



# ***Passive Activity Using Thermal Infrared Cameras/ Radiometers: Fumaroles, Mud Pots and Mud Volcanoes***



*“fun with ice” by the esteemed Dr. Prada  
(at the IAVCEI Workshop in Argentina in 2004)*

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FLIR

35

FLIR

19

Trefl=45 Tatm

1/12/11 8:54:

FLIR images of my new house in Pittsburgh, PA

Trefl=45 Tatm=36 Dst=675 FOV 24

1/12/11 8:55:21 AM -40 - +120 e=1.00

°C

13





# Outline

- **FLIR Measurements for Passive Eruptions**
  - been a series of side projects
    - document the detection thresholds for the FLIR
    - proxy for future Mars rover missions to detect CH<sub>4</sub> fumaroles
  - fumarole measurements
    - Cerro Negro, Nicaragua
      - thermal flux comparison to gas geochemistry
    - Salton Sea, CA
      - gas detection
  - mud pots & mud volcanoes
    - Seltun, Iceland and Salton Sea, CA
      - temperatures





# Fumaroles: Cerro Negro

- **Objectives:**

- characterize thermal flux of the crater fumarole field
  - comparison with day/night thermal IR satellite data
  - support gas geochemistry measurements
  - integrate day/night FLIR data into a thermal inertia model of the crater's surface materials
    - better describe variable nature of the emissivity of crusts, sublimates, and multiple temperatures



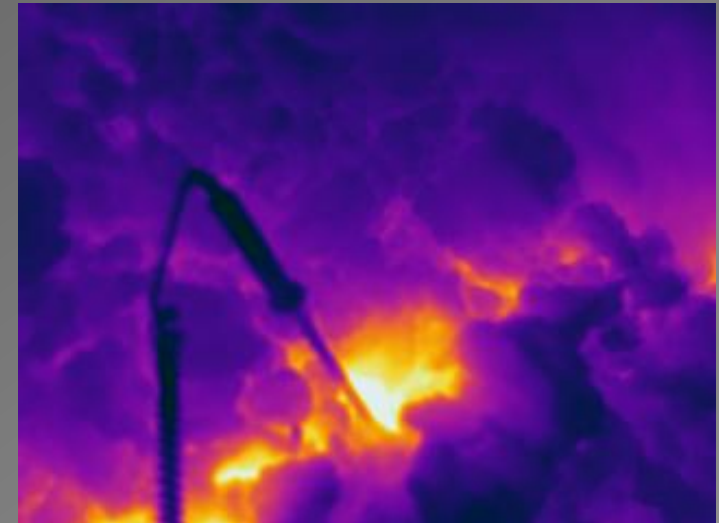
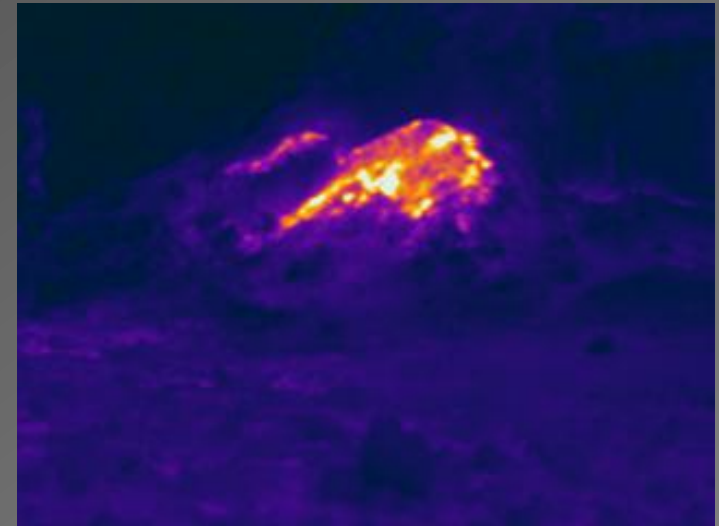




# Fumaroles: Cerro Negro



fumaroles were thermally sampled both directly and using the FLIR (near & far field)





