1st EnMAP User Workshop - 10-11 October 2023

The Copernicus Hyperspectral Imaging Mission For The Environment (CHIME): Current Status

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European Space Agency

Tim Lemmens, Peter Strobl, Cristina Ananasso***
European Commission

Andrew Skidmore, Heike Bach, Eyal Ben-Dor, Sabine Chabrillat, Cindy Ong, Claudia Giardino, Giovanni Rum, Jean-Baptiste Feret, Luis Guanter#, Martin Schlerf, Martin Schodlok, Michael Schaepman, Robert O. Green, Roberto Colombo, Stuart Marsh, Tobias Storch
Members of the CHIME MAG

CHIME
Copernicus Hyperspectral Imaging Mission for the Environment

* now at ISSI Bern
** now at University of Zurich
*** now at ECMWF
# now in ACEO

PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

co-funded with esa

CHIME

Copernicus Hyperspectral Imaging Mission for the Environment

soil properties
crop health
raw materials
biodiversity
water quality

ROSE-L

L-band Radar Observing System

geohazards
polar ice
forest management
food security
maritime surveillance

LSTM

Land Surface Temperature Monitoring

sustainable agriculture
water resources management
drought
urban heat islands

CIMR

Copernicus Imaging Microwave Radiometer

sea-ice concentration/extent
global ocean and cryosphere
soil moisture and vegetation

CO2M

Copernicus Anthropogenic Carbon Dioxide Monitoring

carbon dioxide and methane from human activity

CRISTAL

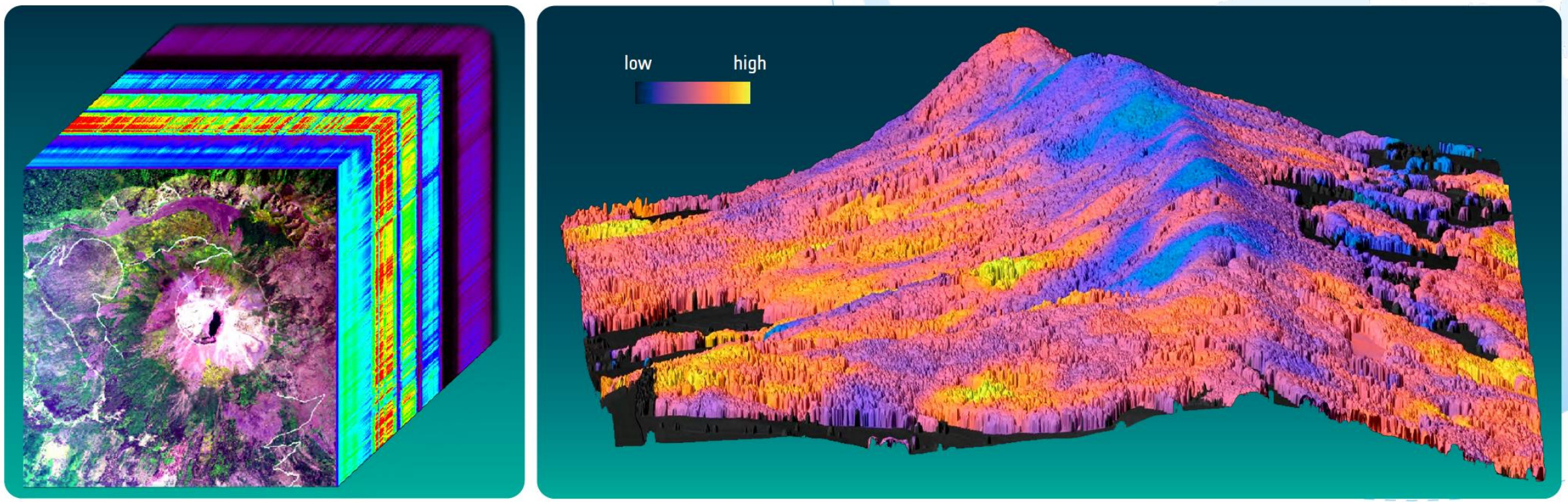
Copernicus Polar Ice and Snow Topography Altimeter

sea-ice thickness
ice sheets and glaciers
snow
polar oceanography
coastal and inland waters

