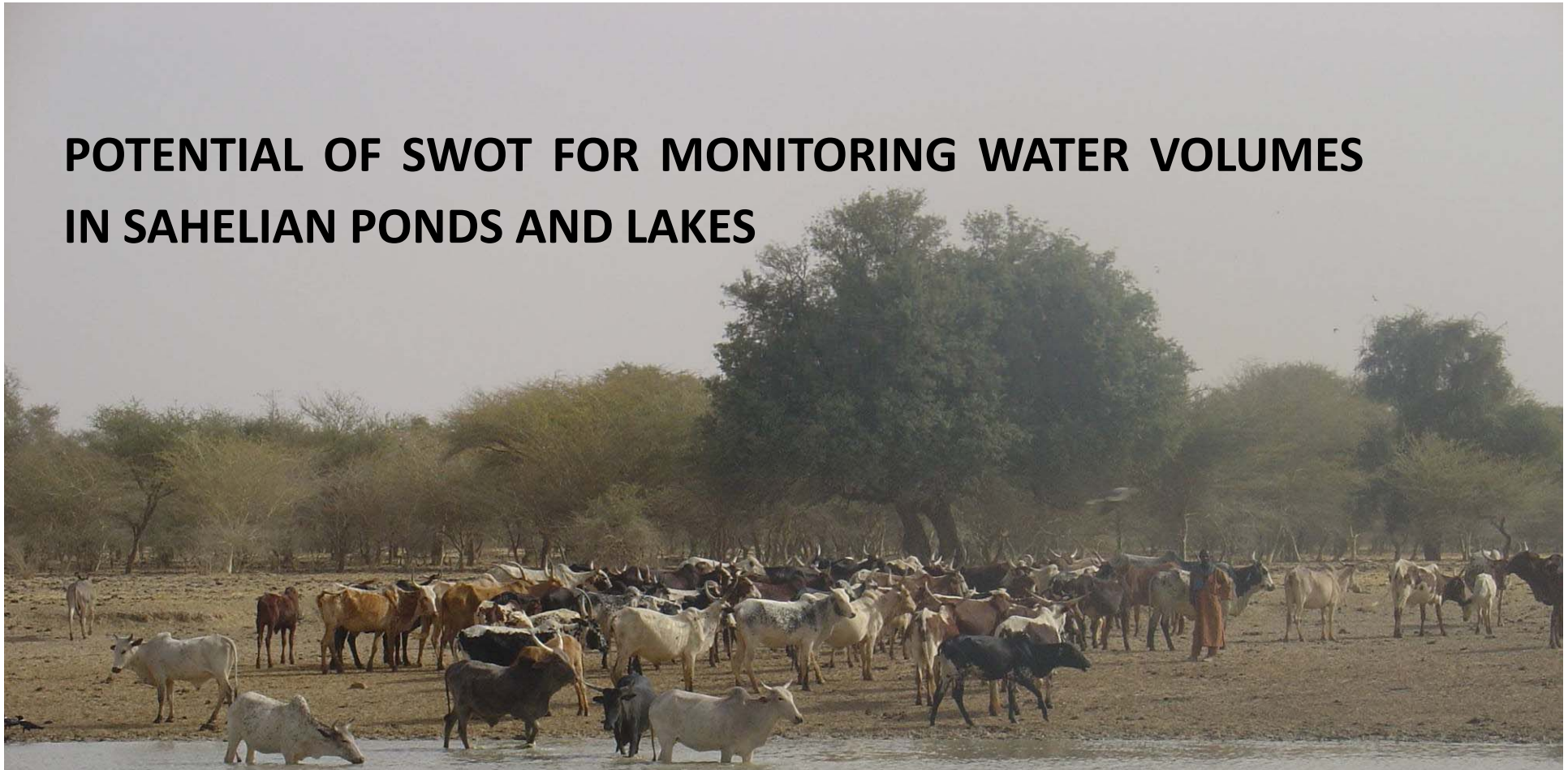
POTENTIAL OF SWOT FOR MONITORING WATER VOLUMES IN SAHELIAN PONDS AND LAKES



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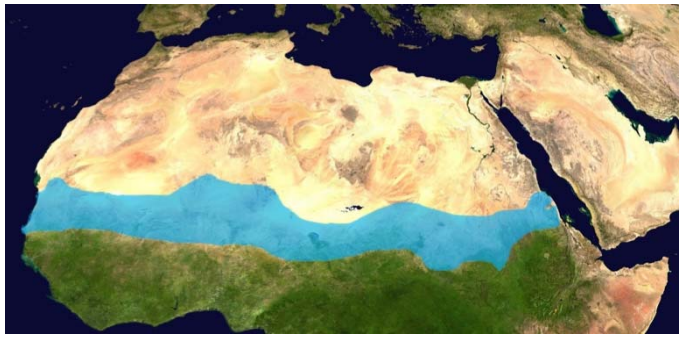
ST SWOT, Bordeaux, 17-20 June 2019

CONTEXT

Sahelian and West African context



Semi-arid climat, monsoon regime

Region in transition (climate, demography) very sensitive to globale changes

Important **rainfall variability**:

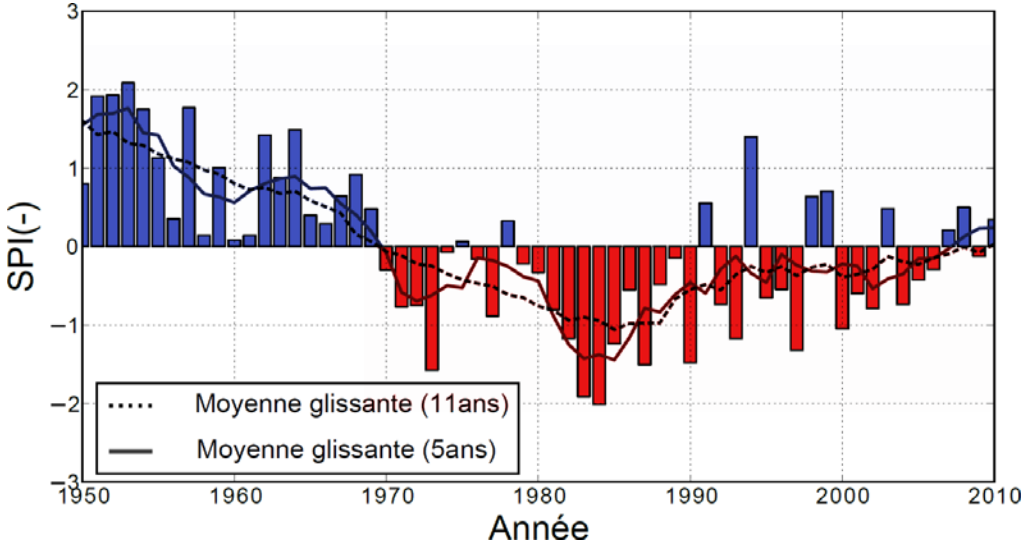
- **seasonal**
- **interannual**
- **long term evolution**

