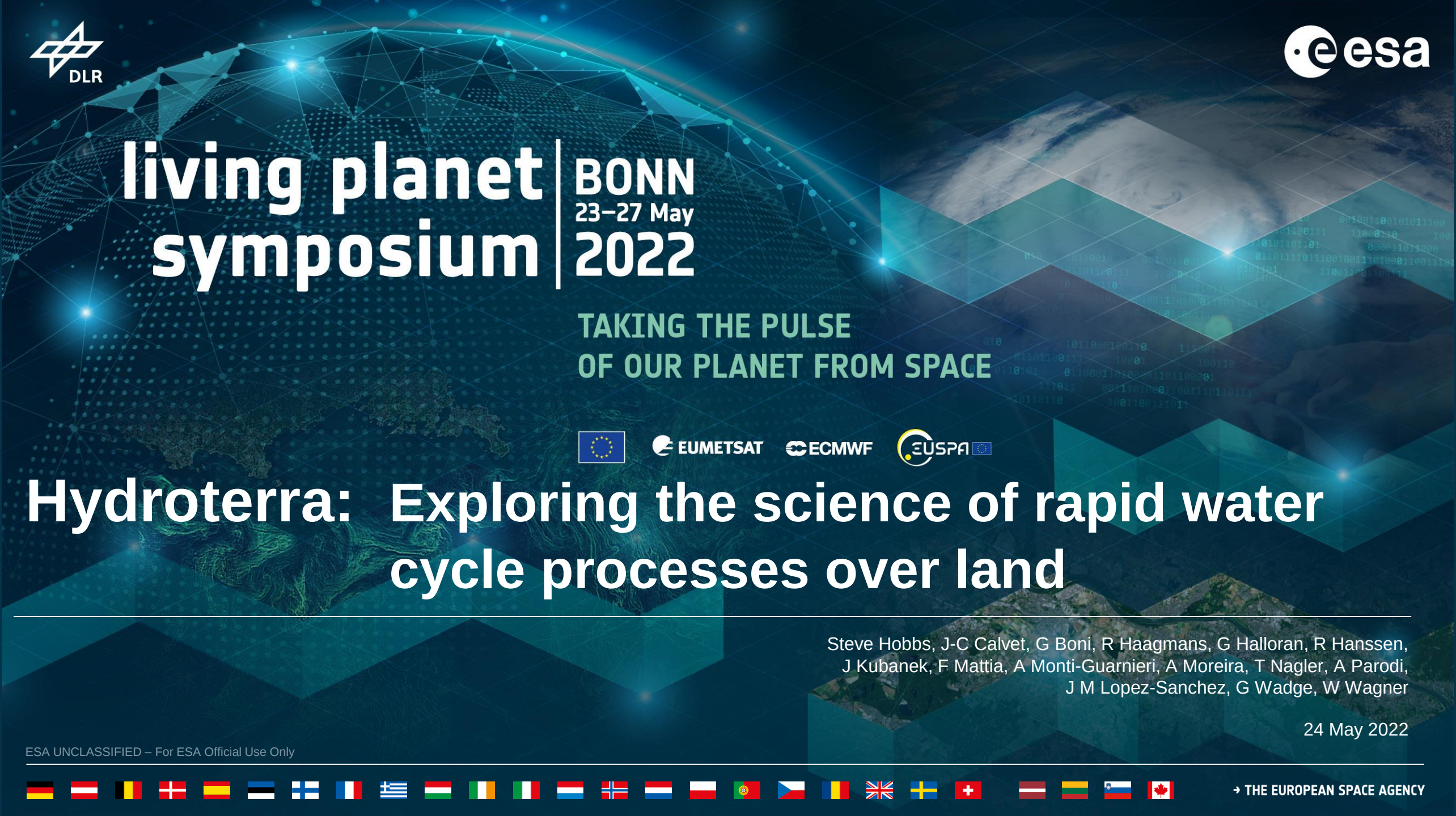


Hydroterra: Exploring the science of rapid water cycle processes over land

Steve Hobbs, J-C Calvet, G Boni, R Haagmans, G Halloran, R Hanssen, J Kubanek, F Mattia, A Monti-Guarnieri, A Moreira, T Nagler, A Parodi, J M Lopez-Sanchez, G Wadge, W Wagner

