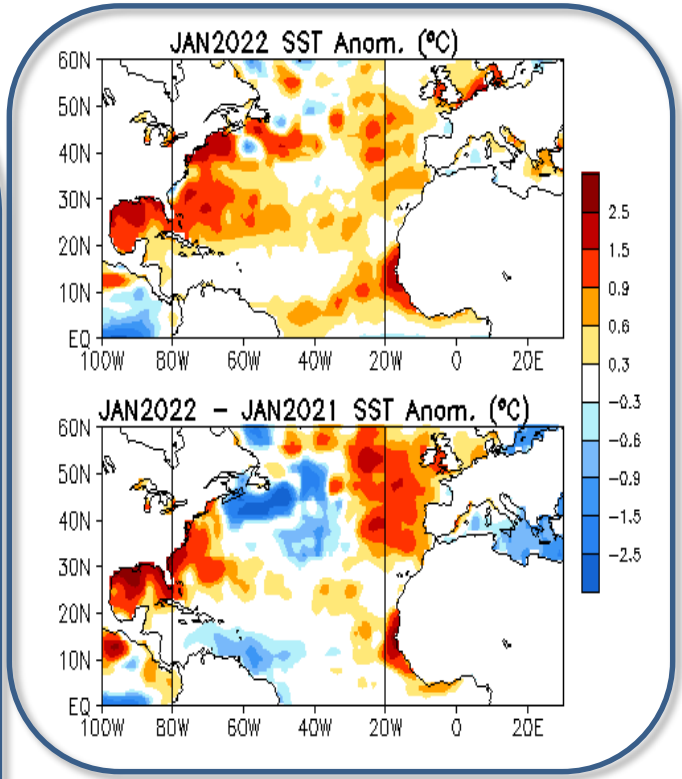
- SSTAs in the tropical Atlantic were small.
- The Atlantic Niño event ended in Dec 2021.

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 OI SST analysis, and anomalies are departures from the 1991-2020 base period means.

NAO and SST Anomaly in North Atlantic







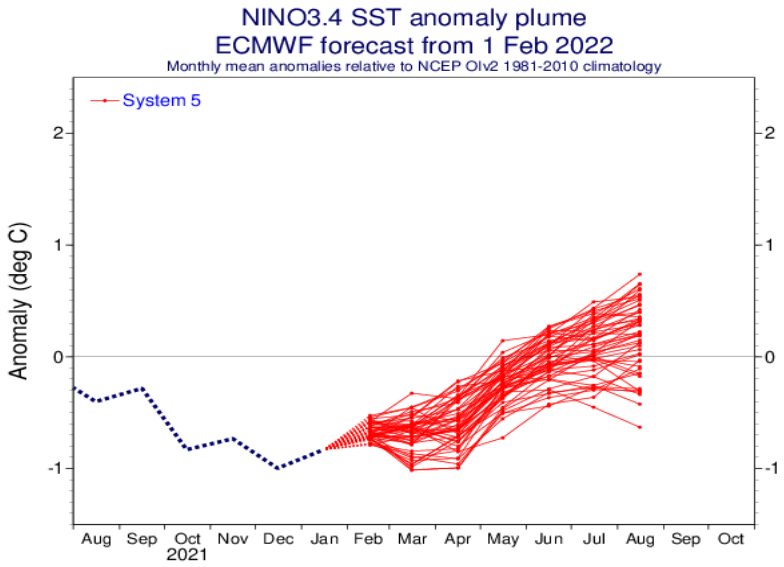
- NAO switched to a positive phase in Dec 2021 with NAOI= 0.74 in Jan 2022.
- The positive SSTAs in the mid-high latitudes of the North Atlantic Ocean were evident during last year.

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 OI SST analysis, and anomalies are departures from the 1991-2020 base period means.

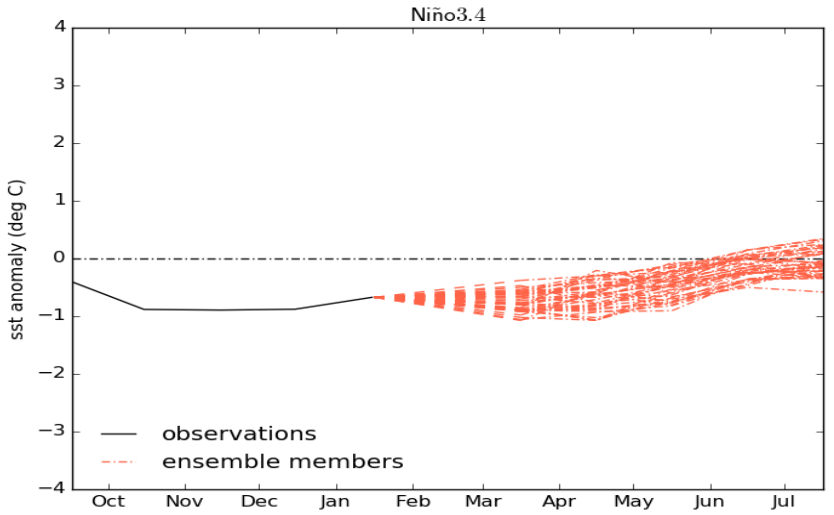
ENSO and Global SST Predictions

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

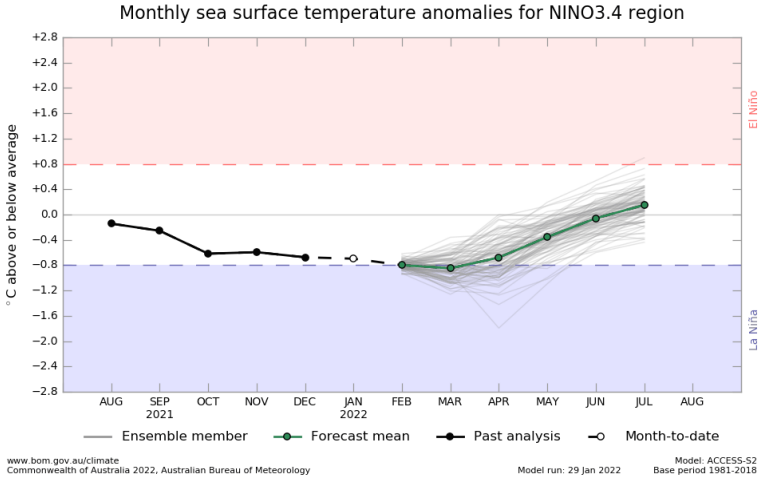
EC: Niño3.4, IC= 01Feb 2022



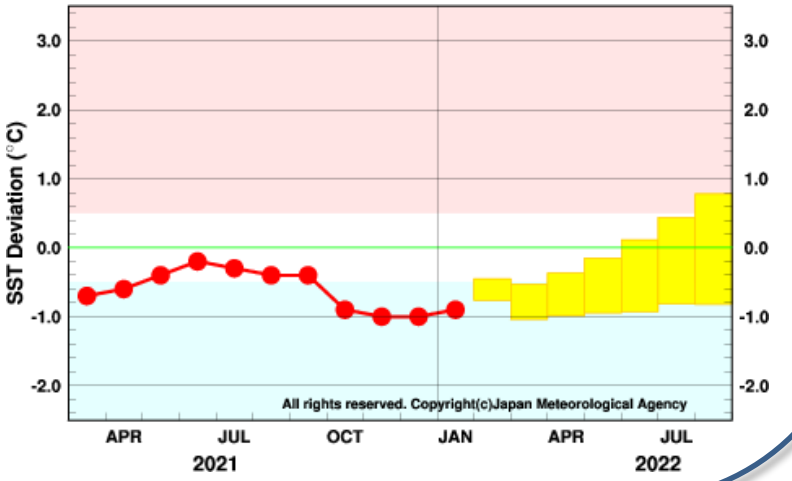
UKMO: Niño3.4, Updated 11Feb 2022



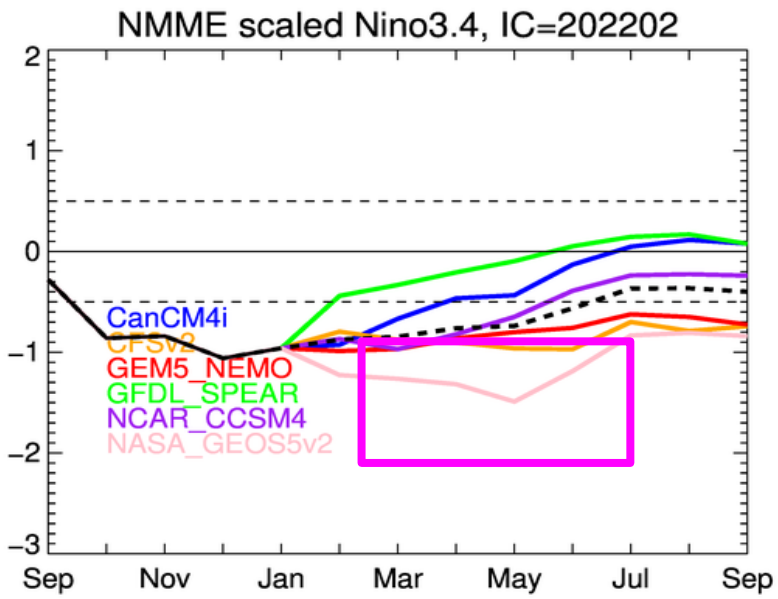
Australian BOM: Niño3.4, Updated 29Jan 2022

