Monitoring of Effusive Eruptions: Bezymianny, Sheveluch & Mt. St. Helens Volcanoes

FLIR observation of Bezymianny Volcano
photograph by J. Dehn (U. Alaska Fairbanks)

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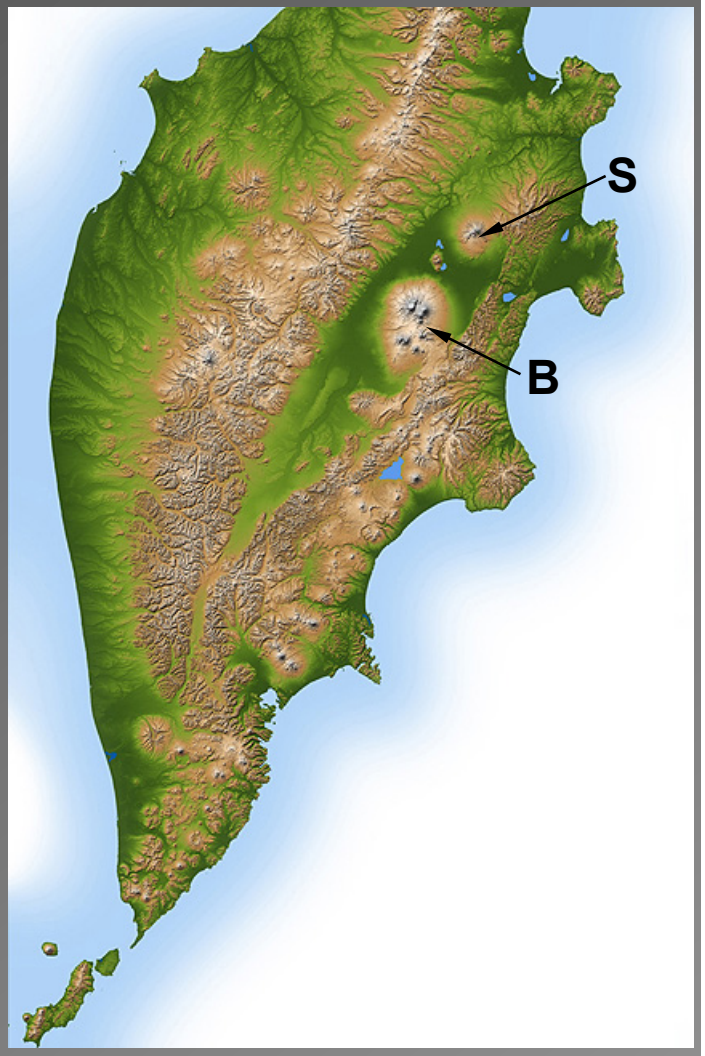
Overview

- **Background**
  - FLIR camera details
  - why the focus on Kamchatka since 2004 by the U. Pittsburgh group?
  - primarily → ASTER orbital sensor
    - Urgent Request Protocol
      - new integrated systems for rapid scanning, detection, triggering, and scheduling of rapid ASTER data
- **Review of Results**
  - Bezymianny Volcano (2000 – 2008)
  - Shiveluch Volcano (2004 – 2010)
  - *Mt. St. Helens (2004)*

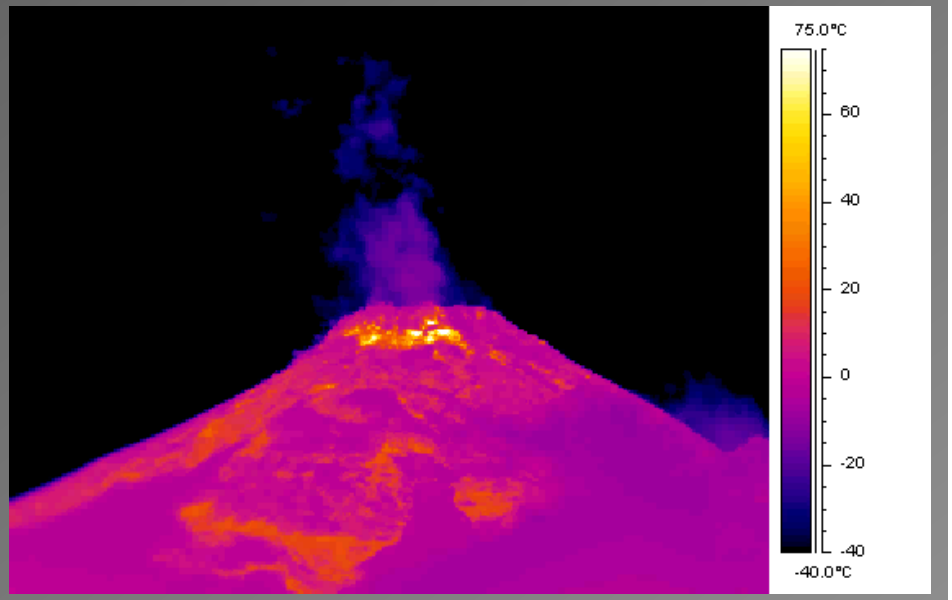


Overview

- **FLIR Camera**
  - Forward Looking Infrared Radiometer S40 camera
  - broadband radiometer 7.5-13 μm (TIR window)
  - 320 x 240 pixels (76,000)
  - thermal sensitivity of < 0.1 °C at 30 °C
  - accuracy of +/- 2 °C
  - light weight (1.4 kg)
  - still (1 image/sec) or video (60 Hz) function available
  - three gain settings: -40°C to 120°C / 0°C – 500°C / 350°C – 1500°C

Measuring with the FLIR

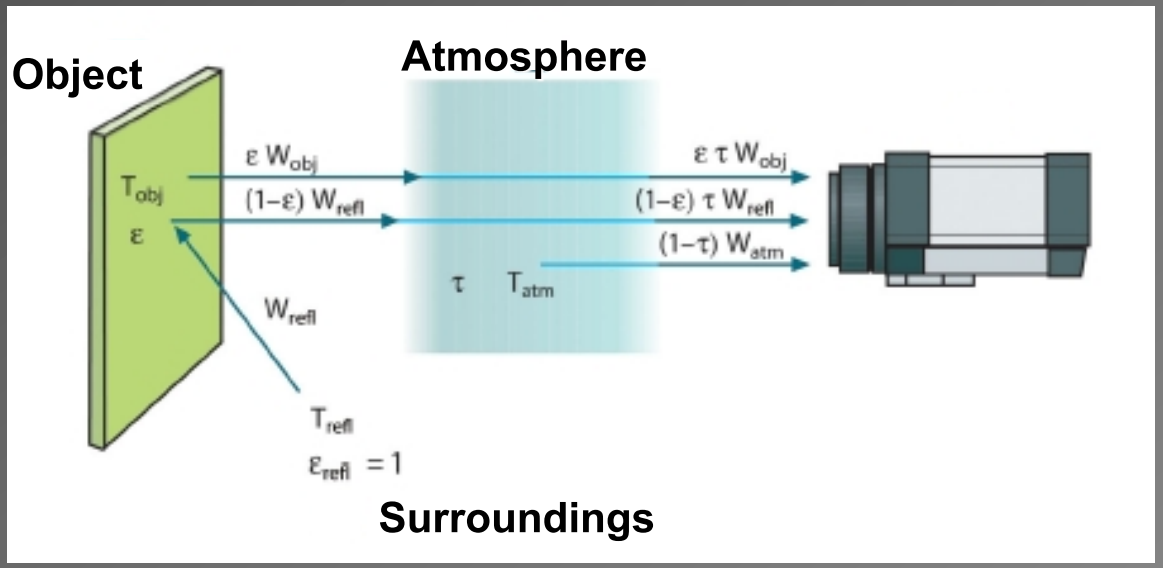
- **Operator Input Values:**
  - object emissivity (ε)
  - relative humidity (RH%)
  - object distance (D_{obj})
  - average atmospheric temperature (T_{atm})
  - reflected ambient temperature (T_{refl})



degassing of the Bezymianny lava dome

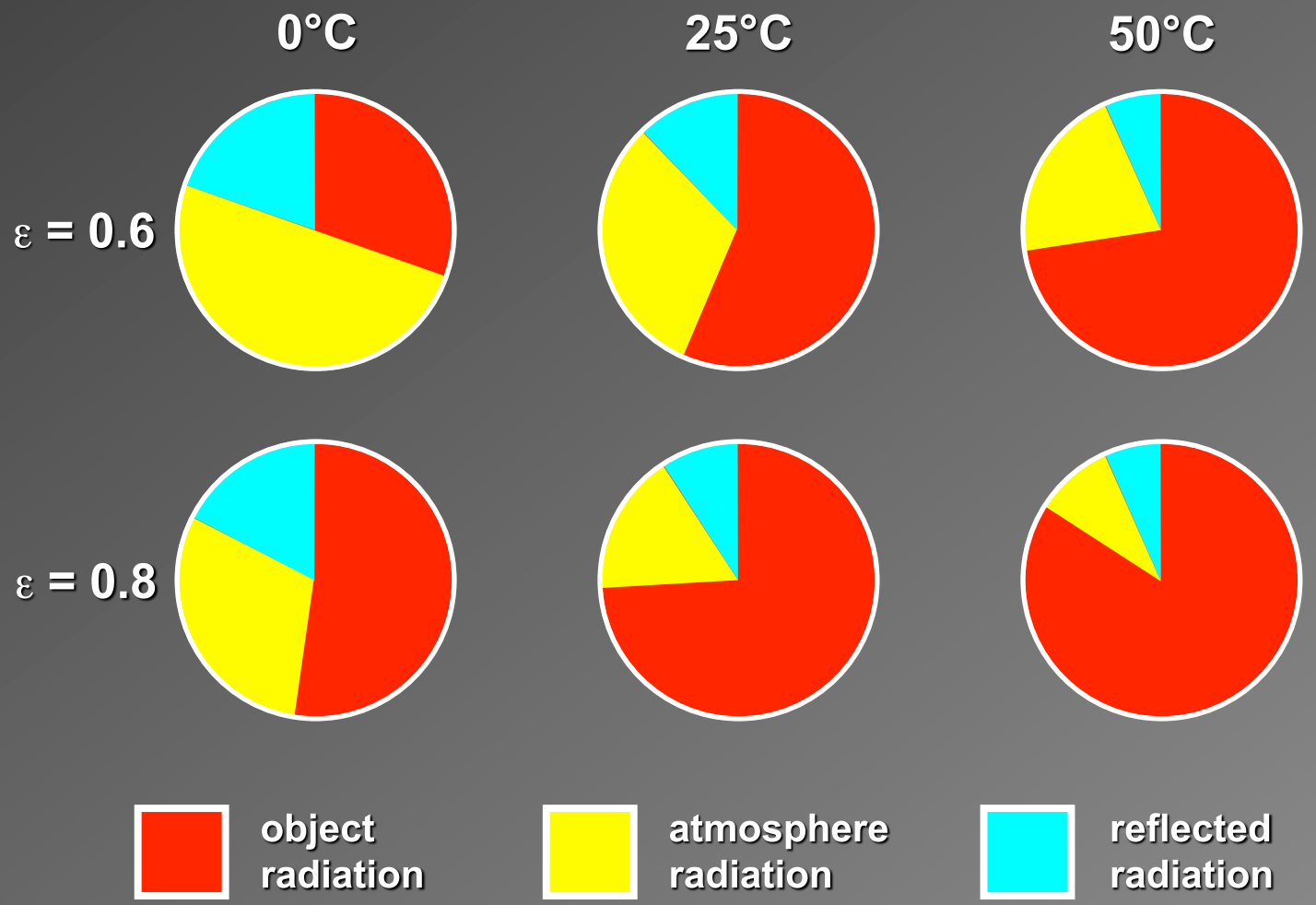
Measuring with the FLIR

- **Measurement Conditions:**
  - need to account for other thermal energy sources
    - surrounding emitting objects
    - atmosphere
      - camera has built-in atmospheric look-up parameters



$$W_{tot} = \varepsilon\tau W_{obj} + (1-\varepsilon)\,\tau\, W_{refl} + (1-\tau)\, W_{atm}$$

