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Comparison of Destriping Methods of GRACE Satellite for Total Water Storage Calculation in Peatland Borneo Island

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Abstract

GRACE satellites frequently used to calculate total water storage in terrestrial areas, including peatland. Total water storage (TWS) needed to monitor Peatland fires risk. However, processing methods need to be considered carefully. This study intends to find out the best destriping method for estimating total water storage. This study compared data from the CSR model with a maximum degree of 96, from 2002 to 2017, located in Borneo Island. The destriping method compared namely Chen P3M6, Chen P5M8, Chambers 2007, Chambers 2012, Duan, and Swenson. This study used GRAMAT toolbox developed [1]. Results shows of the 6 methods that compared, 3 unique values are produced. Chen P5M8 and Swenson method produced the same value. Chambers 2007, Chambers 2012, and Duan method also produced the same value. Only Chen P3M6 produce different results without similarities. The correlation matrix between methods shows value close to 1, means there is no significant difference between methods. This study concluded that the type of destriping method for TWS calculation in peatland aren't significantly affecting the result.

Keywords: Destripping, Peatland, Water Storage

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1. Introduction

Gravity Recovery and Climate Experiment missions are capable in providing observational data in use to monitoring large-scale mass transport, also for analyzing the redistribution in the Earth's fluid envelopes with a footprint close to 300 kilometer. Parameter frequently observed using GRACE is Total Water Storage. Numerous studies have used data from GRACE to calculate total water storage in terrestrial areas. Most of these studies took up the research area in the basin or large water bodies, but some took a place in peatland area.

Total water storage information is urgently need in peatland area. This information can be used as an alternative solution to collect hydrology data in peatland area. The data later use to monitoring the conditions of the peatland. Once the condition is known,

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the fires risk can be mitigated to preserve the peatland. However, peatland area is different from the basin area, mass dynamics in the region are more varied. Therefore, the processing methods of the total water storage calculation using GRACE data need to be considered carefully

In this paper, the processing methods will be compared to find the best method that produces the most accurate results. The method compared and tested is the destriping method. This method was chosen because it took an important role in the software used to process GRACE data.

2. Destriping Methods

Destriping method is procedure to remove the correlated errors in the gravity field coefficients. This error could result in north-south stripes in the spatial domain. Destriping first introduced [2] and Wahr in 2006 to reduce the correlation among the gravity field coefficients based on polynomial fitting. Afterward, destriping methods were proposed in many type to interpret various case of mass variations. Destriping methods used in this research are list down below

2.1. Chen P3M6

P3M6 method developed [3] to estimate the post-seismic and co-seismic gravity changes from GRACE data. The changes caused by the Sumatra-Andaman earthquake. Gravity field disturbance expand over ~1800 km along Andaman and Sunda subduction zones, and changes with time following events.

2.2. Chen P5M8

This method is a modification of Chen P4M6 method that used for estimating the mountain glaciers, terrestrial water storage change, and mass balance of ice caps. P4M6 method developed for the drought event in the Amazon River basin as estimated by climate models and measured by GRACE. The P5M8 method used polynomial value equal to 5, and order start from 8.

2.3. Chambers 2007

Chamber filters has been applied to estimate and remove systematic errors in the coefficients that cause erroneous patterns in the maps of equivalent water height. [4] kept the coefficients of degrees no more than 7 unchanged. This method fit a 7th-order polynomial to the remaining coefficients of degrees. Then, with the same parity for each order up to 50. This type of method only had one polynomial for the odd/even set of a given order.

2.4. Chambers 2012

Chambers 2012 Evaluation of Release-05 GRACE time-variable gravity coefficients over the Ocean, Ocean Science Discussions. The method used polynomial value equal to 4, and order start from 15.

2.5. Duan

The method developed in 2009 was determined the unchanged portion of coefficients based on the error pattern of the coefficients. Their unchanged portion of coefficients and the width of the moving window depend on both degree and order in a more complex manner. Duan propose a refined approach for choosing parameters of the decorrelation filter based on the error pattern of the SCs in the monthly GRACE Geopotential solutions.

2.6. Swenson

The method identify the spectral signature of the correlations between SH coefficients that are manifested in the striped patterns seen in GRACE maps. Swenson derive a filter designed to isolate and remove smoothly varying coefficients of like parity. To do this, we smooth the Stokes coefficients for a particular order with a quadratic polynomial in a moving window of width w centered about degree.

3. Methodology

The calculation methodology starts from removing the C20 coefficient (degree 2, order 0), this is done because the coefficient has a relatively large error, the coefficient is replaced by the coefficient of SLR measurement.

