Estimates of ice thickness distribution and surface roughness from Envisat and CryoSat satellite altimetry

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The sea ice covering the Arctic Ocean is perhaps the most visible evidence for changes on the Earths surface as a possible consequence of global warming. Computer models of the Earth's climate system suggest that the Arctic Ocean will become ice-free within this century and recent satellite data have shown a consistent retreat of the ice pack during the last 30 years (Figure 1). The time-series show that the past five summers have shown summer ice extents below anything observed in the previous 25 years. In 2007 ice extent in the Arctic reached a record minimum leading to wide speculation that Arctic ice had reached a tipping point. Although the retreat of ice is apparently significant much less is known about whether the ice is also thinning, or perhaps even thickening in some areas. Submarine data have suggested a thinning of ice but data are only available in the central Arctic with the most recent data gathered in 1997.

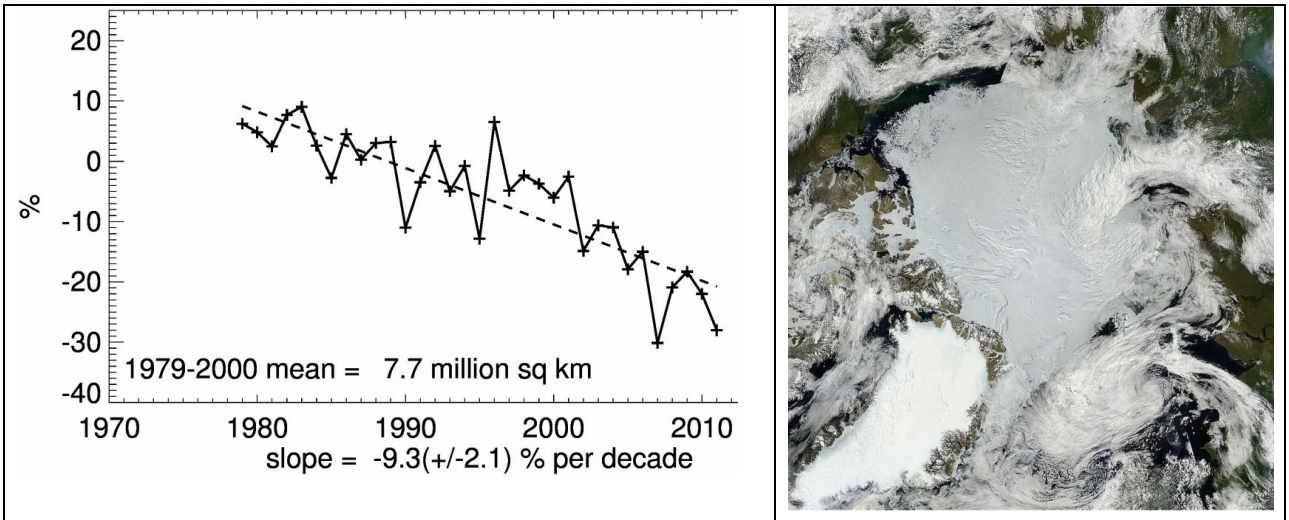

Figure 1. Time series of Arctic sea ice extent (left) and a satellite image of the Arctic in July 2011 (right).

A unique capability has been developed within the Centre for Polar Observation and Modelling (CPOM; part of UCL Earth Sciences) to measure the thickness of ice in the Arctic using satellite radar and laser ranging. This technique estimates the level of the ice above the water by bouncing either radar or laser pulses off the top of the ice and surrounding water to measure the ice freeboard. This can then be converted into ice thickness by assuming hydrostatic equilibrium and verified using contemporary data gathered on the surface. The resulting data has important applications in determining the trends in current Arctic ice thickness, and in evaluating Global Climate Model simulations of current ice conditions to determine the accuracy of their future forecasts of the disappearance of ice cover in the Arctic. The current technique is however limited in providing only a mean elevation over the footprint of each of the instruments. This potentially discards valuable information on the ice thickness distribution that is contained in the profile of the echoes (both laser and radar) from the surface. This studentship will involve the analysis of data from both laser and radar instruments mounted both on satellite systems (the ESA Envisat mission and NASA IceSat

mission) and also data gathered during an aircraft under-flight on both satellites in March 2006, and underneath CryoSat (Figure 2) in April 2011.

