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

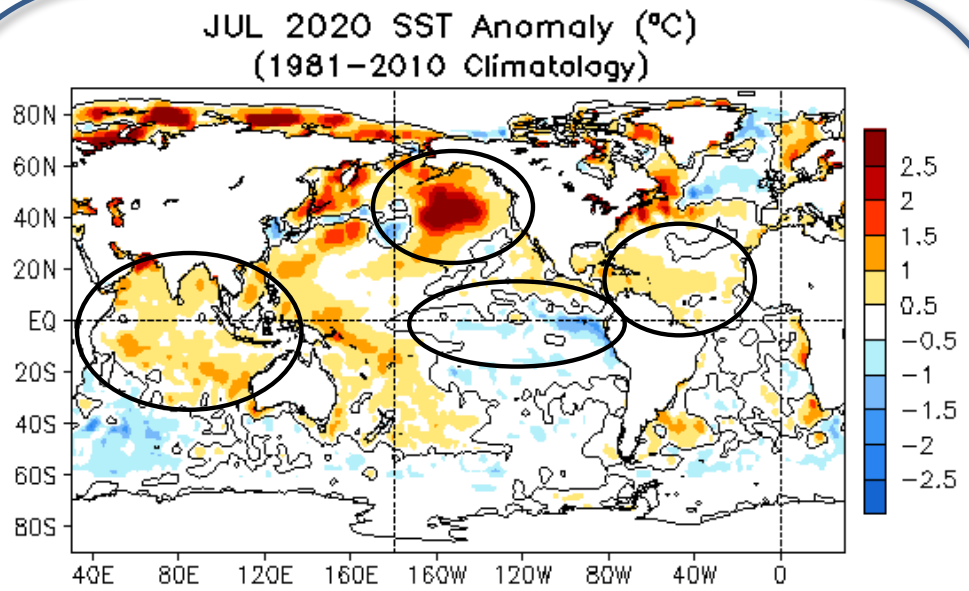
- Overview
- Recent highlights
  - Pacific/Arctic Ocean
  - Indian Ocean
  - Atlantic Ocean
- Global SSTA Predictions
- Special Topics
  - North Pacific Marine Heatwave status and prediction

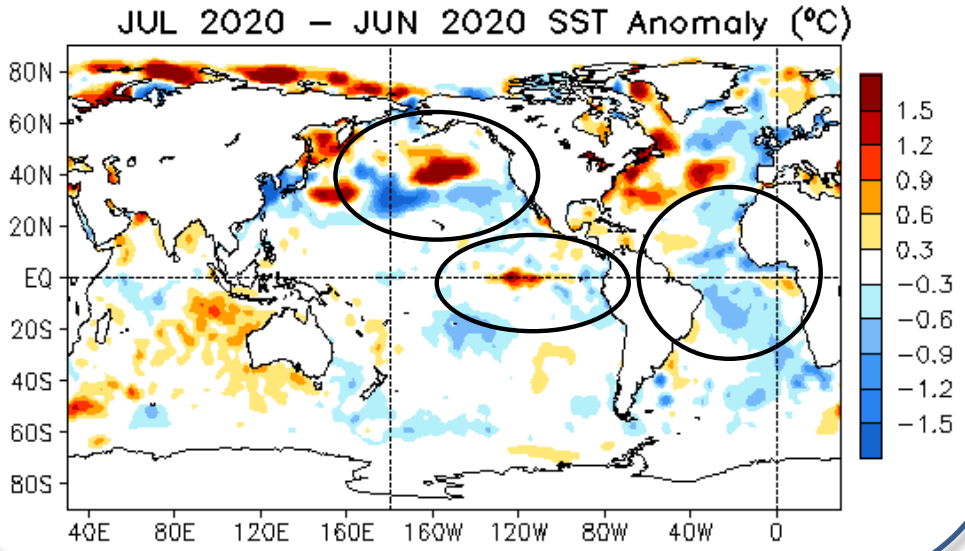
Overview

- Pacific Ocean
  - ENSO neutral condition persisted (NINO3.4 = -0.21^{o}C), but with strong cold anomalies in the far eastern region (NINO1+2 = -1.0^{o}C)
  - Positive SSTAs strengthened in the NE Pacific in July 2020; The PDO was in a negative phase (PDOI = -0.64).
- Indian Ocean
  - Basin-wide SST warming persisted in the tropical Indian Ocean in July 2020.
- Atlantic Ocean
  - Positive SSTAs were present across the tropical North Atlantic basin in July 2020, generating a tropical Atlantic meridional mode.
  - NAO switched to a negative phase in July 2020 with NAOI= -1.19; the prolonged tripole SSTA pattern was absent in the north Atlantic.
- Arctic Ocean
  - The sea ice extent in July 2020 was ranked as the lowest July since 1979.

Global Oceans

Global SST Anomaly (^{0}C) and Anomaly Tendency



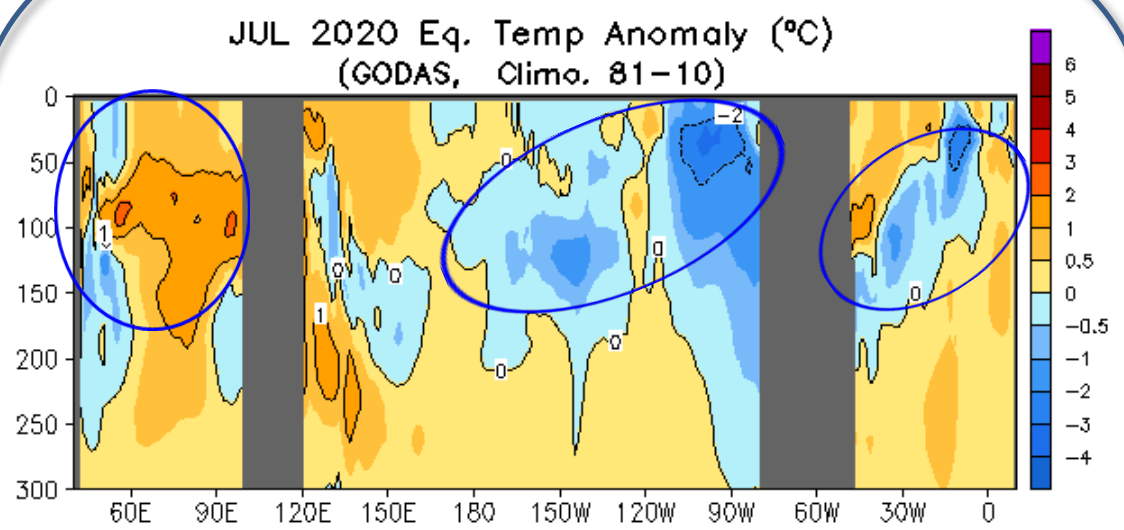


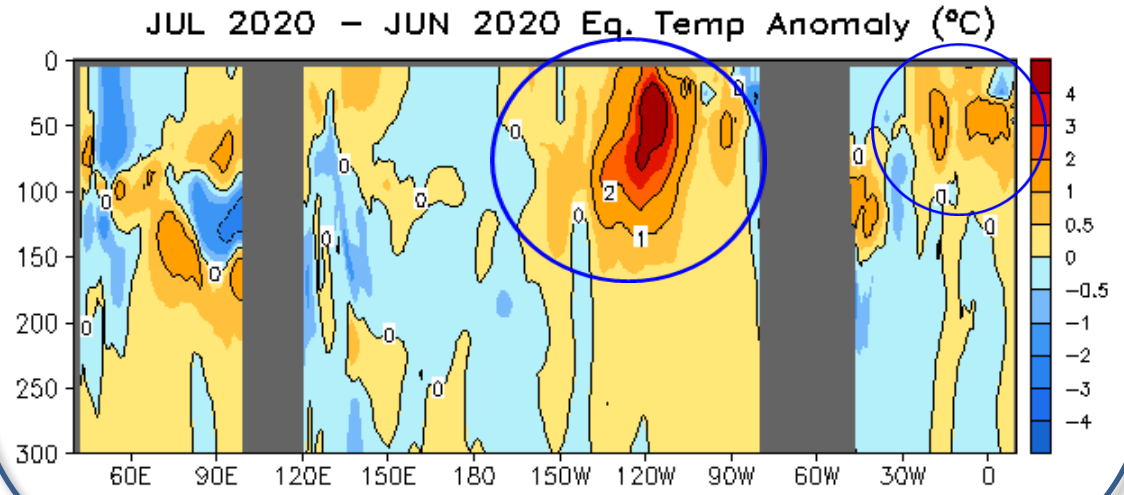
- Negative SSTAs persisted in the eastern equatorial Pacific.
- Strong positive SSTAs appeared in the NE Pacific.
- Positive SSTAs were present over the tropical North Atlantic.
- Positive SSTAs persisted in the tropical Indian Ocean.

- Negative (positive) SSTA tendencies were present in the far eastern (east-central) equatorial Pacific.
- Positive SSTA tendencies appeared in the NE Pacific with negative to its south.
- Negative SSTA tendencies presented across most of the tropical Atlantic.

Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

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





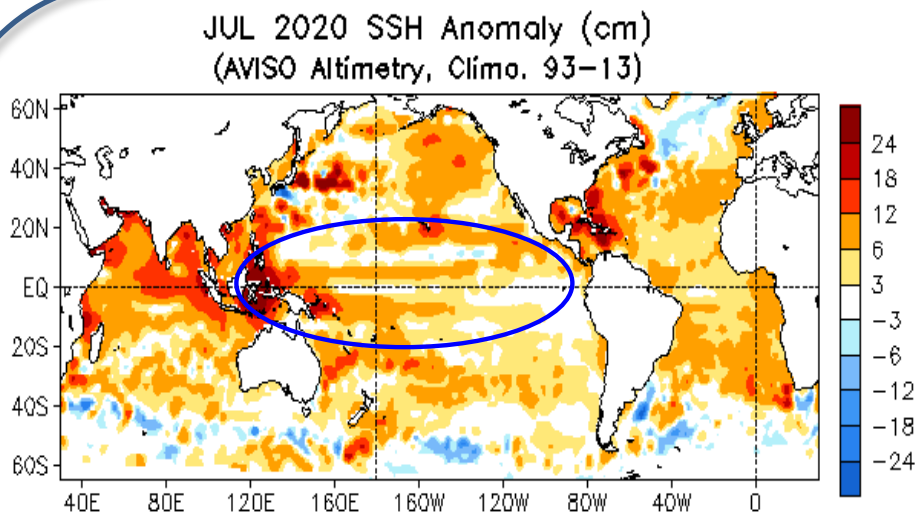
- Weak negative temperature anomalies presented along the thermocline in both the eastern equatorial Pacific and Atlantic Oceans.

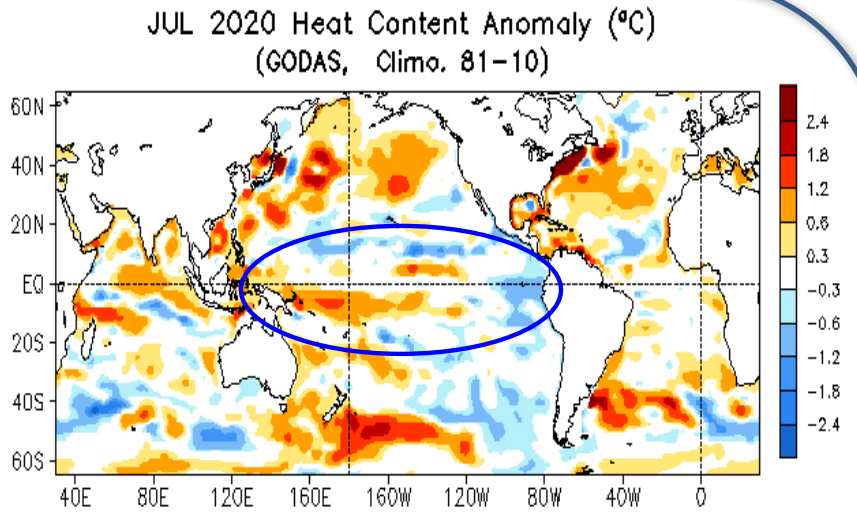
- Positive temperature anomalies were observed in the equatorial Indian Ocean.

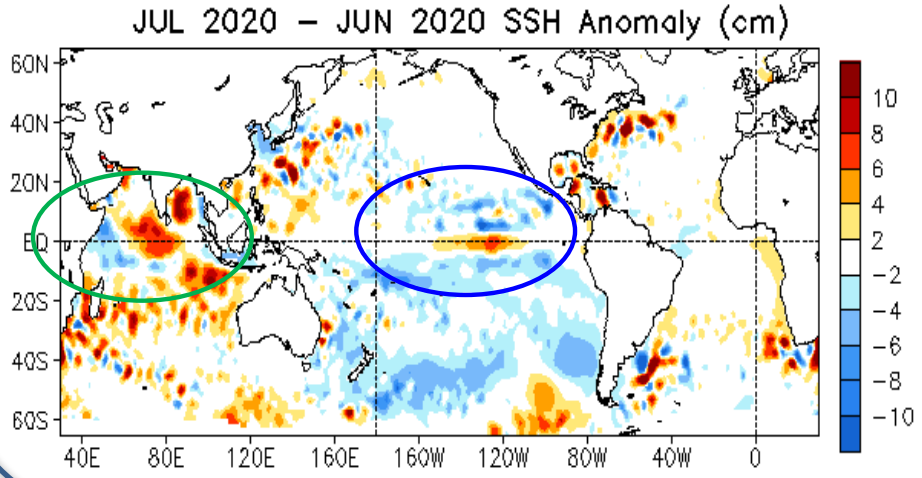
- Temperature anomaly tendency was positive in both the eastern Pacific and eastern Atlantic.

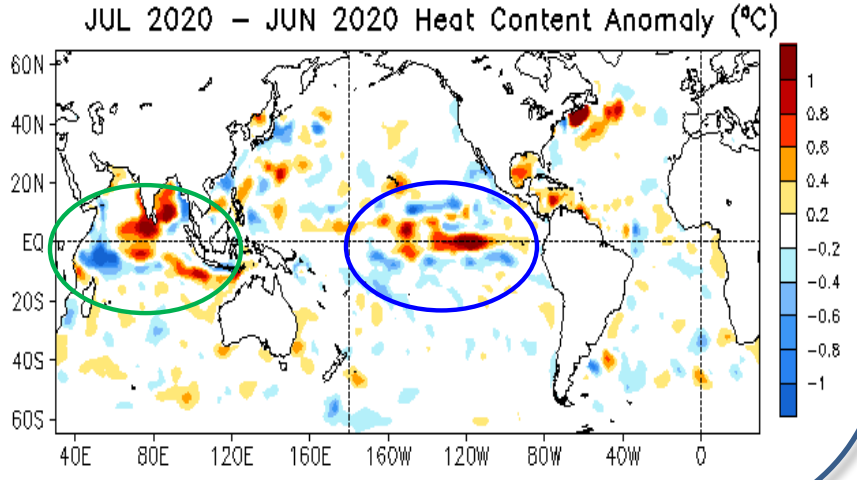
Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data is from the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.

Global SSH and HC300 Anomaly & Anomaly Tendency





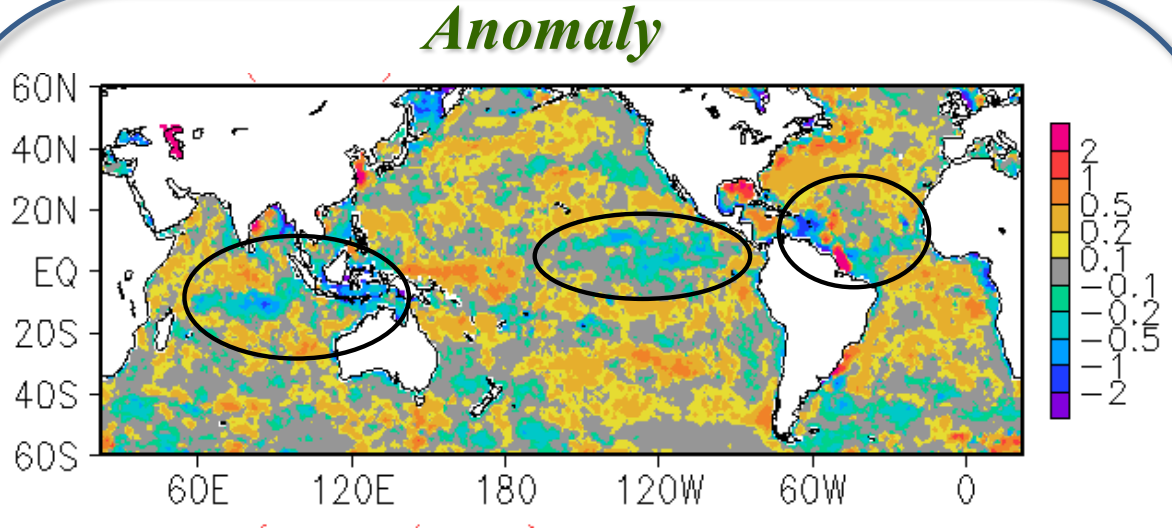


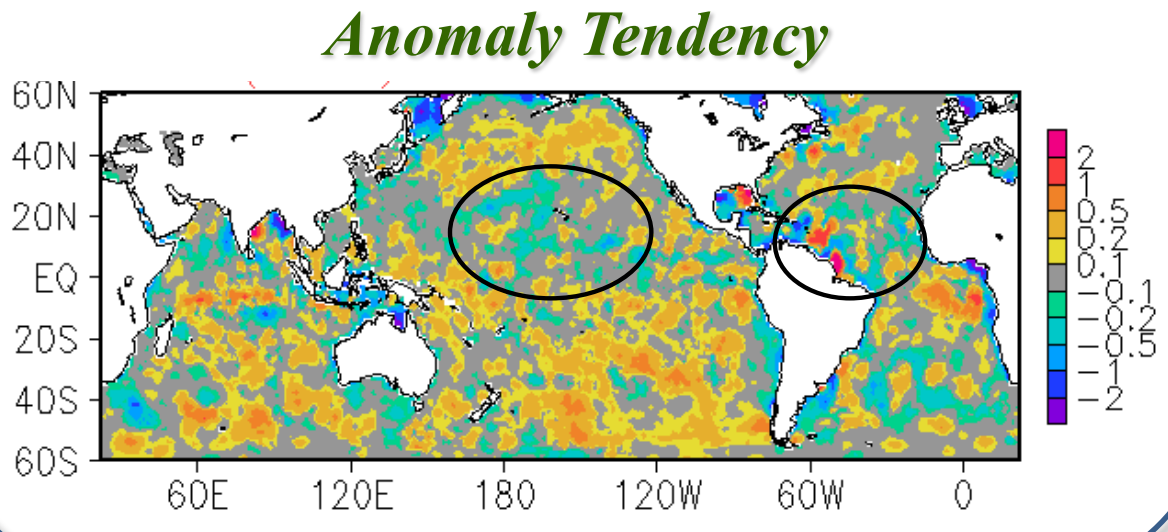


- The SSHA pattern was overall consistent with the HC300A pattern, but with a significant trend component in SSHA.

- Much better consistency for tendencies: negative in the eastern off-equatorial Pacific (and western Indian Ocean) and positive in the eastern equatorial Pacific (and eastern Indian Ocean).

Global Sea Surface Salinity Anomaly and Anomaly Tendency





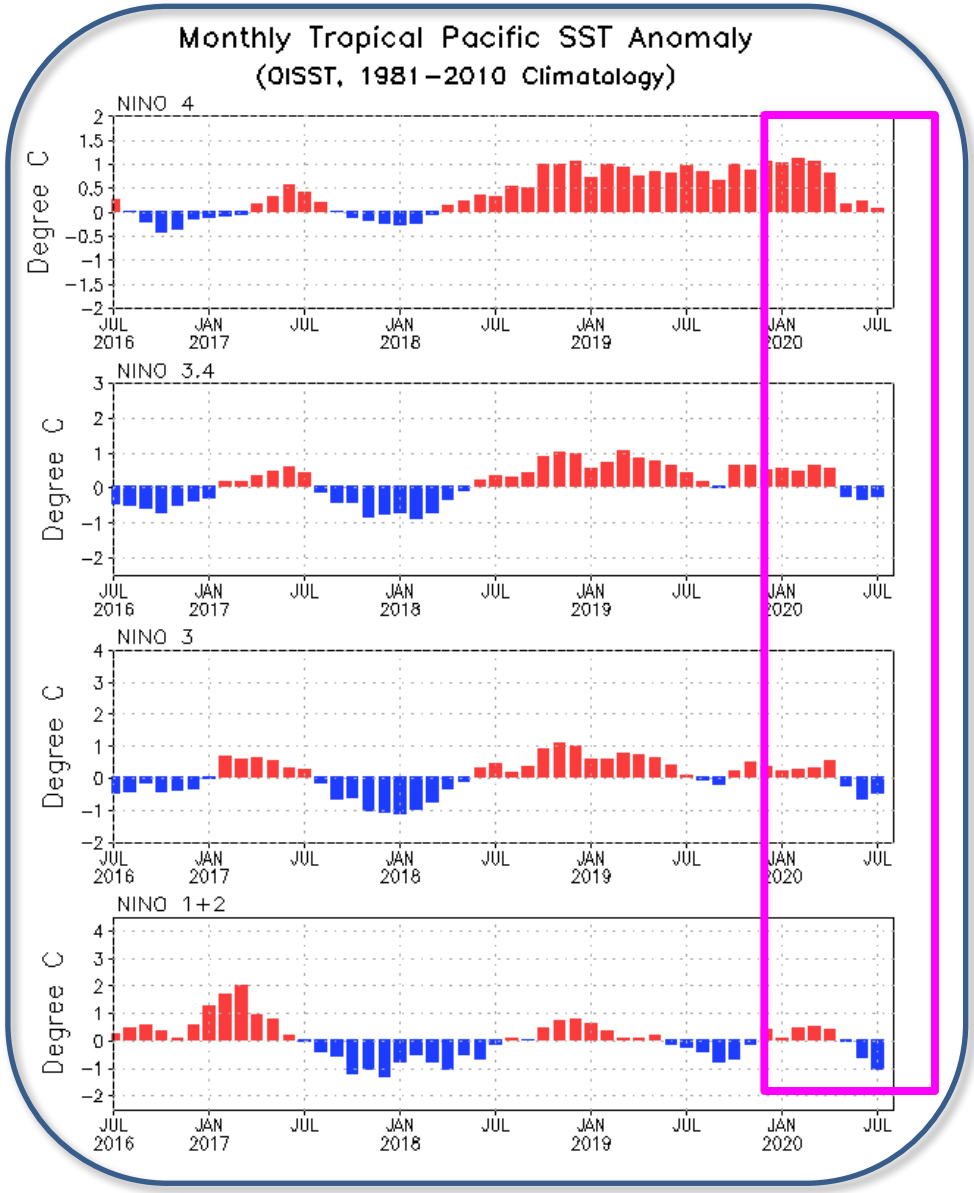
- Positive SSS anomalies present across most of the Pacific and Atlantic Oceans with negative anomalies in the tropical south Indian ocean, the Maritime Continent, the eastern tropical Pacific, and the tropical north Atlantic.

