Observational Constraint on Greenhouse Gas and Aerosol Contributions to Global Ocean Heat Content Changes

Charles, Elodie (1,2); Meyssignac, Benoit (2); Ribes, Aurelien (3)

1: CLS, France; 2: LEGOS - Laboratoire d'études en Géophysique et océanographie spatiales; 3: CNRM-GAME - Groupe d'étude de l'atmosphère météorologique

E-Mail: elodie.charles29@gmail.com

Tide gauge and satellite-based radar altimeter measurements provide evidence that the global mean sea level (GMSL) has been rising during the last two centuries and that this rate has been accelerating since the early 1900's, reaching 2.0±0.3 mm/year over 1971-2010 and 3.2±0.4 mm/year over 1993-2012 (Church et al. 2013). Ocean thermal expansion was identified as one of the main contributors, accounting for about 40% of the GMSL rise over 1971-2010 and 30% over 1993-2012 (Church et al. 2013).

However, the influence of natural and anthropogenic external forcings and of internal variability on the global ocean heat content (OHC) remains unclear. Since the pre-industrial era, a simultaneous increase of greenhouse gases and aerosol emissions has been recorded. Their opposite effect on the heat accumulation in the Earth system results in larger uncertainties when attempting to distinguish their respective contributions. In future scenarios, aerosol rates tend to decrease while greenhouse gas emissions keep increasing. Separating the effects of those two anthropognenic forcings is therefore essential to project sea level rise.

This study aims at (1) providing a new estimate of the contributions of external forcings to OHC, in particular the response to greenhouse gases and aerosols forcings ; (2) highlighting the importance of applying an observational mask before a detection and attribution analysis ; (3) exploring the use of regional and temporal patterns as an additionnal constraint to better understand the response of the global OHC.

Our detection and attribution analysis is based on a new method developed by Ribes et al. (2015). This approach dismisses the usual linear regression and proposes a symmetric treatment of the magnitude and pattern of the climate response to each forcing. We use a large ensemble of forced and unforced simulations issued from CMIP5 to calculate a first estimate of the OHC response to natural, anthropogenic, greenhouse gas and other forcings. Observational datasets issued from reconstructions are then used to constrain this first estimate to a more accurate result. A spatio-temporal observational mask is applied to compare simulations with actual observations and to overcome reconstruction biases.

Results on the layer 0 to 700 m deep from 1971 to 2005 show that the observed OHC trend cannot be explained by climate internal variability and natural forcing only, nor by greenhouse gas emissions or other anthropic activity. The response to the combination of all anthropogenic forcings gives a trend closer to observations, and, as expected, the response to all forcings (historical simulations) explains most of the observed trend. New estimates of the response to each external forcing are obtained with significantly reduced uncertainties. Comparison with the unmasked analysis shows that the consistency between models and measurements is significantly improved when applying the observational mask. Uncertainties are further reduced by applying this statistical analysis to a bivariate case, i.e. to the responses over two different periods and/or regions.

Keywords: Ocean heat content, detection and attribution, observational mask, sea level