Sea Ice Altimetry Interactive Lecture

The aim of this practical is to introduce the key concepts of tracking sea ice thickness from satellite altimetry. You are provided with an extract of CryoSat radar altimeter data recorded over Arctic sea ice. The file is comma separated values, and for each data point the latitude, longitude, satellite altitude (m), satellite range (m), sum of all geophysical corrections to the range measurement (m), and the power in 128 segments (range bins) of the altimeter echo are included.

Follow the steps below to (1) discriminate sea ice floes and leads, (2) retrack floe and lead echoes, (3) estimate floe and lead height, (4) estimate floe freeboard, and (5) estimate floe thickness.

1. Discriminating floes and leads

It is possible to classify echoes recorded from sea ice floes and leads using their shape (Fig. 1); lead echoes are specular (peaky) and floe echoes are diffuse (broad).

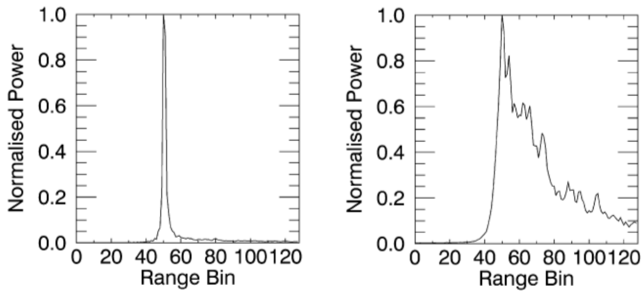

Figure 1. Example CryoSat radar altimeter echoes from a lead (left) and from a sea ice floe (right)

Calculate the echo pulse peakiness (*PP*) as:

$$PP = P_{max} / P_{mean} \qquad \text{Eq. (1)}$$

where P_{max} is the maximum echo power and P_{mean} is the average power of echo range bins exceeding the noise floor. The noise floor can be estimated as the average echo power in range bins 10 to 20.

Then classify the echoes as floes ($PP < 9$), leads ($PP > 18$), and indeterminate ($9 < PP < 18$).

2. Retracking floe and lead echoes

The range to a surface can be precisely determined by retracking radar altimeter echoes; this process is designed to locate the dominant scattering horizon. The retracking procedure is different for leads and floes.

Lead echoes can be retracked by fitting a gaussian curve to each echo and identifying the range bin corresponding to the peak of each gaussian curve.

Floe echoes can be retracked by finding the location of a fixed point on the rising edge of the first peak in each echo that exceeds a defined threshold. First smooth each floe echo with a 3-point moving average to reduce speckle. Then identify the maximum power of the smoothed echo. Next identify the location of each peak in the smoothed echo. Then identify the first peak which exceeds 20% of the maximum power in the smoothed echo. Finally, by interpolation, identify the range bin corresponding to the location where the rising edge of this peak exceeds 70% of its maximum power.

Each CryoSat echo range bin corresponds to a distance of 0.234212857 m; compute the retracked range correction ΔR for each lead and floe echo relative to the echo centre (bin 64) as:

$$\Delta R = (\text{retracked bin} - 64) * 0.234212857 \qquad \text{Eq. (2)}$$

3. Estimating floe and lead height

Estimate the height of each floe and lead echo as:

$$H = A - (R + \Delta R + G + B) \qquad \text{Eq. (3)}$$

where H is the surface height, A is the satellite altitude, R is the satellite range, ΔR is the retracker range correction computed in step 2, G is the sum of all geophysical corrections to the range measurement and B is the retracker bias (zero for leads and 0.1626 metres for leads).

4. Computing floe freeboard

Fit a polynomial to the lead heights to describe the ocean surface and remove this polynomial from the floe heights to compute the floe freeboard (f).

5. Estimating floe thickness

The floe can be approximated as a layer of ice with a superficial snow layer, floating in hydrostatic equilibrium (Fig. 2):

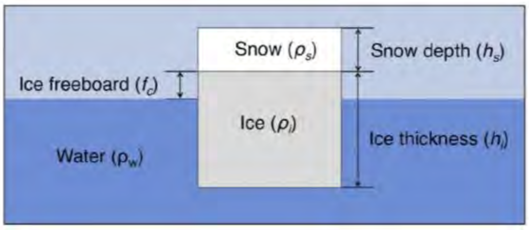

Figure 2. Schematic of a sea ice floe, floating in hydrostatic equilibrium

In this approximation, the floe ice thickness (h_i) is:

$$h_i = \frac{f_c \rho_w + h_s \rho_s}{\rho_w - \rho_i} \qquad \text{Eq. (4)}$$

where f_c is the floe ice freeboard, h_s is the thickness of the snow layer, ρ_w is the water density (1024 kg m^{-3}), ρ_i is the ice density (900 kg m^{-3}), and ρ_s is the snow density (600 kg m^{-3}). The floe ice freeboard f_c can be calculated as the ice freeboard f computed in step 4 minus the snow layer thickness, h_s.

Estimate the floe thickness assuming (i) that there is no snow layer and (ii) that the snow layer is equal to the floe freeboard.