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
- Special topic:

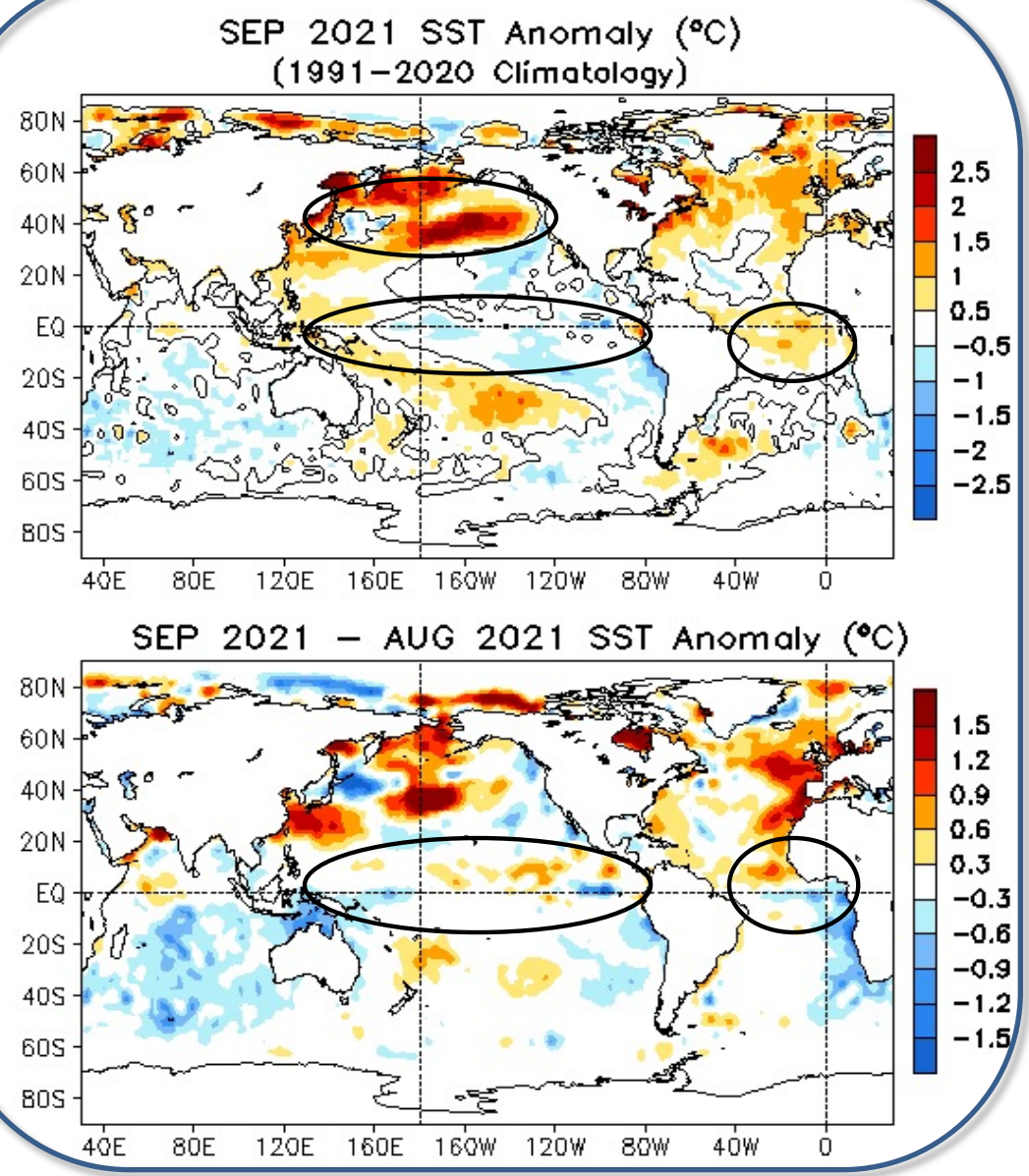
- Potential impact of GODAS and CFSR bias on ENSO predictions

Overview

- Pacific Ocean
  - Ocean NINO indices remained within the ENSO-neutral range, while negative SSTAs extended to the dateline and some key atmospheric variables were consistent with La Nina conditions.
  - Negative phase of PDO amplified substantially in Sep 2021, with PDOI = -1.6.
  - Marine Heat Waves (MHWs) persisted in the N.E. Pacific and expanded to the N.C. Pacific.
- Indian Ocean
  - Negative Indian Ocean dipole (IOD) event weakened, with IOD index drop to -0.2° C in Sep 2021.
- Atlantic Ocean
  - 2021 Atlantic Niño event weakened in Sep 2021.
  - Atlantic hurricane genesis was very active in September, consistent with NOAA's updated Atlantic Hurricane season outlook.
- Arctic Ocean
  - The monthly average sea ice extent for Sep 2021 ranks the twelfth lowest in the satellite record.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency

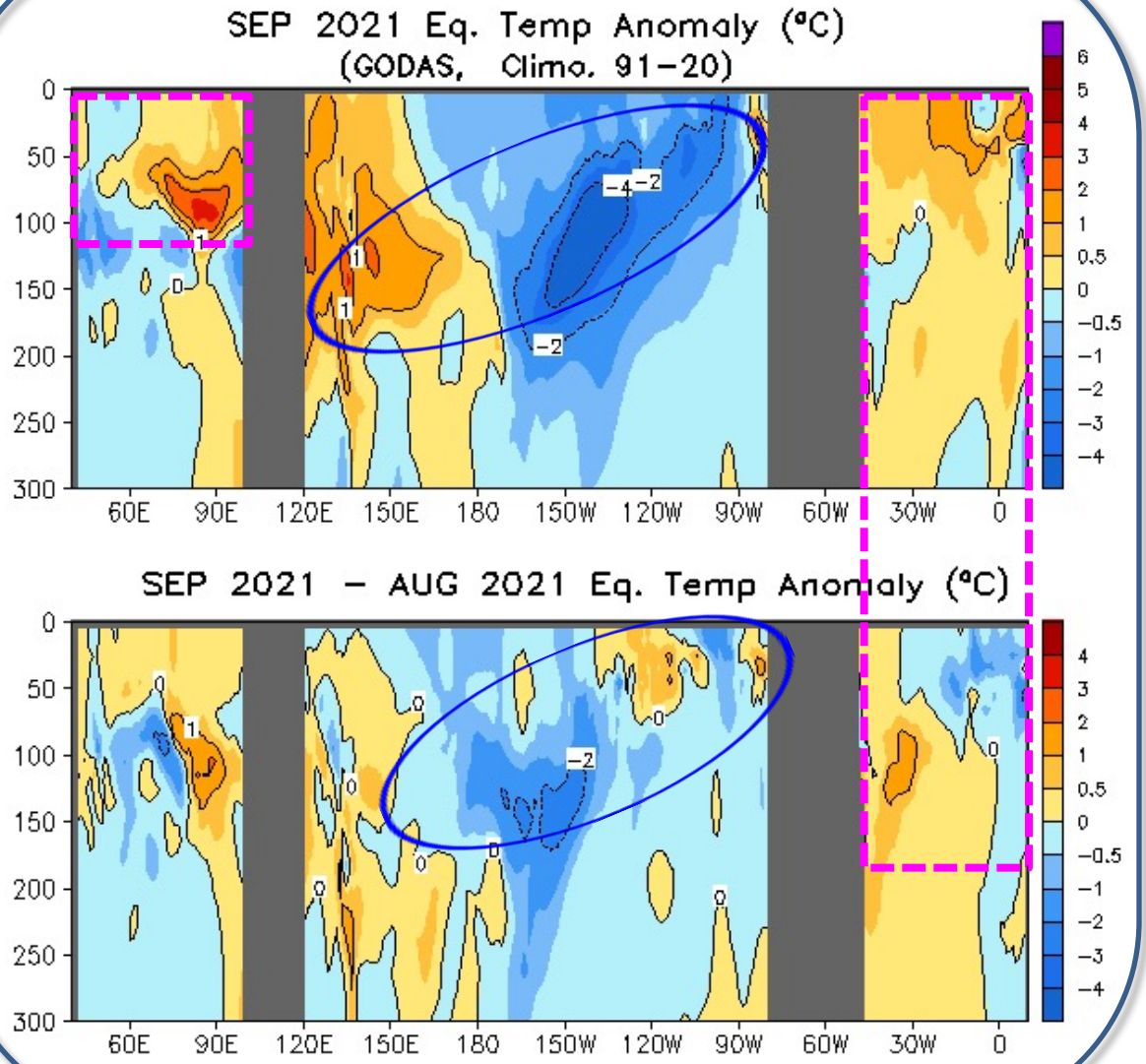


- SSTs were near-to-below(above) average in the central-eastern (western) tropical Pacific Ocean.
- Strong SSTAs continued in mid-to-high latitude of north Pacific.
- SSTs were above average across most of Atlantic Ocean.

- Negative (positive) SSTA tendencies were present in the far eastern (central-eastern) equatorial Pacific Ocean.
- Negative SSTA tendency was present in the equatorial Atlantic Ocean and along the west coast of Africa.
- 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



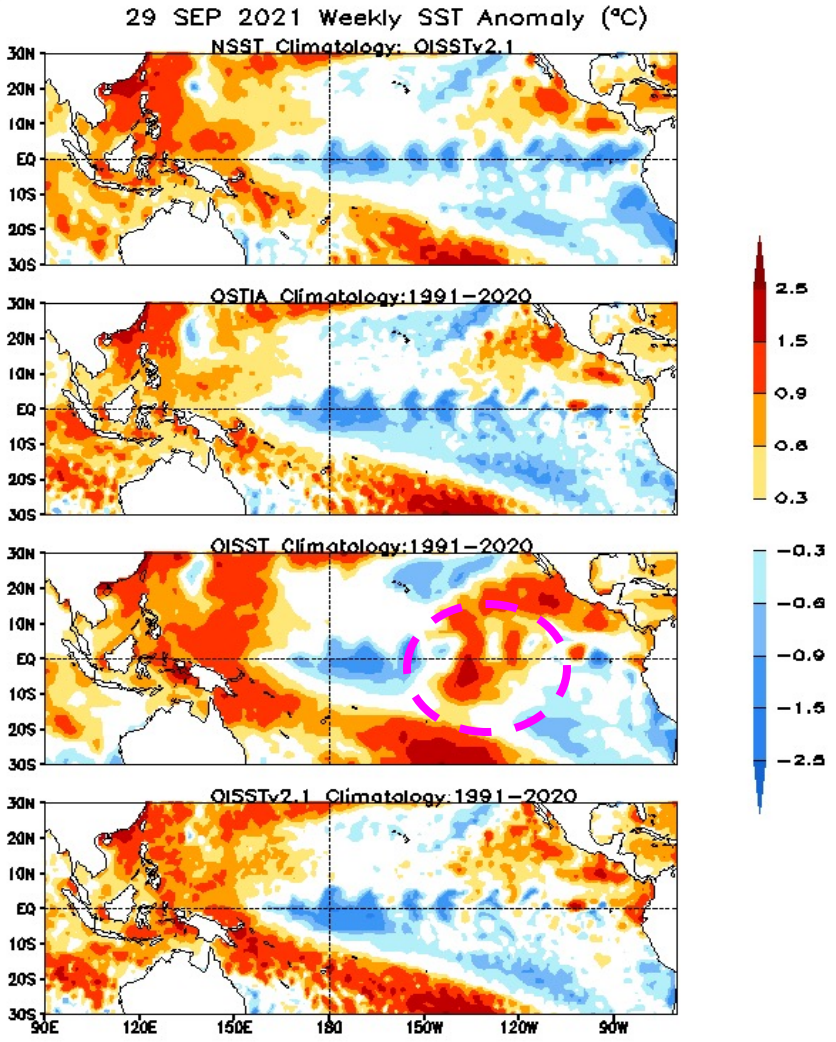
- Strong negative subsurface temperature anomalies were present along the central-eastern thermocline in the Pacific Ocean.
- Positive anomalies weakened in the eastern equatorial Atlantic Ocean, associated with the decayed Atlantic Niño event.
- Positive subsurface anomalies persisted in the eastern Indian Ocean.

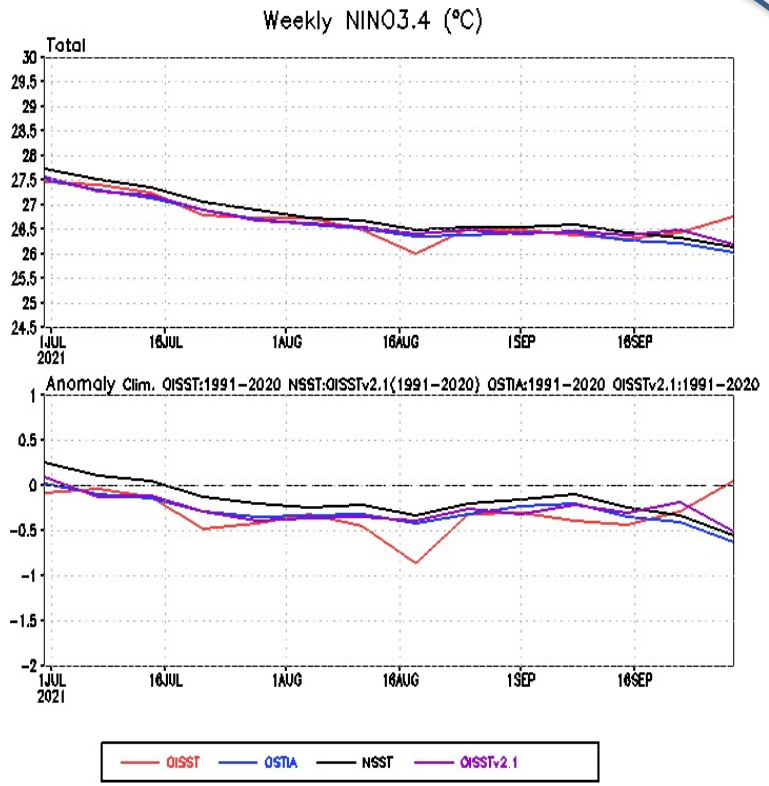
- Subsurface temperature anomaly tendencies were fairly localized near the thermocline in the equatorial Pacific.
- Negative (positive) temperature anomaly tendency was observed in the eastern (western) Atlantic Ocean.

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

Large Uncertainty in SST Products



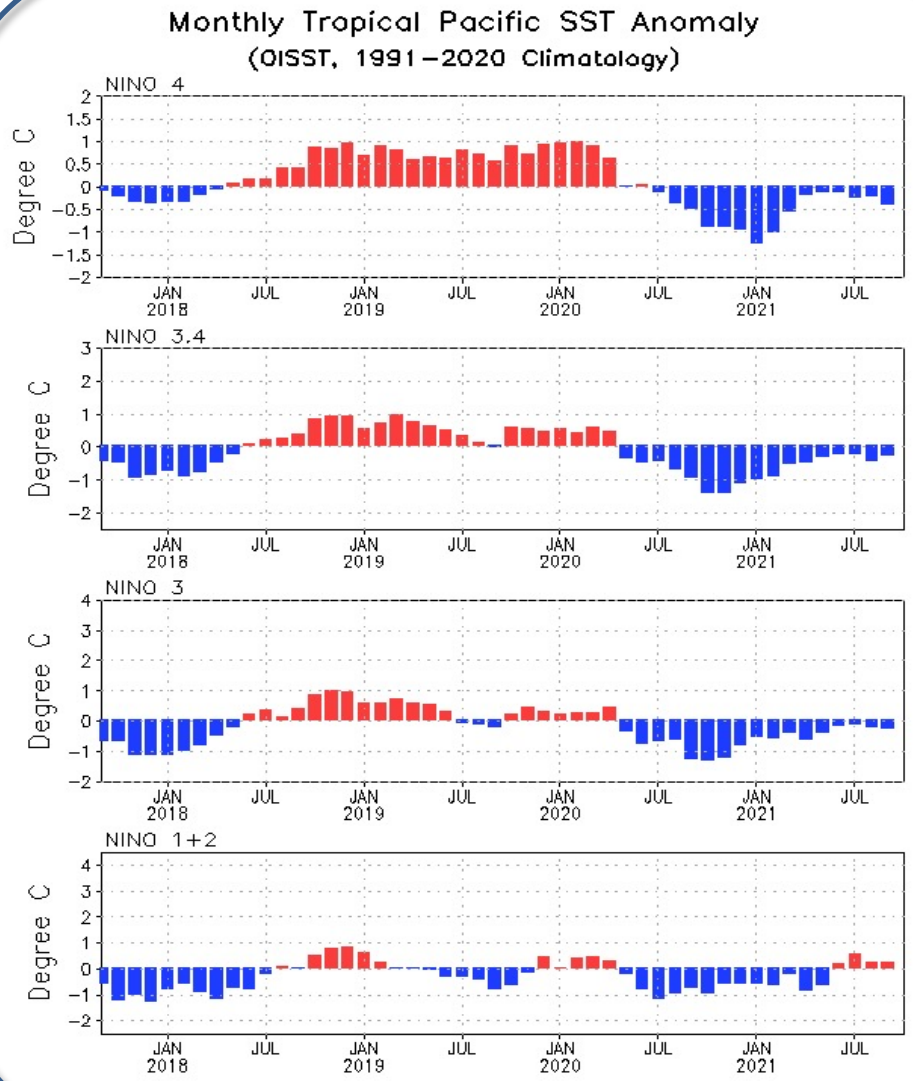


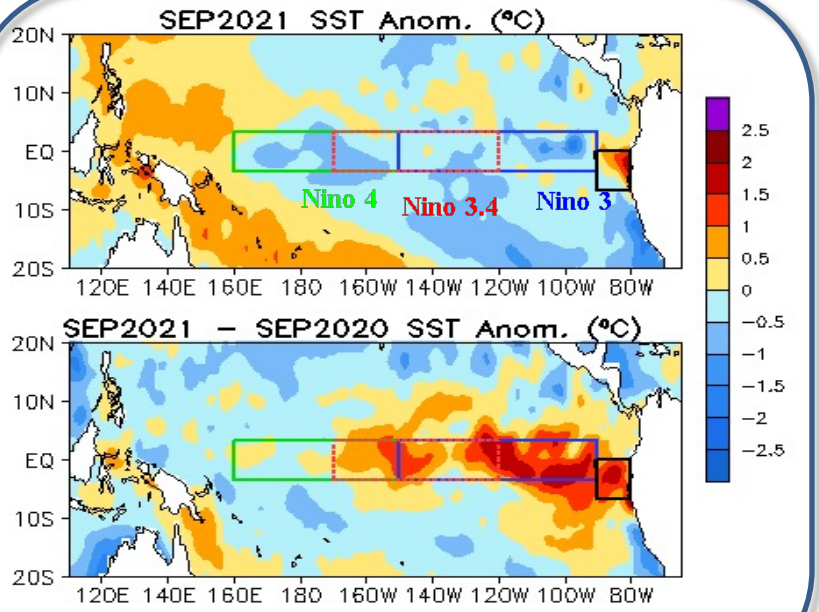
- Large difference between weekly NCEP OISST anomalies and other SST products are present in the eastern Pacific .

- NCEP OISST had been the official SST product for CPC Weekly ENSO update until Oct, 4, 2021.

- NCEI OISSTv2.1 is the currently the official SST product for CPC Weekly ENSO update since Oct 11, 2021.

Evolution of Pacific Niño SST Indices





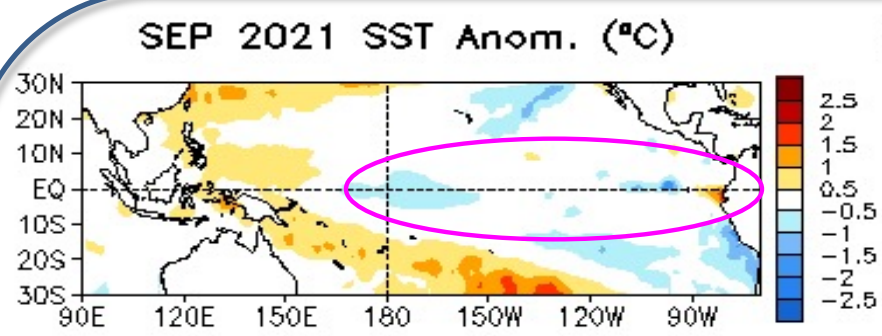
- Negative Niño3.4 decreased slightly in Sep 2021, with NINO3.4 = -0.3°C .

