SWOT Hydrology Cal/Val: Post-Launch

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Overall Hydrology Cal/Val Approach

2 types of approaches will be adopted:

- **Global Cal / Val**
  - Comparison with existing in situ network
  - Comparison with global satellite products
- **On site Cal / Val**

  2 types of sites are proposed
  - “Tier-1” : High level of perennial and operational in situ measurements associated to field works
  - “Tier 2”: opportunity site with limited in situ measurements and occasional field works.

2 Phases of cal/val:

- 1D-Orbit during 3 months at the beginning of the mission
- Nominal Orbit at 21 days during the 36 months of lifetime

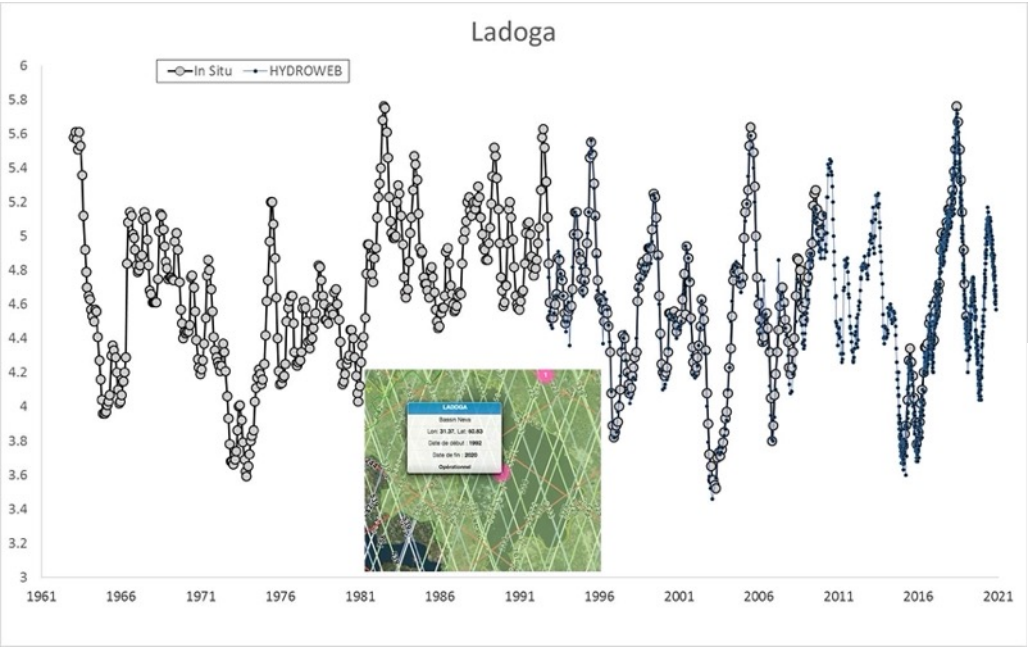
U.S., French, and Canadian teams will work together, leveraging the different strengths of each team

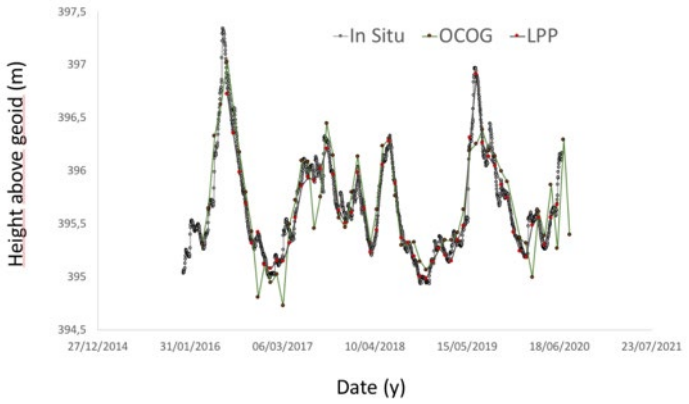
Global validation: comparison to in situ data

Database available from different projects and different sources:

-Lakes network gauges: USGS, Canadian environment services, Hydrological services in Argentina, Chile and Brazil, Hydrolare in Russia, citizen for science (USA, Garonne basin & Pyrenées), Swiss, Spain, Norvegian and Swedish hydrological services …..

-River network gauges: Rhine, Garonne, Rhône, Po, Amazon, Sao Fransisco, North America, GRDC ……



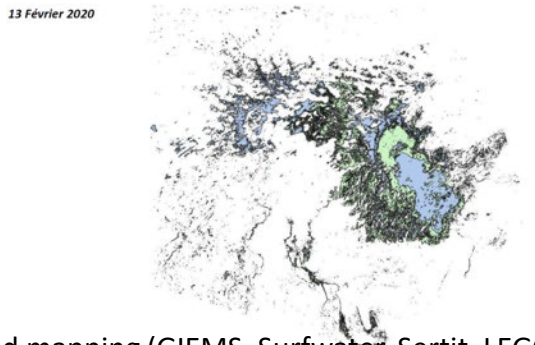


Global validation: comparison to global satellite products

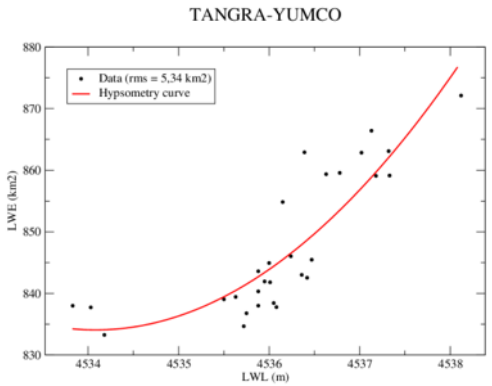
Nadir altimeters: Jason-CS/S6, Sentinel-3, ICESAT-2 → Water level on lakes & rivers

Radar and optical imageries: Landsat-8, Sentinel-1, Sentinel-2 → Water extent on lakes and width on rivers

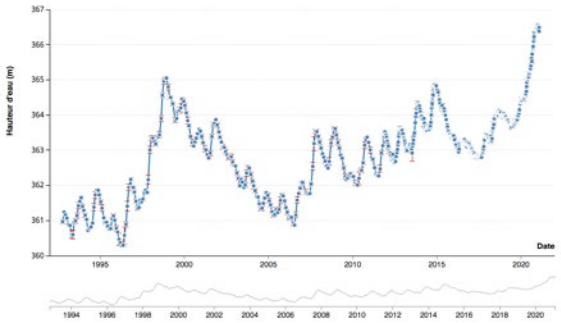
A priori satellite products: rating curves, hypsometry, bathymety → River Discharge, lake storage changes