70s-80s :

long dry period with extremes drought events

since the 90-2000: rainfall recovery but still important droughts + intensification daily rainfall

RAINFALL ANOMALIES 1950-2010 (CENTRAL SAHEL)



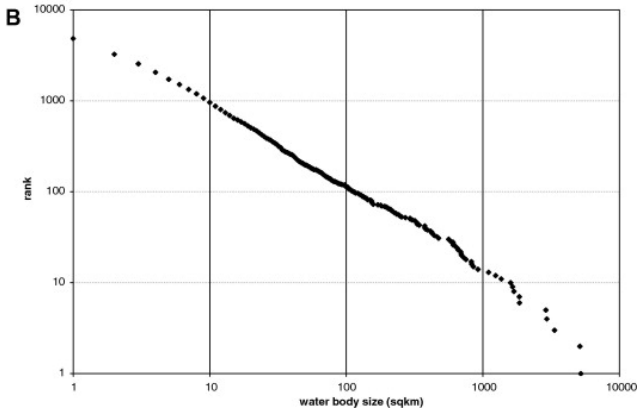
Panthou et al. I.J. Climatology, 2014

→ Significant, and sometimes paradoxical, consequences on the hydrological cycle and water bodies

Importance of waterbodies in the Sahel

- Critical **resource**: domestic uses, irrigation, livestock
- **Health issues**: water-borne diseases, diarrheas
- **Carbon and methane** cycles:
  smaller water bodies contributing more
- Different ecosystems services

Small water bodies!



WB distribution over the Sahel as a function of size

Haas et al. 2009

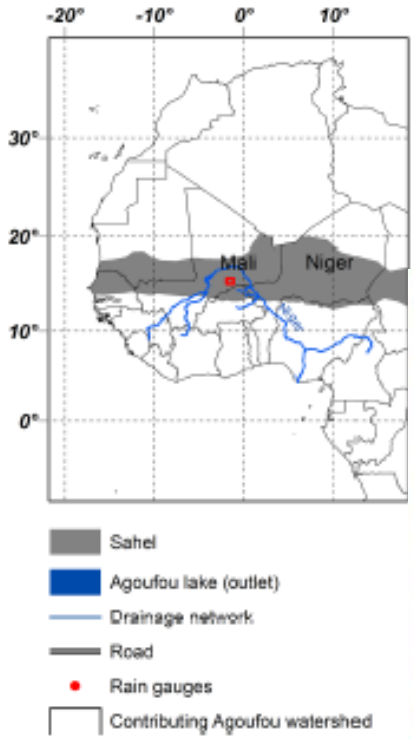
But poorly known

- **Lack of infrastructures** and monitoring networks
- **Complex hydrology** (Sahelian paradox), **difficult for modelling**

→ Remote sensing well suited but challenging

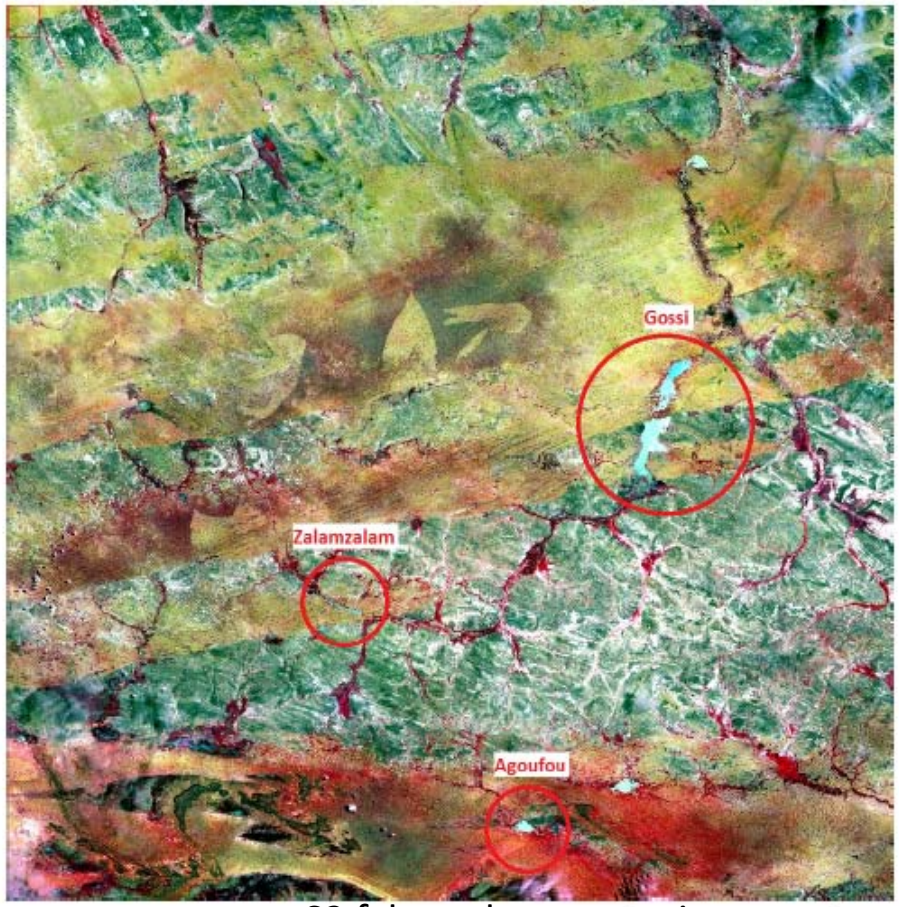
- High spatio-temporal **variability**
- **Extremes values** (turbidity and SPM→ optical reflectance;
  soil dielectric properties→ radar backscatter)
- Important and variable **atmospheric load** (aerosols, water vapour)
  → atmospheric corrections

STUDY AREA



Gourma region - Mali

- Long term measurements by the AMMA-CATCH observatory (Galle et al 2019)
- Pastoral region: no major land use changes



S2 false color composite

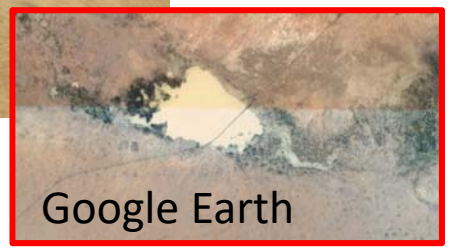
Two hydrological systems:
- deep sandy soils, with no runoff
- shallow soils generating runoff ending up in ponds and lakes

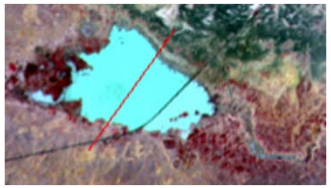
AMMA CATCH
Observatoire éco-hydro-météo en Afrique de l'Ouest

