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

Prepared by
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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)
• Overview

• Recent highlights
  – Pacific/Arctic Ocean
  – Indian Ocean
  – Atlantic Ocean

• Global SST Anomaly Predictions
• Pacific Ocean
  – La Niña condition continued in Nov 2021.
  – NOAA “ENSO Diagnostic Discussion” on 9 Dec 2021 states that “La Niña is favored to continue through the Northern Hemisphere winter 2021-22 (~95% chance) and transition to ENSO-neutral during the spring 2022 (~60% chance during April-June)”
  – Strong negative phase of PDO persisted in Nov 2021, with PDOI = -2.1.
  – Marine Heat Waves (MHWs) persisted in the north central Pacific, and strong SST warming emerged in the northeast Pacific.

• Indian Ocean
  – Negative Indian Ocean dipole (IOD) event continued, with IOD index = -0.5° C in Nov 2021.

• Atlantic Ocean
  – The 2021 Atlantic hurricane season was the third most active season on record, producing twenty-one tropical storms.

• Arctic Ocean
  – The monthly average sea ice extent for Nov 2021 ranks the 10th lowest in the satellite record.
Sea surface temperature anomalies (top) and anomaly tendency (bottom). Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means.

- SSTs remained well-below average in the central-eastern equatorial Pacific.
- Strong SSTAs continued in mid-to-high latitude north Pacific.
- SSTs were above average across most of the Atlantic Ocean.

- Negative SSTA tendencies dominated in the central-eastern equatorial Pacific Ocean.
- Large SSTA tendencies were present in the mid latitudes of both hemispheres.
Overall, the SSHA pattern was consistent with the HC300A pattern, but with a significant trend component in SSHA.
- Positive tendency anomalies were present in the central-eastern Pacific both in AVISO Altimetry and GODAS H300 data.
Equatorial depth-longitude section of ocean temperature anomalies (top) and anomaly tendency (bottom). Data is from the NCEP’s global ocean data assimilation system. Anomalies are departures from the 1991-2020 base period means.

- Negative (positive) subsurface ocean anomalies persisted along the central-eastern (western) thermocline in the Pacific Ocean.
- Positive anomalies continued in the upper 100m of the equatorial Atlantic Ocean.
- Positive subsurface anomalies persisted in the eastern Indian Ocean.

- Strong positive temperature anomaly tendency presented along the thermocline in the central-eastern Pacific Ocean.
- Negative temperature anomaly tendency dominated in the thermocline of Atlantic Ocean.
Tropical Pacific Ocean and ENSO Conditions
Latest 3-month Tropical Pacific SST, OLR, & uv925 anomalies

- Positive SSS anomaly persisted around 140E-170W in Nov 2021.

Sea surface salinity (SSS) anomalies are derived from Blended Analysis of Surface Salinity (BASS) V0.2 (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.
Negative NINO1+2 increased substantially in Nov 2021.
Negative NINO34 persisted, with NINO34 = -0.9°C.
Compared with Nov 2020, the central and eastern equatorial Pacific was warmer in Nov 2021.
The indices may have slight differences for different SST products.

Niño region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (°C) for the specified region. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means.
Evolution of NINO34 in La Niña Years

Nino 34 index is derived from the NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means.
Evolution of Monthly Mean SST Anomaly across [5S-5N]

Data source: NCEP OISST
Evolution of Monthly Mean D20 Anomaly across [5S-5N]

Data source: NCEP GODAS
Evolution of Monthly Mean Zonal Wind Stress Anomaly across [5S-5N]

Data source: NCEP R2 reanalysis
- Strong anomalous westward currents has persisted most of the equatorial Pacific in GODAS since Jul 2021, while OSCAR data was dominated by subseasonal variations.
- TIW-associated signatures were clearly observed in GODAS.
- Anomalous westward currents weakened in both OSCAR and GODAS in Nov 2021.
- Observed SSTA tendency (dT/dt) in Nino3.4 region (dotted black line) switched to positive in Nov 2021.
- Zonal advection (Qu, red line) is the primary term contributing to the total budget tendency (solid black line).
- Zonal advection reduced substantially in recent pentads.