→ THE EUROPEAN SPACE AGENCY

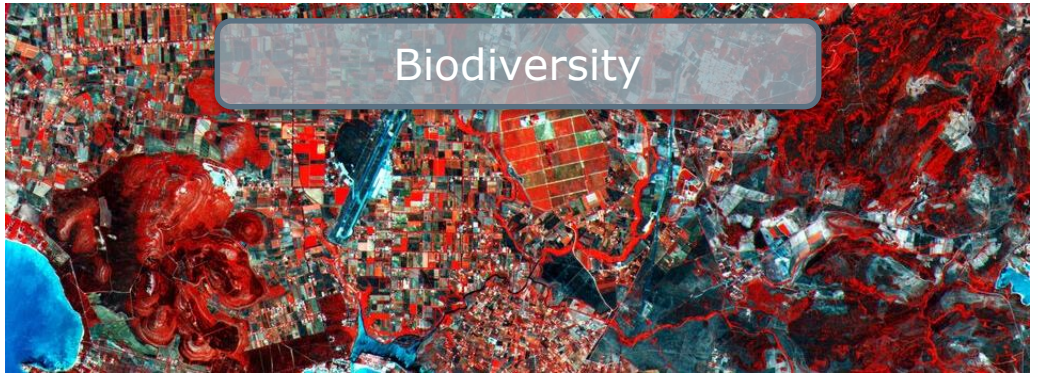
CHIME Mission Objectives

- Provide routine hyperspectral measurements in support of EU- and related policies for the management of natural resources & assets
- Support food security, agriculture and raw materials, soil properties
- Secondary Applications: biodiversity and ecosystem sustainability, forestry management, environmental degradation, lake/coastal ecosystems and water quality, snow grain size/albedo, snow impurities)



Physiological diversity of a temperate forest (Airborne imaging spectroscopy APEX data - Schaepman, Jehle et al. 2015)

Not forgotten: secondary applications!



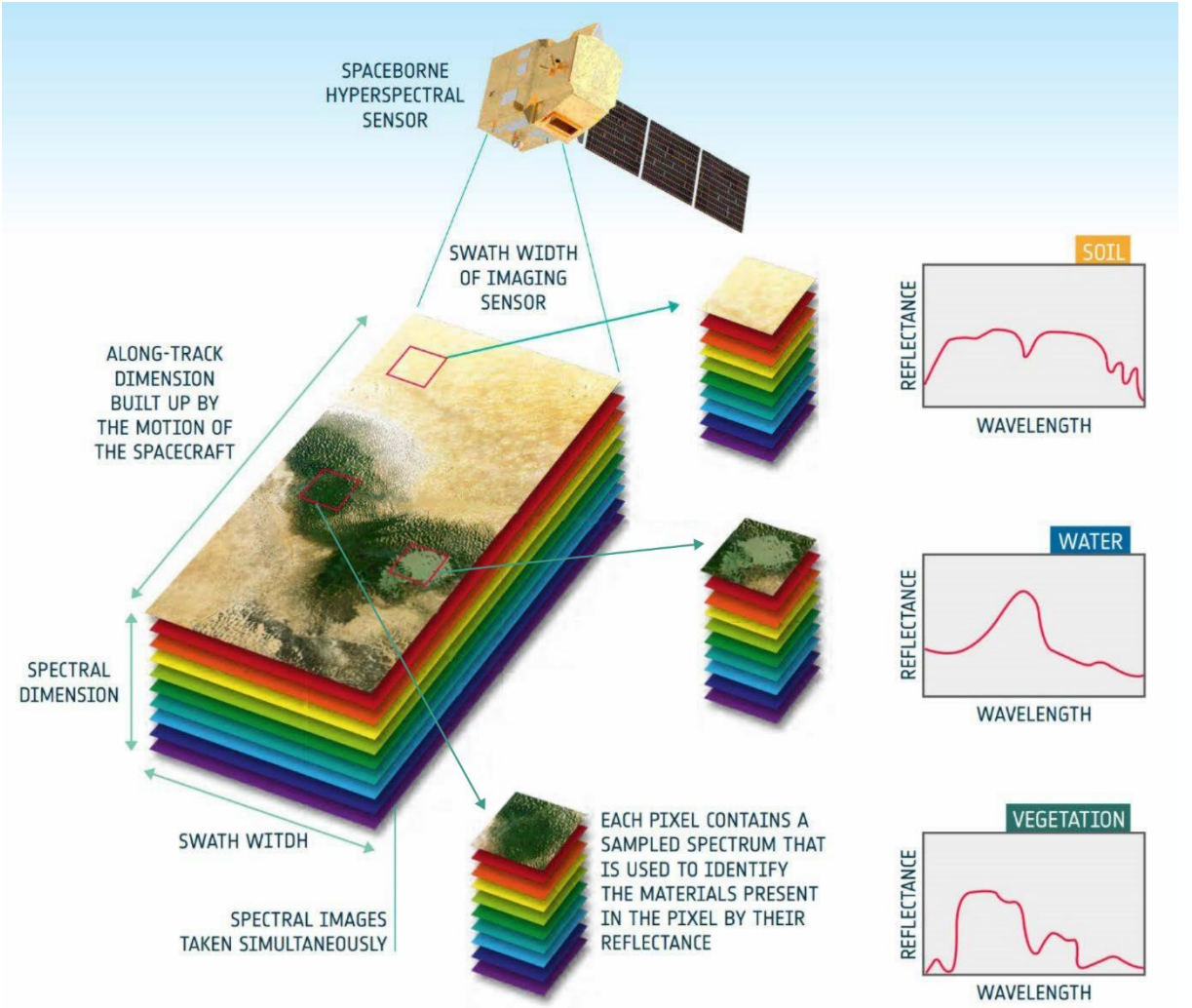
CHIME Key Specifications

- Carpet-mapping observations of land and coastal areas (current mask: up to 370 km offshore)
- SZA < 84°
- Spectral range: 400 – 2500 nm
- FWHM ≈ 10 nm, SSI ≈ 8.4 nm
- Ground Resolution: 30 m
- Swath ≈ 130 km
- Revisit 11 days (w/ 2 satellites)
- High radiometric accuracy and SNR, low spectral/spatial mis-registration

