SWOT

Global Hydrology Cal/Val

Comparison with in situ and satellite data

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OUTLINE

- Introduction
  - Cal/Val objectives
  - Tier 1 vs. Tier 2 sites
  - Principal variables
- Use of satellite and in situ measurements
  - Use of satellite images to compute reference area
  - Use of gauge networks for height/discharge
  - Use of nadir altimeters / IceSat-2 for height/slope
  - Use of reference bathymetry for storage change

Introduction

Basic objectives of Cal/Val[1]

- Calibration → processing parameters
- Error budget validation → system behavior (e.g. random height noise)
- Data product validation → w.r.t. science requirements

Hydrology Cal/Val sites

- Tier 1 sites – "Gold standard" → dedicated measurement campaigns, equipment
- Tier 2 sites – more numerous → rely on existing infrastructure (gauges, satellites…)

Hydrology Cal/Val variables

- Mainly water surface elevation (WSE), slope, area/width
- But also discharge, storage change…

[1] SWOT Cal/Val Plan, Sects. 1.2-1.3

Hydrology Cal/Val – Tier 2 sites

What can be done with existing infrastructure for Tier 2 sites?

- The goal is to cover a large number of sites
- Possibly accepting lower accuracy than for Tier 1 sites

Both under 1-day and 21-day orbit!

Examples

- Use of satellite images to compute reference area
- Use of gauge networks for height/discharge
- Use of nadir altimeters and IceSat-2 for height/slope
- Use of precise bathymetry and gauges for storage change

SWOT Cal/Val Plan:
"The Tier 2 Cal/Val network optimally will consist of ~200-300 sites with good global coverage of different hydroclimatic and ecosystem zones. Each gage will be levelled to have a required minimum vertical accuracy to ±5cm at 1σ (minimum) or ±2cm at 1σ (target)."

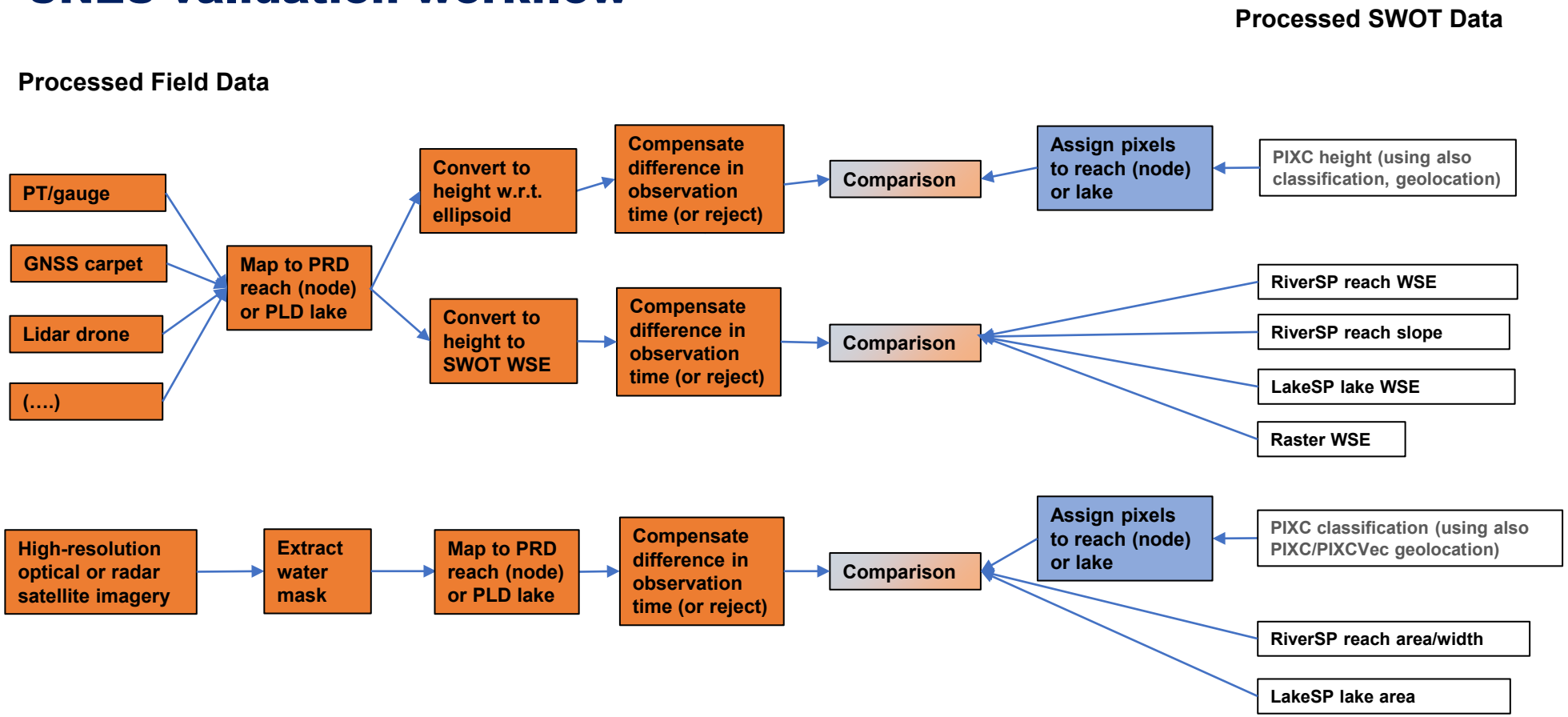
Also OECS & LOCSS citizen science measurements, as presented by N. Picot this morning

