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
  – Will a strong La Niña develop during winter 2020-21?
  – North Atlantic Hurricane season and oceanic conditions
  – Global Marine Heatwave Monitoring
• **Pacific Ocean**
  – La Niña conditions continued in Sep 2020.
  – NOAA “ENSO Diagnostic Discussion” on 8 Oct 2020 states that “La Niña conditions are likely to continue through the Northern Hemisphere winter (~85% chance)”.
  – Marine Heat Waves (MHWs) emerged near the west coast of United States.
  – Negative PDO phase continued, with PDOI = -0.8.
• **Indian Ocean**
  – Negative Indian Ocean Dipole index strengthened in Sep 2020.
• **Atlantic Ocean**
  – Sep 2020 was the most active month on record.
  – Strong warming near the Atlantic warm pool continued in Sep 2020.
• **Arctic Ocean**
  – The sea ice extent in Sep 2020 was ranked as the 2nd lowest since 1979.
  – MHWs persisted north of Eurasia.
Global Oceans
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.

- Negative SSTA strengthened in the central-eastern equatorial Pacific.
- Strong positive SSTAs continued in the NE Pacific and Northern Hemispheric subpolar regions.
- Positive SSTAs persisted in the tropical Indian Ocean and the western tropical Pacific.

- Negative SSTA tendencies dominated in the tropical oceans.
- Large SSTA tendencies presented in the high-latitude of North Pacific.
MHWs were active in subarctic regions north of Eurasia and mid-latitude of North Pacific. (Left panel) Monthly SST anomaly (shaded) and locations experience Marine heat waves (hatched) by the date labelled in the plot. (right panel) SST evolution at a specific location. Green line and blue line denote the seasonal 90th percentile and daily climatology, respectively. Shaded area denotes the periods experiencing MHW. MHW is defined as a discrete prolonged warmer than 90th percentile of daily SST for at least 14 days. Data is derived from NCEI OISSTv2.1 and the climatology reference period is 1982-2010.
Ocean temperature reached more than 4°C cooler than average near the thermocline in the eastern Pacific Ocean.

Positive temperature anomalies continued in the upper equatorial Indian and the western Pacific Oceans.

Negative temperature anomaly presented in the eastern Atlantic Ocean.

Negative(positive) temperature anomaly tendency presented in the eastern Pacific (western-central Pacific).

Negative temperature anomaly tendency dominated in the Indian Ocean.
Tropical Pacific Ocean and ENSO Conditions
Most of NINO regions cooled further in Sep 2020, with NINO3.4 = -0.95°C. Compared with Sep 2019, the central and eastern (far western) equatorial Pacific was cooler (warmer) in Sep 2020. The indices may have slight differences if based on different SST products.

- Most of NINO regions cooled further in Sep 2020, with NINO3.4 = -0.95°C.
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- 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.
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 in to 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.
Anomalous Depth (m) of 20°C Isotherm: SEP 2020

(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html)
Real-Time Ocean Reanalysis Intercomparison: Equatorial Temperature Anomaly

(http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html)
- Negative SSTA strengthened in the central-eastern Pacific in Sep 2020, consistent with the persistent negative subsurface temperature anomalies.
- Low-level zonal wind anomalies were easterly across most of Pacific during Sep 2020.
Positive (negative) SSS anomaly presented east (west) of 140E during 2010, 2011, 2016, 2017 La Nina events.

- Strong positive SSS anomaly persisted around 140E-170W in Sep 2020.

Sea surface salinity (SSS) anomalies are derived from Blended Analysis of Surface Salinity (BASS) V0.Z (Xie et al. 2014). Since June 2015, the BASS SSS is from in situ, SMOS and SMAP; before June 2015, the BASS SSS is from in situ, SMOS and Aquarius. Data is available at ftp.cpc.ncep.noaa.gov/precip/BAS.
Anomalous westward currents dominated the equatorial Pacific Ocean, favoring further SST cooling.
North Pacific & Arctic Oceans
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.
Last Three Month SST, SST tendency and Net heat flux anomalies

Data source: NCEP/NCAR Reanalysis 1
- Weather circulation played an important role in modulating net heat flux anomaly and hence SST anomaly tendency.
- Southerly wind anomaly along the west coast of N. America favors downwelling.
North America Western Coastal Upwelling

(top) Total and (bottom) anomalous upwelling indices at the 15 standard locations for the western coast of North America. Derived from the vertical velocity of the NCEP’s GODAS and are calculated as integrated vertical volume transport at 50-meter depth from each location to its nearest coast point (m³/s/100m coastline). Anomalies are departures from the 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.

Weekly SST anomaly and MHWs in the North Pacific

(Left panel) Weekly SST anomaly (shaded) and locations experience Marine heat waves (Hatched) by the date labelled in the plot. (right panel) SST evolution at a specific location. Green line and blue line denote the seasonal 90th percentile and daily climatology, respectively. Shaded area denotes the periods experiencing MHW. MHW is defined as a discrete prolonged warmer than 90th percentile of daily SST for at least 14 days. Data is derived from NCEI OISSTv2.1 and the climatology reference period is 1982-2010.

- MHWs emerged near west coast of United States.
- MHWs persisted near the Bering Sea and East Siberian Sea since late Aug 2020.
Subsurface Temperature Anomaly in the NE Pacific

Anomalous Temperature (°C) in [150W–125W, 28N–50N]
Black Line: Mixed Layer Depth (m)

- Positive subsurface temperature anomaly confined within a shallow mixed layer in Sep 2020.
Two Oceanic PDO indices

SST-based PDO (Wen et al. 2014: GRL)


- Negative SST-based PDO index continued in Sep 2020, with PDO index= -0.8.

- Negative H300-based PDO index has persisted 48 months since Nov 2016, with HPDO = -1.4 in Sep 2020.

