



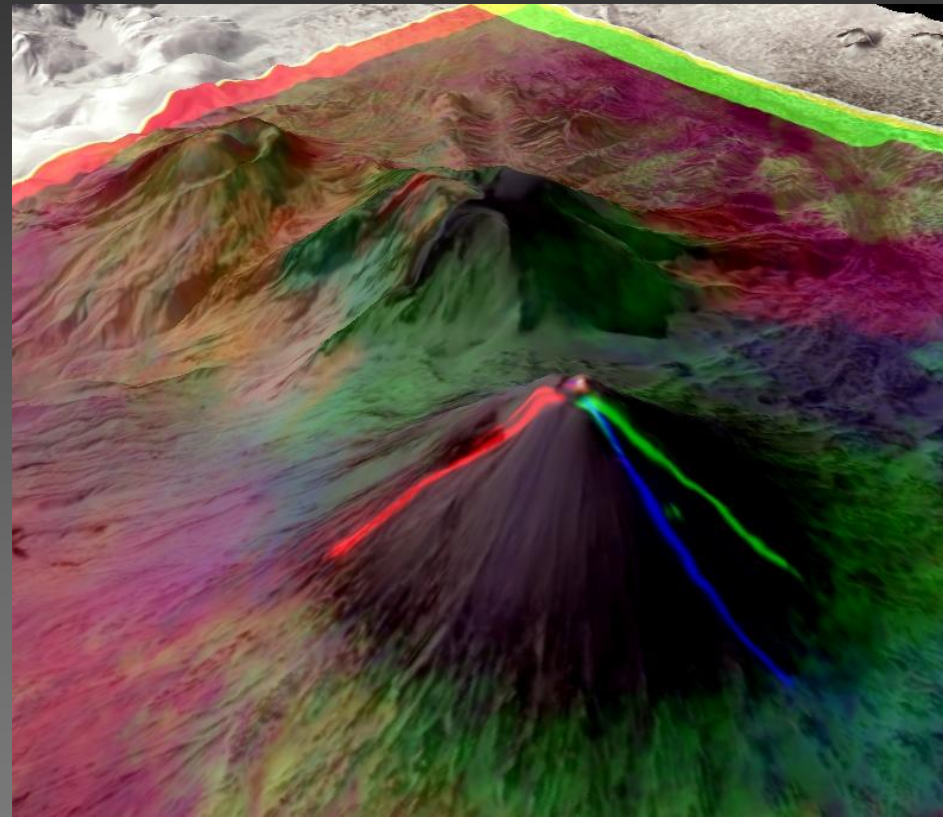
# How will remote sensing of volcanic activity evolve with HyspIRI?

**Michael Ramsey**

*Department of Geology and Planetary Science  
University of Pittsburgh, Pittsburgh, PA, USA*

**Andrew Harris**

*Laboratoire Magmas et Volcans, Université Blaise Pascal,  
Clermont-Ferrand, France*



*ASTER data of the 2007 eruption and lava flows of  
Kliuchevskoi Volcano, Kamchatka Russia  
(red: 6 June / green: 28 May / blue: 12 May)*



# Overview

- **Review**

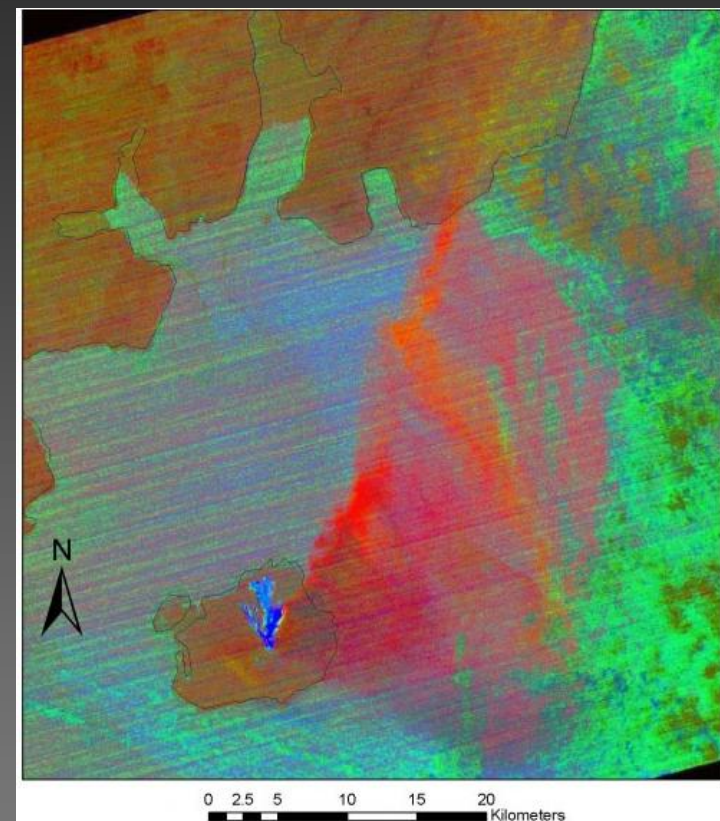
- past techniques/sensors/science
  - remote sensing of volcanic processes

- **Current State of the Art**

- improving the temporal/spatial resolution divide
- volcano science returned from multispectral TIR data

- **A Look Ahead**

- what can volcanologists hope to accomplish as the current spaceborne infrastructure ages
- a future with HyspIRI?



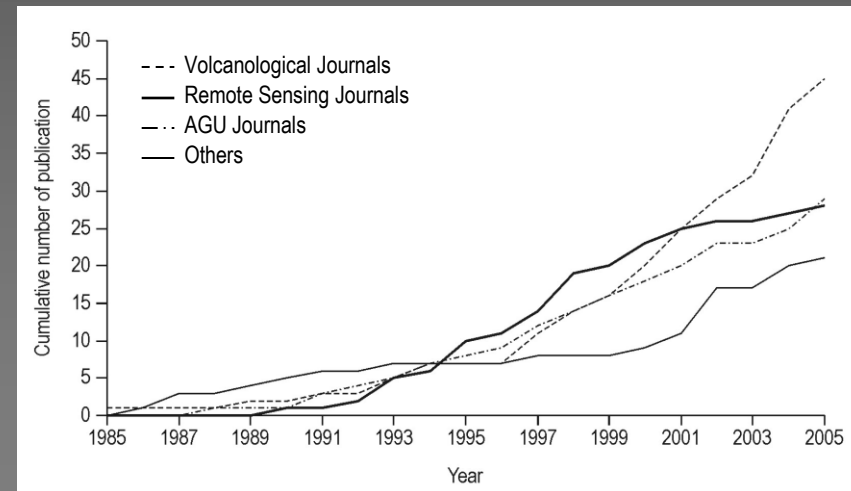
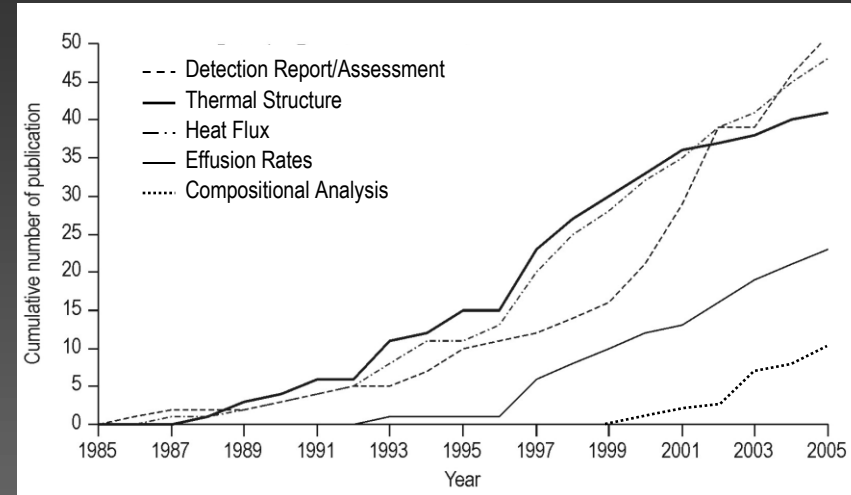
Augustine eruption (ASTER URP - TIR): 1 Feb 2006



