Quantifying global volcanic unrest with HyspIRI: near-real-time algorithms and products

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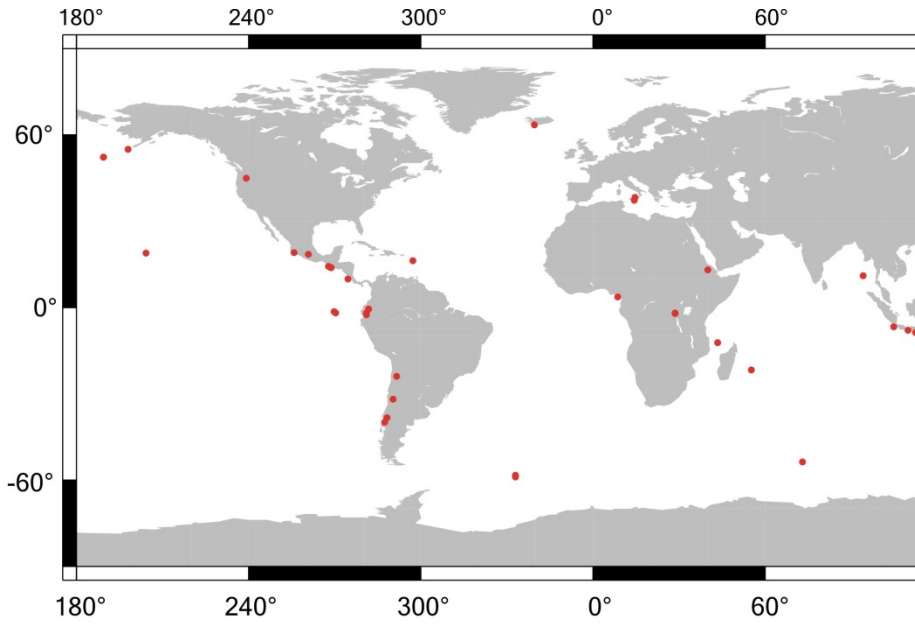
MĀNOA

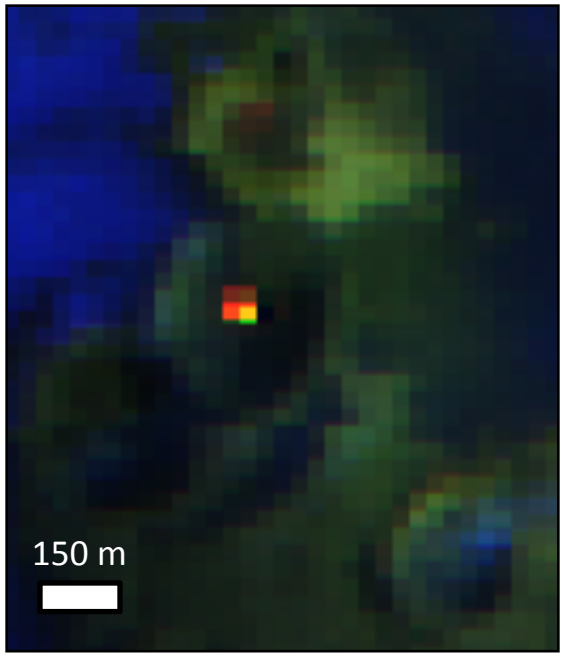
What are we trying to detect, quantify, and monitor?

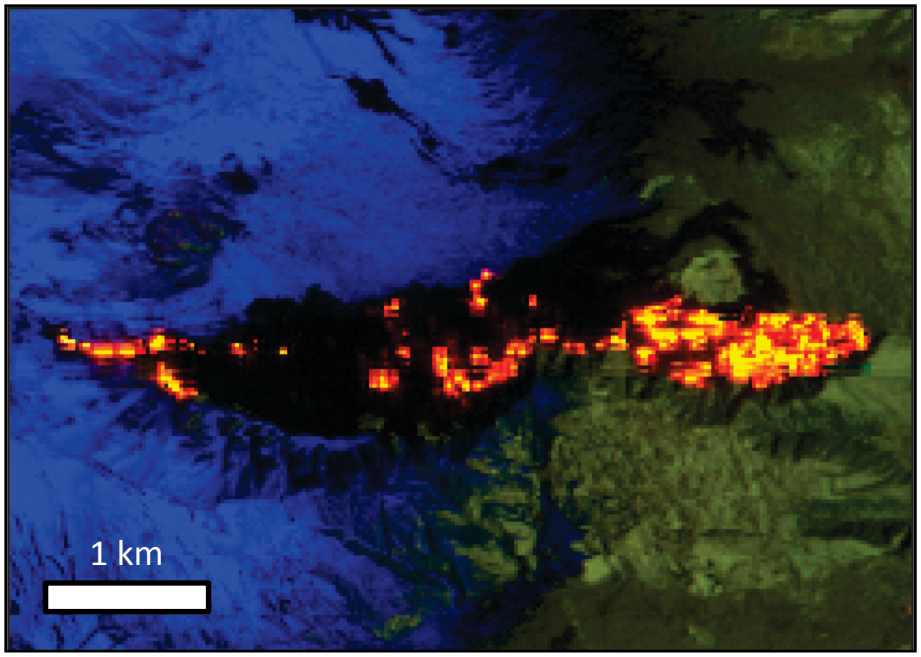
-1500 potentially active volcanoes distributed around the globe

- Can display high temperature (1100 ^{o}C) and/or low temperature (<100 ^{o}C) manifestations of unrest



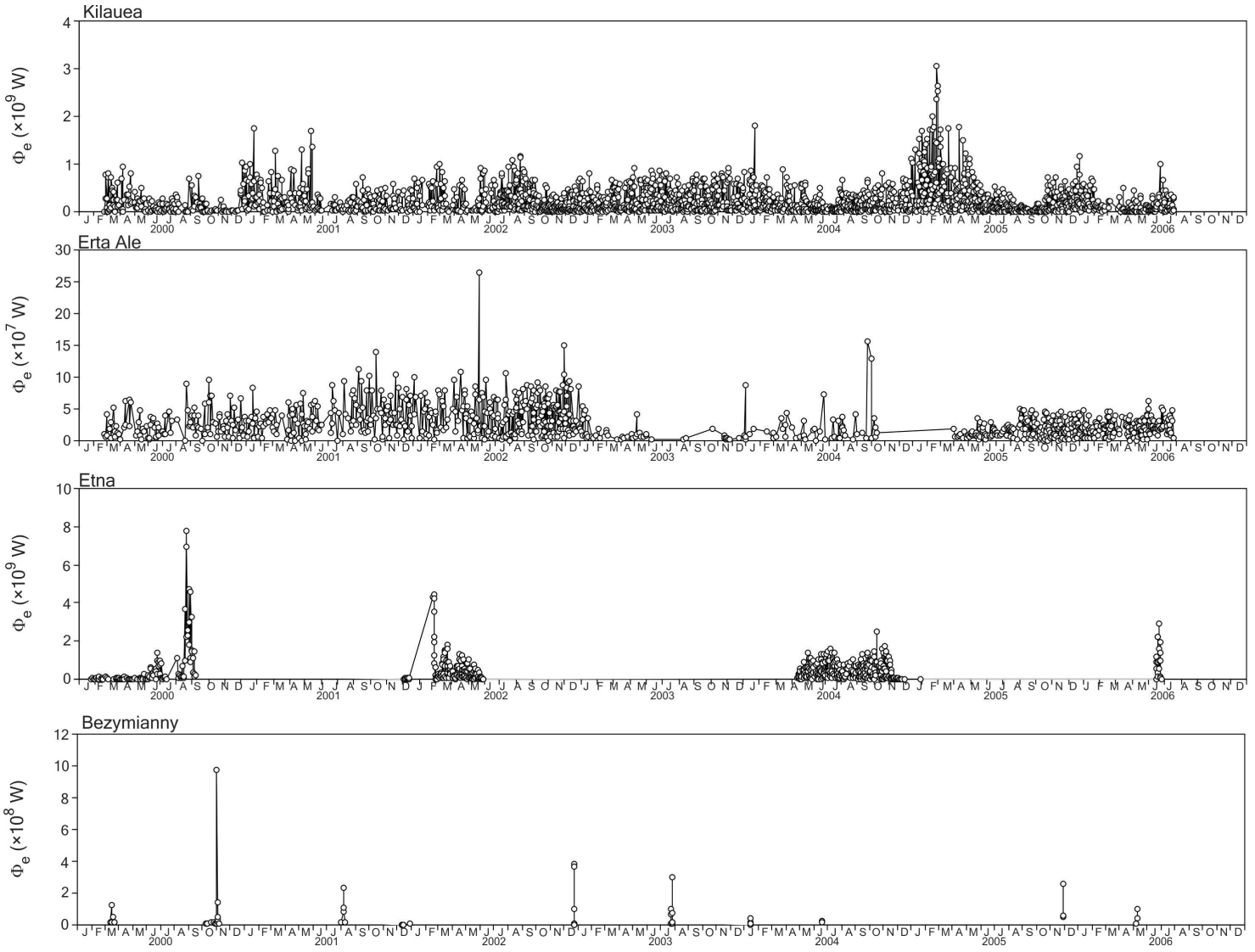
What are we trying to detect, quantify and monitor?





Volcanic activity can be on small spatial scales (decameter) or large (kilometer)

What are we trying to detect, quantify and monitor?

