
SURREY
CHANGING THE ECONOMICS OF SPACE

# HydroGNSS - Spaceborne Use of GNSS for Climate Variable Sensing

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# Introduction to HydroGNSS Team

- European Space Agency - programme initiator and customer
- Surrey Satellite Technology Ltd (SSTL) – Prime, payload, platform and ground segment

**Science Team:**

- Sapienza University of Rome – Soil Moisture and End to End simulator
- Institut d'Estudis Espacials de Catalunya (ICE-CSIC/IEEC) – Inundation and GNSS signal processing
- Finnish Meteorology Institute – Freeze Thaw State
- Tor Vergata University – Surface interaction simulation
- IFAC-CNR – Forest Biomass
- National Oceanography Centre (NOC) – Ocean-based calibration, wind speed and ice extent
- University of Nottingham – GNSS instrumentation and signal processing
- Technical University of Vienna – participating in Data Fusion study

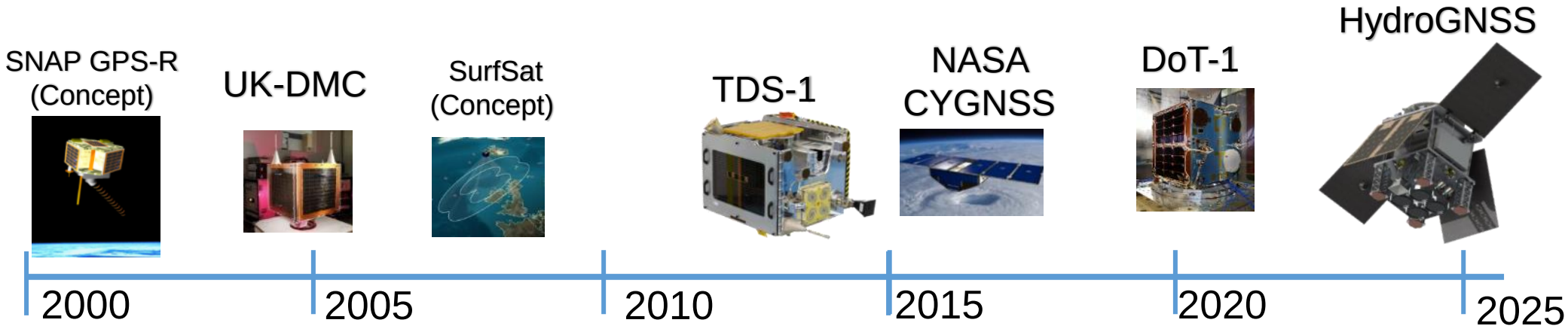
# European Space Agency - Scout Programme


- New initiative from ESA's Earth Observation directorate
- Small satellite missions, demonstrating science with small budget and rapid schedule
- Missions fully funded by ESA, characterised by an agile and low-cost development process to prove new concepts for future ESA endeavours
- Aiming to tap into New Space approach to achieve a launch within 36 months after KO, budget < €30m
  - Managing higher risks, use of COTS components, reuse of existing designs, lower cost, faster to service
- Free, full and open data, delivered using service-based approach
- **HydroGNSS** selected as one of first two Scout missions in Feb 2021
  - Oct 2021 Project kicked off;  Feb 2023: Second HydroGNSS satellite approved

# GNSS Reflectometry Heritage

**GNSS Reflectometry** (GNSS-R) surface reflections collected from low Earth orbit of *Global Navigation Satellite Systems*, including GPS and Galileo