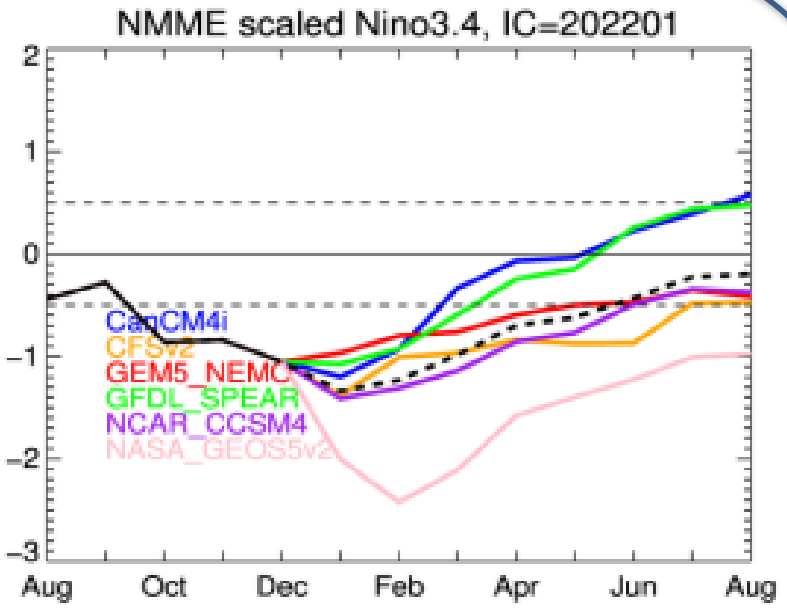


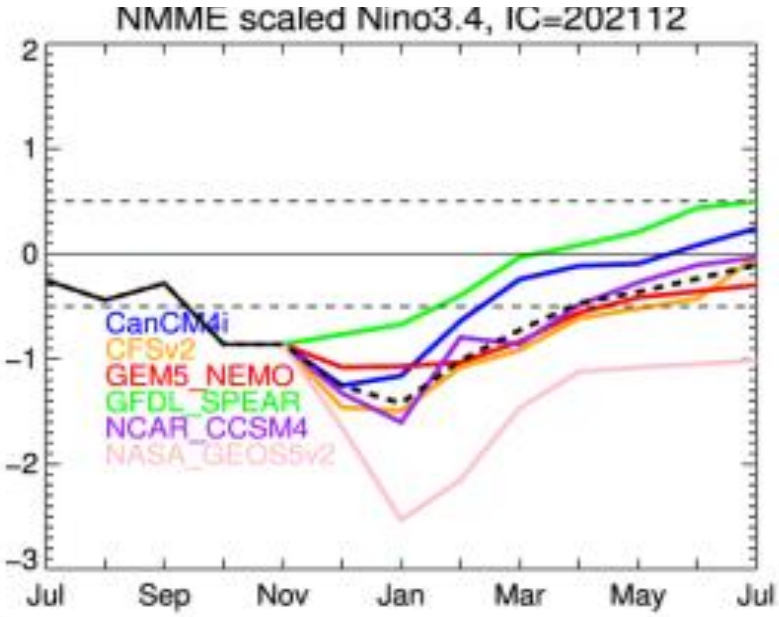
JMA: Niño3.4, Updated 10Feb 2022

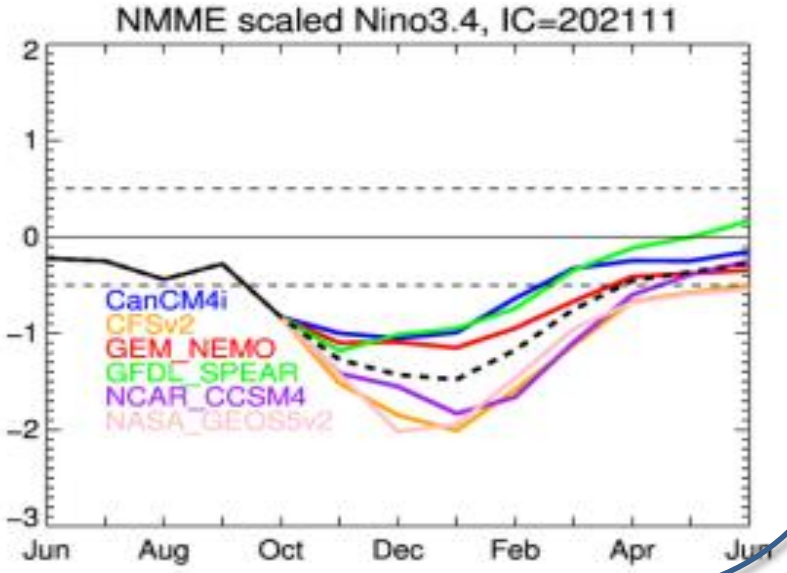


NMME forecasts from different initial conditions

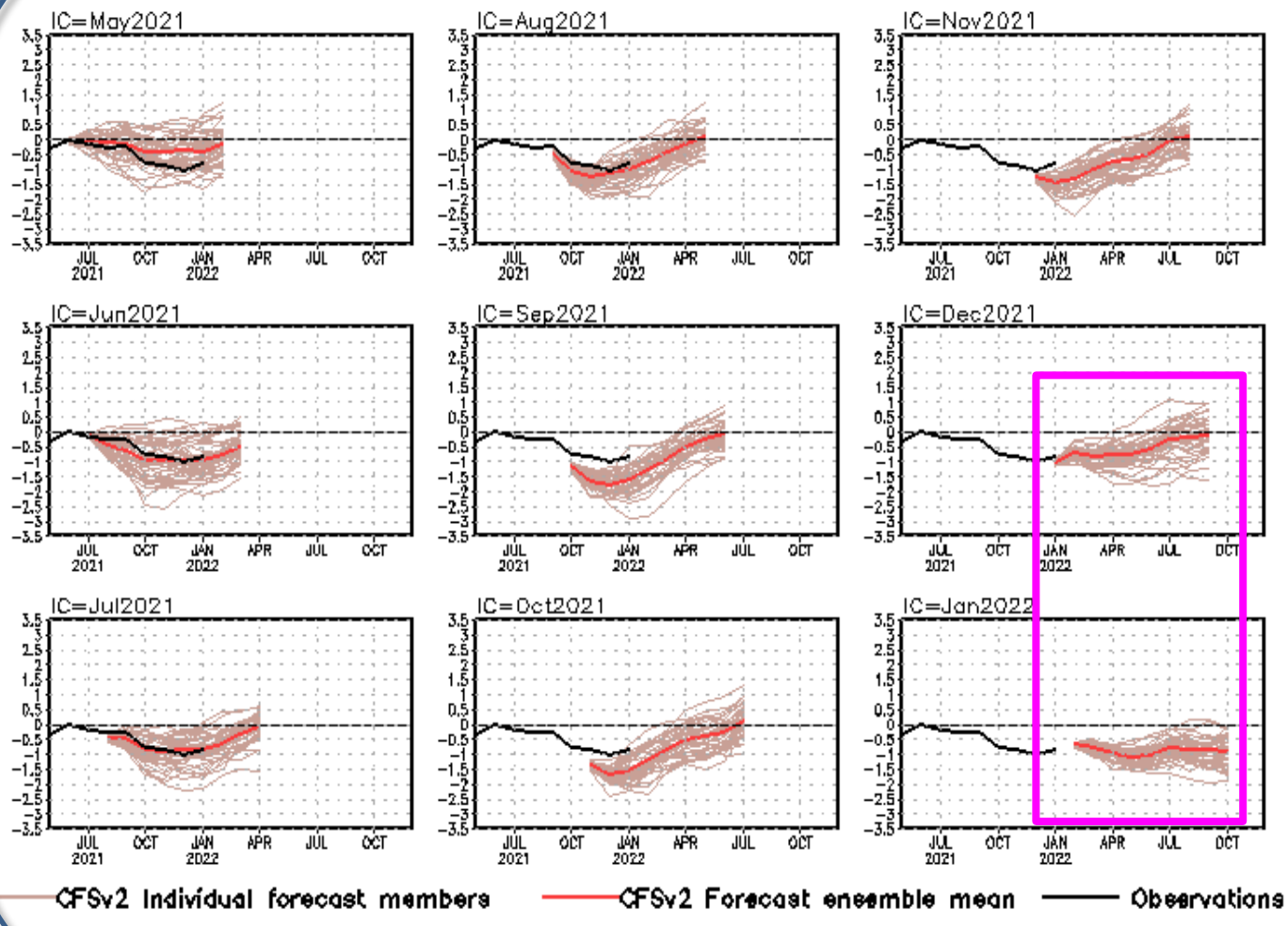








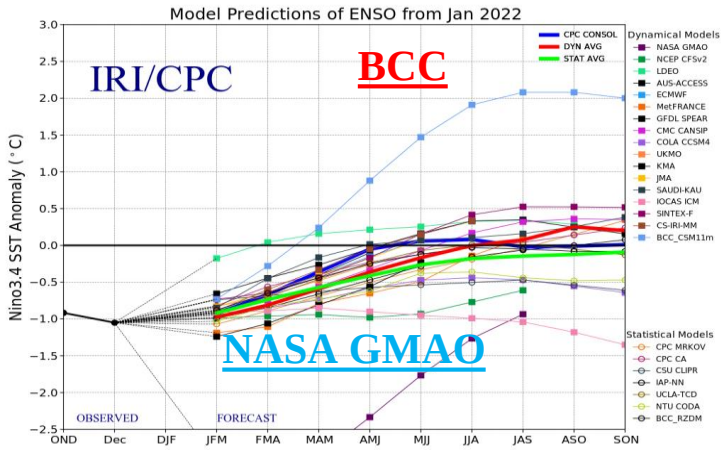
CFS Niño3.4 SST Predictions from Different Initial Months

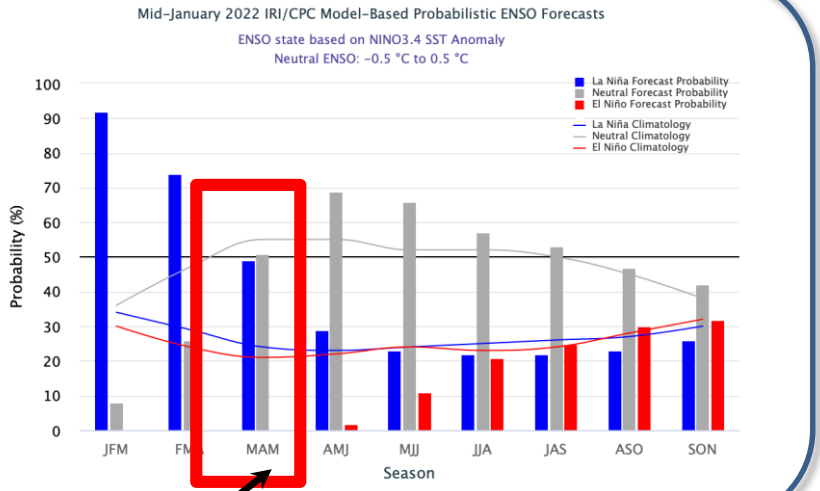


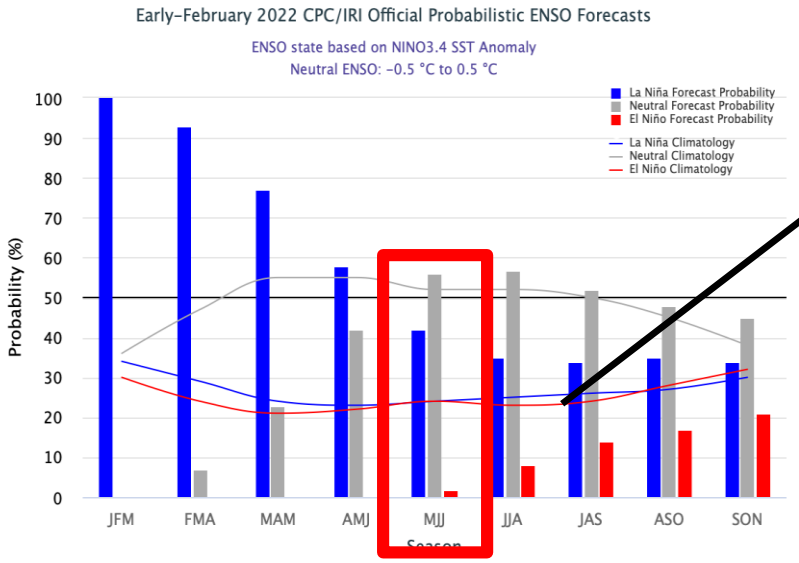
- The latest CFSv2 forecasts call that La Niña will persist in summer – autumn 2022.

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.

IRI/CPC Niño3.4 Forecast: Jan 2022

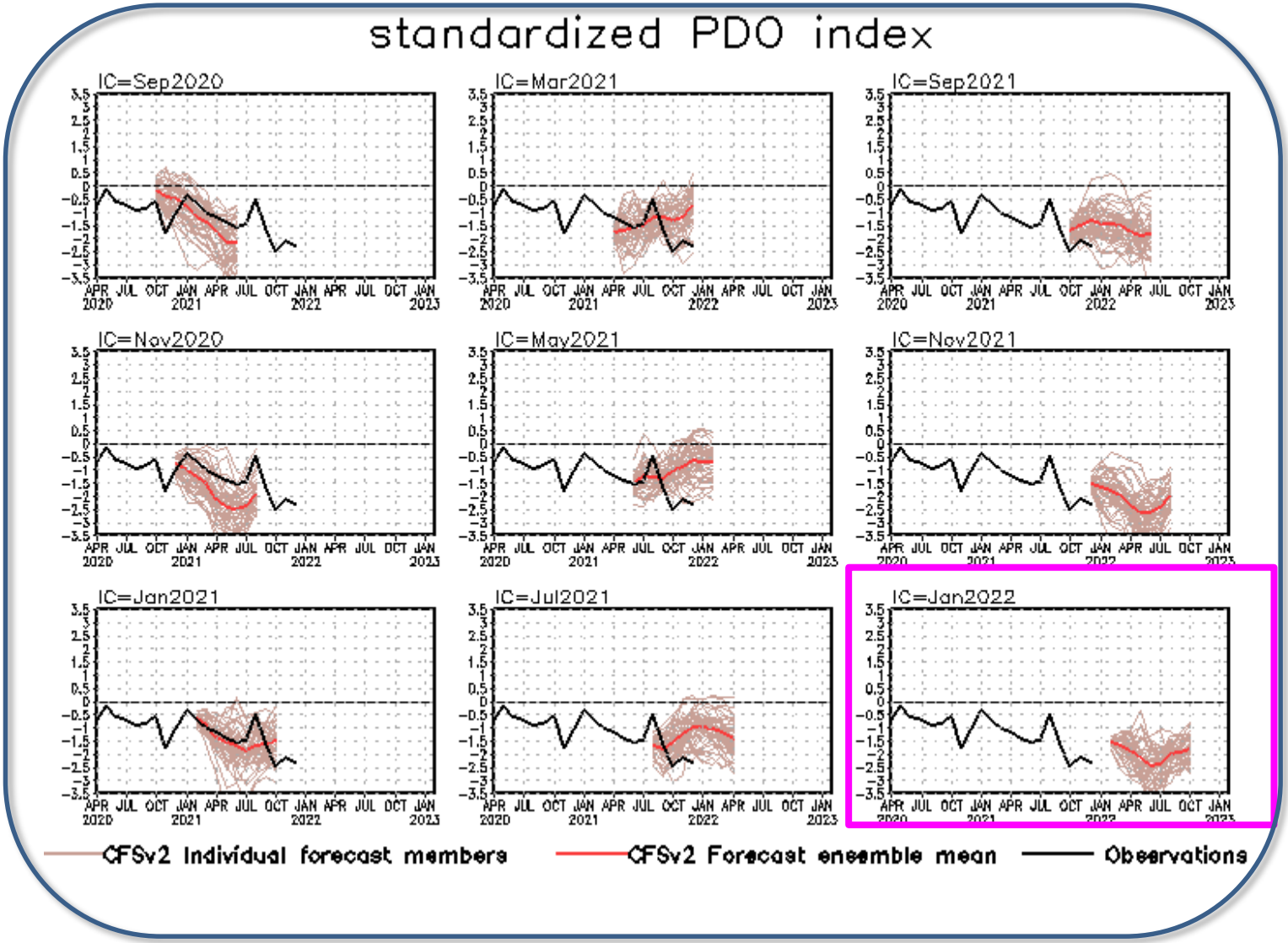






- **ENSO Alert System Status: La Niña Advisory**
- Synopsis: *La Niña is likely to continue into the Northern Hemisphere spring (77% chance during March-May 2022) and then transition to ENSO-neutral (56% chance during May-July 2022).”*

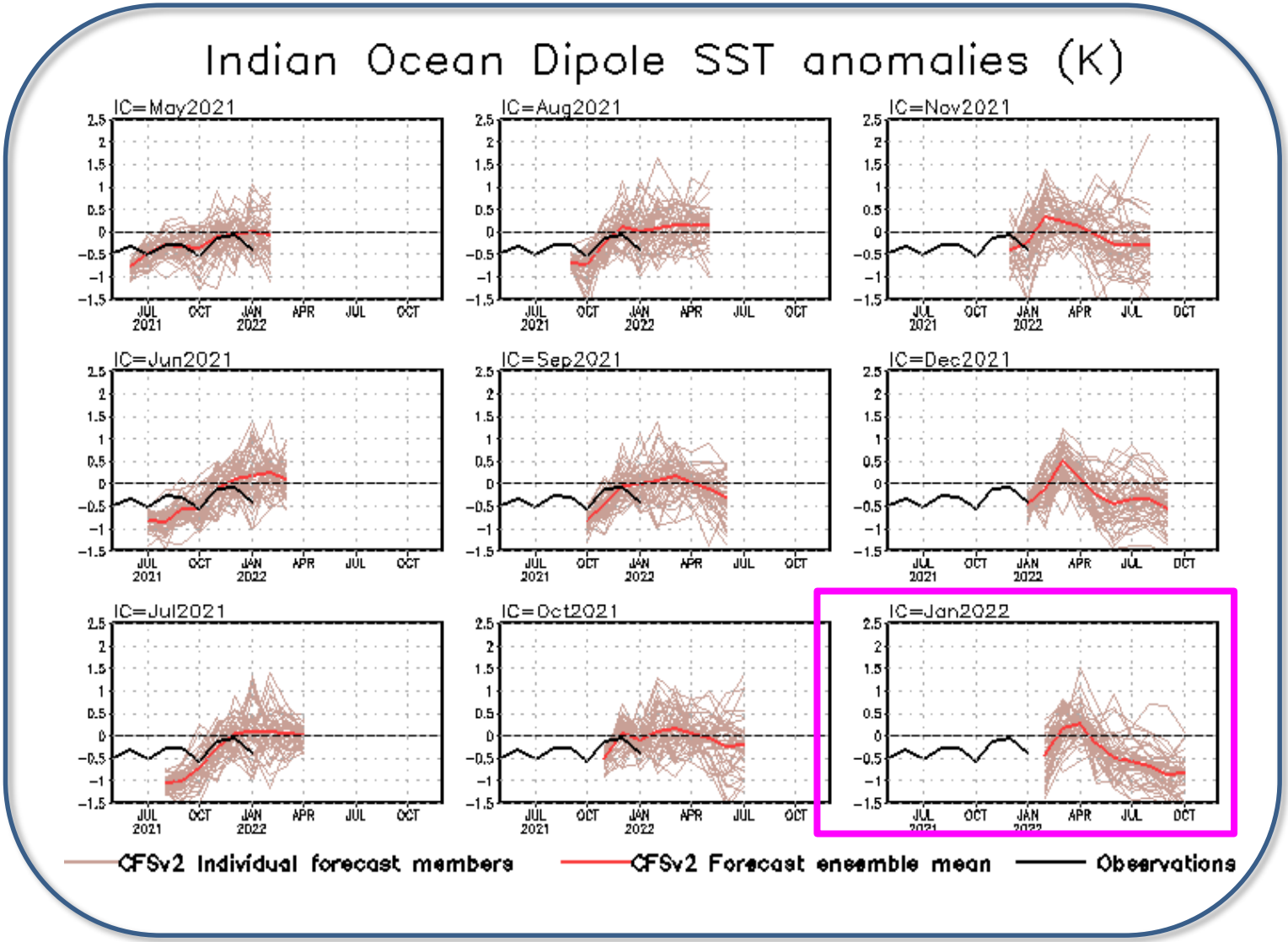
CFS Pacific Decadal Oscillation (PDO) Index Predictions from Different Initial Months



- CFSv2 predicts a negative phase of PDO in 2022.

