

# PANAMA

## OBSERVATIONAL ACTIVITIES

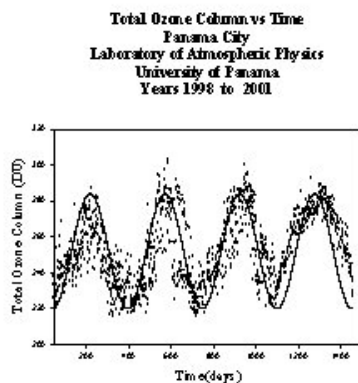
### Column measurements of ozone and other gases/variables relevant to ozone loss.

The Laboratory of Atmospheric Physics of the University of Panama has been monitoring total ozone column since 1998. Total ozone column is measured with portable multifilter sunphotometers, model Microtops II, manufactured by Solar Light Co. This kind of ozone meter has five channels and measures beam UV-B radiation at the spectral lines of 305 nm, 312 nm, 320 nm and beam infrared radiation at the spectral lines of 940 nm and 1020 nm. Total ozone column is proportional to the ratio between irradiances corresponding to two UV-B wavelengths. A Radiometric and Meteorological Monitoring Network has been established in the cities of Panama, David and Santiago. At the three monitoring sites, the total ozone column shows an annual seasonal behaviour with a minimum value during January (230 DU) and a maximum value during August (280 DU).

Table N° 1 shows the total ozone column monthly mean values at the Republic of Panama.

<i>Table N° 1</i>	
<i>Total Ozone Column Monthly Mean Values</i>	
January	231
February	235
March	241
April	247
May	255
June	263
July	273
August	275
September	266
October	254
November	244
December	236

Figure N° 1 shows the seasonal behaviour of the ozone column in Panama City, from February 1998 to December 2001.



**Figure 1: Total Ozone Column Seasonal Behaviour.**

The fitting equation corresponding to the continuous curve is as follows:

$$OZONE = 252 + 30sen\left\{\frac{2\pi[d_n + 225]}{353}\right\}$$

### Profile measurements of ozone and other gases/variables relevant to ozone loss

Actually, the Laboratory of Atmospheric Physics is not working on the profile measurements of ozone or other gases relevant to ozone loss.

### UV measurements

At the three sites of the National Radiometric and Meteorological Network, Ultraviolet B radiation is measured in a continuous way, by means of broad band UV-B meters, model 501 UV-Biometers, manufactured by Solar Light Co. At sites 1 (Panama City) and 2 (David City), global solar radiation and other atmospheric parameters are being measured. Global solar radiation is measured by means of Pyranometers Eppley, model PSP and Pyranometers Kipp and Zonen. For the monitoring of the rest of atmospheric parameters, Campbell meteorological stations has been installed at sites 1 and 2. At site N° 3 (Santiago City), only UV-B radiation is measured up to now. We are planning to install another Campbell meteorological station at site N°3 on October 2005. The three monitoring sites with their respective coordinates are as follows:

<b>Table N° 2</b>				
<b>National Radiometric Network</b>				
Site	Location	Latitude	Longitude	Elevation
1	Main Campus of the University of Panama	8° 59' N	79° 32' W	50 msnmm
2	David City	8° 24' N	82° 25' W	27 msnmm
3	Santiago City	8° 6' N	80° 25' W	140 msnmm

At site N° 1, the monitoring process was initiated on July 1997. At site N° 2, the monitoring process was initiated on December 2001. At site N° 3, the monitoring process was initiated on March 2002. Radiometers and other sensors store data every five minutes, in a continuous way. Data from the three monitoring sites are downloaded from the Laboratory of Atmospheric Physics (Main Campus) through INTERNET by means of a software called PC ANYWHERE. Raw data is then processed, using statistical and graphical software.

Actually, the Radiometric Network administered by the Laboratory of Atmospheric Physics covers one site at the central part (Santiago City) of the Republic of Panama and two sites at the Pacific coastline (Panama City and David City). Up to now, the Laboratory of Atmospheric Physics has no monitoring site at the Caribbean coastline.

