Vers une observation journalière : le concept SMASH

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et tous les membres des groupes mission et projet SMASH

1. LEGOS, 2. GET, 3. CNES

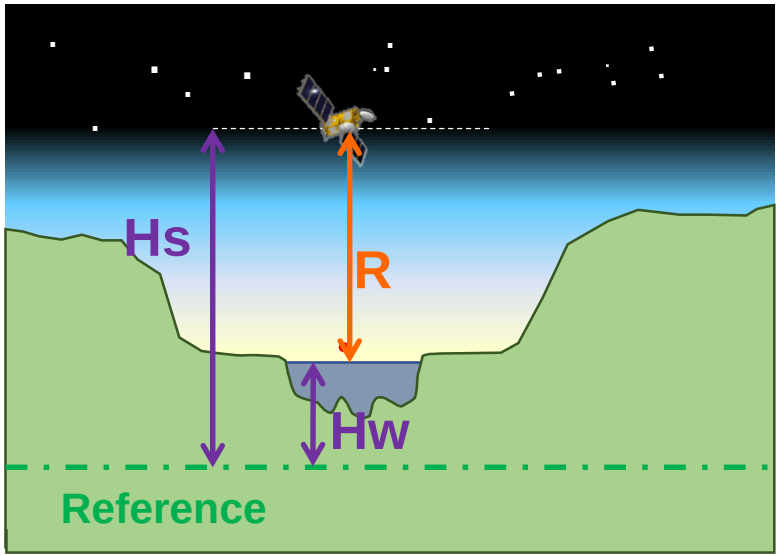
SMASH : a space altimetry mission dedicated to inland waters hydrology (daily revisit)

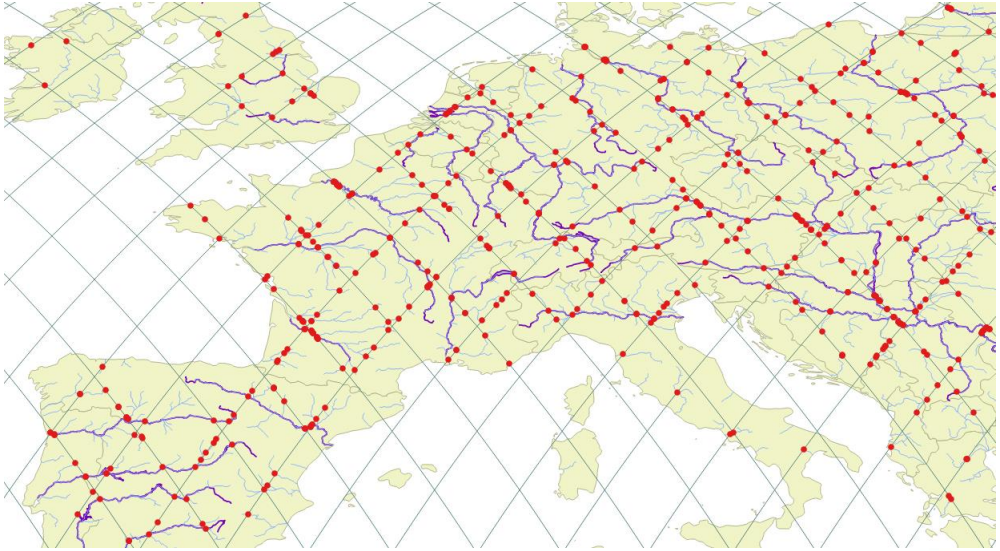
Why do we need such a mission ?

- Science
  - Lake and river discharge and water levels are identified as Essential Climate Variables (ECV).
    GCOS recommends their daily observation
  - To study the dynamics of small to medium size watersheds
- Applications
  - Water resources management, energy and hydroelectricity, natural disaster management, climate change adaptation, …
  - Need accurate knowledge of flood statistics (dynamic behavior of watersheds) for proper sizing of infrastructures

