Prospective study on ice2 retracking improvements

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- Integration of a MLE approach
- Computation of geo and echo corrections @ level 2

Study done for ESA on Envisat/RA-2 data, presented during the QWG in May 2012

First Part

Results on the integration of a MLE algorithm in the Ice2 retracking

SUMMARY

- Subject :

  To introduce a MLE algorithm in the Ice-2 retracking in order to estimate Epoch and SigmaL. A test is also performed with a MLE-3 (Amplitude estimation). The rest of the algorithm remains unchanged.

- Goals :
  - To improve the calculation time ➔ the MLE algorithm converges in few iterations whereas Ice-2 explores all possible solutions.
  - To improve the accuracy of the estimates ➔ the MLE algorithm is not quantified.

- Principle :

  The MLE algorithm fits the waveform with a mean return power model. It is an iterative process stopped when the mean quadratic error between the waveform and the model is low and stable enough.

  An Ice-1 algorithm is performed before the MLE algorithm in order to initialize it.

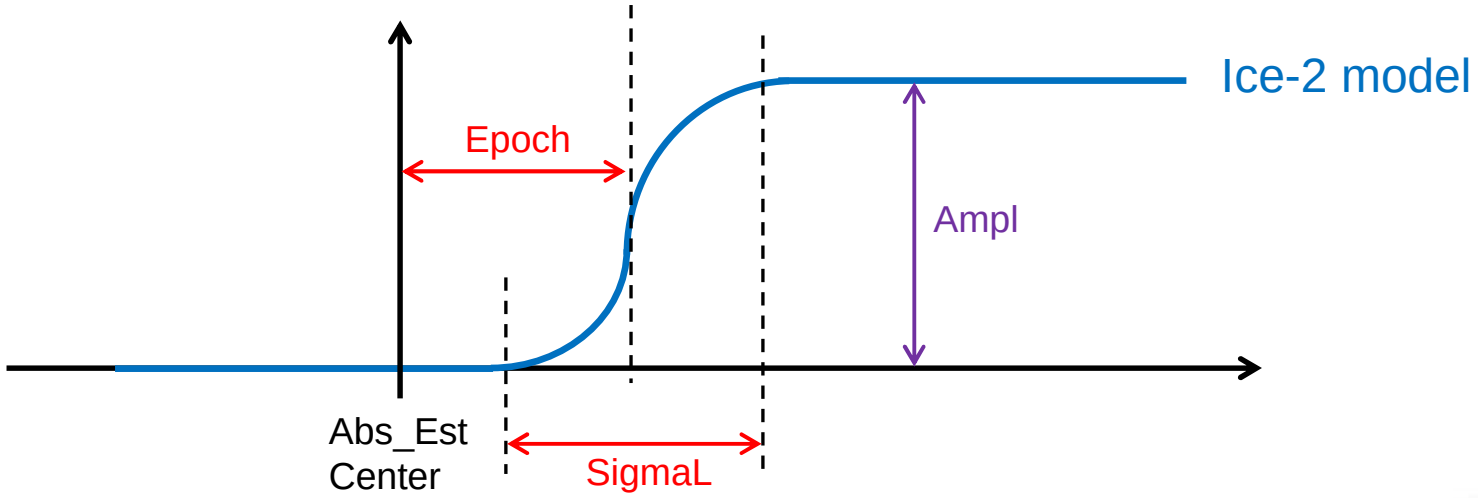
Ice-2 model :

$$V(x) = \frac{1}{2} * [1 + erf(x)]$$

with : $x(i) = \frac{(Wf\_Abs(i) - Abs\_Est\_Center) - Epoch}{SigmaL}$

and : $erf(x) = \frac{2}{\sqrt{\pi}} * \int_0^x e^{-t^2} dt$

ALGORITHMS : Ice-2MLE-2/ Ice-2MLE-3



Ice-2MLE-2

- Epoch
- SigmaL

Estimated by the MLE algorithm

- Ampl

Computed as in the original Ice-2 algorithm

Ice-2MLE-3

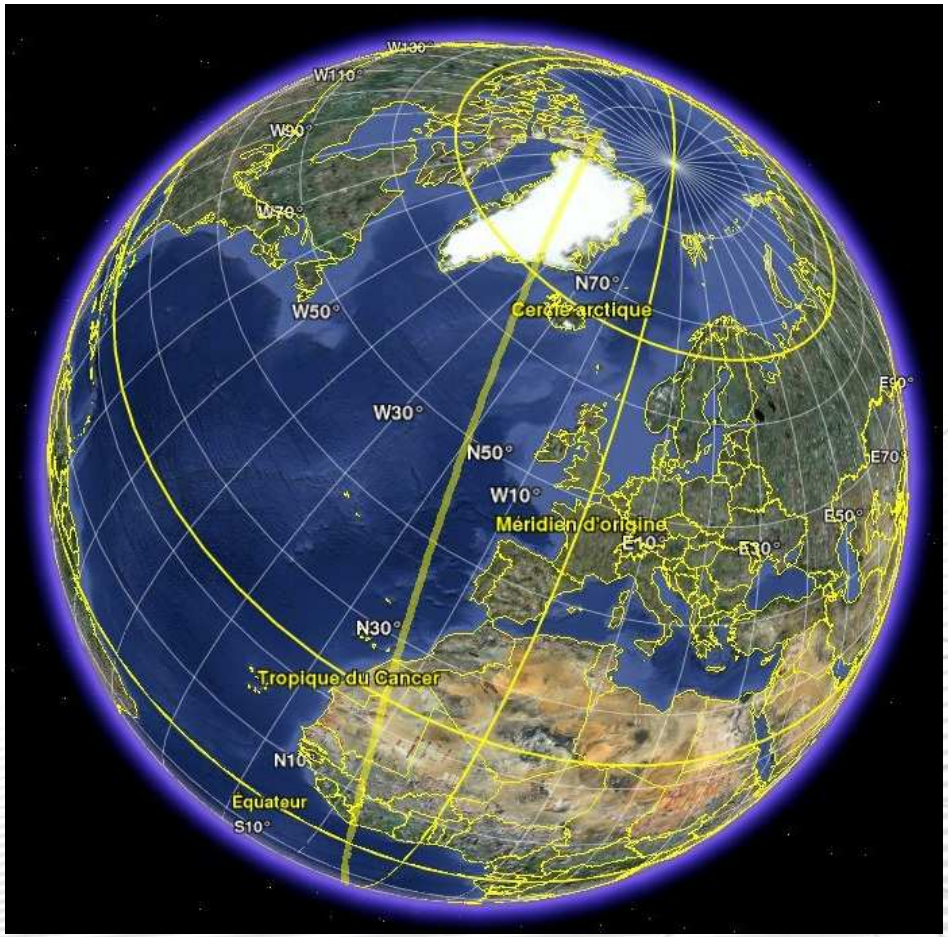
- Epoch
- SigmaL
- Ampl

Estimated by the MLE algorithm

Results on pass 889 from cycle 74
ENVISAT/RA-2

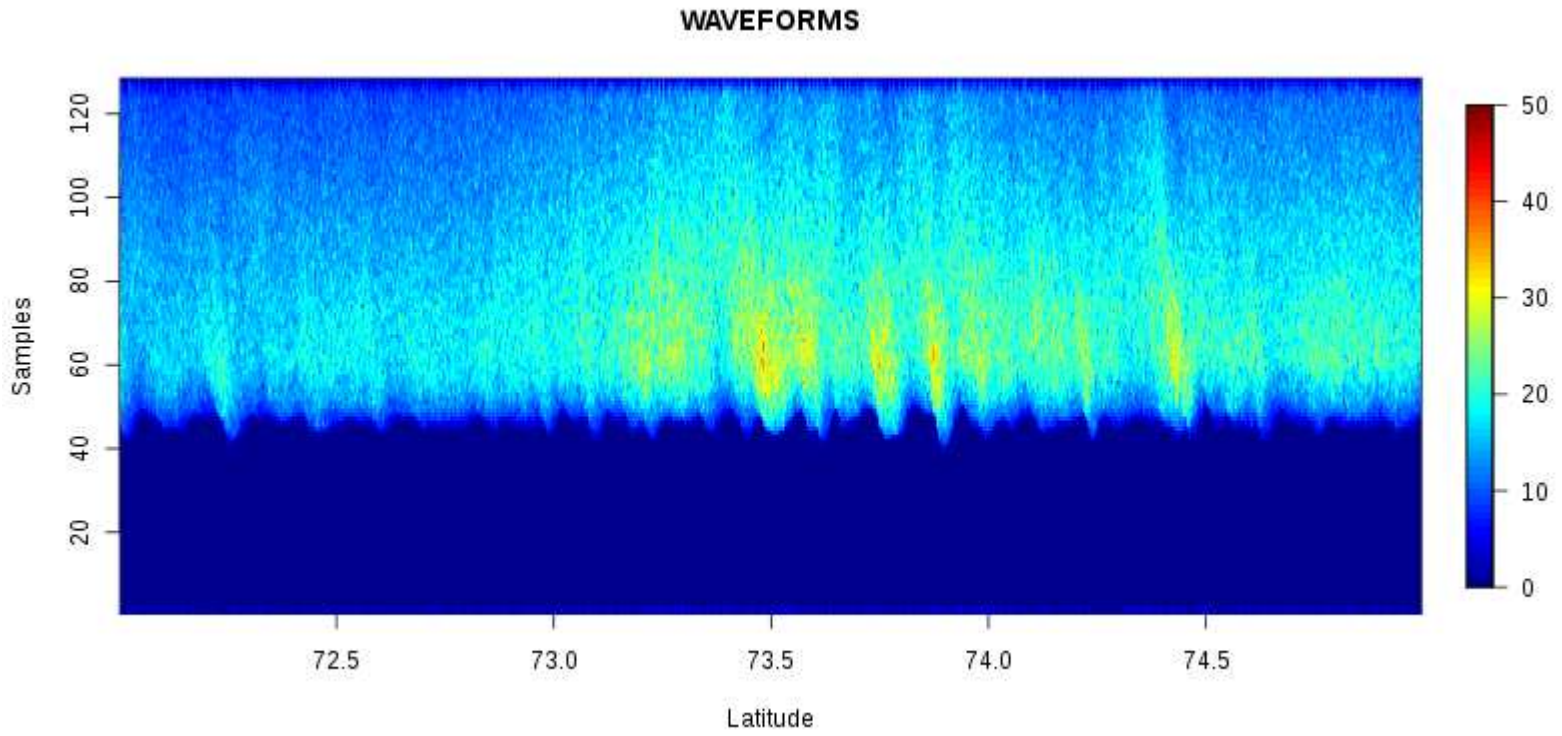
FIRST STUDIED PASS

- Pass 889 from cycle 74 ENVISAT (18/12/2008)



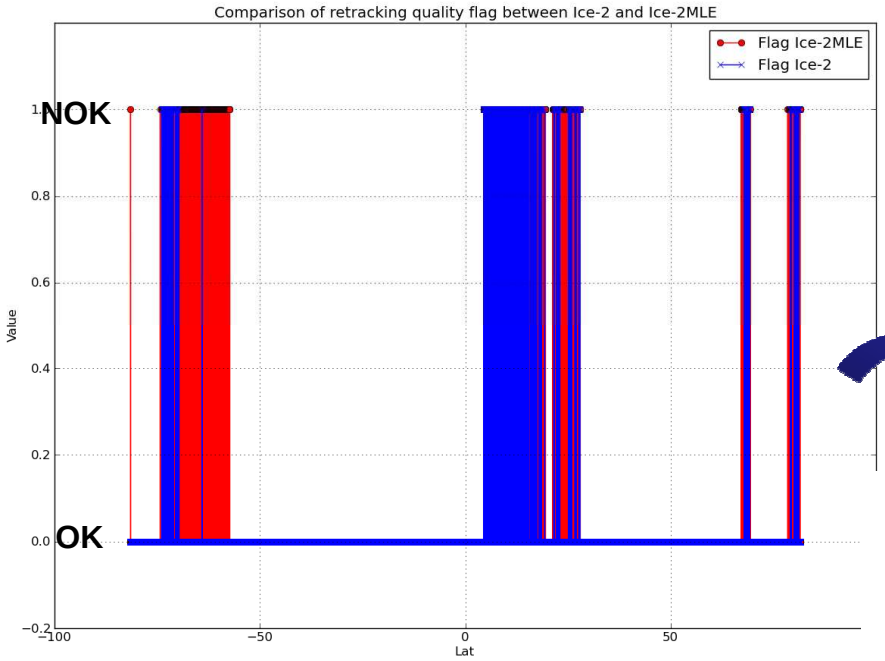
WAVEFORMS

- Zoom : 72°N < LAT < 75°N (Greenland)



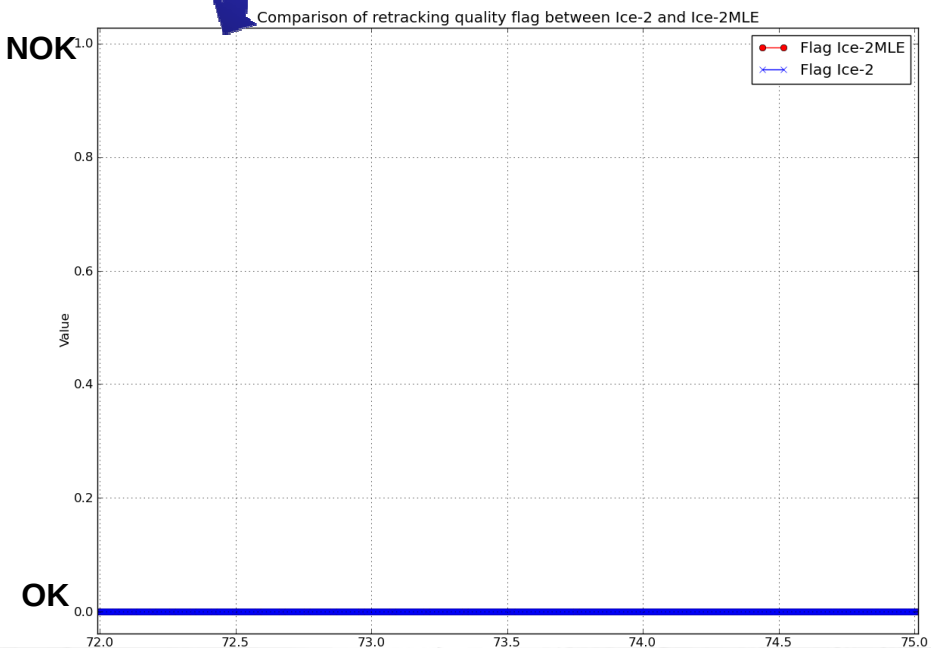
Waveforms are similar to oceanic echoes but the leading edge position is very noisy and there is strong variations of the slope of the trailing edge.

RESULTS OF THE ICE-2MLE2



Comparison of retracking quality flag

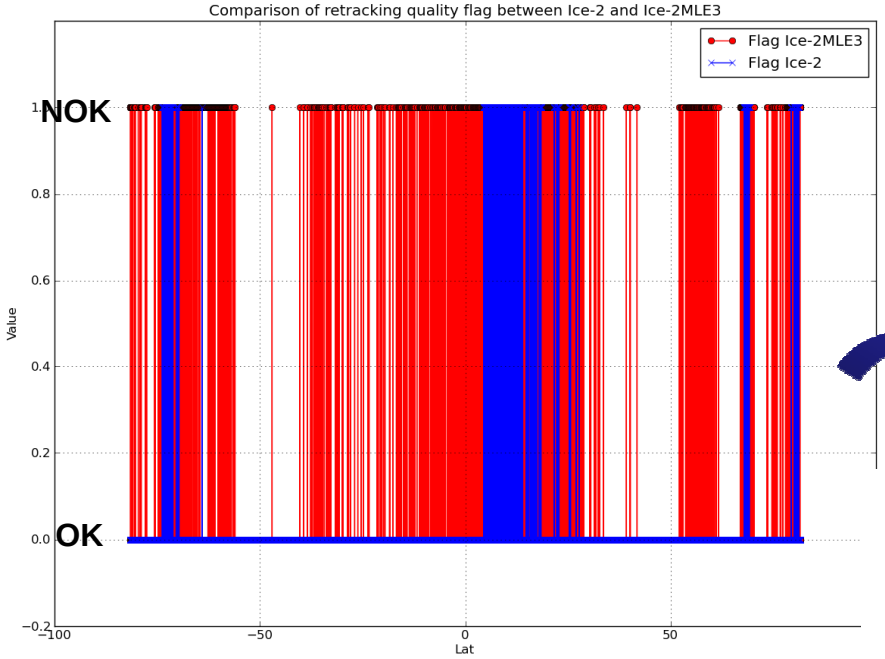
Zoom



Nb measures in this pass : ~54 000
Nb measures rejected by Ice-2 : ~2 500
Nb measures rejected by Ice-2MLE : ~5000

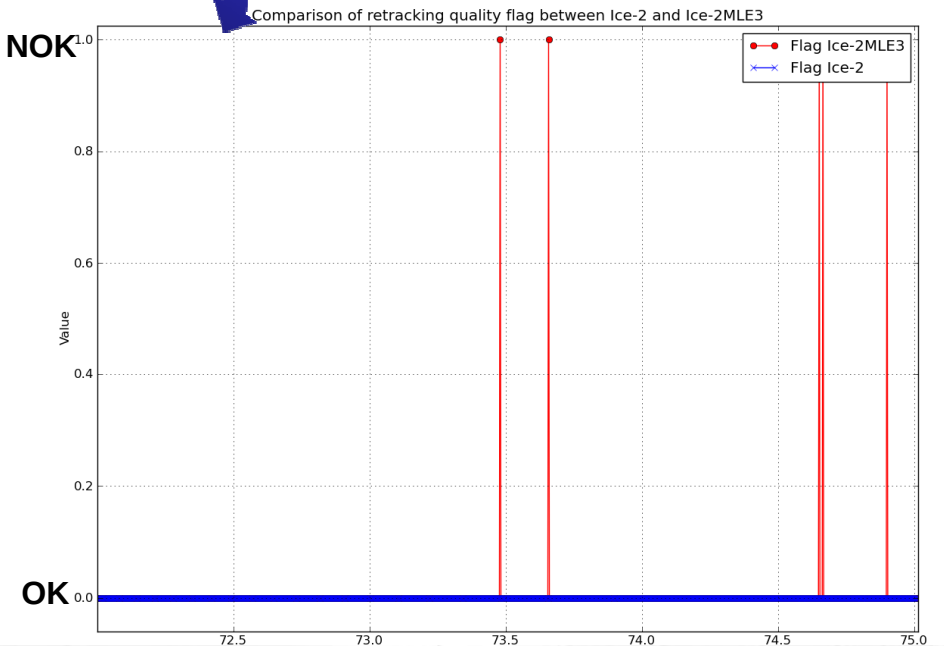
The Ice-2MLE always performed in the selected area.

RESULTS OF THE ICE-2MLE3



Comparison of retracking quality flag

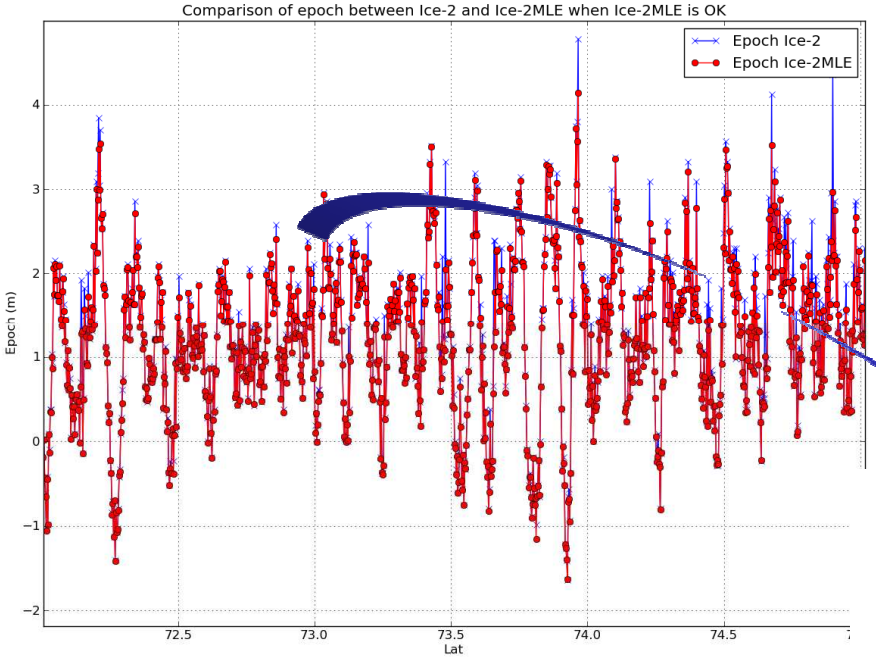
Zoom



Nb measures in this pass : ~54 000
Nb measures rejected by Ice-2 : ~2 500
Nb measures rejected by Ice-2MLE3 : ~10000

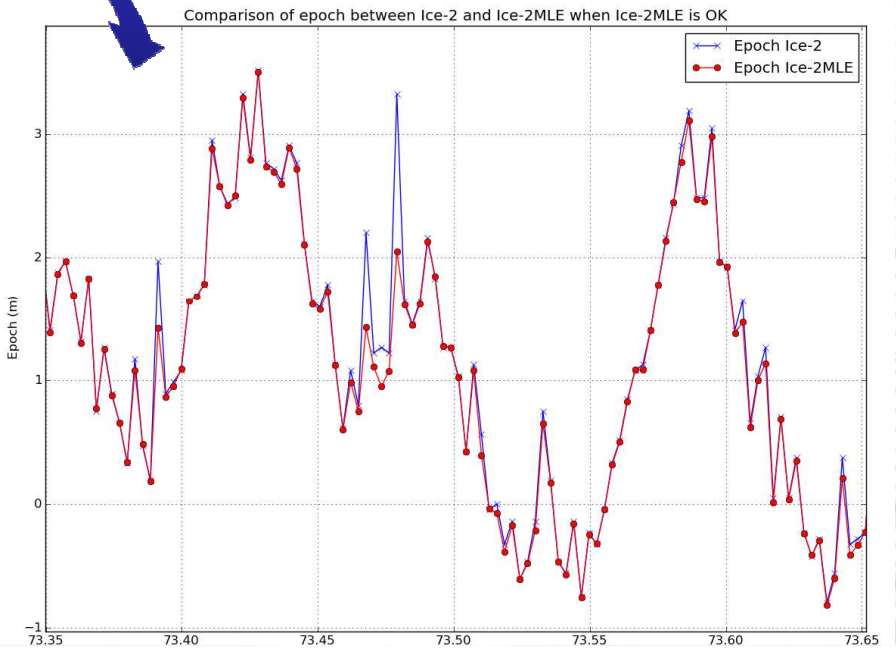
The Ice-2MLE3 rejects 5 points on the selected area.