# Fumaroles: Cerro Negro



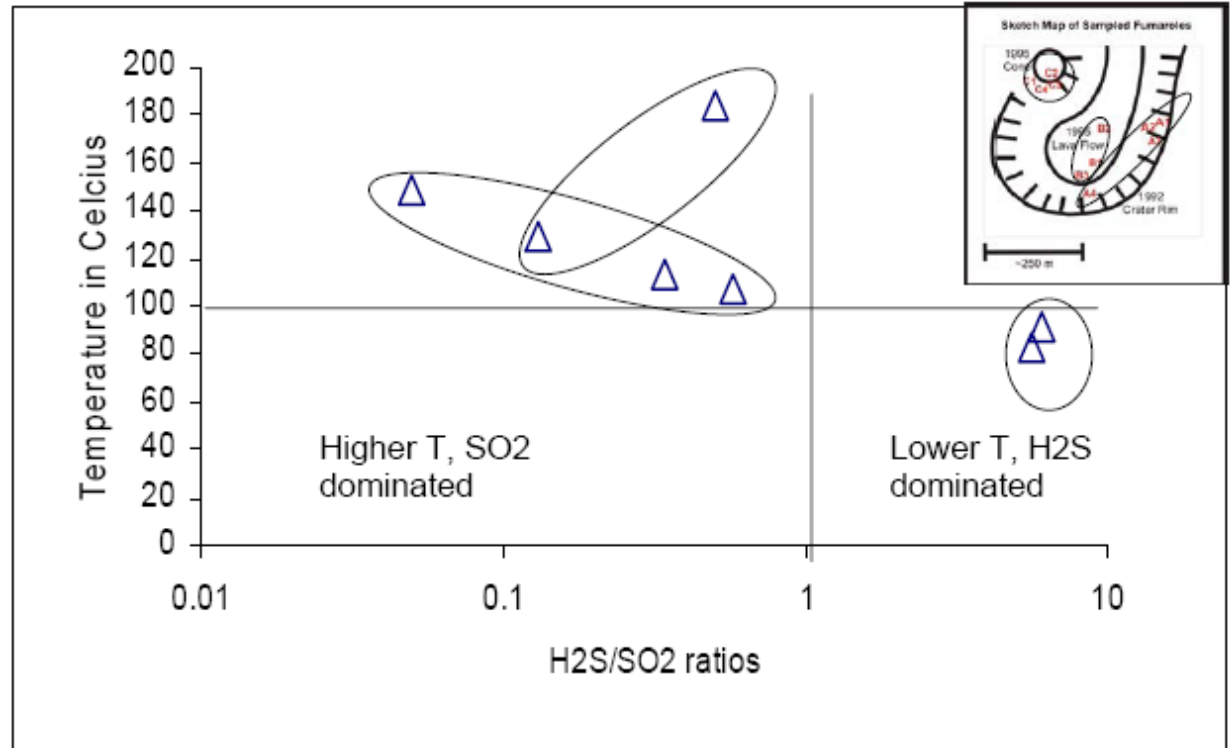
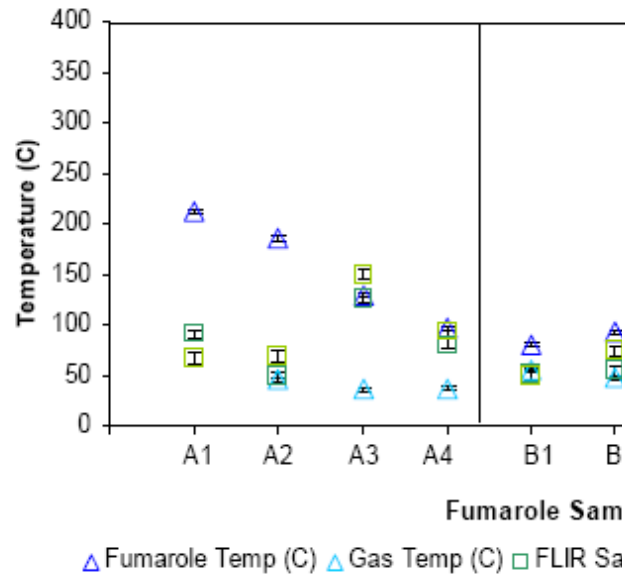
nighttime sampling (radiometer,  
FLIR, thermocouple)





