Precise Times Series of Ice Surface Height: Case Study of the Amery Ice Shelf.

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Abstract

A time series of altimetric observations over an ice shelf, the floating part of Antarctic ice cover, includes contributions from many sources. These contributions include corrections we need to apply to altimeter measurements to access the long term ice shelf changes, such as ice thickness. In addition to the classic altimeter propagation errors, there are other errors to cope with when measuring over the ice. Over ice shelves, the non repeat of the satellite track must be accounted for even with little topographic variation. The tides are not as well modeled here as elsewhere in the ocean, especially related to our lack of knowledge in coastline and sub-ice shelf cavity geometry, and the fact that this geometry changes with time due to ice shelf advection, accumulation and melt/freeze processes.

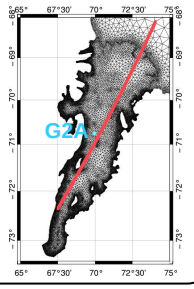
Here we extend the work on along track repeat radar altimetry to the case of the Amery Ice Shelf (AIS). To this end, we test the impact of tidal corrections and of ice shelf flow advection of small scale topography. We use the ENVISAT altimeter data processing using the ICE2 algorithm, a new hydrodynamic model for the Amery region and ice flow vectors determined from InSAR analysis of Radarsat imagery. We discuss the results of these tests and estimate the impact of the various corrections.

Method

Tidal model[1]

- Finite element modeling (*MOG2D/T-UGOm*)
- New bathymetry beneath the AIS[2]
- Open boundaries : elevation of FES2004

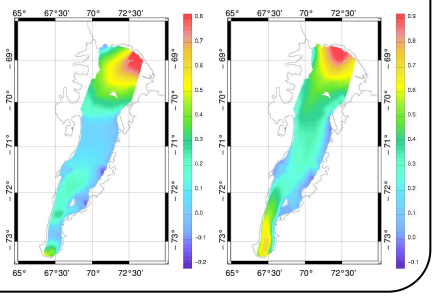
Tidal prediction:
- using modeled amplitudes and phases
- including nodal factor correction
- based on Schureman formulation



Finite element mesh, and 494 ENVISAT altimeter track

Ice flow velocities[3]

- Obtained from SAR images (RADARSAT)
- Error estimation:
  along track: 8 m.an^{-1}
  across track: 26 m.an^{-1}
  bias: 15m.an^{-1}
- Grid: 1kmx1km
- Vertical velocities obtained using the continuity equation



Eastward and northward components on the left and right panel respectively

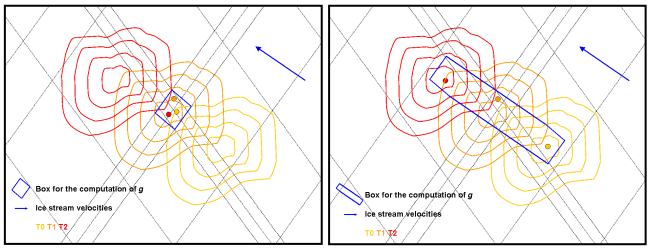
Altimetric data processing[4,5]

Classical algorithm

h = h_0(lon,lat) - r(LeW,Bs,TeS) - g(lon,lat)
r : retracking function using wave form characteristics (LeW, Bs, TeS)
g : geographical function

Geophysical correction before geographical function computation : g →g'

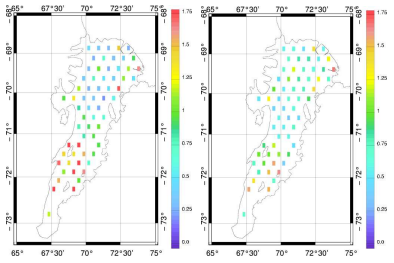
$h = h_0(lon_0,lat_0) + v_z(t-t_0) - r(LeW,Bs,TeS) - g'(lon_0+v_{lon}(t-t_0),lat_0+v_{lat}(t-t_0))$



Left: we don't take into account ice stream effects. The size of boxes for the geographical function computation only considers altimeter positioning errors. Right: we consider ice flow. The boxes are **ex**tended in the flow direction with a $V_{ice} \times$ *time elapsed* distance.

Results

Impact of tidal corrections at crossovers[6]

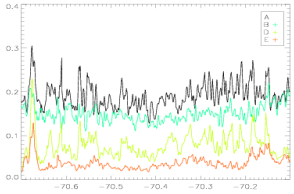


Model	RMS (m)
No correction	0.97
FES2004	*0.90* *
CATS	0.90
TUGO	0.86

* FES2004 only covers the northern part of the AIS, where the bathymetry is better known.

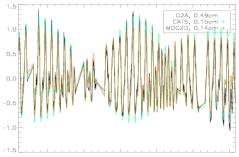
Standard deviation (m) without tidal corrections (left) and with MOG2D corrections (right).

Along track processing of time variability



A: No velocities, no tides, no IB
B: Velocities, no tides, no IB
C: Velocities, no tides, IB
D: Velocities, tides MOG2D, IB
E: Velocities, tides CATS, IB
h: raw elevations
hg: h with geographical correction
hge: hg with echo shape correction

Top: along track RMS (m) for the A, B, D, E, cases using hge corrections. Bottom: G2A GPS elevations, and CATS and MOG2D tidal predictions.



RMS (m)	h	hg	hge
A	0.52	0.49	0.42
B	0.52	0.44	0.39
C	0.34	0.30	0.23
D	0.32	0.29	0.20
E	0.31	0.28	0.18

NB: IB=Inverse Barometer

Improvements due to
- Geographical echo shape corrections
- Velocities, atmospheric pressure and tidal correction

Error estimations

Tide: **4.8cm**
IB: **4cm**
Velocities: tide errors are equivalent to 2-3-m.an^{-1} → 30cm
Geophysical error estimation > residual standard deviation

Conclusion

We have used crossover analysis and along-track repeat radar altimetry over the AIS to assess the impact of ICE2 retracking and geophysical corrections (ice velocities, tides from CATS and MOG2D models, and atmospheric pressure as IB). The results presented here show clearly how these various corrections reduce the variance of altimeter time series.

The final RMS (case E) is of the order of altimeter measurement noise over ice regions. Moreover, data have been corrected from long period tide components. We can thus use the corrected data set for climate applications and estimate the ice thickness variation trends.

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References

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