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

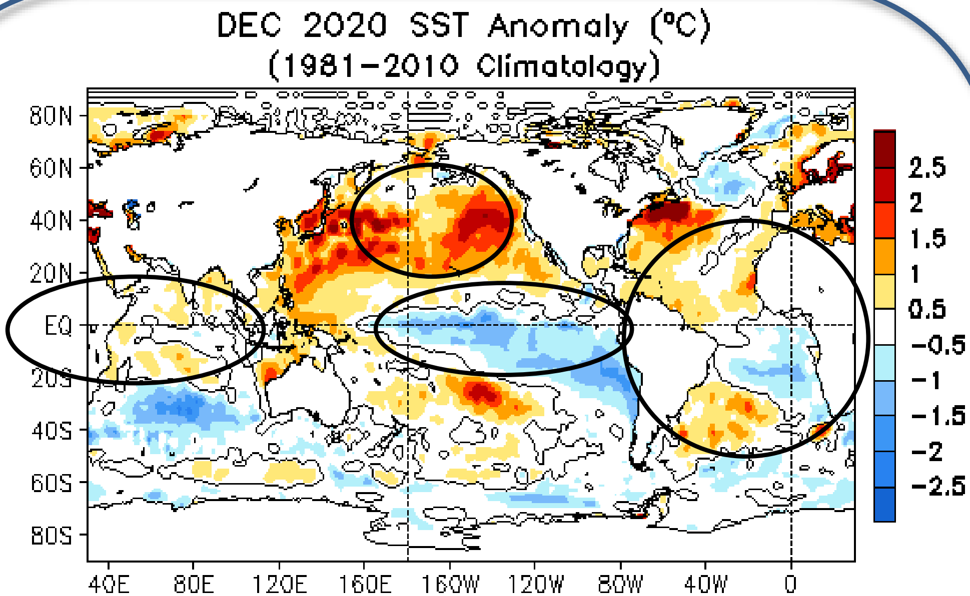
- Overview
- Recent highlights
  - Pacific/Arctic Ocean
  - Indian Ocean
  - Atlantic Ocean
- Global SSTA Predictions
- Special Topic
  - Multi-year La Nina

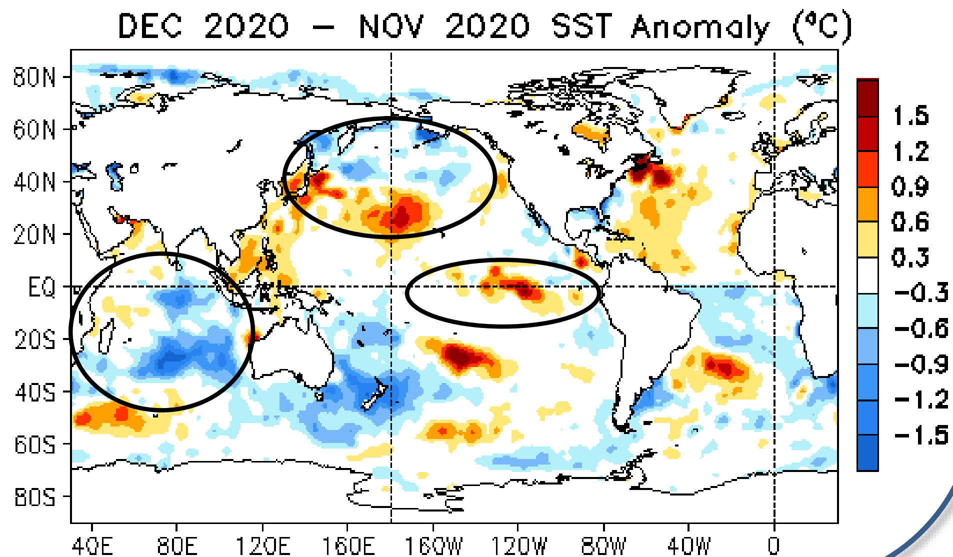
Overview

- Pacific Ocean
  - NOAA "ENSO Diagnostic Discussion" on 10 Dec 2020 stated *"La Niña is likely to continue through the Northern Hemisphere winter 2020-21 (~95% chance during January-March), with a potential transition during the spring 2021 (~50% chance of neutral during April-June)."*
  - La Nina condition persisted with Nino3.4 = -1.0^{o}C in Dec 2020.
  - Positive SSTAs continued in the NE Pacific in Dec 2020.
  - The PDO was in a negative phase since Jan 2020 with PDOI = -1.1 in Dec 2020.
- Indian Ocean
  - SSTA in the tropical Indian Ocean was small in Dec 2020.
- Atlantic Ocean
  - NAO switched to a negative phase in Dec 2020 with NAOI= -0.4.
  - The prolonged tripole pattern with positive SSTAs in the middle latitudes was evident during the last 5-6 years.
- Arctic Ocean
  - The sea ice extent in Dec 2020 ranked as the 3rd lowest since 1979, and its rate of increase after the minimum in Sep was greater than average.

Global Oceans

Global SST Anomaly (°C) and Anomaly Tendency



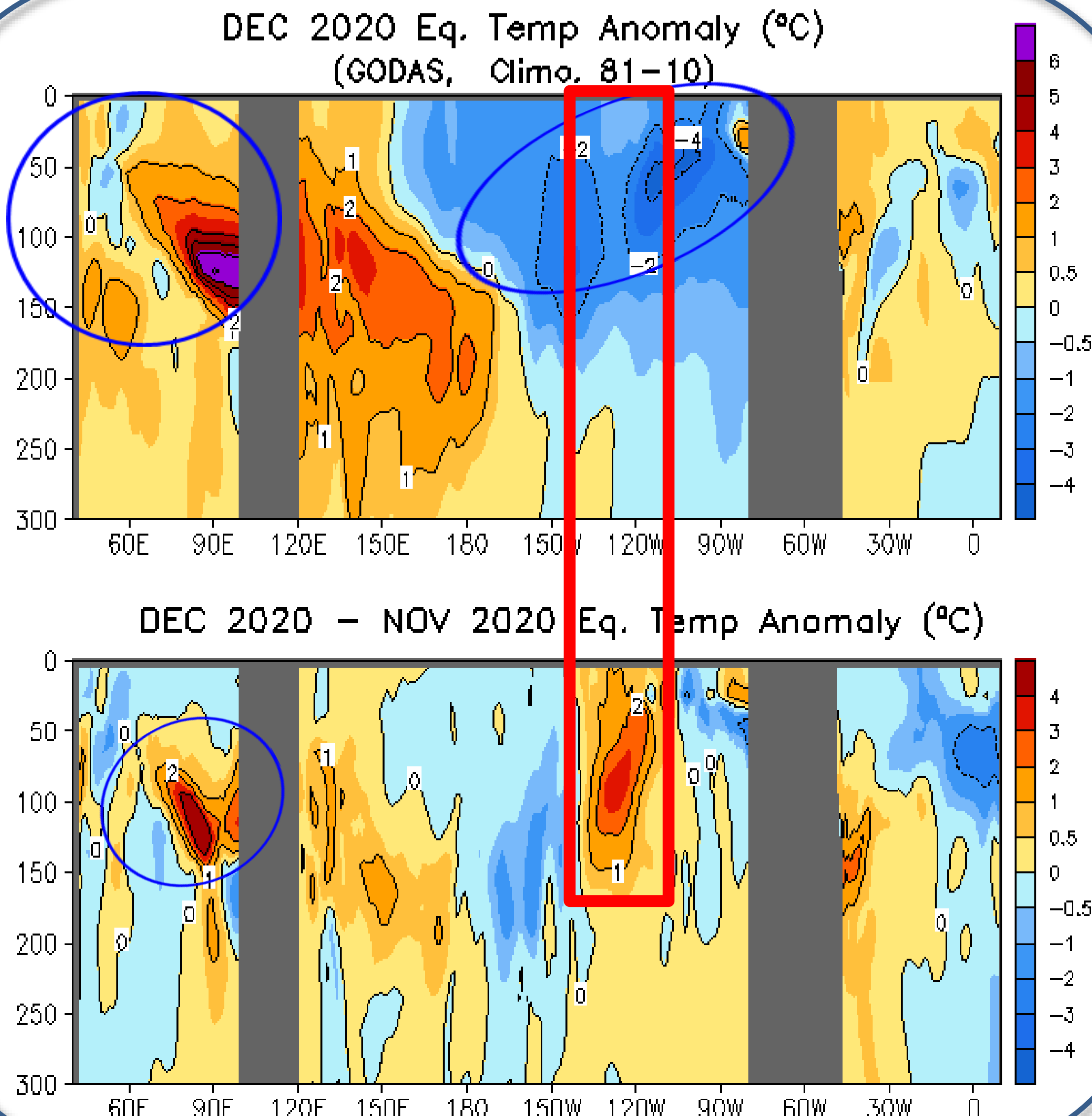


- Negative SSTAs persisted in the central and eastern equatorial Pacific.
- Positive SSTAs persisted in the northeastern Pacific.
- Weak positive (negative) SSTAs were present across the tropical North (South) Atlantic.
- SSTs were near average in the tropical Indian Ocean.

- Positive SSTA tendencies were observed in the east-central equatorial Pacific.
- Positive SSTA tendencies were evident in the central North Pacific.
- Negative (small positive) SSTA tendencies presented in the eastern (northwestern) Indian Ocean.

SSTAs (top) and SSTA tendency (bottom). Data are derived from the OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

Longitude-Depth Temperature Anomaly and Anomaly Tendency in 2ºS-2ºN

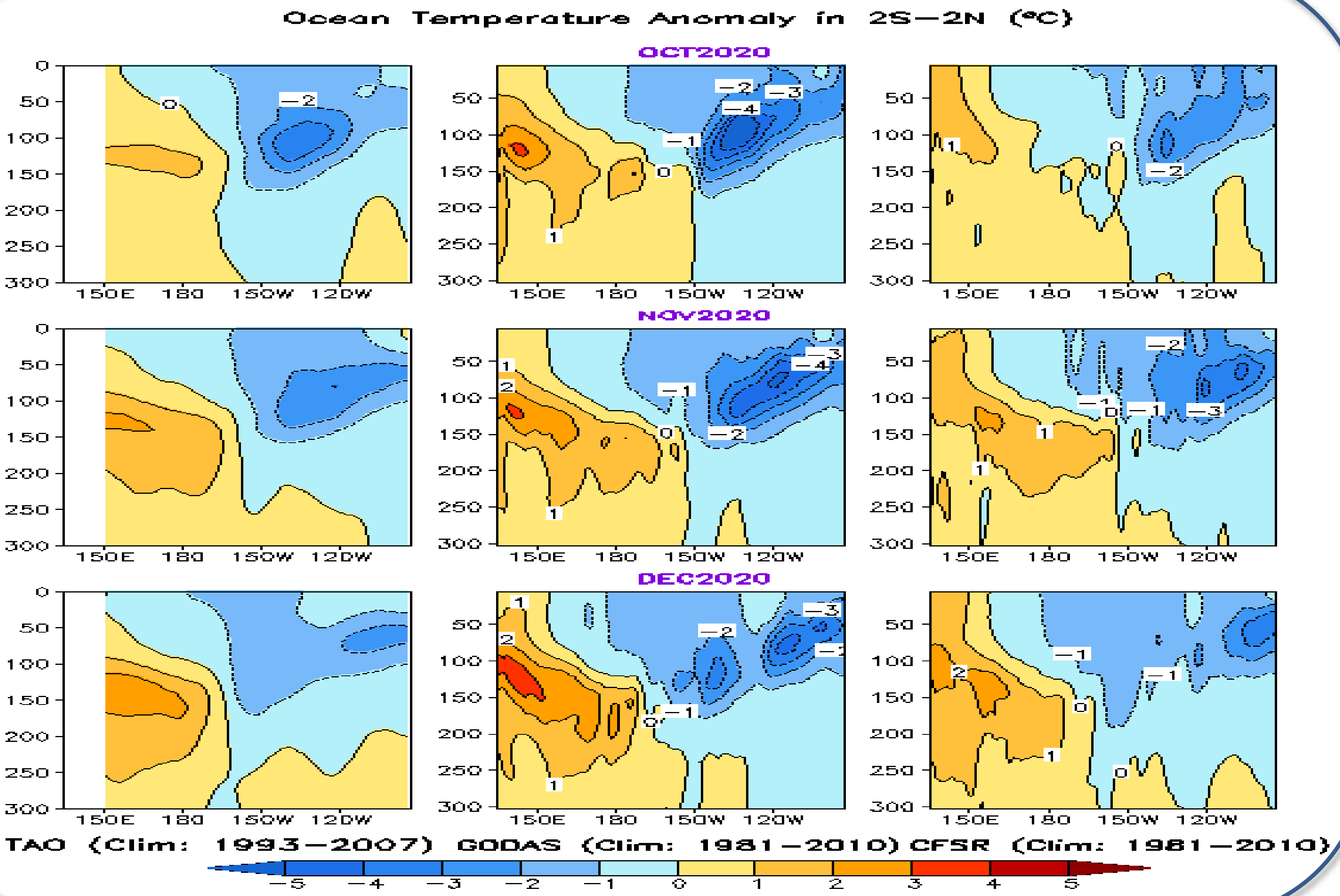


- Negative (positive) temperature anomalies presented along the thermocline in the central and eastern (western) equatorial Pacific.
- Strong positive temperature anomalies were observed in the eastern equatorial Indian Ocean.

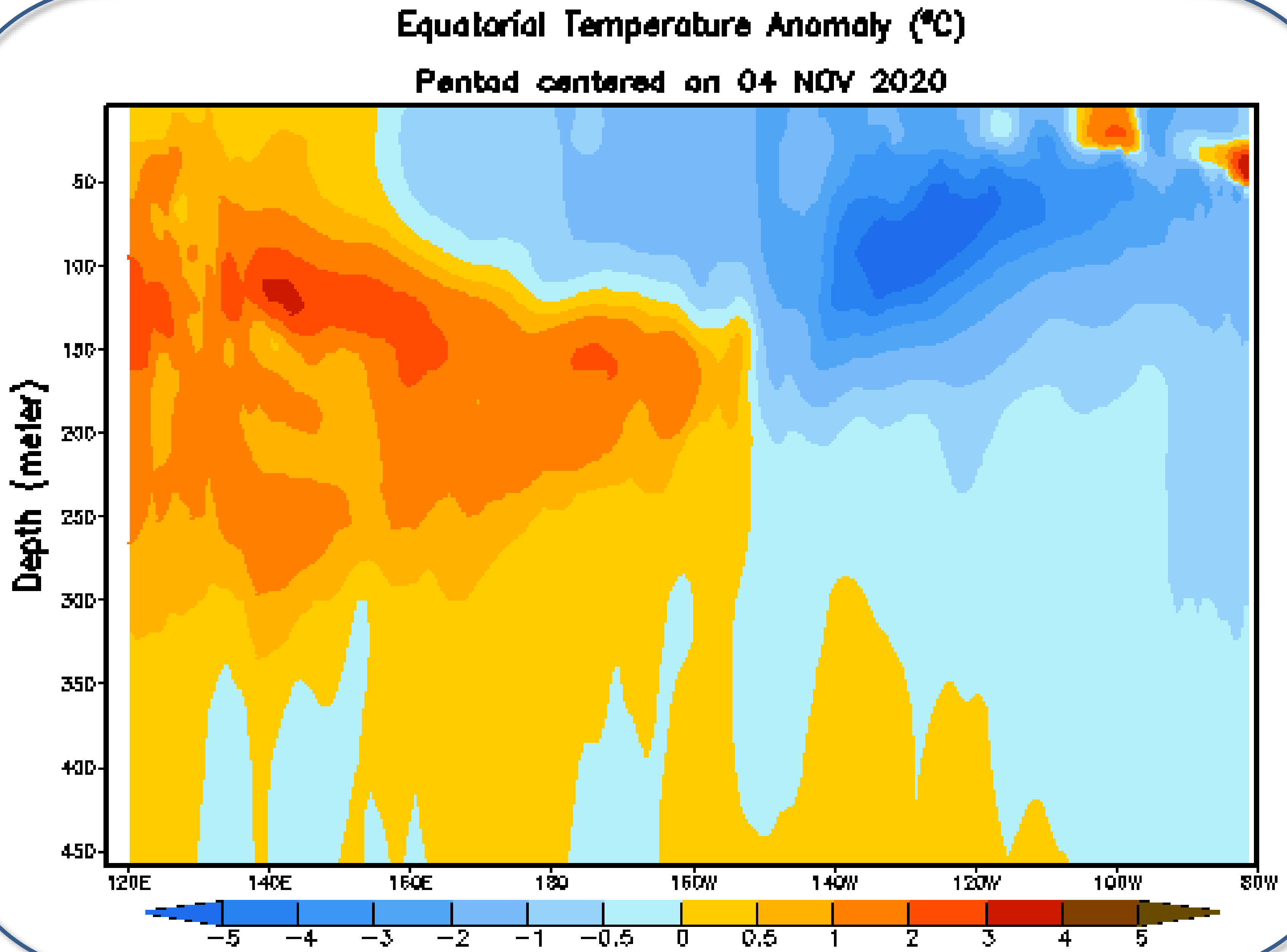
- Temperature anomaly tendency was positive along the thermocline in the east-central Pacific.
- Positive temperature anomaly tendency was evident in the eastern Indian Ocean.

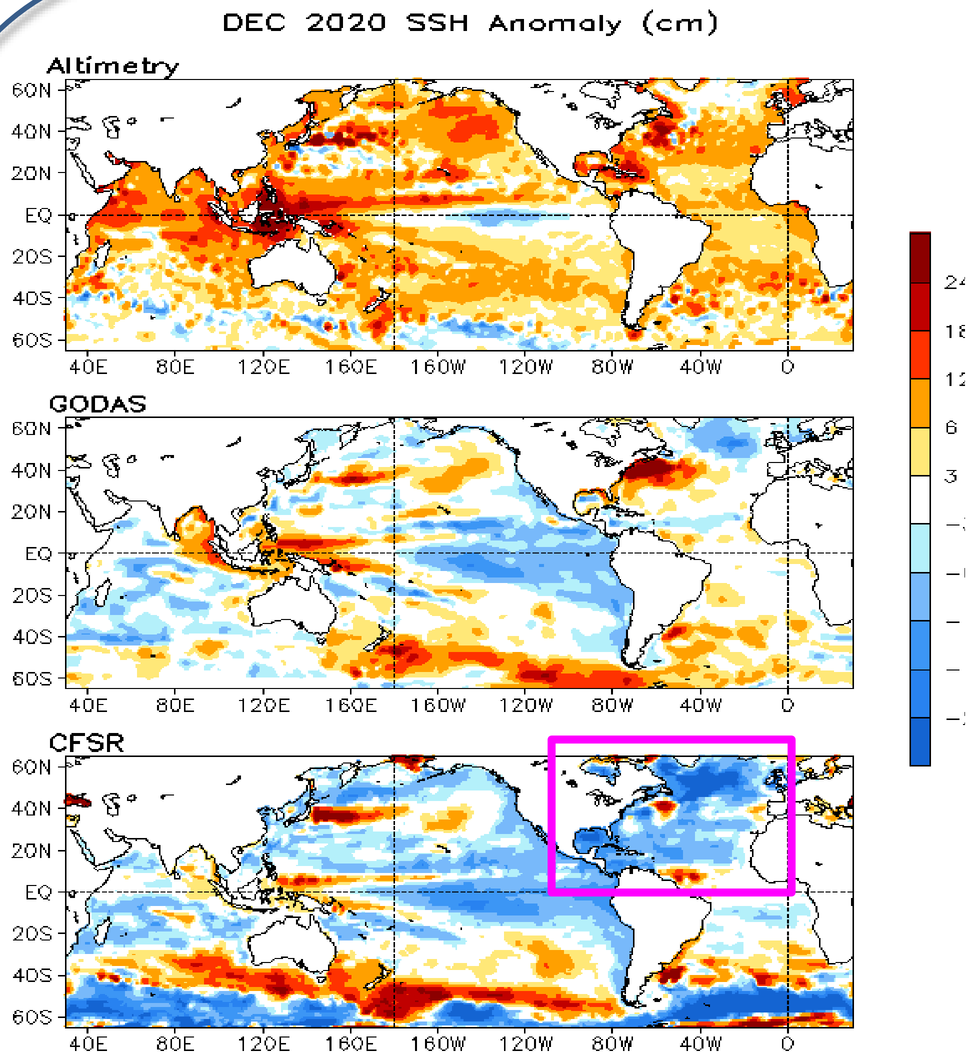
Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data is from the NCEP's GODAS. Anomalies are departures from the 1981-2010 base period means.

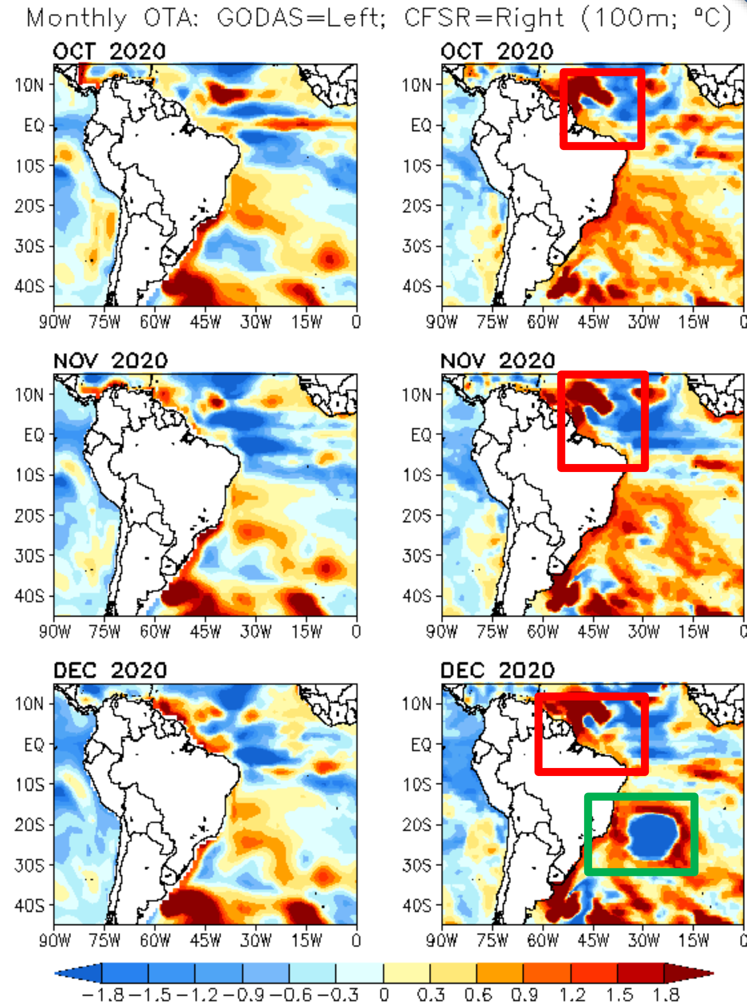
TAO, GODAS, & CFSR monthly mean subsurface temperature anomaly along the Equator during the last 3 months: Consisting and weakening



Evolution of Longitude-Depth Pentad Temperature Anomaly along the Equator



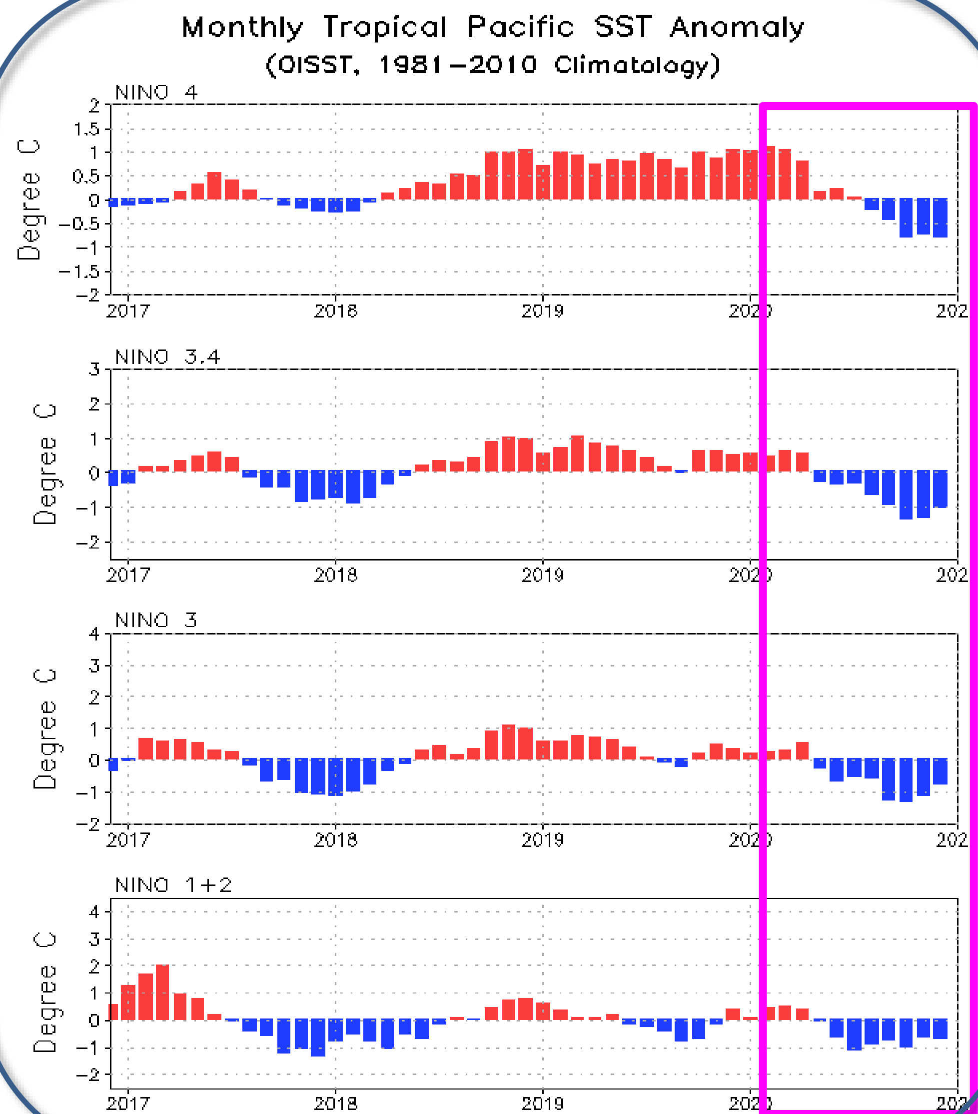


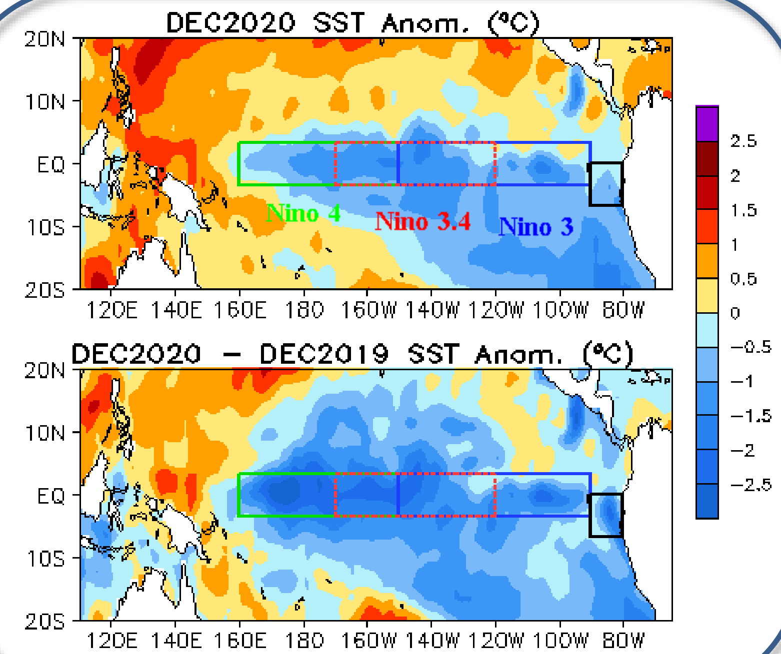


- Unrealistic cooling of CFSR presented in the North & South Atlantic.
- NCEP/EMC is proposing to reset CFSV2 ocean reanalysis on 12 Jan 2021.