# Literature Review

## • Volcanic Remote Sensing Using TIR Data

- over the past 2.5 decades
  - publications in all of the main thermal remote sensing topic areas have been steadily increasing
  - quantitative applications are relevant/improving
  - a shift towards publication in volcanological journals
  - *a transfer to science and system driven applications*



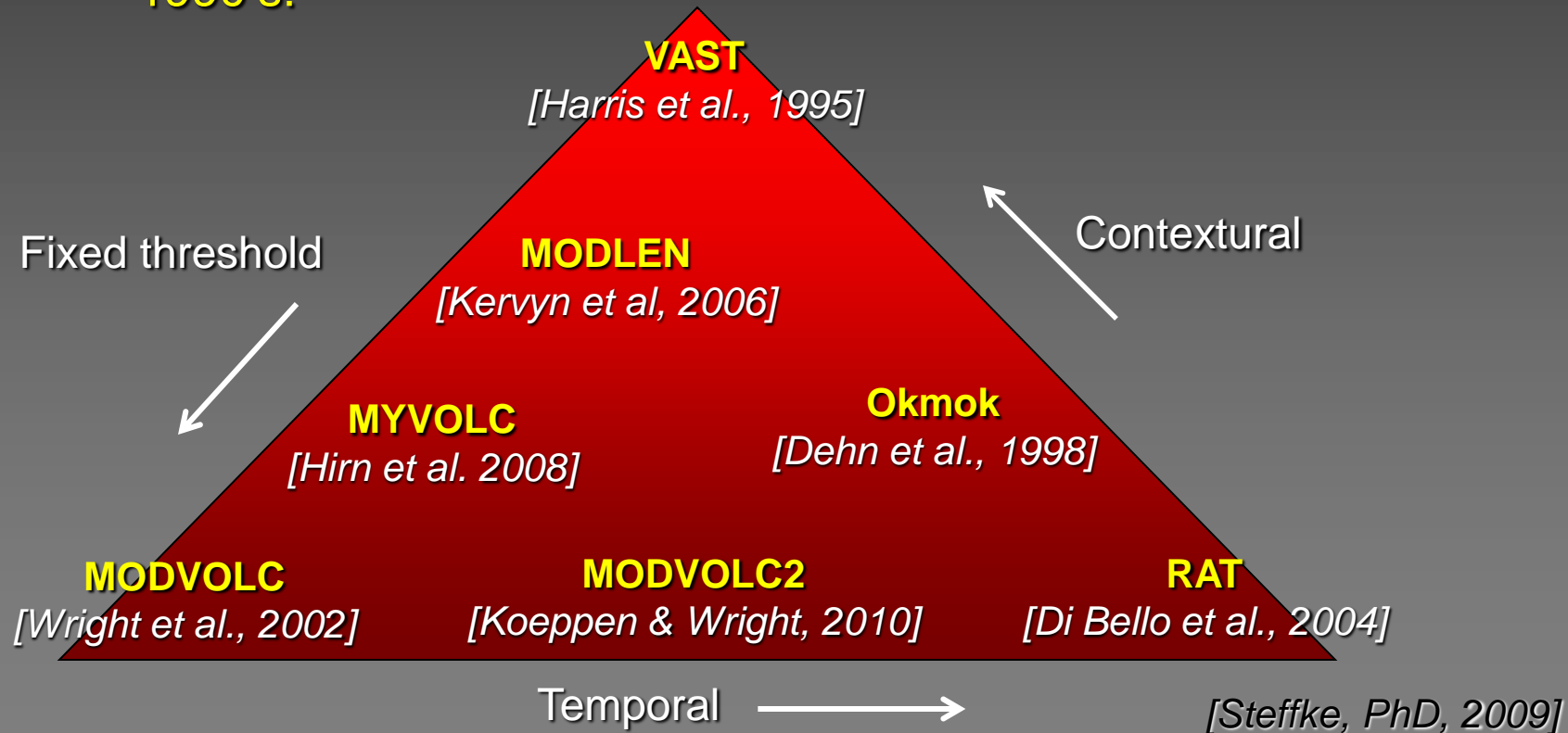


# Review: *Thermal*

- **Operational Algorithms**

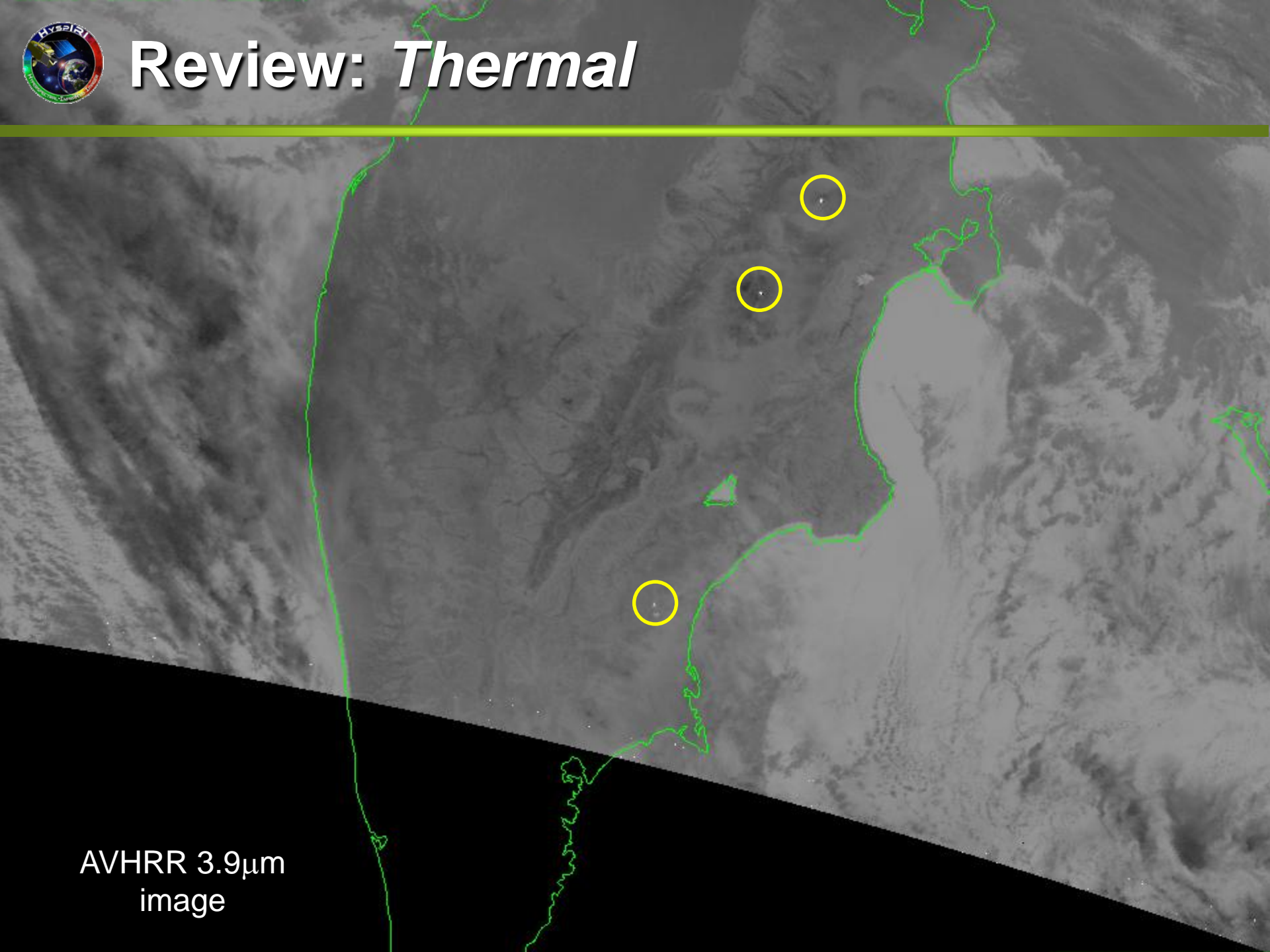
- used for routine thermal anomaly detection

