# The BAQUNIN (Boundary layer Air Quality-analysis Using Network of INstruments) Super-Site for atmospheric science and satellite data validation

**A.M. Iannarelli (1), M. Cacciani (2), A. Burini (3), S. Casadio (1), M. Campanelli (4), A.M. Siani (2), G. Casasanta(4), H. Diemoz (5), J. von Bismarck (6), and B. R. Bojkov (6)**

1) Serco
2) Physics Department, “Sapienza” University of Rome
3) RHEA
4) CNR-ISAC
5) ARPA Valle d'Aosta, Saint-Christophe, Aosta
6) ESA/ESRIN

**Abstract.** In the context of the IDEAS+ support contract (ESA/ESRIN SPPA) and in the framework of the PANDONIA project (ESA), the Physics Department of “Sapienza” University of Rome and ESA/ESRIN EOP-GMQ section have set-up a joint instrumental suite for validating the atmospheric chemical and optical level 2 products retrieved from satellite, and for the studies about Planetary Boundary Layer (PBL). This instrumental set-up composes a so called “Super Site”, ground based active and passive remote sensing instruments are operating in synergy offering quantitative and qualitative information for a wide range of atmospheric parameters in a urban atmospheric boundary layer such as the Rome city centre (University of Rome), compared to a rural environment (ESA/ESRIN). The list of the BAQUNIN Super Site instrumentation comprises: Raman and elastic LIDAR systems operating day and night (aerosols, H2O, clouds), SODAR (wind profiles in PBL), MFRSR radiometer (aerosols, O3 ,H2O), POM 01 L Prede sun-sky radiometer (aerosols, precipitable water content), Brewer spectrophotometer (O3, SO2, NO2), Pandora Spectrometers (O3, NO2, H2O, aerosols), CIMEL photometer (aerosols), YES broad-band UV radiometer, and meteorological sensors (for air temperature and relative humidity measurements). The atmospheric data acquired during BAQUNIN lifetime will be made available to the scientific community, and will contribute to the validation of the aerosol and tropospheric trace gases products produced by the Copernicus Sentinel-5p, Sentinel 4 and Sentinel 5 and by the ESA Third Party Missions (TPM), such as the ozone Monitoring Experiment (OMI).In this work, the BAQUNIN Super Site structure and operation strategies will be described in details.


Figure 1. BAQUNIN Super Site Locations: “Sapienza” University (Lat: 41.90, Lon: 12.52, Alt: 75 m) in the centre of the city and the European Space Agency – European Space Research Centre ESA-ESRIN(Lat: 41.83, Lon: 12.67 , Alt: 190), ~15 Km away.

Figure 2. University of Rome- BAQUNIN Super Site instrumentation: YES broad-band UV radiometer, Brewer spectrophotometer, meteorological sensor, MFRSR radiometer , SODAR, Prede POM01 and Pandora 2S.

Figure3. ESA- BAQUNIN Super Site instrumentation: Pandora 2S and CIMEL in ESRIN/ESA site.s

The BAQUNIN super site instruments are located at Physics Department of “Sapienza” University of Rome and at the European Space Agency – European Space Research Centre ESA-ESRIN, as shown in Figure 1. In Figure 2, the University instruments are shown, the picture in Figure 3 shows the two additional instruments recently included in the BAQUNIN suite: a PANDORA 2S spectrometer and a CIMEL.

The following instruments operated in the context of BAQUNIN are included in national/international networks:

Pandora -> PANDONIA network
CIMEL -> **AE**rosol **RO**botic **NET**work (AERONET )
Prede -> **E**uropean **S**kynet **R**adiometers network (ESR)
Brewer -> **Eu**ropean **Brew**er **Net**work (EuBrewnet)

In this work, some of the results obtained during the last measurements campaign carried out at the University of Rome, when the instruments have worked in synergy, are showed. The campaign took place from 20 June to 20 July of 2011, with the focus on the characterization of atmospheric aerosol in the urban environment of Rome (URBan Sustainability Related to Observed and Monitored Aerosol, URBS- ROMA). The results shown here, refer only to some instruments of the BAQUNIN super site: the elastic Lidar [1, 2], the Sodar [3, 4], the Prede Pom 01 radiometer [5], the Multi Filter Rotating Shadow-band Radiometer and the Brewer MKIV.

