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EXCELENCIA MARÍA DE MAEZTU

CSIC

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TELE DETECT

Medida de variables climáticas hidrológicas utilizando reflectometría de radio-frecuencia desde drones y satélites

20 de abril, 2023

II Seminario de Las nuevas tecnologías aplicadas al conocimiento de los ecosistemas

Centro Nacional de Educación Ambiental – CENEAM. Valsaín (Segovia)

S. Ribó, E. Cardellach

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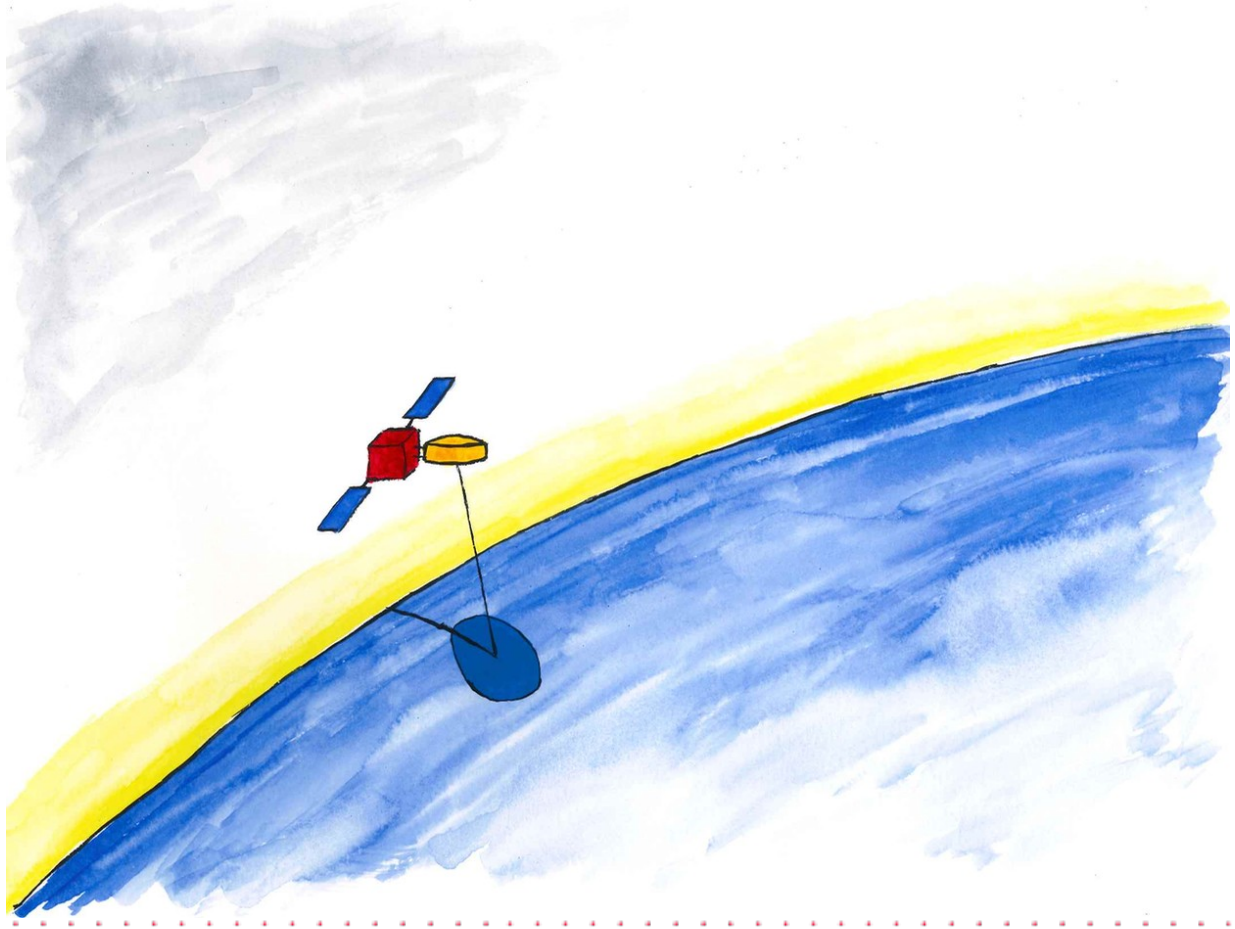
- Existing transmitters are used in a parasitic way as a bi-static/multi-static radar.
- Cost-effective solution (only receiver) **deployable in cubesats**
- Forward scattering geometry
- Broader swath, improved revisit time
- GPS, GALILEO, Glonass, BEIDOU



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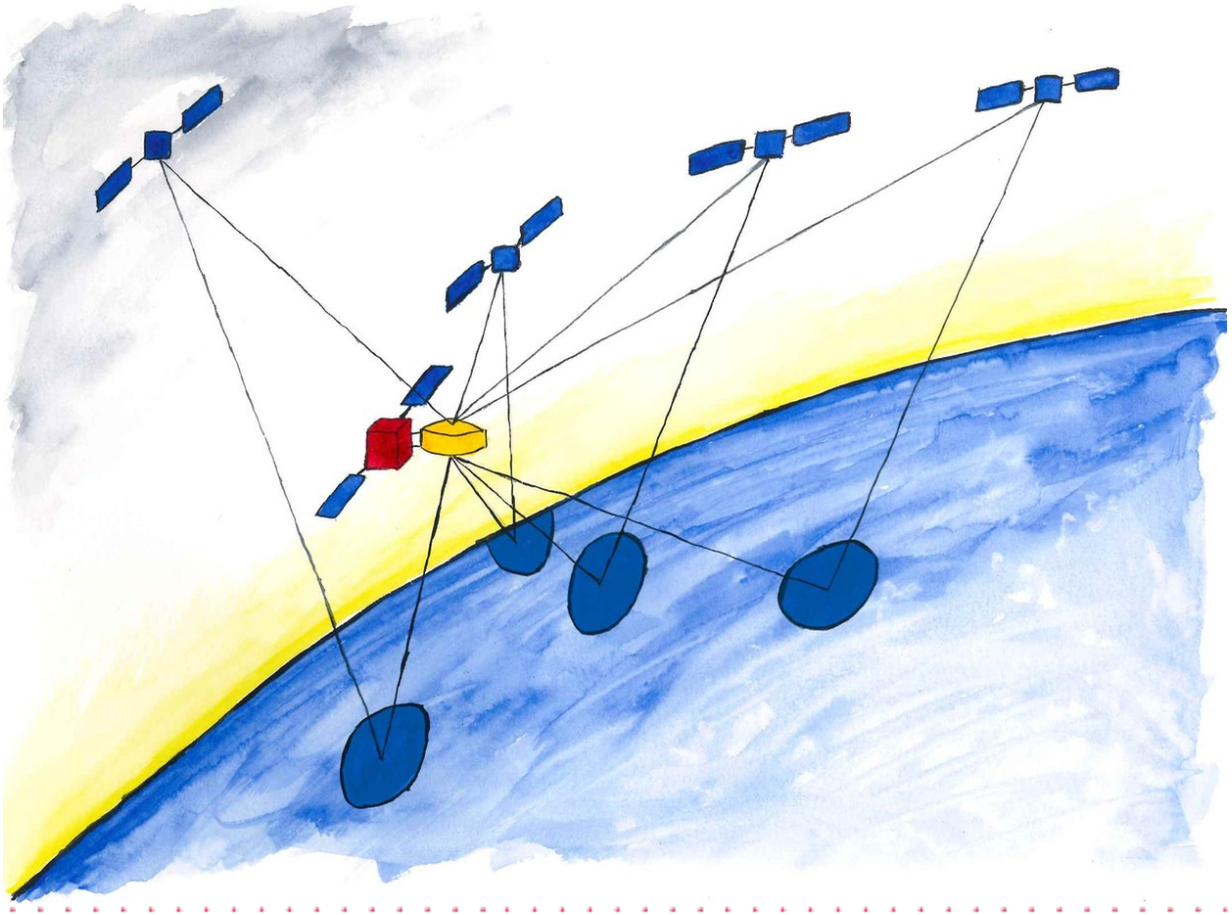

Passive Reflectometry using GNSS Signals (GNSS-R)

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- The signal is reflected from an extensive area (glistening zone)
- The received echo is spread in time and Doppler
- The main observable is the delay-Doppler map

