ALTIBERG, Building up a 20-year Database of Small Icebergs

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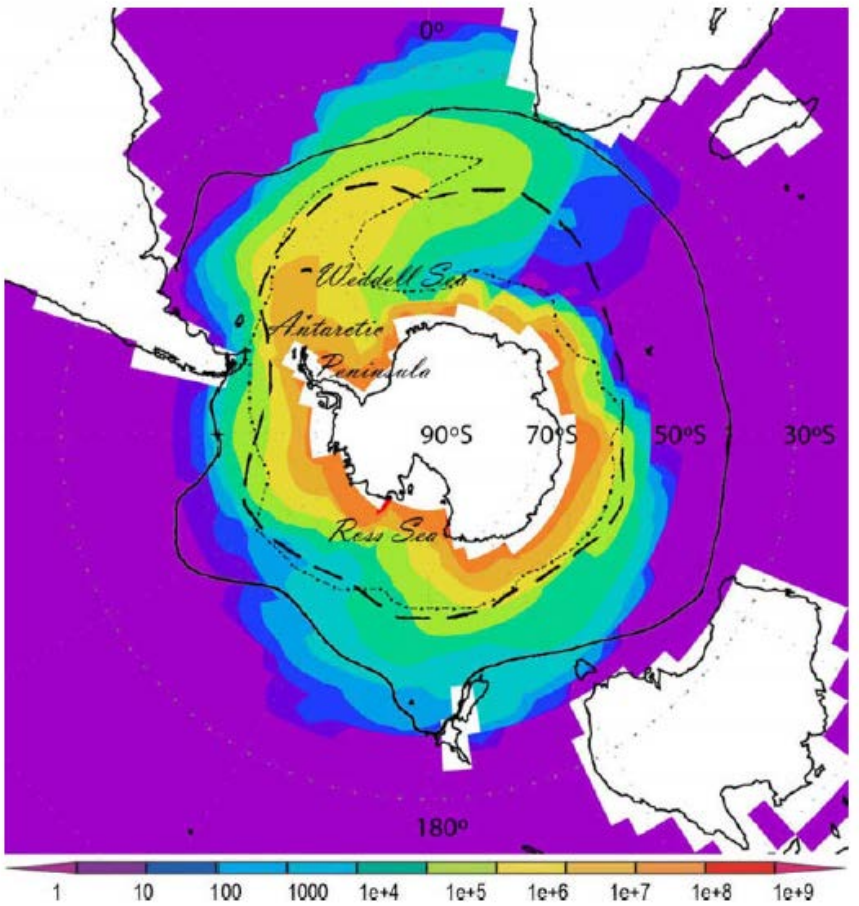
Scientific interest

- Interest for icebergs and their possible impact on southern ocean circulation and biology has increased during the recent years.
- Large icebergs (>6km) tracked routinely tracked and monitored using scatterometer data (BYU, Long et al),
- Smaller icebergs (less than some km) still largely unknown as they are difficult to detect operationally using conventional satellite
- Iceberg may account for a significant part of the freshwater flux in the southern ocean [Silva et al., 2006; Martin and Adcroft , 2010; Gladstone et al., 2001; Jongma et al., 2009]
- They have been shown to transport nutriments (in particular labile iron) that could have a signi
cant impact on ocean primary productivity [Schodlok et al., 2006; Raiswell et al., 2008; Lancelot et al., 2009; Schwarz and Schodlok ,2009],

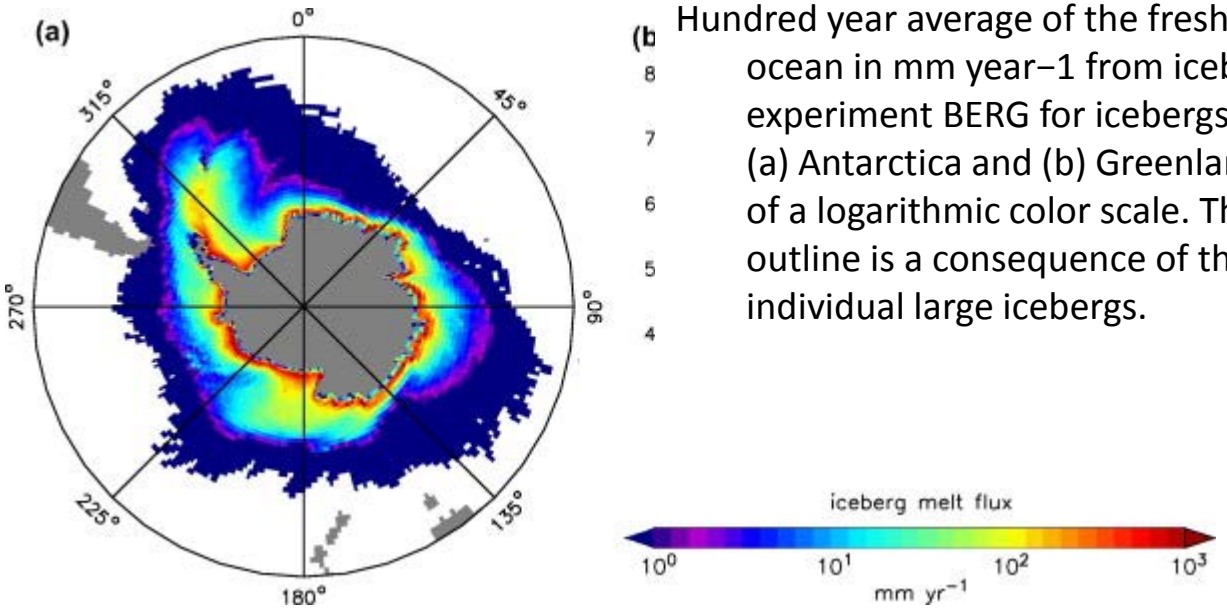
interactive coupling of a global climate model to a dynamic thermodynamic iceberg model, leading (Jongma et al 2009)

Distribution of simulated iceberg melt in the Southern Ocean. The average volume flux of fresh melt water per day (m3/day) provides a combined insight in the distribution of the dynamic icebergs and their melting speed. Note logarithmic scale. Dotted line is the iceberg limit in the Southern Ocean as simulated by Gladstone et al. (2001). Dashed line is an estimate from Russian exploration in 1964 (adapted from Gladstone et al., 2001). The solid line is an estimate of maximum iceberg extent based on a large collection of observational data (adapted from Robe, 1980).



Interactive icebergs in CGCM , Martin and Adcroft (2010)

The frozen fresh-water discharge from land is used as calving to create icebergs in the coupled system which are then free to evolve and interact with the sea-ice and ocean components. Icebergs are fully prognostic, represented as point particles and evolve according to momentum and mass balance equations. About 100,000 individual particles are present at any time in the simulations.



Hundred year average of the fresh-water flux to the ocean in mm year−1 from iceberg melt in experiment BERG for icebergs originating from (a) Antarctica and (b) Greenland. Note the use of a logarithmic color scale. The irregular outline is a consequence of the passage of individual large icebergs.

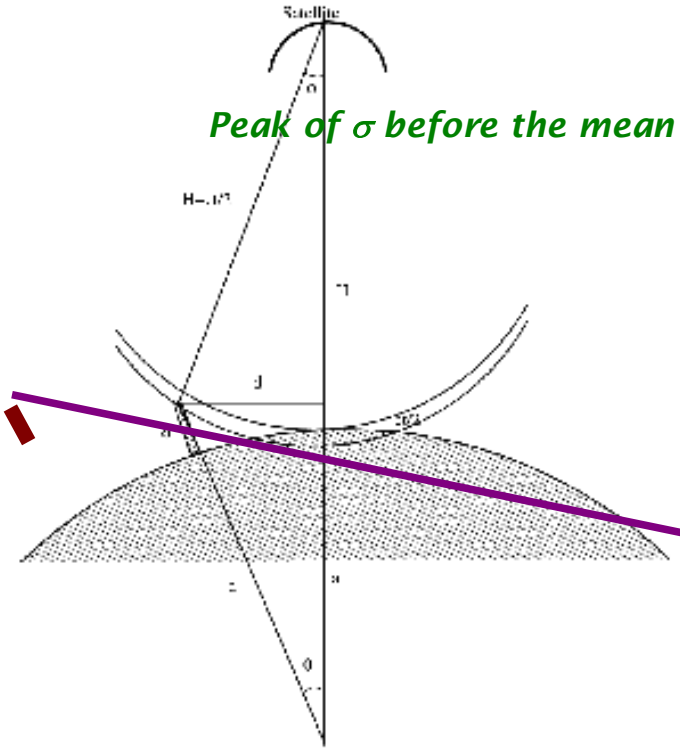
Iceberg Detection from altimeter WF

Targets emerging from the sea (iceberg, ships, lighthouse) : detectable signature in the noise

part of Altimeter WF [*Tournadre et al , 2008, 2012*].

