RADIATION, OZONE, AND AEROSOL MEASUREMENTS AT LAMPEDUSA DURING THE PAUR II CAMPAIGN

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ABSTRACT

During May and June 1999 the *Photochemical Activity and Ultraviolet Radiation modulating factors II*, PAUR II, campaign, took place in the Mediterranean sea. Many instruments for the measurement of ultraviolet and visible atmospheric radiation, ozone, aerosol properties, atmospheric chemical composition, were deployed on the islands of Crete and Lampedusa, and on a ship. In this paper a description of the instrumentation deployed at Lampedusa, and a selection of results, are given. Effects of desert dust aerosols originating from the Sahara on the ultraviolet and visible radiation are evident.

1. INTRODUCTION

The *Photochemical Activity and Ultraviolet Radiation modulating factors II* (PAUR II) campaign, took place in May-June 1999 in the Mediterranean with the aim of studying the atmospheric processes that affect the propagation of the ultraviolet radiation. The Mediterranean sea was selected as a suitable region for different reasons. Among these, of great importance are the frequent occurrence of dust transport events, mostly in spring, and the relatively low latitude of the sites. Thus, a great variability of atmospheric transparency, associated to high levels of ultraviolet radiation, are expected. Two main sites were chosen: the island of Crete, in Greece, and the island of Lampedusa, in Italy. Many instruments were deployed at the two sites for the measurement of ultraviolet and visible radiation, atmospheric chemical composition (in particular ozone distribution), and aerosol properties. In this paper an overview of the instrumentation deployed at Lampedusa is given, and some results showing the effects of desert aerosols on the radiative field are discussed.

Lampedusa is a small island (35.5°N, 12.6°E; 10 km long, approx. 1.5 km wide) in the Mediterranean sea, approximately 100 km east of Tunisia (fig. 1). The maximum elevation of the island, which is relatively flat and rocky, is 120 m.

The ground-based instrumentation at Lampedusa was deployed at the Station for Climate Observations of the National Agency for New Technology, Energy, and Environment (ENEA) of Italy. The Station is at 40 m a.s.l., on the north-east coast of the island.

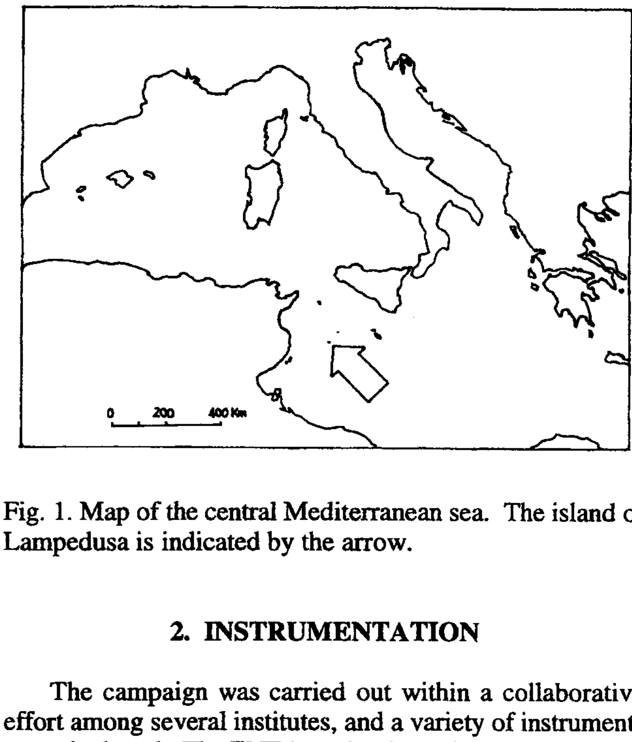

Fig. 1. Map of the central Mediterranean sea. The island of Lampedusa is indicated by the arrow.