G E T

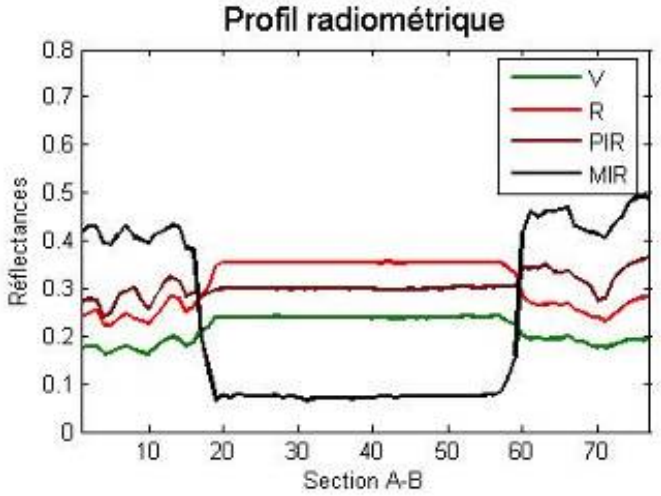
Detecting water areas using optical remote sensing

Agoufou Lake





RGB SPOT



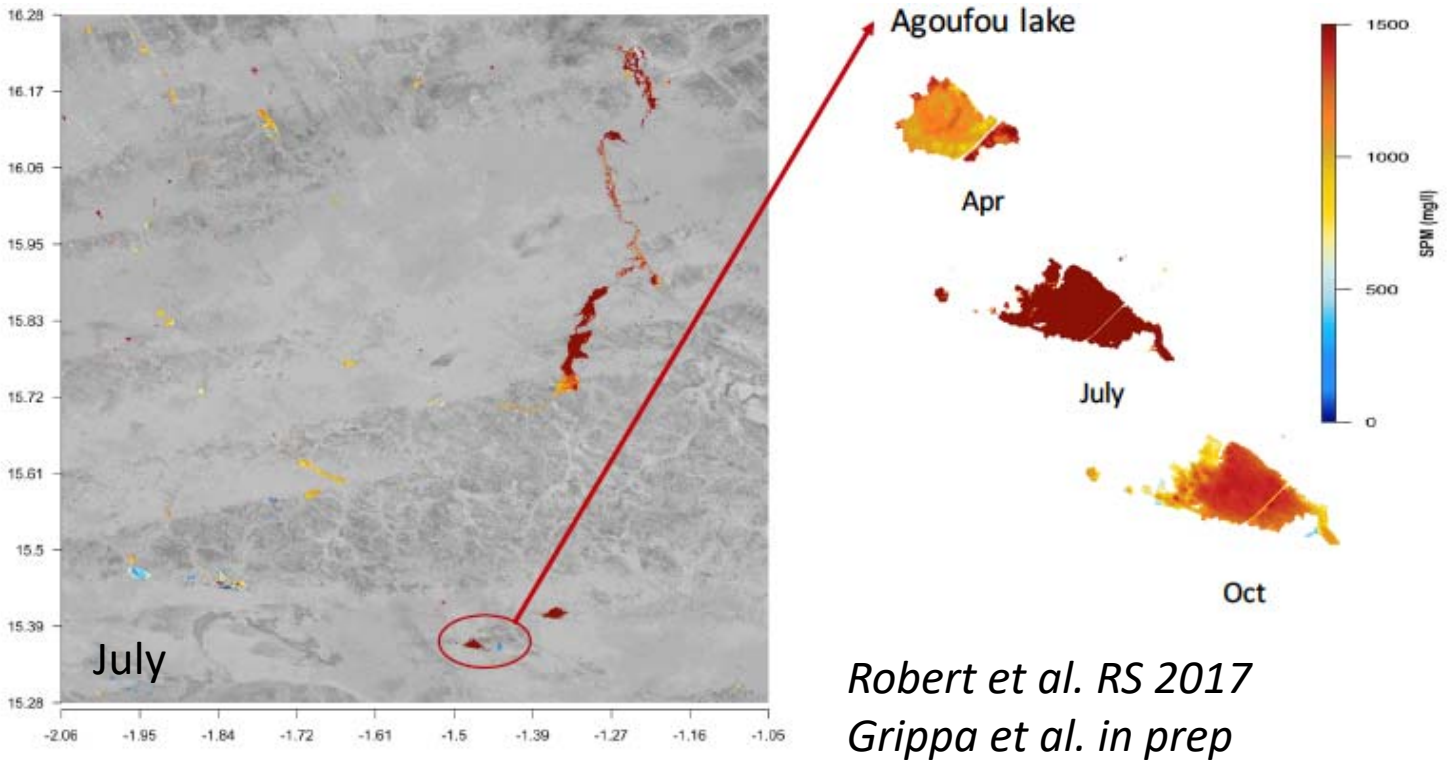
- Extremely high values of reflectance
- In the VIS channels water can be brighter than land, in the NIR roughly the same

→ global algorithms for water detection need to be adjusted

- Open water surface fairly easy, flooded vegetation may be tricky (MIR helps)

WATER AREAS and WATER TURBIDITY

Water area and SPM by Sentinel2

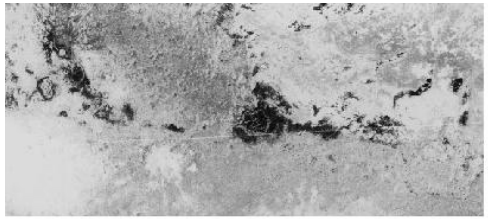


Robert et al. RS 2017
Grippa et al. in prep

- Extremely turbid waters
- Good relationship between the NIR reflectance and SPM up to very high values (2500 mg/l)
- High temporal and spatial resolution necessary for the majority of water bodies in this area

→ Sentinel2 and Lndast 8 well suited

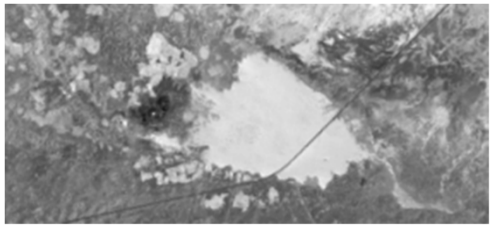
Water area long term evolution by optical remote sensing



