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Investigating the Changes within the Lake Chad Basin Using GRACE and LANDSAT Imageries

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Abstract

Understanding the spatio-temporal characteristics of water storage changes is crucial for Lake Chad, a basin facing a range of challenges in water management caused by anthropogenic impacts as well as climate variability. In addition to this, scarcity of in situ measurements combined with scale limitations of traditional methods used in its hydrological characterization further makes it hard to assess and manage this vital water resource. The primary objective of this study is to apply remotely sensed and modeled data over the lake area in order to investigate the inter-annual and seasonal terrestrial water storage changes within the lake area and its effect on the lake's surface water. The data used in this study includes; monthly gravity field data from the Gravity Recovery and Climate Experiment (GRACE) mission from which water storage trends within the basin were determined, Rainfall data from the Tropical Rainfall Measuring Mission (TRMM) shows an increase in seasonal pattern of rainfall in this area. This study, covers a period from 2003-2013. Results show that GRACE Terrestrial Water Storage within the basin has been somewhat stable with the highest averaged values at 0.69 cm/year occurring in 2012. Correlation analysis indicated a time lag of about a month exists between TWS and rainfall. To understand the possible causes and effects these changes has on the surface water of the lake, investigations using Landsat imagery are underway. These results could serve as an insight on the availability of water resources in the Lake Chad Basin and could also provide baseline data which could be used to monitor the lake for current and future management purposes.

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Keywords:: GRACE; Lake Chad Basin; Landsat; Altimetry; hydrological changes.

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1. Introduction

In some developing parts of the world, very limited and low-quality groundwater data often hinders proper water management studies. Moreover, the estimation of large-scale water balance using these limited ground-based measurements is prone to inaccuracies. Sometimes, obtaining these datasets from the appropriate authorities involves lengthy administrative procedures making such studies extremely difficult.

Gravity Recovery and Climate Experiment (GRACE) is a joint mission between Deutsche Forschungsanstalt fur Luft und Raumfahrt (DLR) and National Aeronautics and Space Administration (NASA) that was launched in 2002. It measures the monthly temporal variations in the gravity field at a distance of about 220 km and 500 km above the land surface. In this study, we tried to combine the updated remotely sensed and hydrological model datasets. These datasets have been used to study the diverse aspects of basin hydrology within the continent. Some of these point out to the lack of readily available in situ data for these studies, some cases validated the in situ measurements in Lake Chad and other parts of the continent. We utilized Satellite Gravimetric, altimetric and Landsat imageries. Lake Chad Basin (LCB) which is under the mandate of the Lake Chad Basin Commission (LCBC).

Numerous studies have been conducted for the problems of Lake Chad. It is agreed that the lake levels have fluctuated considerably over the past decades in response to the climate variability and environmental degradation [1, 3]. [2] Used a hydrological model to simulate the effects of bathymetry, human water use, and decadal climate variability on the lake level, surface area, and water storage.

Remote sensing is an excellent tool for mapping, monitoring and modeling of environmental variables and processes. The widespread availability and reduced cost of remotely sensed imagery and geographic information system allow efficient mapping and detection of surficial changes of the natural resources in a greater scale. Especially in developing countries. Our main objective here will be to use this spatial data set and validate temporal variability from previous studies. To investigate the land use/land cover change around the shrinking Lake Chad and its impact on the Lake as well as the impact of drought on the size of the lake. Finally, use Landsat images to produce annual ET for the LCB.

2. Materials and Methods

2.1. Terrestrial Water Storage (TWS) from GRACE

GRACE is known for estimating high-precision time-varying gravity field and the changes of Earth's surface mass at a high degree of accuracy on a time scale ranging from months to a decade.

For this study, we used the monthly land mass grid observations (Level 3) provided by the Center of Space Research (CSR), University of Texas, at Austin from January 2003 to December 2013.

2.2. LANDSAT

We 2003–2013 data from the Landsat Thematic Mapper (Landsat 5) and the Enhanced Thematic Mapper Plus (ETM +) (Landsat 7), which have overpass frequencies of 16 days.

2.3. Lake height from altimetry

Lakes, rivers, and oceans have all been monitored over the years using these datasets. Surface water level data sets are sometimes given in the form of graphs and tables of height variations for major water bodies based on the combination of various radar altimetry sensors.

ENVISAT altimetry estimates was used for this study.

2.4. TRMM

The rainfall characteristic of LCB will be analyzed using TRMM and other satellites' RFE (3B43 version7). The algorithm of TRMM 3B43 is a combination of three fields from the TRMM instrument package the pentad-average

adjusted merged-infrared (IR) estimate, the monthly average TRMM Microwave Imager (TMI) estimate, and the monthly average Special Sensor Microwave/Imager (SSM/I)

3. Results and Discussion

3.1. TWS

Based on our study period, STL trend of the time series of monthly GRACE TWS shows a decrease in average TWS of LCB (Figure 3) for the periods 2003-2005 and 2009-2010, with the latter being the lowest water estimates at -0.54 cm/year.

There is an increase in TWS concentrations from 2006 to 2008, and 2010 to 2013 with the latter being the highest storage estimates of 0.69 cm/year.

3.2. Land use/cover changes in association with TWS and rainfall

3.3. Evapotranspiration

3. Conclusion

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