Gravimetry and Altimetry in Antarctica

by

A. Kaitheri, A. Memin, F. Remy

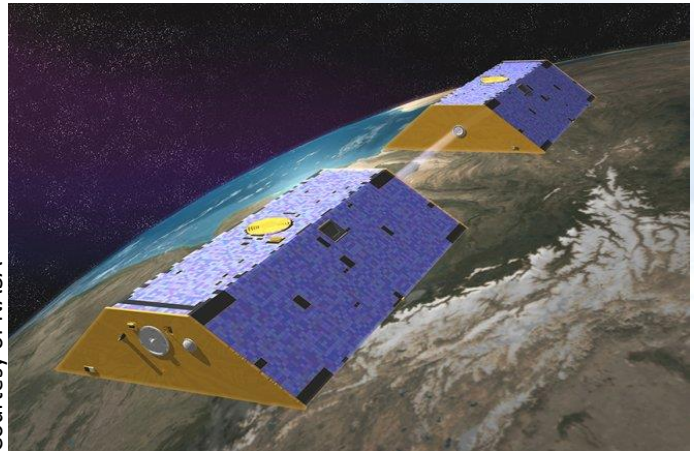
Atelier Altimétrie et Glaciologie

Membre de UNIVERSITÉ CÔTE D'AZUR

25-06-2019

Introduction

- Antarctica ice sheets are undergoing massive changes due to global climate change (Shepherd et al., 2012).
- Long term monitoring is key to understand and forecast climate change scenarios
- Altimetry and gravimetry can be used to monitor and quantify those changes



Courtesy of NASA

Courtesy of ESA

- Altimetric missions estimates height changes which are then used to estimate mass changes and topography studies

Radar Altimetric Missions

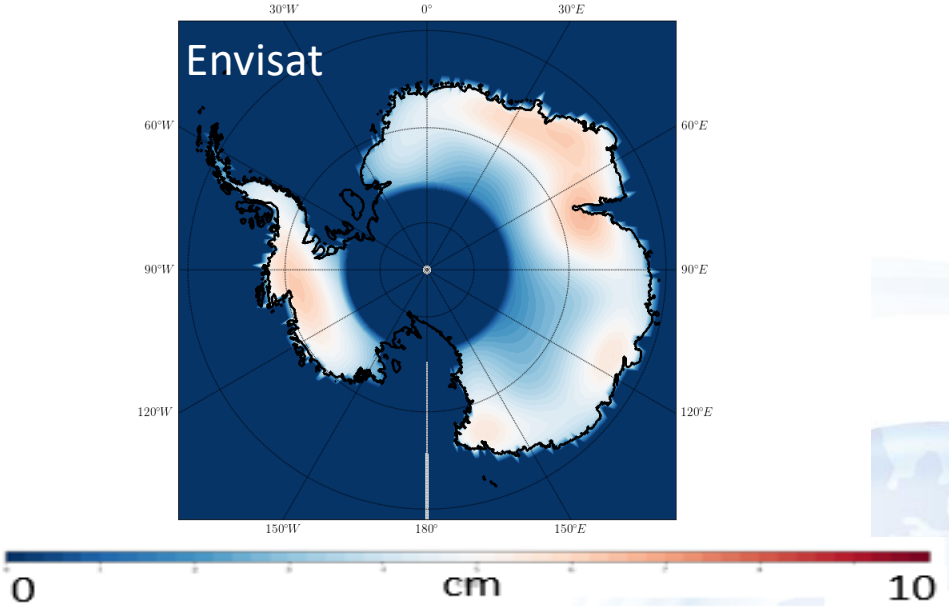
Mission	Operational Period	Altitude (km)	Inclination (deg)	Orbit repetivity	Frequency Band
ERS-1	1991 – 2000	785	81.5	35 days	Ku
ERS-2	1995 – 2003	785	81.5	35 days	Ku
Envisat	2002 – 2010	800	81.5	35 days	Ku, S
Altika	2013 -	800	81.5	35 days	Ka

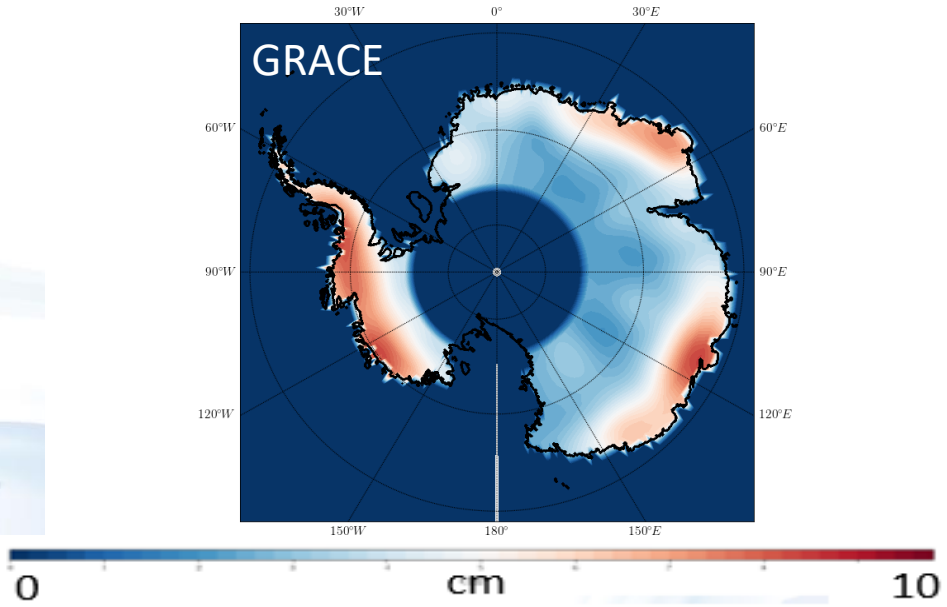
- Gravimetric missions estimates mass changes from measured gravity field anomalies
- Data from GRACE (2002 - 2017) and GRACE-FO (2018 -) mission
- Standard GRACE solutions are provided by CSR (Texas), GFZ (Potsdam), JPL (California) and GRGS (Toulouse)
- Standard GRACE solutions are converted to gravity changes by solving spherical harmonic (SH) coefficients

Processing Strategy

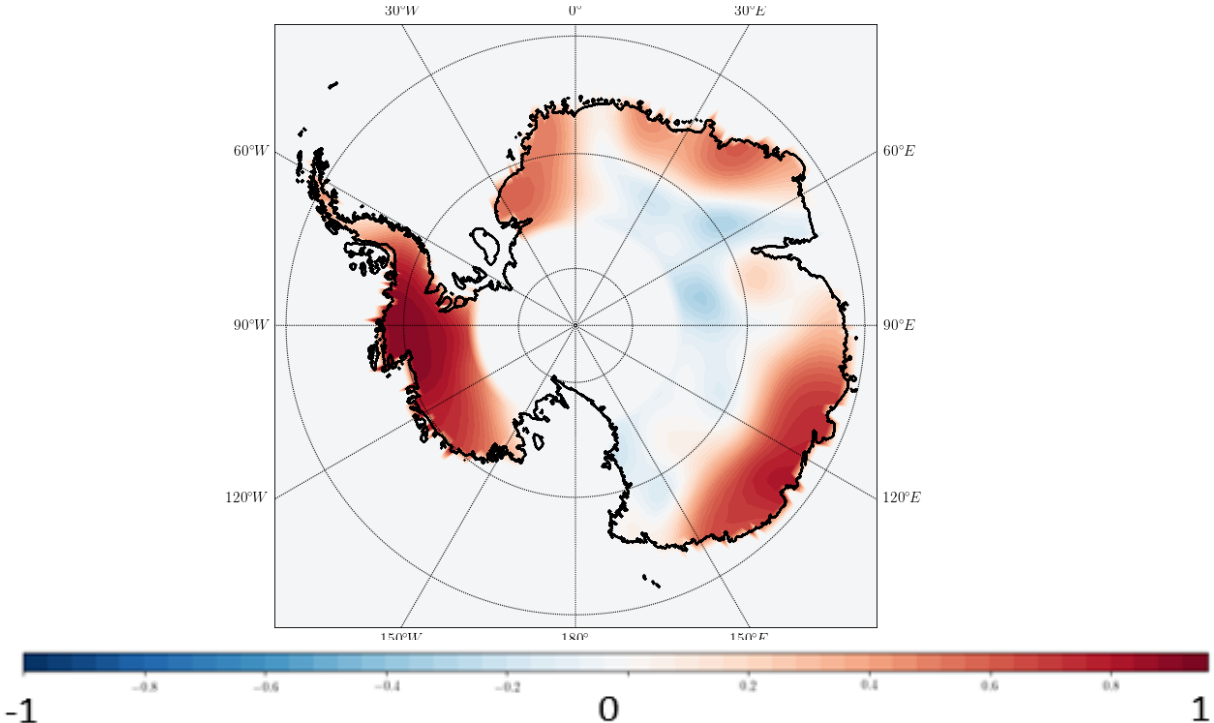
- Mean of the gravity changes from the four solutions is used
- A degree 2 polynomial curve is fit and long term trends are removed
- Envisat height changes data undergoes GRACE like processing methods (Mémin et al., 2014)
- Using Bouguer reduction, gravity changes are inverted to height changes
- Empirical Mode Decomposition (EMD) is carried out to check for intra annual seasonality