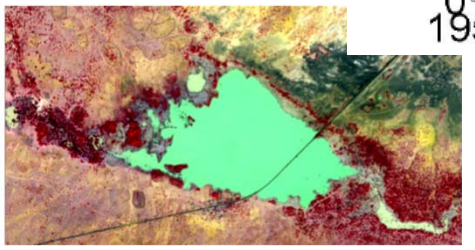
Oct 1966
CORONA

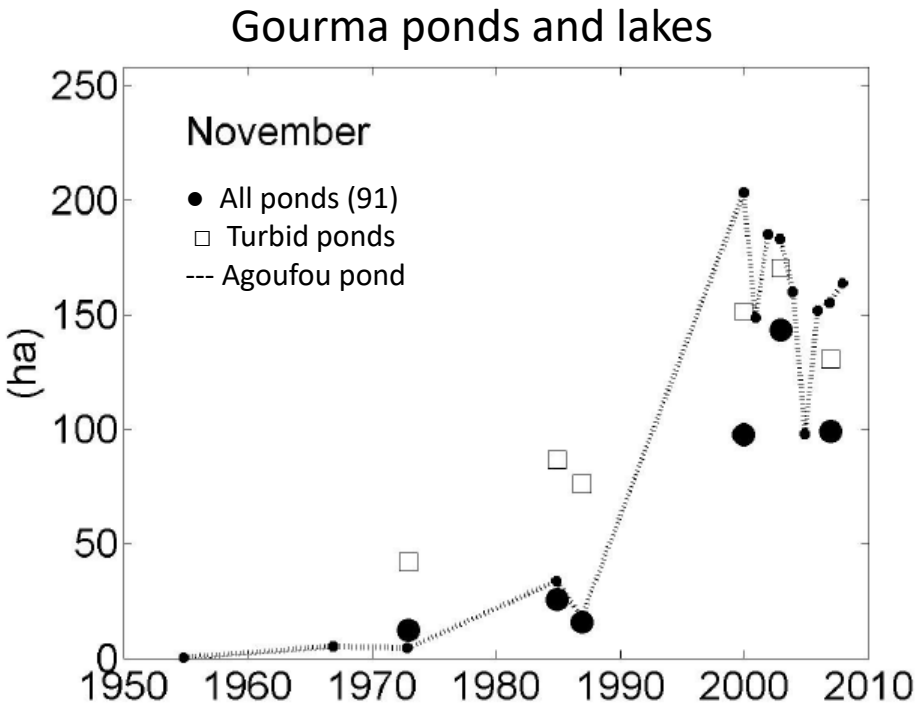
Sept 1996
Aerial
photo

Oct 2006
SPOT



Dec 2015
Sentinel-2



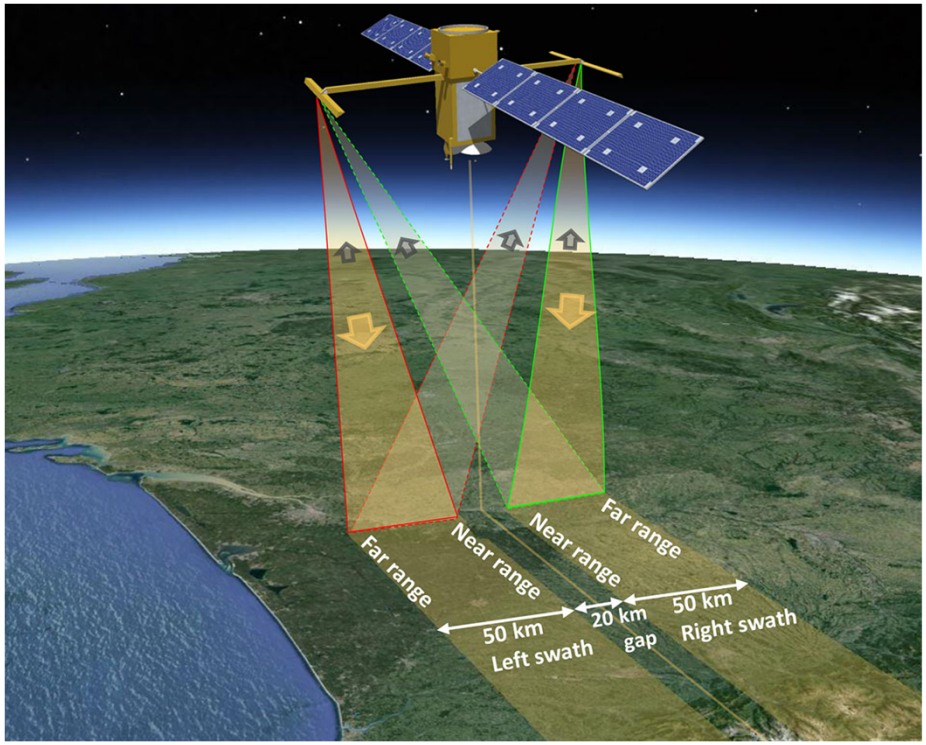


Gardelle et al. , HESS, 2010

General increase of ponds area all over the region (98 %) despite precipitation decrease (**Sahelian paradox**)→ Causes?
Quantification of changes in water amount and runoff necessary!

