USING ENHANCED GRACE WATER STORAGE DATA TO IMPROVE DROUGHT DETECTION BY THE U.S. AND NORTH AMERICAN DROUGHT MONITORS

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ABSTRACT

NASA's Gravity Recovery and Climate Experiment (GRACE) satellites measure time variations of the Earth's gravity field enabling reliable detection of spatio-temporal variations in total terrestrial water storage (TWS), including groundwater. The U.S. and North American Drought Monitors are two of the premier drought monitoring products available to decision-makers for assessing and minimizing drought impacts, but they rely heavily on precipitation indices and do not currently incorporate systematic observations of deep soil moisture and groundwater storage conditions. Thus GRACE has great potential to improve the Drought Monitors by filling this observational gap. The GRACE TWS data was vertically decomposed into groundwater and soil moisture components through data assimilation with the Catchment Land Surface Model. The Drought Monitors combine several short-term and long-term drought indicators expressed in percentiles as a reference to their historical frequency of occurrence for the location and time of year in question. To be consistent, we generated a climatology of estimated soil moisture and ground water based on a 60-year Catchment model simulation, which was used to convert seven years of GRACE assimilated fields into soil moisture and groundwater percentiles. The added benefit of incorporating these GRACE-based drought indicators into the objective blends that constitute Drought Monitor baselines was analyzed through comparison with the current suite of short-term and long-term objective indicators and by correlating detectable differences at the regional and local scale to the final U.S. Drought Monitor product, which incorporates subjective input from a network of local climate and water experts. Furthermore, we evaluated Catchment model output against independent datasets including soil moisture observations from Aqua AMSR-E and groundwater level observations from the U.S. Geological Survey's Groundwater Climate Response Network, in order to further assess the value of incorporating GRACE assimilated fields into the Drought Monitor process.

1. INTRODUCTION

Mapping the onset and severity of drought is of critical national importance [1] and improvements in drought monitoring will be of benefit for end users in the Water resources, Agricultural Efficiency, and Energy Management application areas. The goal of this project is to integrate terrestrial water storage (TWS) data derived from NASA's Gravity Recovery and Climate Experiment (GRACE) satellites [2] into the U.S. and North American Drought Monitors [3,4], two of the premier drought products used by governments and stakeholders as decision-support tools to assess and minimize drought impacts. GRACE twin satellites, launched 17 March 2002,

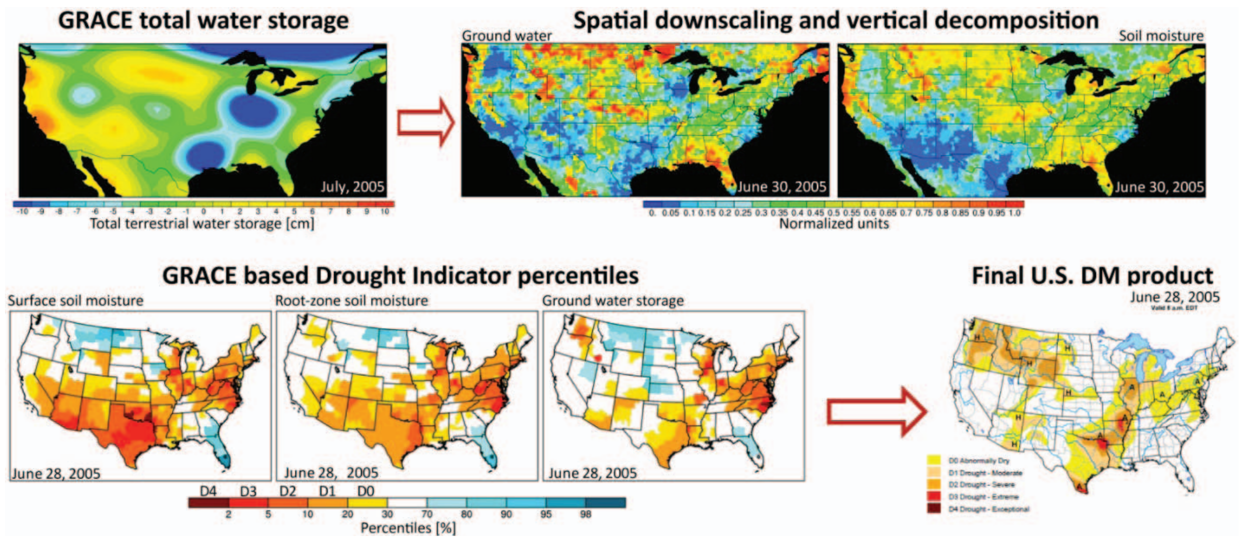

Fig 1. *GRACE terrestrial water storage anomalies (top left) are assimilated into a land surface model, enabling spatial, temporal, and vertical decomposition (upper right panels). From these results we compute GRACE-based Drought Indicators expressed in percentiles relative to their historical frequency of occurrence (lower left panels). Our partners are testing the incorporation of these new indicators into the "objective blends" that serve as baselines for the Drought Monitor products (lower right).*

use GPS and a microwave ranging system to accurately measure the distance between the two satellites to make unprecedented inferences of monthly changes in the distribution of water on land with sufficient precision [5]. While GRACE has a low spatial (no better than ~400 km) and temporal (ten day to monthly) resolution in comparison with other Earth Observation satellites, GRACE is unique in its ability to sense water stored at all levels systematically on a continuous basis. Thus GRACE TWS inferences represent a vertically integrated measure that includes groundwater, soil moisture, surface water, snow and ice, and biomass. The usefulness of GRACE for hydrological applications has been demonstrated in a number of recent studies [6,7,8] but the full potential of GRACE estimates of TWS variability still remains to be unraveled.

The value of GRACE TWS data for hydrological applications can be further advanced through data assimilation, which synthesizes the advantages of observations and numerical land surface models, enabling spatial and temporal downscaling and vertical decomposition of GRACE derived TWS into groundwater, soil moisture and snow (Fig. 1). The U.S. and North American Drought Monitor concept is a process that synthesizes multiple objective drought indices, outlooks and local impacts, into an assessment that best represents current drought conditions [3]. However, the analysis relies heavily on precipitation indices and subjective reports, and lack objective information on soil moisture and groundwater storage conditions. A key objective of this study is to demonstrate that drought conditions can be identified more accurately and objectively through the incorporation of spatially, temporally and vertically enhanced GRACE data. Daily estimates of groundwater, soil moisture, and snow conditions were produced by assimilating monthly column-integrated GRACE TWS anomalies into the Catchment Land Surface Model using an ensemble Kalman smoother [9]. The integration of the GRACE data into the U.S. and North American Drought Monitors is being accomplished by generating supplemental GRACE-based drought indicator "objective blends" of groundwater and soil moisture (Fig. 1) consistent with the suite of short-term and long-term indicator blends which currently serve as baselines for the Drought Monitors. We expect that the integration of the enhanced GRACE data into the operational production of objective drought indicator blends will lead to more accurate depictions of short and long-term drought conditions, ultimately benefitting the many stakeholders who depend on these products.

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