Flood mapping (GIEMS, Surfwater, Sertit, LEGOS)

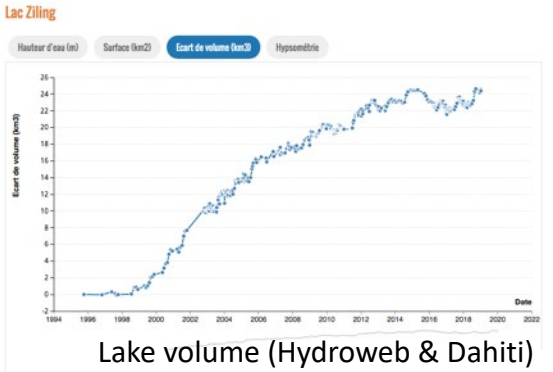


Hypsometry (Hydroweb & Dahiti)

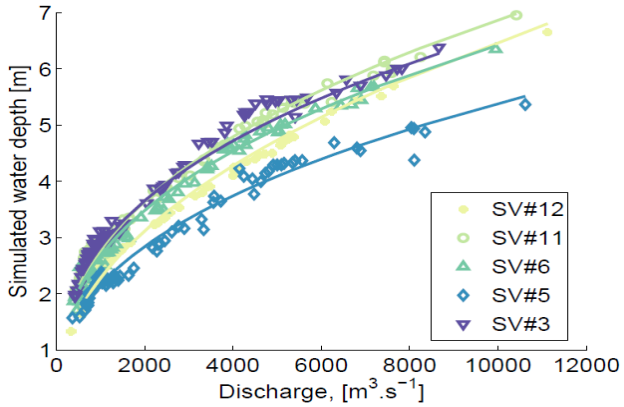


Lake & river level (Hydroweb & Dahiti)

Lake extent (Hydroweb & Dahiti)



Lake volume (Hydroweb & Dahiti)

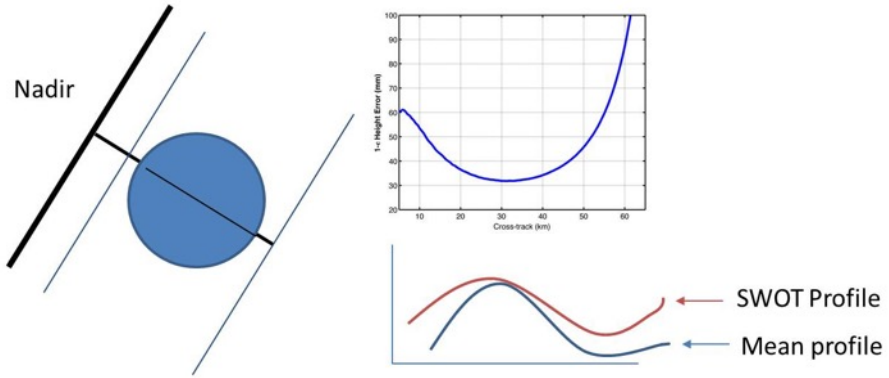


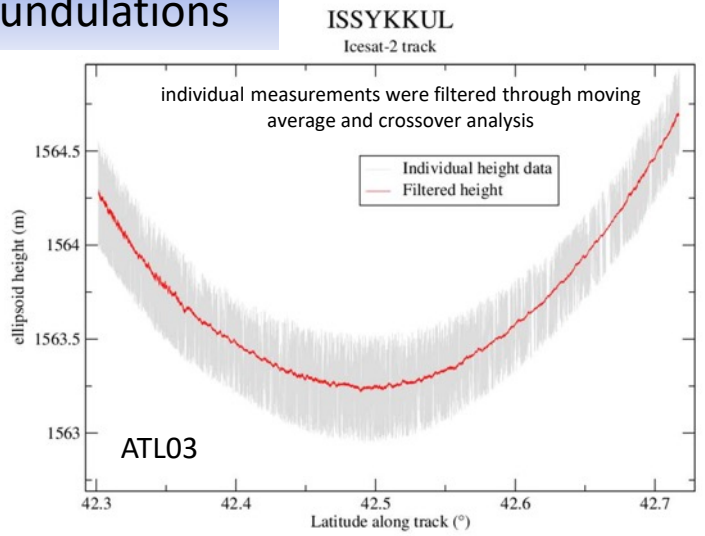
Rating curve (Hydroweb + MGB)

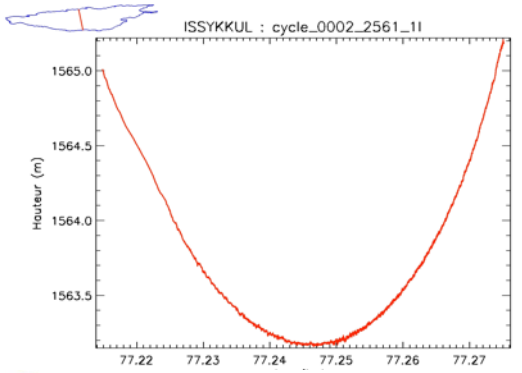
Global calibration: comparison to global satellite products

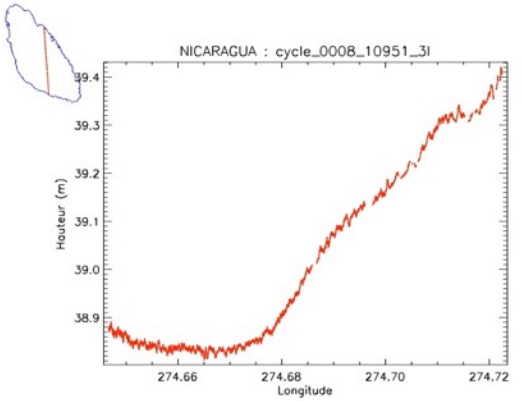
- **Control data for:**
  - calibration of the roll errors
  - validation of SWOT heights across the swath