24 May 2022

Overview of Presentation

Hydroterra

- EE10 candidate, Phase 0 study by science and industry teams 2018-20

(documented in ESA RfA, 2020)

1. Science Motivation
   - Science of water cycle processes over hours to few days – current observation gap
2. Observation Options
   - Radar – either GEO or LEO
3. Hydroterra baseline: Geosynchronous SAR
   - Status on completion of Phase 0
4. Hydroterra LEO constellation
5. Discussion

Earth Explorer 10 Candidate Mission Hydroterra
Report for Assessment

Science need: Rapid water cycle processes over land

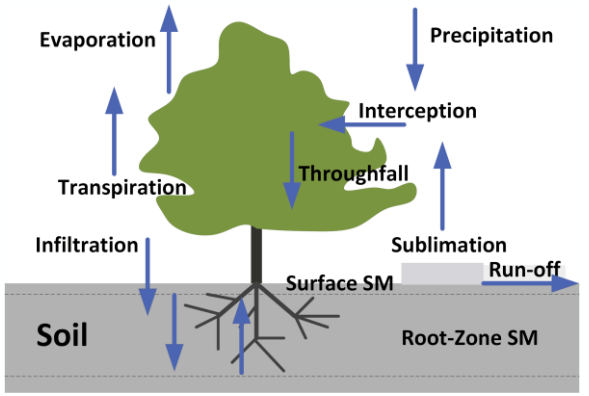
It's surprising that important aspects of the water cycle are not well understood

Our focus

- Rapid (few hours to few days) processes over land – and at scale

Example science questions

- **Mesoscale Convective System** formation and dynamics
  - Responsible for 50+% of rainfall in tropics, and becoming more important as climate changes
  - Significant hazard for regions such as the Mediterranean (floods, landslides)
- **Partitioning of water** over land (rainfall interception, evaporation, soil moisture, run-off; energy balance)
  - Poorly observed (and therefore poorly modelled) in NWP
- **Snow accumulation and diurnal thaw / re-freeze**
  - Significant input for mountain hydrology
- **Hints of new science** from field experiments, e.g. vegetation physiology



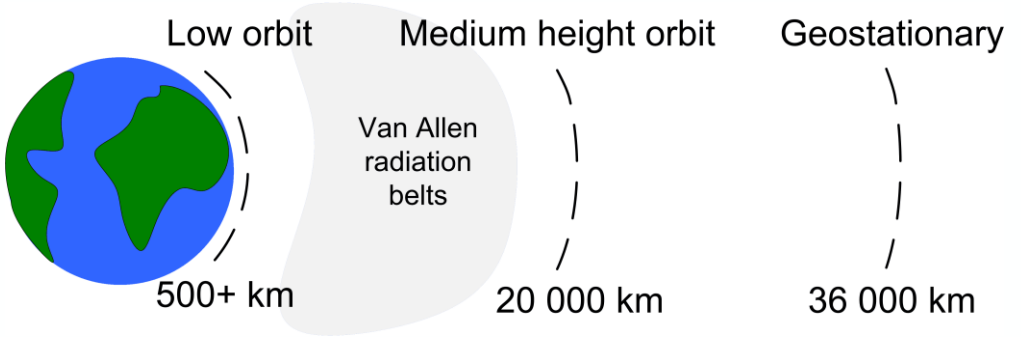
Also opportunistic science from the measurement capability

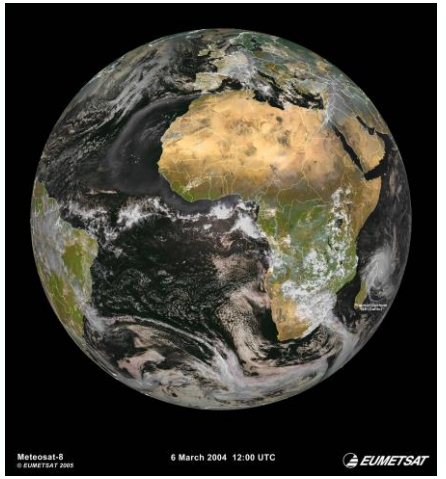
- e.g. Earthquakes, volcanoes, ionosphere, …

Observation Options

How can rapid water cycle processes be observed?

