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Oceanography

Present-day sea level rise: A synthesis

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Abstract

Measuring sea level change and understanding its causes have improved considerably in the recent years, essentially because new in situ and remote sensing data sets have become available. Here we report on the current knowledge of present-day sea level change. We briefly present observational results on sea level change from satellite altimetry since 1993 and tide gauges for the past century. We next discuss recent progress made in quantifying the processes causing sea level change on time scales ranging from years to decades, i.e., thermal expansion, land ice mass loss and land water storage change. For the 1993–2003 decade, the sum of climate-related contributions agree well (within the error bars) with the altimetry-based sea level, half of the observed rate of rise being due to ocean thermal expansion, land ice plus land waters explaining the other half. Since about 2003, thermal expansion increase has stopped, whereas the sea level continues to rise, although at a reduced rate compared to the previous decade (2.5 mm/yr versus 3.1 mm/yr). Recent increases in glacier melting and ice mass loss from the ice sheets appear able to account alone for the rise in sea level reported over the last five years. ***To cite this article: A. Cazenave et al., C. R. Geoscience 340 (2008).***

Résumé

Hausse actuelle du niveau de la mer : synthèse. La mesure des variations du niveau de la mer et la compréhension des phénomènes responsables ont beaucoup progressé ces dernières années, grâce à l'existence de nouvelles observations d'origines variées. Dans cet article, on présente les résultats les plus récents obtenus sur la mesure de l'évolution du niveau de la mer par altimétrie spatiale depuis 1993. On présente aussi les estimations basées sur les enregistrements marégraphiques des dernières décennies. On discute ensuite les différentes contributions climatiques à la hausse actuelle du niveau de la mer : expansion thermique des océans, fonte des glaciers de montagne, perte de masse de glace des calottes polaires et variation des stocks d'eaux continentales. Sur la période 1993–2003, l'expansion thermique et la variation de masse de l'océan (effet des glaces et eaux continentales) contribuent pour environ 50 % chacune. Depuis 2003, l'expansion thermique de l'océan fait une pause. Mais la contribution accrue des glaces et eaux continentales permet d'expliquer presque totalement la hausse du niveau de la mer des dernières années. ***Pour citer cet article : A. Cazenave et al., C. R. Geoscience 340 (2008).***

Keywords: Sea level; Climate; Thermal expansion; Land ice; Glaciers; Ice sheets

Mots clés : Niveau de la mer ; Climat ; Expansion thermique ; Glaces continentales ; Glaciers ; Calottes polaires

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1. Introduction

The IPCC Fourth Assessment Report (IPCC AR4) published in 2007 provides a synthesis of recent progress realized in precisely measuring global mean sea level change as well as understanding causes of the observed rise [4]. For the last 15 years, sea level is routinely measured by satellite altimetry from Topex/Poseidon and Jason satellites [2,6].[1] Quasi global in situ ocean temperature data available for the past few decades have allowed the quantification of the contribution of ocean warming to sea level rise. Glaciers and ice sheets mass balance estimated from in situ and remote sensing observations have also provided important information on the land ice contribution to sea level. The land water storage component can now be determined from space-based gravity data of the recently launched GRACE mission. In addition, GRACE allows a direct estimate of the ocean mass component to sea level change, and when combined with satellite altimetry, provides a measure of thermal expansion, totally independent of in situ ocean temperature data. In this review, we briefly summarize recent sea level results and discuss new developments, in particular since 2003.

2. Satellite altimetry observations of sea level change

We now have a 15-year old time series of global sea level change measurements from the Topex/Poseidon and Jason-1 satellites. Fig. 1 shows the global mean sea level curve since January 1993 computed at Collecte Localisation Satellite (CLS) (data available on the AVISO web site: www.aviso.fr). This curve is based on Topex/Poseidon data from January 1993 to September 2002, a combination of Topex/Poseidon and Jason-1 between September 2002 and November 2005, and Jason-1 data alone since then. Data are averaged between 65°S to 65°N latitude. All geophysical and environmental corrections to sea level data have been applied.[1] In Fig. 1, annual and semiannual cycles have been removed and a three-month smoothing has been applied to the raw 10-day global mean sea level values. The global mean sea level increases almost linearly except at the end of the period where the rate is slightly reduced. The linear trend computed over the whole time span (January 1993 to February 2008) amounts 3.1 ± 0.1 mm/yr. This rate agrees well with earlier estimates (e.g., [2,6]). The 0.1 mm/yr uncertainty quoted above represents the formal error. According to Mitchum [33] and Leuliette et al. [24], comparison between altimetry-based sea level change and tide gauge records over their overlapping time span suggests a more realistic error of 0.4 mm/yr. Such a value is considered below. A small correction of –0.3 mm/yr due to the global deformation of ocean basins in response to postglacial rebound (or glacial isostatic adjustment [GIA]) has to be subtracted from the above trend, leading to a rate of sea level rise of 3.4 ± 0.4 mm/yr for 1993–2008.[2]

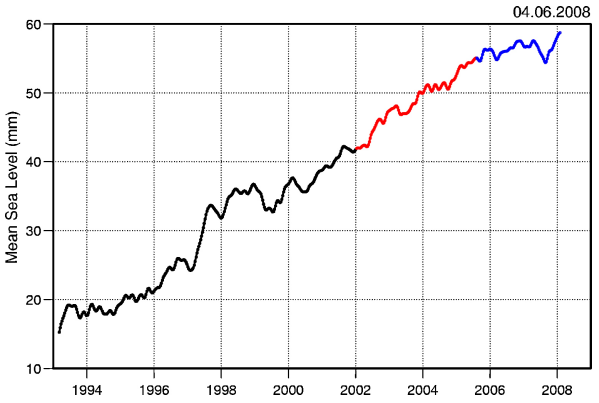

Fig. 1. Sea level curve from Topex/Poseidon and Jason-1 satellite altimetry over 1993–2008 (data averaged over 65°N and 65°S; three-month smoothing applied to the raw 10-day data). Black: Topex/Poseidon; red: Topex/Poseidon plus Jason-1; blue: Jason-1.
Évolution du niveau de la mer, entre 1993 et 2008, mesurée par les satellites altimétriques Topex/Poseidon et Jason-1 (données moyennes sur le domaine 65°N et 65°S de latitude ; un lissage sur trois mois a été effectué). Noir : Topex/Poseidon ; rouge : Topex/Poseidon plus Jason-1 ; bleu : Jason-1.

For the past century, the rate of sea level rise is estimated from tide gauges data (e.g., [16,17,19,44]) and from reconstruction methods that combine tide gauge records and regional variability from Topex/Poseidon altimetry [10], thermal expansion data [3] or general ocean circulation model outputs.[3] Fig. 2 shows the global mean sea level evolution over the past century from some of the above studies. Over the past 50 years, these studies report a mean rate of sea level rise on the order of

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