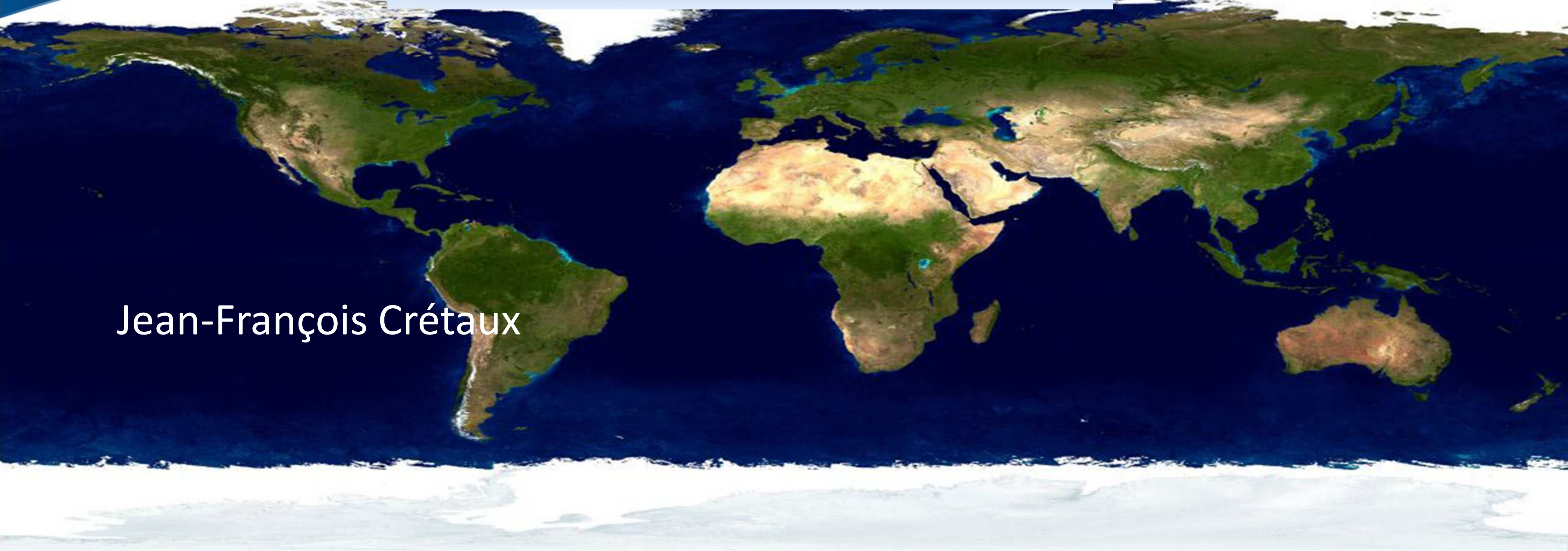
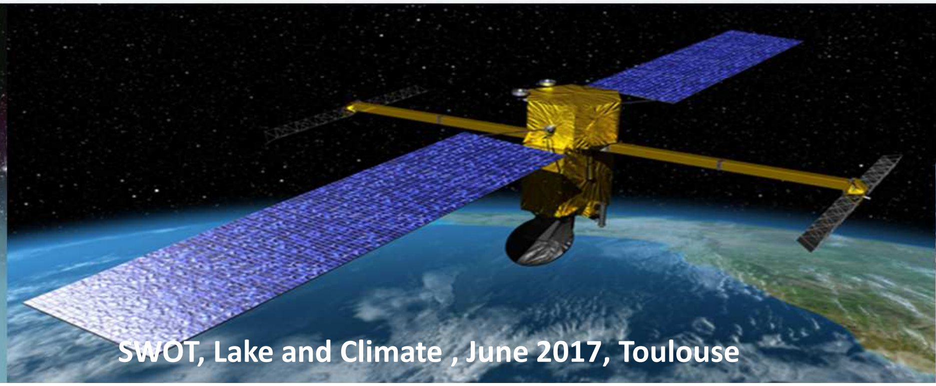
Current status on global lakes observations from satellites

