Hot Target Saturation Report

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26 August 2010

Acknowledgements

Hot Target Saturation Subgroup
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Instrument	Central Wavelength	Spatial Resolution (at nadir)	Temporal Coverage (daytime)	Saturation Temperature
AVHRR	3.7 μm	1.1 km	Daily (NOAA 18 + 19)	~ 321.5 K
VIRS (TRMM)	3.75 μm	2.4 km	2 day revisit	321K
ATSR/AATSR	3.7 μm	1 km /1.5 x 2 km	3 day revisit	311 K
MODIS	3.95 μm	1 km	Daily (Terra + Aqua)	478 K /506 K (Ch. 21) 330 K (Ch. 22)
GOES Imager	3.9 μm	2.3 x 4 km	3 hr/15-30 min	335 K
SEVIRI (MSG)	3.9 μm	3 km	15 min	335 K
HSRS (BIRD)	3.4 – 4.2 μm	370 m	Targeted	600 K

Heritage for HyspIRI 4-μm Channel

~ 30 Year Record of Measurements at 4-μm

Data Used in Fire and Hot Spot Detection Programs

HyspIRI Spatial Resolution (60 m) is Unprecedented

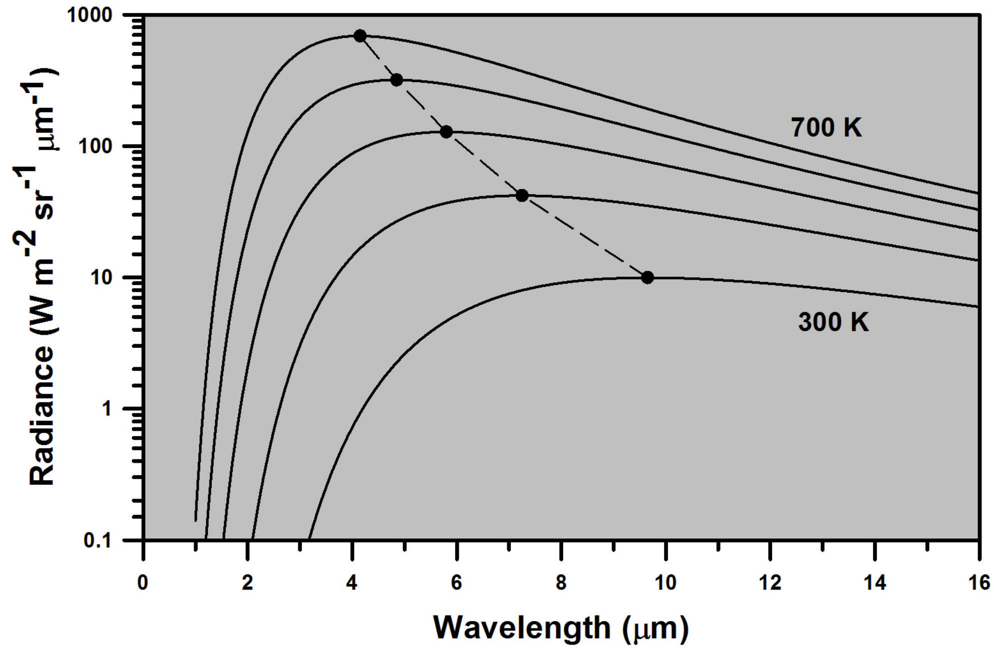
Why Do We Want a 4-μm Channel?

Planck's Law: Radiance as a Function of Temperature and Wavelength

$$B_\lambda(T) = \frac{C_1}{\pi\lambda^5 \left[exp(C_2/\lambda T) - 1\right]}$$

$C_1 = 3.74151 \times 10^8$ W m^2 μm^4

$C_2 = 1.43879 \times 104$ μm K



Wien's Displacement Law: Position of Peak Radiance is Inversely Proportional to Temperature

$\lambda_{max} = b/T$

$b \sim 3 \times 10^{-3}$ m K

High-Temperature Targets – Peak Radiance near 4 μm

Why Do We Want a 4-μm Channel?

Sub-Pixel Temperature Mix:
Presence of Hot Fraction Increases Radiance Near 4 μm

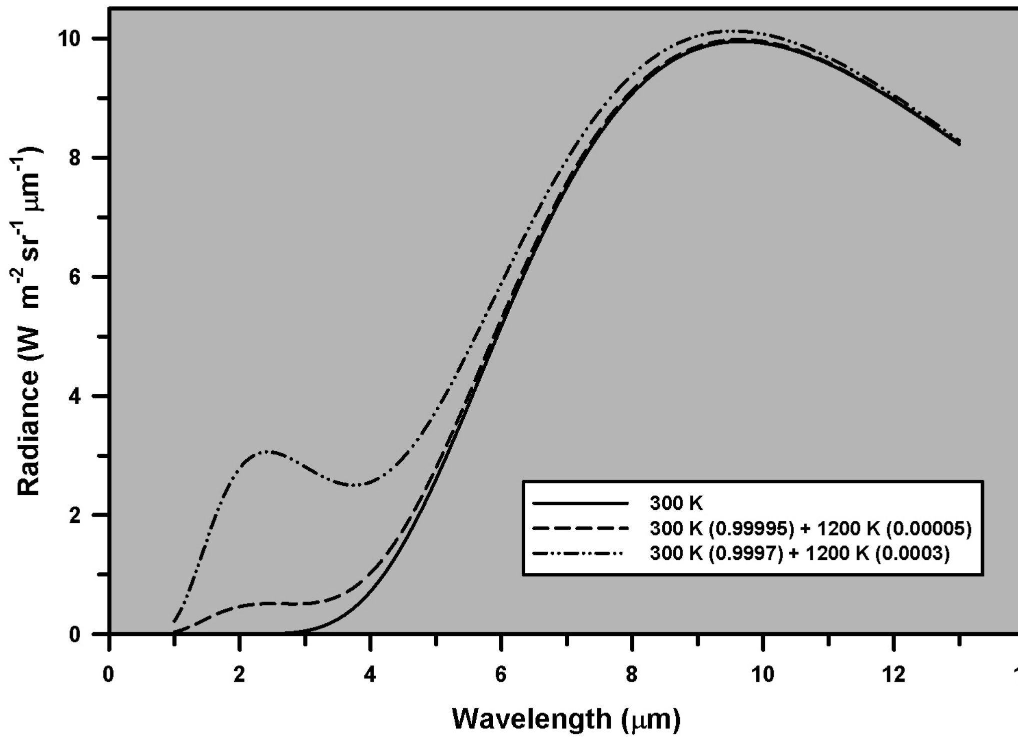
Need Multispectral Data to Recognize Sub-Pixel T Mixing

Two-Component Model:

$$B_\lambda(T_{app}) = B_\lambda(T_{bg})\,[1 - f\,] + B_\lambda(T_h)\,[\,f\,]$$

f = Fractional Area of Hot Comp
T_{app} = Apparent Temperature
T_h = High Temperature
T_{bg} = Background Temperature

(modified from Wright et al., 2002)



Increase in 4-μm Radiance Relative to 11-μm Radiance is the Foundation of:

- Estimation of Sub-Pixel Temperature (Dozier Method)
  - a) Inversion of Two-Component Model
  - b) Conservative Estimate When We Ignore Surface Emissivity and Atmospheric Transmission
- Automated Detection of Hot Spots
  - a) MODIS Fire Algorithm
  - b) MODVOLC Hot Spot Algorithm