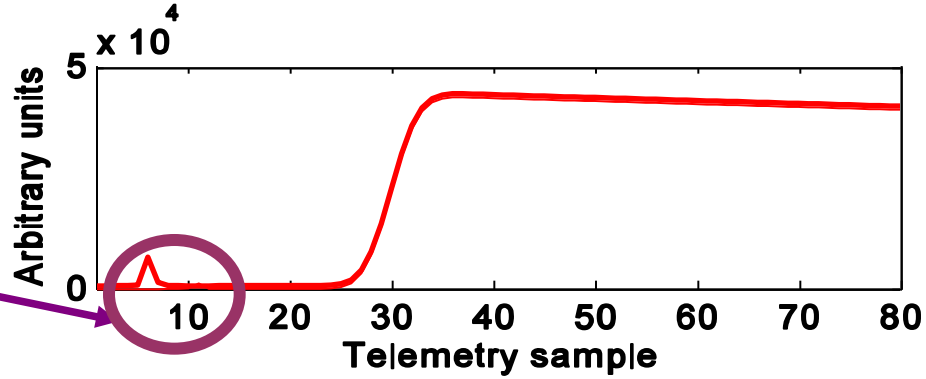
In the waveform space the signature is a parabola determined by the orbital parameters.

Detection algorithm: detection of parabola in the noise part of the WF. Works only in open water.

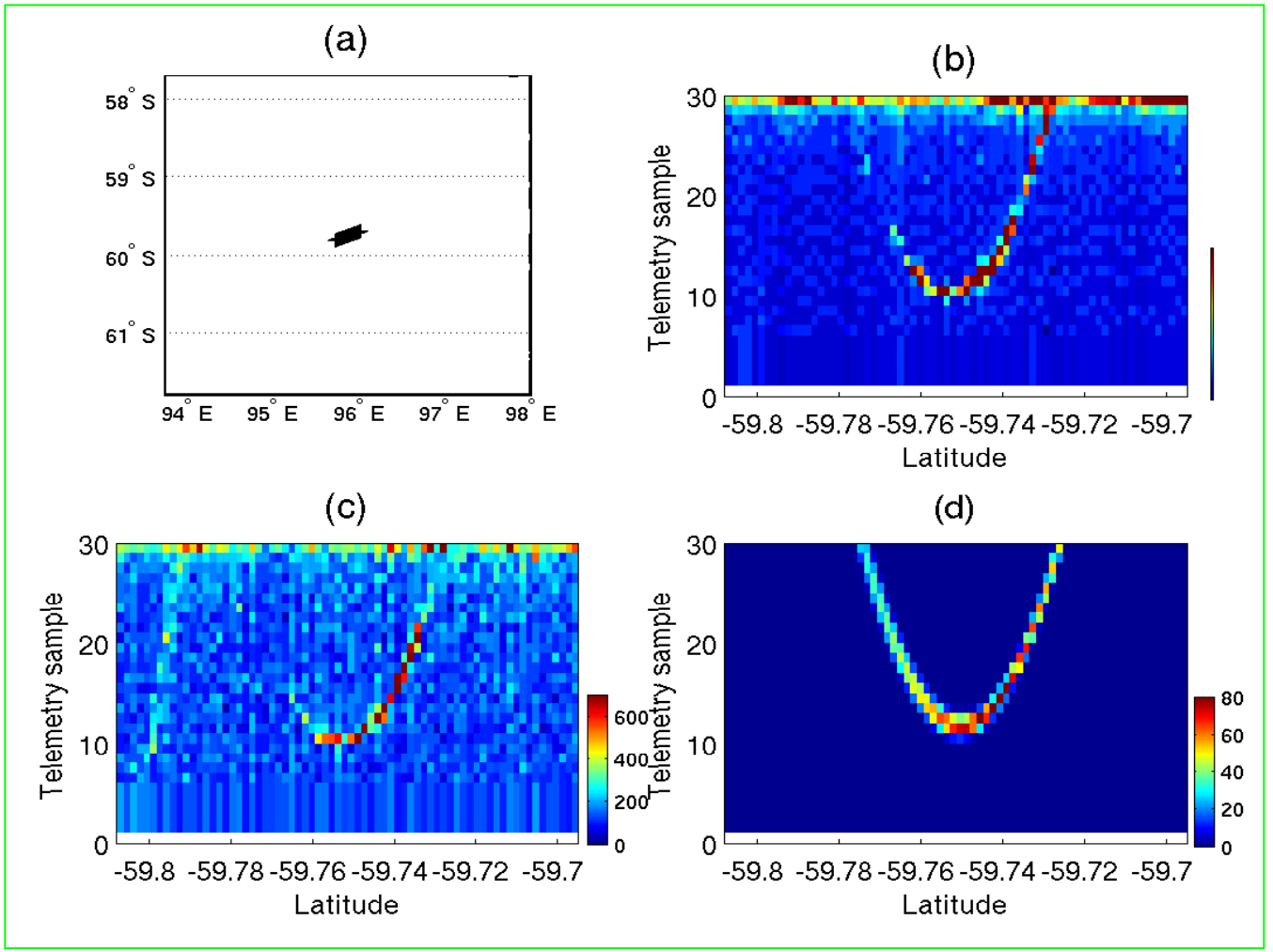


Peak of σ before the mean sea level

EX. signature of single iceberg (Jason WF)



Exemple of iceberg signature and detection



Estimation of the iceberg surface

For climatology, ocean circulation modeling, impact on biology :

volume of ice is the key parameter.

Detection gives 2 parameters (range (t_{ech}) and backscatter σ_{ice}) depending on distance from nadir (*d*), iceberg area (*A*), iceberg freeboard elevation *(h)* and iceberg surface backscatter (σ_1). Two parameters, 4 unknowns, hypotheses necessary.

Freeboard fixed to 28 m, i.e. thickness of 250 m (Gladstone et al 2001)

Surface backscatter of icebergs 19 dB (Tran et al 2008 Legresy et al 2005).

Analytical model of WF used to compute the signature of icebergs as a function of distance from nadir (0 to 12 km), and area (0.01 to 9 km^2), icebergs are assumed square.

Time of the echo

Iceberg backscatter

$$t_{ech} = f(d,A)$$

estimated from the modeled waveforms.

$$\sigma_{iceb} = g(d,A)$$

Inverse model

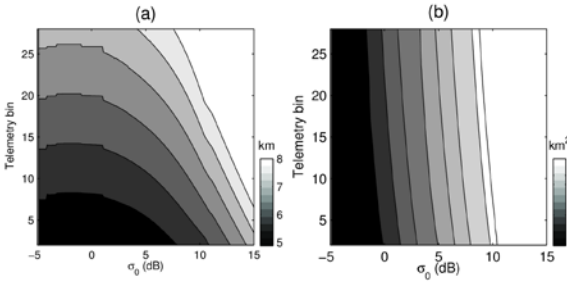
$$d = m(t_{ech}, \sigma_{iceb})$$

Model shows that backscatter saturates

$$A = l(t_{ech}, \sigma_{iceb})$$

around 15 dB for icebergs larger than 8km².

Value close to observed mean max backscatter.



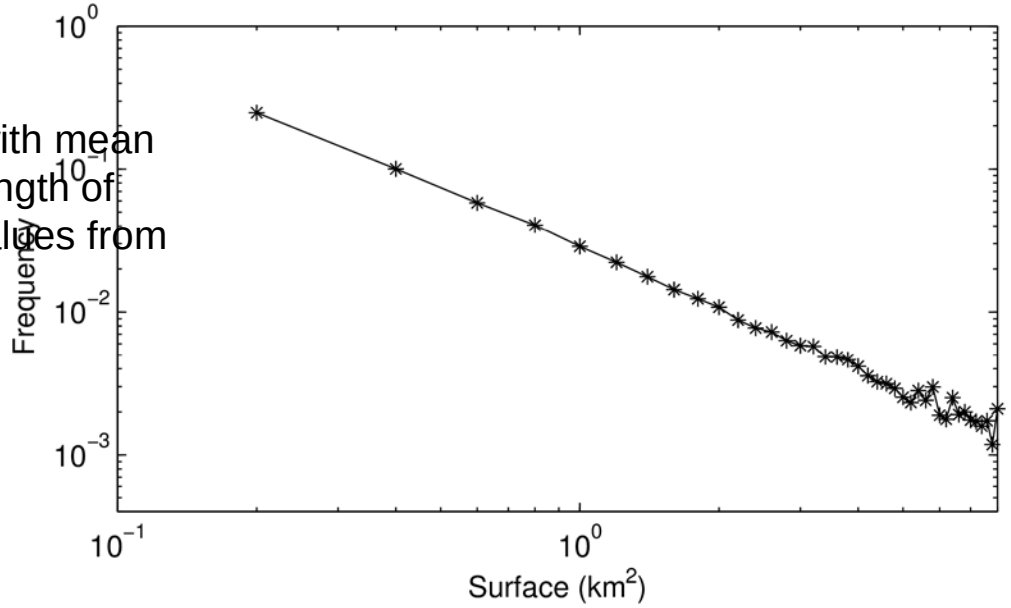
Estimation of the volume of ice

From iceberg database: estimation on regular polar stereographic grid of Probability **P** of presence of iceberg, mean surface **A**, **N** of valid sample.