- **Radar**
  - Sensitive to water as liquid and vapour
- Orbit choice:
  - **Geosynchronous** (GEO): permanent view, single satellite, large range
  - **Low Earth Orbit** (LEO): requires constellation for sub-daily imaging





Technology maturity?

- Radar – high maturity; but often a demanding payload
- GEO radar – not yet demonstrated (but Chinese mission due)
- LEO radar – good heritage; some “New Space” commercial constellations now in orbit

Status of the Hydroterra Baseline – GeoSAR

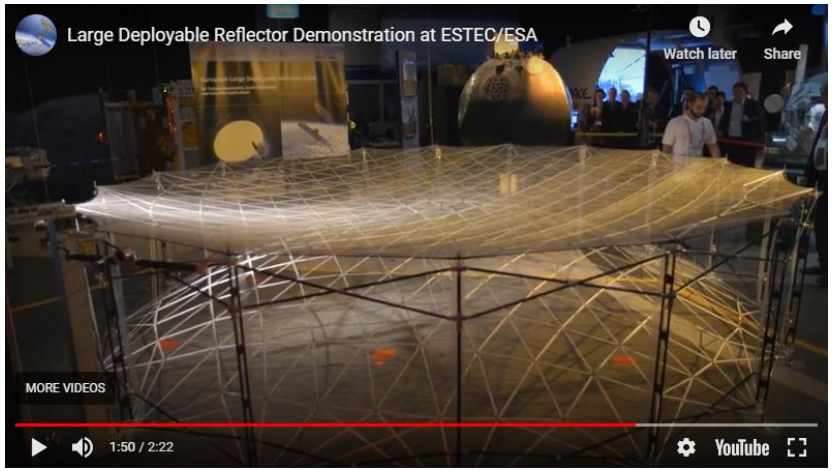
On completion of Phase 0

- **Science Case validated**
  - Community of interested scientists keen to exploit its excellent temporal sampling
- **Mission Concept validated**
  - No show-stoppers, but some technology challenges – especially large deployable antenna, high power RF amplifiers, polarimetry, retrievals; *and mission cost*

Recent continuation studies

- **Field campaigns**
  - Continuing analysis
  - Hints of new science from observing the diurnal cycle
- **Simulation**
  - End-to-end simulation

    Demonstrating atmospheric corrections with retrieval of surface changes



Field Campaigns related to Hydroterra

Field campaigns provided important validation of the proposed observation concepts

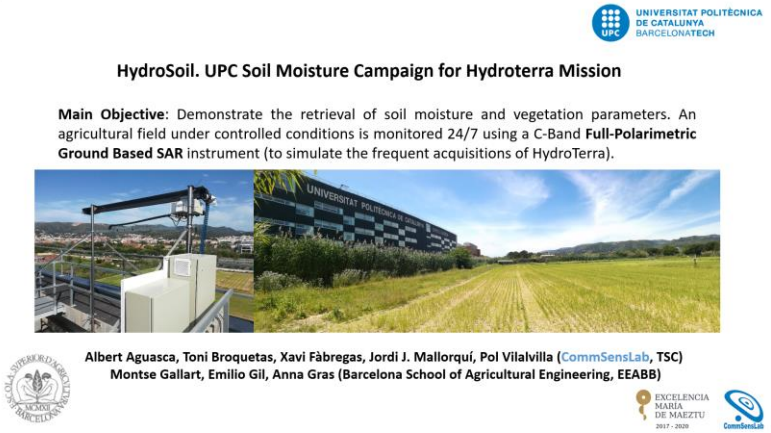
- We are still analysing the observations