Main approach

- Adapt in situ data to SWOT data (temporally/spatially)
  - Can also be done the other way around

Many common points with yesterday's presentations by Nielsen, Schwatke, Girard, de Fleury, Riggs…

CNES validation workflow

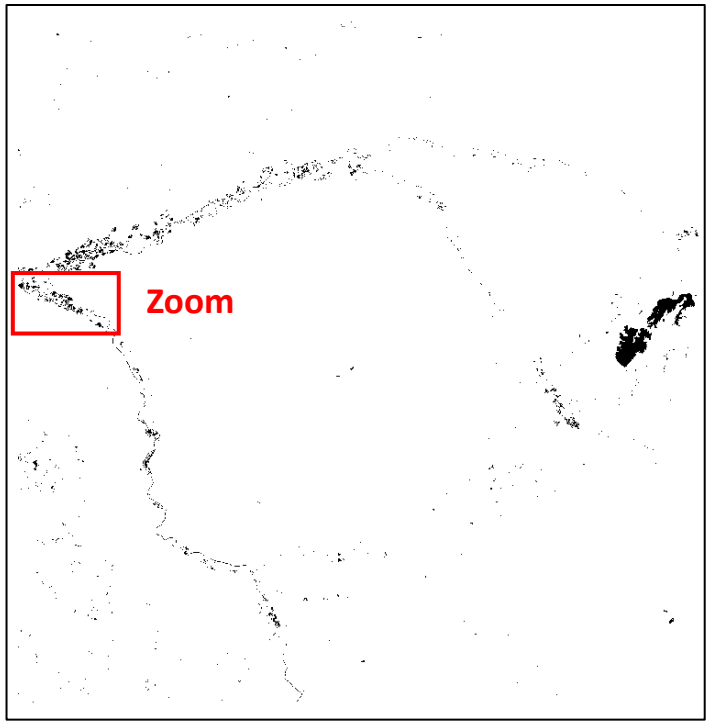


Lake and river reach water surface area (1/2)

Courtesy: L. Labat-Allée, H. Yesou, S. Pena Luque

Use of reference water masks based on satellite images

- Input data
  - Sentinel-2, Sentinel-1
  - Pleiades, SPOT6/7, RadarSat-CS, NISAR…
- Extract reference water mask:
  - ExtractEO (SERTIT)
  - SurfWater (CNES)
    - Will be produced routinely in many regions
- Example: ExtractEO mask (from Sentinel-2)
  - Yonne meets Seine area, France

