ENEA
ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

Optical Coatings Laboratory

UV-Solar irradiation measurements

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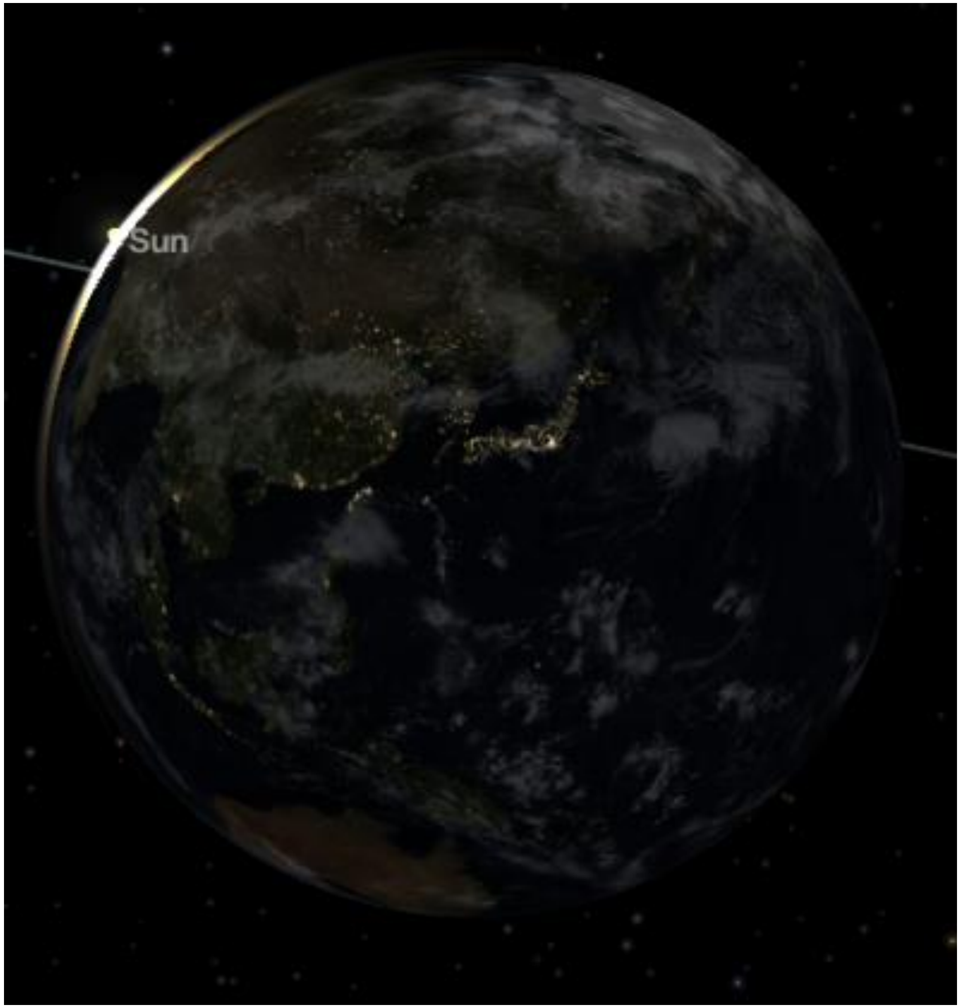
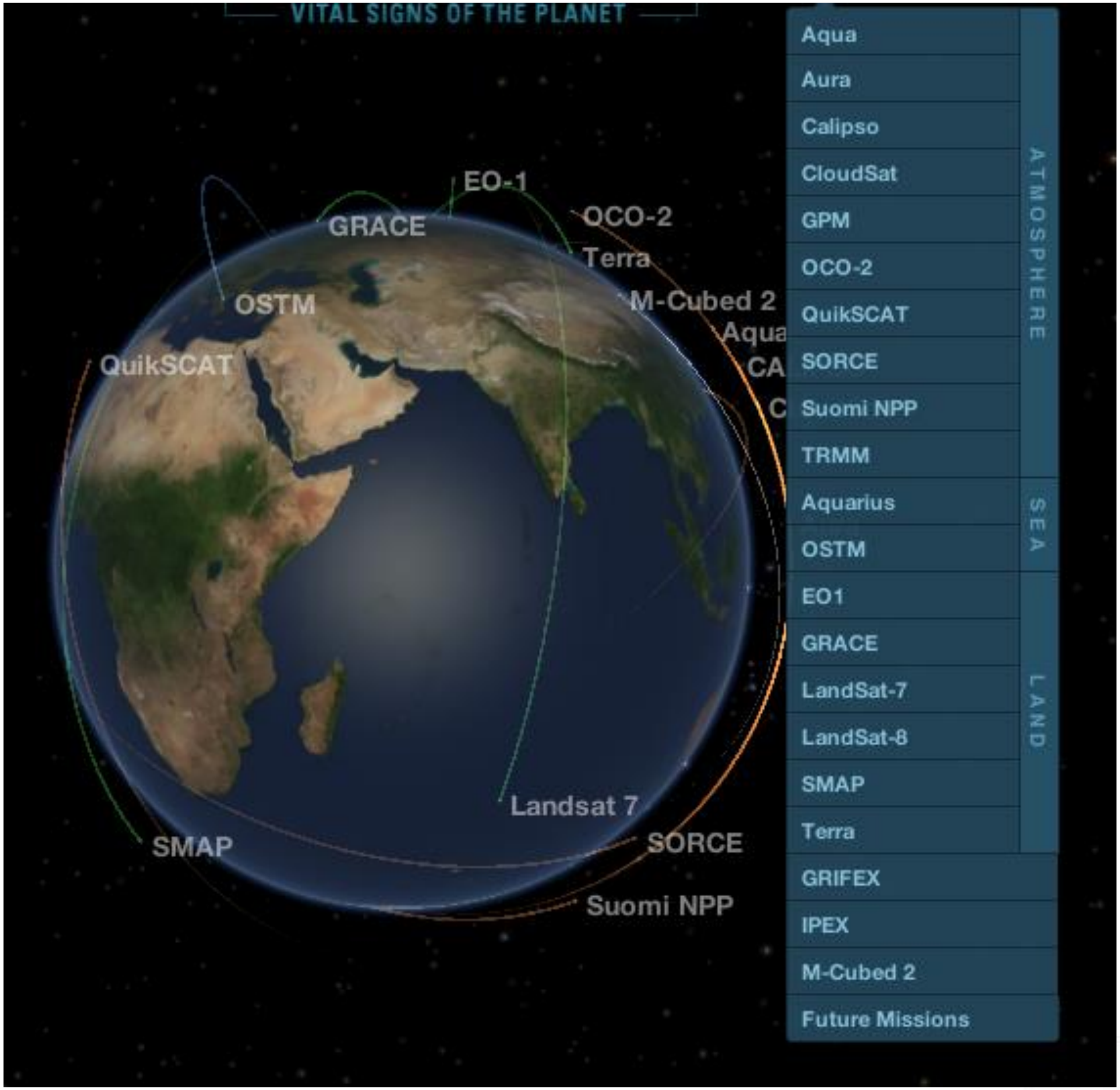
Winter College on Optics
Light: a bridge between Earth and Space
09 - 20 February 2015, Trieste, Italy.

Earth

Earth, our home planet, is the only planet in our solar system known to harbor life - life that is incredibly diverse. All the things we need to survive exist under a **thin layer of atmosphere** that separates us from the cold, airless void of space