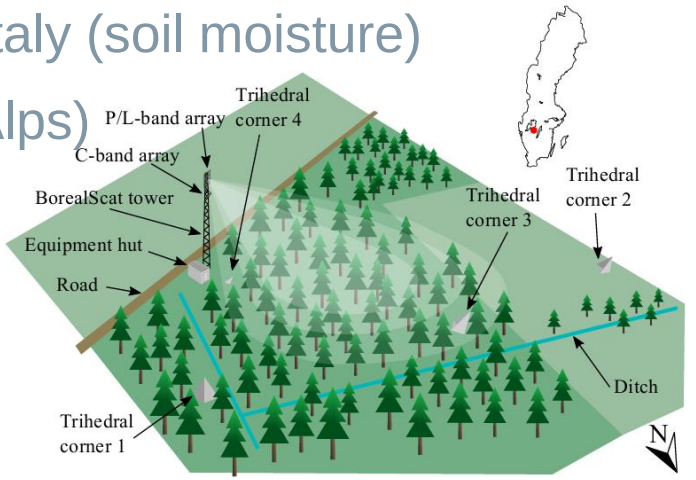
Relevant campaigns:

- **HydroSoil** (intensive SAR imaging of agricultural area through growing seasons – Spain)
- **BorealScat** (forest monitoring of boreal forest - Sweden
- **SARSim-HT** - DLR Airborne SAR: simulated GeoSAR acquisitions, diurnal processes – Germany (vegetation), Alps (snow water content by InSAR), and Italy (soil moisture)
- **Alpine snow** observations (winter – spring snow observations – Alps)

Significant effort has gone into these from several of Europe's leading research teams with ESA support

