Workshop on Aerosol-Climate Interactions: Mechanisms, Monitoring, and Impact in Tropical Regions
11-15 February, 2008  Hurgada, Egypt

Integrated Measurement Techniques for Aerosol Characterization

Maria Rita Perrone

Physics Department, Universita' del Salento, Italy
Marine aerosols and long-range transported pollution

Urban, industrial, and biomass burning aerosols

Desert aerosols

Urban, industrial, and biomass burning aerosols
Summary

♦ Experimental Facilities

(a) active and passive remote sensing techniques
(b) in situ samplings

♦ Integrated Measurements techniques for Aerosol Characterize over south-east Italy
Lidar UniLe

Newton telescope
30 cm diameter
120 cm focal length

Interferential filter
+ photomultiplier

Polarizer

Transient recorder
( A/D + photon counting)
EARLINET 2000-2003

EARLINET - ASOS (2006-2011)

European Aerosol Research Lidar Network
Advanced Sustainable Observation System

25 stazioni
$\beta(z) \sim N_i(z), \ n_i(z), \ k_i(z)$

$R_{m} = 0.014$ (pure molecular atmosphere)

$R = \frac{S_s}{S_p}$
Starting Location Station (red dot): Lecce University
7-Day Back-Trajectories: kinematic, 2006-06-28

Initial Pressure
- 850.0 hPa
- 850.0 hPa
- 700.0 hPa
- 500.0 hPa

Ore 2:00 legale locale
Ore 14:00 legale locale
LIDAR Range Corrected Signal
VAISALA Radio Sounding System

♦ Pressure
♦ Temperature
♦ Relative Humidity
♦ Water Vapor Mixing Ratios
Altitude (m)
20051011
18:19 -19:14

Mixing ratio (g/kg)
7000
6000
5000
4000
3000
2000
1000
0

0  2  4  6  8  10
Mixing ratio (g/kg)
AERONET Sun Photometer

\[ I_\lambda = I_{0\lambda} \exp(-AOD_\lambda) \]
MODIS (angle of view ±110°)
Operates at 36 spectral bands (0.405 μm - 14.385 μm)
True color MODIS image of July 16, 2003
In situ samplings

♦ Particle samplings
♦ Particle analyses
System components

A complete FH 62 I-R particulate measuring system consists of:
FH 62 I-R central unit, sampling system, vacuum pump 1 m³/h, data recording unit.

PTS, PM10 e PM2.5
7-10 July 2004

Concentrations (µg/m³):
- 6/7 12:00 00:00
- 7/7 12:00 00:00
- 8/7 12:00 00:00
- 9/7 12:00 00:00
- 10/7 12:00 00:00
- 11/7 12:00 00:00

Graph showing concentration levels over the specified dates.
PM Sampler FH 95 KF (Thermo ESM Andersen) PTS, PM10, PM2.5. 2.3 m³ h⁻¹.
Campionatore automatico bicanale HYDRA (Fai Instruments, Italia): 0.8÷2.5 m³/h

PTS, PM10, PM2.5, PM1
APS - Aerodynamic Particle Sizer (TSI, USA)

52 channels

0.5 a 20 µm di diametro.
7-Stage IMPACTOR
OH-610-C Kalman System
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_i = 20$ [°C]</td>
<td>$d_{ae}$ [μm]</td>
<td>$d_{ae}$ [μm]</td>
<td>$d_{ae}$ [μm]</td>
<td>$d_{ae}$ [μm]</td>
<td>$d_{ae}$ [μm]</td>
<td>$d_{ae}$ [μm]</td>
<td>$d_{ae}$ [μm]</td>
</tr>
<tr>
<td>$q=1.0$ [m$^3$/h]</td>
<td>7</td>
<td>3.4</td>
<td>1.8</td>
<td>0.81</td>
<td>0.45</td>
<td>0.19</td>
<td>0.11</td>
</tr>
<tr>
<td>$q=1.2$ [m$^3$/h]</td>
<td>6.4</td>
<td>3.1</td>
<td>1.6</td>
<td>0.74</td>
<td>0.4</td>
<td>0.17</td>
<td>0.09</td>
</tr>
<tr>
<td>$q=1.5$ [m$^3$/h]</td>
<td>5.7</td>
<td>2.7</td>
<td>1.4</td>
<td>0.65</td>
<td>0.35</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>$q=1.8$ [m$^3$/h]</td>
<td>5.2</td>
<td>2.5</td>
<td>1.3</td>
<td>0.59</td>
<td>0.32</td>
<td>0.13</td>
<td>0.07</td>
</tr>
<tr>
<td>$q=2.0$ [m$^3$/h]</td>
<td>4.9</td>
<td>2.4</td>
<td>1.2</td>
<td>0.6</td>
<td>0.3</td>
<td>0.1</td>
<td>0.06</td>
</tr>
</tbody>
</table>
SAMPLE CHARACTERIZATION TECHNIQUES
Elemental and morphological characterization of particles: SEM/EDAX (JEOL, Model JSM-6480 LV),
SEM ANALYSIS

