Assessing changes in terrestrial water storage in Africa using GRACE satellite gravity data and JLG terrestrial water storage model

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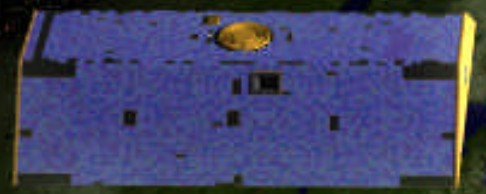
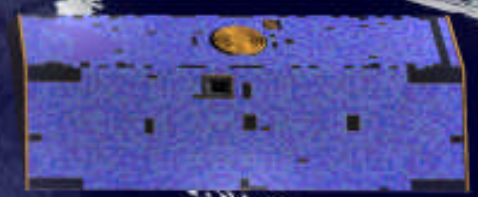
GRACE satellite gravity data

- GRACE satellite gravity mission has been providing monthly gravity field solutions since the launch in 2002.
- The variable components of GRACE gravity field solution can be converted to mass variation by





$$\Delta\sigma(\theta,\lambda) = \frac{a\rho_E(2l+1)}{3(1+k_l)} \sum_{l=0}^{L} \sum_{m=0}^{l} (\Delta\overline{C}_{lm} \cos m\lambda + \Delta\overline{S}_{lm} \sin m\lambda) \overline{P}_{lm}(\sin\theta)$$

- Useful for the studies of landwater movements, ocean flow, ice sheet mass changes etc.

What's the advantage of using GRACE data for the study of landwater?

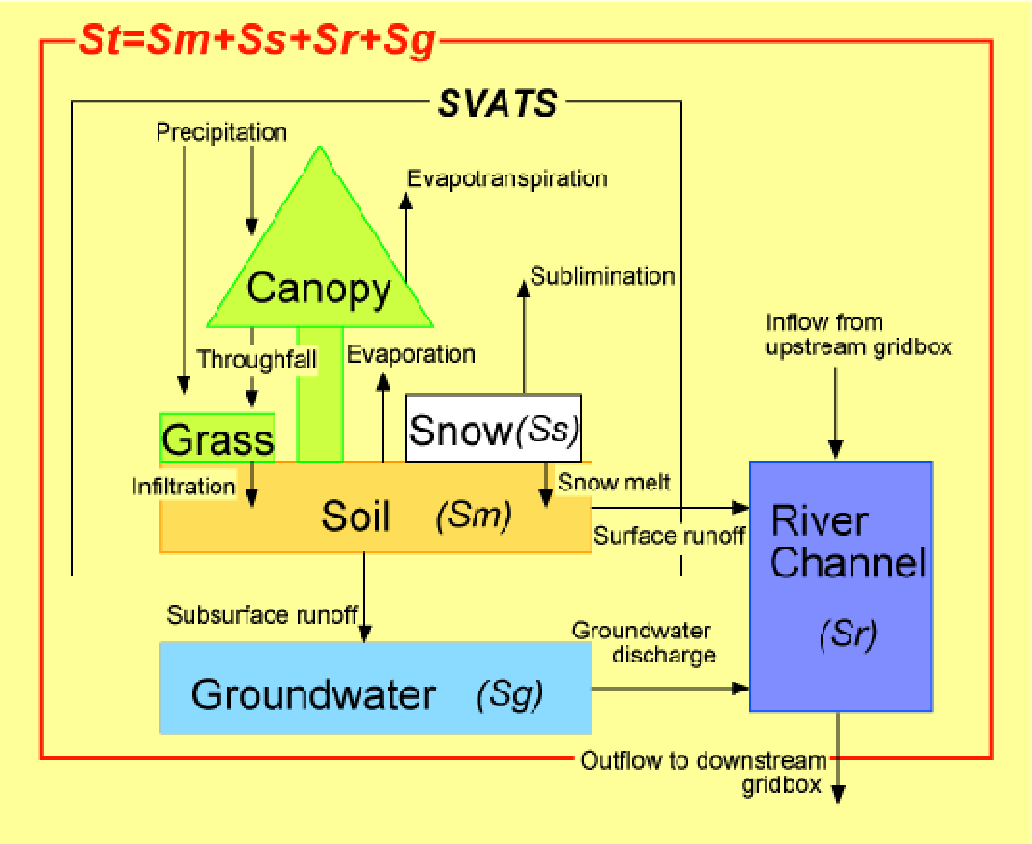
$\Delta\sigma_{GRACE}$ = Vertical integration of total mass variation
$\simeq$variation of Total terrestrial water storage (over land area)

-We can know large scale total landwater variations including groundwater movement.

