MATLAB tools for the post-processing of GRACE temporal gravity field solutions

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INTRODUCTION

We present a collection of MATLAB tools for the post-processing of temporal gravity field solutions from the Gravity Recovery and Climate Experiment (GRACE) satellite mission, developed and used by the Gravity and Earth Observation group at the department of Geomatics Engineering, University of Calgary. A variety of techniques and tools for the post-processing of GRACE data are implemented, tested and analyzed. All tools use different levels of parameterization in order to assist both expert users and nonspecialists. Such a software would make the comparison between different GRACE processing methods and parameters used easier, leading to optimal strategies for the estimation of surface mass changes and to the standardization of GRACE data post-processing. It could also facilitate the use of GRACE data to non-geodesists.

SOFTWARE CAPABILITIES

Some of the main features of our software are:

- Extraction of spherical harmonic coefficients, formal/calibrated standard deviations and full covariance matrices from GRACE Level 2 products.
- Conversion between several formats for storing the spherical harmonic coefficients.
- Spherical harmonic synthesis of equivalent water height (EWH) and main gravity field functionals (i.e., potential, geoid undulations, gravity anomalies).
- Estimation of surface mass changes on the Earth's spherical, ellipsoidal and topographic surface (Fig. 1).
- Implementation of filtering techniques (Fig. 2) in the spatial and spherical harmonic domains, such as:
  - Empirical decorrelation filter (EDF).
  - Isotropic Gaussian filter.
  - Non-isotropic Gaussian filters.
- Reduction of leakage error and isolation of signals using iterative methods based on forward gravity field modeling (Fig. 3).
- Averaging in the spatial and spherical harmonic domains (Fig. 4).
- Calculation of leakage-in and leakage-out effects that can be used to correct the spatially-averaged surface mass change estimates for filter-induced signal damage.

Auxiliary tasks include:

- Forward gravity field modeling of tesseroidal mass elements using Gauss-Legendre numerical integration and 4^{th}-order Taylor series expansion.
- Techniques for time series smoothing, such as:
  - Savitzky-Golay filter.
  - Locally weighted regression (Loess).
- Techniques for time series decomposition, such as:
  - Least-squares spectral analysis with simultaneous polynomial modeling of long-term trend.
  - Seasonal-trend decomposition using Loess (STL) (Fig. 4).

To further facilitate the estimation of GRACE-derived surface mass changes, the following auxiliary files are included:

- Sets of load deformation coefficients (Love numbers) for a spherical Earth.
- Masks for land, ocean and river basins.
- Pre-calculated matrices for the conversion of surface mass changes on the Earth's topographic surface.

SOFTWARE AVAILABILITY

- Please, note that parts of the software are undergoing updates at the moment. An early version of the software can be made available to users upon request.

