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HiVE – A satellite constellation towards Global Water Monitoring for a growing planet – Data Products and Processing

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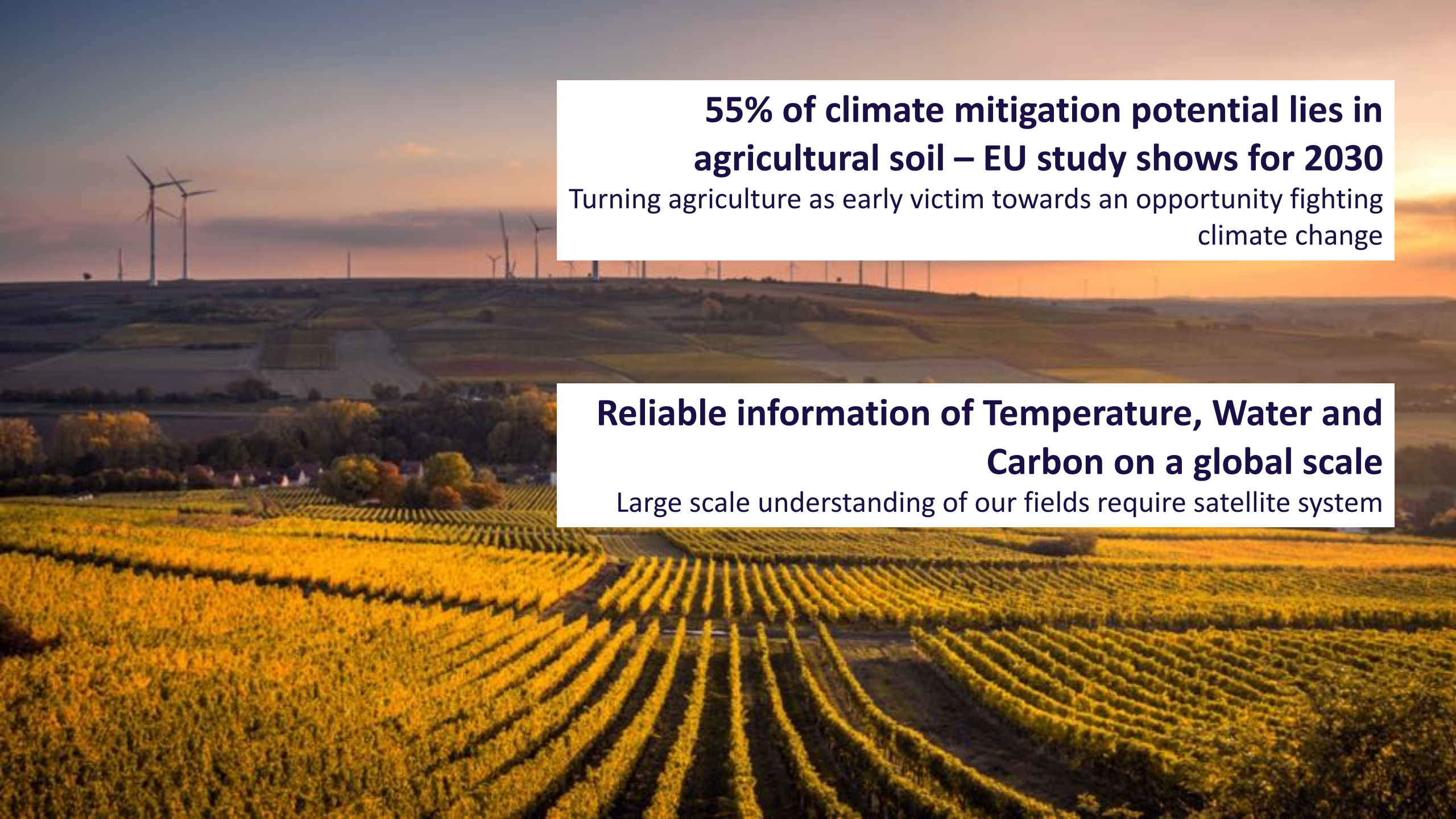
Expecting -20% drop in crop yields by 2030
Humanity is not prepared for the biggest challenge of the century
Land use responsible for 20% CO2 emissions
70% of freshwater in agriculture – 60% wasted
Turning agriculture from an early victim towards an opportunity
fighting climate change



55% of climate mitigation potential lies in agricultural soil – EU study shows for 2030

Turning agriculture as early victim towards an opportunity fighting climate change

