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Dynamics and Change of the Devon Island Ice Cap, Nunavut

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Dates in the field: 18 April – 17 May, 2011.

This research program, initiated in 2004, aims to quantify the mass change rate of Canada's Arctic ice caps, determine the underlying causes and mechanisms of ongoing changes, and evaluate the significance of these changes for global sea level. Given its regional scale focus, much of the program relies on remote sensing to achieve these goals. However, fieldwork is essential to validate remote sensing measurements and develop understanding of the mechanisms of change. My program on the Devon Island Ice Cap is thus integral to the success of the program as a whole. Currently it has two major components: (i) calibration and validation of the radar altimeter on the CryoSat2 satellite (a collaboration with David Burgess of the Geological Survey of Canada), a new tool for monitoring changes in the thickness, volume, and mass of Arctic ice caps, and (ii) a study of ice dynamics, hydrology, and iceberg calving at the Belcher Glacier that is designed to explore how tidewater outlet glaciers respond to climate change and contribute to overall mass loss from Arctic ice caps.

Recent Progress

Changes in the mass balance of Canada's Arctic ice caps in the 21st century are unprecedented in the 53-year period of observations. Year-to-year changes in the mass balance of these glaciers are mainly due to changes in summer climate and surface melting. The decade of the 2000s had the warmest summer temperatures in the last 60 years, and 2005-2009 was the warmest 5-year period. Across the Queen Elizabeth Islands, the warming after 2005 extended the summer melt season by 5-12 days and measured rates of mass loss rates after 2005 were up to 3.8 times higher than the ~50 year mean. Modeling of the regional surface mass balance and geodetic analyses of mass change using data from IceSat laser altimetry and GRACE satellite gravity show that total annual mass loss from glaciers in the Queen Elizabeth Islands increased from ~9 Gt/yr in 2004-6 to ~62 Gt/yr in 2007-9. From 2007-2009, the Canadian Arctic was probably the single largest regional mass contributor to global sea level rise outside the large ice sheets in Greenland and Antarctica. Our annual surveys of the Devon Ice Cap, based on snow pits, shallow ice cores, and ground penetrating radar (GPR) surveys show that there has been a huge change in how rapidly snow on the Devon Ice Cap is transformed into glacier ice since 2005. Every year now, surface meltwater penetrates deeply into snow and firn near the glacier surface and then refreezes to form ice even in areas that are high enough that, until the 2000s, surface melt occurred only once or twice a decade.

<u>2011 Field Season.</u>

(a) ***CryoSat calibration-validation***. Spatial and temporal changes in the abundance of ice layers in the upper parts of the ice cap change the way in which energy transmitted by the CryoSat2 radar altimeter is reflected from the ice cap. With more ice layers in the snow and firn, less of the energy is returned from the ice cap surface and more from ice layers within the snow pack. This changes the shape of the waveforms received by the satellite radar altimeter, and may have a negative impact on the accuracy of the surface height measurement that is obtained from the waveform. To test for, and quantify, this effect, we used GPS to make independent measurements of surface height and height change along the "CryoSat line" (which we have surveyed annually since 2004). We also measured the ice layer content of snow and firn using 500 MHz snow radar, shallow ice cores, and snow pit measurements. The results allow us to assess the accuracy of measurements of surface height and height change made by the satellite altimeter. In 2011, we established a new grid around the Cryosat line and made GPS and snow radar measurements across this grid. Grid lines were spaced 1km apart across a 10km wide swath centered on the CryoSat line. We surveyed over 300 km of GPS/radar ground track, allowing us to produce a detailed three-dimensional map of the structure of the upper 8m of the ice cap. We logged shallow ice cores to aid interpretation of the GPR data, and used infrared photography to map the distribution of ice layers in snow pits and cores. This helps us to interpret the snow radar measurements, which link together the sites where snow pits and cores were collected. We are comparing repeat snow radar profiles measured in different years to map changes in the abundance and distribution of ice layers in the snow and firn, and assess how these may have affected the radar altimeter measurements.

