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D2.3.4: Time series of Greenland ice sheet mass balance from 1992 to present (combining all techniques) and improved ”overall” freshwater input trend to the oceans surrounding Greenland.

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PP	Restricted to other programme participants (including the Commission)	
RE	Restricted to a group specified by the consortium (including the Commission)	
CO	Confidential, only for members of the consortium (including the Commission)	

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SUMMARY

The joint American-German GRACE satellite mission has since 2002 provided very valuable data for ice sheet mass balance time series.

Form the deliverable D2.3.3 "Gridded time series of GRACE-based Greenland mass changes" we computed the time series of mass changes for the northern basins of Greenland.

From the deliverable D2.3.1, provided by Kirill Khvorostovsky, "Grid of elevation change time series from ERS-1, ERS-2 and Envisat measurements 1992-2008" we computed the time series of mass changes for the same northern basins of Greenland.

We compared the 2 time series and we find a suitable way to combine them to provide a mass change time series since 1992.

By using a published precipitation grid over Greenland, we estimate the average freshwater input in the Arctic ocean from Greenland, of about 145 Gt/yr.

MONARCH-A CONSORTIUM

Participant no.	Participant organisation name	Short name	Country
1 (Coordinator)	Nansen Environmental and Remote Sensing Center	NERSC	NO
2	The University of Sheffield	USFD	UK
3	Universität Hamburg	UHAM	NO
4	Centre National de la Recherche Scientifique	CNRS	FR
5	Scientific foundation Nansen International Environmental and Remote Sensing Center	NIERSC	RU
6	Universitetet i Bergen	UiB	NO
7	Danmarks Tekniske Universitet	DTU	DK
8	Institut Francais de Recherche pour l'Exploitation de la Mer	IFREMER	FR

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1 Introduction

GRACE (Gravity Recovery and Climate Experiment) mission is a pair of satellites which measure Gravity field variation with time. They provide monthly snapshots of gravity field with a resolution of 350 km. The time variations of the gravity are supposed to be caused by surface mass redistribution. We convert the variation of the gravity field in the surface mass variation which produced it (D2.3.3). Then we derive mass balance.

Altimetry instead provides volume changes (D2.3.1) at much higher resolution with respect to GRACE, however the conversion of volume into mass changes is not trivial. As a first order approximation the volume to mass conversion can be done by using an average density of 900 kg/m^3, however a more accurate conversion should take into account firn compaction.

The trend for the entire Greenland derived from altimetry (ICESat, D2.3.2) and from GRACE shows a good agreement within the errors. Moreover DTU GRACE derived trends and time series show a very good agreement with solutions of other international teams as shown in the IMBIE 2011-12: International Mass Balance Intercomparison Experiment (Shepherd et al. 2012).

2 Net Mass balance and Freshwater flux

The freshwater flux into the Arctic Ocean from Greenland is the sum of water runoff and ice discharge. A way to obtain that information is to make use of the net mass balance observed by GRACE and a precipitation model. In fact the net mass balance observed by GRACE is the result of precipitation (input mass) minus ice discharge and melt water runoff (output mass).

2.1 Basins definition

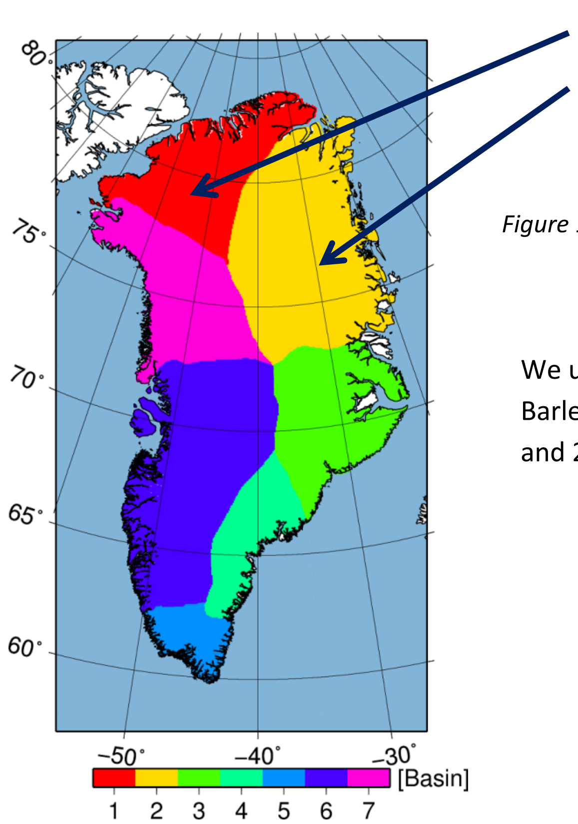

Figure 1: Basin definition for Greenland.