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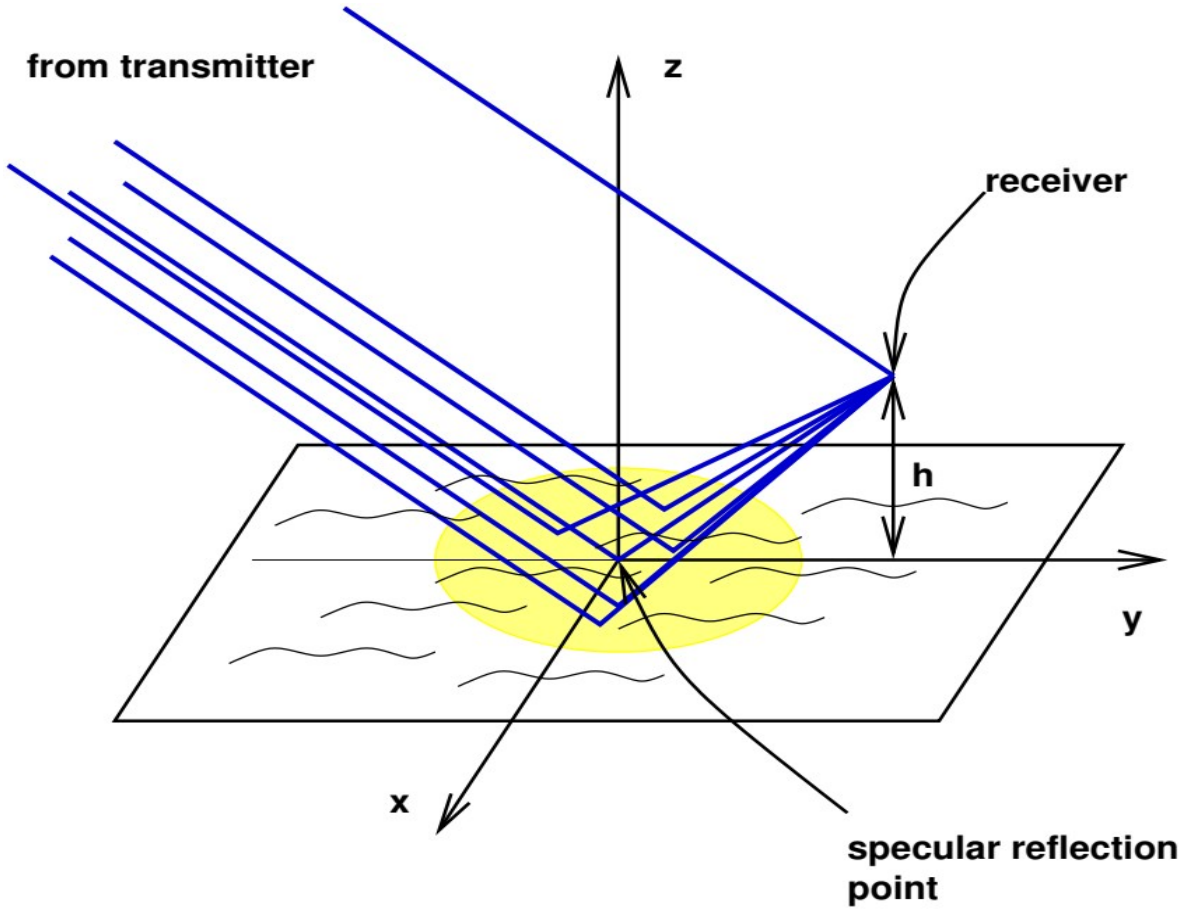

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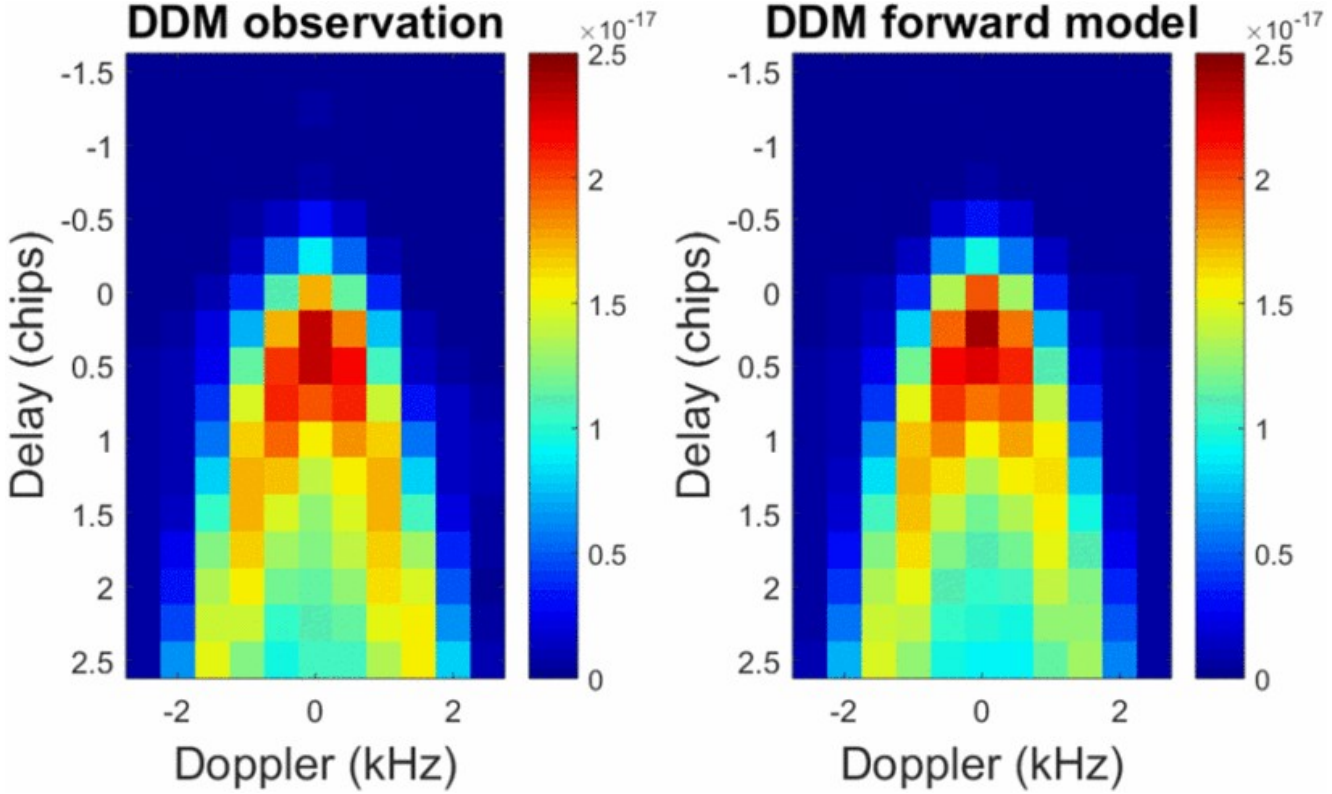
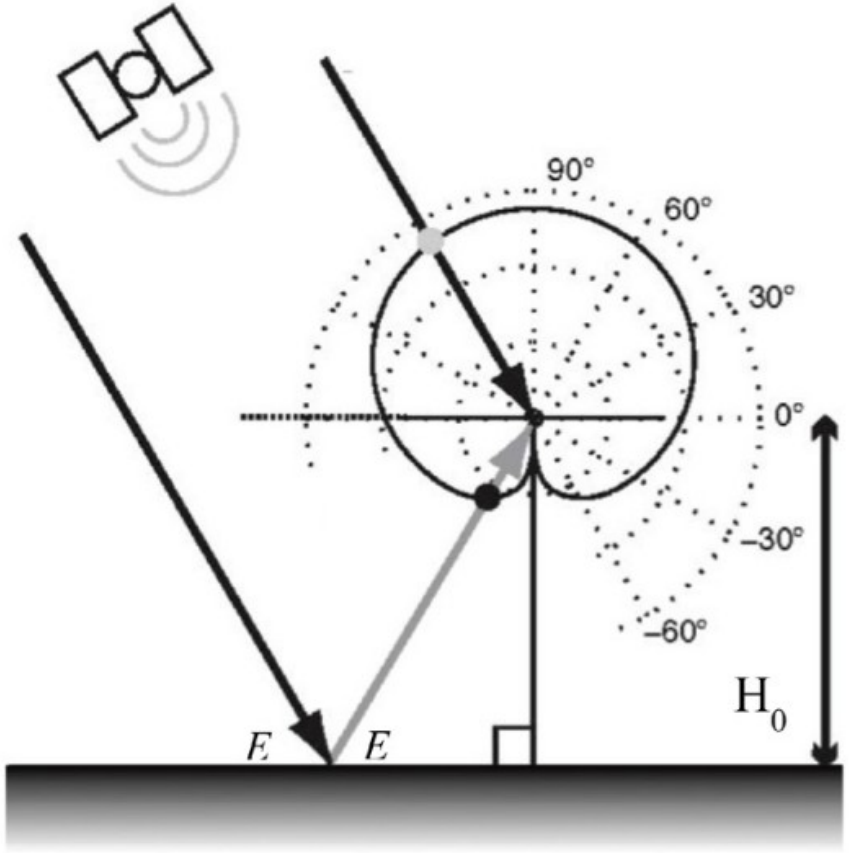


Huang et at. 2018. 10.1109/IGARSS.2018.8518987

Ground-Based measurement concept

- GPS receiver base stations also acquire the signal reflected off the surface surrounding their antenna.
- Usually this multipath is a disturbing effect (Electric Field Interference).
- But it can be used for sensing the ground, vegetation or snow around the antenna



Ochsner et al. 2013. https://doi.org/10.2136/sssaj2013.03.0093

Ground-Based measurement concept

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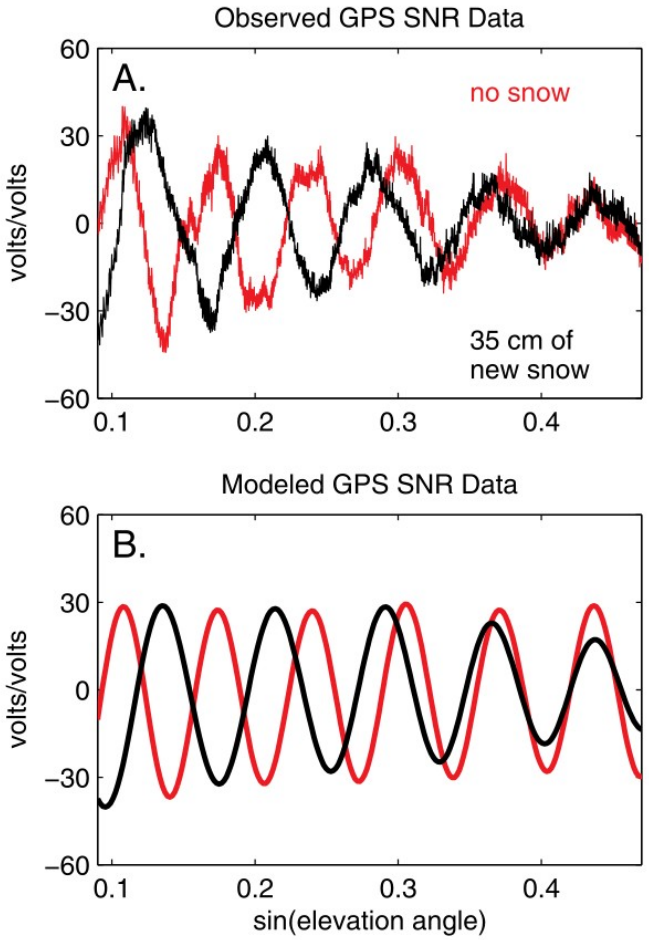