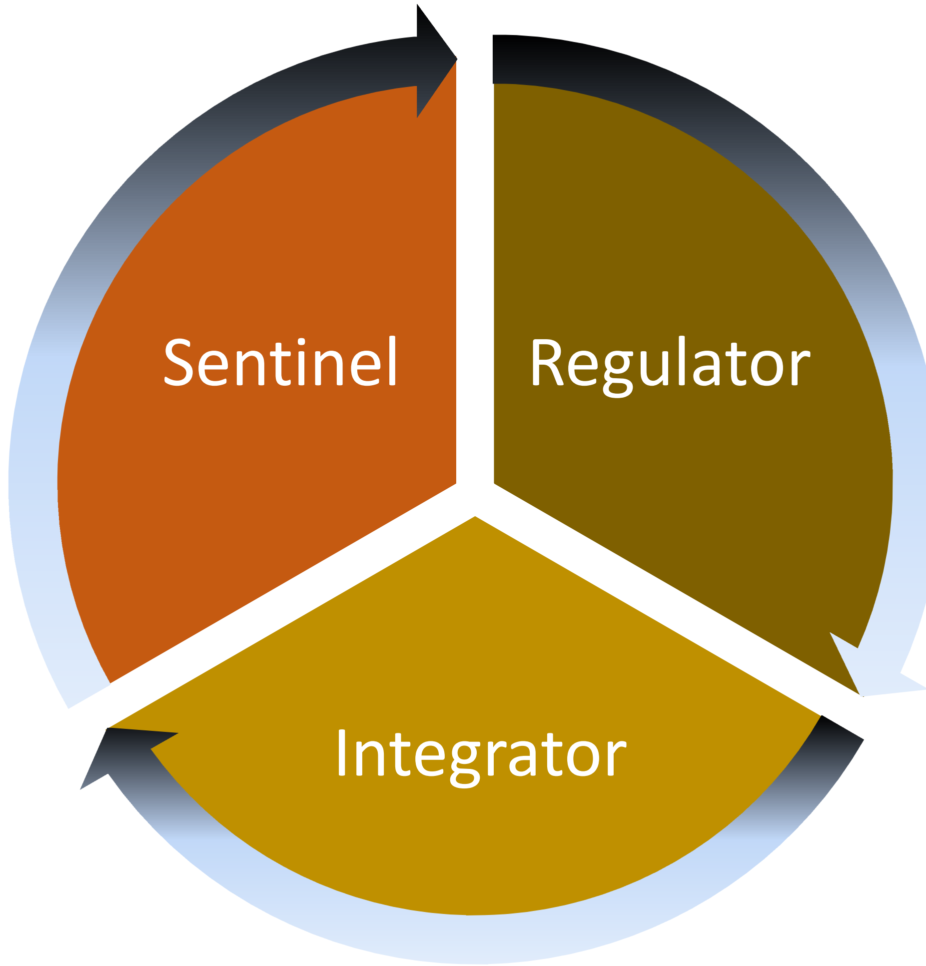


Jean-François Crétaux



See presentation of J. Brentrup

Lakes and climate



What are the variables possibly inferred from satellites?

Definition of ECVs: 79 lakes were selected by GCOS organisation and TOPC panel in a first step to caracterise Climate Changes related to lakes

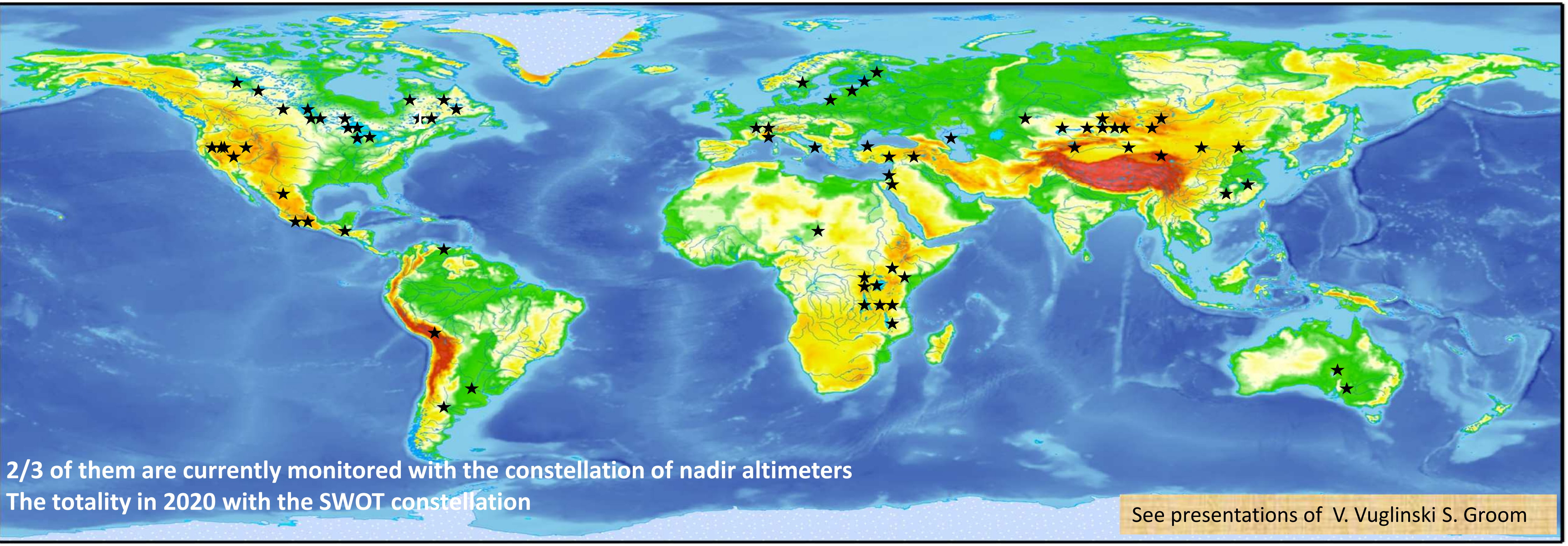
Sentinel of CC

5 types of ECVs have been defined

- Daily/Weekly/Monthly water level changes
- Daily/Weekly/Monthly water extent changes
- Daily/Weekly/Monthly water temperature
- Date of Freezup and thawing of lake ice at high latitude, ice depth
- Water colour

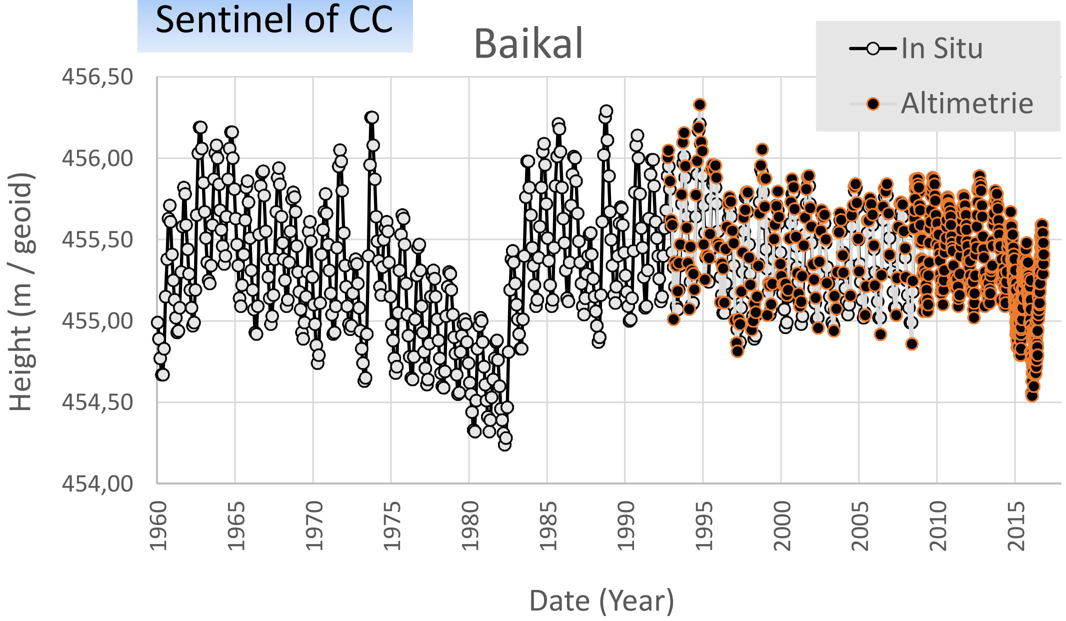
Are there measurable from remote sensing?
What are the climate issues adressed?

