

## **Changes in the Mass Balance of the Greenland Ice Sheet in a Warming Climate During 2003-2009**

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Mass changes of the Greenland ice sheet (GIS) derived from ICESat and GRACE data both show that the net mass loss from GIS during 2003-2009 is about 175 Gt/year, which contributes 0.5 mm/yr to global sea-level rise. The rate of mass loss has increased significantly since the 1990's when the GIS was close to balance. Even though the GIS was close to mass balance during the 1990's, it was already showing characteristics of responding to a warmer climate, specifically thinning at the margins and thickening inland at higher elevations. During 2003-2009, increased ice thinning due to increases in melting and acceleration of outlet glaciers began to strongly exceed the inland thickening from increases in accumulation. Over the entire GIS, the mass loss between the two periods, from increased melting and ice dynamics, increased by about 190 Gt/year while the mass gain, from increased precipitation and accumulation, increased by only about 15 Gt/year. These ice changes occurred during a time when the temperature on GIS changed at rate of about 2K/decade. The distribution of elevation and mass changes derived from ICESat have high spatial resolution showing details over outlet glaciers, by drainage systems, and by elevation. However, information on the seasonal cycle of changes from ICESat data is limited, because the ICESat lasers were only operated during two to three campaigns per year of about 35 days duration each. In contrast, the temporal resolution of GRACE data, provided by the continuous data collection, is much better showing details of the seasonal cycle and the inter-annual variability. The differing sensitivity of the ICESat altimetry and the GRACE gravity methods to motion of the underlying bedrock from glacial isostatic adjustment (GIA) is used to evaluate the GIA corrections provided by models. The two data types are also combined to make estimates of the partitioning of the mass gains and losses among accumulation, melting, and ice discharge from outlet glaciers.