- Significant resource for research in EO generally



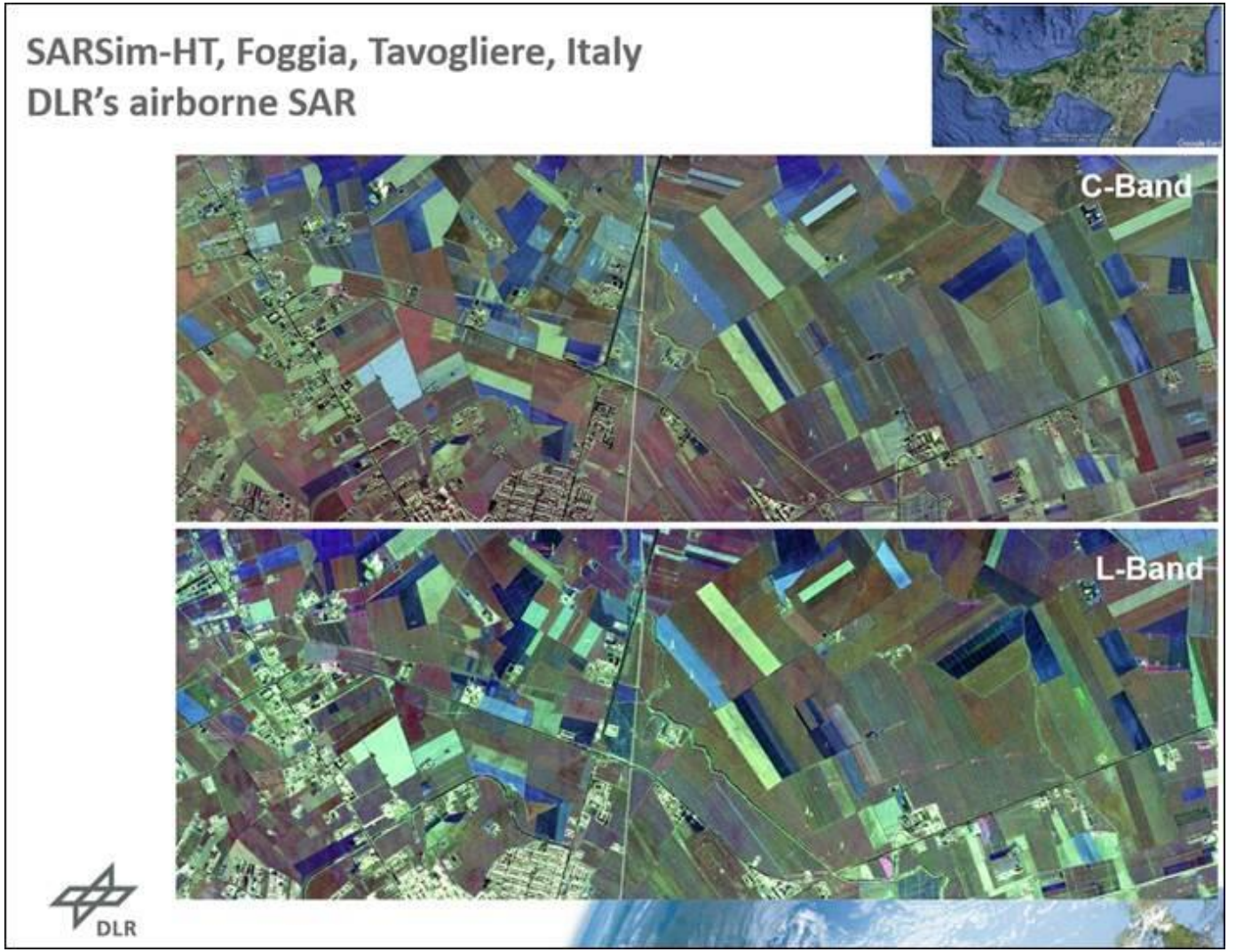


BorealScat expt (Monteith, 2020)

Field Campaigns Update

SARSim-HT - DLR / CNR Soil moisture using DInSAR

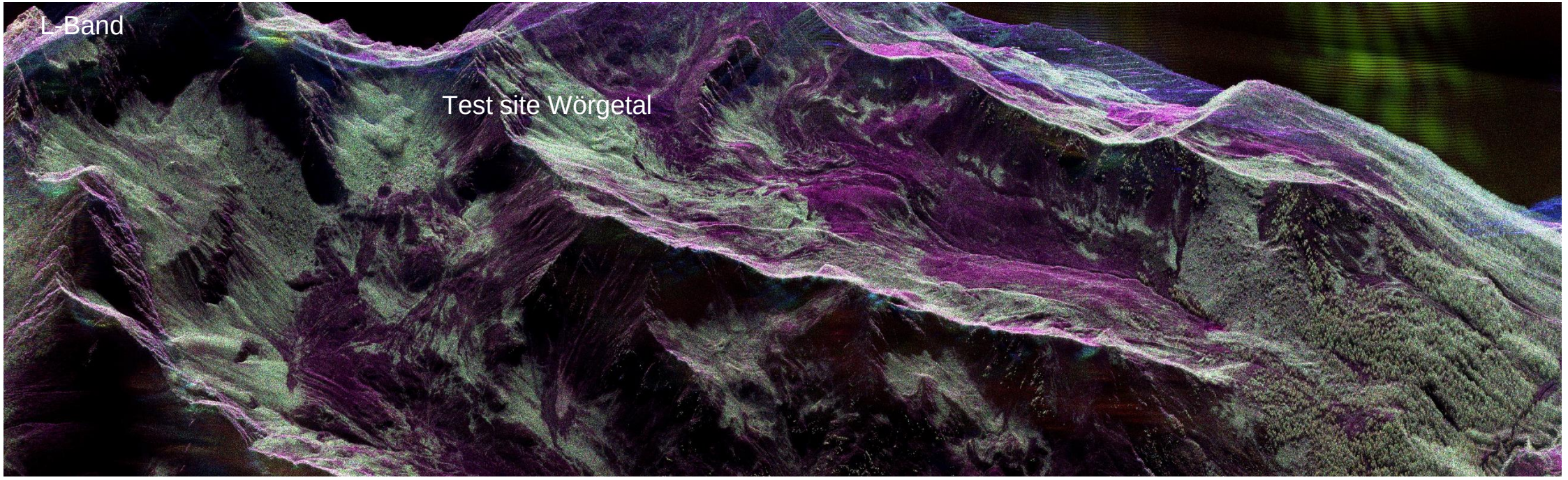
- Soil moisture signals investigated using frequent InSAR imaging
- Observations during the 2022 growing season

