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NEAR REAL TIME AUTOMATED ONLINE UV MONITORING AND ALERT NETWORK IN ECUADORIAN TERRITORY (HIPERION RAN)

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Abstract

The high UV indexes detected in equatorial latitudes lately calls for an automated, near real time, online system that constantly monitors UVB and UVA radiation and can warn the population of the potential health risk accordingly to the WHO UV index standard. Until October 2008 no such system existed in Ecuadorian territory where high UV indexes can be found in the Andean region as well as in the coastal regions, but since October 2008 the HIPERION Reactive Alert Network, designed, created and maintained by the Ecuadorian Civilian Space Agency (EXA) provides information to more than 5 million people in both Andean and coastal regions in highly populated areas where extreme UV indexes are present the most of the time throughout the year. The information provided by the HIPERION RAN is broadcasted by 3 national TV networks, 106 radios and hundreds of websites, it is available also by cellular phones and SMS text messages, it updates automatically every 5 minutes.

Introduction/Background: EXA is the Ecuadorian Civilian Space Agency, a civilian NGO in charge of the administration and execution of the Ecuadorian Civilian Space Program.

Such Space Program has a strong planetary sciences component, and for that reason, EXA organized its Planetary Sciences Division, which was charged with its first task of determining the ozone layer state over the equatorial region of the planet, and so, since December of 2007 began the field study, methodology was twofold: the first step was to collect satellite data from a wide range of satellites and foreign agencies like the Canadian Environmental Agency, the German DLR, the KNMI in Netherlands, the American NASA to name a few.

The second step was to take field measures in the ground using automated equipment trying to minimize human processing and intervention in order to render the most accurate results.

The study, called HIPERION, collected 28 years of satellite data and 240 days of ground measures in 2 keys points of Ecuadorian territory, the coastal city of Guayaquil, with coordinates 2° 08' 00" S, 79° 52' 58" W at 15 mts above sea level and the andean city of Quito with coordinates 0° 08' 18" S, 78° 32' 58" W at 2880 mts above sea level. These are the most populated cities in the country, summing up to more than 4 million inhabitants.

The results were alarming: The WHO/WMO UV Index measured as:

$$(1)\quad I_{UV} = k_{er} \cdot \int_{250\ nm}^{400\ nm} (E_\lambda) \cdot S_{er}(\lambda) d\lambda$$

Where E_λ is the spectral irradiance expressed in W/(m^2.nm) of the wavelength λ and dλ is the differential of the wavelength used in the integration, also the term $S_{er}(\lambda)$ is the spectral reference for erythemal dose and k_{er} is a constant equal to $40m^2/W$ as defined by ISO 17166:1999/CIE S 007/E-1998.[1]

The maximum UV index registered by the study in Guayaquil was 14 UVI and the maximum UV index for Quito was 24 UVI considering that the formula (1) defines the UVI table as:

UV Index	Description	Media Color
0–2	No danger to the average person	Green
3–5	Little risk of harm from unprotected sun exposure	Yellow
6–7	High risk of harm from unprotected sun exposure	Orange
8–10	Very high risk of harm from unprotected sun exposure	Red
11+	Extreme risk of harm from unprotected sun exposure	Violet

Figure A: The WHO/WMO UV human skin tolerance index table

The indexes found in this 2 cities were clearly off the tolerable scale, in Figure B it is clearly visible how the UVB radiation levels evolved throughout the day, but the most interesting fact is the permeability of the clouds to the intense radiation levels, reflected in the difference between the blue lines depicting solar visible spectrum, versus the red dotted line depicting UV index

Also in Figure C, the evolution of the radiation throughout the month versus the humidity is depicted, which is very interesting to compare in this case due the effect of humidity on the diffusion of UV radiation.

On October 20, 2008 a copy of the report was sent to Ecuadorian, Colombian and Peruvian governments, two days later, on October 22, the report was made public, causing widespread media attention and the

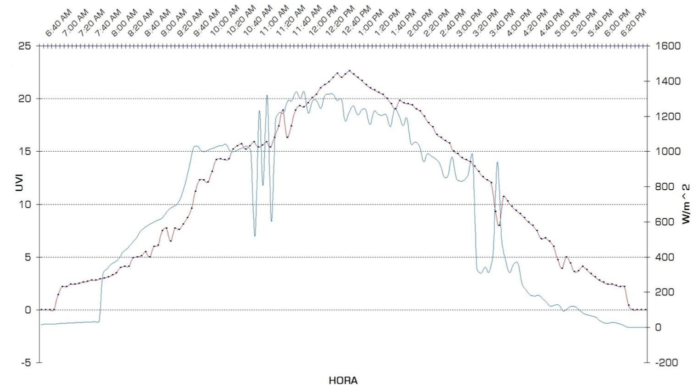

Figure B: UV index radiation evolution throughout the day in Quito on August 7, 2008

public reaction was to give full credit to the report. In the words of many people: “The report finally put in numbers what we already have been feeling in our skin every day since the latest years”, the population began to follow the recommendations of the report immediately and the HIPERION Reactive Alert Network – RAN started operations the very same day the report was published.