On the other hand, landwater model is useful for the discussion on

*variations of each landwater component

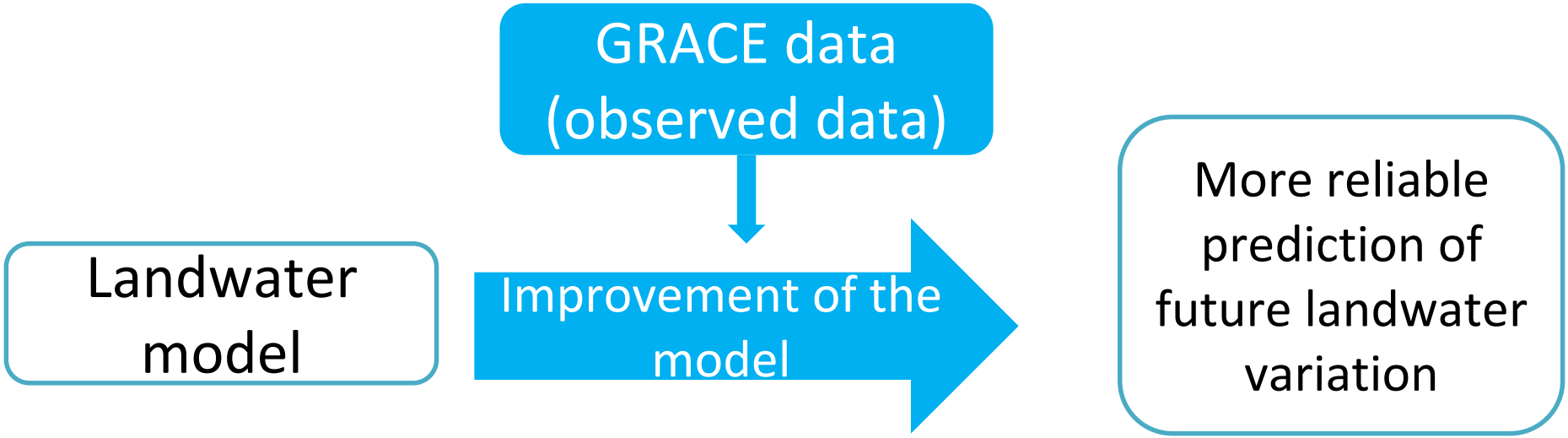
*future prediction of the landwater storage



- JRA-JCDAS LDA and GRiveT (JLG) model is one of the global scale terrestrial water storage model developed by Nakaegawa et al.