2. INSTRUMENTATION

The campaign was carried out within a collaborative effort among several institutes, and a variety of instruments were deployed. The ENEA station is equipped with a 10 m tall meteorological tower; ordinary meteorological parameters, global solar radiation (Kipp and Zonen pyranometer) as well as greenhouse gas concentrations (*Chamard et al.*, 2000) are routinely acquired. A double monochromator Brewer spectrometer MK III is also operational at the site. The instrument was calibrated with the National Oceanic and Atmospheric Administration UV field calibrator (*Early et al.*, 1998) at the end of April 1999.

For the campaign the following instruments were also installed:

- a Multi-Filter Rotating Shadowband Radiometer (MFRSR)

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- two UV-B radiometers of the Robertson-Berger type
- a Precision Spectral Pyranometer, and Black and White pyranometer
- an UV-A broadband radiometer
- a Licor-1800 spectrometer
- a POM-01L aureole photometer
- a GUV-511 radiometer
- a ground-based lidar dedicated to the measurement of tropospheric aerosol backscattering and depolarization.

The ground-based instrumentation was run continuously during daytime. The Licor spectrometer was calibrated with an external reference lamp shortly before the campaign. The calibration of the broad-band radiometers was performed by the Central UV Calibration Facility, at NOAA.

Many instruments were installed aboard the ultralight aircraft of the Fraunhofer Institute of Garmisch (Germany). The aircraft performed 16 flights from the Lampedusa airport between May 10 and 28, reaching a maximum altitude of 4300 m. The aircraft payload was constituted by:

- an ozone UV-photometer
- 2 (up- and downward looking) filter radiometers for the determination of $J(O^1D)$
- 2 (up- and downward looking) filter radiometers for the determination of $J(NO_2)$
- 2 Licor pyranometers (up- and downward looking)
- a Forward Scattering Spectrometer Probe (FSSP)
- a laser particle counter, for particles of diameter d>0.3 µm
- a condensation nuclei counter, for particles of diameter between 0.01 and 3 µm
- a laser scatterometer (AVMIII)
- a UV-B radiometer
- digital cameras, pressure, temperature, humidity and position sensors.

On a clear-sky day the airborne UV radiometer was run at the ground beside the other UV radiometers, to derive an intercalibration of the instruments. Detailed information on the spectral distribution of ultraviolet, visible, and near infrared radiation at the ground was thus obtained. Measurements of the vertical distribution of ultraviolet and visible radiation were obtained during the flights. Information on the aerosol optical depth and optical properties, included the columnar size distribution, were derived from the sun photometers (MFRSR, POM-01L); aerosol profiles were measured by lidar. From the aircraft, aerosol size distribution and scattering coefficient (at 137°, and 870 nm) profiles were determined.

3. RESULTS

Very different conditions, i.e. total ozone amounts and aerosol optical depths, were found during the campaign. Desert aerosol was observed often over Lampedusa during the campaign: lidar observations show that during dust transport events aerosol was present up to 8 km. Isentropic trajectories reaching Lampedusa appear to always originate from Africa when a large aerosol load was observed. In these cases the analysis of the lidar data shows that larger values of the backscatter and depolarization ratio are found throughout the lowest and middle troposphere (di Sarra A., T. Di Iorio, M. Cacciani, G. Fiocco, and D. Fuà, 2000: Saharan dust profiles measured by lidar from Lampedusa, submitted to Journal of Geophysical Research).

In this paper we focus our attention on the effects of the aerosol on the ultraviolet and visible irradiance at the ground. In figure 2 ultraviolet spectra measured at the solar zenith angle of 60° on two days are shown. The spectra have been corrected for changes of the Sun-Earth distance. Cloud-free conditions on both days, at the measurement time, were found at Lampedusa. In the top graph, the ratio between the two spectra is depicted. The two days, May 18 and 27, were characterized by very different conditions. At the time of the measurements the total ozone (measured by the Brewer) was 294 Dobson units (DU) on May 18, and 347 DU on May 27. The effect of the different ozone amounts clearly appears for wavelengths shorter than 320 nm.