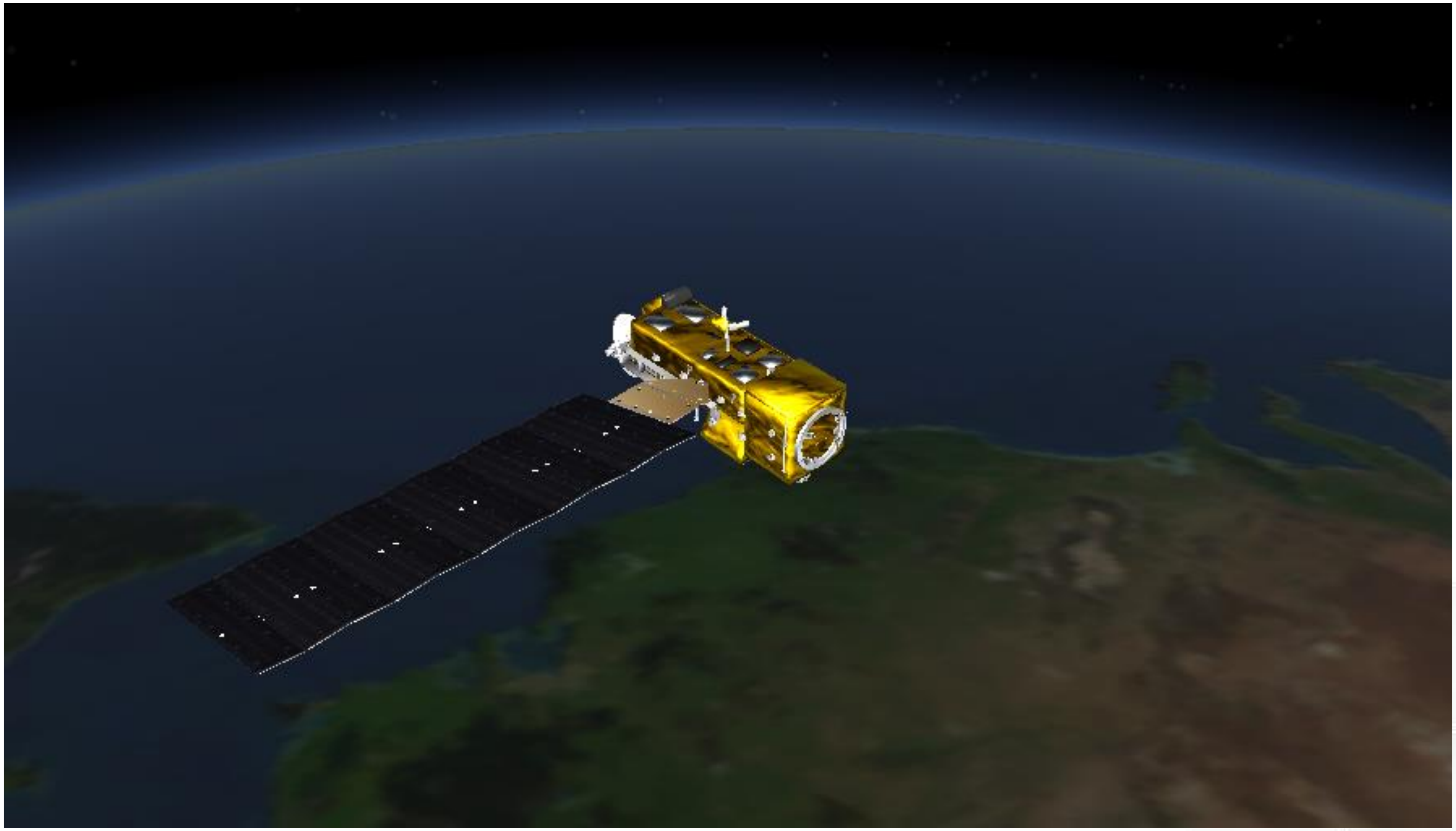
Missions



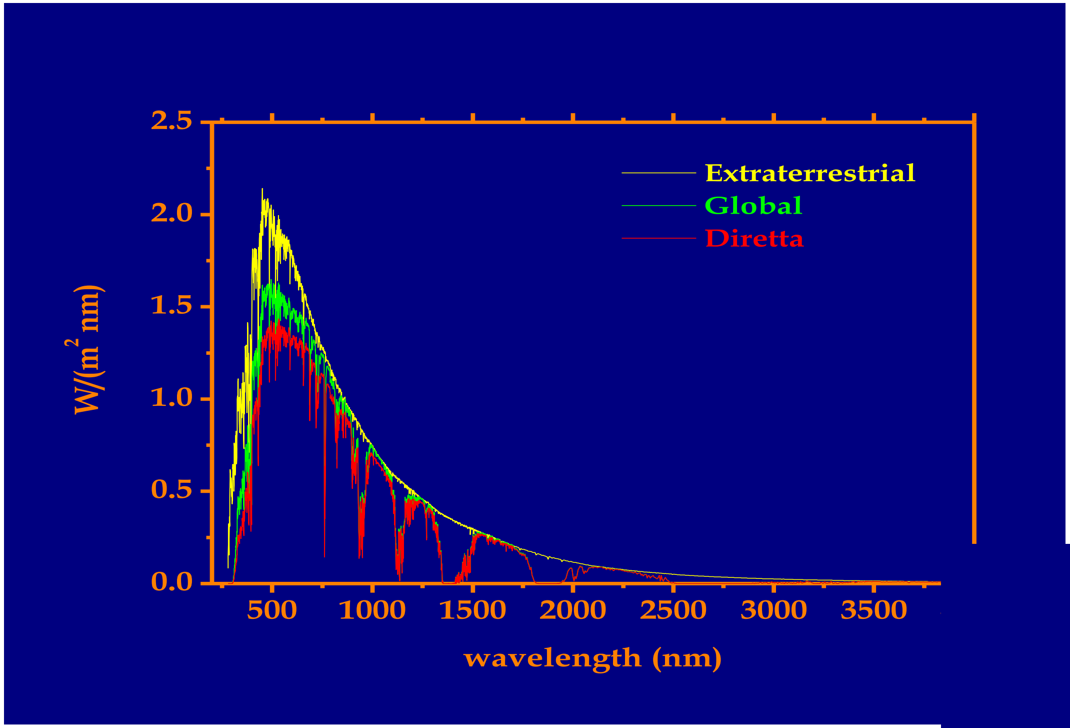
VITAL SIGNS OF THE PLANET
EO-1
GRACE
OCO-2
Terra
OSTM
M-Cubed 2
Aqua
QuikSCAT
Landsat 7
SMAP
SORCE
Suomi NPP
Aqua
Aura
Calipso
CloudSat
GPM
OCO-2
QuikSCAT
SORCE
Suomi NPP
TRMM
ATMOSPHERE
Aquarius
OSTM
SEA
EO1
GRACE
LandSat-7
LandSat-8
SMAP
Terra
LAND
GRIFEX
IPEX
M-Cubed 2
Future Missions

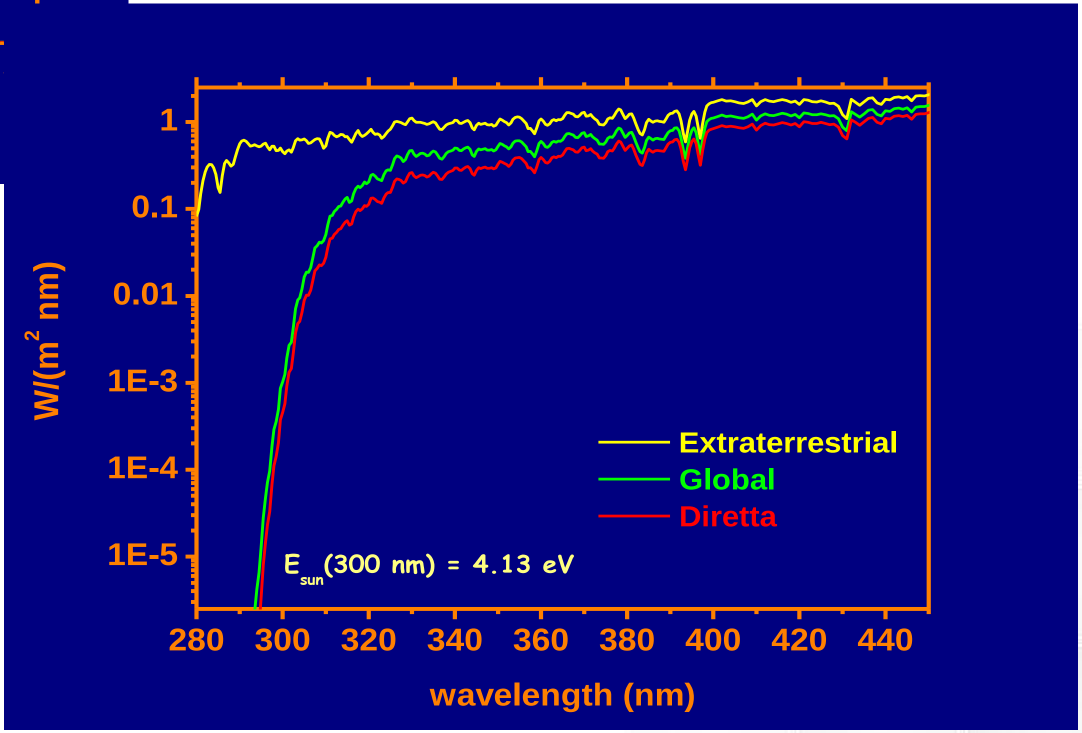
Aura mission

The Aura spacecraft provides the essential services for operating the four scientific instruments over the life of the mission. The spacecraft, based on the EOS Common Spacecraft design, was built by Northrop Gurmman Space Technology and adapted for the Aura instrument payload. EOS Aura's Instruments, HIRDLS, MLS, OMI, and TES, contain advanced technologies that have been developed for use on environmental satellites. Polar Orbit, 705 km high, 13 orbits per day.

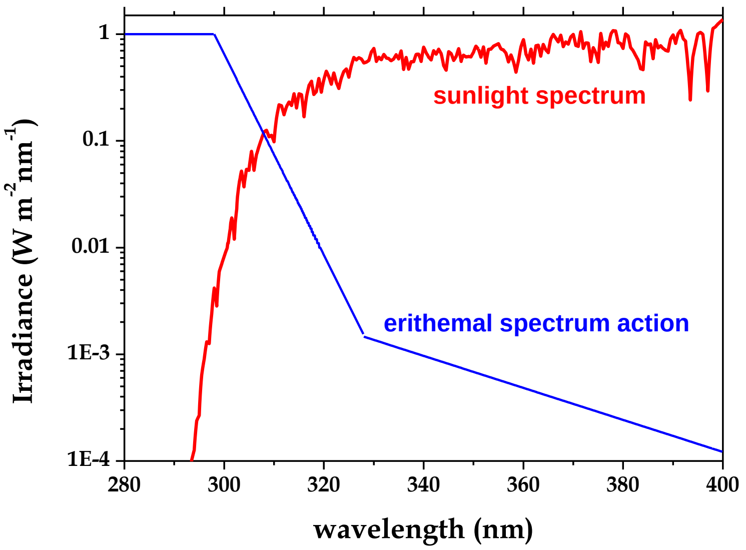


Solar spectra

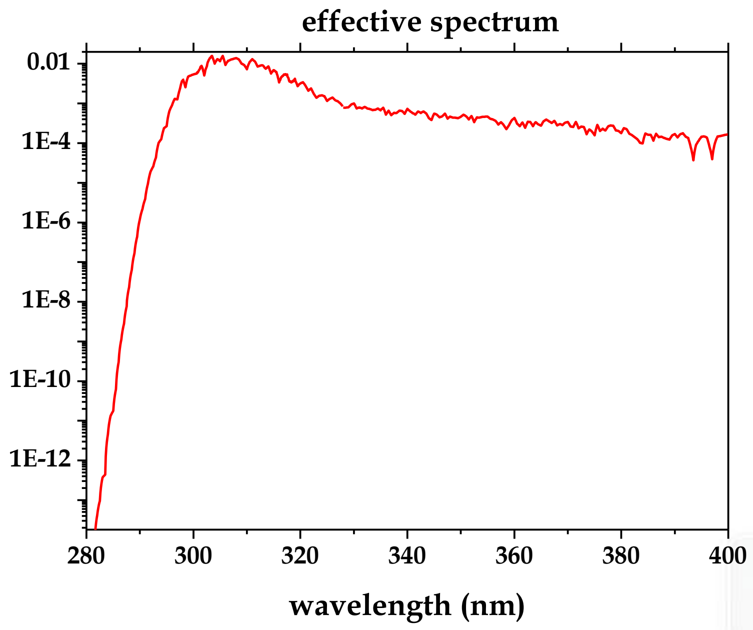




UV index



Irradiance (W m^-2 nm^-1)
1
0.1
0.01
1E-3
1E-4
280
300
320
340
360
380
400
wavelength (nm)
sunlight spectrum
erithemal spectrum action



effective spectrum
0.01
1E-4
1E-6
1E-8
1E-10
1E-12
280
300
320
340
360
380
400
wavelength (nm)

UV index

The Global Solar UV Index (UVI) described in this document was developed in an international effort by WHO in collaboration with WMO, UNEP and ICNIRP, and is a simple measure of the UV radiation level at the Earth's surface.

$$UV_0 = k_{UVI} \int_{250}^{298} IRR_{FRAD}(\lambda) \cdot E_0(\lambda) \cdot d\lambda$$

