DUST DEPOSITION FLUXES TO NORTHEASTERN SUBTROPICAL ATLANTIC (CANARY ISLANDS)

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ABSTRACT

African dust transport constitutes a large fraction of the annual atmospheric deposition in the Canary Islands. The analyses of aerosol samples and deposition measurements have been carried out during CLIMAAT Project at Tafira (28º 06' N, 15º 24' W; 269 m a.s.l.) located in Gran Canaria. Total dust deposition flux was 18.6 g m^{-2} yr^{-1} from May 2003 to April 2005. Highest dust depositions were observed during winter, especially during January and February. Winter events account up to 35% of the total annual flux. Seasonal distribution of concentrations of total suspended particles(TSP) indicates that dust outbreaks are more frequents in winter. Composition of trace metals(Al, Fe, Co) in the mineral aerosol and the possible impact of large dust pulses in the Canary basin are discussed.

METHODOLOGY

Levels of TSP have been sampled daily in Tafira (269 m a.s.l) and Taliarte stations (6 m a.s.l.) for 12 hours using high volume captors (HVC, see Figure1: right) with a flow rate of 60 m^3 h^{-1}. Particles were colleted in Tafira on filters Whatman GF/A and the concentrations have been calculated by gravimetry. Chemical characterisation from Whatman 41 filters collected in Taliarte. After acidic digestion (details Guieu, 1991), solutions were analysed for trace metals by Graphite Furnace Atomic Absorption Spectroscopy (GFAAS) and Flame Atomic Absorption Spectroscopy (FAAS).

For dry and wet deposition fluxes measurements an automatic wet & dry sampler (ARS 1000, MTX Italia: see Figure 1, left) with cubic containers with a surface area of 660 cm^2 equipped with a rain sensor was used. The dry atmospheric deposition was collected continuously from May 2003 to April 2005 at Tafira, in 23 samples representing time periods ranging from 11 to 50 days. Wet depositions were collected after each rainfall in the same period.

The origin of air masses for each day sampled was interpreted based on: a) determination of daily 5-days isentropic back trajectories (at 750, 1500, 2000 and 2500 m.a.g.l.,6 hours step) twice a day (00:00 y 12:00 UTC) using the HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) model (Draxler and Rolph, 2003); b) evaluation of daily TOMS (NASA; Herman et al., 1997) and SKIRON (Athens University) aerosol maps (Kallos et al., 1997); c) evaluation of SeaWIFS-NASA satellite images to detect dust plumes (McClain et al., 1998); and d) evaluation of meteorological data (Dorta, 1999).

Figure 1.- Automatic Dry & Wet sampler in Tafira station (left) and HVC in Taliarte station (right).

RESULTS AND DISCUSSION

The Figure 3 shows the strong variability of the daily concentrations of TSP during the years 2004-2005 at the Tafira station. Higher concentrations of particles were observed in summer and winter, especially for January and February. Values up to 2000 µg/m^3 were recorded in February and March of 2004 (see Figure 3). African dust outbreaks during winter are characterized by intrusions in the lower atmospheric levels. On the contrary, higher concentrations of dust have been observed in summer in Pico de la Gorra at 1930 m.a.s.l in Gran Canaria (Hernández-Brito et al., 2004). Typical meteorological situations during the summer events produce dust transport at higher altitudes. Special geographic features of relief in Gran Canaria have been suggested that could determinate the altitude of dust intrusion (Falke et al., 2001).
Seasonal distribution in Tafira has been calculated (from December 2003 to December 2004) from the frequency of days which rise up the average TSP concentration (50 µg m^{-3}). This also indicates that dust outbreaks are more frequents in winter (34%) and summer (23 %).

Seasonal variations of the dry and wet deposition fluxes in Tafira are given in the Figures 4 and 5, respectively. Higher dry and wet fluxes were observed in winter which is agree with the highest average concentration of TSP in the air during that season (see Figure 3).

Figure 2.- Panoramic view of a dust outbreak in Taliarte on 3 March , 2004 . This image was taken by C.Collado.

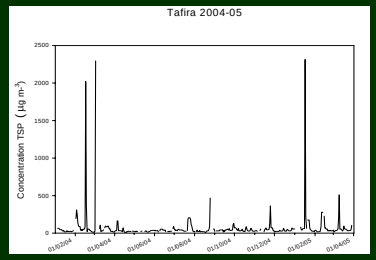

Figure 3.- Concentration of TSP (in µg m^{-3}) at Tafira from January 2004 to April 2005.

