



Land Surface Temperature Monitoring LSTM Mission

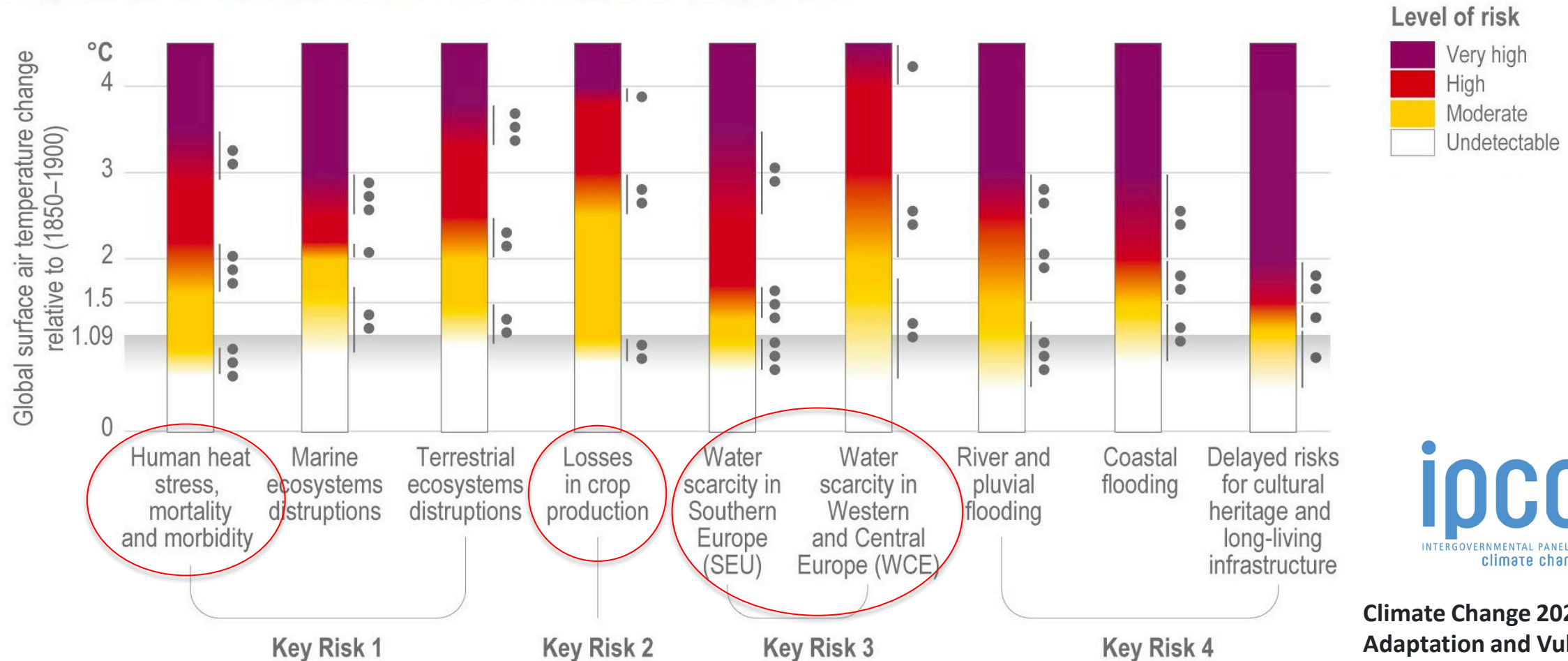
Benjamin Koetz, Björn Baschek, Wim Bastiaanssen, Michael Berger, Joris Blommaert, Ana Bolea Alamanac, Itziar Barat, Maria Buongiorno, Raphael D'Andrimont, Pierre Defourney, Umberto Del Bello, Matthias Drusch, Mark Drinkwater, Riccardo Duca, Phillipe Gamet, Ferran Gascon, Darren Ghent, Radoslaw Guzinski, Jippe Hoogeveen, Simon Hook, Yann Kerr, Jean-Pierre Lagouarde, Ilias Manolis, Philippe Martimort, Jeff Masek, Michel Massart, Massimo Mementi, Claudia Notarnicola, Albert Oliso, Inge Sandholt, Jose Sobrino, Peter Strobl, Thomas Udelhoven, Miguel Such, Francois Bernard

