TQ1. Volcanoes/Earthquakes

How can we help predict and mitigate earthquake and volcanic hazards through detection of transient thermal phenomena?

TQ1. How can we predict and mitigate earthquake and volcanic hazards through detection of transient thermal properties?

Science Issue:

•Volcanoes can exhibit idiosyncratic behaviors leading up to eruptions. For example, SO2 production can increase dramatically, or decrease dramatically. Thermal anomalies manifest themselves in many forms: crater lakes, fumaroles, domes, etc. Transient thermal anomalies may precede earthquakes. Systematic monitoring can provide potentially effective information to aid in predicting possible eruptions and improve earthquake forecasts.

Tools:

•Satellite observations from HyspIRI TIR; requires multispectral capability to separate volcano plume constituents; requires bands in 3-5um and 8-12um for temperature determinations in range -20 to 1200C

• Historical baseline of characteristic thermal and gas emission behavior for each volcano to compare with HyspIRI observations.

Approach:

•Schedule systematic day & night TIR observations with HyspIRI over several hundred up to 1000 active volcanoes.

• Implement automatic analysis algorithms to flag anomalous thermal or gas emission activity.

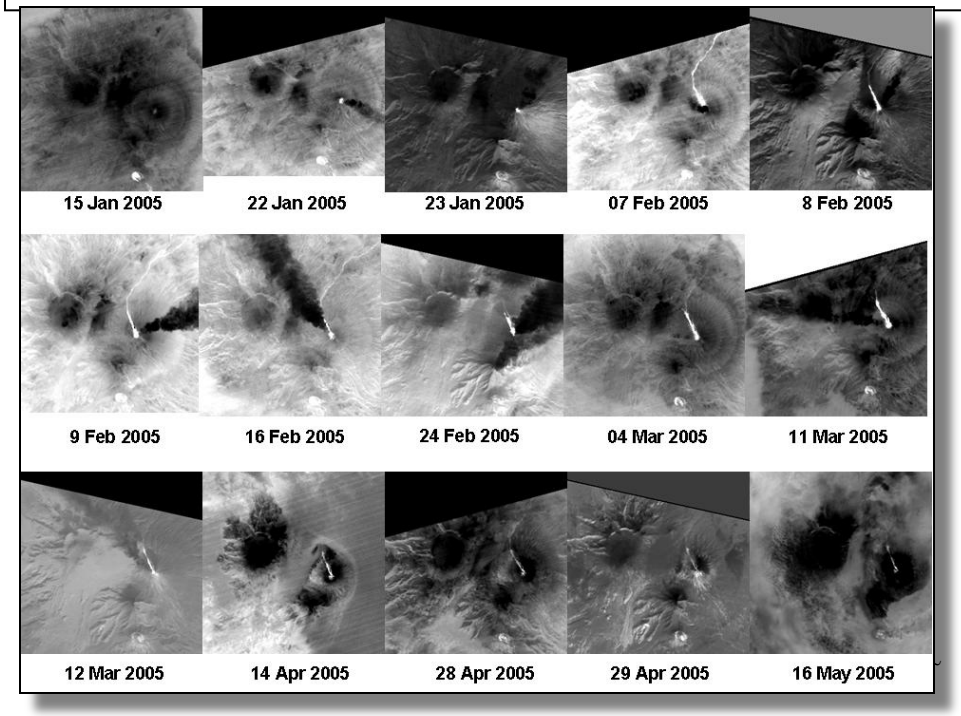
•Monitor potentially active faults with nighttime observations

Results:

• Unique, high spatial resolution TIR data from HyspIRI will improve our understanding of pre-eruption volcanic behavior; this will in turn lead to improvements in our ability to predict volcanic eruptions.

•Unique, high spatial resolution TIR data from HyspIRI will lead to improved earthquake forecasts.

TQ1a. Do volcanoes signal impending eruptions through changes in surface temperature or gas emission rates, and are such changes unique to specific types of eruptions?



Kliuchevskoy and Bezymianny volcanoes in Siberia, observed by ASTER. 15 clear-sky nighttime observations in 5 months show changes in thermal behavior of summit domes, development of lava flows and pyroclastic flows, and presence of ash and SO2 plumes. Courtesy of M. Ramsey, U. Pittsburgh.