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

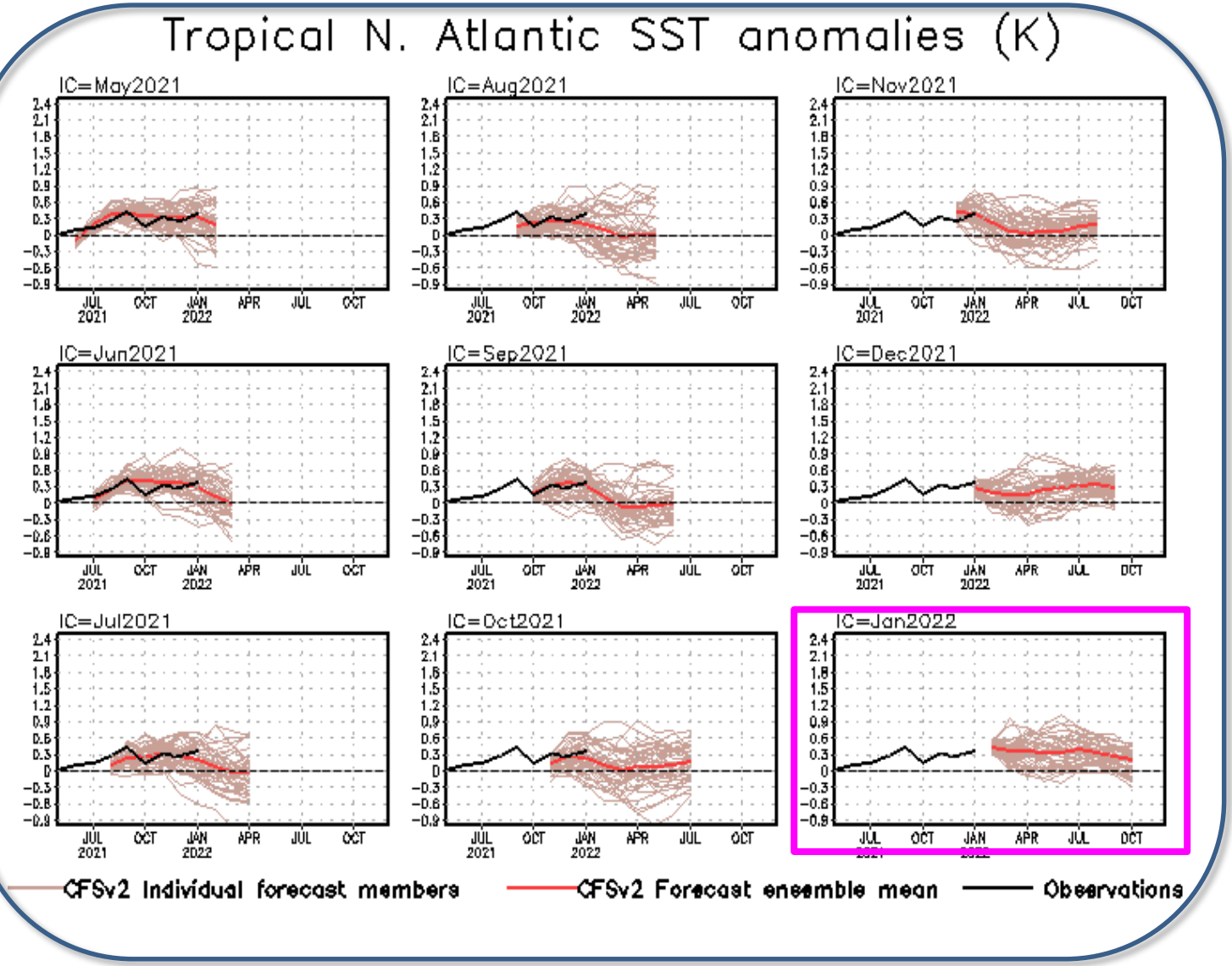
NCEP CFS DMI SST Predictions from Different Initial Months



- CFSv2 predicts a negative phase of IOD in summer-autumn 2022.

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.

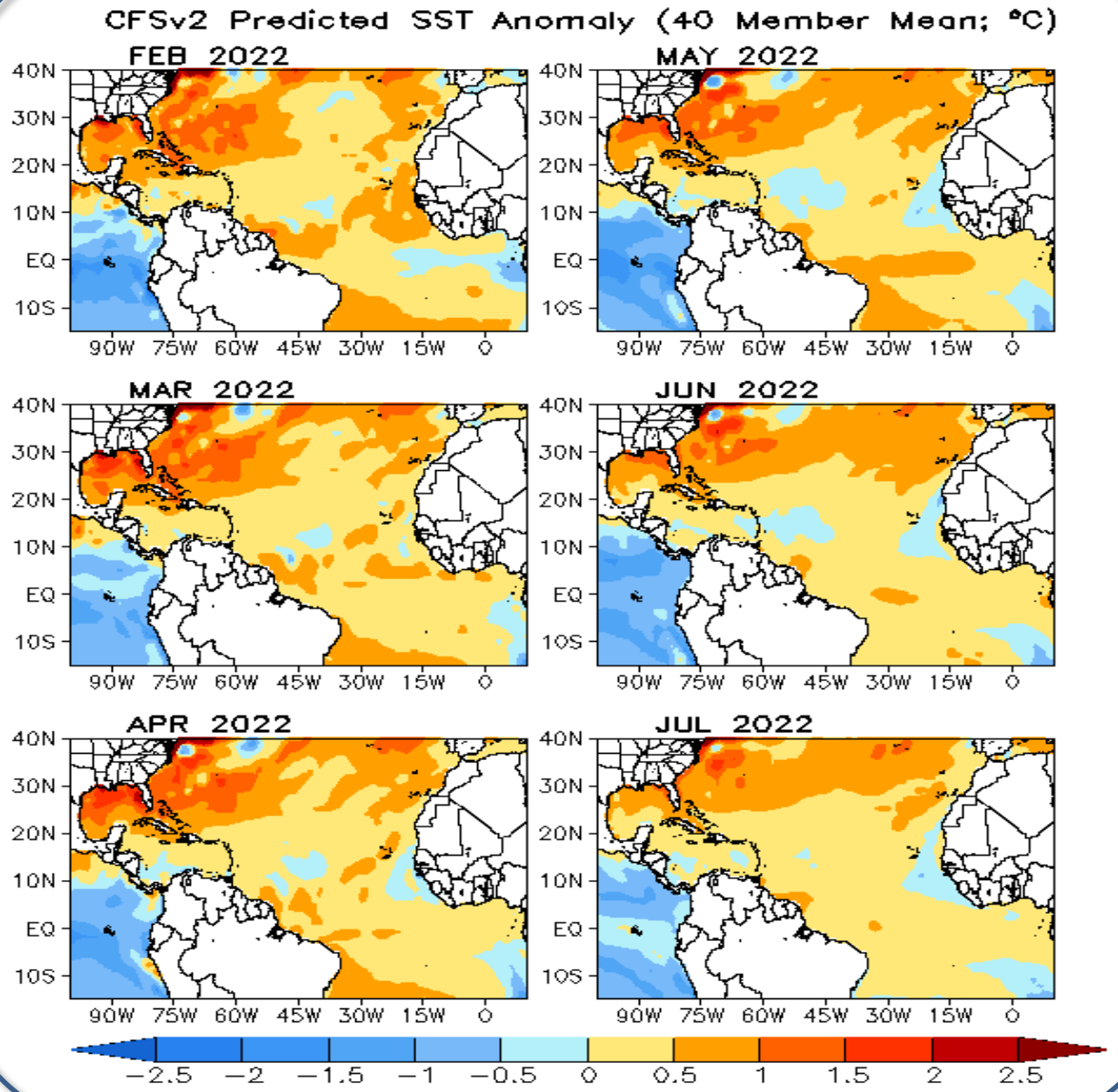
CFS Tropical North Atlantic (TNA) SST Predictions from Different Initial Months



- Latest CFSv2 predictions call for above normal SST in the tropical North Atlantic in 2022.

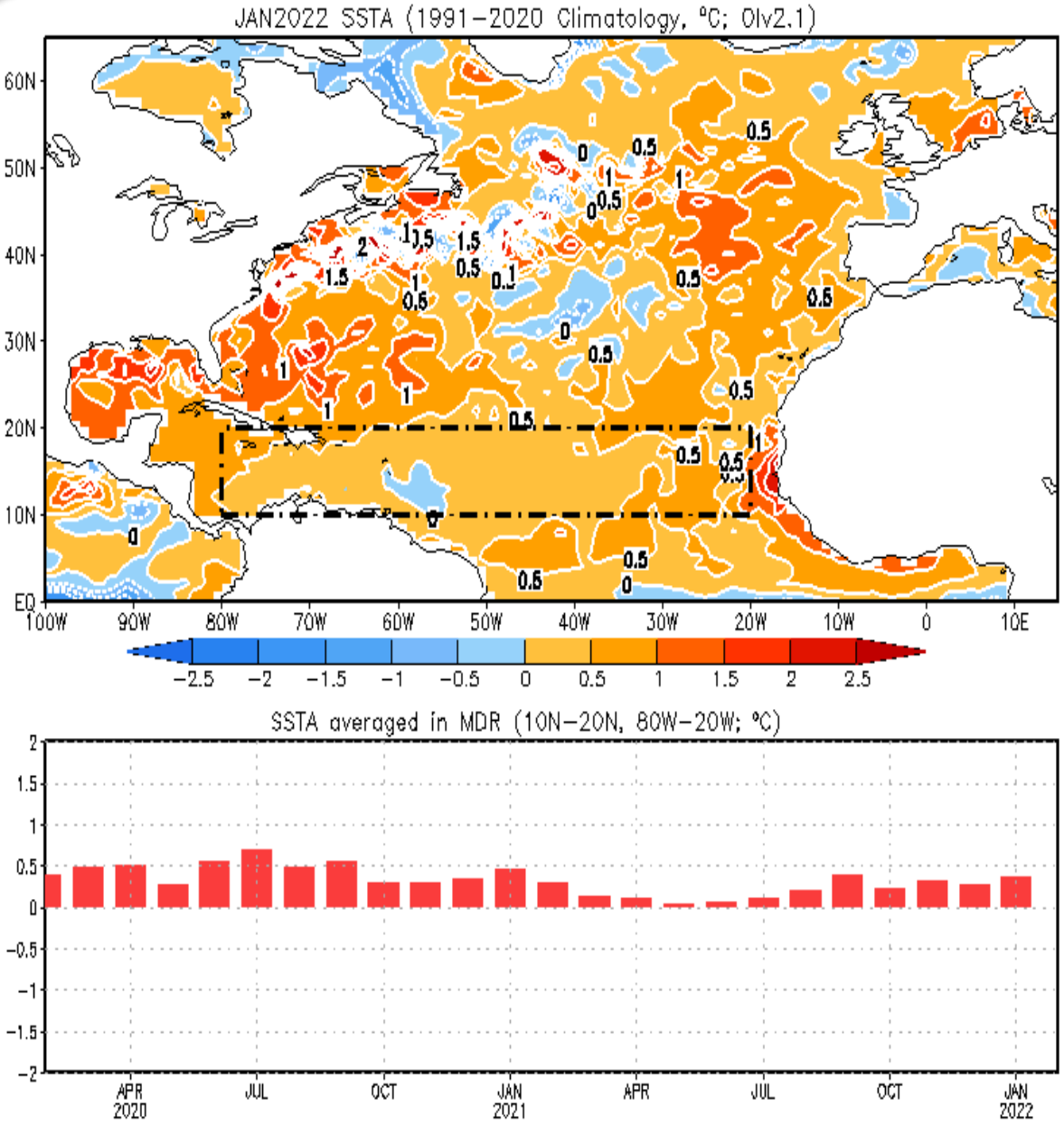
CFS Tropical North Atlantic (TNA) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were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

CFSv2 Atlantic SSTA Predictions



- Latest CFSv2 predictions call above or near normal SST in the next 6 months.

SSTAs in the North Atlantic & MDR



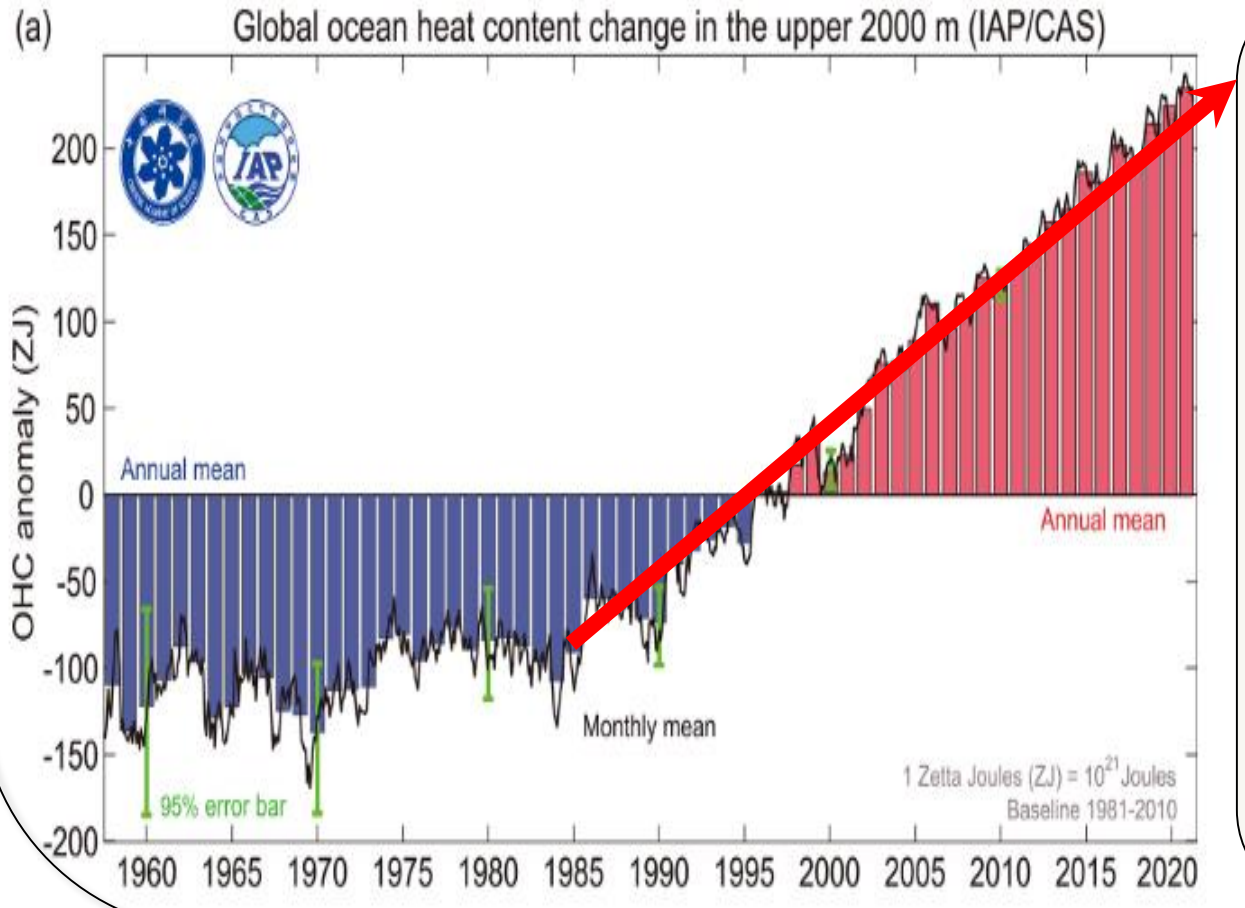
- SST in MDR was above average during the last two years.