- based on three end-member algorithms developed in the 1990's:





# Review: *Thermal*



AVHRR 3.9 $\mu$ m  
image



# Review: *Thermal*

- **MODVOLC: Operational Since 2000**

- a decade of global hot spot data from MODIS

- output can be converted to heat or mass flux

- *accuracy improved with emissivity data*

- *must be applied with caution (process dependant)*

- example

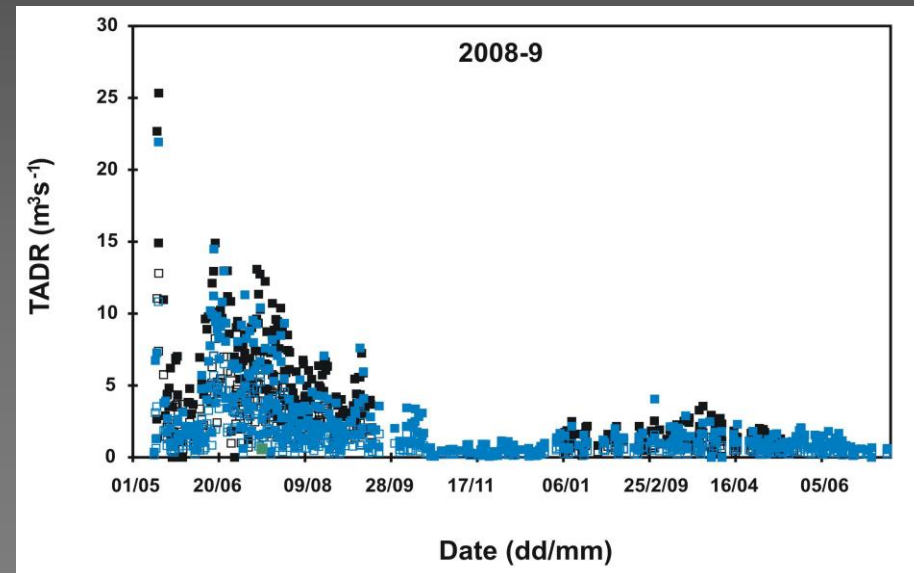
- time-averaged discharge rates for Etna's 2008-2009 eruption:

- final volume from time-integration:

- $68 \times 10^6 \text{ m}^3$

- field volume:

- $62\text{-}80 \times 10^6 \text{ m}^3$  [*Boris Behncke, pers. comm.*]



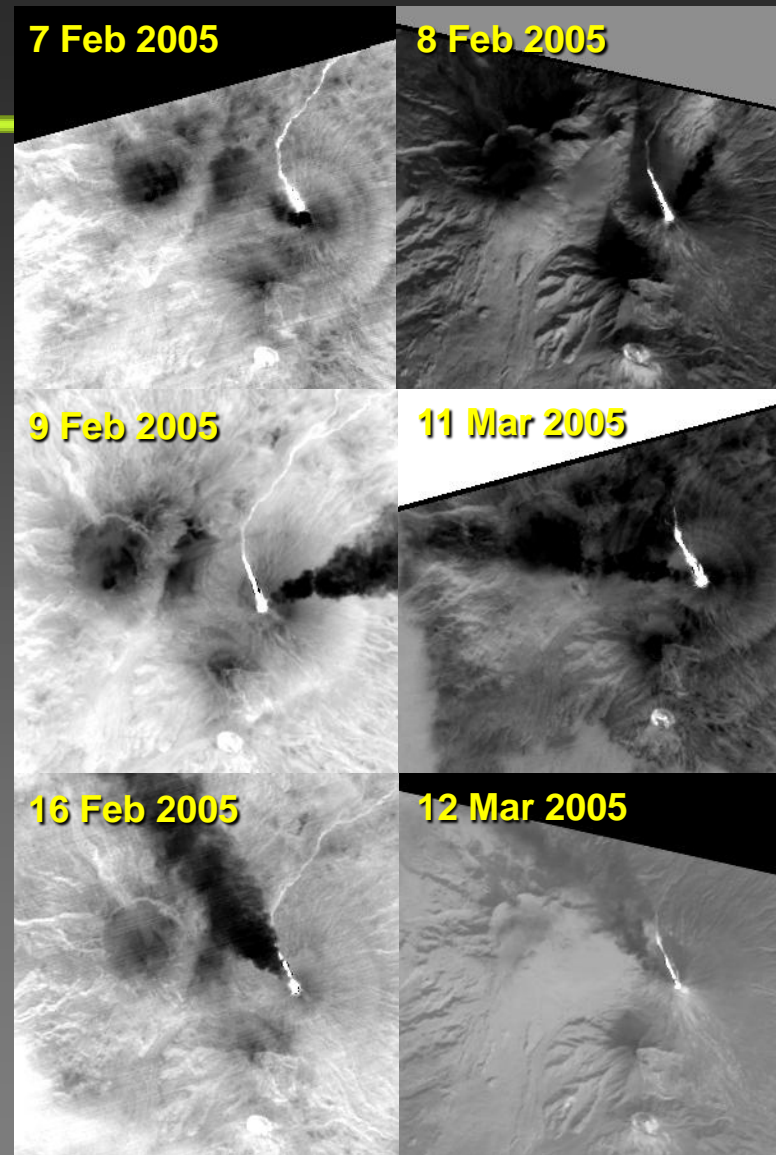
black = AVHRR (281 pts)

blue = MODIS (375 pts)



# Integration

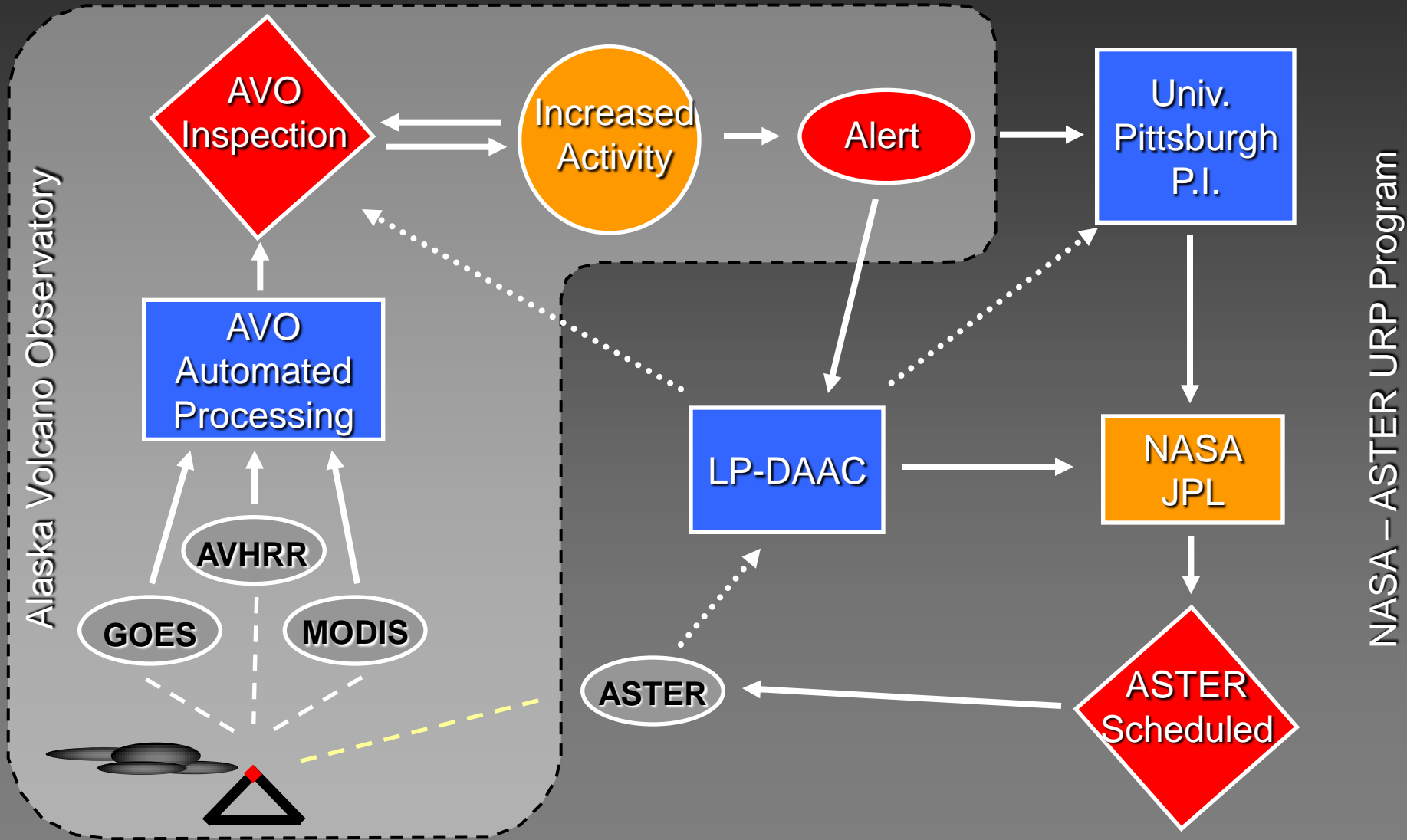
- **ASTER Urgent Request Protocol (URP) Program**
  - integrates Alaska Volcano Observatory monitoring into the ASTER Urgent Request stream
    - focused on the northern Pacific volcanic arc
    - thermal (AVHRR/MODIS) alerts
      - detection and filtering algorithm at UAF-AVO (*Okmok-II*)
        - improved noise detection & minimize false positives
      - trigger automated request which is sent to the LP DAAC



