Land Surface Temperature Monitoring
LSTM Mission

A Copernicus Mission for **Agricultural Monitoring**

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Copernicus for Agricultural Monitoring

National Centre for Earth Observation — NATURAL ENVIRONMENT RESEARCH COUNCIL

UKRI — Natural Environment Research Council

CEOS — Committee on Earth Observation Satellites

Source: CEOS ACQUISITION STRATEGY FOR GEOGLAM PHASE 1

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/M					X
5	10-70m	optical + SWIR + TIR	Weekly (min. 1 per 16 days)	Sample	All	X	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		X

Sentinel-3 (MODIS)

Observational Gap: TIR for Evapotranspiration

Sentinel-2 (Landsat)

Sentinel-2 (Landsat)

Sentinel-1 (PalSAR)

Global & EU relevant Policies

- EU Common Agriculture Policy
  - Greening Element e.g. Ecological Focus Areas,
    Crop diversification
  - Yield predictions at EU and Global scale
- EU Water Framework Directive & Nitrate Directive
  - Water resource management
  - Water pollution
- Sustainable Development Goals
  - SDG 6.4 Water Efficiency & 6.3 Water Quality
- UN Convention for Combating Desertification & Land Degradation
- UN Framework Convention of Climate Change

Land Surface Temperature Mission (LSTM)
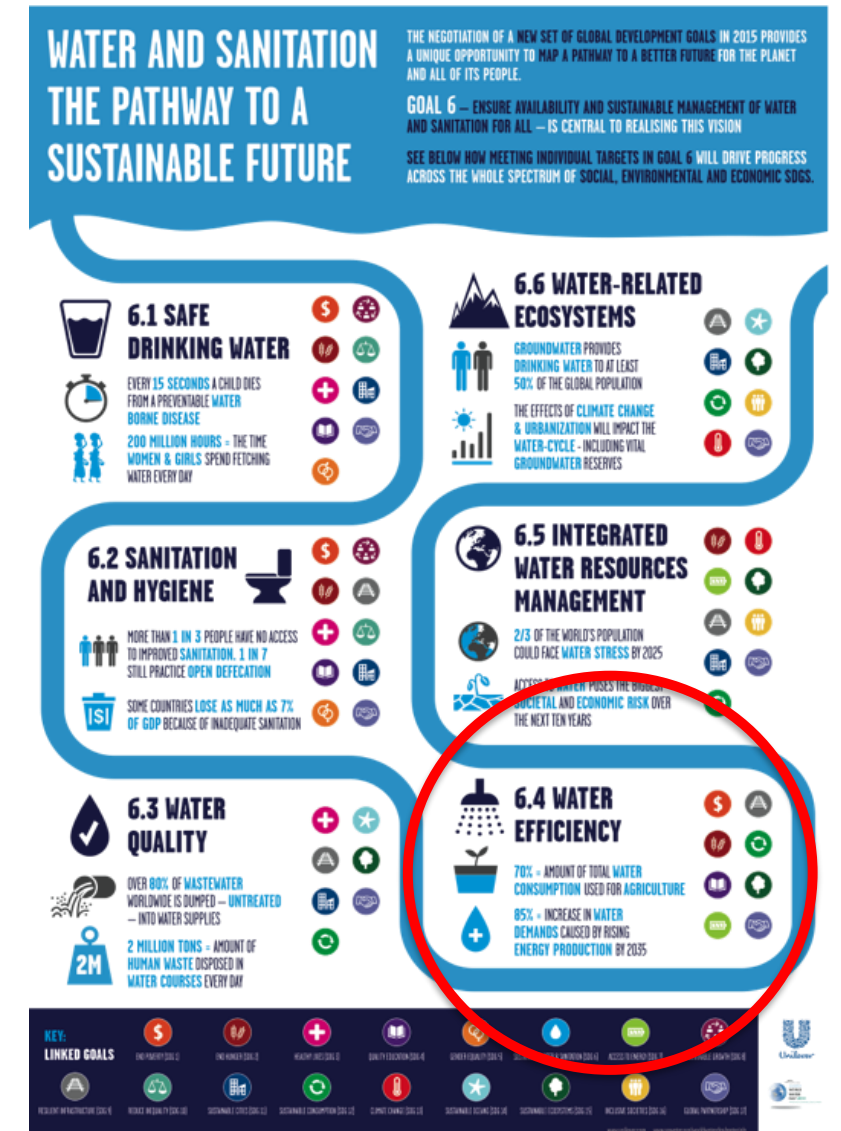
LSTM Main Mission Objective:

"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)
  - Mission Requirement Document Version 2.0 approved in April 2019
- **Mission Phase A/B1** completed
- Evaluation of bids for **Mission Phase B2/C/D/E1**
- On-going **Scientific Studies, End-to-End Simulator**, **Airborne Campaigns** and **LWIR Detectors pre-development**

LSTM – Mission Objectives

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.

- **LST goal:** accuracy 1.0 K at 300 K
- **LST & LSE threshold:** LST accuracy 1.5 K at 300 K, LSE accuracy 2%
- **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 objectives: to support a range of additional services benefitting from TIR observations – in particular:

- soil composition
- urban heat islands
- coastal zone management
- High-Temperature Events.

LSTM System Design

Observation Requirements:

- 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

- 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)

Key requirement	Design Concept
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**

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	9.15	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

Objectives of the activity

- To deliver essential input information for the system studies and related technical support activities.

- To quantify the impact of different instrument performances on the LST retrieval models.

- Analysis of user requirements to translate them into mission requirements

- To quantify the impact of different LST observational assumptions on the performance of evapotranspiration (ET) retrieval models.

- To consider leading ET models and benchmark their performance, taking into account model parameterisation and available ancillary inputs

- Trade-offs in the Industrial system studies between possibly conflicting requirements might be necessary

TIR-TRP Algorithm Assessment

	Accuracy (K)			Precision (K)		
	GSW	**OE**	**TES**	**GSW**	**OE**	**TES**
Maize	1.17	1.97	2.19	1.48	2.00	3.75
Wheat	2.07	1.19	3.58	1.48	2.35	0.98
Orange Grove	0.55	1.04	1.92	0.60	1.87	3.05

- All algorithms can benefit from the VNIR/SWIR channels for good quality LSE and TCWV a priori data to optimise the performance

- Both OE and TES capitalise on the use of all the TIR channels to retrieve both LST and LSEs per channel. These maximise the value of the instrument design for LSTM

- Overall the OE shows the most stable performance to instrument errors, and is primarily influenced by the quality of the a priori data. If the a priori data is of good quality then the OE would meet the accuracy requirements in the MRD