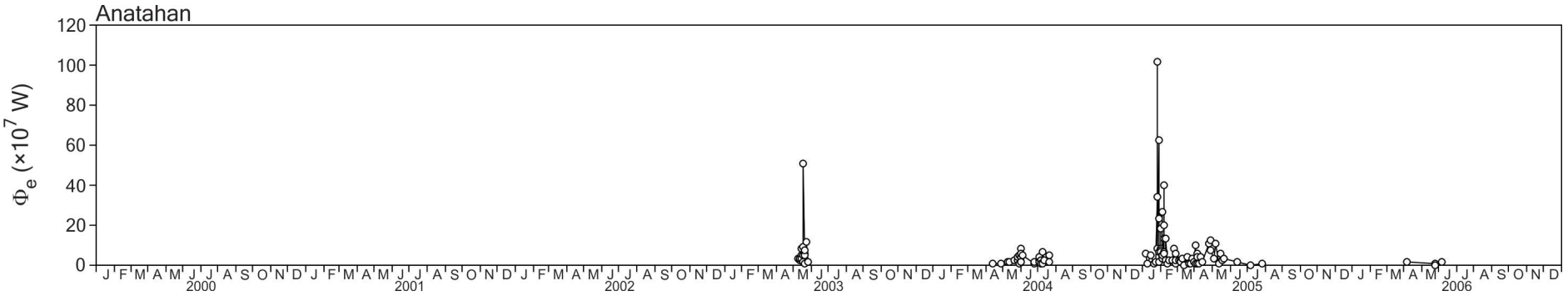


Volcanic activity can be episodic or persistent

What are we trying to detect, quantify and monitor?

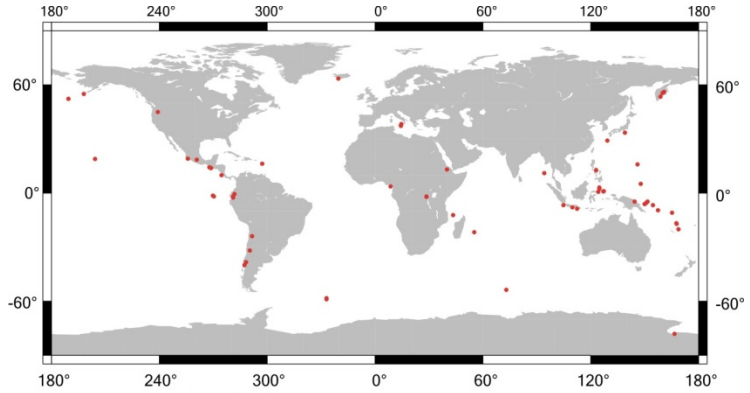
Eruptions can take us by surprise

Photo: T. Fischer (Univ. New Mexico)

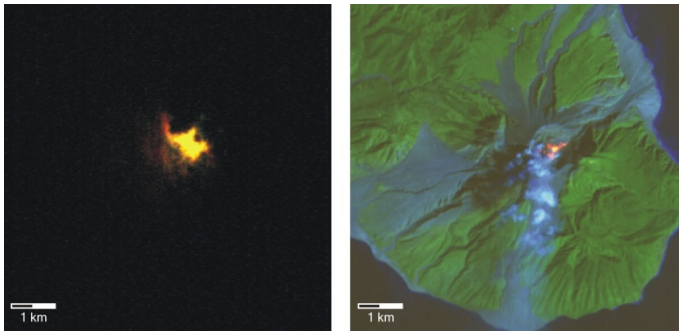


Resulting requirements for a monitoring algorithm

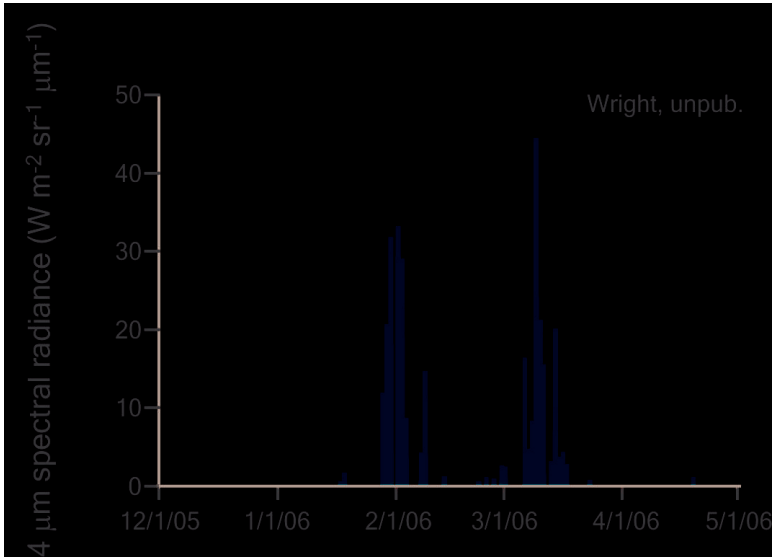
Global mapping mission



Night and day



Timely delivery of information to users (direct broadcast; on-board

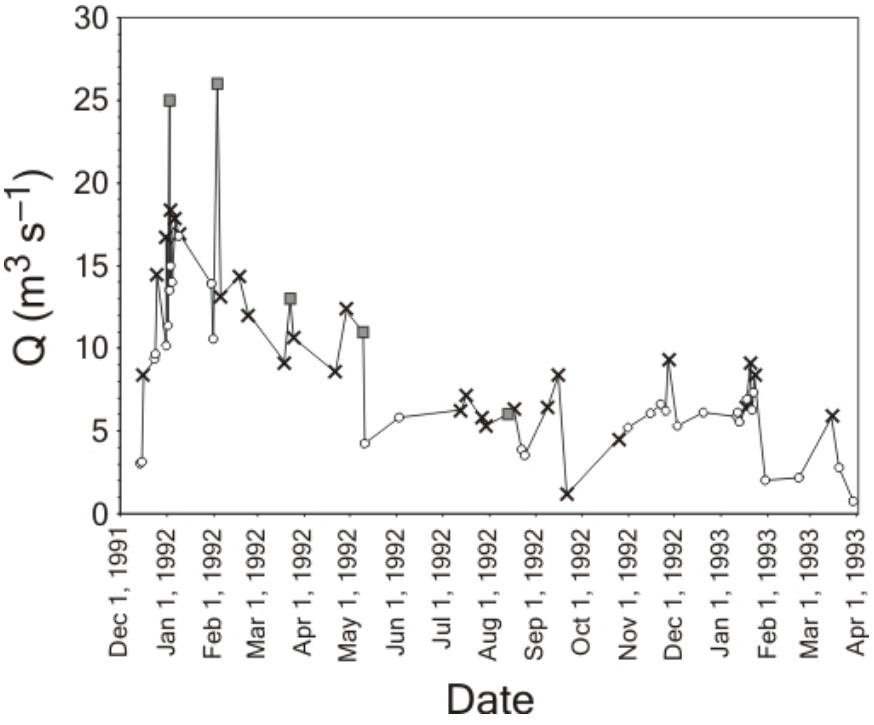


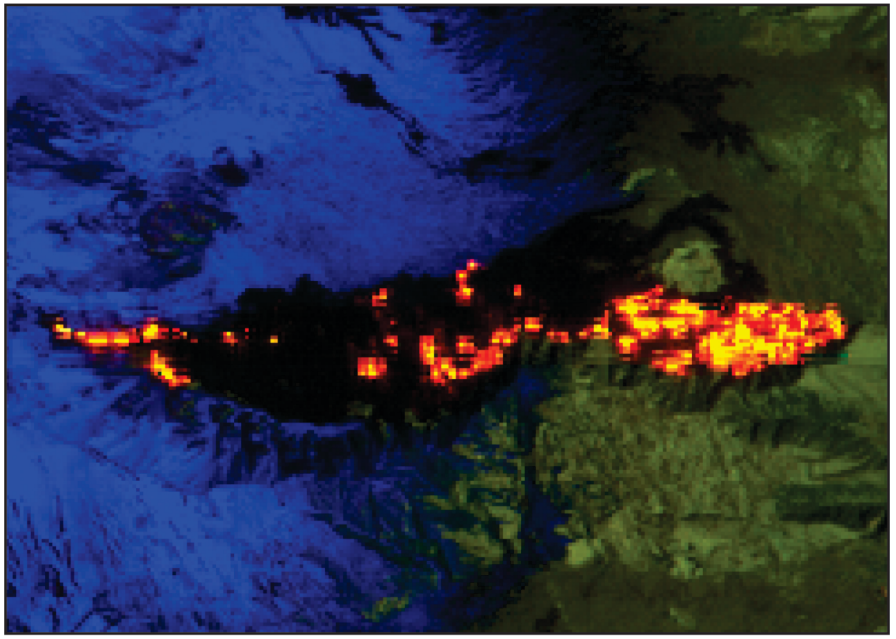
Results/data delivered in a useable (and useful) format

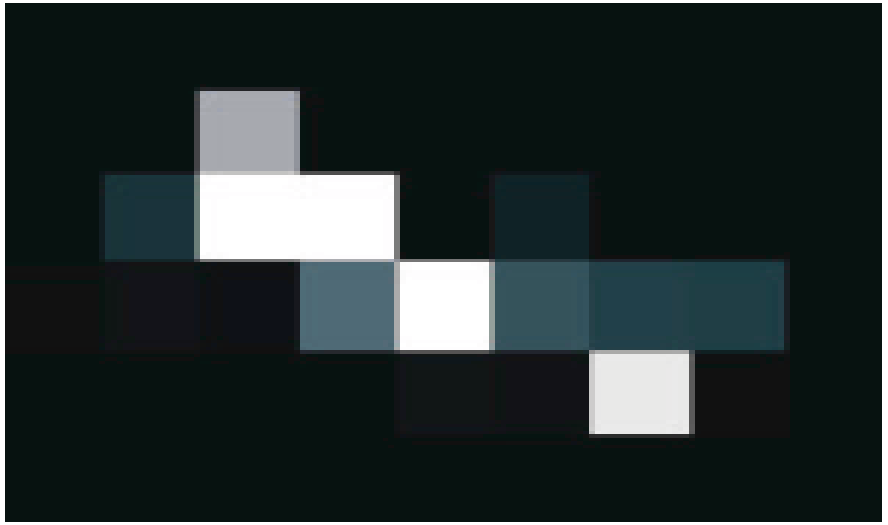
Unix time	Satellite	Longitude	Latitude	W m^{-2} sr^{-1} μm^{-1}				
				L_{21}	L_{22}	L_6	L_{31}	L_{32}
1089853500	A	159.424927	54.047855	0.775	0.802	177.015	7.087	6.790
1089838800	T	159.439728	54.049419	2.228	-10.000	166.546	8.392	7.967
1089853500	A	159.448288	54.052444	1.440	1.453	177.015	7.786	7.453
1089853500	A	159.453903	54.045853	1.218	1.235	177.015	7.558	7.156

