Observation of volcanoes through webcams: Tools and techniques

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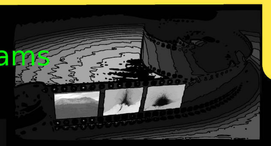
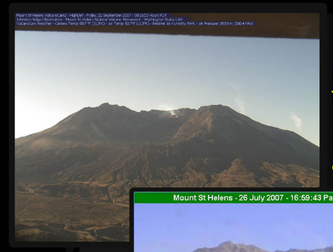
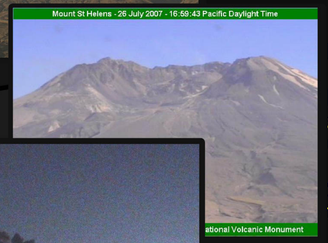
Why use Webcams





Popular with the public, good for outreach.

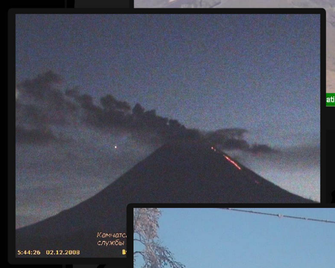
Provide a near real time view of activity.

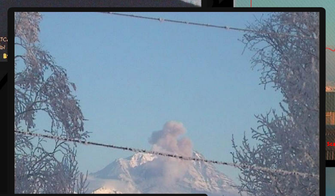


Easy to interpret.

More accessible than seismogram's, to untrained observers.

Some sensitivity in the Near IR.





Tools that aid manual analysis

Image date extraction and duplicate image removal. makes it easy to see when the webcam has got stuck or is otherwise offline, so duplicate reports are minimized.

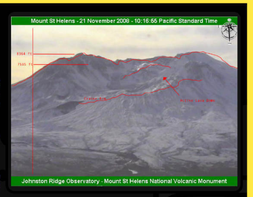
Ability to hide images which are dark or completely cloudy, so they dont need review.

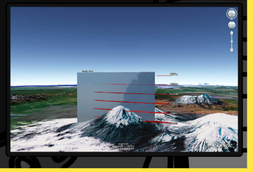
Automatic pre-generation generation of movies, so that it is quick and easy to review the previous 24 hours worth of activity.

Image annotation to place a scale and highlight key features allows better description of activity, and also easier interpretation of dark or partly cloudy images.

Generation of kml files, to allow images to be placed into Google Earth, for easier interpretation and integration with other datasets.

Possible integration with other data streams, seismic, or satellite images.





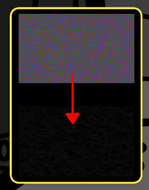
Automatic Webcam Processing and Interpretation

Removal of noise

Dependent on source of noise

Uncorrelated across channels (RGB) noise sources
Dependent on digital sensor type..... (CCD or CMOS)
Signal Amplification technique.... (Analogue or Digital)

Correlated noise sources
Temperature of camera.
Period of image exposure.
File format compression technique.... (JPEG, PNG, etc)



Techniques

Uncorrelated RGB noise removal, such as that in the night time St. Helens Low resolution camera, effectively removed through multiplying the signal magnitude.

Intensity =Red·Blue·Green

Correlated noise removal, Image pixel averaging through time, and Irani-Peleg style, super-resolution technique (ensemble back projection to simulate low resolution images, then minimizing the SNR ratio through altering the high resolution image.)

Isolation Of Uninteresting Images

Technique is based on Image Statistics. First the image is divided into a number of regions, several control regions where no activity is expected, and also 1 or more target regions where we expect to find activity.

The mean, min, max, variance, and histograms are calculated for the DN values of each of these regions. The control regions are then combined. If the target regions are not distinguishable from the control regions then the image is classified as uninteresting and can be excluded from further processing. criteria on deciding if the an image is distinguishable is adjusted on per webcam basis, but typically are decided through low variance, and mean DN values being close to each other.

Example Application

Mt St Helens

Analysis of St Helens Hi-Def webcam data

Individual Images effected by jpeg compression artifacts, so a Irani-Pelleg "Super-Resolution" algorithm used to combine images. A Gaussian edge detection algorithm was used to highlight regions of strong contrast without offsetting the data in pixel space.

