Documentation for the Trends in Global Freshwater Availability from the Gravity Recovery and Climate Experiment (GRACE)

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Abstract

The Trends in Global Freshwater Availability from the Gravity Recovery and Climate Experiment (GRACE), 2002-2016, is a global gridded data set at a spatial resolution of 0.5 degrees that presents trends (rate of change measured in centimeters per year) in freshwater availability based on data obtained from 2002 to 2016 by NASA GRACE. Terrestrial water availability storage is the sum of groundwater, soil moisture, snow and ice, surface waters, and wet biomass, expressed as an equivalent height of water. GRACE measures changes in the terrestrial water cycle by assessing small changes in Earth's gravity field. This observation-based assessment of how the world's water cycle is responding to human impacts and climate variations provides an important tool for evaluating and predicting emerging threats to water and food security.

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We appreciate feedback regarding this data set, such as suggestions, discovery of errors, difficulties in using the data, and format preferences. Please contact:

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Contents

I. Introduction

This data set is part of SEDAC's Satellite Derived Environmental Indicators (SDEI) data collection. Environmental indicators simplify complex information about the state of the environment and human-environment relationships, identifying problem areas and revealing underlying trends. Satellite data have many worthwhile characteristics, including broad spatial coverage and consistent measurement over time. The development of a scientifically robust set of satellite-derived environmental indicators has the potential to help policymakers make informed decisions and ultimately support policies and programs that protect the environment and human health (de Sherbinin et al., 2012).

This data set provides the mean rate of change ("trends") of terrestrial water storage in centimeters/year at each location on the land surface as observed by the Gravity Recovery and Climate Experiment (GRACE) satellites during the period from April 2002 to March 2016 (Rodell et al., 2018). Terrestrial water storage is the sum of groundwater, soil moisture, snow and ice, surface waters, and wet biomass, expressed as an equivalent height of water. At each location on Earth, the average seasonal cycle of terrestrial water storage was first computed and removed from the original monthly terrestrial water storage anomaly data set, then the best fit trend was computed from the remaining time series using linear regression. The trend map was smoothed with a 150 km radius Gaussian filter and transferred to a 0.5° grid for the purpose of visualization, however, all calculations were performed at the native 3° resolution of the original data product. The latter was produced by the Jet Propulsion Laboratory and is available from https://grace.jpl.nasa.gov/data/get-data/jpl_global_mascons/.

II. Data and Methodology

This terrestrial water storage trends data set and the related science, including attribution of the trends to natural interannual variability, climate change, or direct human impacts, are described in:

Rodell, M., J. S. Famiglietti, D. N. Wiese, J. T. Reager, H. K. Beaudoing, F. W. Landerer, and M.-H. Lo. Emerging trends in global freshwater availability, *Nature*, 557, 651-659, doi:10.1038/s41586-018-0123-1, 2018.

Input data

The JPL RL05M GRACE mass concentration ("mascon") product (Watkins et al., 2015; Wiese et al., 2016) is the basis for the global terrestrial water storage trend map. The JPL mascon solution parameterizes each monthly gravity field in terms of 4,551 equal-area surface spherical cap mass concentration functions, and uses a regularization approach that implements both spatial and temporal correlations to remove correlated errors during the gravity inversion. A Coastline Resolution Improvement (CRI) filter is used to separate between land and ocean mass within mascons that span coastlines. GRACE does not produce a reliable estimate of the Earth's oblateness (C_{20} coefficient), and as such, we follow the standard protocol of using Satellite Laser Ranging (SLR) to provide this estimate. Further, GRACE gravity field anomalies are measured in the Earth's center of mass reference frame, and therefore needs to be augmented with a 'geocenter' estimate to capture all surface mass changes. Glacial Isostatic Adjustment (GIA) corrections are made using the updated ICE-6G_D model, with an exception for Antarctica, for which we reduce the fitted rate of mass change by 9.2 Gigatonnes/year based on a regional model that potentially provides a better GIA estimate for Antarctica. Finally, corrections are made to the C_{21} and S_{21} coefficients in order to fully remove the pole tide from the GRACE data. Jumps in the background atmosphere and ocean de-aliasing product are corrected as well.