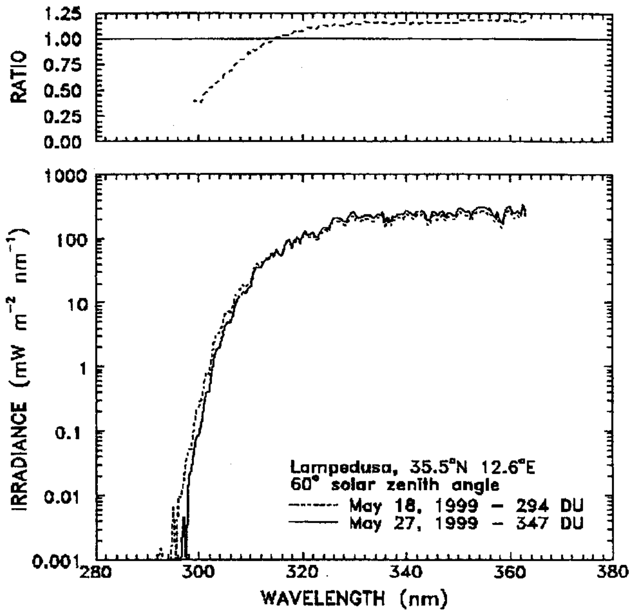

Fig. 2. Bottom graph: ultraviolet spectra measured by the Brewer spectrophotometer on May 18 and 27, 1999, at a solar zenith angle of 60°, for cloud-free conditions. Top graph: ratio between the spectra of May 27 and May 18.

In figure 3 the spectra from the Licor spectrometer, corrected for the differences in the Sun-Earth distance, are shown. Both spectra are obtained at 60° solar zenith angle. At wavelengths longer than 320 nm, and throughout the visible and near infrared range, the irradiance appears larger on May 27. A somewhat different behavior appears in correspondence to the water vapor absorption bands around 723, 820, and 940 nm. Evidently, on May 27 the water vapor content of the atmosphere was much larger than on May 18. As for the Brewer data, on May 27 the irradiance at wavelengths shorter than 320 nm is smaller than on May 18, as a consequence of the large total ozone difference (53 DU) between the two days.

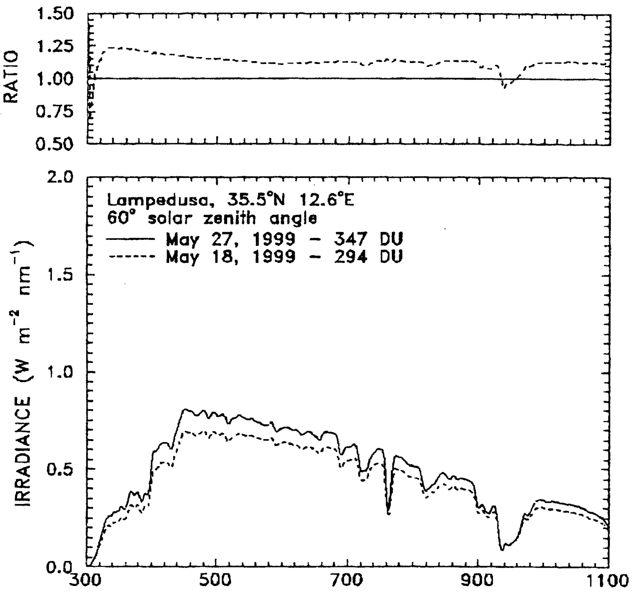

Fig. 3. Bottom graph: spectra measured by the Licor spectrophotometer on May 18 and 27, 1999, at a solar zenith angle of 60°, for cloud-free conditions. Top graph: ratio between the spectrum of May 27 and that of May 18.

Large differences in the aerosol distribution and properties existed between the two selected days, as will be shown. The effect of the ozone absorption is thus dominating over the attenuation due to the aerosol for wavelengths shorter than 320 nm; at longer wavelengths, the effect of the atmospheric aerosol is larger.

