Lake science and progress

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ST, bordeaux, June 18, 2019

SWOT and lakes

SWOT products : provide a global inventory of all lakes and reservoirs whose surface area exceeds 250m^2 => height, extent and storage changes

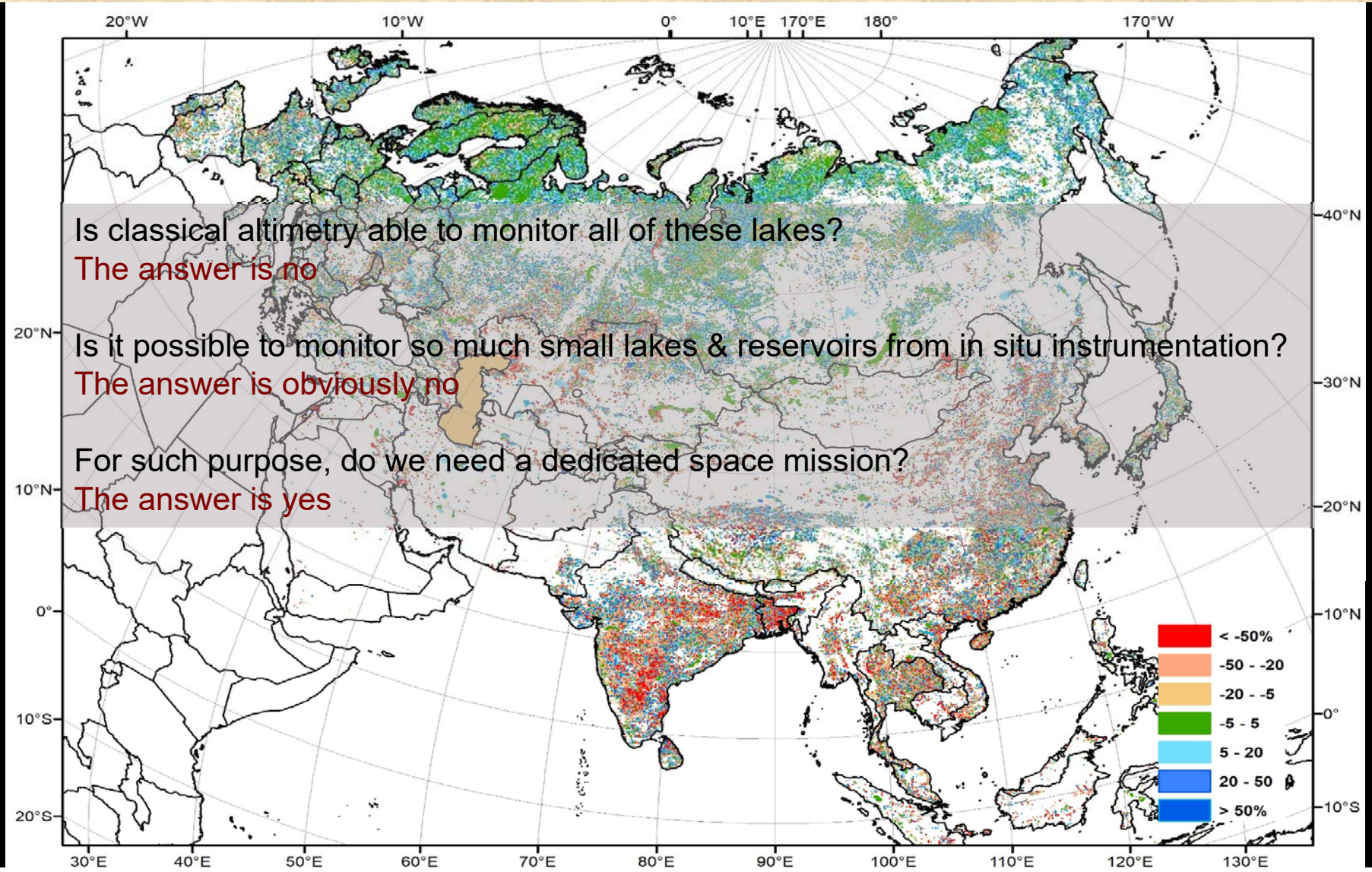
Objective : Explore how SWOT can help improve the modeling of