# Fumaroles: Cerro Negro

Temperatures Measured for Sampled Fumaroles



from T. Lopez (2006)







# Mud Volcanoes: Salton Sea

## • Data Collection

- thermal imaging/video (FLIR) and kinetic temperatures recorded
- soil samples collected from mud volcanoes, mud pots, active deposition areas and surrounding sediment
  - analyzed using laboratory thermal emission spectroscopy laboratory
  - compared to 128 channel airborne TIR system (SEBASS)



Salton Sea geothermal field zones

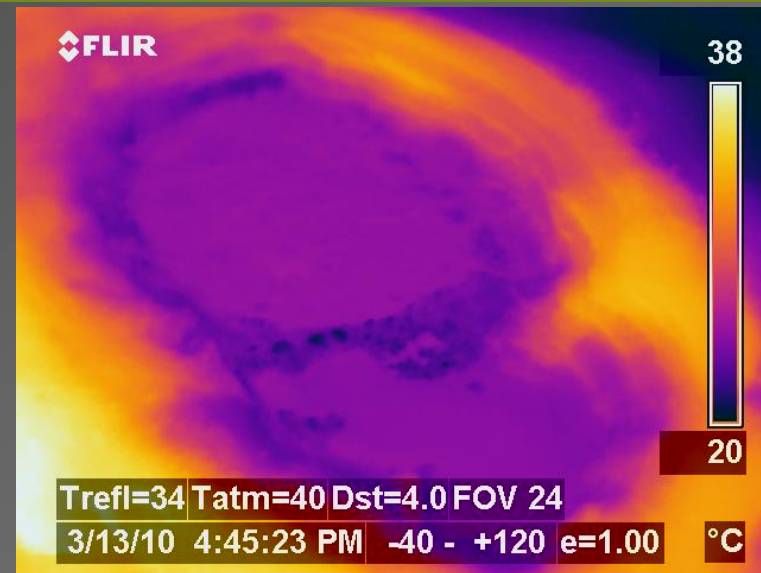
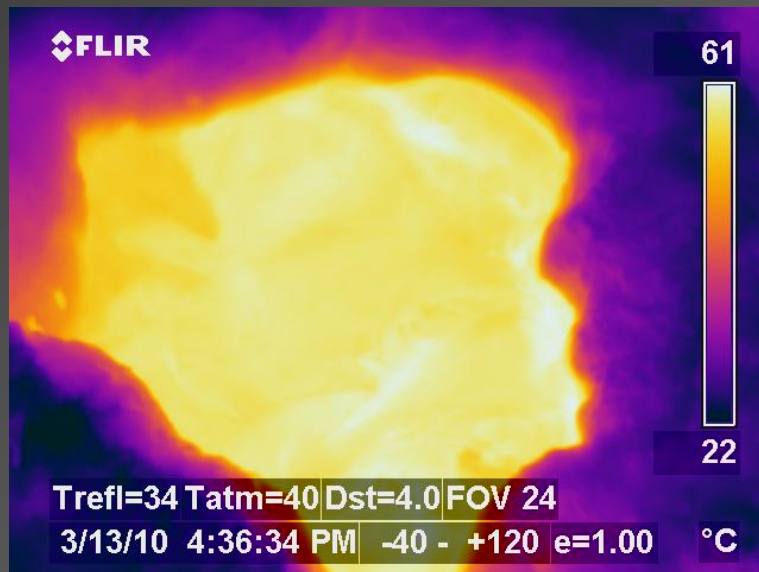