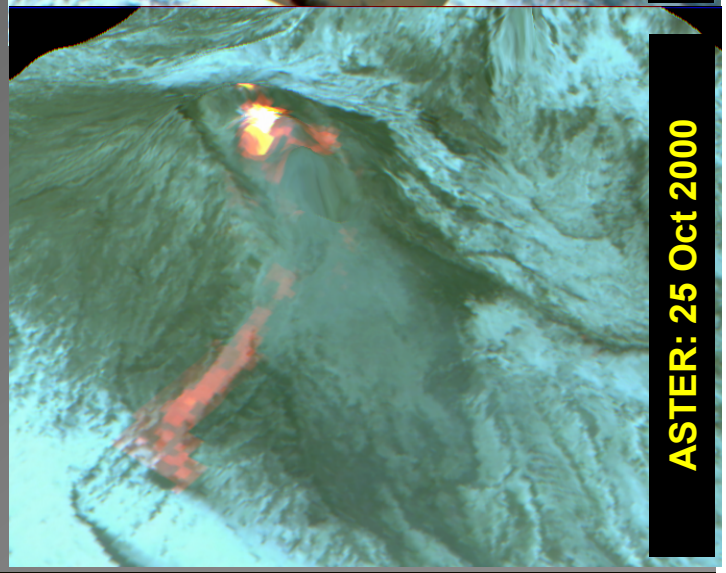
Radiation Source Variation



Why the Focus on Kamchatka?

- **Began as a Test Location**
  - new ASTER sensor in early 2000
    - captured the products of the March, 2000 Bezymianny eruption
  - large data volumes continued
    - high latitude, weather, orbit of the sensor, activity levels
  - funded NASA program for ASTER rapid eruption response
    - renewed for years 7 – 9
    - collaborative program of sensor integration, monitoring and science
      - universities, USGS, IVS-KVERT

AVHRR: 9 Oct 2000



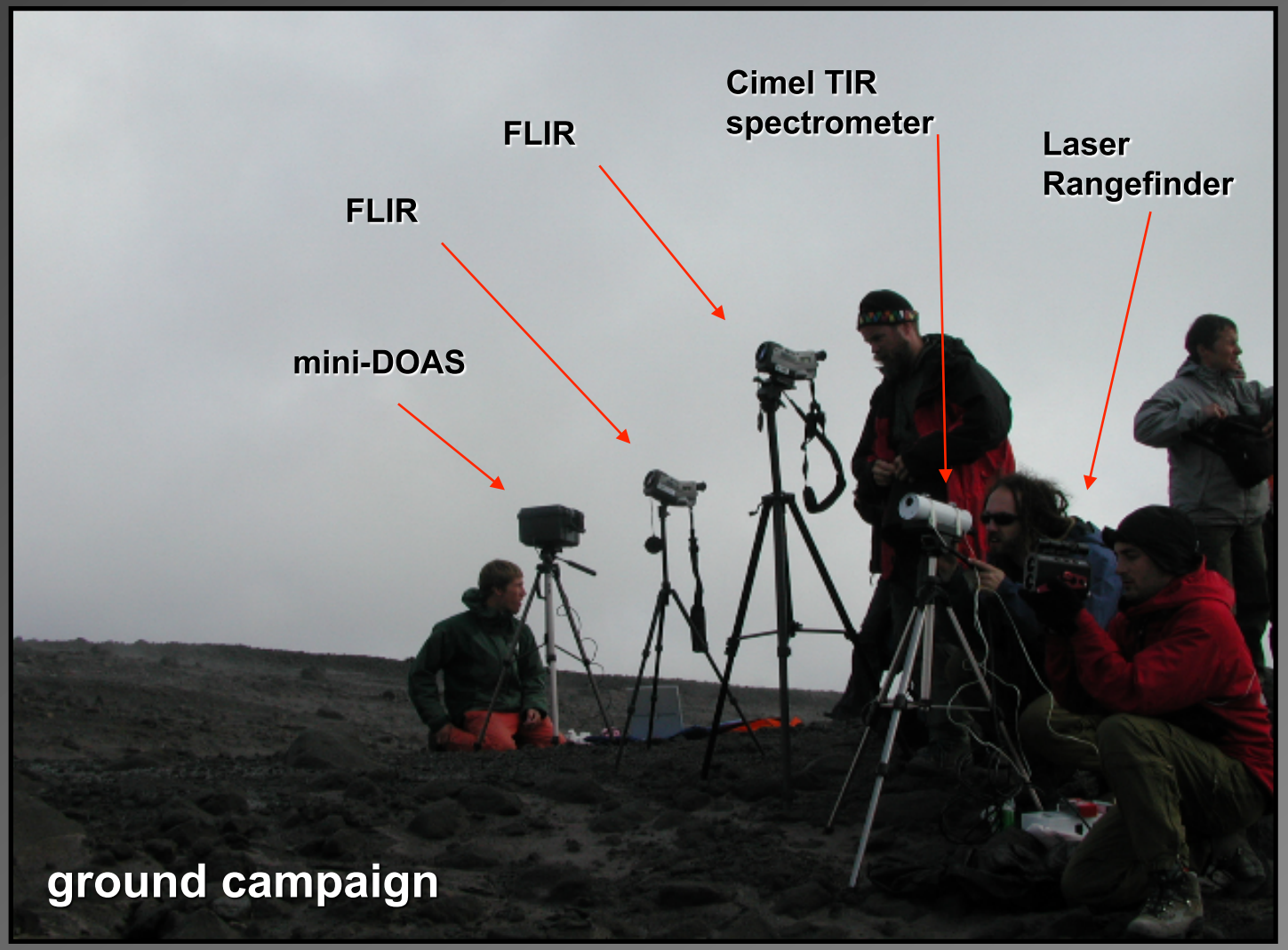
ASTER: 25 Oct 2000

Bezymianny Volcano

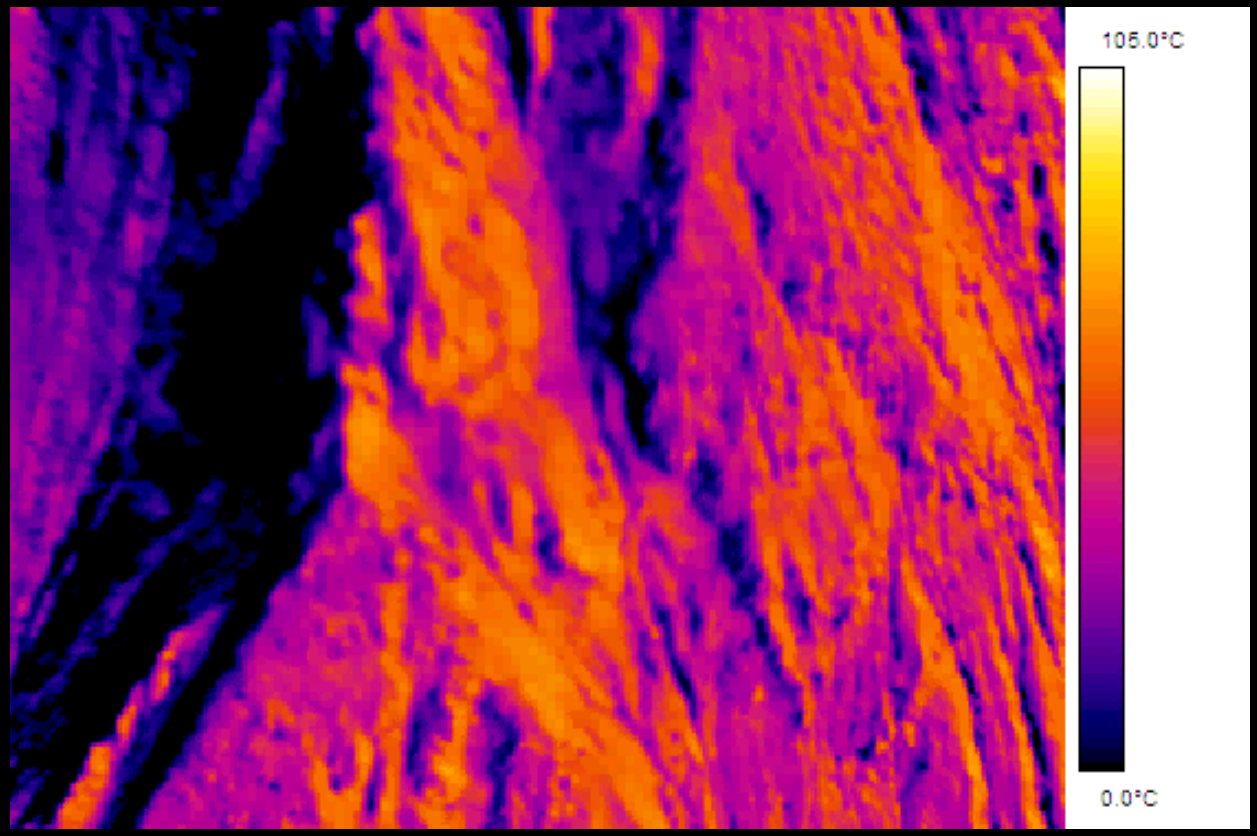
Kamchatka FLIR Data Collection

- **"Primitive" Data Collection**
  - multiple field campaigns to examine thermal flux of the dome regions
    - 2004, 2005, 2007, 2011
  - coincident handheld thermal camera(s) (FLIR) and/or visible video data over the summit/ dome
    - 500 – 800 m above dome
- **Long-Distance Ground Based Acquisitions**

