Using LST and SSE from Hyperspectral Thermal Infrared Airborne Data for Satellite Validation: Application to AisaOWL

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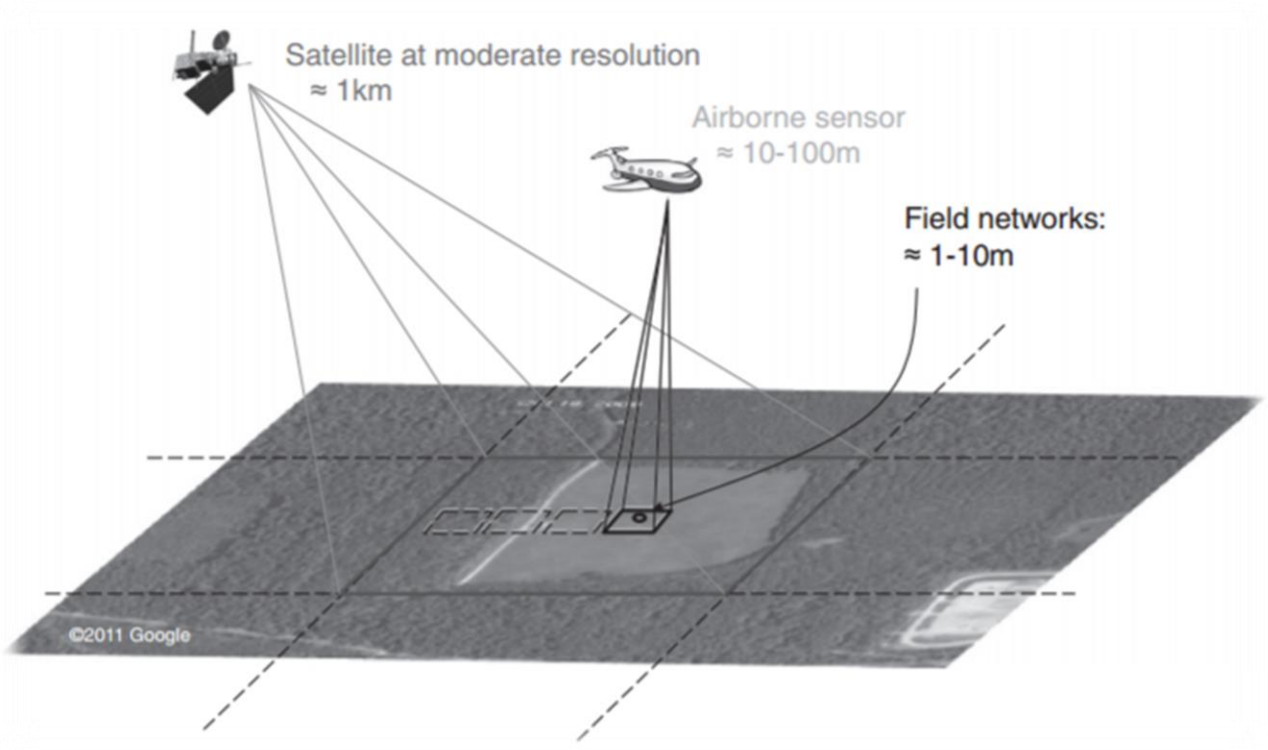
FRM4STS Workshop – 16 -18 October 2017

Outline

- Context & goal of the project and field campaign
- Methodology of the field campaign
  - Temperature data
  - Emissivity data
  - Airborne data
- Implications for satellite validation

Context

- LST and SSE data increasingly recognised as key to wide variety of Earth system studies
- Satellite-borne TIR sensors best option for regular data on global scale but require validation
  - Difficult to find sites where skin temperature observations representative of satellite pixel scale
  - Concept of 'up-scaling' measurements useful for validation



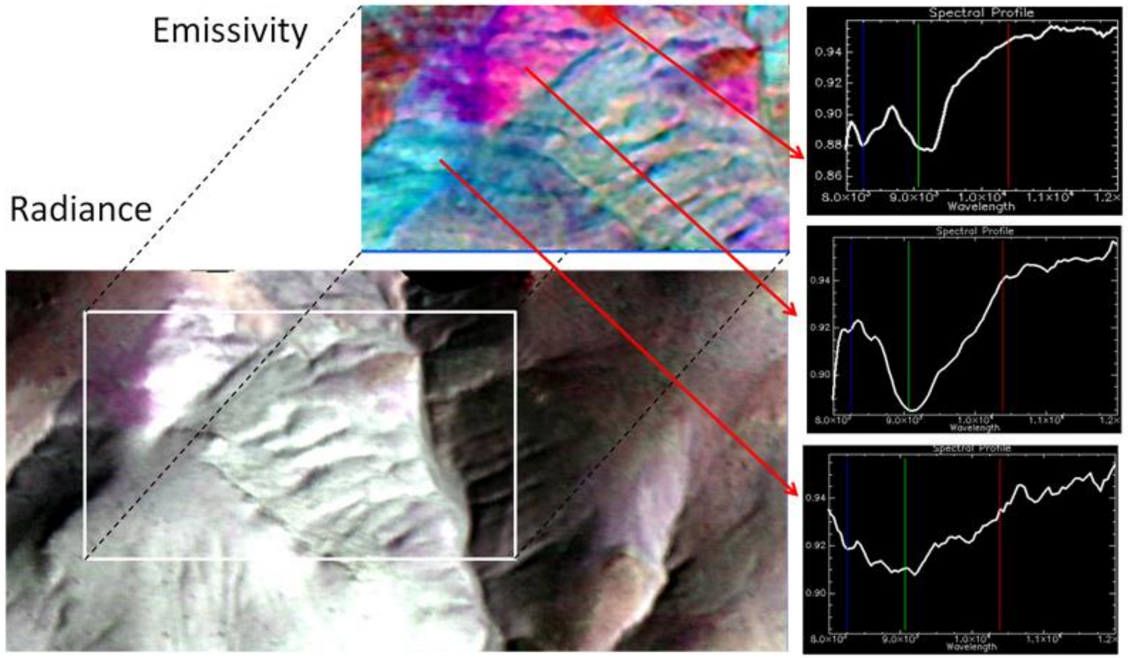
Guillevic *et al.*, 2012

Context (2)