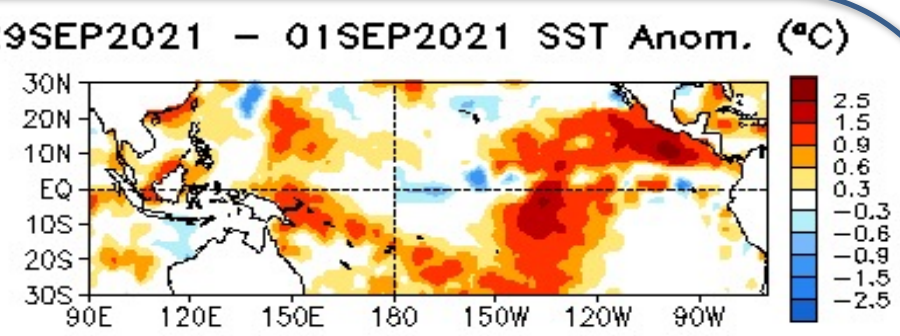
- Compared with Sep 2020, the central and eastern equatorial Pacific was warmer in Sep 2021.

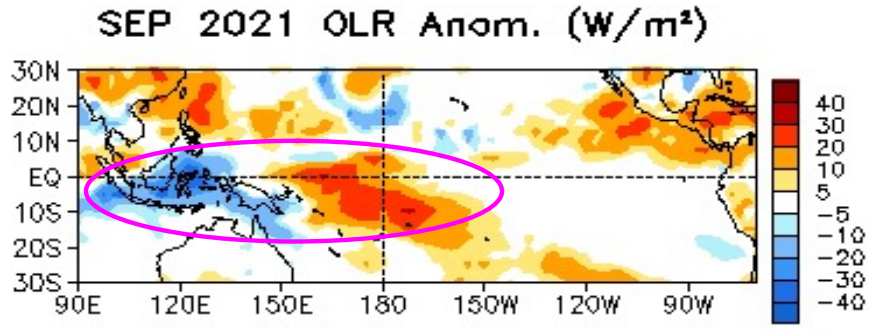
- The indices may have slight differences for different SST products.

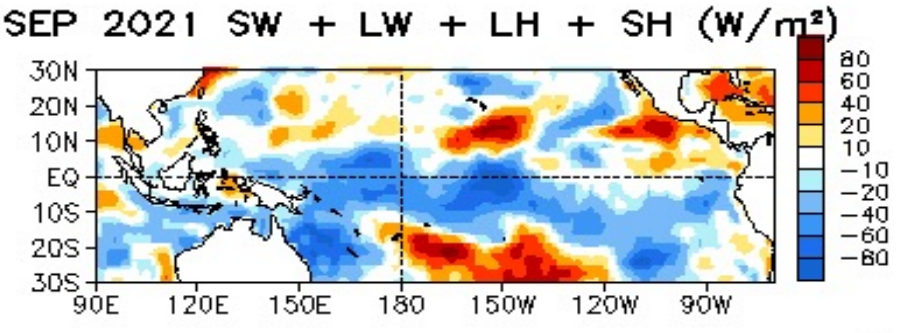
Niño region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means.

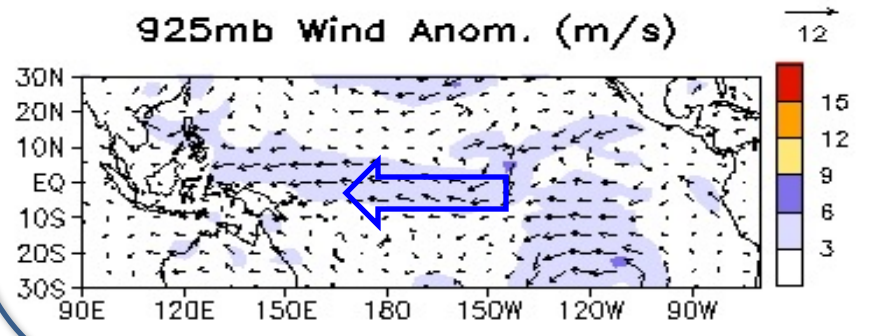
Tropical Pacific: SSTA, SSTA Trend, OLR, heat flux, uv925 & uv200 anomalies

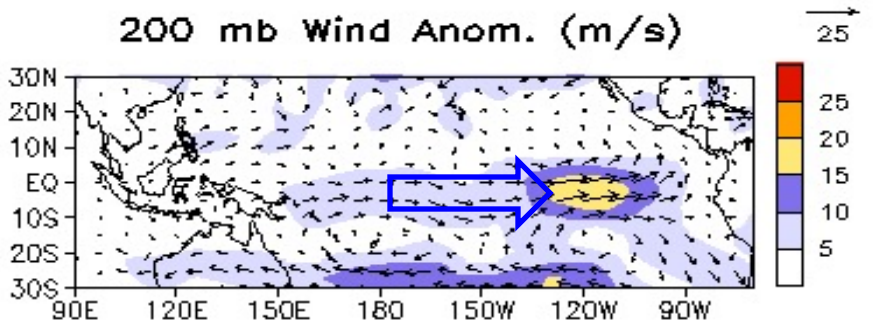






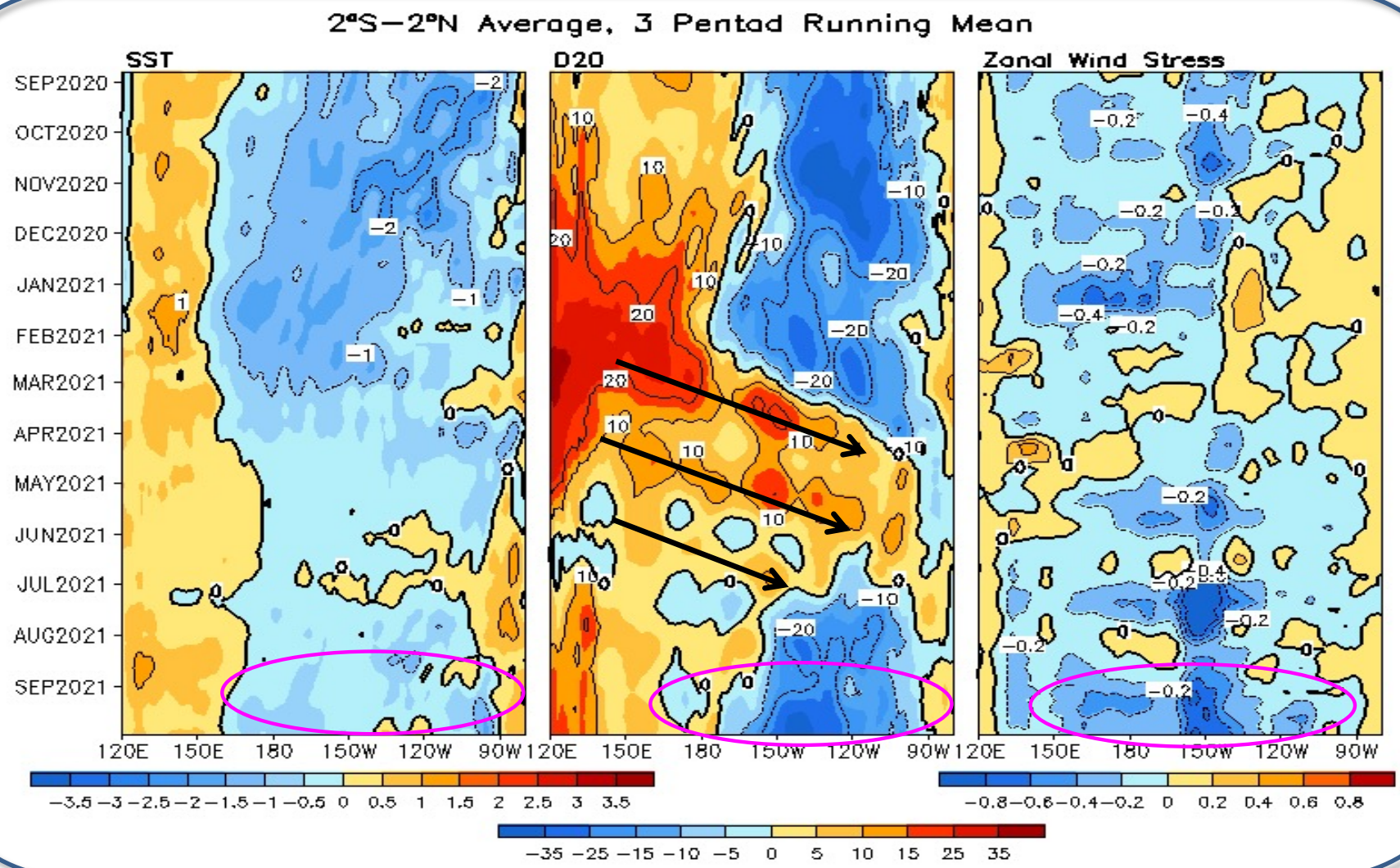






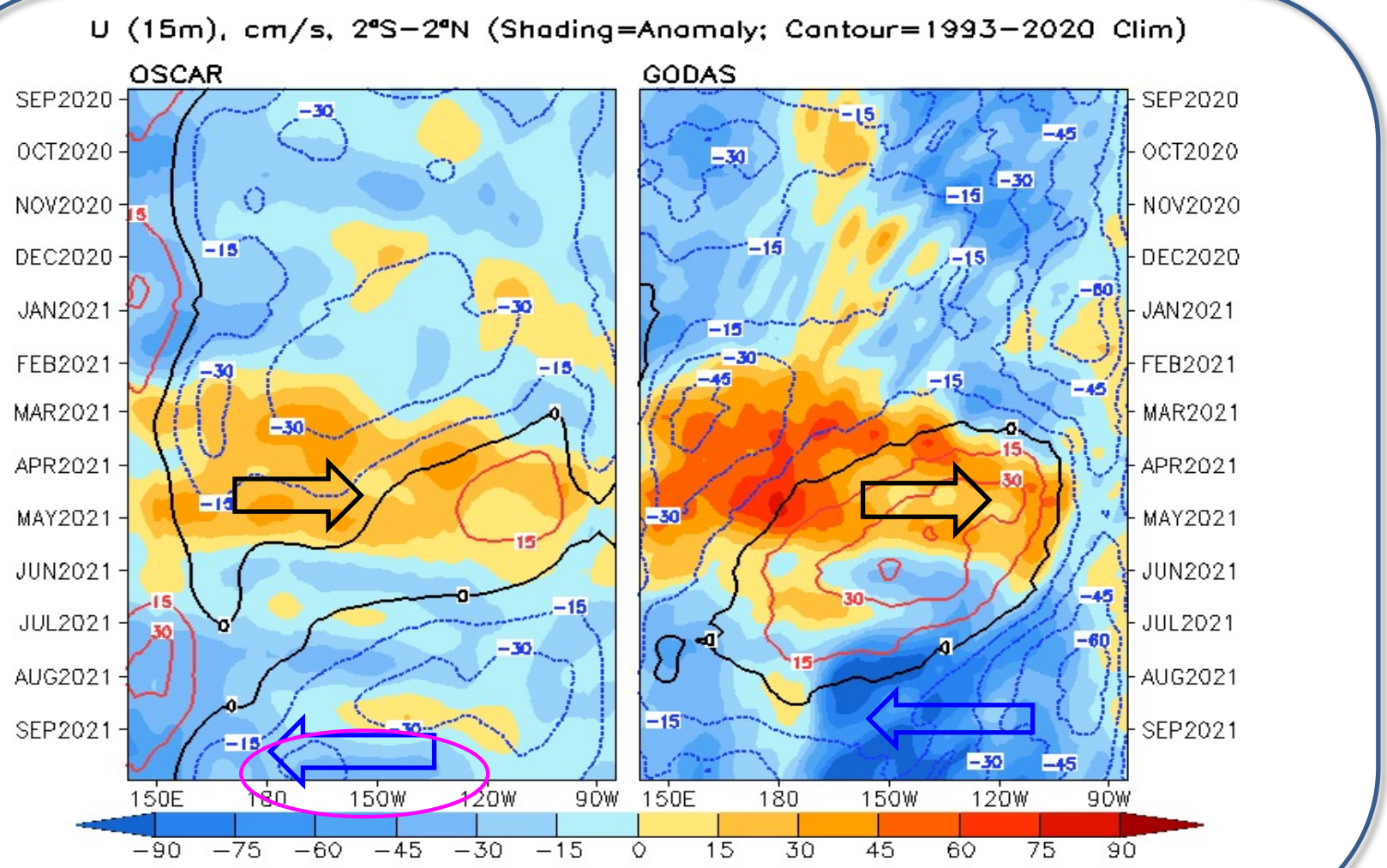
Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly 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), D20 (m), zonal wind stress (dyn/cm ^{2}) Anomalies



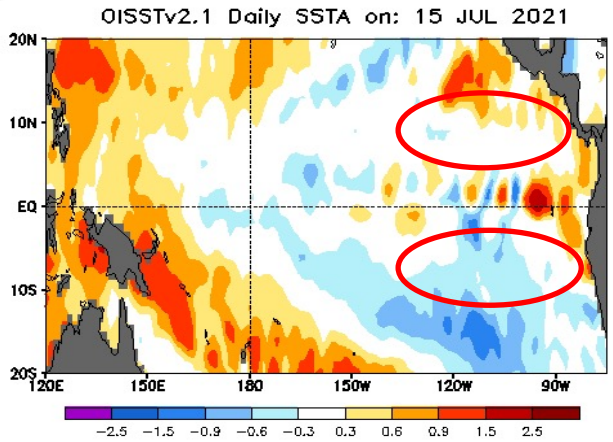
- Negative D20 anomaly enhanced in the central-eastern Pacific in Sep 2021, consistent with strengthening of easterly trade winds.

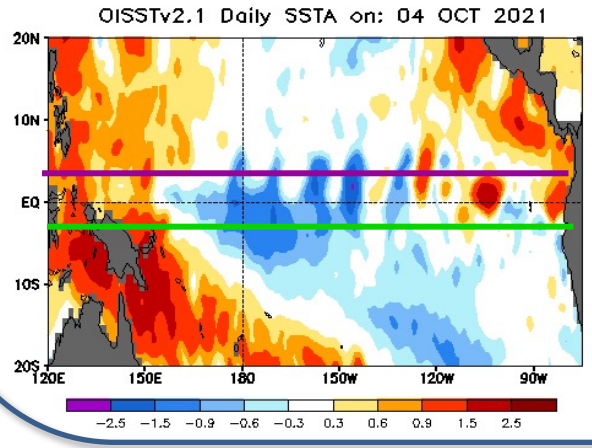
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)

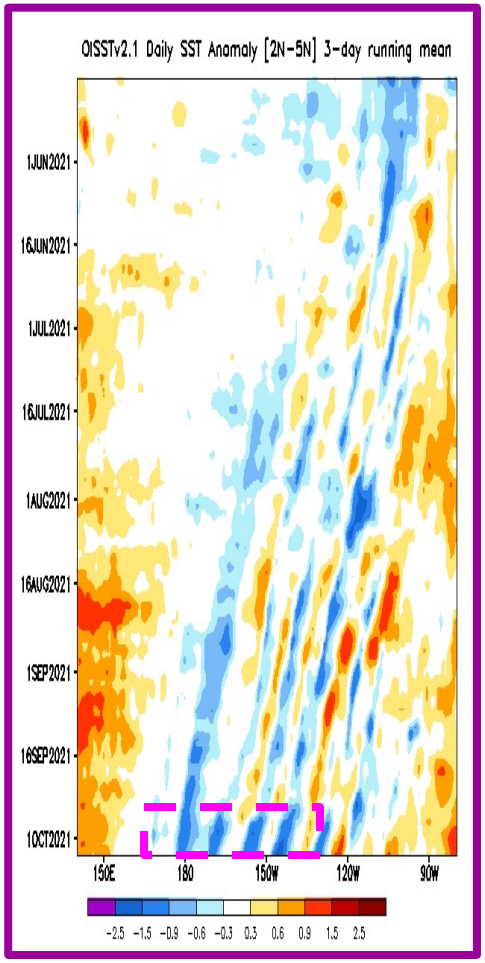


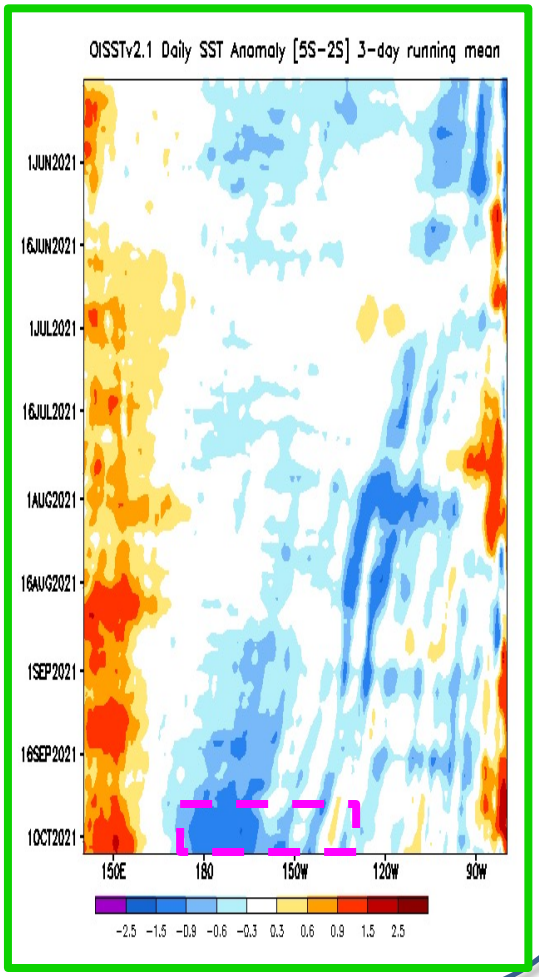
- Strong anomalous westward currents has persisted most of the equatorial Pacific in GODAS since Jul 2021, while OSCAR data was dominated by subseasonal variations.
- Anomalous westward currents were present most of the equatorial Pacific in both OSCAR and GODAS in Sep 2021, favoring of SST cooling.

