

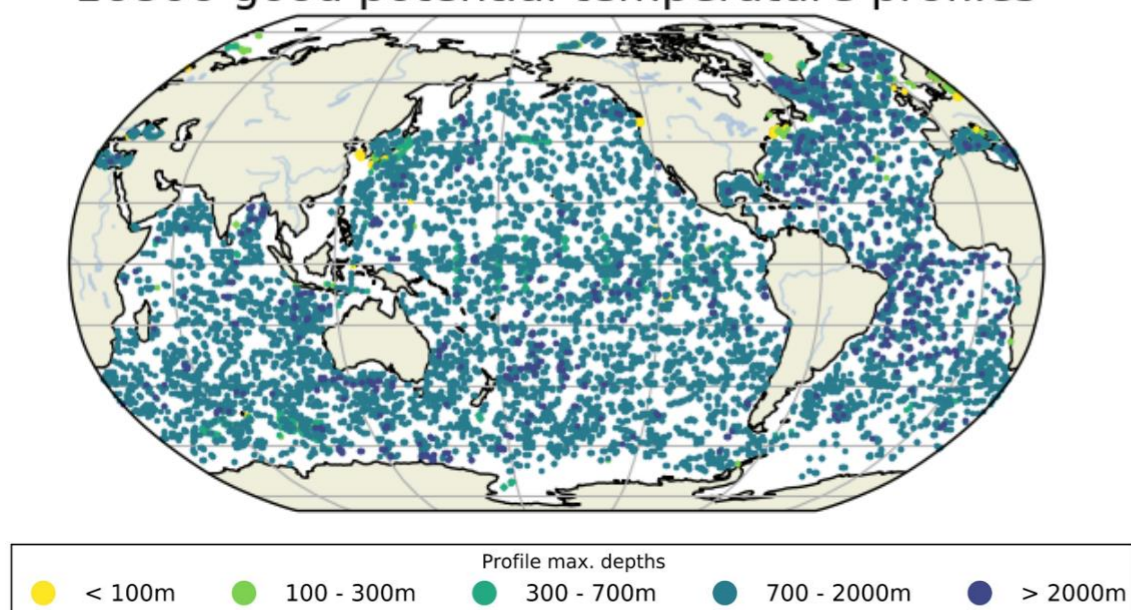
# Marine Databases Produced by the UK Met Office

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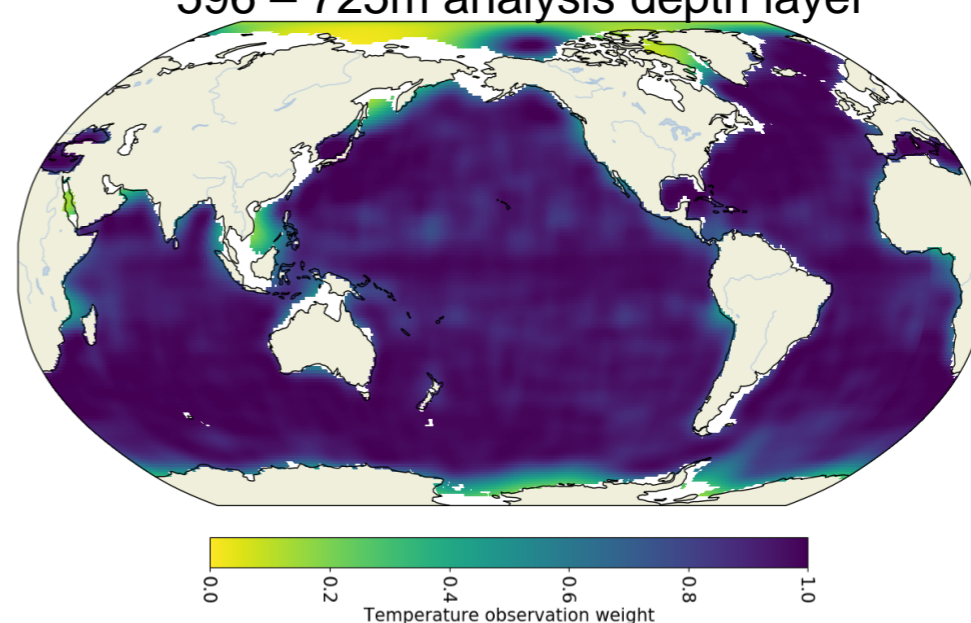
## EN4 Headline Facts:

- Current version: **EN.4.2.1**
- Components: **Temperature and salinity profiles and analyses**. Analyses are formed by combining a background with the quality controlled profiles from the month being processed and are accompanied by uncertainty estimates down to 1000m. The **observation weights in the analyses** show how much the grid box value has been informed by observations and how much it has been influenced by its initial background values. In the absence of any observations from profiles the **analyses relax back to climatology** (1971 – 2000).
- Data: Combines data from Argo, Arctic Synoptic Basinwide Oceanography (ASBO), the Global Temperature and Salinity Profile Program (GTSP) and the World Ocean Database (WOD13).
- Bias corrections: **Two bias corrections are available** for Expendable Bathythermographs (XBTs) and Mechanical Bathythermographs (MBTs), Levitus et al., 2009 (updated) and Gouretski and Reseghetti, 2010 (updated). **All profile data have quality control (QC) flags**.
- Time period: **1900 to the present day**.
- Coverage: Global (down to a maximum of 5500m for the analyses).
- Update frequency: **Monthly updates** using data from GTSP and Argo, with full reprocessing approximately once a year using all four data sources mentioned in 'Data'.
- Availability: **Freely available for research purposes from** <http://www.metoffice.gov.uk/hadobs/en4/>.
- Resolution: Monthly files for download containing data at a higher time resolution for the profile dataset. Analysis files are monthly with a 1° by 1° grid box resolution and 42 increasing depth levels.
- Downstream datasets: EN4 feeds into the Hadley Centre Integrated Ocean Database (HadIOD), see below.
- **Upcoming version: EN.4.2.2. Two more XBT correction schemes:** Cowley et al., 2013 and Cheng et al., 2014. **New MBT correction scheme:** Gouretski and Cheng 2020 will replace the Gouretski and Reseghetti, 2010 MBT correction scheme.
- Reference: S. A. Good, M.J. Martin and N. A. Rayner (2013): EN4: Quality Controlled Ocean Temperature and Salinity Profiles and Monthly Objective Analyses with Uncertainty Estimates, *Journal of Geophysical Research: Oceans*, 118, 12, pg 6704-6716

December 2020 -  
16866 good potential temperature profiles



December 2020 -  
596 – 725m analysis depth layer



## HadIOD Headline Facts:

- Current Version: **HadIOD.1.2.0.0**
- Data: Combines **subsurface temperature and salinity profile data from EN4 with surface data from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) and the Copernicus Marine Environmental Monitoring Service (CMEMS)** and a few smaller sources.
- Observation errors: Observations in the database are accompanied by various **uncertainty estimates and QC flags**. **Bias corrections** are also applied where available. Errors are modelled as a macro-bias (at the level of the platform e.g. XBT, MBT, bucket), a micro-bias (at the individual ship or float level) and a random measurement error.
- **XBT bias corrections:** Levitus et al., 2009, Gouretski and Reseghetti 2010 (updated), Gouretski 2012 and Cowley et al., 2013. **Ship sea surface temperature (SST) corrections** available based on adjustments taken from HadSST3 (Hadley Centre SST Dataset).
- Time period: **1850 to the present day (surface temperature data only pre-1900)**.
- Update frequency: **Monthly updates** – our expectation is that new versions be built every few years incorporating latest data and any other improvements.
- Availability: **Freely available for research purposes from** <https://www.metoffice.gov.uk/hadobs/hadiod/>.
- Coverage: Global.
- Resolution: **Daily netCDF files**.
- User guide: **HadIOD.1.2.0.0 user guide** available from the above webpage.
- References: C. P. Atkinson, N. A. Rayner, J. J. Kennedy and S. A. Good (2014): An Integrated Database of Ocean Temperature and Salinity Observations, *Journal of Geophysical Research: Oceans*, 119, 10, pg 7139 – 7163.