- Hyperspectral TIR airborne sensors capable of retrieving LST/SSE simultaneously at high spectral/spatial resolutions

- NERC-ARF have new LWIR sensor (Specim AisaOWL)
  - Pushbroom sensor 7.6 – 12.6 µm with 96 bands
- So far no validated method for deriving LST and SSE

Simultaneous opportunity for satellite validation and for product users



Specim sample data: Cuprite, Nevada, USA
(http://www.specim.fi/products/aisaowl/)

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Goal

- Collect ground measurements of temperature and emissivity for validation of OWL LST and SSE products
- Develop, test and optimise algorithm for LST and SSE retrieval from OWL data
- Use LST and emissivity map for validation of satellite LST and SSE products

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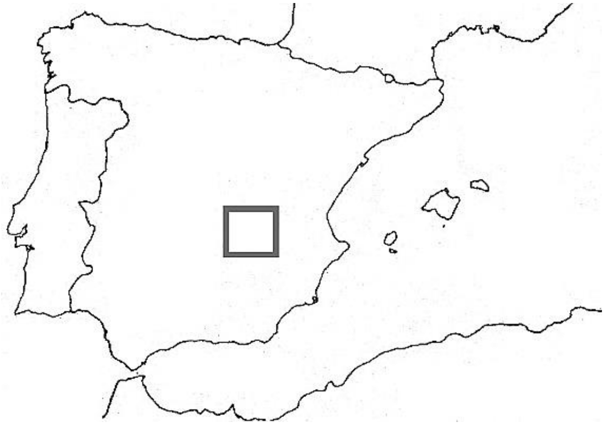
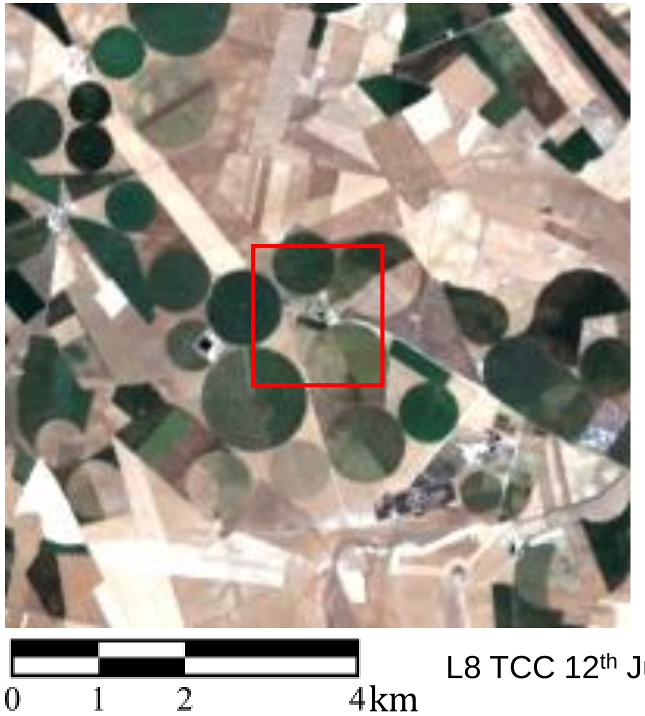
Methodology

- Dedicated field campaign near Barrax, Spain in June 2017
- Multiple flights over two days:

  1. Repeated flights over smaller area at varying times of day *(aim: consider diurnal LST cycle and test variance SSE over day)*
  2. One flight over larger area *(aim: emissivity map for r-based satellite validation)*
  3. Same flightline flown over different heights (*aim: consider how degrading resolution affects temperature/emissivity)*

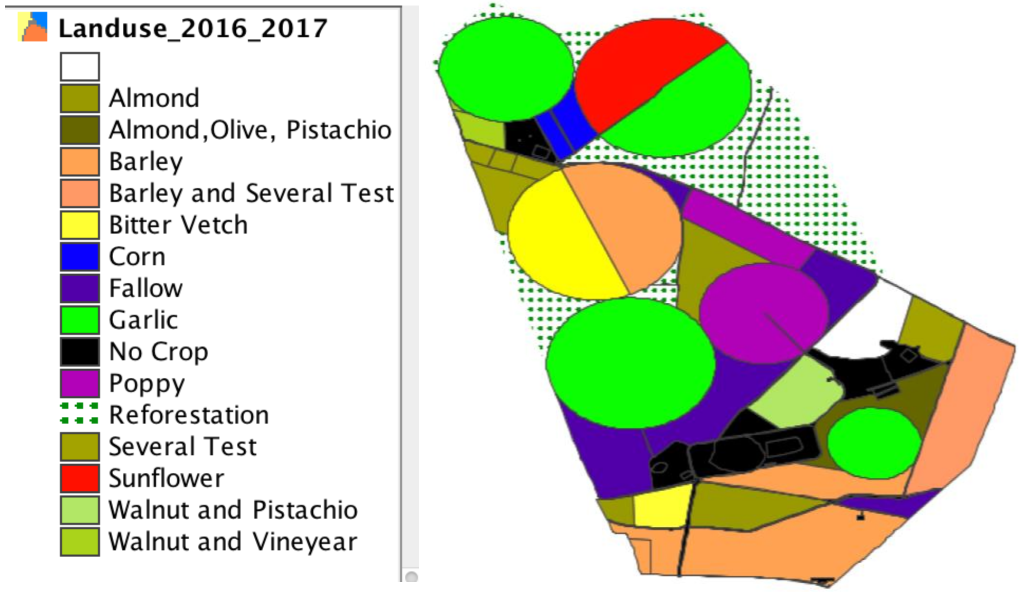




L8 TCC 12th June 2017

Site Characterization

- Cultivated agricultural area with moderate to low spectral contrast
  - Additional aluminium foil sheet ground targets laid out to provide increased spectral contrast to test OWL