Tropical Instability Waves (TIWs) activities



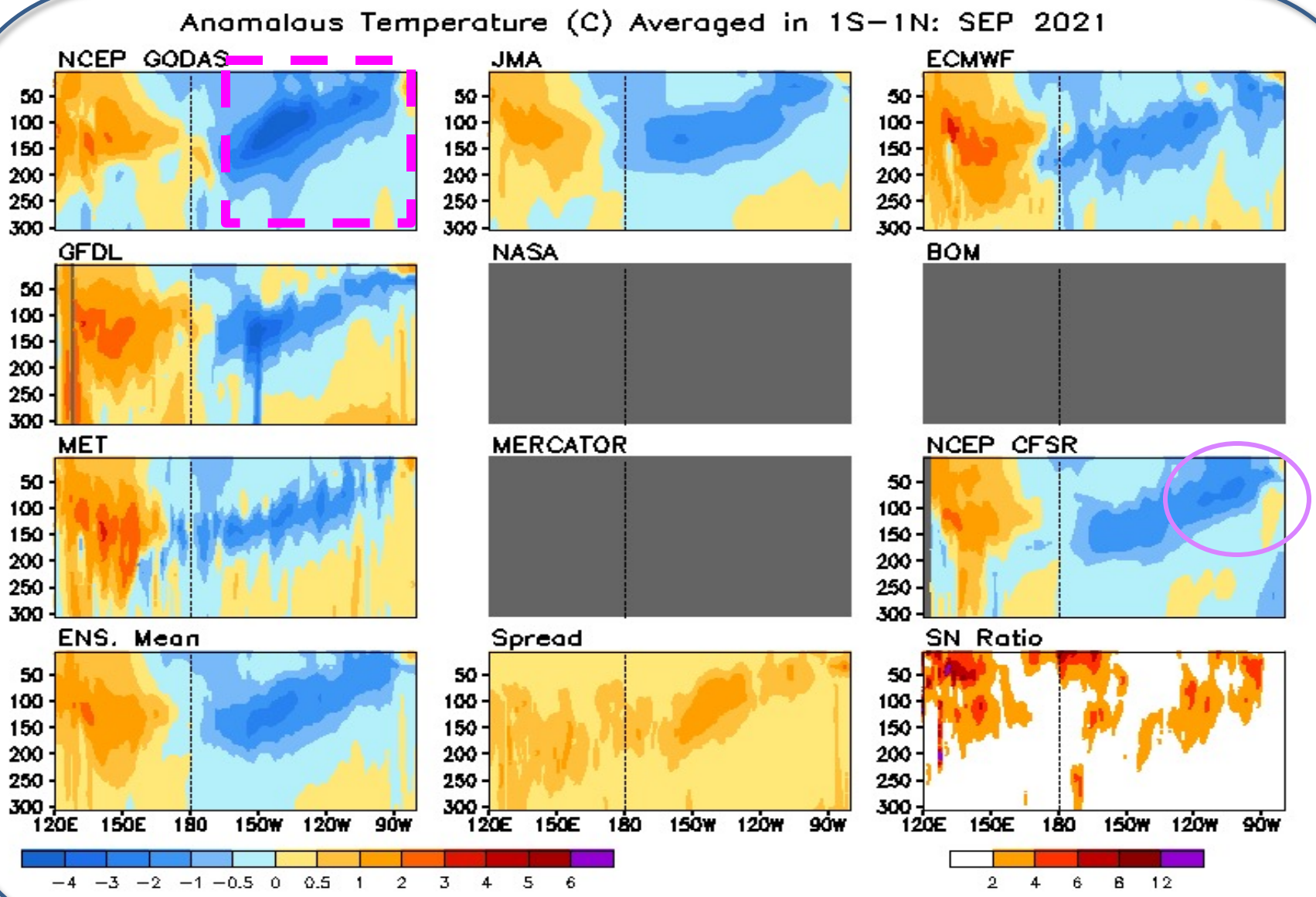




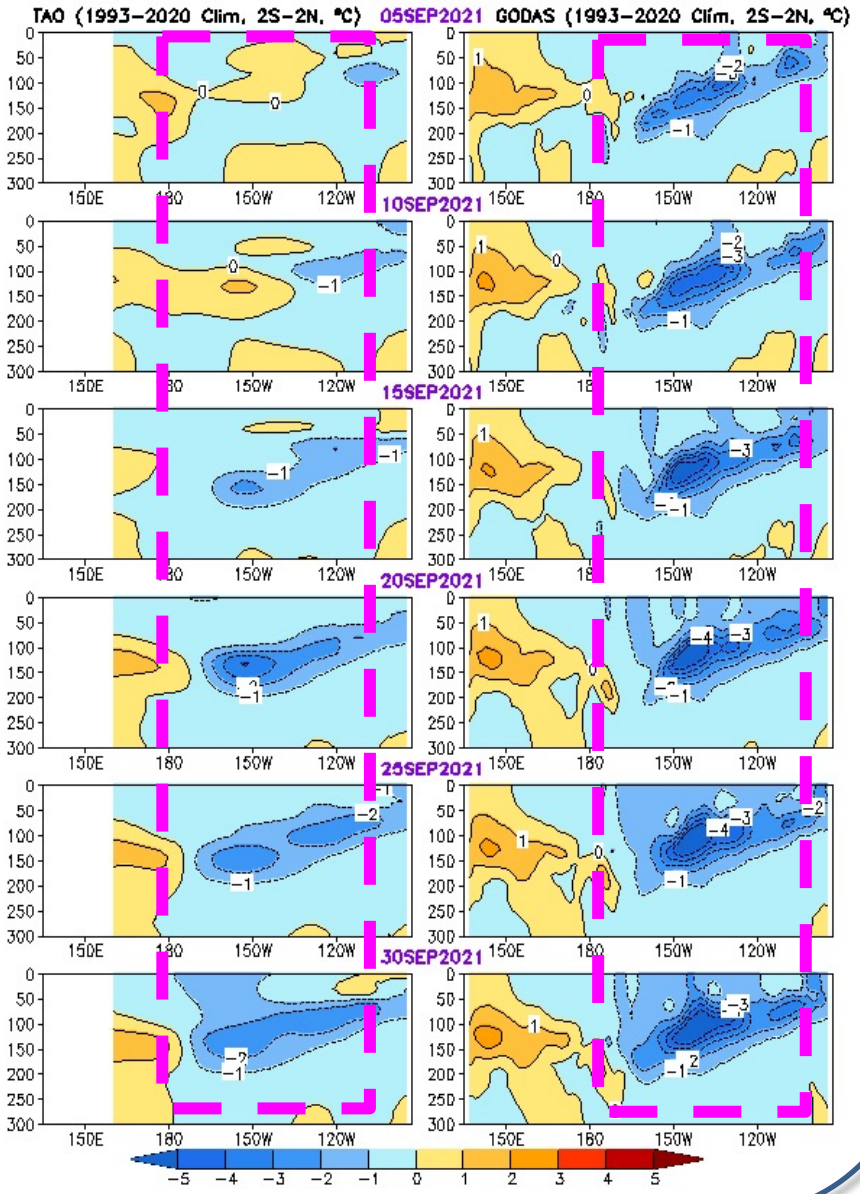


- Negative SSTA were generally located just to the south of the equator, consistent with asymmetric SSTA signals carried by TIWs in the northern and southern hemispheres.
- TIWs played an important role in hinder 2016 La Niña development by transporting off-equatorial heat into the Pacific cold tongue (Xue et al. (2021))

Multiple Ocean Reanalysis: Temperature anomaly at Equator

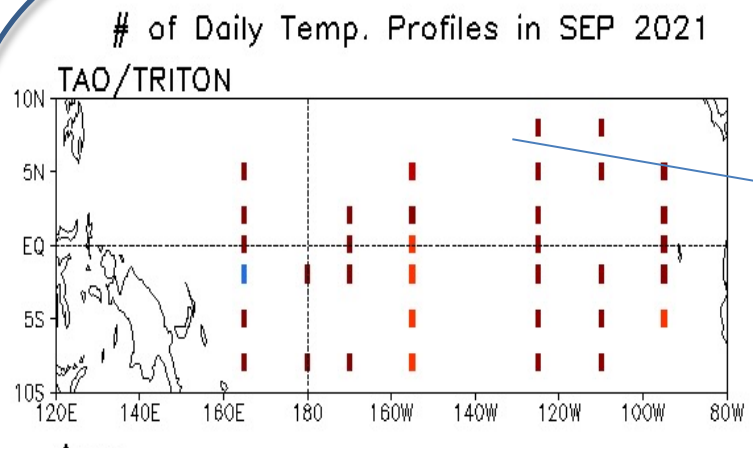


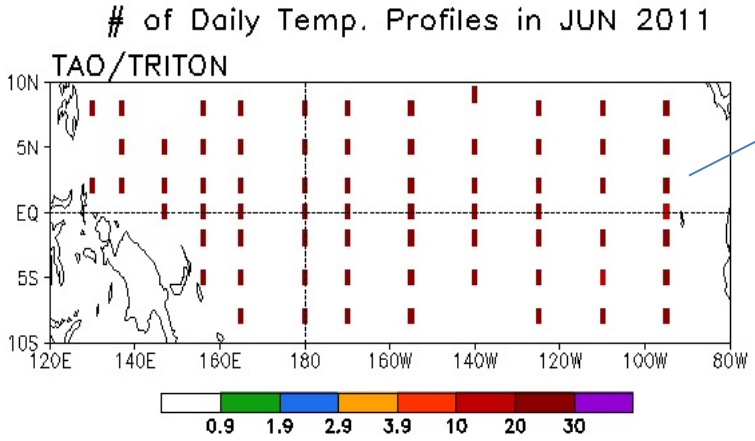
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

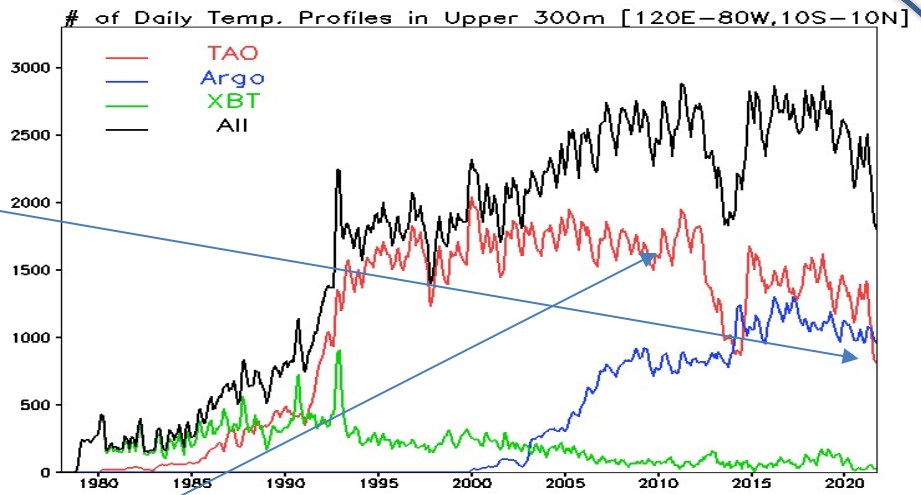


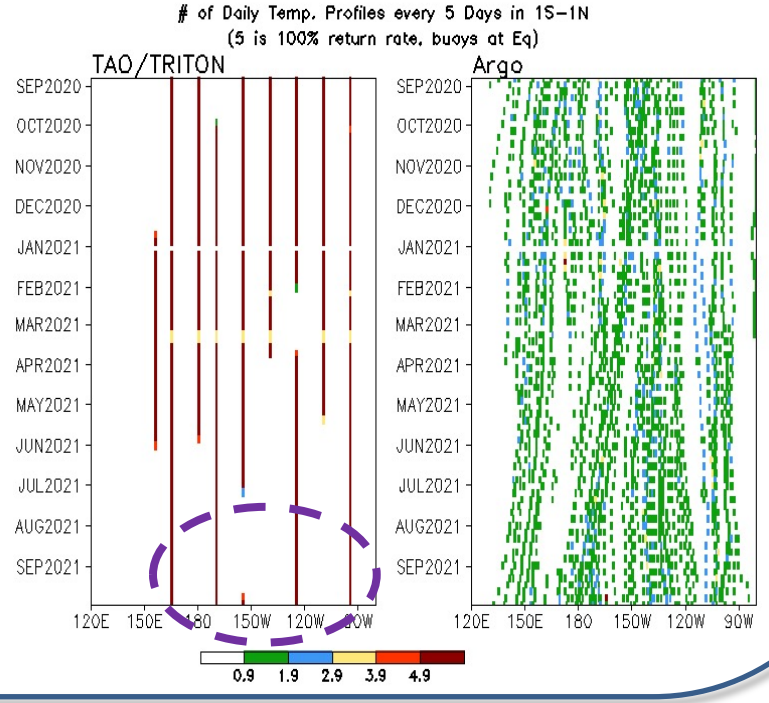
- Subsurface cooling east of 170W in GODAS was much stronger than in TAO.
- Large difference between TAO and GODAS was partially associated with the missing TAO data near the equator (next slide) that potentially affects the TAO and GODAS analysis.

Potential Impact of Missing TAO DATA on GODAS





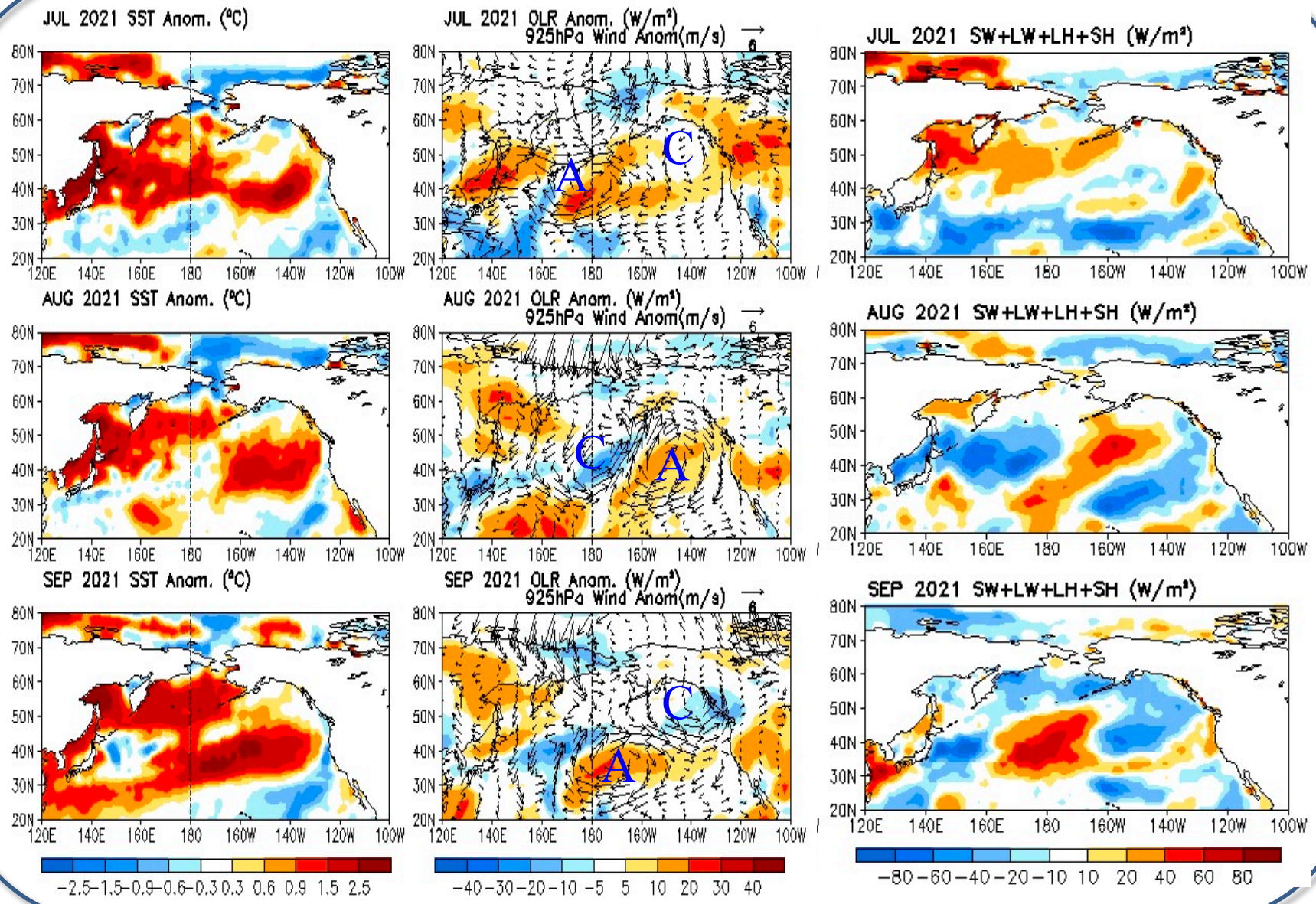




- TAO array declined significantly since March 2021 and TAO mooring profiles number is close to the historical low during 2013-2014.

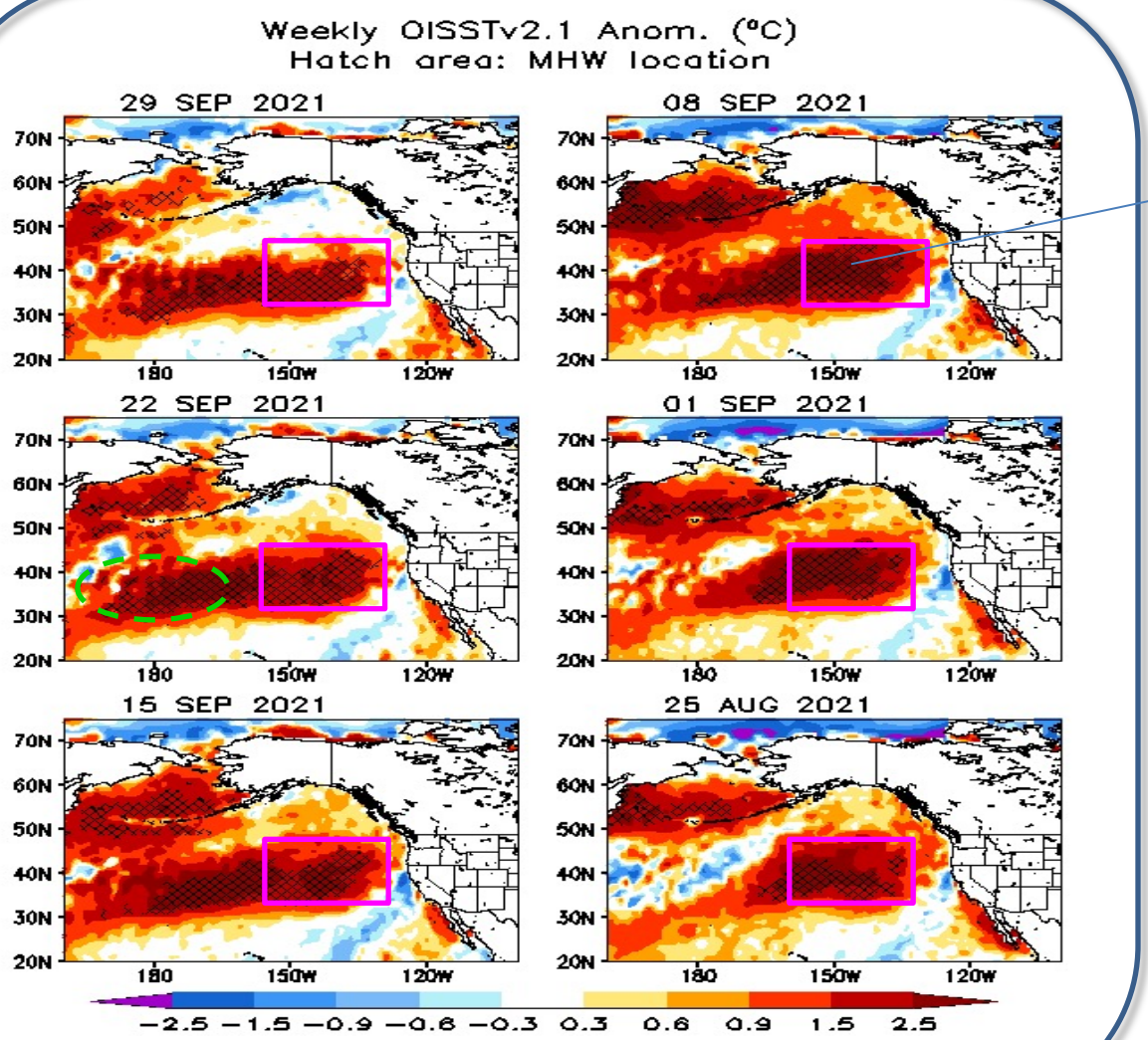
North Pacific & Arctic Oceans

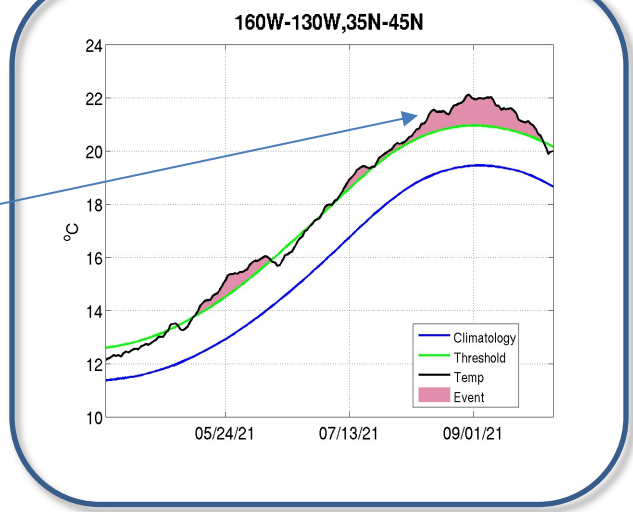
Latest 3-month North Pacific SST, OLR & uv925 anomalies



Data source: NCEP/NCAR Reanalysis 1

Weekly SST anomaly and MHWs in the North Pacific



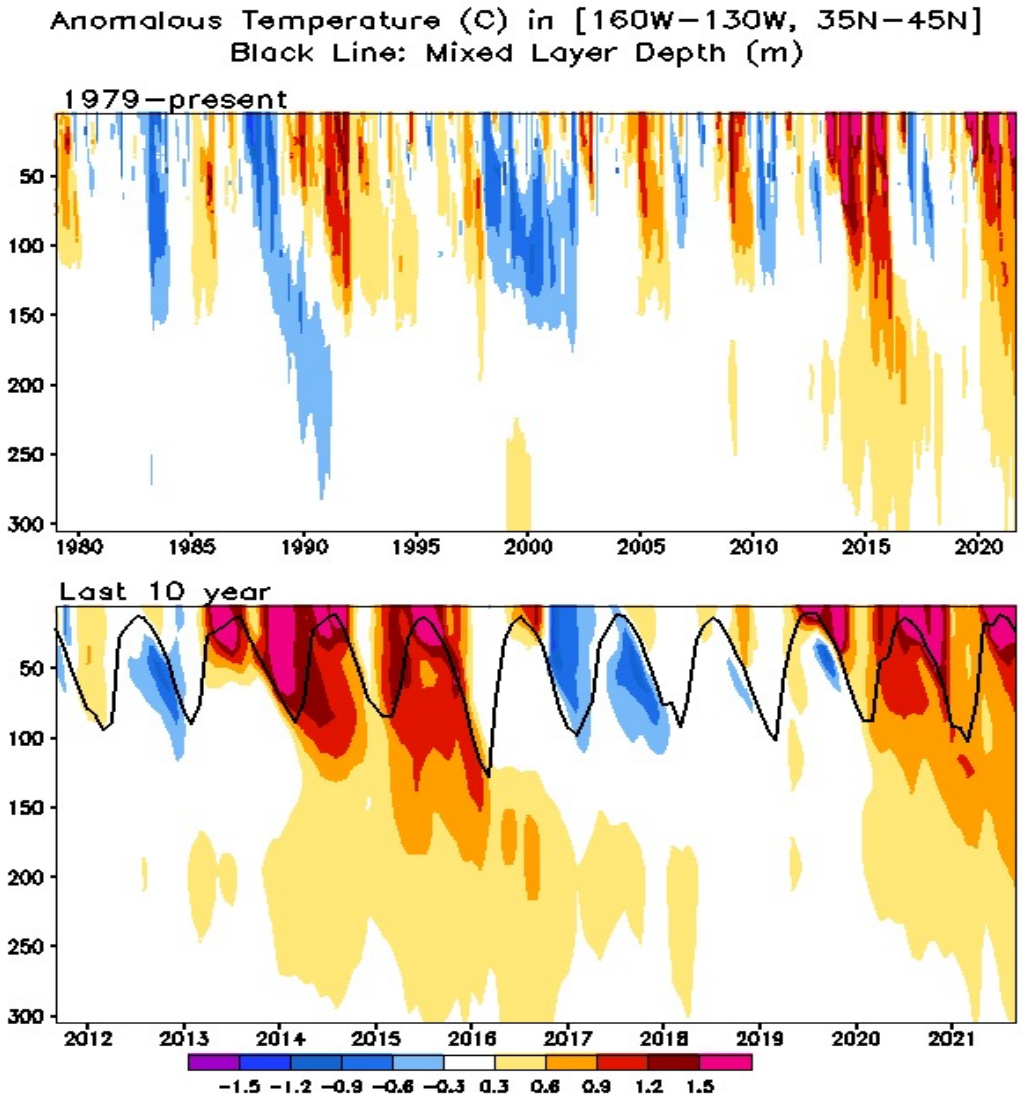


- MHWs were observed in the N.E Pacific since early July and continue to expand westward to date line in Sep 2021.