Reliable information of Temperature, Water and Carbon on a global scale

Large scale understanding of our fields require satellite system

constellr – water & carbon monitoring at scale

Data fusion platform for comprehensive crop monitoring

Globally scalable

Single, comparable dataset for the whole planet

Affordable

Few Euros per hectare per year

Reliable

Real physical measurement at field level

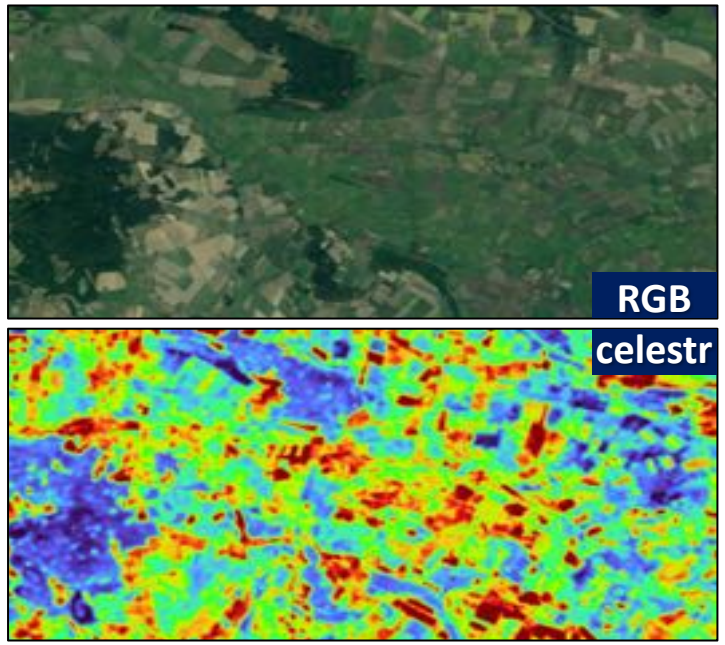
Symptoms instead of damage

Sees vegetation stress days to weeks before crop damage

constellr provides key solutions

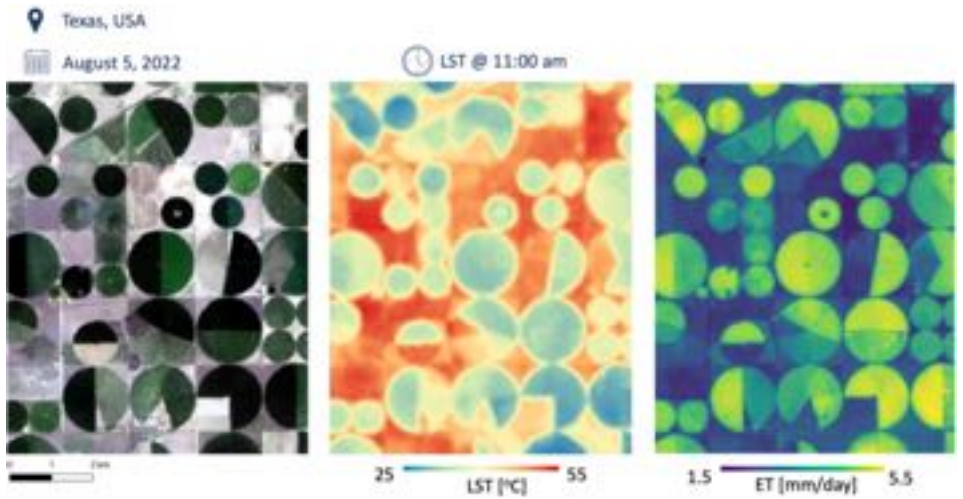
Three products to improve efficiency, predictability and sustainability

Celestr



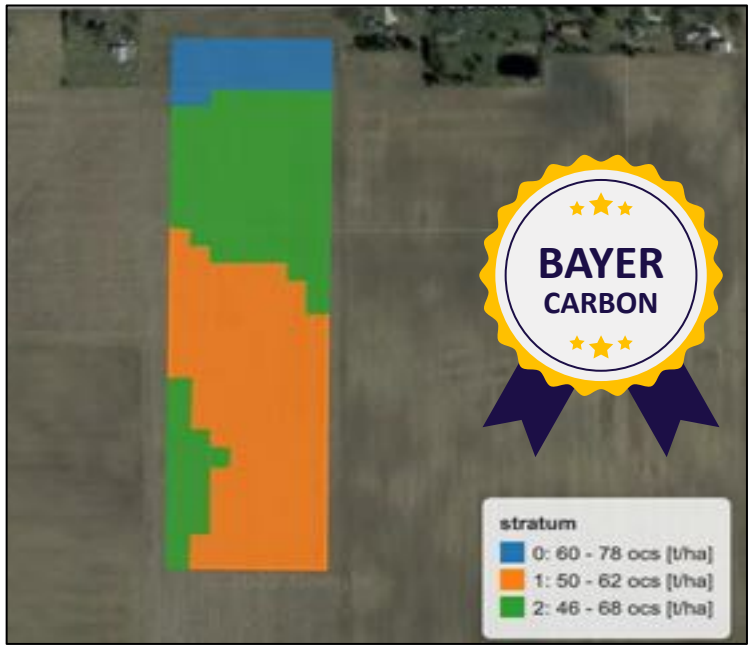
A satellite-agnostic data stream for high-revisit land surface temperature (LST)