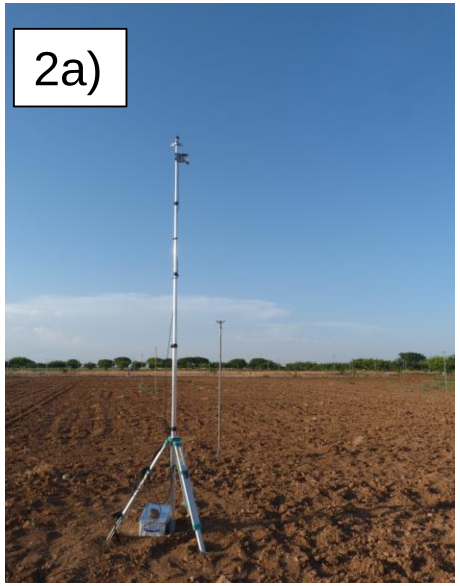
Data collection: LST

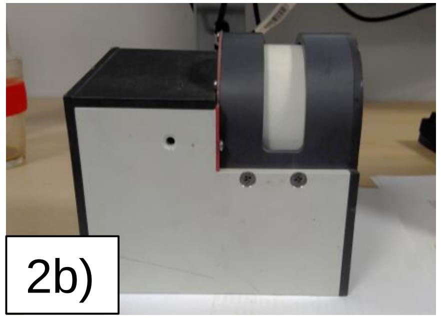
- Areas of varying thermal inertia and temperatures chosen: vegetation (grass, wheat, maize plant), soil (bare, maize soil), concrete, pondwater, foil

1. Kinetic temperature measured continuously on four sites (bare soil, grass, concrete and maize) using thermocouples

2. Radiometric temperature measurements:
   a) Fixed Apogee SI-111 on 3.5m mast continuously measuring bare soil
   b) Transects using near-nulling radiometer on loan from JPL concurrent with flights, multi-angular measurements (0, 15, 30, 40) including downwelling (127, 180)

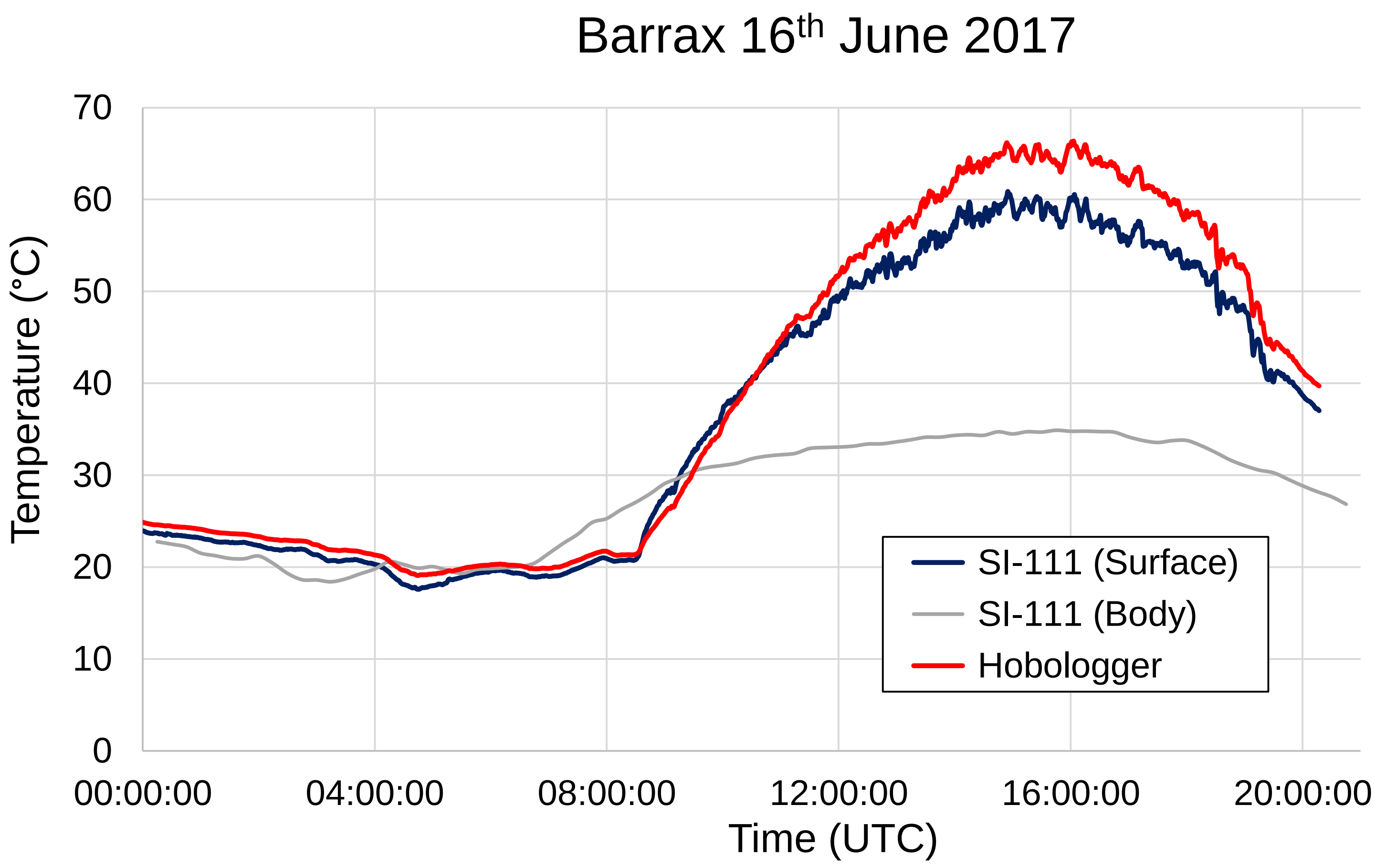
Must be corrected for downwelling radiation and emissivity effects





