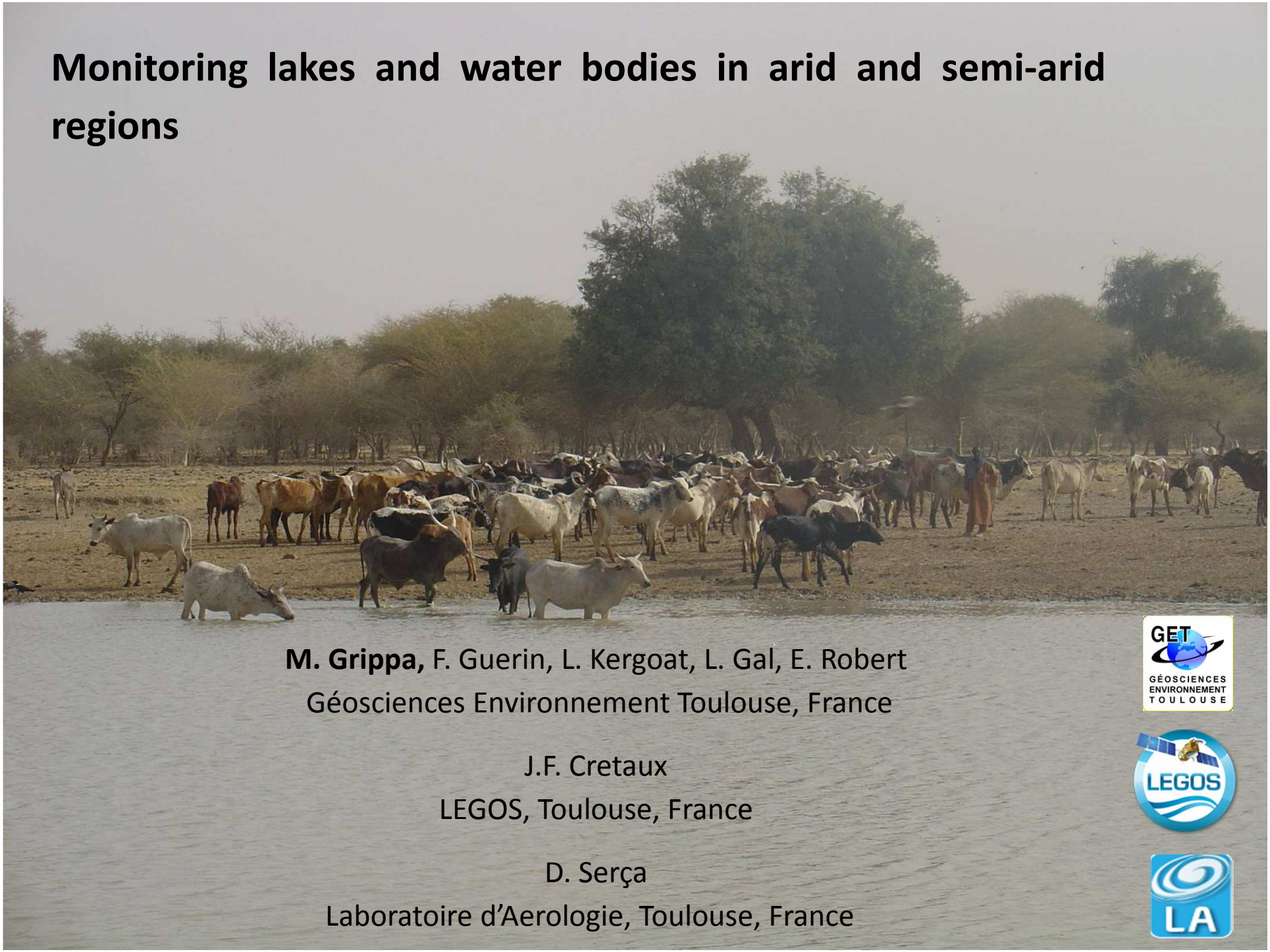
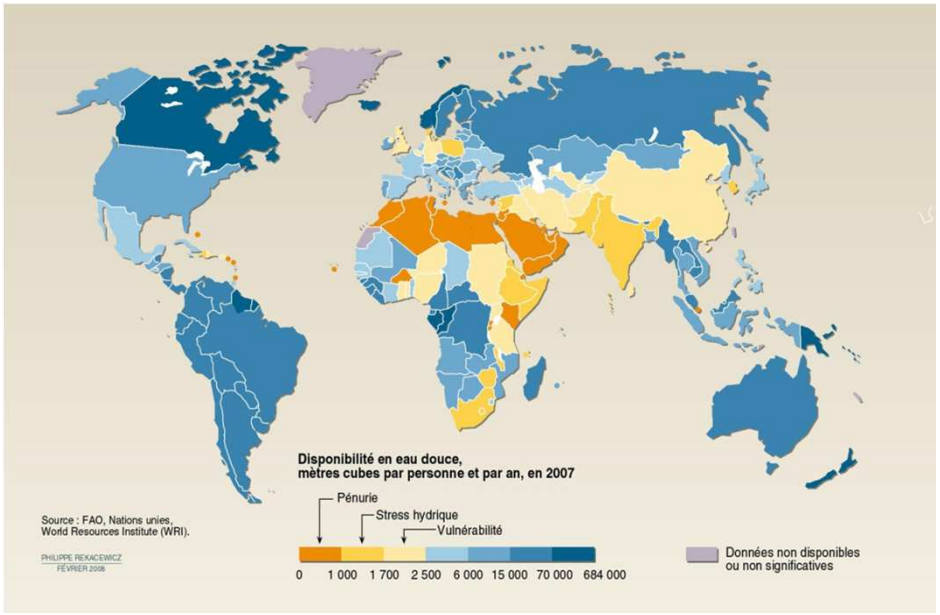
Monitoring lakes and water bodies in arid and semi-arid regions



