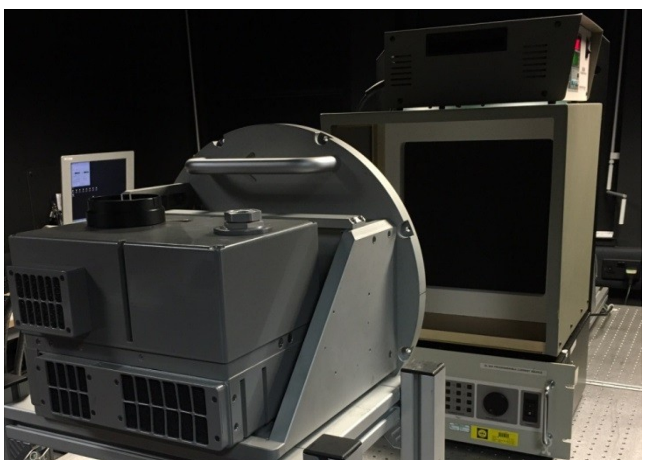
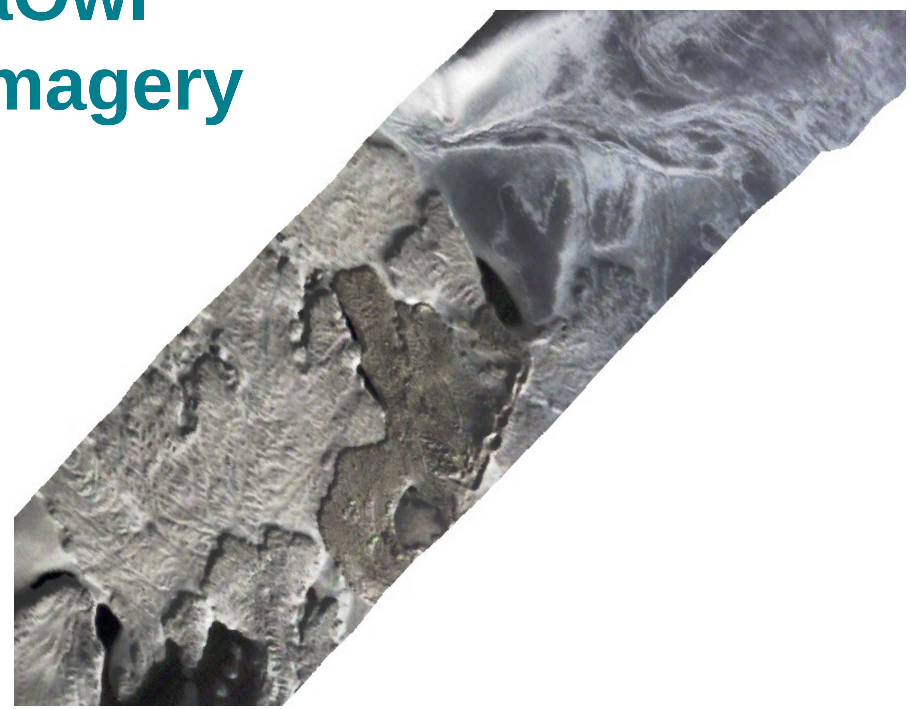
PML | Plymouth Marine Laboratory

Listen to the ocean

Introduction to the AisaOwl and Thermal Spectral Imagery

Aser Mata, Laura Harris; 14th March 2018

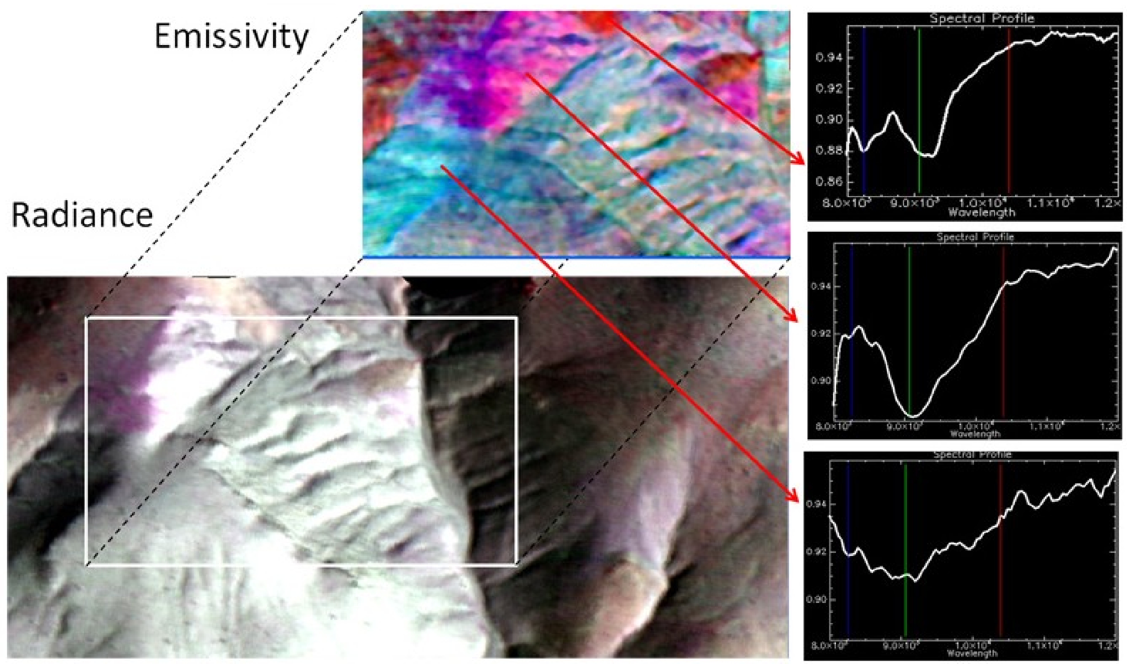




Contents

Why Thermal Imagery?

