

BOLIVIA

OBSERVATIONAL ACTIVITIES

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

In Bolivia, there is only one station measuring the ozone layer. This station is run by the Atmospheric Physics Laboratory (LFA) at the Physical Research Institute (IIF) of the University of San Andres (UMSA), at La Paz.

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

There is ozone column profile data from Umhker measurements for three years, based on the Brewer data and using a standard atmospheric model.

UV measurements

Broadband measurements

From December 1995, when the laboratory started measurements, until May 1997, we were using a Solar Light 501 Biometer. Since July 1998, there are two YES broadband radiometers. One of the YES is kept fixed at the LAF, and the second is used for the field campaigns.

Spectroradiometers

The LFA has a special agreement with the Brazilian National Institute for Space Research (INPE) which allows the LFA to run the Brewer #110 at La Paz since 1996. There is a nearly continuous data series of the ozone layer depth from July 1996 to July 2004, when the equipment breakdown and was shipped back to Brazil for repair. It is scheduled to be returned next September.

Calibration activities

One of the YES broadband radiometers was recalibrated at Innsbruck, Austria in 2002. Two intercomparison campaigns were held at the LFA. The first as an extension of the Argentinean calibration of the National network in year 2000, and the second during the Second Latin American Congress on Ultraviolet Radiation, with equipments from several countries.

RESULTS FROM OBSERVATIONS AND ANALYSIS

Several reports were written and published locally on the ozone layer trends measured at the LFA station in the outskirts of La Paz (16.5° S, 68.0 °W, 3200 m asl). Also there are studies comparing satellite-based data (from NASA's TOMS) and our ground station, with a neat fit. The main result from the analysis was the discovery of a small depletion of the ozone layer over the Bolivian high plateau (Altiplano) in relation to other locations at the same latitude. This effect was first attributed to the high altitude of the measuring station; as it misses the first three kilometers of the atmosphere, but more refined calculations show that the "altitude effect" is not enough to account for the difference, which has values around 15 DU.

One of the main findings was the discovery that the ozone layer at La Paz shows no large change when we compared the profiles obtained during two ozone-sounding campaigns, one in 1963, and the second in 1998. Therefore, one can postulate that the ozone layer over the Bolivian Altiplano has remained unchanged for the last 40 years.

The main work of the LFA is on the solar Ultraviolet Radiation monitoring. Due a combination of several factors like, latitude, altitude, clear sky and open horizons; the Bolivian Altiplano receives very high UV doses, sometimes tagged as the highest in the world, with values above $8 \text{ kJ m}^{-2} \text{ yr}^{-1}$. The average UV Index at La Paz is 11, corresponding to 0.275 W m^{-2} . Also, there is a seasonal dependence of the UV values, with the higher values on summer and lower at winter months. The climate favors our case in the sense that when the solar zenithal angles is minimum (even zero twice a year) usually correspond to the rainy season, and the cloud cover filters out a lot of the solar UVR. But, in the case of drought (as when ENSO appears) November becomes with clear skys and the UVI values jump out of the scale. We reported an exceptional value of (extrapolated) UVI = 23 for one day.

THEORY, MODELLING, AND OTHER RESEARCH

Aiming to get a better spatial coverage of the UVR in Bolivia, the LFA uses both the STAR model, and data from TOMS. The first is used to get an approximation of the UV irradiance in selected locations, to be contrasted with field-campaign data. These campaigns are carried out only for short periods, usually 3-5 days in each location.

In terms of modeling, there is a couple of works aimed to explain the “ozone anomaly” over the Bolivian Altiplano. Both works use TOMS and local data, and are based on the assumption that the ozone layer over the region is thinner due an effect of the gravity waves. The main hypothesis is that the air coming from the lowlands is trapped between the double chain of mountains, and the bouncing cause perturbations that in the end, erode the ozone layer. This is a permanent situation, contrasting to the seasonal “ozone hole” over Antarctica.

Another line of research is on the effects of the UV radiation over technological materials, on cultivable plants, on plankton and the food chain, and on the human health. On the first case, the LFA research focused on the effects of the high level of solar UVR in the Altiplano on the corrosion process of base metals exposed to the open environment. The main finding (yet to be confirmed) is a depletion of the corrosion rate of copper. A second line of research in this area is on the UVR effects on polymers, specially textile fibers (nylon and rayon), plastic sheets for greenhouses (Agrofilm™) and plastic bottles (PET). In the first case, we found that the damaging effects on the fibers depends more on the coloring treatment of the yarn than on the amount of UV absorbed by the fiber. In the second study, we found that the Agrofilm™ loses most of its good properties after being irradiated with 1 MJ of UVB. The films becomes almost opaque to the visible light, but allows a lot more (60%) of the UV radiation to come through. The changes on the heat transmission properties are still under study, as the behavior of the PET bottles.

