Simulating the response of the HyspIRI 4 μm channel to active lavas, using EO-1 Hyperion

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Topics

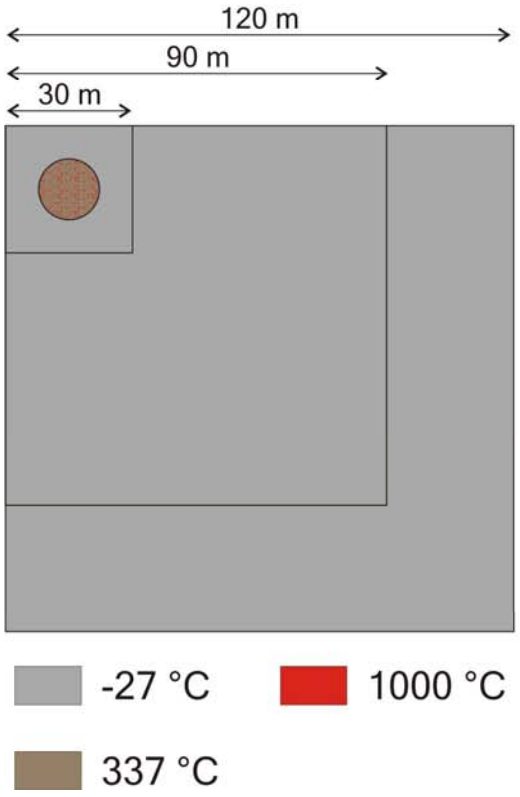
- Data driven predictions of surface leaving radiance from active lavas based on non-linear unmixing of Hyperion data

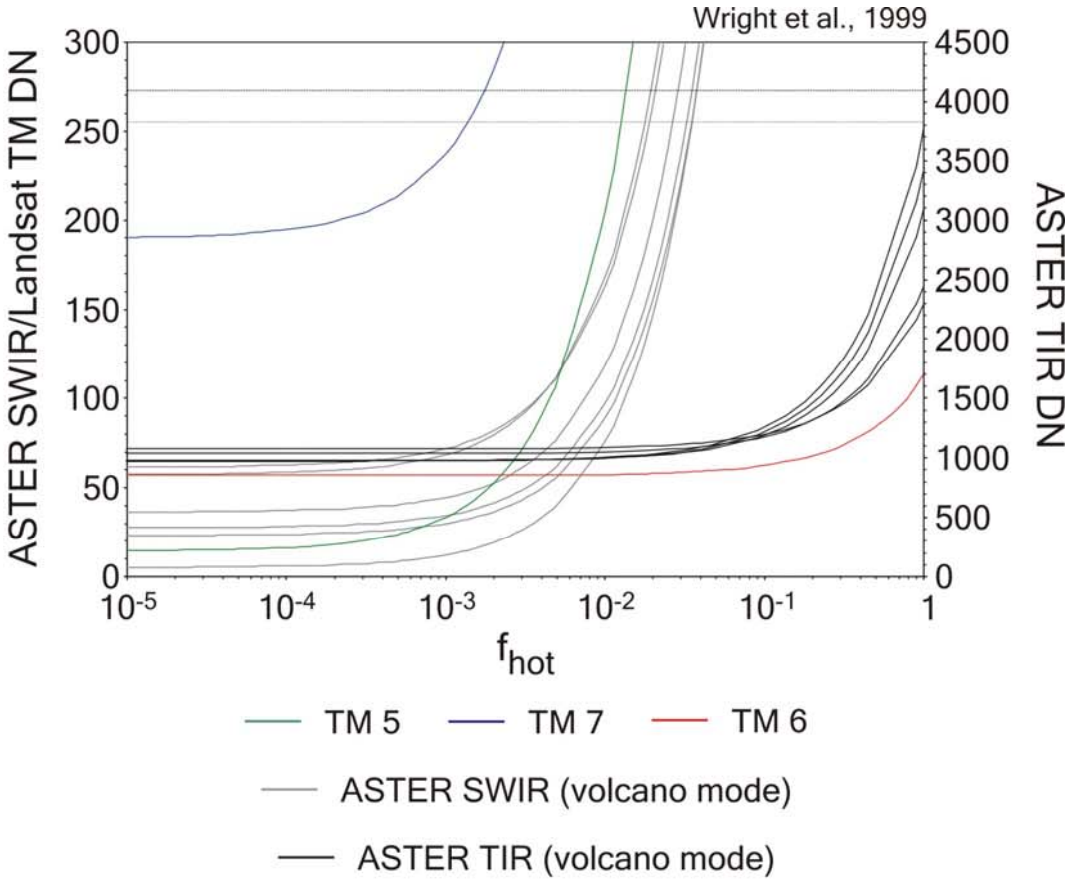
- Simulating HyspIRI at-satellite radiance from these predictions

- The propensity of HyspIRI's 4 μm channel to saturate over terrestrial lavas: recommendation for setting L_{max}

- Some science results

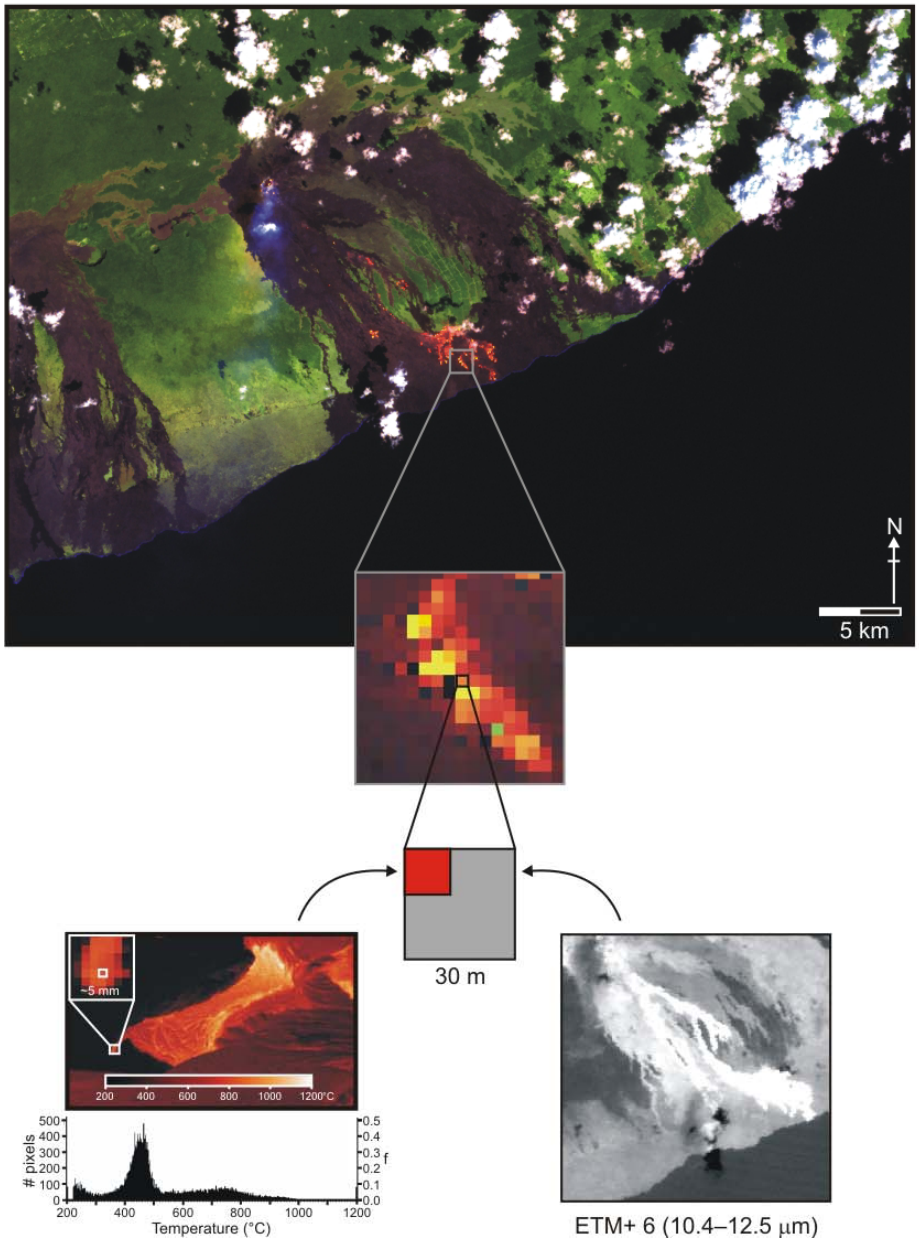
What is the surface leaving radiance from Earth's active lavas?
a) simple modeling

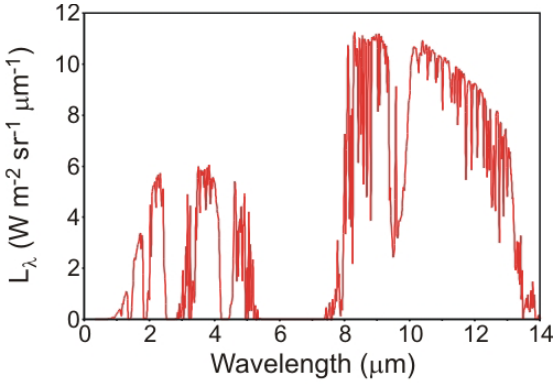


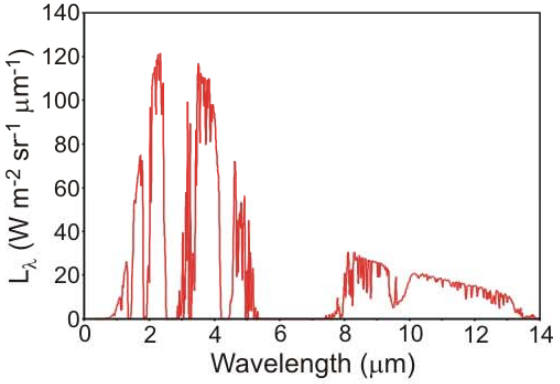


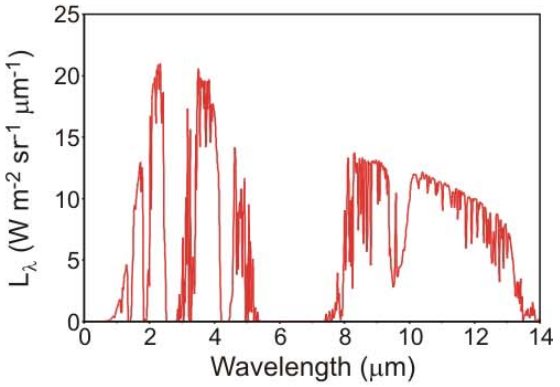
- Largely unconstrained by data
- How large? How hot? In what proportions?

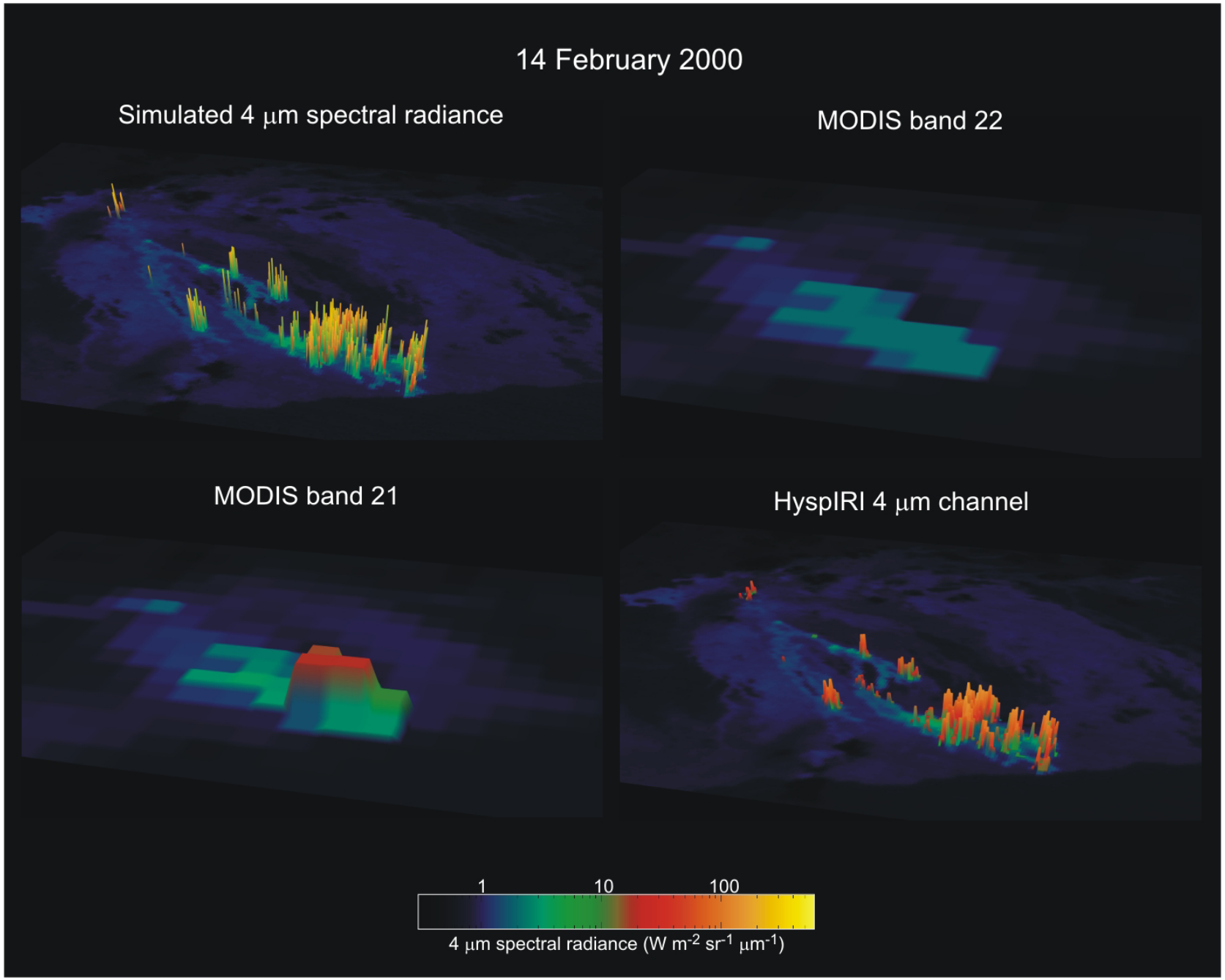
What is the surface leaving radiance from Earth's active lavas?
b) combining modeling with real data



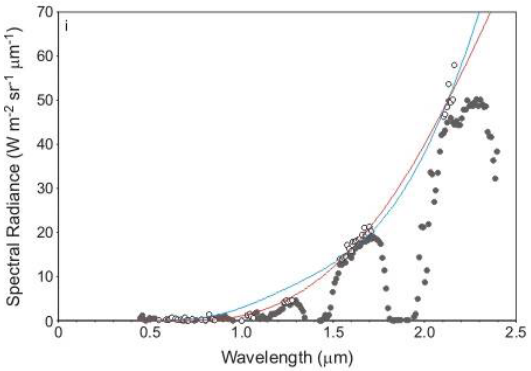


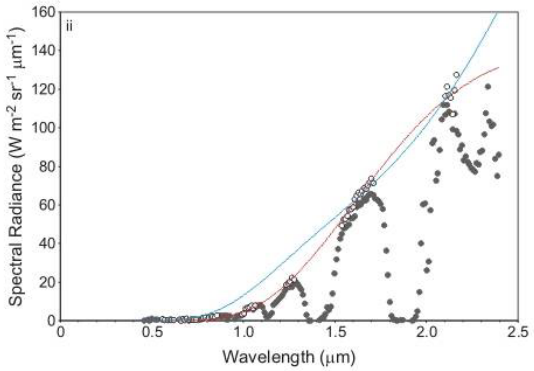


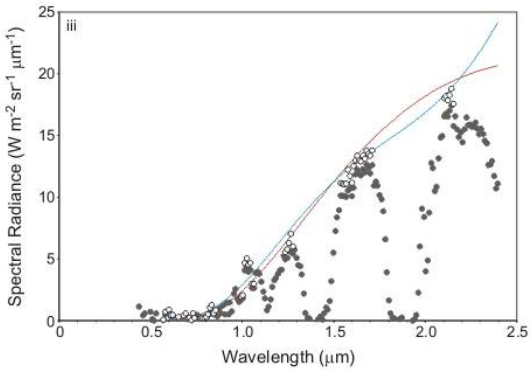



14 February 2000
Simulated 4 μm spectral radiance
MODIS band 22
MODIS band 21
HyspIRI 4 μm channel
1
10
100
4 μm spectral radiance (W m-2 sr-1 μm-1)

