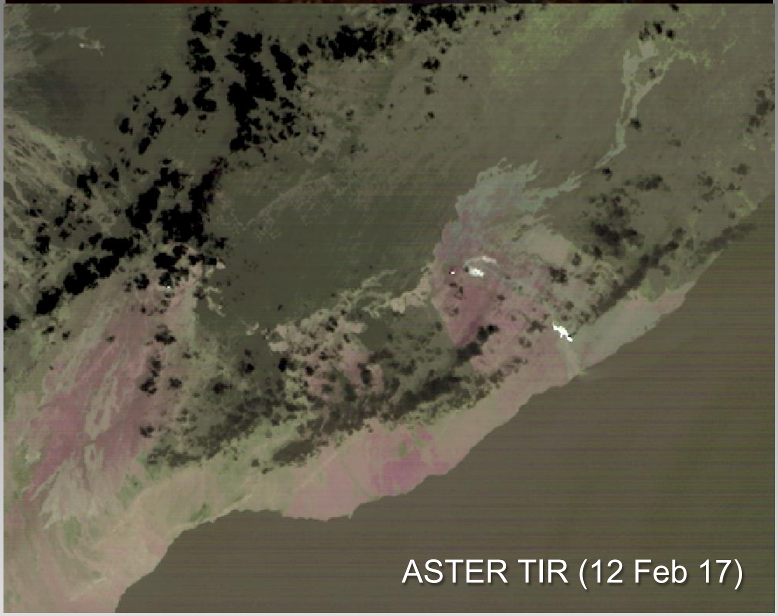
Can HyspIRI-like data constrain accurate temperature and emissivity measurements of *active* volcanic surfaces?

Michael Ramsey & James Thompson

University of Pittsburgh, Department of Geology and Environmental Science, Pittsburgh, PA, USA



2017 HyspIRI Science and Applications Workshop
Pasadena, CA (17-19 October 2017)

Original Proposed Work

overview | background | data | results | summary

❖ Quantifying Active Volcanic Processes and Mitigating Their Hazards with HyspIRI Data

- proposed science questions:
  - how does the cooling and formation of a viscoelastic hot glassy surface affect the average emissivity of basaltic lava over time?
    - can these constituents be quantitatively extracted from future HyspIRI data of active flows to produce improved temperature and compositional estimates?
  - what are the ideal spatial resolution and band positions for the HyspIRI IR instrument to extract quantitative volcanological data?
  - can this approach in total be helpful for the prediction of lava flow advance over time through quantitative modeling of HyspIRI data?

Science Goals

❖ Build, Test and Calibrate New Field Instrument

- in time for the field campaign
- miniature multispectral TIR Camera *(MMT-Cam)*
  - calibrate and fully automate collection, processing and analysis
  - see James Thompson's poster tomorrow *(MMT-Cam$_{|v3.5}$ on display)*

❖ Emissivity Change

- evaluate the change as lavas propagate and cool
- evaluate the impact on extracted temperatures
- compare field data to coincident MASTER and ASTER data

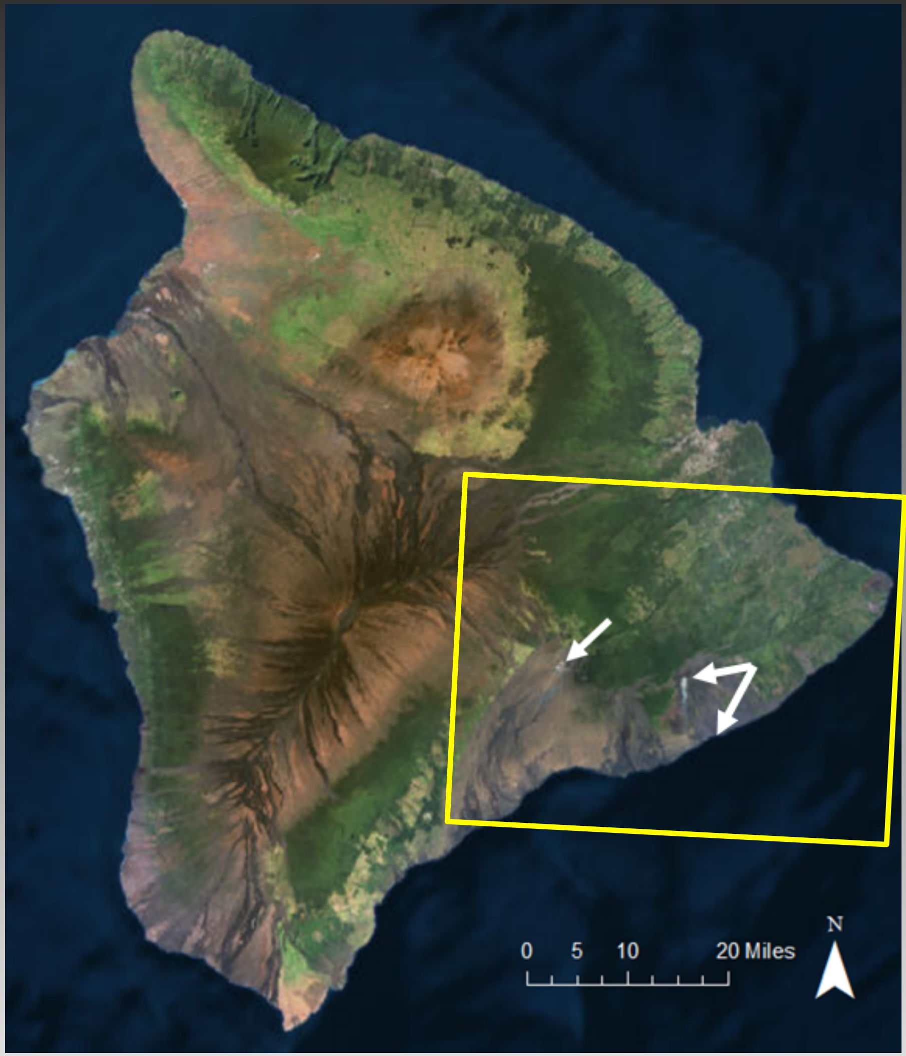
❖ Modelling

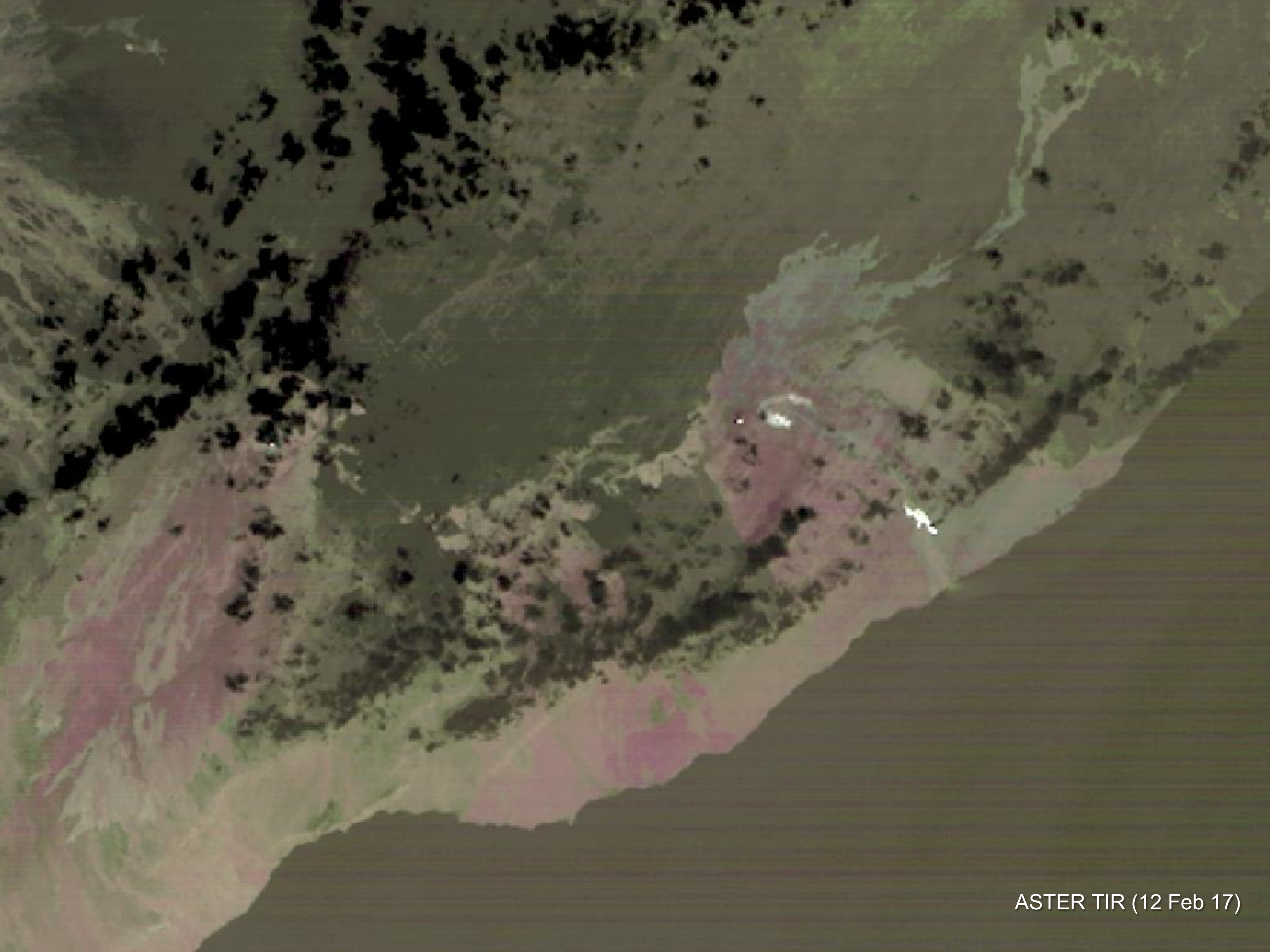
- determine the affect of emissivity on rheological models used to forecast lava flow propagation and eruption rates

