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

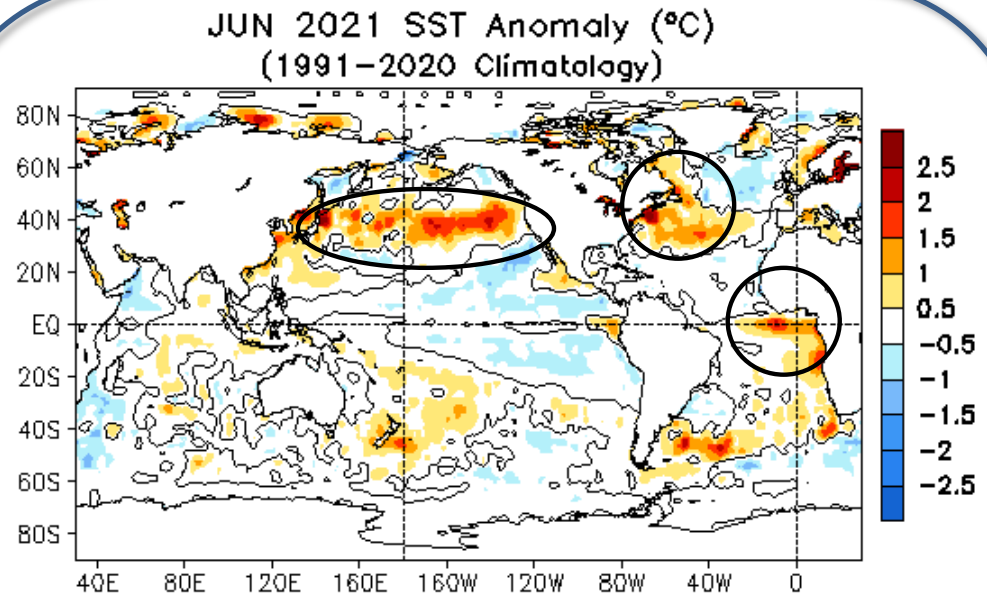
- Overview
- Recent highlights
  - Pacific/Arctic Ocean
  - Indian Ocean
  - Atlantic Ocean
- Global SST Anomaly Predictions
- Special Topics
  - Will a double-dip La Niña occur?
  - Atlantic Niño and its impact on ENSO

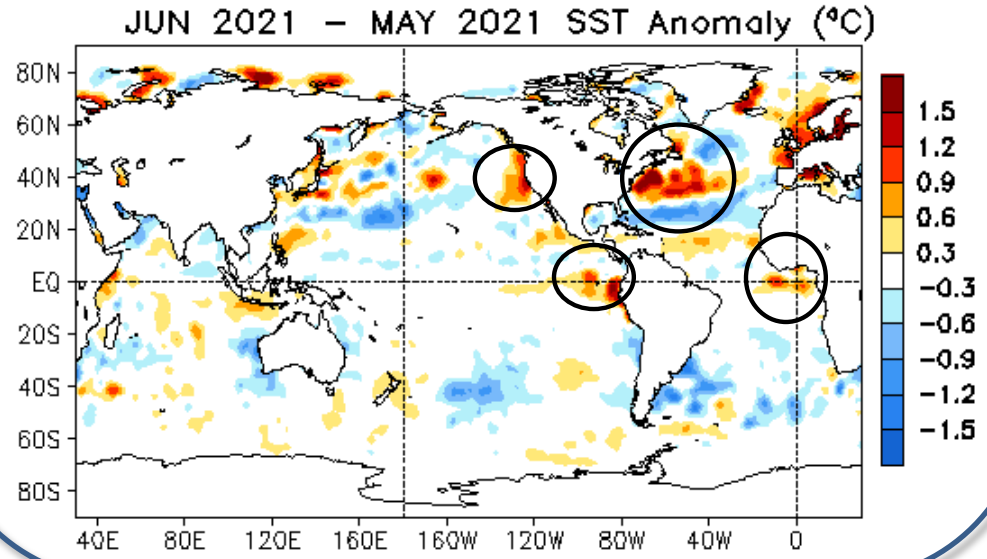
Overview

- Pacific Ocean
  - NOAA “ENSO Diagnostic Discussion” issued La Niña Watch on 8 Jul 2021
  - ENSO neutral conditions continued in Jun 2021.
  - The negative phase of PDO has persisted since Jan 2020 with PDOI = -1.5 in Jun 2021.
  - Strong SSTA expanded toward to the N.W. coast of North America.
- Indian Ocean
  - Negative Indian Ocean dipole (IOD) index strengthened in Jun 2021, with IOD = -0.63C.
- Atlantic Ocean
  - Positive SSTA increased substantially in the equatorial Atlantic Ocean in Jun 2021, with potential development into a strong Atlantic Niño.
  - NAO switched to a positive phase in Jun 2021 with NAOI= 1.1.
- Arctic Ocean
  - The monthly average extent for Jun 2021 ranks the sixth lowest in the satellite record.
  - With ICs in Jun 2021, NCEP/CPC predicted a well below-normal sea ice extent during summer and autumn 2021.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency



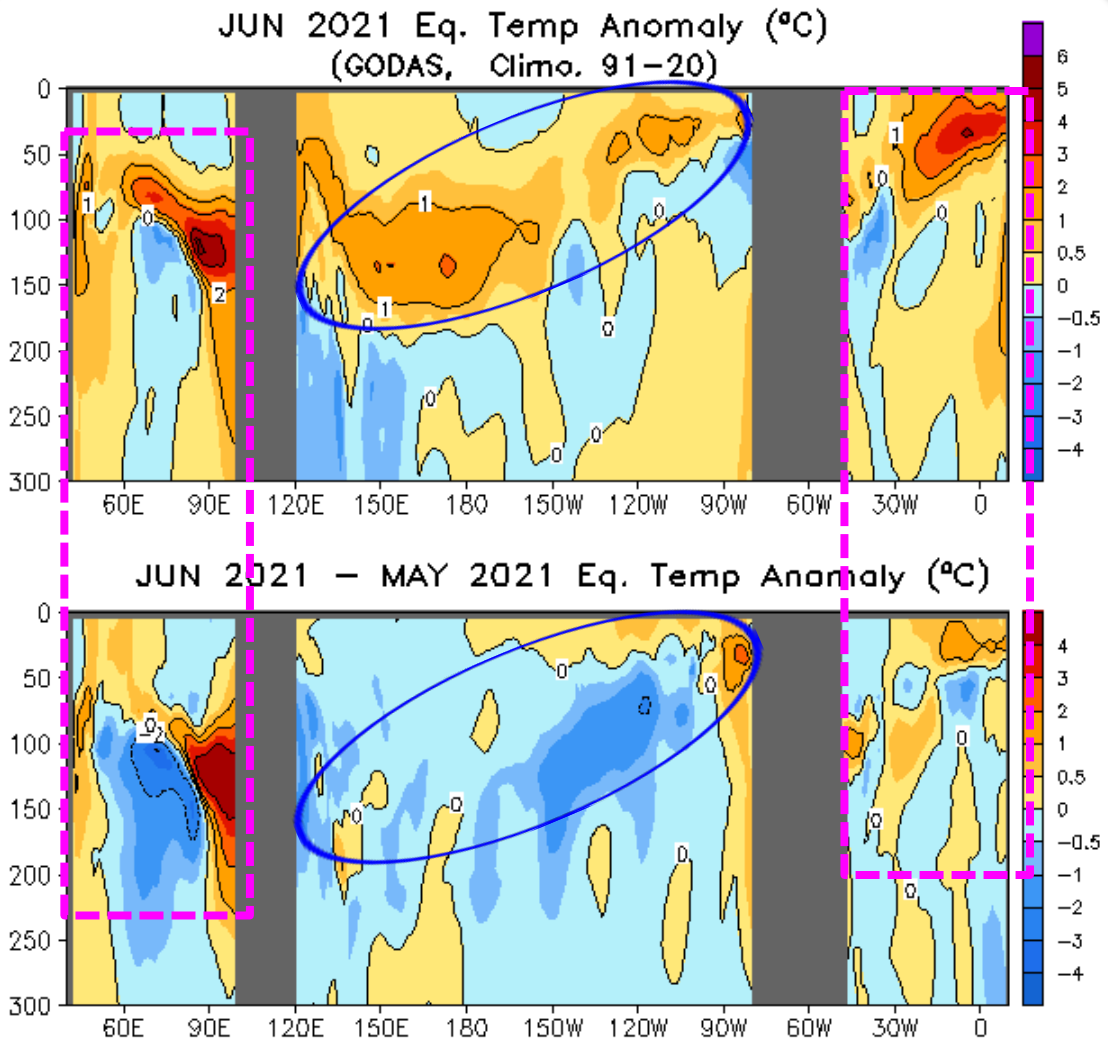


- SSTAs were small in the tropical Pacific and Indian Oceans.
- Positive SSTAs were present in mid-latitude of north Pacific.
- Positive SSTAs were present in the equatorial Atlantic Ocean and along the African coast.

- Positive SSTA tendencies were present in the eastern equatorial Pacific and Atlantic Oceans.
- A north-south dipole pattern of SSTA tendency was observed in the north Atlantic Ocean.

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

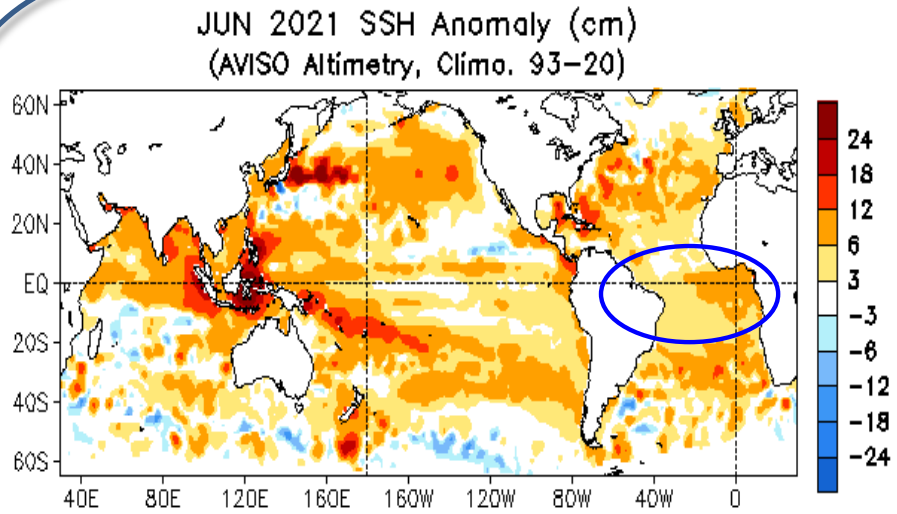


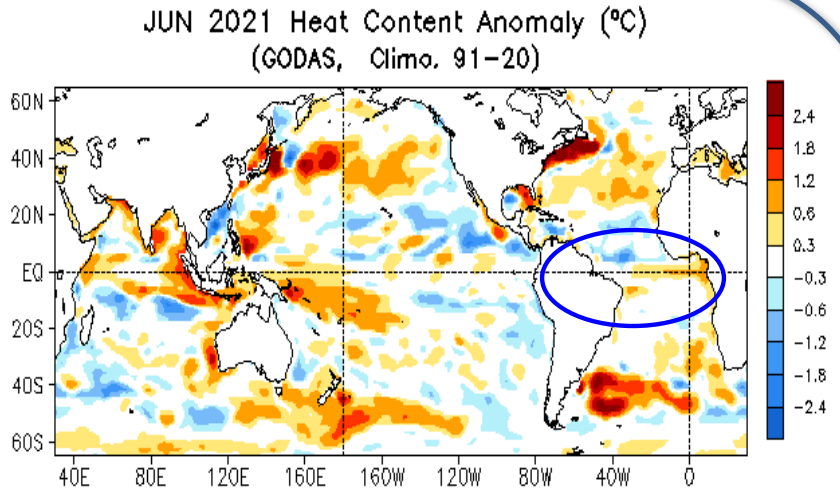
- Positive subsurface ocean anomalies were present along the thermocline in the equatorial Pacific.
- Positive anomalies continued in equatorial Atlantic Ocean, associated with the potential for development of an Atlantic Niño.
- Compared with May, dipole pattern at 50-200m was reversed in the Indian Ocean in Jun 2021 .

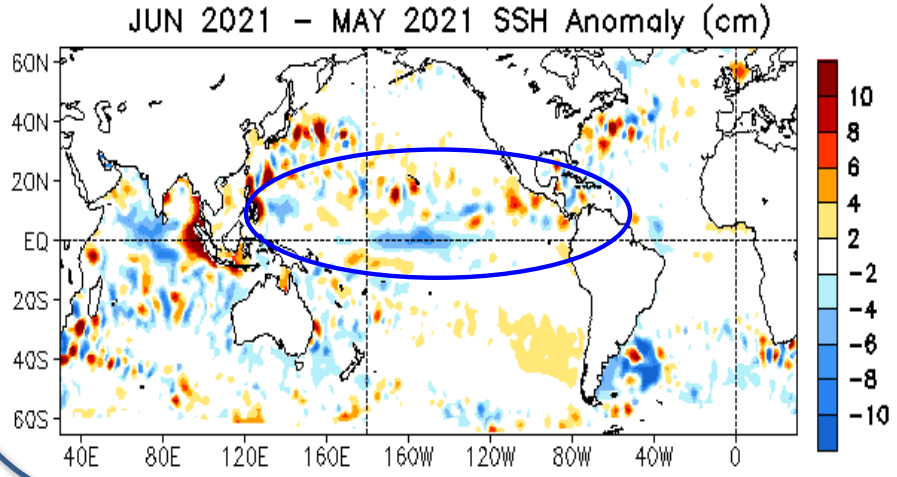
- Negative (positive) temperature anomaly tendency was present along central-eastern (far eastern) thermocline in the equatorial Pacific.

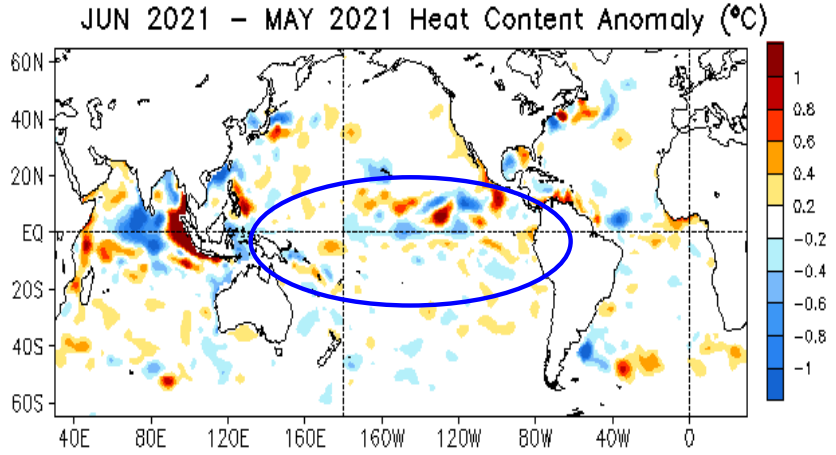
Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data is from the NCEP's global ocean data assimilation system. Anomalies are departures from the 1991-2020 base period means.

Global SSH and HC300 Anomaly & Anomaly Tendency





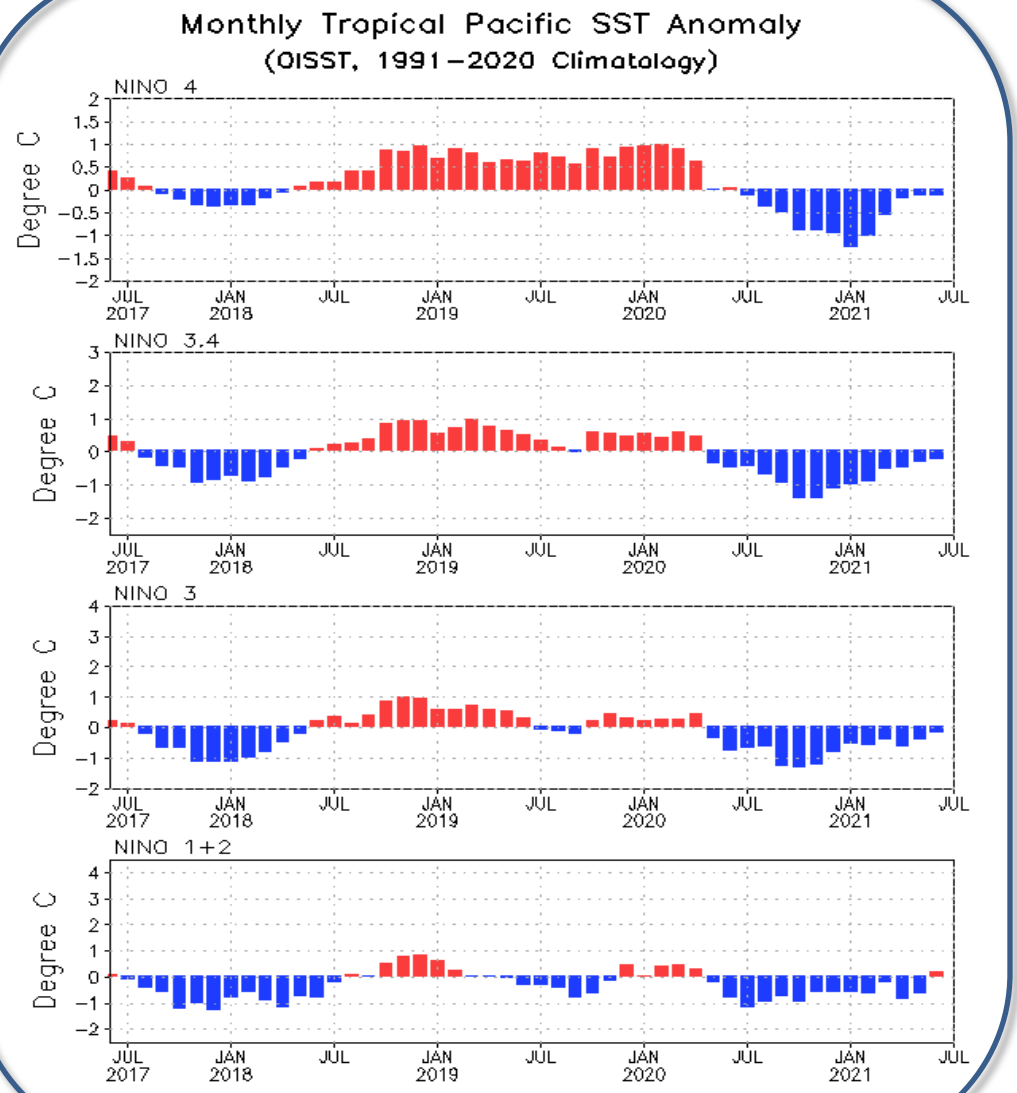


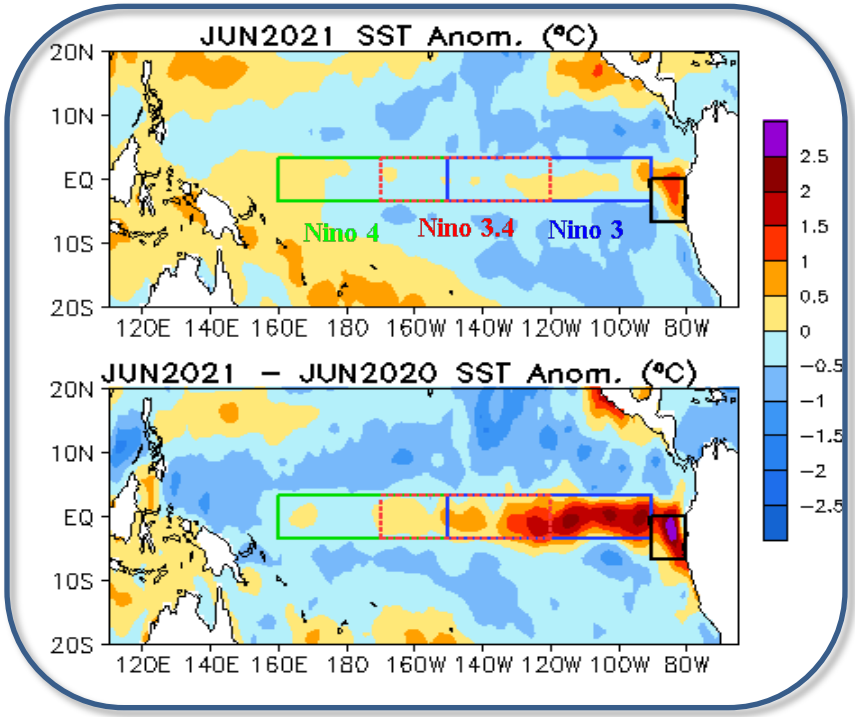


- The SSHA pattern was overall consistent with the HC300A pattern, but with a significant trend component in SSHA.
- Positive anomalies were present in the equatorial Atlantic.
- Negative tendencies were observed in the central equatorial Pacific and Indian Oceans, consistent with the subsurface ocean temperature anomaly tendency (previous slide).

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific Niño SST Indices





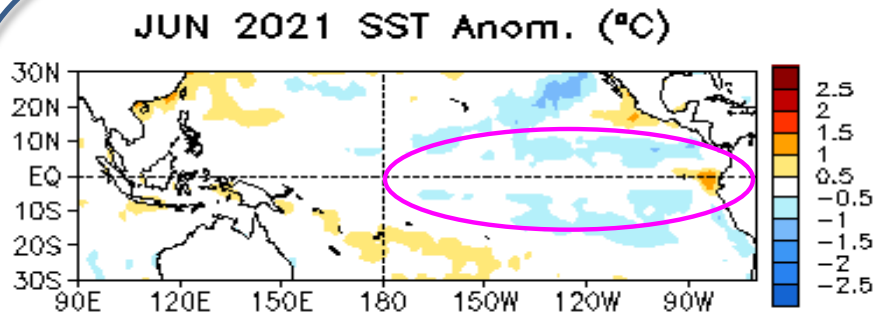
- All negative Niño indices weakened in Jun 2021, with Niño3.4 = -0.2°C .