(b) ***Belcher Glacier:*** We replaced the batteries on the continuously recording GPS sensors that we operate on Belcher Glacier, collected the data that they recorded in 2010, and set them up to record for another year. These sensors record changes in the glacier's velocity throughout the year. We also deployed 3 new GPS sensors, to create a diamond-shaped array of 5 sensors near the glacier's terminus that will allow us to monitor both velocities and rates of ice deformation and investigate how they change when iceberg calving takes place. We re-measured a longitudinal profile up Belcher Glacier using GPS in order to determine changes in the glacier's thickness over the past year. We also serviced our weather stations and air temperature loggers, and retrieved 3 time-lapse cameras that had been overlooking the glacier terminus. These cameras will be replaced in 2012.

NRI-ᑯᓐᓄᑦ ᐊᕐᕌᒍᑕᒪᖅᓯᐅᑎ ᓇᐃᒡᓕᒋᐊᕐᓗᒍ ᐅᓂᒃᑲᖅ (ᔭᓐᓄᐊᕆ)
ᐊᑐᐊᕐᓗᒍ ᖃᐅᔨᓴᕈᓐᓇᐅᑎ ᓚᐃᓴ ᓇᒪ 02 067 10N-M

ᖃᓄᐃᑦᑑᓂᖏᑦ ᐊᓯᔾᔨᖅᐸᓪᓕᐊᓂᖏᓪᓗ ᑕᓪᓗᕈᑎᒥ ᓯᕐᒥᐊᓗᐃᑦ, ᓄᓇᕗᒥ