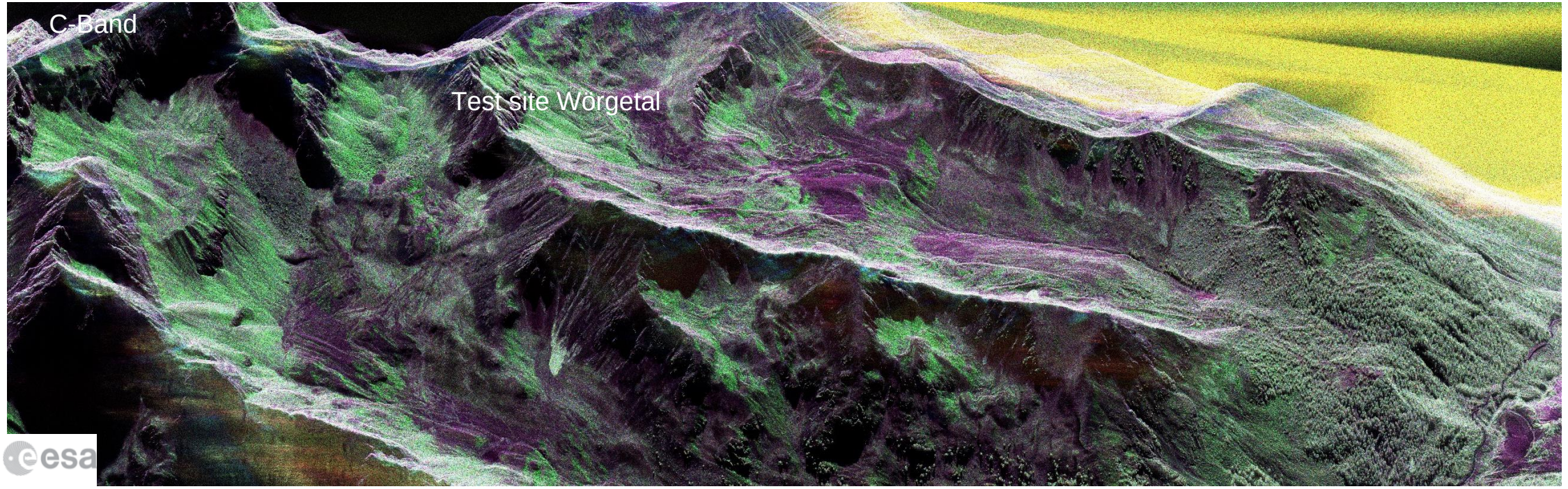


SARSim-HT – Snow Mass Campaign Wörgetal / Kühtai Austria, March 2021

Setting-up Corner Reflectors as Reference and in situ Measurements of Snow Properties during Data takes

Austrian Alps: Dual-band acquisitions





A Hydroterra LEO Smallsat SAR Constellation?