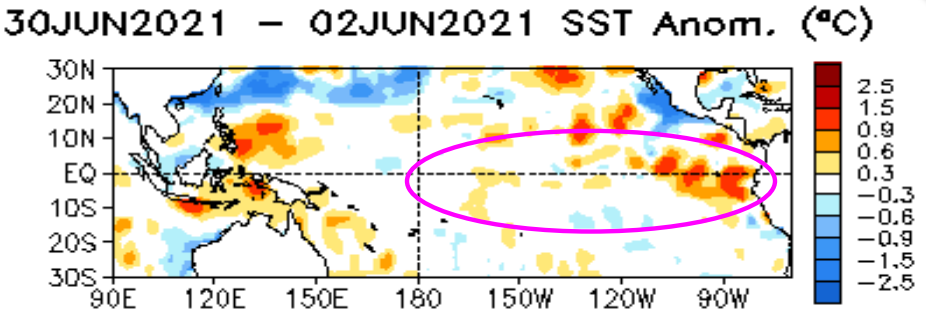
- Compared with Jun 2020, the central and eastern equatorial Pacific was warmer in Jun 2021.

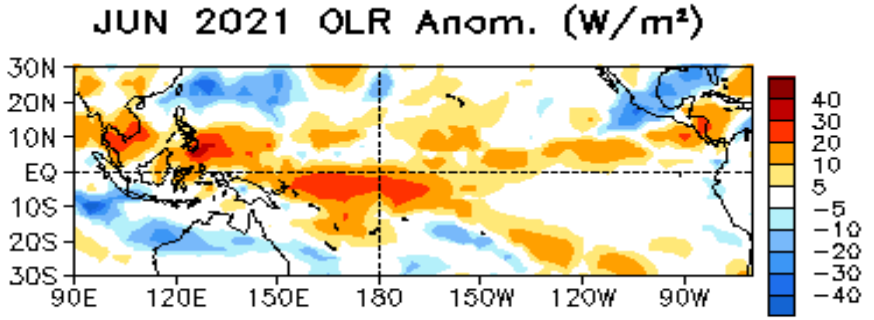
- The indices may have slight differences if based on different SST products.

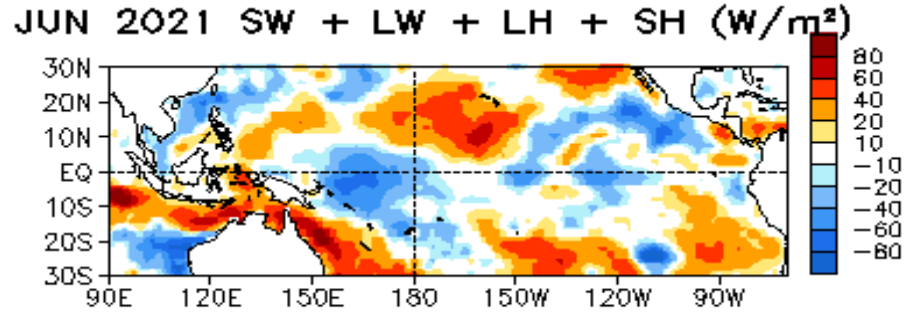
Niño region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means.

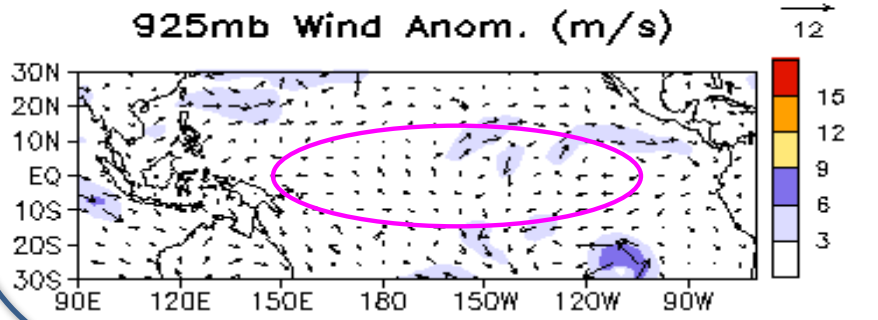
Tropical Pacific: SSTA, SSTA Trend, OLR, heat flux, uv925 & uv200 anomalies

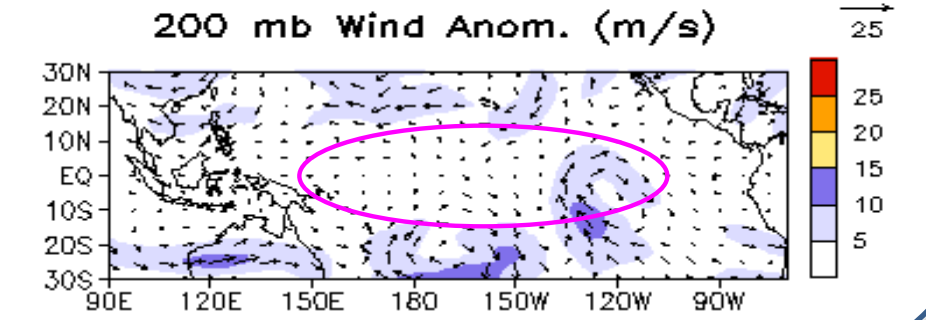






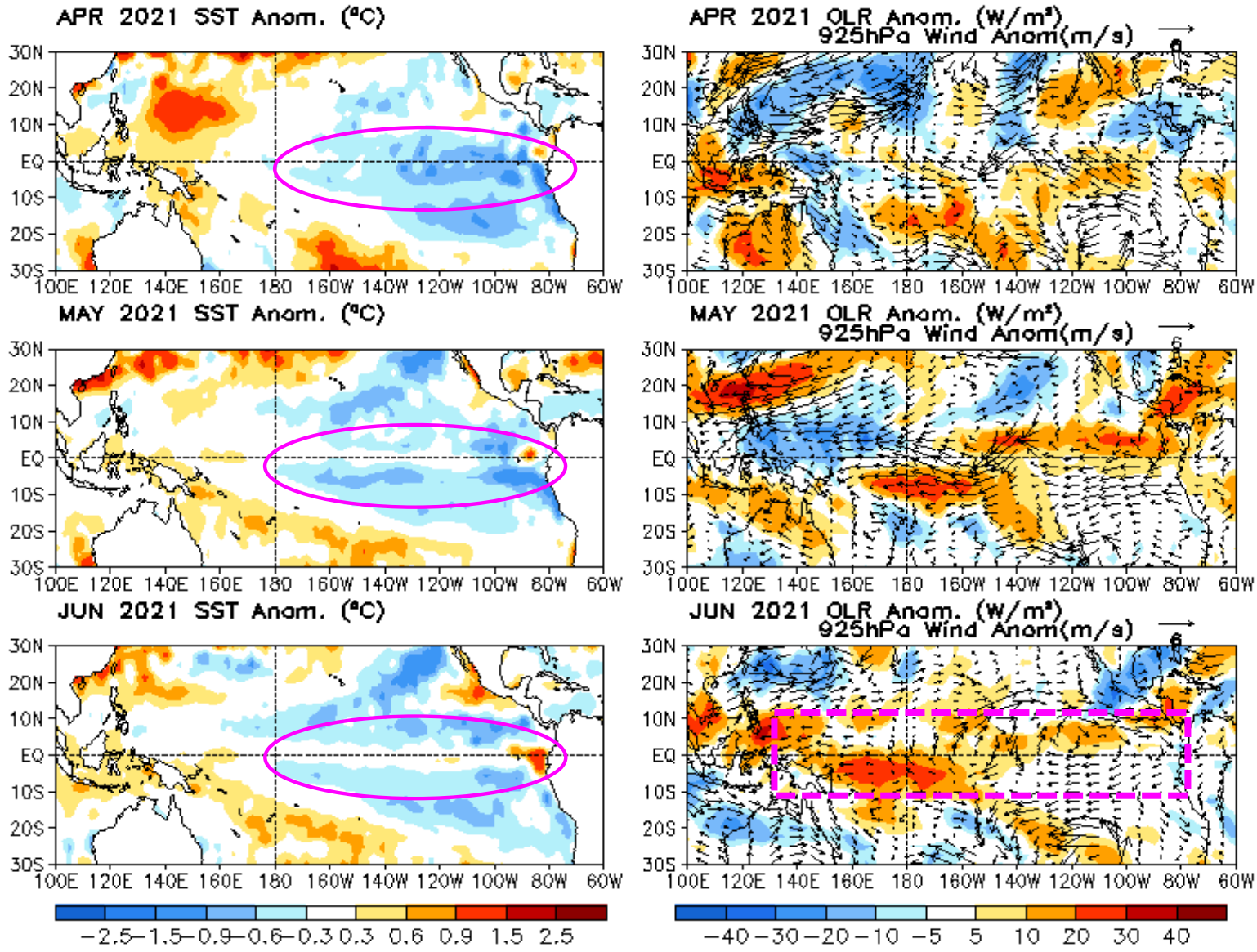




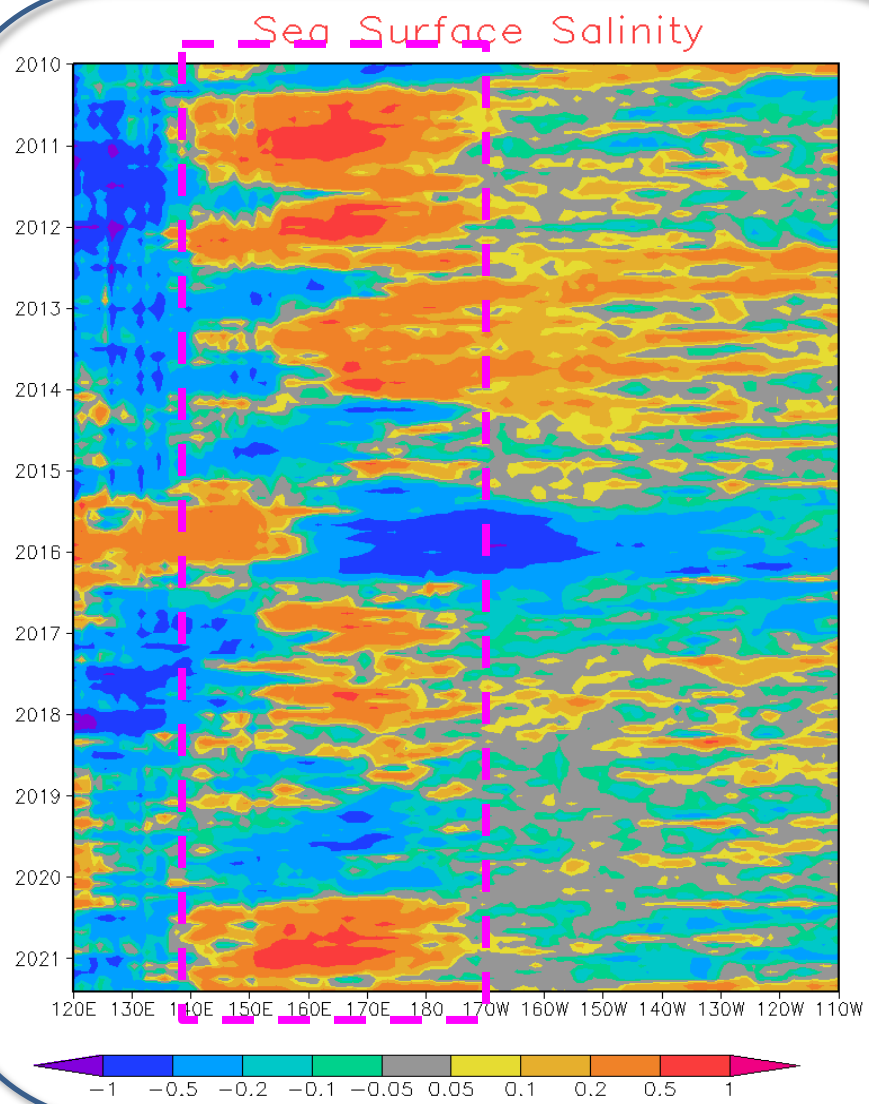


Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly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

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



Equatorial Pacific Sea Surface Salinity(SSS) Anomaly

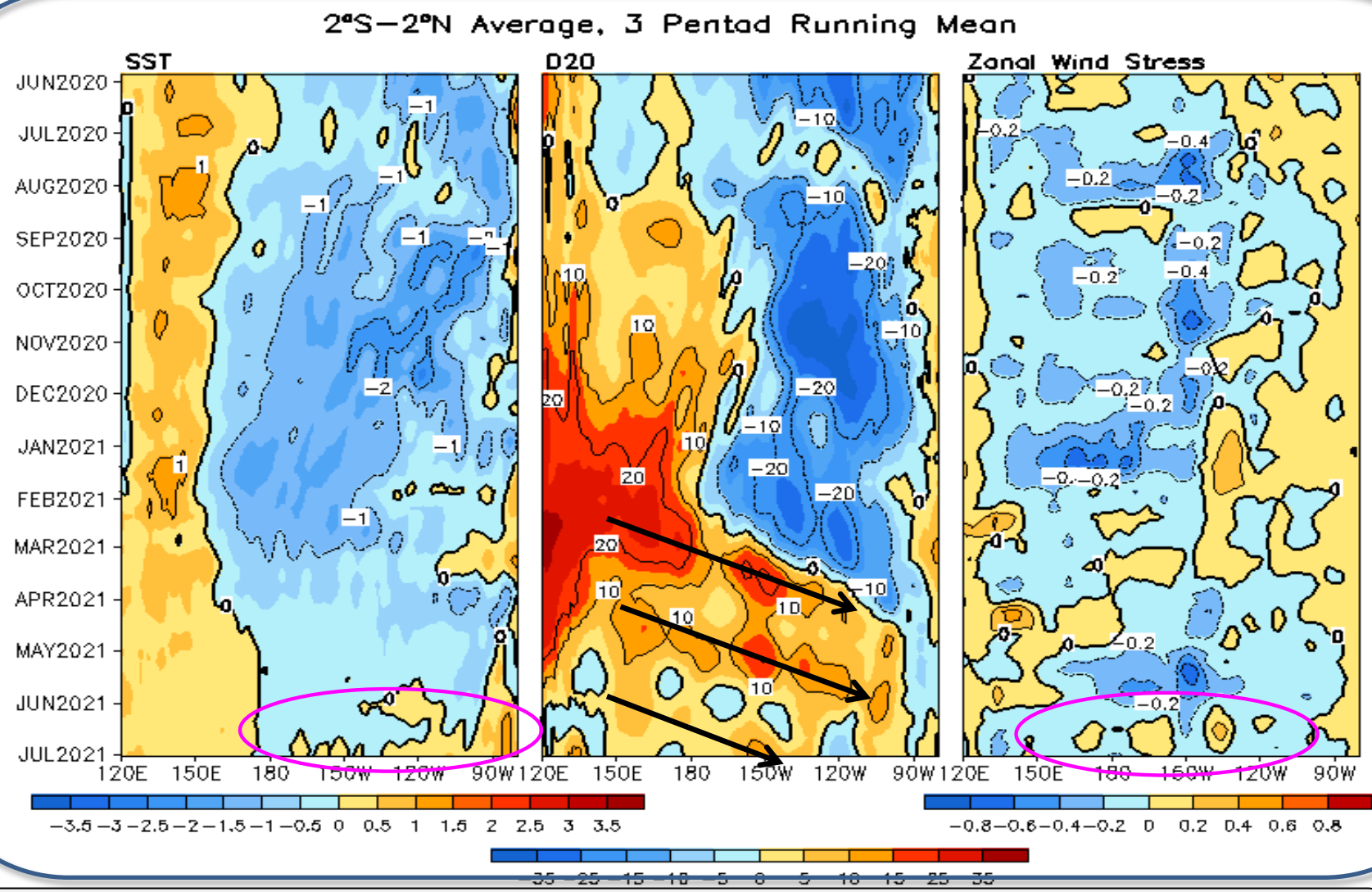


- Positive (negative) SSS anomaly presented east (west) of 140E during 2010, 2011, 2016,2017, 2020 La Nina events.

- Positive SSS anomaly was present around 140E-170W in Jun 2021.

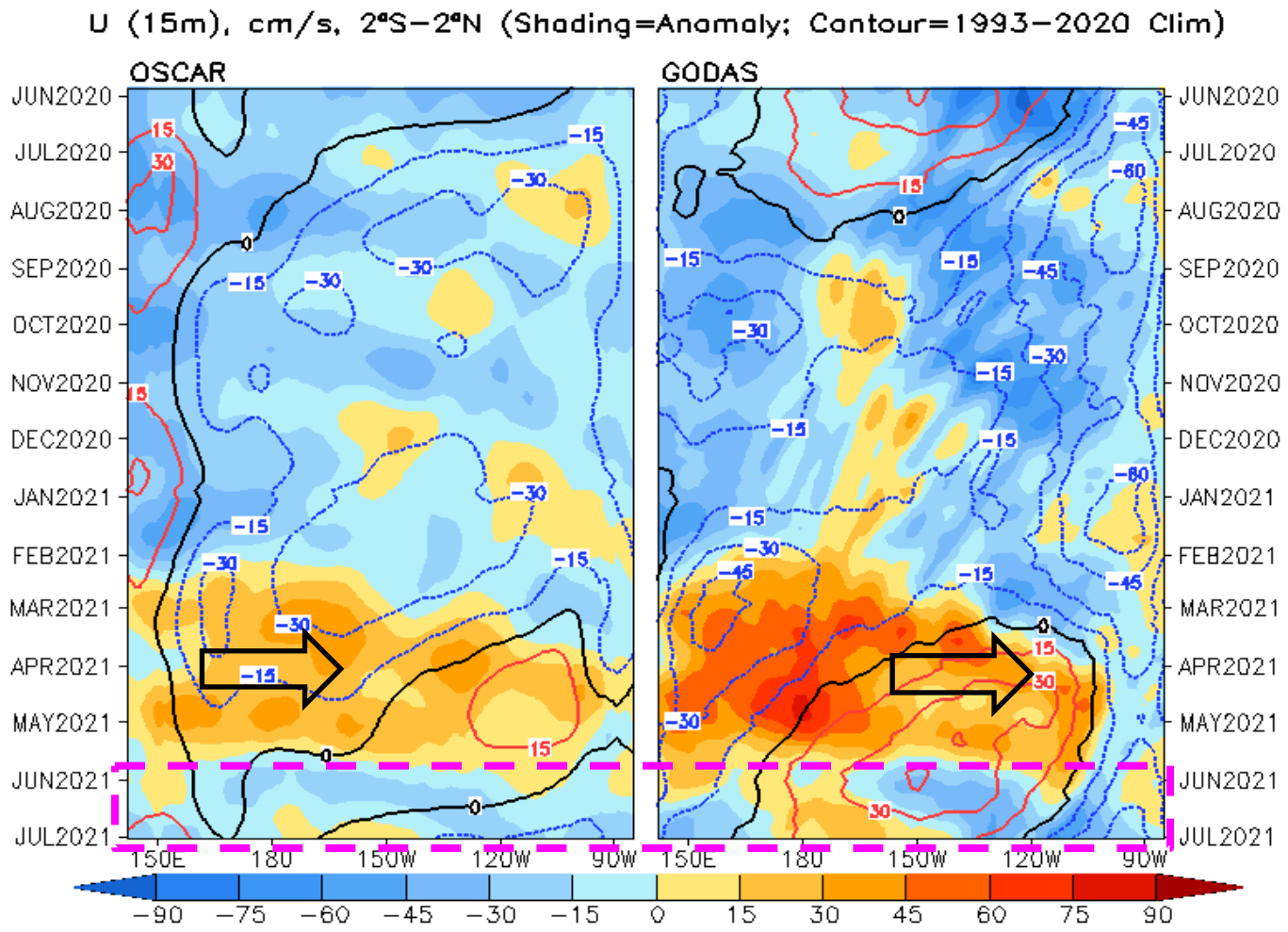
Sea surface salinity (SSS) anomalies are derived from Blended Analysis of Surface Salinity (BASS) V0.Z (Xie et al. 2014). Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015,The BASS SSS is from in situ, SMOS and Aquarius. Data is available at ftp.cpc.ncep.noaa.gov/precip/BAS.

Equatorial Pacific SST (°C), D20 (m), zonal wind stress (dyn/cm ^{2}) Anomalies



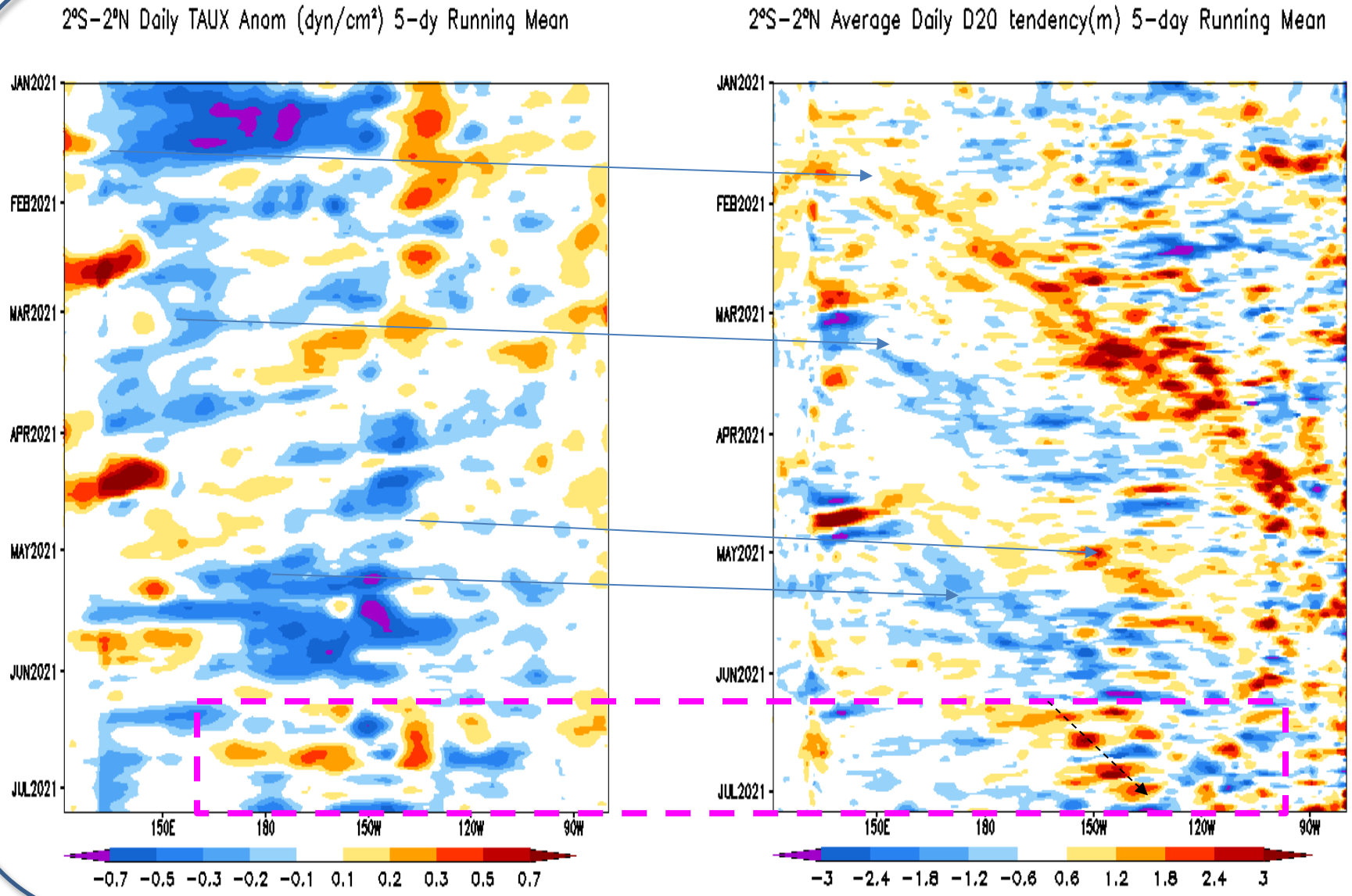
- Positive SSTA emerged in the eastern Pacific in Jun 2021, which was associated with the subsurface warming at the far eastern Pacific.
- Surface zonal wind stress was dominated by the meso-scale activity.