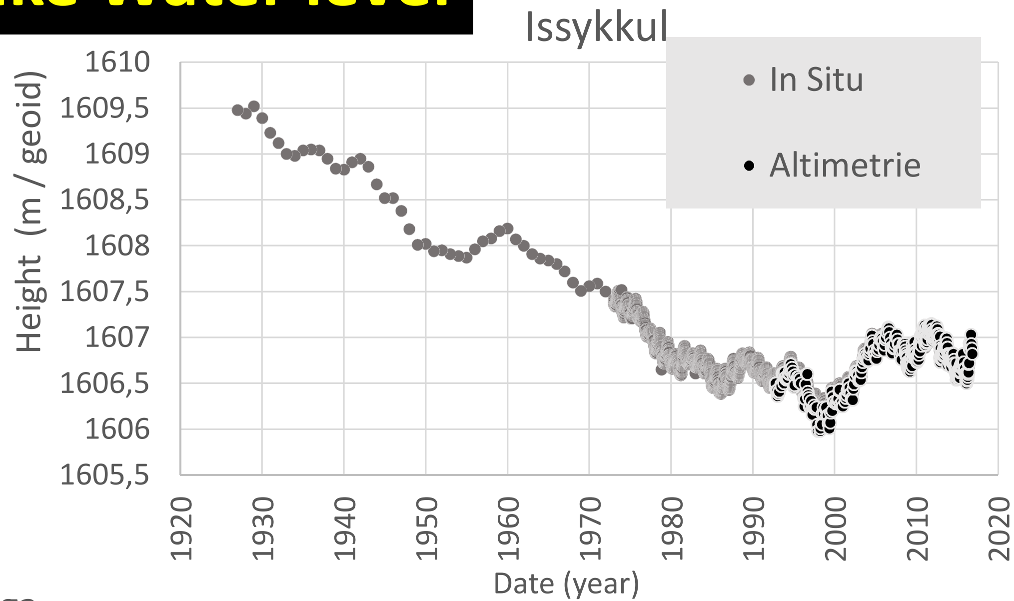
- Water cycle
- GhG cycle
- Biophysical processes