M. Grippa, F. Guerin, L. Kergoat, L. Gal, E. Robert
Géosciences Environnement Toulouse, France

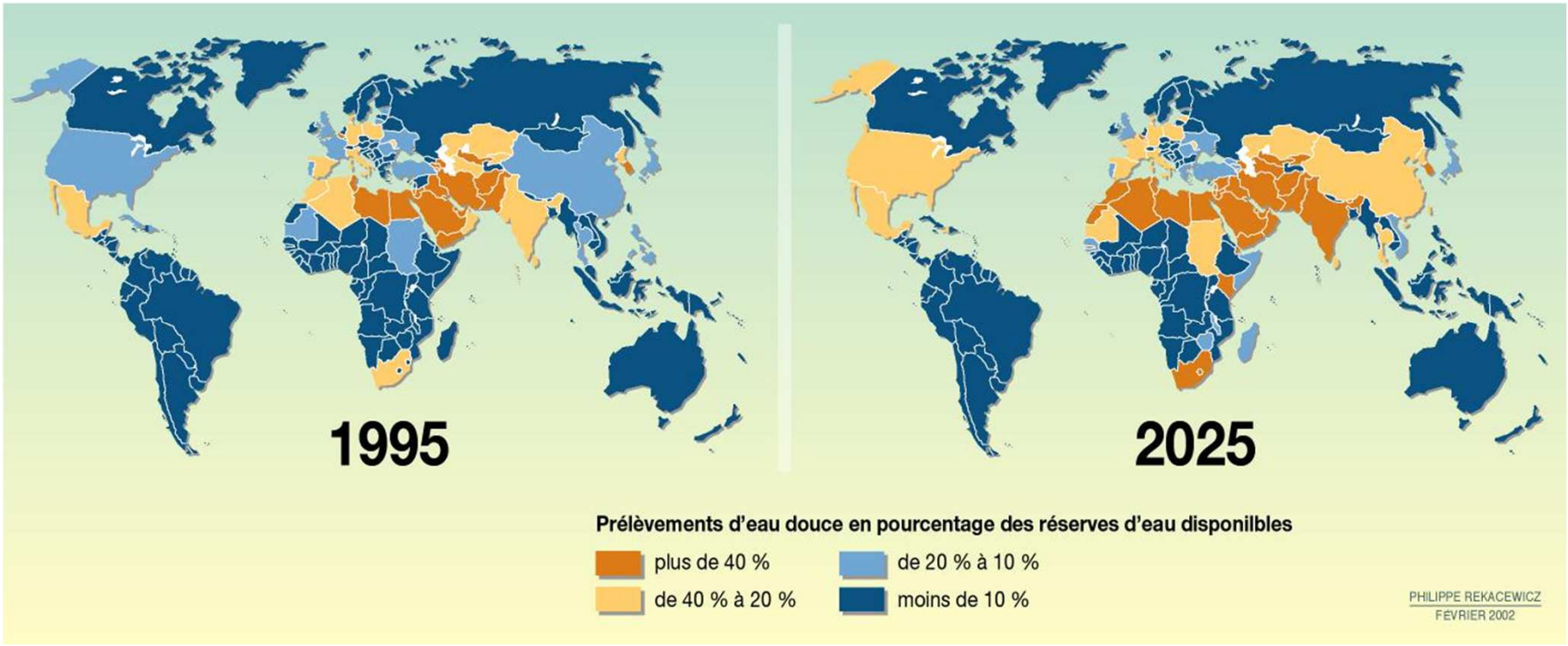
J.F. Cretaux
LEGOS, Toulouse, France

D. Serça
Laboratoire d'Aerologie, Toulouse, France



Distribution of fresh water over the continents

- High geographycal correlation between the water widthdrawal and available water per person and per year
- High water intake from 1995 to 2025 in the sahelian zone, the middle east, central Asia, India and China where the most arid zones are located



Context

- **Arid and semi-arid regions characateristics:**

- High spatio-temporal climate variability (precipitation)
- High anthropogenic pressure

- **Surface water is fundamental!**

- Critical resource (people-domestic use-, irrigation, livestock)
- Health issues: water-borne diseases (malaria, diarrheic diseases)
- Carbon and methane cycles

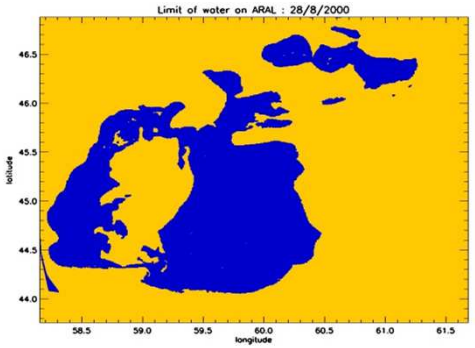
- **But poorly known:**

- Lack of infrastructure and monitoring network
- Hydrology poorly understood, difficult for modelling
- GHGs emissions almost unknown

→ **remote sensing** well suited for monitoring surface water (water extent, water level, turbidity and sediments, temperature) in these regions, even if challenging (atmospheric perturbations, important seasonal dynamics, extreme values)

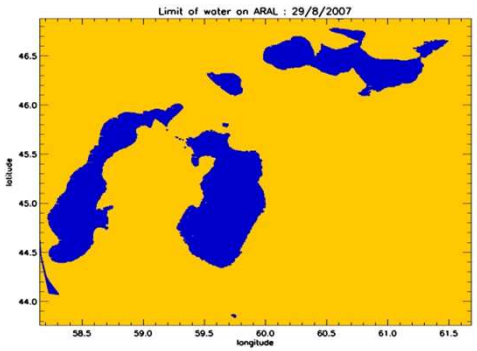
The Aral Sea (Kazakstanμ/Uzbekistan)

