Scene Setting for the ESA HydroGNSS GNSS-Reflectometry Scout Mission

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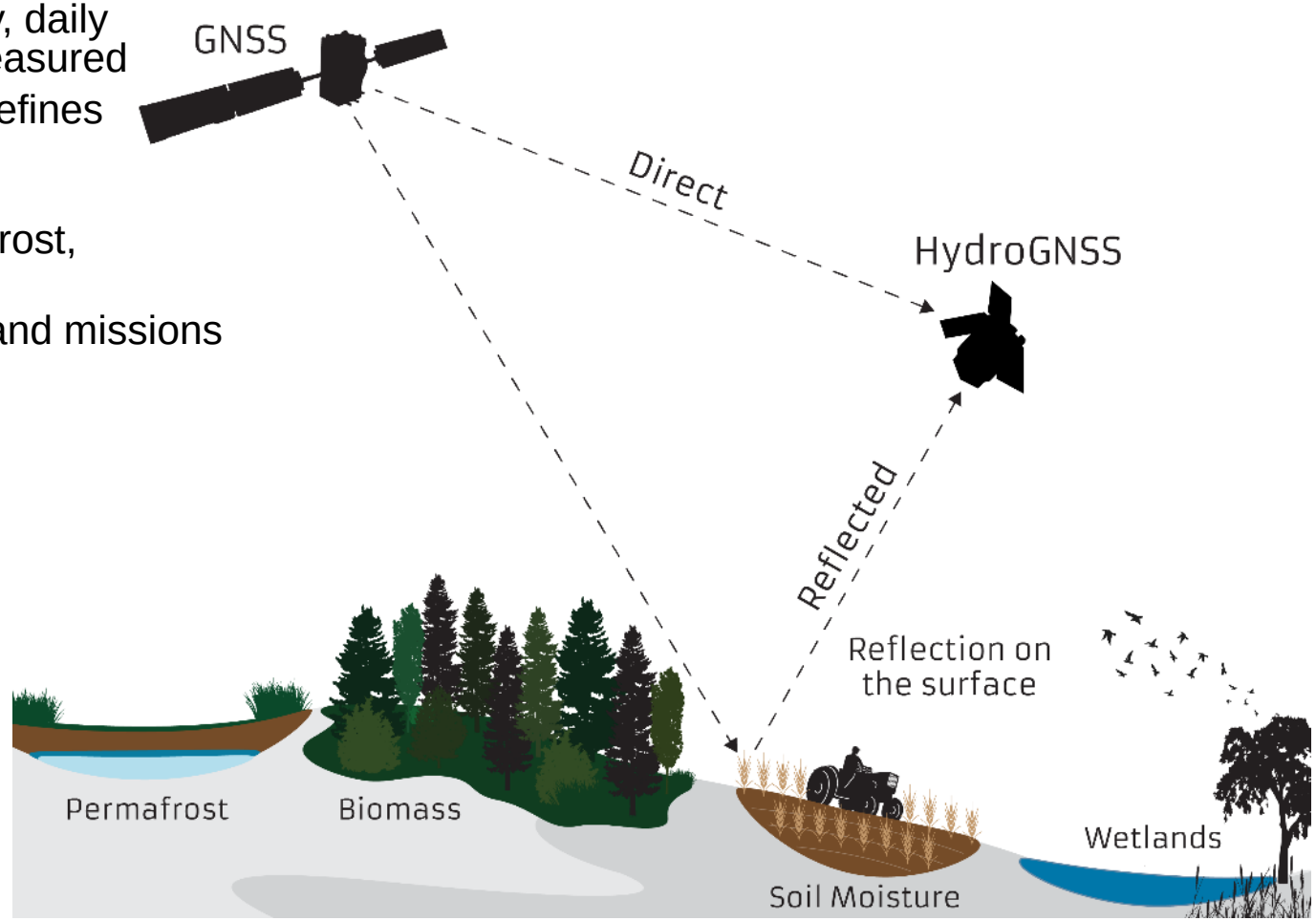
HydroGNSS Scout Opportunity