LSTM – The Where in the Climate Warming



Climate Warming Stripes, #ShowYourStripes
Ed Hawkins 2021, University of Reading

Key risks for Europe under low to medium adaptation



**3 Key Climate Risks
addressable by LSTM**



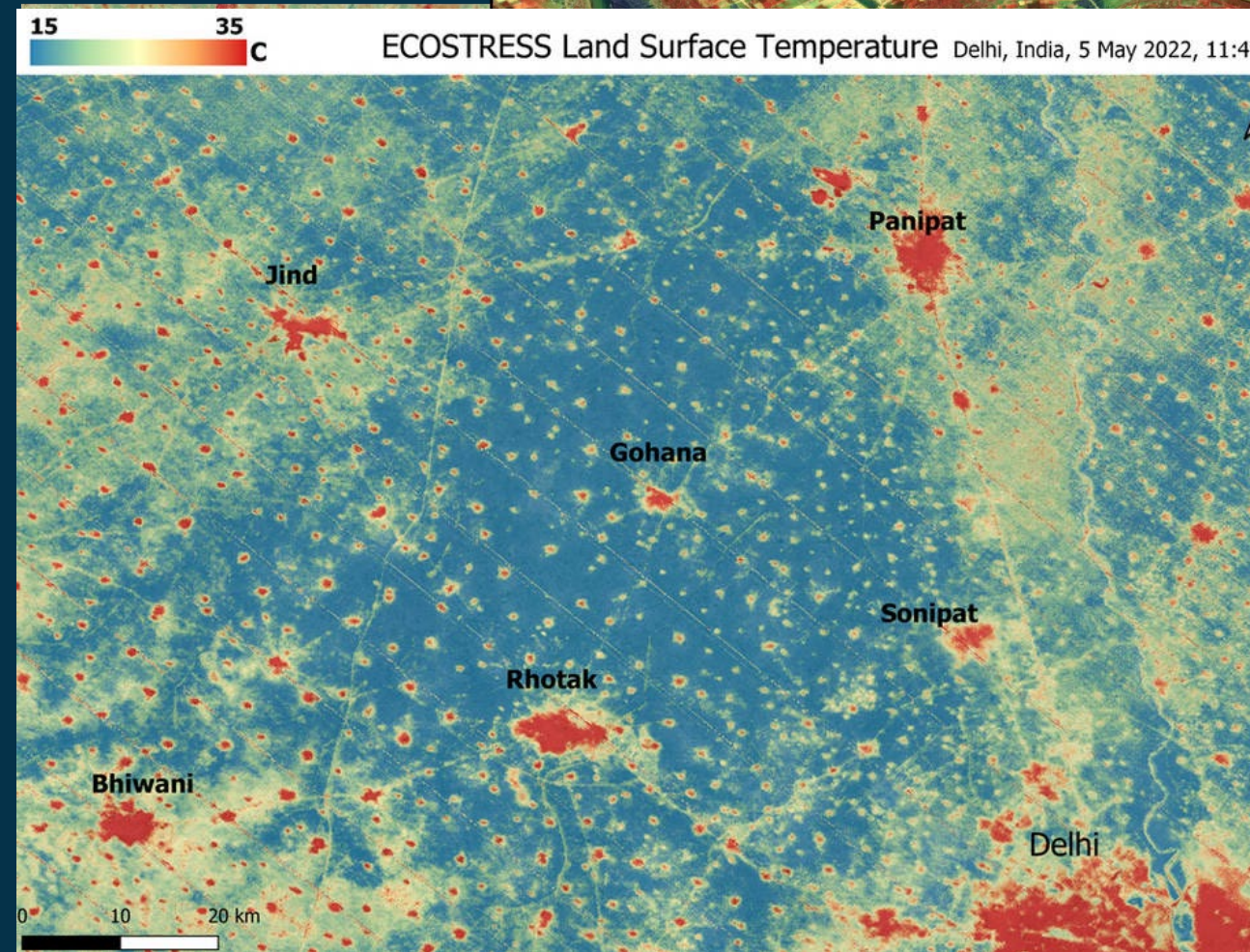
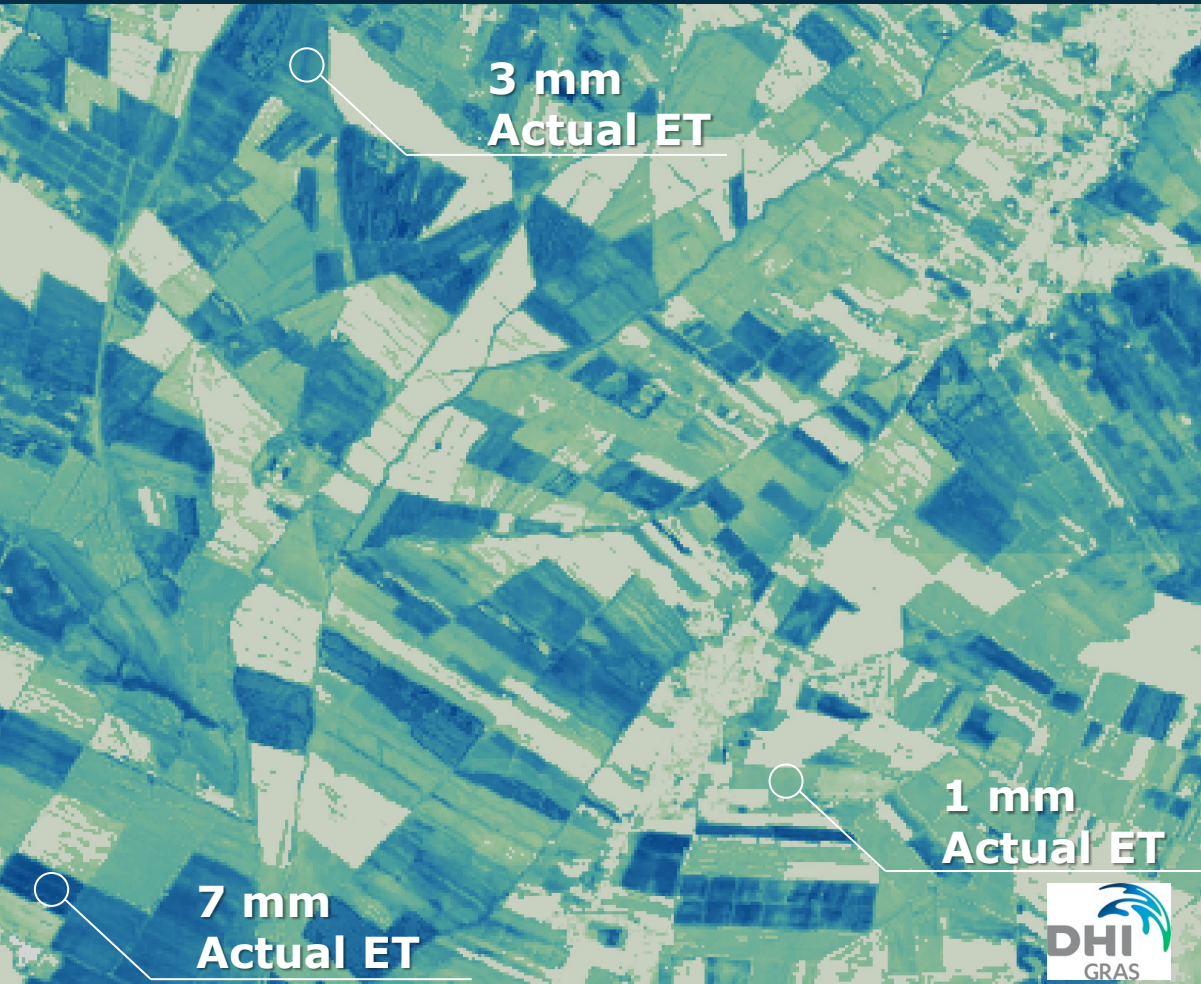
Climate Change 2022: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the IPCC Sixth Assessment Report