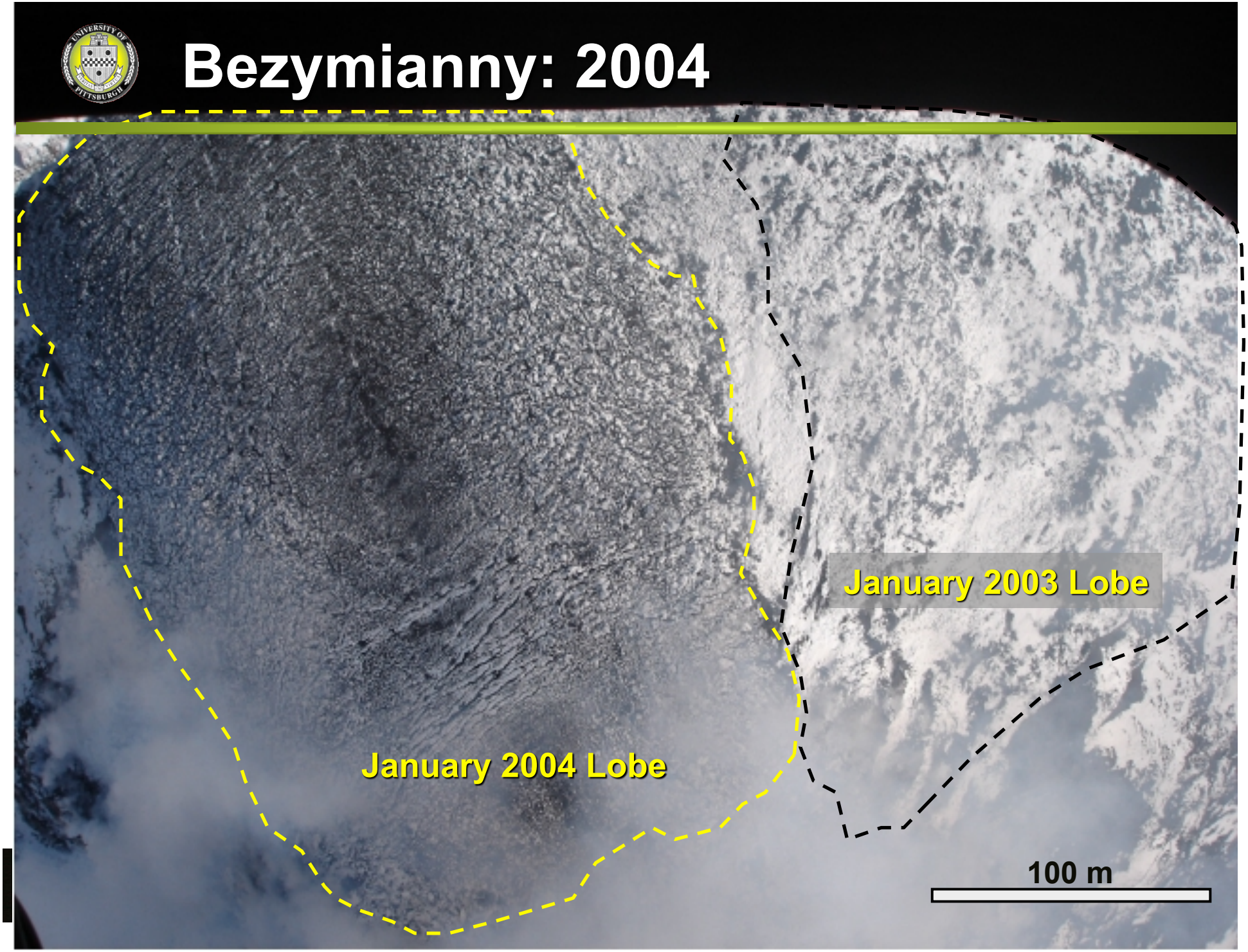
Typical Ground Deployments



Typical Bezymianny Overflight



Bezymianny: 2004



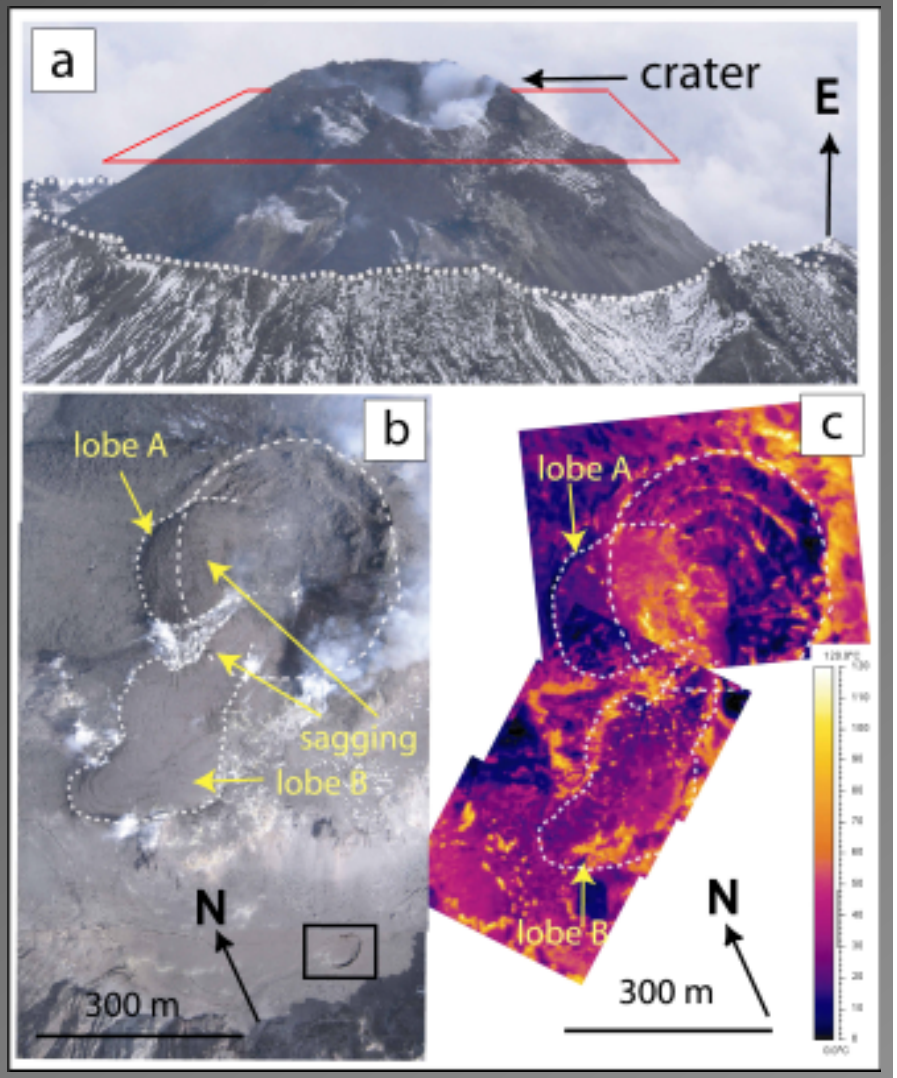
16 Aug 2004 *(A. Carter)*

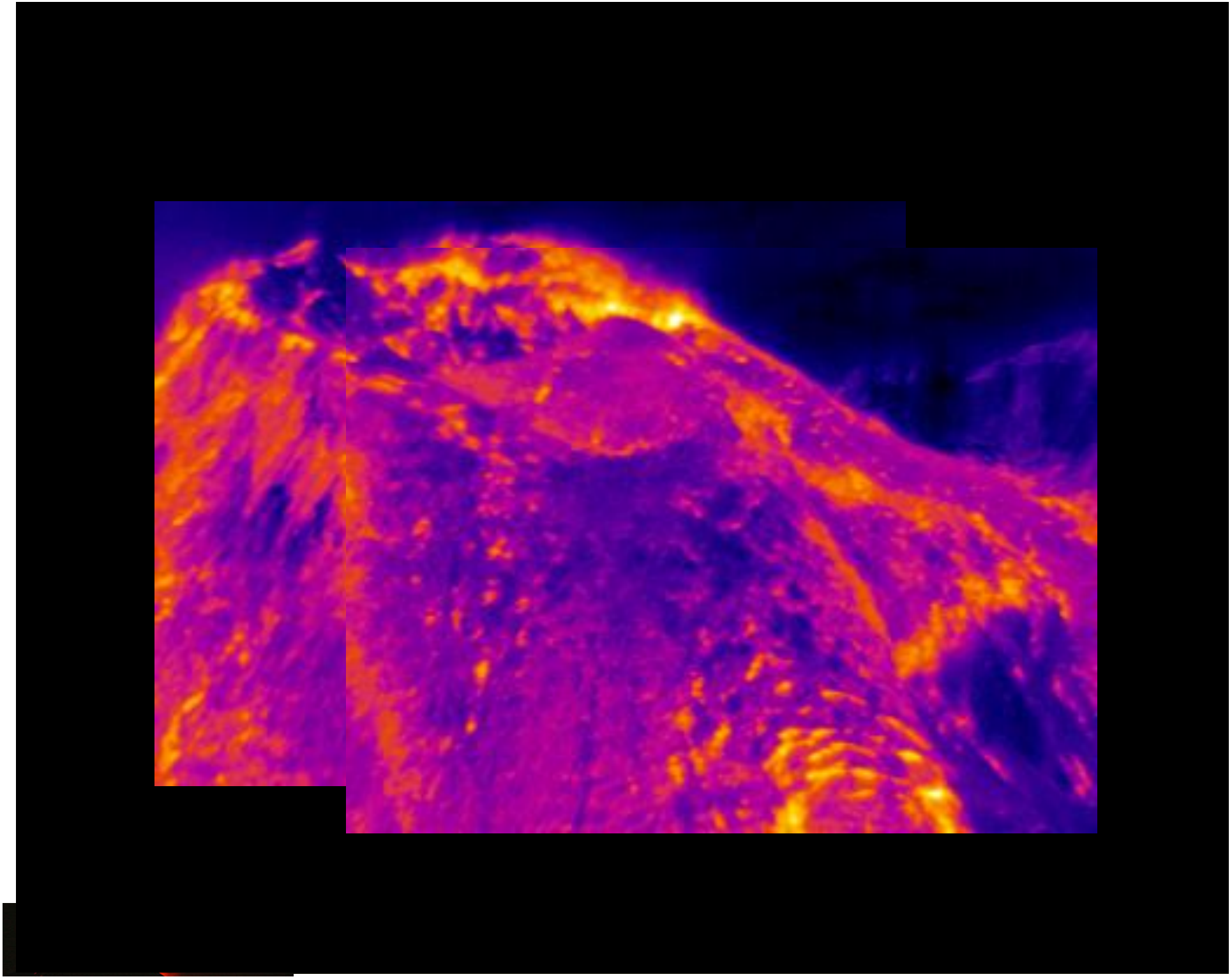
27 Jul 2005 *(I. Abkadyrov)*

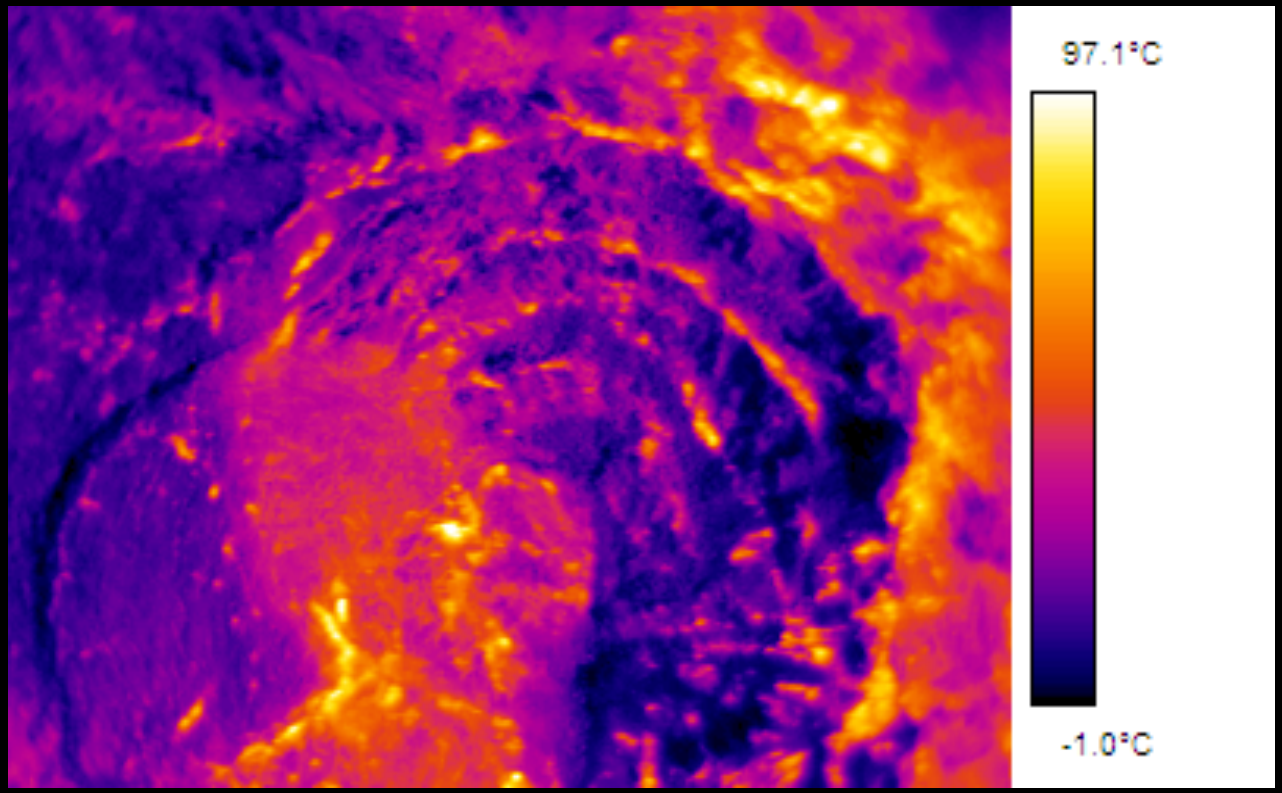
Bezymianny: 2005

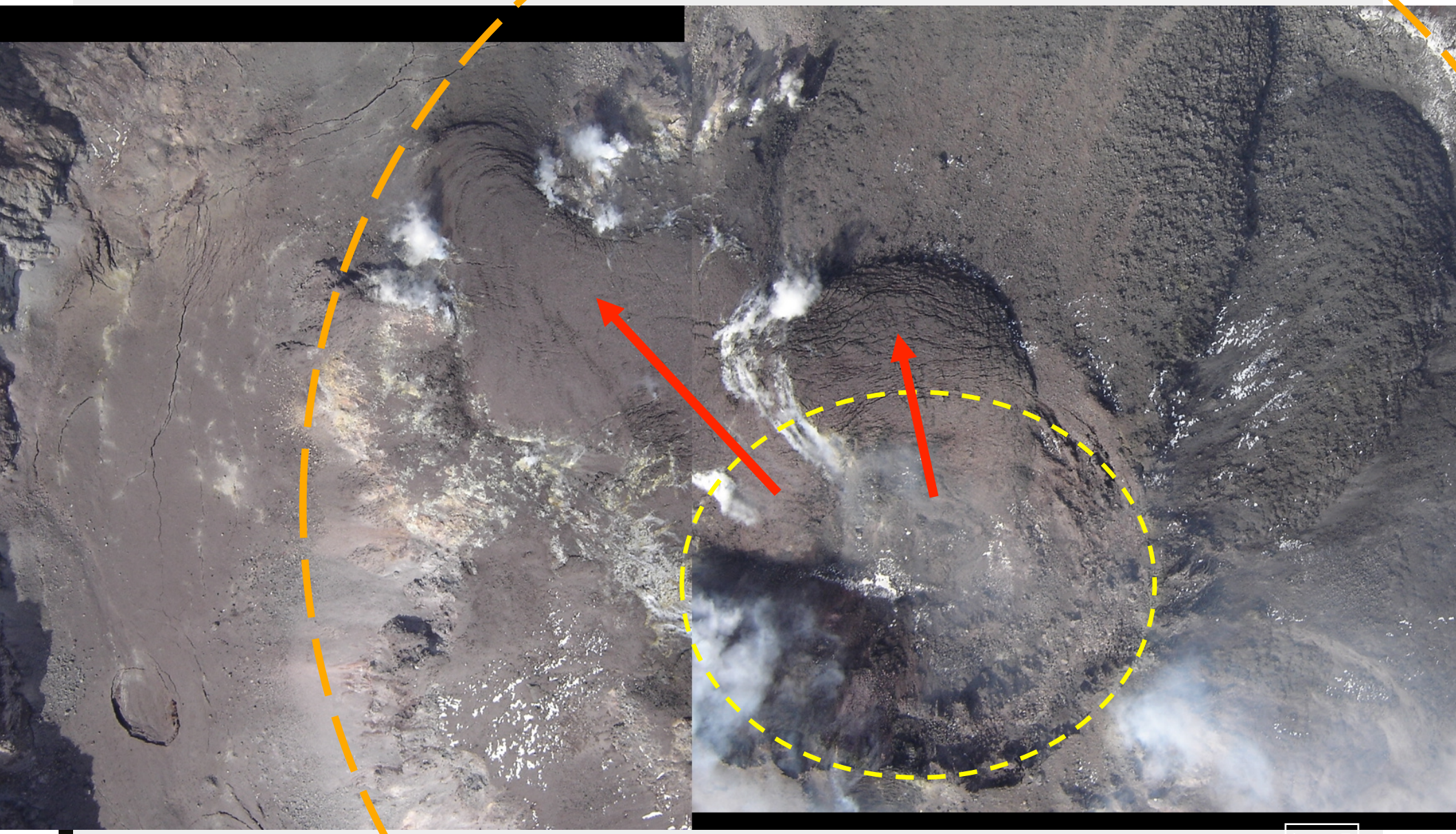
- **Observations & Results**
