MASCON versus spherical harmonic solutions to global monthly time varying gravity field

EGU General Assembly 2020
G4.1 Satellite Gravimetry:
Data Analysis, Results and Future Mission Concepts

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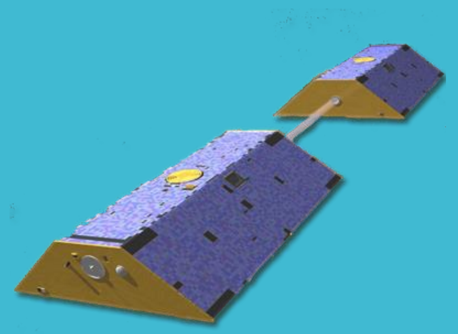
GRACE satellite mission

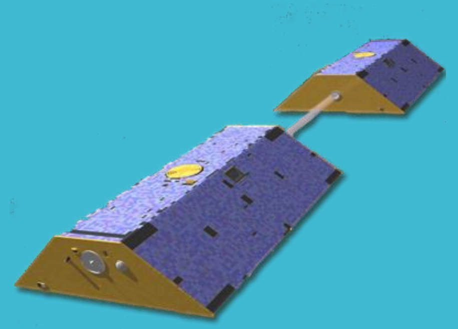


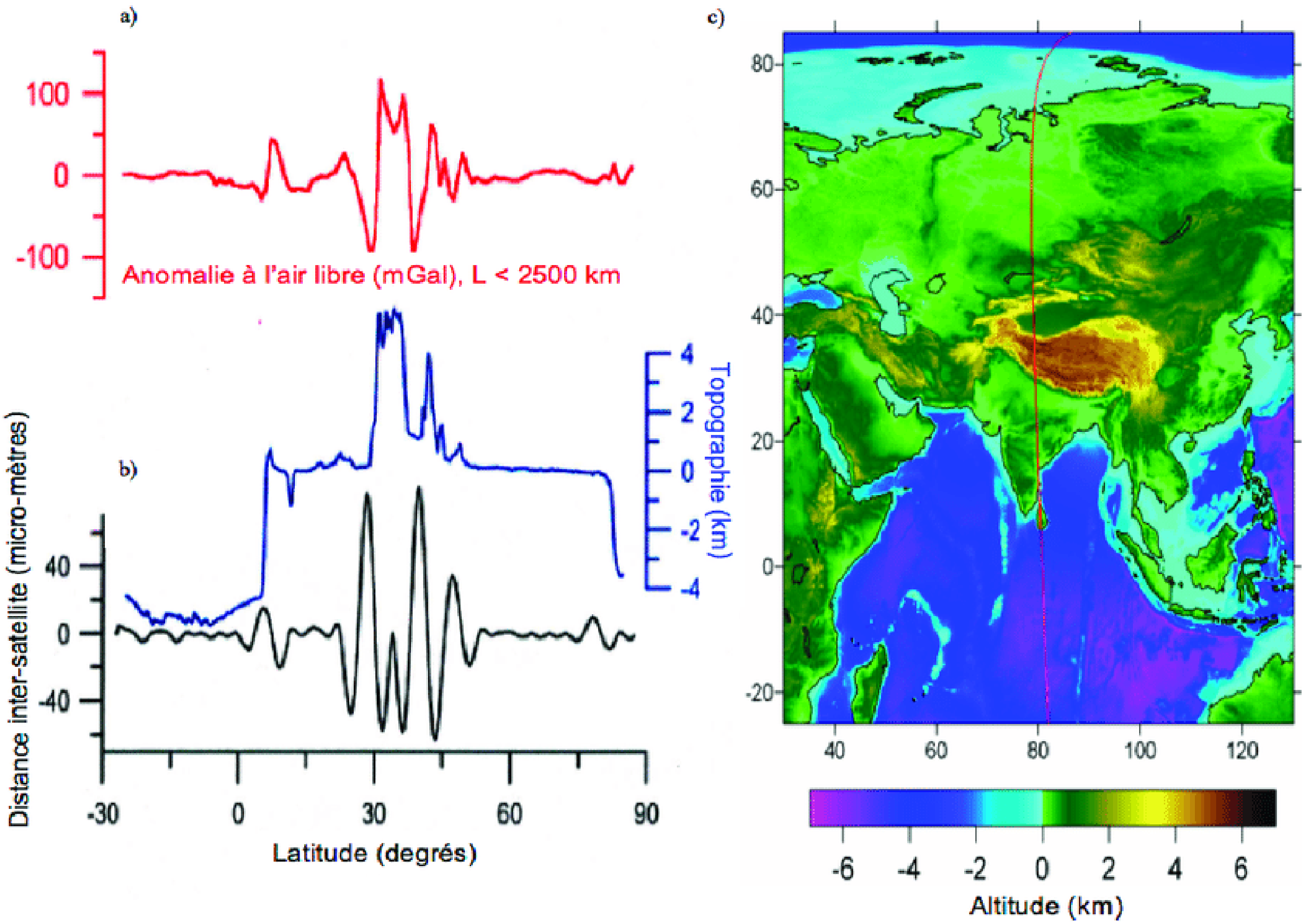
- provided necessary data
  for temporal global geopotential models (GGMs)
- one of the main aims –monitoring of mass redistribution
  on and below the Earth surface
- monthly intervals

  (although several authors and institutions now provide more continuous solutions - up to 10 days)
- 300 – 400 km data resolution

  (maximum degree and order of SHC 96)

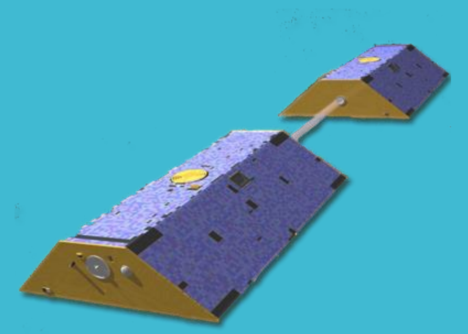
GRACE satellite mission





Correlation between free air anomaly, inter – satellite distance, latitude and altitude (Frappart et al., 2018)

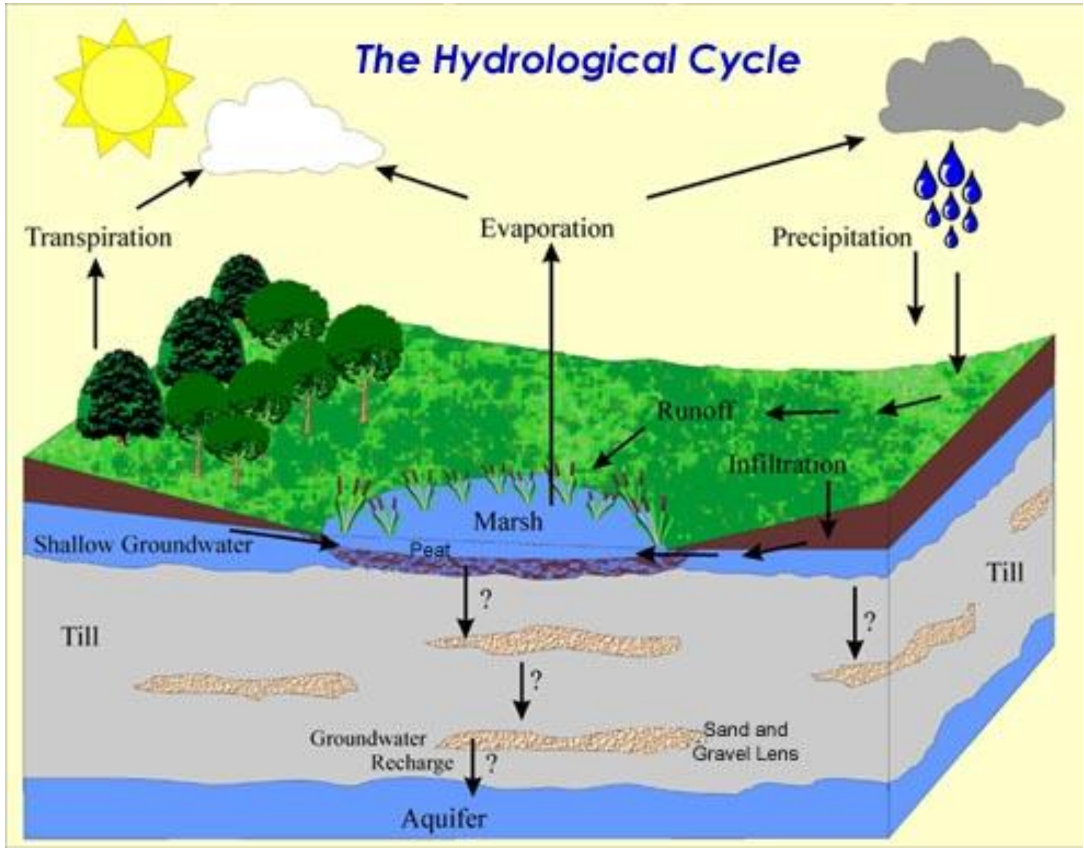
Equivalent water thickness



- Short – wavelength signal
  recovered by GRACE
  is caused predominantly
  by changes in total water storage
  (Ramilien a kol.,2008)

- Equivalent water thickness
  or total water storage consists of:

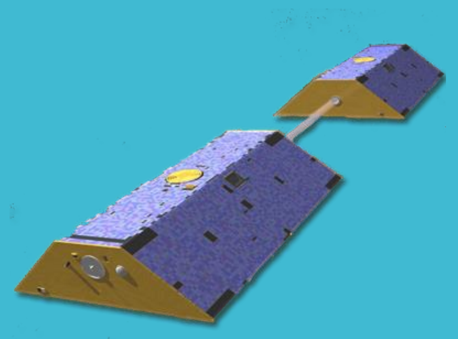
- groundwater
- soil moisture
- water stored as snow and ice
- rivers, wetlands, lakes, reservoirs
- water stored in plants



