Land Surface Temperature Monitoring
LSTM Mission

A Copernicus Candidate Mission for
Agricultural Monitoring

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Copernicus 2.0 – New Monitoring Missions

Six High Priority Candidate Missions
Progress Status

- Preliminary Requirements Review concluded successfully for all 12 Phase A/B1 studies

- Consolidation of inputs for preparation of ESA ITTs for Phase B2/C/D/E1 contracts

Copernicus for Agricultural Monitoring

Req#	Spatial Resolution	Spectral Range	Effective observ. frequency (cloud free)*	Sample Type	Field Size	Target Products							
						Crop Mask	Crop Type Area and Growing Calendar	Crop Condition Indicators	Crop Yield	Crop Biophysical Variables	Environ. Variables	Ag Practices / Cropping Systems
Coarse Resolution Sampling (>100m)												
1	500 - 2000 m	thermal IR + optical	Daily	Wall-to-Wall	All		X			L		
2	100-500 m	optical + SWIR	2 to 5 per week	Cropland Extent	All	X	X	X	L	L		L
3	5-50 km	microwave	Daily	Cropland Extent	All			X	X	X	X	
Moderate Resolution Sampling (10 to 100m)												
4	10-70m	optical + SWIR + TIR	Monthly (min 2 out of season + 3 in season). Required every 1-3 years.	Cropland Extent	All	X						X
5	10-70m	optical + SWIR + TIR	Weekly (min. 1 per 16 days)	Sample	All	X	X	X		X		X
6	10-100m	SAR	Weekly (min. 1 per 2 weeks)	Cropland Extent of persistant cloudy areas/Rice	All	X	X	X		X		X

Sentinel-3 (MODIS)

Observational Gap: TIR for Evapotranspiration

Sentinel-2 (Landsat)

Sentinel-2 (Landsat)

Sentinel-1 (PalSAR)

Scientists say a **hotter earth** is the **new normal**
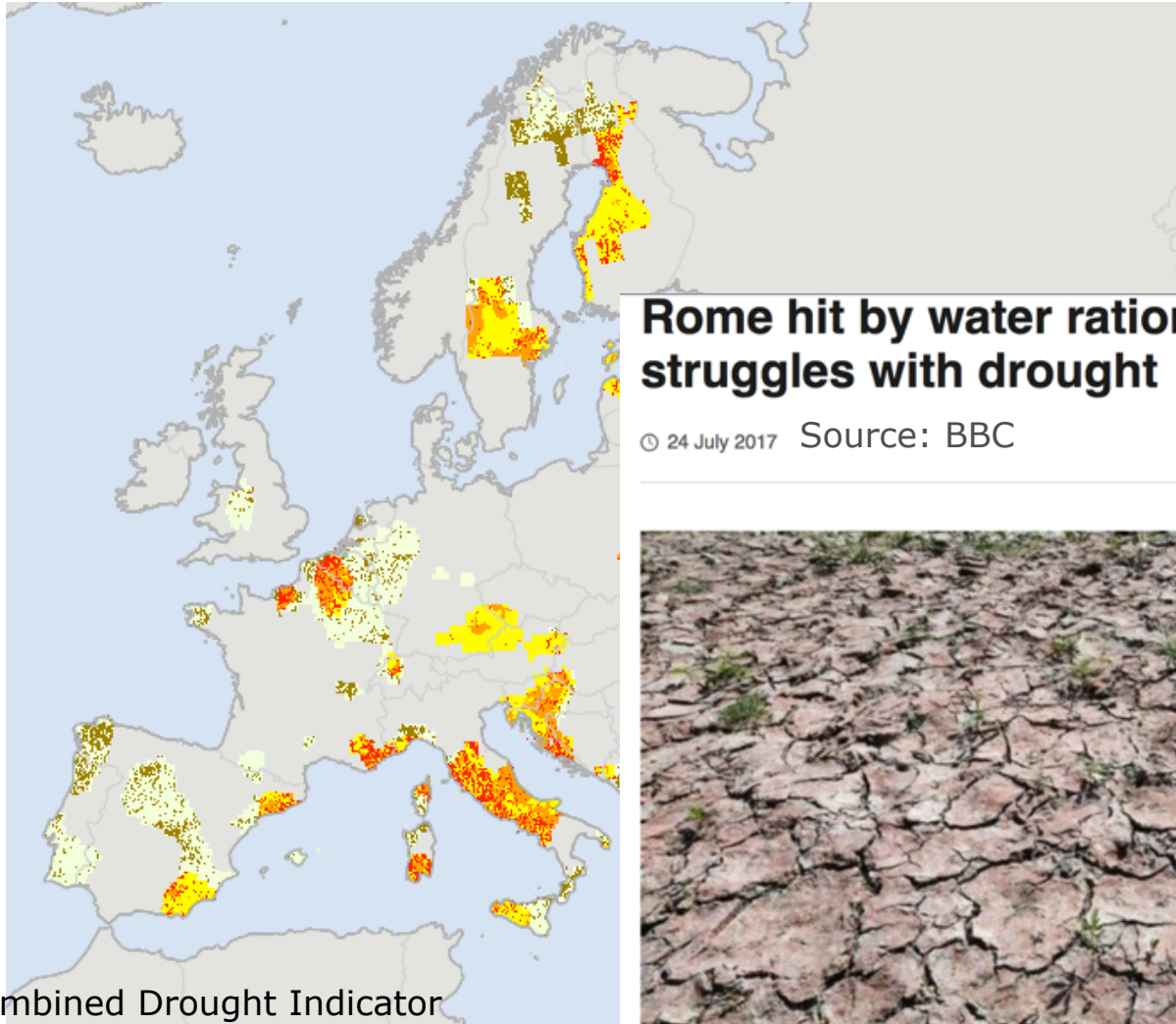
Water Scarcity in Europe – Summer 2017