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



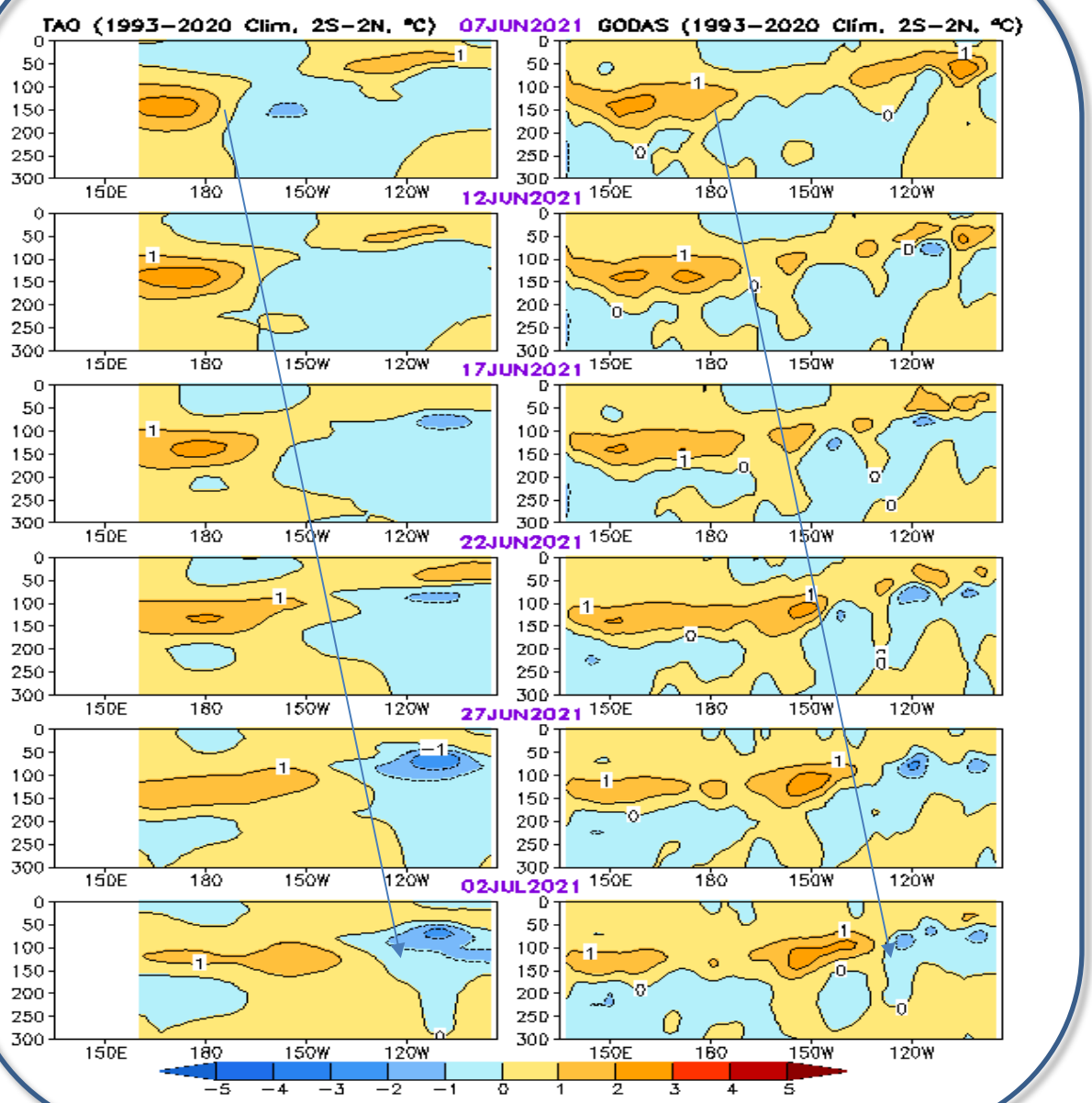
- Anomalous eastward currents emerged in the western & central equatorial Pacific in both OSCAR and GODAS in Feb-Apr 2021.
- Both anomalous eastward and westward currents were observed in Jun 2021..

Daily Equatorial Zonal Wind stress anomaly and D20 Tendency



Data source: NCEP GODAS

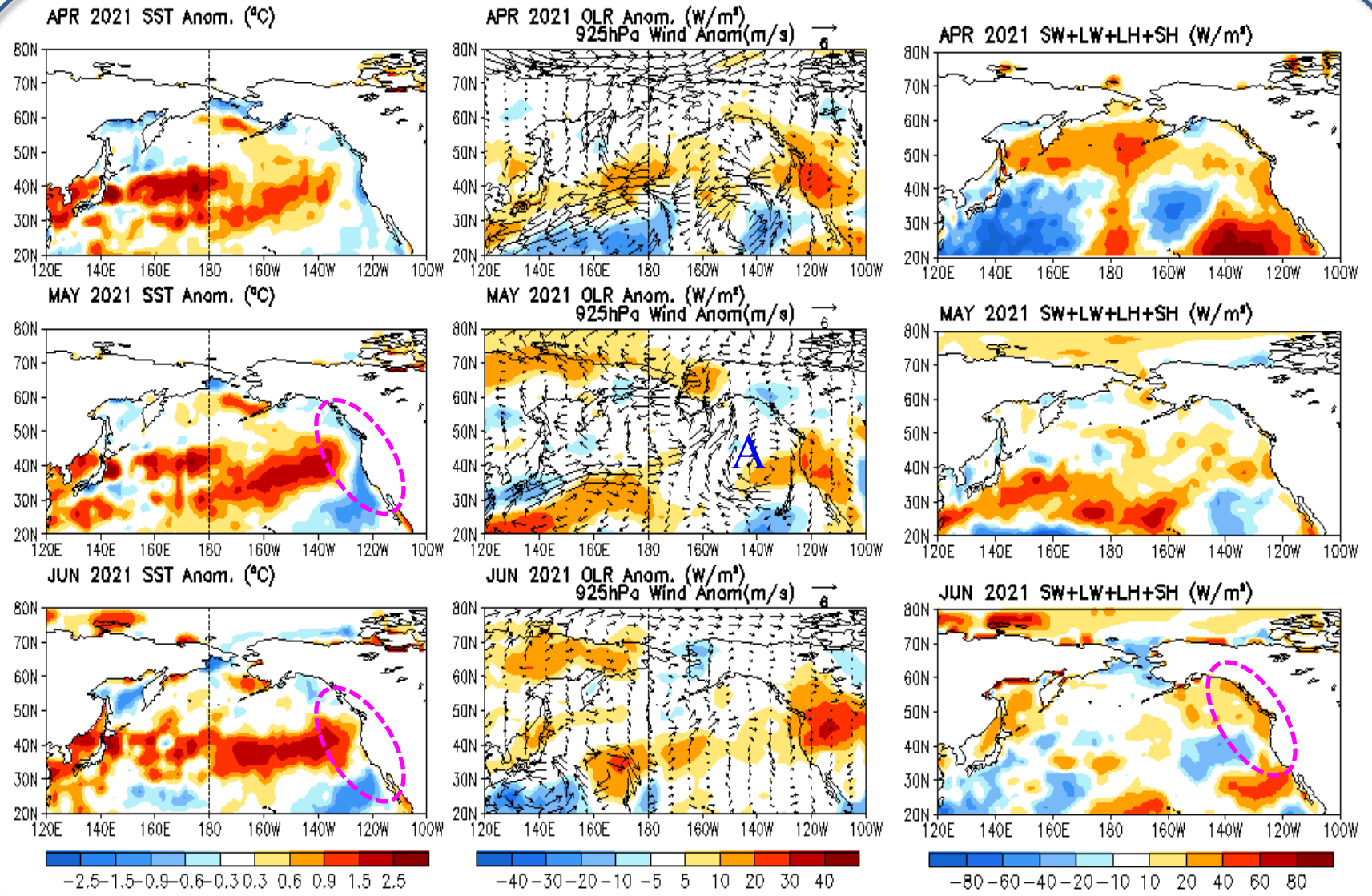
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly



- Positive ocean temperature anomalies propagated eastward along the thermocline, consistent with daily D20 tendency evolution (previous slide).
- Negative subsurface temperature anomaly were present in the far eastern Pacific.
- The features of the ocean temperature anomalies were similar between GODAS (model based) and TAO (objective) analysis.

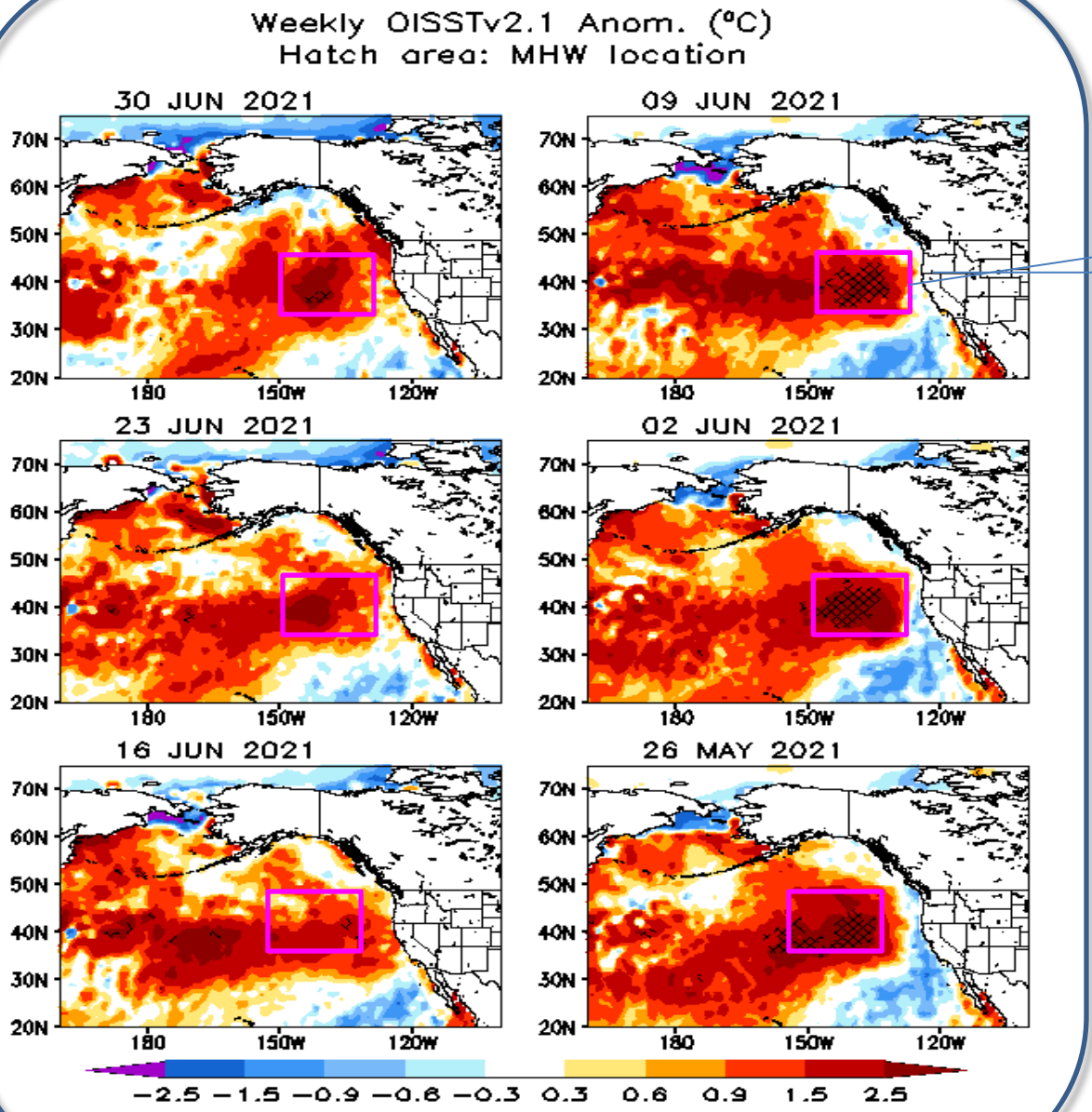
North Pacific & Arctic Oceans

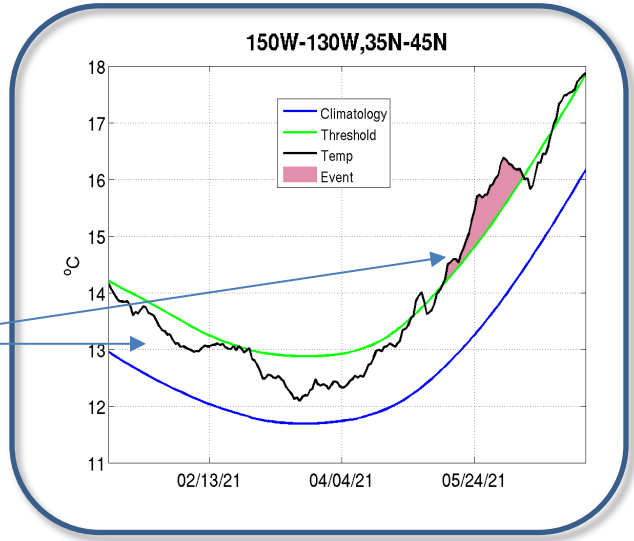
Latest 3-month North Pacific SST, OLR & uv925 anomalies



Data source: NCEP/NCAR Reanalysis 1

Weekly SST anomaly and MHWs in the North Pacific



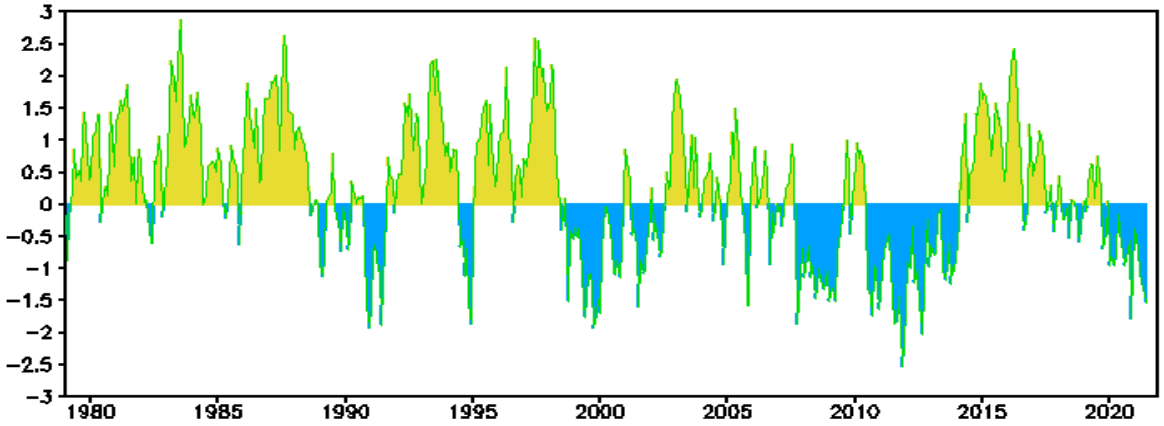


- MHWs were observed in the N.E Pacific during late May to early June.

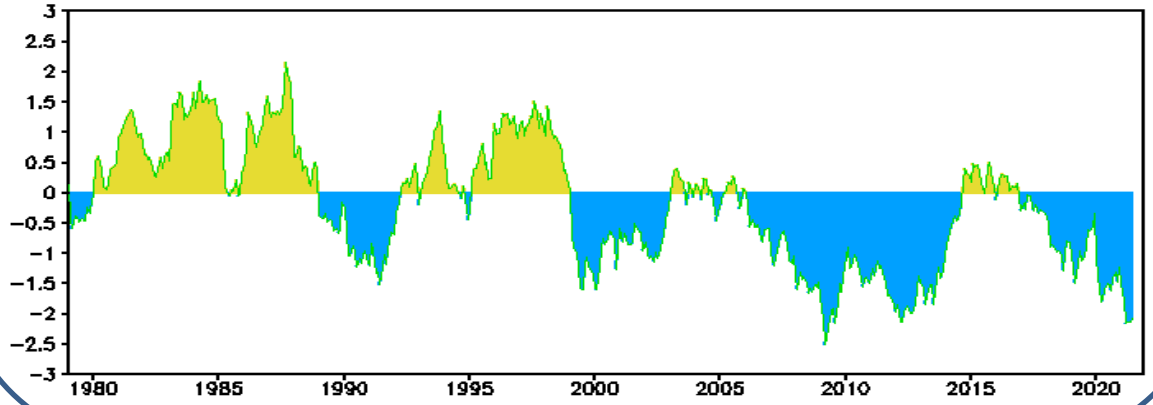
- Strong SSTA expanded toward to the N.W coast of North America in recent weeks.

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 has persisted since Jan 2020 with PDOI = -1.5 in Jun 2021.

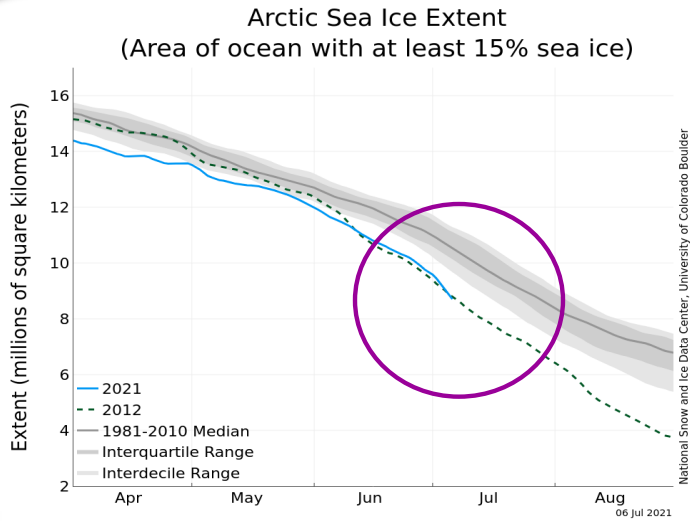
- Negative H300-based PDO index has persisted 57 months since Nov 2016, with HPDO = - 2.1 in Jun 2021.

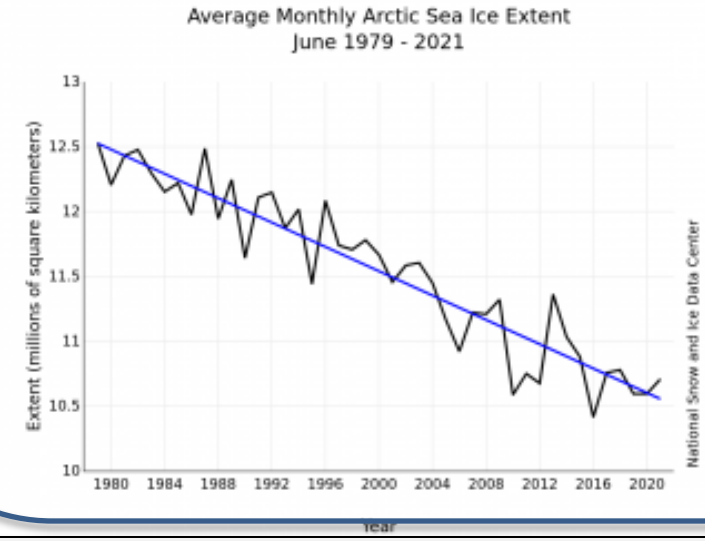
- SST-based PDO index has considerable variability both on seasonal and decadal time scales.

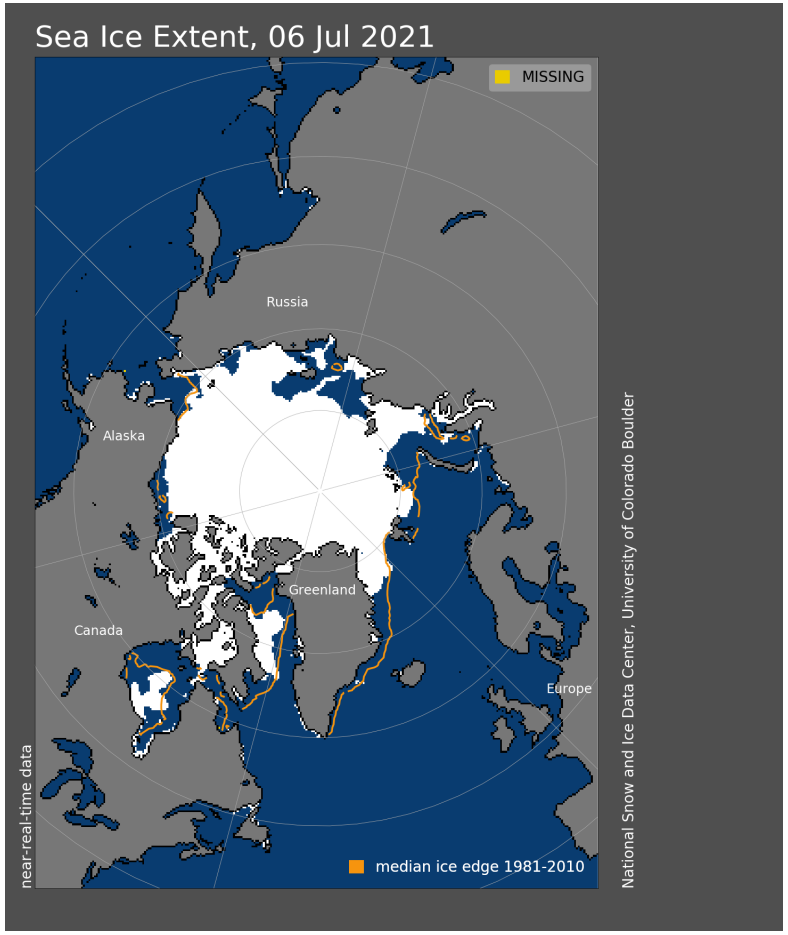
- H300-based PDO index highlights the slower variability and encapsulates an integrated view of temperature variability in the upper ocean.