large mud volcano cluster (3 m diameter)  
within zone 2





# Mud Volcanoes: Salton Sea



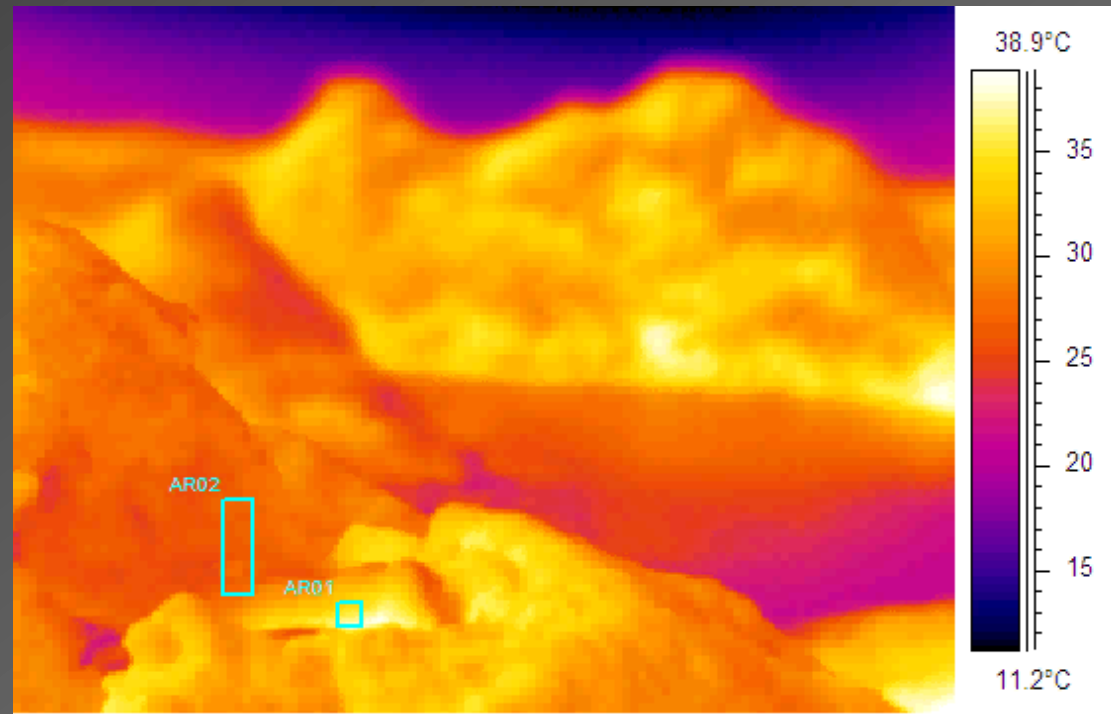
## • TIR Data Collection

- ground cal/val at four most active geothermal areas
  - mud volcano vents were warmer (25-40°C)
  - mud pots were 15-10°C cooler than the surrounding area
  - examples: mud volcano (left) and a pair of mud pots (right)
    - at some mud pots, the solar heating was larger than the temperature of the mud → would result in cool TIR anomalies