RESULTS OF THE ICE-2MLE2



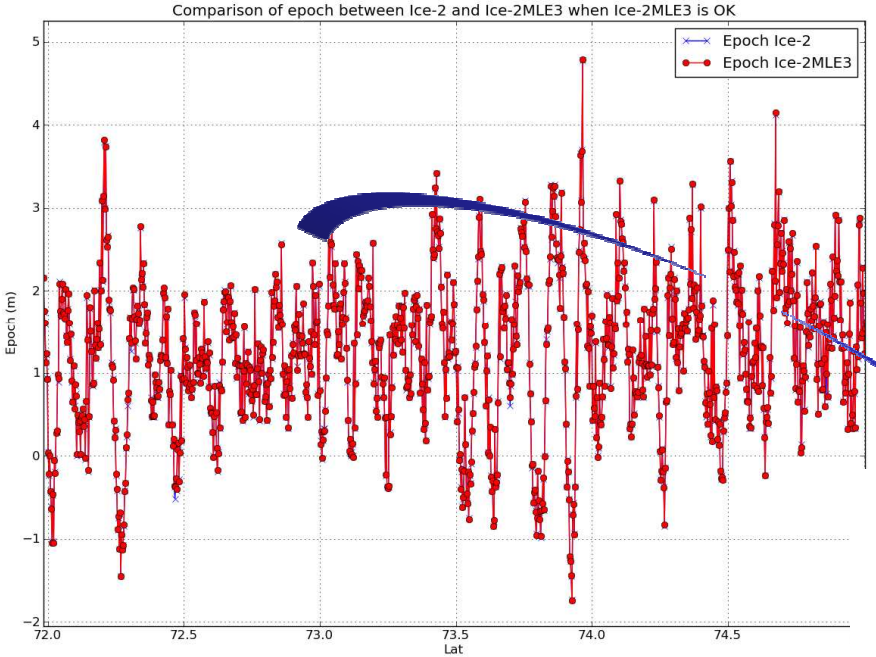
Comparison of epoch

Zoom



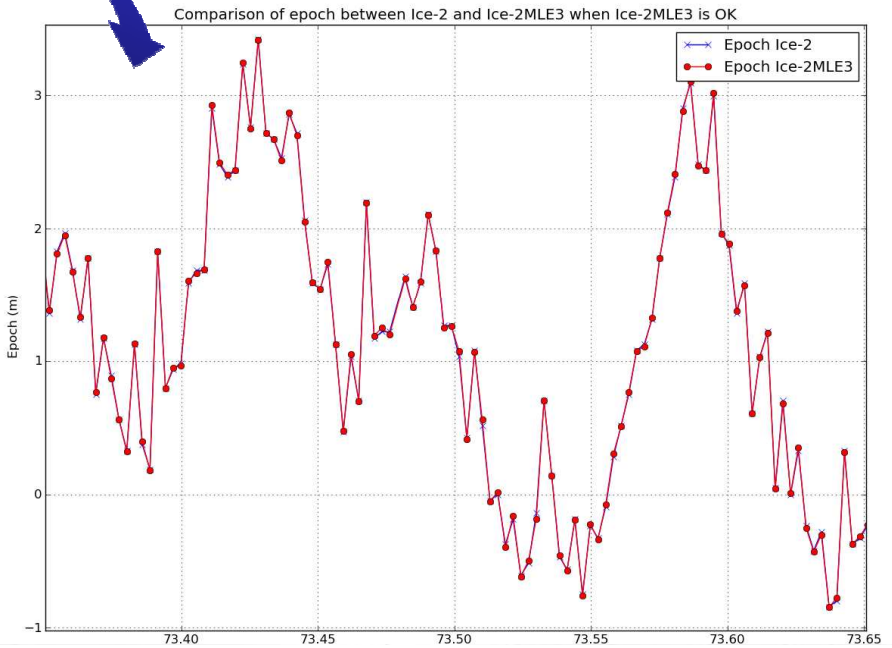
Good agreement between the two estimates except on some isolated measurements. We observe a better precision of the estimates with the new algorithm (no quantization)

RESULTS OF THE ICE-2MLE3



Comparison of epoch

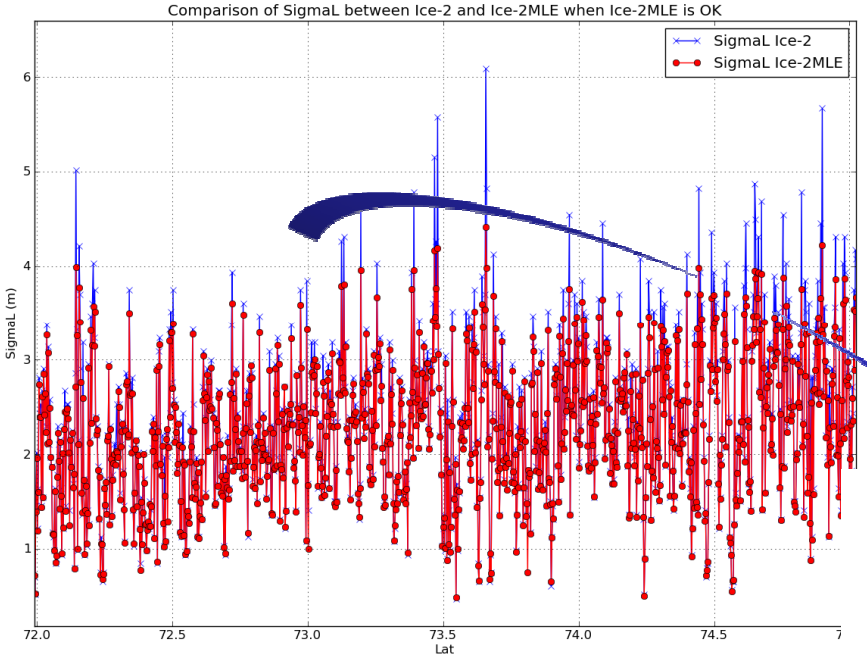
Zoom



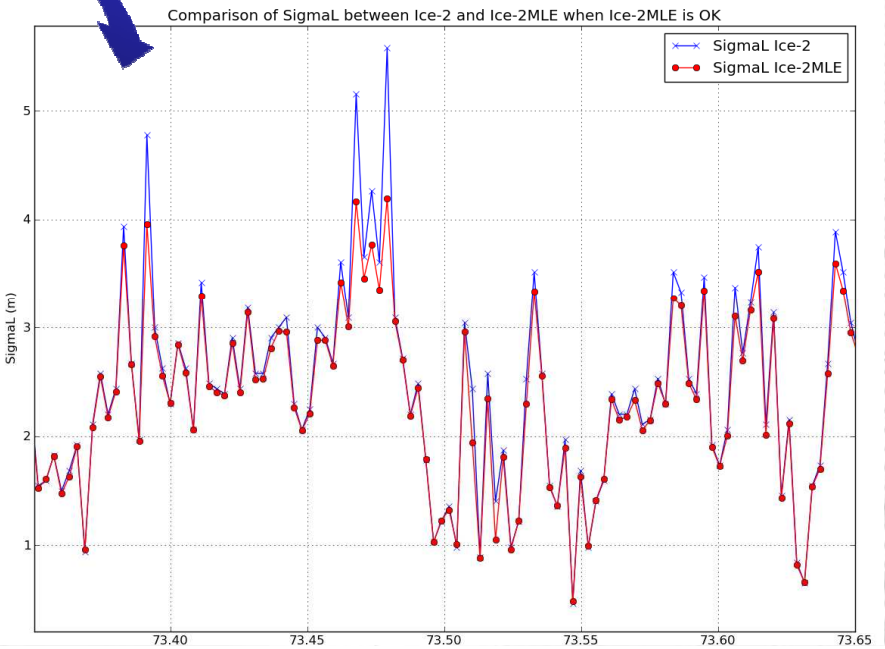
Good agreement between the two estimates except on rejected points. The Ice-2MLE3 seems to provide better estimates than the MLE-2 but reject more points.

RESULTS OF THE ICE-2MLE2

Comparison of SigmaL



Zoom



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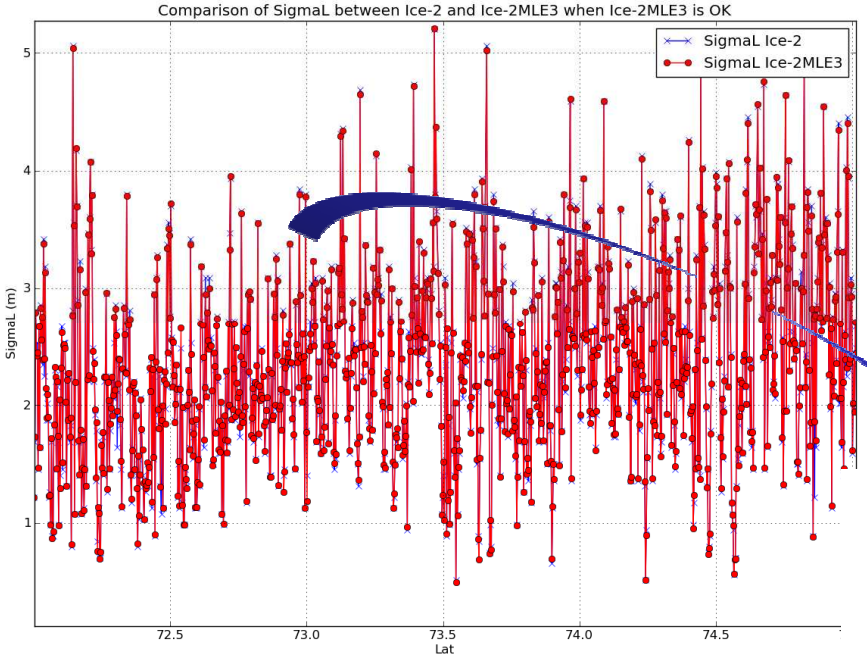
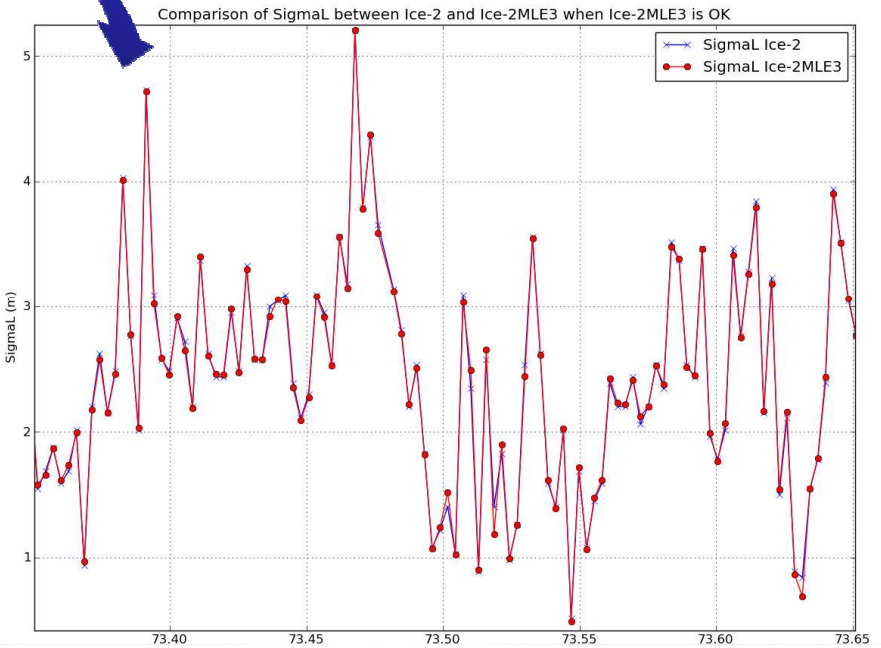
RESULTS OF THE ICE-2MLE3

Comparison of SigmaL



Zoom



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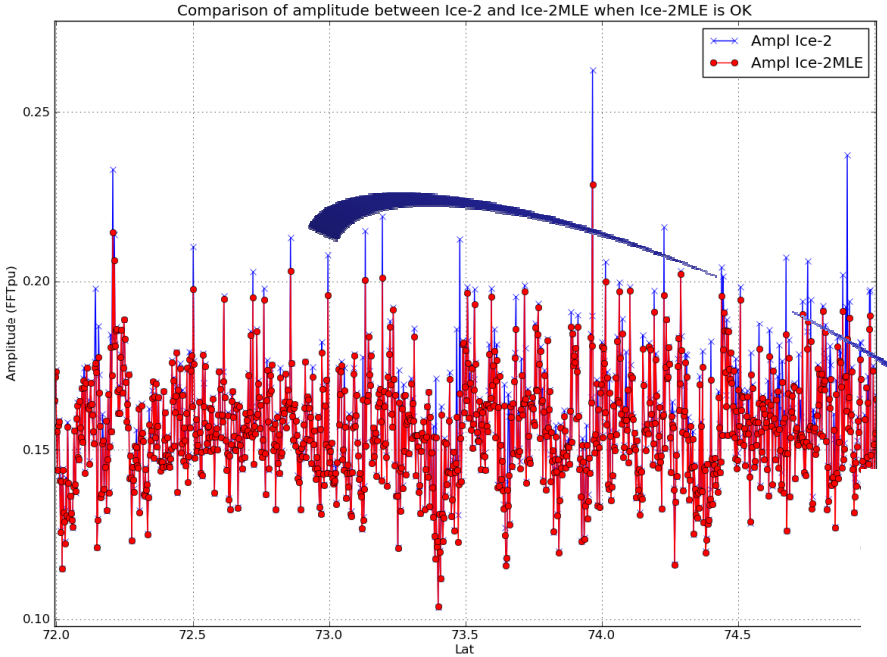
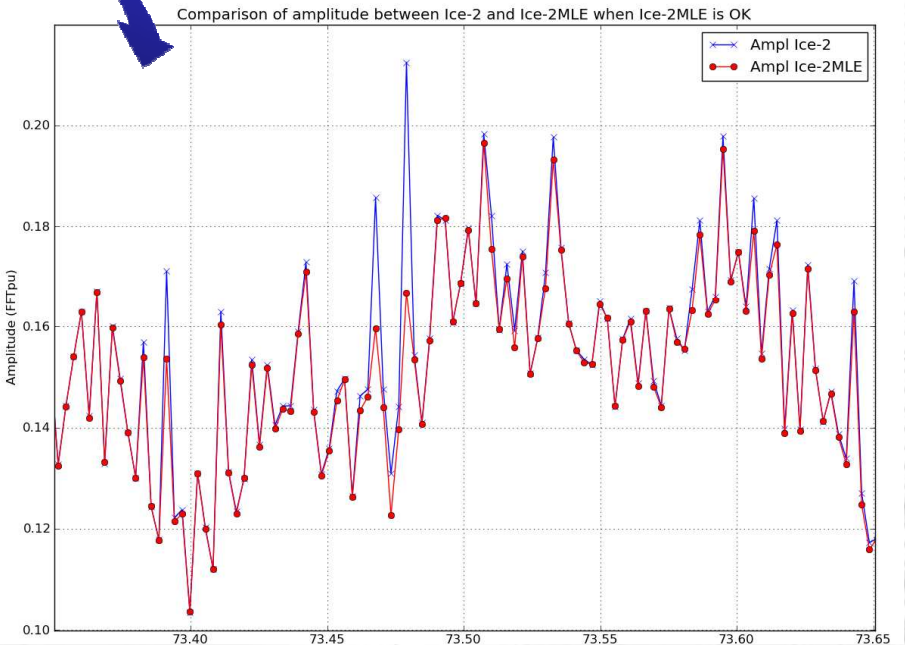
RESULTS OF THE ICE-2MLE2



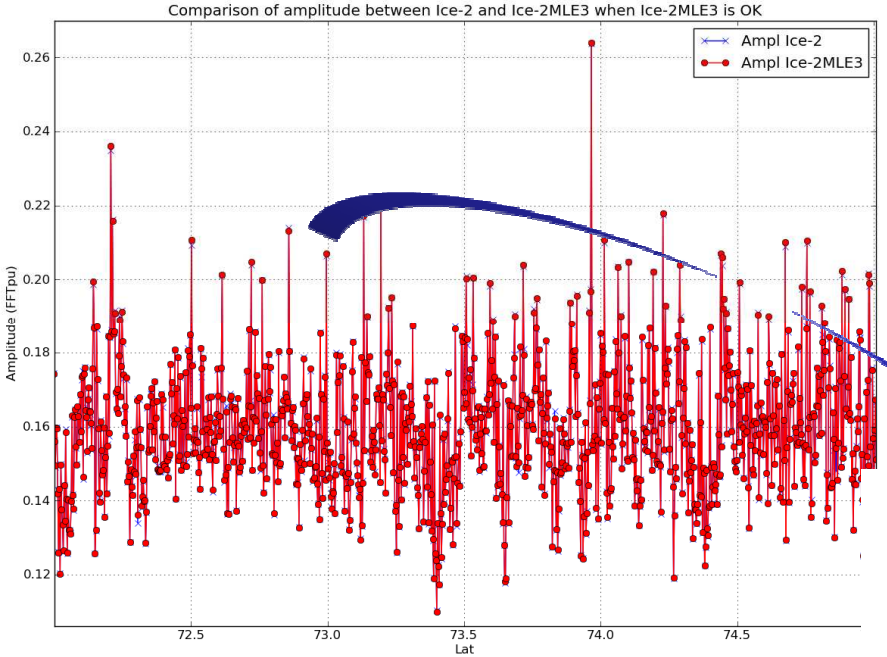
Comparison of amplitude

Zoom



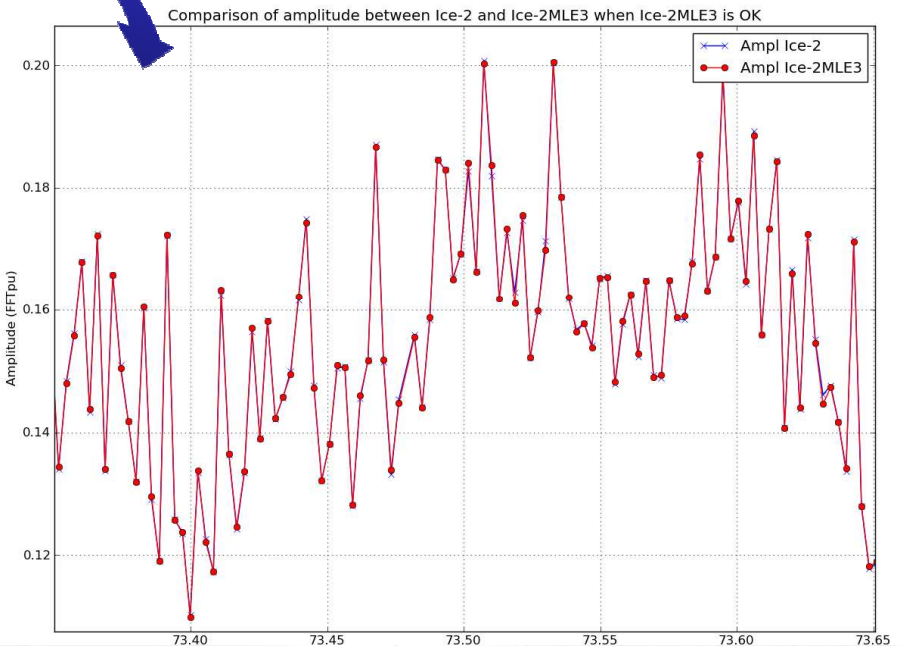
Good agreement between the two estimates except on some isolated measurements.

RESULTS OF THE ICE-2MLE3



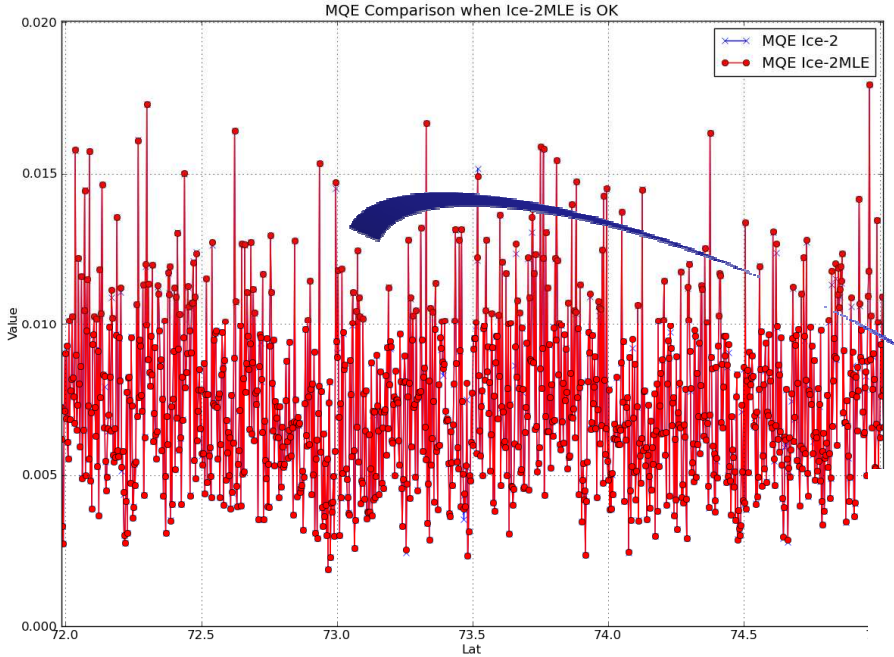
Comparison of amplitude

Zoom



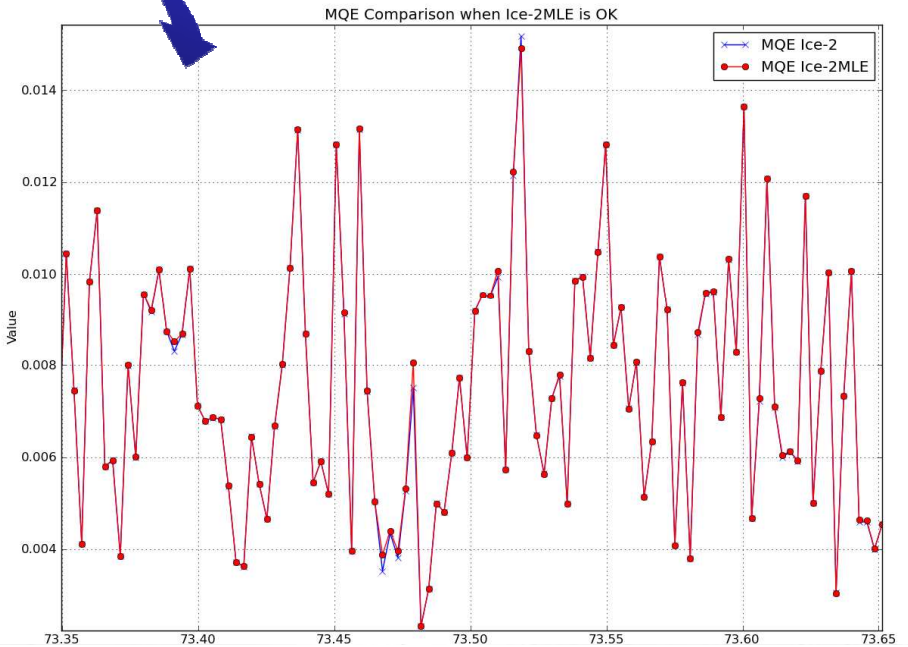
Good agreement between the two estimates except on rejected points. The Ice-2MLE3 seems to provide better estimates than the MLE-2 but reject more points.

RESULTS OF THE ICE-2MLE2



Comparison of MQE

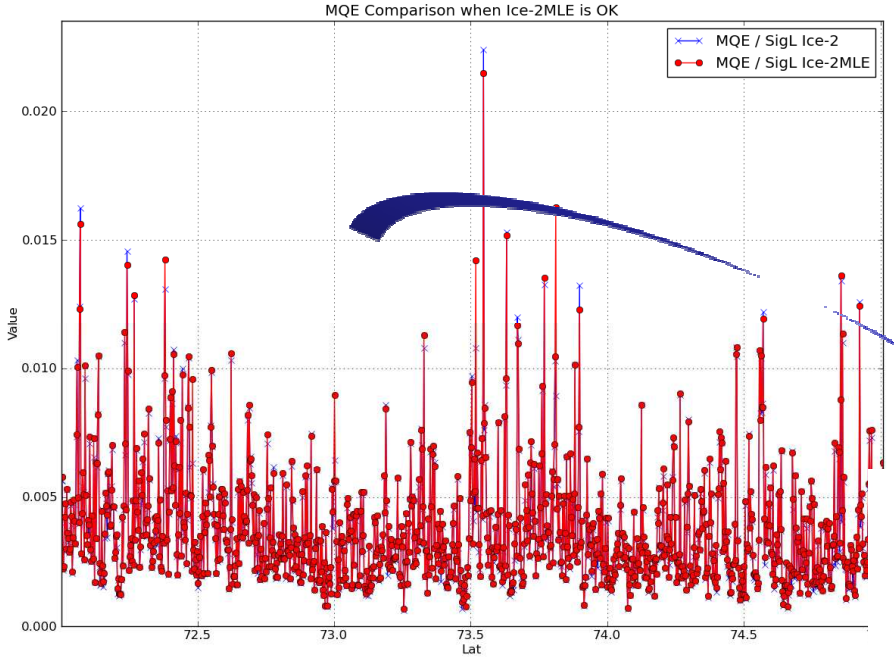
Zoom



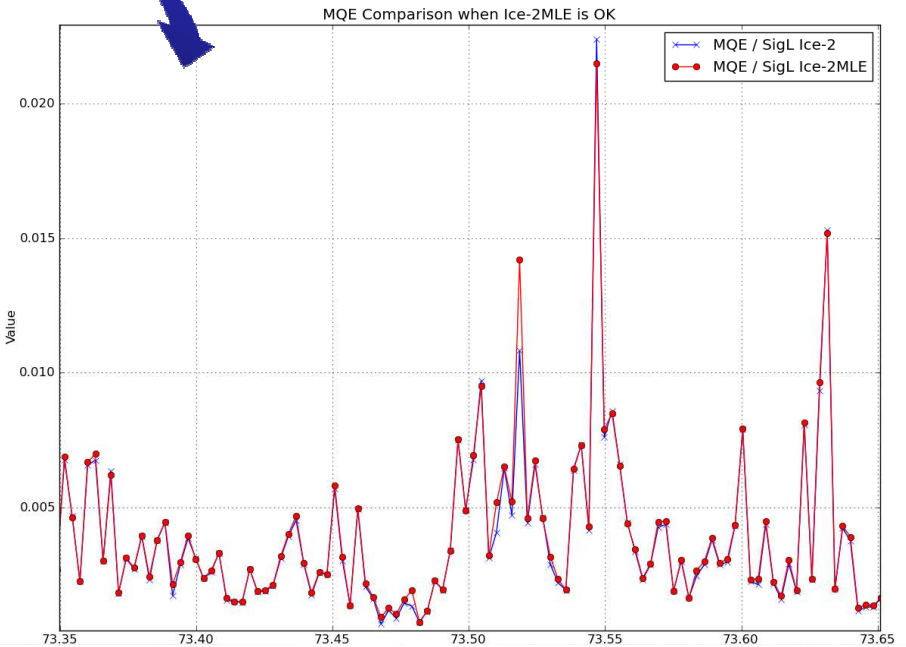
Good agreement between the two estimates except on some isolated measurements.