Core data products:

- Top-of-atmosphere (TOA) radiance in sensor geometry
- Ortho-rectified TOA reflectance
- Bottom-of-atmosphere (BOA) land surface and aquatic reflectance in sensor and ortho-rectified geometry

>> with associated uncertainties



CHIME High Priority Prototype Products

DOMAIN	THEMATIC AREA	VARIABLES CHPPP	CHIME Candidate Algorithms
AGRICULTURE / FOOD SECURITY	 Assessment of biophysical and biochemical variables related to the crops and of agronomic interest	Leaf/Canopy Pigment Content	Semi-empirical modelling based on narrow-band vegetation indices; Hybrid methods based on ANN/LUT or other machine learning algorithms applied to vegetation canopy radiative transfer models outputs (e.g. PROSAIL).
		Leaf/Canopy Nitrogen Content	Narrow-band vegetation indices; Hybrid methods based on ANN/LUT or other machine learning algorithms e.g. GPR methods applied to vegetation canopy reflectance models (e.g. PROSAIL).
		LAI	
		Canopy Water Content	
		Leaf/Canopy Pigment Content	
		Leaf Mass/Area	
	 Topsoil properties	Soil organic carbon content	Chemometrics modelling (e.g. PLSR); Spectral analysis; Spectral indices; Machine learning (e.g. Random Forest)
		Soil texture (clay, silt, sand)	
GEOLOGY & MINERALS	 Raw material detection	Mineral identification / classification (Kaolinite, Smectite, Jarrosite, Dolomite)	Sub-pixel linear unmixing Tetracorder type (EnGeoMap/PRISM)
		Hematite – Goethite distribution	
		Ferric oxide content	
		Kaolinite abundance	ML regression

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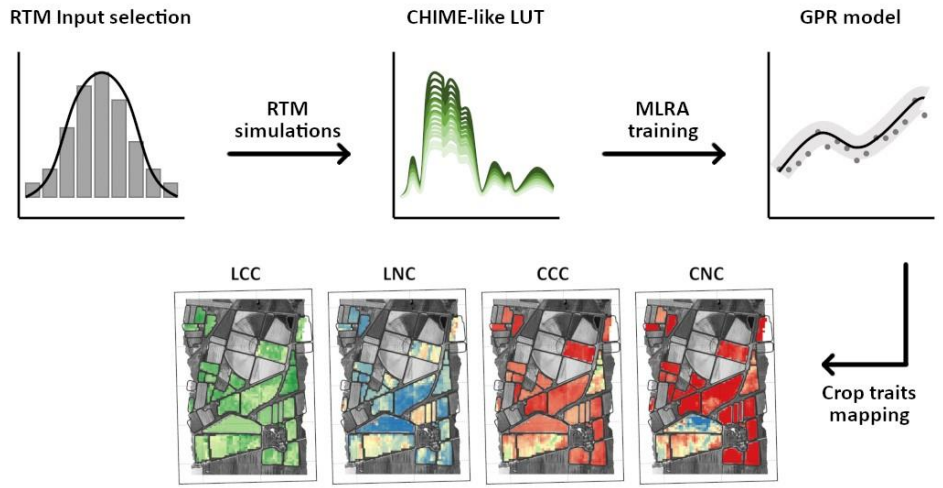
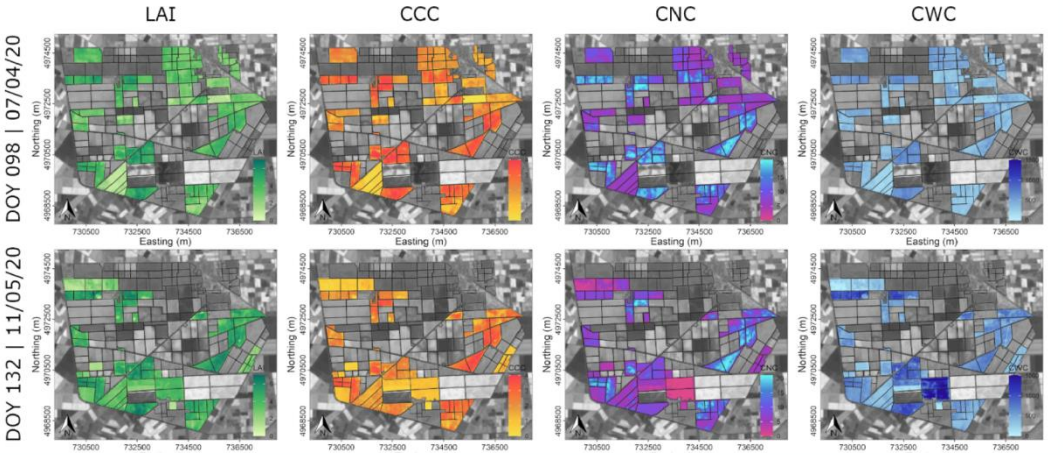
Retrieval of Leaf and Canopy Nitrogen Content