Airborne Campaigns

- SurfSense 2018:
  - Sensors: TASI & HyPlant
  - Test site: close to Grosseto, Italy
    - Irrigated / non- irrigated corn
  - Flights 17th - 24th July
  - Field validation data
- 2019 HyTES Joint Campaign
  - ESA, NASA, NCEO-KCL, NERC, BAS aircraft
  - Sensors: HyTES
  - Test site: Grosseto area, Italy
  - Flights 17th - 25th June
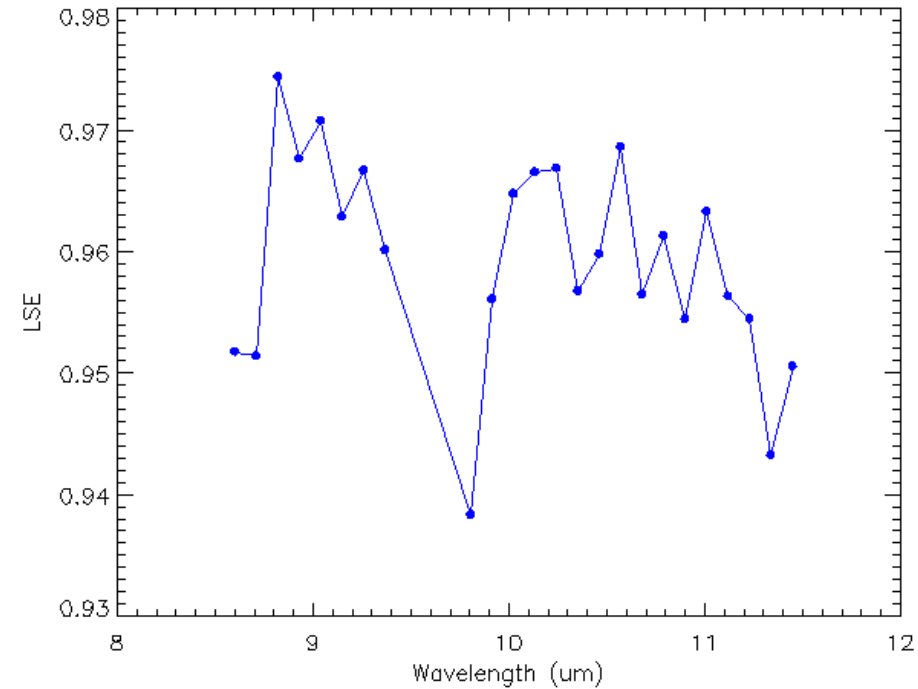 - Field validation data
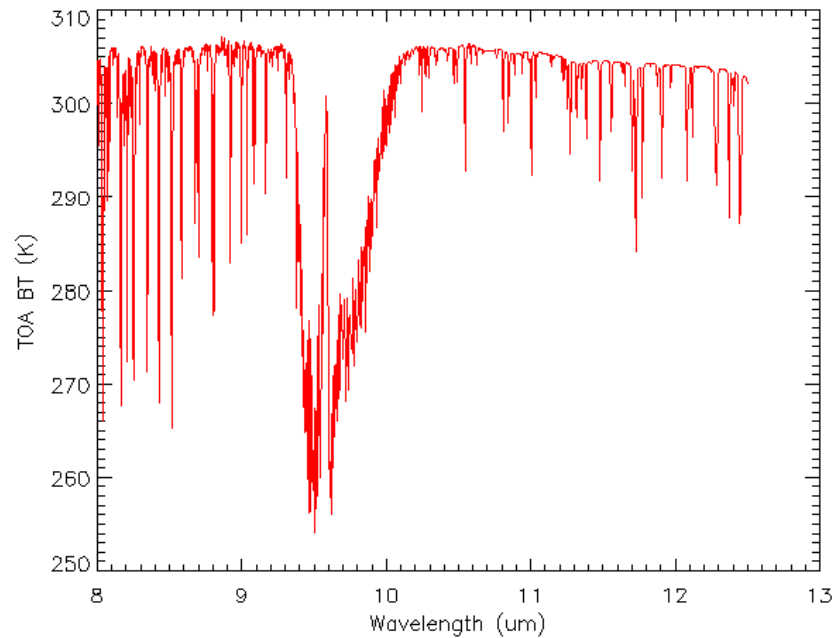- 2020 Campaign in planning

TASI data was propagated to TOA BTs:

The TASI data contains 24 spectral LSE point in the range 8.6 to 11.6 microns.

The LST and LSE data as assimilated into the Line-By-Line Radiative transfer model RFM.

RFM generates TOA BTs for 1200 spectral samples between the range of 8-12.6 Microns.

Summary of Statistics

|		GSW NI	GSW WI	OE NI	OE WI
Bias	Median:	-0.42	-0.49	-0.25	-0.43
	Standard deviation:	1.24	2.20	0.72	0.76
Uncertainty	Median:	0.73	1.57	1.23	1.35
	Standard deviation:	0.02	0.09	0.10	0.26

*NI = No Instrument Artefacts
*WI = With Instrument Artefacts:

Campaign Data: Grosseto – 11:47:30

Region contains measurement points from the Insitu dataset.