LSTM Applications & Services



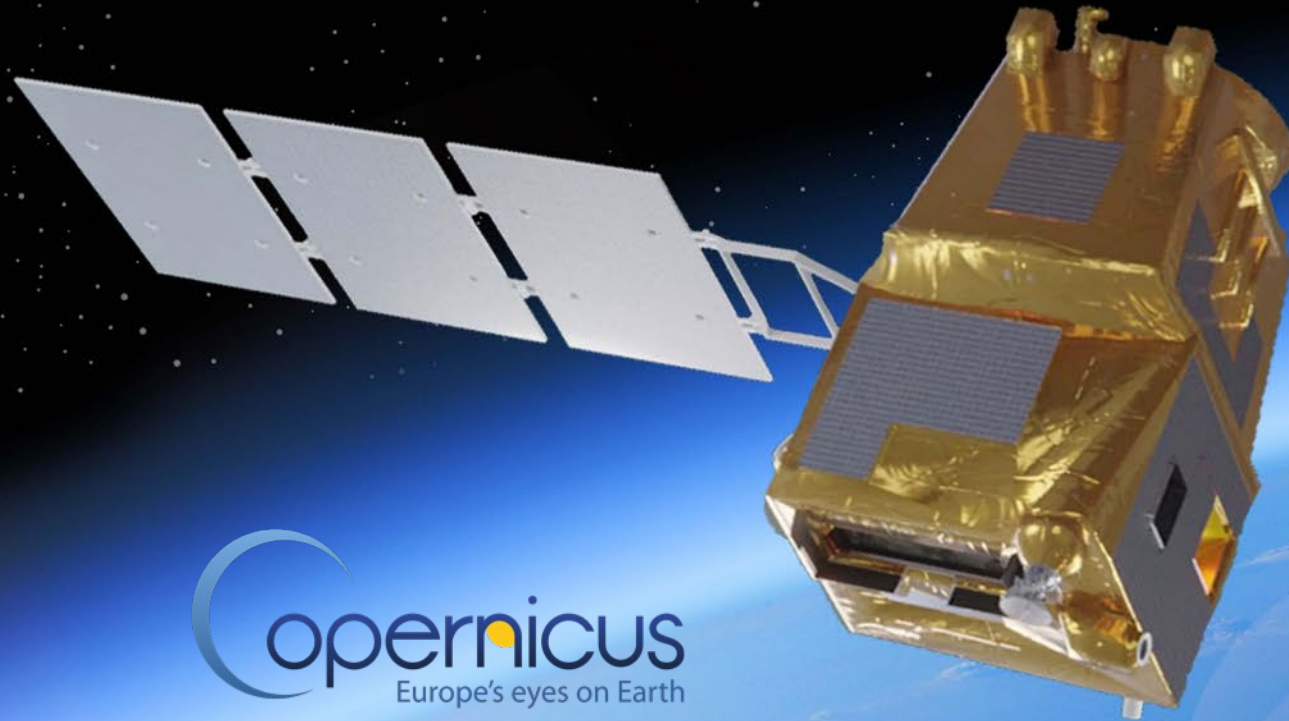
Water Productivity
for sustainable agriculture

Urban Planning
for Urban Heat Island



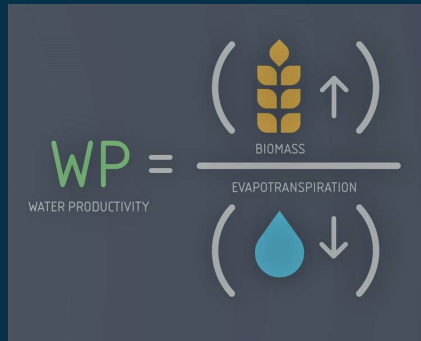
LSTM Mission Objective:

Provide high spatio-temporal resolution Thermal Infra-Red observations over land and coastal regions *in support of agriculture management services*, and a range of additional applications



Primary objective:

To enable monitoring evapotranspiration (ET) rate at European field scale by capturing the variability of Land Surface Temperature (LST) (and hence ET) allowing more robust estimates of field-scale water productivity.