(Gimeno et al., 2012)

- 2 different approaches to recover mass distribution in time

Spherical harmonics solution

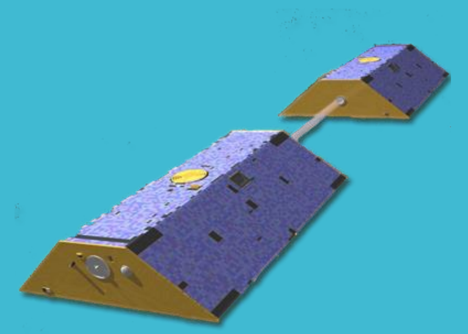


- Approach proposed by (Wahr et al., 1998)
- Based on monthly GGMs stored as spherical harmonic coefficients

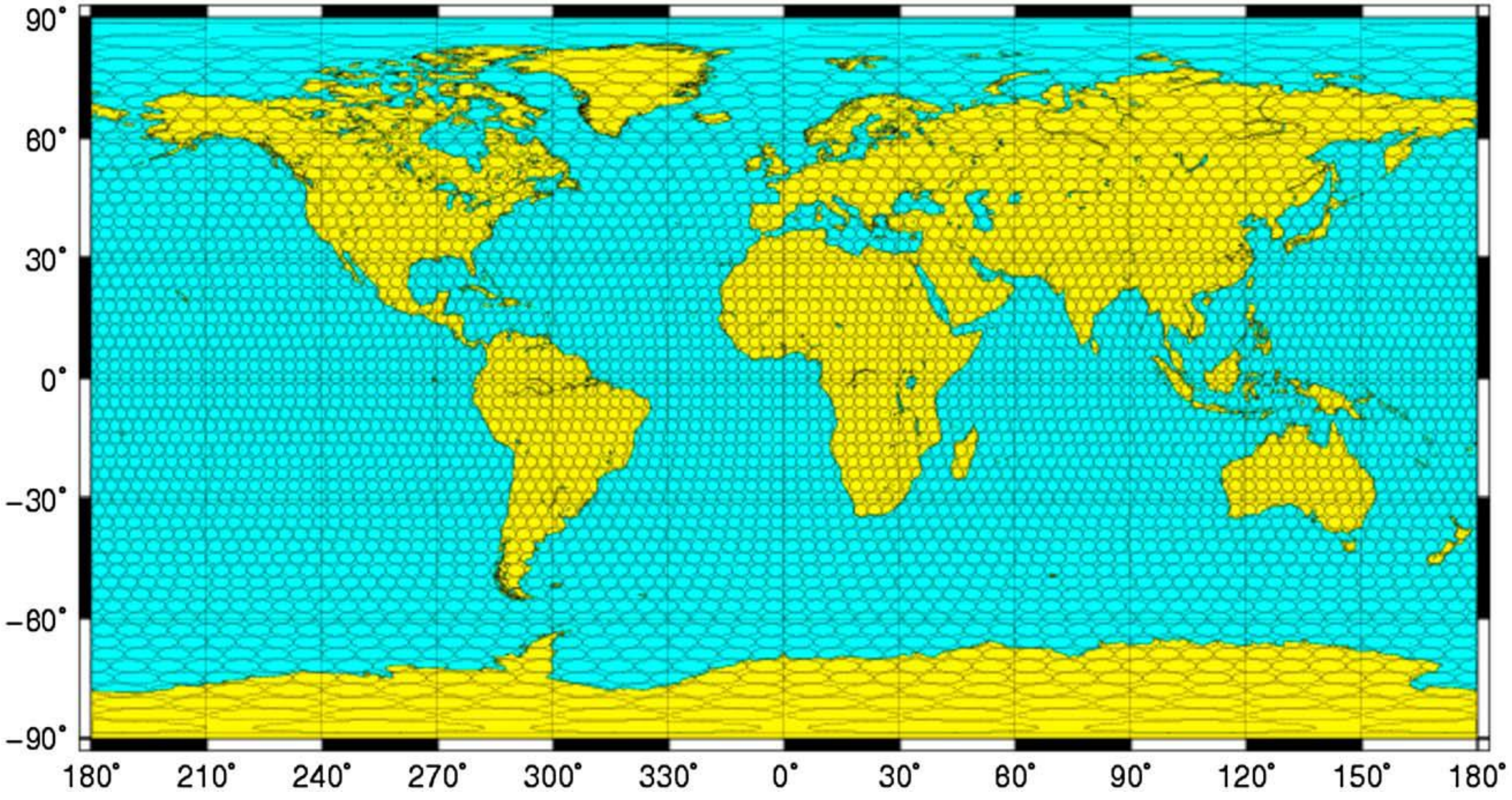
$$EWT = \frac{R \cdot \rho_{av}}{3} \sum_{n=0}^{n_{max}} \frac{2n+1}{1+k_n} \sum_{k=0}^{n} \left(C_{n,k} \cdot \cos k\lambda + S_{n,k} \cdot \sin k\lambda\right) \cdot \bar{P}_{n,k}(\sin\varphi)$$

- Use of computational platforms such as GrafLab (Bucha, Janák, 2013) , GRAVSOFT (Nielsen et al., 2012), IGiK–TVGMF(Godah, Walyeldeen, 2018) can speed up the computational process

MASCON solution

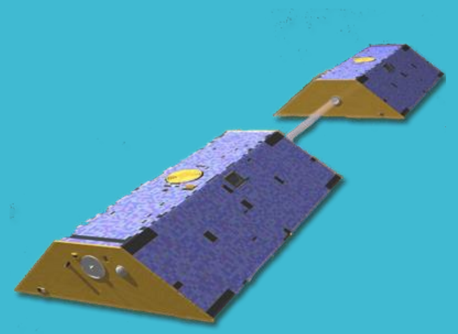


- Abbreviation of words Mass-Concentration
- Recent solution in mass variation monitoring



Global 3° equal – area spherical cap mascons (Watkins et al. 2015)

MASCON solution



Advantages (Watkins et al. 2015)

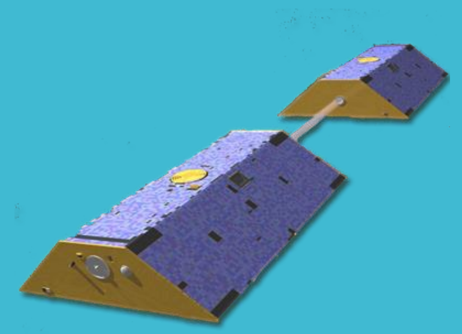
- Derived from inter-satellite distance
- Doesn't require use of filtration
- Scaling based on hydrological model - GLDAS
- Reducing EWT signal leakage in coastal areas

Global 1° equal – area spherical cap mascons monthly solutions available at:

https://earth.gsfc.nasa.gov/geo/data/grace-mascons

(Luthcke et al., 2013)

Data comparison



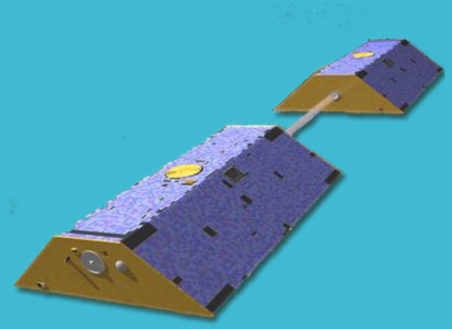
Quantifying mutual differences of both solutions (taking mascon solution as reference) using following values:

- Standard deviation of differences [cm]
- Agreement [%] - computed as a ratio between number of months within 2 sigma confidence interval of MasCon solution to total number of compared months
- Comparing monthly averages of EWT values through selected regions

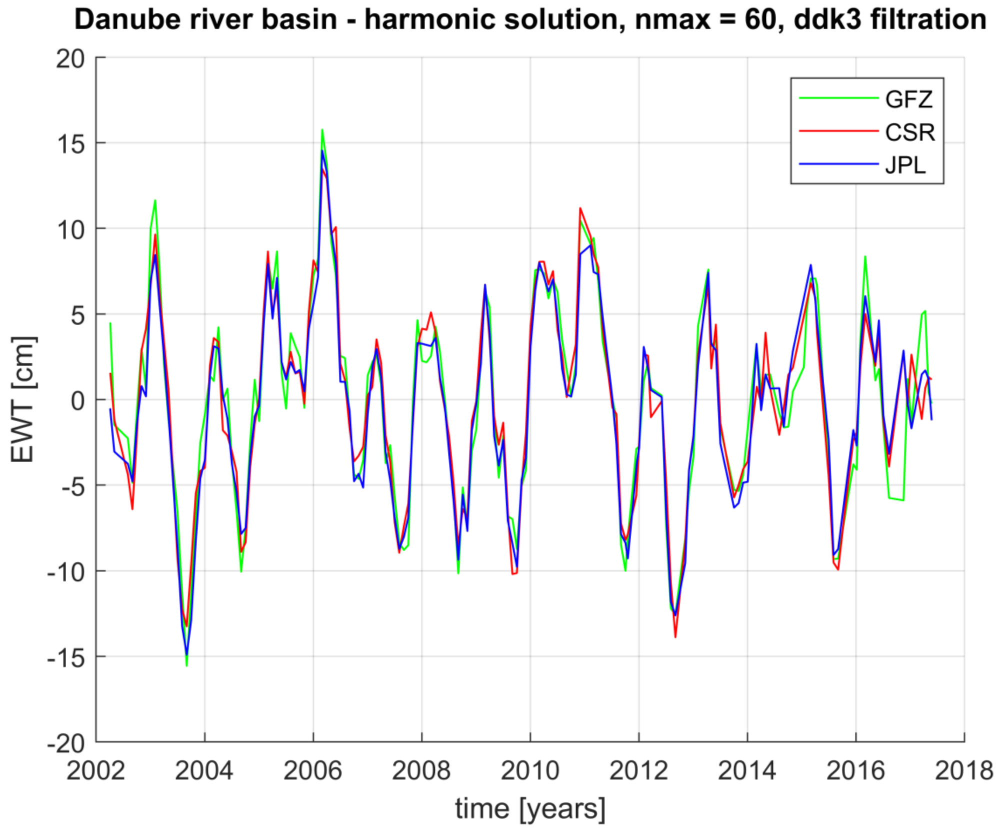
Computational regions – river basins varying in size of area, seasonal changes and latitude and 3 points representing the area of Greenland

