Study of Planetary Boundary Layer evolution in urban/rural sites in Southern Italy

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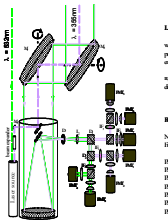
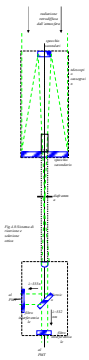
Recently there is a growing interest in the study of aerosol compounds in the troposphere because of their influence in many atmospheric processes. The monitoring of aerosol particles in the atmosphere can be realised in real time with lidar systems using optical backscattering for the study of atmospheric properties. Furthermore, lidar technique is becoming a powerful tool for study the aerosols optical properties in urban area giving time-dependent aerosols mapping of the urban atmosphere. A field measurements campaign aimed to study comparatively the PBL structure and evolution in two sites differing for orography and urbanization level has been worked out in Southern Italy by applying the lidar technique. The two sites (Naples and Pontecagnano) are located 50 km apart on the Tyrrhenian coast. Naples (40°50'N-14°10'E, 118m a.s.l.) is an urban area with a very high level of urbanization and a huge aerosol content located mainly below the PBL. Pontecagnano (40°37'N-14°53'E) is a rural and flat area. The effect of the orography and the closeness of the sea influence the local circulation phenomena related to diurnal changes in surface temperature and the PBL evolution and affect the aerosol vertical distribution. Using aerosols as tracers, the lidar technique has been applied in order to follow the evolution of the Planetary Boundary Layer in both sites during a complete diurnal cycle. Futhermore, airborne atmospheric measurements of mass, momentum, and energy fluxes of boundary layer research have been available by the use of a Sky Arrow 650 Environmental Research Aircraft (ERA) flying over Pontecagnano. A study of correlations between PBL height and the temperature measured at ground level in Naples and sensible heat in Pontecagnano has been performed by evaluating the correlation coefficient between these parameters as a function of the relative delay. We found the maximum correlation for a delay of about 100 min in Naples and of about 180 min in Pontecagnano. This difference in the response of PBL to the heat flux from the surface to atmosphere is due to the different kind of use of soil.

EXPERIMENTAL SETUP



NAPLES SETUP

EXPERIMENTAL SETUPs
On the left, the multiwavelength Raman Lidar system of University of Naples – CNISM, operating in Naples is shown. It is based on a Nd:YAG laser, working simultaneously at the fundamental wavelength (1064nm) and at doubled and tripled frequency, corresponding to 532nm and 355 nm, respectively. Fast photomultipliers are used for detection at any wavelength. Data acquisition is achieved both in analogic and in photon counting mode in order to extend the sounded range from 200 m to about 20 km above the ground . To relate the lidar data to atmospheric parameters, temperature, pressure, relative humidity, speed and direction of the wind are measured by means of ground based sondes.



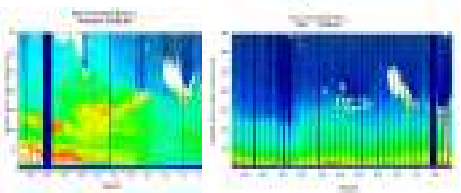
CO.RI.STA. SETUP

In the figure is also shown the Elastic Lidar moving system of CORISTA, operating in Pontecagnano. It is based on a Nd:YAG laser, working for this experiment at the wavelength of 532nm.
This apparatus has been used for first time during this campaign. During this campaign also measurements of air speed, temperature, CO2 and H2O concentration, altitude, latitude, longitude, pressure, potential temperature, wind speed and direction, radiation by means of airborne instrumentation have been performed over Pontecagnano.

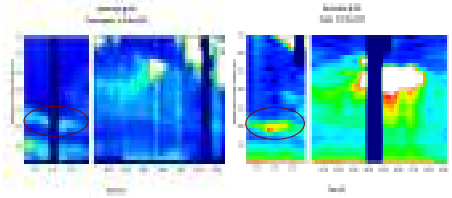
ISAFOM SETUP

The aircraft is shown on the left; it is a Sky Arrow 650 Environmental Research Aircraft (ERA), produced by Iniziative Industriali Italiane Spa, and instrumented by NOAA's Atmospheric Turbulence and Diffusion Division.
The Sky Arrow is a two-seat aircraft, made of carbon fibre and epoxy resin and is operating altitudes range from 10 m above ground level to more than 3500 m above sea level.
The NOAA/ATDD Mobile Flux Platform system mounted on Sky Arrow ERA for monitoring of atmosphere consists of the MFP computer, the Auxiliary box, and the BAT probe assembly.