A priori database on lakes: geoid height undulations

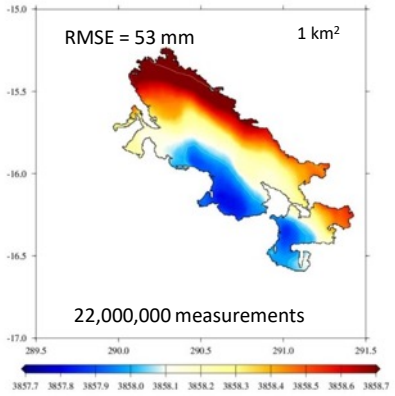




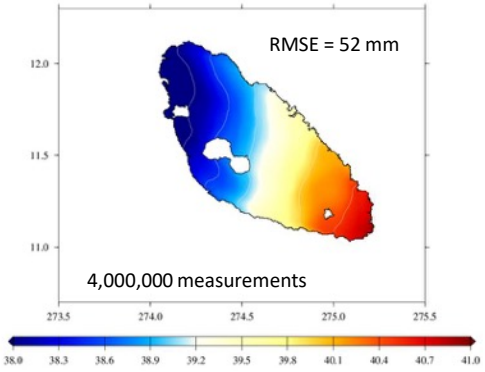




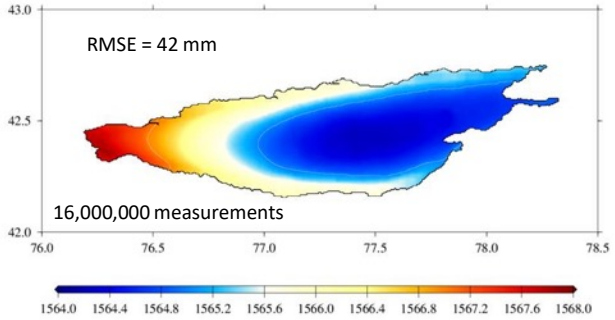
Mean lake surface on Titicaca

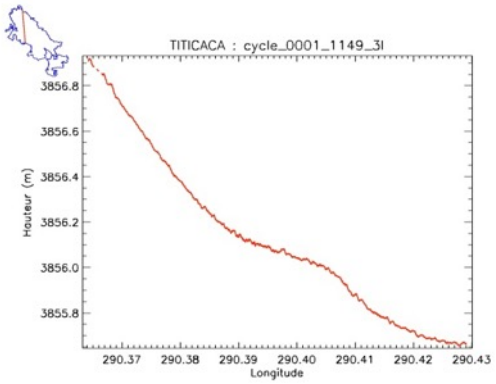


Mean lake surface on Nicaragua



Mean lake surface on Issykkul



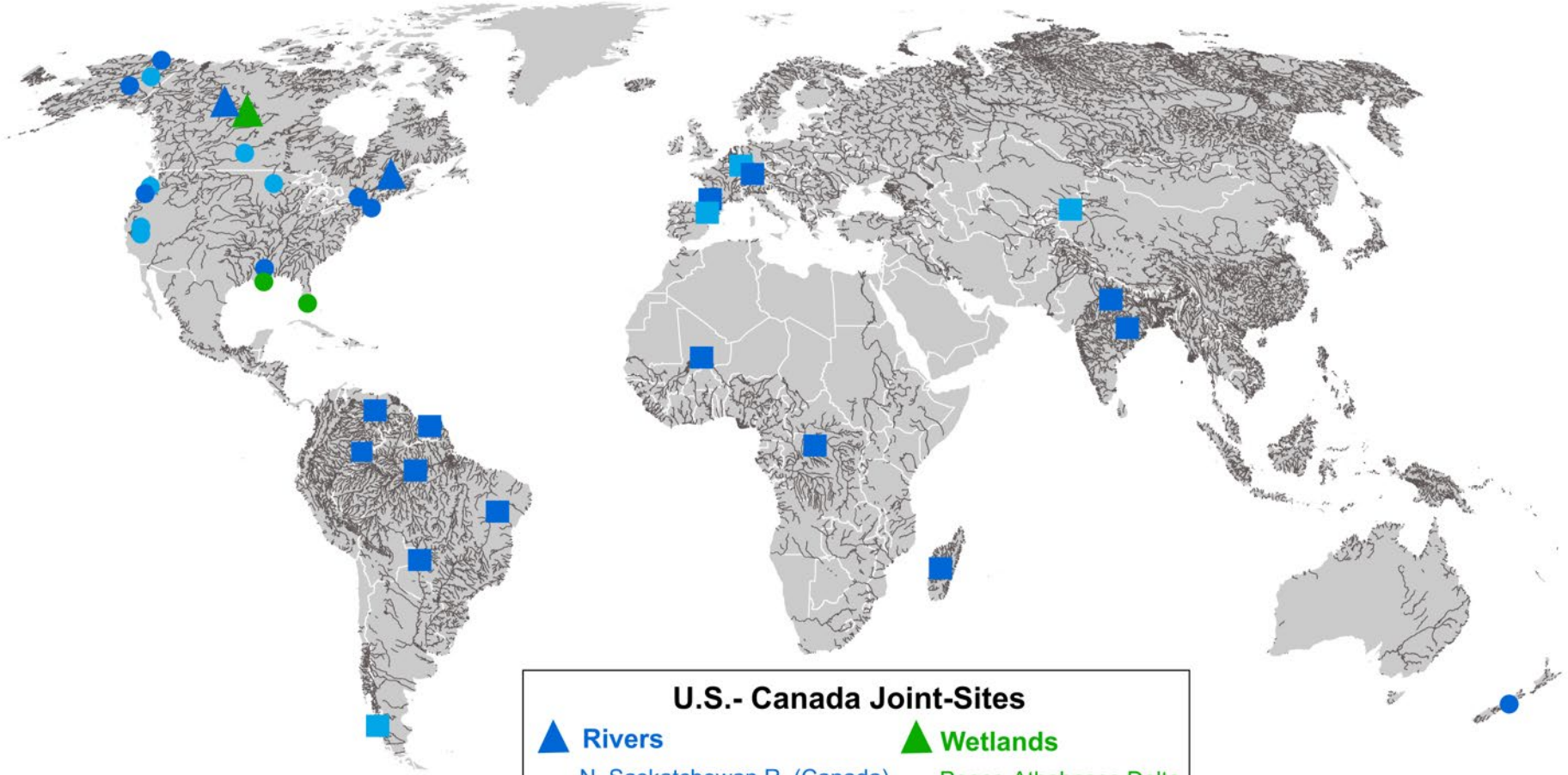


ICESAT-2 filtered ellipsoid height

A set of ~ 3000 to 4000 mean tracks from ICESAT-2 and 40 to 50 mean lakes surface from combination of several altimeters will be used to calibrate SWOT height measurements

Berge-Nguyen et al., 2021

SWOT Hydrology Validation Sites



U.S.- Canada Joint-Sites

Rivers
- N. Saskatchewan R. (Canada)
- St. Lawrence R.

