DETECTION OF NATURAL AND ANTHROPOGENIC SIGNALS IN THE OCEAN CLIMATE RECORD USING THE MET OFFICE EN3 DATA SET

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ABSTRACT

We present a method to quantify ocean warming that filters out the natural internal variability from both observations and climate simulations and better isolates externally forced air-sea heat flux changes. As a result, we gain a much clearer picture of the drivers of oceanic temperature changes and are able to detect, for the first time, the effects of both anthropogenic and volcanic influences simultaneously in the observed record.

Our analyses are based upon Met Office climate models and the EN3 quality-controlled subsurface ocean observations, which include XBT bias corrections and cover the period 1950 to present. We present an overview of the EN3 data sources, quality control procedures and data products.

1. SCIENTIFIC RESULTS

1.1. Time series of ocean warming

Following previous work by [1], we present annual time series of temperature anomaly for the observations and HadCM3 model [2] for the upper 220m (T_{220m}, Fig. 1) and for waters warmer than 14°C (T_{14C}, Fig. 2). The four-member model ensembles use: (i) anthropogenic (ANT) external forcings; (ii) natural (NAT) external forcings; and (iii) both anthropogenic and natural forcings (ALL). The ALL simulations, which include anthropogenic forcings, show considerably better agreement with the observations than the NAT simulations (Figs. 1 and 2).

As well as the long-term rise in ocean temperature for the ALL ensemble, we can see the short-lived cooling events associated with major volcanic eruptions in 1963, 1982 and 1991 in both the ALL and NAT simulations. The 1982 event is not so clear in the observations, since it was coincident with a large El Niño, which offset the volcanic cooling. The T_{14C} results show a 15-40% reduction in the RMS error between model ensemble-mean and the observations compared to the T_{220m} analysis, depending on ocean basin. The T_{14C} analysis better isolates changes in air-sea heat fluxes and reduces the signal of ocean advection [1,3] – resulting in improved agreement between observed and simulated time series.

1.2. Optimal detection analysis

We carry out an optimal detection analysis [4] using T_{14C} and T_{220m} in order to attribute the observed ocean warming to anthropogenic and/or natural causes. The optimal detection analysis determines whether the expected anthropogenic and natural "fingerprints" have emerged significantly in the observations, above the "noise" of internal variability. The optimal detection results presented here are based on a five-point spatial model fingerprint, composed of 2-year average temperature anomaly in the N. Atlantic, S. Atlantic, N. Pacific, S. Pacific and Indian Oceans.

Both ANT and NAT forcings are robustly detected for T_{14C} and the magnitude of the response in the HadCM3 model is consistent with the observations. There is no robust detection of either NAT or ANT for T_{220m} and the model appears to over estimate the observed response to anthropogenic forcings. The lack of robust detection is consistent with a larger component of internal variability for T_{220m} than T_{14C}. Please see [5] for further information.

1.3. Conclusions

The historical climate records contain a strong imprint of internal variability associated with the climate mode evolution. Ensemble climate model runs seek to average out this internal variability. We have reduced the internal variability in the observations by computing ocean temperature changes relative to a fixed isotherm, rather than a fixed depth, which better isolates the externally forced air-sea heat flux signals. Climate mode variability is similarly reduced in the climate model runs, resulting in a much improved observation-model comparison and a robust detection of both natural and anthropogenic influences on ocean subsurface temperatures for the first time.

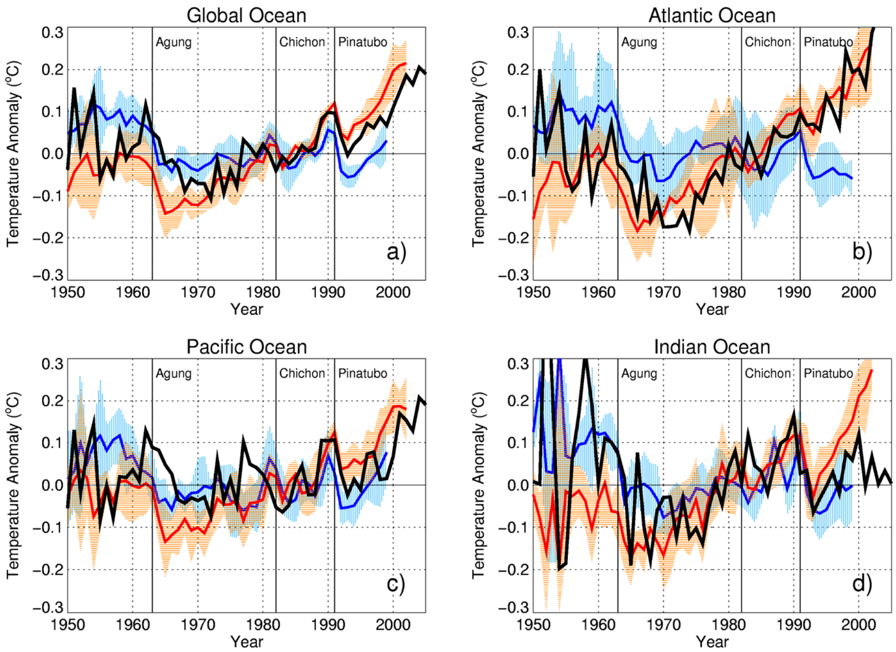

Figure 1: Time series of ocean temperature above 220m (T_{220m}) relative to 1950-1999 average. Shown are: the EN3 XBT-corrected observations (black); the HadCM3 ALL ensemble average (red) and ensemble standard deviation (orange shading); and the HadCM3 NAT ensemble average (blue) and ensemble standard deviation (light blue shading). The model data have been re-gridded and sub-sampled to match the observational coverage. Figure reproduced from [5].