The past

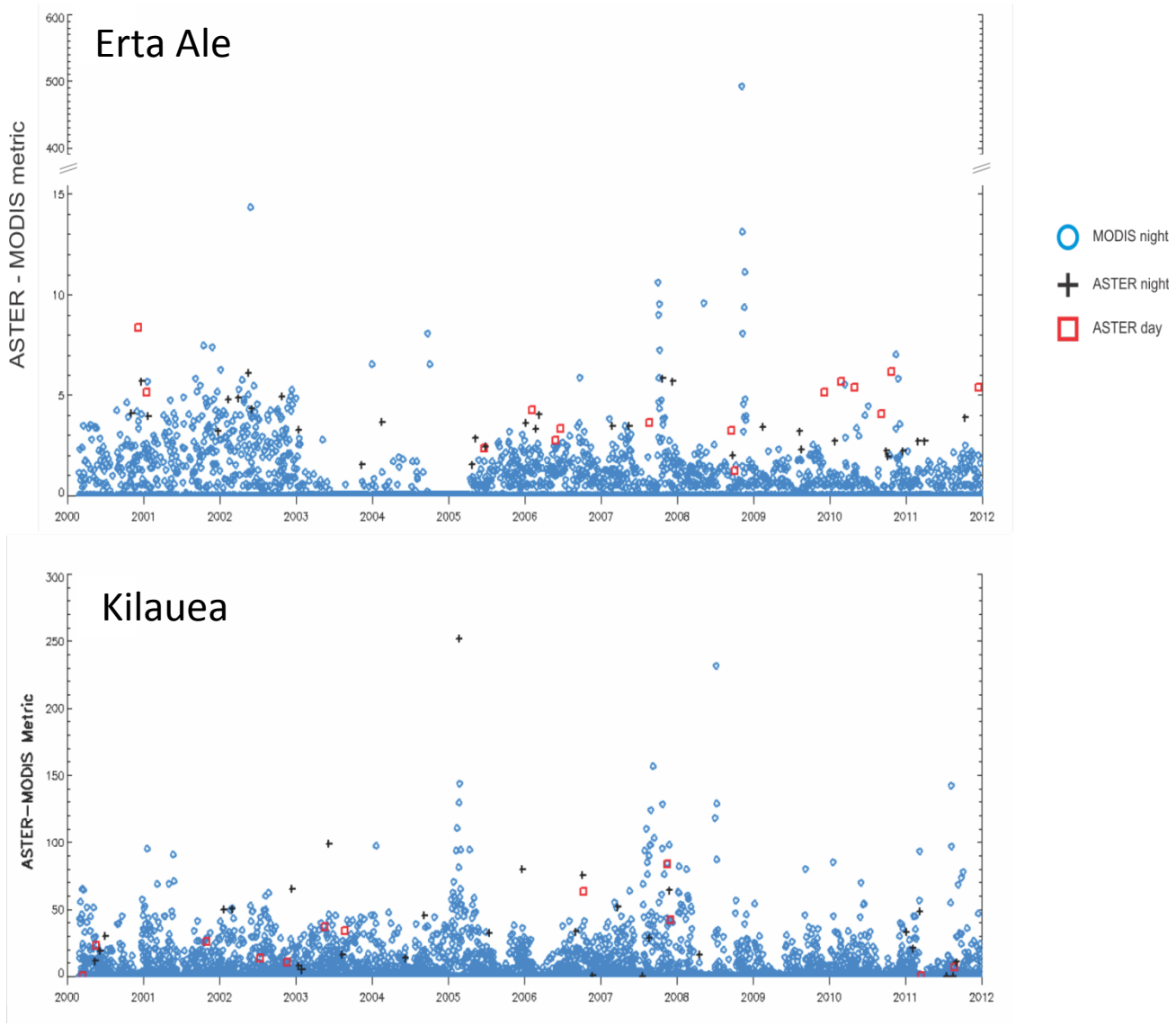
Reliant on low spatial resolution data because of its high temporal resolution





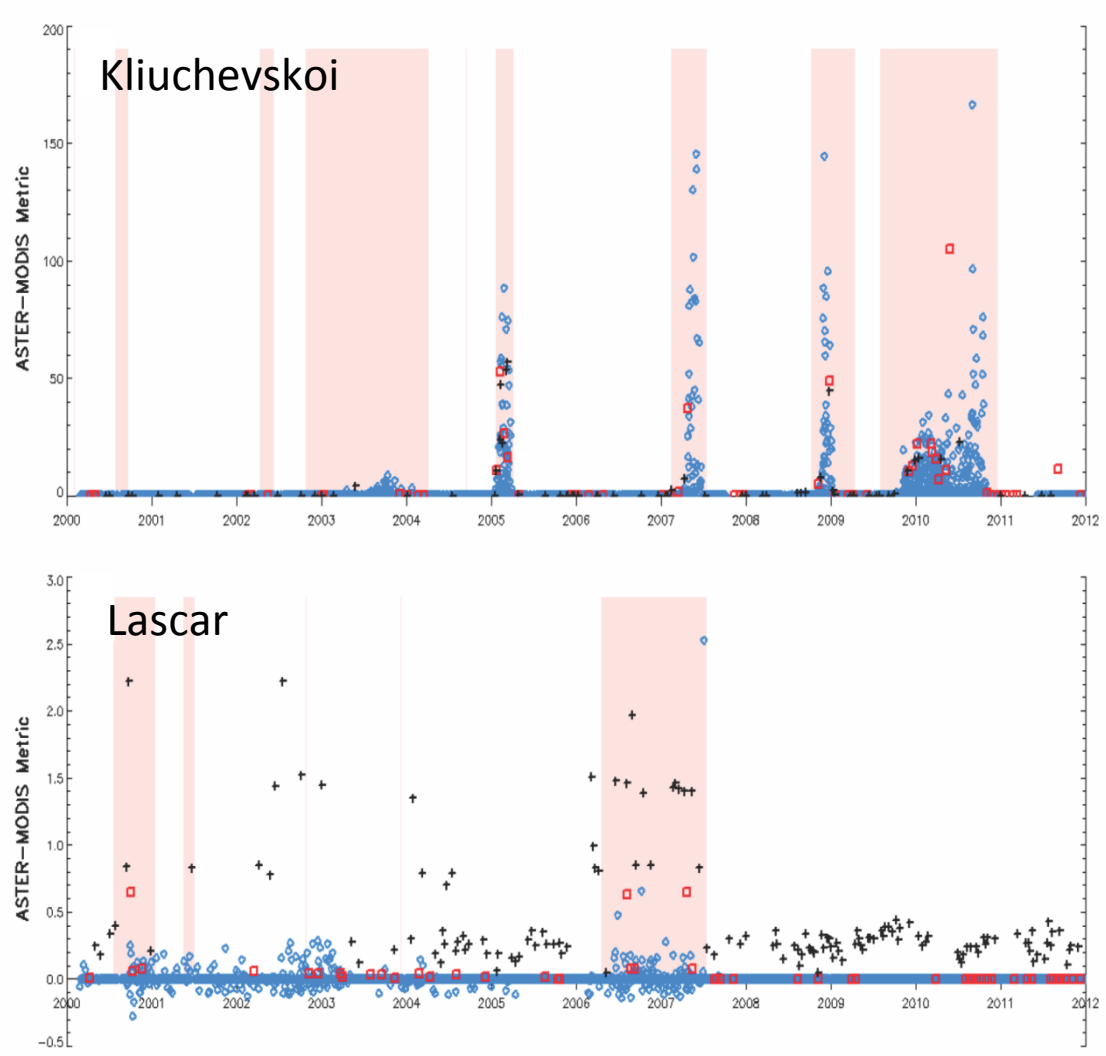


HyspIRI fills the gap between MODIS and LDCM/ASTER



Hulme, Wright, Oppenheimer & De Souza (in review)