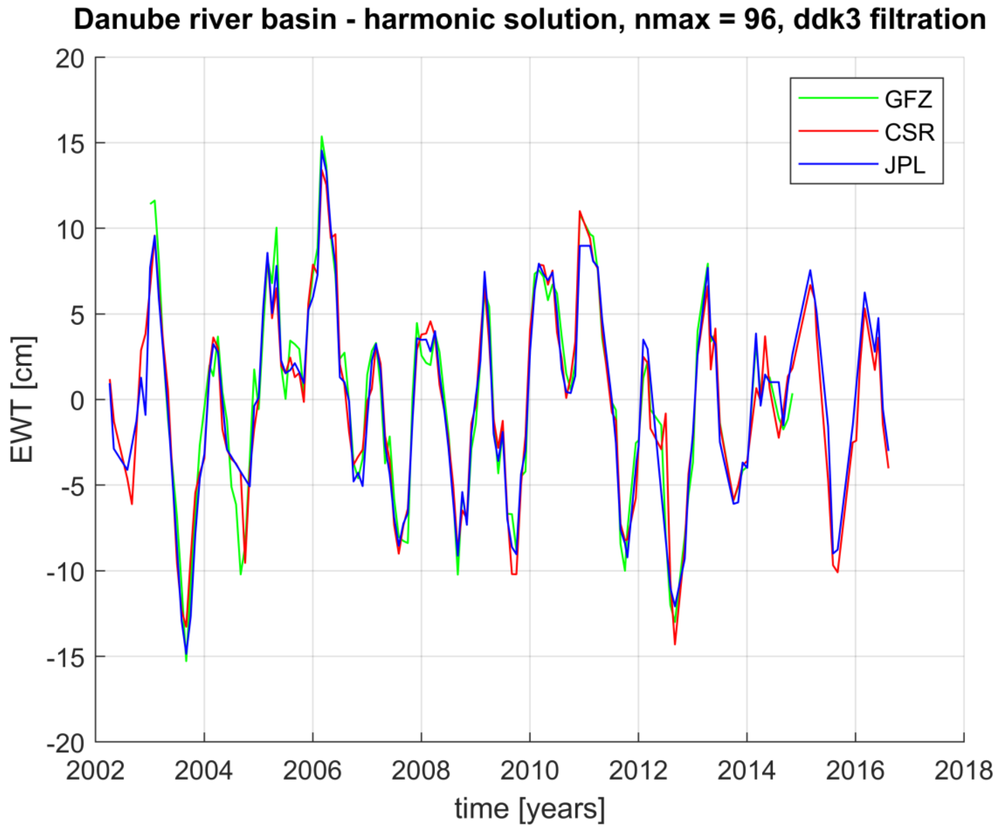
Chosen basins have minimal area neighboring coast to minimalize the signal leakage in spherical harmonics solution

Areas
of interest



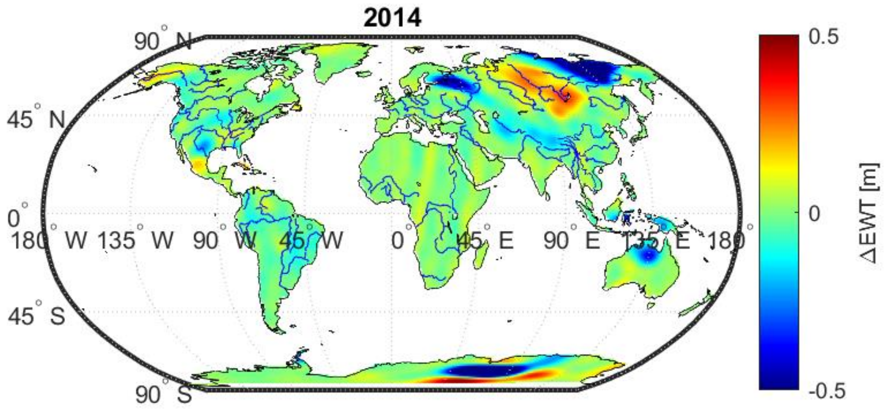
Differences between maximum degree and order of GGMs 60 and 96 (BA and BB) in spherical harmonic solution



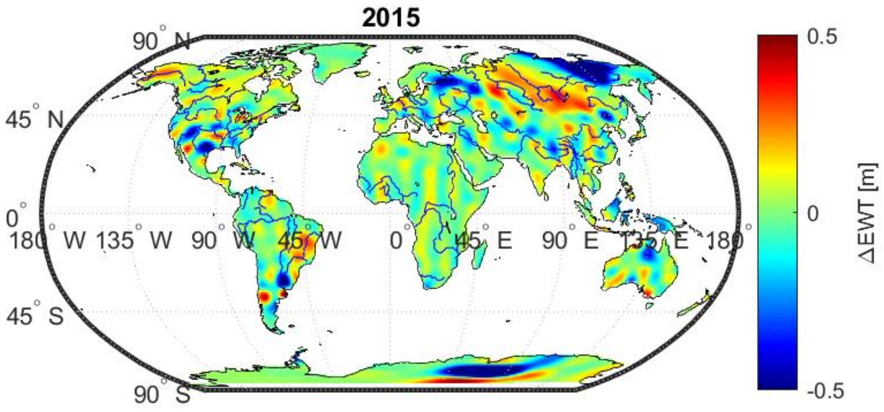


Additional 36 degrees and orders haven't brought significant improvement, just increase of spatial resolution

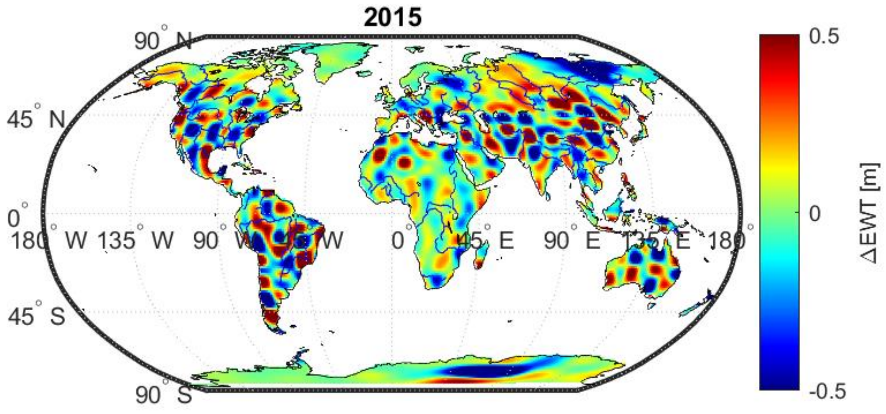
Identifying wrong months of CSR solution (nmax = 96)