Science Issue:

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Tools:

•Satellite observations from HyspIRI TIR; requires multispectral capability to separate plume constituents; requires bands in 3-5um and 8-12um for temperature determinations in range -20 to 100C

• Historical baseline of characteristic thermal and gas emission behavior for each volcano to compare with HyspIRI observations.

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Results:

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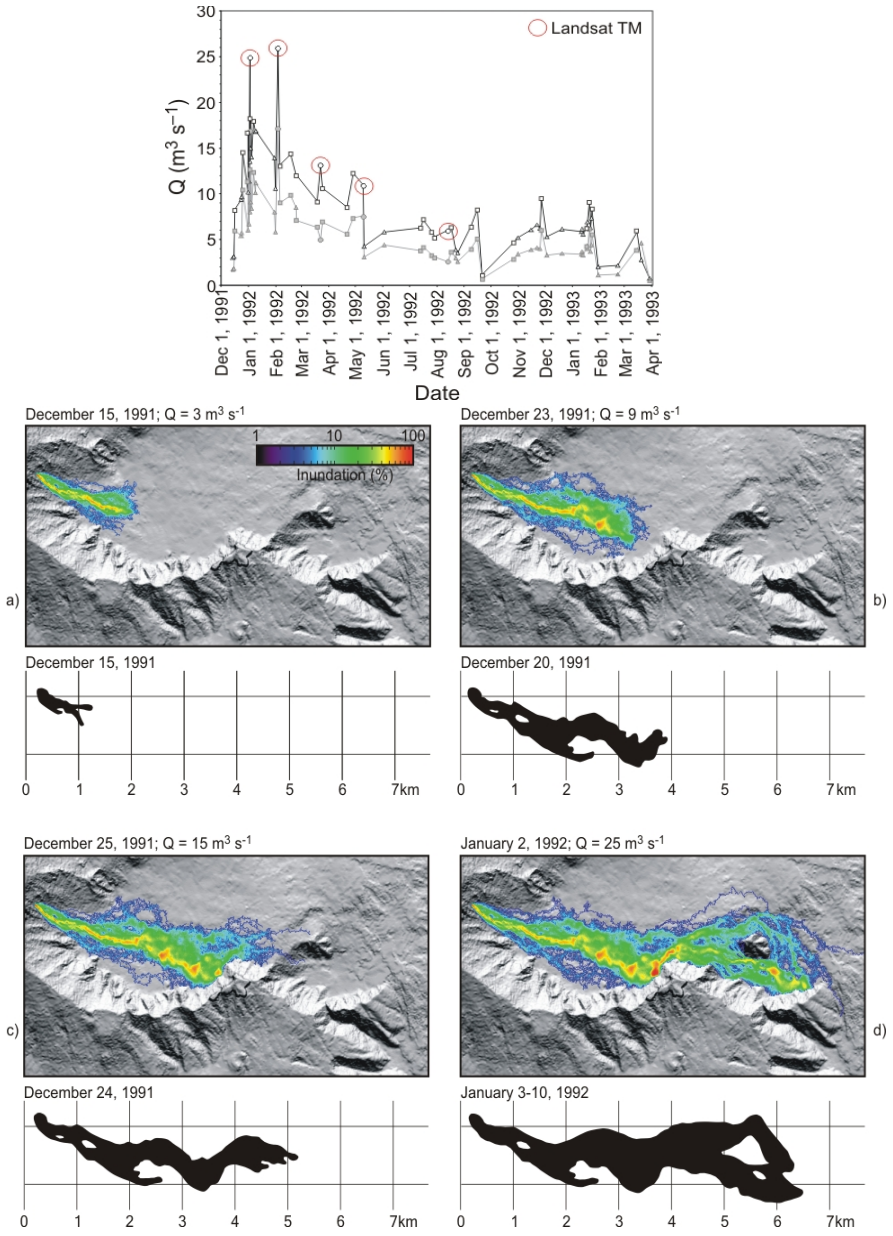
• This will in turn lead to improvements in our ability to predict volcanic eruptions.