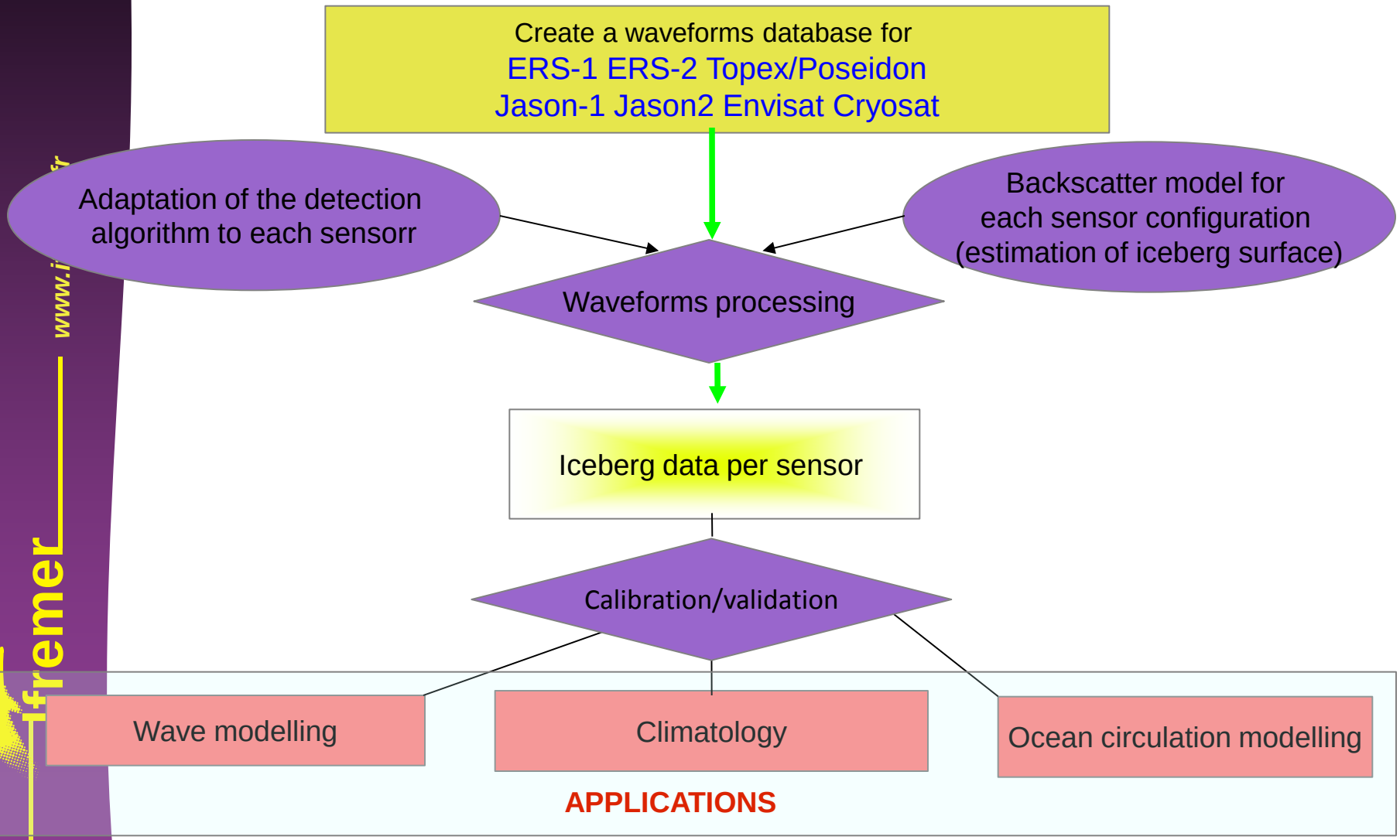
Volume ***V***: *Probability of presence P* x *mean iceberg surface A* x *Thickness* (250m) H_T x *area of grid cell* ($\Delta x \Delta y$) / *area covered by the altimeter swath within the cell* (A_{SW})

$$V(i,j,t) = \frac{A(i,j,t)P(i,j,t)N(i,j,t)H_T \Delta x \Delta y}{A_{SW} N(i,j,t)} = P(i,j,t)A(i,j,t)H_T \frac{\Delta x \Delta y}{A_{SW}}$$

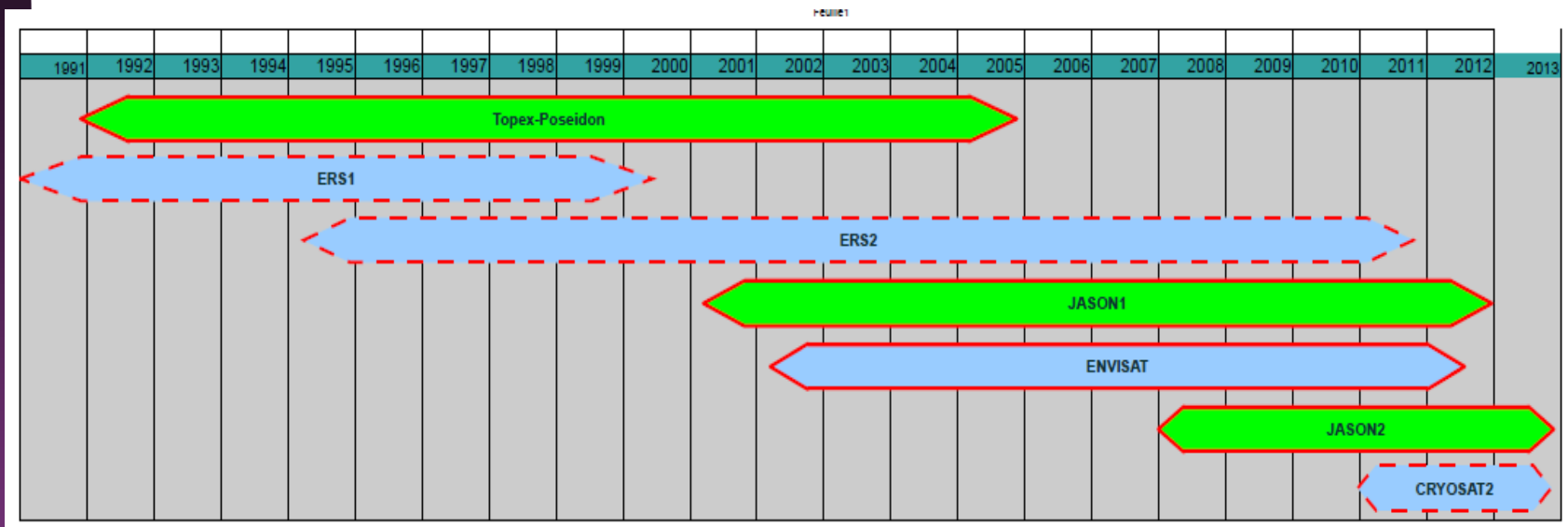
Log-normal distribution with mean area of 0.73km^2, mean length of 630 m. Same order as values from *Romanov et al 2011*



Small iceberg data base



Altimetry Missions used in Altiberg



7 Missions covering the 1992-2012 period. 2 altimeter or more at anytime

For Cryosat problem of availability of LRM in regions of high iceberg concentration