Qu: Zonal advection;  Qv: Meridional advection;
Qw: Vertical entrainment;  Qzz: Vertical diffusion
Qq: (Qnet - Qpen + Qcorr)/ρcph;
Qnet = SW + LW + LH + SH;
Qpen: SW penetration;
Qcorr: Flux correction due to relaxation to OI SST

Multiple Ocean Reanalysis: Temperature and Tendency anomalies at Equator

Anomalous Temperature (°C) Averaged in 1S-1N: NOV 2021

NOV 2021 – OCT 2021 1S-1N Temp Anomaly (°C)
- Positive subsurface temperature in the western Pacific extended eastward near the thermocline in TAO.
- Large negative difference between GODAS and TAO near the central Pacific thermocline [150W-130W] decreased in recent pentads.
- Reduced difference between TAO and GODAS coincides with the return of TAO data near the eastern equator (next slide) that potentially affects the TAO and GODAS analysis.
TAO array declined significantly since March 2021 and TAO mooring profiles number is close to the historical low during 2013-2014.

Four mooring sites have been fixed in recent TAO cruise service (155W-Sep 2021, 110W-Nov 2021 Courtesy of NDBC Karen Grissom).
North Pacific & Arctic Oceans
Latest 3-month North Pacific SST, OLR & uv925 anomalies

Data source: NCEP/NCAR Reanalysis 1
Weekly SST anomaly and MHWs in the North Pacific

- MHWs continued in the north central Pacific.
- Strong SST warming emerged in northeast Pacific in the last two weeks.

(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 1991-2020.
Subsurface Temperature Anomaly in N.E. Pacific

- Positive subsurface temperature anomaly in the northeast Pacific has extended to 200m.
- Subsurface warming after 2019 is the strongest event since 1979.

Data source: NCEP GODAS
Two Oceanic PDO indices

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


- The negative phase of PDO decreased slightly in Nov 2021, with PDOI = -2.1.
- Negative H300-based PDO index has persisted 62 months since Nov 2016, with HPDO = -2.4 in Nov 2021.
- SST-based PDO index has considerable variability both on seasonal and decadal time scales.
- H300-based PDO index highlights the slower variability and encapsulates an integrated view of temperature variability in the upper ocean.

SST-based PDO is defined as the 1st EOF of monthly ERSST v3b in the North Pacific for the period 1900-1993. PDO index is the standardized projection of the monthly ERSSTv5 SST anomalies onto the 1st EOF pattern. H300-based Pacific Decadal Oscillation is defined as the projection of monthly mean H300 anomalies from NCEP GODAS onto their first EOF vector in the North Pacific. PDO indices are downloadable from https://www.cpc.ncep.noaa.gov/products/GODAS/ocean_briefing.shtml.
- The monthly average extent for November 2021 was 9.77 million square kilometers and it ranks the 10\textsuperscript{th} lowest in the satellite record.
- For ICs in Nov 2021, NCEP/CPC model predicted the 2022 sea ice extent maximum will be slightly below climatology.

Indian Ocean
Indian Ocean Dipole region indices, calculated as the area-averaged monthly mean sea surface temperature anomalies (OC) for the SETIO [90°E-110°E, 10°S-0] and WTIO [50°E-70°E, 10°S-10°N] regions, and Dipole Mode Index, defined as differences between WTIO and SETIO. Data are derived from the NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means.

- Negative Indian Ocean Dipole Mode index (DMI) continued in Nov 2021, with IODI = -0.5 °C.
Tropical Indian: SSTA, SSTA Trend, OLR, heat flux uv925-mb & uv200 anomalies

- Weak SST warming persisted in the eastern Indian Ocean.
- Convection was enhanced over the eastern Indian Ocean, consistent with the negative Indian Ocean Dipole condition.

SSTAs (top-left), SSTA tendency (top-right), OLR anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1991-2020 base period means.
Tropical and North Atlantic Ocean
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 1991-2020 base period means.