  - formation of a new crater
    - two exogenous lava lobes that predate the crater
  - ASTER data confirmed lava emplacement, crater formation, and a PF deposit that travelled to the SE
  - predicted a more explosive eruption due to choking of the conduit
    - validated in the May 2006 eruption

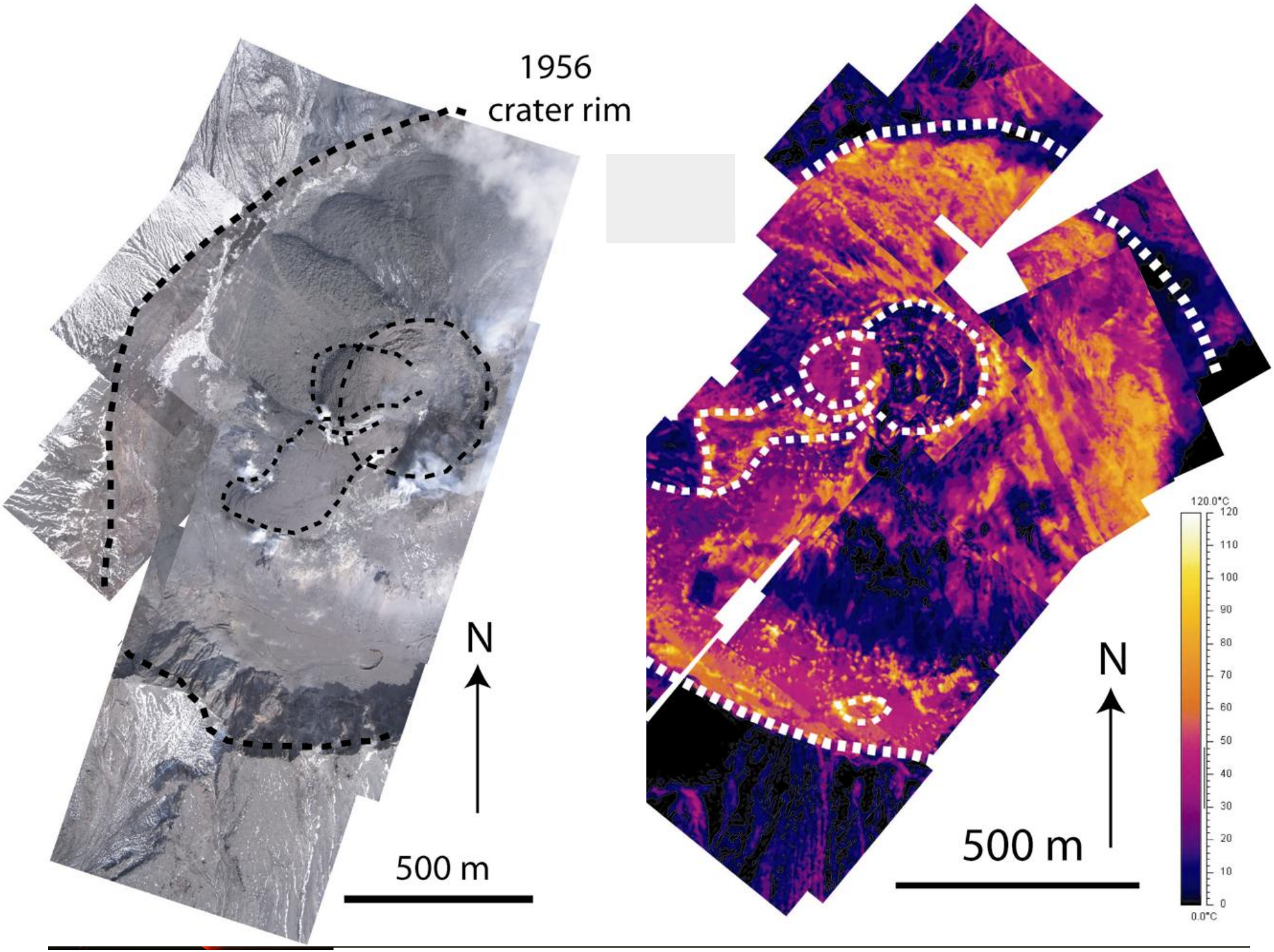
[Carter et al., 2007]