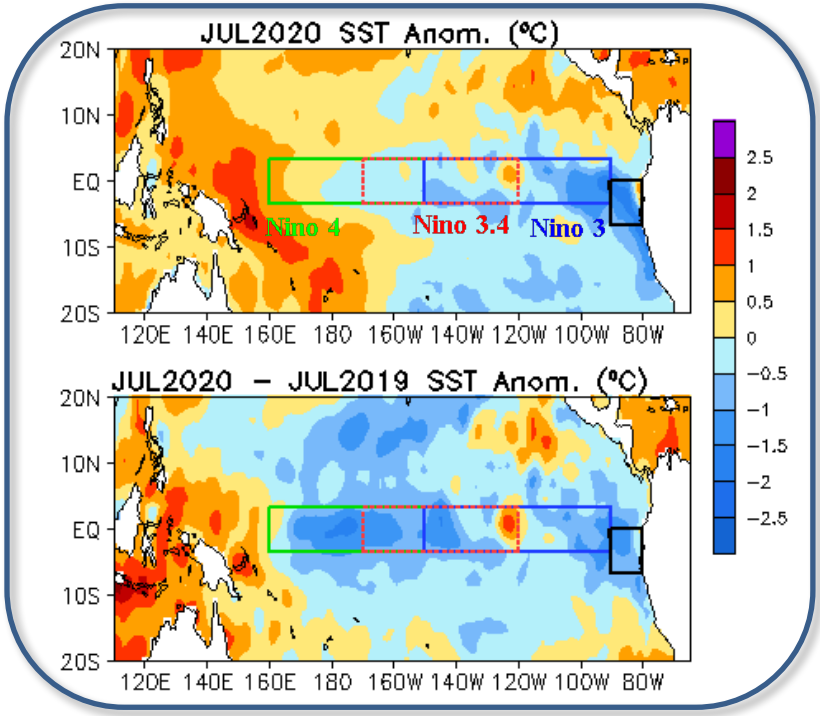
-Negative tendencies appeared in central tropical north Pacific and the tropical north Atlantic.

Blended analysis of surface Salinity (BASS) V0.Z (Xie et al. 2014); Curtesy of Dr. Li Ren

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific NINO SST Indices





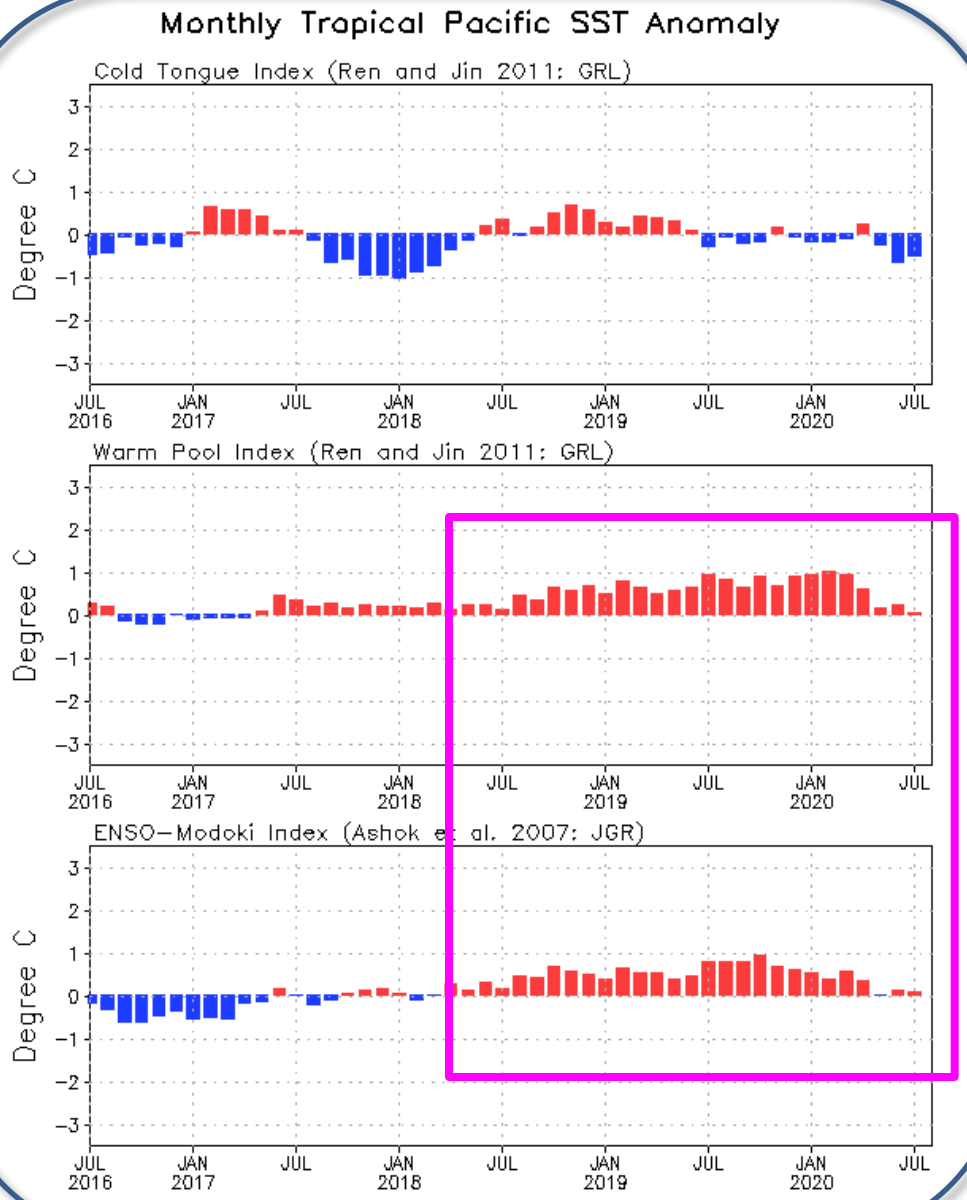
- All Nino indices cooled considerably since May 2020, with Nino3.4 = -0.21°C in July.

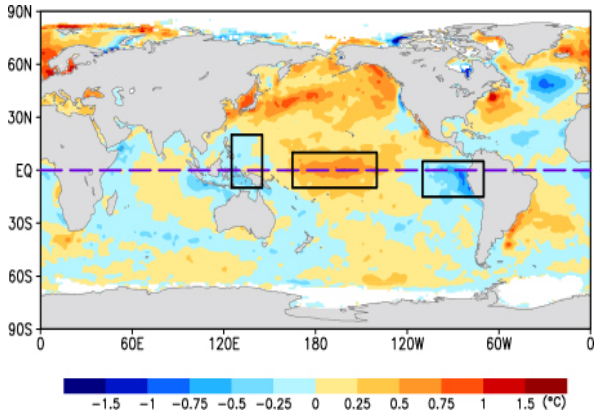
- Compared with July 2019, the central and eastern (far western) equatorial Pacific was cooler (warmer) in July 2020.

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

Nino 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 1981-2010 base period means.

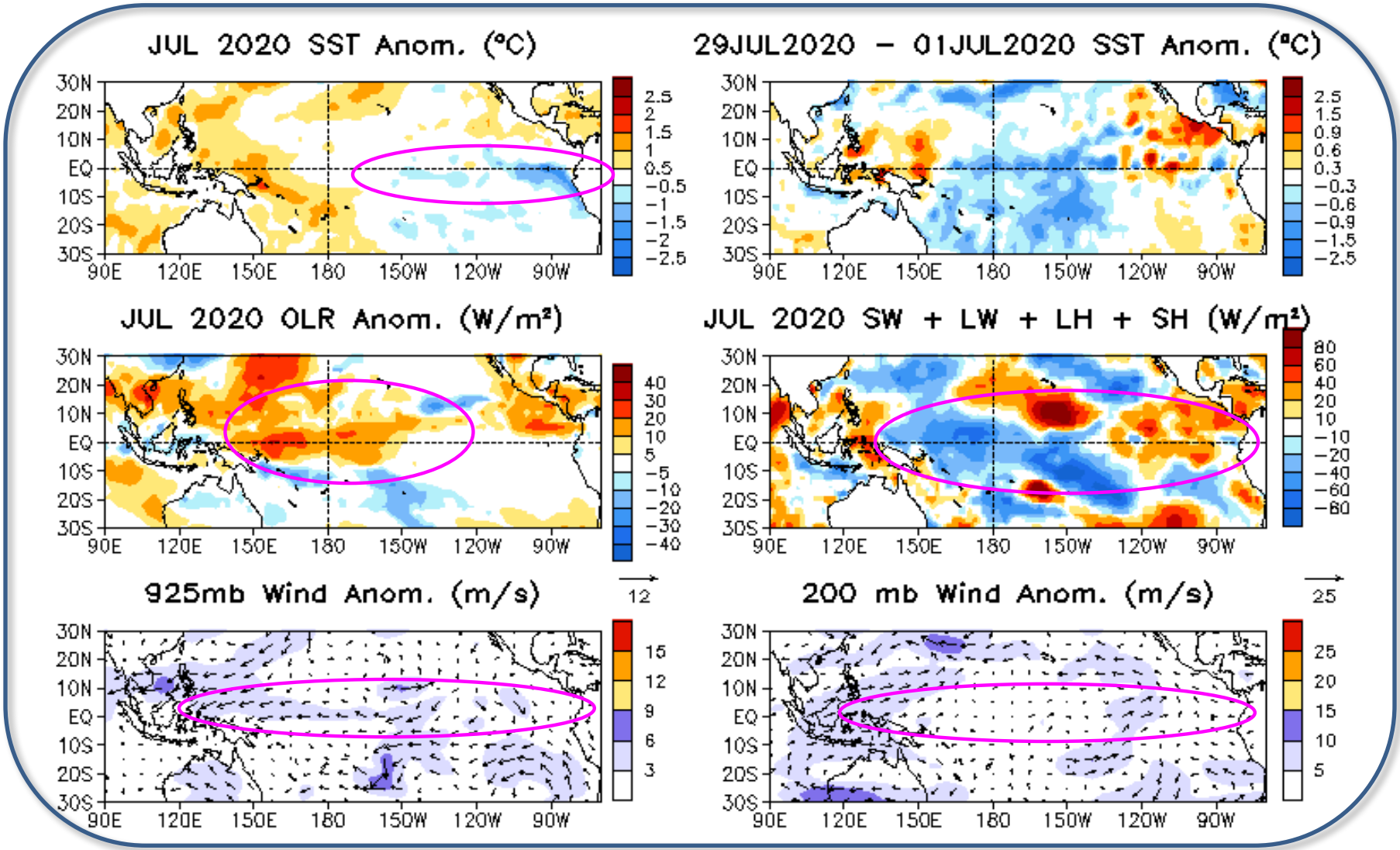
Monthly Tropical Pacific SST Anomaly





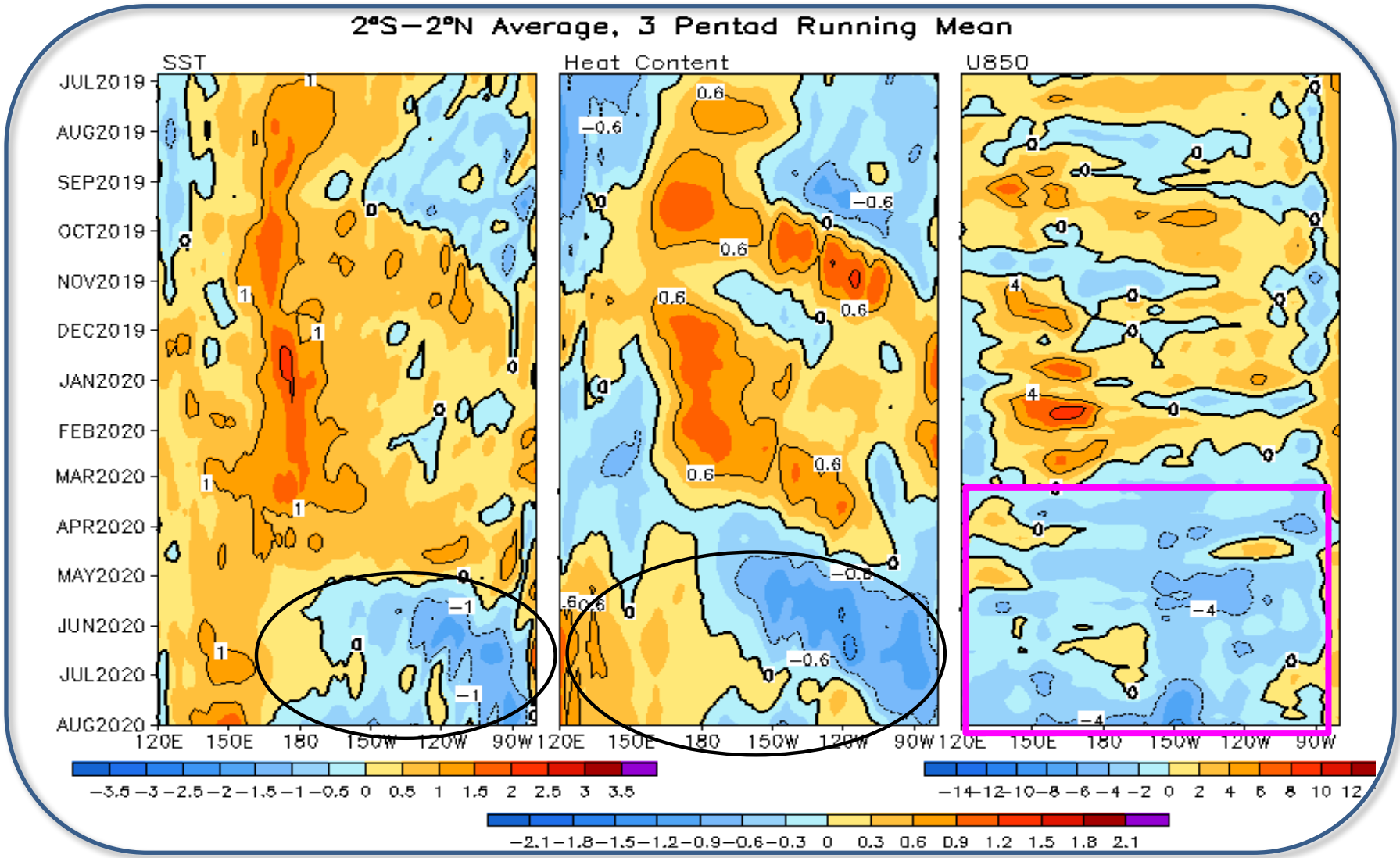
- Warm pool/ENSO-Modoki indices were positive since 2018 but weakened after May 2020.

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



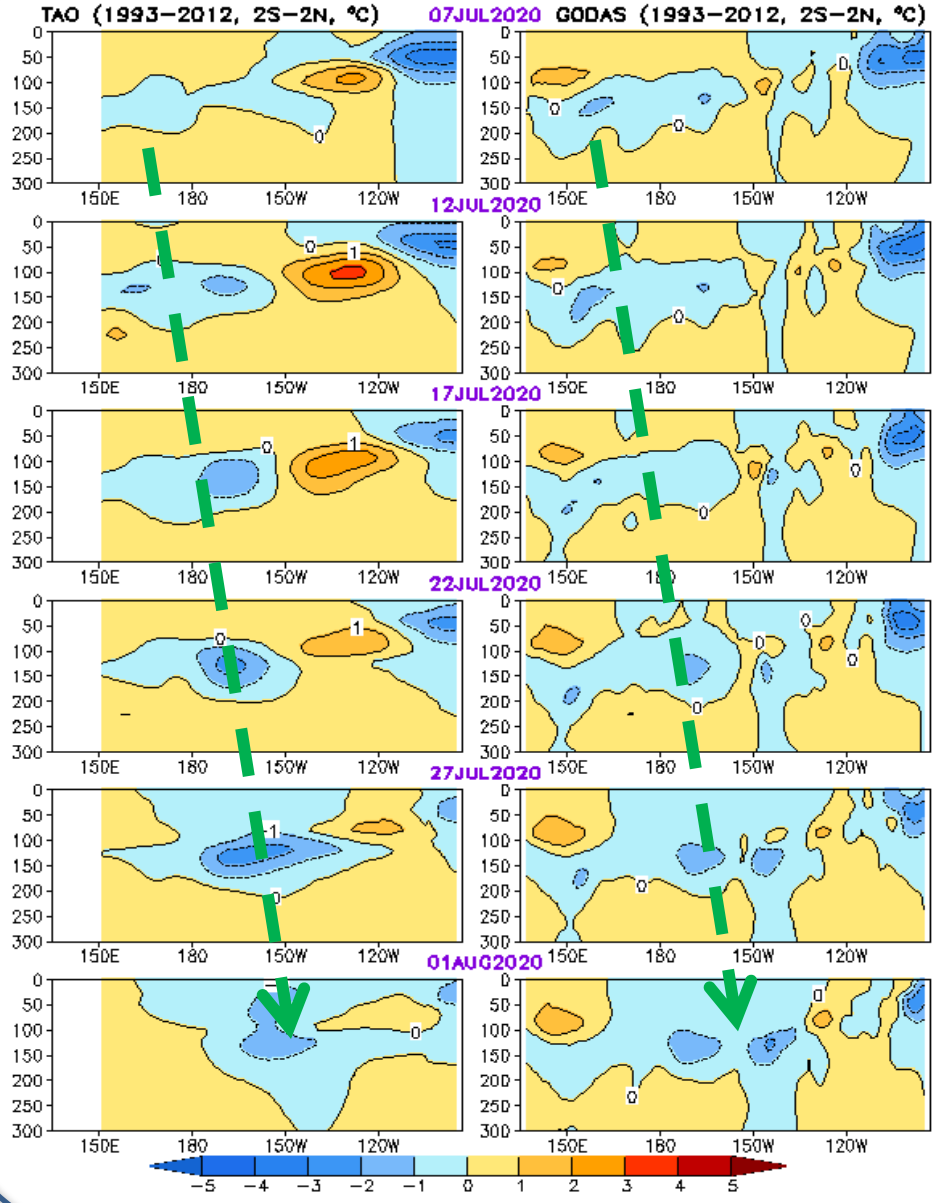
Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly 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 1981-2010 base period means.

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



- Easterly wind anomaly was present across the equatorial Pacific since March 2020.
- The contrast between western positive and eastern negative HC300 reduced by a weak downwelling KW in July 2020.
- Negative SSTA appeared in the eastern equatorial Pacific.

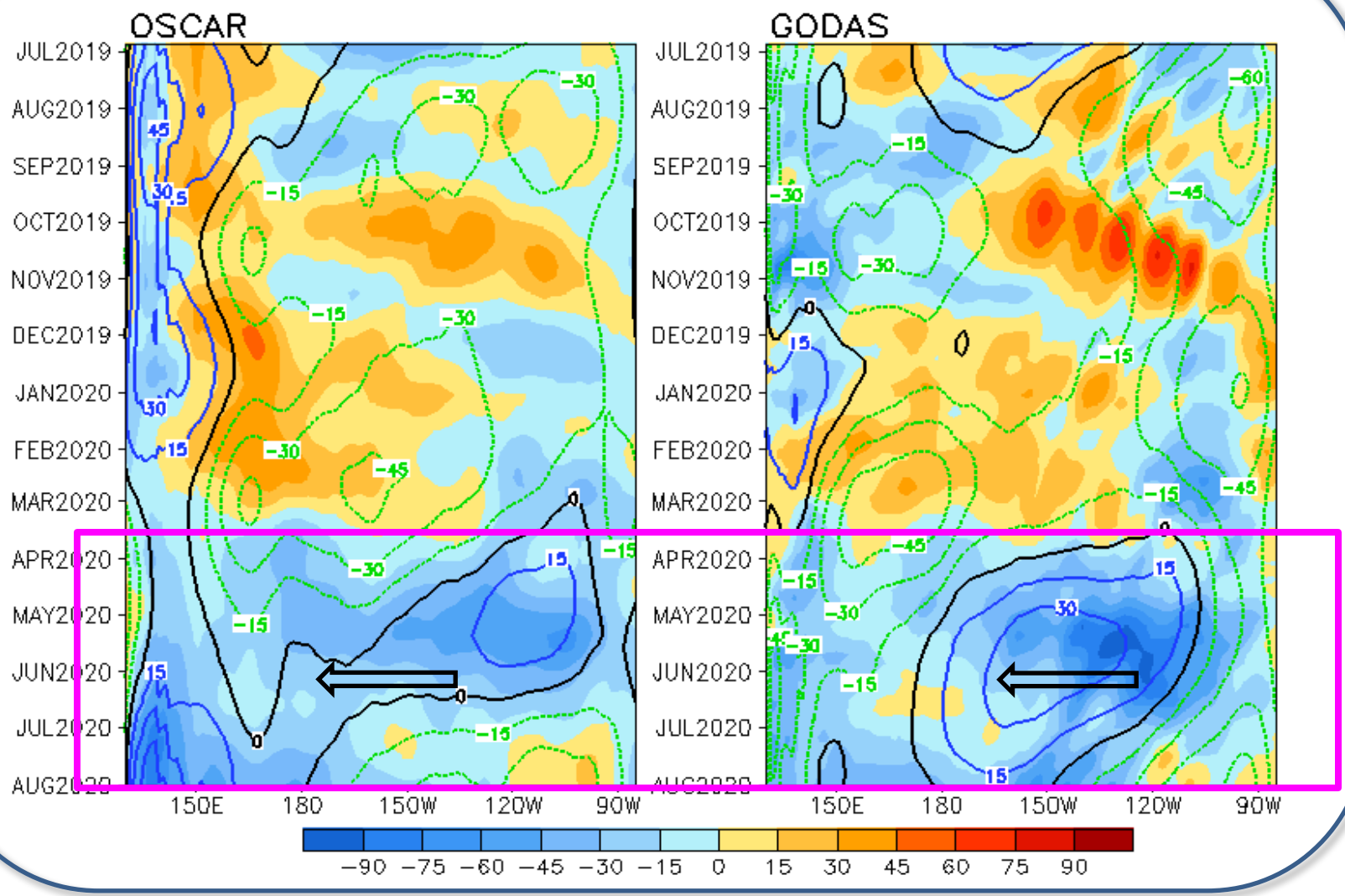
Equatorial Pacific Ocean Temperature Pentad Mean Anomaly



- Due to weak signals, some uncertainties between GODAS and TAO analysis about the features of the ocean temperature anomalies;

-Negative ocean temperature anomalies were present along the thermocline and propagated eastward.