Second, includes degree 1 coefficients (C10, C11, and S11). This process to re-add seasonal geo-center variations, degree-1 coefficients included from the data provided [2]. Third, reducing errors in the GRACE data. (i) correlated errors among the odd and even degrees of the same order that produce north-south stripes when transformed into spatial domain and (ii) errors in the high degree coefficients. This error is reduced by performing an ocean-leakage process and destriping the spherical harmonic coefficient.

3.1. Data and Tools

Data used in this research are GRACE Satellite Gravity Model by Center for Space Research (CSR) version RL05, with maximum degree 96, hereinafter referred to as CSR96 model. The tool used for this research are Matlab R2016a for GRAMAT toolbox platform, ArcGIS 10.3 to convert grid data to raster, and Global Mapper v.19 to visualize the raster result.

3.2. Area Research

The analysis was carried out on 2 different peatland areas on the island of Borneo, while the limitations of 4 areas are as follows in Table 1.

Table 1: Area Boundary.

	Boundary (long, lat)
Area 1	111.5,1.86; 109,1.86; 109,-0.74; 110,-2.28;111.5,-2.28
Area 2	111.5,-3.82; 111.5,-0.97; 116,-0.97;116, -3.8

3.3. GRAMAT Toolbox

GRACE Matlab Toolbox (GRAMAT) is a program tool in the form of a *matlab* script to process GRACE parameter of total water storage. GRAMAT is equipped with a GUI that can facilitate use. GRAMAT was developed [1] from the Institute of Geodesy and Geophysics, Chinese Academy of Sciences.

GRAMAT toolbox helps to manage GRACE in hydrology field which requires switching and signal errors that cannot be ignored during direct GRACE level-2 data processing. The toolbox focus on processing methods for analyzing noise reduction to process GRACE data spherical harmonic (SH) coefficient products.

1. **Total Water Storage** Total water storage values represent as equivalent water height (EWH). While the EWH value can be expressed in the equation as:

$$\Delta\sigma(\theta,\lambda) = a_e\rho_w \sum_{l=0}^{\infty}\sum_{m=0}^{l} \overline{P}_{lm}(cos\theta)(\Delta\hat{C}_{lm}cos(m\lambda) + \Delta\hat{S}_{lm}sin(m\lambda)) \tag{1}$$

As $\Delta\hat{C}_{lm}$ and $\Delta\hat{S}_{lm}$ are normalized spherical harmonic of the gravity model data model that can be obtained from

$$\Delta\hat{C}_{lm} = \frac{\rho_{ave}}{3_{\rho_w}}\frac{2l+1}{1+k_l}\Delta C_{lm} \tag{2}$$

$$\Delta\hat{S}_{lm} = \frac{\rho_{ave}}{3_{\rho_w}}\frac{2l+1}{1+k_l}\Delta S_{lm} \tag{3}$$

Where the parameter $\Delta\sigma$ is EWH, a_e is average earth radius, ρ_w is water density, $\overline{P}_{lm}$is polynomial Legendre, ρ_{ave} is average earth mass density (5517 kg/m^3), l, m are degree and order, last k_l is *love number*.

4. Result & Discussion

4.1. Result

Harmonic analysis of EWH time series is done to obtain information related to the annual amplitude value, annual phase value and the value of the change pattern (trend). Harmonic analysis result for area 1 and area 2 present sequentially on Table 2. and Table 3.

Based on Tabel 2. and Table 3. the difference between harmonic analysis in area 1 and area 2 only seen on annual amplitude parameter. The annual phase and annual trend parameter almost the same. This might be caused by location of both of the area are in the southern part of the Borneo Island. Based on [6] the southern part of the Borneo have the similar result. The annual amplitude in the other hand, have a variance result expected cause by the number of area of the peatland. Area 2 have larger peatland area than Area 1.

The destriping methods give variation in values below 0.01 for annual amplitude and annual trend. Where, the unique values from 6 methods only 3. P5M8 and Swenson

Table 2: Harmonic Analysis in Area 1.

	Annual Amplitude (cm)	*sd*	Annual Trend (cm/year)	*sd*	Annual Phase (degree)	*sd*
P5M8	0.502	0.061	0.067	0.012	262.5	7.1
Swenson	0.502	0.061	0.067	0.012	262.5	7.1
Cham07	0.503	0.058	0.062	0.010	262.2	6.7
Cham12	0.503	0.058	0.062	0.010	262.2	6.7
Duan	0.503	0.058	0.062	0.010	262.2	6.7
P3M6	0.501	0.058	0.063	0.010	261.5	6.8

Table 3: Harmonic Analysis in Area 2.

