Estimates of Heat output from the Yellowstone Plateau Volcanic Field using different approaches

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Yellowstone is one of the largest and most restless calderas on Earth and its magmatic system is one of the most focused heat sources on Earth. The most recent caldera-forming eruption occurred around 0.64 Ma ago, though smaller explosive and lava-effusing eruptions have continued up until approximately 70 ka. The magmatic system remains active as manifested by abundant seismicity, deformation and the presence of more than 10,000 thermal features. Quantifying heat flux through the ground surface can provide insight into magma intrusion rates and hydrothermal flow, but is a daunting task because of the vast extent of thermal areas in and around the Yellowstone Caldera. Nevertheless, obtaining such data could provide an improved understanding of magmatic processes, which in turn, allows for a better estimate of hazards. Heat is transported to the surface by conduction and by advection of liquid water and steam. Heat is transported away from the surface by evaporation from lakes, pools, and rivers, conduction to the atmosphere, and radiation. Diverse methods are used to quantify heat discharged through these various modes. Estimates in the early 20th century that were based on the integration of discharge and temperature measurements of individual thermal features throughout Yellowstone yielded a total heat output of about 1 GW [Allen and Day, Carnegie Inst. Publication, 1935]. The chloride-inventory method, which was initially applied to Yellowstone in the 1970s, assumes that all the chloride discharged by rivers draining Yellowstone is derived from a single deep parent fluid [Fournier, AREPS, 1989]. With this method and a set of plausible parameter values, estimates of heat output vary by a factor of two. A minimum output of 4 GW corresponds to a chloride concentration of 450 mg/L, a temperature of 320 C, and a chloride flux of 45 kt/yr, and a maximum output of 8 GW corresponds to a Cl concentration of 350 mg/L, 360 C, a flux of 55 kt/yr Shallow conductive temperature gradient measurements and evaporation from thermal pools are restricted to very small areas [Morgan et al., JGR, 1977; Hurwitz et al., JGR, 2012] and the extrapolation of these data to the entire Yellowstone Plateau incorporates many assumptions. Extrapolation of the average heat flux from two small vapor dominated areas to the approximately 35 km2 of vapor dominated areas in Yellowstone yields more than 3.6 GW [Hurwitz et al., JGR, 2012]. Satellite-based thermal infrared (TIR) remote sensing methods provide estimates for the entire Yellowstone thermal anomaly, but measure only the radiative component of heat output. For example, nighttime ASTER TIR data were used to estimate a radiative heat output of about 2.0 GW [Vaughan et al., JVGR, 2012]. Future studies aimed at integrating these disparate approaches and characterizing temporal variations will require a combination of ground-based methods, airborne infrared, and improved satellite radiometers.