Wetlands
- Peace-Athabasca Delta

U.S. Led-Sites

Rivers
- Willamete R. (Oregon)
- Conneticut R.
- Mississippi R.
- Tanana R. (Alaska)
- Sagavanirktok R. (Alaska)
- Waimakariri R. (New Zealand)

Lakes
- Lake Tahoe
- Central U.S. Prairie Lakes
- Sierra Nevada Lakes
- Pacific Northwest Lakes
- Yukon Flats Lakes

Wetlands
- Yukon Flats
- Mississippi Delta
- Everglades

French Led-Sites

Rivers
- Rhine R. (FR)
- Garonne R. (FR)
- Meta R. (SA)
- Madagascar R. (SA)
- Maroni R. (SA)
- Negro R. (SA)
- Sao Francisco R. (SA)
- Paraguay/Pentanal R. (SA)
- Niger R. (AF)
- Congo R. (AF)
- Upper Ganges R. (India)
- Mahanadi R. (India)

Lakes
- Lake Issyk-Kul
- Chilean Glacial Lakes
- Rhine Valley
- Pyrenees

U.S. Post-launch Tier 1 Validation Sites

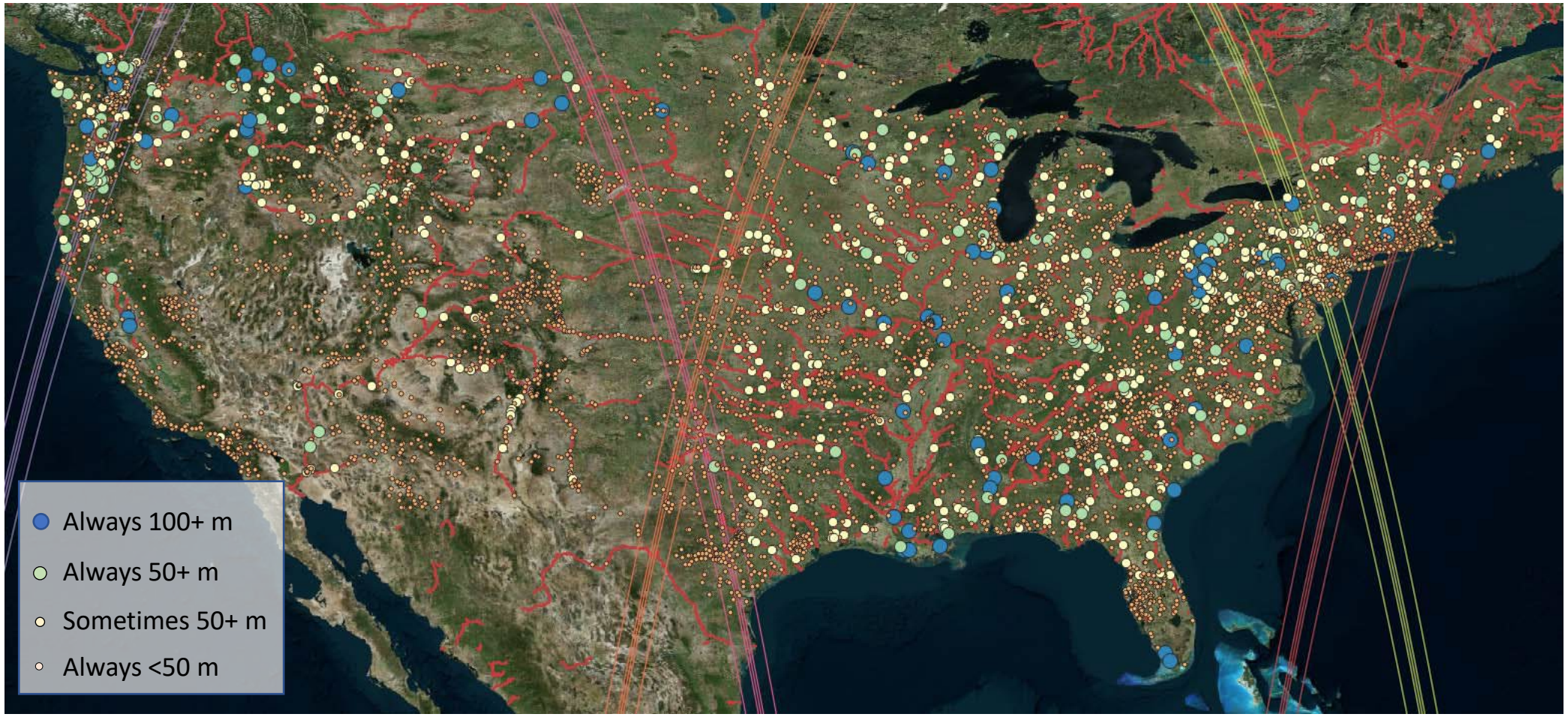
Connecticut River (Lead: C. Gleason)
Willamette River (Lead: T. Minear)
Waimakariri River (Lead: T. Pavelsky)
Tanana River (Lead: T. Pavelsky)
Sagavanirktok River (Lead: C. Gleason)
N. Saskatchewan River (U.S. Lead: L. Smith)
Mississippi River (Lead: T. Minear)

Pacific Northwest Lakes (Lead: T. Minear)
Yukon Flats Lakes & Wetlands (Lead: T. Pavelsky)
Sierra Nevada Lakes (Lead: T. Pavelsky)
Lake Tahoe (Lead: T. Pavelsky)
Peace-Athabasca Delta (Lead: L. Smith)
Mississippi Delta (Lead: T. Pavelsky)
Everglades (Lead: TBD)

Fast Sampling Phase Science Phase Both Phases

- At all sites, we will install or leverage dense arrays of levelled pressure transducers and airborne & field-based measurements of inundation extent.
- At river sites, we will measure repeat long profiles of water surface elevation.
- At select sites, we will collect airborne measurements of water surface elevation.