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

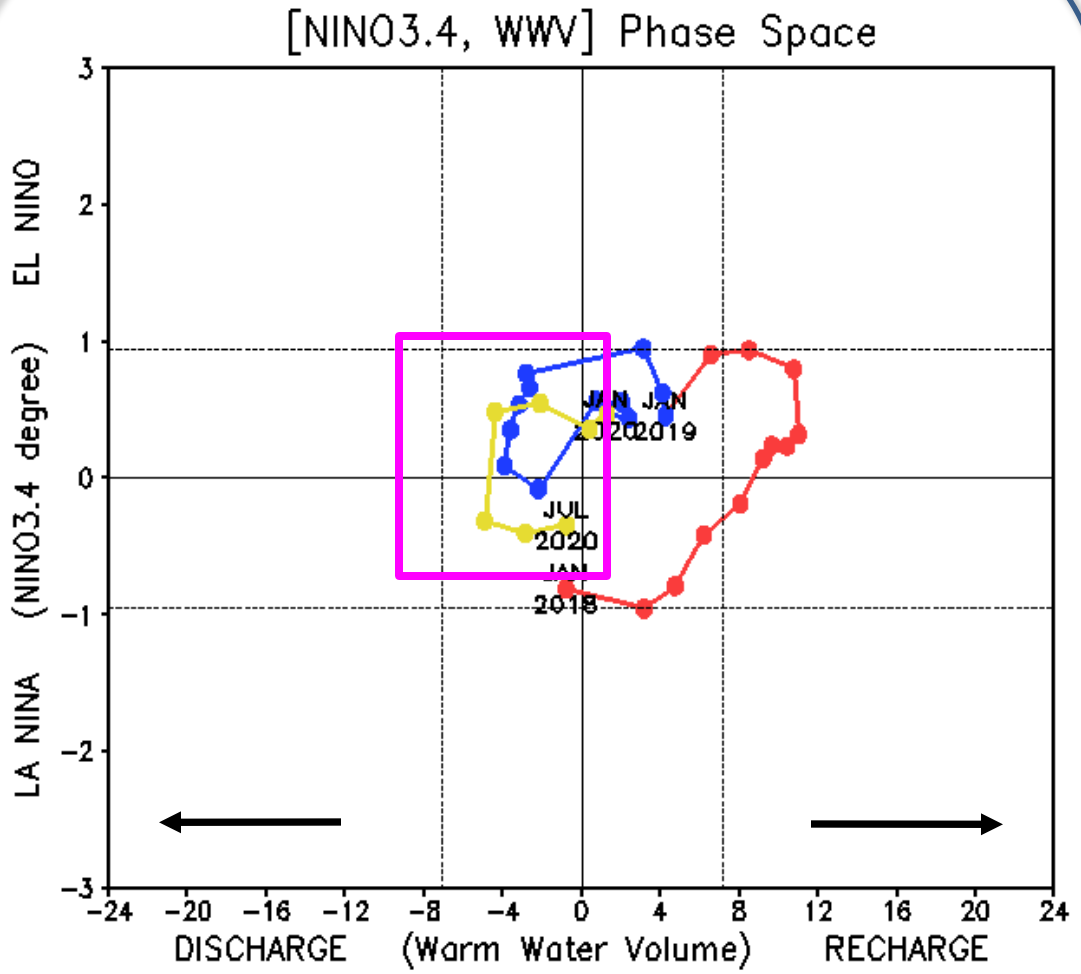


- Anomalous westward currents were observed across the equatorial Pacific in both OSCAR and GODAS since late March 2020.

Warm Water Volume (WWV) and NINO3.4 Anomalies

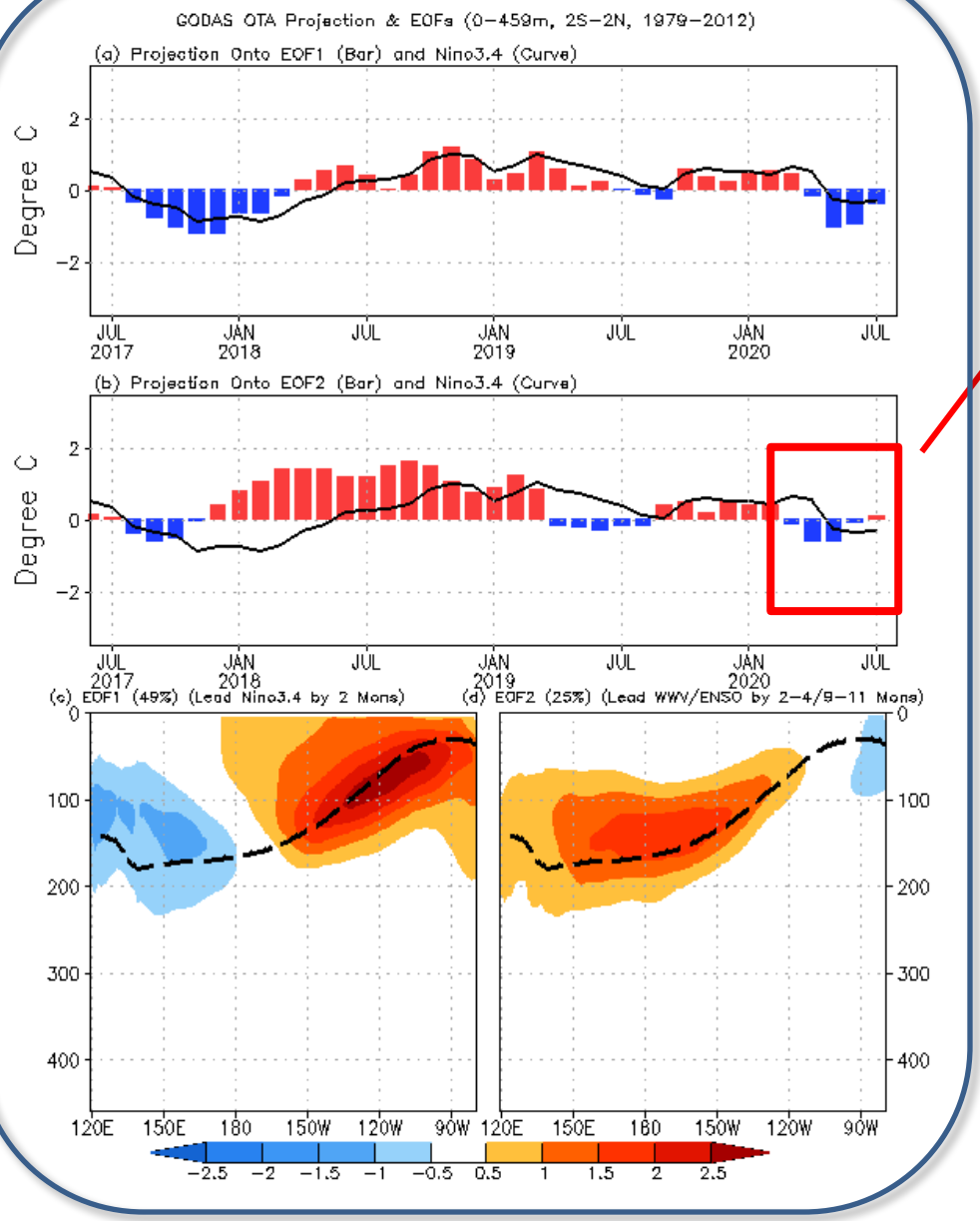
- Equatorial Warm Water Volume (WWV) has been in a discharge phase since March 2020 but became neutral in July.

-As WWV is intimately linked to ENSO variability (Wyrtki 1985; Jin 1997), it is useful to monitor ENSO in a phase space of WWV and NINO3.4 (Kessler 2002).
- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.



Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN] calculated with the NCEP's GODAS. Anomalies are departures from the 1981-2010 base period means.

Equatorial Sub-surface Ocean Temperature Monitoring



- The equatorial Pacific became neutral after June 2020.

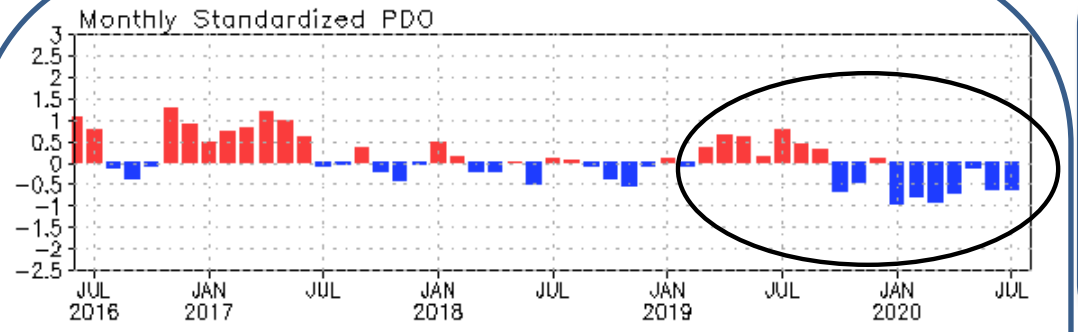
- Projection of ocean temperature anomalies onto EOF1 and EOF2;
EOF1: Tilt mode (ENSO peak phase);
EOF2: WWV mode.

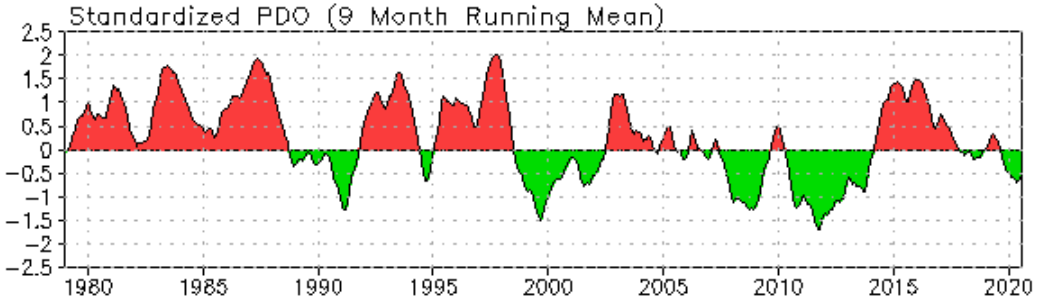
- Recharge/discharge oscillation (ENSO transition phase); Recharge process: heat transport from outside of equator to equator;
Negative -> positive phase of ENSO

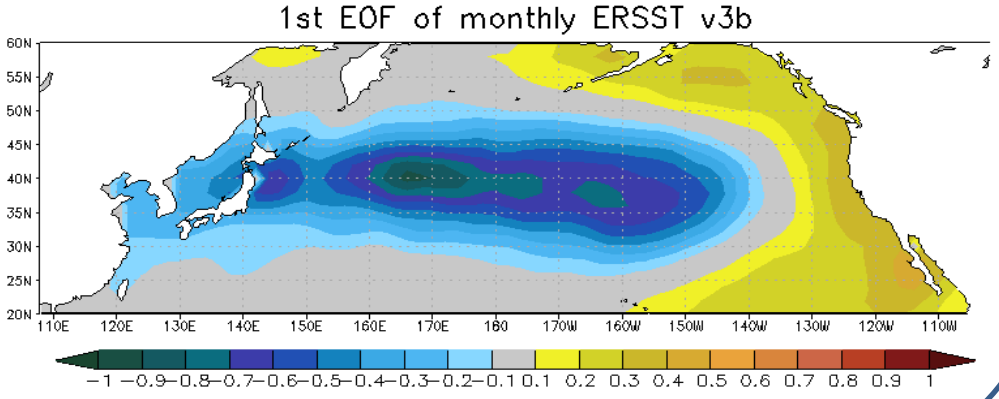
- For details, see: Kumar A, Z-Z Hu (2014) DOI: 10.1007/s00382-013-1721-0.

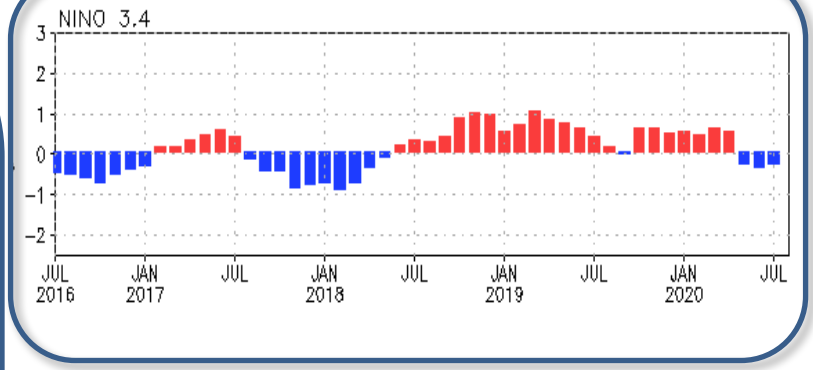
North Pacific & Arctic Oceans

Pacific Decadal Oscillation (PDO) Index







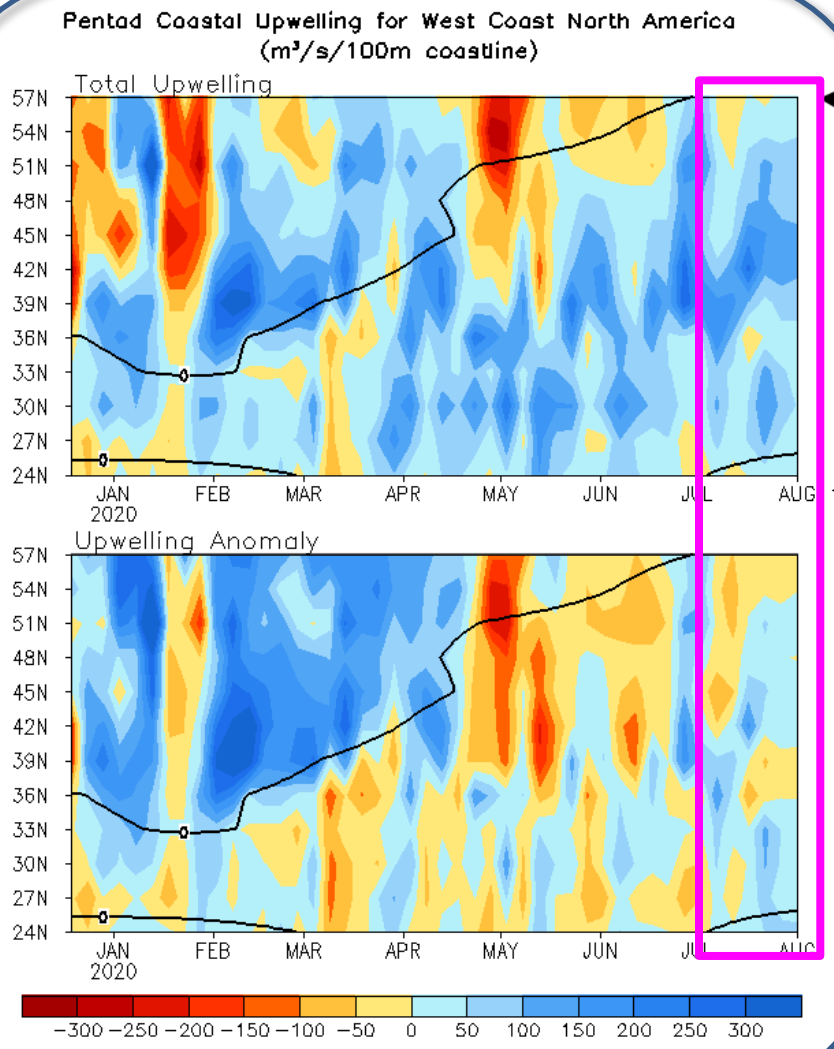


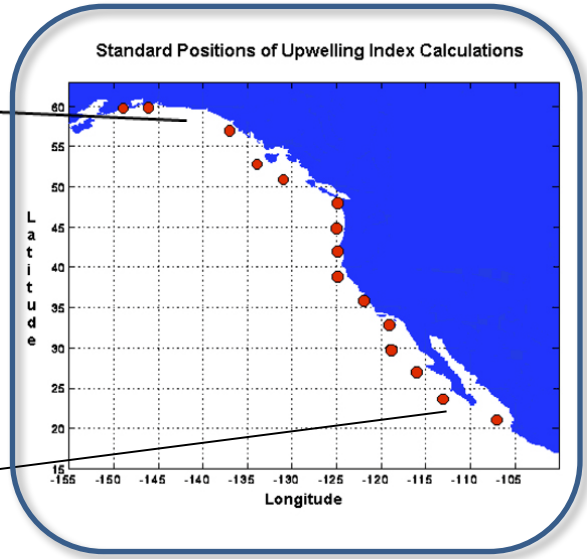
- The PDO was in a negative phase with PDOI = -0.64 in July2020.

- Statistically, ENSO leads PDO by 3-4 months, through teleconnection via atmospheric bridge, with El Nino (La Nina) associated with positive (negative) PDO Index.

• PDO is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly SST anomalies onto the 1st EOF pattern.
• The PDO index differs slightly from that of JISAO, which uses a blend of UKMET and OIv1 and OIv2 SST.

North America Western Coastal Upwelling

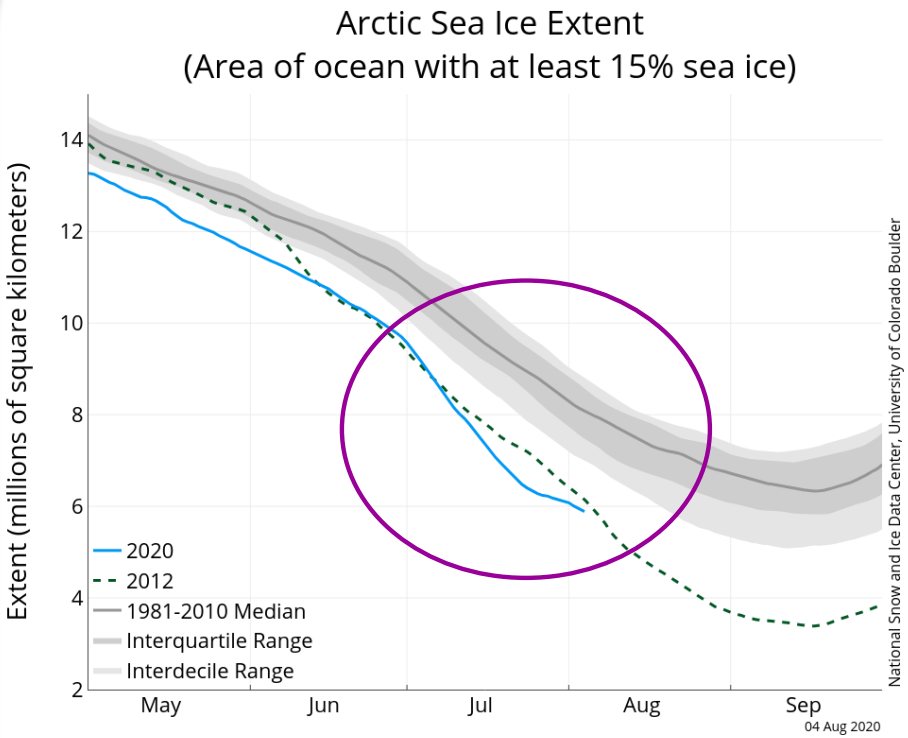


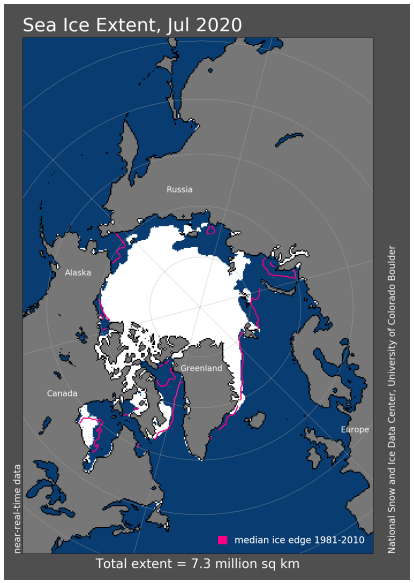


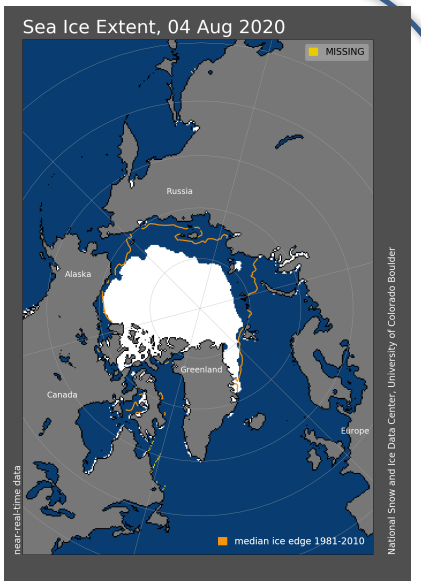
- Upwelling was near average in July 2020, with upwelling occurring over almost the whole coastal region from 24N-57N.

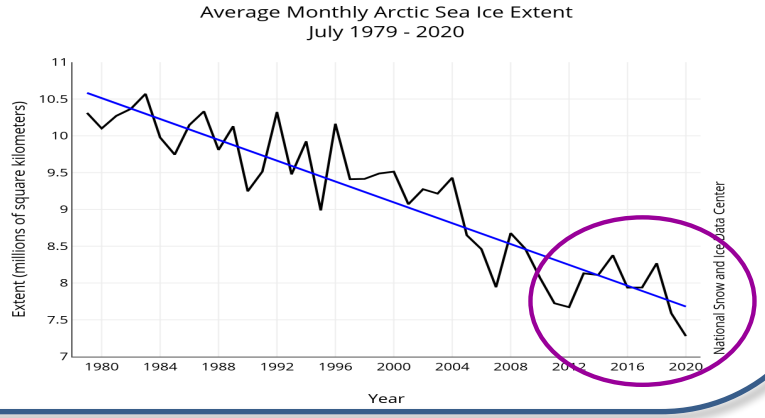
(top) Total and (bottom) anomalous upwelling indices at the 15 standard locations for the western coast of North America. derived from the vertical velocity of the NCEP's GODAS and are calculated as integrated vertical volume transport at 50-meter depth from each location to its nearest coast point ($m^3/s/100m$ coastline). Anomalies are departures from the 1981-2010 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.