The Figure 4 shows the aerosol backscatter ratio (BKR) during the entire campaign as retrieved from elastic Lidar measurements. Values of BKR in the range (0.15-2.50) reveal the presences of aerosols, values outside this range refer to clouds or "clean" atmosphere. The two days 11 and 17 July are of particular interest: in fact it is possible to appreciate during the first day the enhanced presence of aerosol in the BKR values in the 2-4 km altitude range respect the second day. This difference is also clearly visible in Figure 5, where the size distribution vs. radius of particles (as estimated from Prede POM 01 sun sky radiometer instrument) is shown for the two days. A further confirmation comes from the results of the BSC-DREAM model displayed in Figure 6 where the different forecasts of dust optical depth and cloudiness for these days are shown.

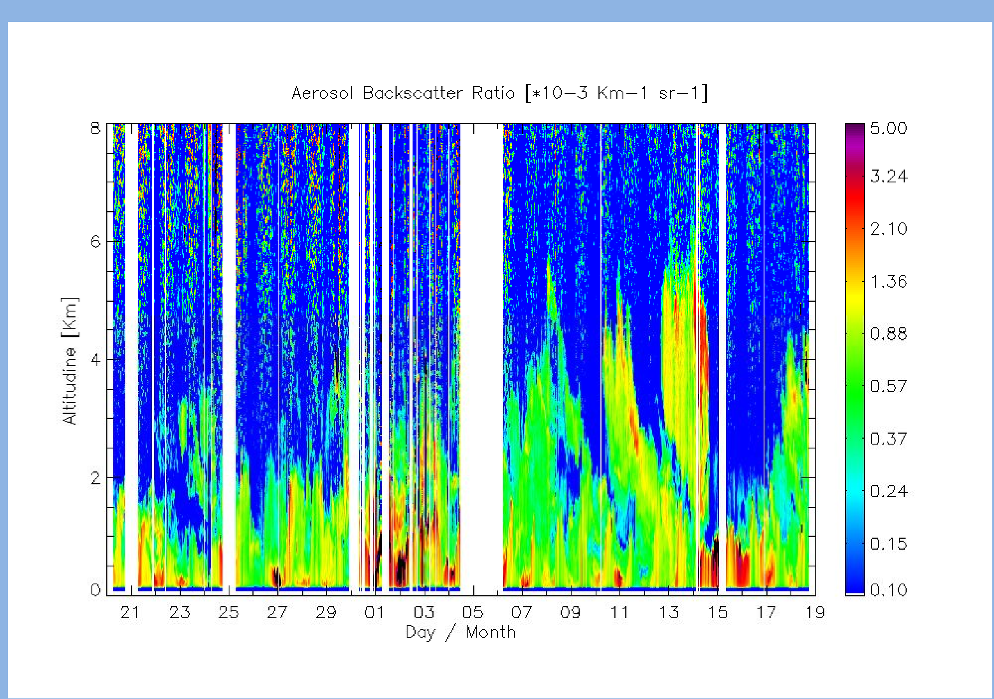


Figure 4. Aerosol Backscater Ratio (BKR) recorded during URBS-ROMA campaign observation with an elastinc Lidar (Light Detection And Ranging) system at the wavelength 532 nm.