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)

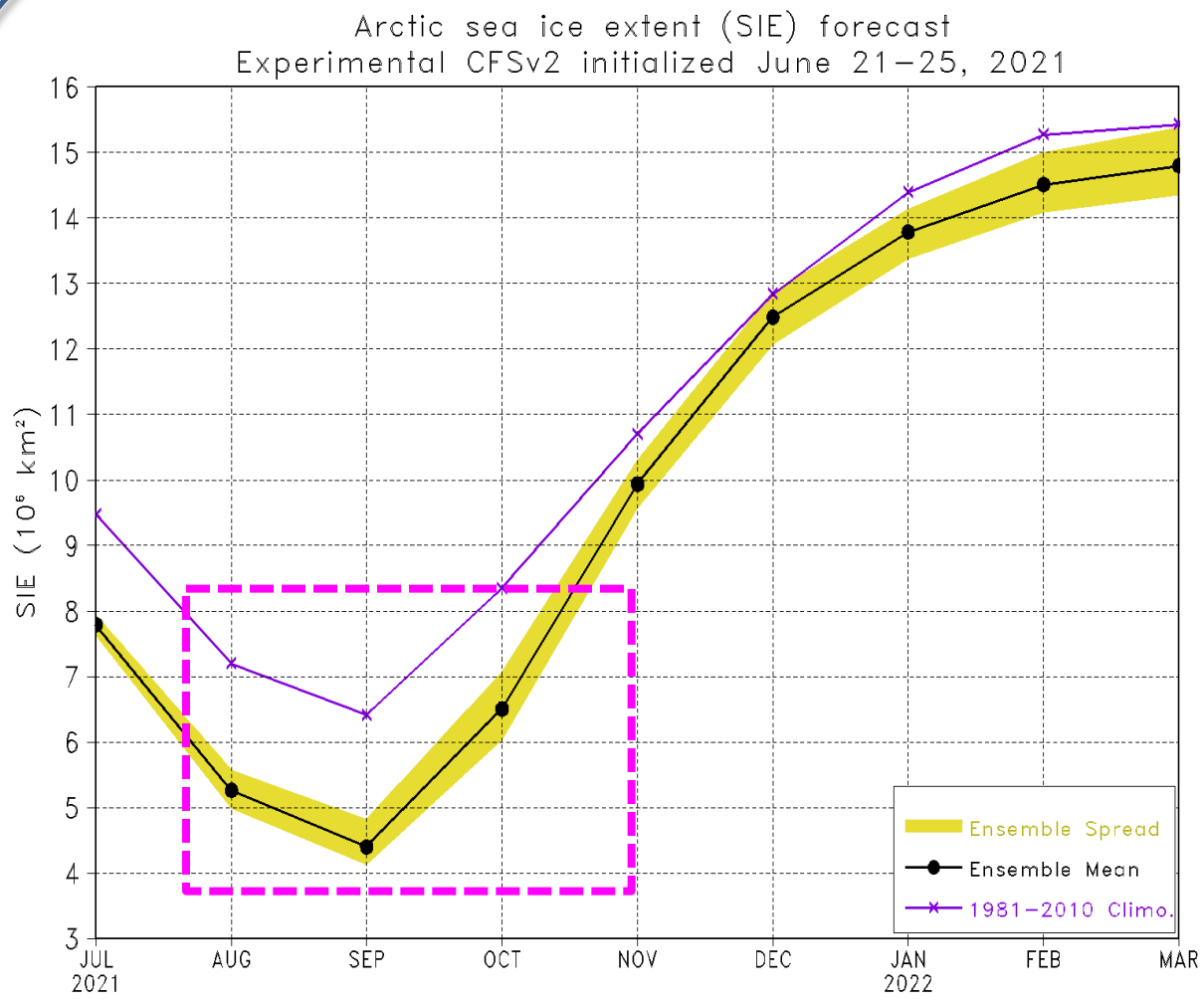






- The monthly average extent for Jun 2021 was 10.71 million square kilometers and it ranks the sixth lowest in the satellite record.

NCEP/CPC Arctic Sea Ice Extent Forecasts

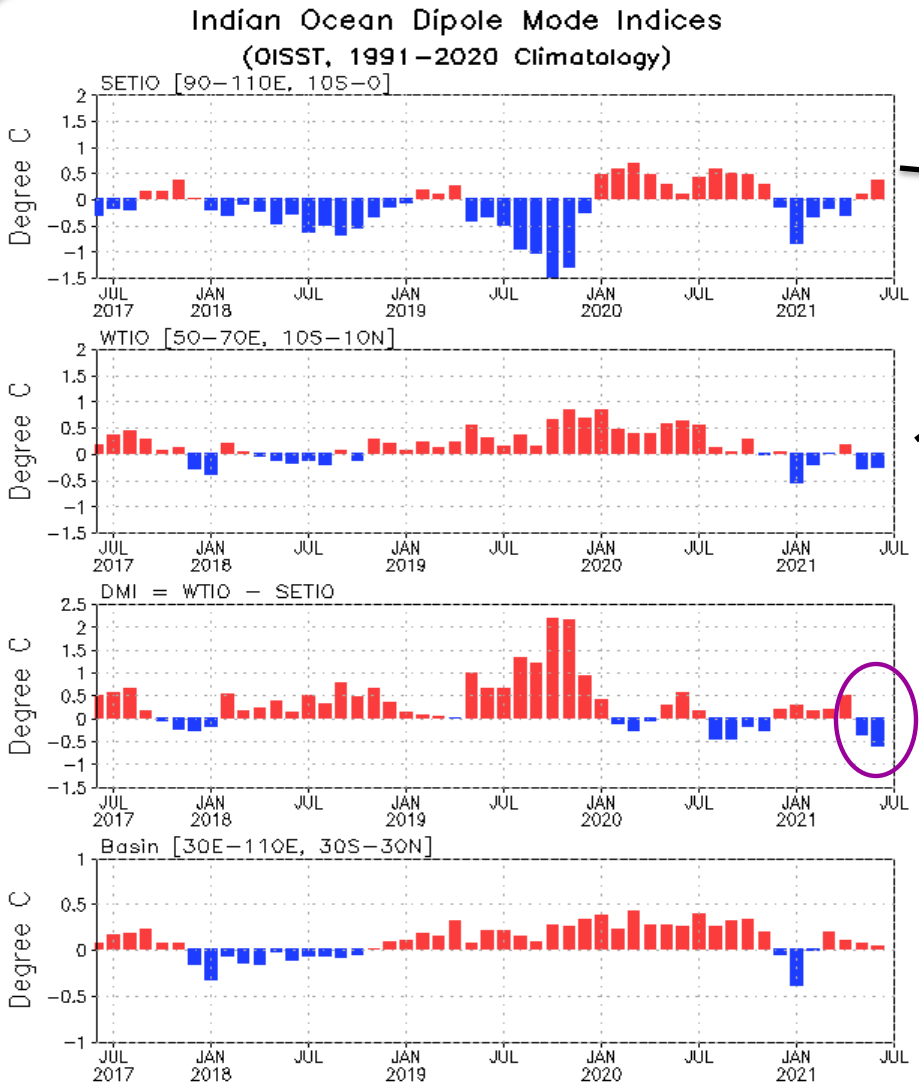


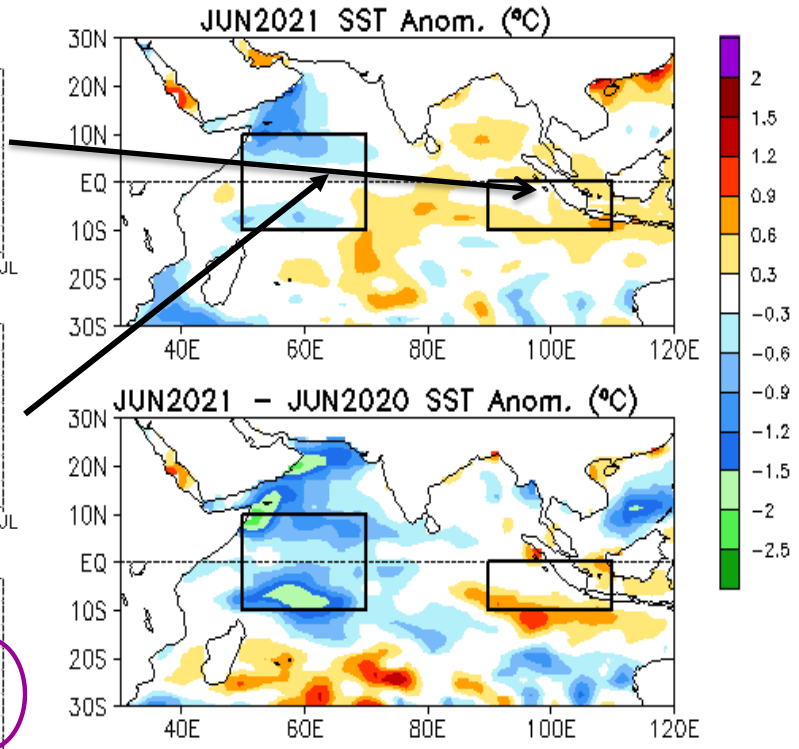
For ICs in Jun 2021, NCEP/CPC predicted a well below-normal sea ice extent during summer and autumn 2021.

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

Indian Ocean

Evolution of Indian Ocean SST Indices

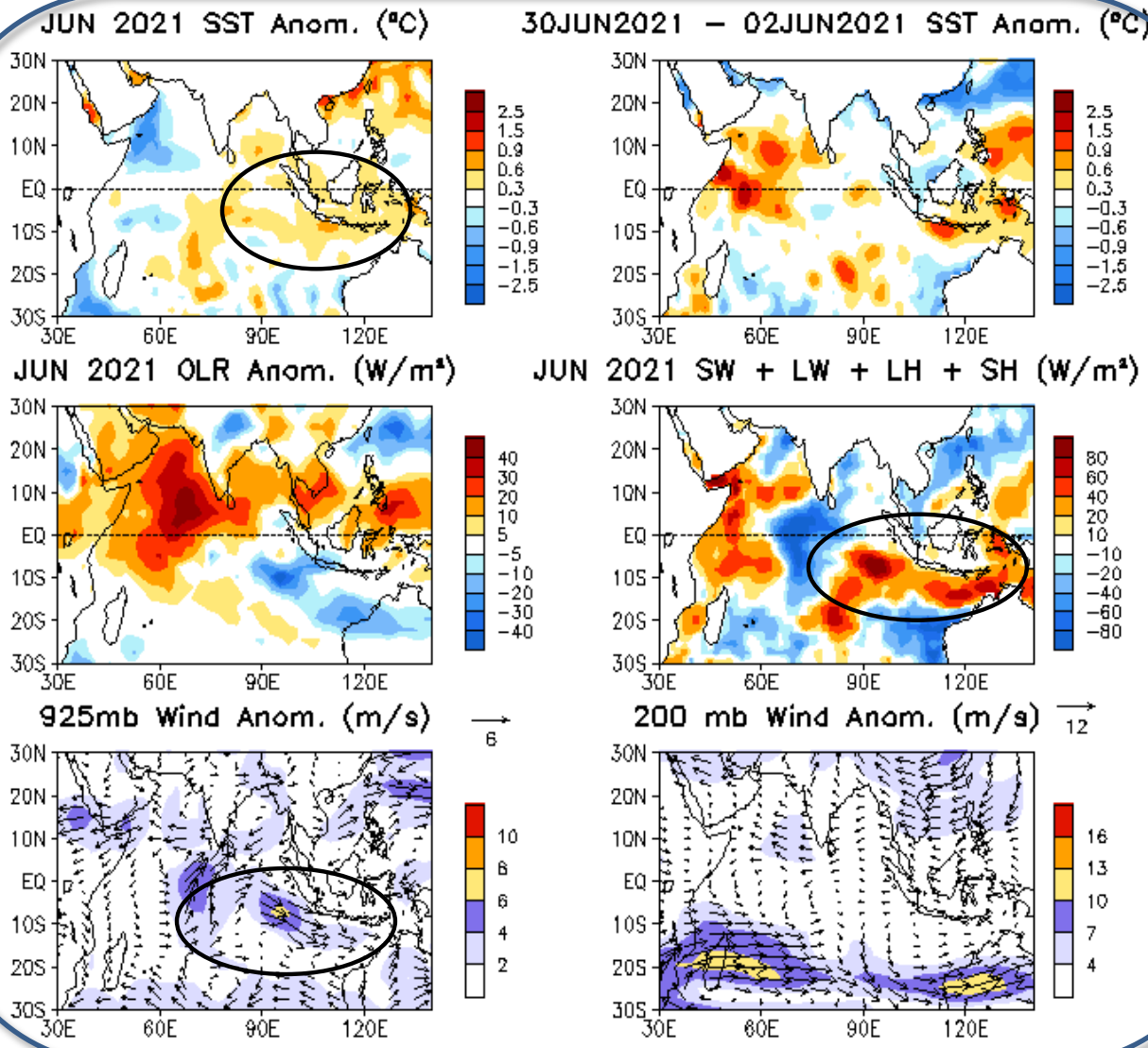




- Negative Indian Ocean dipole index strengthened in Jun 2021, with IOD = -0.63° C.

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

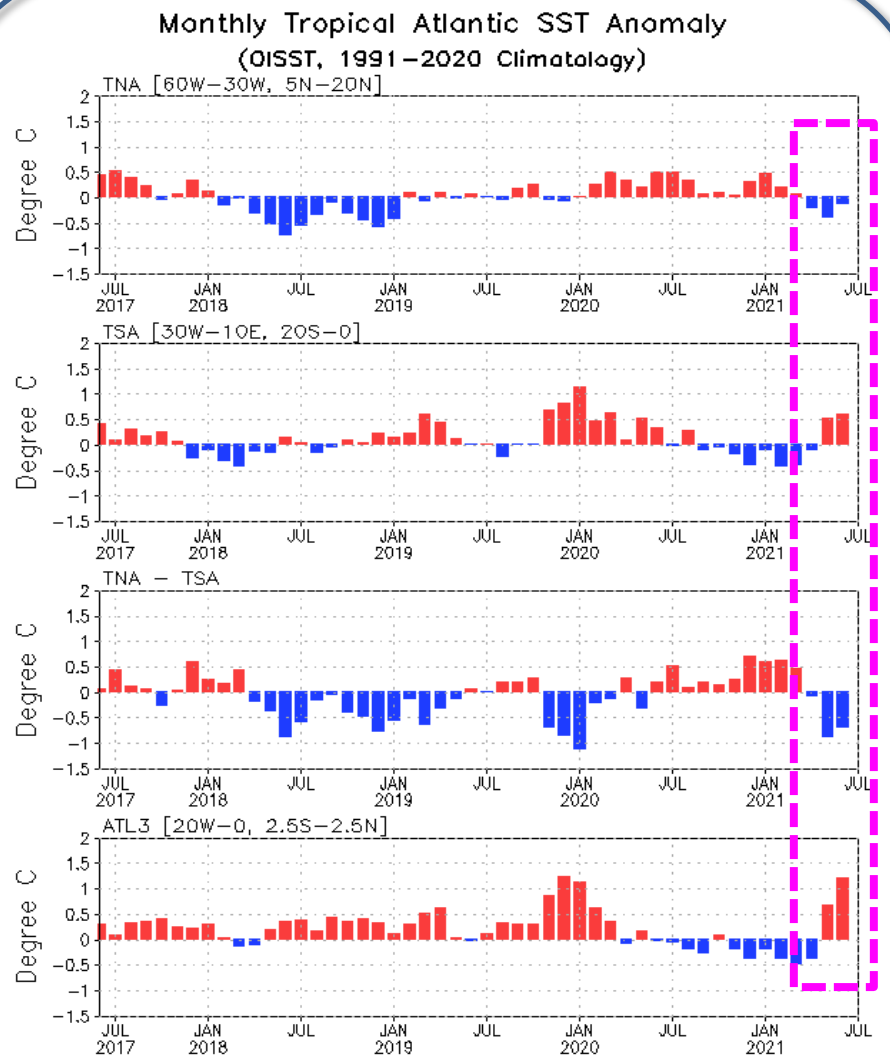


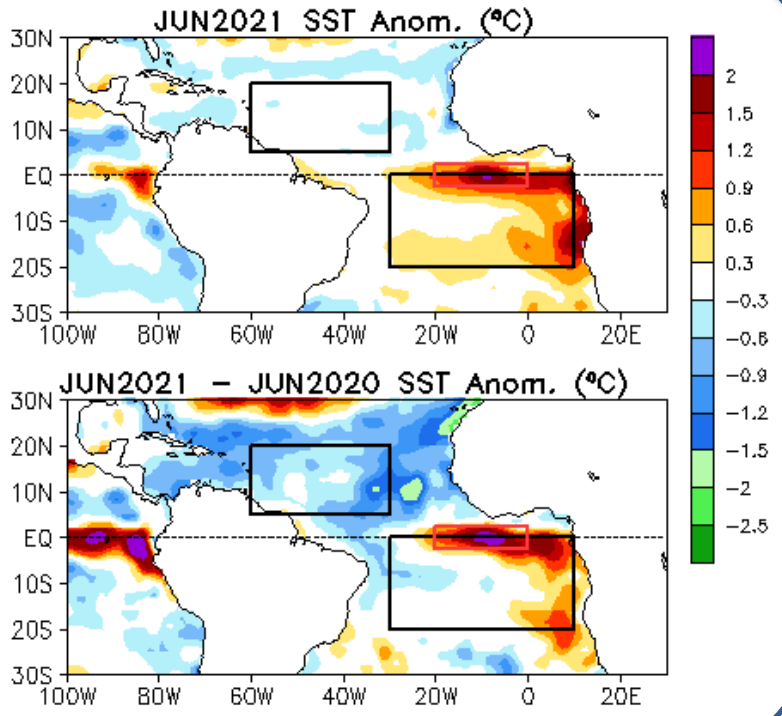
- Westerly wind anomaly prevailed over the southern eastern Indian Ocean, favoring further warming in the eastern Indian Ocean.

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.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices





- Negative meridional dipole index continued in Jun 2021.
- ATL 3 index in Jun 2021 hit a historical record since 1982, with ATL3 = 1.3°C.

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.

Atlantic Niño and associated rainfall variability

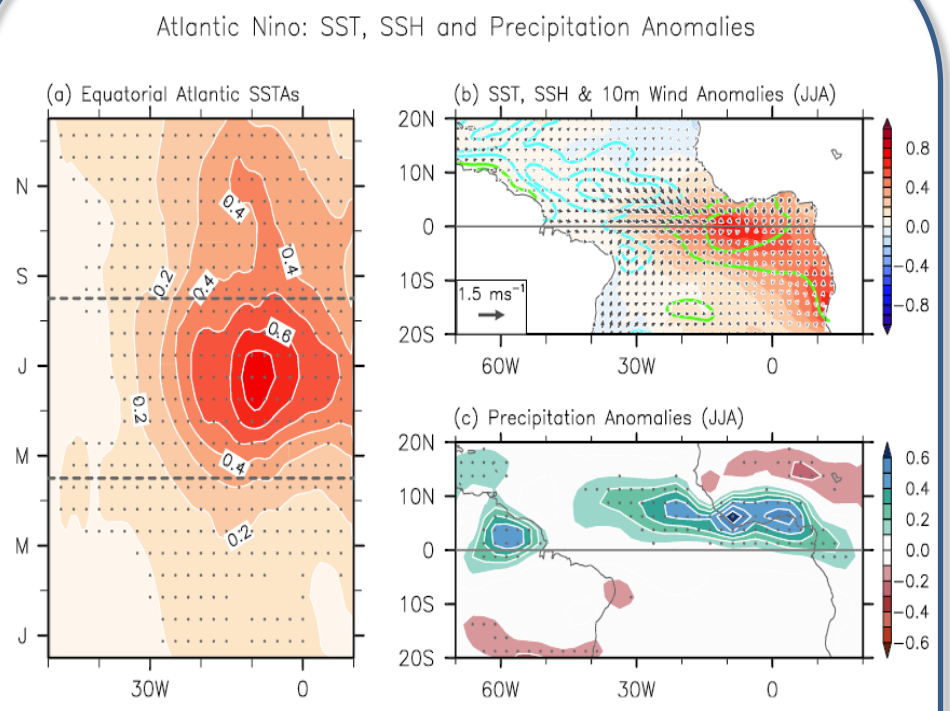
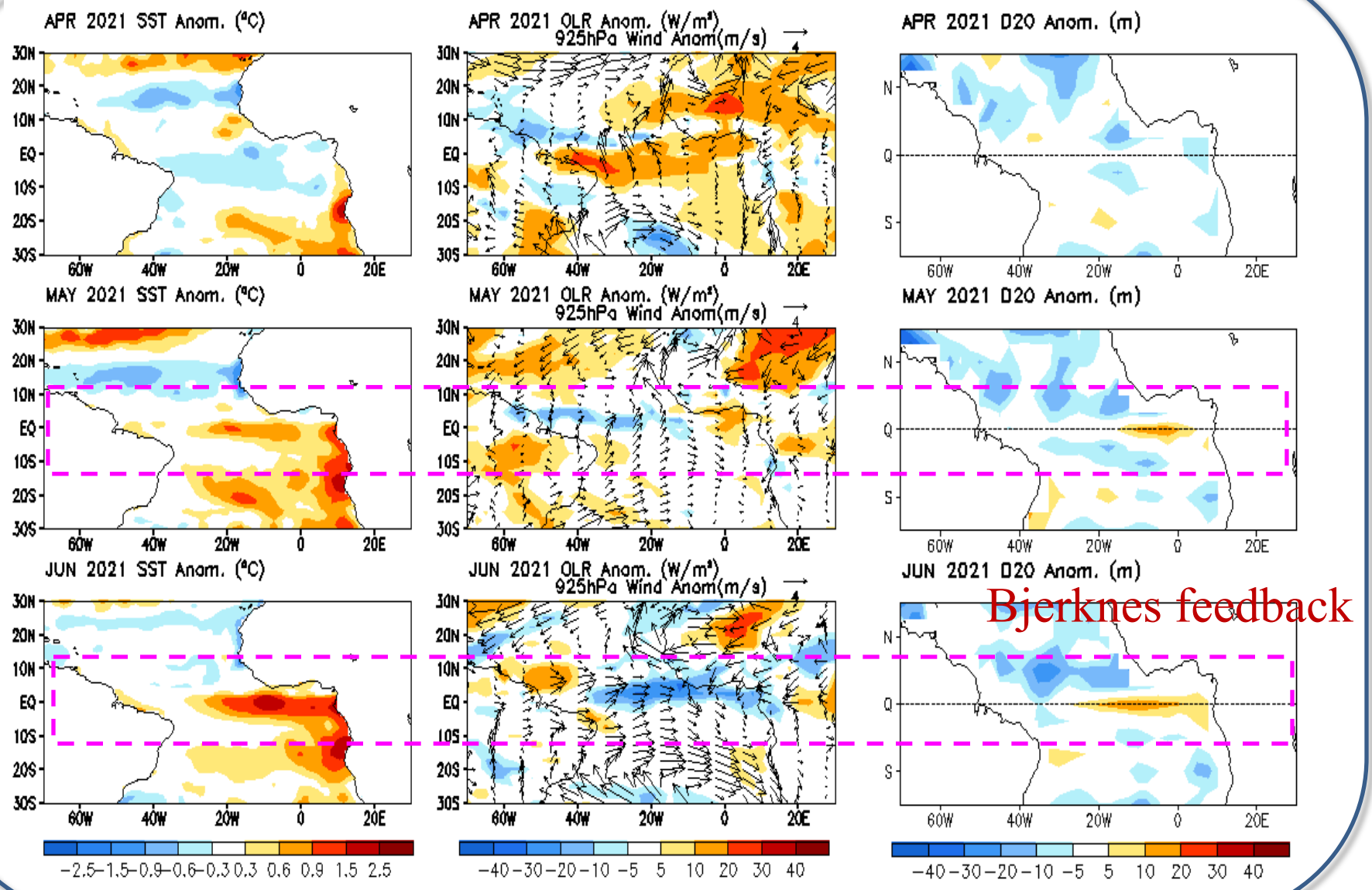


Figure 1. (a) Time-longitude plot of composite mean equatorial Atlantic SSTAs, averaged between 3°S and 3°N, from January to December derived from observed Atlantic Niño events. Significant SSTA values at 99% or above based on a Student's *t* test (two tailed) are indicated by gray dots. (b) Composite mean tropical Atlantic SST (shades), SSH (contours), and 10-m wind (vectors) anomalies; and (c) precipitation anomalies during June–August derived from observed Atlantic Niño events. Positive and negative SSHAs are indicated by green and cyan contour lines, respectively in (b). Significant precipitation anomaly values at 95% or above based on a Student's *t* test (two tailed) are indicated by gray dots in (c). The units for SST, SSH, winds and precipitation are in °C, cm, m s^{-1}, and mm day^{-1}, respectively. The contour interval for SSH anomalies is 0.5 cm.