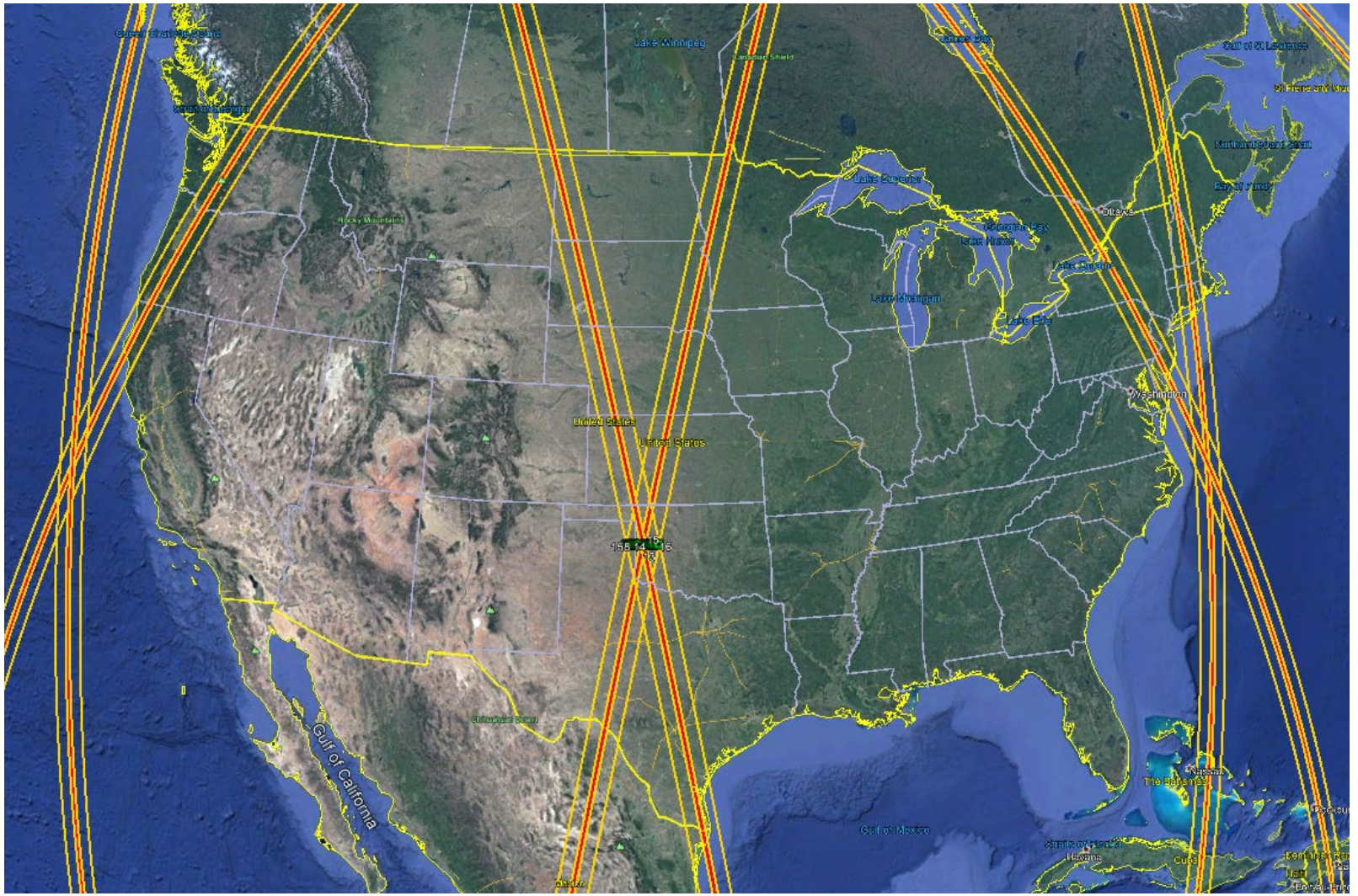
Tier 2 Sites: Example of U.S. Rivers



In addition to Tier 1 sites that we will instrument, we will also make use of existing high-quality measurements such as those from USGS stream gauges in the U.S.

SWOT Calibration: Corner Reflectors

- The US inland cross over (Texas / Oklahoma) is the only one in the Continental US
- Reflectors need to be bright and relatively immobile (<1cm vertical motion)
- Objectives for pilot project: Evaluate issues affecting corner reflectors prior to installation of the full array:
  - Stability / ground movement
  - Factors influencing reflection (dust on corner, cleaning, leaf accumulation)
  - Logistics / personnel / land permissions