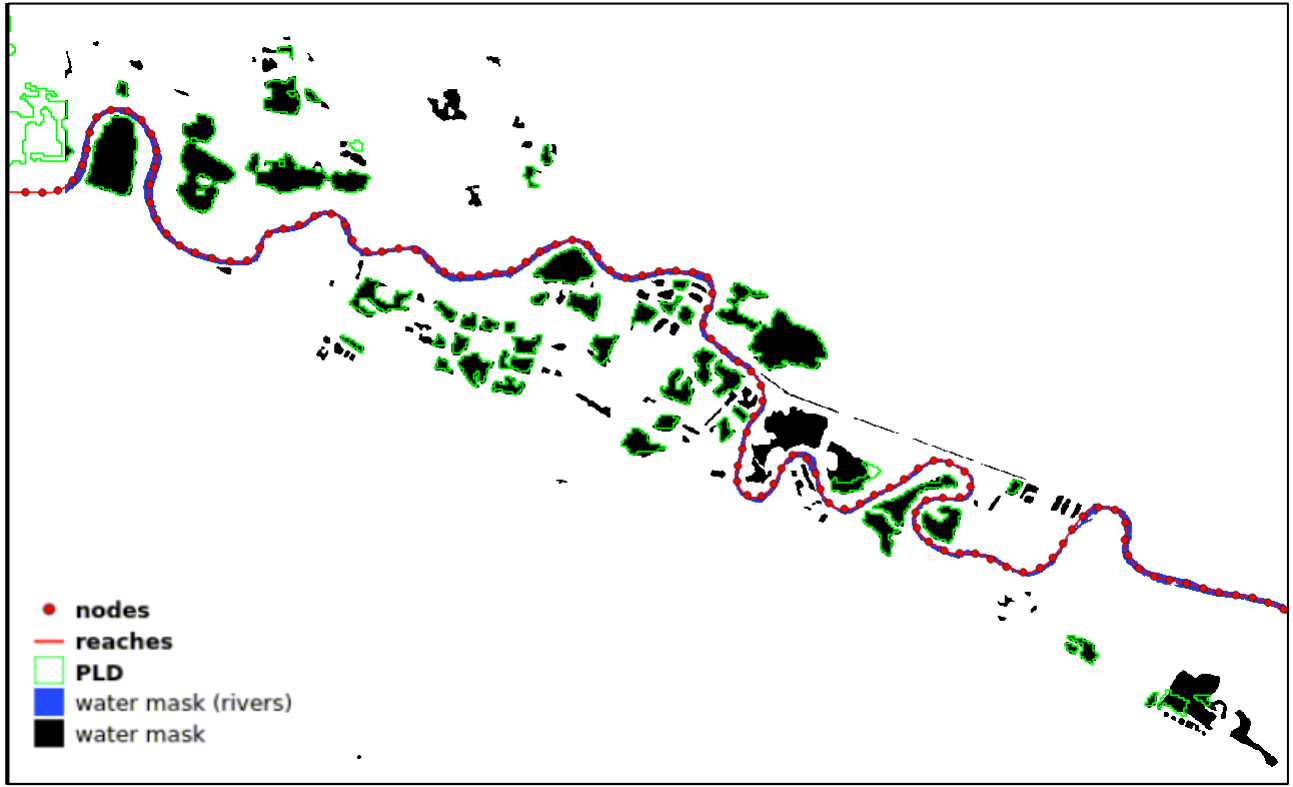


Lake and river reach water surface area (2/2)

Courtesy: L. Labat-Allée, H. Yesou, S. Pena Luque

Use of reference water masks based on satellite images

- Example: ExtractEO mask extract (Yonne, France)
- PRD centerlines and PLD polygons superposed
- Assignment of water pixels to PRD reaches/nodes and PLD lakes (intersection)
- Compute reach/lake areas
- Compare with RiverSP and LakeSP areas (if sufficiently accurate and close in time)