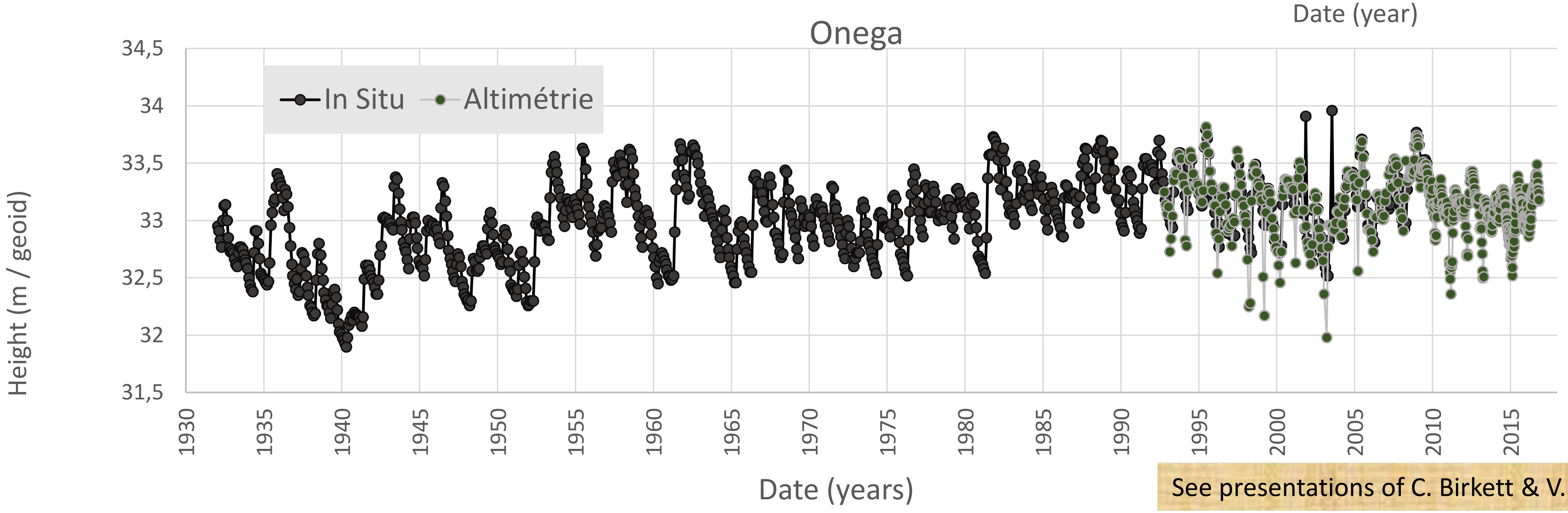


Sentinel of CC

Lake Water level





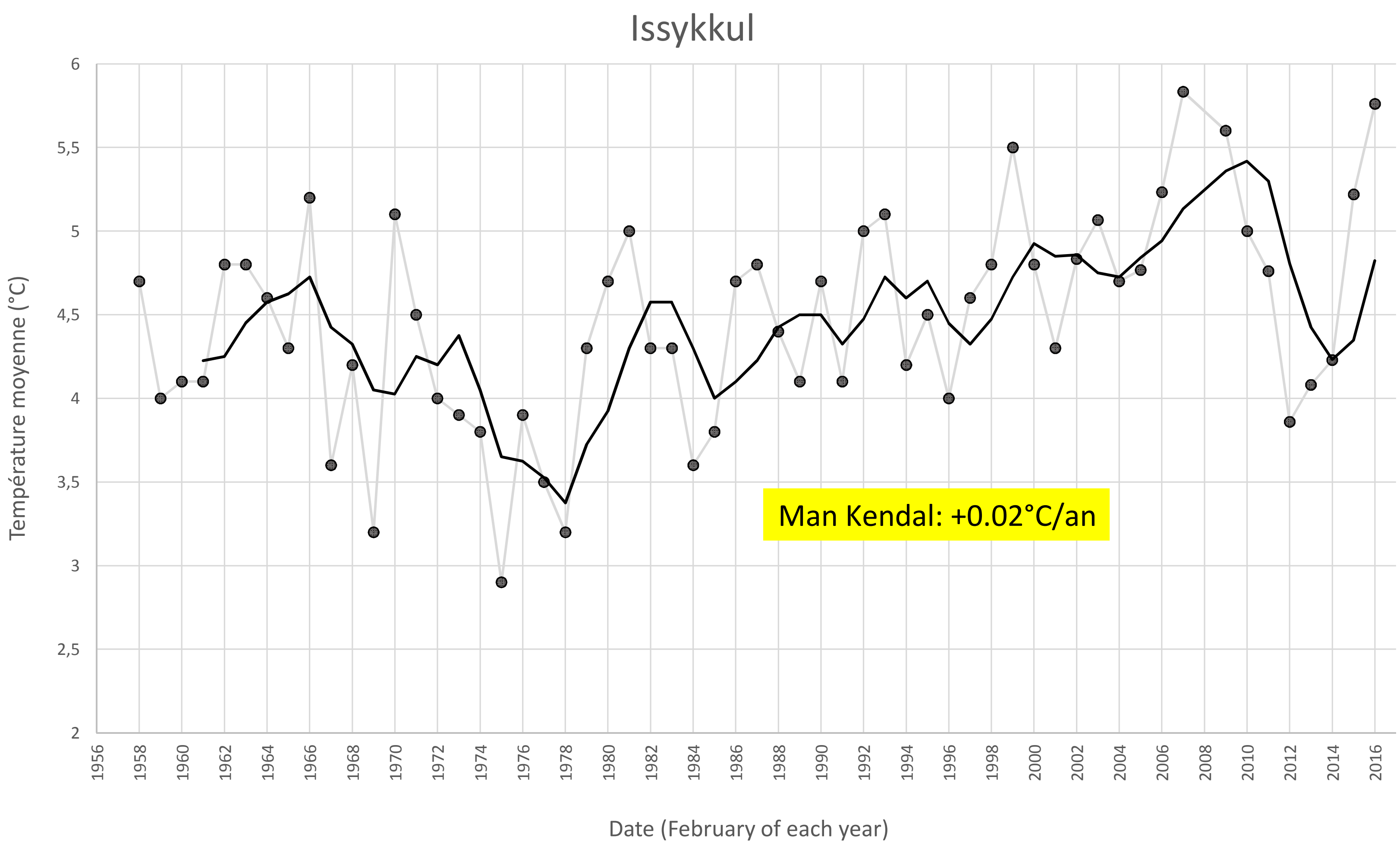


See presentations of C. Birkett & V. Vuglinski

Sentinel of CC

Lake water temperature

See presentations of I.Woolway, P. Hunter & S. Groom



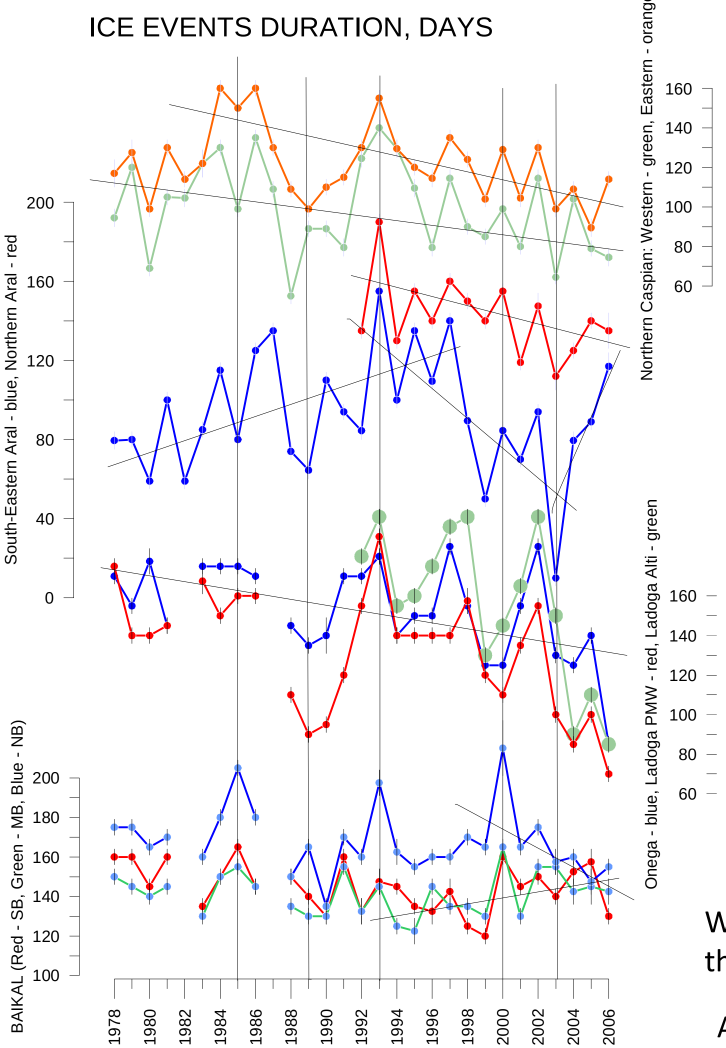
In Situ measurements are very sparse and only for some big lakes=> Thermal Remote sensing allows to generalise this survey

Integrator of CC

Lake Ice (1/2)