Tropical Pacific Ocean and ENSO Conditions

Evolution of Pacific NINO SST Indices





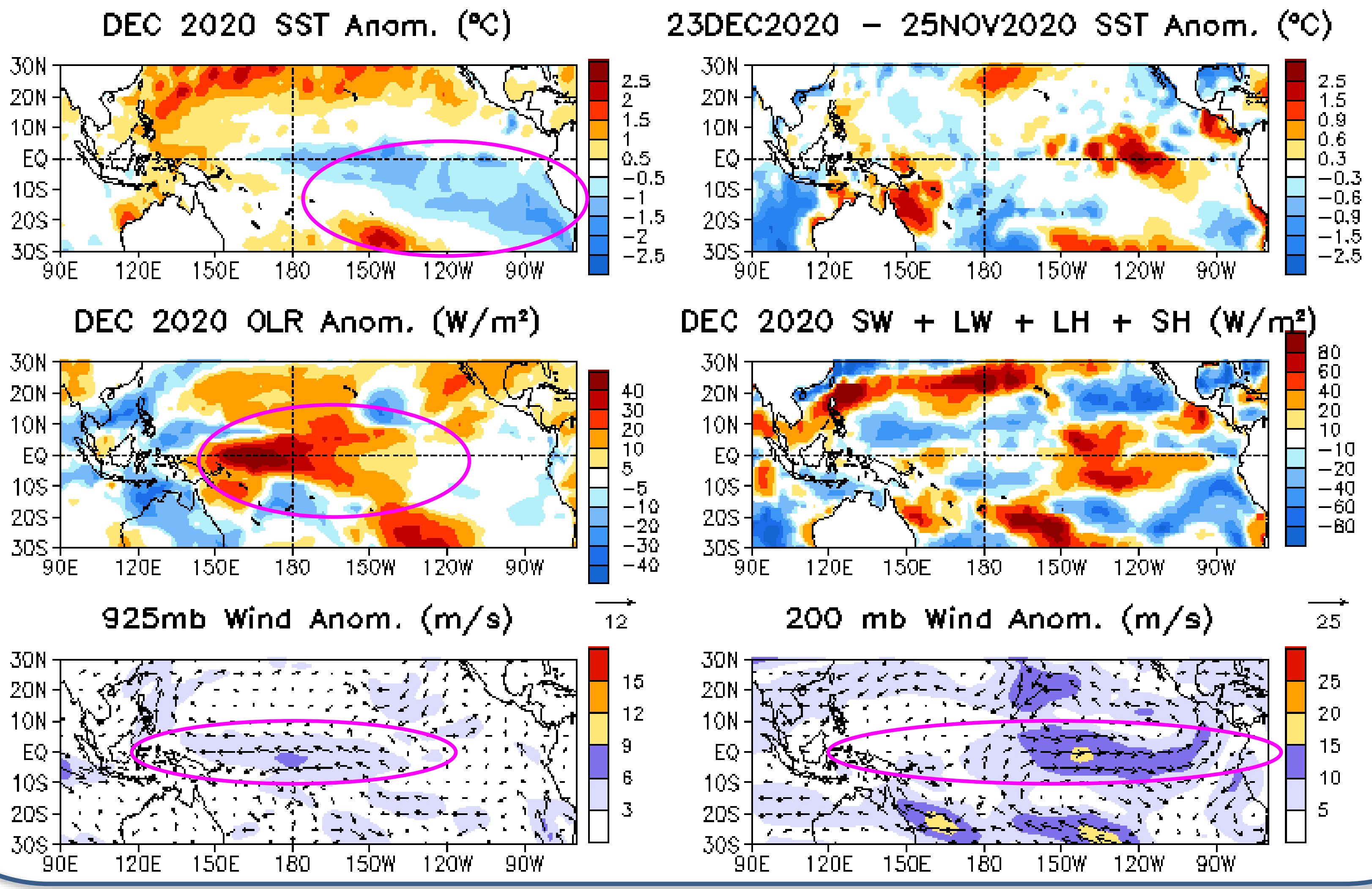
- The Nino3.4 and Nino3 indices weakened slightly in Dec 2020, with Nino3.4 = -1.0C.

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

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

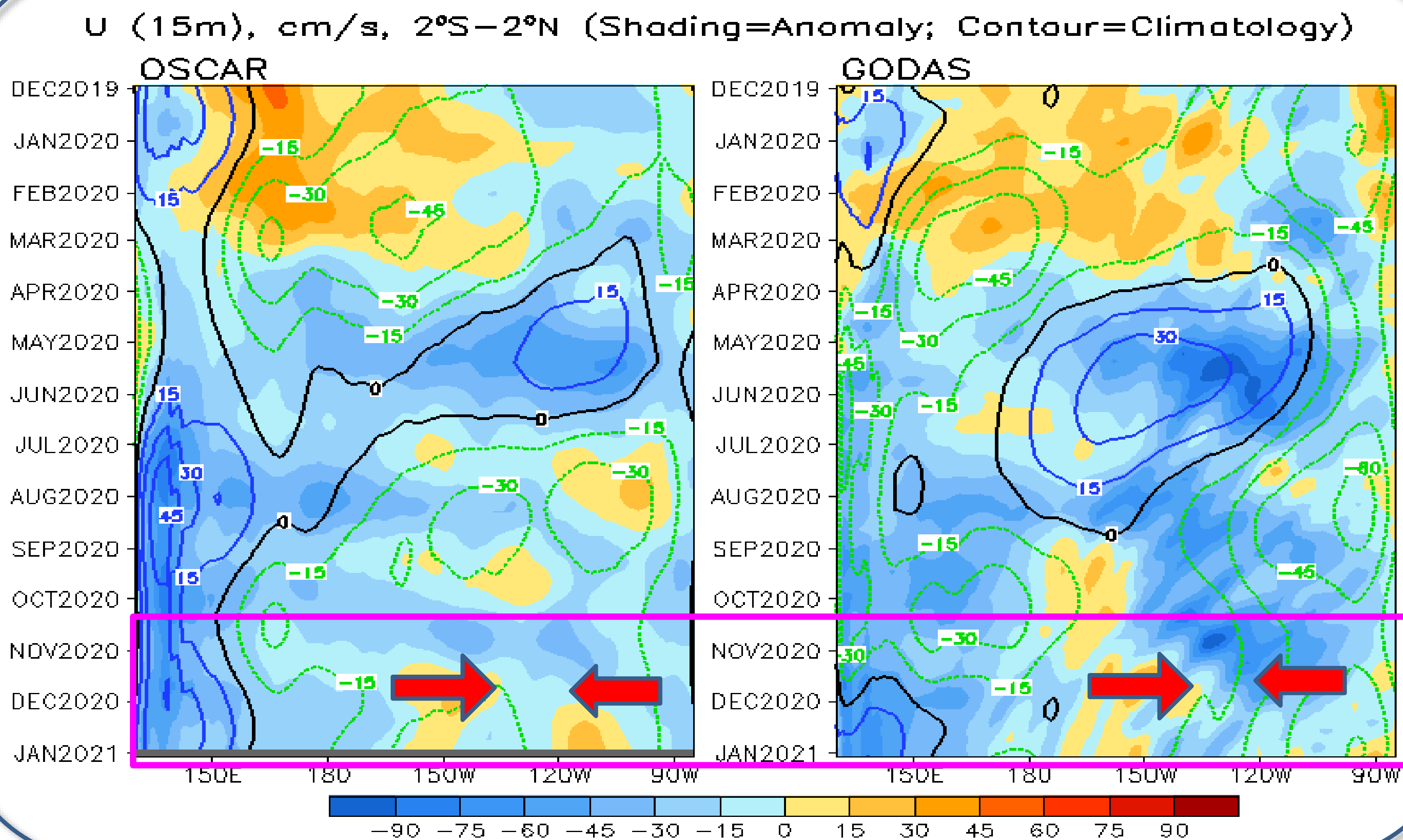
Nino region indices, calculated as the area-averaged monthly mean SSTAs (°C) for the specified region. Data are derived from the OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

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



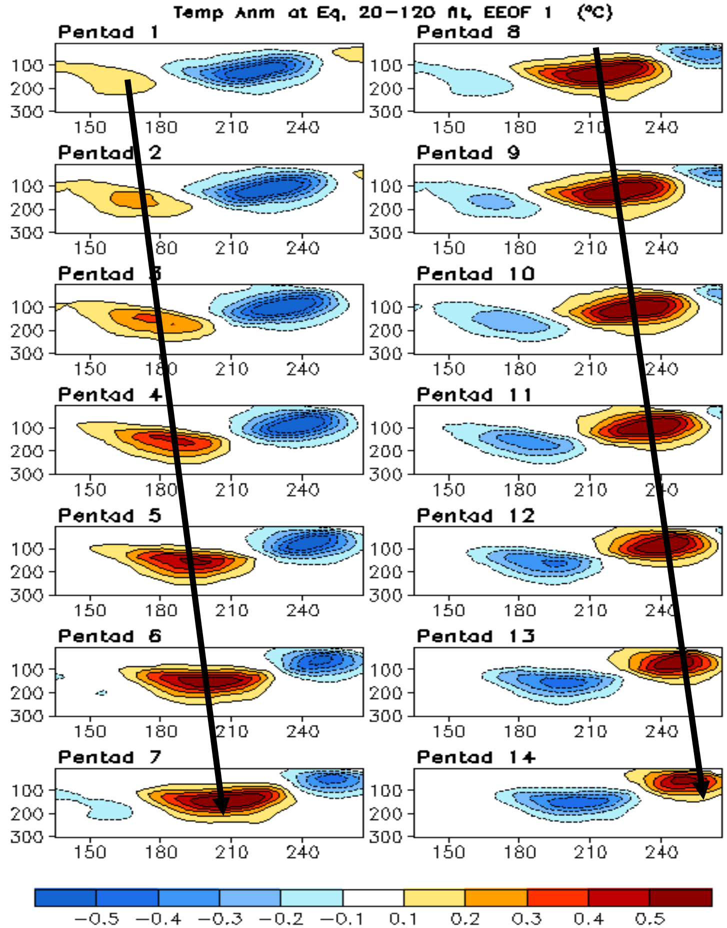
SSTAs (top-left), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1981-2010 base period means.

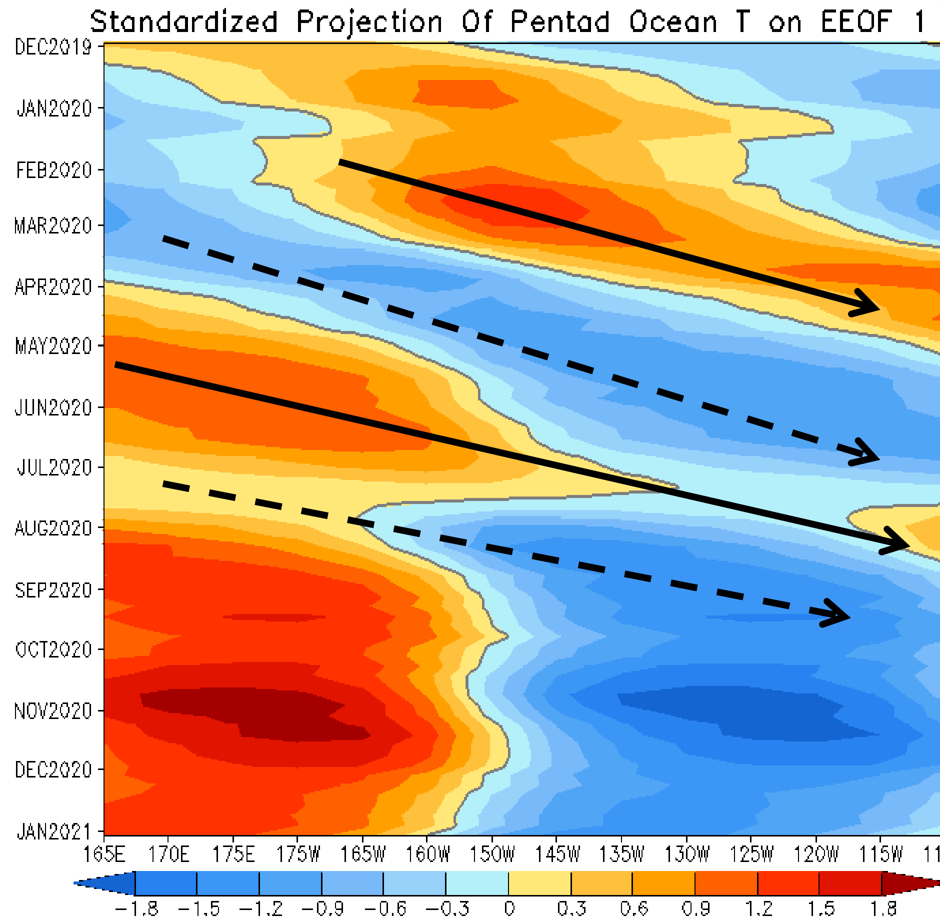
Evolution of Equatorial Pacific Surface Zonal Current Anomaly (cm/s)



- Anomalous westward currents and pockets of eastward currents were observed in the equatorial Pacific in both OSCAR and GODAS in Dec 2020.

Oceanic Kelvin Wave (OKW) Index



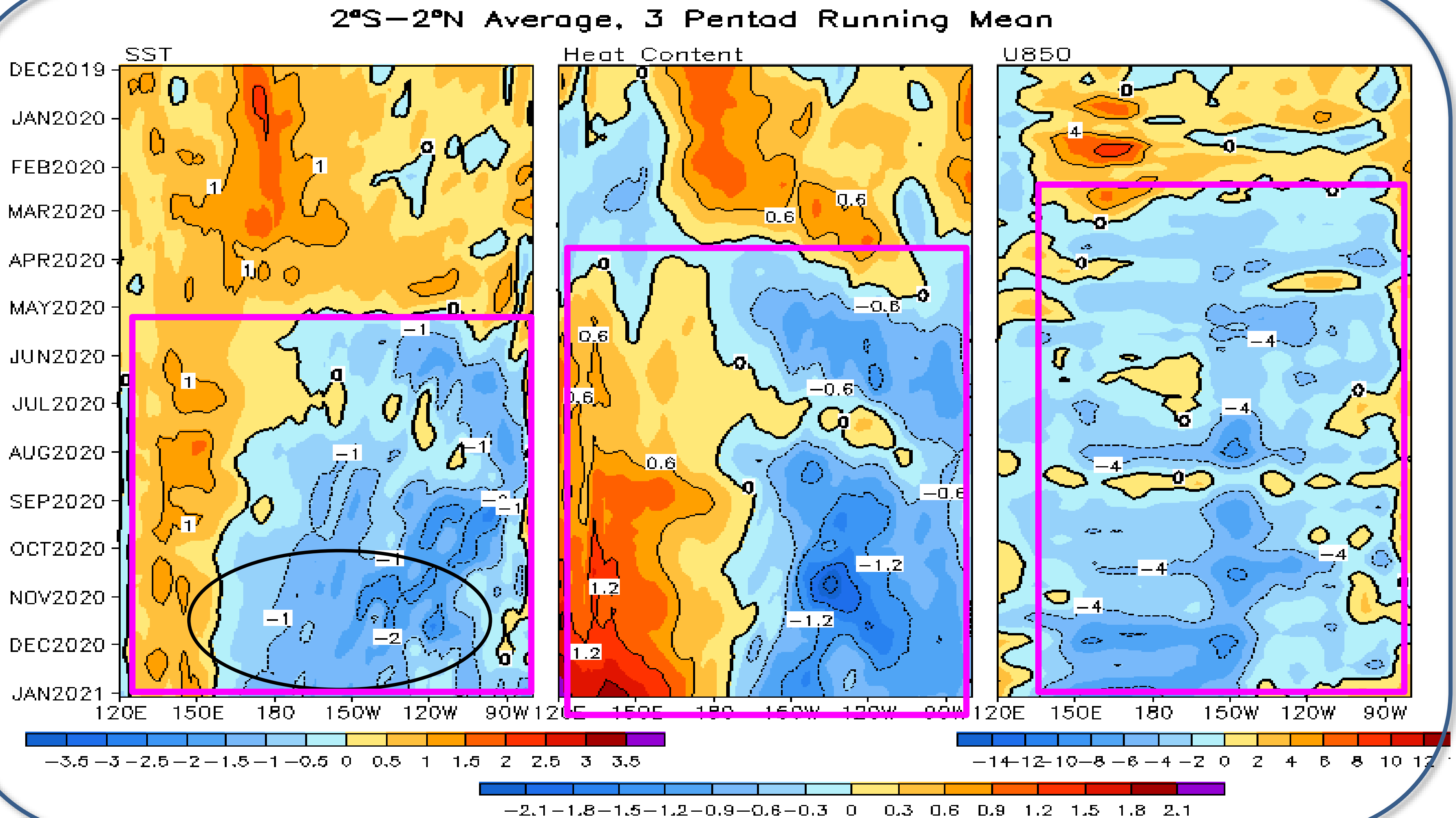


- **Upwelling Kelvin waves were initiated in Feb & Jul 2020, leading to the subsurface cooling in the eastern equatorial Pacific.**

- **Since Aug 2020, stationary component has dominated.**

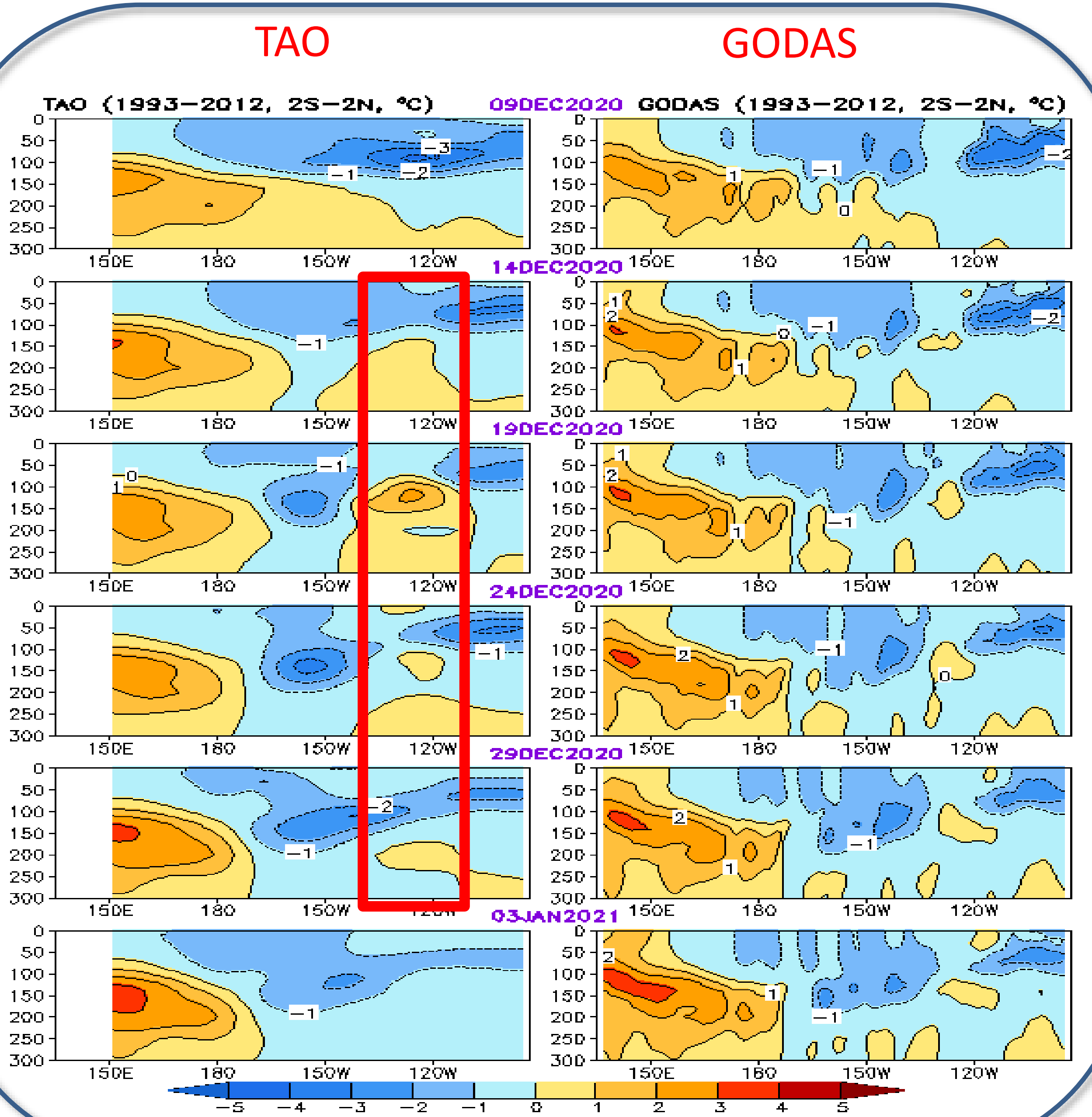
(OKW index is defined as standardized projections of total anomalies onto the 14 patterns of Extended EOF1 of equatorial temperature anomalies (Seo and Xue , GRL, 2005).)

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



- Easterly wind anomaly was present across the equatorial Pacific since Mar 2020.
- Below- (above-) average HC300 was observed in the eastern (western) Pacific since Apr 2020.
- Negative SSTA persisted in the central and eastern equatorial Pacific in Dec 2020.

Equatorial Pacific Ocean Temperature Pentad Mean Anomaly

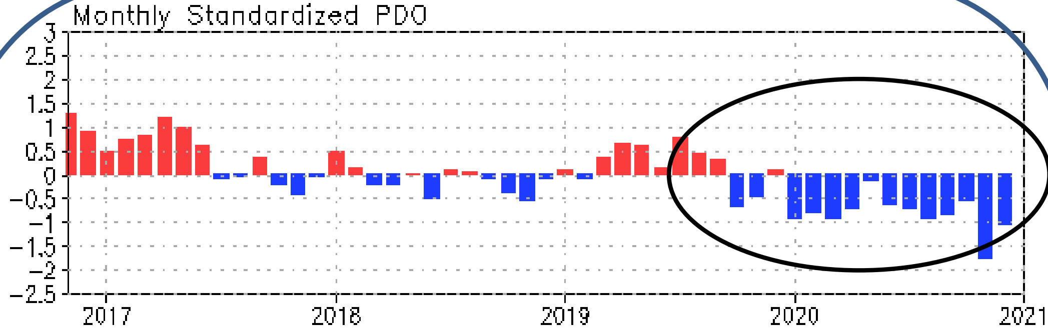


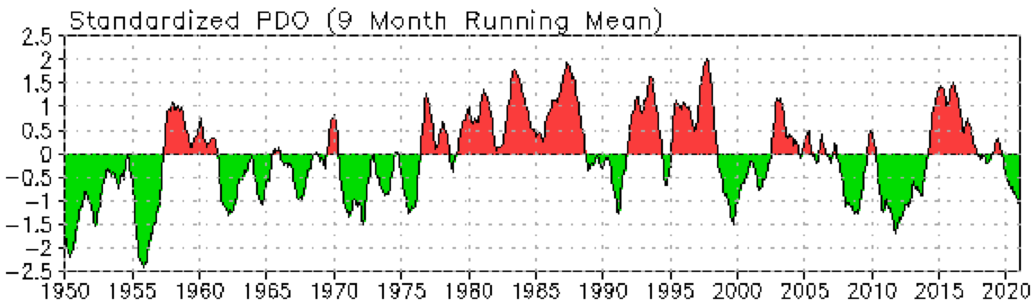
- Negative (positive) ocean temperature anomalies along the thermocline in the eastern (far-west) weakened (strengthened) in the last month;

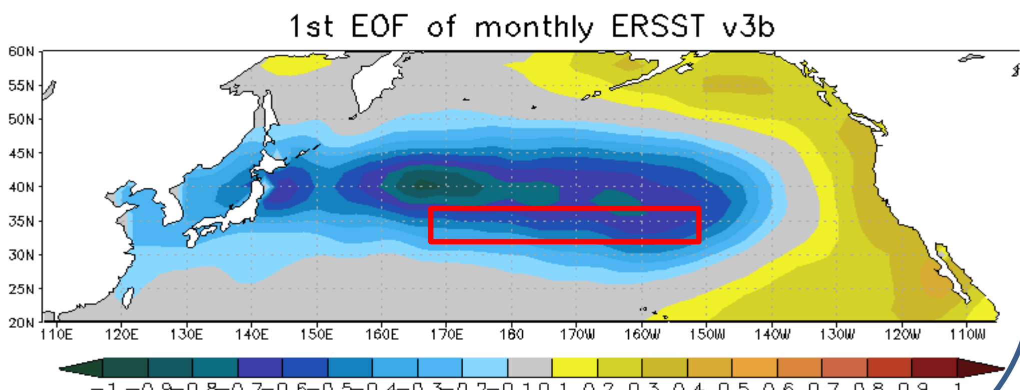
- The features of the ocean temperature anomalies were similar between GODAS and TAO analysis.

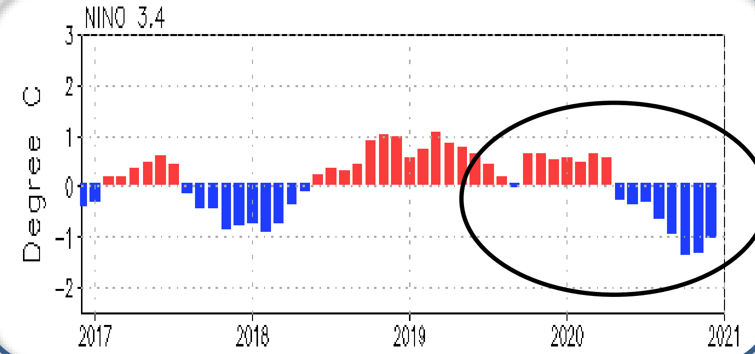
North Pacific & Arctic Oceans

Pacific Decadal Oscillation (PDO) Index







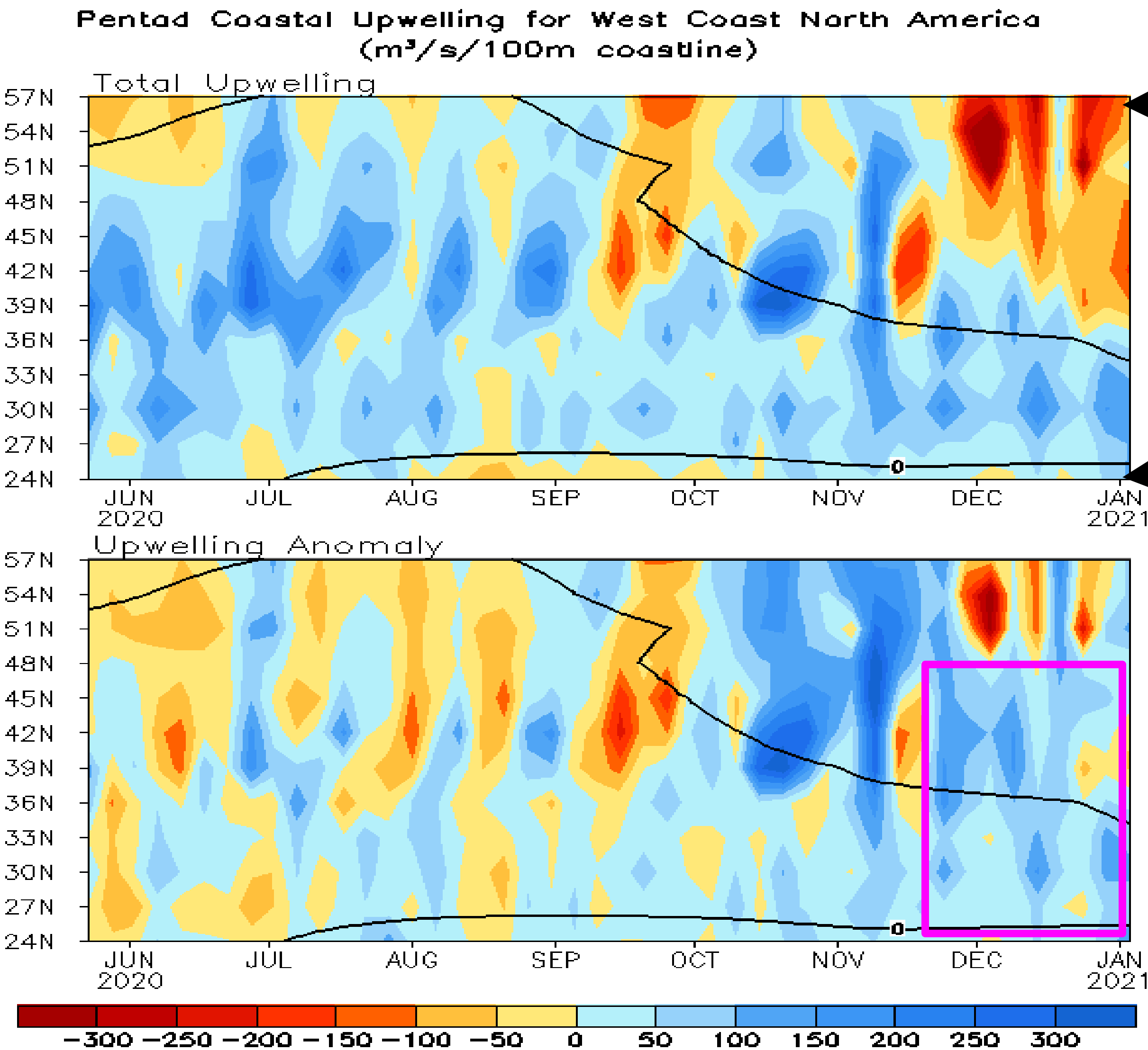


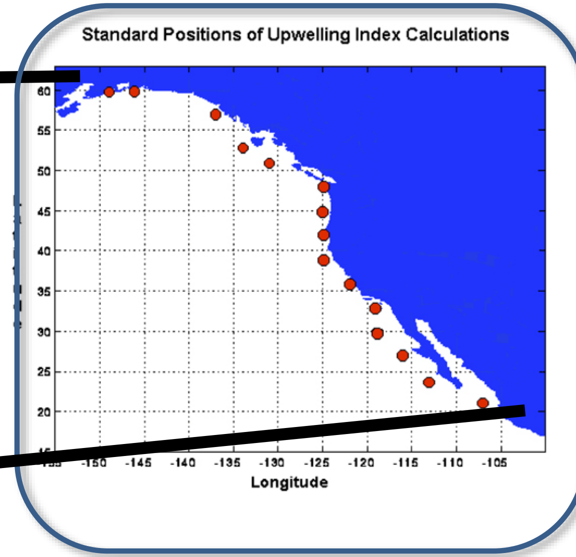
- The PDO was in a negative phase since Jan 2020 with PDOI = -1.1 in Dec 2020.