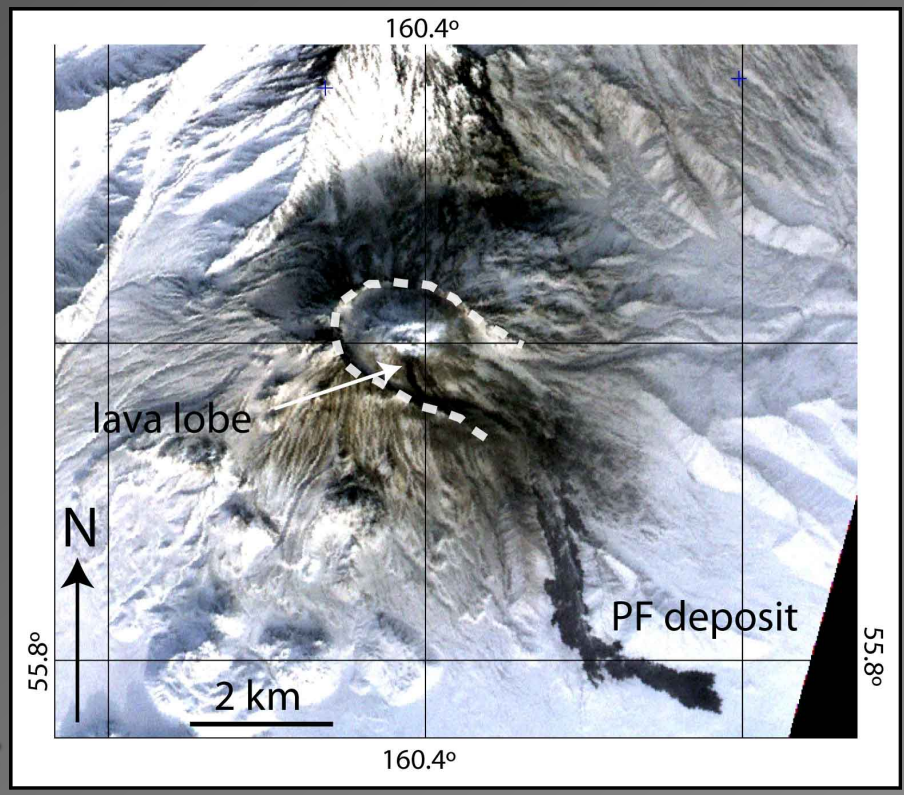

97.1°C
-1.0°C




1956
crater rim
N
500 m
N
500 m
120.0°C
120
110
100
90
80
70
60
50
40
30
20
10
0
0.0°C

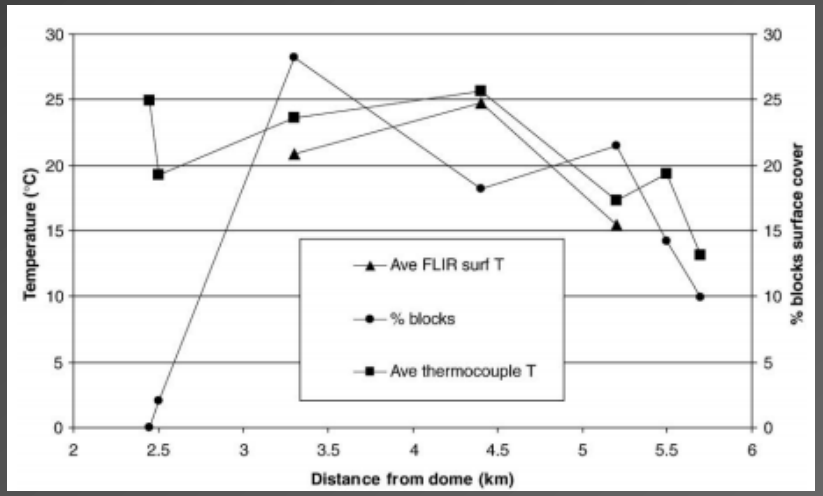
Bezymianny: 2006

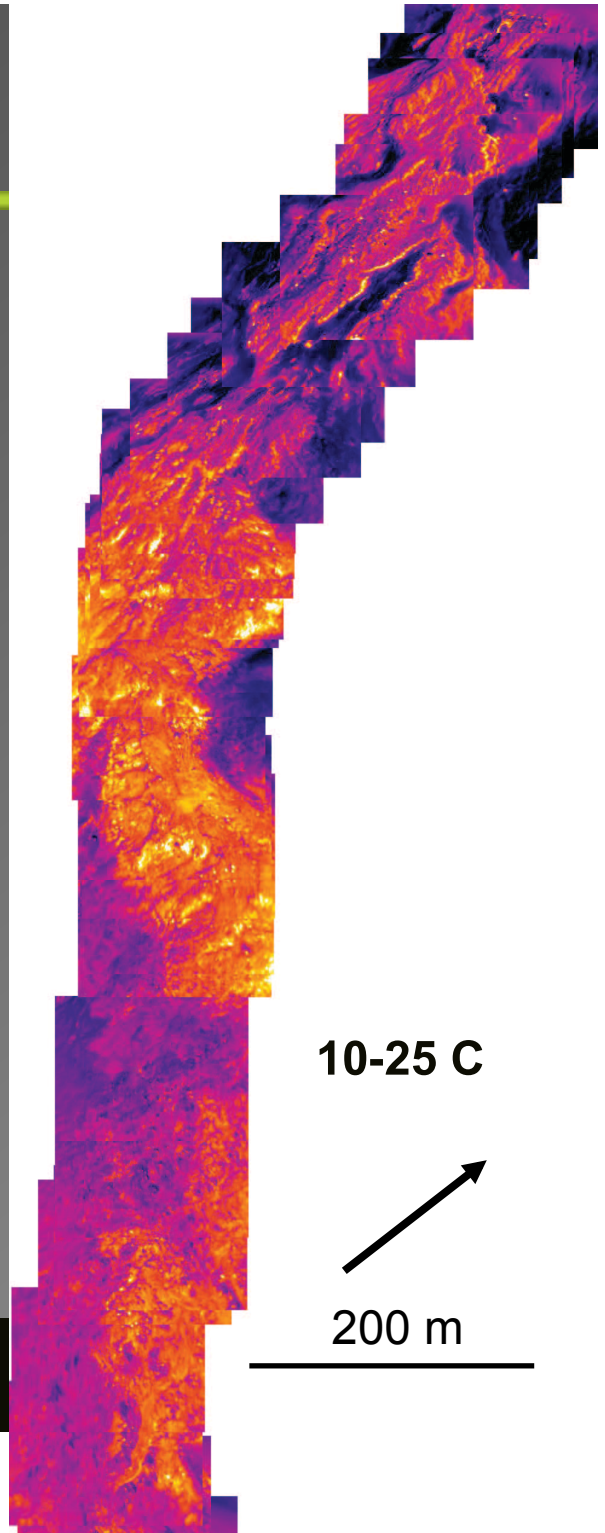
- **Observations & Results**
  - three months of precursory seismic activity
    - followed by an explosive eruption on 24 December 2006
      - PF deposit emplaced 6.5 km to the SE
  - triggered the ASTER urgent request protocol
  - VNIR data confirmed the PF
  - SWIR thermal anomalies (> 400° C) on the dome
  - TIR thermal anomalies (> 100° C) on SE flank and PF
    - confirmed precursory signal (45° C) four days prior



[Carter et al., 2008]

