Case Study-Assessment of the impacts of climate variability on total water storage

Friday 14 August 2020, 14:30-15:30 via Zoom
Talk by Tales Carvalho Resende

Attendance: *type name and affiliation in the chat*

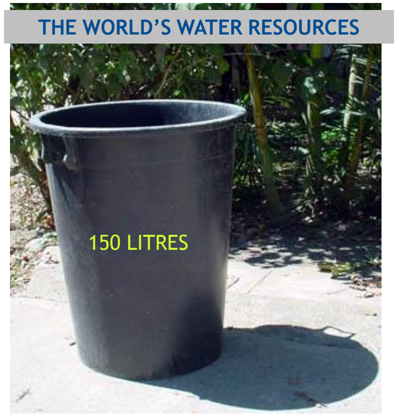
Questions: *type questions in the chat*

Courtesy: *switch off / mute your microphone and camera*

www.gwd.org.za

www.iah.org.za

The importance of groundwater



Imagine:

All the water on the planet
=

150 litre container
BUT JUST 4 LITRES ARE FRESH !!

The remaining 146 litres are SEAWATER

Source: Prof Ken Howard, Osaka Cut, 2003

The importance of groundwater

Out of these 4 litres:

3 litres are frozen (earth's ice caps, permafrost regions)

… leaving one lonely litre of freshwater

… and 99% the lonely litre of freshwater is GROUNDWATER !!

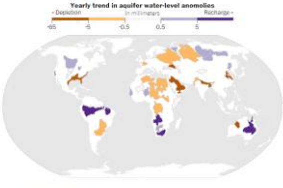
It is essential that we protect and manage groundwater resources effectively!

Source: Prof Ken Howard, Osaka Cut, 2003

Global context

The Washington Post

New NASA data show how the world is running out of water



Source: Water Resources Research

The New York Times

SCIENCE

World's Aquifers Losing Replenishment Race, Researchers Say

TECHNOLOGY

The Earth's Evaporating Aquifers

NASA satellites are tracking the planet's underground fresh-water supply.

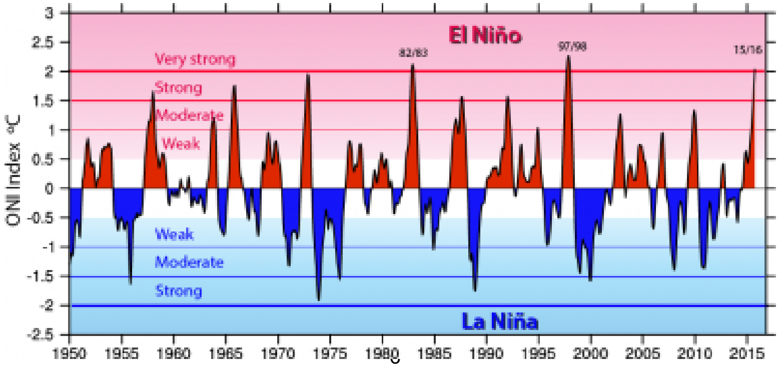
The Atlantic

Global context

- **Earth’s climate has exhibited marked "natural" changes**
- **Factors influencing natural climate variability are changes in circulation and overturning in the oceans**
- **Over periods of a few years, fluctuations in global surface temperatures of a few tenths of a degree are common**
- **The changes are “measured” through climate indices**
- **Among the known climate indices:**
    - ***El Niño Southern Oscillation (ENSO),***
    - ***Indian Ocean Dipole (IOD),***
    - ***Pacific Decadal Oscillation (PDO),***
    - ***Atlantic Multidecal Oscillation (AMO)***
- **These climate indices are often correlated but it is still very difficult to assess to what extent**

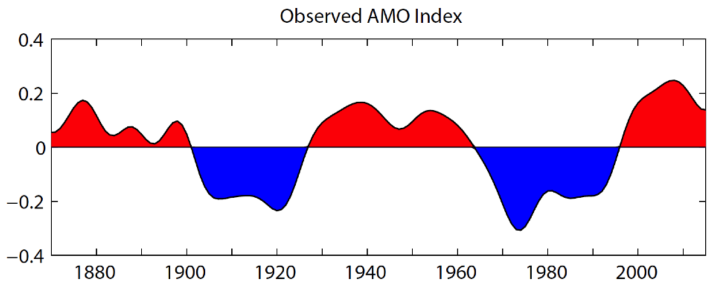
Climate indices

- **Climate indices have cycles (a couple of years, decadal, multi-decadal….) and have what we call positive and negative phases**
- **El Niño Southern Oscillation (ENSO) → cycles of a couple of years**