We used the same basins definition (Figure 1) used in Barletta et al. 2012 and we assumed that basins number 1 and 2 are discharging into the Arctic Ocean.

2.2 Grace Mass balance

As net mass balance we used -27.8 +/- 8 Gt/yr that is the sum of a GRACE derived mass budget obtained for basins number 1 and 2 as in Barletta et al. 2012.

2.3 Precipitation

In order to derive the input mass we use the precipitation grid (Figure 2) same as in Ettema et al. (2009), which are publicly available in netCDF format. We integrate the precipitation grid over the area of basin number 1 and 2 and we obtain 123 Gt/yr. From that number we have to remove 6 Gt/yr for the evaporation contribution, which is about 5% (Ettema et al. 2009) of precipitation.

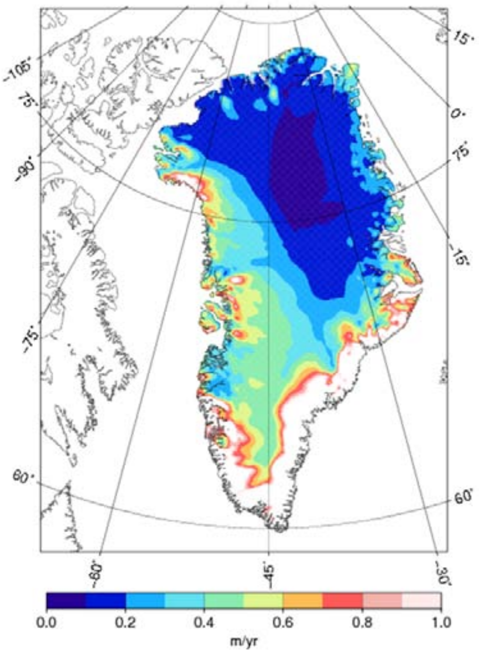

Figure 2: Precipitation grid (Ettema et al. 2009)

2.4 Freshwater flux

The freshwater input into the Arctic Ocean is given by the difference of the above contributions summarized in Table 1. In fact if the net mass balance (MB) derived by GRACE can be written as

MB = IMB – OMB

where IMB is the input mass balance, obtained by precipitation (P) minus evaporation (E), and OMB is the output mass balance that is the freshwater (FW) input into the Arctic Ocean.

So we obtain that OMB = IMB – MB, that is FW = P – E – MB.

Table 1: Summary of value used to compute the freshwater input into the Arctic Ocean (FW) as FW = P – E – MB

	Symbol	Value in Gt/yr
Precipitation	P	123
Evaporation	E	6
GRACE mass balance	MB	-28
Freshwater	FW	**145**

3 Time series from 1992 to present

3.1 Altimetry derived mass time series

We use grid of elevation change time series from ERS-1, ERS-2 and Envisat measurements 1992-2008, MONARCH-A deliverable D2.3.1, updated and provided by Kirill Khvorostovsky.

We integrate over the northern basins (basins number 1 and 2) the elevation change so we obtain the time series of volume changes. And then we use the first order approximation to convert volume into mass, i.e. we use the average density of 900 kg/m^3.

Since the grid of elevation change time series has values missing for some pixels at some epochs, we interpolate the grid in order to obtain the missing value only when the overall data were sufficient to do that.

Note that the grid of elevation change time series has a temporal resolution of 3 months, so we have to apply a smoothing filter to GRACE-derived mass time series for a fair comparison.

3.2 GRACE derived mass time series

Monthly solution of GRACE data are obtained as in deliverable D2.3.3 and in Barletta et al. 2012, i.e. using the point-like mass inversion method. Here we update the time series using the latest GRACE data release 05.
Then the monthly solutions are integrated over each basin area, i.e. for each basin we sum the point-like masses belonging to the same basin. Results for basin number 1 and 2 are shown in Figure 3.