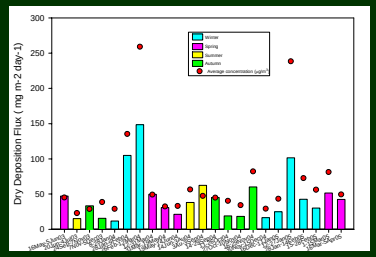

Figure 4 .- Seasonal variation of the Dry Deposition Fluxes (mg m^{-2} day^{-1}) measured in Tafira for the time periods considered. Red dots are average concentration of TSP(in µg m^{-3}) in the air at the same periods.

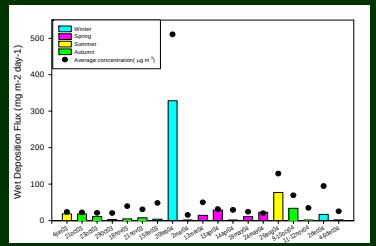

Figure 5 .- Seasonal variation of the Wet Deposition Fluxes (mg m^{-2} day^{-1}) measured in Tafira for the time periods considered. Black dots are average concentration of TSP(in µg m^{-3}) in the air days before the dates considered.

Dry deposition velocity is about 1 cm s^{-1} as inferred from the experimental dry deposition flux. The experimental total flux was 18.6 g m^{-2} yr^{-1}. For a surface of 80.000 km^2 such as the Canary basin, the total deposition is 1.5 X 10^6 tons yr^{-1}.

Chemical Characterisation

The arithmetic mean concentrations of Al, Fe, Co, Mn, Cu, Pb, Cd, Zn and Cr are reported in Table 1. Their concentrations during different events are showed in the Figure 6 and the five-day isentropic back trajectories calculated for the same days are presented in the Figure 7. High standard deviations from the mean concentrations of each element are presented during the studied outbreaks, due to the strong variability of concentration of mineral aerosol in the analysed samples (TSP= 20-2295 µg m^{-3}).

Al is very closely correlated with Mn (r=0.980, n= 62), Fe (r=0.999, n=62), Co (r= 0.980, n= 62) and Ca (r= 0.984, n= 40) in the dust samples. These elements are typical crustal tracers. High enrichment factors of Mg and Na are probably due to the presence marine aerosol inTaliarte (a coastal station). Mg and Ca seem to have an additional source probably from sea salt, however, Ca correlation with Al is 0.984 (n= 40) and with the concentration of TSP is 0.990 (n= 40) so additional Ca concentrations could be origined from crustal calcite and gybsum.

There were no correlations between the Al and Pb, Zn and Cd in the samples. These elements are enriched elements (EEs) and are affected by pollution sources. The non-crustal fraction (Xs) mainly represents material of man-made origin. In the analyzed aerosol, Cu, Zn, Cd and Pb were 80-95% anthropogenic. For Fe, Co and Mn the average non-crustal fractions are 4-22%. The excess number for the average concentrations of Cr is 61%. This element could be enriched by local anthropogenic activities. However, Cr present a correlation (r= 0.880, n=40) with the Al in this study.

The Fe/Al was 0.45 ± 0.15 (n= 61) in the total particulate samples analyzed from the filters in this study. This is comparable to a crustal average of 0.44 (Taylor and McLennan, 1985) and the mass ratios observed in the atmosphere over the North Atlantic (Arimoto et al., 1995). The average Fe/Al ratio was highest in the dust samples collected during days which back trajectories were origin in the Sahelian region.
The concentrations established for the dry and wet metal fluxes are scattered. This may be due to the fact that particulate phase had an important contribution of local input. During the strong event of 17-19 on February of 2004, dust samples were collected using rectangular plastic containers. In this particulate phase, the Fe/Al was 0.57 similar to the ratio determined in the erodible crust (Martin and Withfield, 1983).

CONCLUSIONS

Mineralogical characteristics of the mineral aerosol collected and back trajectories of the air masses appear to indicate two main regional African sources of dust in the Canary region. Winter events are mainly originated from the Sahelian source and samples present high Fe/Al ratio. Most of the samples collected during the spring and summer events present lower Fe/Al ratios and the dust is origin from the north and west of Sahara.
The variability of the mineral dust concentrations collected during the present study is large. Aerosol concentration as TSP ranges from 6 to 2315 µg m^{-3}. during this study, the mean concentration of dust was 58 (±160) µg m^{-3}.
On the basis the observed Xs, trace metals as Pb, Cd, Cu and Zn, have an important anthropogenic component in the aerosols collected in Taliarte station.

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Metal	Arithmetic mean (±σ)	Min-Max
Al	3642 (± 4642)	296-19517
Ca	6068 (± 5366)	950-24709
Cd	0.40 (± 0.68)	0.01-2.75
Co	1.06 (± 0.94)	0.16-3.63
Cr	12. 93 (± 10.95)	1.20-51.82
Cu	9.79 (± 10.48)	1.76-62.85
Fe	1435 (± 1758)	90- 6982
Mn	31.44 (± 44.80)	2.12-222.83
Pb	11.49 (± 8.00)	3.22-44.78
Zn	476 (± 476)	84-1771

Table 1.- The trace metal aerosol composition (ng m^{-3}), to dusty days samples colleted at Taliarte.