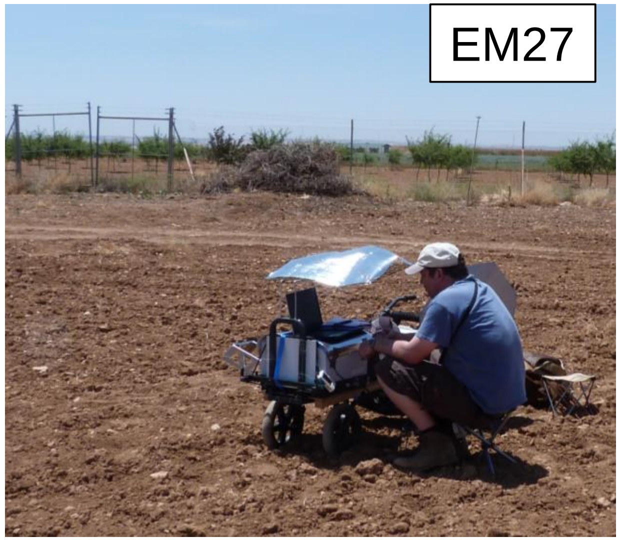
Data collection: LST (2)

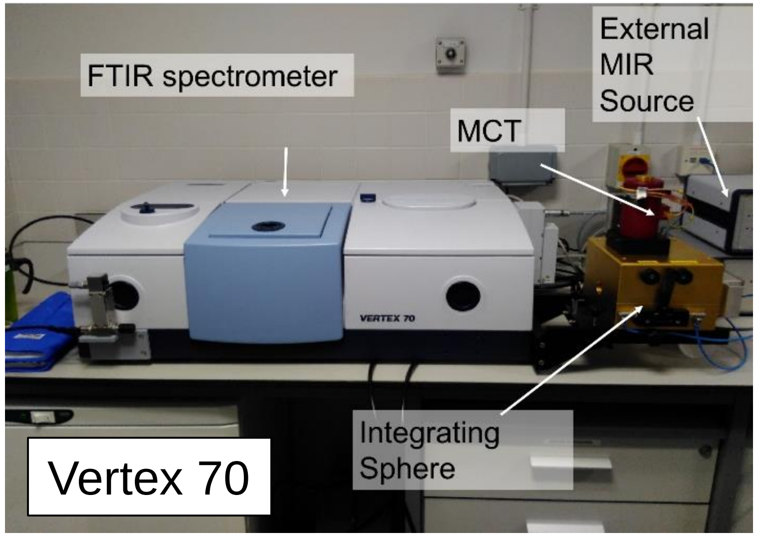
- Example: bare soil temperature measurements from radiometer (SI-111) and thermocouples (Hobologger)
  - Heatwave → soil temperatures nearly 70°C
- Difference between radiometric and kinetic readings
  - Radiometric = surface skin temperature, whereas kinetic measurements are top 2mm
- Accuracy of SI-111 decreases from ± 0.2 °C to ± 0.5 °C if $|T_{body} - T_{surface}| > 20$ °C