2. EN3 OBSERVATIONS

2.1. Overview

• Global dataset containing subsurface ocean temperature (T) and salinity (S) profiles that have been quality controlled using a comprehensive set of checks. In addition, objective analyses have been formed from the quality controlled data.

• Freely available for download for private study and scientific research purposes from www.metoffice.gov.uk/hadobs. The data are provided as NetCDF files.

• Extends from 1950 to the present and is updated monthly with new data. A version is available that includes the XBT corrections from Table 1 of [6].

2.2. Summary of data processing

• Profile data are sourced from the World Ocean Database 2005 (WOD05) [7], the Global Temperature and Salinity Profile Project (GTSPP), the Argo project and, in the latest version, Arctic data compiled within the Arctic Synoptic Basin-wide Oceanography (ASBO) project.

• Comprehensive automated quality checking, including: checks for constant values, spikes, steps and density inversions; track checking; and statistical "background" checks.

• The background objective analysis is created using damped persistence of anomalies.

• The quality controlled profiles and background fields are used to create spatially complete 3-D objective analyses of T and S for each month. These gridded fields have a 1°×1° horizontal resolution and 42 vertical levels. The data are available as NetCDF files.

• More details can be found in [8].

2.3. Data source acknowledgements

Argo: Argo data were collected and made freely available by the International Argo Project and the national initiatives that contribute to it (http://www.argo.net). Argo is a pilot programme of the Global Ocean Observing System.

ASBO: Data collated by Takamasa Tsubouchi (NOCS); http://www.nerc.ac.uk/research/areas/polar/asbo.asp; http://www.noc.soton.ac.uk/ooc/ASBO/index.php. See the EN3 pages at www.metoffice.gov.uk/hadobs for full details of the data sources.

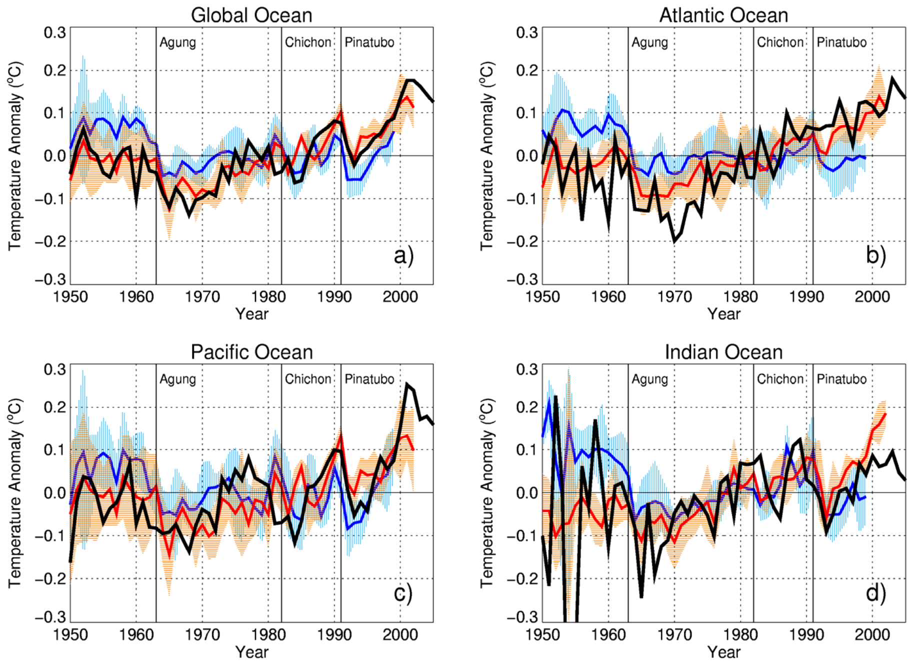

Figure 2: As Fig. 1 but for the average temperature above the 14°C isotherm (T_{14C}). Figure reproduced from [5].

GTSPP: Operational Oceanography Group: Global Temperature-Salinity Profile Program. June 2006. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Oceanographic Data Center, Silver Spring, Maryland, 20910; http://www.nodc.noaa.gov/GTSPP/.

WOD05: T.P. Boyer, J.I. Antonov, H.E. Garcia, D.R. Johnson, R.A. Locarnini, A.V. Mishonov, M.T. Pitcher, O.K. Baranova, and I.V. Smolyar, 2006. World Ocean Database 2005. S. Levitus, Ed., NODC Atlas NESDIS 60, U.S. Government Printing Office, Wash., D.C., 190 pp., DVDs.

3. REFERENCES

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