ᒪᑎᓐ ᓴᑉ: ᓄᓇᕐᔪᐊᒥᒃ ᓯᓚᒥᒡᓗ ᖃᐅᔨᓴᖅᑏᑦ ᐃᐊᓪᔫᑕᐅᑉ ᓯᓚᑦᑐᒃᓴᕐᕙᔪᐊᖓᓂ

<u>ᓄᓇᒨᖅᓯᒪᓚᐅᖅᑐᑦ 2011-ᒥ:</u> ᒫᑎᓐ ᓵᑉ, ᒋᐳᓇᐊᓕ ᒎᒡᑲᓐ, ᐳᕊᑦ ᑕᓂᐊᓪᓴᓐ (ᐃᐊᓪᔫᑕᒥᐅᑦ ᓯᓚᑦᑐᒃᓴᕐᕙᔪᐊᖓᓂᑦ)
<u>ᓄᓇᒦᓚᐅᖅᑐᑦ</u> 18 ᐃᐳᓗ – 17 ᒪᐃ, 2011.
ᖃᐅᔨᓴᕈᑕᐅᔪᖅ ᑖᓐᓇ ᐱᒋᐊᖅᑎᑕᐅᓚᐅᕐᒪᑦ 2004-ᒥ, ᑐᕌᒐᕐᑲᖅᓯᓂ ᓇᓗᓇᐃᔭᐃᔪᒪᓪᓗᑎᒃ ᖃᓄᑎᒋ ᐊᓯᔾᔨᖅᐸᓪᓕᐊᓂᖏᓐᓂᒃ ᓯᕐᒥᑦ ᑲᓇᑕᐅᑉ ᐅᑭᐅᖅᑕᖅᑐᖓᓂ, ᑐᑭᓯᐅᒪᓪᓗᑎᓗ ᑭᓯᐅᑦ ᖃᓄᕐᓗ ᐊᓯᔾᔨᖅᐸᓪᓕᐊᖕᒪᖔᑕ, ᐊᒻᒪᓗ ᐃᓱᒪᒃᓴᖅᓯᐅᕈᑎᒋᔪᒪᓪᓗᒋᑦ ᖃᓄᑎᒋ ᐃᑉᐱᖕᓇᕐᓂᕐᑲᕐᒪᖔᑕ ᓄᓇᕐᔪᐊᒥ ᓯᒡᔭᓄᑦ. ᑕᐃᒪᓐᓇᑎᒋ ᐃᑉᐱᖕᓇᕐᓂᕐᑲᖅᑐᓂᒃ ᖃᐅᔨᓴᖅᓯᑕ, ᕿᒪᒃᑕᐅᓯᒪᔪᓂᒃ ᐆᒃᑐᕋᐅᑎᓂᒃ ᐃᓕᐅᕐᑲᐃᓚᐅᖅᑐᒍᑦ ᓇᒥᑐᐃᓐᓇᖅ. ᑭᓯᐊᓂᓕ, ᓄᓇᒨᑲᑕᒋᐊᕐᑲᓚᐅᕋᑕ ᐃᓕᐅᖅᑲᐃᒋᐊᖅᑐᖅᓯᑕ ᐆᒃᑐᕋᐅᑎᓂᒃ ᐊᒻᒪᓗ ᑕᑯᔭᖅᑐᖅᓯᑕ ᖃᓄᐃᓕᖏᓪᓕᐊᓂᖏᓐᓂᒃ ᓯᓚᒧᑦ ᐊᓯᔾᔨᖅᐸᓪᓕᐊᑎᑕᐅᔪᑦ. ᑕᕝᕙ ᐱᓇᓱᐊᕆᔭᕋ ᑕᓪᓗᕈᑎᐅᑉ ᓯᕐᒥᐊᓗᐊᓂ ᑲᔪᓯᑦᑎᐊᕆᐊᖅᑲᖅᐳᖅ ᐃᓕᒋᔭᐅᖕᒪᑦ ᓄᓇᕐᔪᐊᒥ ᐊᖏᔪᓂᖅᓴᓗᑦ. ᒫᓇ ᒪᕐᕈᐃᓕᖕᒐᓪᓗᓂ ᐱᓇᓱᐊᕆᔭᐅᖕᒪᑦ (i)ᓯᓚᒧᑦ ᖁᕝᕙᖅᑎᑕᐅᓯᒪᔫᒃᑯᑦ ᐆᒃᑐᕋᖅᑕᐅᓪᓗᑎᒃ ᓄᓇᒥᓗ ᓱᓕᓂᖏᑦ ᑕᑯᔭᖅᑐᖅᑕᐅᕐᑲᑦᑕᖅᓱᑎᒃ ᐱᔭᐅᔪᕙᓃᑦ CryoSat2 satellite-ᒥᑦ (ᑖᒃᑯᐊ ᐱᔭᐅᕙᓪᓕᐊᖕᒪᑕ ᑎᕙᑦ ᐳᔨᔅᓗᑦ ᐅᔭᕋᖕᓂᐊᖅᑎᒃᑯᓐᓂᑦ ᑲᓇᑕᒥ), ᓄᑕᒥᒃ ᓴᓇᖅᑯᑎᕐᑲᓕᕐᒥᔪᒍᑦ ᐆᒃᑐᕋᐅᑎᒥᒃ ᓯᕐᒥᐅᑉ ᐃᔾᔪᓂᖓᓂᒃ, ᐊᒃᑎᒋᓂᖓᓂᓗ ᐅᕐᑭᖕᒋᓐᓂᖓᓂᓗ ᓯᕐᒥᐊᓗᐃᑦ ᐅᑭᐅᖅᑕᖅᑐᒥ ᐆᒃᑐᕈᓐᓇᖅᑐᒥᒃ, ᐊᒻᒪᓗ (ii) ᖃᐅᔨᓴᕐᒥᔪᑦ ᓯᑯᐃᑦ ᖃᓄᐃᑦᑑᓂᖏᓐᓂᒃ, ᐃᒪᑦᑎᐊᕙᐅᓂᖏᑦ, ᓄᑎᒃᑐᕐᑲᑦᑕᕐᓂᖏᑦ ᑕᕝᕙᓂ ᐱᐊᓪᓯ ᓯᕐᒥᐊᓗᐊᓂ ᑐᑭᓯᓇᓯᐊᖅᓯᑎᒃ ᖃᓄᑎᒋ ᓯᕘᓪᓕᐅᑕᐅᕐᑲᑦᑕᕐᒪᖔᑕ ᓯᒡᔭᒧᑦ ᐊᒃᑐᐊᔪᑦ ᓯᕐᒥᐊᓗᐃᑦ ᓯᓚᐅᑉ ᐊᓯᔾᔨᖅᐸᓪᓕᐊᓂᖓ ᒪᓕᒡᓱᒍ ᐊᒻᒪᓗ ᖃᓄᑎᒋ ᓄᖑᑉᐸᓪᓕᐊᓂᖏᑦ ᑕᒪᐃᑎᒍᑦ ᐅᑭᐅᖅᑕᖅᑐᒥ ᓯᕐᒥᐊᓗᐃᑦ.