Larson et al. 2009. https://doi.org/10.1029/2009GL039430

Ground-Based measurement concept

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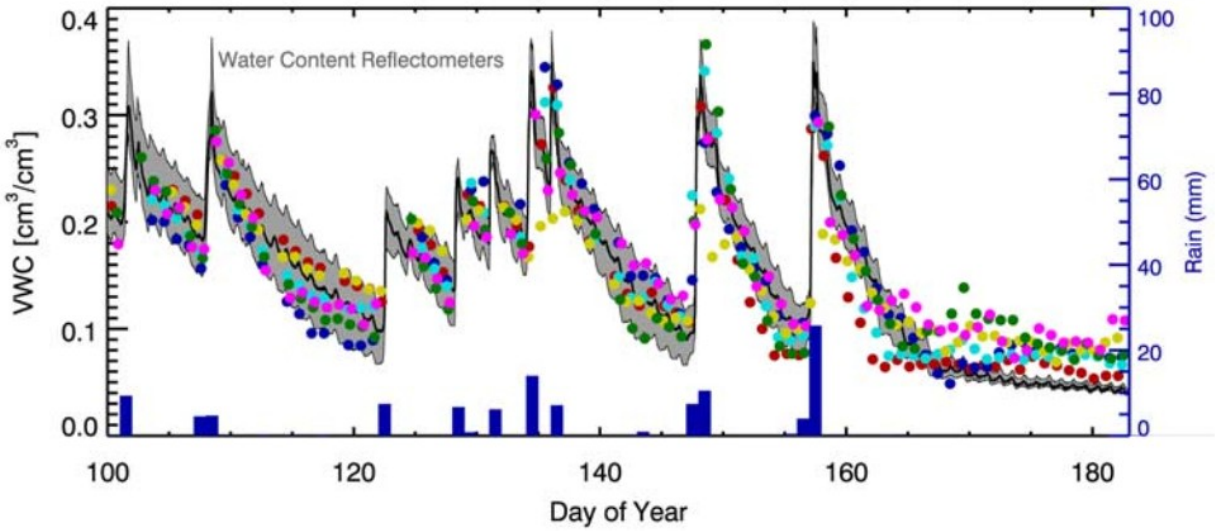

Larson et al. 2008. 10.1029/2008GL036013

Applications of GNSS-R Ocean Altimetry

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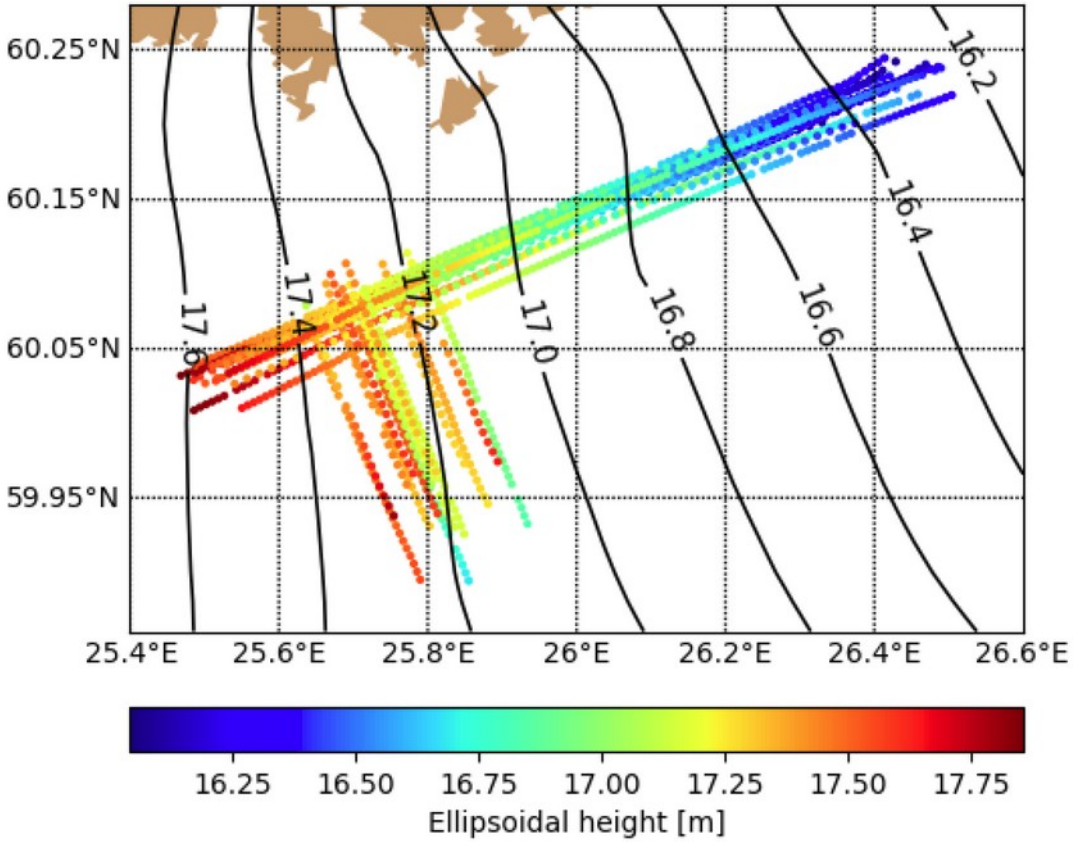
- The altimetry concept has been demonstrated experimentally from airborne and spaceborne platforms
- Expected performace for spaceborne platforms confirmed through noise-models and simulations
- No dedicated altimetry GNSS-R mission has been launched, but **few cm precision in grazing geometries!**



Fabra et al. 2019. 10.3390/rs11050505

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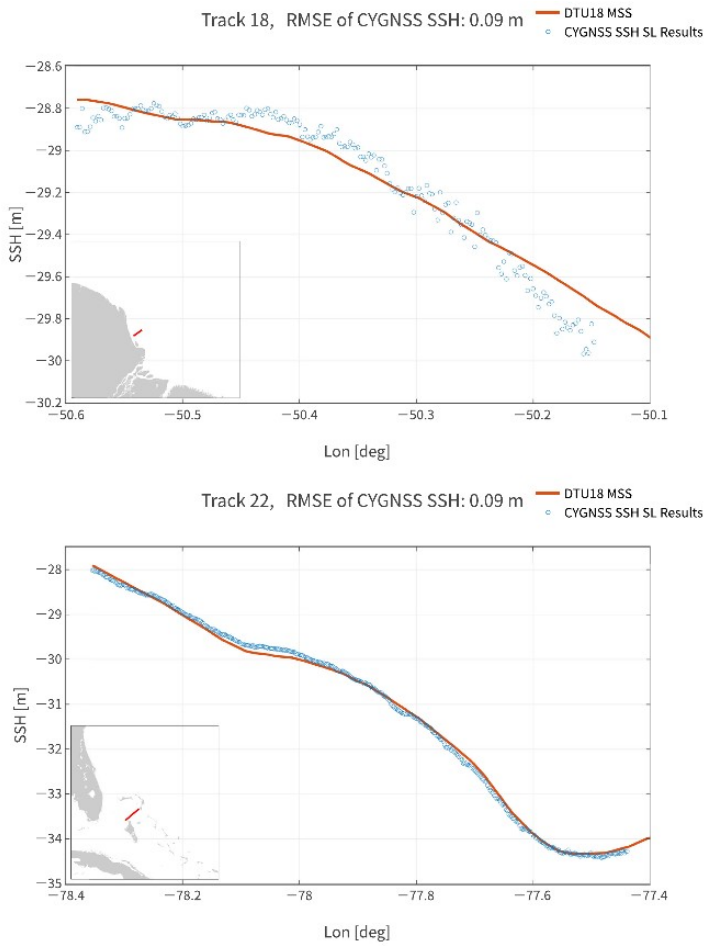