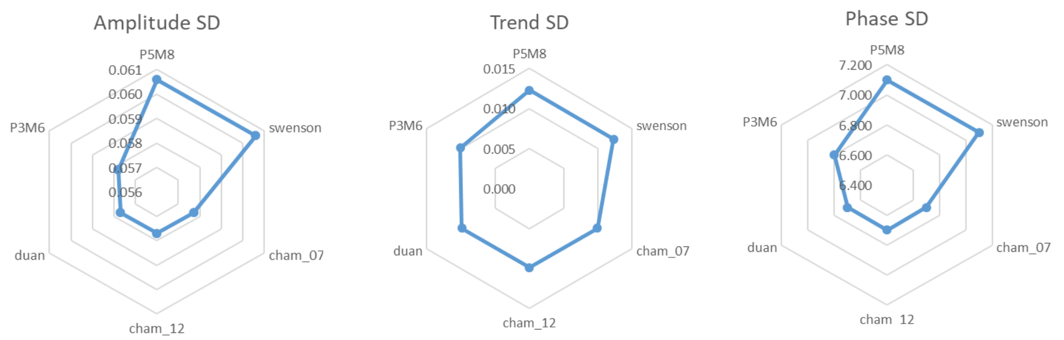
	Annual Amplitude (cm)	*sd*	Annual Trend (cm/year)	*sd*	Annual Phase (degree)	*sd*
P5M8	0.504	0.061	0.067	0.012	262.5	7.1
Swenson	0.504	0.061	0.067	0.012	262.5	7.1
Cham07	0.505	0.058	0.062	0.010	262.2	6.7
Cham12	0.505	0.058	0.062	0.010	262.2	6.7
Duan	0.505	0.058	0.062	0.010	262.2	6.7
P3M6	0.503	0.058	0.063	0.010	261.5	6.8

contribute 1. Cham07, Cham12, and Duan contribute 1. Last, P3M6 is the only methods without any similarities to the other methods.

Following this similarity in value, a statistical test of the results is done by making a correlation matrix between methods. The matrix shows values close to 1 (0.999999467 to 0.999999901), this means that there is no significant difference between the destriping method and the value of the harmonic analysis parameters.

Deeper searches are carried out by analyzing and compares the accuracy of the standard deviation results generated by each method. This analysis done for each parameter of the harmonic analysis. The comparison shown in Figure 1 below. The graph form shown by the three parameters is almost the same, where the method Cham07, Cham12, Duan, and P3M6 has smaller standard deviation value in each parameter.

Although there a lot similarities between all the methods, if there a choice to select the best from the 6, the author would suggest to use the P3M6 methods. Because it had the least value in standard deviation means fewer errors exist. Also, the P3M6 give the only unique values, means if there are out-layer result it can be seen.



(a) Amplitude standard deviation comparison

(b) Trend standard deviation comparison

(c) Phase standard deviation comparison

Figure 1: Comparison between standard deviation of each parameter of harmonic analysis in Area 1. The graphic of the Area 2 is similar.

4.2. Discussion

The similarity of the results of each destriping method does not mean that the destriping method does not affect GRACE data processing for TWS. Please note as the definition of the destriping method says that the methods is purposely to reduce the errors among the odd and even degrees of the same order that produce north-south stripes when transformed into spatial domain. So, the location of area in the order and spatial domain is also need to be considered. As this results shown, noted that Borneo area error of the north-south stripes is much less.

In addition, there are several criteria criteria that affect the results of the destriping method for GRACE. The criteria as mentioned [1]such as determine the stable portion of coefficients, for example the stable portion of coefficients of Cham 2007 method are the first 14 degrees and orders. Then selecting the best version of degree of polynomial fitting. Last, is applying the best version polynomial fitting of coefficients.

5. Summary

Based on the results of this study, some point that need to point out are:

1. Based 6 methods that compared 3 unique values are produced. Chen P5M8 and Swenson method produced the same value. Chambers 2007, Chambers 2012, and Duan method also produced the same value. Only Chen P3M6 produce different results without similarities. This means that the methods results did not significantly different.

2. The correlation matrix between methods shows value close to 1, means there is no significant difference between methods.

3. This study concluded that the type of destriping method did not affect the accuracy results of total water storage calculation in peatland area in Borneo Island significantly. Although, author would suggest to use the P3M6 methods because of the independence result and accuracy.

5.1. Suggestion

First, suggesting further research can be carried out further verification and validation of the EWH results by using data such as climatology data and groundwater level data provided by the Peat Restoration Agency at several locations in Kalimantan. Second, other type of the method need also to be compared such as, *GIA effect, ocean-leakage remove*, etc. To find the best processing procedure to produce the most accurate result.

5.2. Where to Find Further Information

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