Kluichevskoi Time Series



# Integration (ASTER/AVHRR)



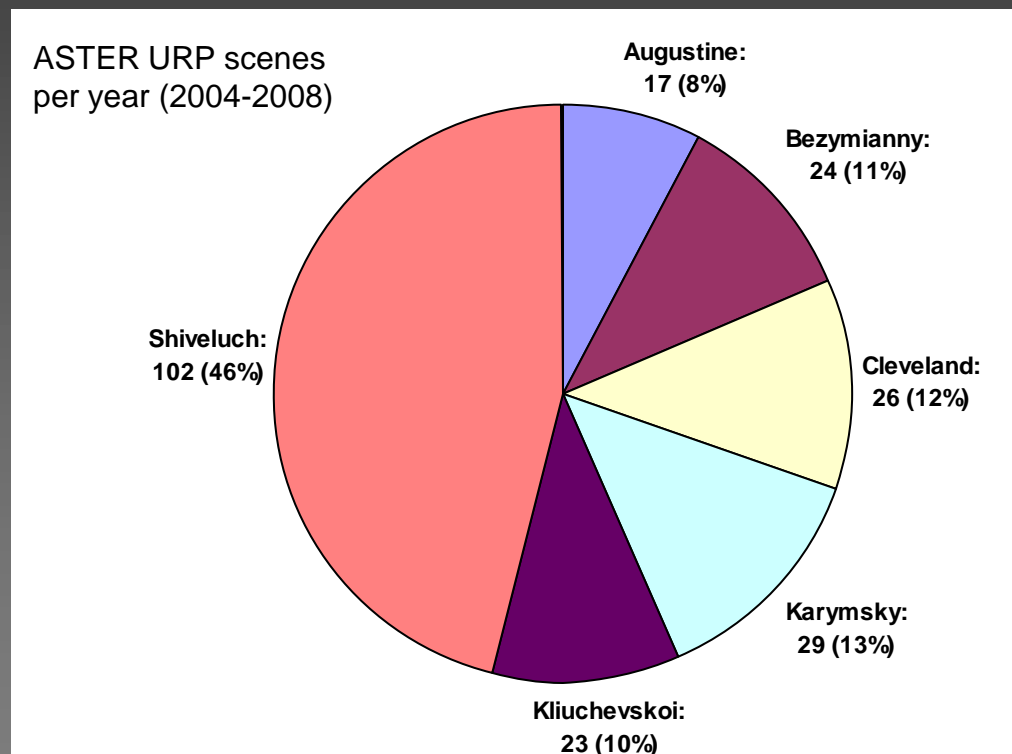




# ASTER URP Summary

- **North Pacific (2004 – 2008)**

- 18 different volcanoes targeted
- 93% from the automated algorithm based on thermal alerts from AVHRR
- 7% from user-defined requests
- similar % to the AVHRR alerts



average: 1 TIR scene / 8 days



4 Jan 07

ASTER VNIR



ASTER SWIR

$T_{max} = 218^{\circ}\text{C}$





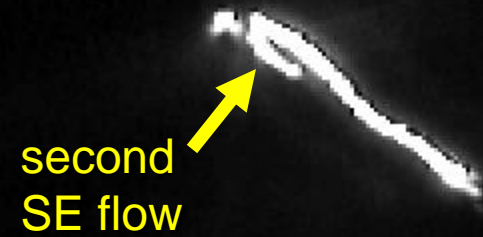
5 June 07

ASTER TIR (night)



ASTER SWIR (night)

$$T_{b(max)} = 467^{\circ}\text{C}$$





6 June 07

ASTER VNIR (day)

0 3km

ASTER SWIR (day)