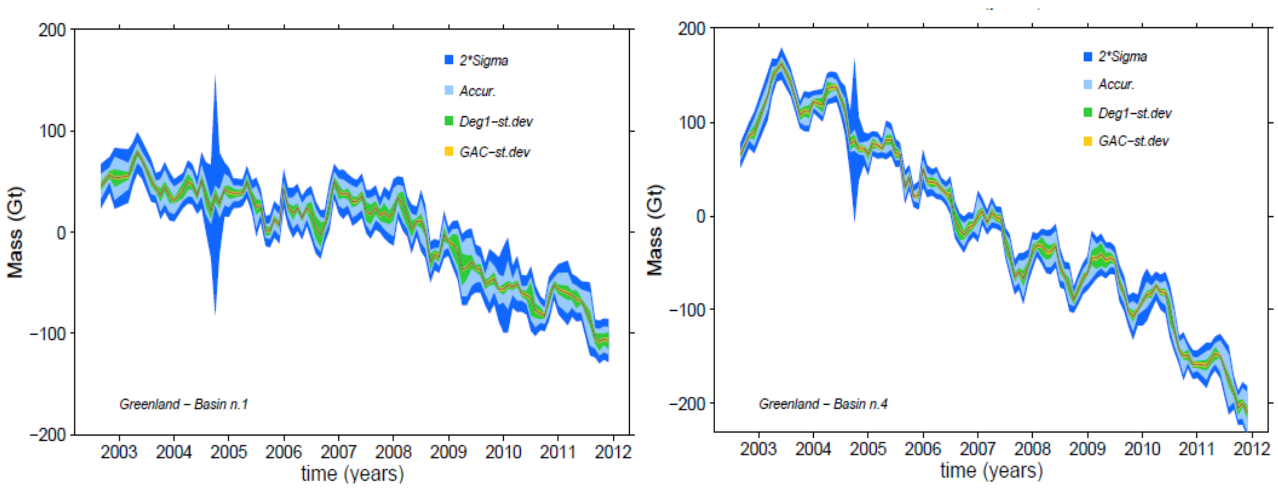

Figure 3: RL04 monthly solution for Greenland basin 1(left) and 2 (right).The time series is obtained as average of the release from two different data centers (CSR and GFZ). The colour band represents a contribution to the total error estimate, see more details in Barletta et al. 2012

3.3 Comparison of Altimetry and GRACE time series

The comparison between the mass time series derived from Altimetry (red line in Figure 4) and from GRACE (blue line) has the purpose to assess if the time series derived from Altimetry can be used as extension (or as a replacement) of the GRACE-derived time series.

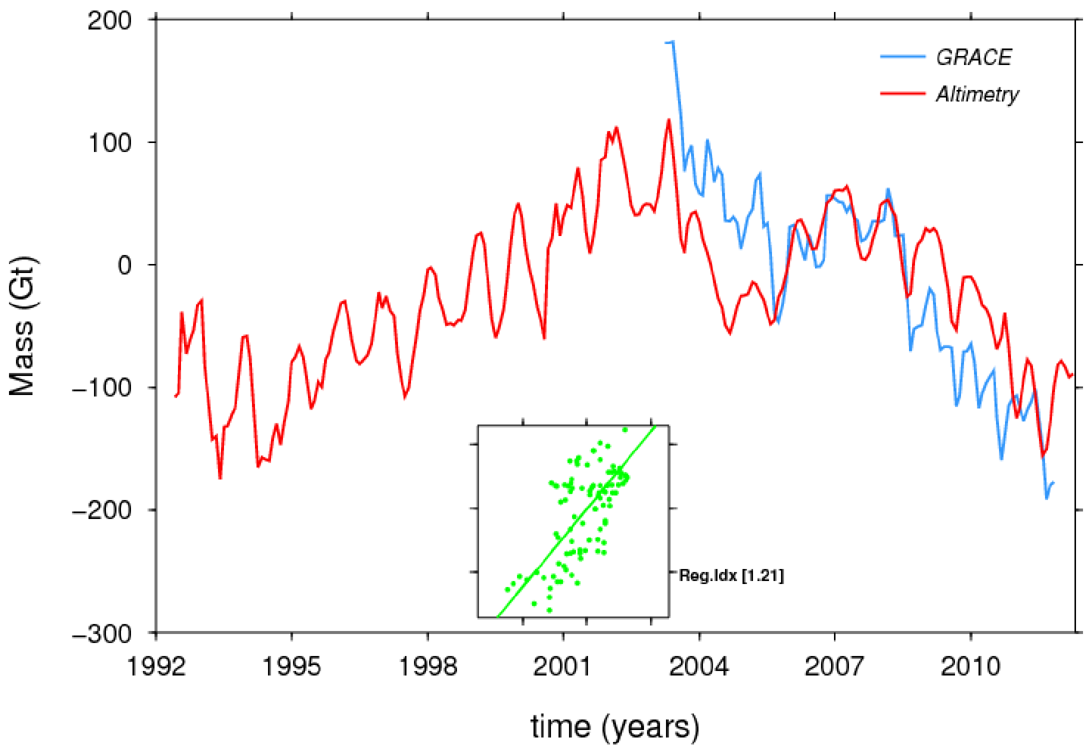

Figure 4: Time series for mass changes derived from Altimetry (red line) and from GRACE (blue line). The small inset represents the scatter plot between the two time series (for the common period only) and the regression index is 1.21.