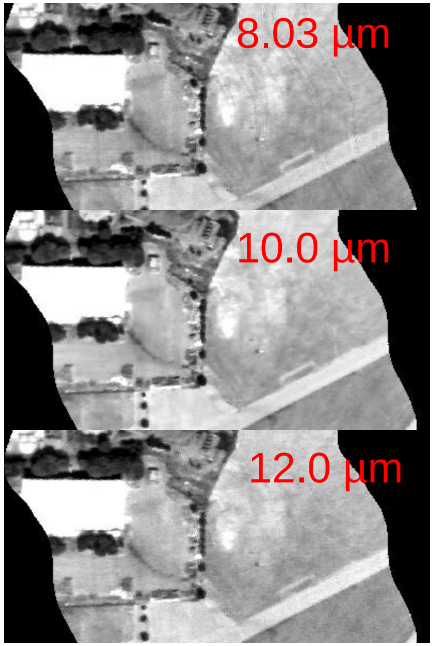
- Thermal data = Long Wave InfraRed (LWIR), 7 to 14 µm
- Differences in temperatures are associated with different materials
- Useful for identification of minerals, (particularly silicates, feldspars and serpentines) which are featureless VNIR/SWIR hyperspectral imaging.

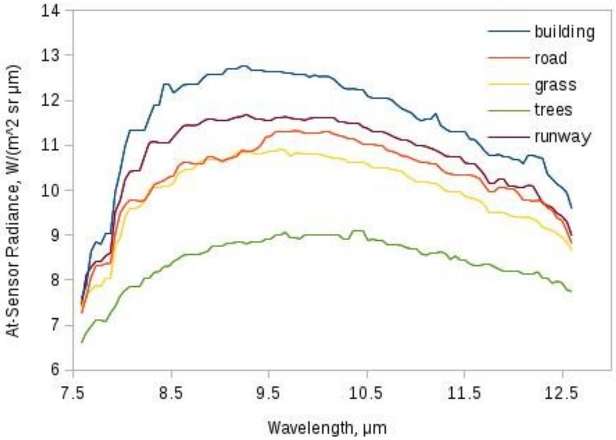


Specim sample data: Cuprite, Nevada, USA
(http://www.specim.fi/products/aisaowl/)

The Specim's AisaOwl Sensor

- NERC-ARF acquired Owl sensor in 2014
- Long Wave InfraRed (LWIR), specifically 7.6 – 12.6 µm
- Detects thermal radiation, so bright objects are generally hotter (also depends on emissivity)
- Hyperspectral Imager
  - 102 continuous bands (spectrum for each image pixel)
  - 50 nm band spacing (100 nm resolution)
  - FWHM of 100 – 135 nm
- 384 spatial pixels (pushbroom system)
- 24.2° Field of View (FoV), Fenix is 31.94°

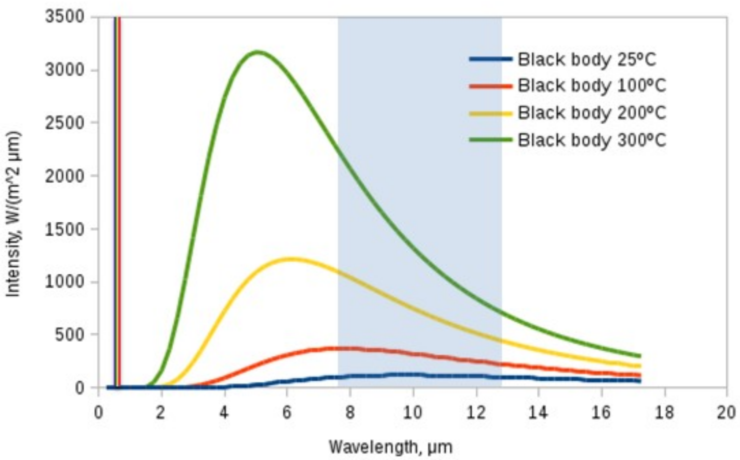




Basics of Thermal Spectral Imagery

- Every object radiates EM radiation across the whole spectrum
- We feel LWIR as heat, hence "thermal"
- Ideal "black body" absorbs all incident EM radiation at every frequency and angle
- Ideal "black body" in thermal equilibrium (T=constant) emits spectral radiation according to Planck's Law:

$$B_\lambda(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda k_B T}} - 1}$$



Basics of Thermal Spectral Imagery (2)

- Real objects are not black bodies, they emit a fraction of the black body radiation, indicated by their emissivity (ε)
- Black body ε=1
- Grey bodies have ε<1 independent of frequency, they always emit less radiation than a black body at the same temperature
- Most objects ε depends on frequency
- Material composition, surface roughness and temperature(!) affect ε

…so to determine temperature from thermal imagery, we need to know the emissivity of every pixel

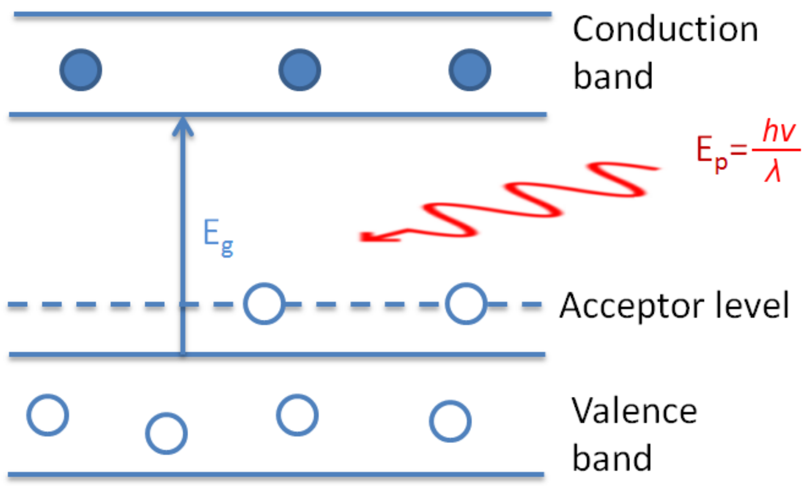
- Not to mention the effects atmospheric absorption!

The MCT Detector

-Owl detector is made from Mercury Cadmium Telluride (HgCdTe), a semiconductor.