Standard Deviation of Height Changes during 2002 - 2010

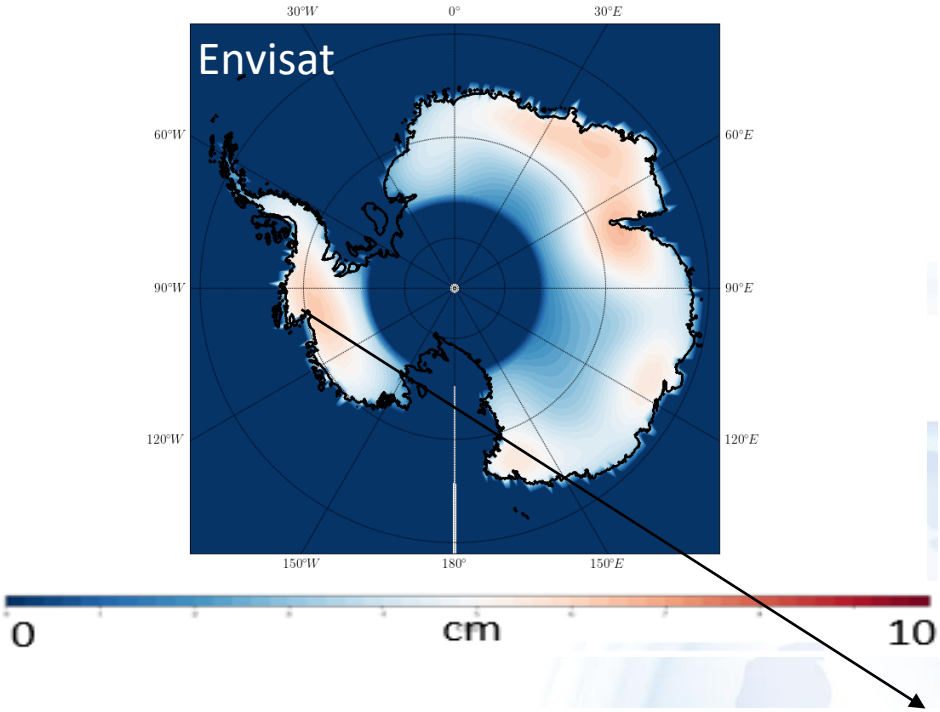


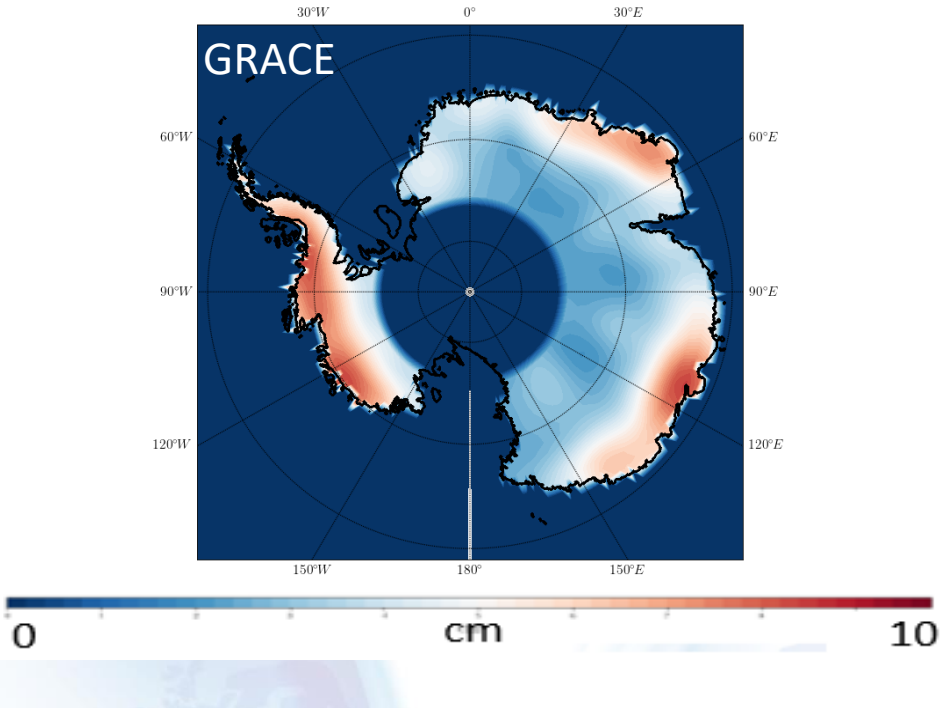


Correlation between Envisat and GRACE

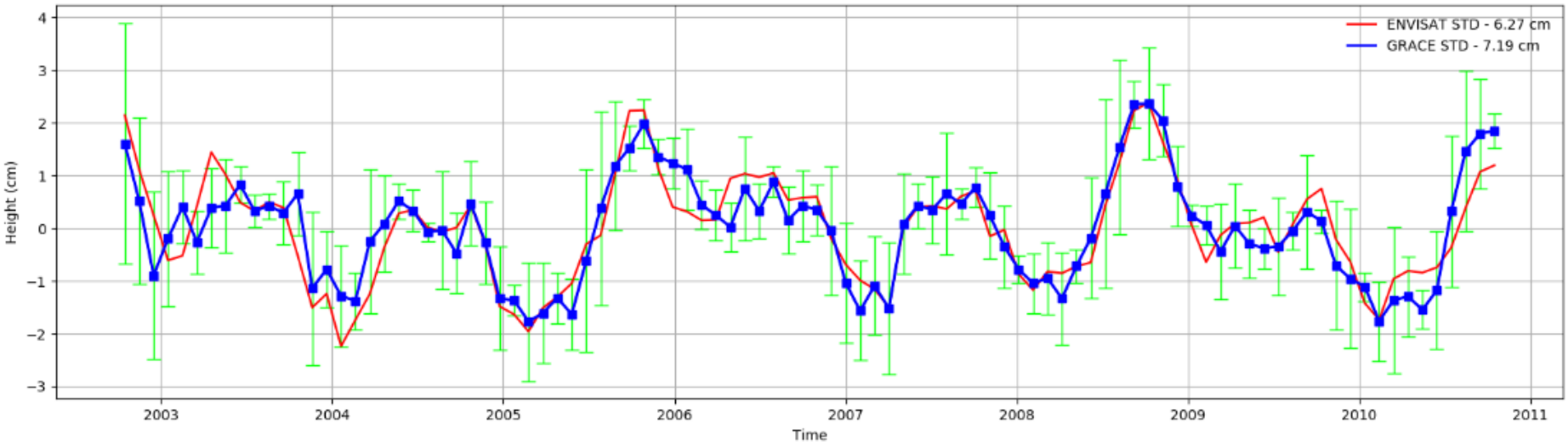


Standard Deviation of Height Changes during 2002 - 2010

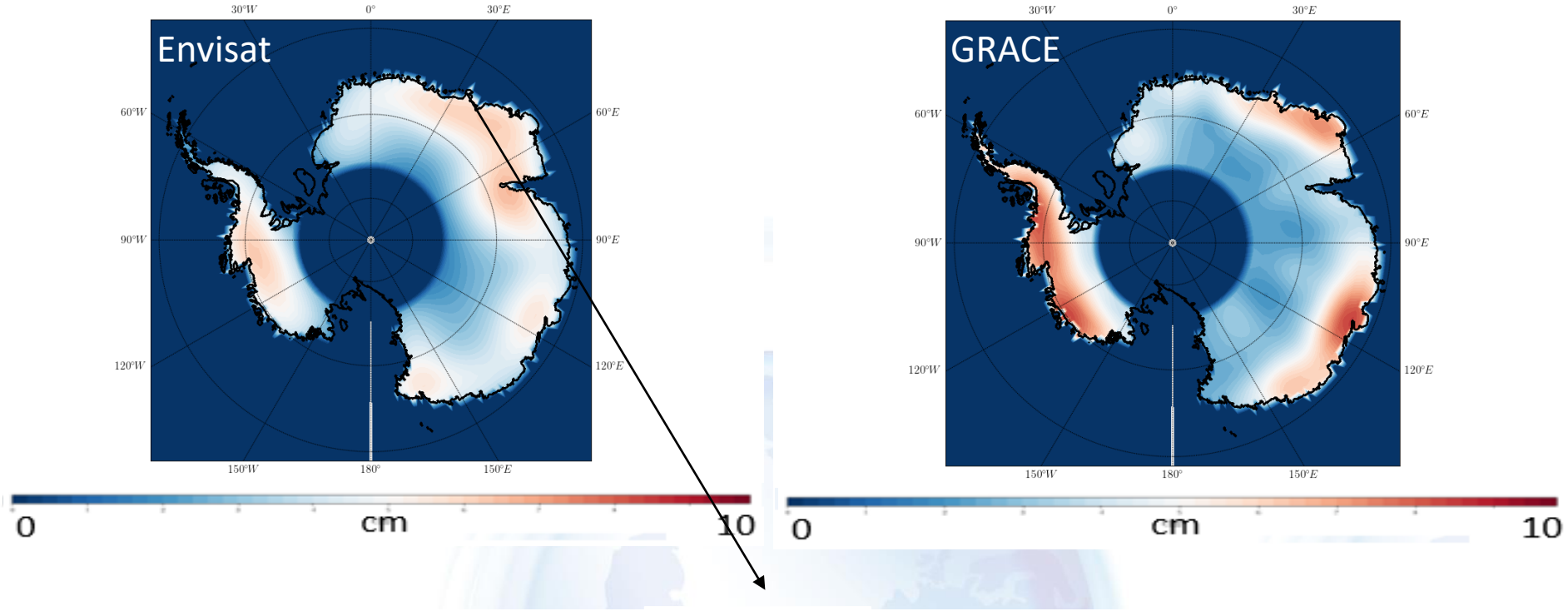




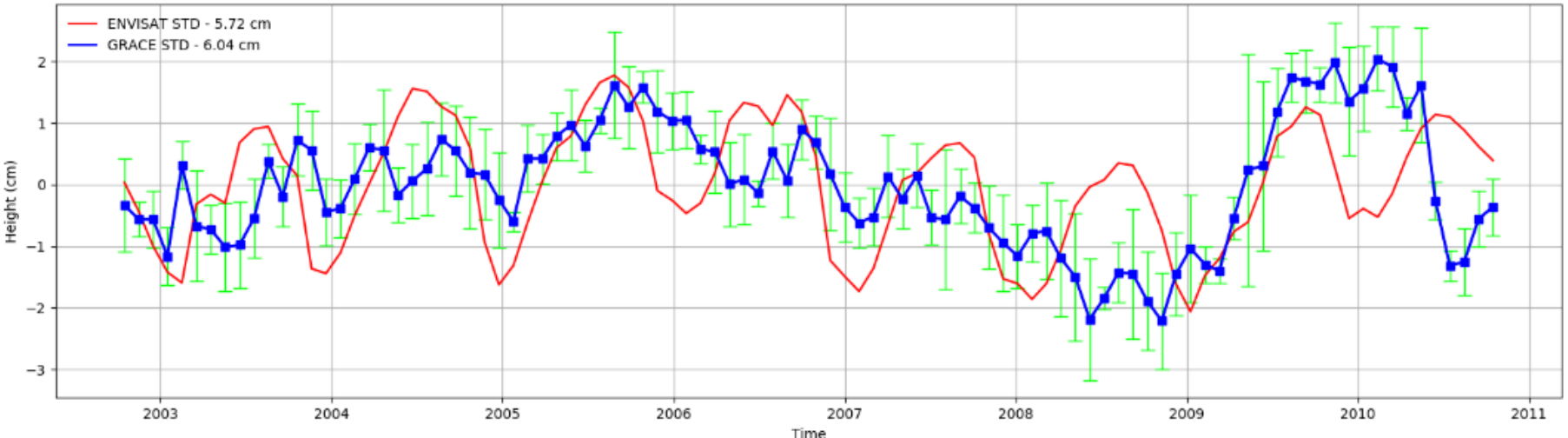
PIG



Standard Deviation of Height Changes during 2002 - 2010