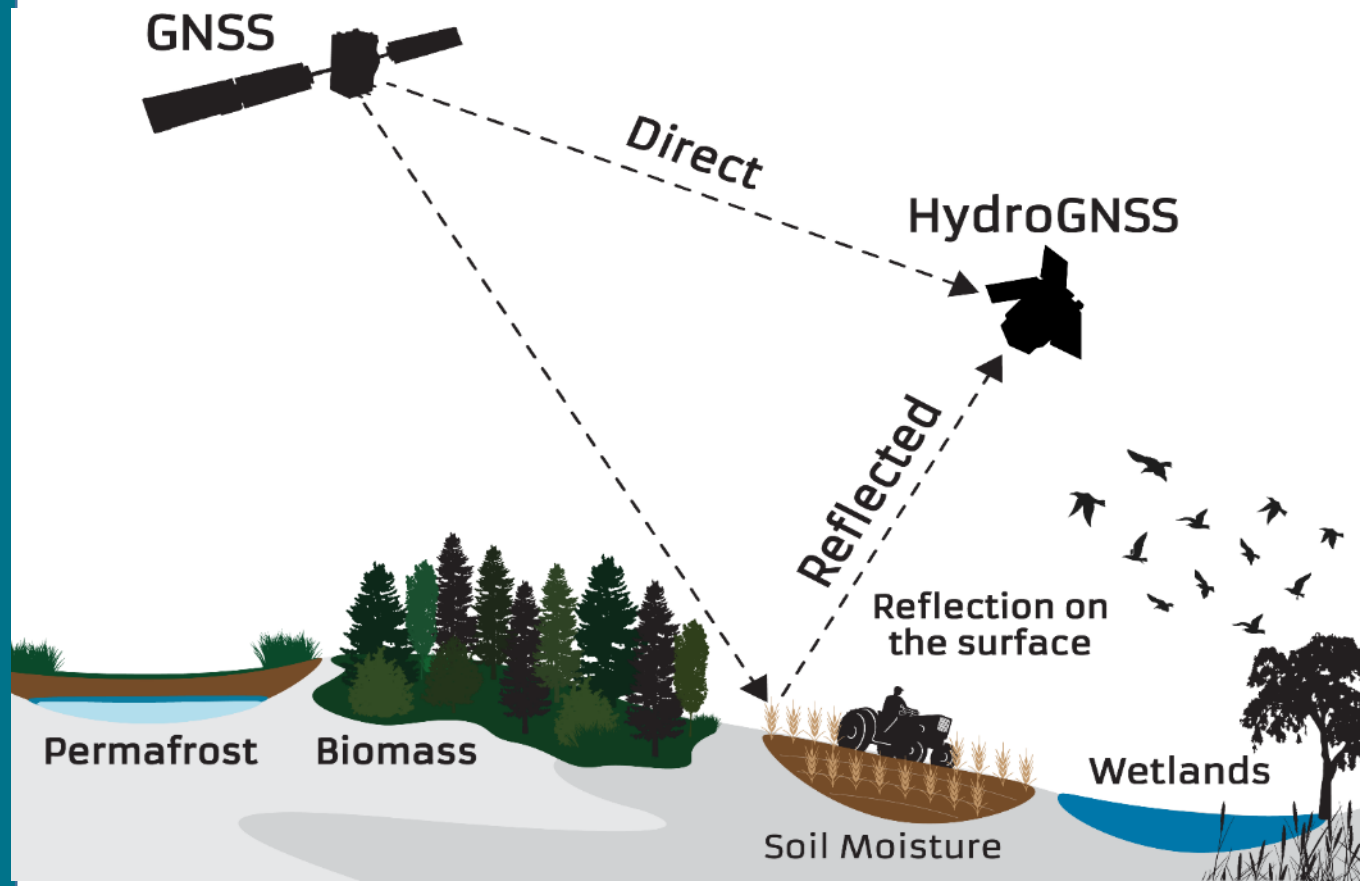
HydroGNSS is latest in long heritage of SSTL's work on reflectometry



