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

Prepared by

Climate Prediction Center, NCEP/NOAA

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

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

Outline

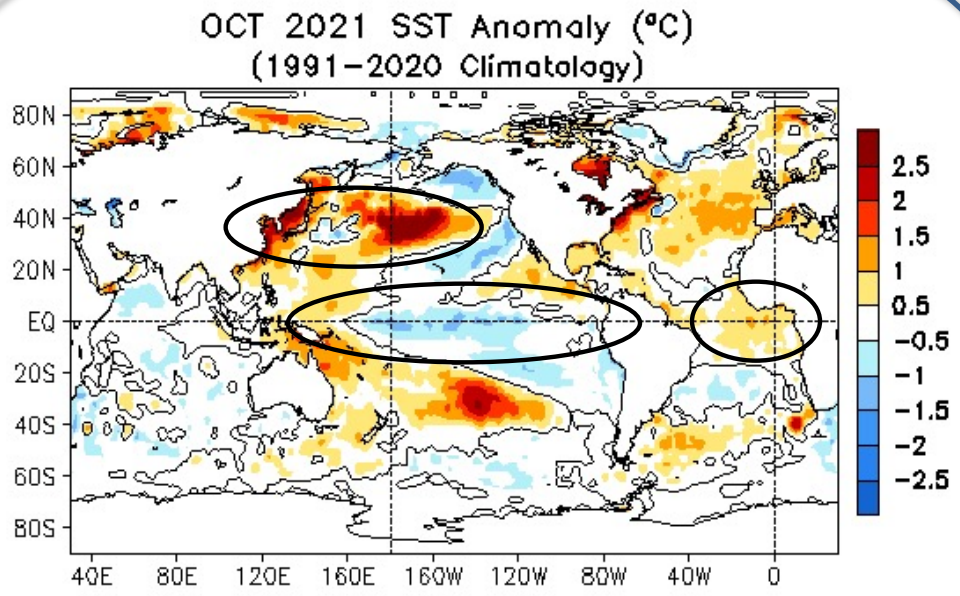
- Overview
- Recent highlights
  - Pacific/Arctic Ocean
  - Indian Ocean
  - Atlantic Ocean
- Global SST Anomaly Predictions

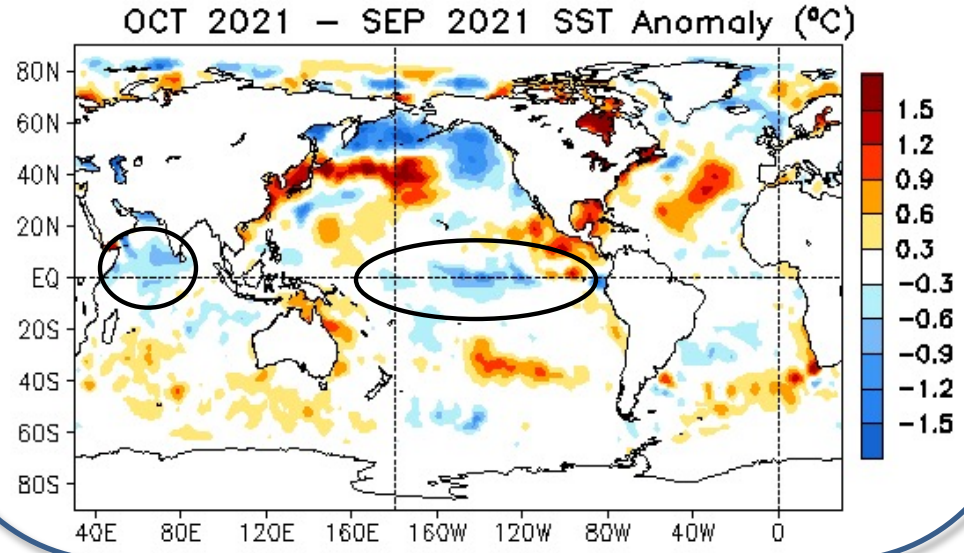
Overview

- Pacific Ocean
  - La Niña strengthened in Oct 2021.
  - NOAA "ENSO Diagnostic Discussion" on 11 Nov 2021 states that "La Niña is likely to continue through the Northern Hemisphere winter 2021-22 (~90% chance) and into spring 2022 (~50% chance during March-May)"
  - Negative phase of PDO amplified substantially in Oct 2021, with PDOI = -2.5.
  - Marine Heat Waves (MHWs) persisted in the N.C. Pacific, while dissipated in the N. E. Pacific.
- Indian Ocean
  - Tendency toward a negative Indian Ocean dipole (IOD) event continued, with IOD index = -0.6° C in Oct 2021.
- Atlantic Ocean
  - 2021 Atlantic Niño event weakened in Oct 2021.
  - Atlantic hurricane genesis was quiet in October, consistent with enhanced zonal wind shear in the hurricane main development region.
- Arctic Ocean
  - The monthly average sea ice extent for Oct 2021 ranks the 8th lowest in the satellite record.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency



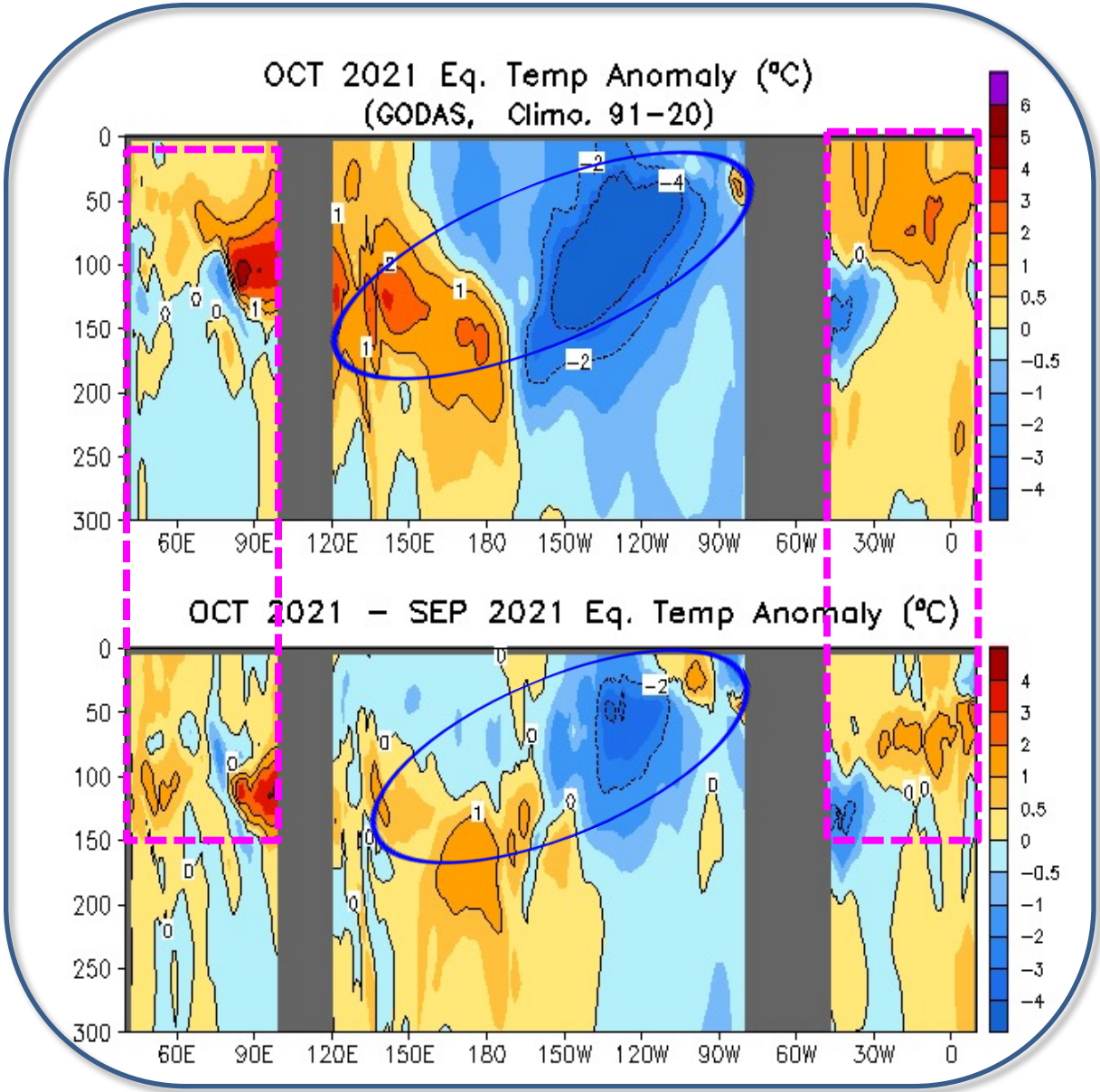


- Equatorial SSTs were below average across most of Pacific Ocean, and were above average in the far western Pacific.
- Strong SSTAs continued in mid-to-high latitude north Pacific.
- SSTs were above average across most of the Atlantic Ocean.

- Negative (positive) SSTA tendencies were present in the central-eastern (far eastern) equatorial Pacific Ocean.
- Negative SSTA tendency was present in the western tropical Indian Ocean.
- Large SSTA tendencies were present in the mid-to-high latitudes of northern hemisphere.

Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP 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



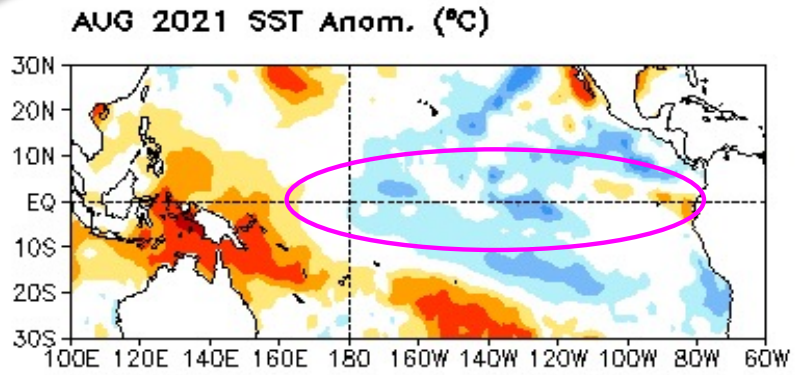
- Strong negative subsurface ocean anomalies were present along the central-eastern thermocline in the Pacific Ocean.
- Positive anomalies continued in the upper 100m of equatorial Atlantic Ocean.
- Positive subsurface anomalies persisted in the eastern Indian Ocean.

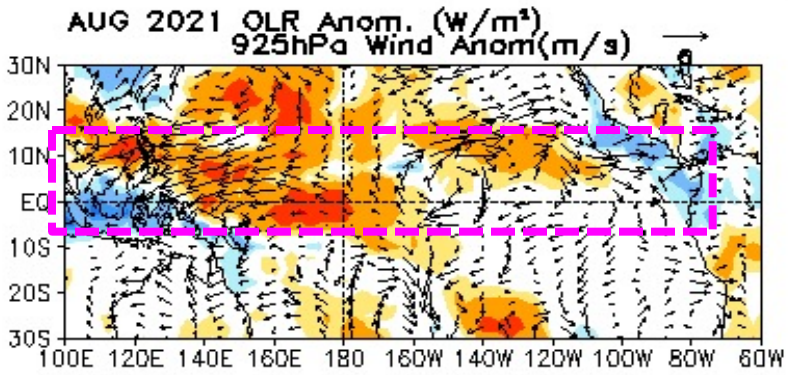
- Negative (positive) temperature anomaly tendency presented along the thermocline in the eastern (western) Pacific Ocean.
- Positive temperature anomaly tendency dominated in the Indian Ocean.

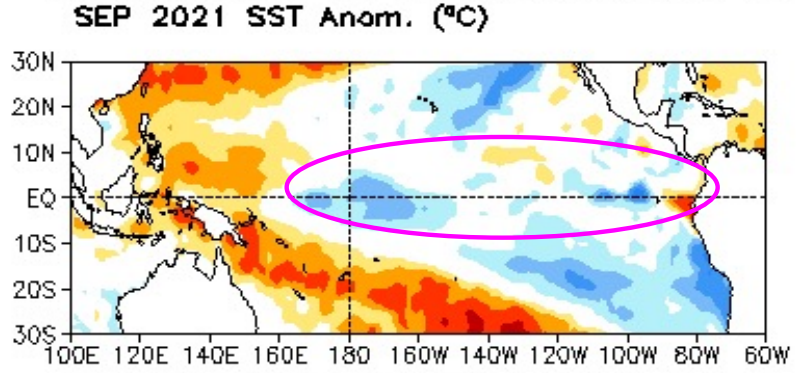
Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data is from the NCEP's global ocean data assimilation system. Anomalies are departures from the 1991-2020 base period means.

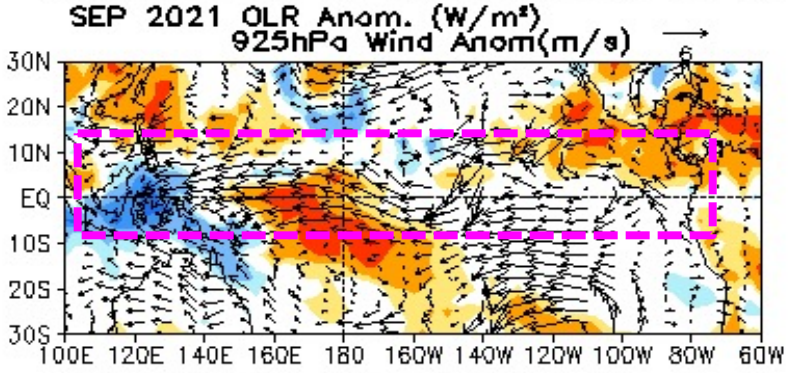
Tropical Pacific Ocean and ENSO Conditions

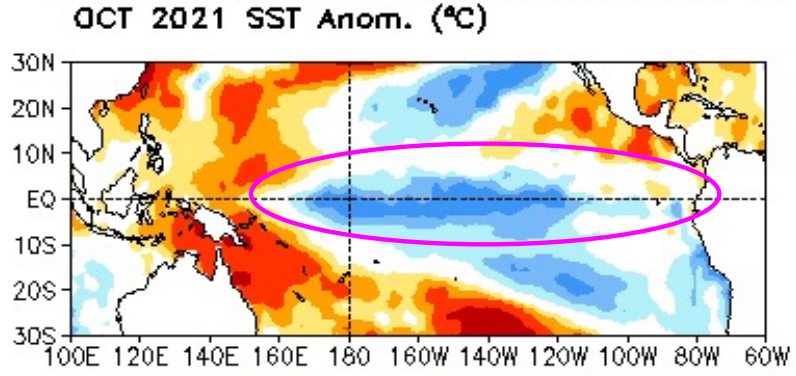
Latest 3-month Tropical Pacific SST , OLR, & uv925 anomalies

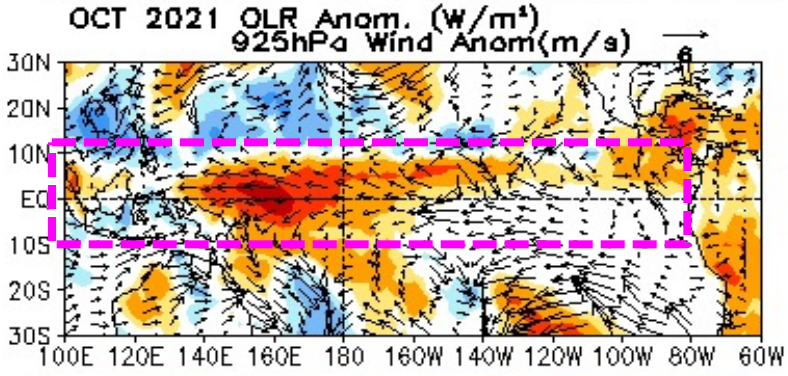




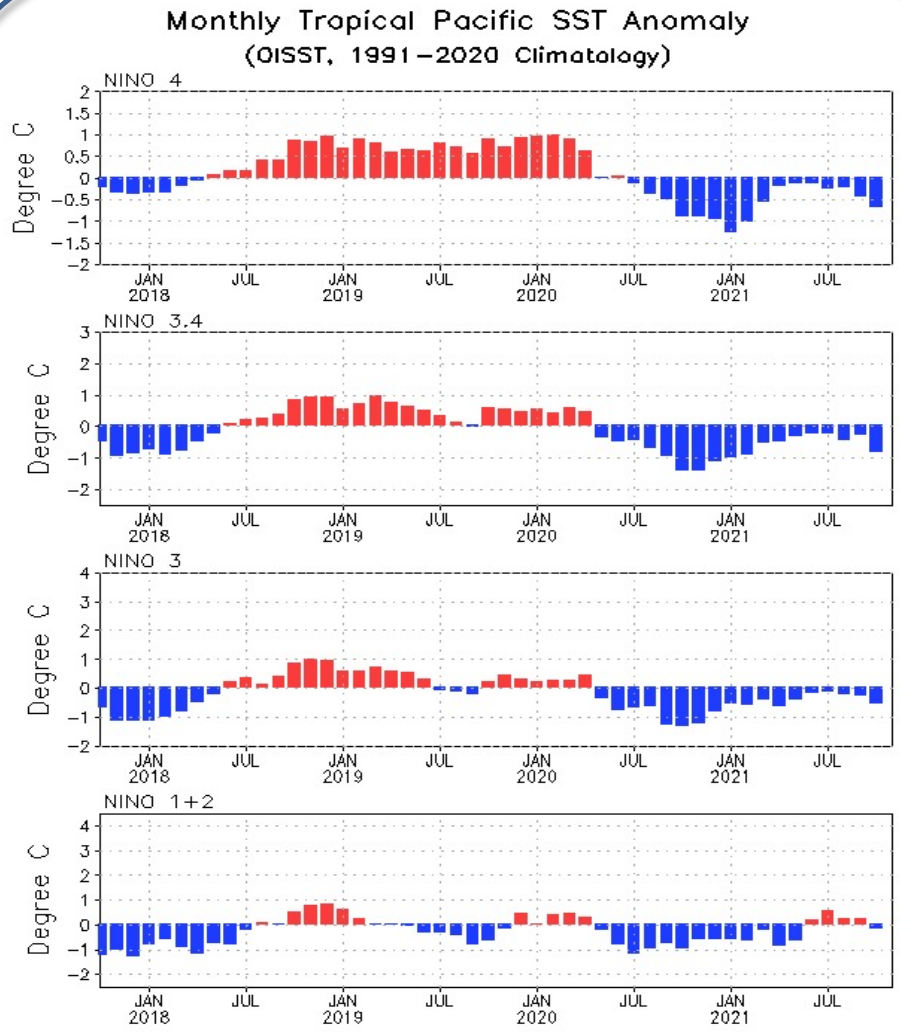


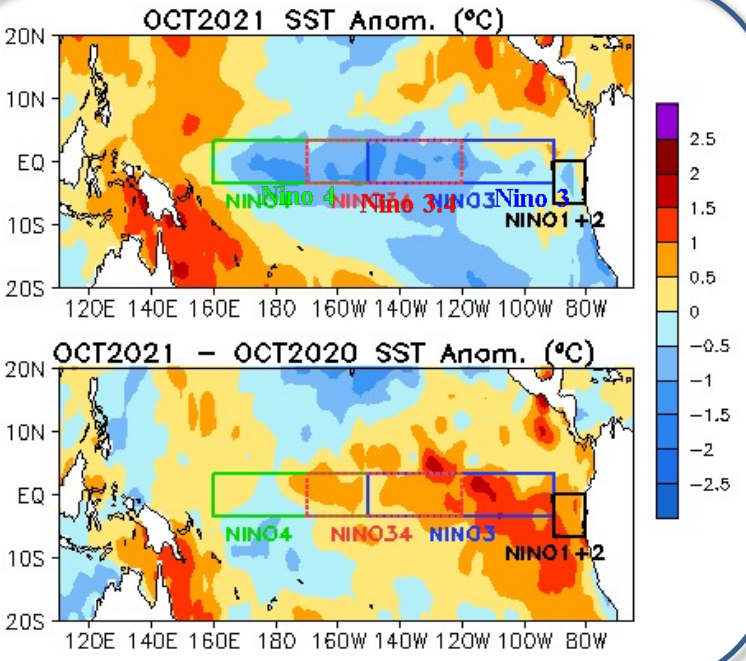






Evolution of Pacific Niño SST Indices





- All Niño indices cooled down in Oct 2021.