RESULTS OF THE ICE-2MLE2

Comparison of MQE / SigmaL



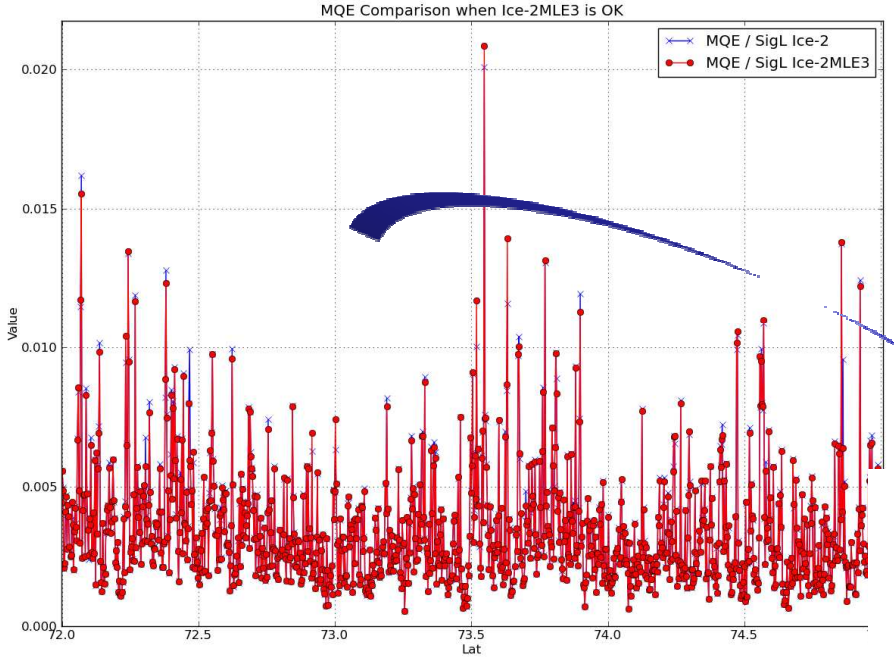
Zoom



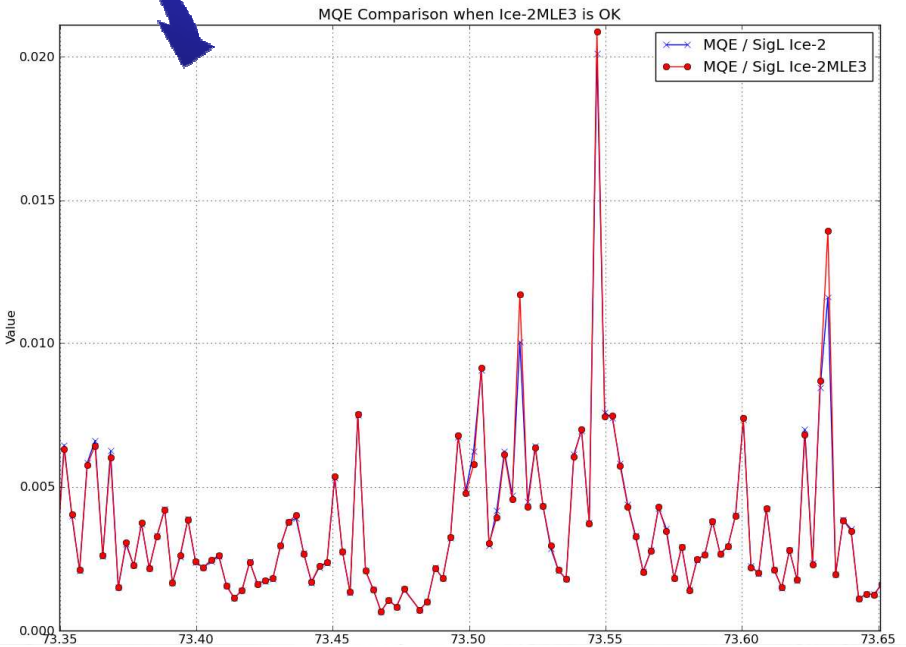
Good agreement between the two estimates except on some isolated measurements.

RESULTS OF THE ICE-2MLE3

Comparison of MQE / SigmaL



Zoom



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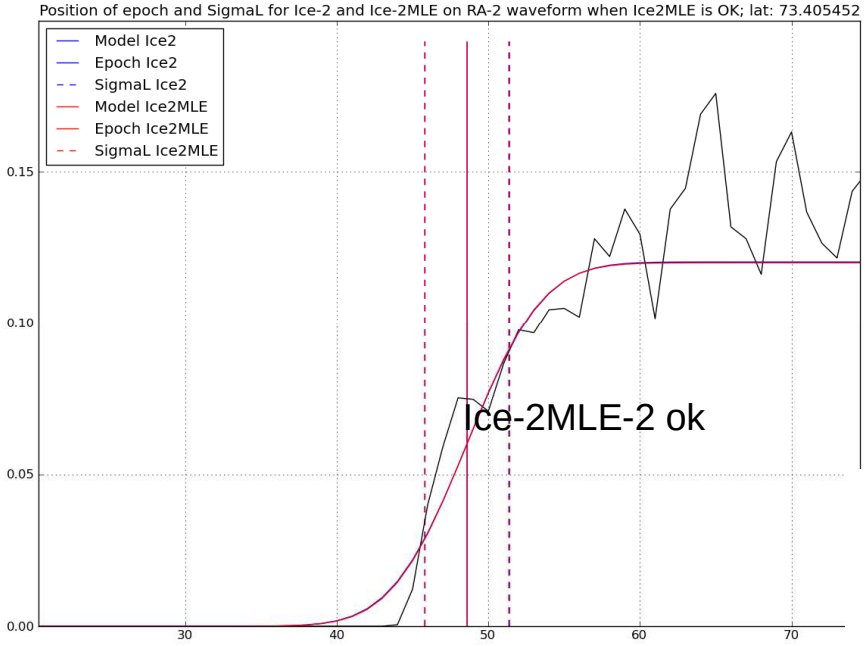
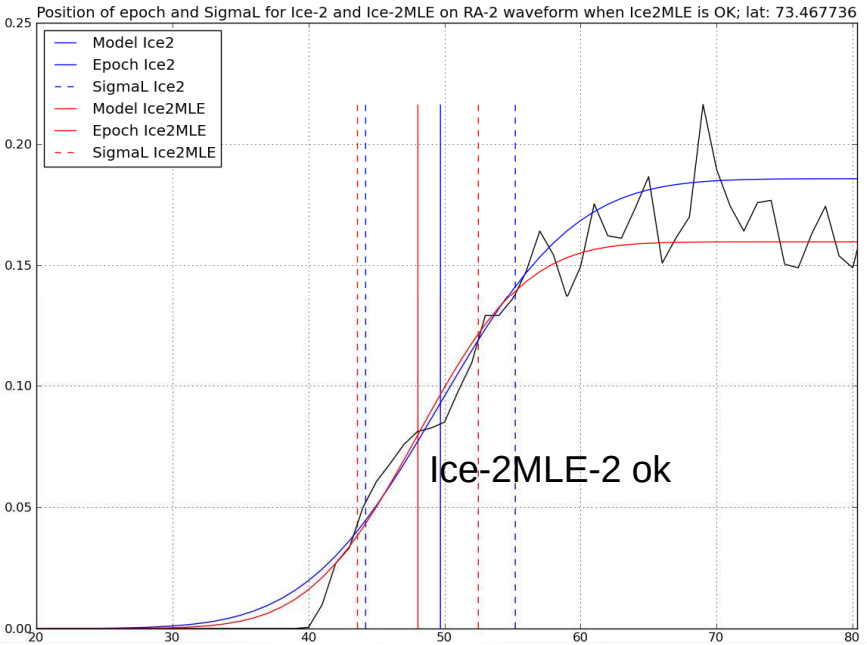
RESULTS OF THE ICE-2MLE2



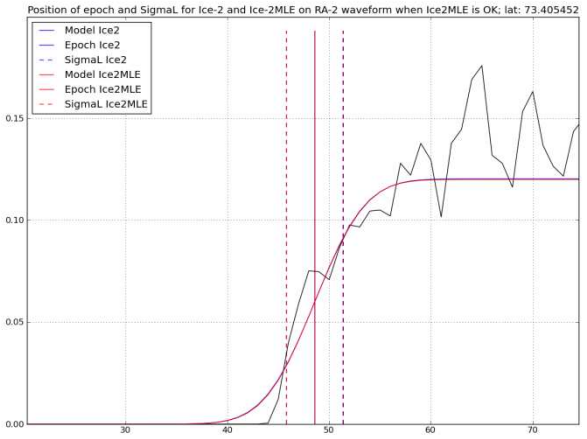
Comparison of epoch and sigmaL plotted on the waveform

Here is an isolated measurement where Ice-2 and Ice-2MLE provide different estimates.

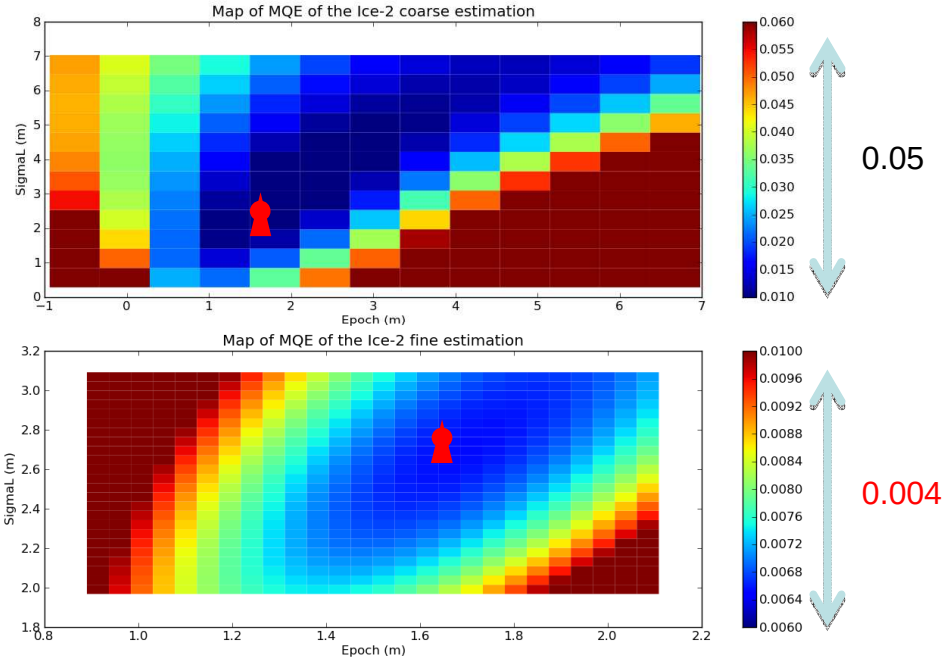


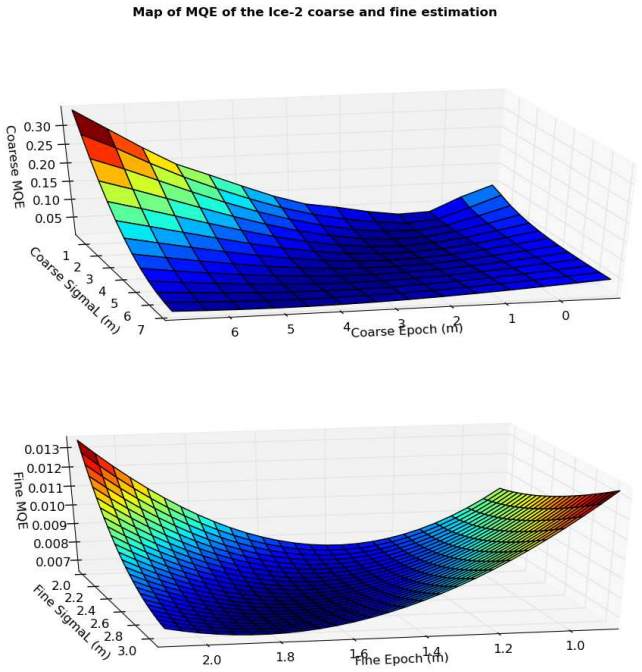
RESULTS OF THE ICE-2MLE2

Visualization of the Ice-2 MQE map



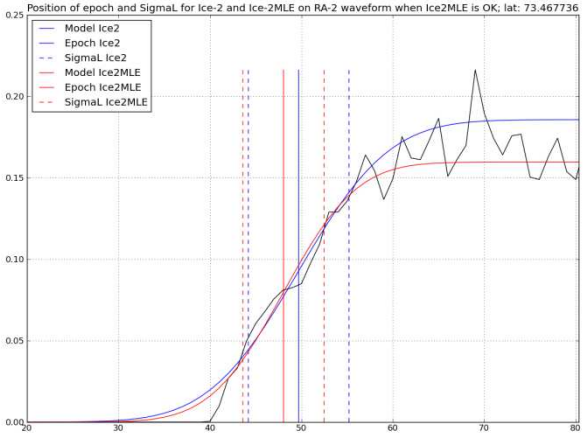
● Ice-2 : 0.0064 ▲ Ice-2MLE : 0.0064



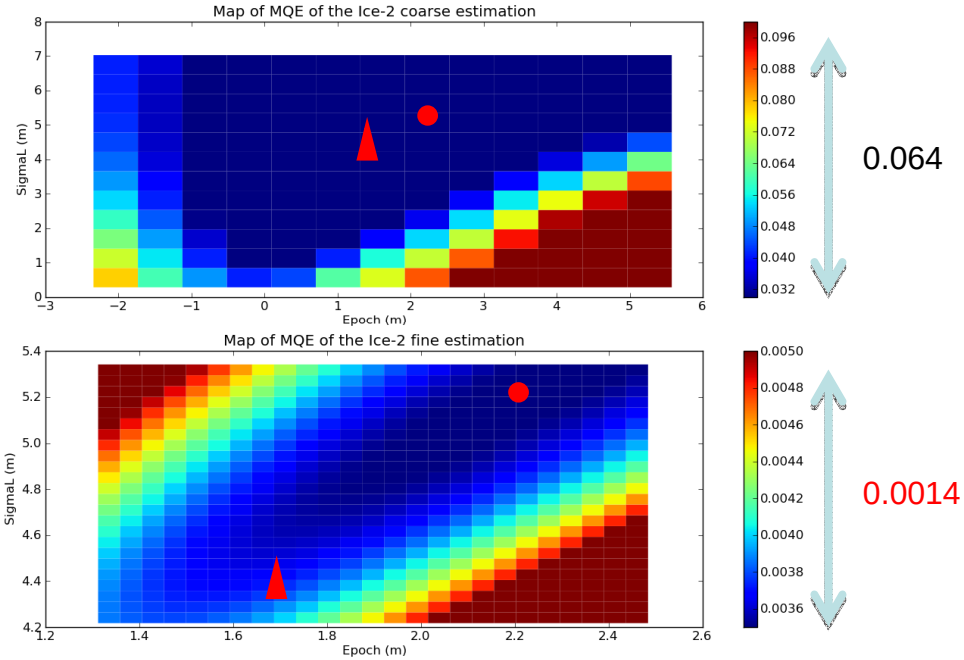


RESULTS OF THE ICE-2MLE2

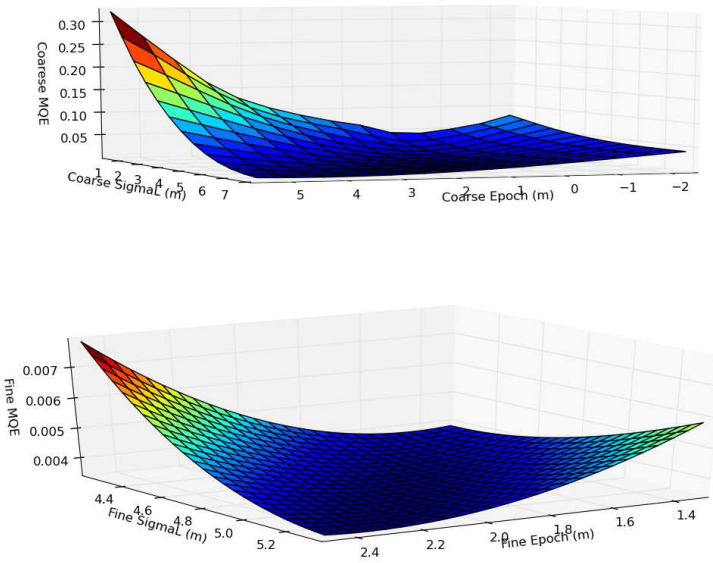
Visualization of the Ice-2 MQE map



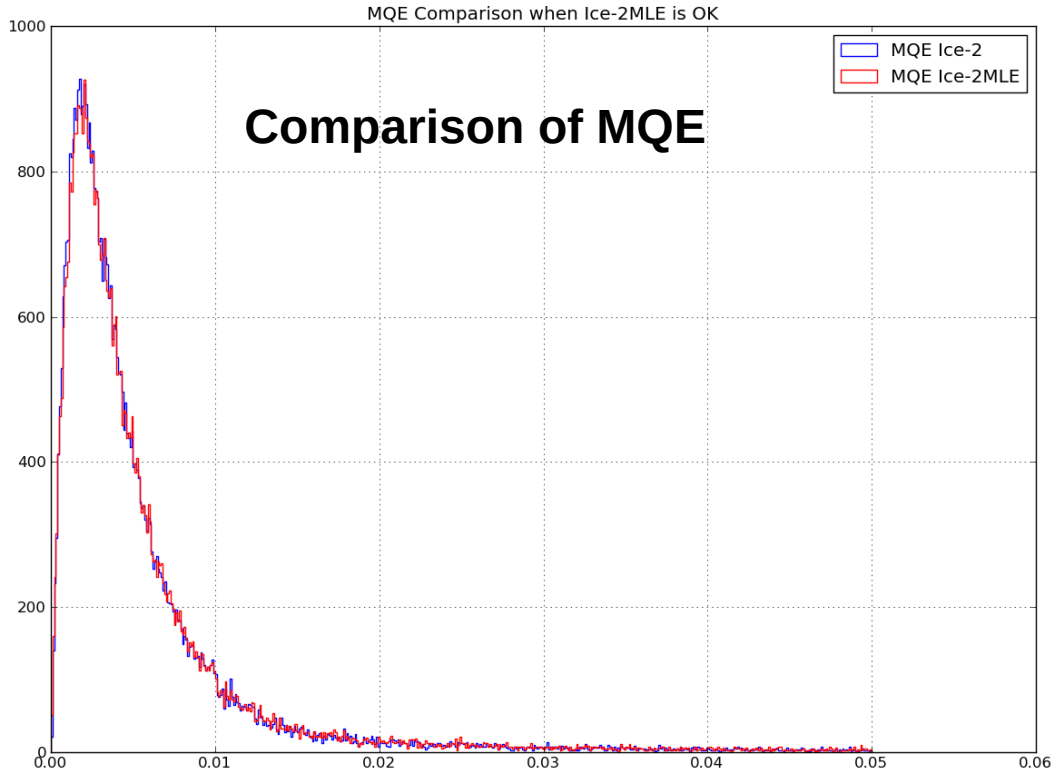
● Ice-2 MQE : 0.0035 ▲ Ice-2MLE MQE : 0.0039



Map of MQE of the Ice-2 coarse and fine estimation



RESULTS OF THE ICE-2MLE2

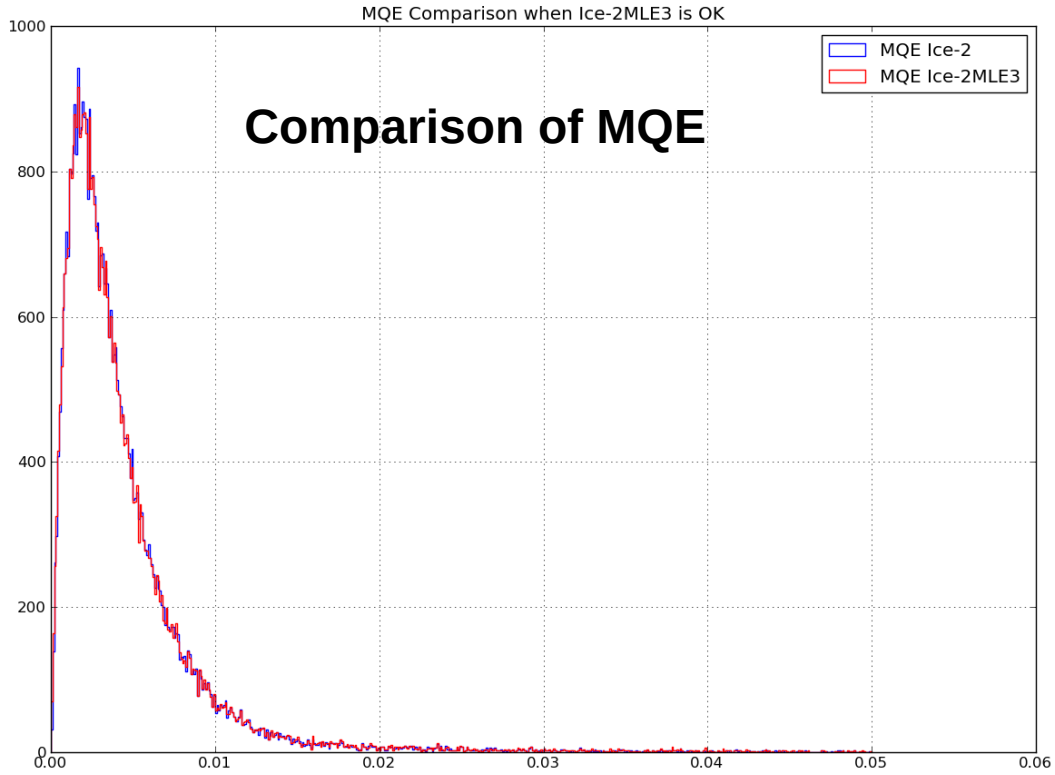


Computation duration for the full pass 889 ENVISAT (54000 measurements) :

- Ice-2 : ~1 min 10 sec
- Ice-2MLE : ~45 sec

} MLE 40% faster

RESULTS OF THE ICE-2MLE3



Computation duration for the full pass 889 ENVISAT (54000 measurements) :

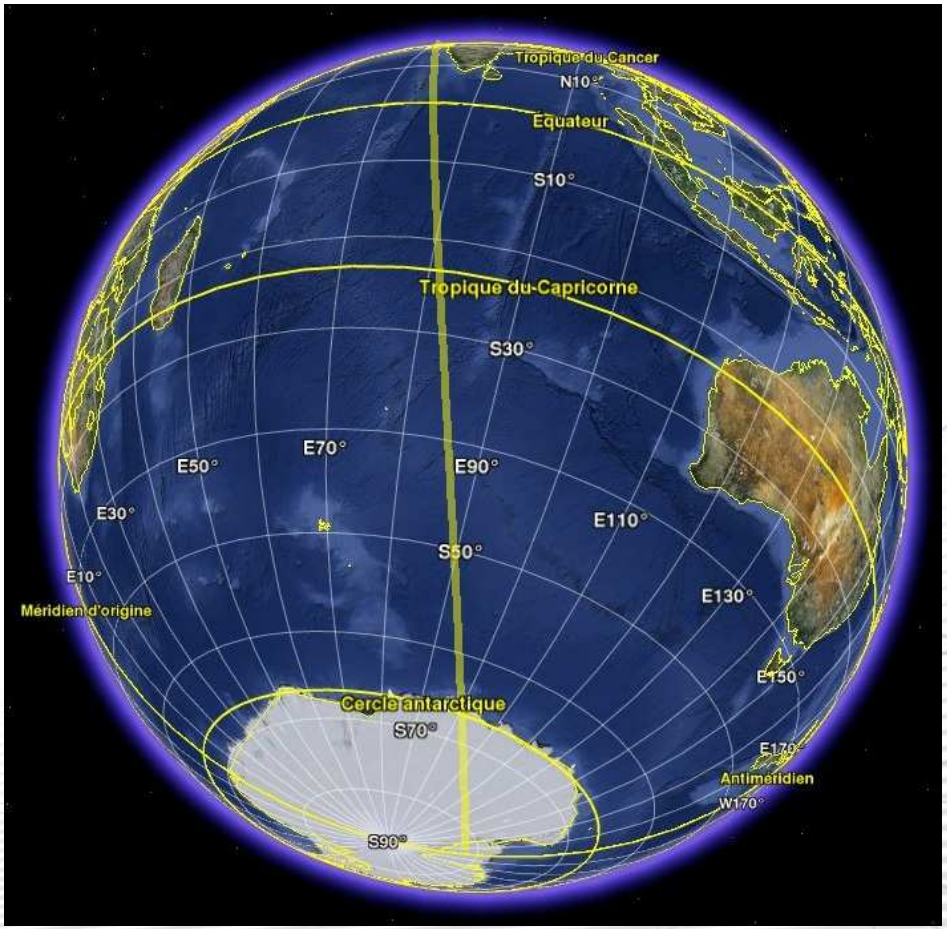
- Ice-2 : ~1 min 10 sec
- Ice-2MLE : ~45 sec