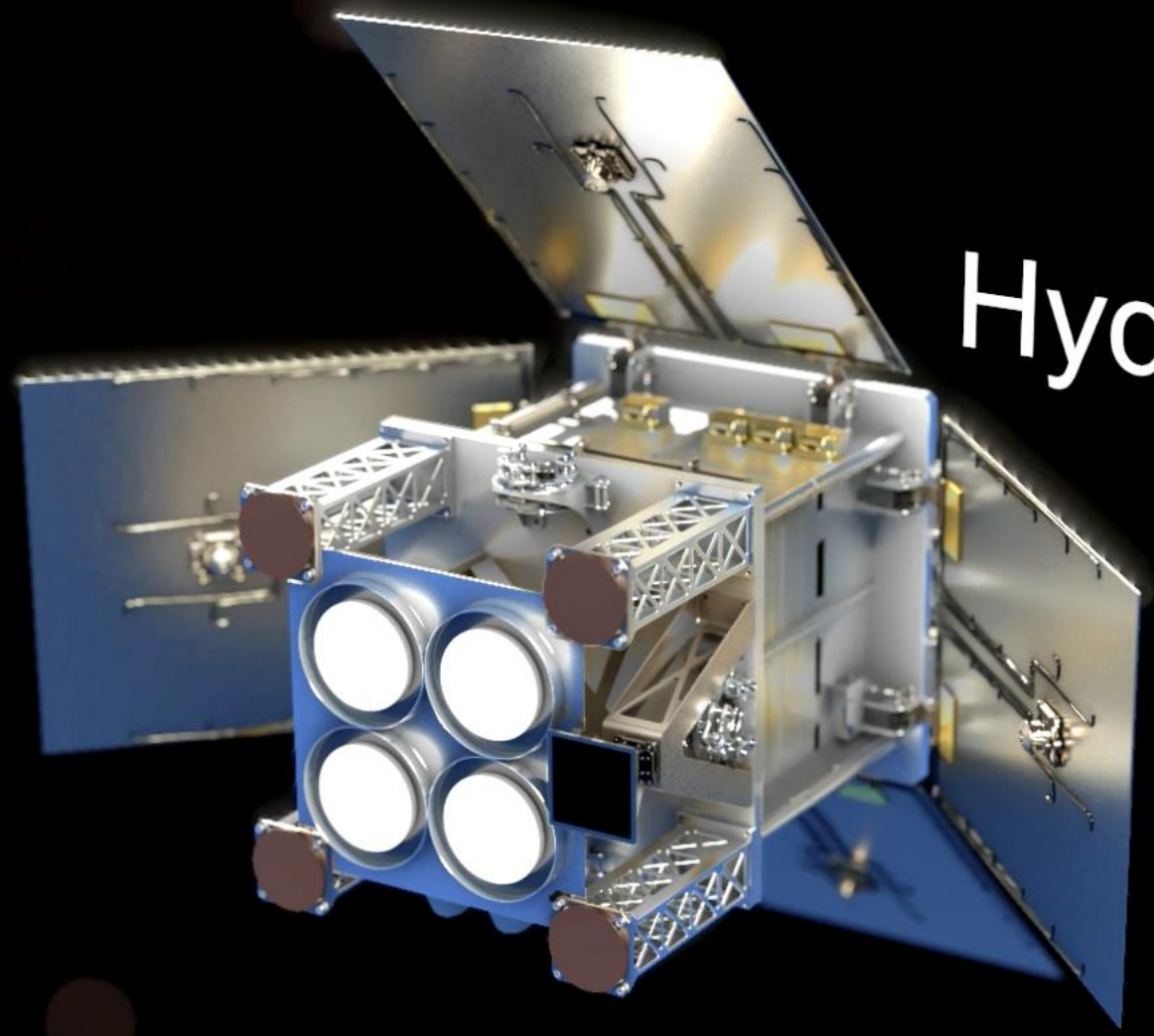

- UK-DMC-1 demonstrated feasibility, differences due to surface characteristics
- TechDemoSat-1 shared millions of measurements over **ocean, land and ice**
  - Same instrument flown on 8 CYGNSS satellites, measurements continue today
- Further potential of GNSS-R still to be tapped into
  - High resolution and phase information accessible from flat surfaces
  - Dual polarisation and dual frequencies still to be explored and exploited

# Scout HydroGNSS and ECVs

- WEF identifies land water-related issues as amongst greatest challenges facing population for future - drought, flooding, biosphere and climate
- HydroGNSS targets land parameters closely linked to hydrological **Essential Climate Variables** (ECVs) defined by GCOS, as needing measurement




- **Soil Moisture** (ECV)
- **Freeze/Thaw** (SM ECV flag, closely linked to Permafrost ECV)
- **Inundation** (SM ECV flag, links wetlands, water extent)
- **Biomass** (Biospheric ECV)
- Evidence that GNSS-Reflectometry can address these ECVs gathered from TDS-1 and CYGNSS studies
  - Uniquely, L-Band forward scattering senses inundation under vegetation