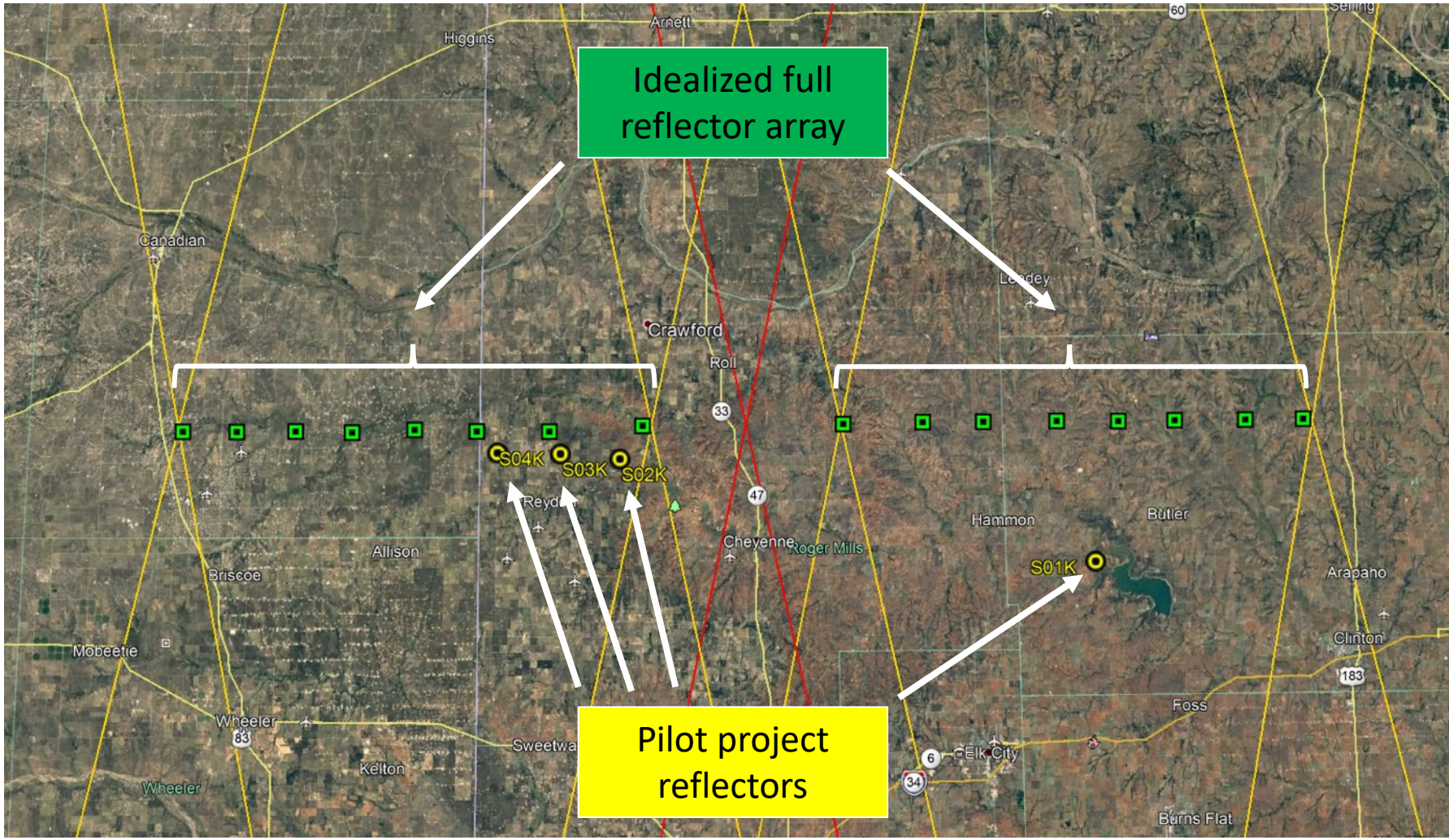
Courtesy T. Minear

Pilot corner reflector project

Three pilot corner reflectors were installed June 2-5, 2021 in the western swath

Personnel: JPL, Univ. of Oklahoma / Mesonet, Univ. of Colorado

The remaining reflector S01K will be installed in fall 2021



Courtesy T. Minear

Pilot corner reflector project

Design:

- Corner cube (square trihedral) in a cradle
- 0.80m a side, 90 deg orthogonality (+/- 0.1 deg)
- Pointing cradle

Chosen to maximize dB reflections (minimum deviations in cube surface)

All GNSS data and descriptions of reflector sites:

https://uavsar.jpl.nasa.gov/cgi-bin/calibration-swot.pl

Site S02k pilot corner cube during GNSS metrology measurements

Courtesy T. Minear

On site validation

measurements and product performance

- **Validation of height, extent on lakes, and height, width and slope on rivers:**
  - GPS ground leveling, drones, installation of limnigraphs
  - Extent by aerial imagery, or GPS mapping (experiment done in lake Chad in April 2019)

- **Validation of storage change & river discharge**

  Some bathymetries exist (Reservoirs in France, lakes in Chile) or generated using satellite imagery and laser altimetry (Lac Poopo, Sobradinho reservoirs).
  Discharge in situ measurements (ADCP) can be performed during field campaigns

On site calibration

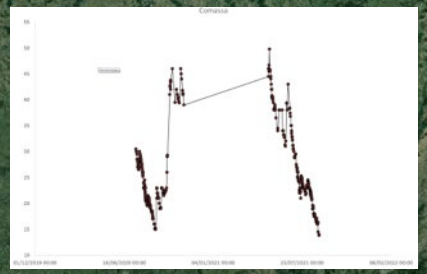
Estimate calibration parameters on Large water bodies

- **Error budget, and calibration of Karin instrument**

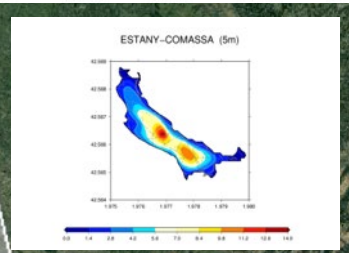
  Random cross track error, roll error, phase screen, EM, nadir altimeter bias, processing chain, atmospheric corrections (GPS network, boat campaigns on lakes and rivers)

On site Cal / Val: French lakes and rivers

Rhine



Lake Leman



Garonne

Lakes Pyrenées

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus

232 km

Google Earth

Deployment of drones with GPS leveling

Installation of level gauges

On small lakes

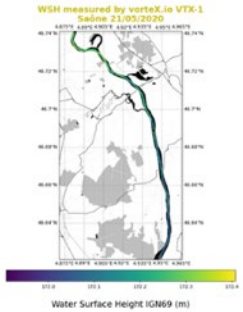
along the rivers

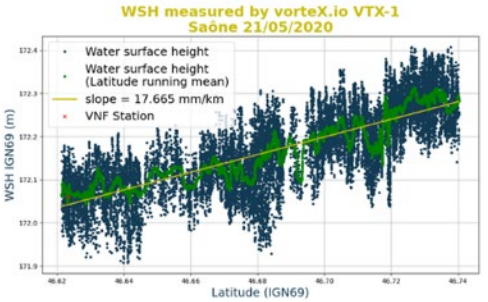
} Citizen Sc Project, st3TART & TOSCA prog

Bathymetry of lakes using echosounding
OECS & LOCSS projects

Validation of:

-Lakes & rivers water levels and river slopes (st3TART project)
-Lake volume changes