Presence of water over land impacts weather, climate, ecosystems, human welfare and agriculture

- Water systems need to be measured globally, daily at good resolution; currently inadequately measured
- Global Climate Observing System (GCOS) defines Essential Climate Variables requiring better measurement
- Special needs at higher latitudes incl. permafrost, biomass
- Gap foreseen as vital SMOS and SMAP L-Band missions have no immediate successors

- **HydroGNSS** – Dual satellites using GNSS-Reflectometry to sense 4 ECVs
  - Soil Moisture
  - Inundation / wetlands
  - Freeze / Thaw state
  - Biomass
- ESA Scout opportunity
  - Science driven mini-Explorer
  - €30m launch in 2024
  - Four candidate missions under study



HydroGNSS Science Objectives

- To deliver new satellite observations of sensitive climate change indicators of the global Earth Water Systems
- **Primary Products:**
  - **Soil Moisture** – contributes towards weather forecast, climate predictions, agriculture
  - **Inundation and Wetlands** – methane emissions, fragile ecosystems, inland and coastal flooding, agriculture
  - **Freeze / Thaw** – permafrost cycles, CO_2 source/sink, large potential methane source
  - **Biomass** – CO_2 source/sink, water & energy exchange with atmosphere
- **Secondary Products**
  - **Ocean and cryosphere** - ocean wind speed, ice extent, ice melt, sea ice type, ice thickness, snow water equivalent

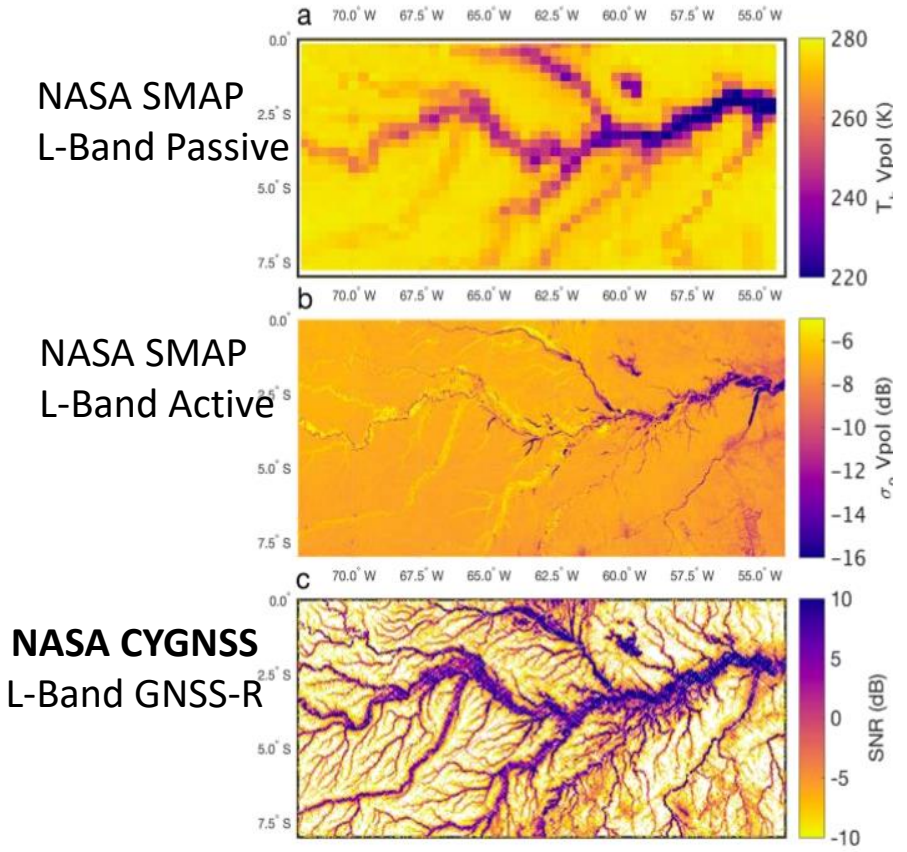
HydroGNSS – Complementarity and Uniqueness