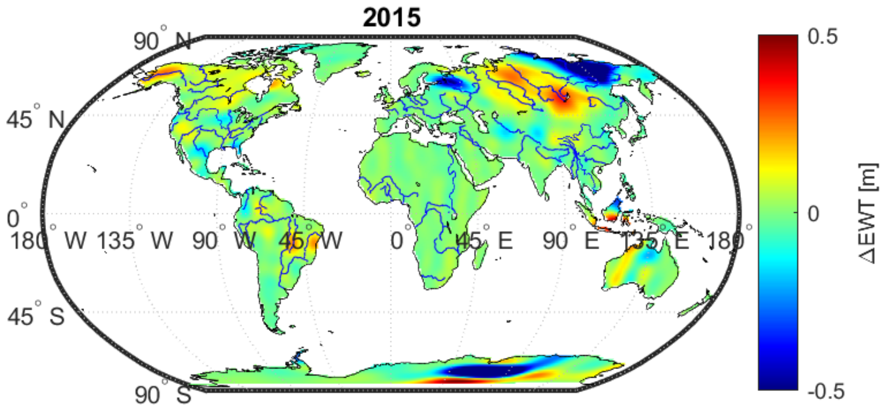
December 2014



January 2015

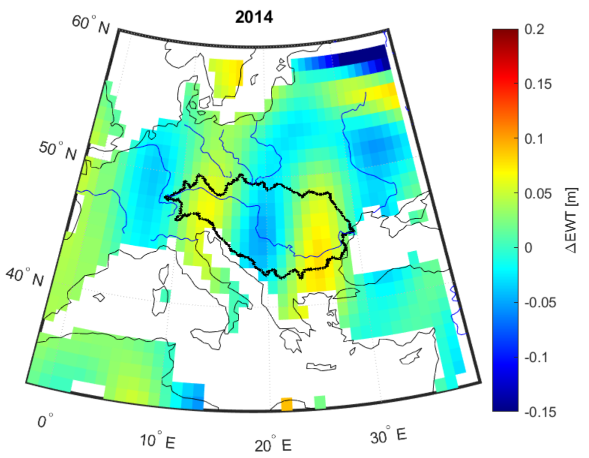


February 2015

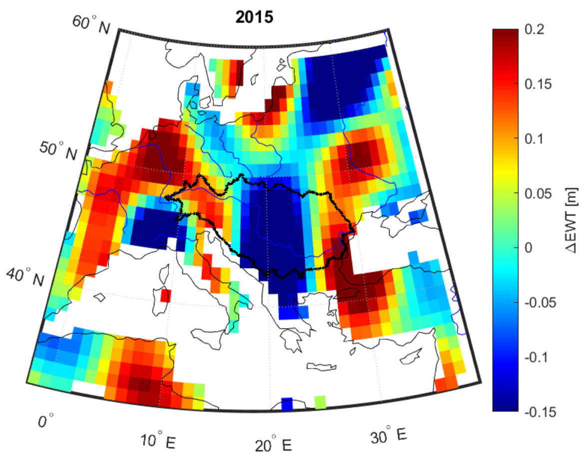


March 2015

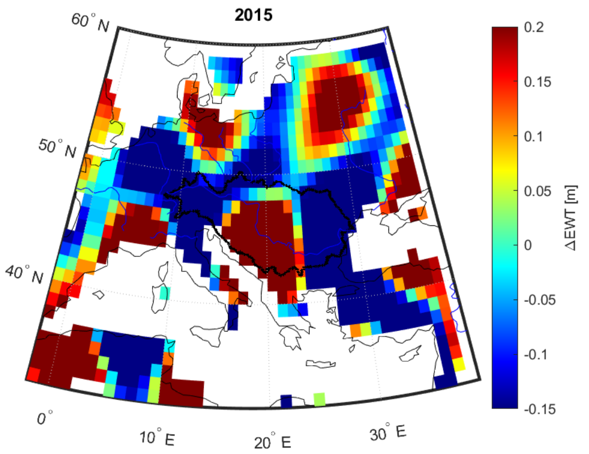
Identifying wrong months of CSR solution (nmax = 96) *in detail*



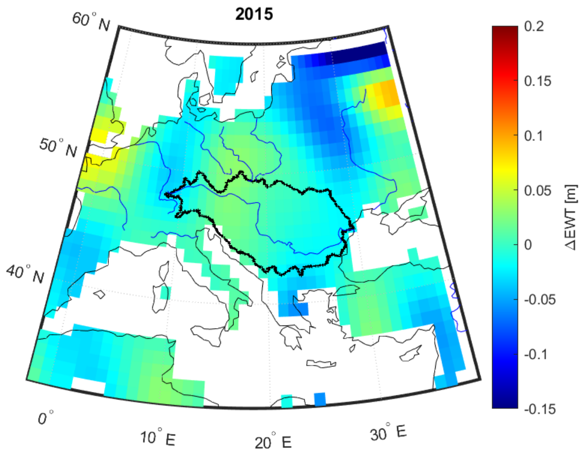
December 2014



January 2015



February 2015

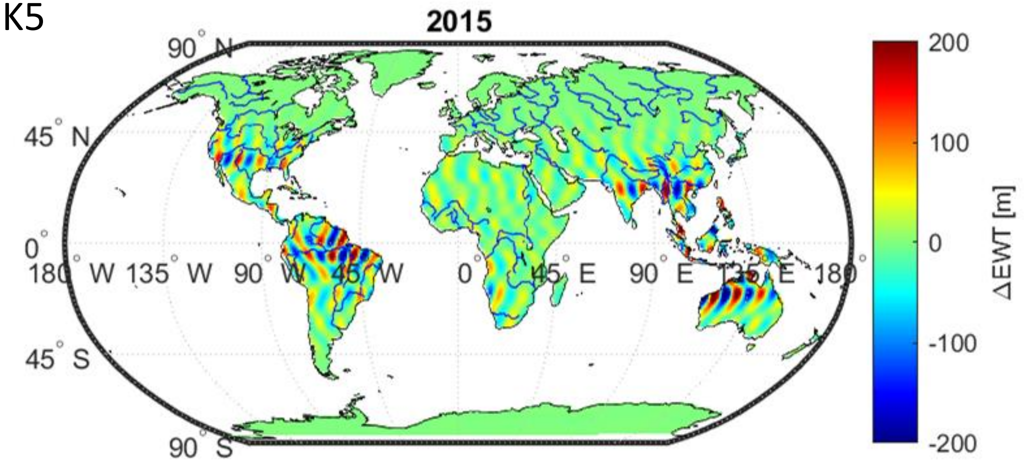


March 2015

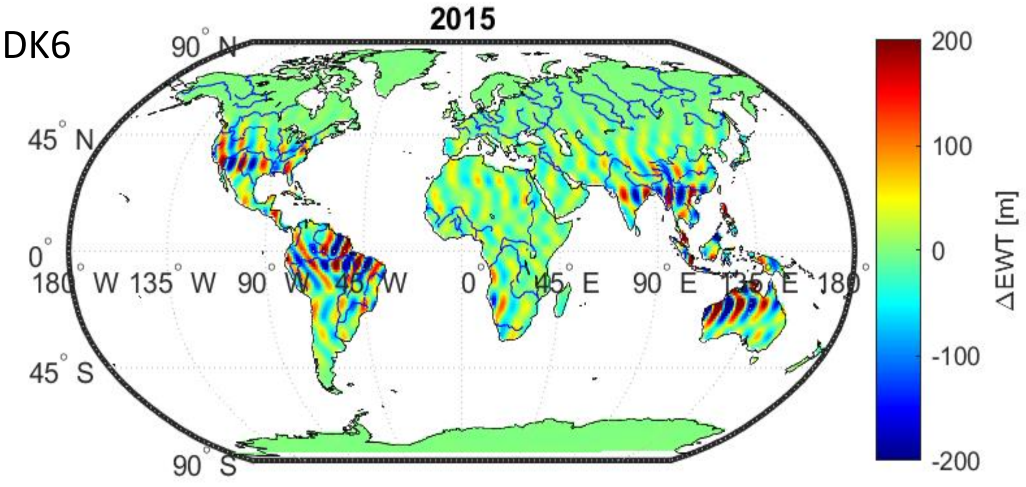
- EWT values in months January and February of 2015 weren‘t used in comparison due to strong presence of artifacts
- Artifacts were present in all filtrations DDK1 to DDK8
- Stronger filtration tend to make greater artifacts

Different filtrations of January 2015, JPL solution (nmax = 96)