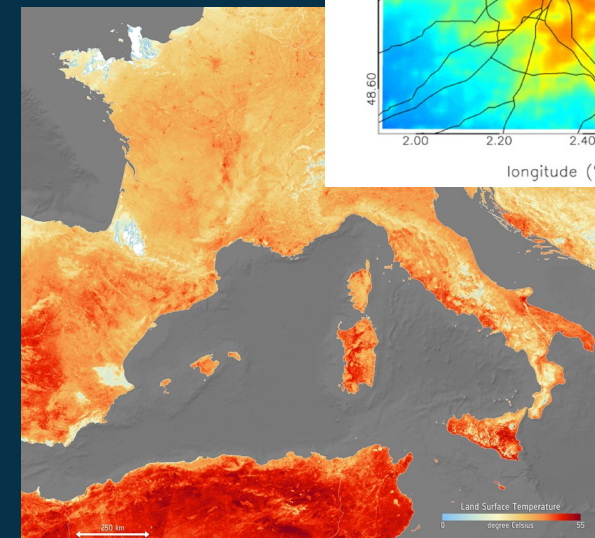
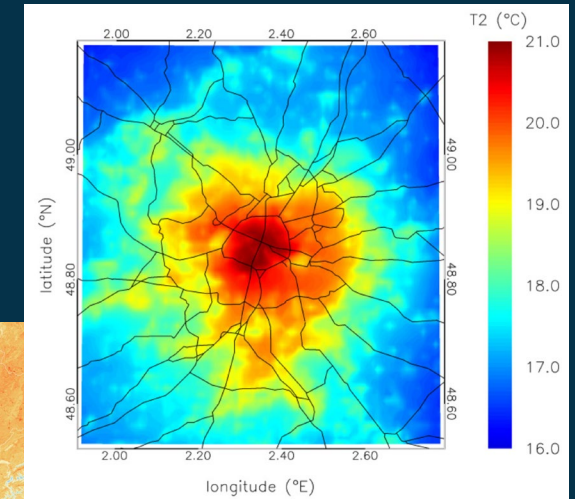
www.fao.org -WaPOR

- ET Accuracy 15% (G) 20% (T) [mm/day]
- ET Precision 5% (G) 10% (T)
- Field scale [0.5 ha]
- Daily (G) 3 days (T) observations

Complementary objective:

To support a range of additional services

- Soil composition
- Urban heat islands
- Coastal zone management
- High-Temperature Events



ECOSTRESS

Sentinel-3 www.esa.int

LSTM Key Features

Key requirement*

Geometrical revisit	2 days/2 satellites
Local time	13:00 (Europe) & night observations
SSD	50 m (37m at nadir)
Spectral Bands	5 TIR, 4 VNIR, 2 SWIR
Nominal swath	687 km, at 651 km altitude
Acquisition system	Whiskbroom scanner
Geo-location L1c	0.5 SSD (GCP) / 1 SSD (without GCP)
MTF	0.2-0.3
Data latency (L2)	6-12 hours
NeDT	< 0.15 K
ARA	< 0.5 K

User requirement**

Evapotranspiration (goal)

- Accuracy 15% [mm/day]
- Precision 5%
- Field scale [0.5 ha]
- Daily observations

LST observations**

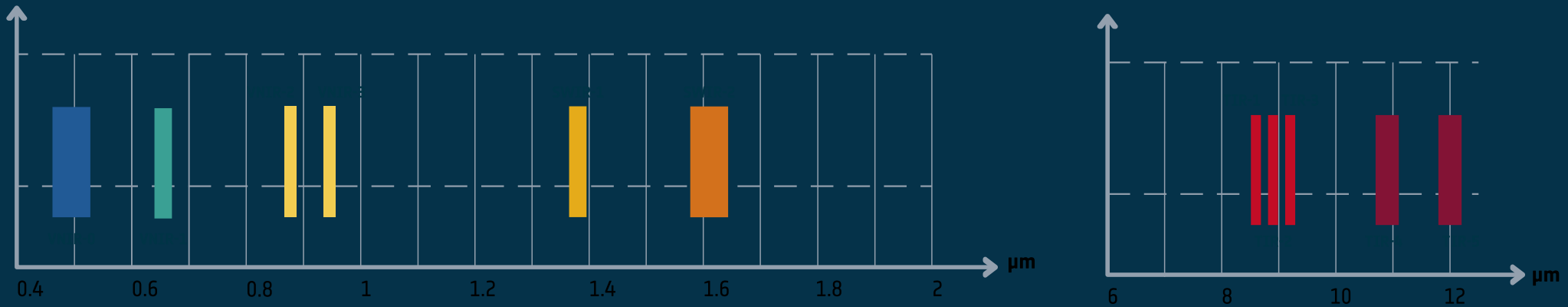
- 50 meters resolution
- 1-3 days revisit
- 1-1.5 K LST accuracy

* Copernicus LSTM Phase B2/C/D/E1 System Requirements Document

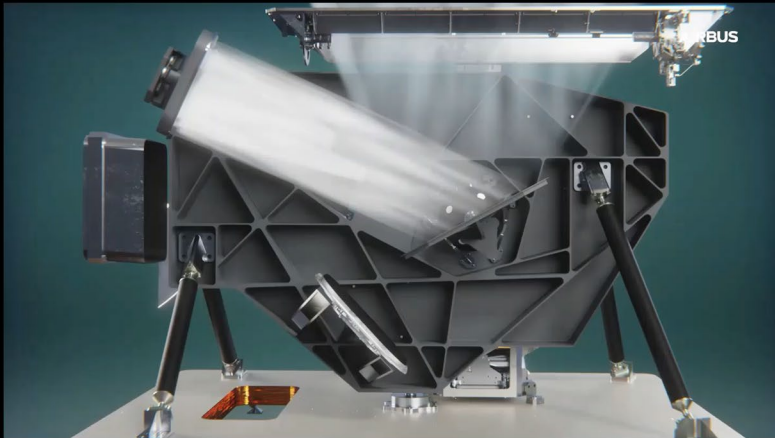
**Mission Requirement Document V3

https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Copernicus_Sentinel_Expansion_missions

