ESA Scout - HydroGNSS GNSS-Reflectometry Mission

Exploiting Satellite Navigation Signals to Monitor Earth's Water Systems

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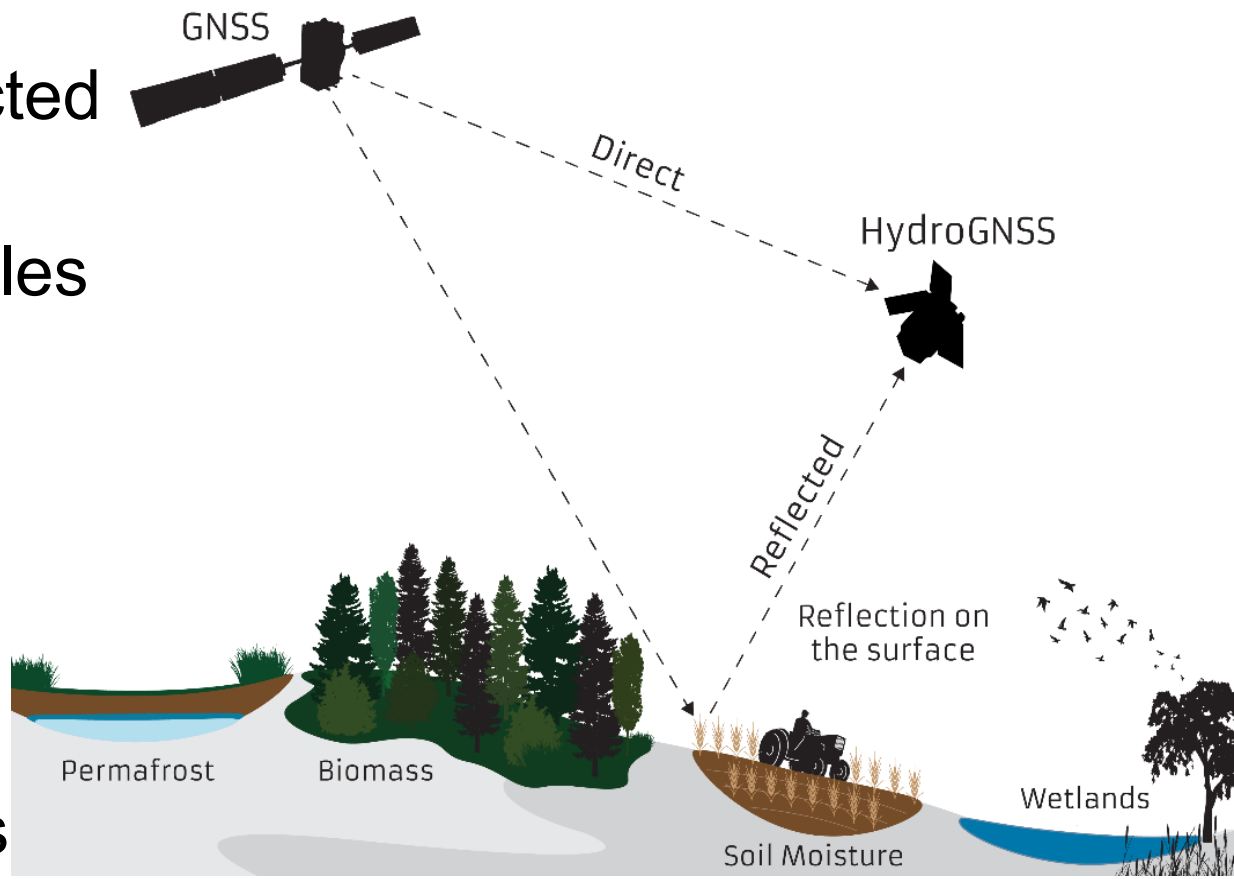
HydroGNSS Scout Mission

- **ESA Scout opportunity**
  - Science driven mini-Earth Explorer mission, €30m budget, KO 2021, Launch in 2024
  - 4 candidate missions down-selected
- **HydroGNSS**: 2 small satellites for sensing Essential Climate Variables
  - *Soil Moisture*
  - *Inundation / Wetlands*
  - *Freeze / Thaw*
  - *Biomass*
- **GNSS-Reflectometry (GNSS-R)** cost-efficient remote sensing exploiting navigation satellite signals as forward scattering radar sources