Processing completed for all missions

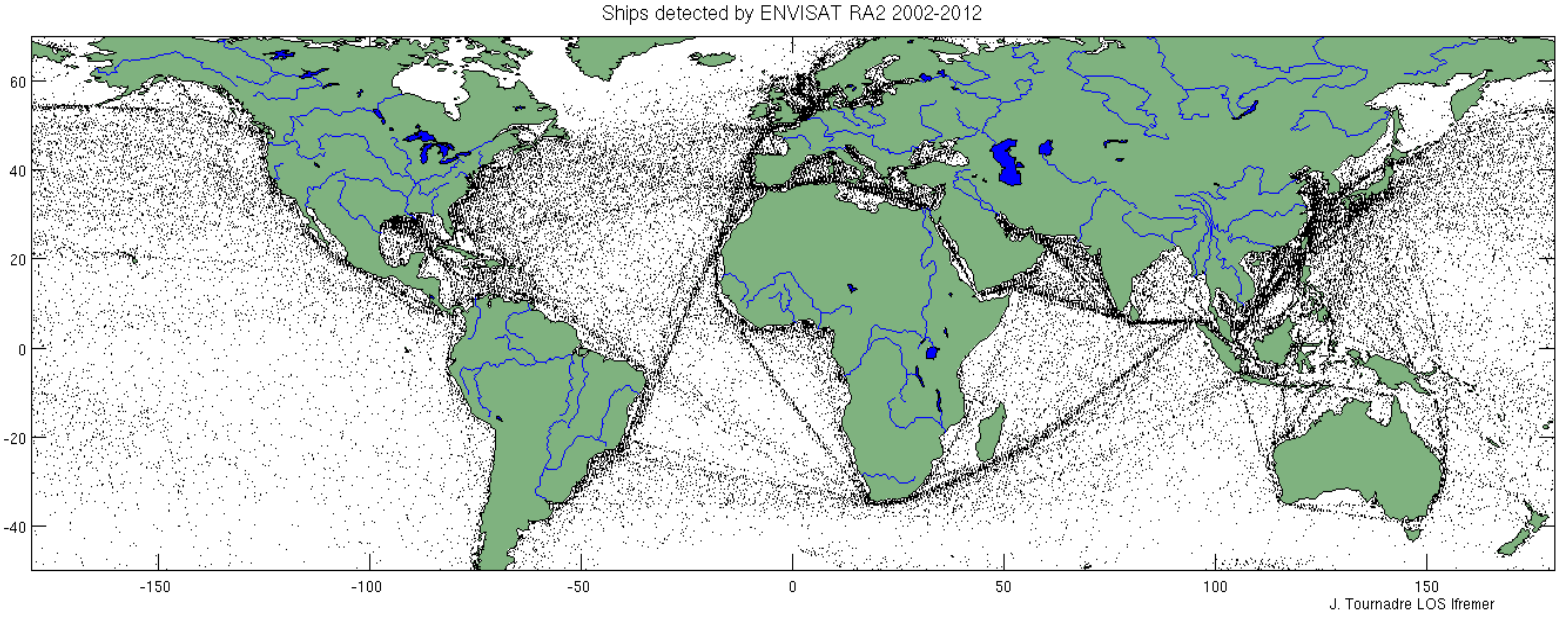
Available Parameters

- **Icebergs data base**
  - Location(latitude longitude)
  - Time
  - Backscatter of the iceberg
  - Range
  - Size (estimated from range of the echo and backscatter)
- **Gridded products**
  - Probability of presence
  - Mean surface
  - Volume of ice
  - PDF of size
  - Others (user defined)

Detection

Detection depends on the noise part of the waveform

Validation : detection of ships and oil rigss



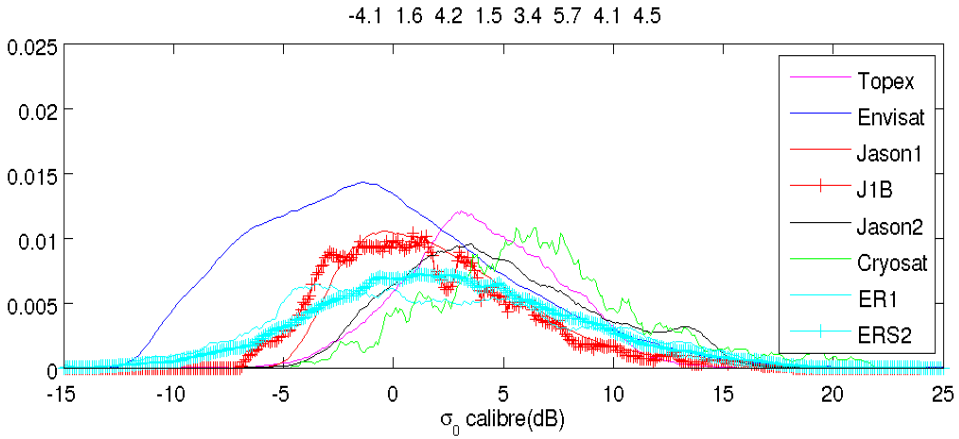
Building a coherent time series of icebergs 1 : sigma0 intercalibration

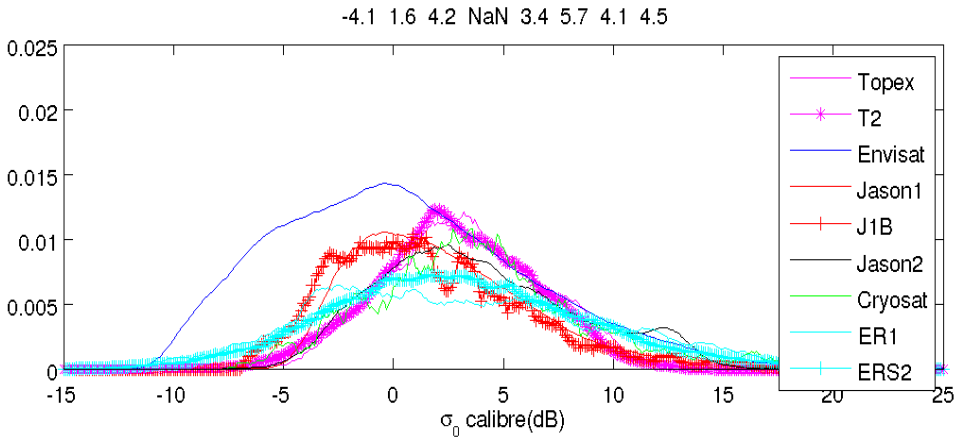
Comparison of the iceberg sigma0 for the different altimeters

-sigma0 1Hz calibration from Queffeulou study appleid

-Jason1 and Jason2 almost similar
-ER1 and ERS2 similar distribution
-Topex narrower distribution. 10 Hz vs 20 Hz, less sensibility to smaller icebergs
-Envisat wider PDF, better sensitivity to smaller icebergs, larger number of bin in the noise part of the waveform
'Cryosat distribution wide ; Large number of gates

Used to recalibrate the backscatter between missions.



