The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

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2210-13

MedCLIVAR Workshop on: "Scenarios of Mediterranean Climate Change under Increased Radiative Active Gas Concentration and the Role of Aerosols

23 - 25 September 2010

Measurements of Mediterranean aerosol radiative forcing and the intense Saharan dust event of March 25-26, 2010, at Lampedusa

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Measurements of Mediterranean aerosol radiative forcing and the intense Saharan dust event of March 25-26, 2010, at Lampedusa

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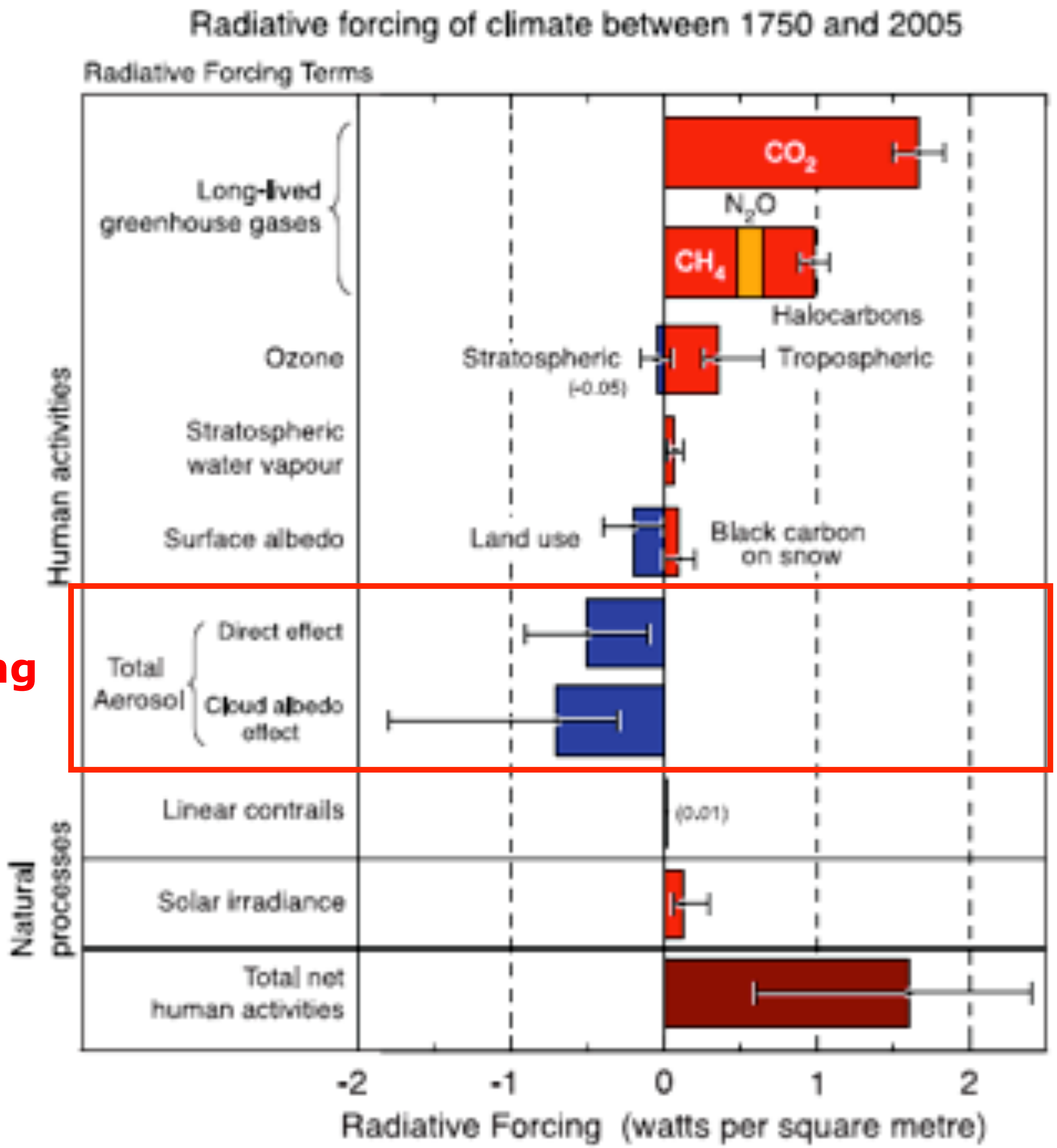
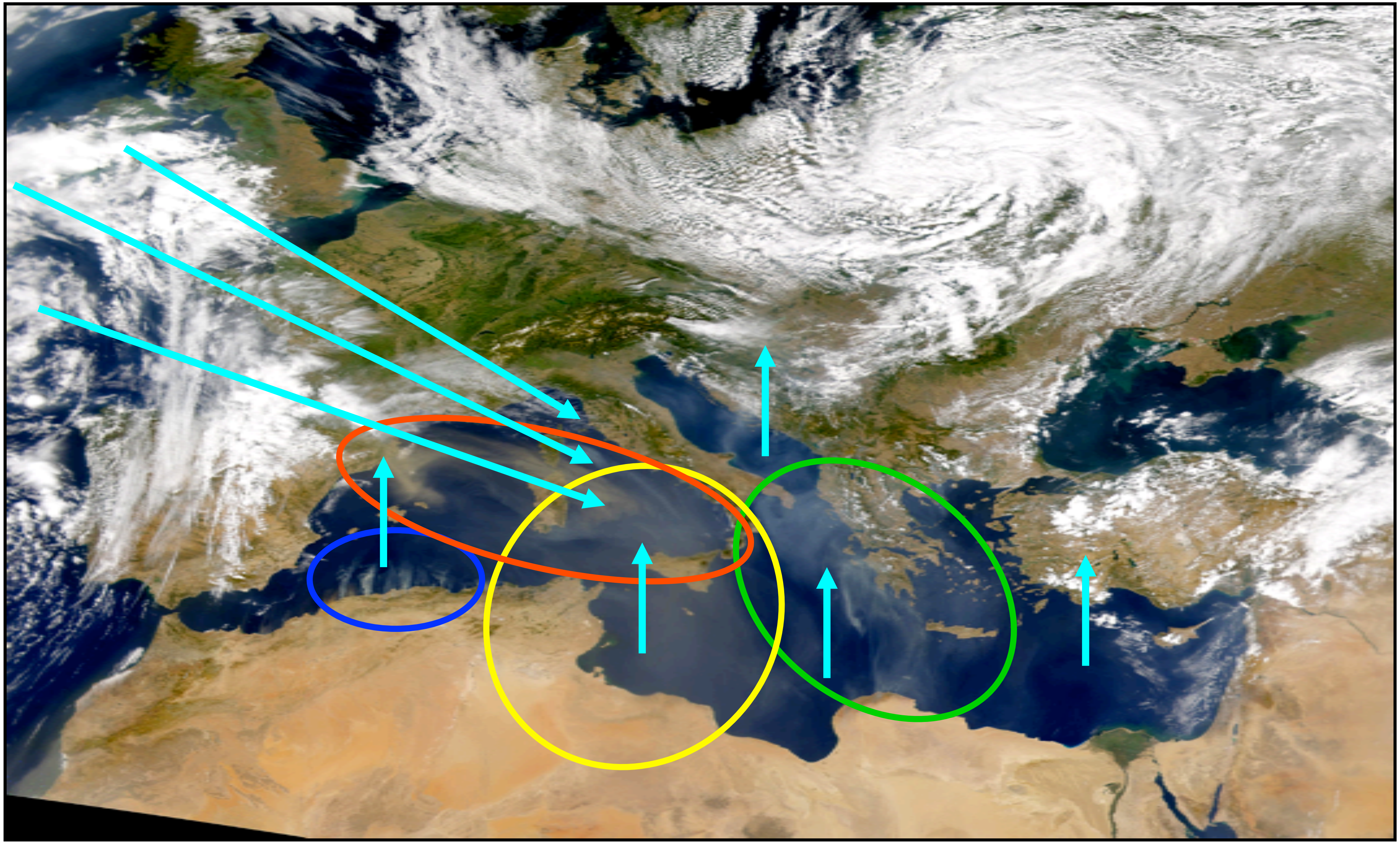
MedCLIVAR Workshop on Scenarios of Mediterranean Climate Change, Trieste 23-25 September 2010