- 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

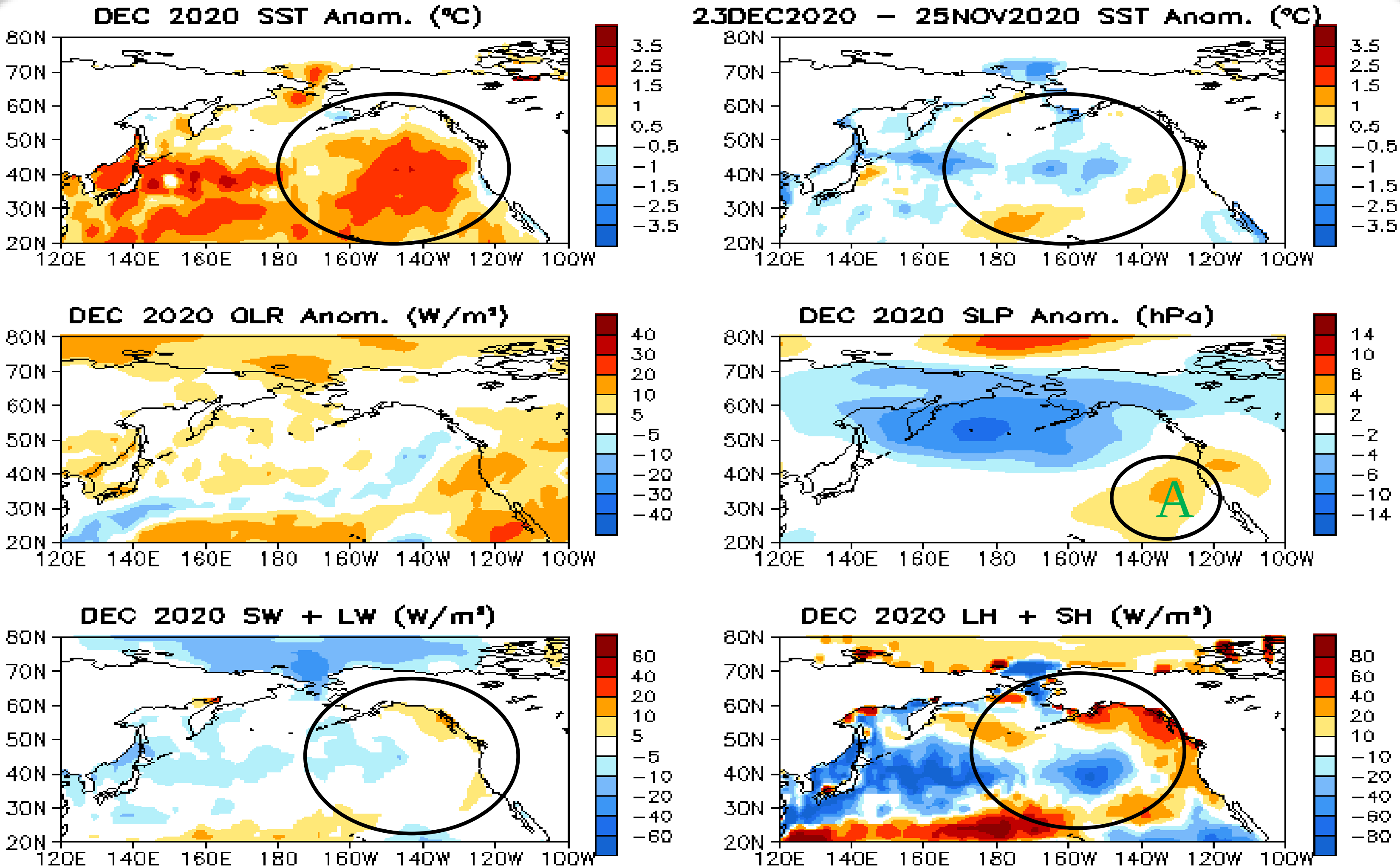




- Coastal anomalous upwelling was present south of 51ºN in Dec 2020.

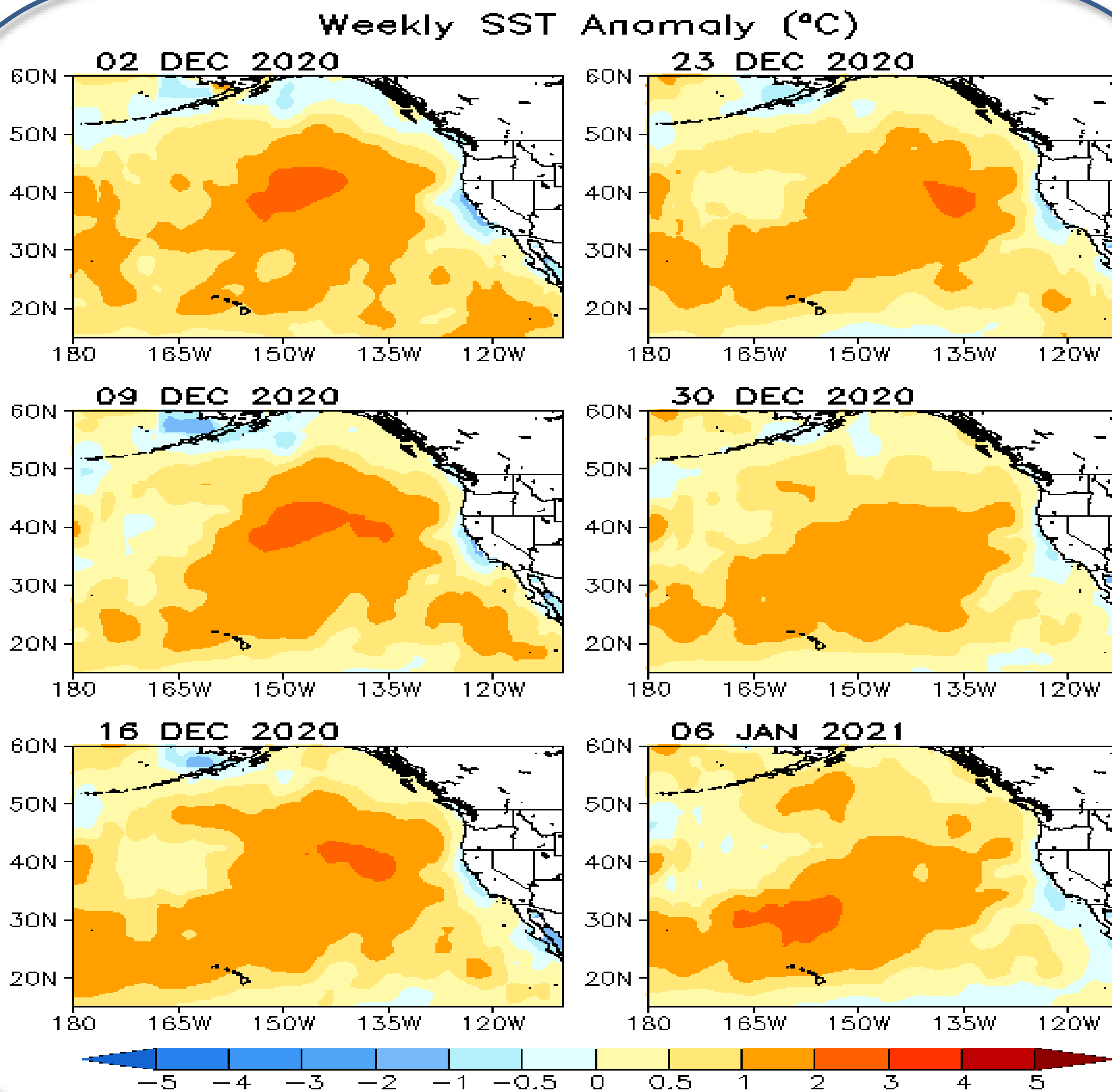
(top) Total and (bottom) anomalous upwelling indices at the 15 standard locations for the western coast of North America. Derived from the vertical velocity of the NCEP's GODAS and are calculated as integrated vertical volume transport at 50-meter depth from each location to its nearest coast point ($m^3/s/100m$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

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



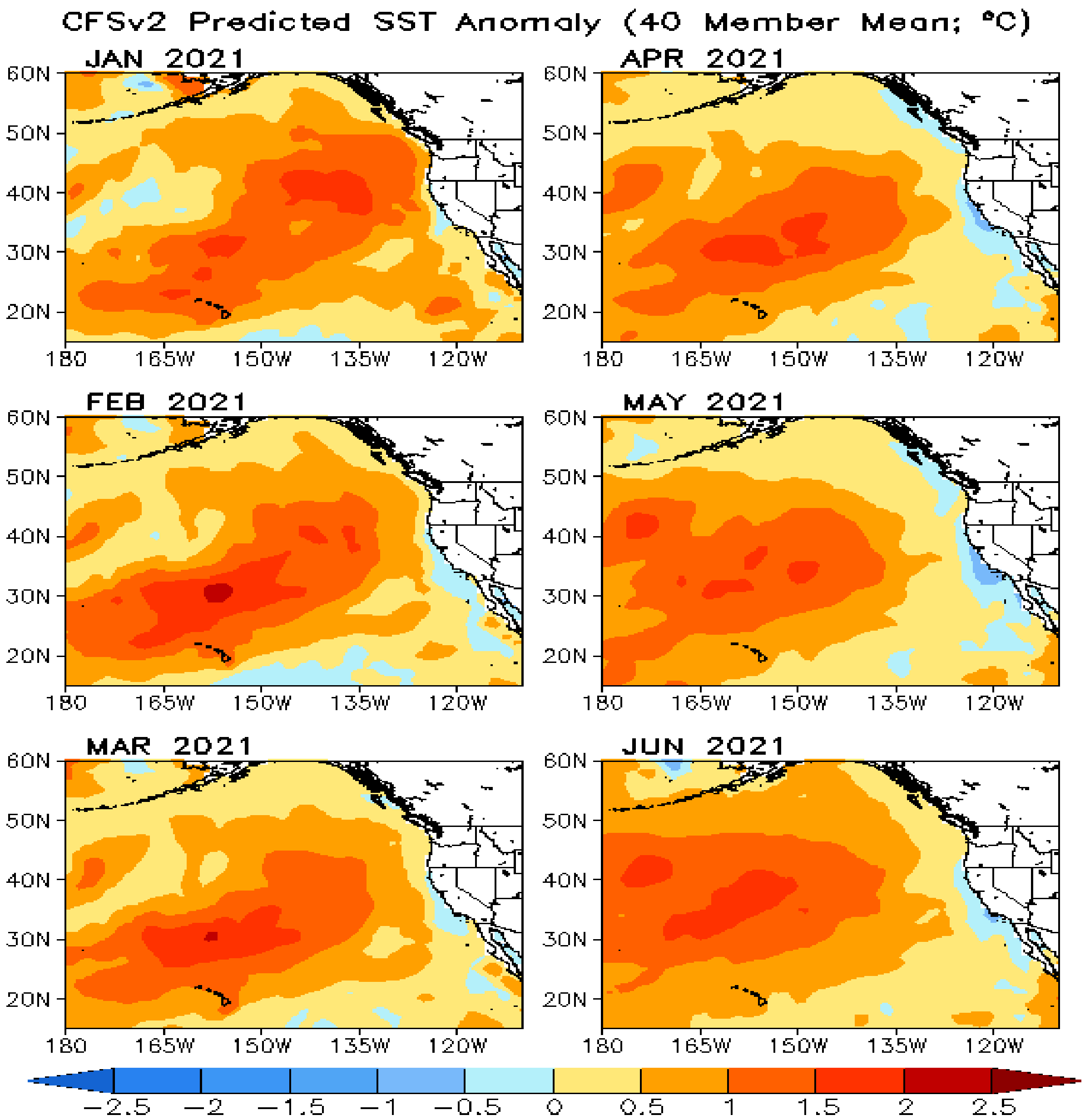
SSTA (top-left; OI SST Analysis), SSTA tendency (top-right), Outgoing Long-wave Radiation (OLR) (middle-left; NOAA 18 AVHRR IR), sea surface pressure (middle-right; NCEP CDAS), sum of net surface short- and long-wave radiation (bottom-left; positive means heat into the ocean; NCEP CDAS), sum of latent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

Weekly SSTA evolutions in the NE Pacific



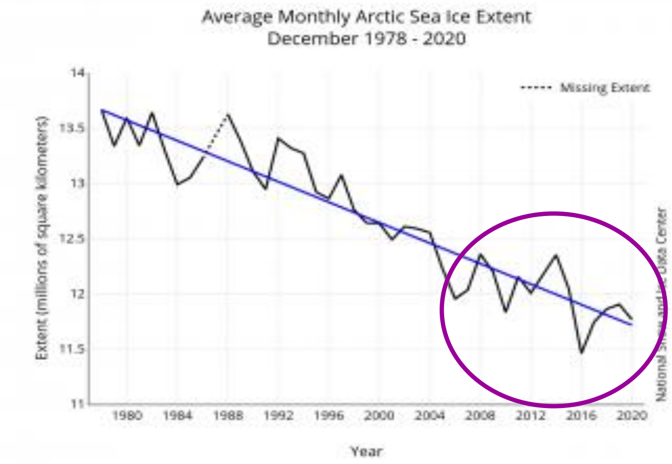
- The northern Pacific SST warming persisted during the last six weeks.

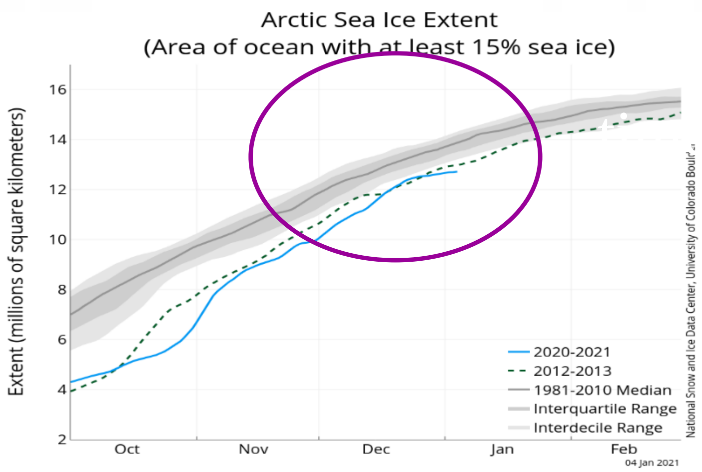
CFSv2 NE Pacific SSTA Predictions

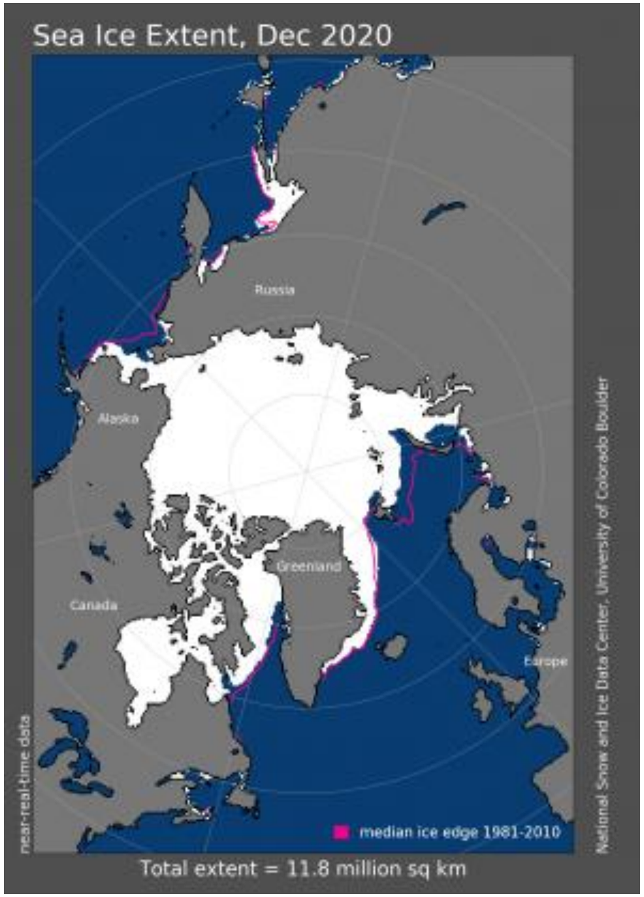


- The CFSv2 predicts the current SST warm state will continue.

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

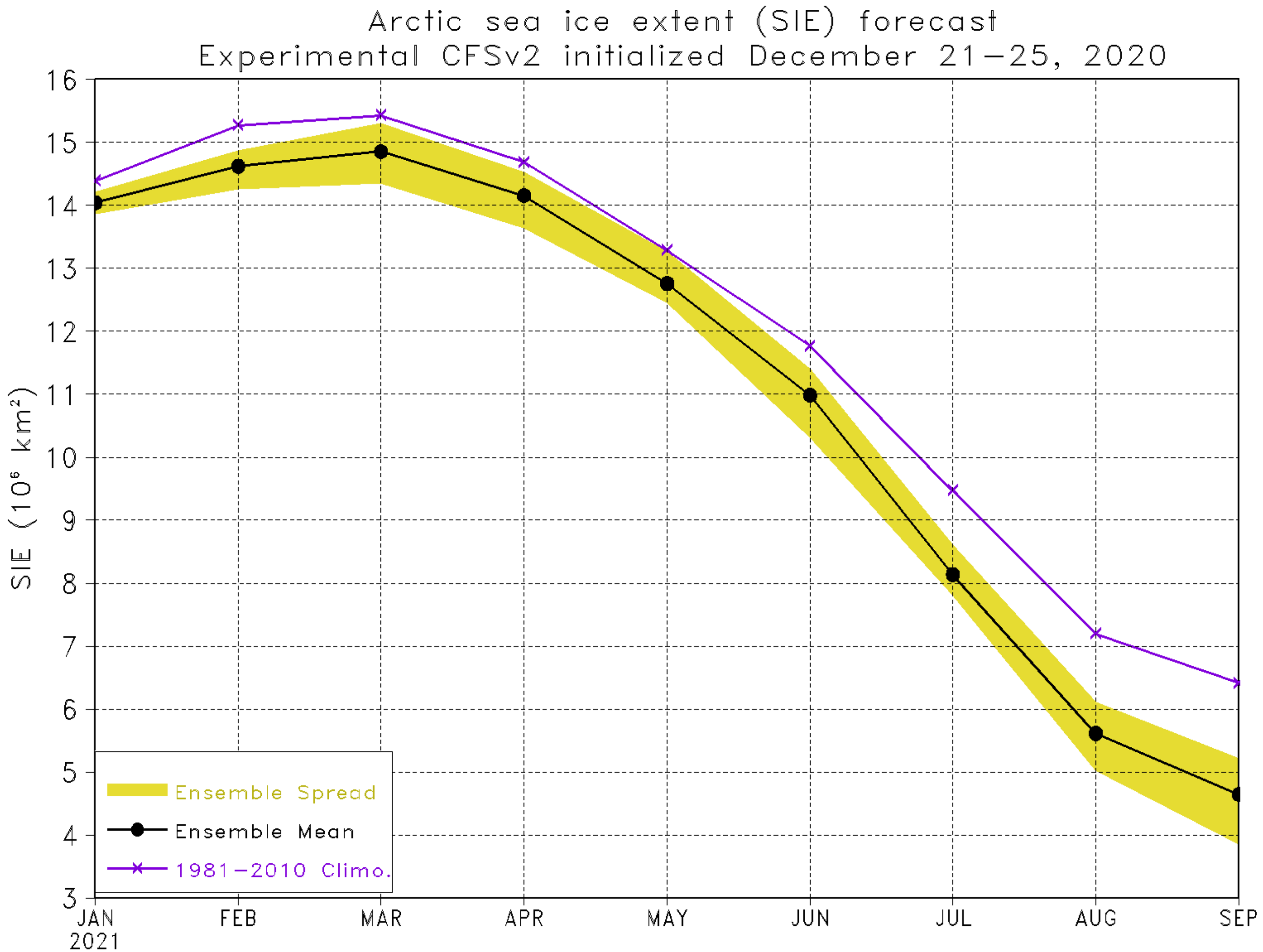






- Arctic sea ice extent averaged for Dec 2020 was the 3rd lowest in the satellite record.
- Sea ice extent increased by 2.71 million km^2 during Dec 2020, greater than the 1981-2010 average gain in Dec of 1.99 million km^2.
- Through 2020, the linear rate of decline for Dec sea ice extent is 3.6% per decade.

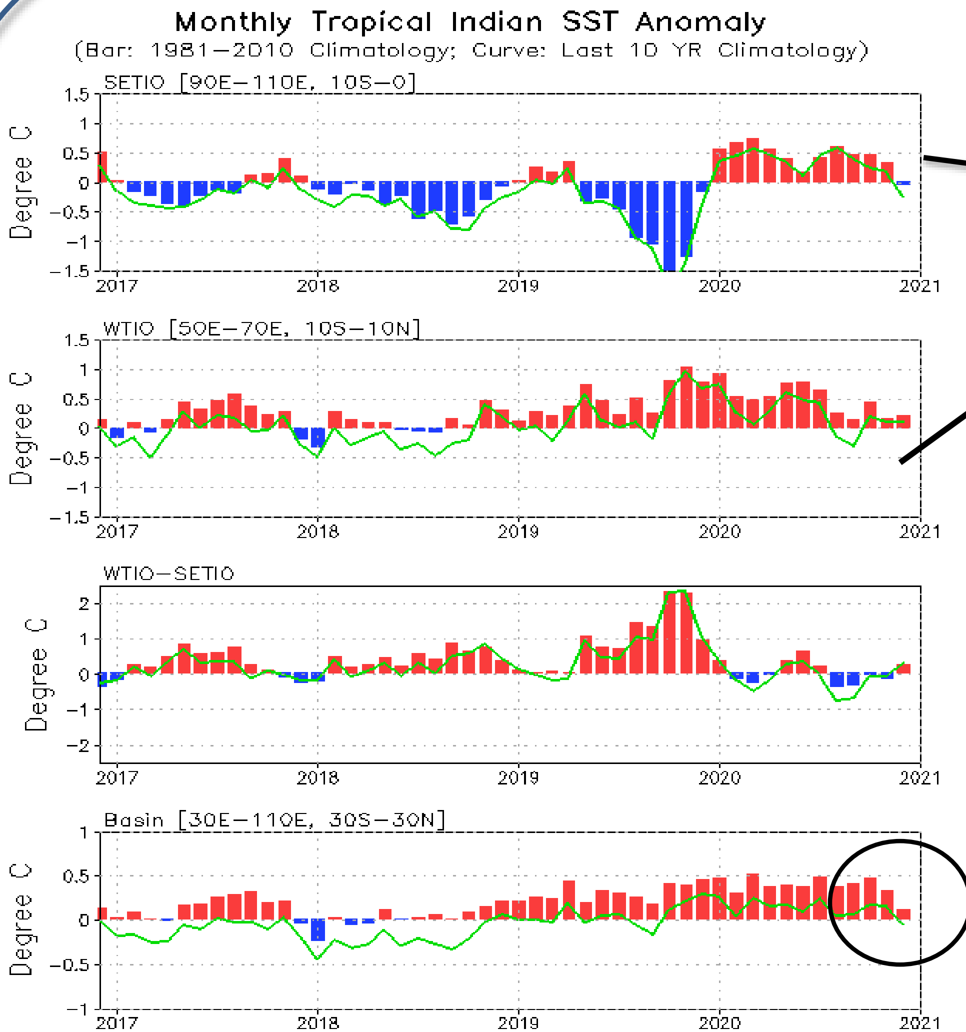
NCEP/CPC Arctic Sea Ice Extent Forecast

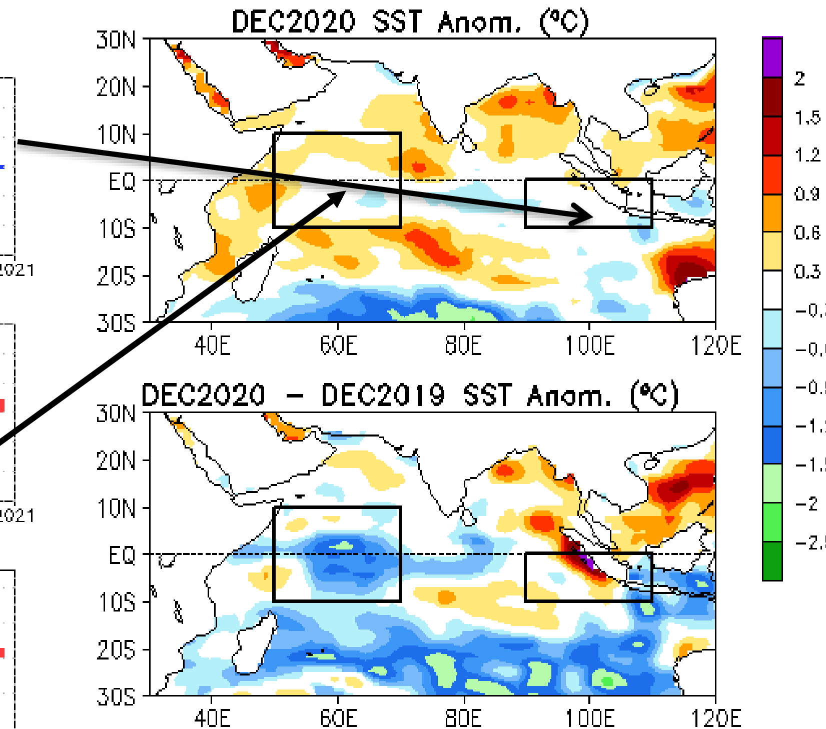


https://www.cpc.ncep.noaa.gov/products/people/wwang/seaice_seasonal/index.html

Indian Ocean

Evolution of Indian Ocean SST Indices

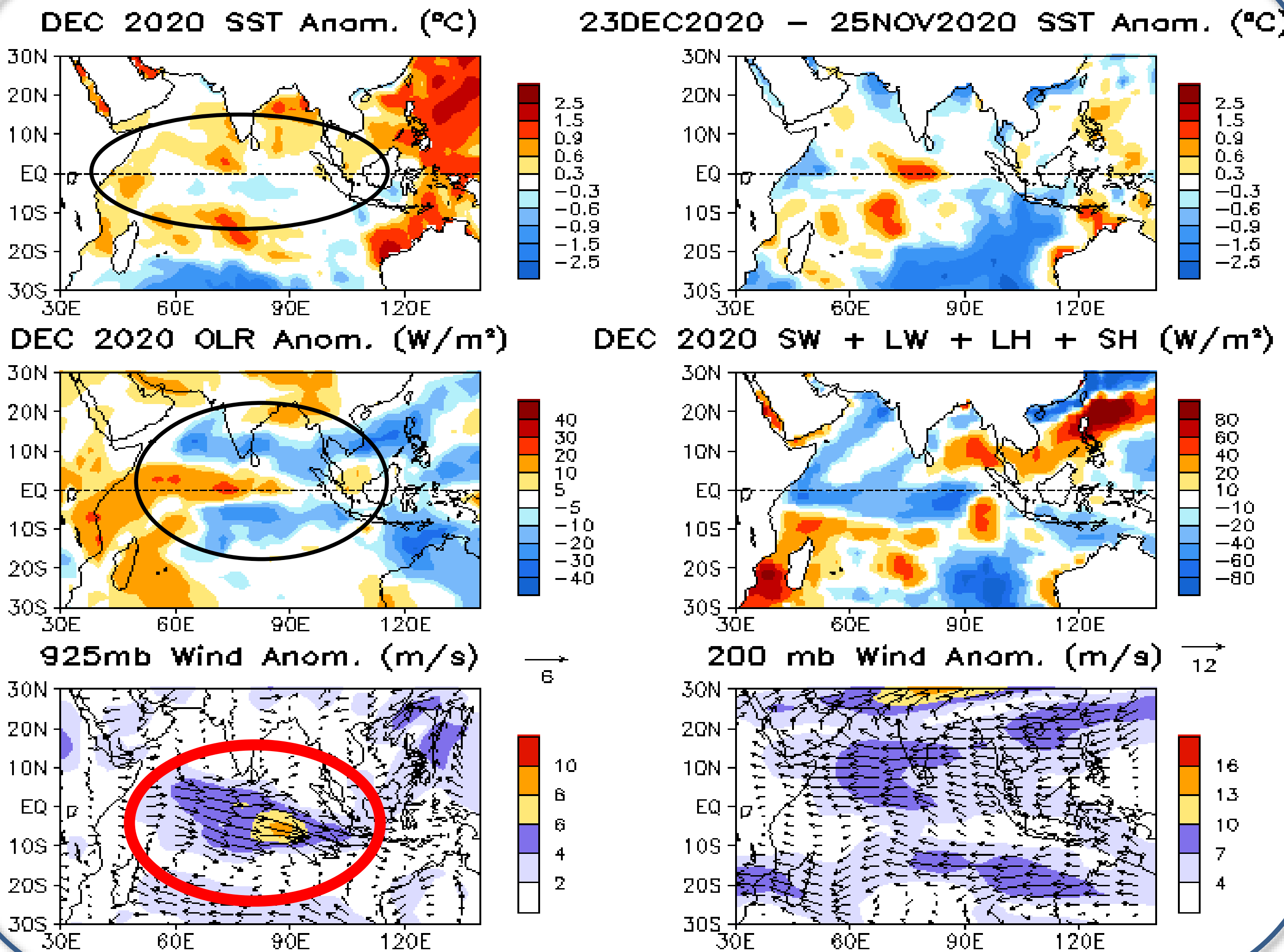




- Overall, SSTAs were small in the tropical Indian Ocean in Dec 2020.