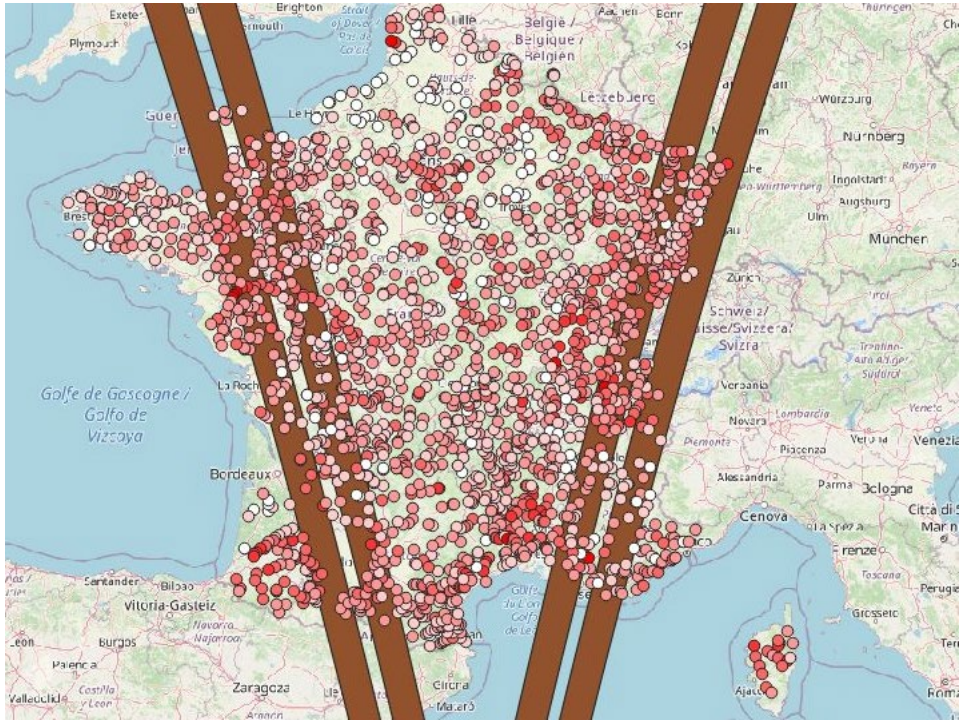


Height and discharge from gauge networks (1/2)

Gauge networks measuring water elevation and/or discharge exist in many countries

- USGS (US)
- SCHAPI (France)
- BAFU (Switzerland)
- SMHI (Sweden)
- NVE (Norway)
- …

Example: SCHAPI gauge network

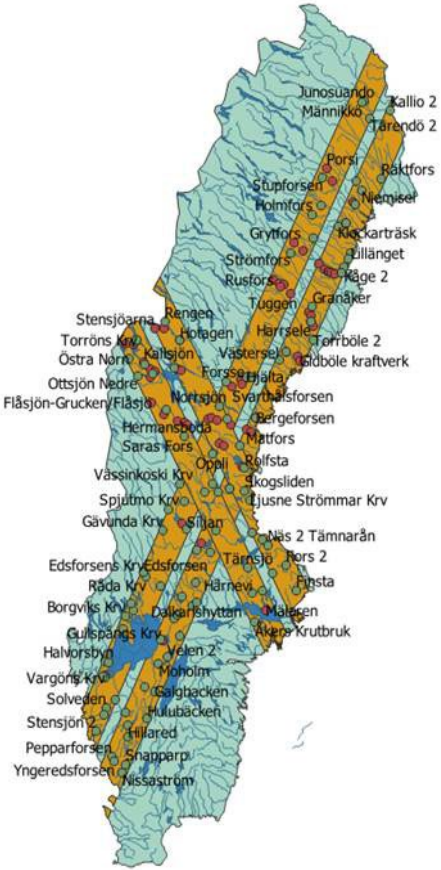


Height and discharge from gauge networks (2/2)

Gauge networks measuring water elevation and/or discharge exist in many countries

- Networks of variable density, acquisition rate
- Data often publicly available (but not always)
  - Automatically through APIs, interactively…
- Not always levelled, different height systems
  - Absolute levelling, or use differently?
  - Which corrections to add or subtract?
- Comparable to RiverSP and LakeSP data?
  - Medium-size lakes generally easier than reaches
  - Discharge may be more representative than height