- Atlantic Niño (Niña) is defined as the 3-month averaged SSTAs exceeding 0.5°C (-0.5 °C) in the ATL 3 region [3°S- 3°N, 20°W-0°] for at least two consecutive overlapping seasons.
- Atlantic Niño usually develops in boreal spring(MAM), peaks in summer (JJA) and dissipates in fall.
- Some Atlantic Niño events are responsible for a failure of the west African summer monsoon and increased frequency of flooding in the west African countries near the Gulf of Guinea and in the northeastern South American.
- Atlantic Niño and associated rainfall variability display large diversity.

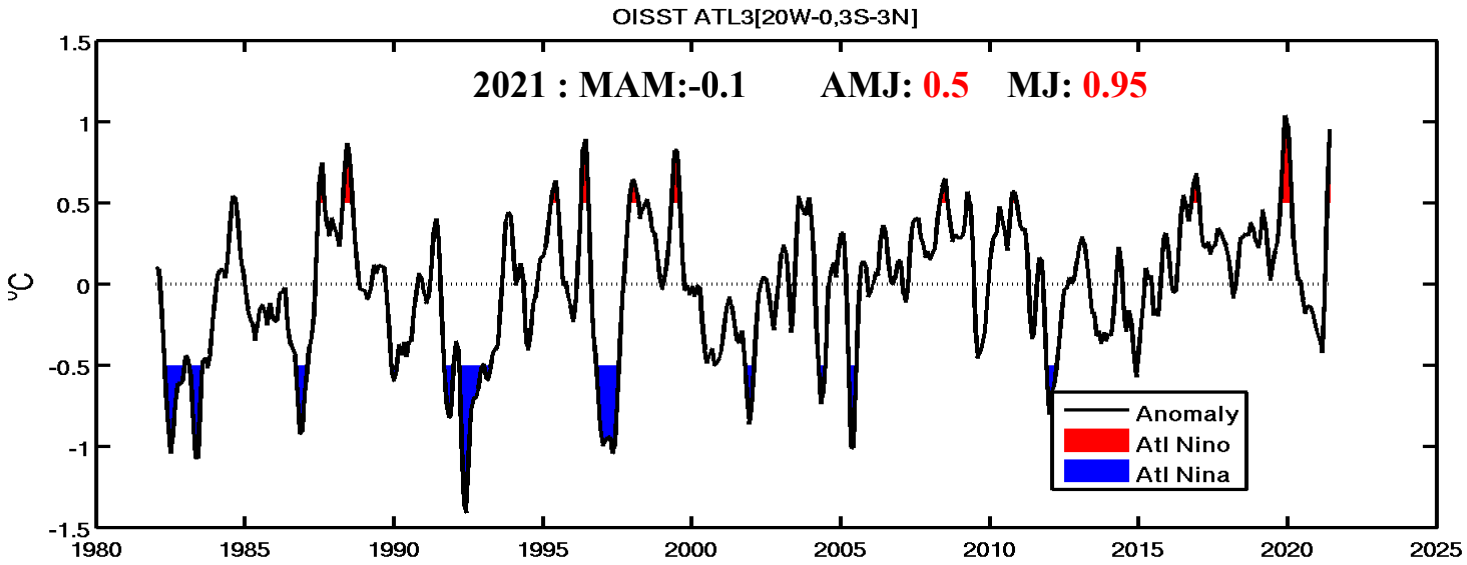
Vallès-Casanova, I., Lee, S.-K., Foltz, G. R. & Pelegrí, J. L. On the spatiotemporal diversity of Atlantic Niño and associated rainfall variability over West Africa and South America. *Geophys. Res. Lett.* **47**, e2020GL087108 (2020)

Latest 3-month Tropical Atlantic SST , OLR & uv925 and D20 anomalies



Bjerknes feedback

Historical Atlantic Niño & Niña Events



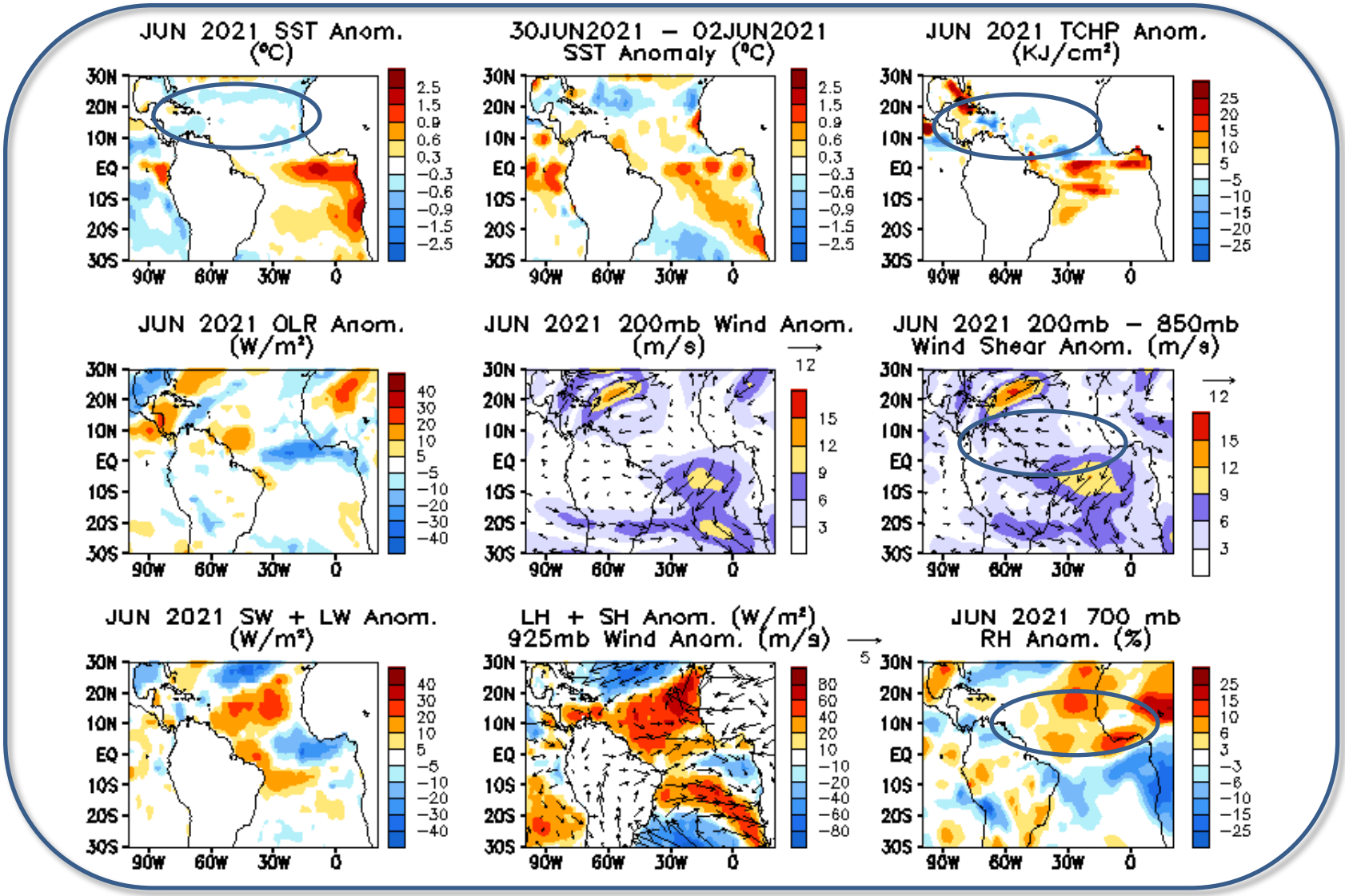
ATL Niño:

Aug 1984-Sep 1984
Jul 1987 -Aug 1987
May 1988 - Aug 1988
May 1995 – Jun 1995
May 1996 – Jul 1996
Dec 1997 – Mar,1998
May 1999 – Aug 1999
May 2008 - Jul 2008
Oct 2010 - Nov 2010
Nov 2016 – Jan 2017
Nov 2019 – Feb 2020
May 2021 - ??

ATL Niña:

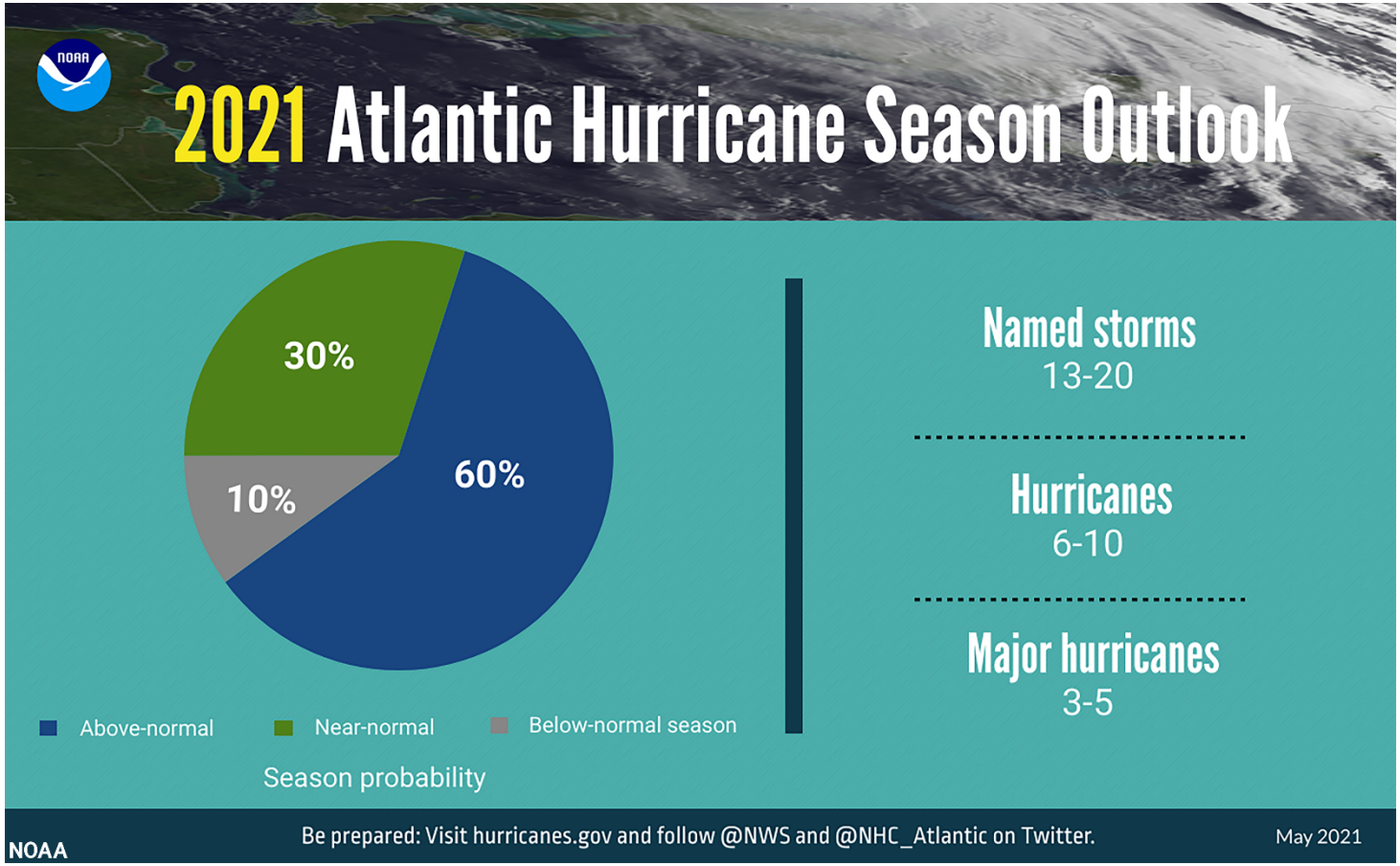
May 1982 - Dec 1982
Mar 1983 -Jul 1983
Oct 1986 - Feb 1987
Dec 1989 – Feb 1990
Oct 1991 – Jan 1992
Apr 1992 – Dec 1992
Feb1993 – Apr 1993
Nov1996 - Jul 1997
Nov 2001 - Jan 2002
Apr 2004 – Jun 2004
Apr 2005 – Jul 2005
Dec 2011 – Apr 2012

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 Outlook



- NOAA 2021 Atlantic Hurricane Season Outlook: above-normal Atlantic hurricane season with a 60% chance of an above-normal season, a 30% chance of a near-normal season, and a 10% chance of a below-normal season.
- However, experts do not anticipate the historic level of storm activity seen in 2020. *(https://www.noaa.gov/media-release/noaa-predicts-another-active-atlantic-hurricane-season)*

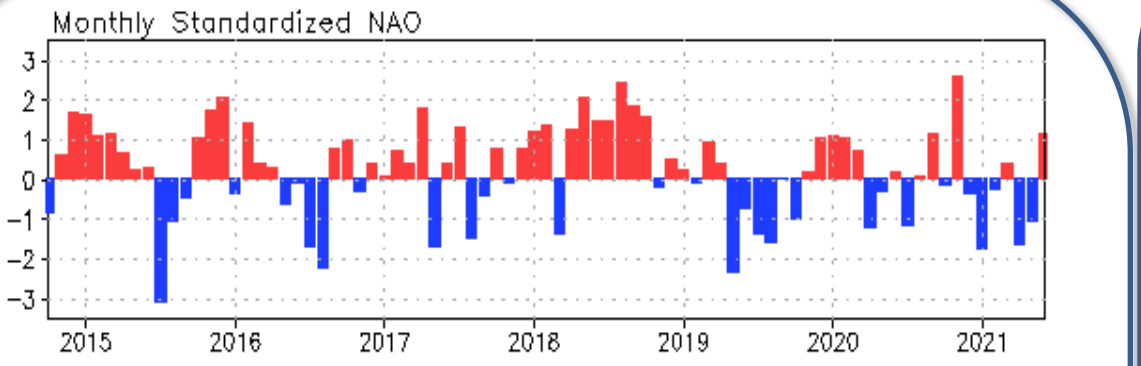
2021 Atlantic Hurricane Season Activities

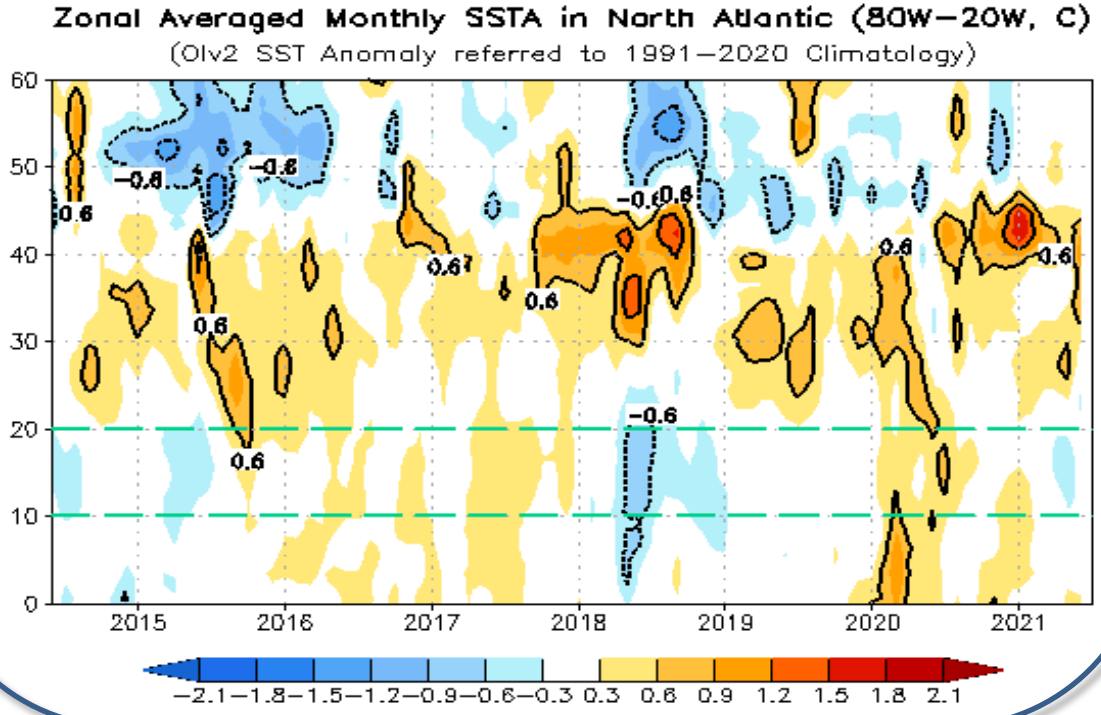
https://en.wikipedia.org/wiki/2021_Atlantic_hurricane_season

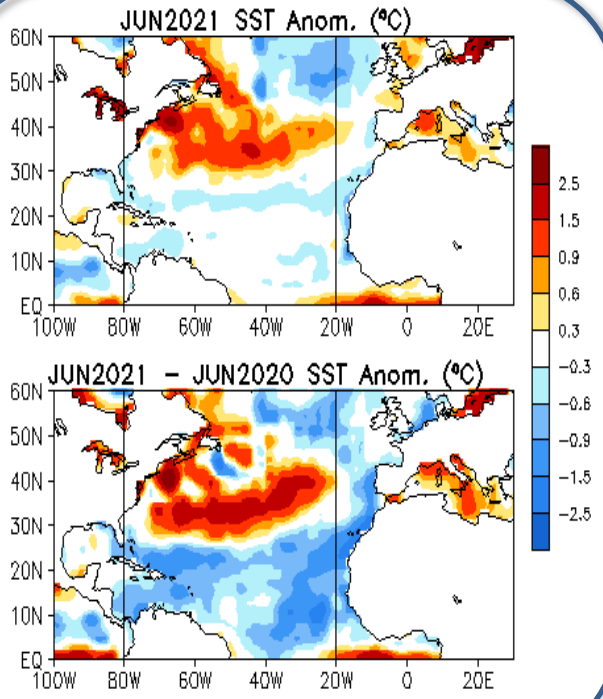
- By Jul 10 2021, five tropical storms formed with one developing into hurricane.