Evapotranspiration



From field-level precision to the entire global water cycle

SOC stratification

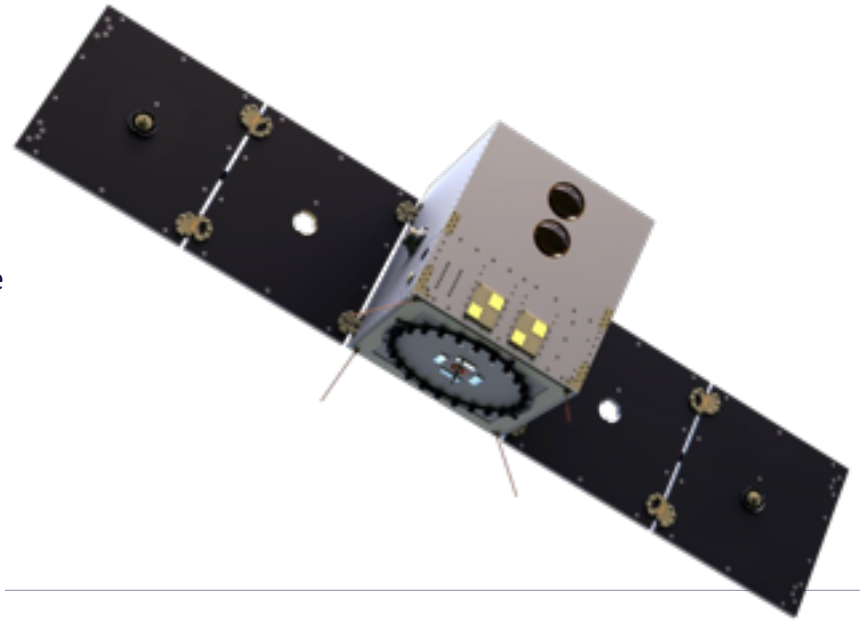


Scalable estimation of soil Organic Carbon Stock (OCS) strata for field level insights

The High-precision Versatile Ecosphere monitoring mission (HiVE)

Objectives

- Quantifying water, temperature & carbon balance
- Helping farmers saving water & inputs → saving costs
- Build an affordable, reliable, biophysical atlas of the planet for vegetation monitoring (evapotranspiration, LST, soil organic carbon)