HydroGNSS Science Objectives

- Using GNSS-R 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

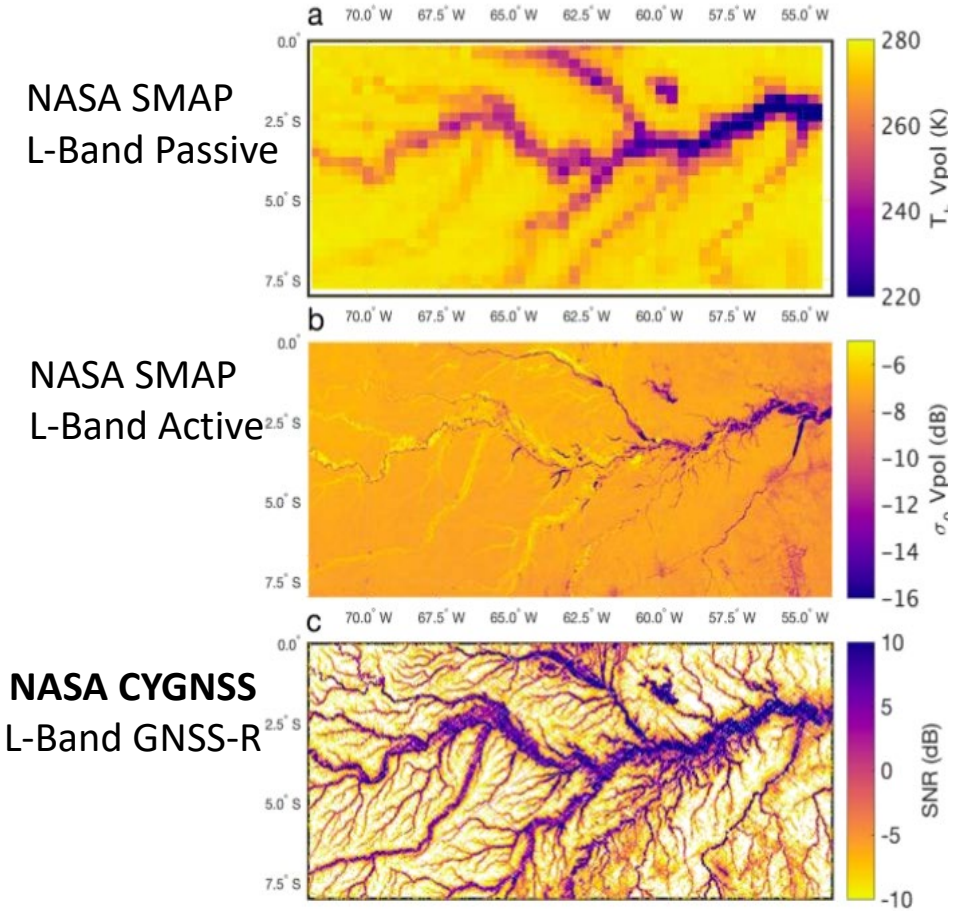
GNSS-Reflectometry - Unique & Complementary

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

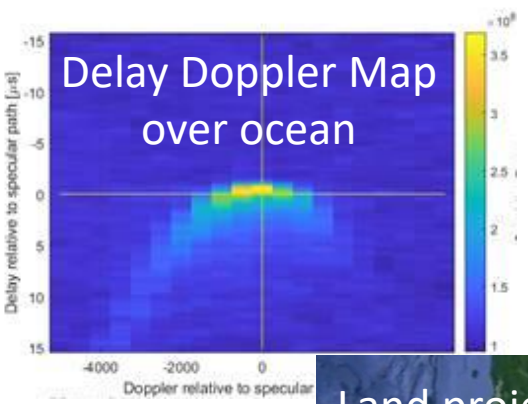
Complementarity

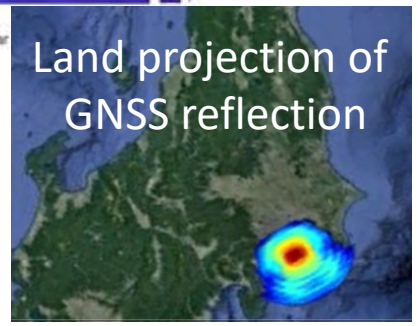
- Complements SMOS, NASA SMAP, L-Band satellites at end of life with *no immediate successors*
- Complements Earth Explorer Biomass – covers high latitudes where Biomass cannot operate
- Good complement to C-band radar (ASCAT, Sent-1)