$S_t \simeq S_{GRACE}$

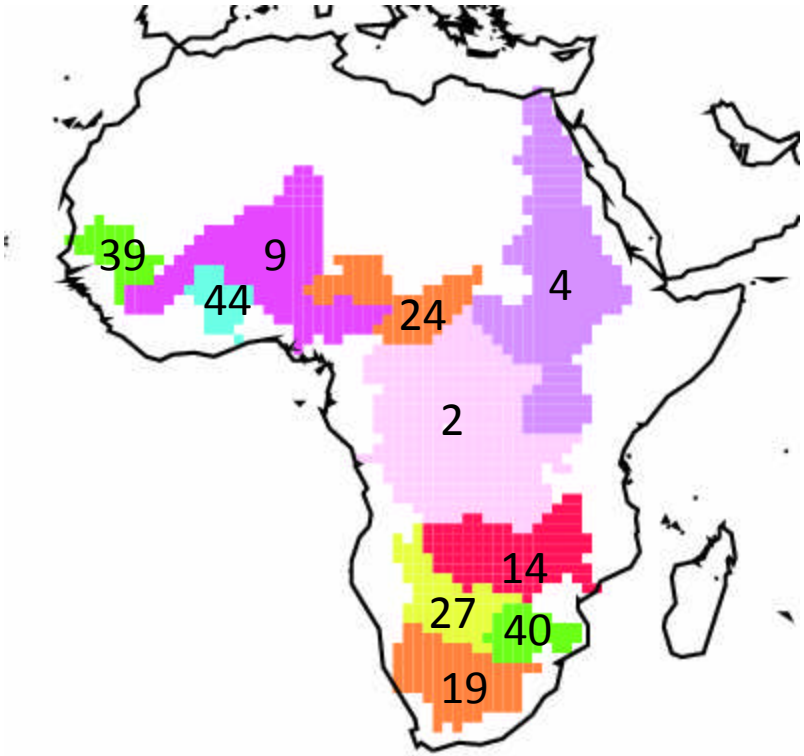
Our Purpose



Today's presentation:

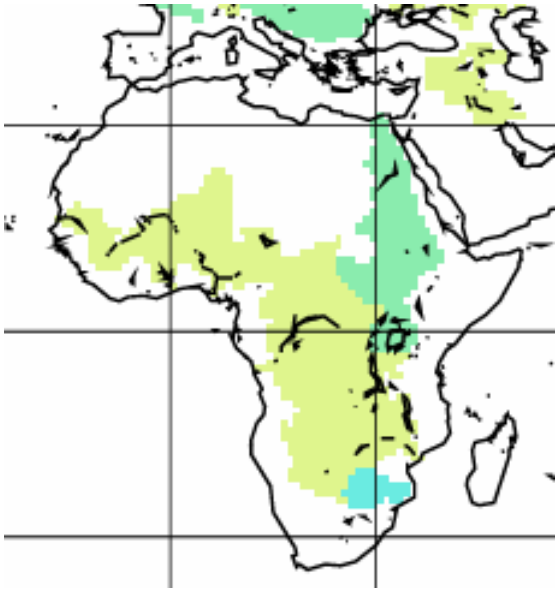
1. Landwater mass variations over Africa observed by GRACE
2. Comparison GRACE's mass variation with global terrestrial water storage model (JLG)
   *several major river basins in Africa