Figure 2. First CryoSat sea ice thickness map generated by CPOM-UCL (Jan/Feb 2011) (left); (right) CPOM Ph.D. student Rosie Willatt, and CPOM Fellow Katharine Giles measuring sea ice near Alert, Elsemere Island Canada (82N, 62W) in April 2011 in support of Cryosat.

The project will involve the analysis of the satellite data and evolve to forward model the expected response of each instrument to surface topography using airborne laser data (Figure 3). The aim will be to develop algorithms to estimate ice thickness distribution.

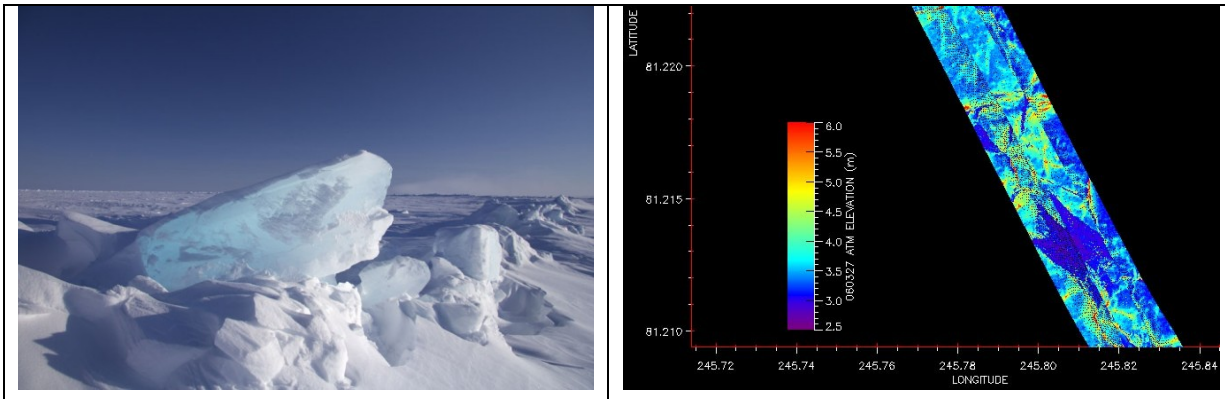

Figure 3. Photo of ridged ice taken during the UCL-ESA CryoSat Validation Campaign, April 2011 at 83N; and as observed using airborne laser data (right); (left) laser data shows level ice as dark blue with ridges visible as yellow/red linear features (Courtesy Bill Krabill).

This project will form an integral part of the CPOM research programme and the student will work closely with existing CPOM postgraduate and postdoctoral researchers. They will also benefit from active collaborations with NOAA, NASA and the wider polar research community.

Key references:

Giles, K. A., S. W. Laxon, and A. L. Ridout, Circumpolar thinning of Arctic sea ice following the 2007 record ice extent minimum, Geophysical Research Letters, 35, L22502, doi:10.1029/2008GL035710, 2008.

Laxon, S. W., Peacock, N. R. & Smith, D. M. High interannual variability of sea ice thickness in the Arctic region. Nature, doi:10.1038/nature2050, 947-950, 2003.

Willatt, R,; Laxon, S,; Giles, K.; et al., 2011, Ku-band radar penetration into snow cover Arctic sea ice using airborne data, Annals of Glaciology Volume: 52 Issue: 57 Pages: 197-205.

Student Prerequisites: The student needs to be competent in data analysis and should have a reasonably strong physics background.