What is the surface leaving radiance from Earth's active lavas?
c) simulating surface leaving radiance using real data

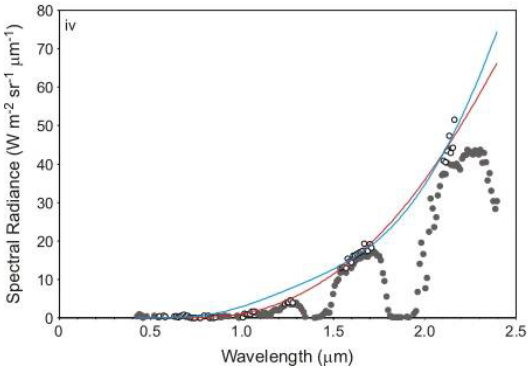


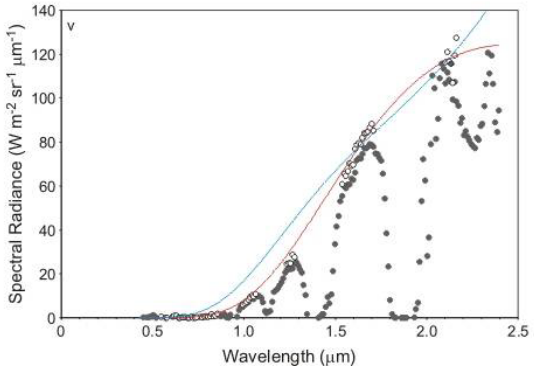


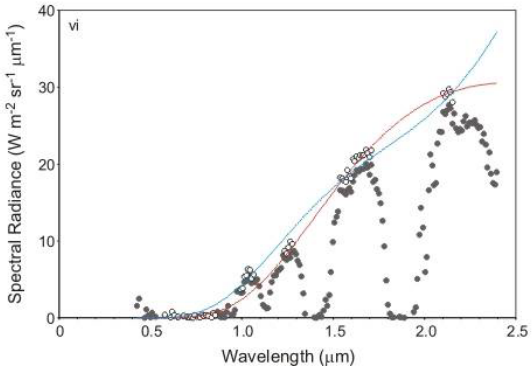


Wright et al., 2010

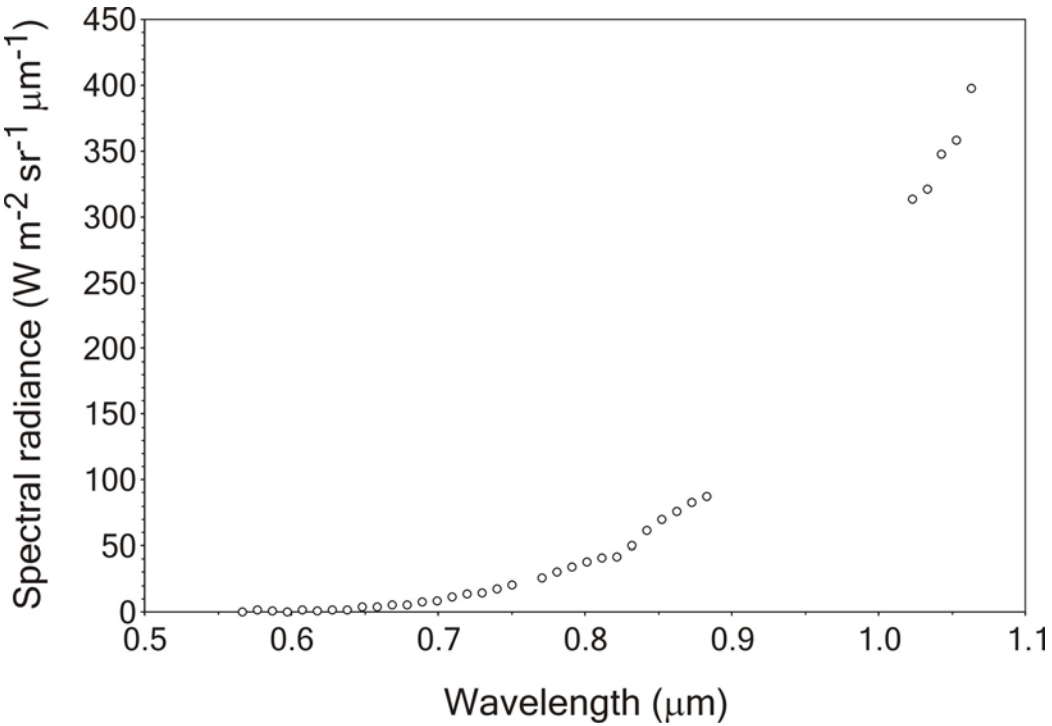
Pixel	i	ii	iii	iv	v	vi
Dual-band						
T_1	1150°C	1150°C	1150°C	1150°C	1150°C	1150°C
f_1	0.0006	0.0027	0.0006	0.0006	0.0035	0.0009
T_2	328°C	351°C	233°C	320 °C	328°C	254°C
f_2	0.9994	0.9973	0.9994	0.9994	0.9965	0.9991
rms	1.3	3.6	0.5	1.2	4.8	0.8
Unconstrained						
T_1	874°C	1067°C	1138°C	1001°C	920°C	963°C
f_1	0.003	0.0002	0.0005	0.0008	0.008	0.002
T_2	421°C	790°C	697°C	500°C	899°C	587°C
f_2	0.2	0.02	0.003	0.05	0.005	0.001
T_3	128°C	489°C	*	377°C	*	230°C
f_3	0.6	0.002	*	0.2	*	0.06
rms	0.7	1.2	0.4	0.7	1.8	0.7

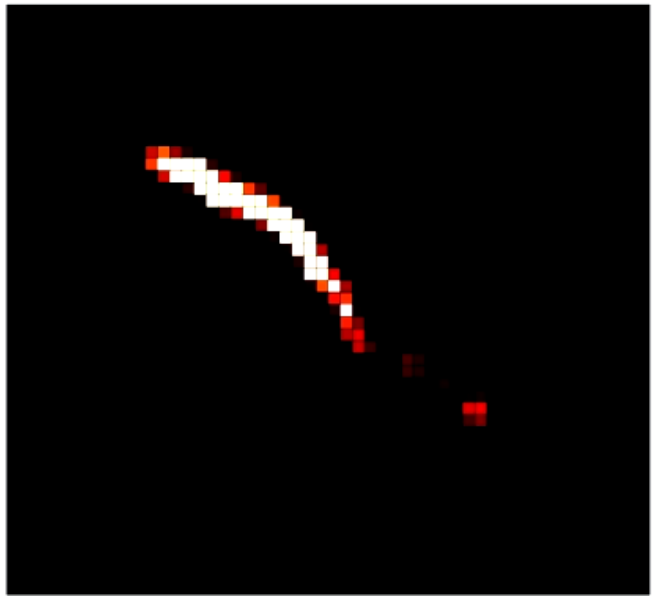






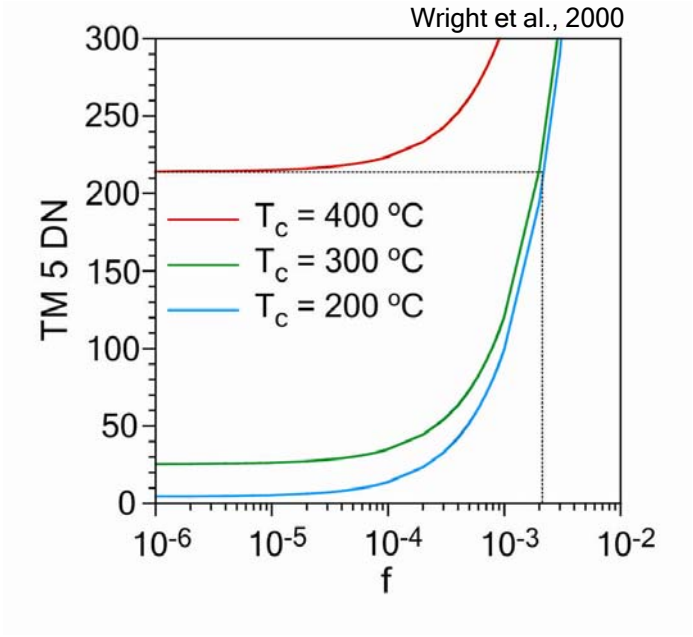
The ability to retrieve sub-pixel temperature characteristics using an imaging spectrometer

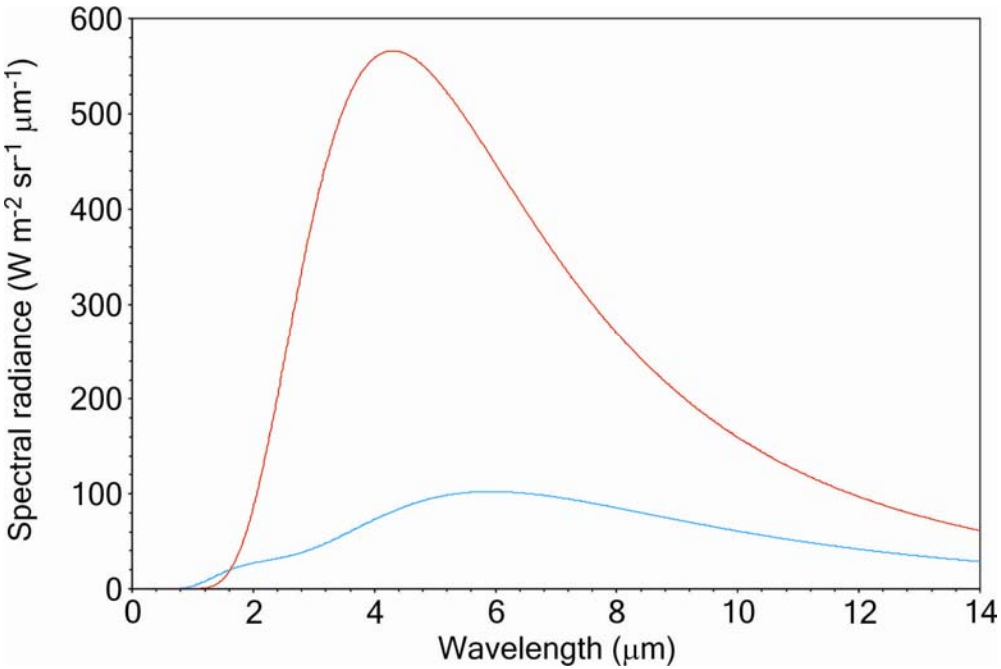


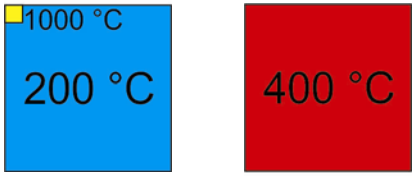


- Sub-pixel temperature characteristics can be determined for even the most radiant active lava surfaces

The desirability to quantify sub-pixel temperature mixing

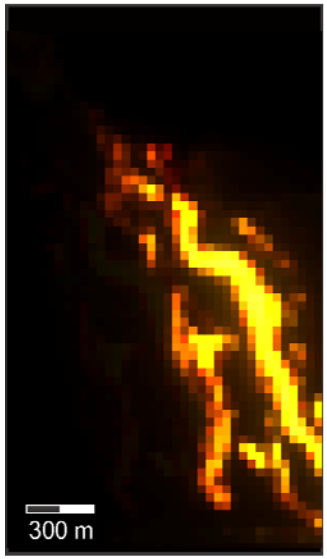


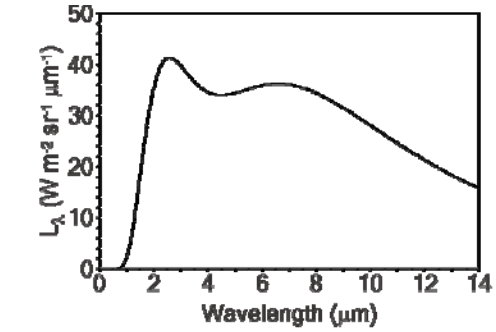


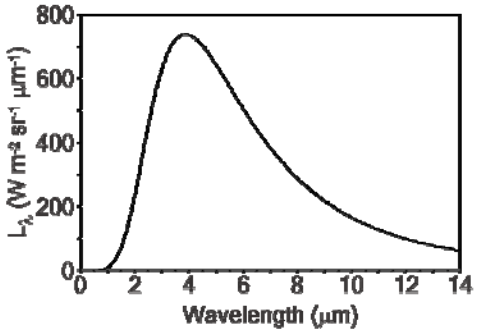


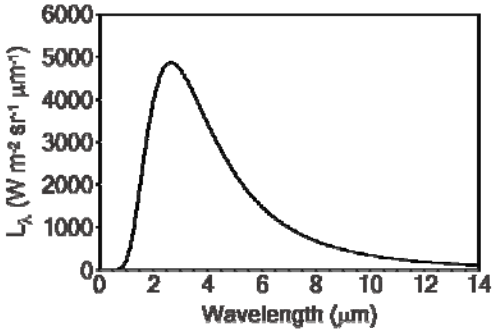
- Whole pixel/"Dozier" temperatures can easily misrepresent the nature of emitted spectral radiance from thermally complex active lava surfaces

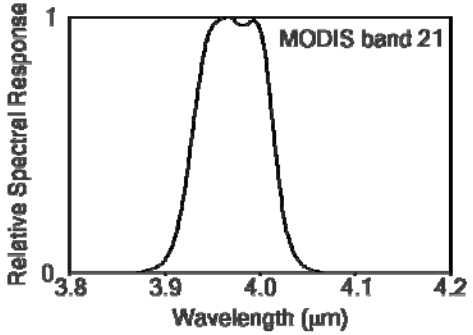
Simulating HyspIRI data from Hyperion data

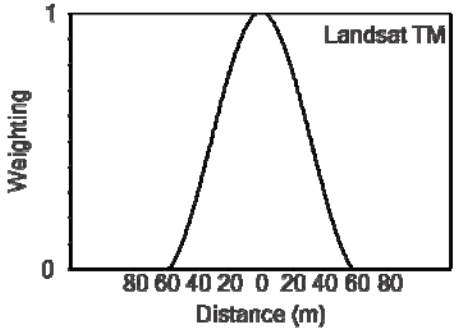


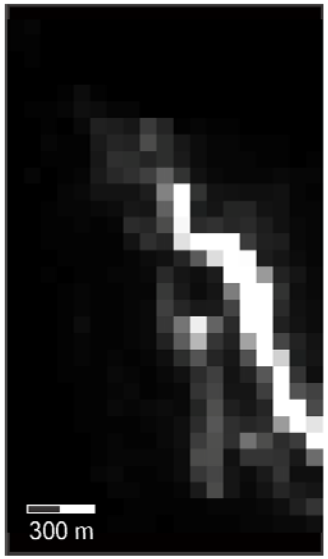












- Analyzed 60 Hyperion images encompassing the full spectrum of terrestrial active lava bodies