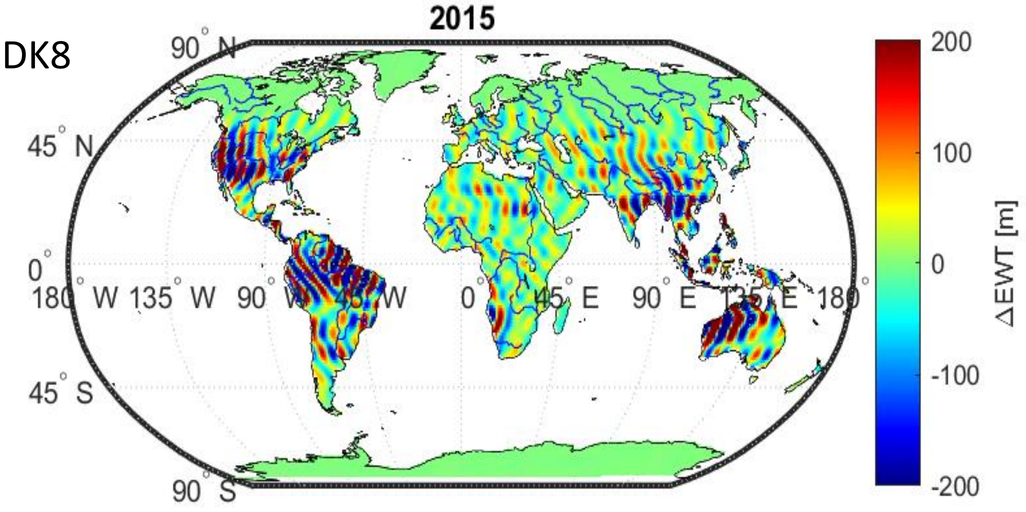
DDK5



DDK6

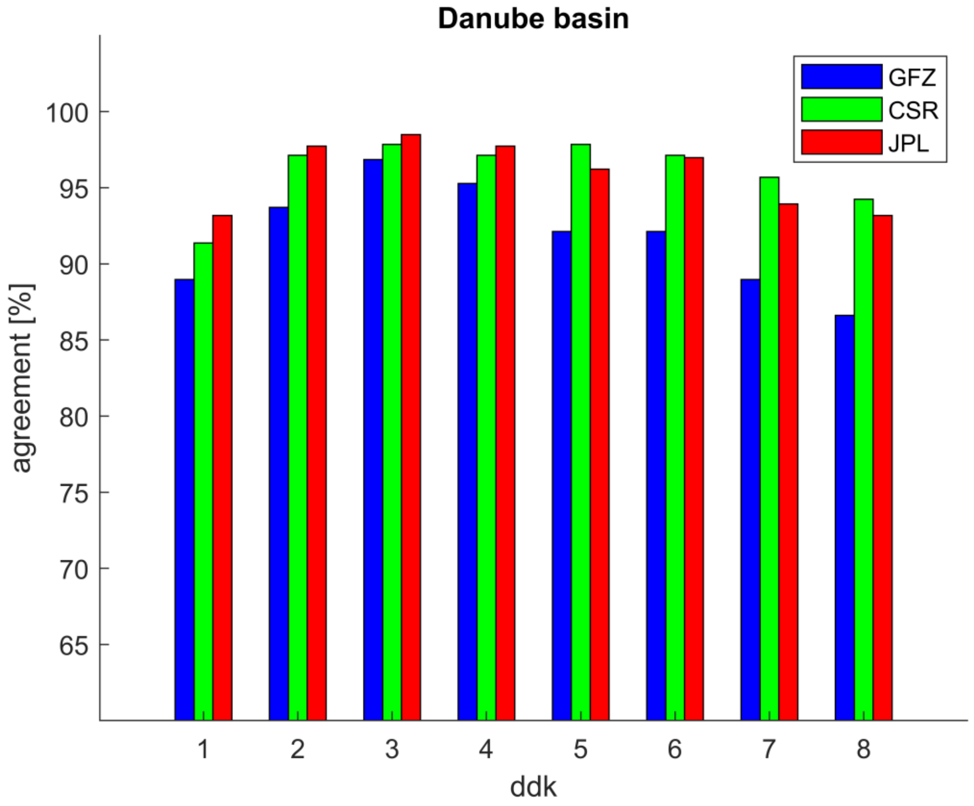


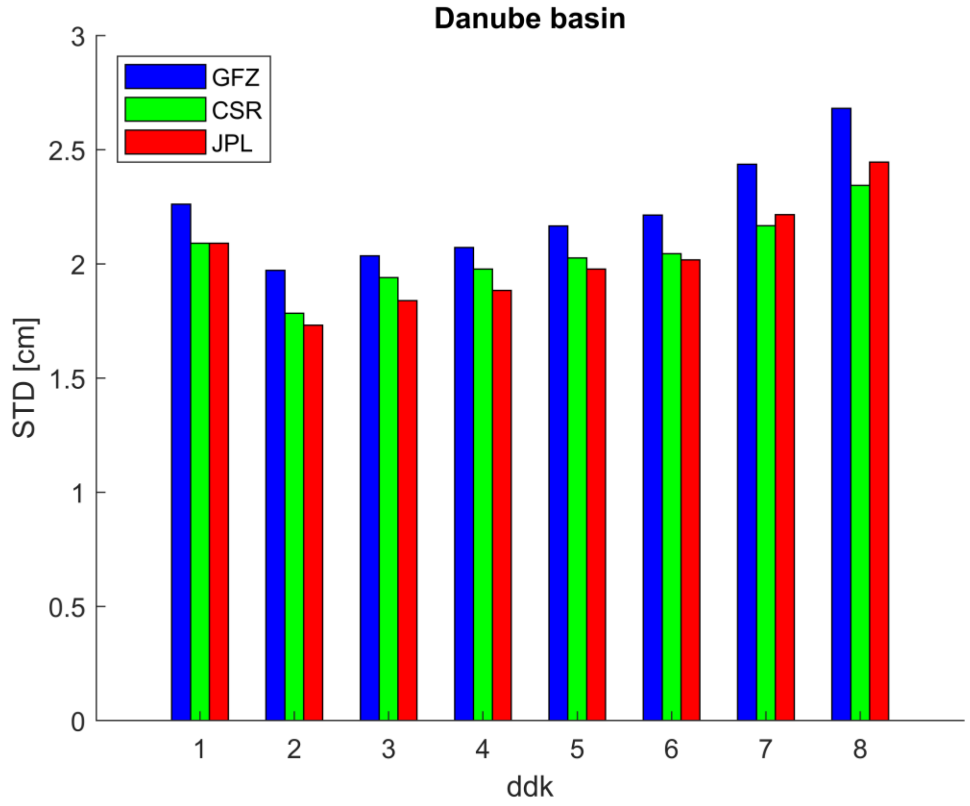
DDK8



- Artifacts present in all filtrations (DDK1 - DDK8)
- Stronger filtration tends to make artifacts smaller
- Later comparisons don‘t include these months

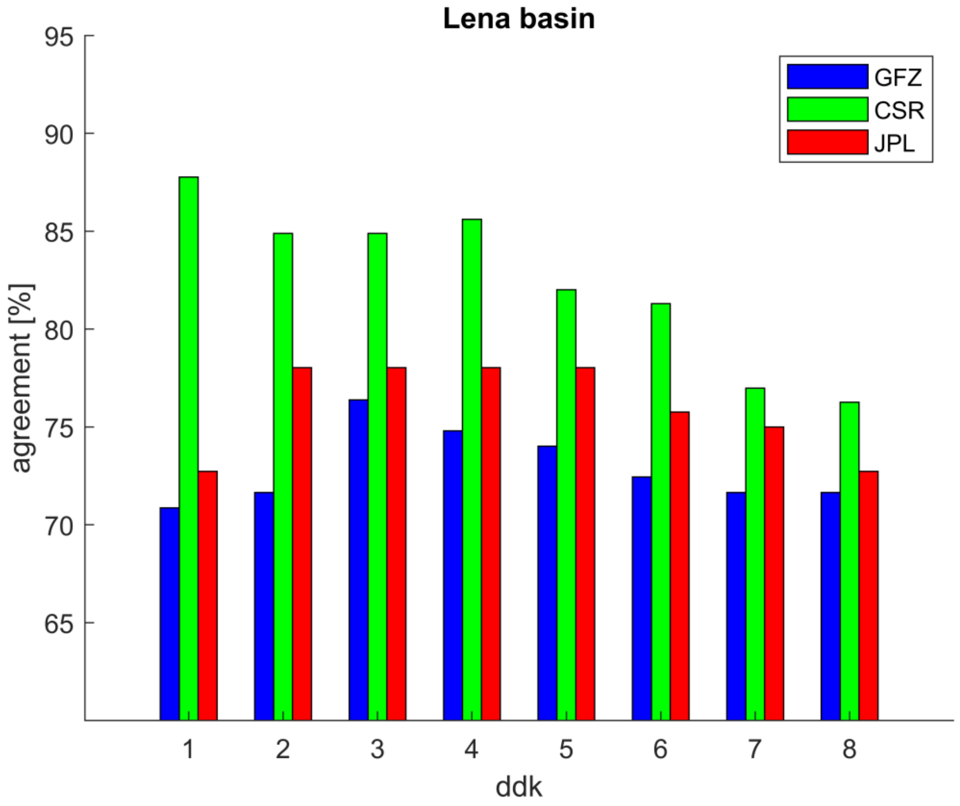
Different filtrations of monthly GGMs in comparison with global 1° GSFC Mascon solution in Danube river basin

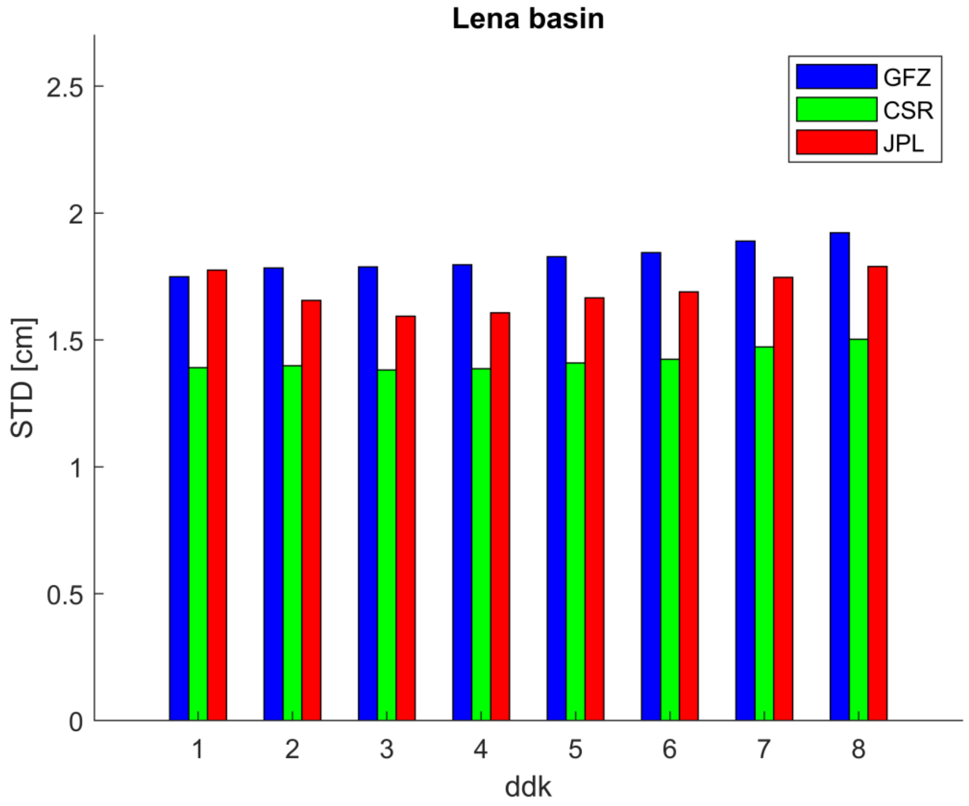




- Comparison of corresponding months
- Excluding months january and february of 2015 in both CSR and JPL solutions