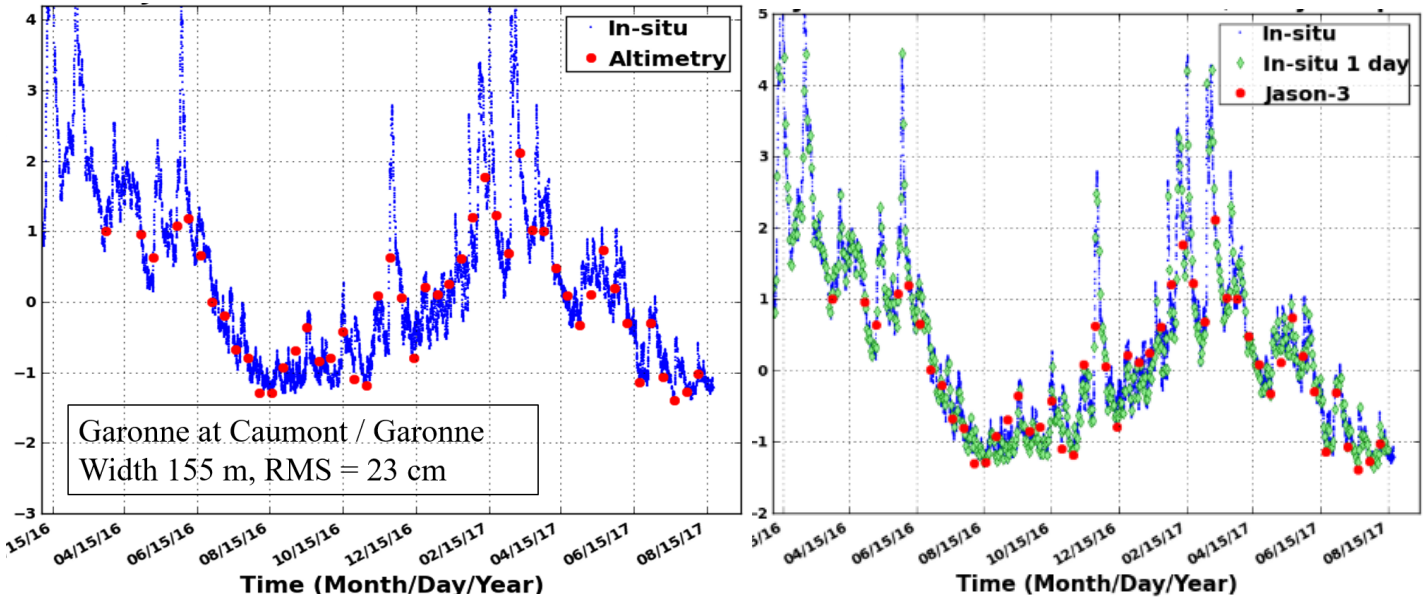
Space nadir altimetry: a simple principle

- Water levels (Hw) = Satellite altitude (Hs) – altimetric measurement (R)
- Virtual stations (VS): crossing between satellite tracks and water bodies (lakes or rivers)
- Nadir altimeter is able to measure narrow rivers (~50m)
  - Observe only under the satellite ground tracks (no observations between ground tracks)