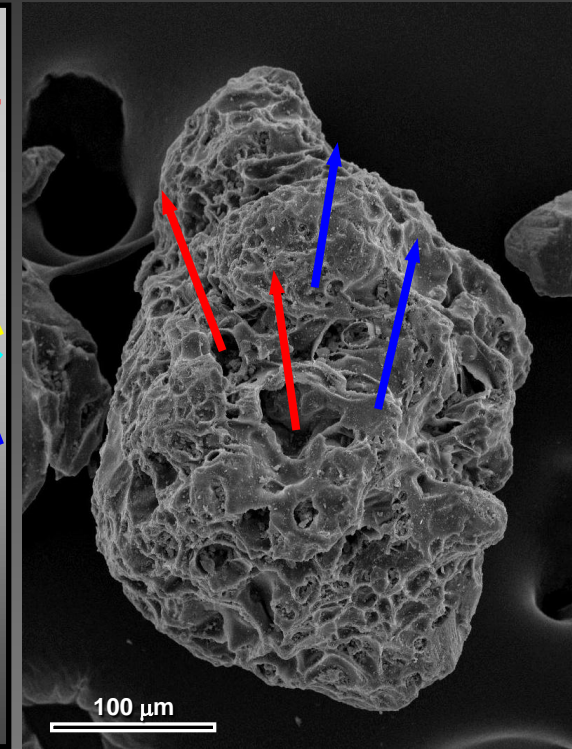
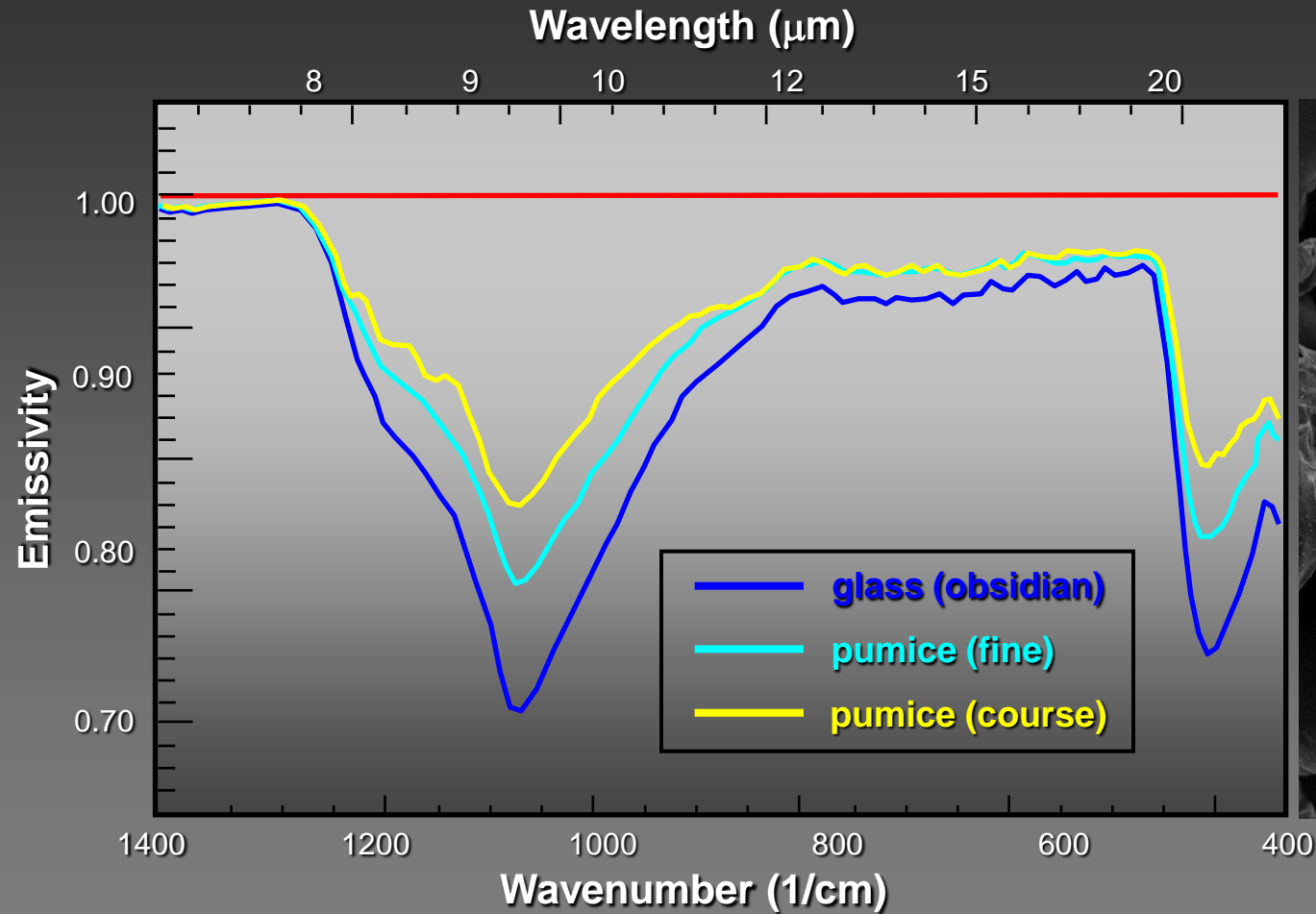
$T_{max} = 465^{\circ}\text{C}$