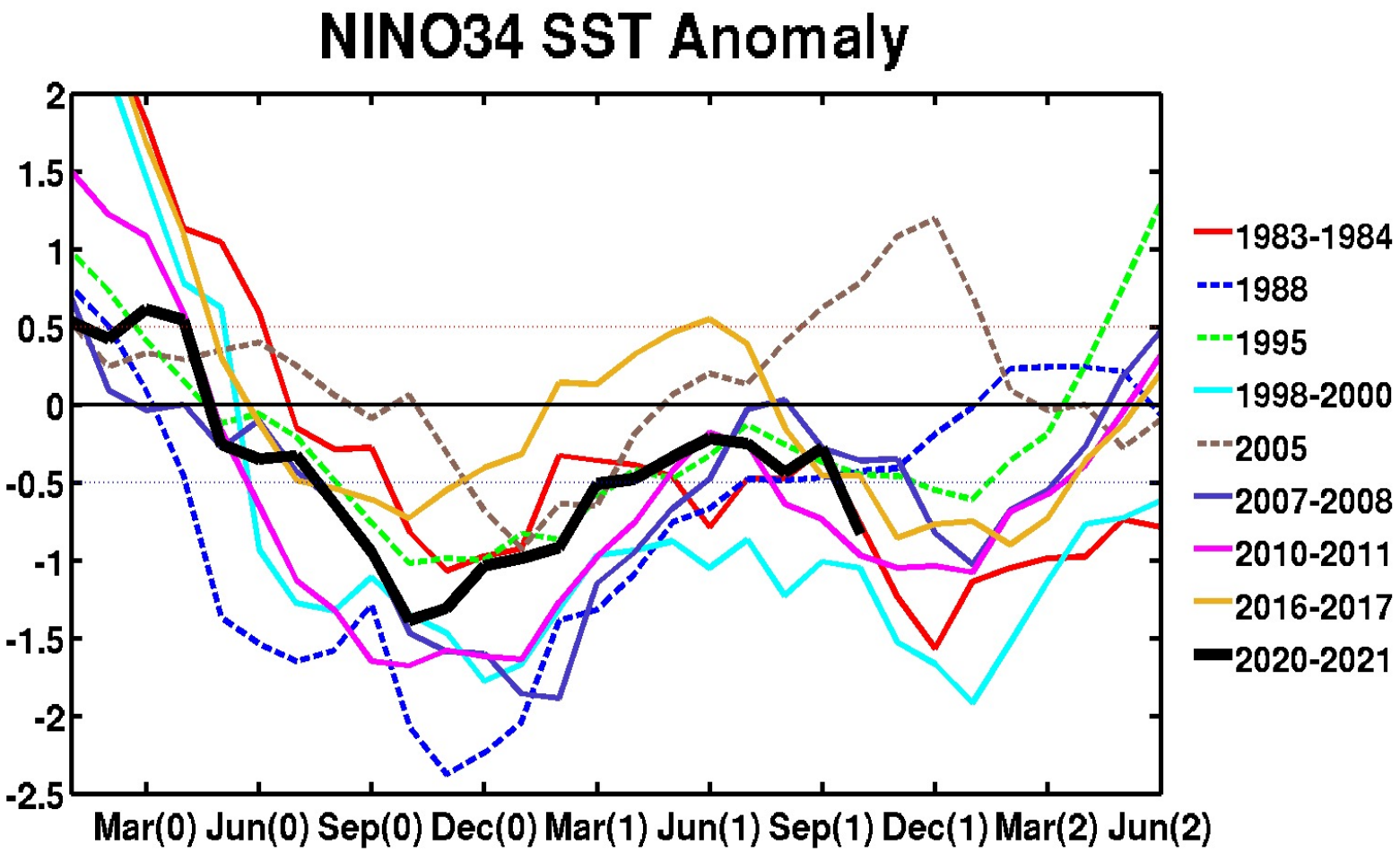
- Negative Nino34 increased substantially, with NINO3.4 = -0.9°C .

- Compared with Oct 2020, the central and eastern equatorial Pacific was warmer in Oct 2021.

- The indices may have slight differences for different SST products.

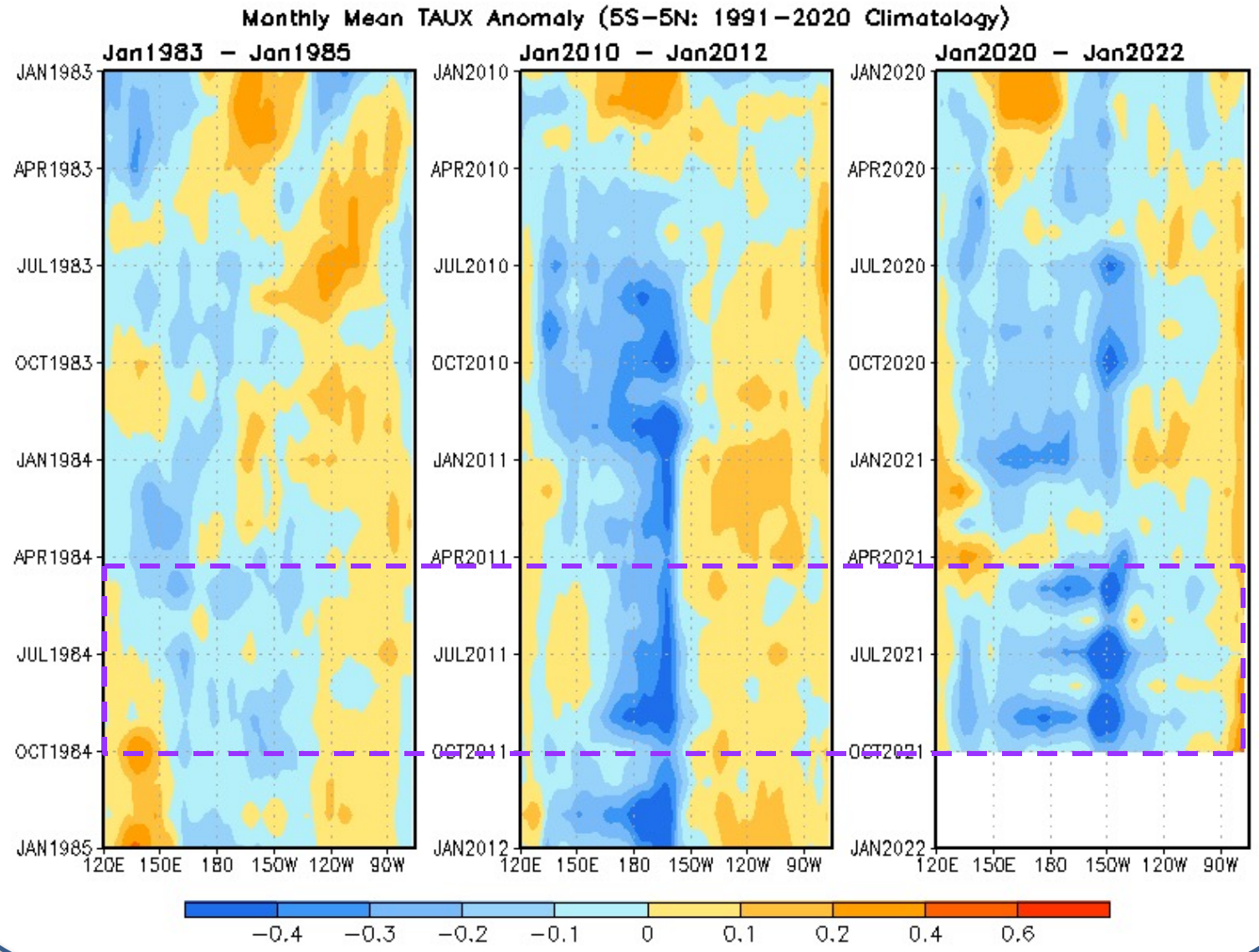
Niño region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means.

Evolution of NINO34 in La Niña Years



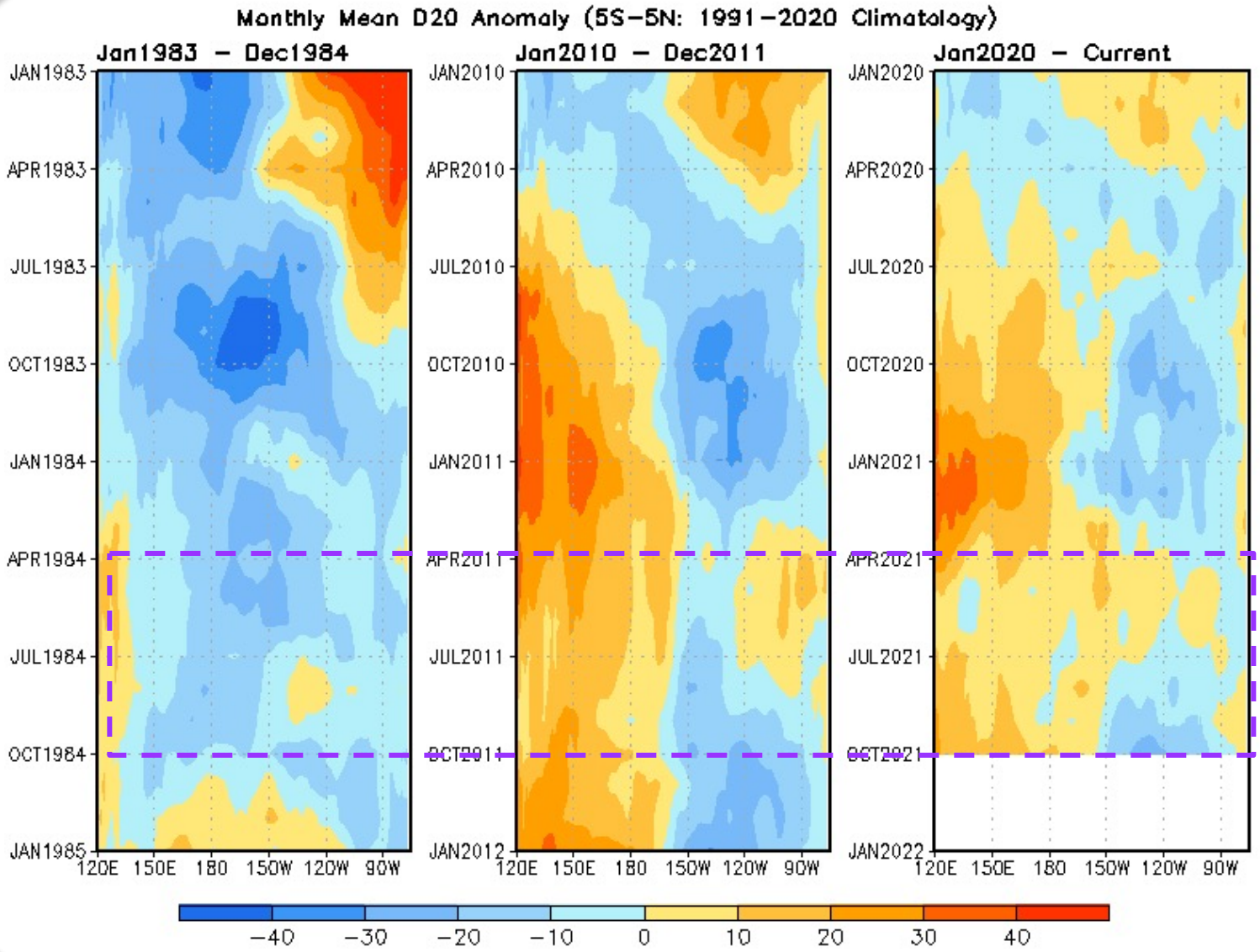
Nino 34 index is derived from the NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means.

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



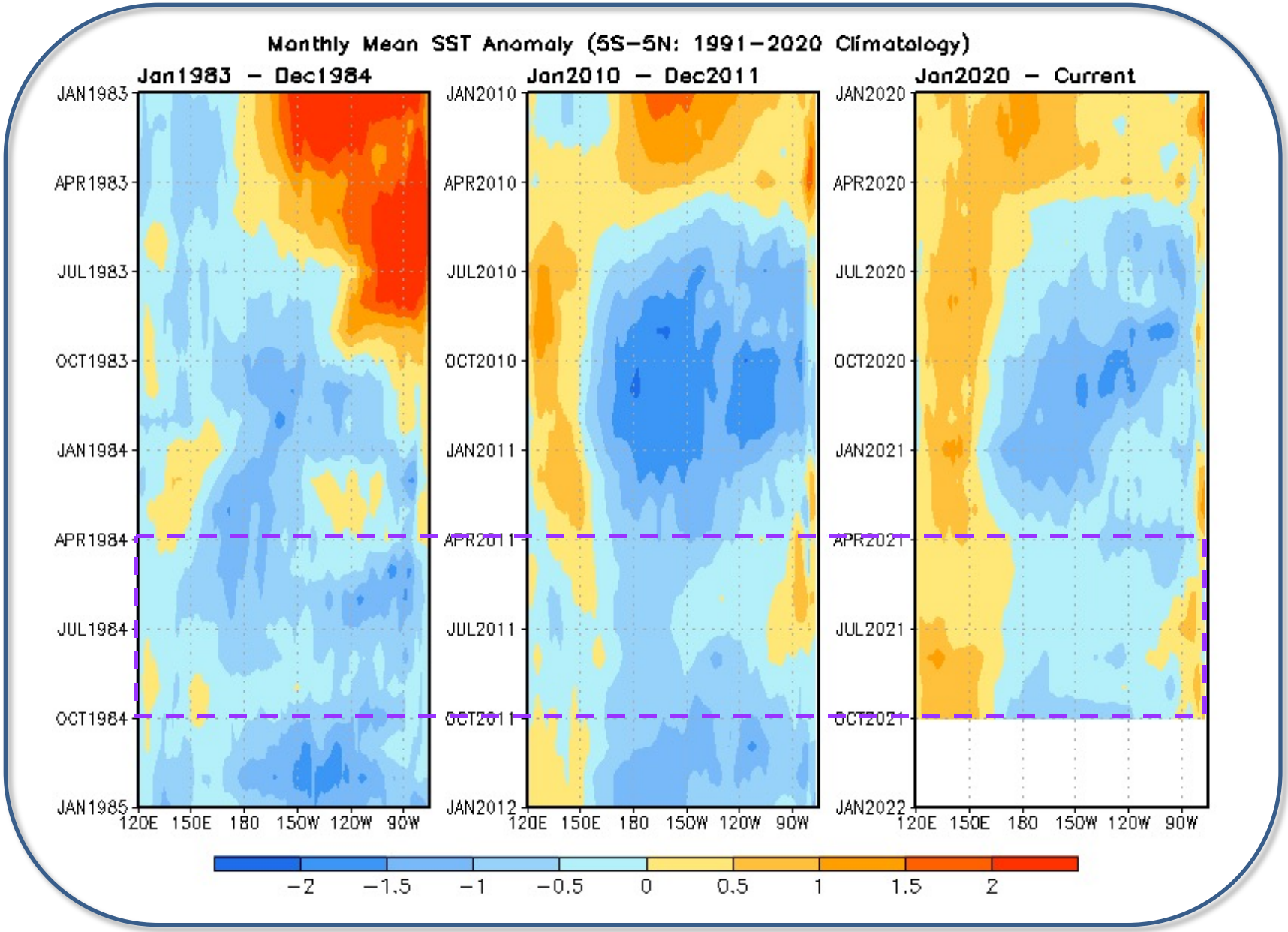
Data source: NCEP R2 reanalysis

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



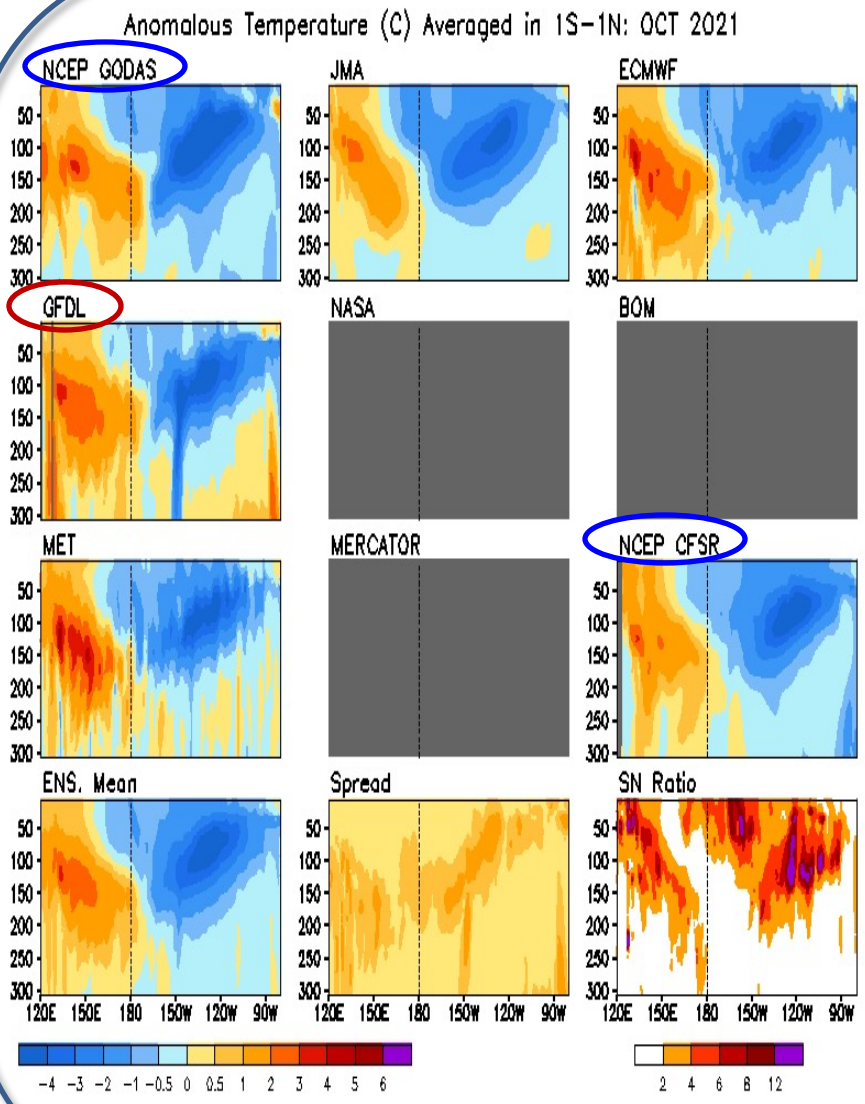
Data source: NCEP GODAS

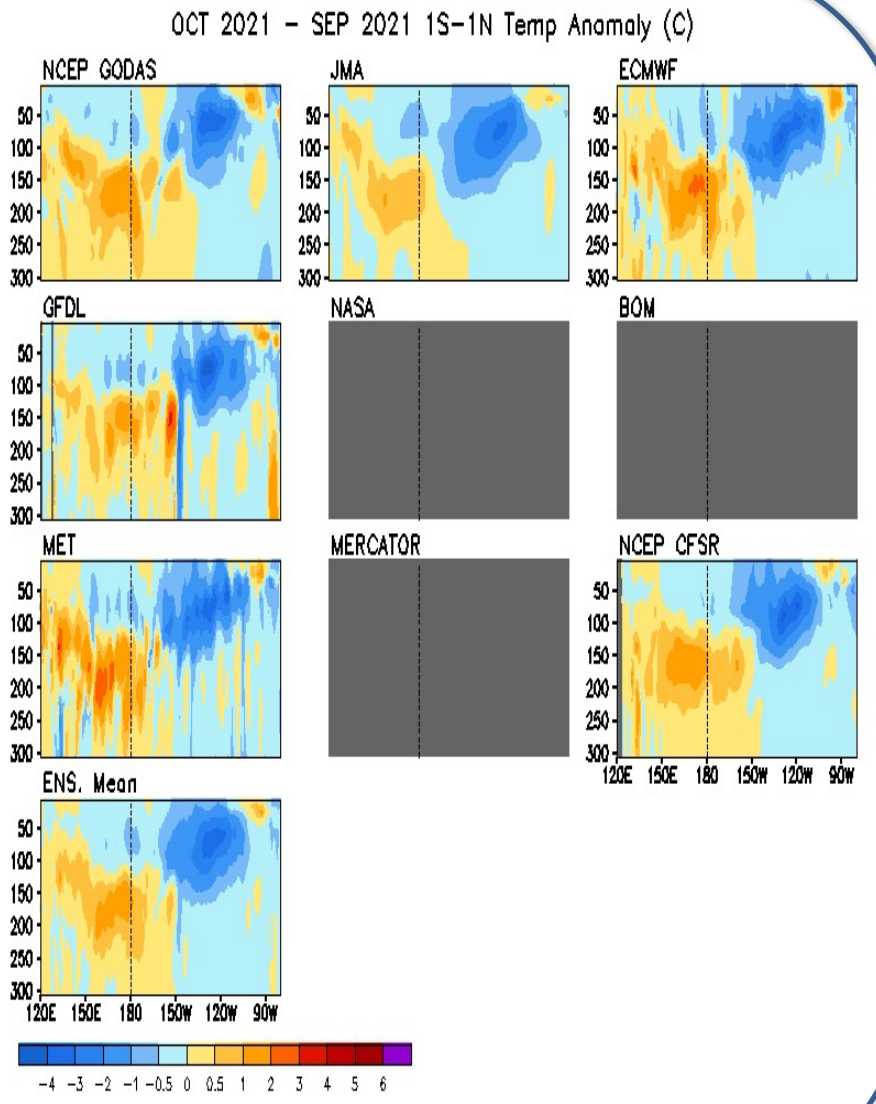
Evolution of Monthly Mean SST Anomaly across [5S-5N]