Example: SMHI gauge network



Coverage of SWOT 1-day orbit in Northern Europe

Height and slope from nadir altimetry (1/2)

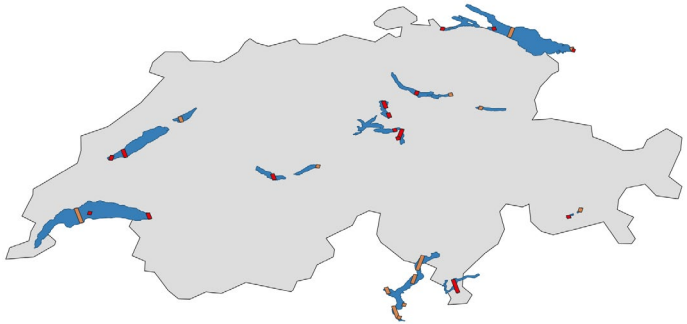
Courtesy: F. Boy

Boy et al., "Improving Sentinel-3 SAR mode processing over lake using numerical simulations", IEEE TGRS, 2021

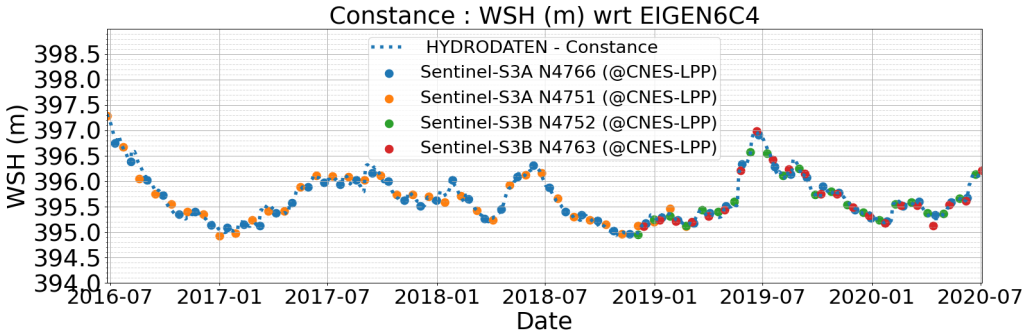
Thousands of virtual stations monitored (HydroWeb)

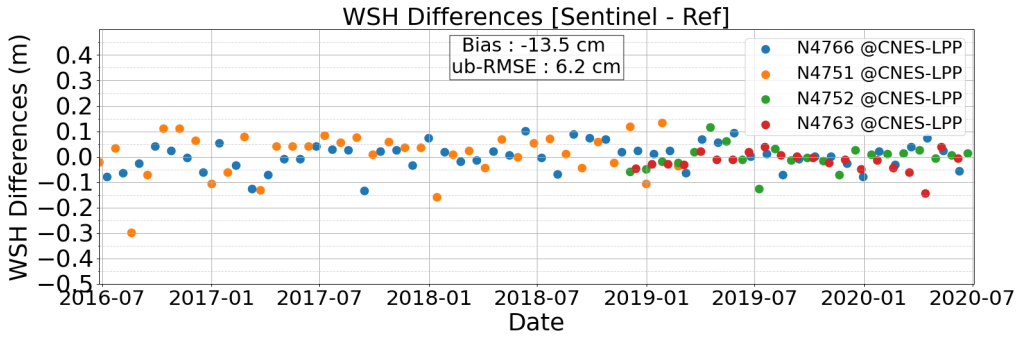
New dedicated processing techniques for lakes and rivers

- Example: Assessment on Swiss lakes
  - 17 lakes – mountainous region – areas between 2.7 km² to 580 km²



  - Processing of Sentinel-3A and Sentinel-3B time series for all lakes (52+21 passes)





~10 cm RMS even for small lakes(<1km²)
~1,000 lakes to be processed for SWOT Cal/Val

Height and slope from nadir altimetry (2/2)