Active area of commercial development, e.g. Iceye, Capella

Iceye X-band SAR (85 kg satellite)

Full constellation for ~hourly coverage would be hugely expensive

- So sacrifice coverage to achieve ~hourly repeat through (part of) the day with 24 hr repeat
- Complement with Sentinel and commercial images as available – innovative mission concept

Recent study of the mission feasibility at Cranfield suggests that a constellation of ~6 satellites *may be* capable of much of the Hydroterra science case (and more) within an Earth Explorer budget

- Global science, but < 10% of globe is imageable
- Justifies further study

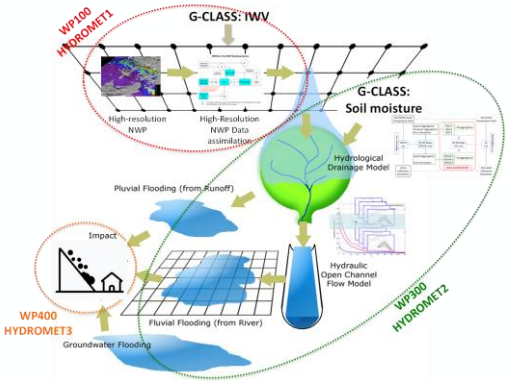
The following simulation shows one day of SENTINEL-1A acquisitions using the Interferometric Wide swath mode over land with a 250 km swath width.

Sentinel-1 acquisition (1 day) – illustrates minimal constellation coverage with 1-day orbit repeat (smallsat swath ~80 km?)

Discussion

Hydroterra

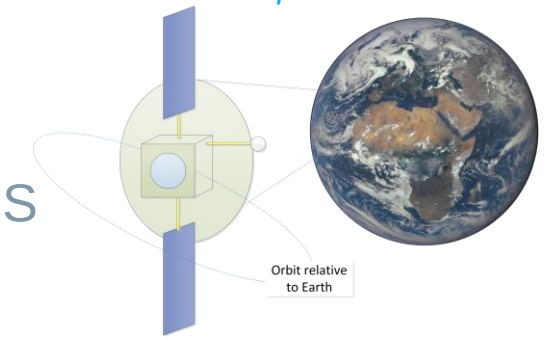
- **Science need** is still valid; climate change only strengthens its case
  - Opportunity for “routine” monitoring, e.g. high resolution NWP?
- **GEO SAR** would be a significant innovation
  - Likely to reveal new capabilities; complements existing LEO systems
- Phase 0 matured our understanding of the mission concept and science rapidly



Hydroterra (= G-CLASS) science and mission concepts

LEO SmallSat SAR Constellation – significant alternative to GEO SAR

HAPS for technology demonstration / regional service – growing interest in HAPS



Study highlights underlying questions which mission PIs (and reviewers, funders) wrestle with:

1. How to measure the relative **scientific value** of different missions / mission options?
2. **Estimating cost** of mission concepts (relatively and absolutely)?

Conclusions

Thank you to the industry and science teams which contributed to Hydroterra

- Significant effort by ESA and partners for the Phase 0 study

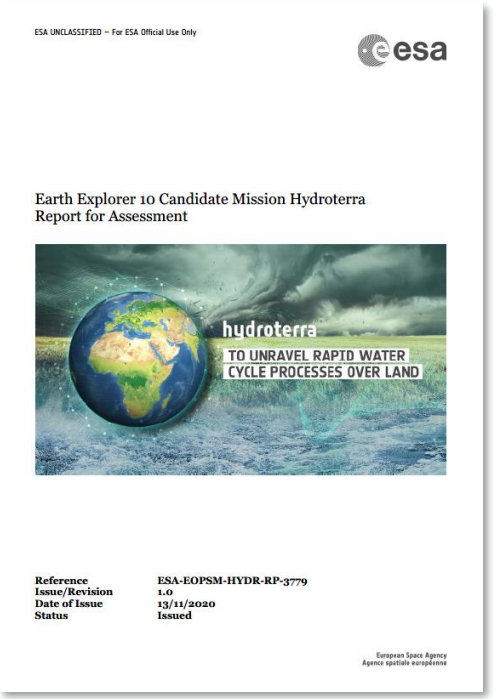
Science need to understand rapid water cycle processes still stands

- We note the important **societal impacts** related to the science; likely to worsen as climate changes

Geosynchronous SAR – powerful measurement capability, seems feasible

- Exciting potential, with manageable implementation challenges

Study of the Hydroterra science and mission concept(s) is continuing



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