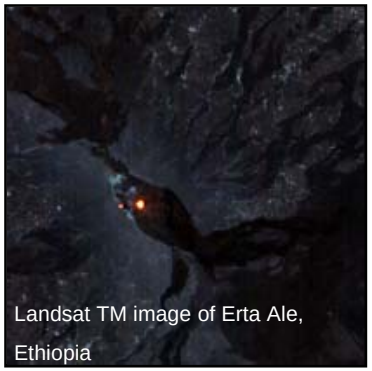
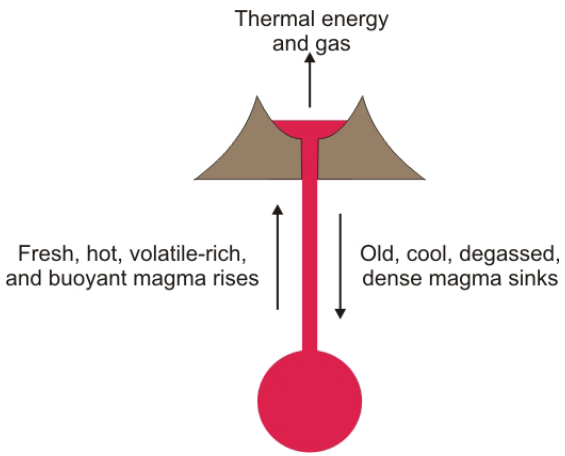
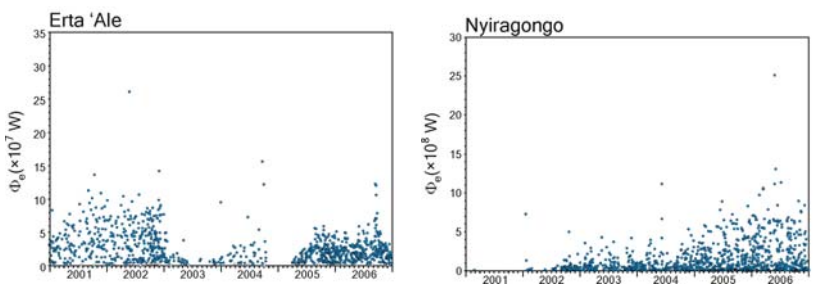
CQ3a: What do comparisons of thermal flux and SO_2 emission rates tell us about the volcanic mass fluxes and the dynamics of magma ascent? (DS 227; 230)





Francis et al. (1993). *Nature,* 366, 554-557.



Wright & Pilger (2008). *J. Volcanol. Geotherm. Res.*, 177, 687-694.

Science Issue:

• The flux of gas and thermal energy from a volcano can be used to determine the mass of magma required to balance those fluxes. Over what time scales do mass fluxes at Earth's volcanoes vary and by how much? Does this vary as a function of tectonic setting? During ascent, how is magma partitioned between the surface (the erupted component) and the subsurface (the intruded component)?

Tools:

• Satellite observations from HyspIRI. Requires multispectral TIR capability to detect, quantify, and monitor SO_2 flux; requires hyperspectral VSWIR data as well as multispectral data in the 4 μm (saturation temperature of ~1600 K) and 8-12 μm (at least one band with a measurement temperature of ~1000 K) regions for determining lava surface temperatures. This will be used to determine the thermal flux from the free surface of the magma-conduit system.

• Published geochemical and enthalpy models relating these fluxes to the volume of magma cooled and degassed.

• Knowledge of local wind field and volcano altitude of aid computation of SO_2 mass flux.

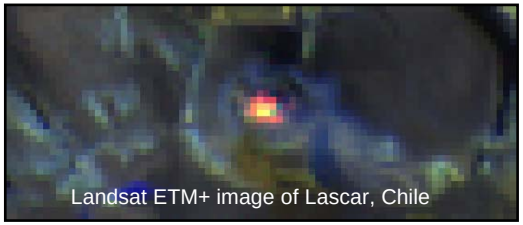
•Historical baseline of characteristic thermal (*e.g.* from MODIS, lower left) and gas emission behavior for each volcano to provide multi-year/decadal context for the HyspIRI observations.