Photo: J. Durieux

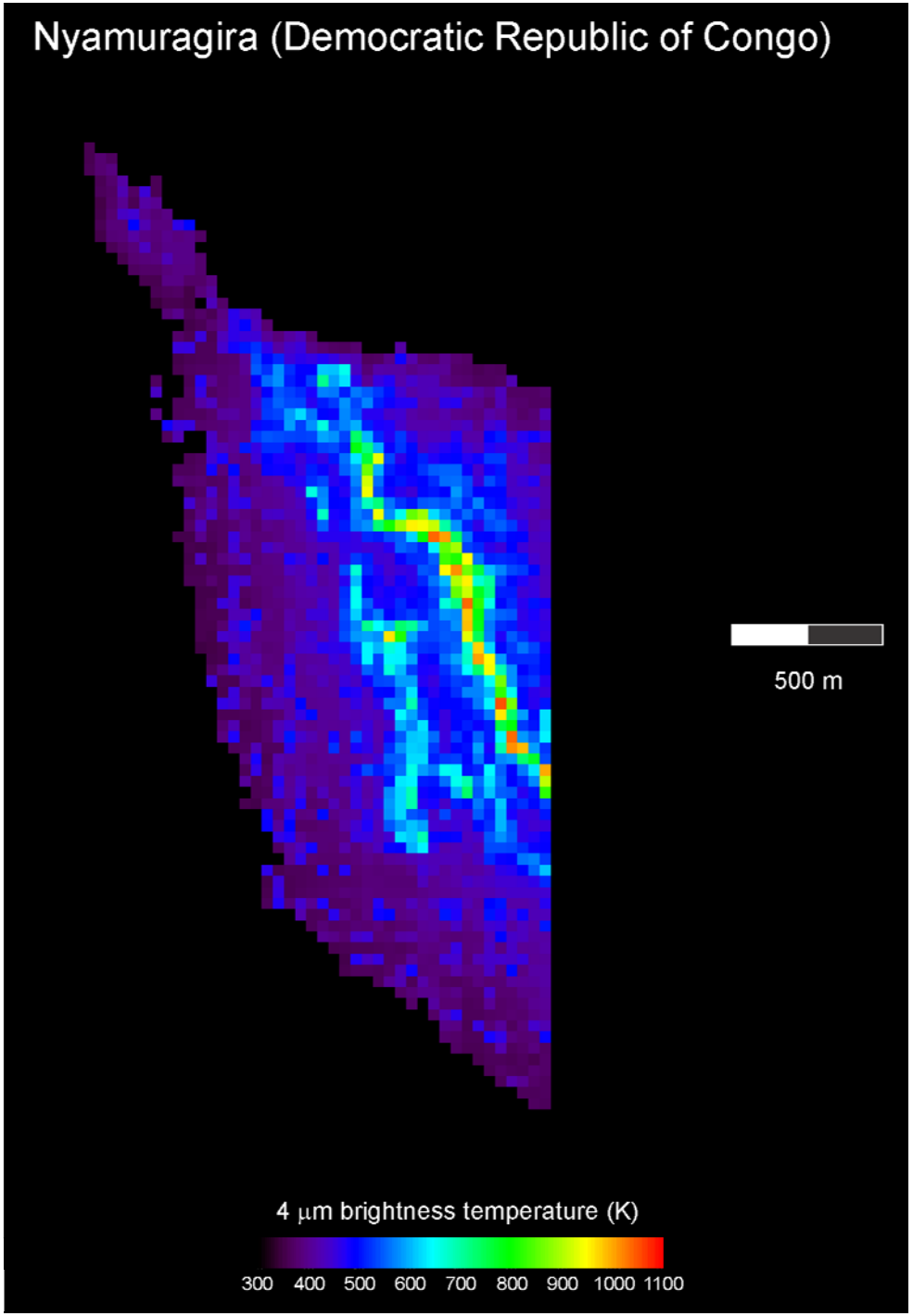

Nyamuragira (Democratic Republic of Congo)
500 m
4 μm brightness temperature (K)
300 400 500 600 700 800 900 1000 1100


Photo: M. Fulle

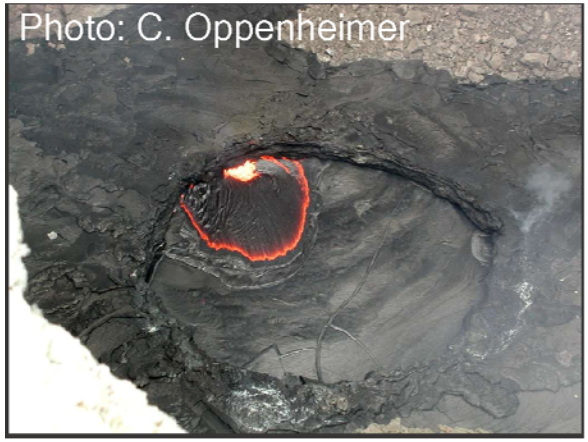


Photo: C. Oppenheimer

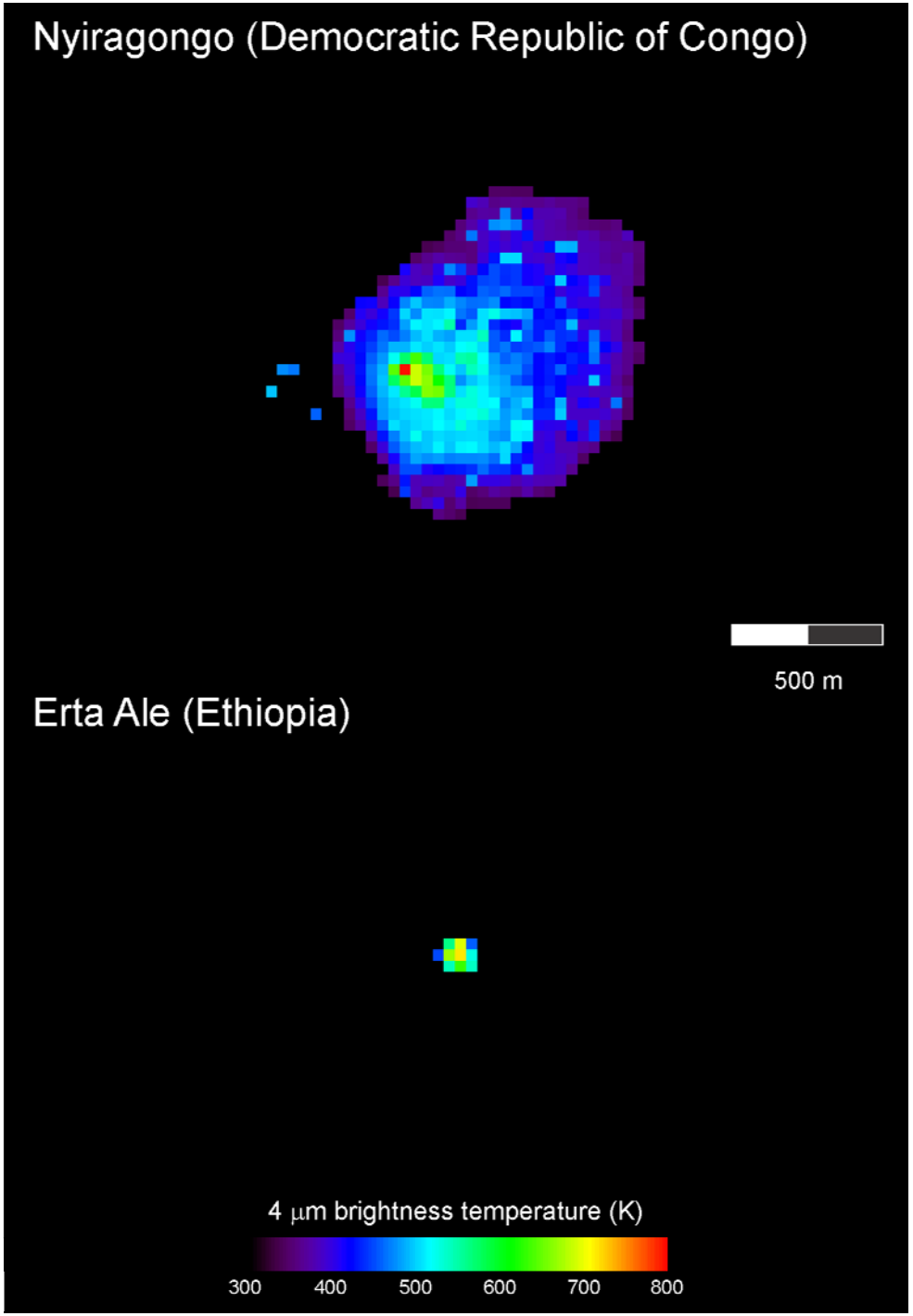
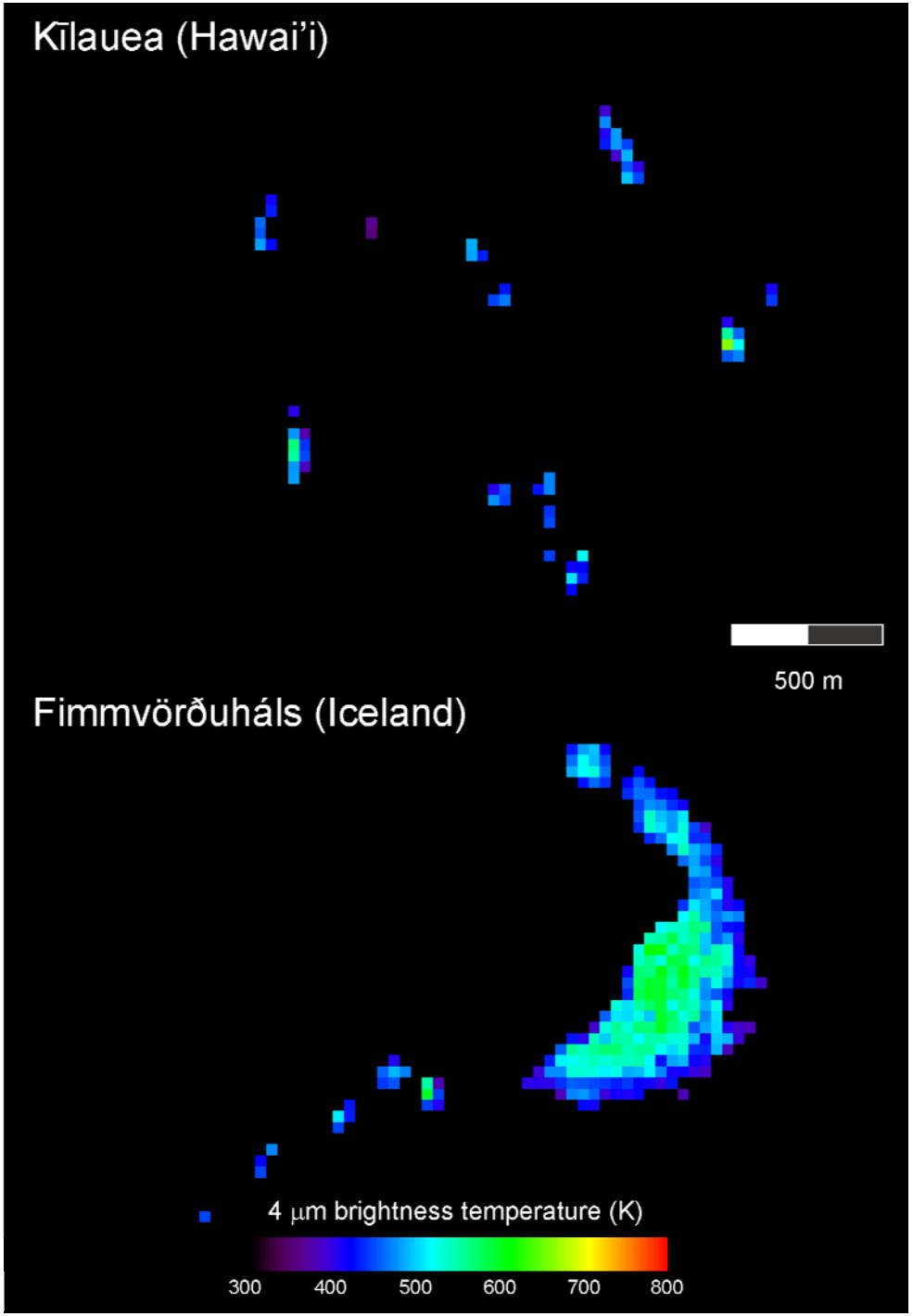
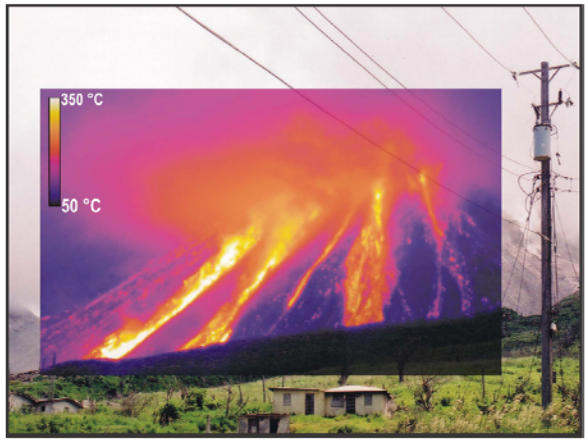
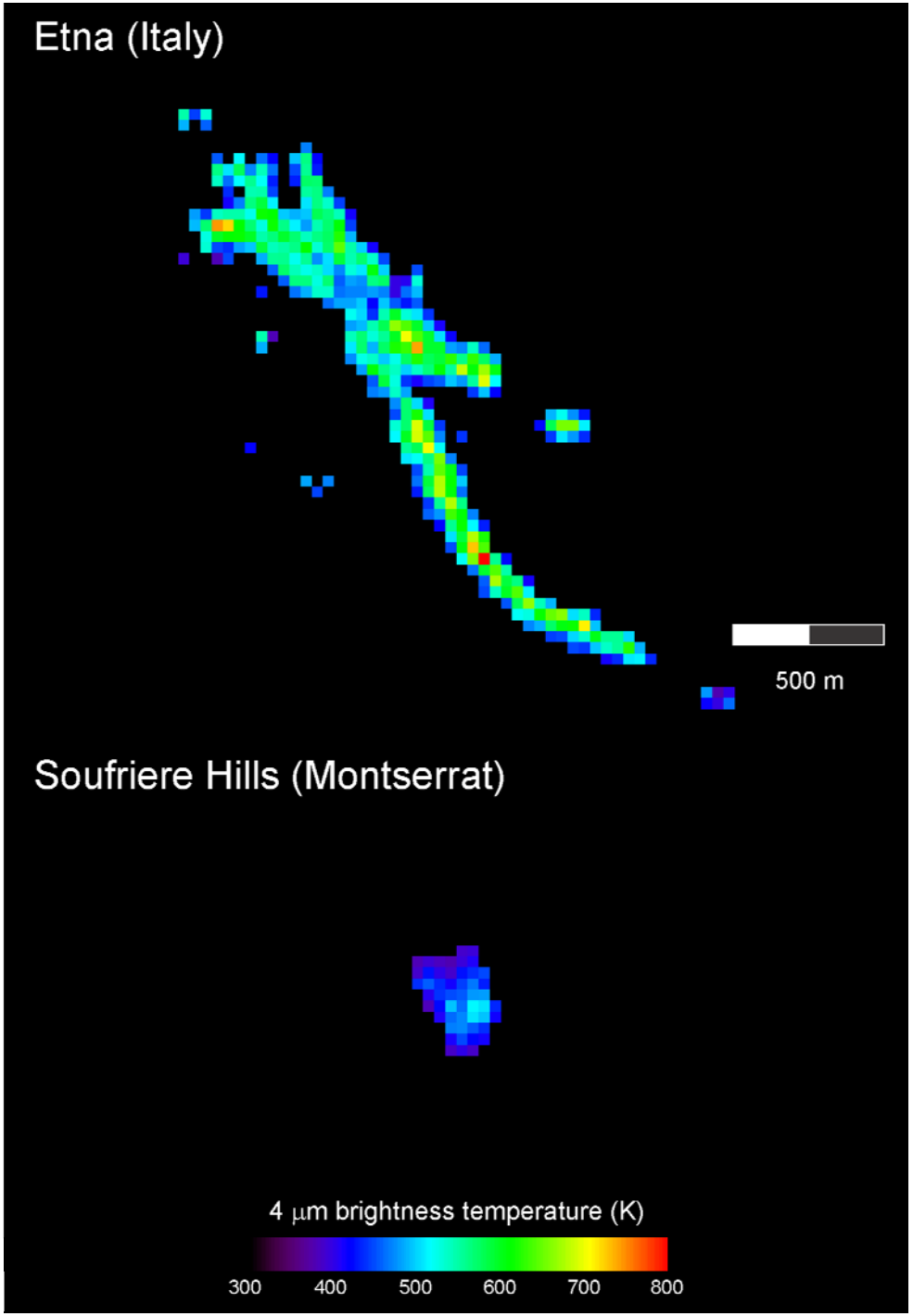
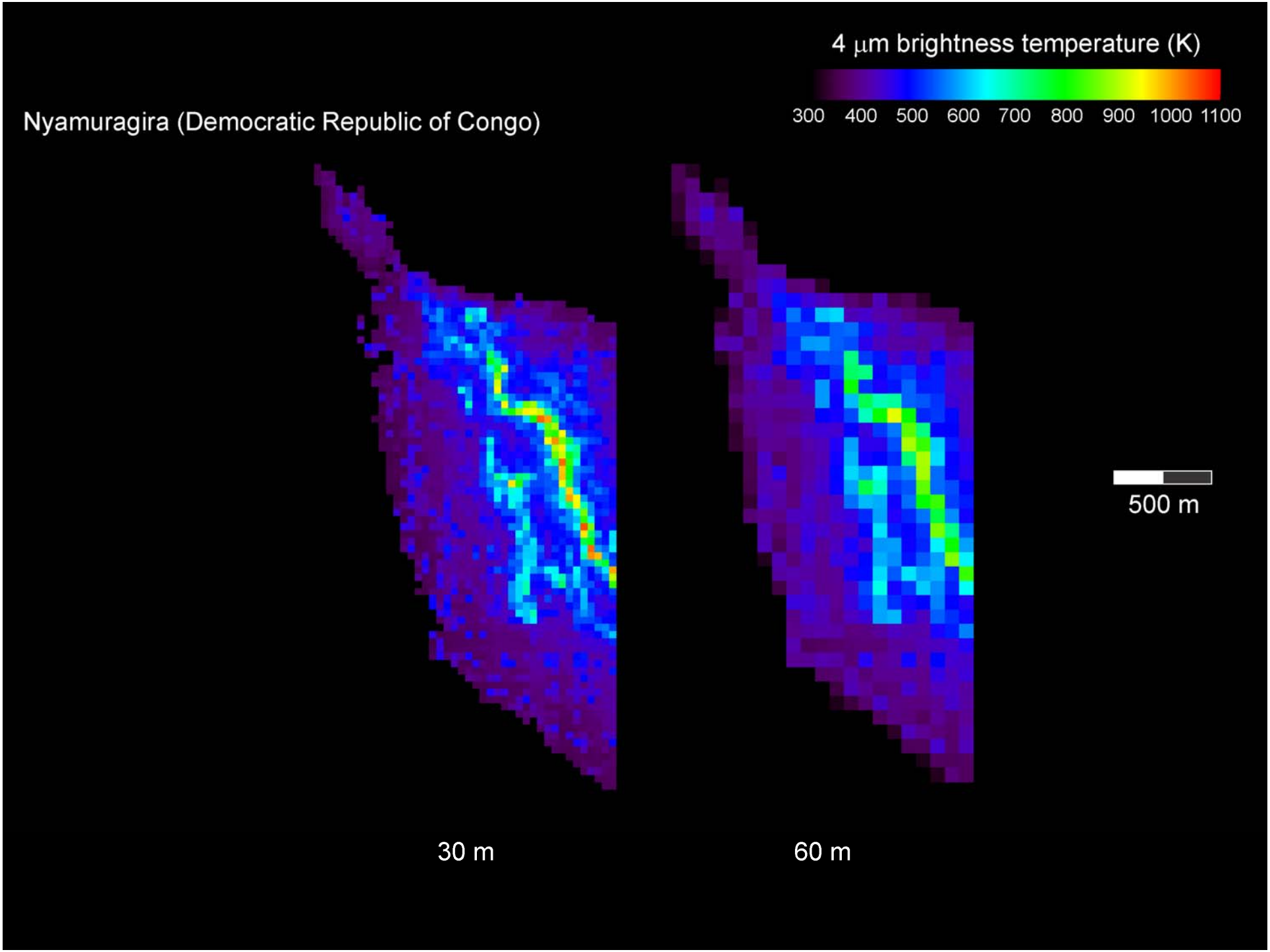