IPCC 2007



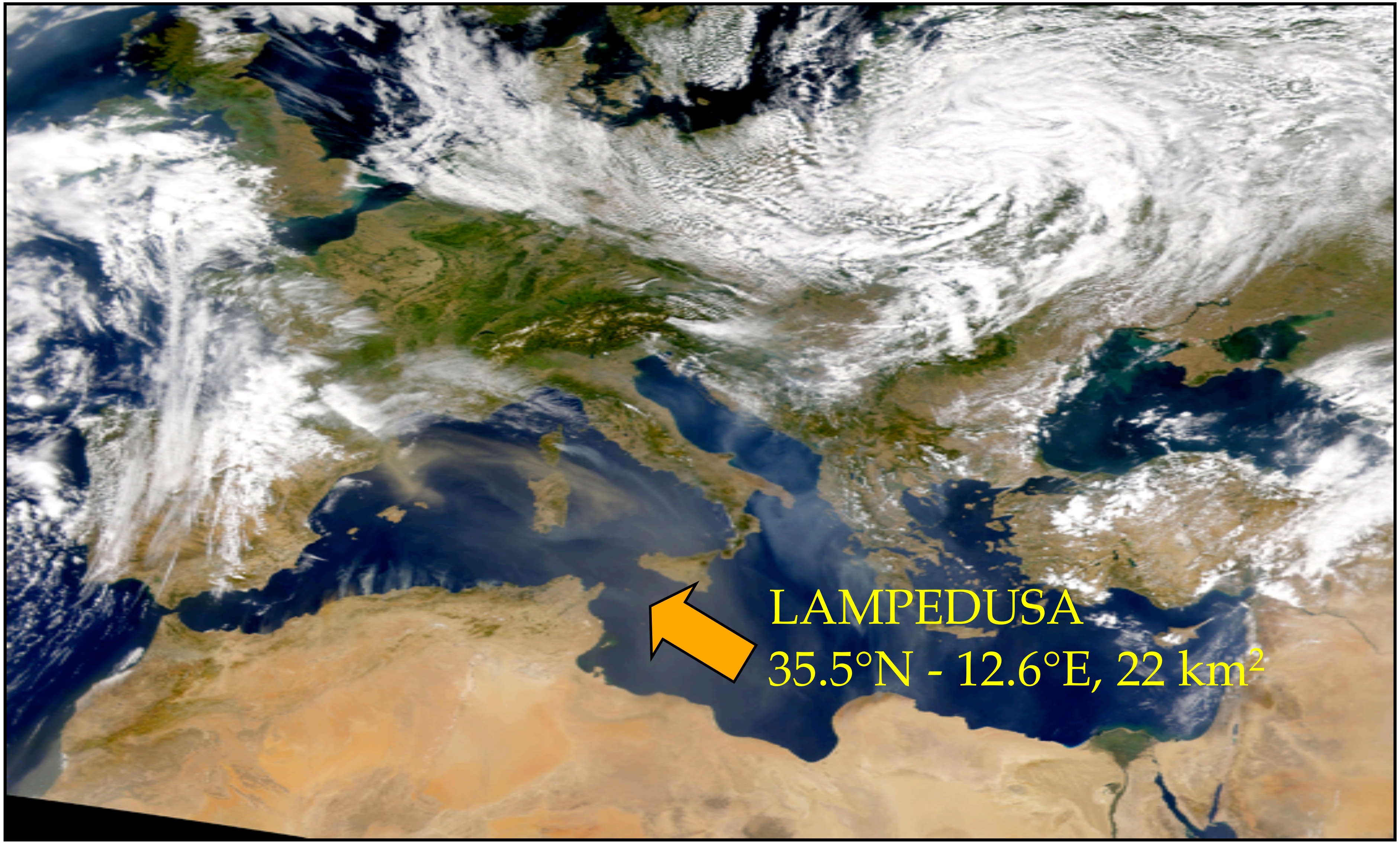
Aerosol radiative forcing

Aerosols in the Mediterranean region



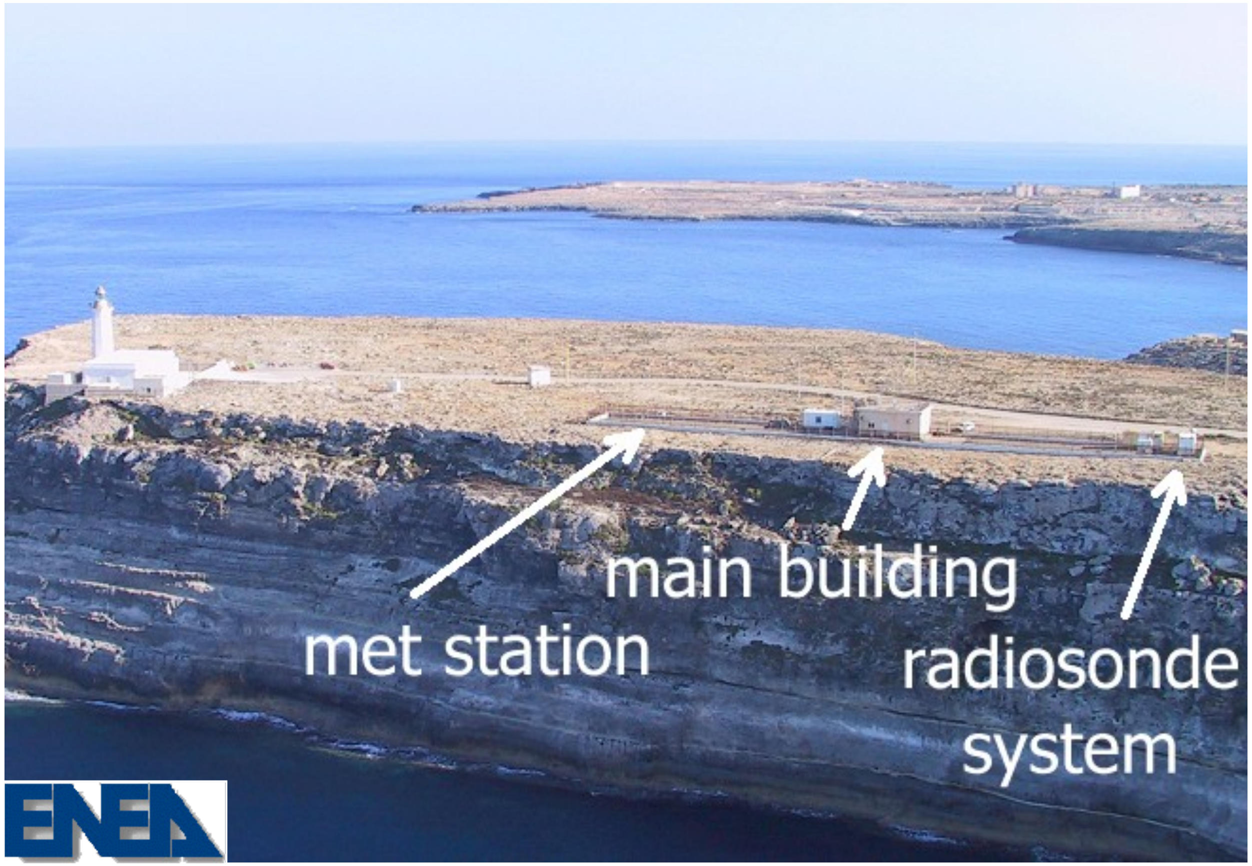
25/08/2005 (SeaWIFS Image)