Cardellach et al. 10.1109/JSTARS.2019.2952694

Applications of GNSS-R Ocean Scatterometry

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TELE DETECT

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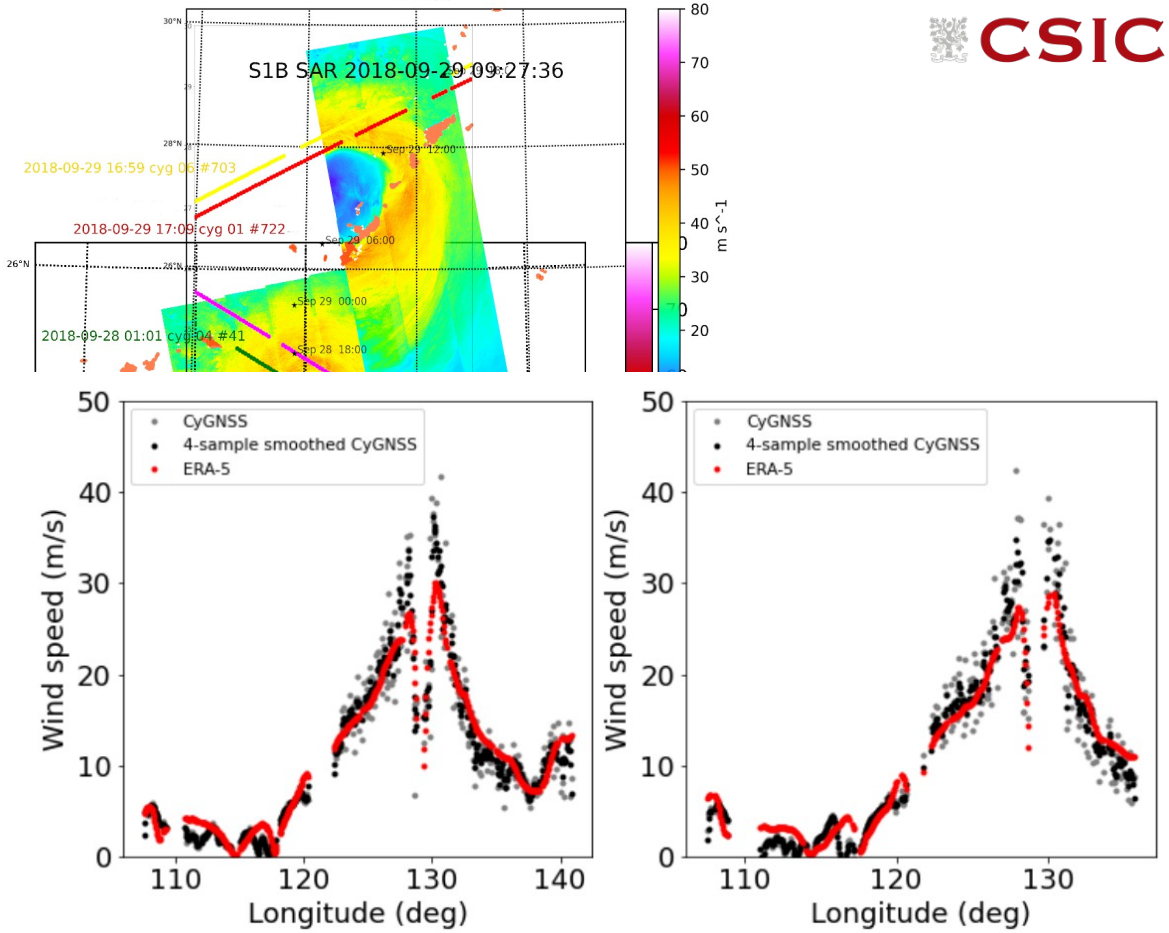
- The sea surface is rough due to **wind** and **waves**.
- Sea surface roughness affects the power of the reflected signal and the shape of the delay-Doppler map
- Measurement concept implemented in several missions, eg.: TDS-1, CYGNSS
- CYGNSS is a NASA mission dedicated to the observation of strong winds in cyclones



Cardellach et al., doi:10.3390/rs12233930

Applications of GNSS-R Cryosphere

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TELE DETECT

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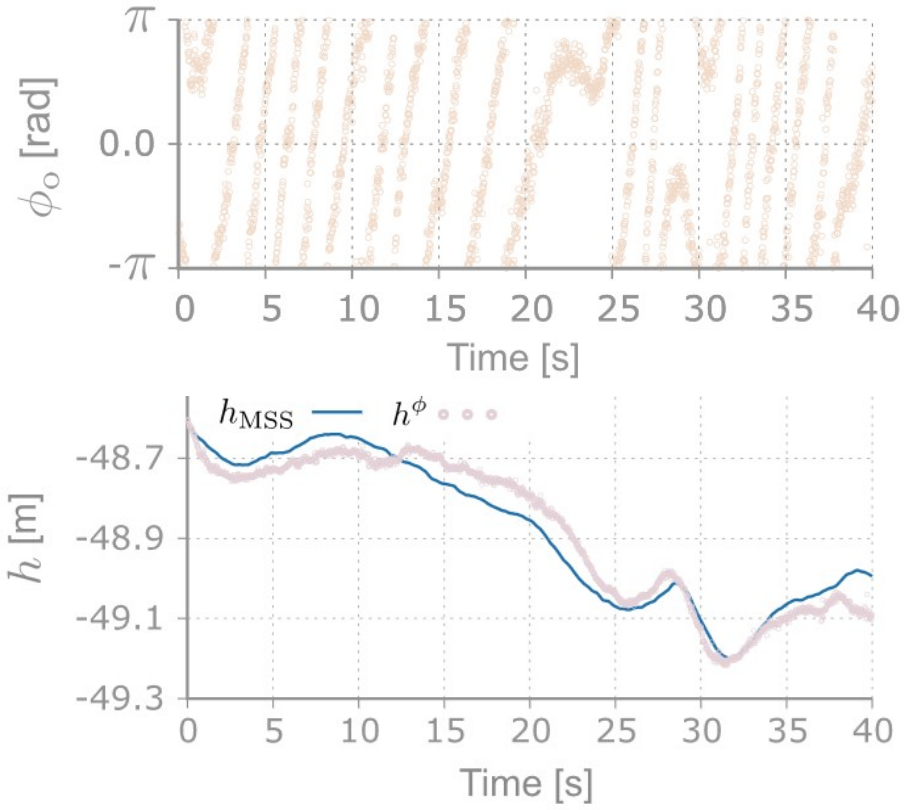
- Young sea ice has a flat surface
- Reflected GNSS signals show high coherence
- Sea-ice cover maps
- Phase altimetry (cm precision) is possible
- Dry-snow layer can be monitored using GNSS-R (land application)
- Greenland ice sheet monitored with GNSS-R. High correlation with melting events.



Li et al. 2017. 10.1002/2017GL074513

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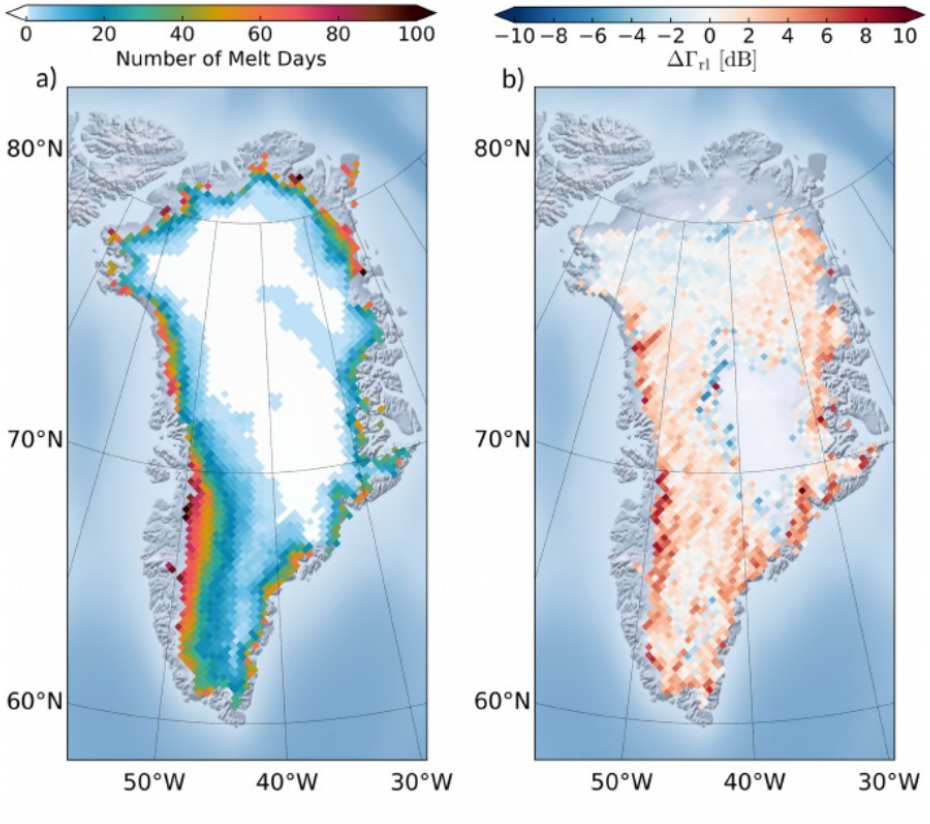