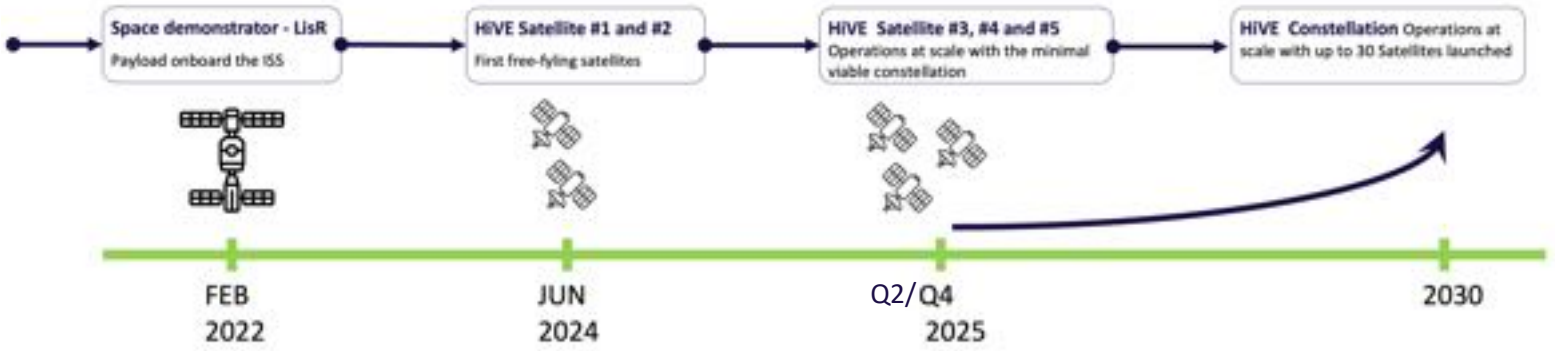


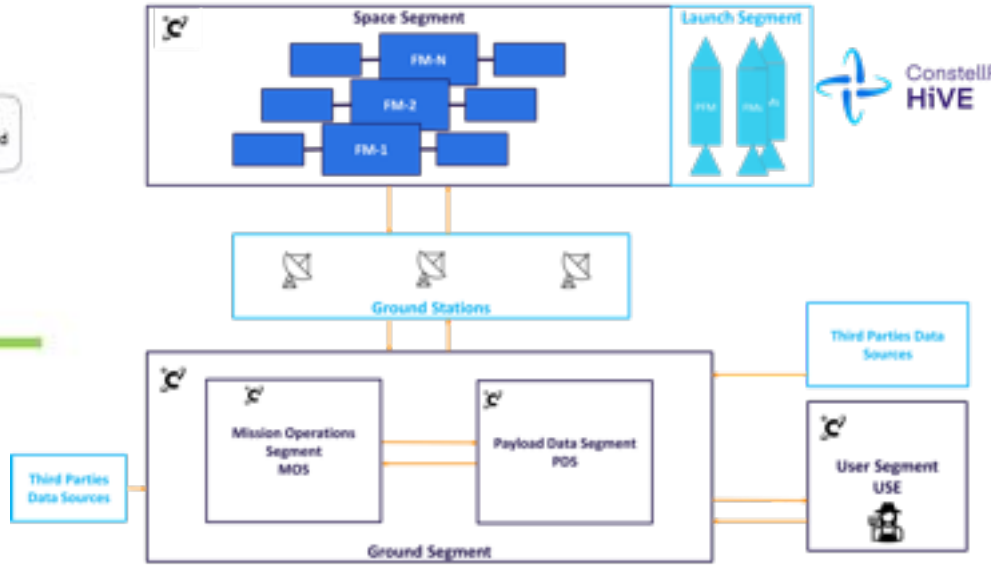
Computer rendition of FM1 satellite

Technology

- Constellation of thermal & hyperspectral satellites
- Global mapping of the planet with daily revisit
- Planned launch of FM-1 and FM-2 in 2024
- First generation with multispectral VNIR and LWIR Thermal bands
- Space segment 1st gen. under development in consortium with OHB, Nanoavionics and Fraunhofer EMI and co-financed by ESA & DLR via **Incubed** programme

HiVE architecture & deployment timeline





FM-1

Instrument	Resolution (m)	Number of bands	Wavelength range (µm)	Pixel pitch (µm)	Focal length (mm)	Orbit height (km)	Lifetime (years)
VNIR: Simera MultiScape100 (CMOS) TIR: Custom MCT (HgCdTe) cryo-cooled	VNIR: 10-60 TIR: 30	VNIR: 10 TIR: 4	VNIR: 0.44 – 0.94 (same as Sentinel 2) TIR: 8.6 (c) – 0.3 FWHM 9.2 (c) – 0.3 FWHM 10.6 (c) – 0.5 FWHM 11.75 (c) – 0.5 FWHM	VNIR: 5.5 TIR: 15	VNIR: 580 TIR: 280	540	5

HiVE Performance goals

High performance at scale for agriculture applications

Ground Sampling Distance and Swath

Swath = 20km

VNIR spectral bands match Sentinel 2 GSD & SNR (no SWIR)

TIR: 28.9m (30m sampling intervals for products)