Uniqueness

- GNSS-R forward scatter gives stronger echoes and finer resolution over smooth surfaces
- L-Band offers deeper penetration of soil, vegetation and snow
  - Ability to sense water under forest canopy
- Sensitivity to freeze / thaw at high latitudes
- Using multiple GNSS transmit sources
  - Radar without transmitter on small satellite
- Low mass, low cost approach to L-Band sensing, suitable for constellation
- New capabilities: dual polar, coherent channel

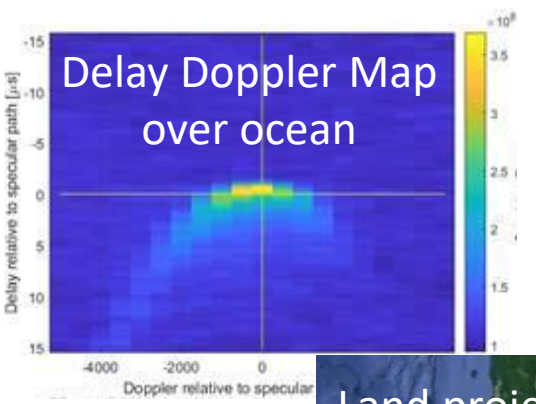
Complementarity

- Builds on NASA CYGNSS, providing new higher latitude capability
- Complements SMOS, SMAP, Biomass, Met-Op-SG, Copernicus Sentinel missions



Satellite observations of streams and tributaries across the Amazon basin *(Chew et al. 2018)*

Established & New GNSS-R Measurements

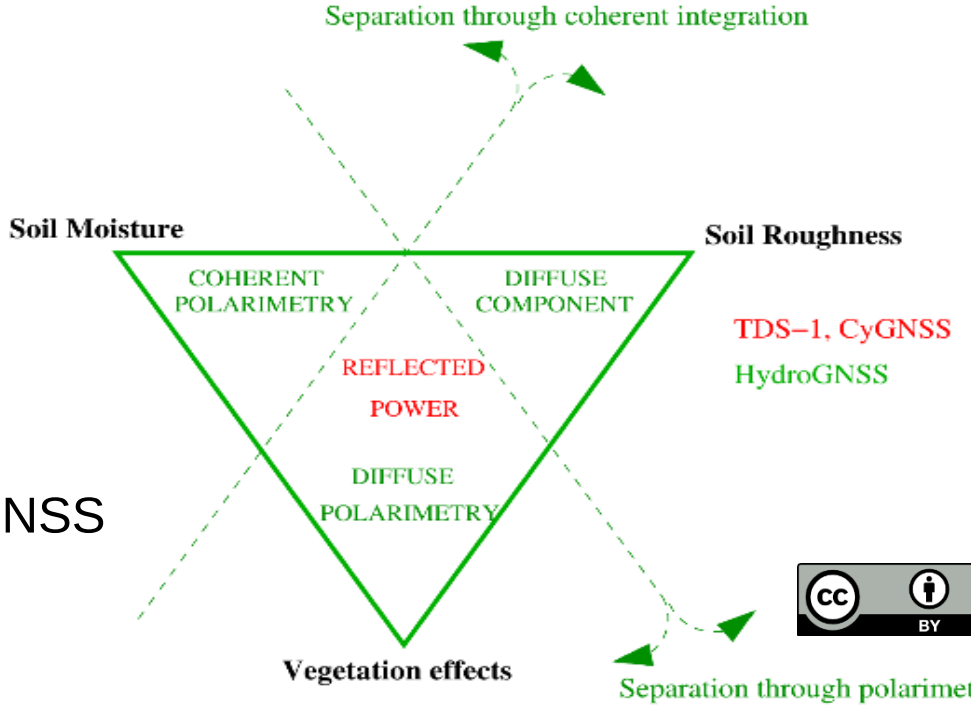


Heritage from TechdemoSat-1 and NASA CYGNSS

- Global processing of 1 Hz Delay Doppler Maps (DDMs) from GPS L1 C/A Code
- On-board black-body load & Antarctic targeting for radiometric calibration
- Improving antenna pattern & transmit power sensing