-MHWs persisted in N.W Pacific.

(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 1982-2010.

Subsurface Temperature Anomaly in N.E. Pacific



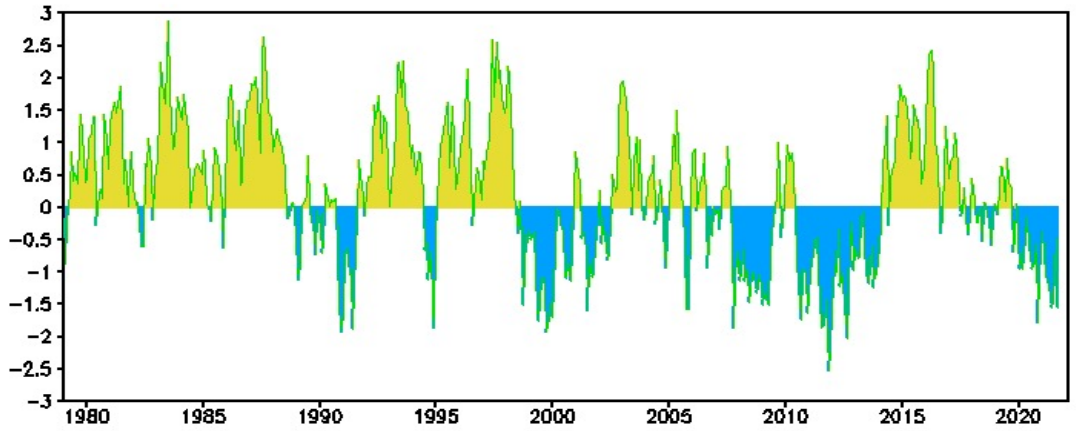
- Positive subsurface temperature anomaly in the N.E Pacific has persisted since 2019.

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

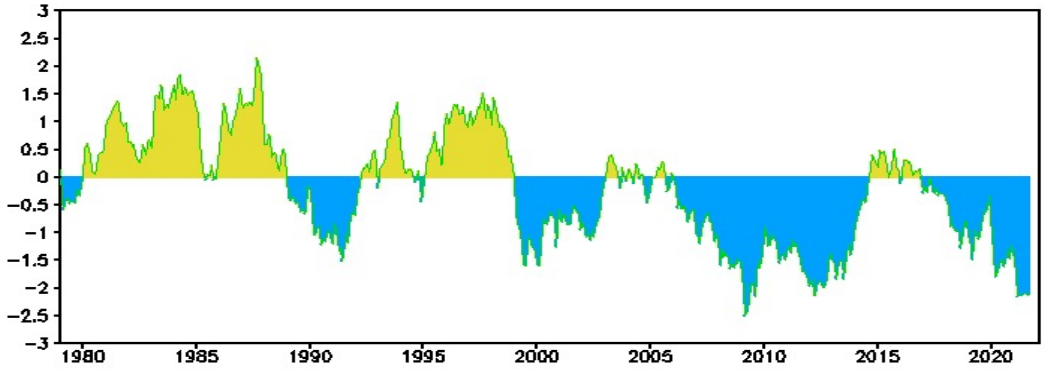
Data source: NCEP GODAS

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 Sep 2021, with PDOI = -1.6.

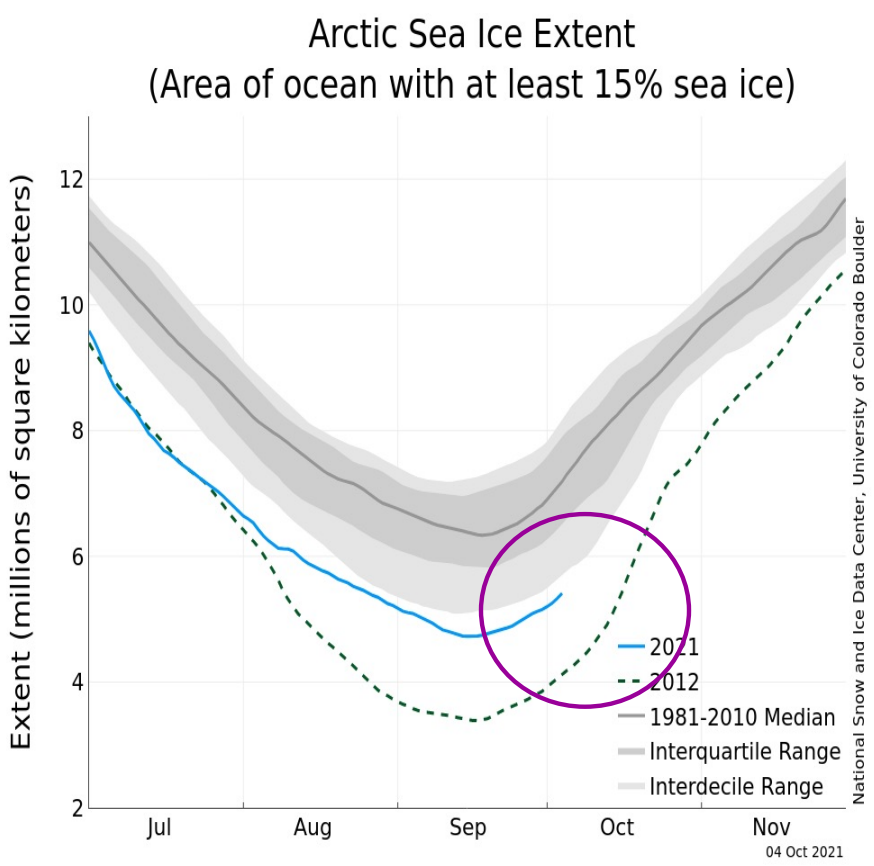
- Negative H300-based PDO index has persisted 60 months since Nov 2016, with HPDO = - 2.1 in Sep 2021.

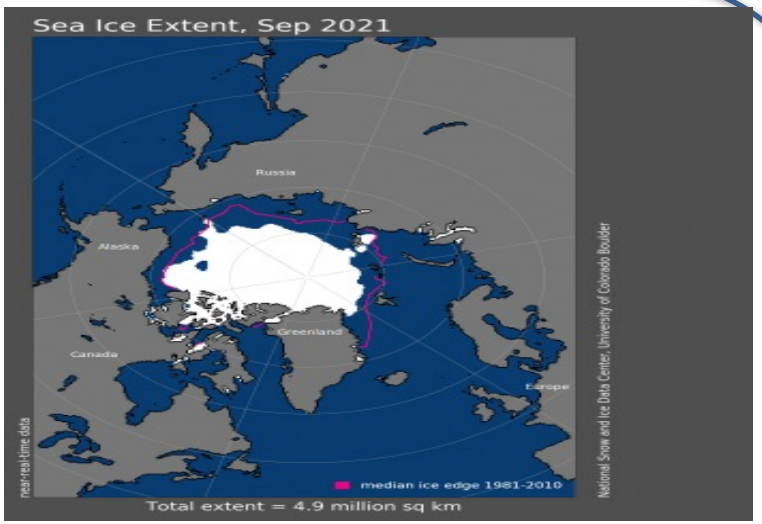
- SST-based PDO index has considerable variability both on seasonal and decadal time scales.

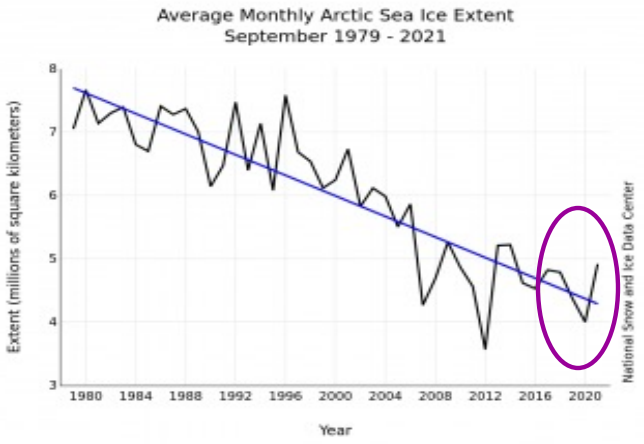
- H300-based PDO index highlights the slower variability and encapsulates an integrated view of temperature variability in the upper ocean.

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)

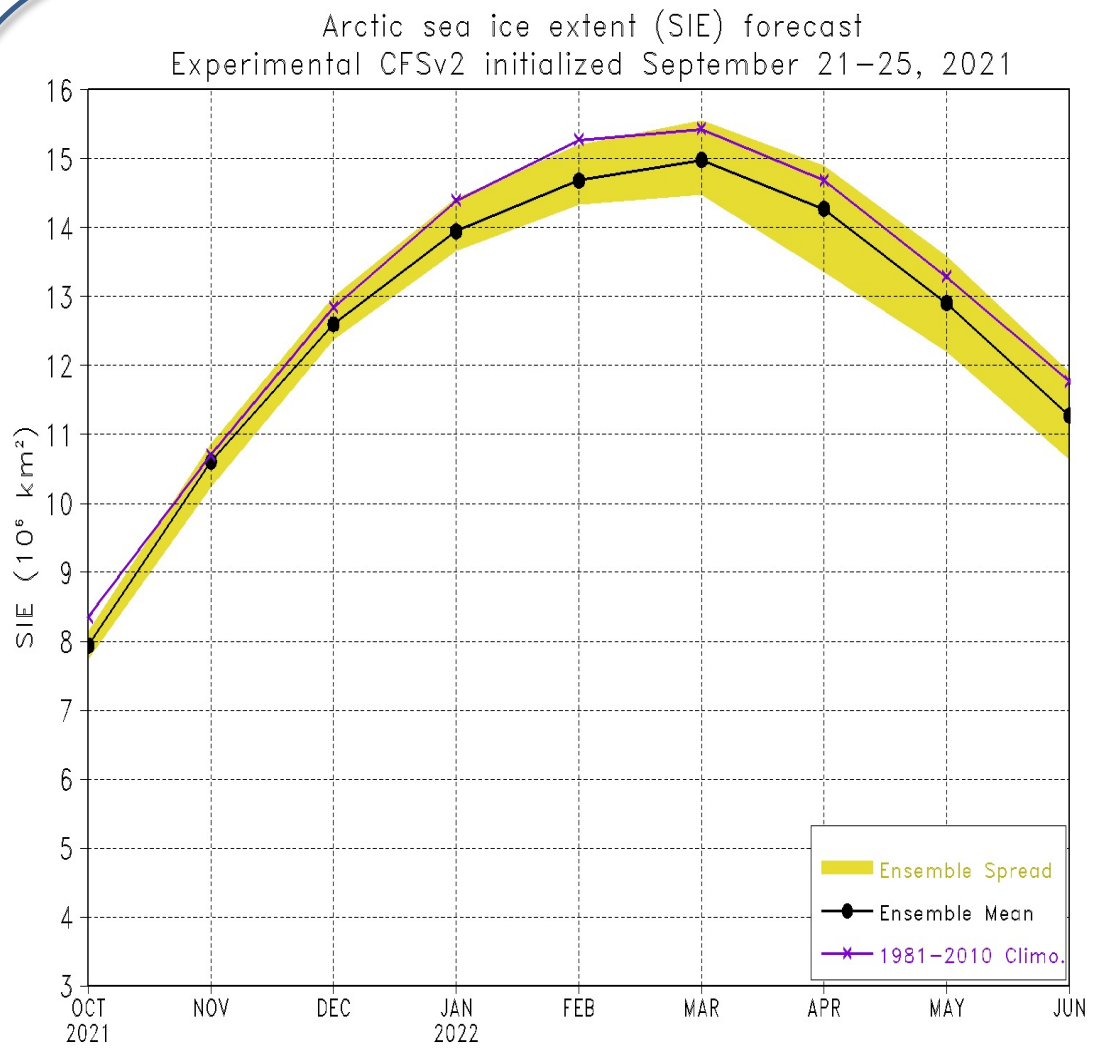






- The monthly average extent for September 2021 was 4.92 million square kilometers and it ranks the twelfth lowest in the satellite record.

NCEP/CPC Arctic Sea Ice Extent Forecasts

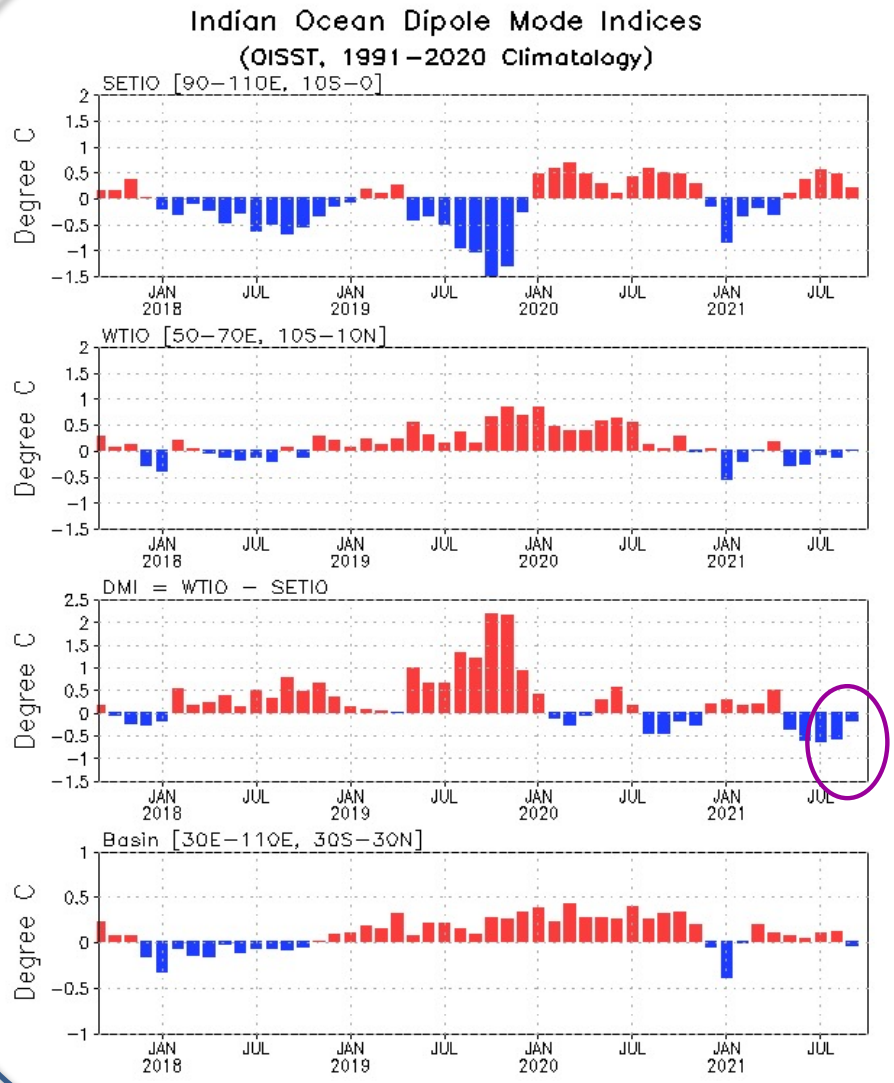


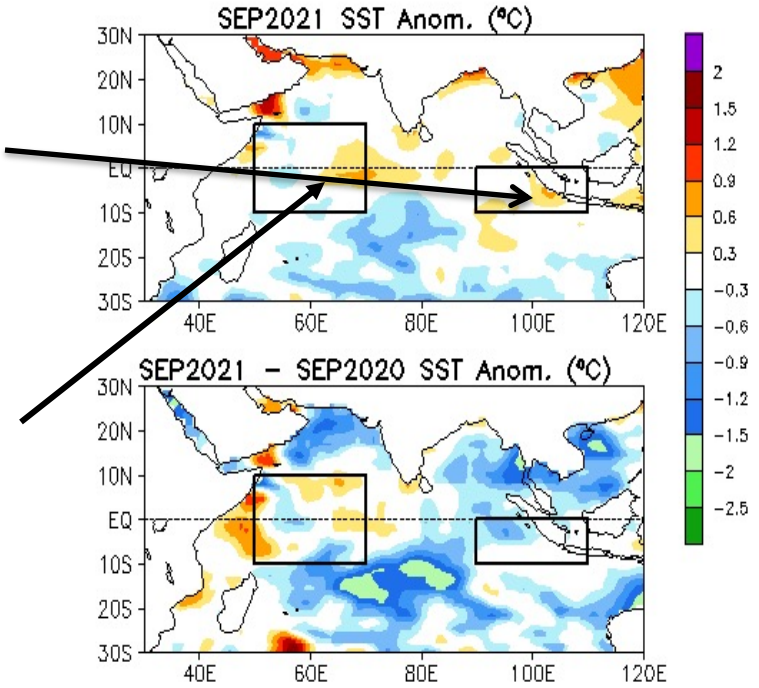
- For ICs in Sep 2021, NCEP/CPC model predicted the 2022 sea ice extent maximum will be slightly below climatology.

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

Indian Ocean

Evolution of Indian Ocean SST Indices

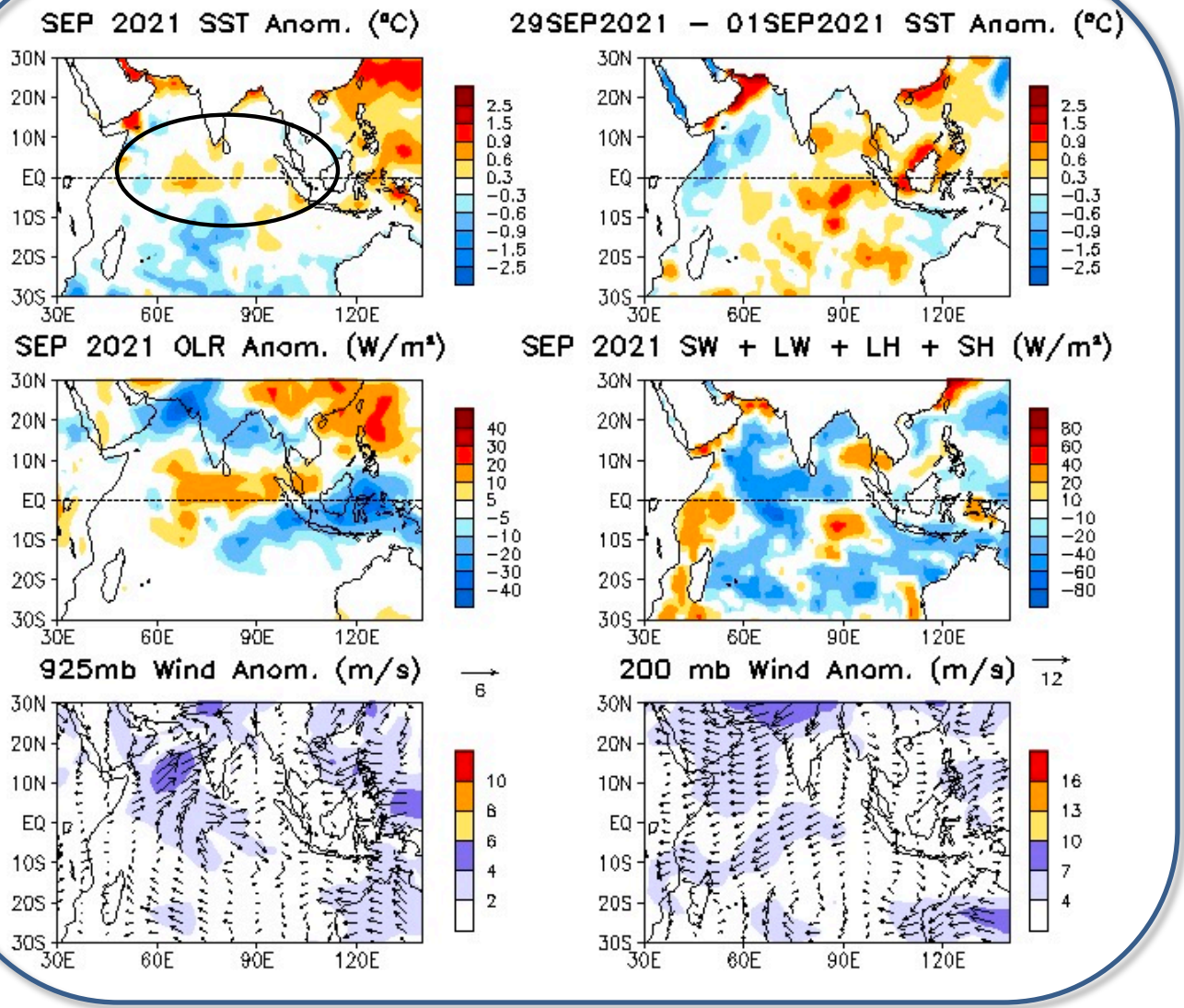




- Negative Indian Ocean Dipole Mode index (DMI) dropped within the neutral range in Sep 2021, with IODI = -0.2° C.