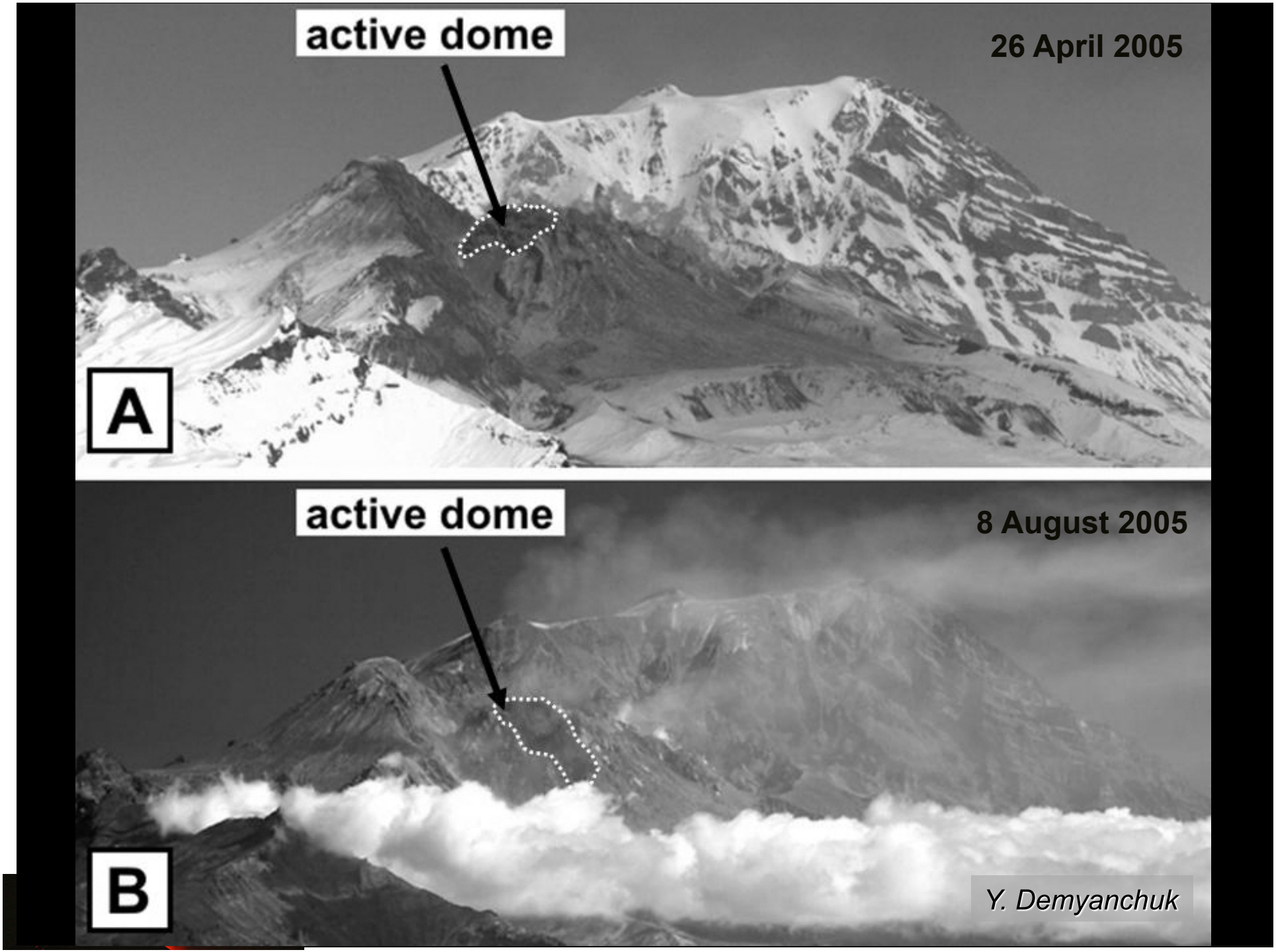
Bezymianny: 2006



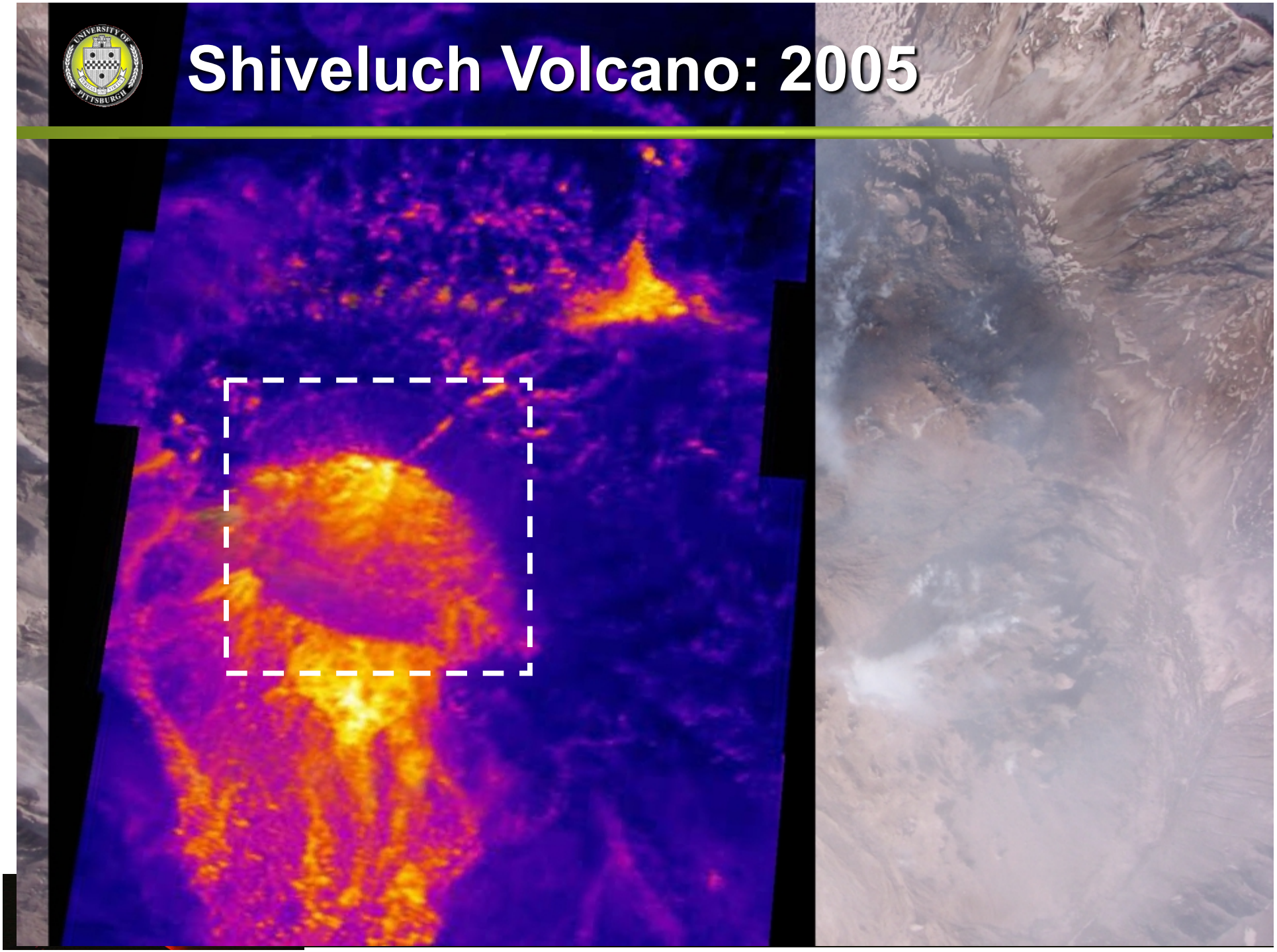


Sheveluch Volcano

Shiveluch Volcano: 2004


active dome
26 April 2005
A
active dome
8 August 2005
B
Y. Demyanchuk

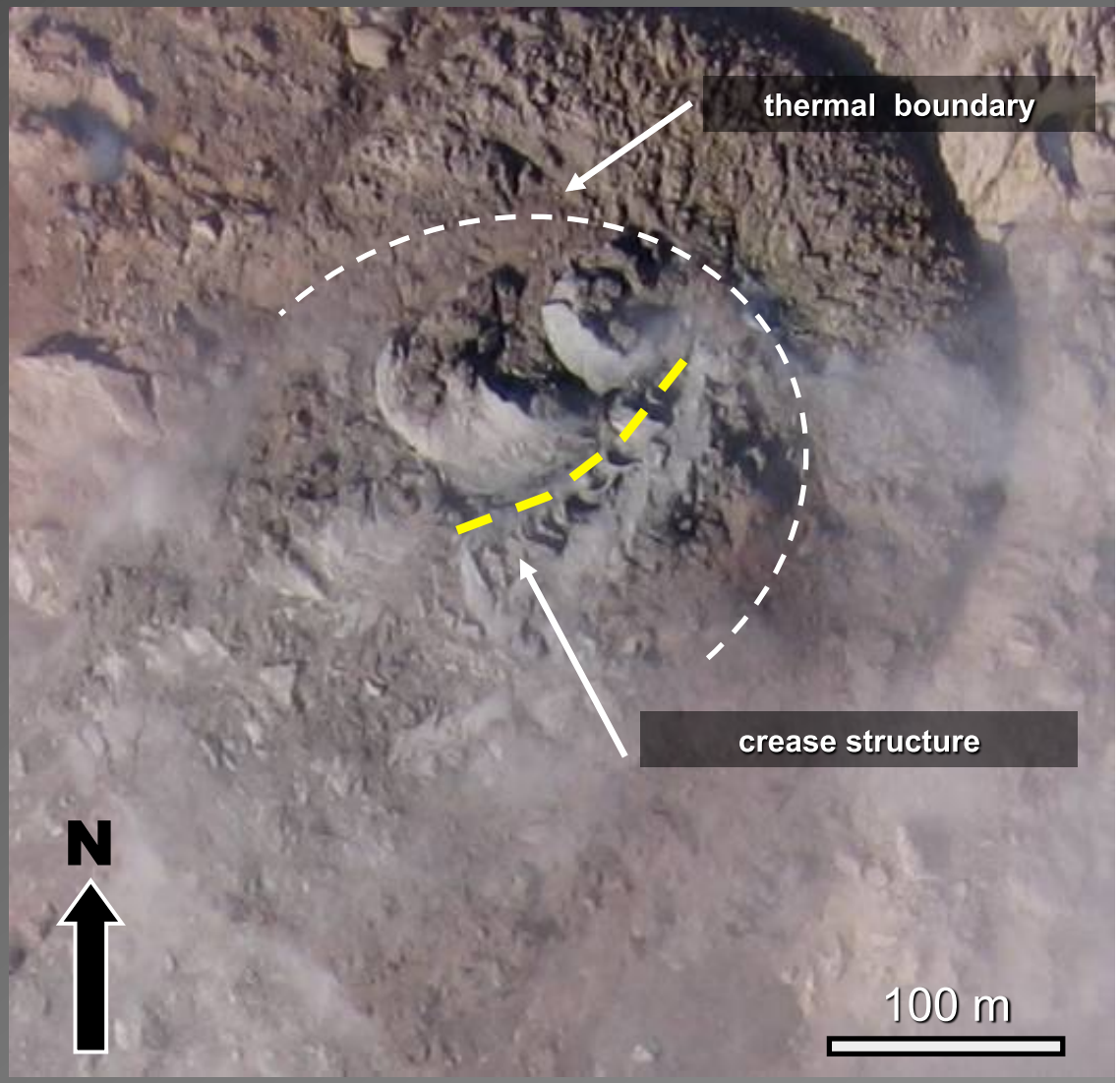
Shiveluch Volcano: 2005

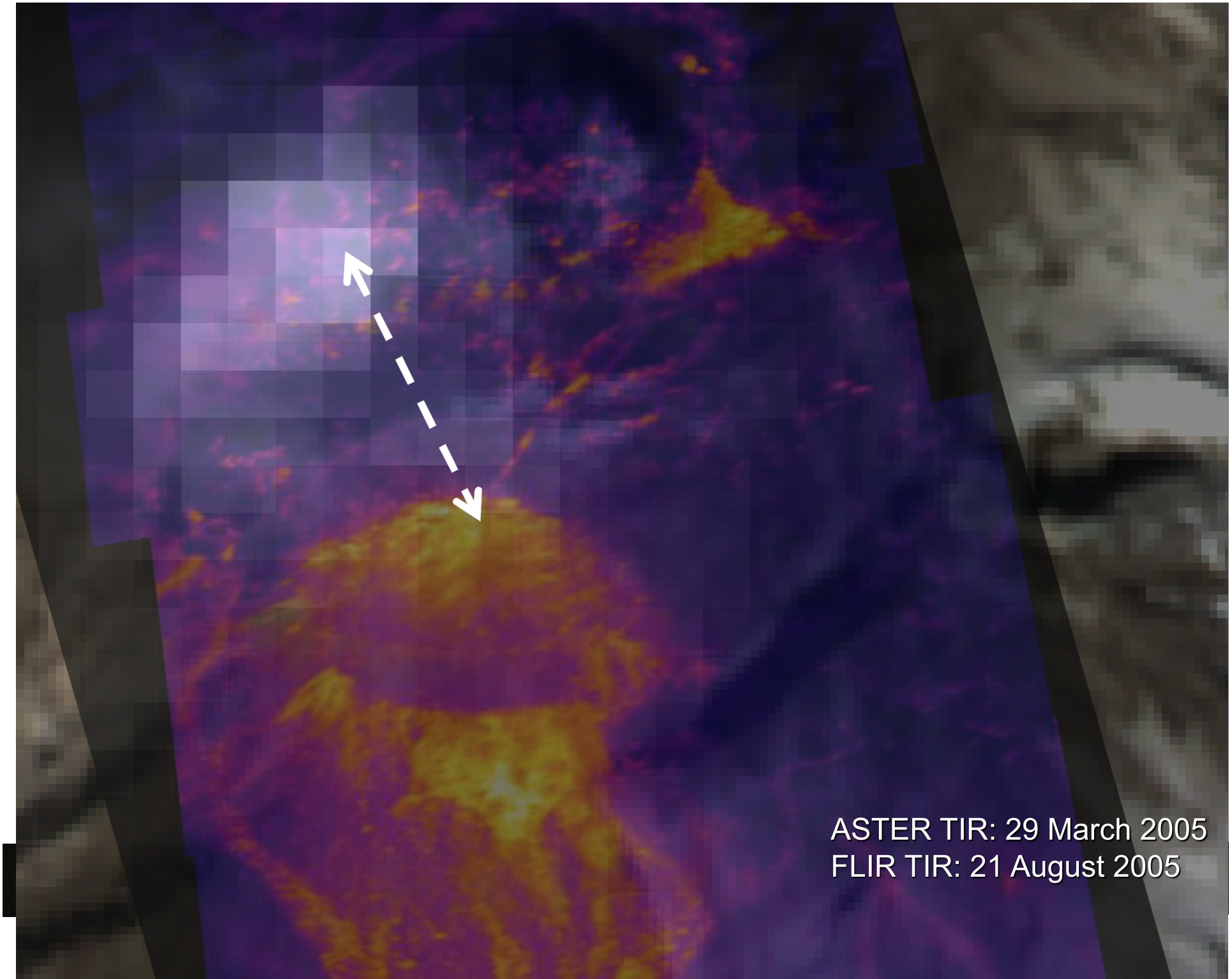


Shiveluch Volcano: 2005

- **Observations & Results**
  - new dome
    - crease structure
    - 335 x 410 m
    - 32 m high
    - 3.5 x 10^6 m^3
    - T_{max} = 405°C
  - ASTER data
    - linear growth:
      - 6.2 m/day
    - volume change:
      - 0.35 m^3/s

