ARISTOTLE UNIVERSITY OF THESSALONIKI - AUTH
LABORATORY OF ATMOSPHERIC PHYSICS - LAP

Davos UV conference, September 18-20, 2007

Changes in surface radiation over Greece caused by the total solar eclipse of 29 March 2006

S. Kazadzis[1], A. Bais[1], M. Blumthaler[2], A. Webb[3], N. Kouremeti[1], R. Kift[3], B. Schallhart[2], A. Kazantzidis[1]

[1] Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki, Greece

[2] Division of Biomedical Physics, Innsbruck Medical University, Austria

[3] School of Earth Atmospheric and Environmental Sciences, University of Manchester, UK

Correspondence to: S. Kazadzis (skazan@auth.gr)

Introduction

On 29th March, 2006 a total solar eclipse was visible along a narrow corridor which traversed half the Earth, starting in Brazil, extending across the Atlantic, through North Africa, and central Asia and ending in northern Mongolia. The umbra traversed the Mediterranean passing directly over the Greek island of Kastelorizo (36.150° N, 29.596° E). (figure 1-station number 8)

A campaign including various radiation and other atmospheric parameters' measurements, took place at the island of Kastelorizo, Greece, during the 28th and 29th (eclipse day) of March 2006, with the participation of three groups:
- Innsbruck Medical University, division of biomedical physics, Austria ,
- Aristotle University, Physics Department, Thessaloniki, Greece and
- School of Earth Atmospheric and Environmental Sciences, University of Manchester, UK .

In addition the variability of ultraviolet and photosynthetically active radiation during the total solar eclipse of 29 March 2006 was also examined. The measurements from NILU-UV multichannel actinometers at 7 stations (see figure 1) of the Greek UV Network were used, where the maximum eclipse percentage ranged from 73.1% to 94.8%. Finally, an extra instrument was established at the island of Kastelorizo..

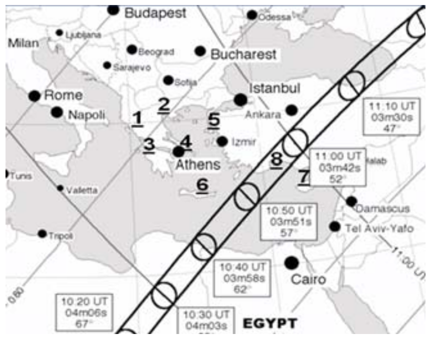

Figure 1: Eclipse map and ground based stations (numbers 1-8). Kastelorizo island is shown as number 8. The eclipse map is provided by NASA, Goddard Space Flight Center

Instrumentation

Kastelorizo:

- Two double monochromator spectroradiometers (Bentham DTM 300 and Brewer MKIII), measuring spectral, Global irradiance (GI), Actinic flux (AF) and direct irradiance (DI).
- Two diode arrays (PDA) and a coupled charged device (CCD) spectrometers (all single monochromators) used to record spectral measurements of GI, DI and AF. Their advantage is the simultaneous recording of the spectrum, which eliminates distortions from clouds or from the change in the Extraterrestrial irradiance during the eclipse.
- Broadband and filter radiometers were also available. A NILU-UV multi-filter radiometer measured GI at 5 narrow bands (~10 nm FWHM) in the UVB, the UVA and the photosynthetically active radiation with a frequency of 1 Hz. In addition, an erythemal detector, a UVA detector and a pyranometer operated continuously, recording 1 min averages.
- Direct sun measurements with 2 handheld sun-photometers (Microtops) with filters centred at 300, 305, 312, 340, 380, 440, 500, 675, 940 and 1020 nm were used to derive total ozone and aerosol optical depth.
- Two cameras with fish-eye lenses were taking pictures of the full sky; one camera was equipped with an additional adjustable polarization filter. Pictures were taken every 10 minutes, with an increased frequency of one picture per min during the eclipse.

Greek UV-Network

The Greek UV monitoring network was designed to cover geographically Greece and Cyprus, with nine stations distributed at locations with different environments. At the central station, located in Thessaloniki, a suite of spectral and broadband radiation and other related measurements are also available. The network is equipped with NILU-UV multi-channel radiometers, providing UV irradiance measurements at five wavelength bands centered at 305, 312, 320, 340 and 380 nm, with full width at half maximum (FWHM) of approximately 10 nm. (More details can be found at: http://www.uvnet.gr/)

Measurements at Kastelorizo

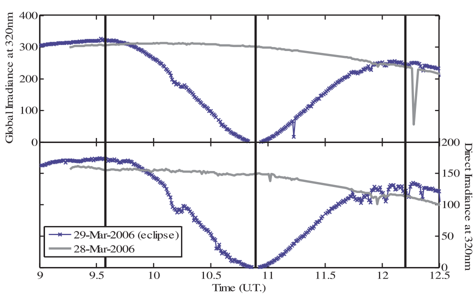

Figure 2: Global (Top) and direct (Bottom) spectral irradiance at 320 nm measured with the Brewer spectroradiometer on the eclipse day (blue symbols) and on the previous day (grey lines).