$E_0(\lambda) = 1$ when $250\ nm < \lambda < 298\ nm$,

$E_1(\lambda) = 10^{0.094(298-\lambda)}$ when $298\ nm < \lambda < 328\ nm$

$E_2(\lambda) = 10^{0.015(139-\lambda)}$ when $328\ nm < \lambda < 400\ nm$

$k_{UVI} = 40\ m^2\ watt^{-1}$

$$UV_1 = k_{UVI} \int_{298}^{328} IRR_{FRAD}(\lambda) \cdot E_1(\lambda) \cdot d\lambda$$

$$UV_2 = k_{UVI} \int_{328}^{400} IRR_{FRAD}(\lambda) \cdot E_2(\lambda) \cdot d\lambda$$

$$UV_{index} = UV_0 + UV_1 + UV_2$$

UV index

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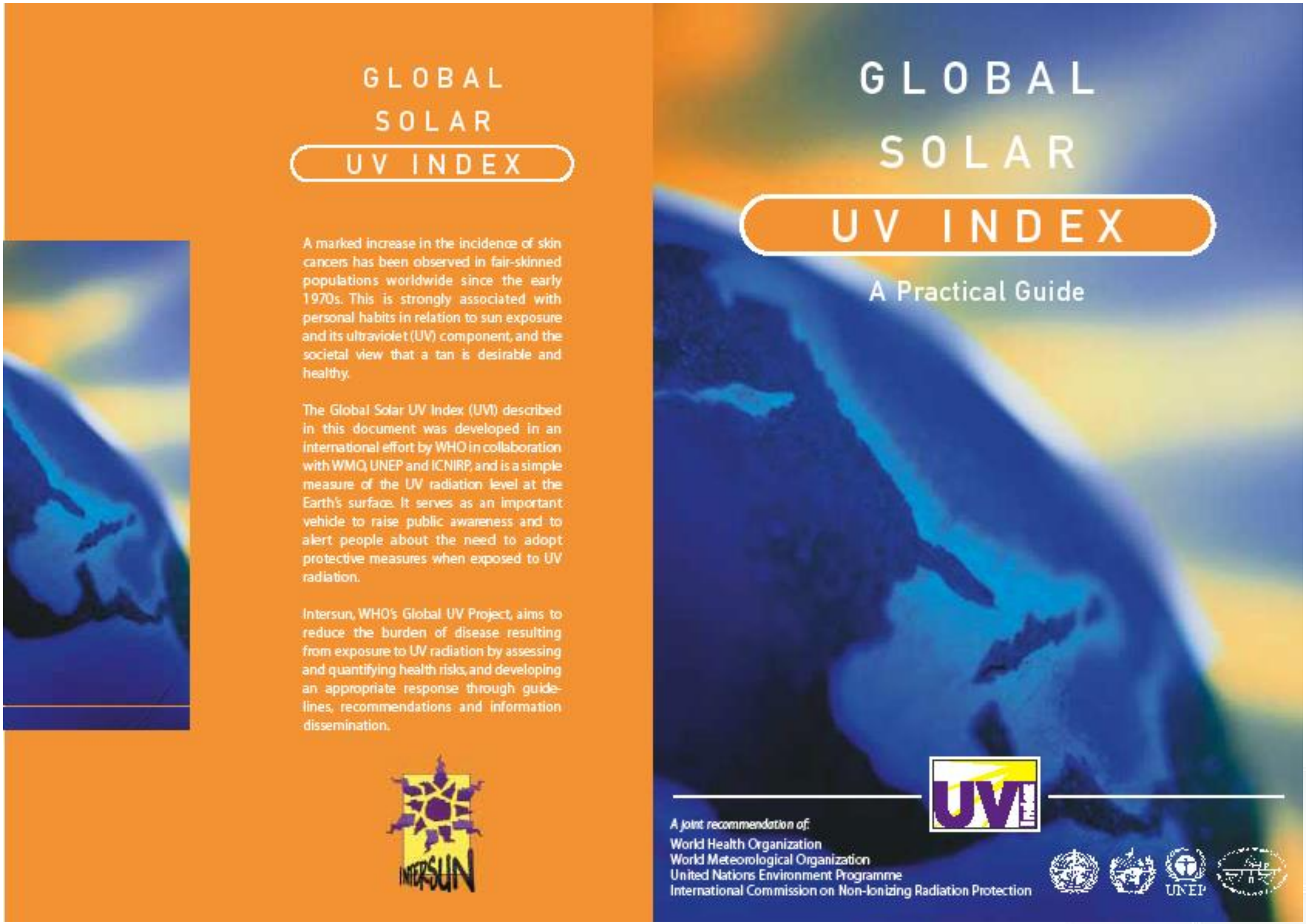


GLOBAL SOLAR UV INDEX

A marked increase in the incidence of skin cancers has been observed in fair-skinned populations worldwide since the early 1970s. This is strongly associated with personal habits in relation to sun exposure and its ultraviolet (UV) component, and the societal view that a tan is desirable and healthy.

The Global Solar UV Index (UVI) described in this document was developed in an international effort by WHO in collaboration with WMO, UNEP and ICNIRP, and is a simple measure of the UV radiation level at the Earth's surface. It serves as an important vehicle to raise public awareness and to alert people about the need to adopt protective measures when exposed to UV radiation.

Intersun, WHO's Global UV Project, aims to reduce the burden of disease resulting from exposure to UV radiation by assessing and quantifying health risks, and developing an appropriate response through guidelines, recommendations and information dissemination.

INTERSUN

GLOBAL SOLAR UV INDEX

A Practical Guide

UV Index

A joint recommendation of:
World Health Organization
World Meteorological Organization
United Nations Environment Programme
International Commission on Non-Ionizing Radiation Protection

UNEP

UV RADIATION LEVELS ARE INFLUENCED BY:

SUN ELEVATION

The higher the sun in the sky, the higher the UV radiation level. Thus UV radiation levels vary with time of day and time of year. Outside the tropics, the highest levels occur when the sun is at its maximum elevation, at around midday (solar noon) during the summer months.

LATITUDE

The closer to equatorial regions, the higher the UV radiation levels.

CLOUD COVER

UV radiation levels are highest under cloudless skies but even with cloud cover, UV radiation levels can be high. Scattering can have the same effect as the reflectance by different surfaces and thus increase total UV radiation levels.

ALTITUDE

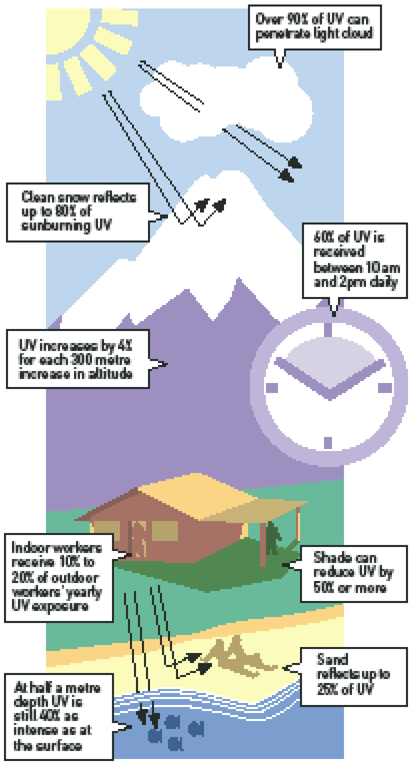
At higher altitudes, a thinner atmosphere absorbs less UV radiation. With every 1000 metres increase in altitude, UV radiation levels increase by 10% to 12%.

OZONE

Ozone absorbs some of the UV radiation that would otherwise reach the Earth's surface. Ozone levels vary over the year and even across the day.

GROUND REFLECTION

UV radiation is reflected or scattered to varying extents by different surfaces, e.g. fresh snow can reflect as much as 80% of UV radiation, dry beach sand about 15% and sea foam about 25%.



Small amounts of UV radiation are beneficial for people and essential in the production of vitamin D. UV radiation is also used to treat several diseases, including rickets, psoriasis and eczema. This takes place under medical supervision and the benefits of treatment versus the risks of UV radiation exposure are a matter of clinical judgement.

Prolonged human exposure to solar UV radiation may result in acute and chronic health effects on the skin, eye and immune system. Sunburn and tanning are the best known acute effects of excessive UV radiation exposure; in the long term, UV radiation-induced degenerative changes in cells, fibrous tissue and blood vessels lead to premature skin ageing. UV radiation can also cause inflammatory reactions of the eye, such as photokeratitis.

Chronic effects include two major public health problems: skin cancers and cataracts. Between two and three million non-melanoma skin cancers and approximately 132000 melanoma skin cancers occur globally each year. While non-melanoma skin cancers can be surgically removed and are rarely lethal, malignant melanoma substantially contributes to mortality rates in fair-skinned populations. Some 12 to 15 million people are blind from cataracts. According to WHO estimates, up to 20% of these cases of blindness may be caused or enhanced by sun exposure, especially in India, Pakistan and other countries of the "cataract belt" close to the equator.

Furthermore, a growing body of evidence suggests that environmental levels of UV radiation may enhance the risk of infectious diseases and limit the efficacy of vaccinations. Please see Annex A for a detailed description of the health effects of exposure to UV radiation.

People's behaviour in the sun is considered to be a major cause for the rise in skin cancer rates in recent decades. An increase in popular outdoor activities and changed sunbathing habits often result in excessive exposure to UV radiation. Many people consider intensive sunbathing to be normal; unfortunately, even children, adolescents and their parents perceive a suntan as a symbol of attractiveness and good health.

Sun protection programmes are urgently needed to raise awareness of the health hazards of UV radiation, and to achieve changes in lifestyle that will arrest the trend towards more and more skin cancers. Beyond the health benefits, effective education programmes can strengthen national economies by reducing the financial burden to health care systems caused by skin cancer and cataract treatments. Billions are spent worldwide to treat these diseases, many of which could have been prevented or delayed. The Global Solar UV Index should be an important element of an integrated and long-term public health approach to sun protection.

THE BASIC SUN PROTECTION MESSAGES

- ***Limit exposure during midday hours.***
- ***Seek shade.***
- ***Wear protective clothing.***
- ***Wear a broad-brimmed hat to protect the eyes, face and neck.***
- ***Protect the eyes with wrap-around-design sunglasses or sunglasses with side panels.***
- ***Use and reapply broad-spectrum sunscreen of sun protection factor (SPF)15+ liberally***
- ***Avoid tanning beds.***
- ***Protect babies and young children: this is particularly important.***

Shade, clothing and hats provide the best protection – apply sunscreen to parts of the body that remain exposed, like the face and hands. Sunscreen should never be used to prolong the duration of sun exposure.

Two different concepts of sun protection have been proposed: a binary response with a defined threshold UVI value beyond which sun protection is recommended, or a graded response with increasing UVI values that would involve the successive use of different sun-protective measures. There is little scientific basis to support the latter: if sun protection is required, this should include all protective means, i.e. clothing, sunglasses, shade and sunscreen (*Figure 1*). Nevertheless, a graded approach is relevant in the sense that more sun protection is needed at higher UV radiation levels.

Even for very sensitive fair-skinned people, the risk of short-term and long-term UV radiation damage below a UVI of 3 is limited, and under normal circumstances no protective measures are needed. Above the threshold value of 3, protection is necessary, and this message should be reinforced at UVI values of 8 and above.

