**HOMAGE\_STERIC\_OHC\_TIME\_SERIES\_v01**

**Data Description**

The [HOMAGE\_STERIC\_OHC\_TIME\_SERIES\_v01] dataset contains monthly global mean ocean heat content (OHC) anomalies as well as thermosteric, halosteric and total steric sea level anomalies computed from various gridded ocean data sets of sub-surface temperature and salinity profiles as provided by different institutions:

1. Scripps Institution of Oceanography (SIO)
   1. <http://sio-argo.ucsd.edu/RG_Climatology.html>
2. Institute of Atmospheric Physics (IAP)
   1. <http://159.226.119.60/cheng/>
3. Barnes objective analysis (BOA from CSIO, MNR)
   1. ftp://[data.argo.org.cn/pub/ARGO/BOA\_Argo/](http://data.argo.org.cn/pub/ARGO/BOA_Argo/)
4. Ishii et al. 2017 (I17)
   1. <https://climate.mri-jma.go.jp/pub/ocean/ts/v7.3.1/>
5. Met Office Hadley Centre:
   1. EN4\_c13
   2. EN4\_c14
   3. EN4\_g10
   4. EN4\_I09
      1. <http://hadobs.metoffice.com/en4/download.html>

The data are averaged over the quasi-global ocean domain (i.e., where valid values are defined; note that gaps exist, in particular towards polar latitudes), at monthly intervals. The input profiling data (i.e, temperature and salinity profiles at depth levels), editing, quality flags and processing schemes vary across the different gridded products, please refer to the documentation for each institution’s data product for details. Since 2005, the profiling data are dominated by the observations from the global Argo network (e.g., <https://argo.ucsd.edu/>), which comprises nearly 4000 active floats (as of 08/2022). Before 2005, non-Argo data such as XBT profilers were used, and the global ocean coverage was significantly more sparse. Data sets from SIO and BOA are Argo-only, while the others also include other observations, such as expendable bathythermographs (XBTs) and Conductivity-Temperature-Depth (CTD) observations. The data are active forward stream data files and will be frequently updated as new observations are acquired by Argo, and processed by the data centers.

**Citation**

Frederikse, T., Landerer, F., Killett, E. 2022 JPL MEaSUREs HOMAGE Steric Sea Level and Ocean Heat Content Anomalies Version v01. PO.DAAC, CA, USA. Dataset accessed [YYYY-MM- DD] at https://doi.org/10.5067/HMSSO-4TJ01

**User Mini-Guide: HOMAGE\_STERIC\_OHC\_TIME\_SERIES\_v01**

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**Credit**

When using these data, please cite

Frederikse, T., Landerer, F., Killett, E. 2022 JPL MEaSUREs HOMAGE Steric Sea Level and Ocean Heat Content Anomalies Version v01. PO.DAAC, CA, USA. Dataset accessed [YYYY-MM- DD] at https://doi.org/10.5067/HMSSO-4TJ01

**Overview**

The [HOMAGE\_STERIC\_OHC\_TIME\_SERIES\_v01] dataset contains monthly global mean ocean heat content (OHC) anomalies as well as thermosteric, halosteric and total steric sea level anomalies computed from various gridded ocean data sets of temperature and salinity profiles, typically spanning the depth range from the surface down to 2000m. These data can be used to assess the global ocean heat uptake and sea level budget (i.e., the contribution of temperature and salinity changes to sea level variations in the upper 2000m), as done in *Hakuba et al.* (2021). Note that the 0-2000m depth level contains approximately 50% of the total ocean volume; steric changes below 2000m depth are not included in this data set.

