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Recent advances in sea level studies and land hydrology from satellite observations (Arthur Holmes Medal Lecture)

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Sea level and terrestrial waters are now currently studied using space techniques, in particular satellite altimetry and space gravimetry. In this presentation, I first discuss recent results obtained in measuring sea level rise from space. Since early 1993, sea level variations are accurately measured by Topex/Poseidon satellite altimetry, complemented for the recent years by Envisat and Jason-1. This $>$12 years long data set indicates that, in terms of global mean, sea level is presently rising at a rate of $\sim$ 3.2 +/- 0.4 mm/yr, a value significantly higher than the mean rate recorded by tide gauges during the past 50 years (on the order of 1.8 +/- 0.3 mm/yr). This eventually suggests that sea level rise is currently accelerating due to enhanced land ice melting and/or increased ocean warming. Owing to its global coverage, satellite altimetry also reveals high regional variability in the rates of sea level change, with some regions exhibiting rates of 5-10 times the global mean. Quasi-global ocean temperature data sets, recently published, allow quantitative estimate of one of the two major contributions to present-day sea level rise : thermal expansion. Results indicate that for the past 50 years, thermal expansion accounts for 0.4 mm/yr sea level rise, i.e., 25% of the observed rise. For the recent years (1993-2003), enhanced thermal expansion accounts for 50% of the observed sea level rise (1.5 mm/yr of 3 mm/yr). For both periods (last 50 years and last decade), there is $\sim$1.5 mm/yr global mean sea level residual not explained by thermal expansion, and thus attributed to water mass exchange with the continents and land ice. While melting of mountain glaciers contributes to $\sim$1 mm/yr sea level rise for the 1990s, other water mass contributions (ice sheet mass balance and terrestrial waters) are still very uncertain. New perspectives are now envisaged with the new space gravimetry mission, GRACE, launched in 2002, which precisely measures

change in land waters storage and mass balance of the ice sheets. Preliminary results show that GRACE is indeed able to determine the contribution of terrestrial waters to sea level and associated ocean mass component. By combining satellite altimetry with GRACE, it appears also possible to estimate the mean thermal expansion, totally independently of in situ ocean temperature measurements. Over the ice sheets, GRACE observations are also sensitive to ice mass change, hence provides a new tool to quantify the corresponding contribution to sea level. In the second part of this presentation, I focus on land surface waters observed from space. Besides GRACE which measures the spatio-temporal change in total water storage (soil plus underground waters and snow), satellite altimetry on surface waters (rivers, lakes and floodplains) provides additional information such as water levels and river slope. If combined with radar or visible imagery data, it also provides information on floodplains water volume and extent. In view of the current decline of ground-based river gauging networks as well as lack of global-scale in situ measurements of water storage in soil and underground reservoirs, remote sensing observations of selected hydrological parameters are of primary importance for improving our knowledge of the terrestrial branch of the global water cycle, with important perpectives in several areas such as climate change and sea level, as well as global water ressources inventory.