Innovative GNSS-R Measurements

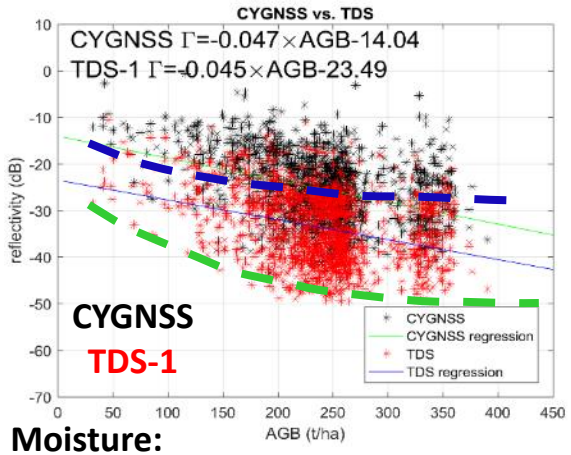
- Multi-GNSS reception, including GPS and Galileo
  - Better sampling and coverage, finer resolution
- Left and Right Polarisation DDMs
  - Mitigation of vegetation and soil roughness
- Higher rate coherent complex channel
  - Separation of diffuse / coherent terms
  - Fine scale mapping over wetlands, rivers,
- Dual frequency L1/E1 and L5/E5
  - Exploring potential of dual frequency and wideband GNSS (fine resolution)



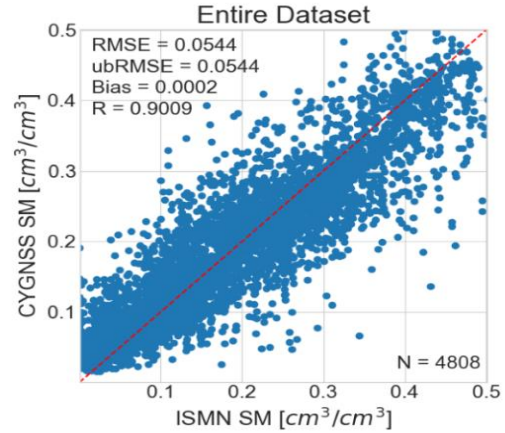
HydroGNSS Scientific Readiness

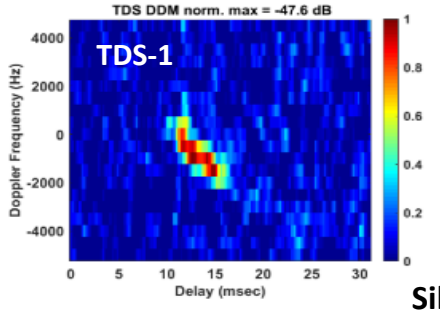
- Sensitivity of GNSS-R signals to HydroGNSS primary products demonstrated in orbit
  - Using data from TechDemoSat-1 and CYGNSS
  - Maturity in Level 2 Geophysical Model Functions and validation methods
- End-to-End simulators in place and validated against TDS-1 in-orbit measurements
- Recent refinements include
  - Incorporation of freeze/thaw
  - Dual polarisation modelling
  - Coherent channel modelling
  - Behaviour at dual frequencies
  - Signal bandwidth changes

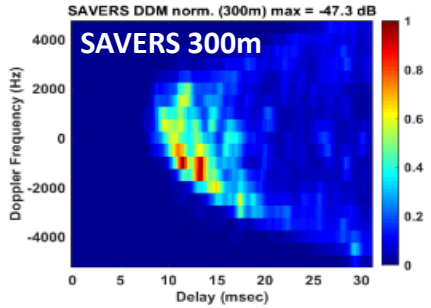
Biomass: (Santi et al., 2020, in review)