<u>ᒫᓐᓇᑦᑎᐊᕋᑖᖅ ᐱᓚᐅᖅᑕᕗᑦ</u>

ᐊᓯᔾᔨᖅᐸᓪᓕᐊᖕᒪᑕ ᓯᕐᒥᐊᓗᐃᑦ ᐊᖏᔪᑎᑦ ᑲᓇᑕᐅᑉ ᐅᑭᐅᖅᑕᖅᑐᖓᓂ ᑕᐃᒪᖓᓂᑦ ᑕᒪᑐᒪᓂ Hᐊᓇᓚᓂ ᐅᑭᐅᓂ ᐅᐊᑲᓪᓚᓗᐊᖑᓂᖅᐹᖑᓪᓗᑎᒃ 53-ᓂ ᐅᑭᐅᓂ ᐆᒃᑐᕋᖅᑕᐅᓕᖅᑎᓪᓗᒋᑦ ᐊᕐᕌᒍᑕᒫᑦ ᖃᐅᔨᓯᒪᔪᑦ ᐊᐅᔭᒃᑯᑦ ᐅᖅᑰᓂᖓ ᒪᓕᒡᓱᒍ ᒪᓂᕋᖏᑦ ᐊᐅᕐᑲᑦᑕᕐᒪᑕ. ᓯᕗᓪᓕᖅᐹᒥ ᐅᑭᐅᑦ ᖁᓖᑦ 2000-ᓂ ᑕᒫᓂ ᐊᐅᔭᖏᑦ ᐅᖅᑰᓂᖅᐹᖑᓚᐅᕐᒪᑕ 60-ᓂ ᐅᑭᐅᓂ, ᐊᒻᒪᓗ 2005-2009 ᐅᖅᑰᓂᖅᐹᖑᕆᓪᓗᑎᒃ ᑕᓪᓕᒪᓂ ᐅᑭᐅᓂ.. ᑕᒪᑐᒪᓂ ᖃᐅᔭᐃᑦᑐᒥ ᑯᐃ ᕿᑭᖅᑕᖏᓐᓂ, ᐅᖅᑰᓯᕚᓪᓕᖅᓯᒪᓕᖅᑎᓪᓗᒍ ᑭᖑᓂᖓᒍᑦ 2005 ᓯᕙᑐᓕᖅᐹᓪᓕᓚᐅᕐᒪᑦ ᐊᐅᔭᖅ 5-12 ᐅᓪᓗᓂᒃ ᓯᕐᒥᐊᓗᒃ ᐊᐅᑉᐸᓪᓕᐊᓂᕐᑲᓚᐅᖅᑐᖅ 3.8-ᖑᓂᖅᓴᐅᓪᓗᓂ ᐆᒃᑐᕋᐅᑎᒃᑯᑦ ᑕᒪᑐᒪᓂ ~50-ᓂ ᐅᑭᐅᓂ..ᐆᒃᑐᕋᐅᑎᕆᓪᓗᒍ ᑕᒪᐃᓐᓂ ᒪᓂᕋᖓᓂ ᐊᐅᒃᐸᓪᓕᐊᓂᖏᑦ ᓇᓴᖅᑕᐅᕙᓪᓕᐊᓪᓗᑎᒃ ᓯᓚᒧᑦ ᖁᕝᕙᖅᑎᑕᐅᓯᒪᔪᒧᑦ IceSat ᖃᐅᒻᒪᖅᑯᑎᒃᑯᑦ GRACE-ᒥ ᖁᕝᕙᖅᑎᑕᐅᓯᒪᔪᒥᑦ ᐆᒃᑐᕋᖅᑕᐅᕙᓪᓕᐊᓪᓗᑎᒃ ᐅᕐᑭᖕᒋᓐᓂᖏᑦ ᓯᑯᒥᒃ ᐅᓯᐅᔨᕙᓪᓕᐊᓚᐅᖅᑐᑦ ᖃᐅᔭᐃᑦᑐᒥ ᑯᐃ ᕿᑭᖅᑕᖏᓐᓂ ᐊᕐᕌᒍᑕᒫᖅ ~9 Gt/ᐅᑭᐅᖅ 2004-6 ᐅᕙᖓ ~62 Gt/ᐅᑭᐅᖅ 2007-9. ᐅᑯᓇᓂᓕ 2007-2009, ᑲᓇᑕᒥᐅᑦ