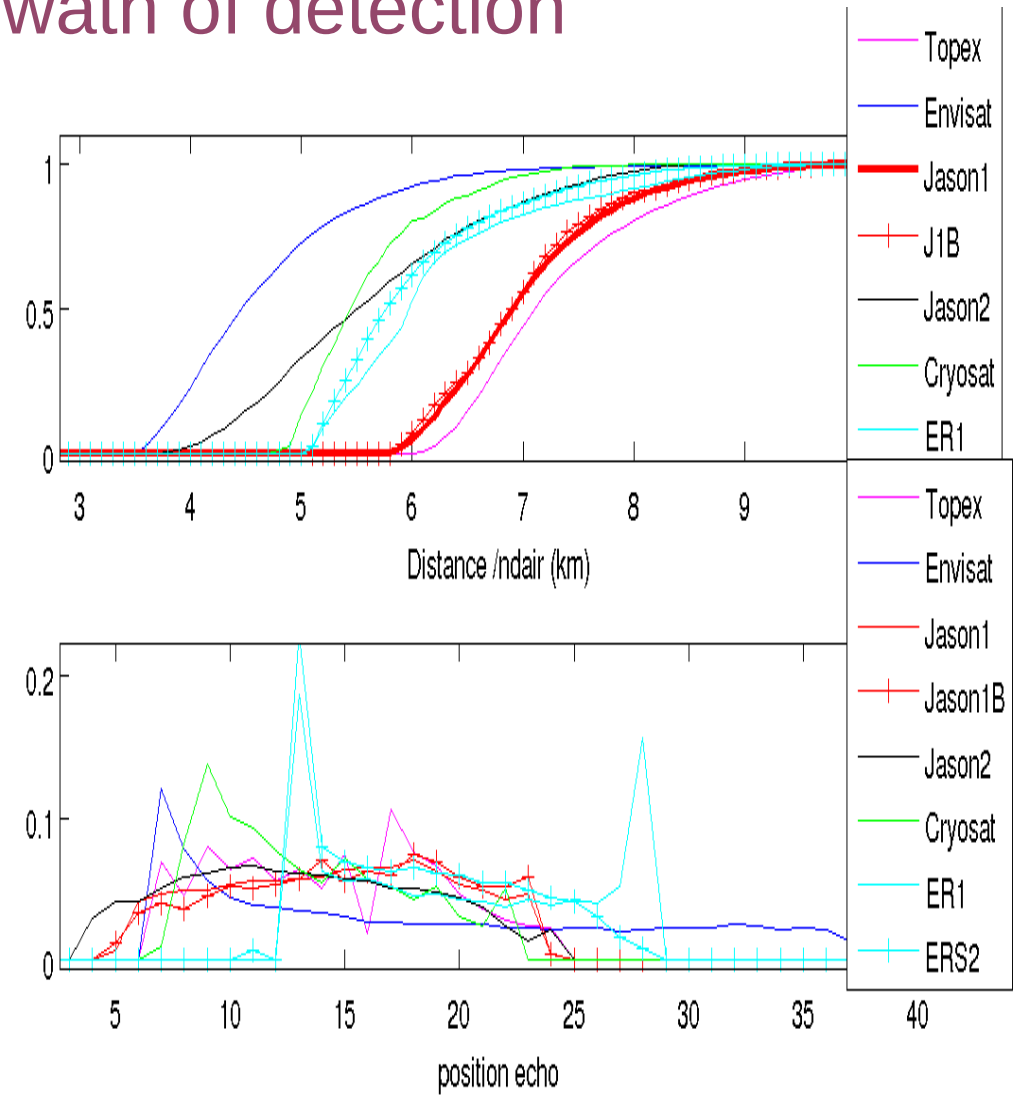


Building a coherent time series of icebergs 2 : swath of detection

The swath of detection, i.e., depend on the satellite characteristics and on the characteristics of the noise and the bin that can be used.

Envisat from 3.5 to 7 km
Jason1 from 6 to 9 km
Jason2 from 4 to 8 km
ERS1 et 2 from 5 to 8.5 km

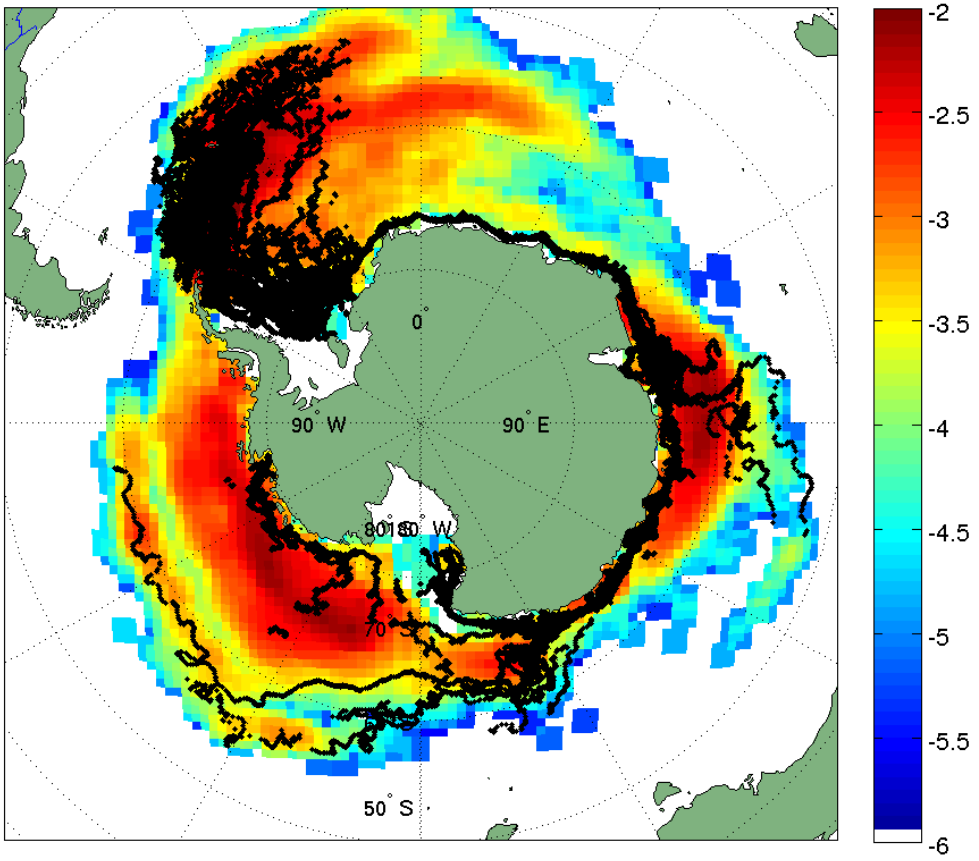
The swath width the along track resolution gives the normalisation factor for the volume computation