At-sensor radiance

VNIR: 5% 1σ

TIR: 2% MAX

Main Image Products

Land Surface Temperature (1.5K RMSE): celestr

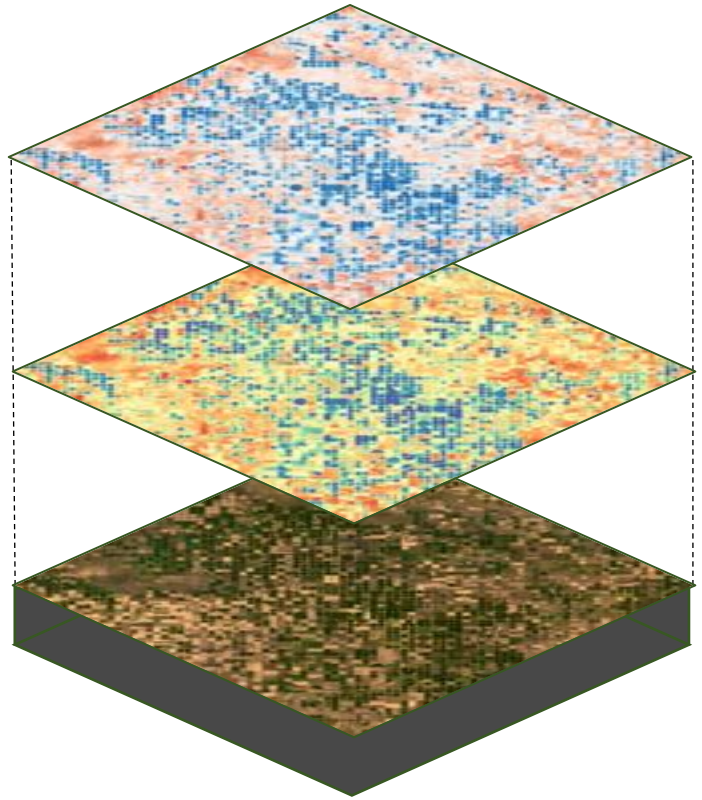
Surface Reflectance

Surface Emissivity

Derived products

Evapotranspiration

Soil organic carbon



Cal/Val

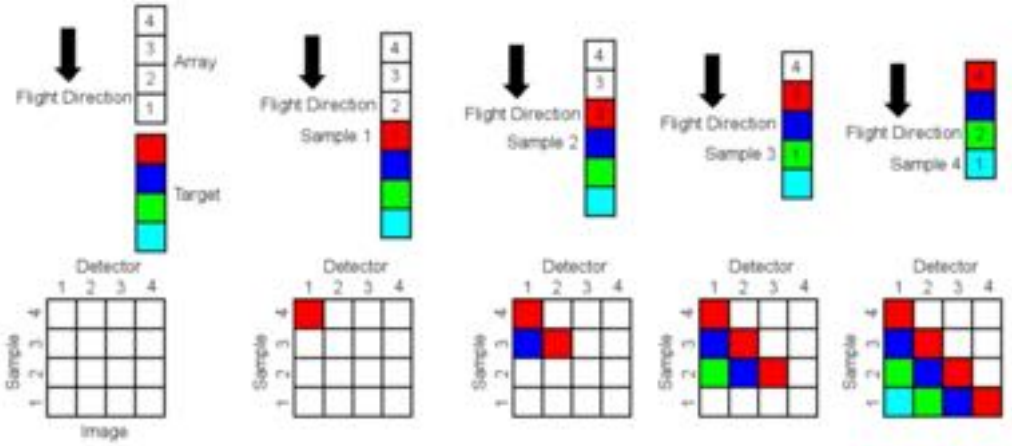
Different methods needed for VNIR and TIR

VNIR

- *PRNU*: Side slither, deep space images, detector statistics
- *Absolute calibration*: vicarious calibration

TIR

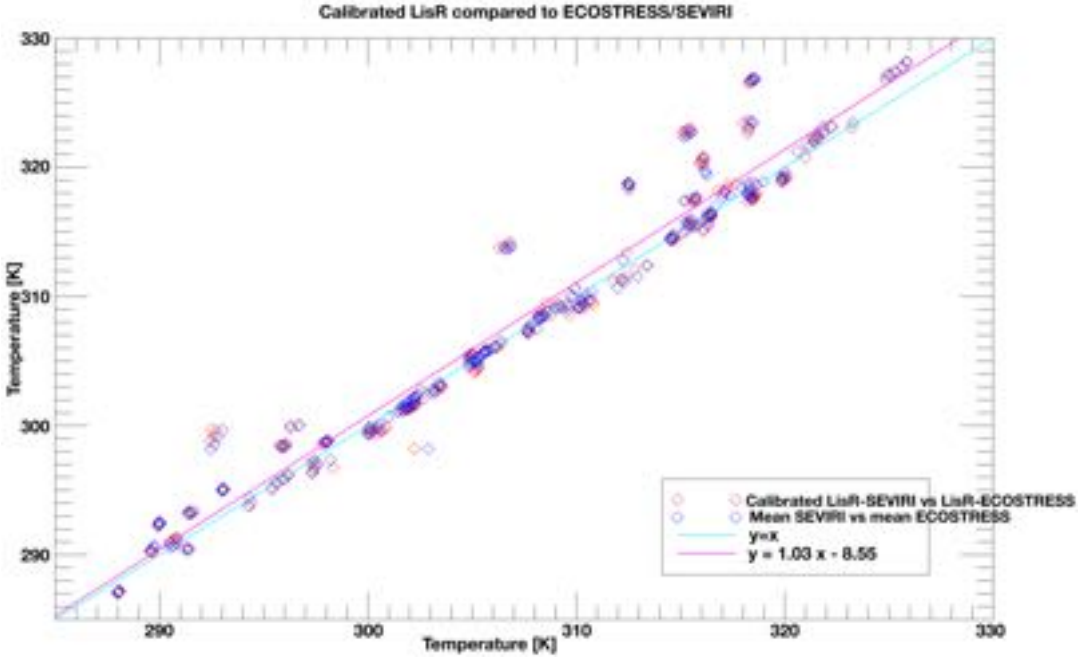
- *PRNU*: Side slither, deep space images, detector statistics
- *False light*: Deep space images, dark currents
- *Absolute calibration*: Cross-calibration, vicarious calibration in development