Indian Ocean region indices, calculated as the area-averaged monthly mean SSTA (OC) for the SETIO [90ºE-110ºE, 10ºS-0] and WTIO [50ºE-70ºE, 10ºS-10ºN] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

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



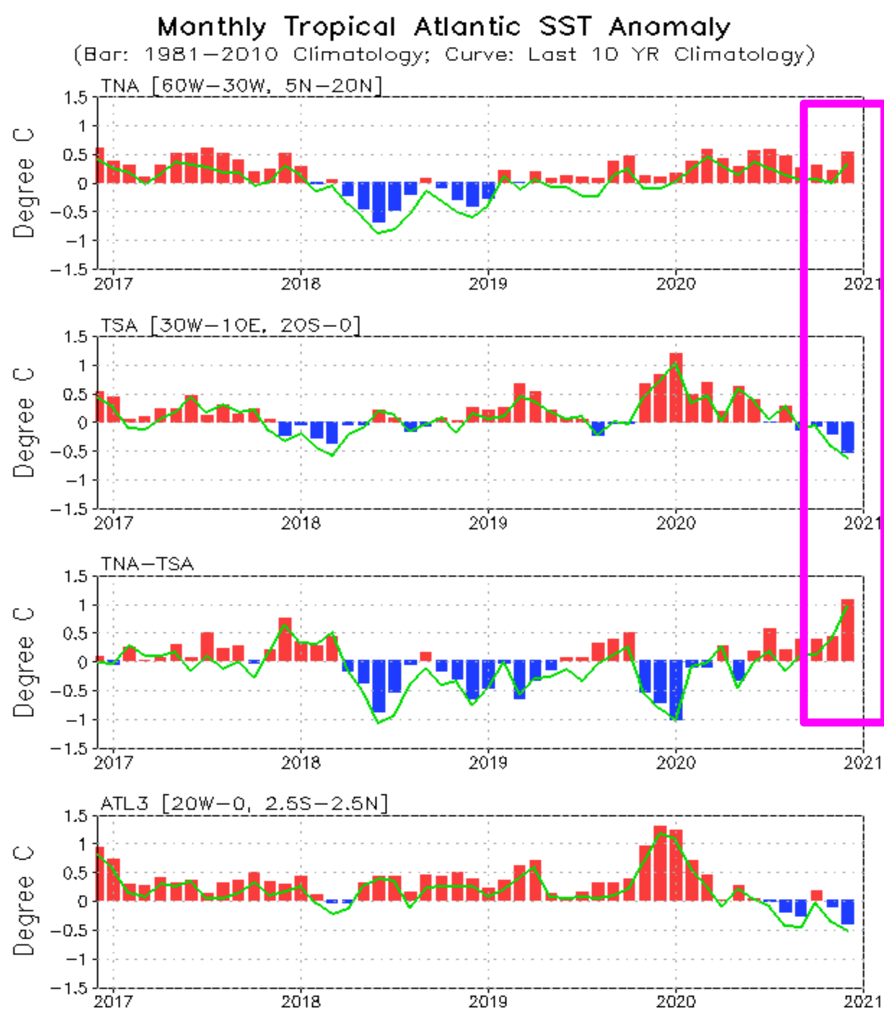
- SSTAs were overall small in the tropical Indian Ocean.

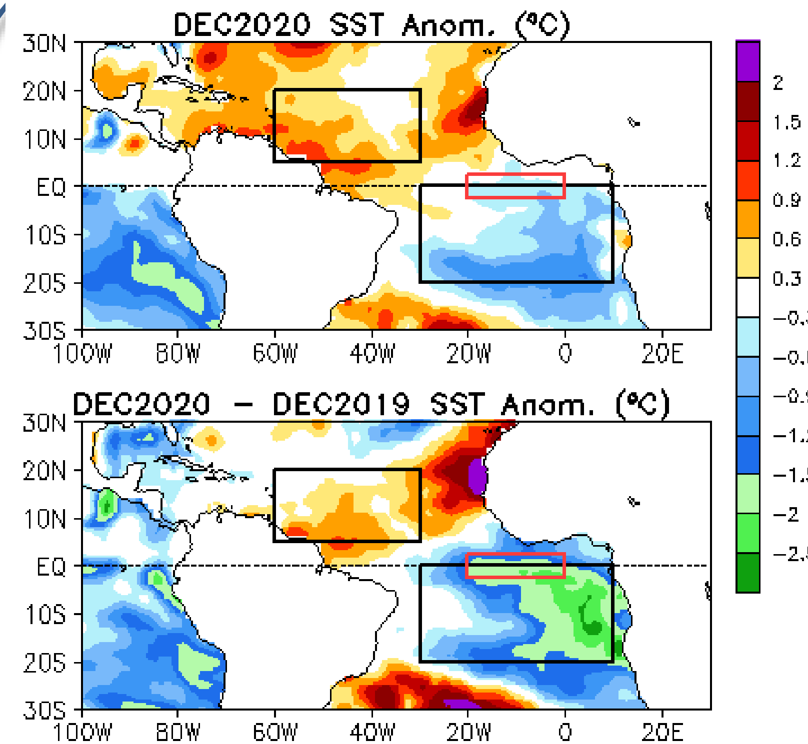
- Convection was enhanced over the off-equatorial Indian Ocean.

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 1981-2010 base period means.

Tropical and North Atlantic Ocean

Evolution of Tropical Atlantic SST Indices

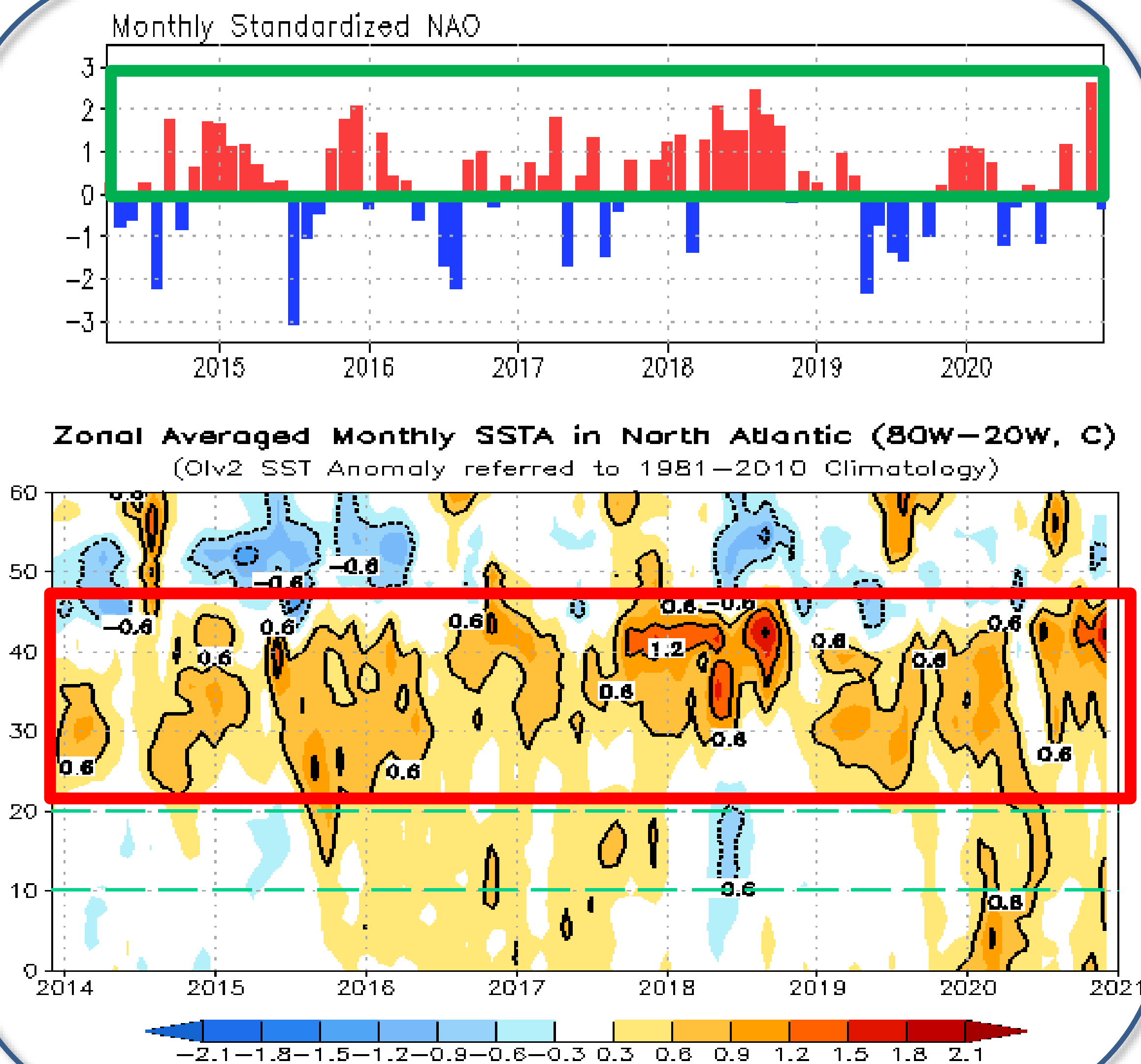


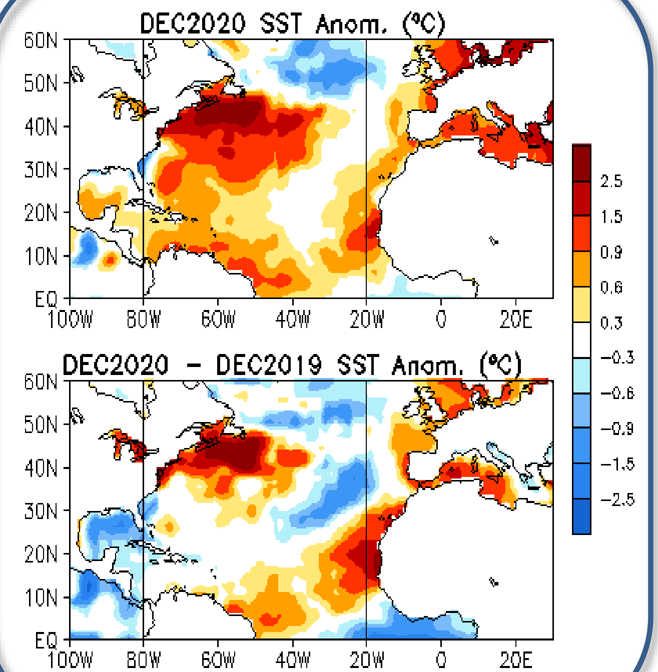


- Positive (negative) SSTAs in the tropical North (South) Atlantic feature a strong Atlantic meridional dipole mode.

Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean SSTAs (°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 OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

NAO and SST Anomaly in North Atlantic



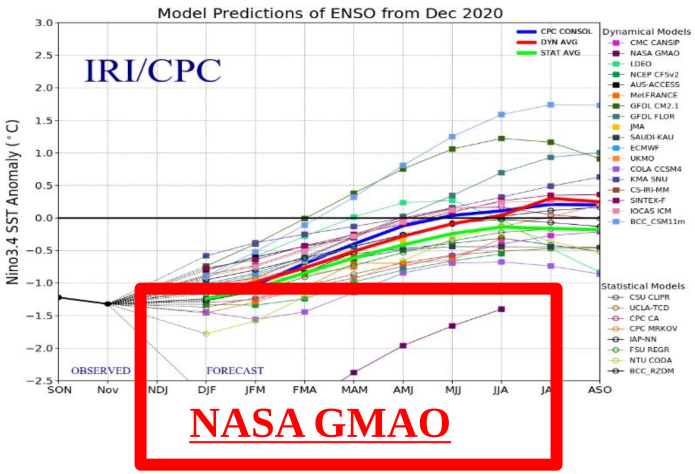


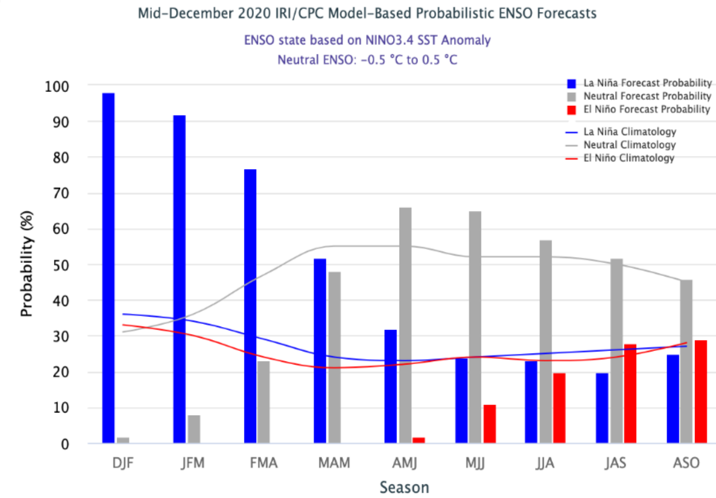
- NAO switched to a negative phase in Dec 2020 with NAOI= -0.4.
- The prolonged positive SSTAs in the middle latitudes were evident, due to the domination of the positive phase of NAO during the last 5-6 years.

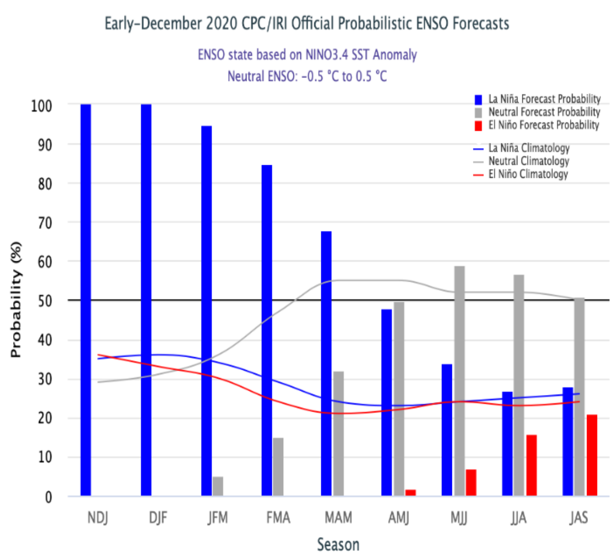
Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20^{O}N-90^{O}N. Time-latitude section of SSTAs averaged between 80ºW and 20ºW (bottom). SST are derived from the OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

ENSO and Global SST Predictions

IRI/CPC NINO3.4 Forecast: Dec 2020



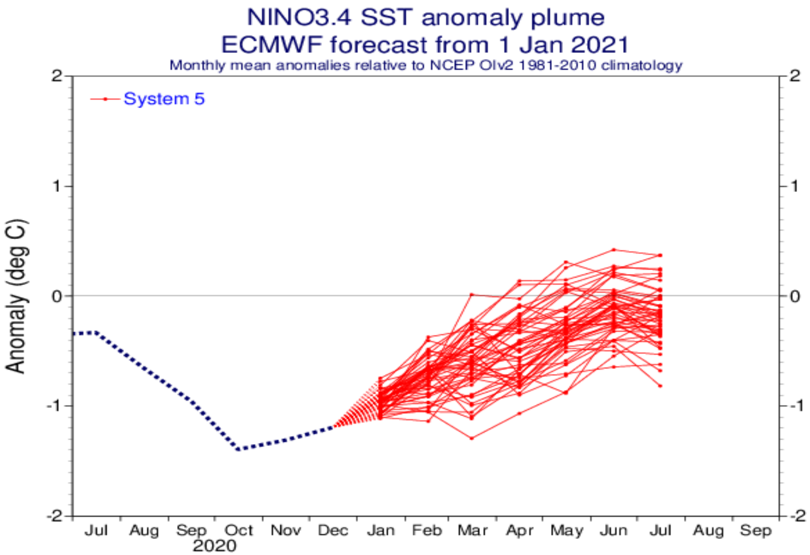




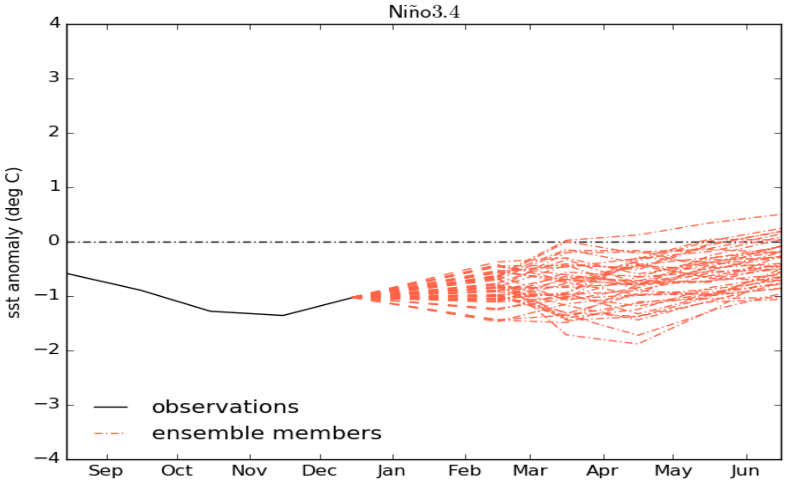
- **ENSO Alert System Status: La Niña Advisory**
- Synopsis: *La Niña is likely to continue through the Northern Hemisphere winter 2020-21 (~95% chance during January-March), with a potential transition during the spring 2021 (~50% chance of neutral during April-June).*

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

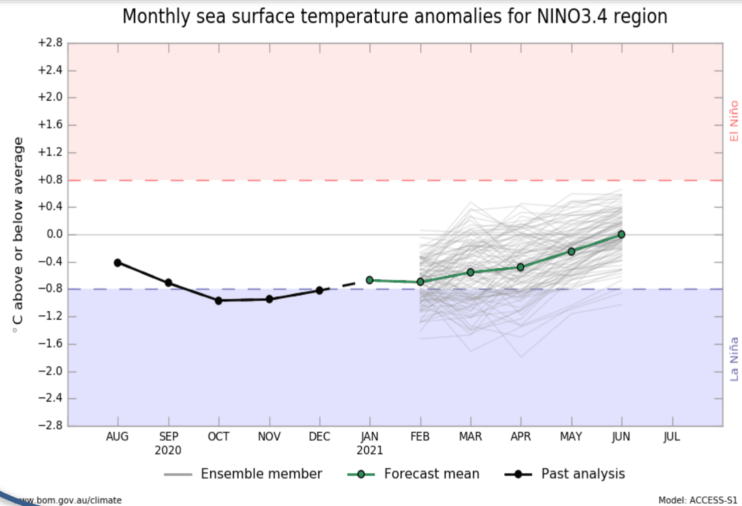
EC: Nino3.4, IC= 01Jan 2021



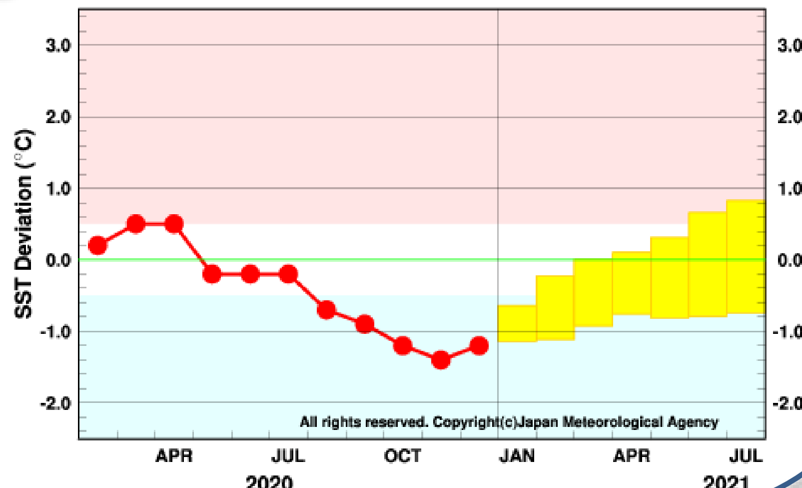
UKMO: Nino3.4, Updated 11 Jan 2021



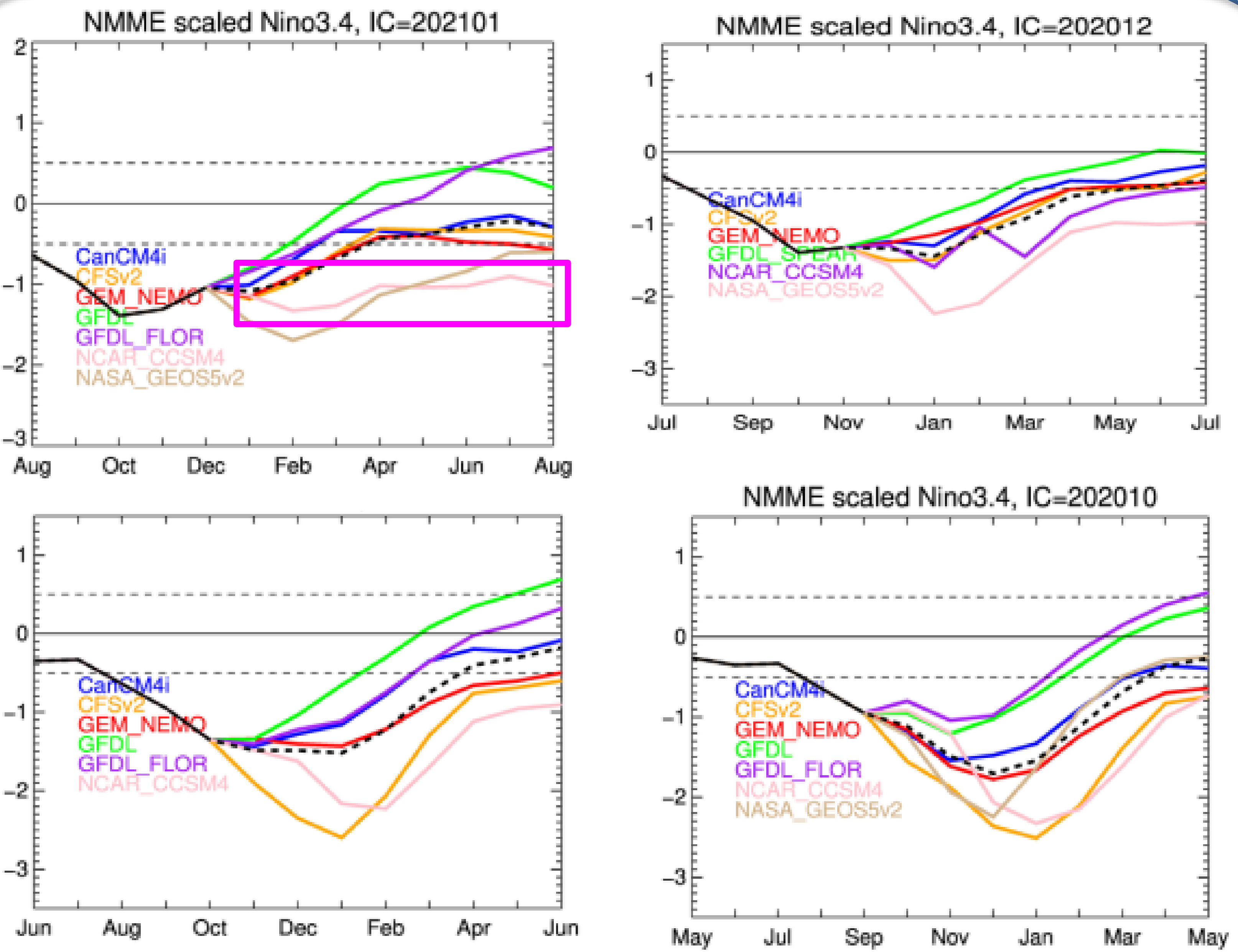
Australian BOM: Nino3.4, Updated 2 Jan 2021



