LASER SENSING OF THE CRYOSPHERE: ICESAT-1 RESULTS AND FUTURE MISSIONS

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During the last decade, large changes have been occurring in the Earth's cryosphere. Laser remote sensing has been an essential tool for quantifying these changes. In particular, NASA's Ice, Cloud, and Land Elevation Satellite (ICESat), which began operation in February 2003, has provided critical cryospheric data, especially for the Greenland and Antarctic ice sheets and polar sea ice. Although ICESat's three lasers where expected to provide continuous laser operation for 3 to 5 years, early failure of one laser and unexpected degradation of output power of the other two lasers led to a data collection strategy of 2 to 3 laser campaigns per year. So far, science data has been acquired during fifteen campaigns ranging from 33 to 54 days each.

The primary purpose of ICESat has been to acquire time-series of ice-sheet elevation changes to determine the present-day mass balance of the ice sheets, identify changes in the surface input and output and in the ice dynamics, and estimate the contributions to global sea-level rise. ICESat data has enabled the most accurate elevation maps of Greenland and Antarctic ice sheets for detailed characterization of topographic features on ice sheet, ice shelves, grounding lines, and ice streams. Maps of ice sheet elevation changes derived from nearly 6 years of intermittent data are showing that some significant changes in the rates of mass input and output and ice dynamics have occurred since the 1990's. In particular, the Greenland ice sheet has changed from a state of near balance (mass input equal to mass output) to an annual mass loss of about 150 Gt/yr, which is about 25% of the total mass input rate. Parts of the Antarctic ice sheet appear to be losing mass at an increasing rate, but other parts appear to be gaining mass also at an increasing rate.

In addition, ICESat has been making pioneering measurements of sea-ice freeboard (height of snow/ice surface above the ocean surface) from which the sea-ice thickness is estimated. Comprehensive maps of sea ice thickness made 2 or 3 times per year since 2003 show a significant decline in the thickness and volume of the Arctic sea ice pack.

The Decadal Survey report, Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, by the US National Research Council recommended a follow-on ICESat-2 mission as early as 2010, "given the rapidity of the change in polar sea ice and ice sheets". The current funding and development plans for ICESat-2 are aimed at a launch in 2014. ICESat-2 will continue the assessment of polar ice changes in a changing climate, with special emphasis of understanding the climatic and glaciological causes of the ice changes and development of an improved capability for predicting changes over the next century. ICESat-2 will also measure vegetation-canopy depths for estimating land-carbon storage to understand biomass responses to climate and land-management changes. It will also make measurements of clouds and aerosols similar to ICESat-1, but with somewhat less sensitivity. The payload will include a single-channel lidar system, GPS navigation for precision orbit determination, an attitude control system for precision near-nadir pointing to reference tracks and off-nadir targeting, and a precision laser-attitude determination system similar to that on ICESat-1. It will correct technical issues such as laser lifetime limitations, signal saturation, and laser beam alignment uncovered during the ICESat-1 mission. A 5-year mission is planned with consumables for extended operations. The science requirements for an additional laser channel with multiple cross-track beams are under review, as well as technical options for implementation. One option for the cross-track channel is to include more laser beams (e.g. 4 total) of the same type as the primary channel and the other is to utilize a high-repetition-rate laser to create multiple push-broom-type tracks (e.g 8 to 16) along with photon-counting signal detection methods.