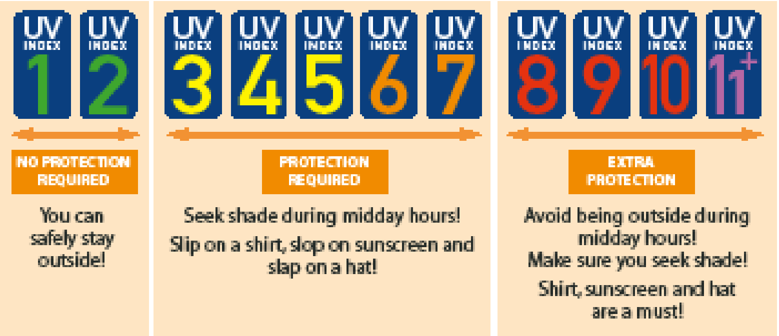


Figure 2: Recommended sun protection scheme with simple "sound bite" messages

GRAPHIC PRESENTATION OF THE UVI

A standard graphic presentation of the UVI promotes consistency in UVI reporting on news and weather bulletins, and serves to improve people's understanding of the UVI concept. Ready-made materials for UVI reporting facilitate successful media uptake, and more than one option is given to allow different media to cope with technical limitations. The graphics package (see Annex D) can be downloaded from the website of WHO's Global UV Project Intersun http://www.who.int/uv/ and includes the UVI logo, icons for UVI reporting, sun protection icons, and colour codes for different values of the UVI.

Figure 3: Examples of UVI graphics

Sun Protection Messages

CREATING VARIETY

ADDITIONAL SUNSMART MESSAGES

The basic scheme for UVI reporting and sun protection can be varied and expanded through the use of additional messages at the national or local level. Messages on suntanning, sun protection and people's inability to perceive UV radiation underlie the basic message and can be used in all settings.

Environment-based, activity-based or risk group-based messages can be geared specifically to local weather conditions, or the particular environmental or societal situation of a given country. Annex E lists examples of such additional sun protection messages adapted from Australia, Canada and France.

Figure 4: Children require special protection

Targeted groups must include children and young people *(Figure 3)*, since frequent UV radiation exposure and a history of sunburn during childhood and adolescence is an important risk factor for skin cancer, especially for potentially lethal malignant melanoma. Additional messages can also be used to correct common misconceptions about UV radiation and its effects on human health *(Table 3)*.

FALSE	TRUE
A suntan is healthy.	A tan results from your body defending itself against further damage from UV radiation.
A tan protects you from the sun.	A dark tan on white skin offers only limited protection equivalent to an SPF of about 4.
You can't get sunburnt on a cloudy day.	Up to 80% of solar UV radiation can penetrate light cloud cover. Haze in the atmosphere can even increase UV radiation exposure.
You can't get sunburnt while in the water.	Water offers only minimal protection from UV radiation, and reflections from water can enhance your UV radiation exposure.
UV radiation during the winter is not dangerous.	UV radiation is generally lower during the winter months, but snow reflection can double your overall exposure, especially at high altitude. Pay particular attention in early spring when temperatures are low but the sun's rays are unexpectedly strong.
Sunscreens protect me so I can sunbathe much longer.	Sunscreens should not be used to increase sun exposure time but to increase protection during unavoidable exposure. The protection they afford depends critically on their correct application.
If you take regular breaks during sunbathing you won't get sunburnt.	UV radiation exposure is cumulative during the day.
If you don't feel the hot rays of the sun you won't get sunburnt.	Sunburn is caused by UV radiation which cannot be felt. The heating effect is caused by the sun's infrared radiation and not by UV radiation.

Table 3: UV radiation danger: Facts and fiction

USING COLOUR TO INCREASE VARIABILITY

Specific colours should be used for presenting the solar UVI. These do not have a scientific basis but are a means of making the presentation of the UVI more appealing. The colour coding facilitates variation between geographic areas of high and low UV radiation levels, and a basic colour is defined for each category *(Table 4; see also Annex D)*.

Low (1,2)	Moderate (3,4,5)	High (6,7)	Very high (8,9,10)	Extreme (11+)
Green PMS 375	Yellow PMS 102	Orange PMS 151	Red PMS 032	Purple PMS 265

Table 4: Presenting the UVI: International colour codes[1]

The colour within categories can be graded to allow for variation at the national level where values often remain within one category throughout the summer months (see Annex D).

Not all media will be able to integrate the variation in colour into their presentation. Television media generally use standardized maps and changing the colours may not be feasible due to technical limitations. Similarly, black and white print media will not be able to use the recommended colour scheme.

EMPHASIZING DANGEROUS HOURS

In countries where UV radiation levels are high and where knowledge about UV radiation and sun protection in the population is widespread, a further concept may be applied to increase variability. This was introduced in Australia in 2000.

The approach focuses on the hours of the day during which the UVI is above a given threshold value *(Figure 5)*. While on one day the UVI may reach a value of above 3 for no more than 30 minutes, on another day it may remain above 3 for several hours. The advice to the public emphasizes the need to adopt sun-protective practices during these hours.

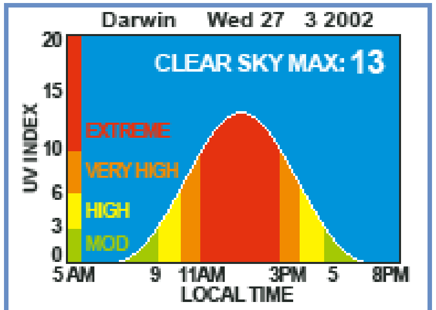
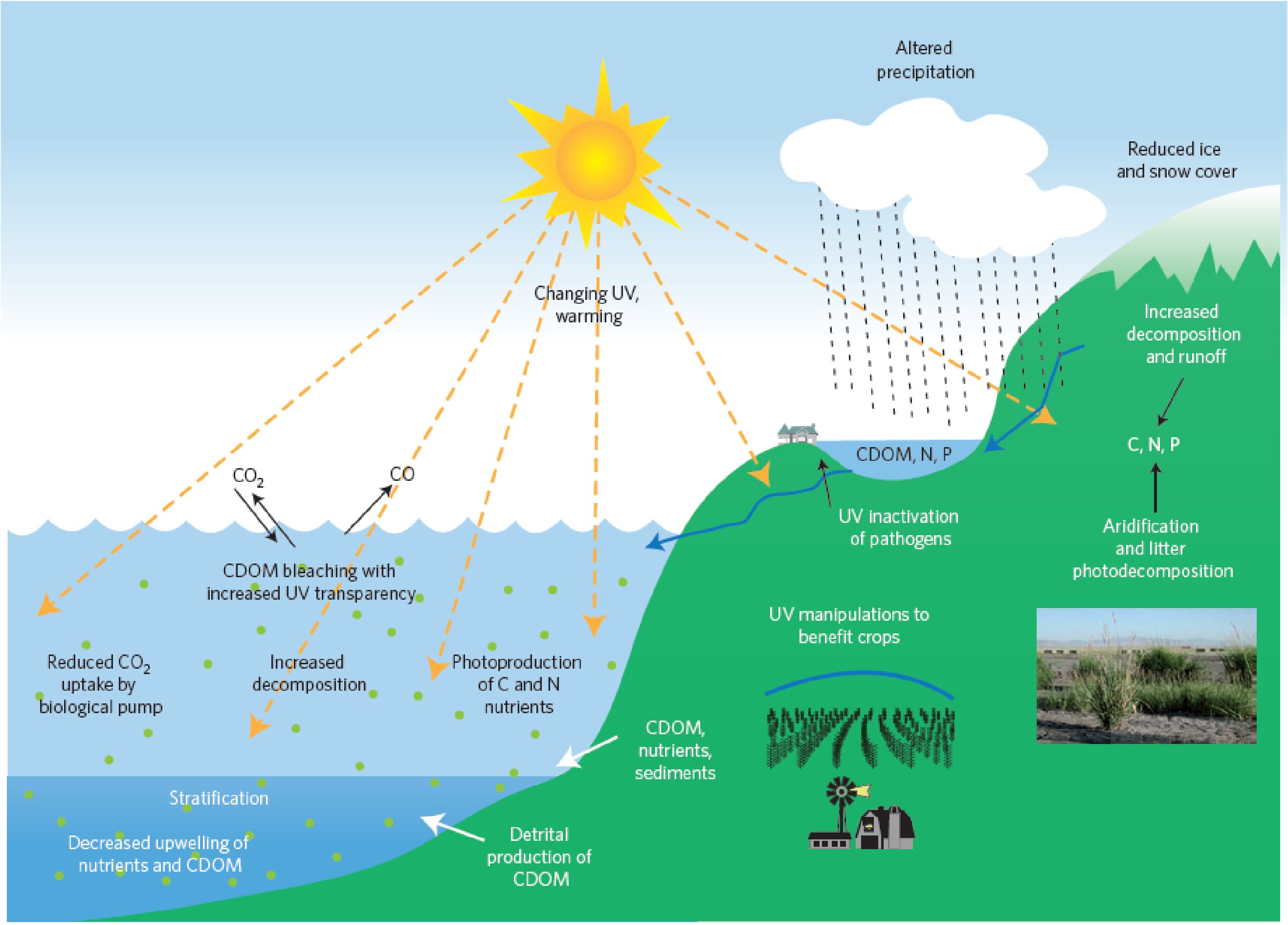


Figure 5: A graphic representing dangerous hours (Bureau of Meteorology, Australia)[2]

1 The eps graphic files, which are downloadable from the website of WHO's Global UV Project Intersun http://www.who.int/uv/, will reproduce satisfactorily in most cases, allowing the worldwide reproduction of a standardized colour scheme. Pantone Matching System (PMS) colour references may be used for minor colour correction.

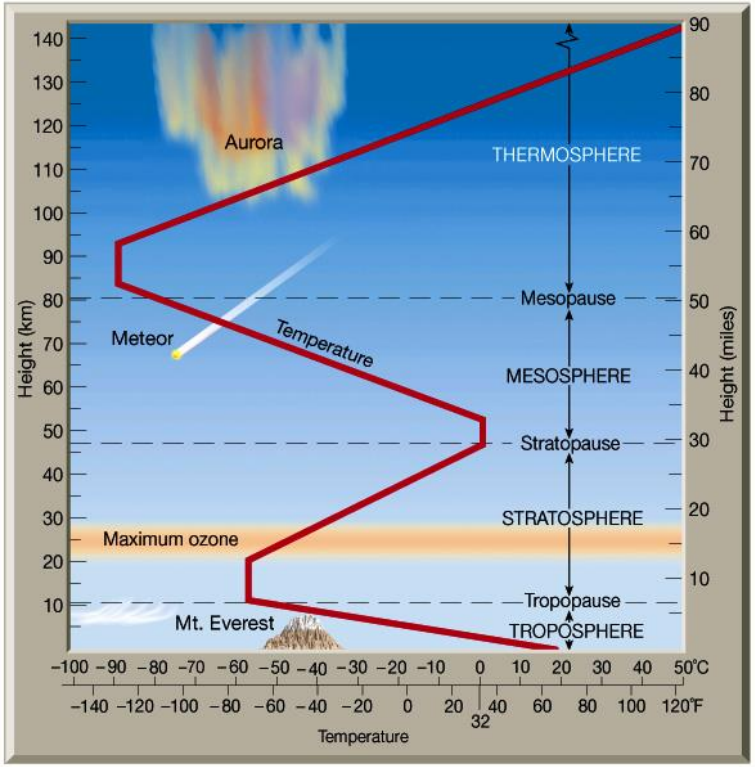
2 The colour scheme currently used by the Bureau of Meteorology, Australia does not comply with the international colour codes promoted in this publication.