**Data sources**

The [HOMAGE\_STERIC\_OHC\_TIME\_SERIES\_v01] dataset are derived from various gridded ocean data sets of temperature and salinity profiles as provided by different institutions:

1. Scripps Institution of Oceanography (SIO, Roemmich and Gilson, 2009)
   1. <http://sio-argo.ucsd.edu/RG_Climatology.html>
2. Institute of Atmospheric Physics (IAP, Cheng et al., 2016, 2020)
   1. <http://159.226.119.60/cheng/>
3. Barnes objective analysis (BOA from CSIO, MNR, Li et al. 2016)
   1. ftp://[data.argo.org.cn/pub/ARGO/BOA\_Argo/](http://data.argo.org.cn/pub/ARGO/BOA_Argo/)
4. Ishii et al. 2017 (I17)
   1. https://climate.mri-jma.go.jp/pub/ocean/ts/v7.3.1/
5. Met Office Hadley Centre [Good et al. 2013]:
   1. EN4\_c13
   2. EN4\_c14
   3. EN4\_g10
   4. EN4\_I09
      1. <http://hadobs.metoffice.com/en4/download.html>

The input profiling data (i.e, temperature and salinity profiles at depth levels), editing, quality flags and processing schemes vary across the different gridded products, please refer to the documentation for each institution’s data product for details. Since 2005, the profiling data are dominated by the observations from the global Argo network (e.g., <https://argo.ucsd.edu/>), which comprises nearly 4000 active floats (as of 08/2022). Before 2005, non-Argo data such as XBT profilers were used, and the global ocean coverage was significantly more sparse. Data sets from SIO, JAMSTEC, and BOA are Argo-only, while the others also include other observations, such as expendable bathythermographs (XBTs) and Conductivity-Temperature-Depth (CTD) observations.

**Spatial Coverage**

The hydrographic products do not cover the full ocean (Figure 1). Some of the hydrographic products do not include shelf seas and other shallow areas, as well as polar areas. The data are averaged over the quasi-global ocean domain (i.e., where valid values are defined) at monthly intervals. *Hakuba et al.* (2021) demonstrated that the masking effect is small.