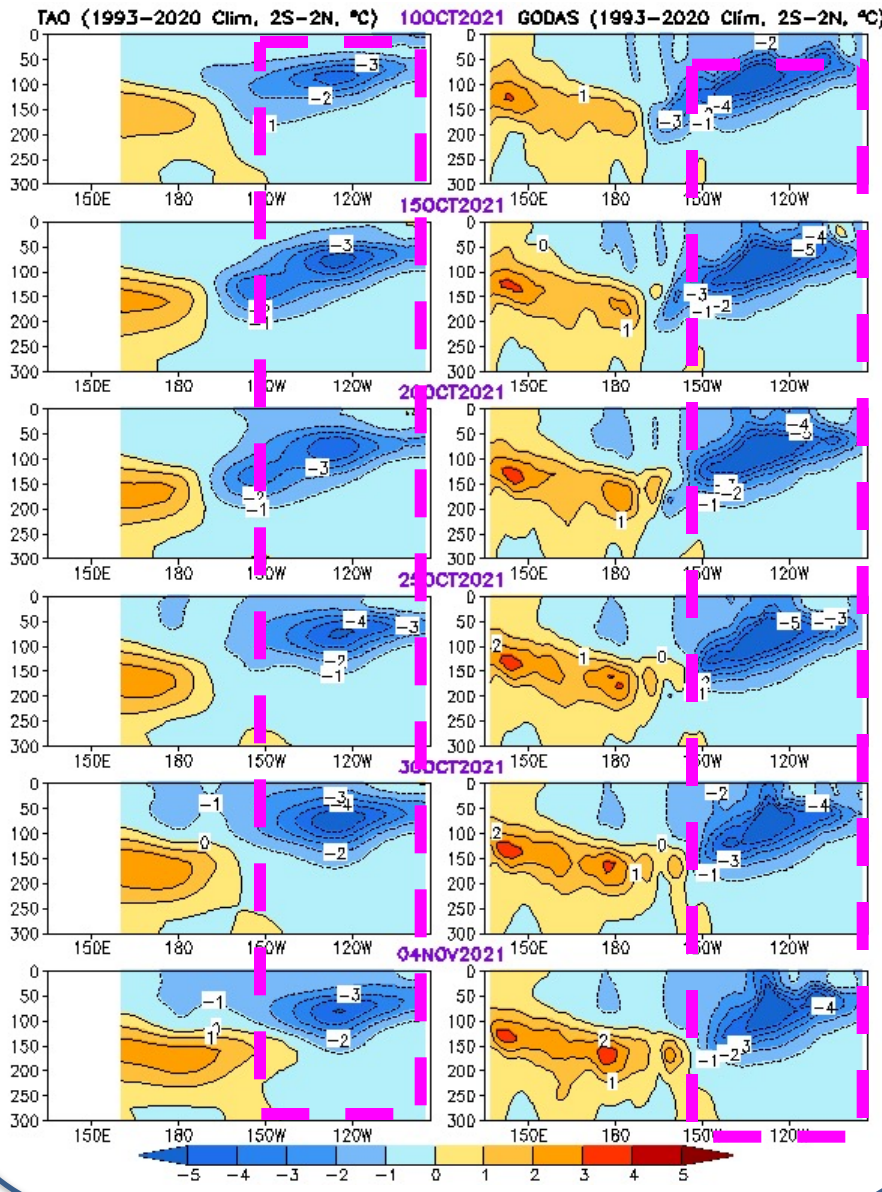
Data source: NCEP OISST

Multiple Ocean Reanalysis: Temperature and Tendency anomalies at Equator



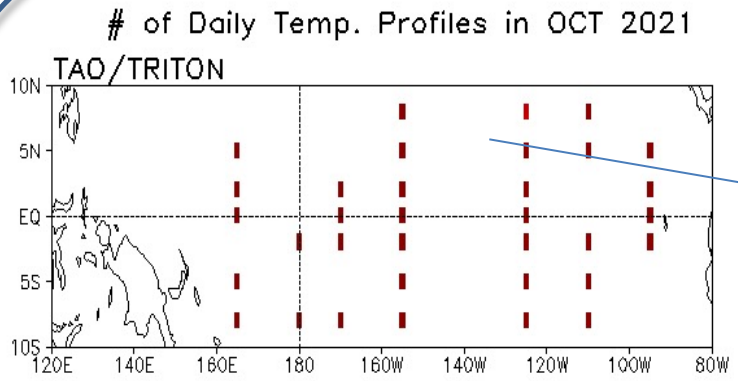


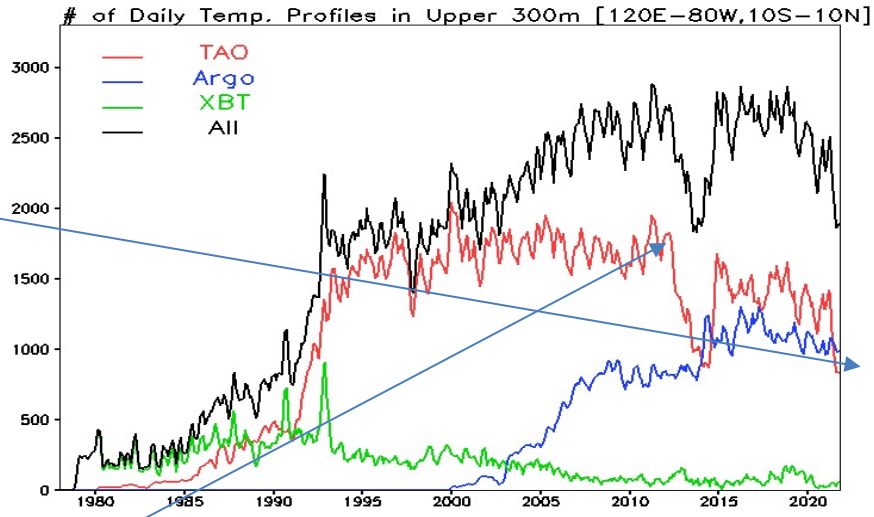
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

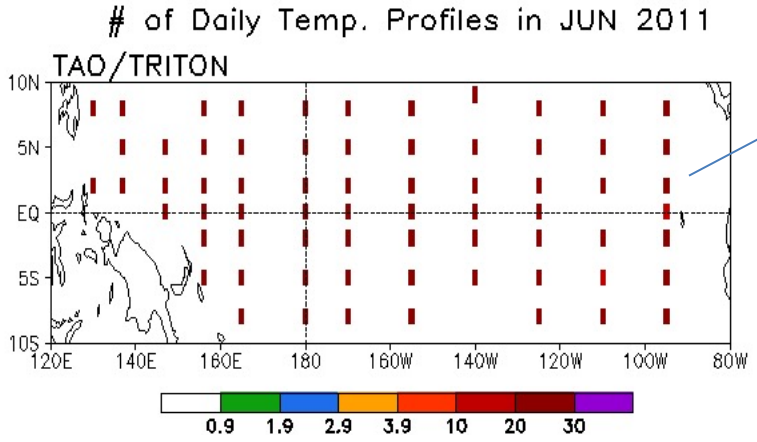


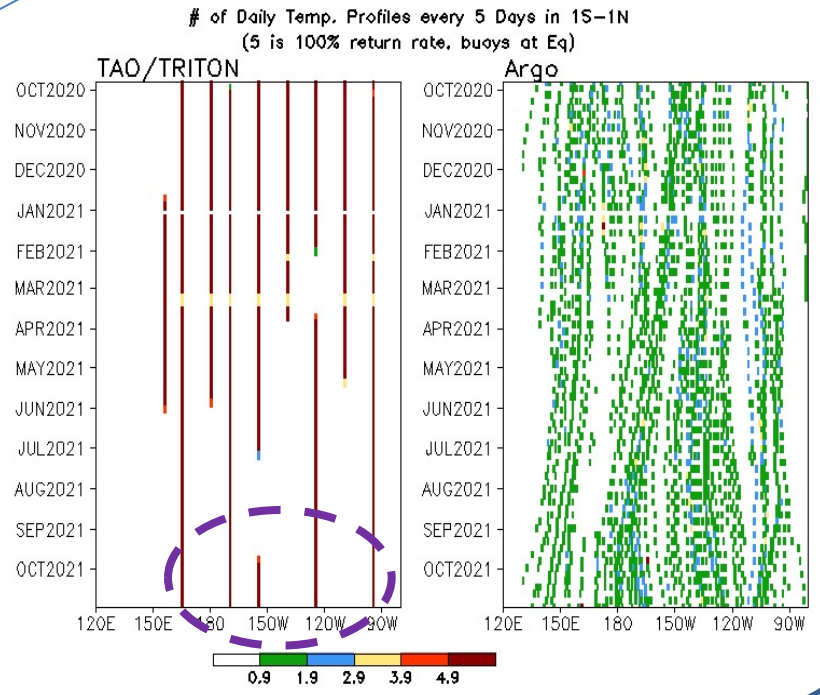
- Strong negative temperature anomaly between 50-100 m in the eastern Pacific reached -4℃ in TAO during Oct 2021 and then deceased slightly at the early Nov.
- Subsurface cooling east of 150W in GODAS was much stronger than in TAO.
- Large difference between TAO and GODAS is partially associated with the missing TAO data near the equator (next slide) that potentially affects the TAO and GODAS analysis.

Potential Impact of Missing TAO DATA on GODAS



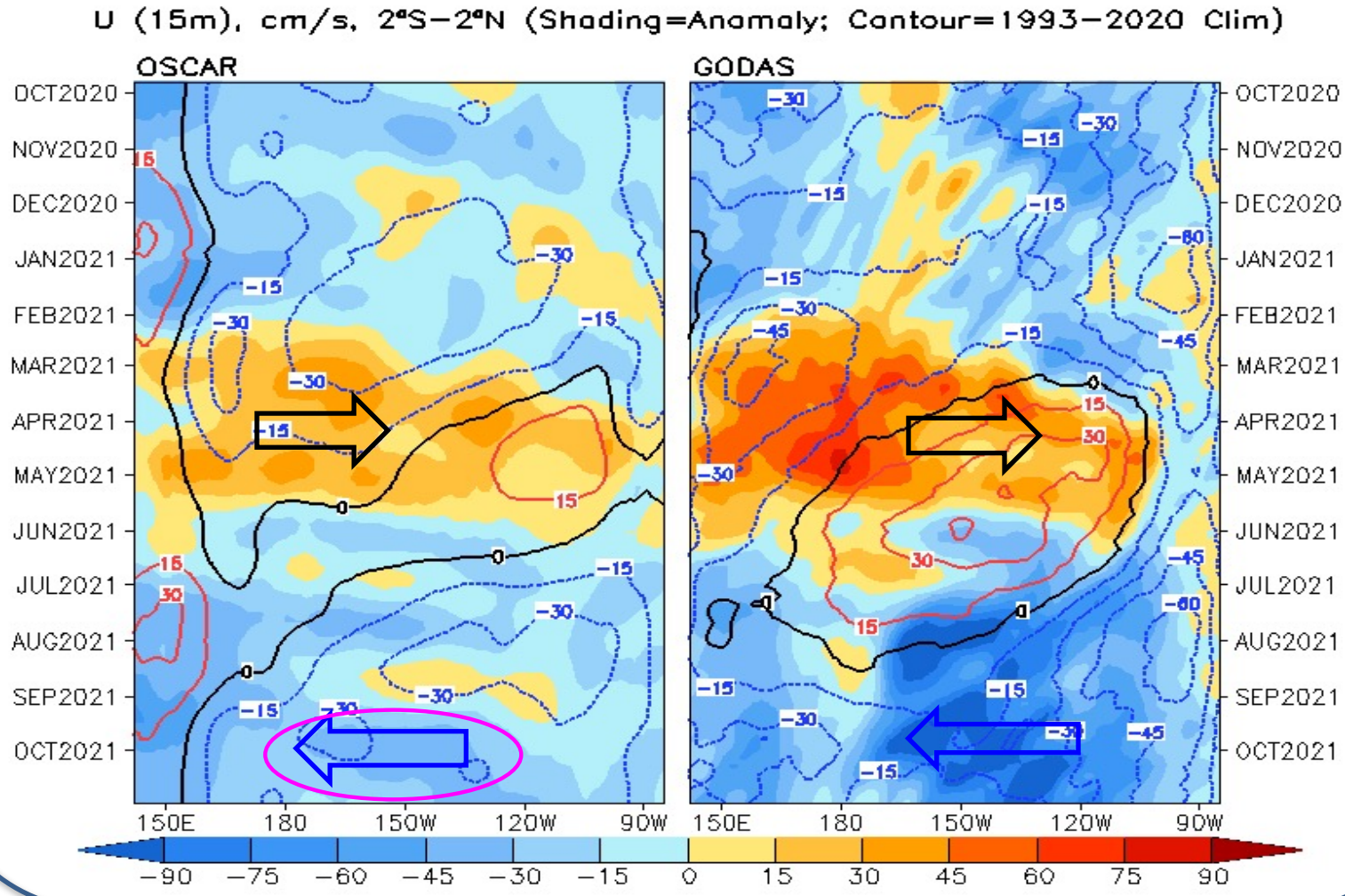






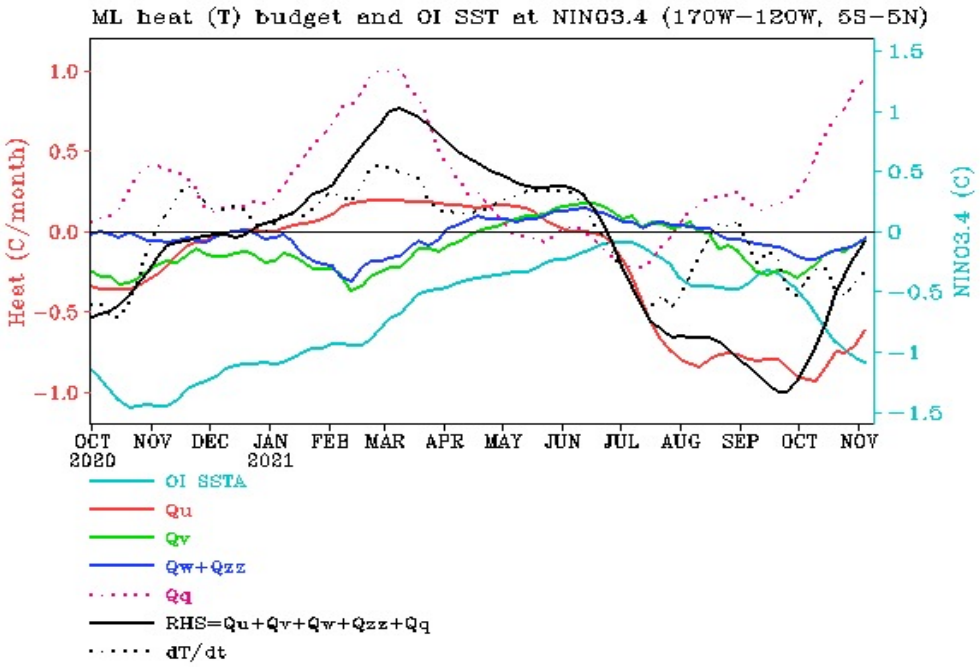
- TAO array declined significantly since March 2021 and TAO mooring profiles number is close to the historical low during 2013-2014.

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



- Strong anomalous westward currents has persisted most of the equatorial Pacific in GODAS since Jul 2021, while OSCAR data was dominated by subseasonal variations.
- Anomalous westward currents were present most of the equatorial Pacific in both OSCAR and GODAS in Sep-Oct 2021, favoring further SST cooling.

NINO3.4 Heat Budget



Qu: Zonal advection; Qv: Meridional advection;

Qw: Vertical entrainment; Qzz: Vertical diffusion

Qq: (Qnet - Qpen + Qcorr)/ρcph;

Qnet = SW + LW + LH +SH;

Qpen: SW penetration;

Qcorr: Flux correction due to relaxation to OI SST

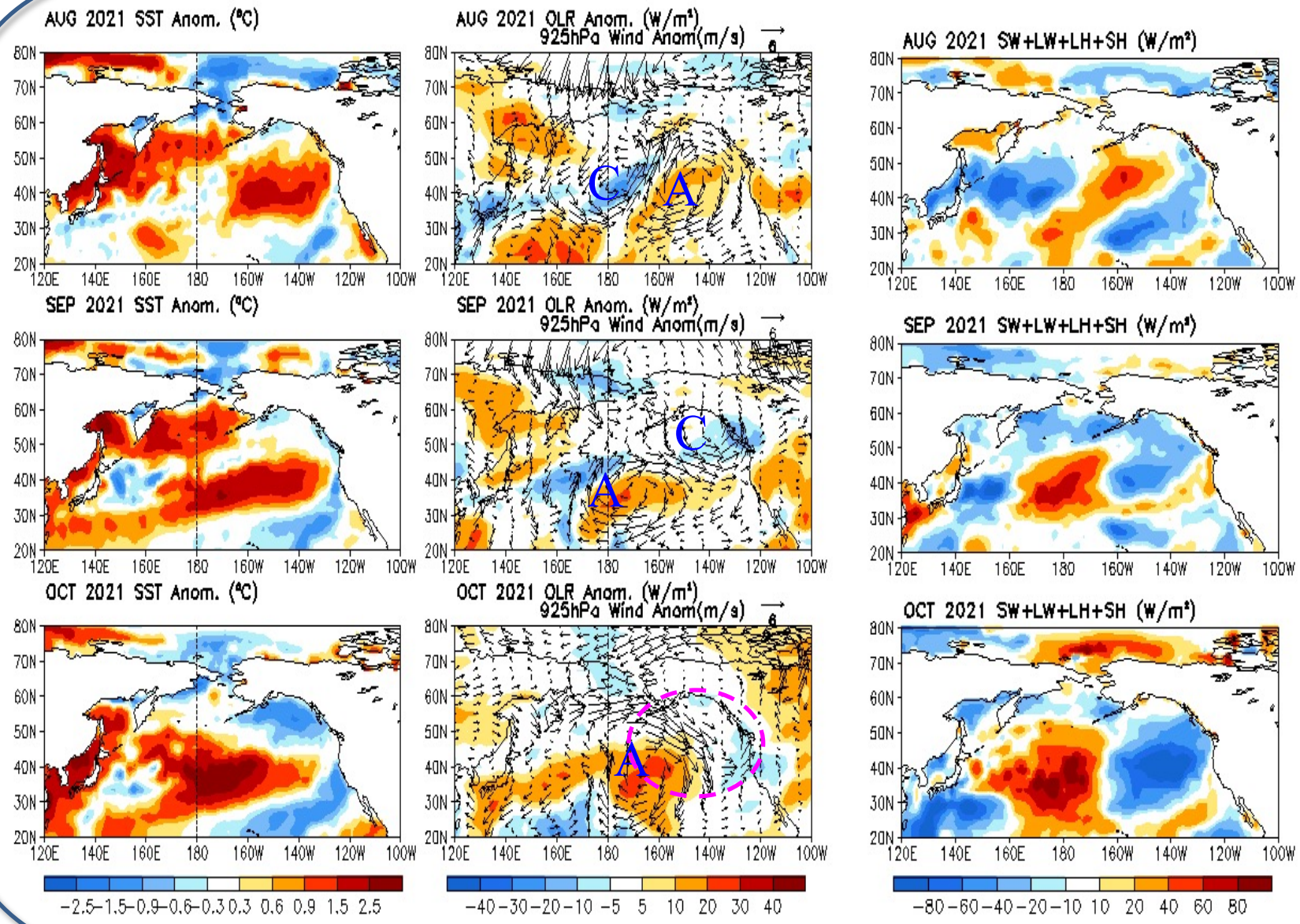
- Observed negative SSTA tendency (dT/dt) in Nino3.4 region (dotted black line) reemergent since Sep, 2021.

- All the dynamical terms including zonal advection (Qu, red line), meridional advection (Qv, green line) and vertical advection (Qw,+Qzz blue line) contribute to the cooling tendency (black line) since Jul 2021.

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

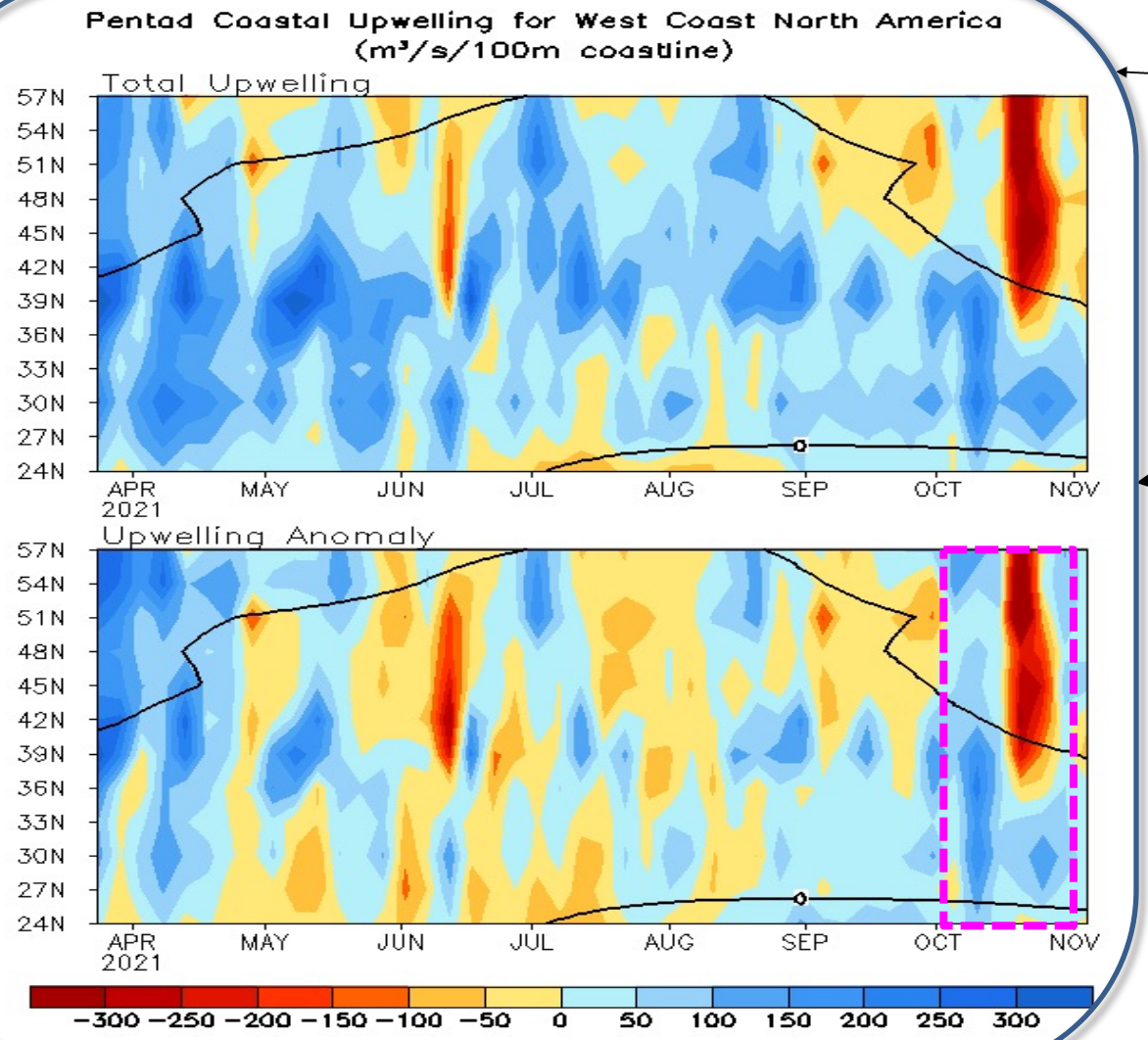
North Pacific & Arctic Oceans

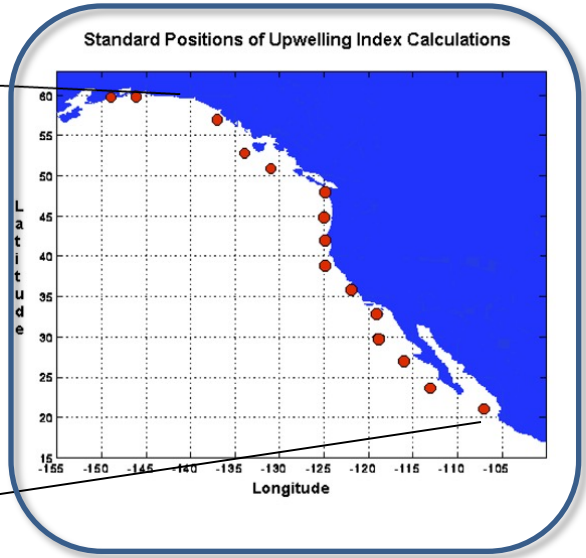
Latest 3-month North Pacific SST, OLR & uv925 anomalies