Methods

The seasonal cycle was removed from the monthly terrestrial water storage anomaly time series as follows. First, missing months of data were filled by linear interpolation. Next, the mean monthly seasonal cycle was computed by averaging all January's, all February's, etc. Finally, for each month in the original, non-gap-filled time series, the mean for the corresponding month of the year was subtracted. The first step, gap filling, was necessary because, for example, the month of May was under-sampled in the second half of the study period, which caused the mean for May to be biased in locations where a consistent trend existed (i.e., most of the regions of this study). Finally, linear regression was applied to determine the best fit linear rate of change of terrestrial water storage at each location. See Rodell et al. (2018) for a detailed description of the methods.

III. Data Set Description

This data set represents the mean rate of change ("trends") of terrestrial water storage in centimeters/year at each location on the land surface as observed by the Gravity Recovery and Climate Experiment (GRACE) satellites during April 2002 to March 2016. Terrestrial water storage is the sum of groundwater, soil moisture, snow and ice, surface waters, and wet biomass, expressed as an equivalent height of water. The trend map was smoothed with a 150 km radius Gaussian filter and transferred to a 0.5° grid for the purpose of visualization, however, all calculations were performed at the native 3° resolution of the original data product.

Data set web page:

SEDAC URL:
http://sedac.ciesin.columbia.edu/data/set/sdei-trends-freshwater-availability-grace

Permanent URL: https://doi.org/10.7927/H4TT4P2C.

Data set format:
The data are available as a global grid in GeoTIFF format. The downloadable is a compressed zip file, containing: 1) the global GeoTIFF and 2) PDF documentation.

Data set downloads:
sdei-trends-freshwater-availability-grace-2002-2016-geotiff.zip

IV. How to Use the Data

As indicated, this data set is part of the Satellite-Derived Environmental Indicators (SDEI) data collection. Like all of the data sets in that collection, this product can assist in better understanding environmental trends in different regions in the world. While this data set cannot provide spatially precise information for localities, it can provide an important understanding of trends in freshwater availability over broader regions, recognizing that it is a trend data set (not a water scarcity data set) and limited to a baseline of 2002, so therefore cannot speak to trends before that date (See Section VI below).

V. Potential Use Cases

The most well-known uses of GRACE terrestrial water storage data are for quantifying the rates of ice sheet losses from Greenland and Antarctica and for estimating groundwater depletion in major agricultural regions of the world (e.g., Rodell et al., 2009). Taking the latter as an example, to estimate the rate of groundwater depletion from northern India during 2002-2016, one would calculate the area-weighted mean of all the grid cells that compose the specific study region in northern India, while accounting for the fact that the 0.5° x 0.5° grid cells become smaller as they approach the poles. Note, this method relies on the assumption that trends in soil moisture, surface water, and snow water storage are negligible.

VI. Limitations

The effective spatial resolution of the GRACE satellites at mid-latitudes is about 150,000 square kilometers. Therefore, as rule of thumb, an estimate of the trend in terrestrial water storage over a region of interest is only meaningful if the region is at least that size. It is also important to recognize that 14 years is too short a period to say with certainty that an apparent trend is real and likely to continue without supporting information.

While this data set cannot provide spatially precise information for localities, it can provide an important understanding of trends in freshwater availability over broader regions, recognizing that it is a trend data set (not a water scarcity data set) and limited to a baseline of 2002, so therefore cannot speak to trends before that date.

GRACE provides data over land and oceans, but the interpretation of GRACE trends data over oceans is more challenging than over land areas. GRACE measures changes in mass, whether it is salt water, freshwater, or the solid earth. Over land, the majority of mass change, after removing atmospheric mass changes, is freshwater mass change. To show only trends in terrestrial water availability, an ocean mask should be used. SEDAC provides a water bodies mask at 30 minute (approximately 55km) resolution (see https://doi.org/10.7927/H42Z13KG), which is the same as resolution as the Trends in Global Freshwater Availability from GRACE, v1 data set.

VII. Acknowledgments

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X. Recommended Citation(s)

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Scientific publication:

Rodell, M., J. S. Famiglietti, D. N. Wiese, J. T. Reager, H. K. Beaudoing, F. W. Landerer, and M.-H. Lo. 2018. Emerging Trends in Global Freshwater Availability. Nature 557(7707): 651-659. https://doi.org/10.1038/s41586-018-0123-1.

XI. Source Code

No source code is provided.

XII. References

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Appendix 1. Data Revision History

No revisions have been made to this data set

Appendix 2. Contributing Authors & Documentation Revision History

Revision Date	ORCID	Contributors	Revisions
May 20, 2019	0000-0002-8875-4864 0000-0003-0106-7437	A. de Sherbinin M. Rodell	This document is the 1st instance of documentation.