HyspIRI fills the gap between MODIS and LDCM/ASTER



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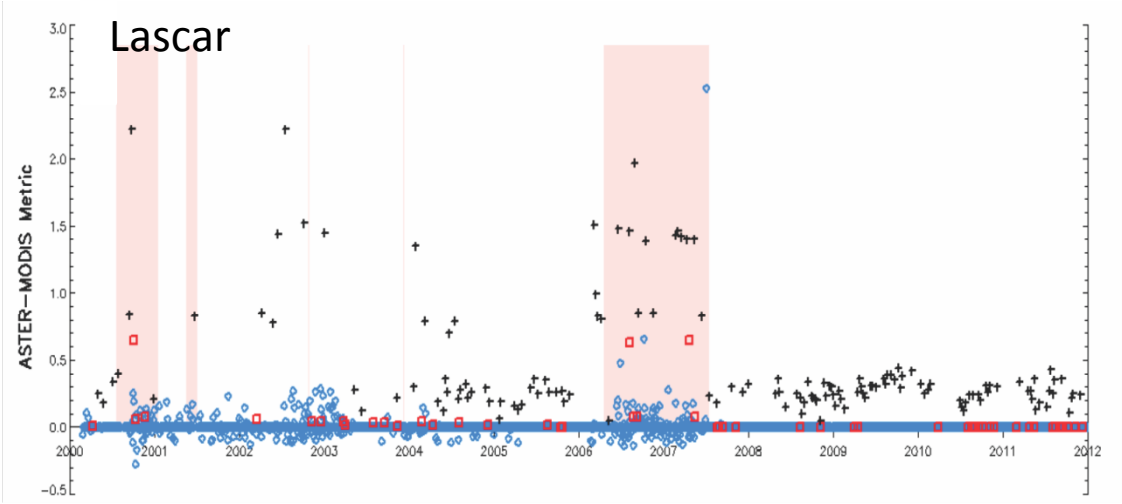
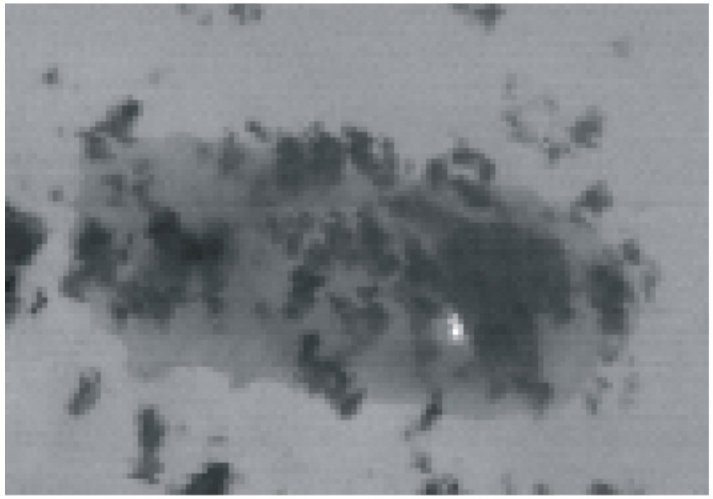
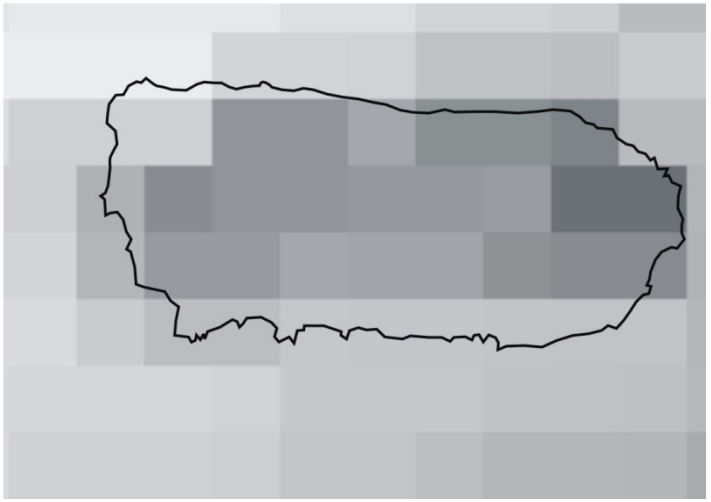


Anatahan

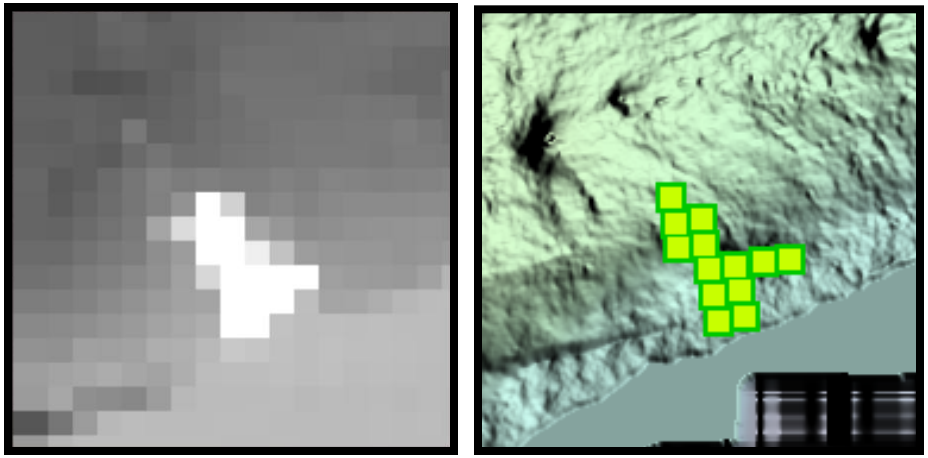


ASTER



MODIS

Potential HyspIRI hot-spot detection algorithms



1. Class of algorithm
2. "Plug and play" with the HyspIRI data stream?
3. Computational complexity

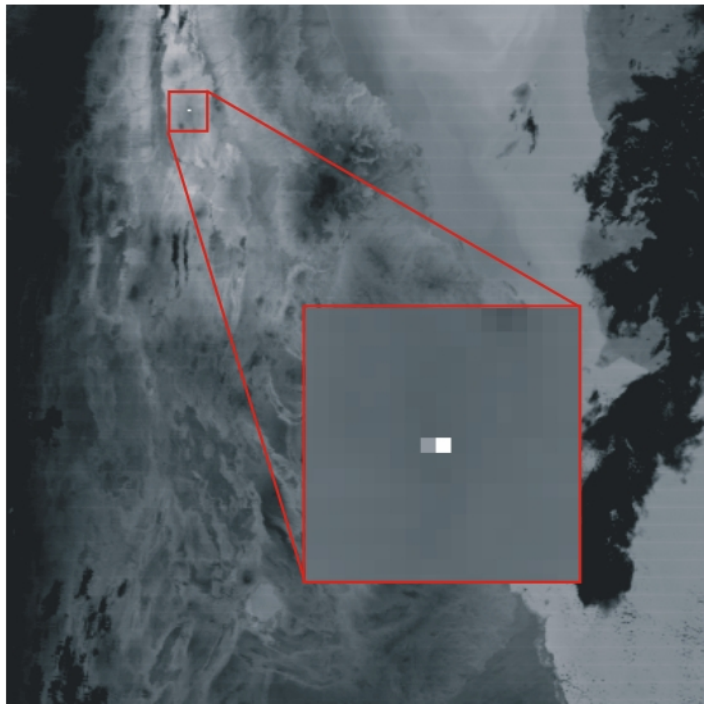
The basis of existing, low resolution algorithms

300 K, 100%

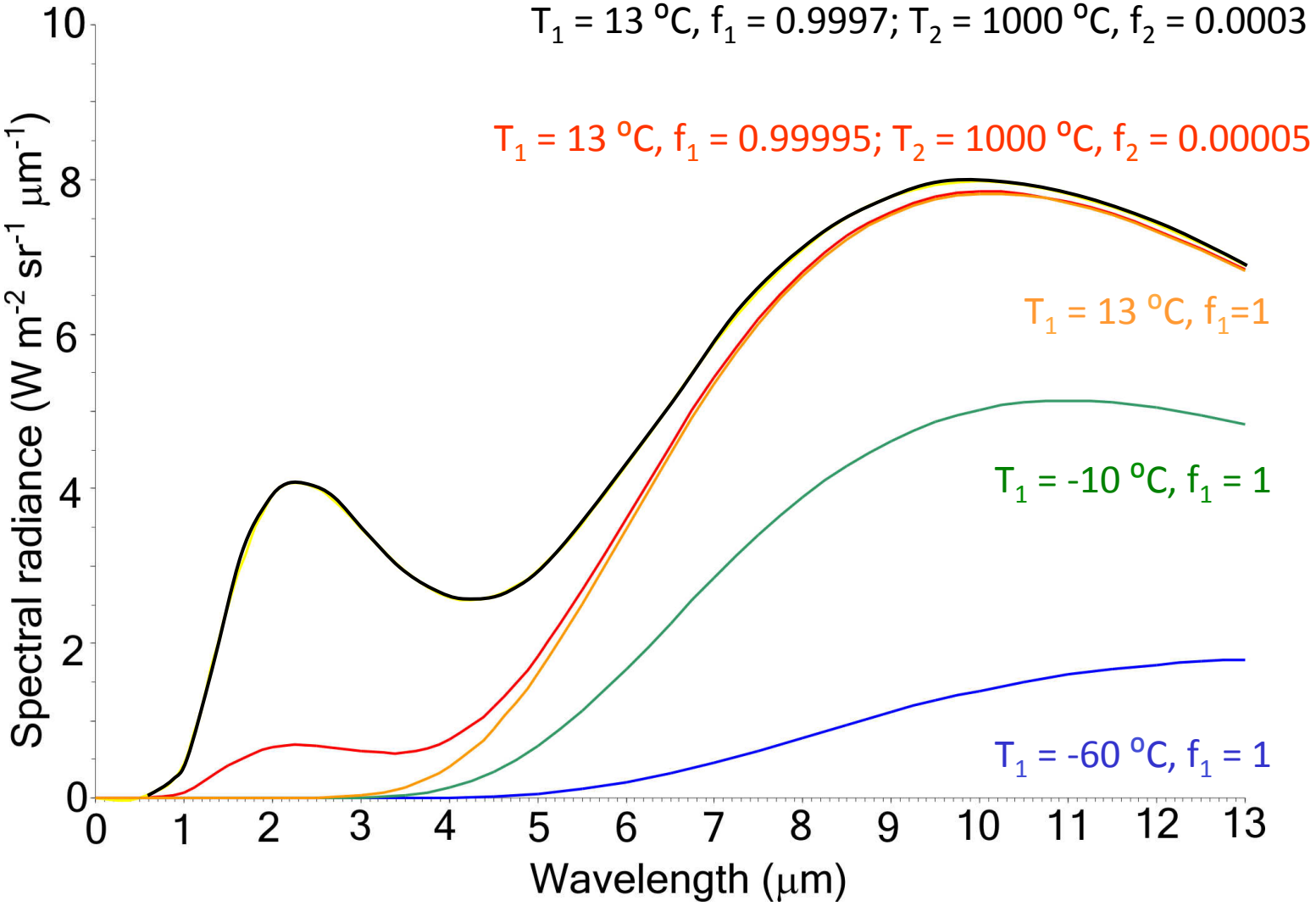
At 11 μm, L_λ = 9.5 W m^{-2} sr^{-1} μm^{-1}
At 4 μm, L_λ = 0.4 W m^{-2} sr^{-1} μm^{-1}