See presentations of C. Duguay

Date of ice formation, breakup, duration and depth



Caspian Sea

Constant gradual warming

Aral Sea

Cooling followed by warming

Ladoga, Onega

Very similar recent warming

Baikal

Warming in the north but cooling in the center & the South

A. Kouraev, Legos

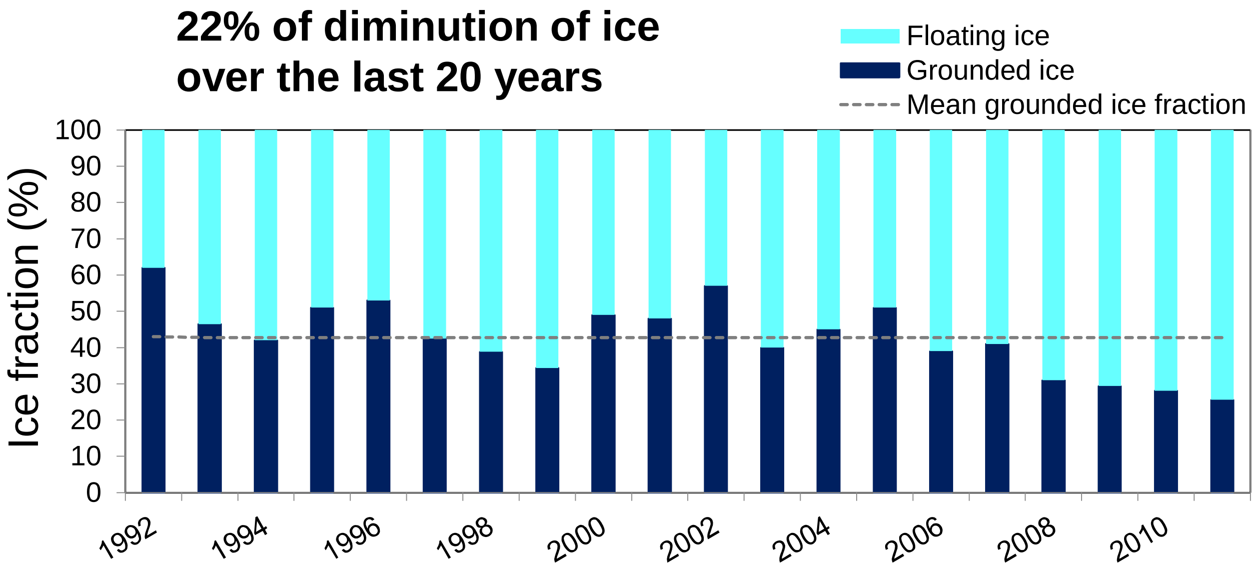
- Long term trends, cycles?
- Geographycall patterns?
- Which CC processed has been integrated in these variables?
- Which type of sensors to monitor them?

variables defined as ECVs by GCOS

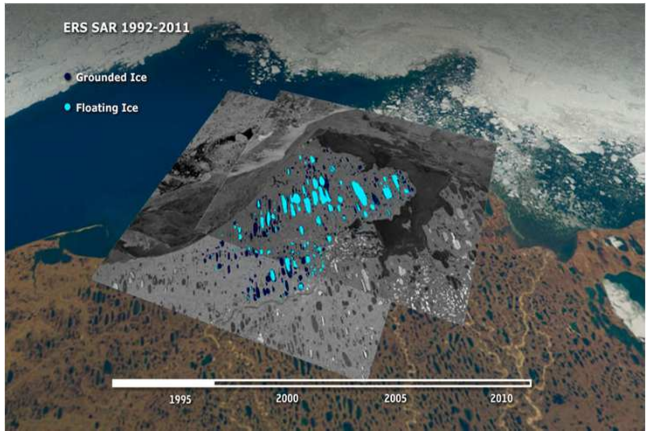
Sentinel of CC

Lake Ice (2/2)

See presentations of C. Duguay



20 years of SAR data on ERS1/2, S1A/B, Radarsat constellation
400 lakes studies in the Barrow region in Alaska



This result suggests that the general diminution of ground ice is due to a general diminution of depth's ice but:
It does not take into account yearly dynamic of lake level when the ice is formed in winter.
Definitive conclusion on impact of global warming is therefore not possible

Ground cover of the classical nadir altimeters does not allow to determine the lake level of each of the small lakes in the area of study, and this is not possible to obtain this information from in situ measurements.
=> Would SWOT be able to solve this issue?

Regulator of climate change (1/3)

1- Lakes receive and store high quantity of carbon from the surface runoff

It depends on the type of the surrounding soils (In arid region poor in biomass, high in tropical regions)

See presentations of M. Grippa, T. Le Toan

2- The lakes store the carbon and re-emit GhG to the atmosphere

3- Lakes may change the regional climate through evaporation and cloud formation

Shrinkage of the Aral Sea reinforced the gradient of temperature between winter and summer and the intensity of wind (Micklin 1980)

Permafrost thawing due to climate change enhanced the global warming in the boreal region through the emission of CO_2 and NH_4 in shallow lakes

4- The stock of carbon into lake sediments is much higher than the total contained in the ocean (Tranvik et al., 2009)

Regulator of climate change (2/3)

DIC: Dissolved Inorganic Carbon
DOC: Dissolved Organic Carbon
POC: Particulate Organic Carbon
TOC: Total Organic Carbon

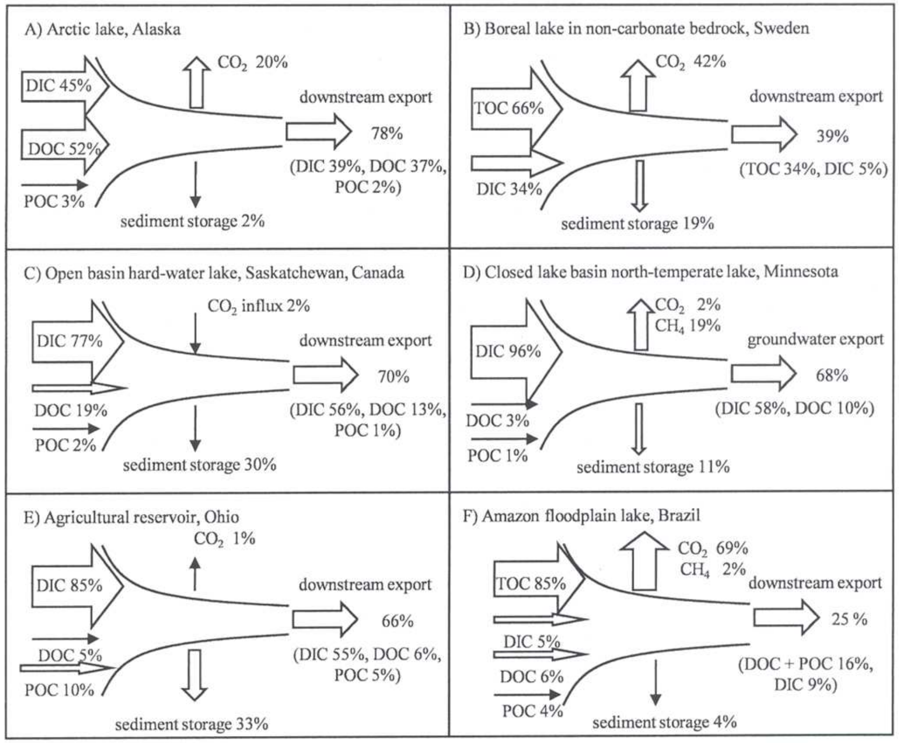
The quantity of CO_2 stored in a lake is modified by the duration ice period in winter (Catalan et al., 2009)