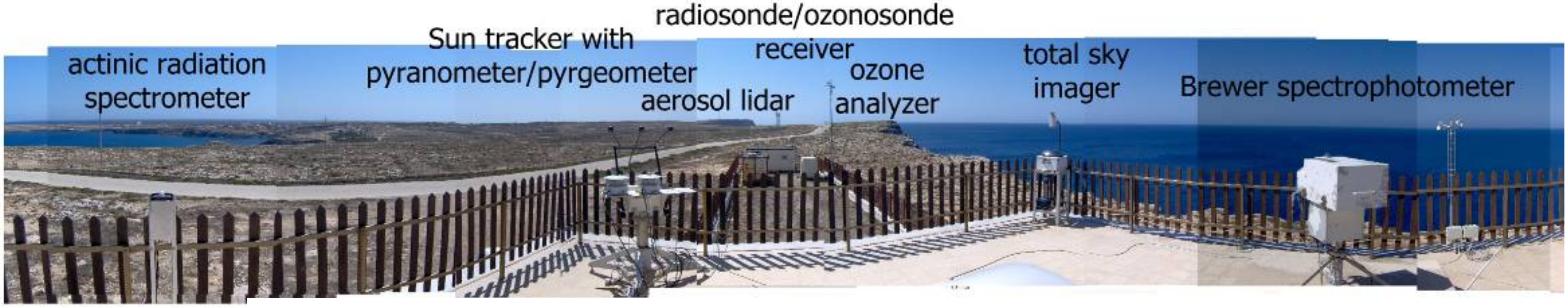
Aerosols in the Mediterranean region

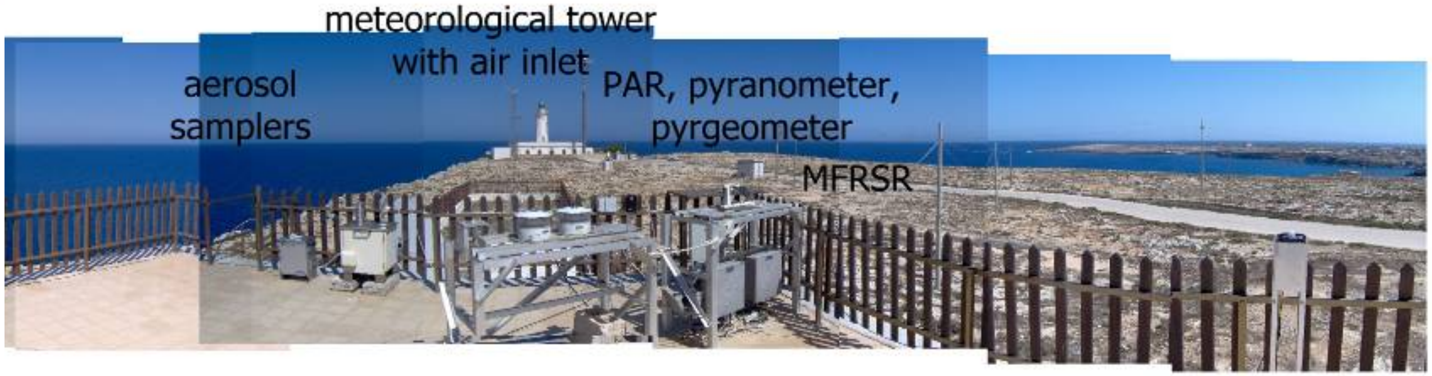


25/08/2005 (SeaWIFS Image)

ENEA Station for Climate Observation, since 1999







- Meteorological station [air pressure, temperature, humidity, wind direction and velocity, precipitation (Vaisala); solar irradiance (Kipp and Zonen)].
- Non-dispersive Infra-red (NDIR) analyzer [atmospheric CO_2 concentration (the system includes a Siemens 5E analyzer)].
- Gas chromatograph [atmospheric concentration of CH_4, N_2O, CFC-11 and CFC-12 (HP 6890)].
- Brewer MK III spectrophotometer [total ozone, spectral UV, aerosol optical depth].
- Aerosol lidar [together with University of Rome; aerosol backscattering and depolarization profiles].
- Visible Multi Filter Rotating Shadowband Radiometer [MFRSR; aerosol optical depth at several wavelengths, diffuse-to-direct irradiance ratio, column water vapor, aerosol single scattering albedo (Yankee Environmental Systems MFR-7)].
- PM-10 aerosol sampler [Tecora Skypost, daily chemical analyses performed at the University of Florence].
- Precision Spectral Pyranometer [downward shortwave irradiance (Eppley)].
- Precision Infrared Pyranometer [downward longwave irradiance (Eppley)].
- CGR4 [downward longwave irradiance (Kipp and Zonen)].
- Shaded Precision Spectral Pyranometer [diffuse downward shortwave irradiance (Eppley)].
- Photosynthetic radiation radiometer [downward photosynthetically active radiation].
- Actinic radiation spectrometer [actinic radiation spectra, photo dissociation rates (Metcon GmbH)].
- F-RAD UV filter radiometer [UV irradiance at 7 bands].
- Total sky imager [cloud cover (Yankee Environmental Systems TSI 440)].
- Water vapor Raman lidar [day/nighttime vertical profiles of water vapor, aerosol extinction (jointly with University of Rome)].
- Vaisala radio/ozonesonde [temperature, pressure, humidity, wind, ozone vertical profiles (Vaisala Digicora III)].
- Hat-Pro Microwave Radiometer [temperature and water vapor vertical profiles, integrated water vapour, liquid water content, cloud base height].
- Cimel sun photometer [aerosol optical depth and optical properties (jointly with University of Modena and Reggio Emilia)]
- SODAR [wind vertical profiles, three components, ERSE].
- ENEA gas sampling unit [weekly analyses of 15 different halogen compounds, made at ENEA, Rome].
- NOAA gas sampling unit [weekly analyses of CO_2, CH_4, SF_6, CO, ^{13}C, H_2, ^{18}O, made at NOAA].

a) MFRSR Radiometers
b) Cimel photometer (*http://aeronet.gsfc.nasa.gov/*)