Sampling of current altimetry missions (> 10 days) is not sufficient

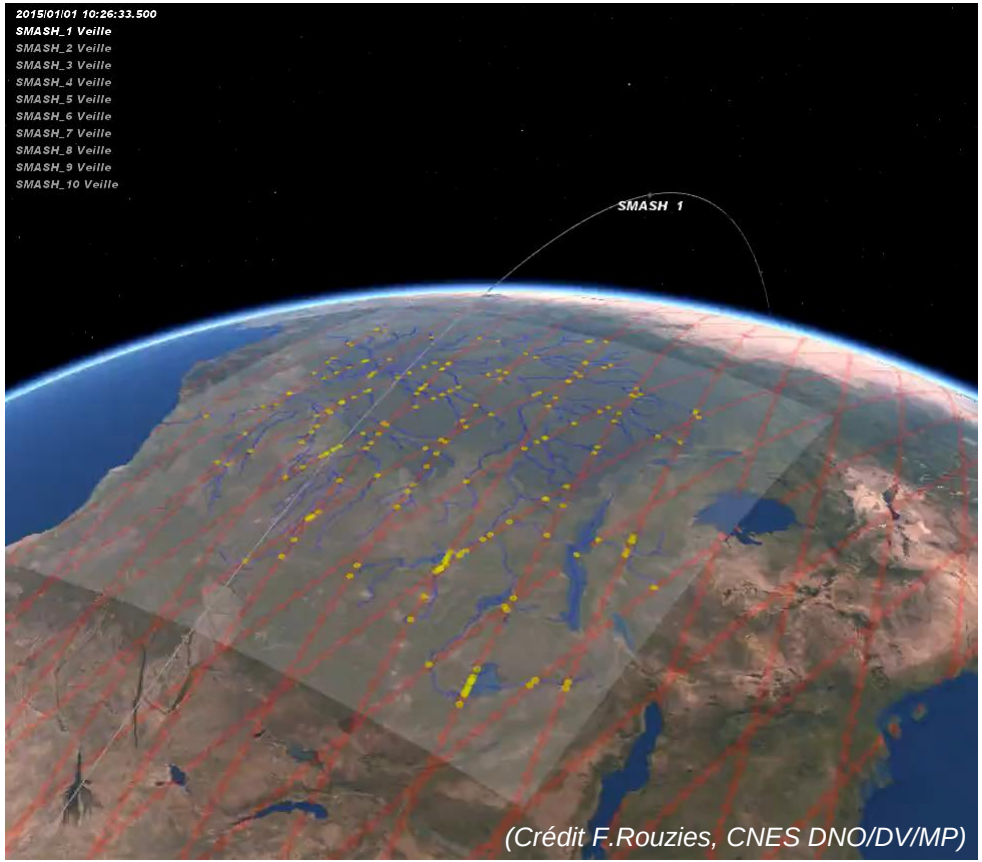


Water levels of the Garonne river: *in situ* (blue), Jason-3 (red), *in situ* measurements under sampled every day (green, SMASH simulation)

« Clearly, proper discharge monitoring will require sampling frequencies well above the revisiting frequency of typical low-orbit satellites »