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



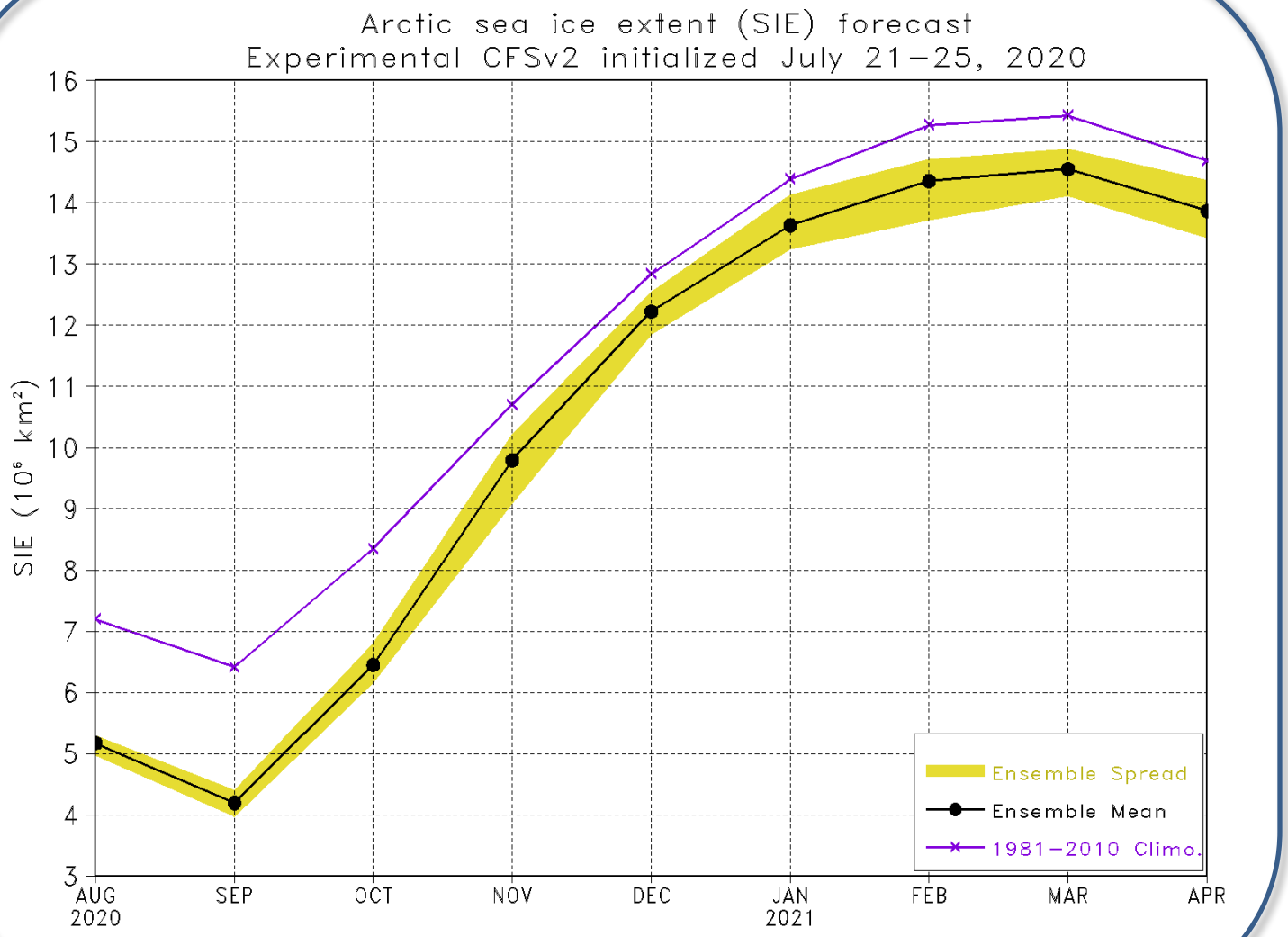






- Arctic sea ice extent was well below normal in July 2020.
- The monthly average extent for July 2020 of 7.28 million square kilometers ended up as the record lowest since satellite observations in 1979.

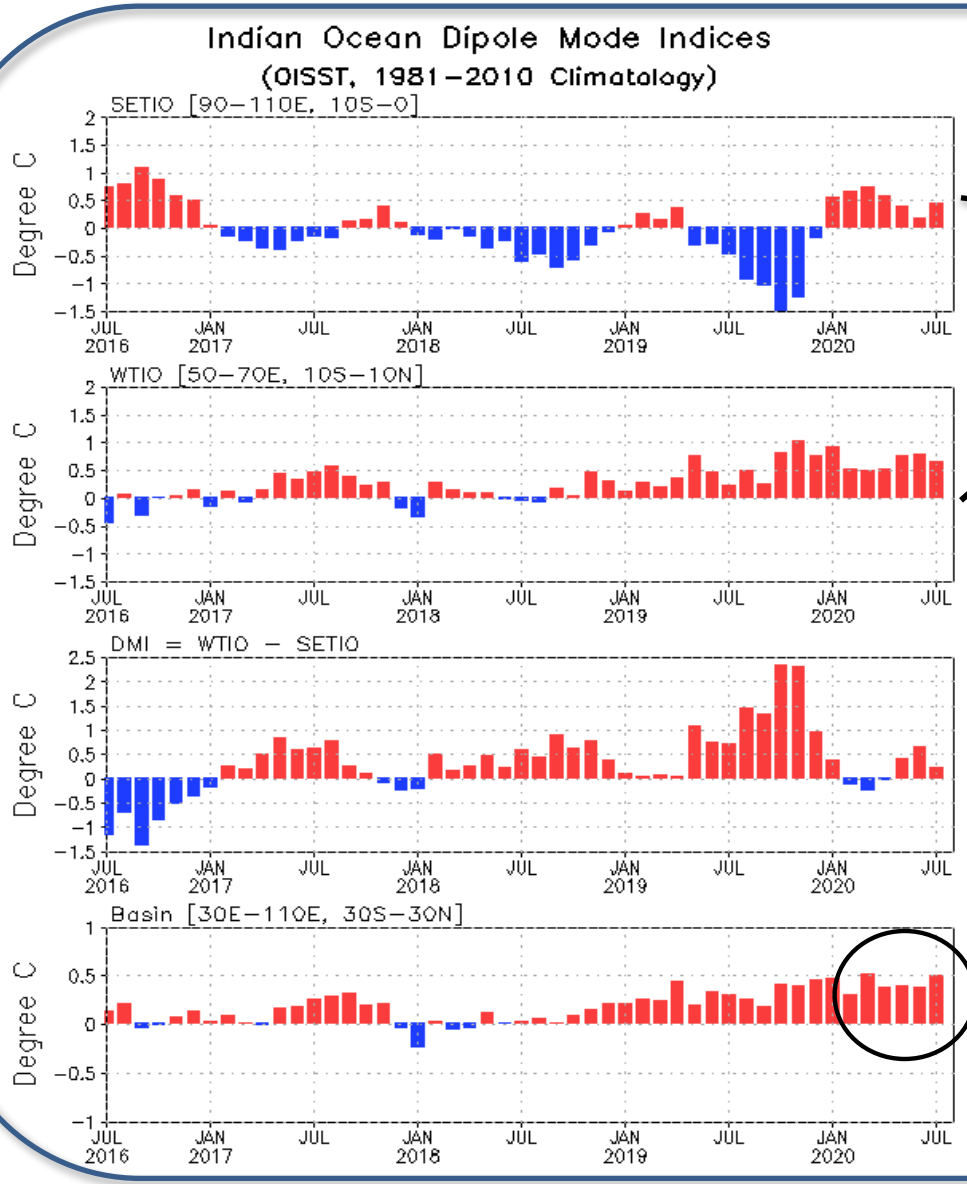
Arctic Sea Ice extent forecast

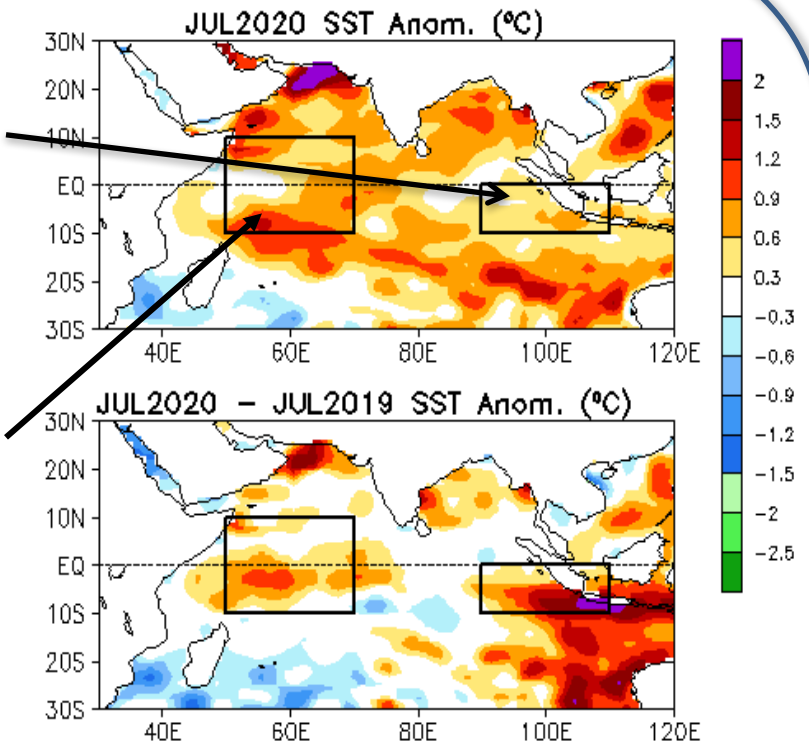


https://www.cpc.ncep.noaa.gov/products/people/wwang/seaice_seasonal/index.html

Indian Ocean

Evolution of Indian Ocean SST Indices

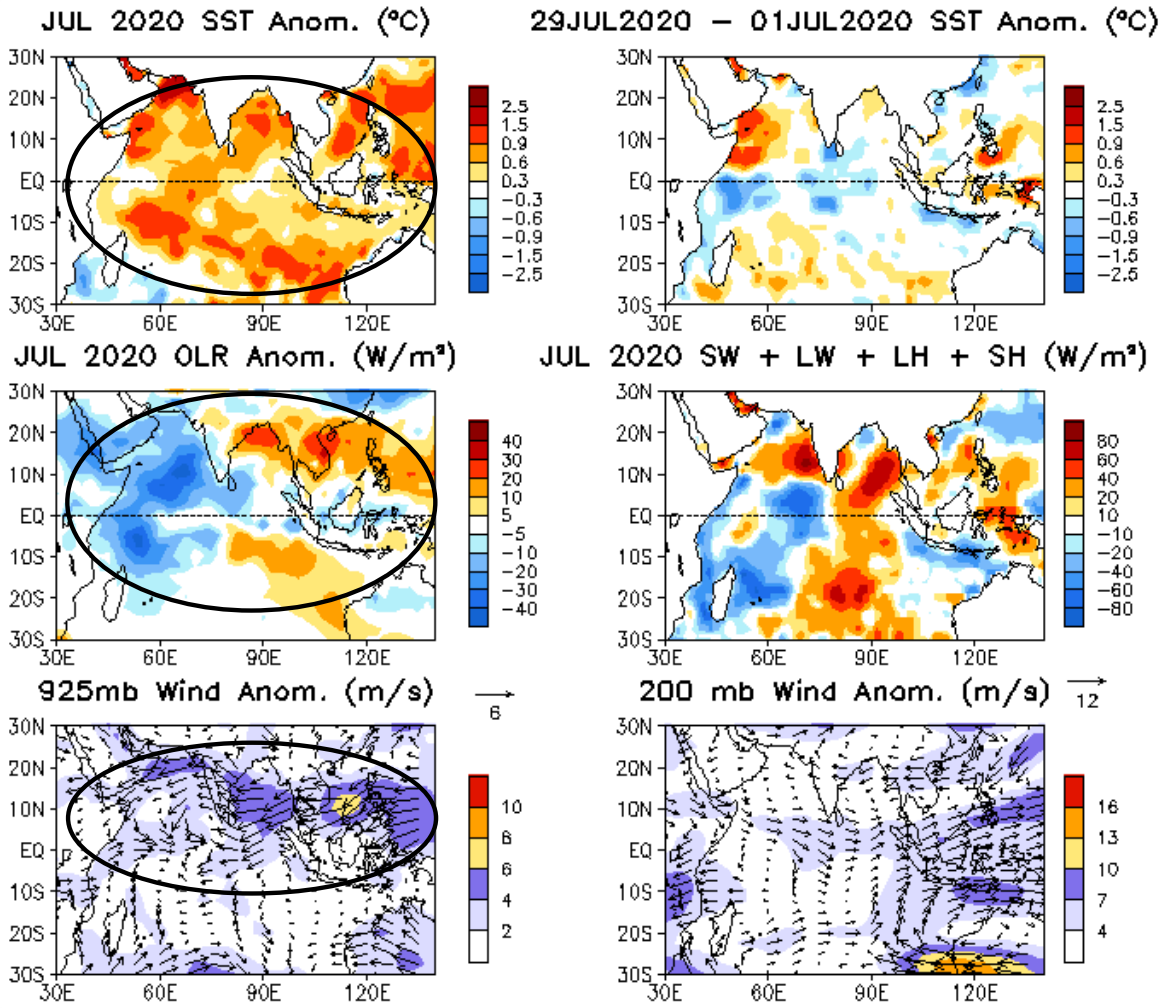




- Positive SSTAs were present in the tropical Indian Ocean in July 2020.

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 1981-2010 base period means.

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



- SSTAs were positive across most of the tropical Indian Ocean.

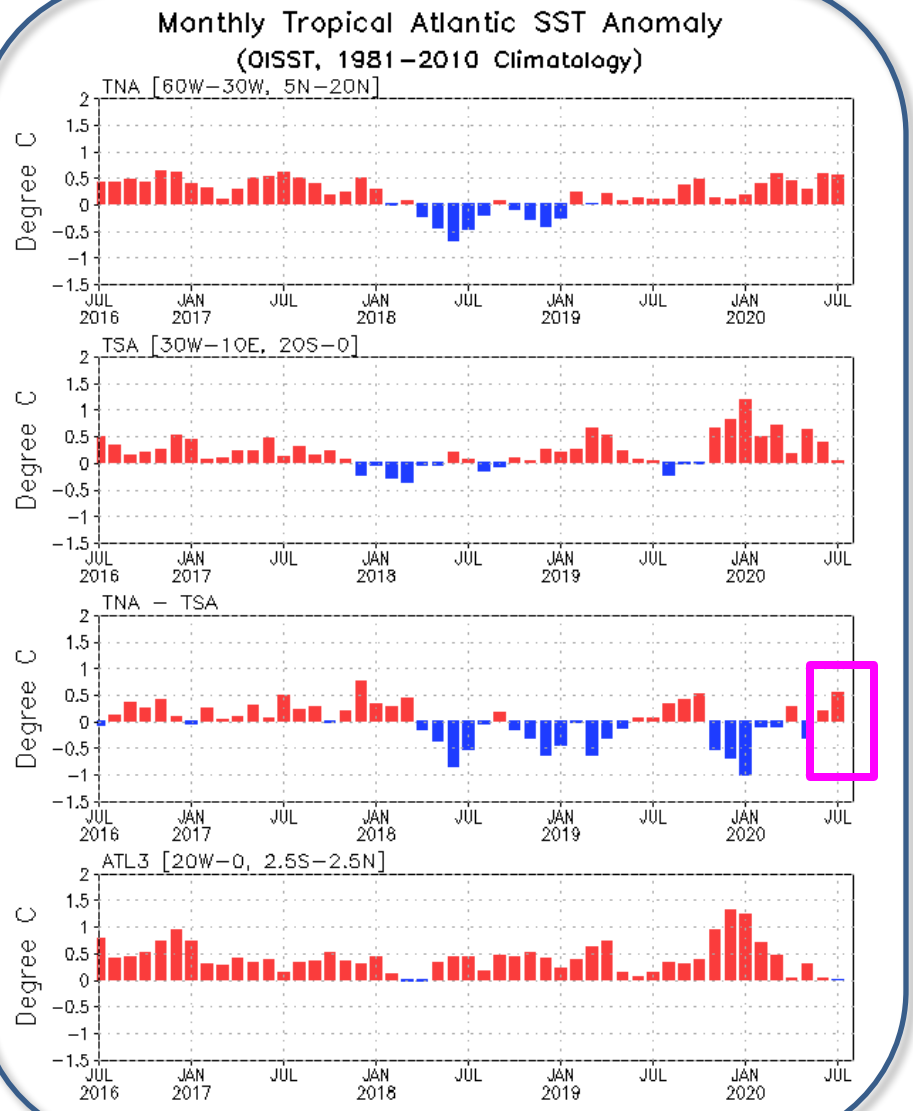
- Convection was enhanced over the tropical western Indian Ocean and the Maritime Continent and was suppressed over the belt from the northern Bay of Bengal to the tropical western North Pacific.

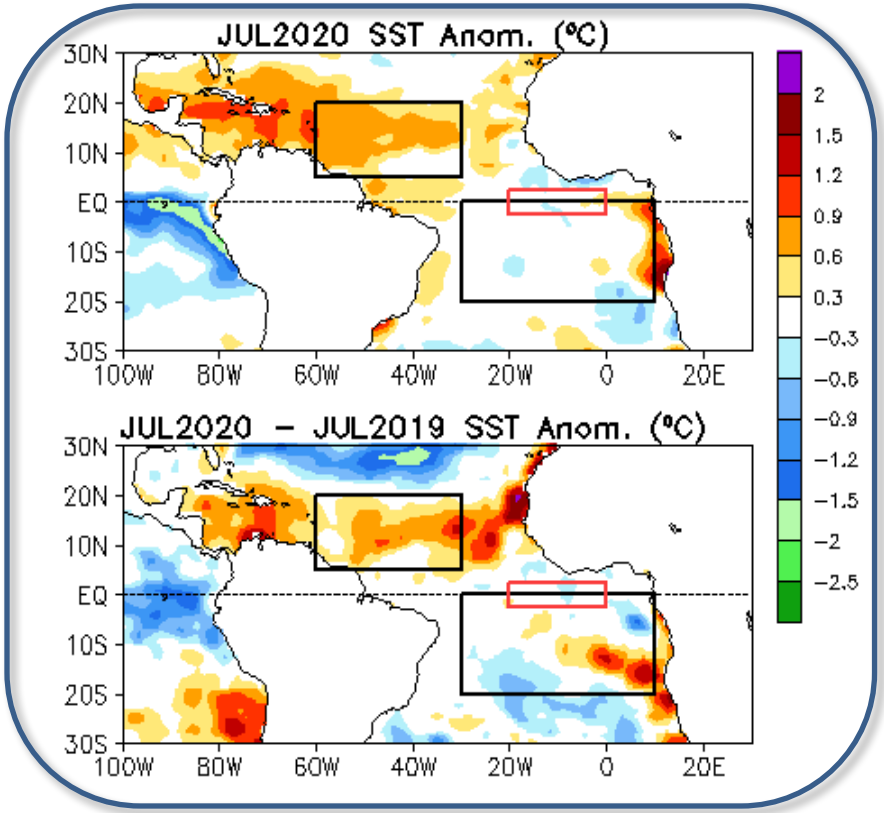
- Stronger easterly winds were present at low levels over the tropical North Indian Ocean.

SST anomalies (top-left), anomaly 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 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 1981-2010 base period means.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices





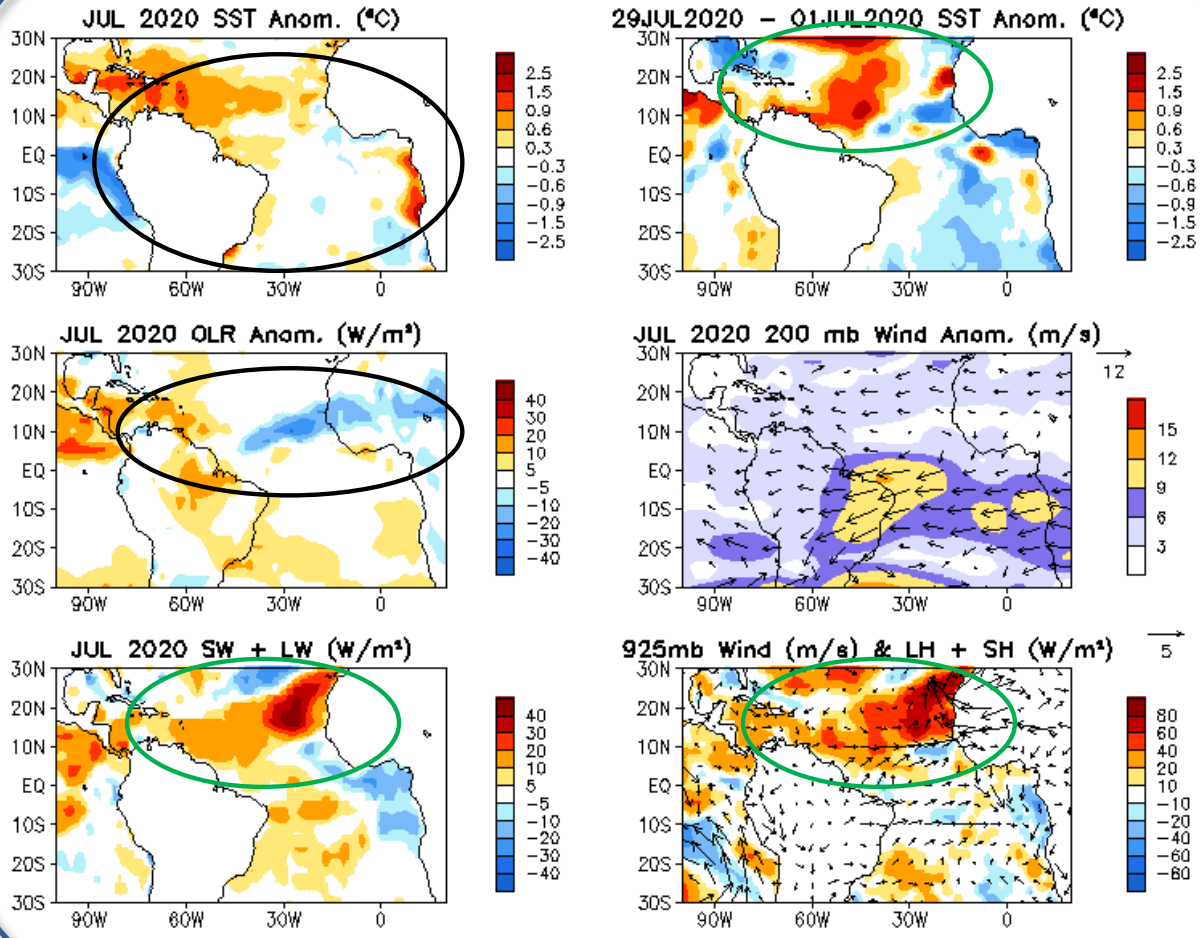
- Positive SSTAs were present across the tropical North Atlantic basin in July 2020.