Nyiragongo (Democratic Republic of Congo)
500 m
Erta Ale (Ethiopia)
4 μm brightness temperature (K)
300
400
500
600
700
800

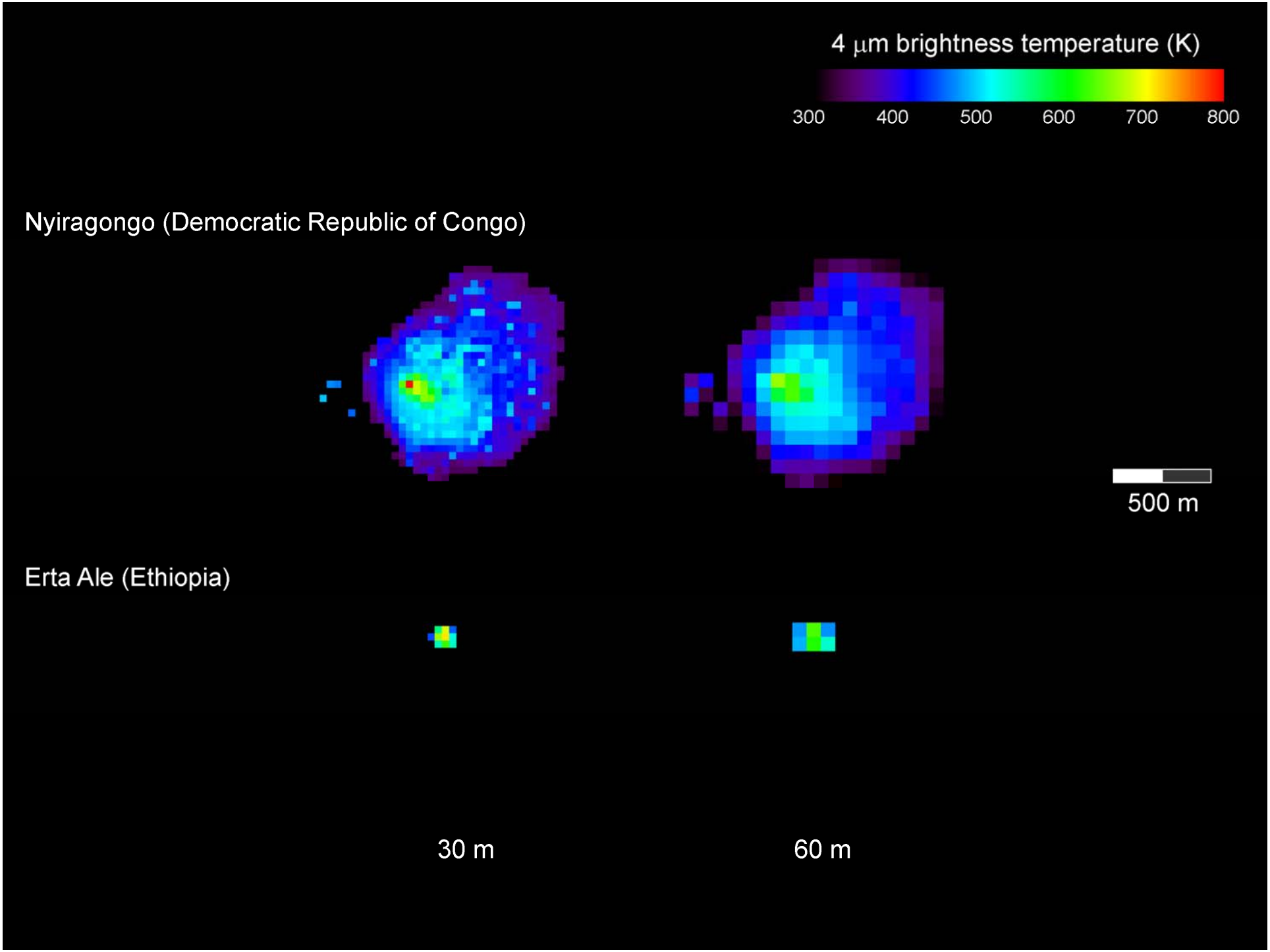

Photo: M. Wibe Lund

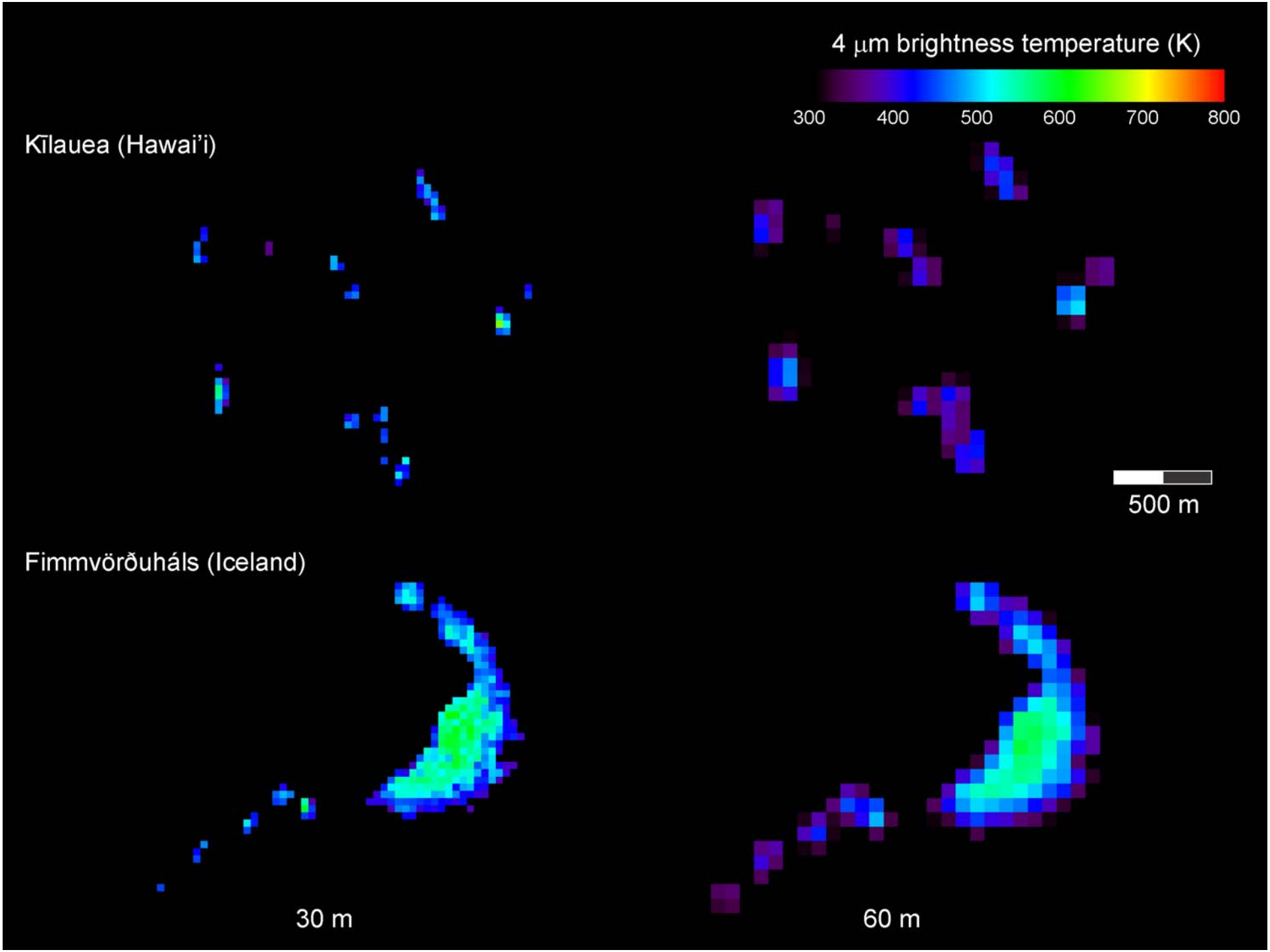

Kīlauea (Hawai'i)
500 m
Fimmvörðuháls (Iceland)
4 μm brightness temperature (K)
300
400
500
600
700
800

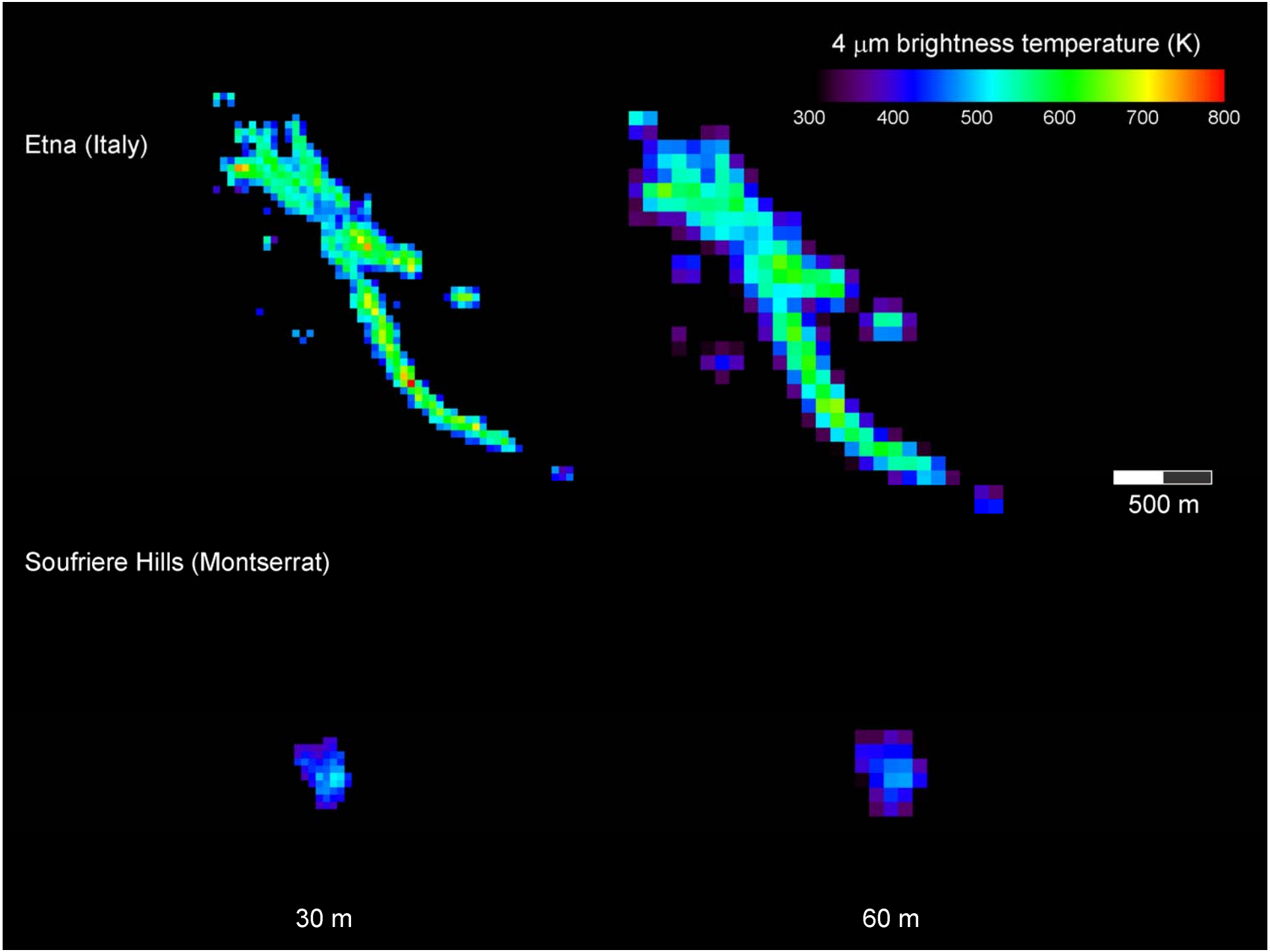

350 °C
50 °C


Etna (Italy)
500 m
Soufriere Hills (Montserrat)
4 μm brightness temperature (K)
300
400
500
600
700
800