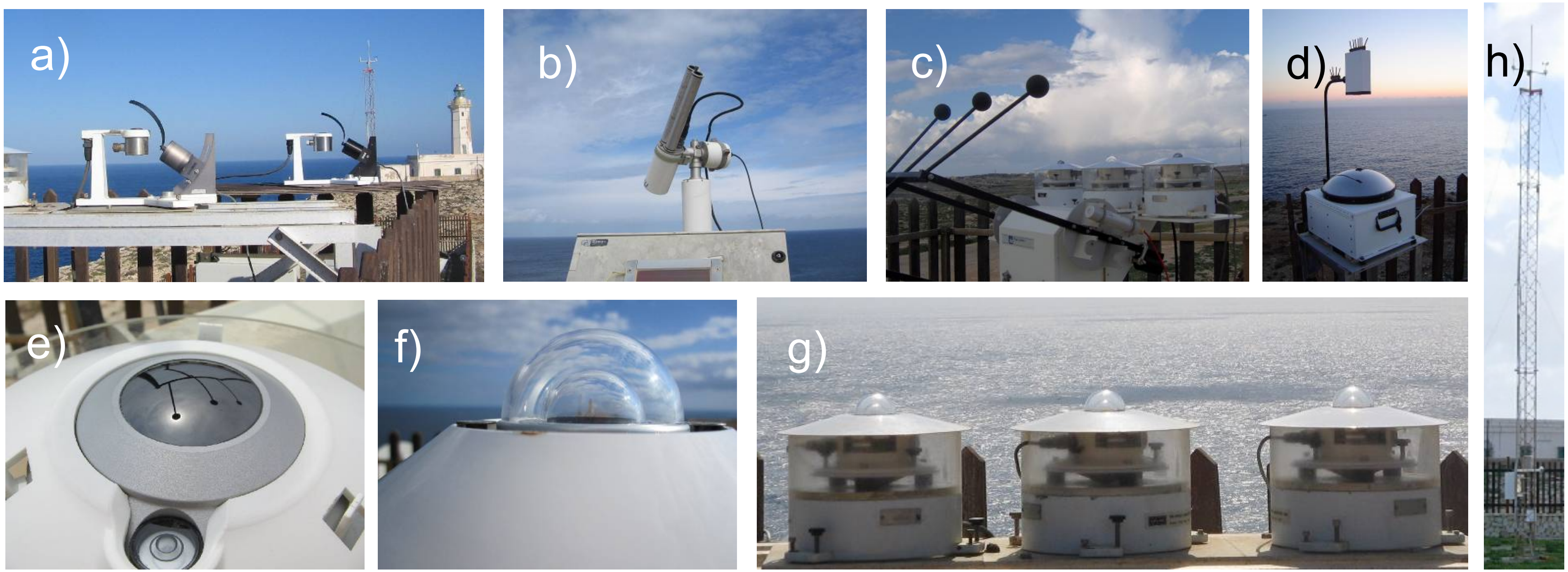
Aerosol optical properties

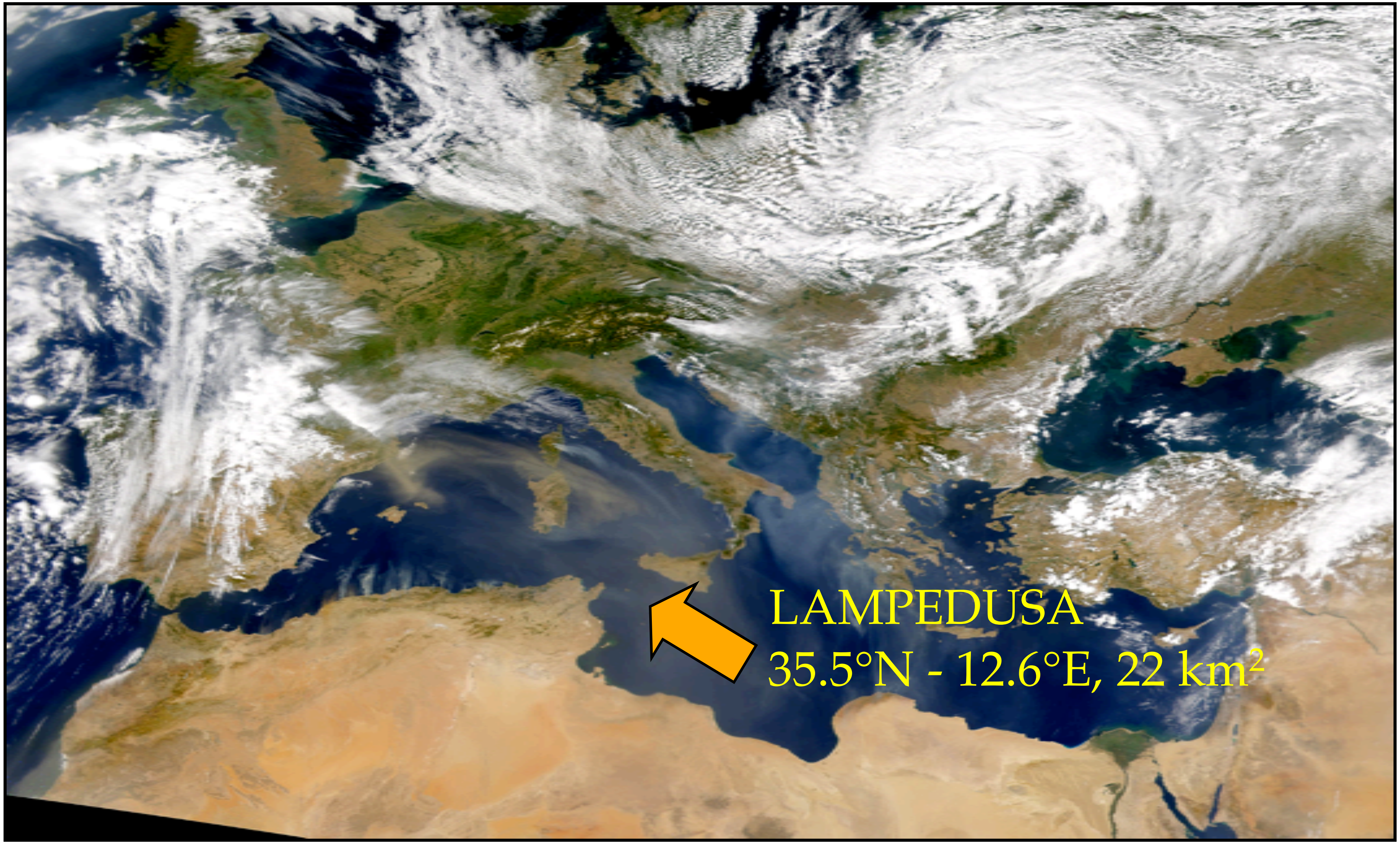
c) Solar tracker with PIR (infrared) and PSP (solar) radiometers
e) CGR4 pyrgeometer (infrared)
f) CMP21 pyranometer (solar)
g) PIR and PSP radiometers

Radiative fluxes at the surface (global/diffuse sw and lw)

d) Total Sky Imager (TSI)
h) Meteorological tower

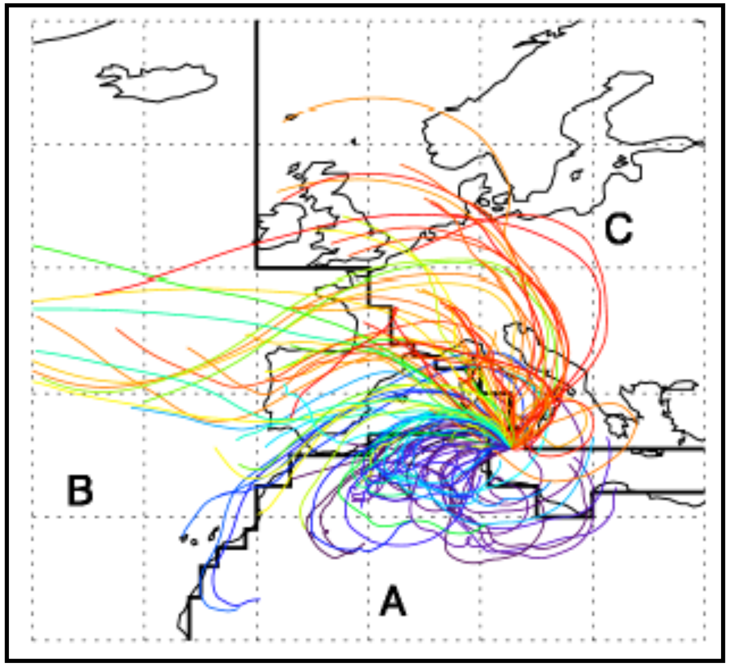
Meteorology and sky conditions





25/08/2005 (SeaWIFS Image)

Different aerosol types at Lampedusa



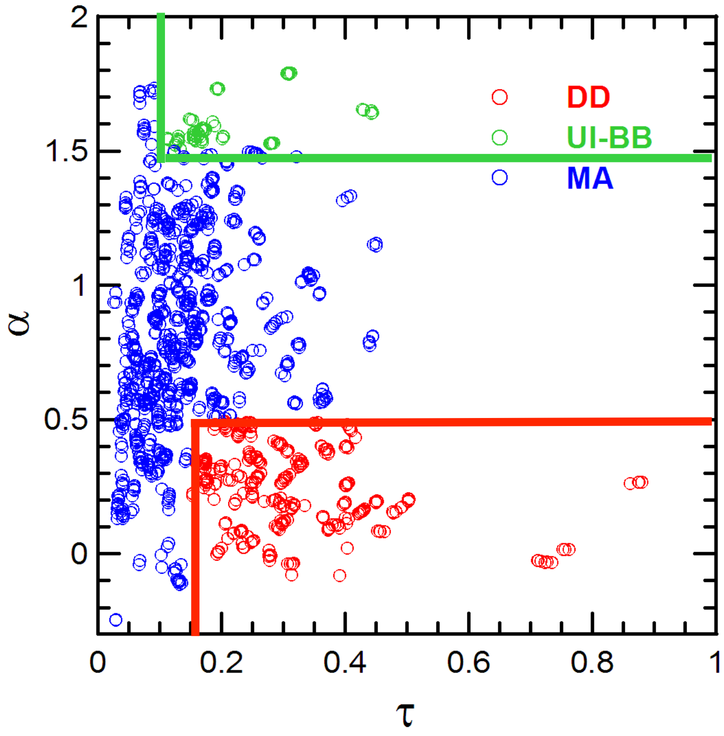
Pace et al., ACP 2006

Backward airmass trajectories (HYSPLIT)
+
Aerosol optical properties
↓

DD: desert dust
UI-BB: urban/industrial-biomass burning
MA: mixed aerosols (marine and mixed)

2004 - 2007

Aerosol type	τ (495.7 nm)	α
DD	0.31 ± 0.13	0.25 ± 0.15
UI-BB	0.21 ± 0.09	1.60 ± 0.09
MA	0.14 ± 0.08	0.85 ± 0.37



Aerosol Radiative Forcing (RF) at Lampedusa

2004-2007

Shortwave RF at TOA (top of atmosphere) - surface - atmosphere

DD – desert dust
UI-BB – urban/industrial-biomass burning aerosols
MA – mixed aerosols (marine + DD + UI-BB)

surface data + satellite data

2010: the most intense desert dust event ever observed at Lampedusa since 1999

Shortwave and *Longwave* RF at TOA - surface - atmosphere

DD – desert dust

surface data + satellite data + radiative transfer model

How to derive the aerosol Radiative Forcing (RF)?

At a given atmospheric level

At a given spectral band

radiative transfer model

$$RF = F_{net} - (F_{net})_{aerosol\text{-}free}$$

Forcing Efficiency $\Rightarrow$ $$FE = \frac{d(F_{net})}{d\tau}$$

[*Satheesh and Ramanathan*, NATURE 2000]