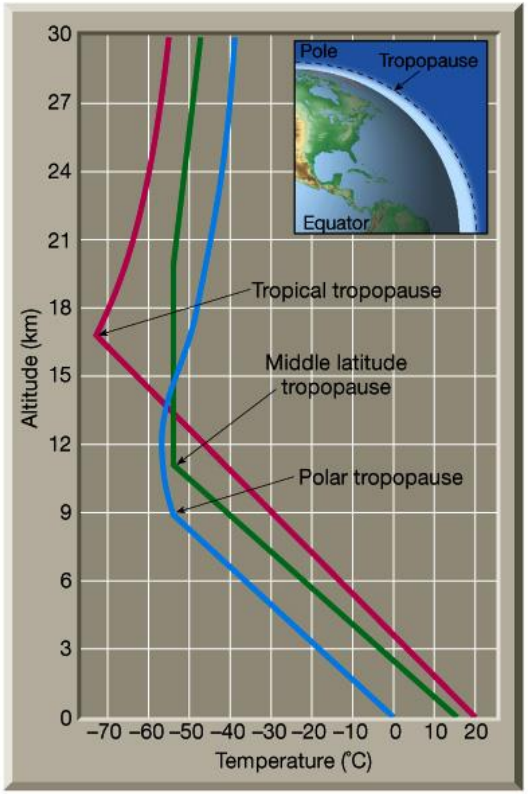
Influence between the ultraviolet radiation and climate change



Craig E. Williamson et al. Solar ultraviolet radiation in a changing climate, NATURE CLIMATE CHANGE, VOL 4 (2014) p 434.

Structure of the atmosphere





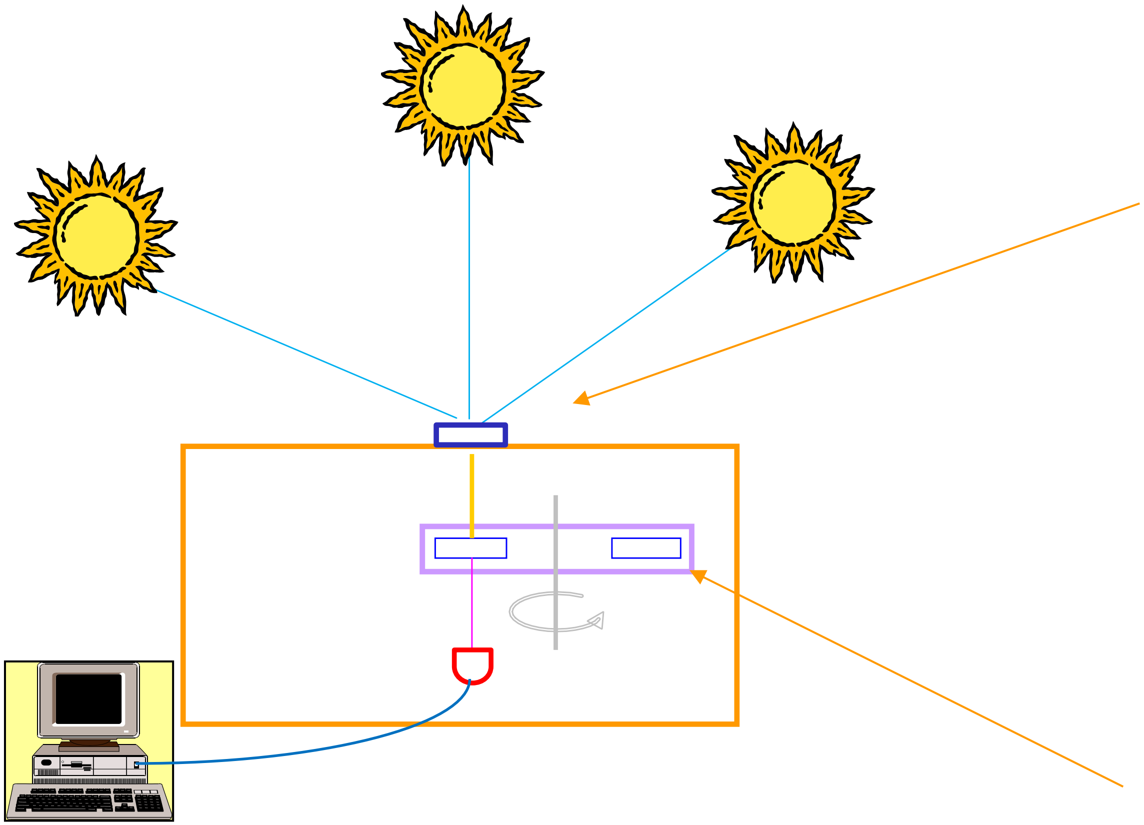
Ozone hole

Each year for the past few decades during the Southern Hemisphere spring, chemical reactions involving chlorine and bromine cause ozone in the southern polar region to be destroyed rapidly and severely. This depleted region is known as the 'ozone hole.'

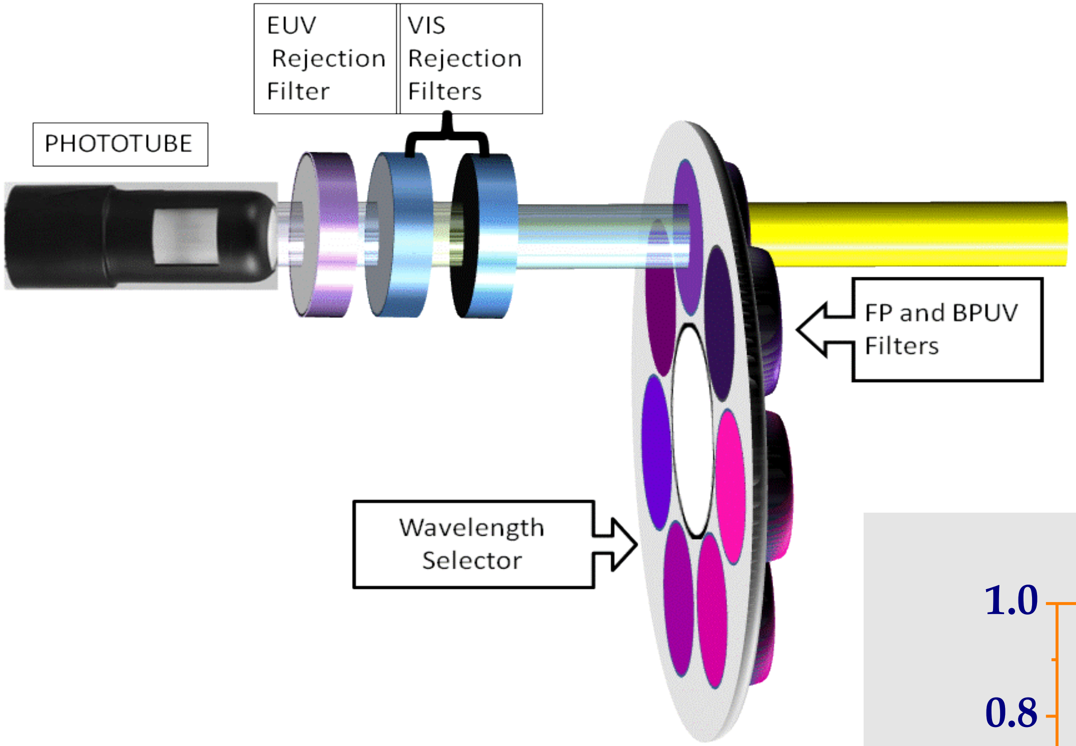
Ozone measurements from space: Aura

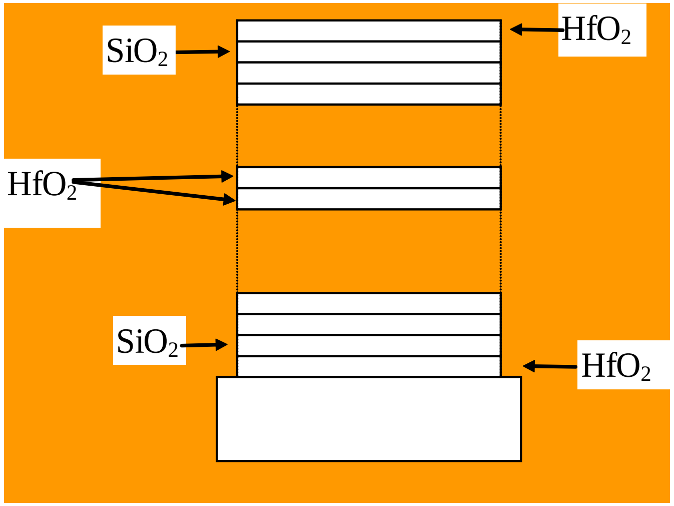
The Aura spacecraft provides the essential services for operating the four scientific instruments over the life of the mission. The spacecraft, based on the EOS Common Spacecraft design, was built by Northrop Gurmman Space Technology and adapted for the Aura instrument payload. EOS Aura's Instruments, HIRDLS, MLS, **OMI**, and **TES**, contain advanced technologies that have been developed for use on environmental satellites. Each instrument provides unique and complementary capabilities that will enable daily global observations of Earth's atmospheric ozone layer, air quality, and key climate parameters.