- **Kilauea, Hawai'i**
  - shield volcano
  - eastern slope of Mauna Loa
  - island of Hawai'i

- **Lava Flow *(primary target)***
  - Pu'u 'Ō'ō episode 61g flow

- **Lava Lake *(secondary target)***
  - Halema`uma`u Crater
  - continuous activity since 2010
  - 250 m long and 190 m wide




ASTER TIR (12 Feb 17)

Field Campaign

❖ Kilauea, Hawai’i

- shield volcano
- eastern slope of Mauna Loa
- island of Hawai‘i

❖ Lava Flow *(primary target)*

- Pu‘u ‘Ō‘ō episode 61g flow

❖ Lava Lake *(secondary target)*

- Halema`uma`u Crater
- continuous activity since 2010
- 250 m long and 190 m wide

❖ Kilauea, Hawai'i

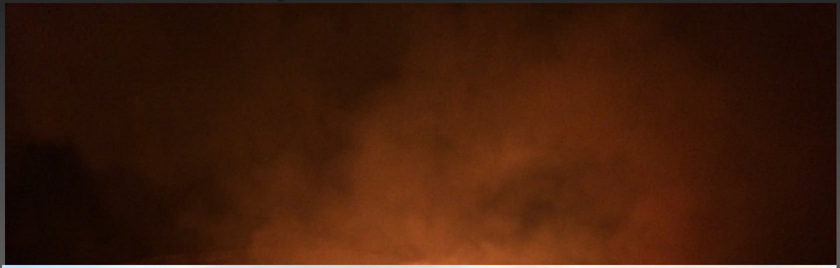
- shield volcano
- eastern slope of Mauna Loa
- island of Hawaiʻi

❖ Lava Flow *(primary target)*

- Puʻu ʻŌʻō episode 61g flow

❖ Lava Lake *(secondary target)*

- Halema`uma`u Crater
- continuous activity since 2010
- 250 m long and 190 m wide



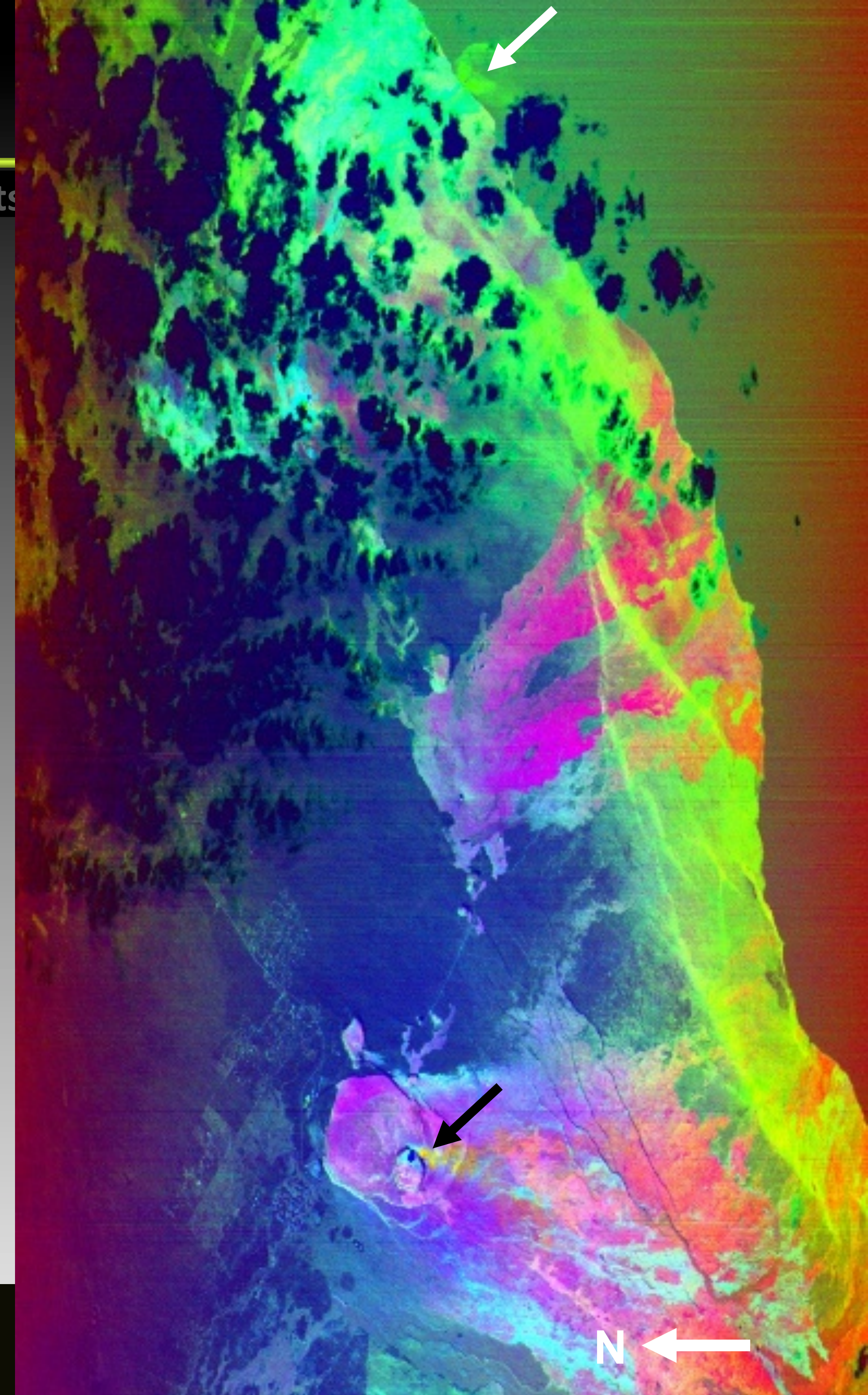
❖ TIR Data

- 19 Jan to 31 Jan 2017
  - 8 acquisition opportunities
- 4 MASTER overpasses
  - 2 day and 2 night
- 4 ASTER overpasses
  - 1 day and 3 night
- critical for us: MASTER + ASTER
  - only ONE daytime collect
  - NO nighttime collects