2000

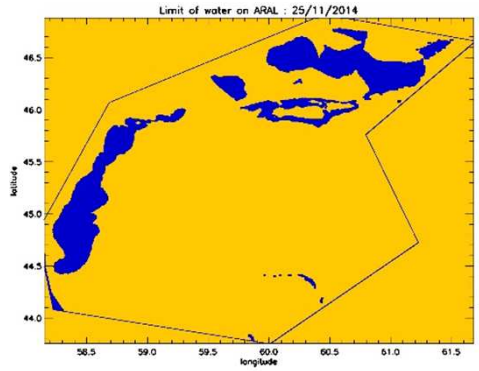


satellite altimetry + imagery to survey large lakes in arid zones

2007

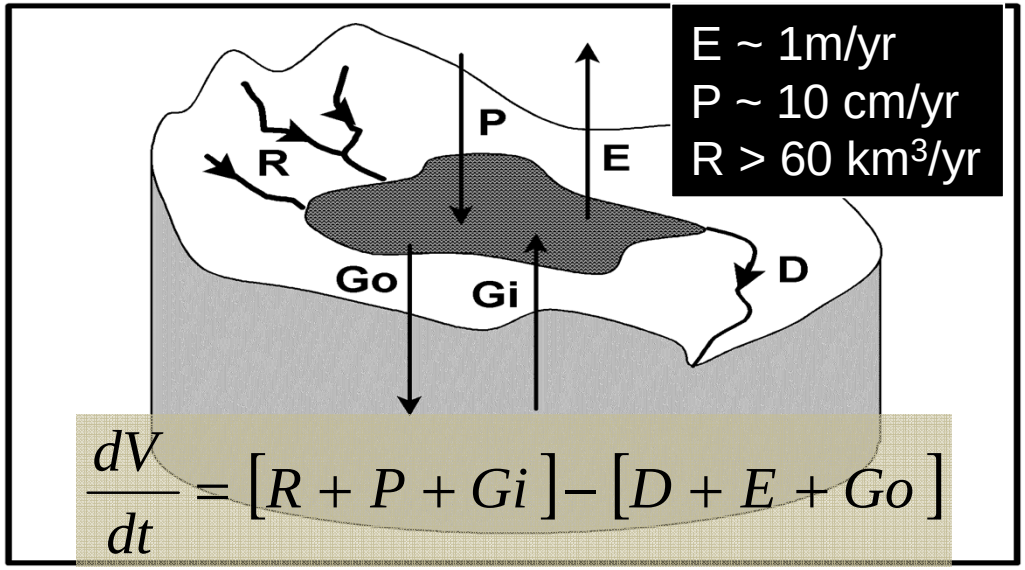


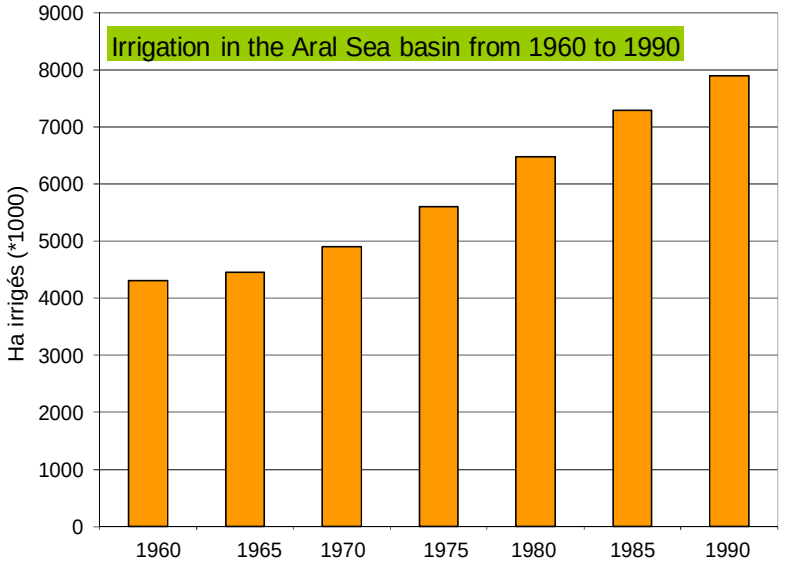
2014



MODIS data

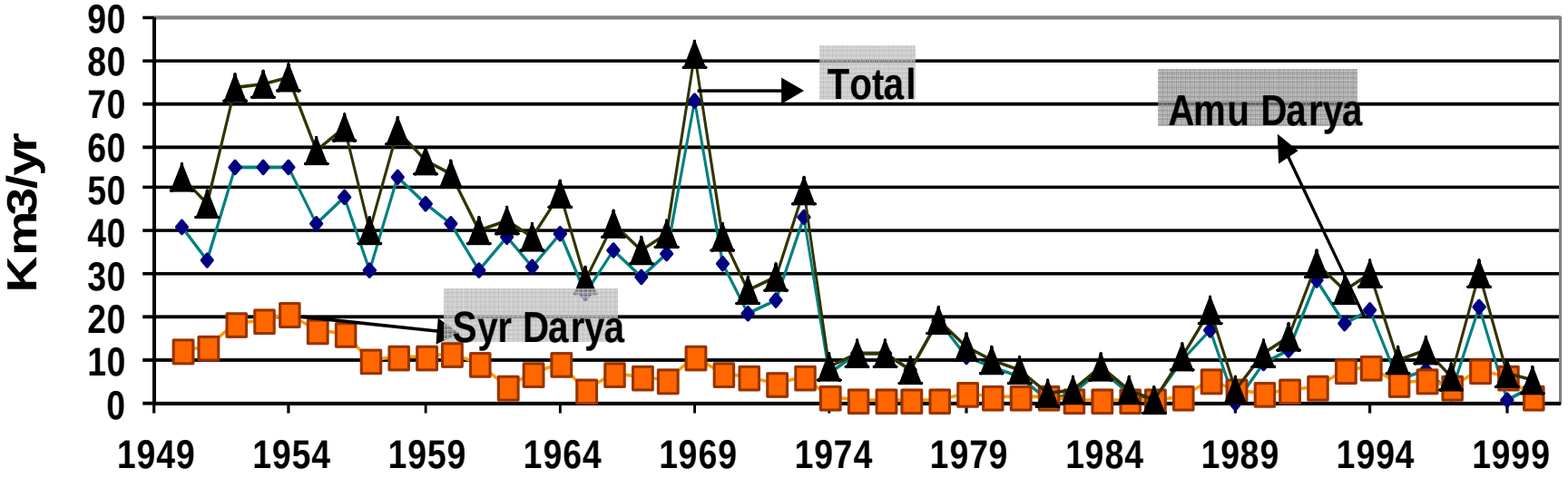
Water budget of the Aral Sea: dV/dt = inflow - outflow





Discharge into the Aral Sea

Cretaux et al. 2013



A lake is an integrator of climate change: it always tend towards equilibrium
=> Observing changes will allow interpreting their origin

Current desiccation of the Aral Sea

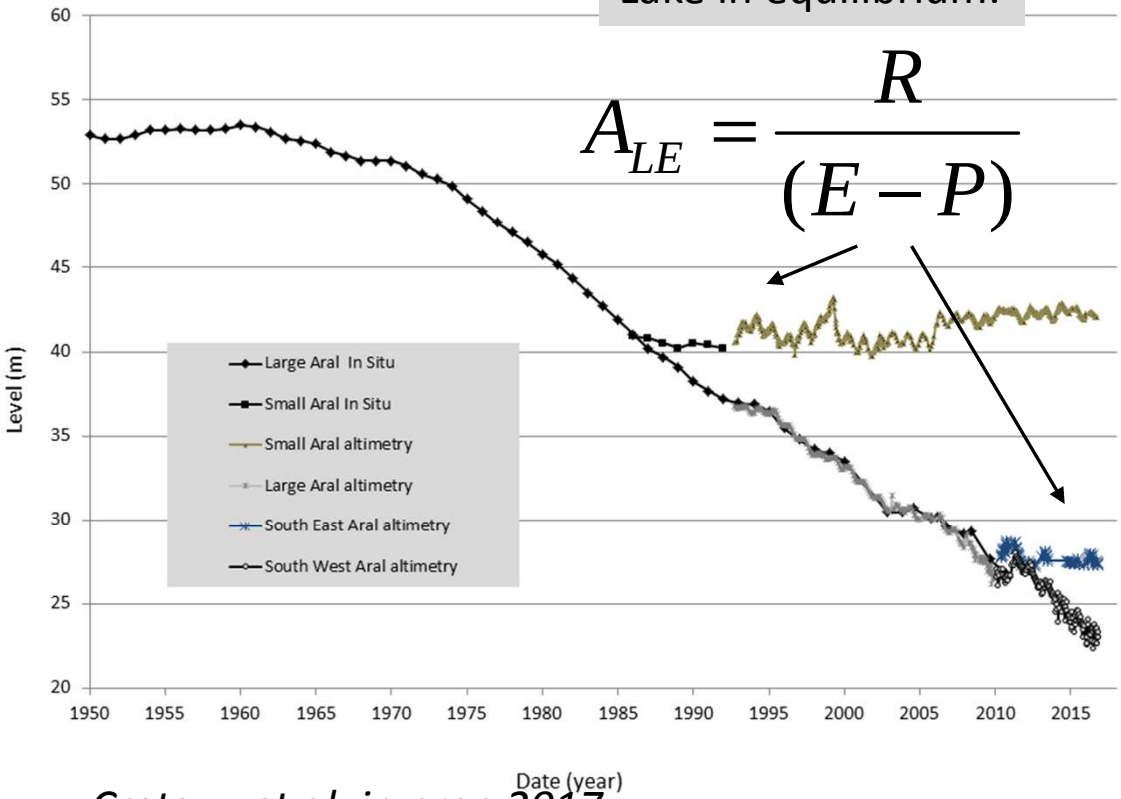
No in operationnal in situ observations after 2000=> Altimetry offers a continuous operationnal survey monitoring of all inividual water bodies

Separation of Aral Sea in 1989 into small (North) and big (South) Aral Sea=> Small Aral at long term equilibrium

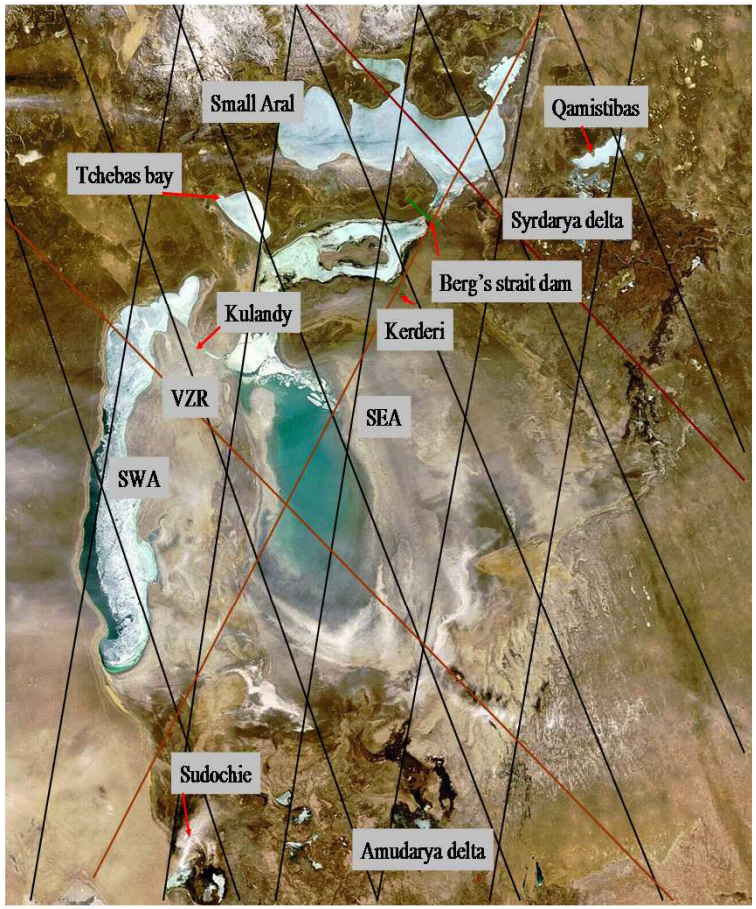
Separation of Big Aral after 2010-2012 into SW and SE Aral Sea => SE Aral in relatively stable equilibriu since SW Aral continues to shrink