Data source: NCEP/NCAR Reanalysis 1

North America Western Coastal Upwelling

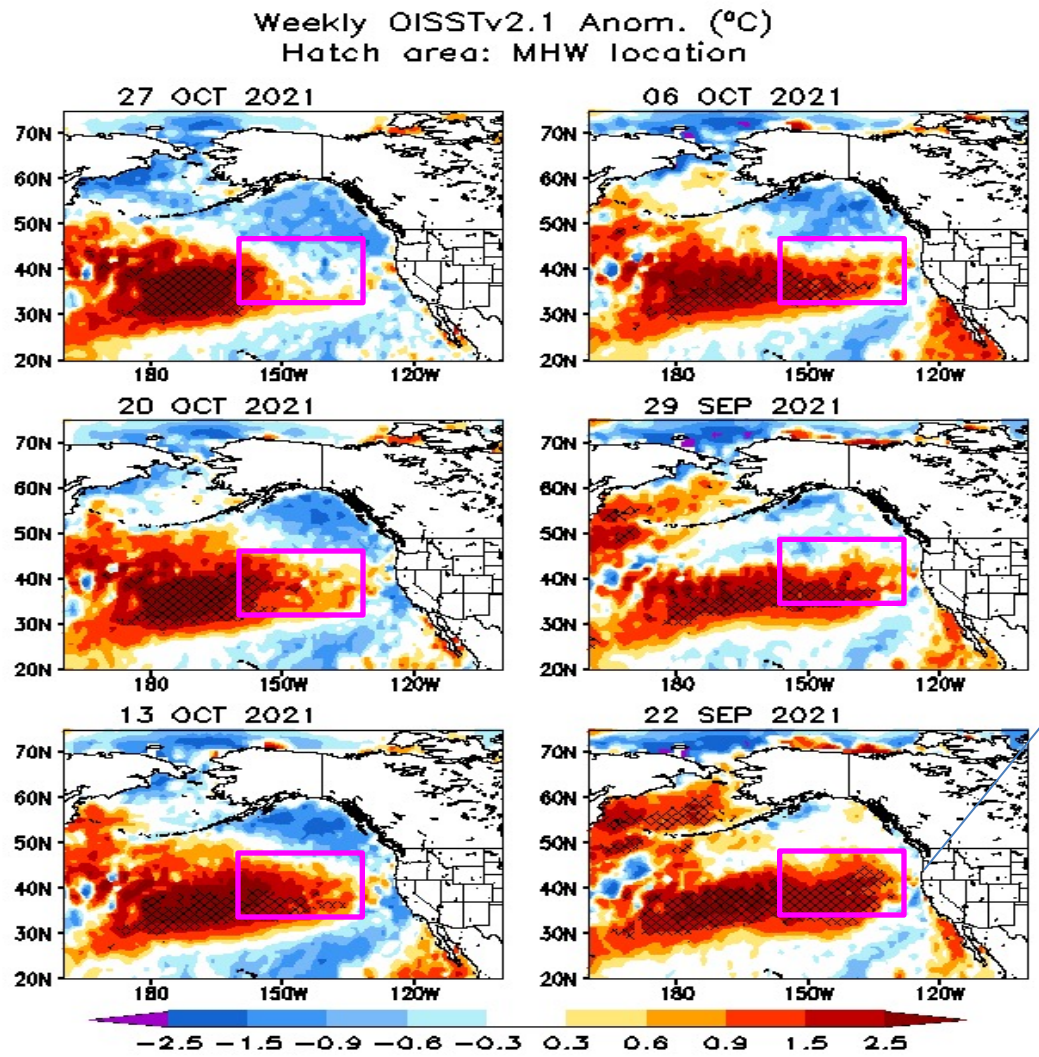


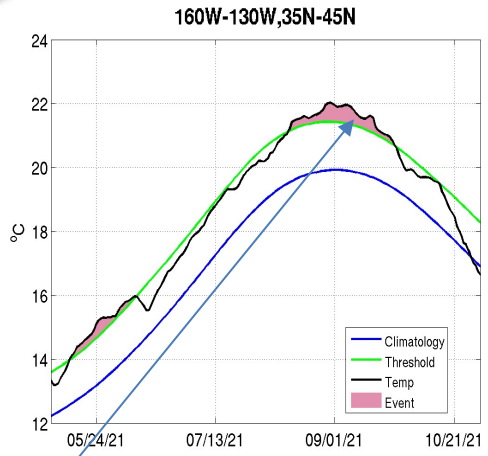


- Strong downwelling anomaly emerged north of 40N in the second half of Oct, 2021 , consistent with northwesterly wind anomaly near the coast.

(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 (m³/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.

Weekly SST anomaly and MHWs in the North Pacific

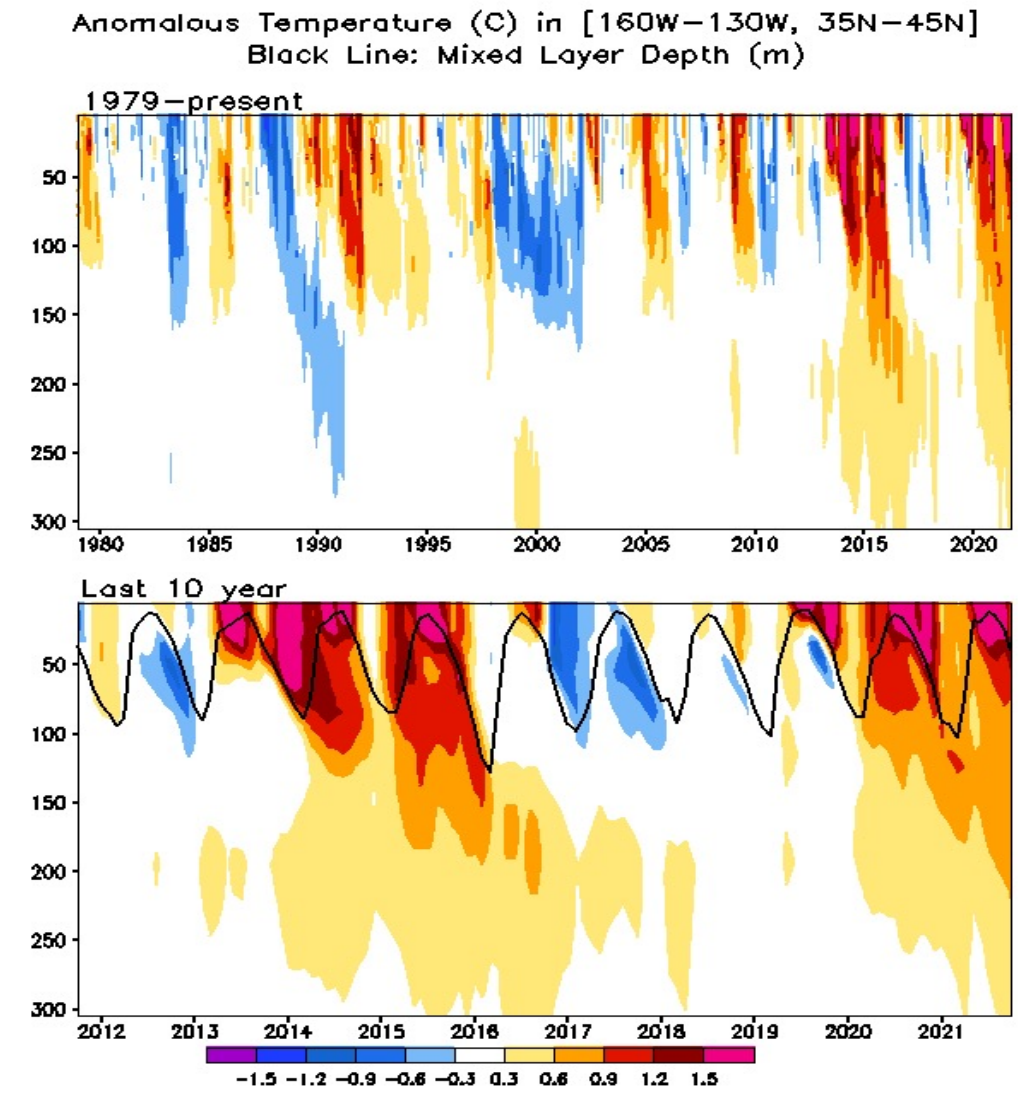




- MHWs continued in the N. C Pacific, while dissipated in N.E Pacific in the last two weeks.

(Left panel) Weekly SST anomaly (shaded) and locations experience Marine heat waves (hatched) by the date labelled in the plot. (right panel) SST evolution at a specific location. Green line and blue line denote the seasonal 90th percentile and daily climatology, respectively. Shaded area denotes the periods experiencing MHW. MHW is defined as a discrete prolonged warmer than 90th percentile of daily SST for at least 14 days. Data is derived from NCEI OISSTv2.1 and the climatology reference period is 1991-2020.

Subsurface Temperature Anomaly in N.E. Pacific



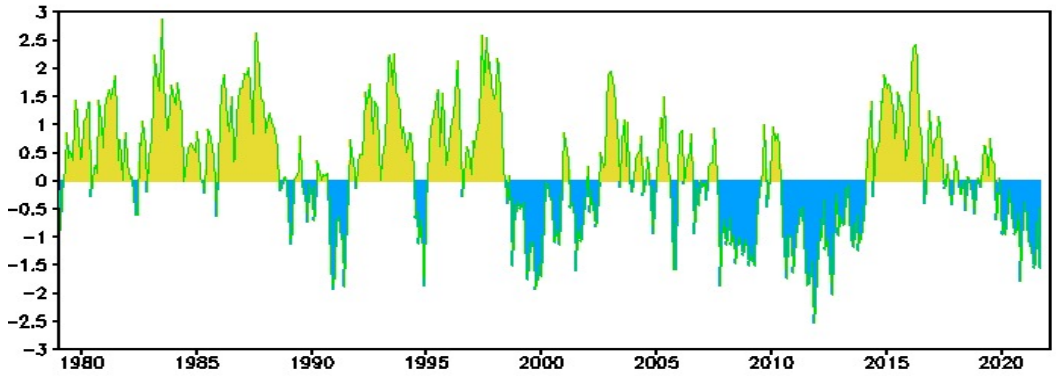
- Positive subsurface temperature anomaly in the N.E Pacific has persisted since 2019.

- Subsurface warming in recent months has extended to 200m, close to the strongest event during 2015-16.

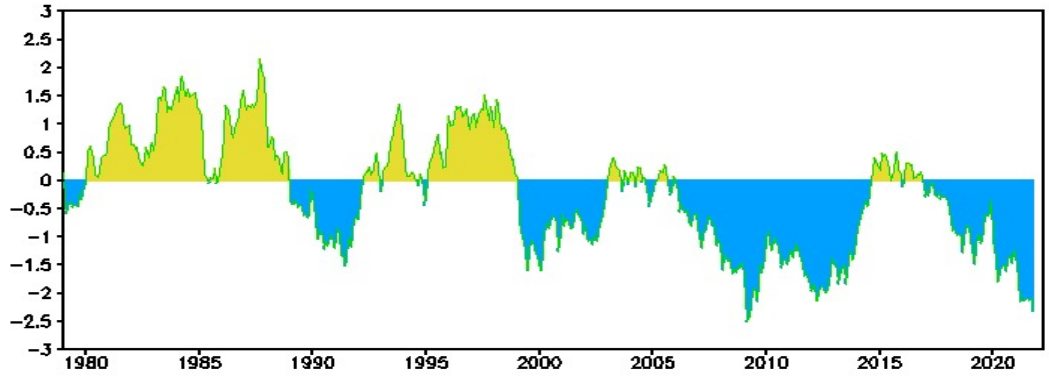
Data source: NCEP GODAS

Two Oceanic PDO indices

SST-based PDO (Wen et al. 2014: GRL)



H300-based PDO (Arun and Wen 2016:Mon.Wea.Rev.)



- The negative phase of PDO enhanced substantially in Oct 2021, with PDOI = -2.5.

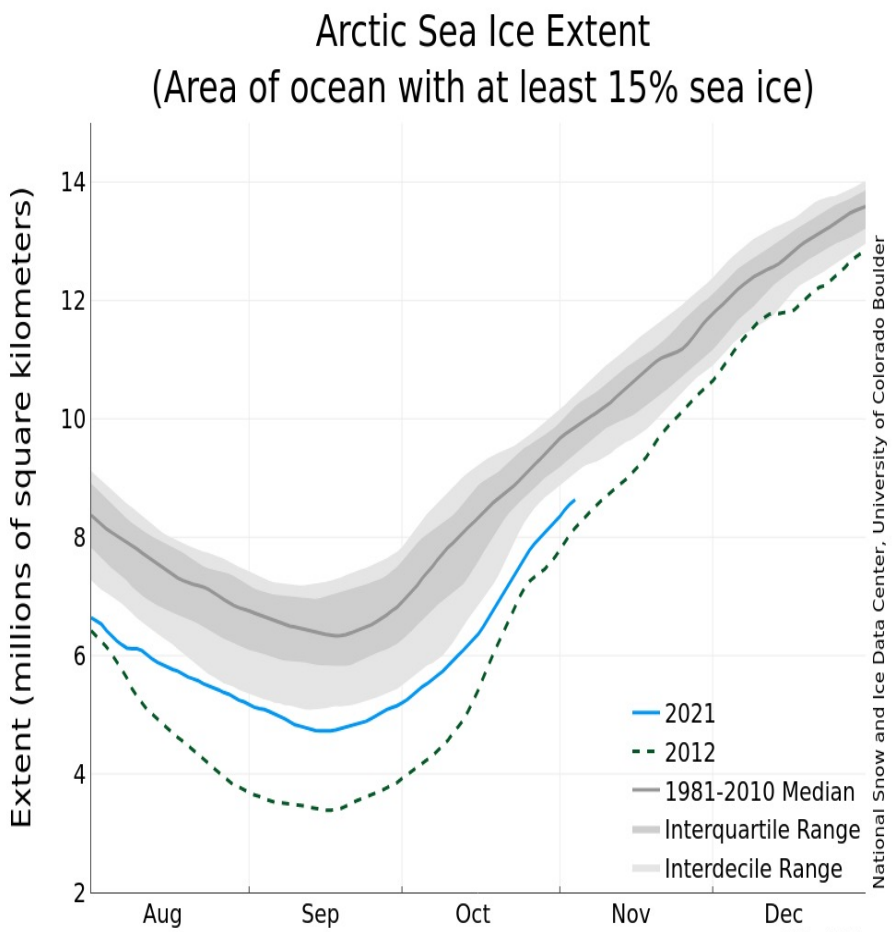
- Negative H300-based PDO index has persisted 61 months since Nov 2016, with HPDO = - 2.3 in Oct 2021.

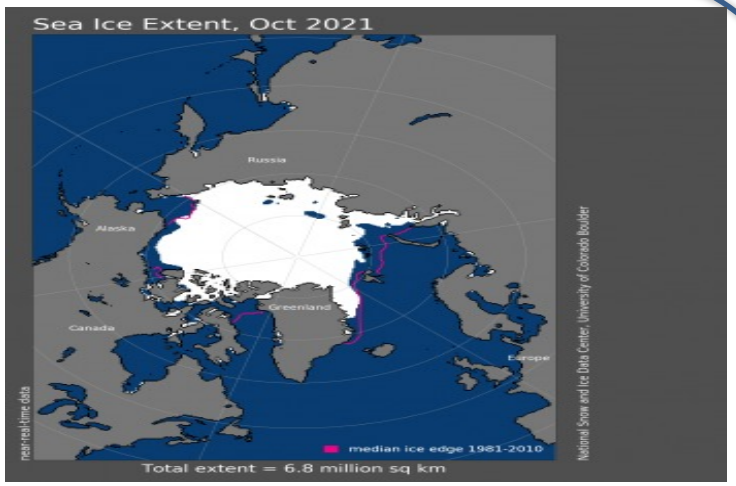
- SST-based PDO index has considerable variability both on seasonal and decadal time scales.

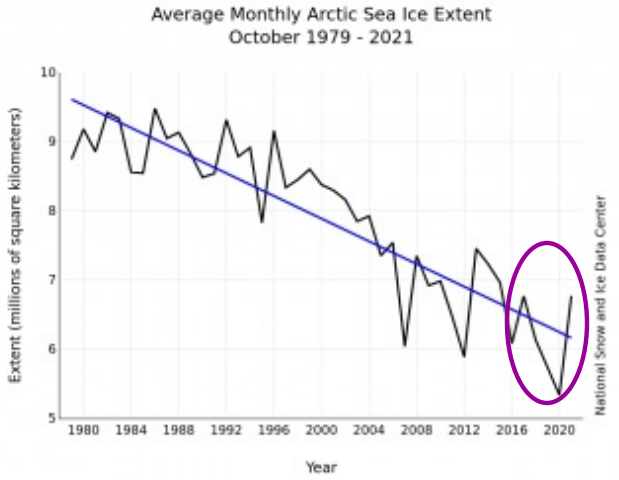
- H300-based PDO index highlights the slower variability and encapsulates an integrated view of temperature variability in the upper ocean.

SST-based PDO is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly ERSSTv5 SST anomalies onto the 1st EOF pattern. H300-based Pacific Decadal Oscillation is defined as the projection of monthly mean H300 anomalies from NCEP GODAS onto their first EOF vector in the North Pacific. PDO indices are downloadable from https://www.cpc.ncep.noaa.gov/products/GODAS/ocean_briefing.shtml.

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

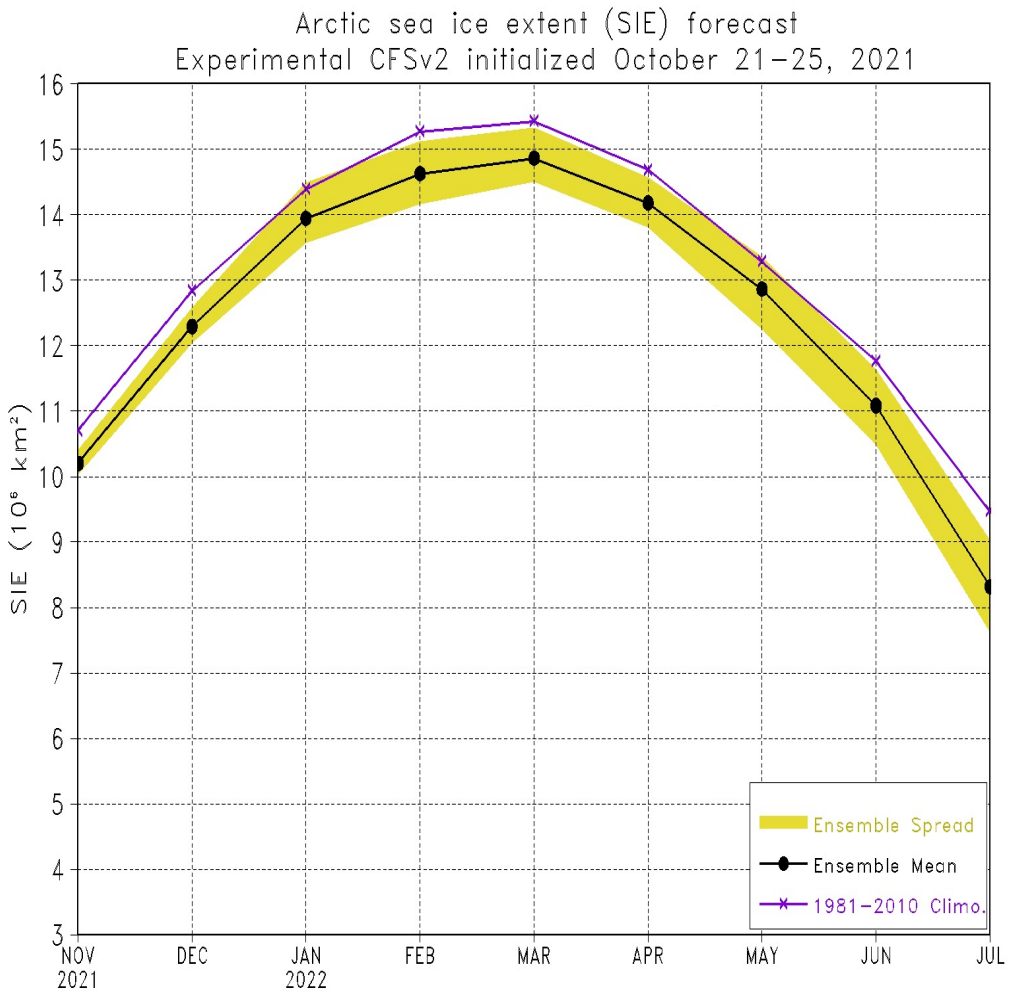






- The monthly average extent for October 2021 was 6.77 million square kilometers and it ranks the 8th lowest in the satellite record.