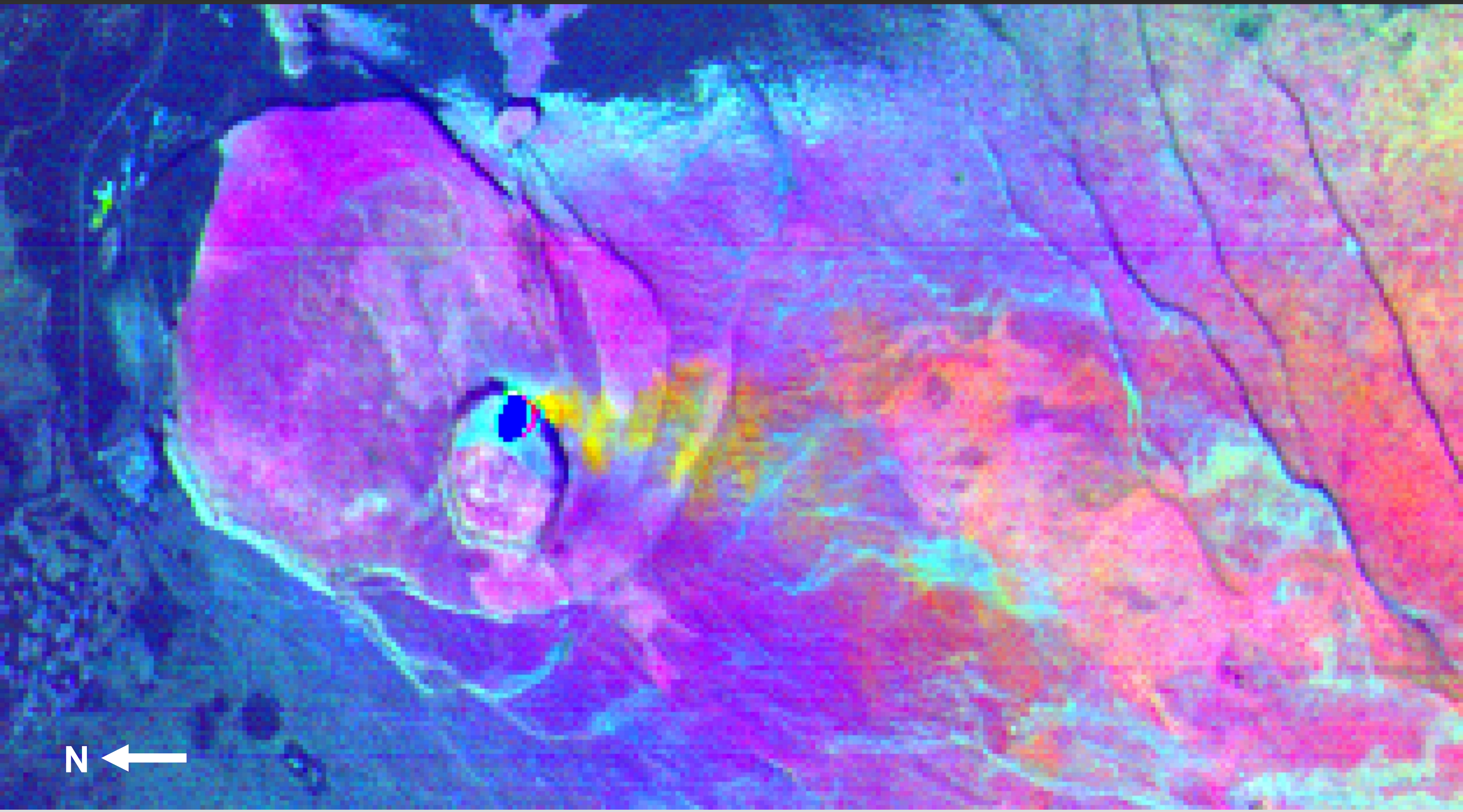
❖ Primary Airborne Instruments

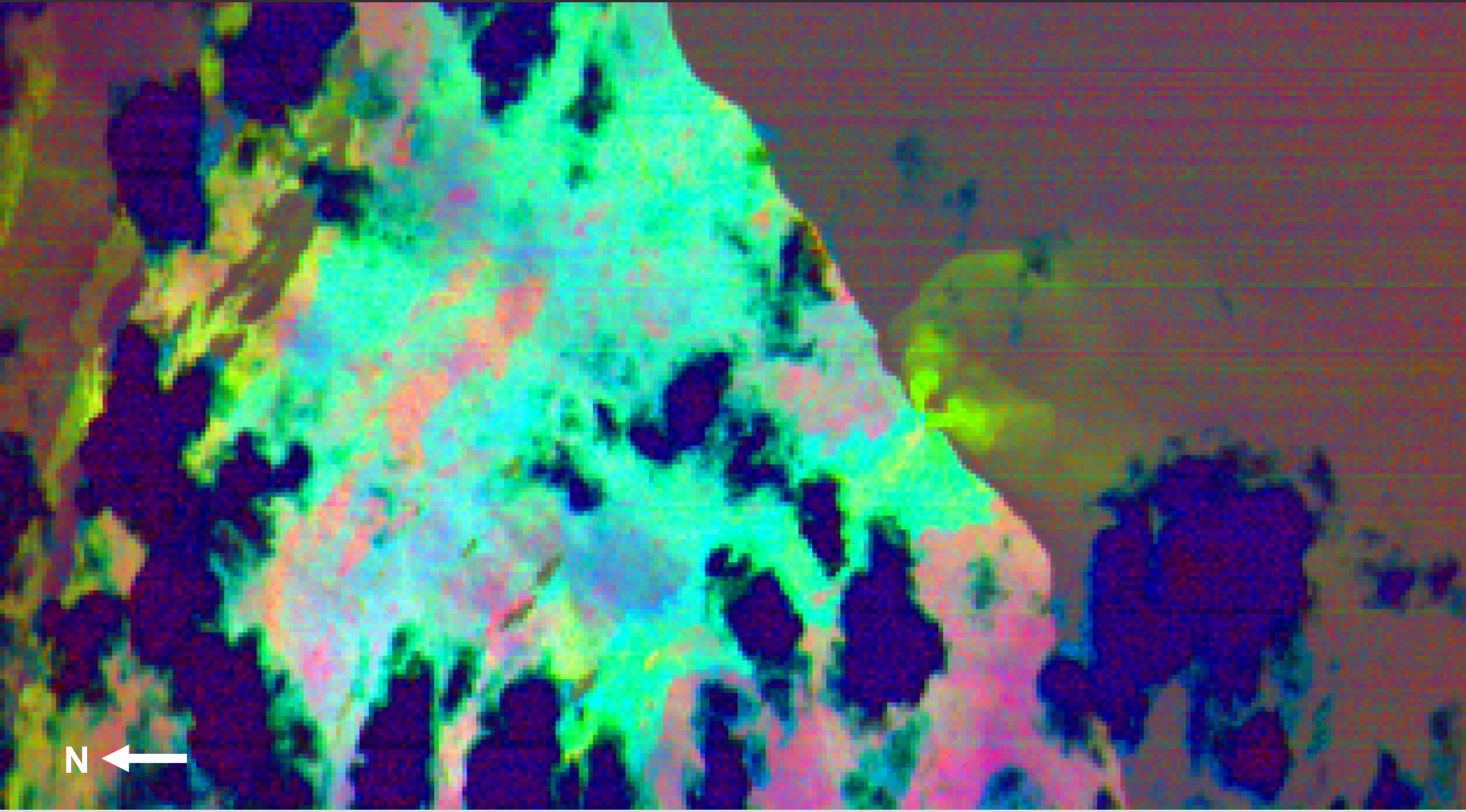
- MASTER
  - 0.4-13 microns wavelength range
  - 50 channels
  - saturation
    - MIR band 26 (4.07µm) at 640 K *(850 K at low gain)*
    - TIR bands at ~420K