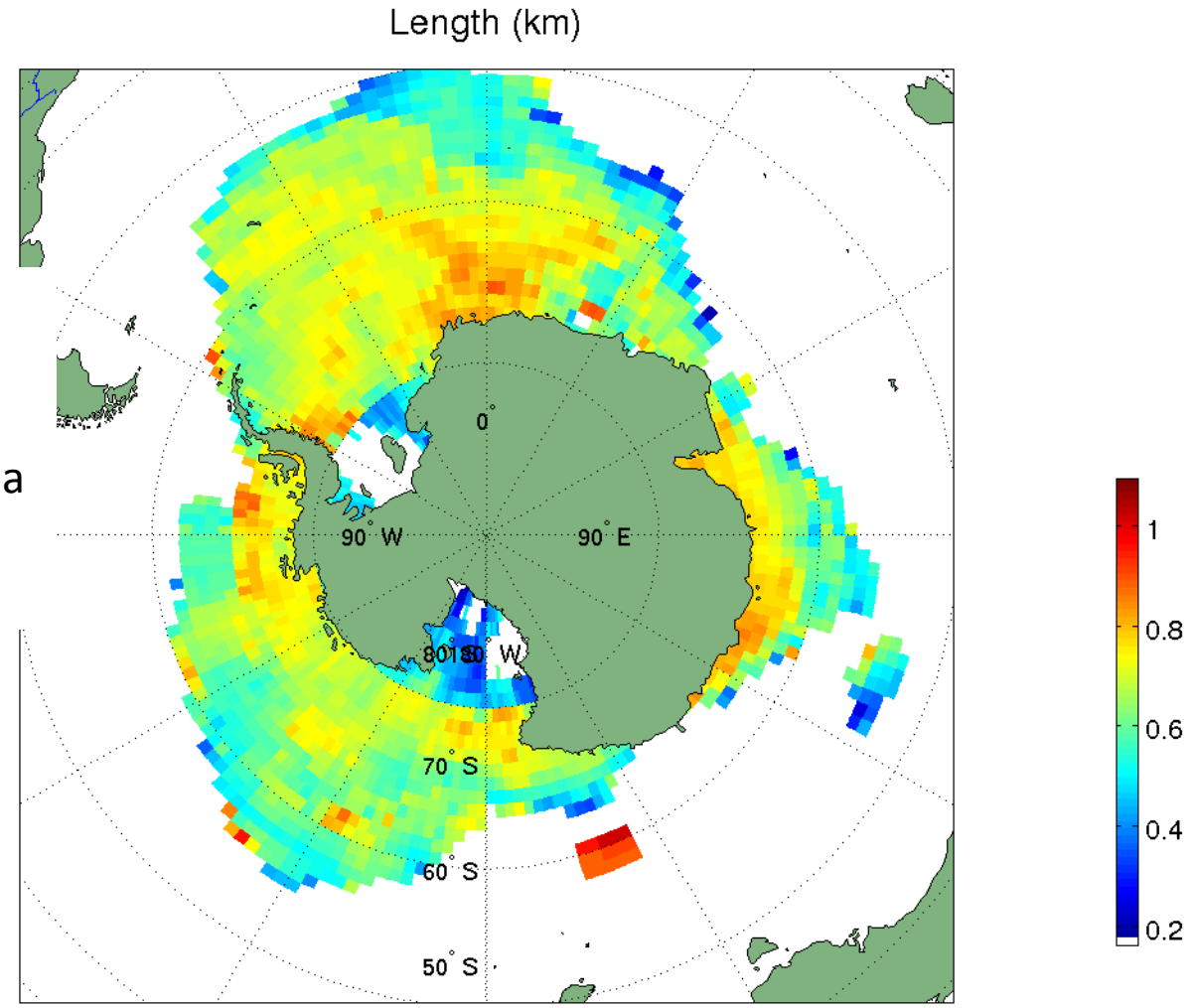
Mean monthly probability

Well known three gyres structure Wedell, Ross ,Indian

Atlantic ~60 % of the iceberg

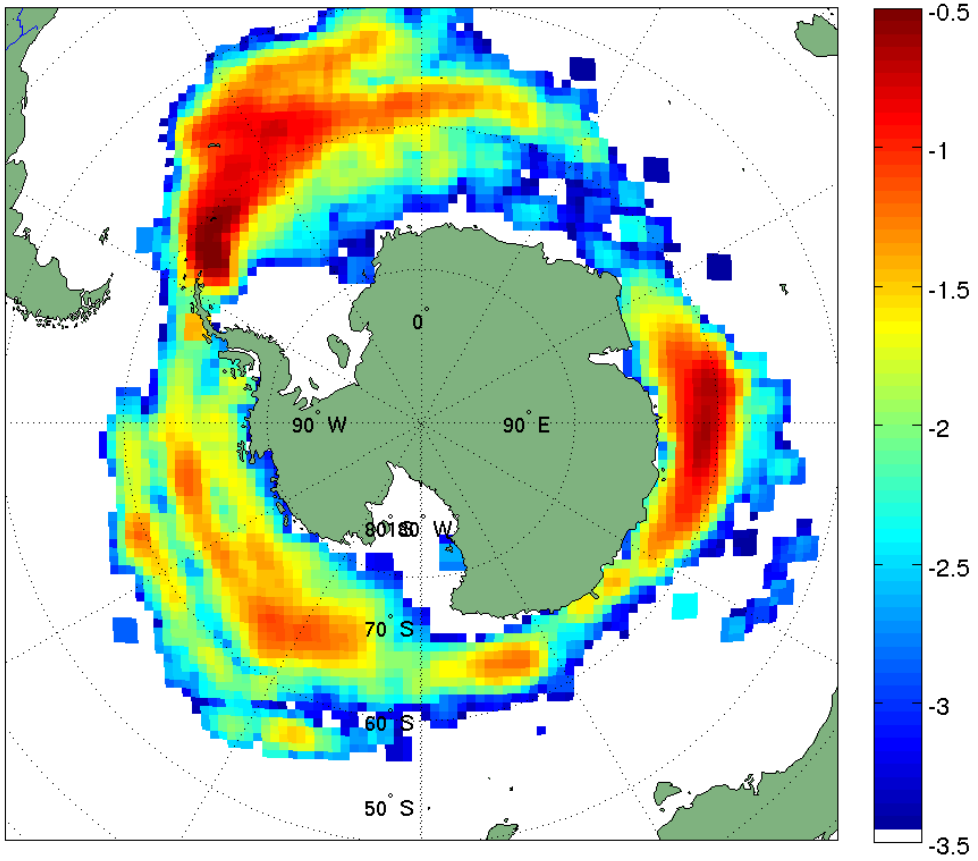


Icebergs are larger in the Indian ocean(calving in the futhest north) ;
Smaller iceberg in the Ross sea

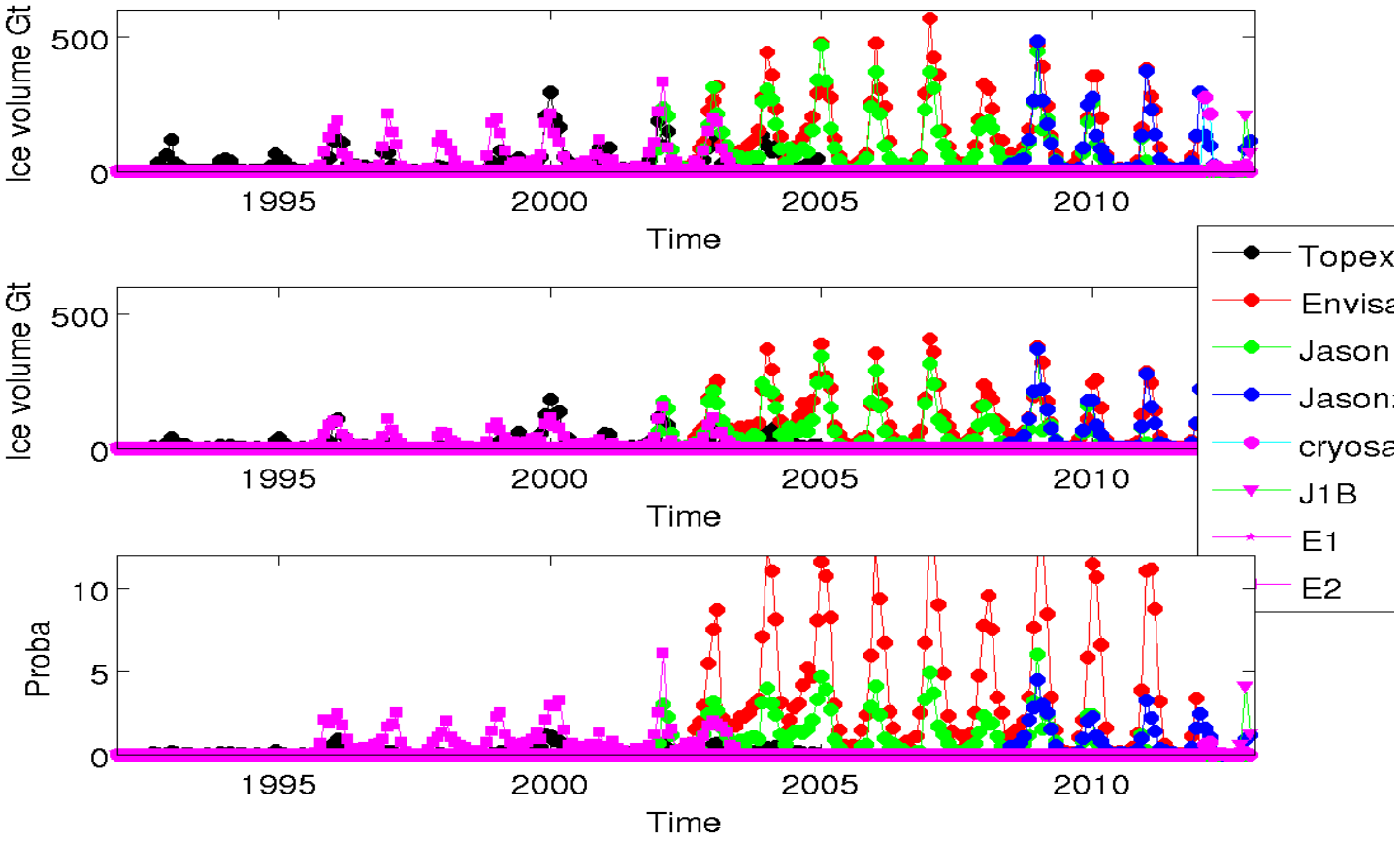


Mean monthly ice volume

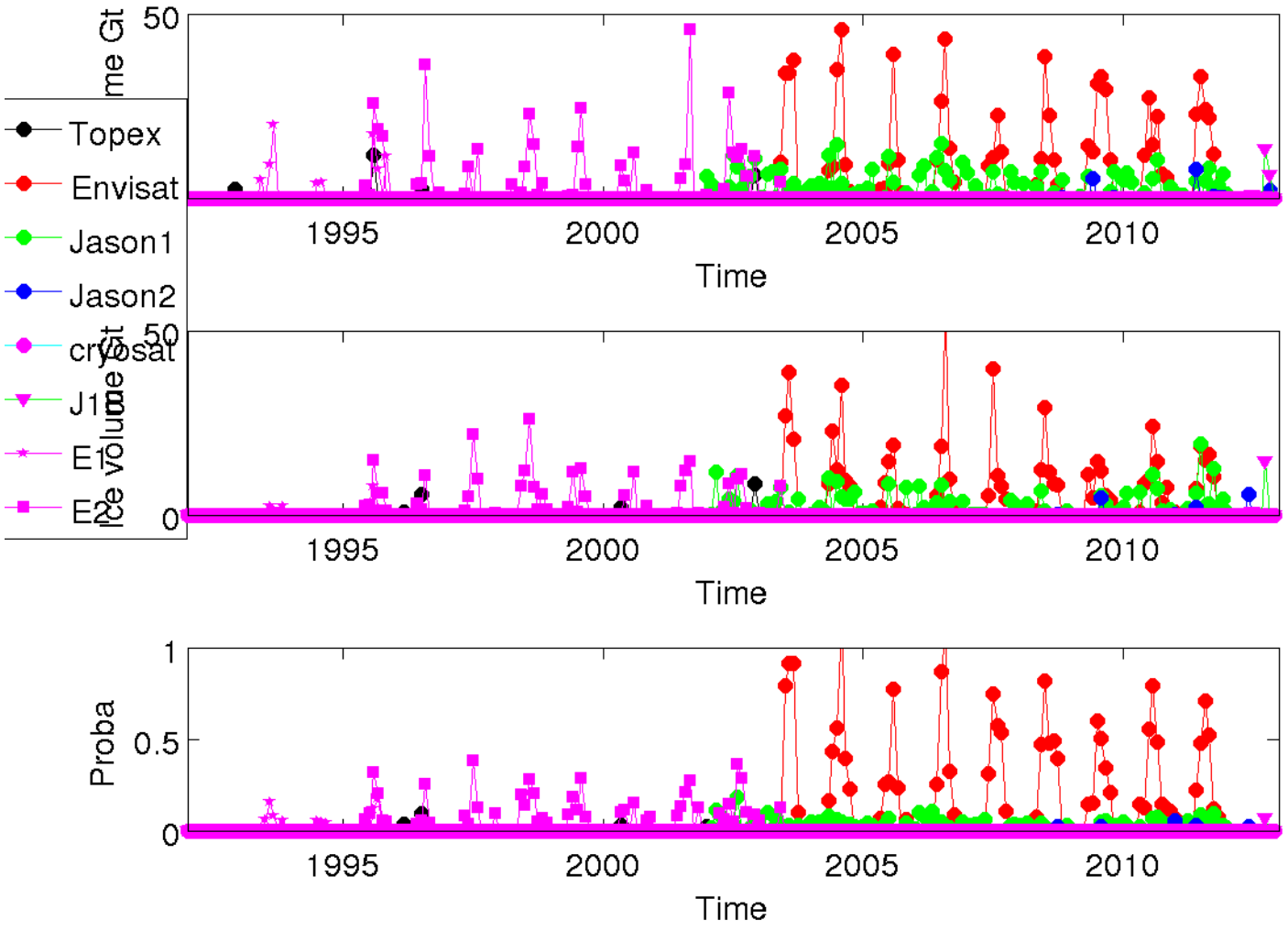
Give an idea of the fresh water flux time and space variability