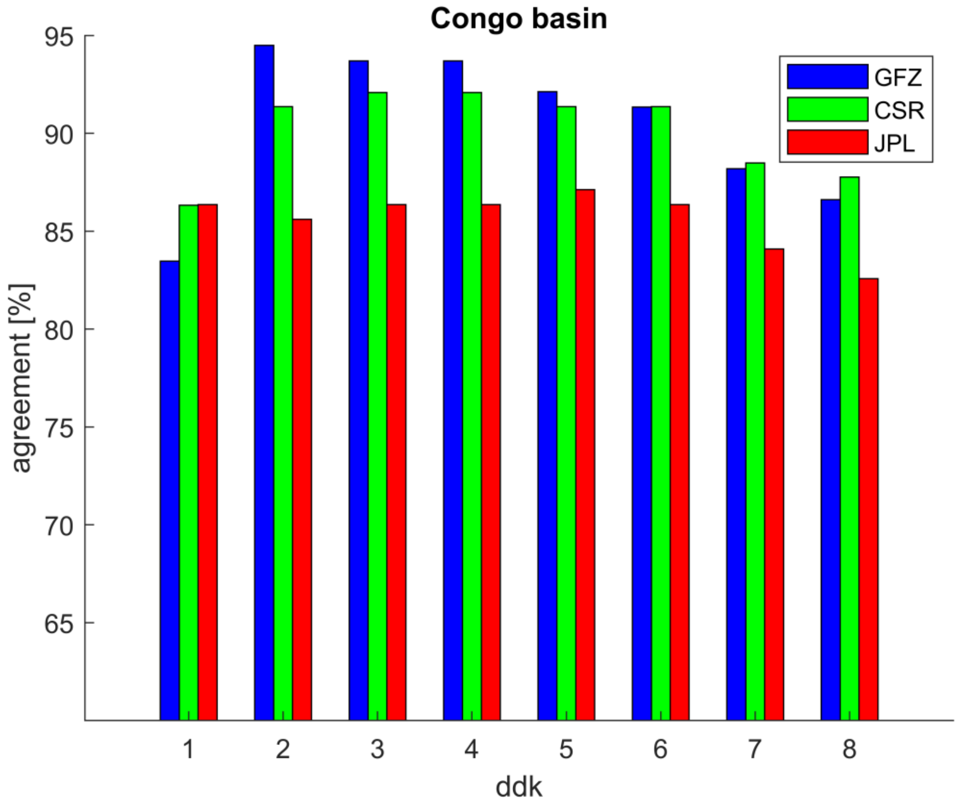
Different filtrations of monthly GGMs in comparison with global 1° GSFC Mascon solution in Lena river basin

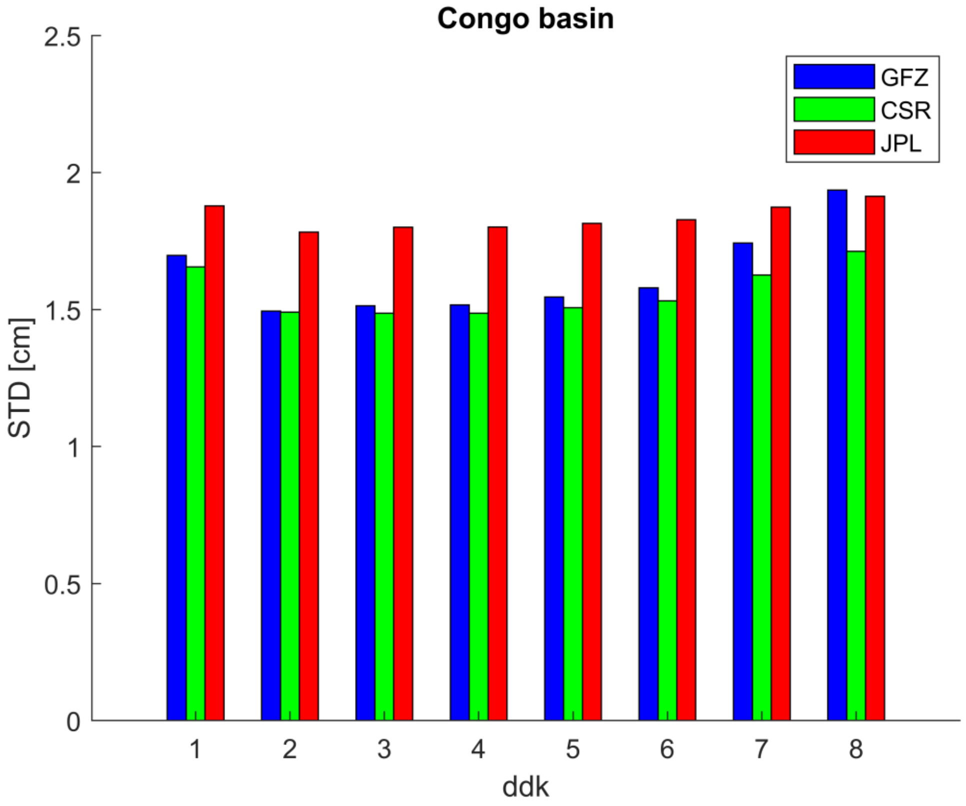




- Comparison of corresponding months
- Excluding months january and february of 2015 in both CSR and JPL solutions

Different filtrations of monthly GGMs in comparison with global 1° GSFC Mascon solution in Congo river basin





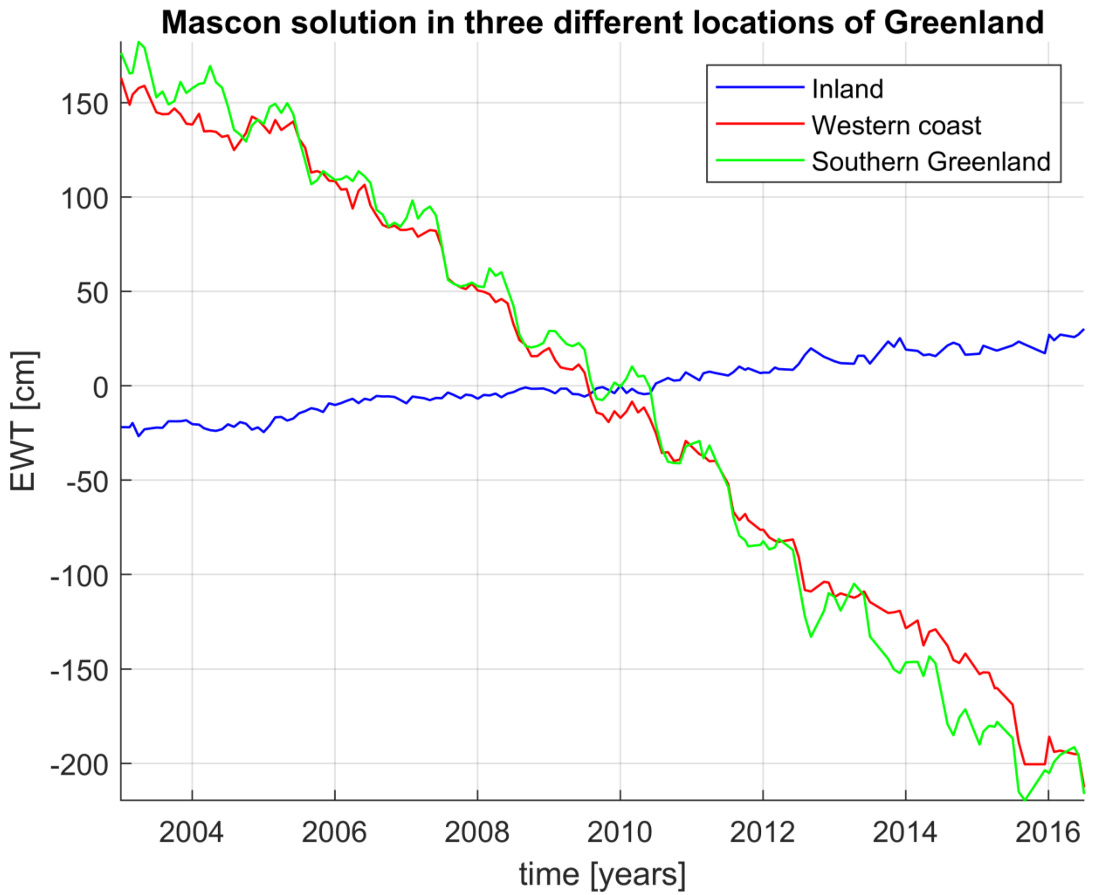
- Comparison of corresponding months
- Excluding months january and february of 2015 in both CSR and JPL solutions