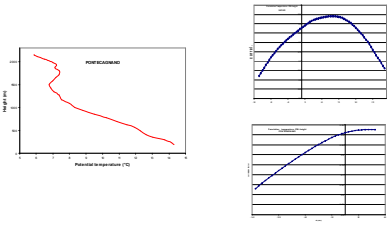
PBL evolution and correlation



Lidar measurements have been performed during a complete diurnal cycle starting at 16:37 UT in both sites. In the above reported figures, a map of the range corrected signal (RCS) is reported as a function of time, showing the evolution of lower troposphere and PBL in Naples (λ=355 nm) and in Pontecagnano (λ=532 nm) during a period of about 24 hours.
Differences in the PBL evolution between urban area of Naples and rural area of Pontecagnano are mainly due to local forces like breeze and to different orography.



Vertical profiles of the backscattering coefficient have been obtained in Naples by applying Raman algorithm (Ansmann A., Wandinger U., 1992) while in Pontecagnano by Klett-Fernald (Klett, 1991) algorithm because in this case only the elastic signal is available.

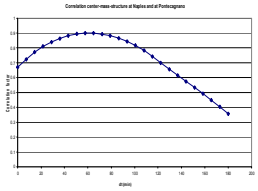


The PBL height has been evaluated as a function of time in both sites, it is obtained by the first derivative method, by searching a minimum of the quantity: $\frac{d}{dz}\ln(RCS)$

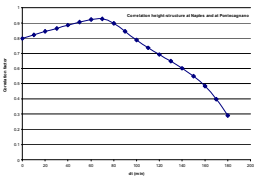
The potential temperature profile measured by airborne instruments (at 17:00 UT) shows an inversion about 1500 m, in agreement with the value of PBL height as calculated from lidar signal. In figures above on the left two graphs are reported, showing the correlation between temperature and PBL height as a function of the relative delay, in Pontecagnano and in Naples respectively. We found the maximum correlation for a delay of about 100 min in Naples and of about 180 min in Pontecagnano. In other words this means that changes in the PBL height follow the surface temperature variations with different delays in the two sites.
This difference can be linked to the different kind of soil. In fact, the influence of heterogeneities extends vertically in the atmosphere up to some level, generally within the planetary boundary layer, as also indicated by observational and modelling studies (Claussen 1995; Mahrt 2000).

Correlation analysis of aerosol transport above PBL

In addiction to study aerosols and PBL evolution, it's interesting to follow the dynamics about aerosol transport phenomena on synoptic scale: layer present during 16:37 – 24:00 UT above the PBL between 2000 m and 4000 m in Naples and in Pontecagnano (Naples is far from Pontecagnano about 70 km).



Since the beginning of measurements until 04:00 UT, a same aerosol structure has passed from Naples to Pontecagnano as can be seen by backscatter maps. A correlation criterion (0.89) between the centres of the mass aerosol structure in Naples and in Pontecagnano has been used to evaluate the temporal delay.
The delay is about 60 minutes, in according to wind velocity (60 km/h, WE) as measured by radiosonde at Pratica di Mare (far from Naples about 200 km).



Similar results are obtained by analysing the the correlation curve between the height of the layer in Naples and in Pontecagnano. The maximum value for the correlation coefficient is 0.92 at the same temporal delay (see above). This suggest that the aerosol transport phenomenon can be considered as laminar.

To identify the nature and the source regions of the aerosol layer we used the analysis of backtrajectories. Trajectory models are important tools for studying trasport phenomena in the atmosphere (Stohl, 1998). The picture on the left show the backtrajectories calculated by FLEXTRA model (Stohl et al.), based on model level data of the numerical weather prediction model of the European Centre for Medium-Range Weather Forecasts (ECMWF)
These backtrajectories are related to 18:00 UT and the different colours are related to different heights. Bactrajectories are practically the same for Naples and Pontecagnano; they show that the origin of the aerosol structure is continental, in agreement with the value of the lidar ratio as determined by simultaneous measurement of extinction and backscattering coefficient performed in Naples.

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