- **Nitrogen (N)** is one of the most important plant macro-nutrients
- a proper management of N is a key factor for effective agricultural practices

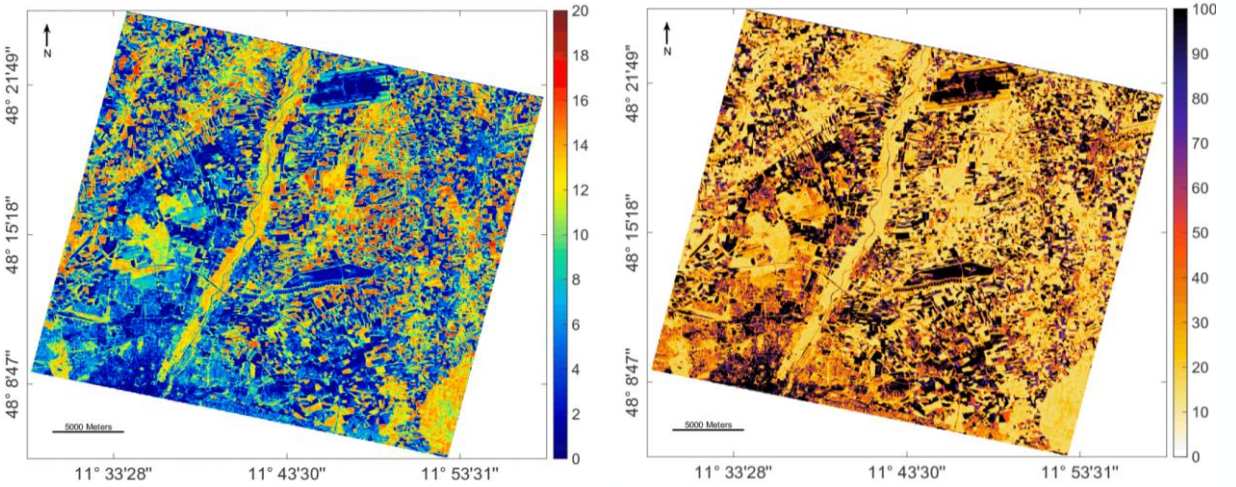
→ CHIME will provide routinely Leaf and Canopy N Content maps to support precision farming