new flow  
in 13 hrs  
 $v = 26 \text{ m/hr}$



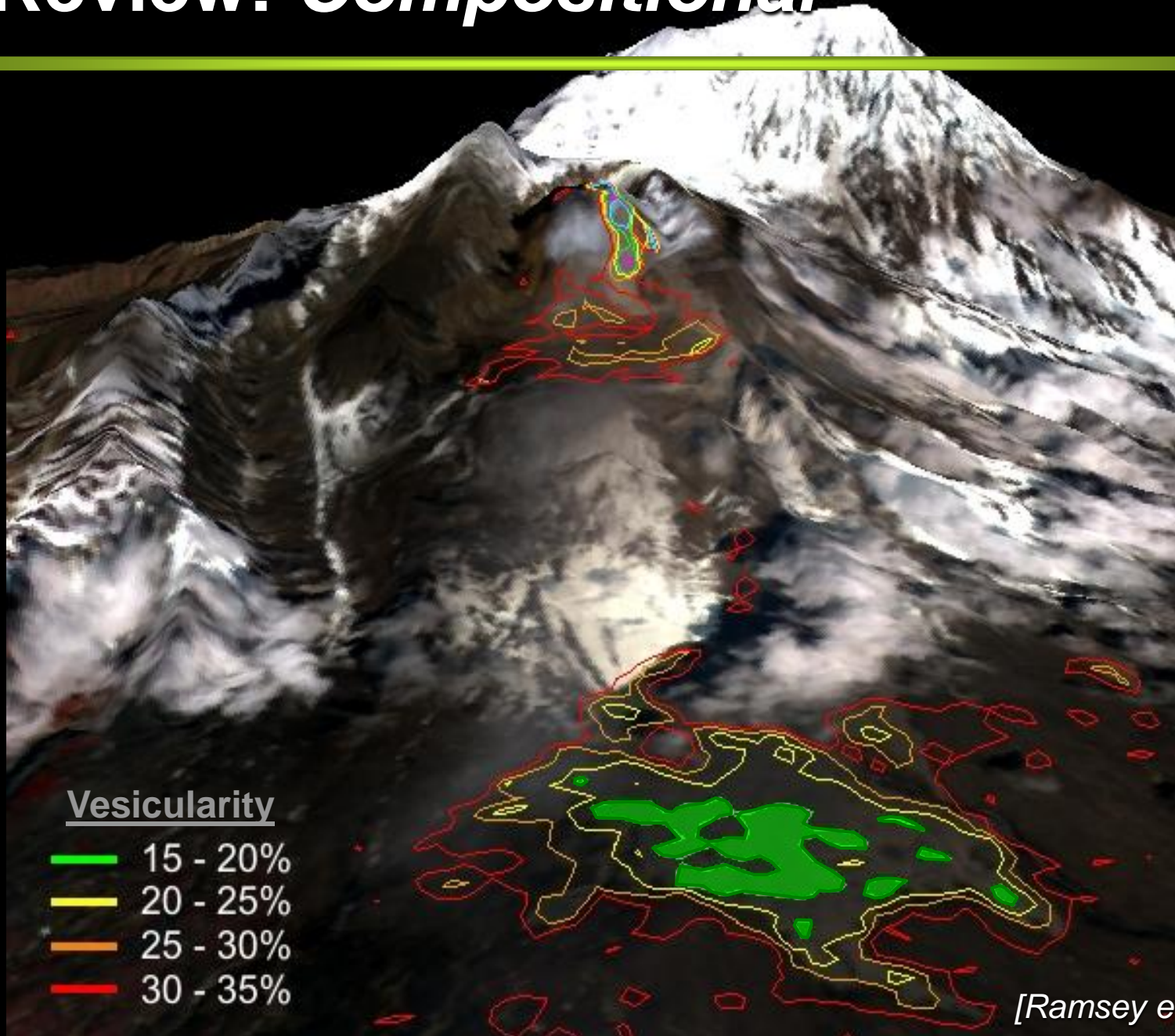


# Review: *Compositional*





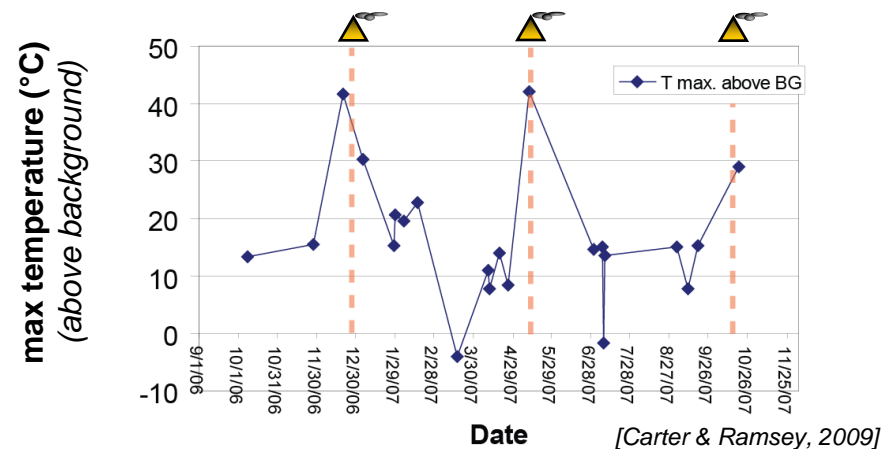
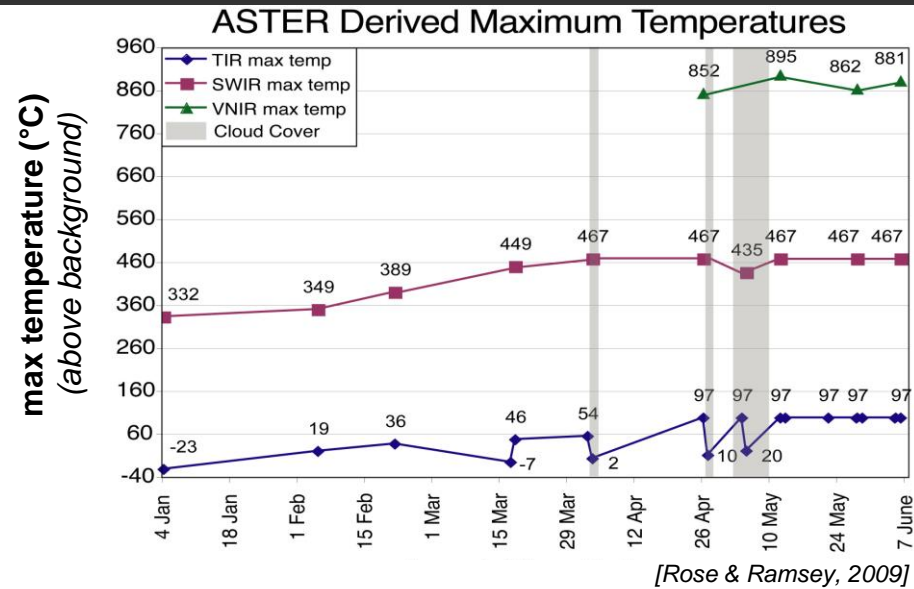
# Review: Compositional





# Science Results

- **Kluichevskoi Volcano**
  - 2007 eruption phases based on increasing temperatures
    - progressive saturation
- **Bezymianny Volcano**
  - thermal precursory signals detected in the ASTER TIR data prior to 2 of the 3 eruptions
  - similar behavior of the dome over the long term

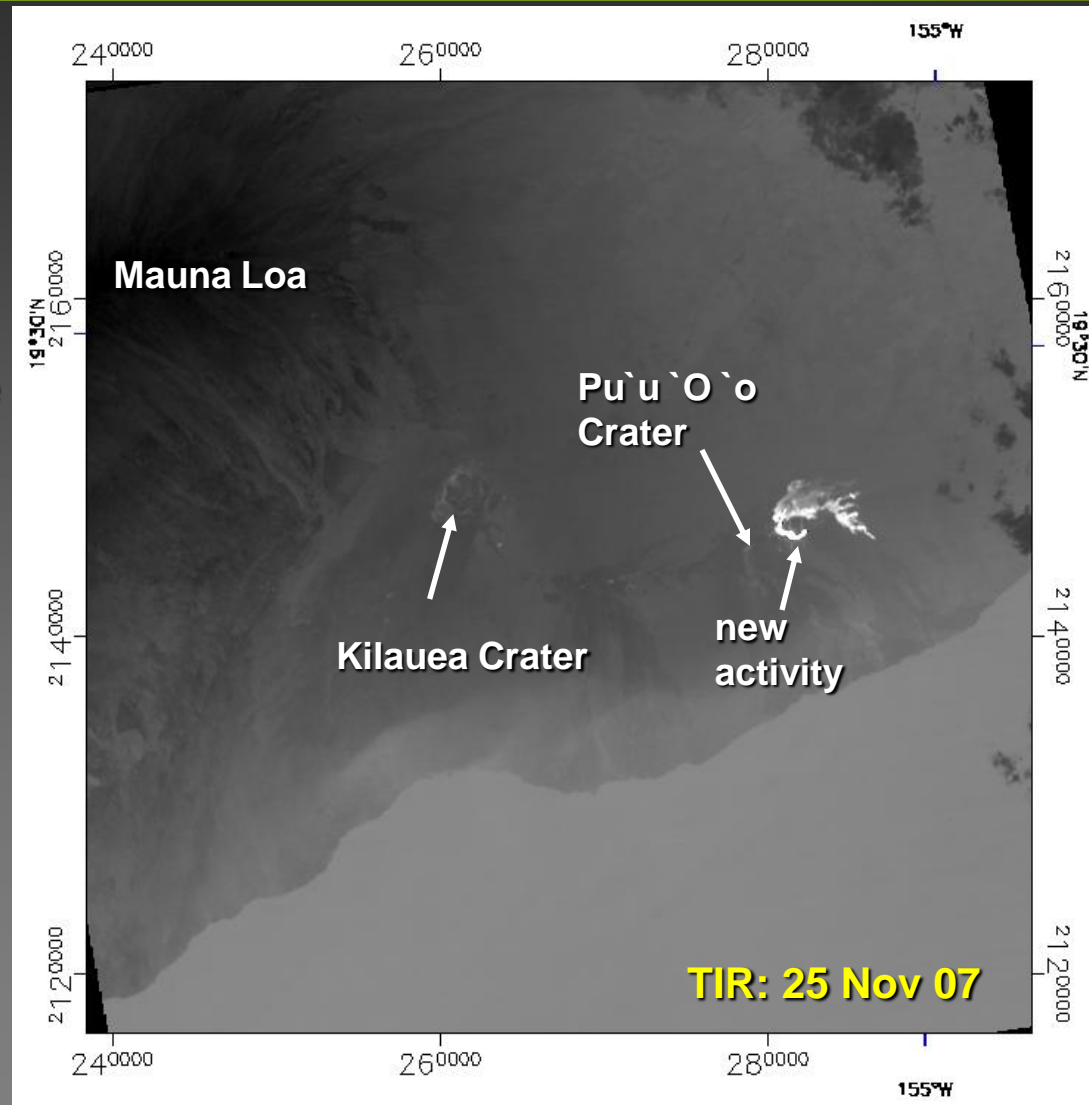


**large eruptions:** 24 Dec 2006, 11 May 2007, 14 Oct 2007



# Temperature Response

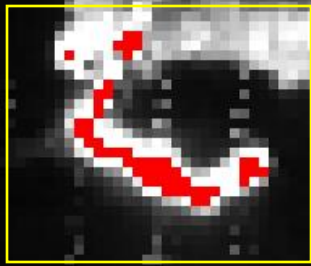
- **2007 Kilauea Eruption**
  - 15 observations: July-Dec 2007
    - full mode night time imaging (11/25/07)
      - VNIR: HGH gain
      - SWIR: LO2 gain
- **HyspIRI Analysis**
  - VNIR radiance degraded to 60 m
  - reference channel T- $\epsilon$  separation