SELECTION OF REFERENCE SURFACE

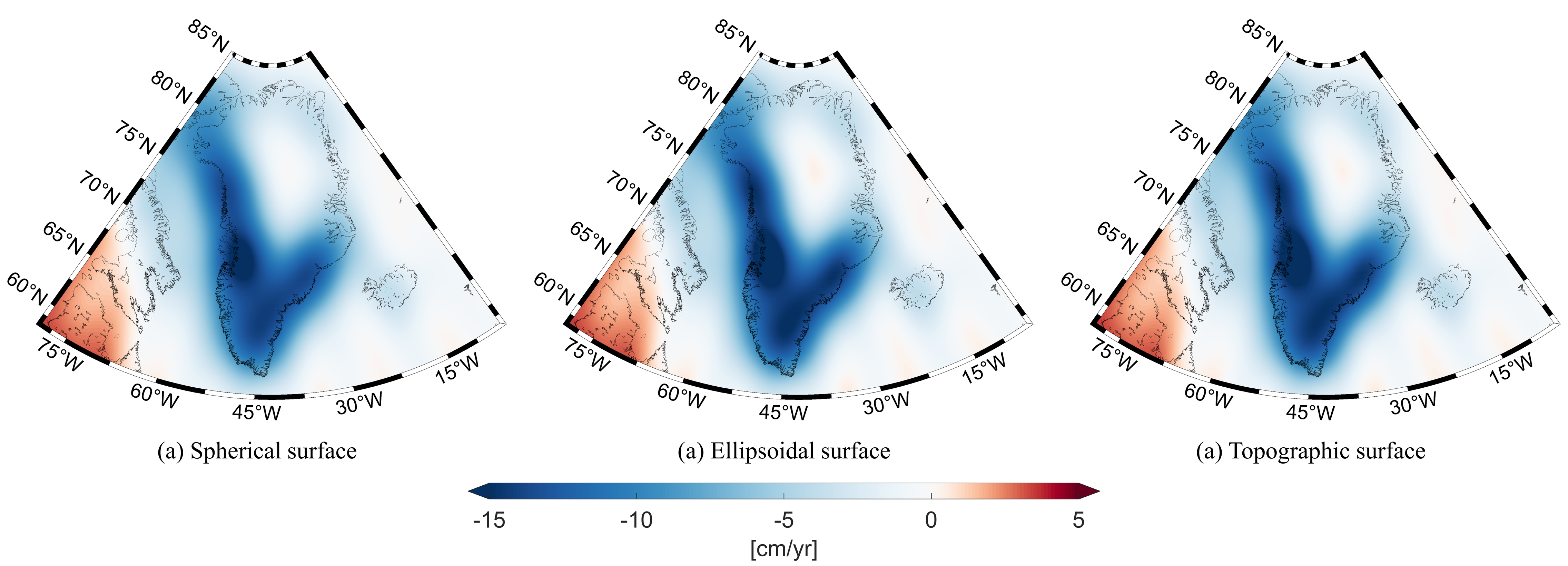

Figure 1: Greenland long-term trend of EWH changes estimated on different reference surfaces. An isotropic Gaussian filter of 250 km is applied.

FILTERING OF GRACE MONTHLY SOLUTIONS

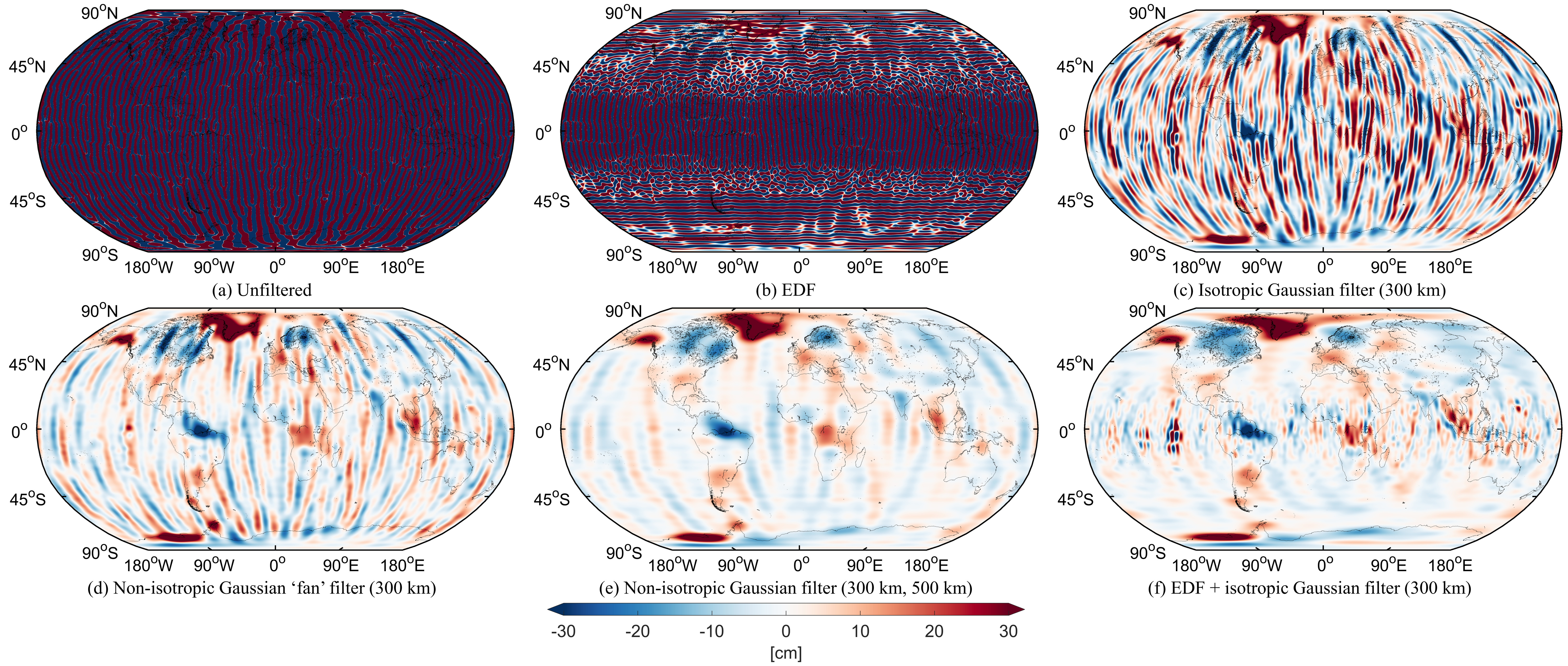

Figure 2: Comparison of filtering techniques on monthly GRACE-derived EWH changes.