LSTM Instrument Key Features



11 Spectral Bands: 5 TIR, 4 VNIR, 2 SWIR

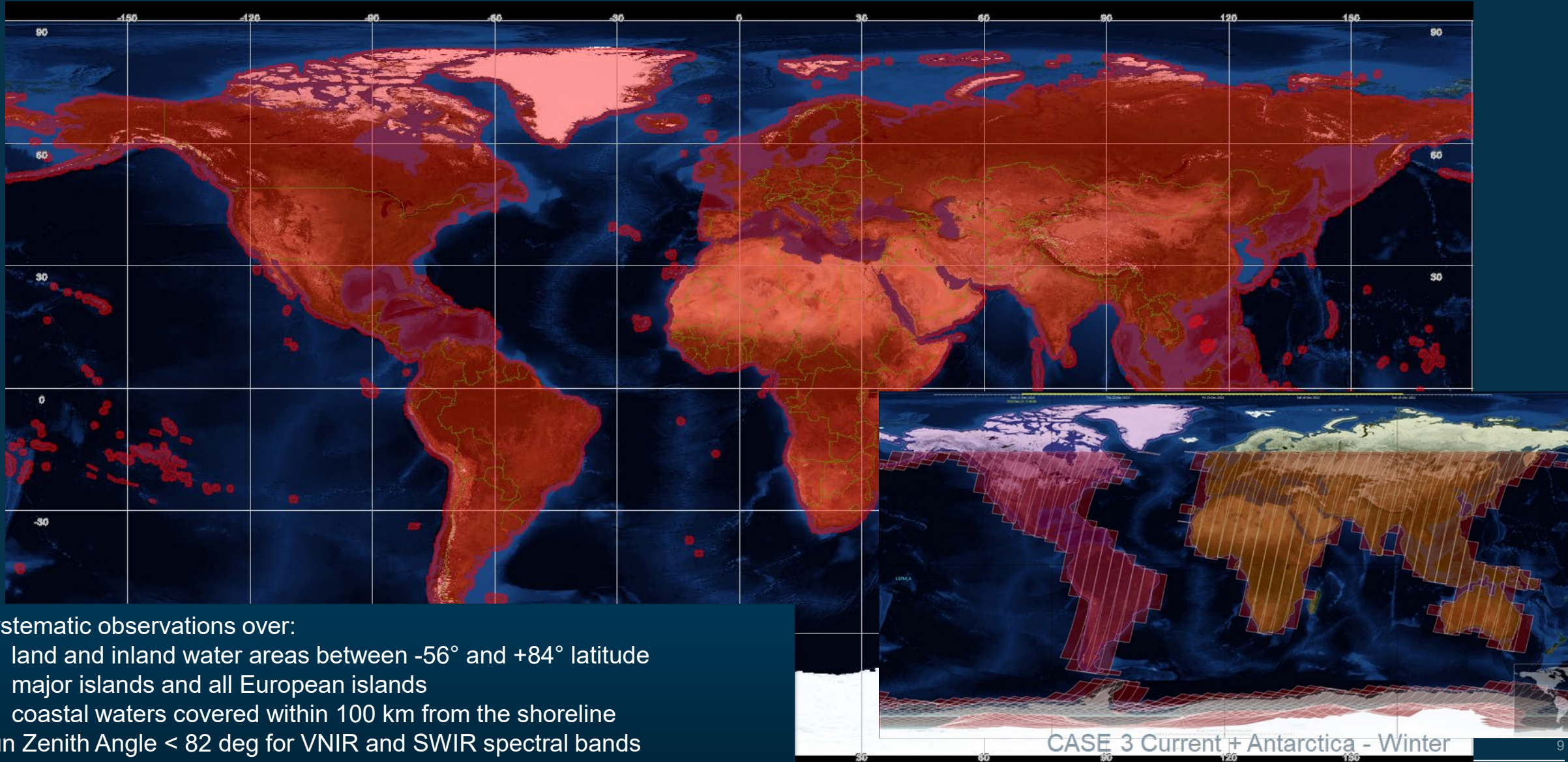


Airbus courtesy

Whiskbroom instrument

- MTF 0.15 to 0.3
- NeDT < 0.1 K @ 300 K
- ARA < 0.3 K @ 300 K

LSTM Acquisition and Coverage



Systematic observations over:

- land and inland water areas between -56° and $+84^{\circ}$ latitude
 - major islands and all European islands
 - coastal waters covered within 100 km from the shoreline
- Sun Zenith Angle < 82 deg for VNIR and SWIR spectral bands

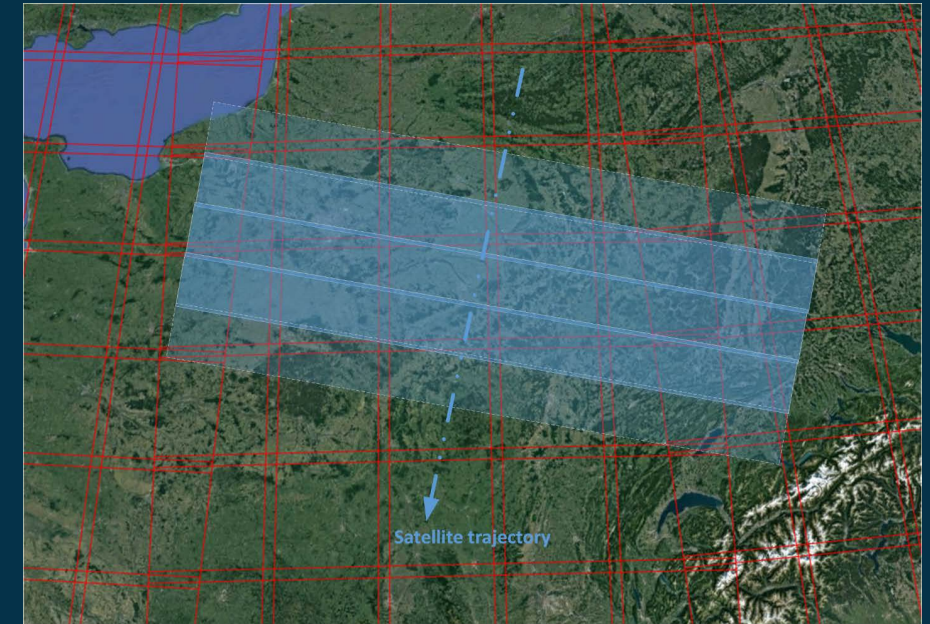
LSTM Data Products & Latency

The LSTM Level-1c products:

- Radiometrically & geometrically calibrated TOA radiance
- Top of atmosphere brightness temperature

The LSTM Level-2a products:

- Land Surface Temperature
- Land Surface Emissivity per TIR spectral band
- Bottom of atmosphere surface reflectance
- Total Column of Water Vapor (intermediate product required for LST retrieval)
- Cloud mask (intermediate product provided as a quality flag)



Airbus courtesy

Maximum Data Latency

- Level-1c: 3 hours (goal) & 6 hours (threshold), highest priority over Europe and Africa.
- Level-2a (LST): 6 hours to 12 hours (TBC), highest priority over Europe and Africa.



Objectives:

- Supports LSTM, NASA-SBG & TRISHNA missions
- Directionality experiments
- Urban overflights
- GEWEX LIASE campaign (2021)
- Methane study (2021)

Campaigns:

- 2021: July/August 2021
 - HyTES in UK and Sweden
 - TASI in Spain
 - Data access open
- 2022: (2 airplanes)
 - focus on Italy
 - May & June

International Collaboration: SBG & TRISHNA Synergies



- **Compatible mission objectives:**

- LSTM: Improved water productivity & agriculture management
- TRISHNA & SBG: Ecosystem stress and water use



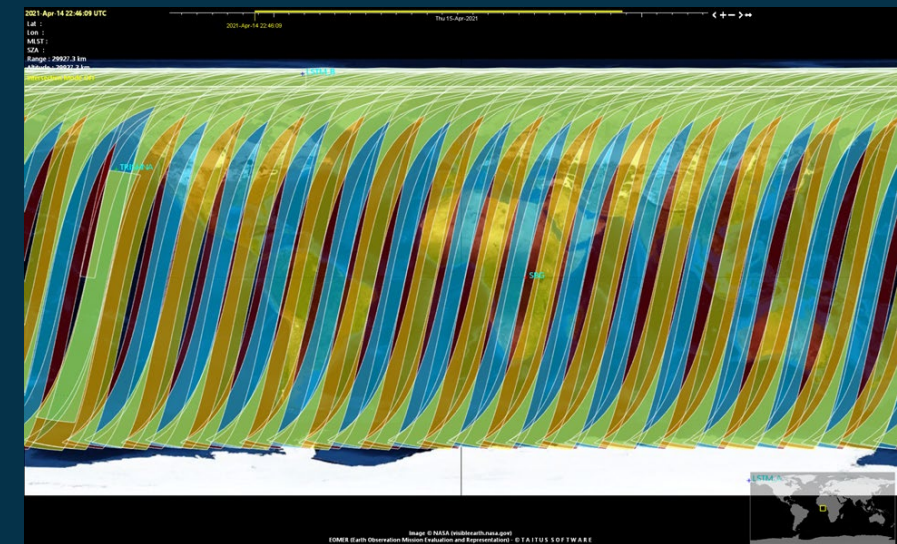
- **Common User requirement for ET:** daily effective observation (cloud free)

- Combined revisit of LSTM, TRISHNA, SBG, Landsat-9/Next & small-sats
- Pre-requisites: Comparable Observations & Inter-Calibration
- Similar MLST and optimized cross-overs