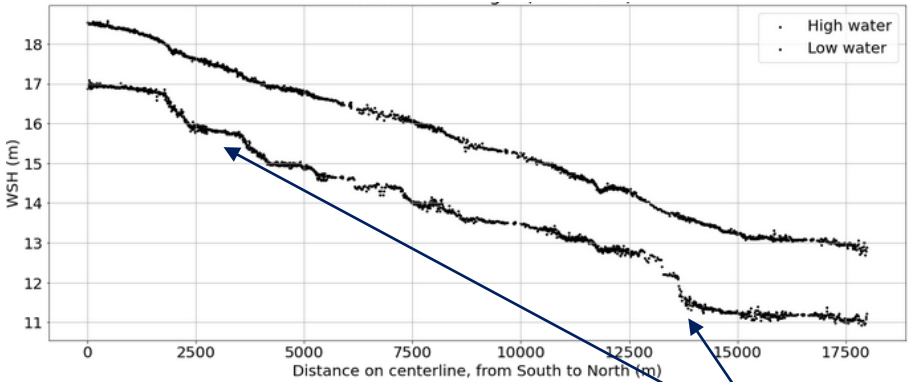
Courtesy: F. Boy

Thousands of virtual stations monitored (HydroWeb)

New dedicated processing techniques for lakes and rivers

- Example: Garonne River, Marmande, France

S6 water surface height profiles



Sentinel-6 track

Height profile computed along 18-km centerline (10-m along-track posting/resolution)

Riffles and pools at low water

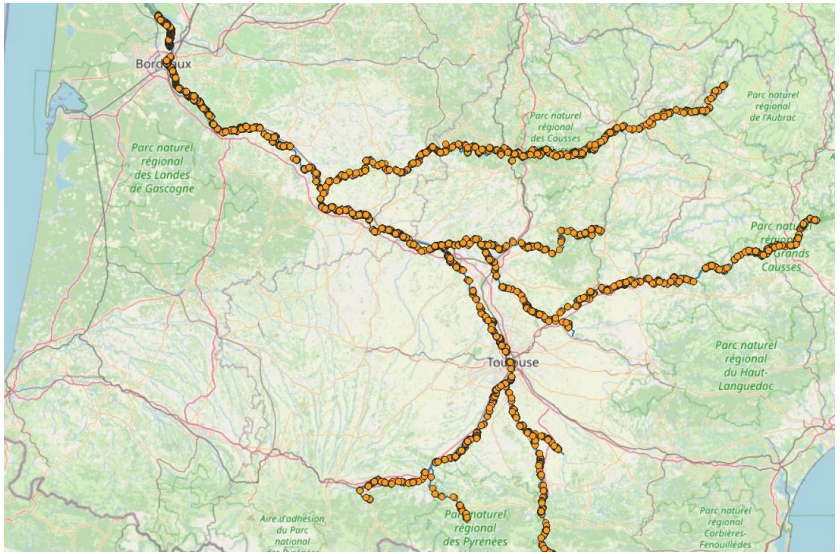
Height and slope from IceSat-2

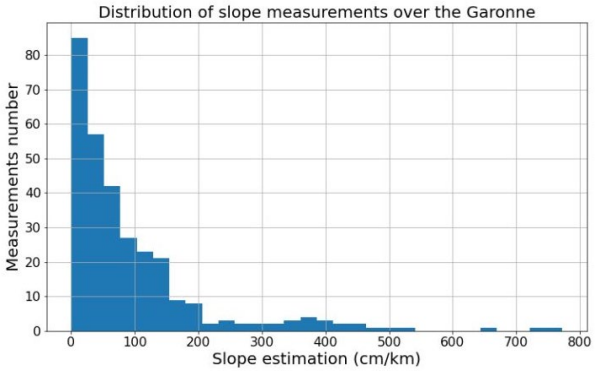
Courtesy: M. Vayre, J. Renou, N. Taburet

