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A calibrated visual web camera network for measuring volcanic plume heights: technical aspects and implementation for operational use

Talfan Barnie, Tryggvi Hjörvar, Eysteinn Már Sigurðsson, Melissa Anne Pfeffer, Þórður Arason, and Sara Barsotti
Icelandic Meteorological Office, Reykjavík, Iceland (talfan@vedur.is)

The Icelandic Meteorological Office (IMO) maintains a network of web cameras for monitoring the environment and identifying possible hazards, including reduced atmospheric visibility, changing river flow conditions and snow accumulation. Recently, the network has been expanded to improve the volcano monitoring capacity, with the specific aim of observing eruption onset and estimating volcanic plume heights. Here, we present how sites for cameras are chosen, the environmental constraints that inform the two camera designs currently in use, how the data is transmitted to the institute, stored, and pushed through the data processing system, and the different techniques used to calibrate the cameras and calculate the orientations of plumes such that measurements can be made from the images they produce. Camera calibration is a particular challenge for such a diverse range of cameras and environments, with some cameras already installed and inaccessible, and here we show how we use laboratory calibration, feature matching, horizon matching and star matching to find the internal camera geometry and camera orientation in different scenarios. Once calibrated, geometric measurements can be extracted from the images by either providing constraints from Numerical Weather Prediction (NWP) models on the likely orientation of the plume, or by using two images with different views, which provide enough information to pin down a point in three dimensions. In the latter case we show how ray projection can be used to locate a point. These plume calculation tools and final images are made available to the forecasters and natural hazard specialists on-duty using an interactive webpage. The plume height time series are easily saved for ingestion into the Volcanic Eruptive Source Parameter Assessment (VESPA) inversion system designed to assess eruption intensity and to provide calculated eruption source parameters in input to the tephra dispersion forecasting model.