- AVIRIS
  - 0.4-2.5 microns wavelength range
  - 224 channels



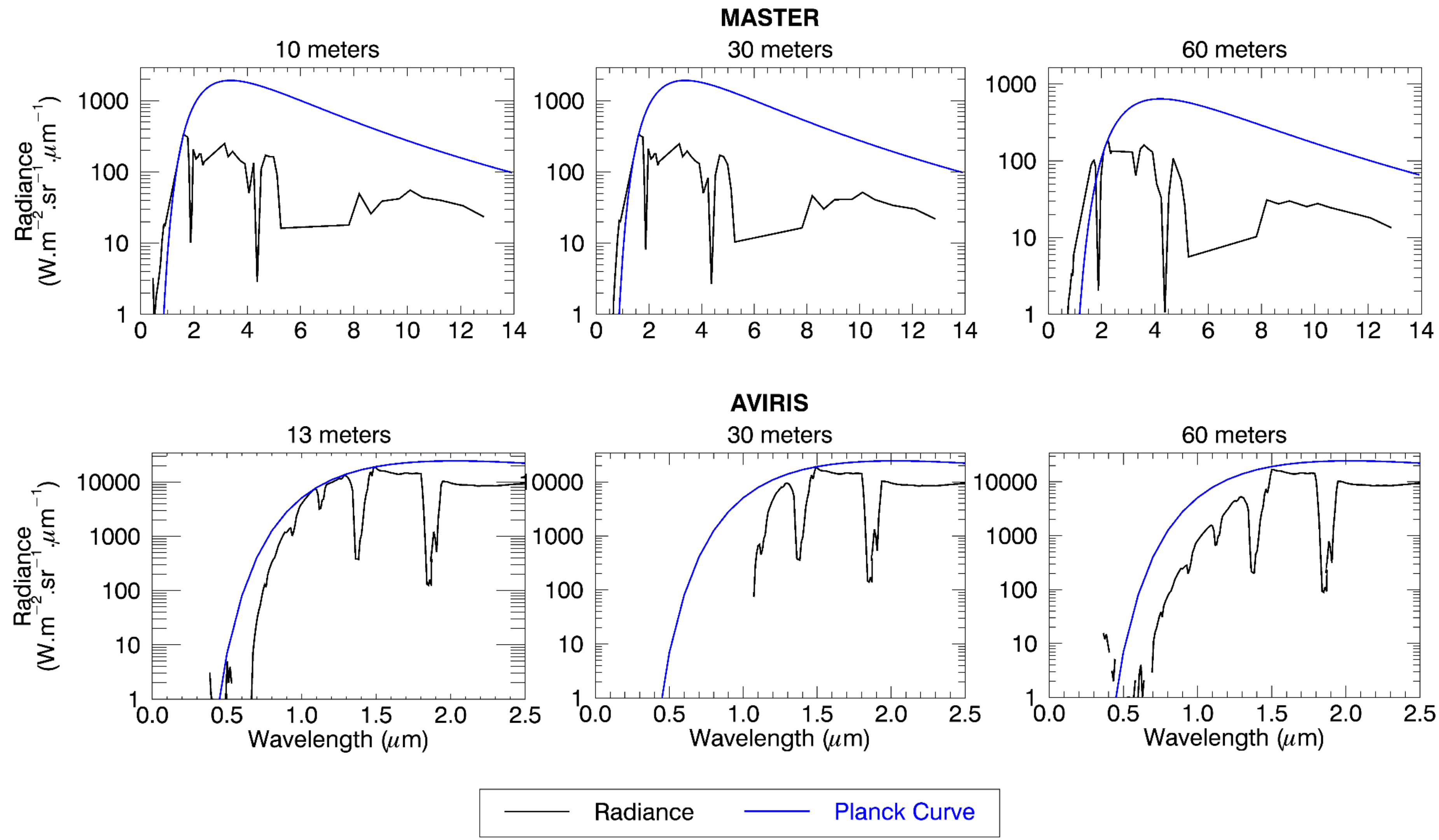
Airborne/Spaceborne




N

Initial Data Analysis

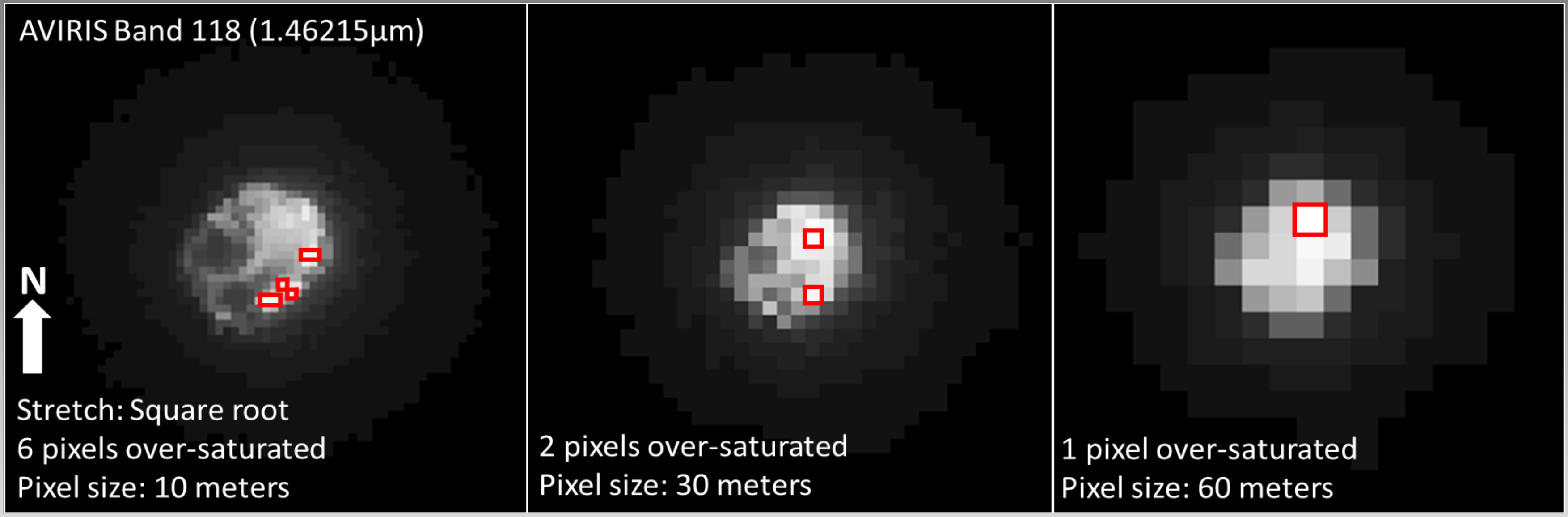
overview | background | data | **results** | summary



Initial Data Analysis

❖ **AVIRIS: 26 Jan 2017 at 05:57 UTC *(19:57 HST on 25 Jan)***

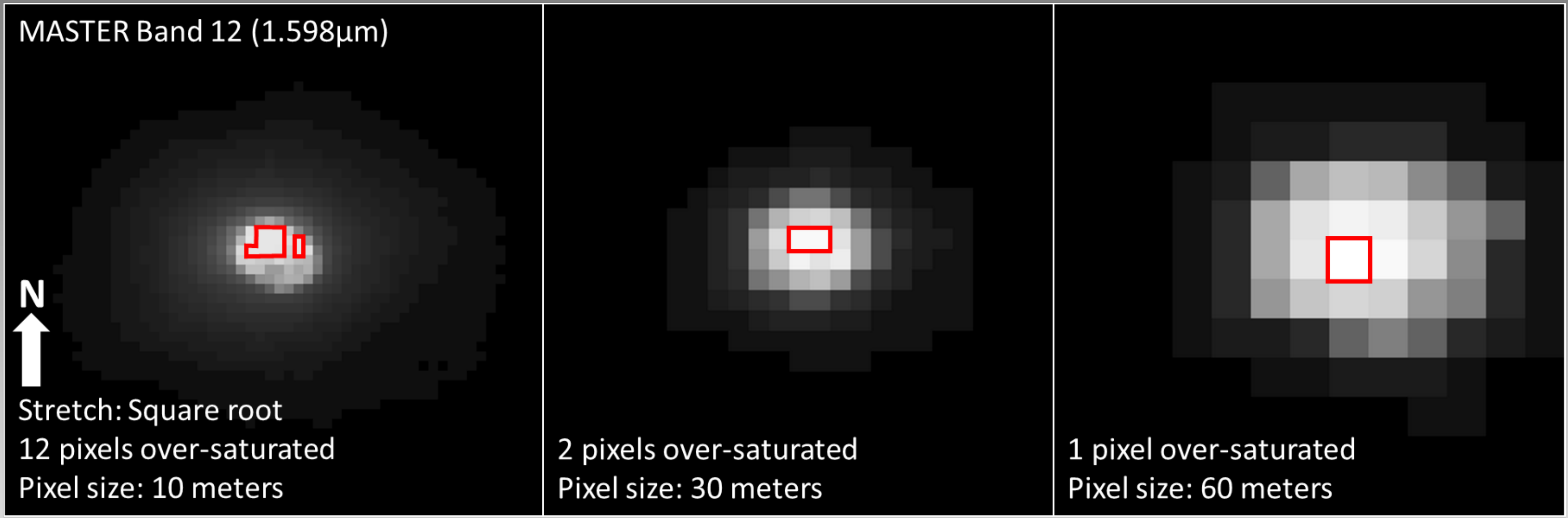
- maximum Plank-derived temperatures:
  - center:
    - 13 m: ~1430 K (λ_{max} = 1.49 µm)
    - 30 m: ~1430 K (λ_{max} = 1.49 µm)
    - 60 m: ~1400 K (λ_{max} = 1.49 µm)
  - edge:
    - 13 m: ~1010 K (λmax = 2.26 µm)
    - 30 m: ~950 K (λmax = 2.26 µm)
    - 60 m: ~1050 K (λmax = 2.26 µm)