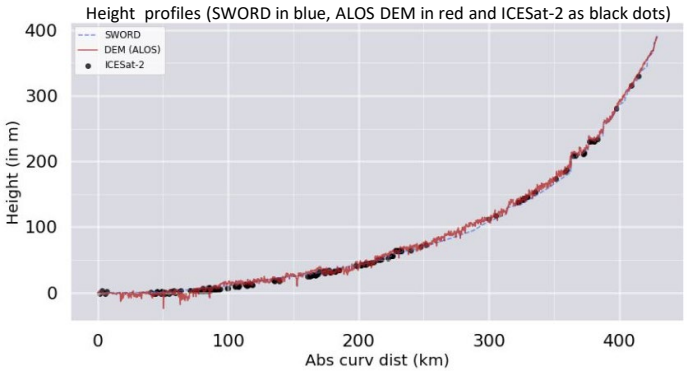
Lakes: See next presentation by J.-F. Cretaux

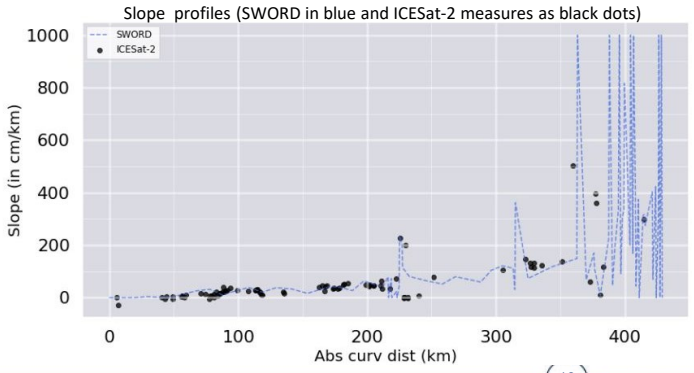
Rivers:

- Extraction of ICESat-2 ATL13 data over SWORD prior river database
- Instantaneous measurements of height and slope across 3 pairs of beams separated by 3.3 km
- Example: Garonne river (basin)









Height and slope from nadir altimetry and IceSat-2

How can these measurements be used for SWOT Cal/Val?

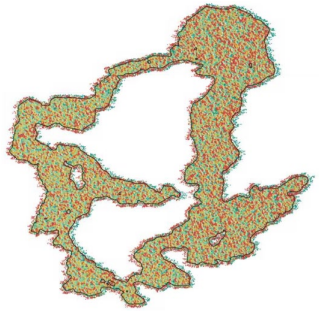
- Direct comparison in case of acceptable colocation in time and space
  - Time colocation can be relaxed for slowly varying water bodies
- Absolute levelling of gauges for which only relative height is available
  - Or to cross-check levelling
- Establish height profiles as a function of water stage
  - E.g. to be able to propagate gauge height measurements to reach average WSE
- …

Lake storage change

Courtesy: M. Delhoume

Use of reference bathymetry and heights from gauges

1. Time series of SWOT observations of lake



Extract of PIXC product for one of the dates of the time series

Estimated storage change in LakeSP product for each observation date

Estimated storage change between SWOT observation and reference state (PLD)

2. Precise bathymetry and time series of gauge water heights

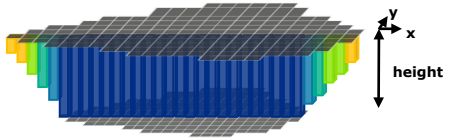
Lake bathymetry

date	height
20190101	233.06
20190102	233.04
20190103	233.03
20190104	233.02
20190105	233.01
...	...

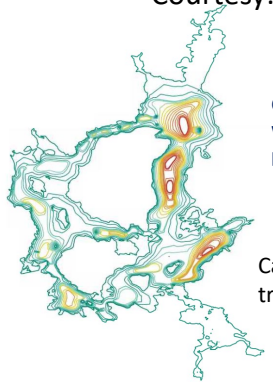
Time series of water heights

Computation of "true" storage change for each SWOT observation date (or gauge measurement)

3. Comparison



"True" storage change w.r.t. reference state based on precise bathymetry and gauge water elevation



Corresponding water mask polygons

Can serve as ground truth for area/extent

Bathymetry can serve directly as ground truth for Floodplain DEM (FPDEM) product