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

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

SST-based PDO is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly ERSSTv5 SST anomalies onto the 1st EOF pattern. H300-based Pacific Decadal Oscillation is defined as the projection of monthly mean H300 anomalies from NCEP GODAS onto their first EOF vector in the North Pacific. PDO indices are downloadable from https://www.cpc.ncep.noaa.gov/products/GODAS/ocean_briefing.shtml.
- Arctic sea ice extent was well below normal in Sep 2020.
- The monthly average extent for Sep 2020 is 3.92 million square kilometers, ranking the second lowest since satellite observations in 1979.
Indian Ocean
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.

- Negative Dipole index increased slightly in Sep 2020.
- Positive SSTA dominated the tropical Indian Ocean.

- Convection was enhanced over the northern tropical 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

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.

- TNA, TSA and Atl3 indices cooled down in Sep 2020.
- The Index representing the Atlantic Meridional Mode enhanced slightly in Sep 2020.
2020 Atlantic Hurricane Season Activities

- With 10 storms, Sep 2020 was the most active month on record in the Atlantic.
- Twenty-five tropical storms with nine developing into hurricane and three becoming major hurricane by Oct 7.
- 12 out of 25 tropical storms were formed either Gulf of Mexico or extratropics.

https://en.wikipedia.org/wiki/2020_Atlantic_hurricane_season

<table>
<thead>
<tr>
<th>Atlantic</th>
<th>Observations (By Oct 7)</th>
<th>Outlook (Aug. 6) 85% above-normal</th>
<th>Outlook (May 21) 60% above-normal</th>
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<td>Total storms</td>
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<td>Major hurricanes</td>
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<td>3-6</td>
<td>3-6</td>
<td>3</td>
</tr>
</tbody>
</table>
- MHWs near the Gulf of stream and the Baffin Bay retreated since the late September.
- Weakened MHW along the east coast of N. America was associated with Hurricane Teddy.

Weekly SST anomaly (shaded) and locations experience Marine heat waves (Hatched) by the date labelled in the plot. MHW is defined as a discrete prolonged warmer than 90th percentile of daily SST for at least 14 days. Data is derived from NCEI OISSTv2.1 and the climatology reference period is 1982-2010.
Real-Time Ocean Reanalysis Intercomparison: Tropical Cyclone Heat Potential Anomaly

-2020 TCHP anomaly (JAS) averaged in Gulf of Mexico and western North Atlantic region ranked the second largest since 1993.

https://www.cpc.ncep.noaa.gov/products/GODAS/muji93_body.html
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 80°W and 20°W (bottom). SST are derived from the NCEP OI SST analysis, and anomalies are departures from the 1981-2010 base period means.

- Positive NAO strengthened substantially in Sep 2020, with NAOI= 1.11.
ENSO and Global SST Predictions
CFSv2 and NMME SST predictions

CFSv2 IC: Oct for 2020 Nov

NMME IC: Oct for 2020 Nov

[Map of CFSv2 SST anomalies]

https://www.cpc.ncep.noaa.gov/products/CFSv2/CFSv2seasonal.shtml

[Map of NMME SST anomalies]

(https://www.cpc.ncep.noaa.gov/products/NMME/)
- A Majority of the models predict the continuation of La Niña through the Northern Hemisphere winter 2020-21.
- NOAA “ENSO Diagnostics Discussion” on 8 Oct stated that “La Niña conditions are likely to continue through the Northern Hemisphere winter (~85% chance) and into spring (~60% chance during February-April)”. 
NINO Indices Evolution in La Niña Years

Weak La Niña (-0.5°C~0.9°C): 1983, 1995, 2008, 2016, 2017
Moderate (-1°C~1.4°C): 1984, 2011,
Current La Niña Condition Compared with Historical Strong Events

- 1998
- 2007
- 2010
- 2020

SEP 1998 SST Anom. (°C)
SEP 2007 SST Anom. (°C)
SEP 2010 SST Anom. (°C)
SEP 2020 SST Anom. (°C)

SEP 1998 OLR Anom. (W/m²)
SEP 2007 OLR Anom. (W/m²)
SEP 2010 OLR Anom. (W/m²)
SEP 2020 OLR Anom. (W/m²)

SEP 1998 D20 Anom. (m)
SEP 2007 D20 Anom. (m)
SEP 2010 D20 Anom. (m)
SEP 2020 D20 Anom. (m)

925hPa Wind Anom. (m/s)
925hPa Wind Anom. (m/s)
925hPa Wind Anom. (m/s)
925hPa Wind Anom. (m/s)
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].

Latest CFSv2 predictions suggest DMI will be near normal in the coming months.
Drs. Zeng-Zhen Hu, Jieshun Zhu, 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

Please send your comments and suggestions to:
Zeng-Zhen.Hu@noaa.gov
Arun.Kumar@noaa.gov
Caihong.Wen@noaa.gov
Jieshun.Zhu@noaa.gov
Weekly Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)
Extended Reconstructed SST (ERSST) v5 (Huang et al. 2017)
Daily Optimum Interpolation SST (OISST) version 2.1 (Huang et al. 2020)
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
- The SSHA pattern was overall consistent with the HC300A pattern, but with a significant trend component in SSHA.
- Negative (positive) tendencies of SSHAs and HC300As presented in the central-eastern (western) tropical Pacific.
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 in to 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 Ocean Temperature Pentad Mean Anomaly
Global Sea Surface Salinity (SSS)

SSS: Blended Analysis of Surface Salinity (BASS) V0.Z (Xie et al. 2014) [ftp.cpc.ncep.noaa.gov/precip/BASS]

Precipitation: CMORPH adjusted satellite precipitation estimates
Evaporation: Adjusted CFS Reanalysis