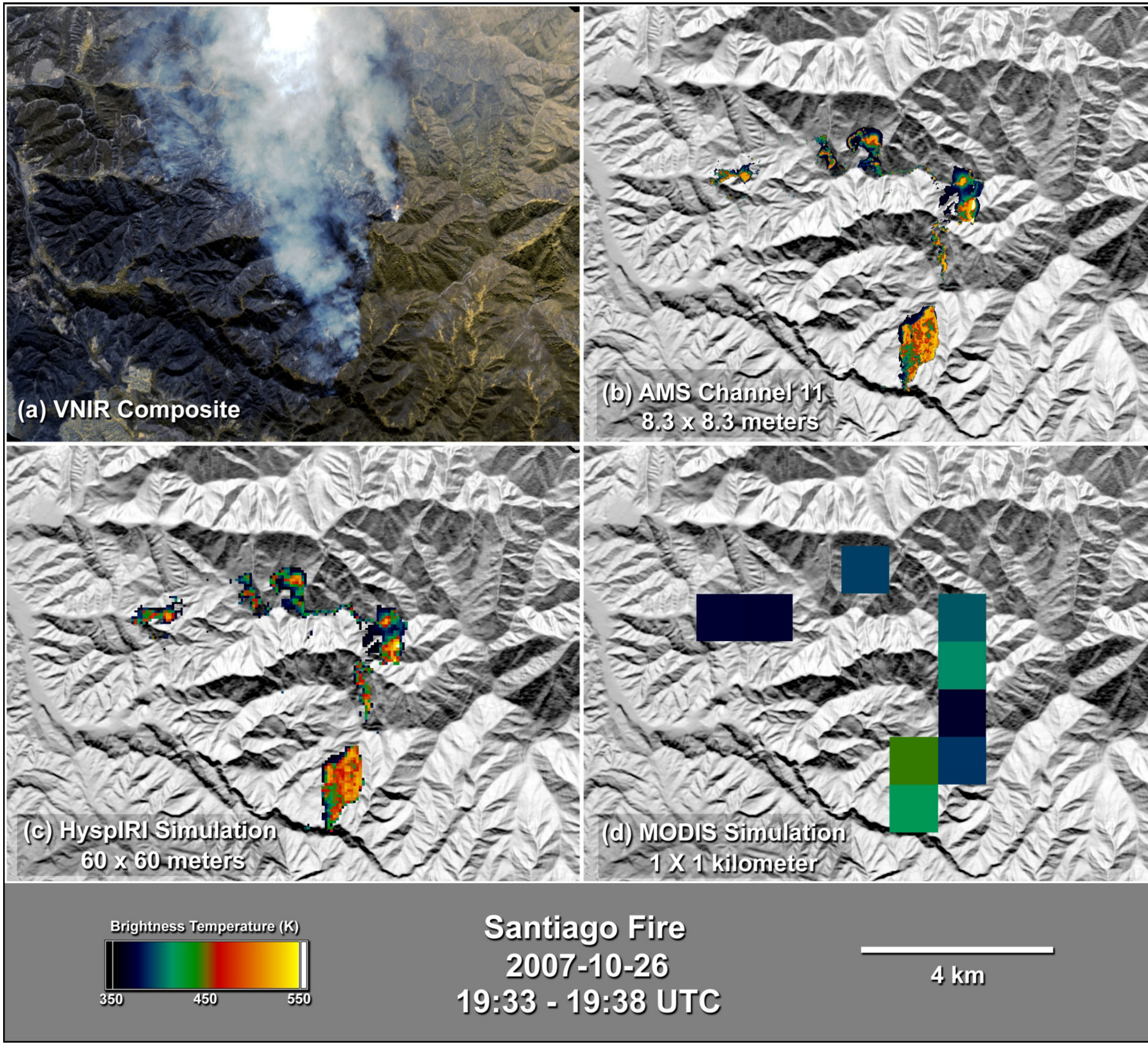
Why Do We Want 60-m Spatial Resolution?

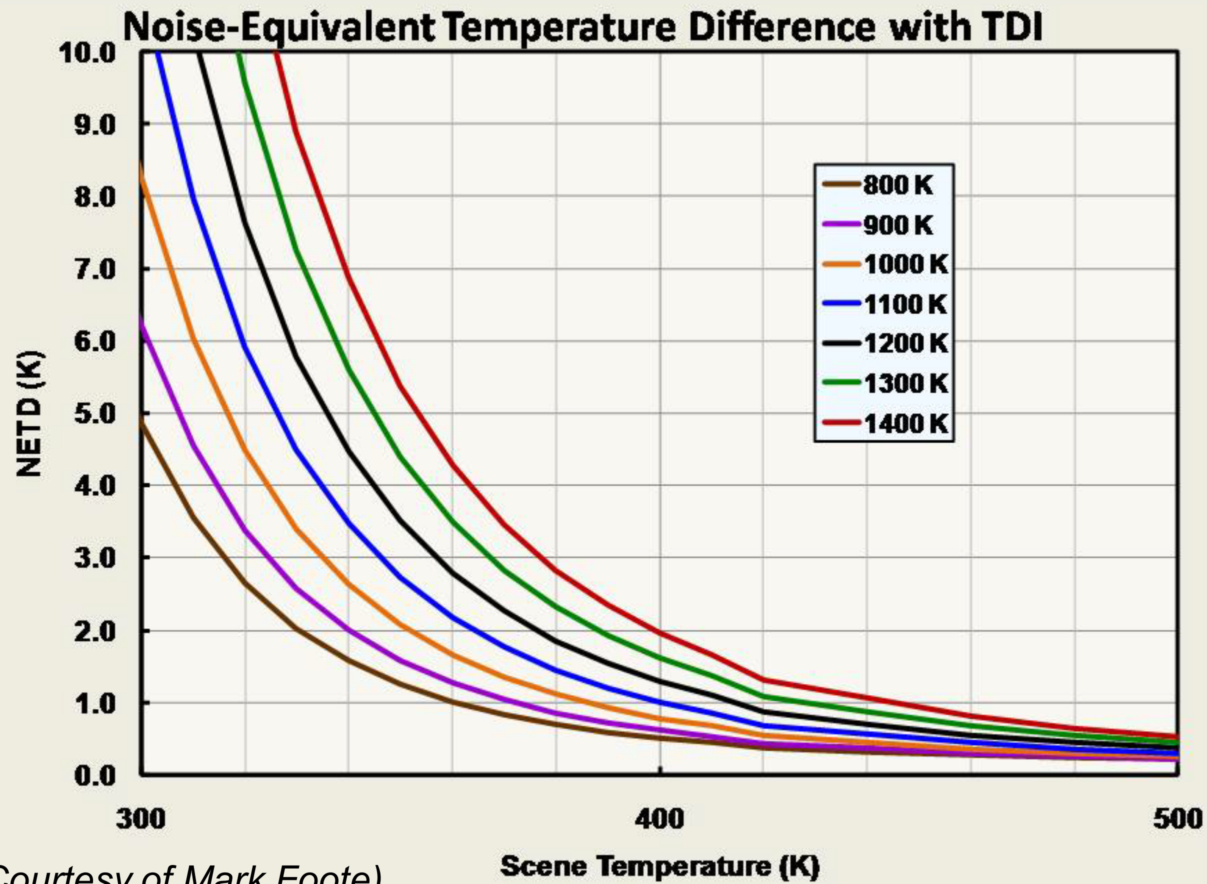
Sub-Pixel Mixing Decreases with Decrease in Pixel Size (IFOV)

HyspIRI:
Temp Distribution Retained

Apparent Temp Decrease ~25 K

MODIS:
Apparent Temp Decrease ~100 K





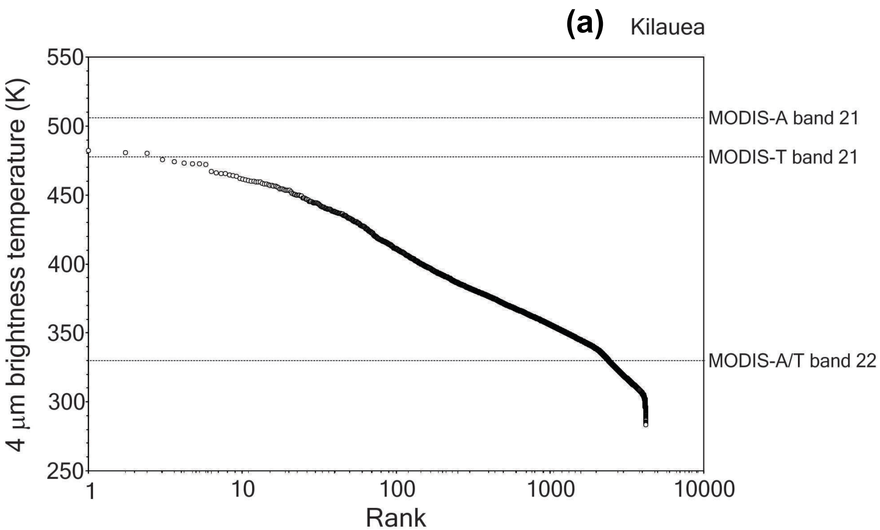
(Courtesy of Mark Foote)

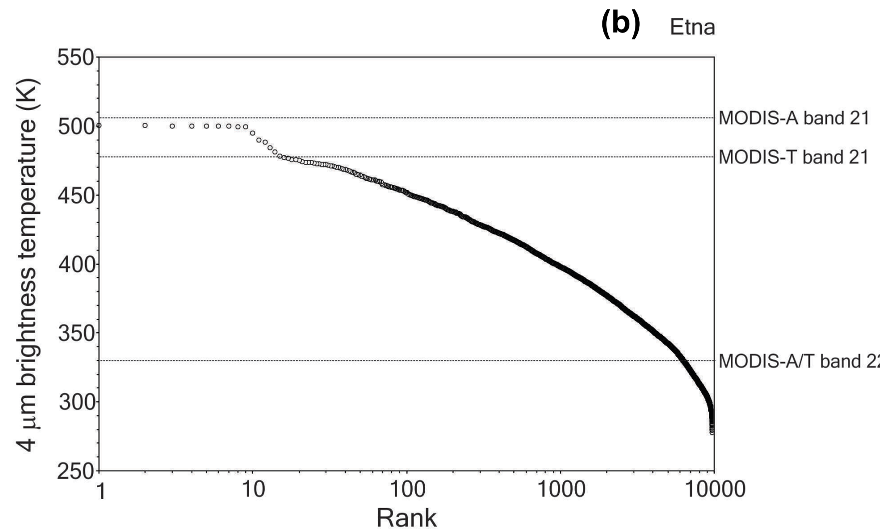
Sensitivity vs. Saturation Temperature

Sensitivity Decreases With Increase in Saturation Temperature

Low Sensitivity of MODIS Ch. 21 (NE∆T = 3 K @ 330 K) Precluded Use in an Operational Sub-Pixel Temperature Estimation