The aerosol optical depth, τ, at 868 nm, as derived from the MFRSR at the time of the measurement, was 0.43 and 0.09 on May 18 and 27 respectively. At 500 nm τ was 0.65 and 0.23 on the same days. From these values of the optical depth an Ångström exponent of 0.75 and 1.8 is derived for May 18 and 27 respectively. This result seems to indicate that the aerosol layer contained larger particles on May 18. From the volume size distributions derived from the aureole meter POM-01L, it appears that on May 27 the volume integrated over the column of the particles of radii larger than approximately 1 µm was 52-84% smaller than on May 18. A much smaller reduction (28% for radii of 0.25 µm) is derived for the volume of smaller particles (Campanelli, M., W. Junkermann, B. Olivieri, and G. Tonna, 2000: Characterization of the Mediterranean aerosol from simultaneous measurement by an aureolemeter and a forward scattering spectrometer probe (FSSP). Submitted to Applied Optics).

The aerosol profile of May 18, as appears from quasi simultaneous lidar and ultralight aircraft measurements shown in figure 4, was characterized by a thick layer between 2.5 and 4.5 km; lidar measurements showed evidence of enhanced aerosol concentrations up to 7 km. The maximum value of the backscatter ratio was around 5 at 3.5 km. On May 18 all the trajectories reaching Lampedusa at altitudes between 2.5 and 6 km had spent a large fraction of the last 10 days over central Sahara. Below 2 km, airmasses marginally passed over the African coast.

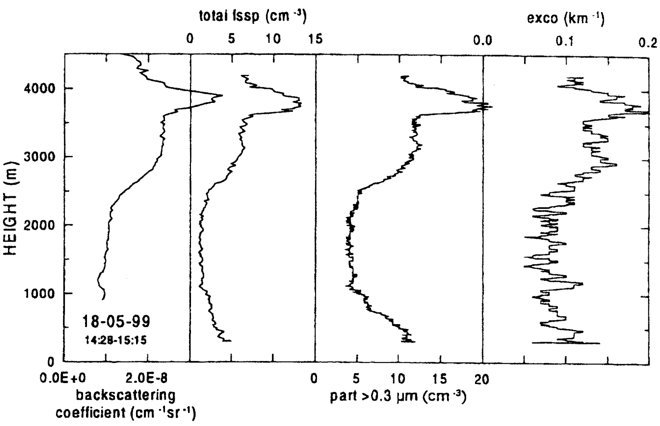

Fig. 4. Aerosol profiles measured on May 18, 1999 by the ground-based lidar and by some of the instruments aboard the ultralight aircraft. The measurements were obtained in the same time interval. The left graph shows the lidar backscattering coefficient profile. Total number of particles with 0.4<d<8 µm from the FSSP, number of particles with diameter>0.3 µm, and scattering coefficient at 870 nm and 137° appear in the other graphs.

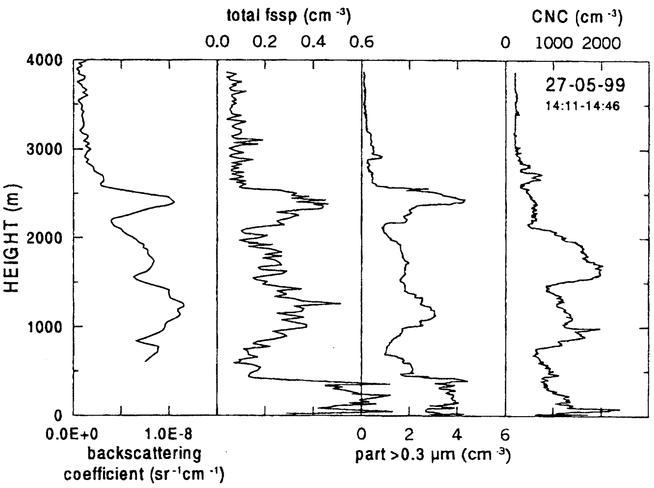

Fig. 5. Aerosol profiles measured by the ground-based lidar and by the instrumentation aboard the ultralight aircraft on May 27, 1999, in the same time interval. The left graph shows the lidar backscattering coefficient. Total number of particles with 0.4<d<8 µm from the FSSP, number of particles with diameter>0.3 µm, and number of particles with 0.01<d<3 µm appear in the other graphs.