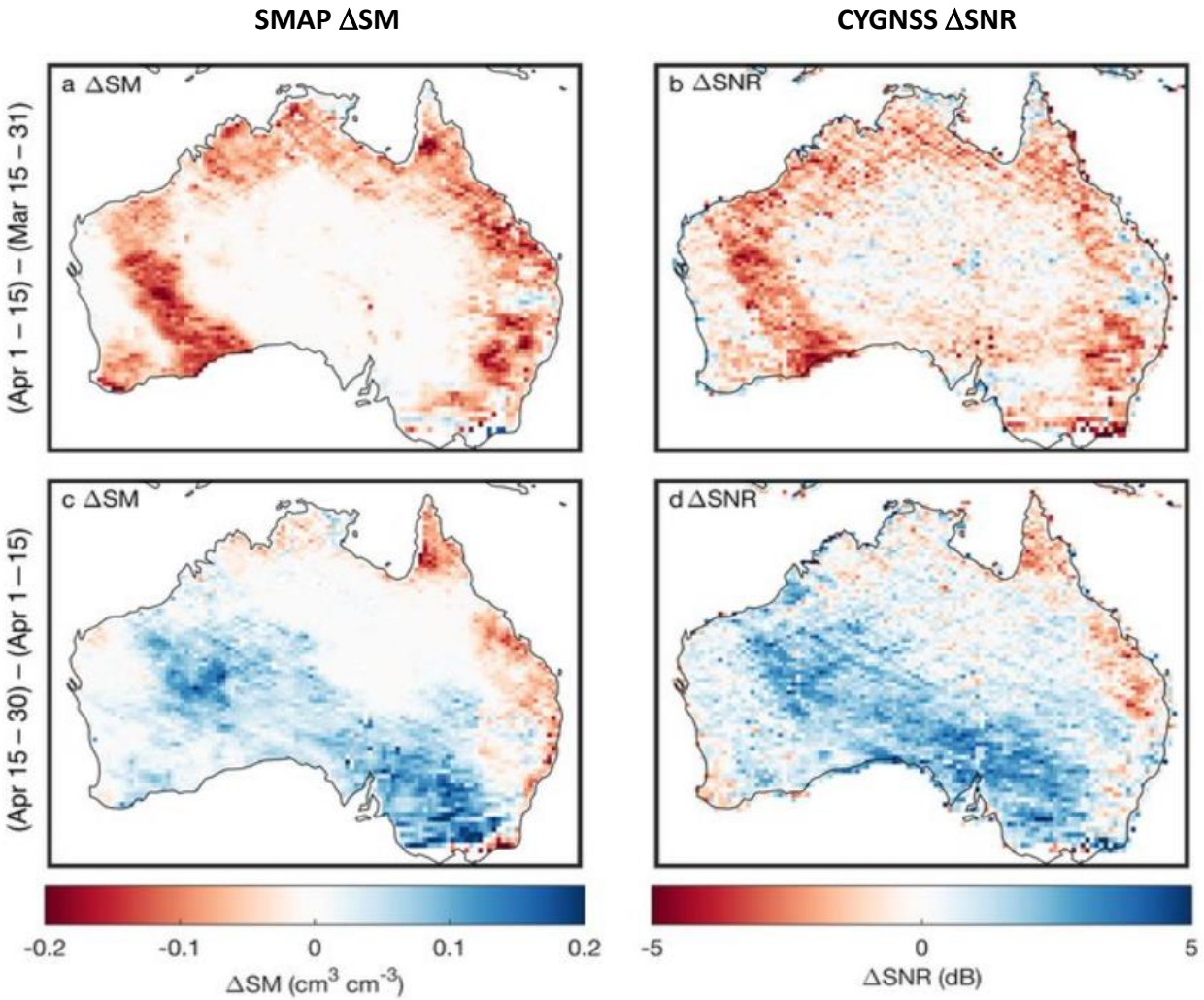


# HydroGNSS

# GNSS-R Evidence – Soil Moisture

- Sensitivity to soil permittivity comparable to monostatic SAR
  - ~**1.5 dB** for 10% soil moisture
- Potential resolution of **2-7 km**
  - Improves as signal becomes coherent
- GNSS-R soil moisture product at low latitudes developed from CYGNSS
  - Now need higher latitude coverage
- Dual polarisation will help detangle moisture and roughness effects