# Mud Volcanoes: Salton Sea



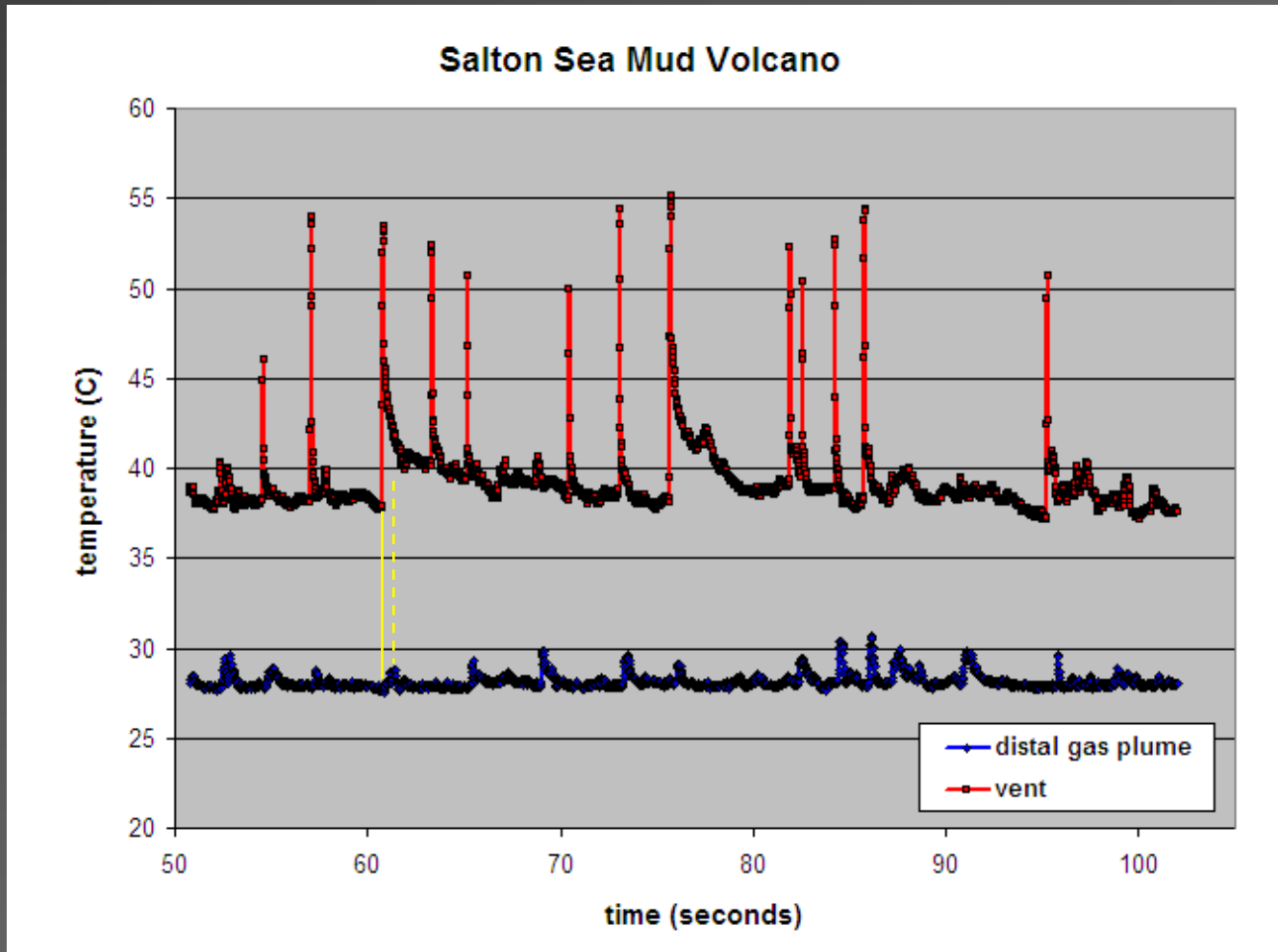
- **Time Series of Mud “Eruptions”**

- 60 Hz frame rate
- two areas (regions of interest) designated to capture the hot mud and warm gas emissions





# Mud Volcanoes: Salton Sea



initial statistical analysis of “eruption” data:

- *average*: 3.4 s
- *max*: 9.5 s
- *min*: 0.7 s
  
- *bkgnd*: 38.5°C
- $\Delta T$ : 14.1°C

gas pulses:

- *bkgnd*: 27.9°C
- $\Delta T$ : 1.9°C

time lag:

- $\Delta T$ : 0.75 s

temperature/time plot of thermal emissions from the Salton Sea mud volcanoes





# Mud Pots: Seltún, Iceland

- **Two Primary Objectives**

- analysis of smaller geothermal features using available instruments to document small-scale thermal events (e.g. boiling water/phreatic activity, mud pools, hot springs, etc.) in collaboration with ÍSOR



- mapping of natural geothermal features using ASTER data over the available data archive (2000 – present)