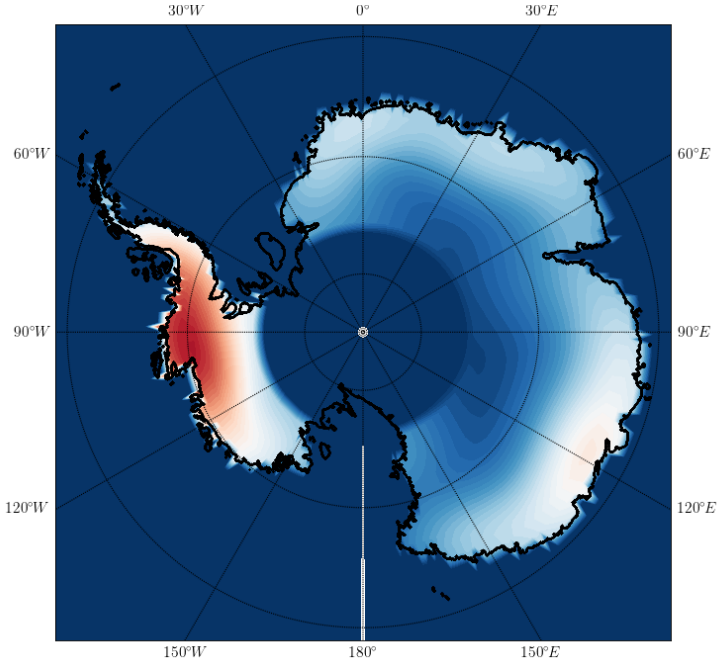
DML

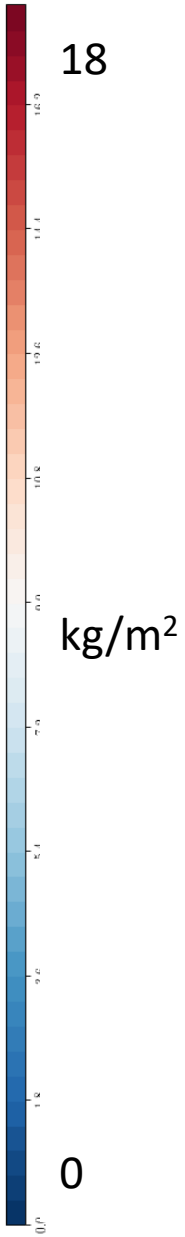


Climate Models

- Regional Climate Model (RACMO) designed with polar climate forcing (JM van Wessem et al., 2018
- Surface mass balance (SMB) estimates from RACMO 2.3p2 gives accumulation changes

Standard Deviation of SMB changes during 2002 - 2010





- Li & Zwally (2002), height changes is composed of:

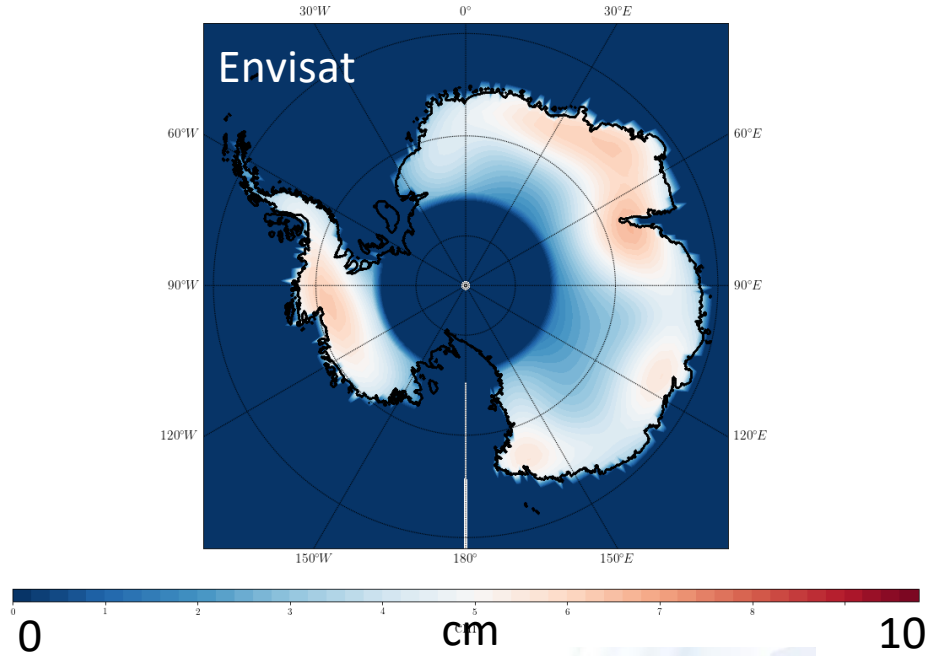
$$\frac{dH(t)}{dt} = \frac{A(t)}{\rho_{sf}} - V_{fc}(t) - \frac{A_b(t)}{\rho_i} - V_{ice} + \frac{dB}{dt}$$

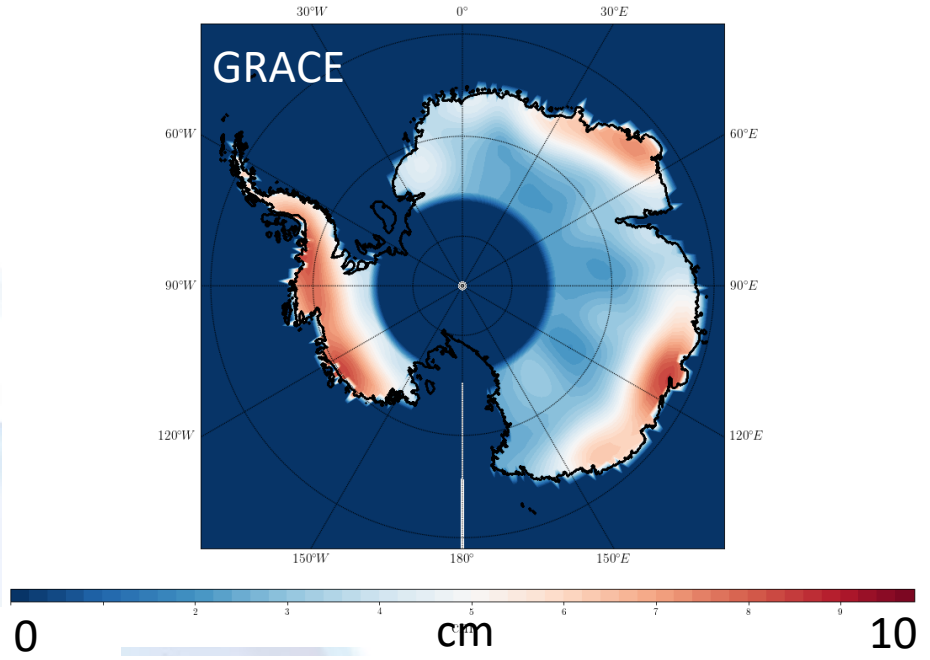
Accumulation Compaction Ablation Ice motion Bedrock upliftment

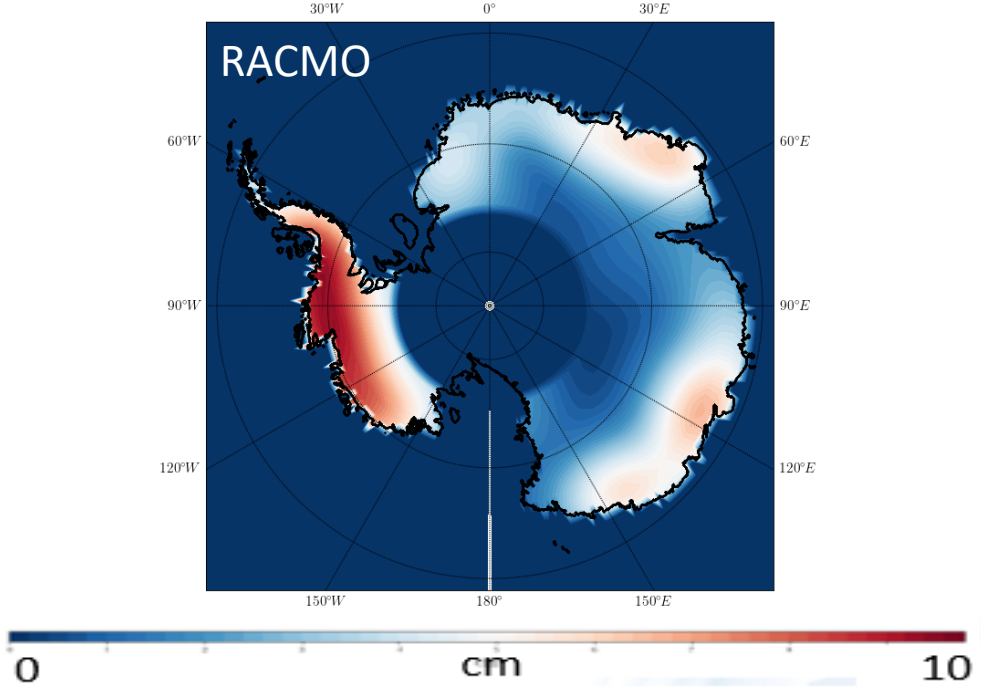
- Remy et al. (2004), in steady state equilibrium, height changes is directly linked to accumulation fluctuations

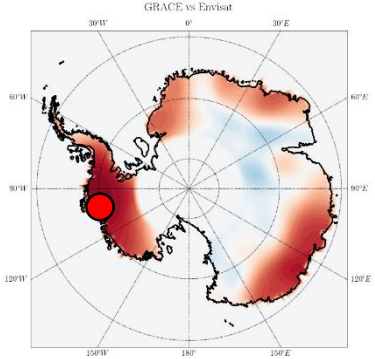
$$\frac{\mathrm{dH(t)}}{\mathrm{d}t} = \frac{A(t)}{\rho_{sf}} - V_{ice}$$