Li et al. 2019, 10.1029/2019GL086477

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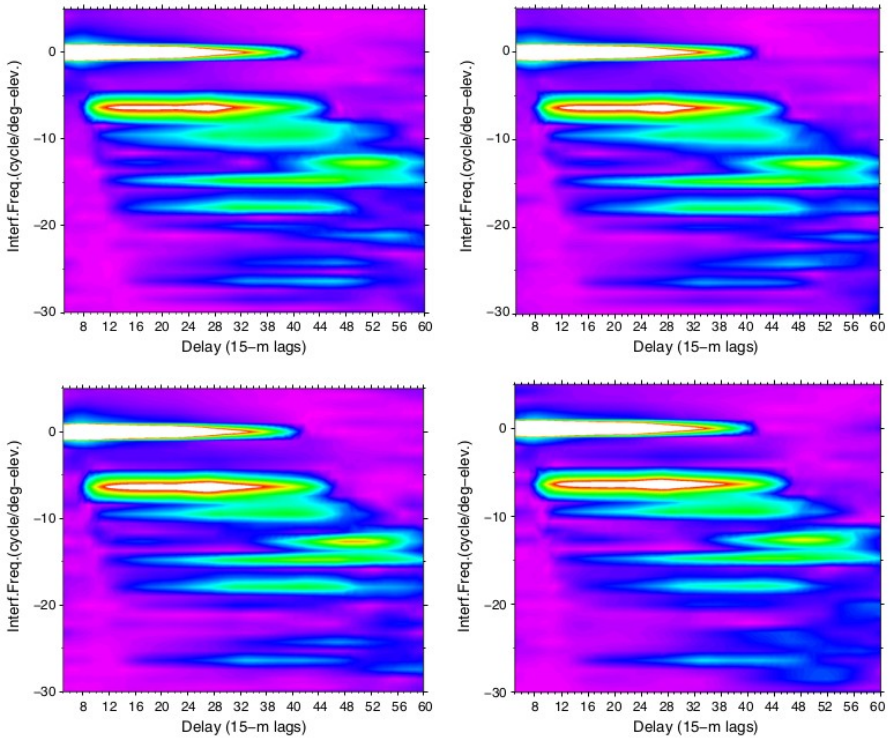
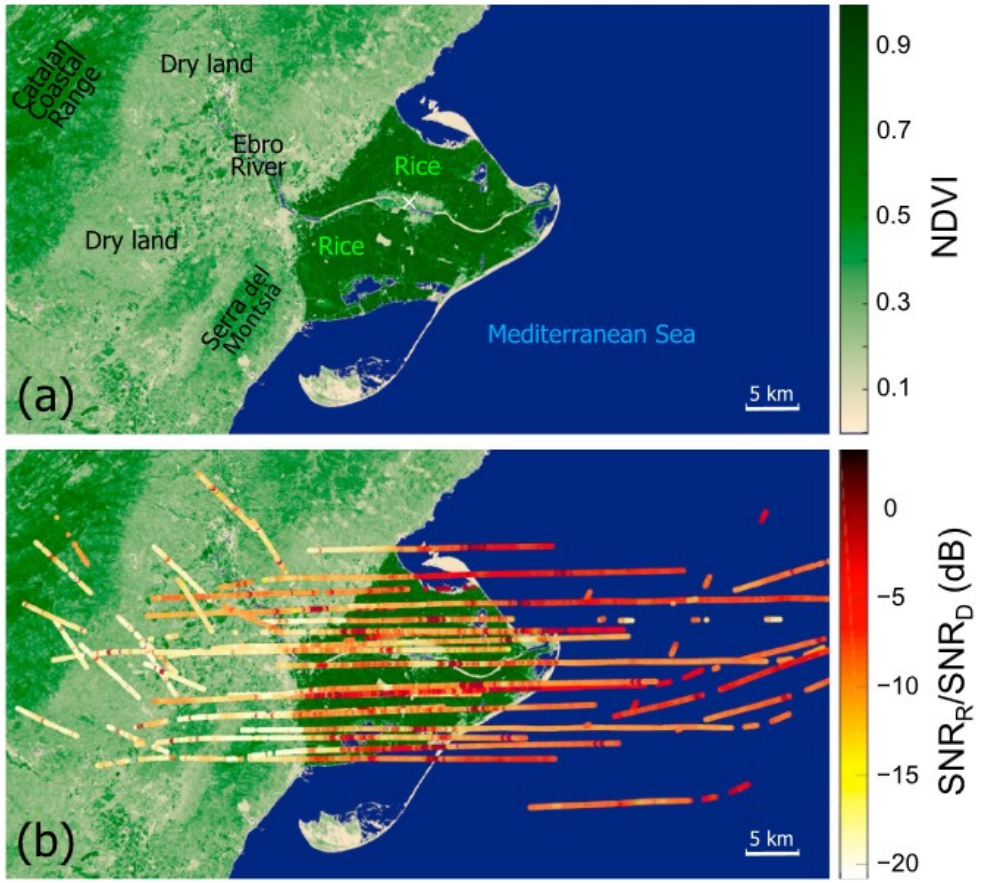


Cardellach et al. 2012. 10.1016/j.rse.2012.05.012

Applications of GNSS-R Wetlands/Innundation

- Water bodies have a higher reflectivity than surrounding land
- Inland waters tend to have a flat surface (wind protected by vegetation, small size does not allow for sufficient fetch)
- Typically, strong coherent reflected signals from inland water bodies.
- Monitoring of inland water bodies extension
- Even below vegetation



Nghiem et at. 2017. 10.1002/2016EA000194

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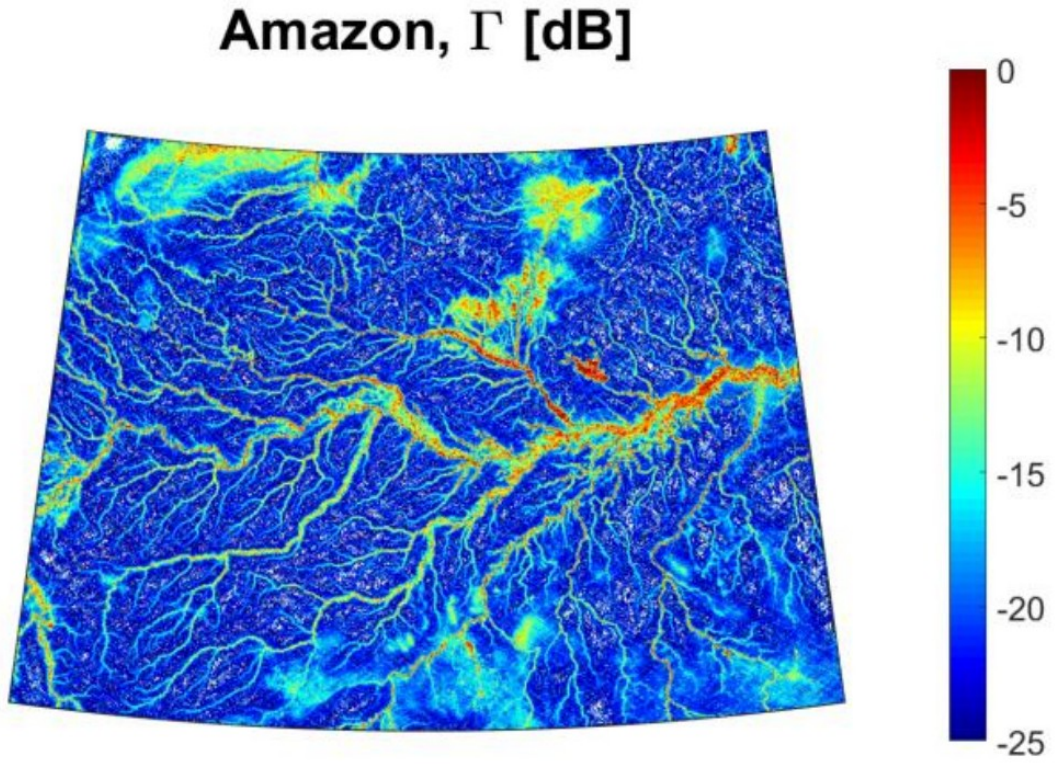

Carreno et at. 10.3390/rs12091368

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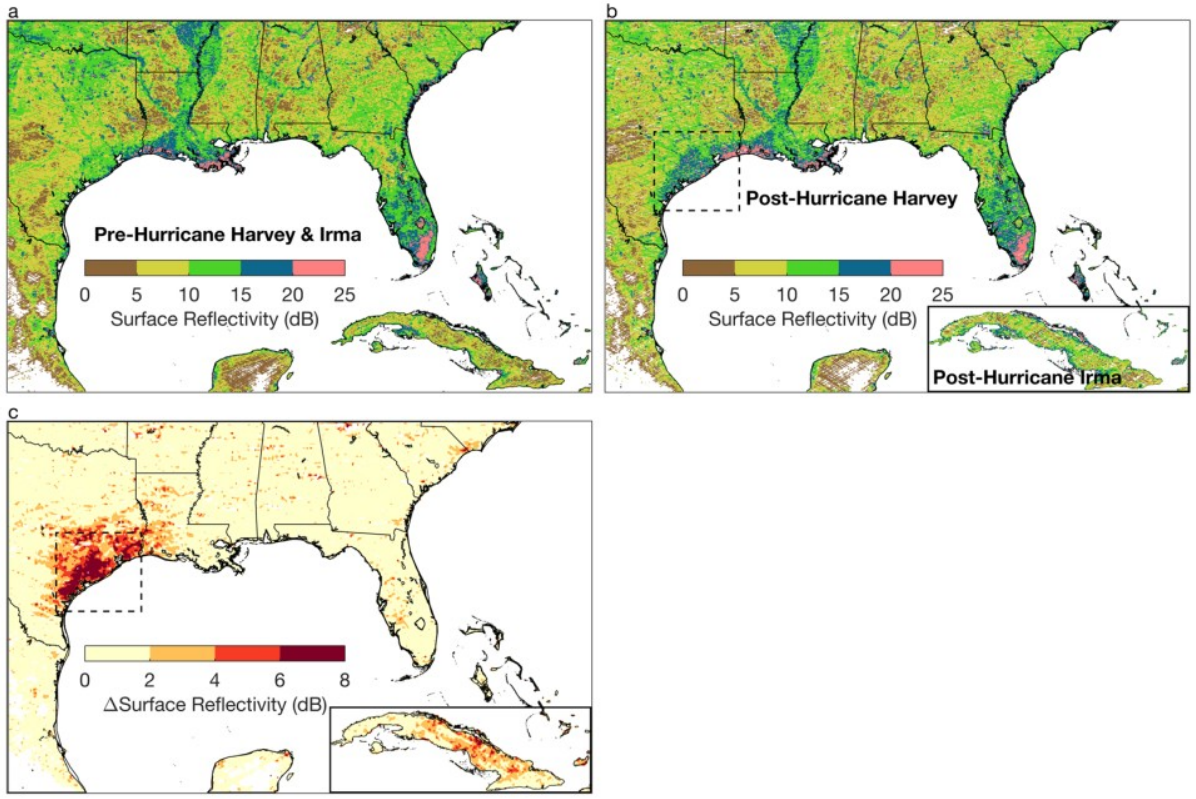