} MLE 40% faster

Results on pass 997 from cycle 74
ENVISAT

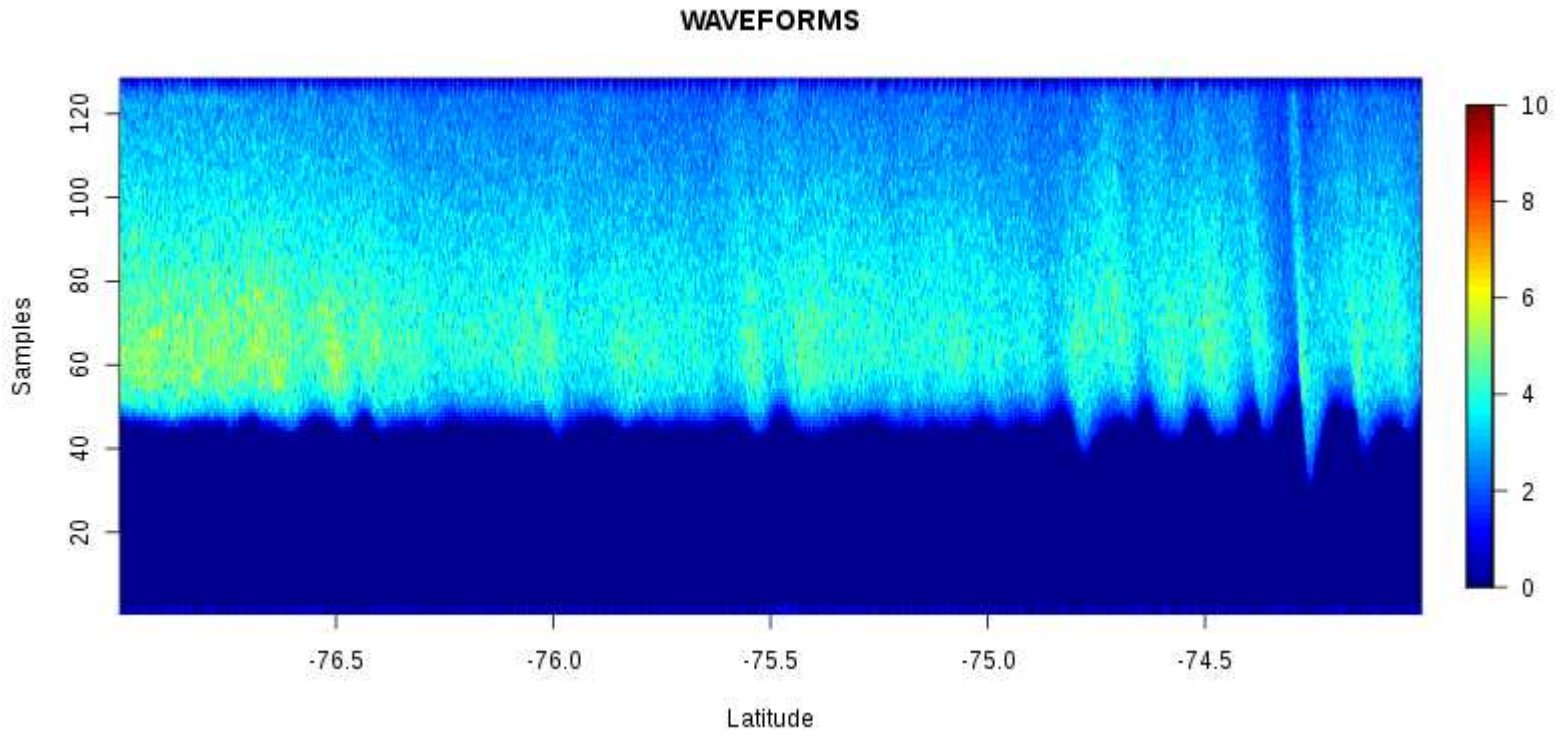
SECOND STUDIED PASS

- Pass 997 from cycle 74 ENVISAT (22/12/2008)



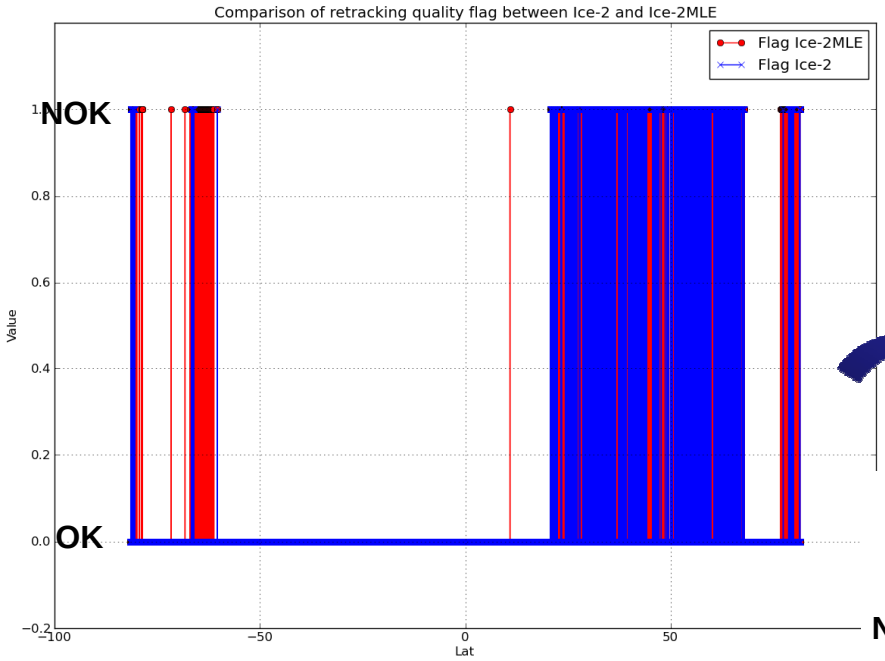
WAVEFORMS

- Zoom : -77°N < LAT < -74°N (antarctique)



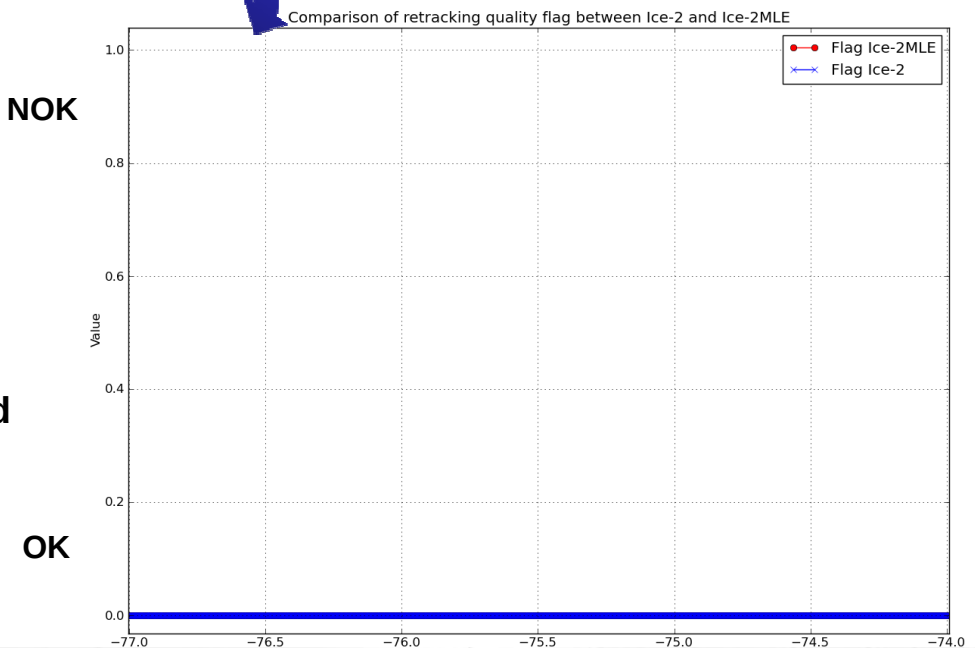
Strong perturbations of the position of the leading edge.

RESULTS OF THE ICE-2MLE2



Comparison of retracking quality flag

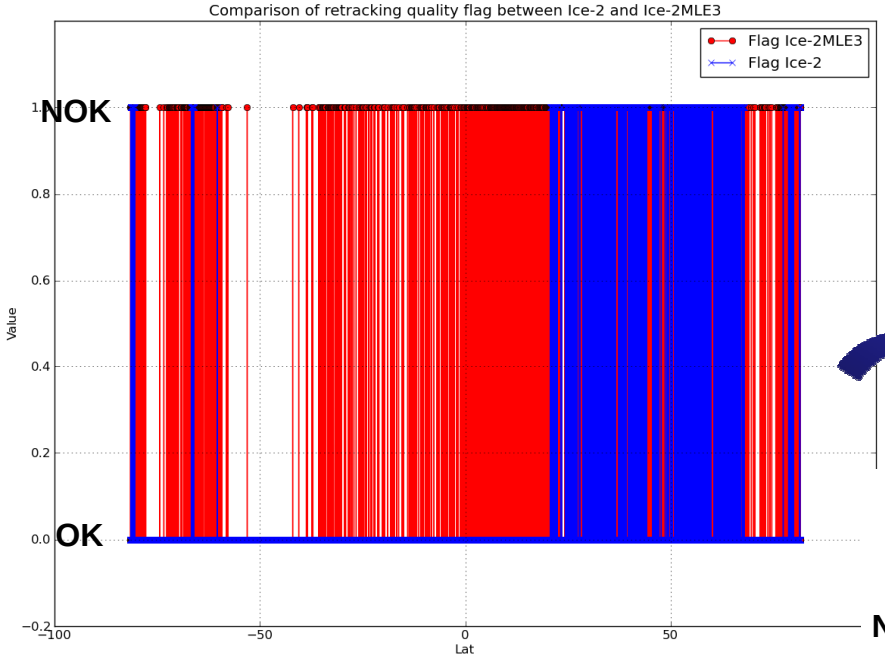
Zoom



Nb measures in this pass : ~ 54 400
Nb measures rejected by Ice-2 : ~ 5 600
Nb measures rejected by Ice-2MLE : ~ 8 700

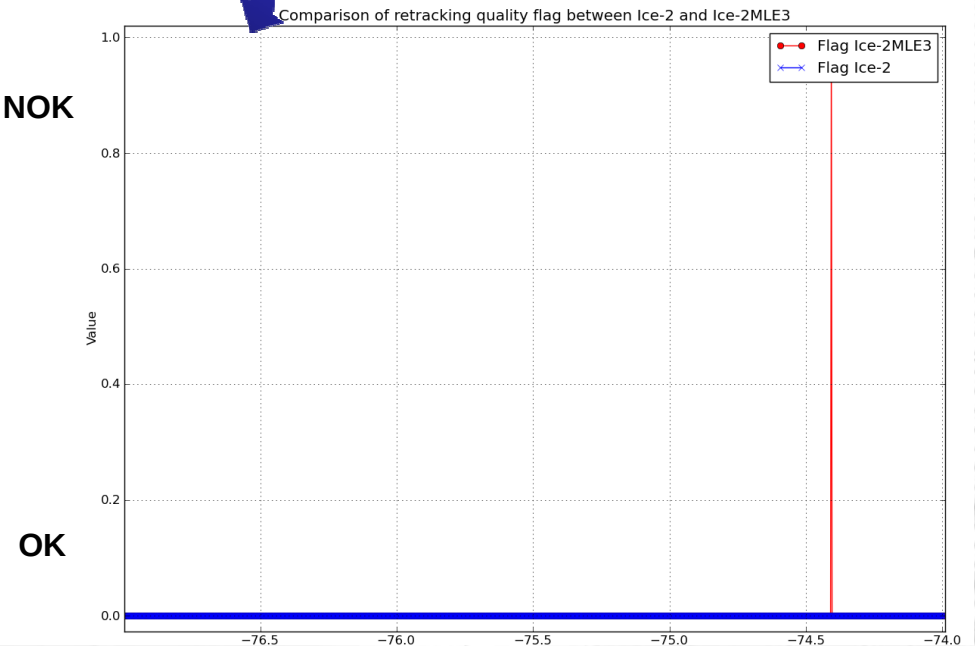
The Ice-2MLE always performed in the selected area.

RESULTS OF THE ICE-2MLE3



Comparison of retracking quality flag

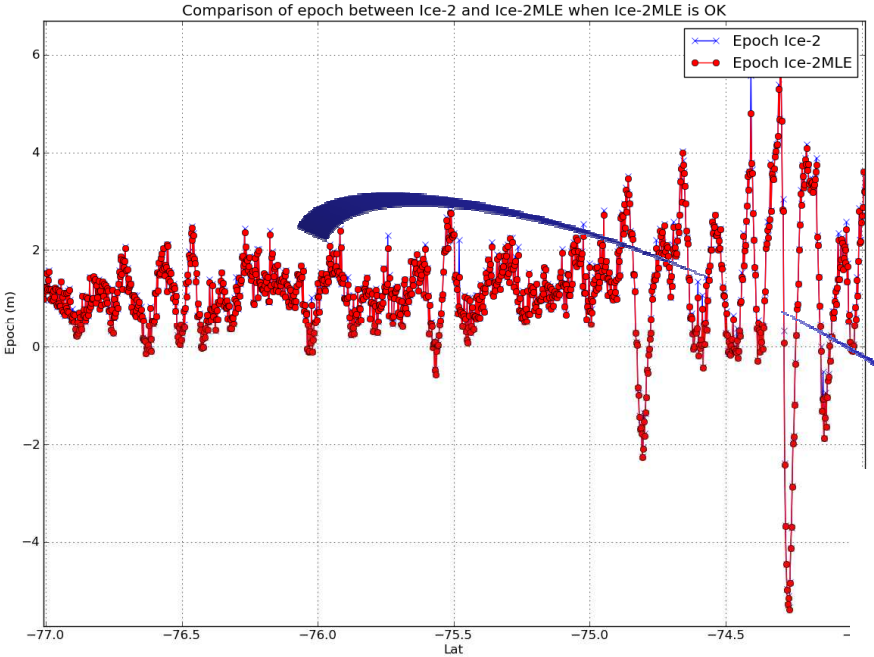
Zoom



Nb measures in this pass : ~ 54 400
Nb measures rejected by Ice-2 : ~ 5 600
Nb measures rejected by Ice-2MLE : ~ 15 400

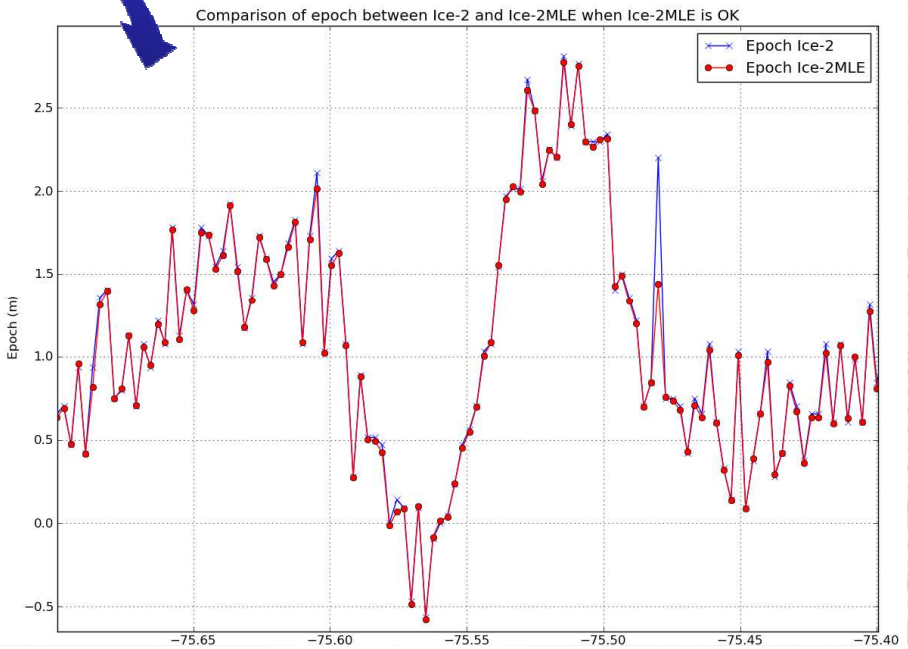
The Ice-2MLE3 rejects 1 point in the selected area.

RESULTS OF THE ICE-2MLE2



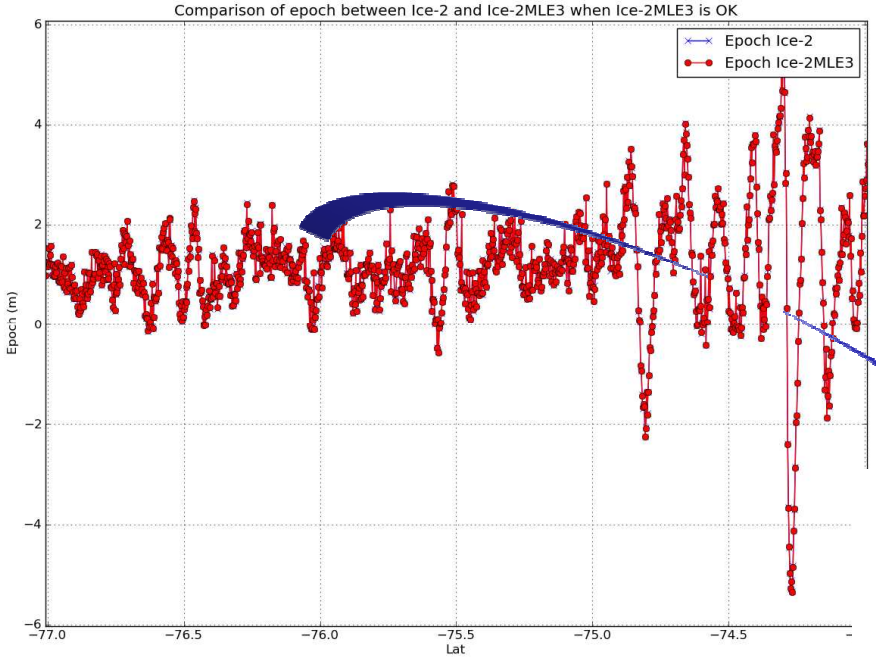
Comparison of epoch

Zoom



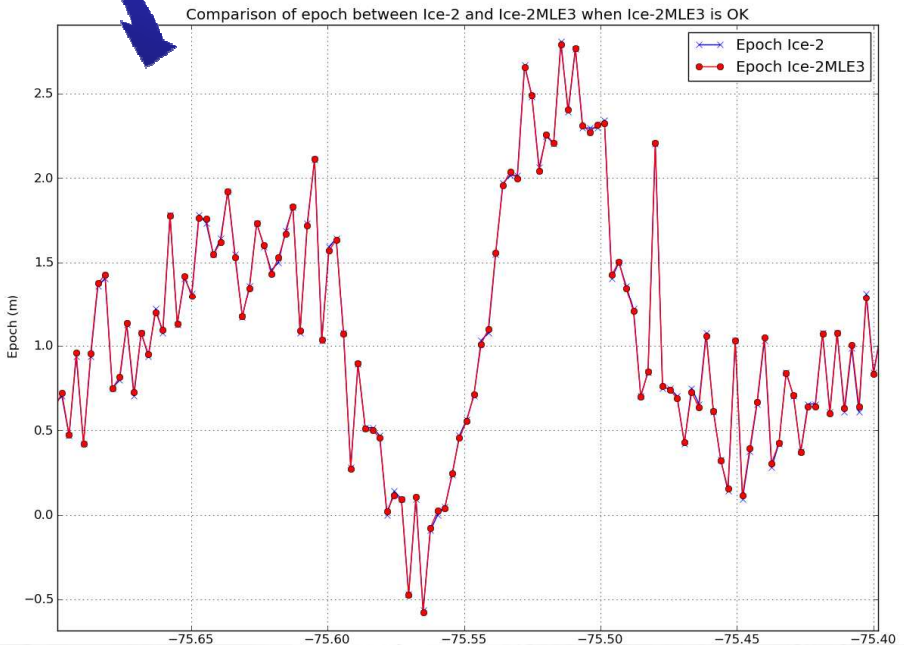
Good agreement between the two estimates except on some isolated measurements. We observe a better precision of the estimates with the new algorithm (no quantization)

RESULTS OF THE ICE-2MLE3



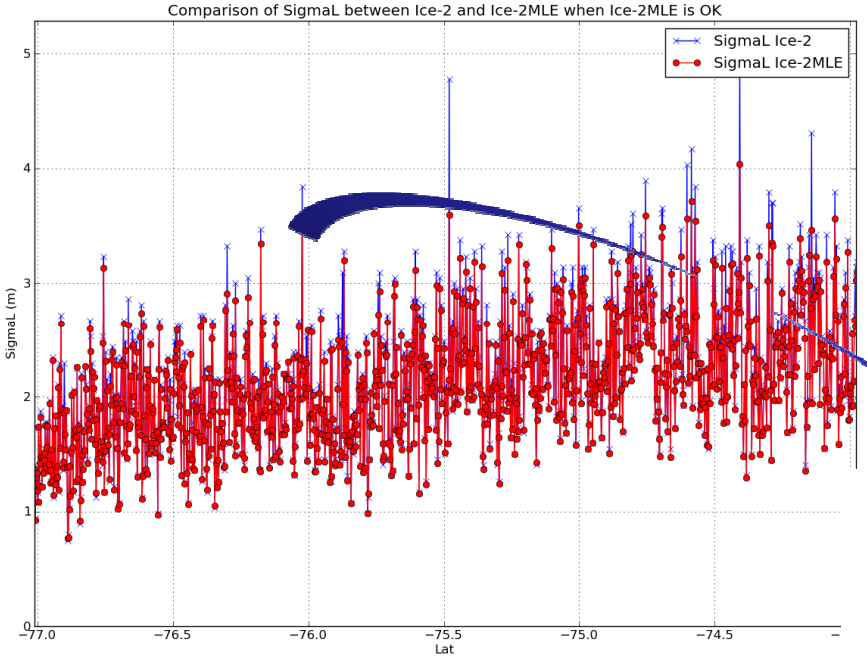
Comparison of epoch

Zoom



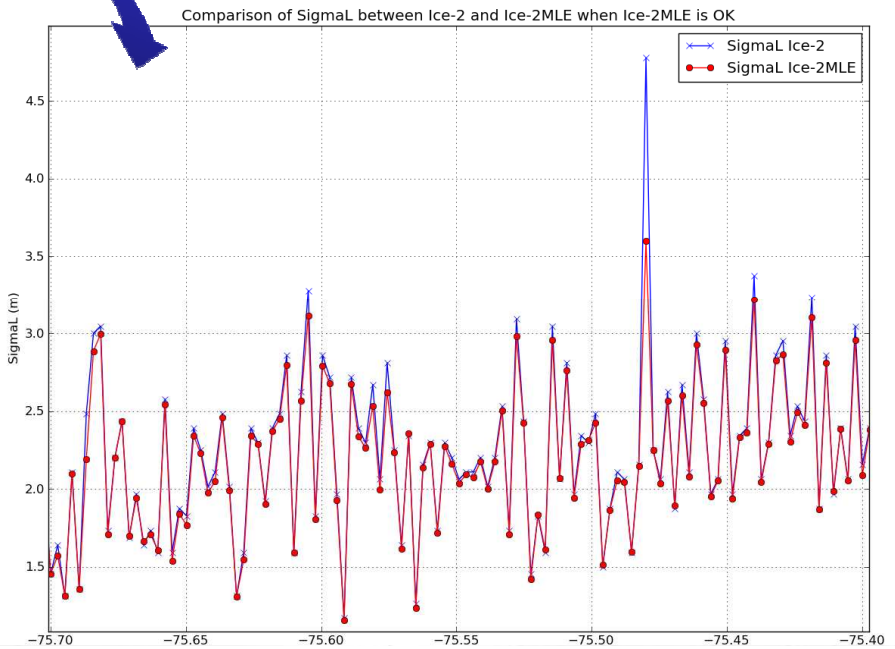
Good agreement between the two estimates except rejected points. The Ice-2MLE3 seems to provide better estimates than the MLE-2 but reject more points.

