^{7}Be as tracer on the investigation of upper tropospheric dispersion of Saharan dust during the Mid-Winter 2000 Storm Events (Azores).

Félix Rodrigues[1] - Charles Holmes[2] - Casimiro Pio[3] - Marci Marot[2] - Paulo Fialho[1]

1-Departamento de Ciências Agrárias da Universidade dos Açores. 2 -Eastern Surface Processes Team (United States Geological Survey). 3 -Departamento de Ambiente e Ordenamento da Universidade de Aveiro.

Introduction and Experimental

^{7}Be is a nuclide that acts like a tracer of input from the stratosphere and upper troposphere, where it is produced by spallation processes of light atmospheric nuclei such as nitrogen 14, oxygen 16 and carbon 12, with protons and neutrons (Zanis et al. 2000). By measuring the activity of beryllium isotopes attached to submicrometer aerosol particles, information on the mechanisms of exchange between the stratosphere and troposphere is obtained.

An atmospheric baseline station was established on the western coast of Terceira Island-Azores in order to improve our knowledge about the marine aerosol characteristics and formation (latitude: 38º41'26''N; longitude: 27º21'15''; altitude: 50 m, about 15 Km of Angra do Heroísmo, the main town of Terceira island, with 20000 inhabitants).

The aerosol collected at the Azores, during the 2000 Saharan mid-winter dust storm events, represent four day integral samples, and were collected, between February 26 and March 18. They were collected on quartz fibre filters, put on sealed bags containing a small amount of air and express mailed to the USGS for measure Beryllium-7 activities by the Eastern Surface Processes Team at St. Petersburg, Florida , to assess the magnitude of stratospheric influence in the aerosol.

The strength and position of the subtropical Azores anticyclone, unusually situated near British Islands, dominated the meteorological features on Central North Atlantic, during this period.

An unusually large dust storm emerged from the Northwest coast of Africa about the 26 of February, and were transported trough Iberian Peninsula, Central Europe and North Atlantic. Our study is reported to this unusual events, probably the biggest of the 20th Century.

Results and Discussion

^{7}Be activities over the study period, fit a best-fit least-squares linear regression equation:

$$^{7}\text{Be activity}=4.3 \times 10^{-3} (\text{max50m})+4.2 \times 10^{-3} (\text{max1000m})-9 \times 10^{-4} (\text{min5000m})$$

(Equation 1)

where max50m is the maximum altitude obtained on the isentropic air mass trajectory of 50m, max1000m the maximum altitude obtained on the isentropic air mass trajectory of 1000 m and min5000m the minimum altitude obtained on the isentropic air mass trajectory of 5000m. The beryllium activity is expressed in mBqm^{-3} and the multilinear regression coefficient (r) was 0.95 at 95% of significance.

Backward isentropic air mass trajectories, for the study period, were obtained from NOAA Ready Hysplit 4 model, at 50 m, 1000m and 5000 m.

This kind of dependence observed by the equation 1 means that: the indirect influence from the stratosphere-troposphere exchange on ^{7}Be activity observed at lower tropospheric level, depends on the upper-troposphere synoptic patterns and the time-scale of vertical mixing versus dilution. Similar behaviour was reported by Zanis et al. 1999.

Using backward trajectories for 10 km a.s.l. air masses (near tropopause), was digitalized their pression associated to the potential temperature along the trajectory on figure 1. Again was used the NOAA Ready Hysplit 4 model.

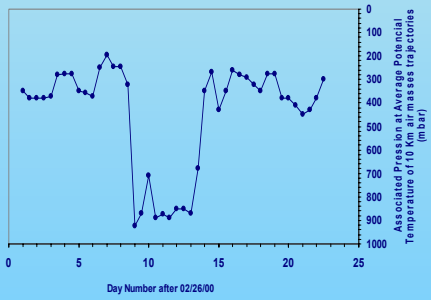

Figure 1 - Oscillation of Potential Temperature over Terceira Island in the study period.

Figure 1 shows a strong increase on pression associated to the potencial temperature of air masses at 10km a.s.l. over Terceira Island, between 4 and 9 of Mars 2000. This kind of feature, could be responsible by downward transports from high troposphere to lower tropospheric layers. This vertical transports are also responsible for an increase on the activity of ^{7}Be attached to the mineral aerosol.

^{7}Be activities found on Azores, results mainly from vertical transports that occurs somewhere on a trajectory plot, and then by long range transport, transported to these Region .