**GNSS-R SNR vs SMAP soil moisture changes** [9]



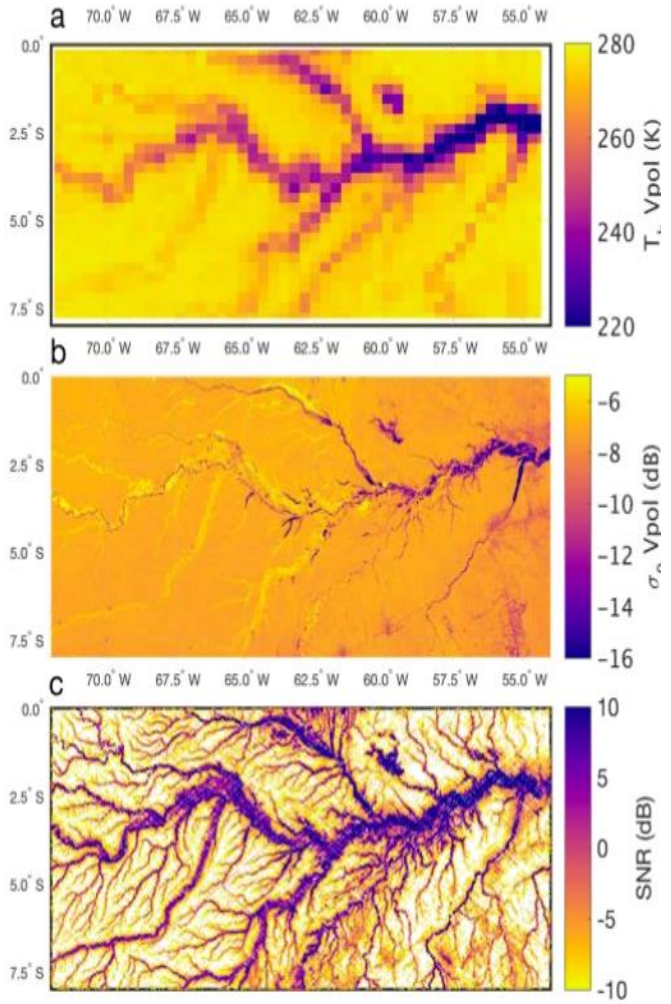
# GNSS-R Evidence – Inundation / Wetlands

- GNSS-R bistatic forward scattering stronger over flat wetlands
- GNSS (L-band) signals can penetrate thick vegetation
  - Uniquely senses water underneath jungle canopies
- Proven concept from spaceborne GNSS-R data (TDS-1, CYGNSS)
- With proposed coherent channel, increased resolution and may allow:
  - Water detection with weaker signals
  - River width and lake altimetry measurements