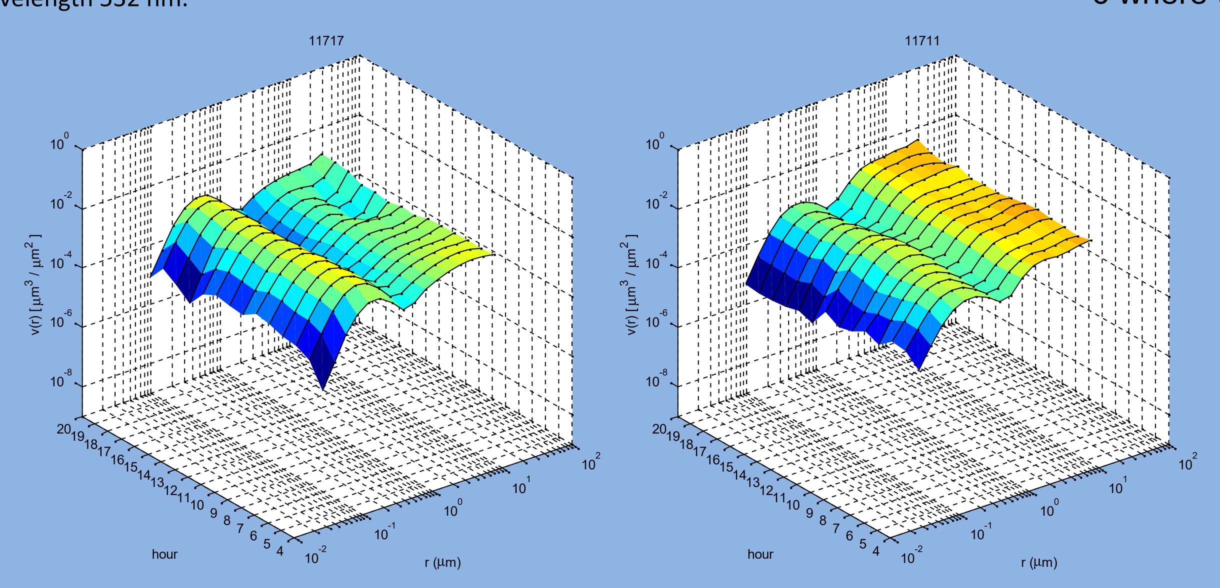

Figure 5. Daily evolution of aerosol volume size distributions are shown for a day with only anthropogenic aerosol ( 17 July ) and with the passage of desert dust (11 July). The difference is highlighted by the increase of the volume occupied by particles with radius between 1-5 um.

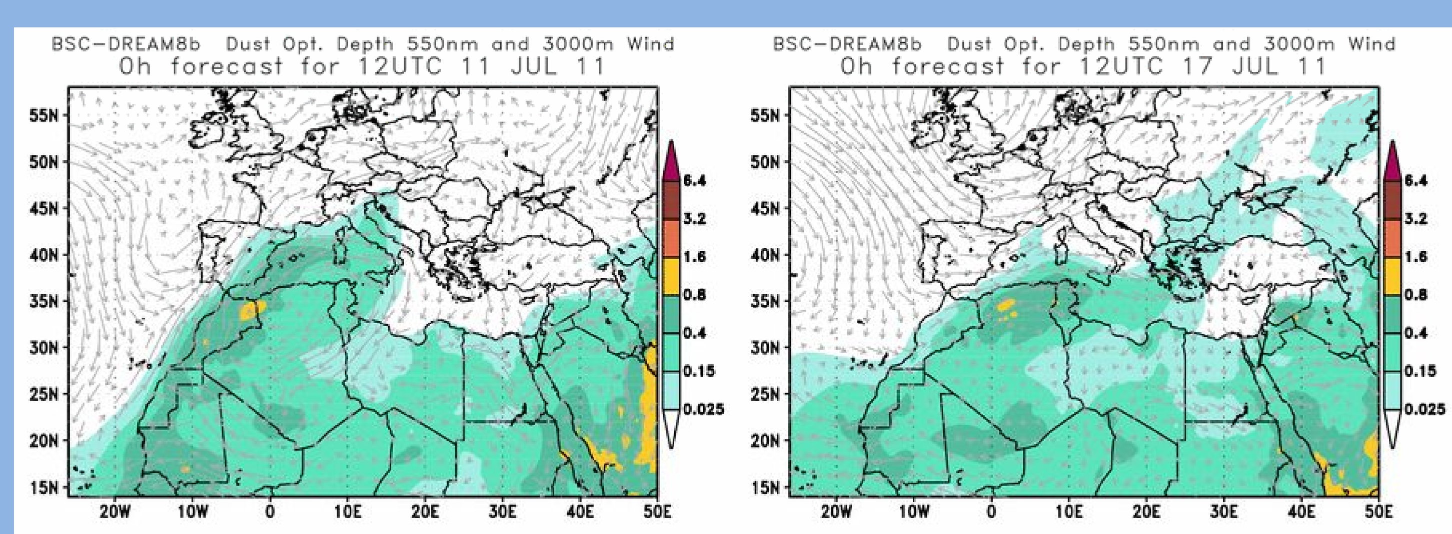


Figure 6. Dust optical depth and cloudiness for the days 11 and 17 July 2011 obtained with BSC-DREAM model.