- Negative meridional dipole index enhanced substantially in Nov 2021, with MDI = -0.9 °C.
- 2021 Atlantic Niño conditions continued in Nov 2021, with ATL 3 = 1.3 °C.
- North Atlantic hurricane activity was quiet in Oct – Nov 2021.

- The 2021 Atlantic hurricane season was the third most active season on record, producing twenty-one tropical storms.

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

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<th>Outlook (May 21) 60% above-normal</th>
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Last 6-month of North Atlantic zonal wind shear anomaly

- Negative zonal wind shear anomalies dominated in the hurricane main developing region (MDR, green box) during June-Sep 2021.

- Positive zonal wind shear anomaly was present in the MDR region during Oct 2021, which tends to suppress the tropical storm development.

Data source: NCEP/NCAR Reanalysis 1
August-October SST anomaly 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 80°W and 20°W (bottom). SST are derived from the NCEP OI SST analysis, and anomalies are departures from the 1991-2020 base period means.

- Negative NAO deceased substantially in Nov 2021, with NAO = -0.3.
- The prolonged positive SSTAs in the middle latitudes were evident, partially due to the dominance of the positive phase of NAO during 2015-2019.
ENSO and Global SST Predictions
A majority of dynamical and statistical models predict a continuous La Niña through winter 2021-22 and return to ENSO neutral during spring 2022.

- NOAA “ENSO Diagnostics Discussion” on December 9 stated that “La Niña is favored to continue through the Northern Hemisphere winter 2021-22 (~95% chance) and transition to ENSO-neutral during spring 2022 (~60% chance during April-June)”.

IRI/CPC Niño3.4 Forecast
Multiple Ocean Reanalysis: SST Anomalies

Anomalous Temperature (°C) at z=5m: NOV 2021

NCEP GODAS

JMA

ECMWF

GFDL

NASA

BOM

MET

MERCATOR

NCEP CFSR

ENS. Mean

Spread

SN Ratio

Legend:

-2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2.5

2 4 6 8 12
CFS Niño3.4 SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1991-2020 base period means.

- CFSv2 with IC Sep-Oct overestimated the strength of SST cooling in Oct-Nov.
- Latest CFSv2 predictions call for a strong La Niña in the northern hemisphere 2021/22 winter.
Potential Impact of NSST bias on CFSv2 Predictions

- CFSR nudges to NSST since Feb 2020.
- Cold bias in NSST gives rise to the systematic cold bias in CFSR.
- Large cold CFSR SST bias in the E. Pacific during Sep- Oct 2020 is consistent with overshooting La Nina forecast initiated with Oct., Nov. condition.
- CFSv2 might overestimate SST cooling in 2021-22 winter owing to the large cold SST biases in CFSR.
- Cold bias in CFSR weakened in Nov 2021.
CFSv2 DMI SST Predictions

Indian Ocean Dipole SST anomalies (K)

- Latest CFSv2 forecasts favors neutral IOD conditions in winter.

CFS Dipole Model Index (DMI) SST predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). The hindcast climatology for 1981-2006 was removed, and replaced by corresponding observation climatology for the same period. Anomalies were computed with respect to the 1991-2020 base period means.
CFSv2 Pacific Decadal Oscillation (PDO) Index Predictions

CFSv2 Pacific Decadal Oscillation (PDO) index predictions from the latest 9 initial months. Displayed are 40 forecast members (brown) made four times per day initialized from the last 10 days of the initial month (labelled as IC=MonthYear) as well as ensemble mean (blue) and observations (black). Anomalies were computed with respect to the 1991-2020 base period means. PDO is the first EOF of monthly ERSSTv3b anomaly in the region of [110°E-100°W, 20°N-60°N]. CFS PDO index is the standardized projection of CFS SST forecast anomalies onto the PDO EOF pattern.