SMAP Passive

SMAP Active

**GNSS-R** SNR (CYGNSS)

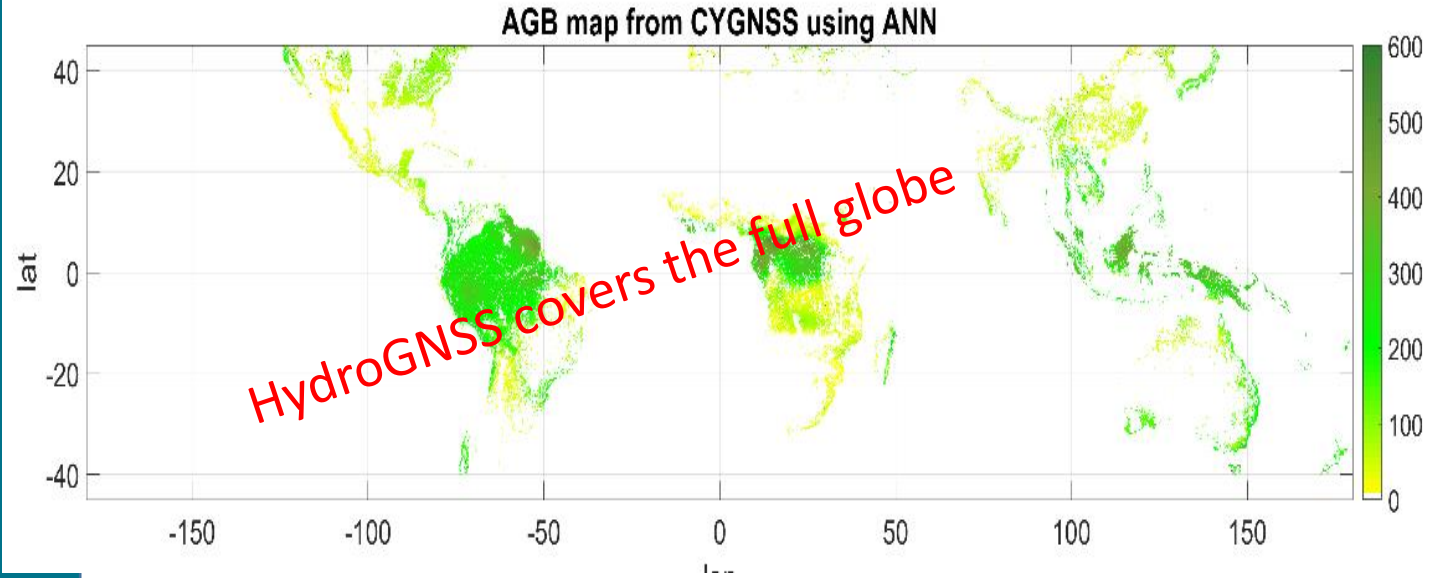


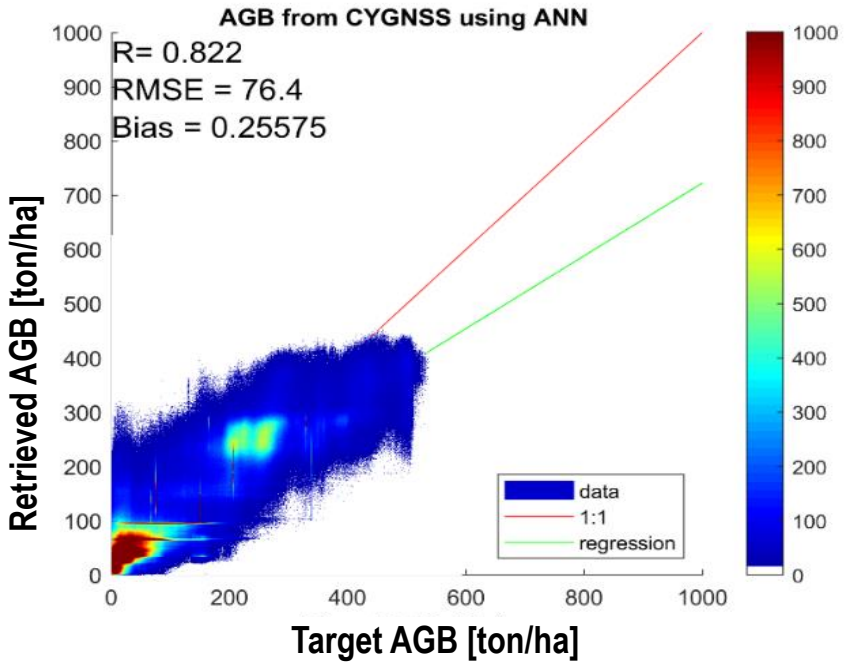

*Amazon basin*

*(Clara Chew, UCAR)*

# GNSS-R Evidence – Forest Biomass

- Vegetation attenuates soil specular reflection due to absorption and scattering
  - Sensitivity of signal wrt biomass (AGB) does not saturate as for L-band backscatter
- Long coherent integration (20msec) highlights that dependence
- Coherent channel and polarisation will help separation and increase gain