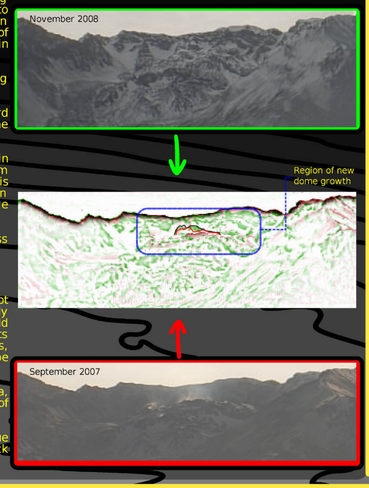
Despite this processing features delineating the dome region are still difficult to isolate.

Each pixel is approximately 4m by 4m, hard to estimate accurately due to effects of the camera optics.

The area between the lines, (outlined in blue) is presumed to be dome growth from September 2007 to November 2008. This is broadly consistent with closer hi resolution camera's and the end of the current eruptive phase in Feb 2008.

Equivalent to a height gain of a little less than 10m

Image Comparison to Determine Dome growth

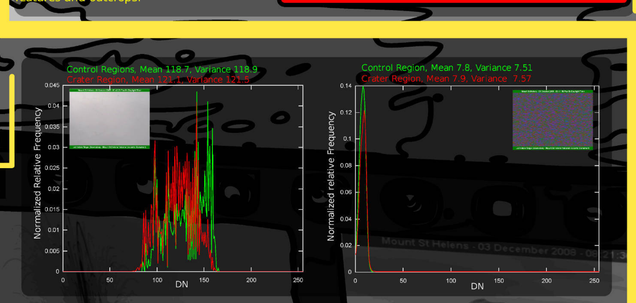


Conclusion and Recommendations,

Even the Hi-Res St Helens webcam is not adequate to estimate dome growth, ideally at least a 50% greater pixel density would be needed before compression artifacts could be excluded from the image analysis, and boundaries between regions could be isolated.

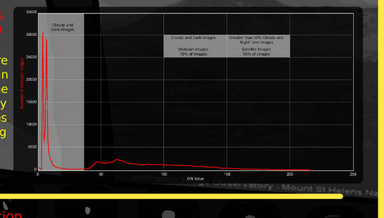
Very demanding on the optics of the camera, soft images make discerning the regions of growth tricky.

Presence of steam makes isolating true edges difficult as they may mask rock features and outcrops.



Comparison of Cloudiness between Satellite and Webcam views

Cloudiness and nighttime images are established based upon the difference in variance between different parts of the image, which results in approximately 75% of all webcam images at St Helens being cloudy or Dark, the coresponding figure for satellite images is 90%.



Towards Automatic plume detection

A number of techniques are being developed to establish if any are suitable for automatic plume detection, the aim is to identify in which images their is significant steaming and eruptive atmospheric emissions.

The most promising technique so far is to establish the ratio of brighter pixels contained with in different regions of the image to those of selected control images. The plume-control image set would vary in the amount of snow on the ground and similarly different background sky brightness, thorough matching control regions within the target image, to the most similar plume-control image, it is hoped that the subtraction of common elements would lead to a DN brightness difference that would be indicative of images with steaming and plumes present.

This work is ongoing, and is most likely to result in a system that would aid rather than replace the work of manually interpreting the webcam images.

Database and System Design for Open-Ended Analysis

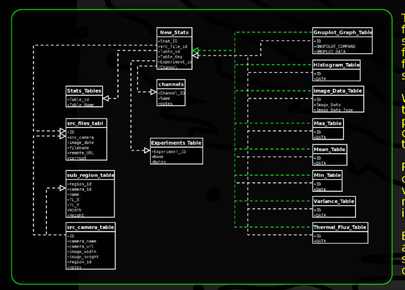
Our System is developed to allow rapid processing of both current and historic webcam images, utilizing a MySQL database and set of simple ruby scripts.

The system automatically imports existing images from local storage or over the web to populate its source image tables. In addition images are only fetched to local storage when they are needed for further processing, this removes the need for a large storage capacity.