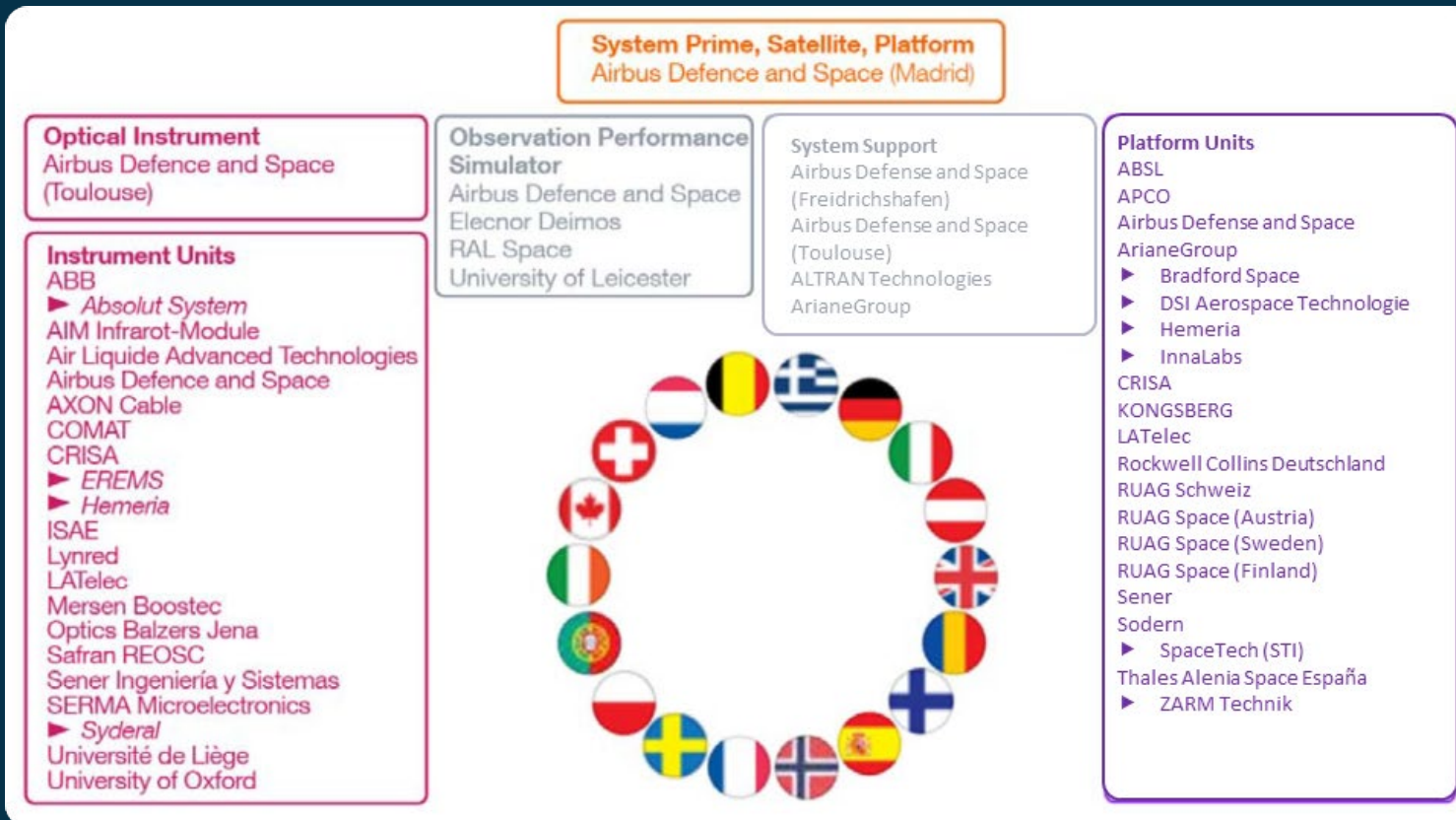


- **Cooperation** – facilitated through MAG & Science Group

- Scientific collaboration – algorithm development, campaigns
- Common Cal/Val approach, protocol, sites
- Multi-mission in-flight inter-comparison



LSTM Consortium & mission status



AIRBUS S.A.U (ES) as Prime
 AIRBUS SAS (FR) as Instrument Prime

The industrial consortium comprises more than 45 companies and institutions from up to 18 different countries.

- LSTM phase B2 ongoing: end 2021 successful Instrument Baseline Design Review
- Preparing Preliminary Design Review for Q4 2022
- Prototype Flight Model QAR: End 2028

What

- Provides Thermal Infra-Red observations in high spatial resolution and temporal frequency *in support of agriculture management services*

Why

- Improves sustainable water productivity at European field scale
- Addresses increasing Water and Food Security issues in a world of increasing water scarcity and variability
- Responds to major EU agricultural & environmental policies

How

- Unprecedented **50 meter** observations in **5 thermal bands**
- Frequent Land Surface Temperature (LST) at **2 days revisit**
- World-class instrument providing **1-1.5K LST** radiometric accuracy

Backup





PROGRAMME OF THE EUROPEAN UNION



co-funded with



CHIME
Copernicus Hyperspectral Imaging Mission for the Environment

- soil properties
- crop health
- biodiversity
- water quality

ROSE-L
L-band Radar Observing System



- geohazards
- polar ice
- forest management
- food security
- maritime surveillance



CIMR
Copernicus Imaging Microwave Radiometer

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



CRISTAL
Copernicus Polar Ice and Snow Topography Altimeter

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



LSTM
Land Surface Temperature Monitoring

- sustainable agriculture
- water resources management
- drought
- urban heat islands