- SST Meridional gradient was clear in July (MGI=0.52°C).

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

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 1981-2010 base period means.

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



- SSTAs were featured by a meridional gradient structure.

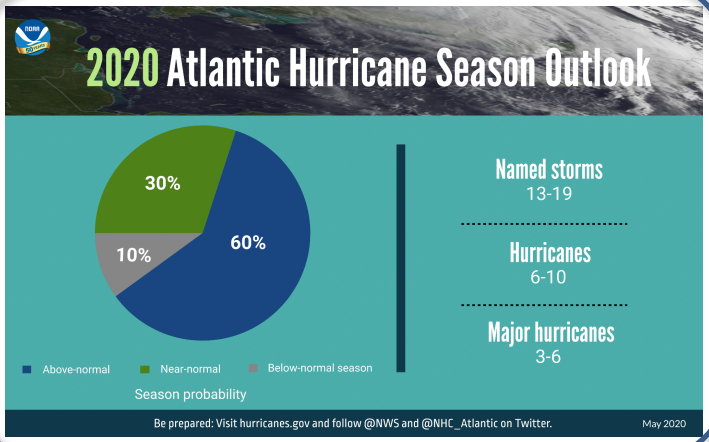
- The Atlantic ITCZ migrated northward.

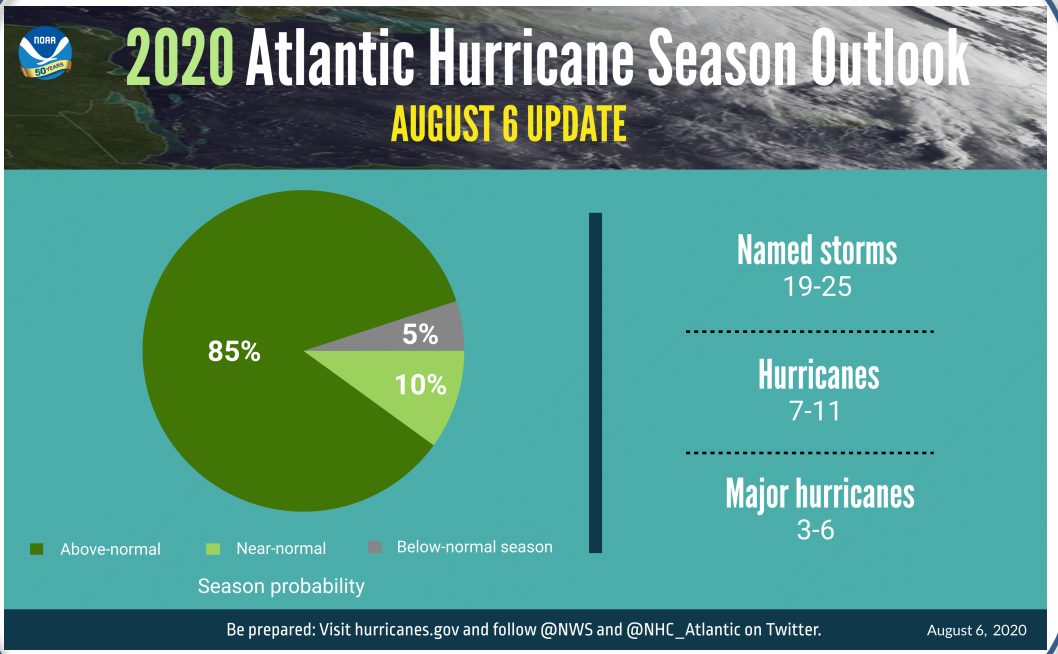
- The trade winds was weaker than average over the tropical North Atlantic.

-The thermodynamic processes (e.g., WES feedback) controlled SST evolutions in the tropical North Atlantic.

SST anomalies (top-left), anomaly 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 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 1981-2010 base period means.

NOAA 2020 Atlantic Hurricane Seasonal Outlook (August 6 update)





- The biggest changes from the May outlook are:

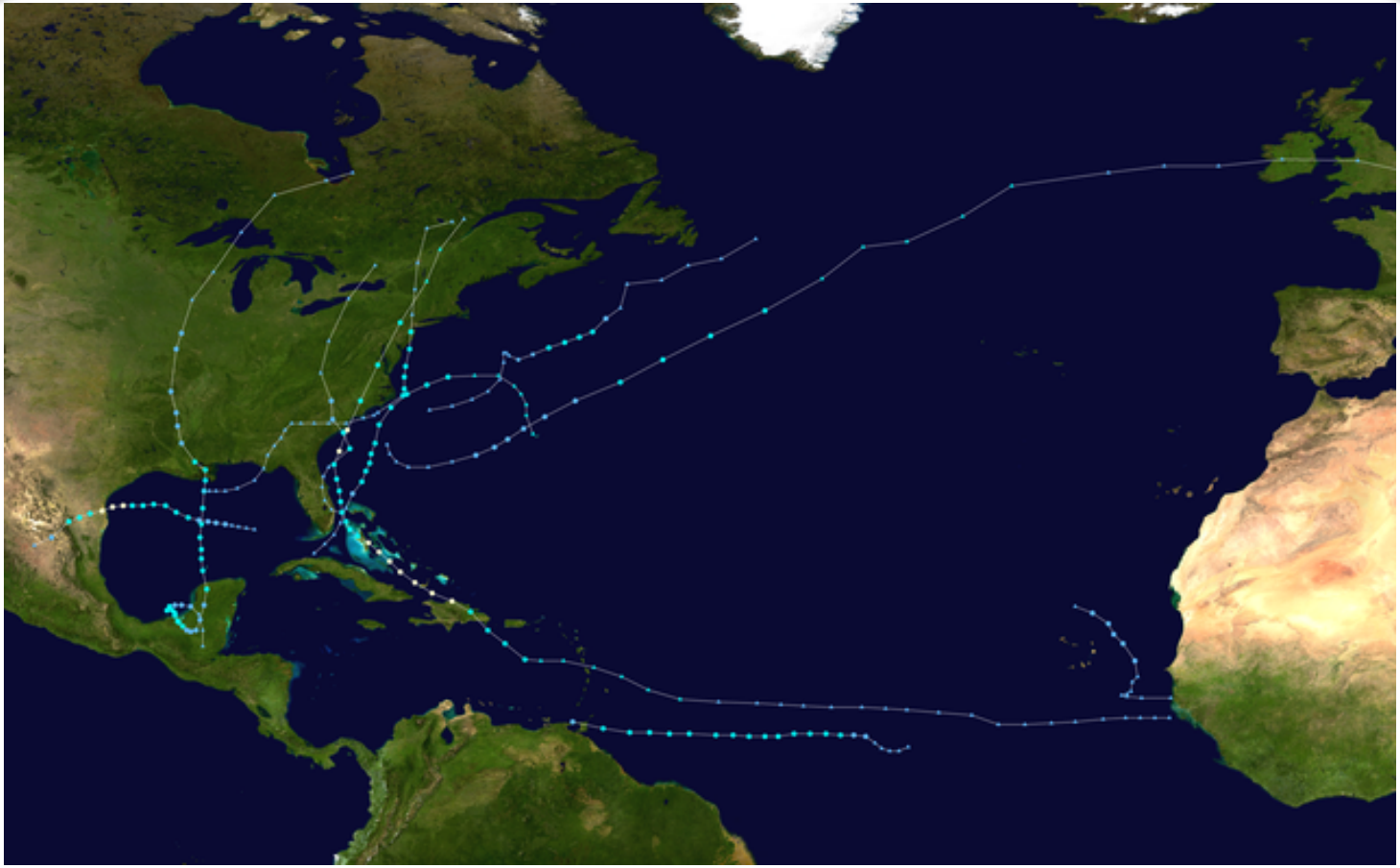
1) The likelihood of an above-normal season increased (85% now compared to 60% in May), and an extremely active season is more likely;

2) The likely number of named storms increased sharply (19-25 now compared to 13-19 in May); and

3) We could also see more hurricanes (7-11 now compared to 6-10 in May).

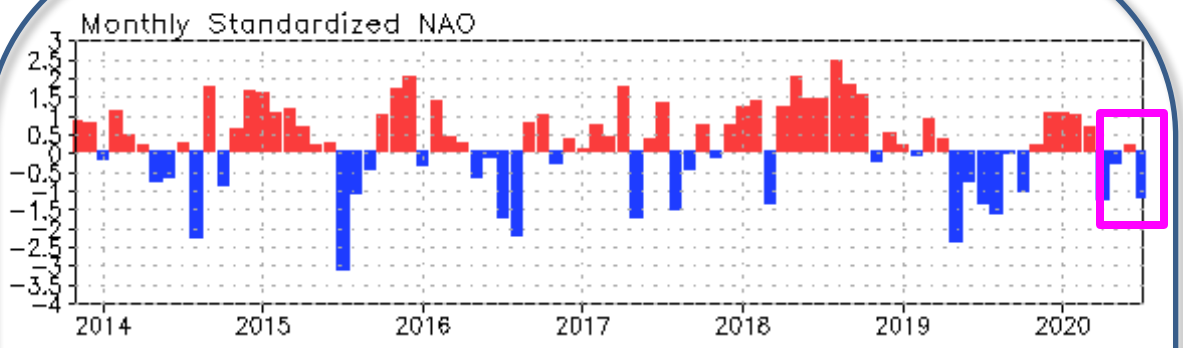
-https://www.noaa.gov/media-release/extremely-active-hurricane-season-possible-for-atlantic-basin

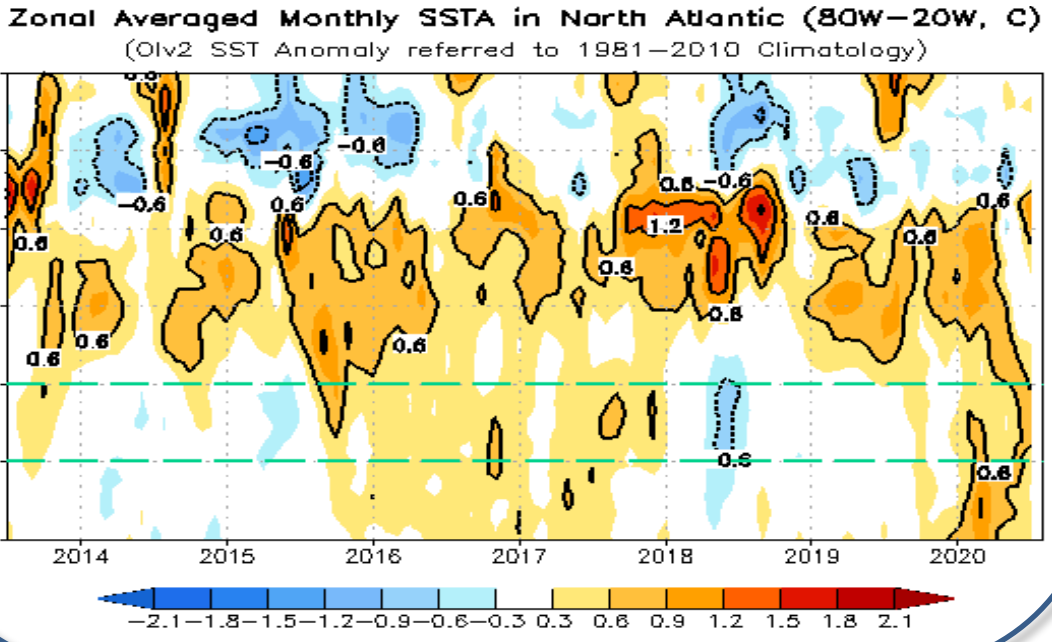
The Atlantic Hurricane Season – The current status

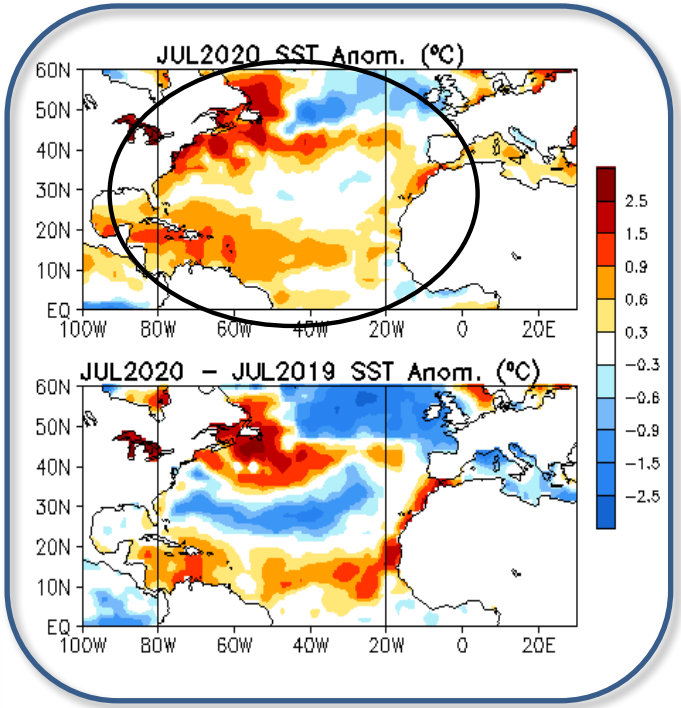


2020		Outlook (Aug. 6)	Outlook (May 21)	(1981-2010)
Total storms	**9**	19-25	13-19	12
Hurricanes	**2**	7-11	6-10	6
Major hurricanes (Cat. 3+)	**0**	3-6	3-6	3

NAO and SST Anomaly in North Atlantic







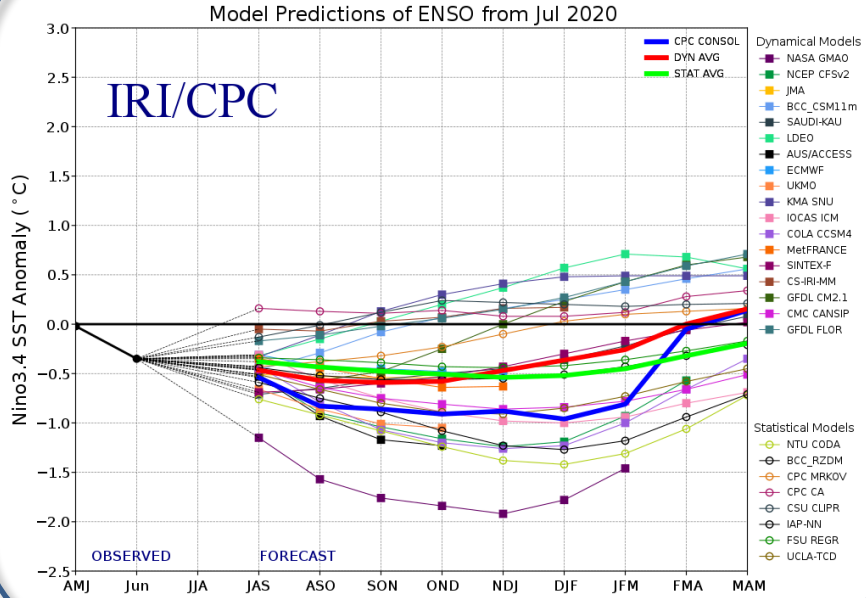
- NAO switched to a negative phase in July 2020 with NAOI= -1.19.

- The prolonged tripole SSTA pattern was absent in July 2020, but featured by a quadrupole-like structure in the North Atlantic.

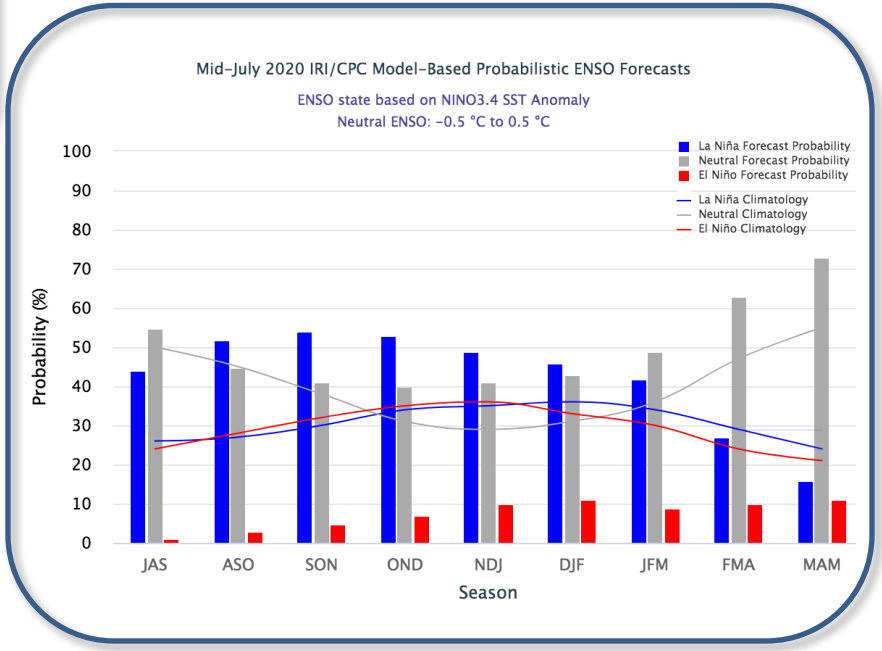
Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20°N-90°N (http://www.cpc.ncep.noaa.gov). Time-Latitude section of SST anomalies averaged between 80ºW and 20ºW (bottom). SST are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

ENSO and Global SST Predictions

IRI/CPC NINO3.4 Forecast Plume: July, 2020

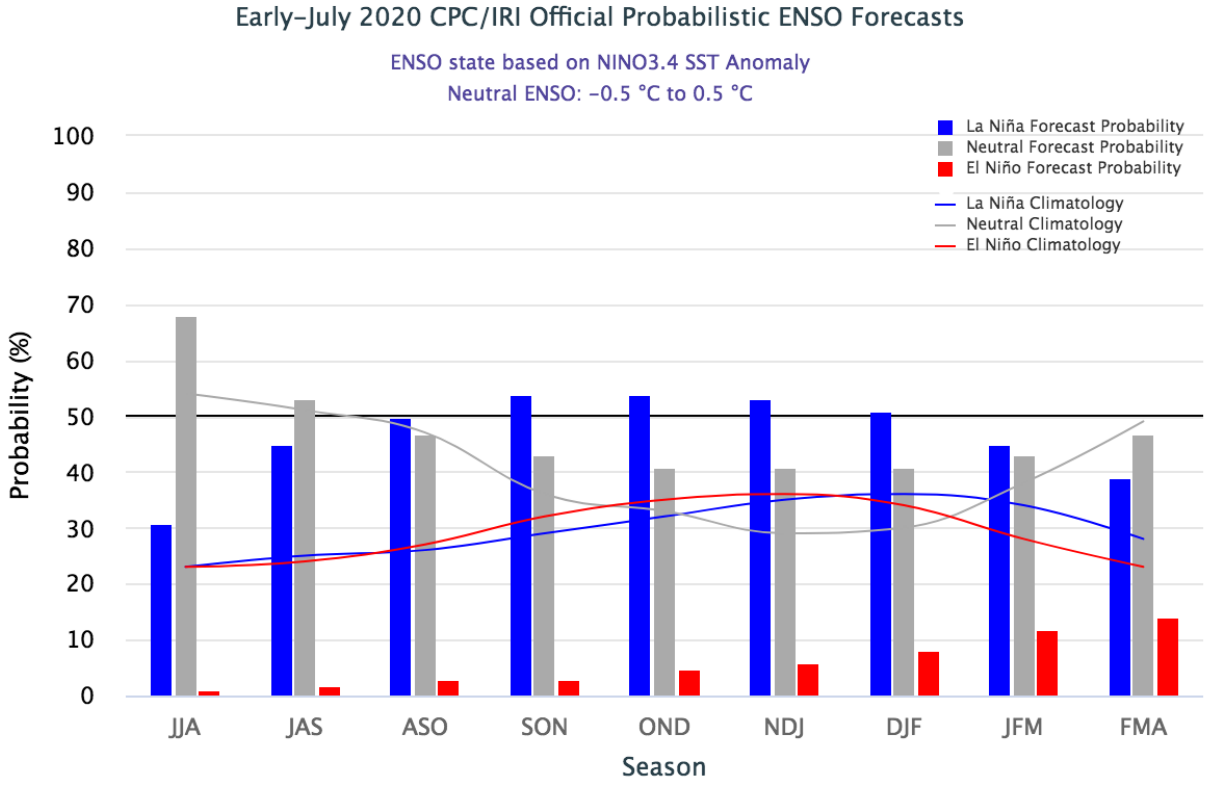


- Most predictions with ICs in July 2020 predicted a La Nina state through boreal summer/fall 2020.