- role of lake in global climate change
- role of lake in the water cycle
- investigate lake at local, regional and global scale

Outline : Current research by the Science Team

- Global studies
- Regional cases studies (Arctic lakes, Sahelian lakes)
- A priori database and storage changes algorithm development

Eurasia Lake Changes (2000-2015) (Sheng 2019)



Is classical altimetry able to monitor all of these lakes?
The answer is no

Is it possible to monitor so much small lakes & reservoirs from in situ instrumentation?
The answer is obviously no

For such purpose, do we need a dedicated space mission?
The answer is yes

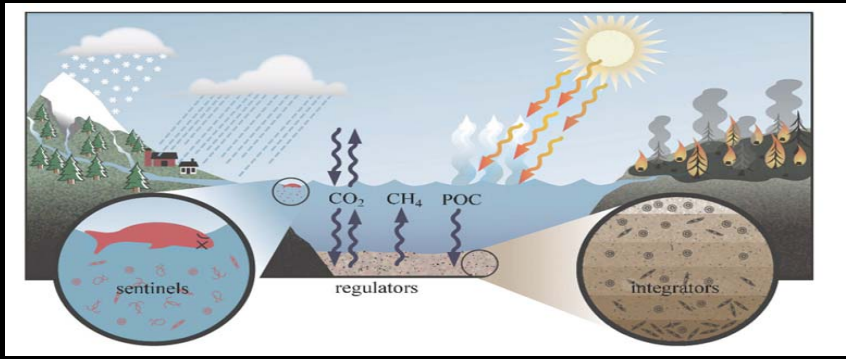
Because lakes are:

1) sentinels, regulators and integrators of climate change (Williamson et al., 2009)

