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

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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 Ocean Observing and Monitoring Division (OOMD)
Outline

• Overview

• Recent highlights
  – Pacific/Arctic Ocean
  – Indian Ocean
  – Atlantic Ocean
  – Global SSTA Predictions

• Comparison of ENSO evolution in 2014/2016 and 2018/2019
• NOAA Atlantic and Eastern/Central Pacific Hurricane Outlooks
Overview

Pacific Ocean

- NOAA “ENSO Diagnostic Discussion” on 9 May 2019 continuously issued “El Nino Advisory” and indicated that “El Niño is likely to continue through the Northern Hemisphere summer 2019 (70% chance) and fall (55-60% chance).”

- El Nino conditions persisted. Positive SSTAs persisted in the central and eastern tropical Pacific with NINO3.4=0.71°C in May 2019.

- Positive (negative) subsurface ocean temperature anomalies were above (blow) the thermocline along the equatorial Pacific in May 2019.

- Positive SSTAs dominated in the N. Pacific in May 2019. The PDO index switched to positive phase since Mar 2019 with PDOI= 0.7 in May 2019.

Indian Ocean

- Positive (negative) SSTAs were in the west (east), and IOD was in a strong positive phase in May 2019.

Atlantic Ocean

- NAO switched into a negative phase with NAOI=-2.4 in May 2019, and SSTAs were a tripole/horseshoe pattern with positive anomalies in the middle latitudes of N. Atlantic during 2013-2019.

- NOAA's outlook for the 2019 Atlantic hurricane season indicates that a near-normal season has the highest chance of occurring (40%), followed by equal chances (30%) of an above-normal season and a below-normal season.
Global Oceans
Global SST Anomaly (°C) and Anomaly Tendency

Fig. G1. 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.

- Positive SSTAs persisted in the central and eastern tropical Pacific, consistent with El Nino conditions.
- Positive SSTAs dominated in the North Pacific.
- Horseshoe/tripole-like SSTA pattern was observed in the North Atlantic.
- In the Indian Ocean, SSTAs were positive in the west and negative in the east.

- Both positive and negative SSTA tendencies were observed in the tropical Pacific Ocean.
- SSTA tendencies in the Indian and Atlantic Oceans were mostly negative.
Longitude-Depth Temperature Anomaly and Anomaly Tendency in 2°S-2°N

- Positive (negative) ocean temperature anomalies presented above (blow) the thermocline along the equatorial Pacific.

- Anomalous ocean temperature tendency was negative in the Pacific Ocean, particularly in the east.
- Anomalous ocean temperature tendency was also negative in the Atlantic Ocean.

Fig. G3. Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP’s global ocean data assimilation system which assimilates oceanic observations into an oceanic GCM. Anomalies are departures from the 1981-2010 base period means.
- The SSHA pattern was overall consistent with the HC300A pattern, but there were many detailed differences between them.
- Both SSHA and HC300A in the tropical Pacific were consistent with El Nino conditions.
- Negative tendencies of SSHA and HC300A presented in the eastern tropical Pacific.
Tropical Pacific Ocean and ENSO Conditions
- Positive ocean temperature anomalies persisted during the last few months, while negative anomalies were mainly below the thermocline and in the western Pacific.

- The differences of the ocean temperature anomalies between GODAS and TAO were large in the eastern Pacific.
A downwelling Kelvin wave presented from Jan-Mar 2019, leading to increasing positive subsurface temperature anomalies in the eastern tropical Pacific.

A upwelling Kelvin wave initiated in late Jan 2019 and propagated eastward.

(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).)
Anomalous eastward (westward) currents persisted in the western (eastern) Pacific during the last 2 months in both OSCAR and GODAS.

- The anomalous currents showed some differences between OSCAR and GODAS both in the anomalies and climatologies.
- Positive SSTA in the central and eastern Pacific persisted in the last month.
- Positive HC300A propagated eastward in Mar 2019, and low-level westerly wind bursts were observed in Feb-Mar, and May 2019.
Warm Water Volume (WWV) and NINO3.4 Anomalies

- WWV is defined as average of depth of 20°C in [120°E-80°W, 5°S-5°N]. Statistically, peak correlation of Nino3 with WWV occurs at 7 month lag (Meinen and McPhaden, 2000).

- Since 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.

- Equatorial Warm Water Volume (WWV) switched to a discharged phase since Apr 2019.

