K. Steffen: **Cryosphere and Sea-Level Variability and Change**

The mean surface mass balance (SMB) of the Greenland ice sheet, based on four 50-year records, is 354 Gt/yr with a range between estimates of 54%. This is on the order of magnitude of the standard deviation of the interannual variability, which ranges from 62 Gt/yr to 124 Gt/yr. Since the mid-1990s, runoff has increased significantly with only a modest change in accumulation, resulting in a reduction in the SMB of around ~200 Gt over the last 13 years. Much of the ice loss from the Greenland ice sheet occurs by ice discharge into the surrounding ocean and has been estimated at 50% of the mass loss. Observations during the past decade have shown that ice discharge can increase by a factor of two within a few years and, in some cases at least, that this can also be reversed. Gravity satellite data show that the Greenland mass loss doubled over the period from 2002 to 2009 to roughly 250 Gt/yr, 0.7 mm/yr sea level rise.

Comprehensive estimates for Antarctica mass change are only available since the early 1990s. Several new studies using the GRACE satellite gravity data all show net loss from the Antarctic since 2003 with a pattern of near balance for East Antarctica, and greater mass loss from West Antarctica and the Antarctic Peninsula. The rate of mass loss from the Antarctic ice sheet is increasing from 104 Gt/yr for 2002-2006 to 246 Gt/yr for 2006-2009 (the equivalent of almost 0.7 mm/yr of sea level rise. Satellite glacier velocity estimates from 1974 imagery show that the outlet glaciers of the Pine Island Bay region have accelerated since then, changing a region of the ice sheet that was in near balance to one of considerable loss. The recent acceleration of ice streams in West Antarctica explains much of the Antarctic mass loss, but narrow fast-moving ice streams in East Antarctica are also contributing to the loss.

Glaciers can potentially contribute a total of approximately 0.7 meters to global sea-level, and their contribution to sea level at the beginning of the 21st Century was about 0.8 mm/yr. New assessments show that the mass loss of glaciers and ice caps has increased considerably since the beginning of the 1990s and now contribute about 1.2 mm/yr to global sea level rise. Glaciers and ice caps are not in balance with the present climate.

The cryospheric contribution to sea level rise has risen above 2mm/yr in recent years with equal parts from the two ice sheets.

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Dr Konrad Steffen is responsible for vital instrumentation deployed in the Arctic to help us monitor the significant changes taking place on the Greenland ice sheet. Without his work, human knowledge of Arctic climate, warming, and melting dynamics would be substantially diminished. He has led field expeditions to the Greenland ice sheet, Antarctica and Kilimanjaro, as well as other polar regions, for the past 35 years to measure the dynamic response of ice masses under a warming climate. Dr Steffen has published over 100 peer-reviewed papers and 10 book chapters. He received his education from the Swiss Federal Institute of Technology (ETH) in Zürich and has been teaching since 1991 at the University of Colorado at Boulder. He is currently the chair of the WCRP/CliC Programme, participates in the NASA Earth Science Subcommittee advising board, is a member of the Advising Board of the Alfred Wegner Institute for Polar and Marine Sciences in Germany, and a lead author of the assessment for the cryosphere chapter in the IPCC Fifth Assessment Report.