300 K, 99.5%
850 K, 0.05%

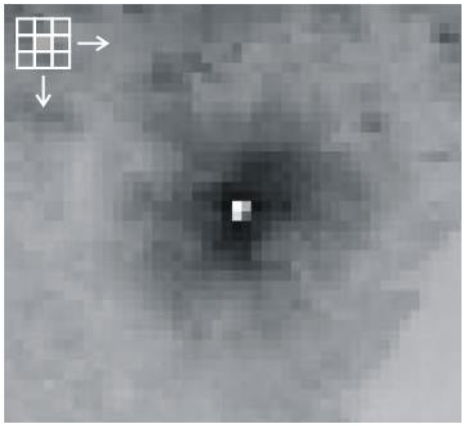
At 11 μm, L_λ = 9.6 W m^{-2} sr^{-1} μm^{-1}
At 4 μm, L_λ = 1.3 W m^{-2} sr^{-1} μm^{-1}

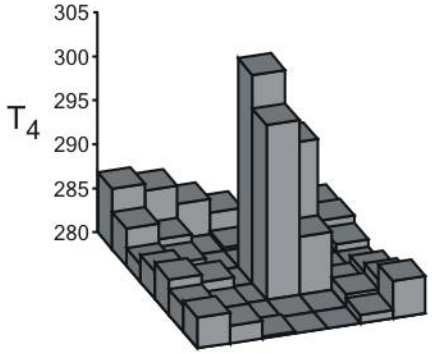


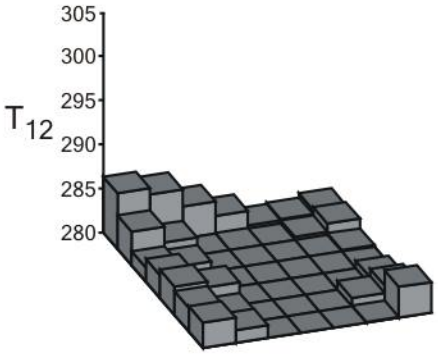
The basis of existing, low resolution algorithms

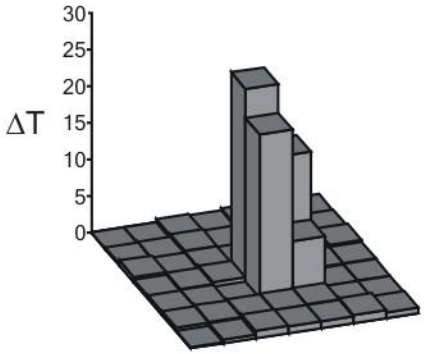


Spectral-contextual hot-spot detection algorithm

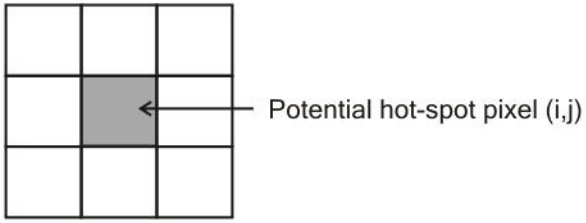




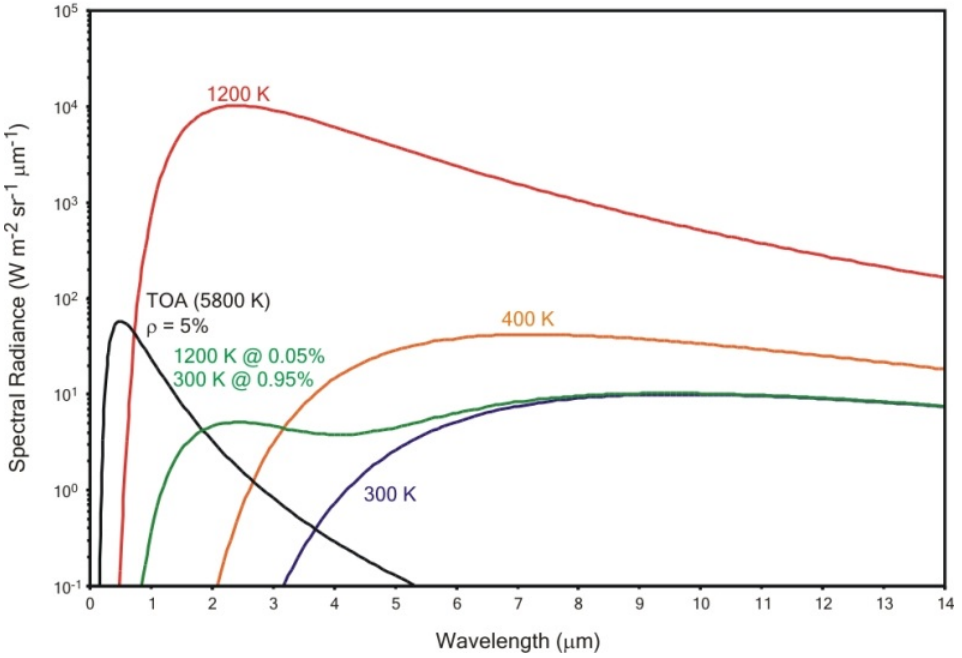




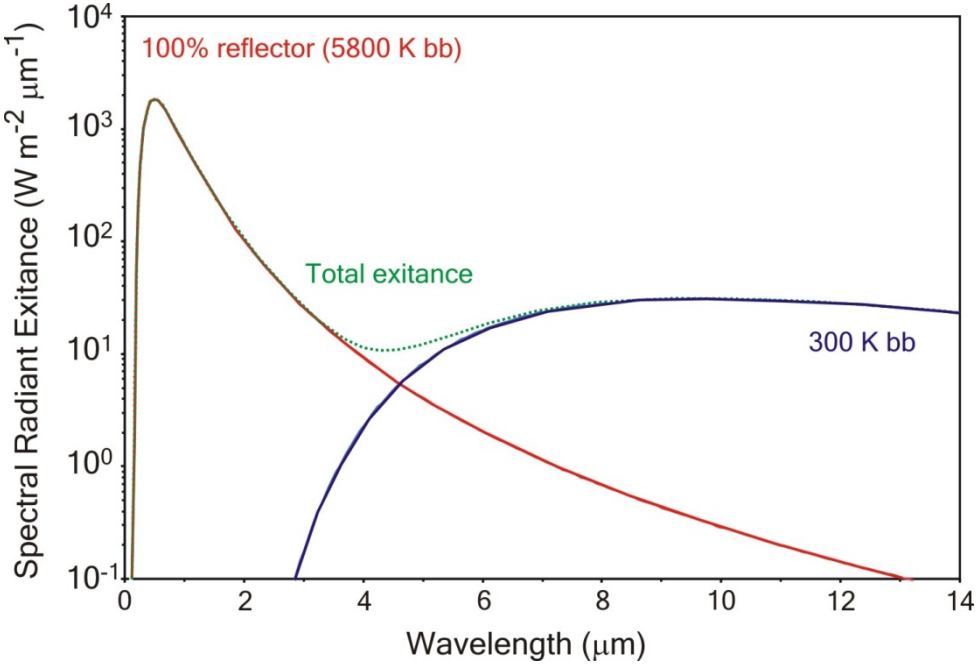
e.g. MODIS Fire Product



How does ΔT still work when the hot-spots are no longer sub-pixel-sized?

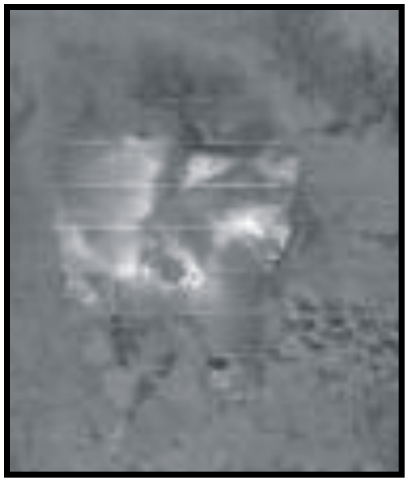


Dealing with daytime 4 μm data



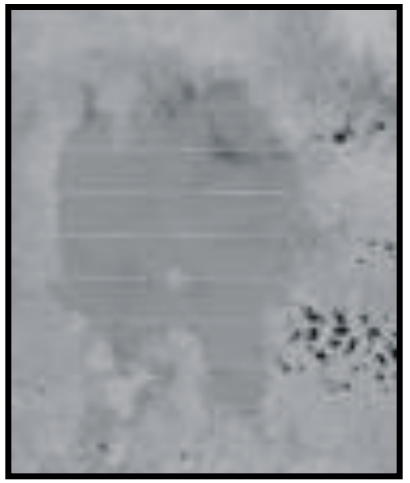
How to estimate excess radiance in the presence of reflected sunlight, while just using the HyspIRI TIR subsystem?