Shortwave FE

$$FE_S = \frac{d\left[(1 - A_S) \cdot I_{SW\downarrow}\right]}{d\tau}$$

$$FE_{TOA} = \frac{d\left[-I_{TOA\uparrow}\right]}{d\tau}$$

$$FE_{ATM} = FE_{TOA} - FE_S$$

τ = aerosol optical depth

A_S = surface shortwave albedo

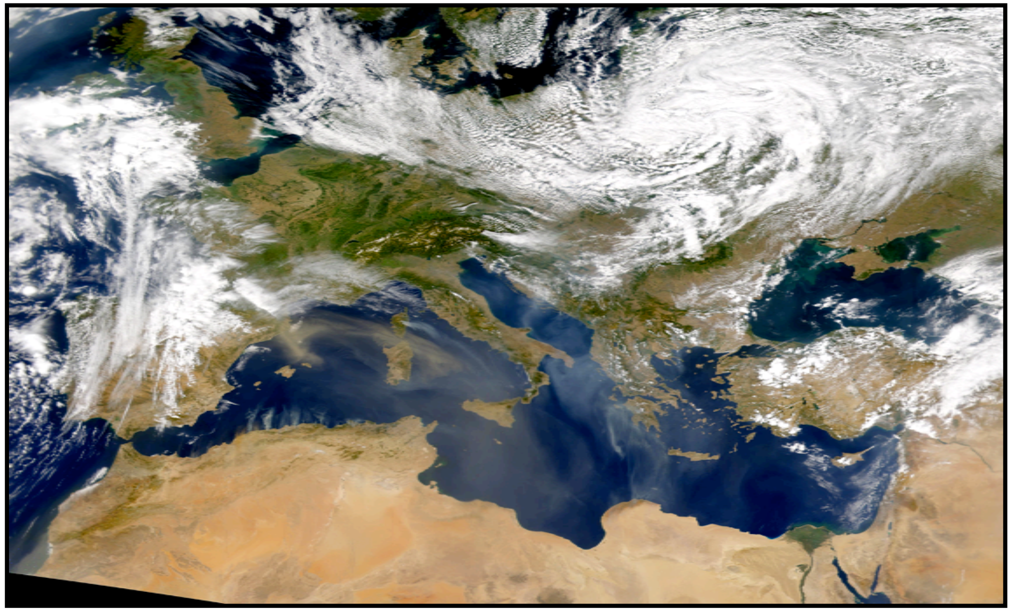
$I_{SW\downarrow}$ = surface downward shortwave irradiance

$I_{TOA\uparrow}$ = TOA upward shortwave irradiance

only observational data

needs a large dataset

DIRECT SHORTWAVE RF FOR DIFFERENT AEROSOL TYPES (DD, UI-BB, MA) OBSERVED IN THE PERIOD 2004-2007

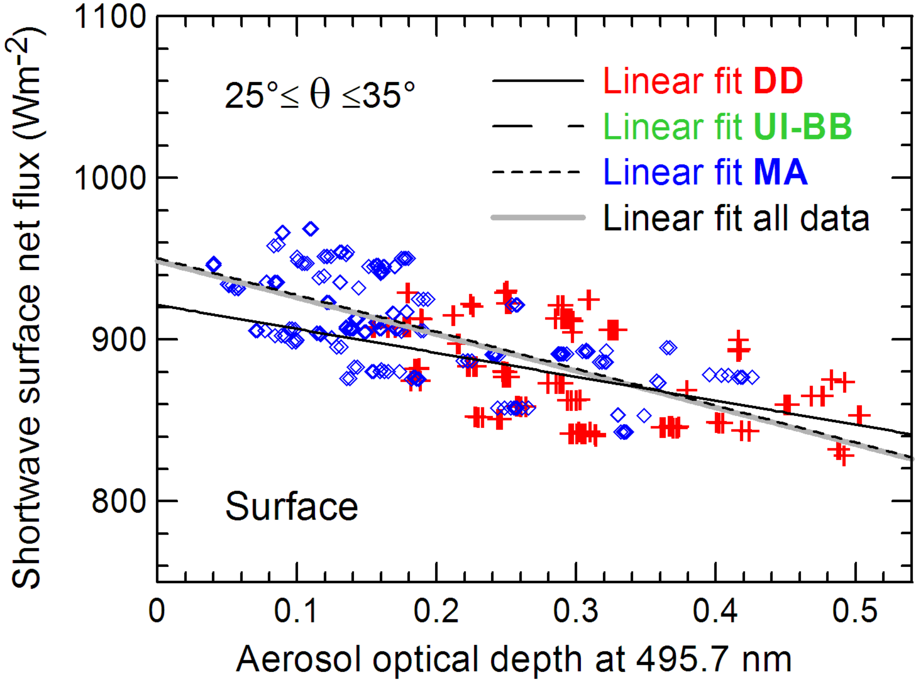


DIRECT SHORTWAVE RF FOR DIFFERENT AEROSOL TYPES (DD, UI-BB, MA) OBSERVED IN THE PERIOD 2004-2007

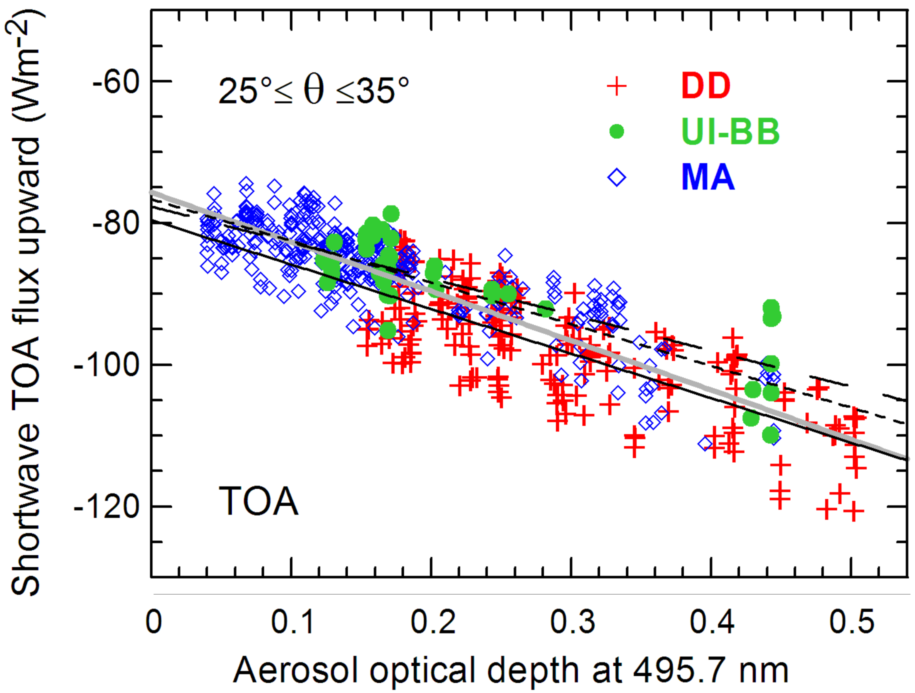
FE_S FE_{TOA} FE_{ATM}

→ surface observations (aerosol optical properties, surface sw fluxes)
→ satellite observations (surface sw albedo, TOA sw outgoing fluxes)

SURFACE



TOA (top of atmosphere)



Di Biagio et al., JGR 2010

FE at different θ → integrated to obtain the daily forcing efficiency $(FE)_d$

The **daily mean forcing efficiency** (**FE_d**) is largest for DD at TOA and for MA at surface; lowest values are obtained for UI-BB. The atmospheric forcing is ~30-50% of the surface forcing for DD, ~70% for UI-BB, and ~60% for MA.

	FE_d at the equinox (Wm^{-2})		
	TOA	**Surface**	**Atm**
DD	-45.5 ± 5.4	-68.9 ± 4.0	23.4 ± 6.7
UI-BB	-19.2 ± 3.3	-59.0 ± 4.3	39.8 ± 5.4
MA	-36.2 ± 1.7	-94.9 ± 5.1	58.7 ± 5.4

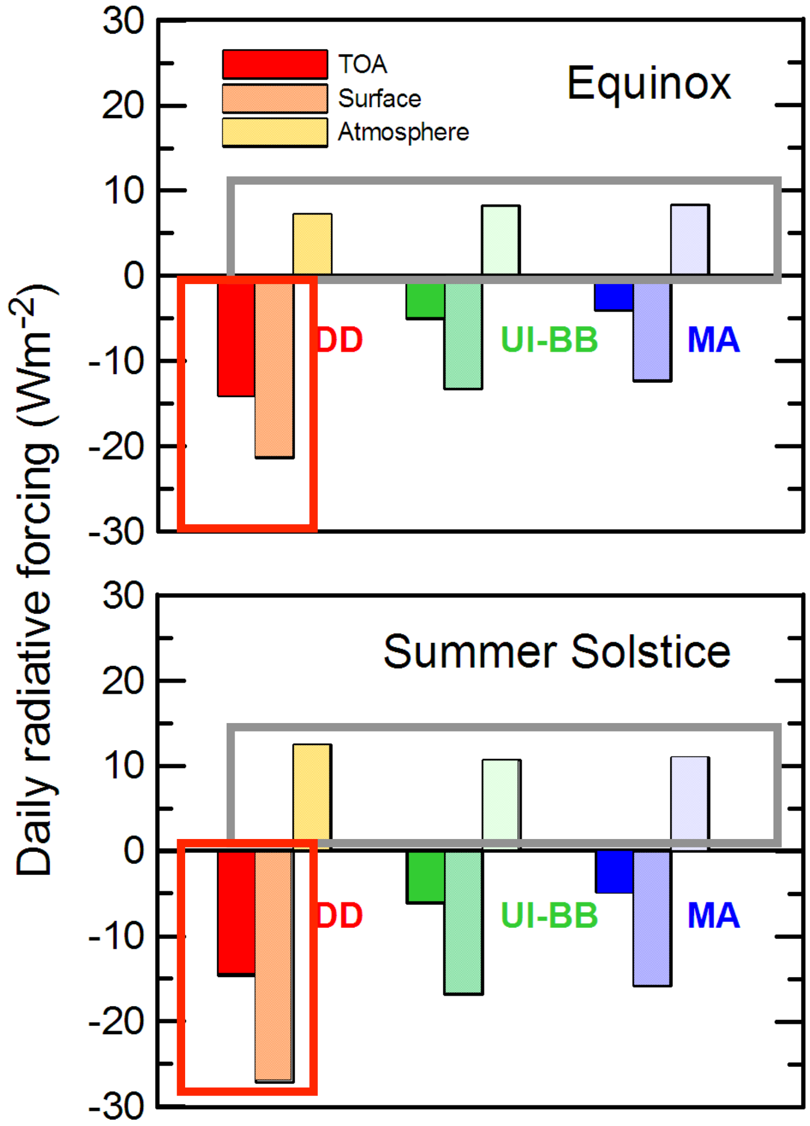
	FE_d at the summer solstice (Wm^{-2})		
	TOA	**Surface**	**Atm**
DD	-47.3 ± 5.6	-87.5 ± 5.0	40.2 ± 7.5
UI-BB	-23.3 ± 4.1	-75.6 ± 7.9	52.3 ± 8.9
MA	-44.2 ± 2.1	-120.5 ± 6.5	76.3 ± 6.8