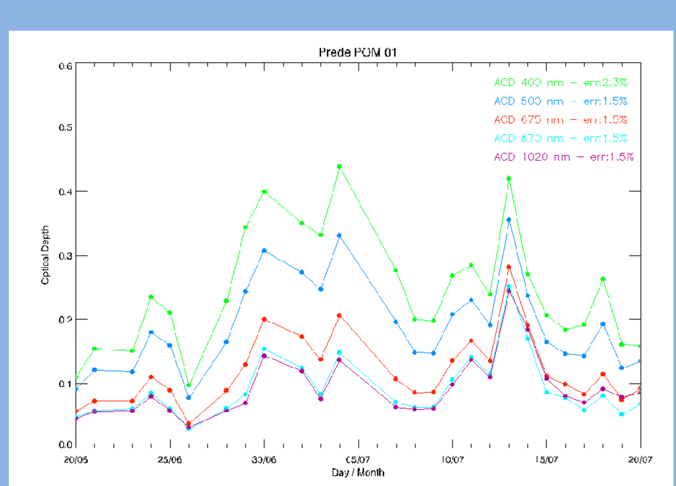


Figure 7. Time pattern of aerosol optical depth retrieved from Prede POM 01 in clear sky during the URBS-ROMA campaign.

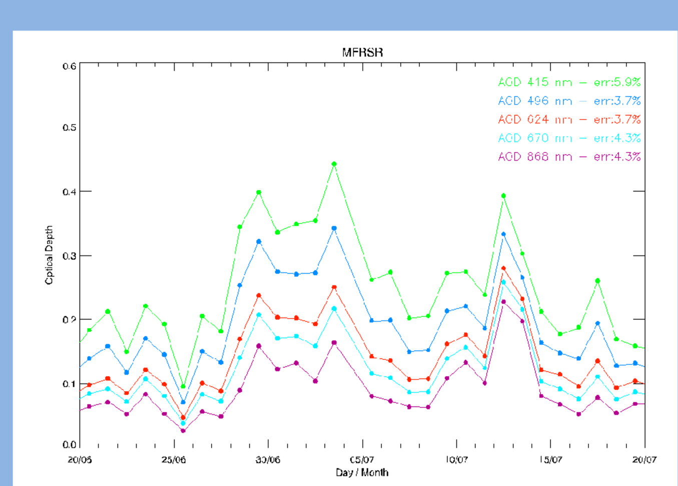


Figure 8. Time pattern of aerosol optical depth retrieved from MFRSR in clear sky during the URBS-ROMA campaign.