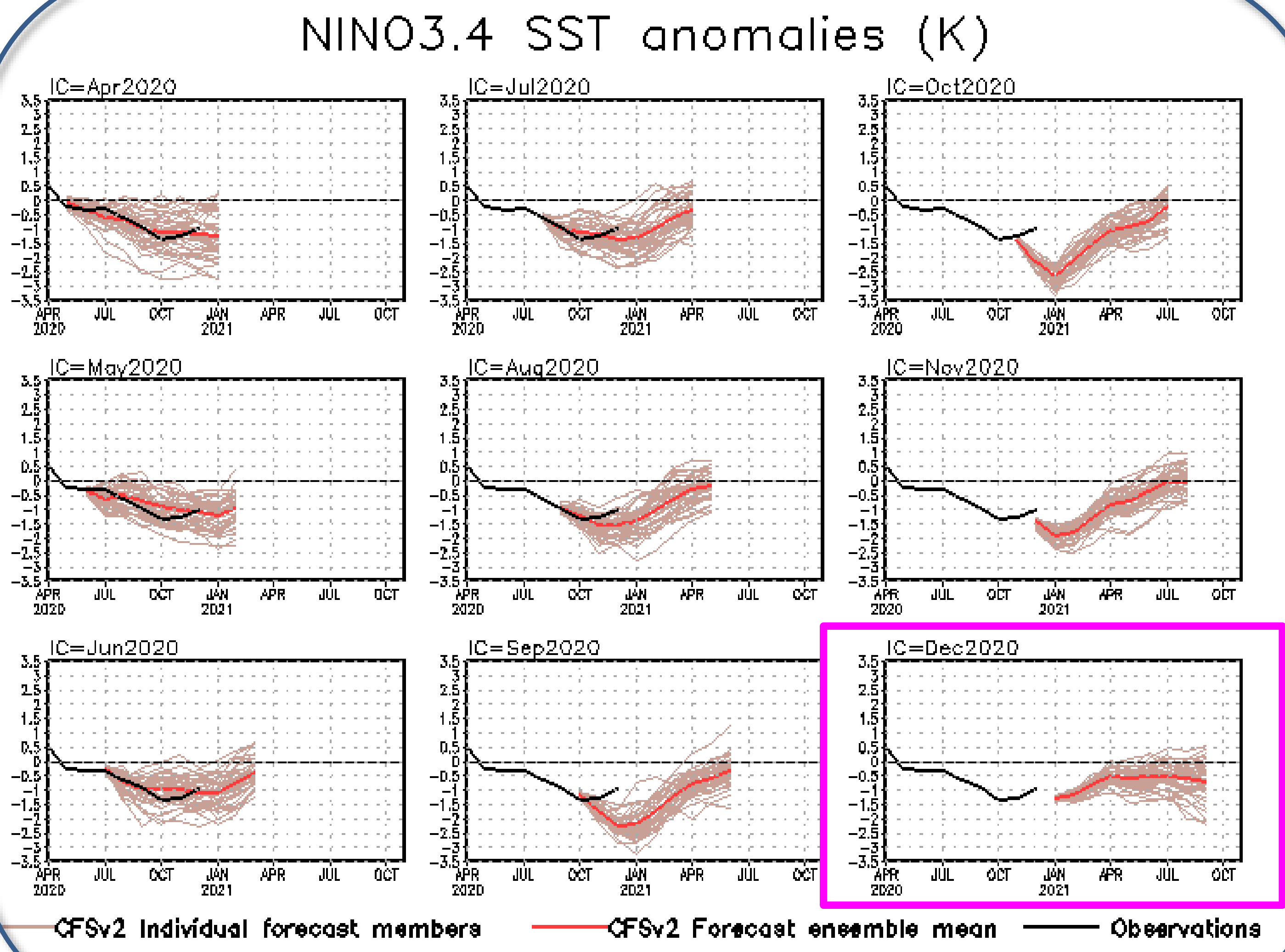
JMA: Nino3.4, Updated 12 Jan 2021



NMME forecasts from different initial conditions



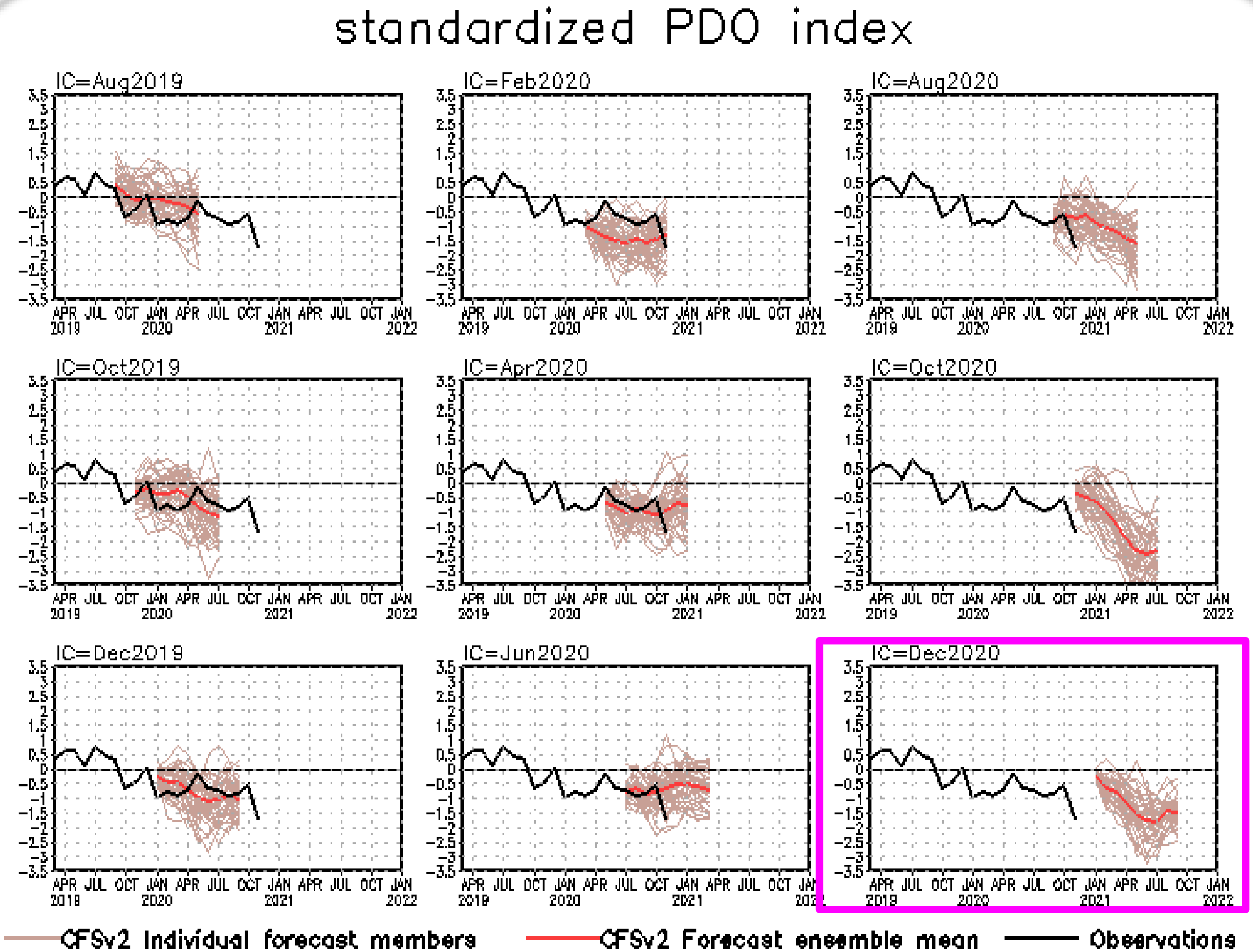
CFS Niño3.4 SST Predictions from Different Initial Months



- The latest CFSv2 forecasts call that the La Nina state will return to a neutral condition in spring 2021.

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.

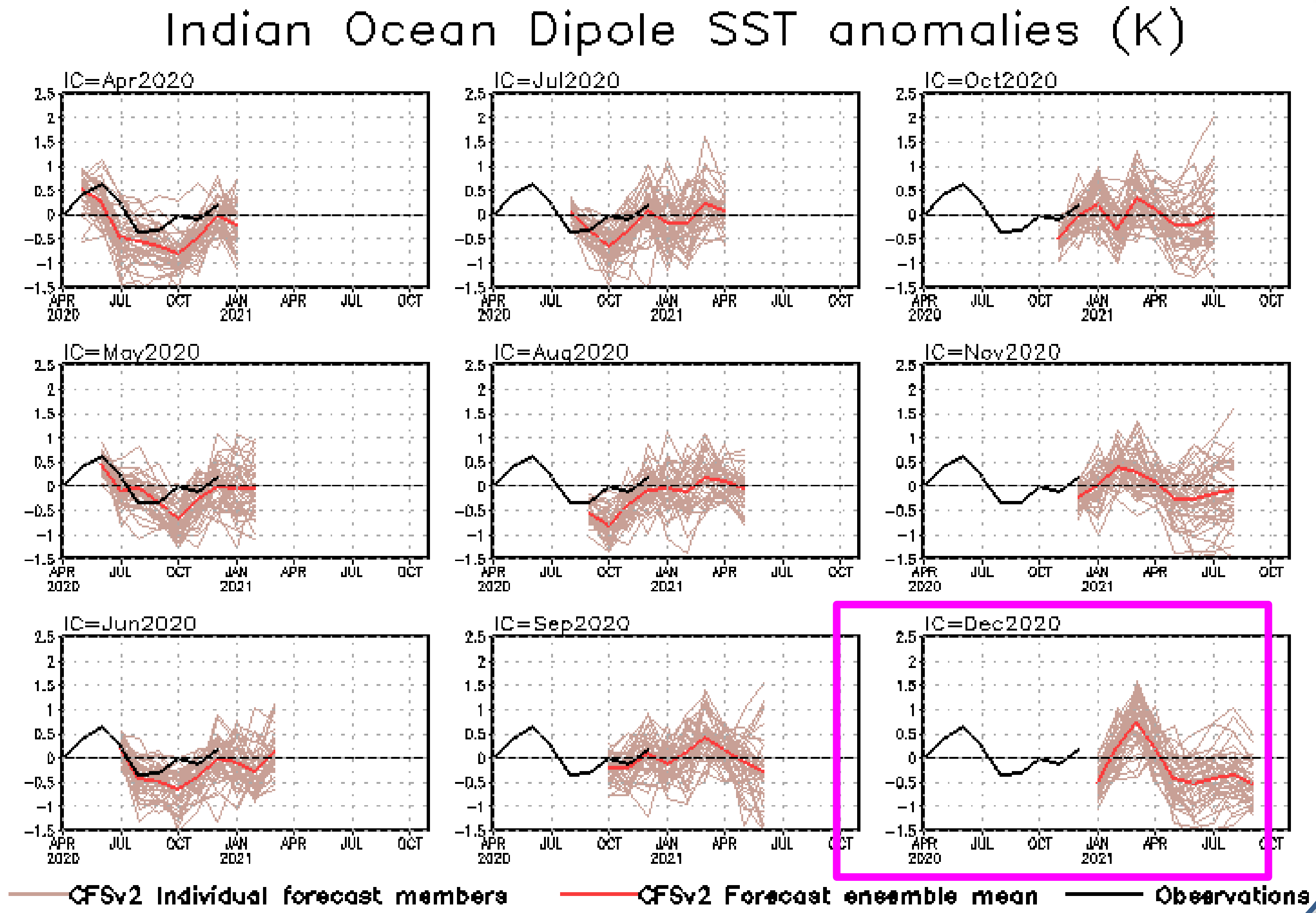
CFS Pacific Decadal Oscillation (PDO) Index Predictions from Different Initial Months



- CFSv2 predicts a negative phase of PDO in 2021.

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.

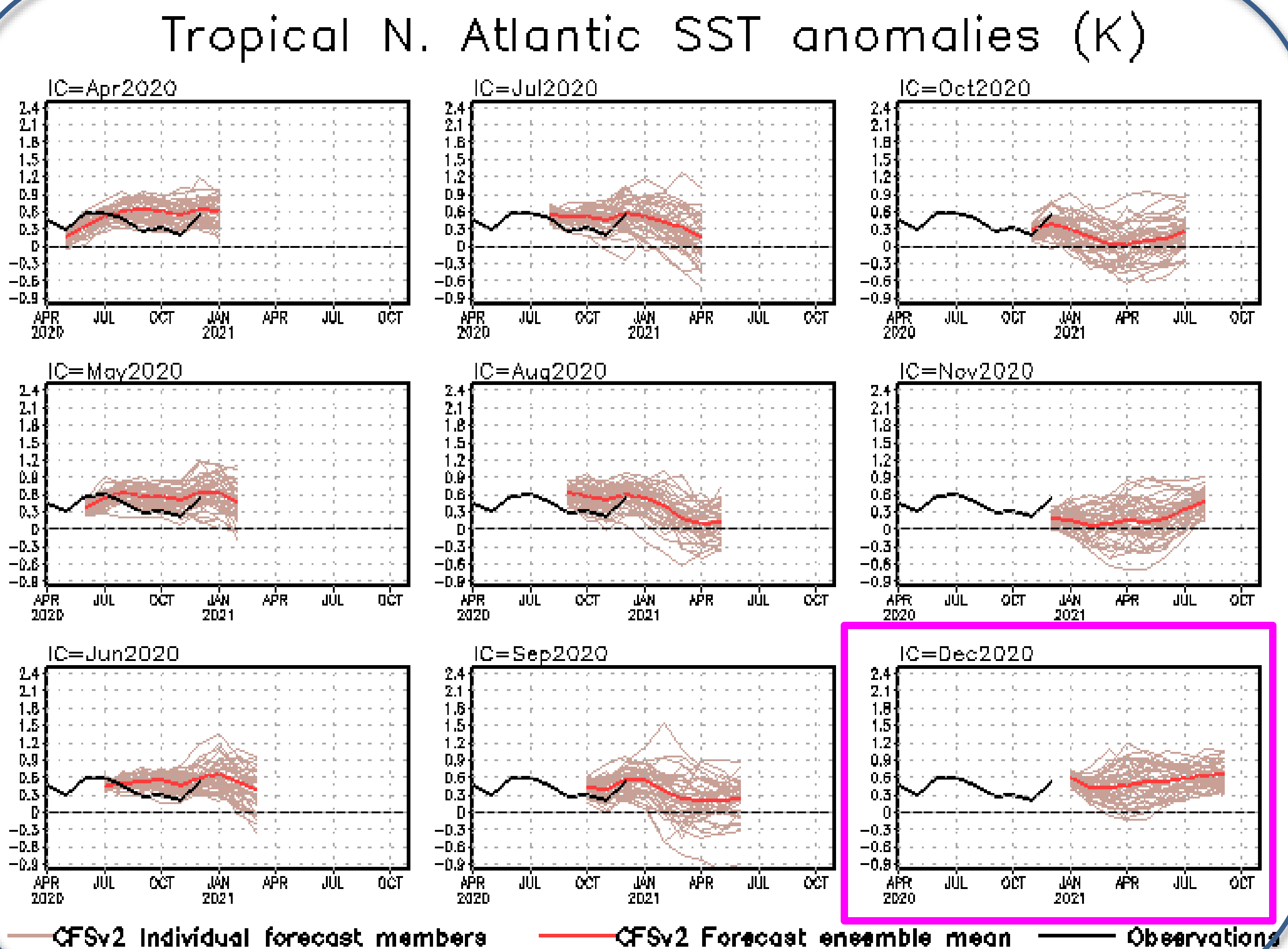
NCEP CFS DMI SST Predictions from Different Initial Months



- CFSv2 predicts a positive phase of IOD in spring 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 1981-2010 base period means.

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



- Latest CFSv2 predictions call for above normal SSTA in the tropical North Atlantic in 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 1981-2010 base period means. TNA is the SST anomaly averaged in the region of [60oW-30oW, 5oN-20oN].

Multi-Year La Nina: Evolution, Impact & Predictability

- DiNezio, P. N., C. Deser, Y. Okumura, and A. Karspeck, 2017: Predictability of 2-year La Niña events in a coupled general circulation model. Clim. Dyn., 49, 4237–4261. DOI: 10.1007/s00382-017-3575-3

- Hu, Z.-Z., A. Kumar, Y. Xue, and B. Jha, 2013: Why were some La Niñas followed by another La Niña? Clim. Dyn. , 42 (3-4), 1029-1042. DOI: 10.1007/s00382-013-1917-3

- Iwakiri, T., and M. Watanabe, 2020: Multiyear La Niña impact on summer temperature over Japan. JMSJ, 98. DOI: 10.2151/jmsj.2020-064

- Okumura, Y. M., P. DiNezio, and C. Deser, 2017: Evolving impacts of multiyear La Niña events on atmospheric circulation and U.S. drought. GRL, 44. DOI: 10.1002/2017GL075034

- Park, J-H, An, S-I, Kug, J-S, Yang, Y-M, Li, T, H.-S. Jo, 2021: Mid-latitude leading double-dip La Niña. Int J Climatol. 1– 18. https://doi.org/10.1002/joc.6772

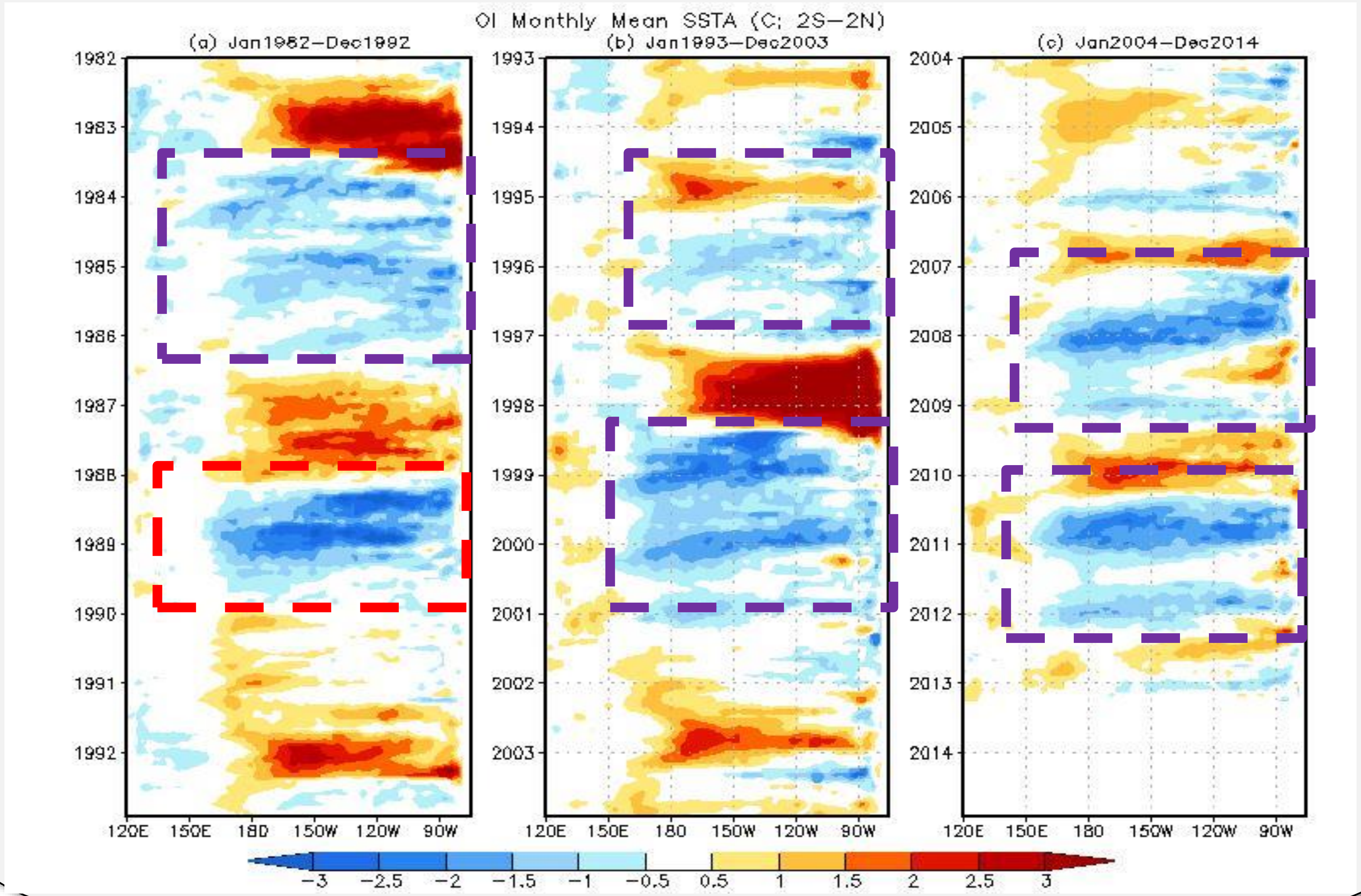
According to ENSO definition of CPC/NCEP/NOAA

(http://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php)

During 1951-2019, there are total 12 La Ninas

1. 2 three-year La Ninas (17%): 1973/76, 1998/2001
2. 6 two-year La Ninas (50%): 1954/56, 1970/72, 1983/85, 2007/09, 2010/12, 2016/18
3. 4 one-year La Ninas (33%): 1964/65, 1988/89, 1995/96, 2005/06

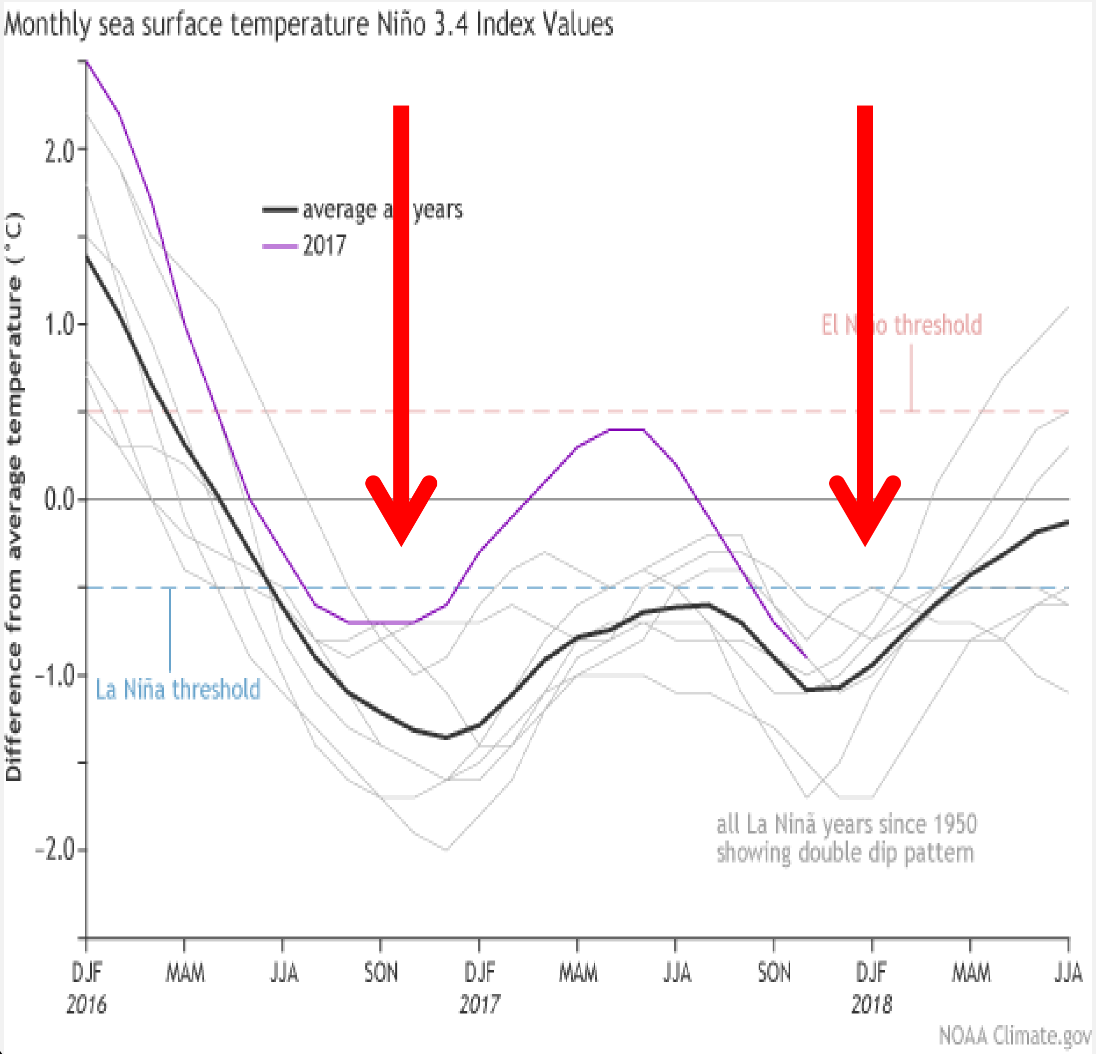
Observational Evidence: Most La Ninas are followed by another La Nina or weak negative SSTA, showing an asymmetry of ENSO duration



Hu, et al., 2014: Why were some La Niñas followed by another La Niña? Clim. Dyn. , 42 (3-4), 1029-1042. DOI: 10.1007/s00382-013-1917-3

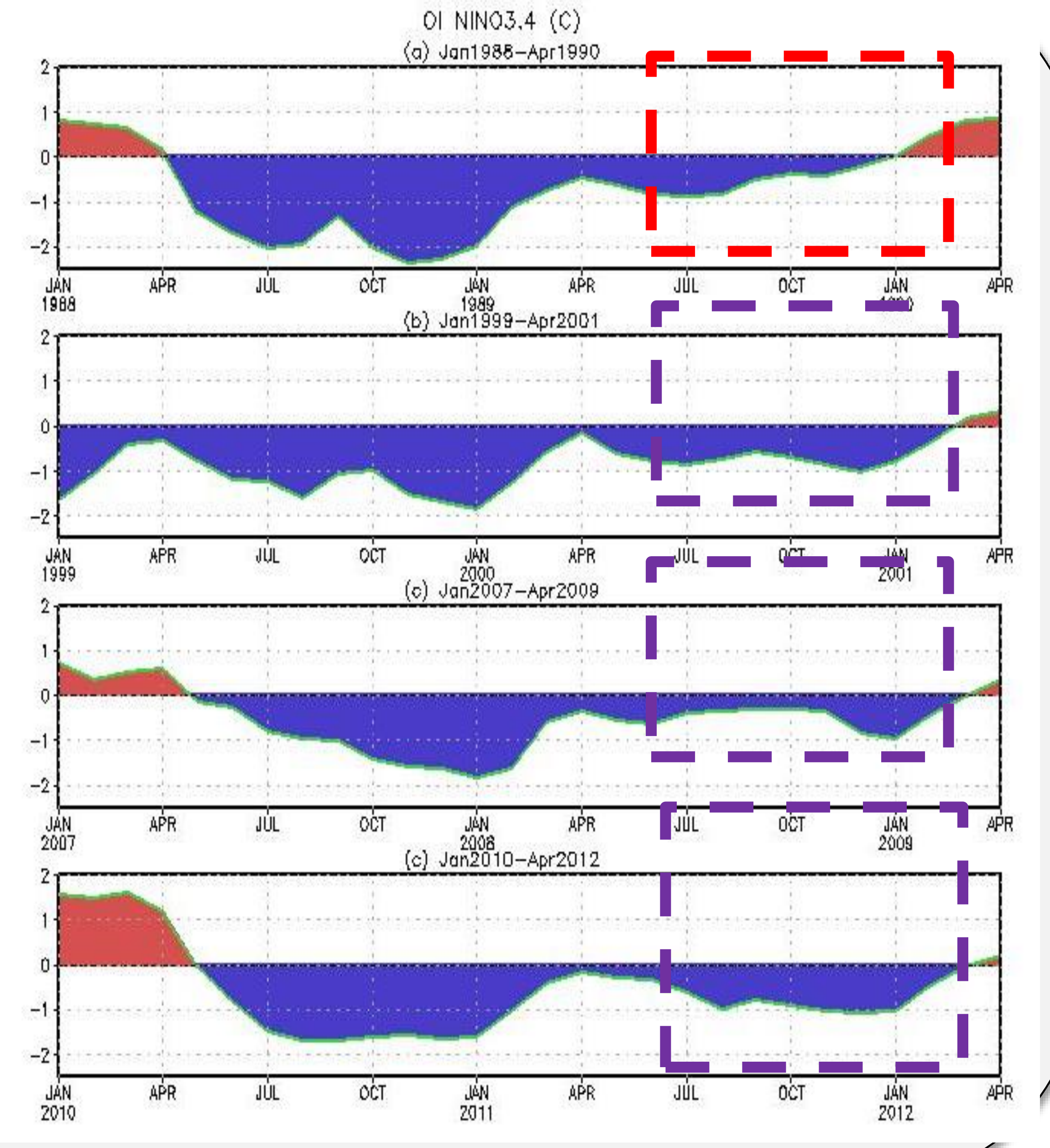
More U.S. drought in a second-year La Niña? (by Nat Johnson)

(https://www.climate.gov/news-features/blogs/enso/more-us-drought-second-year-la-ni%C3%B1a)



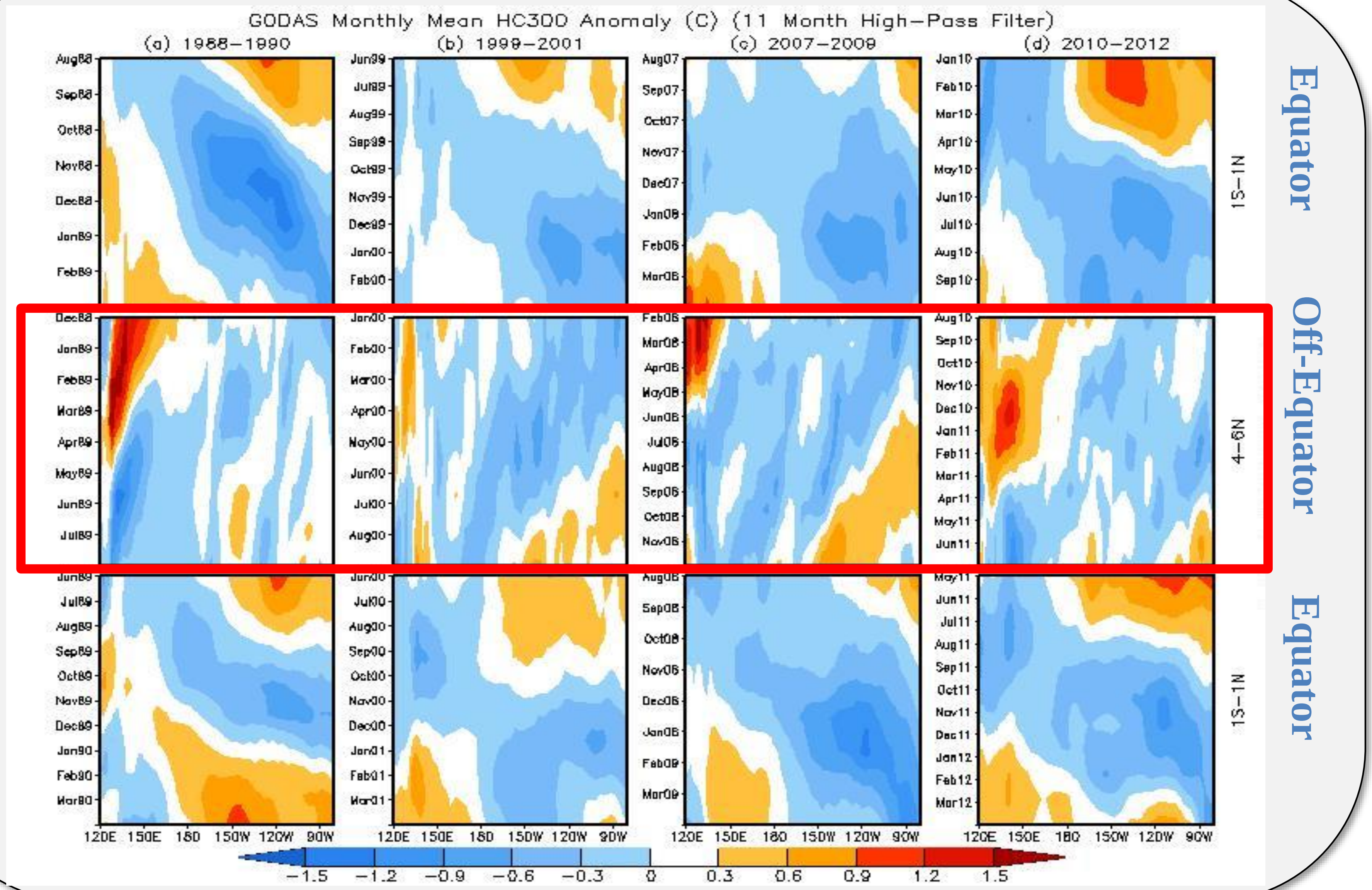
- Three-month seasonal Niño 3.4 compared to the long-term average for all multi-year La Niñas since 1950, showing how the average Niño 3.4 amplitude (black line) evolves in time. The purple line shows the evolution since Dec-Mar of 2015, and the light grey lines show the other seven events.
- Multi-year La Niña events are defined as at least 2 years in a row where the La Niña criteria are met. Both continuous events, when the Oceanic Niño Index remained below -0.5°C, and years when the ONI warmed mid-year before again cooling, are included here. Climate.gov graph based on ERSSTv5 temperature data.