Fig. P3. Phase diagram of Warm Water Volume (WWV) and NINO 3.4 SST anomalies. WWV is the average of depth of 20°C in [120°E-80°W, 5°S-5°N] calculated with the NCEP's global ocean data assimilation system. Anomalies are departures from the 1981-2010 base period means.
Equatorial subsurface ocean temperature monitoring: ENSO was in a discharged phase in May 2019.

Projection of OTA onto EOF1 and EOF2 (2S-2N, 0-459m, 1979-2010)

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

Discharge process: heat transport from equator to outside of equator: Positive -> Negative phase of ENSO

For details, see: Kumar A, Z-Z Hu (2014) Interannual and interdecadal variability of ocean temperature along the equatorial Pacific in conjunction with ENSO. Clim. Dyn., 42 (5-6), 1243-1258. DOI: 10.1007/s00382-013-1721-0.
Evolution of Pacific NINO SST Indices

- Nino3 and Nino3.4 slightly weakened, and Nino4 and Nino1+2 slightly strengthened in May 2019.
- Nino3.4 = 0.71°C in May 2019.
- Compared with last May, the central and eastern equatorial Pacific was much warmer in May 2019.
- The indices were calculated based on OISST. They may have some differences compared with those based on ERSST.v5.

Fig. P1a. 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.
Positive SSTAs were larger in the warm pool than in the cold tongue, so the 2018/19 event is CP or CP/EP mixed type El Nino.

Qu: Zonal advection;  Qv: Meridional advection;  Qw: Vertical entrainment; Qzz: Vertical diffusion
Qq: \((Q_{\text{net}} - Q_{\text{pen}} + Q_{\text{corr}})/\rho_{\text{cph}}\); \(Q_{\text{net}} = \text{SW} + \text{LW} + \text{LH} + \text{SH}\);
Qpen: SW penetration; Qcorr: Flux correction due to relaxation to OI SST

- Observed SSTA tendency \((d\text{SSTA}/dt; \text{bar})\) was positive in last 2 pentads, and total heat budget (RHS; black line) was negative since mid-Mar 2019.

- Dynamical terms \((Qu, Qv, Qw+Qzz)\) were small and heat-flux term \((Qq)\) were negative in May 2019.
Fig. P2. 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), 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.
North Pacific & Arctic Oceans
PDO index

The PDO index switched to positive phase since Mar 2019 with PDOI = 0.7 in May 2019.

Statistically, ENSO leads PDO by 3-4 months, may through atmospheric bridge.

During the last 1~2 years, ENSO and PDO seem disconnected.

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

Fig. NP1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible heat flux anomalies (bottom-right).

SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, sea surface pressure and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1981-2010 base period means.
North America Western Coastal Upwelling

Monthly Coastal Upwelling for West Coast North America (m$^3$/s/100m coastline)

- Anomalous upwelling was dominated north of 39N since Jan 2019.

Fig. NP2. Total (top) and anomalous (bottom) upwelling indices at the 15 standard locations for the western coast of North America. Upwelling indices are derived from the vertical velocity of the NCEP’s global ocean data assimilation system, 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 36°N to 57°N.
- Arctic sea ice extent was below the normal in 2019.
- At the end of May, Arctic sea ice daily extent stood at second lowest in the 40-year satellite record.
Indian Ocean
Evolution of Indian Ocean SST Indices

Fig. I1a. Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) 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.

- Positive (negative) SSTAs were in the west (east), and IOD was in a strong positive phase in May 2019.
SSTAs were positive in the west and negative in the east.

- SSTA tendency seems largely driven by heat flux.

- Convections were suppressed over the eastern Indian Ocean.

Fig. I2. 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), 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

Fig. A1a. Tropical Atlantic Variability region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the TNA [60°W-30°W, 5°N-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:

- MAY 2019 SST Anom. (°C)
- 29MAY2019 – 01MAY2019 SST Anomaly (°C)
- MAY 2019 TCHP Anom. (KJ/cm²)

- MAY 2019 OLR Anom. (W/m²)
- MAY 2019 200mb Wind Anom. (m/s)
- MAY 2019 200mb – 850mb Wind Shear Anom. (m/s)

- MAY 2019 SW + LW Anom. (W/m²)
- LH + SH Anom. (W/m²)
- MAY 2019 700 mb RH Anom. (%)
NAO and SST Anomaly in North Atlantic

Fig. NA2. Monthly standardized NAO index (top) derived from monthly standardized 500-mb height anomalies obtained from the NCEP CDAS in 20ºN-90ºN (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.

