NOAA/APT Satellite Data for Online and Real Time Monitoring of Tungurahua Volcanic Eruption and Temperature Profile in Ecuador

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Introduction and Scientific Objectives

In our daily life, an increasing frequency of natural disasters can be observed due to rapid change in anthropogenic activities. Meteorological studies of our planet require atmospheric data available through space agencies like NASA, ESA and/or from freely available NOAA weather satellites. The **automated picture transmission (APT)** data from NOAA can be received throughout the world using commercial or homebrew Quadrifilar Helix Antenna (QHA) and a wideband receiver operating at 137 MHz frequency range FM mode. By times, NOAA satellites are already being used in remote sensing applications to monitor almost all types of natural disasters. The accuracy of analysed data can be used in forecasting, monitoring and damage assessment caused by eruptions.

Ecuadorian Space Agency (**EXA**) has built **HERMES**; an online and real time ground station (GS) available to participating universities and schools for free access to NOAA and other remote sensing satellites. The GS can be used by students and scientists anywhere in the world to access NOAA satellites and spacecrafts online using only a computer and an internet connection with immediate access to satellite imaging and science data in the field of climate research, educational student projects, and government access to real time disaster information, prevention and mitigation. The HERMES internet-to-orbit gateway transforms a laptop into a full space-qualified GS on-the-move.

Tungurahua is an active **stratovolcano** (Lat. 01°28‘ S; Long. 78°27‘ W) located in the Cordillera Central of Ecuador. The volcano gives its name to the province of Tungurahua. Volcanic activity restarted in 1999, and is ongoing as of 2010, with major eruptions on 16 August 2006, 6 February 2008, 28 May 2010, and 4 December 2010. With its elevation of 5,023 m, Tungurahua just over tops the snow line (about 4,900 m). Tungurahua's top is snow covered and did feature a small summit glacier which melted away after the increase of volcanic activity in 1999 [1] . Recent volcanic eruption caused melting of glaciers due to high temperatures 30 °C.

Tungurahua is considered to be a dangerous volcano which threatens the tourist town of Baños, as well as other small villages. A few kilometers east of Baños, the large Pastaza river is contained by the Agoyan dam and used for hydroelectric power generation. Future eruptions of Tungurahua threaten this dam and reservoir, the second most important in Ecuador [2].

The purpose of this paper is to present results of Andean mountain area in Ecuador being affected by high temperatures over 30 °C (~ 20 °C on average) located over 3000 m high. On May 15 through May 20, 2010, we have received and processed images from NOAA-18 and NOAA-19 using HERMS GS and measured this high temperature variations. Records from the meteorological station network validated these results and also showed that these temperatures set new highs never recorded in this particular region, where many glaciers are located. Also, visual observations reveal that those glaciers are in fact receding and exposing terrain never seen before. The paper will also highlight possible causes of this rapid thermal change.

We have used **Surface Temperature (ST)**, a remote sensing tool to extract the precise information from the NOAA/APT data and processed with thermal enhancement using freely available weather software. The results have been validated by other remote sensing tools and available local weather records.

The second event this paper deals is May 28th, we captured a large ash cloud emanating from Tungurahua volcano eruption in the Andean region along with a large ash cloud from the **Pacaya volcano in Guatemala** using far infrared images form NOAA-18 satellite with geo-reference coordinates.

Both events are analysed with remote sensing tools and image enhancement schemes like thermal, hvct and fire, available in the free software using free APT data. The aftermath correlation results of volcanic eruption with high temperature profile in the same region are presented in this paper. The image we got of the fleeting ash cloud and taking into account that no one else had a station in range is most probable that HERMES is the only one around, that remarks the importance of having this kind of stations around the world and the most important too is that geologists and scientists have remote access via **HERMES Delta**, operational mode for NOAA.

NOAA has granted free access to the world; now users must move forward to build new or network existing worldwide ground stations to get composite, 3D and animated information of the meteorology, atmospheric conditions and keeping an eye on environmental changes. As comes out from current studies, real time monitoring of natural disasters is a key to receive first hand remote sensing data that can play a decisive role in evaluating damages and to prepare for current and future disaster management.

We have tested and verified HERMES to be used as **online and real-time virtual GS** [3], [4], e.g. LiNSAT by tracking, commanding and downloading telemetry from several satellites, e.g. NOAA satellites, amateur and university-class nanosatellites.

NOAA APT Virtual Ground Station

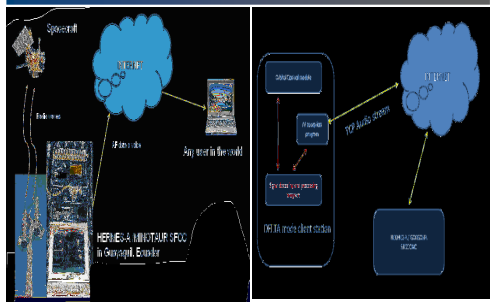

Fig 1 (a): HERMES at EXA, (b): Remote user virtual ground station

The EXA [5] has conceived and built an internet to orbit gateway called **HERMES-A / MINOTAUR**. The GS is designed to give free access to participating universities and schools for hands-on-training in the field of space operations and research. Virtual multinational students (North America (Michigan), South America (Ecuador), Europe (Austria) and Asia (Japan) have already participated for simultaneous tracking Amateur satellites, decoding NOAA satellites images to enhance their understanding towards weather science. The GS is open to all schools for real-time analysis of weather data.