In the case of the cultivars, the LFA team worked with one of the most popular Andean cereals, the quinoa grain (*Chenopodium quinoa*, Wild.). We choose this plant by several reasons: it is a strong component of the Altiplano's people, being the main protein source; it grows in the Southern Altiplano, which a region with very high UV levels, but at the same time is one of the poorest regions of the country, due its extreme aridity. We were exploring the relation of the UV exposure of the plant, and the protein and saponine content of the grain. Those substances are in competition inside the grain, the more saponine the plant develop, the less protein it has, and viceversa. A high content of saponine is bad news for the use of the grain as food, but is good for its industrial use. The main result of the study is that the high UV levels cause a delayed growing and maturation times, shifting the phenic stages. We could not get conclusive results on the saponine production as function of the UV irradiance due the lack of equipment (a spectrometer) and some other logistical problems.

The studies on plankton and UV were two fold. One side was carried out in the Titikaka lake, which is the highest navigable lake in the world (3860 m asl). Among the results of the campaigns we found that the phytoplankton has adapted it self to the very high solar UV levels producing a series of “sun screening” compounds, mainly of the mycosporine-acid type. The zooplankton did not produce this substance, but takes it from the phytoplankton and bioaccumulates it. The second stage was carried out several years later, in the First Bolivian

Scientific Expedition to Antarctica, merged to the Peruvian “XV Antar” when a similar study was taken, including the next step of the food chain: the krill. The result is also positive: the krill has the same UV-protecting substances as the zooplankton eaten by the crustacean, also keeping it by bioaccumulation.

Besides these activities, the LFA is also engaged in other research activities like air quality, air pollution monitoring, measurements of carbon dioxide and smoke from forest burning, climate change and their impacts on the ecosystems, etc.

DISSEMINATION OF RESULTS

Data reporting

The UV and ozone layer thickness values obtained with the Brewer are reported monthly to the INPE headquarters in Brazil for validation and later dissemination. This is done according the working agreement between our institutions. A copy of the data, in a booklet format is kept at the LFA and a second copy is given to the IIF library.

The UV data taken with other equipment (like the YES broadband radiometers) is available on request, and if the requester has not any commercial purpose, the LFA release the data for free.

Information to the public

The LFA is in charge to broadcast the UV Index on behalf of the Bolivian Ministry for Health. The UV Index is calculated from the measurements with several instruments at the LFA, and it is extrapolated for other cities in the country, or even neighboring countries (e.g Peru & Paraguay). As the weather forecast system in Bolivia is not very well developed (mainly due the complex topography of the country) the UV forecast is released as a table, with columns for three weather conditions: clear sky, cloudy, overcast; and rows for three skin types: I or Nordic, III or Mediterranean and V or dark. The forecast is released each day before noon, with the values for the next day, and it is transmitted to the media via fax and e-mail. Actually, the LFA is working with 2 national newspapers, 10 TV stations and 15 radio stations.

Also, as the LFA has been named as “National Institution of Reference” by the Pan American Health Organization (PAHO) and recognized as such by the Bolivian Ministry for Health, it has the task to monitor the UV levels in order to point out to the Ministry when to declare an “UV alert” which work in a similar way as the “epidemiological alerts”.

The LFA had published two books, the first one were the Proceedings of an International Seminar on Ultraviolet Radiation and the Ozone Layer, (R.Forno & M.Andrade, eds.1997) and the second book and a compendium of the activities around UVR in Bolivia during the LFA life (“La Radiación Ultravioleta en Bolivia”, F.Zaratti & R. Forno, eds. 2002) A Third volume is in press, with the activities during the PAHO-sponsored Technical Cooperation among Countries Programme between Peru and Bolivia (“TCC Peru – Bolivia, Activities Report”, D.Daza & E.R.Palenque, eds., 2005).

Relevant scientific papers

Among other publications, the next is a short list of the main results from the research activity at the LFA during the years 1996- 2004:

Blacutt, L.A. & Palenque, E.R. “Efectos de la RUV sobre Materiales Tecnológicos. Metales Base”. Informe de Labores 1998, IIF – UMSA.

Blacutt, L.A., Limachi, O. & Palenque, E.R. “Efectos de la RUV sobre Materiales Tecnológicos. Parte III: Fibras textiles”. Informe de Labores 2003, IIF – UMSA.