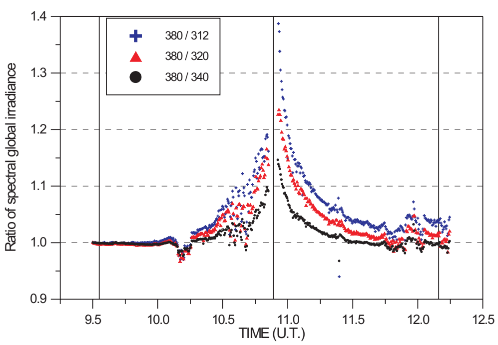

Figure 3: Normalized (with their ratio before the start of the eclipse) and solar zenith angle corrected ratios of global irradiance at 380 nm relative to 312 nm (blue), 320 nm (red) and 340 nm (black) during the eclipse day.

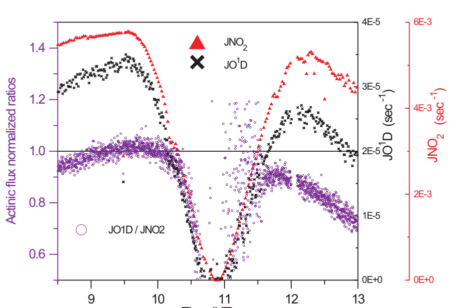

Figure 4. Variation of JO^1D (triangles) and JNO_2 (crosses) photolysis frequencies, normalized with their values at the time of the first contact. The ratio JO^1D/ JNO_2 is also shown in purple circles.

Greeek UV Network measurements and model comparison

The change in irradiance during totality, measured with the NILU-UV multi-channel radiometer at Kastelorizo, is compared with theoretical calculations for cloud free skies with the MYSTIC 3-D model (Emde and Mayer, 2007). The modeled spectra in the spectral region 300-500 nm were weighted with the spectral responses of the NILU-UV channels, to simulate the actual irradiance measurements of the NILU-UV instrument. Then, the ratio of irradiance for eclipse and non-eclipse conditions was calculated for every second during a period extending 5 minutes before and after the totality. All ratios were normalized with the value corresponding to the beginning of the period (i.e. 5 min before the eclipse maximum (figure 6).

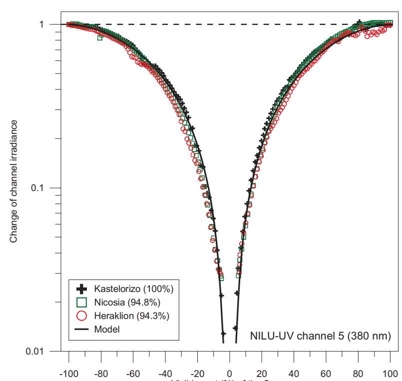

Figure 5: Change of solar irradiance for NILU-UV at 380 nm for sites 6-8. For each site the maximum eclipse percentage is provided.

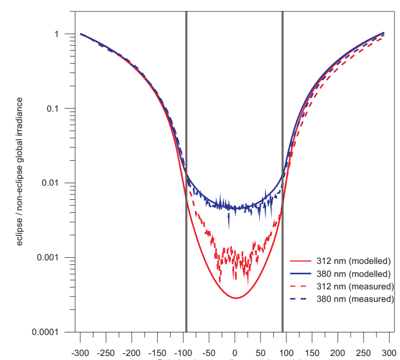

Figure 6: The ratio of global solar irradiance between the NILU-UV instrument and MYSTIC 3-D model calculations during the eclipse at Kastelorizo. The time t=0 denotes the maximum of the eclipse and the grey lines correspond to the beginning and the end of the totality.

Conclusions

- Global, direct irradiance and actinic flux spectral measurements showed that all quantities are spectrally affected by the limb darkening during the eclipse. The effect leads to wavelength dependent changes in the measured solar spectra showing a much more pronounced decrease in the radiation at the lower wavelengths as the percentage of the sun coverage is increased for all the above quantities.(see figure 3)
- The comparison of model results and measurements showed that previous 1D model calculations underestimate this spectral limb darkening effect especially close to the totality of the solar eclipse. This result was confirmed by measurements from two different instruments.
- Calculations of the ET solar spectrum and the effective sun's temperature as derived from direct irradiance measurements at the surface, showed an artificial change in both quantities. The limb darkening effect induces spectral changes in the ET spectrum measured from remote sensing techniques. The derived ET spectrum is a mixture of black body radiation spectra originating from parts of the solar disk with different temperatures. Thus, fitting a Plank function on these data, in order to derive the corresponding black body temperature of the Sun, leads to false estimates.
- At three network sites and for 94% eclipse percentage, the solar irradiance at 305nm is 50 times weaker when compared with values at non-eclipse conditions. The irradiance at UVA and visible spectral regions was almost 30 times less for the same conditions. The comparison of measured irradiance with 1-D model calculations (accounting for the limb darkening effect) reveals differences in UVB region of 10% for sun coverage up to 40%, while the differences rise to 30% for higher eclipse percentages. In UVA and visible regions the differences are within measurement and model uncertainties.
- The reduction of irradiance during the totality as predicted by a 3D model agrees with the measurements in the UV-A. The agreement worsens in the UV-B.

References

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