Candiani *et al.* (2022) Remote Sensing



Tagliabue *et al.* (2022) ISPRS



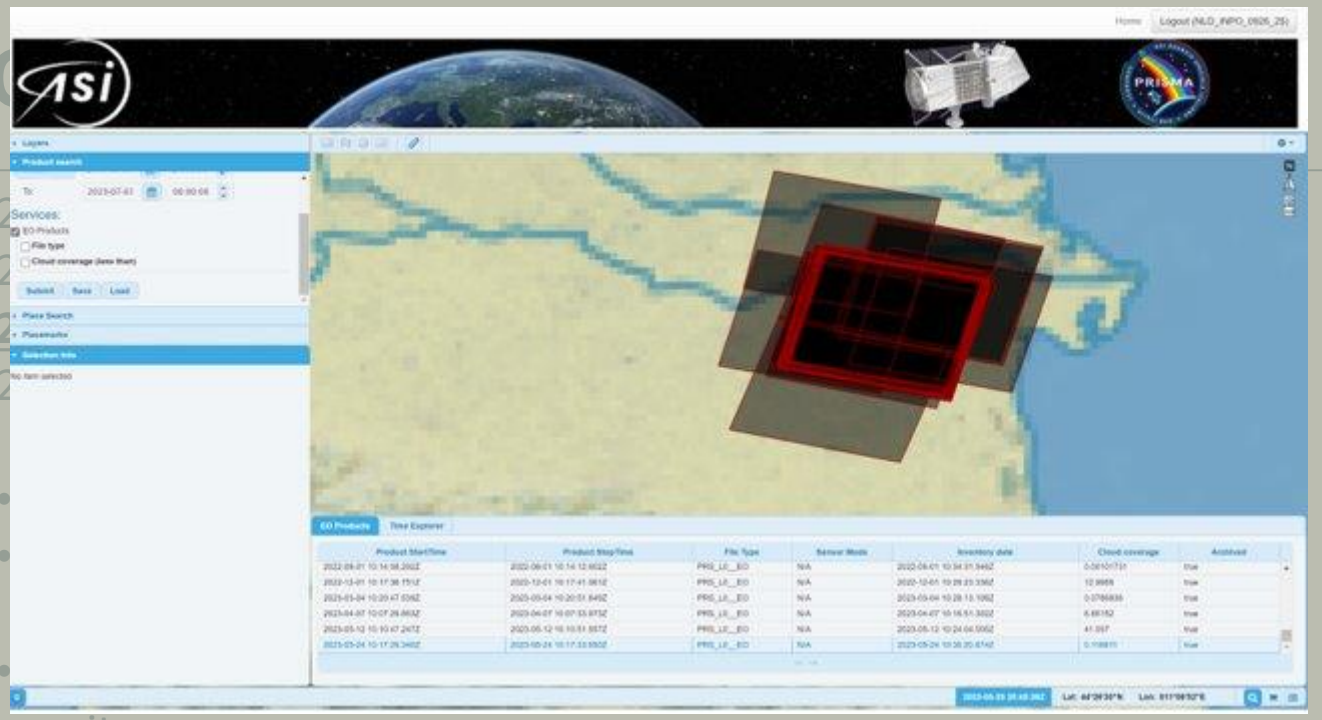
Verrelst *et al.* (2021) ISPRS

CHIME “Hypersense” Campaigns

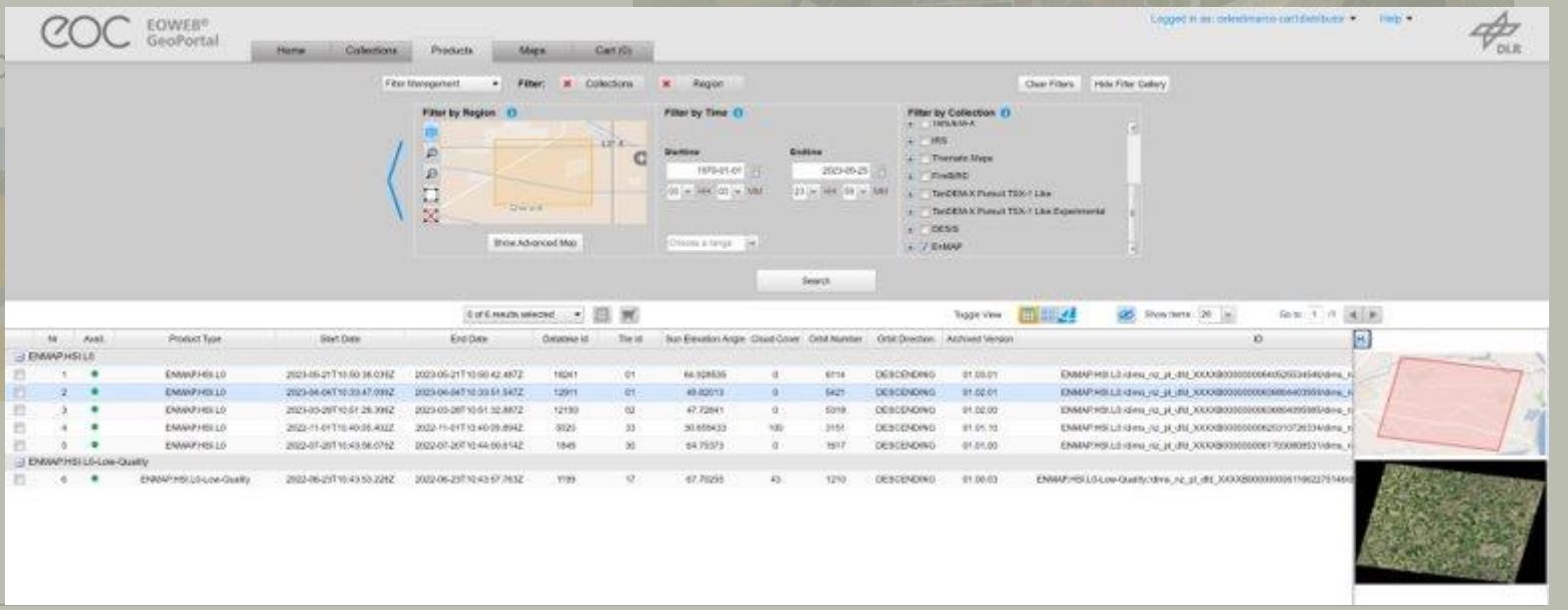
2018 – Ground / Airborne
2020 – Ground / ~~Airborne~~ / Spaceborne
2021 – Ground / Airborne / Spaceborne
2023 – Multi-scale reference dataset

- 17 fully successful sites (+1) across Europe
- Exceptional coordination between all teams (including PRISMA, DESIS and HISUI)
- Concurrent Ground / Airborne / Spaceborne acquisitions over 8 sites
- Open data policy fostering community exploitation

AVIRIS-NG Surface Reflectance (RGB)
22nd June 2021 - Jolanda di Savoia (IT)