Data collection: Emissivity

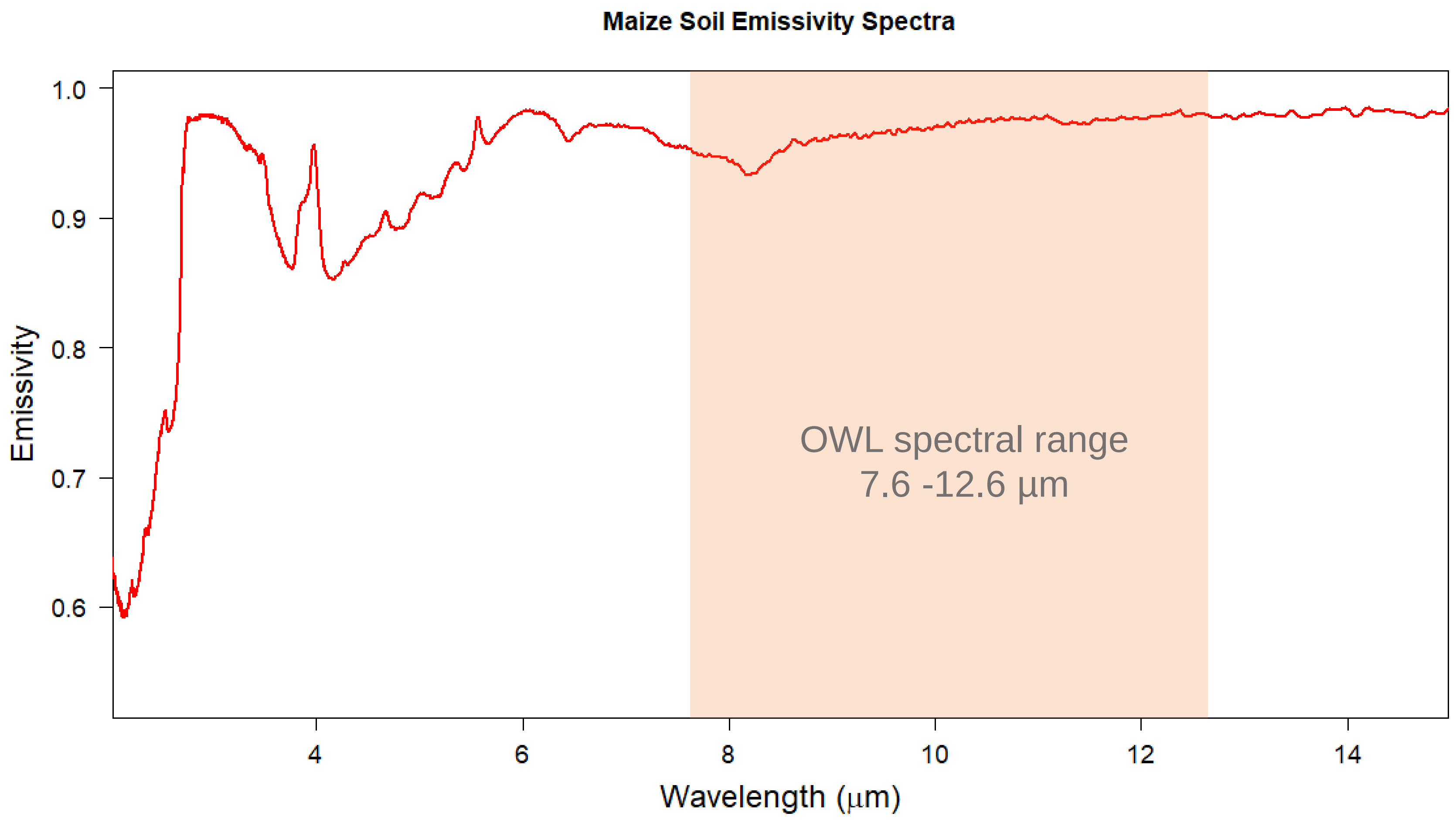
- State-of-the-art equipment used to collect emissivity at high spectral resolutions
  1. Field measurements obtained using Portable FTIR Spectrometer (EM27)
  2. Soil and water samples collected for laboratory-based measurements using new hyperspectral FTIR spectrometer setup at King's College London (Vertex 70)





Maize soil sample

Data collection: Emissivity (2)



$4 cm^{-1}$ resolution

Data collection: Emissivity (3)

Issues to consider:

1) Soil samples measured nearly a week after collection

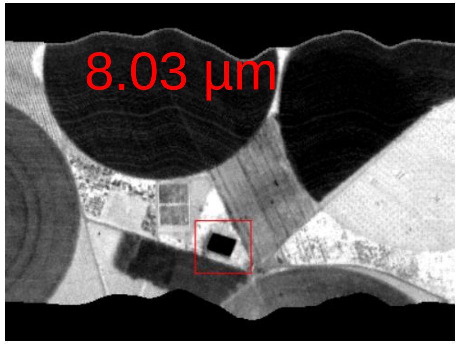
- Mean weight loss of 1% (3g) between collection and measurements suggests change in soil moisture content
- SMC impacts on emissivity, particularly in 8-9µm (Mira *et al*., 2007)
- Impact on emissivity to be determined through comparison between field measurements (EM27) and laboratory measurements (Vertex)

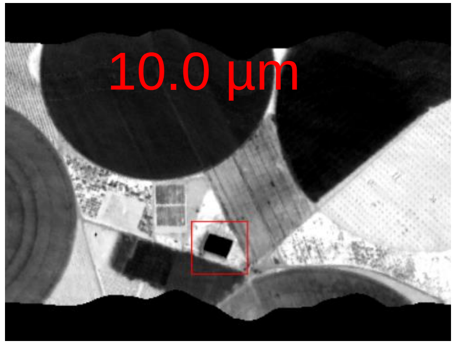
2) Vertex measures hemispherical reflectance while EM27 and OWL measured directional emittance/radiance

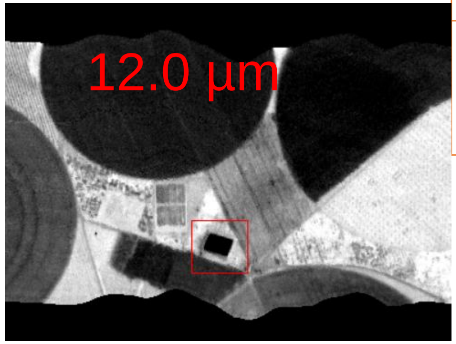
Airborne Instrument Specifications

- Two hyperspectral instruments on board: Fenix (VIS/SWIR) and Owl (LWIR)
- Owl has MCT detector cooled through stirling cycle cooler
- Owl has two on-board BBs allowing full calibration after each line

FENIX	OWL
Spectral range: 0.4 – 2.5 µm	Spectral range: 7.6 – 12.6 µm
620 spectral bands	96 spectral bands (50nm bandwidth)
FOV = 32.3°	FOV = 24.2°
At 1000m, pixel size 1.52m; swath ~600m (384 pixels)	At 1000m, pixel size 1.2m; swath ~410m (384 pixels)
12-bit output (VNIR); 16-bit output (SWIR)	14-bit output