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| **Figure 1**. Areas covered by altimetry (panel a) and each of the in-situ hydrographic products (panel b-g). The black lines in panels b-g encircle the area covered by altimetry. [Source: Hakuba et al., 2021]  **Methods & Processing Steps**  The time series of basin-mean and global-mean OHC and steric sea-level changes from all gridded products are computed using the TEOS-10 GSW software (McDougall et al., 2011). This procedure yields time series of upper-ocean steric changes and OHC on a grid, from which global-mean quantities are computed.  The effects of salinity (i.e., *halosteric*) and temperature (i.e., *thermosteric)*  on steric sea level are assessed following *Gregory et al.* (2019), equations 29-31(see snapshot below). On a global scale, halosteric sea-level changes are expected to be negligibly small (Gregory et al., 2019). Recently, a salinity drift in some Argo floats has been discovered (Roemmich et al., 2019), which leads to an overestimation of the salinity and thus an underestimation of halosteric sea level. This salinity drift has a profound impact on global-mean halosteric sea level: global-mean halosteric sea level drops by more than 5 mm after 2015 in most estimates, which translates into negative halosteric trends on the order of 0.4 mm/yr. Therefore, any global steric estimate should be based on the *thermosteric* component for any quantitative sea level and or water/energy cycle assessments (Hakuba et al., 2021).    *Gregory et al.* (2019) <https://doi.org/10.1007/s10712-019-09525-z>  To facilitate process-studies of ocean warming and heat uptake, each data set also contains ocean heat content estimates averaged over different depth intervals: 0-2000m, 0-300m, and 0-700m.  **File name convention**  All time series files follow naming convention as follows:  XXX**\_steric\_ohc\_time\_series\_**StartTime\_EndTime\_v01.nc  Where  XXX – data source center short name.  StartTime – data coverage start time with yyyymmdd.  EndTime – data coverage endtime with yyyymmdd.  v01 – dataset version number.  **A Sample file:**  SIO\_steric\_ohc\_time\_series\_20040116\_20211216\_v01.nc  dimensions:  time = 216;  variables:  float ohc\_ts\_300m(time=216);  :units = "joules";  :long\_name = "ocean heat content anomaly";  :coverage\_content\_type = "physicalMeasurement";  :comment = "Global average time series of ocean heat content anomalies, in joules. Sum from sea level down to 300 meters depth.";  :valid\_max = 1.0E25; // double  :valid\_min = -1.0E25; // double  int time(time=216);  :units = "days since 2004-01-01";  :long\_name = "time";  :axis = "T";  :calendar = "gregorian";  float ohc\_ts\_700m(time=216);  :units = "joules";  :long\_name = "ocean heat content anomaly";  :coverage\_content\_type = "physicalMeasurement";  :comment = "Global average time series of ocean heat content anomalies, in joules. Sum from sea level down to 700 meters depth.";  :valid\_max = 1.0E25; // double  :valid\_min = -1.0E25; // double  float halosteric\_ts(time=216);  :\_FillValue = -9999.0f; // float  :units = "meters";  :long\_name = "halosteric anomaly";  :coverage\_content\_type = "physicalMeasurement";  :comment = "Global average time series of halosteric anomalies, in meters.";  :valid\_max = 10.0f; // float  :valid\_min = -10.0f; // float  float ohc\_ts(time=216);  :valid\_max = 1.0E25; // double  :valid\_min = -1.0E25; // double  :coverage\_content\_type = "physicalMeasurement";  :comment = "Global average time series of ocean heat content anomalies, in joules.";  :units = "joules";  :long\_name = "ocean heat content anomaly";  float thermosteric\_ts(time=216);  :\_FillValue = -9999.0f; // float  :units = "meters";  :long\_name = "thermosteric anomaly";  :coverage\_content\_type = "physicalMeasurement";  :comment = "Global average time series of thermosteric anomalies, in meters.";  :valid\_max = 10.0f; // float  :valid\_min = -10.0f; // float  float totalsteric\_ts(time=216);  :\_FillValue = -9999.0f; // float  :units = "meters";  :long\_name = "total steric anomaly";  :coverage\_content\_type = "physicalMeasurement";  :comment = "Global average time series of total steric (thermosteric plus halosteric) anomalies, in meters.";  :valid\_max = 10.0f; // float  :valid\_min = -10.0f; // float  // global attributes:  :Conventions = "CF-1.7";  :standard\_name\_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention";  :title = "Time series of global average steric height anomalies and ocean heat content estimates (Scripps Institution of Oceanography)";  :short\_name = "HOMAGE\_SIO\_STERIC\_OHC\_TIME\_SERIES\_v01";  :id = "HOMAGE\_SIO\_STERIC\_OHC\_TIME\_SERIES\_v01";  :long\_name = "Monthly time series of global average steric height anomalies and ocean heat content