NCEP/CPC Arctic Sea Ice Extent Forecasts

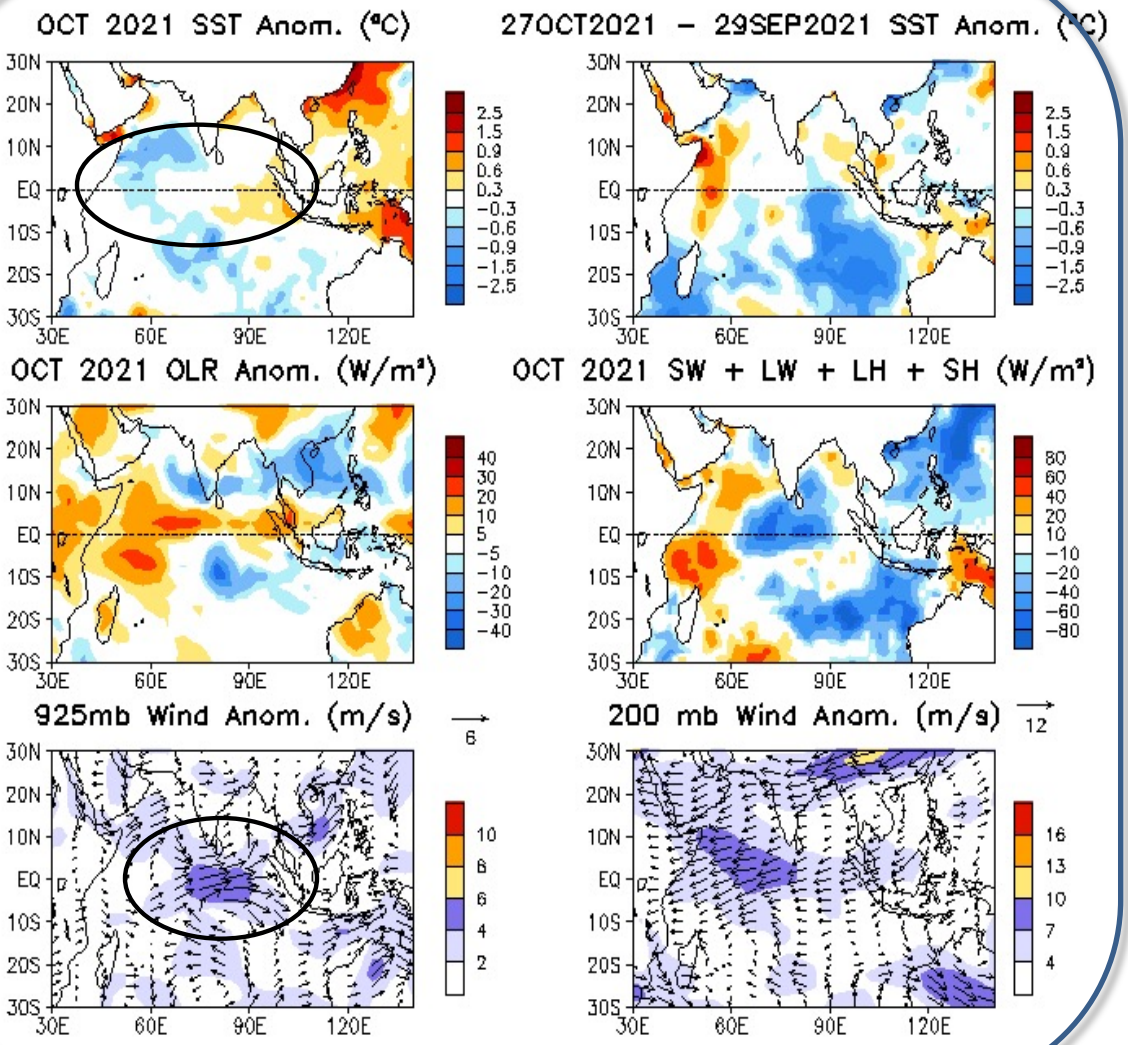


- For ICs in Oct 2021, NCEP/CPC model predicted the 2022 sea ice extent maximum will be slightly below climatology.

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

Indian Ocean

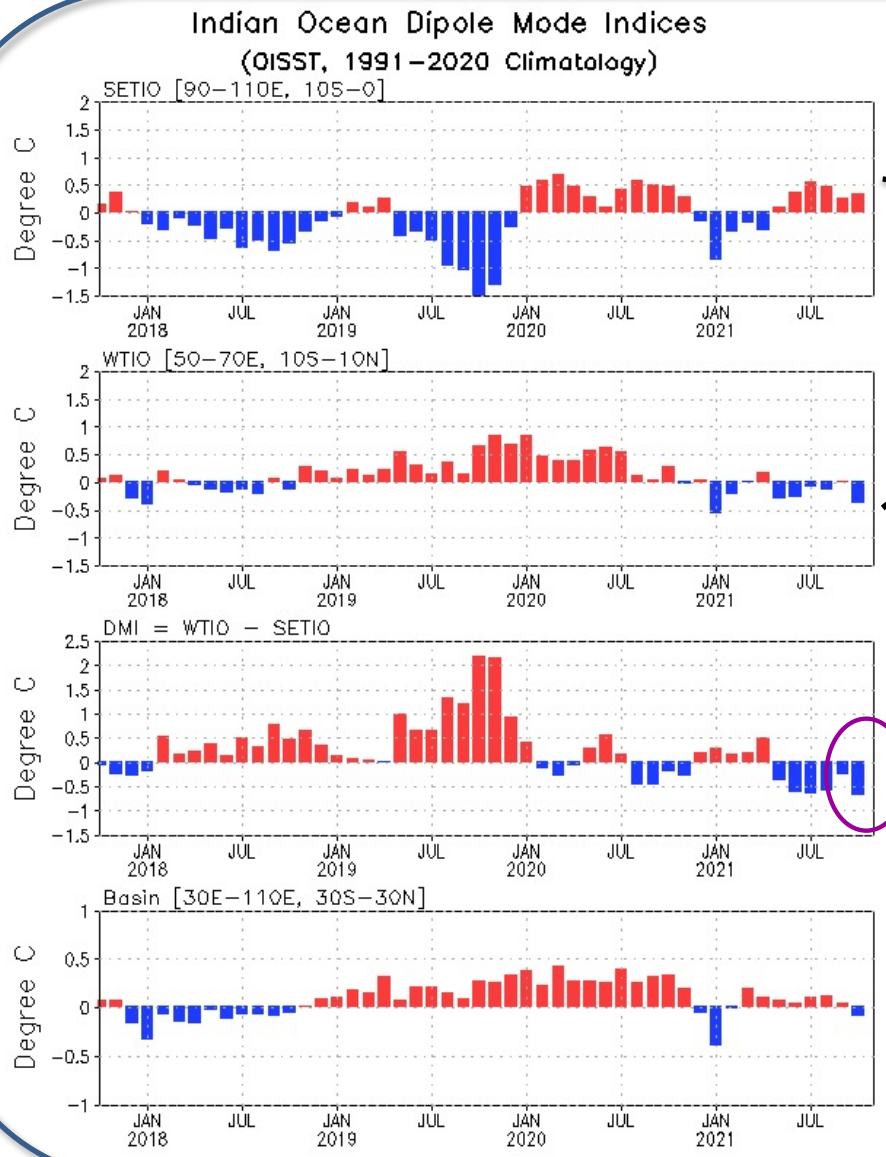
Tropical Indian: SSTA, SSTA Trend, OLR, heat flux uv925-mb & uv200 anomalies

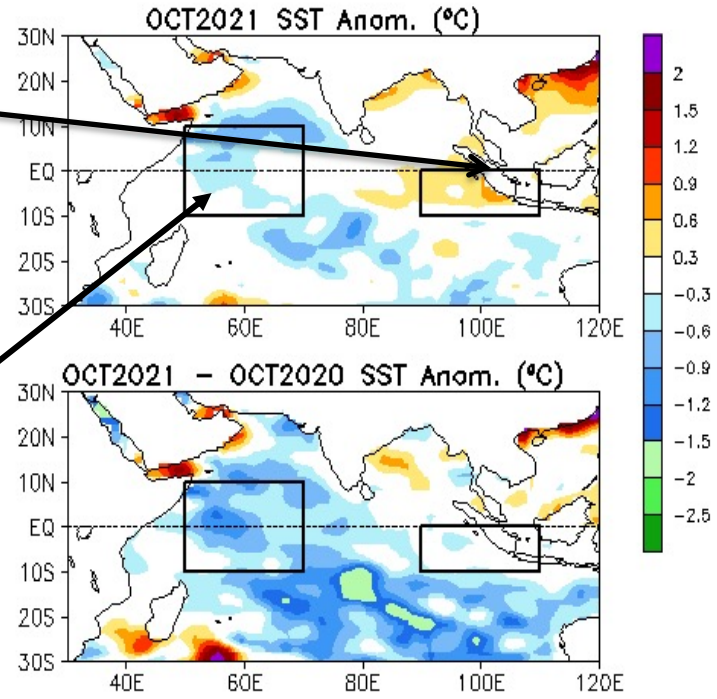


- Weak SST warming continued in the eastern Indian Ocean.
- Negative SST anomaly was present in the western Indian Ocean.
- Easterly wind anomaly favors of continuous SST warming in the eastern Indian Ocean.

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 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 Indian Ocean SST Indices



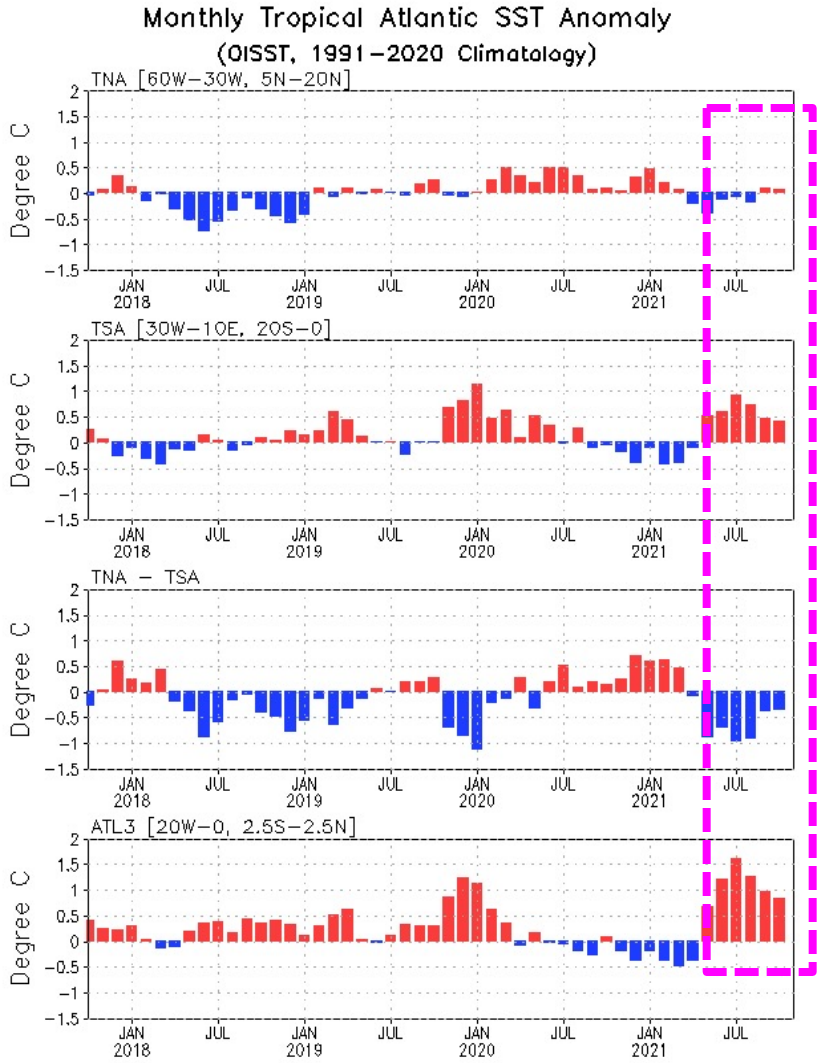


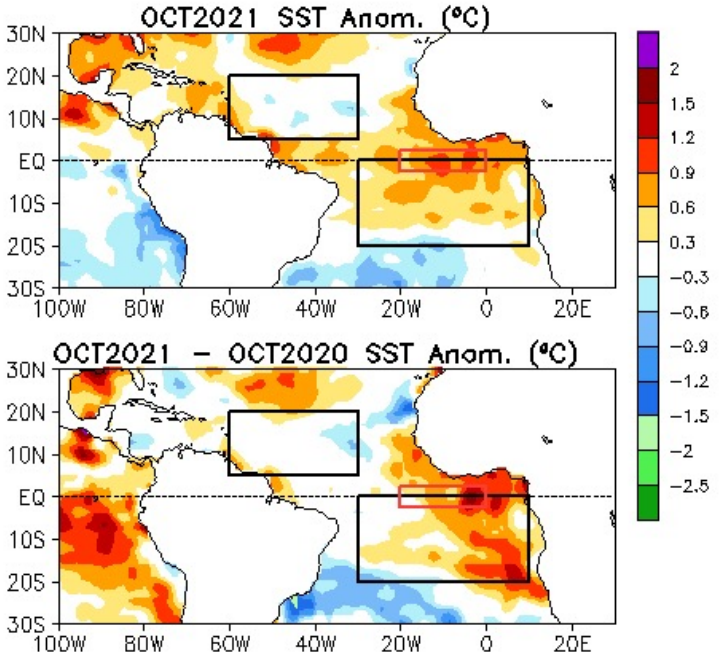
- Negative Indian Ocean Dipole Mode index (DMI) enhanced in Oct 2021, with IODI = -0.6 °C.

Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (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 NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

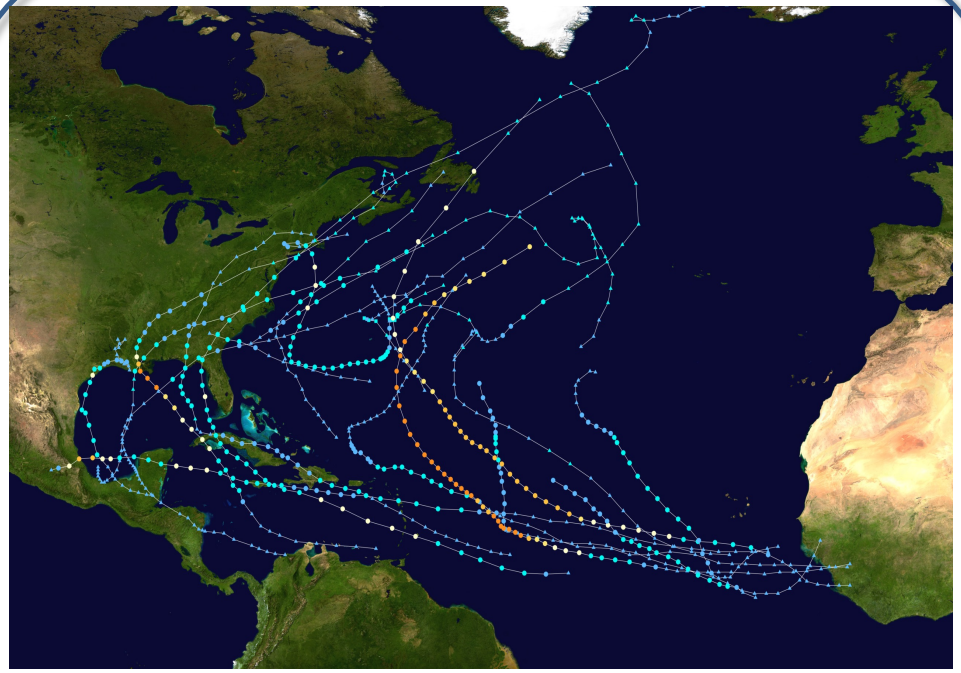




- Negative meridional dipole index persisted in Oct 2021, with MDI = -0.4 °C.
- Positive ATL 3 index continued to weaken in Oct 2021, with ATL 3 = 0.8 °C , implying the weakening of Atlantic Niño.

Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (^{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 NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means.

2021 Atlantic Hurricane Season Activities

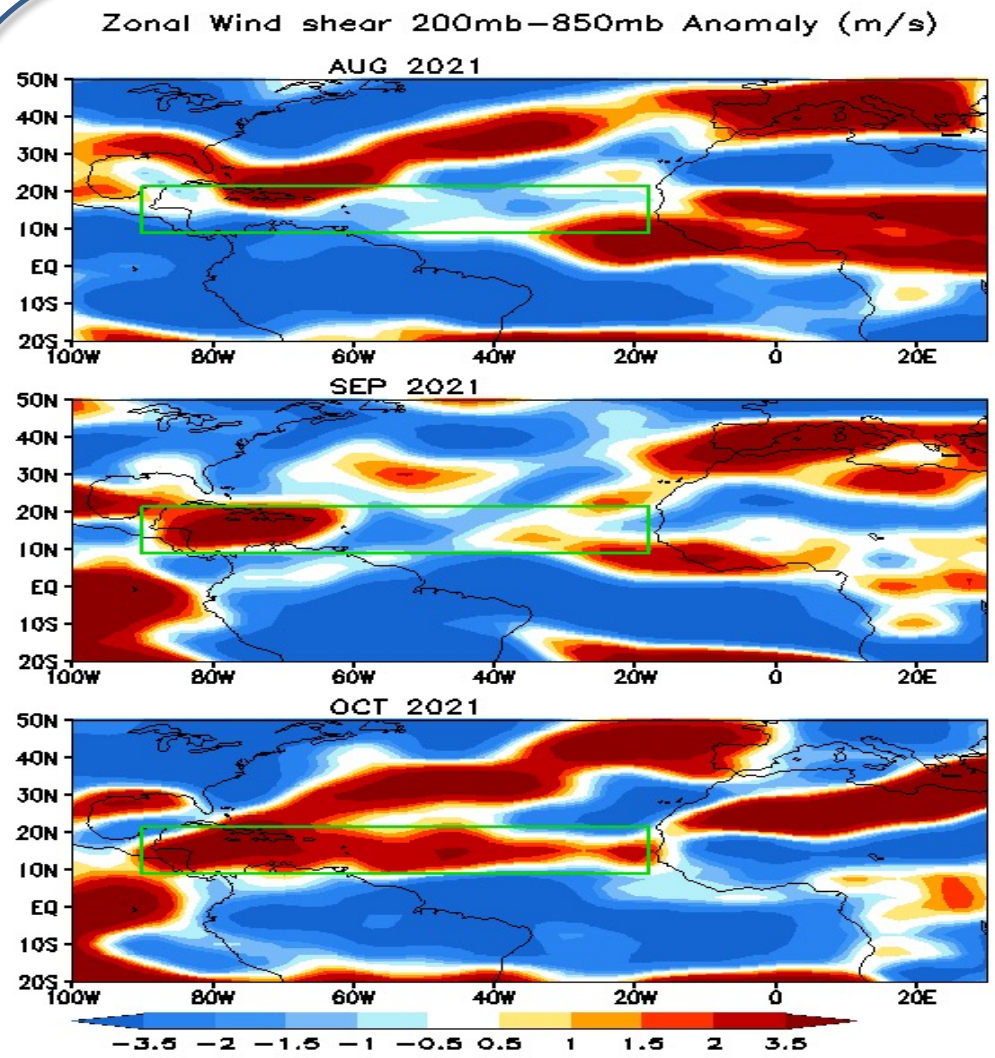


https://en.wikipedia.org/wiki/2021_Atlantic_hurricane_season

- North Atlantic was quiet in Oct 2021.
-By Nov 6, 2021, twenty-one tropical storms formed, making 2021 the third-most active Atlantic hurricane season.

Atlantic	Observations (By Nov 6)	Updated Outlook (Aug 4) 65% above-normal	Outlook (May 21) 60% above-normal	(1991-2020)
Total storms	21	15-21	13-20	14
Hurricanes	7	7-10	6-10	7
Major hurricanes	4	3-5	3-5	3

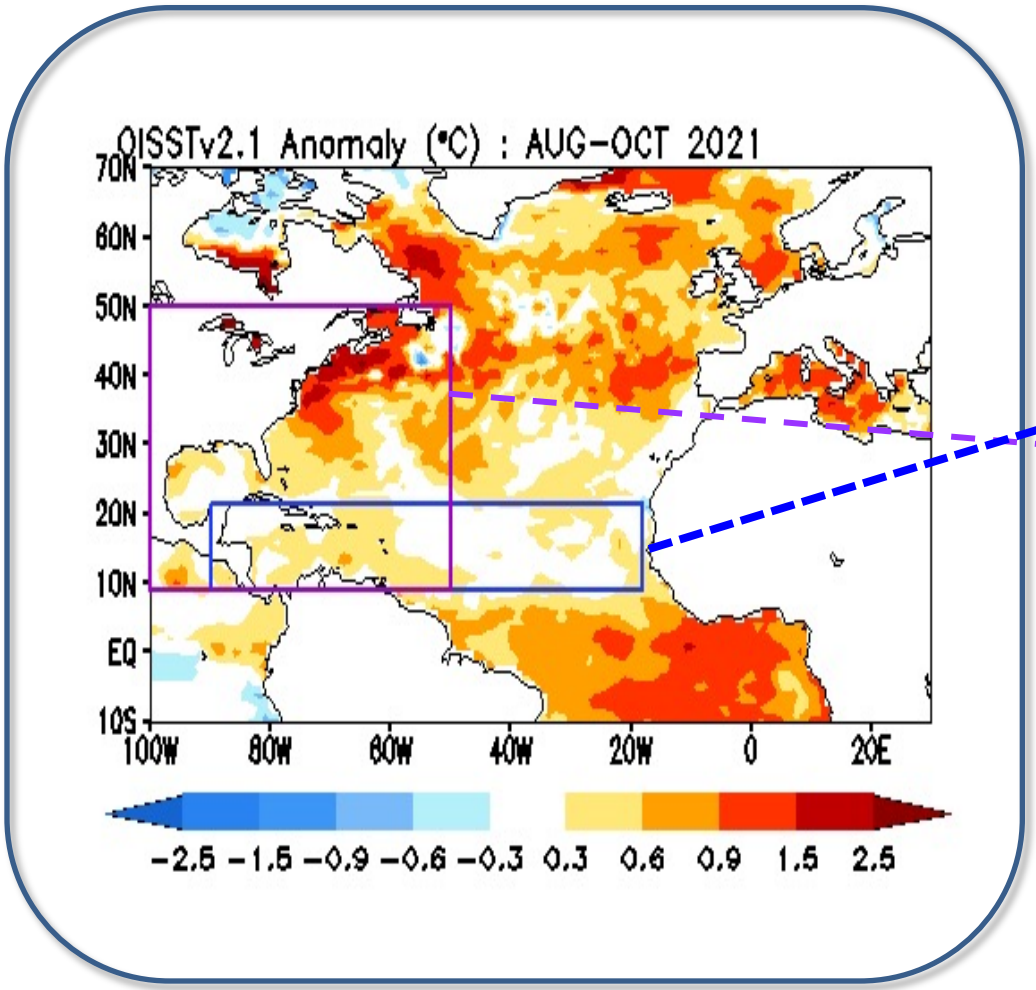
Last three months of zonal wind shear anomaly

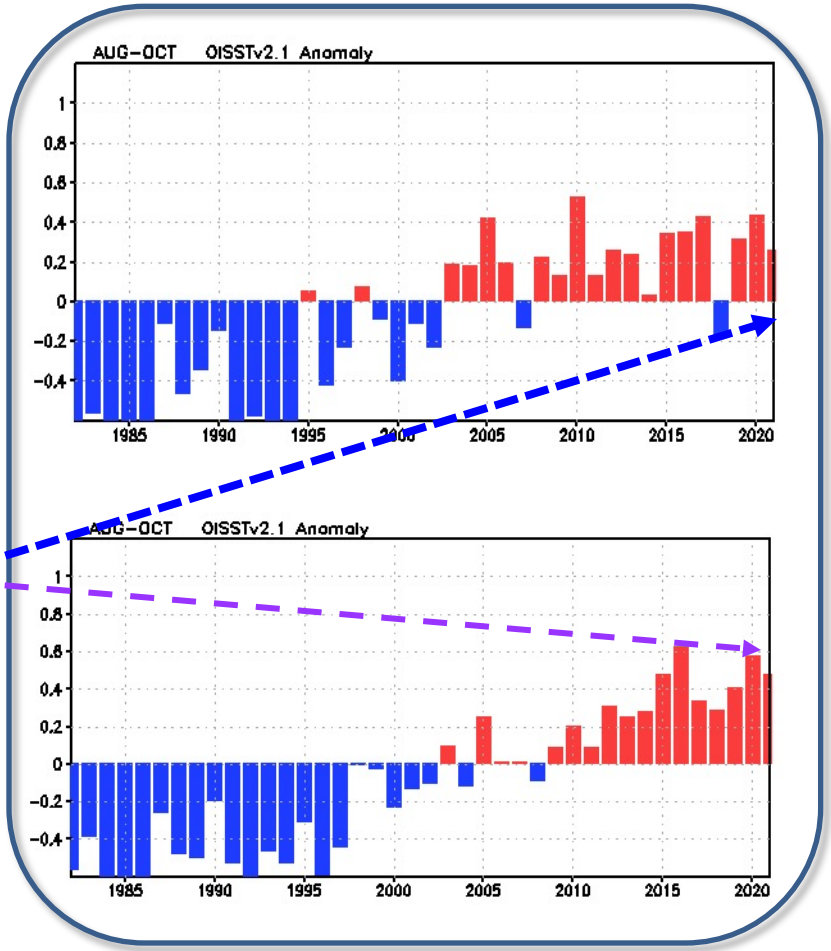


- Negative zonal wind shear anomalies dominated in the hurricane main developing region (MDR, green box) during Aug-Sep 2021.