Combined Drought Indicator

	Watch
	Warning
	Alert

Source: JRC

Rome hit by water rationing as Italy struggles with drought

24 July 2017   Source: BBC

At least 10 Italian regions are preparing requests for a state of natural calamity to be declared

Land surface temperature [°C]   0   60

...tion Workshop EO Mission Study in the MWIR-LWIR

Almost two-thirds of Italy's farmland has been hit by a prolonged drought, costing Italian agriculture some €2bn ($2.3bn; £1.8bn), farmers say.

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Water Scarcity in Europe – Summer 2018

Combined Drought Indicator

Watch	
Warning	
Alert	

Source: JRC

© European Drought Observ
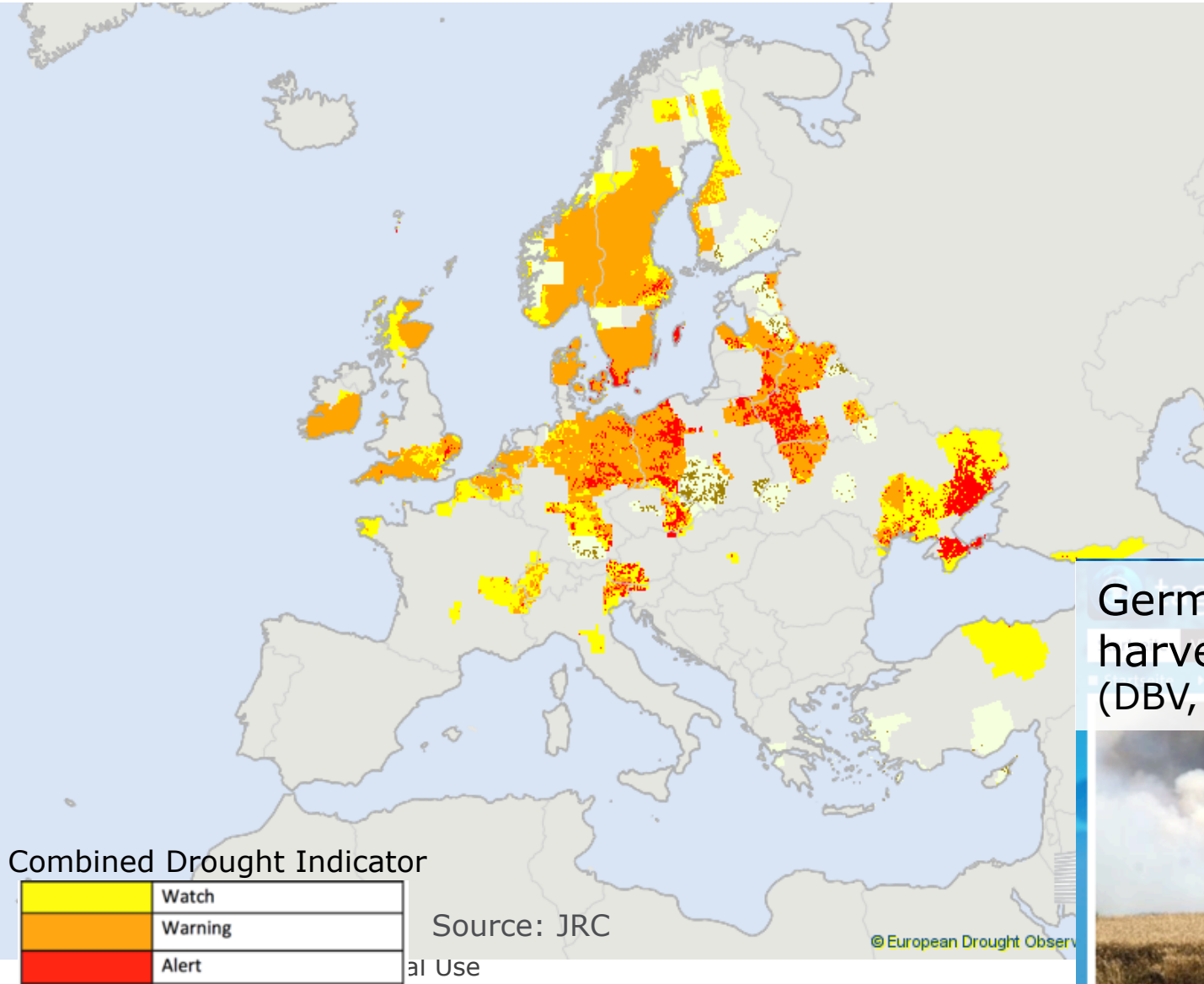
German Farmers' Association predicts heavy harvest losses – e.g. 18% less Winter barely
(DBV, 18.07)

Waldbrände, Trockenheit, Wassernot
Sommerhitze mit Schattenseiten

LSTM Main Mission Objective:

To complement Sentinel observation capabilities with high spatio-temporal resolution Thermal Infra-Red observations over land and coastal regions ***in support of agriculture management services,*** and possibly a range of additional applications and services

Mission Status:

- **Mission Advisory Group (MAG)** shaping the mission requirements
  - Consolidated High Level Requirements (HLR) – mid of July 2017
- **Mission Requirement Document Version 2.0** approved in April 2019*
- Start of **Mission Phase A/B1** in 2018
  - Successful Preliminary Requirements Reviews (2 studies) – February 2019
  - On-going Scientific Studies and airborne campaigns

*https://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Candidate_missions

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.
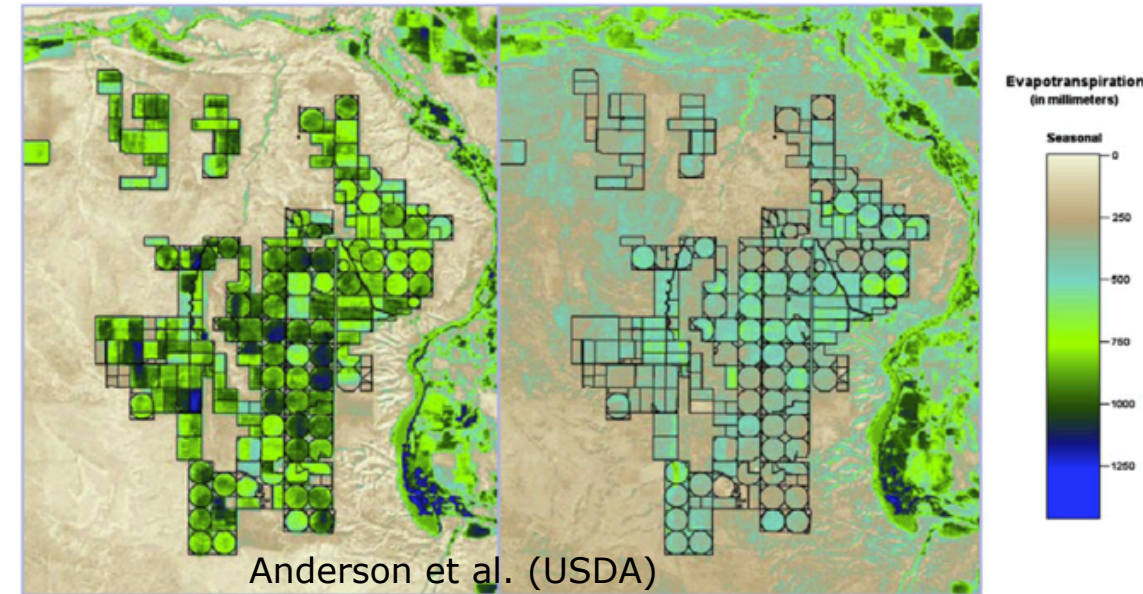
ET goal: accuracy 15% [mm/day], precision 5%, field scale MFU [0.5 ha], daily

