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Influence of the surface permeability on the GRACE water mass variations: the case of the Lake Chad basin.

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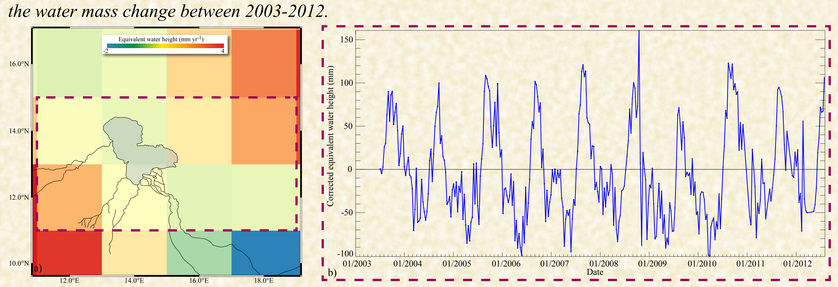
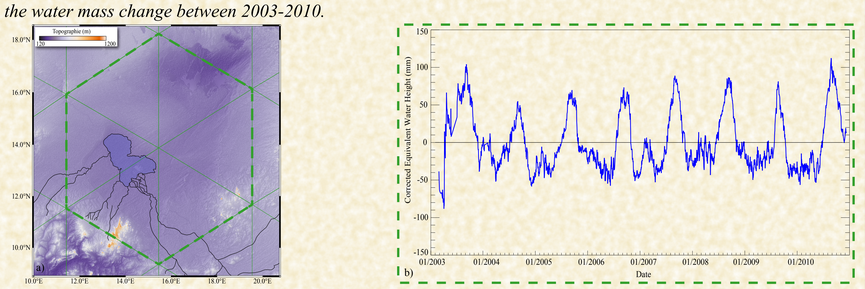
Figure 1 : a) 2°x2° 10-days mean GRACE land water mass trends (mm yr^{-1}) . b) Spatial average (purple box) of the water mass change between 2003-2012.



Abstract: Semi-arid to arid regions show an important coupling between subsurface processes and the atmosphere[1,2,3]. In the Lake Chad basin, it has been shown that these exchanges are mainly associated to the **evapotranspiration/condensation (ETC)** cycle and have a significant role on the surface temperature evolution [1, abstract 11811]. The Gravity Recovery and Climate Experiment (GRACE) data may give interesting information to better understand the relationship between ETC cycle and land water mass changes.

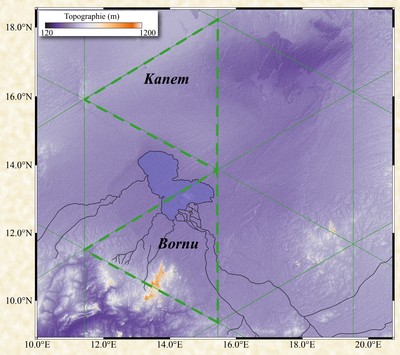
In this study, land water mass changes are evaluated in using a new set of GRACE daily solution [4, abstract 5529]. Comparison of 10 days mean GRACE solutions (Fig. 1, [5]) and daily ones (Fig. 2) shows the same behaviour. The interannual evolution of the water mass is easily explained by the monsoon that takes place from June to September. Both curves show an increase of the water storage during the dry season, also observed in [6]. The interplay of subsurface, surface and atmospheric processes can lead us to propose an hypothesis to explain this water mass increase during the dry season.

Figure 2 : a) Daily GRACE triangles with a spatial resolution equivalent to 3°x3°. b) Spatial average (green box) of the water mass change between 2003-2010.

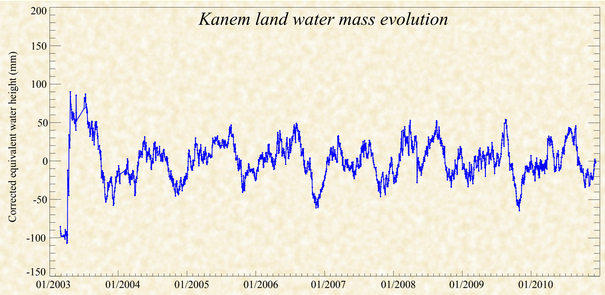


1. Latitudinal dependance

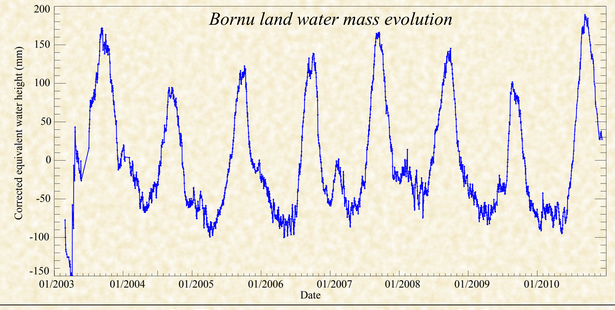
Daily GRACE triangles



Kanem land water mass evolution



Bornu land water mass evolution



Kanem:

> Small amplitudes variation between the rainy season and the dry one; easily explained by the latitudinal decrease of the monsoon intensity.