- Set Q33 (24 ore) 21/11/05 h 10:47

X 7000

Stadio 1 (5.7 μm)    Stadio 3 (1.4 μm)

Stadio 5 (0.35 μm)    Stadio 7 (0.08 μm)
Spectrum photometer

Perkin Elmer Spectrum 2000 FT-IR
(15000 a 30 cm\(^{-1}\) )
The dotted line represents the Illite spectrum.

The solid line shows the spectrum from dust collected on April 12, 2002.
EC/OC Analyzer SUNSET
Integrated Measurements Techniques for aerosol Characterization to Dust Event of June 29 - July 1, 2005

29 June 2005 at 09:55 UTC
1st July 2005 at 09:45 UTC
**DATA on PM mass concentrations**

<table>
<thead>
<tr>
<th>Date</th>
<th>TSP</th>
<th>PM10</th>
<th>PM10/TSP</th>
<th>PM2.5</th>
<th>PM2.5/TSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>June, 29</td>
<td>52 ± 2 μg/m³</td>
<td>46 ± 1 μg/m³</td>
<td>88%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June, 30</td>
<td>55 ± 3 μg/m³</td>
<td>33 ± 1 μg/m³</td>
<td></td>
<td></td>
<td>60%</td>
</tr>
</tbody>
</table>
\[ \frac{dV}{d\ln r} \left( \mu m^3/\mu m^2 \right) \]

Radius (\(\mu m\))

29/06 (3)  30/06 (4)  1/07 (6)
Daily average values at 440 nm and corresponding standard deviations of the real ($n$) and imaginary ($k$) refractive index, and of the single scattering albedo (SSA) retrieved from sun/sky radiometer measurements.

<table>
<thead>
<tr>
<th>Date</th>
<th>$n$</th>
<th>$k$</th>
<th>SSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>29/06/05</td>
<td>1.57 ± 0.04</td>
<td>0.010 ± 0.002</td>
<td>0.93 ± 0.01</td>
</tr>
<tr>
<td>30/06/05</td>
<td>1.5 ± 0.1</td>
<td>0.006 ± 0.003</td>
<td>0.90 ± 0.03</td>
</tr>
<tr>
<td>01/07/05</td>
<td>1.58 ± 0.04</td>
<td>0.005 ± 0.004</td>
<td>0.94 ± 0.05</td>
</tr>
</tbody>
</table>
Misure LIDAR del 30 Giugno 2005
\[ S(z) = \frac{\alpha(z)}{\beta(z)} \]
LIDAR ratios by AERONET aerosol products

\[ S(\lambda) = \frac{4\pi}{[SSA(\lambda) \times P(\lambda, 180^\circ)]} \]

- Column averaged S value at 440nm

\[ S(440 \text{ nm}) = 49 \pm 11 \ (\text{Sr}^{-1}) \]

\[ S_{\text{lidar}}(351 \text{ nm}) \approx 53 \ (\text{Sr}^{-1}) \]
30 June - 1st July (48 hours)
LIDAR ♦ backscatter coefficient profiles
♦ depolarization ratio profiles
♦ lidar ratio profiles a
♦ AERONET lidar ratio values

Sunphotometer volume size distribution
Impactor mass size distribution

↓

rather uniform particle distribution in the whole column ⇒ ground collected particles are representative of whole column
$(K, H_3O)(Al, Mg, Fe)_2(Si, Al)_4O_{10}[(OH)_2, H_2O]$  \( \text{CaCO}_3 \quad \text{MgCa(CO}_3)_2 \quad \text{NaCl} \)

\text{SEM: } D = 2.70 \, \mu m
C, N, Na$_2$SO$_4$, K$_2$SO$_4$  \[ D = 0.35 \mu m \]
ION Mass concentrations (µg/m³) of the investigated ion species in the 24-hour PM2.5 sample collected on 30 June.