Chew et at. 2018. 10.1038/s41598-018-27673-x

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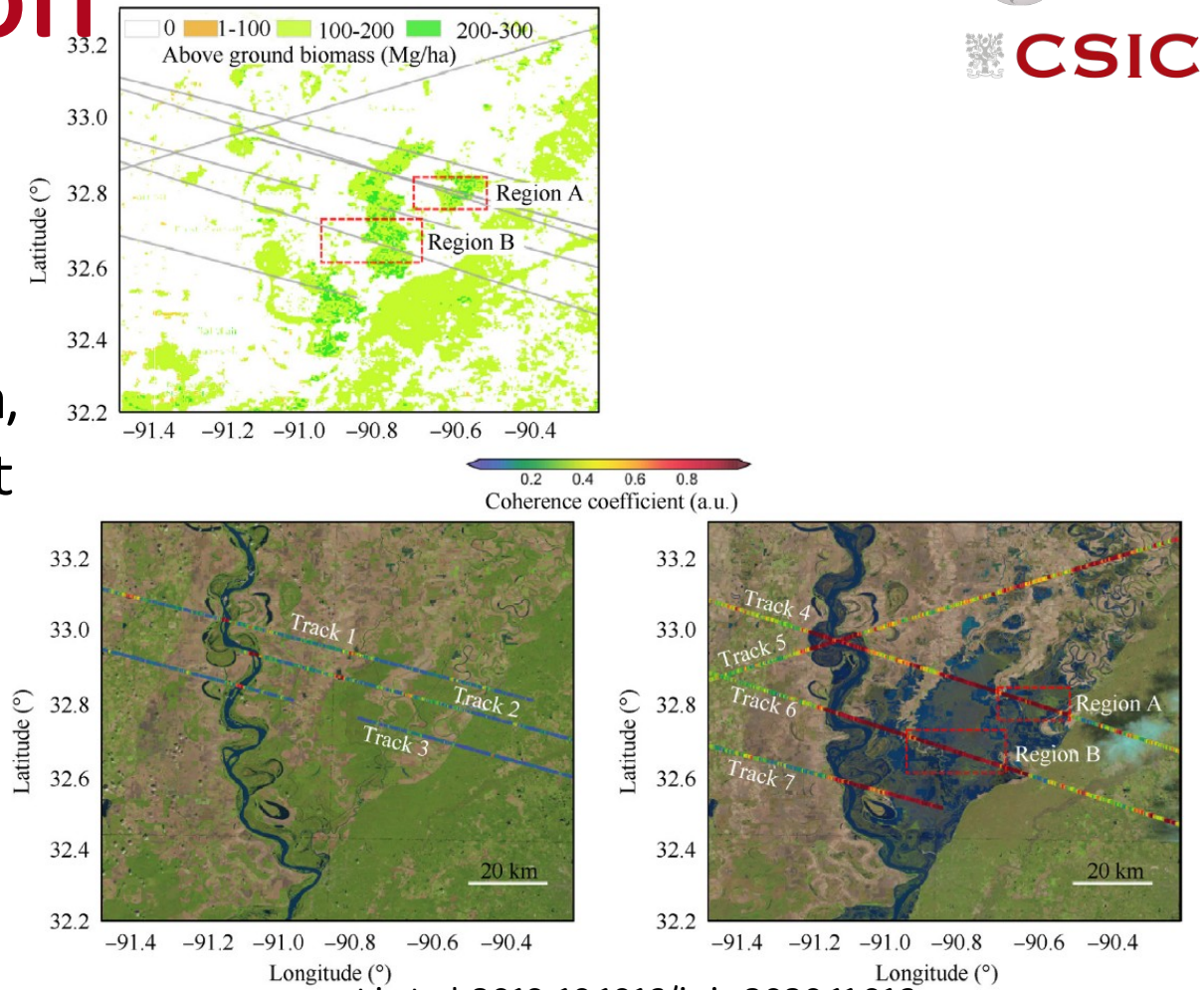
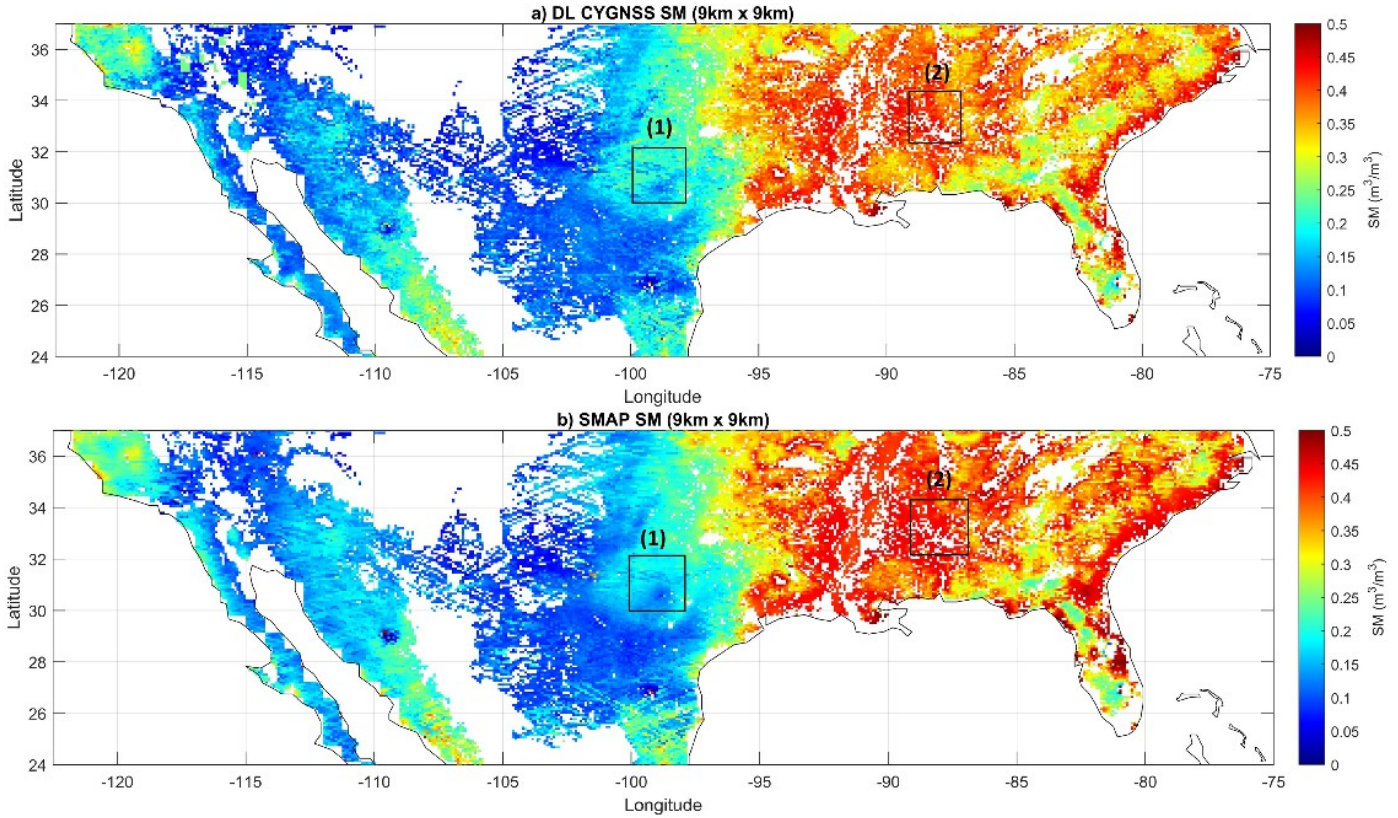


Li et al. 2019, 10.1016/j.cja.2020.11.016

Applications of GNSS-R Soil Moisture

- L-band reflectometry is sensitive to changes in soil moisture.
- NASA/CyGNSS has demonstrated SM retrievals similar to SMAP at <0.04 m3/m3 level
- ESA is launching HydroGNSS to further explore and improve the SM using GNSS-R



Nabi et al. 2022. 10.1109/JSTARS.2022.3196658

Passive Reflectometry at P-band Root Zone Soil Moisture (RZSM)

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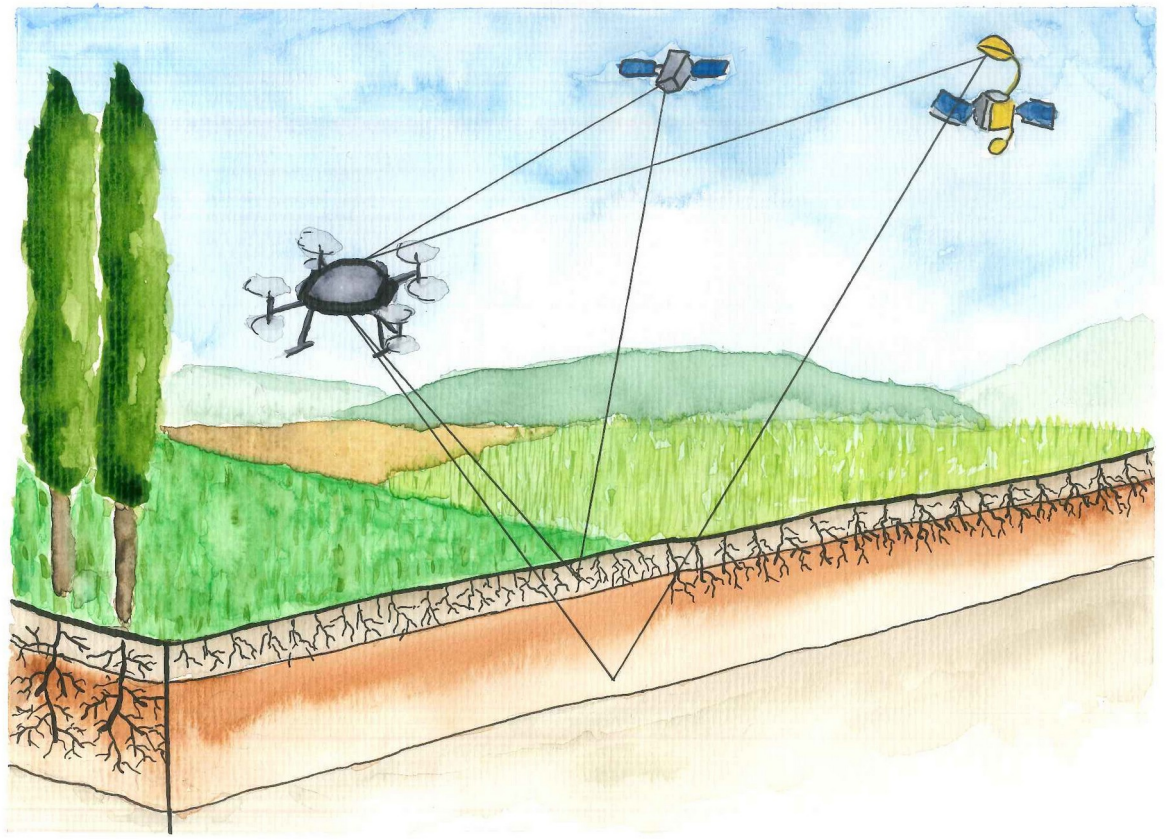
TELE DETECT