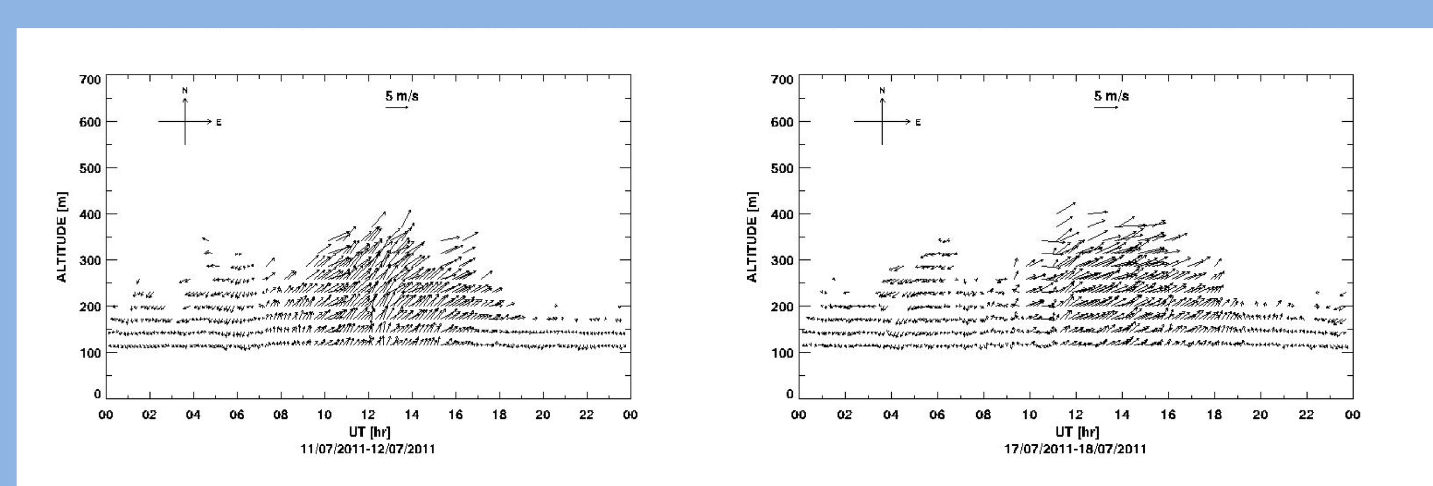


Figure 9. Horizontal wind speed and direction by a triaxial Doppler Sodar on 11 and 17 July 2011. The arrows are oriented along the wind direction, and their length is proportional to the wind speed.

The aerosol optical depth (AOD) is also estimated with the Prede POM 01 sun sky radiometer and the MFRSR for several wavelengths in the range 415 to 1020 nm. In the Figure 7 and 8 the AOD values obtained from the radiometers are reported during observation of 11 and 17 July. For these days the Sodar horizontal wind speed profiles are shown in Figure 9, in both days is present a sudden change in wind direction and strength after 10 UT driven by the sea-breeze development.

The columnar amount of $O_3$ and $NO_2$ are estimated from the Brewer measurements: the Figures 10 and 11 show the Brewer daily amounts of $0_3$ and $NO_2$ (green dots) during the entire campaign, along with the collocated Ozone Monitoring Experiment, OMI (red dots) [6] . At this stage, the OMI 0.25°x0.25° daily fields are used; the use of satellite Level 2 products will be the baseline for the operational comparison/validation activities of BAQUNIN. For what concern $O_3$ , there is a good agreement between Brewer and OMI. For the $NO_2$ the agreement between daily average Brewer data and OMI is poor (Figure 10). Selecting the Brewer $NO_2$ values acquired in a range of ±two hours from the OMI overpass time (about 1:45pm, local time), the agreement with OMI improves significantly, as shown in Figure 12, demonstrating that diurnal variations on $NO_2$ must be carefully considered when comparing ground based and satellite products. (Table 1)

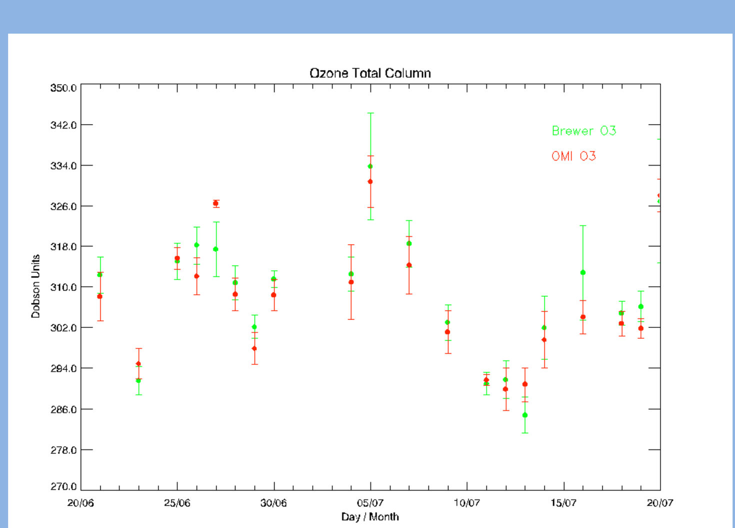


Figure 10. Brewer daily vertical column density (DU) of $0_3$ during the entire campaign, with the collocated OMI .