Standard Deviation of Height Changes during 2002 - 2010



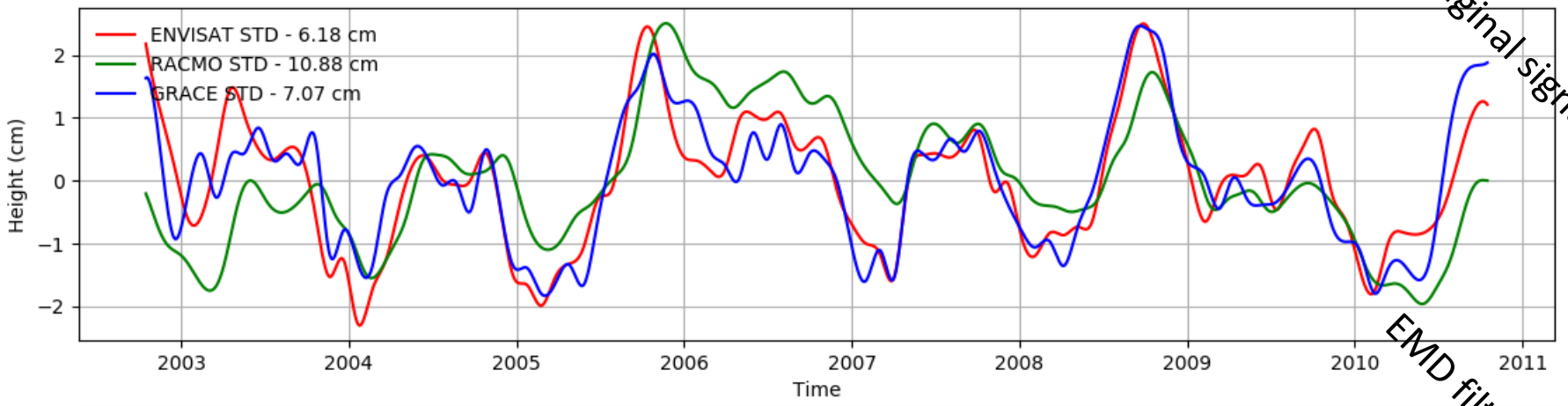




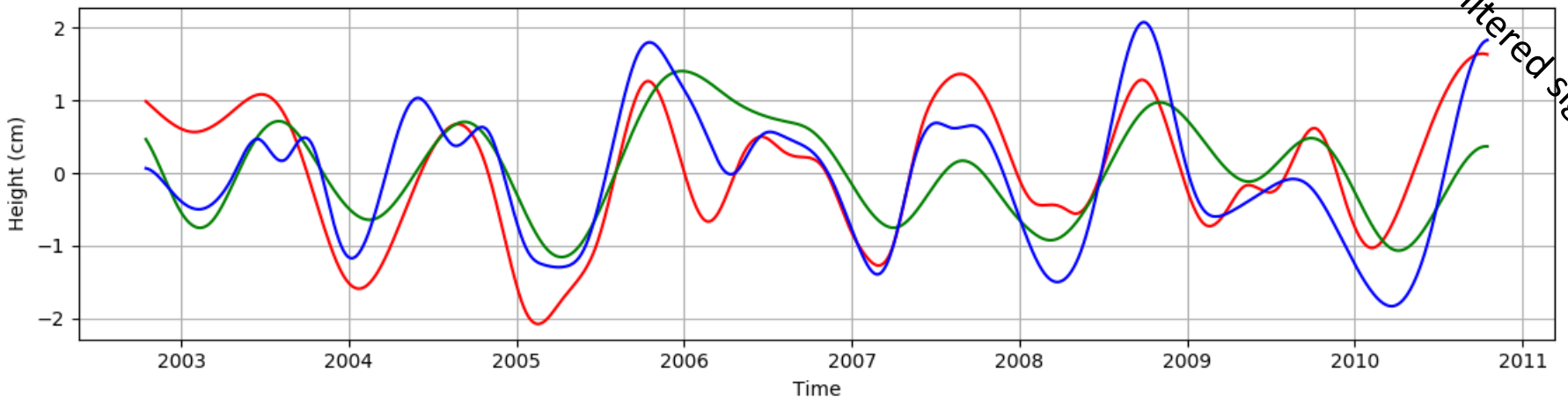


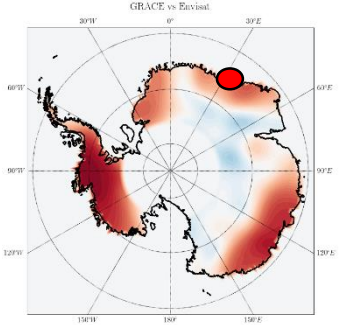
PIG

Original signal



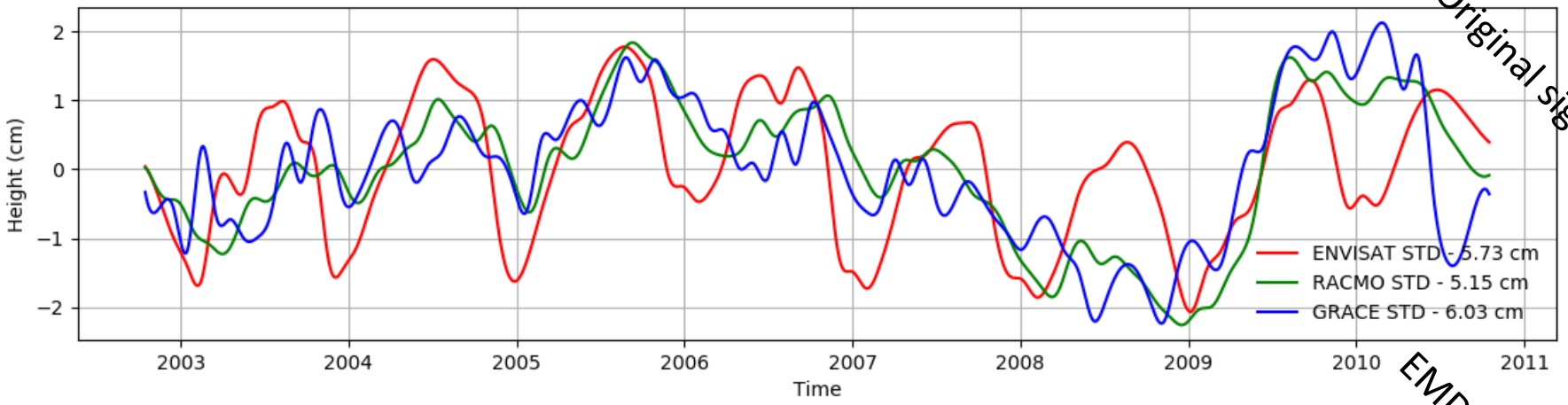
EMD filtered signal



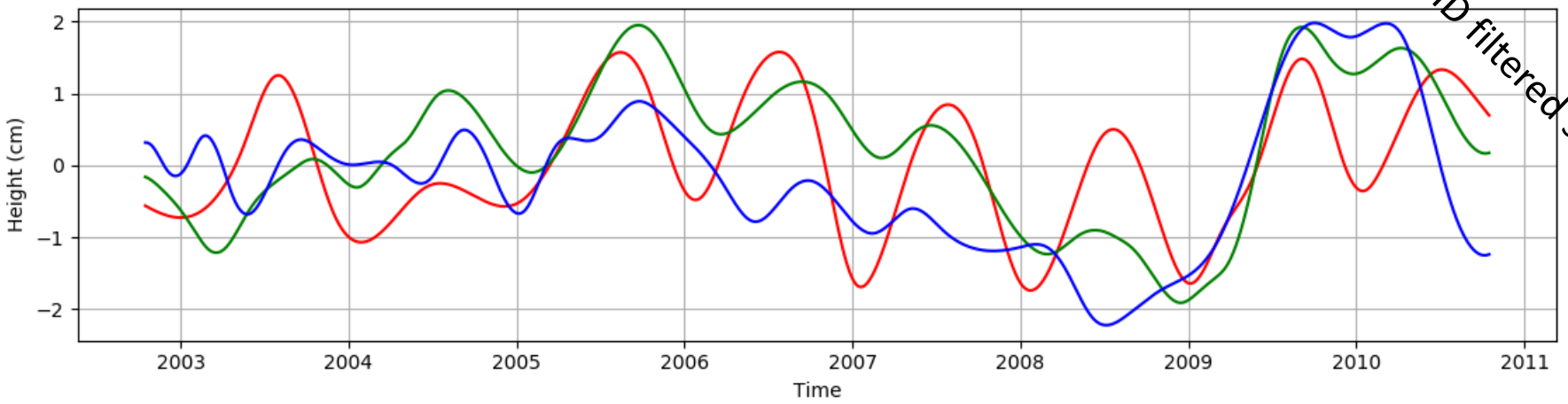


DML

Original signal

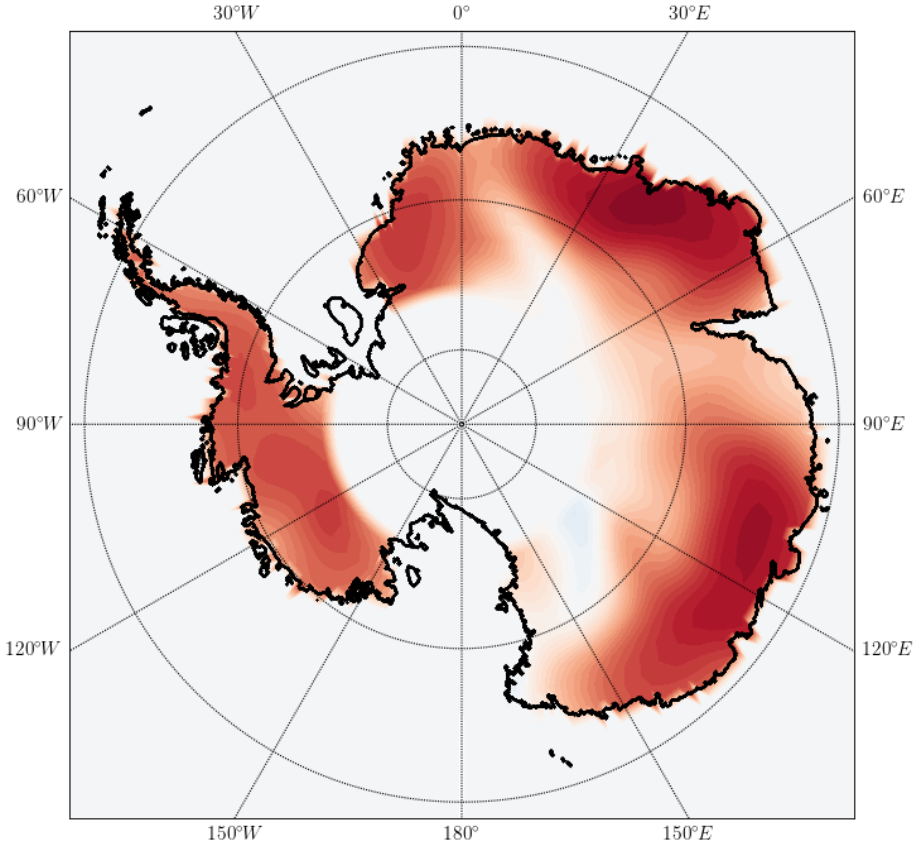


EMD filtered signal

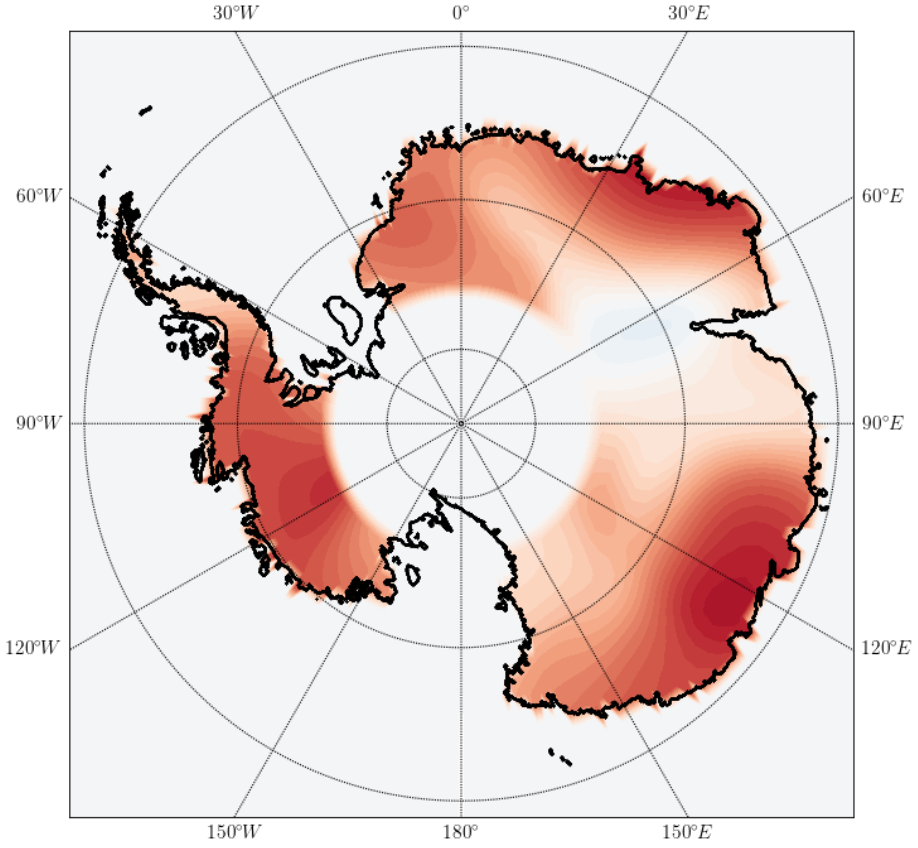


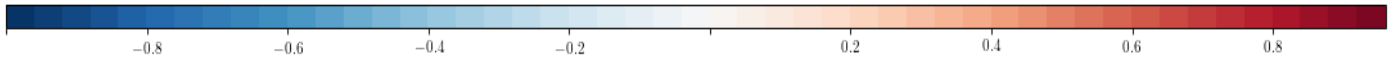
Correlation between

GRACE and RACMO



Envisat and RACMO





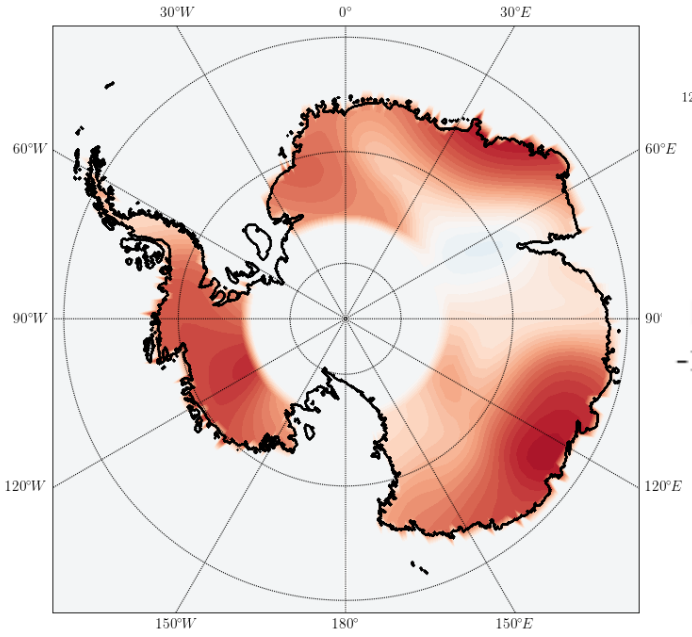
-1 0 1

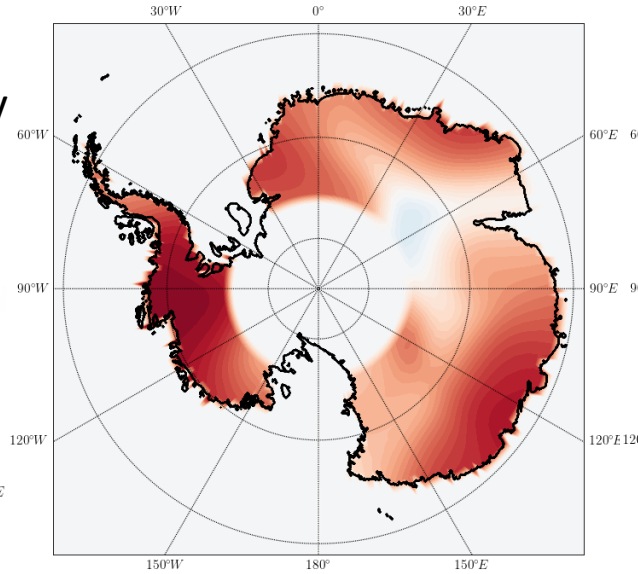
1 month

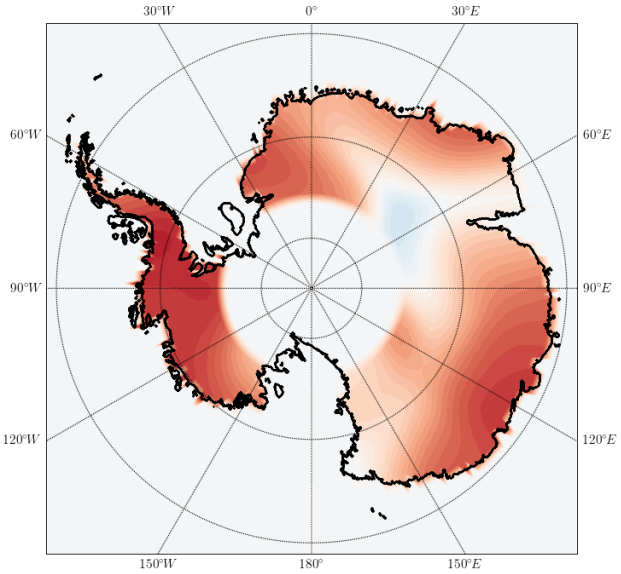