ISOLATION OF ICE MELTING SIGNAL

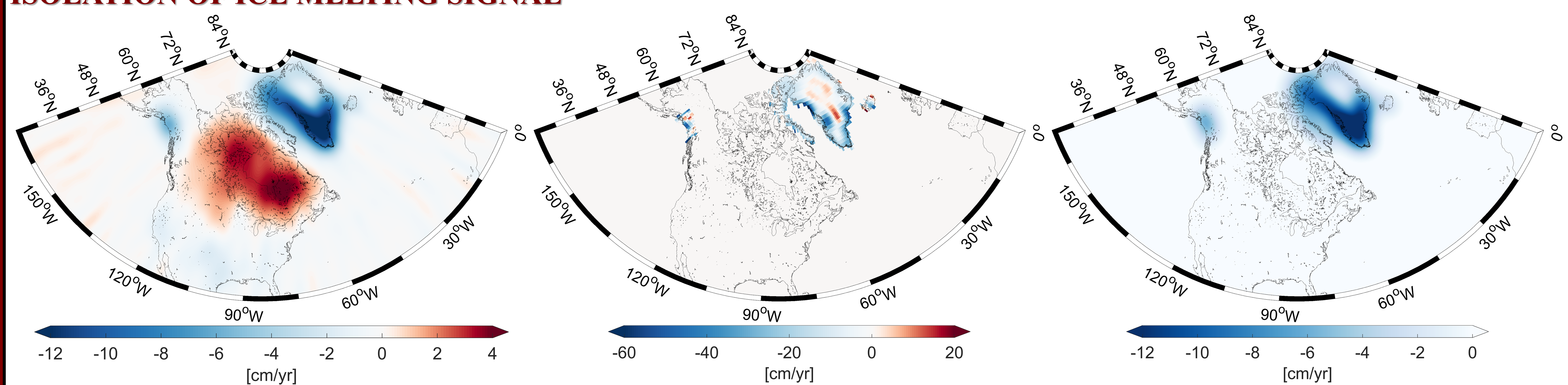

Figure 3: Smoothed GRACE-derived long-term trend of EWH changes in North America (left). Isolated leakage-reduced (center) and smoothed (right) ice melting signal in Greenland and Alaska.

STL DECOMPOSITION

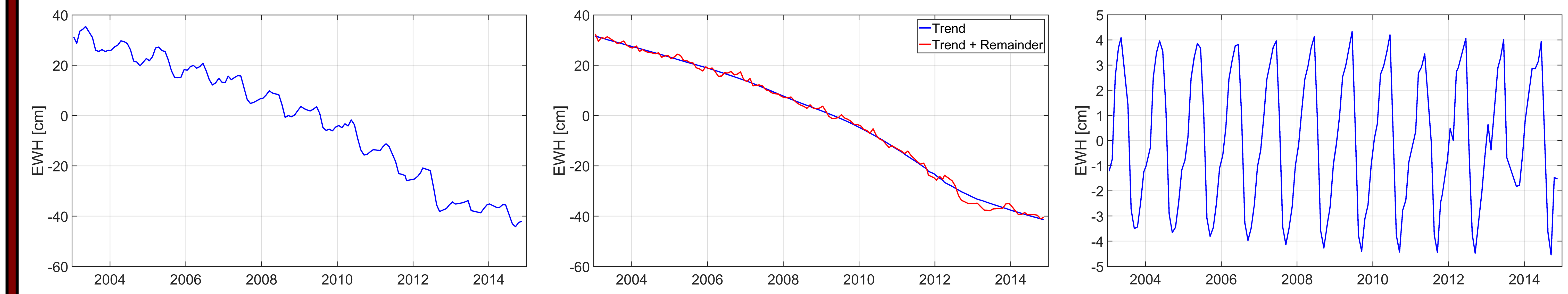

Figure 4: GRACE-derived spatially averaged EWH changes for Greenland (left). Decomposition to trend and remainder components (center) and annual component (right).

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