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

Low Risk, High Gain: Established & New Measurements



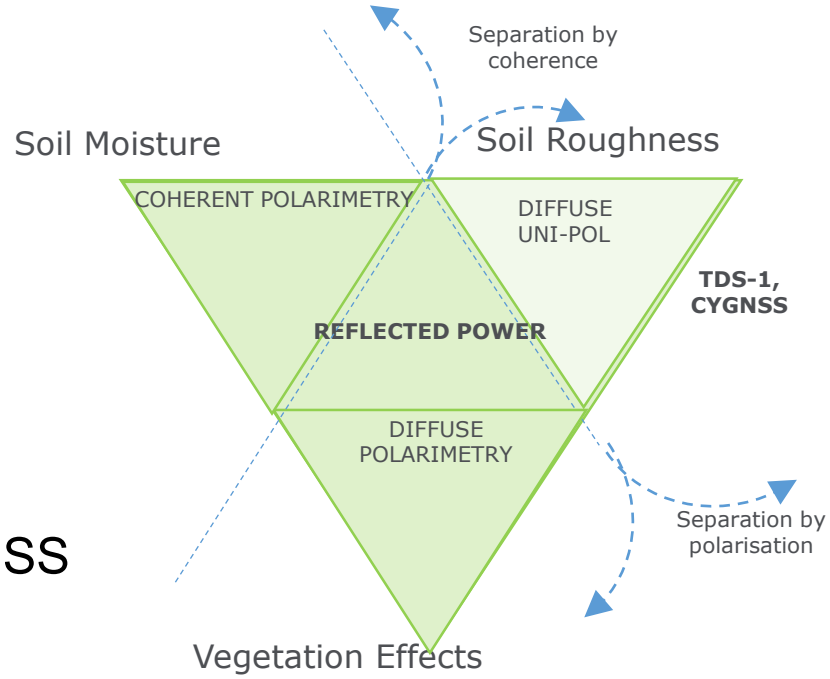


Heritage from TechdemoSat-1 and NASA CYGNSS

- 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

Plus Innovative GNSS-R Measurements

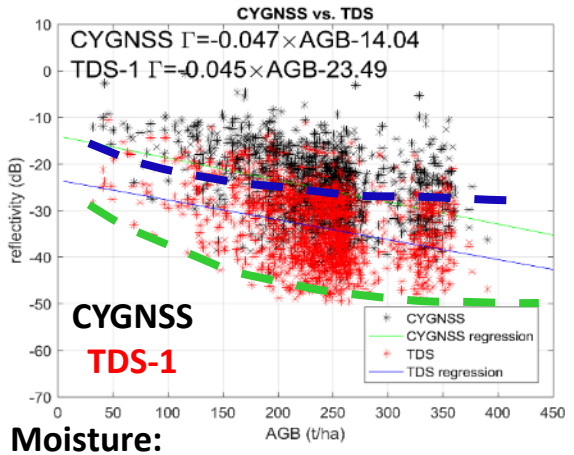
- Multi-GNSS reception, including GPS and Galileo
  - Better sampling and coverage, finer resolution
- Left and Right Polarisation DDMs
  - Mitigation of vegetation and soil roughness
- Higher rate coherent complex channel
  - Separation of diffuse / coherent terms
  - Fine scale mapping over wetlands, rivers => 1 km
- Dual frequency L1/E1 and L5/E5
  - Exploring potential of dual frequency and wideband GNSS (fine resolution)