2 months

Advanced RACMO by

Correlation between Envisat and RACMO



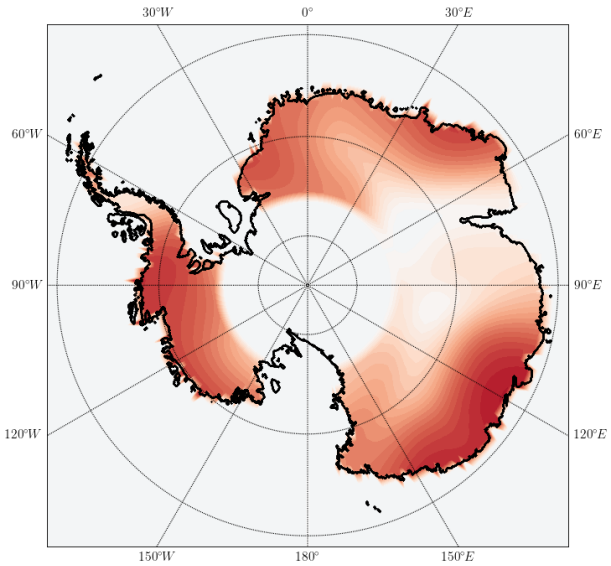


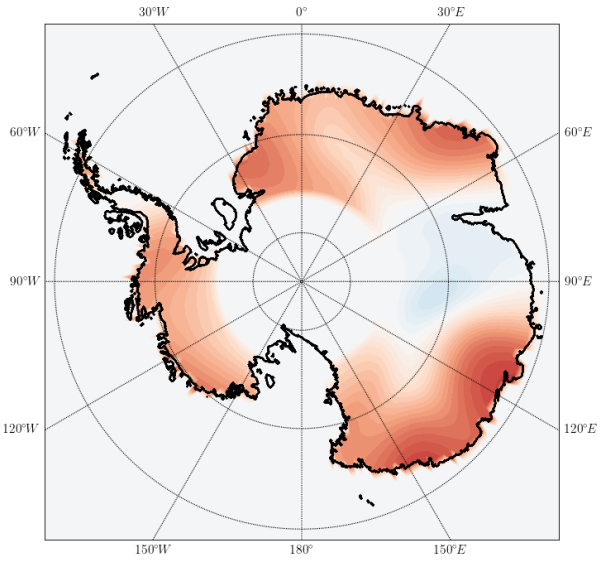


1 month

2 months

Delayed RACMO by



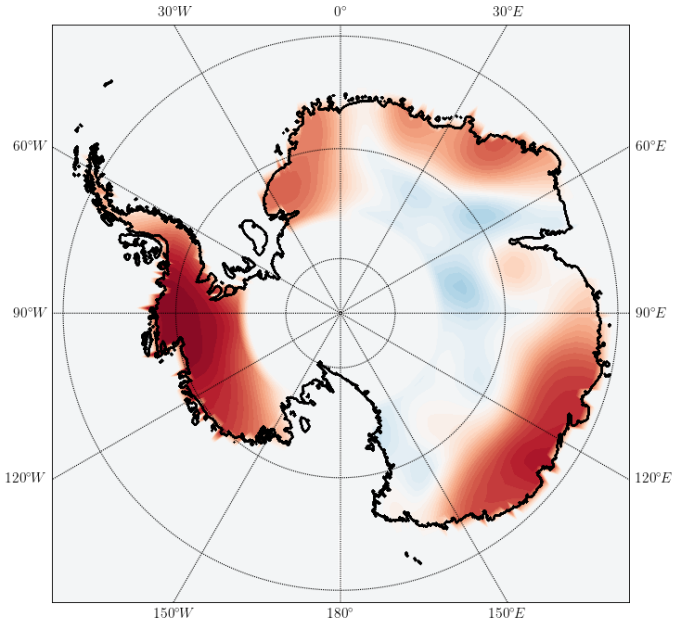


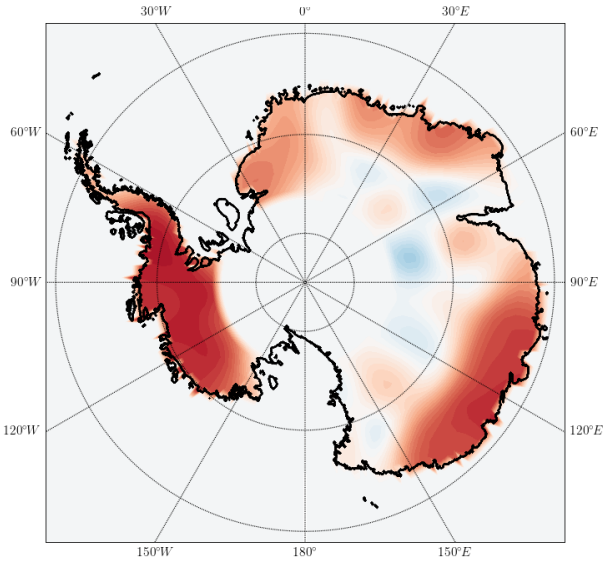
1 month

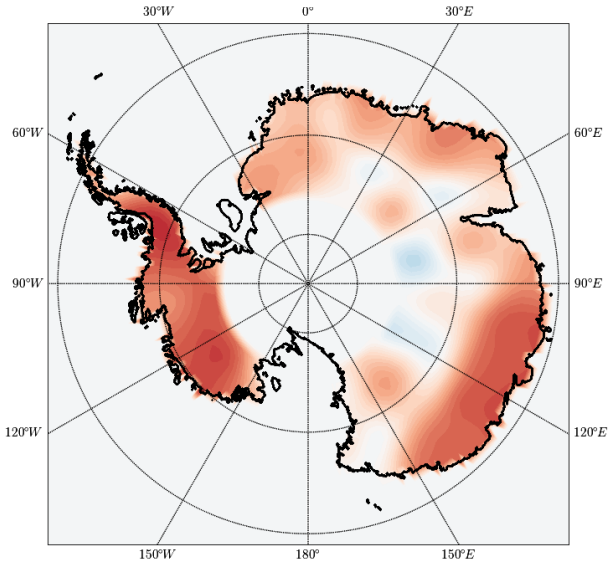
2 months

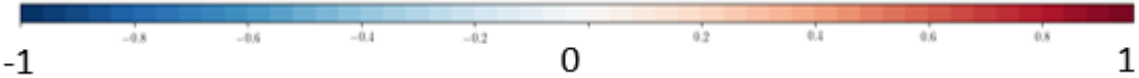
Advanced GRACE by

Correlation between
Envisat and GRACE





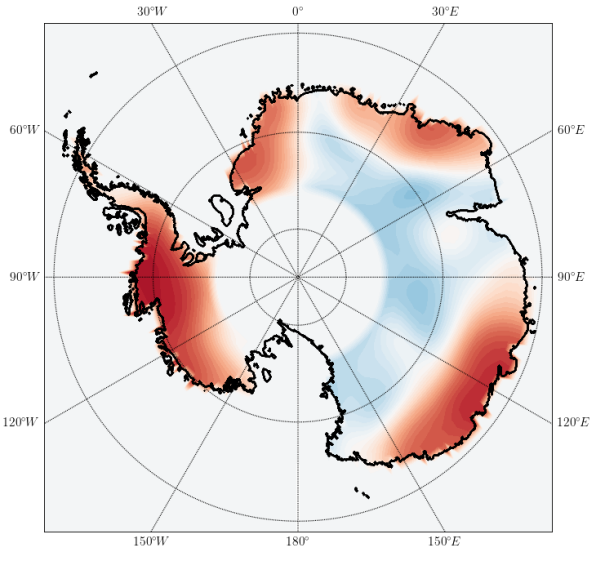


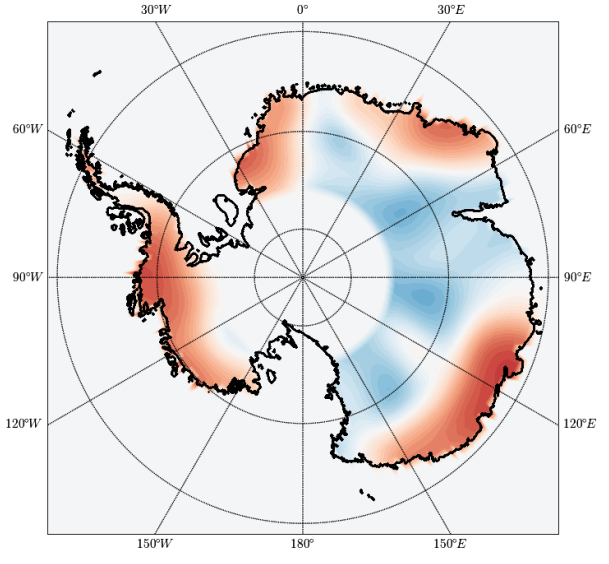


1 month

2 months

Delayed GRACE by



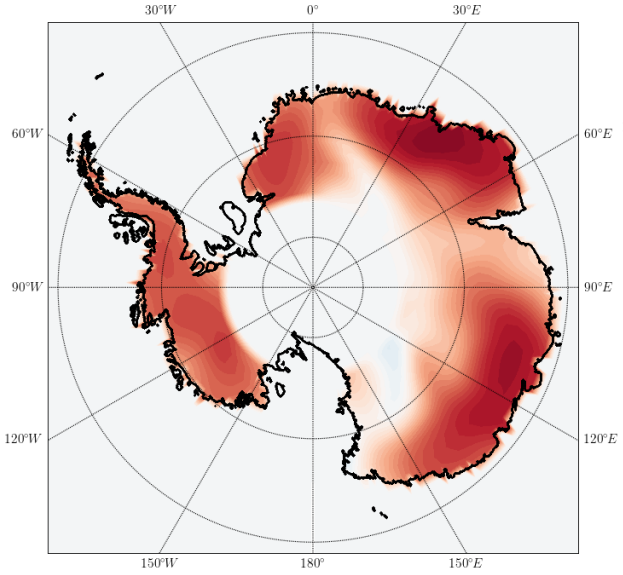


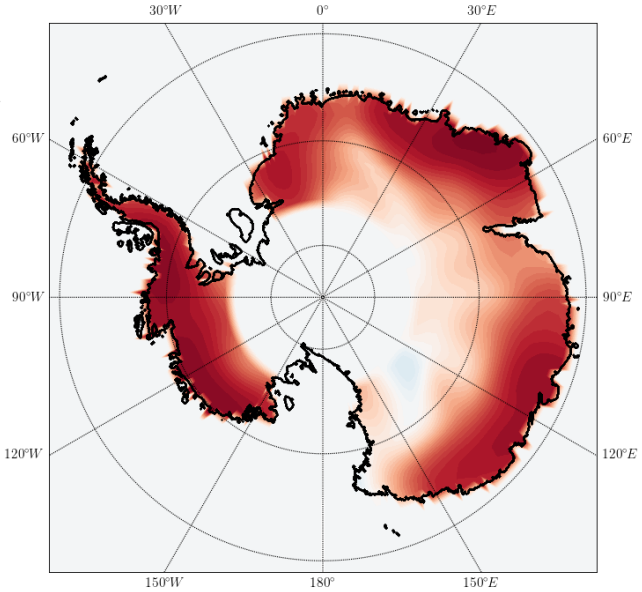
1 month