B. M. Fekete, "Rationale for monitoring discharge on the ground", *Journal of Hydrometeorology*, 13, 1977-1986, 2012

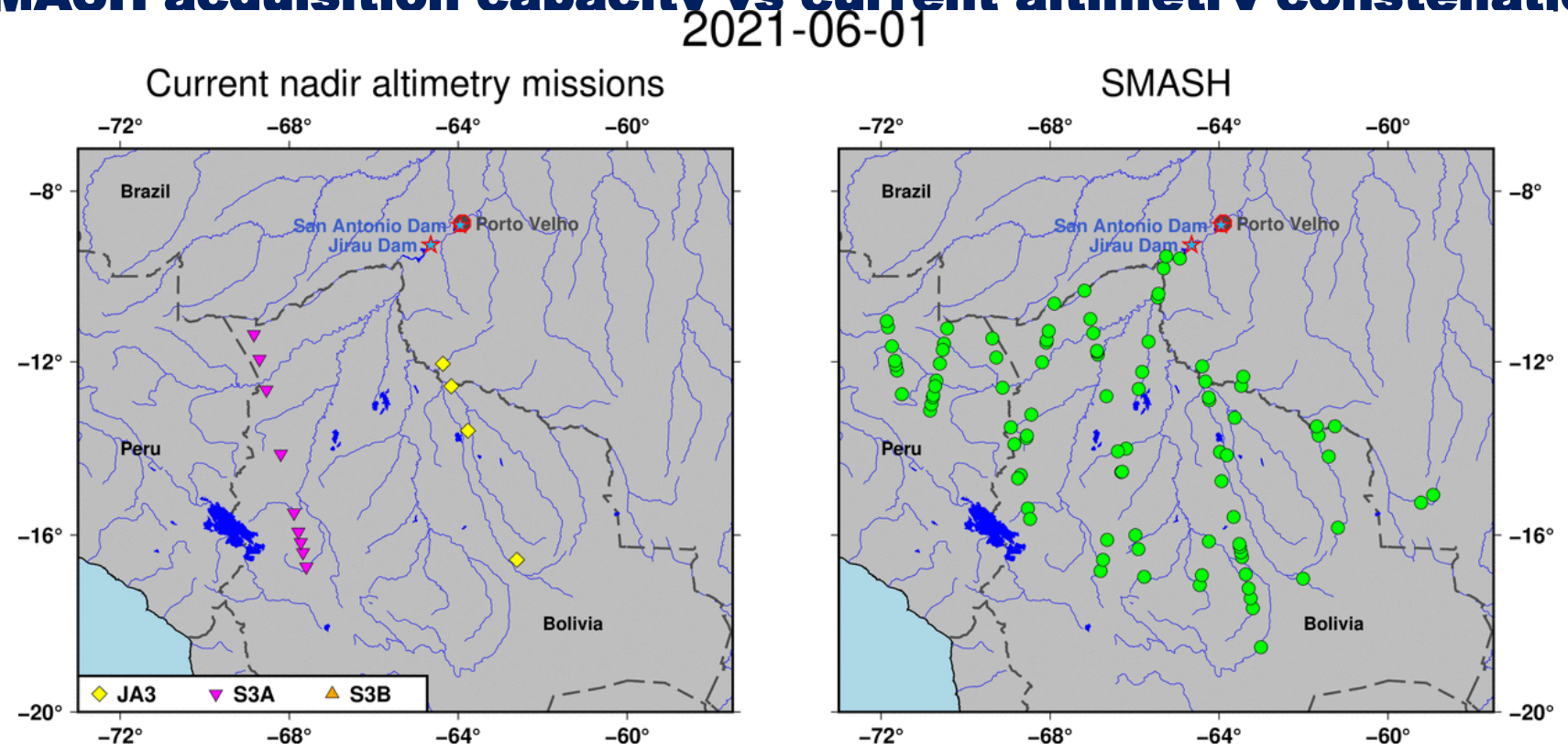
Constellation



(Crédit F.Rouzies, CNES DNO/DV/MP)

- 10 satellites in the same orbit plane
  - Launch cost
  - Constellation maintenance
- Daily measurement over each VS
- Twice a day revisit for large watersheds
  - Almost instantaneous snapshot of water levels over the entire basin (70 min)
  - Taken every 24 hours for ascending passes
  - Taken every 24 hours for descending passes
  - Around 12 hours between ascending and descending overflights

SMASH acquisition capacity vs current altimetry constellation



(Sylvain Biancamaria)

Current constellation : Jason-3/Sentinel-6, Sentinel-3A, Sentinel-3B

- **i.e. guaranteed long term availability**

SMASH Phase A study funded by CNES

Mission Working Group established

- 20 international members → Mission specification (science and applications)

System

- End-to-end performance, constellation formation and maintenance, station acquisition and station keeping, ground segment, interfaces

Payload

- Altimeter : phase A with TAS (Thales Alenia Space) industrial support
- GNSS receiver

Satellite

- CNES + Hemeria support

Final review in April 2021 → successful

Main requirements for the SMASH mission

Revisit time :	**1 day**
Water level accuracy :	**10 cm (1σ)**
➢ Altimeter (incl. processing)	5 cm (1σ)
➢ Orbit determination	5 cm (1σ)
➢ Atmospheric corrections	5 cm (1σ)
➢ Other	5 cm (1σ)
Size of observable waterbodies :	**> 50 m (rivers), > 100 m x 100 m (lakes)**
Data latency :	**< 6 hours (possibly < 3hrs over some VS)**
Spatial sampling (mid-latitude) :	**200 km (repeat track +/- 1 km, goal +/- 200 m)**
Products :	**- water levels over Virtual Stations** **- discharges over a subset of river VS**

SMASH Phase A study : Altimeter (TAS end of 2020)

Careful analysis of the functions (optimized to observe inland waters)

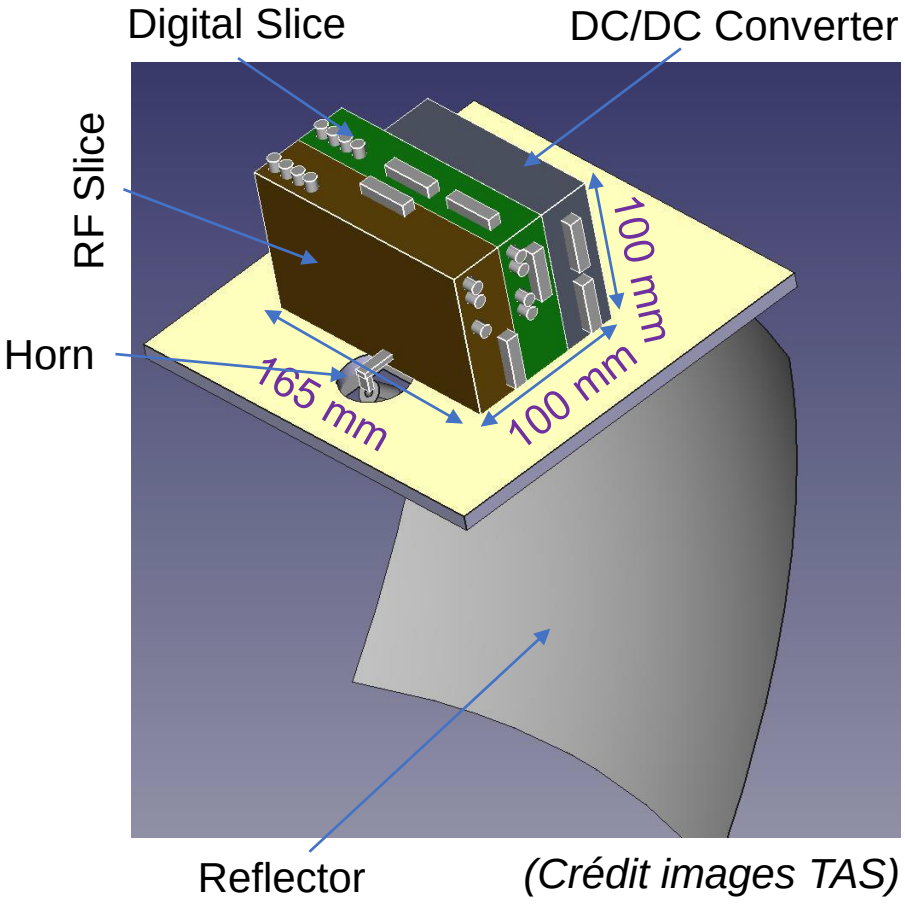
- Very large and very quick variations of topography and returned power + peaky waveforms
- Use Onboard DEM technology : proved on Jason-3, Sentinel-3A and 3B, Sentinel-6
  - Improvements foreseen in the next years thanks to the worldwide observations of SWOT
- Increase of the acquisition window needed (size of the waveforms)