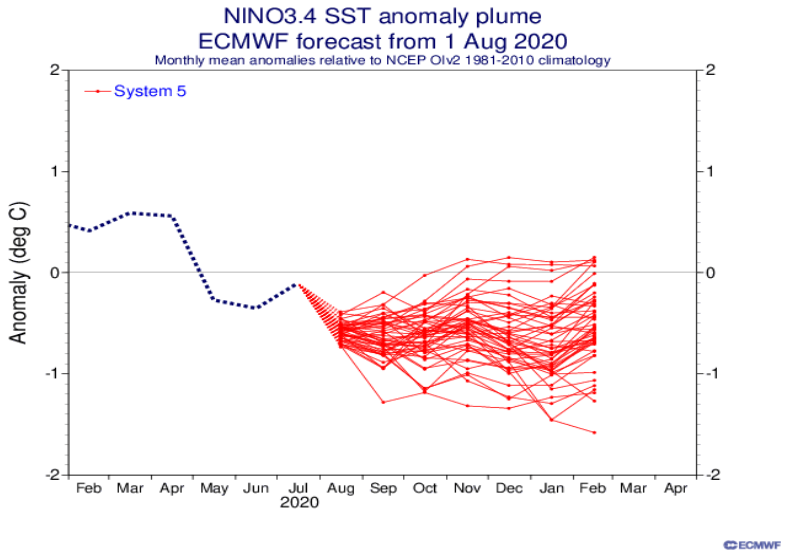
NOAA "ENSO Diagnostics Discussion (EDD)": 9 July 2020

- **ENSO Alert System Status**: La Niña Watch
- **Synopsis**: ENSO-neutral is favored to continue through the summer, with a 50-55% chance of La Niña development during Northern Hemisphere fall 2020 and continuing through winter 2020-21 (~50% chance).

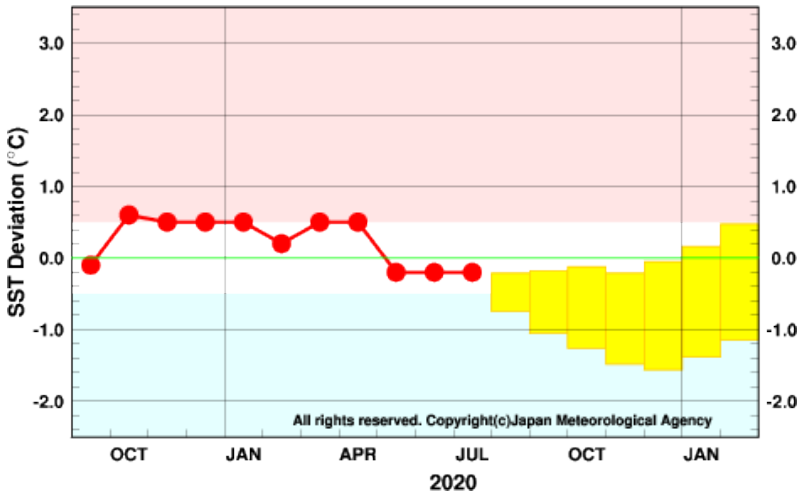


Individual Model Forecasts: ENSO-Neutral or La Nina

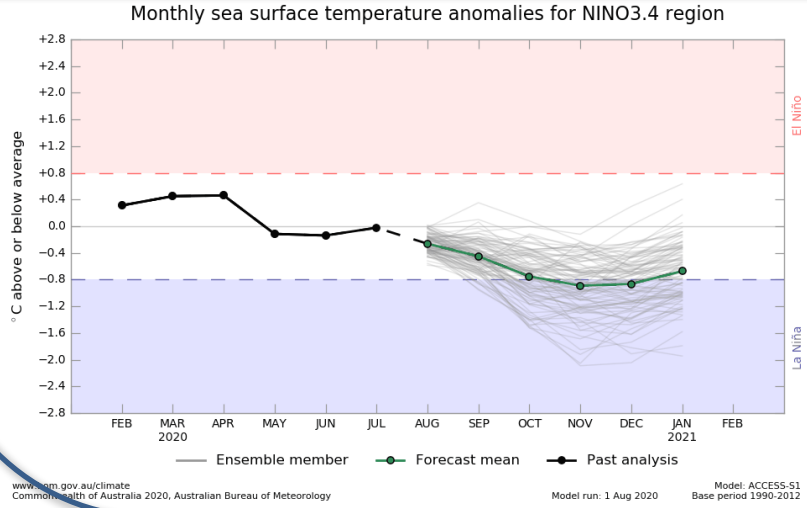
EC: Nino3.4, IC=01August 2020



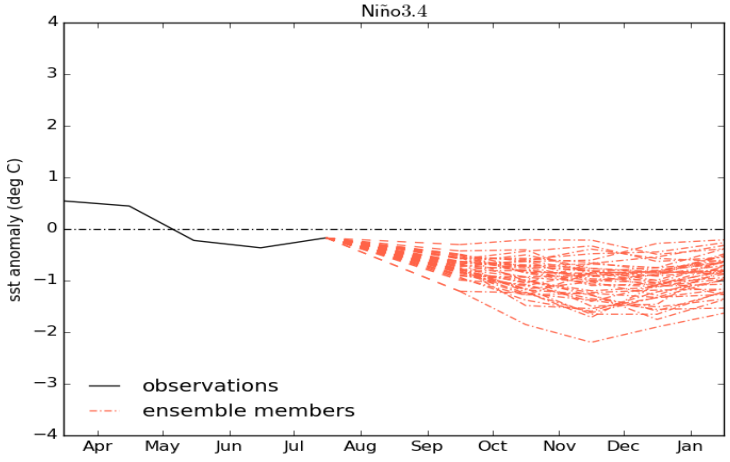
JMA: Nino3.4, Updated 11 August 2020



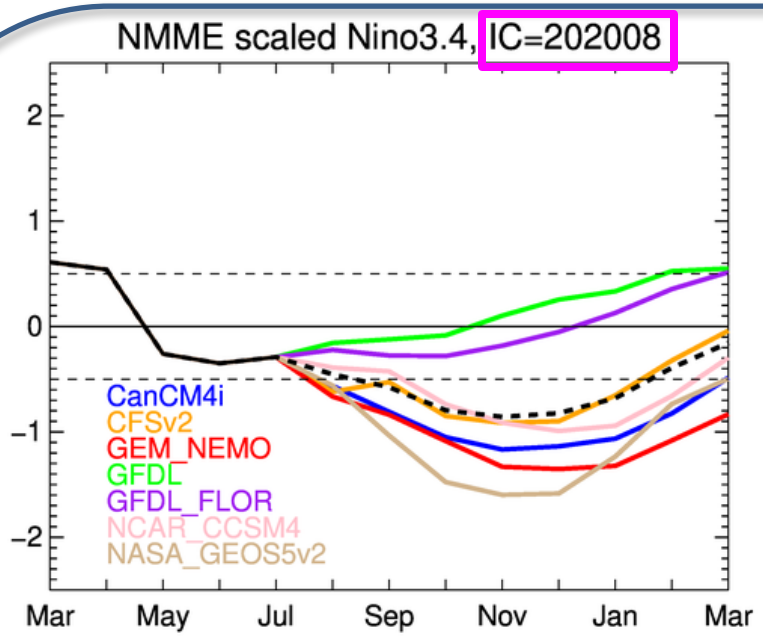
Australian BOM: Nino3.4, Updated 1 August 2020

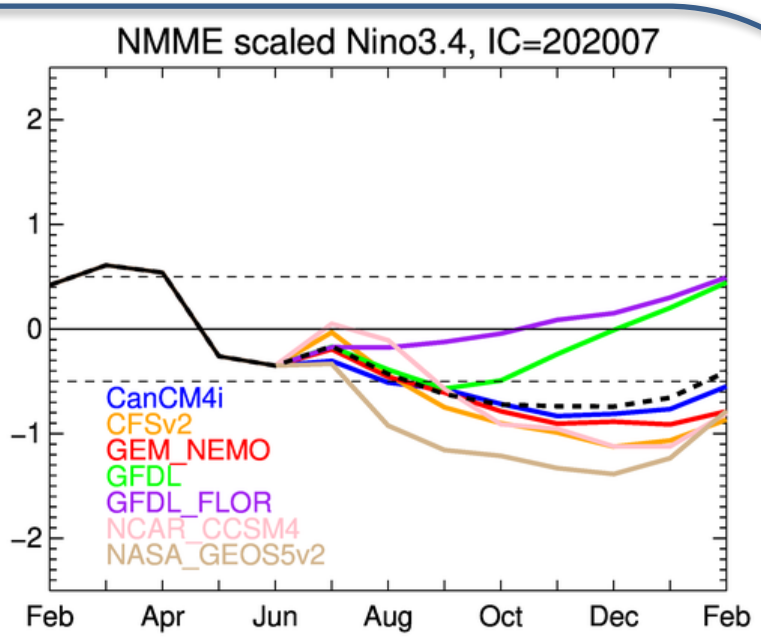


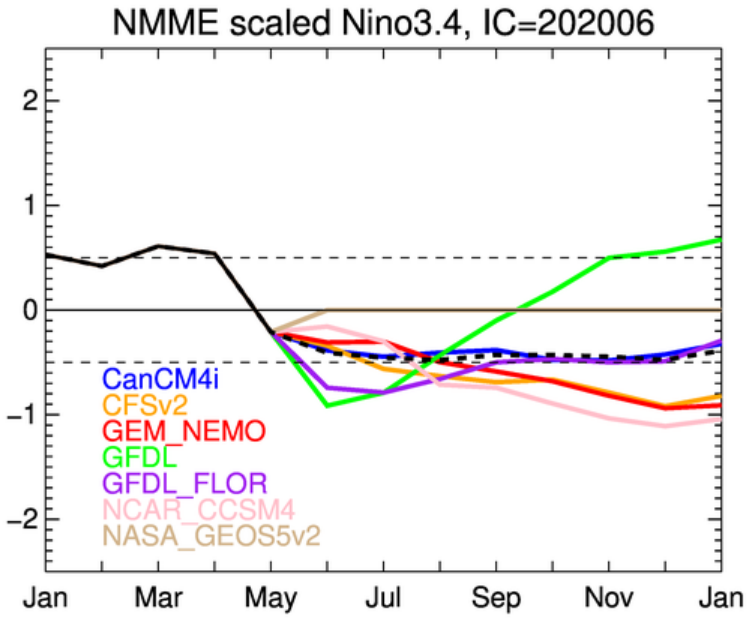
UKMO: Nino3.4, Updated 11 August 2020

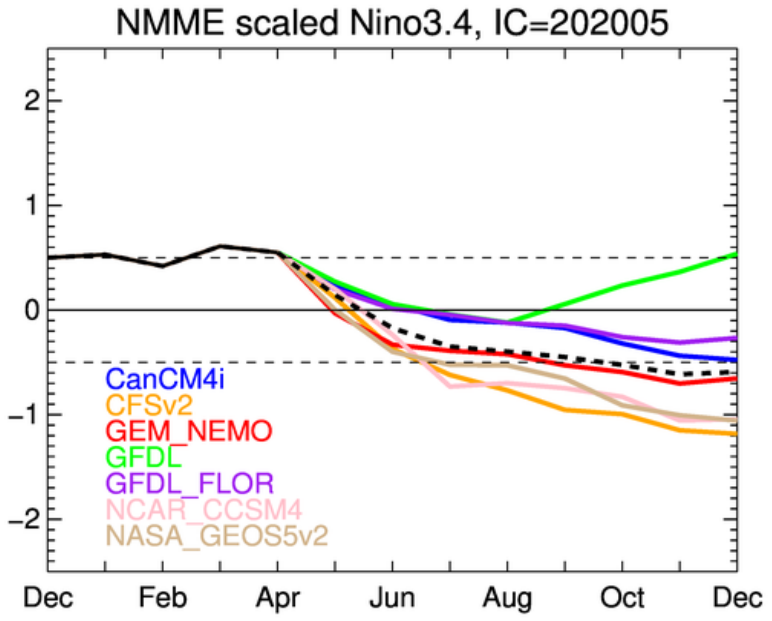


NMME forecasts from different Initial Conditions

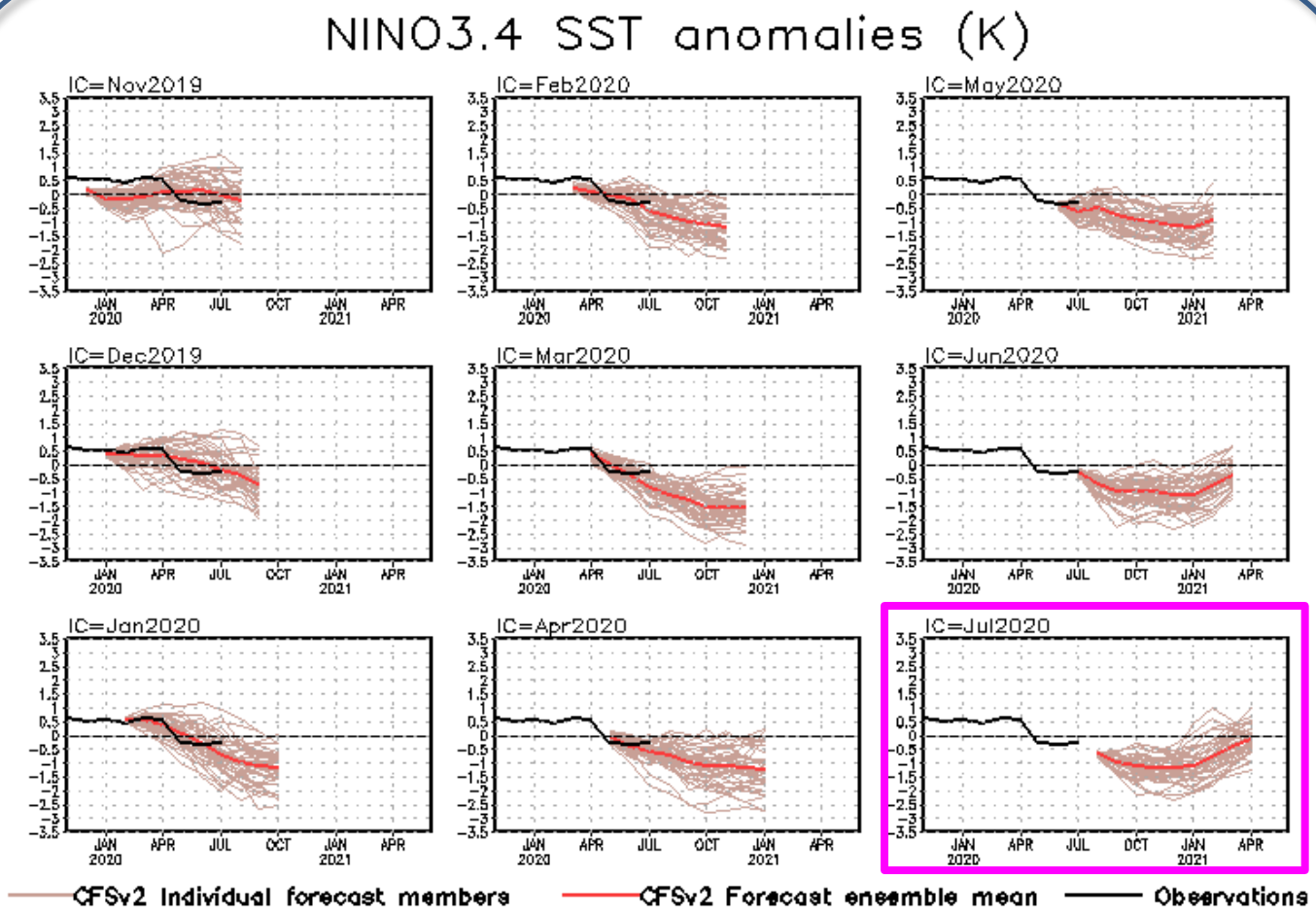








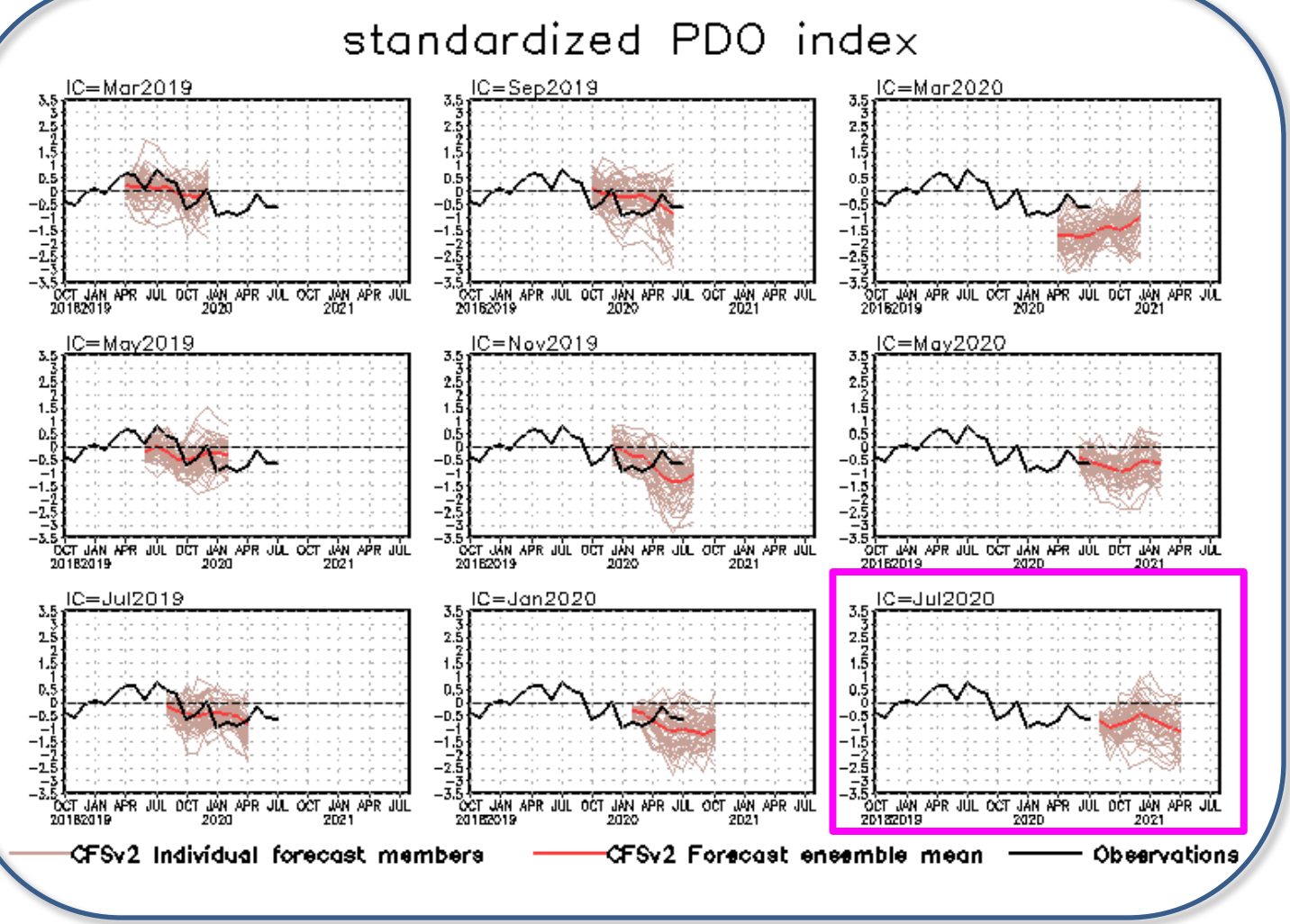
CFS Niño3.4 SST Predictions from Different Initial Months



- The latest CFSv2 forecasts call for a La Nina state through this summer/fall.

CFS Nino3.4 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 1981-2010 base period means.

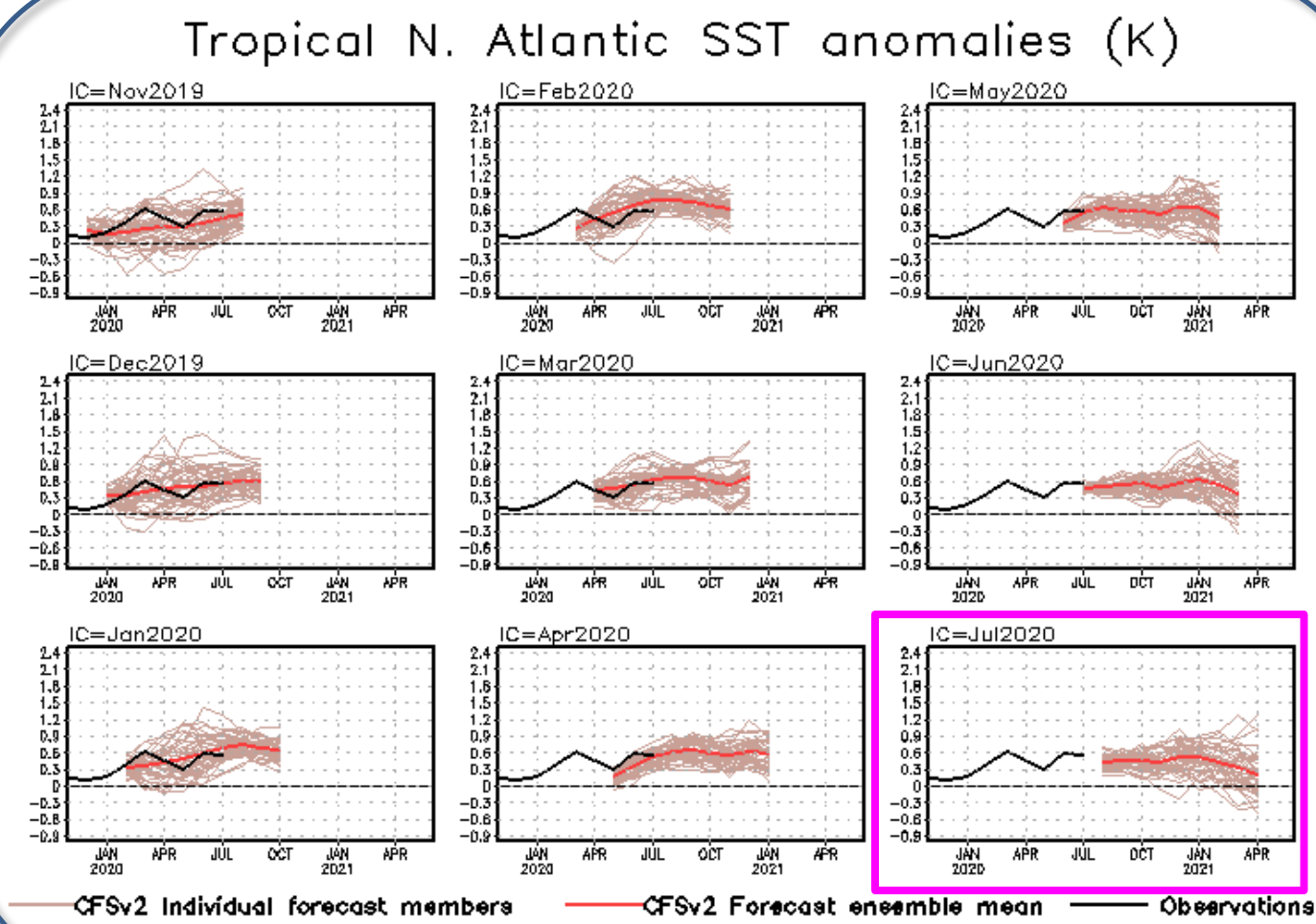
CFS Pacific Decadal Oscillation (PDO) Index Predictions from Different Initial Months



- CFSv2 predicts a negative phase of PDO in 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 1981-2010 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.