Up to now, only few « big » lakes can be monitored using current altimeters

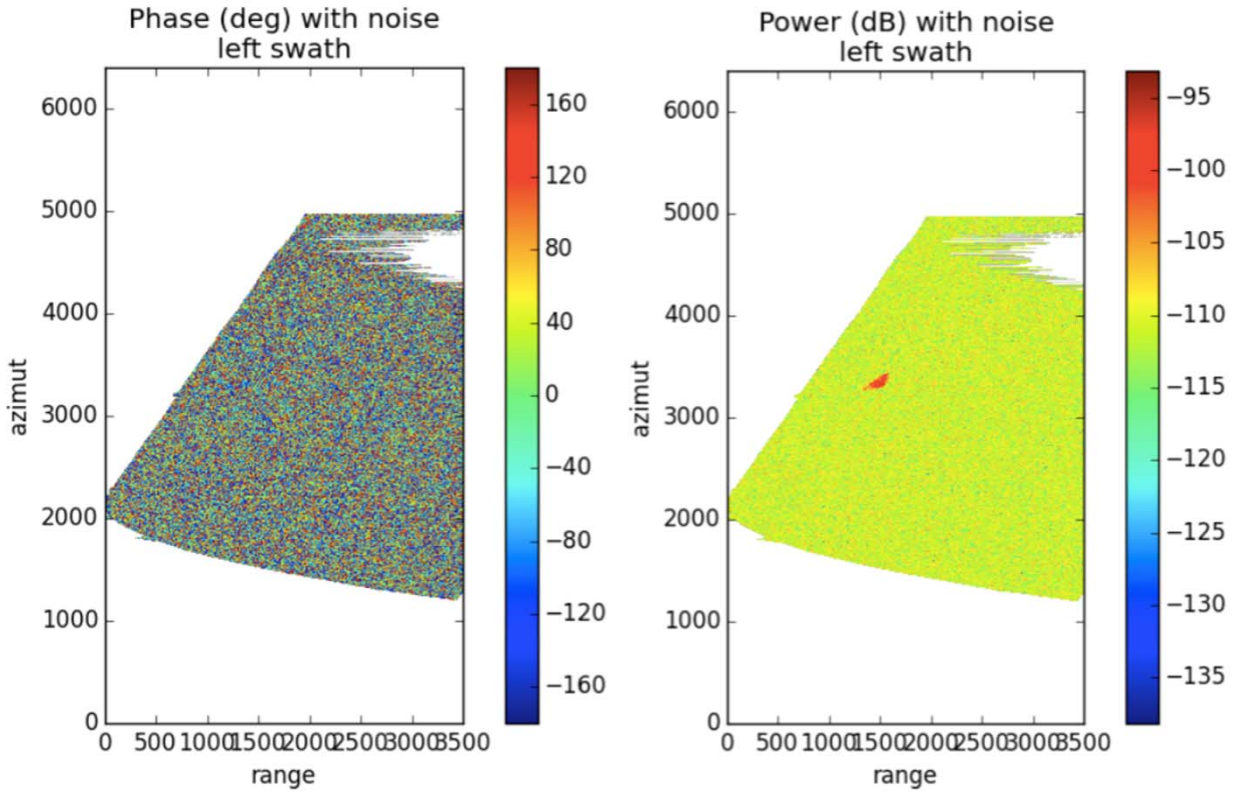
SWOT Surface Water and Ocean Topography



Biancamaria et al 2016

→ Estimate the potential of SWOT for monitoring water levels and areas in this region

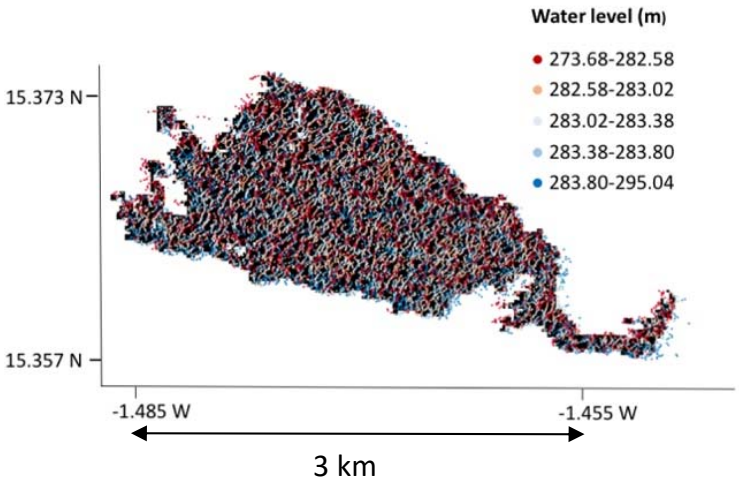
SWOT HR simulator: phase and backscatter



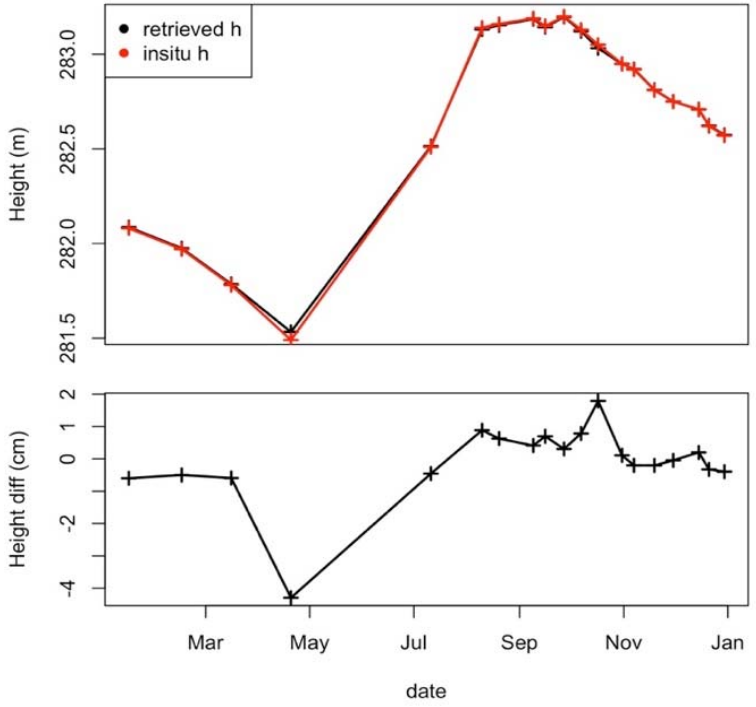
Phase and power by SWOT_HR on the Agoufou lake

Grippa et al. , J-STARS, 2019

Retrieved height by SWOT HR simulator from phase changes over the Agoufou lake



Grippa et al. , J-STARS, 2019

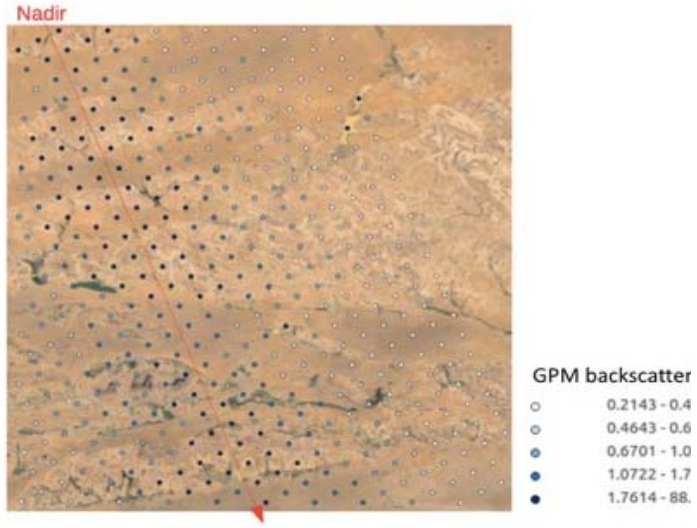


- High potential for SWOT to retrieve height seasonal cycle
- For the Agoufou lake: precision < 4 cm

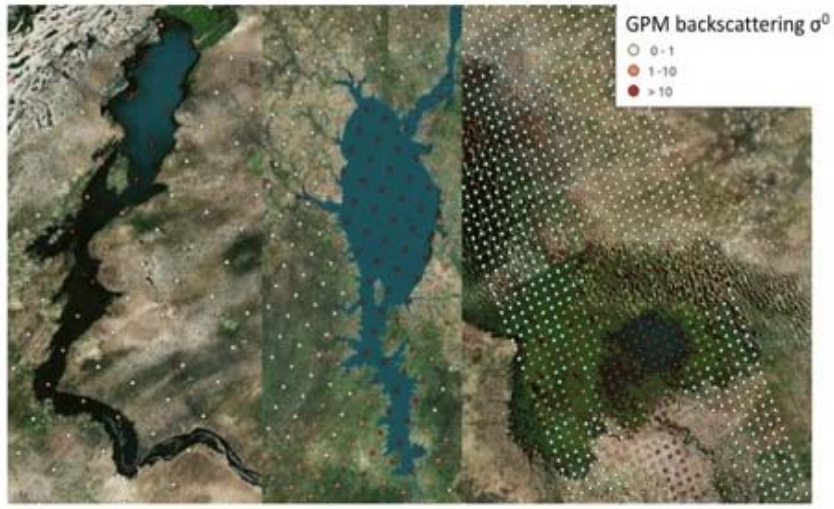
- More challenging for lakes with a more complicated shape: poorer performances over Zalam-Zalam (6.3 cm to 15.1 cm for two different orbits).