RESULTS OF THE ICE-2MLE2



Zoom

Comparison of SigmaL



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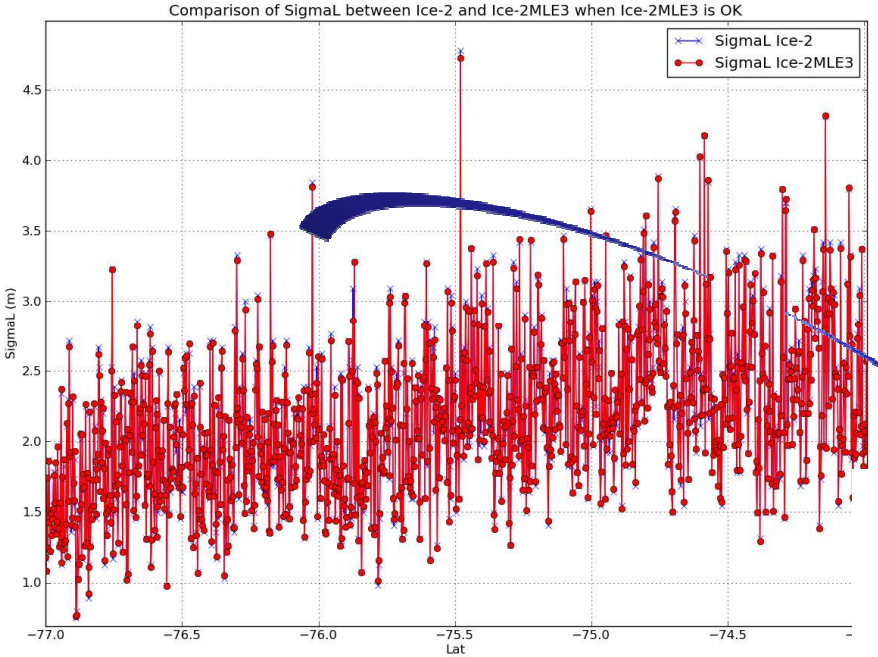
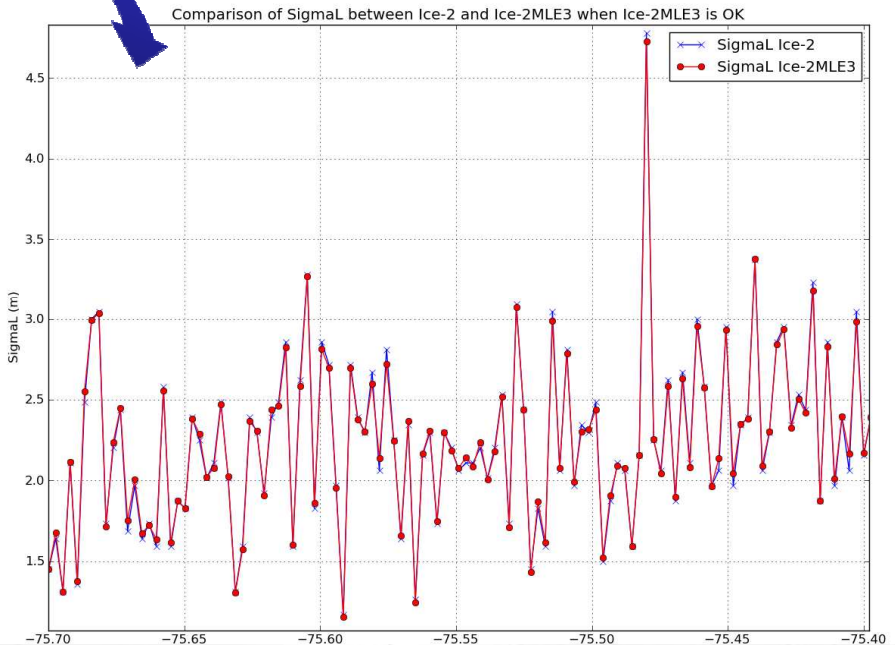
RESULTS OF THE ICE-2MLE3



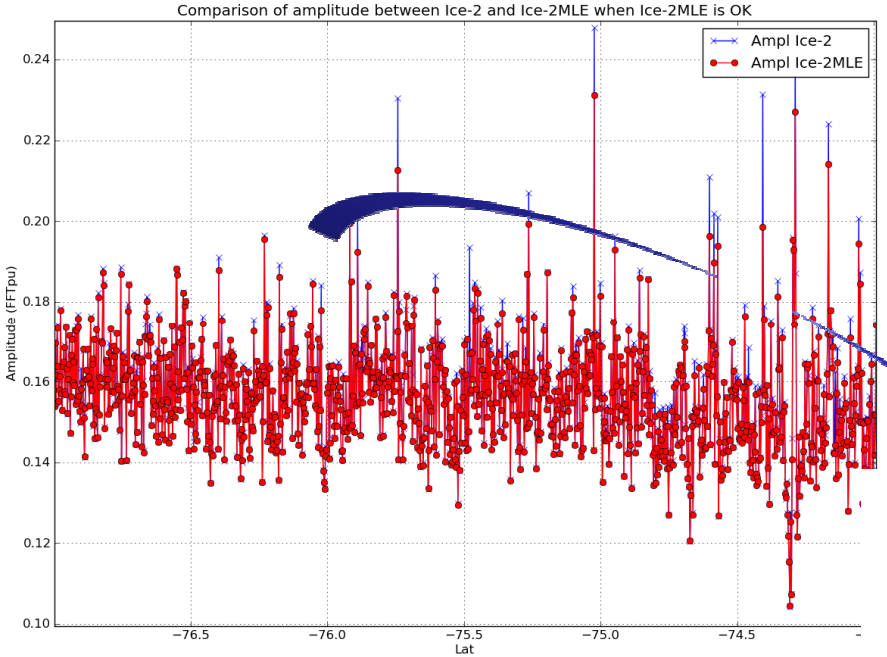
Comparison of SigmaL

Zoom



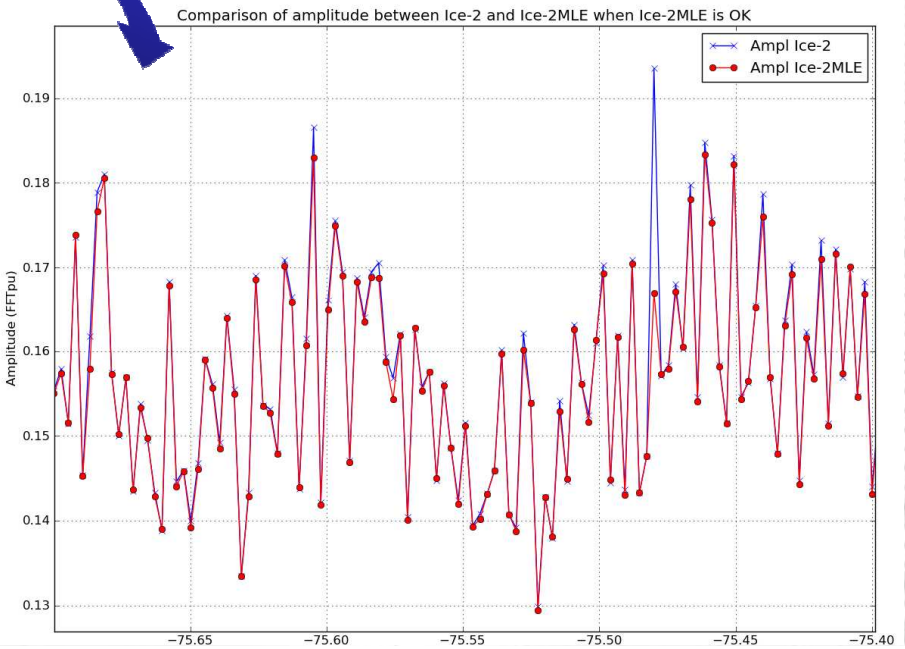
Good agreement between the two estimates except on rejected points and on some isolated measurements. The Ice-2MLE3 seems to provide better estimates than the MLE-2 but reject more points.

RESULTS OF THE ICE-2MLE2



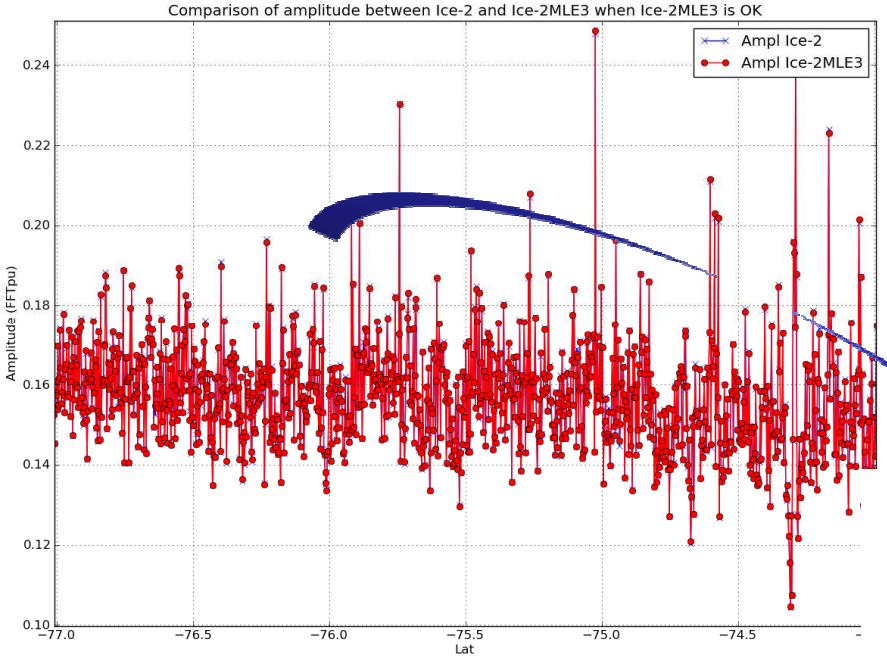
Comparison of amplitude

Zoom



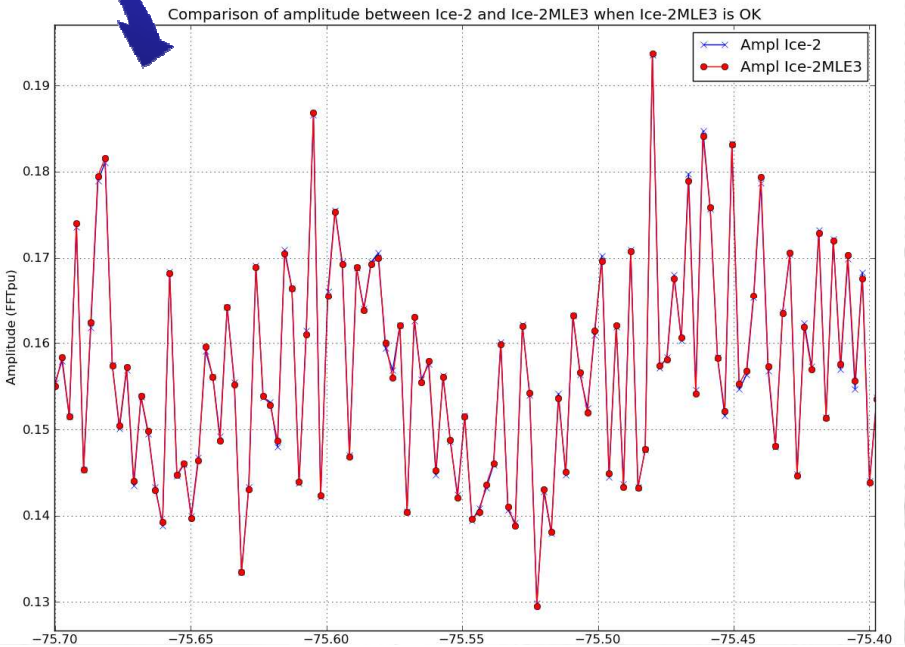
Good agreement between the two estimates except on some isolated measurements.

RESULTS OF THE ICE-2MLE3



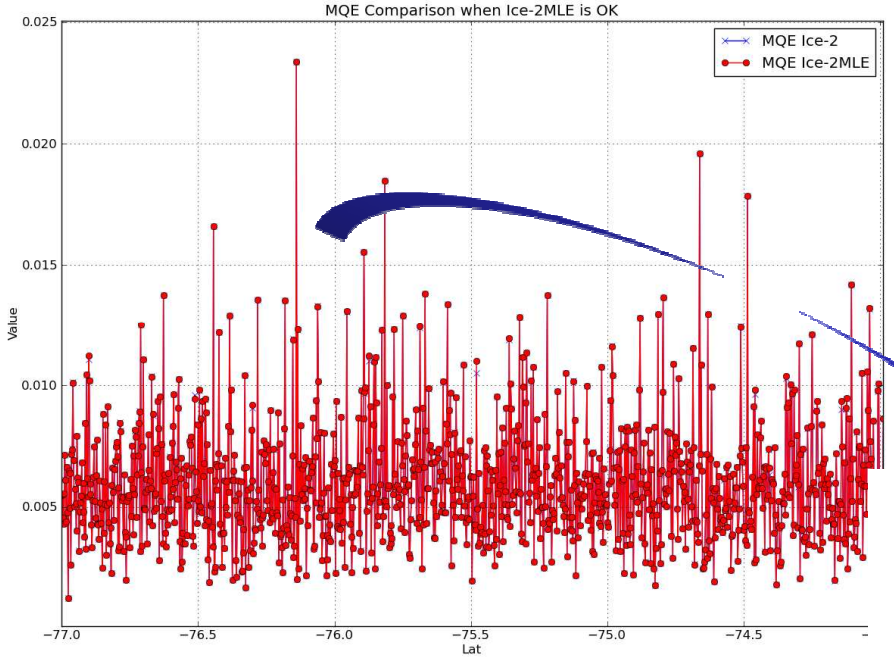
Comparison of amplitude

Zoom



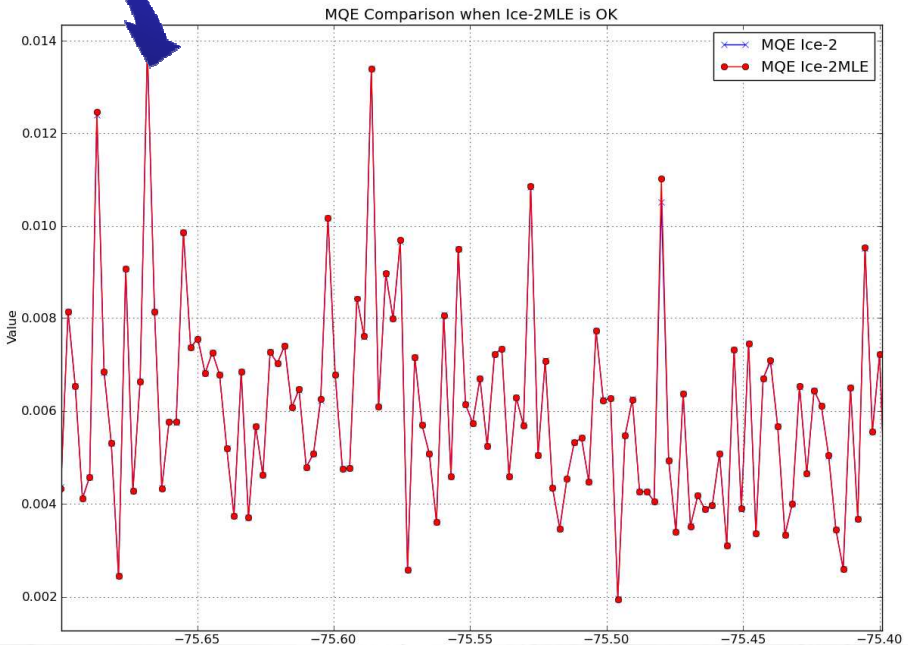
Good agreement between the two estimates except on rejected points. The Ice-2MLE3 seems to provide better estimates than the MLE-2 but reject more points.

RESULTS OF THE ICE-2MLE2



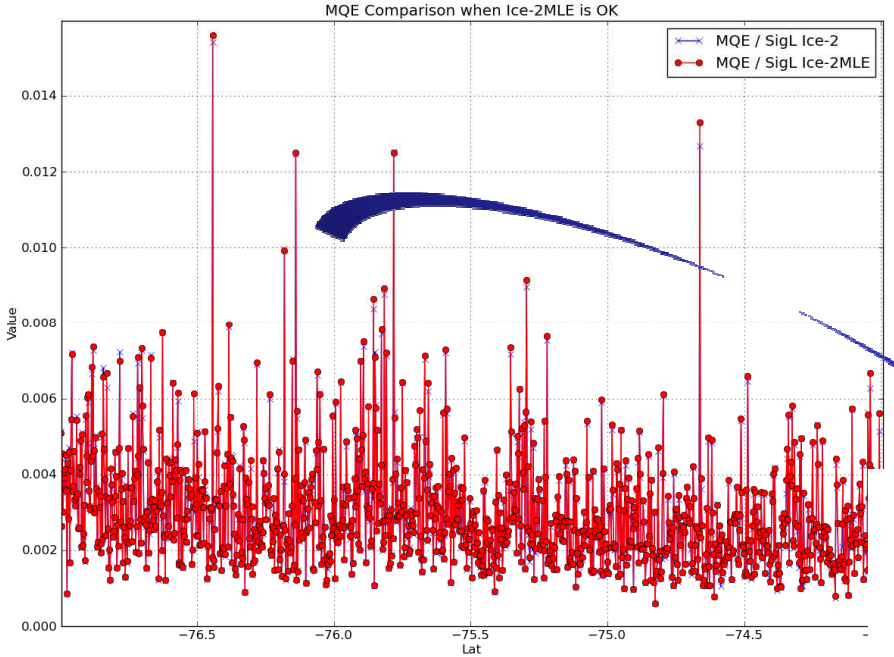
Comparison of MQE

Zoom



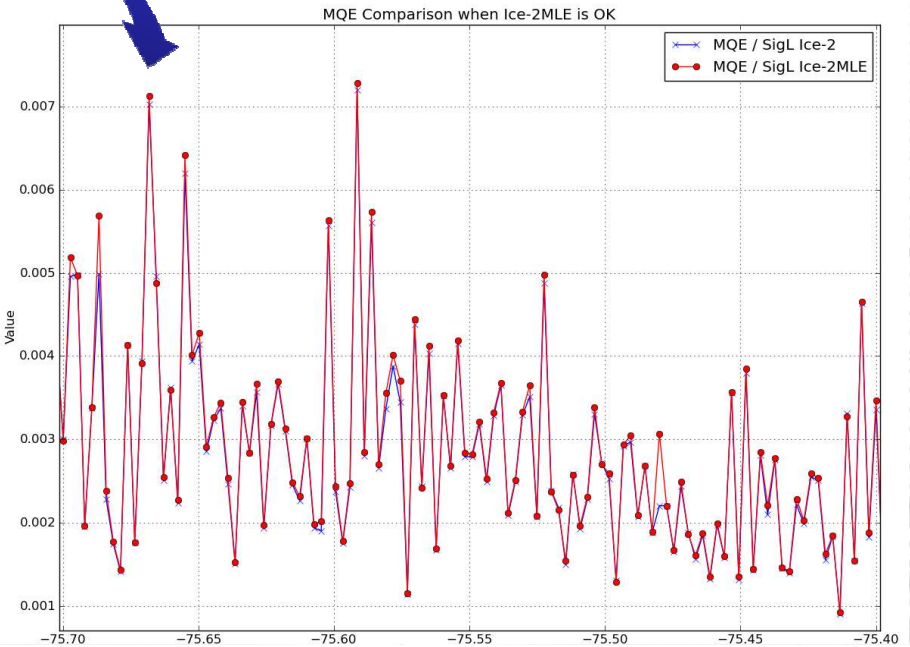
Good agreement between the two estimates except on some isolated measurements.

RESULTS OF THE ICE-2MLE2



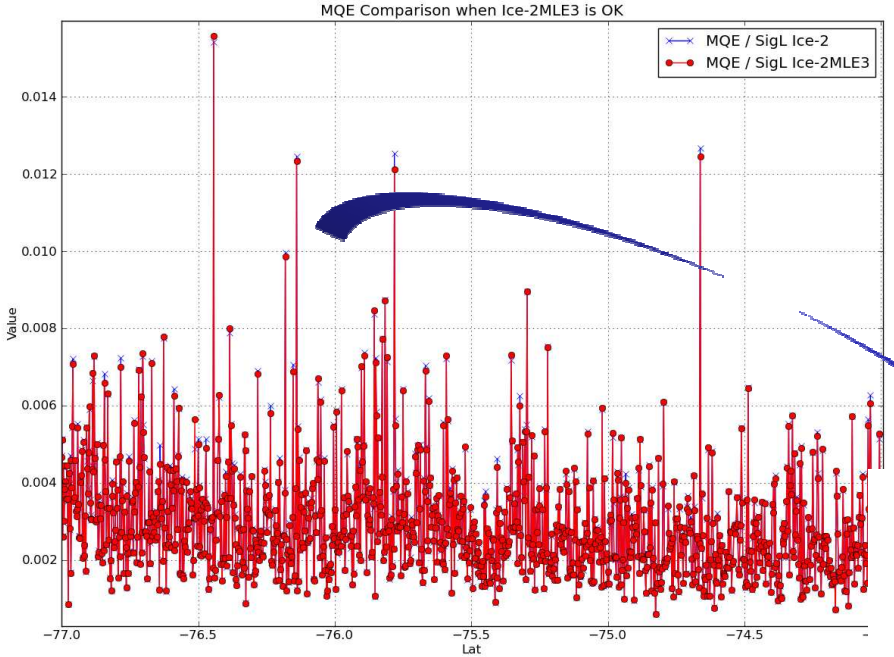
Comparison of MQE / SigmaL

Zoom



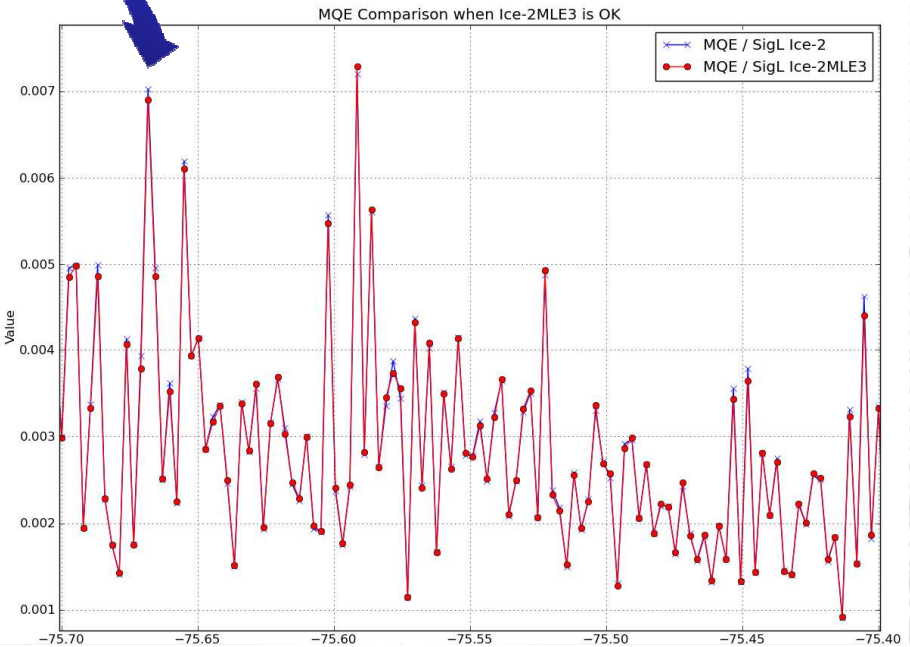
Good agreement between the two estimates except on some isolated measurements.

RESULTS OF THE ICE-2MLE3



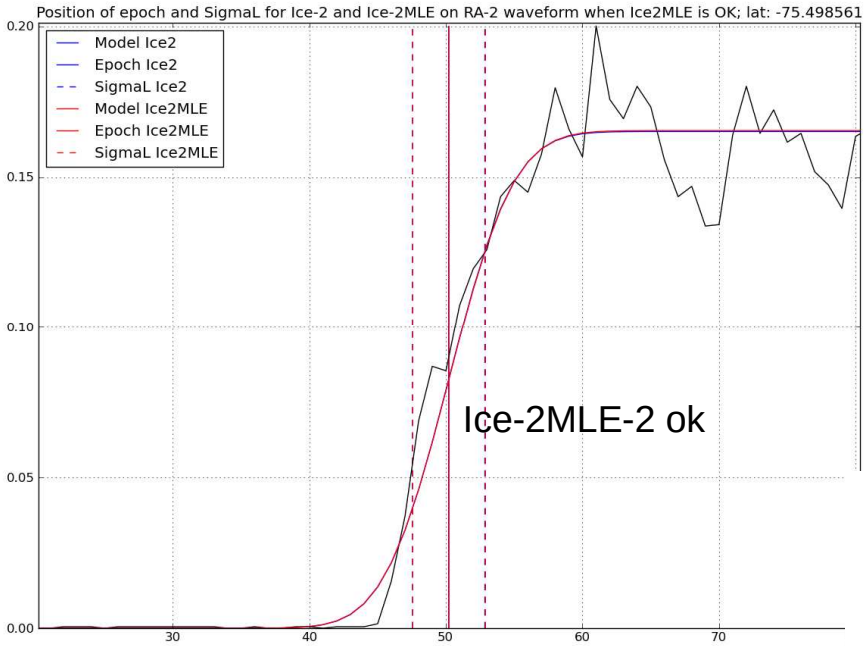
Comparison of MQE / SigmaL

Zoom



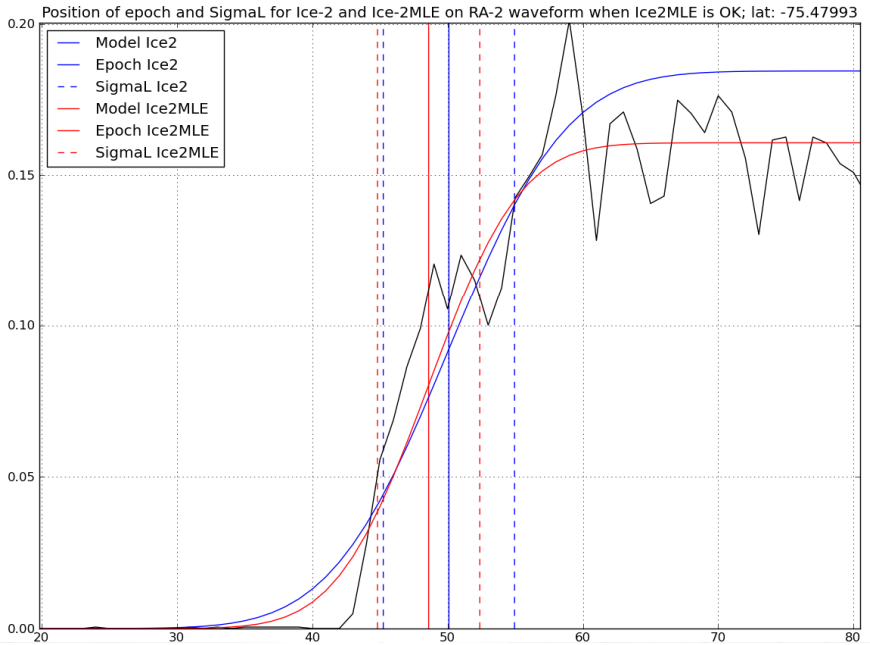
Good agreement between the two estimates except rejected points and some isolated measurements.