- For example, 1999-2001 and 2007-2009, 2010-2012 La Ninas were followed by weak La Ninas;
- But 1988-1990 La Nina did not.
- A weak La Nina occurs in second winter following a major La Nina.



Hu, et al., 2014: Why were some La Niñas followed by another La Niña? Clim. Dyn. , 42 (3-4), 1029-1042. DOI: 10.1007/s00382-013-1917-3

HC300 propagation along equator and off-equator: 4 Strong La Ninas



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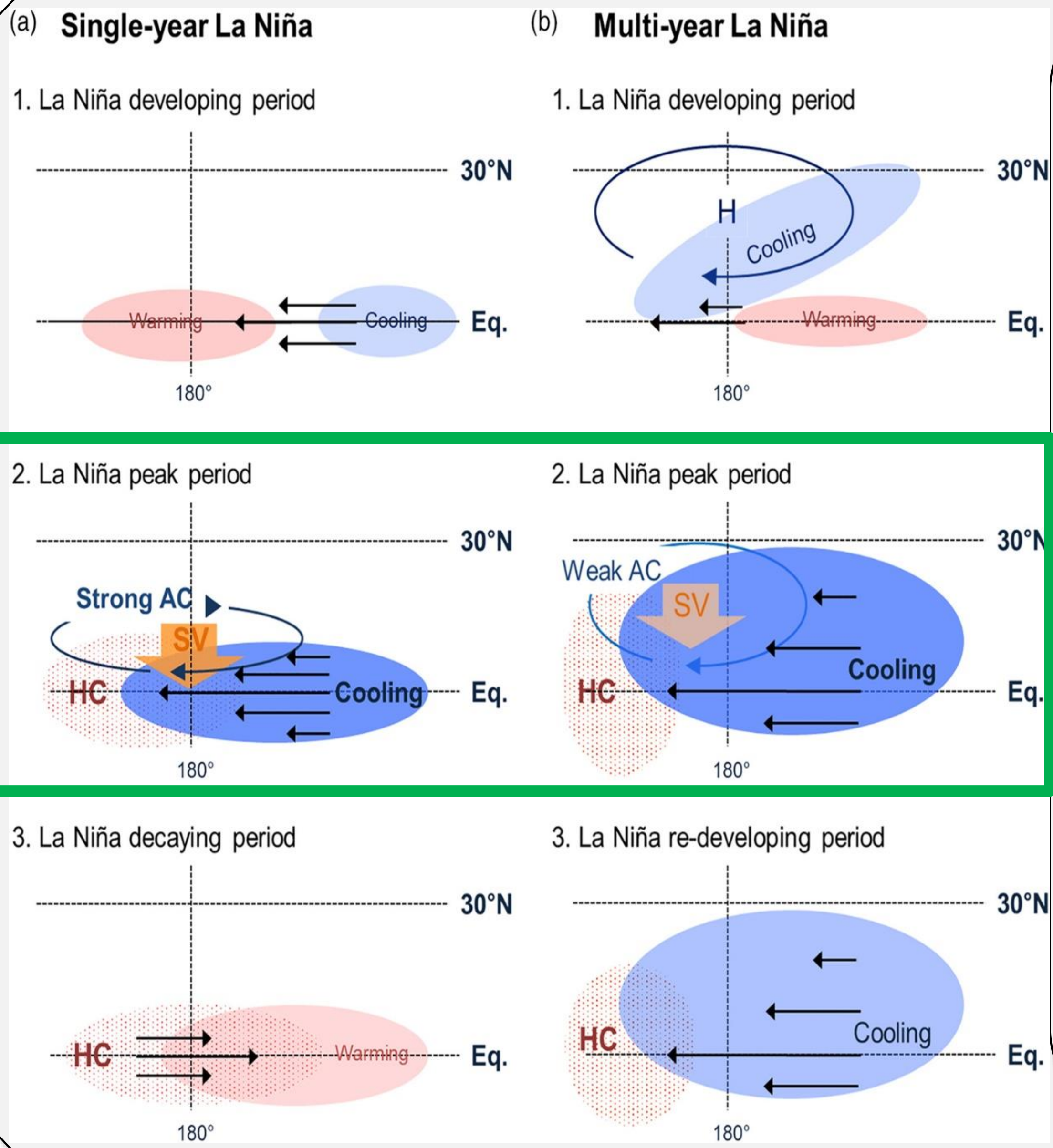
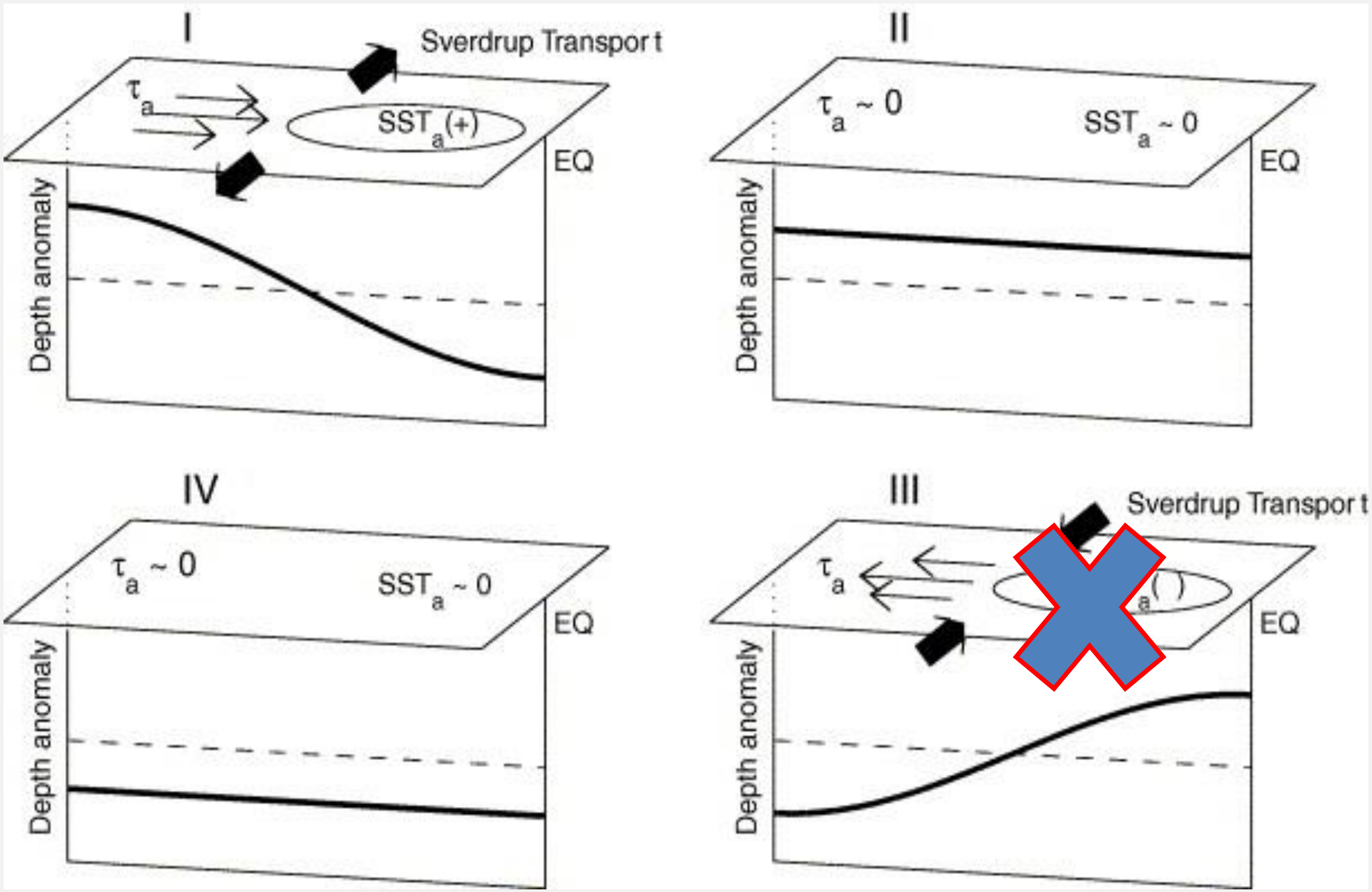


- **For single-year La Niña, efficient ocean recharging due to a narrower anti-cyclonic circulation causes a fast transition to an El Niño or a fast termination of a La Niña.**
- **For multi-year La Niña, a weaker recharging causes surface cooling to persist, leading to another La Niña in the following year.**
- Fig. 10: (a) Schematic diagram of single-year La Niña evolution. Red and blue shaded ellipses indicate anomalous SST warming and cooling, respectively. Black solid line arrows indicate anomalous zonal wind-stress. Blue line ellipse in peak-phase means lower-level atmospheric anti-cyclonic circulation (wind-stress curl) and orange-filled arrow shows equatorward Sverdrup transport due to the anti-cyclonic circulation. Red stippled ellipses indicate heat content accumulation over the tropical Pacific. (b) Is same with (a), but for a multi-year La Niña. The weak wind-stress curl in the peak phase does not favour efficient downwelling Rossby waves/equatorward Sverdrup transport. Consequently, significant cooling persists in the equatorial Pacific.

Park, et al. 2021: Mid-latitude leading double-dip La Niña. Int J Climatol., 1– 18. https://doi.org/10.1002/joc.6772

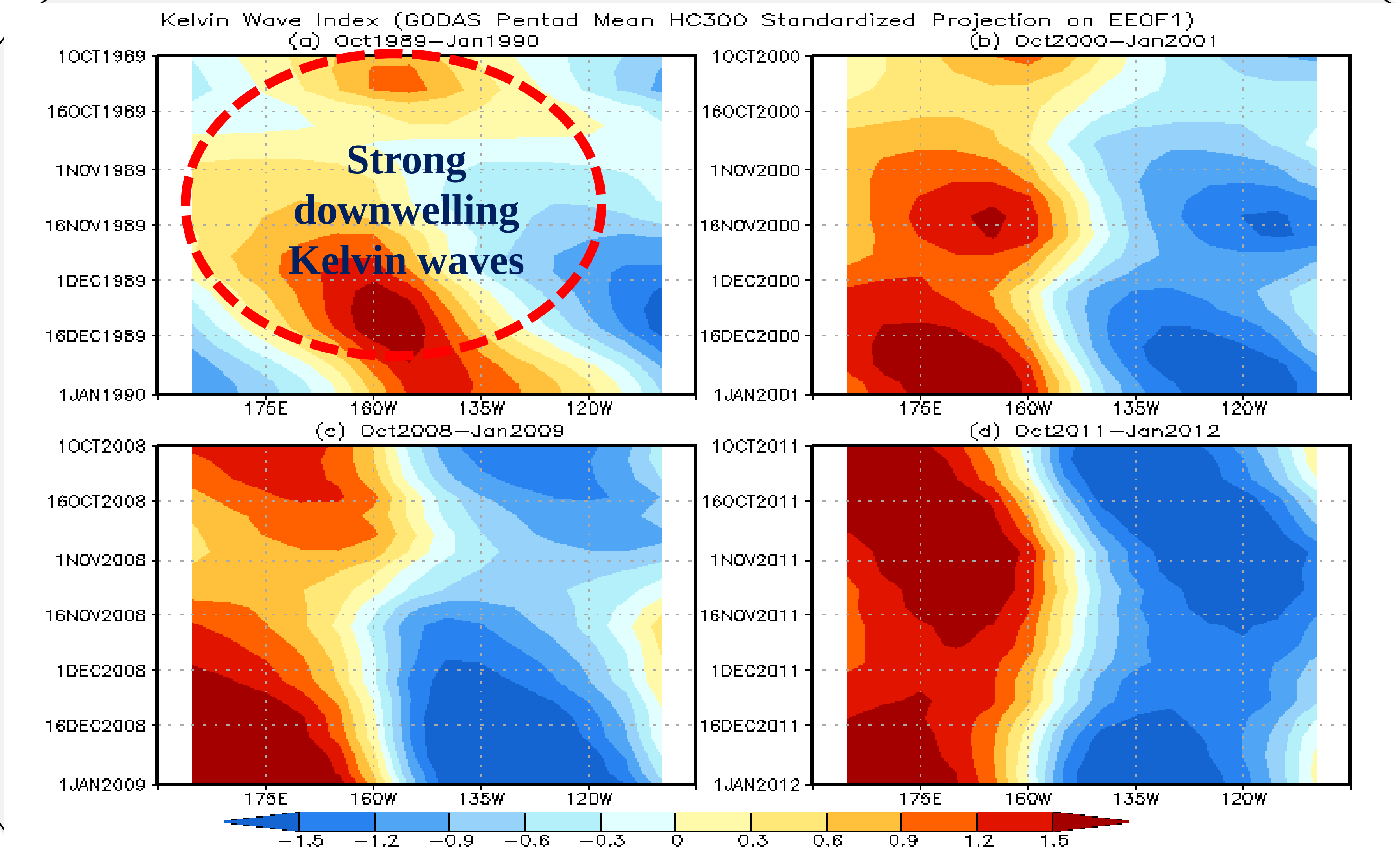
Phase I: Discharge process: *Equator to off-Equator*
Phase III: Recharge process: *off-Equator to Equator*



Wang, C., and P. Fiedler, 2006: ENSO variability and the eastern tropical Pacific: A review. *Prog. Oceanogr*. 69, 239–266.

Why 1988-89 didn't have 2nd year La Nina?

Strong Downwelling Kelvin Wave



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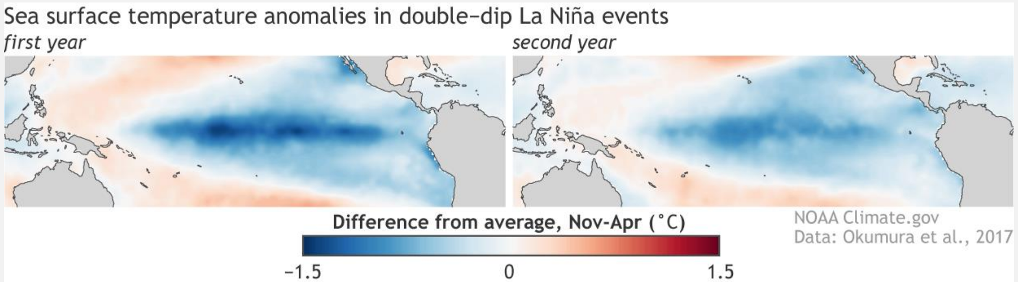
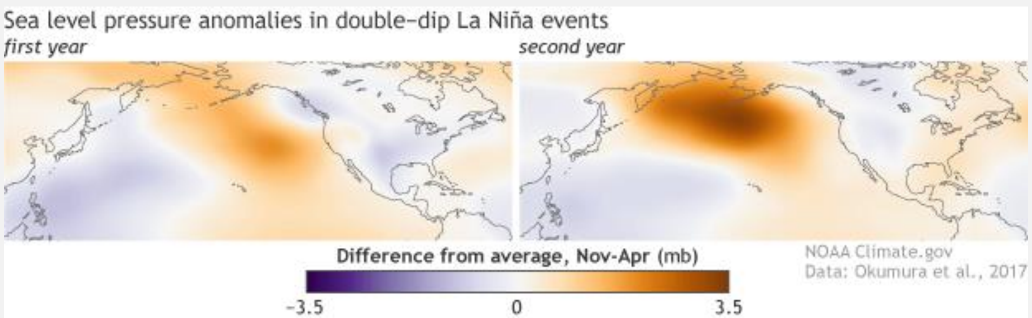
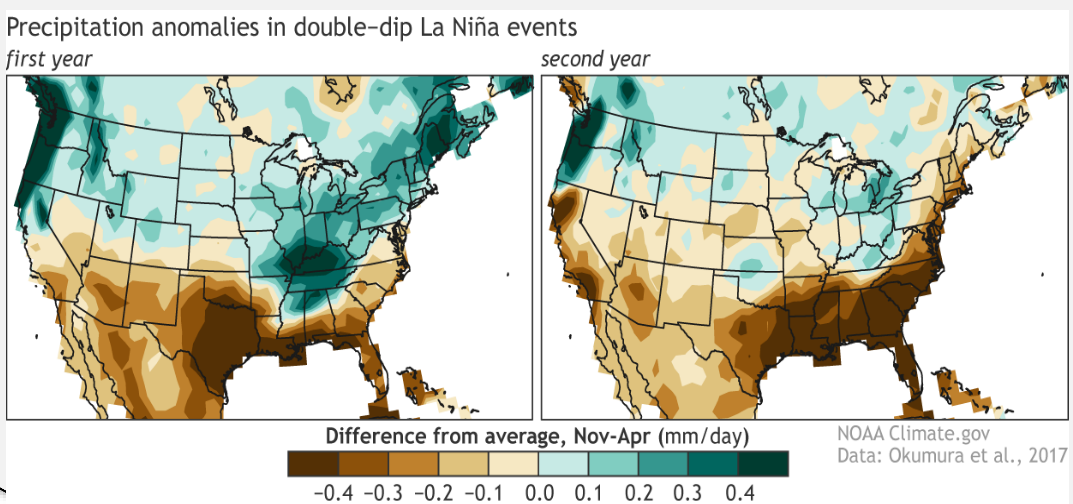
More U.S. drought in a second-year La Niña? (by Nat Johnson)

(https://www.climate.gov/news-features/blogs/enso/more-us-drought-second-year-la-ni%C3%B1a)







- Averaged SSTAs in Nov–Apr for the first (left) and second (right) extended winters of all multi-year La Niñas since 1900. Anomalies are compared to the 1900-2012 average, with the linear trend removed. Adapted from Okumura et al. (2017).
- Average SLPa during Nov–Apr for the first (left) and second (right) extended winters of all multi-year La Niñas since 1900. Anomalies are compared to the 1900-2012 average, with the linear trend removed. Adapted from Okumura et al. (2017).
- Average precipitation anomalies (mm/day) for Nov–Apr for the first (left) and second (right) extended winters of all multi-year La Niñas since 1900. Anomalies are compared to the 1900-2012 average, with the linear trend removed. Adapted from Okumura et al. (2017).

Multiyear La Niña impact on summer temperature over Japan

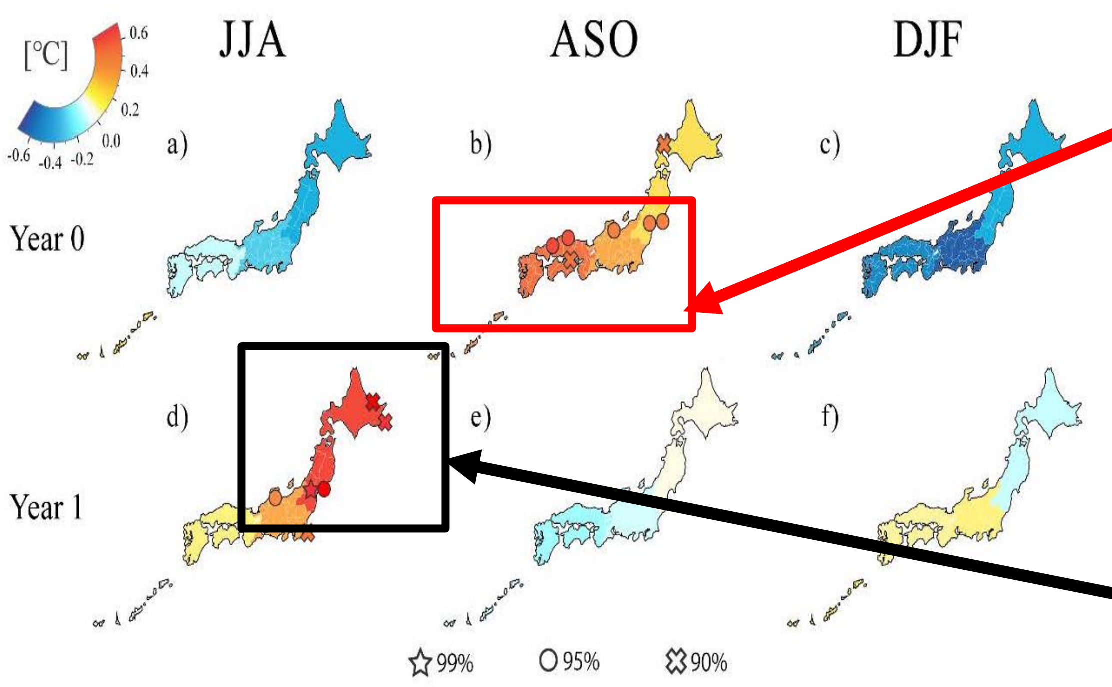
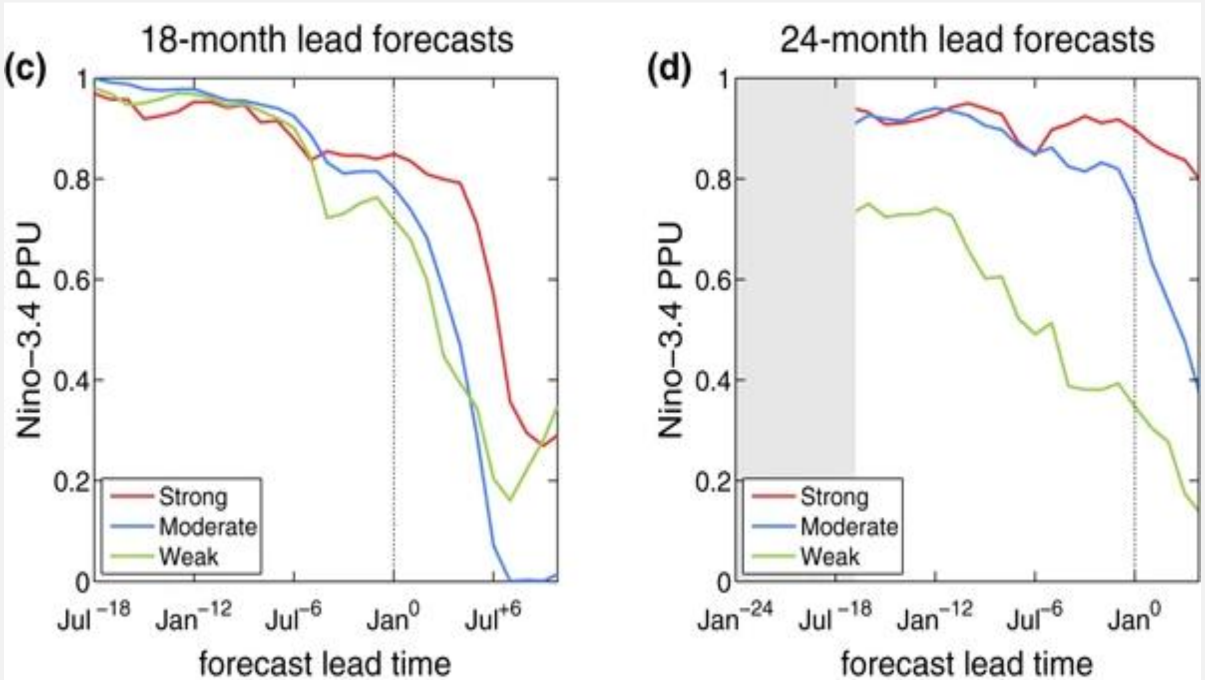


Fig. 4 As in Fig. 2b, but for multiyear La Niña events: (a) JJA(0), (b) ASO(0), (c) DJF(0/1), (d) JJA(1), (e) ASO(1), and (f) DJF(1/2).

- In the first summer, warm conditions are found in Aug-Oct (ASO) in the SW Japan, due to anomalous southwesterly winds in the lower troposphere associated with a La Niña-induced decrease in precipitation over the equatorial western Pacific.
- In the second summer, warm anomalies are found in Jun–Aug (JJA) over NE Japan which are accompanied by an anomalous barotropic high-pressure induced by negative precipitation anomalies over the equatorial Pacific.

Iwakiri, T., and M. Watanabe, 2020:. J. Meteor. Soc. Japan, 98. https://doi.org/10.2151/jmsj.2020-064)

2-year La Nina may be predictable 18 to 24 months in advance



IC: -WWV

IC: El Nino

Temporal evolution of potential prediction utility (PPU) of the Nino-3.4 index for "***perfect CESM1***" in forecasts initialized a during the discharge phase (c) and at the peak of the preceding El Niño event (d). The dashed black line indicates January of the second year (Jan0).

- A 1800-year long control simulation of CESM1 & forecasts with the perfect model approach.
- A strong thermocline discharge or a strong El Niño can lead to La Niña conditions that last 2 years (2-year LN).

- Forecasts initialized with strong thermocline discharge or strong peak El Niño amplitude show higher predictability than those with initial conditions of weaker magnitude.
- **2-year La Nina may be predictable 18 to 24 months in advance under *specific* initial conditions.**

DiNezio, et al, 2017: Predictability of 2-year La Niña events in a coupled general circulation model. Clim. Dyn., 49, 4237–4261.

Multi-Year La Nina: Evolution, Impact & Predictability

- For most cases, strong La Nina would last more than one year unless a strong downwelling Kelvin wave presents.
- It seems that the ocean heat condition in off-the equator play an important role which leads to a less effective recharge process and a failure of the transition to El Nino.
- 1st year and 2nd La Ninas may have different impacts on regional climate.
- 2-year La Nina may be predictable 18 to 24 months in advance under specific initial conditions (*large Nino3.4 or WWV*).