CO2M
Copernicus Anthropogenic Carbon Dioxide Monitoring

- carbon dioxide and methane from human activity

Combatting Climate Change

Food Security and Water Management

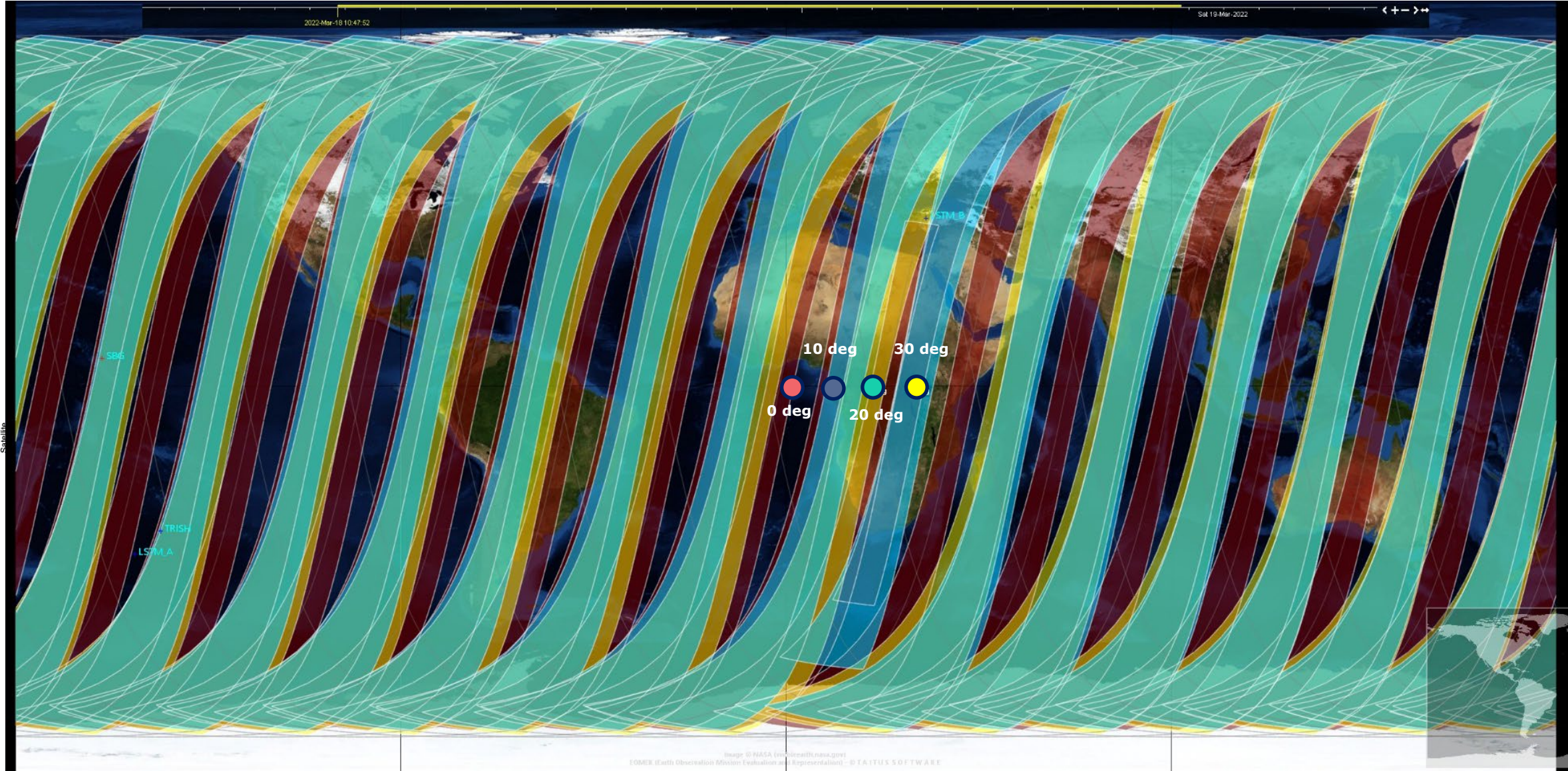
Monitoring Land and Natural Resources

Safeguarding the Arctic

Copernicus Sentinel Expansion Missions



Example of revisit over a point at equator



- **Spatial resolution: 30-50 m** to match European field scale variability
- LST observations should optimally be **acquired daily (goal)**, with a minimum threshold of 3 days
- LST over all land surfaces with an **uncertainty of 1 K (goal)** to 1.5 K (threshold)
- **Minimum 3 bands in TIR** range for ET rate estimation – recommended additional narrow thermal bands for improved LST/emissivity separation
- **Simultaneous VIS/NIR/SWIR** observations are required for atmospheric correction, cloud detection and emissivity estimations
- Collocation of S-2 & S-3 observations within +/-3 days for ancillary parameters
- Optimal LST observations **early afternoon** (goal around 13:00 hrs).

- 2 satellites, 4 days geometric revisit time each
→ **two days geometric revisit globally**
- **50 meters resolution** (37 meters nadir)
- Mean Local Solar Time over **Europe at 13:00** descending
- Spectral bands: 5 TIR, 4 VISNIR, 2 SWIR
- Nominal **swath 687 km**
- Maximum **OZA 30.3 degrees**
- TIR observations **day and night**
- VNIR/SWIR observations when SZA < 82 deg.
- **651 km** average geodetic altitude, (643km to 665km)
- 7 years lifetime following 6 months commissioning.
Consumables for 12 years.



LSTM Spectral Bands - Performances

- The mission shall measure TOA radiance with 3 (threshold) to 5 (goal) spectral bands in the TIR spectral range (8 - 12.5 μm) for the primary mission objective
- The mission shall measure TOA radiance with 6 (threshold) spectral bands in the VNIR-SWIR spectral range (0.4 - 2.5 μm)

Band #	Centre λ_{centre} (μm)	Spectral width $\Delta\lambda$ (μm)	Tolerance λ_{centre} (\pm nm)	Tolerance $\Delta\lambda$ (\pm nm)	Knowledge λ_{centre} (\pm nm)	Knowledge $\Delta\lambda$ (\pm nm)
VNIR-0	0.490	0.065	5	2.5	0.5	0.5
VNIR-1	0.665	0.030	5	1.5	0.5	0.5
VNIR-2	0.865	0.020	5	2	0.2	0.2
VNIR-3	0.945	0.020	5	2	0.2	0.2
SWIR-1	1.380	0.030	10	5	0.5	0.5
SWIR-2	1.610	0.090	10	10	1	1

Band #	Centre λ_{centre} (μm)	Spectral width $\Delta\lambda$ (μm)	Tolerance λ_{centre} (\pm nm)	Tolerance $\Delta\lambda$ (\pm nm)	Knowledge λ_{centre} (\pm nm)	Knowledge $\Delta\lambda$ (\pm nm)	Goal/Threshold
TIR-1	8.6	0.18 (G)/0.30 (T)	10	10	5	5	G
TIR-2	8.9	0.18 (G)/0.30 (T)	10	10	5	5	G
TIR-3	9.2	0.18 (G)/0.30 (T)	10	10	5	5	T
TIR-4	10.9	0.40 (T)	10	10	5	5	T
TIR-5	12.0	0.47 (T)	10	10	5	5	T

Antartica Meltzones (in red) vs Sentinel-2 Antarctica (in yellow)