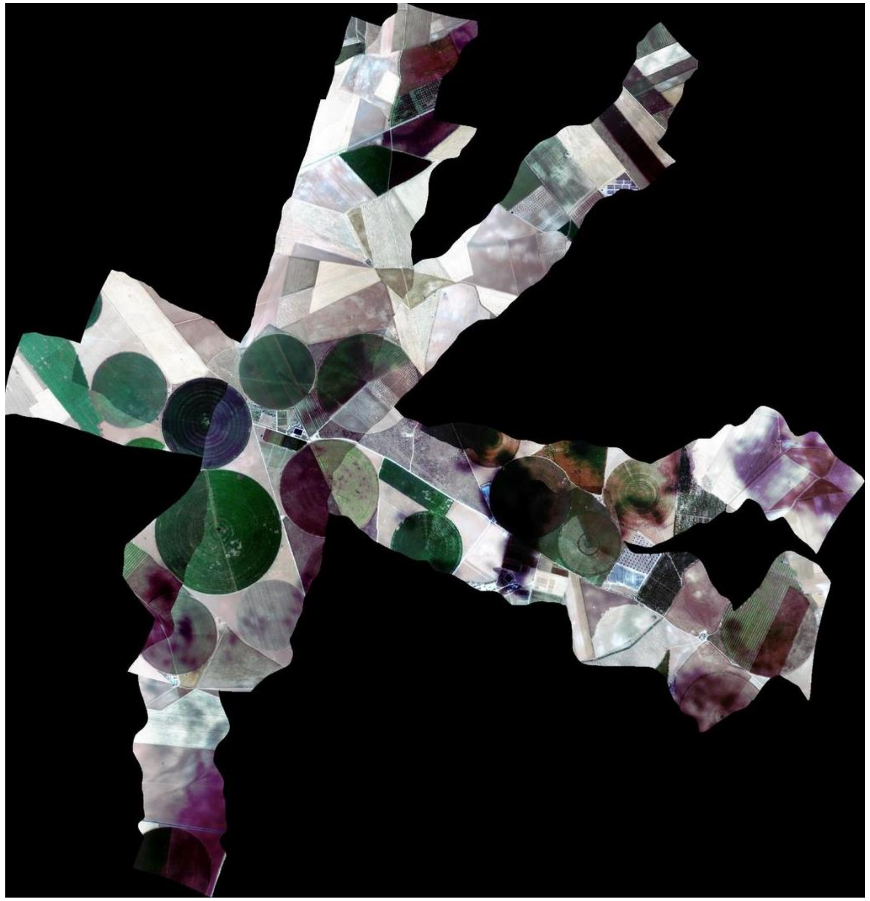






Airborne data

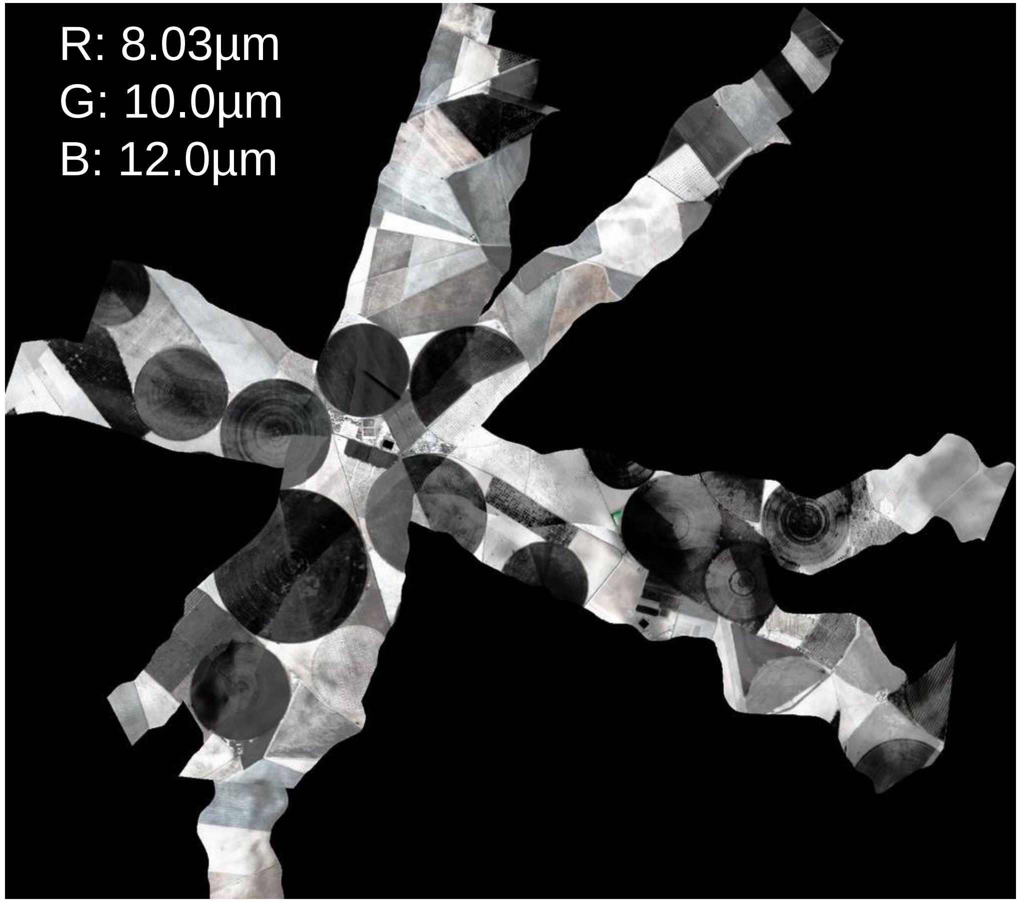
15th June 2017



RGB mosaic of Fenix data

Altitude:
~1500m

Pixel size:
~2.25m
(Fenix)
~1.8m
(Owl)