The comparison (Figure 4) between the time series derived from Altimetry and from GRACE shows strong similarities but it is also visible an overall difference. On the common time span the difference can be ascribed to a trend or to an overall scaling factor.

Altimetry technique has problems to fully resolve the elevation changes close to the margins of glaciated area, while GRACE has a lower resolution (300 km) but it can resolve the full mass loss over an area much larger than its spatial resolution.

We partially ruled out the role of the approximated volume-mass conversion by testing different combinations of density factor associated with positive and negative signal, and the main difference still remain.

In the period 1992-2003 the northern basins experienced a positive mass trend that can be due to increase in accumulation rather far from the margins. However in the common time span the two time series have negative trend which can be due to increased discharge very close to the margin.

The two periods (before and after 2003) show very different behavior and therefore it is difficult to assess a suitable correction for the period 1992-2003 for Altimetry-derived time changes.

The second period (2003-2010) can be corrected multiplying by 1.21 the Altimetry-derived time changes (Figure 5) and we can see an improved agreement.

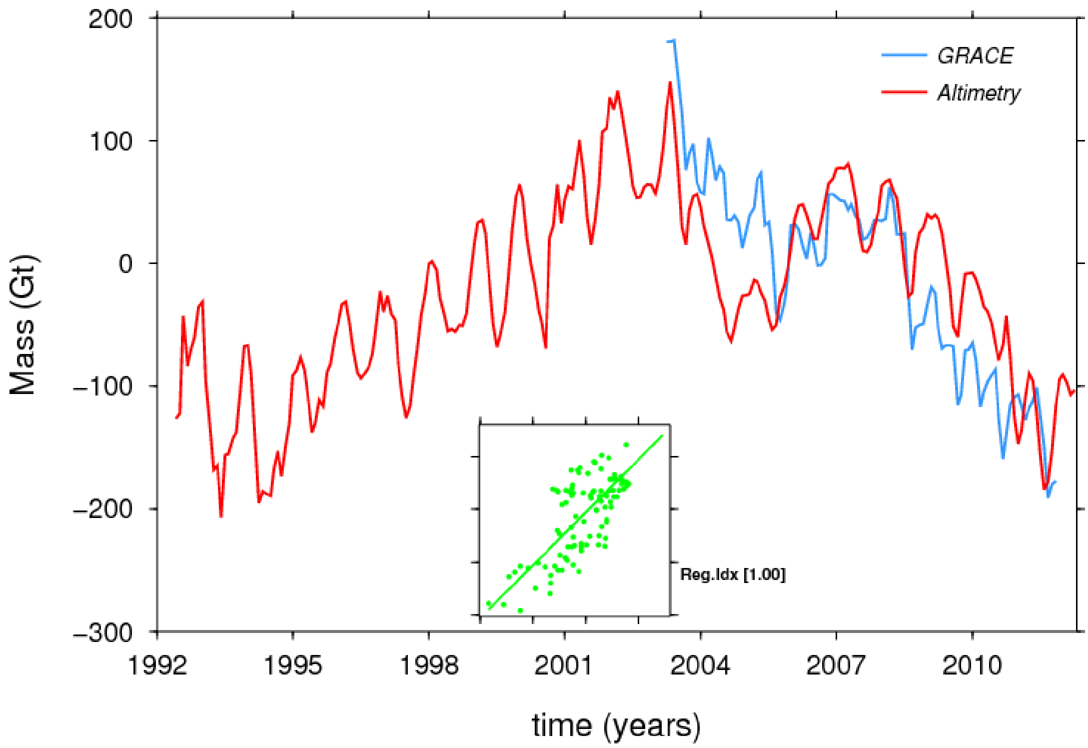

Figure 5: Time series for mass changes derived from Altimetry RESCALED by 1.21 (red line) and from GRACE (blue line). The small inset represents the scatter plot between the two time series (for the common period only) and after rescaling the altimetry derived time series by 1.21 the regression index is 1.0 as expected.

3.4 Results and Conclusions

Further and dedicated studies on differences between the two techniques to retrieve mass changes (Altimetry and GRACE) are necessary. However the altimetry-derived time series rescaled by 1.21 can be a good approximation of the mass changes in the period from 1992 to present

We provide a file Northern_Basin_GRL_mass.txt which contain such time seies with the following format: [year] [value in Gt].

4 References

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