ᓯᕐᒥᐊᓗᖏᓐᓂᑦ ᐊᐅᒃᐸᓪᓚᐊᔪᓂᑦ ᓄᓇᕐᔪᐊᒥ ᑲᓇᑕᒥᑦ ᓯᕐᒥᐊᓗᐃᑦ ᓄᓇᕐᔪᐊᒥ ᓯᒡᔭᓄᑦ ᖁᕗᕙᖅᐹᓪᓚᑎᑦᑎᓂᖅᐹᖑᓚᐅᖅᑐᑦ ᐊᓯᖏᓐᓂᑦ ᓄᓇᕐᔪᐊᒥ ᓯᕐᒥᖃᐅᖅᑐᓂᑦ ᐊᑯᑭᑦᑐᒥᐅᓂ ᓄᓇᕐᔪᐊᓪᓗ ᐊᑖᓂᒥᐅᓂᕐ. ᐊᕐᕚᒍᑕᒫᑦ ᐆᒃᑐᕋᓇᐊᖅᑐᖃᑦᑕᕋᑦᑎᒍ ᑕᓪᓗᕈᑎᐅᑉ ᓯᕐᒥᐊᓗᐊ, ᐊᑐᖅᓯᑕ ᐃᓚᐅᕐᑲᖅᑕᐅᓯᒪᔪᓂᒃ ᓯᕐᒥᐅᑉ ᐊᐃᔪᕋᖏᓐᓂ, ᐃᑖᑦᑲᑦᑕᖅᓯᑎᒃ ᓯᑯᓂᒃ ᑕᐅᓄᖓ ᒪᓂᕋᖓᓄᑦ, ᐊᒻᒪᓗ ᓯᕐᒥᑦ ᖃᖓᓂᑦ ᓇᓚᐅᑎᒃᑯᑦ ᒪᓂᕋᖓᓄᑦ ᐃᔾᔪᓂᖏᑦ (GPR) ᐆᒃᑐᕋᖅᑕᐅᕐᑲᑦᑕᓚᐅᕐᒥᔪᑦ ᐊᐳᑎ ᓯᕐᒥᖑᖅᐸᓪᓚᐊᓂᖓ ᑕᒪᑐᒪᓂ 2005-ᒥ..ᐊᕐᕚᒍᑕᒫᖅ ᐊᐳᑎ ᐊᐅᓚᕚᖓᑦ ᓯᕐᒥᐅᑉ ᖄᖓᓂ ᓯᑯᒃᑲᓐᓂᕐᑲᑦᑕᖅᓯᓂ ᑕᐃᒪᓐᓇ ᓯᕐᒥ ᐳᖅᑐᓕᖅᐸᓪᓚᐊᕐᑲᑦᑕᖅᑐᖅ 2000-ᓂ, ᐆᒃᑐᕋᖅᑕᐅᕙᓪᓚᐊᓕᖅᑎᓪᓗᒍ ᖃᐅᔨᓚᐅᖅᑐᑦ ᒪᓂᕋᖓᓂ ᓯᕐᒥᐊᓗᐸ ᐊᑕᐅᓯᐊᖅᓯᑎᑦ ᖁᓕᓂ ᐅᑭᐅᓂ ᐊᐅᓐᓂᖅᒧᑦ ᑎᑭᑕᐅᓚᐅᖅᑐᖅ.