RESULTS OF THE ICE-2MLE2



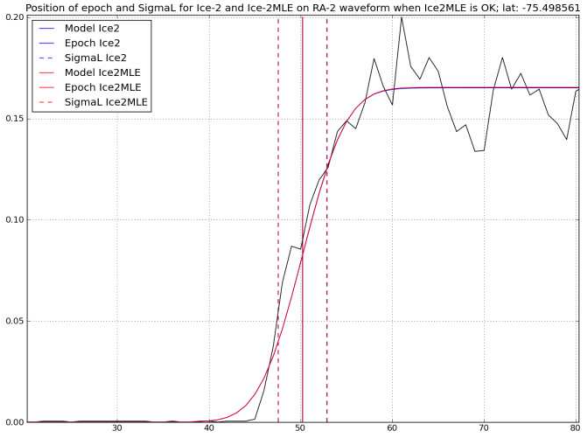
Comparison of epoch and sigmaL plotted on the waveform

Here is an isolated measurement where Ice-2 and Ice-2MLE provide different estimates.

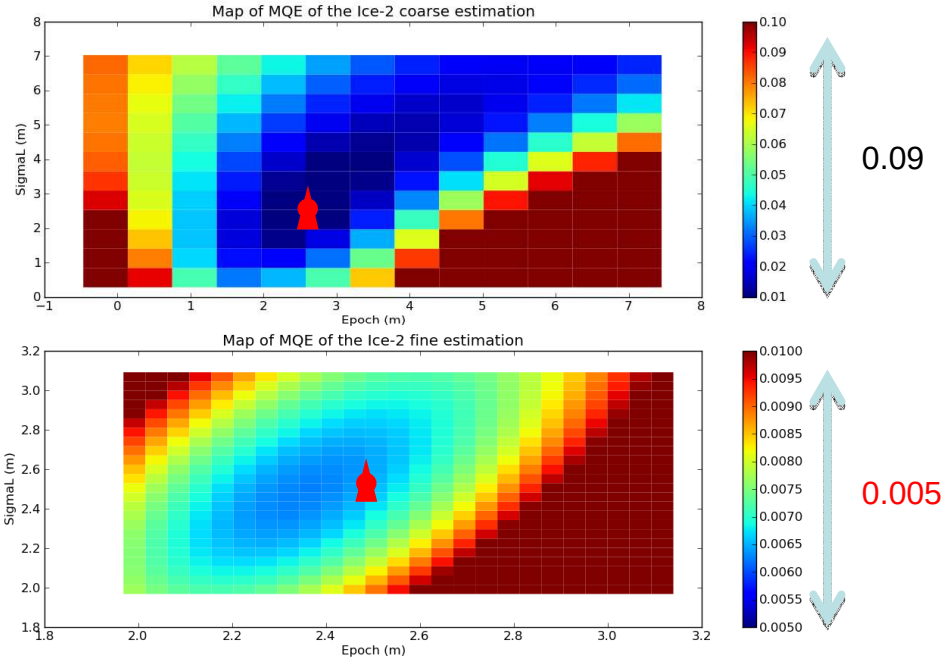


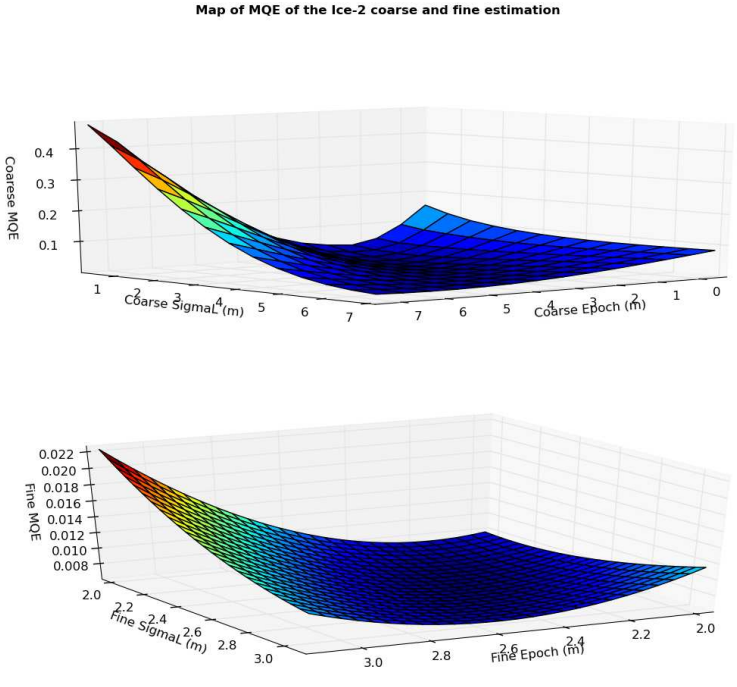
RESULTS OF THE ICE-2MLE2

Visualization of the Ice-2 MQE map



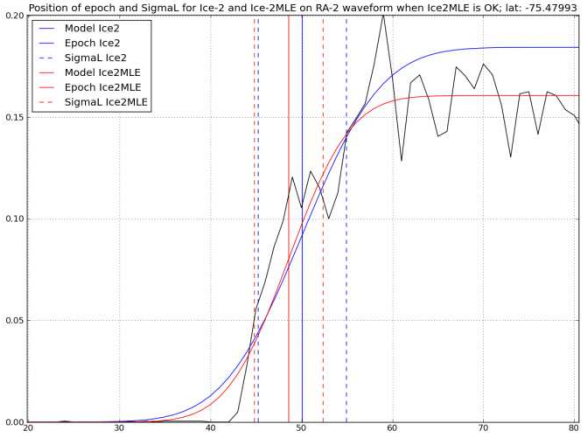
- Ice-2 MQE : 0.0063
- Ice-2MLE MQE : 0.0063



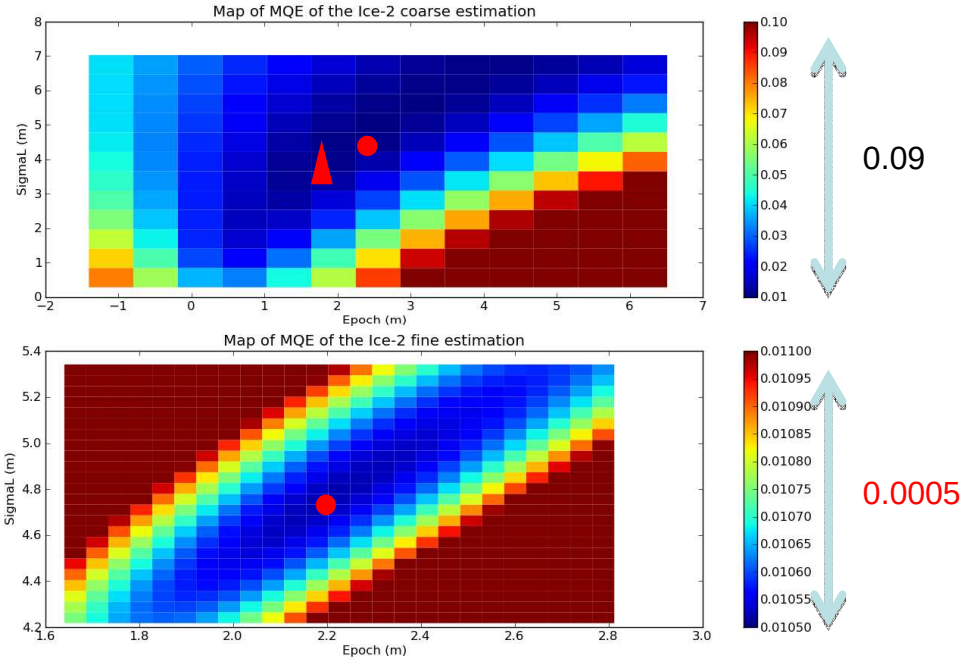


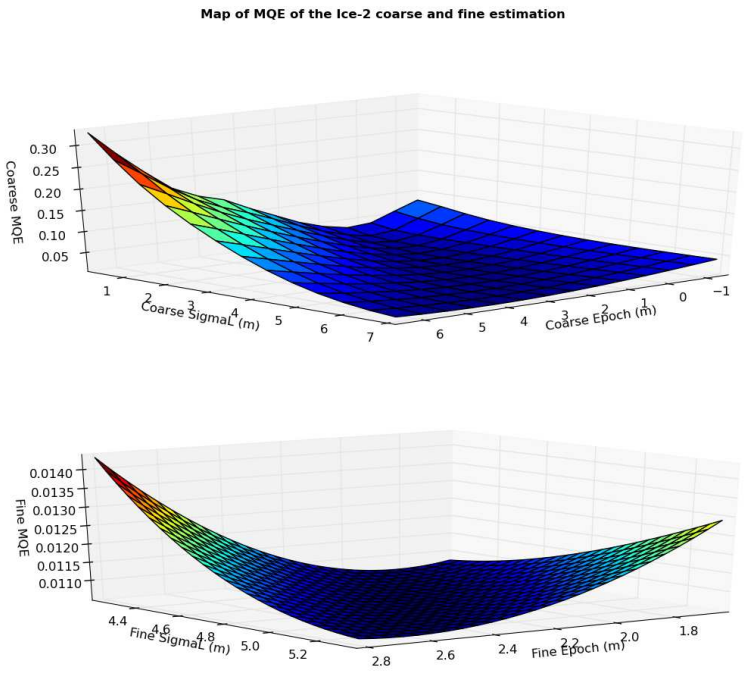
RESULTS OF THE ICE-2MLE2

Visualization of the Ice-2 MQE map



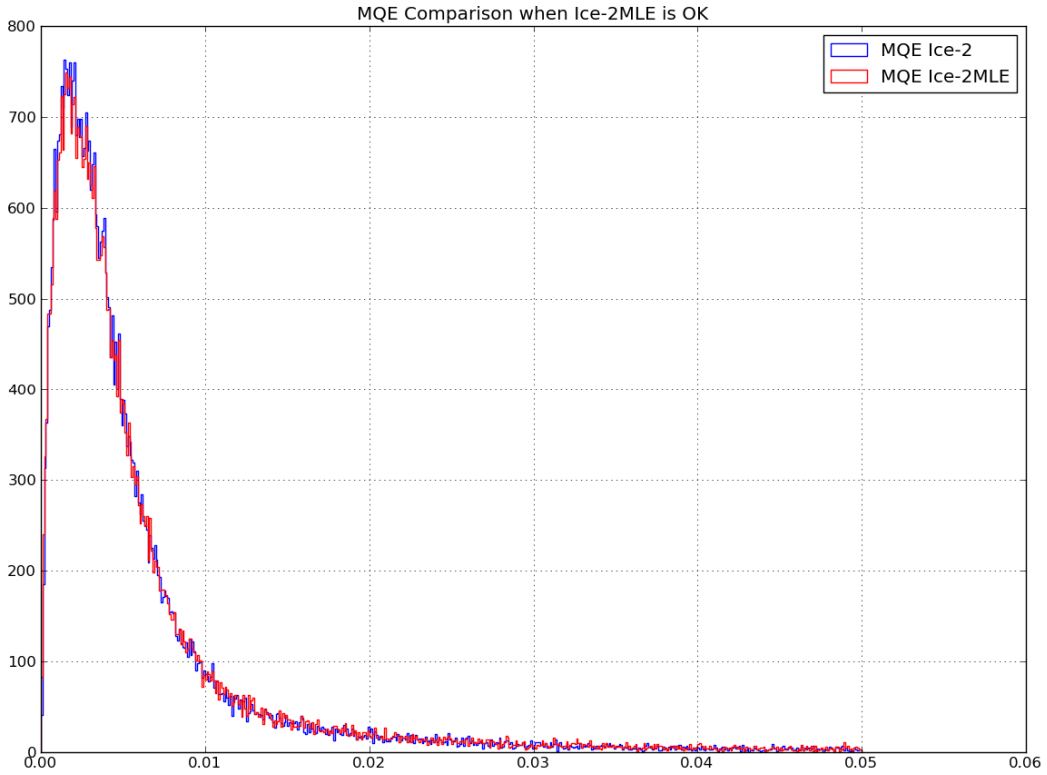
● Ice-2 MQE : 0.0105 ▲ Ice-2MLE MQE : 0.011





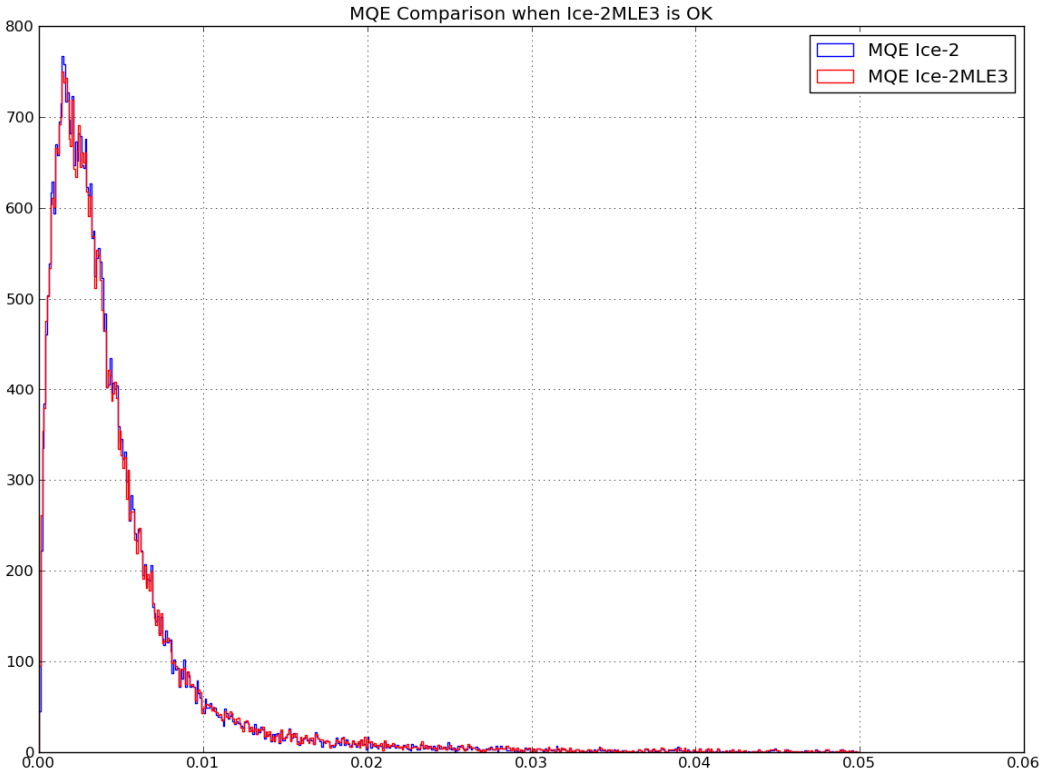
RESULTS OF THE ICE-2MLE2

Comparison of MQE



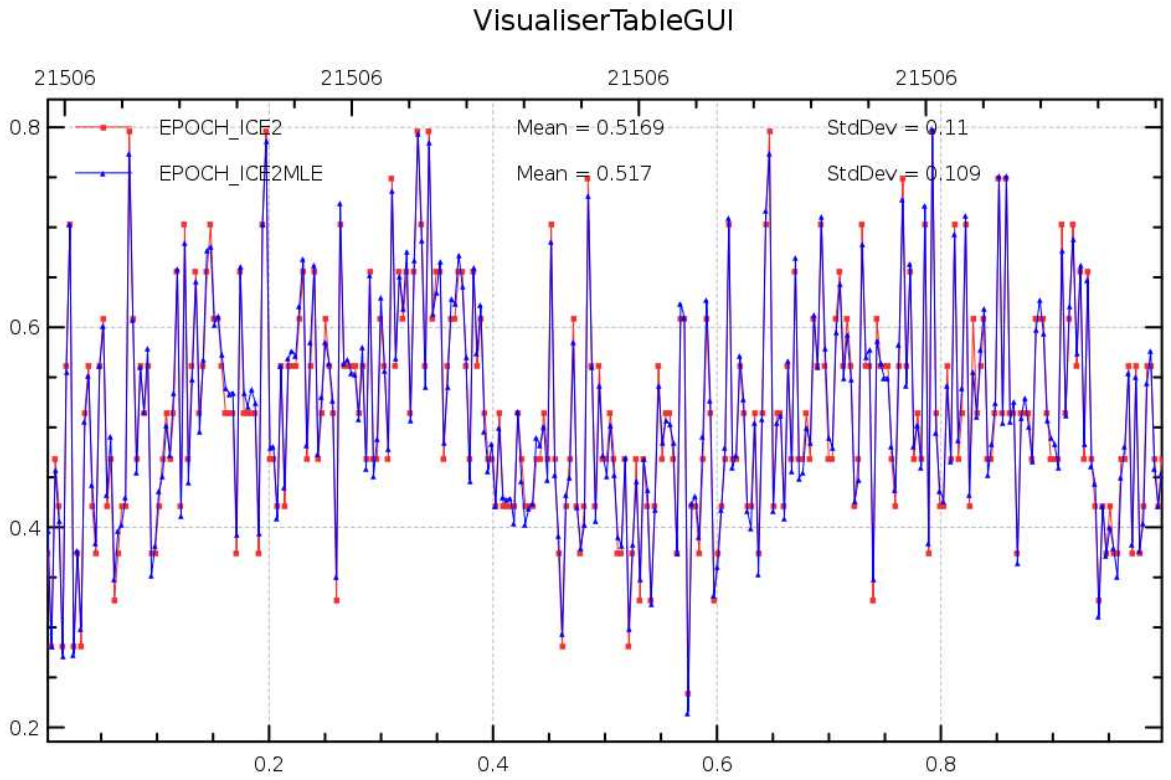
RESULTS OF THE ICE-2MLE3

Comparison of MQE



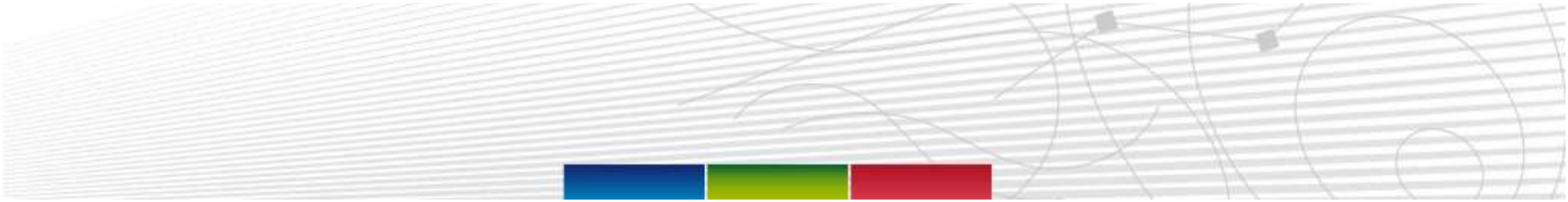
RESULTS OF THE ICE-2MLE2

Example of Ice-2 epoch quantization over ocean



Conclusions on the First Part

- The integration of MLE2 and MLE3 in place of the iterative double loop MQE exploration
- This integration works quite well in a lot of cases and **saves 40% CPU**.
- The MLE versions fail to solve the waveform fit more often than the classic ICE2.
- MLE2 which fits the same 2 parameters as the classic double loop has often small differences difficult to qualify in an MQE criteria.
- **MLE3 gives result strictly compatible with the classic approach**, this mean that the pb is numerically better constrained.
- **Failure of MLE on mostly tricky echoes** (those not conforming to the a priori model)
- Processing the echoes failing in MLE with the classic way would raise the CPU by another 10%.
- MLE3 gives smoother results, avoiding the quantization of the classic approach (will impact ERS retracking when operating in 80MHz bandwidth).

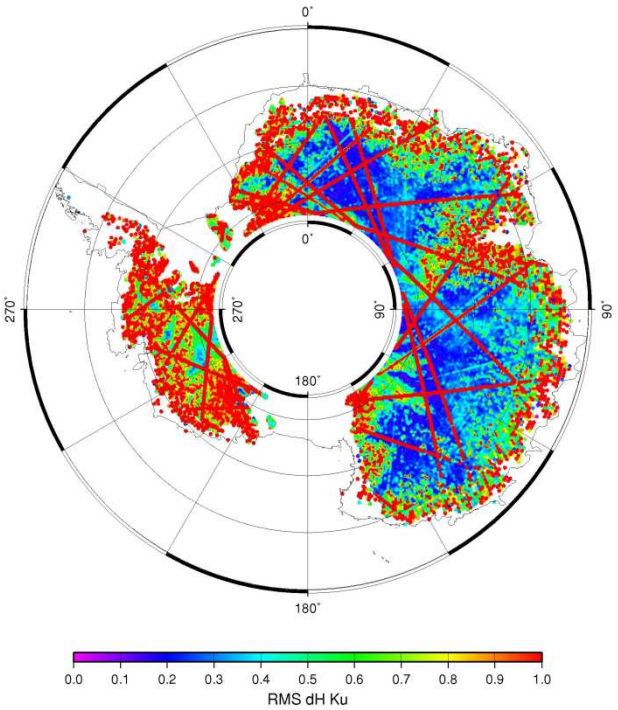


Second Part

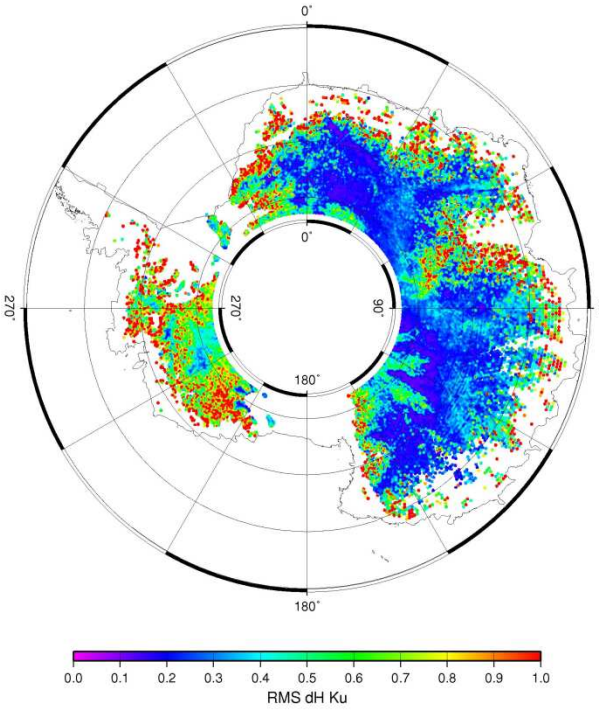
ICE-2 echo and geo corrections

ICE-2 echo and geo corrections

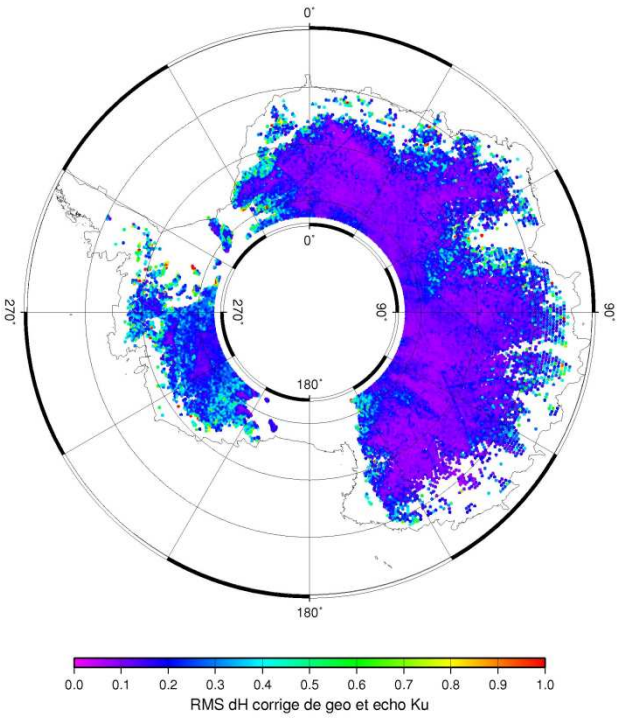
RMS of intracycle crossover surface height difference dH (m)