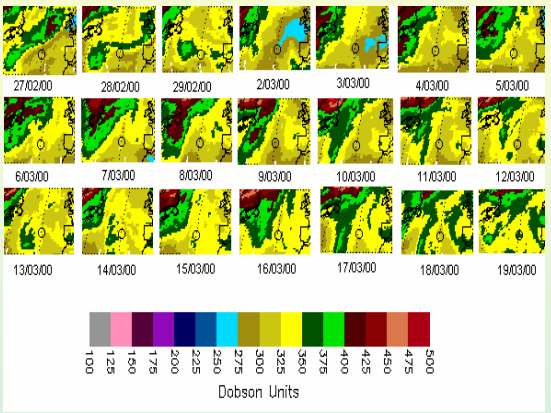

Figure 2 - Total Global Ozone (Earth Probe - Total Ozone Mapping Spectrometer -TOMS) on North Atlantic Region Near Azores over the study period.

Along the mineral aerosol transport from North Africa, decreases in ozone's total over Terceira Island, detected by TOMS (Earth Probe – Total Ozone Mapping Spectrometer), were negatively correlated with ^{7}Be activities. We verified that the changes in ozone are related to changes in ^{7}Be activities, trough a linear regression at 95% of significance level. The best-fit least-squares linear regression, gives the equation:

$$\Delta\text{Ozone} = -1.86\Delta^{7}\text{Be activity}+6.97$$

(Equation 2)

where Δozone is the variation of the total ozone over Terceira Island in Dobson unit (DU), Δ^{7}Be activity the variation of beryllium-7 activity in mBqm^{-3}. The linear regression coefficient was 0.98, suggesting a stronger dependence between the ozone losses and vertical transports from upper troposphere to lower tropospheric layers.

The PM10 mass in this period was not directly correlated with ^{7}Be activity, but with exception of one point, decreases on ^{7}Be activity corresponds to decreases on PM10 mass in agreement with a more strong dry deposition during longer trajectories. During the February-March 2000 Saharan events, the highest PM10 mass observed in Azores was 181µgm^{-3} and the lowest, under typical meteorological conditions, 18µgm^{-3}. The highest ^{7}Be activity registered was 9.4 mBqm^{-3} and the lowest (under typical meteorological conditions) 1.3 mBqm^{-3}. The transport of the mineral aerosol from North Africa which crossed Central Europe before arriving to the Azores Archipelago, had a PM10 mass of 125, 101 and 64 µgm^{-3}.

If we assume the data published by Dibb et al. 2000 for the upper-troposphere on Central North Atlantic, the ^{7}Be activity under typical meteorological condition exhibits a exponential behaviour with altitude. The ^{7}Be activity which results from the empirical model that uses the data published by Dibb et al. 2000, for the 50m altitude, is in complete accordance with the minimum observed at 50m on Terceira Island during the study period. The minimum ^{7}Be activity observed at Terceira is also in accordance with the soil level ^{7}Be activity, estimated by Bhandari et al. 1966 for the Globe surface. Based on the empirical model, the minimum altitude for the long-range transport of mineral aerosol from the 2000 sand storm was estimated. It was seen that the submicrometer fraction of the aerosol collected in February-March travelled in an altitude between 3.4 to 6.5 km in troposphere before its arrival to Azores. The lowest altitude was associated to the strong transport of mineral aerosol directly from Magrebe to Azores. The highest altitude was associated to long range transport from North Africa to Central Europe, then by the influence of the Azores High located during this period near British Islands, it moved towards Azores Archipelago.

Acknowledgements

Authors are deeply indebted to the Fundação para a Ciência e Tecnologia and to the Regional Government of the Azores, for the financial support of this work. We are also obliged to EDA-Electricidade dos Açores for the electrical supply in the sampling area .
We want to acknowledge the collaboration of Maria de Lurdes Salgueiro, Francisco Carmona, Ana Maria Martins and Celina Miguel.

References

Bhandari, N.; Lal, D. and Rama. 1966. Stratospheric circulation studies based on natural and artificial radioactive tracer elements. *Tellus*. **18** : 391-406.
Dibb, J.E.; Talbot, R.W. and Scheuer, E.M.. 2000. Composition and distribution of aerosols over the North Atlantic during the Subsonic Assessment Ozone and Nitrogen Oxide Experiment (SONEX). *Journal of Geophysical Research*. **105 (D3):** 3709-3717.
Lide, D.R.. 1997. *Handbook of Chemistry and Physics*. 78TH Edition 1997-1998. CRC Press. Boca Raton.
NOAA. 2000. *Ready Hysplit 4. Backtrajectories FNL, run with archived data*. http://gus.noaa.gov/ready/hysplit4.html .
NASA Goddart Space Flight Center. 2000. *TOMS (Earth Probe Total Ozone Mapping Spectrometer)*. http://jwocky.gsfc.nasa.gov/aerosols.
Zanis, P.; Schuepbach, E.; Gaggeler, H.W.; Hubener, S. and Tobler, L.. 1999. Factors controlling beryllium-7 at Jungfraujoch in Switzerland. *Tellus*. **51B** : 789-805.