Water areas by difference in backscatter from water and land (not well know for nadir looking configuration and Ka band)

GPM measurements (Ka and Ku bands, nadir view, res: 4 km)



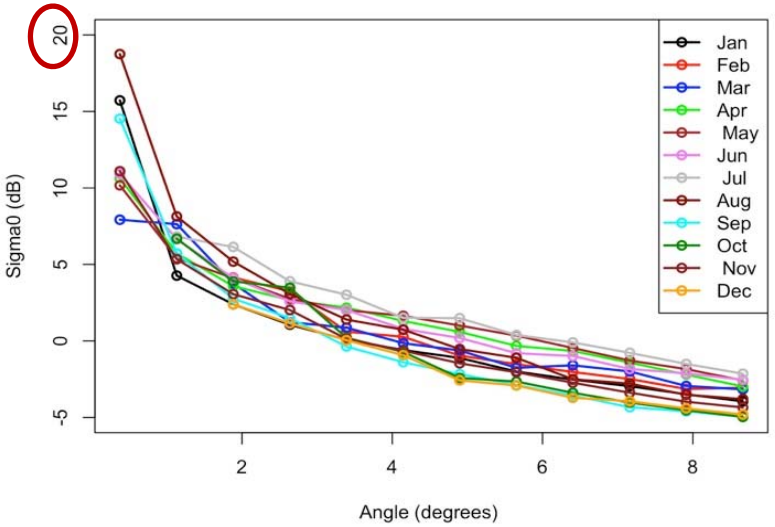
GPM sigma0 over soils in the Gourma region



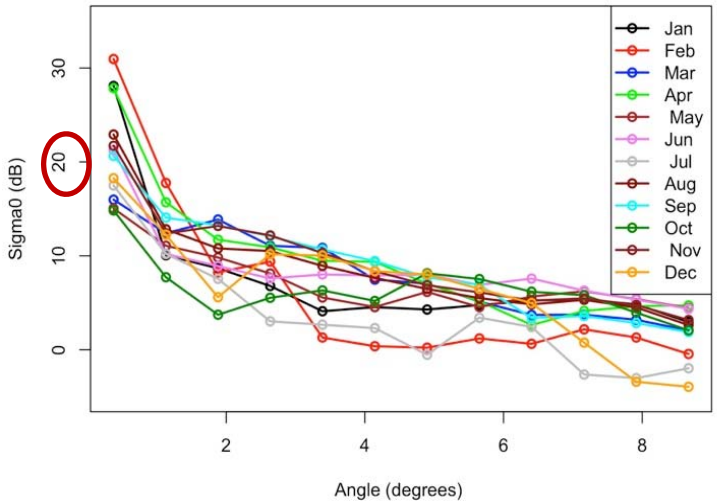
GPM sigma0 over big Sahelian lakes

Grippa et al. , J-STARS, 2019

Soils



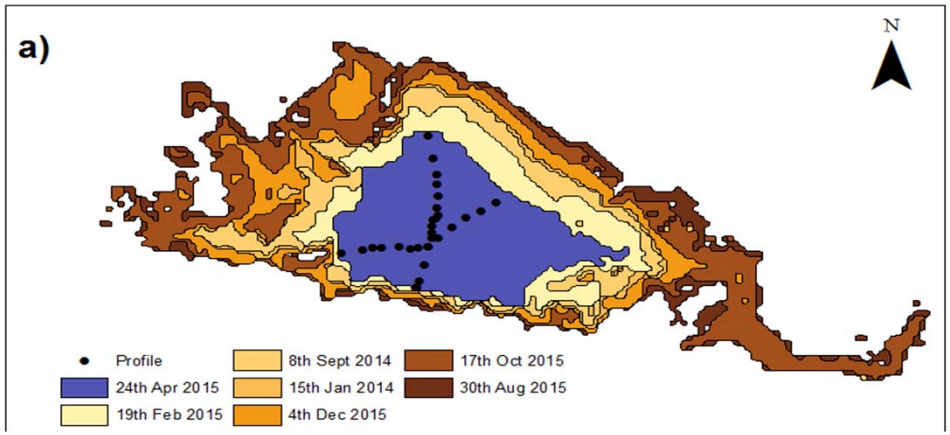
Water



Grippa et al. , J-STARS, 2019

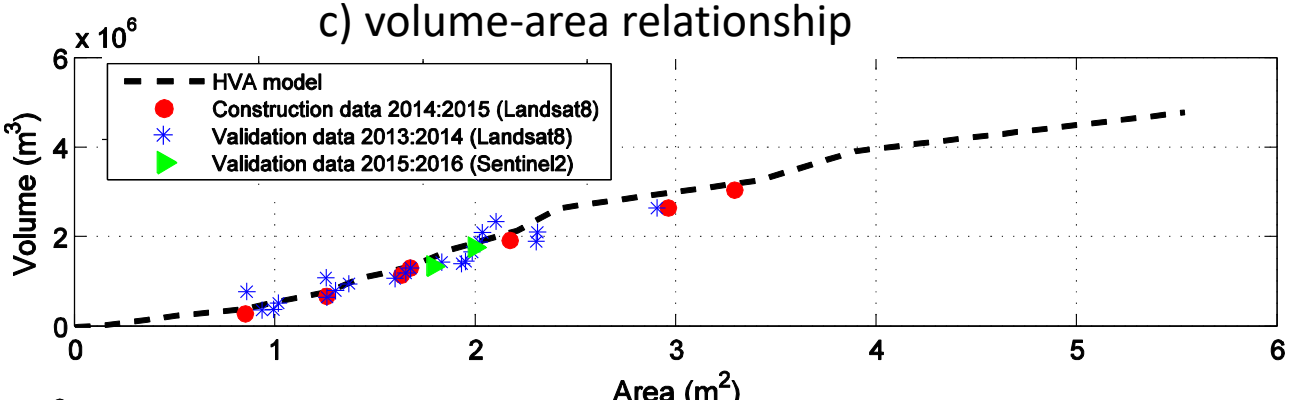
- Deriving water masks by SWOT in this region may not be straightforward due to the sometime small difference in backscattering coefficients between water and soil
- Wind effects on water surface roughness also play a role and need to be assessed