- NAO switched to a negative phase with NAOI= -2.4 in May 2019.
- SSTA was a tripole/horseshoe-like pattern with positive in the mid-latitudes and negative in the lower and higher latitudes, due to the long-term persistence of a positive phase of NAO.
NOAA's outlook for the 2019 Atlantic hurricane season indicates that a near-normal season has the highest chance of occurring (40%), followed by equal chances (30%) of an above-normal season and a below-normal season.
NOAA’s 2019 Hurricane Season Outlooks

Central Pacific
5-8 Tropical Cyclones
Average is 4-5 TCs

Eastern Pacific
Above-normal season (70%)
15-22 Named Storms
8-13 Hurricanes
4-8 Major Hurricanes
100%-180% Median ACE
Averages are 15 NS, 8 H, 4 MH

Atlantic
Near-normal season most likely
9-15 Named Storms
4-8 Hurricanes
2-4 Major Hurricanes
65%-140% Median ACE
Averages are 12 NS, 6 H, 3 MH

For 2019 the probabilities of each season type are:

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<th>Atlantic</th>
<th>Eastern Pacific</th>
<th>Central Pacific</th>
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<tbody>
<tr>
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<td>30%</td>
<td>70%</td>
<td>70%</td>
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<tr>
<td>Normal</td>
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<tr>
<td>Below Normal</td>
<td>30%</td>
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- Accumulated Cyclone Energy (ACE) measures the overall strength of the hurricane season.
- Tropical Cyclones (TCs) include tropical depressions, tropical storms and hurricanes.

https://www.cpc.ncep.noaa.gov/products/outlooks/Slide1.JPG
Reasoning behind the outlook

NOAA's 2019 Atlantic hurricane season outlook reflects three competing factors:

1) **Unfavorable due to El Niño:** The likely continuation of El Niño during the peak months (ASO) of the hurricane season. El Niño typically suppresses Atlantic hurricane activity by causing increased vertical wind shear, anomalous sinking motion, and increased atmospheric stability across the western MDR (i.e., mainly the Caribbean Sea) (Gray 1984).

2) **Favorable due to +SSTA in MDR:** Competing with the possible suppressing influence of El Niño this year is the expectation of above-average SSTs in the MDR. Nearly all climate models predict SSTs to be above average in this region during ASO, with most predicting departures of +0.2°C to +0.4°C. These predictions are consistent with the warm phase of the AMO, which has persisted during the ASO season since 1995 and has favored more active hurricane seasons.

3) **Favorable due to weaker trade wind and enhanced west African Monsoon and warm phase of AMO:** Also competing with El Niño this season is the expectation for weaker trade winds in the eastern portion of the MDR, along with an enhanced West African monsoon. These conditions favor more active hurricane seasons, and are also typical of the warm AMO phase.

https://www.cpc.ncep.noaa.gov/products/outlooks/hurricane.shtml
ENSO and Global SST Predictions
- Majority of models predict continuation of El Nino with ICs in May 2019.

- NOAA “ENSO Diagnostic Discussion” on 9 May 2019 continuously issued “El Nino Advisory” and indicated that “El Niño is likely to continue through the Northern Hemisphere summer 2019 (70% chance) and fall (55-60% chance).”
Individual Model Forecasts: Neutral or Weak El Nino

**EC: Nino3.4, IC=01Jun 2019**

**JMA: Nino3, Updated 10 Jun 2019**

**Australia: Nino3.4, Updated 8Jun 2019**

**UKMO: Nino3.4, Updated 11Jun 2019**
CFS Niño3.4 SST Predictions from Different Initial Months

NINO3.4 SST anomalies (K)

- CFSv2 predicted a decline of positive SSTAs with ICs since Mar 2019.
- The latest forecasts call for ENSO neutral since late-summer 2019.