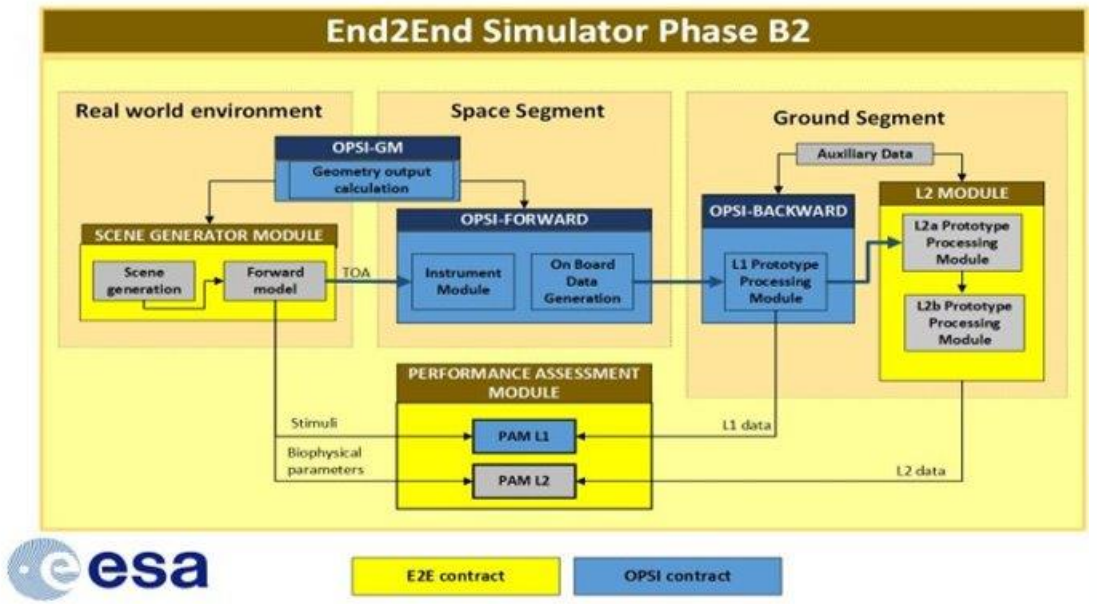


- sites
- Open data policy fostering community exp



Phase B2CDE Science Support Activities

- **CHIME Phase B2CDE E2E simulator**
  - Consortium: GMV (ES/PL) prime + GFZ (DE), ISPRA (IT), University of Valencia (ES) as subcontractors
  - Algorithms prototyping and performance assessment