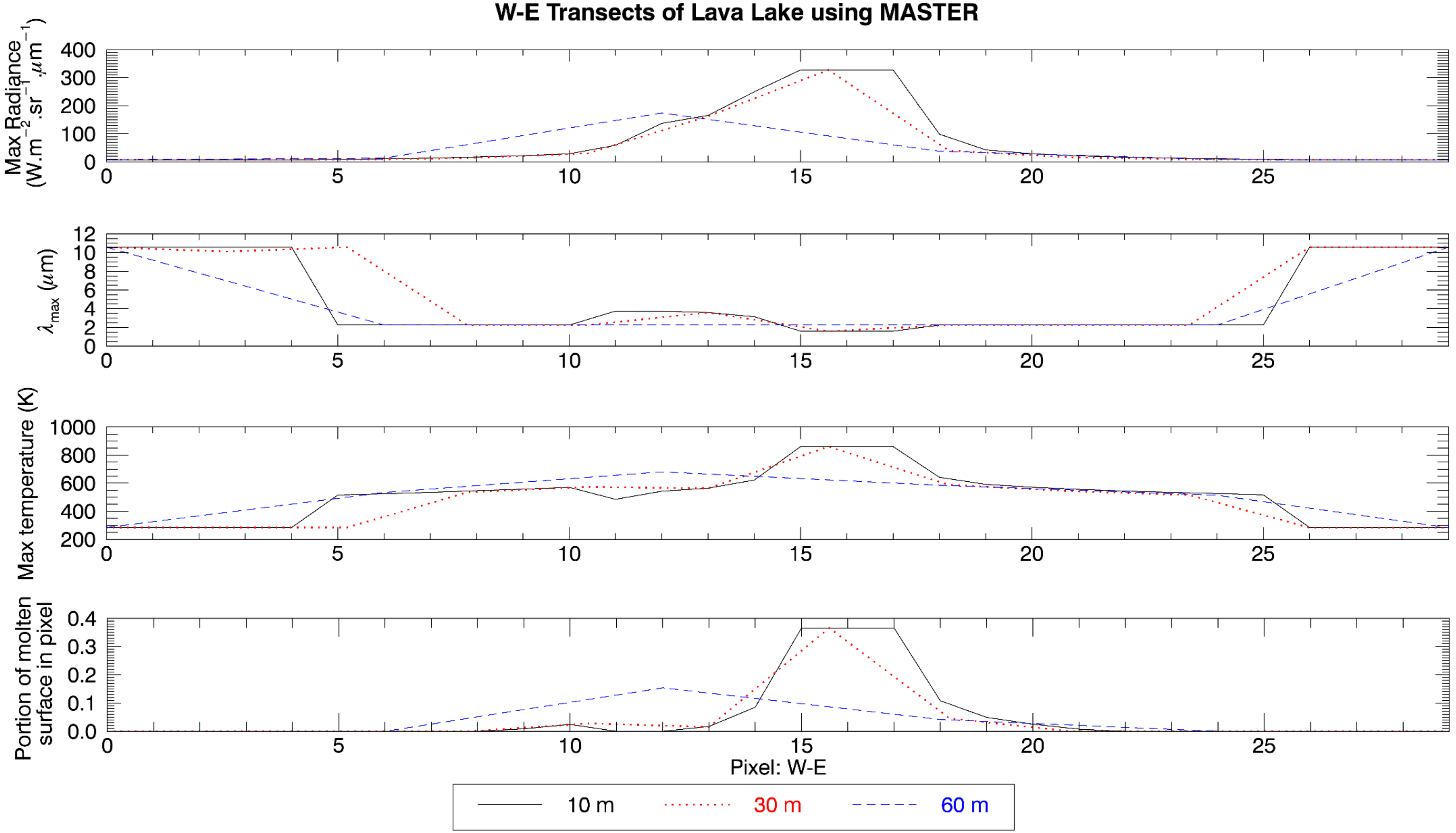
Initial Data Analysis

❖ MASTER: 26 Jan 2017 at 05:57 UTC *(19:57 HST on 25 Jan)*

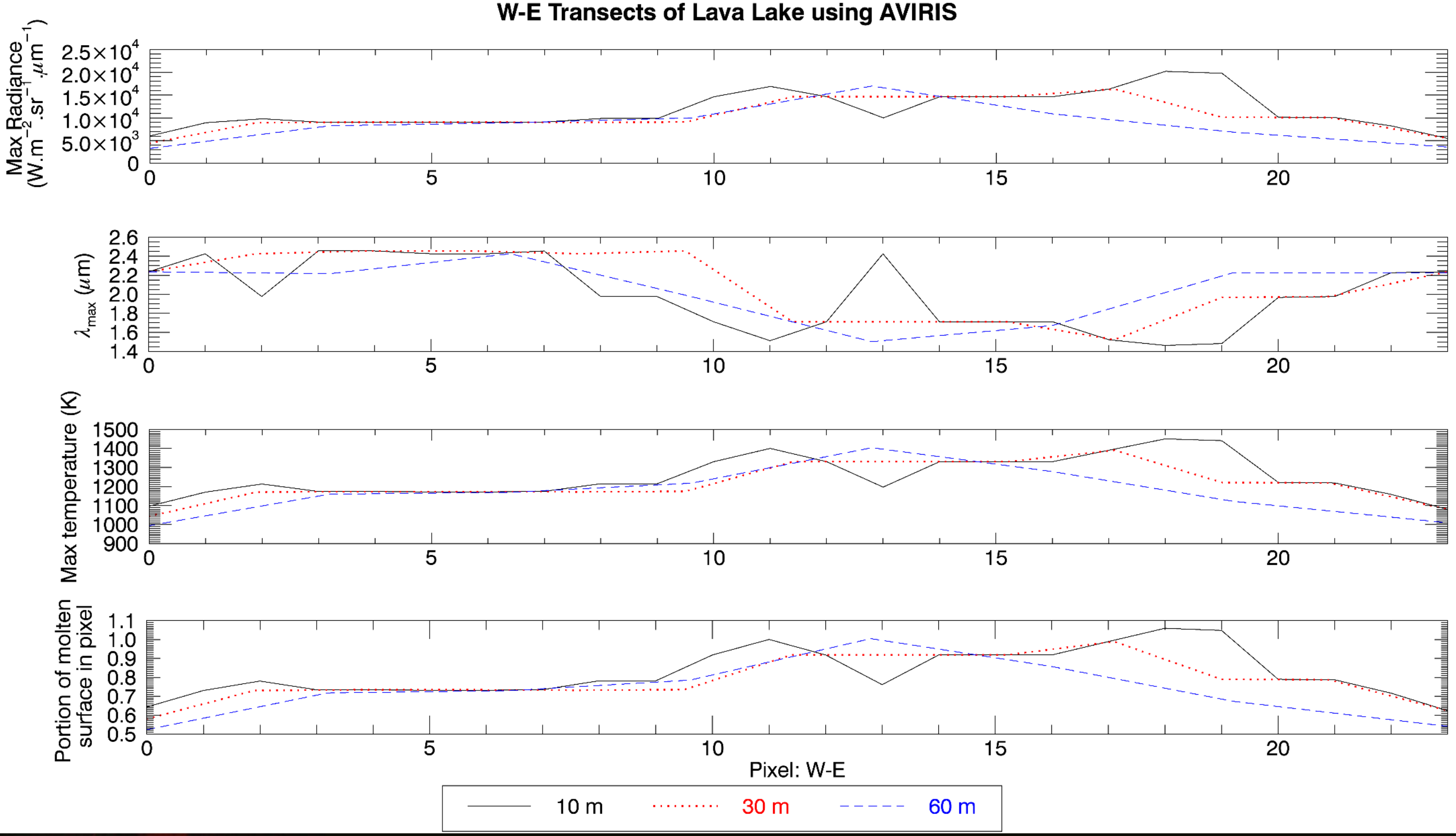
- maximum Plank-derived temperatures:
  - center:
    - 10 m: ~860 K (λ_{max} = 1.59 μm)
    - 30 m: ~860 K (λ_{max} = 1.59 μm)
    - 60 m: ~690 K (λ_{max} = 2.21 μm)
  - edge:
    - 10 m: ~550 K (λ_{max} = 2.26 μm)
    - 30 m: ~570 K (λ_{max} = 2.26 μm)
    - 60 m: ~570 K (λ_{max} = 2.26 μm)



Initial Data Analysis



Initial Data Analysis

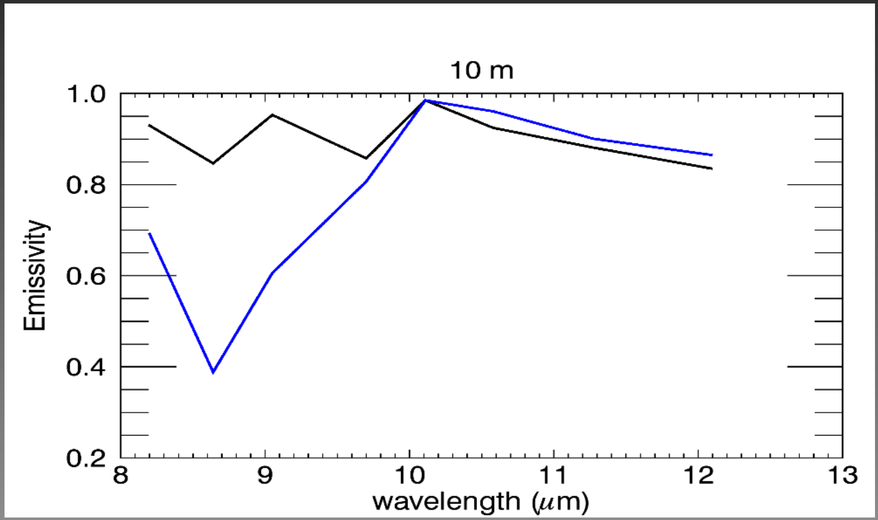


Initial Data Analysis

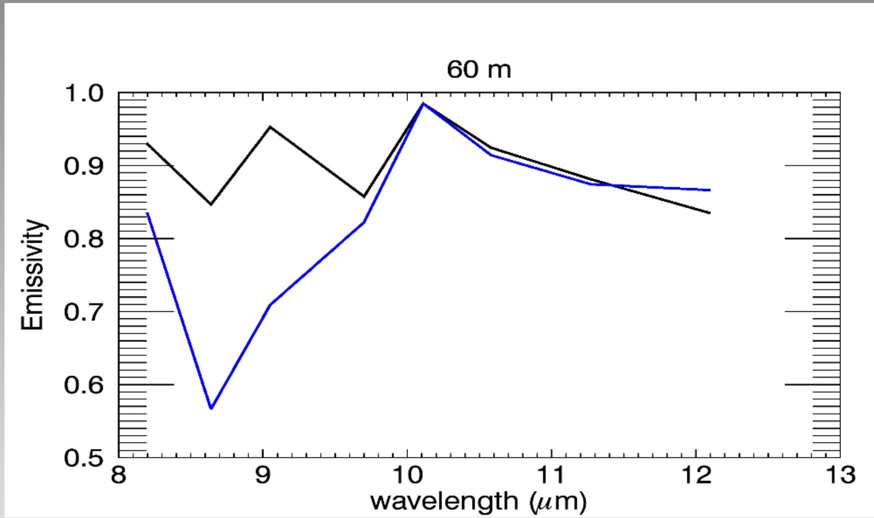
overview | background | data | **results** | summary

❖ Emissivity Extraction

- saturation over lava lake produces inaccurate spectra as one would expect
  - documented numerous time with ASTER TIR L2 data