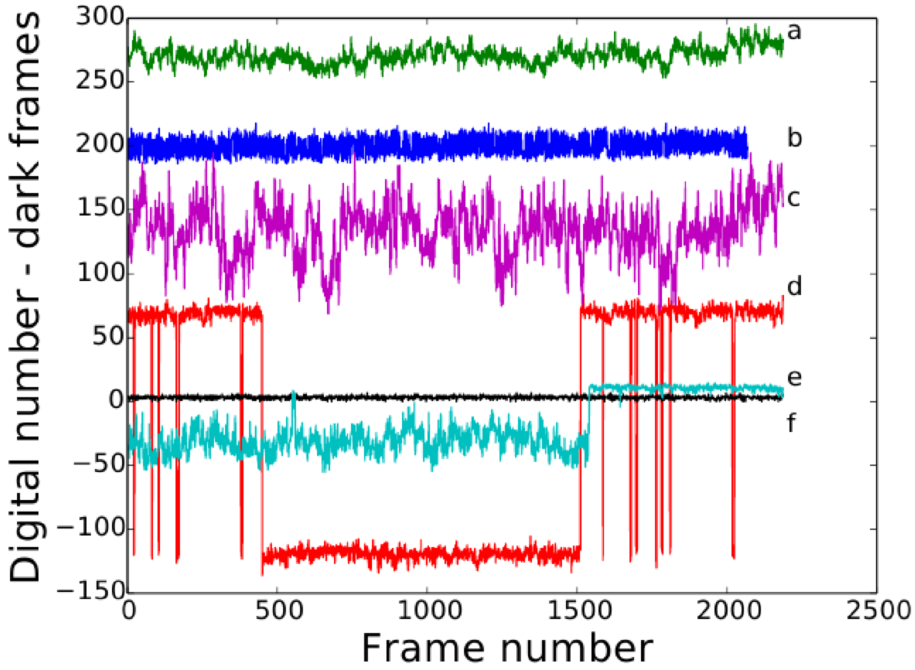
- When radiation (photons) of the correct wavelength (energy of the gap) reaches the detector, it excites an electron into the conduction band, which can then be detected as an electrical signal (current).

-The amount of Cd can be tailored for different wavelengths. Creating different crystal impurities with Cd allows to have different gap energies.



Blinking Pixels

- There is a problem with the Owl's MCT detector: a randomly varying dark current
- Affects different pixels each time the sensor is turned on, they "blink" jumping between energy levels (less than 2% are expecting to blink).
- Specim provide a tool for radiometric calibration and blinking pixels replacement

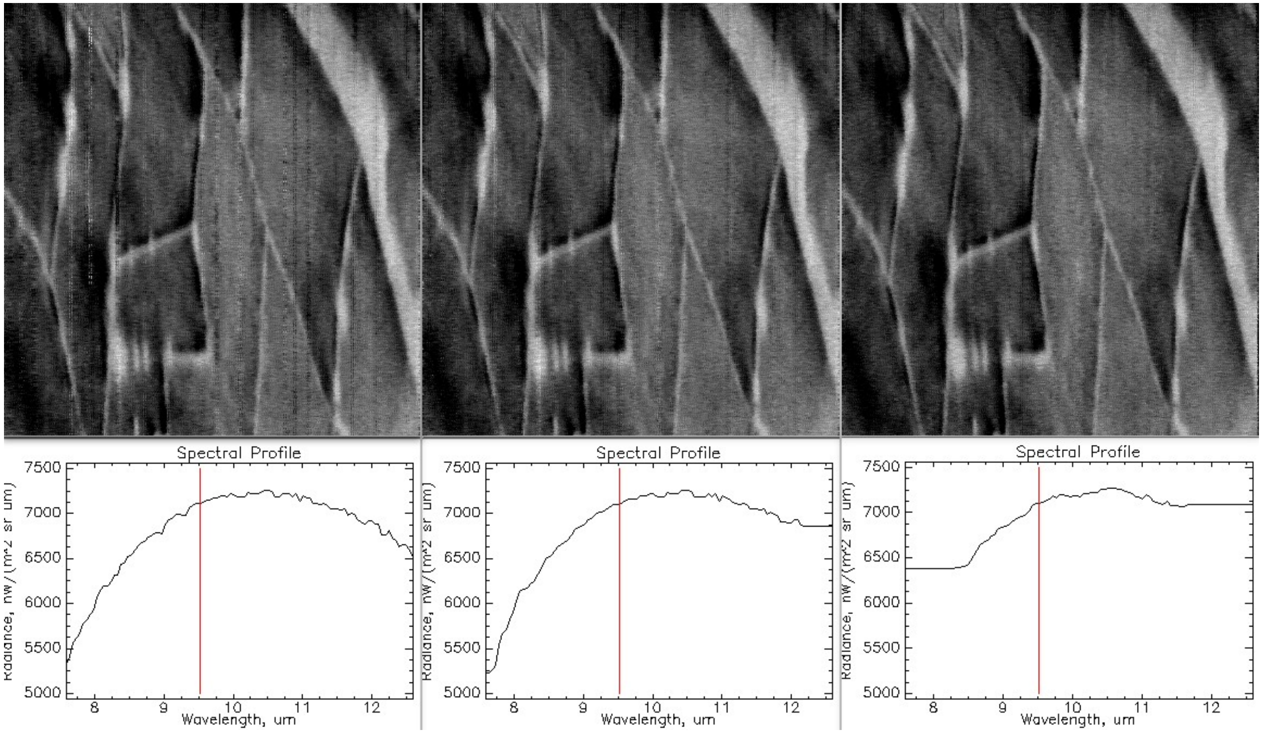


– **a**: good pixel
– **b**: Frequently blinking pixel
– **c**: Bad pixel (high standard deviation)
– **d**: Pixel strongly blinking
– **e**: Noisy blinking pixel
– **f** : good pixel

Blinking Pixels (2)

- Can only be detected in the dark frames
- Their random nature makes them difficult to detect
- Seen in data as intermittent vertical stripes (in level 1b)