The salt lakes contribute two times more to the emission of CO_2 than freshwater lakes (Duarte et al., 2008)
=>
Shrinkage due to warming or rainfall decrease amplifies the carbon re-émission
=> Shallow & small lakes are more active in GhG re-emission

Due to the high role of lakes as source and sink of CO_2 & CH_4, & the sensitivity to their geographycal distribution (number, type of surrounding ecosystem), their morphology (size, depth) and their type (salt/fresh)

=> are there some window in studying lakes and CC under multi-sensors & multidisplinary context, with high role to play by remote sensing:

SWOT, BIOMASS, Sentinel, others?



Flux of Carbon from and to the lakes differs from the location and the type of lake (Schindler et al., 2009, Tranvik et al., 2009)

This is certainly one of the main objective of this workshop

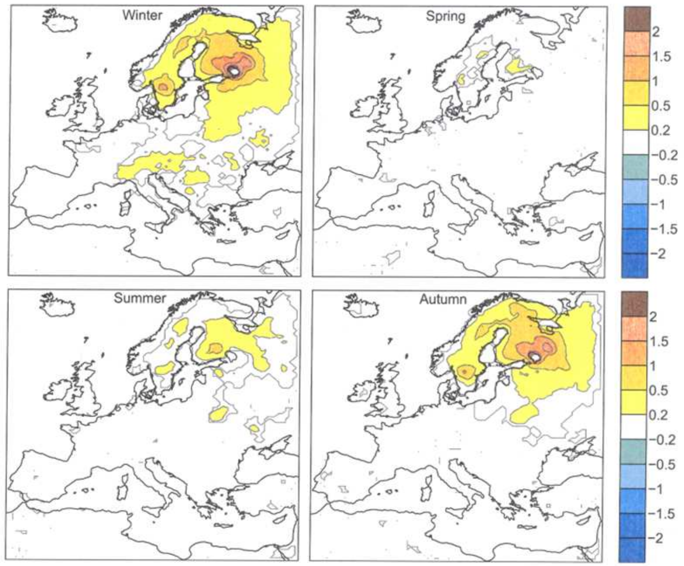
See presentations of J. Brentrup, O' Reilly, Cael, Le Toan, Giardino & others

Regulator of climate change (3/3)

See presentations of P Le Moigne, & I Woolway

Simulation by Flake of the impact of lakes on the air température and précipitations in Europe

Temperature changes by season



Rouse et al., 2005

2 simulated cases : lakes taken into account and lakes erased from a 30 years simulation

Increasing air temperature in summer, autumn and winter up to 1/1.5°C
Deep lakes like the Ladoga provoke a slight cooling in spring

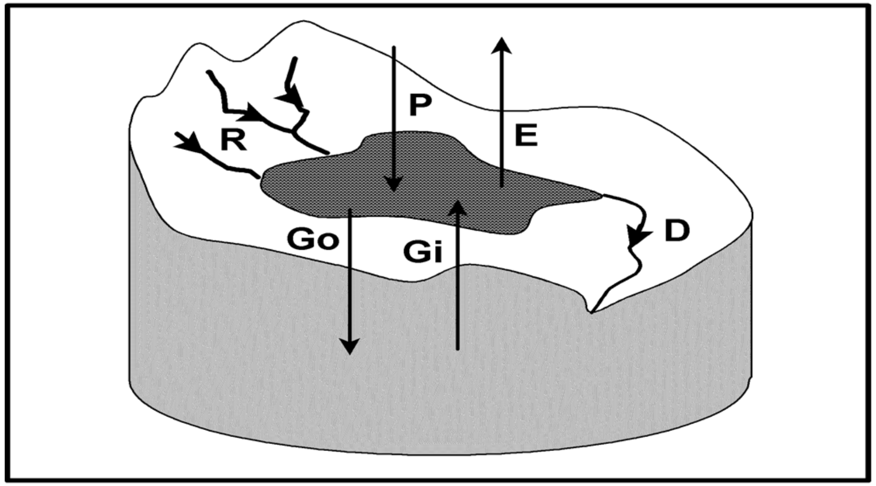
It also has an impact on rainfall but in a lower amplitude