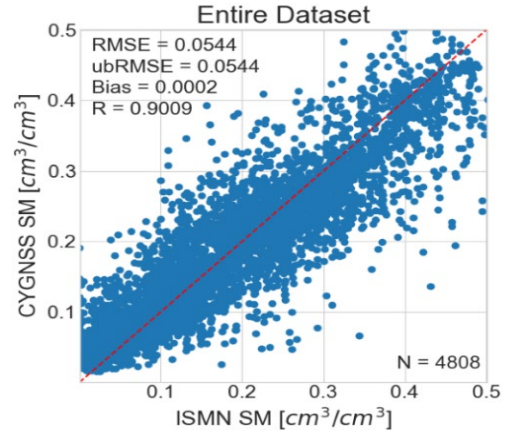
HydroGNSS Scientific Readiness

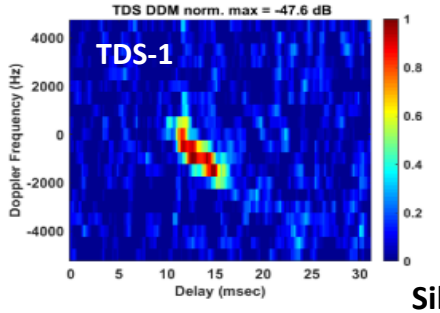
- Sensitivity of GNSS-R signals to HydroGNSS primary products demonstrated in orbit
  - Using data from TechDemoSat-1 and CYGNSS
  - Maturity in Level 2 Geophysical Model Functions and validation methods
- End-to-End simulators in place and validated against TDS-1 in-orbit measurements
- Recent refinements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

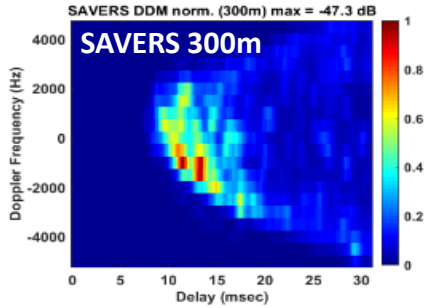
Biomass: (Santi et al., 2020, in review)



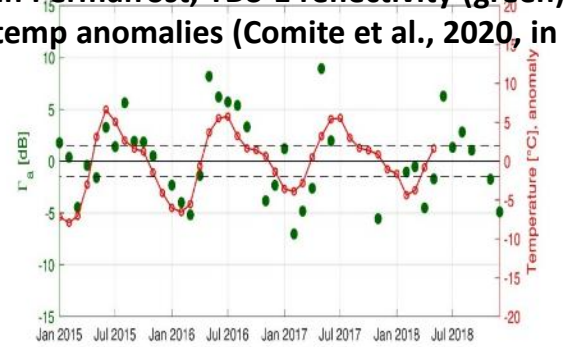
Soil Moisture:
Eroglu et al., 2019 doi:10.3390/rs11192272