### Calibration activities

All radiometers and other sensors are calibrated each year. Calibrations have been performed by Solar Light Co and by the Solar Radiation Observatory, at the UNAM, Mexico.

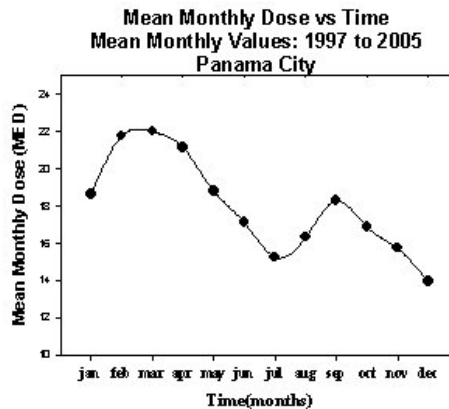
### RESULTS FROM OBSERVATION AND ANALYSIS

Table N° 3 shows the evolution of annual total dose in Med registered at the three monitoring sites (Panama City, David City and Santiago City). The station at Panama City has more stored data than the other two, because it is the first Network Site established.

<b>Table N° 3</b>			
<b>Annual Total Dose (MED)</b>			
Years	Panama City	David City	Santiago City
1998	5907		
1999	5697		
2000	7363		
2001	6510		
2002	7011	6972	
2003	6232	7458	4466
2004	6193	7170	5813

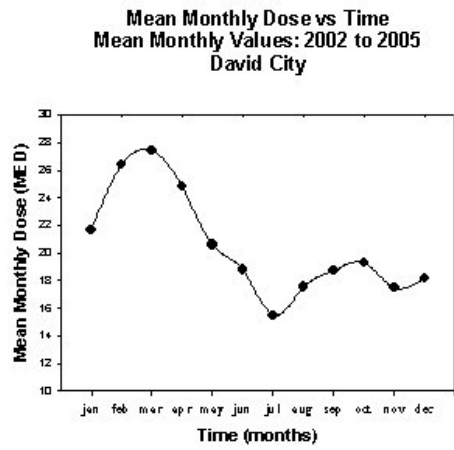
The analysis of the time series for Site N° 1 (Panama City) shows that the highest annual total dose corresponds to year 2000 (7363 MED) whereas the lowest annual total dose corresponds to year 1999 (5697 MED). A high anti-correlation between UV-B dose and cloud cover has been observed. During year 2000, a decrease in cloud cover for Central America was observed. Even during that year, there was a drought all over Central America. A probable cause of this phenomenon is the fact that “The Bermudas” anticyclone was strengthened during several months of 2000. As a consequence of the significant decrease in cloud cover during year 2000, the annual total dose increased with respect to the mean value of annual total dose, which corresponds to the period from 1998 to 2004. During year 1999, a significant increase in cloud cover was observed. Cloudiness was higher during 1999, compared with the other years of the time series. As a consequence of this fact, the annual total dose registered during 1999 was the lowest of the time series.

In Figure 2, the mean monthly dose (mean values has been evaluated for the period from 1997 to 2005) behaviour for Site N° 1 is observed.



**Figure 2: mean monthly values at Site N° 1.**

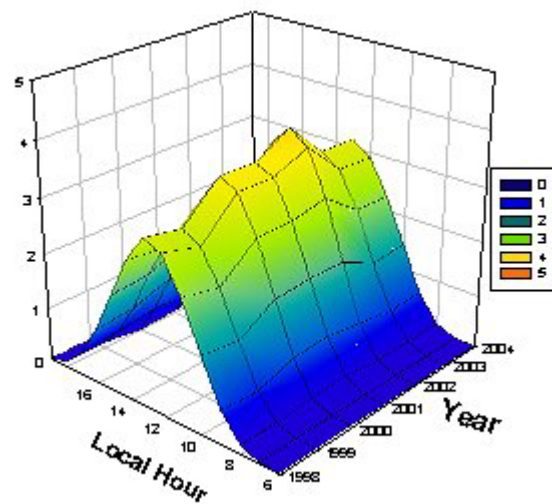
In Figure N° 3, the mean monthly dose (mean values has been evaluated for the period from 2002 to 2005) behaviour for Site N° 2 is observed.