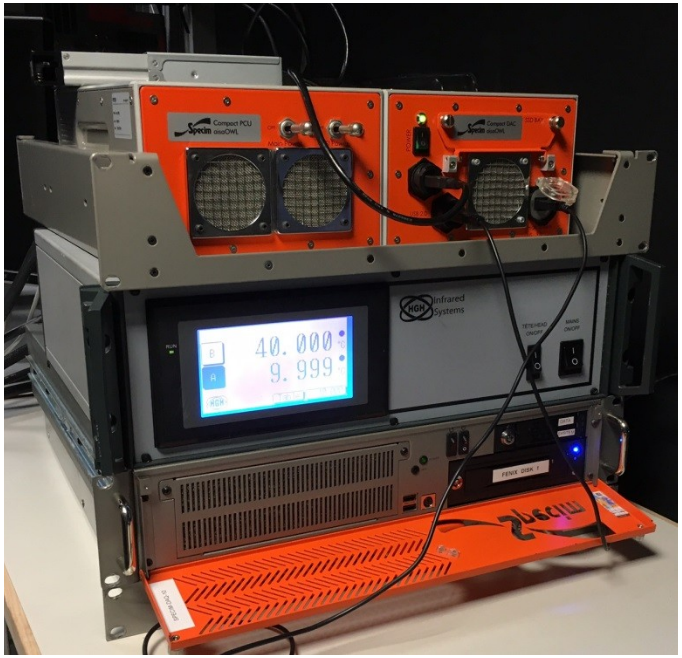
Decreasing blinker threshold ⟶



Owl Operation

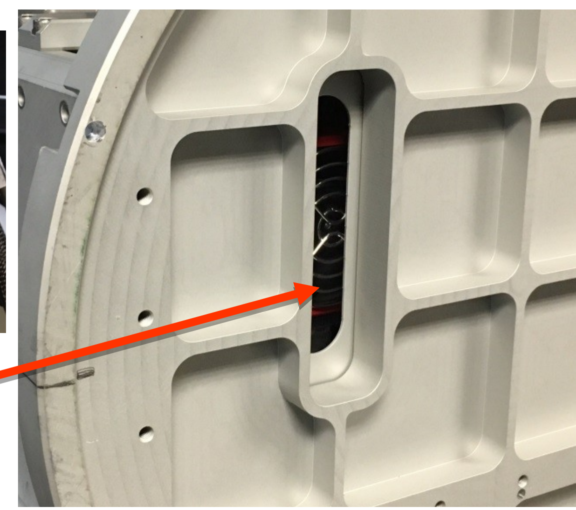
- Must be turned on for ~30 mins before use
  - Detector cools down and stabilises
  - Internal black bodies reach set temperatures

  (one below and one above target temperature)



Owl Operation (2)

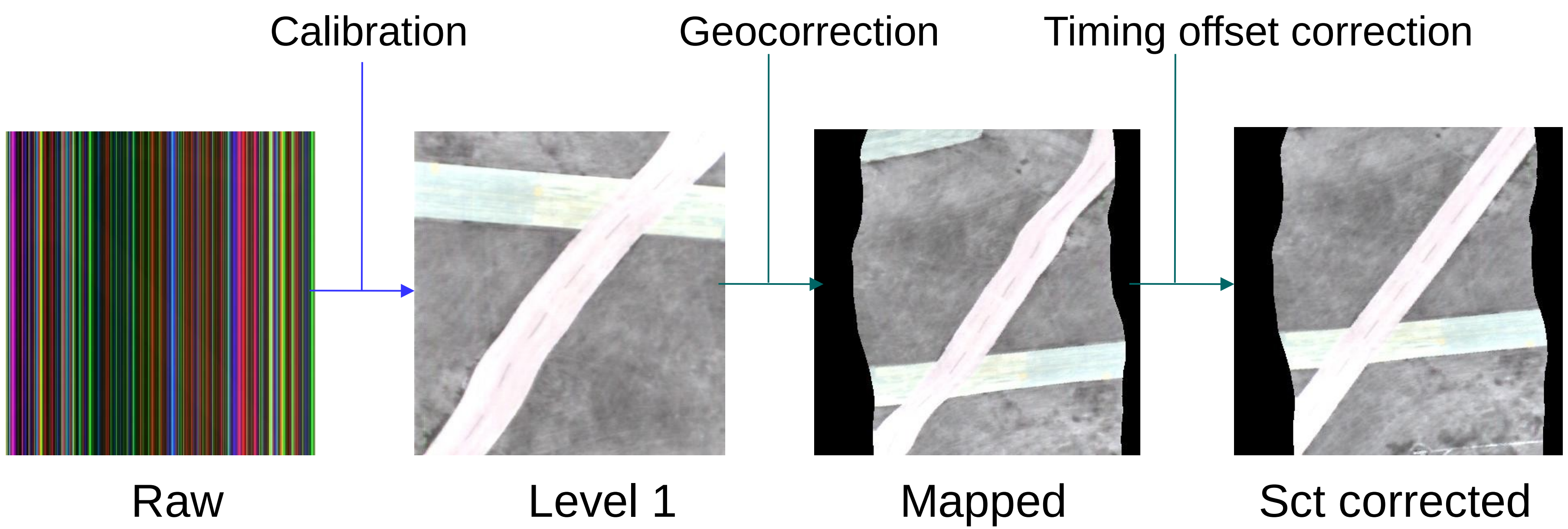
- At the end of each flight line, dark frames and calibration data are collected.
- Calibration data is taken from ‘cold’ and ‘warm’ internal black bodies → A and B
- Black bodies are mechanically moved in front of the detector



Owl Sensor Slit

Owl Processing

- Many similarities with Fenix processing
- Use Specim's tool for calibration
- Geocorrection with APL