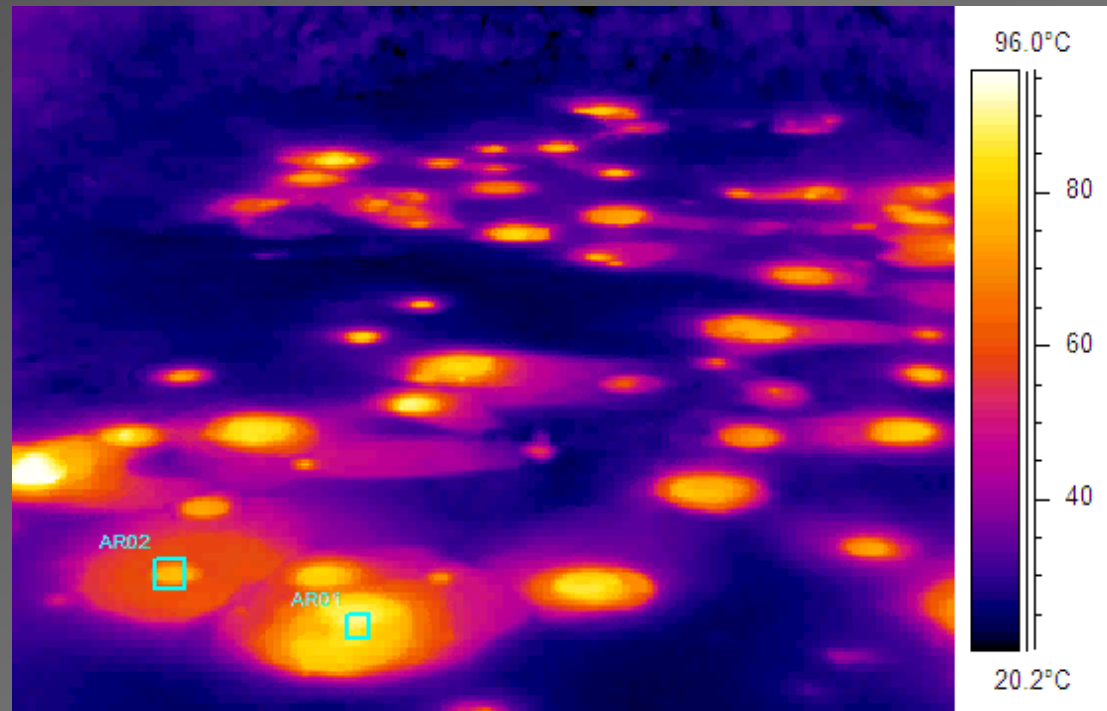




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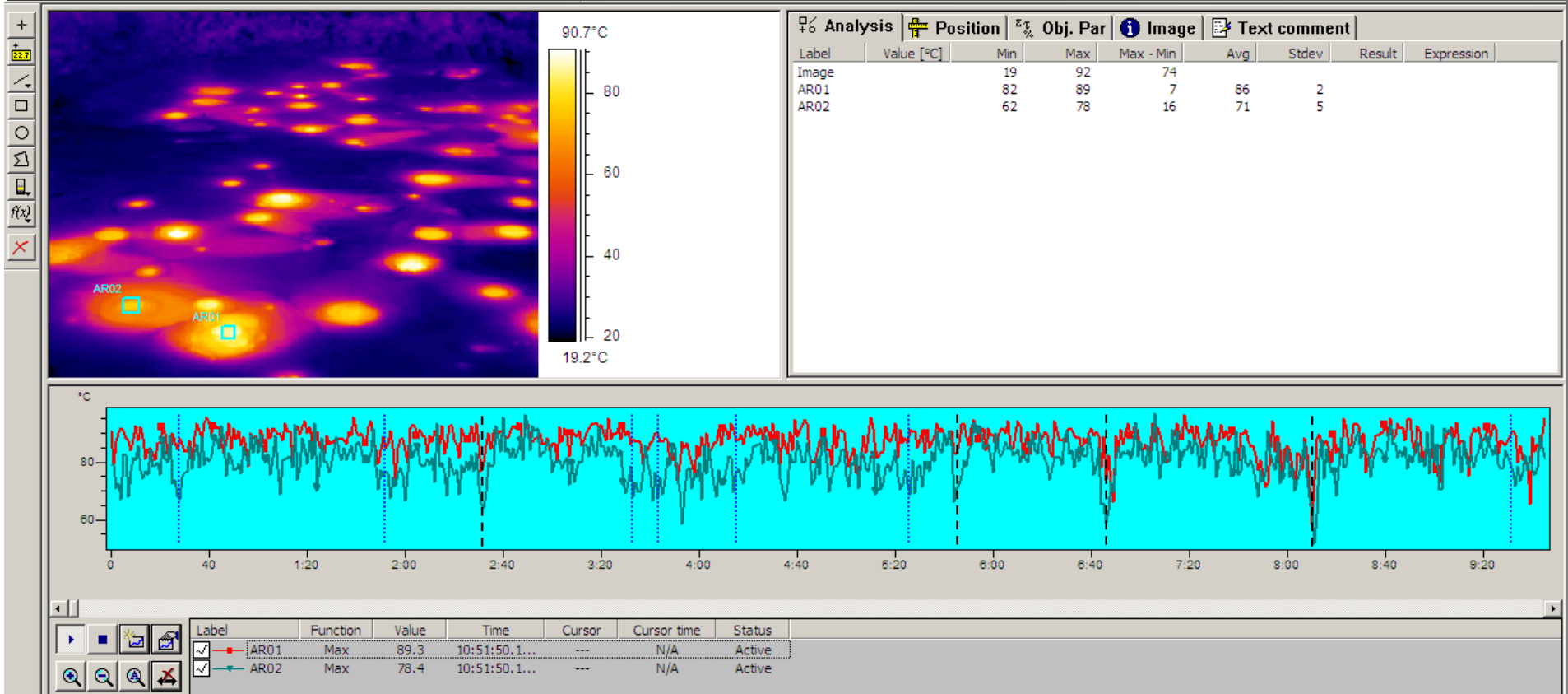