Lake in equilibrium:

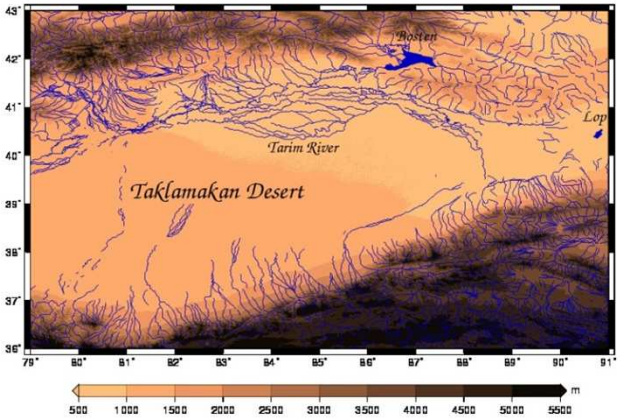
$$A_{LE} = \frac{R}{(E-P)}$$



Cretaux et al. in prep 2017

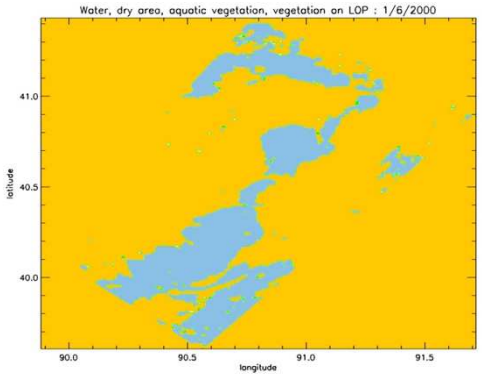


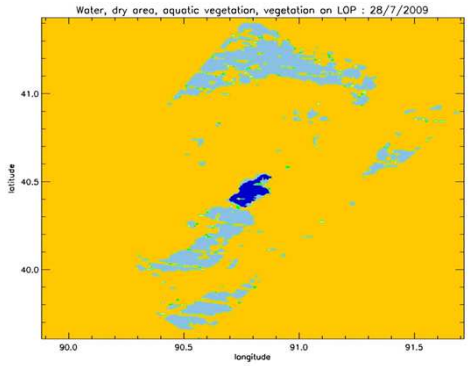
The Lop Nur & Bosten (China)



- Lop Nur lake is a terminal lake in very arid region within the Tarim Basin
- It is highly ephemeral

2000 2009

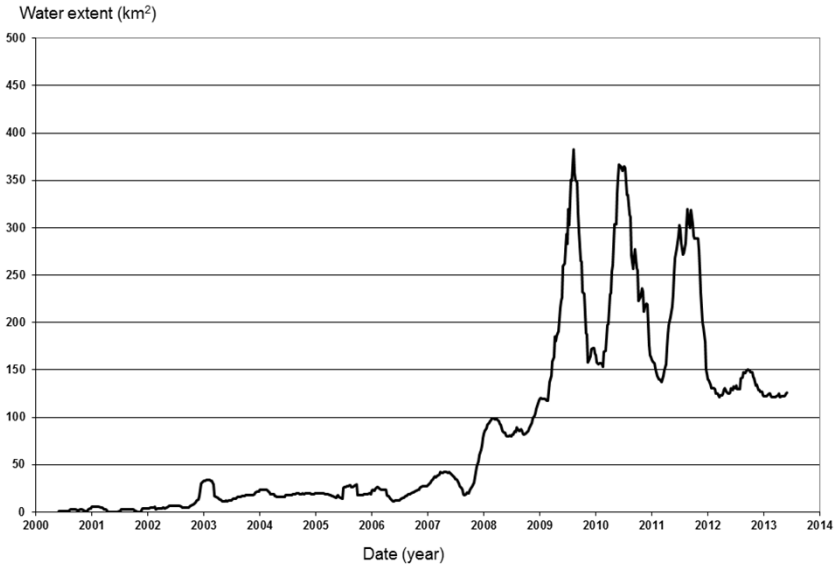




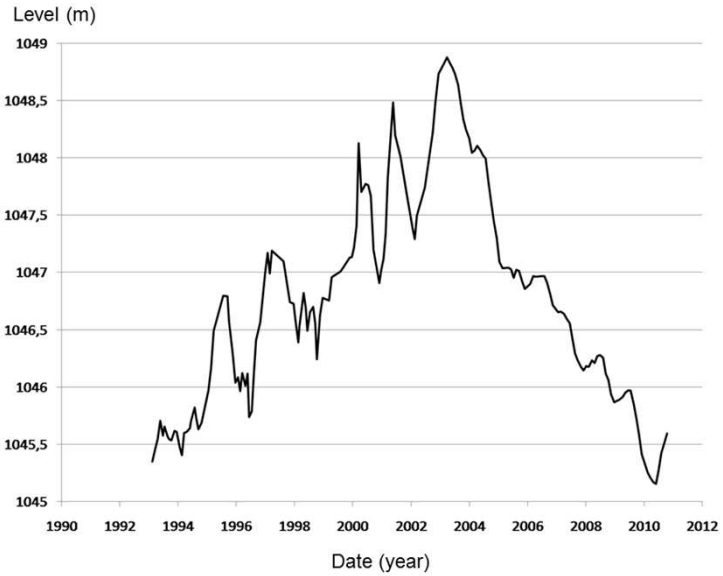
MODIS

- Lop Nur is linked to irrigation along the Tarim river and to the water release from the Bosten lake

Water surface from Modis analysis

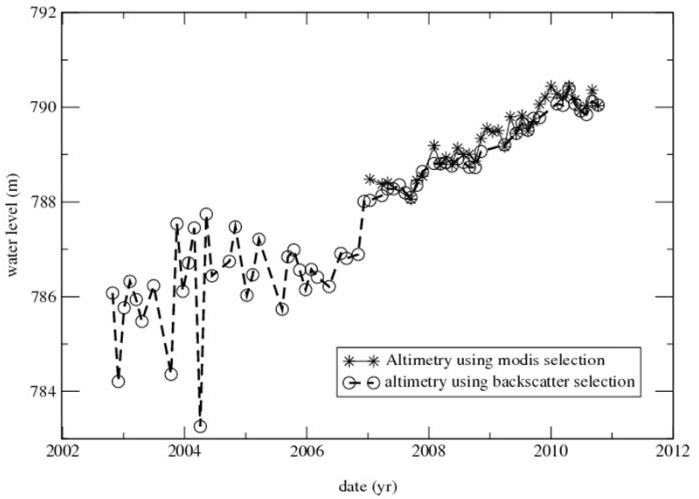


Bosten lake (release from dam after 2002)

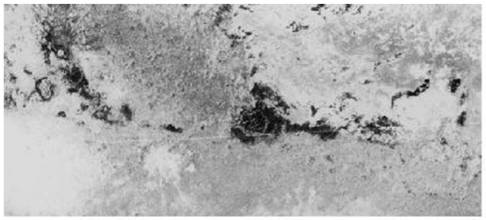


Water level from altimetry multi missions

Water level using combination of Modis and altimetry

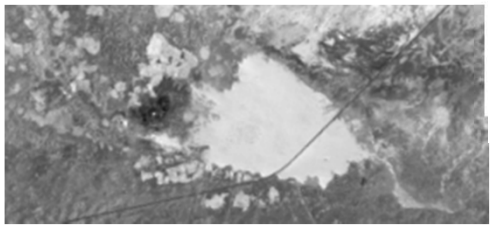


The Agoufou lake (northern Mali)