Estimation of the total volume of ice



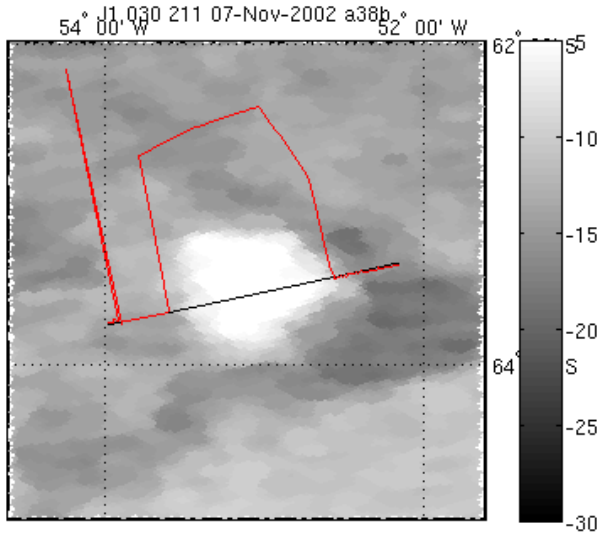
Estimation of the total volume of ice Arctic

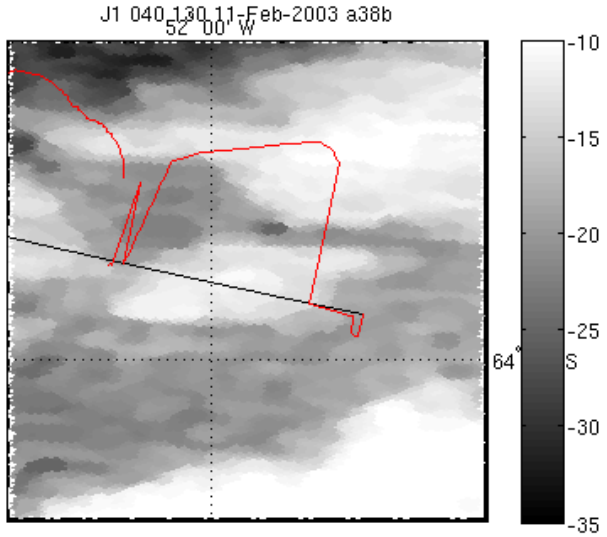


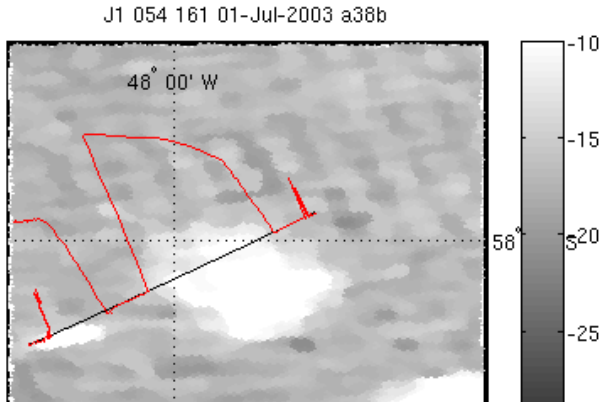
Perspective

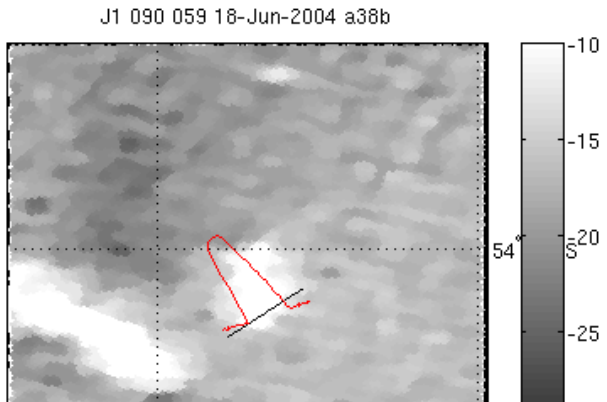
- Processing completed, Altika underway
- Use of Cryosat SAR mode (pseudo LRM or SAR)
- Arctic data base completed
- Operational product for wave modelling (one a month)
- Contact with modelling group
- Users defined products
- Web site under-construction

Bonus : large iceberg freeboard ands backscatter from waveform analysis .
Collocation between Long BYU data base and altimeter

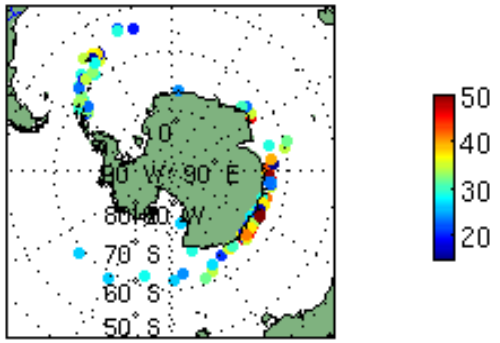




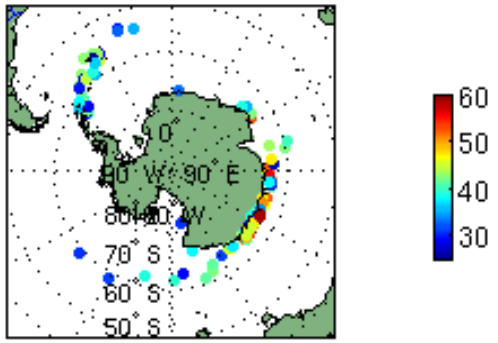




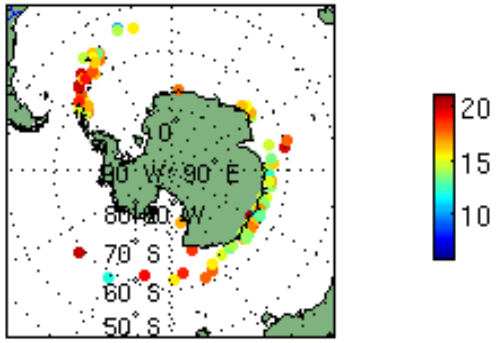
Mean Freeboard (m)



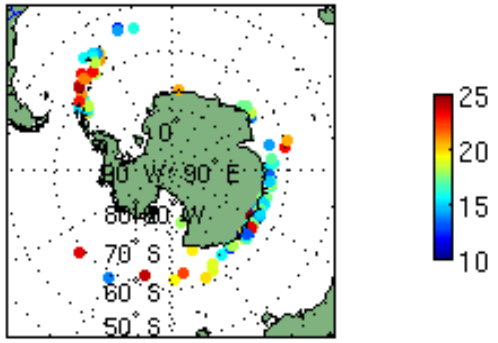
Max Freeboard (m)



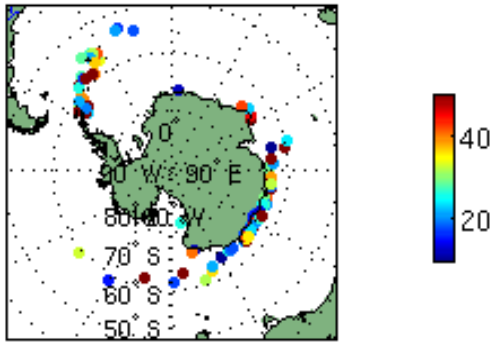
Mean Backscatter (dB)



