Deltas in Depth scientific sessions	
Deltas in Depth Theme 1. Climate projections and extremes	
DD 1.2 Sea level rise and impacts	
Chair	Prof. Eelco Rohling, Australian National University, Australia
Presentations	• Dr. John Church FAA, FTSE, CSIRO Fellow, Centre for Australian Weather and Climate Research, Australia
	• Prof. Eelco J.Rohling, Research School of Earth Sciences, The Australian National University, Australia
	• Dr. Hylke de Vries, KNMI, the Netherlands
	• Cynthia Rosenzweig, NASA GISS/Columbia University, USA
	• PhD Rezaur Rahman, Bangladesh University of Engineering and Technology, Bangladesh

Introduction
Eelco Rohling introduces this session by highlighting the various high-level speakers from a range of countries that will present their work. This session will encompass some of the latest and most innovative advances in the study of sea level rise and its impacts. Prof. Rohling hands over to 'Mr Sea Level', Dr. John Church.

Dr. John Church, News from the IPCC chapter on Observations, Understanding and Projections of Sea Level Change
In this keynote contribution, Church presents the main findings of Chapter 13 (Sea Level Rise) of the IPCC report 'Climate Change 2013'. This report once again emphasized that understanding of the past is crucial for projecting future changes. In the last interglacial (129ka – 116ka) the sea level was more than 5m higher than present. The melting of Greenland contributed significantly to this.

Between 1901 and 1990, the rate of sea level rise (SLR) averaged 1.3 - 1.7 mm per year. In the period 1993 – 2010, this rate was substantially higher at 2.8 – 3.6 mm per year. This increase in the rate of SLR is found consistently in many studies. The main reasons for SLR are thermal expansion of ocean water; change in mass of glaciers and ice sheets; and changes in liquid water storage on land. Recent advances in research show that we can now skilfully understand and model these individual components, and produce reliable estimates of global SLR. Projections show that 21st century SLR rates will exceed those of 1971 – 2010, under all emission scenarios. A large source of uncertainty in these projections is the potential breaking off of marine parts of the Antarctic ice sheets, which could potentially lead to significantly higher rates of SLR.

Prof. Eelco J. Rohling, A geological perspective of sea-level change
Compared to the previous presentation, this one focuses on SLR over a much longer time scale of hundreds of thousands of years. Prof Rohling shows the latest findings based on a unique data set from the Red Sea, going back 520.000 years.

The results show that there is a clear match between Antarctic temperature and SLR. It is shown that ice sheets respond slowly to temperature changes, but that there is an eventual balance between atmospheric CO_2 and sea level; for example, it is shown that a concentration of 400ppm tends to be related to a sea level 9-31 m above currently (68% probability interval; modal value at 24 m). The maximum changes in sea level follow changes in Antarctic temperature within a few centuries. The rates of SLR depend highly on the amount of ice that is available globally – after ice ages, there is more to melt and rates of rise are higher. For the last interglacial, in which global temperatures were about 2 degrees warmer than today, the mean sea level was 4-6 meters above the present level, with peaks up to 8 or 9 m. At such ice volumes close to the present value, the paleo-date suggest rates of SLR of 1 to 1.5 m per century. These paleo-climatological results were used to put current trends in perspective, and show that recently observed SLR is within (but toward the high end of) the 68% probability envelope of 'natural' changes from the last 500,000 years. A key observation was that, once started, sea level rise due to adjustment to the current climate state would continue for centuries.

Dr. Hylke de Vries, The KNMI'14 scenarios for sealevel rise along the North Sea coast
A large portion of the Netherlands is located below sea level. SLR can cause this portion to become even larger and, additionally, cause rivers to flood more frequently. Improved SLR scenarios can help inform adaptation programmes needed to deal with SLR along the Dutch coast. Dr. de Vries presents the latest work on developing specific SLR scenarios for the Netherlands by the KNMI.

The research team used two scenarios: average and warm. For those two scenarios, the pathways of temperature and other driving forces were computed. Then, a regionalisation exercise was conducted to specify SLR for the Dutch coast, based for example on mass changes of the Greenland and Antarctica ice sheets. Results show that the model outcomes are well in line with measured sea level changes. Dr De Vries emphasises that this approach can easily be reproduced to assess SLR at other locations around the world.

Cynthia Rosenzweig, Preparing for Sea Level Rise in New York City
Hurricane Sandy caused the highest water levels on record and had an enormous impact in New York City (NYC). It resulted in an increased interest in location-specific SLR projections and other climate risk information, which was then produced within the framework of the *Special Initiative for Rebuilding and Resilience.*

The research used an innovative multi-component approach to develop probabilistic SLR projections for the region, based on CMIP5 data. Results showed that SLR in NYC has been around double the global average since 1900, which is partly caused by land subsidence in the region. By 2100, the sea level is expected to be 38cm (10^{th} percentile) to 191cm (90^{th} percentile) higher than currently. These estimates were then used to produce coastal flood risk maps for future time periods. One of the main challenges in adaptation to increasing risks is the fact that risks spread across multiple levels of jurisdiction, with each level (local, state and national) playing a role in regulations. There is a clear need for federal coordination that recognises local and state initiatives as well as public-private partnerships.

Dr. Rezaur Rahman, Natural hazards and migration in the coastal region of Bangladesh

Bangladesh is a heavily flood-prone country, suffering from flash floods, river flooding and coastal surges. Many adaptation measures have been taken over the centuries, including coastal polders and levees. The coastal polders have suffered from lack of maintenance, siltation, and disastrous effects of the 2007 (Sidr; 3,363 fatalities) and 2009 (Ailia; 190 fatalities) cyclones.

Dr. Rahman presents ongoing work of the ESPA study, which is studying this problem. Interestingly, results from this study show that population growth is slowing in Bangladesh and that several parts of the country face an absolute population decline. This is often caused by environmental degradation, such as salinity and drainage congestion, as well as the destruction of the two major cyclones. It is concluded that long term planning is needed to re-establish the habitability and resilience of coastal Bangladesh, especially in the face of a changing climate.