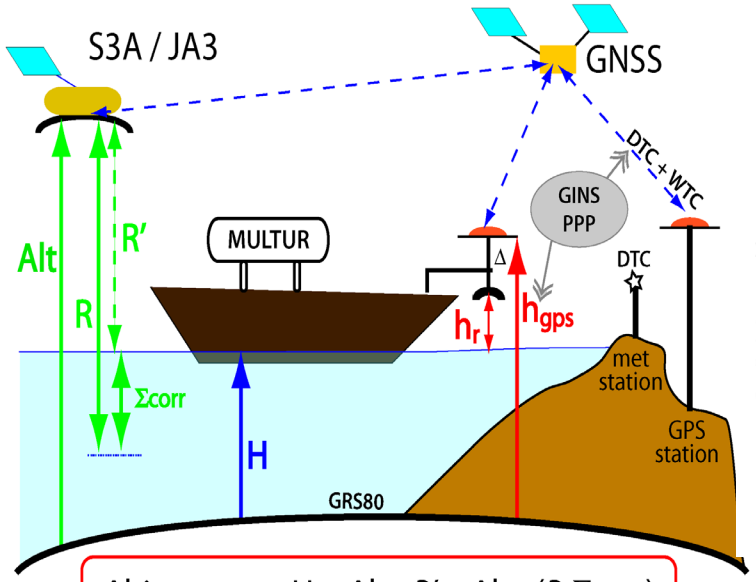




Courtesy Vortex

On site Cal / Val (Tier 1): Lake Issykkul

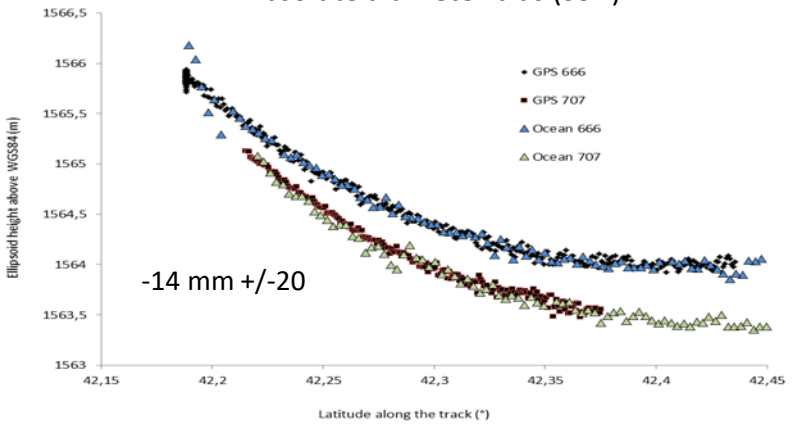
1-day orbit : Cal/Val phase

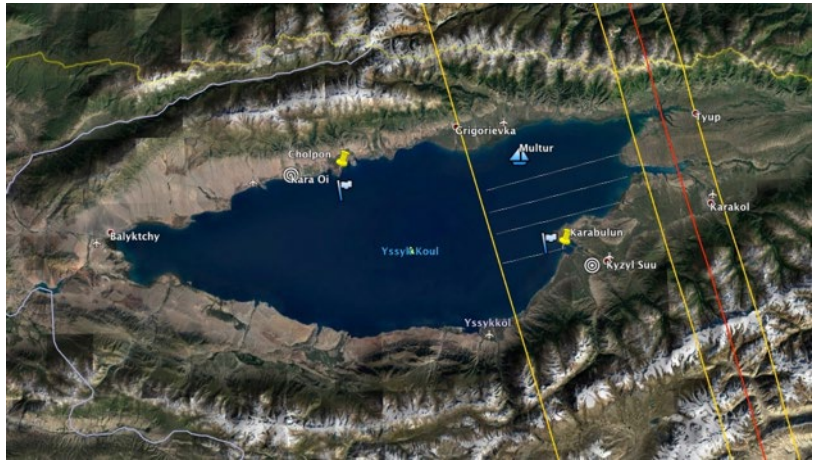


Altimetry : $H = Alt - R' = Alt - (R - \Sigma corr)$

Validation : $H = h_{gps} - (h_r + \Delta)$

Absolute altimeter bias (S3A)

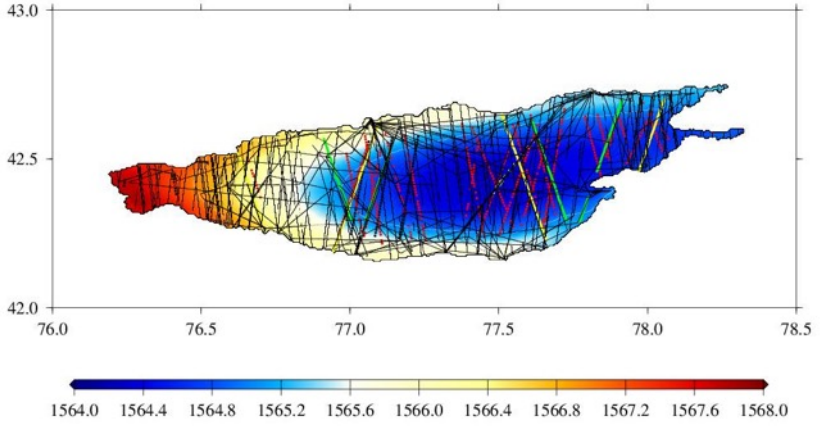




A 2 months field work will be setup during the C/V phase

- Calibration of absolute Height
- Phase Screen Calibration (small dynamic & geoid known very precisely)
- Atmospheric corrections using GPS ground network
- Validation of ocean and land processing simultaneously
- EM bias (possibly dependent on incidence angle) estimation would be possible
- Potential validation of Karin SWH and Wind estimation