0.0 1.0



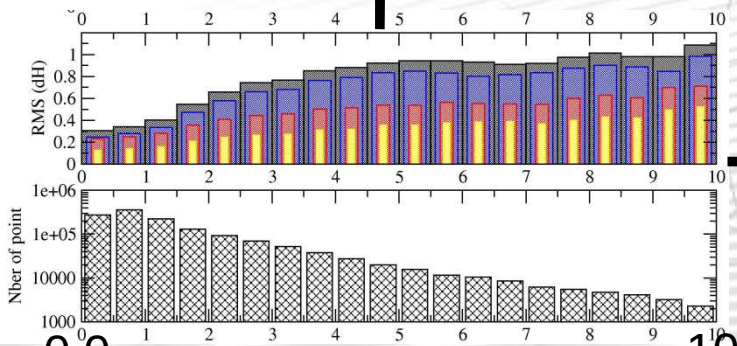
Validation



Echo and Geo corrections

Raw data input

from standard GDR



Distr. des rms validés par classe de pente
Idem avec echo corrections
Idem avec géo corrections
Idem avec echo et geo corrections

ICE-2 echo and geo corrections

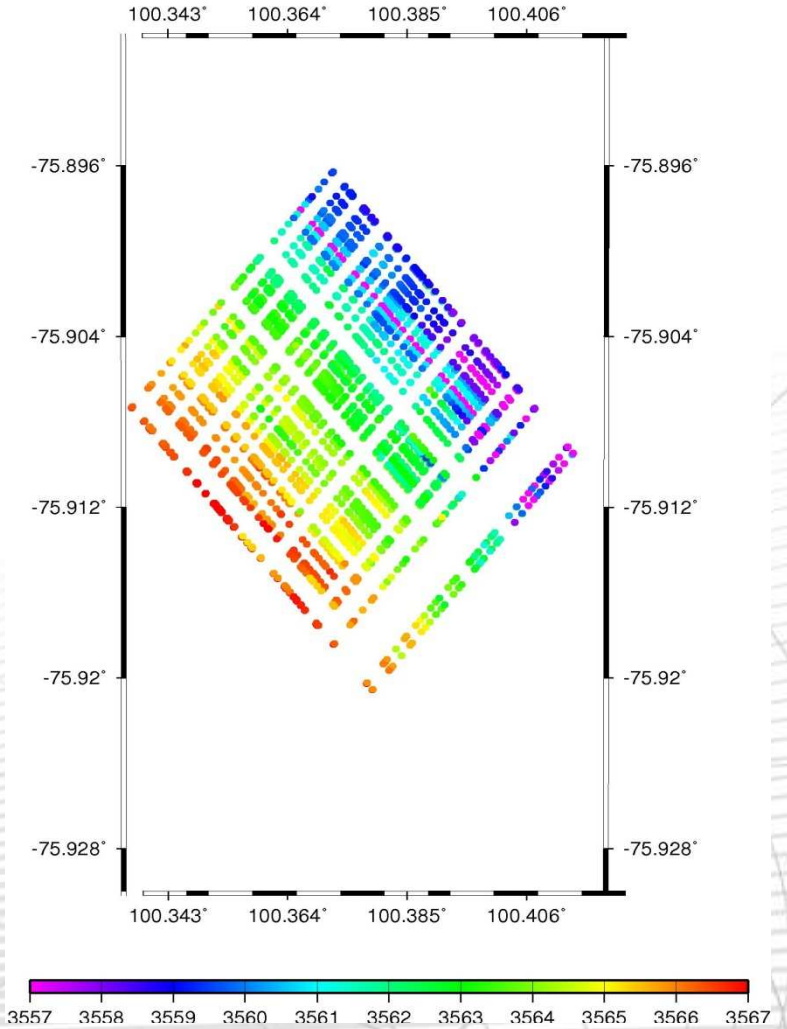
Echo and geographical cross track correction (following Legresy et al. 2006)

- **Geographical**

  Surface height (or echo shape param.) spatial variability induced by geographical height (resp.) change (legresy and Remy, 1997, Roemer et al. 2007)

- **Echo**

  Surface height temporal variability induced by echo shape change (legresy and remy, 1998)



Both corrections successfully developed and applied by Legresy et al., 2006 and shown full of sense in Lacroix et al., 2009, Horwath et al., 2012a, 2012b

A box is the area where all the repeat points spread. Typically for a crossover it would be a 2km by 2km diamond, for a point along track it would be a 2km wide and 380m long rectangle.

ICE-2 echo and geo corrections

Tables of function coefficients are built :

- Find the function in the table corresponding to the actual measurement
- Apply the geo (p^x) correction to Bs, LEW, TES.
- Apply the geo and echo (f and g) corrections to h.

These 3 operations can easily be implemented in the GDR production.

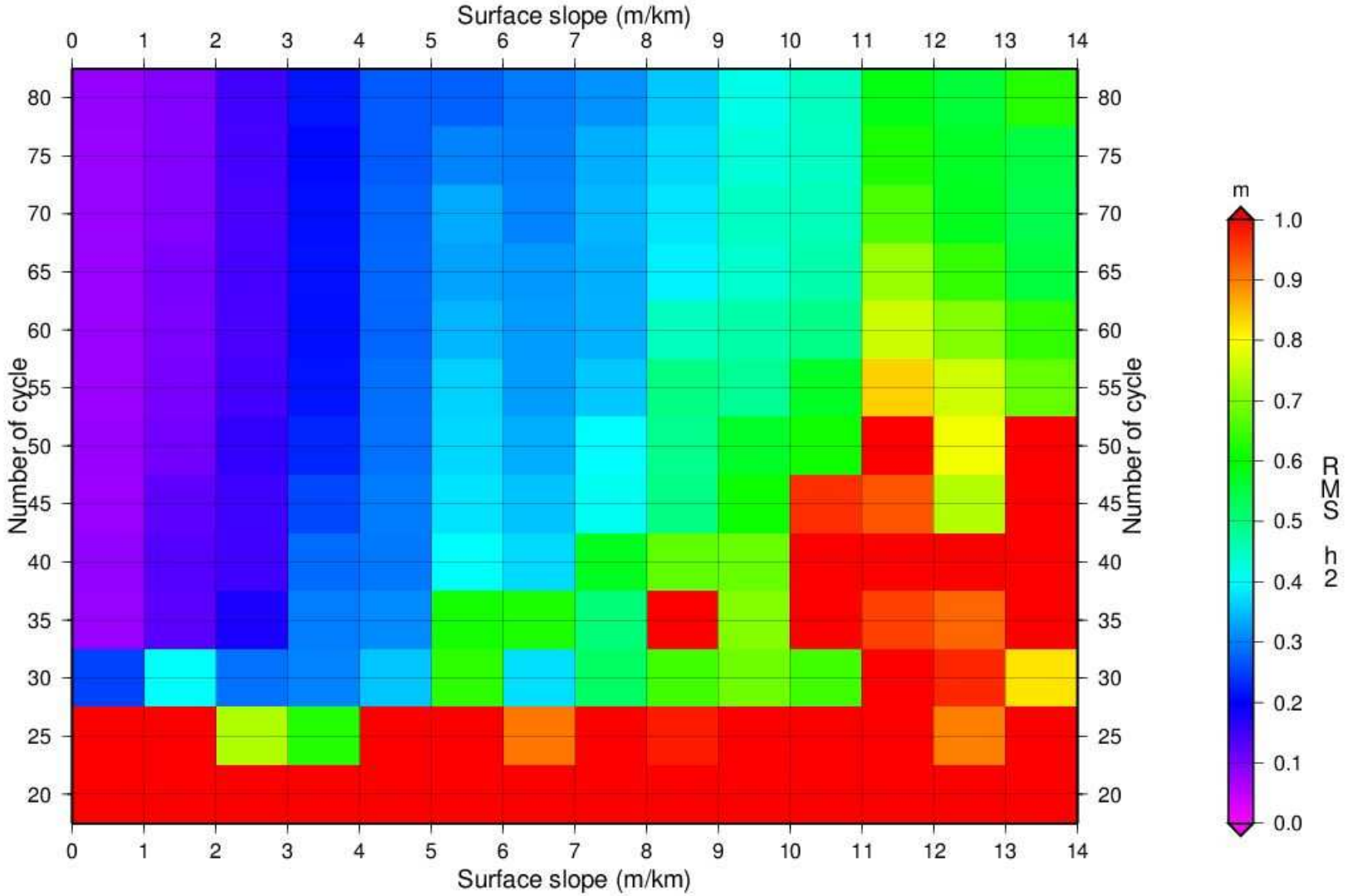
ICE-2 echo and geo corrections

- In practice : g(lon,lat), f(lon,lat) and p^x(lon,lat)
- We built these tables of function coefficients for **ERS2** and **ENVISAT**.
- In absence of suitability of the correction (i.e. where the altimetry measurement are unreliable, like strong topographic mountains, abrupt transitions, some crevassed areas,...) there need to be a flag.
- As these corrections are empirical, alike the SSB corrections, there need to be a learning stage.
- For this study, we investigated the number of repeat cycles necessary to achieve the corrections efficiently. We used the ENVISAT repeat mission data.
- The parameters are :
  - ❑ the number of minimum repeats
  - ❑ the number of repeat cycles available in general
- We computed intra-cycle height difference at crossovers in the same way as our validation chain and plot the result as a function of slope.
- This has been done with the 10, 15, 25, 30, 35, ... first cycles (from cycle 9) with data validated using our chain.