2021 Ocean Annual Review

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

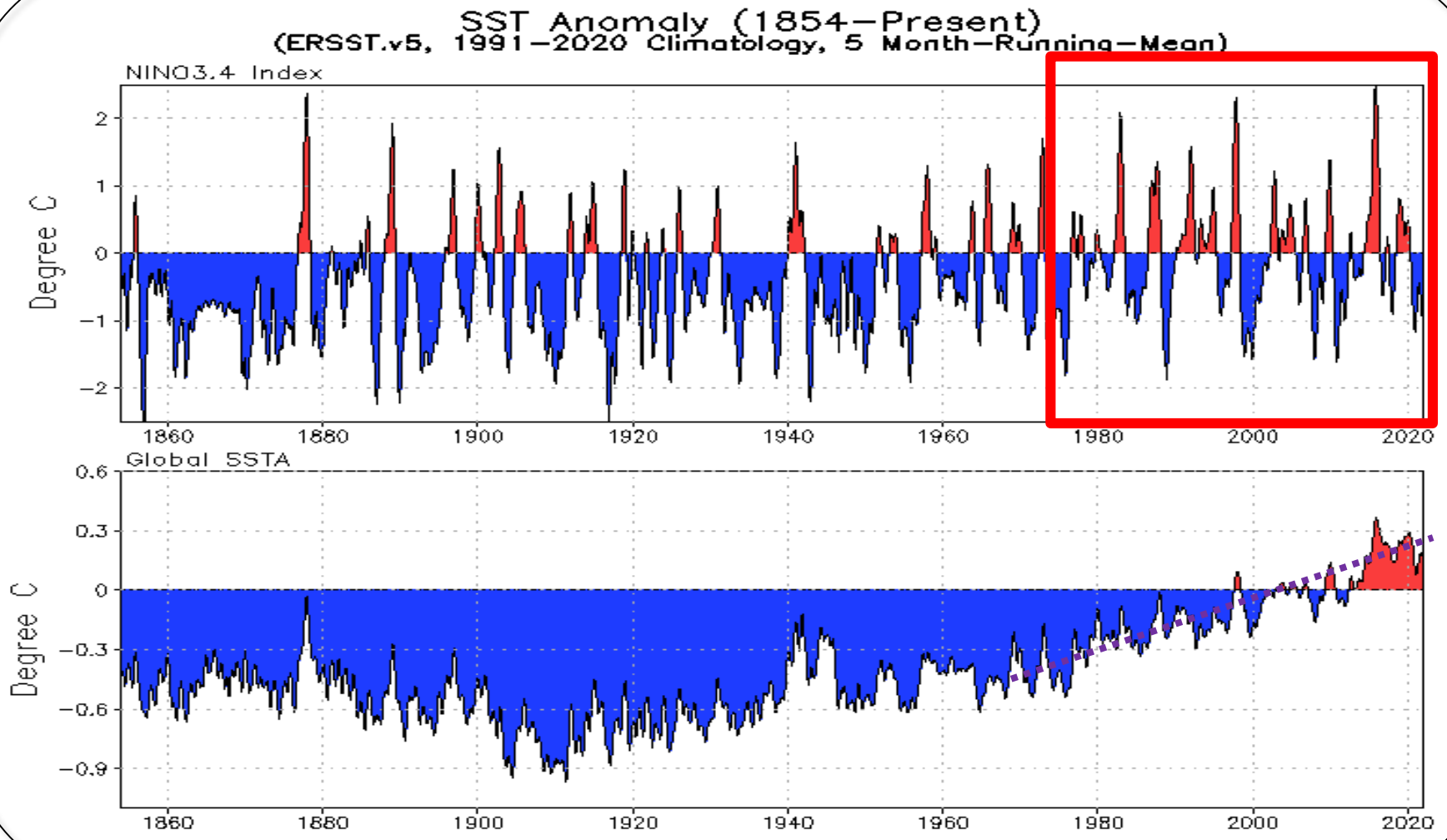
Rank	Year	IAP/CAS	NCEI/NOAA
1	2021	235	227
2	2020	221	211
3	2019	214	210
4	2017	202	189
5	2018	195	196

2021 was the warmest ocean since 1955 based on global ocean HC of upper 2,000 m.



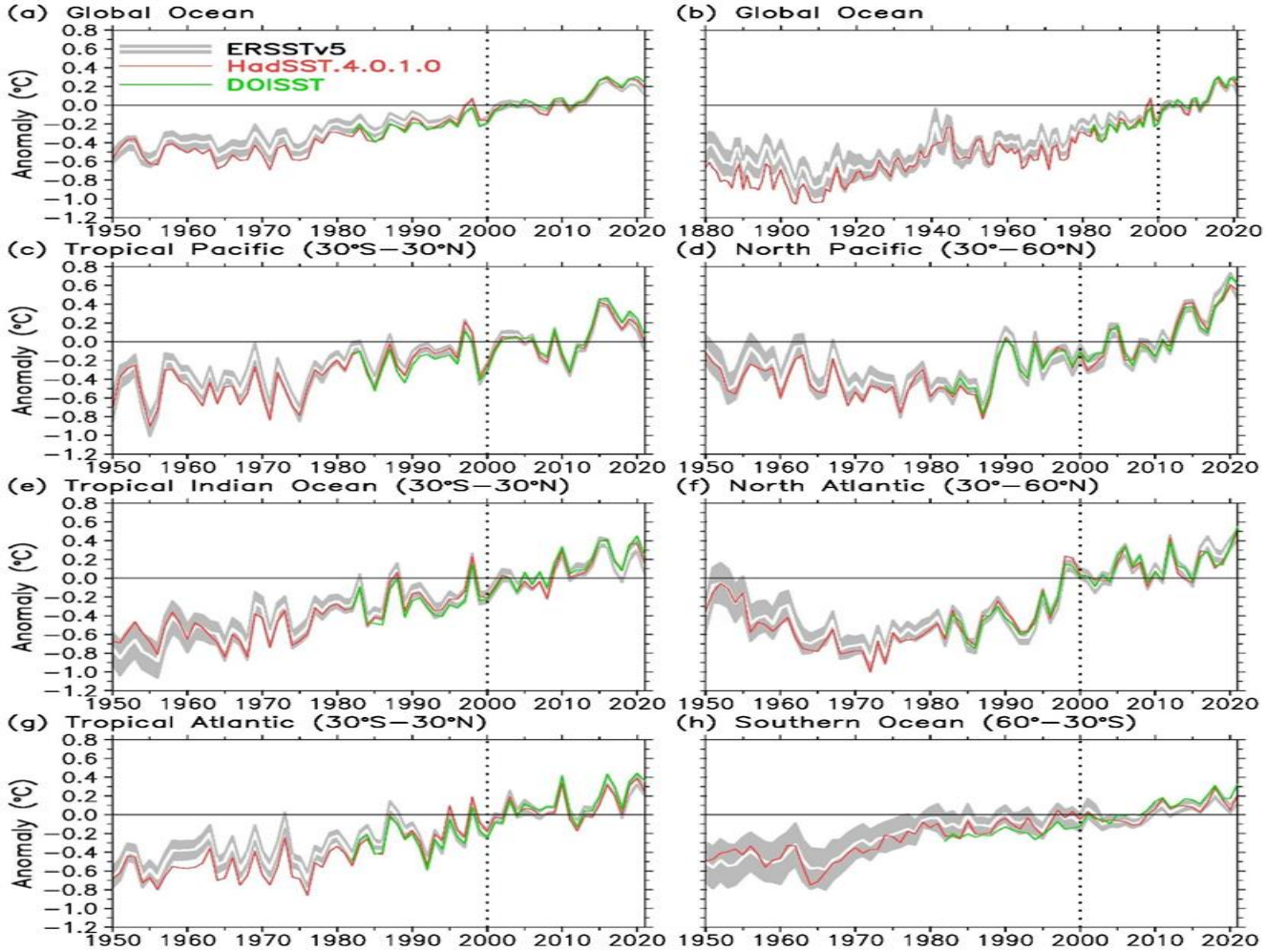
Global upper 2000 m OHC from 1958 through. 2021. The histogram presents annual anomalies relative to a 1981−2010 baseline, with positive anomalies shown as red bars and negative anomalies as blue. Units: ZJ.

Cheng, et al. 2022: Another Record: Ocean Warming Continues through 2021 despite La Niña Conditions. Adv. Atmos. Sci. DOI: 10.1007/s00376-022-1461-3



- Strong warming tendency was observed for global SST; but 2021 wasn't the warmest year based on global averaged ERSSTv5.
- Warming tendency was ambiguous in the Niño3.4.

Yearly Mean SSTA Indices



- Global averaged SSTAs in 2021 (+0.29°C) were smaller than that in 2019 (0.41°C), 2020 (0.39°C), and the record year of 2016 (+0.44°C).

- 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 1950–2021 except for (b). (a) Global, (b) Global in 1880–2021, (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 2021 by Huang et al.

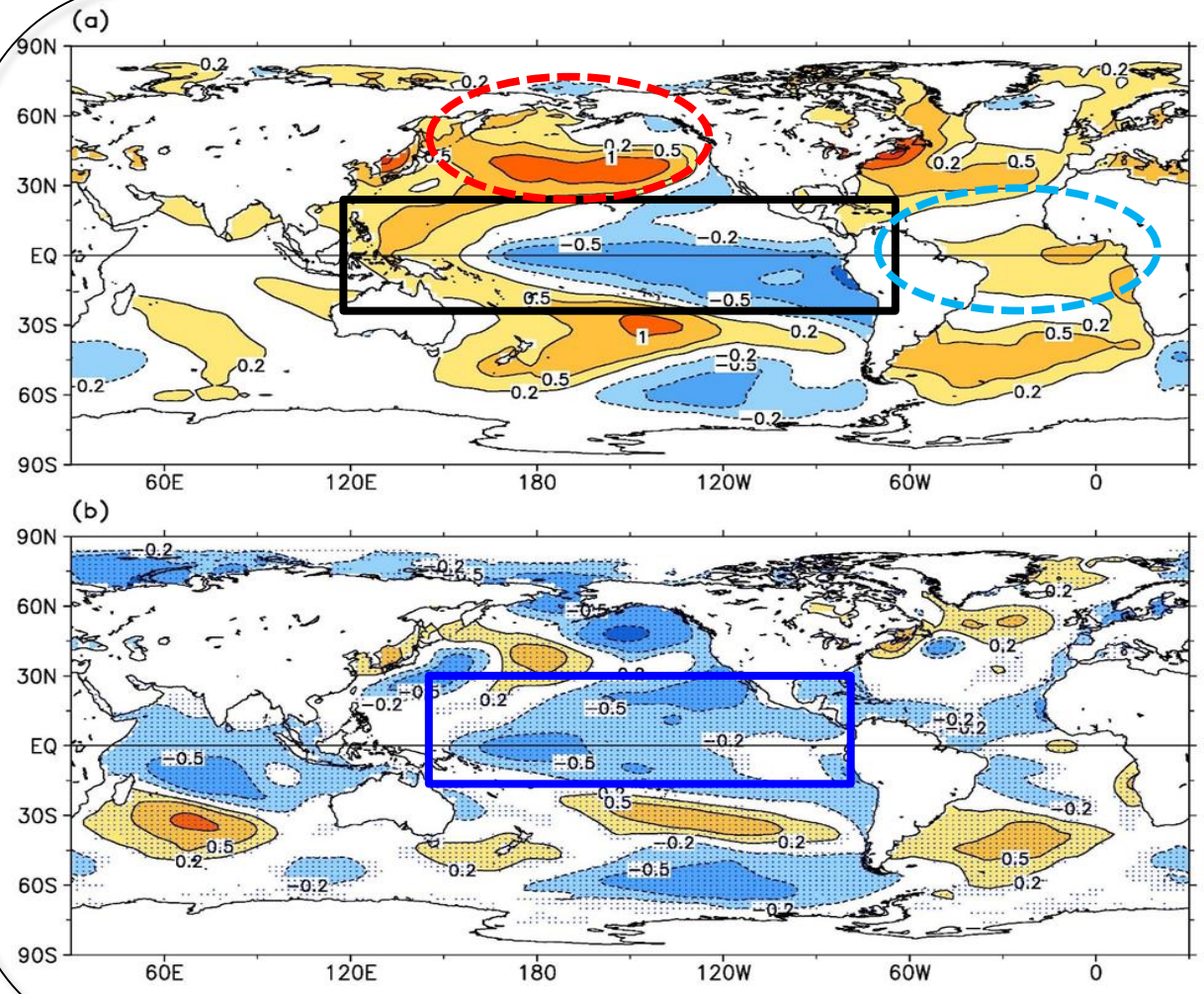
Linear Trend Values

Product	Region	2000–2021	1950–2021
HadSST.4.0.1.0	Global	0.175±0.067	0.12±0.02
DOISST	Global	0.190±0.057	N/A
ERSSTv5	Global	0.158±0.065	***0.10±0.01***
ERSSTv5	Tropical Pacific (30°S–30°N)	0.141±0.163	0.10±0.03
ERSSTv5	North Pacific (30°–60°N)	0.364±0.127	***0.09±0.04***
ERSSTv5	Tropical Indian Ocean (30°S–30°N)	0.184±0.083	***0.14±0.02***
ERSSTv5	North Atlantic (30°–60°N)	0.158±0.088	0.12±0.05
ERSSTv5	Tropical Atlantic (30°S–30°N)	0.151±0.084	0.11±0.02
ERSSTv5	Southern Ocean (30°–60°S)	0.117±0.053	0.10±0.02