Regulation

They receive, store and re-emit GhG to the atmosphere

They may change the regional climate through evaporation and cloud formation

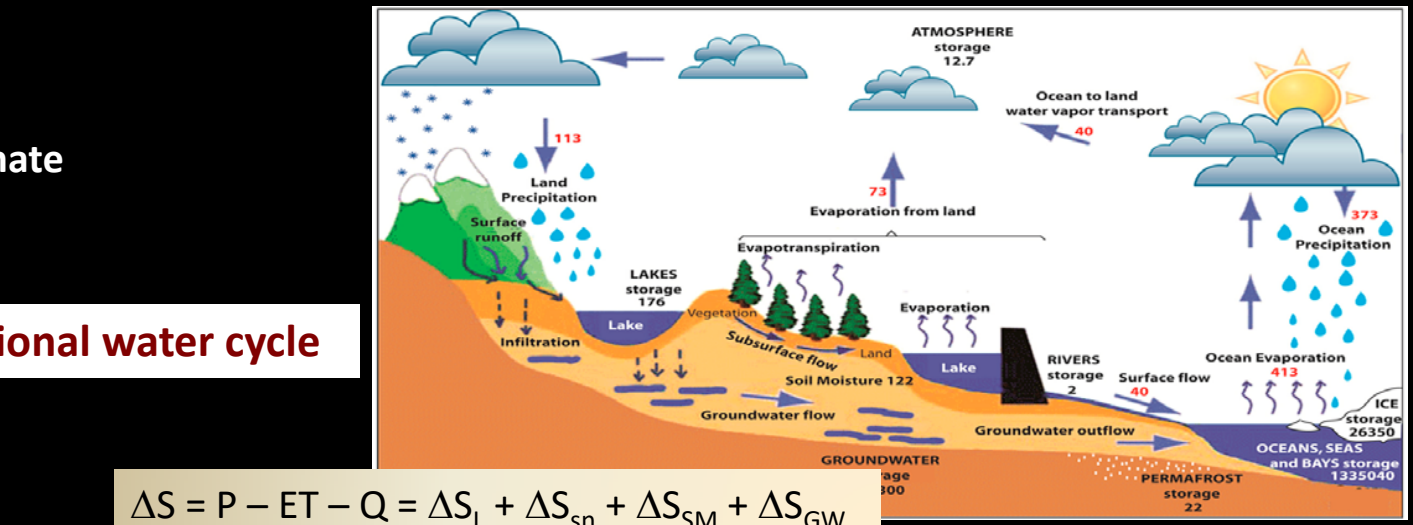


Sentinels

Many variables like height or surface temperature are proxies of CC and considered as ECVs

Integration

Sediments stored are archives of past climate



2) They are essential contributors to regional water cycle

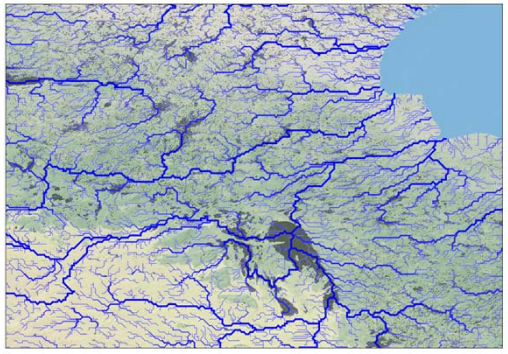
$$\Delta S = P - ET - Q = \Delta S_L + \Delta S_{sn} + \Delta S_{SM} + \Delta S_{GW}$$

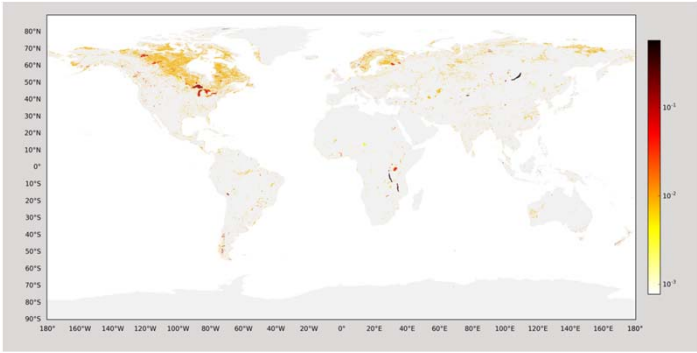
Water mass balance in lakes @ CNRM/Meteo-France

Guinaldo T, Boone A, Munier S, Leroux D, Le Moigne P

Objective: Development of a model for global water cycle assimilating lakes and reservoirs products: MLake.

Localization of lakes is extracted from the global 1-km ECOCLIMAP database and the global lake mask is clipped on the CTRIP-12D river network at 1/12°.