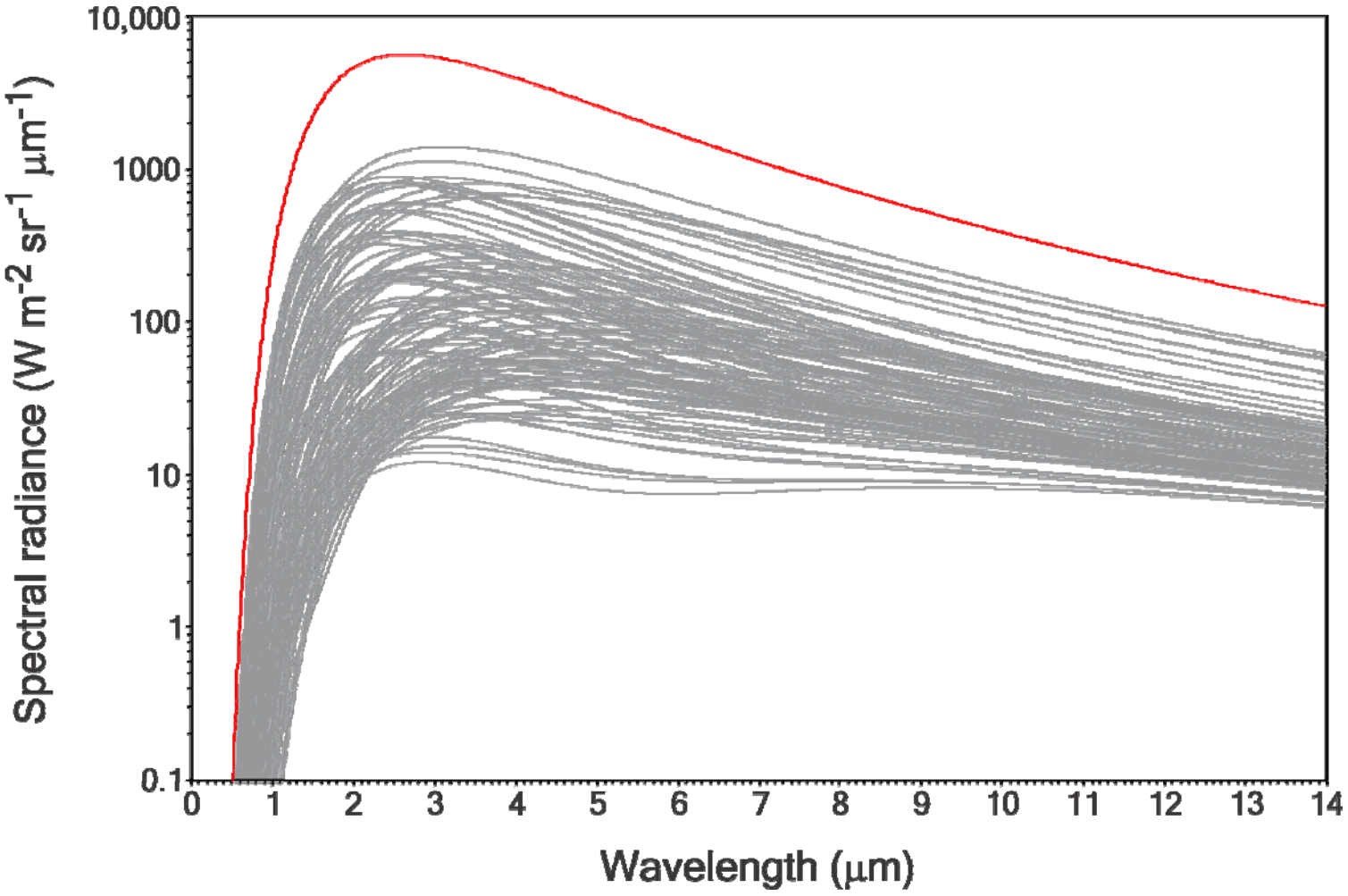

4 μm brightness temperature (K)
300 400 500 600 700 800 900 1000 1100
Nyamuragira (Democratic Republic of Congo)
500 m
30 m
60 m


4 μm brightness temperature (K)
300
400
500
600
700
800
Nyiragongo (Democratic Republic of Congo)
500 m
Erta Ale (Ethiopia)
30 m
60 m


4 μm brightness temperature (K)
300
400
500
600
700
800
Kīlauea (Hawai'i)
500 m
Fimmvörðuháls (Iceland)
30 m
60 m


4 μm brightness temperature (K)
300
400
500
600
700
800
Etna (Italy)
500 m
Soufriere Hills (Montserrat)
30 m
60 m

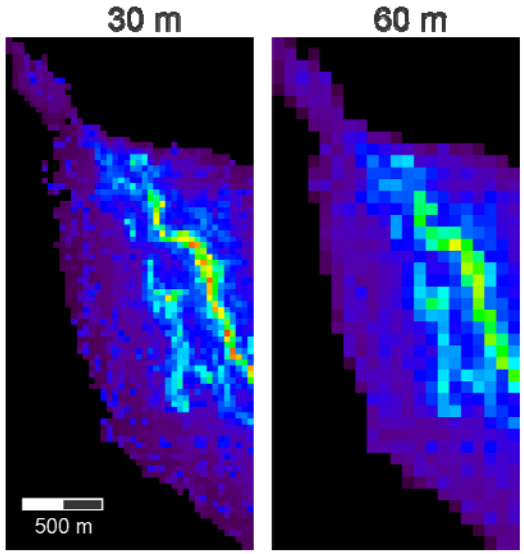
T_{sat} for the HyspIRI 4 μm channel

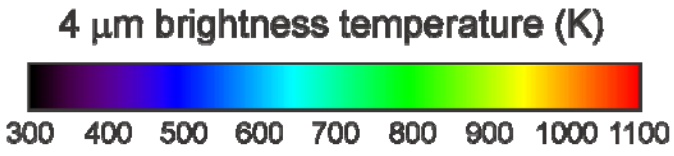


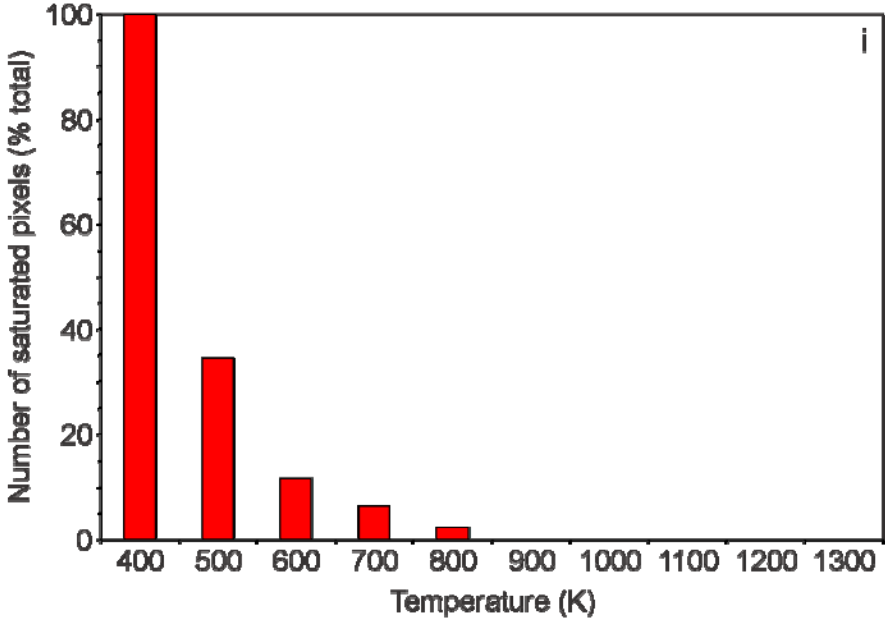
- What should the HyspIRI 4 μm channel saturation be set to?

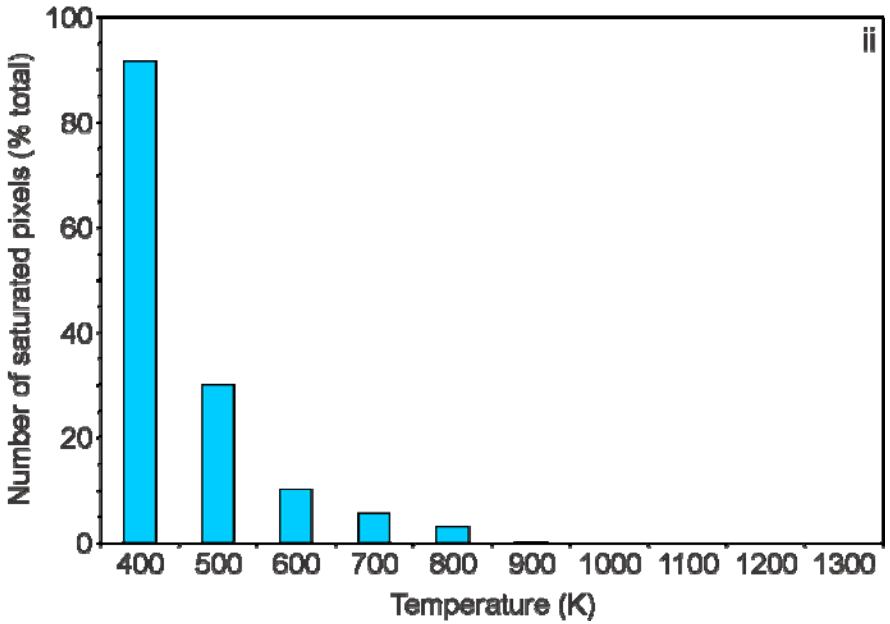
Incidence of saturation as a function of assumed T_{sat}

T_{sat}(K)	#$_{sat}$(i)	#$_{sat}$(ii)
400	471	432
500	163	142
600	55	48
700	30	26
800	11	14
900	0	1
1000	0	0