FCC mosaic of Owl data

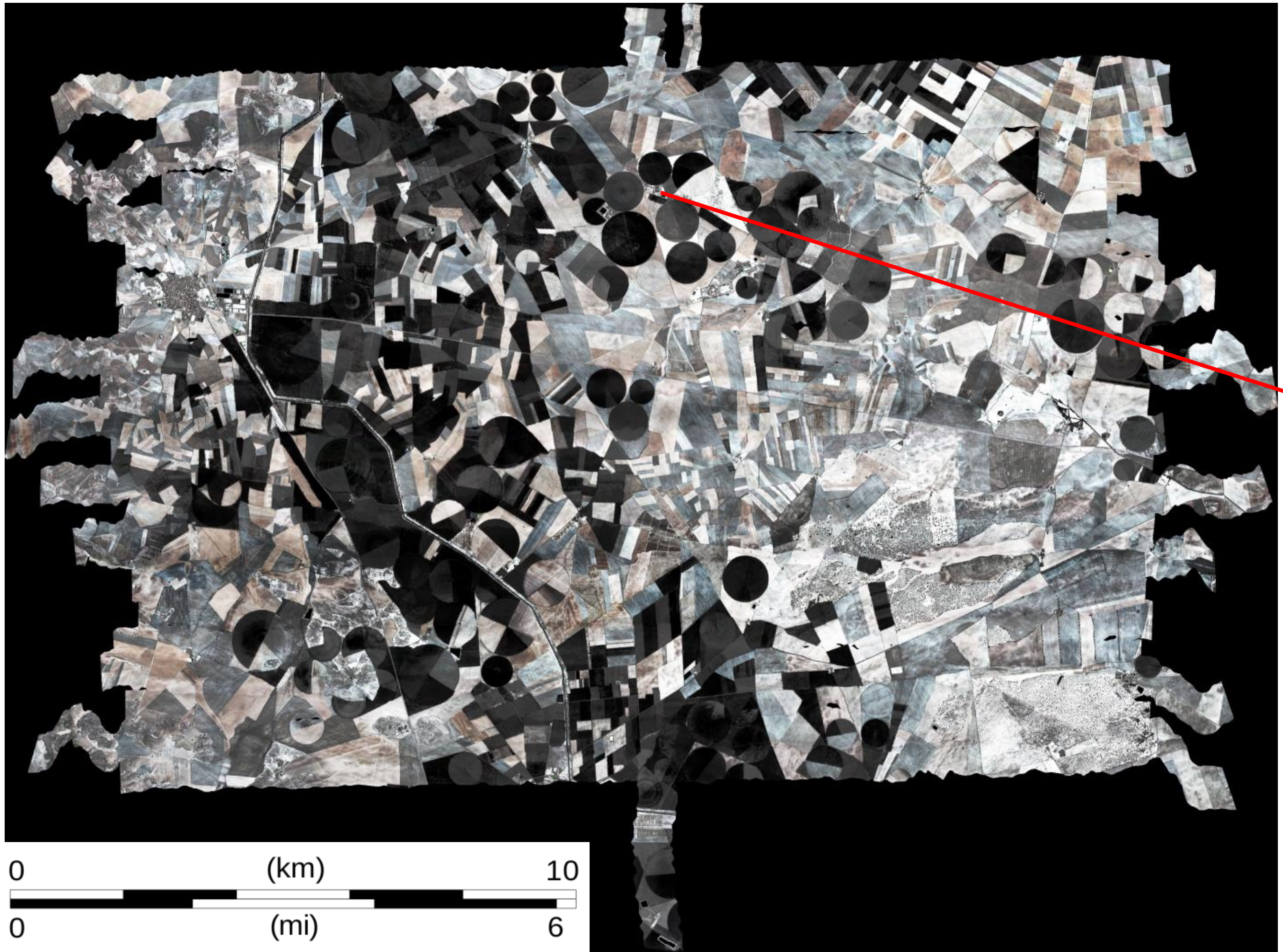
Potential for satellite validation

R: 8.03µm
G: 10.0µm
B: 12.0µm

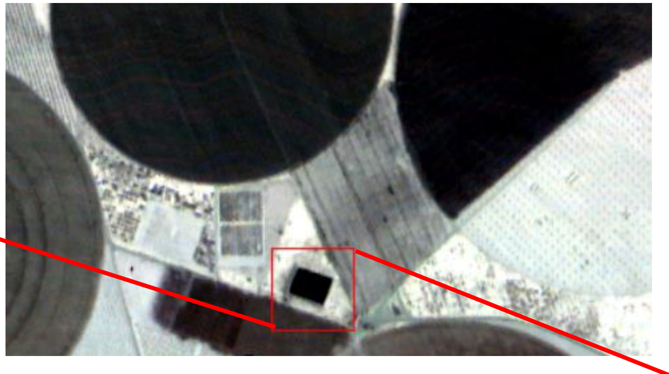
Altitude: ~2400m
Pixel size: ~2.9m

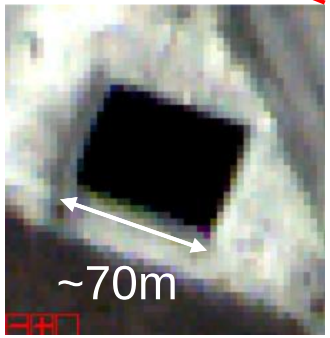
0 (km) 10
0 (mi) 6

Potential for satellite validation (2)



