SPACECRAFT AND IN-SITU OBSERVATIONS OF THE MT. EREBUS, ANTARCTICA, LAVA LAKE: A TERRESTRIAL ANALOGUE FOR PELE ON IO. A. G. Davies[1] and P. Kyle[2]; [1]Jet Propulsion Laboratory-California Institute of Technology, ms 183-501, 4800 Oak Grove Drive, Pasadena, CA 91109 (email: Ashley.Davies@jpl.nasa.gov); [2]Mount Erebus Volcano Observatory (MEVO), New Mexico Institute of Mining and Technology, Socorro, NM 87801.

Introduction: We have obtained multiple contemporaneous ground and space-based visible and hyperspectral infrared observations of a persistent active lava lake, one of the rarest volcanonological phenomenon. This unique dataset advances our understanding of remote sensing of lava lake activity on Earth and Io.

The Mt. Erebus lava lake: Active lava lakes are the top of an open magma system and provide a view into the magma supply and circulation process in volcanic conduits. Such features are currently found at Erta'Ale, Ethiopia; Nyiragongo, Democratic Republic of Congo; and at Mt. Erebus, on Ross Island, Antarctica. The latter, the world's southernmost active volcano, is the focus of this study.

Figure 1. The Mt. Erebus lava lake on 2005 Dec 14 (UT), taken from the crater rim (3794 m). The lava lake is ~40 m across.

The Mt. Erebus lava lake (Figure 1) was first observed during the early 1970's [1] and has been active ever since. A review of the remote-sensing of this volcano from Earth orbit, up to the launch of the *Earth Observing 1* (*EO-1*), *Terra* and *Aqua* spacecraft, is found in [2]. In the fall of 2005 the lava lake, about 40 m in diameter, was undergoing a period of elevated strombolian activity the like of which had not been seen since 1984. Volcanic activity is characterised by a persistent, convecting lake of somewhat unusual magmatic composition, an anorthoclase phonolite, which feeds a plume of acidic gases and aerosols [3,4]. As a location of persistent volcanic activity, Erebus is a prime target for study of thermal emission from a rare volcanological feature, both on the ground [5] and using remote-sensing techniques [6-9]. Mass eruption rates, based on observations of thermal emission, have been estimated in the range 30-76 kg s^{-1} [10]. There is evidence, in the form of multiple growth phases of phenocrysts [11], to support a circulation model [7] where magma rises via a conduit to the surface, cools, increases in density, and sinks back down to the magma chamber, where reheating take place.

The Pele lava lake: Currently-active lava lakes are not confined to Earth. An active, persistent lava lake has been proposed for Pele, on the jovian satellite Io, primarily based on the analysis of *Galileo* Near Infrared Mapping Spectrometer (NIMS) data, which revealed persistent short wavelength (1-5 micron) thermal emission consistent with vigorous eruption of lava, but without the emplacement of extensive lava flows [12]. Much larger than the lake at Mt. Erebus, Pele is an important contributor to Io's volcanic thermal budget with eruption rates estimated at 644,000-889,000 kg s^{-1}. Even so, thermal flux and mass densities are similar to those seen at the Kupaianaha, Hawaii, lava lake during relatively brief periods of vigorous crustal disruption and overturning, accompanied by lava fountaining [12]. Magma composition is therefore probably very different to that found at Erebus. The integrated thermal emission spectrum from Pele always peaks between 2 and 4 microns, implying continual exposure of incandescent lava [12]. Janus, another Ionian volcano, may have exhibited a similar style of activity at one point during the *Galileo* era (1996-2003).

While some studies of NIMS Pele data indicate magma at high (ultramafic) temperatures may be present [13], temperatures derived using sophisticated lava cooling models to combined *Galileo* NIMS infrared data which are constrained at short wavelengths with *Galileo* Solid State Imager (SSI) visible and short-infrared wavelength data indicate magma temperatures in the mafic liquidus range (1200-1400 K) [12], and recent advances in modelling the response of the SSI camera appear to confirm the lower temperature range [14], although the presence of ultramafic temperatures cannot be conclusively ruled out.

For Pele, only remotely-sensed data are available, obtained from ground-based telescopes and from the Hubble Space Telescope in Earth orbit, and from fly-bys by the *Voyager*, *Galileo* and *Cassini* spacecraft [15]. In most cases, the thermal source is sub-pixel. Only a few observations have been obtained where the lava lake has been resolved [12,13,15].

Observations of Mt. Erebus - establishing groundtruth: In December 2005 we obtained contemporaneous infrared thermal emission data of the lava lake, *in situ* and from instruments onboard spacecraft in Earth orbit. This (1) provides ground-truth of data obtained by a number of different visible and infrared instruments on three different spacecraft in orbit, especially the Hyperion hyperspectral imager on *EO-1* to help evaluate the performance of the thermal classifiers used by the Autonomous Sciencecraft Experiment (ASE) that is onboard [16]; (2) creates a dataset of hyperspectral and multispectral observations that can be used to test models developed for interpreting data of volcanism on Io, only here the model fits can be compared with established ground-truth to determine their accuracy; and (3) aids further development of the Jet Propulsion Laboratory Volcano Sensor Web, which uses triggers generated from *in situ* acoustic detectors installed and maintained by the Mount Erebus Volcano Observatory (MEVO) [17] to autonomously re-target *EO-1* to obtain more data [18].

Ground-based observations: Observations were obtained using two Forward Looking Infrared (FLIR) cameras, a ThermaCAM P65 sensitive up to 1500 C (thus capable of observing lava at or close to eruption temperature (1000 C) without saturating), and a ThermaCAM EX320 that could observe temperatures up to ~250 C without saturating. We used the two cameras, set to different sensitivity ranges, to obtain simultaneous observations of the lava lake.

Space-based observations: The *EO-1*, *Terra* and *Aqua* spacecraft are in 705 km altitude, highly inclined orbits yielding many opportunities every 16-day cycle to observe high-latitude targets. On four occasions during the field deployment, the FLIR cameras were used to establish ground-truth for observations made by ASTER and MODIS on *Terra*, and Hyperion and ALI on *EO-1*. Instrument capabilities and numbers of observations obtained between 7-18 Dec 2005 are shown in Table 1. Not shown are additional *Aqua* MODIS observations obtained but not ground-truthed.

Expected results: This is very much a work in progress. We have high hopes for a better understandding of the capability of remote sensing of this particular mode of volcanic activity. In particular, each the ground-truthed observations are part of a larger observation sequence. For example, *Hyperion* obtained 53 observations of Erebus from 9 November 2005 to 9 Januray 2006. MODIS obtains at least four observations per day. A short minutes-long IR movie was also shot. We therefore now have sequences of multi-wavelength data that will lead to quantification of thermal emission, temperature distribution, and eruption rate, on different time scales and at different instrument resolutions. We will test models of thermal emission and apply this to observations of Io.

Table 1 Spacecraft Instrument Capabilities[a]

Spacecraft	*EO-1*	*EO-1*	*Terra*	*Terra*
Instrument	Hyperion	ALI	ASTER	MODIS
Bands	220	10	14	36
λ , µm	0.4-2.5	0.4-2.5	0.5-14	0.5-14
Resolution, m/pixel	30	10-30	15-90	250-1000
Observations 7-18 Dec 05	14	14	7	22+

a 1999 EOS Reference Handbook http:/eos.nasa.gov

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