Climate indices

- **Atlantic Multidecal Oscillation (AMO) → cycles of several decades**

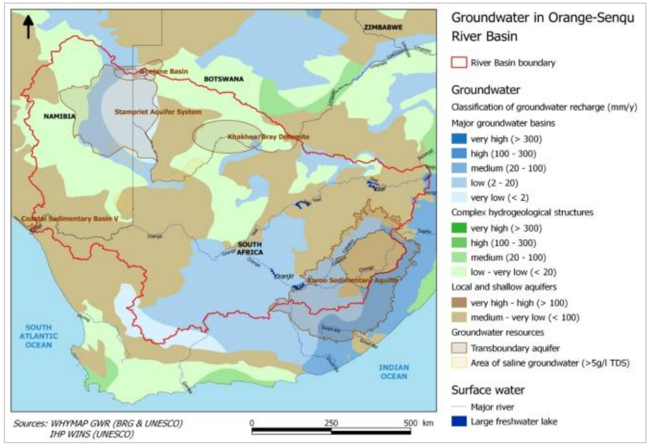


Main objective of the study

- **Assess the impact of climate variability on recharge of two large aquifers (Stampriet and Karoo Sedimentary) in the Orange-Senqu River Basin <u>despite the lack of continuous data</u> as a means to support sound management strategies**

- **Focus on two climate indices:**
  - ***El Niño Southern Oscillation (ENSO)***
  - ***Atlantic Multidecal Oscillation (AMO)***

Groundwater in the Orange-Senqu River Basin



Sources: WHYMAP GWR (BRG & UNESCO)
IHP WINS (UNESCO)

Groundwater in the Orange-Senqu River Basin

- **Potential impacts of climatic oscillations on groundwater dynamics in the Orange-Senqu River Basin have still not been largely addressed**
- **Two large transboundary aquifers in the Orange-Senqu River Basin: Stampriet and Karoo Sedimentary**
- **Lack of long-term groundwater level data to assess the dynamics of these large aquifers on the ground**

Challenges in a data-scarce setting

- **Use of gravity data supplied by satellites can provide a means to monitoring large scales changes in groundwater storage**
- **However, satellite time observations are limited in time (e.g. GRACE data is available only since 2002) and therefore may not capture full climate cycles (e.g. AMO)**
- **Hence, there is a need to <u>"extend" GRACE time frame to the past with adequate models to "reconstruct" (ground)water storage fluctuations</u>**

Methodology

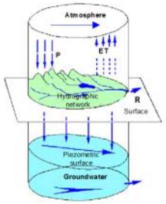
<u>Step 1:</u> Run a simplified water balance model that "reconstructs" past total water storage changes in the Stampriet and Karoo Sedimentary Aquifers from 1980 to 2016

<u>Step 2:</u> Validation of the simplified water balance model with GRACE and groundwater level data

<u>Step 3:</u> Assessment of correlations between total water storage changes and climatic indices, e.g. El Nino/La Nina (ENSO) and the Atlantic Multidecadal Oscillation (AMO)

Step 1: Simplified water balance model

- From Carvalho Resende et al., 2018 (Hydrogeology Journal)
- Model allows extending evaluation time-frame to the last 30-more years and therefore covers climatic oscillations cycles
- Independent from GRACE data
- <u>Two variables only:</u> Precipitation and Actual Evapotranspiration
- Uses only global datasets for precipitation (GPCC) and evapotranspiration (GLEAM)
- Data available in a monthly basis from 1980 to 2016



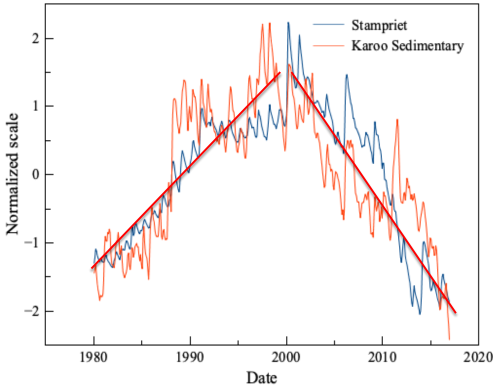
$$\frac{dS}{dt} = P - E - R$$

S	Total water storage variations
P	Precipitation
E	Actual ET
R	Surface runoff

Assumption: *R = constant because at long term, total water storage variations are driven by groundwater storage variations*

$$GWS_{model} \approx S_{model} = \int P\,dt - \int R dt - \int E\,dt \approx \text{detrend}\left(\int P\,dt - \int E\,dt\right)$$