Di Biagio et al., JGR 2010

The **daily mean radiative forcing** (**RF_d**) at TOA and at the surface are largest for DD due to the high value of both FE_d and average τ.

The atmospheric RF_d, conversely, is approximately independent of the aerosol type.

Aerosol type	τ (495.7 nm)
DD	0.31 ± 0.13
UI-BB	0.21 ± 0.09
MA	0.14 ± 0.08



Di Biagio et al., JGR 2010

DEPENDENCE OF THE FE ON THE SINGLE SCATTERING ALBEDO (ω)

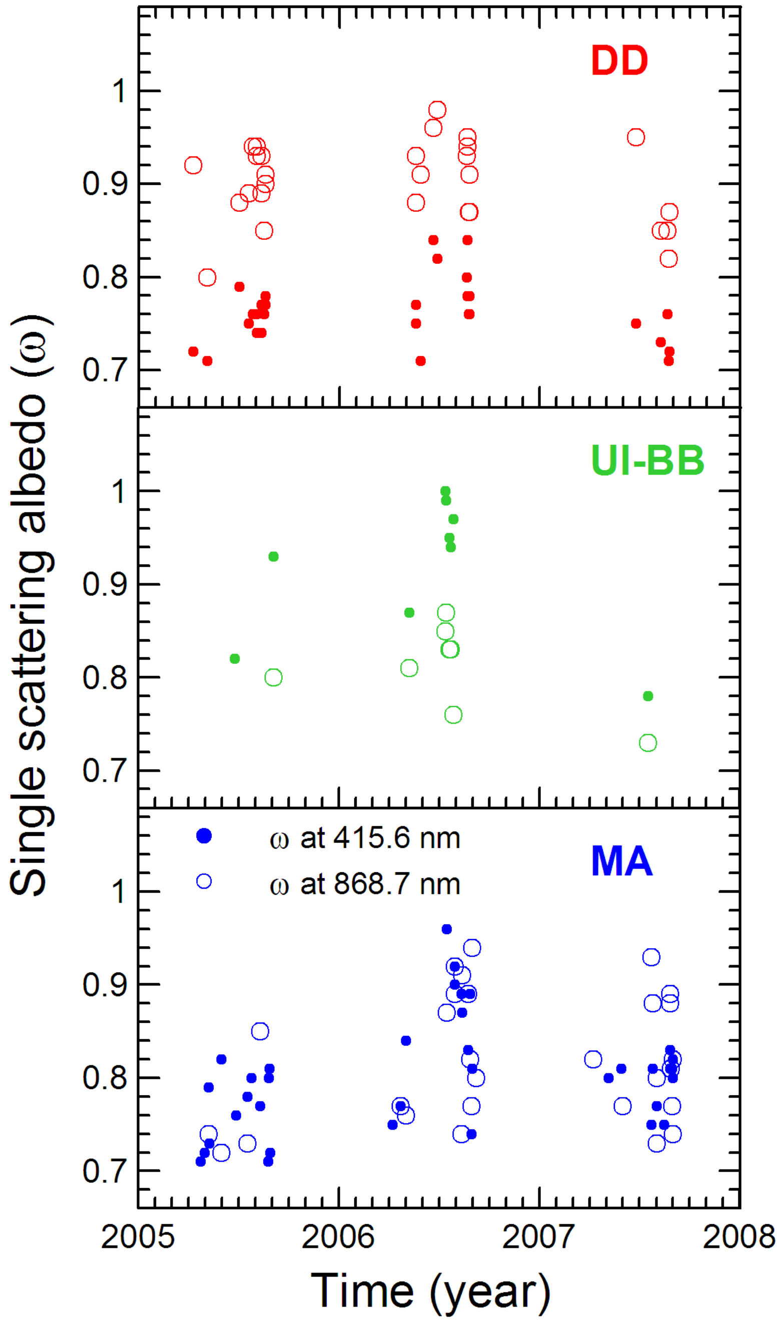
measurements (DDR + τ)
+
radiative transfer model (UVSPEC)

Meloni et al., ACP 2006

Single scattering albedo: $0 \leq \omega \leq 1$

2004 - 2007

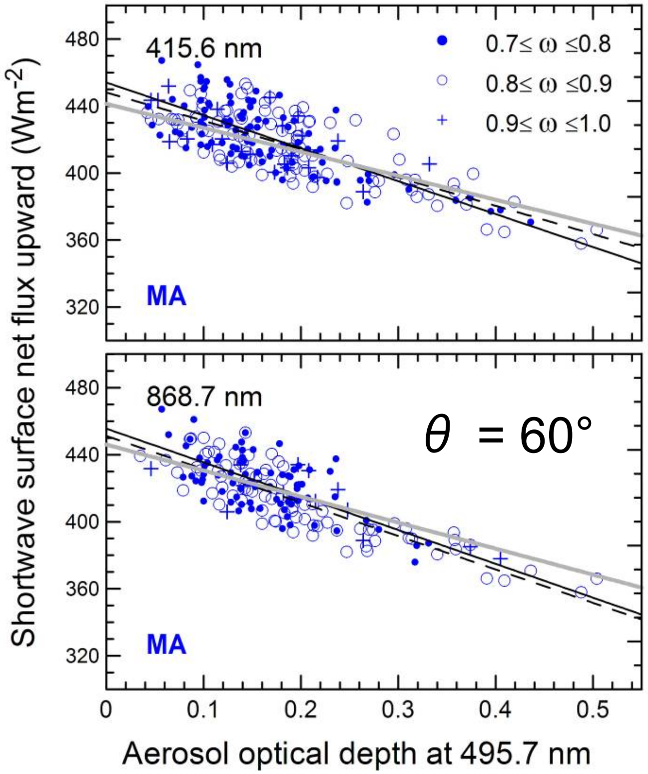
aerosol type	ω (415.6 nm)	ω (868.7 nm)
DD	0.76 ± 0.03	0.89 ± 0.05
UI-BB	0.91 ± 0.06	0.81 ± 0.04
MA	0.81 ± 0.06	0.82 ± 0.07



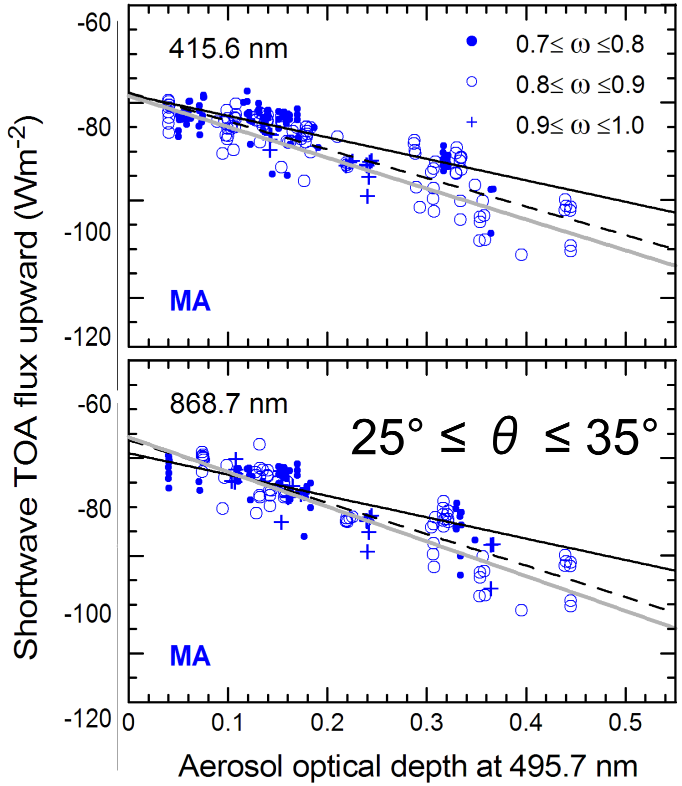
FE for DD and MA

- $0.7 \leq \omega < 0.8$
- $0.8 \leq \omega < 0.9$
- $0.9 \leq \omega \leq 1.0$

Surface



TOA (top of atmosphere)