<table>
<thead>
<tr>
<th>Date</th>
<th>Na⁺</th>
<th>NH₄⁺</th>
<th>K⁺</th>
<th>Mg²⁺</th>
<th>Ca²⁺</th>
<th>F⁻</th>
<th>Cl⁻</th>
<th>NO₃⁻</th>
<th>SO₄²⁻</th>
<th>PM2.5</th>
<th>Ions/PM2.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>30/0</td>
<td>0.5</td>
<td>0.5</td>
<td>0.3</td>
<td>0.3</td>
<td>2.5</td>
<td>0.4</td>
<td>0.2</td>
<td>1.4</td>
<td>6.4</td>
<td>33</td>
<td>36%</td>
</tr>
</tbody>
</table>
LIDAR backscatter coefficient $\beta(z, \lambda)$

$$\beta(z, \lambda) = \sum_i N_i (z) \left[ d\sigma_{i, \text{scat}} (\lambda, 180^\circ)/d\Omega \right]$$
Size distribution by AERONET on 30 June at 16:26 UTC
June 30, 2005
16:30 UTC

Fine 2 μg/m³
Coarse 2.5 μg/m³
Conclusion

♦ Integrated Measurements of ground-based systems can allow characterizing the vertical distribution of the

♦ aerosol number concentration,
♦ aerosol mass concentration,
♦ aerosol elemental and/or chemical composition
How a good knowledge on particle properties helps calculations of DIRECT RADIATIVE EFFECTS by Aerosol?
AOT 440 nm


0.0 0.2 0.4 0.6 0.8

440nm

AOT

1.0 0.8 0.6 0.4 0.2 0.0

η
Volume size distribution

radius (um)

1807/2005 am

1807/2005 pm

1707/2005
Fig. 14.3 Backscatter coefficient vertical profiles retrieved by lidar measurements on July 18, 2005. Grey lines provide depolarization ratio vertical profiles.
Annual cycle of aerosol direct radiative effect over southeast Italy and sensitivity studies

Anna Maria Tafuro,1 Stefan Kinne,2 Ferdinando De Tomasi,1 and Maria Rita Perrone1

Received 20 November 2006; revised 22 May 2007; accepted 5 June 2007; published 17 October 2007.

Aerosol direct radiative effect (DRE) calculations are presented to illustrate the annual cycle of the aerosol impact on the radiative energy balance of the Earth-atmosphere system over southeast Italy. Meteorological parameters from radiosondes, aerosol vertical profiles by lidar, aerosol optical and microphysical properties by ground-based Sun/sky photometry and satellite (MODIS) derived data of solar surface albedo, all referring to the 2003–2004 years, constitute the necessary input to radiative transfer simulations. The monthly evolution of both the solar and infrared aerosol direct radiative effect is examined at the top of the atmosphere (ToA), within the atmosphere and at the Earth’s
In accordance with AERONET products, the particle fine-mode number concentration \( (N_f) \) is given by all particles with radius \( r \)

\[
0.06 \, \mu m \leq r < 0.5 \, \mu m
\]

Then we set:

\[
N_a(r) = f \times N_f(r)
\]

where \( N_a(r) \) is the number concentration of anthropogenic aerosols and \( f = 0.8 \) (S. Kinne)
<table>
<thead>
<tr>
<th></th>
<th>Solar Wavelengths (0.3-4 μm)</th>
<th></th>
<th>IR Wavelengths (4-80 μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Anthropogenic</td>
<td>Natural = (Tot-Anthr)</td>
</tr>
<tr>
<td>sfc</td>
<td>-26</td>
<td>-15</td>
<td>-11</td>
</tr>
<tr>
<td>ToA</td>
<td>-12</td>
<td>-9.5</td>
<td>-2.5</td>
</tr>
<tr>
<td>Atm Forcing</td>
<td>14</td>
<td>5.5</td>
<td>8.5</td>
</tr>
</tbody>
</table>
### DRE (W/m²) Solar Wavelengths (0.3-3.5 μm)