Atlantic	Observations (By Jul 10)	Outlook (May 21) 60% above-normal	(1991-2020)
Total storms	5	13-20	14
Hurricanes	1	6-10	7
Major hurricanes	0	3-5	3

NAO and SST Anomaly in North Atlantic





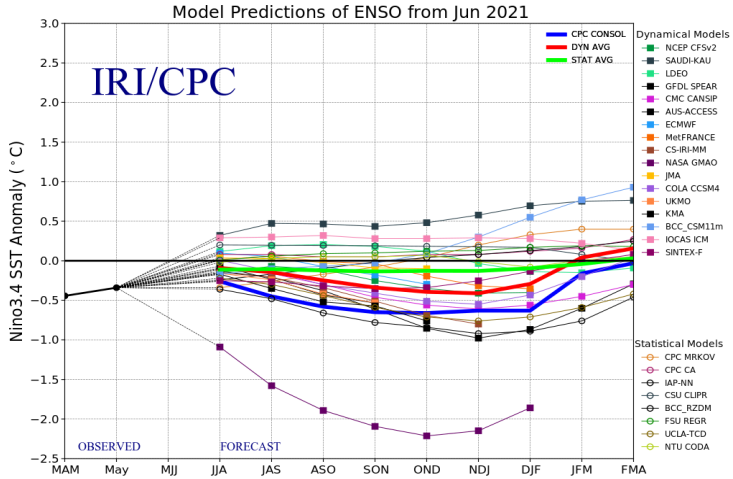


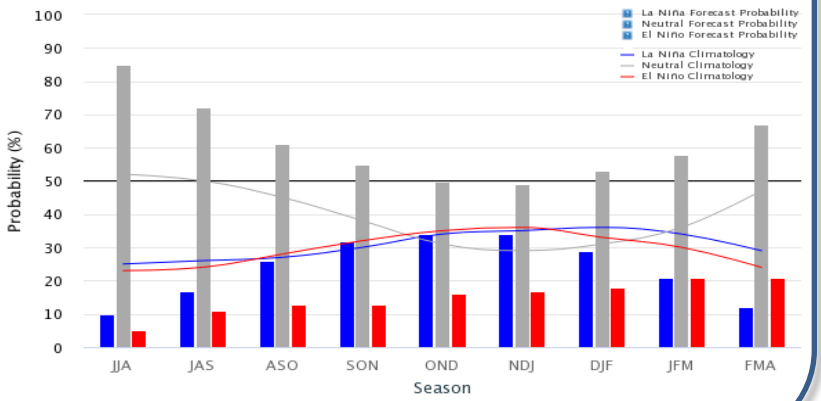
- NAO switched to a positive phase in Jun 2021 with NAOI= 1.1.
- The prolonged positive SSTAs in the middle latitudes were evident, due to the domination of the positive phase of NAO during the last 5-6 years.

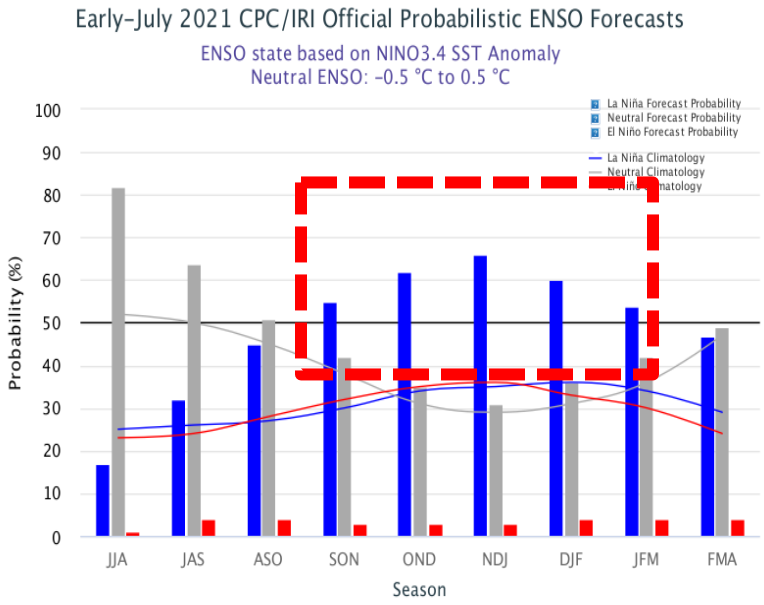
Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80ºW and 20ºW (bottom). SST are derived from the NCEP OI SST analysis, and anomalies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

ENSO and Global SST Predictions

IRI/CPC Niño3.4 Forecast



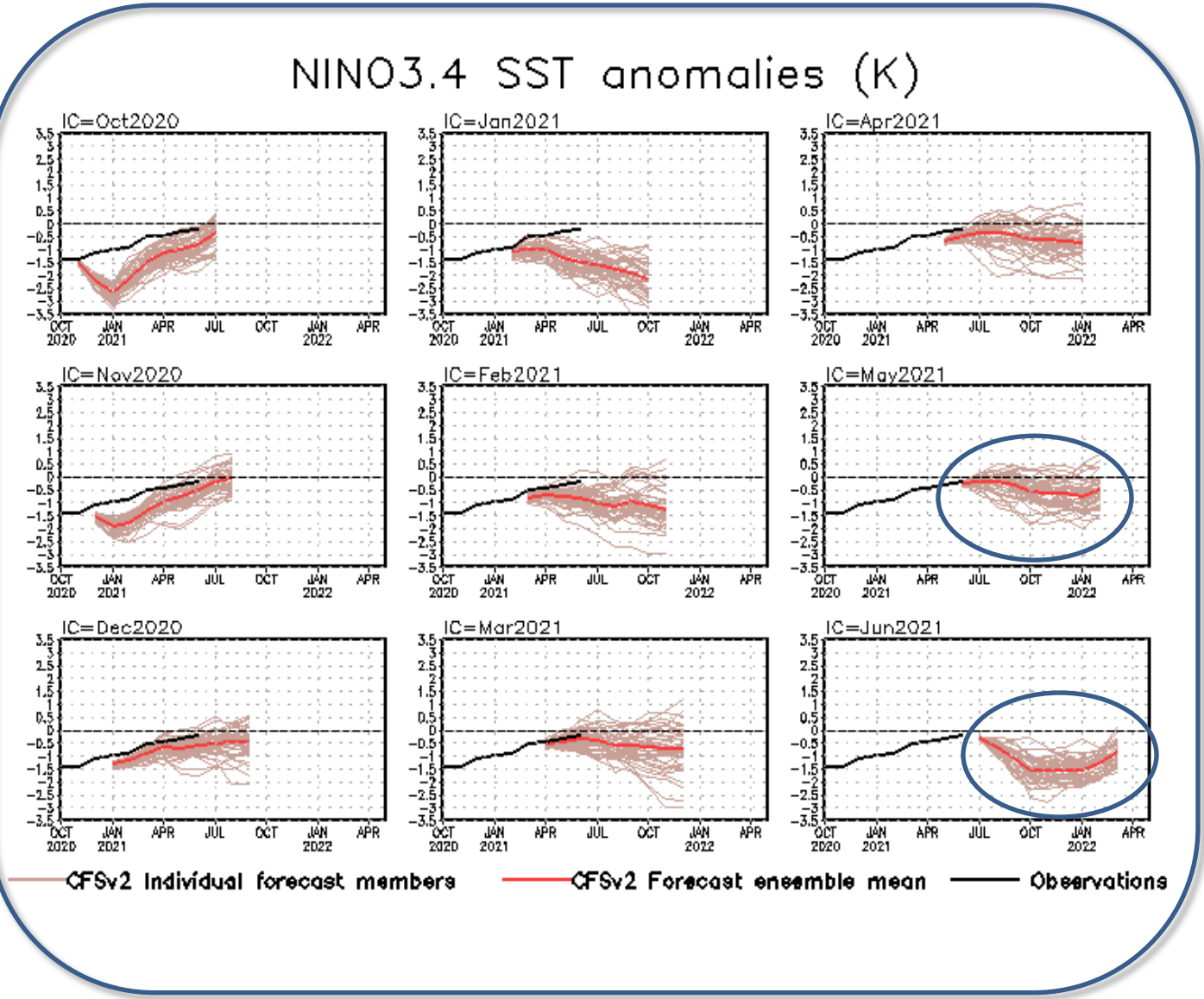




- ENSO Alert System Status: La Niña Watch Issued on 8 Jul 2021

- <u>Synopsis:</u> *ENSO-neutral is favored through the Northern Hemisphere summer and into the fall (51% chance for the August-October season), with La Niña potentially emerging during the September-November season and last through the 2021-22 winter (66% chance during November-January).*

CFSv2 Niño3.4 SST Predictions

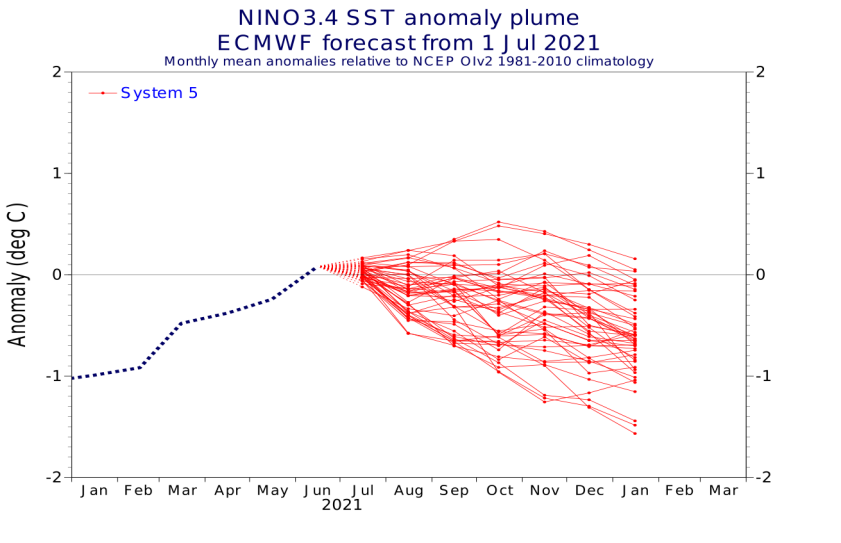


- Latest CFSv2 predictions call for a moderate La Niña in the northern hemisphere 2021/22 winter.

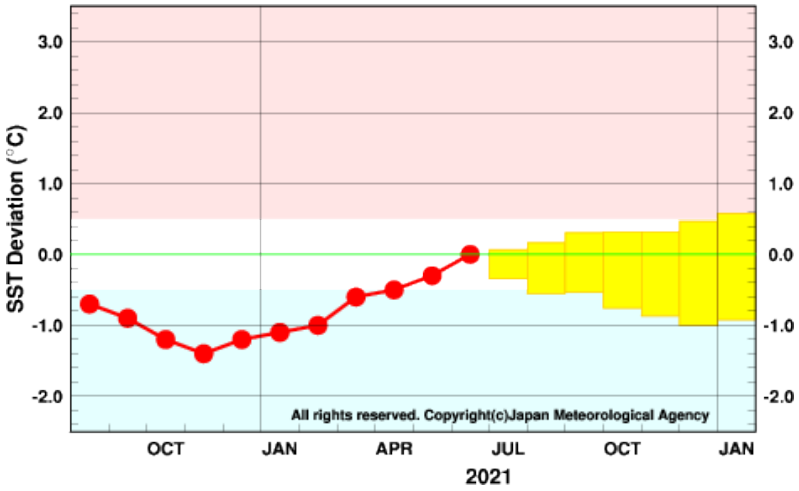
CFS Niño3.4 SST prediction from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect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