ET threshold: accuracy 20% [mm/day], precision 10%, field scale MFU [1 ha], 3 days
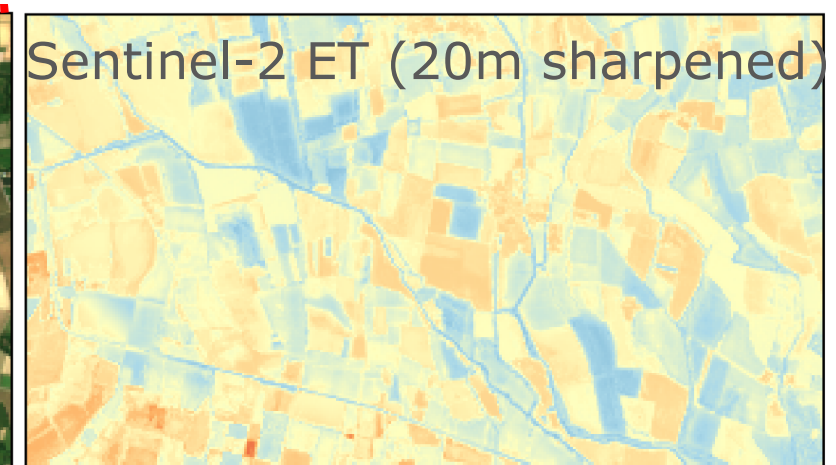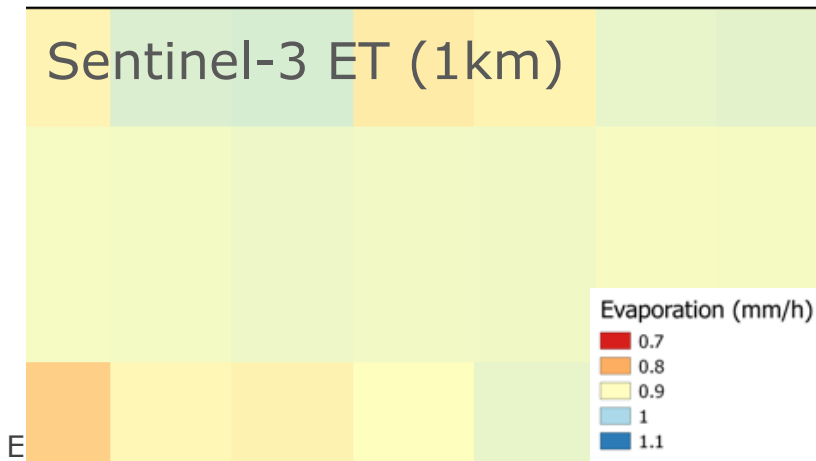
Complementary objective: to support a range of additional services benefitting from TIR observations – in particular soil composition, urban heat islands, coastal zone management, High-Temperature Events.