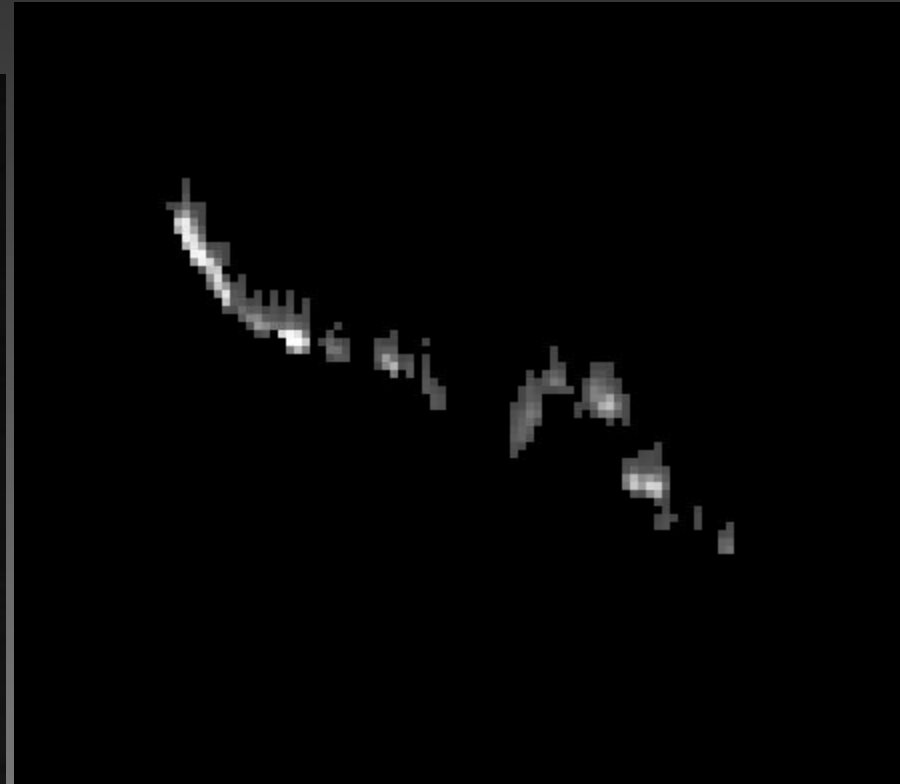


# Temperature Response



**TIR temp (90m)**

$T_{\text{TIR}}$  (max detected) = 100 C  
*saturated pixels (red)*



**Band 3 (HGH gain) temp (15m)**

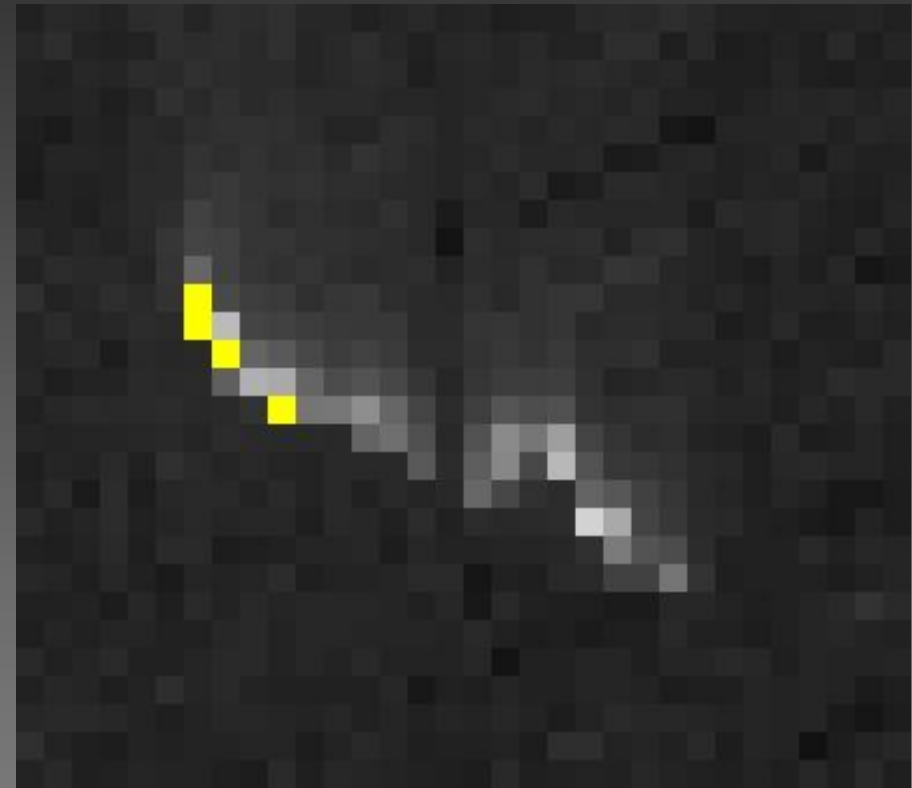
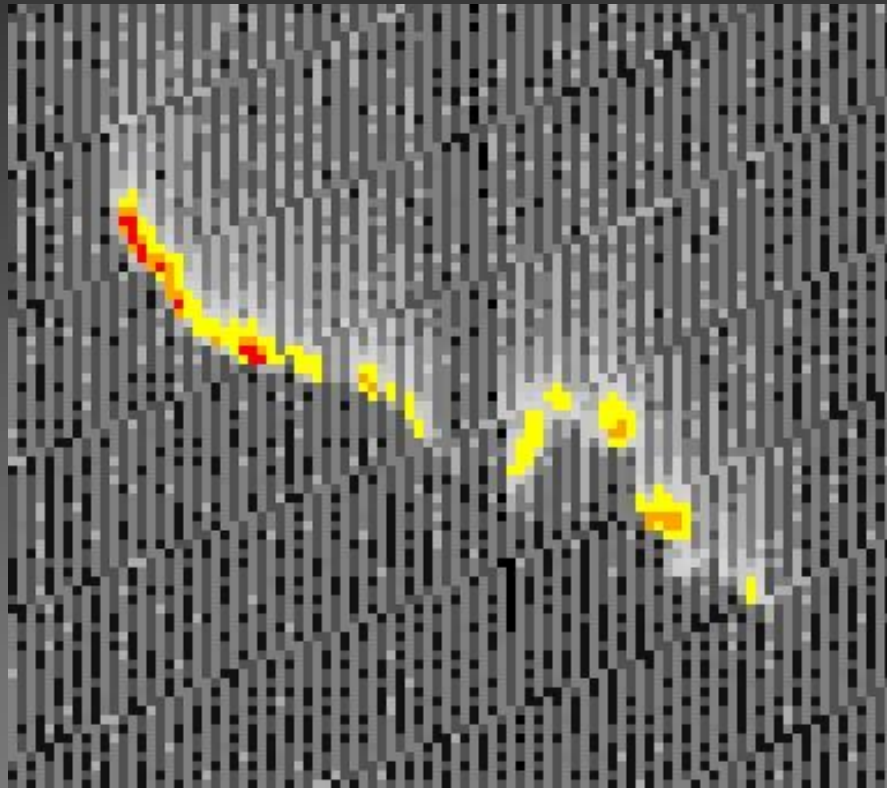
$T_{\text{b3}}$  (max detected) = 849 C  
 $T_{\text{saturation}} = 999 \text{ C}$





# Temperature Response

*VNIR Night Time Data: L1B*



**Band 3 (HGH gain) temp (15m)**

$T_{b3}$  (max detected) = 849 C

700-750 C (yellow), 750-800 C (orange),  
800-850 C (red)