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

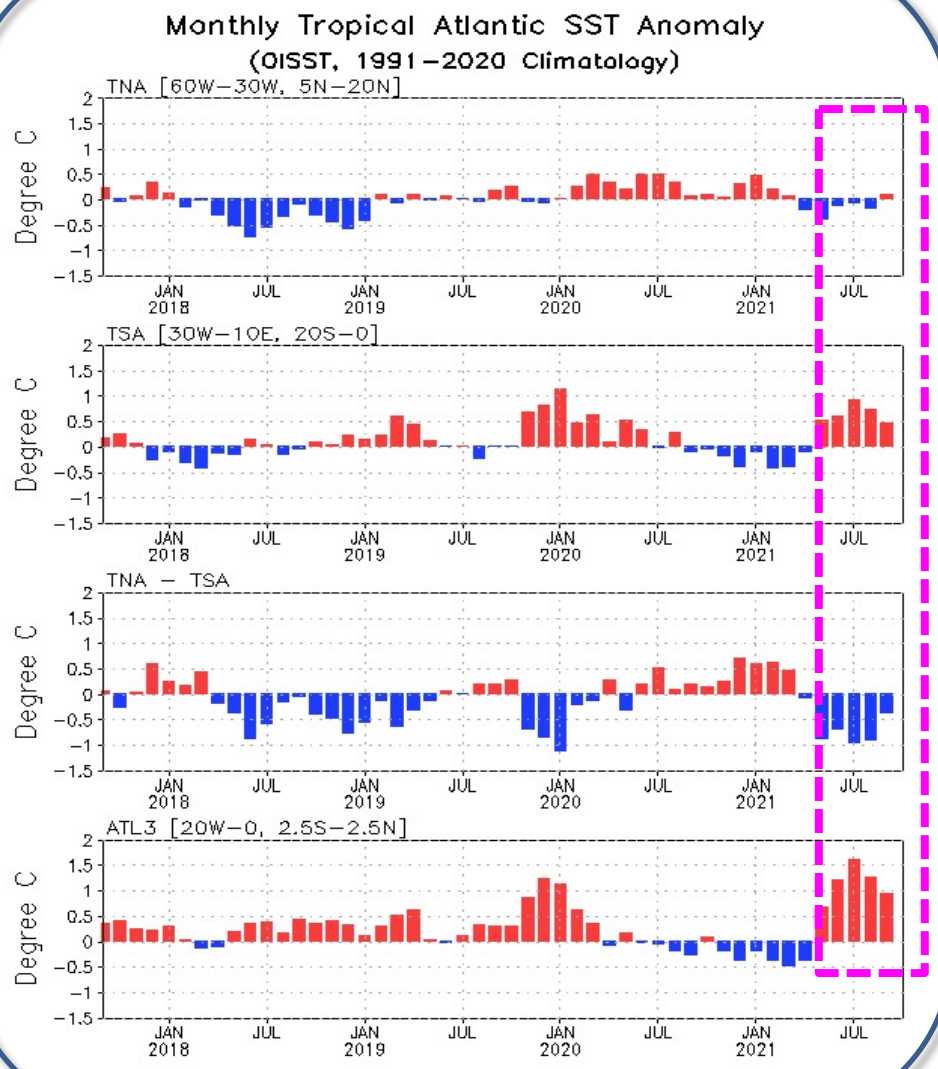


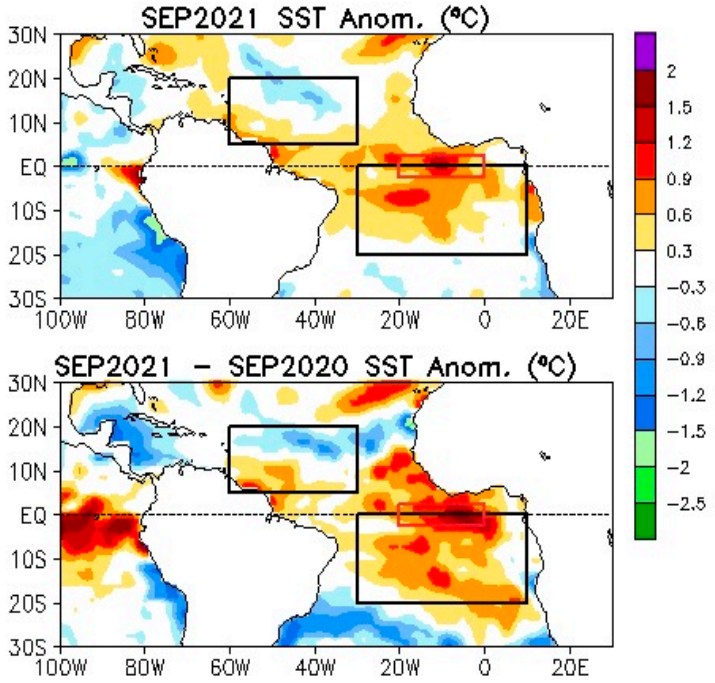
- SSTAs were near average in most of tropical Indian Ocean.

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.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

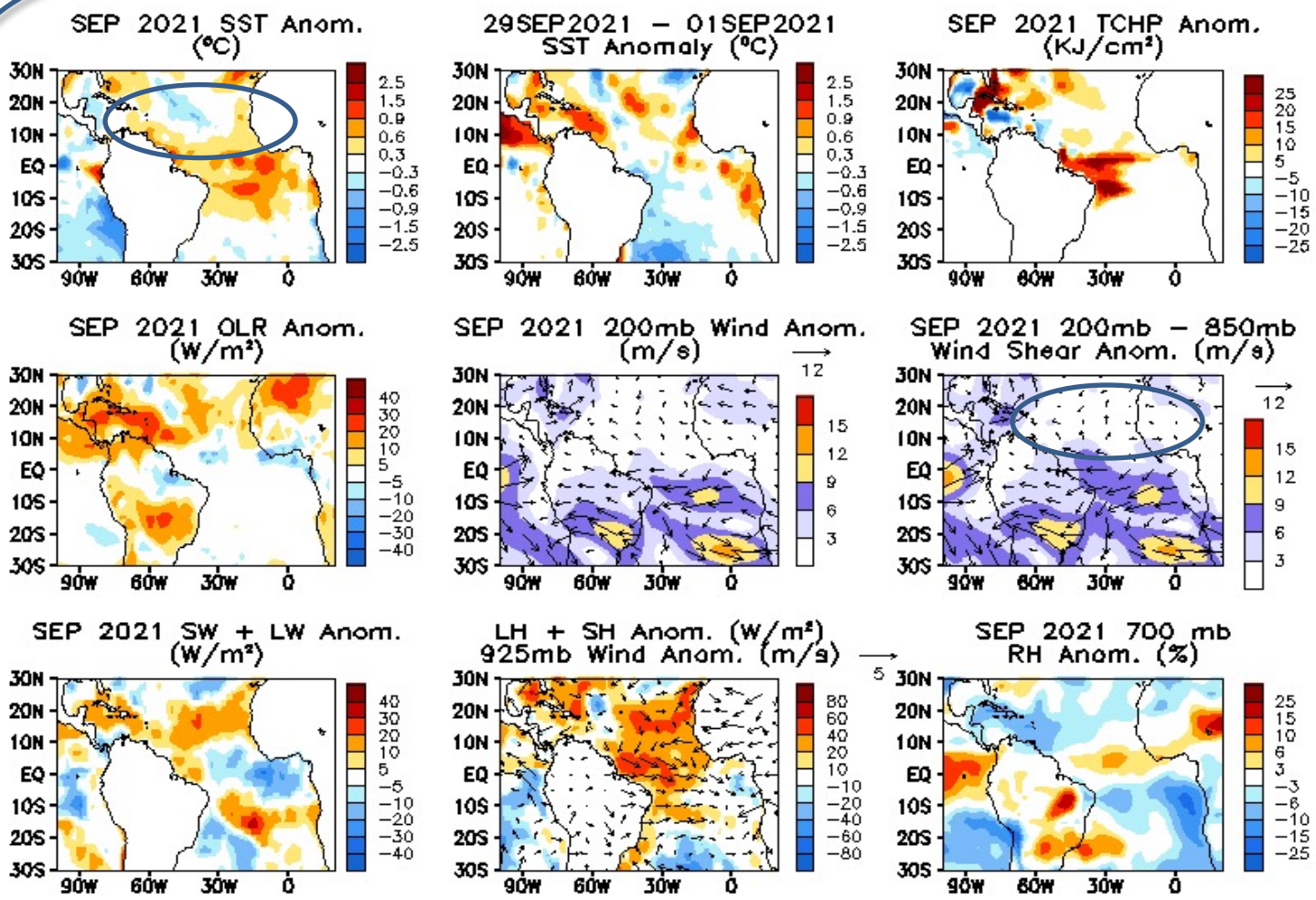




- Negative meridional dipole index weakened in Sep 2021, with MDI = -0.4 °C.
- Positive ATL 3 index continued weakening in Sep 2021, with ATL 3 = 0.9 °C , implying the weakening of Atlantic Niño.

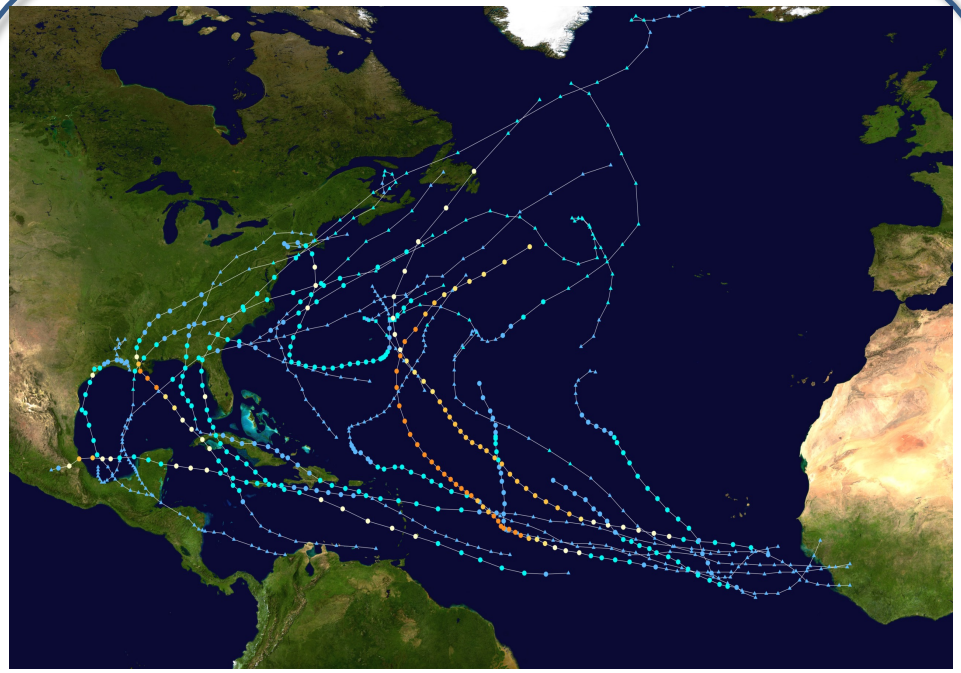
Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5ºN-20°N], TSA [30°W-10°E, 20°S-0] and ATL3 [20°W-0, 2.5°S-2.5°N] regions, and Meridional Gradient Index, defined as differences between TNA and TSA.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

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.

2021 Atlantic Hurricane Season Activities



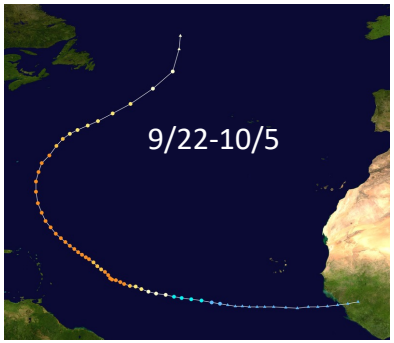
https://en.wikipedia.org/wiki/2021_Atlantic_hurricane_season

- By Oct 6, 2021, twenty tropical storms formed with seven developing to hurricane, and four developing to major hurricanes.

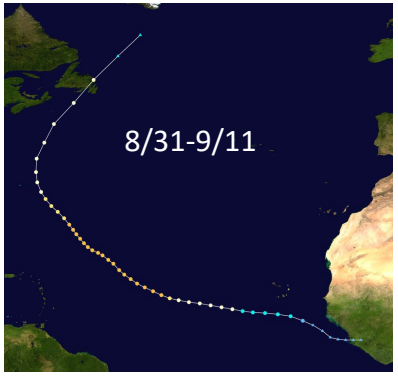
Atlantic	Observations (By Oct 6)	Updated Outlook (Aug 4) 65% above-normal	Outlook (May 21) 60% above-normal	(1991-2020)
Total storms	20	15-21	13-20	14
Hurricanes	7	7-10	6-10	7
Major hurricanes	4	3-5	3-5	3

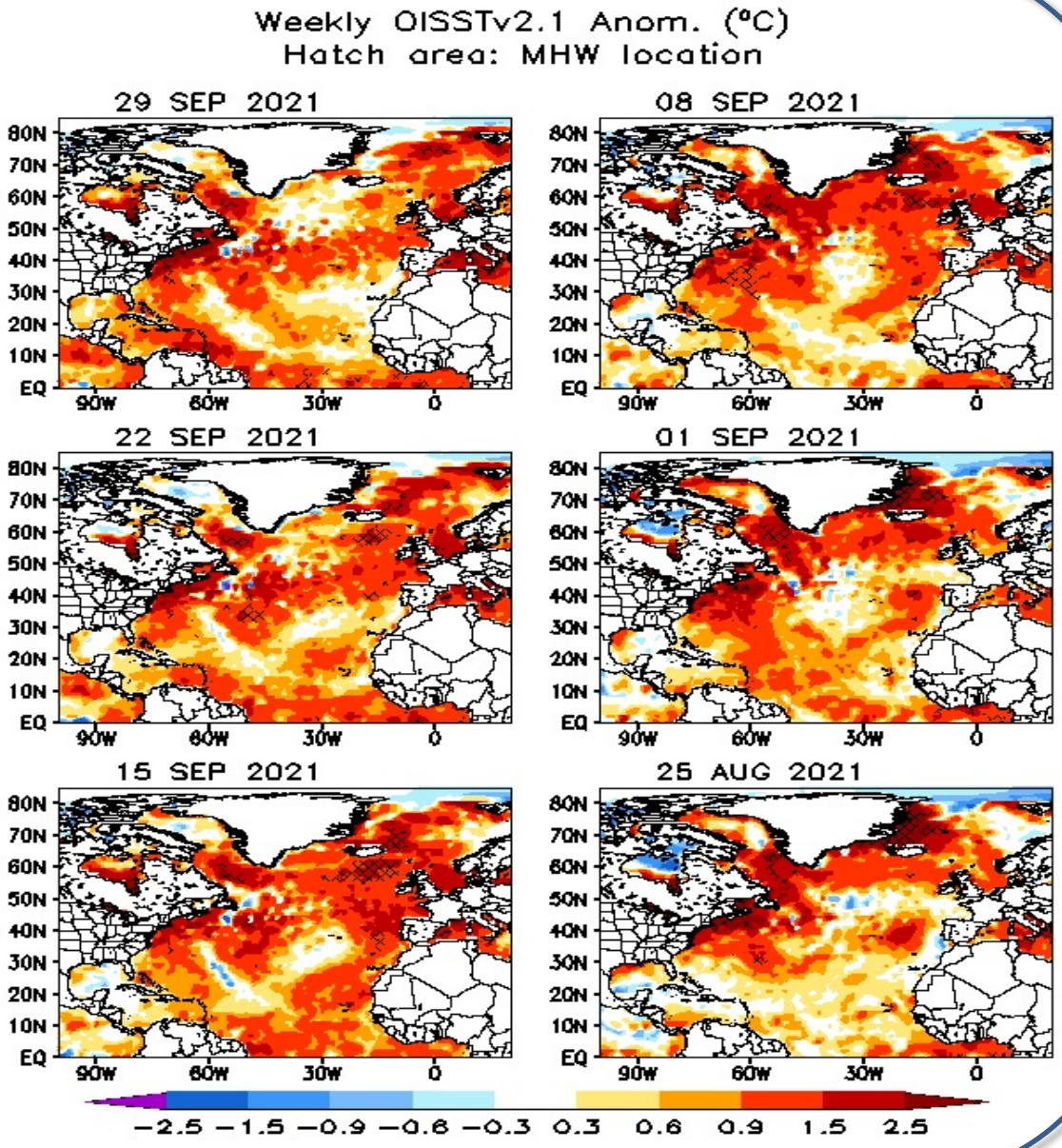
Weekly SST Anomaly and MHWs in the North Atlantic Ocean

Hurricane Sam



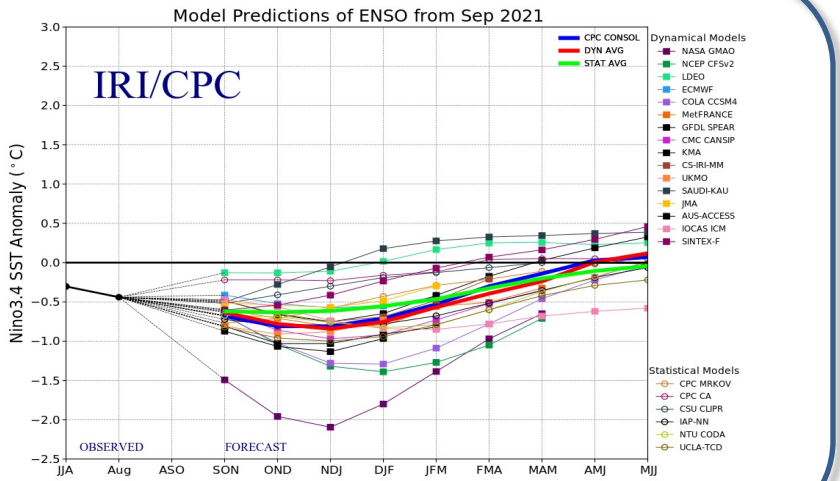
Hurricane Larry

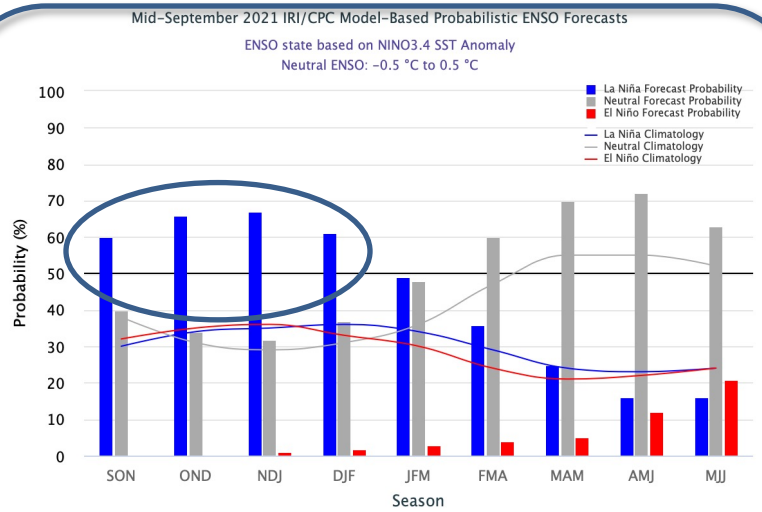




ENSO and Global SST Predictions

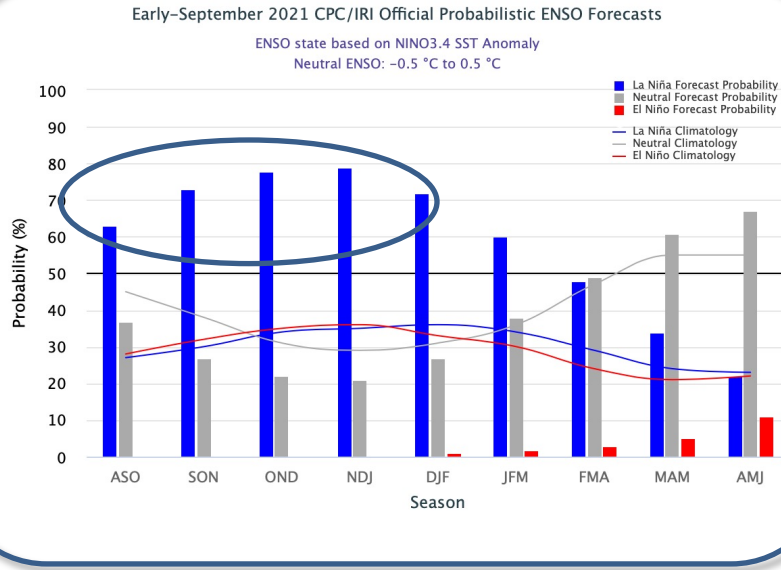
IRI/CPC Niño3.4 Forecast





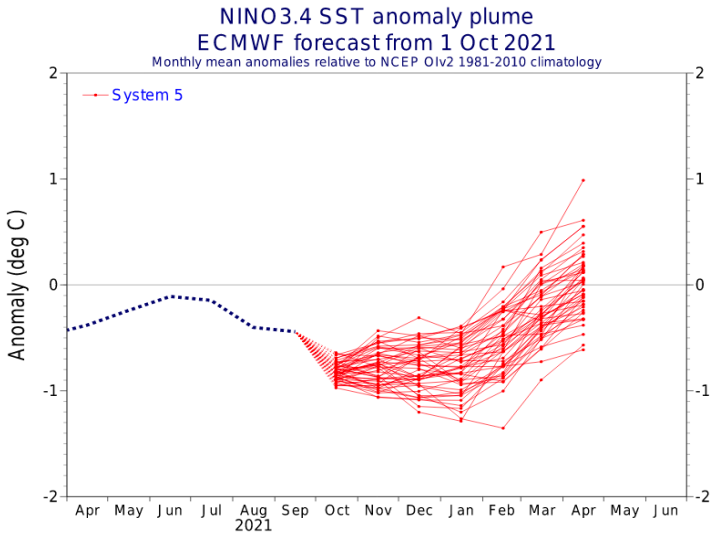
- A majority of dynamical and statistical models calls for La Niña to emerge during Sep-Nov and persist through Dec-Feb 2022.