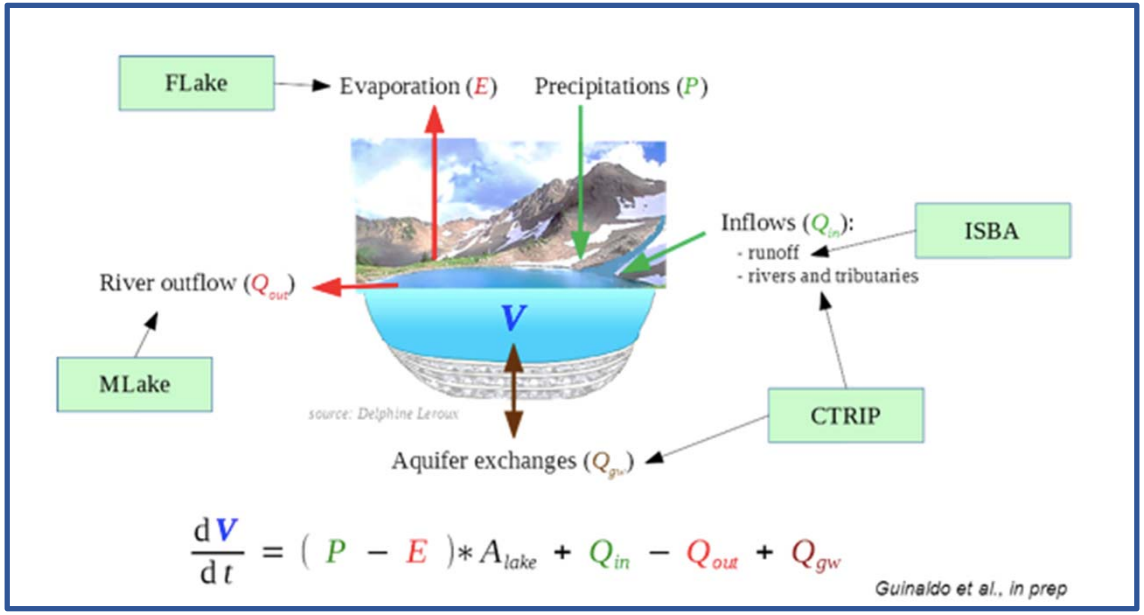




Calibration of a Gaussian shape for bathymetry to estimate volumes.

MLake currently under development is designed to represent the water dynamics in lakes all over the globe.

It is based on a water mass balance equation and will be coupled to various models within the SURFEX modeling platform: lake model (FLake), river routing model (CTRIP) and land surface model (ISBA).



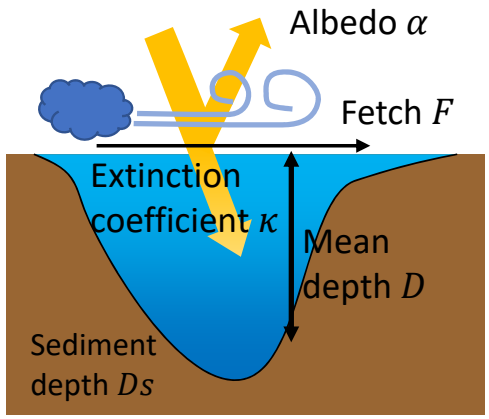
Variance based sensitivity analysis of FLake lake model for global land surface modeling

C. Ottlé, A. Bernus, K. Petrus, A. Jost, S. Biancamaria, D. Desroches, LSCE-IPSL, METIS, LEGOS, CNES, France

Objective: Develop a representation of lakes in the **ORCHIDEE-LMDZ climate model** constrained by SWOT observations

First step: Representation of the **energy budgets**

Approach:
- Coupling with **FLake** lake model to calculate **surface temperature and fluxes (evaporation)**
- Inventory of **lake databases** to characterize lakes at global scales
- Perform model **global sensitivity analysis (SA)** to identify dominant parameters and their time variability
- Develop data assimilation strategies to **calibrate/constrain model parameters**



7 parameters: depth, albedo, extinction coeff., fetch, relaxation coeff., sediment layer depth and bottom temperature

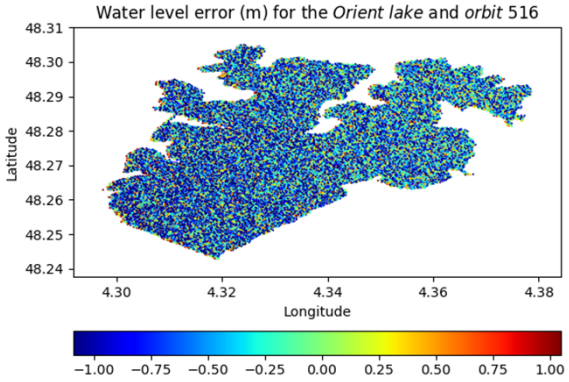
SA results:
- **Depth** and **Extinction coeff.** dominant parameters for **shallow lakes**
- **Albedo** and **Relaxation coeff.** dominant for **deeper lakes**