'Raw' 4 μm daytime data

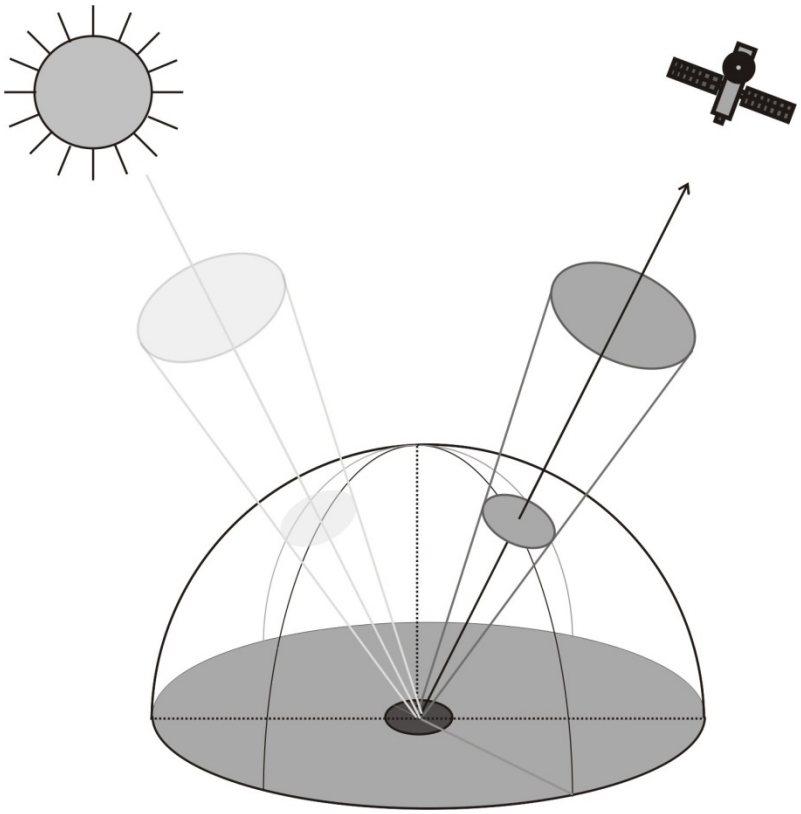


$$L_{4corr} = L_4 - 0.0426 \times L_{1.6}$$

Corrected 4 μm daytime data

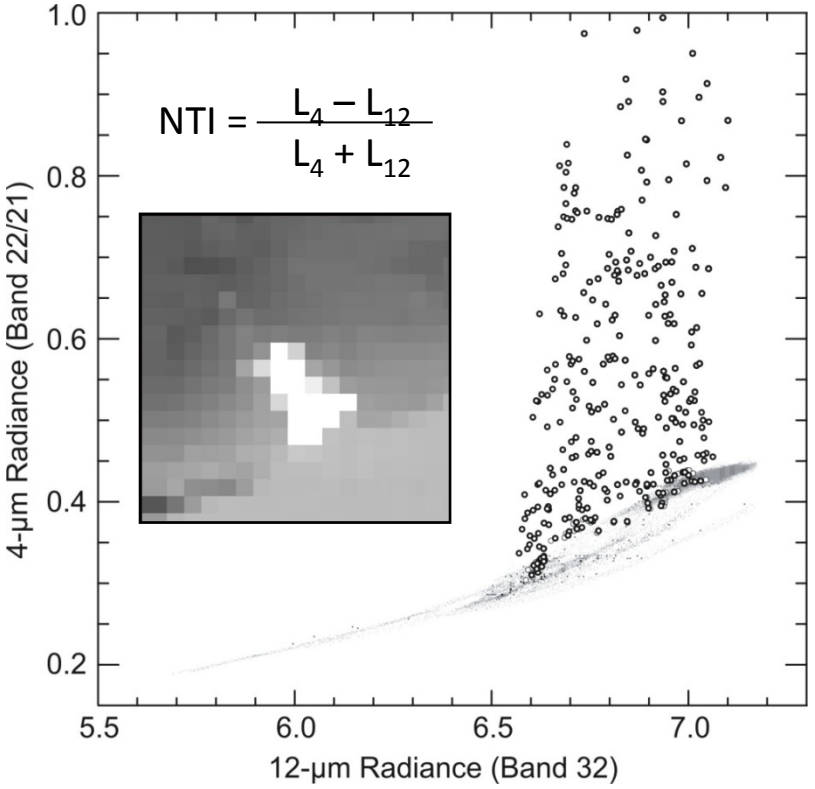


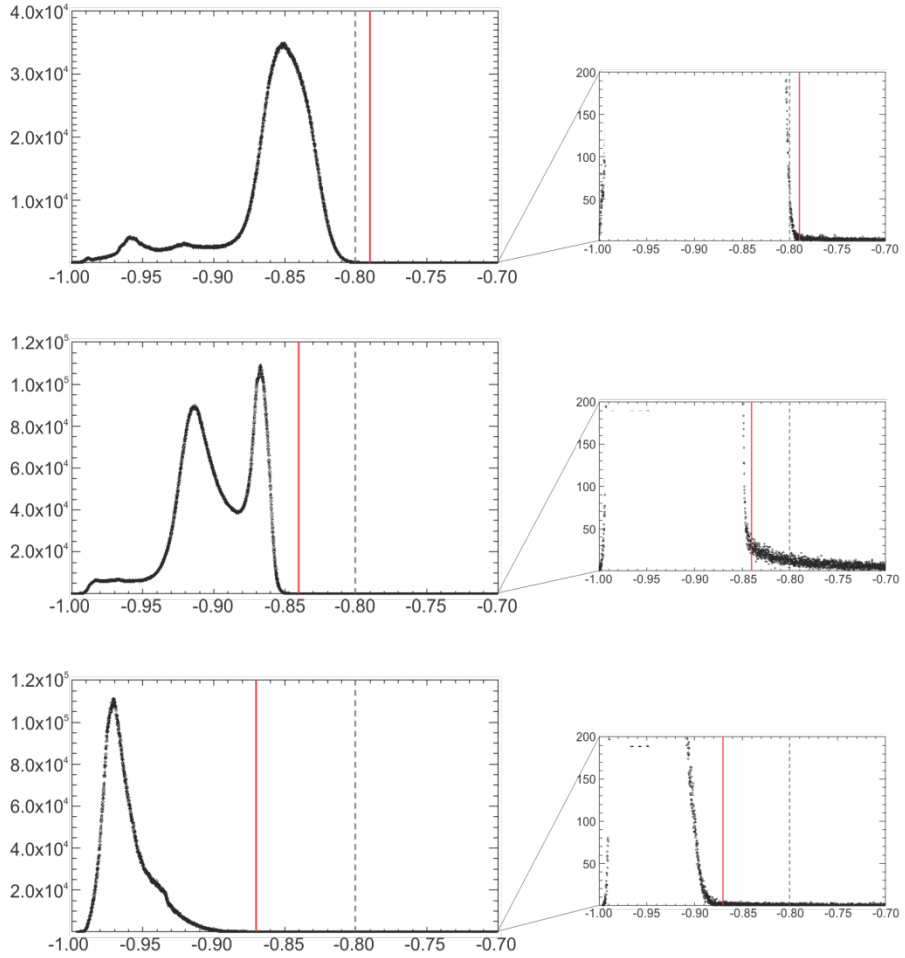
Must also account for sunglint in daytime data



Just use an angular threshold

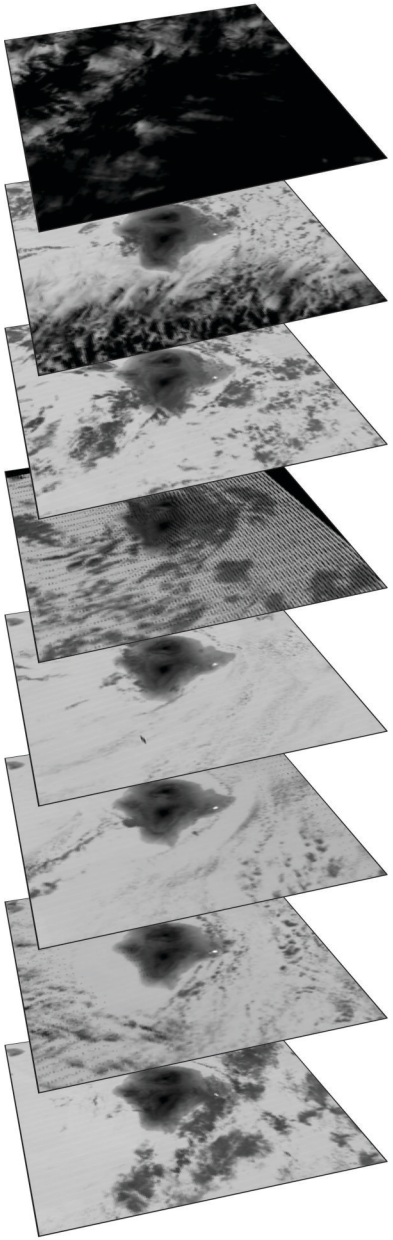
MODVOLC: spectral point operation, algorithm, and output