Acknowledgement

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

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

❖ Dr. Wanqiu Wang provides the sea ice forecasts and maintains the CFSv2 forecast archive

Please send your comments and suggestions to:
Zeng-Zhen.Hu@noaa.gov
Arun.Kumar@noaa.gov
Caihong.Wen@noaa.gov
Jieshun.Zhu@noaa.gov

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

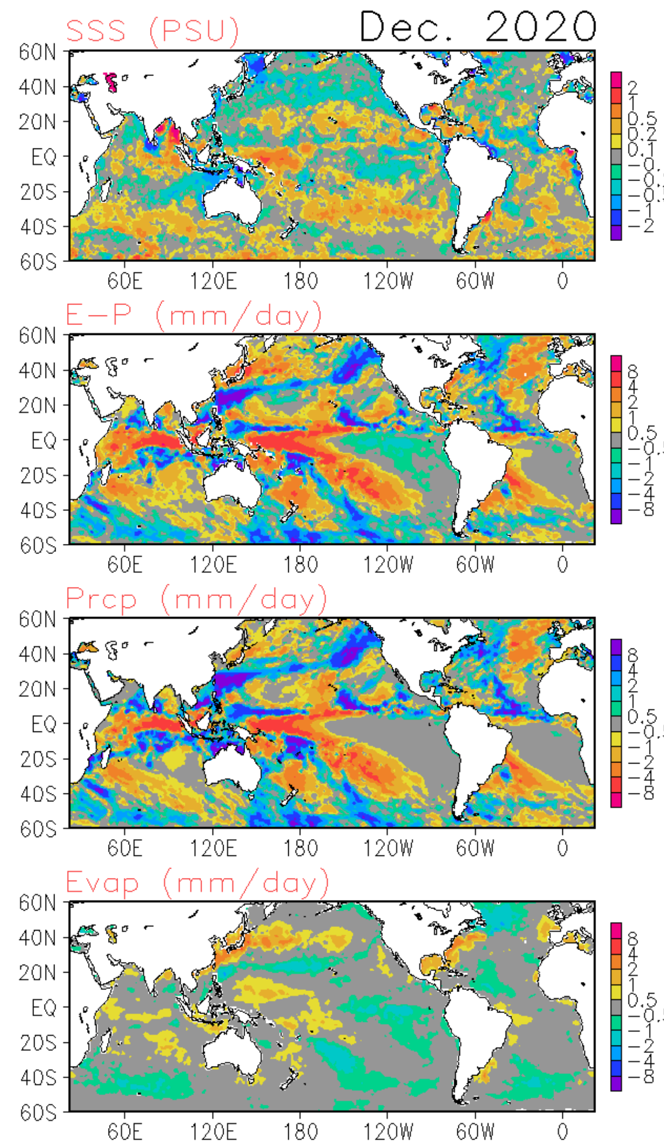
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html

Backup Slides

Global Sea Surface Salinity (SSS): Anomaly for December 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/strengthens in the western equator Pacific Ocean, which is likely caused by the reduced precipitation. Positive SSS anomaly continues in the subtropics of N. Pacific Ocean. Negative SSS anomaly continues in the subarctic of N. Pacific Ocean. Negative SSS anomaly appears in the east basin of equatorial Atlantic Ocean and extends northwest. Such signal is companied with increased precipitation. Positive SSS anomaly in the Bay of Bengal continues with reduced precipitation appearing in this area.



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

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

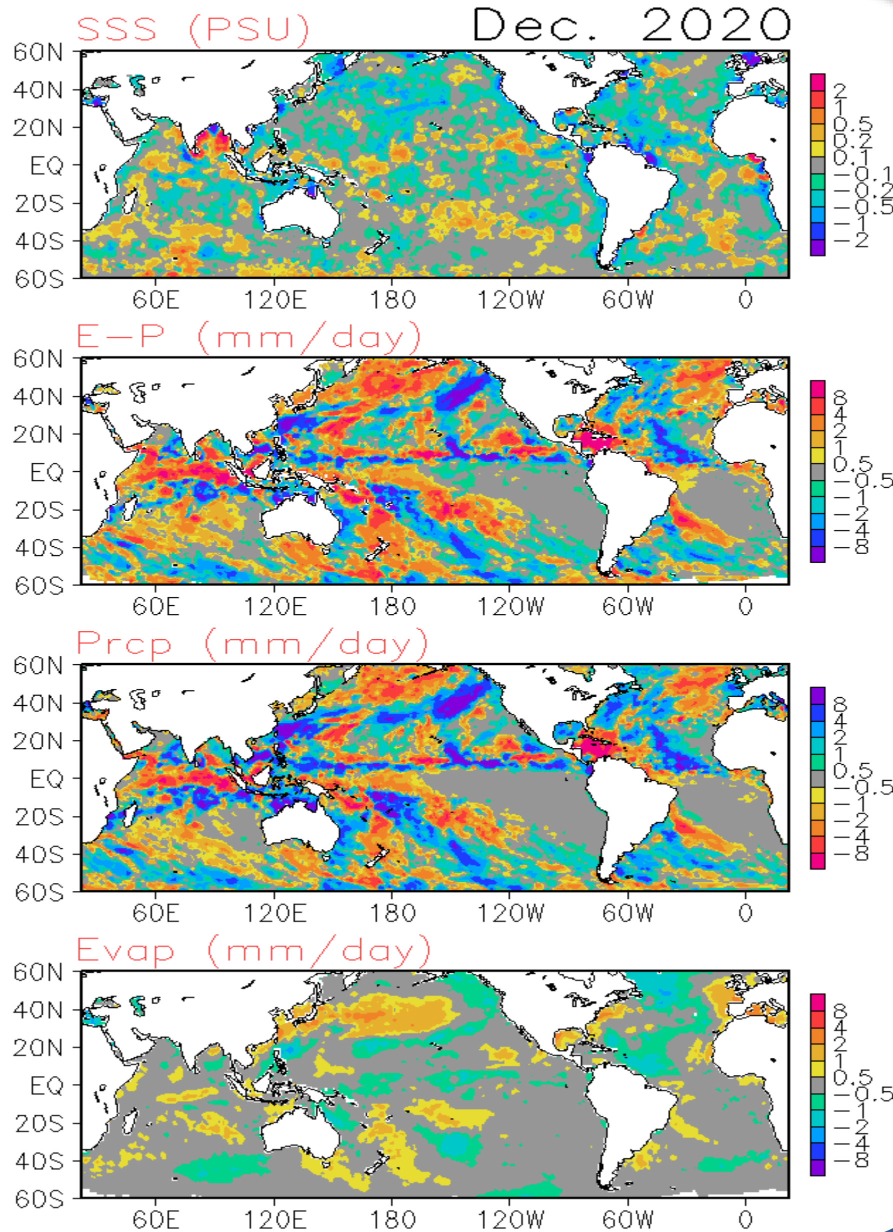
ftp.cpc.ncep.noaa.gov/precip/BASS

Precipitation: CMORPH adjusted satellite precipitation estimates

Evaporation: Adjusted CFS Reanalysis

Global Sea Surface Salinity (SSS): Tendency for December 2020

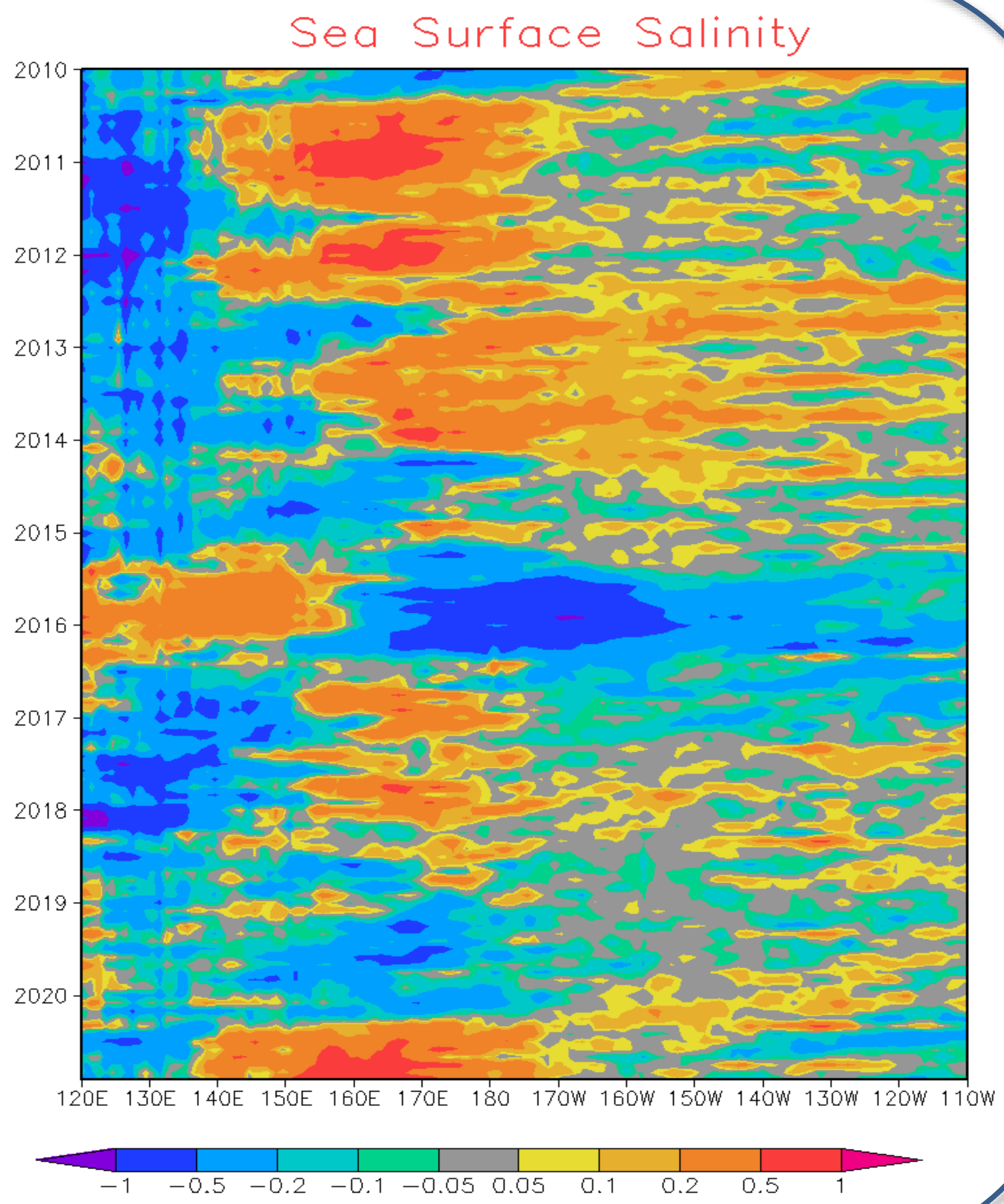
Compared with last month, SSS in the western Equatorial Pacific Ocean increased. SSS in most areas north of 20° N in Pacific Ocean decreased. SSS in the North Atlantic Ocean decreased as well with stronger signals appear in the west basin. In the Bay of Bengal, SSS continued increasing. SSS decreased in most areas south of Equator in the Indian Ocean, which is likely caused by oceanic advection/entrainment.



Monthly SSS Anomaly Evolution over Equatorial Pacific

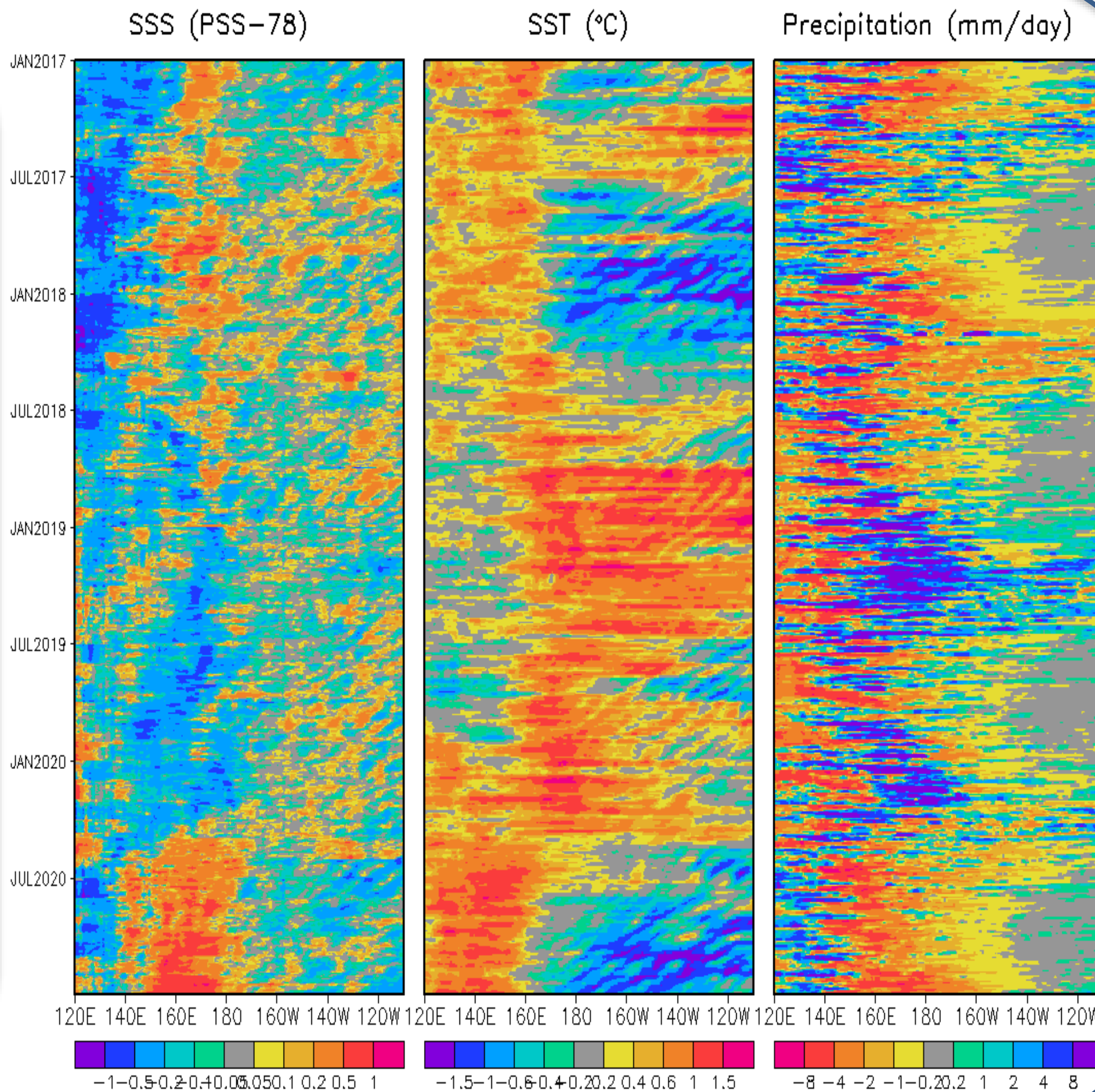
NOTE: Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015,The BASS SSS is from in situ, SMOS and Aquarius.

- 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 signals also continue between 140° E and 170° W; while positive and/or neutral SSS signal appears east of 160° W.

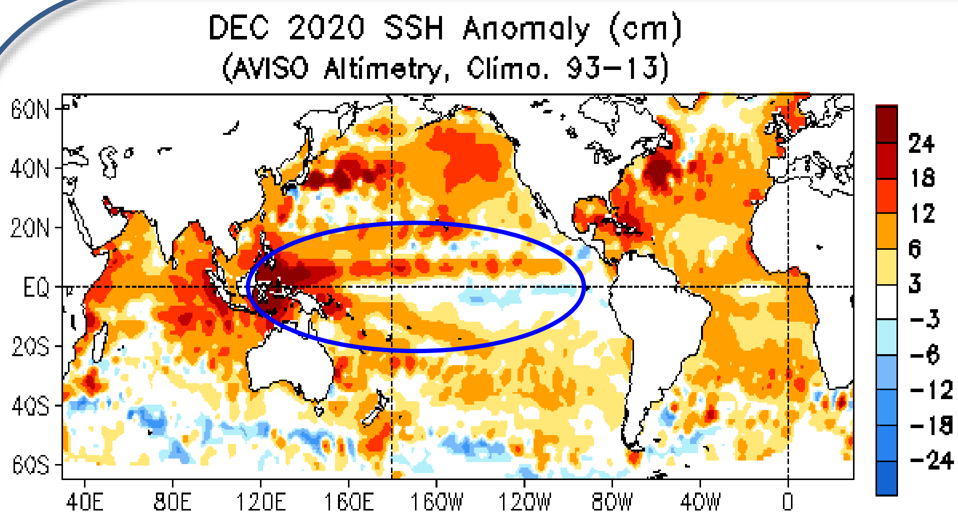


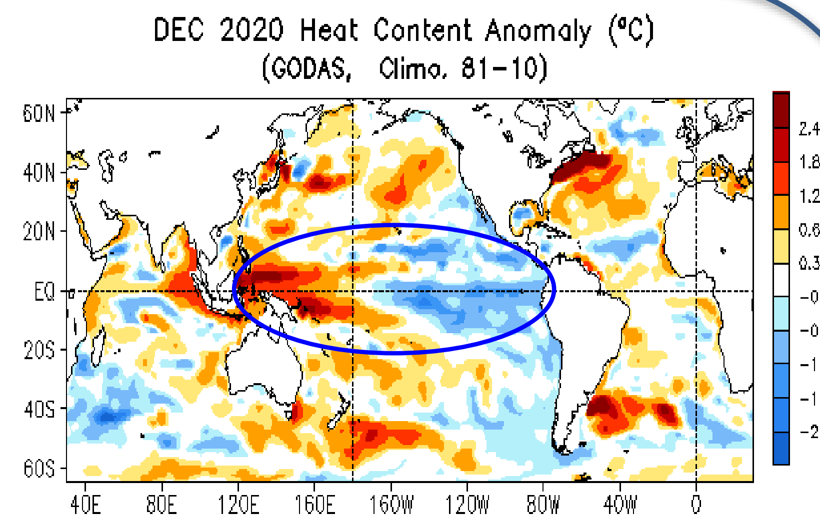
Pentad SSS Anomaly Evolution over Equatorial Pacific

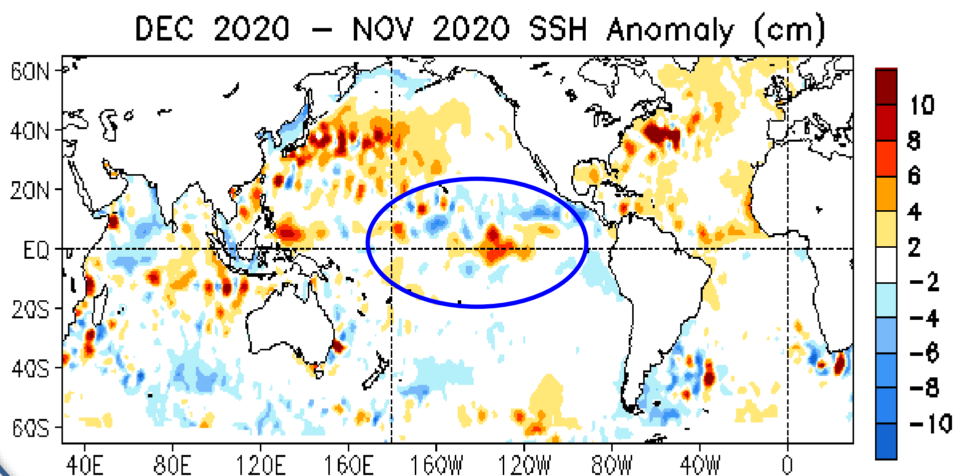
Figure caption: Hovemoller diagram for equatorial (5° S-5° N) 5-day mean SSS, SST and precipitation anomalies. The climatology for SSS is Levitus 1994 climatology. The SST data used here is the OISST V2 AVHRR only daily dataset with its climatology being calculated from 1985 to 2010. The precipitation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

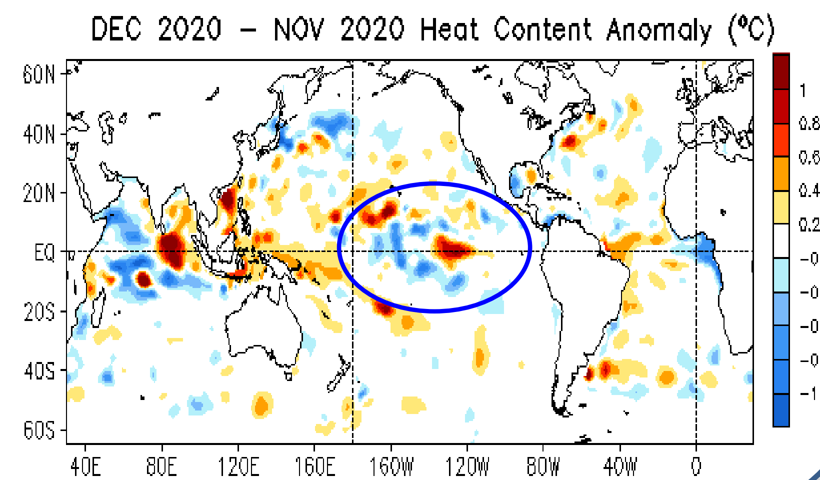


Global SSH and HC300 Anomaly & Anomaly Tendency



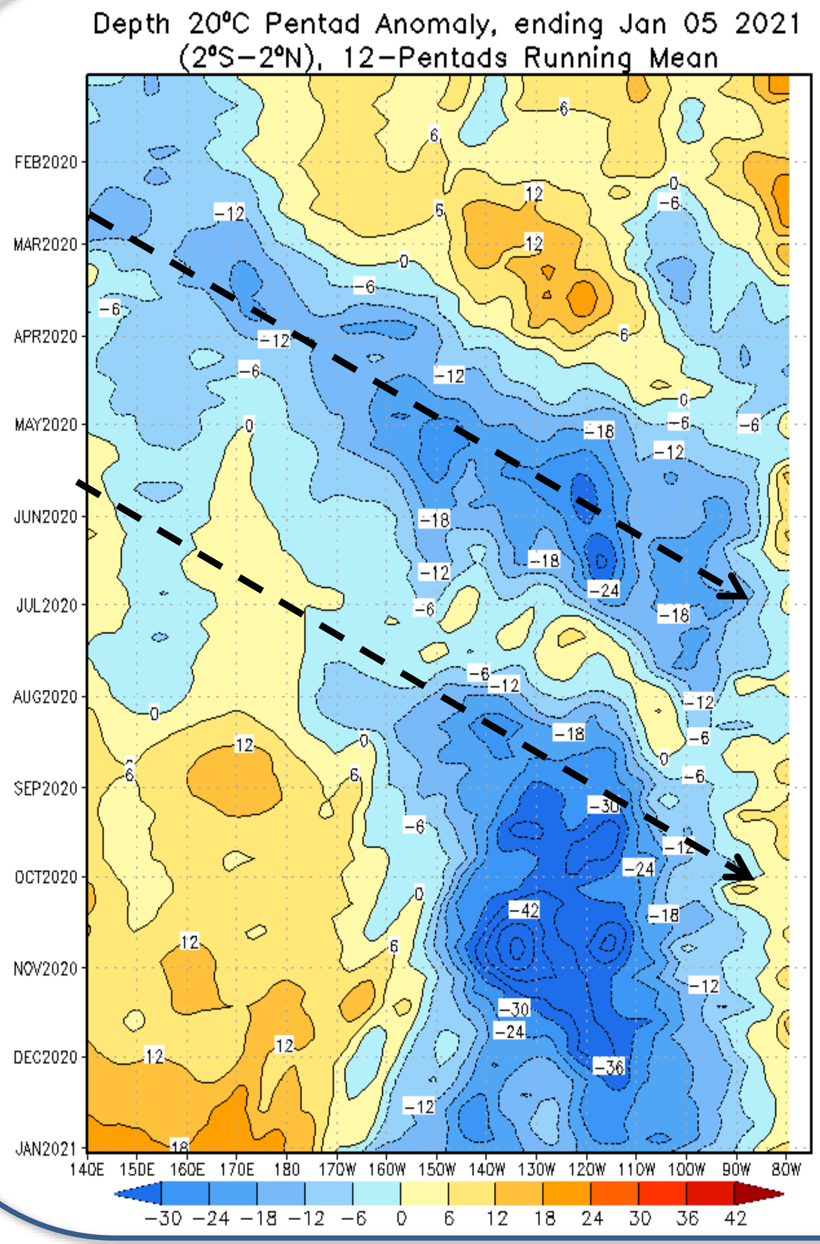


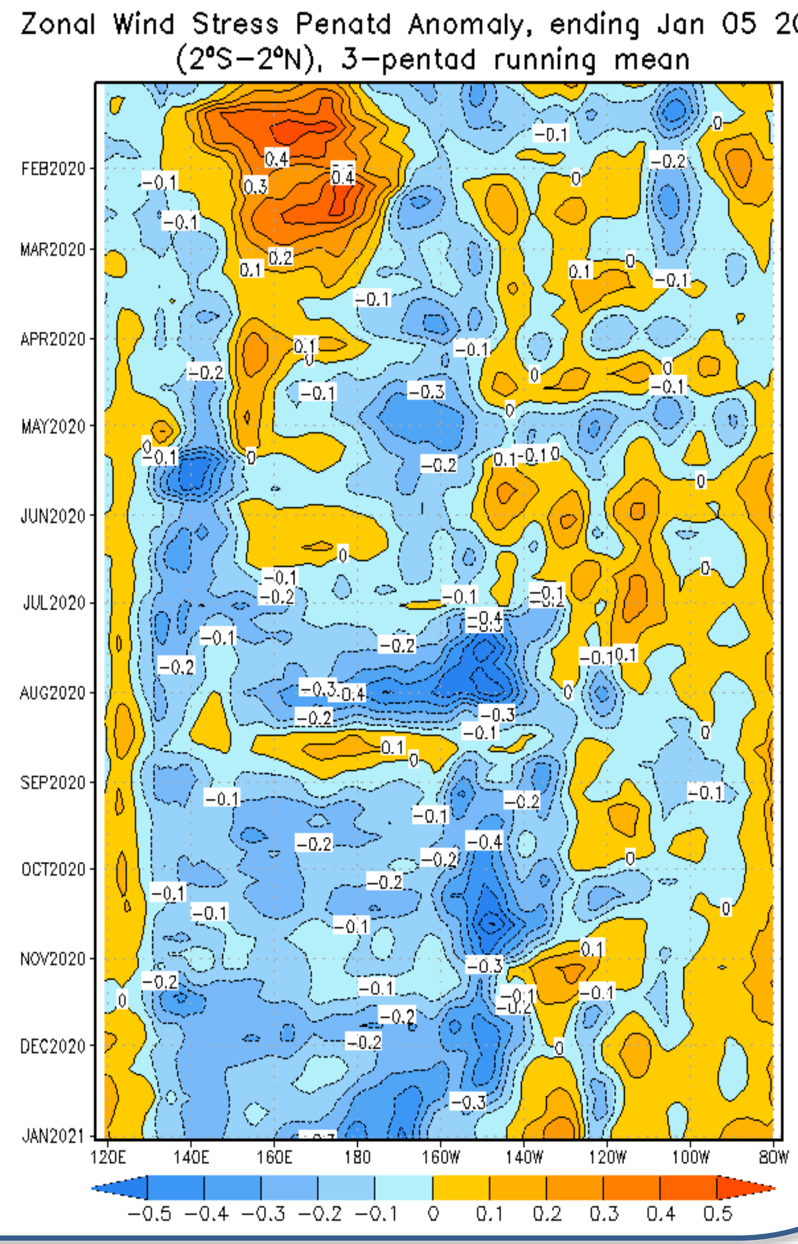




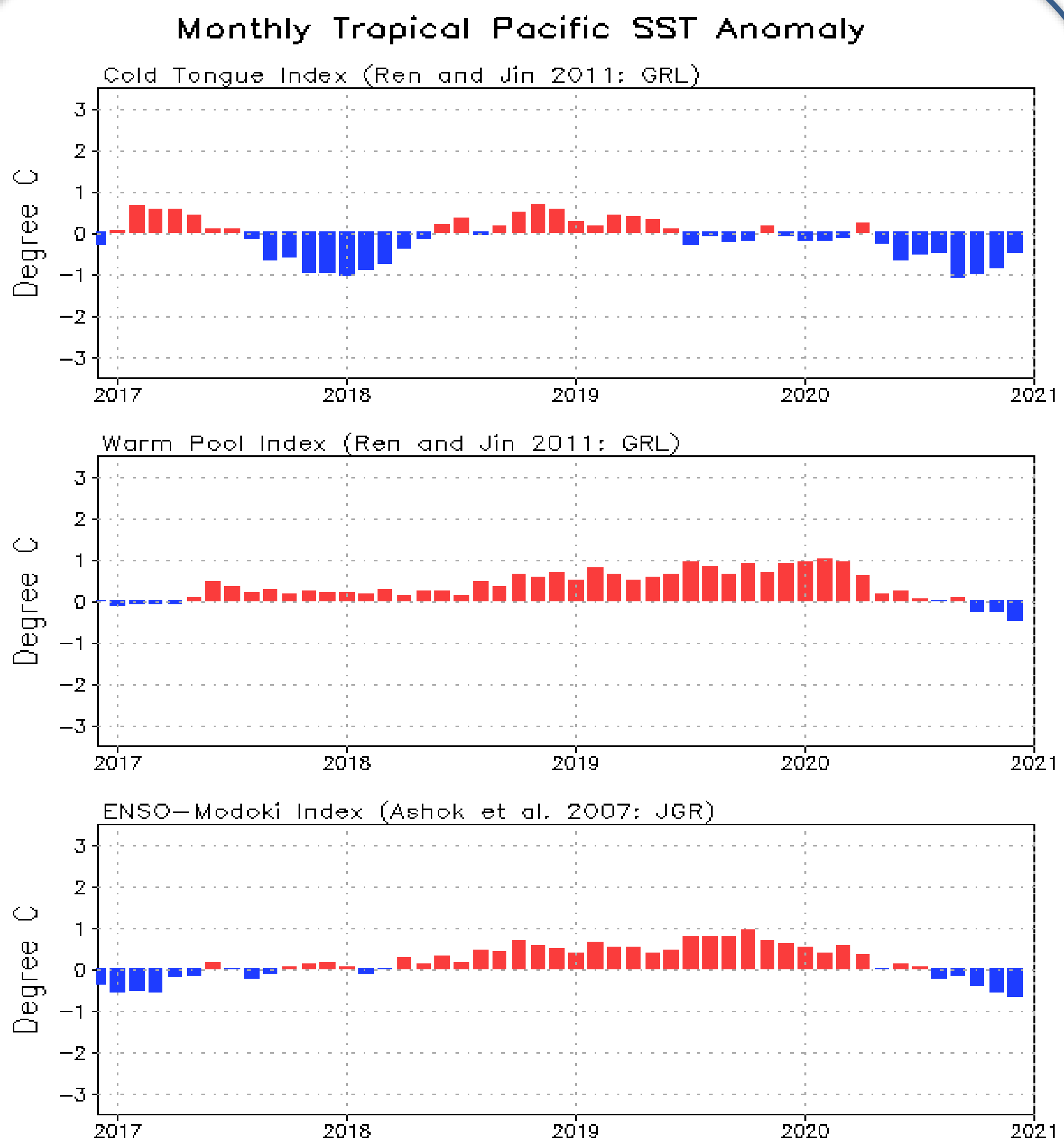
- The SSHA pattern was overall consistent with the HC300A pattern, but with a significant trend component in SSHA.
- Positive tendencies presented in the east-central equatorial Pacific.