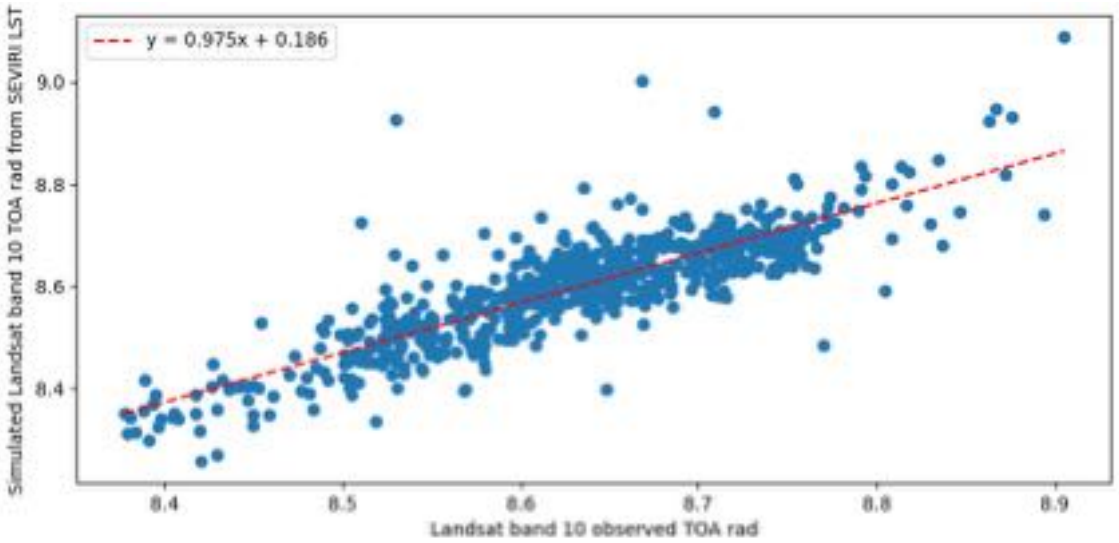


Cross-calibration methodology

Objective

Radiometrically calibrate a thermal sensor without using an on-board black body





Test using constellr patent

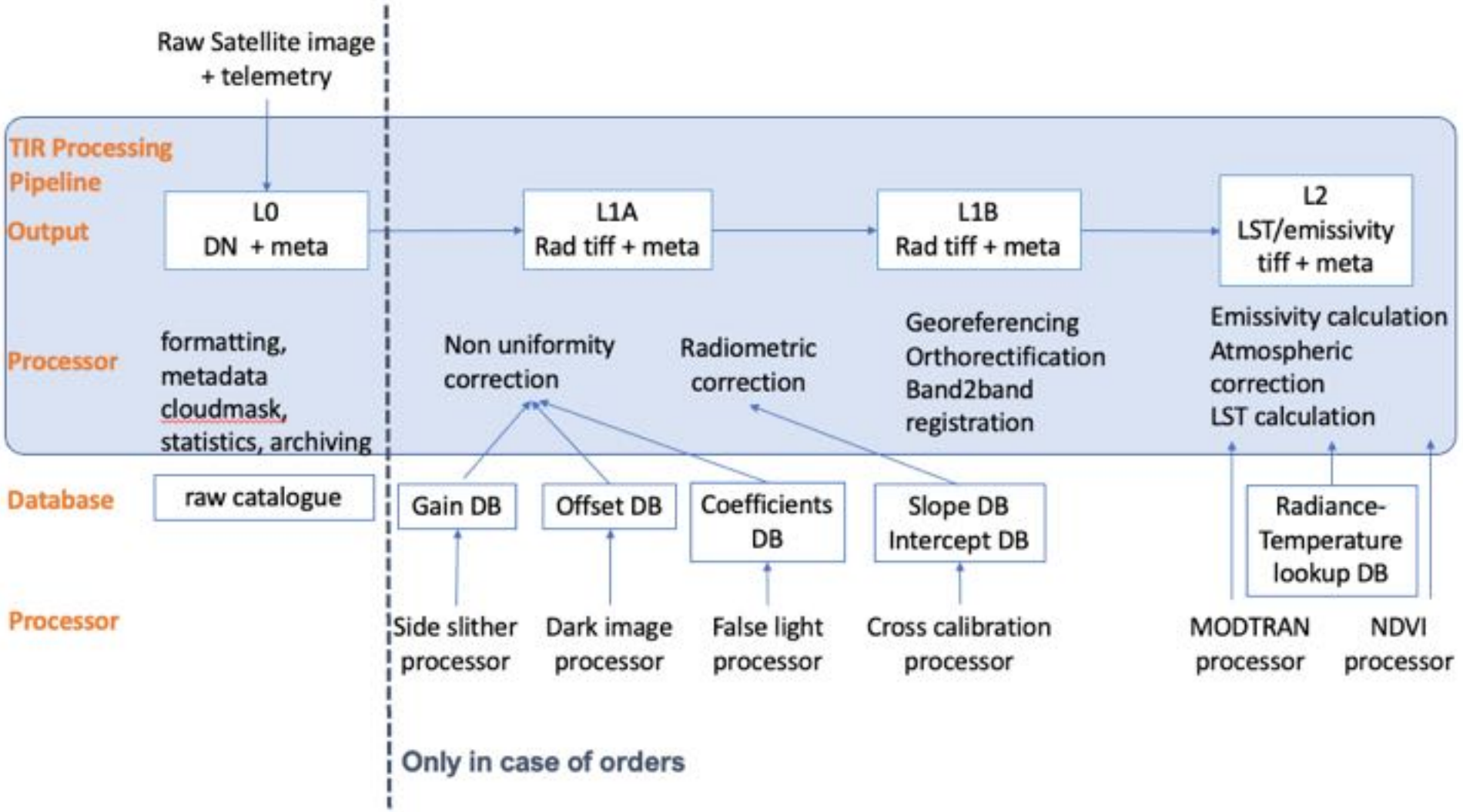
- calibrate the sensor using a reference instrument BT (e.g. SEVIRI or ECOSTRESS) with a coarser resolution
- compare the resulting temperature
- methodology has been confirmed with our own **LisR** instrument