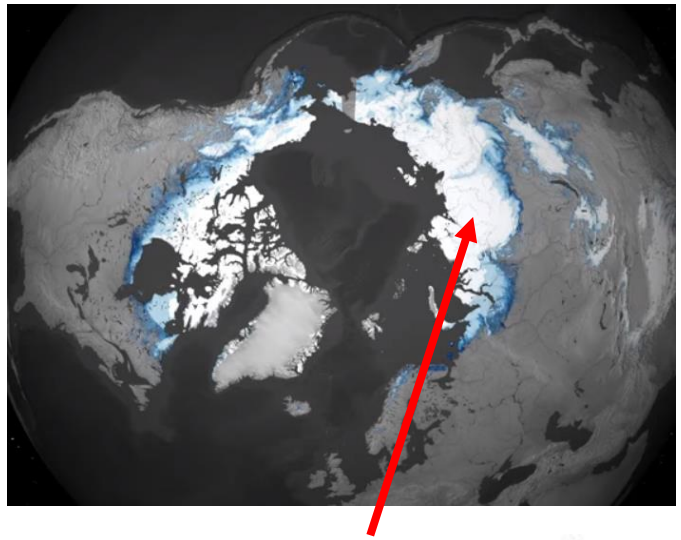


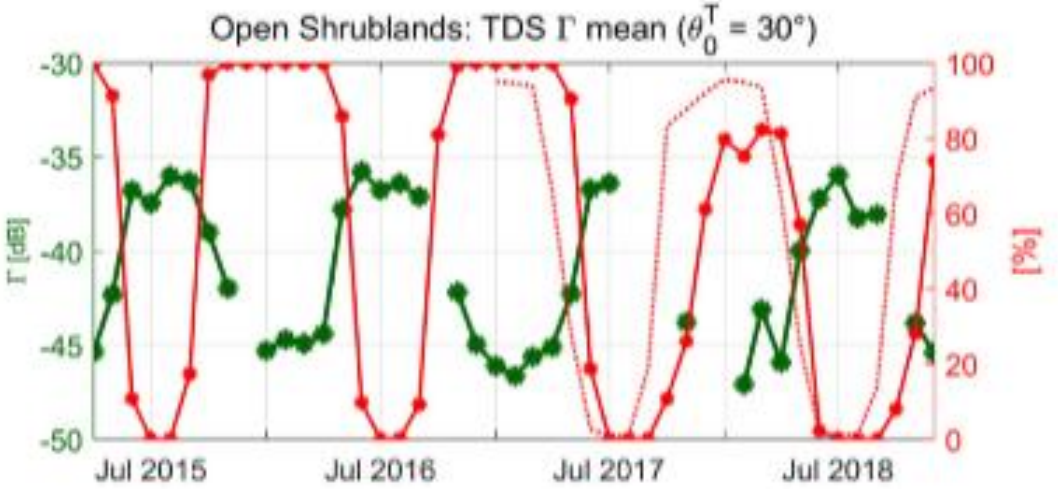




CYGNSS GNSS-R ANN derived Above Ground Biomass (AGB) compared to pan-tropical map from Avitabile [27],[1]

# GNSS-R Evidence – Soil Freeze/Thaw & Permafrost

- Recently demonstrated GNSS-R reflection diminishes in frozen conditions
  - Frozen soil has lower permittivity than thawed soil
  - Unrelated to temperature, c.f. radiometry
- Observed change in reflectivity with F/T matches models
- High similarity between SMAP F/T products, in situ temperatures and GNSS-R (TDS-1) monthly means





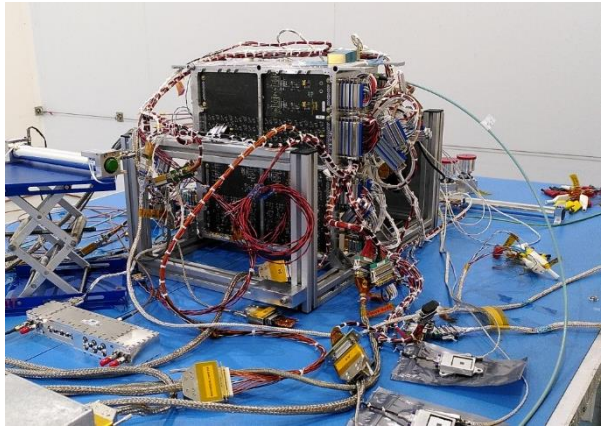

Plot: TDS-1 seasonal reflectivity (green) compared to SMAP F/T product (red) over Siberian permafrost shrublands

# Progress on HydroGNSS Project

- Scientific Readiness Level 5 (SRL-5) achieved on baseline and innovative measurements
  - Science Advisory Group assesses progress
- Technology Readiness Level 6 (TRL-6) achieved in all sub-systems
- Calibration Validation workshop held with science partners and ESA in March 2023