CTOH
Legos

ICE-2 echo and geo corrections

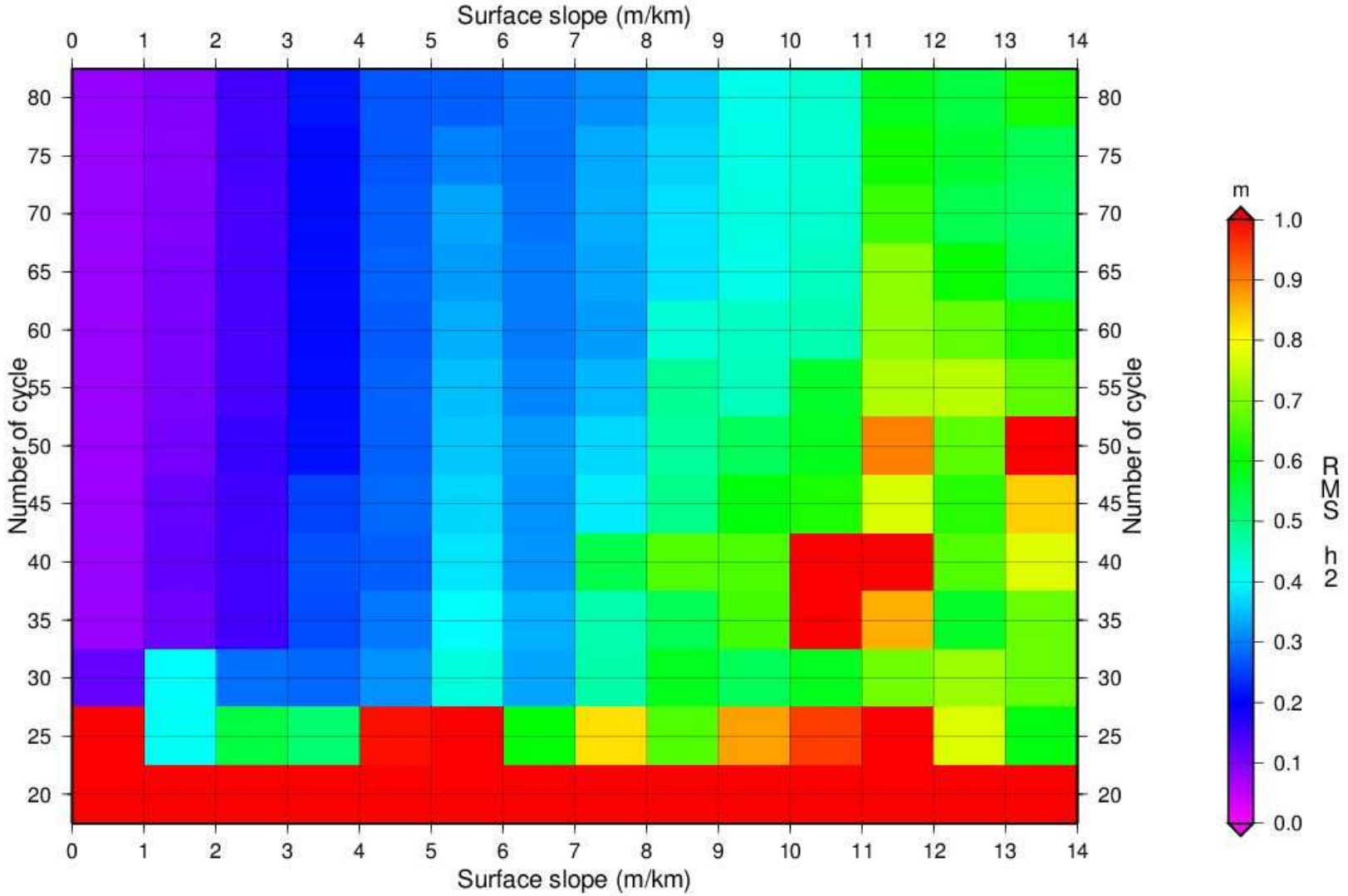
Antartica cycle min 10



CTOH
Legos

ICE-2 echo and geo corrections

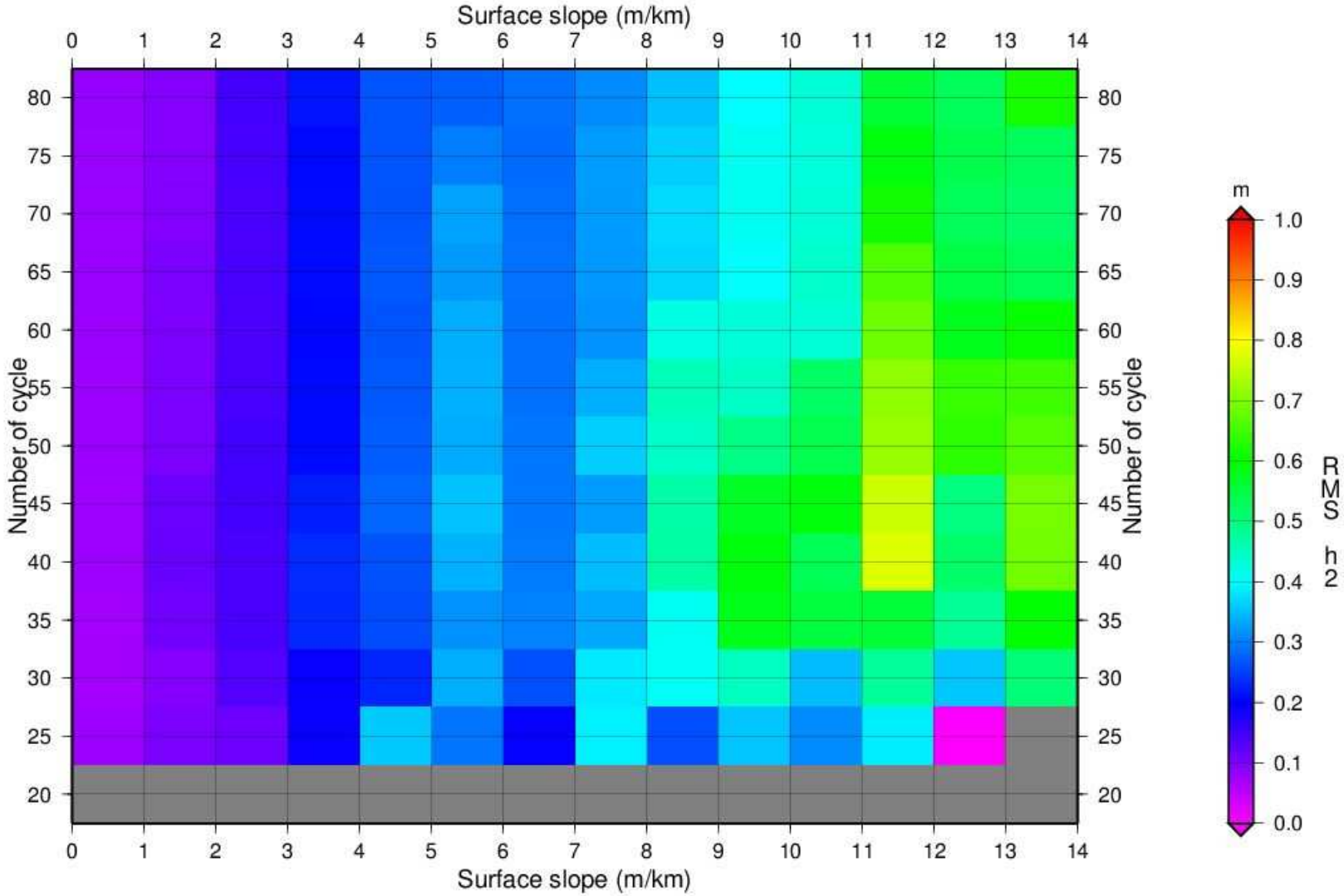
Antartica cycle min 15



CTOH
Legos

ICE-2 echo and geo corrections

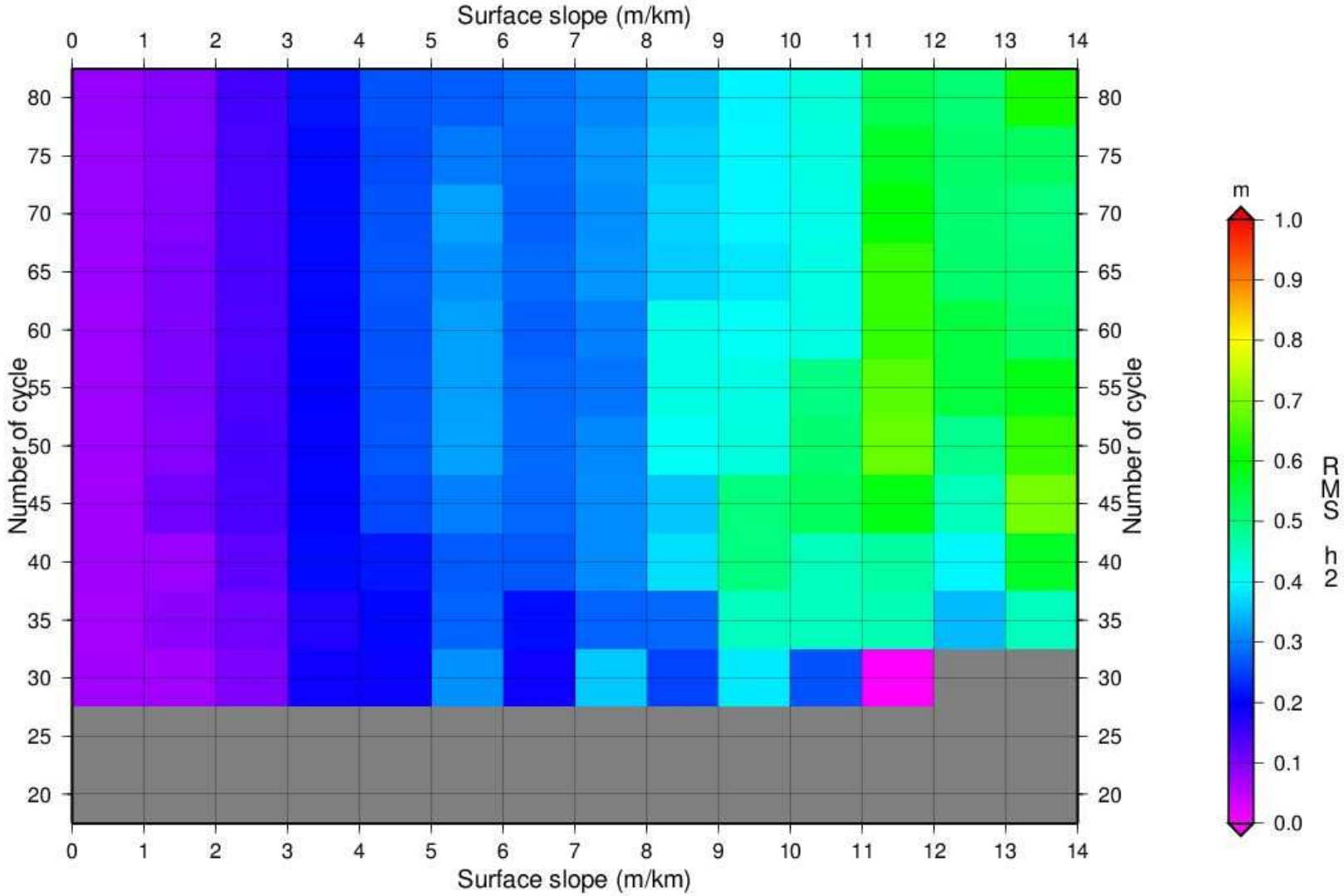
Antartica cycle min 20



CTOH
Legos

ICE-2 echo and geo corrections

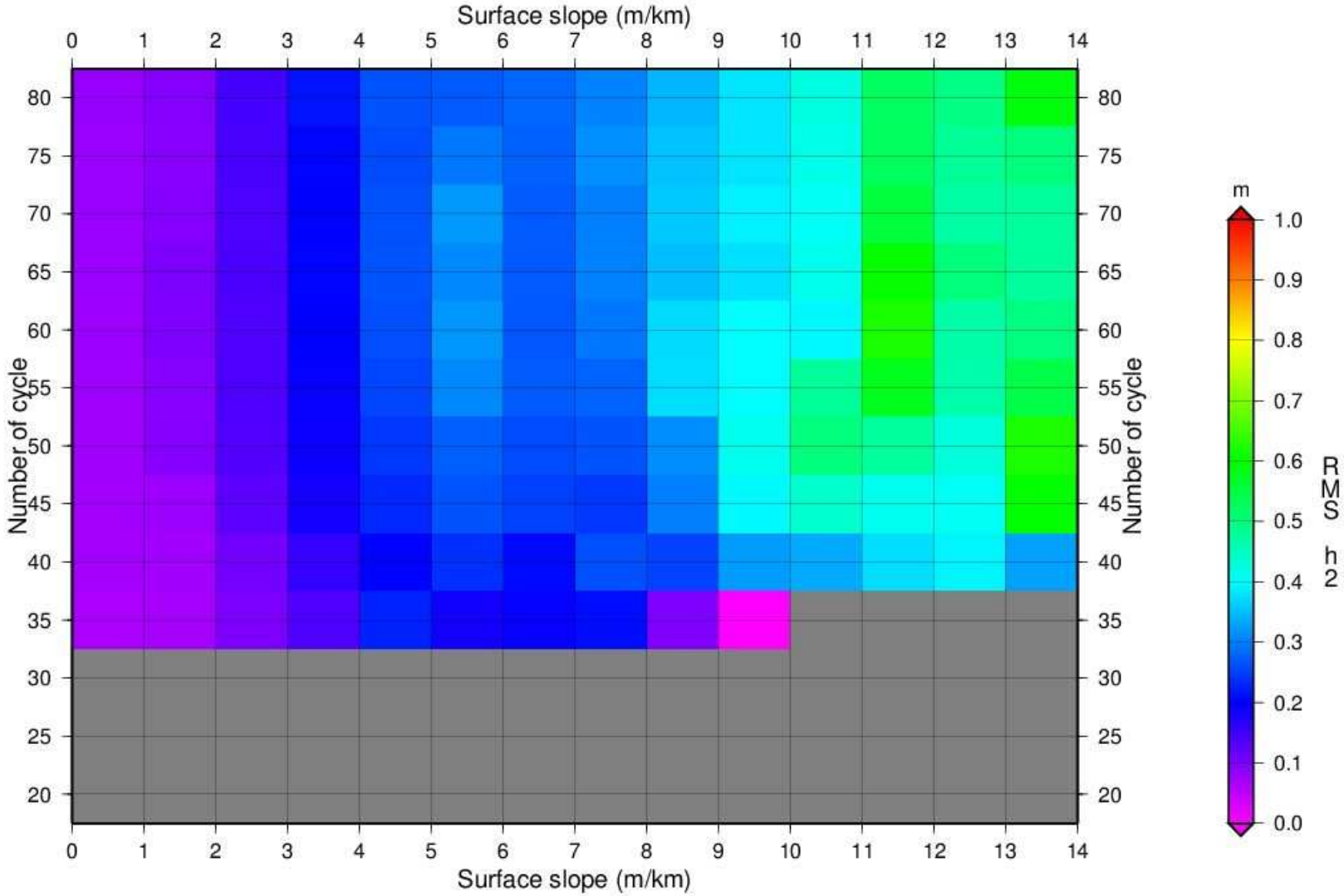
Antartica cycle min 25



CTOH
Legos

ICE-2 echo and geo corrections

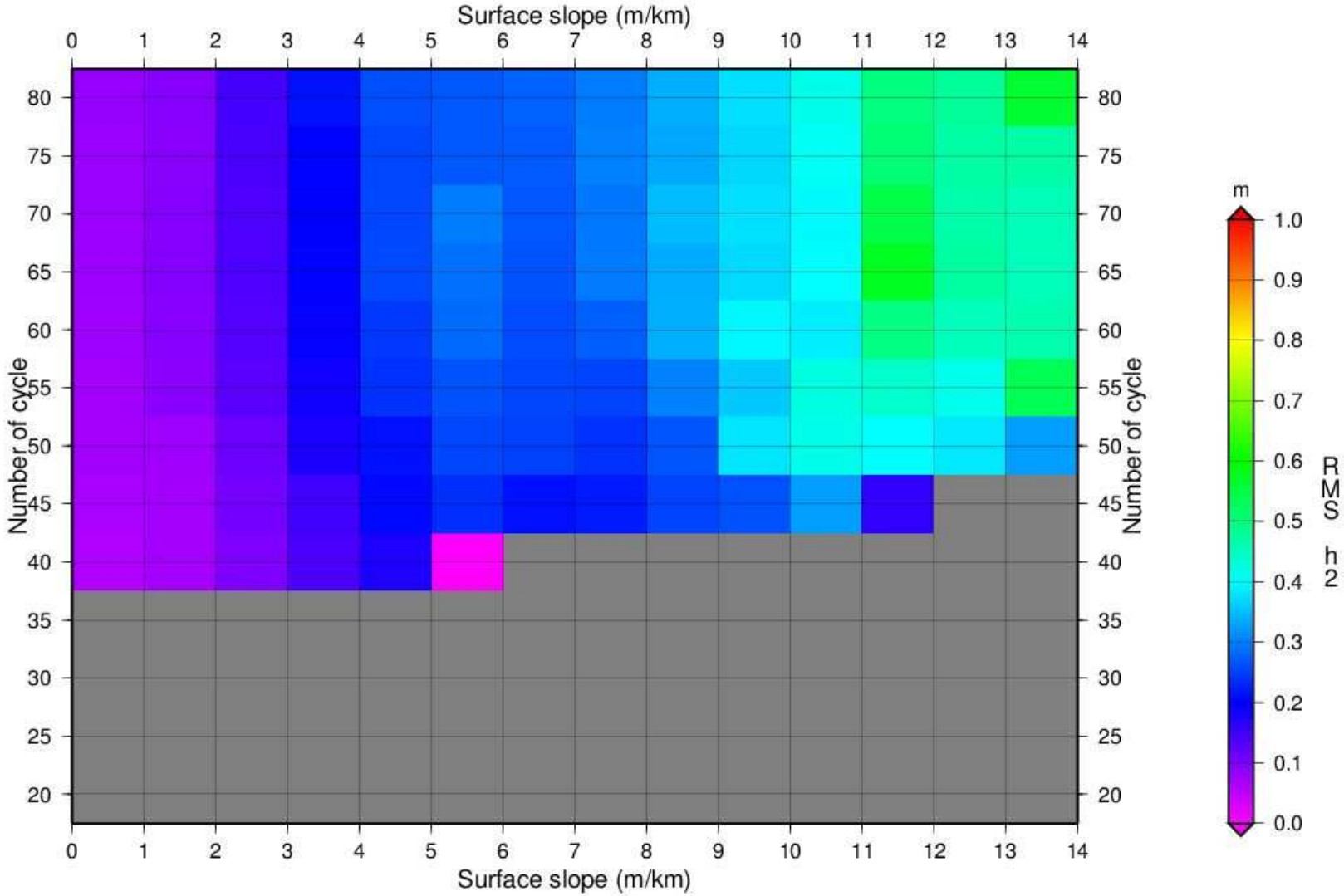
Antartica cycle min 30



CTOH
Legos

ICE-2 echo and geo corrections

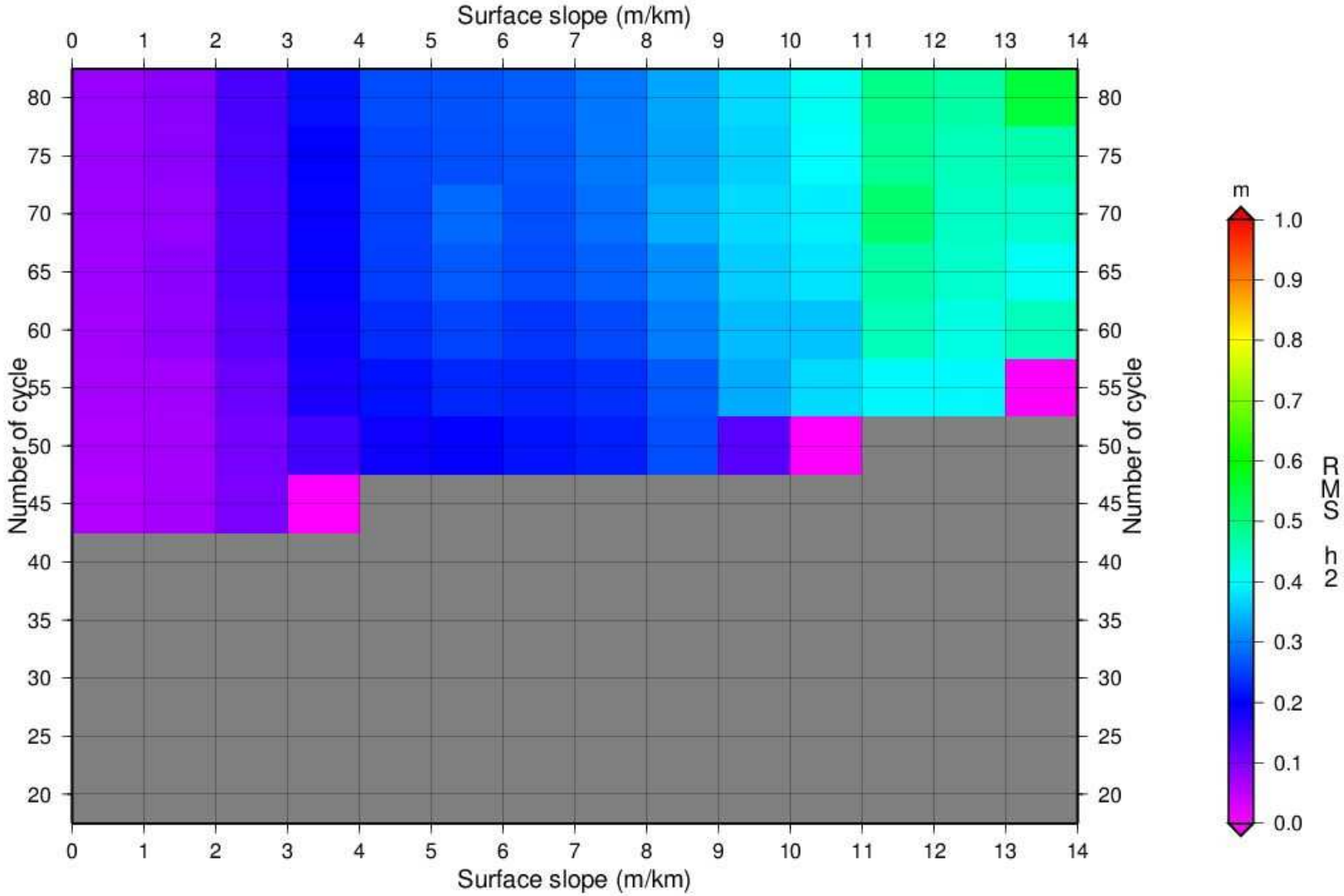
Antartica cycle min 35



CTOH
Legos

ICE-2 echo and geo corrections

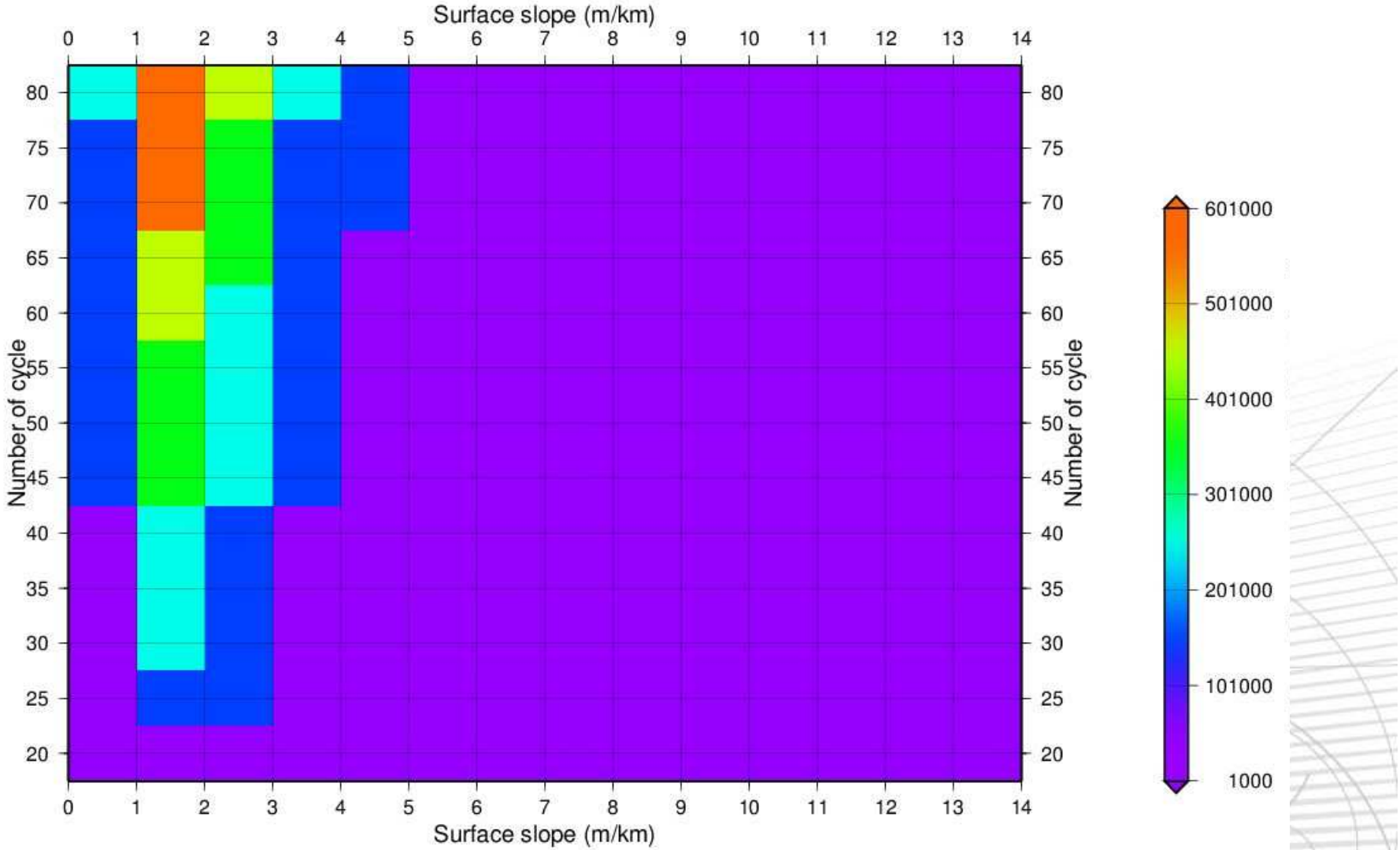
Antartica cycle min 40



CTOH
Legos

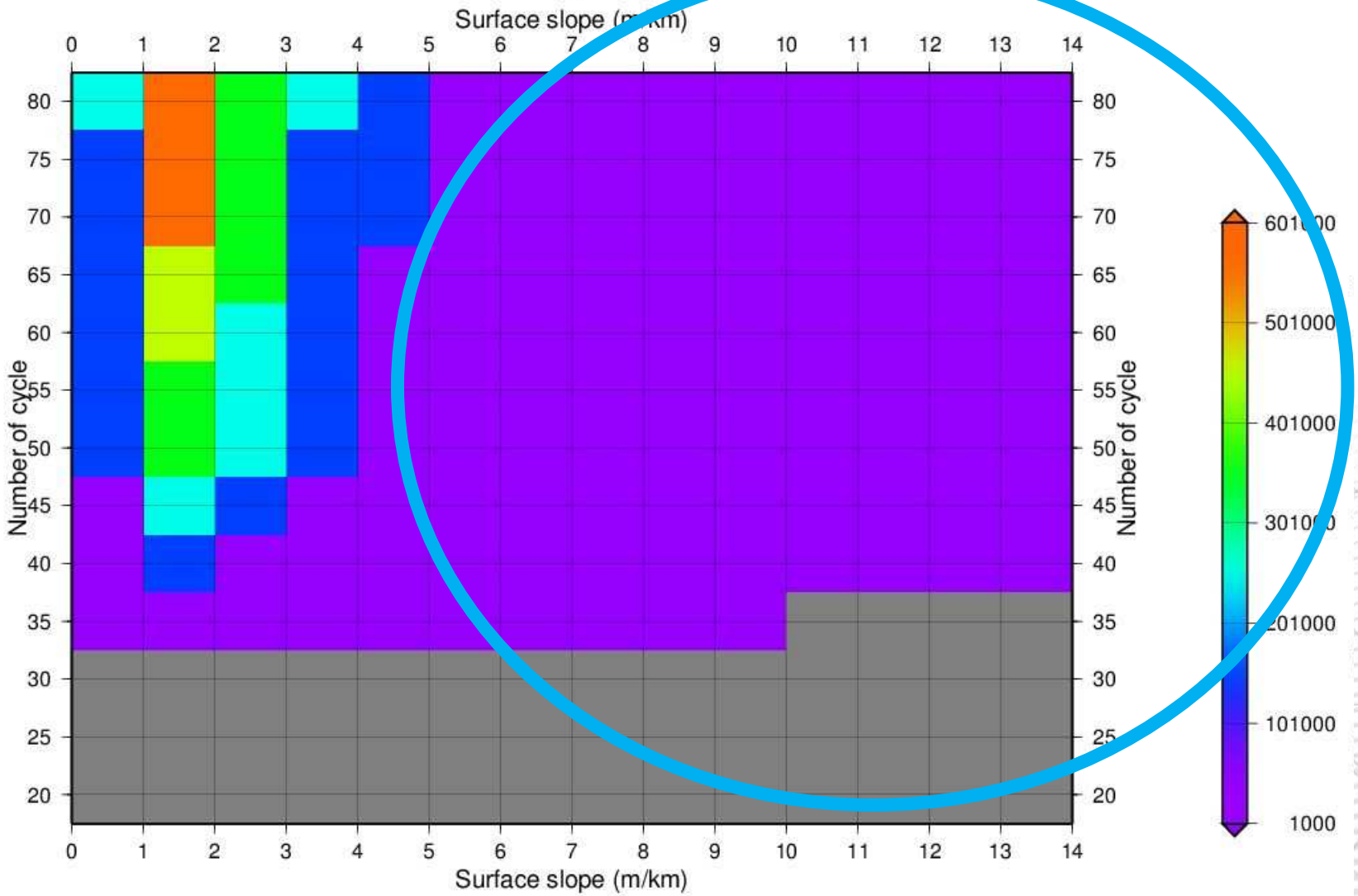
ICE-2 echo and geo corrections

Antartica cycle min 10



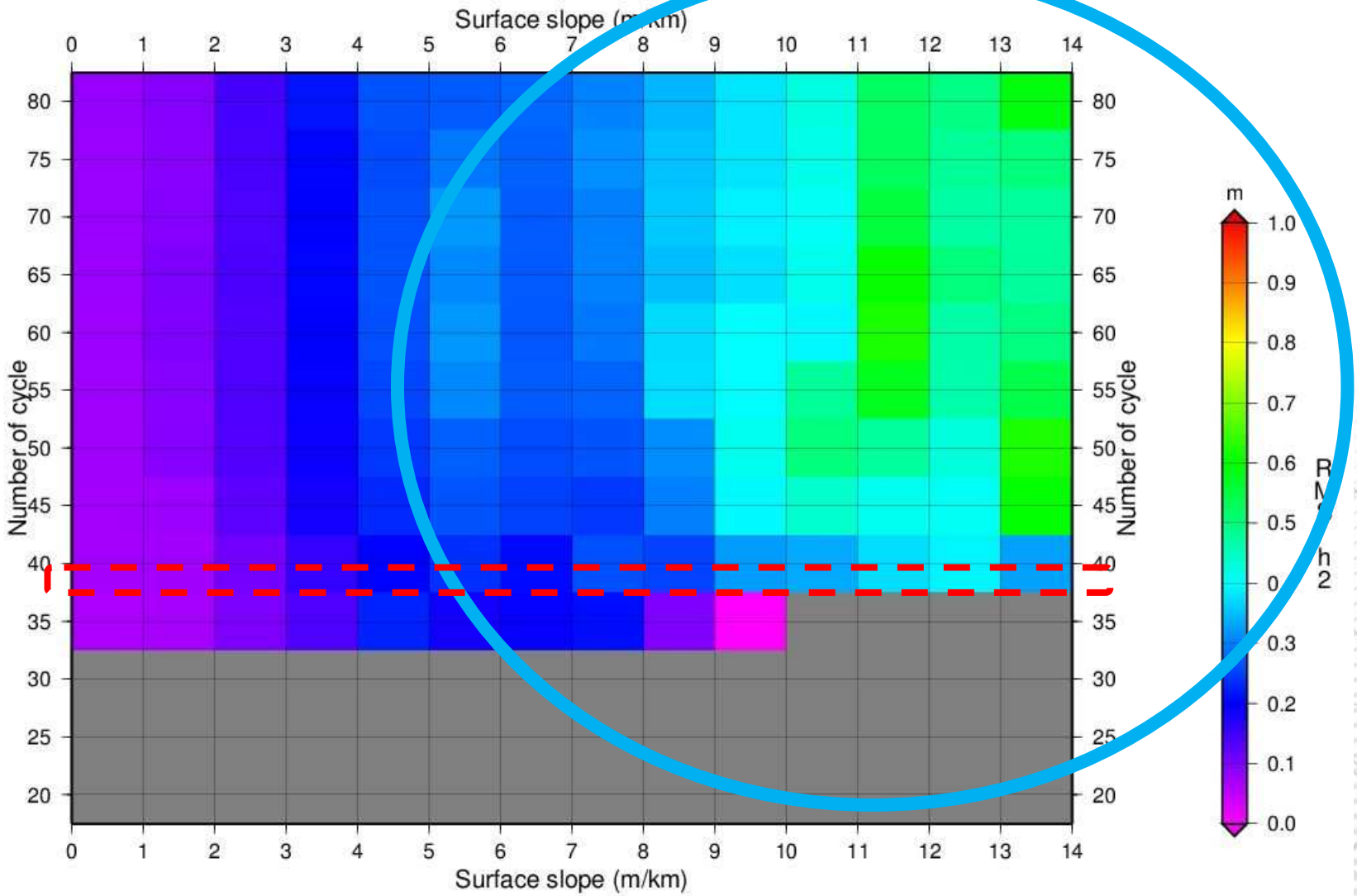
ICE-2 echo and geo corrections

Antartica cycle min 30



ICE-2 echo and geo corrections

Antartica cycle min 30

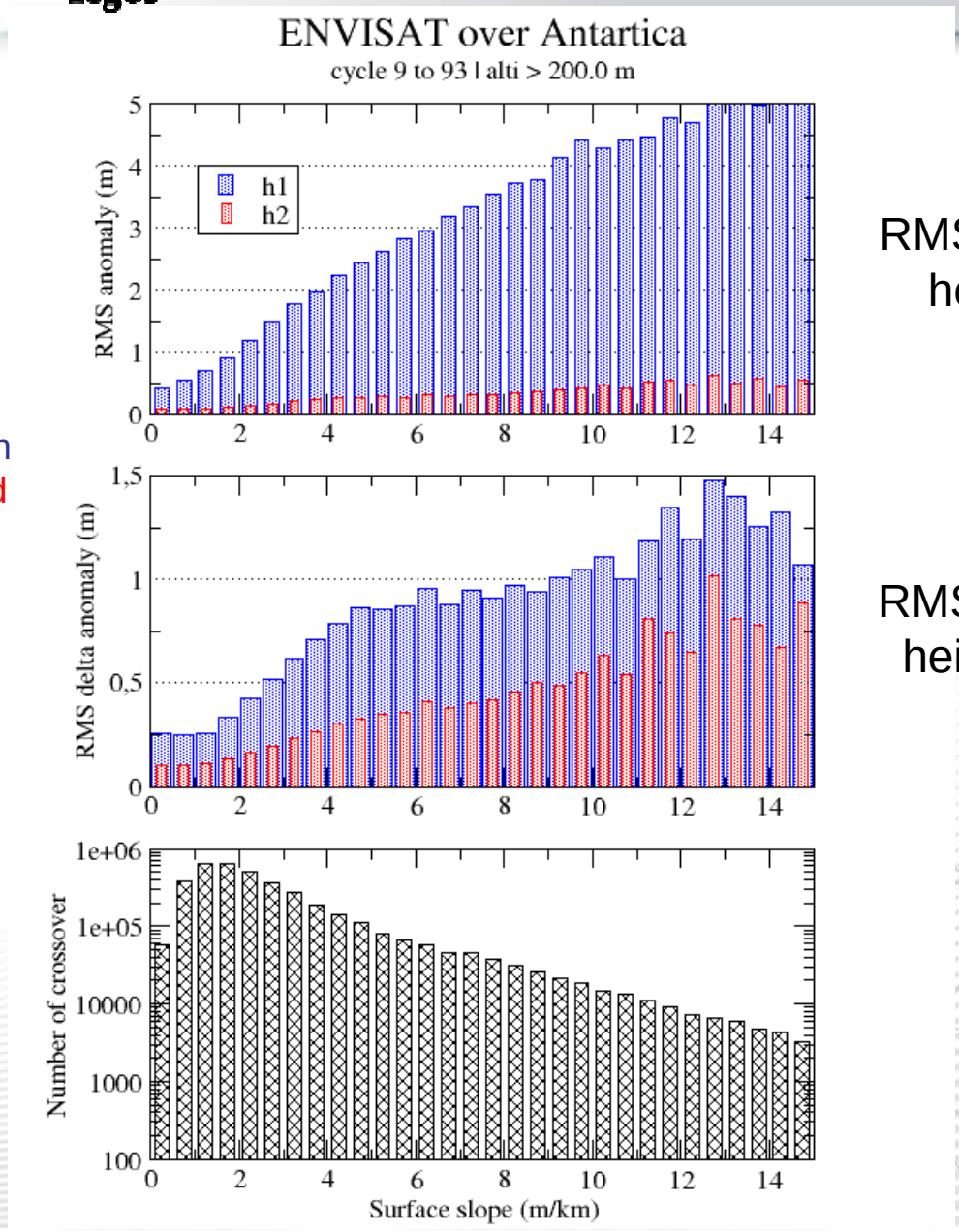


ICE-2 echo and geo corrections

- How many valid repeat cycles do we need to build these tables before being able to apply them?
- Choosing a configuration (nb of effective minimum and number of repeat cycles) correspond to one line in the previous series of plots.
- A minimum of 30 effective repeats (i.e. 30 valid repeat measurements for each point)to start the process is a good decision.
- Beyond 30-40 repeats, the impact on the height measurement is pretty steady up to 80. rq : ENVISAT case leads to a larger difference between min repeats and min nb cycles
- Of course the more cycles used in building the corrections tables the more effective the corrections.
- From this preliminary study, we understand that implementing the echo and geo corrections into GDR is feasible for exact repeat phases.
- An extensive set of processing help us to recommend to gather the necessary information over a minimum 30+ repeat cycles to establish the correction tables.
- Implementing the corrections is just applying tables to information within the GDR product (lon, lat, Bs, LEW and TES) and outputs corrections for (2 for Range, Bs, LEW and TES).

ICE-2 echo and geo corrections

CTOH
Legos



h1 : heigths after validation
h2 : heigths after echo and geo corrections

RMS of the temporal height anomaly

RMS of the asc/desc height differences

Conclusions of the study

- ❑ A MLE (2 or 3) has been implemented and tested for RA-2 WF
  - ✓ Very coherent results compared to ice-2 results
  - ✓ Improvement of the resolution of the parameters
  - ✓ CPU reduction around 40 to 50 %
  - ✓ Abnormal behaviors on some WF (both Ice-2 and ice-2MLE)

- ❑ Echo and Geo corrections have been computed
  - ✓ At least 30 to 40 cycles are required to compute efficient corrections
  - ✓ implementing echo and geo corrections into GDR is feasible for exact repeat phases. (To be tested on ERS data with 80MHz bandwidth)
  - ✓ important reduction of temporal rms and at crossovers