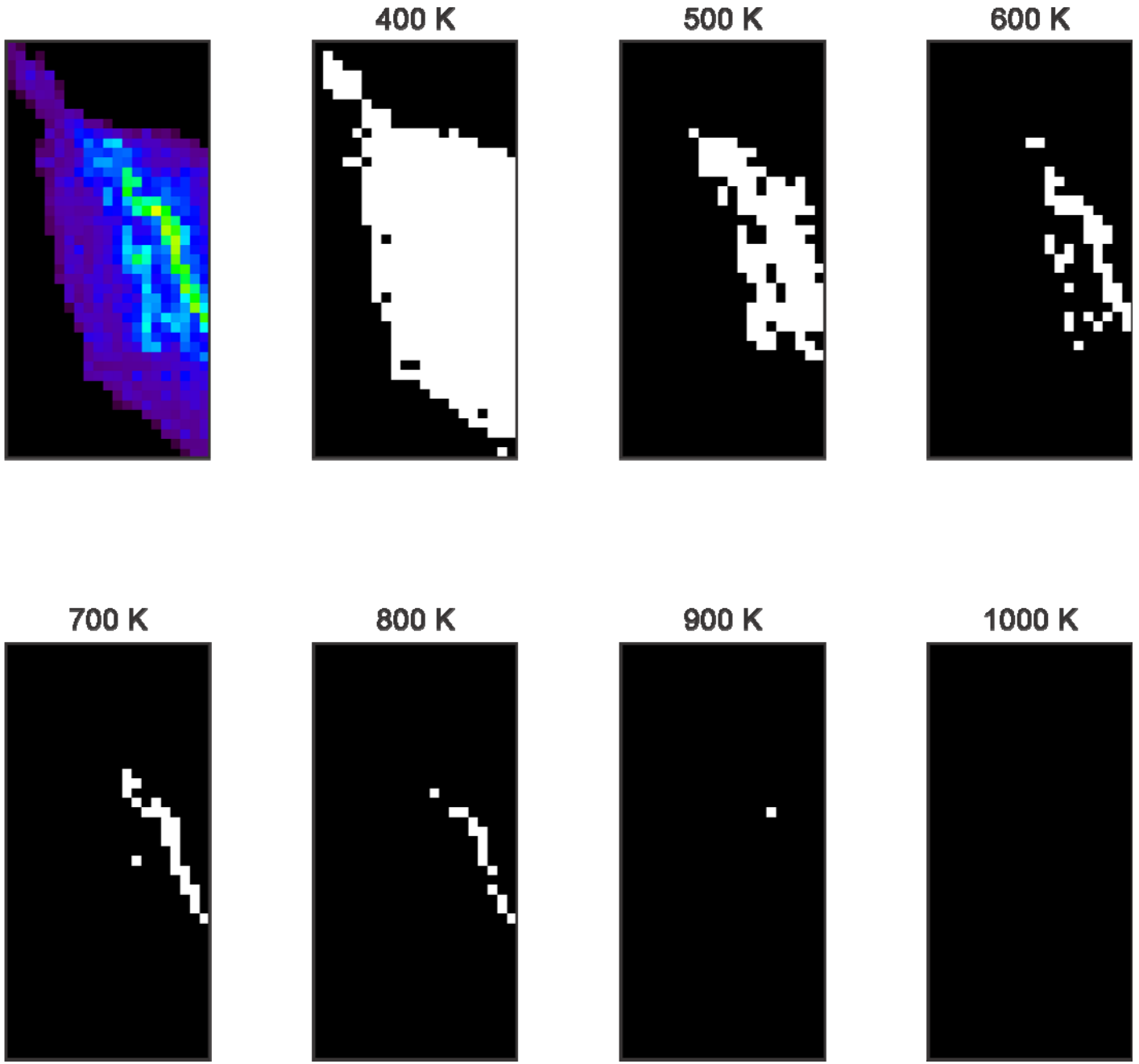




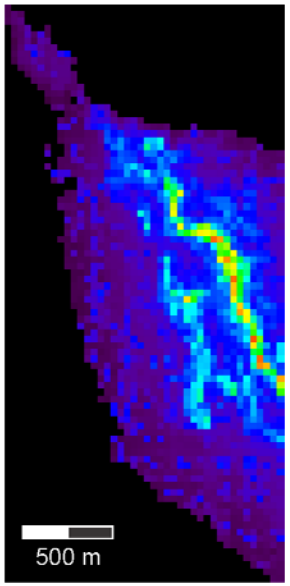


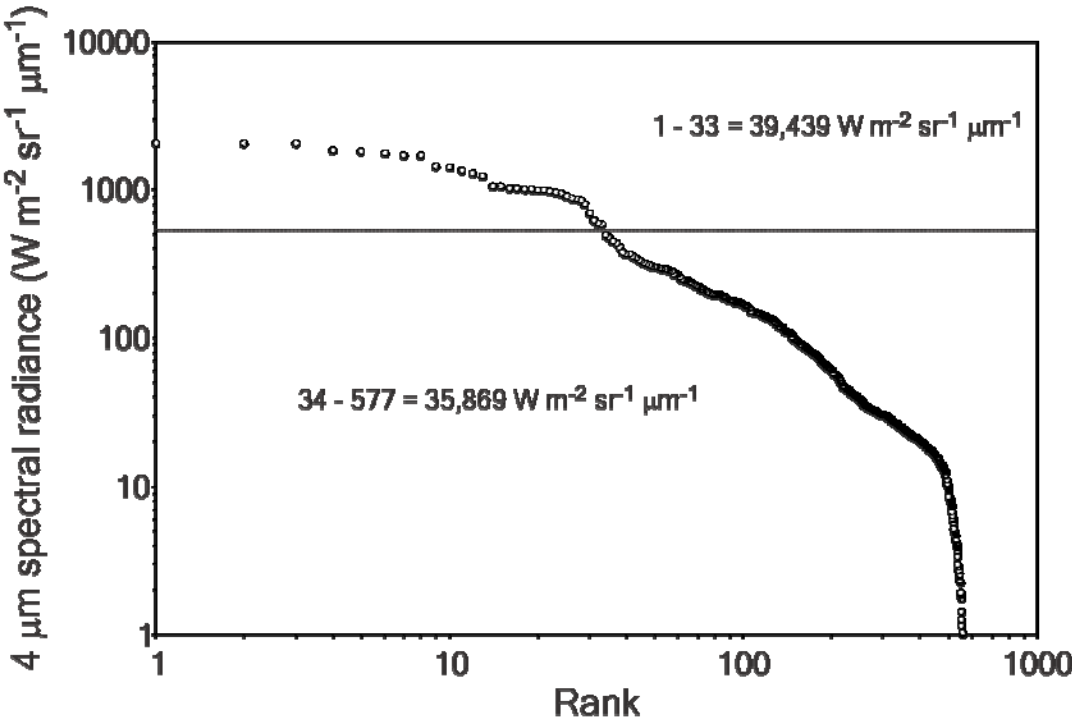


The important pixels are the ones which drive T_{sat} higher



Recommendation: HyspIRI 4 μm T_{sat} not less than 1100 K

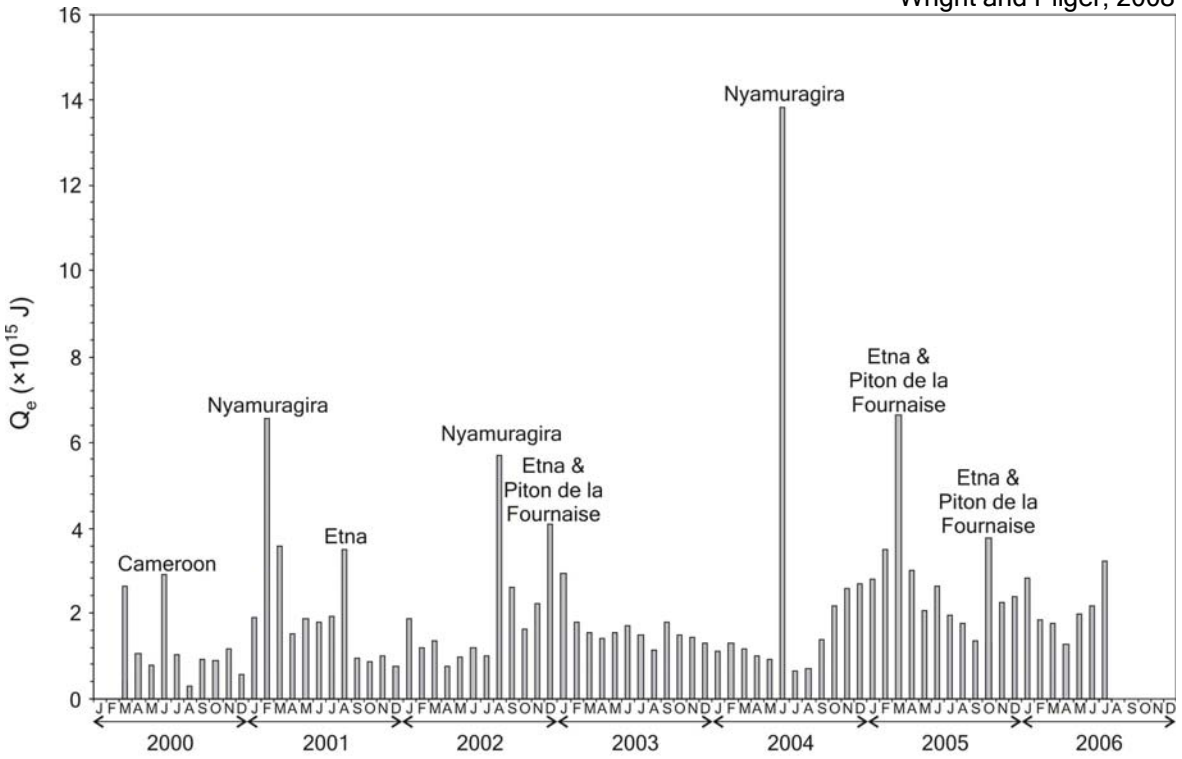


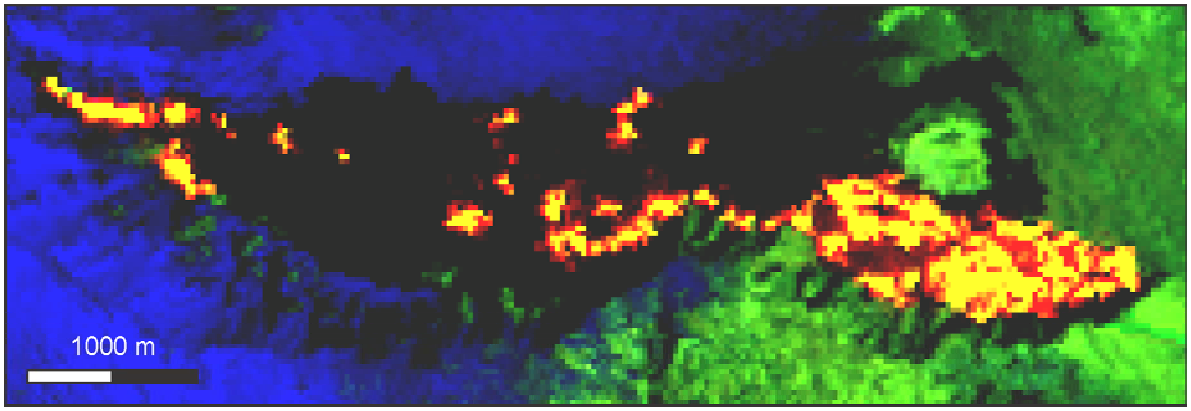


Aggregation of four most radiant pixels in simulated
30 m data set yields a maximum temperature of 1041 K at 60 m

Large lava-flow-forming eruptions are not uncommon

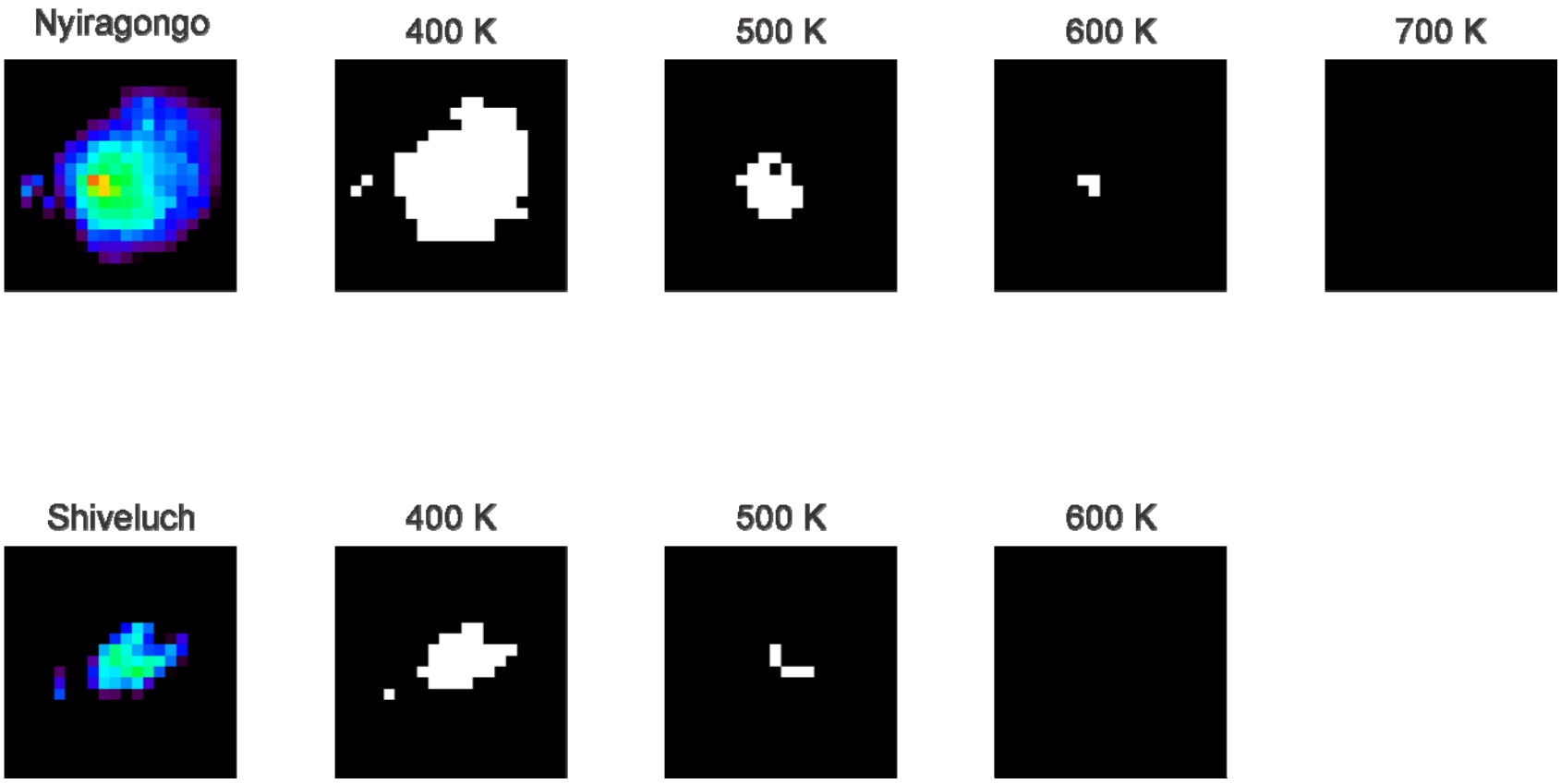
Wright and Pilger, 2008





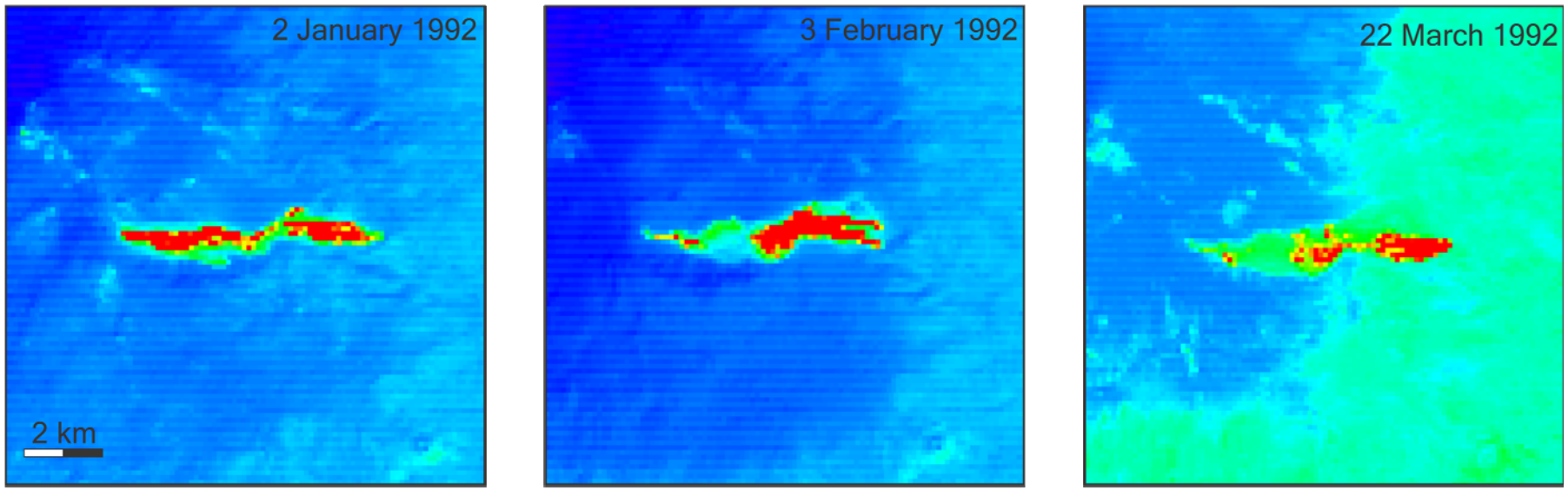
Mount Etna, 1991-1993 eruption

Lower predicted incidence of saturation over lava lakes and domes



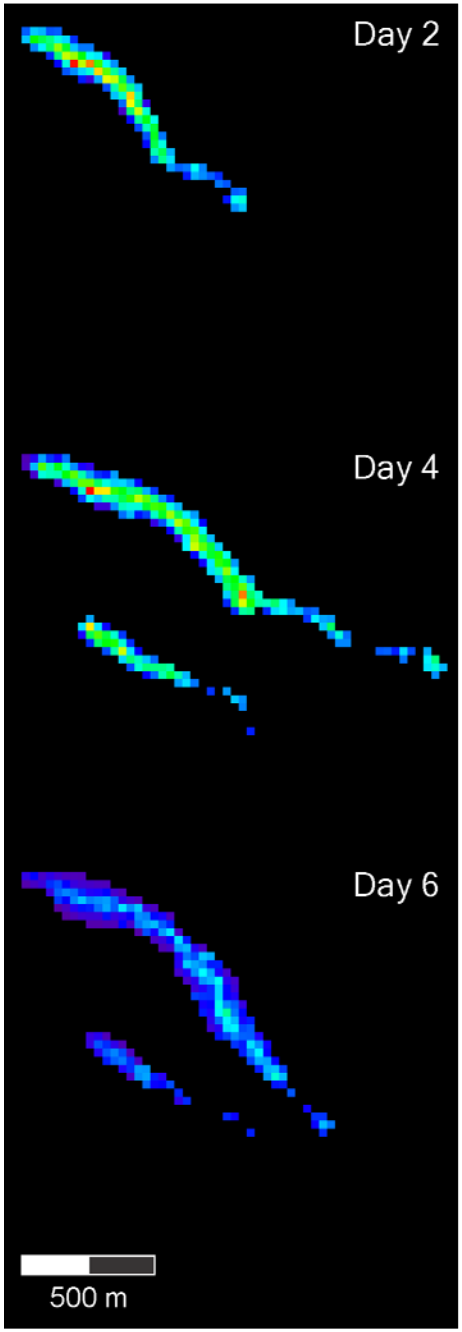
HyspIRI 11-14 μm data should prove useful for volcanologists

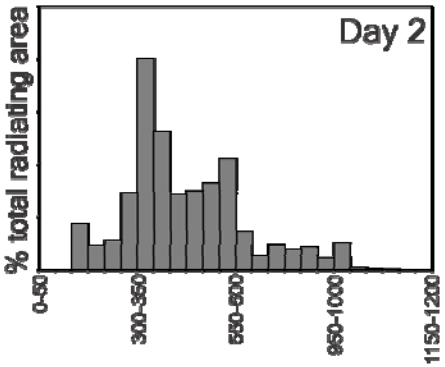
Mount Etna, Sicily

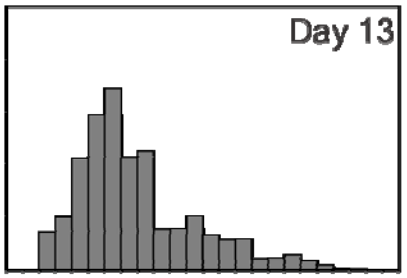


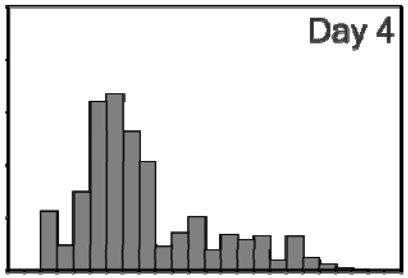
Red pixels are saturated in Landsat TM band 6, indicating a whole pixel temperature exceeding ~80 °C.

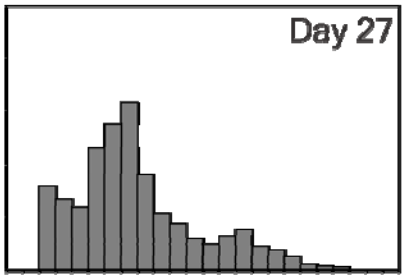
Temporal evolution of lava flow surface temperatures