Sensitivity of depth/radiative parameters vary with incoming radiative forcing

→ **Results** will drive the **choice of data assimilation method** and in **time periods** used in the **optimization process**

SWOT contribution on the lake **energy budget** modeling will be **larger on shallow lakes** and **cold climates/seasons**

Use of the **large scale (LS) simulator** to compute **water elevation errors** given **lake geometry and instrumental noise** including **geolocation error**



Sensitivity experiments in FLake model allow to show the **contribution of depth monitoring** on surface temperature and fluxes with **error reductions up to 50%** and simulation show only few cm of errors for small reservoirs

Regional study (Small Water Bodies in the Sahel)

M. Grippa, L. Kergoat, J-F Cretaux, S. Biancamaria (GET-LEGOS)

Why

- Critical water ressources
- Complex hydrology and paradoxical climatic evolution
- Region very sensitive to climate and anthropogenic changes
- Studying the water balance and estimation of lake-water table exchanges

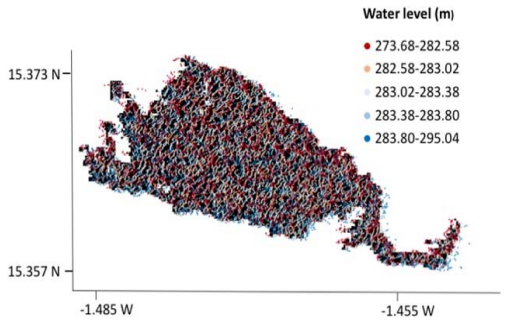
Planned future work

- Hyspometric curves and volumes by Sentinel2+altimetry/SWOT at the regional scale

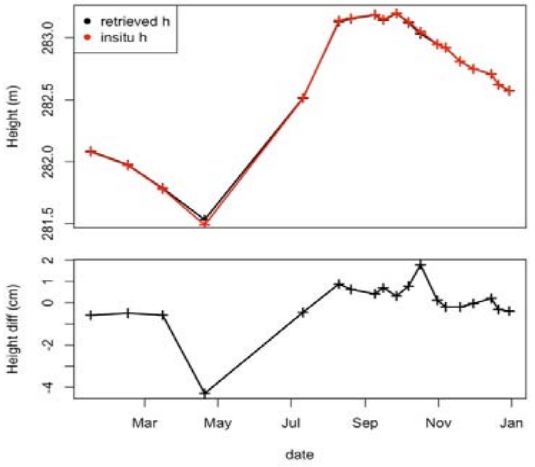
- Water balance and evaluation of runoff and surface/groundwater exchanges in ungauged areas

- Links between water amount and water sediments (hydrology and erosion processes, water quality and health issues)

→ **Get an integrated view of Sahelian small water bodies dynamics and predict future trajectories under climate and anthropogenic changes**



SWOT HR Simulator over the Agoufou lake (Gourma region, Mali)