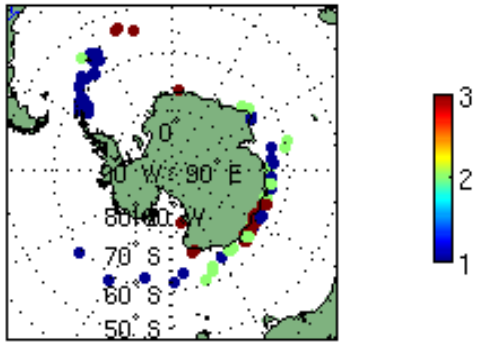
Max Backscatter (dB)



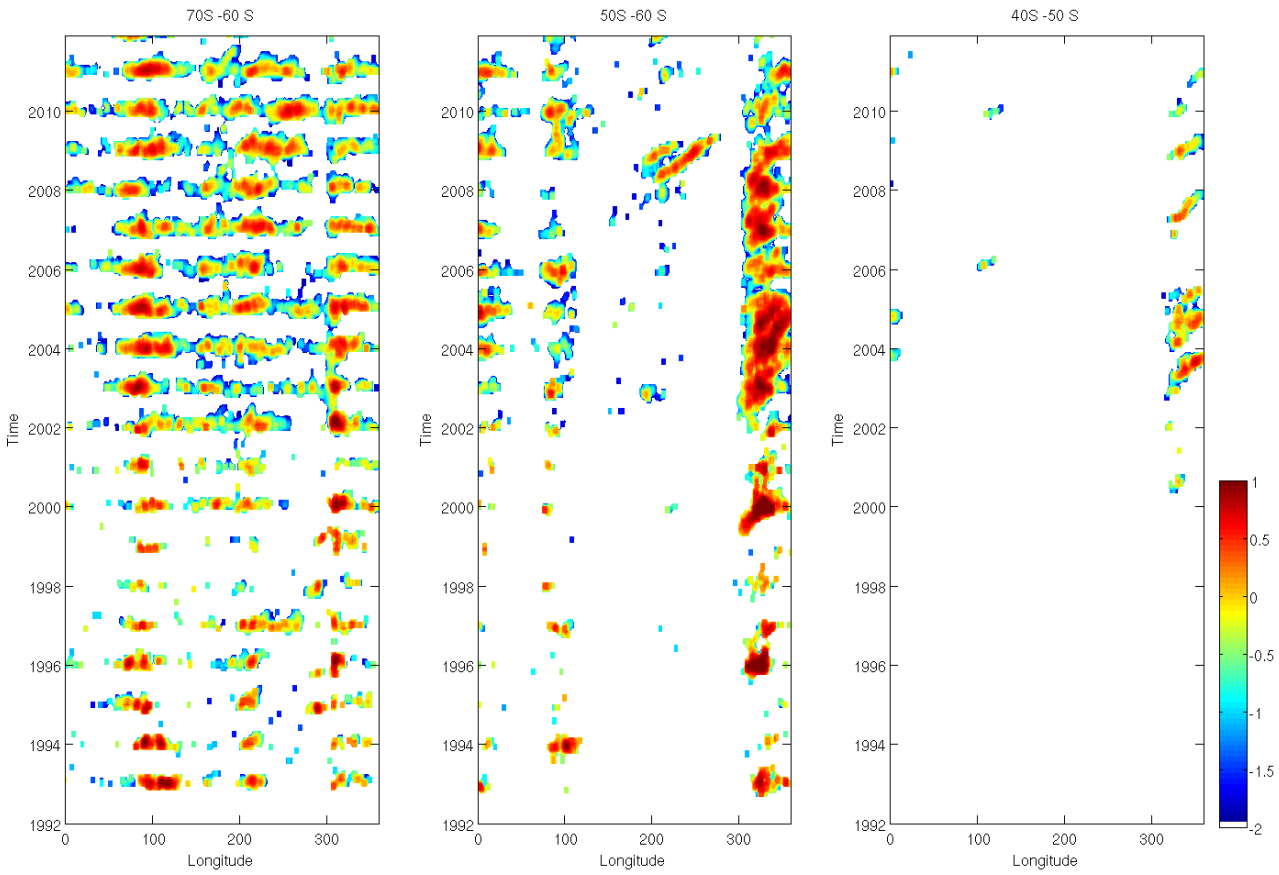
Max length (km)



sensor



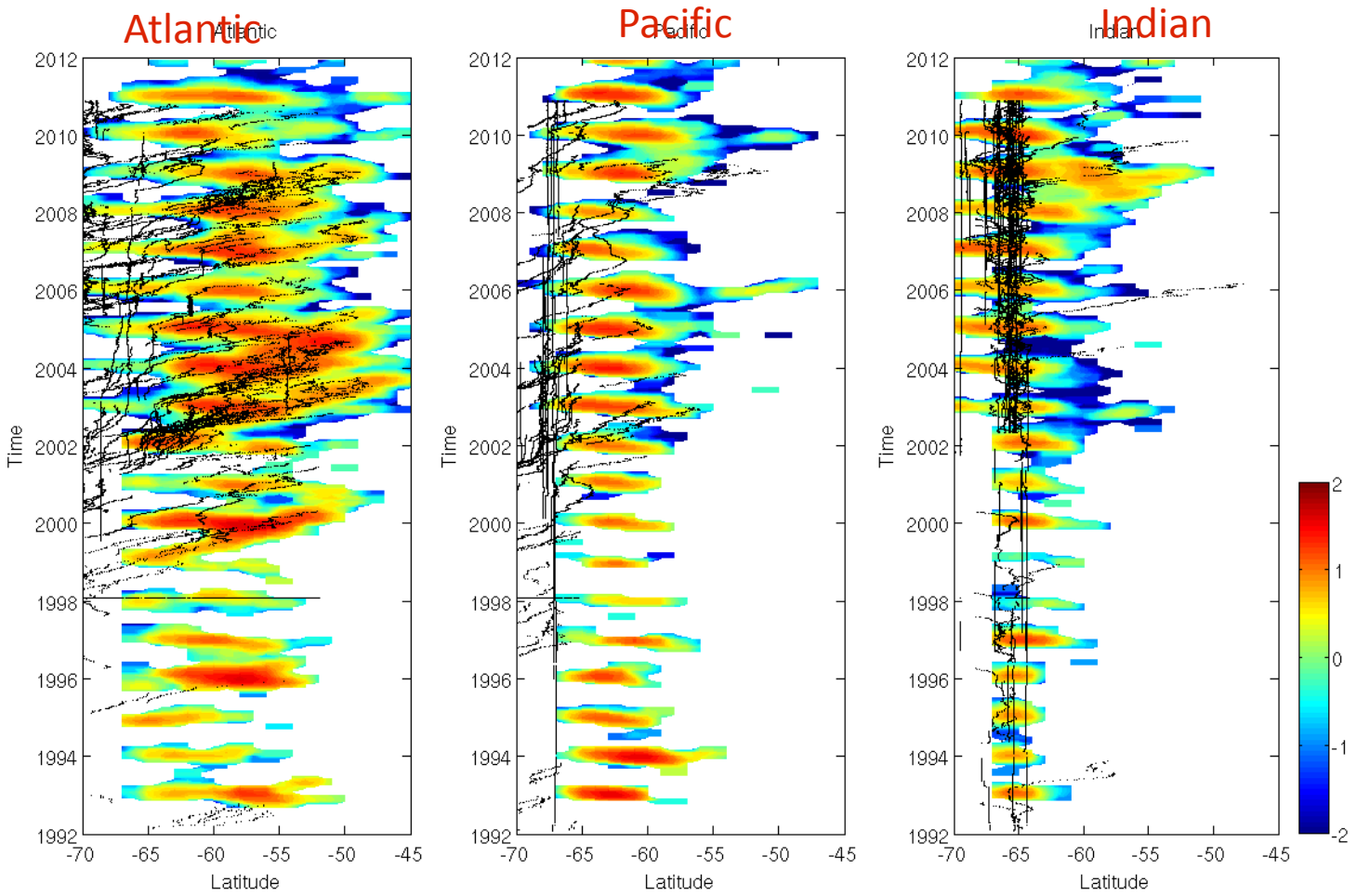
Time/longitude howmüller diagram of ice volume for three latitude band



Comparison of ice volume

Time/latitude Howmüller diagram in the three main basins

Merged ice volume data. Black Lines : large iceberg trajectories



Comparison of ice volume

Time/latitude Howmüller diagram in the south atlantic (40W 20E)
For the 4 altimeters