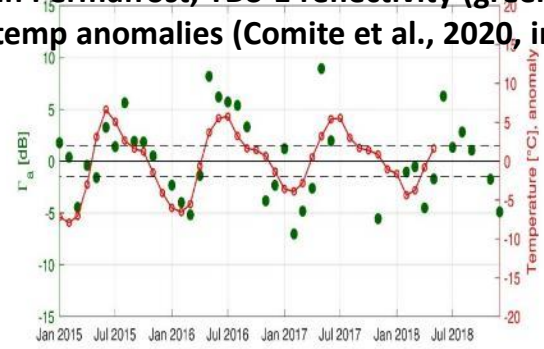
Soil Moisture:
Eroglu et al., 2019 doi:10.3390/rs11192272







Siberian Permafrost, TDS-1 reflectivity (green) vs in-situ soil temp anomalies (Comite et al., 2020, in review)



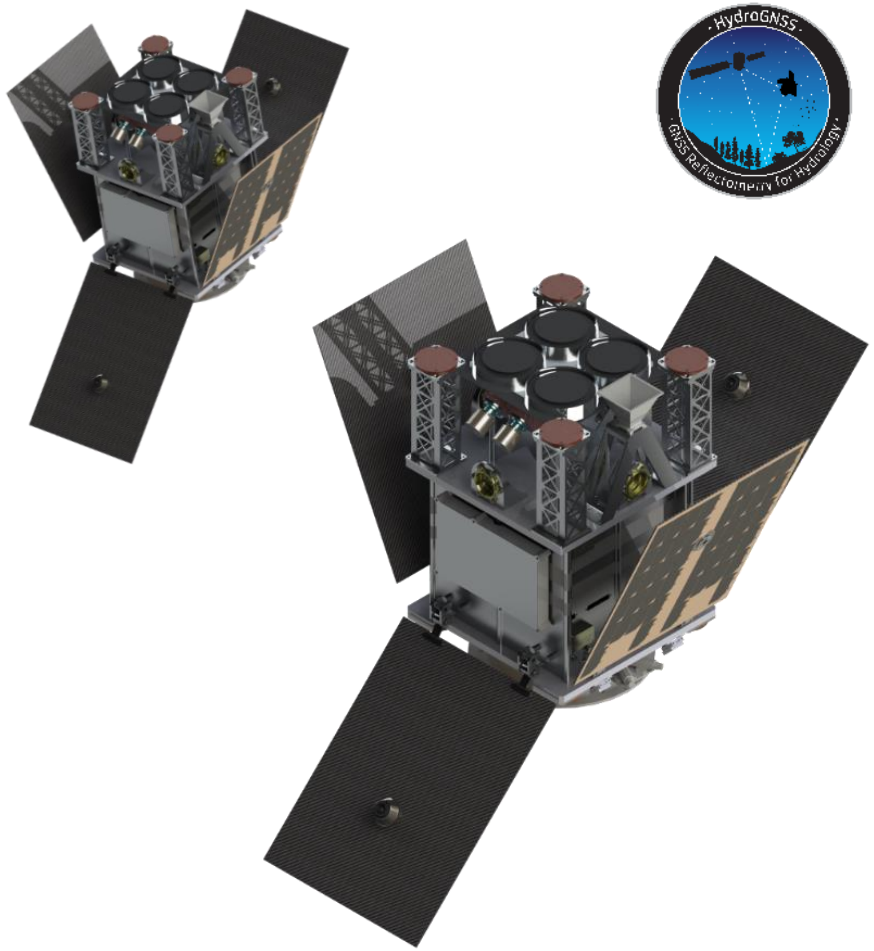
HydroGNSS Instrument & Mission

Payload

- New GNSS-R Instrument based on TDS-1 and CYGNSS missions
- Compatible with Galileo and GPS, reconfigurable in orbit
- Nadir antenna ~13 dBi dual polarised, dual frequency
- Continuous on-board 1 Hz Delay Doppler Map
  - plus coherent data channels
- Raw sampling capability, both polarisations and frequencies