Step 1: Simplified water balance model

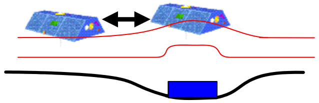


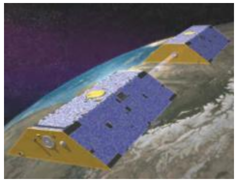
- Total water storage changes in the Stampriet and the Karoo Sedimentary aquifers follow the same multi-decadal trend, i.e. increase from 1980 to late 1990s and decrease from late 1990s to current days
- Inter-annual trend is however different

Step 2: Validation of the model with GRACE data

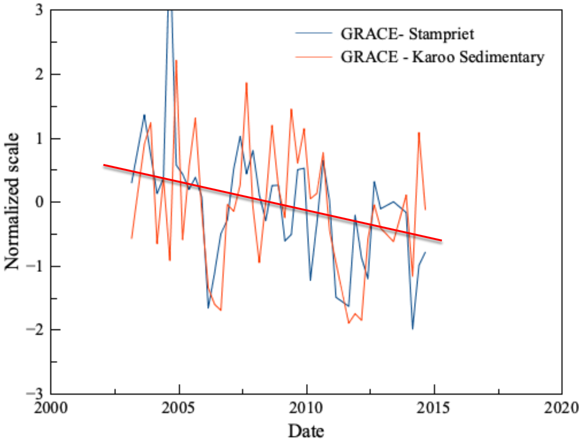
Gravity Recovery and Climate Experiment (GRACE)

- *First satellite mission able to monitor total water-storage changes (including groundwater) remotely*
- *Data available in a monthly basis since 2002*
- *Data obtained from http://www.thegraceplotter.com*



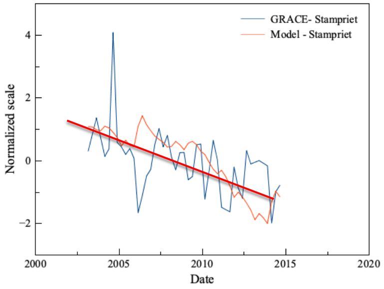


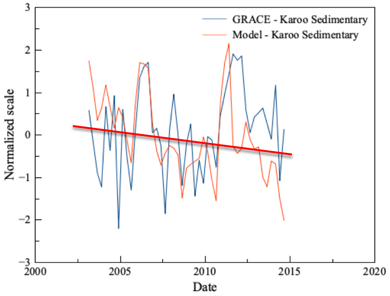
Step 2: Validation of the model with GRACE data



- **Total water storage changes in the Stampriet and the Karoo Sedimentary have a decreasing trend since 2002**

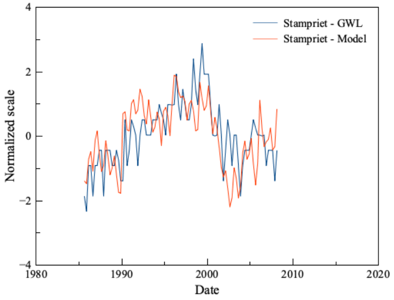
Step 2: Validation of the model with GRACE data

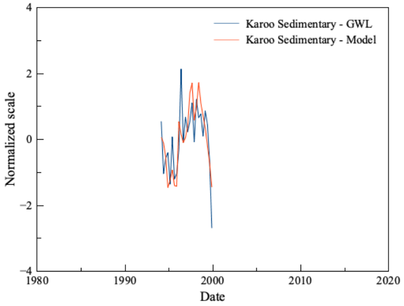




- **<u>Validation:</u> GRACE and Model total water storage changes in the Stampriet and the Karoo Sedimentary follow the same decreasing trend**

Step 2: Validation of the model with groundwater level data

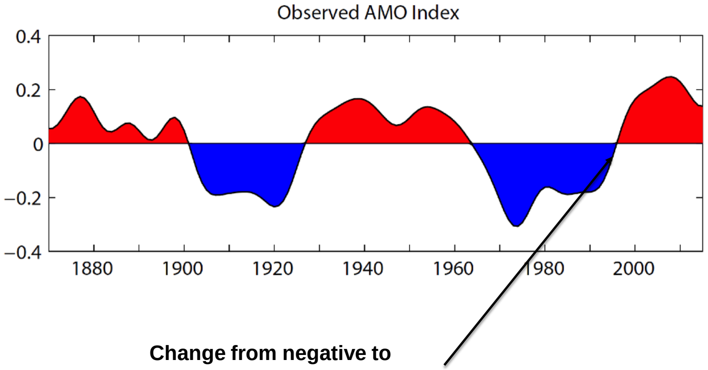




- **<u>Validation:</u> Groudwater level and Model total water storage changes in the Stampriet and the Karoo Sedimentary follow the same trend**