Comparison of solutions in Greenland

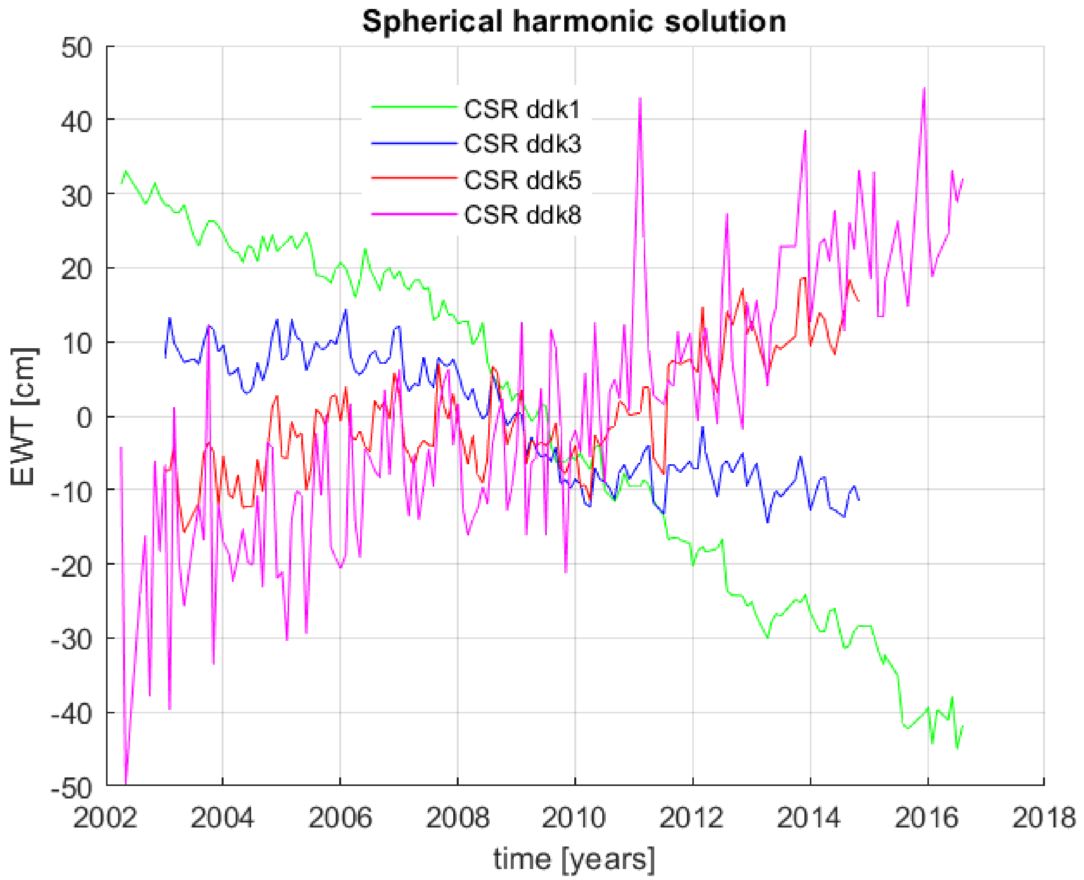
As Greenland is a very complex area, at the same time in one part of the region an increase in mass amount can be recorded and decrease in a different part.
Therefore we decided to substitute the area of Greenland with 3 single points:
Point 1: $\varphi = 78°$, $\lambda = 312°$ (-48°) - Inland
Point 2: $\varphi = 72°$, $\lambda = 308°$ (-52°) – Western coast
Point 3: $\varphi = 65°$, $\lambda = 310°$ (-50°) – Southern Greenland

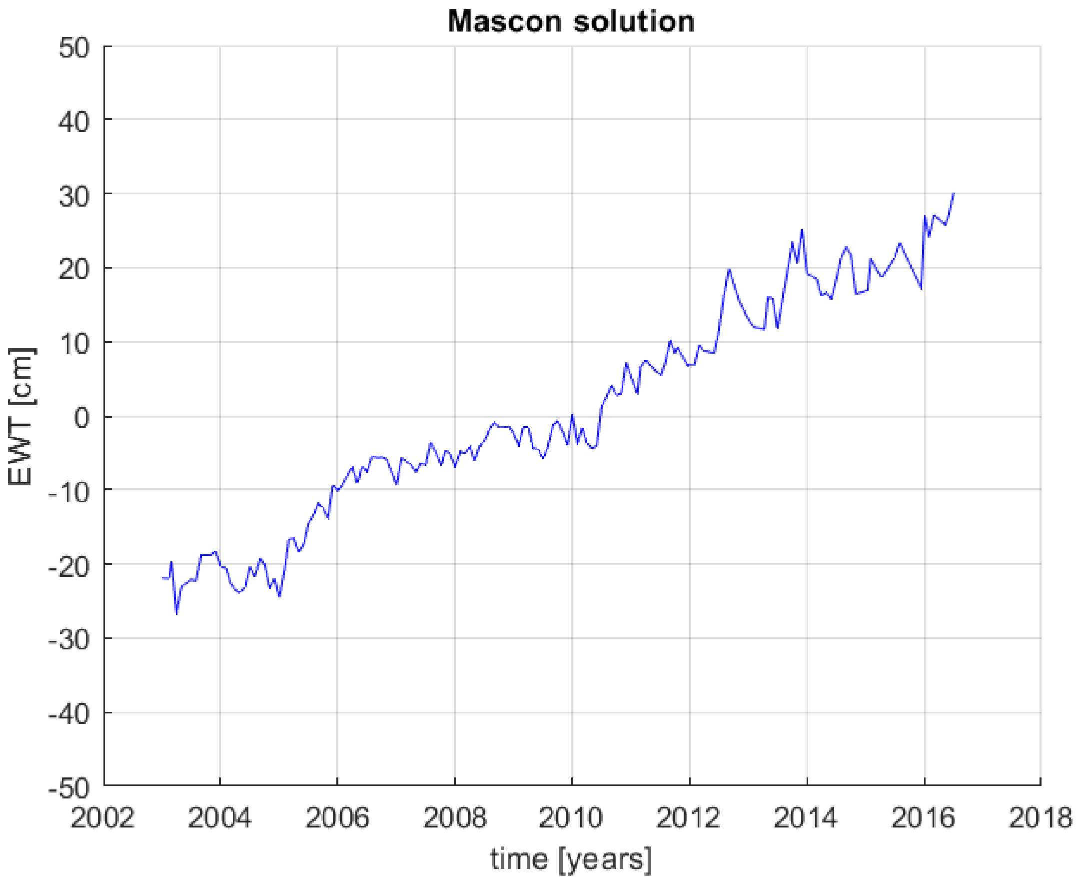
Due to much greater differences between the two solutions we decided to aim more for linear trend than for the earlier mentioned values.

Surprisingly point located inland showed a small long-term increase in the recovered mass amount in Mascon solution.