User GS is based on **suite of free softwares**

i. WXTOIMG [6]

ii. Ham Radio Deluxe (HRD, -Radio, -Sat Track, -DM 780) [7]

iii. VRS-Remote Monitor (VRS-RM) [8]

The **operational modes** consist of [ALPHA: telemetry (TLM), BETA: housekeeping (HK), Science/Engineering payload data, GAMMA: HDX voice and DELTA: TLM- WX images]. The bandwidth is so efficiently handled by the system such that 1200 users at a time, can be connected to access real-time weather audio frequency (AF) signals relayed on internet.

Volcanic Eruption, NOAA and GOES

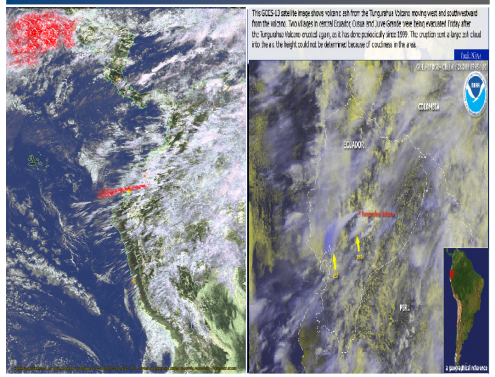

Fig 2: Tungurahua volcanic eruption (a) Captured by NOAA 18 using APT on May 28th 2010, processed with WXtoImg using ‘hvct’ false colour enhancement, (b) Same event monitored by GOES 13 satellite and processed by NOAA (Courtesy of NOAA).

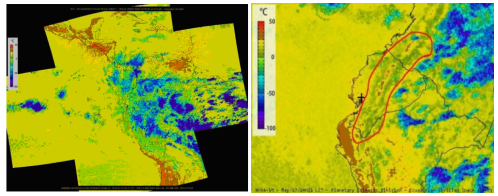

Fig 3: (a) Regional temperatures, (b), High temperature variations (up to 30 °C) at Andean mountain region, on May 15 through May 20, 2010, received and processed images from NOAA-18 and NOAA-19 using HERMES GS and after effects in the form of glaciers melting are visually observed.

HERMES Network: Future Expansion

In order to have worldwide coverage for better understanding towards weather science and climate research in the long run, we need to expand HERMES network. The future plans are as under.

- HERMES-A is the first **Space Flight Control Center (SFCC)** of a planned network of maximum 5 SFCC.
- HERMES-B will be installed in the Galápagos Islands.
- HERMES-C and HERMES-D are proposed to be installed on Tacna, Peru and in Puerto Montt, Chile.
- HERMES-E will be installed on the Ecuadorian Antarctic research base Pedro Vicente Maldonado.
- HERMES expansion to Europe, UAE, India and Pakistan is proposed.

As NOAA swath 30-40° Lat-Long area is covered with one GS. Actually we could see up to Austria from Ecuador 5000 and 22000 km with highly elliptical orbit (HEO) Molnya satellite. So one GS in Spain or in Austria would be enough to cover this region.

In its final **configuration**, the network can offer more than an hour of uninterrupted connection between Internet users and the earth orbit that would a boon for multi-satellite communications.

Satellite In Classroom

Fig 4: A Satellite in classroom: 2nd Graders at a school in Ecuador are tracking, downloading and analysing real-time data from a NOAA satellite constellation for educational purposes.

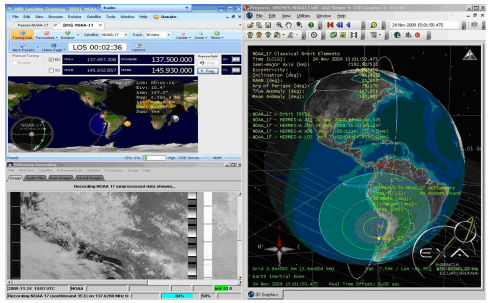

Fig 5: Real-time AF reception and decoding using suite of free softwares: HRD (Upper left), WXtoImg (Lower left), Satellite ToolKit (Right).

Conclusions and Future Aspects

- HERMES embodies an excellent laboratory for high end education and research in worldwide through internet.
- Distributed team, tracking, controlling and decoding a NOAA and other Amateur satellites transmissions using a suite of free softwares.
- International collaboration among universities with students participation.
- Cost-free real-time data access using only internet and computer.
- Network expansion throughout the world is realistically feasible.

Acknowledgements

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Date of access to all URLs is Dec., 10, 2010