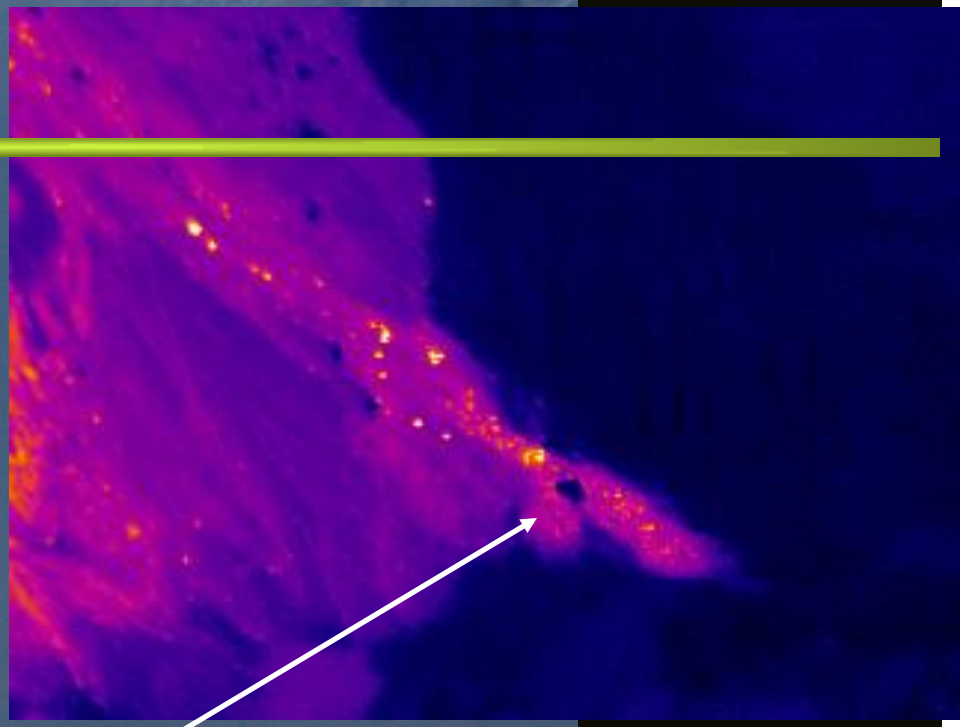
[Ramsey et al., 2010]