- NOAA "ENSO Diagnostics Discussion" on September 9 stated that " *A transition from ENSO-neutral to La Niña is favored in the next couple of months, with a 70-80% chance of La Niña during the Northern Hemisphere winter 2021-22 ".*

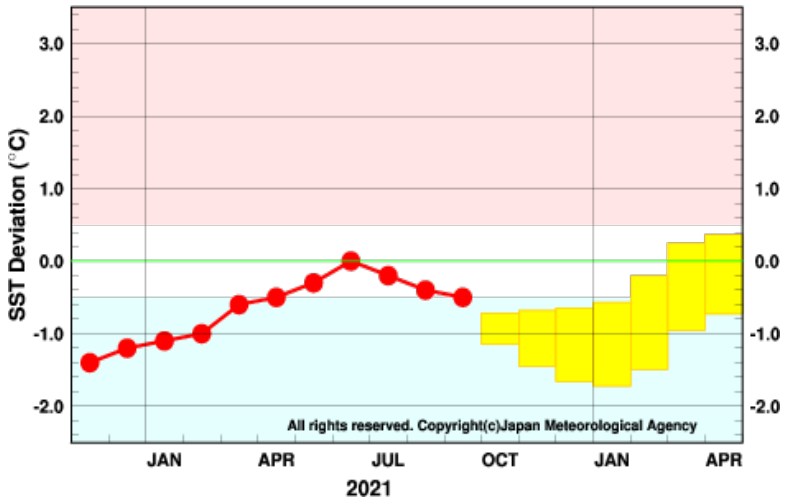


Individual Model Niño3.4 Forecasts

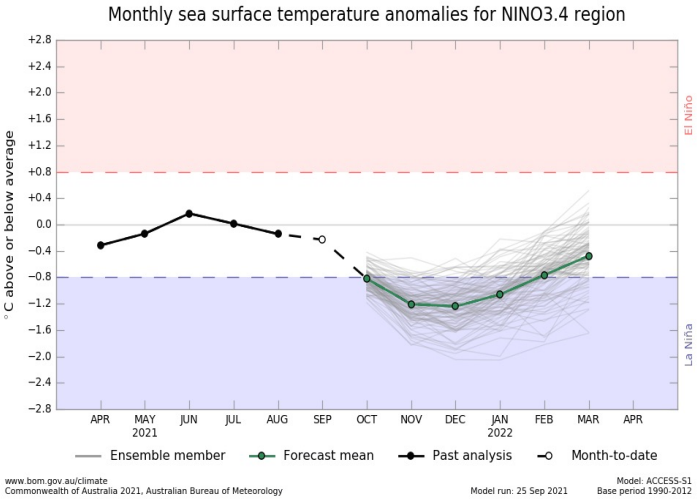
EC: IC= 01 Oct, 2021



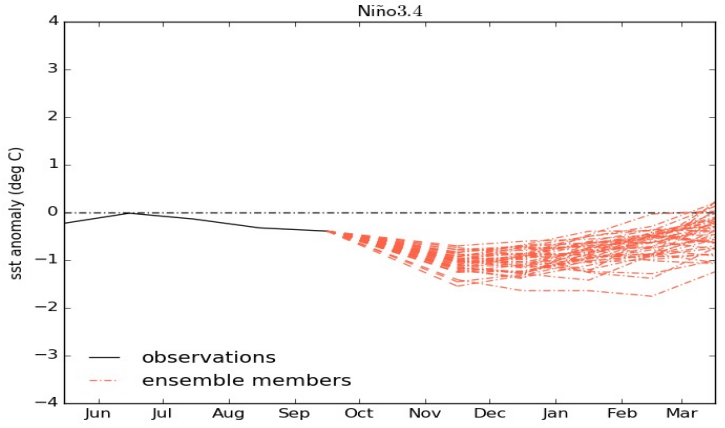
JMA: Updated 11 Oct, 2021



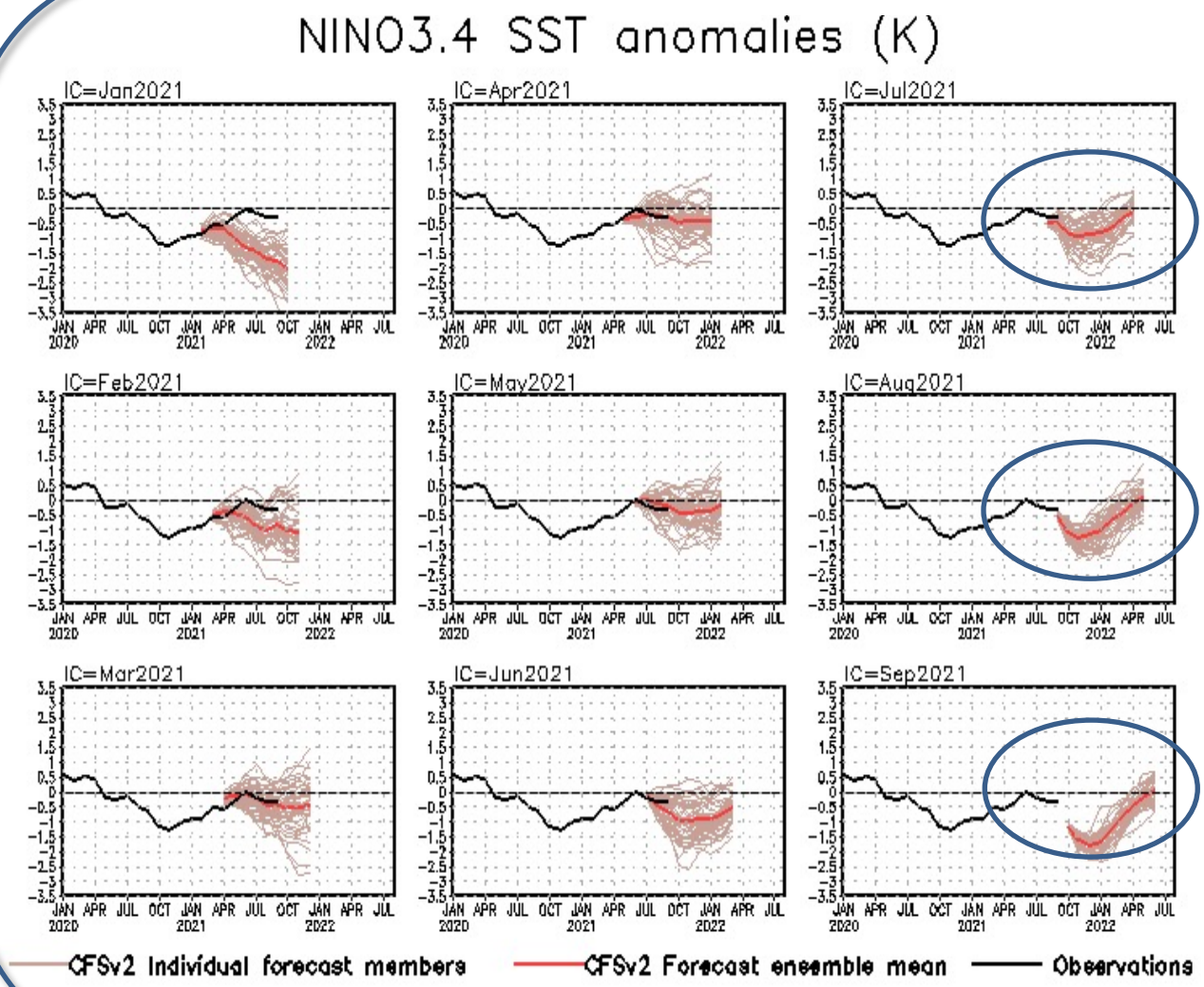
BOM: Updated 25 Sep, 2021



UKMO: Updated 11 Oct, 2021



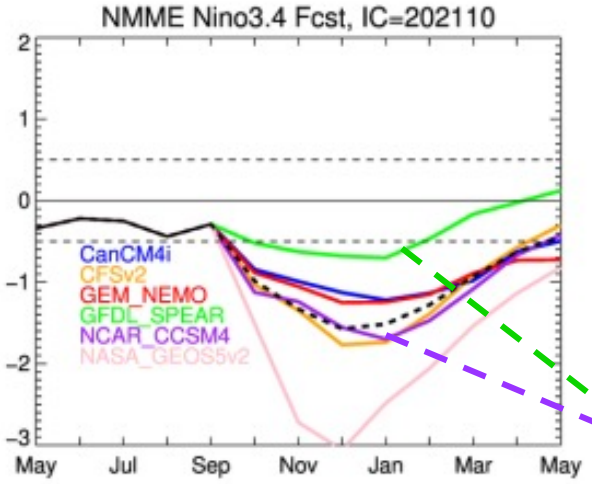
CFSv2 Niño3.4 SST Predictions

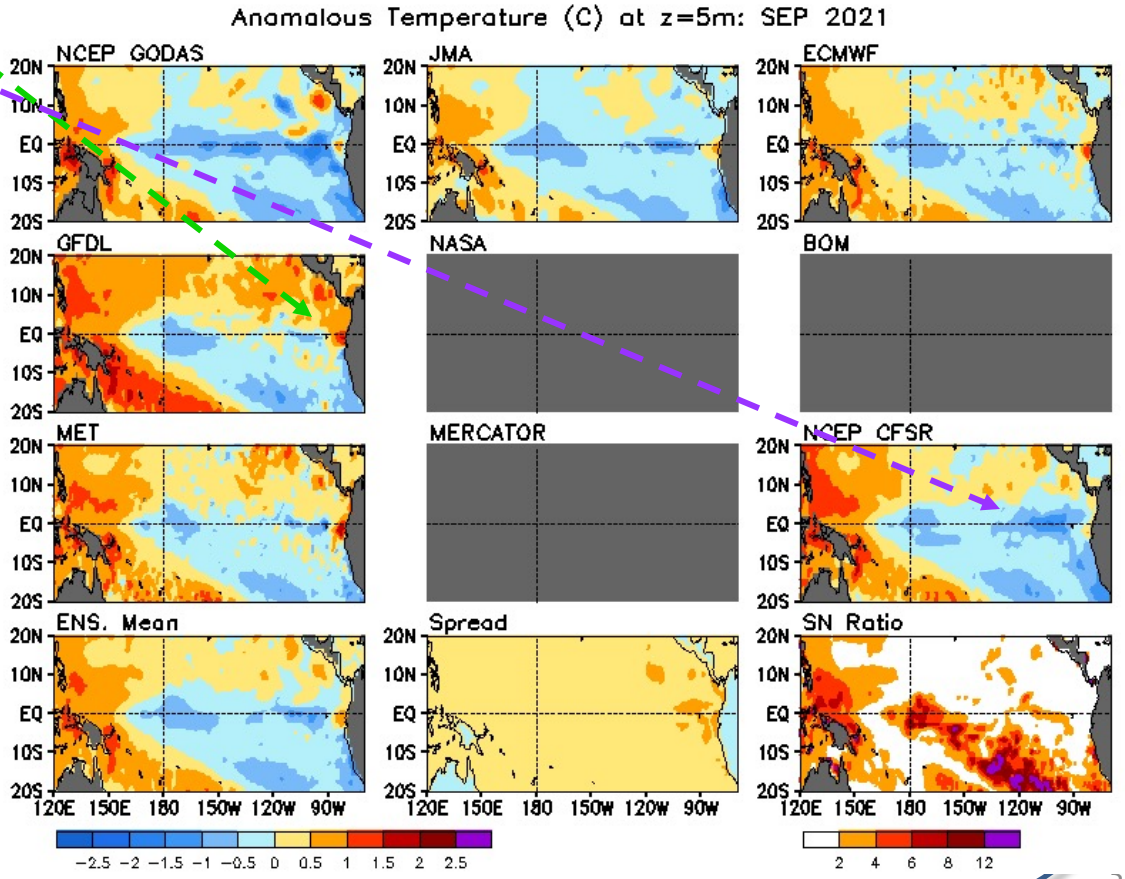


- Latest CFSv2 predictions call for a strong La Niña in the northern hemisphere 2021/22 winter.

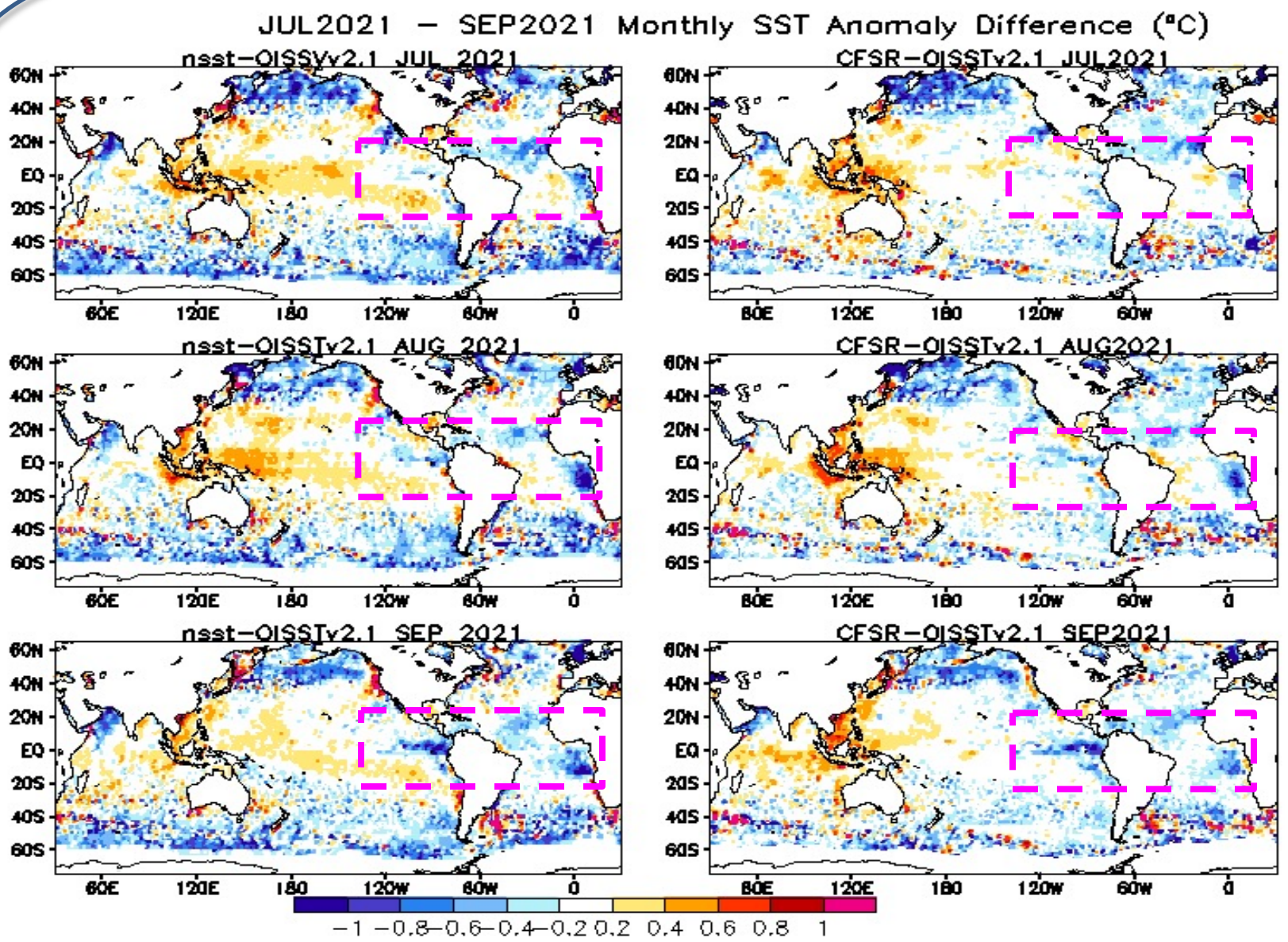
CFS Niño3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect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