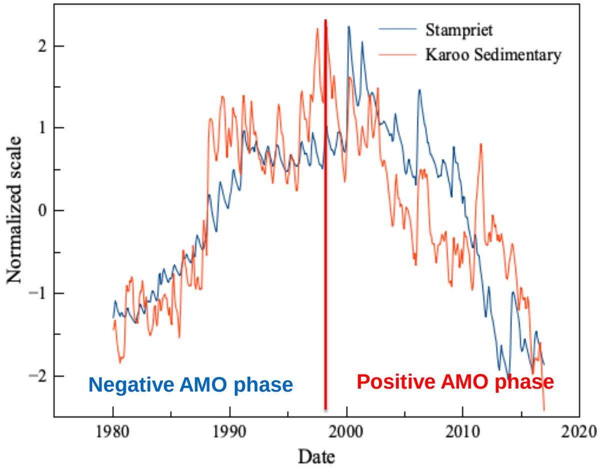
Step 3: Correlations between total water storage changes and climatic indices

- **Atlantic Multi-decadal Oscillation (AMO)**



Change from negative to positive phase in late 1990s

Step 3: Correlations between total water storage changes and climatic indices

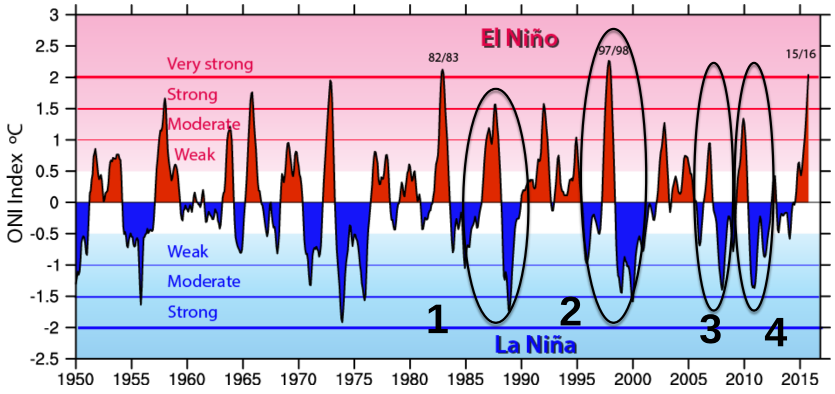


Negative AMO phase

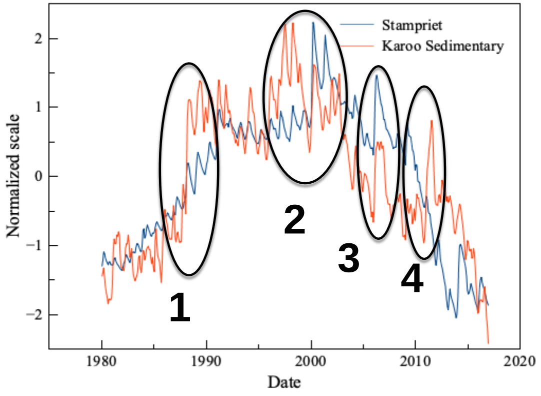
Positive AMO phase

Step 3: Correlations between total water storage changes and climatic indices

- **El Niño/La Niña (ENSO)**



Step 3: Correlations between total water storage changes and climatic indices



Most significant total water storage changes usually occur when there is a El Niño/La Niña shift

Conclusions and recommendations

- **The shallow aquifers of the Stampriet and Karoo Sedimentary aquifer systems aquifers are highly responsive to rainfall**

- **Total water storage changes in the Stampriet and Karoo Sedimentary aquifers are correlated to changes of phases of climatic indices:**
  - **Multi-decadal scale: from the Atlantic Multi-decadal Oscillation (AMO)**
  - **Inter-annual scale: El Niño/La Niña (ENSO)**

- **Need to strengthen links with metereological agencies in order to better understand rainfall patterns**

- **Further work can provide insights for agriculture and livestock planning (especially during drought periods) and Managed Aquifer Recharge schemes**

A big thanks to…

- **UNESCO Intergovernmental Hydrological Programme**
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