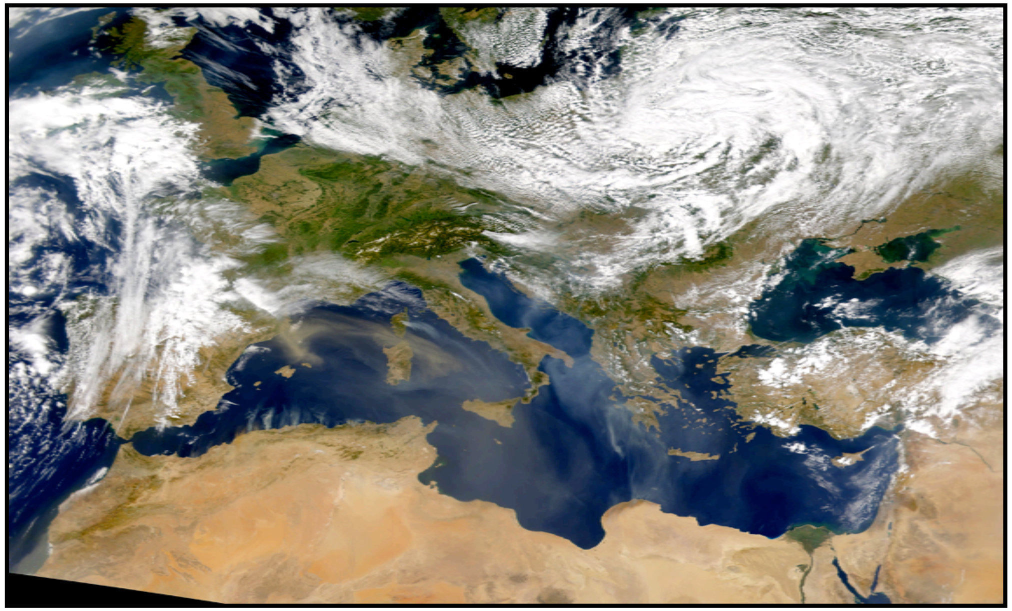
FE_{TOA}: $\Delta\omega = +0.1$ → $\Delta FE_{TOA} \approx$ ↓ ~25%