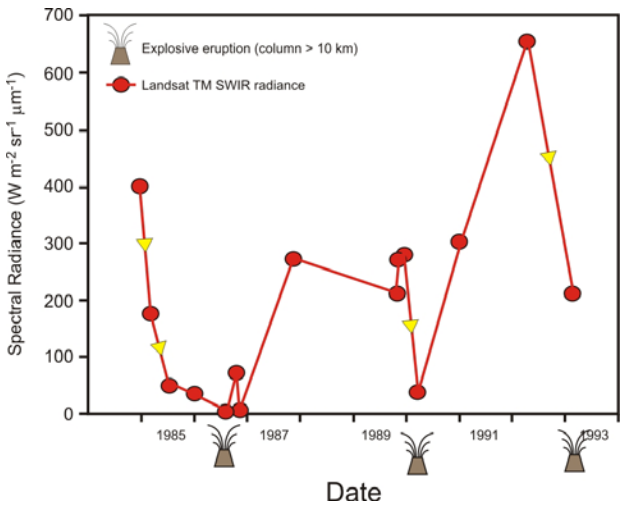
Approach:

• Use systematically acquired day and night VSWIR and TIR observations for several basaltic volcanoes that exhibit persistent lava lake activity (*e.g.* Erta Ale, Nyiragongo) and several volcanoes that frequently produce basaltic lava flows (*e.g.* Etna, Piton de la Fournaise).

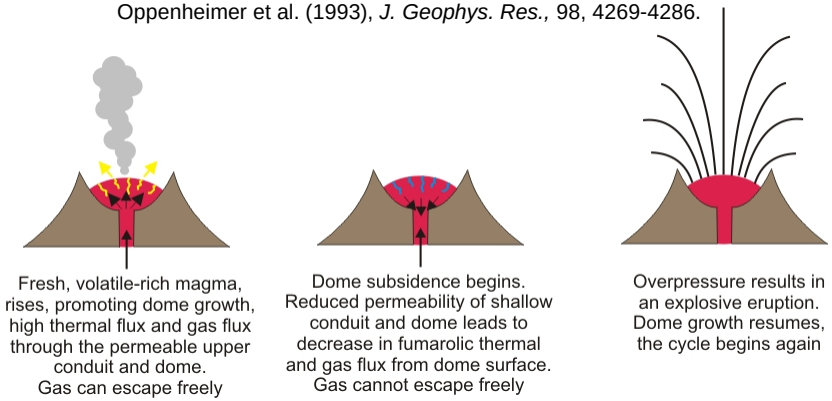
• Field campaign to acquire in-situ SO_2 and thermal flux data at a single target for calibration purposes.

CQ3b: Does pressurization of the shallow conduit produce periodic variations in SO_2 flux and lava dome surface temperature patterns that may act as precursors to explosive eruptions? (DS 50; 227; 230)





Oppenheimer et al. (1993), *J. Geophys. Res.,* 98, 4269-4286.



Matthews et al. (1997), *Bull. Volcanol.,* 59, 72-82.

Science Issue:

• Cyclicity is increasingly recognized as characteristic of explosive silicic dome-forming volcanoes. Precipitous drops in SWIR radiance detected by Landsat TM from Lascar's summit crater during the 1980s and 1990s were followed by significant explosive eruptions (middle left). A model, based on field observations, has been proposed to explain these cycles (bottom left). Explosive overpressure results when gas cannot escape freely from the shallow conduit resulting in a decreased gas flux *and* decreased abundance of high temperature fumaroles on the dome surface. Can we use HyspIRI to recognize similar patterns, at other potentially explosive volcanoes?

Tools:

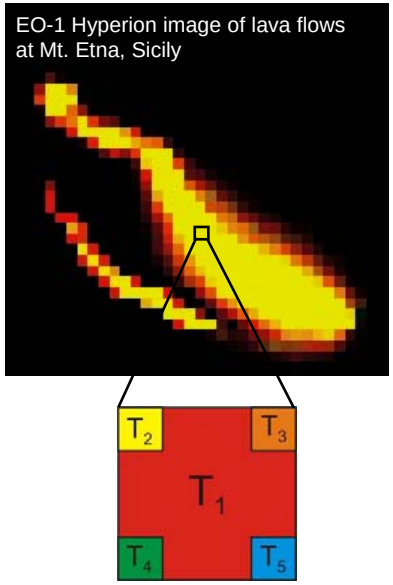
• Satellite observations from HyspIRI. Requires multispectral TIR capability to detect and monitor SO_2 degassing rates over time; requires hyperspectral VSWIR data as well as multispectral data in the 4 µm (saturation temperature of ~1600 K) and 8-12 µm (at least one band with a measurement temperature of 800 K) regions for determining the abundance of high temperature fumaroles on dome surfaces and how this changes through time.

Approach:

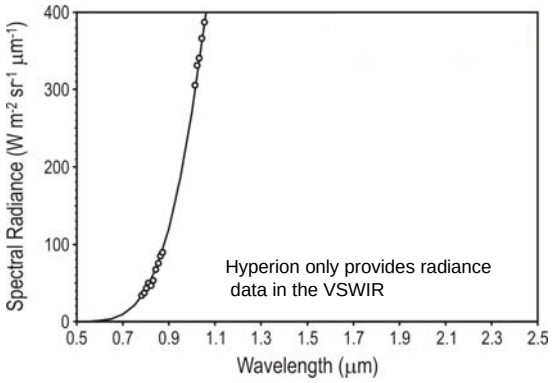
• Use systematically acquired day and night VSWIR and TIR observations for a subset of active volcanoes known to host silicic lava domes (*e.g.* Popocatepetl, Soufriere Hills Volcano) to determine temporal changes in degassing rate and the surface temperature characteristics of active lava dome surface.

