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Opinion paper

Present contributions to sea level rise by thermal expansion and ice melting and implication on coastal management

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A R T I C L E I N F O

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A B S T R A C T

Increasing ocean heat content has been suggested on the basis of theories. Reconstructions (modelling results based on selected scattered measurements) and simulations (modelling results not based on observations) have both shown a significant warming since the year 1970 that increased at an ever faster rate over the 14 years this century. It is shown here that, contrary to this claim, the detailed measurements of the ocean temperature and salinity by the sampling buoys of the ARGO project show only minor changes of temperature and salinity since the early 2000s. The ARGO results cover the ocean layers 0–2000 m except for the North and South Poles. The satellite NSSTC surface air temperature measurements over the world oceans show a global cooling over the last 11 years, and the satellite NSDIC sea ice extent measurements show globally increasing ice coverage over the North and South Poles. The North Pole sea ice is certainly reducing, but over the last 11 years the growth of the South Pole sea ice has more than compensated that loss. The true measurements are in marked contrast to theoretical reconstructions and simulations. This result has a huge implication on coastal management that should be based on observationally derived forecasts rather than "*projections*" of models lacking validation.

1. Introduction

It is claimed (Climate Change, 2014) that thermal expansion and ice melting from global warming significantly contribute to sea level rise, and ocean and coastal management should move primarily to address the issues of catastrophic sea level rises.

Aim of the present paper is to present and discuss the experimental data bases available to assess the current rate of rise of sea levels for thermal expansion, ice melting and other contributions, and to properly weight the global warming threat vs. other environmental threats that may be relevant to ocean and coastal management.

The method adopted here is to apply a simple regression analysis to the data available while keeping in mind their accuracy limits and the opportunity there may be a bias in the results.

Regression is the most common example of a pattern recognition technique. Regression statistically estimates the potential relationships among variables. It helps understanding which among the independent variables are related to the dependent variable and explores the forms of these relationships. In the case of time series, the independent variable is the time, and the regression analysis may help understanding of how the value of the dependent variable changes when the independent variable is varied.

The relative sea level – what is measured by tide gauges – is not a measure of the absolute global sea level. The land is indeed subject to subsidy or isostasy, and the sea level may rise or fall simply because the land is moving and not because the mass or the volume of the ocean waters are increasing because of ice melting or because the warming induced thermal expansion. The paper is dealing with the effects of global warming on the mass and volume of the ocean waters, to be assessed through measurements of relative sea level by tide gauges, land motion nearby the tide gauges by GPS, temperatures and salinities by probes, and finally sea and land surface air temperatures and sea ice extent by satellite.

2. Climate models for predicting thermal expansion and ice melting contributions

According to the latest IPCC report (IPCC, 2014), for what concerns the ocean temperature "*It is virtually certain that the upper ocean (above 700 m) has warmed from 1971 to 2010, and likely that it has warmed from the 1870s to 1971.*" and "*It is likely that the ocean warmed between 700 and 2000 m from 1957 to 2009, based on 5-year averages. It is likely that the ocean warmed from 3000 m to the bottom*

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from 1992 to 2005, while no significant trends in global average temperature were observed between 2000 and 3000 m depth during this period".

For what concerns the ocean salinity, "*It is very likely that regional trends have enhanced the mean geographical contrasts in sea surface salinity since the 1950s: saline surface waters in the evaporation-dominated mid-latitudes have become more saline, while relatively fresh surface waters in rainfall-dominated tropical and polar regions have become fresher*" and "*It is very likely that large-scale trends in salinity have also occurred in the ocean interior*".

According to the theory of global warming, the heat uptake of the oceans is increasing proportional to the carbon dioxide emissions. The reconstructions by NOAA/NESDIS/NODC (NODC, 2014), that are called "*observations*" are actually "*computations*" based on the above theory. The number of real, direct historical measurements of temperatures and salinities is very limited, due to which the temperature and salinity results are computed through a far from transparent "*reconstruction*" procedure of climate parameters. The reconstructions show a significant warming since the year 1970 that has increased at an even faster rate over the 14 years this century.

3. Measured data sets for estimation of thermal expansion and ice melting contributions

The global warming theory and the result of climate models are not based on actual measurements nor validated by real measurements. The results of the ARGO project (ARGO, 2014) coupled with the NSSTC satellite monitoring of sea surface temperature (NSSTC, 2014) and the NSDIC satellite monitoring of North and South Poles sea ice extent (NSIDC, 2014) may certainly help to determine if there is any present warming of the oceans. This is relevant to the discussion of whether the global sea level has risen due to the thermal expansion of the oceans and the loss of land-based ice.

