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Foreword

The papers compiled in this special issue originate from presentations given at the 26th General Assembly of the European Geophysical Society, which was held in Nice, France, in March 2001. In the symposium *Sea Level Changes from Global to Local*, more than 30 papers were presented covering the full range of sea level science. The symposium was made up of two sub-symposia, namely *Sea level changes; advances in techniques and observations: satellite altimetry and tide gauges* and *Causes and consequences of sea level changes* (*long term*, *short term*).

In the context of the climate change debate, focus has been on the sea level signal both as an indicator of climate change and as a key quantity for its potentially severe impact on human well-being due to sea level rise caused by future global warming. Sea level changes are a consequence of complex interactions of the cryosphere, ocean, atmosphere, hydrosphere, solid earth and possibly anthropogenic processes and they cover a wide range of temporal and spatial scales. The outstanding scientific questions include: (1) Can one accurately determine the sea level rise during the last century? (2) Is there evidence of accelerated sea level rise since the industrial revolution? (3) Can one explain the observed 20th century sea level rise? (4) Can one predict the future rates of global sea level rise and of sea level changes on regional to local scale?

Over recent years, the satellite altimetry missions have added a wealth of new observations to the already existing global tide gauge data set. Moreover, tide gauges are increasingly co-located with space-geodetic techniques thus allowing for the determination of absolute sea level changes. The improved data base and particularly the availability of the satellite altimetry data has prompted a rapid improvement of our understanding of the causes of sea level variations. New insight can be expected from the full use of integrated data sets comprising tide gauge data, satellite altimetry observations, and observations of relevant oceanographic and meteorological variables such as sea surface temperature, salinity, currents, wind and air pressure. Theoretical and numerical modelling of ocean only and coupled ocean–atmosphere processes using both complex GCM's and a range of simpler models is also helping to elucidate the mechanisms involved.

In the first of the two sub-symposia, focus was on the recent technological improvements in sea level observation as well as the methodological progress in the use of integrated data sets. Particular emphasis was on the use of long-term tide gauges co-located with space geodetic stations, such as GPS and DORIS, and the availability of satellite radar altimetry in the last decade.

Tide gauges, on the one hand, record local relative sea level changes. If combined with observations from properly co-located space-geodetic techniques, absolute sea level changes can be extracted. Some of the tide gauges have been recording for almost two centuries, thus providing local records of the long-term variability of relative sea level. On the other hand, for more than a decade, satellite altimetry observations from the GEOSAT, TOPEX/POSEIDON and ERS missions provide near-global and quasi-continuous monitoring of sea level variations, while the current (T/P, ERS-2, GFO) and very recently started missions (Jason-1 and ENVISAT) will extend the observation during the next decade. The combination of terrestrial and space-borne observations allows for an absolute calibration of the satellite altimeters while the combined use of multi-mission altimetry data increases the spatial and temporal resolution and extends the time series length, which is fundamental for long-term sea level change studies.

The second sub-symposium highlighted new findings related to the causes of sea level changes and also focused on new evidence and estimates of consequences of sea level changes. The topics included improved estimates of contribution to sea level from phenomena such as ice sheet melting and accumulations, thermal expansion of the ocean, ocean circulation due to mass redistribution, atmospheric circulation, and anthropogenic effects. Advances in the modelling and observations of glacial isostatic adjustment, which remains one of the primary uncertainties in the use of tide gauge data to estimate the global sea level rise during the last century, were also addressed.

Global average mean sea level and regional to local mean sea level is affected by many factors causing fluctuations and changes at different time scales. Over the last century, an upward trend has become evident. In the coming century, the rate of rise is predicted to increase as a result of anthropogenic climate change. In the

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attempt to understand the causes, much focus has been directed towards ocean thermal expansion and on mass exchanges between the ocean and terrestrial ice and water reservoirs. On regional to local scales, changes in the patterns of atmospheric pressure and wind stress, changes in the spatial distribution of heat flux into the ocean, and oceanic circulation changes may also be important. The relative sea level is additionally affected by vertical crustal motion. Moreover, the characteristics of short lived storm surge events may also vary. Significant consequences of sea level changes can be expected in some continental coastal areas and on oceanic islands as a result of both the changes in mean sea level and the changes in extreme surge events.

The 10 papers collected in this special issue give a comprehensive overview of the topics addressed in the symposium. The first two papers by Nielsen et al. and Drago and Boxall are examples for recent developments in the analysis of sea level observations using EOF and wavelet analysis, respectively. The paper by Teferle et al. discusses the co-location of tide gauges with continuous GPS in order to decontaminate the relative sea level observations for vertical land movements. Satellite altimetry is a major source for sea level observations and the combination of the relatively short altimetry record with the much longer tide gauge records is addressed in the paper by Chambers et al. Several presentations studied long-term sea level variations on the basis of satellite altimetry, and the papers by Andersen and Knudsen and Fenoglio-Marc are examples of global and regional studies, respectively. Increasingly, focus is on assimilation of satellite altimetry data in ocean models, and Wenzel and Schröter discuss the effect of the assimilation for a global model.

Hydrological processes and in particular glaciers and ice sheets are considered as major contributions to the observed secular sea level trend. Chen et al. discuss the relative importance of mass exchange versus thermal expansion while Braithwaite & Raper give an overview of the contribution due to glaciers. The last paper by Nicholls gives an example of an impact study addressing the impact of sea level rise on flooding.

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