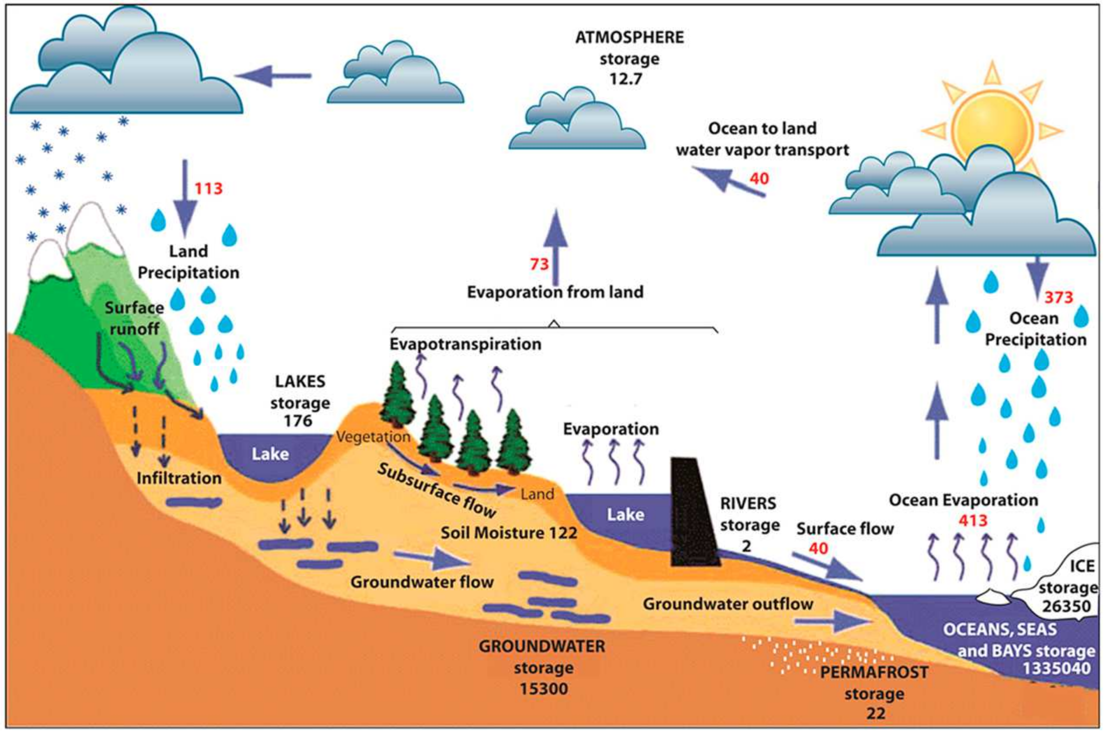
There is a high sensitivity of the Flake model to the depth of lake, often unknown for small lakes
Impact also of ice duration over the lakes and of water temperature.

Can we assimilate satellite data on those parameters to improve the models outputs and consequently the climate change prediction?

Contribution of lakes and reservoirs to basin scale water balance (1/3)

$$\frac{dV}{dt} = [R + P + Gi] - [D + E + Go]$$





Lake in equilibrium:

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

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

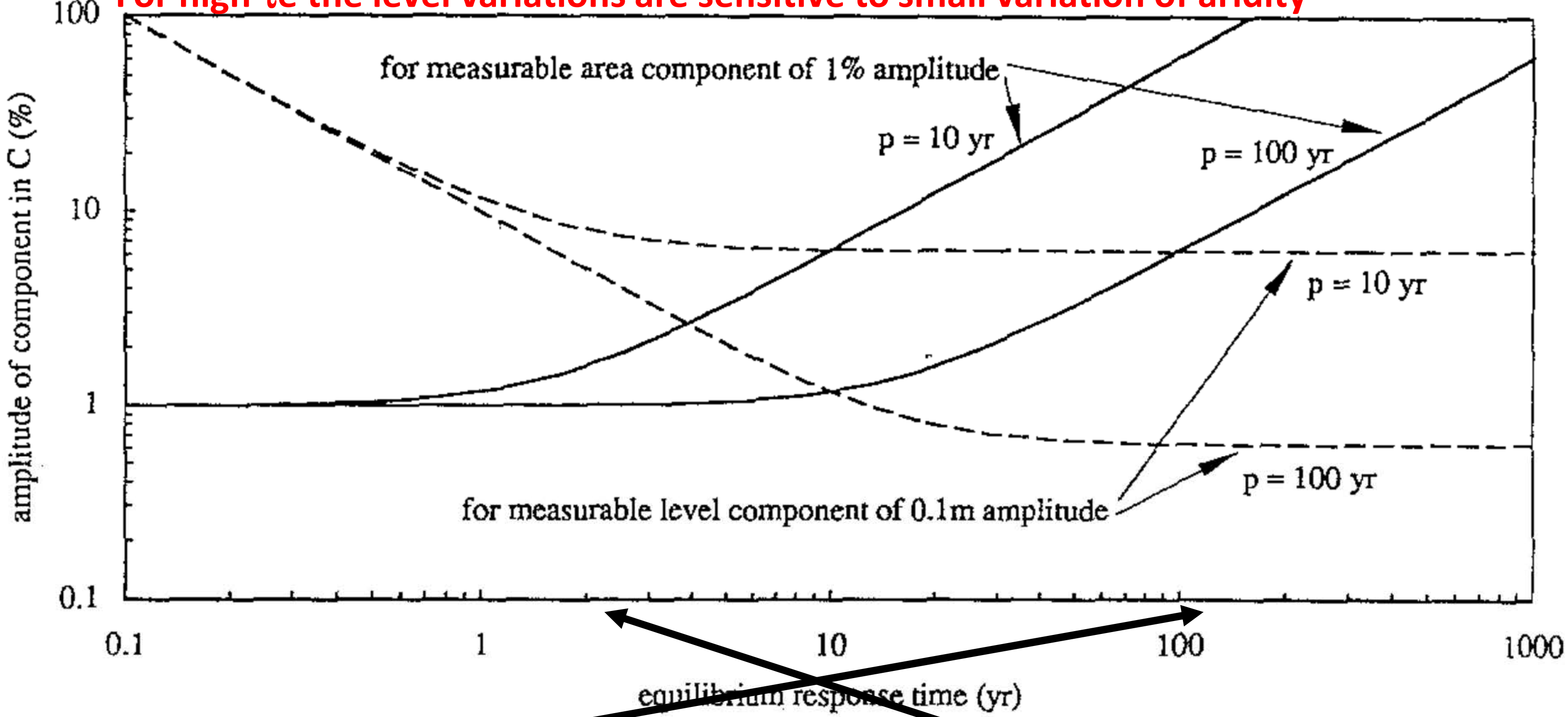
Equilibrium response time: to reach a fraction (1-1/e), ⇔ 63% of the total change:

$$\tau_E = \frac{1}{dA/dV(E-P)}$$

When changes occurs on the hydrological parameters of a lake, it always tends towards a new equilibrium

For small τe the extent area variations are sensitive to small variation of aridity