estimates version 01 from the In-Situ Argo measurements by Scripps Institution of Oceanography";  :summary = "Global average time series of steric anomalies and ocean heat content anomalies from Argo.";  :processing\_level = "4";  :creator\_name = "HOMaGE SDS NASA/JPL";  :creator\_email = "grace@jpl.nasa.gov";  :creator\_url = "https://www.grace.jpl.nasa.gov";  :date\_created = "2022-07-06T10:56:33";  :date\_issued = "2022-07-06T10:56:33";  :acknowledgement = "These data were collected and made freely available by the International Argo Program and the national programs that contribute to it. (https://argo.ucsd.edu, https://www.ocean-ops.org). The Argo Program is part of the Global Ocean Observing System.";  :license = "https://science.nasa.gov/earth-science/earth-science-data/data-information-policy";  :product\_version = "v01";  :northernmost\_latitude = 80.0; // double  :southernmost\_latitude = -80.0; // double  :easternmost\_longitude = 180.0; // double  :westernmost\_longitude = -180.0; // double  :journal\_reference\_1 = "[Frederikse, T., Landerer, F., Caron, L. et al. The causes of sea-level rise since 1900. Nature 584, 393–397 (2020). https://doi.org/10.1038/s41586-020-2591-3]";  :journal\_reference\_2 = "[Argo (2000). Argo float data and metadata from Global Data Assembly Centre (Argo GDAC). SEANOE. http://doi.org/10.17882/42182]";  :journal\_reference\_3 = "[Roemmich, D. and J. Gilson, 2009: The 2004-2008 mean and annual cycle of temperature, salinity, and steric height in the global ocean from the Argo Program. Progress in Oceanography, 82, 81-100. https://doi.org/10.1016/j.pocean.2009.03.004]";  :project = "NASA MEaSUREs: HOMaGE project";  :program = "NASA MEaSUREs";  :keywords = "Sea Level, Sea Level Anomaly, Sea Level Rise, Ocean Heat Budget, Steric Height";  :keywords\_vocabulary = "NASA Global Change Master Directory (GCMD) Science Keywords";  :institution = "NASA/JPL";  :naming\_authority = "org.doi.dx";  :source = "A global average of Argo measurements compiled by the Scripps Institution of Oceanography.";  :platform = "Argo\_Float";  :platform\_vocabulary = "NASA Global Change Master Directory platform keywords";  :instrument = "thermometers, conductivity sensors";  :instrument\_vocabulary = "NASA Global Change Master Directory instrument keywords";  :creator\_type = "group";  :creator\_institution = "NASA/JPL";  :publisher\_name = "Physical Oceanography Distributed Active Archive Center";  :publisher\_email = "podaac@jpl.nasa.gov";  :publisher\_url = "https://podaac.jpl.nasa.gov";  :publisher\_type = "group";  :temporal\_resolution = "monthly";  :time\_coverage\_start = "2004-01-16T05:38:33.281250";  :time\_coverage\_end = "2021-12-16T19:21:23.203125";    References  Gregory, J.M., Griffies, S.M., Hughes, C.W. et al. Concepts and Terminology for Sea Level: Mean, Variability and Change, Both Local and Global. Surv Geophys 40, 1251–1289 (2019). <https://doi.org/10.1007/s10712-019-09525-z>    Hakuba, M. Z., Frederikse, T., & Landerer, F. W. (2021). Earth's energy imbalance from the ocean perspective (2005–2019). Geophysical Research Letters, 48, e2021GL093624.<https://doi.org/10.1029/2021GL093624>.  **EN4:**  Good, S. A., Martin, M. J., & Rayner, N. A. (2013). EN4: Quality controlled ocean temperature and salinity profiles and monthly objective analyses with uncertainty estimates. Journal of Geophysical Research: Oceans, 118(12), 6704–6716. <https://doi.org/10.1002/2013JC009067>  **IAP:** Cheng, L., Trenberth, K. E., Gruber, N., Abraham, J. P., Fasullo, J. T., Li, G., Mann, M. E., Zhao, X., & Zhu, J. (2020). Improved Estimates of Changes in Upper Ocean Salinity and the Hydrological Cycle. Journal of Climate, 33(23), 10357–10381. <https://doi.org/10.1175/JCLI-D-20-0366.1>  Cheng, L., & Zhu, J. (2016). Benefits of CMIP5 Multimodel Ensemble in Reconstructing Historical Ocean Subsurface Temperature Variations. Journal of Climate, 29(15), 5393–5416. <https://doi.org/10.1175/JCLI-D-15-0730.1>  **BOA**  Li, H., Xu, F., Zhou, W., Wang, D., Wright, J. S., Liu, Z., & Lin, Y. (2017). Development of a global gridded Argo data set with Barnes successive corrections. Journal of Geophysical Research: Oceans, 122(2), 866–889. <https://doi.org/10.1002/2016JC012285>  **I17**  Ishii, M., Fukuda, Y., Hirahara, S., Yasui, S., Suzuki, T., & Sato, K. (2017). Accuracy of Global Upper Ocean Heat Content Estimation Expected from Present Observational Data Sets. SOLA, 13(0), 163–167. <https://doi.org/10.2151/sola.2017-030>  **SIO**  Roemmich, D., & Gilson, J. (2009). The 2004–2008 mean and annual cycle of temperature, salinity, and steric height in the global ocean from the Argo Program. Progress in Oceanography, 82(2), 81–100. <https://doi.org/10.1016/j.pocean.2009.03.004> |
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