A rift zone fire fountain model and a silicate lava flow model are used to explain the Io thermal IR outburst of 9th January, 1990. This is the best observed large thermal outburst from Io. The dataset is multispectral with respect to time, and is therefore unique. These data cannot be fitted by some scenarios, such as an active lava flow or cooling body of magma, or an overturning lava lake. The 9th January 1990 event can be modelled as a two-component silicate eruption, consisting of a rift eruption producing a line of large fire fountains, feeding a large clastogenic lava flow.

The 9th January 1990 thermal outburst from the Loki region of Io was observed with the IRTF [1]. This dataset is unique in as much as the observations are multispectral as a function of time. This has made possible analysis of the event beyond that of simply producing colour temperatures, which is necessarily the case with observations at a single wavelength. The implied temperatures from the 4.8 and 8.7 micron observations are at silicate liquidus temperatures (1475 K). The 9th January 1990 outburst is characterized by a decrease in 4.8 micron output with time and a simultaneous increase in 8.7 micron output. Simple models of eruption scenarios that do not fit the observed trends include an active silicate flow, a stationary cooling flow, and an overturning or overflowing lava lake. Additionally, the event is time-constrained. None of this anomaly was seen during Io observations two days earlier. Any eruption model has to reach the observed stage within this time period. This event can be modelled as a two-component silicate eruption. The first component consists of silicate flow, increasing in area at $\sim 7 \times 10^4$ m$^2$ s$^{-1}$, implying a large mass eruption rate. The second consists of a hot area, at near silicate liquidus temperatures, that is gradually reducing in size. This is interpreted as a rift zone producing a line of fire fountains, the ejecta from which coalesce on landing to feed the lava flow. Such eruptions have been observed on Earth [2]. On Io the absence of a thick (terrestrial) atmosphere and lower gravity than Earth means that an identical magma would produce a much larger fire fountain. The force driving the fire fountaining is primarily the expansion of volatiles that have degassed from the magma. The degassing process, and the flow of material in the conduit, accelerate as pressure decreases as the magma nears the surface [3]. Only a small magma volatile content is required to produce fire fountain eruption velocities sufficient to cover the hot area required by the model on Io. Clast distribution is aided by further expansion of the gas phase. In one solution, the hot area has an initial area of about 45 km$^2$, at a temperature of 1473 K. If the fissure feeding the flow is 10 km long, this zone is 4.5 km wide. On Earth, a much smaller area would be covered by the ejecta as a thick atmosphere and higher gravity results in lower eruption velocities. Eruptions on Io take place in a lunar-like environment (ie, no atmosphere and similar gravity). The discussed style of high-volume, short duration eruption, with associated optically thick fire fountains, has been predicted for some lunar eruptions [3]. The hot area is reducing in size with time. This might be due to a number of processes, including (a) the fire fountains reducing in size due to a reduction in volatile content of the erupting magma (this suggests that some fractionation and degassing in the magma chamber is taking place); (b) changes in the vent geometry as a clastogenic lava pool forms (through which the erupting material has to pass) changes the deposition pattern of the clasts; or (c) there is a reduction in the total crack area of the flow crust, reducing thermal output at shorter wavelengths even as the cooler crust area increases, as would be the case with the formation of lava tubes. A combination of these processes is probably taking place.

The addition of the thermal output from the flow (which increases with time) and the thermal output from the fire fountains (which is reducing with time), reproduces the observations of 9th January 1990 (see figure: solid lines are the Veeder et al. observations: dashed lines are output from the Io Flow Model). Observations of Io over the next few years by the NIMS instrument on the Galileo spacecraft and from Earth-based observatories will undoubtedly yield more multispectral thermal IR data of eruptions, relevant for constraining eruption models.
FIRE FOUNTAINS ON IO.  A.G. Davies

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Figure: Comparison of observations of 9th January 1990 event (Veeder et al. 1994) with output from Io Flow Model (dashed lines), combining thermal output from line of fire fountains and active lava flow. Data shown for 4.8 and 8.7 microns.