Scientist investigates changing sea levels

March 17 2015

The sea level has been rising by an average of 3.1 millimetres a year since 1993. Long-term measurements recorded since the start of the 20th century indicate an acceleration in the averaged sea level change. Coastal flooding and land loss are just some of the severe consequences. Geodesist Dr.-Ing. Luciana Fenoglio-Marc, is currently using satellite data to analyse sea level change and its causes.

The carbon dioxide (CO_2), methane and other gasses entering the atmosphere as the result of human activity are changing its radiation balance leading to increasing temperatures and, consequently, to a rising sea level.

Traditionally, sea level changes are recorded at coastal tide gauge stations, which measure the water level relative to a fixed point of the Earth's crust.

Some of the records go back to the 19th century and provide important insights into sea level evolution. Since 1991 it has been possible to measure the surface of the oceans across the entire globe using satellite altimetry, whereby the satellite emits a signal towards the ocean's surface and receives the reflected echo. The sea level is calculated from the round-trip time between the satellite and the sea surface and the position of the satellite along its trajectory. Whilst the data from tide gauges provides information about local changes relative to the land, the use of altimeter satellites enables the recording of data in a global reference frame.

Dr.-Ing. Luciana Fenoglio-Marc, a scientist specialised in physical and satellite geodesy at the TU Darmstadt's Faculty of Civil and Environmental Engineering, employs these and other satellite geodetic observation data in her research. Her work is based on altimeter data in combination with positional and gravitational field data derived from satellites. Her objective is to analyse sea level changes and to understand its causes improving the processing of the satellite measurements as well as their use in simulations and forecasting methods.

Protection from rising water levels

The increase of around 3.1mm per year since 1993 indicates a marked rise in the average sea level when compared to previously recorded values, which show a sea level rise of one to two millimetres per year in the 20th century. In its 5th report (IPCC AR5, 2013), the Intergovernmental Panel on Climate Change (IPCC) predicts a further increase in the global sea level of 30 to 70cm by the end of the 21st century based on a scenario involving a medium rate of global warming. The increase will not be even, but will instead have a greater impact on some regions than others. The result could be coastal flooding and rising ground water levels – an outlook that makes it essential to have a reliable data basis for dealing with the concomitant dangers. Protecting coasts from the rising seas will require considerable adaptations, particularly such low lying coastal regions as the North Sea coast of Germany and islands in the tropics.

In the course of her project, Fenoglio-Marc first improved altimeter data for near-shore areas and compared it with local geodetic measurements. New ways of analysing the radar echoes significantly extended the functional range of altimetry in the coastal zone. In this way, in collaboration with the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and in close consultation with the German Federal

Institute of Hydrology (BFG) as well as the German Federal Maritime and Hydrographic Agency (BSH), it proved possible to validate the sea level, wind speed, and wave height data derived from satellite altimetry against a large variety of in-situ and model data in the German Bight. "This exchange of data", Fenoglio-Marc explains, "is extremely beneficial for the analysis, calibration, and interpretation of the results from satellite altimetry. Unfortunately, such smooth exchange of data and information cannot be taken for granted and is not possible at global level." The combination of various altimeter missions and measurements from past years requires a high degree of adaptation of the data yield as well as due consideration for the respective environmental influences. As Fenoglio-Marc explains, "this can only be achieved through an international collaboration such as the ESA's Climate Change Initiative in which we participate." By this means it is possible to build improved sea level products which lead to an improved integration of altimeter and tide gauge measurement – still one of the biggest challenges in the field of satellite altimetry.

The causes of rising sea levels

In addition to improving altimeter data and sea level quantification, Fenoglio-Marc's work also focuses on the causes of the observed changes.

Among other reasons, rising global temperatures in the wake of climate change result in an increased volume of the heated water as well as in a mass increase through the influx of melting continental ice sheet run off. Both of these factors result in higher sea levels. According to the IPCC, about 35 per cent of the sea level increase between 1993 and 2010 was the result of thermal expansion, whilst around 45 per cent can be traced to melting ice. The remaining 20 per cent of the sea level increase can be due to additional contributions, as from continental water, and to the two above listed causes, which individual contributions are still under study.

With the aid of an additional satellite application, satellite gravimetry, it is possible to record changes in the oceanic mass and to use them, in combination with the altimetry results, to reveal the causes of sea level rise.

In the framework of a German Research Foundation (DFG) priority programme, Fenoglio-Marc has taken a new approach involving the direct estimation of mass changes in the Mediterranean Sea based on data from the satellite-based gravimeter mission GRACE (Gravity Recovery and Climate Experiment). Her results show mass changes to be the cause of an average sea level rise in the Mediterranean Sea of about 2.1mm per year since 1993. The programme required an integrated approach, which could only be achieved through interdisciplinary data analyses and modelling.

Fenoglio-Marc's research work is consistently confirming one basic insight, namely the fact that interdisciplinary studies and the reliable integration of observations are crucial for the interpretation and causal determination of sea level changes.

Provided by Technische Universitat Darmstadt