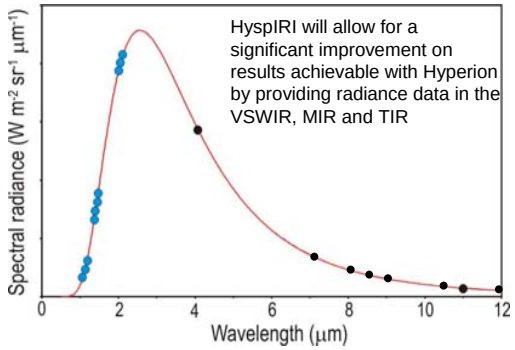
• Use historic archive of thermal flux data from MODIS to place the HyspIRI observations in temporal context.

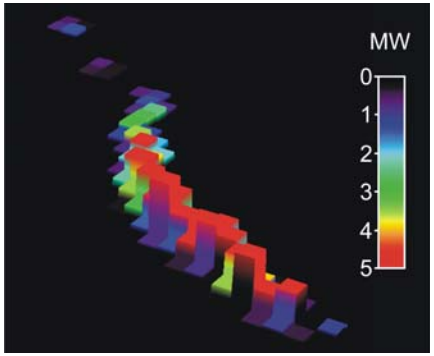
CQ3c: Can measurements of the rate at which lava flows cool allow us to improve forecasts of lava flow hazards? (DS 50; 226)



$$L(\lambda) = \sum_{i=1}^{n} f_i L(\lambda, T_i)$$







Radiant cooling of the active lava channel shown above, determined from the EO-1 Hyperion VSWIR imaging spectrometer

Science Issue:

• The rate at which a lava flow cools exerts a fundamental control on the distance from the vent at which it solidifies. The surface temperature of an active lava flow and how this vary spatially and temporally, is therefore key information for parameterizing, and validating, numerical models that forecast lava flow hazards.

Tools:

• Satellite observations from HyspIRI. Requires hyperspectral VSWIR data as well as multispectral data in the 4 μm (saturation temperature of ~1600 K) and 8-12 μm (at least one band with a measurement temperature of 800 K) regions for un-mixing the sub-pixel radiative components of active lava flow surfaces (right). These temperature data can be used to estimate energy fluxes from flow surface and subsequently, lava cooling rates (bottom right).

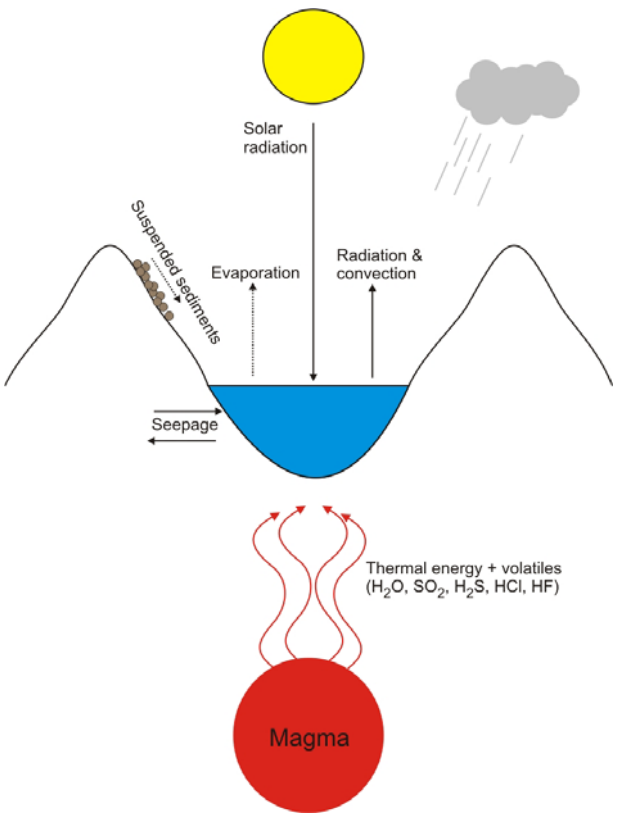
• Published numerical models of lava flow motion which will take the HyspIRI-derived temperature/cooling data as an input.

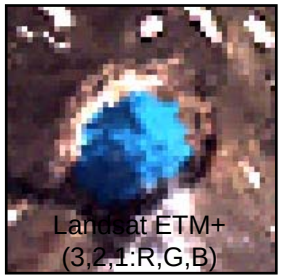
• Heat flux estimates derived from simultaneously acquired high temporal/low spatial resolution sensors (*e.g.* MODIS) as both a point calibration and to assess the short time scale variability of heat fluxes during eruptions.