Main characteristics

- Single frequency altimeter (Ka)
- Antenna reflector size 30 cm
- Altimeter volume < 2U (not including antenna volume), i.e. 2 liters

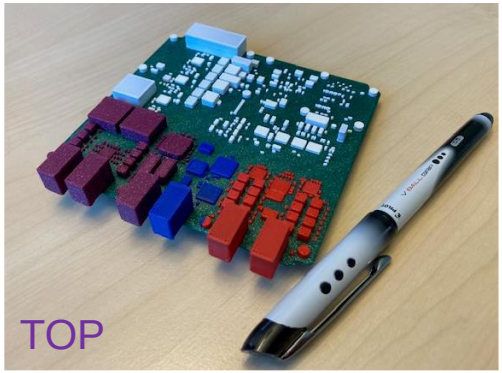
Breadboard of altimeter RF functions available

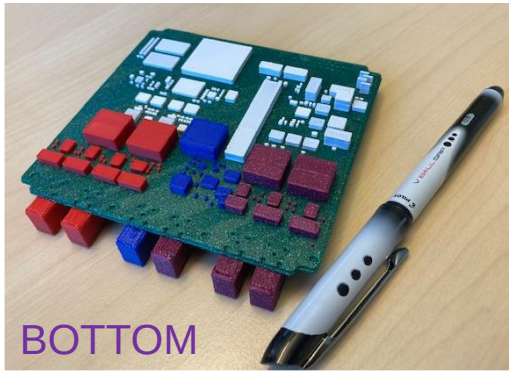
SMASH Altimeter



(Crédit images TAS)

Digital Slice 3D mockup

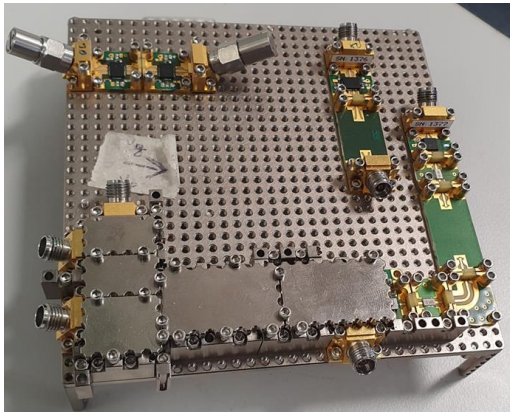




Volume
100x100x165 mm³

Consumption **22 W**

Mass < 4 kg
(incl. antenna)