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



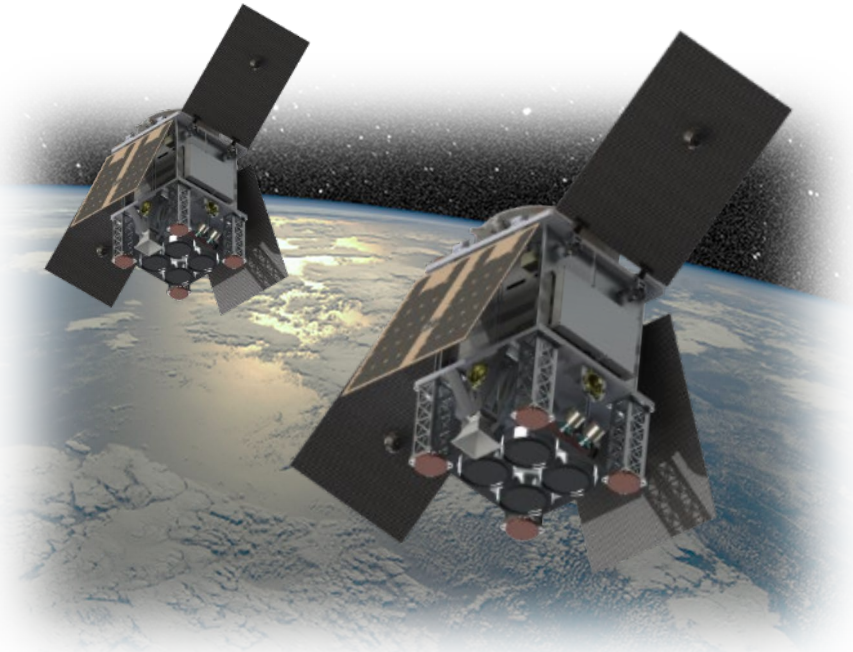
HydroGNSS Instrument & Mission

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

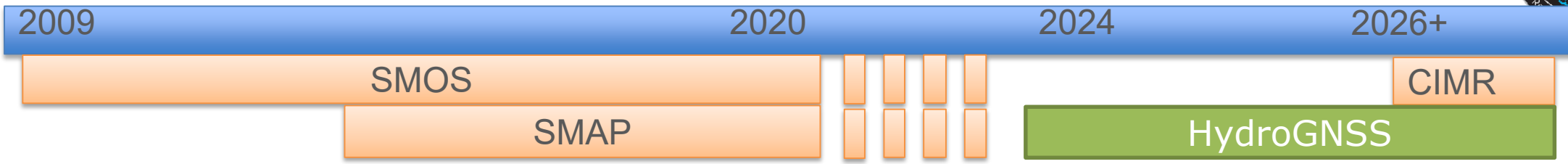
- SSTL-21, 40 kg variant of SSTL-Micro, 5 year life target
- 3-axis attitude stabilised with star tracker
- Xenon propulsion, 30 m/s for phasing and end of life disposal
- Commissioning and command from Guildford
- Up to 160 Mbps X-band downlink via Svalbard
- Payload Data Ground Segment built upon www.merrbys.org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

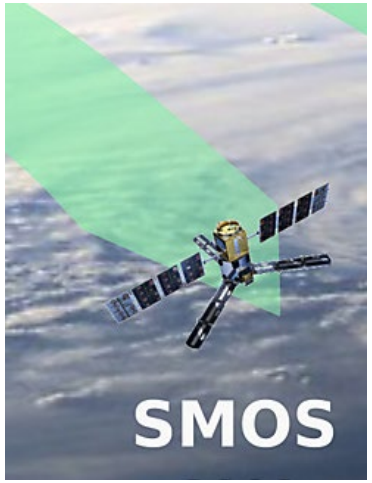


Constellation

- 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

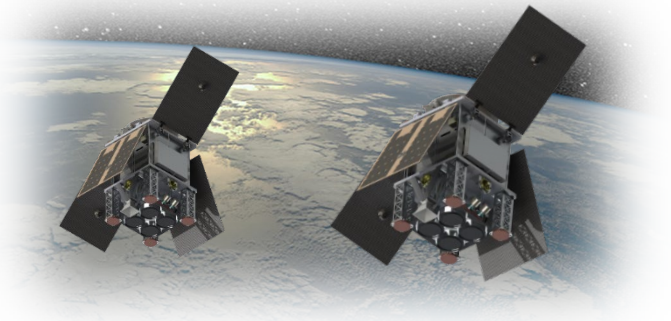
HydroGNSS Cost-Efficient L-Band Continuity Mission



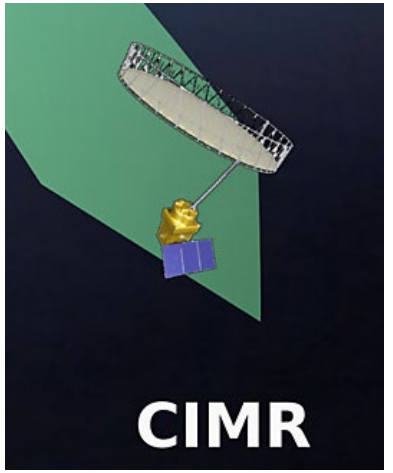


SMOS (2009)
Resolution 35-50 km
Mass – 670 kg
Cost - €315m (2009)
(c.f. NASA SMAP ~1 tonne, $1b)
Operating beyond end of life

HydroGNSS offers better resolution at L-band for order less in cost



HydroGNSS (2024)
Resolution 1-25 km
Mass 40 kg per craft
Budget €30m for 2 craft
(Requires ~6 craft
to match SMOS
coverage)



CIMR (2026+)
L-Band (plus others)
Resolution 36 x 64 km
Mass >700 kg TBD
7 metre antenna
Budget >€400m TBD

HydroGNSS Conclusions

- Soil moisture and other hydrological variables remain inadequately measured, especially at higher latitudes (more so after SMAP and SMOS missions end)
- HydroGNSS targets four ECVs:
  - Soil moisture, inundation, freeze / thaw, and biomass
- Two small GNSS Reflectometry satellites, 40 kg each
  - Low risk, but high rewards with first of a kind new GNSS-R measurements
- Low cost route towards unprecedented temporal and long-term continuity with following constellation
- Phase B mission kick-off ~Q2 2021, launch in 2024
  - Subject to mission selection in October 2020

Thank you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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