Data examples - UK

Fenix

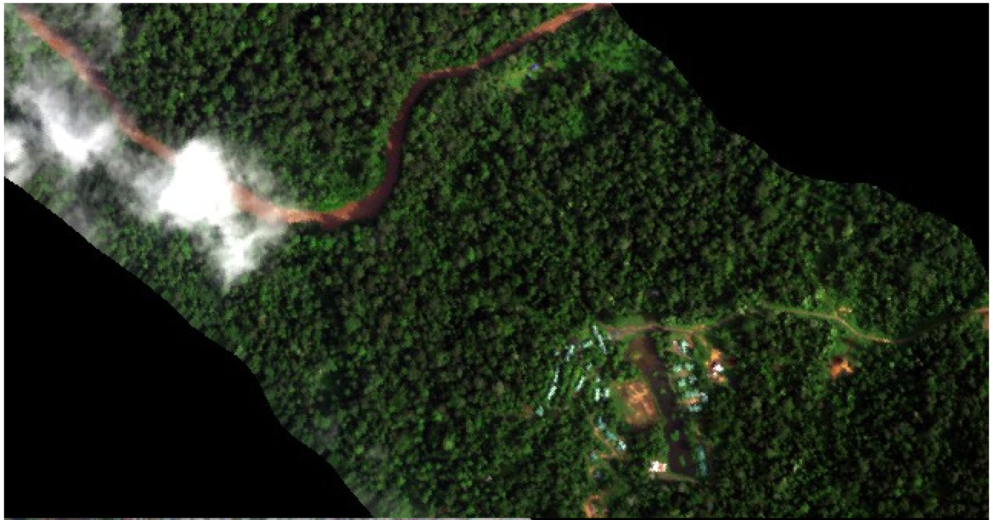
Owl

Data examples - UK

Owl

Owl

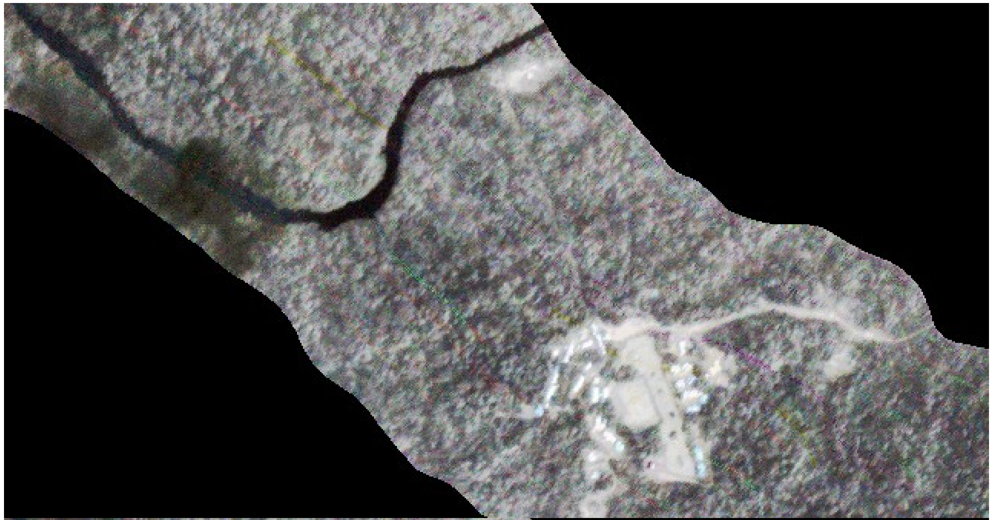
Data examples - Malaysia



Fenix

Owl

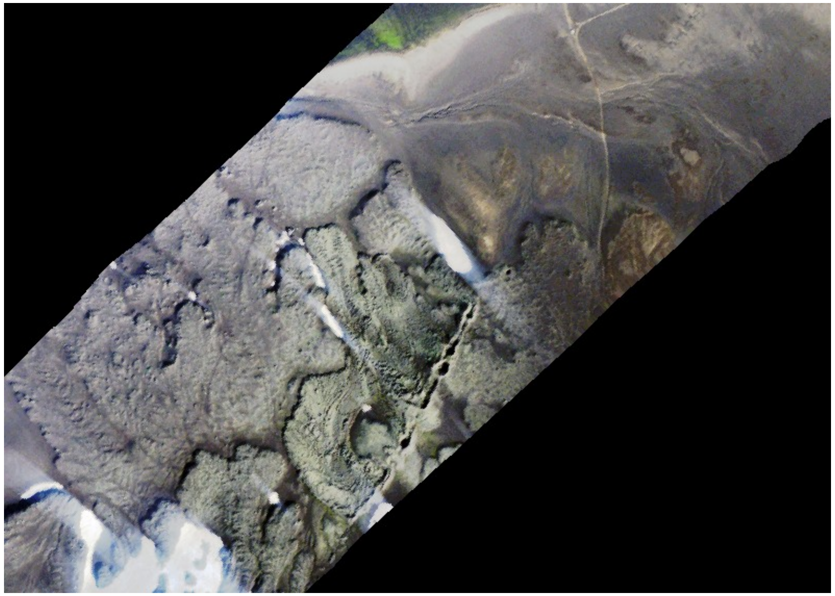
Data examples - Malaysia



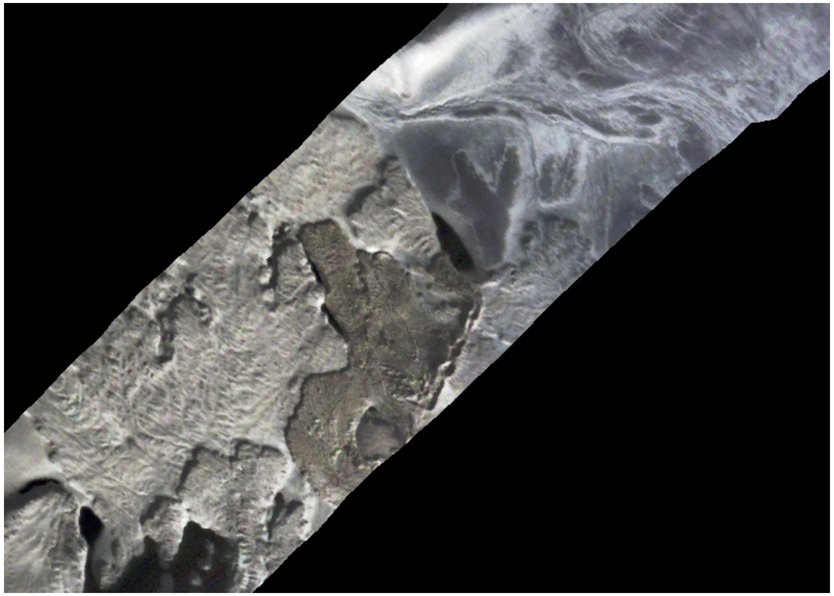
Owl

Owl

Data examples - Iceland

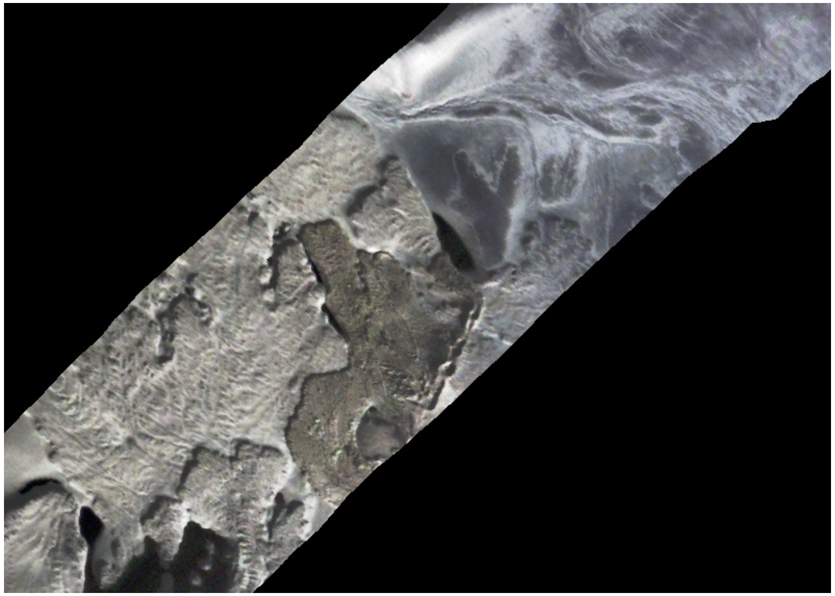


Fenix

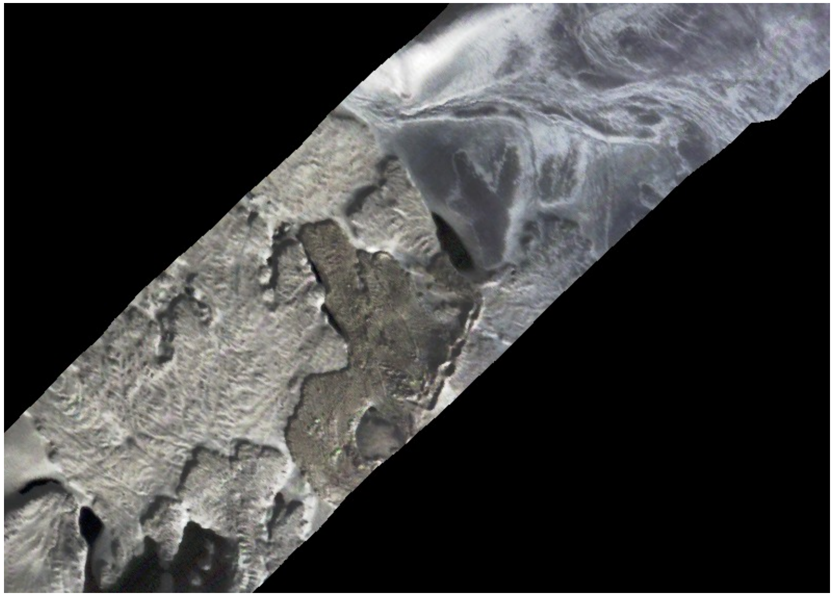


Owl

Data examples - Iceland



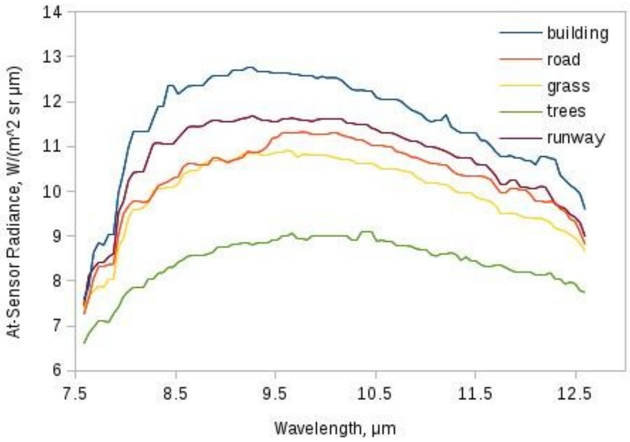
Owl



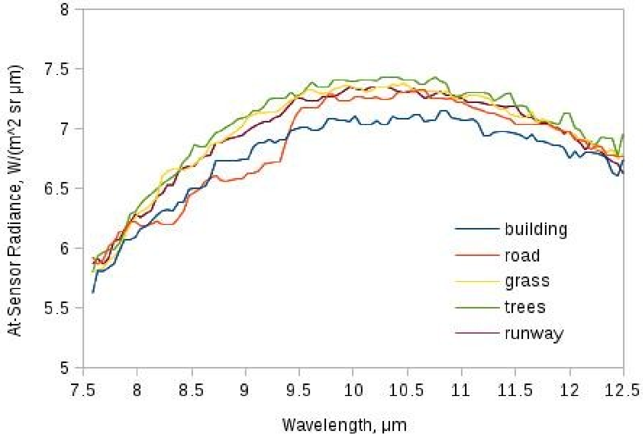