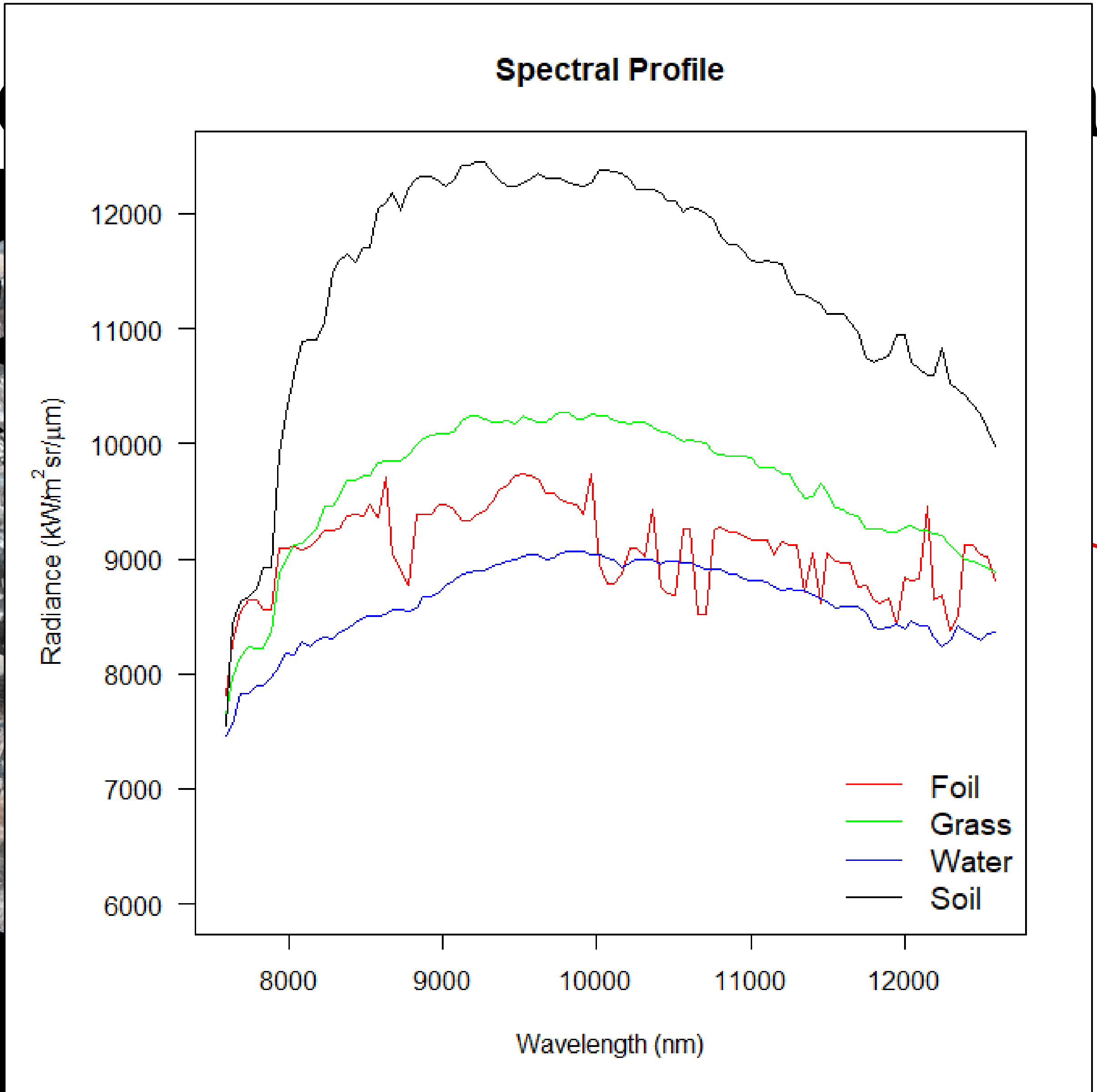
High levels of spatial and spectral detail





R: 8.03µm
G: 10.0µm
B: 12.0µm

Pot… tion (2)



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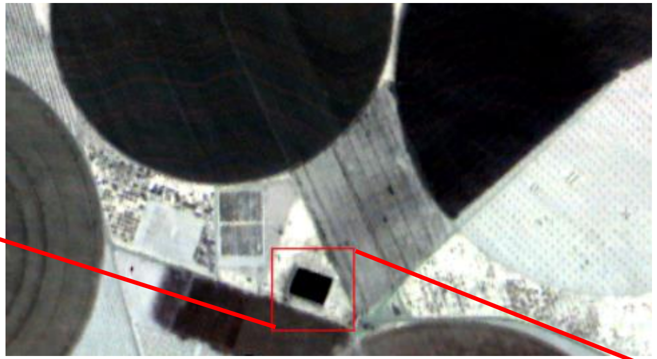

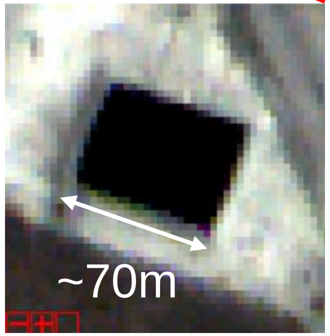

R: 8.03µm
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Potential for satellite validation (3)

- High spectral + spatial resolution emissivity (and temperature) map collected by OWL
- Emissivity map can be used with atmospheric profiles from radiosonde launches from site for radiance-based validation
  - Radiosonde data concurrent with flight also used for atmospheric correction of airborne data
- Flights coincident with local Sentinel and MODIS overpasses

Summary

- Field campaign conducted in Barrax in Summer 2017 to collect data for validation and optimisation of OWL LST and SSE algorithm
- Temperature and emissivity data collected for a range of surfaces using different methods and instrumentation
- OWL has significant potential for radiance-based validation of LST and SSE products from satellites

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