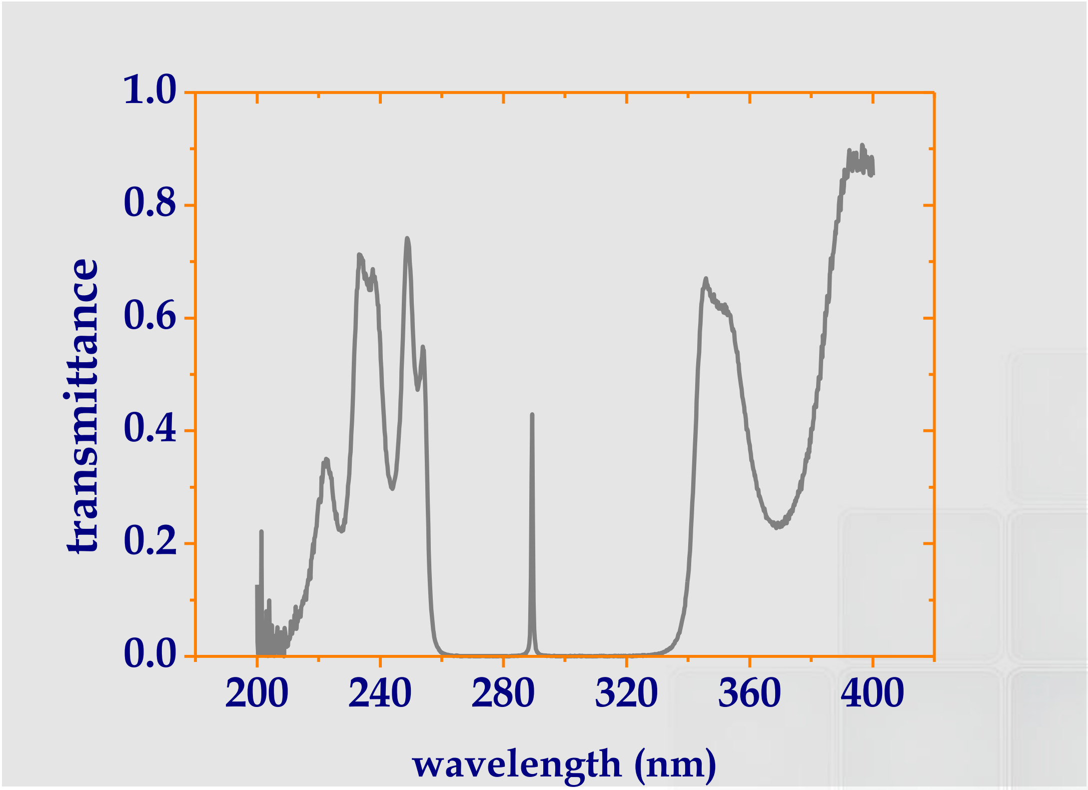
Multi-filter Radiometer

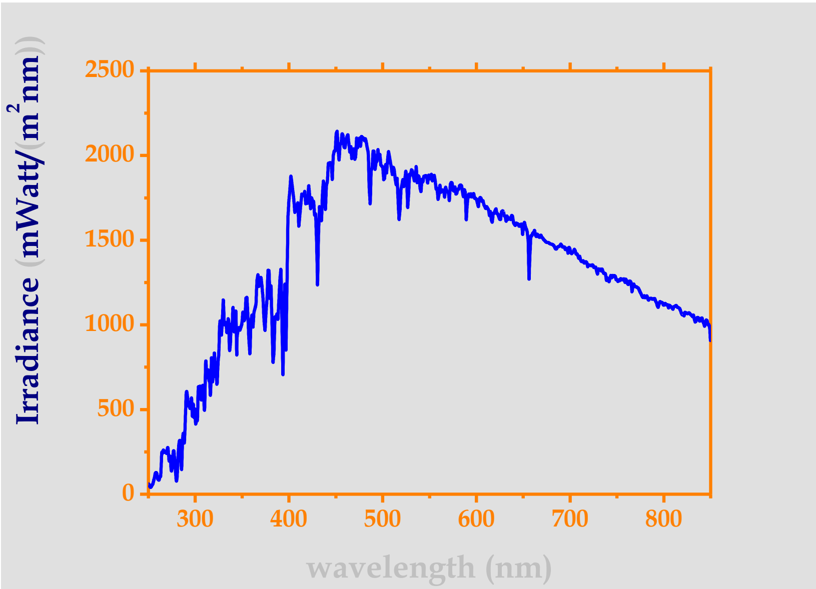


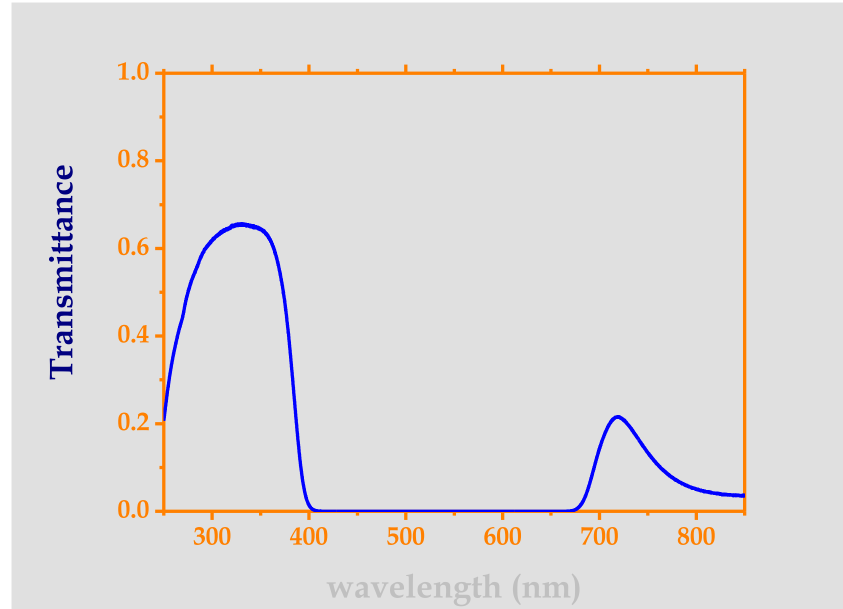
Narrow band filter radiometer

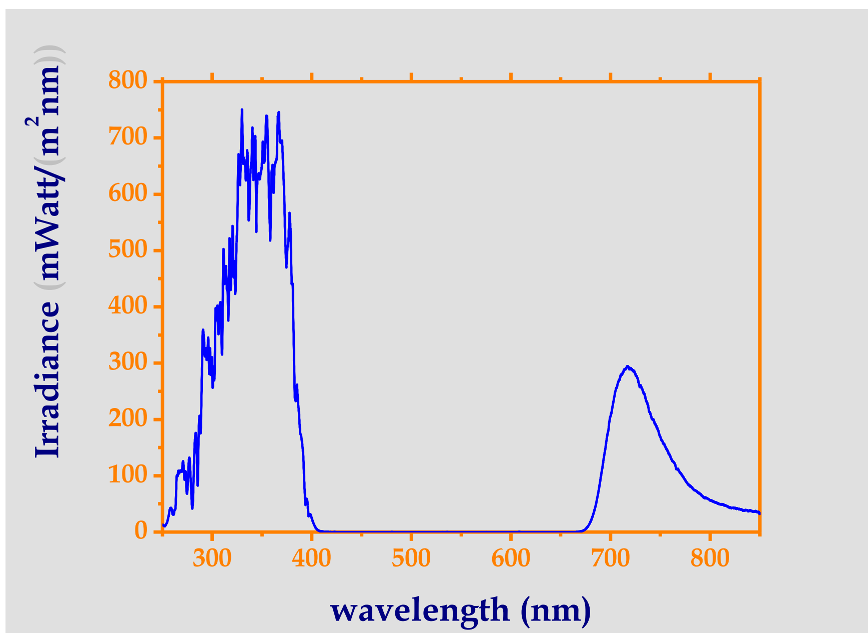


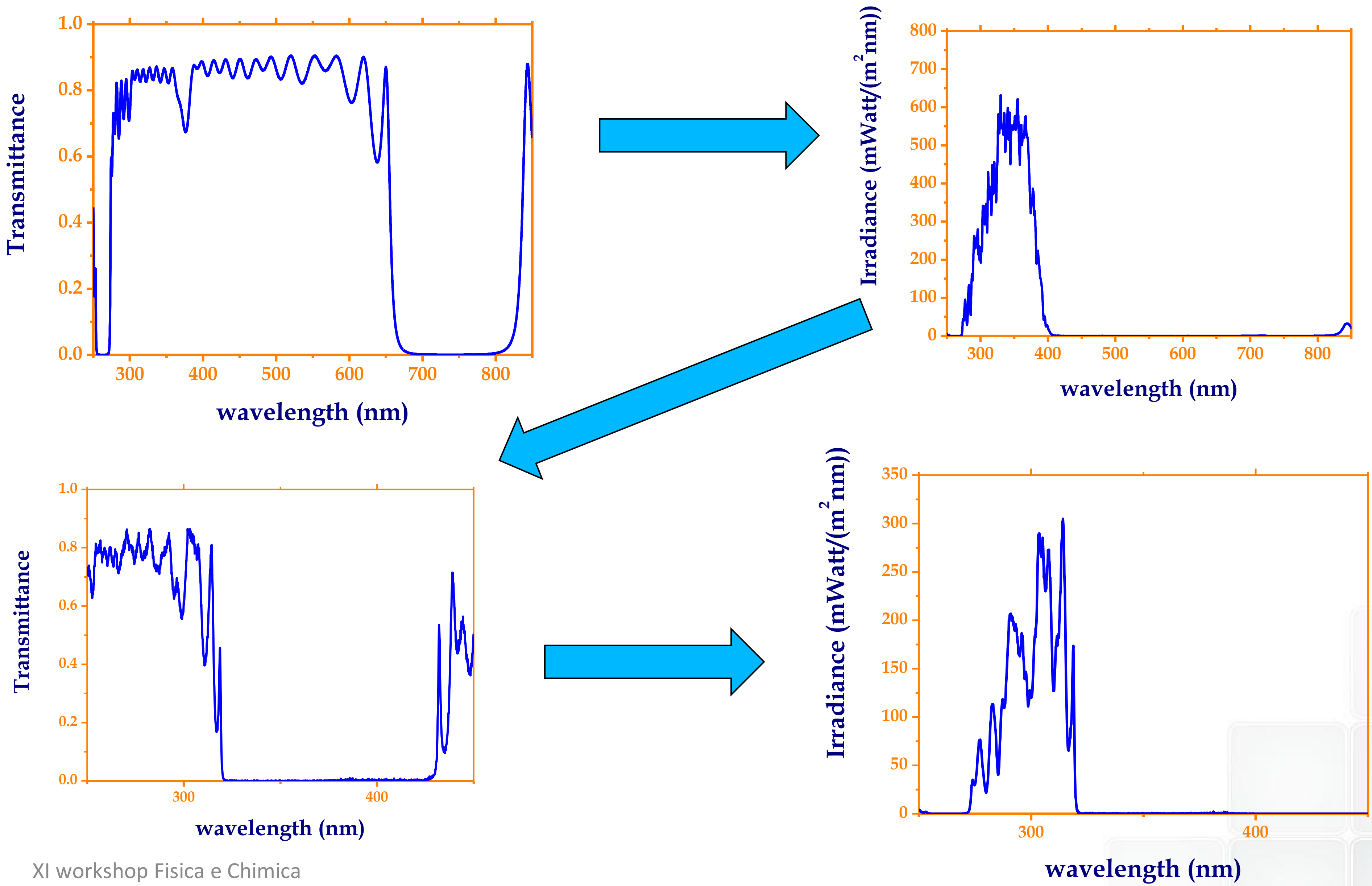


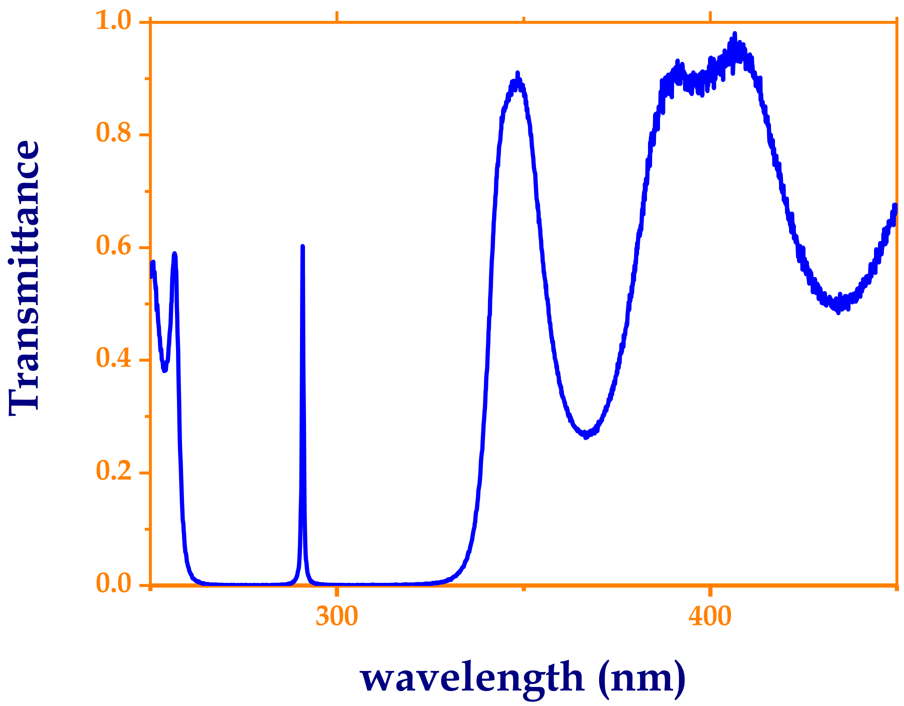



Irradiance (mWatt/(m2nm))
2500
2000
1500
1000
500
0
300
400
500
600
700
800
wavelength (nm)

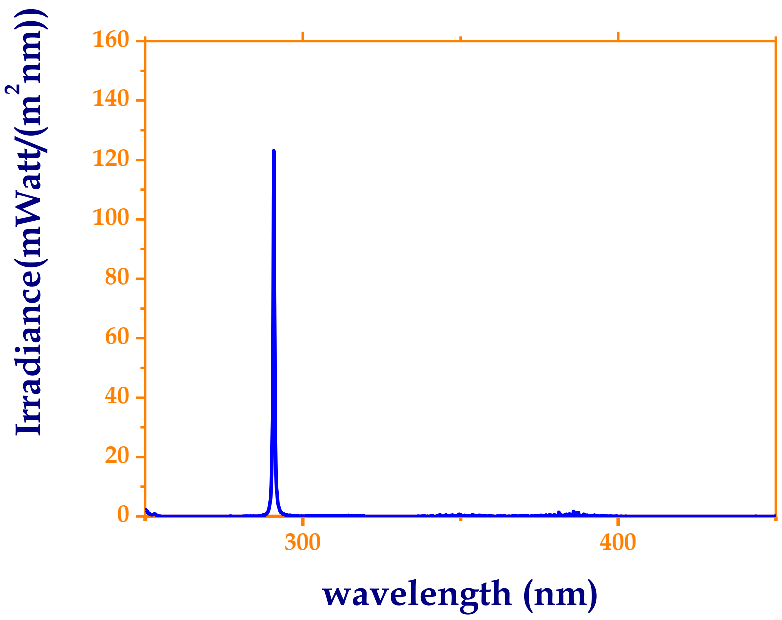

Transmittance
1.0
0.8
0.6
0.4
0.2
0.0
300
400
500
600
700
800
wavelength (nm)