- CFSv2 predicts a negative phase of PDO in the coming seasons.
Drs. Arun Kumar, Zeng-Zhen Hu, and Jieshun Zhu: reviewed PPT, and provided insightful suggestions and comments

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

Dr. Wanqiu Wang provided the sea ice forecasts and maintained the CFSv2 forecast archive

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Data Sources (climatology is for 1991-2020)

- Weekly Optimal Interpolation SST (OI SST) version 2 (Reynolds et al. 2002)
- Extended Reconstructed SST (ERSST) v5 (Huang et al. 2017)
- Blended Analysis of Surface Salinity (BASS) (Xie et al. 2014)
- CMORPH precipitation (Xie et al. 2017)
- CFSR evaporation adjusted to OAFlux (Xie and Ren 2018)
- NCEP CDAS winds, surface radiation and heat fluxes (Kalnay et al. 1996)
- NESDIS Outgoing Long-wave Radiation (Liebmann and Smith 1996)
- NCEP’s GODAS temperature, heat content, currents (Behringer and Xue 2004)
- Aviso altimetry sea surface height from CMEMS
- Ocean Surface Current Analyses – Realtime (OSCAR)
- In situ data objective analyses (IPRC, Scripps, EN4.2.1, PMEL TAO)
- Operational Ocean Reanalysis Intercomparison Project
  
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora_body.html
  http://www.cpc.ncep.noaa.gov/products/GODAS/multiora93_body.html
Backup Slides
Sea surface temperature (SST) anomalies (top-left), anomaly tendency (top-right), Outgoing Long-wave Radiation (OLR) anomalies (middle-left), sum of net surface short- and long-wave radiation, latent and sensible heat flux anomalies (middle-right; positive means heat into the ocean), 925-mb wind anomaly vector and its amplitude (bottom-left), 200-mb wind anomaly vector and its amplitude (bottom-right). SST are derived from the NCEP OI SST analysis, OLR from the NOAA 18 AVHRR IR window channel measurements by NESDIS, winds and surface radiation and heat fluxes from the NCEP CDAS. Anomalies are departures from the 1991-2020 base period means.
- Negative H300 anomaly continued in the central-eastern Pacific Nov 2021, contributing to further SST cooling.
- Easterly wind anomalies prevailed over the equatorial Pacific.
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 1991-2020 base period pentad means.
- Area below (above) black line indicates climatological upwelling (downwelling) season.
- Climatologically upwelling season progresses from March to July along the west coast of North America from 36ºN to 57ºN.

- Upwelling anomaly dominated in Nov 2021.
Tropical Atlantic Ocean: SSTA, SSTA Tend, TCHP, OLR, UV200, UV200-UV850, Heat Flux Anomalies

Top Row: SSTA (left; OI SST), SSTA tendency (central), Tropical Cyclone Heat Potential anomaly (right; GODAS).
Middle row: OLR (left; NOAA 18 AVHRR IR), UV200 (central; NCEP CDAS), UV200-UV850 (right; NCEP CDAS) anomalies.
Bottom row: SW+LW (left), LH+SH (central), Relative humidity at 700 hPa (right; NCEP CDAS) anomalies.
Anomalies are departures from the 1991-2020 base period means.
Individual Model Niño3.4 Forecasts

**EC: IC= 01 Dec, 2021**

**JMA: Updated 11 Nov, 2021**

**BOM: Updated 20 Nov, 2021**

**UKMO: Updated 11 Nov, 2021**
New Update: The NCEI SST data used in the quality control procedure has been updated to version 2.1 since May 2020;

Positive SSS anomaly continues/strengthens in the western equatorial Pacific Ocean with reduced precipitation in this area. While, negative SSS anomaly shows in the eastern equatorial Pacific Ocean (east of 120°W) with increased precipitation in this area. Negative SSS anomaly in the northeast Pacific Ocean continues. Positive SSS anomaly appears between 20°N and 40°N in the Atlantic Ocean. Negative SSS anomaly is accompanied with increased precipitation in the east basin of Indian Ocean south of Equator.

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
Compared with last month, SSS increased in the western Equatorial Pacific Ocean likely due to reduced precipitation; SSS decreased along the equator in the eastern Equatorial Pacific Ocean. SSS increased between Equator and 20°N in the Atlantic Ocean. SSS increased in the west basin of South Pacific Ocean between 20°S and 40°S, which is possibly due to oceanic advection/entrainment.
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.