Retrieved seasonal cycle by **SWOT -HR**

Gal et al JH 2016, Gal et al HESS 2017, Grippa et al. J-STARS 2019

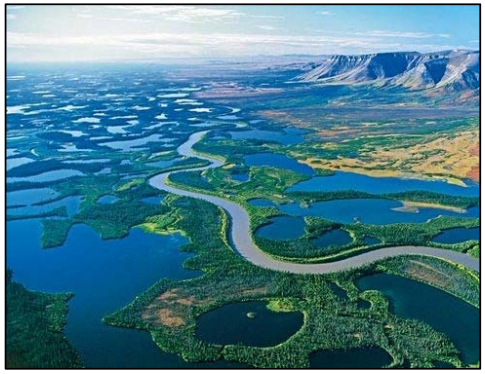
Arctic lake science

L. Smith, J. Fayne, S. Cooley, E. Kyzivat, L. Pitcher, T. Pavelsky (UCLA, IBES, UNC)

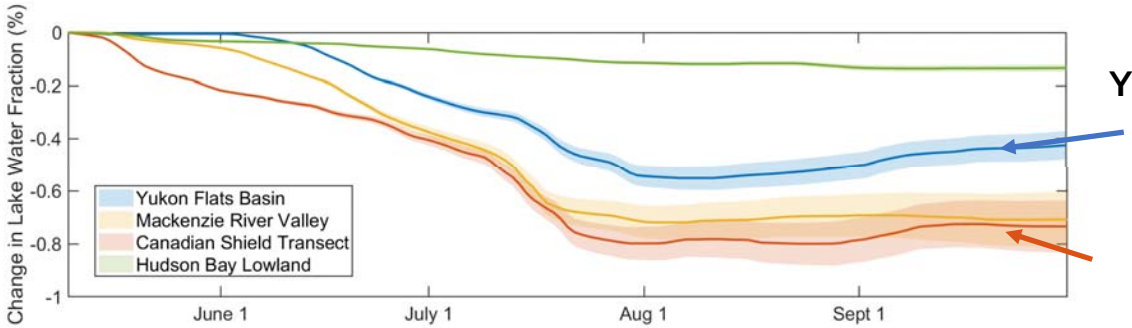
Motivations

The Earth's Arctic/sub-Arctic latitudes are home to the world's **highest abundance of lakes,** making this region critically important for CH_4 emissions, ecological habitat, landscape disturbance (thermokarst), and traditional subsistence cultures

The polar regions are **highly seasonal,** yet research on **sub-seasonal dynamics** of Arctic/sub-Arctic lakes has been limited by lack of *in situ* and high temporal/spatial resolution satellite of dA/dt and dH/dt

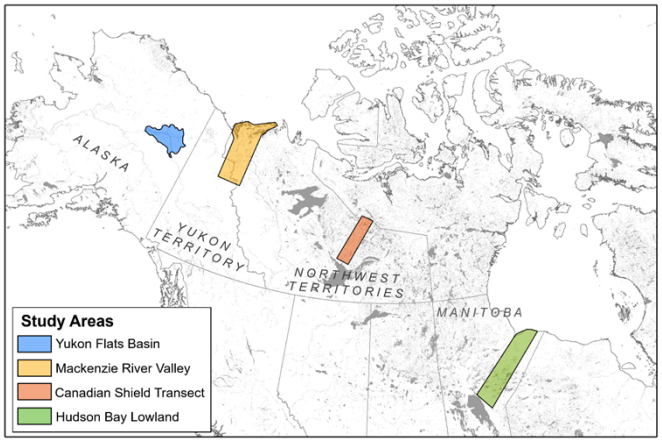


Dynamism = Seasonal maximum lake area – seasonal minimum lake area (km^2)



