This study assesses the possibility to monitor large-scale mass transport in the Murray-Darling Basin (MDB) using GRACE time-variable gravity, TRMM precipitation and river level/flow observations between May 2003 and April 2009 (6 years). Results based on the Multi Linear Regression and Principal Component Analyses show distinct differences between the northern and southern climatic regions of the MDB. While the north is mostly dominated by monsoonal rainfall in the early part of each year (austral summer) the south is dominated by increased rainfall in the second half of each year (austral winter). Furthermore, the analysis clearly detects the severe drought that gripped the whole MDB during the year of 2006. The analysis of seasonal variations shows that the detection of a gravity change is preceded by precipitation by about one month in the northern part of the MDB and the inverse behaviour happens in the southern part. Considering an approximate 6 month shift in seasons between the two regions, this behaviour suggests a general mass transport taking in average about 4 to 5 months to cross the MDB from north-east to south-west. This finding is consistent with the general flow direction of the river system and confirmed by ground truth data in the form of river level and river flow observations.

**Data / Methodology**

**GRACE-derived Surface Mass Changes (SMC):**
- This study uses GRACE level-2 RL04 monthly gravity field solutions (CSR, degree and order 60) between May 2003 and April 2009.
- The gravity field solutions have been converted into SMCs (Wahr et al., 1998) as equivalent water height (EWH) and evaluated on a 15-arc-min by 15-arc-min grid.
- The solutions have been filtered with a Gaussian filter (R = 500 km) and according to Swenson and Wahr (2006).

**TRMM Precipitation Data:**
- Precipitation data are provided by the Tropical Rainfall Measurement Mission (TRMM) with a 15-arc-min by 15-arc-min resolution.
- The precipitation data have been filtered with a Gaussian filter (R = 500 km) in order to be comparable to the SMCs.

**Hydrology:**
- In-situ data are provided by hydrological observations of river level and river flow. These data are treated as point observations (e.g. not smoothed).

**Methodology**

- **This study uses three types of analyses tools:**
  1. Multiple linear Regression Analysis (MLRA)
  2. Principal Component Analysis (PCA)
  3. Cross Correlation

- **MLRA** is used to find statistically significant trends and periodic signals (here: annual signal).
  The functional model used is:
  \[ F(t) = c_0 + c_1 t + \cos(\omega t) + b_1 \sin(\omega t) \]
  Amplitude: \( A = \sqrt{c_1^2 + b_1^2} \)
  Phase: \( \Phi = \arctan \left( \frac{b_1}{c_1} \right) \)

- **PCA** is used to find the most dominant spatial and temporal variations in each data set (PCs). The PCA uses the scatter matrix of each data set (e.g. original data reduced by the average over the 6-year period).

- **Cross Correlation** techniques are applied to study the mutual relation between the data sets used. It also refers to average flow times of water along the rivers within the MDB.

**Data**

**The Murray Darling Basin (MDB)**

- The climate over the MDB has a distinct north-south pattern: Summer rainfall in the north. Winter rainfall in the south.
- All-year rainfall in a transitional zone between north and south is the southernmost climatic zone.

**Monitoring Mass Change and Transport in the Murray Darling Basin**

- **MLRA Results**
- **PCA Results**

**Some Observations**

**MLRA Results**
- All data show a north-south pattern following the major climatic regime.
- Trends show an increase in the north and a decrease in the south.
- Amplitudes of annual signals are generally larger in the north and smaller in the south and smaller than those in the north.
- Most of the annual signals are early in the year in the south and about 12 years later in the north. This follows the general climatic regime.
- In the south, different phases are present for SMC along the rivers Darling and Murray (difference of about 2 months). This behaviour is not present in the precipitation data. This indicates that either the SMC data or the SMC along the Murray and Darling have different flow regimes driven by the major climatic regimes. For decision on mass transport on the right.

**PCA Results**
- The spectral EOFs (and temporal PCs) patterns of the first 5 modes of the data types considered are very similar. This shows their strong relation.
- All principal components (PCs) of modes 1 show an annual signal and the seasons through variations in 2005/06 affecting the whole MDB (i.e. empirical orthogonal function EOFs)
- SPECS matrix for mode 1 shows an annual signal sometimes shifted in time. The EOFs show the signals for the whole climatic pattern, e.g. different seasons between north and south.
- All EOFs of mode 3 shows a change in mean-water content. This may indicate that the Darling river and its catchment have a different behaviour than the Murray and river and its catchments.

**Some Concluding Remarks**

- **Analysing SMC and precipitation separately (e.g. MLRA and/or PCA) can only reveal information on mass changes but no information on mass transport.**

This study has shown that the latter can be provided by the inclusion of in-situ hydrology data.

- **Using only SMC and precipitation data mass transport can be revealed through phase differences of major signals present (e.g. annual signal)**
- **This study confirms the hypothesis made in Rieser et al. (2010) regarding a cause for the peculiar phase differences present in the MDB**

**References**


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