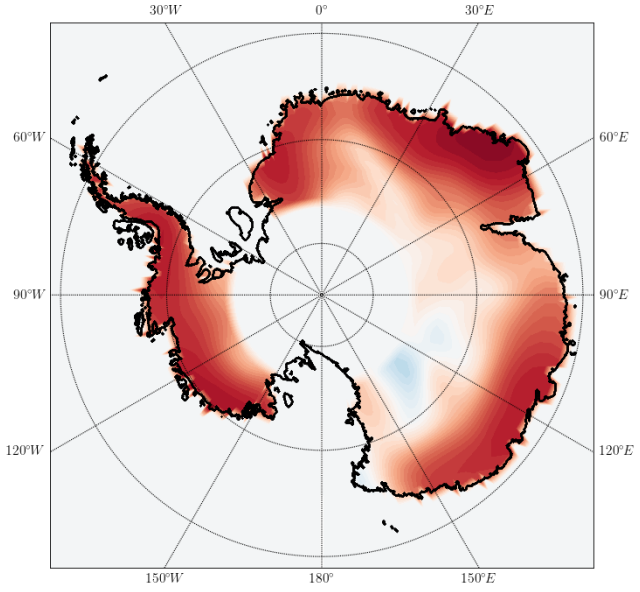
2 months

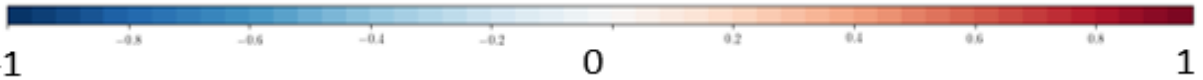
Advanced RACMO by

Correlation between GRACE and RACMO





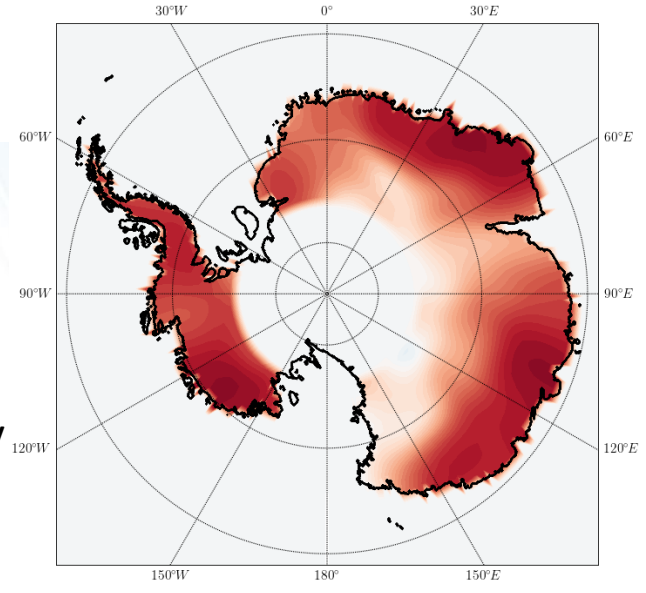


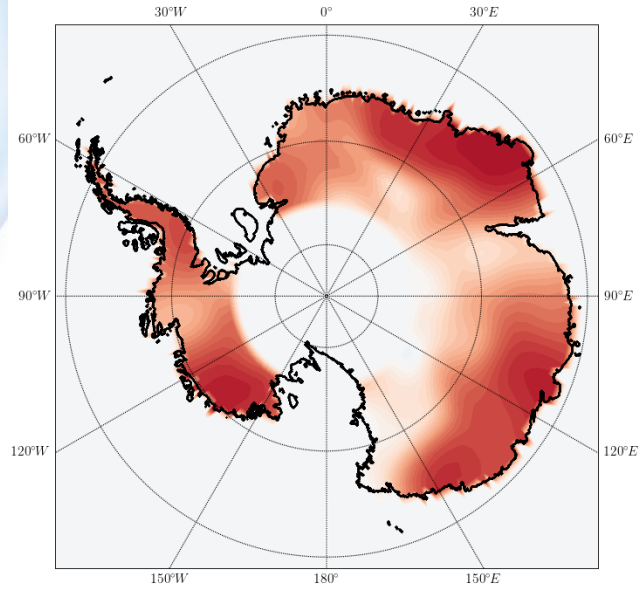


1 month

2 months

Delayed RACMO by





Conclusions

- Good seasonal signals observed in Western Antarctica
- Good correlation exist between GRACE and Envisat in Western Antarctica
- Correlation improved when RACMO signal shifted by a month which may be due to the effect of densification
- Adding densification may give better insights into height change estimation from RACMO

Thank You

Refernces

- Mémin, A., et al. "Snow-and ice-height change in Antarctica from satellite gravimetry and altimetry data." *Earth and Planetary Science Letters* 404 (2014): 344-353.
- Li, Jun, and H. Jay Zwally. "Modeling of firn compaction for estimating ice-sheet mass change from observed ice-sheet elevation change." *Annals of Glaciology* 52.59 (2011): 1-7.
- Rémy, Frédérique, and Frédéric Parrenin. "Snow accumulation variability and random walk: how to interpret changes of surface elevation in Antarctica." *Earth and Planetary Science Letters* 227.3-4 (2004): 273-280.
- van Wessem, Jan Melchior, et al. "Modelling the climate and surface mass balance of polar ice sheets using RACMO2: Part 2: Antarctica (1979-2016)." *Cryosphere* 12.4 (2018): 1479-1498.