Owl

Day and Night Comparison

Day



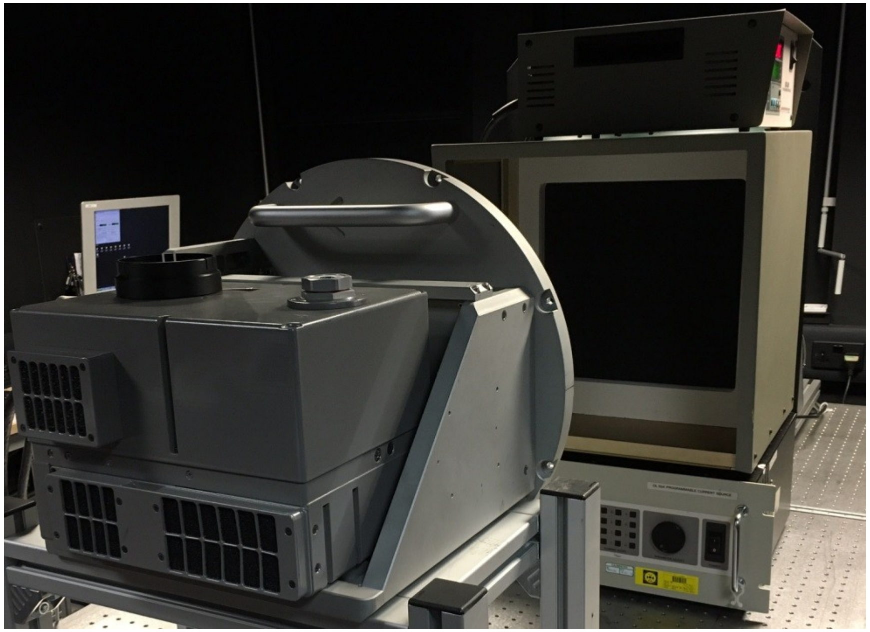
Night



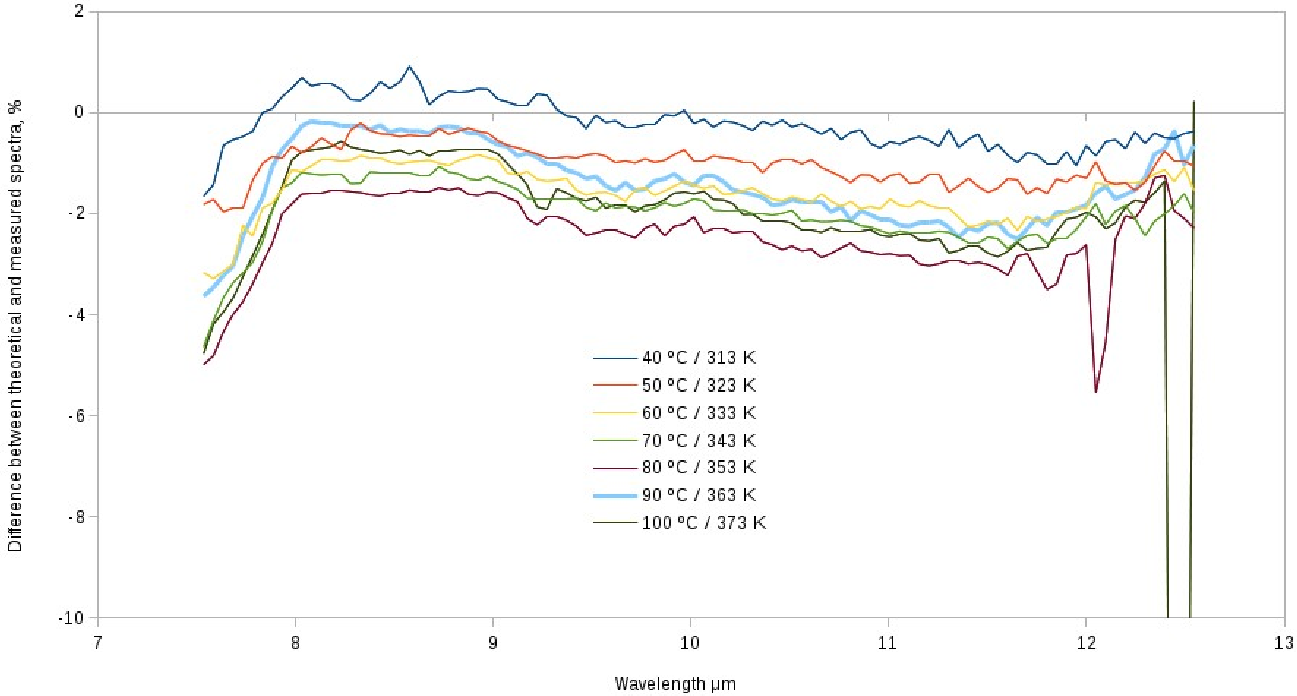
- Spectra (and imagery) are very different at night.
- False colour imagery (R: 9419 nm, G: 8774 nm, B: 8130 nm) highlights different features.
- The large rectangular metal roof appears bright in the day image, but dark in the night image.
- The trees can barely be distinguished from grass in the night image.
- The night image has a much poorer signal to noise ratio.

Owl Performance

