Quantifying Total Water Storage in Minnesota River Watershed

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Abstract

During the past few decades various methods have been developed to quantify the total amount of water stored in watersheds. These methods include water balance techniques, baseflow recession analyses, pointwise measurements of groundwater levels, soil moisture and lake levels, differential gravimetry, and finally satellite signal technologies. Some reasons for measuring total water storage include enabling the planning for periods of water deficit or water excess, to quantify initial storage conditions for hydrologic models, and to relate water quality conditions to streamflow discharge. The objective of the present study is to quantify the storage of all water (groundwater, soil moisture and surface water) in the Minnesota River Basin. For this study we are using a myriad of techniques including water balances, streamflow analyses, point measurements (wells, soil moisture and lake levels), and satellite sensors. The satellite data are derived from the GRACE (Gravity Recovery and Climate Experiment) satellite and the SMOS (Soil Moisture and Ocean Salinity) satellite In this presentation we will show the results of our estimates of water storage and water storage change in one of the subwatersheds of the Minnesota River Basin, the Blue Earth River Watershed.

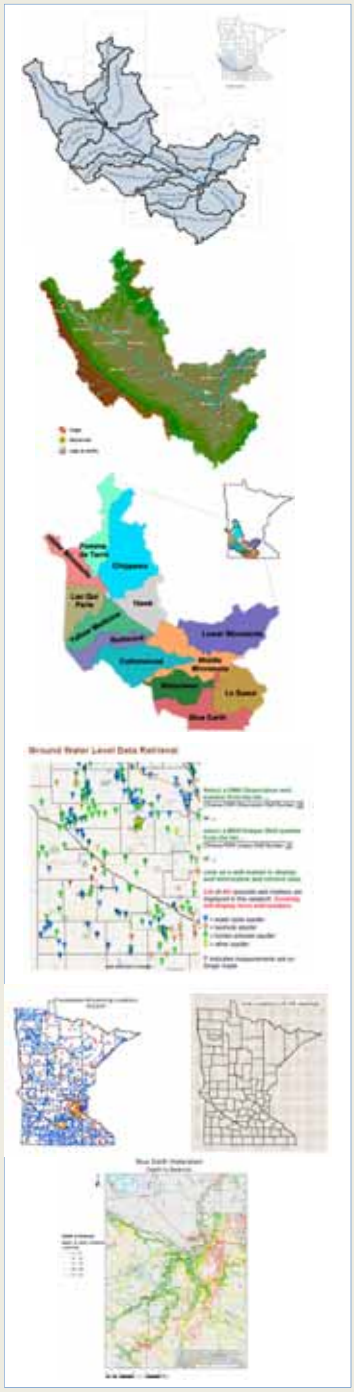
Introduction

Minnesota is known for its plentiful water resources. While many other states in the U.S. are experiencing shortages in water supplies, Minnesota has seemed to escape the problem of shortages. However, in recent years some signs have arisen indicating that Minnesota's water resources may not be sufficient to meet the combined needs for human habitation and industry and for ecosystem health. Occurrences such as the water level lowering of White Bear Lake in Twin Cities Metro Area, reduction of streamflows in some creeks and rivers, and reduction of water levels in natural wetlands point to this evidence. High flows in rivers, such as the documented increases of flows in the Minnesota River, are also a result of changes in water storage in the landscape. Hydrologist recognize that the storage of water in the soil and aquifers affects the flow of water into lakes and wetlands, and the flows in streams, creeks and rivers. Therefore, quantifying the volume stored will assist with assessing the availability of water for human and ecosystem use.

Hypothesis and Objectives

In this research we propose remote sensing techniques to estimate the storage of water in the soil and aquifers of the Blue Earth watershed. The GRACE satellite is used for groundwater storage, and the SMOS/SMAP satellites are used for soil moisture storage. Independent measures of storage are being derived using ground-based data including streamflow measurements, groundwater well levels, soil moisture measurements, weather data, and water balance calculations.

Minnesota River Watershed

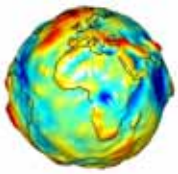


Grace

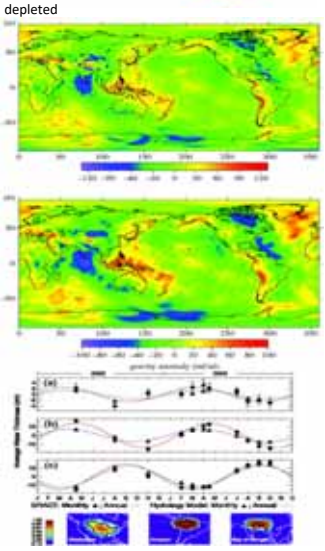
Gravitational Satellites
.- Launched March, 2002.
.- 2 twin satellites that measure the earth's gravitational field.

How does it work?

- 2 twin satellites fly one in front of the other
- The lead one is deflected when it goes over an area of the earth with a different gravity field.
- GRACE 1 & 2 can detect a change in distance between them up to 1 micron!
- They circle the earth 16 times per day
- Complete a full map of the earth's gravity once per month.



GRACE can be used to detect if aquifers are filling or being depleted



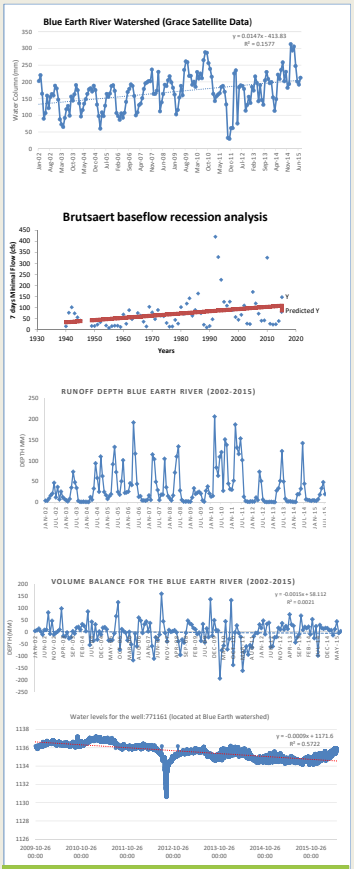
Limiting factors for GRACE gravity field determination:
- sensor accuracy
- disturbances
- spatial-temporal sampling
- parameterization, modeling, representation

SMOS

SMOS soil moisture retrievals are available at 40km global grids with a 4% accuracy expectation. SMOS revisit time is 2-3 days for each grid. Details of the SMOS soil moisture data can be found here: http://www.cesbio.ups-tlse.fr/us/smos/smos_atbd.html

Preliminary Results for the Blue Earth Watershed

Independent storage estimation methods:
- **Water balance calculations**
- **Water levels in wells**
- **Baseflow recession analysis**



Preliminary Conclusions

The GRACE satellite indicates a gradual rise in storage in groundwater, in agreement with the baseflow analysis. The water balance analysis shows a minimum decrease . The result from the groundwater well data show a minimal variance for 6 years of record.

A similar analysis is being conducted for other watersheds within the Minnesota River Basin.

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