<table>
<thead>
<tr>
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<th>Total</th>
<th>Anthropogenic</th>
<th>Nat+Dust =Tot-Ant</th>
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<tbody>
<tr>
<td>sfc</td>
<td>-32</td>
<td>-13</td>
<td>-19</td>
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<td>-6</td>
</tr>
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<td>13</td>
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### DRE (W/m²) IR Wavelengths (4-80 μm)

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<th>Nat + Dust</th>
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<tr>
<td>sfc</td>
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<td>1</td>
<td>6</td>
</tr>
<tr>
<td>ToA</td>
<td>2</td>
<td>0.1</td>
<td>1.9</td>
</tr>
</tbody>
</table>
### DRE (W/m²) Solar Wavelengths (0.3-3.5 μm)

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<th>Anthropogenic</th>
<th>Nat+Dust =Tot-Ant</th>
</tr>
</thead>
<tbody>
<tr>
<td>sfc</td>
<td>-32 (-26)</td>
<td>-13 (-15)</td>
<td>-19 (-11)</td>
</tr>
<tr>
<td>ToA</td>
<td>-15 (-12)</td>
<td>-9 (-9.5)</td>
<td>-6 (-2.5)</td>
</tr>
<tr>
<td>Atm Forcing</td>
<td>17</td>
<td>4</td>
<td>13</td>
</tr>
</tbody>
</table>

### DRE (W/m²) IR Wavelengths (4-80 μm)

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Anthropogenic</th>
<th>Nat + Dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>sfc</td>
<td>7 (3)</td>
<td>1 (1)</td>
<td>6 (2)</td>
</tr>
<tr>
<td>ToA</td>
<td>2 (0.9)</td>
<td>0.1 (0.1)</td>
<td>1.9 (0.8)</td>
</tr>
</tbody>
</table>
Solar sfc: $-19 \text{ (W/m}^2\text{)} < \text{DRE}_{\text{dust}} < -8 \text{ (W/m}^2\text{)}$

(Solar+IR) sfc: $-13 \text{ (W/m}^2\text{)} < \text{DRE}_{\text{dust}} < -4 \text{ (W/m}^2\text{)}$

Solar ToA: $-6 \text{ (W/m}^2\text{)} < \text{DRE}_{\text{dust}} < -3.5 \text{ (W/m}^2\text{)}$

(Solar +IR) ToA: $-4 \text{ (W/m}^2\text{)} < \text{DRE}_{\text{dust}} < -2.7 \text{ (W/m}^2\text{)}$
MODIS data can allow inferring if local data can be representative of a larger area?

YES

AERONET versus MODIS aerosol parameters at different spatial resolutions over South East-Italy (JGR, 2007)
AERONET versus MODIS aerosol parameters at different spatial resolutions over southeast Italy

M. Santese,1 F. De Tomasi,1 and M. R. Perrone1

Received 3 July 2006; revised 22 December 2006; accepted 27 January 2007; published 22 May 2007.

[3] Aerosol parameters retrieved by Aerosol Robotic Network (AERONET) Sun photometer measurements at the Physics Department of Lecce’s University (40°20′N, 18°6′E) are compared to similar Moderate Resolution Imaging Spectroradiometer (MODIS) data retrieved at different spatial resolutions colocated in space and time to contribute to the validation of MODIS aerosol products over southeast Italy and to investigate the correlation dependence on spatial resolution and identify
LECCE
MODIS AODs versus AERONET AODs at 550 nm

Ichoku et al., 2002
ANNUAL EVOLUTION OF MODIS AODs versus AERONET AODs at 550 nm

50 km x 50 km
± 30 min

100 km x 100 km
± 60 min

300 km x 300 km
± 90 min
Correlation studies between MODIS and AERONET data can allow inferring the regional area where local data can be extended.
F. De Tomasi, Univ. Researcher
G. Mannarini, post-doc
A. Tafuro, PhD student
M. Santese, PhD student
V. Bellantone, PhD student
I. Carofalo, PhD student
V. Nicolardi, Technician
F. De Donno, Technician