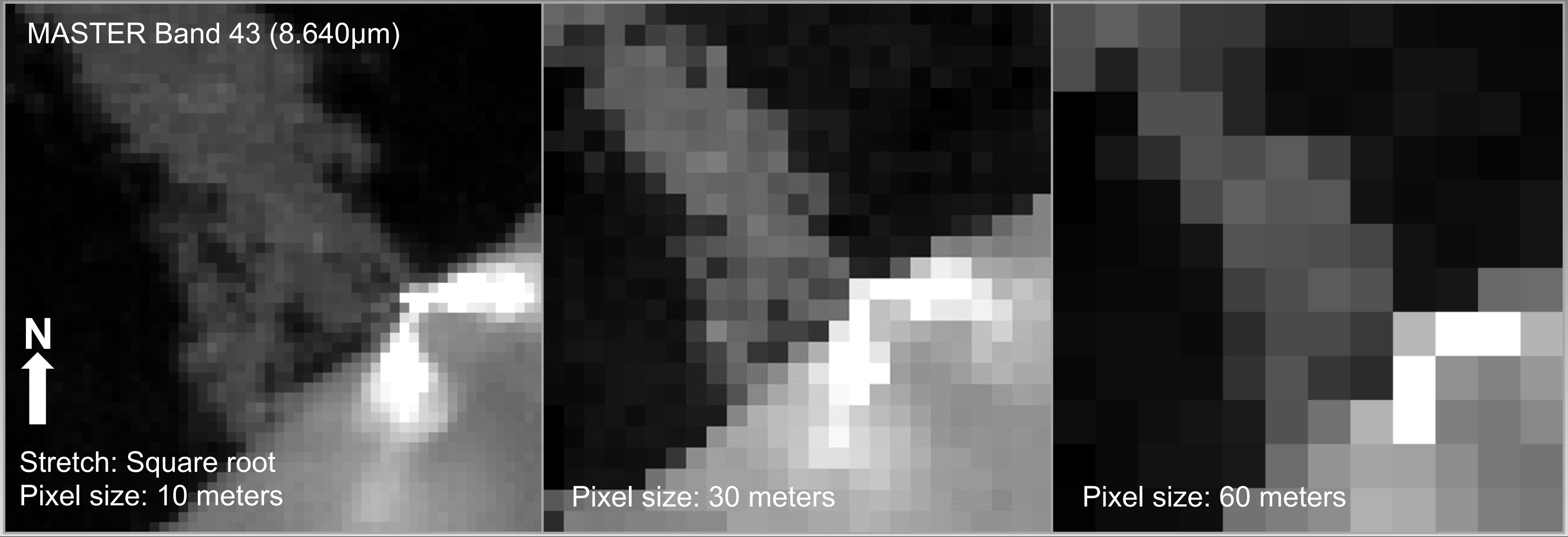


- at crater-edge pixels, mixing with cooler/older basaltic lavas minimizes saturation
  - emissivity is resolved
  - loss off spectral depth with spatial resolution degradation

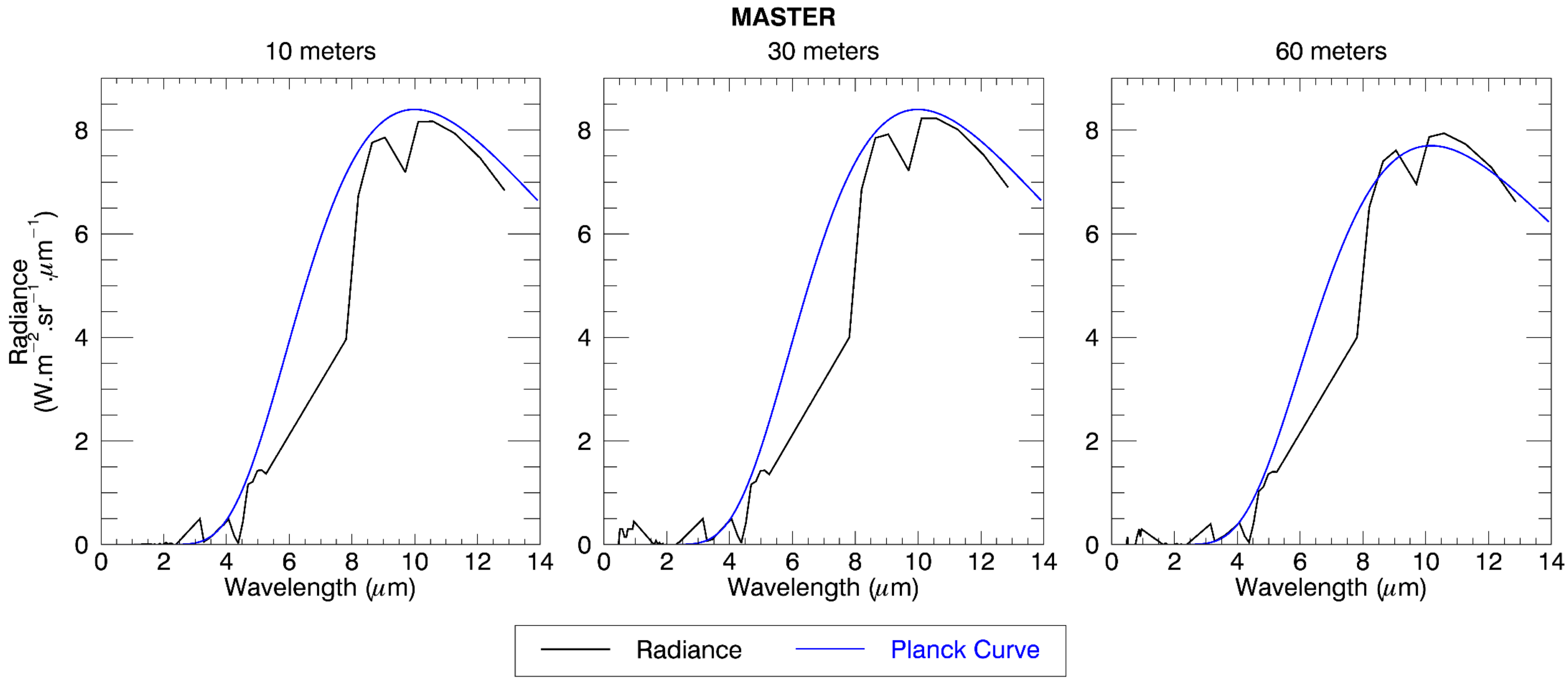


Initial Data Analysis

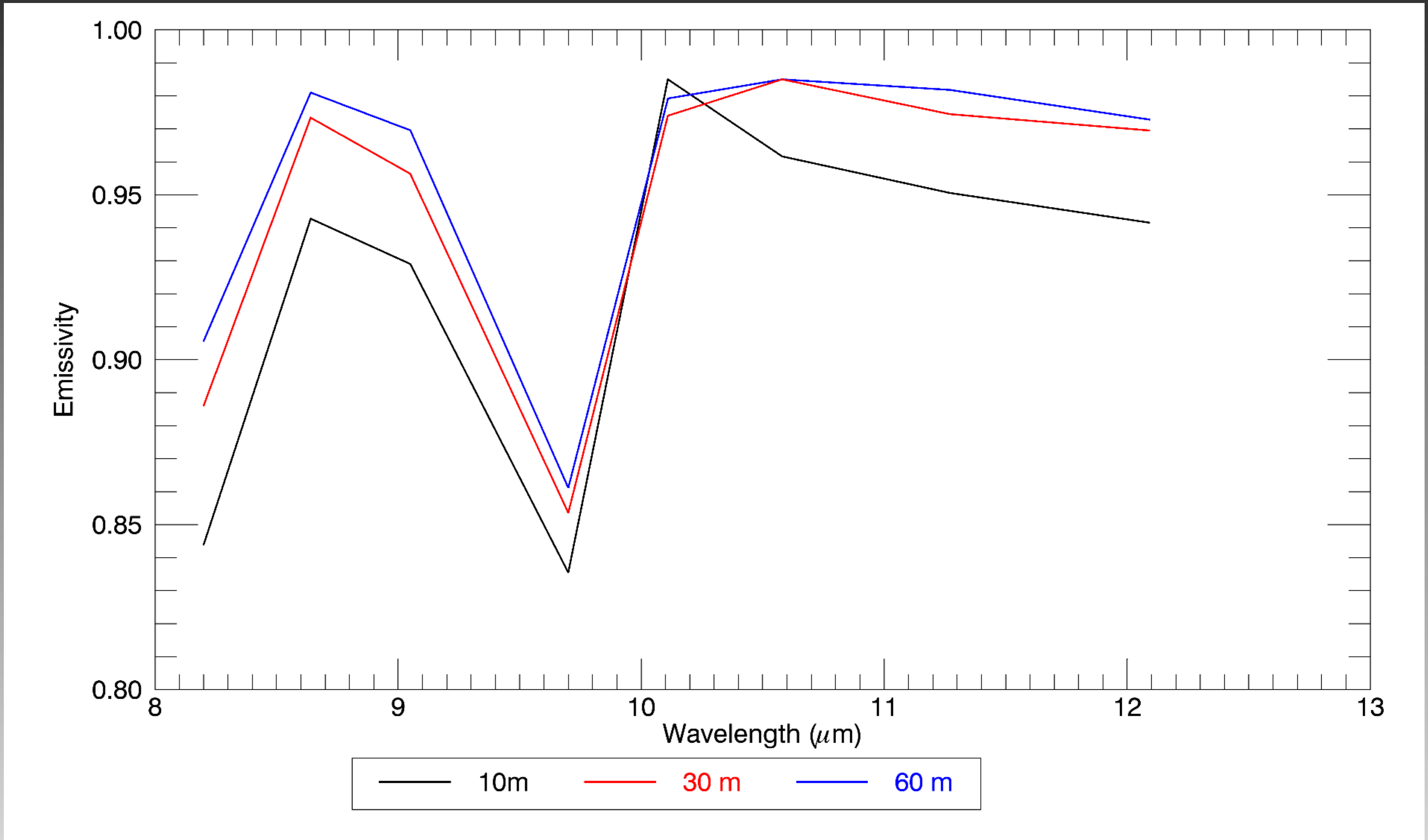
- **MASTER: 26 Jan 2017 at 05:57 UTC *(19:57 HST on 25 Jan)***
  - maximum Plank-derived temperatures:
    - center:
      - 10 m: ~290 K (λ_{max} = 10.58 µm)
      - 30 m: ~290 K (λ_{max} = 10.11 µm)
      - 60 m: ~285 K (λ_{max} = 10.58 µm)