Saturation Temperature ≤ 450 K for 1-km IFOV Based on Study of Fire Pixels from 40 MODIS Scenes [*Gao et al.*, 2007]





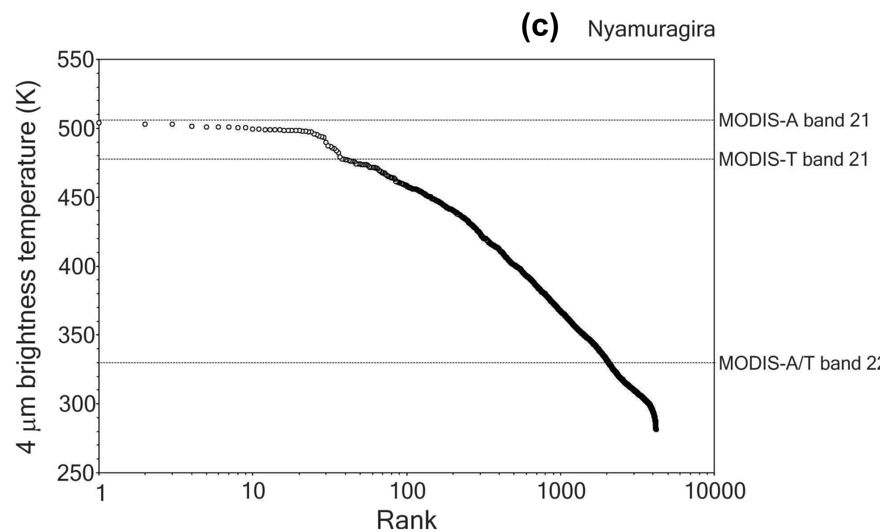
MODVOLC Record (2000 – 2009)

Ch. 21 Brightness Temperatures Corresponding to MODVOLC Hot Spots: (a) Kilauea, (b) Etna, and (c) Nyamuragira

Temperatures > 450 K Recorded for Each Volcano

High-Temperature Events are Rare (Over Time) – Very Low Probability in Statistical Analysis

HyspIRI Science Questions Require Estimates of High Temperatures



(Courtesy of Rob Wright)

Precursor Data Sets

Ground Rules:

(1) Sub-Pixel Temperature: Need to Know Sub-Pixel Area

(2) Spatial Resolution Better than 60 m

Minimize Sub-Pixel Mixing

Critical for Single-Channel Temperature Estimates

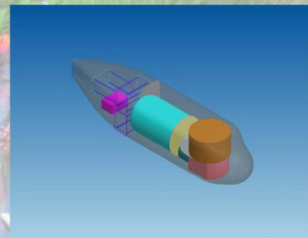
(3) Single-Channel MIR (3 – 5 μm) Data Preferable to Single-Channel TIR (8 – 12 μm) Data

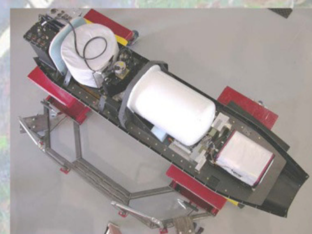
(4) SWIR (~ 2 μm) Data from Night-Time Acquisitions

AMS Wildfire Sensor

Band	Wavelength µm	
1	0.42- 0.45	
2	0.45- 0.52	(TM1)
3	0.52- 0.60	(TM2)
4	0.60- 0.62	
5	0.63- 0.69	(TM3)
6	0.69- 0.75	
7	0.76- 0.90	(TM4)
8	0.91- 1.05	
9	1.55- 1.75	(TM5)
10	2.08- 2.35	(TM7)
11	3.60- 3.79	(VIIRS M12)
12	10.26-11.26	(VIIRS M15)

Total Field of View: 85.9 degrees
IFOV: 2.5mrad
Altitude: 25000'
Spatial Resolution: 20m (at sea level)

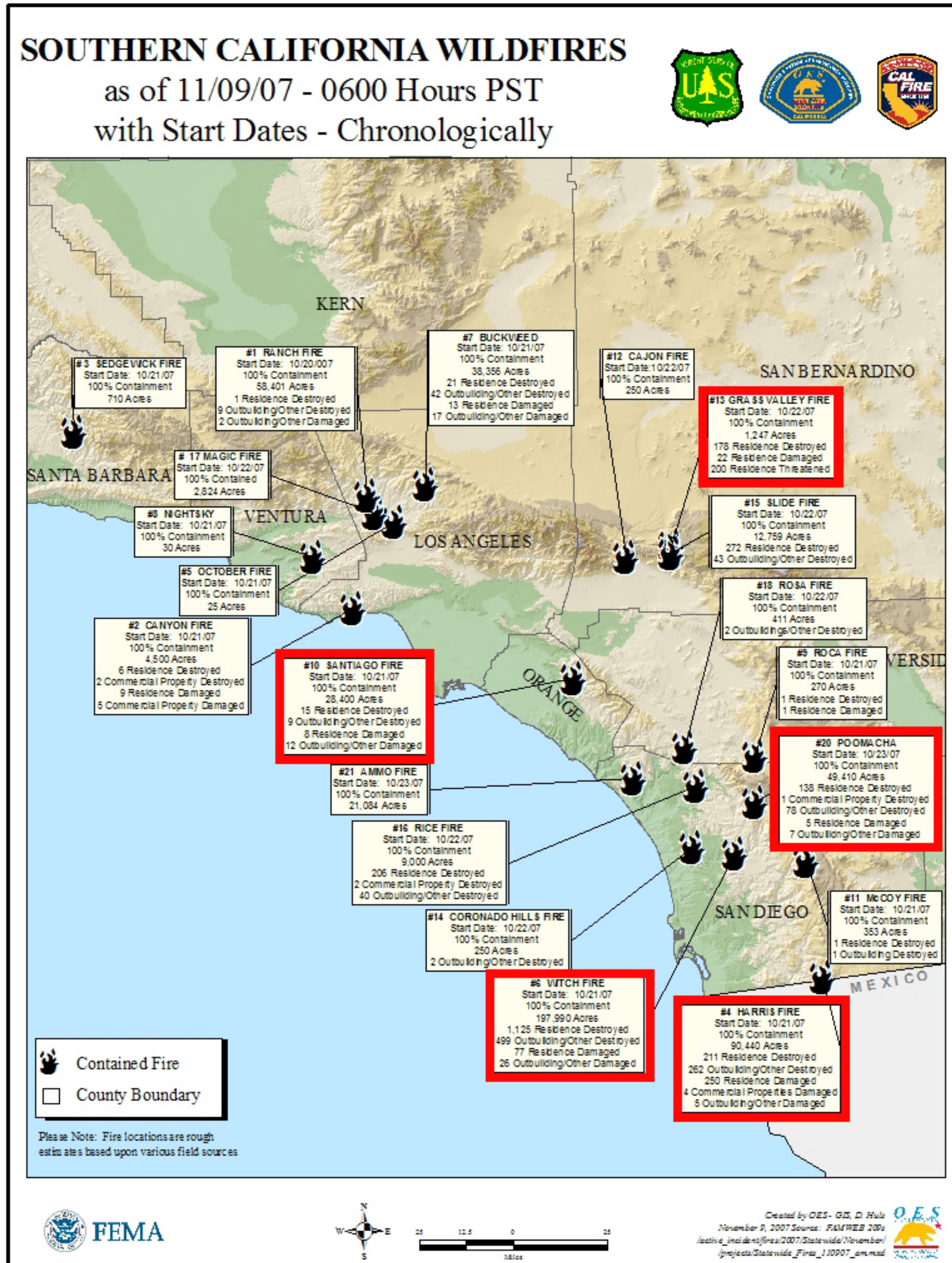




Flights Conducted Between 24 – 28 October 2007

Flight Line Count:

Grass Valley Fire:	25
Poomacha Fire:	19
Harris Fire:	15
Witch Fire:	26
Santiago Fire:	9