**Figure N° 3: mean monthly values at Site N° 2.**

At both monitoring sites (Panama City and David City), UV-B mean monthly dose shows a similar behaviour, with a maximum during the dry season (highest levels are registered on March) and a secondary maximum on September-October, during the rainy season. Concerning Site N° 3 (Santiago City), there is not, yet, enough data in order to establish the mean monthly dose behaviour.

Figure 4 shows a contour map of the Monthly Mean Maximum Irradiance vs Local Hour at Site N° 1, for the entire year since 1998 to 2004.



**Figure 4: monthly mean max. irradiance behaviour at Site N° 1.**

In Figure 5 and Figure 6, the inter comparative UV-B doses for the three monitoring sites, during 2003 and 2004, respectively, are shown.

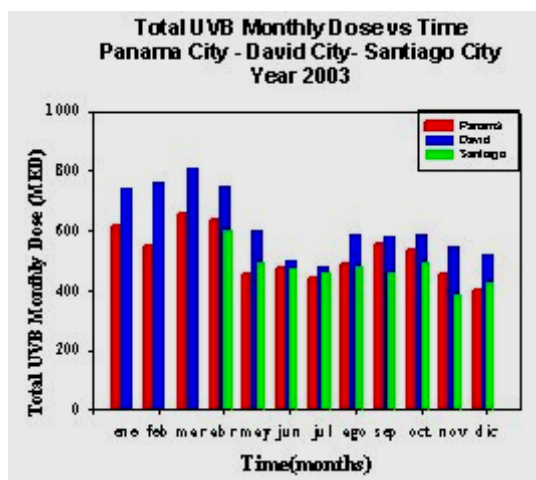


Figure 5: Stations inter comparative doses (2003).

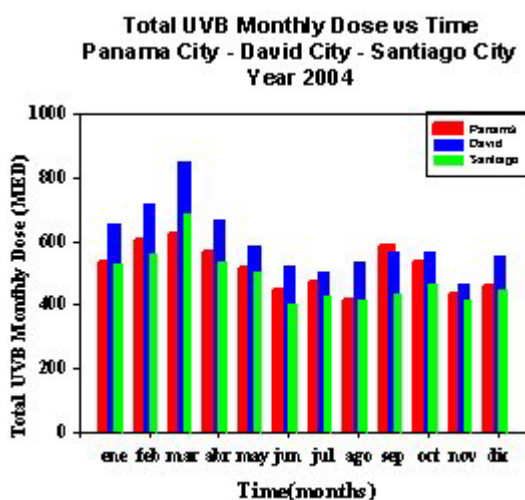


Figure 6: Stations inter comparative doses (2004).

Although Panama and David Stations belong to the same climatic zone (Awi zone, according to Köppen classification), UV-B doses and Indexes are higher at David City due to the proximity of the mountain chain of the central part of the country. This mountain chain acts as a barrier for low cloudiness which is frequently transported by winds proceeding from the Caribbean Sea. Due to this fact, cloud cover over David City tends to be lesser than over Panama City during the morning. Cloud cover at David City increases after local noon due to convection processes which intensify when the Inter Tropical Convergence Zone is passing over the Republic of Panama.

The average total ozone column is **252 DU**. The minimum value (**231 DU**) is registered during the month of January. The maximum value (nearly **280 DU**) is registered during the month of August. Nevertheless, these values lie within the variability margin correspondent to the Panama City latitude. The analysis of the evolution of the total ozone column measured by the Laboratory of Atmospheric Physics of the University of Panama indicates that there is no statistically significant depletion of total ozone column at the latitudes corresponding to the Republic of Panama.

## THEORY, MODELLING, AND OTHER RESEARCH

In order to forecast UV Indexes at different regions of the Republic of Panama, the Laboratory of Atmospheric Physics of the University of Panama, is working with the Tropospheric Ultraviolet-Visible Radiation Model (TUV Model) developed by *Dr Sasha Madronich at NCAR*. This model, which runs in Fortran 77, has a main programme, approximately 50 subroutines, external functions and nearly 300 data files. With TUV Programme, which is based on “two streams” model, UV irradiance and UV irradiation could be forecasted under cloudless condition as well as under overcast condition.