Individual Model Niño3.4 Forecasts

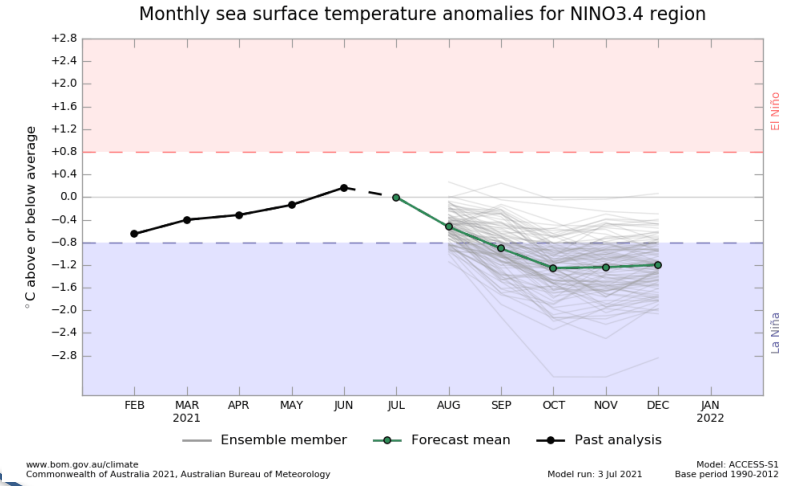
EC: IC= 01 July, 2021



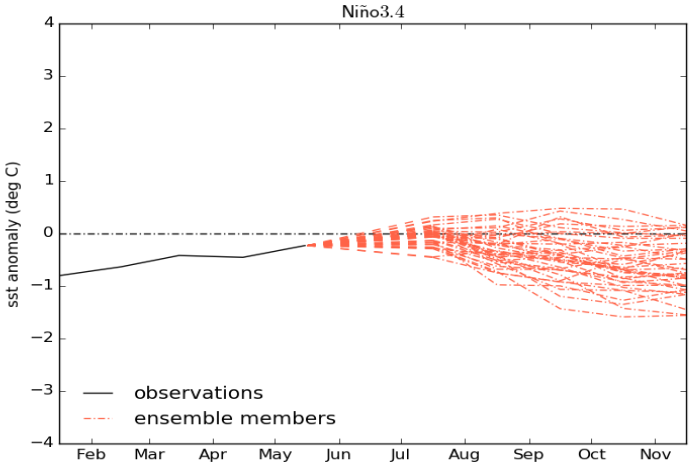
JMA: Updated 10 June, 2021



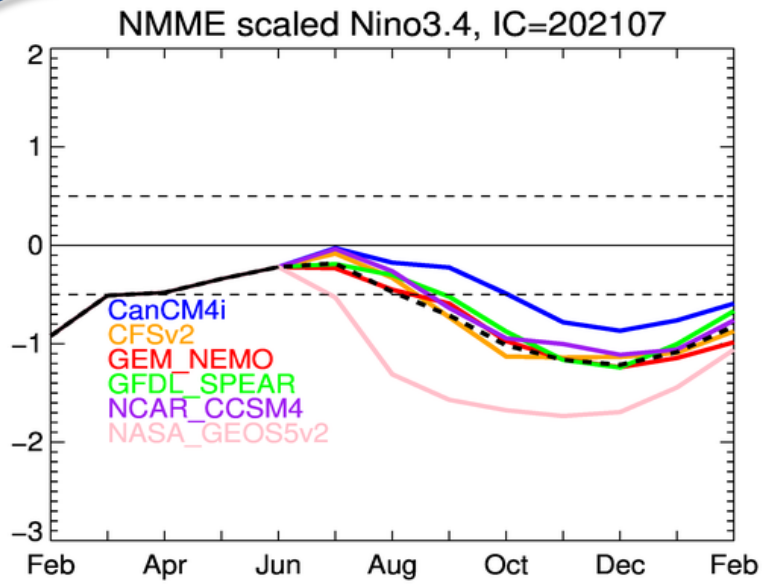
BOM: Updated 03 July, 2021

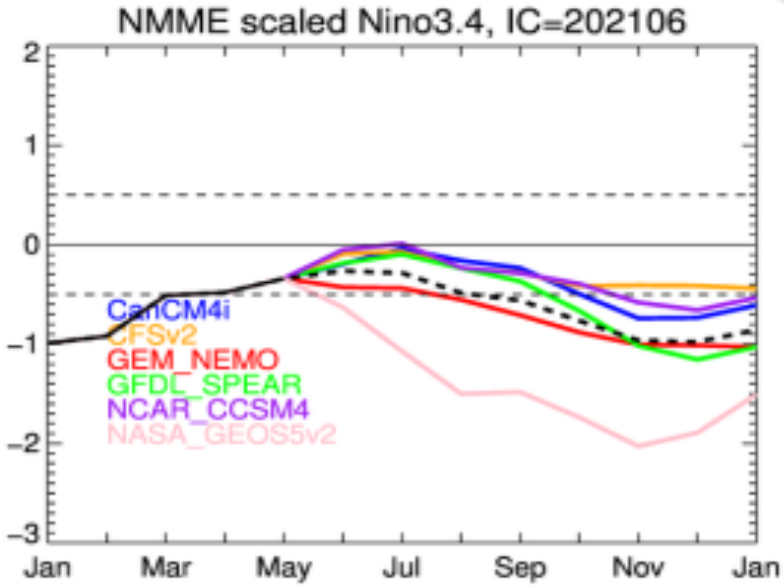


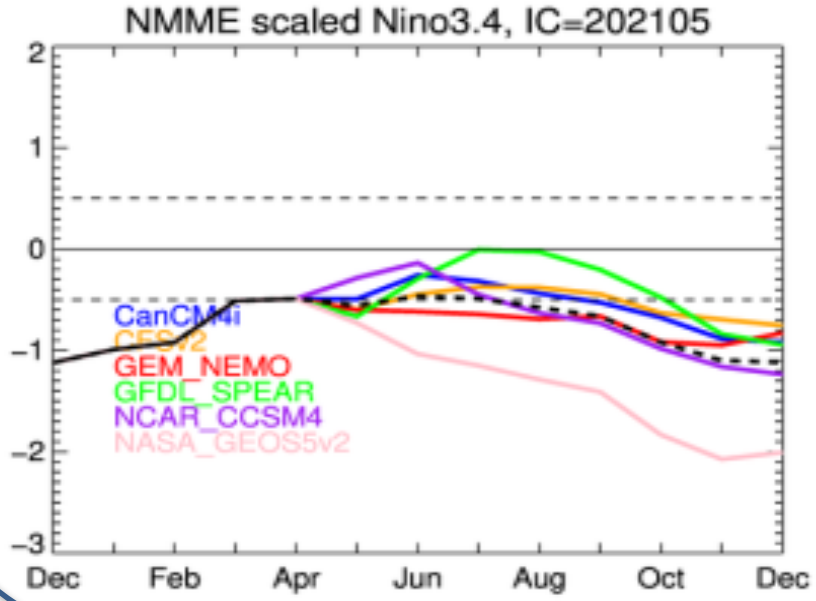
UKMO: Updated 11 June, 2021

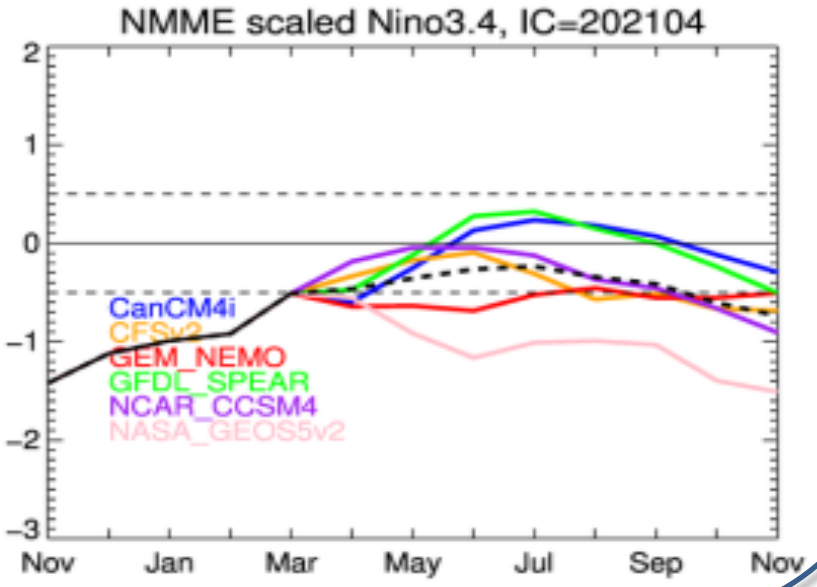


NMME forecasts with the latest 4-month initial conditions

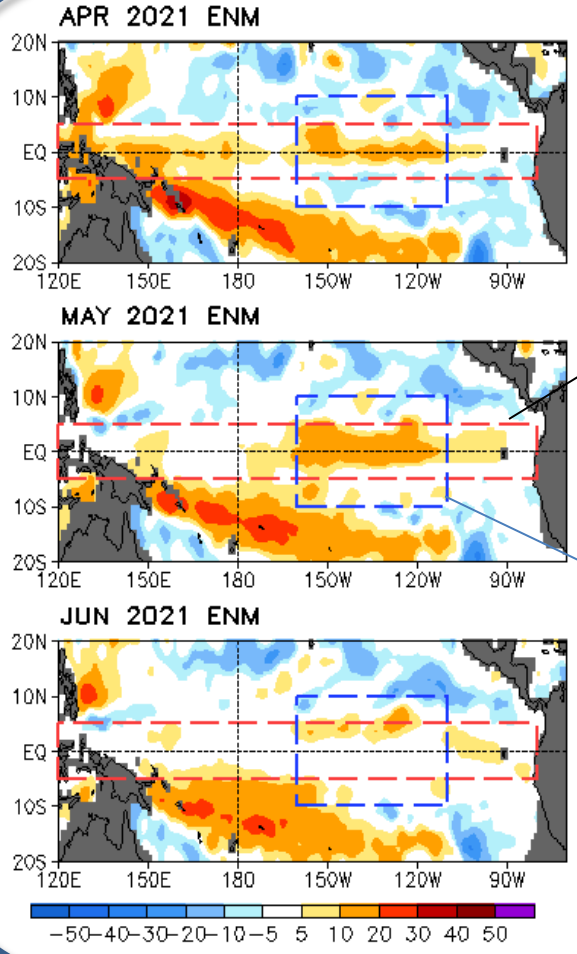


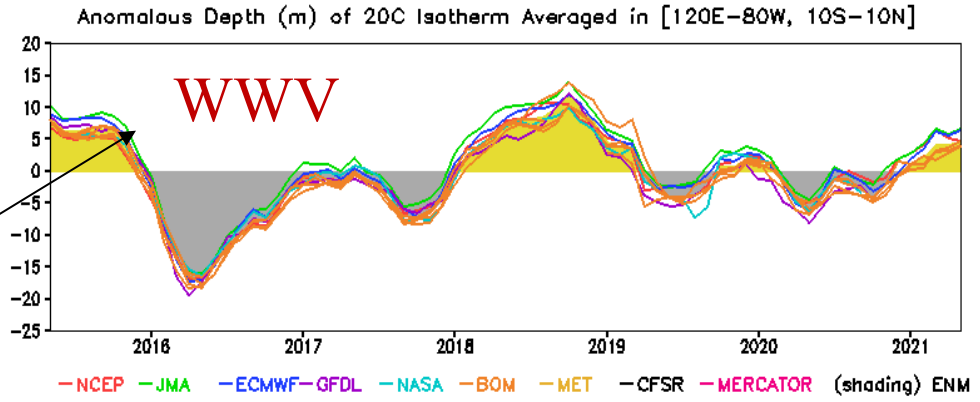


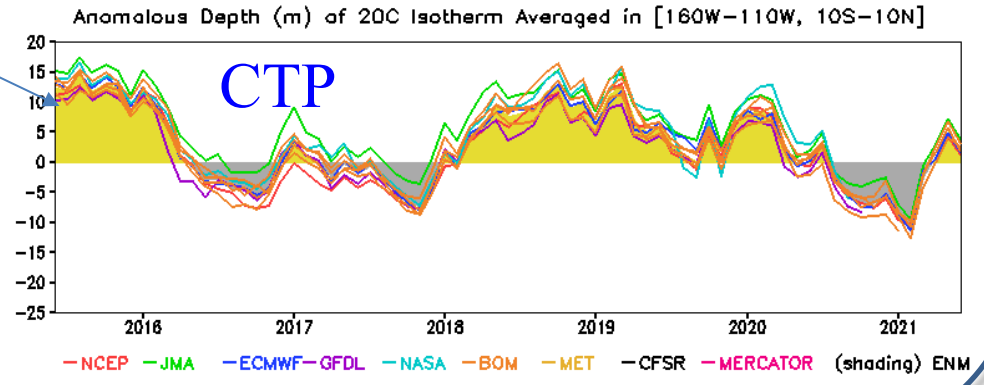




Oceanic ENSO Precursors: WWV & CTP

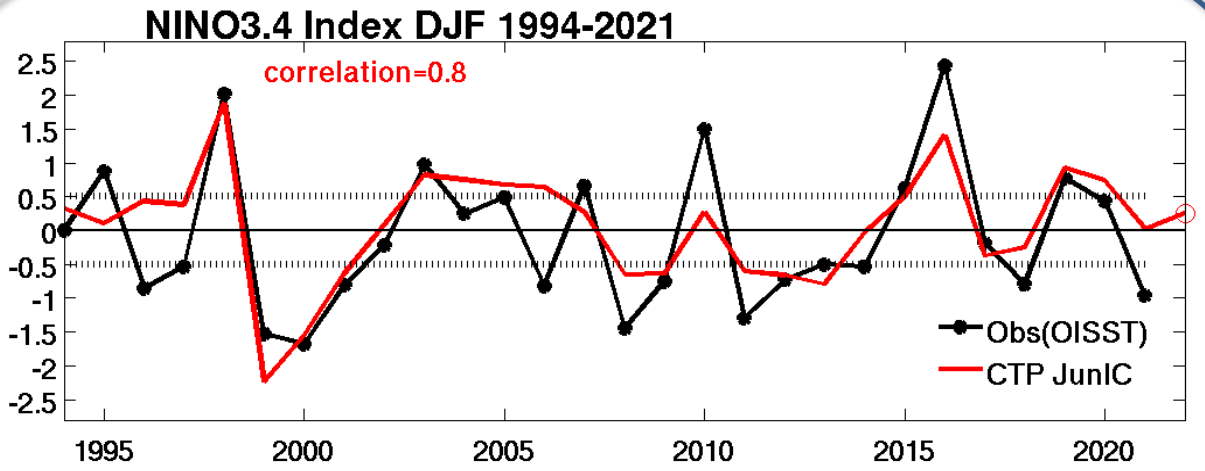


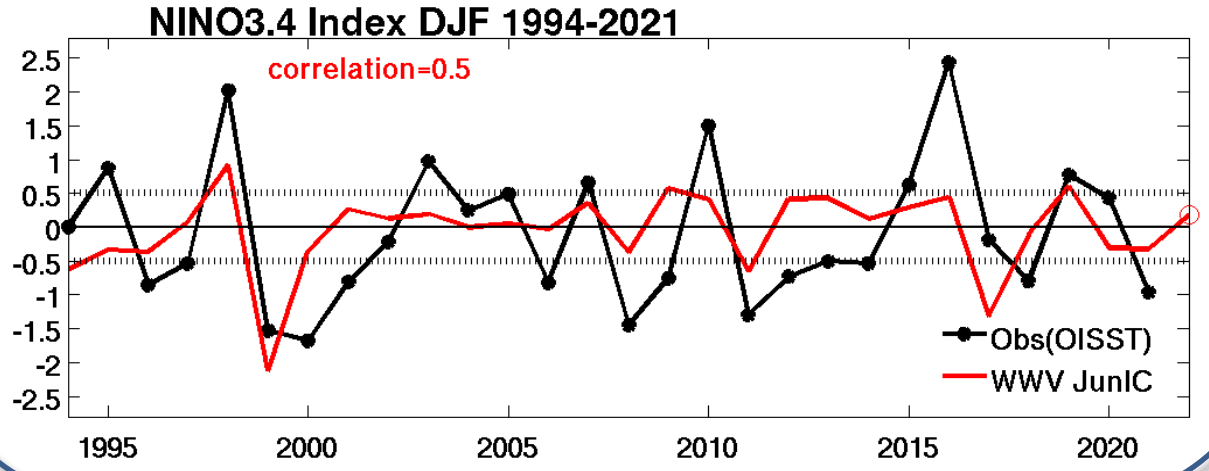




Warm water volume (WWV) is defined as an average of D20 anomaly across the equatorial Pacific (120° E – 80° W, 5° S-5° N) (Meinen and McPhaden 2000). Central tropical Pacific (CTP) index is calculated as the averaged D20 anomaly in the central tropical Pacific (160° W-110° W, 10° S-10° N) (Wen et al. 2014). The monthly D20 data is obtained from the Real-time Ocean Reanalysis Intercomparison Project(https://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html).

DJF Nino34 predictions based on ENSO precursors





- Both WWV and CTP in June predict ENSO neutral condition in DJF 2022.

Prediction models are constructed using leave-one-year-out cross validation over the full period by iteratively recomputing the coefficients with the target prediction year removed. For details Wen et al. (2021) DOI: https://doi.org/10.1175/JCLI-D-20-0648.1

Impact of equatorial Atlantic SST on ENSO

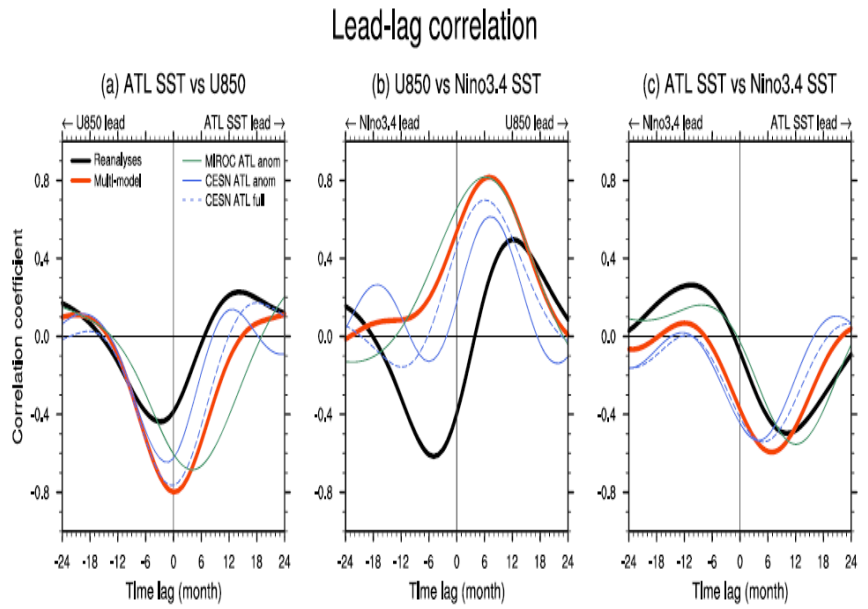
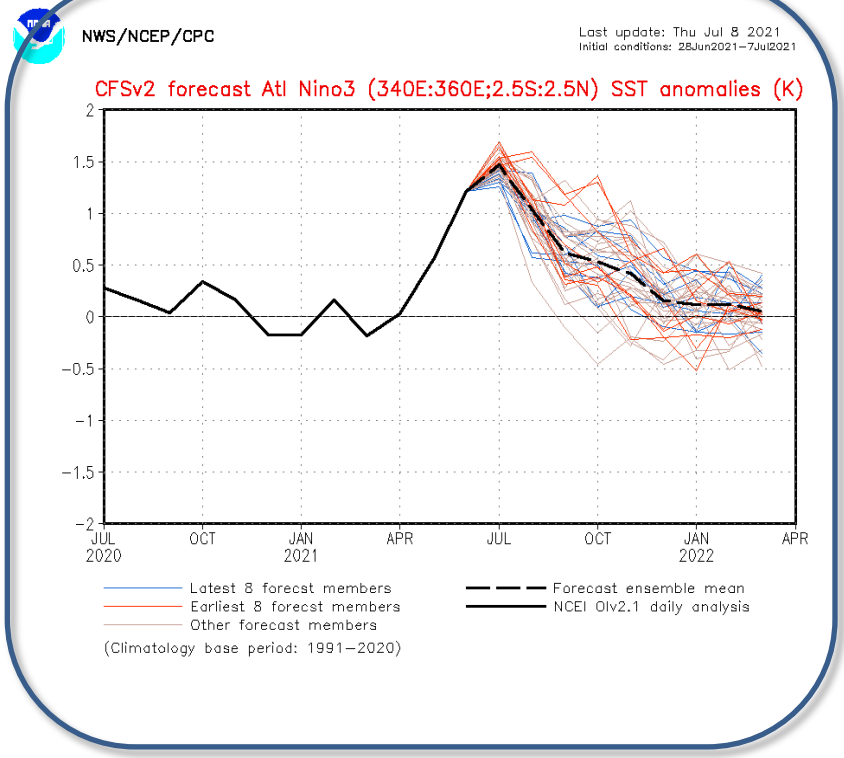


Figure 6. Lead-lag correlations between (a) equatorial Atlantic SST (5°S to 5°N, 50°W to 0°) and zonal wind anomalies at 850 hPa in the Indo-Pacific region (5°S to 5°N, 90–150°E), (b) zonal wind anomalies at 850 hPa in the Indo-Pacific region and Nino 3.4 index (SST anomalies in 5°S to 5°N, 170–120°W), and (c) equatorial Atlantic SST and Nino 3.4 index. Black and red lines are observations and multimodel ensemble of ATL runs, respectively. Green, blue solid, and blue dashed lines correspond to the MIROC ATL anomaly, CESM ATL anomaly, and CESM ATL full runs, respectively.

- Equatorial Atlantic warming (cooling) induces enhanced (weakened) trade winds in Indo-Pacific regions and leads to subsequent tropical Pacific cooling (warming) 7 month later.

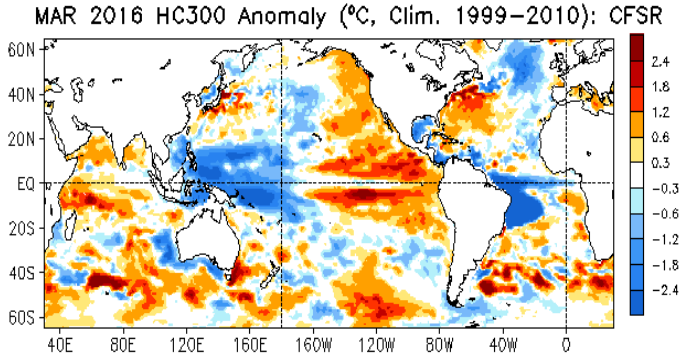
Chikamoto, Y., Johnson, Z.F., Wang, S.Y.S., McPhaden, M.J. and Mochizuki, T., 2020. El Niño–Southern Oscillation Evolution Modulated by Atlantic Forcing. *Journal of Geophysical Research: Oceans*, *125*(8), p.e2020JC016318.

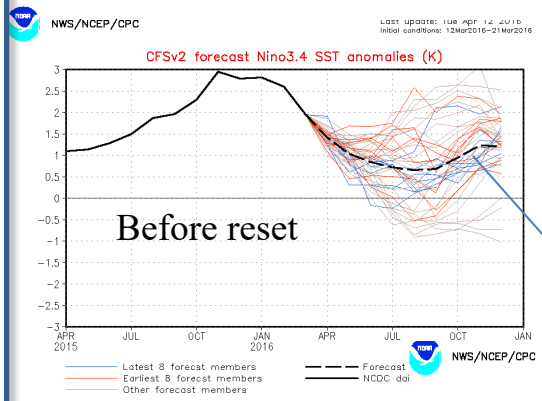
CFSv2 ATL3 predictions

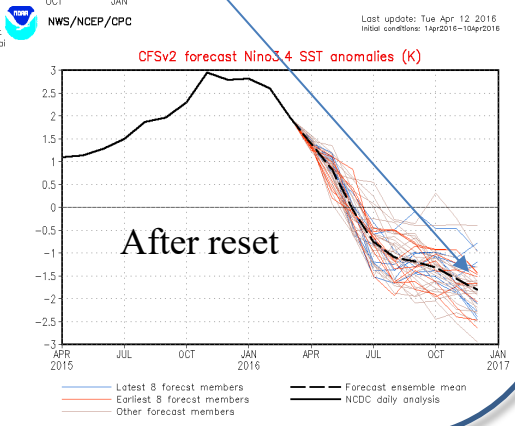


- Large cold bias in CFSR in March 2016 (ocean IC for CFSv2) led to a false El Nina prediction, providing evidence for the impact of tropical Atlantic SST on ENSO.
- Latest CFSv2 predict ATL3 will reach 1.5°C in July, a historical high on record.

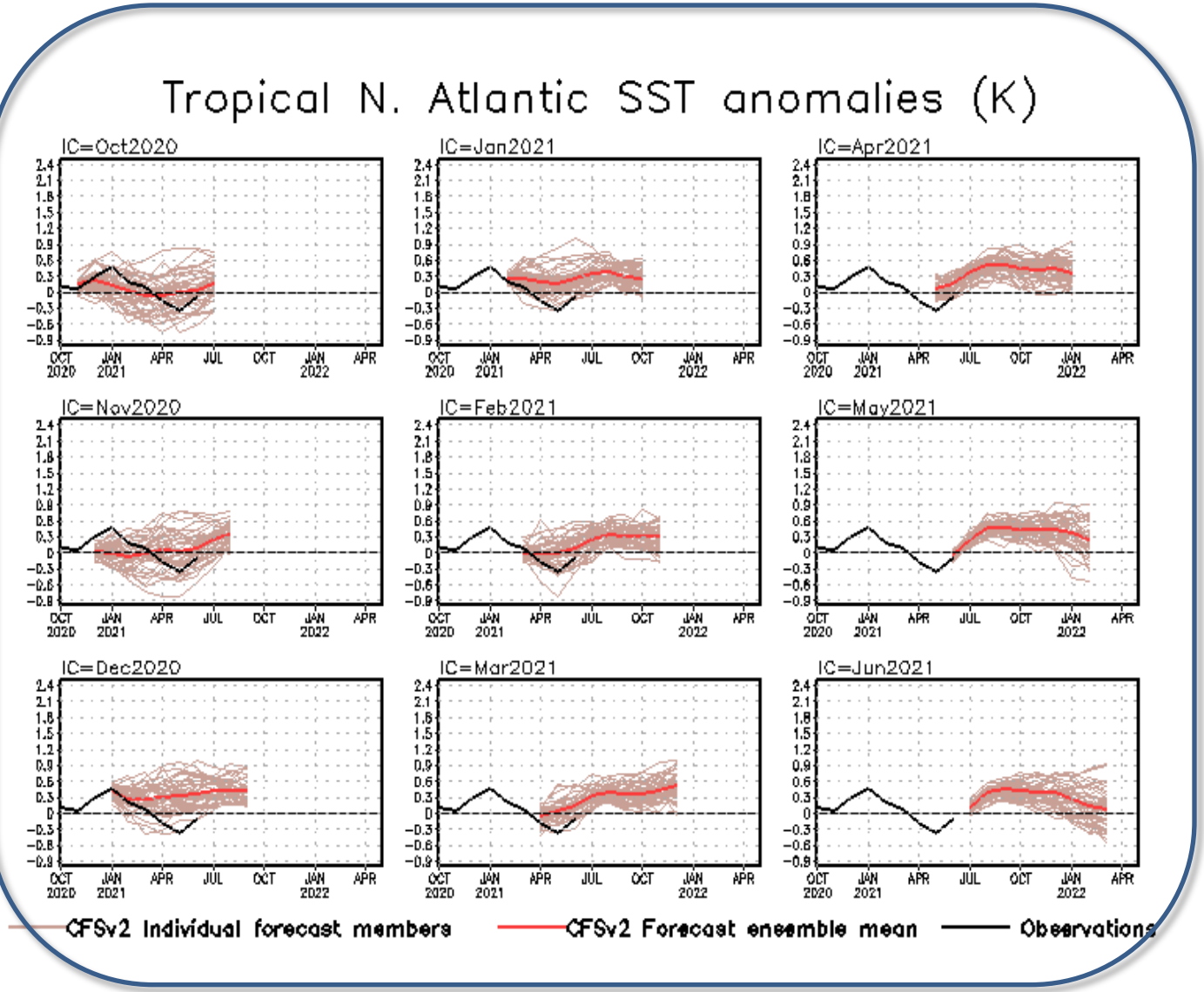
Impact of CFSR cold bias in tropical Atlantic on ENSO predictions







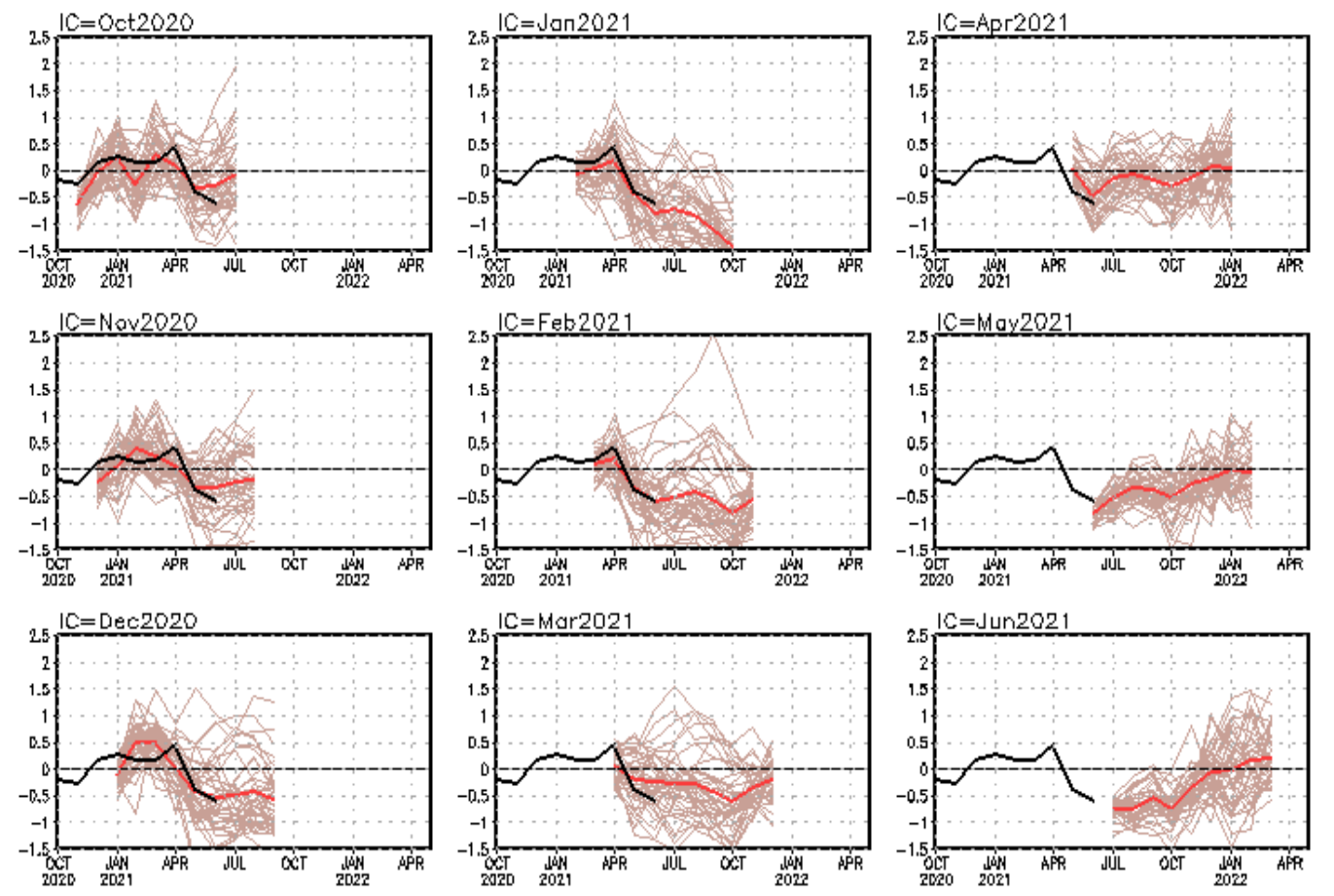
CFSv2 Tropical North Atlantic (TNA) SST Predictions



- Latest CFSv2 predictions call for above normal SSTs in the tropical N. Atlantic in 2021 hurricane season.
- There are warm biases with ICs in Dec 2020-Feb 2021.

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].

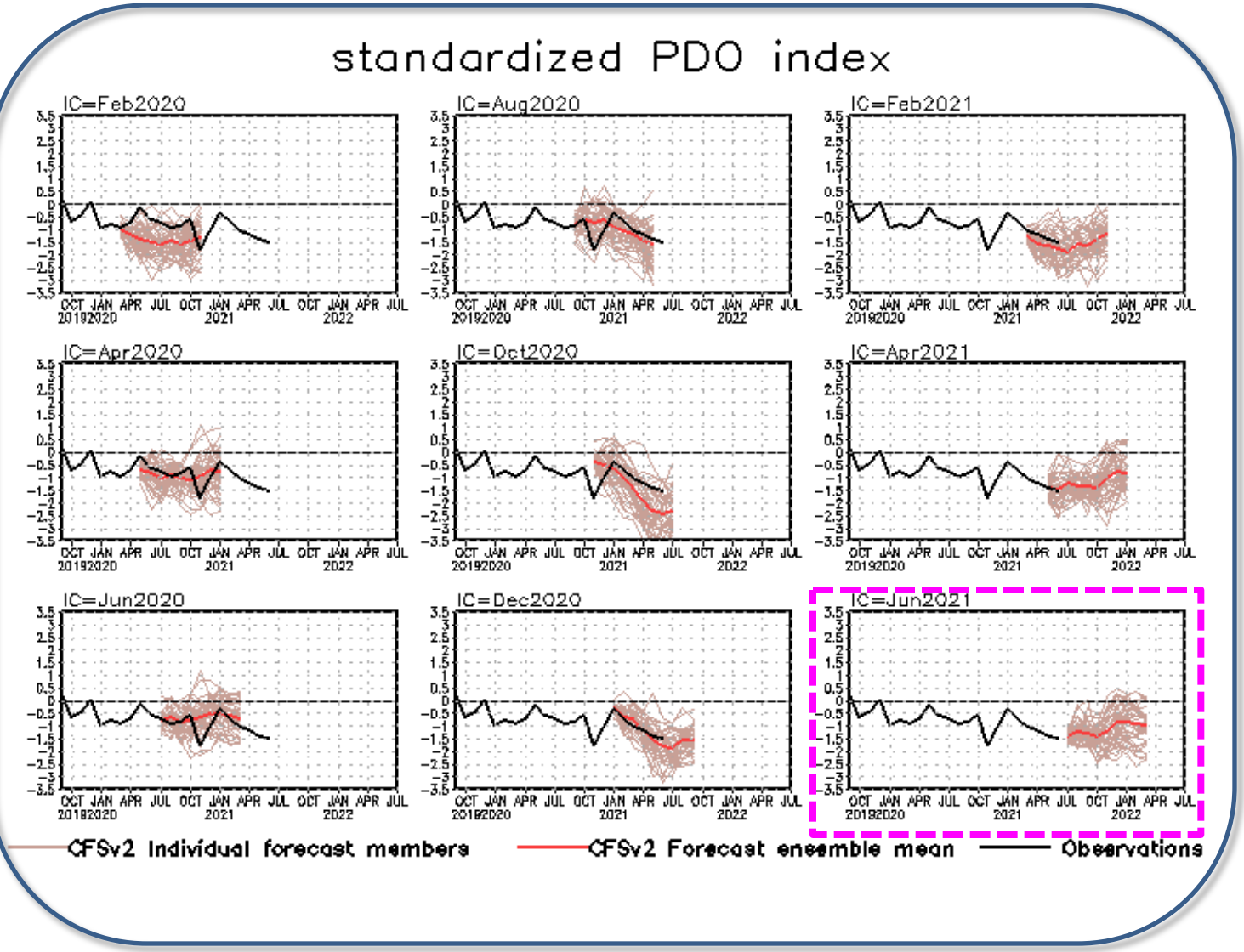
CFSv2 DMI SST Predictions



- Latest CFSv2 predicts a negative phase of IOD in 2021.