Fig. M1. 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 1981-2010 base period means.
For historical purposes, periods of below and above normal SSTs are colored in blue and red when the threshold is met for a minimum of 5 consecutive overlapping seasons. The Oceanic Nino Index is one measure of the ENSO, and other indices can confirm whether features consistent with a coupled ocean-atmosphere phenomenon accompanied these periods.

https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php
Nino3.4 Evolution In El Nino Years

Provided by Yan Xue
SST Anomalies along the Equator

SSTA: Olv2 (Shading) & ERSSTv5 (Contour)
(a) Mar2018~Jun2020
(b) Mar2014~Jun2016
D20 Anomalies along the Equator

D20A: CFSR (Contour) & GODAS (Shading)

(a) Mar2018~Jun2020

(b) Mar2014~Jun2016
CFS Tropical North Atlantic (TNA) SST Predictions from Different Initial Months

Tropical N. Atlantic SST anomalies (K)

- Predictions had warm biases for ICs in Sep 2018-Feb 2019.
- Latest CFSv2 predictions call above normal SSTA in the tropical N. Atlantic in summer-autumn 2019, corresponding to the lag impact of the El Nino.

Fig. M3. 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.
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.

- CFSv2 predicts a neutral phase of PDO in 2019.

Fig. M4. 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.
NCEP CFS DMI SST Predictions from Different Initial Months

Indian Ocean Dipole SST anomalies (K)

IC=Sep2018  IC=Dec2018  IC=Mar2019
IC=Oct2018  IC=Jan2019  IC=Apr2019
IC=Nov2018  IC=Feb2019  IC=May2019

Latest CFSv2 predictions call decline of the positive phase of IOD in 2019.

Fig. M2. 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.
Acknowledgements

• Drs. Caihong Wen, Yan Xue, and Arun Kumar: reviewed PPT, and provide insight and constructive suggestions and comments

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

• Dr. Emily Becker provided the NMME NINO3.4 plot

• Dr. Wanqiu Wang maintained the CFSv2 forecast achieve
Backup Slides
Global Sea Surface Salinity (SSS) Anomaly for May 2019

- New Update: The input satellite sea surface salinity of SMAP from NSAS/JPL was changed from Version 4.0 to Near Real Time product in August 2018.
- Attention: There is no SMAP SSS available in July 2018
- In the equatorial Pacific ITCZ region, negative SSS anomalies are persistent and co-incident with increased precipitation. Negative SSS anomalies also appear in the equatorial Pacific SPCZ region. A significant negative SSS signal showed in the eastern Equatorial pacific region. A large scale of negative SSS signal in the Northeast pacific region continues, which is accompanied with heavier precipitation in some regions. Meanwhile, in the Sea of Okhotsk, negative SSS anomalies is co-incident with increased precipitation.

- **Data used**
  SSS: Blended Analysis of Surface Salinity (BASS) V0.2
  (a CPC-NESDIS/NODC-NESDIS/STAR joint effort)
  (Xie et al. 2014)
  [ftp.cpc.ncep.noaa.gov/precip/BASS](ftp.cpc.ncep.noaa.gov/precip/BASS)
  Precipitation: CMORPH adjusted satellite precipitation estimates
  Evaporation: Adjusted CFS Reanalysis
Compared with last month, the SSS decreased in the Equatorial Pacific region, particularly the eastern basin. Such SSS decreasing is likely caused by increasing precipitation. The SSS continues increasing between equator and 40°N in both Pacific and Atlantic ocean, particularly in the east basin. The SSS significantly decreases in the Sea of Okhotsk, which is likely caused by 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 positive SSS signal becomes weaker or neutral from 140°E to 160°E, the SSS shows negative anomalies east of 160°E and the negative signal is stronger between 160°E and dateline.
Global Sea Surface Salinity (SSS)
Anomaly Evolution over N. of Equatorial Pacific from Pentad SSS

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.
SSS Anom. in [160E-160W, 5S-5N] (PSU), Levitus Clim
GODAS (dash black), CFSR (dash purple), BASS (solid black)
IPRC (red), SCRIPPS (green), EN4.2.1 (blue)

1979–present

Last 4 years

North Atlantic: SST Anom., SST Anom. Tend., OLR, SLP, Sfc Rad, Sfc Flx

Fig. NA1. Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sea surface pressure anomalies (middle-right), sum of net surface short- and long-wave radiation anomalies (bottom-left), sum of latent and sensible heat flux anomalies (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, sea surface pressure and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1981-2010 base period means.
H300A: TAO, GODAS, CFSR

Ocean Temperature Anomaly (0–300m, 2S–2N, Climatology: 1993–2018)
Data Sources and References
(climatology is for 1981-2010)

- Weekly Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)
- Extended Reconstructed Sea Surface Temperature (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
- NCEP’s Global Ocean Data Assimilation System 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 reanalyses from Real-time 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

Please send your comments and suggestions to Yan.Xue@noaa.gov. Thanks!