Calibrate using ground temperature measurements

- Simultaneously, collect imagery of uniform areas with HiVE and GeoSat thermal imagers (e.g. SEVIRI, GOES-R)
- Co-register areas on the ground and consolidate to same pixel sizes
- Use GeoSat ground temperature as ground truth for HiVE
- Use on-board VNIR data (aerosol and water vapor bands) with external atmospheric profile

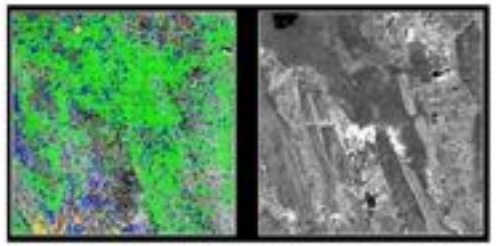
Processing Workflow

automated cloud-based processing pipeline for all orders



Geometric correction

Pinkmatter selected to provide SAAS solution for geocal and geo processing



1. Using the Attitude and Ephemeris data, and the latest updated CPFs, a Systematic model for the data is created. No data is resampled yet.
2. GCPs are collected from the imagery using the Systematic model using the reference data.
3. The Orbit Model is refined using the obtain GCPs.
4. A resampling grid is generated, incorporating the Reference DEM and the refined geometric model.
5. The image is orthorectified using the refined geometric model using single resampling stage.

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pinkmatter

LST algorithm analysis

High LST accuracy for commercial use cases

Objective

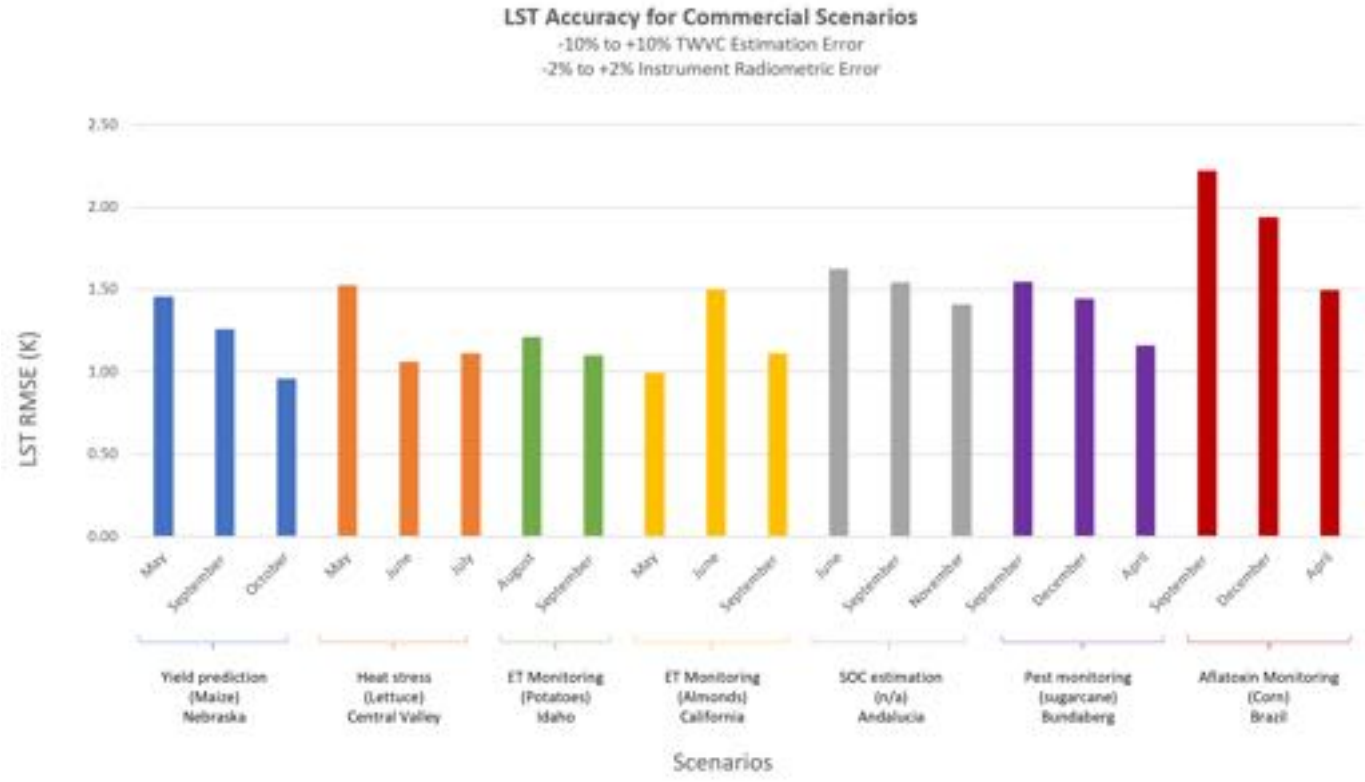
- LST accuracy of the HiVE system for different commercial use cases
- Thermometric accuracy dependent on geo-location, atmosphere, terrain and season