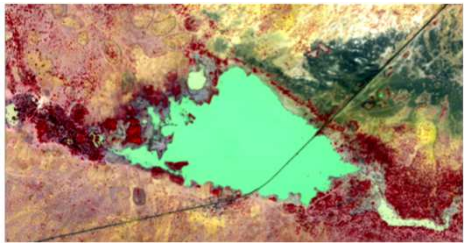


Oct 1966
CORONA

Sept 1996
Aerial
photo

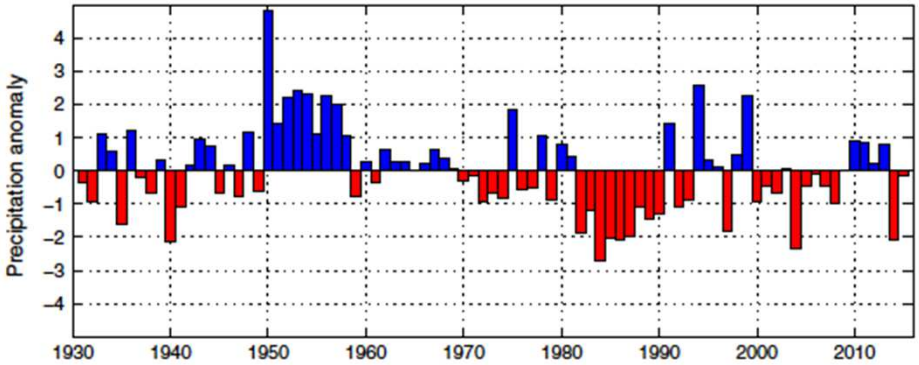


Oct 2006
SPOT

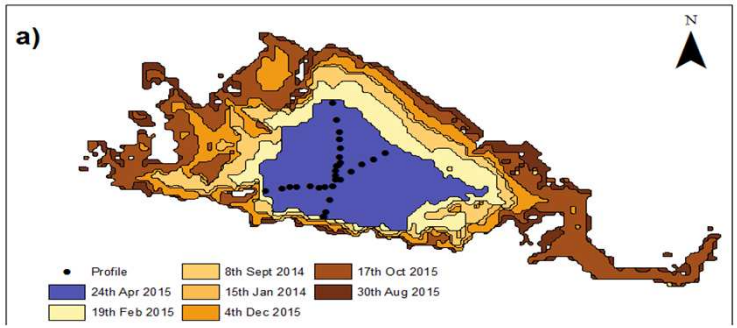


Dec 2015
Sentinel-2

Sahelian paradox: General increase of ponds area (mostly turbid ponds) despite the precipitation decline (*Gardelle et al. , HESS, 2010)*

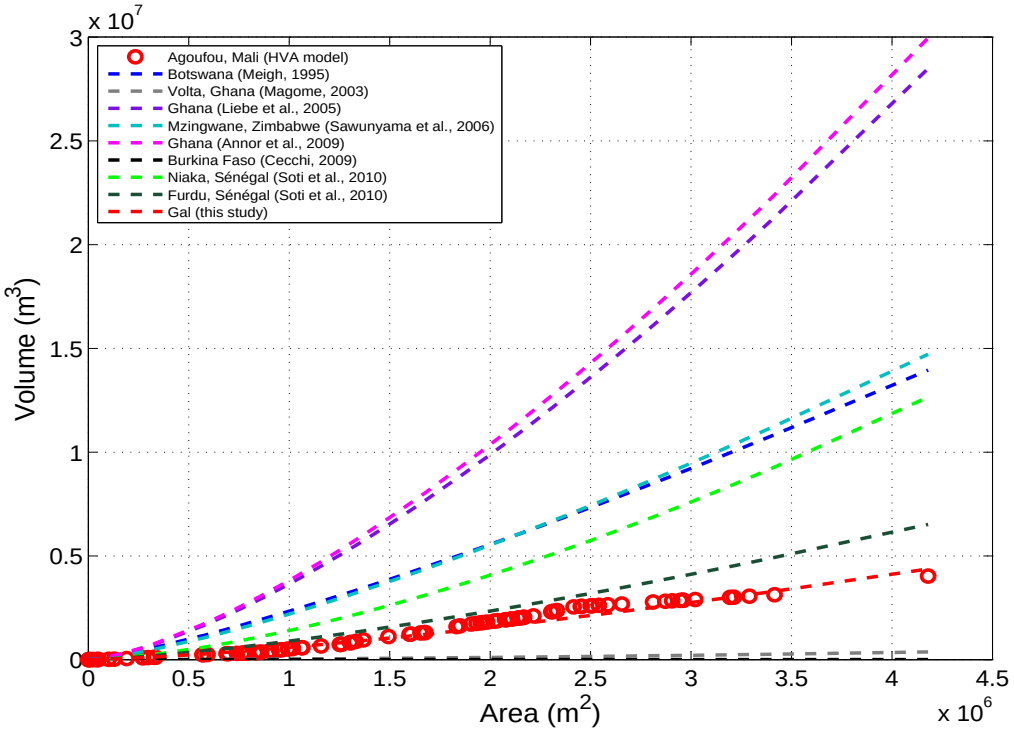


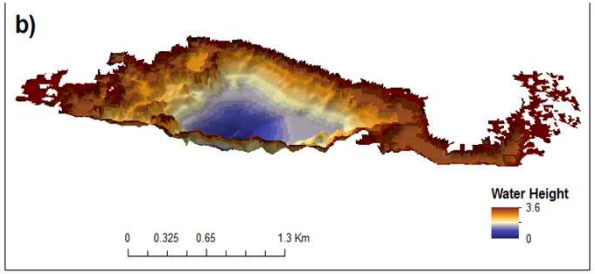
Estimation of water volumes



+

In situ height measurements
by the AMMA-CATCH observatory





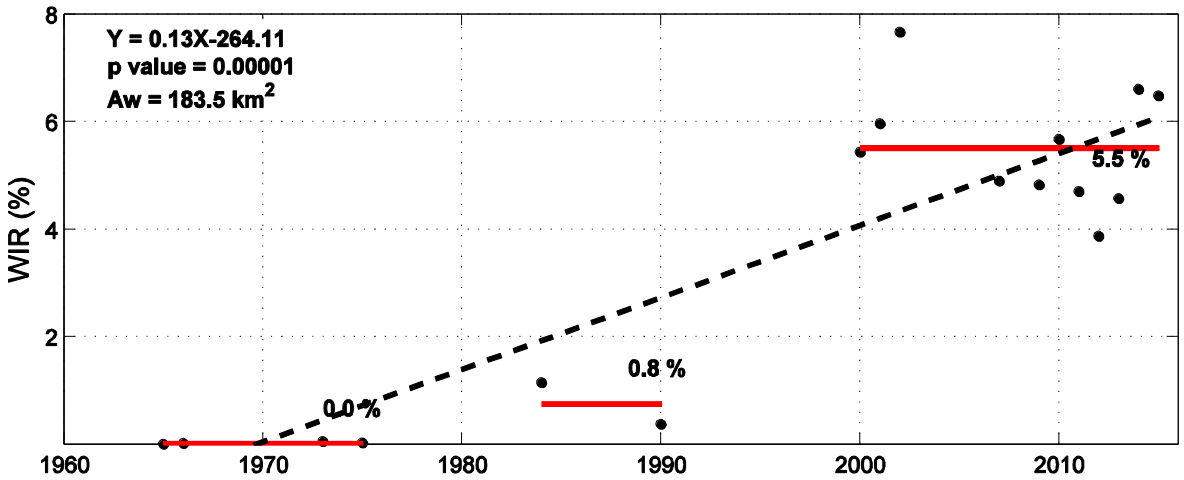
Gal et al. , JH, 2016

Water inflow estimation : lakes used as gauges!