- Overall, the warming trends of the global oceans since the 1950s persisted.
- The linear trends of globally annually averaged SSTAs were 0.10°±0.01°C/decade over 1950–2021.
- The warming trend was the largest in the tropical Indian Ocean (**0.14±0.02°C/decade)** & the smallest in the North Pacific (0.09±0.04**°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 2021 by Huang et al.**

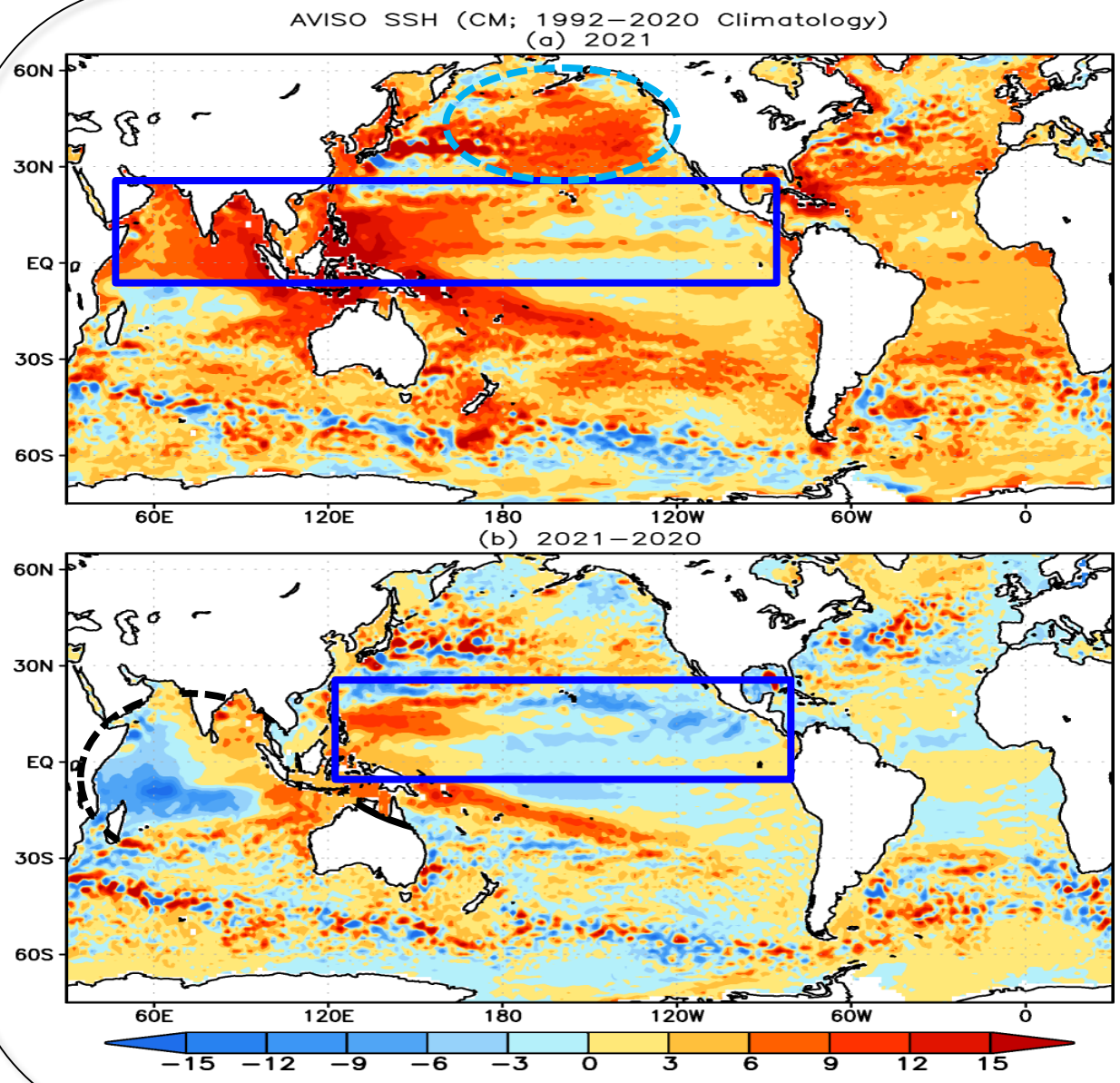
2021 Yearly Mean ERSSTv5 SSTA & Tendency



- **The cooling (warming) in the eastern (western) tropical Pacific, associated with the La Niña in 2021.**
- **Warming in the North Pacific was consistent with the negative phase of PDO in 2021.**
- **Warming in the tropical Atlantic Ocean was linked to the Atlantic Niño in the 2nd half of 2021.**
- **The central and eastern tropical Pacific was cooler in 2021 than in 2020.**

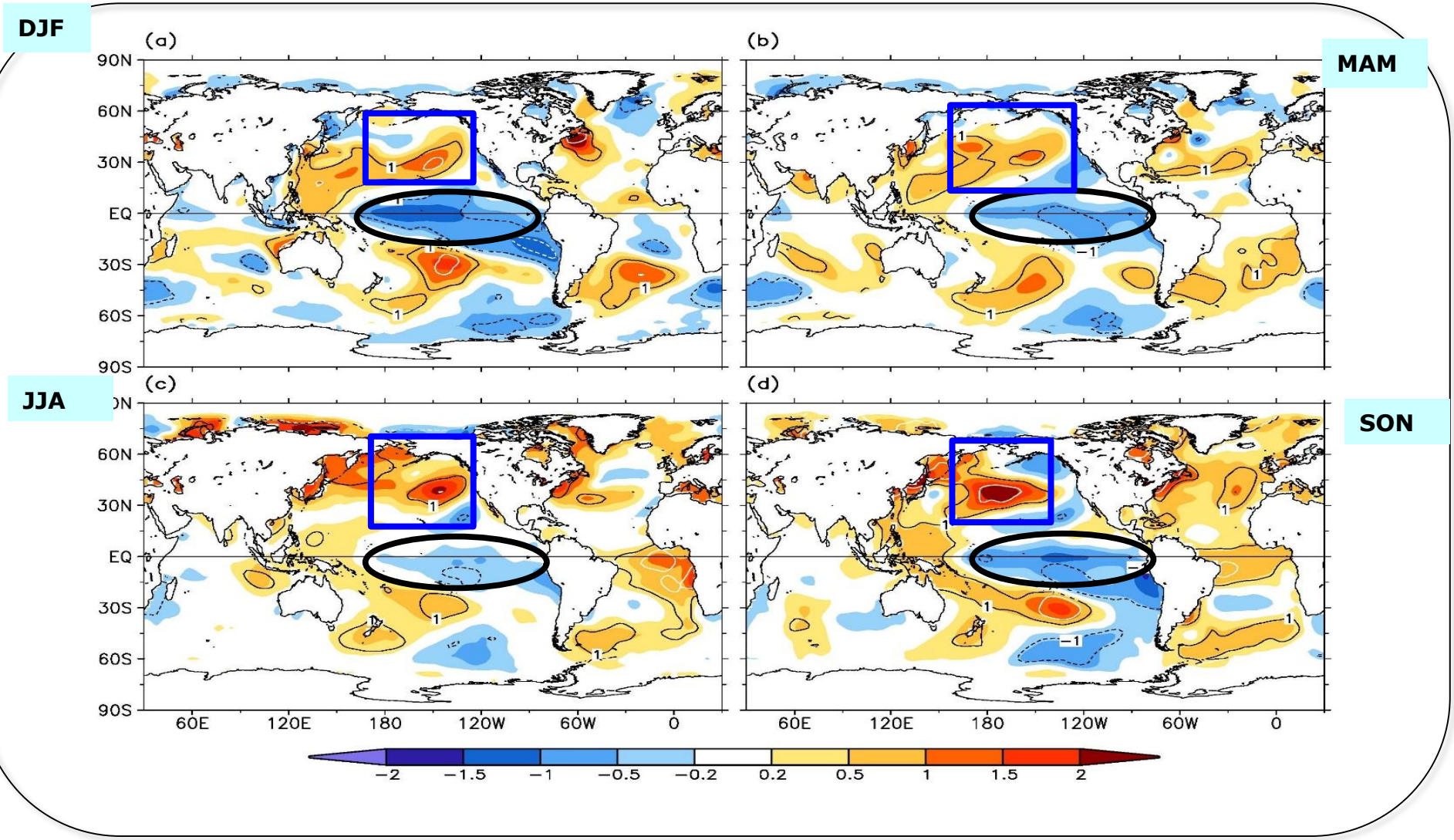
- Fig. 3.1. Fig. 3.1. (a) Annually-averaged SSTAs in 2021 and (b) difference of annually-averaged SSTAs between 2021 and 2020. Values are relative to 1991–2020 climatology and the SSTA difference in is significant at 95% level in stippled areas.
- **BAMS State of the Climate in 2021 by Huang et al.**

2021 Yearly Mean AVISO SSH Anomalies & Tendency

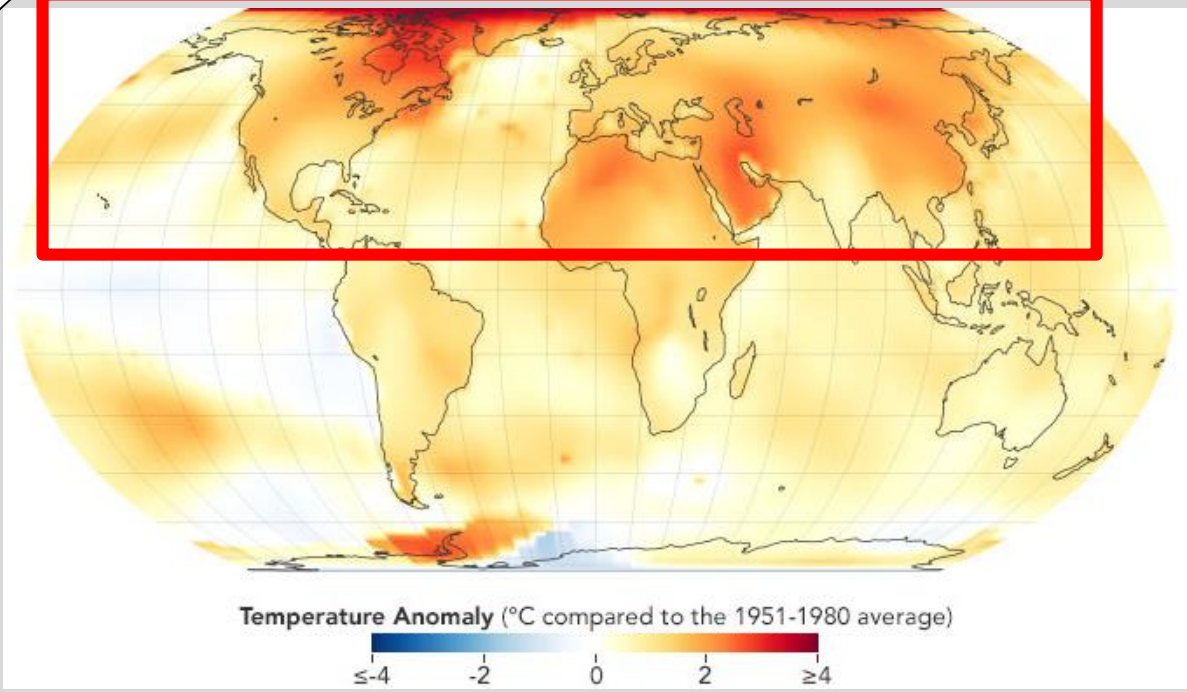


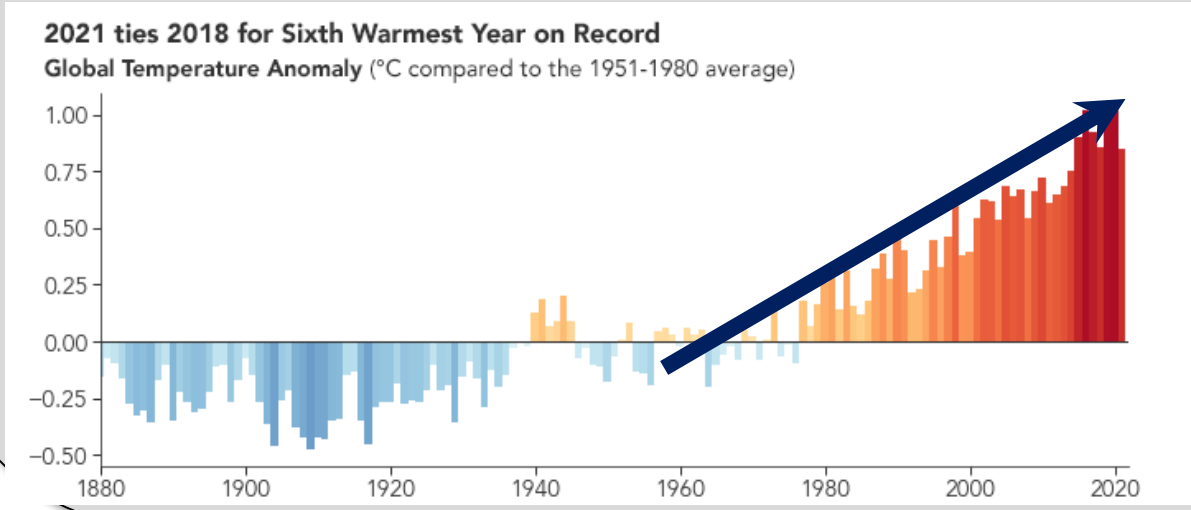
- **Pronounced positive SSH anomalies were present in the tropical northern Indian Ocean and tropical western Pacific, consisting with La Niña in 2021.**
- **Positive SSH anomalies were observed in the North Pacific.**
- **The east-west contrast across the tropical Pacific was larger in 2021 than in 2020.**

Seasonal Mean ERSSTv5 SSTA in 2021



- Fig 3.2. Seasonally-averaged SSTAs of ERSSTv5 (°C; shading) for (a) Dec 2020 to Feb 2021, (b) Mar to May 2021, (c) Jun to Aug 2021, and (d) Sep to Nov 2021. 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 2021 by Huang et al.**





- "Earth's global average surface temperature in 2021 tied 2018 as the sixth-warmest year on record, according to independent analyses from NASA & NOAA."
- **"2021 was a La Niña year, and NASA scientists estimate that those ocean conditions may have cooled global temperatures by about 0.03°C from what the average might have been."**

https://www.nasa.gov/press-release/2021-tied-for-6th-warmest-year-in-continued-trend-nasa-analysis-shows

2021 Annual Review

- 2021 global ocean (HC2000) was the warmest since 1955.
- Global averaged SSTAs in 2021 (+0.29ºC) were smaller than that in 2019 (0.41ºC), 2020 (0.39ºC), and the record year of 2016 (+0.44°C).
- Overall, the warming trends of the global oceans since the 1950s persisted with the linear trends of globally annually averaged SSTAs of 0.10º±0.01ºC decade^{-1} over 1950–2021.
- The warming trend was the largest in the tropical Indian Ocean and the smallest in the North Pacific.
- Earth's global average surface temperature in 2021 tied 2018 as the sixth-warmest year on record, according to NASA & NOAA.