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

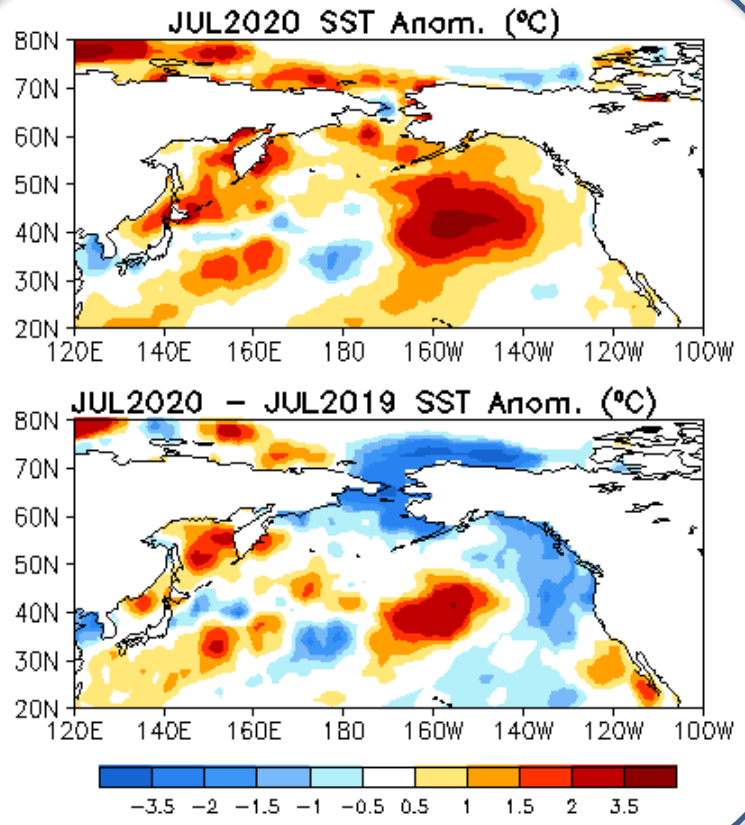


- Latest CFSv2 predictions call for above normal SSTA in the tropical N. Atlantic in 2020.

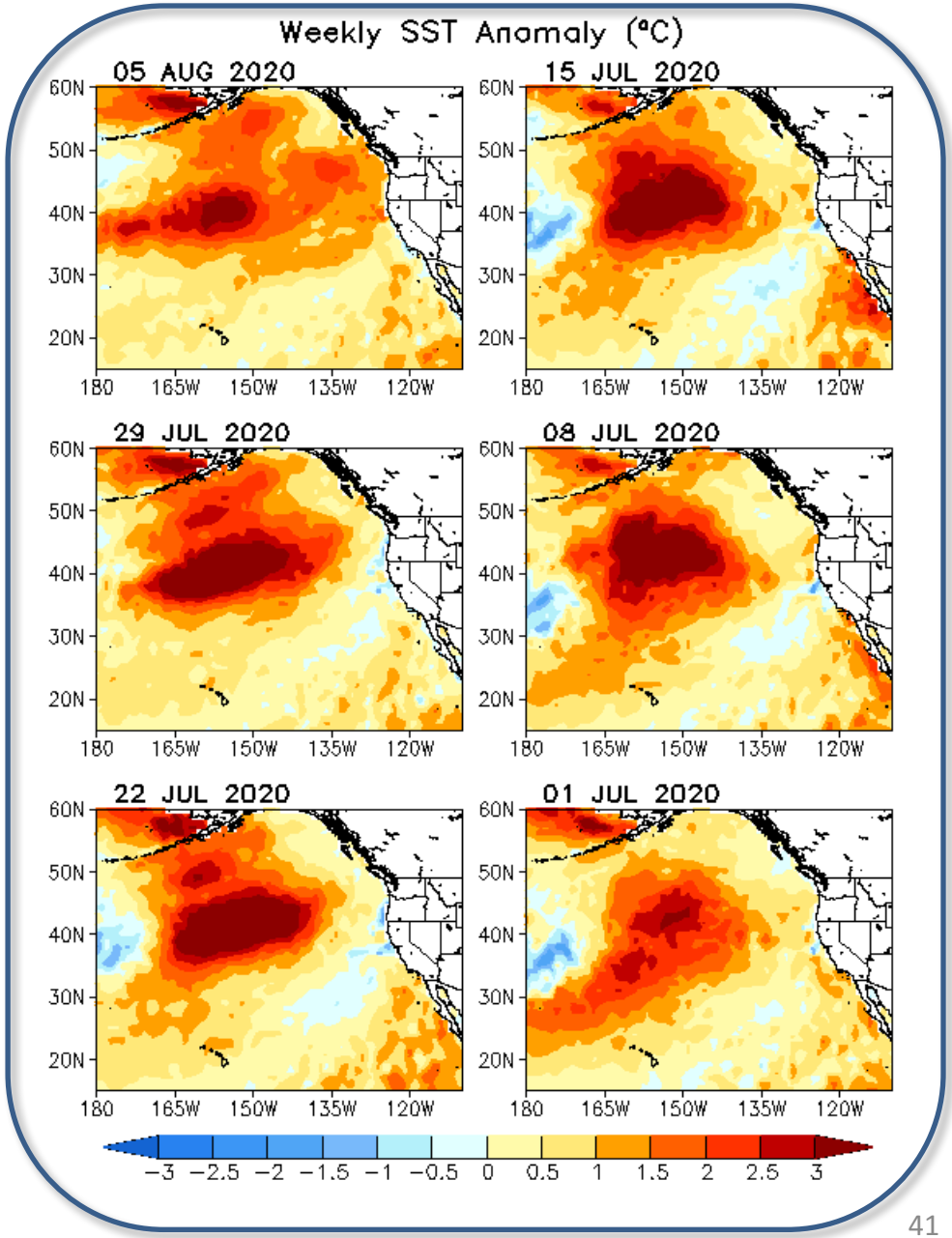
CFS Tropical North Atlantic (TNA) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1981-2010 base period means. TNA is the SST anomaly averaged in the region of [60oW-30oW, 5oN-20oN].

North Pacific Marine Heatwave Status and Prediction

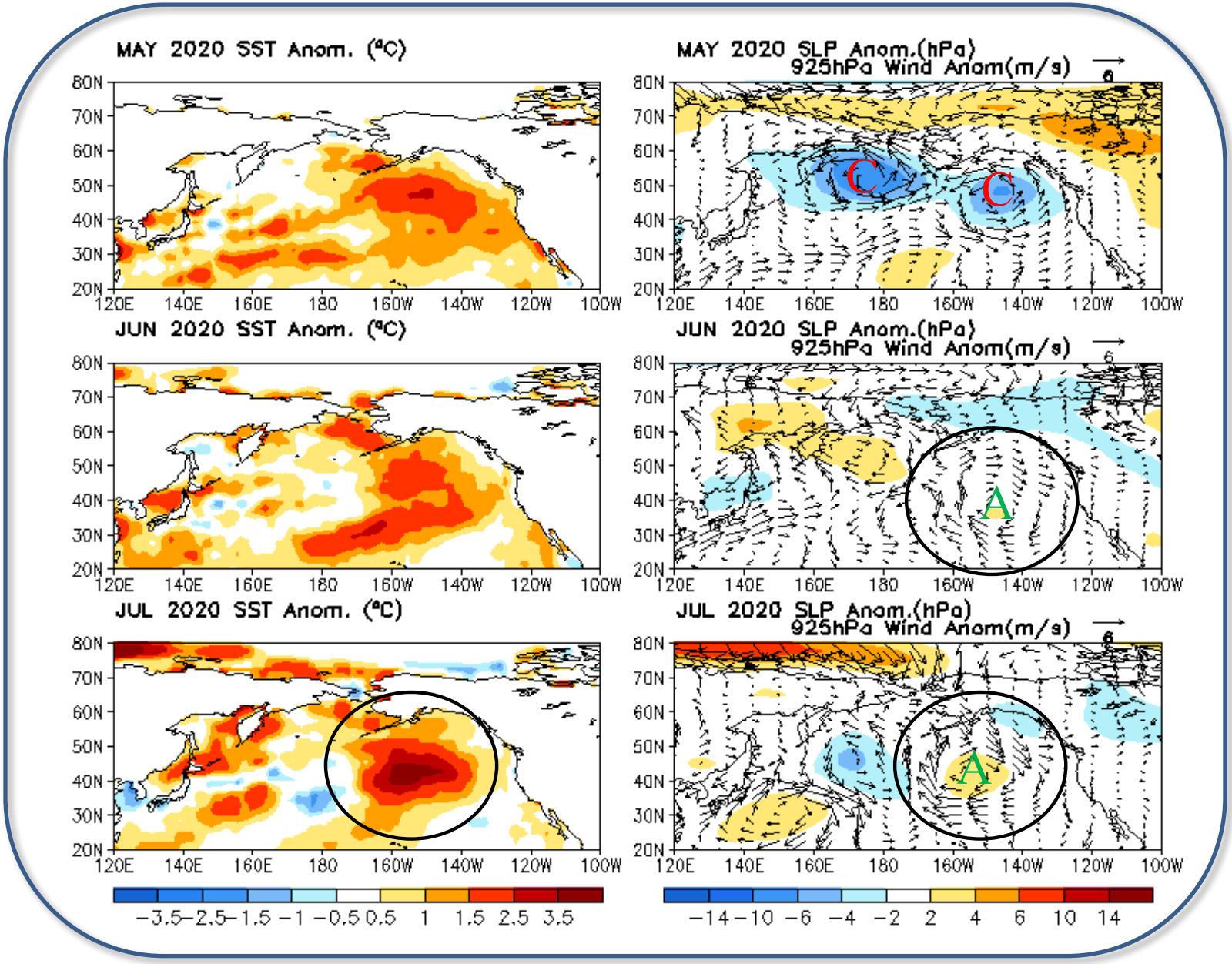
Weekly SSTA evolutions in the NE Pacific



- Marine Heatwave strengthened in North Pacific in July 2020.

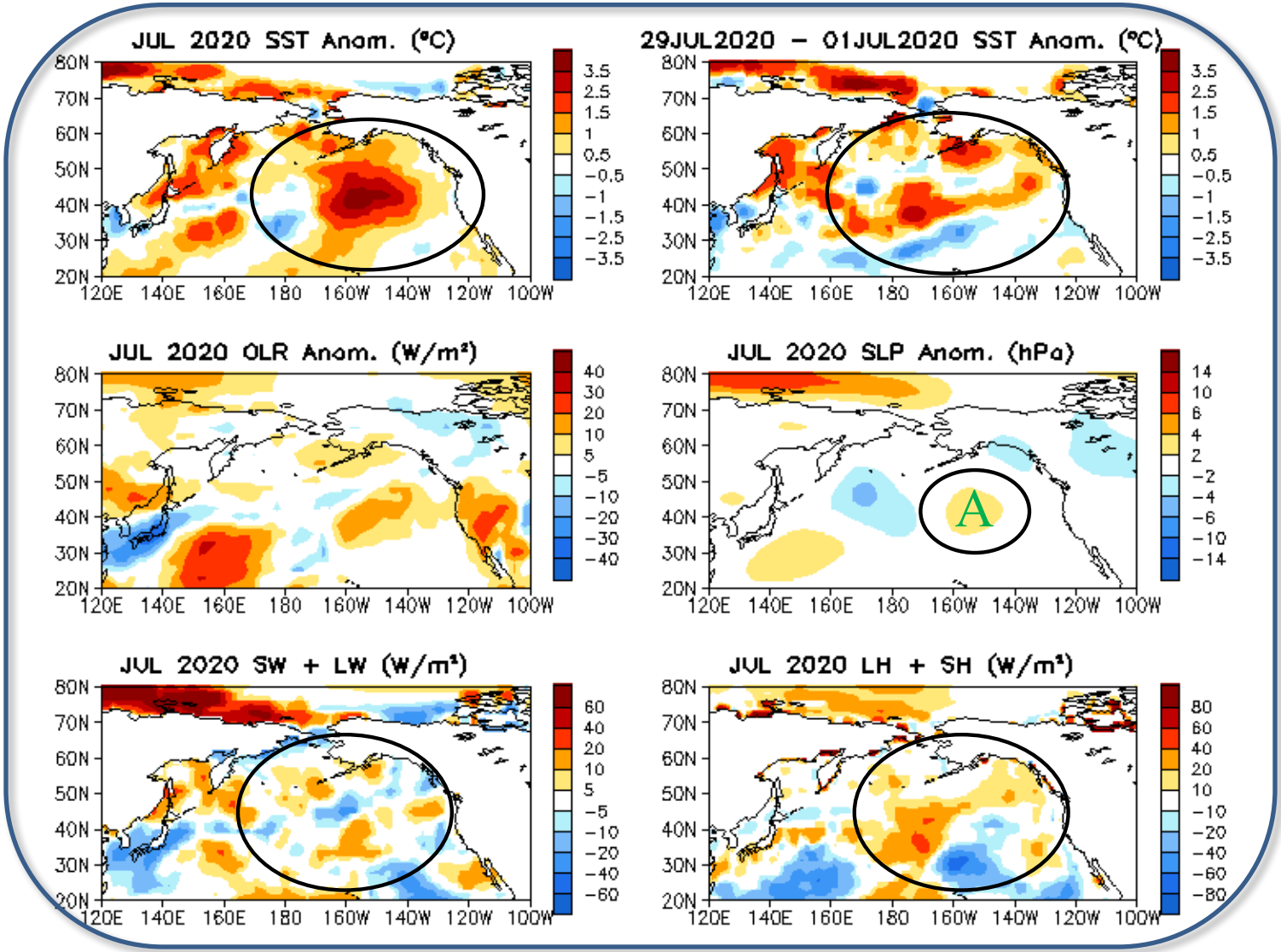


North Pacific surface SST and circulation anomalies



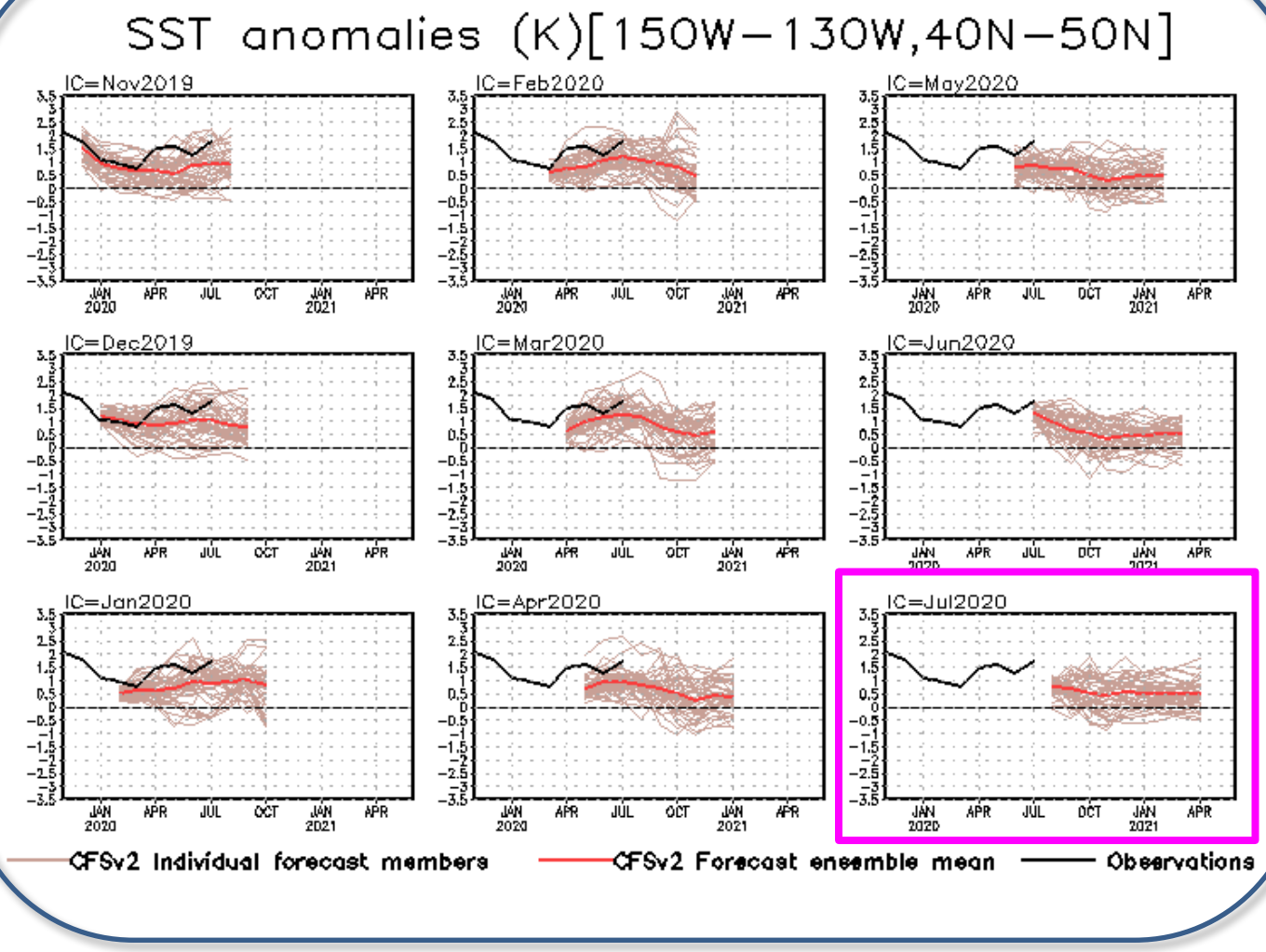
Data source: NCEP/NCAR Reanalysis 1

North Pacific & Arctic Ocean: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx



Sea surface temperature (top-left; NCEP OI SST Analysis), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) (middle-left; NOAA 18 AVHRR IR), sea surface pressure (middle-right; NCEP CDAS), sum of net surface short- and long-wave radiation (bottom-left; positive means heat into the ocean; NCEP CDAS), sum of latent and sensible heat flux (bottom-right; positive means heat into the ocean; NCEP CDAS). Anomalies are departures from the 1981-2010 base period means.

CFS NE Pacific Marine Heatwave Index Predictions from Different Initial Months

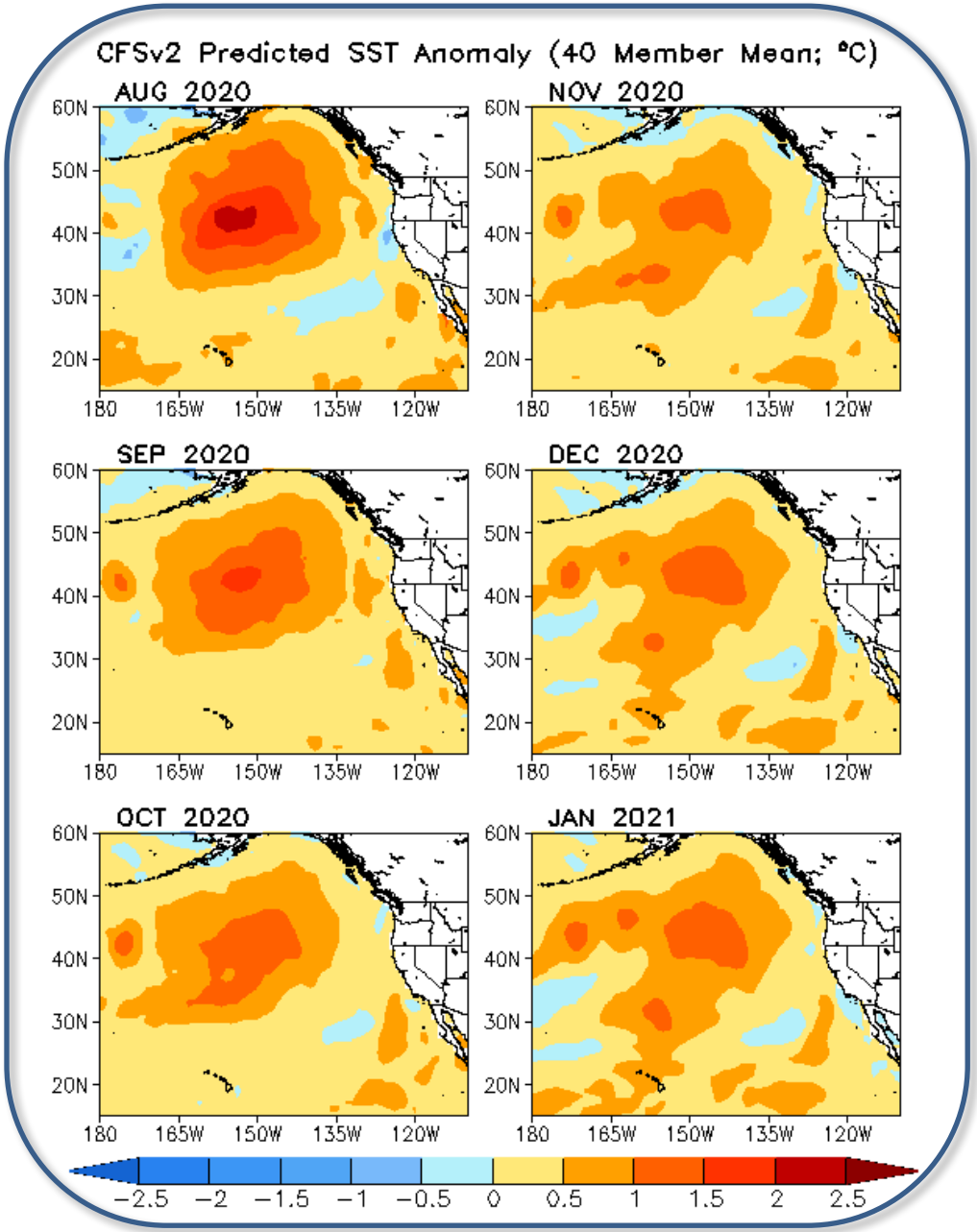


- Earlier CFSv2 predictions underestimated the strength of NP Marine Heatwave;

-Latest CFSv2 predictions suggest that the current warm state will continue in 2020.