2011-ᒥ ᓄᓇᒨᖅᓯᒪᓪᓗᑎᒃ

(a) *CryoSat-ᒥᑦ ᐅᒃᑐᕋᖅᑕᐅᔪᑦ-ᖃᐅᔾᔭᖅᑕᐅᔪᓪᓗ* ᐊᒃᑎᒋᓂᖓ ᖄᖓᓂ ᐊᐅᒃᐸᓪᓚᐊᔪᖅ ᐅᒃᑐᕋᖅᑕᐅᓚᐅᖅᑐᖅ CryoSat2 ᓇᓚᐅᑎᒃᑯᑦ ᖁᕗᕙᖅᑎᑕᐅᓯᒪᔪᒥᑦ ᐳᖅᑐᓂᖏᑦ ᐅᑎᕐᔭᑲᑕᖅᓯᑎᒃ ᓯᕐᒥᐊᓗᐸ ᖄᖓᓂᑦ, ᐊᒃᓵᓗᐊᖏᓐᓂᖅᓴᐅᖕᒪᑦ ᐃᔾᔪᓂᖅᓴᓂ ᓯᕐᒥᓂ, ᐊᒻᒪᓗ ᐊᒃᓴᓃᖅᓴᐅᓪᓗᑎᒃ ᐊᐳᑎᕐᑲᖅᑐᓂ ᓯᑯᓂ. . ᑕᐃᒪᓐᓇ ᐆᒃᑑᑎᕐᑲᓚᐅᖅᑐᑦ ᐃᑎᓂᖏᓐᓂᒃ ᓯᕐᒥᐊᓗᐃᑦ, ᖁᕗᕙᖅᑎᑕᐅᓯᒪᔪᓂᑦ ᓇᓚᐅᑎᒃᑯᑦ ᓲᒃᑲᓕᓂᖏᑦ ᓲᒃᑲᐃᓐᓂᖏᓪᓗ ᐆᒃᑐᕋᖅᑕᐅᓪᓗᑎᒃ ᐅᑎᕐᔮᒃᑎᑕᐅᕐᑲᑦᑕᖅᓯᑎᒃ ᓇᓚᐅᑎᒃᑯᑦ ᐳᖅᑐᓂᖏᑦ ᐆᒃᑐᕋᖅᑕᐅᓚᐅᖅᑐᑦ, ᖃᐅᔨᓇᓱᐊᖅᓯᑎᒃ ᐊᒃᑎᒋᓂᖏᓐᓂᒃ, ᐊᑐᓚᐅᕐᒥᔪᑦ GPS-ᓂᒃ ᐊᑐᓂ ᓂᑭᑦᑖᖅᓯᑎᑦ ᑕᒪᑐᒪᓂ ᖁᕗᕙᖅᑎᑕᐅᓯᒪᔪᒥᑦ ᐆᒃᑐᕋᖅᑕᐅᕖᔪᒥ “CryoSat line” (ᐊᕐᕚᒍᑕᒫᑦ ᐆᒃᑐᕋᕕᒋᓚᑦᑎᒍ 2004-ᒥᑦ) ᐆᒃᑐᕋᐃᓚᐅᕐᒥᔪᒧᑦ ᓯᕐᒥᐊᓘᑉ ᐃᓗᓕᖏᓐᓂᒃ ᓯᑯᓂᒃ ᐊᐳᑎᓂᓗ ᐊᑐᖅᓯᑕ 500 MHz ᐊᐳᑎᒧᑦ ᐆᒃᑐᕋᐅᑎᓂᒃ, ᐃᑎᖏᑦᑐᒥ ᐃᑖᑕᑲᑕᒃᓯᑕ, ᐊᒻᒪᓗ ᐊᐳᑎᓯᒪᐅᕐᓂᖏᓐᓂ ᓯᕐᒥᐊᓗᖕᒥ. ᑕᑯᓪᓗᒋᑦ ᖃᐅᔾᔭᖅᑕᐅᔪᑦ ᑐᑭᓯᓇᓱᐊᖅᓯᑕ ᒪᓂᕋᖓᓂᑦ ᐳᖅᑐᓂᖏᓐᓂᒃ ᐊᒻᒪᓗ ᐊᐅᒃᐸᓪᓚᐊᔪᑦ ᐳᖅᑐᓂᖏᓐᓂᒃ ᖁᕗᕙᖅᑎᑕᐅᓯᒪᔪᓂᑦ ᓇᓚᐅᑎᒃᑯᑦ ᐆᒃᑐᕋᖃᑦᑕᖅᓯᒋᑦ. 