Acknowledgement

- Drs. Jieshun Zhu, Caihong Wen, and Arun Kumar: reviewed PPT, and provide insightful suggestions and comments

- Drs. Li Ren and Pingping Xie 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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Caihong.Wen@noaa.gov
Zeng-Zhen.Hu@noaa.gov

Data Sources (climatology is for 1991-2020)

- **Weekly Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)**
- **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

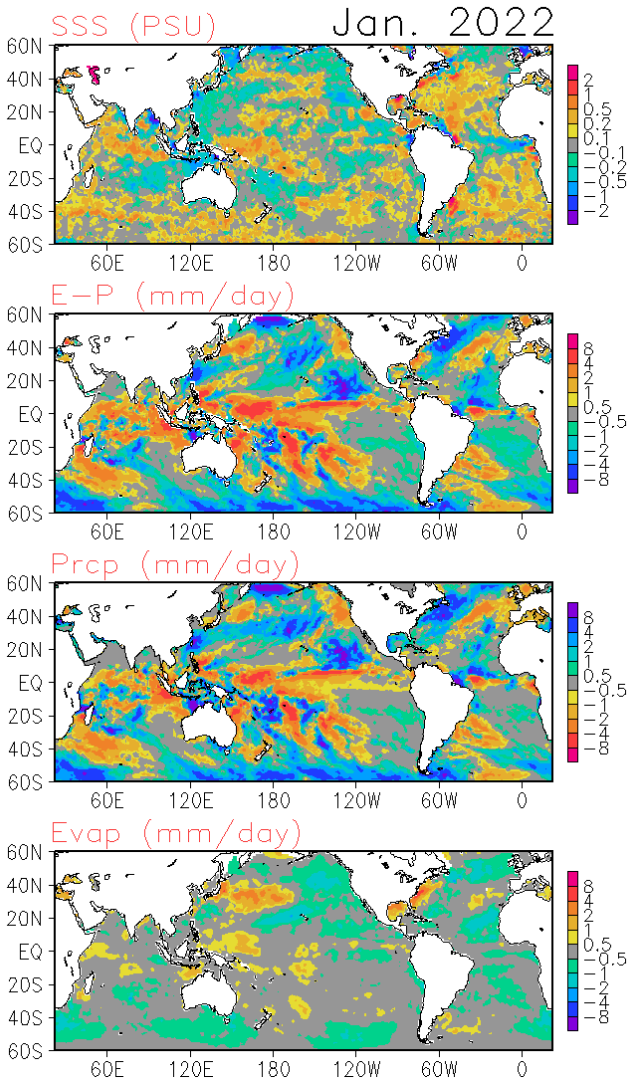
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html

Backup Slides

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

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

Positive SSS anomaly continues in the western equatorial Pacific Ocean with reduced precipitation in this area. Negative SSS anomaly also continues in the eastern equatorial Pacific Ocean (east of 120°W). Positive SSS anomaly continues in the North and South Atlantic Ocean, while negative SSS anomaly shows in the equatorial region of Atlantic Ocean. Negative SSS anomaly appears in the Bay of Bengal.



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

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

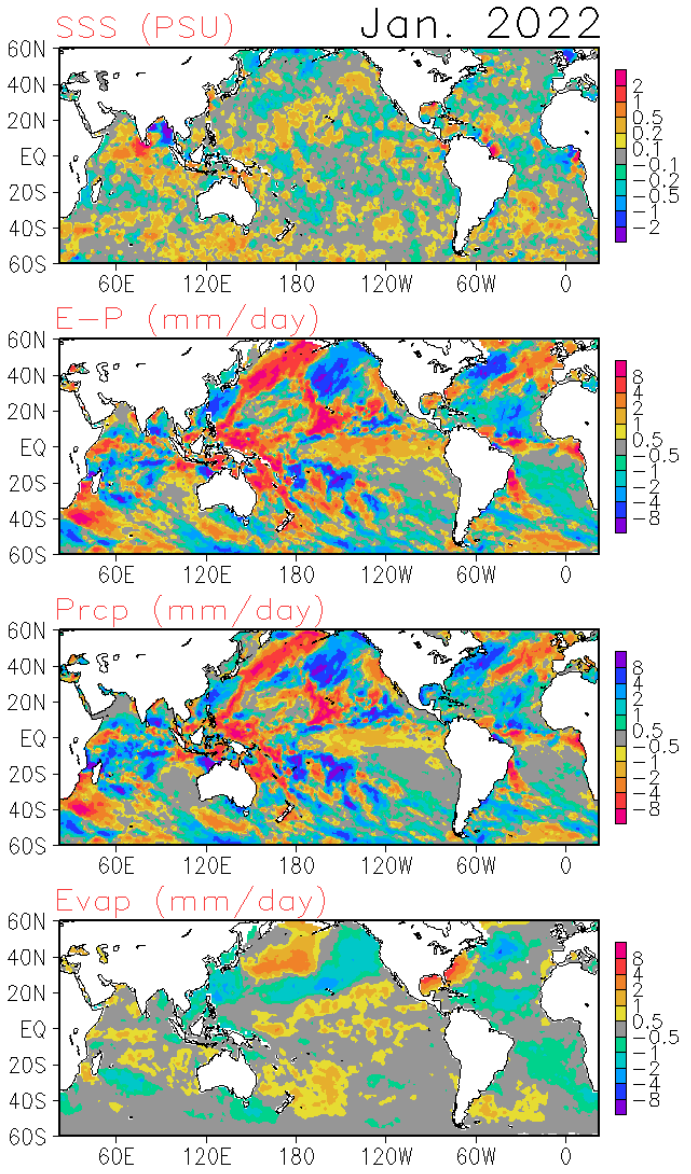
ftp.cpc.ncep.noaa.gov/precip/BASS

Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: Adjusted CFS Reanalysis

Global Sea Surface Salinity (SSS): Tendency for December 2021

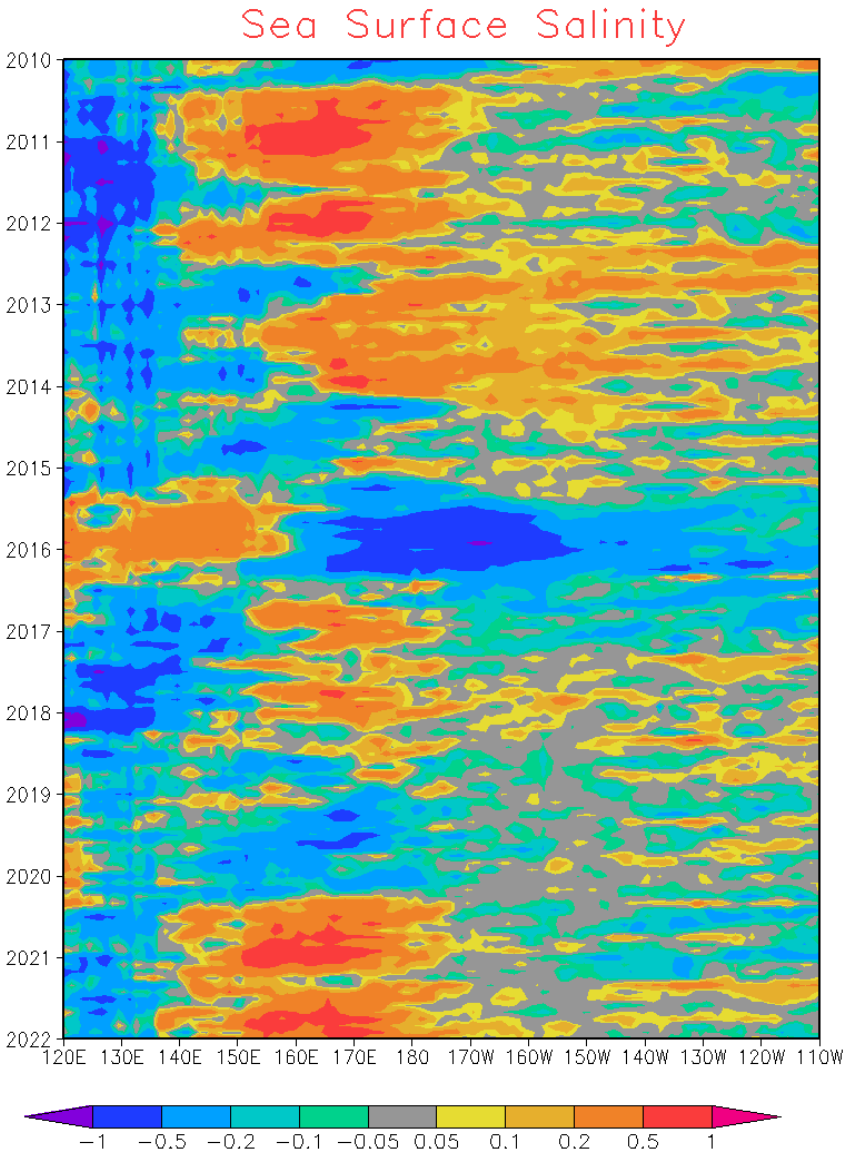
Compared with last month, SSS increased in the central North Pacific Ocean likely due to reduced precipitation. SSS decreased in the equatorial region in the Atlantic Ocean. In Bay of Bengal, SSS decreased which is possibly due to increased precipitation. SSS increased in the Arabian Sea and nearby equator in the Indian Ocean.



Monthly SSS Anomaly Evolution over Equatorial Pacific

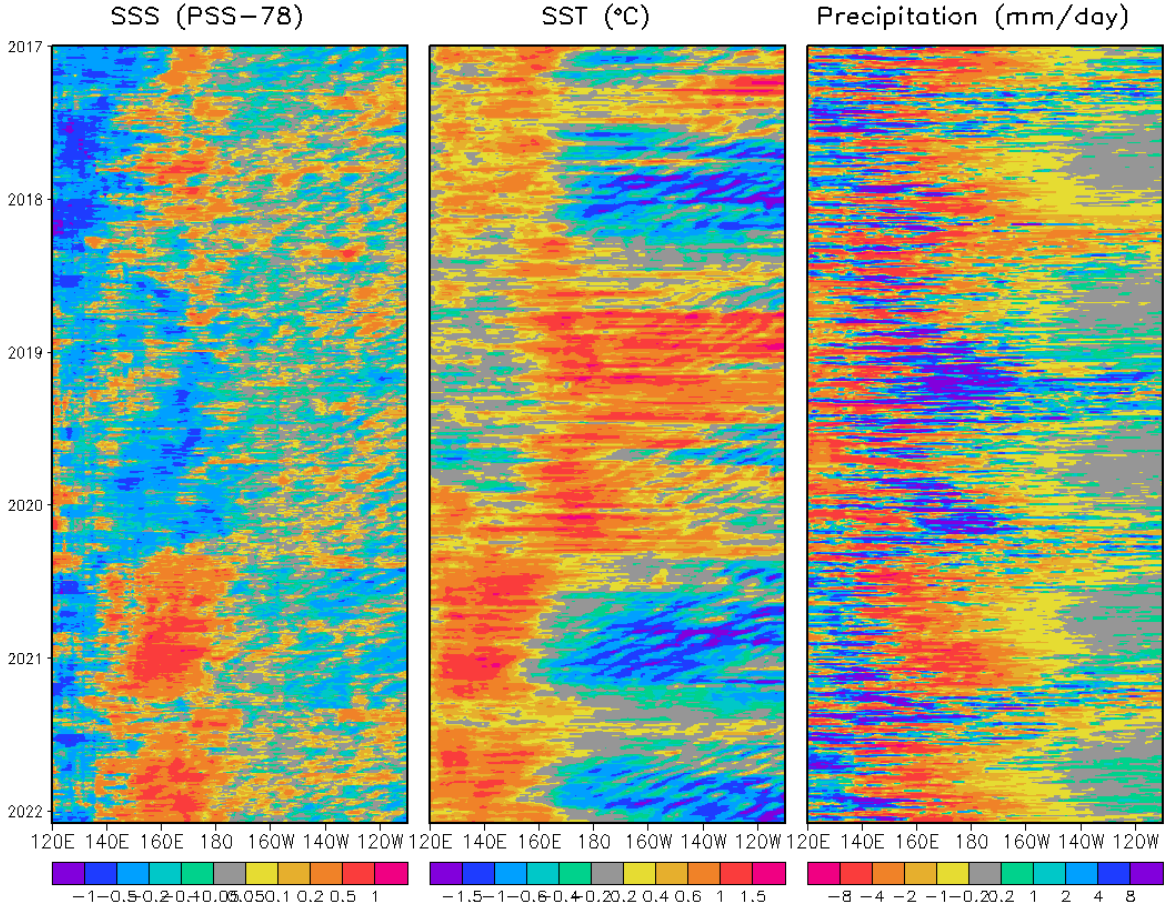
NOTE: Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015,The BASS SSS is from in situ, SMOS and Aquarius.

- Hovemoller diagram for equatorial SSS anomaly **(5˚S-5˚N);**
- In the equatorial Pacific Ocean, west of 140°E, negative SSS signal continues; positive SSS signal continues between 140°E and 170°W; neutral or likely negative signal continues east of 150°W.