Platform

- SSTL-21, 40 kg variant of SSTL-Micro, 5 year life target
- 3-axis attitude stabilised with star tracker
- Xenon propulsion, 30 m/s for phasing and end of life disposal
- Commissioning and command from Guildford
- Up to 160 Mbps X-band downlink via Svalbard
- Payload Data Ground Segment built upon www.merrbys.org
- Level 1 and Level 2 data disseminated via www.earth.esa.int

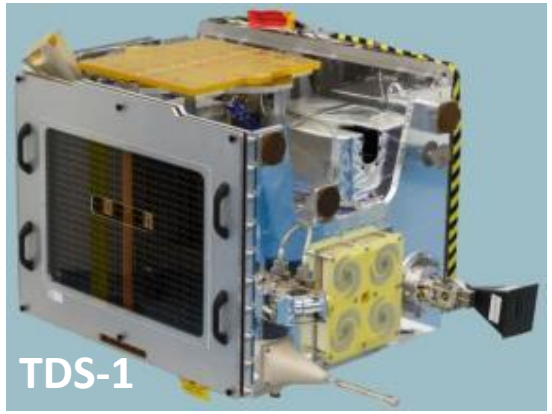


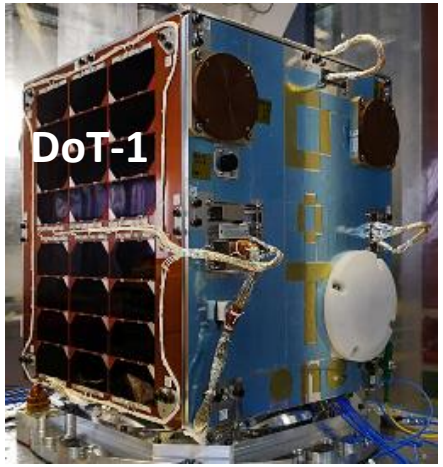
Constellation

- HydroGNSS comprises 2 satellites
  - Global coverage every 15 days
  - More frequent at high latitudes
- Suitable for upscaling to larger (12+) constellation to achieve daily coverage

Precursors to HydroGNSS

- **TechDemoSat-1** launched in 2014
  - UK Technology satellite carrying SGR-ReSI prototype receiver
  - Demonstrated feasibility of GNSS-Reflectometry for ocean wind sensing, soil moisture, biomass and ice
  - ESA-sponsored studies supported TRL, SRL improvements and data dissemination to international community www.merrbys.org
- **NASA CYGNSS** launched in Dec 2016
  - Constellation of 8 satellites carrying SGR-ReSI
  - Low inclination orbit for tropical cyclone monitoring
  - Demonstrated significant capabilities of GNSS-R for soil moisture and inundation
- **DoT-1 –** Launched Summer 2019
  - 18 kg technology demonstration satellite (SSTL avionics)
  - Includes Nadir-pointing GNSS antenna
  - Precursor instrument for ORORO and HydroGNSS concepts
  - Aim: to release GPS and Galileo DDMs by 2021
  - Proof of low cost hosted payload for weather measurements





HydroGNSS Conclusions

- HydroGNSS comprises two small satellites to measure hydrological Essential Climate Variables over land using GNSS-Reflectometry
  - Primary objectives: Soil Moisture, Inundation / Wetlands, Freeze/Thaw, Biomass.
  - Secondary objectives: ocean and cryospheric parameters
- Use of established and new GNSS Reflectometry technology
  - Instrument development built upon TDS-1 and CYGNSS experience
  - Two small satellites (40 kg) operating 100% duty cycle
    - Radiometric stability, accurate attitude knowledge, X-band downlink
  - Scalable to constellation of 12 satellites for global daily coverage
- Large international community of scientists and users
  - Data dissemination via ESA, based upon TDS-1 MERRByS system
- Phase B mission kick-off Jan 2021, launch in 2024
  - Subject to mission selection in August 2020

Thank you