Water rights management
- Impact & control of policy measures
- Buyout of irrigations rights, Idaho US
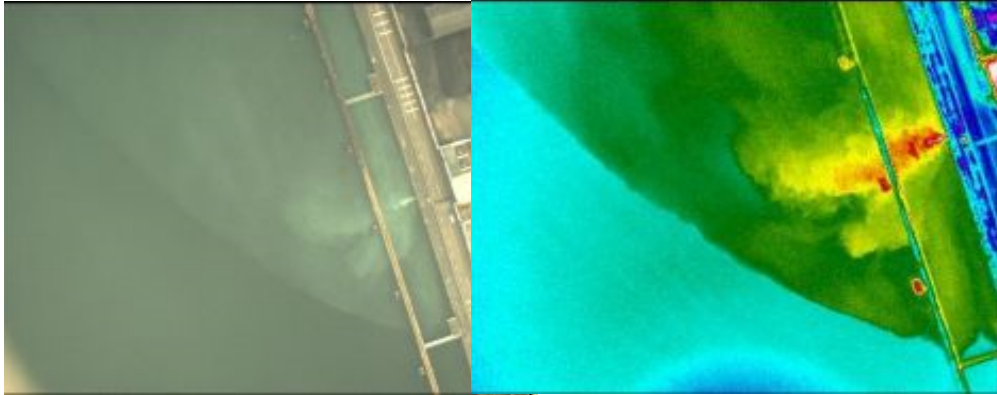- Field scale ET required for water rights, water pricing & water use efficiency

Anderson et al. (USDA)

Evapotranspiration: May 2017, Po Valley - Italy

Sentinel-3 ET (1km)

Evaporation (mm/h)
- 0.7
- 0.8
- 0.9
- 1
- 1.1

Sentinel-2 ET (20m sharpened)

R. Guzinski et al., 2018, RSE

0   1   2   3 km

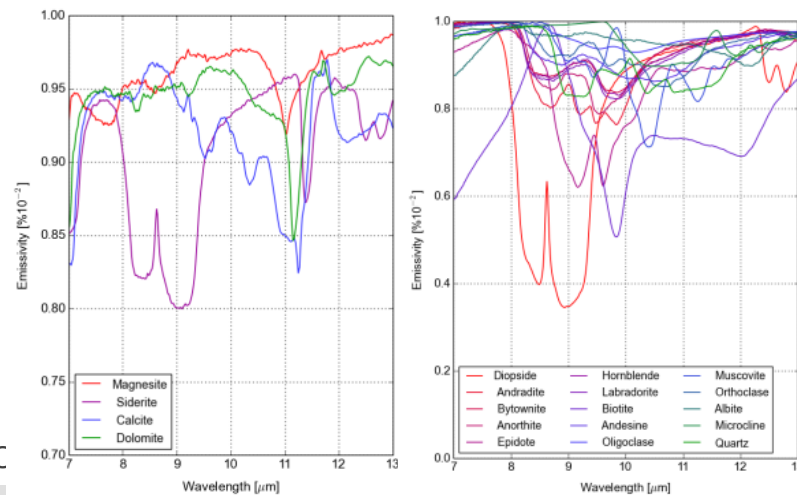## Inland & Coastal Water Quality
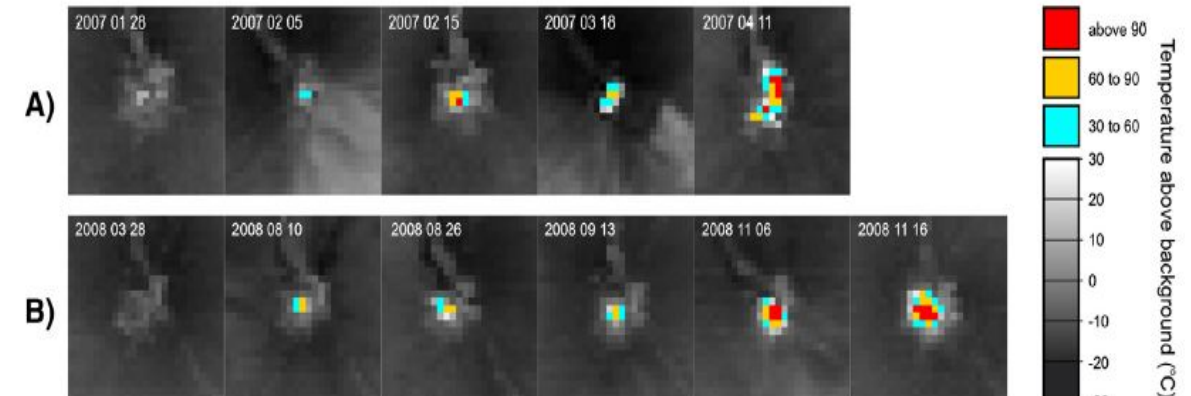