RICE

Bias		In-Situ	Uveg LST	GSW NI	GSW WI	OE NI	OE WI
Bias	Median:	305.19	303.50	303.68	303.82	303.96	303.83
	Standard deviation:	0.22	1.60	1.80	1.98	1.83	1.84

NDVI

NCEO and LSTM
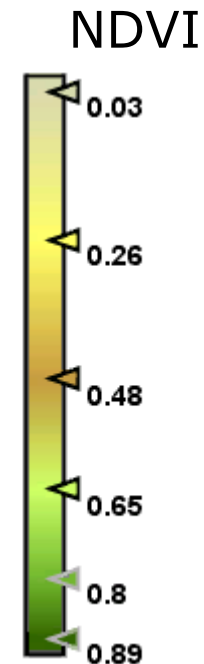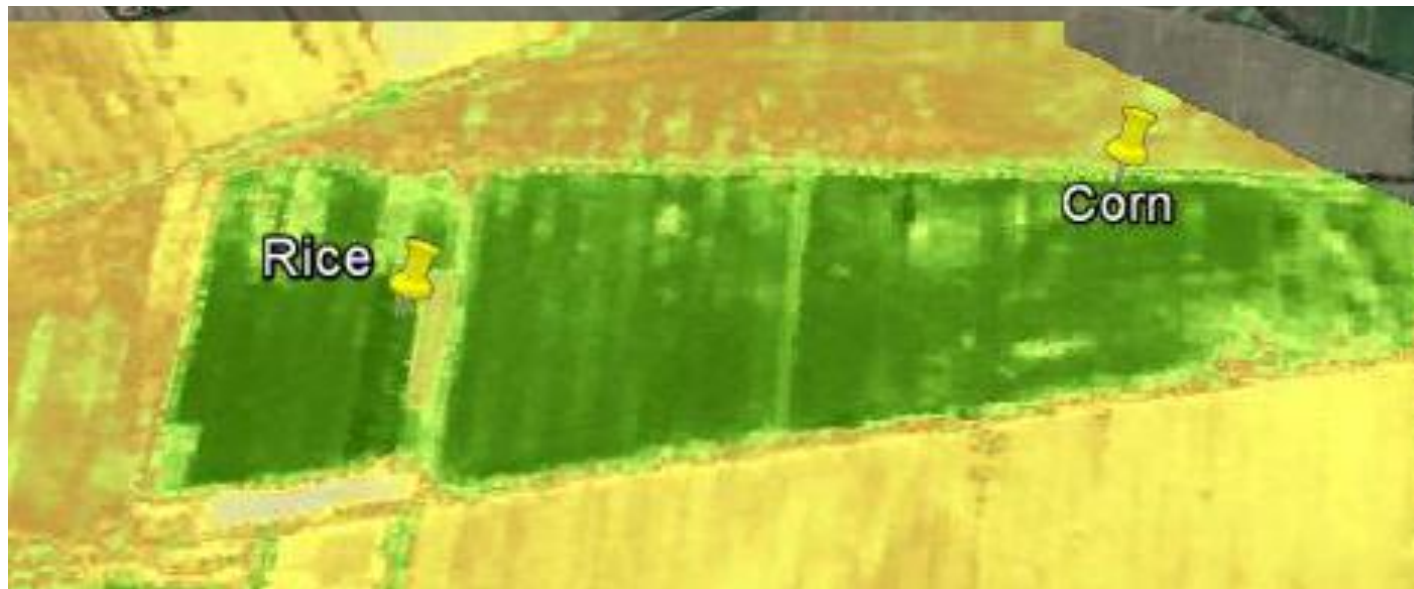
- **Phase A/B1** for technology readiness for LSTM mission implementation [NCEO-Leicester, subcontractor to one of the parallel studies]

- **Mission Advisory Group** [D. Ghent, NCEO-Leicester]

- **Scientific Study (TIR-TRP)** to support MRD requirements consolidation for spectral resolution, retrieval algorithms up to Level 3 [NCEO-Leicester, Project Lead]

- **TIRI-SIM Study** to consolidate existing users requirements for high resolution thermal infrared [NCEO-Leicester, Project Lead]

- **End-to-End Simulator** activities for performance modelling in order to support the verification of the observation and performance requirements [NCEO-Leicester, Lead Science Advisor]

- **Airborne Campaigns** to support MRD requirements consolidation to support local time & ground resolution choices up to Level 3 [NCEO-KCL, aircraft / instrument coordination]