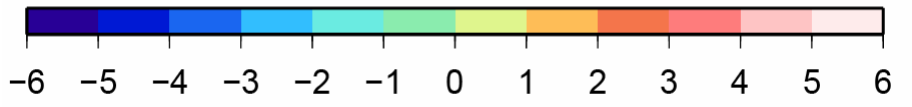
Major river basins in Africa



2. Congo
4. Nile
9. Niger
14. Zambeze
19. Orange
24. Chari
27. Cubango
39. Senegal
40. Limpopo
44. Volta

Comparison of seasonal variations

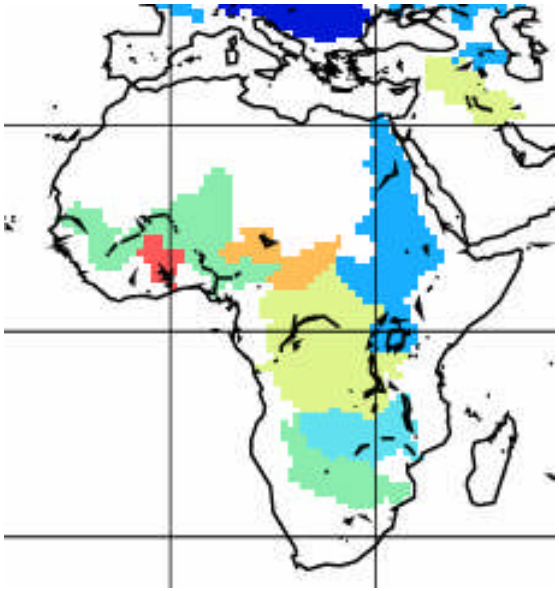




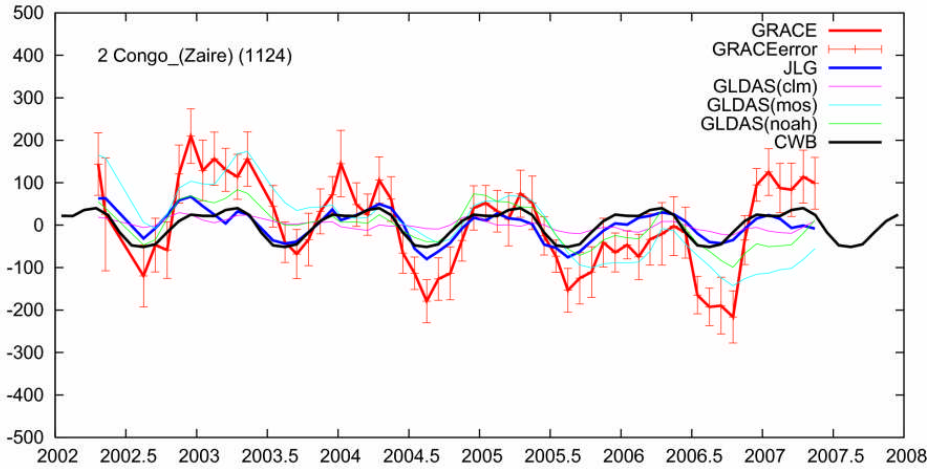
Phase lag of annual components [month]