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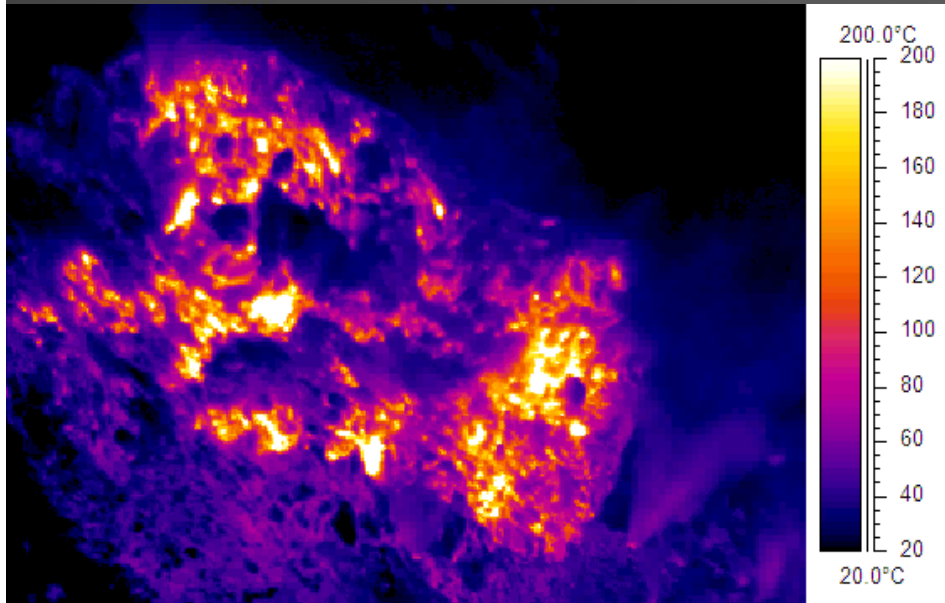
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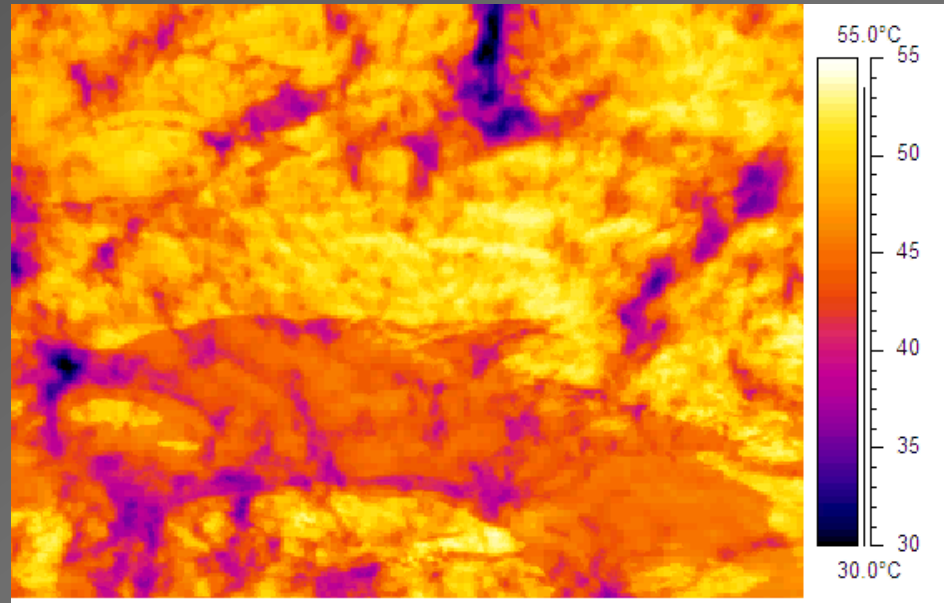
- **ThermaCam Researcher™ software**
  - allows for detailed analyses of FLIR data
  - steady-state thermal output; phase differences btwn. bubbles