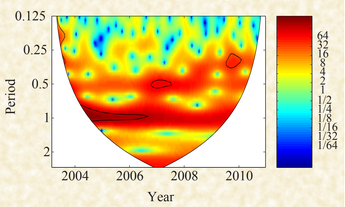
> The increase of the water mass during the dry season is difficult to observe in the plot. The wavelet transform of the GRACE data confirm that this cycle is nearly inexistent in this region.

Bornu:

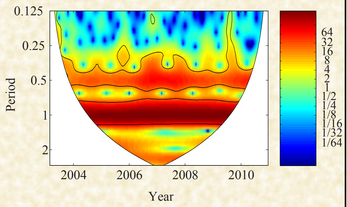
> The intensity of the monsoon at this latitude is more important, explaining the large variations observed between the dry and the rainy season.

> The water mass increases during the dry season can be easily observed; also confirmed by the wavelet transfrom of the GRACE data. This increase occurs in January-February (sometimes until March) and its intensity varies each year.

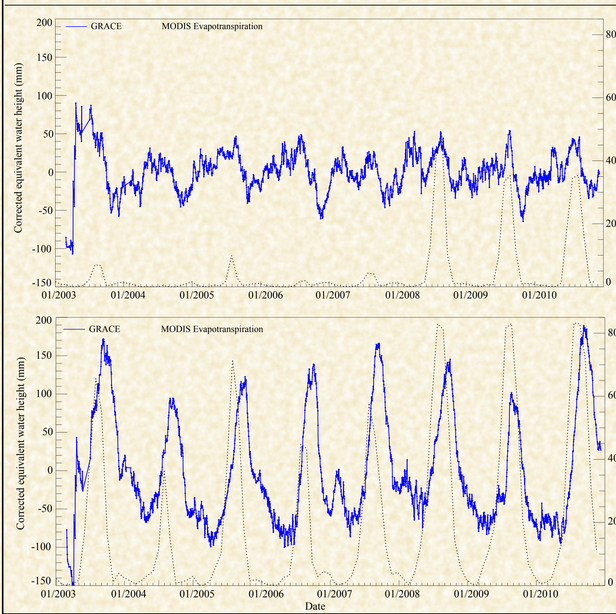
Kanem wavelet transform



Bornu wavelet transform



2. Evapotranspiration and clays concentration



Mean MODIS evapotranspiration (ET) data for Kanem and Bornu, obtained from [7].

Kanem:

> From 2003 to 2007, except during the monsoon of 2003, 2005 and 2007, there is no increase of the ET signal. Between 2007 and 2010, the ET has increased.

> An ET signal during the dry season is nearly inexistant as for the land water mass evolution.

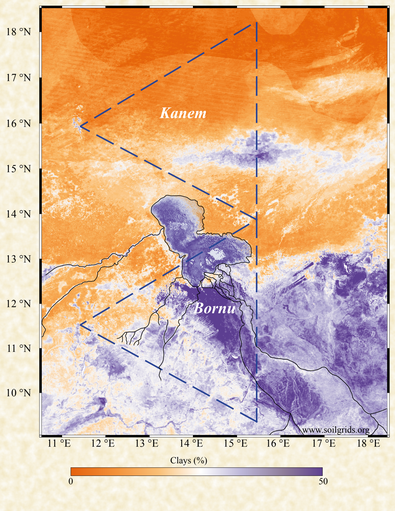
Bornu:

> The ET amplitude is much important in this region during the wet season, linked to the intensity of the monsoon.

> From 2003 to 2008, the ET signal shows an increase during the dry season, between November and March ; in nearly the same period than the water mass increased estimated by GRACE.

> The ET signal varies as a function of the latitude.

Map of clay concentration

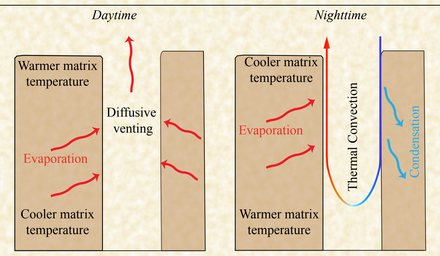


Aside from the monsoon intensity, the only characteristic showing such a strong correlation with the latitude is the clay proportion; as illstrated by the map of the clay concentration.