> 0 GRACE is delay

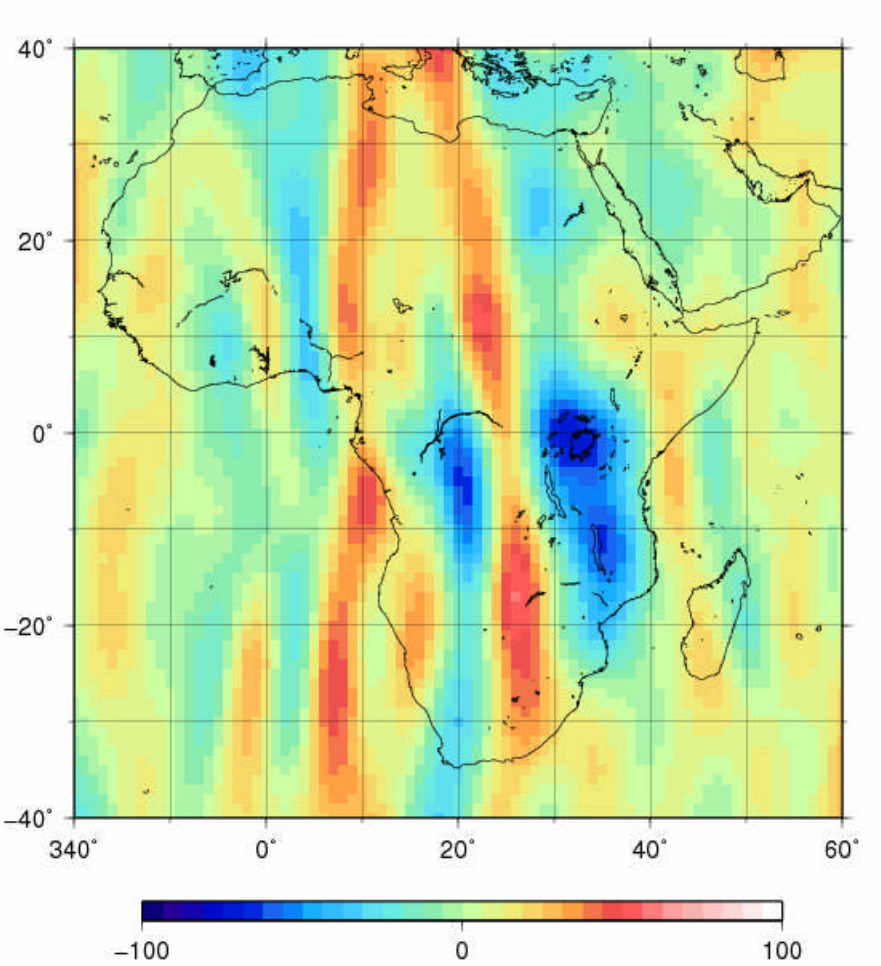
< 0 Model is delay



GRACE/Model ratio of amplitude of annual components



Interannual mass trend (2002 to 2007) observed by GRACE



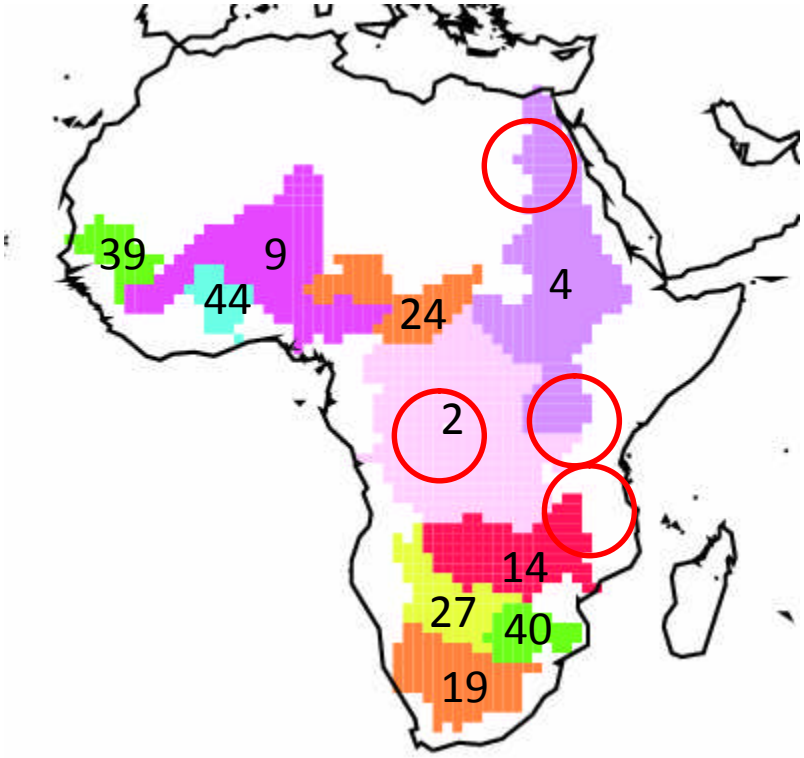
400 km Gaussian filtered solution

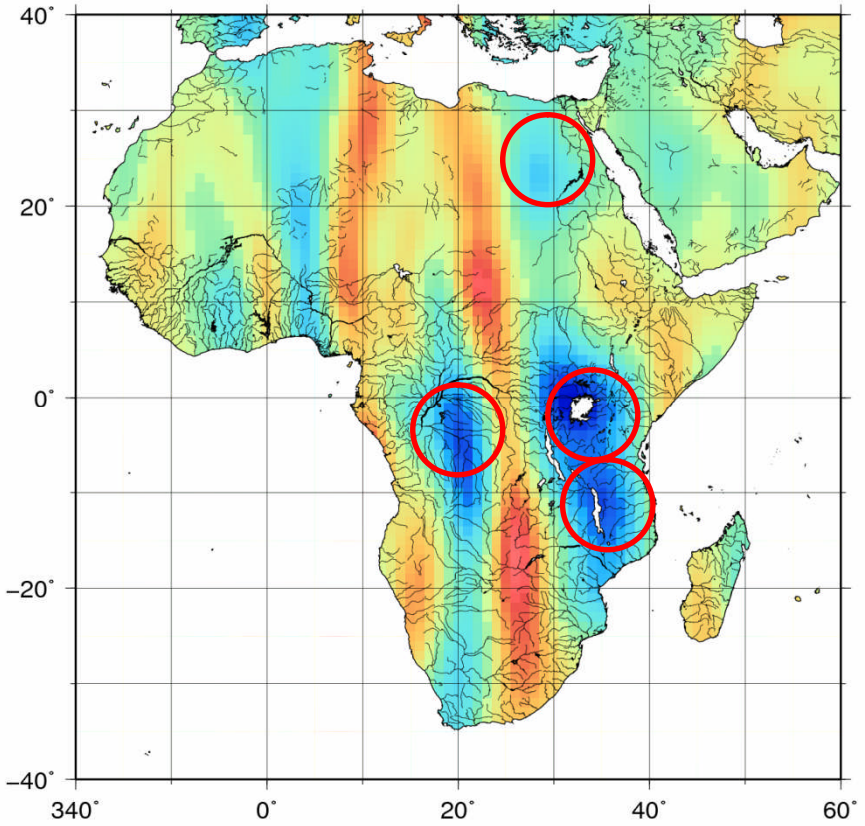
Total mass of Africa:
decreasing
(from 2002 to 2007)