- Positive zonal wind shear anomaly was present in the MDR region, which tends to suppress the tropical storm development.

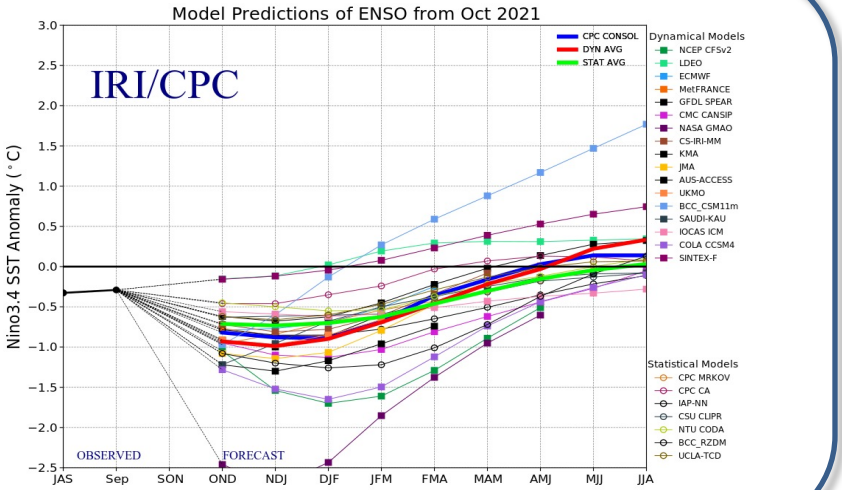
Evolution of SST anomaly in the North Atlantic

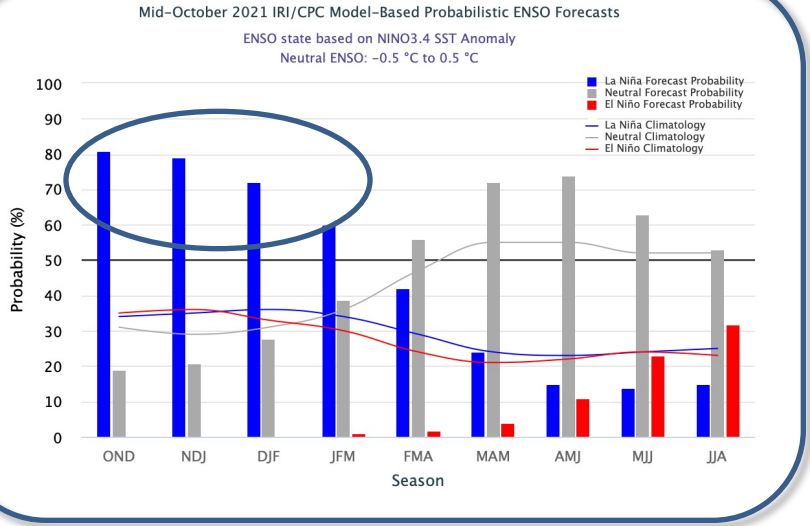




ENSO and Global SST Predictions

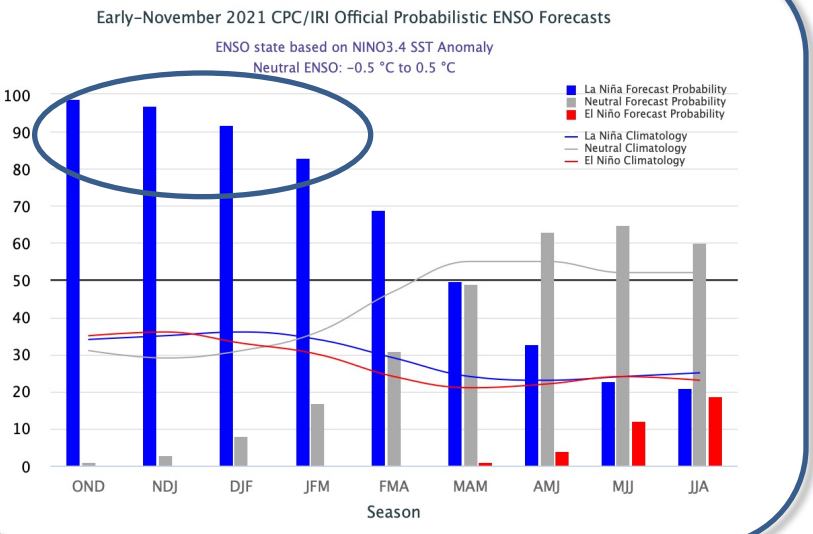
IRI/CPC Niño3.4 Forecast





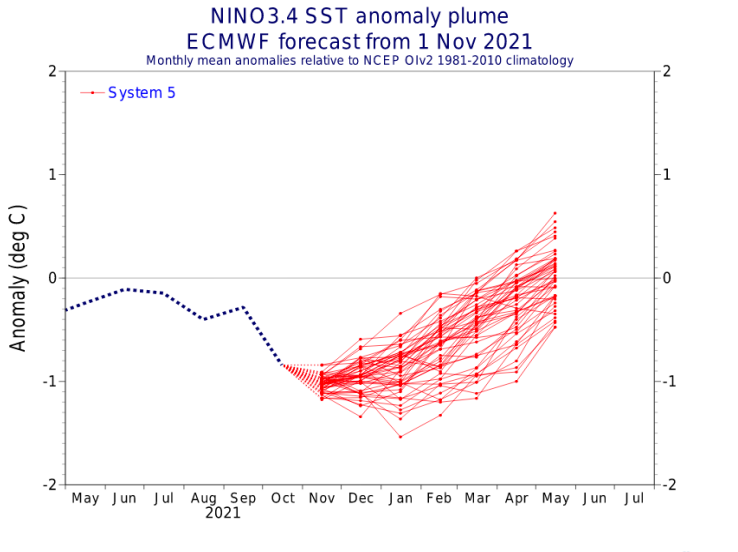
- A majority of dynamical and statistical models predict SSTs to cool further through winter 2021-22 and return to ENSO neutral during spring.

- NOAA "ENSO Diagnostics Discussion" on November 11 stated that "La Niña is likely to continue through the Northern Hemisphere winter 2021-22 (~90% chance) and into spring 2022 (~50% chance during March-May)".

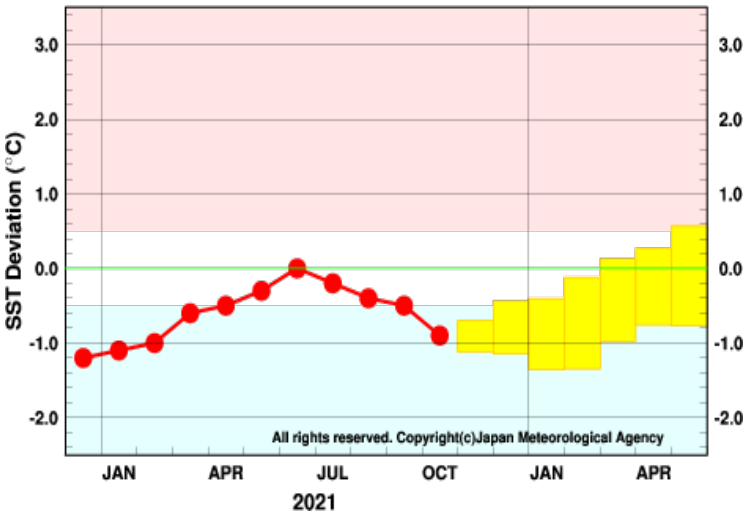


Individual Model Niño3.4 Forecasts

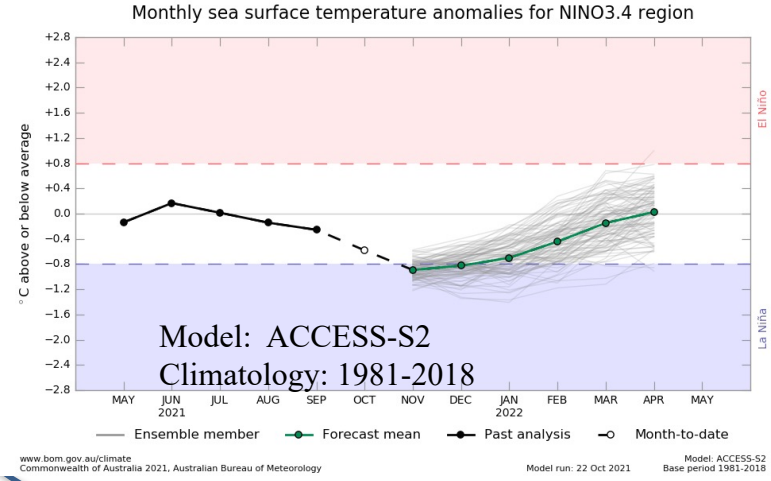
EC: IC= 01 Nov, 2021



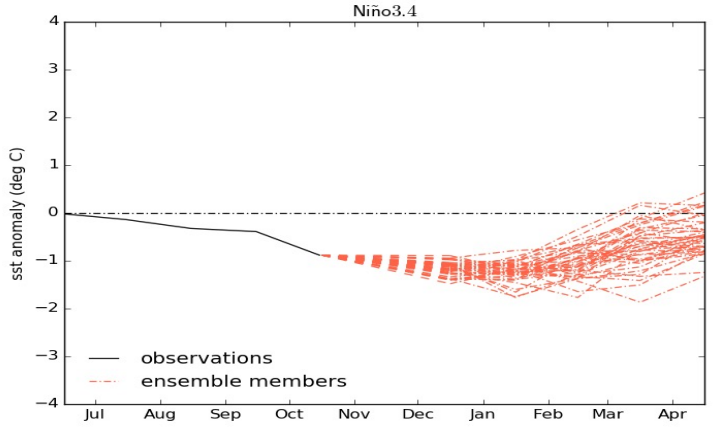
JMA: Updated 11 Nov, 2021



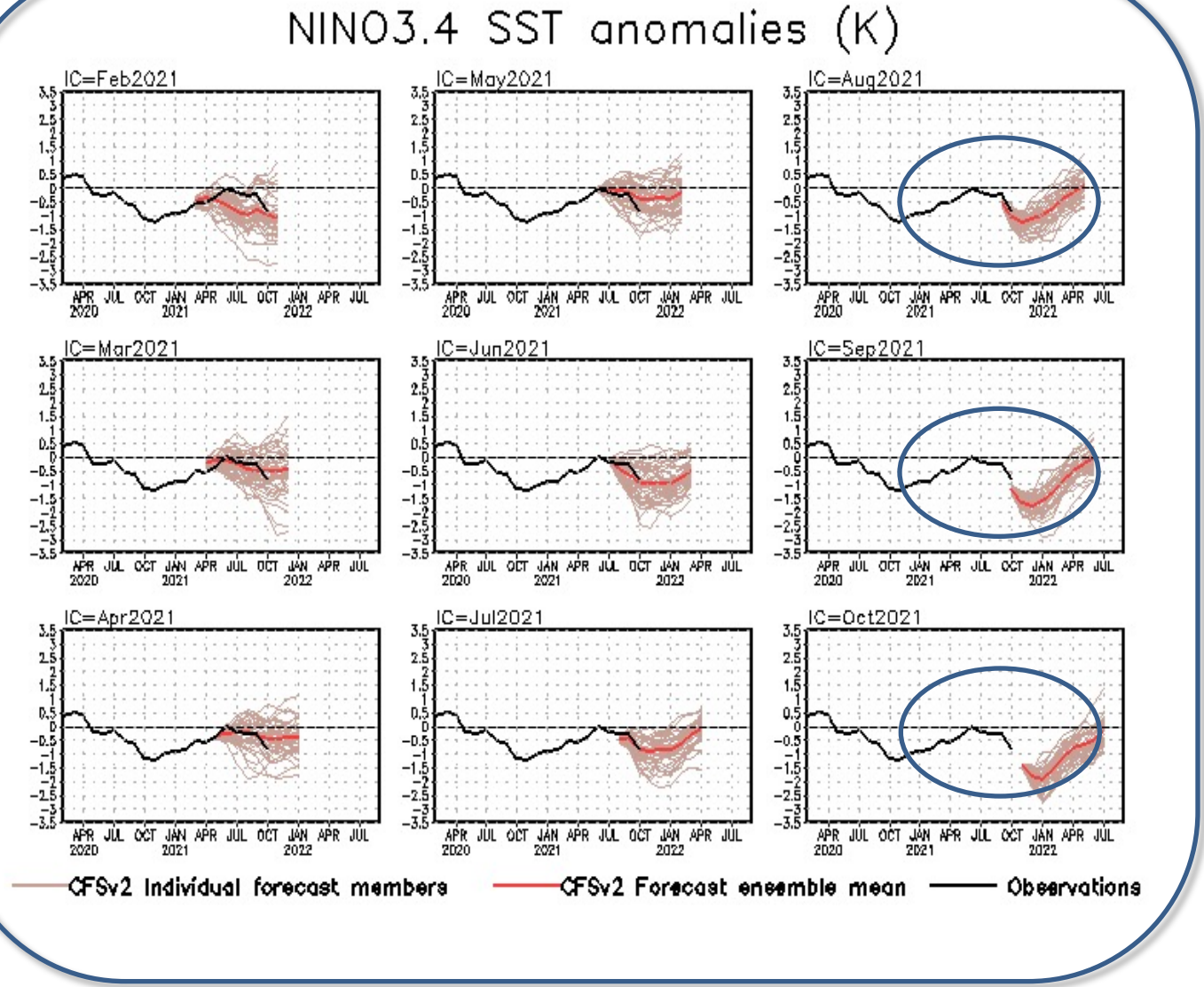
BOM: Updated 22 Oct, 2021



UKMO: Updated 11 Nov, 2021



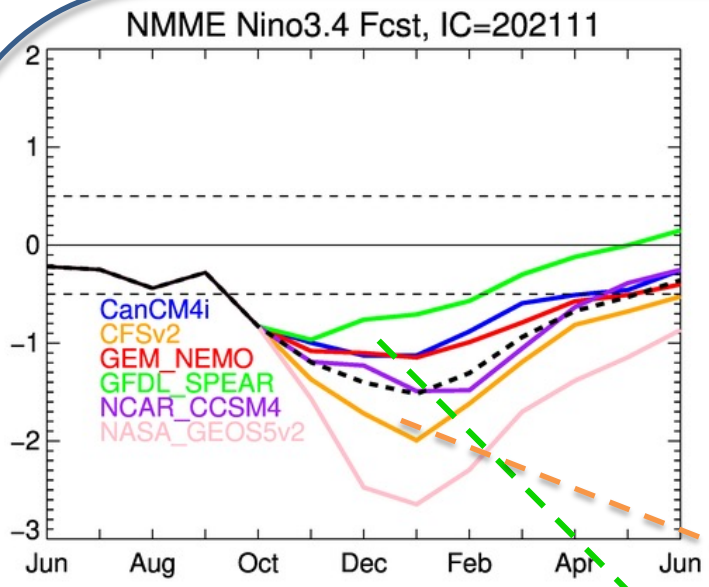
CFSv2 Niño3.4 SST Predictions

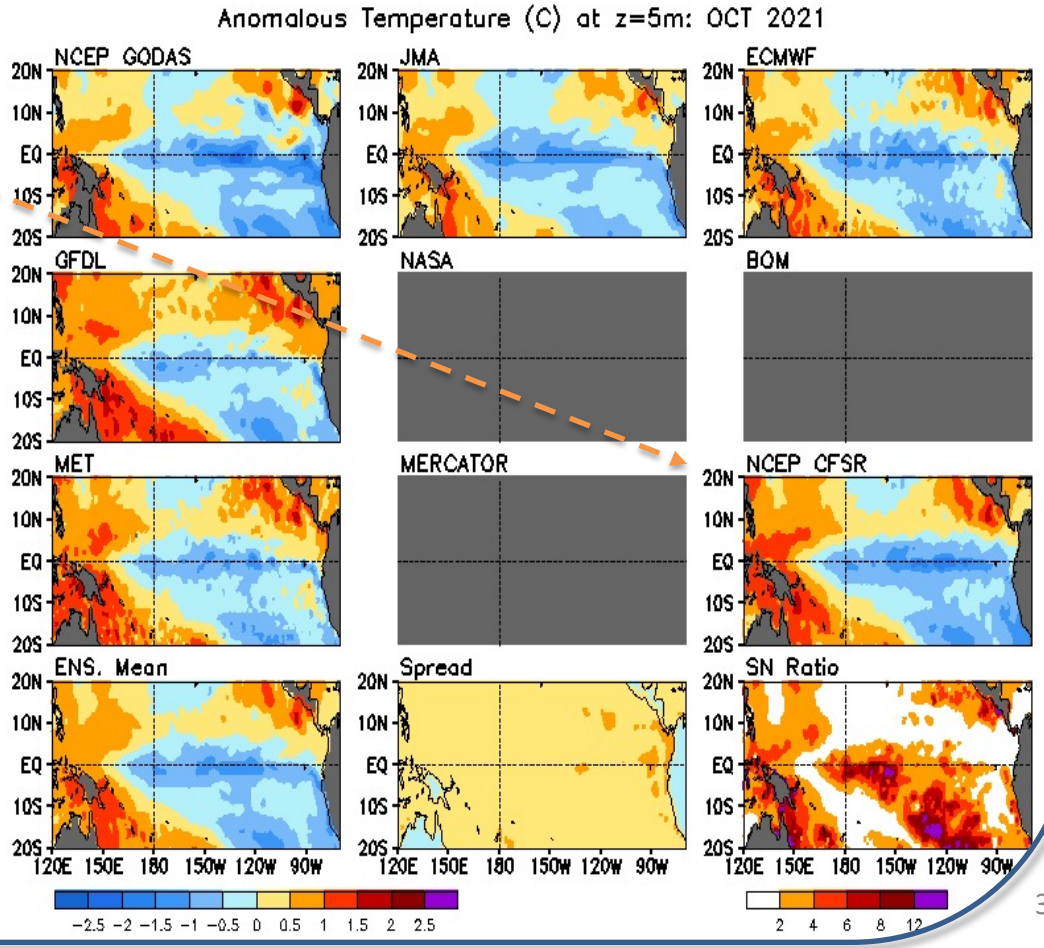


- Latest CFSv2 predictions call for a strong La Niña in the northern hemisphere 2021/22 winter.