Estimation of water volumes: Agoufou lake



In situ height measurements
by the AMMA-CATCH observatory

c) volume-area relationship



Gal et al. , JH, 2016

→ Estimate evolution in lake volume over time

VOLUME→ WATER INFLOW and RUNOFF

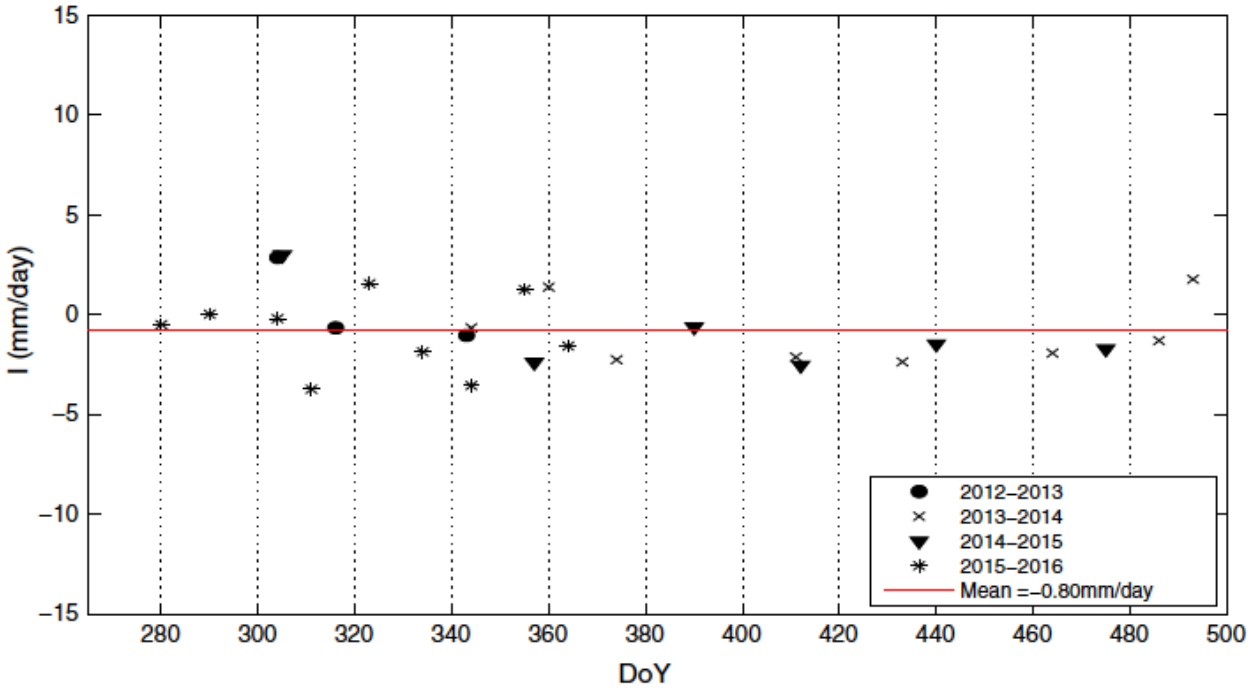
Water inflow to pond

Lake water balance:

dV/dt = Water Inflow +P –E – I

I: surface water exchanges with water table, rarely known

Dry season: dV/dt = ~~Water Inflow +P~~ –E – I



For Agoufou volume changes during the dry season and evaporation compensate
→ Negligeble surface-groundwater interaction

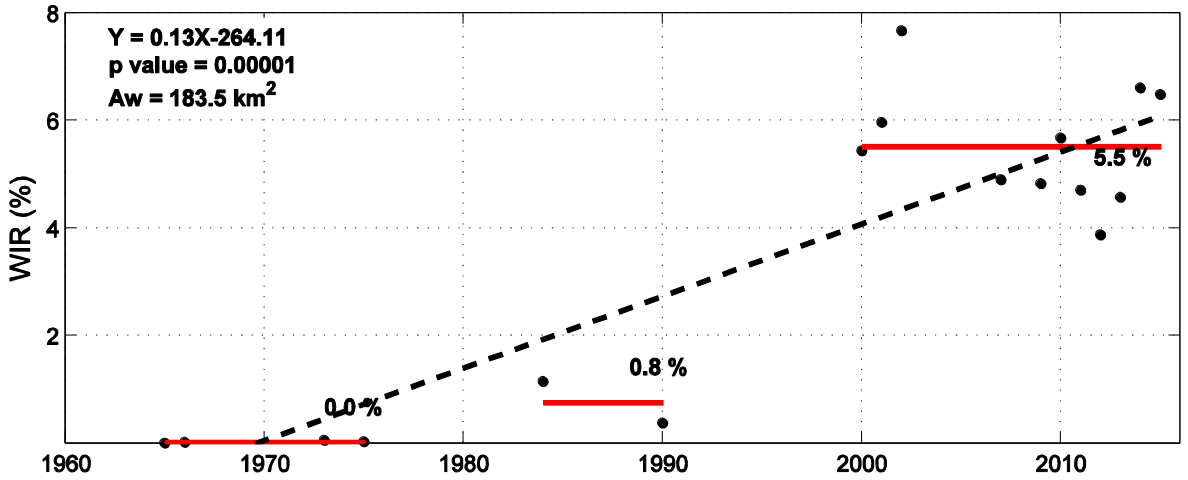
Gal et al. , JH, 2016

SWOT will give precious information on surface – ground water exchanges!