For high τe the level variations are sensitive to small variation of aridity



Tangra-Yumco , 522 years
Nam-co, 160 years
Zigetang-co, 134 years

Ayakkum, 24 years
Large / small Aral, 23 / 17 years
Urmia, 10 years
Large / Small Tchad, 4 / 1 years

Mason et al., 1994, Cretaux et al., 2016

Contribution of lakes and reservoirs to basin scale water balance (2/3)

See presentations of D. Lettenmeir, C. Birkett, G. Dedieu, Y. Kerr, T. Pavelsky, I. Woolway & C. Pottier

FLAKE, VIC (Arclake, OLCI, ERA)

Lake Water Balance

$$\boxed{\frac{dV_{(lac)}}{dt}} = \boxed{Sl_{(t)}} * \left(\boxed{P_{l(t)}} - \boxed{El(t)}\right) + \boxed{G} + \boxed{R - D}$$

Alti+imagery
SWOT

imagery
NISAR, Venus, S2, SWOT

TRMM, APHRODITE, GPCP, CRU
GPM

In Situ, models
SWOT

Watershed balance

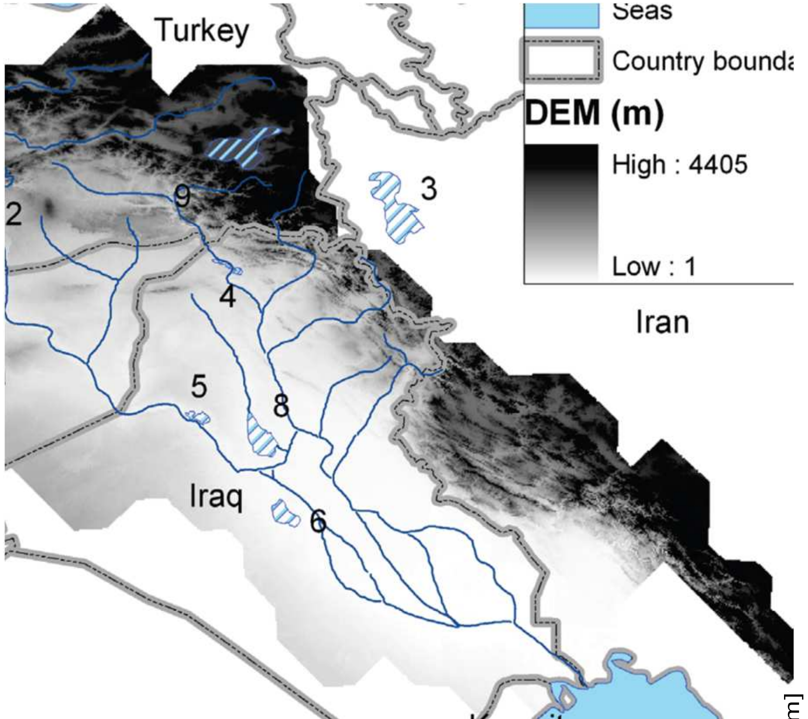
$$\boxed{\frac{dV_{(GW)}}{dt} + \frac{dV_{(sn)}}{dt}} = \boxed{\frac{dV(total)}{dt}} - \boxed{\frac{dV(lac)}{dt}} - \boxed{\frac{dV_{(SM)}}{dt}}$$

GRACE
GRACE-FO

SMOS, GLDAS ESA CCI
SMAP

Yesou, Fruteau, Cretaux

Contribution of lakes and reservoirs to basin scale water balance (3/3)

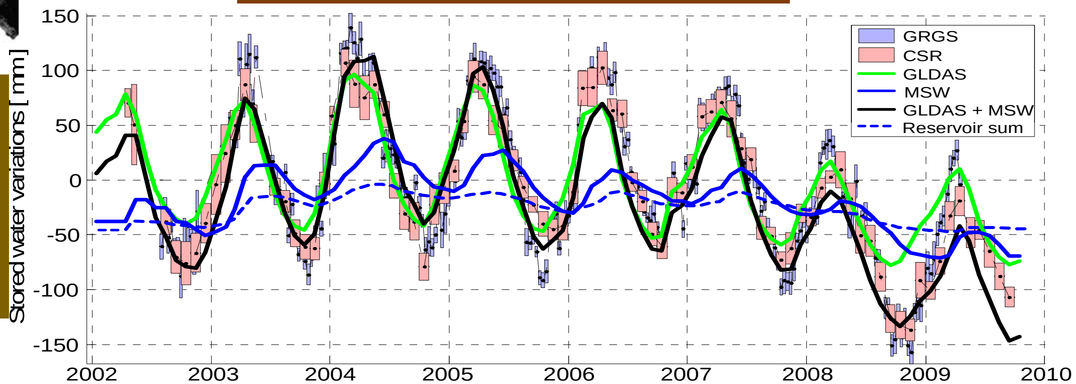


Over the TE basin, the reservoirs contribute for:

- 1 0% of the seasonnal amplitude of TWS
- 40% of the tendency over the whole period
- 50% over the last 3 years
- Improvement of correlation (7%)

- The position and size of reservoir have strong influence on the TWS for a given water mass.

-LSM like GLDAS provide global variables like ETP, soil moisture, snow storage, etc -They are based on the water balance at watershed scale: dV/dt = P-E+R
-They generally do not include open water bodies like lakes and reservoirs that however contribute significantly to water cycle



Longuevergne et al., 2013

See presentations of J-F Peckel & C. Birkett

Conclusions / perspectives

The lakes are a fundamental component of the continental surface when investigating the climate changes

They play the role of proxy, regulator and integrator

Responses are generally regional and mainly depend on the surrounding ecosystem

The variables needed to understand their role in CC are numerous
(level, extent, temperatures, ice, water colour……)

Remote sensing techniques are well suitable to examine the role of lakes in CC and already extensively used

SWOT mission however is the first one fully dedicated to te
study of continental water (lakes, rivers and floodplaisn)

There is probably still a lot to do to better use them in synergy in order to explore the multiple aspects of lakes study in the framework of climate change

This is the objective of this workshop to discuss this question and setup a working group within the perspective of a constellation of satellites in the ERA of SWOT