Lake water balance: dV/dt = R +P –E – G

Dry season dV/dt = –E – G →
possible to derive information on surface-ground water exchanges

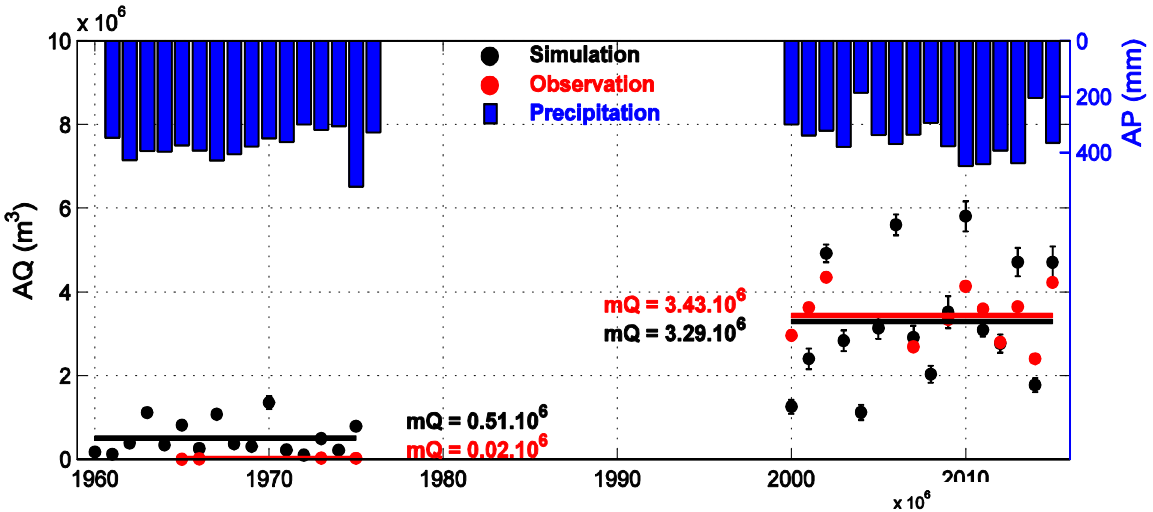
Annual Runoff/Precipitation over the watershed



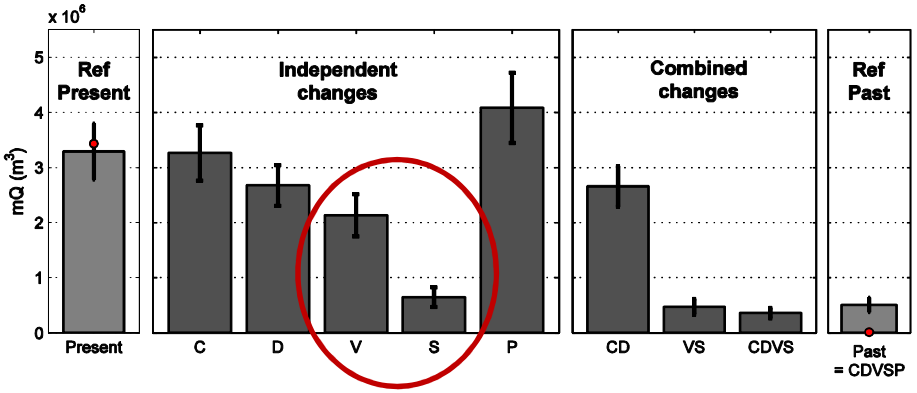
Gal et al. , JH, 2016

→ Quantification runoff increase → base for modelling

KINEROS2 model



Change attribution → better understand the mechanisms responsible for the Sahelian paradox

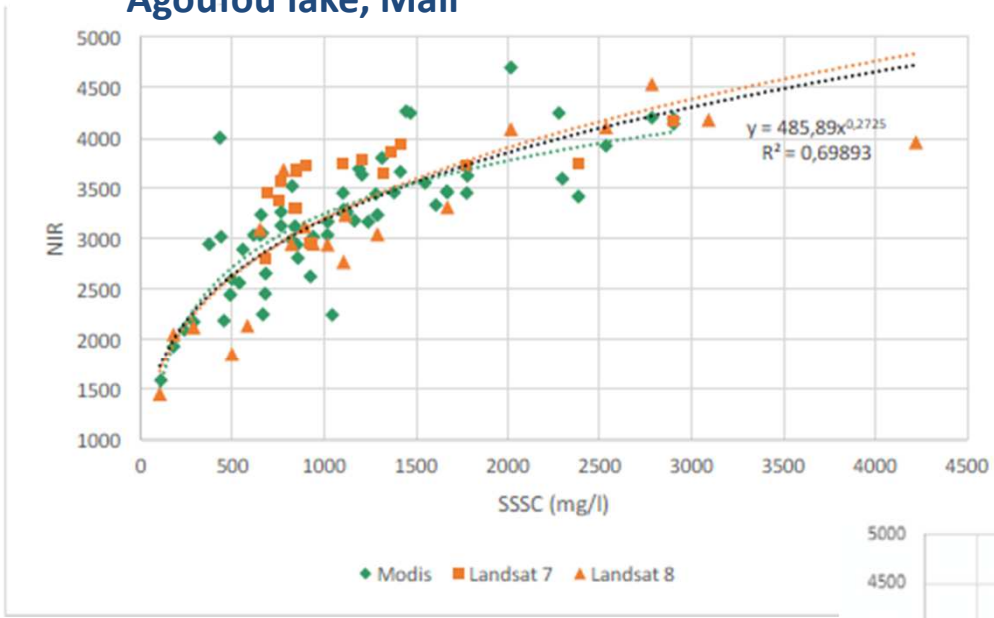


Vegetation degradation on shallow soils after the major droughts and soil erosion are the major factors accounting for the runoff increase between past and present→ climate!

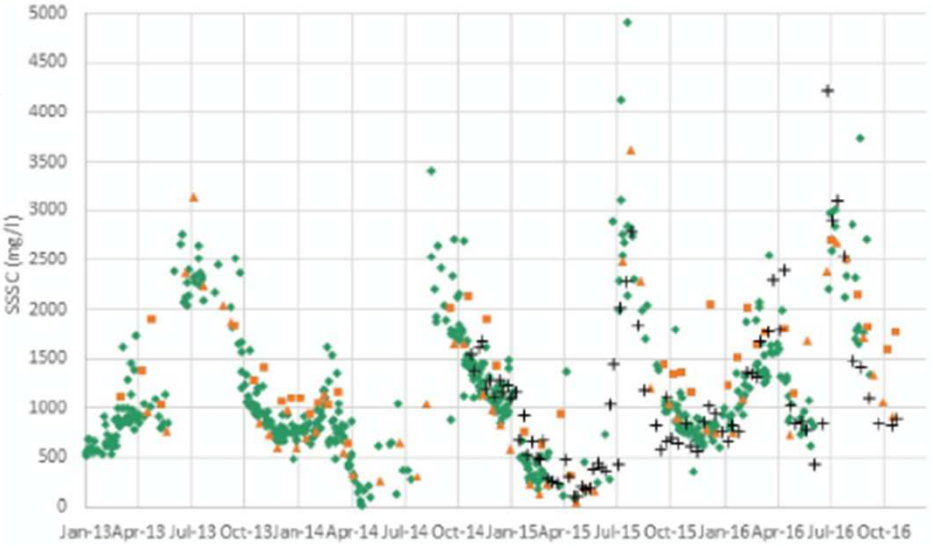
Gal et al. HESS 2017 under rev

Water turbidity and suspended solid concentration

Agoufou lake, Mali



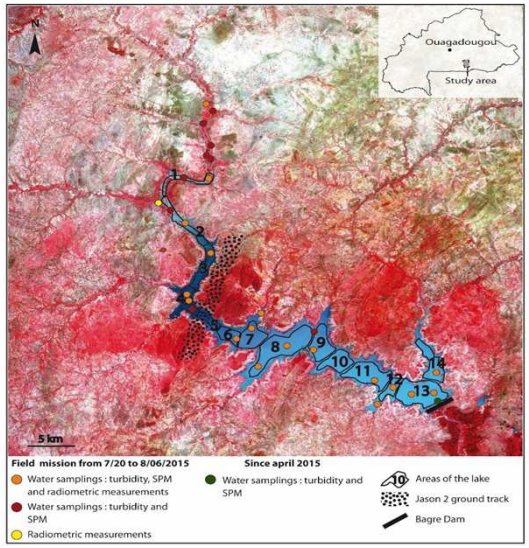
- Extremely high values of turbidity and SSSC (up to 4000 mg/l) linked to important soil erosion
- Good agreement between RS reflectances (MODIS and LANDSAT) and in-situ SSSC