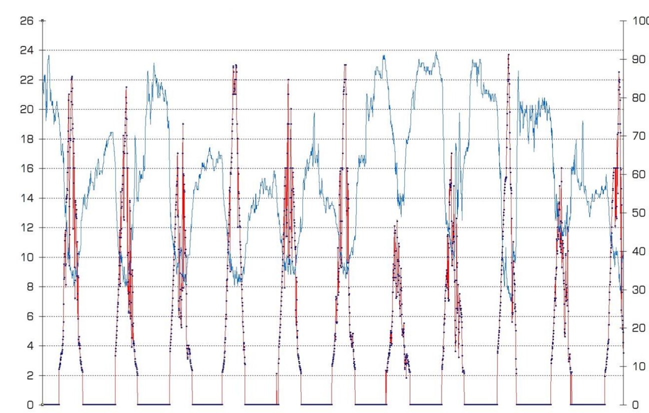

Figure C: UV index radiation evolution in Quito on August 2008

Cost Management: The building of an automated report and alert network needs an special approach when it is being built by a non-government organization which funding sources are very limited, in a region that traditionally does not assign enough importance to science and technology and with nonexistent government financial support. Such approach was to select the key components of the network taking into consideration the following guidelines:

1- Scientific grade accuracy.

2- Cost effective integral solution.

3- Near zero maintenance or maintenance free.

4- Based on free energy, like solar panels.

5- Very small energy footprint.

6- Unattended operation.

7- High fault tolerance ratio.

As for the systems integration, the cost effective solution was to develop an in-house operating system under the following guidelines:

1- Robust and proven software/hardware platform.

2- Maximum software automation.

3- Support for unattended operations.

For the station components our selection was to use the Davis meteorological station model 6163, coupled with an Acer AspireOne mini notebook using a Davis USB data logger and a HuaWei 3G 2126 modem. Total cost per station, including shipping and customs to Ecuador was around US$2500,oo.

The software/hardware platform chosen was RedHat Linux Enterprise on a rack mount SuperMicro Quadcore server with 4Gb RAM and a RAID 5 disk array of 2TB. The cost of this setup was about US$3500,oo.

EXA already had a 2Mbits symmetrical, clear channel internet connection on Guayaquil, for a fixed low price, so we only added this load to our already under used bandwidth.

Each communication line between the server and the stations transfer about 2Mb of data each 5 minutes, we acquired 2 unlimited service plans from the local mobile services provider for US$80,oo per month, to the date of publishing of this paper such cost has gone down to US$ 49,oo including taxes.

Network Design Philosophy: The design philosophy for this type of system rests over the following principles:

1- Maximum availability of service.

2- Minimal human intervention.

3- Minimal maintenance cost.

4- Maximum scalability.

5- Minimal energy footprint.

6- Maximum environmental resilience.

7- Maximum fault tolerance capabilities.

Those principle constraints come from the fact that EXA budget is very limited and has no government financial support and that we have to maintain the best level of service for many years to come.

Information Integration and Distribution: The integration of the information coming from the reporting stations is done by the HIPERION Networked Operating Platform - HNOP, based on the EXA Data Processing and Control Center - DPCC in Guayaquil.

Each ISS station runs its own software platform and every 5 minutes the computer reads the data from the sensor array, which lies on the outdoors of the shelter and communicates with the platform via a built in 915mhz transceiver. The in-shelter transceiver also holds the data logger which communicates with the mini notebook via an USB port, then the software platform receives the data and updates its archives, builds the relevant reports in TXT, HTML, GIF and JPG formats, packs them for transmission and sends them via FTP protocol to the HNOP server every 5 minutes.

The HNOP server receives these files from the stations, currently 4, after security conditions are met from the firewall, each station has its own data repository in the HNOP server from where automated programs, in the form of UNIX daemons, build the relevant reports, archive the data and compare the UV indexes with the data received from the

SCIAMACHY and GOME-2 orbital instruments for calibration purposes.