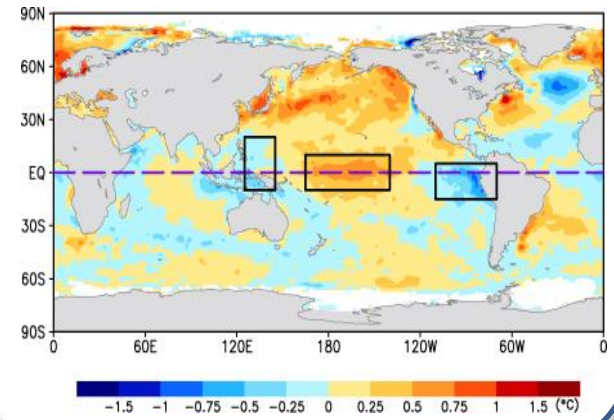
Evolution of Pentad D20 and Taux anomalies along the equator





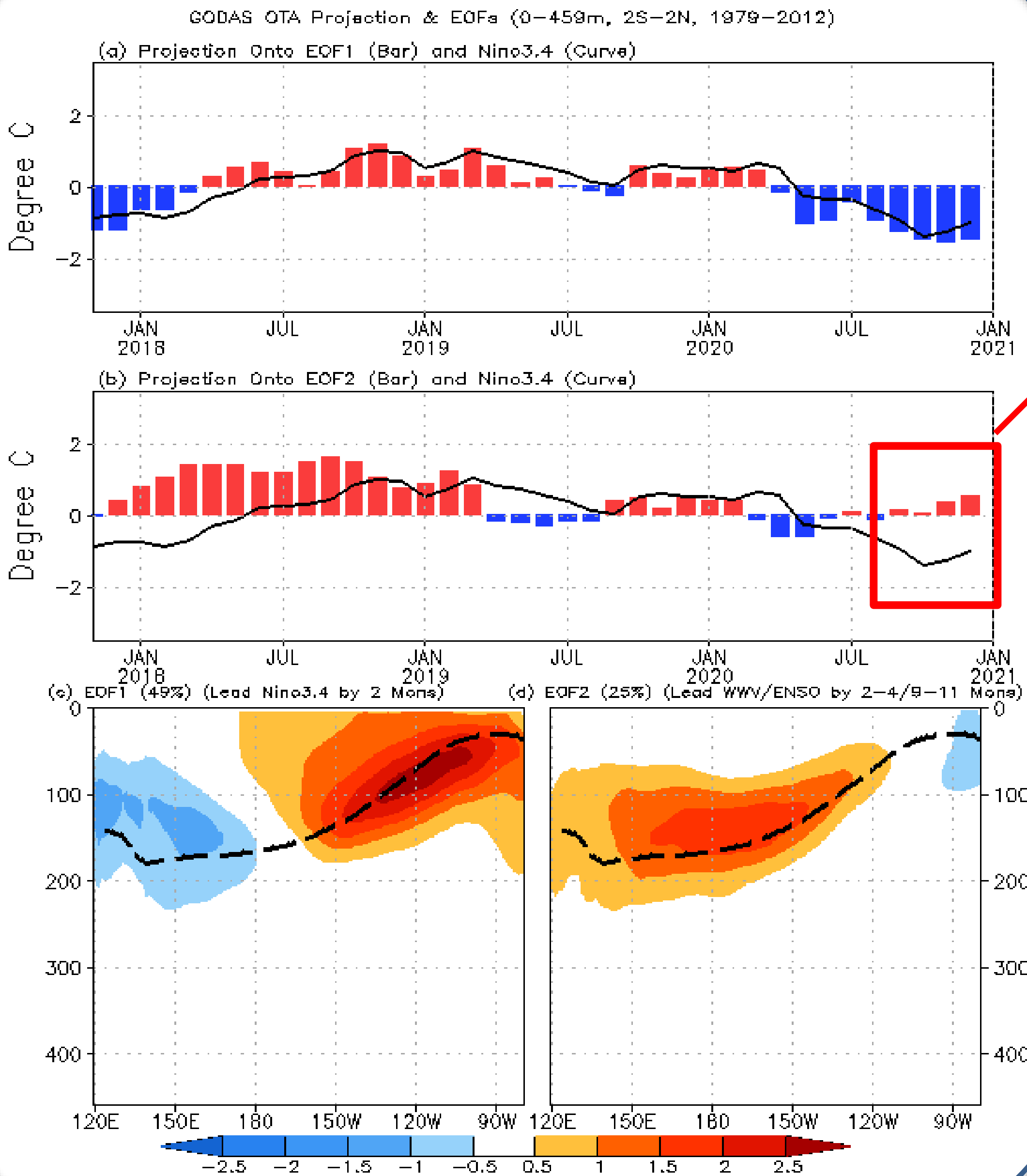
Monthly Tropical Pacific SST Anomaly





- The warm pool, cold tongue, ENSO-Modoki indices were negative in Dec 2020.

Equatorial Sub-surface Ocean Temperature Monitoring



- The equatorial Pacific switched to a recharge phase after Sep 2020, but it is weak.

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

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

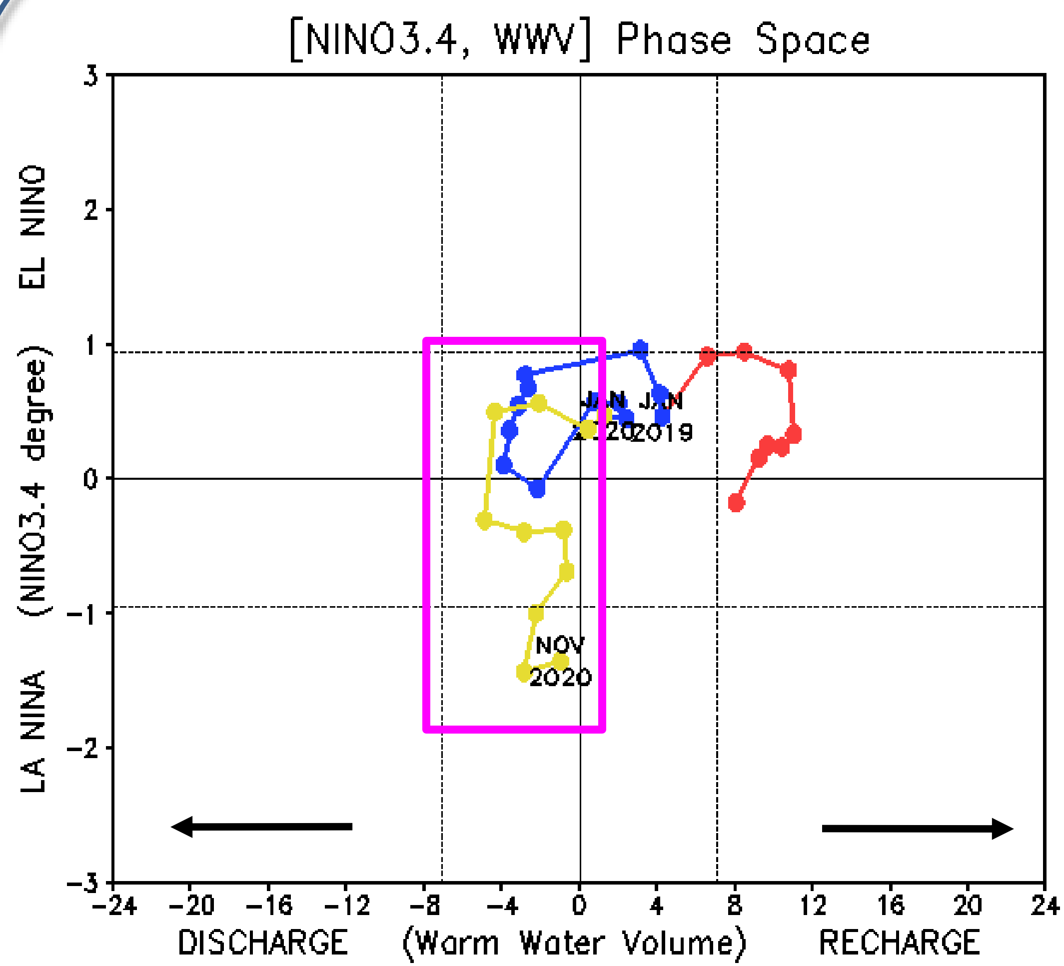
- For details, see: Kumar A, Z-Z Hu (2014) DOI: 10.1007/s00382-013-1721-0.

Warm Water Volume (WWV) and NINO3.4 Anomalies

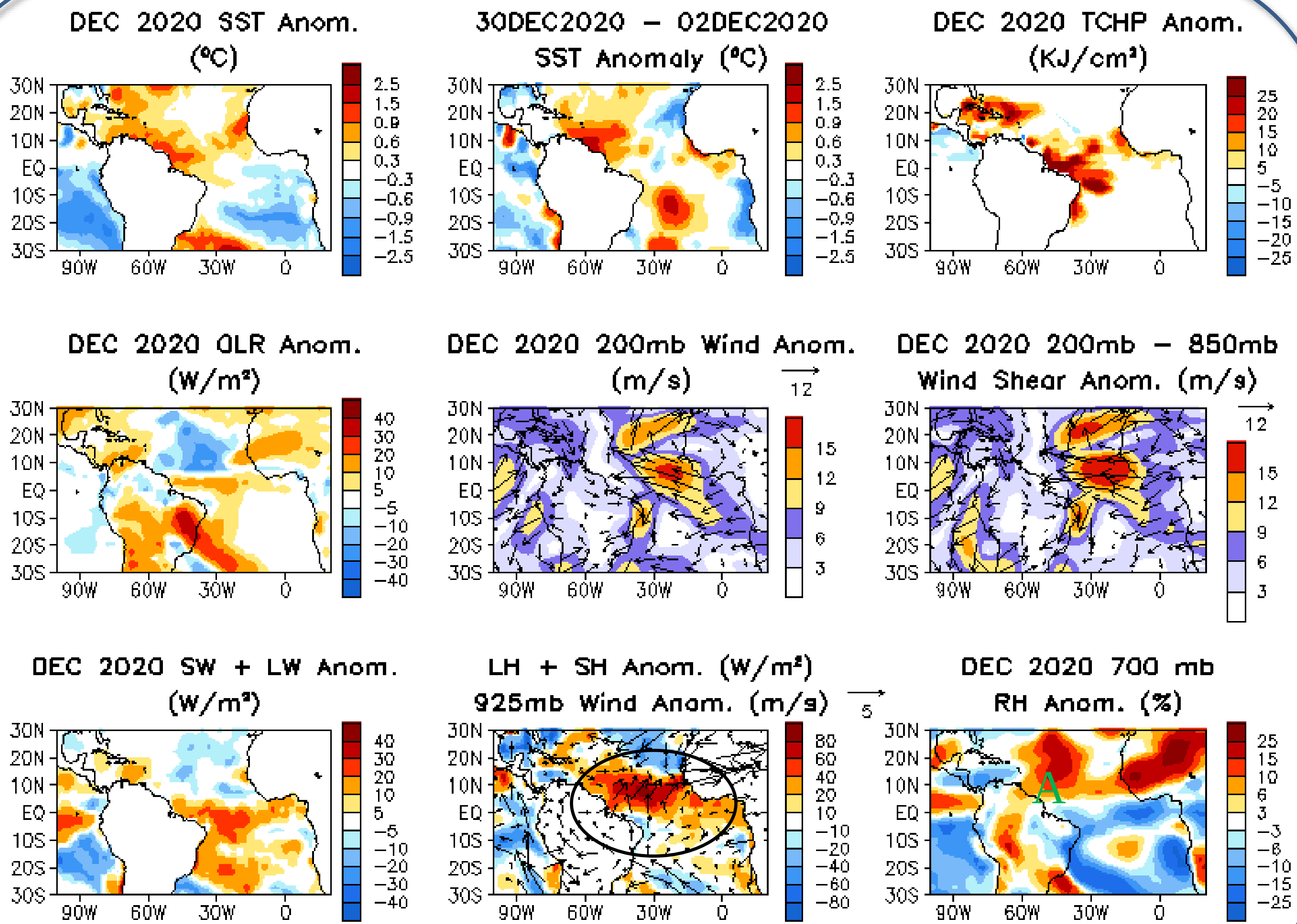
- Equatorial Warm Water Volume (WWV) has been in a discharge phase since Mar 2020.

-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).

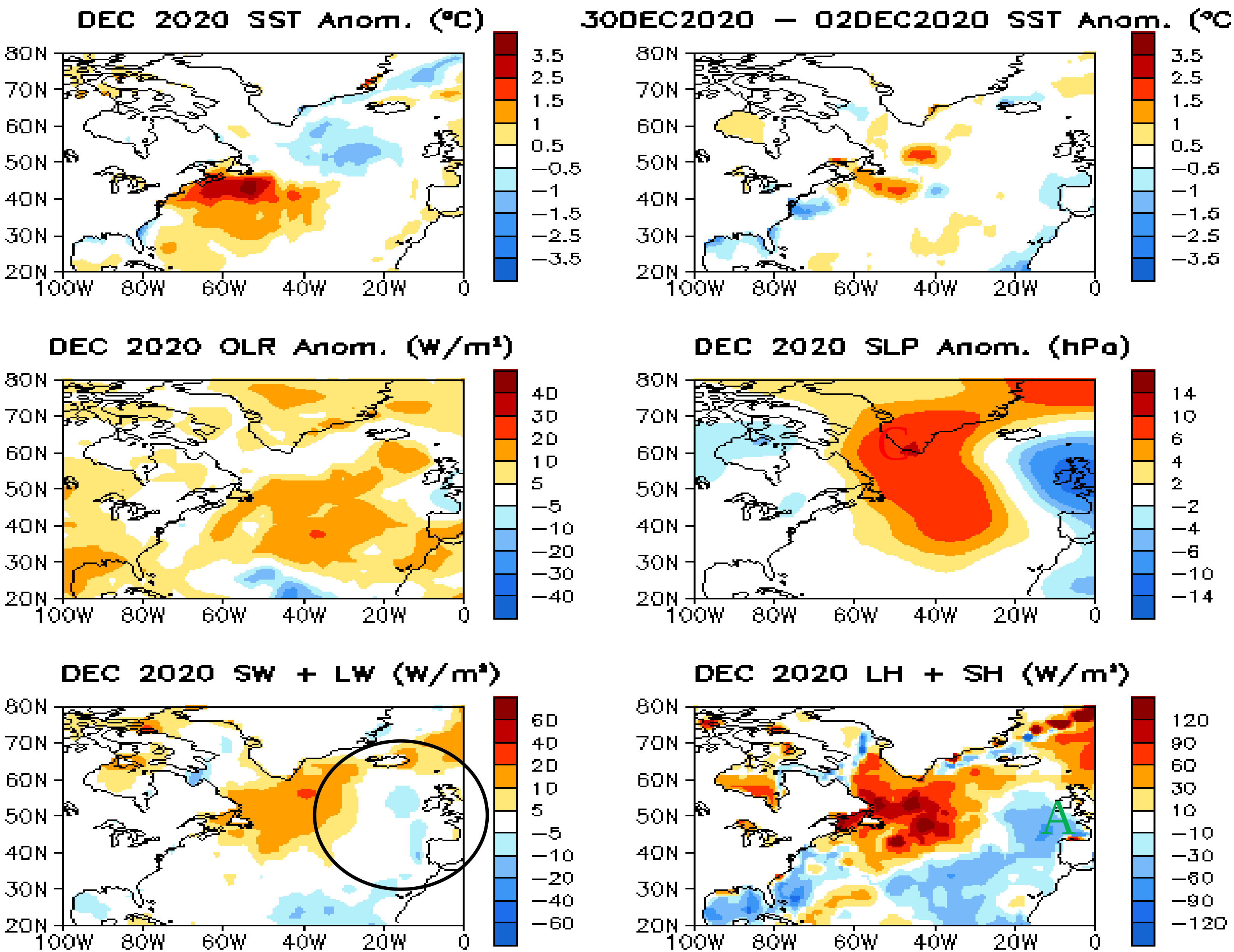
- Increase (decrease) of WWV indicates recharge (discharge) of the equatorial oceanic heat content.



Phase diagram of Warm Water Volume (WWV) and Nino3.4 indices. WWV is the average of depth of 20ºC in [120ºE-80ºW, 5ºS-5ºN] calculated with the NCEP's GODAS. Anomalies are departures from the 1981-2010 base period means.



DEC 2020 SST Anom. (°C)
30DEC2020 – 02DEC2020 SST Anomaly (°C)
DEC 2020 TCHP Anom. (KJ/cm²)
DEC 2020 OLR Anom. (W/m²)
DEC 2020 200mb Wind Anom. (m/s)
12
DEC 2020 200mb – 850mb Wind Shear Anom. (m/s)
12
DEC 2020 SW + LW Anom. (W/m²)
LH + SH Anom. (W/m²) 925mb Wind Anom. (m/s)
5
DEC 2020 700 mb RH Anom. (%)
A
30N 20N 10N EQ 10S 20S 30S
90W 60W 30W 0
2.5 1.5 0.9 0.6 0.3 −0.3 −0.6 −0.9 −1.5 −2.5
25 20 15 10 5 −5 −10 −15 −20 −25
40 30 20 10 5 −5 −10 −20 −30 −40
15 12 9 6 3
80 60 40 20 10 −10 −20 −40 −60 −80
25 15 10 6 3 −3 −6 −10 −15 −25


DEC 2020 SST Anom. (°C)
30DEC2020 – 02DEC2020 SST Anom. (°C)
3.5
2.5
1.5
1
0.5
−0.5
−1
−1.5
−2.5
−3.5
DEC 2020 OLR Anom. (W/m²)
40
30
20
10
5
−5
−10
−20
−30
−40
DEC 2020 SLP Anom. (hPa)
14
10
6
4
2
−2
−4
−6
−10
−14
C
DEC 2020 SW + LW (W/m²)
60
40
20
10
5
−5
−10
−20
−40
−60
DEC 2020 LH + SH (W/m²)
120
90
60
30
10
−10
−30
−60
−90
−120
A
80N
70N
60N
50N
40N
30N
20N
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80W
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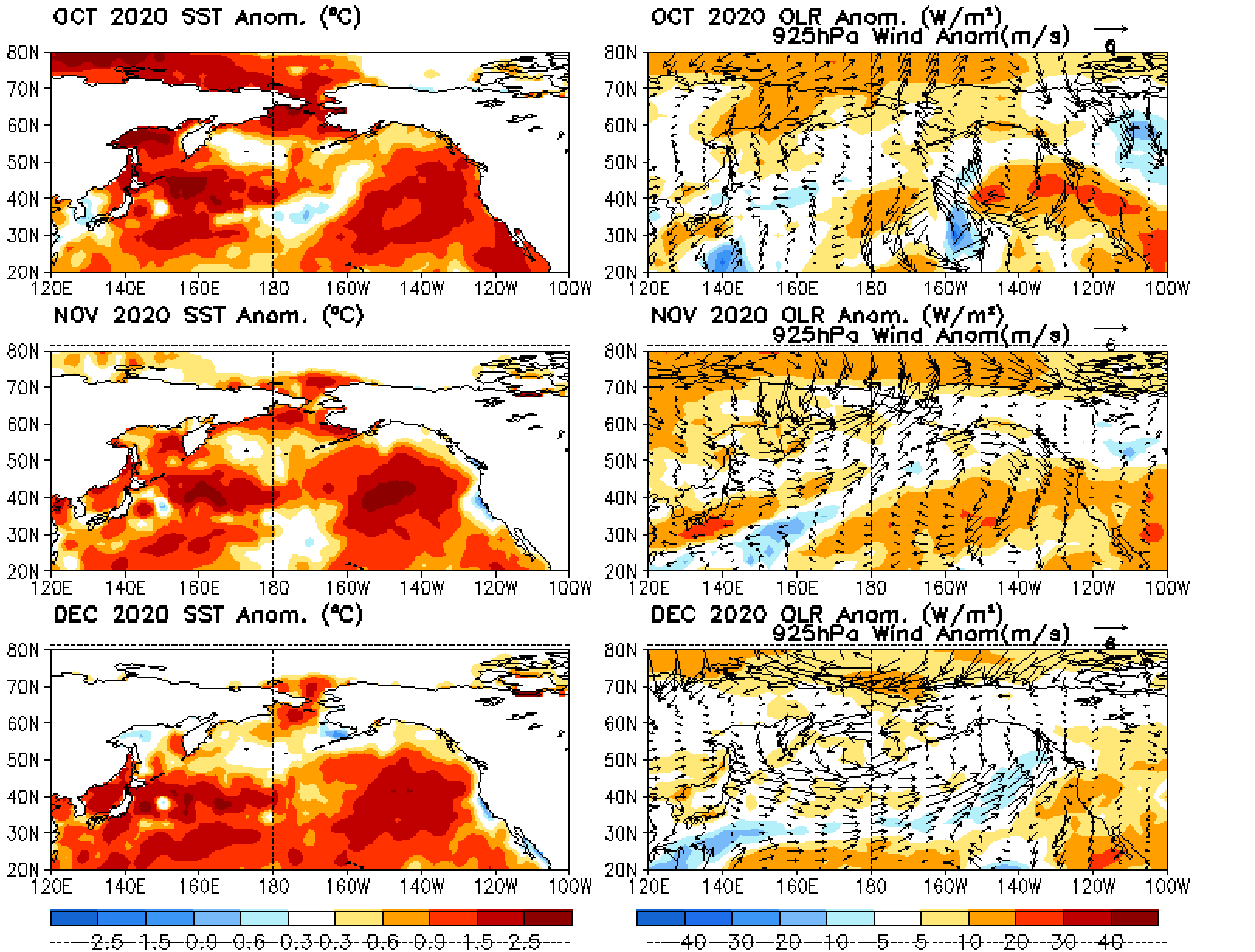
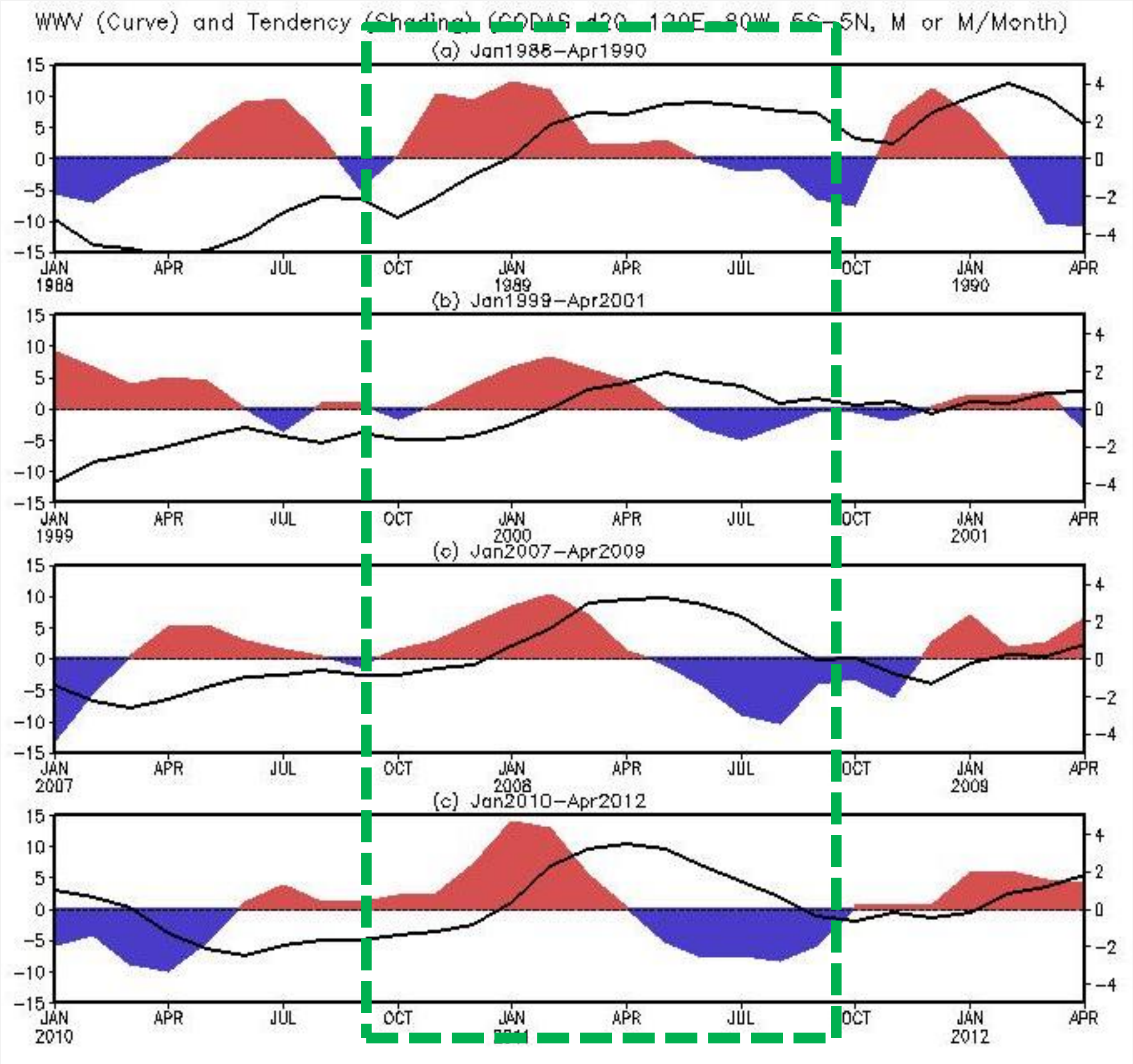
40W
20W
0

North Pacific SST, OLR, and uv925 anomalies





- **During/after a major La Nina, the recharge process is interrupted by the negative heat content off-the equator, due to the convergence from the off-equator to the equator.**
- **The interrupted recharge process prevents formation of El Nino, may lead to a follow-up La Nina developed.**

Hu, et al., 2014: Why were some La Niñas followed by another La Niña? Clim. Dyn. , 42 (3-4), 1029-1042. DOI: 10.1007/s00382-013-1917-3