- A lot of characterisation has been undertaken by NERC-ARF (2 papers published in collaboration with sensor's designer)
- Imaging black bodies at various temperatures lets us test its capability
- More characterisation can be done (wavelength accuracy, spectral response...)



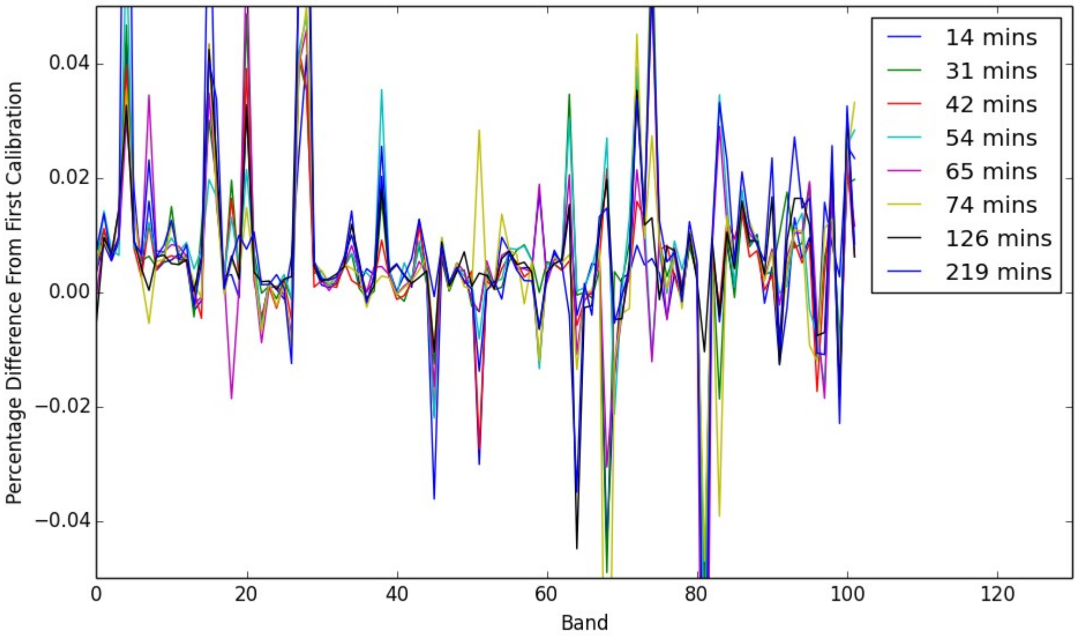
Absolute Temperature Accuracy



- Increasing error with increasing temperature.
- Reduced error between 8 – 9 µm (more noticeable at higher temperatures).
- Some error probably due to uncertainty in target black body temperature.