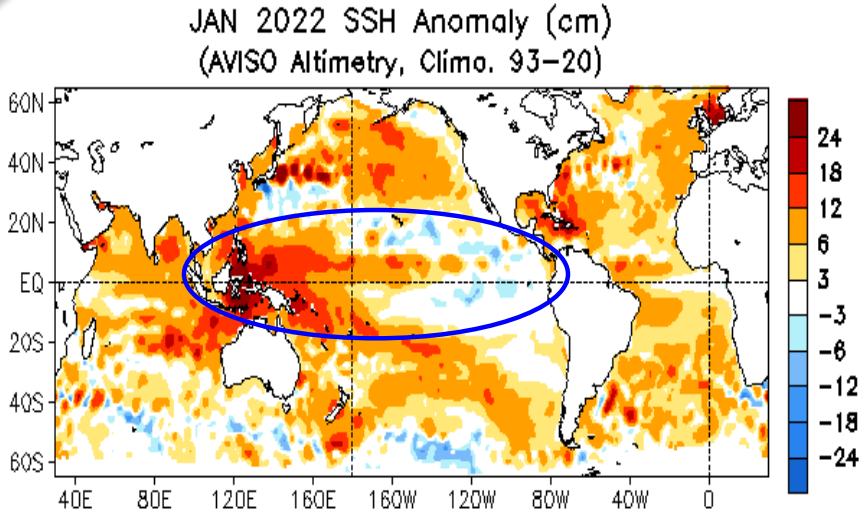


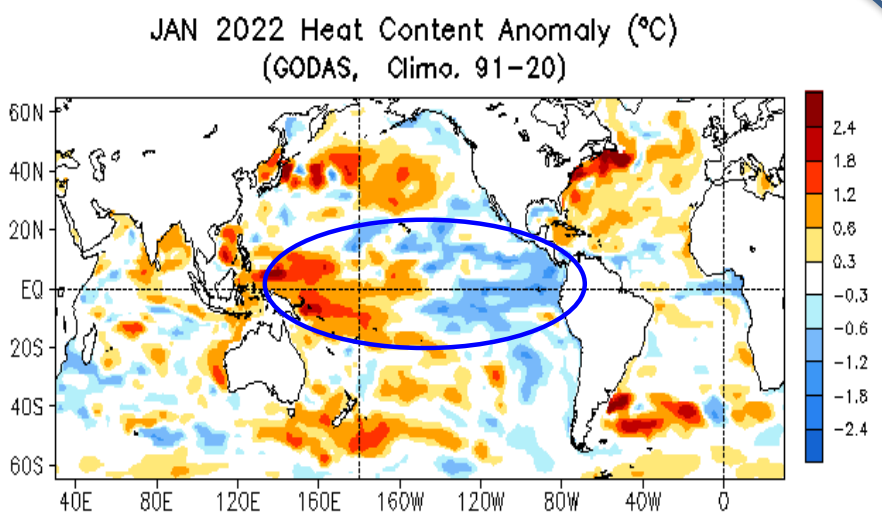
Pentad SSS Anomaly Evolution over Equatorial Pacific

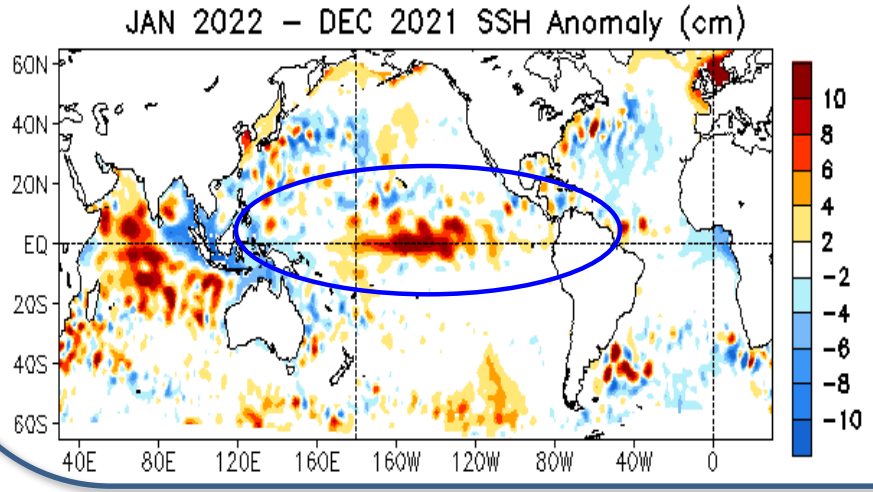
Figure caption:
Hovemoller diagram for equatorial (5°S-5°N) 5-day mean SSS, SST and precipitation anomalies. The climatology for SSS is Levitus 1994 climatology. The SST data used here is the OISST V2 AVHRR only daily dataset with its climatology being calculated from 1985 to 2010. The precipitation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

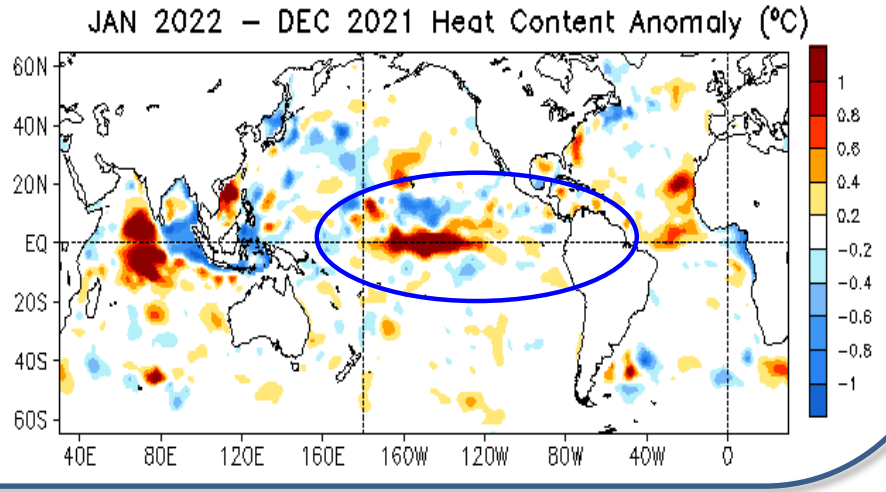


Global SSH and HC300 Anomaly & Anomaly Tendency



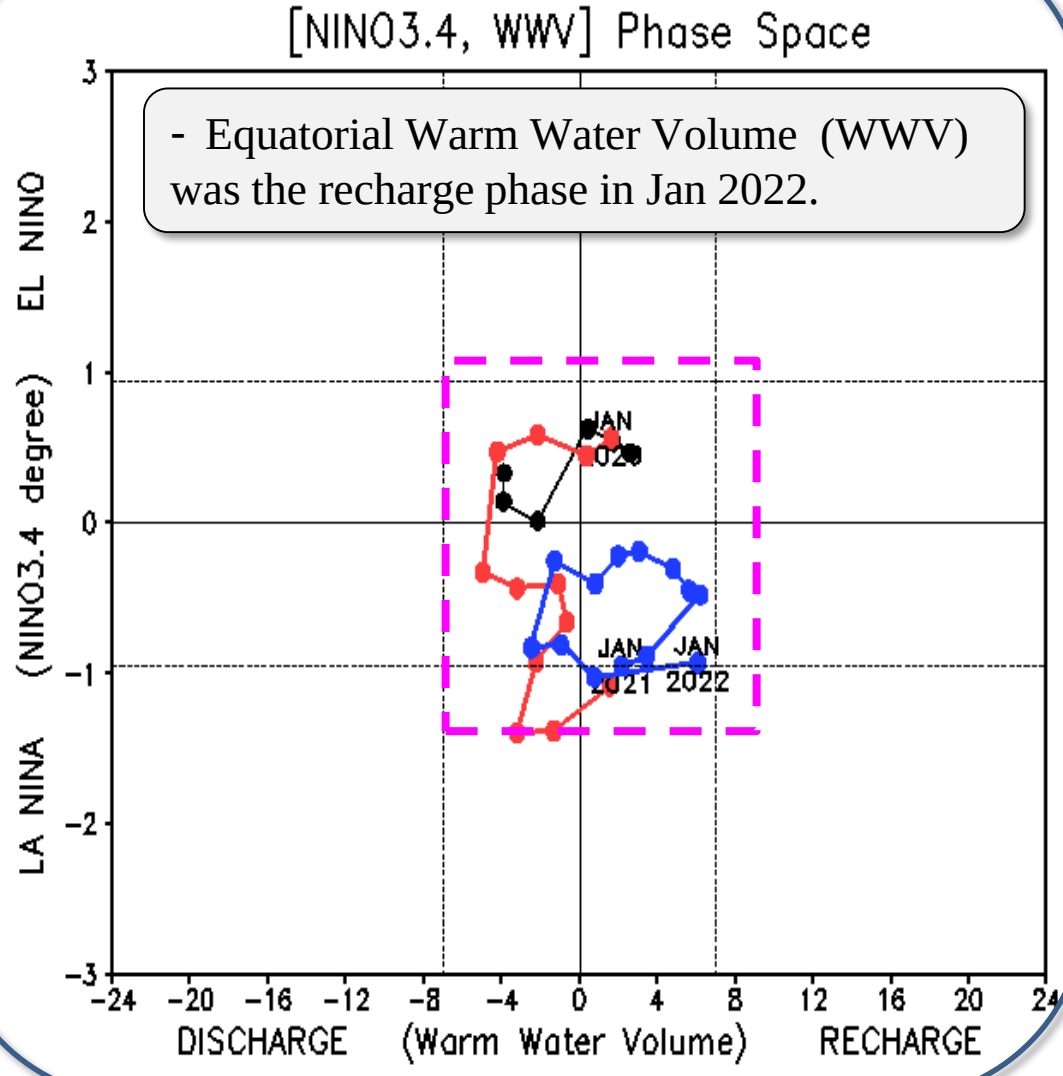






Warm Water Volume (WWV) and Niño3.4 Anomalies

- 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.

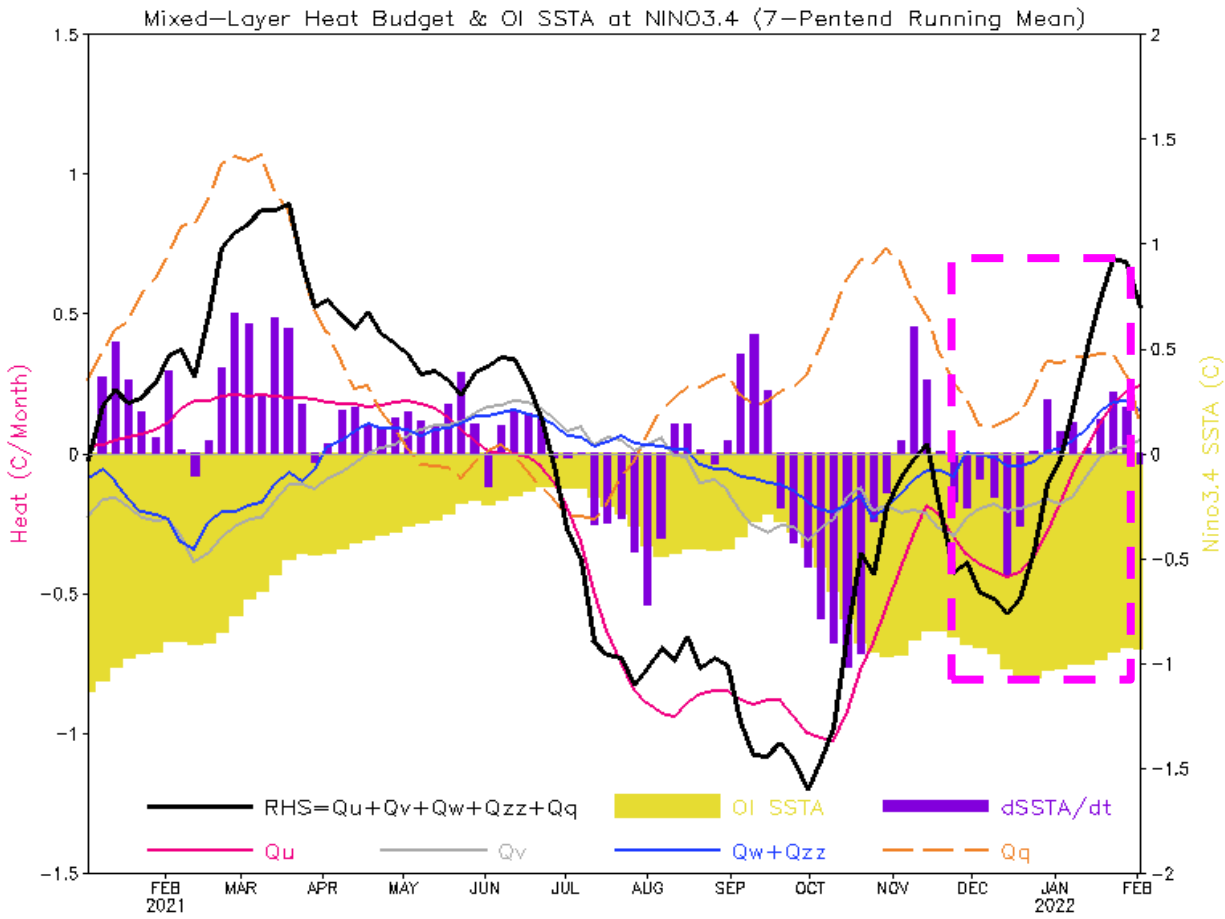


Phase diagram of Warm Water Volume (WWV) and Niño3.4 indices. WWV is the average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN] calculated with the NCEP's GODAS. Anomalies are departures from the 1991-2020 base period means.

Ocean Mixed-Layer Heat Budget

-Observed SSTA tendency (dSSTA/dt; bar) and total heat budget (RHS; black line) was positive recently.

- Dynamical terms (Qu, Qv, Qw+Qzz) were negative and heat-flux term (Qq) were small recently.