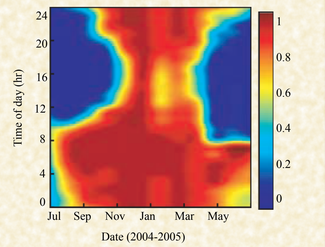
The increase during the dry season of both the ET signal and the water mass indicates that they are under the influence of same processes.

The spatial correlation with the clay concentration leads us to propose that the water content in the clays controls the evolution of the ET and the water mass during the dry season, by the interplay for forced convection (controlled by wind) and thermally driven convection orrucing inside the desiccation cracks.

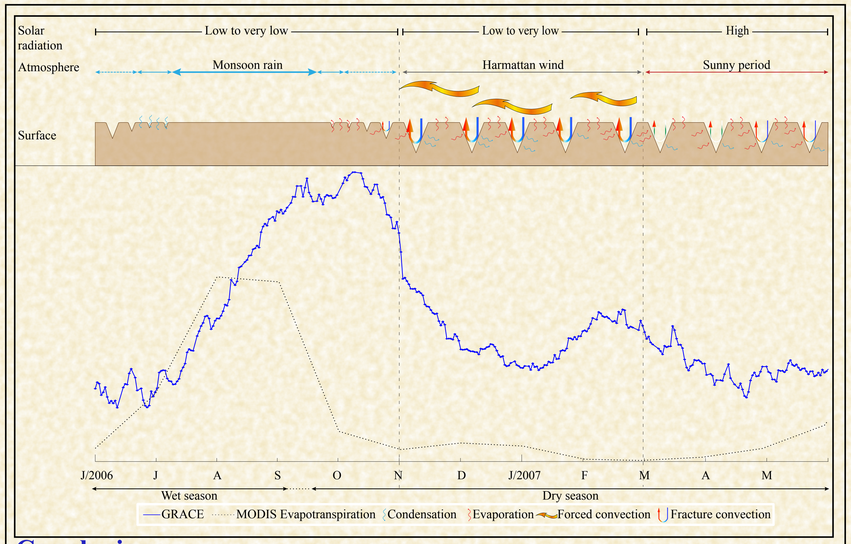
3. Fracture convection



Sketch representing the exchanges of water vapour during day by diffusion. Due a temperature difference inside the fracture, a thermally driven convection occurs and permits the evaporation/condensation cycle during night (modified from [8]).



Probability field that a thermally driven convection occurs during the hours of a day. A value of 1 means that the convection has 100 % to occur during that time (modified from [9]).



Conclusion: The discovery of the water mass increase in the Lake Chad basin, estimated by GRACE, during the dry season is surprising as there is no direct or indirect water input at this time of the year. The evapotranpiration data retrieved from MODIS also show a resumption from November to March. Both signals exhibit a strong relationship with the latitude. The concentration of clays at the surface also depends on the latitude and it suggests that the clays dryness/moisture cycle controls both signals. Indeed, when the clays are sufficently dry to develop desiccation craks, a thermally driven convection occurs inside [8,9]. It permits to bring back some water by condensation but also to suck the water when the air exists warmer. This cycle explains the decrease observed with GRACE and on the ET data at the end of the rainy season. It has been demonstrated by [10] that wind generates a forced convection inside fractures that surimposes with the fracture convection leading to very strong exchanges with the atmosphere. This phenomena corresponds to the increase observed during the Harmattan (dry and dusty wind) period. Finally, in the core of the dry season, fractures convection still occurs, but is less efficient and leads to a stabilisation of GRACE and ET signals.

References: [1] Lopez, T. et al. (2016) Surv. Geophys. doi:10.1007/s10712-016-9363-5; [2] Antoine, R. et al. (2009) J. Volcanol. Geotherm. Res. doi: 10.1016/j.jvolgeores.2008.12.003.; [3] Antoine, R. et al. (2017) Geothermics doi: 10.1016/j.geothermics.2016.01.003; [4] Ramillien, G. et al (2017) EGU abstract conference. 5529; [5] Ramillien, G. et al.(2014) Remote Sensing doi: 10.3390/rs6087379; [6] Grippa, M. et al. (2011) Water Resour. Res. doi: 10.1029/2009WR008856; [7] Qiaozehn, M. et al. (2011) Remote Sensing Env. doi: 10.1016/j.rse.2011.02.019; [8] Weisbrod, N & Dragila, M. I. (2006) J. Arid Env. doi: 10.1016/j.jaridenv.2005.07.011; [9] Weisbrod, N et al. (2009) Geophys. Res. Lett. doi: 0094-8276/09/2008GL036096S05.00; [10] Nachshon, U. et al. (2012) J. Geophys. Res. doi: 10.1029/2011JG001898