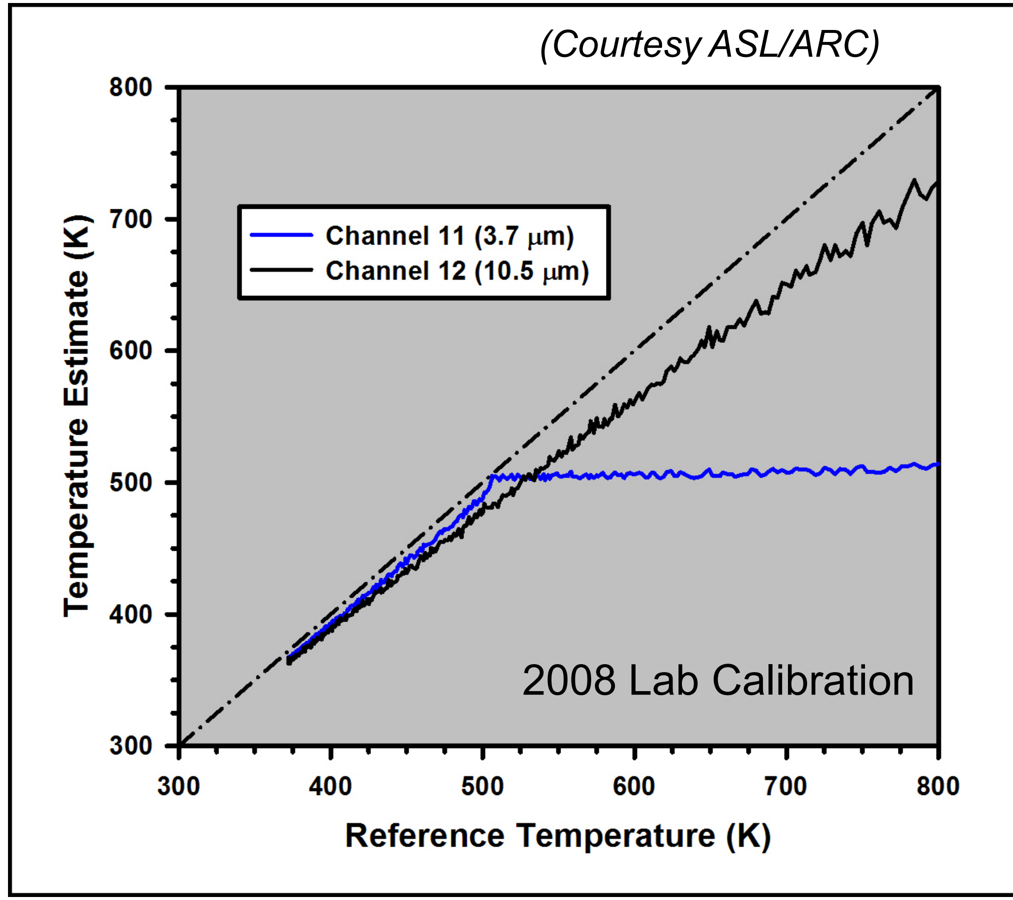
Saturation of Band 11

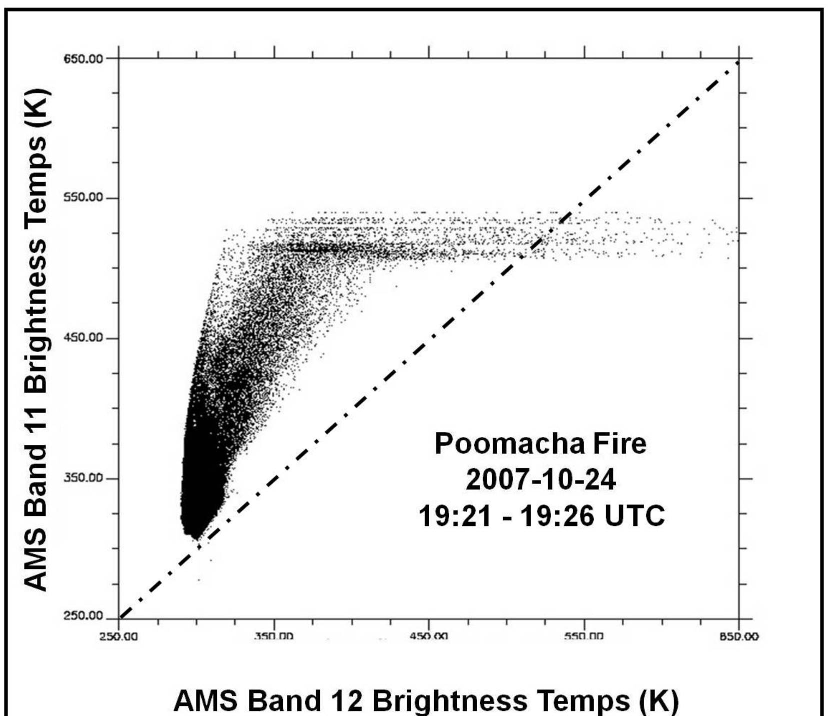
No Data on Temperatures > 530 K

Aggregation to HyspIRI Resolution Mitigates Saturation

Band 11 Radiance is Good Proxy for HyspIRI at Temperatures Below 530 K

Band 11 Temps > Band 12 Temps: Indication of Sub-Pixel Mixing





Can We Use Band 12?

Lab Cal: Band 12 Good to ~ 800 K

Lower Bound on Saturation Temperature

Systematic Under-Estimation of T:

~2 K @ 400 K; 75 K @ 800 K

$$T_{true} = (T_{est} - 71\ K)/0.8175$$

Band 12 Histograms

All Radiance Data Aggregated to 60-m HyspIRI Resolution

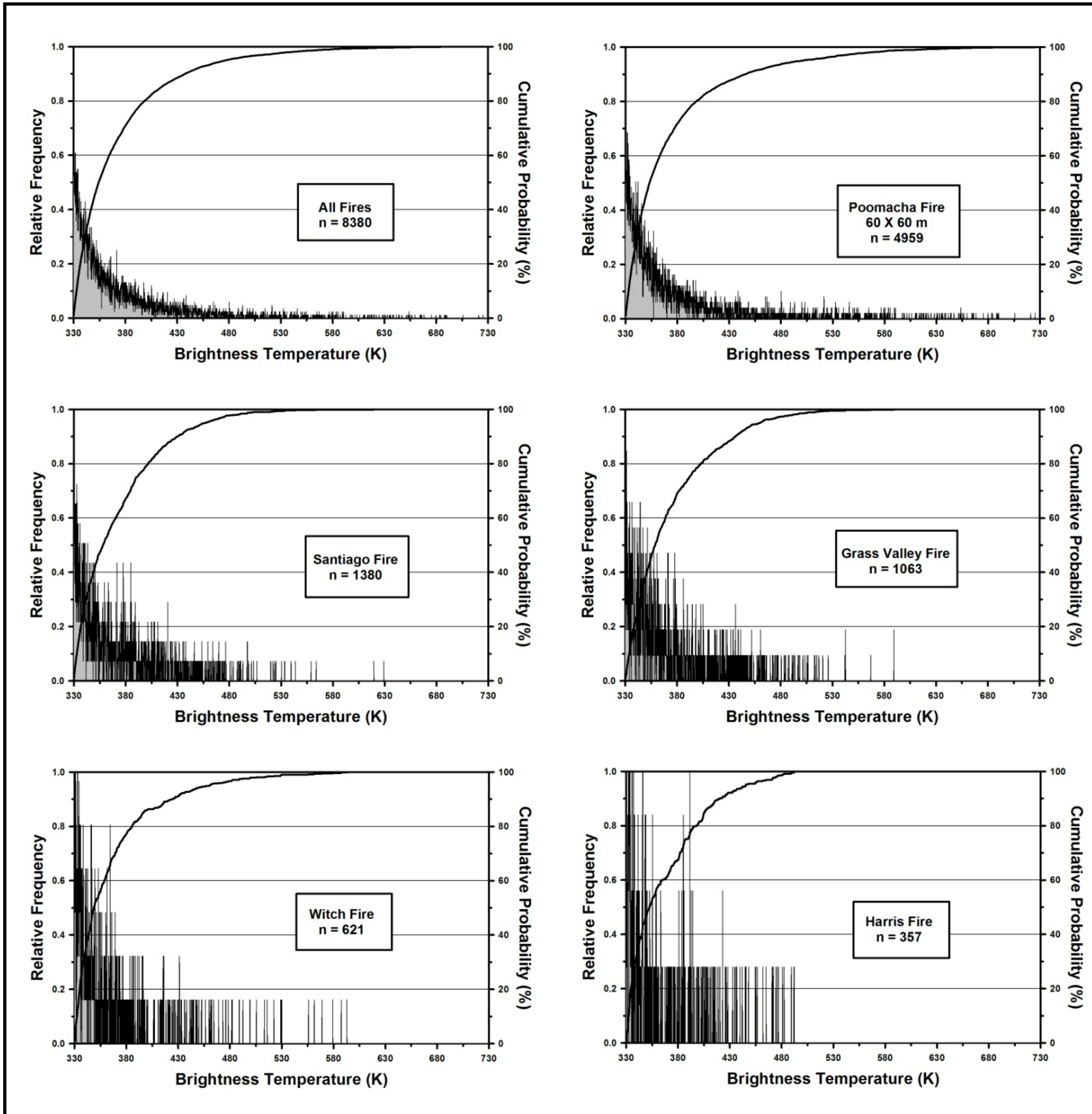
Temp Range 330 – 730 K to Isolate High-T Pixels

Statistics for All Fires Dominated by Poomacha (Contributed ~ 60 % of Hot Pixels)

Poomacha Fire Source of Hot Pixels ~ 720 K

Witch vs. Poomacha:

- Poomacha Burn Area 25% of Witch Burn Area
- Witch Fire Hot Pixels 12.5% of Poomacha Hot Pixels
- Temperature Alone Provides Little Info on Consumption of Biomass



Effects of Sub-Pixel Mixing

Compare Temperatures at Native and Aggregated (60 m) Resolution

Temp Range 330 – 730 K to Isolate High-T Pixels

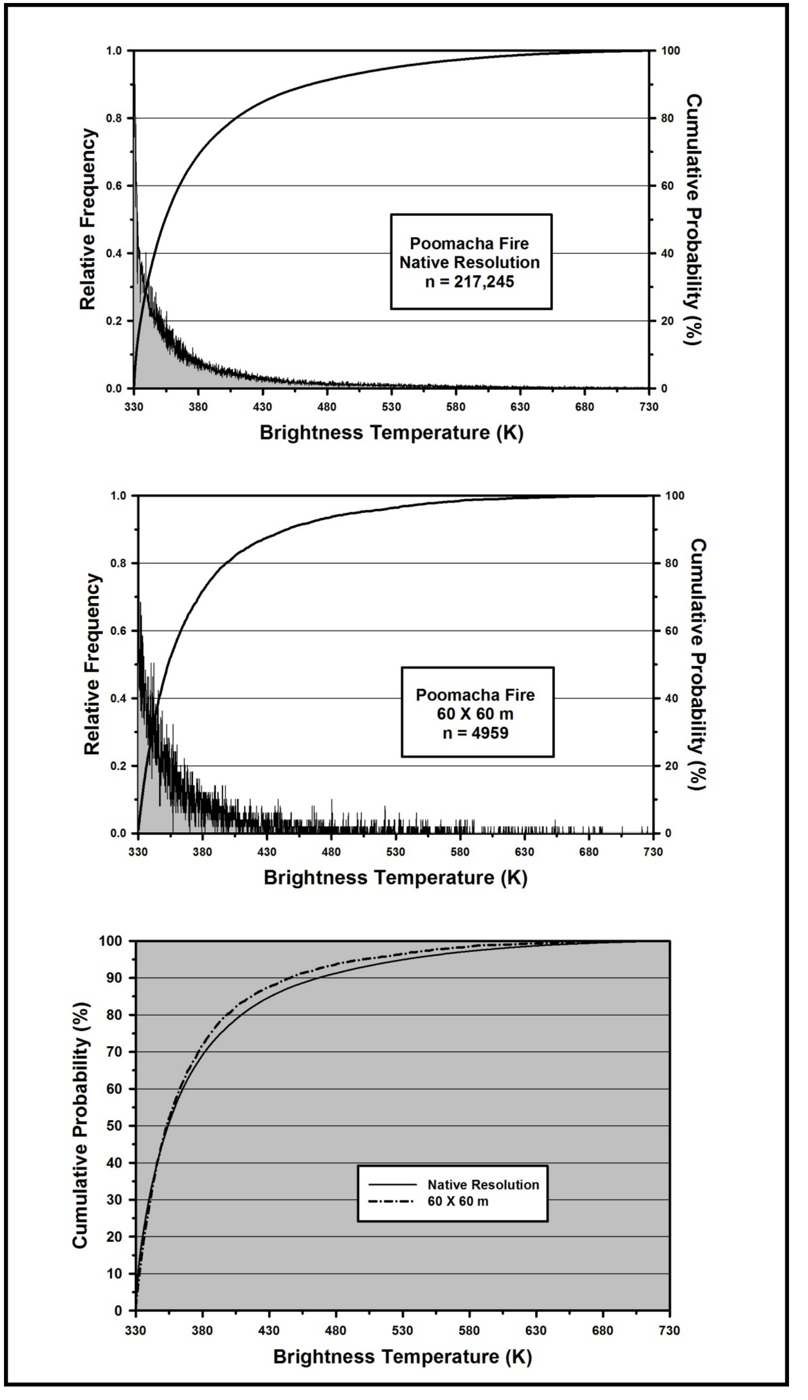
Cumulative Histograms Deviate for Temperatures > 380 K

Cumulative Probabilities Within 5 % for Entire Range of Temperature

Spatial Distribution of Poomacha Fire Temperatures Uniform to 60 m?

Caveats Aside:

Recommended <u>Lower</u> Bound on Saturation Temperature: 795 K



Realistic Saturation Limit for Wildfires?

Compare with BIRD/HSRS Estimates of Fire Temperature and Area

Confine Comparison to Fire Areas ≥ HyspIRI pixel

HyspIRI Pixel (60 X 60 M) = 0.36 Hectares

Highlighted Temperatures Would be Lost with Sat. Temp of 795 K

Kalimantan Peat Fire Yielded Lower Temperatures than “Open Flames” in Australia and Russia

Australia 2002-01-05		Kalimantan 2002-08-24/25		Lake Baikal 2003-06-16		Etna Lava Flow 2002-11-02	
T_f (K)	A_f (Ha)	T_f (K)	A_f (Ha)	T_f (K)	A_f (Ha)	T_f (K)	A_f (Ha)
815	0.48	860	2.5	800 - 920	4.4 - 8.4	540	25
715	2.3	740	1.9	668 – 771	0.7 – 1.5		
893	0.59	650	4.6	716 – 868	1.2 – 3.1		
852	0.92	520	2.1	740 - 839	0.38 – 0.71		
957	1.0	720	1.1	771 – 988	0.23 – 0.70		
796	0.39	690	3.0	819 – 913	1.4 – 2.3		
		590	3.3	694 – 882	0.36 – 1.21		
		560	0.7				

References: Briess et al.,2003; Oertel et al., 2004; Siegert et al, 2005; Zhukov et al., 2006

Volcanic Targets

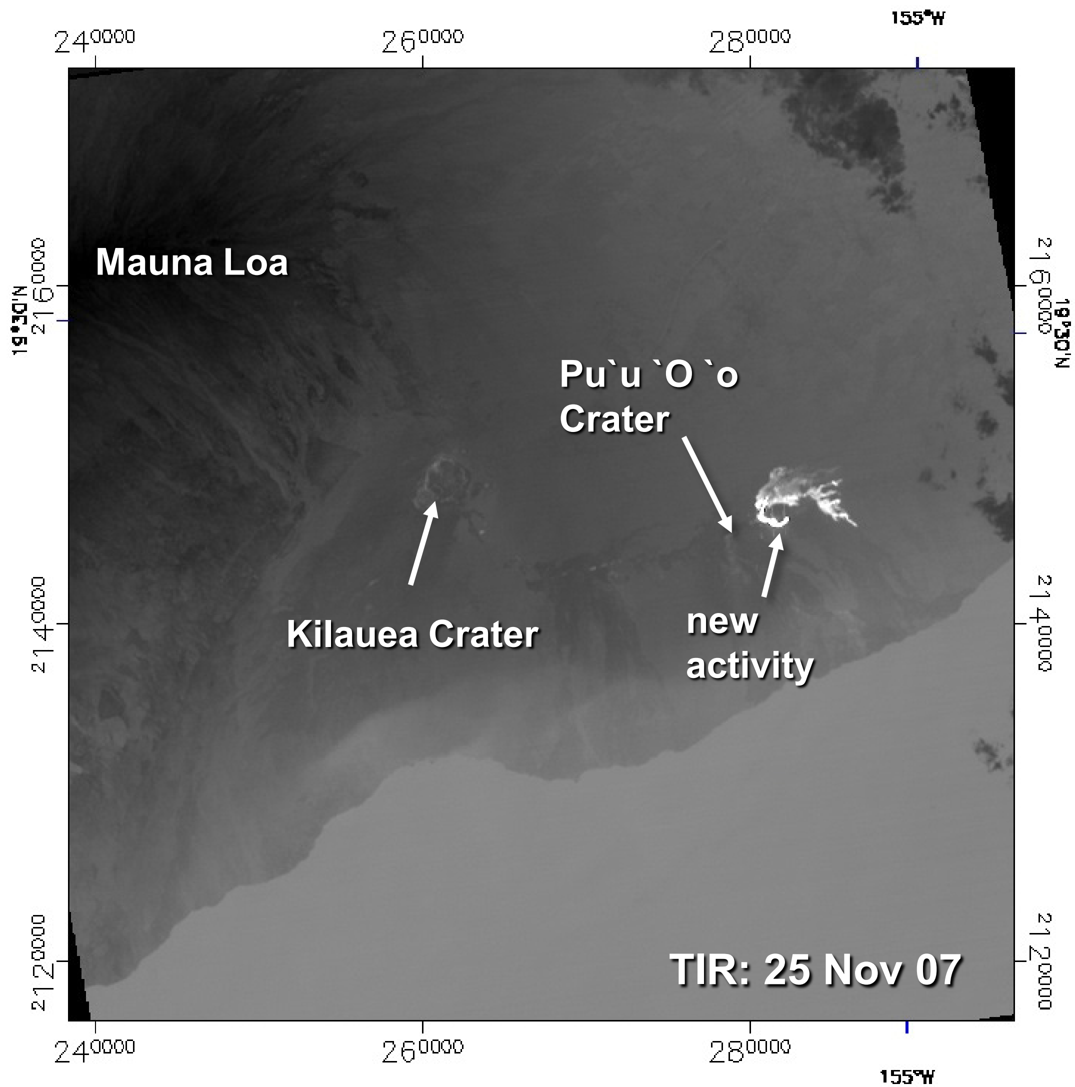
ASTER Data from Hawaii: Aggregate to HyspIRI 60-m Resolution