Algorithm

- Multiple thermal bands employed to simultaneously estimate LST and LSE
- Semi-custom temperature-emissivity separation (TES) algorithm used
- Simulated performance evaluated for radiometric errors -2% to +2%, ± 10% water vapor, target and related conditions

Results

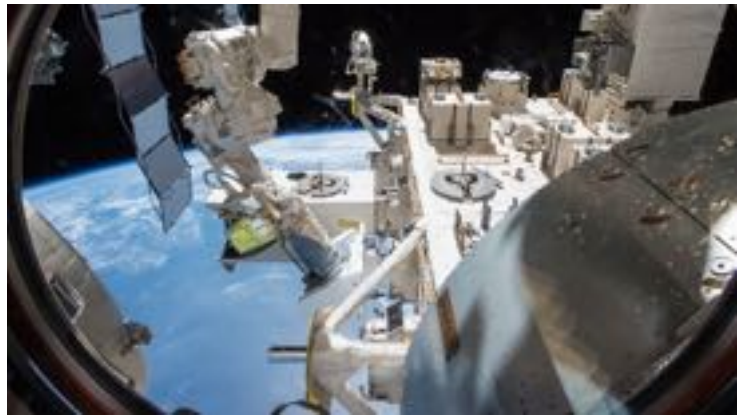
- 1.5K RMSE requirement met for most cases

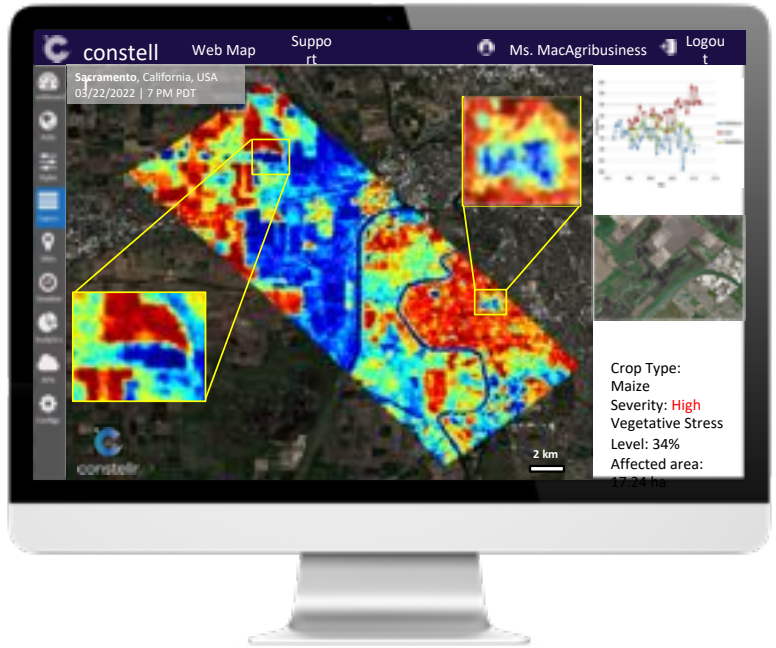


Sample LST accuracy for commercial scenarios (seasonality, atmospheric conditions and terrains)

Summary

- First payload on ISS: LisR has successfully proven and patented calibration approach
- Constellr plans to launch & operate a constellation of thermal and hyperspectral satellites, 5 sats in production
- First launch in 2024 with MS VNIR and TIR detectors
- Multiple calibration methodologies will be employed to correct instrument characteristics: vicarious, cross-calibration, deep space looks, side-slither, etc.
- Anticipated high accuracy LST providing the agriculture industry with crucial water information such as evapotransporation





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