Urban Heat Islands
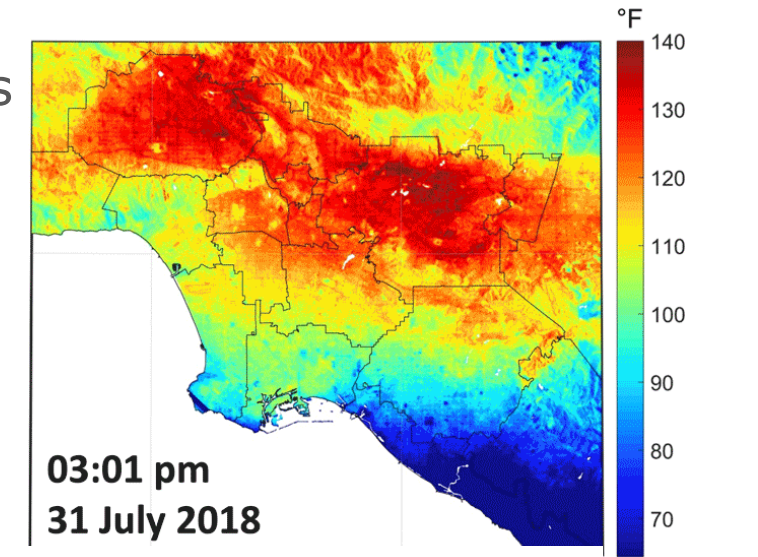
Ecostress 2018, Los Angeles

Soil composition & Mineralogy

Monitoring Volcanoes Activities

Thermal precursors to lava flow at Kliuchevskoi: anomalies in the crater, ASTER data (Murphy et al., 2013)

ESA UNC

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- **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).

LSTM Mission: Spectral Requirements

- 3 (threshold) to 5 (goal) spectral bands in the TIR spectral range (8 - 12.5 μm)
- 6 (threshold) spectral bands in the VNIR-SWIR spectral range (0.4 - 2.5 μm)

TIR spectral bands for the primary mission objectives:

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

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LSTM System Design

Key requirement	Free-flyer
Geometrical revisit	1 day/4 sats (2d/2s)
Local time	13:00 (Europe) & night observations
SSD	50 m (37m at nadir)
Spectral Bands	5 TIR, 4 VNIR, 2 SWIR
Swath	700 km, at 640 km altitude
Acquisition system	Whiskbroom scanner
Geo-location L1c	1 SSD
MTF	0.2-0.3
Data latency (L2)	6-12 hours
NeDT	< 0.1 K
ARA	< 0.5 K
Satellite mass	about 1.1 ton

System design and Preparation:

- 2 parallel industrial **system studies**

- **Airborne Campaign & Scientific Studies** to support MRD requirements consolidation

- **End-to-End Simulator** activities for performance modeling

- LWIR **Detectors pre-development** activity

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LSTM – Managing Water for Agriculture
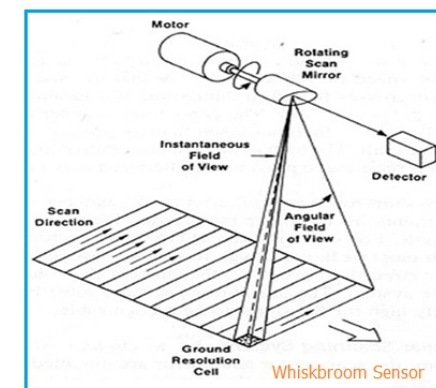
What

- 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 **30-50 meter** observations in **3-5 thermal bands**
- Frequent Land Surface Temperature (LST) at **daily to 3 days revisit**
- World-class instrument providing **1-1.5K LST** radiometric accuracy

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