Yukon Flats Basin

Canadian Shield Transect

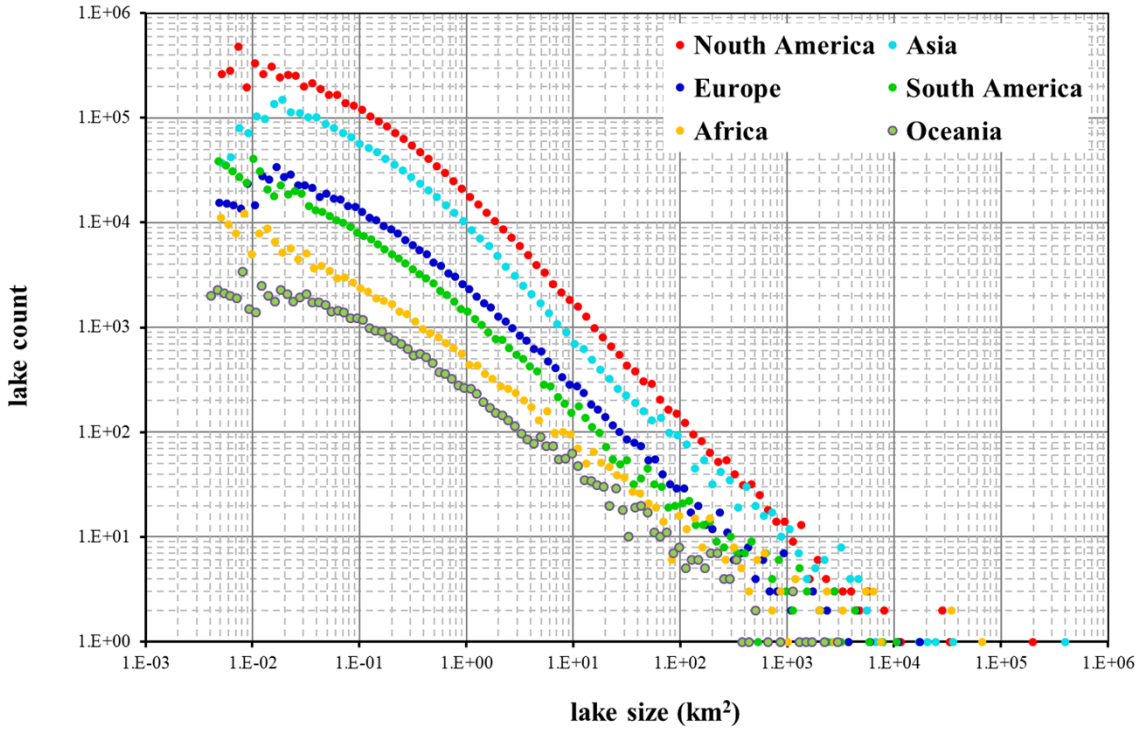


Lakes on the Canadian Shield are surprisingly dynamic, with the greatest absolute change in water fraction

Cooley et al. (2019), Arctic-Boreal Lake Dynamics Observed using CubeSat Imagery, *Geophysical Research Letters*, doi:10.1029/2018GL081584

A priori lake data base & algorithm development

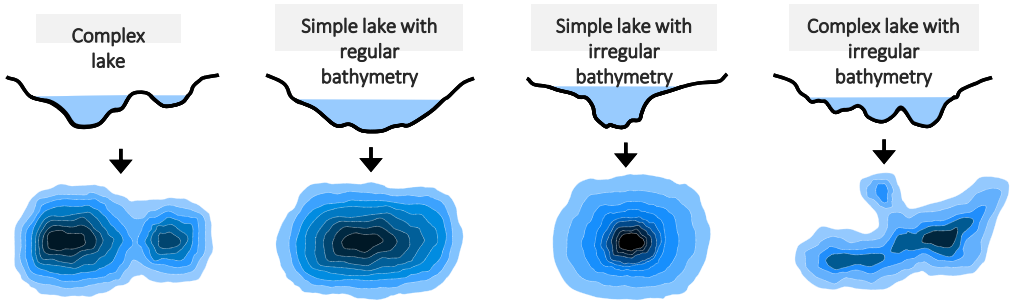
Y. Sheng (UCLA), J-F. Cretaux, M. Bergé-Nguyen & M. Quellec (Legos), J. Wang & F. Yao (Kansas University), H Yésou (SERTIT)



Continent-based Global Lake Size Distribution

-> add reference water height from various sources
-> add a priori geoides of the largest lakes
-> separate between lakes & artificial reservoirs
-> validation (SERTIT) from S1, S2, Landsat over China

Development of processing chain for lake volume changes



- F0 • Select pixels not processed by River Processor (except reservoirs)
- F1 • Identify all separate entities in the water mask
- F2 • Retrieve pixels corresponding to entities entirely inside the tile
- F3 • Refine pixel geolocation
- F4 • Compute lake product
- F5 • Link to prior lake database
- F6 • Update lake product with storage change

Conclusions

SWOT determination of level, area and volume changes will enable

=> closing lake water balance at regional & global scale

=> better take into account lakes into GCM

Sessions during the ST meeting related to lakes

lake study with SWOT splinter
Data product
Cal/val hydro splinter