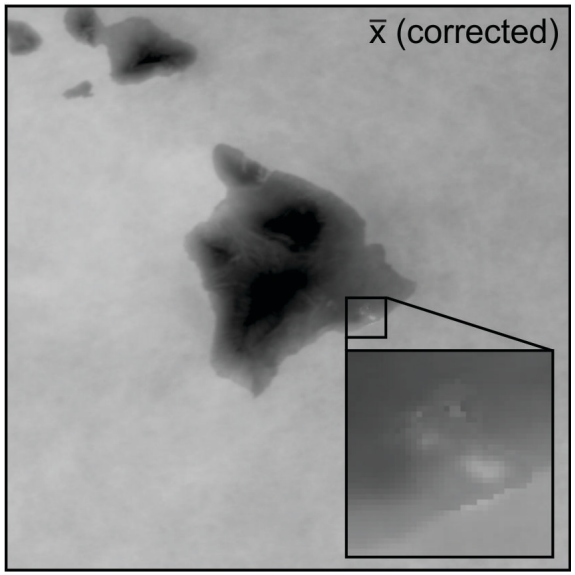




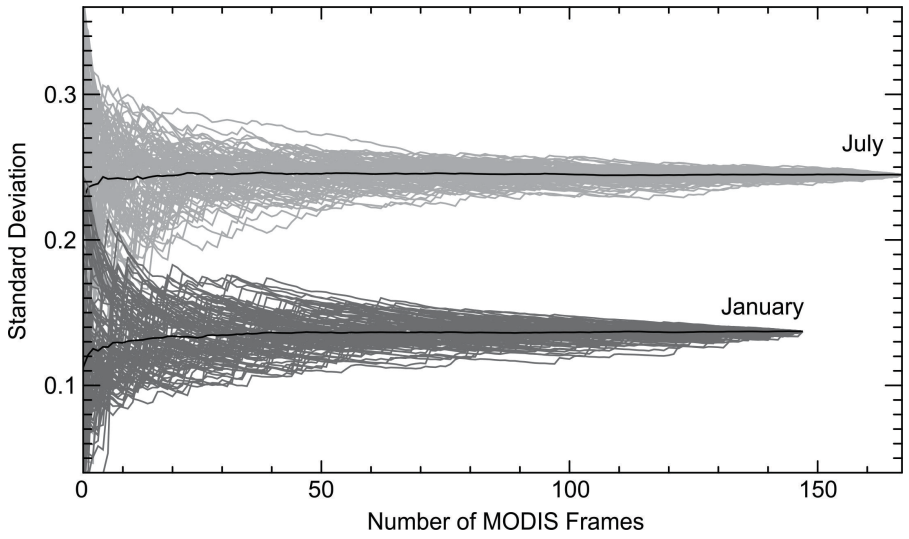
Unix time	Satellite	Year	Month	Day	Hour	Minute	Longitude	Latitude	L_{21}	L_{22}	L_6	L_{31}	L_{32}	Satellite zenith	Satellite azimuth	Sunzenith	Sun azimuth	Line	Sample	NTI	Glint vector
									W m^{-2} sr^{-1} µm^{-1}												
1089853500	A	2004	07	14	15	05	159.424927	54.047855	0.775	0.802	177.015	7.087	6.790	42.97	96.49	101.53	22.91	329	210	-0.789	109.602
1089838800	T	2004	07	14	11	00	159.439728	54.049419	2.228	-10.000	166.546	8.392	7.967	5.88	75.11	98.09	325.58	793	743	-0.563	95.933
1089853500	A	2004	07	14	15	05	159.448288	54.052444	1.440	1.453	177.015	7.786	7.453	42.97	97.57	101.53	22.93	331	211	-0.674	108.869
1089853500	A	2004	07	14	15	05	159.453903	54.045853	1.218	1.235	177.015	7.558	7.156	42.97	96.49	101.53	22.93	329	211	-0.706	109.617

Time-series hot-spot detection algorithms



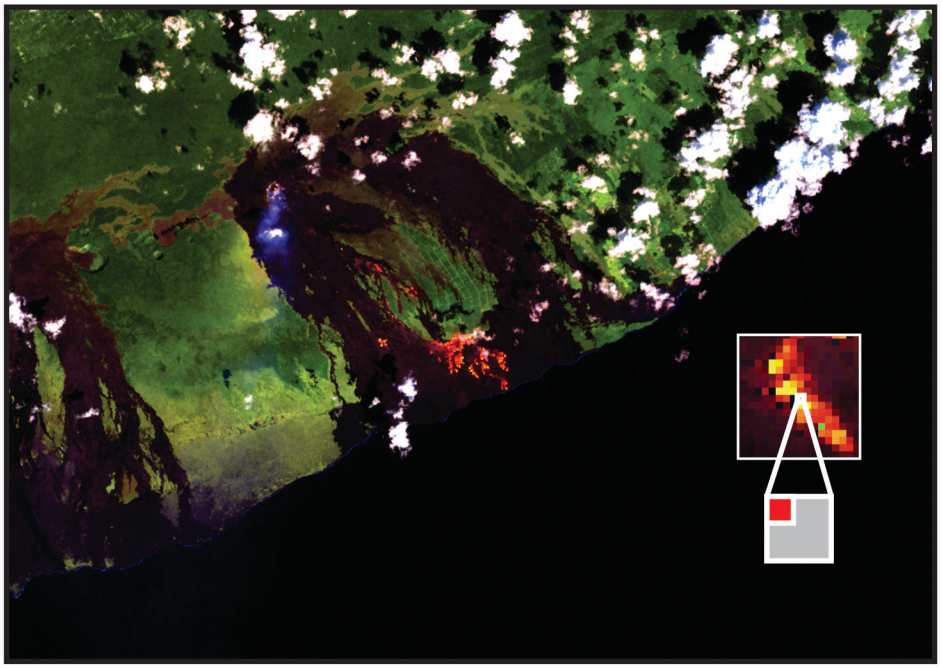


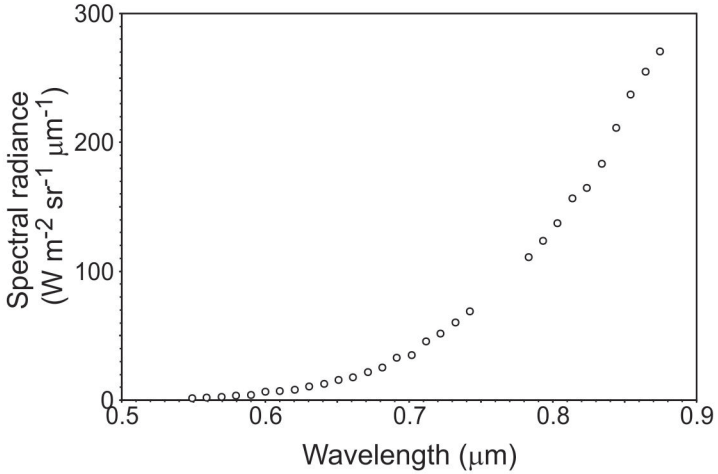
$$\otimes T_4(x,y,t) = \frac{T_4(x,y,t) - \bar{\bar{T}}_4(x,y)}{\sigma_4(x,y)}$$

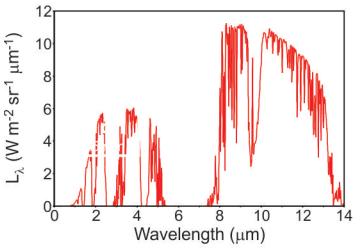


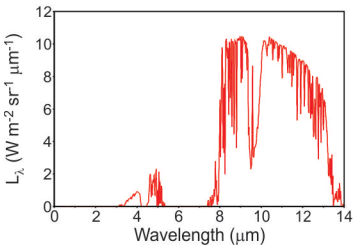
Koeppen et al., 2010, after Pergola et al., 2004

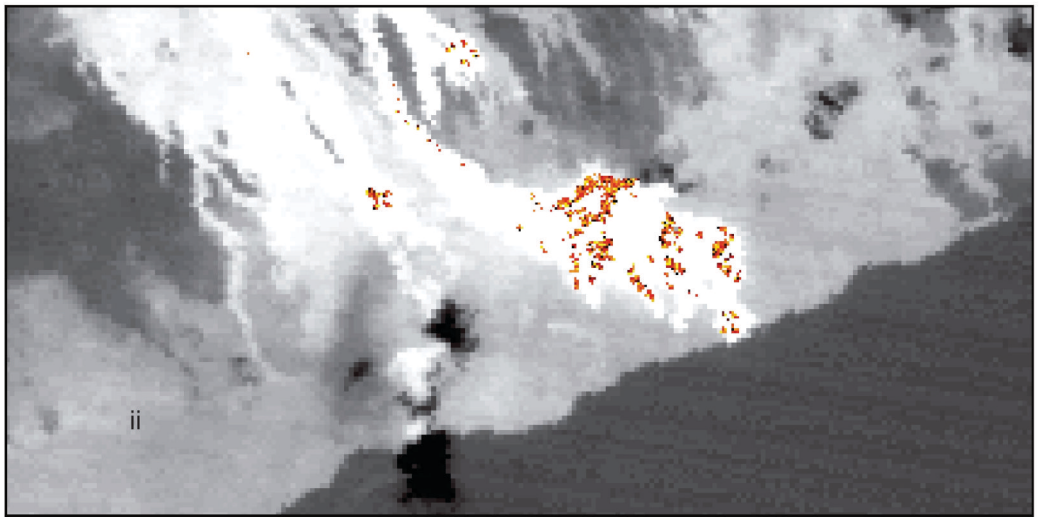
Path forward: simulate HyspIRI data, test algorithms