Such calibration is made over 2 main conditions: A discrepancy of more than 3 UVI between the stations and the SCIAMACHY data, and a more than 15% discrepancy of UVI calculated using the following formula:

$$(2) \quad \mathbf{UVI \sim 12.5\mu_0^{2.42}(\Omega/300)^{-1.23}}$$

Where μ_o is the cosine of the solar zenith angle and Ω is the total vertical ozone column (in Dobson Units, DU), provided by GOME-2 orbital instrument, accordingly to the work of S. Madronich, NOAA, 25-07-07(4)

If a high discrepancy is detected over a sustained period of time, the corresponding station is taken offline and email notifications are sent to the stand by officer, who will implement the corresponding verification and recovery procedures for each case.

The HNOP daemons update the data files that are taken by java applets in the websites that have been licensed to display HIPERION information, update the web pages of the NRM – National Radiation Monitor and the WAP protocol pages, also update the data files that feed the MSDP – Mobile Service Distribution Platform that serve the SMS mobile service.

A UNIX daemon is in charge of serving requests coming from SMS text messaging users and it is part of the MSDP subsystem, such daemon discriminates the request reading the records in the following format:

```
Aug-1-2009
16:21:03
movistar
095617546
216.121.108.19
a8e30a95957f08bec58e4e0ecd5c8f59
UV
uv+guayaquil
GUAYAQUIL
```

Where the fields are:

```
DATE
TIME
MOBILE-OPERATOR
MOBILE-USER-NUMBER
INCOMING-IP-REQUEST
REQUEST-CHECKSUM-NUMBER
TOKEN-SELECTOR
MESSAGE-AS-TYPED-BY-THE-USER
CITY
```

Then it reads the relevant data files and builds the data record for the response in the following format:

```
City: UV level, Level qualification,
Recommendation
```

This information is sent following the UV index publishing guidelines as proposed by the WHO/WMM Global UV Index Guide.

Once processed and properly archived, the information is ready for distribution which is made in a passive form, this means that the interested user takes the information pulling it from the HNOP server via Internet using the following formats and protocols:

-HTTP port 80
-Java class pull port 80
-HTTP WAP pull port 80
-SMS HTTP pull port 80

Some of the users have built their own web pages and embed the graphics of the HNOP web pages in to their own. As the graphics are updated accordingly every 5 minutes, it is the easiest way for them to present the information. In fact, the 3 TV networks publishing the RAN information do it in that way.

Results and Conclusions: Since the day that the HIPERION RAN started operations it has had a 99.97% uptime ratio, with an average of 7126 accesses per day and growing. The times of the day registering most access are between 10h30 and 14h30, this is, noon time.

In this first year of operation new highs have been measured in the city of Guayaquil, were UV indexes of 19 were detected during middle March 2009. In May of this year the RAN also started operations in southern andean city of Cuenca at 2300 mts. above sea level, with a population of over 1 million people. The maximum UV index detected to this date in this city has been 18, and we expect it to raise for the upcoming months as the Sun to Earth mean distance will reduce from 1.01 AU at the date of operations began in Cuenca to 0.98 AU in March next year.

The publishing of the HIPERION report caused a lot of attention to a problem that, at that time, was new to the Ecuadorian society, because no study of this type was ever done before in the country and people felt that "something was wrong with the sun" lately. It also got much attention in other countries of the region: The Peruvian CONIDA made its own study and they found almost equal results as the HIPERION study, the Physics Laboratory in Bolivia had years of experience in this matters and found renewed support throughout the widespread distribution of the report, the El Rosario laboratory in Argentina also made its own studies to sum to others already made in the past. [(3)]

Locally, the society responded in many ways: Many schools changed their times for physical training classes to the early hours of the day, between 07h30 to 09h30, others put some kind of roofing in their court yards, others gave Internet access to the HNOP web pages to the person in charge of the PA system, and when the radiation went up, that person announced the children to go into shadow.

In other fields, the National Football Federation discussed heavily over the possibility to ban games taking place at noon hours and as the debate went on, many other considerations, mostly of economical nature, prevented them to take such decision, but many of its members plan to debate the issue in the upcoming annual sessions.

Maybe one of the facts that illustrate better the public response is the issue of the sun block product types survival: in the local market only those products that have an SPF over 50 are sold to the public, all other products under this SPF level have decreased dramatically and in some cases vanished.

In many interviews, the common people expressed that they felt the phenomenon in their skin, characterizing it as an "itchy" sensation when exposed to the burning sun, but now when that same people feel that same sensation again, go and consult the HIPERION RAN, only to find elevated UV levels that support their own subjective sensation, and with the passage of time, we now see that the system has helped to educate the population, putting numbers to their physical sensations.

In the streets of the Ecuadorian cities, when the days are clear and the sun is high in the sky, one can see the population wielding umbrellas and sun glasses, and such is a behavior that was not present before the publishing of the HIPERION report, so we want to think that this work has contributed to the education of the Ecuadorian population and that the HIPERION report would have been incomplete without a system that can deliver the needed information to the population in a free, efficient and effective way.

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