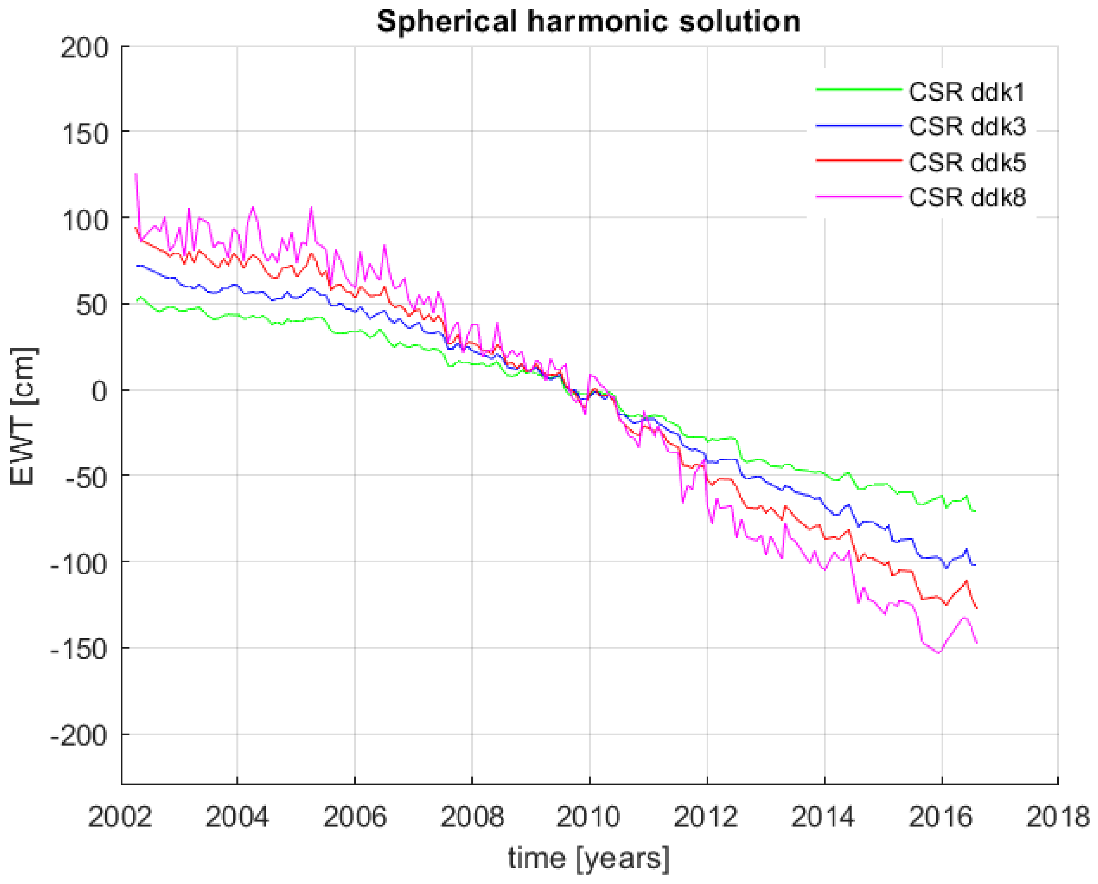


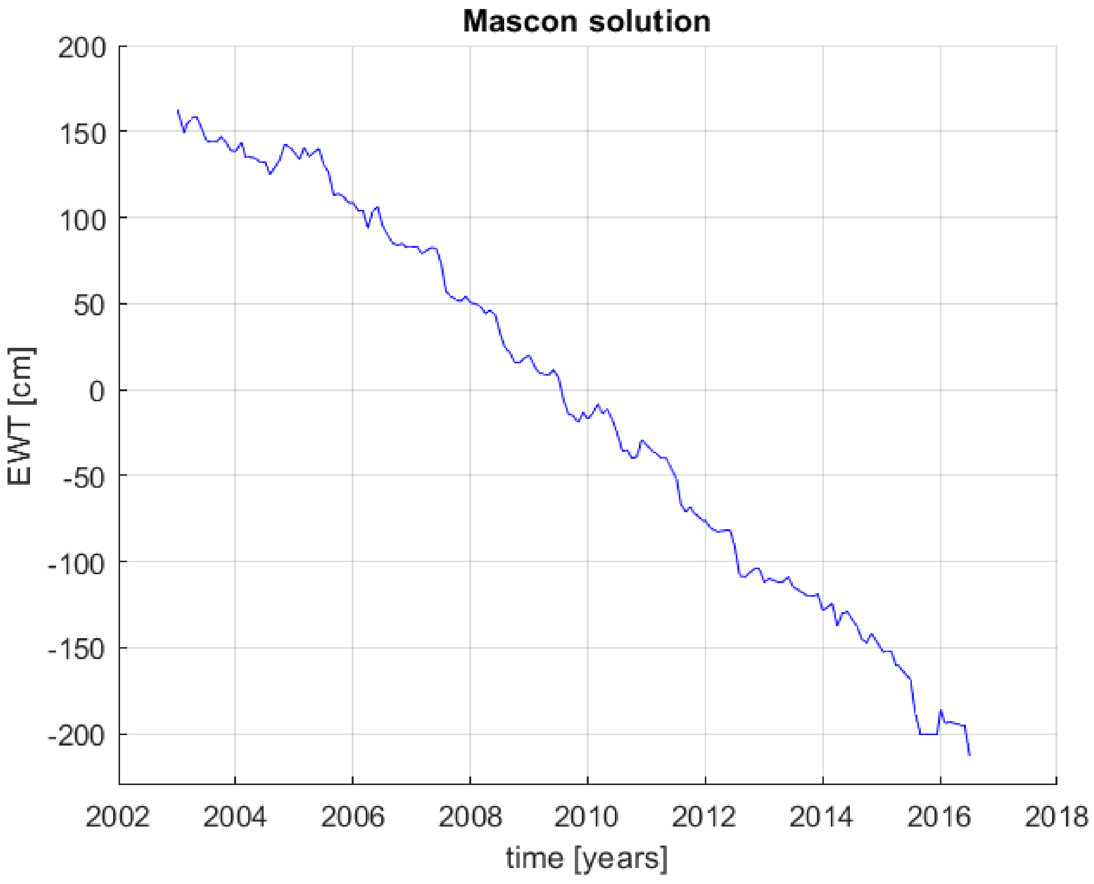
Graphical comparison of spherical harmonics solution with mascon solution for point located inland



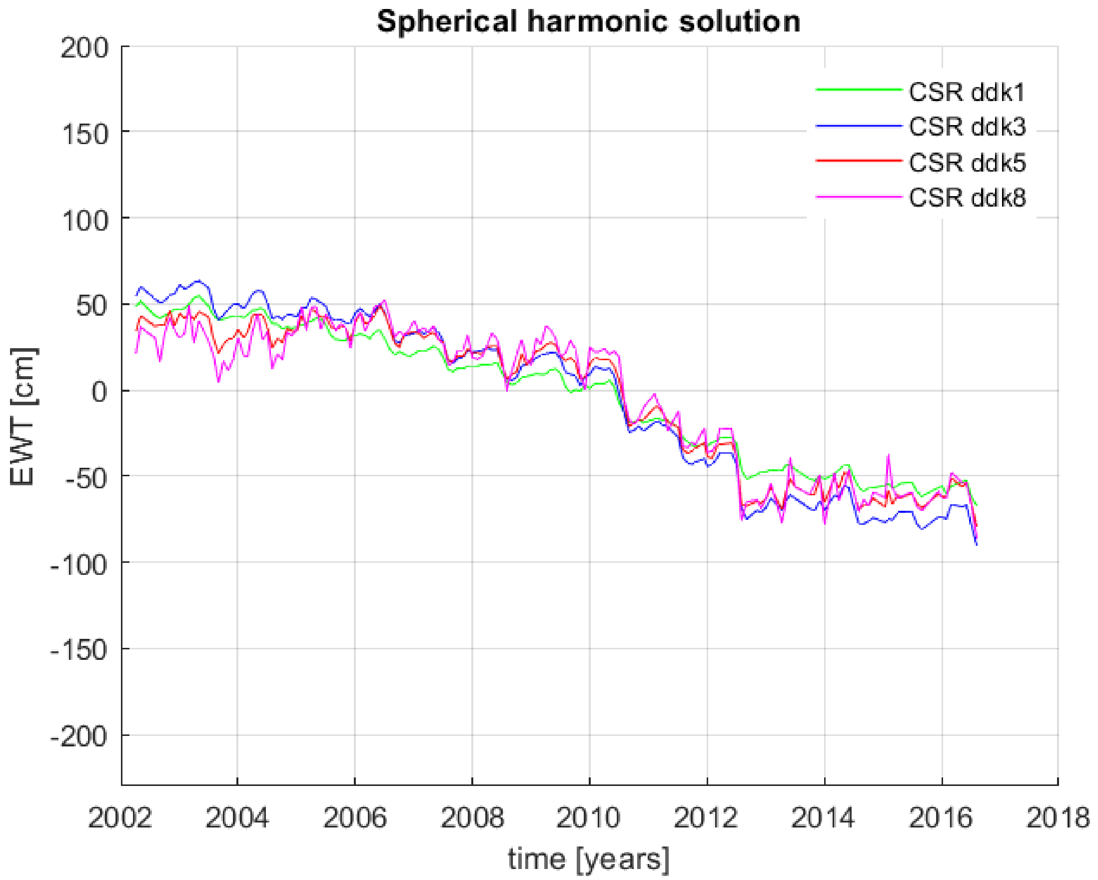


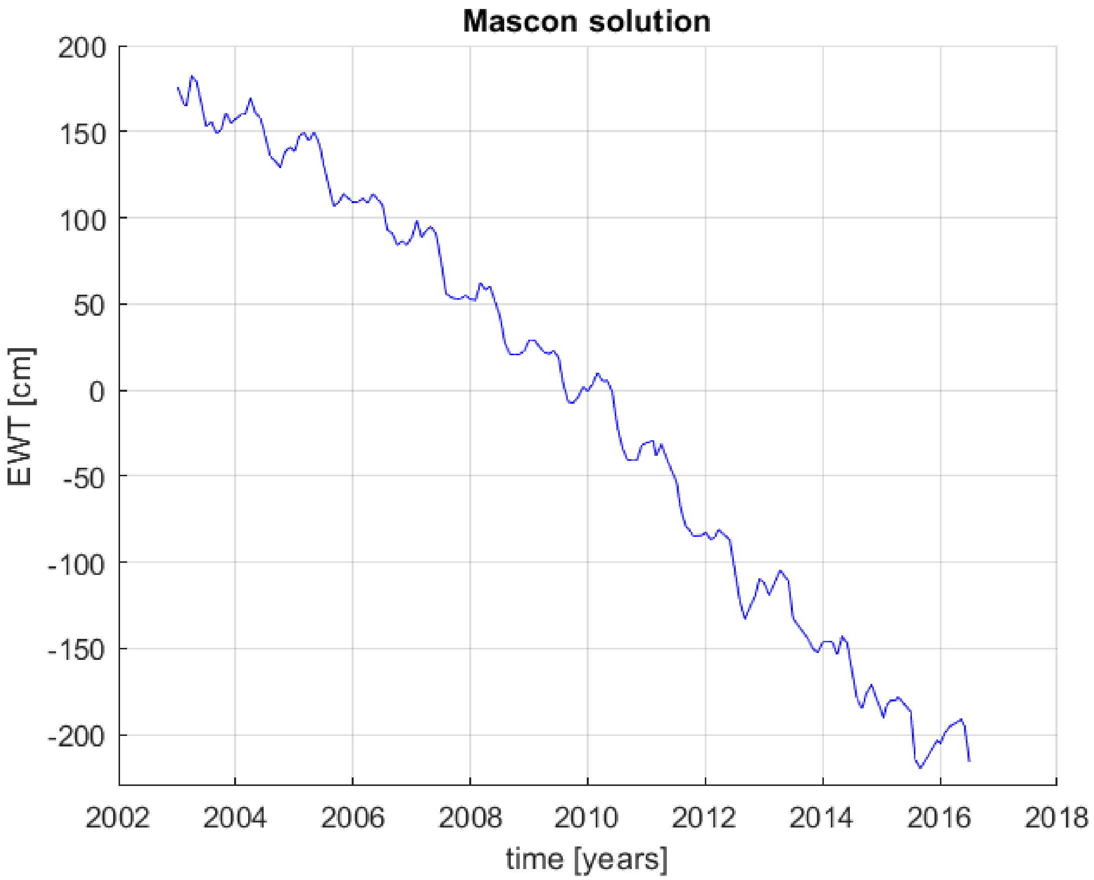
Graphical comparison of spherical harmonics solution with mascon solution for point located on western coast of Greenland





Graphical comparison of spherical harmonics solution with mascon solution for point located in southern Greenland





Different filtrations of monthly GGMs in comparison with global 1° GSFC Mascon solution in river basins

- Differences in river basins with greater area have smaller standard deviation
- Spherical Harmonic solution based on GGMs provided by CSR has smaller differences in higher latitude river basin
- Spherical Harmonic solution based on GGMs provided by GFZ has smaller differences in low latitude river basin with greater seasonal changes
- Spherical Harmonic solution based on GGMs provided by JPL has smaller differences in middle latitude river basin with medium size seasonal changes and medium size area
- ddk2 filtration has the lowest differences when looking at agreement for Danube and Congo river basins
- ddk1 filtration has the lowest differences when looking at agreement for Lena river basins

Different filtrations of monthly GGMs in comparison with global 1° GSFC mascons in Greenland region

- Amplitude size of seasonal changes in all chosen points were best reflected in GGMs provided by CSR
- Differences in EWT monthly values vary significantly when using GGMs with different filtrations
- can even switch the trend orientation (e.g. in some parts of Greenland)
- Amplitude size of seasonal changes in mascon solution best corresponds with spherical harmonic solution using the strongest filtered GGMs
- Linear trend in mascon solution corresponds best with spherical harmonic solution using weaker filtered GGMs

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Thank you
for your attention!