Approach:

• Schedule nighttime VSWIR and TIR observations during eruptions that produce basaltic lava flows. Systematic nighttime VSIW and TIR acquisitions for high priority volcanoes that frequently erupt lava flows (*e.g.* Kilauea, Etna, Piton de la Fournaise). Possibly using the JPL volcano sensor web and U. Hawaii's low resolution MODVOLC global volcano monitoring system to autonomously perform the tasking for other volcanoes that erupt lava flows less frequently (*e.g.* Fernandina, Galapagos).

CQ3d: Does the temperature and composition of volcanic crater lakes change prior to eruptions? (DS 226; 227).





Science Issue:

• Some 100 Holocene active volcanoes host crater lakes. These lakes act as chemical condensers and calorimeters that allow us to quantify energy and chemical fluxes from their associated magma bodies. Several eruptions have been observed to follow increases in lake water temperature. Variations in water color can result from increased suspended sediment content (caused by elevated seismicity and degassing through lake floor sediments), and changes in scattering properties due to changes in chemical composition. HyspIRI's TIR and VSWIR instruments will allow us to monitor these volcanoes to identify changes in the temperature, area, and color of volcanic crater lakes for changes that may indicate enhanced volcanic unrest.

Tools:

• HyspIRI's VSWIR (for quantifying lake color and area) and TIR (two bands in the 8-12 μm region) for monitoring lake water surface temperature.

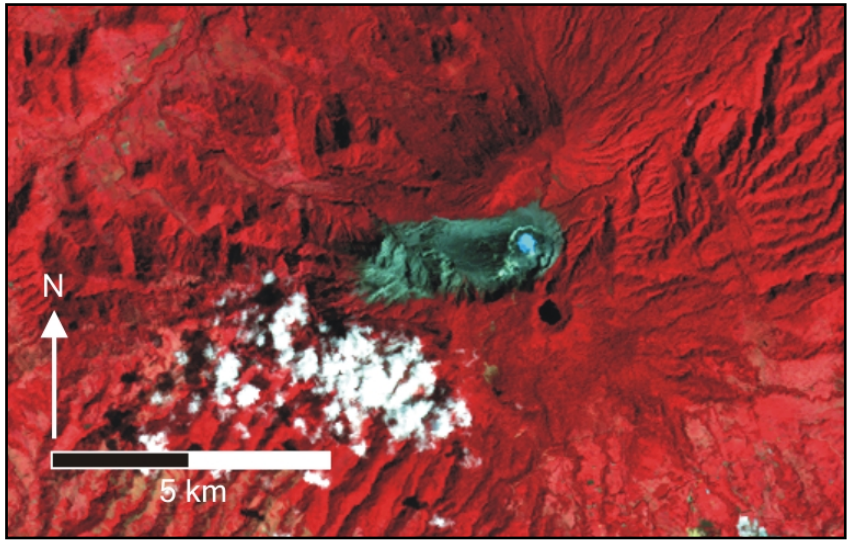
• Published enthalpy models of crater lake systems to be used as the basis for converting lake water temperatures to thermal fluxes.

Approach:

• Systematic day (VSWIR) and day and night (TIR) observations of 100 Holocene active volcanoes know to host crater lakes.

• Field campaigns (Poas volcano, Costa Rica) to acquire ground based VSWIR spectra and thermal camera data for calibration purposes.

CQ3e: Do changes in the health and extent of vegetation cover indicate changes in the release of heat, gas, and ash from crater regions? (DS 230; 231)



Landsat TM, Poas volcano, Costa Rica

Science Issue:

• Gaseous and particulate emissions from active volcanoes adversely impact surrounding ecosystems. SO_2 quickly converts to sulfuric acid aerosol, deposition of which is harmful to both humans and vegetation (below). Fluorine, adsorbed onto ash particles which may be distributed over a wide geographic area, is detrimental to both human and animal physiology. HyspIRI's VSWIR and TIR instruments will allow us to monitor SO_2 fluxes from active volcanoes and the dispersal and deposition of ash clouds, and quantify the effect that these processes have on the surrounding landscape.

Tools:

• HyspIRI's VSWIR instrument for monitoring vegetation health.
• TIR data (two bands in the 8-12 μm region) for mapping low temperature volcanogenic heat sources and the spatio-temporal distribution of volcanic ash.
• TIR data (7 bands in the 8-12 μm region) for quantifying and monitoring SO_2 degassing rates.
• Pre-eruption/archival thematic maps/image maps showing how landscape disturbance has progressed through time prior to HyspIRI launch for a subset of volcanoes.

Approach:

• Automated vegetation health change detection algorithms for a selection of active and potentially active volcanoes.