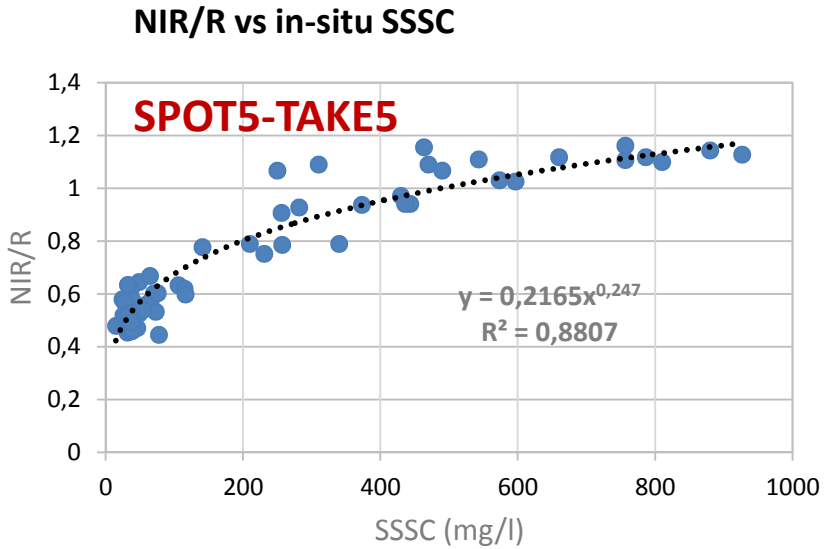


- SSSC increase at the beginning of the rainy season
- Important re-suspension during the dry season

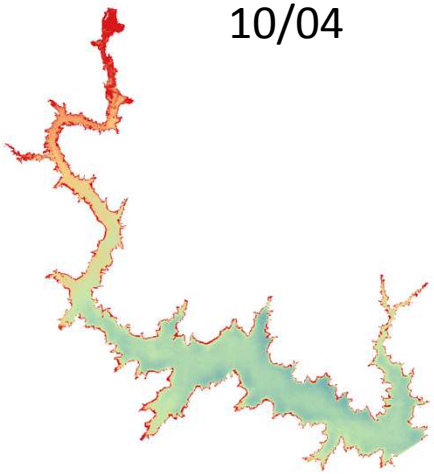
Robert et al. , 2017, in prep

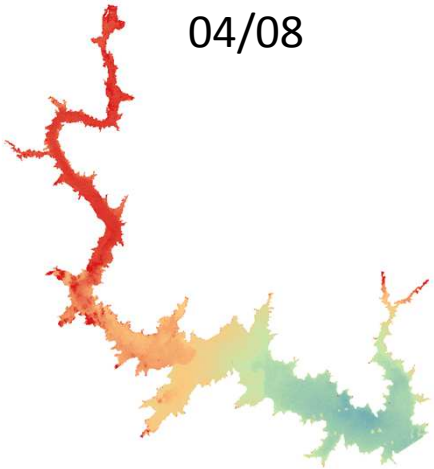
Bagré reservoir, Burkina Faso

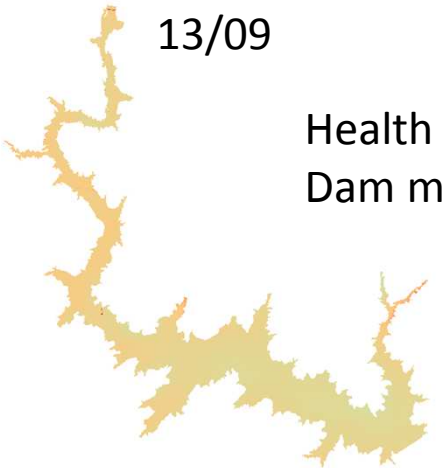




- **Important spatio temporal variability (SPOT TAKE 5)**
- **Significant increase over 2000-2016 (MODIS) possibly linked to LC/LU changes**







Health issues?
Dam management?

Robert et al. , JEAG, 2016

Carbon storage and greenhouse gas emissions from temporary and permanent ponds in semi-arid region (Senegal) (Preliminary results from Assouma et al., 2017, J Arid Land)

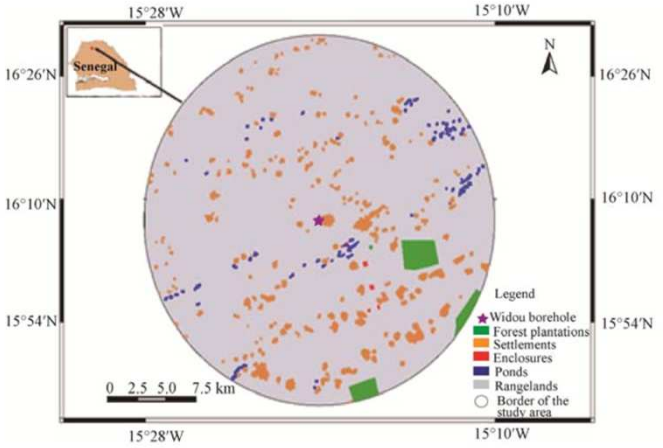
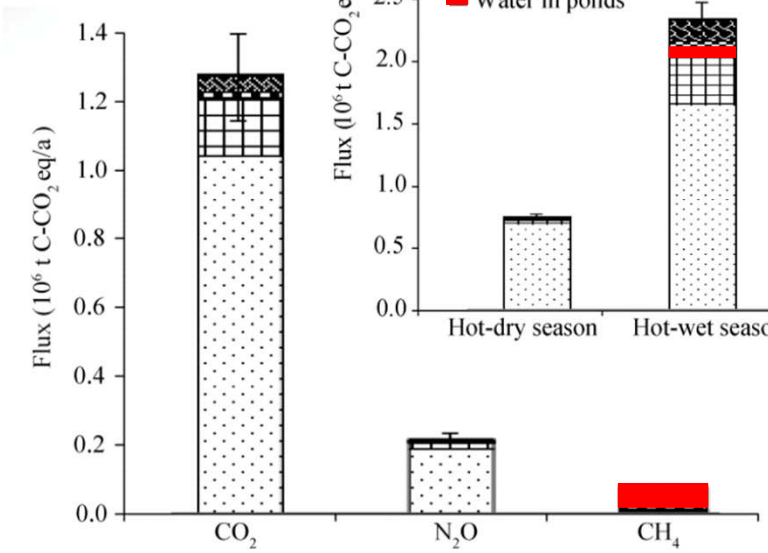
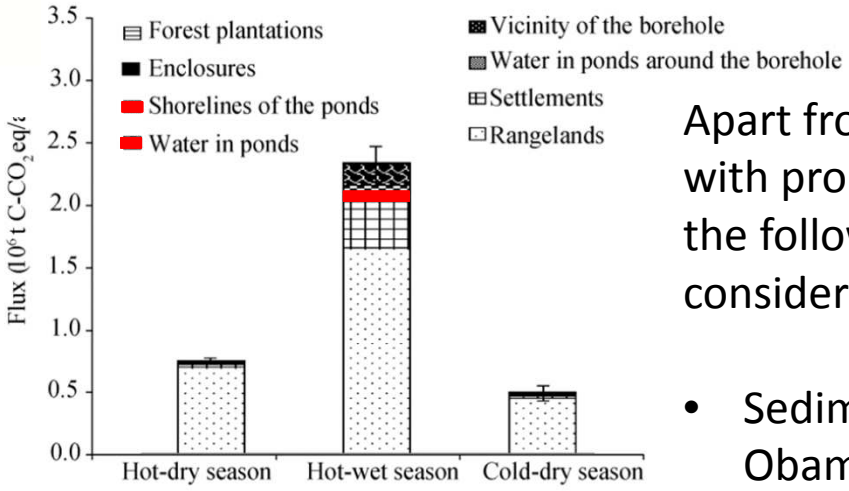


Fig. 1 Map of the study area around Widou borehole

- Lakes and ponds represented about 3% of the sylvo-pastoral landscape
- Those ponds emitted 93% of the CH_4 from the area, mostly in the wet season





Apart from a real quantificatio with proper sampling strategy, the following factors to be considered in the future:

- Sedimentation (Mabicka Obame et al., 2014 showed rates similar to those in large reservoirs)
- Carbon and Nitrogen transfer from the cattle

Conclusions

Lots of scientific questions still open!