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

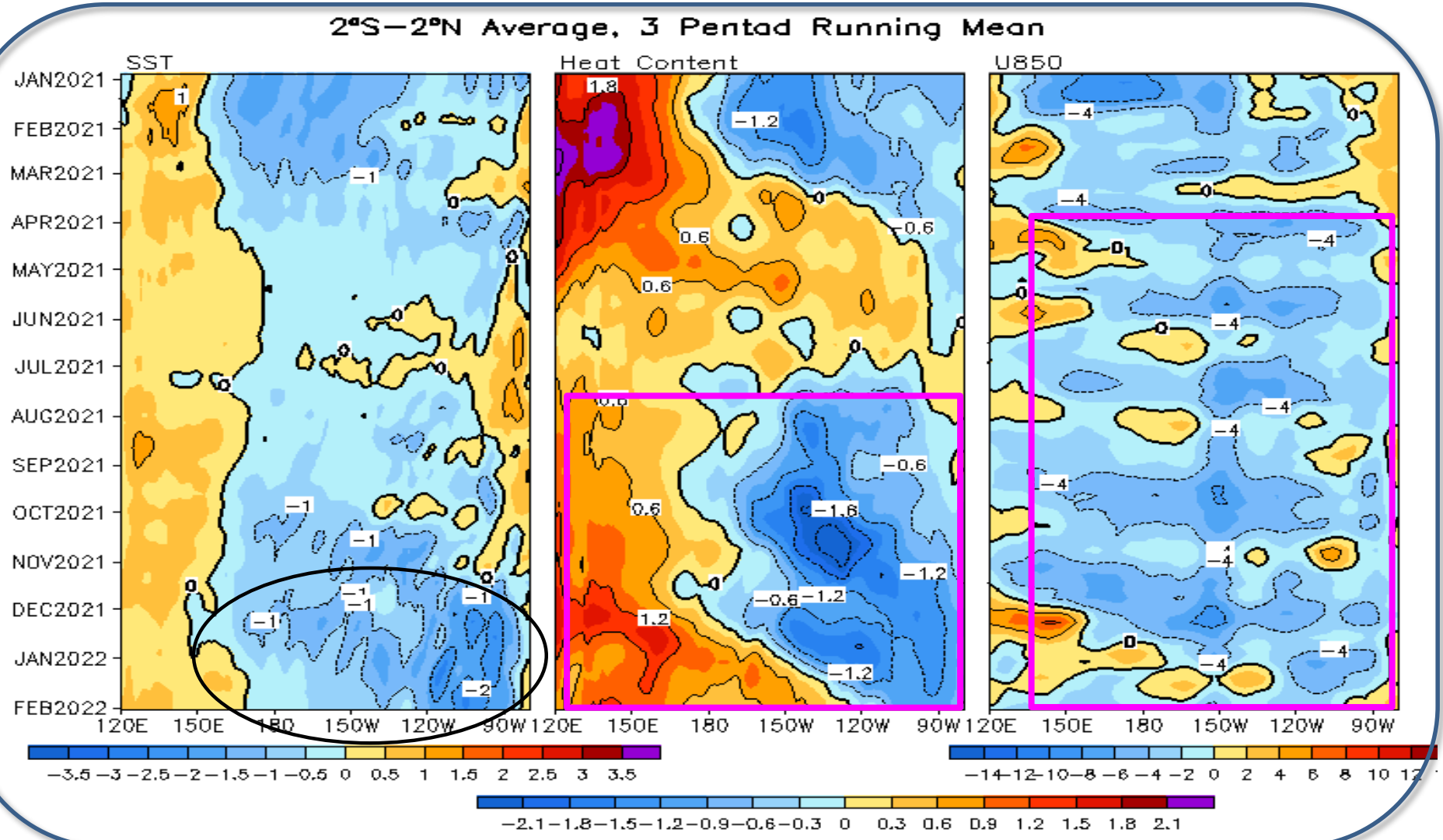
Qu: Zonal advection; Qv: Meridional advection;

Qw: Vertical entrainment; Qzz: Vertical diffusion

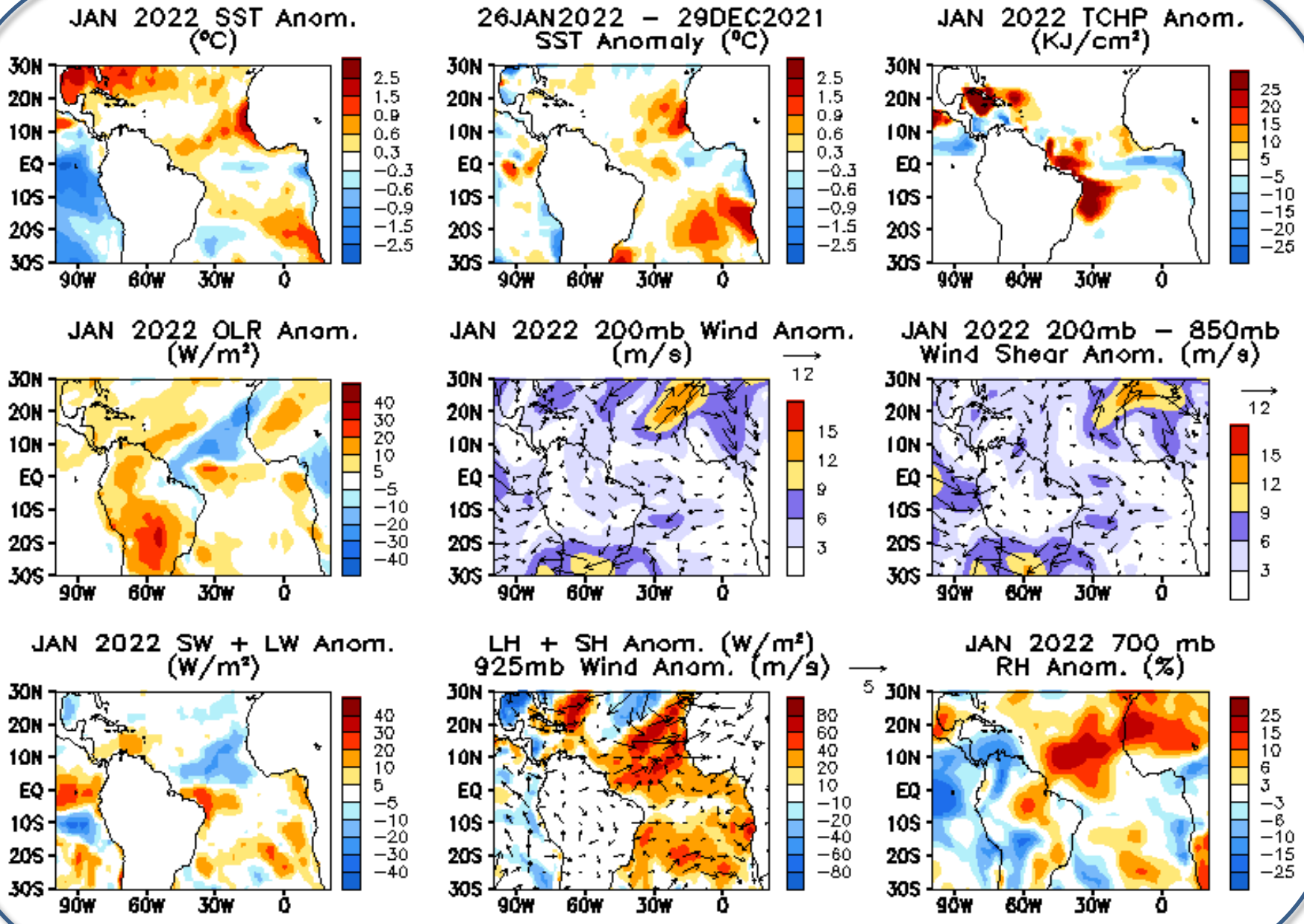
Qq: (Qnet - Qpen + Qcorr)/ρcph; Qnet = SW + LW + LH +SH;

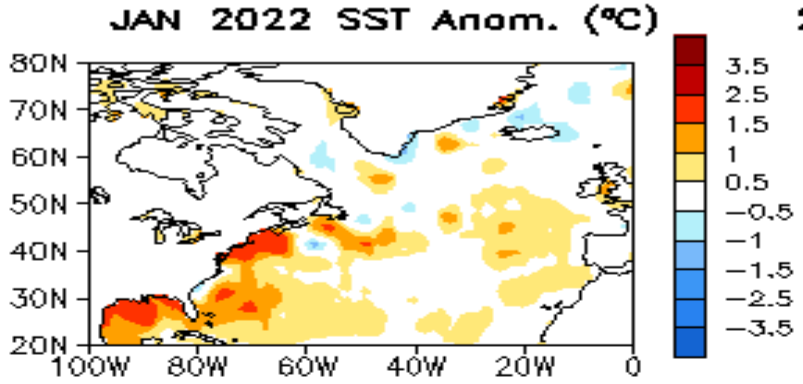
Qpen: SW penetration; Qcorr: Flux correction due to relaxation to OI SST

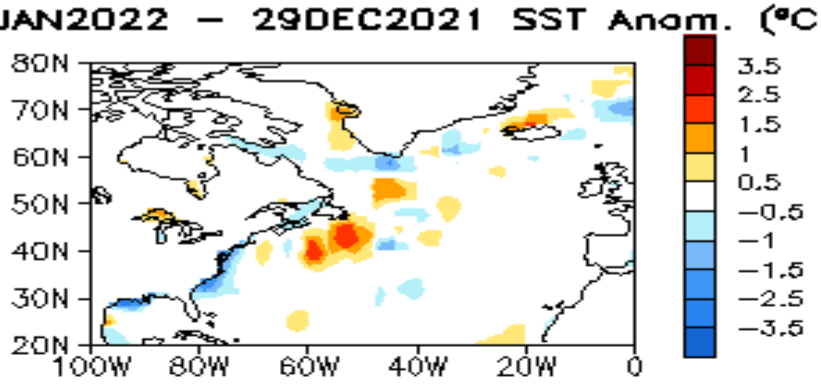
Equatorial Pacific SST (°C), HC300 (°C), u850 (m/s) Anomalies

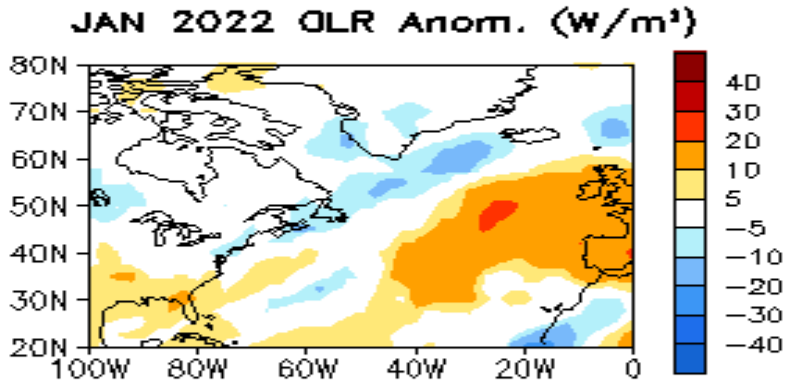


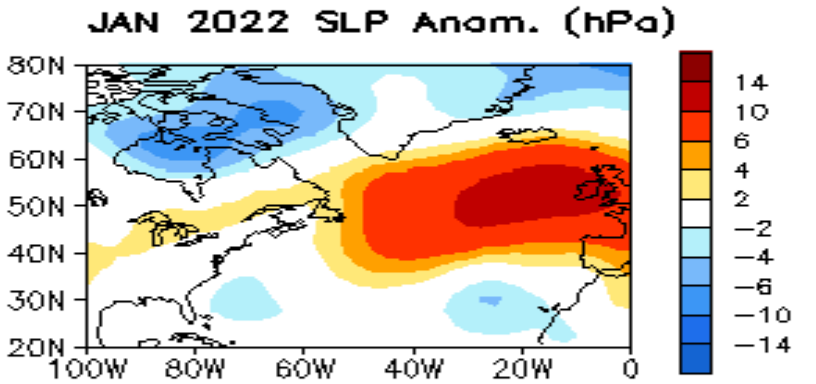
- Easterly wind anomaly was present across the equatorial Pacific since Mar 2021.
- Below- average HC300 was observed in the eastern Pacific since Jul 2021.
- Negative SSTA weakened in the central and eastern equatorial Pacific in Jan 2022.

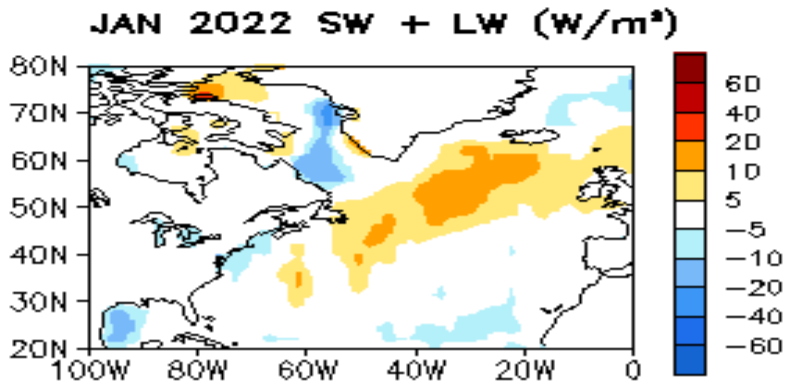

JAN 2022 SST Anom. (°C)
26JAN2022 – 29DEC2021 SST Anomaly (°C)
JAN 2022 TCHP Anom. (KJ/cm²)
JAN 2022 OLR Anom. (W/m²)
JAN 2022 200mb Wind Anom. (m/s)
JAN 2022 200mb – 850mb Wind Shear Anom. (m/s)
JAN 2022 SW + LW Anom. (W/m²)
LH + SH Anom. (W/m²)
925mb Wind Anom. (m/s)
JAN 2022 700 mb RH Anom. (%)
30N
20N
10N
EQ
10S
20S
30S
90W
60W
30W
0

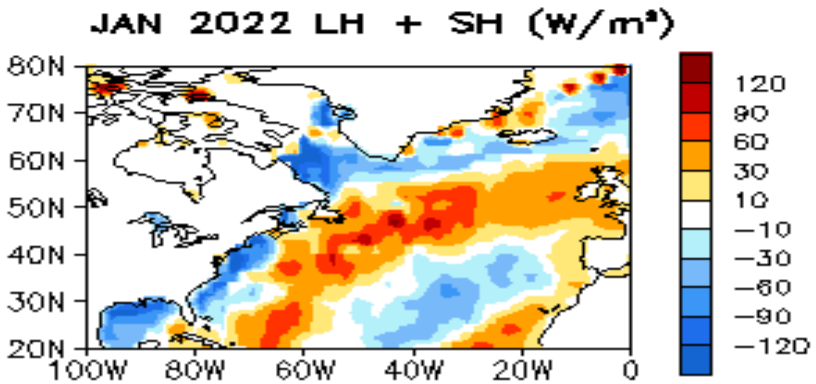

JAN 2022 SST Anom. (°C)
80N
70N
60N
50N
40N
30N
20N
100W
80W
60W
40W
20W
0
3.5
2.5
1.5
1
0.5
−0.5
−1
−1.5
−2.5
−3.5


26JAN2022 − 29DEC2021 SST Anom. (°C)
80N
70N
60N
50N
40N
30N
20N
100W
80W
60W
40W
20W
0
3.5
2.5
1.5
1
0.5
−0.5
−1
−1.5
−2.5
−3.5


JAN 2022 OLR Anom. (W/m²)
80N
70N
60N
50N
40N
30N
20N
100W
80W
60W
40W
20W
0
40
30
20
10
5
−5
−10
−20
−30
−40


JAN 2022 SLP Anom. (hPa)
80N
70N
60N
50N
40N
30N
20N
100W
80W
60W
40W
20W
0
14
10
6
4
2
−2
−4
−6
−10
−14


JAN 2022 SW + LW (W/m²)
80N
70N
60N
50N
40N
30N
20N
100W
80W
60W
40W
20W
0
60
40
20
10
5
−5
−10
−20
−40
−60


JAN 2022 LH + SH (W/m²)
80N
70N
60N
50N
40N
30N
20N
100W
80W
60W
40W
20W
0
120
90
60
30
10
−10
−30
−60
−90
−120