# Results: Poas Volcano



Poas fumarole field  
(data stretched from 20 – 200 °C;  $T_{max} = > 540$  °C)



Poas crater lake  
(data stretched from 30 – 55 °C;  $T_{max} = 58.4$  °C)



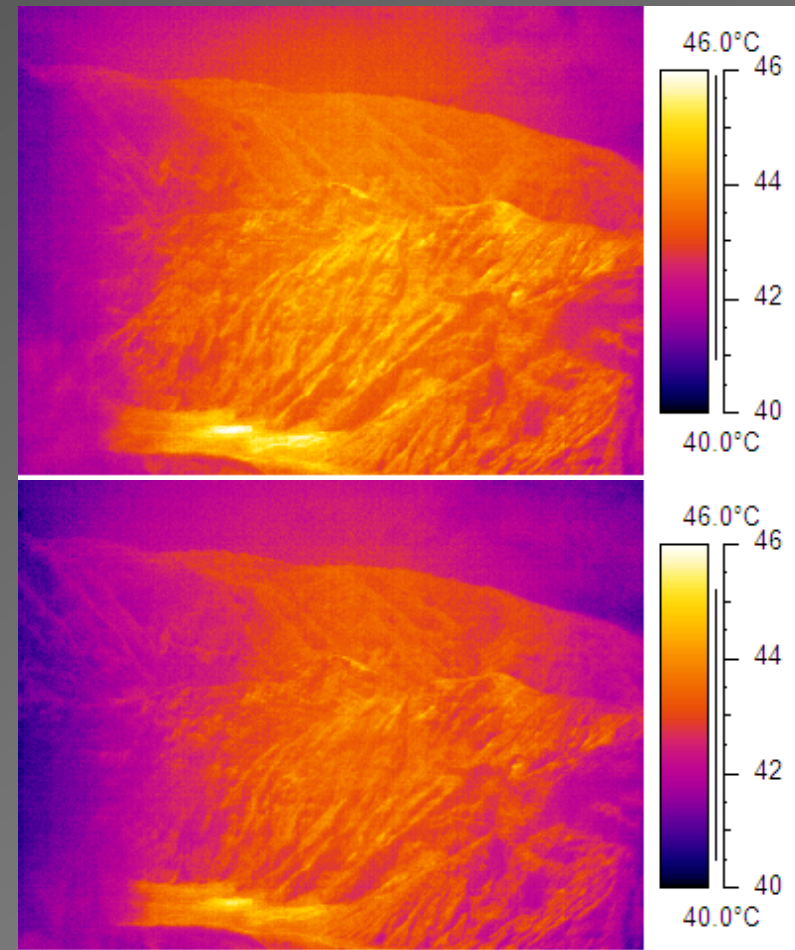




# Conclusions

- **TIR Measurements of Passive Activity**

- direct temperature measurements
  - detection of new (changes in) thermal activity
  - heat flow over time
  - instantaneous thermal flux
- scaling for direct physical measurements
  - gas geochemistry
  - comparison to satellite data



8.6  $\mu\text{m}$  FLIR images of Poas plume (top: "clear"; bottom: higher SO<sub>2</sub> abundance)