SQM on display at CDR Meeting, Nov 2022

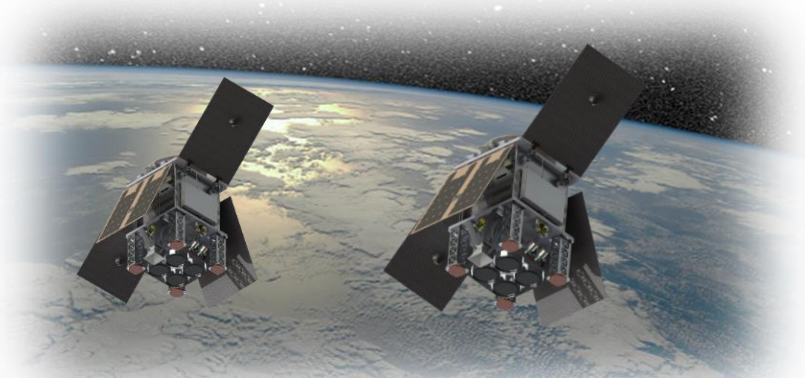
Next Events: Test Readiness Review, Q4 2023
User workshop: ~Q2 2024
Launch: ~Q4 2024
Data available: ~Q3 2025



Preliminary integration of Craft 1 units

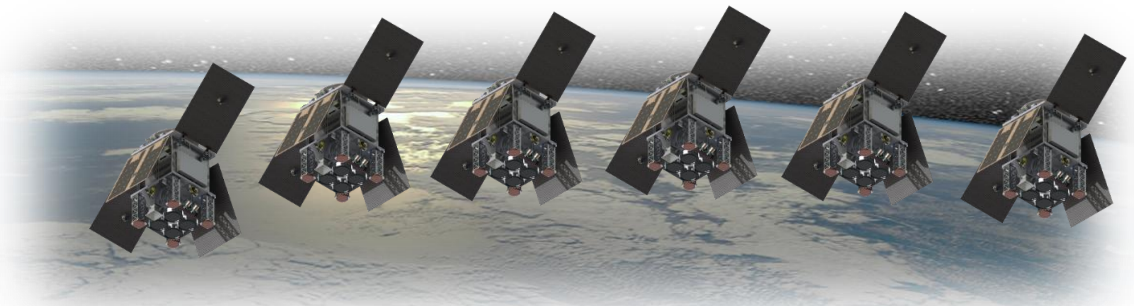
# Conclusions – HydroGNSS

- HydroGNSS is one of the new ESA Scout missions – small satellites for Earth Observation science
  - Mission to measure hydrological climate variables: soil moisture, freeze thaw, inundation, and biomass
  - Next in a series of SSTL GNSS Reflectometry missions going back to UK-DMC (2003)
  - As well as established techniques it explores new ones – dual frequency, dual polarised reception, coherent channels
  - Offers secondary measurements of ocean wind speed and ice extent
- Two HydroGNSS satellites address hydrological ECVs with good spatial resolution, < 25 km
  - Allows coverage at high latitudes, where Freeze/Thaw, and Biomass slowly varying
  - Boreal forests & disturbances can be measured where ESA Biomass Explorer does not operate
  - Covers globe every 15 days, and spatial extrapolation can be used to fill gaps
- Good case for additional GNSS-R satellites
  - Constellation could provide better revisit time and improved temporal resolution, and exploit higher resolution
  - 8 GNSS-R satellites would offer coverage similar to SMOS and SMAP (~3 days) at much lower cost
  - HydroGNSS satellite & instrument design complete, new satellites could be manufactured at low cost
- Sustainable approach - using small satellites for sensing weather and climate as we continue to tackle climate change

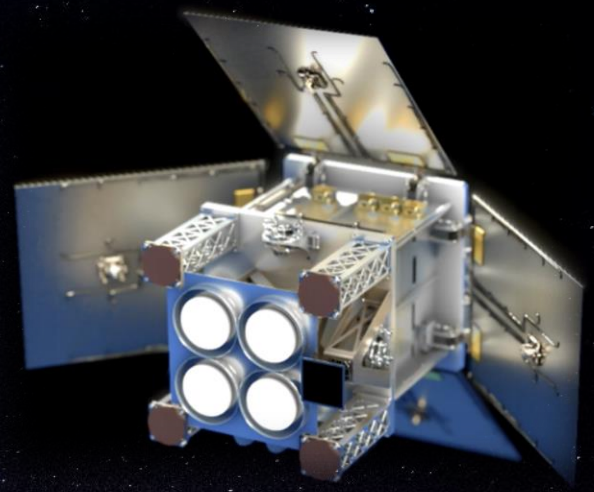


ESA Scout HydroGNSS x 2

Future:



Constellation of HydroGNSS satellites



# Thank you



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