TQ1b: What do changes in the rate of lava effusion tell us about the maximum lengths that lava flows can attain, and the likely duration of lava flow-forming eruptions?



Wright et al. (2008). *Geophysical Research Letters,* 35, L19307.

Science Issue:

• After lava composition, the volumetric effusion rate (modulated by surface cooling) determines how far a lava flow can extend from the vent before it solidifies. Effusion rates vary dramatically during eruptions, but can be quantified using infrared satellite data (top left; AVHRR, ATSR and TM data). By acquiring high spatial resolution TIR data, HyspIRI will allow us to determine effusion rates twice every five days during a lava flow forming eruption for any volcano on Earth. These data can be used to drive numerical models that predict the hazards that these flows will pose

Tools:

• Satellite observations from HyspIRI TIR; requires band at ~4 μm (saturation temperature of ~1600 K) with moderate-high spatial resolution (<100 m) for determining the area of active lava at any given time during as eruption and estimating the radiant energy flux from the flow surface.

• Pre-HyspIRI DEMs (e.g. SRTM) of all volcanoes likely to erupt basaltic lava flows

• Time-series of effusion rates determined using higher temporal resolution MODIS data for calibration.

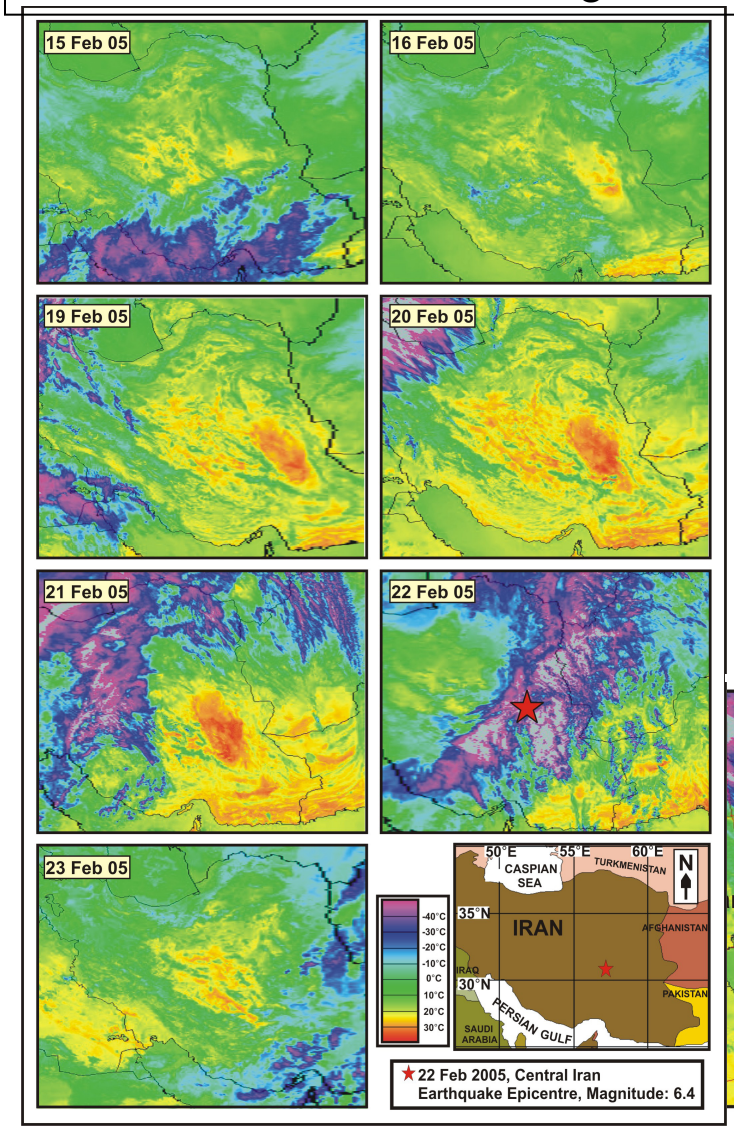
Approach:

• Implement automatic analysis algorithms to flag anomalous thermal activity, determine active lava area and thermal flux, and, subsequently, a HyspIRI-derived effusion rate. Using this, a DEM, the vent location as recorded in the HyspIRI data, and a numerical lava flow model, generate simulations of likely lava flow paths for the given effusion rate. Autonomously update the hazard simulation as most recent HyspIRI derived effusion rates become available (lower left).