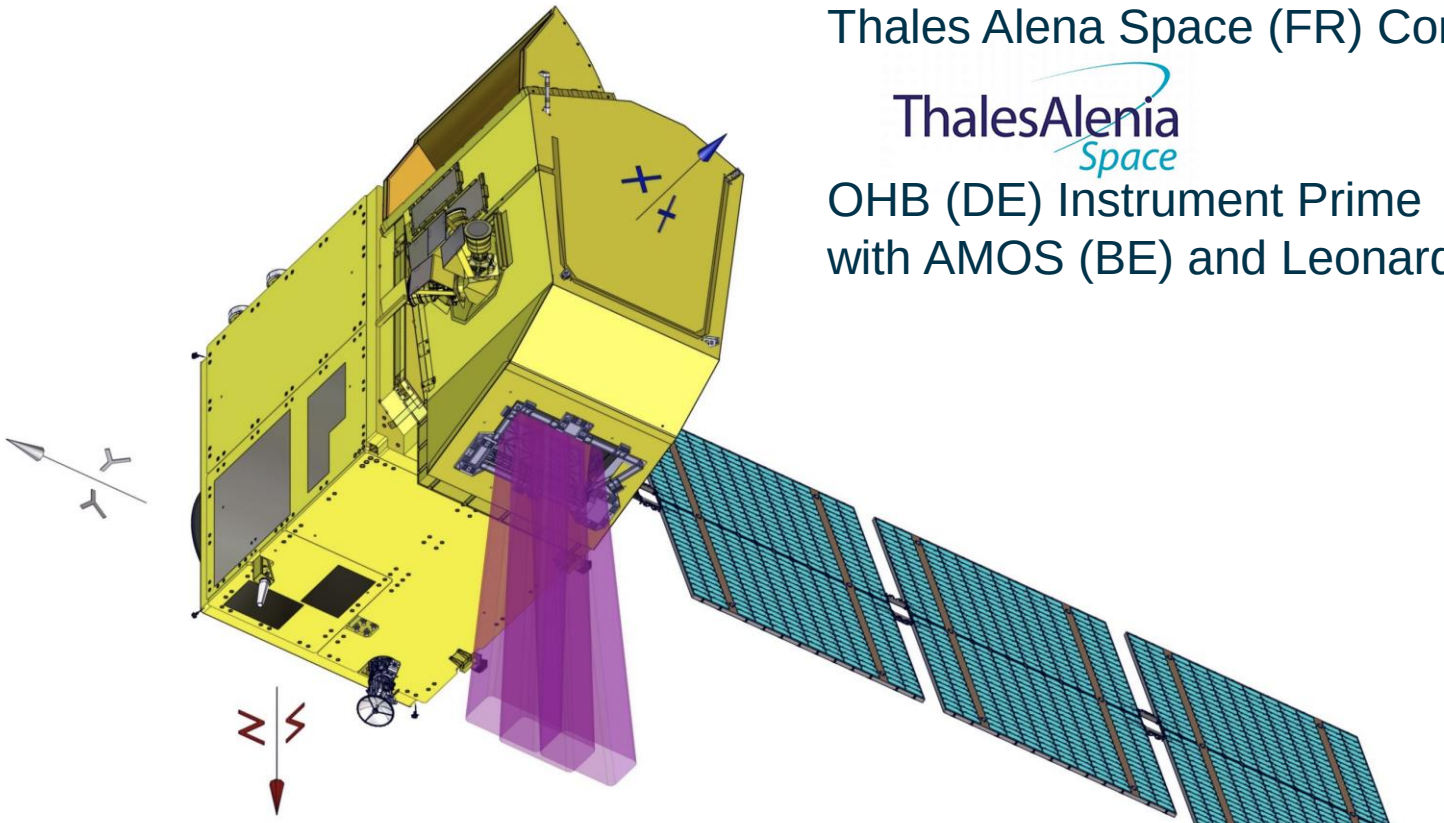


- **Multi-scale reference dataset**
  - Test-case for cal/val and harmonisation between sensors/platforms
  - Reference data for algorithms benchmarking

- **CHIME Level-2 Activity >> processors development and cal / val**
  - ITT published Q1 2023
  - Intended Start Date: Q4 2023
  - Estimated Duration: 6 years

- **Sentinel User Preparation activities**

CHIME Space Segment 1/2



The Industrial Core Team consists of
Thales Alena Space (FR) Consortium Prime

OHB (DE) Instrument Prime
with AMOS (BE) and Leonardo (IT)

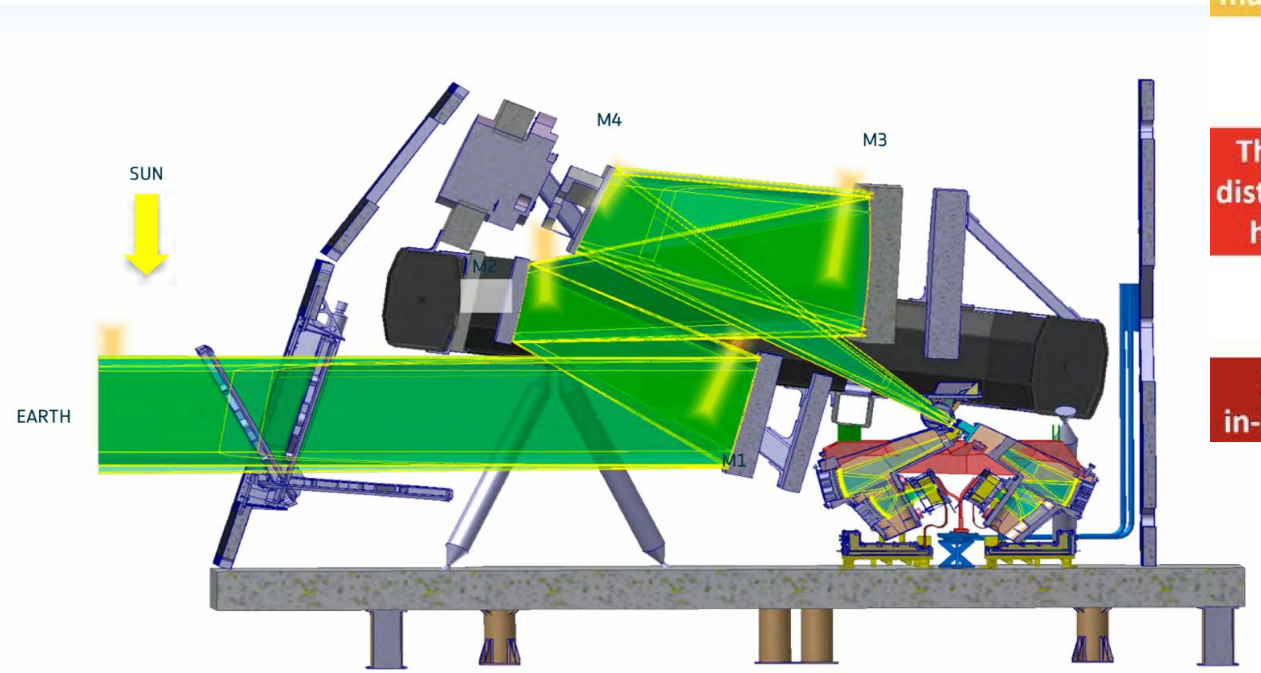
- Currently in Phase C
- CDR Board Q2 2025 (→ possible advancement)
- First CHIME unit ready for launch from Q3 2028