## Upcoming Developments

### Incorporation of random uncertainty into profile data

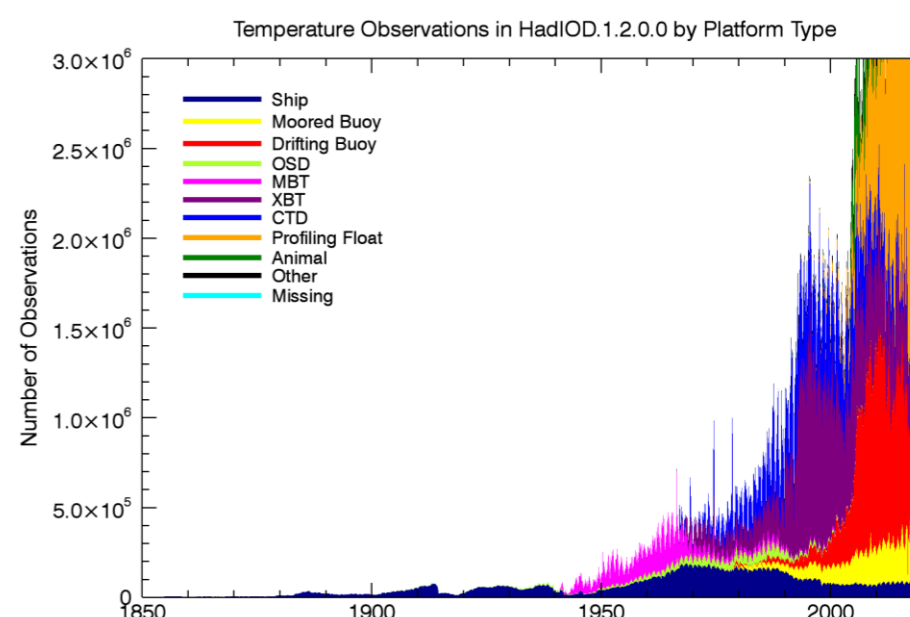
- HadIOD.1.2.0.0 includes a random measurement error uncertainty estimate for profile instrument types.
- The IQuOD initiative has also released IQuOD version 0.1 with random measurement error uncertainties for all temperature data.
- Delayed mode Argo data are accompanied by uncertainty estimates in their **\_ADJUSTED** fields.
- EN4 will take information from these sources in order to provide random measurement error uncertainties for all temperature and salinity observations.
- This will allow profile and depth layer averages to be accompanied by uncertainty estimates.

### Updated analyses

- The current EN climatology is the period 1971-2000. This will be updated to a more modern climatology incorporating Argo data.
- EN4 analysis uncertainty estimates are derived using the number of observations contributing to the analysis values.
- There has been an additional decade of data since EN4 was first produced. These additional data will be used to revise and extend the analysis uncertainty estimates.

### Use of machine learning to improve XBT uncertainty characterisation

- XBT observations are the dominant source of temperature profiles from soon after their introduction in the 1960s to the early 2000s.
- There are multiple XBT instruments with different characteristics, but the instrument type and/or make metadata are missing from around 50% of XBT profiles.
- Bias corrections are often dependent on the XBT type and make, uncertainty here leads to uncertainty in derived quantities e.g. Ocean Heat Content (OHC).
- Decision tree machine learning algorithms have been used to create an ensemble of XBT metadata.
- This ensemble allows the creation of an additional EN4 ensemble where in each split the XBT metadata from a different decision tree cross-validation member is used.
- The spread of these EN ensemble members can be used to represent the uncertainty arising from missing XBT metadata.



### HadIOD.1.3.0.0

- Incorporation of latest EN.4.2.2 data and bias corrections.
- Incorporation of ICOADS 3.0 SST data with updated quality control flags.
- Incorporation of latest SST ship corrections from HadSST4.
- Incorporation of additional surface salinity data, including from GOSUD.