Results:

• A global, near-real-time lava flow hazard assessment tool, driven by HyspIRI TIR data.

What do the transient thermal infrared anomalies that may precede earthquakes tell us about changes in the geophysical properties of the crust?



M=6.4 earthquake in Iran 22 Feb. 2005
Good viewing conditions
(similar to Southern CA)

courtesy Saraf et al. 2008

Science Issue:

- Prior to major earthquakes, the build-up of stresses deep below can manifest itself in the emission of spectroscopically distinct, narrow non-thermal IR bands. When volcanoes become activated, they are expected to exhibit the same type of non-thermal IR emission before the arrival of a thermal pulse at the surface.

Tools:

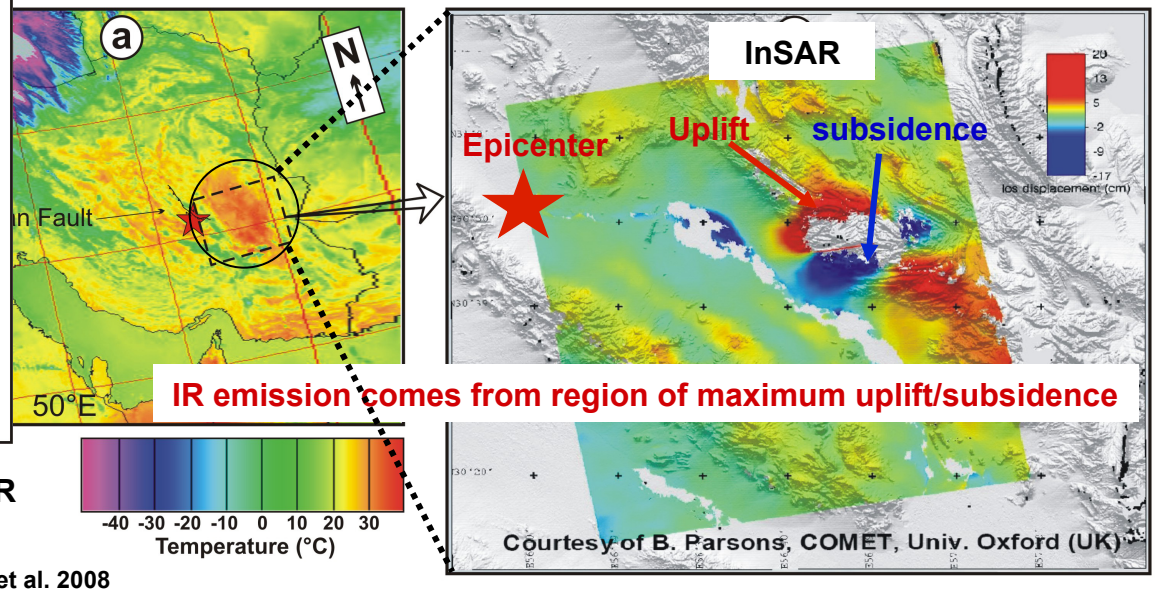
- Satellite observations; Narrow bands in the 10.7-12.5 μm range.

Approach:

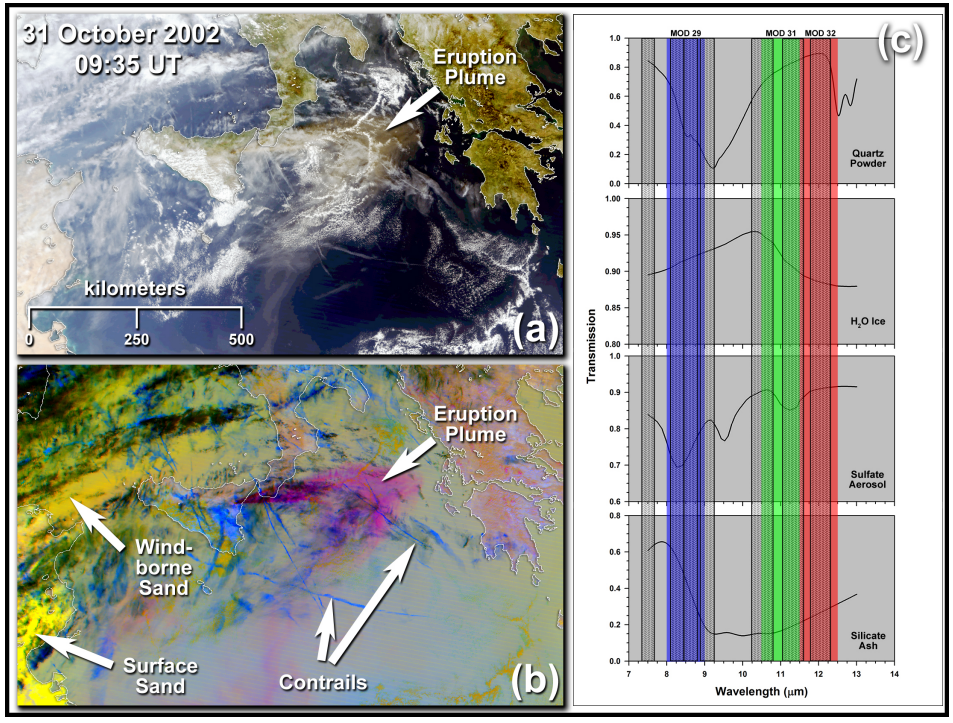
- Schedule repetitive observation. Difference spectra.

Results:

- Spectroscopically distinct non-thermal IR bands can appear before earthquakes, mixing with the thermal signature. Same for volcanoes.



TQ1d: What are the characteristic dispersal patterns and residence times for volcanic ash clouds and how long do such clouds remain a threat to aviation?



Detection of Eruption Plumes in the Thermal Infrared (TIR)

(a) MODIS true-color composite of data acquired over Mount Etna illustrating the difficulty of distinguishing a plume from surrounding meteorological clouds; (b) False-color composite of MODIS TIR data (Ch. 29, 31, 32 displayed in blue, green, and red, respectively) illustrating the unique spectral signatures of the eruption plume (silicate ash), jet contrails (ice), and windborne sand; (c) Model transmission spectra for silicate ash, sulfate aerosol, ice, and quartz powder (representing sand). The blue, green, and red color bars represent MODIS Ch. 29, 31, and 32, respectively; the shaded bars represent the proposed HyspIRI TIR channels. HyspIRI will have three channels in place of MODIS Ch. 29 and three channels in place of MODIS Ch. 31 and 32, enhancing our ability to detect and track eruption plumes and clouds.

Science Issue

The ash plumes generated by explosive volcanic eruptions pose a significant hazard to jet aircraft. Current air traffic protocol is to clear the airspace in the vicinity of the erupting volcano, but the ash plumes may be transported hundreds to thousands of kilometers from their sources. The use of true-color images to discriminate volcanic plumes from meteorological (met) clouds, and other suspended aerosols and particulates, is problematic (Panel (a), at left).

Tools

•HyspIRI multispectral TIR image data, 5-day revisit cycle (daytime acquisitions) at equator, spatial resolution of 60 m, and spectral channels as shown in Panel (c) (at left).

•Profiles of atmospheric temperature and water vapor, measured with radiosondes and spaceborne sounding instruments or model predictions.

•Radiative transfer model to predict radiance at the sensor given atmospheric profiles, length of optical path, and surface temperature, emissivity, and elevation (provided by DEM).

Approach

•Develop Internet portal to provide interactive plume analysis tools and on-demand modeling.

•Statistics-based enhancement of spectral contrast to discriminate eruption plume from met clouds (Panel (b), at left).

•Radiative transfer-based analysis tools to confirm presence of eruption plume and materials derived from plume

Results

On-demand detection and tracking of eruption plumes via Internet portal, with 2 (1 day + 1 night) HyspIRI revisits per 5 day cycle at equator, and more frequent coverage at higher latitudes.