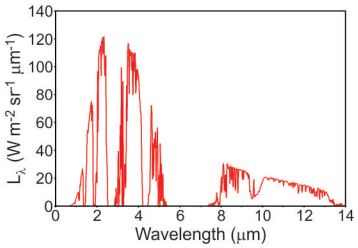


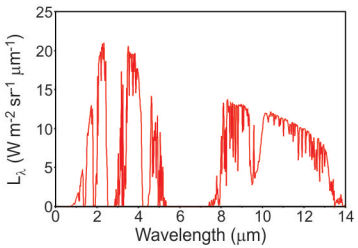


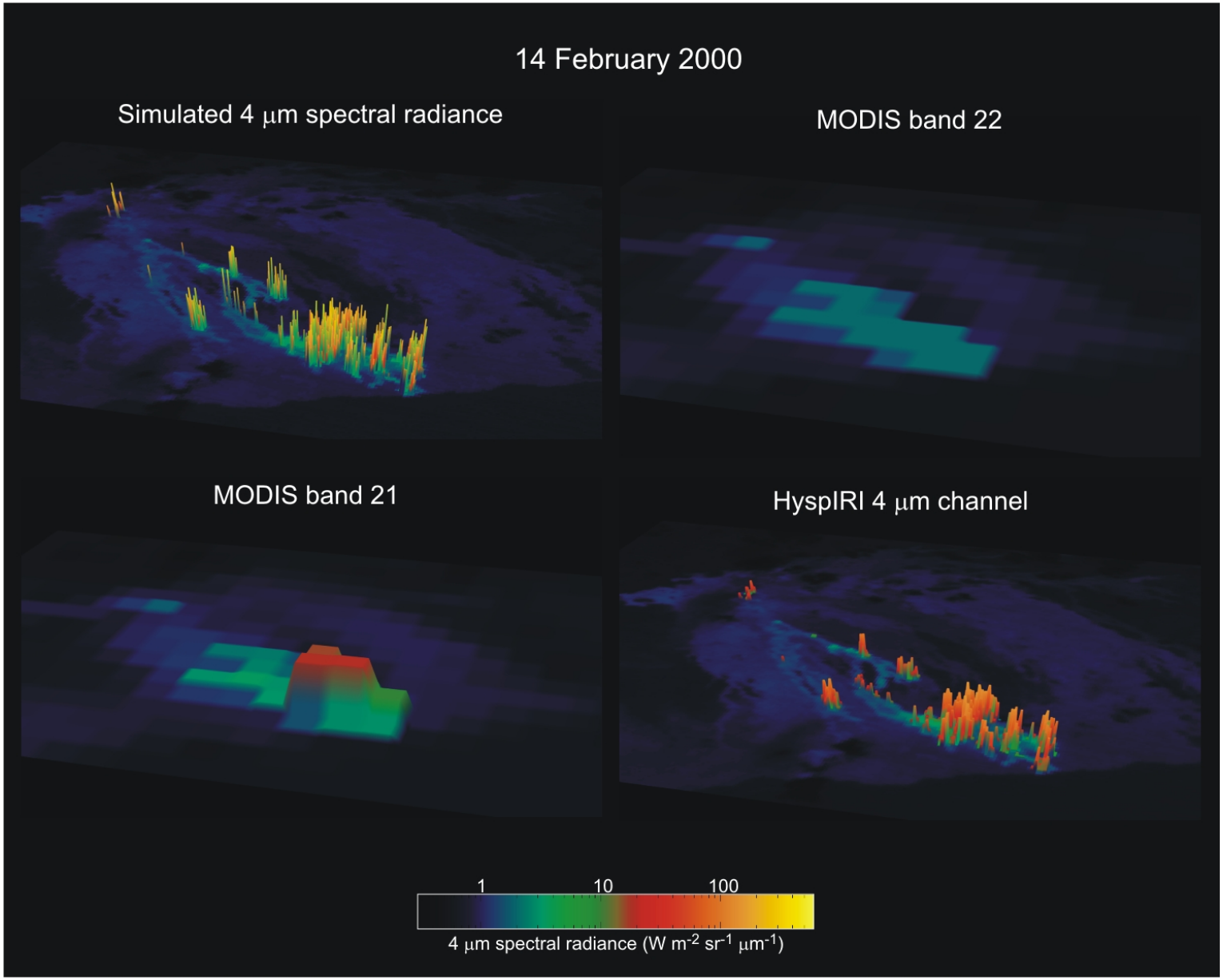


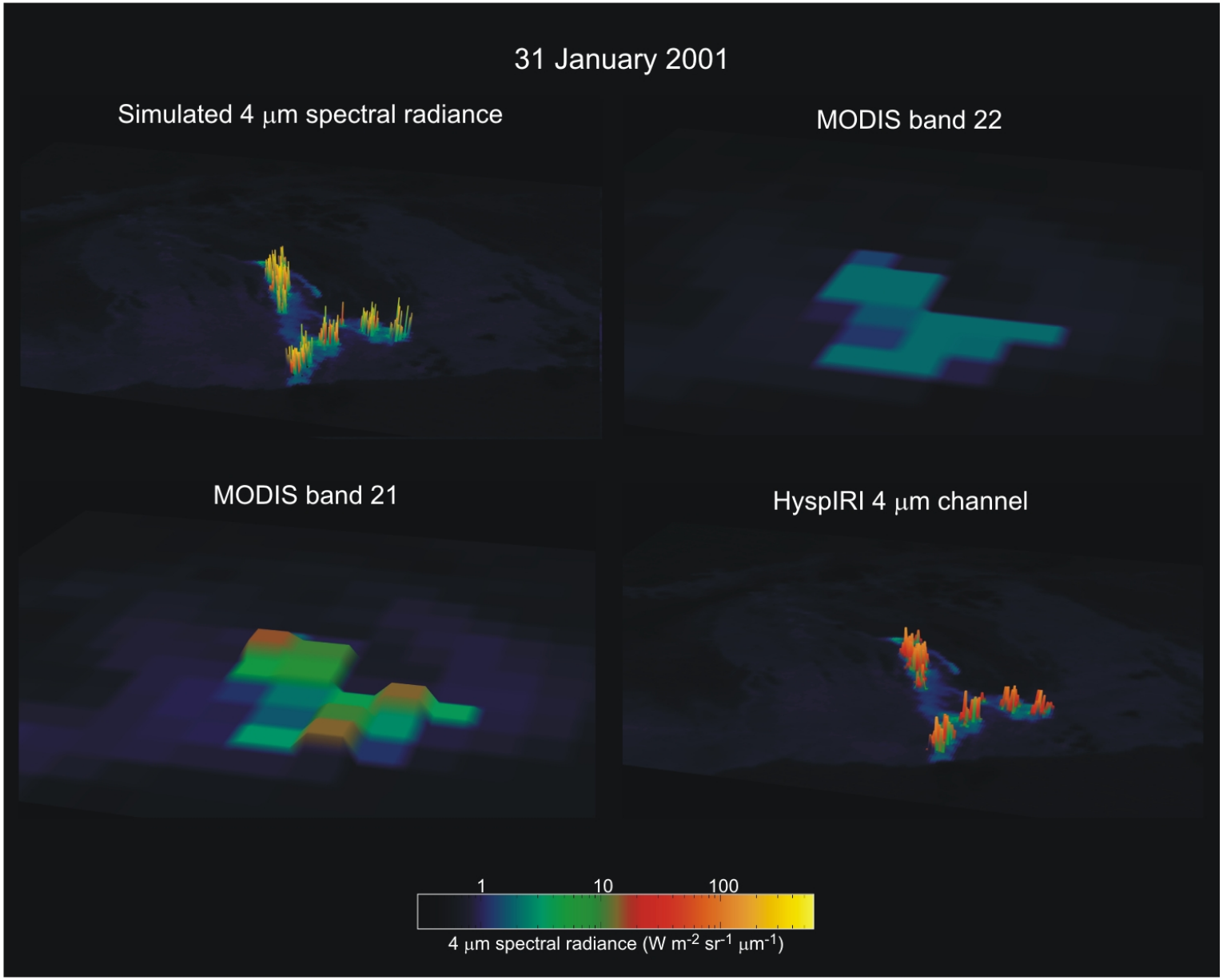




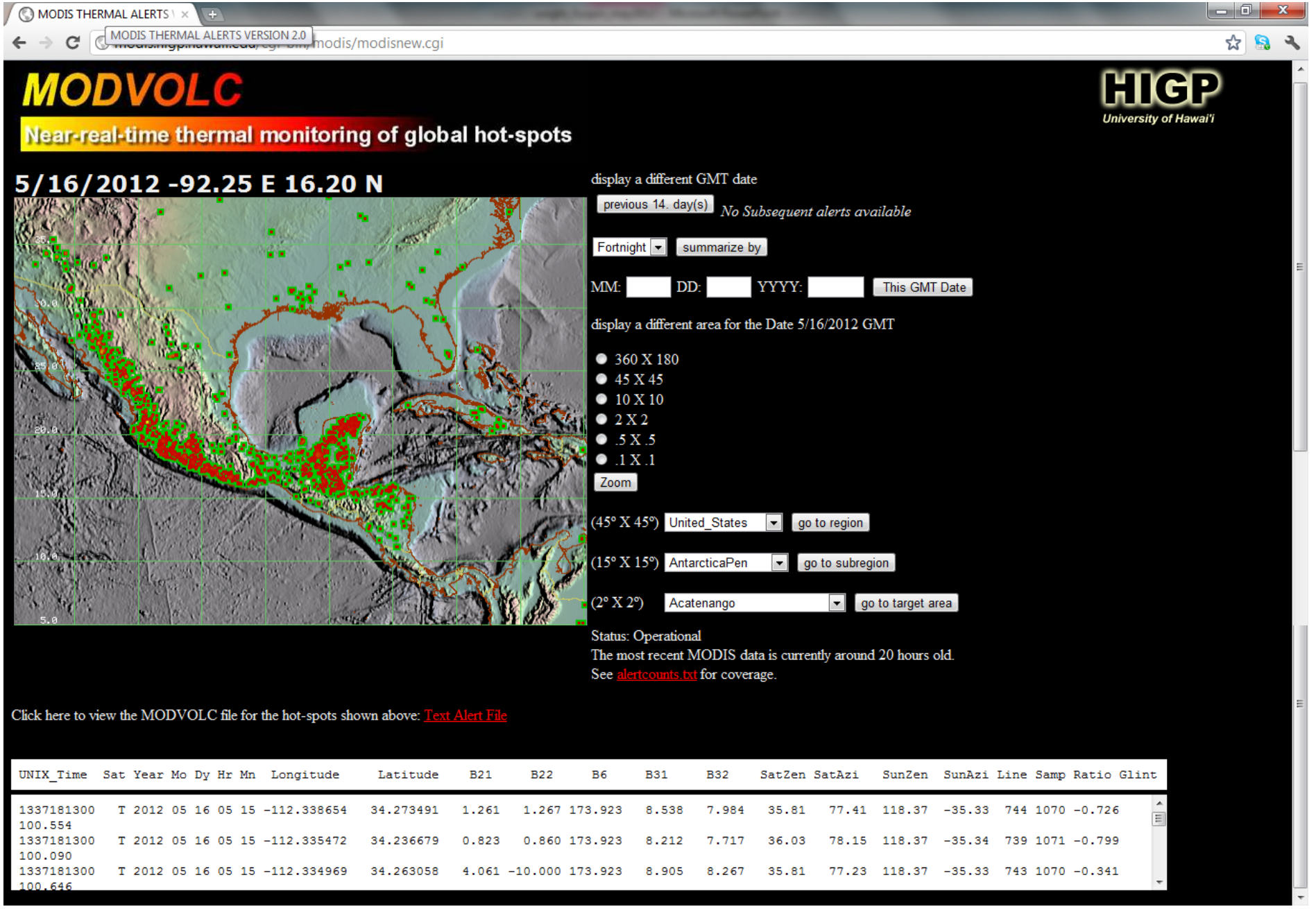





14 February 2000
Simulated 4 μm spectral radiance
MODIS band 22
MODIS band 21
HyspIRI 4 μm channel
1
10
100
4 μm spectral radiance (W m-2 sr-1 μm-1)


31 January 2001
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)

Products: useful and useable



Summary

1. HyspIRI is an important bridge between MODIS class and Landsat class mission, with respect to detecting, quantifying and monitoring global wildfires and volcanic hot-spots

2. Existing algorithms are not directly portable to the analysis of HyspIRI data (smaller IFOV; algorithms must operate independently of the VSWIR sensor) but will need to be tested, compared and adapted