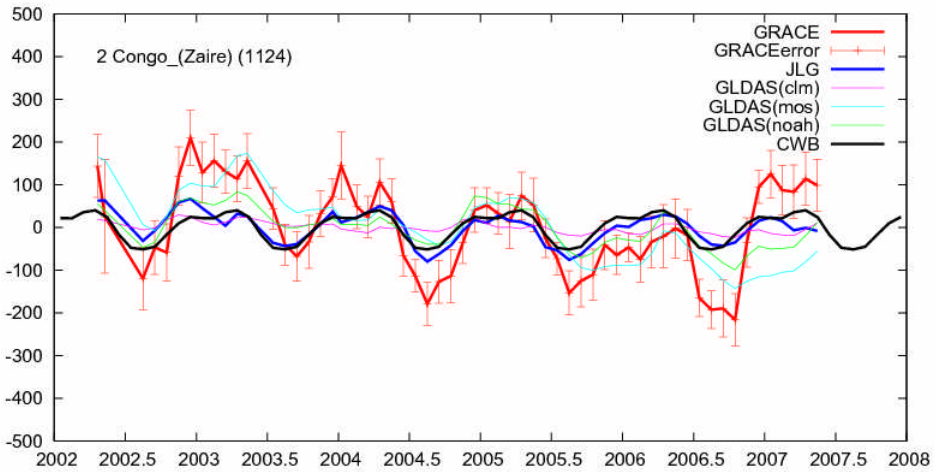
Significant decrease is observed over
Congo river basin
Lake Victoria
Lake Malawi

Major river basins in Africa

JLG model is tuned the discharge for each data basin.