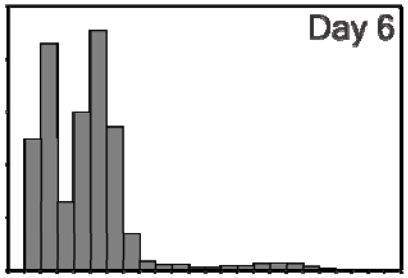


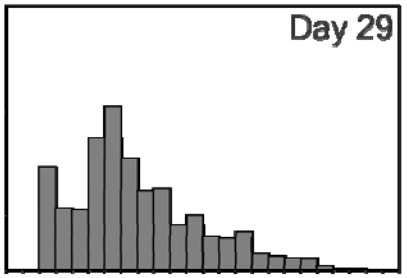


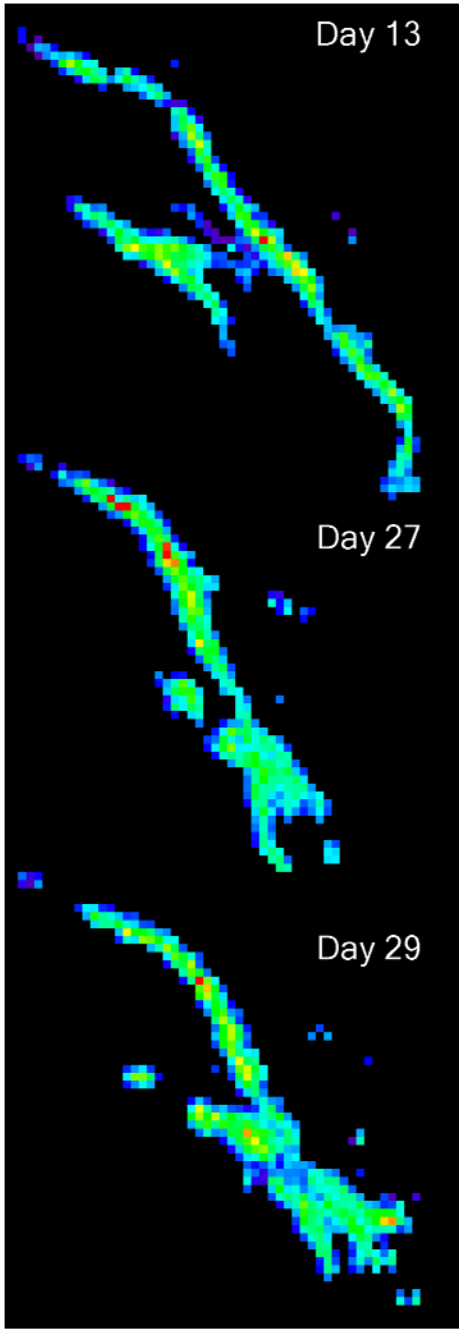




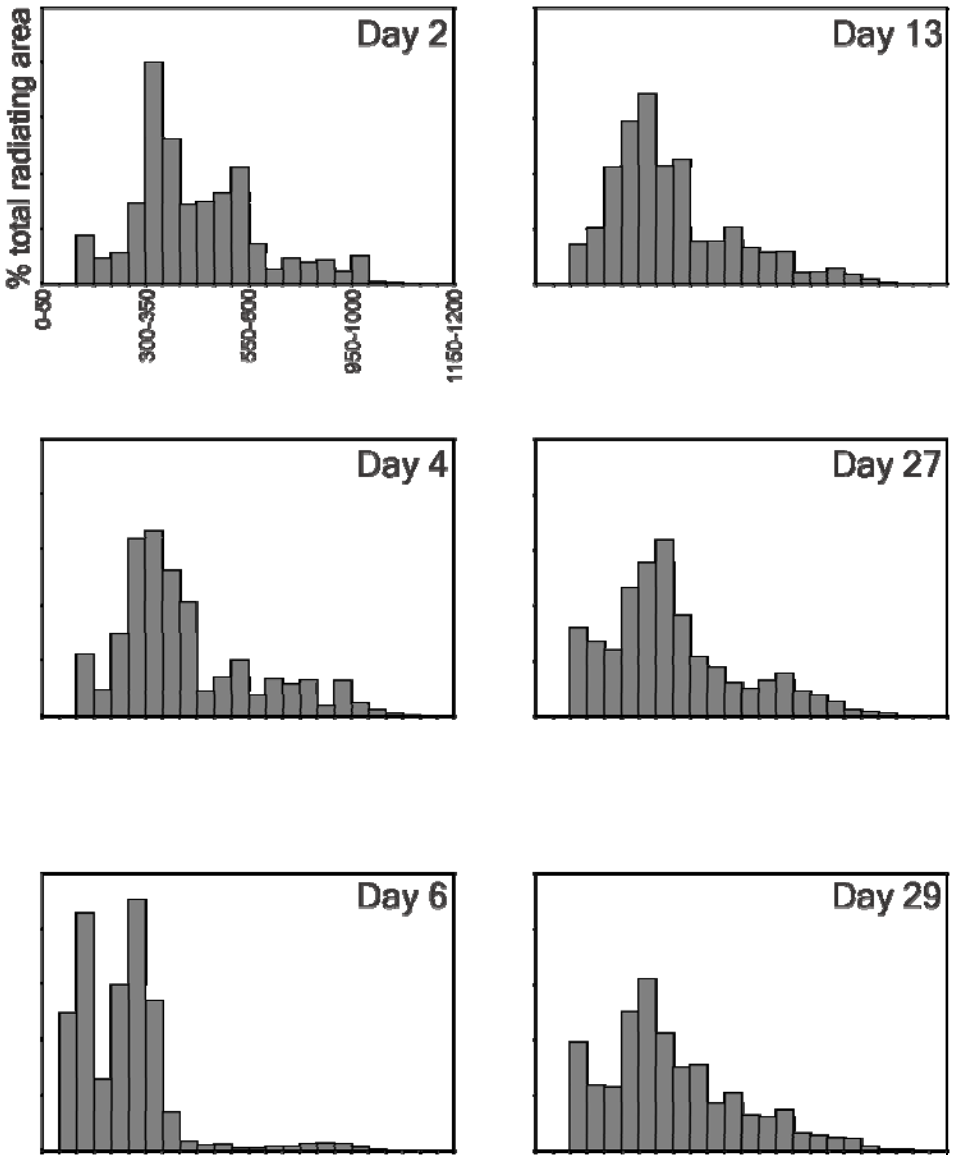


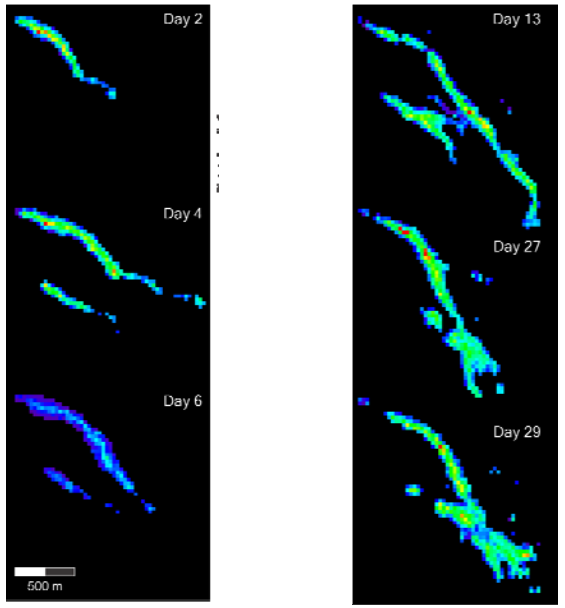


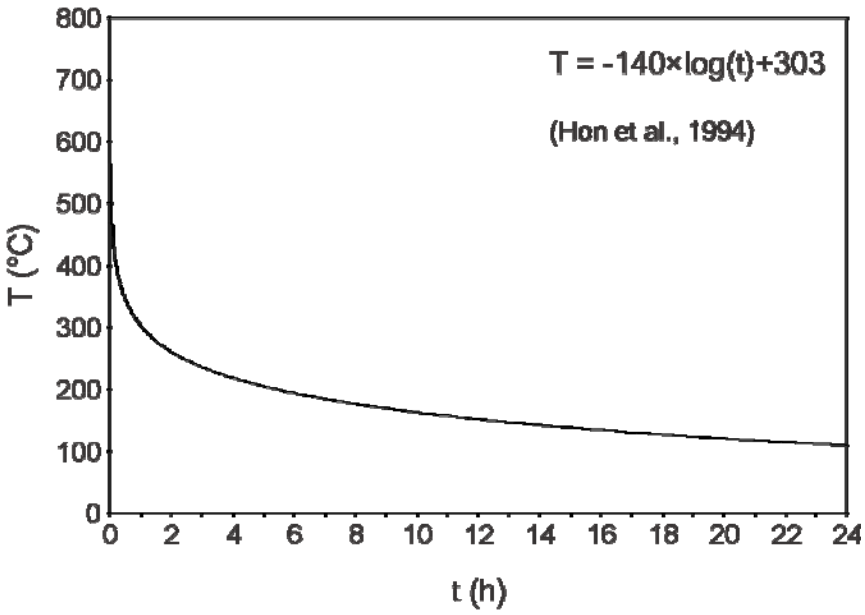




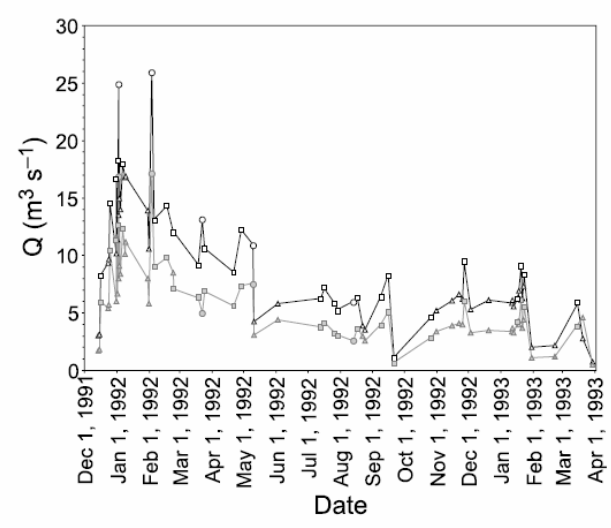
Lava temperature, age, and process that thermally renew active lava surfaces

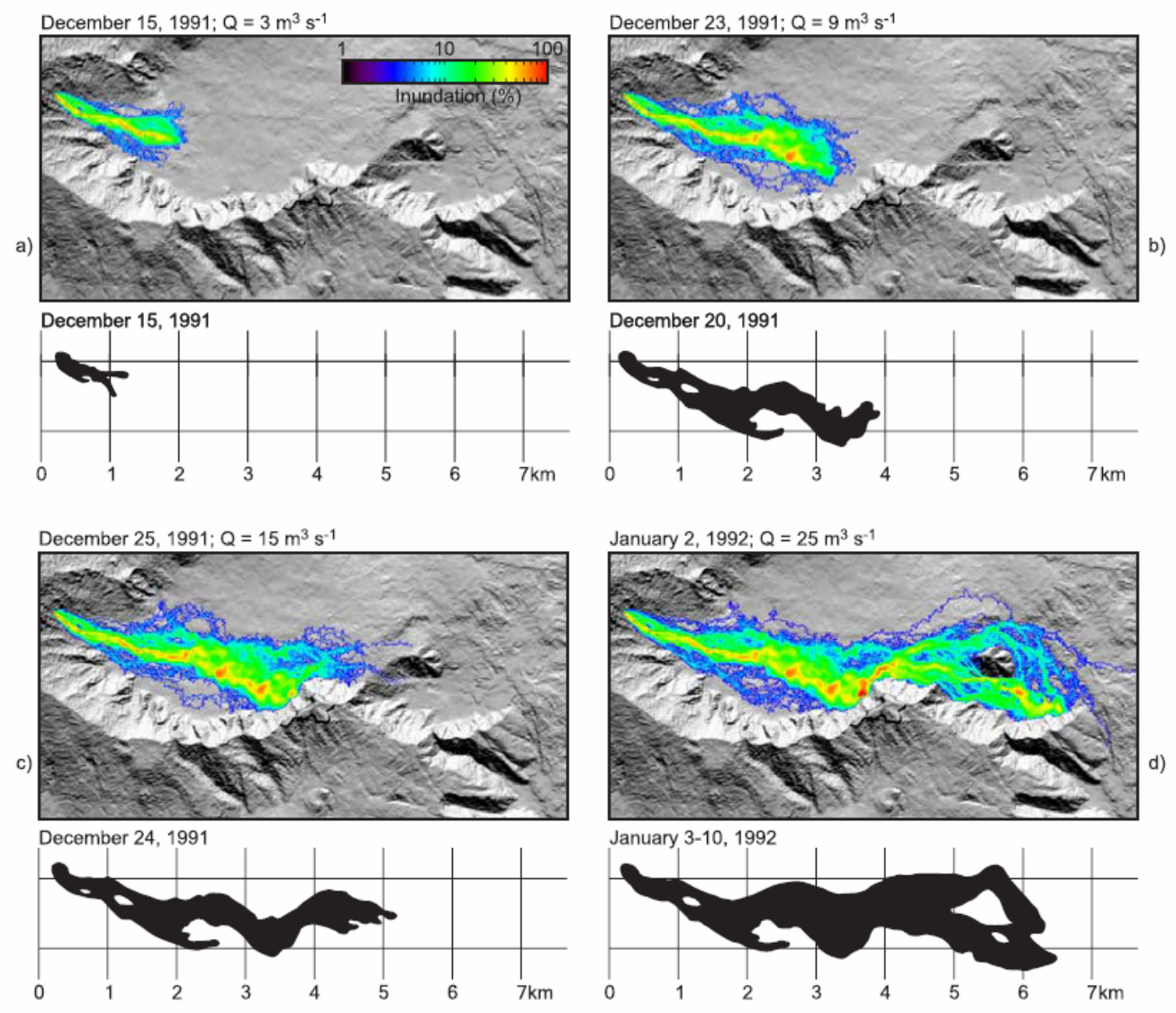






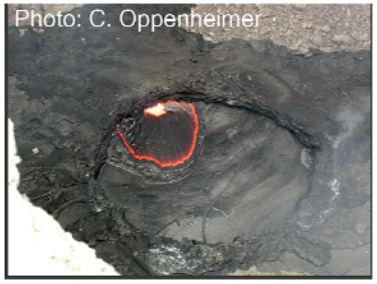
Driving numerical lava flow hazard predictions using satellite data