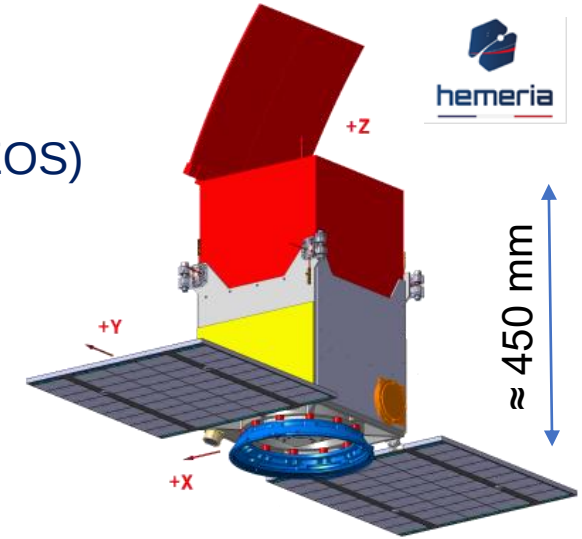


RF breadboard

SMASH Phase A study : system and satellite

Satellite

- Designed altimeter compatible with nanosatellites (25 kg range)
- New Earth Observation platform in development by Hemeria (HP-EOS)
- Electric propulsion compatible with ΔV requirements
- Permanent maintenance of the constellation would require the launch of 2.4 satellites / year on average
  - Based on conservative hypothesis on satellites lifetime / reliability



(Crédit image Héméria)

Dual frequency GNSS receiver

- End to end performance compatible with lightweight, low power, dual frequency GNSS receiver and associated oscillator (Syrlinks)
- In development for other programs. Expected in-flight in 2022.

Conclusion

A constellation of 10 small nadir altimeters provides 1 day sampling

- Viable solution thanks to miniaturized instruments (on nanosats)
- Miniaturization is not detrimental to the performances (water level accuracy 10 cm)
- Homogeneous measurements worlwide
- Expandable by increasing the number of satellites (improve spatial or temporal sampling)

Better time sampling than current missions needed by both science and applications

- River & lakes water levels are identified as Essential Climatic Variables (daily obs.)
- 1 day sampling (instead of > 10 days) is a key enabler for emerging services and applications (water resources & risks management, etc.)
- Very strong synergy with SWOT and Copernicus S3NG-T scenarios

Thank you for your attention

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SMASH

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DIRECTION DES SYSTEMES ORBITAUX
SOUS-DIRECTION « OBSERVATION DE LA TERRE »

SMASH Mission Requirements

	Date	Signature
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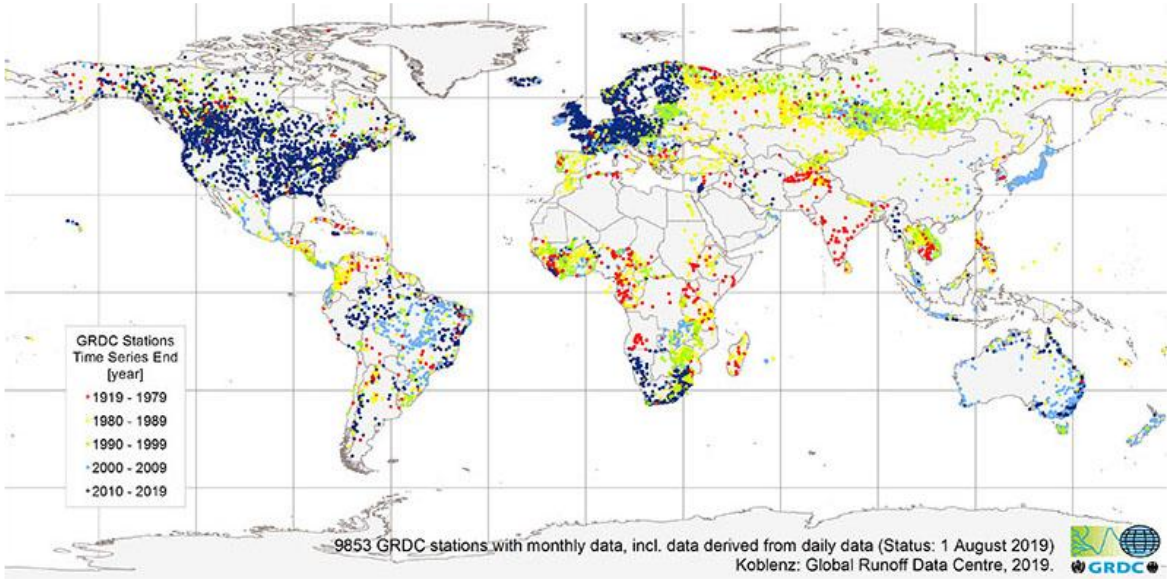
Backup slides

Existing Measurements (in situ and satellites)