Cloudiness is the factor which contributes in a more significant way to the spatial and temporal variability of UV irradiance. Theoretically, it is possible to use Transfer Radiative Models in order to assess the transmittance through clouds. The information required to accomplish this assessment is cloud optical depth. However, partial cloudiness is too difficult to model due to the enormous variability of cloud morphologies and multiple heights of clouds bases. Due to this fact, to assess the attenuation on UV-B irradiance caused by partial cloudiness, the Laboratory of Atmospheric Physics of the University of Panama has developed an empirical or parametric model which simplifies this assessment under partial cloudiness condition. This empirical model was presented by the Laboratory of Atmospheric Physics during the Fifth Ozone Research Managers Meeting, celebrated at Geneva on March 2002.

## DISSEMINATION OF RESULTS

### Data reporting

Actually, the Laboratory of Atmospheric Physics of the Republic of Panama is submitting UV-B data to the RAYENARI Server which is managed by the Solar Radiation Observatory of the Mexican Autonomous National University.

### Information to the public

UV Indexes are forecasted daily by the researchers of the Laboratory of Atmospheric Physics. This information is deployed at the Laboratory Web Site ([www.igc.up.ac.pa/labfisat/lab220.htm](http://www.igc.up.ac.pa/labfisat/lab220.htm)) as well as by some local TV channels. Several educational campaigns have been accomplished in collaboration with the Ozone Unit of the Health Ministry of the Republic of Panama.

### Relevant scientific papers

- Determinación de los coeficientes de regresión del modelo de Angström-Page para la Provincia de Panamá; Revista Tecnociencias, Vol.1, N° 1, mayo de 1997.
- Resumen preliminar del monitoreo de la radiación UV-B en la Ciudad de Panamá; Revista Científica Tecnociencias, Vol.1, N° 2, septiembre de 1997.
- Descripción preliminar de la radiación UV-B y del nivel de la columna de ozono estratosférico en la Ciudad de Panamá; Revista Geofísica, IPGH, N° 54, 2001.
- Datos meteorológicos en la cuenca hidrográfica del Canal de Panamá durante el siglo XIX y su aplicabilidad a la variabilidad climática y al cambio climático; Revista Tecnociencias, Vol. 3, N° 2, 2001.
- Estudio climatológico de los niveles de radiación UV-B, columna de ozono total y cobertura nubosa en Panamá; Revista Scientia, Vol. 17, N° 1, 2002.

## PROJECTS AND COLLABORATION

The Laboratory of Atmospheric Physics of the University of Panama has received a proposal from GKSS Coastal Research Institute, to collaborate in the Research Project that this Institute develops at “Las Minas Bay”, located at the Caribbean coastline of the Republic of Panama. A formal project with objectives, goals and instrumentation required has been presented to GKSS Coastal Research Institute.

## **FUTURE PLANS**

The Laboratory of Atmospheric Physics of the Republic of Panama is projecting to incorporate, into the actual Research Project, the monitoring process of UV-B radiation, global radiation and other meteorological parameters at the Caribbean coastline of the Republic of Panama. In order to characterize the radiometric and meteorological behavior at the Caribbean coastline, two stations must be deployed over this seaboard. It is recommended that the station N° 4 of the Radiometric Network be installed at Las Minas Bay and that station N° 5 be installed in the University of Panama Regional Centre located at “Bocas del Toro”.

## **NEEDS AND RECOMMENDATIONS**

It is important to strengthen the Regional Radiometric Networks and increase the capacity-building for ozone and UV-B measuring stations in developing countries. In order to accomplish this goal, we recommend to look for funding support for those Research Institutions of developing countries that are working on the monitoring of UV-B radiation and ozone, as well as in data analysis and modelling process.

It is urgent to design some procedure which decreases the costs of calibration processes of broadband meters, narrowband filter instruments, ozone meters and other sensors for those Research Institutions of developing countries which are working on this issue. Collaboration of Research Institutions of developed countries, is necessary, in order to facilitate the calibration process for those Research Institutions of developing countries.

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