FE_S: $\Delta\omega = +0.1$ → $\Delta FE_S \approx$ ↑ ~15%

FE_{ATM}: $\Delta\omega = +0.1$ → ↓ ~40%

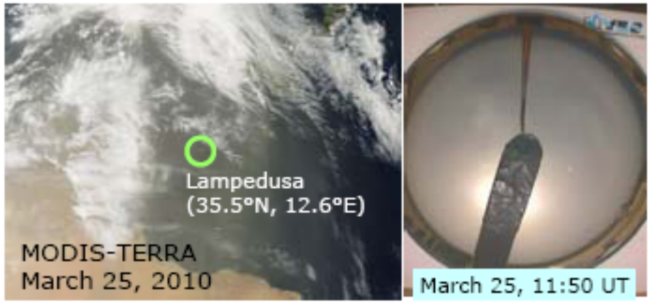
Di Biagio et al., JGR 2009 and 2010

THE INTENSE SAHARAN DUST EVENT OF MARCH 25-26, 2010

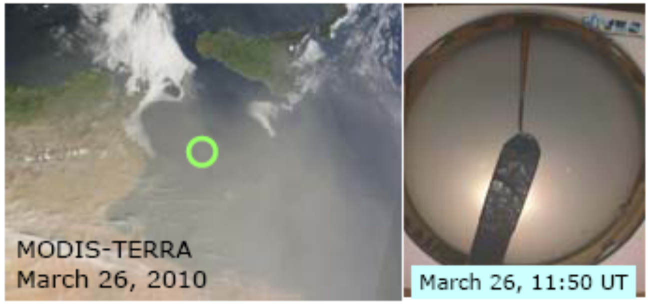


THE INTENSE SAHARAN DUST EVENT OF MARCH 25-26, 2010

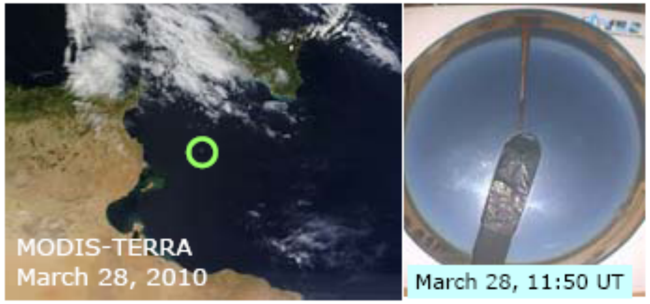
March 25



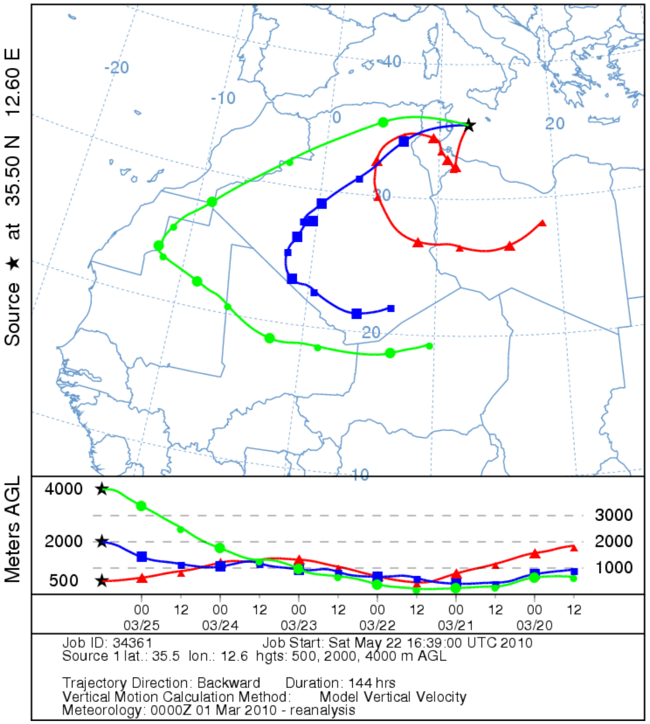
March 26



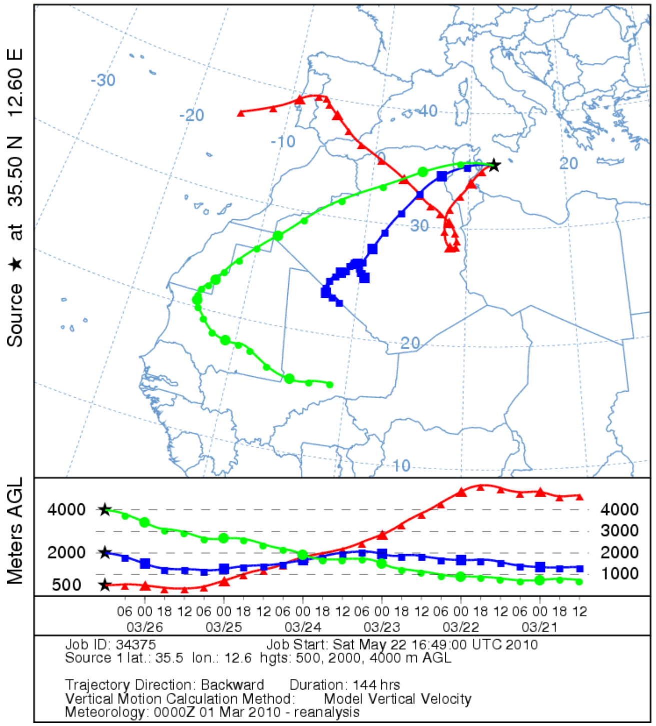
March 28



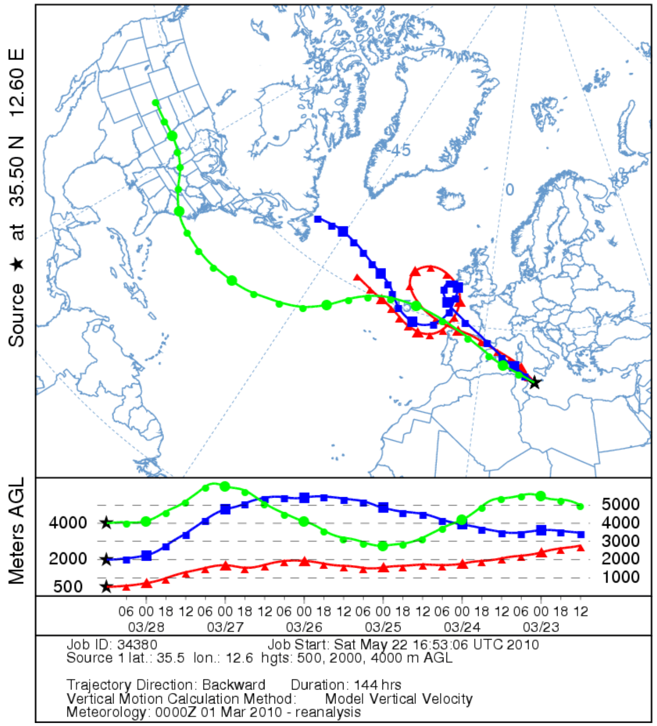
NOAA HYSPLIT MODEL
Backward trajectories ending at 1200 UTC 25 Mar 10
CDC1 Meteorological Data

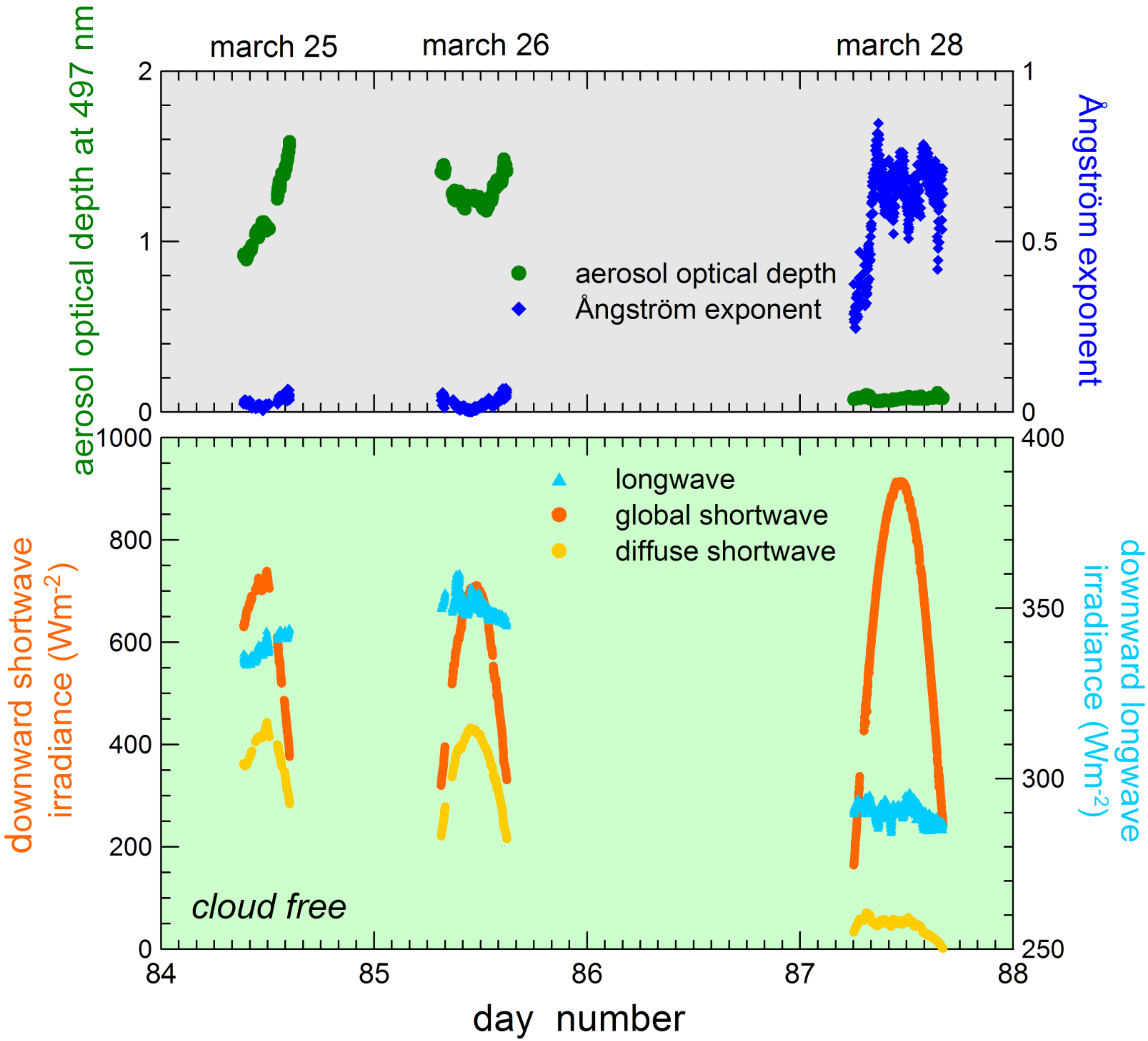


NOAA HYSPLIT MODEL
Backward trajectories ending at 1200 UTC 26 Mar 10
CDC1 Meteorological Data



NOAA HYSPLIT MODEL
Backward trajectories ending at 1200 UTC 28 Mar 10
CDC1 Meteorological Data





march 25
march 26
march 28
aerosol optical depth at 497 nm
Ångström exponent
aerosol optical depth
Ångström exponent
2
1
0
0.5
1000
800
600
400
200
0
400
350
300
250
longwave
global shortwave
diffuse shortwave
downward shortwave irradiance (Wm-2)
downward longwave irradiance (Wm-2)
cloud free
84
85
86
87
88
day number

$$RF = F_{net} - (F_{net})_{aerosol\text{-}free}$$

March 25, 26 ← F_{net} ; $(F_{net})_{aerosol\text{-}free}$ → March 28

→ surface observations
→ satellite observations

no satellite data available for this day

	SHORTWAVE DAILY RF (Wm^{-2})		
	TOA	**Surface**	**Atm**
March 25		-158.2	
March 26	-98.7	-173.5	74.8

7-10 times larger than daily RF at the equinox calculated for DD

→ surface observations
→ satellite observations
→ MODTRAN simulation

	LONGWAVE DAILY RF (Wm^{-2})		
	TOA	**Surface**	**Atm**
March 25	12.4	32.7	-20.3
March 26	15.5	42.7	-27.2

→ it is the first time we have such a complete characterization of both sw and lw aerosol forcing for a very intense event, but…..

….*it is still work in progress*!


Thank you

References

Di Biagio, C., A. di Sarra, D. Meloni, F. Monteleone, S. Piacentino, and D. Sferlazzo (2009), Measurements of Mediterranean aerosol radiative forcing and influence of the single scattering albedo, *J. Geophys. Res.*, 114, D06211, doi:10.1029/2008JD011037.

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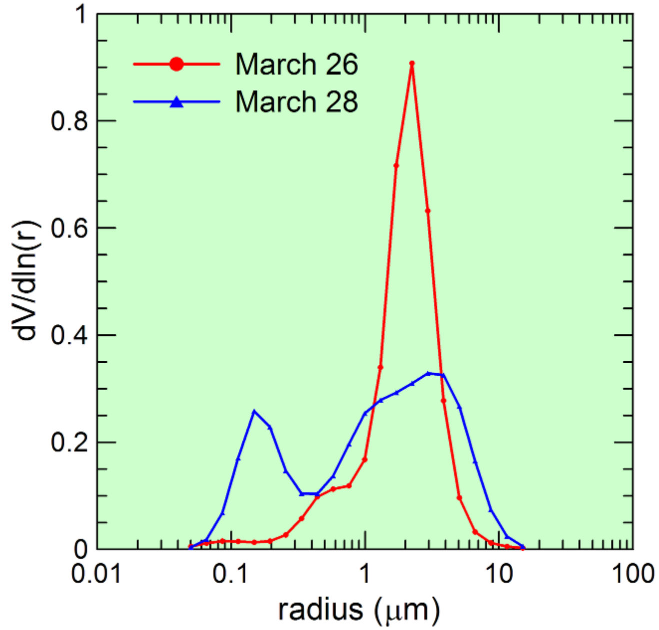

SINGLE SCATTERING ALBEDO (SSA) AND ASYMMETRY FACTOR (g)