- **Future evolution of water bodies (quantity and quality) under climate and anthropogenic changes?**
- **Impact on water resources?**
- **GHGs emission (wetlands, shorelines)?**
- **Health issues (bacteria-turbidity links)?**

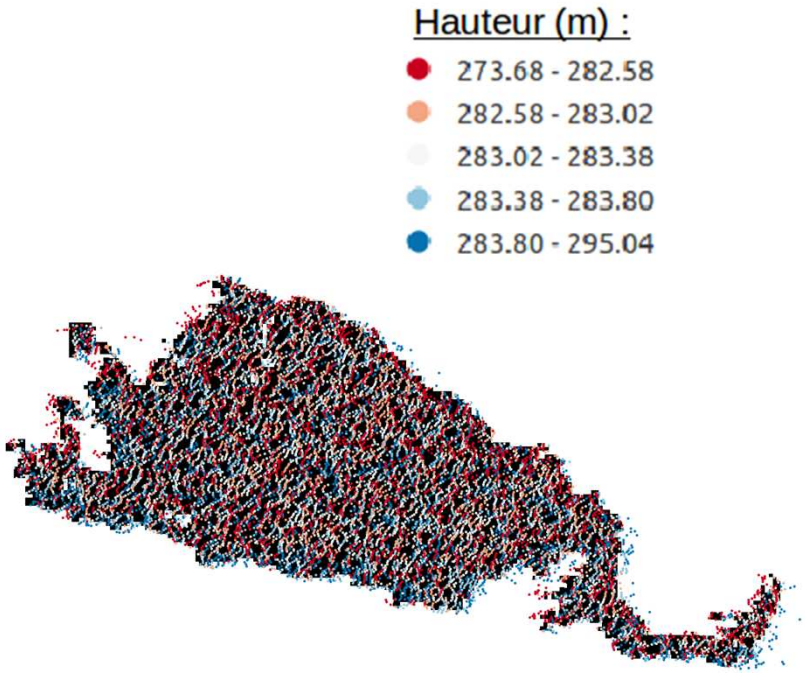
→ Continuous monitoring is fundamental!

- **Remote sensing has proved successful to derive different water parameters in these poorly instrumented regions→ towards and integrated vision of water bodies and lakes**

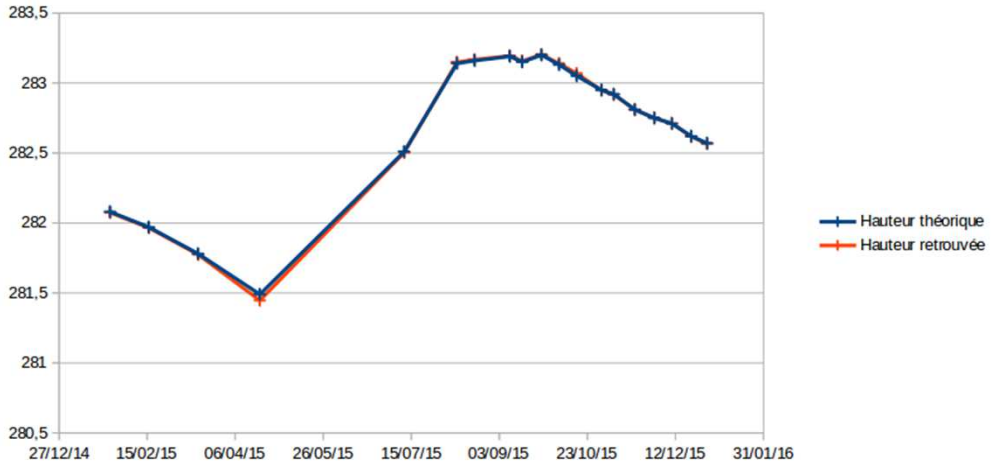
- **New opportunities with Sentinel2 and SWOT to address small and dynamics water bodies!**

Estimation of water heights (SWOT)

Retrieved height by SWOT simulator (stage C. Rouzies, coll GET-LEGOS)



Retrieved seasonal cycle by SWOT simulator



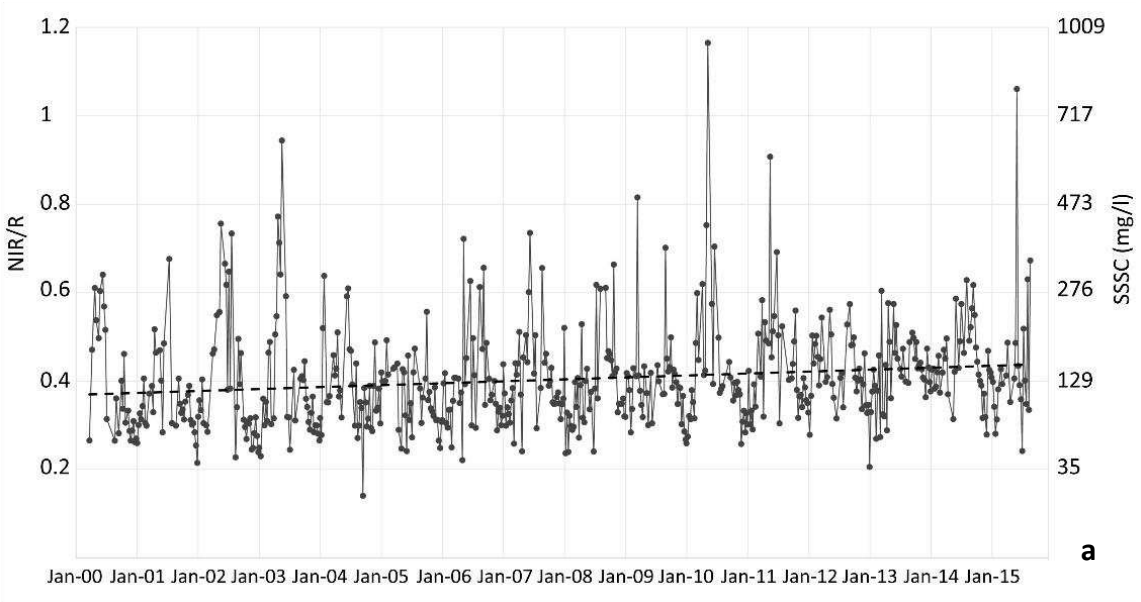
→ High potential for SWOT to retrieve height (but only instrumental errors taken into account: tropospheric delay?).

→ Performances over other kinds of waters (vegetated, different shapes)

→ Water masks can be difficult given the high sigma0 over soil (from GPM): coupling S2/SWOT interesting


THANK YOU FOR YOU ATTENTION!

Decadal evolution, Bagré lake



Increased turbidity over the 2000-2015 period

→ Increased soil erosion
- vegetation degradation due to land use changes?
- land cover changes?
- Increase in precipitation intensity?

Robert et al. , JEAG, 2016