- Ghezzi, F. et al. "Análisis de correlación entre actividad solar y columna de ozono a latitudes tropicales" *Revista Boliviana de Física*, Vol.8, p.16 (2002).
- Helbling, E.W. et al. "Mycosporine-like amino acids protect the copepod *Boeckella titicacae* (Harding) against high levels of solar UVR". *Journal of Plankton Research*, Vol.24, p.225 (2002)
- Palenque, E.R et al. "Efectos de la radiación ultravioleta sobre el desarrollo de la quinua (*Chenopodium quinoa*, Willd.). *Revista Boliviana de Física*, Vol.3, p.120 (1998).
- Torres, R. & Blacutt, L.A. "Magnitud de las componentes UVA y UVB de la radiación solar en Cota –cota" *Proceeding of the "Simposio Nacional de Cambios Globales"*, La Paz, 2000.
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- Zaratti, F. et al. "Erythemally weighted UV-B variations at two high altitude locations" *Journal Geophysical Research*, Vol. 108, D9, p.4263 (2003)

PROJECTS AND COLLABORATION

The LFA is a Collaborating Center for UV Radiation issues of the World Health Organization, since last year. This nomination comes as result of the successful experience of the LFA measuring and broadcasting the UV Index and carrying out the UVI campaign each year. This activity has been named as "National Institution of Reference" by the Pan American Health Organization (PAHO) who sponsors a large share of the campaigns. In addition, the LFA was nominated as "Collaborating Center" by the WHO, for all the issues concerning UV radiation for the Andean Countries. These nominations represent a broader collaboration and, at the same time, more duties for the LFA for the research and dissemination on UV and its effects

Besides the nominations by the PAHO and the WHO, the LFA has a special agreement with the Faculty of Medicine at the UMSA, for provide the UV data needed by the epidemiological studies and by the postgraduate school on Public Health.

On the technical side, the LFA has several agreements with a lot of international partners. The first of them was with the Brazilian INPE which allows the LFA to run the Brewer station at La Paz. This collaboration includes the LFA as a member of the South American Network for Ozone layer Monitoring, with station deployed in Brazil, Bolivia, Chile and Antarctica. The collaboration includes not only the exchange of data but also training and joint research.

The LFA started a expansion of the number of Bolivian sites for UVR monitoring, and next September, we will be installing a station in the city of Tarija, in agreement with the local university (Universidad Autónoma Juan Misael Saracho). It is foreseen a future expansion towards the cities of Cochabamba and Santa Cruz for the next year, depending on the funding side.

Related to the radiation aspects (including the UV bands) the LFA has an agreement with the Meteorological Institute of the University of Munich, Germany on both the theory of the radiative process and the measurements, linked also with the diurnal circulation on the Altiplano.

With the Space Physics Laboratory (SPL) at the Vikram Sarabhai Space Centre (VSCC) of the Indian Space Research Organization (INSO) is an agreement for the monitoring of the atmospheric aerosols and its relation on the radiative transfer properties. This includes studies on the near-UV band and the tropospheric ozone, linked to the generation of urban smog.

With the European Space Agency (ESA) the LFA has an agreement to carry out research on the vertical distribution of aerosols, including stratospheric clouds. For this, the ESA gave the LFA an alexandrite LIDAR which will be starting operations very soon, we estimate at mid-September.

FUTURE PLANS

The LFA had presented a proposal for research to the WHO, one project for a network of UV-monitoring stations distributed among localities in Peru and Bolivia; a second project for a system devoted to ensure the quality of the sun glasses commercialized in the Andean countries; and a third project aimed to refine the Parrish classification of skin types covering the range of the Native American people, specially for the inhabitants of the Andean region. The projects were accepted by the PAHO/WHO Office at La Paz, and redirected to PAHO's central office in Washington, later the documents should be transferred to the WHO's Headquarters.

Besides the route taken by the aforementioned projects, the LFA is opening a new station for solar UVR in the city of Tarija, in the Southern part of Bolivia. Due the recent natural gas boom in the region, there is a lot migration towards the city of Tarija and its surroundings, and as it can be considered also as "high altitude city" (2700 m asl) we considered worthy to start measurements there.

Another project in the planning stage is a new "Technical Cooperation among Countries" (TCC), sponsored by the PAHO, this time would be between Bolivia and Ecuador. This TCC is some like the second chapter of the previous TCC between Peru and Bolivia, where the LFA "exported" the know-how of the UVI campaigns.

The ESA's alexandrite LIDAR will be operating since next September, and we hope to get the first validated results on clouds and tropopause height for the end of the year.

In addition, the LFA is now engaging itself in the development of some small, portable and cheap system for working as dosimeters. These equipments can be based on diodes acting as sensors, or based on the fluorescence of some special materials. This research is at its first stage, just started few months ago.

NEEDS AND RECOMMENDATIONS

Among the several needs of the LFA is the lack of some equipment, as a set of standard UV lamps for calibration, or spectrometers, one for working at the LFA, and other portables, for a better monitoring during the field campaigns. Maybe the most useful equipment for the LFA activities at the moment will be a Microtops (Solar Light Co.) to be used both at fixed locations or during the field campaigns.

On a different side, we need to carry out some atmospheric sounding, in order to get a real temperature profile over our station at La Paz. The profile will be used both for refining the Umhker measurements and the LIDAR data retrieve.

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