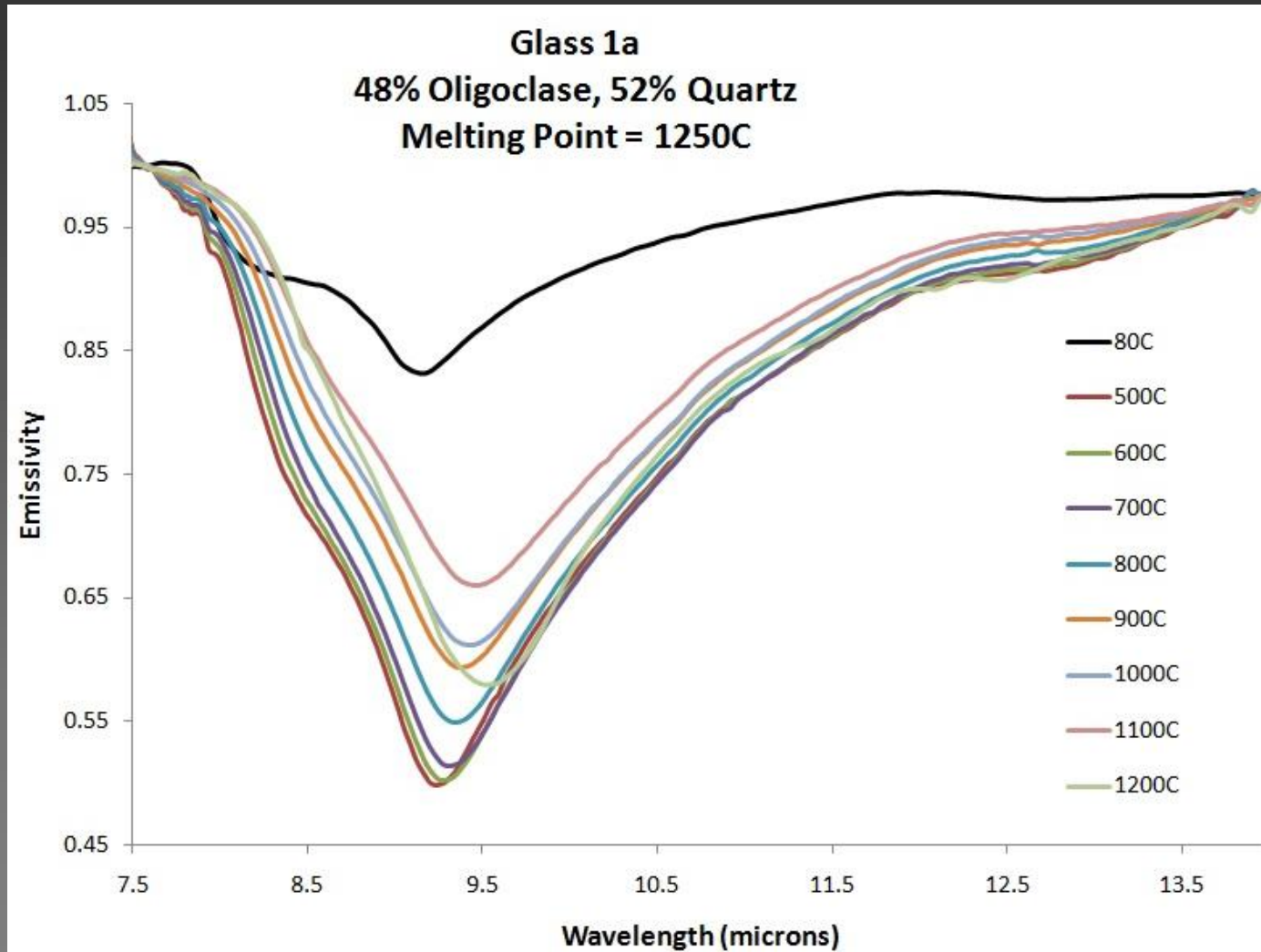
**Band 3 temp (60m)**

$T_{b3}$  (max detected) = 720 C

*simulated HyspIRI*



# Compositional: Melts



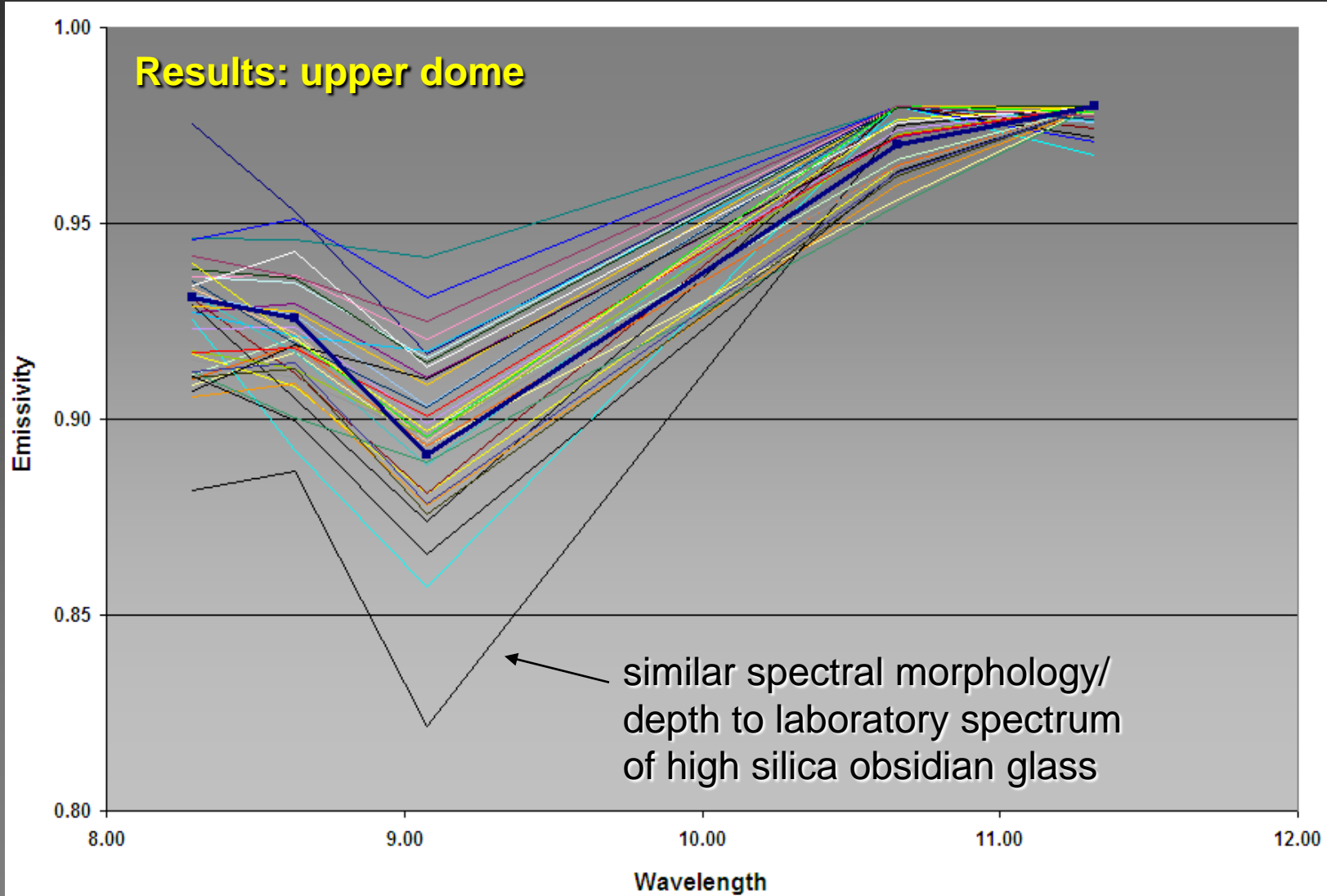
**Mono Craters, Long Valley, CA**



super-resolution  
ASTER DCS  
bands: 13,12,10



# Compositional: Glasses





# Conclusions

- **HypIRI Simulations**

- ASTER temperature data

- 15m/pixel degradation to 60 m/pixel

- maximum extracted temperatures from 850 to 750 °C

- ASTER emissivity data

- newly-developed image processing algorithms (super-resolution) allows fully radiometrically accurate/reversible TIR radiance data to be created

- improvement to 60 m/pixel simulated HypIRI

- extraction of more detail spectral information





# Conclusions

- **The Past Decade**

- capacities (*technological, computing/ processing and algorithm capability*) advanced faster than predicted
- volcanological remote sensing using TIR data expanded exponentially with every new orbital sensor
  - *temperature and compositional data allows exploration of numerous processes from activity onset to eruptive products*

- **The Next Decade**

- routine use of remote sensing metrics for input into integrated monitoring, modeling and hazard appraisal
- concern: looming lack of TIR data for volcano studies
  - essential that we retain a 3.9  $\mu\text{m}$  capability
  - essential that we retain robust TIR capability



# Thanks ...

- **Collaborators:**

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