Irradiance (mWatt/(m2nm))
800
700
600
500
400
300
200
100
0
300
400
500
600
700
800
wavelength (nm)


Transmittance
wavelength (nm)
Irradiance (mWatt/(m²nm))
wavelength (nm)
Transmittance
wavelength (nm)
Irradiance (mWatt/(m²nm))
wavelength (nm)

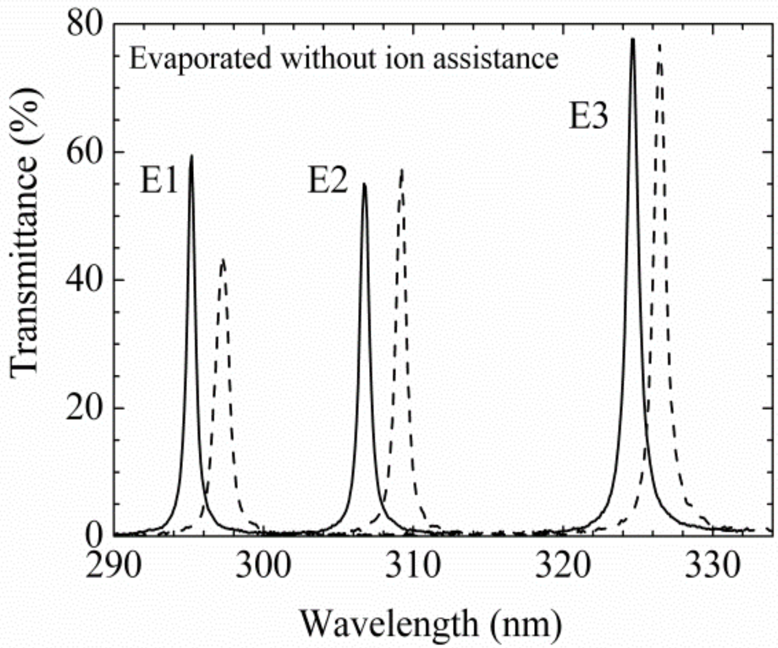


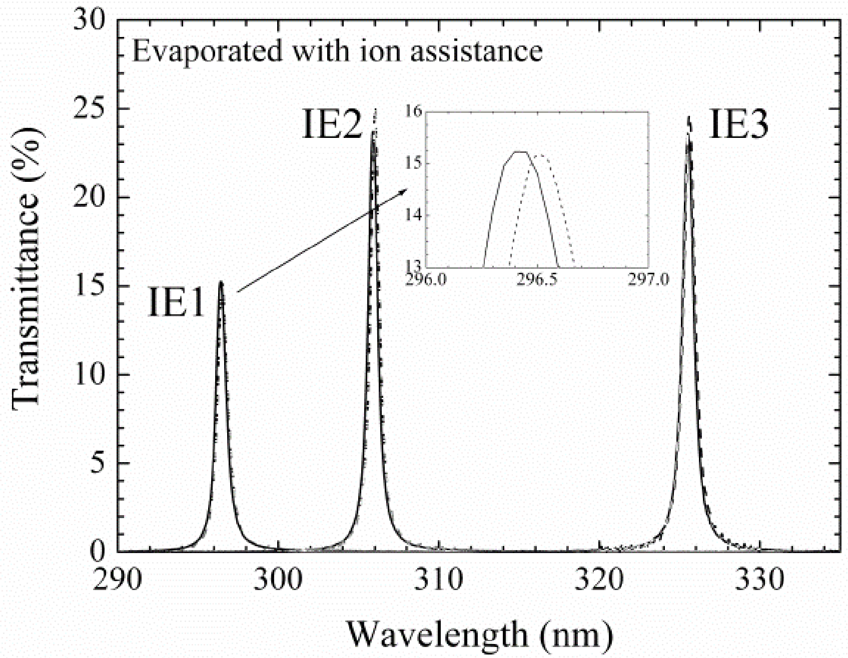
1.0
0.8
0.6
0.4
0.2
0.0
Transmittance
300
400
wavelength (nm)



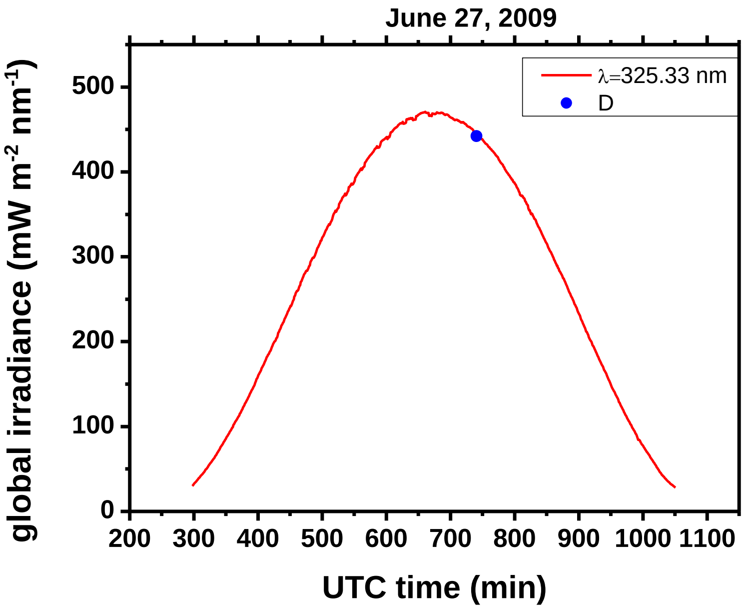
160
140
120
100
80
60
40
20
0
Irradiance(mWatt/(m2 nm))
300
400
wavelength (nm)