On May 27 the atmosphere above 2.8 km appeared devoid of aerosols. The maximum of the backscatter ratio was 2 at approximately 1 km. A much larger concentration of particles with radii between 0.2 and 4 µm (FSSP data), and of particles with radii larger than 0.15 μm (laser counter) was found on May 18 with respect to May 27 (figure 5), according to the aircraft data. The derived values of the Ångström exponent seem to indicate that, as expected, larger particles were present in the airmasses originating from Africa.

The desert dust observed on May 18, and in several other occasions during the PAUR II campaign, determines a large perturbation to the radiative field. The visible irradiance integrated between 400 and 700 nm is 189 W/m^{-2} on May 18, and 215 W/m^{-2} on May 27. The reduction of the global irradiance between 400 and 700 nm due to the aerosols is thus more than 12%, or 26 W/m^{-2} at the solar zenith angle of 60°. By using the measured aerosol optical depth, the attenuation of the direct radiation through the aerosol layer can be calculated for the two days. This attenuation is 73% on May 18 (at the solar zenith angle of 60°), and 37% on May 27. Thus, a much larger fraction of the direct beam is redistributed into the diffuse field, as an effect of scattering due to the large load of dust particles. Although the global surface irradiance decreases, the fraction of the irradiance due to diffuse radiation increases. This effect is confirmed by the measurements of the diffuse-to-direct ratio, that results to be around 2 on May 18, and 0.6 on May 27 (at the same solar zenith angle of 60°, at 500 nm).

On the same days, at 70° solar zenith angle, a reduction of the global irradiance integrated between 400 and 700 nm from 129 to 108 W/m^{-2} (more than 16%) is obtained. At 500 nm, for the same value of the solar zenith angle, the calculated reduction of the direct irradiance due to aerosols on May 18 is 80%, and is 52% on May 27. The measured diffuse-to-direct ratio at 500 nm was 4.3 on May 18, and 0.8 on May 27.

Similar results are obtained by selecting different pairs of days, characterized by low and high values of the aerosol optical depth. During PAUR II, large values of τ were encountered only in correspondence to Saharan dust events. The global irradiance reduction between the two cases appears smaller for smaller values of the solar zenith angles (around 6% for 20 and 30°, around 8% for 40°), for similar values of the aerosol optical depth.

4. CONCLUSIONS

Radiation, aerosol, and ozone measurement have been carried out from the island of Lampedusa, in the Southern Mediterranean, during the PAUR II campaign. The desert aerosols appear to produce a large perturbation of the radiative transfer through the atmosphere. An attenuation of the global irradiance at the surface is observed in the presence of the large aerosol load generally associated to the airmasses originating from Africa. A significant increase of the diffuse radiation at the surface, and a strong reduction of the direct irradiance, resulting in a reduction of the global irradiance, are observed in these cases. These perturbations may produce an important impact on several atmospheric processes. In particular, modifications of the albedo are induced by the aerosol layer; a reduction of the ultraviolet irradiance may influence the photochemical processes that take place in the troposphere; effects on the biosphere may be expected by the reduction of the photosynthetically active radiation.

ACKNOWLEDGMENTS

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REFERENCES

Chamard, P., L. Ciattaglia, F. Monteleone, and A. di Sarra, 2000: The station for climate observations at Lampedusa: Greenhouse gas measurements. Proceedings of the VI CO_2 WMO Expert Meeting, in press.

Early, E.A., E.A. Thompson, and P. Disterhoft, 1998: Field calibration unit for ultraviolet spectroradiometers. *Appl. Opt.*, **37**, 6664-6670.