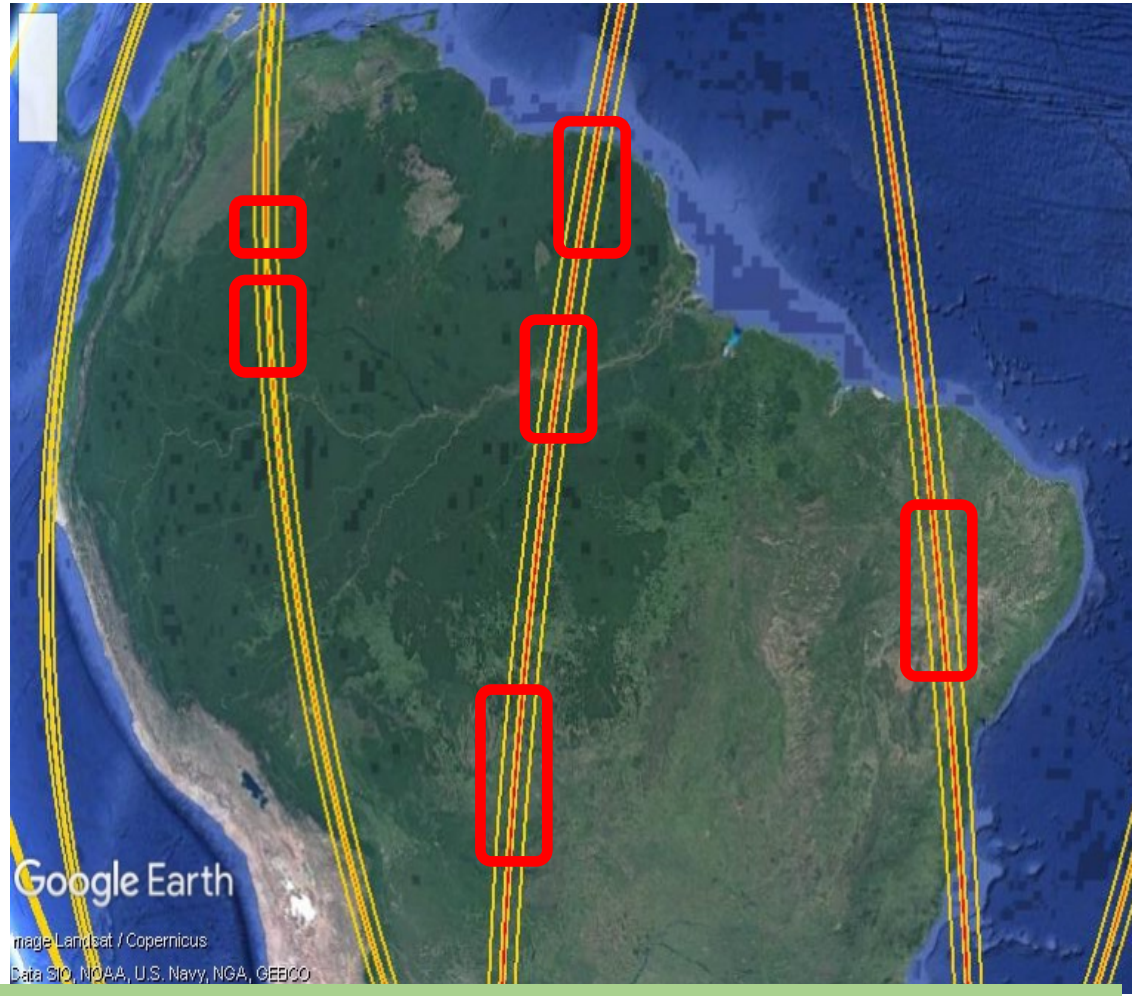
Mean lake surface on Issykkul calculated from 16 years of GNSS & radar + lidar altimeters

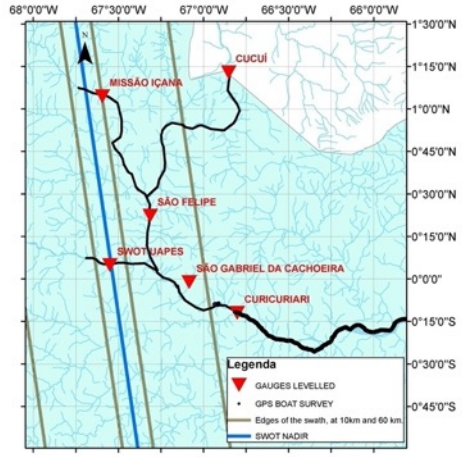


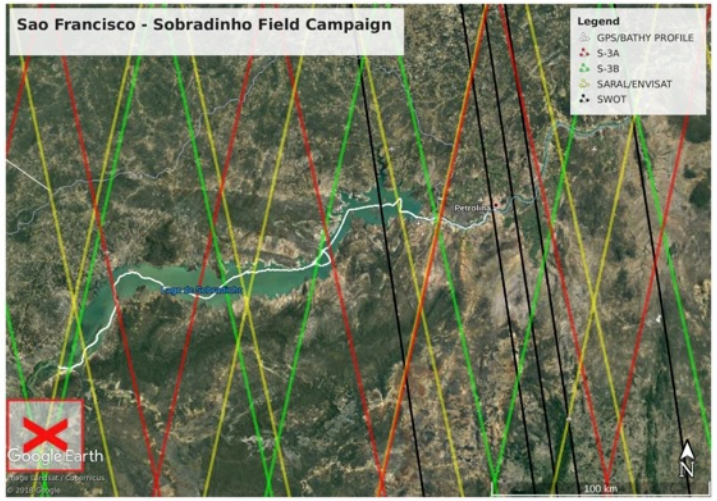
Two campaigns before the launch (oct 21 & May 22) and 2 month campaign during the fast sampling orbit

On site Cal / Val: South American Rivers

~10 campaigns (slopes, bathy, leveling) since 2013, organised and funded by CPRM with support from IRD &CNES







Planed tier 1 sites during the fast sampling phase

French plan through fast sampling phase

Team Leadership

Europe: N. Picot, CNES, S. Calmant (IRD), J-F Cretaux (CNES/LEGOS), P. Bonnefond (Obs Paris), F. Papa (IRD/LEGOS)

South America: D. Moreira (CPRM/RIO)

Prelaunch

- Hire hydrologic technicians to lead field measurements and data processing
- Conduct prelaunch experiment on Issykkul lake in summer 2021
- Conduct prelaunch experiment on Maroni River, on Chilean lakes and along the tsiribinha river, and in the French rivers (Garonne, Rhine) between summer 2021 and launch date
- Conduct two join US/French field works on the Willamete river and on the Issykkul lake in 2022
- Plan logistics for fast sampling phase and early science orbit
- In situ data collection: water level, bathymetry on tier 2 sites in Europe, Africa and South America
- Produce the a priori database on lake geoid undulations over a set of 50 large lakes and along Icesat-2 tracks
- Mitigation of the limitation time for preparation due to covid-19 and be prepared for reduction of ambition

Fast Sampling Phase

- Conduct extensive measurements in Tier 1 sites that are under the fast sampling orbit
- Process data to meet requirements for comparison with SWOT
- Work with colleagues at JPL, CNES, and in the Science Team to begin evaluating SWOT data