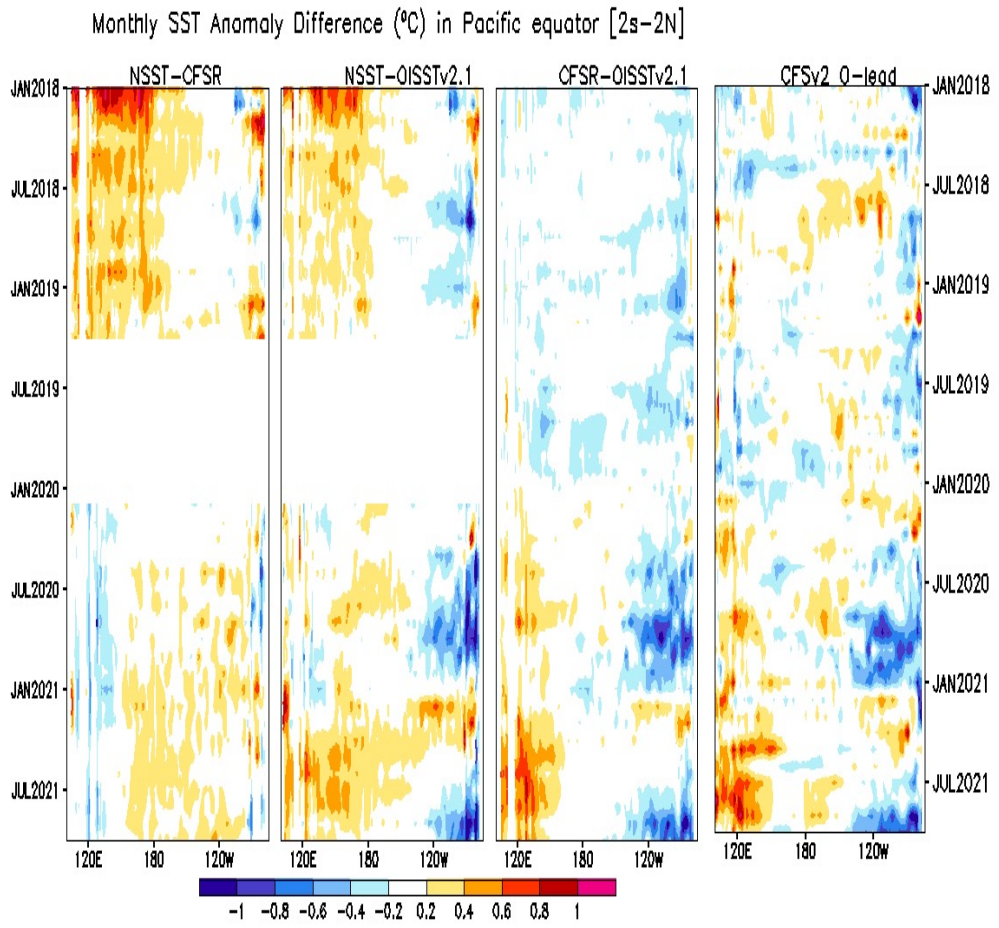
CFS Niño3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect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

Multiple Ocean Reanalysis: SST Anomalies



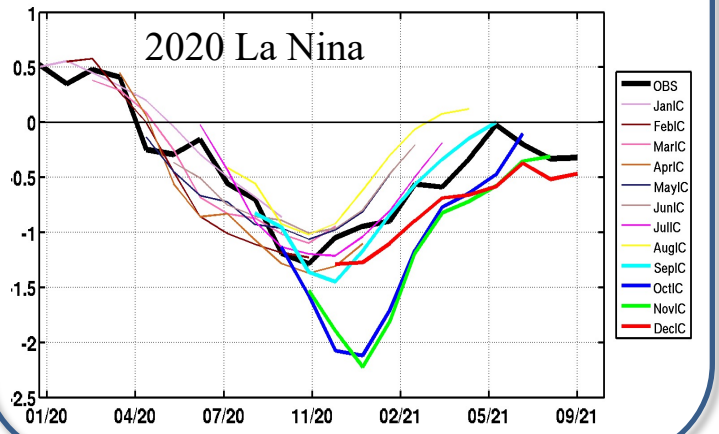


Potential Impact of NSST bias on CFSv2 Predictions



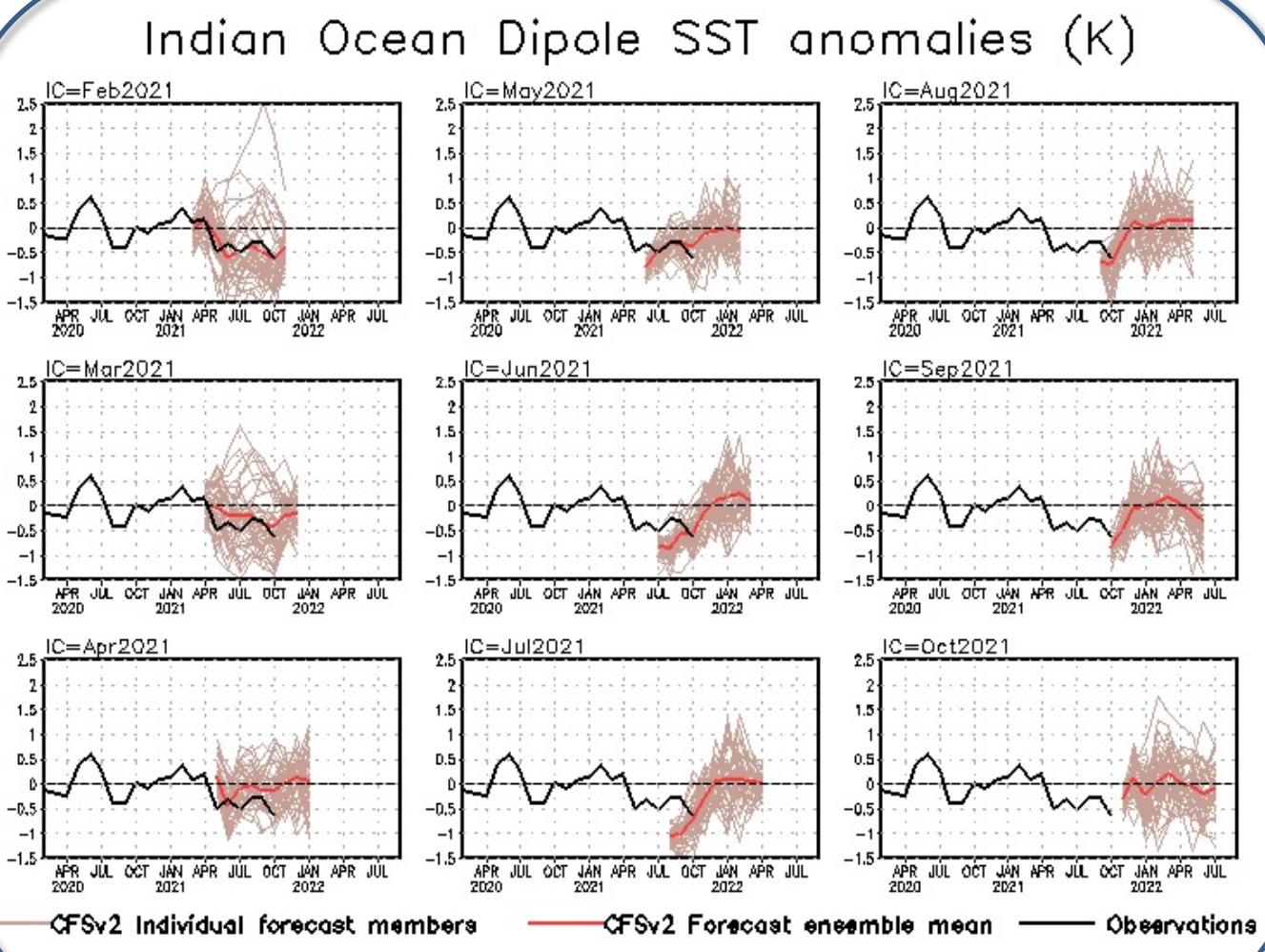
Bias pathway : NSST⟶CFSR⟶ CFSv2

NINO 3.4 Forecast



- CFSR nudges to NSST since Feb 2020.
- Cold bias in NSST gives rise to the systematic cold bias in CFSR.
- Large cold CFSR SST bias in the E. Pacific during Sep- Oct 2020 is consistent with overshooting La Nina forecast initiated with Oct., Nov. condition.
- CFSv2 might overestimate SST cooling in 2021-22 winter owing to the large cold SST biases in CFSR.

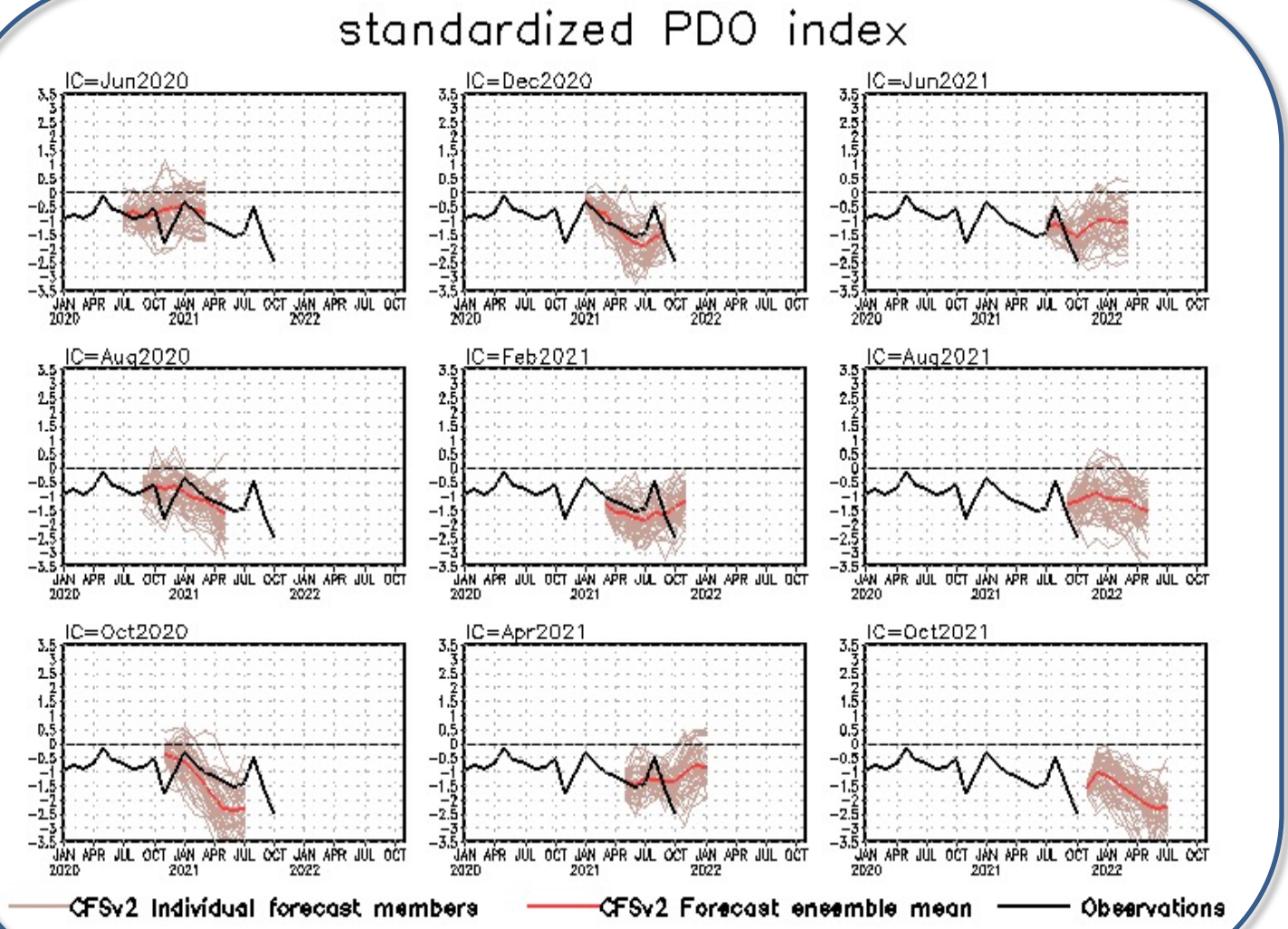
CFSv2 DMI SST Predictions



- Latest CFSv2 forecasts favored neutral IOD conditions in winter.

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.

CFSv2 Pacific Decadal Oscillation (PDO) Index Predictions



- CFSv2 predicts a negative phase of PDO in the coming seasons.

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.

Acknowledgements

- Drs. Arun Kumar, Zeng-Zhen Hu, and Jieshun Zhu: reviewed PPT, and provided insightful suggestions and comments

- Drs. Li Ren and Pingping Xie provided the BASS/CMORPH/CFSR EVAP package

- Dr. Wanqiu Wang provided the sea ice forecasts and maintained the CFSv2 forecast archive

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Zeng-Zhen.Hu@noaa.gov

Data Sources (climatology is for 1991-2020)

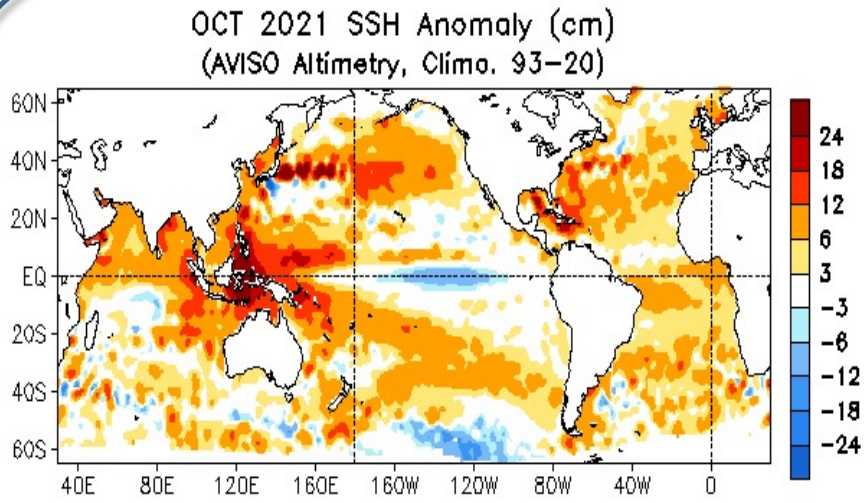
- **Weekly Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)**
- **Extended Reconstructed SST (ERSST) v5 (Huang et al. 2017)**
- **Blended Analysis of Surface Salinity (BASS) (Xie et al. 2014)**
- **CMORPH precipitation (Xie et al. 2017)**
- **CFSR evaporation adjusted to OAFlux (Xie 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**

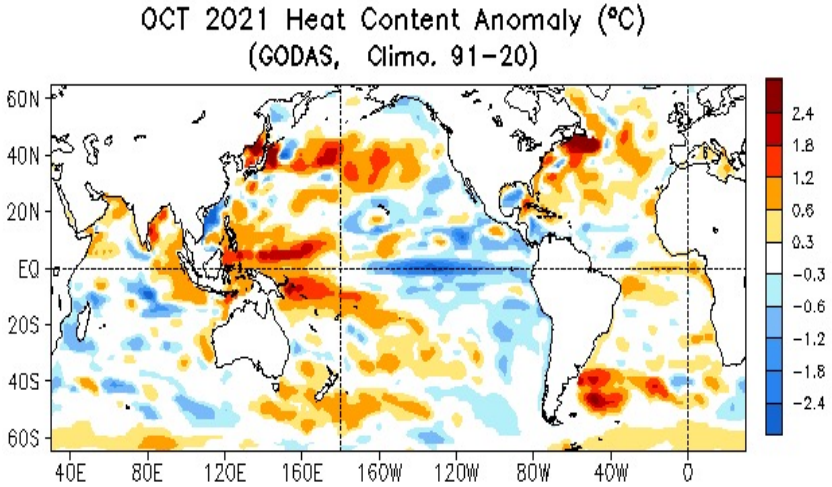
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

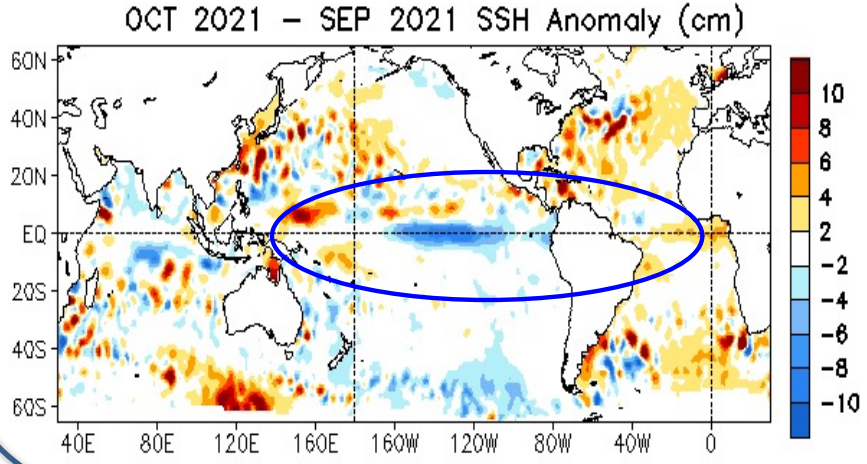
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html

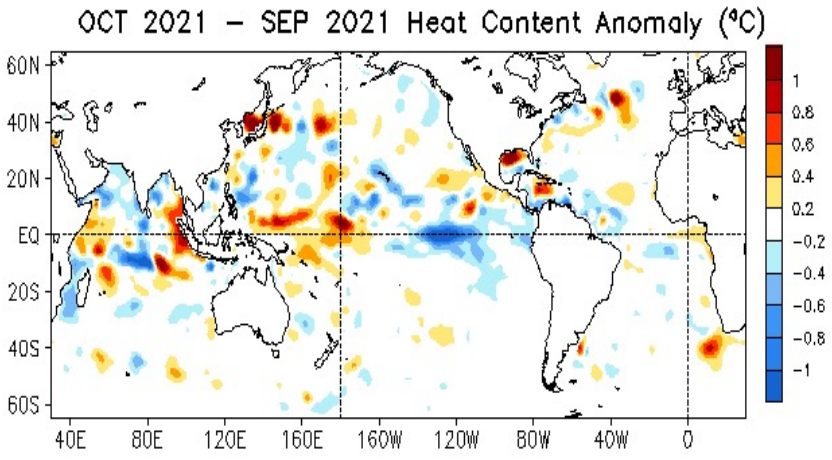
Backup Slides

Global SSH and HC300 Anomaly & Anomaly Tendency



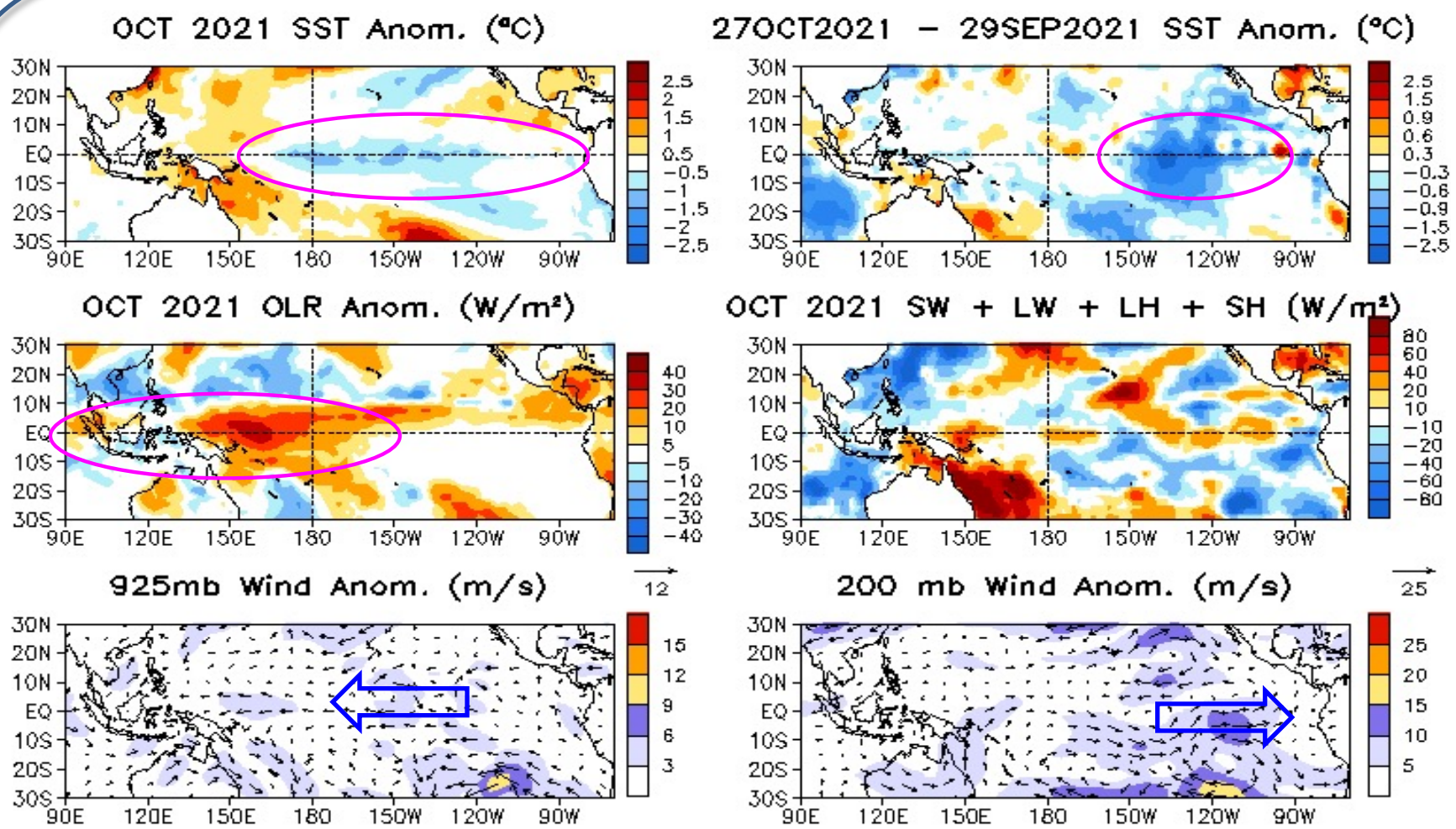






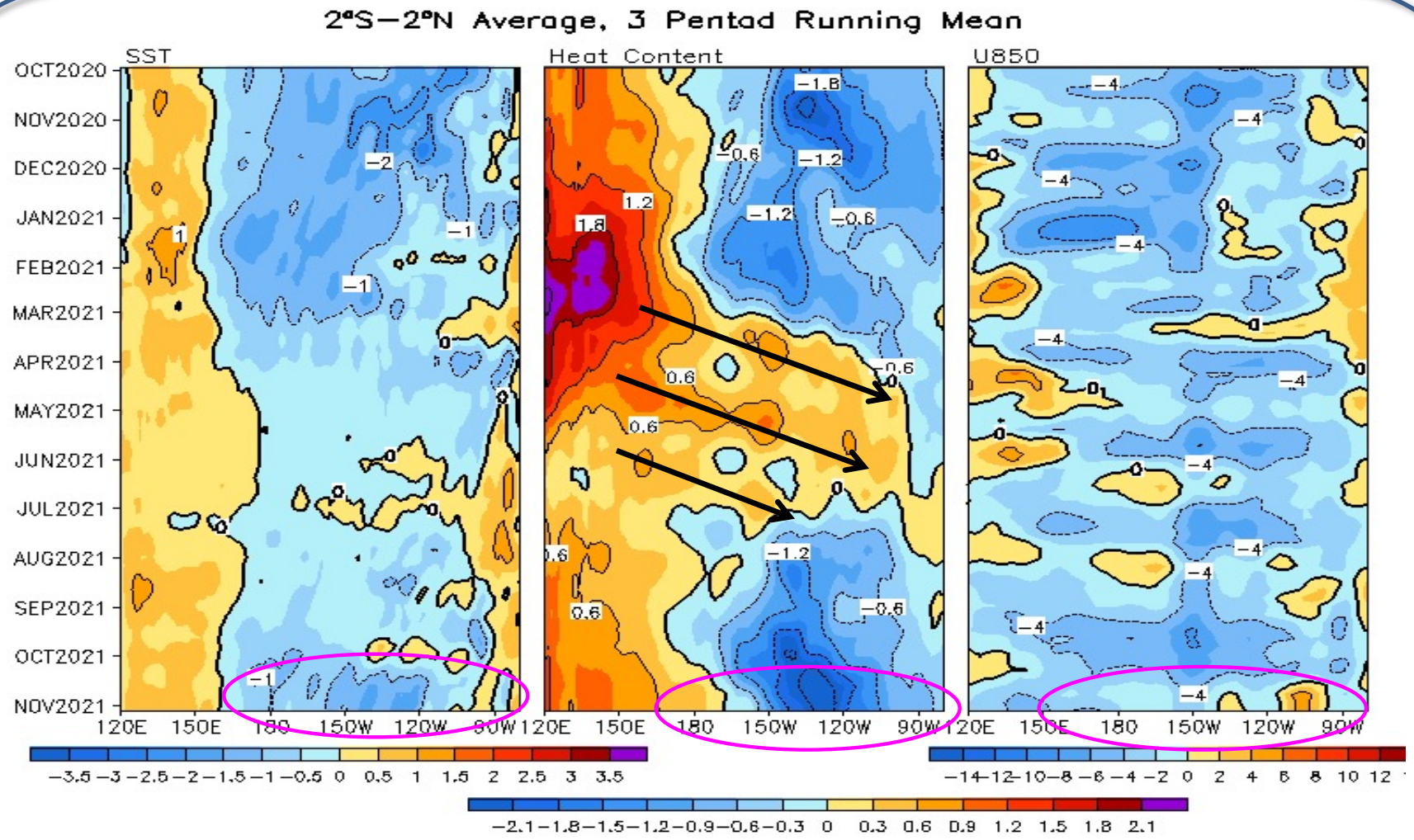
- The SSHA pattern was overall consistent with the HC300A pattern, but with a significant trend component in SSHA.
- Positive anomalies were present in the equatorial Atlantic.
- Both Negative SSHA tendencies and HC300A tendencies were present in the central-eastern Pacific .