Special Night-time Acquisition of VNIR and SWIR

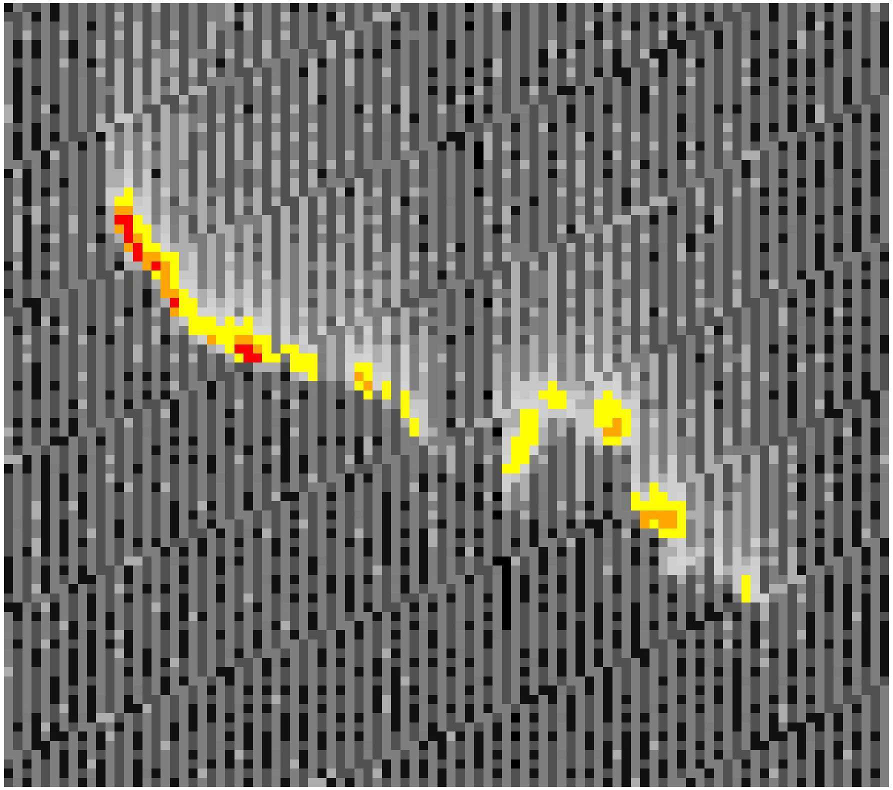
No Solar Component – Radiance from Geothermal Sources

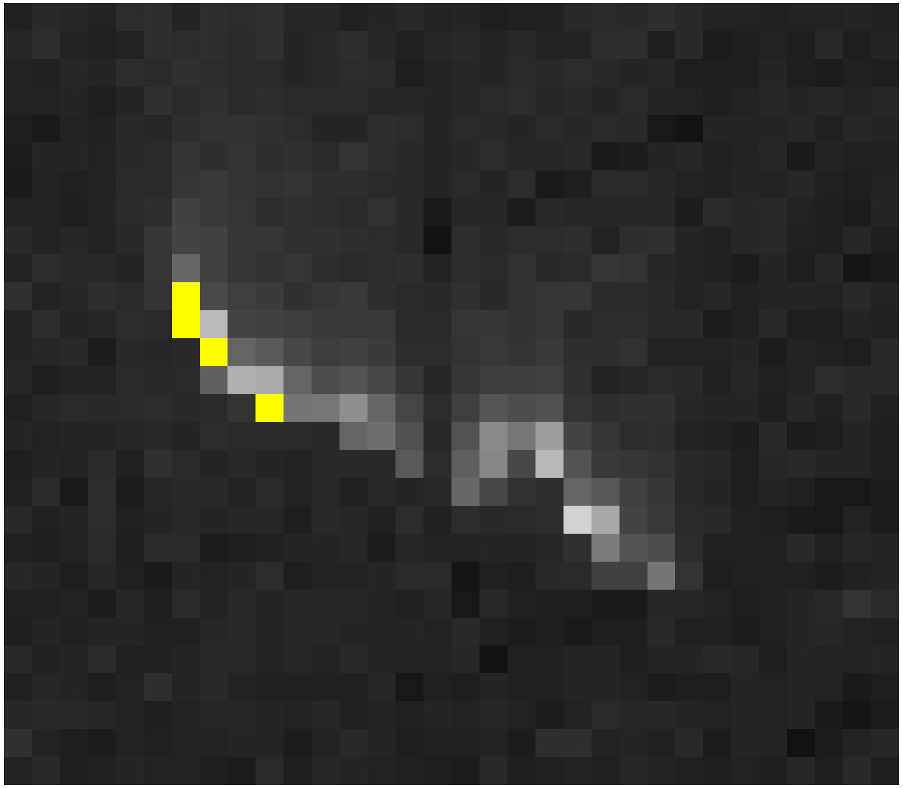
Saturation of TIR and SWIR (Despite Low Gain Setting for SWIR)

No Saturation in VNIR (with High Gain Setting)



(Courtesy of Mike Ramsey)





Band 3 at 15 m (ASTER)

Max. Temperature Detected: 1122 K

Band 3 at 60 m (HyspIRI)

Max. Temperature Detected: 993 K

Color Code for Temperature

Red: 1073 – 1123 K

Orange: 1023 – 1073 K

Yellow: 973 – 1023 K

(Courtesy of Mike Ramsey)

Volcanic Targets

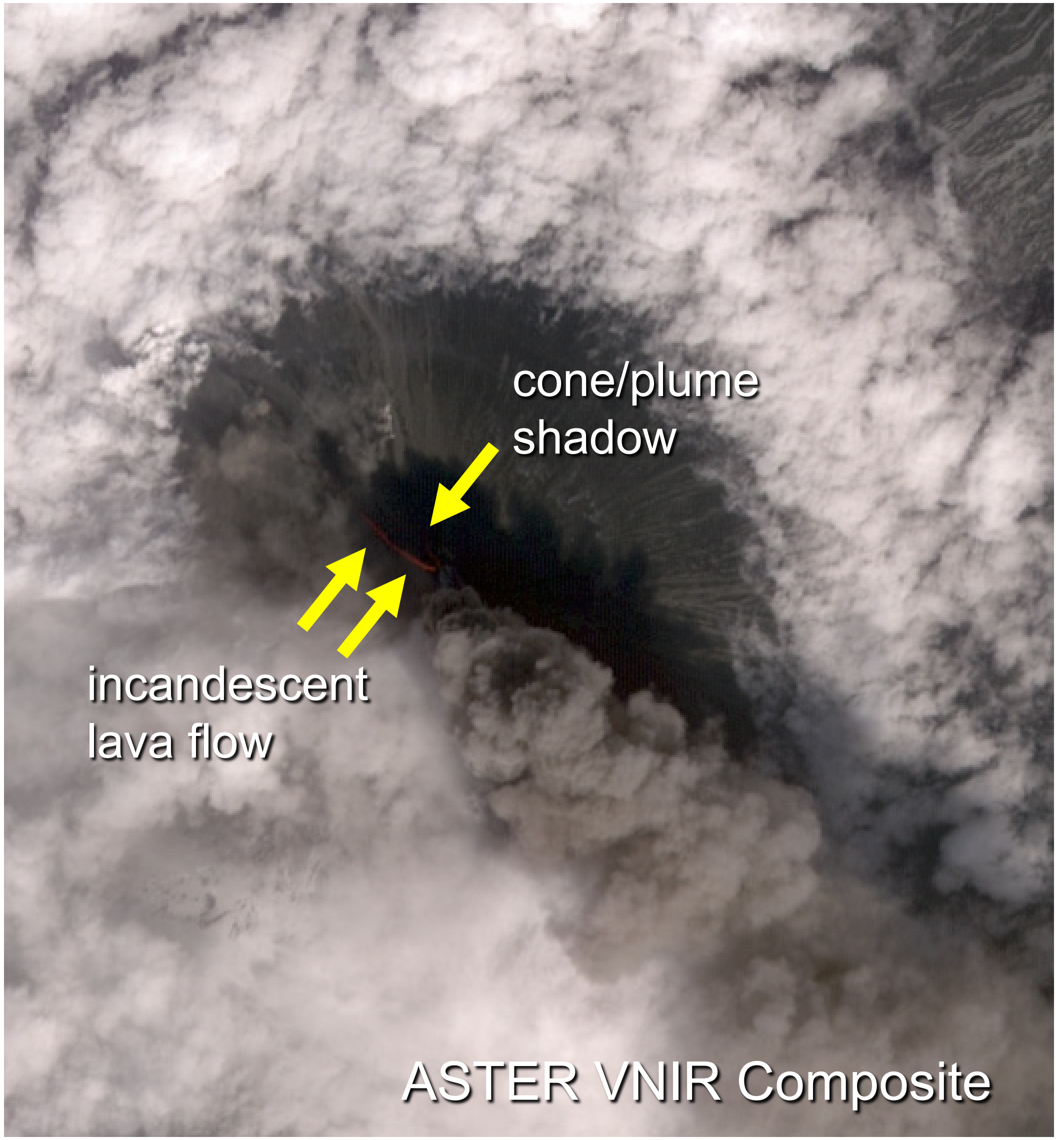
ASTER Data from Kamchatka: Aggregate to HyspIRI 60-m Resolution