Initial Data Analysis



Initial Data Analysis



Preliminary Results

❖ Saturation of all TIR/MIR MASTER Wavelengths

- max radiance between 1.5-4 microns at lava lake
- require high saturation temperature
  - ~1400 K in the MIR
  - ~900 K in the TIR

❖ Thermal Mixing Within Pixels

- <2 – 40 % fraction of molten surface across lava lake

❖ Emissivity Errors From Saturated Pixels *(obviously)*

- becomes less with lower spatial resolution and mixing at thermal boundaries (e.g., perimeter of lake)
- spectral features shallow with spatial resolution degradation

Conclusions

❖ Did Not Achieve Our Primary Goal

- limited lava flow production and access during the time of the field campaign
  - would provide information on lower-temperature processes and smaller-scale mixing
  - much higher spatial resolution for the MMT-Cam data
  - direct connectivity to flow-scale modeling parameters

❖ Real-Time Communication Was Frustrating

- critical considering access to *(and challenging conditions of)* the lava lake
  - limited knowledge of data acquisitions
    - ➢ cancelled flights to due HyTES issues
    - ➢ suggest direct MMS to field parties

Future Work

❖ Redeploy to Hawai'i in 2018

- hopefully access active surface flows / acquire data
- develop operational methodology for propagating lava flows

❖ Evaluate Emissivity Changes

- spatiotemporal variability during active flow propagation
- detailed study of emissivity change with cooling/thickening glassy crust

❖ Integrate IR Measurement and FLOWGO Modeling

- determine influence on model results

Acknowledgements

❖ Thanks To

- Matt Patrick and the rest of the USGS HVO staff
- Hawaii Volcanoes National Park
- NASA ground and flight crews
- HyspIRI Preparatory Campaign group
- our dedicated field-assistant and SPAM connoisseur

Extra Slides

Lava Lake – Radiance Images

- **MASTER: 26 Jan 2017 at 05:57 UTC**
  - Night flight: 19:57 HST on 25 Jan

Maximum temperature:

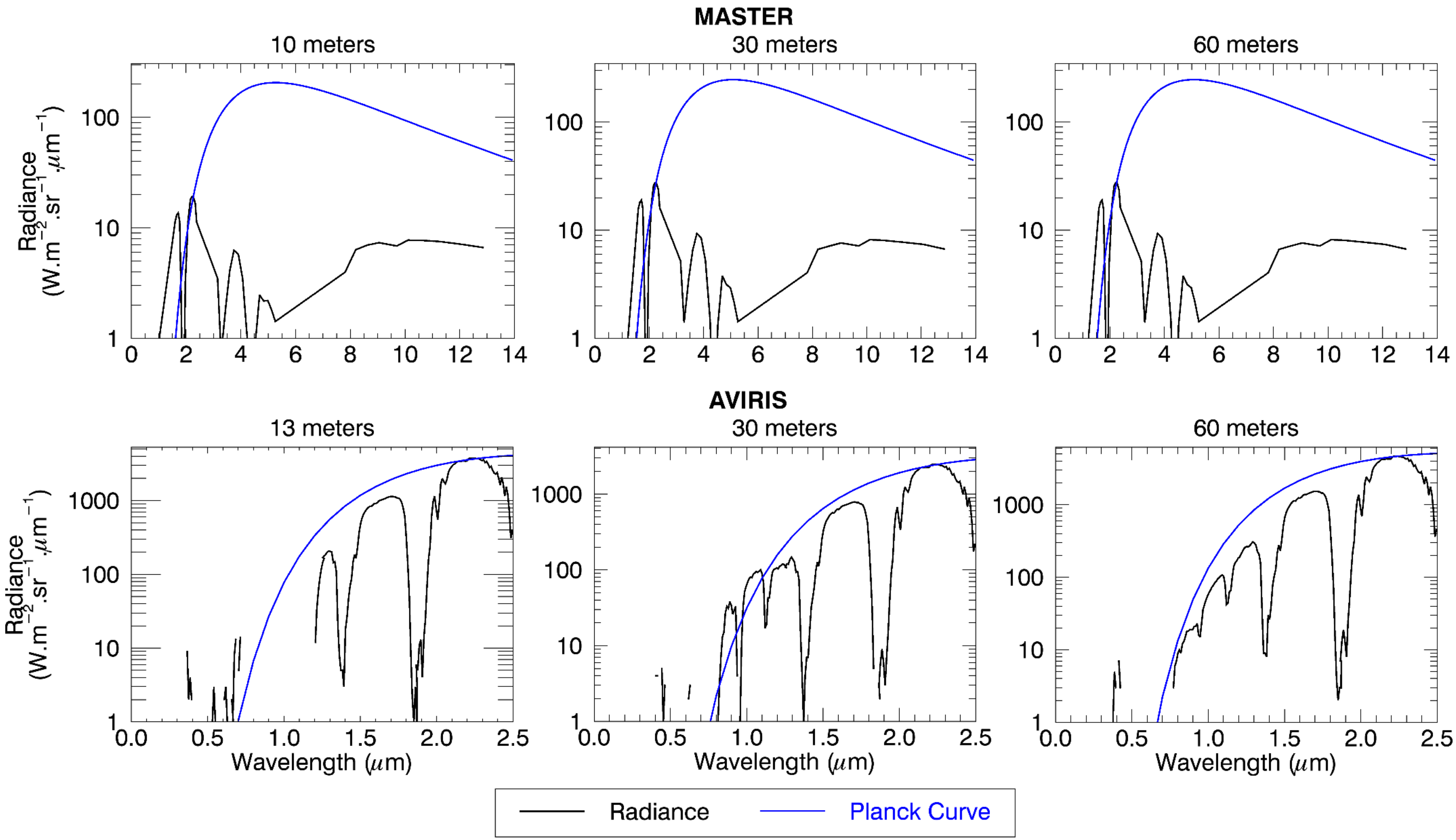
Center:

- 10 m: ~415 K (λ_{max} = 8.64 µm)
- 30 m: ~400 K (λ_{max} = 8.64 µm)
- 60 m: ~380 K (λ_{max} = 8.64 µm)

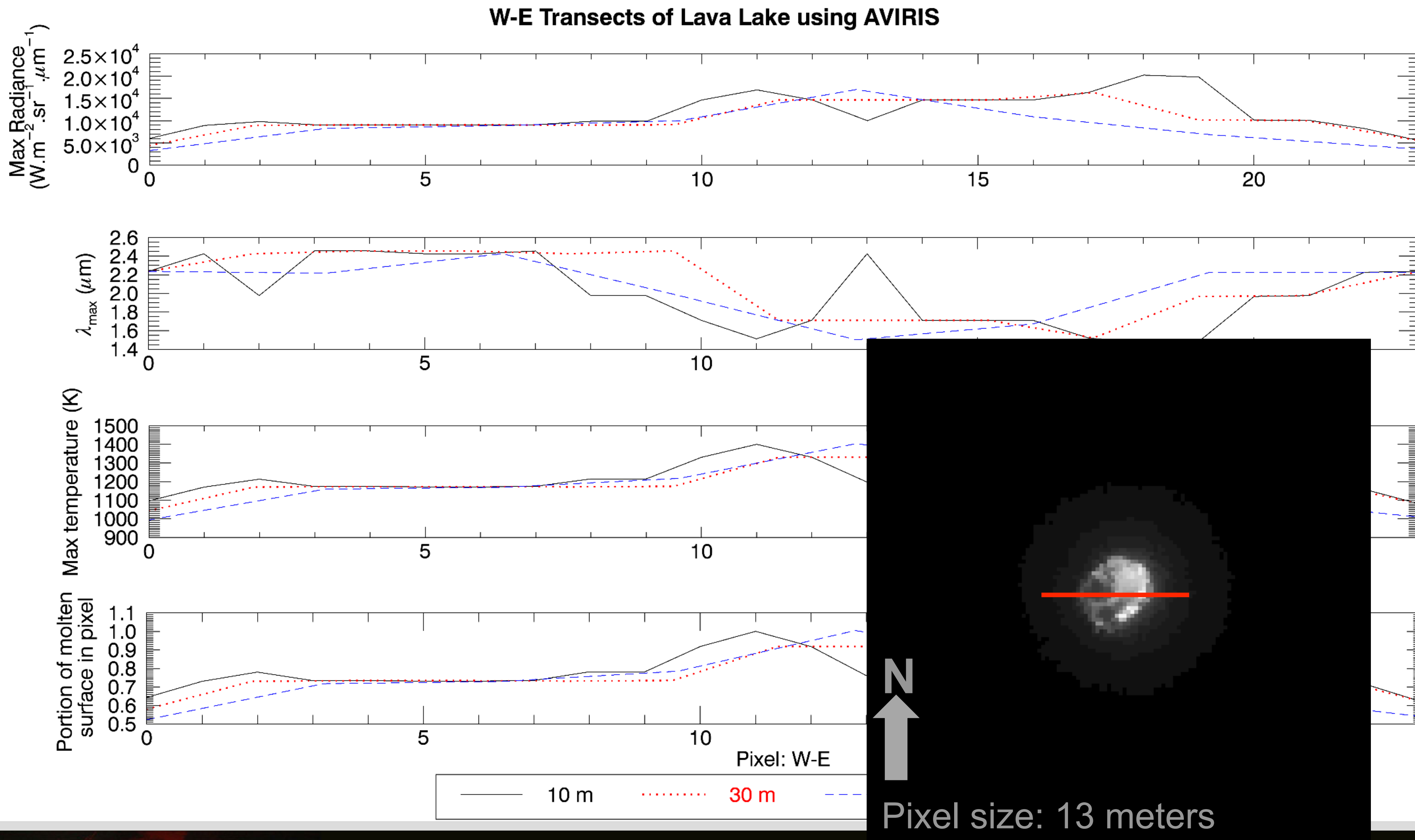
Edge:

10 m: ~400 K (λ_{max} = 8.64 µm)
30 m: ~390 K (λ_{max} = 8.64 µm)
60 m: ~375 K (λ_{max} = 8.64 µm)

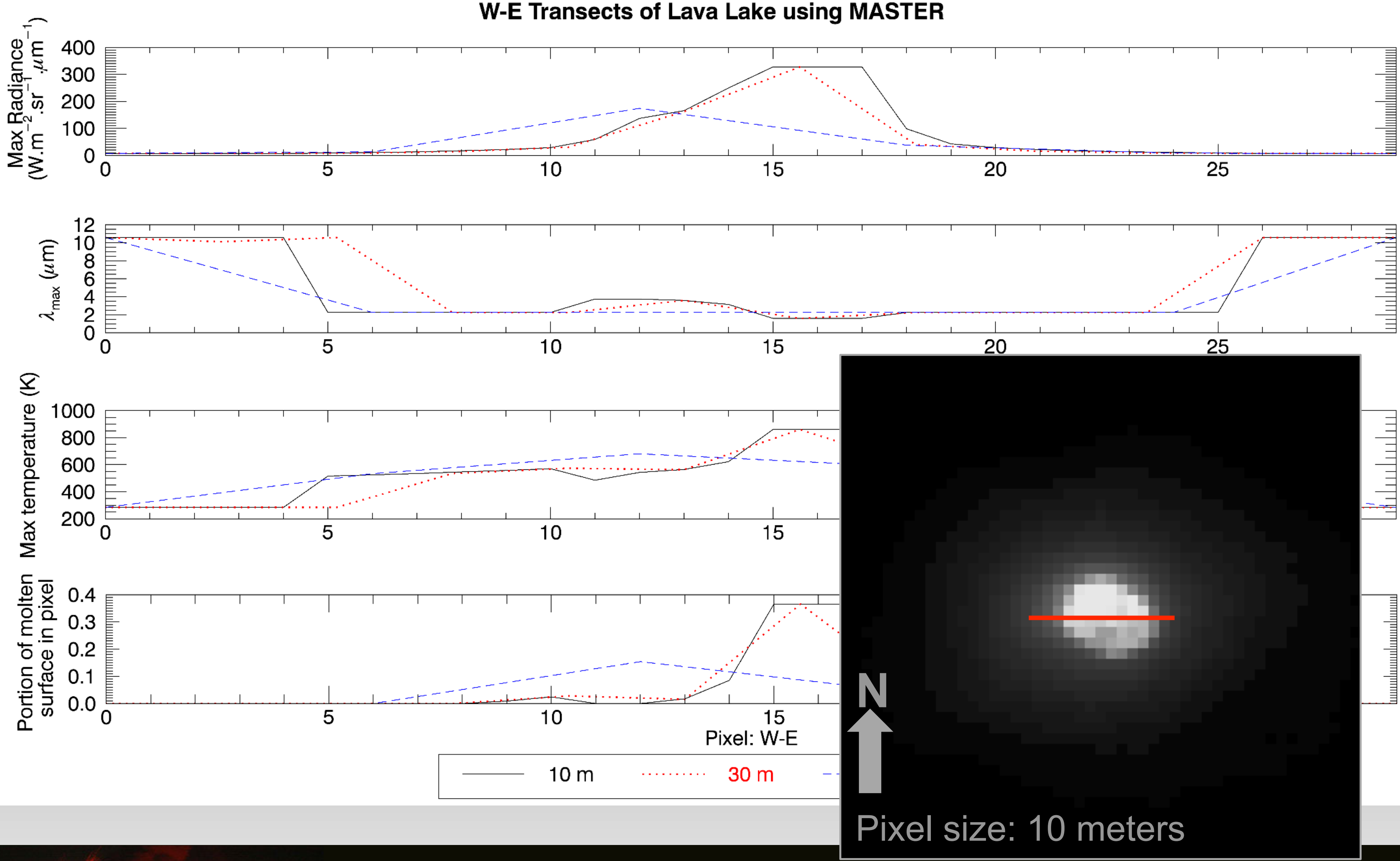
Lava Lake – Radiance Curves (Edge)



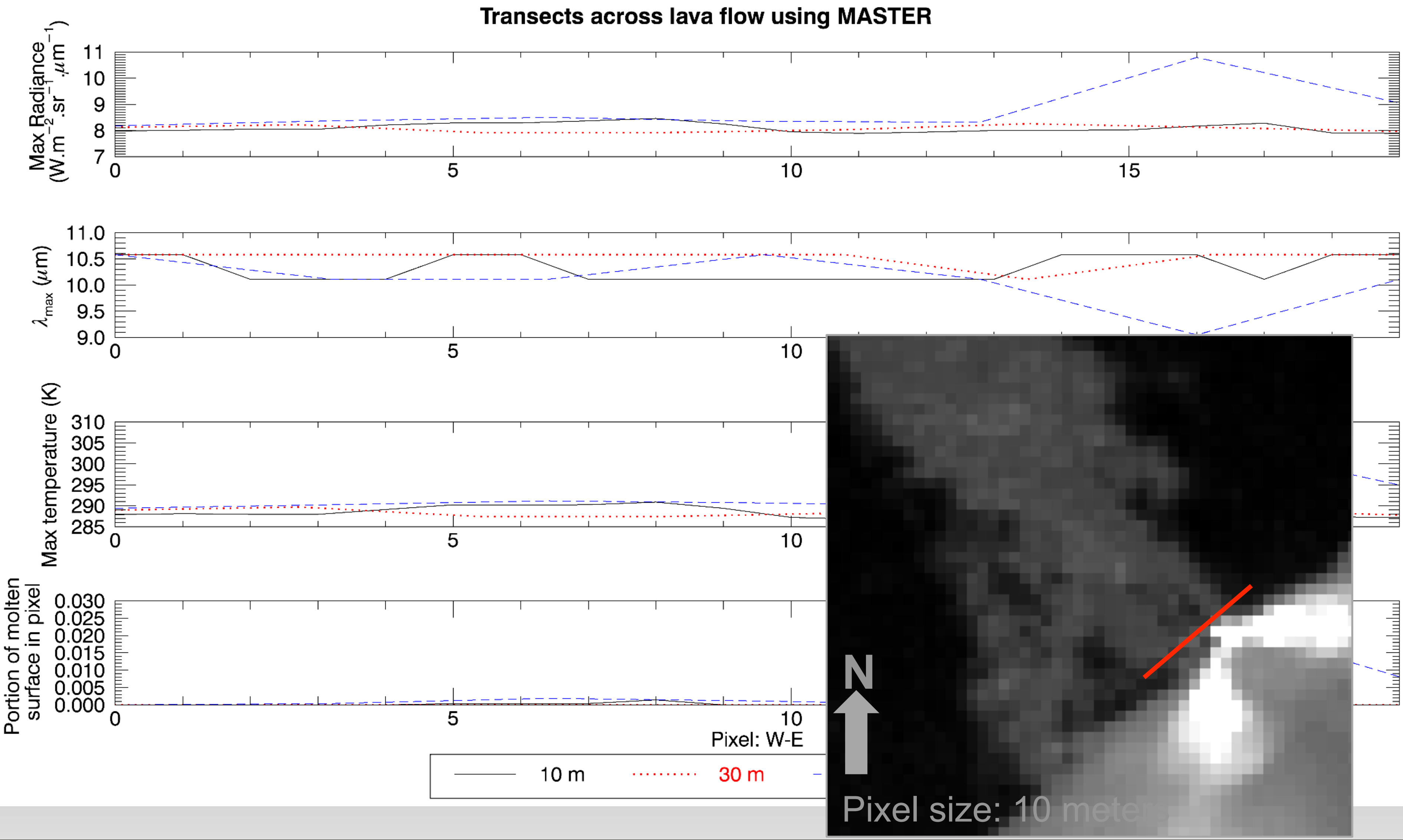
Lava Lake - Transects



Lava Lake - Transects



Lava Flow - Transects



Lava Flow - Transects