CFS NE Pacific 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 (red) and observations (black). Anomalies were computed with respect to the 1981-2010 base period means.

CFSv2 NE Pacific Marine Heatwave Predictions



- Latest CFSv2 predictions suggest that the current warm state will continue, but decay during the remainder of 2020.

Acknowledgements

- Drs. Zeng-Zhen Hu, Caihong Wen, and Arun Kumar: reviewed PPT, and provide insightful suggestions and comments
- Drs. Li Ren and Pingping Xie provided the BASS/CMORPH/CFSR EVAP package
- Dr. Wanqiu Wang provided the sea ice forecasts and maintained the CFSv2 forecast archive
- NOAA Hurricane Outlook Team provided the August update about hurricane seasonal outlook

Please send your comments and suggestions to:

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Data Sources (climatology is for 1981-2010)

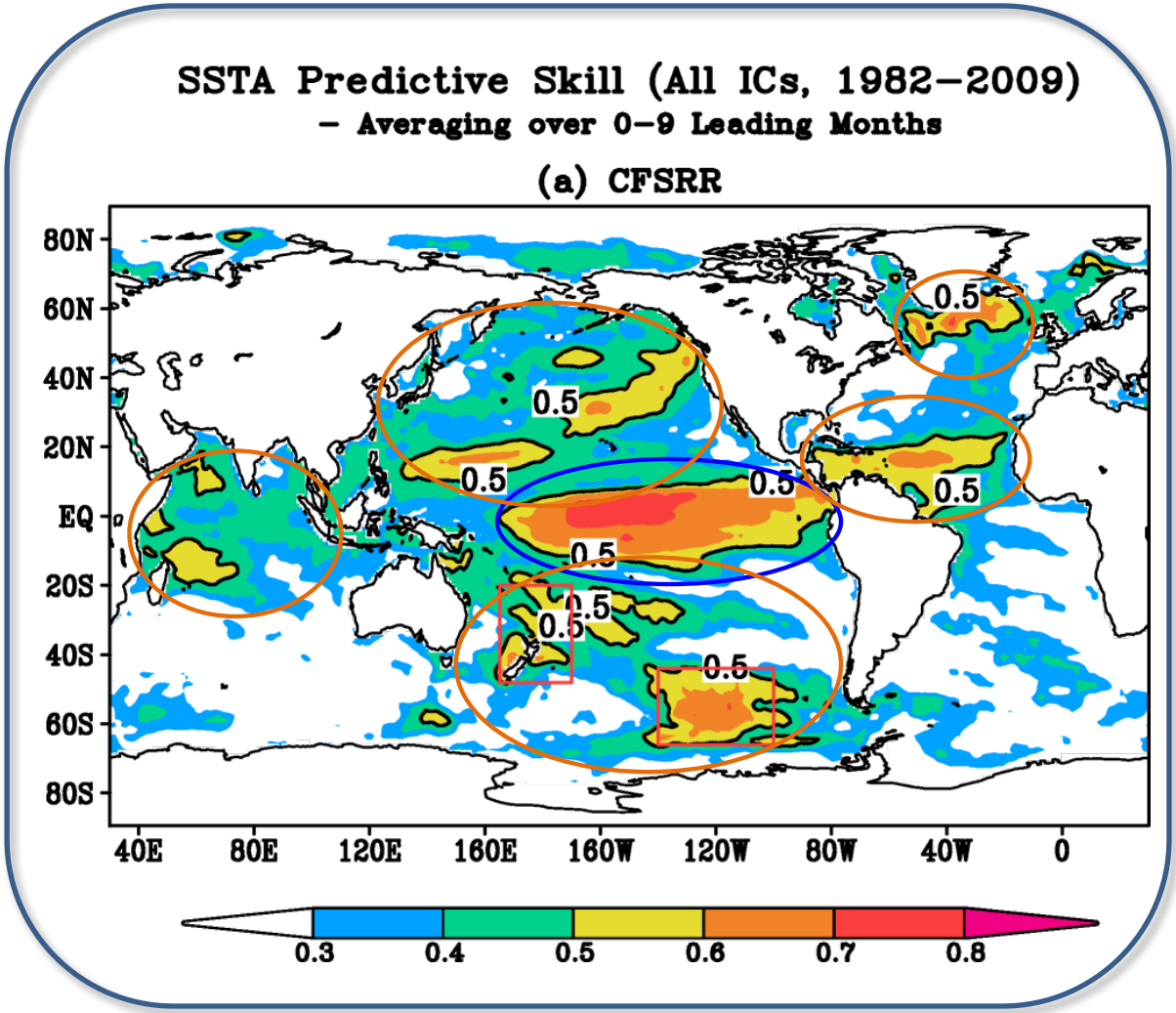
- Weekly Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)
- Extended Reconstructed SST (ERSST) v5 (Huang et al. 2017)
- Blended Analysis of Surface Salinity (BASS) (Xie et al. 2014)
- CMORPH precipitation (Xie et al. 2017)
- CFSR evaporation adjusted to OAFlux (Xie and Ren 2018)
- 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

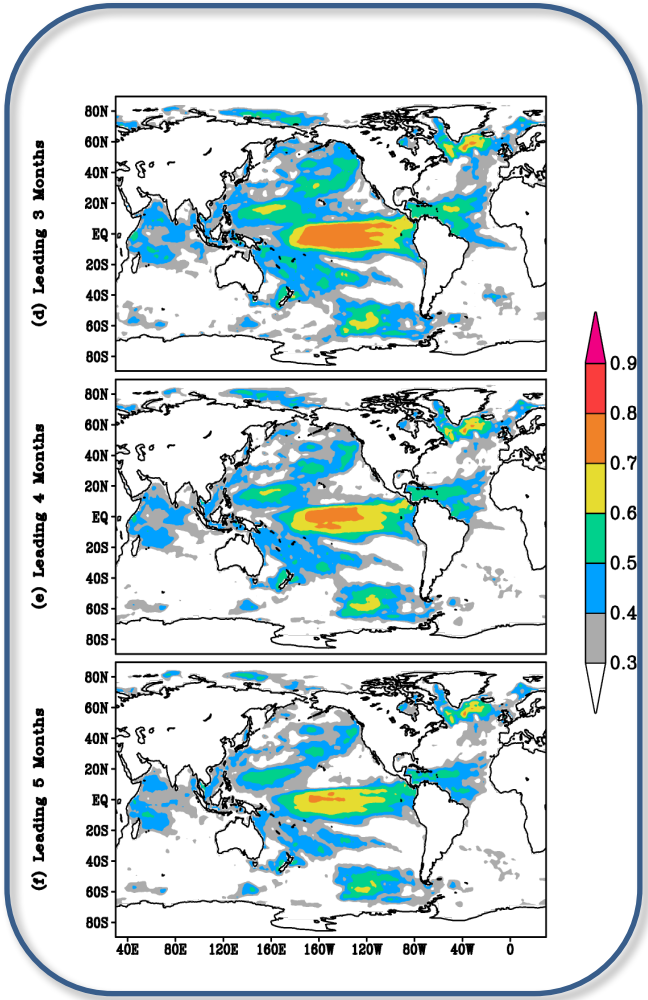
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html

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

Backup Slides

Spatial Distribution of SSTA prediction skill with CFSv2

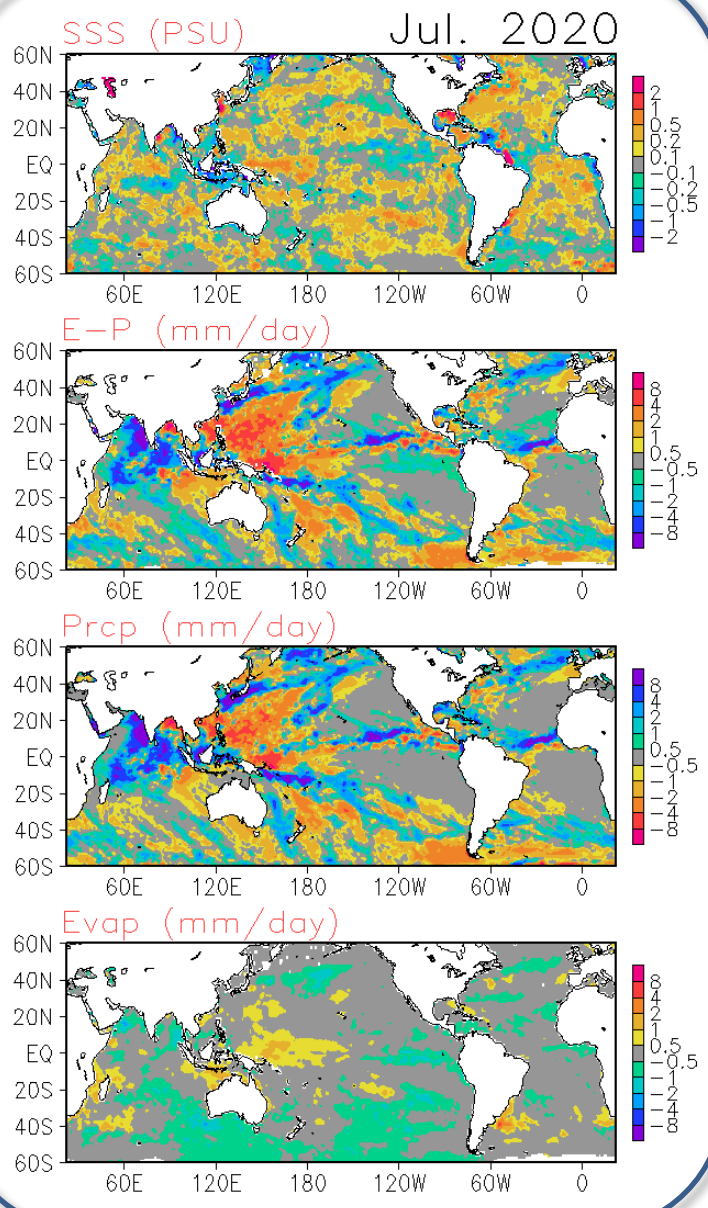




- ENSO-related SST presents the highest prediction skill;
- Other skillful regions include tropical North Atlantic, South Pacific, tropical Indian Ocean, part of extratropical North Pacific,…

Global Sea Surface Salinity (SSS) Anomaly for July 2020

- New Update: The NCEI SST data used in the quality control procedure has been updated to version 2.1 since May 2020
- Positive SSS anomaly continues in the west equatorial Pacific ocean with reduced precipitation, while SSS anomaly became negative with increased precipitation in the east equatorial Pacific. Negative SSS anomaly continues in in the central Indo-Pacific and extends west to the Indian ocean, which is likely caused by the increased precipitation in these regions. Positive SSS anomaly continues in the subtropical Atlantic Ocean. While, negative SSS anomaly appeared in the equatorial Atlantic region, which is being accompanied by intensified precipitation.

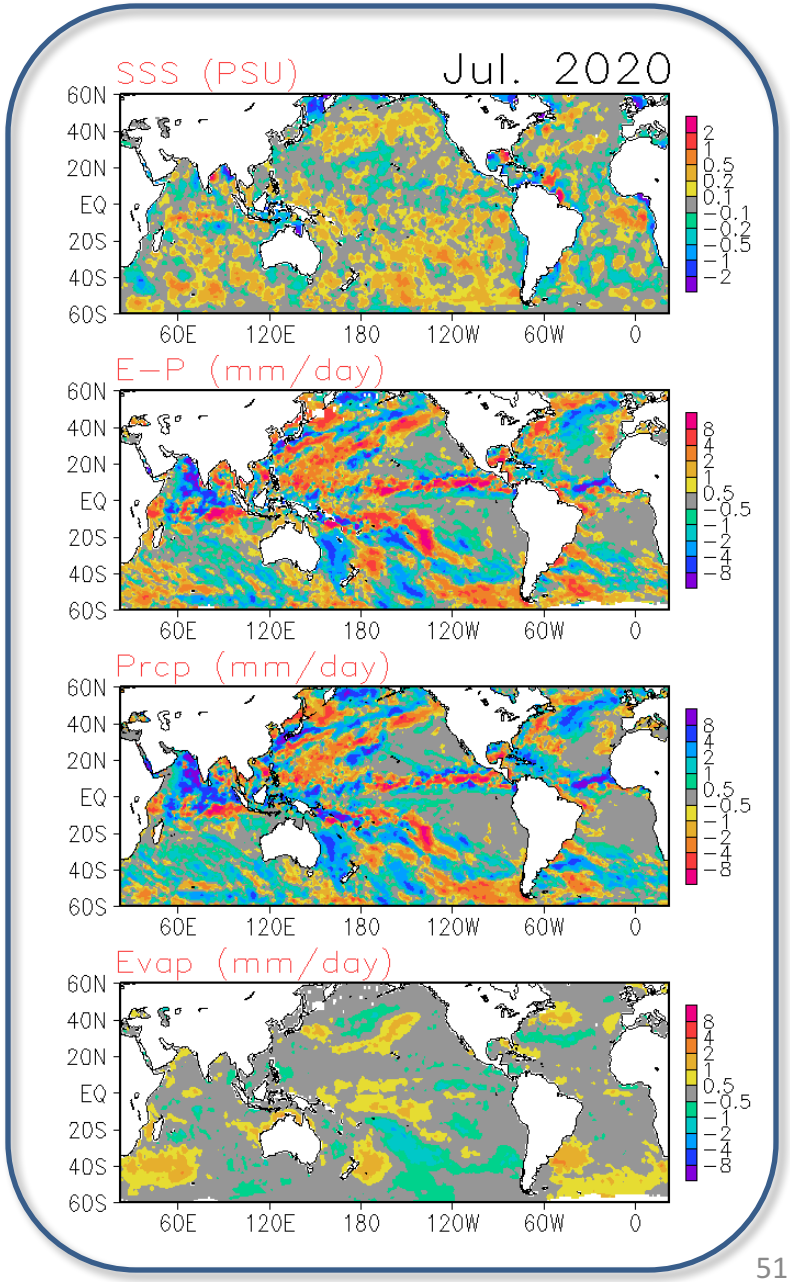


- **Data used**

SSS : Blended Analysis of Surface Salinity (BASS) V0.Z
(a CPC-NESDIS/NODC-NESDIS/STAR joint effort)
(Xie et al. 2014)
ftp.cpc.ncep.noaa.gov/precip/BASS
Precipitation: CMORPH adjusted satellite precipitation estimates
Evaporation: Adjusted CFS Reanalysis

Global Sea Surface Salinity (SSS) Tendency for July 2020

Compared with last month, the SSS continued increasing/decreasing in the west/east equatorial Pacific Ocean. In the central Indo-Pacific region, the SSS continued decreasing with increased precipitation. The SSS also continued increasing in the northeast Pacific ocean, which is likely caused by the oceanic advection/entrainments. The SSS decreased in the Equatorial Atlantic Ocean with increased precipitation.

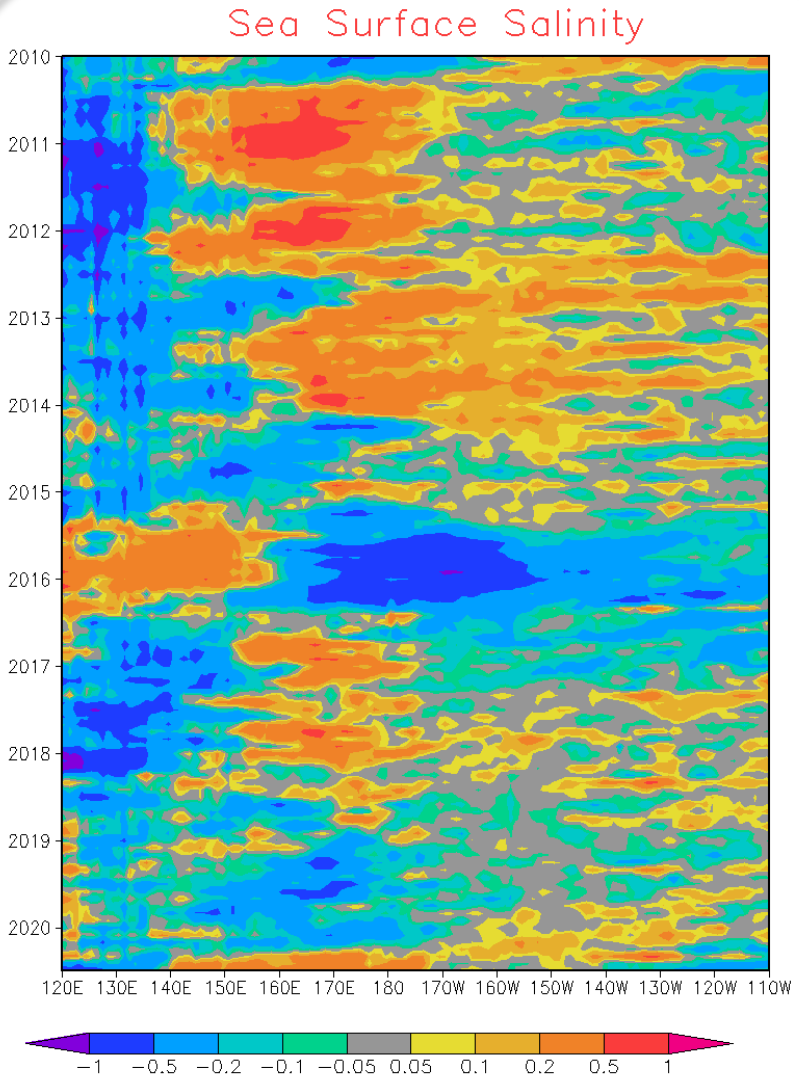


Global Sea Surface Salinity (SSS)

Anomaly Evolution over Equatorial Pacific from Monthly SSS

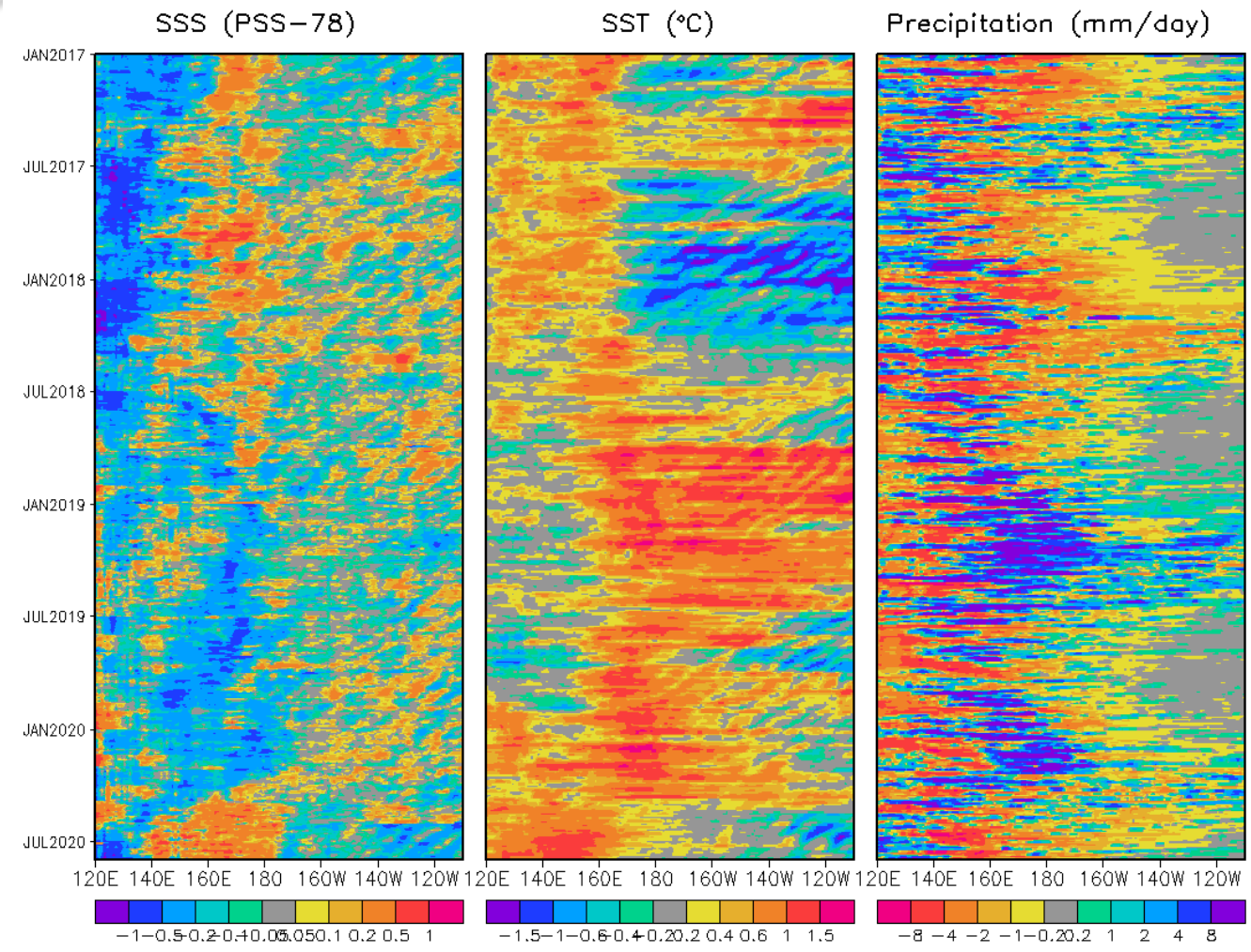
NOTE: Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015,The BASS SSS is from in situ, SMOS and Aquarius.

- Hovemoller diagram for equatorial SSS anomaly **(5˚S-5˚N);**
- In the equatorial Pacific Ocean, the SSS signal is negative west of 140°E; positive SSS signals continues from 140°E to 170°W; while negative and/or neutral SSS signals appear east of 170°W and such signal became stronger eastward.



Global Sea Surface Salinity (SSS)

Anomaly Evolution along the Equatorial Pacific from Pentad SSS



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.