Lava Flow in Shadow of Cone – Decrease Solar Component in VNIR and SWIR

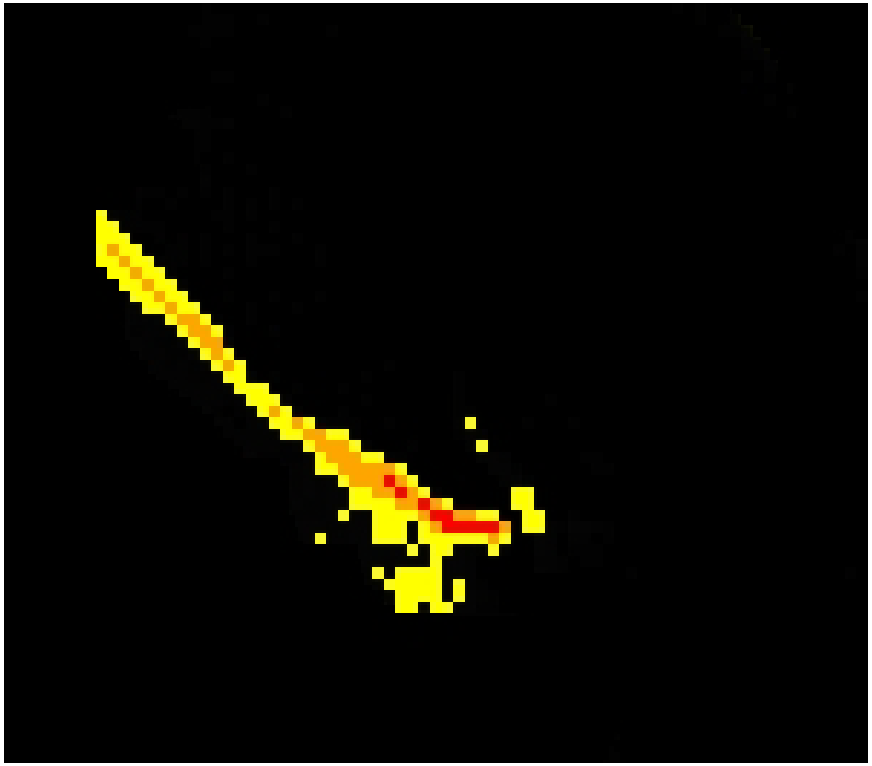
Solar Correction Applied for Remainder

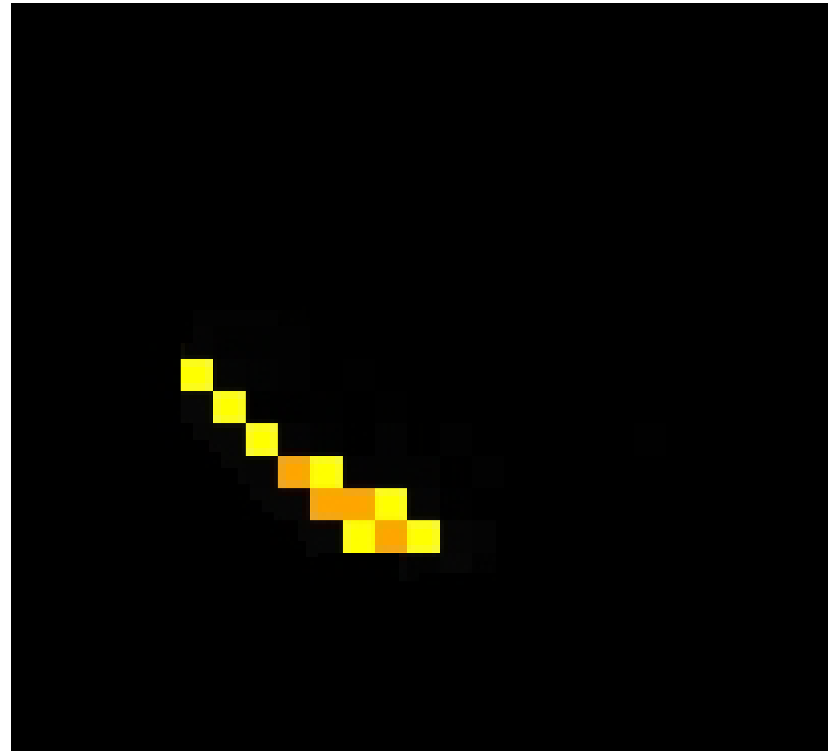
Saturation of TIR and SWIR (Despite Low Gain Setting for SWIR)

No Saturation in VNIR (with Normal Gain Setting)



(Courtesy of Mike Ramsey)





Band 3 at 15 m (ASTER)

Max. Temperature Detected: 1101 K

Band 3 at 60 m (HyspIRI)

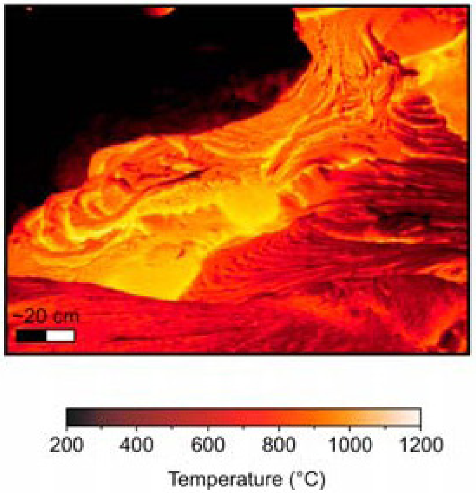
Max. Temperature Detected: 1043 K

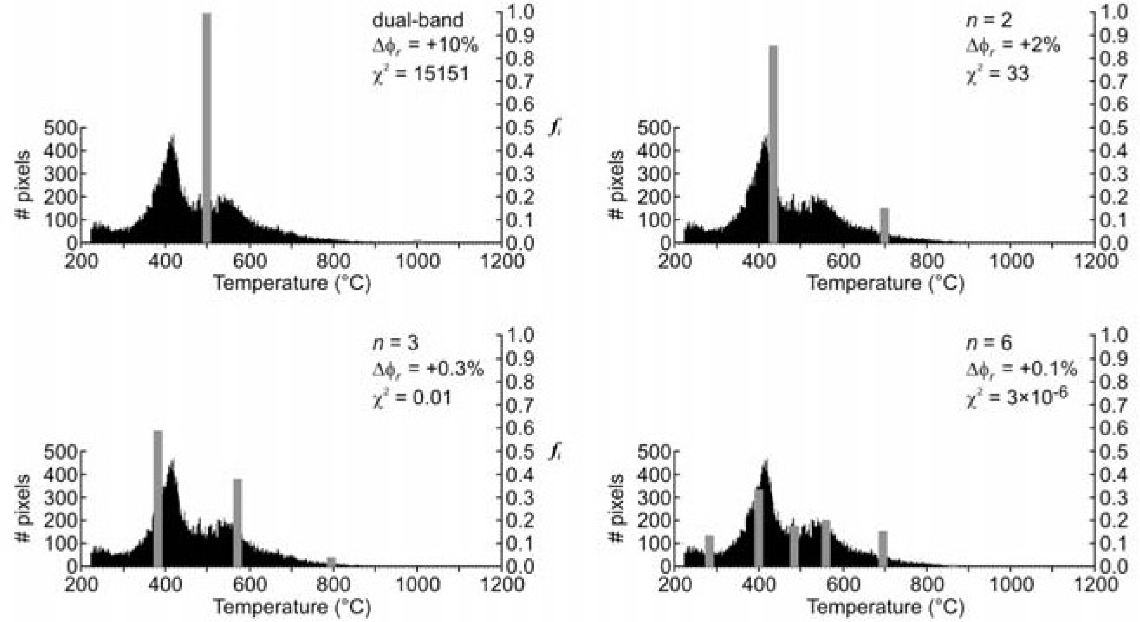
Color Code for Temperature

Red:	1073 – 1123 K
Orange:	1023 – 1073 K
Yellow:	973 – 1023 K

(Courtesy of Mike Ramsey)

FLIR-Based Temperature Map





(Wright et al., 2010)