Multiple Ocean Reanalysis: SST Anomalies



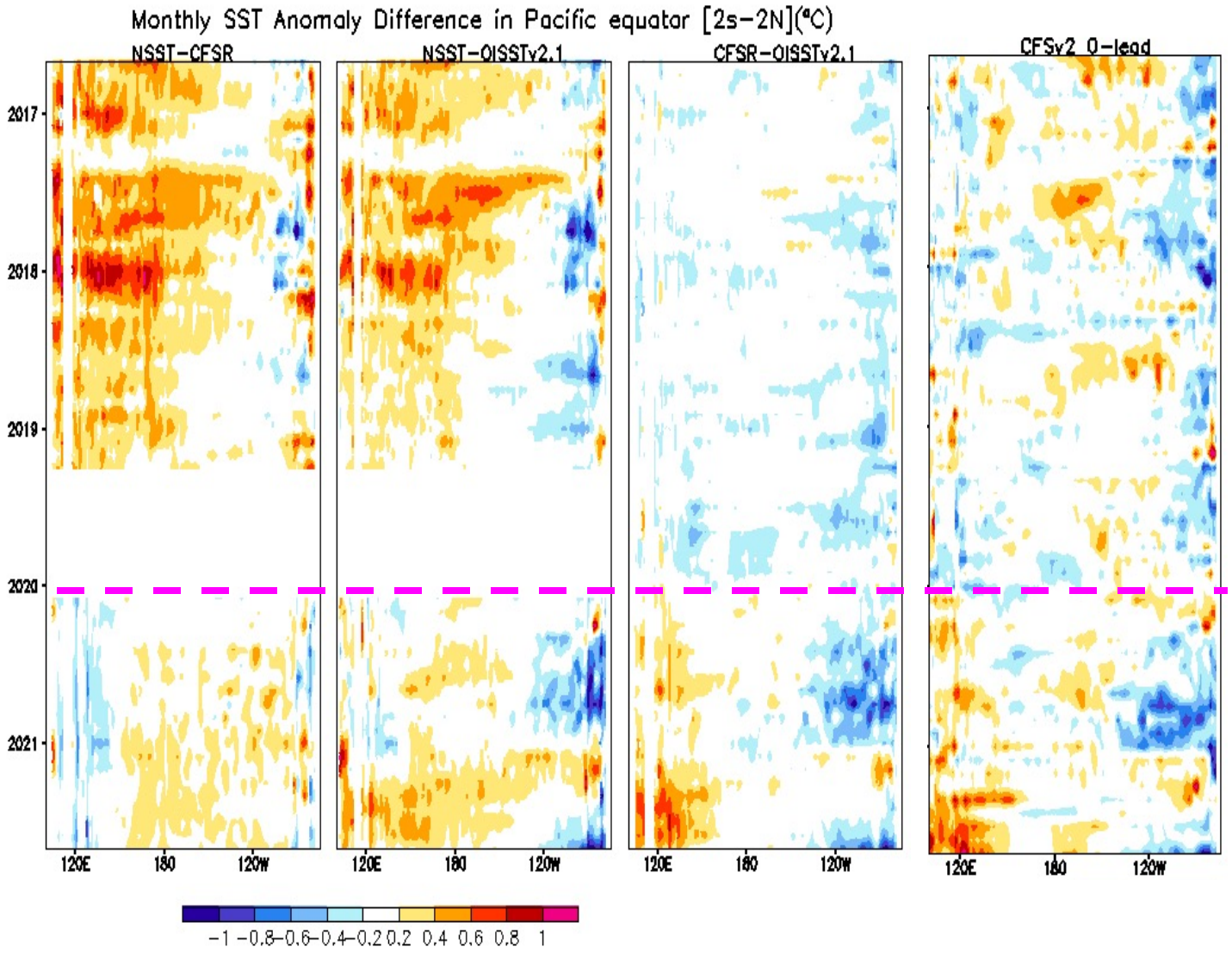


Potential Impact of NSST bias on CFSv2 Predictions



Bias pathway : NSST ⟶ CFSR ⟶ CFSv2

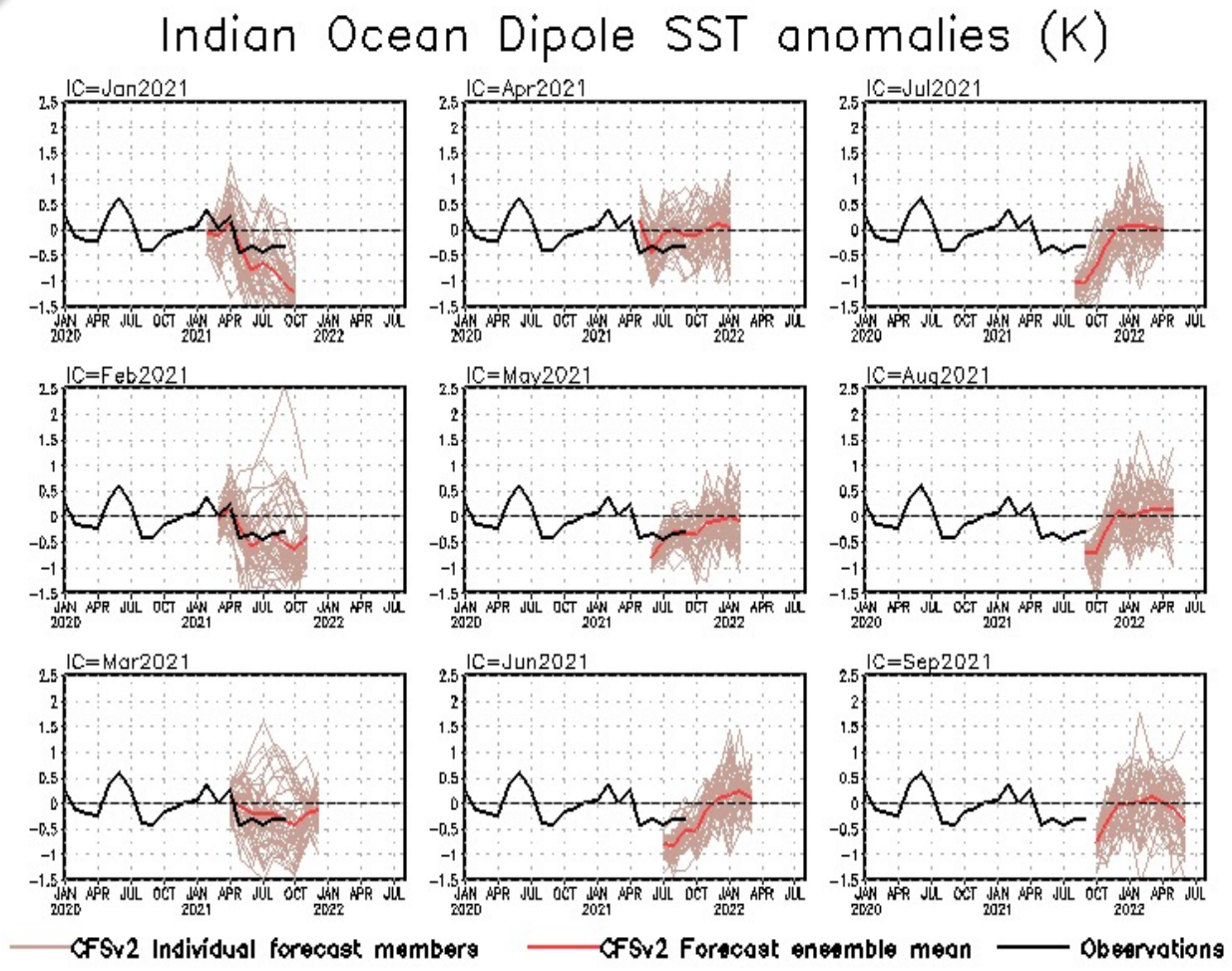
Potential Impact of NSST bias on CFSv2 Predictions



NSST provides SST boundary forcing in CFSR since 2020

Bias pathway : NSST ⟶ CFSR ⟶ CFSv2

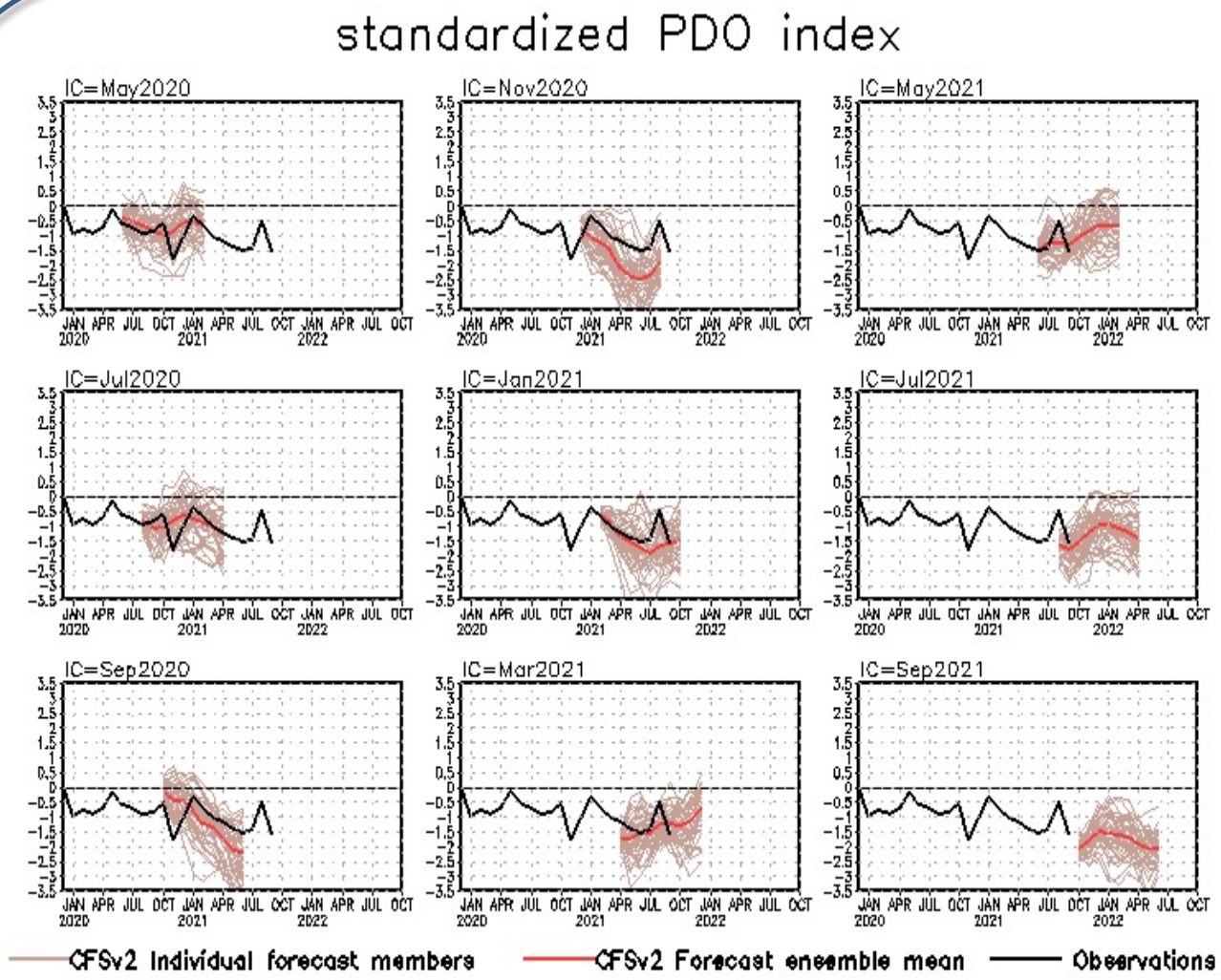
CFSv2 DMI SST Predictions



- 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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Jieshun.Zhu@noaa.gov

Zeng-Zhen.Hu@noaa.gov

Data Sources (climatology is for 1991-2020)

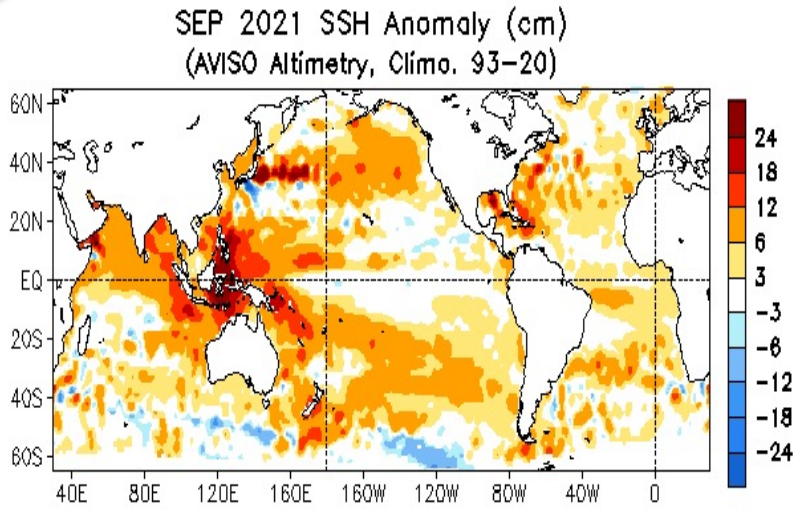
- **Weekly Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)**
- **Extended Reconstructed SST (ERSST) v5 (Huang et al. 2017)**
- **Blended Analysis of Surface Salinity (BASS) (Xie et al. 2014)**
- **CMORPH precipitation (Xie et al. 2017)**
- **CFSR evaporation adjusted to OAFlux (Xie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

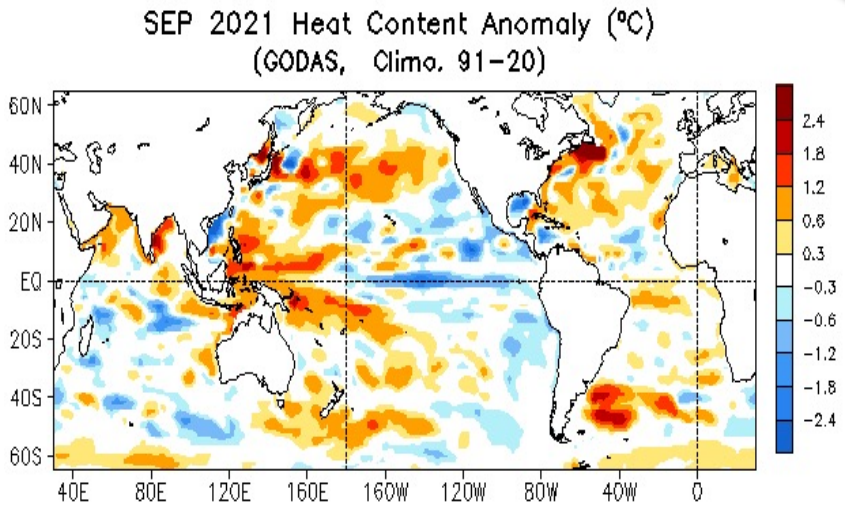
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

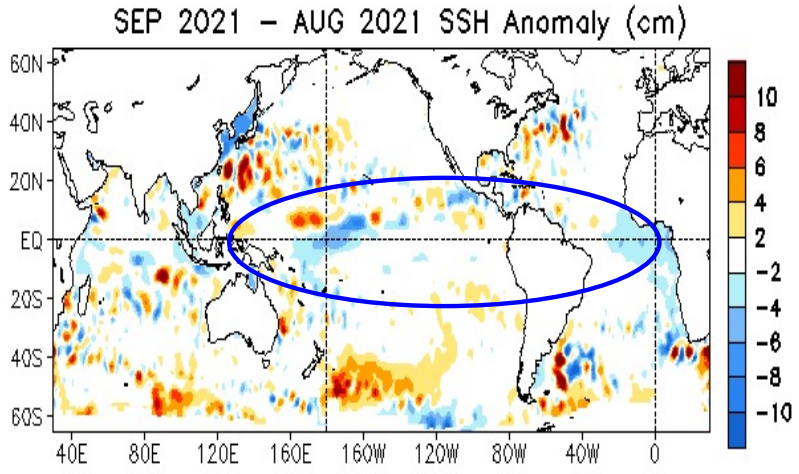
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html

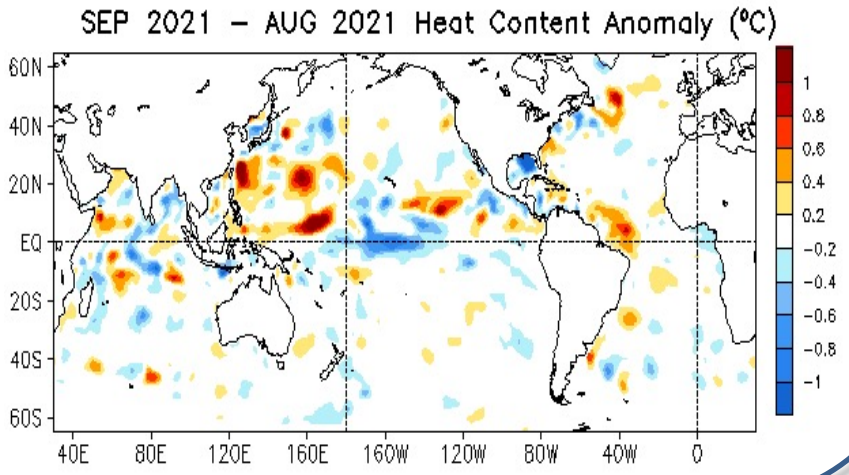
Backup Slides

Global SSH and HC300 Anomaly & Anomaly Tendency



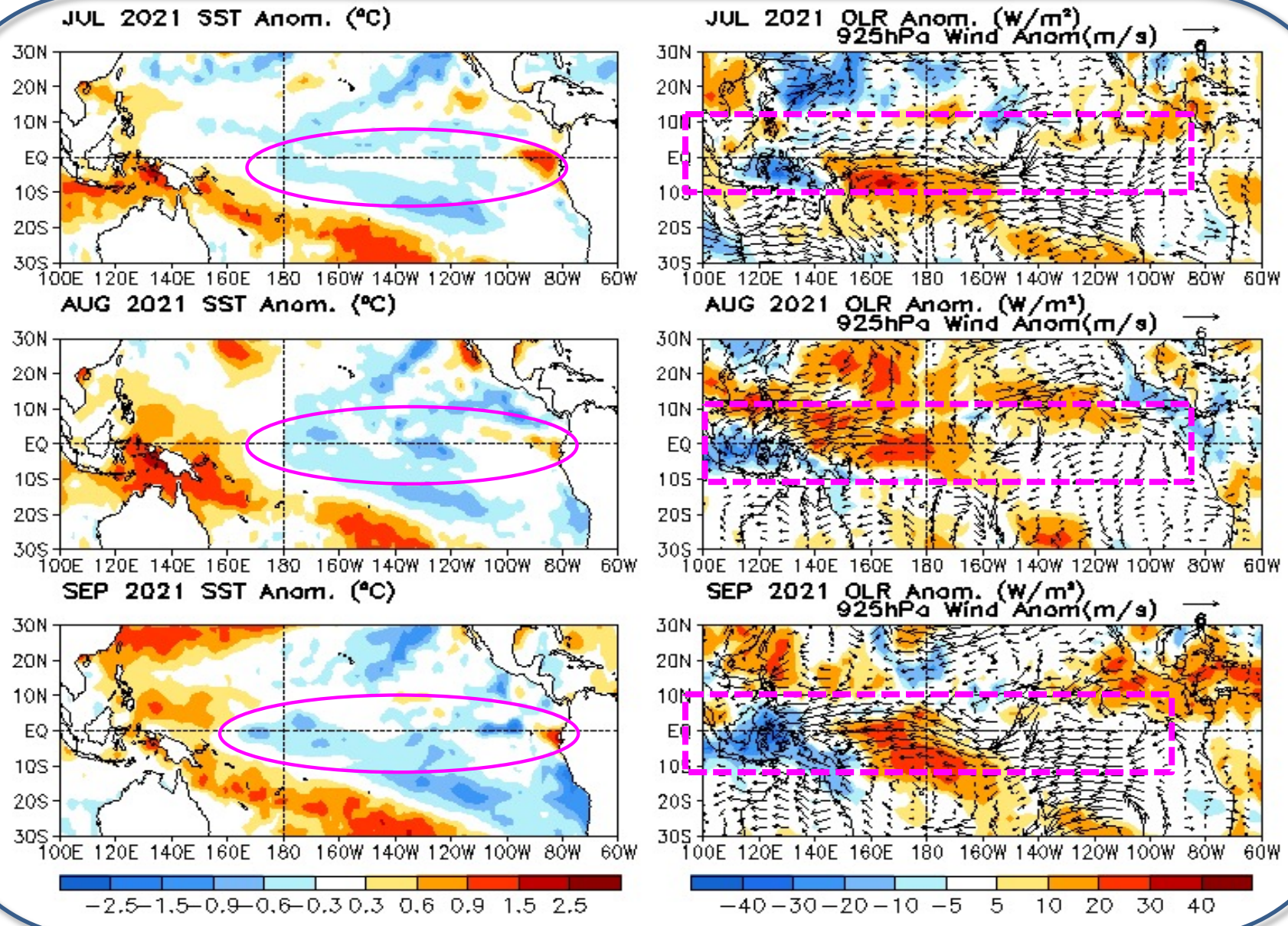




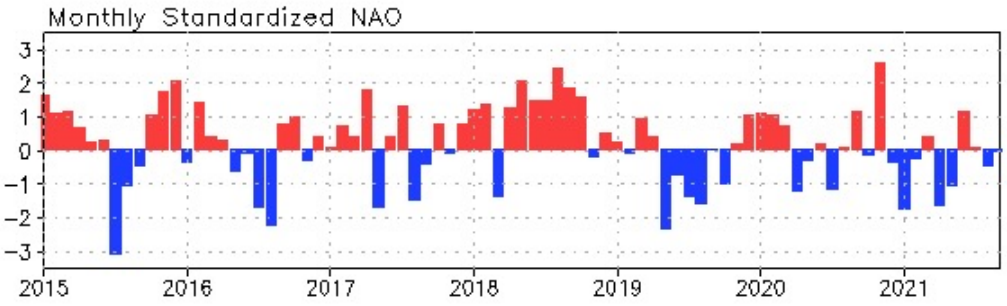


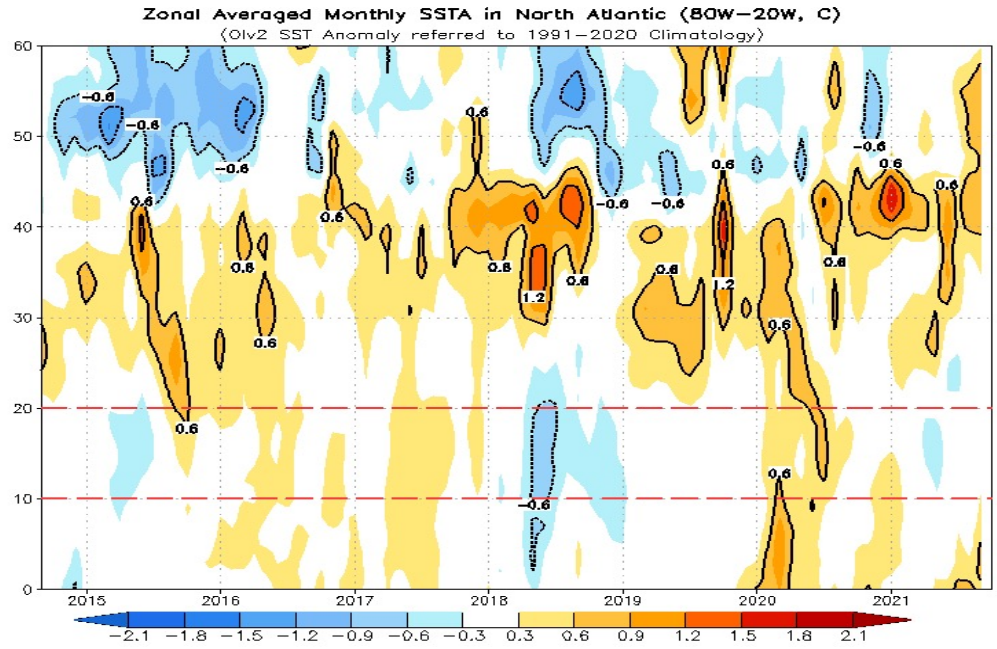
- The SSHA pattern was overall consistent with the HC300A pattern, but with a significant trend component in SSHA.
- Positive anomalies were present in the equatorial Atlantic.
- Negative SSHA tendencies were confined near the dateline, while HC300A tendencies dominated the central-eastern Pacific .