### Additional Dataset and Bias Correction References:

- Cheng 2014: Cheng L., J. Zhu, R. Cowley, T. Boyer and S. Wijffels (2014): Time, Probe Type and Temperature Variable Bias Corrections to Historical Expendable Bathythermograph Observations, *Journal of Atmospheric and Oceanic Technology*, 31, 1793 - 1825
- Cowley 2013: Cowley R., S. Wijffels, L. Cheng, T. Boyer, S. Kizu (2013): Biases in Expendable Bathythermograph Data: A New View Based on Historical Side-by-Side Comparisons, *Journal of Atmospheric and Oceanic Technology*, 30, 1195 - 1225
- Gouretski and Reseghetti 2010: Gouretski V. and F. Reseghetti (2010): On Depth and Temperature Biases in Bathythermograph Data: Development of a New Correction Scheme Based on Analysis of a Global Ocean Database, *Deep Sea Research*, 57, 812 - 833
- Gouretski 2012: Gouretski V. (2012), Using geboco digital bathymetry to infer depth biases in the XBT data, *Deep Sea Research Part I: Oceanographic Research Papers* 62, no. Supplement C, 40 - 52
- Gouretski and Cheng, 2020: Gouretski V., and L. Cheng (2020): Correction for systematic errors in the global dataset of temperature profiles from Mechanical Bathythermographs, *Journal of Atmospheric and Oceanic Technology*, 37, 841 - 855
- Levitus 2009: Levitus S., J. I. Antonov, T. P. Boyer, R. A. Locarnini, H. E. Garcia and A. V. Mishonov (2009): Global Ocean Heat Content 1955-2007 in Light of Recently Revealed Instrumentation Problems, *Geophysical Research Letters*, 36 (7)
- Argo: <http://wo.jcom.mopos.org/cgi-bin/WebObjects/Argo>
- ASBO: See EN4 paper by Good et al., for references of where this dataset sources its own data from and which data are taken.
- CMEMS: <http://marine.copernicus.eu/> Product INSITU\_GLO\_NRT\_OBSERVATIONS\_013\_030 (Global Ocean In Situ Near Real Time Observations), Drifting Buoys.
- GTSP: Sun, C. & Co-Authors (2010). "The Data Management System for the Global Temperature and Salinity Profile Programme" in Proceedings of OceanObs.09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison, D.E. & Stammer, D., Eds., ESA Publication WPP-306, doi:10.5270/OceanObs09.cwp.86
- IQuOD: The IQuOD Team (2018). International Quality Controlled Ocean Database (IQuOD) version 0.1 - aggregated and community quality controlled ocean profile data 1772-2018 (NCEI Accession 0170893). NOAA National Centers for Environmental Information. Dataset. <https://www.ncei.noaa.gov/archive/accession/0170893>.
- WOD: Boyer, T.P., J. I. Antonov, O. K. Baranova, C. Coleman, H. E. Garcia, A. Grodsky, D. R. Johnson, R. A. Locarnini, A. V. Mishonov, T.D. O'Brien, C.R. Paver, J.R. Reagan, D. Seidov, I. V. Smolyar, and M. M. Zeng, 2013: World Ocean Database 2013, NOAA Atlas NESDIS 72, S. Levitus, Ed., A. Mishonov, Technical Ed.; Silver Spring, MD, 209 pp., <http://doi.org/10.7289/V5N285MT>
- ICOADS: S.D. Woodruff, S.J. Worley, S.J. Lubker, Z. Ji, J.E. Freeman, D.I. Berry, P. Brohan, E.C. Kent, R.W. Reynolds, S.R. Smith, and C. Wilkinson (2011): ICOADS Release 2.5: Extensions and enhancements to the surface marine meteorological archive, *Int. J. Climatol.*, 31, 951 - 967
- HadSST3: Kennedy J.J., Rayner, N.A., Smith, R.O., Saunby, M. and Parker, D.E. (2011). Reassessing biases and other uncertainties in sea-surface temperature observations since 1850 part 2: biases and homogenisation. *J. Geophys. Res.*, 116, D14104.
- HadSST4: Kennedy, J. J., Rayner, N. A., Atkinson, C. P., & Killick, R. E. (2019). An ensemble data set of sea-surface temperature change from 1850: the Met Office Hadley Centre HadSST-4.0.0.0 data set. *Journal of Geophysical Research: Atmospheres*, 124. <https://doi.org/10.1029/2018JD029867>