2011-ᒥᓕ, ᓄᑕᒥᒃ ᐆᒃᑐᕋᕕᓕᐅᓚᐅᕐᒥᔪᒧᑦ ᓴᓂᕋᖓᓂ Cryosat-ᑯᑦ ᐆᒃᑐᕋᕖᔪᒥ ᐊᒻᒪᓗ ᓄᑖᖑᓇᐊᖅᑎᑕᐅᓪᓗᑎᒃ GPS-ᑯᑦ ᐆᒃᑐᕋᖅᑕᐅᕐᑲᑦᑕᖅᑐᑦ ᐊᐳᑎᐅᑉ ᐳᖅᑐᓂᖓᓂ ᓇᓚᐅᑎᒃᑯᑦ ᖃᖓᓂᑦ ᒪᓂᕋᕐᒧᑦ 1-ᑭᓚᒥᑐᒥᒃ ᐅᖓᓯᖕᓂᕐᑲᐅᖅᑐᓂᒃ 10-ᑭᓛᒥᑐᒥ ᓯᓕᖕᓂᕐᑲᖅᓯᑎᒃ ᐊᕙᑎᐊᓂᑎ ᑕᒪᑐᒪ ᐆᒃᑐᕋᕐᕖᔪᕖᓂᐅᑉ CryoSat-ᑯᕐ. ᓈᓯᓚᐅᖅᑐᒧᑦ 300-ᑭᓛᒥᑐᒥᒃ GPS/ᓇᓚᐅᑎᒃᑯᑦ ᒪᓂᕋᖓᓂ ᑕᒪᓐᓇ ᒪᓕᒃᓯᒍ, ᑕᐃᒪᓐᓇ ᐊᔾᔨᓕᐅᖅᓯᒍ ᐊᕙᑎᓕᒪᖕᒐ ᐳᖅᑐᓂᖏᑦ ᐃᑎᓂᖏᓪᓗ ᓄᓇᖑᐊᓕᐅᖅᓯᖏᑦ ᖁᑏᓂᑦ 8-ᒥᑐᒥᒃ ᓯᕐᒥᐊᓗᐊᓂ. ᓇᖕᒥᓂᖅ ᐅᐸᒃᓯᑎᒧᑦ ᐆᒃᑐᕋᐃᓚᐅᕐᒥᔪᒧᑦ ᐳᖅᑐᖏᑦᑐᒥ GPR-ᑯᑦ ᐆᒃᑐᕋᖅᑕᐅᔪᕕᓃᑦ ᓱᓕᕆᓗᐊᕐᒪᖔᑕ ᖃᐅᔨᓇᓱᐊᖅᓯᒋᑦ, ᐊᒻᒪᓗ ᐊᐅᐸᖅᑐᒧᑦ ᐅᓐᓄᐊᖅᓰᐊᑎᒧᑦ ᐊᔾᔨᓕᐅᖅᑕᐅᓪᓗᑎᒃ ᓄᓇᖑᐊᓕᐅᖅᑕᓪᓗᑎᒃ ᓯᕐᒥᐊᓘᑉ ᐃᑎᓂᖏᑦ ᓇᑎᕐᓇᓂ ᐃᑖᑕᕐᕕᐅᓪᓗᑎᒃ ᐃᑎᓂᖏᑦ ᐆᒃᑐᕋᖅᑕᐅᓚᐅᖅᑐᑦ. ᐃᑲᔪᓚᐅᖅᑐᑦ ᓈᓚᐅᑎᒃᑯᑦ ᐆᒃᑐᕋᖅᑕᐅᔪᕕᓂᕐᓂᒃ ᐊᐳᑎᓂᒃ, ᐊᑯᓐᓂᖓᓂ ᓯᕐᒥᐊᓗᐃᑦ ᐊᐳᑎᕐᑲᐅᕐᓂᖏᓐᓂ ᓇᑎᕐᓇᓂ ᑲᑎᖅᓯᐃᕖᔪᔪᓂᑦ. ᑕᐃᒪᐃᓕᐅᒃᑲᓐᓂᕐᑲᑦᑕᕐᓂᐊᖅᑐᒧᑦ ᖄᖓᓂ ᐊᐳᑎᕐᑲᕐᕖᔪᓂᒃ ᐆᒃᑐᕋᐃᖅᑲᑦᑕᕐᓗᑕ ᐅᑭᐅᖑᓚᐅᖅᑐᓂᑦ ᐆᒃᑐᕋᖅᑕᐅᔪᕕᓃᑦ ᖃᓄᐃᓕᖁᓪᓕᕐᒪᖔᑕ ᑐᑭᓯᓇᓱᐊᕐᓗᒋᑦ ᓇᓚᐅᑎᒃᑯᑦ ᐆᒃᑐᕋᖅᑕᐅᔪᕕᓃᑦ ᓱᓕᖕᒪᖔᑕ ᓯᕐᒥᕐᑲᕐᓂᖅᓴᐅᔪᓂ ᓴᑦᑐᓂᓗ ᐊᐳᑎ ᓯᕐᒥᓗ ᓇᓗᓇᐃᔭᐃᓇᓱᐊᕐᓗᑕ ᖃᓄᖅ ᓇᓚᐅᑎᒃᑯᑦ ᐆᒃᑐᕋᖅᑕᐅᑦᑎᐊᕈᓐᓇᕐᒪᖔᑕ.