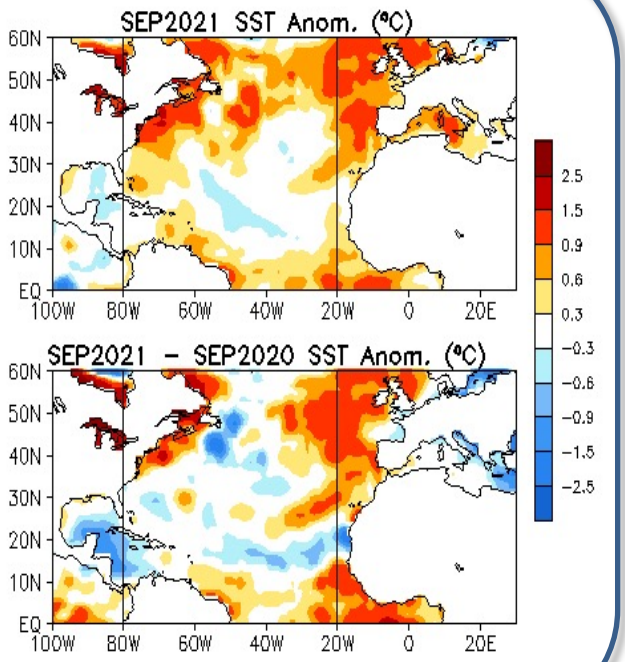
Latest 3-month Tropical Pacific SST , OLR, & uv925 anomalies



NAO and SST Anomaly in North Atlantic



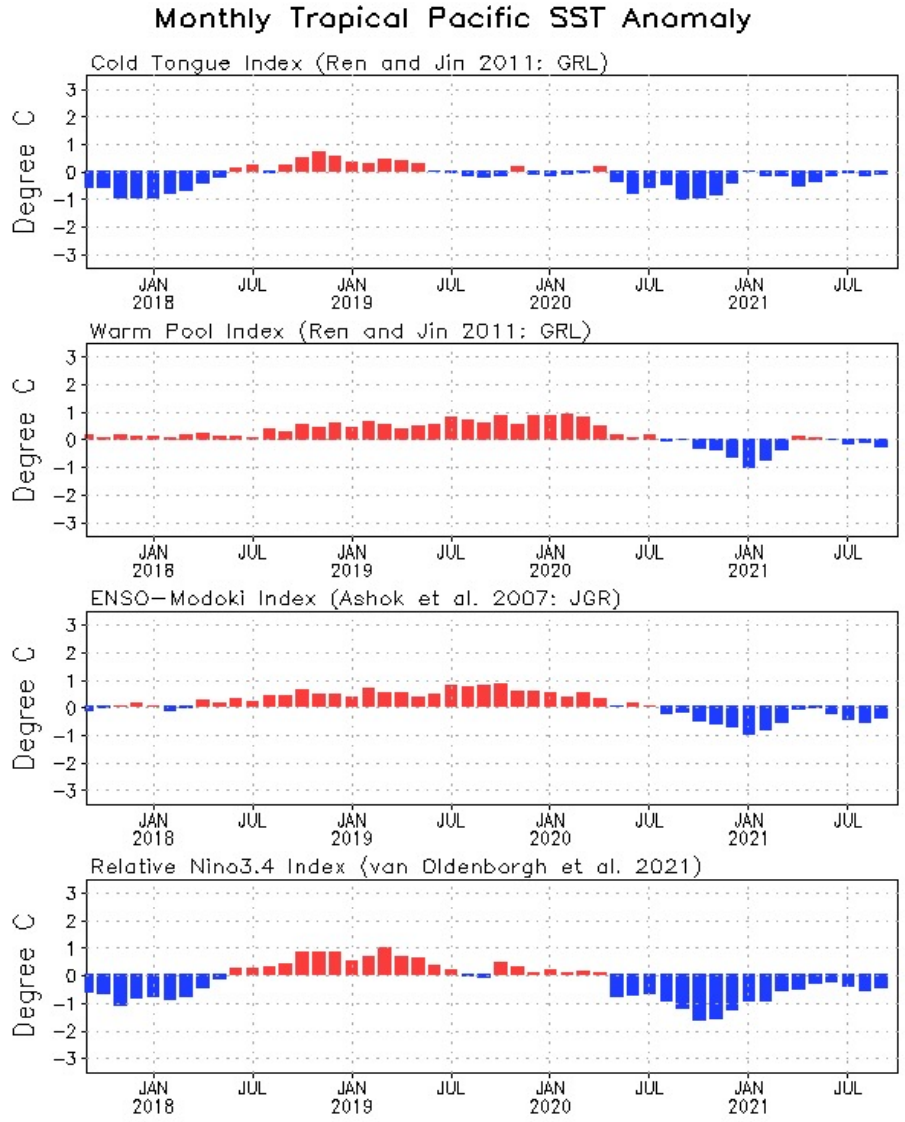


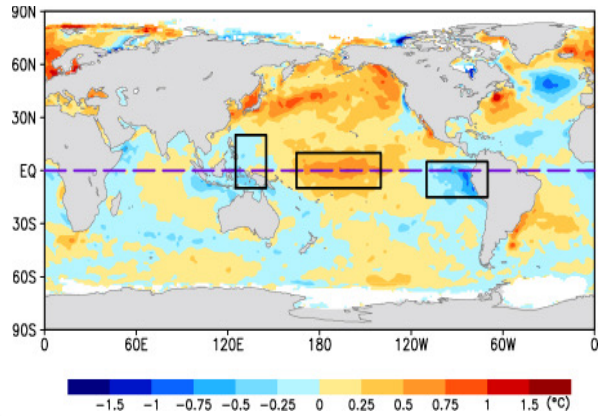


- Negative NAO weakened to near-normal switched in Sep 2021.
- The prolonged positive SSTAs in the middle latitudes were evident, due to the domination of the positive phase of NAO during the last 5-6 years.

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.

Evolution of Pacific Niño SST Indices



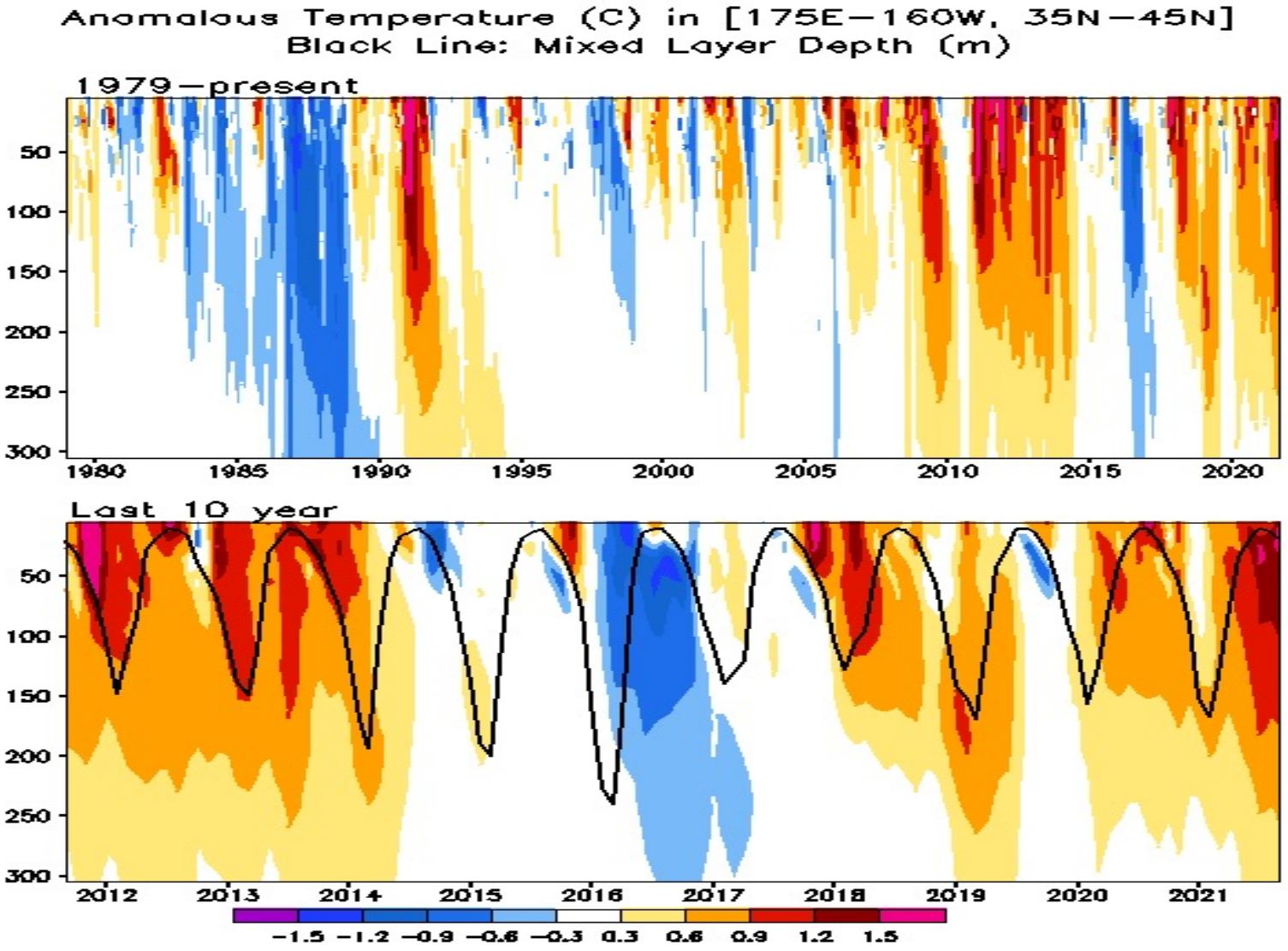


- Relative Niño3.4 index is now included in ENSO monitoring, which is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0º-360º, 20ºS-20ºN), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative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

Relative Niño3.4 data updated monthly at:

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

Subsurface Temperature Anomaly in C.E. Pacific

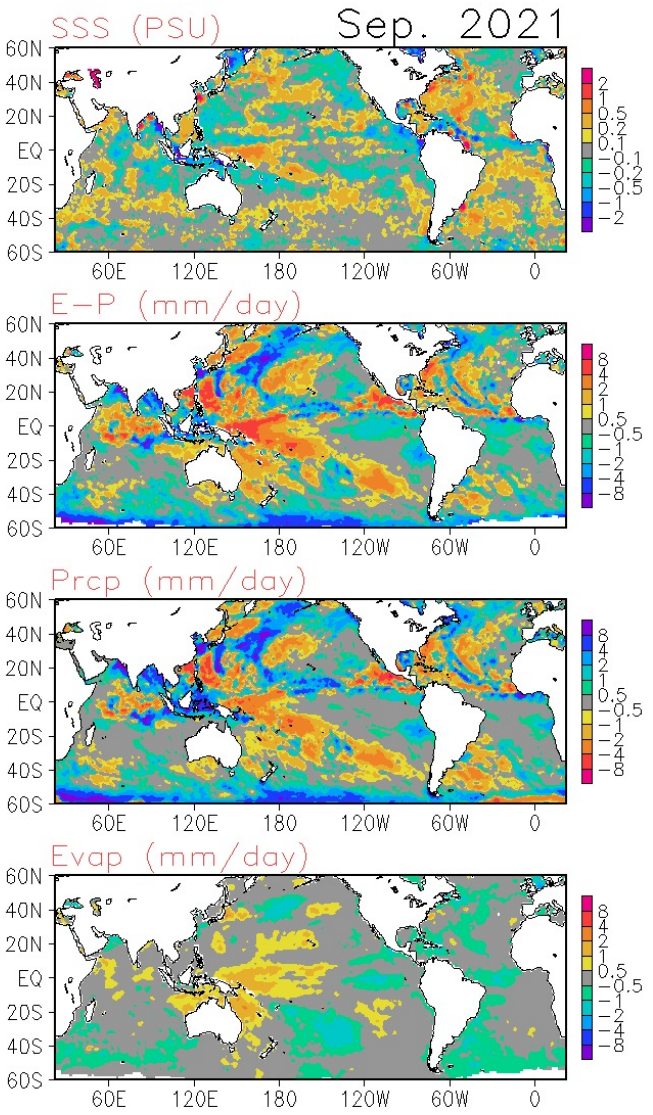


Data source: NCEP GODAS

Global Sea Surface Salinity (SSS): Anomaly for September 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 still continues but likely weakens in the western equatorial Pacific Ocean and SPCZ region. Negative SSS anomaly also continues in the eastern equatorial Pacific Ocean, which is likely caused by increased precipitation. Negative SSS anomaly in the northeast Pacific Ocean is accompanied with enhanced precipitation. Positive SSS anomaly continues between 20°N/20°S and 40°N/40°S in the Atlantic Ocean. Negative SSS anomaly appears in the east Indian Ocean possibly due to increased precipitation.



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

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

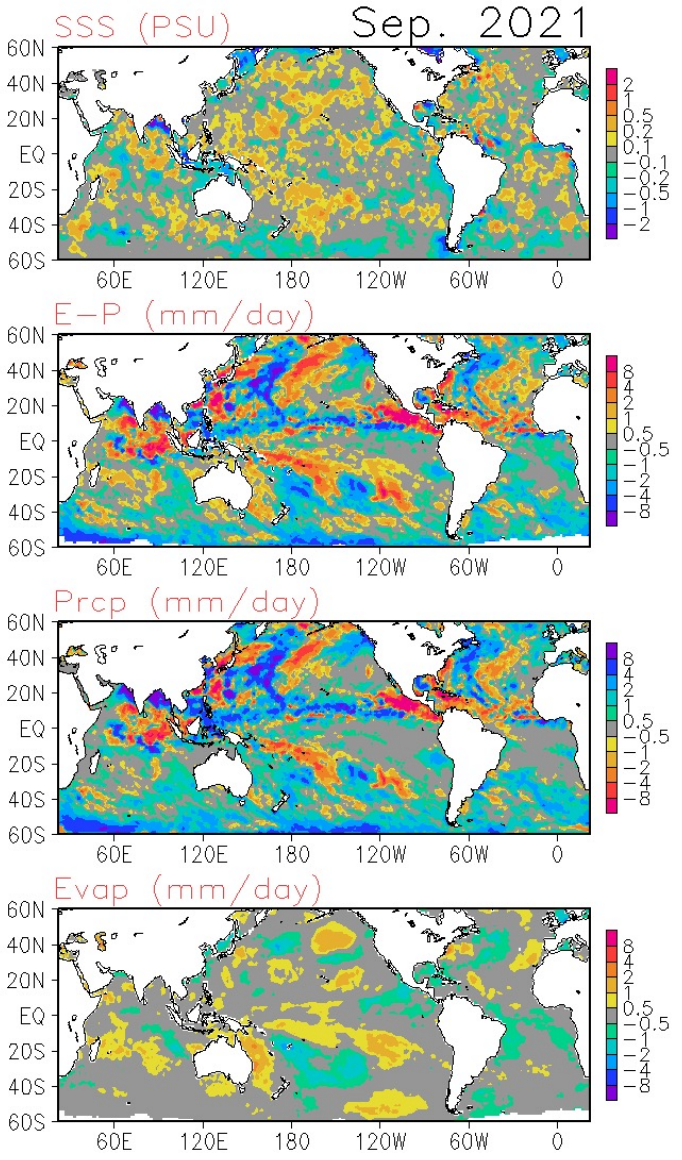
ftp.cpc.ncep.noaa.gov/precip/BASS

Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: Adjusted CFS Reanalysis

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

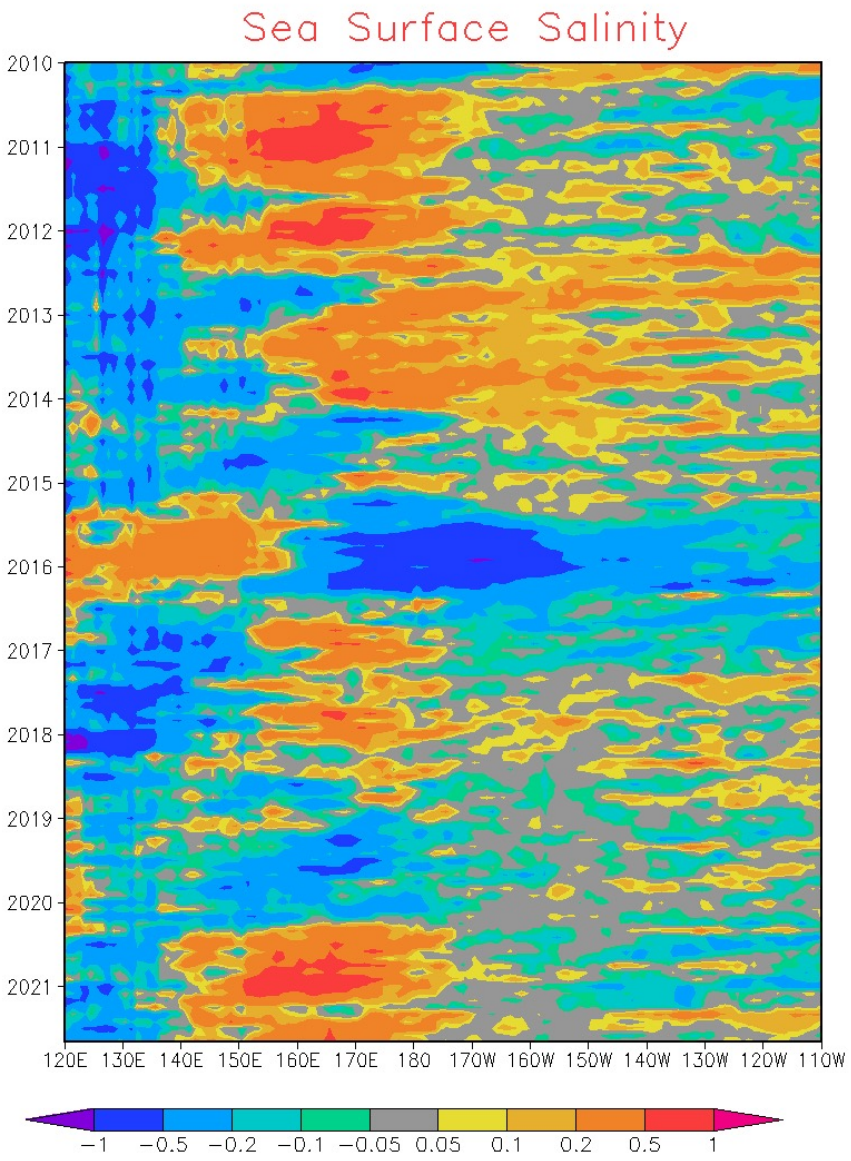
Compared with last month, SSS increased in the east Equatorial Pacific Ocean likely due to reduced precipitation. SSS also increased in the Gulf Stream which is possibly caused by oceanic advection/entrainments. SSS decreased along the equator of Atlantic Ocean. SSS decreased in the Bay of Bengal, which is accompanied 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 neutral and/or weak negative SSS signal appears 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.