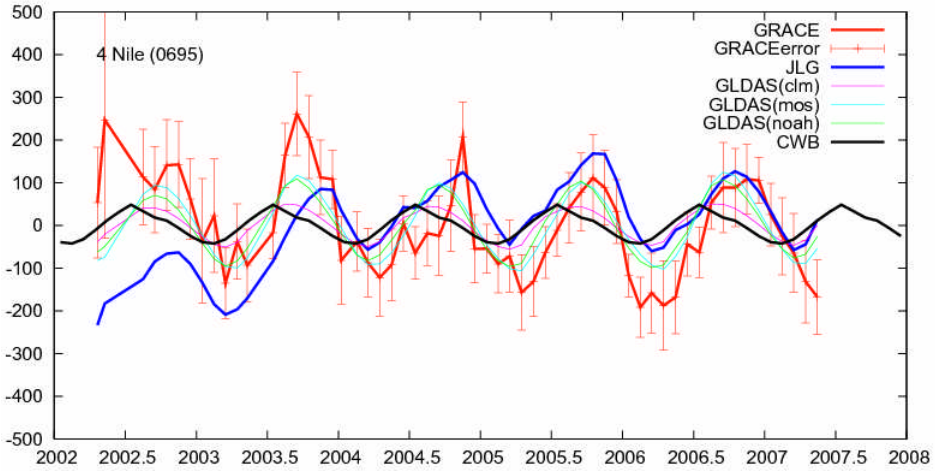
Red: GRACE

Blue: JLG model

Cong basin

GRACE: -20.33 mm/yr

Model: -7.25 mm/yr



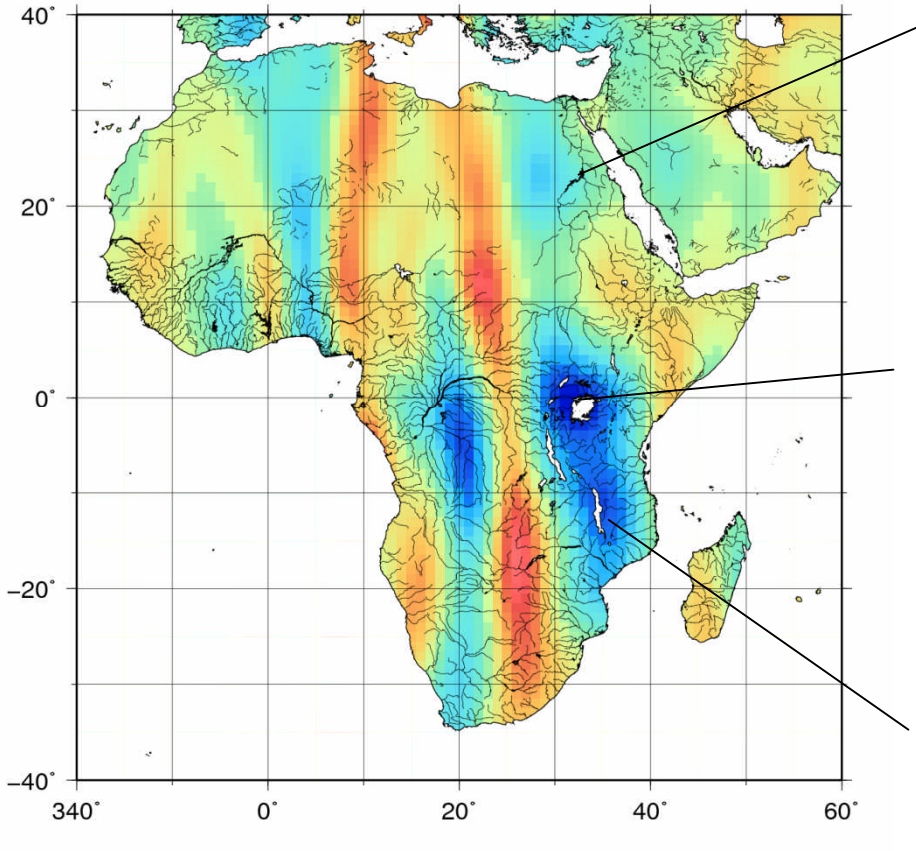
Nile basin

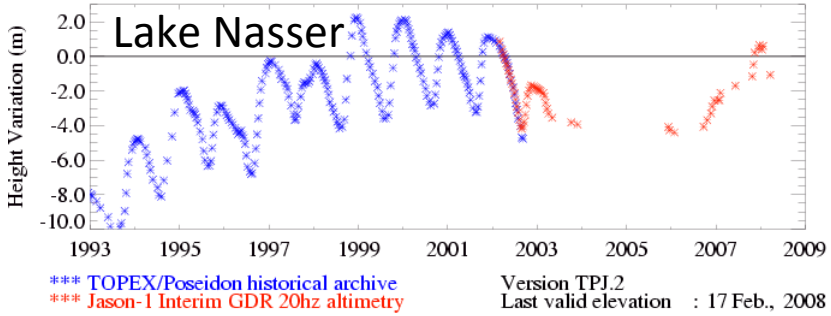
GRACE: -26.73 mm/yr

Model: +37.72 mm/yr

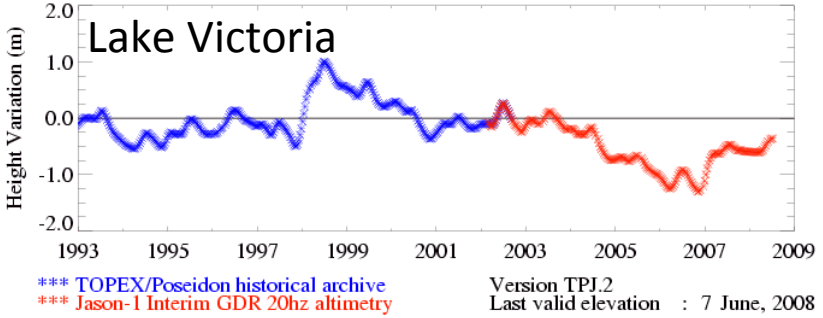
Currently, JLG model does not include the effect of human activities (dam , drawing of groundwater etc.), lakes

Lake water level observed by satellite altimetry

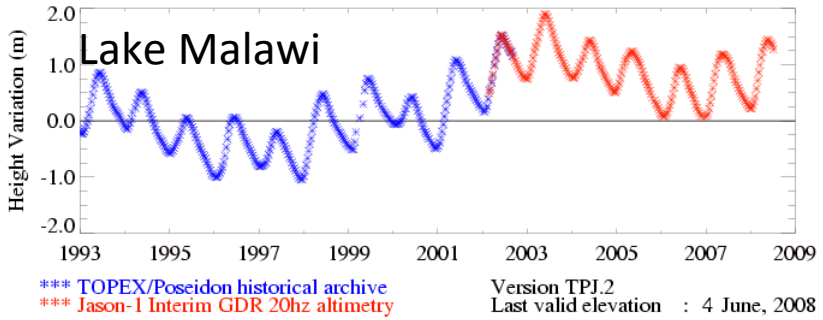




-31.7 cm/yr = -0.9 km3/yr



-24.9 cm/yr = -17.1 km3/yr



-17.3 cm/yr = -5.1 km3/yr

However, the lake effect is not sufficient to explain the discrepancy between GRACE and Model results.