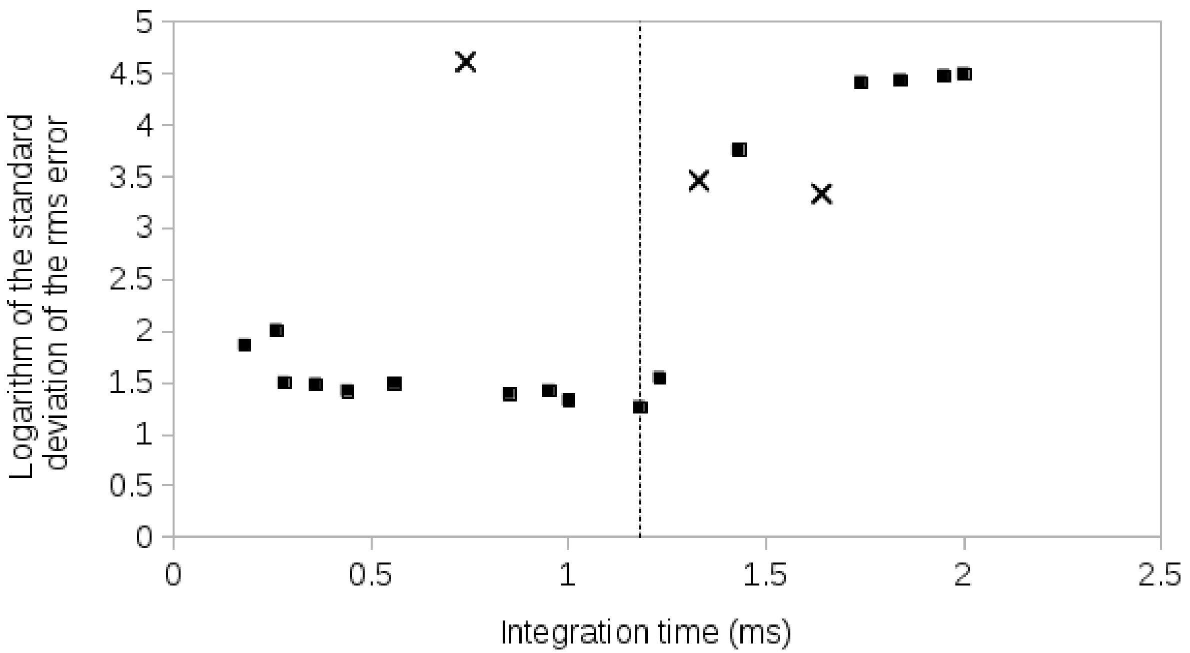
General Detector Stability

- Specim suggest that calibration data should be collected every 30 mins.
- Calibration is usually collected per flightline (around every 5 minutes)
- Test data collected over a 3hr period shows small changes in calculated calibration gains (spikes are due to blinking pixels).



Integration Time Validation

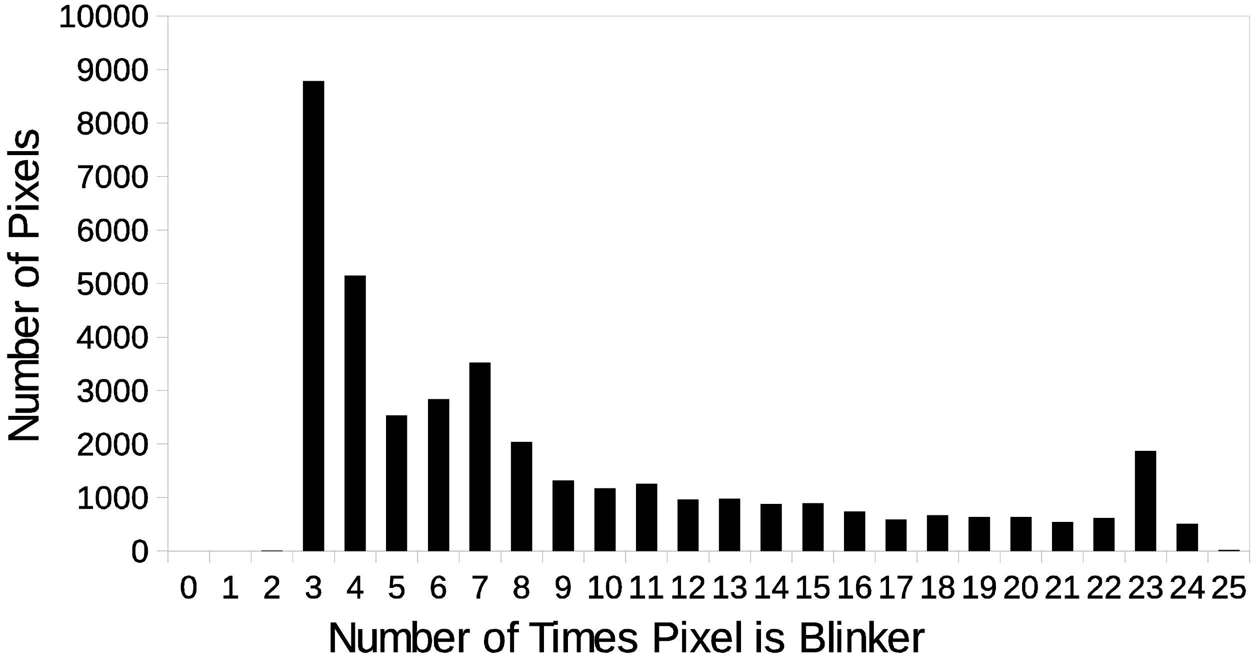
As the integration time increases, the spectra becomes less noisy until the optimum time of 1.18ms (recommended by Specim). Beyond this point, spectra developed a peak in longer wavelengths increasing the error exponentially (possibly due to saturation of these bands)



L. Harris, M. Warren, M. Grant and G. Llewellyn, Spectral Characterisation of the AisaOwl, IEEE Trans. Geosci. Remote Sens, vol 55 (5), 2017, 10.1109/TGRS.2017.2653241.

Blinker Analysis and Characterisation

- The number of blinking pixels is usually very low.
- Most of the pixels are blinking rarely (3 or 4 times only in 25 datasets)
- From a total of 102*384 pixels → 39168 pixels~40000 pixels ~9000 were blinking 3 times and ~5000 only 4 times (~35% blinking 4 or 3 times).
- Data indicates that some pixels are more prone to be blinking



L. Harris, G. Llewellyn, H. Holma, M. Warren and D. Clewley, Characterisation of Unstable Blinking Pixels in the AisaOWL Thermal Hyperspectral Imager, IEEE Trans. Geosci. Remote Sens, vol 56 (Issue: 3), 2018, 10.1109/TGRS.2017.2766186

Outstanding issues & future improvements

- Testing Owl firmware updates (previous failures in mechanical calibration and dark frame acquisition)
- Use of our own calibration procedures (already developed but not implemented)
- Testing and further development of in-house calibration software
- Further performance tests (inc pixel spreading with cavity BB)
- Measure wavelength accuracy and FWHMs
- Temperature and emissivity algorithms (some scripts released in collaboration with Specim, more can be done)
- Silicates mapping algorithms (use of spectral libraries as first approach)
- PI queries and collaborations

Summary

- TI has the potential to provide identification of minerals, particularly silicates
- Thermal radiance depends on temperature and emissivity
- A fraction of the pixels will be blinking (changing between good and bad behaviour) due to random fluctuations in the MCT detector dark current
- Owl data is processed much the same as Fenix, but uses Specim's processing tool for radiometric calibration and blinker detection
- Initial tests against a black body have found that temperature accuracy is within 2°C
- More research to be undertaken (characterisation, FWHMs, new products...)

@NERC_ARF_DAN

Thank you