In situ measurements network available at Global Runoff Data Center (GRDC, http://www.bafg.de/GRDC)

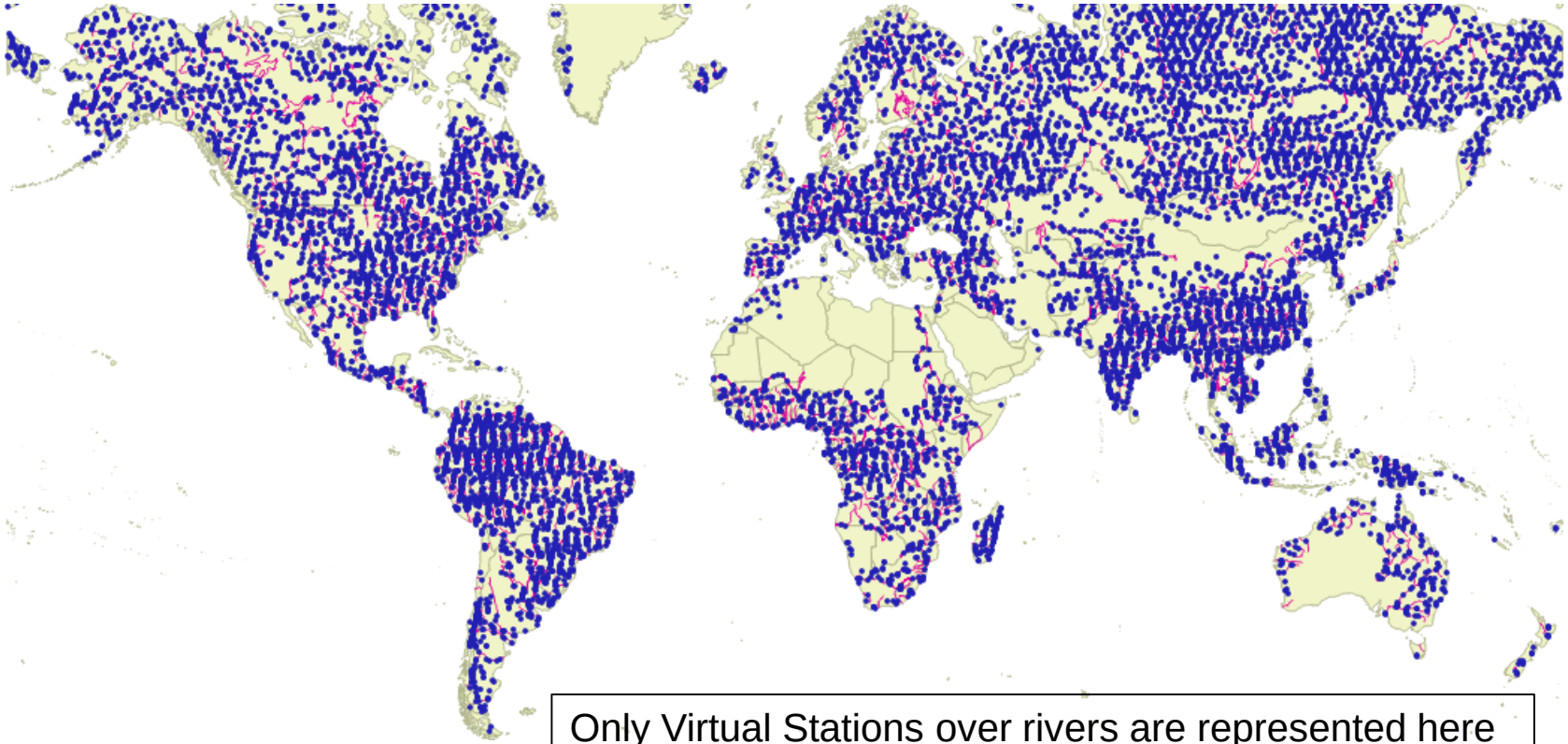
But:

- Heterogeneous (in space and time)
- Many data not available
- Density insufficient in many areas
- Dramatic decrease of available measurements since ca. 1960

Copernicus : Sentinel-3A / 3B, Sentinel-6

- But need a better revisit time : Sentinel-3A / 3B (27 days), Sentinel-6 (10 days)

SMASH potential network of Virtual Stations



Only Virtual Stations over rivers are represented here

With a constellation of 10 satellites : ≈ 50 000 hydrology targets with daily revisit