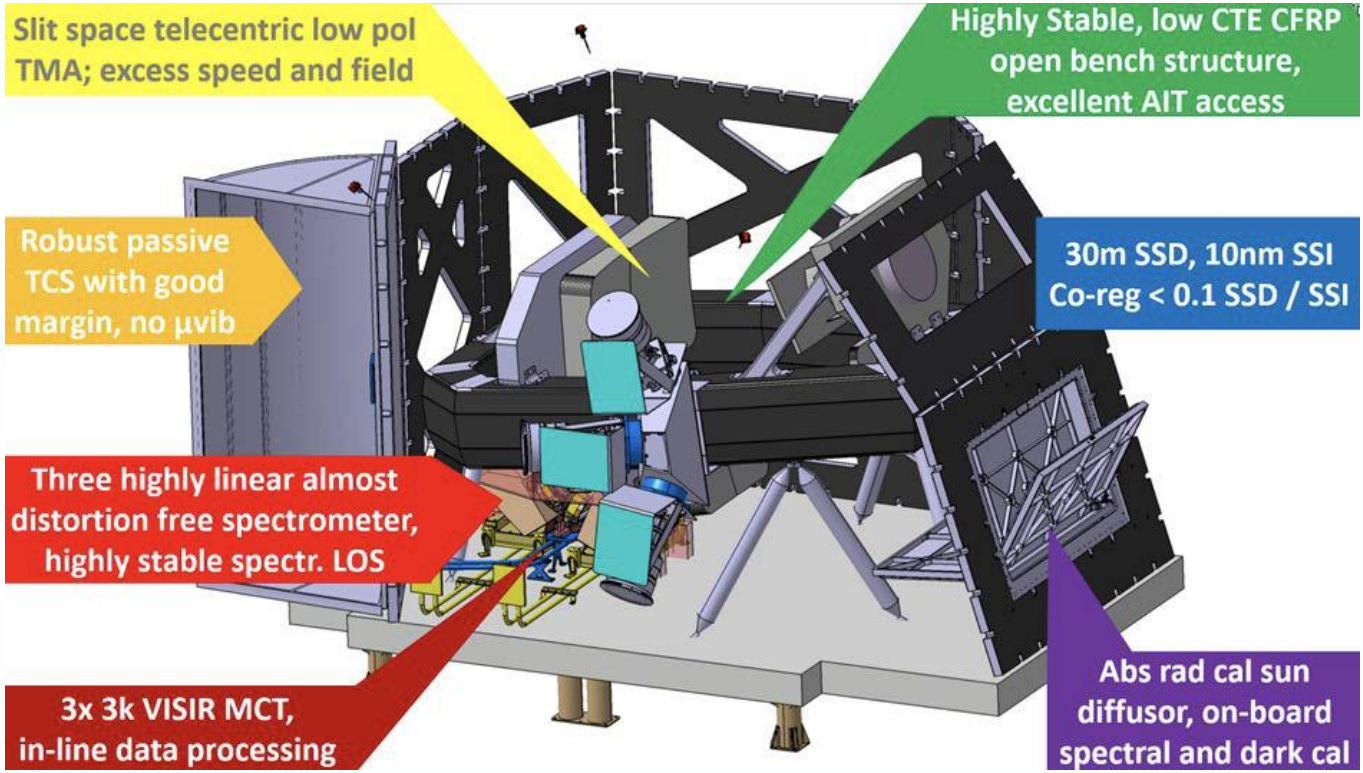
- On-board & vicarious calibration
- On-board cloud detection (ML algo) and selective compression (CCSDS 123.0-B-2 standard)
- Potential mission extension (TBC) based on feature detection outside the nominal acquisition mask (e.g. over open ocean)

→ recent paper from Wijata et al. (2023) in IEEE GRSM

CHIME Space Segment 2/2

Three mirror anastigmat (TMA) telescope including a plane refocusing mirror, feeding three identical staggered grating spectrometers





International Cooperation in Imaging Spectroscopy

Agenzia Spaziale Italiana

PRISMA

- CHIME Campaign
- advancement of algorithm development
- new retrieval techniques such as AI and machine learning are examined

DLR

EnMAP and DESIS

- End to end simulator combined usage
- Exchange of ATBDs at different product levels
- Cooperation on retrieval toolbox and operational processors

US decadal plan priority Mission SBG (Surface Biology Geology)

- established Joint Working Groups consolidating an End-Product harmonisation, Retrieval Simulations and Orbit definitions and CalVal

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Europe's eyes on Earth

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Thank you for your attention!

CHIME

Copernicus Hyperspectral Imaging Mission for the Environment

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CHIME and Sentinel-2 NG Mission Scientist

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