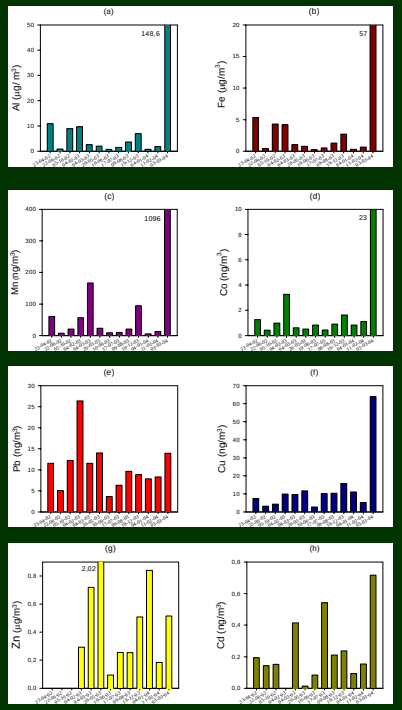

Figure 6.- Concentration of Al, Fe and Zn (µg m^{-3}) and Mn, Co, Pb and Cd (ng m^{-3}) in different dust episodes.

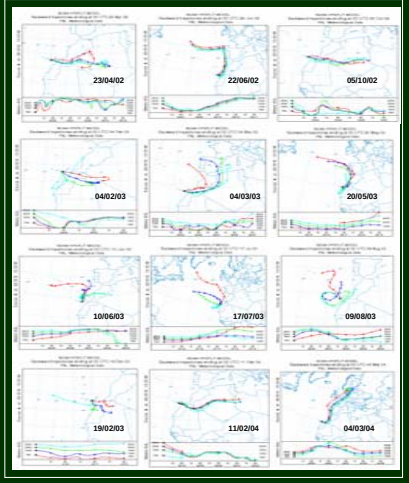

Figure 7.- Isentropic back trajectories (at 750, 1500, 2000 and 2500 m.a.g.l.) using the HYSPLIT model at 00h associated to dusty days sampled at Taliarte.

REFERENCES

Arimoto, R., Duce, R.A., Ray, B.J.Ellis, W.G., Cullen J.D. and Merrill, J.T. 1995. Trace elements in the atmosphere over the North Atlantic. Journal of Geophysical Research,Vol.100,No.D1, 1199-1213.
Dorta Antequera, P.1999. Las invasiones de aire sahariano en Canarias. Consejería de Agricultura Pesca y Alimentación del Gobierno de Canarias, 287 pp.
Draxler, R.R. and Rolph, G.D. 2003. HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) Model access via NOAA ARL READY Website (http://www.arl.noaa.gov/ready/hysplit4.html). NOAA Air Resources Laboratory, Silver Spring, MD.
Falke S.R., Husar R.B. and Schichtel, B.A. 2001. Fusion of SeaWiFS and TOMS Satellite Data with Surface Observations and Topographic Data during Extreme Aerosol Events. Journal of Air & Waste Management Association, November, Vol. 51, number 11.
Hernández-Brito,J.J., Rodriguez-Somoza, M.J., Gelado, M.D., Dorta, P., Collado, C., Cardona, P. and Siruela, V. Characterisation of African dust outbreaks in Gran Canaria (Canary Islands). Communication presented in SOLAS (Surface Ocean-Lower Atmosphere Study) Conference in Halifax, Canada, October 2004.
Guieu, C. 1991. Apports atmospheriques a la Mediterranee Nord-Occidentale. Thesis, L'Universite Paris 6, Paris, 225 pp.
Herman J.R., Bhartia P.K., Torres O., Hsu C., Seftor C., Celarier E.1997. Global distribution of UV- absorbing aerosols from Nimbus7/TOMS data. Journal of Geophysical Research, 201, 16911- 16922.
Kallos G., Kotroni V., Lagouvardos K. 1997. The regional weather forecasting system SKIRON: an overview. In: Proceedings of the Symposium on regional weather prediction on parallel computer environments, University of Athens, Greece, pp. 109-122.
Martin, J.M., and Withfield, M.1983.The significance of the river input of chemical elements to the ocean, in Traces Metals in Sea Water, edited by C.S. Wong et al., pp.265-296, Plenum, New York.
McClain C.R., Cleave M.L., Feldman G.C., Gregg W.W., Hooker S.B., Kuring N. 1998. Science Quality SeaWiFS Data for Global Biosphere Research. Sea Technology, 39 (9), 10-15.
Taylor, S.R., and McLennan, S.M. 1985. The Continental Crust: Its Composition and Evolution, 312 pp., Blackwell, Oxford, England.