ASTER TIR: 29 March 2005
FLIR TIR: 21 August 2005

Mt. St. Helens Volcano

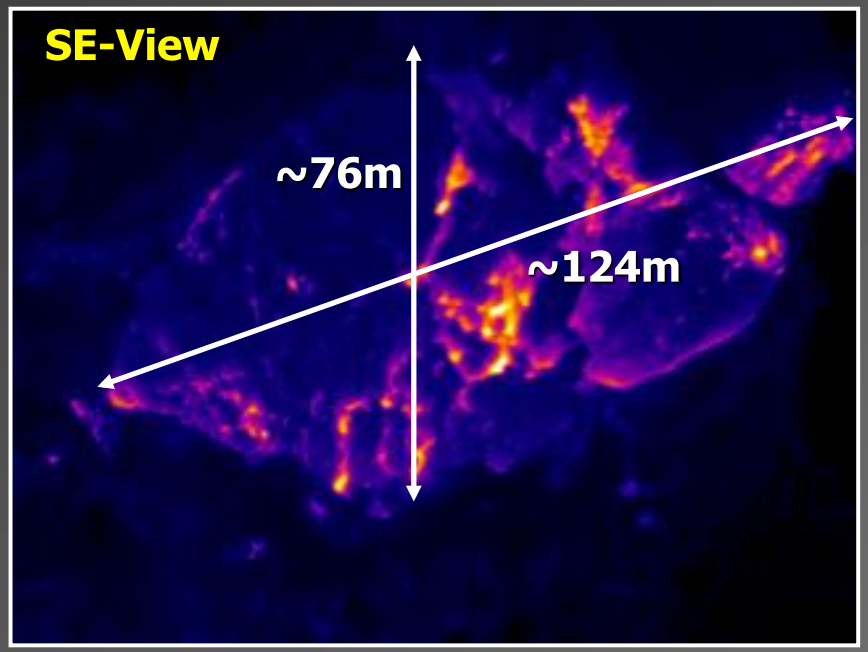
Flow Deposits

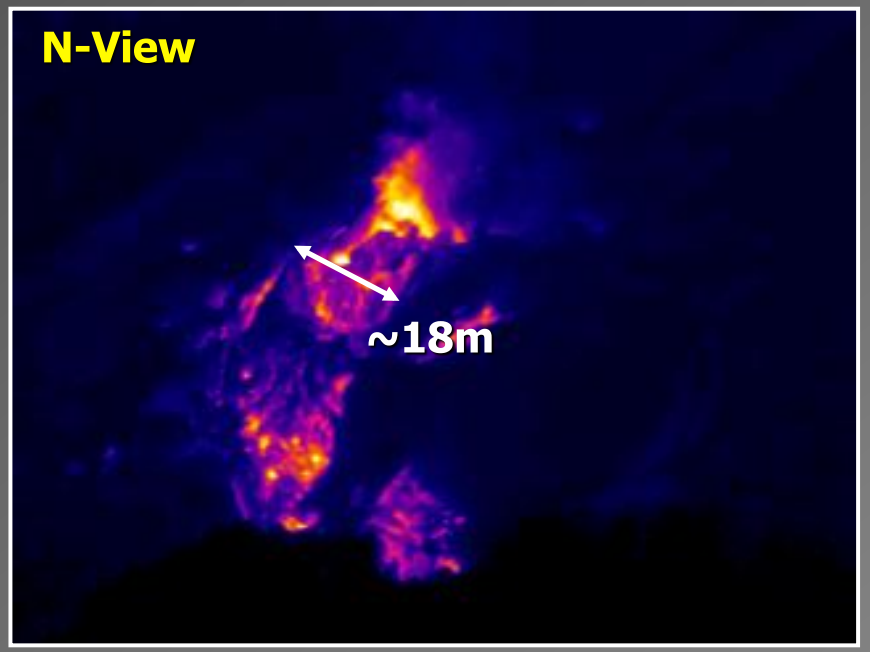


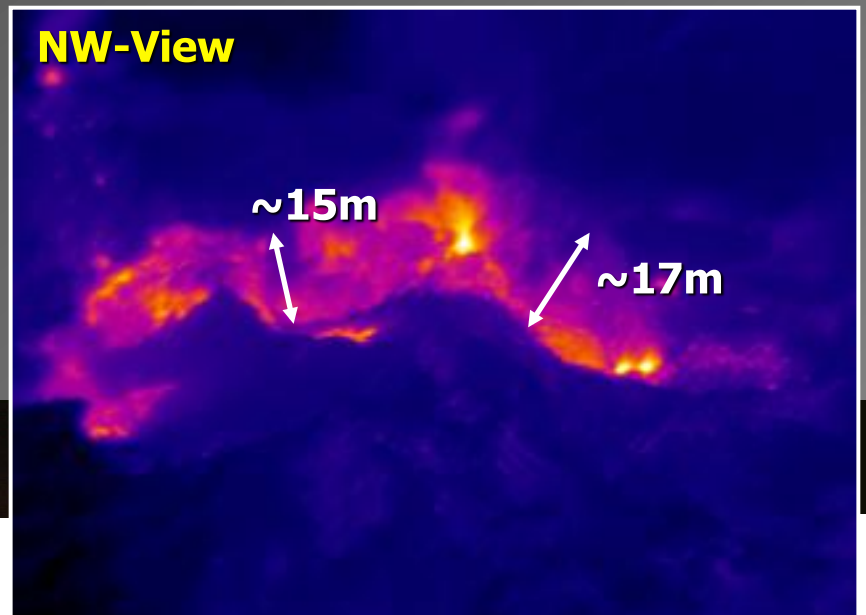
Block Temps:
max =145°C
avg = 101°C


14 October 2004

14 October: Volume Estimate



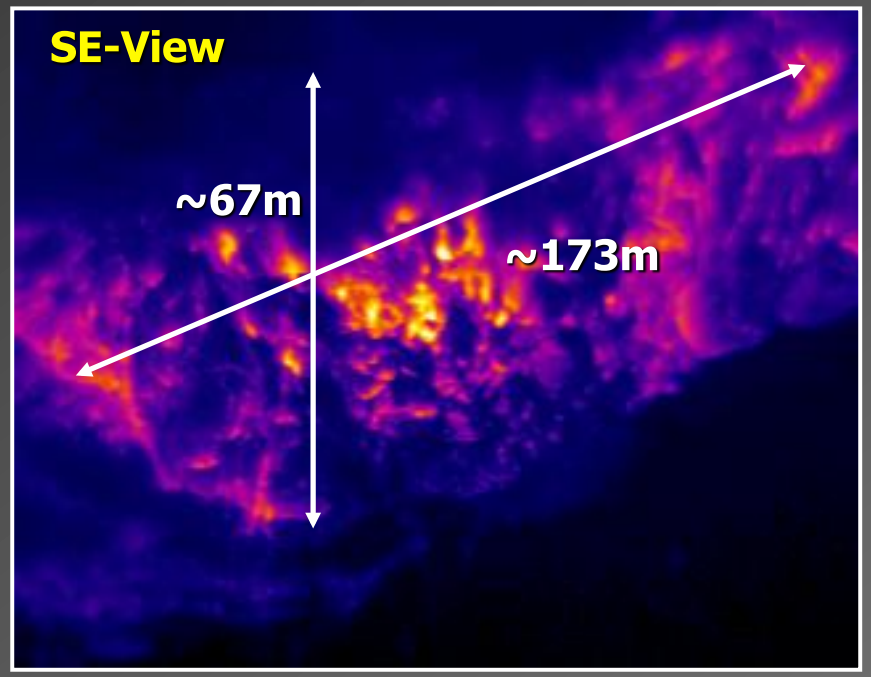


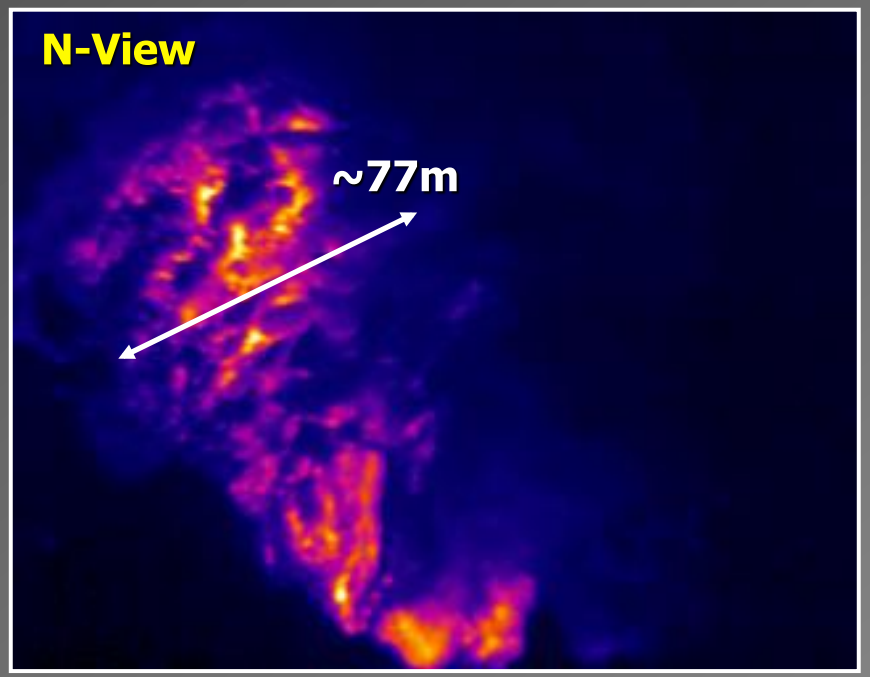


< 300°C 719°C

Extruded Volume:
~ 84,816 m^3

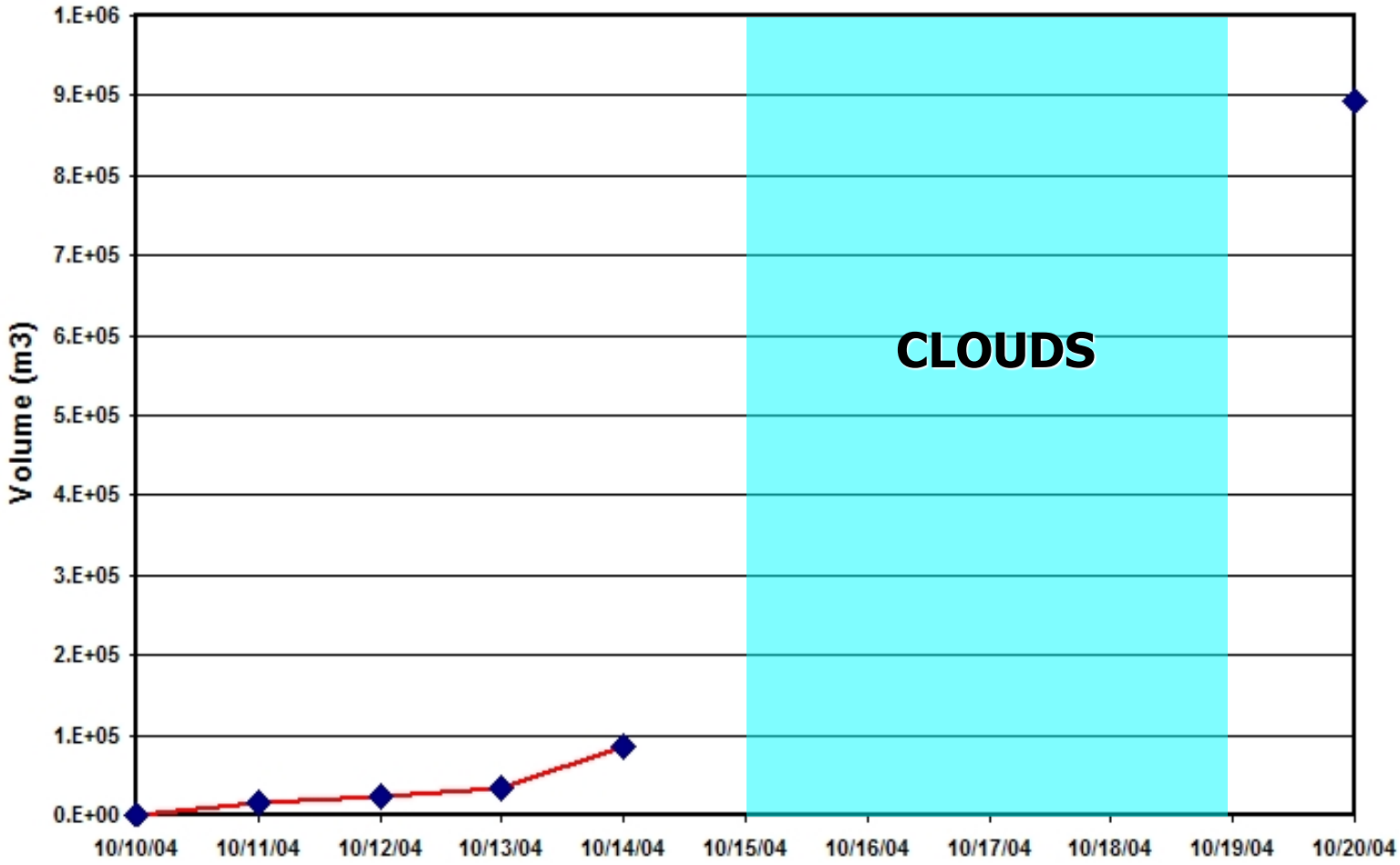
20 October: Volume Estimate



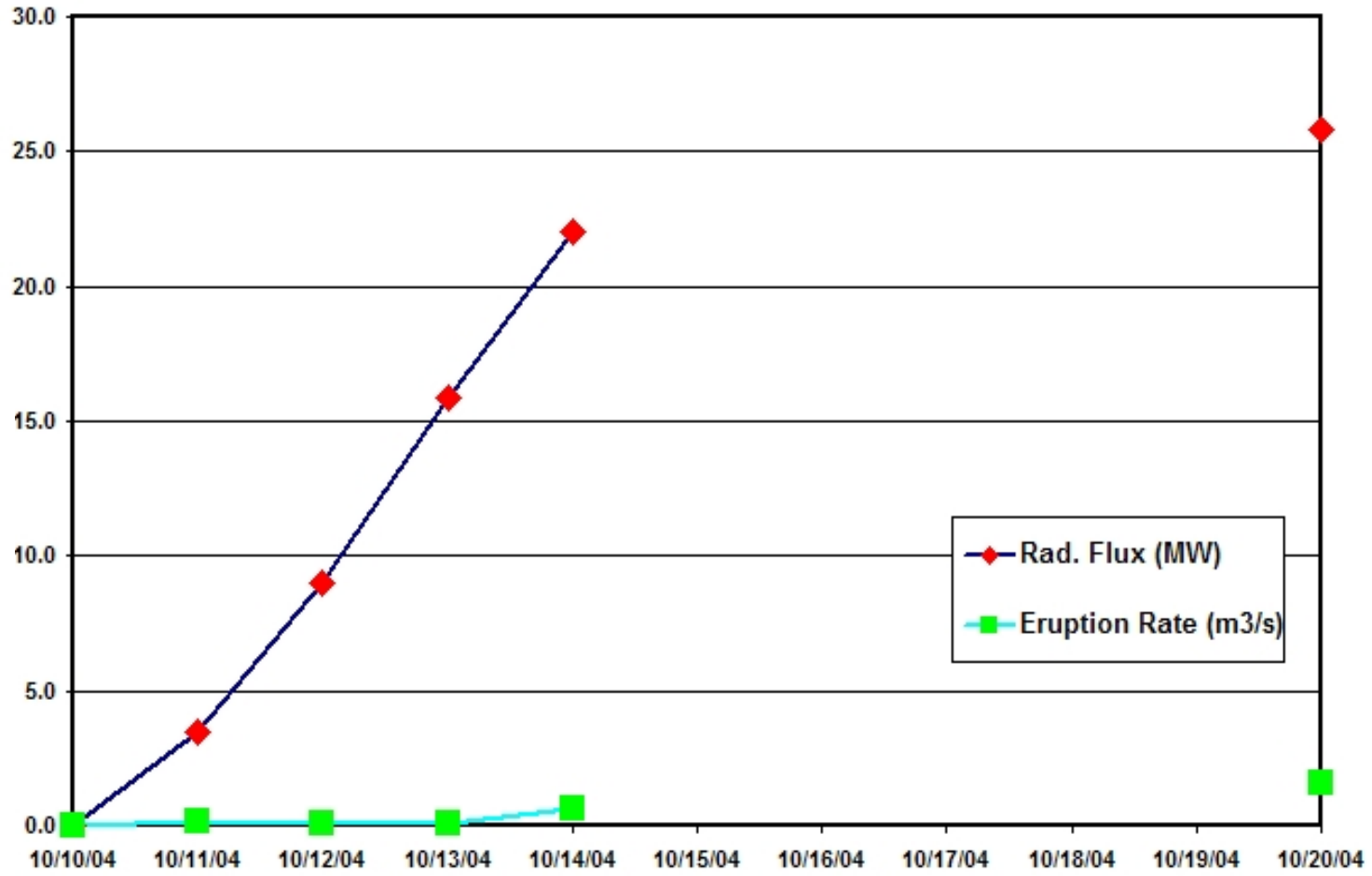


Extruded Volume:
~ 892,500 m ^{3}

Volume Estimates



Volume Estimates



Conclusions

- **Results of FLIR Measurements for Passive Eruptions**
  - direct temperature measurements *(ground and airborne)*
    - detection of new flows/deposits
    - heat flow over time
    - instantaneous thermal flux
  - scaling for direct physical measurements of flows
    - volume changes
    - comparison to satellite data
  - thermophysical measurements
    - apparent thermal inertia: $(1 - a) / \Delta T$
      - percentage of blocks in PF deposits