3.1. ARGO probe measurements of ocean temperature and salinity

The ARGO results are only available over the last decade, but they are statistically significant and accurate measurements of the oceans temperature and salinity up to 2000 m depth. The broad-scale global array of temperature/salinity profiling floats is the most relevant component of the ocean observing system. Deployment of buoys began during the year 2000 and continues today at the rate of about 800 per year. There were 3611 buoys on January 15, 2014. The array provides 100,000 temperature/salinity profiles and velocity measurements per year distributed over the global oceans at an average 3-degree spacing.

Pre-ARGO data are not representative of any global trend for oceans temperature and salinity (Parker, 2014a).

The ARGO measurements still fail to cover the deepest layers (below 2000 m) containing one half of the ocean water, but we may reasonably assume that if temperatures and salinity do not change 0–2000 m, there should be no change also below the 2000 metres, especially if any warming is due to the increased heat caused by the rising carbon dioxide in the atmosphere. ARGO does further not cover the areas above 60N and below 60S.

The ARGO temperature and salinity of the world oceans in the layers from 0 to 2000 m have not changed significantly (Parker, 2014d). There is basically no significant warming or change of salinity within the accuracy limits of the measurements. The lack of any significant difference in the spatial distribution in latitude, longitude and depth from one year to another year shows that the theoretically proposed increased heat is missing.

Fig. 1 presents the ARGO temperatures over the layers 0–100 dbar, 0–700 dbar and 0–2000 dbar and the ARGO salinities over the layers 0–100 dbar and 0–700 dbar over the period January 2004 to December 2012 (data from ARGO, 2014). The salinities over the layer 0–2000 dbar do not have any detectable change.

The upper layer is cooling at a rate of -8.8×10^{-3} °C per year. Over the layer 0–700 and 0–2000 dbar there is a minimal warming of 1.1 and 1.2×10^{-3} °C per year. This is in sharp contrast to the reconstructed result of (NODC, 2014) where the temperatures are significantly warming. The salinity is also minimally reducing, in contrast to the reconstructed result of (NODC, 2014) where it is actually increasing.

Considering the experimental uncertainty of the global measurement (Parker, 2014a), and the correction from an early small cooling to an early small warming to reduce the discrepancy with the model results shown in Fig. 2 and discussed in NPR (2014), NASA (2014); Tallbloke (2014), Lyman et al. (2006), Willis et al. (2007, 2009), Parker (2014a), Jennifer (2014), we may conclude that there has been no increased heat uptake from 2003 to the present between 0–360 E and 60S–60N, and there is great stability both in space, time and depth of both temperatures and salinity.

The ocean heat content has implications on the rate of rise of sea levels (Parker, 2014b). Table 1 presents the salt-water density as a function of temperature, salinity and pressure (from Kaye and Laby, 2014). Without losing too much in generality, a steric rate of rise of sea level may be computed from the results of Fig. 1 and Table 1. Over the layer 0–2000 m, the world oceans had over the last decade average salinity of about 34.7 g/kg and average temperature of about 6.370 °C. While on average the salinity did not changed, the temperature warmed on average 0.012 °C over the decade, at a rate of 1.12×10^{-3} °C per year. By considering a density drop from the 1027.483584 kg/m^3 of an average temperature of 6.364 °C to the 1027.481856 kg/m^3 of an average temperature 6.376 °C, the 2000 m thick layer expanded of about 3.4 mm, or about 0.34 mm/year. Considering the model assisted correction from the early cooling to the early warming that further adds to the accuracy of the global measurement, more likely the 2000 m thick layer did not expand within the accuracy of the measurement.

3.2. NSSTC/NSDIC satellite measurements of surface temperature and sea ice extent

Even this above explained far from dramatic warming and steric rate of rise is very likely an overestimation. The ARGO data have been already revised upwards (Jennifer, 2014; Bob Tisdale, 2014; Wattsup, 2014), most likely because of the bad correspondence between the global warming theory based model results and the real field measurements, the experimental data. The measurements were showing a significant cooling over the period beginning 2003 to end of 2005 and corrections were observed that changed the significant cooling to a small warming. A basically zero global sea level rise is what can be inferred from this ARGO data set and the results for sea surface temperatures and sea ice extent.

Similar to the ARGO measurements of the ocean heat content is the 35 years long satellite data set (NSSTC, 2014) from the National Space Science and Technology Centre (NSSTC) that provides the monitoring of the sea surface air temperatures for the ocean all over the globe including the Arctic and the Antarctic.

Fig. 3 presents the NSSTC world ocean measured temperatures for the Globe, North Pole, Tropics and South Pole (data from NSSTC, 2014) and the NSDIC sea ice extent (data from NSIDC, 2014). Data are analysed January 1, 1979 to December 31, 2013 and January 1, 2003 to December 31, 2013 (11 years Sun-spot cycle).

The data of NSSTC (2014) are available as global, land and ocean averages temperatures for the globe (GL) 85S to 85N, NH 0 to 85N,