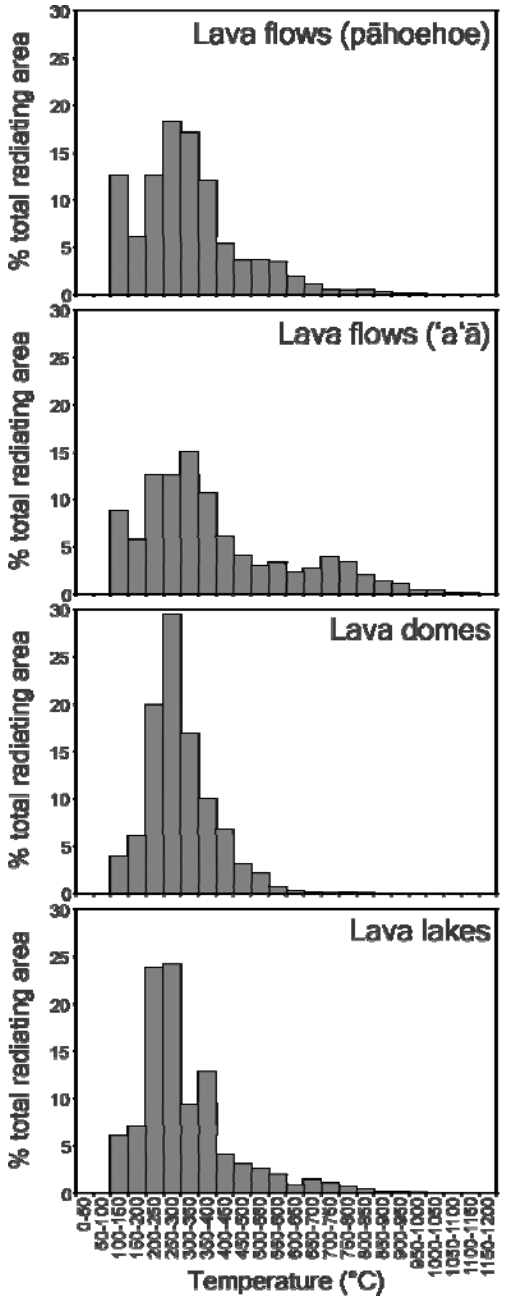


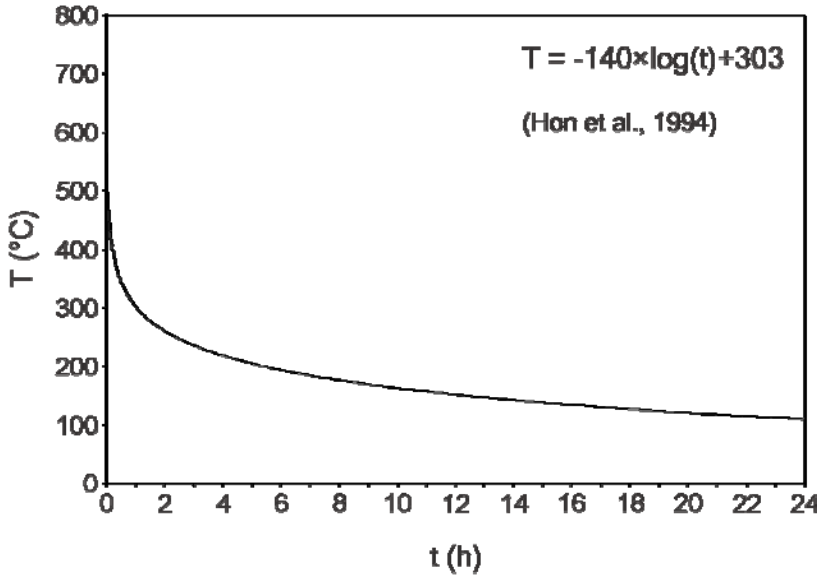


Wright et al., 2008

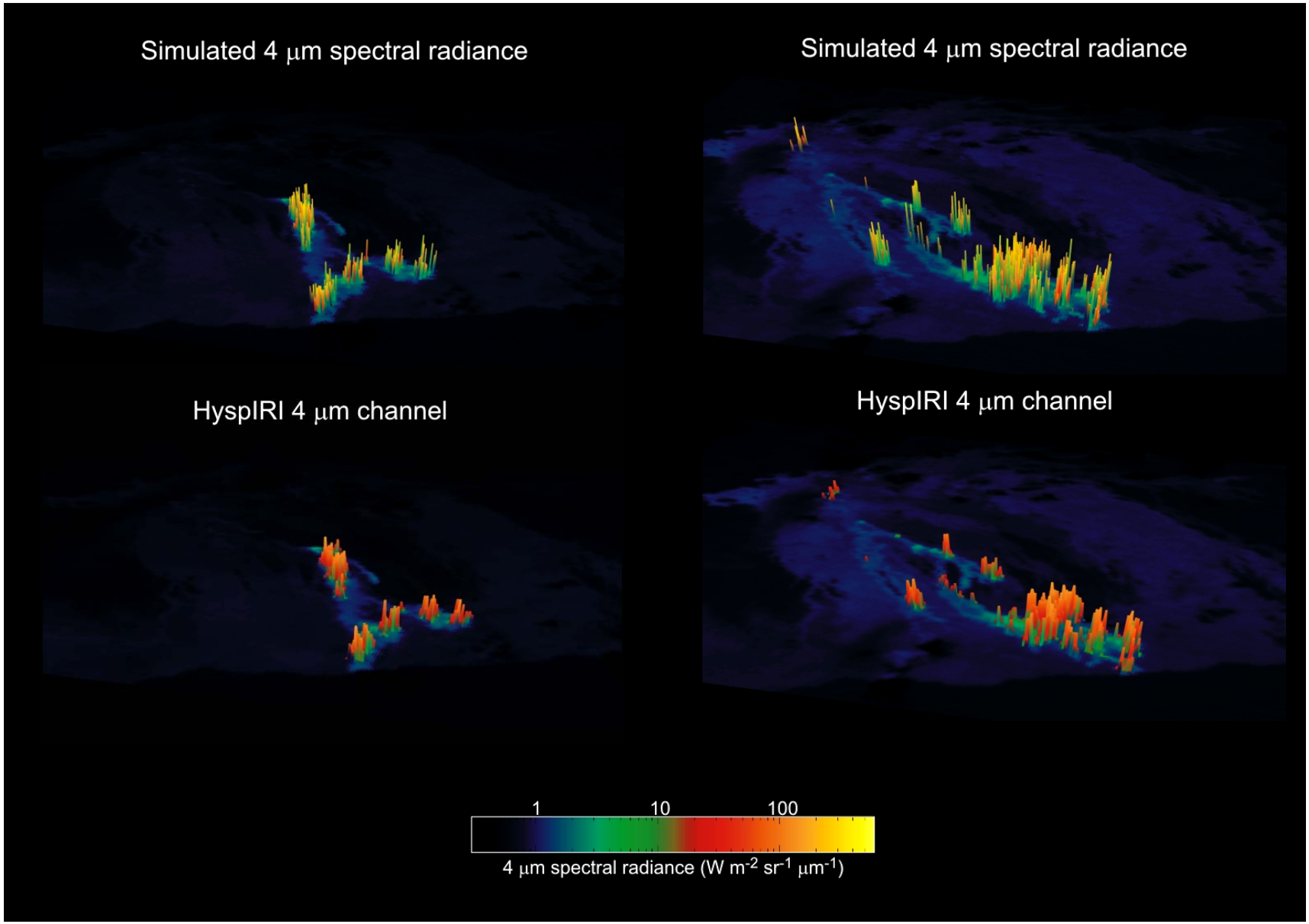
The temperature of Earth's volcanoes





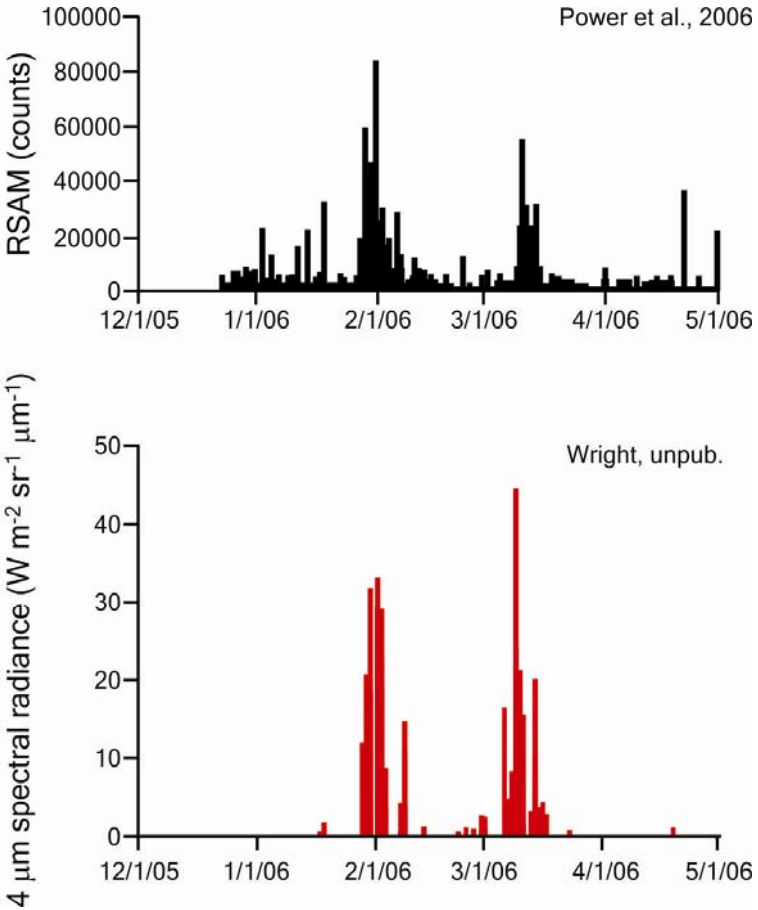


Simulating the performance of a detection algorithm

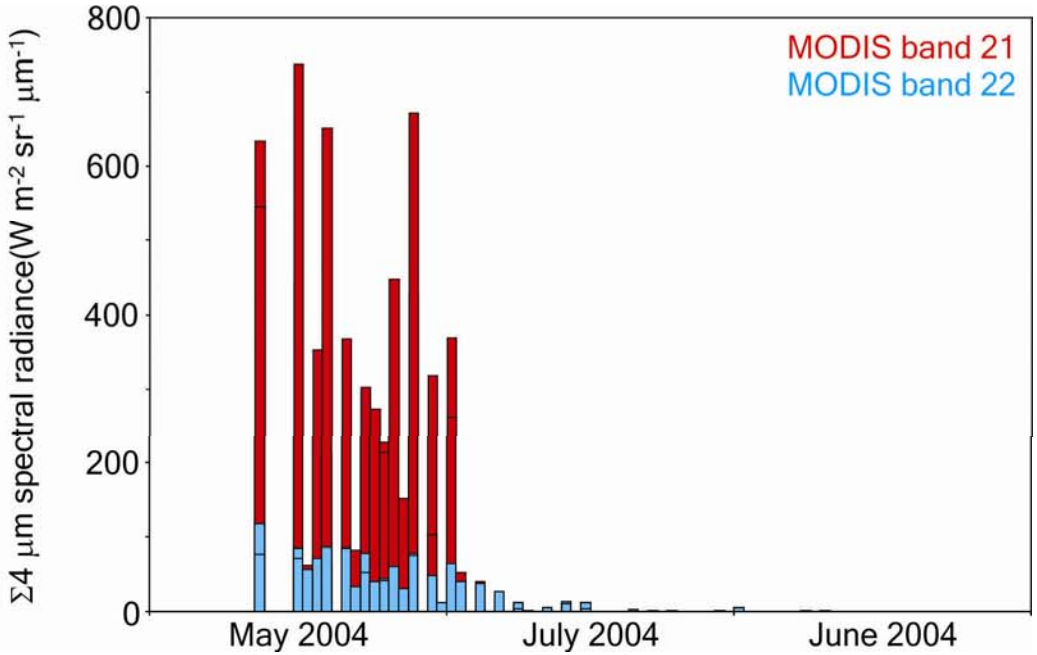


End

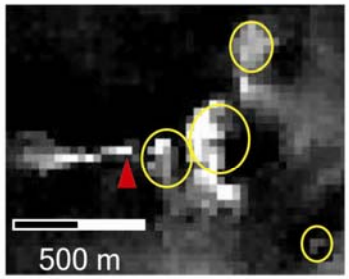
P. Izbekov (UAF/AVO)



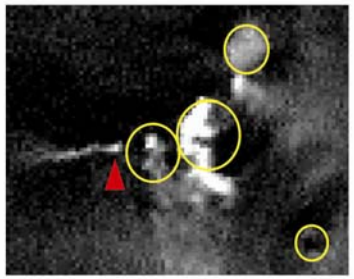
J. Durieux (©)


800
600
400
200
0
Σ4 μm spectral radiance(W m-2 sr-1 μm-1)
MODIS band 21
MODIS band 22
May 2004
July 2004
June 2004

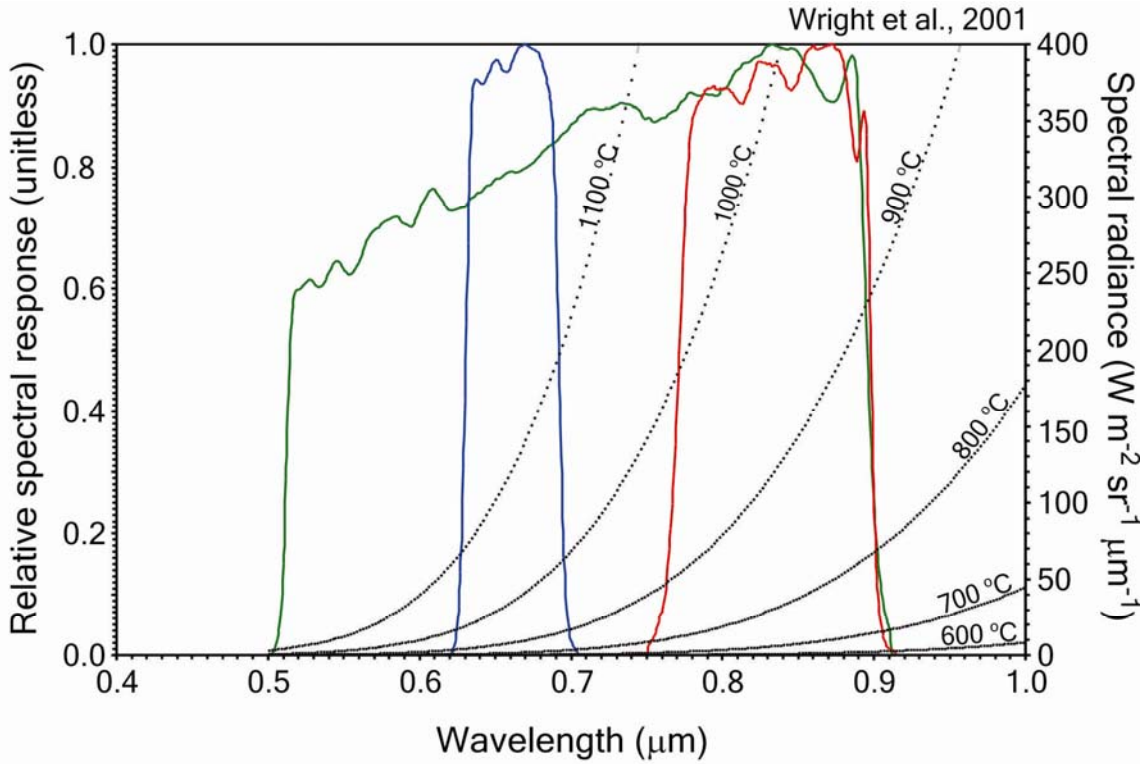
ETM+ 4



ETM+ 8

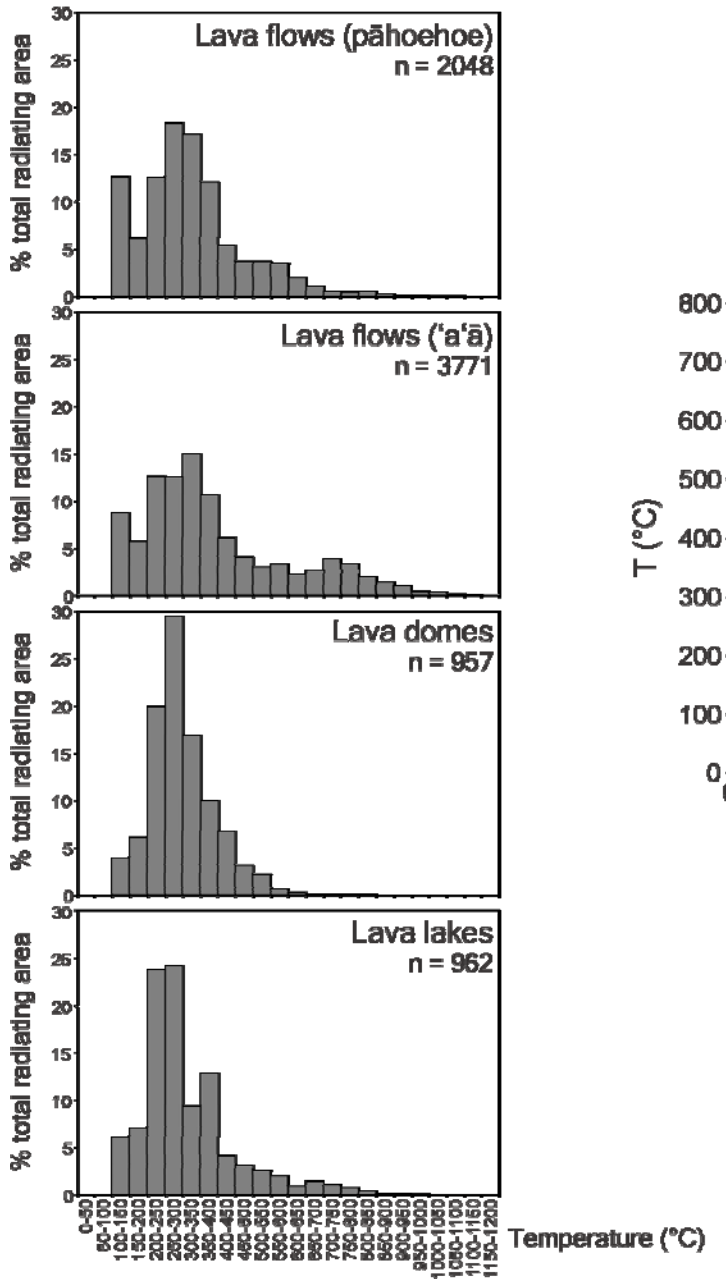


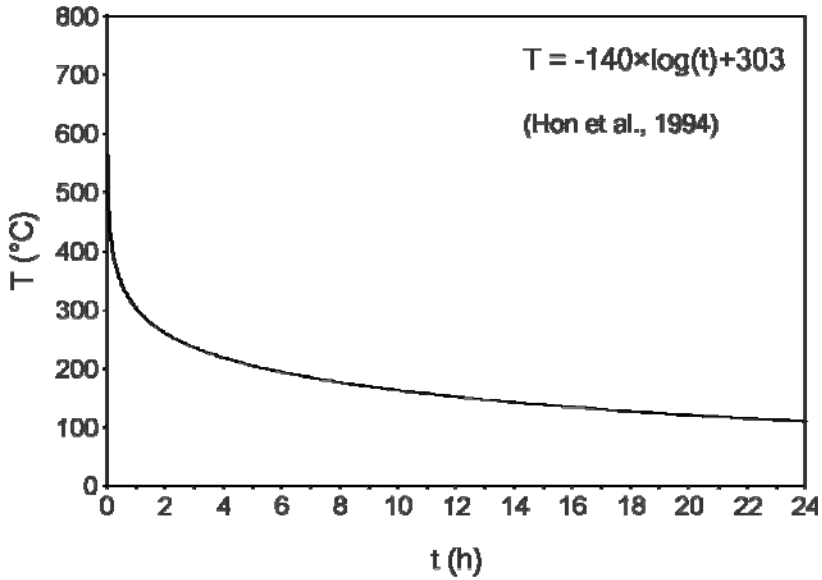
Mount Etna, 28 October 1999



ETM+ 4 = 35.7 W m^{-2} sr^{-1} μm^{-1} = 819 °C
ETM+ 8 = 28.3 W m^{-2} sr^{-1} μm^{-1} = 922 °C

A difference in whole pixel temperature of 100 °C


Lava flows (pāhoehoe)
n = 2048
Lava flows (ʻaʻā)
n = 3771
Lava domes
n = 957
Lava lakes
n = 962
% total radiating area
0
5
10
15
20
25
30
0-50
50-100
100-150
150-200
200-250
250-300
300-350
350-400
400-450
450-500
500-550
550-600
600-650
650-700
700-750
750-800
800-850
850-900
900-950
950-1000
1000-1050
1050-1100
1100-1150
1150-1200
Temperature (°C)


T = -140×log(t)+303
(Hon et al., 1994)
T (°C)
0
100
200
300
400
500
600
700
800
0
2
4
6
8
10
12
14
16
18
20
22
24
t (h)