We are able to create new descriptive tables at will as the system develops and link them to the existing processed source images. This makes the development of new algorithms very quick, and easy to integrate with the running system.

Ruby is used as a scripting language to establish both consistency with the rest of our remote sensing volcano monitoring software, and also to provide a relatively high level interface upon which to base improvements.

Each experiment on the webcam images, can be analyzed independently and run on different webcam sources, such as the Russian webcams, or AVO operated camera's

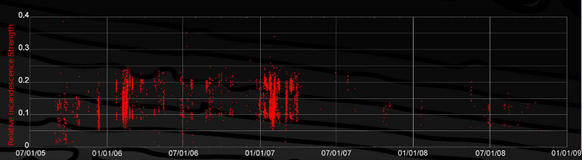


Automatic Incandescence Detection

Detection of Incandescence works in a very similar fashion to the technique used to isolate uninteresting images. In this case the difference signal from the target region and the control region is established, then all the pixels that are brighter than a set threshold are counted and weighted according to their DN brightness.

As a result a pseudo thermal-flux index is created that can then be used to establish the strength of activity over time. While this measure is quite coarse it still provides a strong indication of how active activity is at any particular point in time.

The few instances which do cause false measurements seem to occur when either the moon is above the crater, or when planes are flying in the distance just above the crater rim. To get an idea as to the frequency of these events, it is worth noting that their has been little in the way of activity during 2008, how ever their are 53 images found.



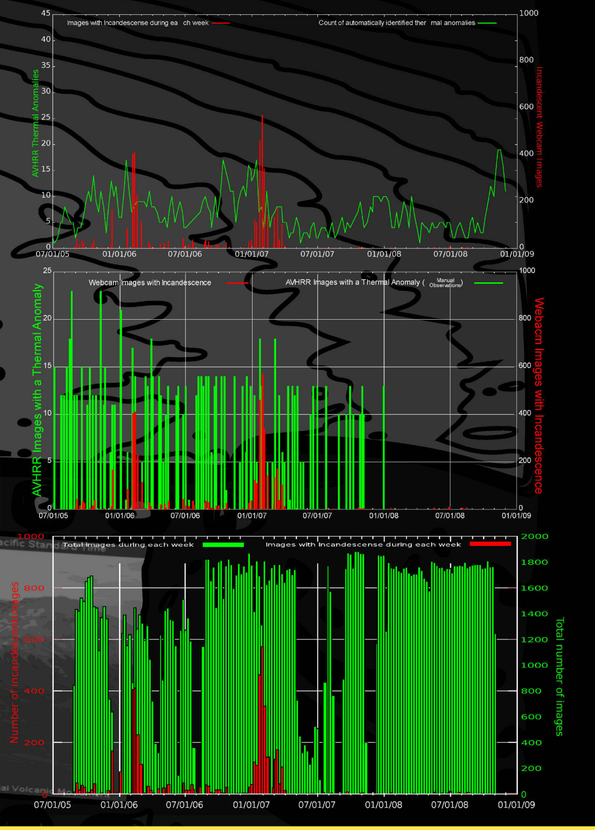
Nocturnal Incandescence

Most Digital Cameras have some degree of sensitivity into the Near IR wavelengths, as a result it is sometimes possible to see incandescence in night time imagery,

The low resolution Mt. St. Helens, is sensitive to these near IR and they appear as correlated signals in each of the RGB channels, this allows them to be separated from the high signal noise of the camera at night. While we do not have a complete collection, we have an archive of webcam images from September 2005 (bottom chart).

When compared to manual observations of AVHRR satellite images (middle chart), the satellite data quantize's the activity to an essentially constant rate of thermal anomalies per week (with some variance due to number of passes, and cloudiness), In contrast the webcam incandescence is able to capture the variations in activity with a greater dynamic range.

When compared to an automatically generated (OKMOK II algorithm) count of thermal anomalies (top chart), it becomes clear that the webcam also captures much less noise. For example little activity has occurred at St. Helens during 2008, in contrast the automated detection technique records a significant number of anomalies.



References and Acknowledgments

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