(ᐱ) *ᐱᐊᓪᓯ ᓯᕐᒥᐊᓗᐊᓂ:* ᐊᓯᔾᔩᖅᑕᐅᓚᐅᖅᑐᑦ ᐹᑐᓅᖏᑦ ᑕᐃᒪᖓᓂᑦ ᖁᕗᕙᖅᑎᑕᐅᓯᒪᔪᒧᑦ ᐆᒃᑐᕋᐅᑏᑦ ᐱᐊᓪᓯ ᓯᕐᒥᐊᓗᐊᓂ, ᑲᑎᖅᓱᖅᑕᐅᓪᓗᑎᒡᓗ ᓈᓴᖅᑕᐅᓯᒪᔪᑦ 2010-ᒥᓂᕐ, ᐊᒻᒪᓗ ᐱᒋᐊᕐᕕᖓᓅᑦᑕᐅᒃᑲᓐᓂᖅᓯᑎᒃ ᐅᑭᐅᖑᓂᐊᖅᑐᒧᑦ

ᑲᑎᖅᓱᐃᓂᐊᕐᒥᖓᑕ. ᑖᒃᑯᐊ ᓇᓴᐅᑎᓂᒃ ᑎᑎᕋᖅᓱᕙᓪᓕᐊᖓᑕ ᓱᕐᒥᐊᓗᐸ ᐊᓯᔾᔨᖅᐸᓪᓕᐊᓂᖔ ᒪᓕᒃᓱᒍ ᓱᒃᑲᓕᓂᖔ ᐅᑭᐅᓕᒫᒥ.ᐊᒻᒪᓗ ᐃᓕᐅᖅᑲᐃᓪᓗᑕ ᐱᖓᓱᓂᒃ ᓄᑖᓂᒃ GPS ᐆᒃᑐᕋᐅᑎᓂᒃ, ᐃ-ᖑᐊᖑᖅᑎᓱᒍ ᑕᓪᓕᒪᑦ 5 ᐆᒃᑐᕋᐅᑏᑦ ᐃᓱᐊᓂ ᓱᕐᒥᐊᓘᑉ ᐆᒃᑐᕋᐅᑕᐅᓂᐊᖅᑐᓂᒃ ᓱᒃᑲᓕᓂᖔᓂᒃ ᑲᑕᕐᑲᑦᑕᕐᓂᖏᓐᓂᓗ ᐱᕐᑲᓗᔭᐃᑦ ᐊᒻᒪᓗ ᓯᑯᕐᓗᐃᑦ ᐱᕈᖅᐸᓪᓕᐊᓂᕆᕙᒃᑕᖏᑦ ᕐᑲᓄᕐᓗ ᐃᕗᐃᑦ ᐋᕐᑭᒃᐸᖕᒪᖕᒫᑕ ᐱᕐᑲᓗᔭᓂᒃ ᑲᑕᒃᑐᕐᑲᕖᖓᑦ. ᐅᒃᑐᕋᖅᑕᐅᒃᑲᓐᓂᕆᓪᓗᓂ ᕐᑯᑦᑎᖕᓂᖏᑦ GPS-ᑯᑦ ᑐᑭᓯᓇᓱᐊᖅᓱᑕ ᓱᕐᒥᐊᓘᑉ ᐃᔾᔪᓂᖓᓂᑦ ᑕᒪᑐᒪᓂ ᐅᑭᐅᑦᑎᓐᓂ. ᐊᒻᒪᓗ ᓯᓚᓐᓂᐊᕈᑏᑦ ᐋᕐᑭᒃᑕᐅᒃᑲᓐᓂᖅᓱᑎᒃ ᓯᓚᐅᑉ ᐅᖅᑰᓂᖓᓂᑦ ᑎᑎᕋᐃᓐᓇᖅᑐᑦ, ᐊᒻᒪᓗ ᑎᒍᔭᐅᓪᓗᑎᒃ ᐃᓕᔭᐅᓯᒪᔪᕕᓃᑦ ᐱᖓᓱᑦ ᐊᔾᔨᓕᐅᕈᑏᑦ ᑕᐃᒪᖓᓂᑦ ᐊᔾᔨᓕᐅᕆᕙᓪᓕᐊᖏᓐᓇᖅᑐᕕᓃᑦ ᓱᕐᒥᐊᓘᑉ ᐃᓱᐊᓂ. ᑖᒃᑯᐊ ᐃᓇᖏᖅᑕᐅᒃᑲᓐᓂᓚᖓᔪᑦ 2012-ᒥ.