CSIC

- Transmitters of opportunity exists at different wavelengths
- Longer wavelengths have a deeper penetration depth into dielectric materials
- Measurement of RZSM for precision agriculture and water resources management
- Drone-based P-band + L-band reflectometry
- MIRROR project: 2022-2024: technological demonstration



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Passive Reflectometry at P-band Snow Water Equivalent (SWE)

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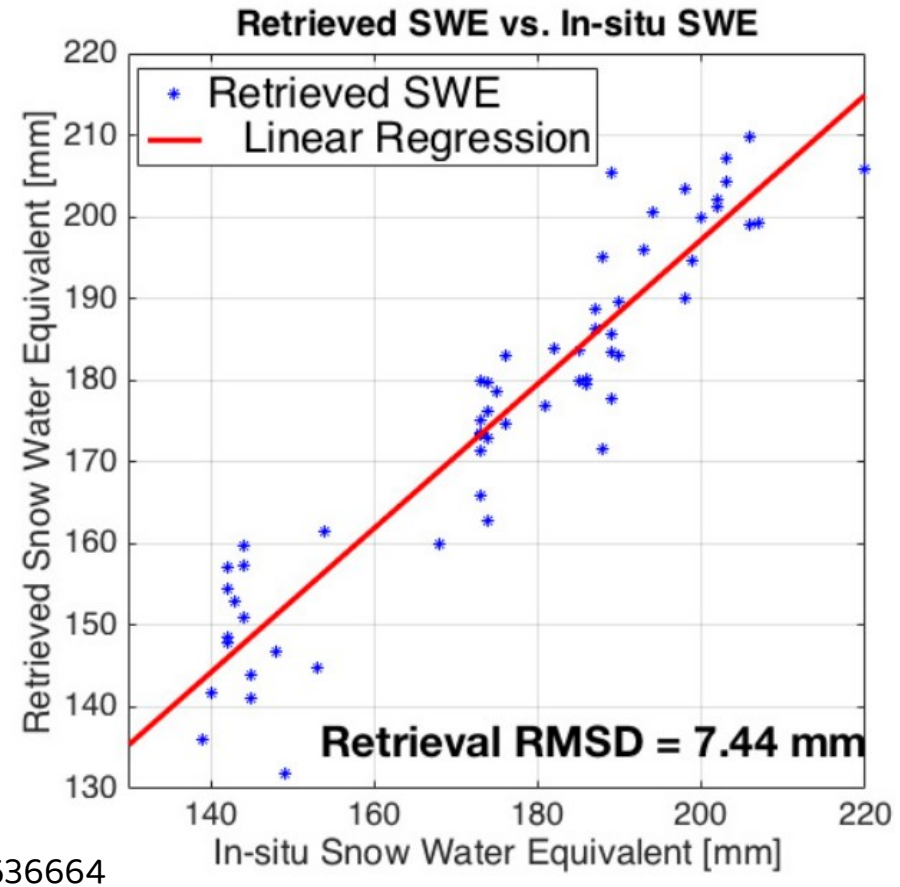
- Tower-based experiments
- Frequency: 260 MHz
- Estimation of SWE



Shah et al. 2017. 10.1109/LGRS.2016.2636664

Past, Current and Future Missions

- **More than 15 satellite carry or have carried GNSS-R payloads**, among them:
  - UK-DMC (2003) : GNSS-R concept demonstration
  - TDS-1 (2014): Technology demonstration
  - CYGNSS (2016): Constellation of 8 satellites. Strong winds in Cyclones
  - FSS-CAT (2020): GNSS-R + L-band radiometry for soil moisture
- **SNOOPI (2024): Technological Demonstrator for P-band reflectometry from Space**
- **HydroGNSS (H2 2024): Hydrological cycle**
- **ATLANTICA Constellation: GNSS-R &** multi & hyper-spectral cameras, IoT, AIS.

SNOOPI: Signals of Opportunity P-band Investigation

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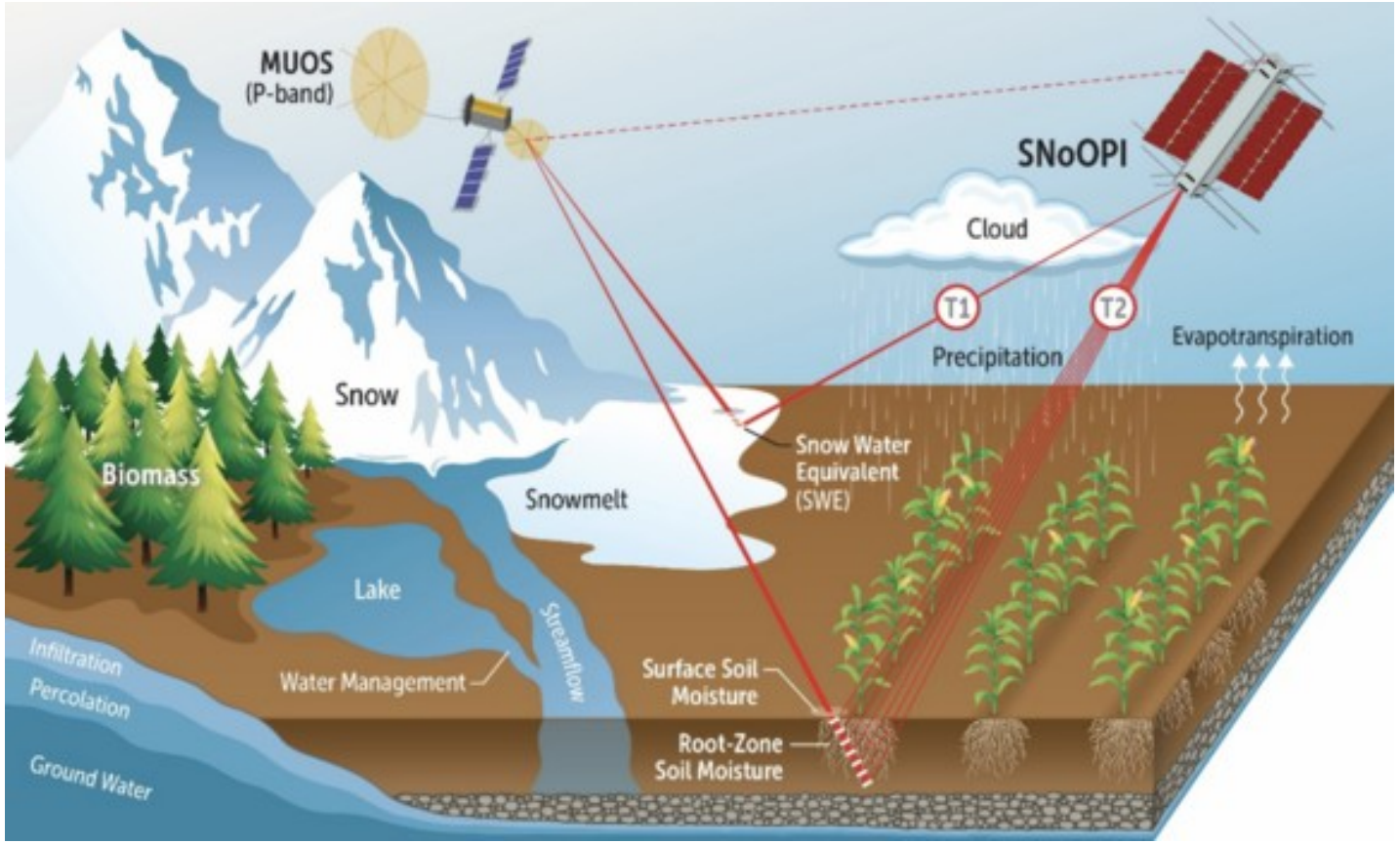
- NASA technology demonstration mission
- 6U Cubesat
- RZSM and SWE
- P-band (240 – 380 MHz)
- Launch in 2024