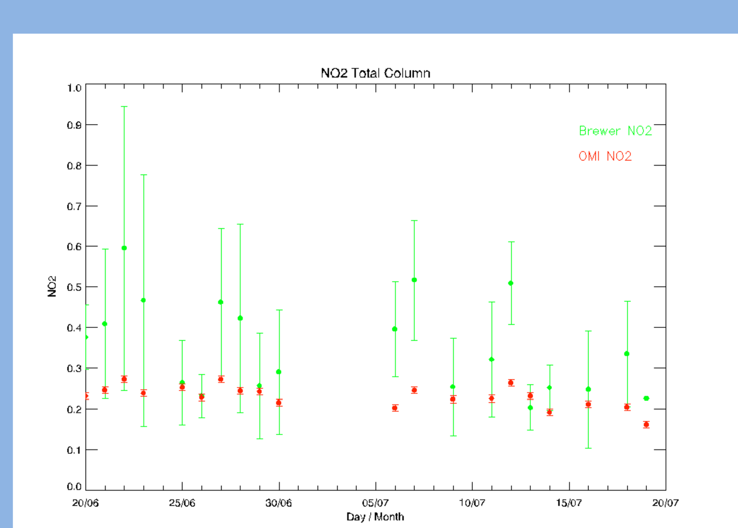


Figure 11. Brewer daily vertical column density (DU) of $NO_2$ during the entire campaign, along with the collocated OMI.

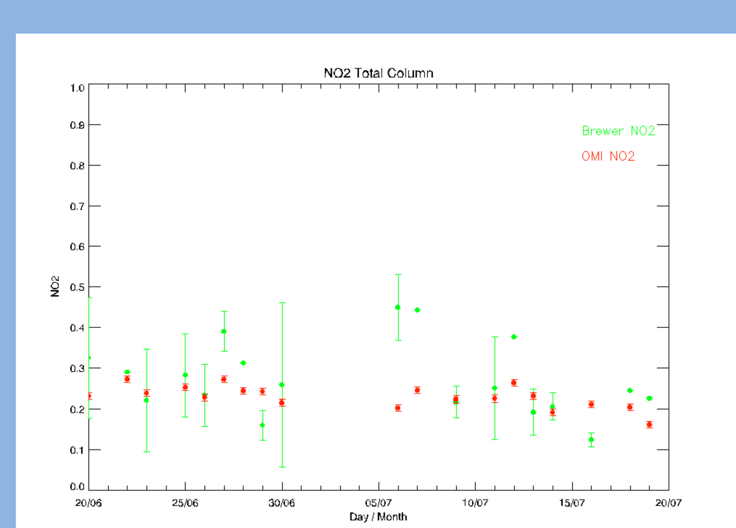


Figure 12. Comparison between the Brewer and the OMI $NO_2$ vertical column density (DU) selecting only data acquired in a range of ±two hours from satellite overpass time (about 1:45pm, local time) .

| | O3 | NO2 | NO2 (±2 hours) |
|---|---|---|---|
| Bias | 1.6108 | 0.1216 | 0.0446 |
| Sdev | 4.0500 | 0.1001 | 0.0844 |
| Bias (%) | 0.5243 | 52.8870 | 19.4631 |
| Corr | 0.9446 | 0.6313 | 0.3484 |

Table 1. Bias calculated as Brewer—OMI value, Standard deviation (Sdev), Bias (%) and correlation coefficient (Corr).

**Acknowledgments**

Giovanni: Analyses and visualizations used in this work were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC.

BSC: Images from the BSC-DREAM8b (Dust REgional Atmospheric Model) model, operated by the Barcelona Supercomputing Center
http://www.bsc.es/projects/earthscience/BSC-DREAM/

## Conclusions

The BAQUNIN site, with its suite of instrument of different types and application domains, is the ideal tool for the validation of satellite instruments aiming at the characterization of atmospheric pollution. The synergistic use of rural (ESA/ESRIN) and urban (“Sapienza” University) measurements will contribute to significantly improve the confidence on the validation results that will be carried out for S5p, S4 and S5 missions.

**Links**

- Pandonia Network
http://www.pandonia.net
- Aeronet Network
http://aeronet.gsfc.nasa.gov/
- Euroskyrad network
http://www.euroskyrad.net/
- Sentinel Mission
https://sentinel.esa.int/web/sentinel/home
- EuBrewnet
http://rbcce.aemet.es/eubrewnet

## References

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