Tropical Pacific: SSTA, SSTA Trend, OLR, heat flux, uv925 & uv200 anomalies



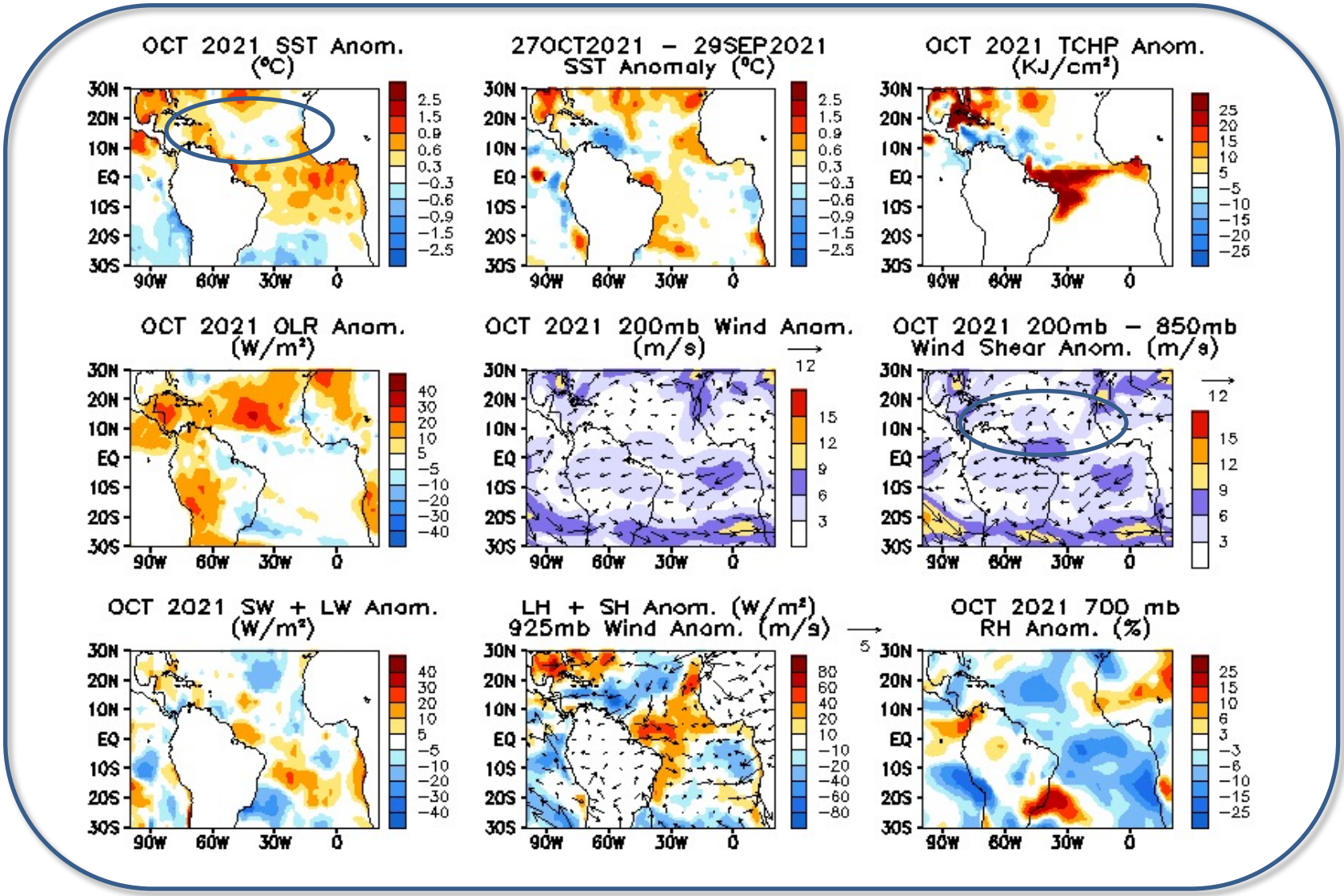
Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly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

Equatorial Pacific SST (°C), H300 (°C), and u850 (m/s) Anomalies



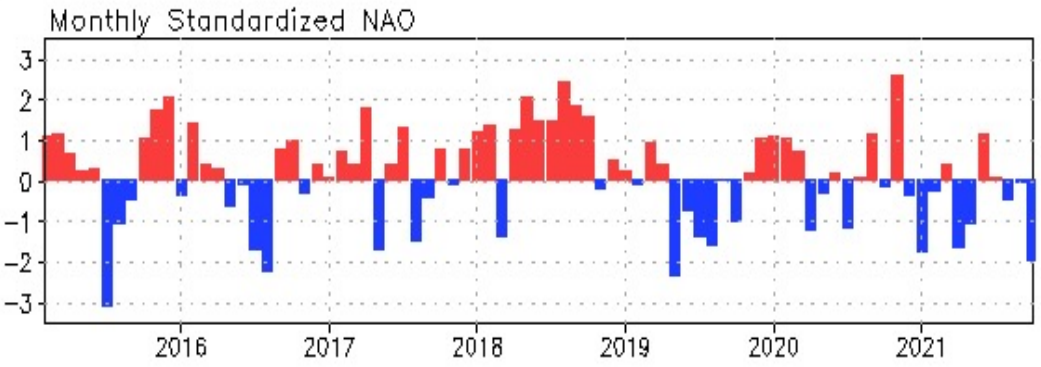
- Strong negative H300 anomaly continued in the central-eastern Pacific Oct 2021, contributing to further SST cooling.

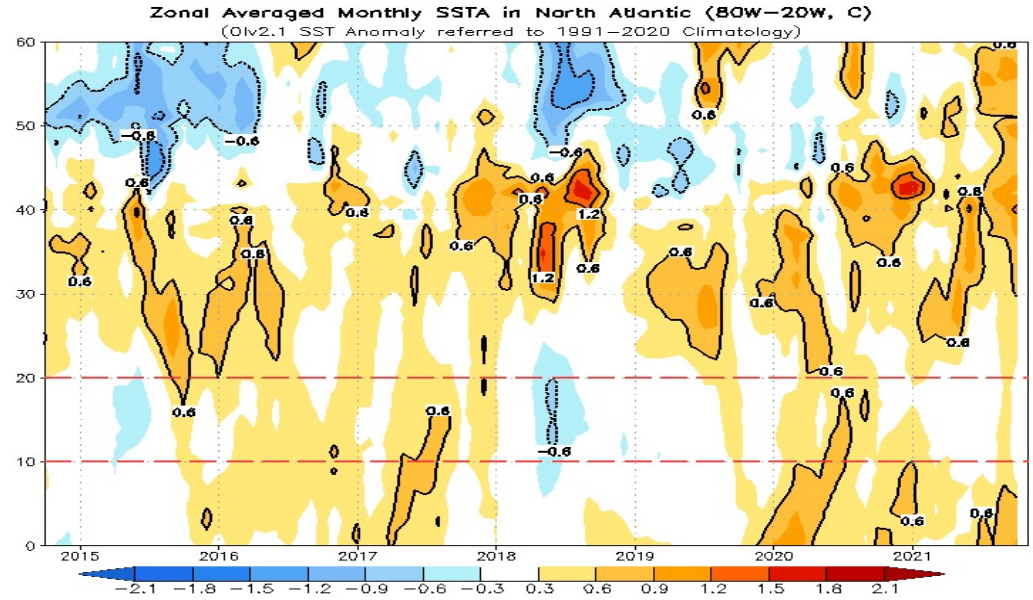
Tropical Atlantic Ocean: SSTA, SSTA Tend, TCHP, OLR, UV200, UV200-UV850, Heat Flux Anomalies

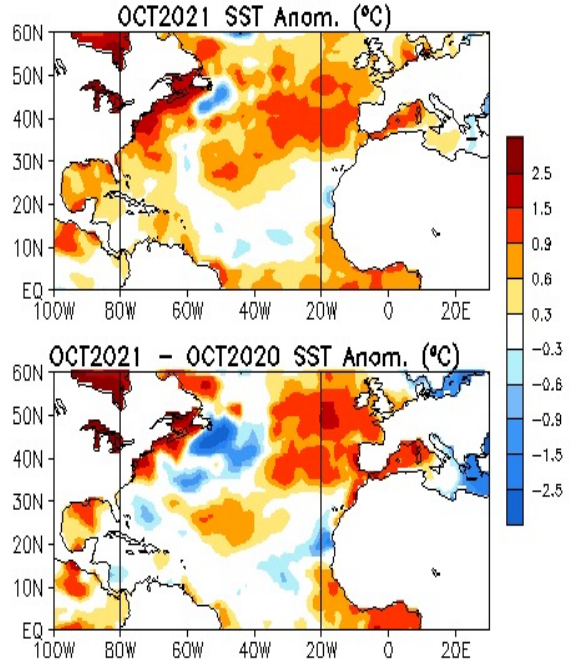


Top Row: SSTA (left; OI SST), SSTA tendency (central), Tropical Cyclone Heat Potential anomaly (right; GODAS).
Middle row: OLR (left; NOAA 18 AVHRR IR), UV200 (central; NCEP CDAS), UV200-UV850 (right; NCEP CDAS) anomalies.
Bottom row: SW+LW (left), LH+SH (central), Relative humidity at 700 hPa (right; NCEP CDAS) anomalies.
Anomalies are departures from the 1991-2020 base period means.

NAO and SST Anomaly in North Atlantic







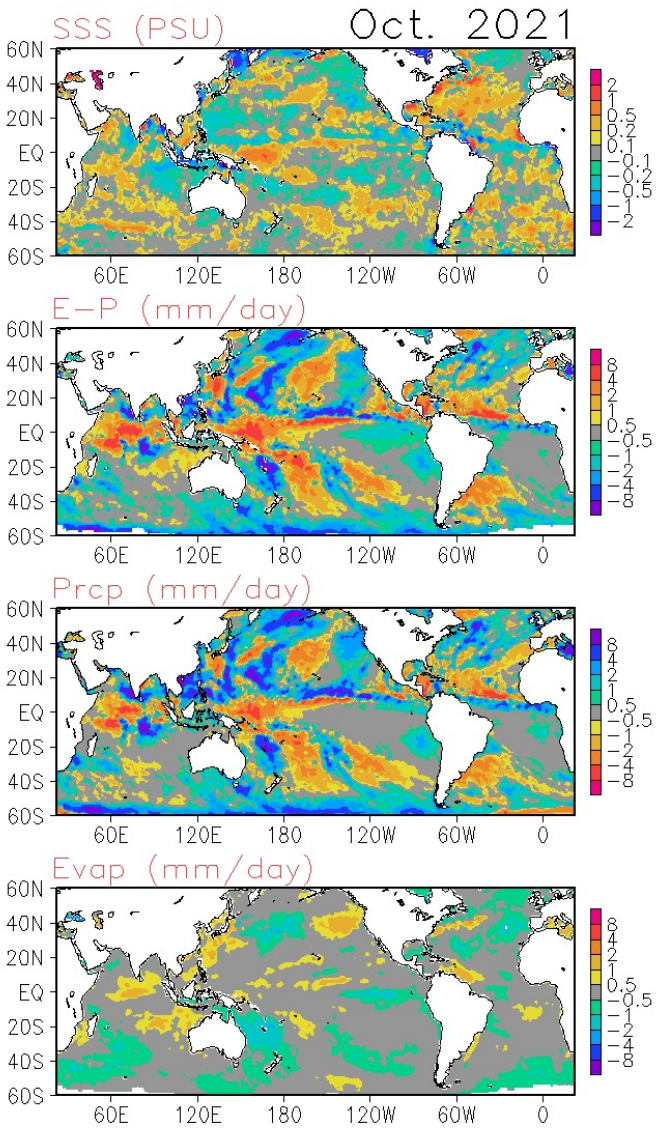
- Negative NAO enhanced substantially in Oct 2021.
- The prolonged positive SSTAs in the middle latitudes were evident, due to the domination of the positive phase of NAO during the last 5-6 years.

Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80ºW and 20ºW (bottom). SST are derived from the NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means.

Global Sea Surface Salinity (SSS): Anomaly for October 2021

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/strengthens in the western equatorial Pacific Ocean with reduced precipitation in this area. Negative SSS anomaly in the northeast Pacific Ocean continues. Positive SSS anomaly also continues between 20°N and 40°N in the Atlantic Ocean. While negative SSS anomaly appears along the equator of Atlantic which is accompanied with increased precipitation. Negative SSS in the Bay of Bengal continues and is possibly due to increased precipitation.



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

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

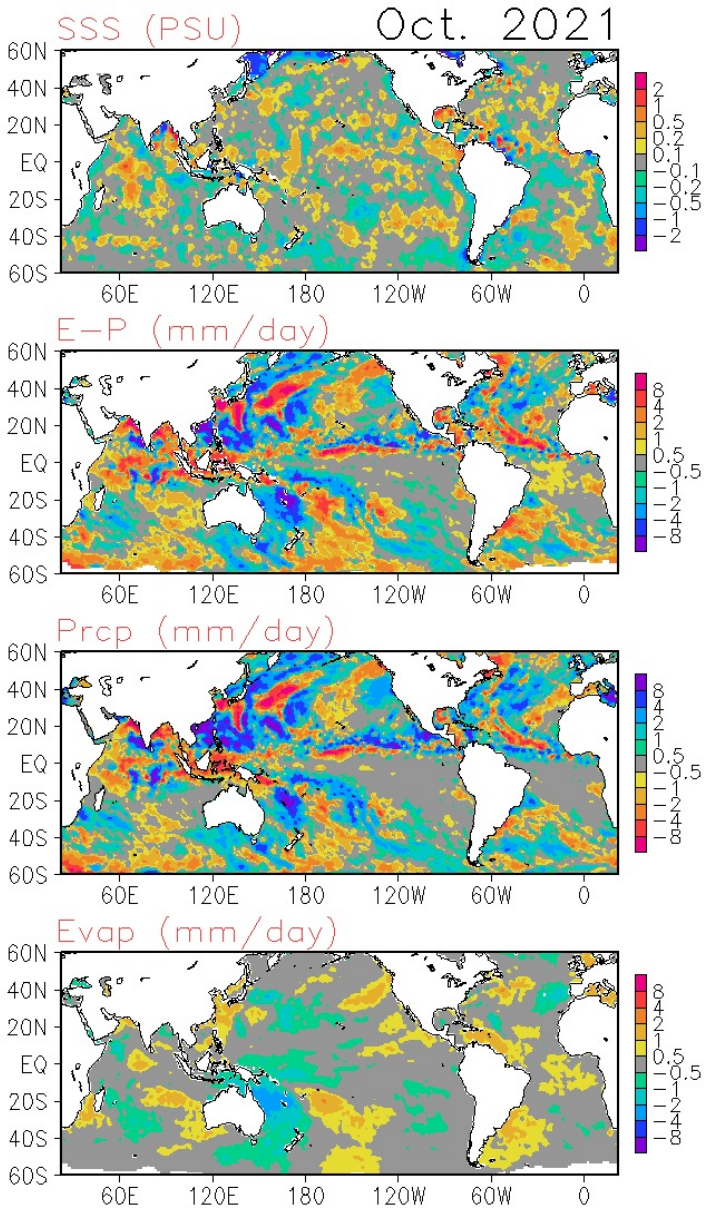
ftp.cpc.ncep.noaa.gov/precip/BASS

Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: Adjusted CFS Reanalysis

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

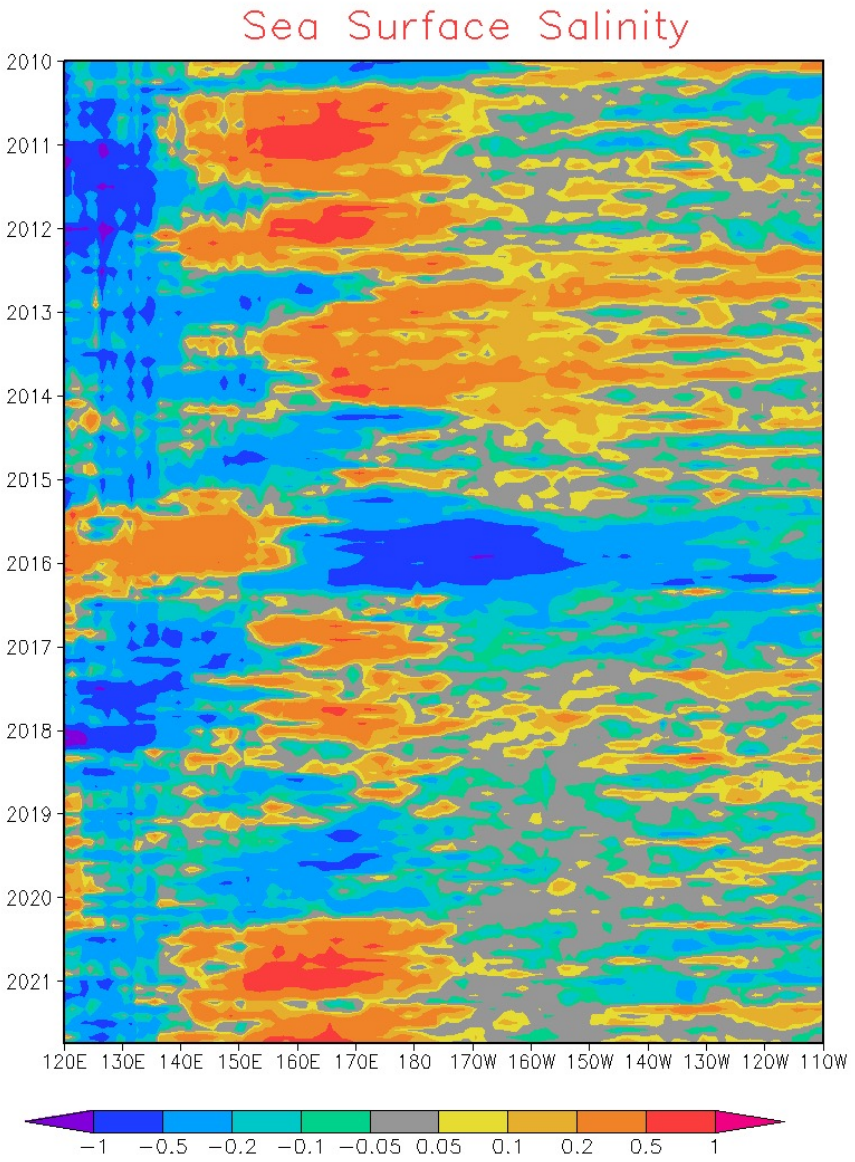
Compared with last month, SSS increased in the west Equatorial Pacific Ocean likely due to reduced precipitation. SSS increased in the east Equatorial Pacific Ocean as well. SSS decreased in the SPCZ region which is possibly caused by increased precipitation. SSS decreased along the equator of Atlantic Ocean with increased precipitation.



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 also continues between 140°E and 170°W; while positive SSS signal started to appear 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.