HydroGNSS

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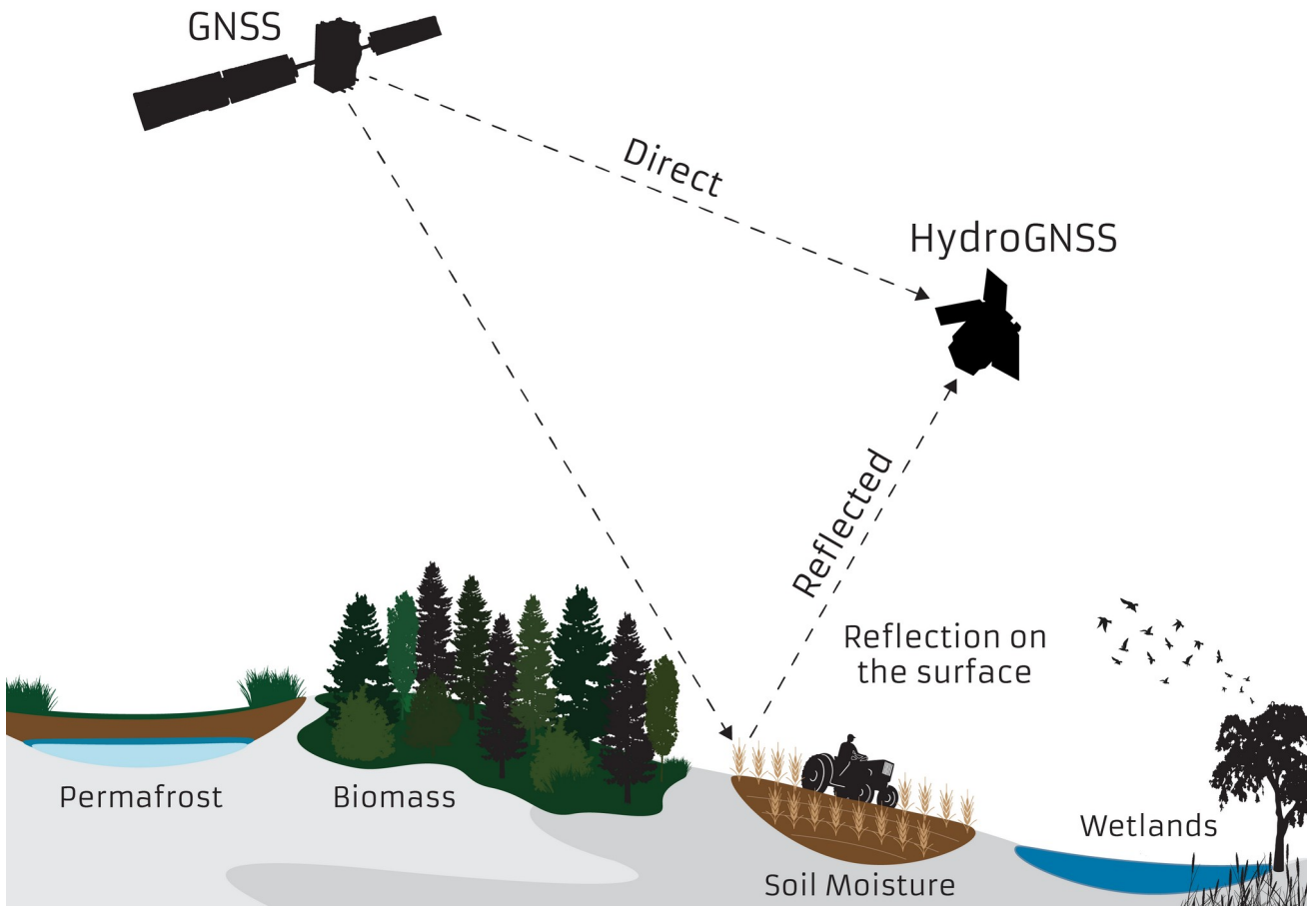
- Scout Programme of the European Space Agency (New Space approach: nanosatellite, cheap & quick)
- Hydrological knowledge
- Two satellites
- Launch: H2 2024



More info in: 10.1109/JSTARS.2021.3089550

HydroGNSS
Mission and Science Objectives

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- **Soil Moisture**
  - Requirement 0,08m3/m3, Goal 0.04 m3/m3.
- **Inundation and wetlands**
  - Requirement: 90% classification
- **Soil freeze/thaw state**
  - Requirement: 90% classification
- **Forest Biomass**
  - Requirement 30%, Goal 20%
- **Resolution**
  - Requirement 25 km, Goal 1 km (depending on signal coherence)

HydroGNSS
Mission and Science Objectives

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Secondary objectives

- Ocean wind speed and sea-ice extent
- Potential for precise sea-ice altimetry
- L1, L2 Delay-doppler maps will be made freely available
- Timeliness: 31 days standard, <7 days goal, view towards <24 h.
- Coverage: >80 % world in 15 days (two satellites)

HydroGNSS
What's new

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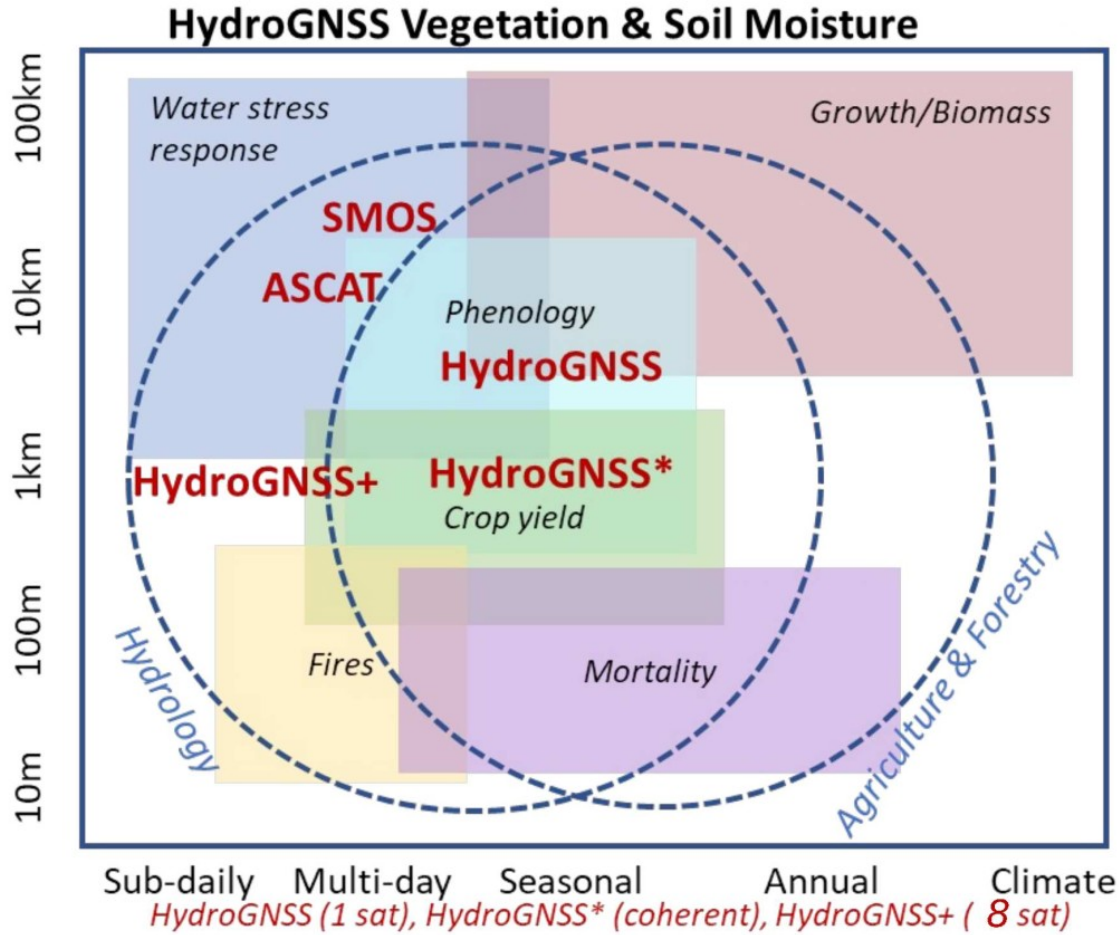
- **Incoherent GPS delay-Doppler maps (1Hz)**
  - Diffuse scattering
- **GALILEO signals**
  - Increased coverage
  - Longer codes→increased coherent gain
- **Polarization LHCP& RHCP**
  - Separation of moisture and soil roughness
- **Coherent channel**
  - Improved resolution→ increased processing gain
- **Second frequency band (L5)**
  - Wideband signals provide better selection coherent features

HydroGNSS Spatio-temporal Resolution



ATLANTICA Constellation

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- Constellation of **16** satellites (construction 2025)
- **Portugal** and **Spain** deliver eight each
- Instruments
  - AIS, VDES: vessel identification, marine traffic
  - IoT: communications transponder
  - **Multi- & Hyperspectral** (very) high resolution camera in visible, NIR, SWIR, TIR bands:
    - Ocean & land imaging
    - Sea surface temperature, chlorophyll, color dissolved organic matter, sea-ice cover,...
  - **GNSS-R:**
    - Sea wind, waves, soil moisture, flooded areas

Conclusions

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- **Passive reflectometry** provides a new way to measure different hydrological variables: **Soil moisture, RZSM, SWE, freeze/thaw, sea-ice extent**,...
- Platforms can be ground-based, **airborne** and **spaceborne.**
- **Reflectometry payloads** can be **deployed in nanosatellites,** orders of magnitude **cheaper** than in big satellites.
- **SNOOPI** technology demonstration mission at **P-band** to be launched in **2024.**
- **HydroGNSS GNSS**-R mission (**L-band**) to be launched in **2025**.
- **ATLANTICA constellation** is being prepared by Portugal and **Spain** and will carry **GNSS-R** and **multi-hyperspectral cameras.**
- **Airborne** (drone) **P-band reflectometer being built** in the frame of the MIRROR project. **Campaings** planned for **2024**.
- The Earth Observation group at **ICE-CSIC** has **pioneered GNSS-R** (since 1998) in Europe.

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