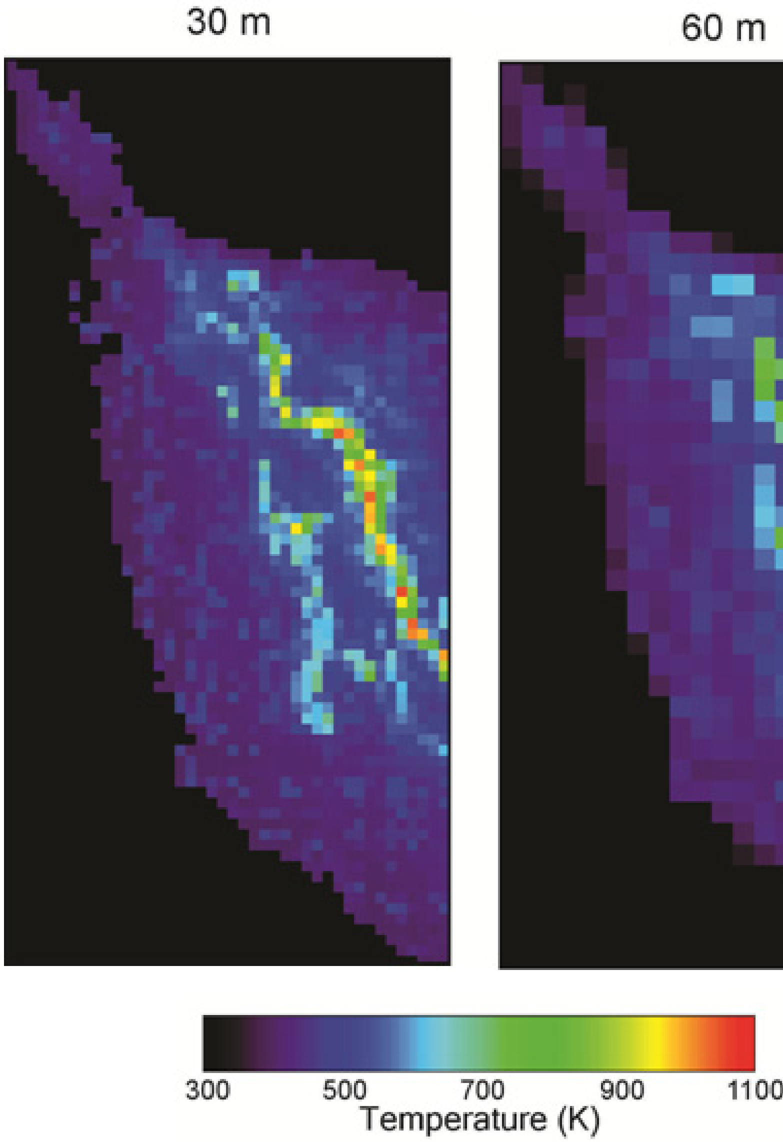
Hyperspectral VSWIR Imaging of Lava Flows

Temperature Distribution w/in Pixel Involves More than Two Components

Multi-Component Models Require Additional Spectral Information

Analyze Hyperion Data (196 Unique Bands between 0.4 – 2.5 μm);

Determine the Minimum Number of Components Needed to Fit Observed Spectrum

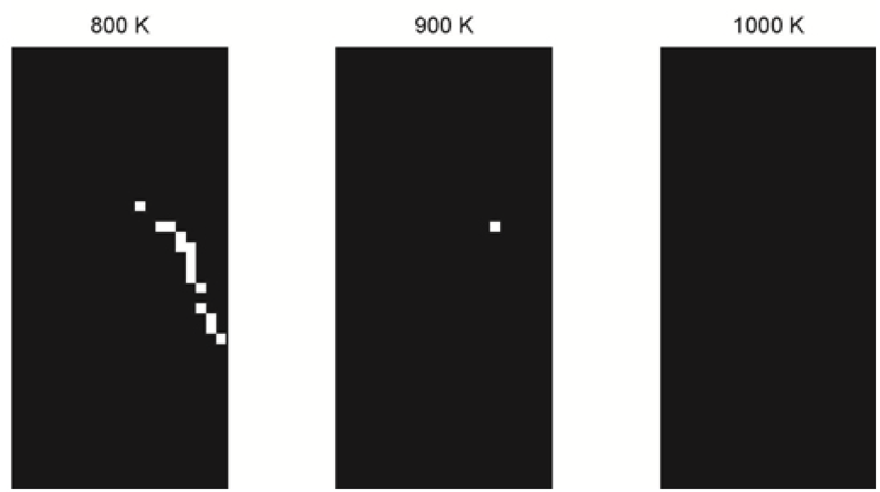


Application to Nyamuragira Lava Flow

Night-time Hyperion: 21 May 2004

Multi-Component Model Run for Each Pixel:

- Resulting Temperature Distribution Used to Generate Synthetic Radiance Spectrum Covering 0.4 – 14 µm
- Convolved With Spectral Response of HyspIRI 4-µm Channel



Sat. Temp. of 1000 K Needed to Avoid All Saturation

(Courtesy of Rob Wright)

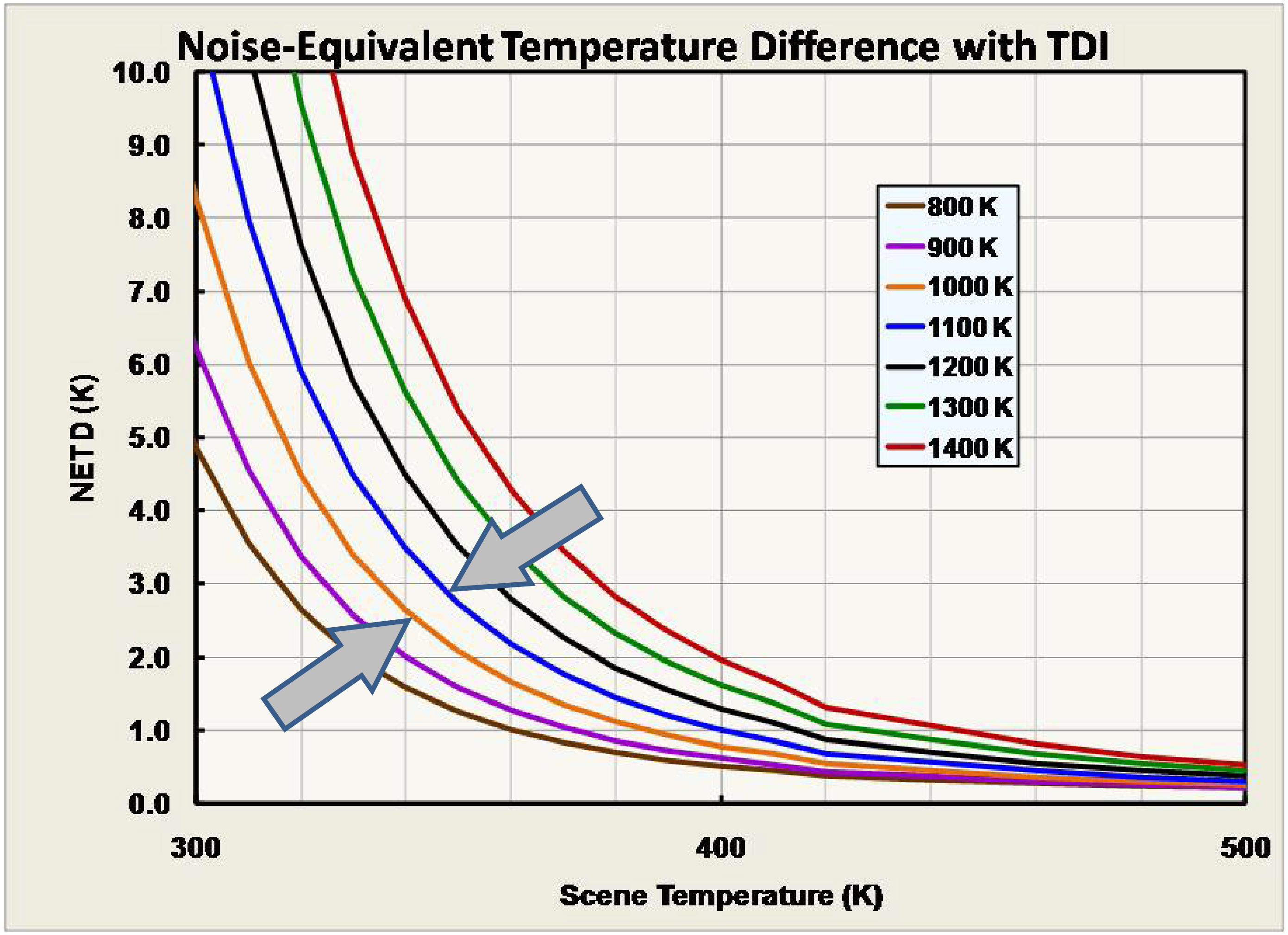
Conclusion

Recommend Saturation Temperature of <u>1100 K</u>

Case Studies and Literature Search Found Temps ~ 1000 K

NEΔT of 1 K at 400 K: 0.25% Uncertainty

High Spatial Resolution: Increase Apparent Temperatures of Hot Spot Pixels



(Courtesy of Mark Foote)