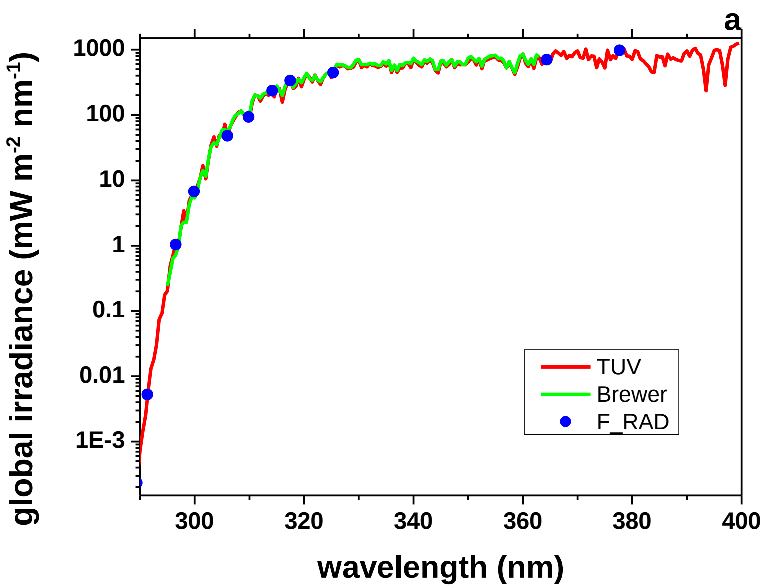
Optical stability

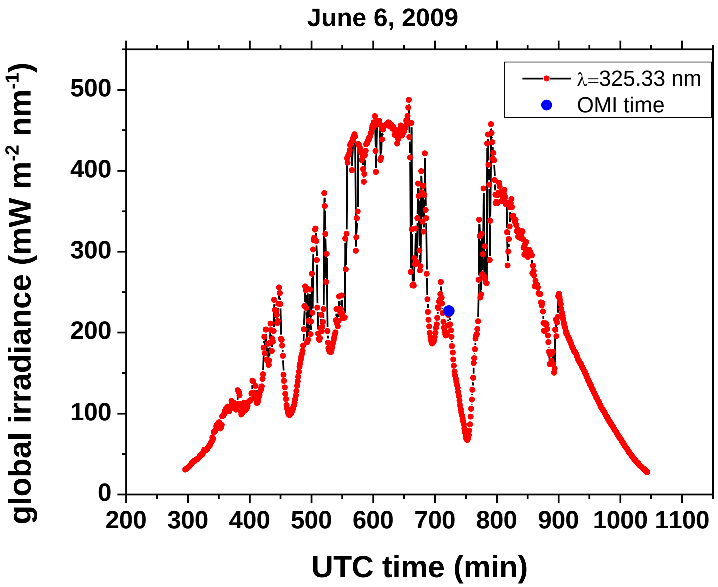


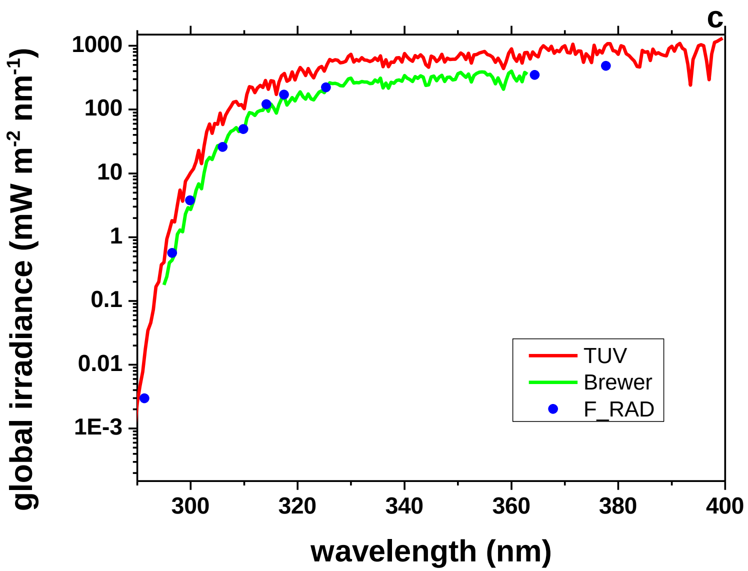


Lampedusa island (lat. 35° 31'N lon. 012° 38'E)

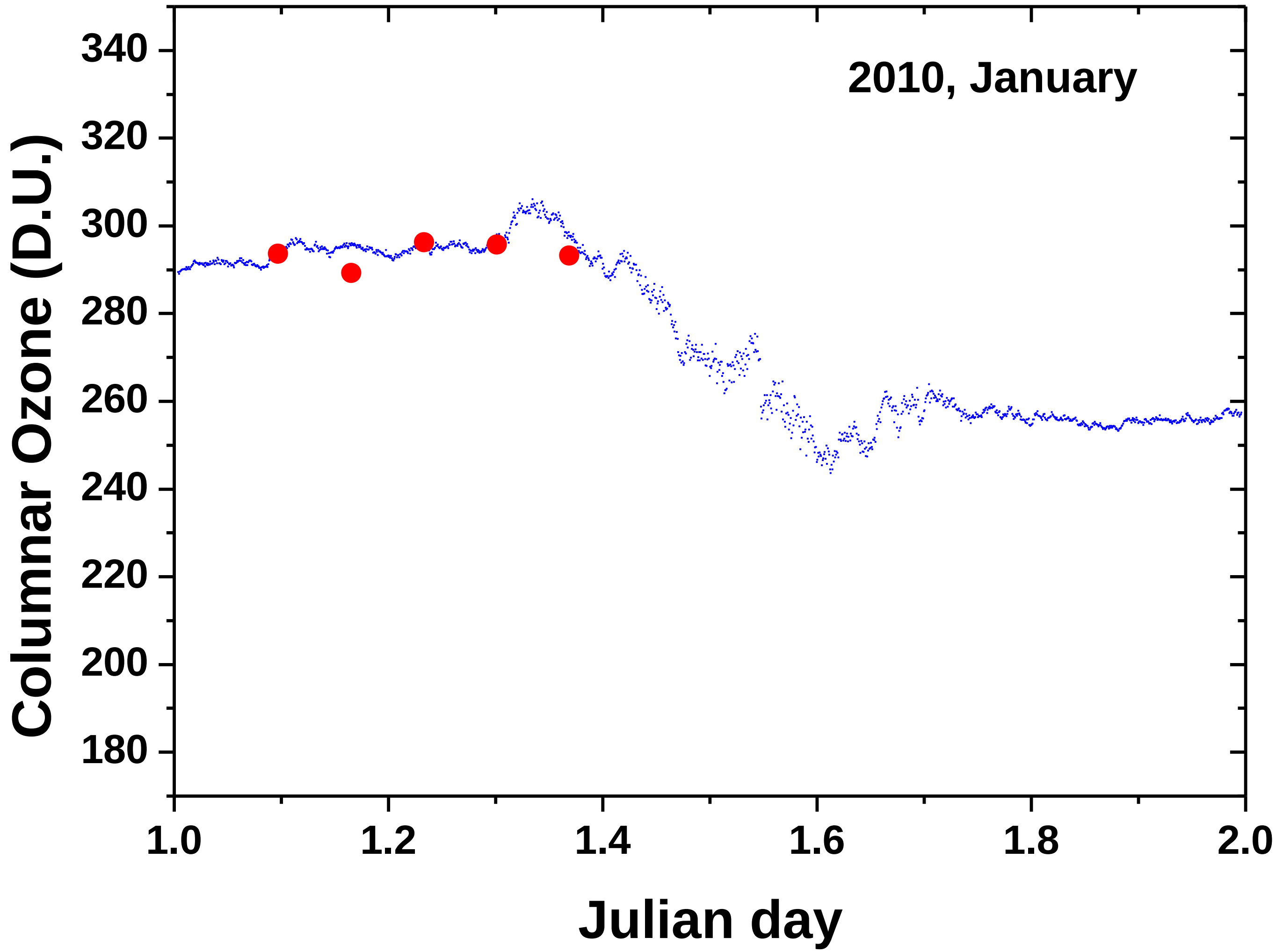








Ozone Content at MZS

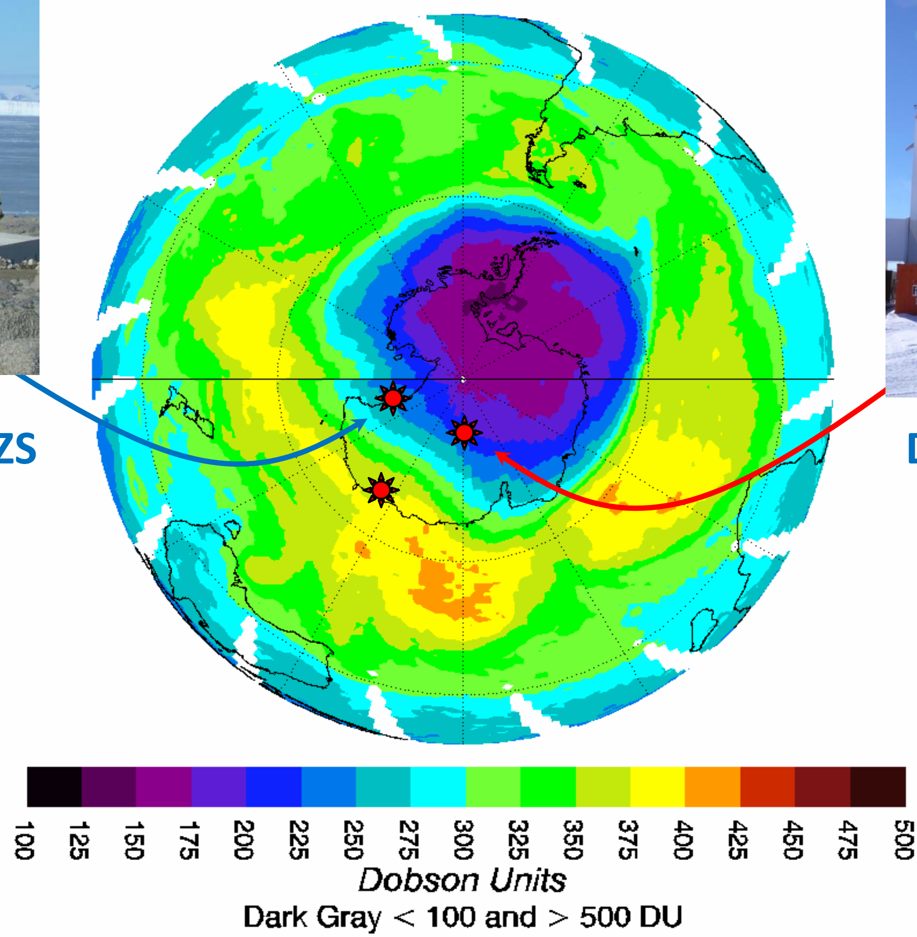


Antarctica

Evaluation of columnar ozone content by measuring direct and diffuse solar irradiance at MZS and Dome C by filter radiometers with high spectral and temporal resolution.

EP/TOMS Version 8 Total Ozone for Nov 3, 2005

Mario Zucchelli Station, MZS



Dome Concorde, Dome C

GSFC/613.3

Columnar ozone content

Comparison between the ozone measurements provided by "Ozone Monitoring Instrument” from NASA AURA satellite and the measurements carried out at a) Mario Zucchelli station (MZS) and b) Dome Concordia Station (Dome C).