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)

Michael Ramsey¹, Adam Carter², Kevin Reath¹

¹ Dept. of Geology and Planetary Science University of Pittsburgh, Pittsburgh, PA, USA
² ExxonMobil, Houston, TX, USA
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
• 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$_4$ 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, sublimes, 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
• **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 \( \rightarrow \) would result in cool TIR anomalies
• **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

**Temperature/Time Plot of Thermal Emissions from the Salton Sea Mud Volcanoes**

- **Initial Statistical Analysis of “Eruption” Data:**
  - Average: 3.4 s
  - Max: 9.5 s
  - Min: 0.7 s

- **Background:**
  - 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
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)
Mud Pots: Seltún, Iceland

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Mud Pots: Seltún, Iceland

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

PASI Workshop
San Jose, Costa Rica (21 Jan 2011)
Results: Poas Volcano

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

Poas crater lake
(data stretched from 30 – 55 °C; $T_{\text{max}} = 58.4$ °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 μm FLIR images of Poas plume (top: “clear”; bottom: higher SO₂ abundance)