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Effects of ice-melt induced gravity changes and solid earth deformation in the Netherlands

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Determining sea-level change caused by continental ice mass variations is a far more complicated matter than one might think. Even if effects like induced changes in ocean currents or thermal expansion of ocean water are neglected, melt water does not redistribute uniformly and homogeneously over the world's oceans. If land ice melts, the gravity field of the earth changes due to the redistribution of the ice and melt water masses.

These gravity changes are not negligible, in fact they cause that within a distance of 20 degrees (2,200 km) from the melting ice cap, sea level will *drop*. Sea level will rise between distances of 20 degrees and 60 degrees (6,700 km) from the melting ice mass, but less than would be expected on the basis of a uniform redistribution of the melt water over the oceans. On the other hand, sea level rise will be larger than the average expected amount for distances further away than 60 degrees from the place where land ice melts. This gravitational effect, that thus needs to be incorporated in sea-level change predictions, was already quite well known in the 19th century. As a consequence, something like 'THE' sea-level change, in the sense of a change over the oceans with a homogeneously uniform magnitude, is something that is at best only a mathematical quantity. Thus, obviously continental ice mass changes '*leave their fingerprints*' in regionally varying sea-level change patterns, so in principle it might be possible to learn about where the melt water from continental ice came from (Greenland, Antarctica or mountain glaciers) by observing and interpreting these regionally varying sea-level patterns.

Induced solid-earth deformation and induced changes in the earth's rotation (polar wander) due to ice–water redistributions make these *regionally* varying sea-level changes even more complicated. For example, around the Bothnic Gulf the land rises due to the disappearance of the great ice masses that covered Northern Europe some 20,000 years ago. This so-called post-glacial rebound with a magnitude of up to one cm per year makes that sea level around the Bothnic Gulf effectively *drops* with respect to coastlines.

Modern satellite observations from low-earth orbits are beginning to reveal the rich regional varieties in sea level change that the earth experiences nowadays. Apart from observing ongoing sea-level change, combined gravity and laser altimetry (height measurement) satellite observations might soon solve a long-standing, vexing problem concerning the Antarctic ice sheet: what is the role of post-glacial rebound in observed mass changes and (ice and land) surface deformation over this continent? A question that is not unimportant for the Netherlands: after all, as has been described above, a change of mass M of the Antarctic ice sheet affects sea-level in the Netherlands more than the same ice mass change M over Greenland.