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)

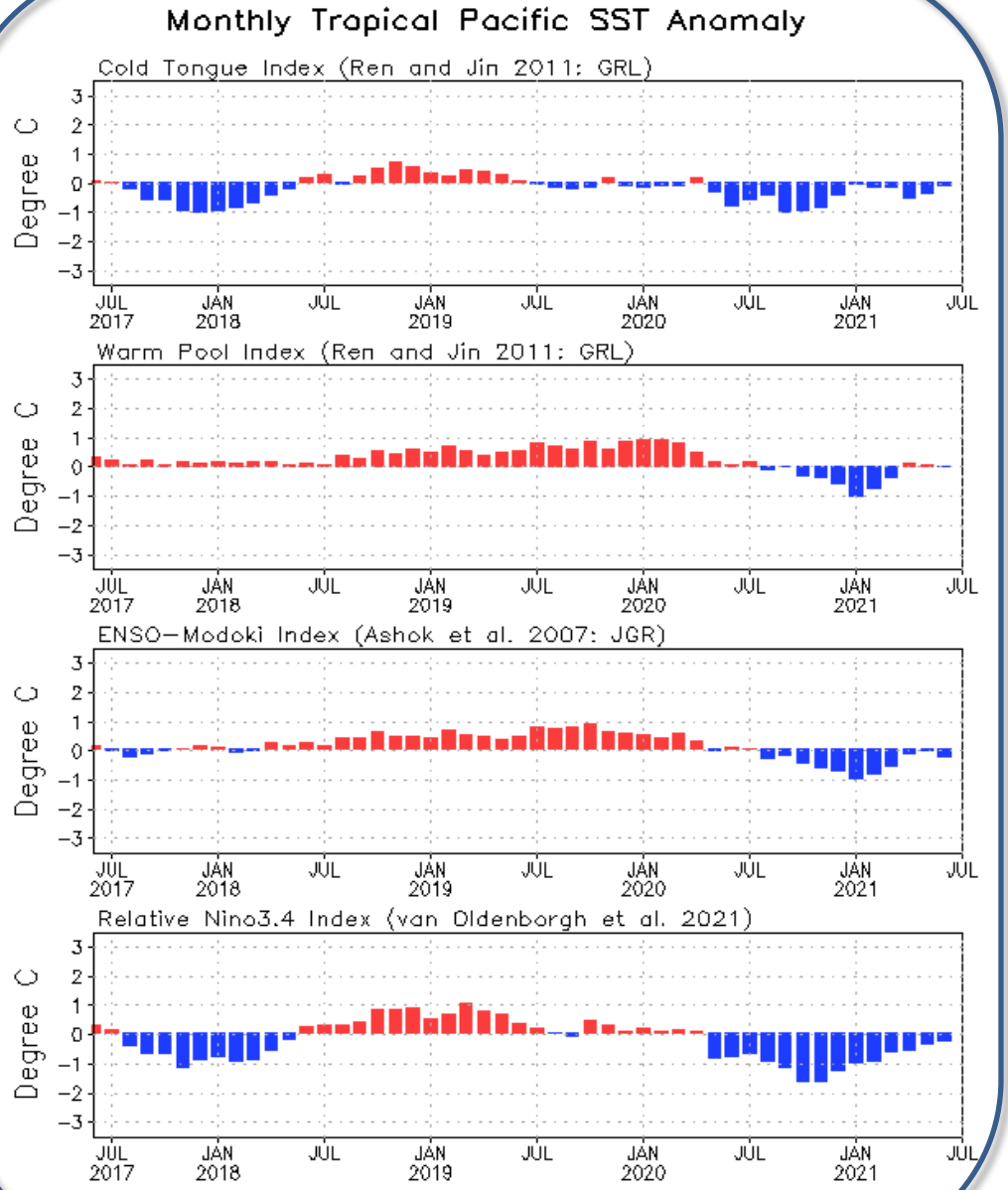
- **Weekly Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)**
- **Extended Reconstructed SST (ERSST) v5 (Huang et al. 2017)**
- **Blended Analysis of Surface Salinity (BASS) (Xie et al. 2014)**
- **CMORPH precipitation (Xie et al. 2017)**
- **CFSR evaporation adjusted to OAFlux (Xie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

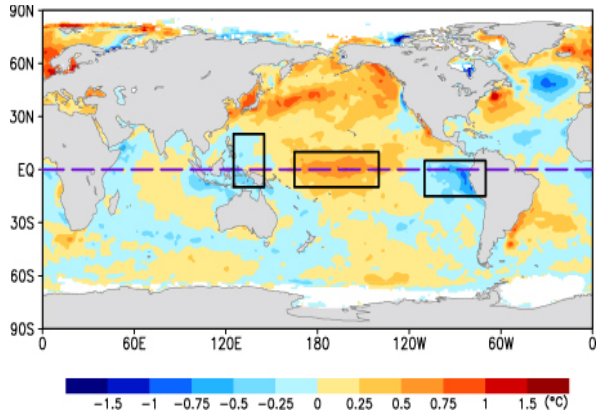
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

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

Backup Slides

Evolution of Pacific Niño SST Indices



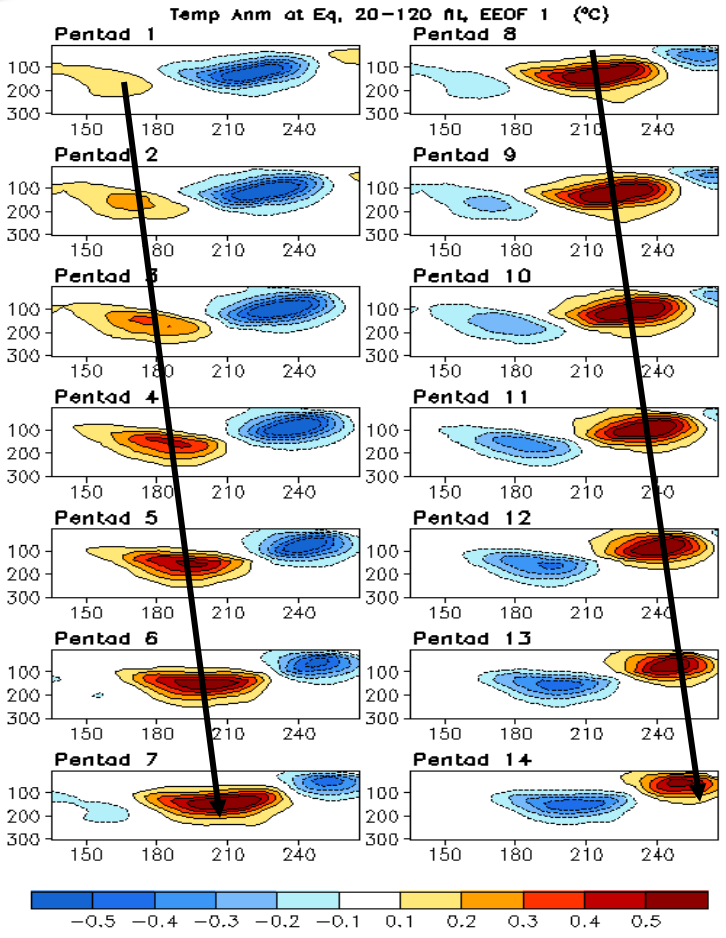


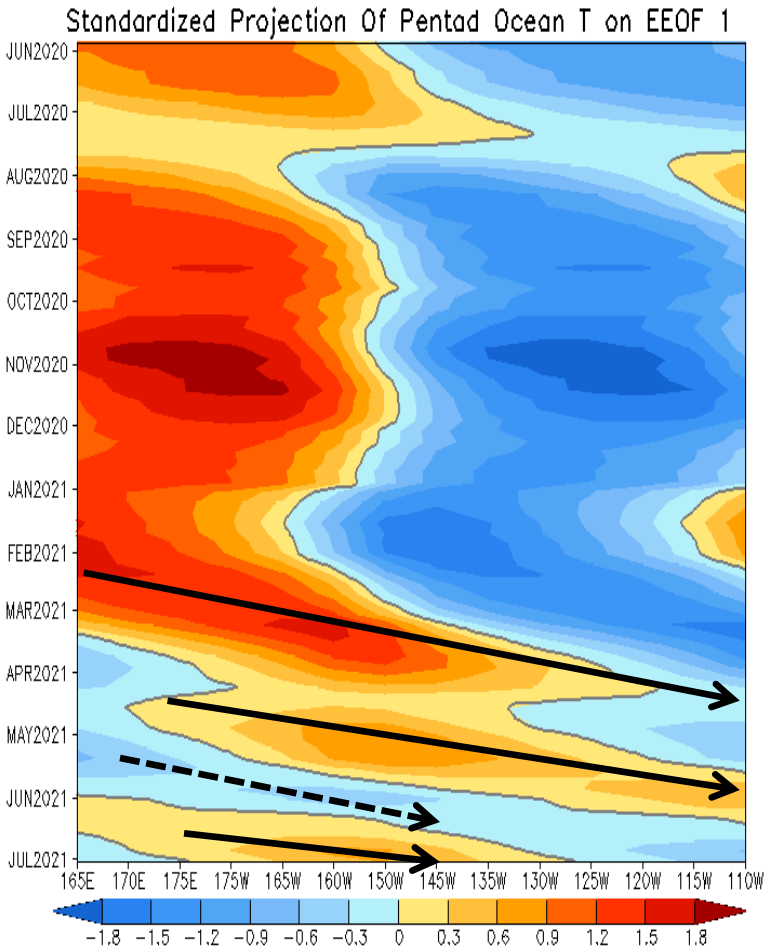
- Relative Niño3.4 index is now included in ENSO monitoring, which is defined as the conventional Niño3.4 index minus the SSTA averaged in the whole tropics (0º-360º, 20ºS-20ºN), in order to remove the global warming signal. Also, to have the same variability as the conventional Niño3.4 index, the relative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

Oceanic Kelvin Wave (OKW) Index

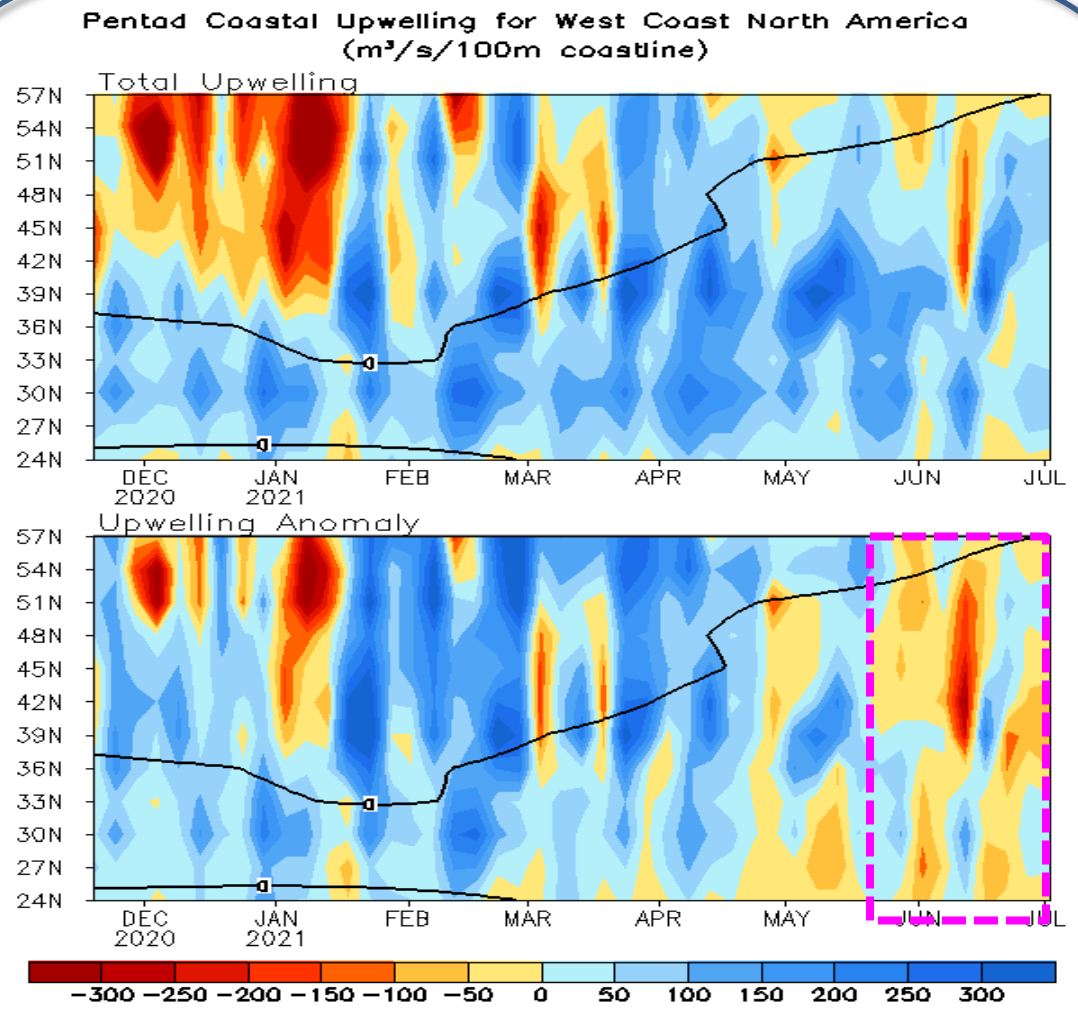


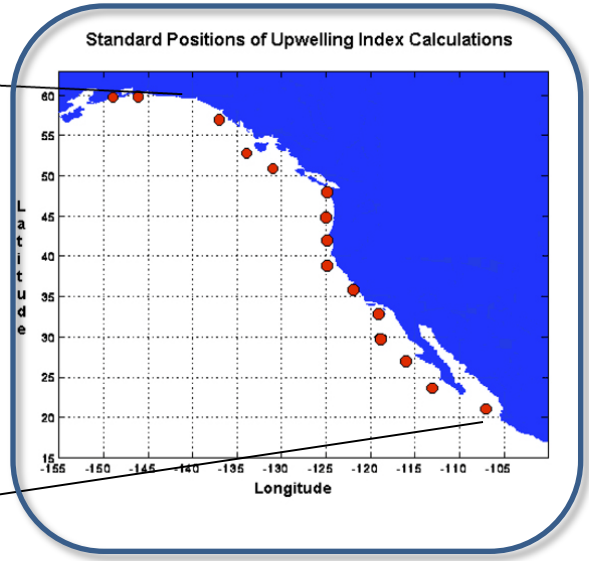


- Two weak downwelling Kelvin waves were initiated in Feb and Apr 2021, respectively, consisting with the weakening of La Niña.

(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).)

North America Western Coastal Upwelling





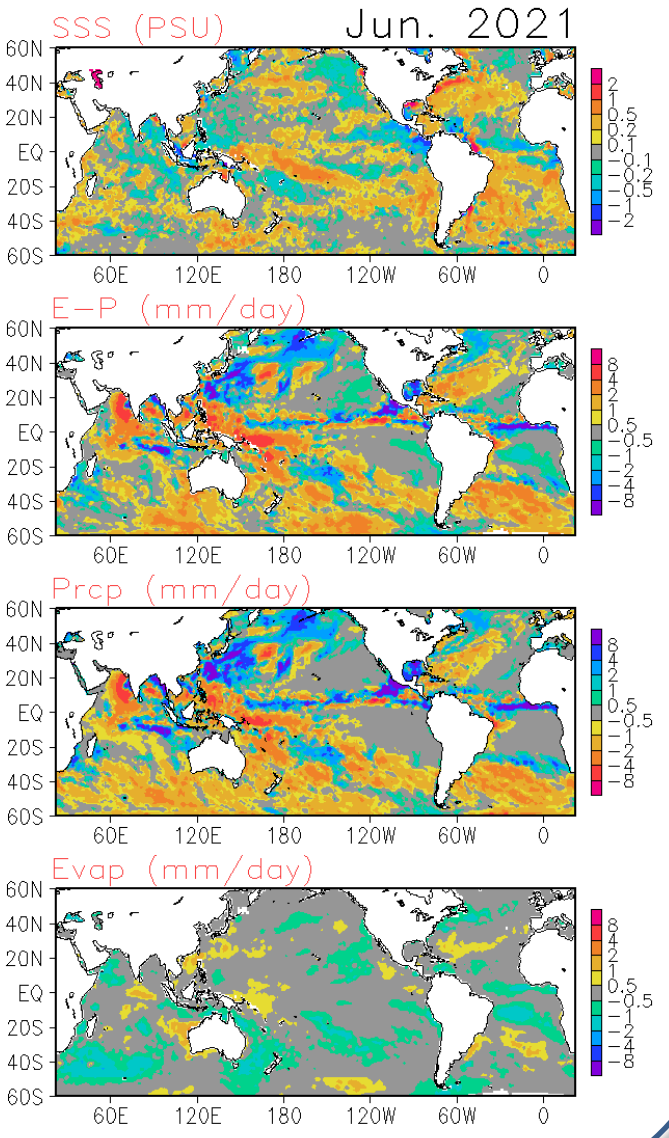
- Both coastal anomalous upwelling and downwelling were present in Jun 2021.

(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.

Global Sea Surface Salinity (SSS): Anomaly for June 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 and likely strengthens in the western equatorial Pacific Ocean and SPCZ region. Negative SSS anomaly appears in the eastern equatorial Pacific Ocean. Negative SSS anomaly shows in the northeast Pacific Ocean. Positive SSS anomaly continues between 20°N and 40°N in the North Atlantic Ocean. While, negative SSS anomaly along the Equatorial Atlantic Ocean continues and strengthens which is likely due to increased precipitation



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

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

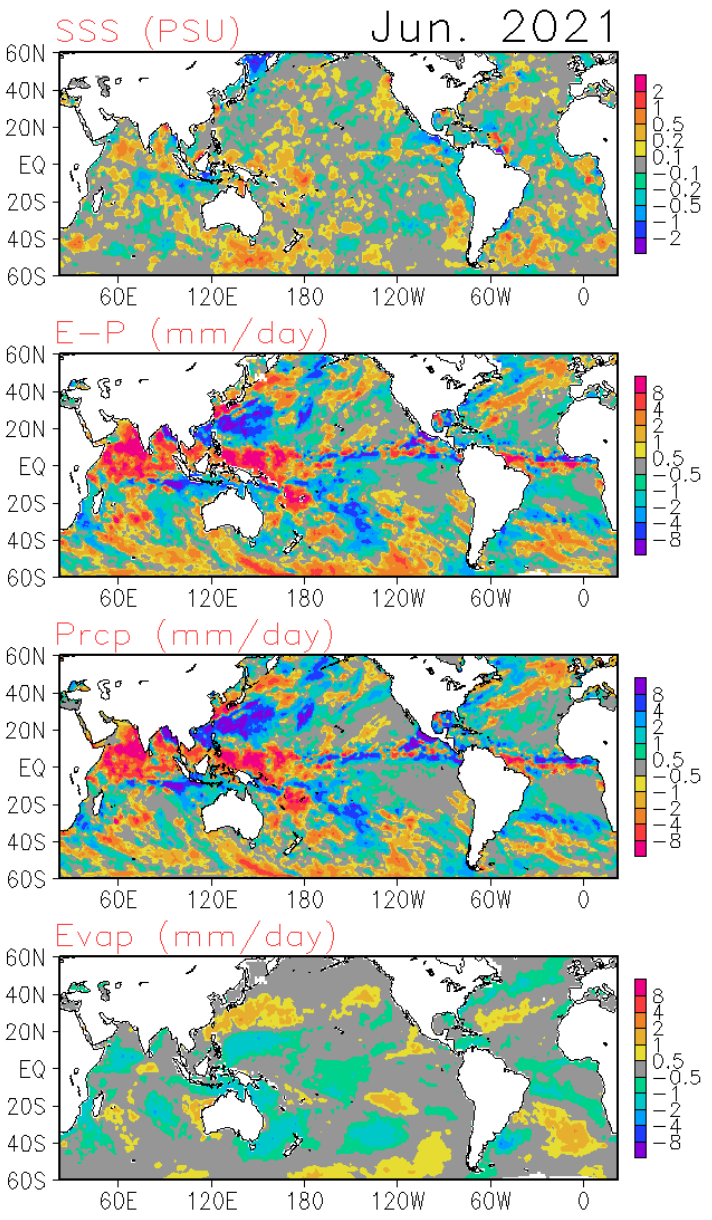
ftp.cpc.ncep.noaa.gov/precip/BASS

Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: Adjusted CFS Reanalysis

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

Compared with last month, SSS increases in the western equatorial Pacific Ocean and SPCZ region. While, SSS decreases in the eastern equatorial Pacific Ocean. SSS also decreases in the equatorial Atlantic Ocean region. SSS increases in the Indian Ocean in most areas north of equator which is likely caused by reduced precipitation.



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.