GRACE detection of seasonal variations in total water storage in southern Lao PDR

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Introduction

The Gravity Recovery and Climate Experiment (GRACE) gravity satellite program was jointly developed by the National Aeronautics and Space Administration (NASA) of the United States and the German Aerospace Centre (DLR) and launched in March 2002 to measure changes in the earth's gravity field (Tapley et al. 2004). These changes are caused by movement of mass in surface water, soil water and ground water. GRACE measurements are processed mathematically to extract estimates of of total water storage (TWS) expressed as equivalent water height (EWH). GRACE date have a spatial resolution of about 200,000 km^2, or ~400 km.

In 2013, a new website for GRACE (Darbeheshti et al. 2013) was developed using the spherical harmonic fields of the French Groupe de Rechercheen Géodesie Spatiale (GRGS). This website provides a Data Visualisation Tool (DVT) by which users can estimate the EWH from a user specified region (polygon) or point (Figure 1). The precision of areal and point data derived from the DVT is not clear. However, qualitative, seasonal variations in EWH in a small region in Southern Laos were mapped with the DVT. Also, time series of point measurements of EWH at Pakse were compared graphically with streamflow measurements of the Mekong River at Pakse.

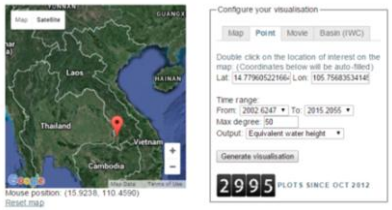

Figure 1: Data entry in the ANU GRACE DVT (Source: http://grace.anu.edu.au/evasph.php)

Study Area

Many studies concluded that GRACE offered satisfactory results at the spatial scale of about 200,000 km^2. However, a region about 25,000 km^2 was utilised to investigate the GRACE detection of TWS changes in Southern Laos. Sukhuma district is situated in this region (Figure 2). Southern Laos is one of the main target areas for agricultural development. However, floods and droughts often occur in this area and availability of water resources is not yet known exactly.

The study area consists of 32.29 percent of sandy loam which is the highest proportion in the area, and follows by clay (25.46 %), loam (23.81 %) and loamy sand (10.87 %). The highest proportion of land use area is covered by shrub land (32.83 percent). The deciduous broadleaf forest covers 24.39 percent of total area and 20.66 percent for dipterocarps. The crop land area covers 16.32 percent. Data from Ministry of Agriculture and Forestry, Lao PDR (MAF, 2000, 2010)

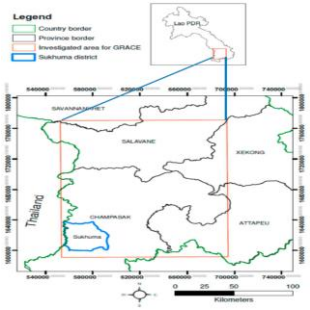

Figure 2: Study area map

Methods and Results

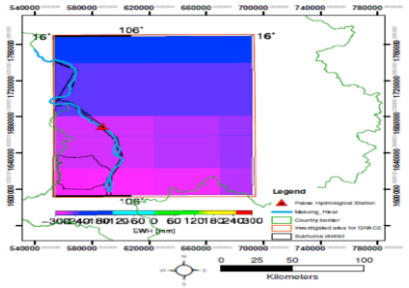

Figure 3: EWH map for April 2011(dry season)

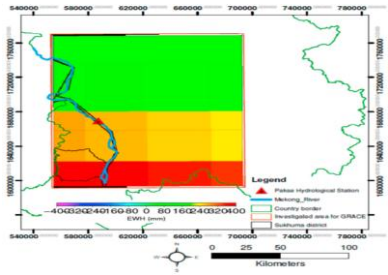

Figure 4: EWH map for September 2011(wet season)

The EWH map of April and September 2011 shows that the area with the lowest and the highest EWH are in the southwest corner of the region, which is in the same area including Sukhuma district. These EWH maps depict that GRACE can detect the seasonal variations in TWS. In the wet season loam has the highest EWH and clay has the lowest EWH but in the wet season loam has the lowest EWH. The influence of land-use vegetation modifies TWS so that EWH in each season is highest on sandy loam and crop land.

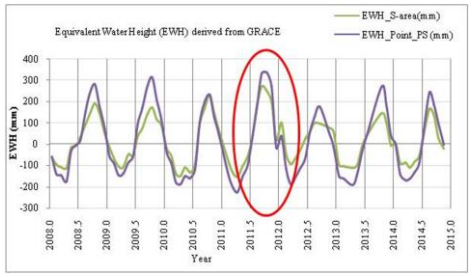

Figure 5: Comparison of the EWH derived from polygon and points during 2008-2014

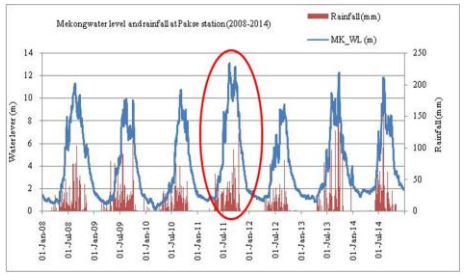

Figure 6: Rainfall and Mekong (MK) water level (WL) at Pakse station during 2008-2014

The time series data of EWH derived from a polygon (25,000 km^2) and a point (at Pakse hydro-meteorology station) from the ANU GRACE DVT are illustrated in Figure 5. These line graphs show the highest value of EWH is detected by GRACE in 2011. The Mekong River Commission (MRC), MRC (2011), reported that serious floods occurred in central and southern Lao PDR in 2011. These floods were caused by rising of water levels at some stations along Mekong River that exceeded the danger level, for instance, the highest water level at the Pakse (PS) hydrological station in Champasak province was recorded in 2011 (MRC 2011).This implies that GRACE satellites could detect the peak flood level in this area quite well.

Conclusions

- GRACE can detect the seasonal EWH flux and the extreme flood events in Southern Lao PDR. This could mean that GRACE data can be used to estimate the total groundwater, surface water and soil moisture in southern Lao PDR and/or Sukhuma area.
- The proportion of soil and land use types could have a high potential influence on the EWH values.

Future work will:

- apply other GRACE data sources to estimate total groundwater availability in southern Laos;
- utilise the Global Land Data Assimilation System (GLDAS) data and land model to estimate soil water in study area;
- investigate how to minimise the errors in GRACE data.

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