Mass trend over Nile basin

GRACE: -79.43km3/yr

Model: +112 km3/yr

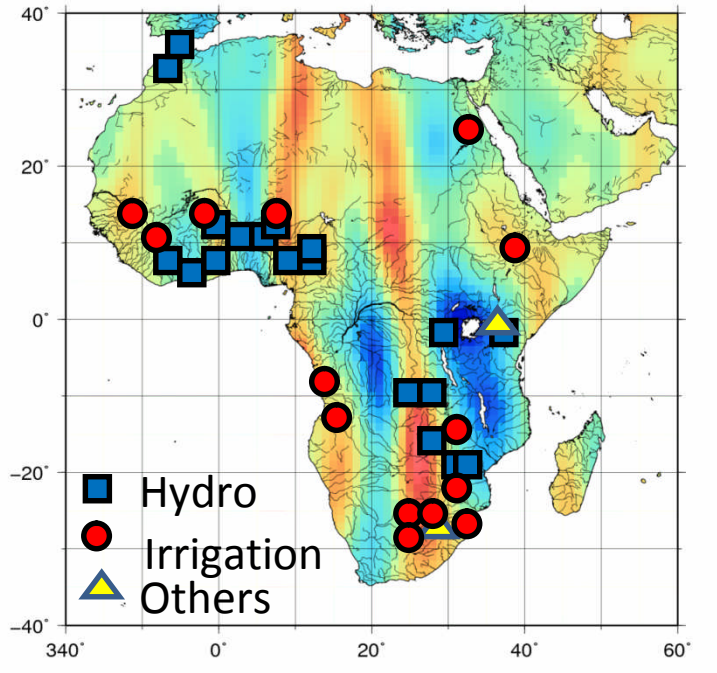
Major lakes over Nile basin

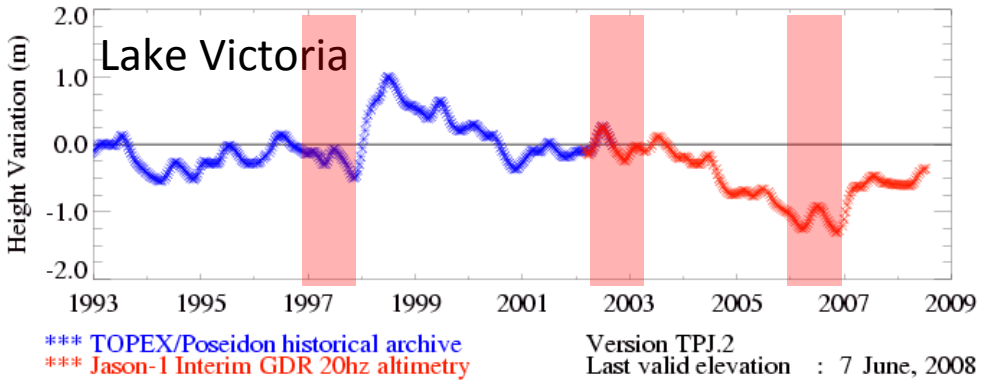
Total: -23.1 km3/yr

*Error of JRA-25 reanalysis model (driving force)
Precipitation, evaporation, etc.
*Error of Model

Future Plan

- Improvement of the model
- Separation of each components of terrestrial water storage
- Estimation of effect of human activity
- Separation of long periodical components
- Separation of the effect like ENSO.





→ Using other satellite data, in situ data sets are important for the purpose.

•GRACE measurement is one of the powerful techniques for the study of large-scale total landwater movement including groundwater.

•However, to discuss each components separately, it is also important to compare the result with other satellite data/ in situ observed data.

•When we determine the environmental policy (e.g. water management) in each country, it is important to use not only the observed result of local area, but also the one of large scale area.