Water Inflow = dV/dt – P +E +I

lakes used as gauged in ungauged regions

Annual water inflow/Precipitation over the watershed → proxy for runoff

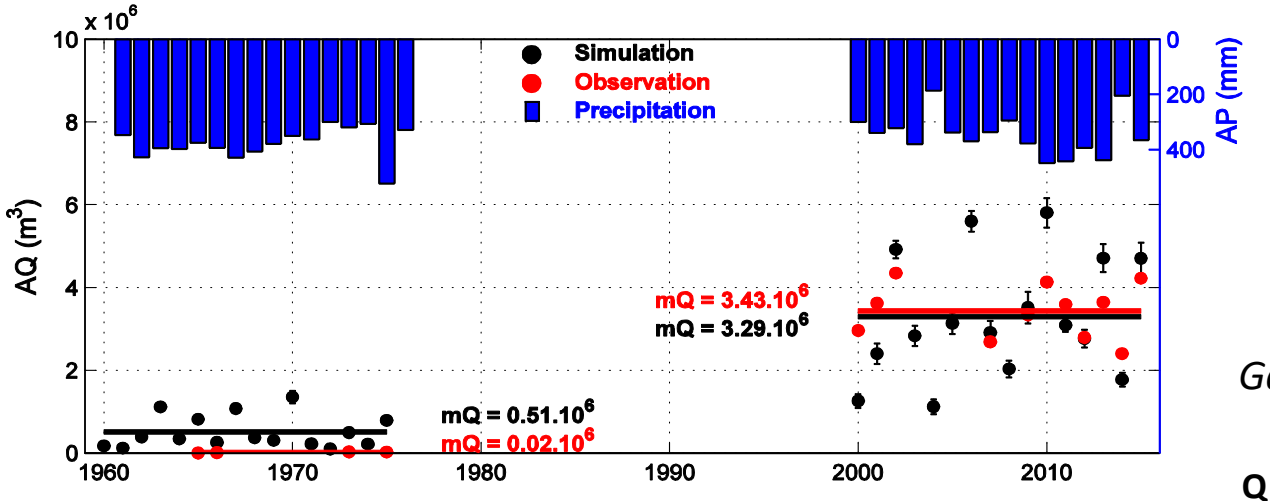


Gal et al. , JH, 2016

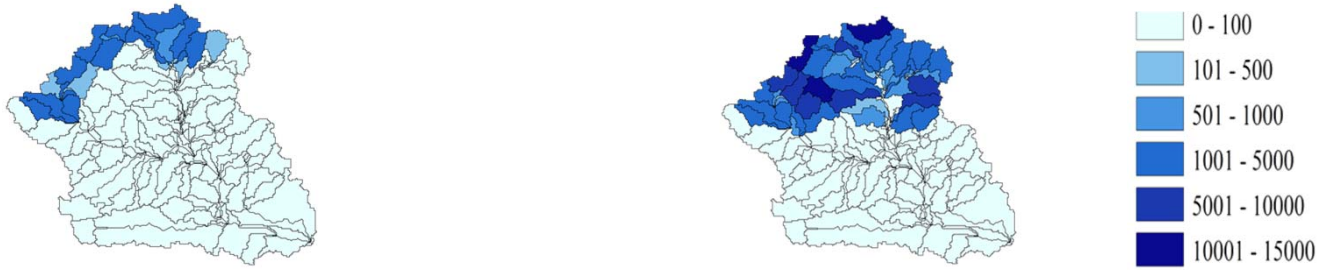
→ Quantification of runoff increase (Sahelian paradox in pastoral areas)
→ base for modelling approaches

SWOT will allow to generalise this approach to all sahelian small lakes!

KINEROS2 hydrological model



Gal et al., HESS, 2017



- Model can reproduce well the runoff evolution in space and time

→ **Change attribution** simulations (climate vs anthropogenic/land use changes)

Major mechanisms accounting for the runoff increase (Sahelian paradox):
vegetation degradation over shallow soils and soil erosion after the major droughts of the 70ies and 80ies

CONCLUSIONS

SWOT capability to monitor water heights and volumes in the Sahel:

- Using SWOT-HR: Seasonal cycle of water levels was retrieved with an accuracy within the SWOT specifications.
- Height retrieval is a bit more difficult for lakes with more complicated shapes Water masks can be tricky in this area→ coupling SWOT to optical RS can be a good option
- The SWOT-HR simulator employed only addresses geometrical errors and instrumental noise. Tropospheric delay in the radar phase may provide another source of error.

SWOT can provide fundamental data for several applications:

→ Estimating water resource variability
→ Estimating surface - water table exchanges, using dry season data
→ Estimating runoff in ungauged regions, necessary for modelling approaches

Scientific questions still open:

Future evolution of water bodies in the Sahel (quantity and quality)?
ecosystem resilience, equilibrium state, possible tipping points

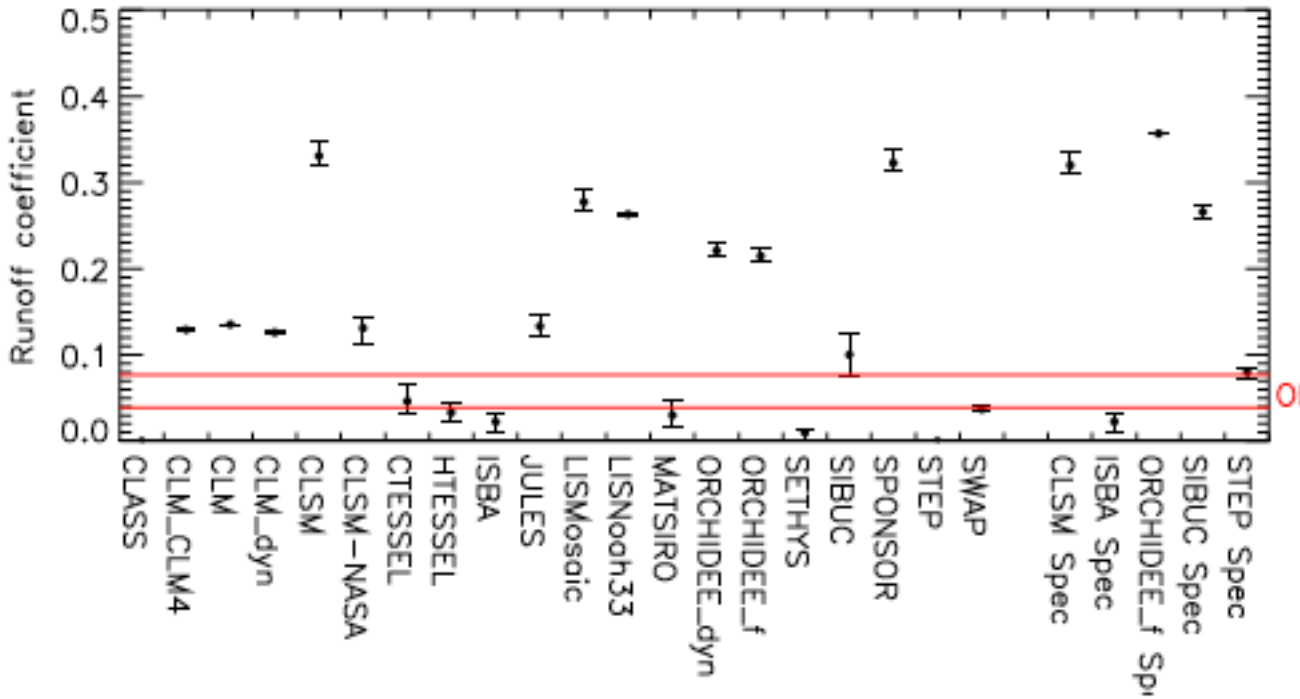
→ New opportunities with Sentinel2, Landsat8 and SWOT to reach an integrated vision of small and dynamics water bodies in this area


Thank you!
Merci!

Extras

Models evaluation

ALMIP2 project. Land surface model intercomparison over the Agoufou watershed



Remote sensing estimations

Grippa et al., J HydroMet, 2017