ATMO ACCESS
Access to Atmospheric Research Facilities

Activity report of the TNA to ATMO-ACCESS research infrastructures

Name and First Name:

Rayonil Gomes Carneiro
Camilla Kassar Borges

TNA title and acronym:

Structure and dynamics of the planetary boundary layer in urban environment ecosystem (BOLAUR).

Facility accessed:

22. WOS - Warsaw Observatory Station

Location: Warsaw, Poland

Web site address: https://www.igf.fuw.edu.pl/en/instruments/

This work has received funding from the European Union's Horizon 2020 research and innovation programme through the ATMO-ACCESS Integrating Activity under grant agreement No 101008004

Instructions

Please limit the report to max 3-5 pages, including tables and figures.
The report should be sent as pdf document and include the subheadings listed below. Please make sure to address any comments made by the reviewers (if applicable).

Is the information provided in the report confidential and should not be made available on the ACTRIS website?

☒ No, the information can be made public.

☐ Yes, the information should not be made public and access should be restricted to the TNA Team, the ATMO-ACCESS access providers, the reviewers concerned and the ATMO-ACCESS Strategic TNA Board.

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1. Short executive summary (can be made available to reviewers and EU experts)

Studies in urban areas are vitally important to understand the dynamics of turbulent fluxes associated to the surface-atmosphere interaction within in the planetary boundary layer (PBL). The objective scientific of the access Remote Sensing Laboratory (RS-Lab) at Warsaw Observatory Station (WOS) is a creation of new knowledge about turbulence within the boundary layer and the relation with atmospheric pollution in urban environment. The joint interest of both teams would be also in assessing the potential for applicability of surface turbulent exchange detection techniques, such as eddy covariance, in Warsaw's urban ecosystem, in order to invest in scaling up measurements in WOS/RS-Lab.

2. User group

Complete the table with details of the user group members who actually accessed the Facility. Duplicate the table below for each member of the user group.

Information on the User group members	
Member # 1	
First and last name	Rayonil Gomes Carneiro
Gender	☐ Female ☒ Male ☐ Prefer not to say
Nationality	Brazil
Profile	☐ Undergraduate ☐ Postgraduate ☐ Expert scientist ☐ Engineer, Technician ☐ Other
Field of activity	☒ ENV-ATMO - Earth and environmental sciences/Atmospheric domain ☐ ENV-HYDRO - Earth and environmental sciences/Hydrosphere domain ☐ ENV-LITHO - Earth and environmental sciences/Lithosphere ☐ ENV-ECOBIO - Earth and environmental sciences/Eco-biosphere ☐ PHY - Physics astronomy, astrophysics and mathematics ☐ CHEM - Chemistry and material sciences ☐ BIO-MED - Biological, medical sciences and biotechnology ☐ ENG-TECH - Engineering and technology

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	☐ EGY - Energy ☐ ART - Humanities and arts ☐ ISC - Information science and communication ☐ SOC - Social sciences		
Are you a new user?	☒ Yes ☐ No		
Institution name (employer)	National Institute of Space Research		
Institution legal status (employer)	☒ Public research (including international research organizations and private research organization controlled by a public authority) ☐ University and higher education ☐ Public authority ☐ Small Medium Enterprise (SME) ☐ Other industrial and/or profit private organization ☐ Other		
Address (employer)	São José dos Campos - SP São José dos Campos - SP	**Country**	Brazil
Email address	rayonilcarneiro@gmail.com		
Access start date	26/09/2022	**Access end date**	21/10/2022

Information on the User group members	
Member # 2	
First and last name	Camilla Kassar Borges
Gender	☒ Female ☐ Male ☐ Prefer not to say
Nationality	Brazil
Profile	☐ Undergraduate ☐ Postgraduate ☐ Expert scientist ☐ Engineer, Technician ☐ Other
Field of activity	☒ ENV-ATMO - Earth and environmental sciences/Atmospheric domain ☐ ENV-HYDRO - Earth and environmental sciences/Hydrosphere domain

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	☐ ENV-LITHO - Earth and environmental sciences/Lithosphere ☐ ENV-ECOBIO - Earth and environmental sciences/Eco-biosphere ☐ PHY - Physics astronomy, astrophysics and mathematics ☐ CHEM - Chemistry and material sciences ☐ BIO-MED - Biological, medical sciences and biotechnology ☐ ENG-TECH - Engineering and technology ☐ EGY - Energy ☐ ART - Humanities and arts ☐ ISC - Information science and communication ☐ SOC - Social sciences			
Are you a new user?	☒ Yes ☐ No			
Institution name (employer)	Federal University of Campina Grande			
Institution legal status (employer)	☐ Public research (including international research organizations and private research organization controlled by a public authority) ☒ University and higher education ☐ Public authority ☐ Small Medium Enterprise (SME) ☐ Other industrial and/or profit private organization ☐ Other			
Address (employer)	Campina Grande - PB	**Country**	Brazil	
Email address	camillakassar@gmail.com			
Access start date	26/09/2022	**Access end date**	21/10/2022	

3. Scientific objectives

This scientific access service by ATMO – ACCESS TNA in Remote Sensing Laboratory (RS-Lab) at Warsaw Observatory Station (WOS) had the objective to deepen the knowledge of the characteristics of turbulence and aerosol concentrations within the planetary boundary layer (PBL) in the urban area of Warsaw.

Through the excellence in measurements and research of the physical properties of the atmosphere by the WOS/RS-Lab and the expertise of the proponent group in studies of turbulence at the surface-atmosphere interaction interface and in PBL modeling.

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Another joint interest research topic of both teams was also in assessing the potential for applicability of surface turbulent exchange detection, eddy covariance techniques, at Warsaw's urban ecosystem, in order to invest in scaling up measurements in WOS/RS-Lab. For integrated ecosystem stations by ICOS (Integrated Carbon Observation System) network and protocols.

4. Reasons for choosing the Facility/ies

The choice of WOS/RS-Lab was due to the remarkable background in the line of research on atmospheric turbulence, physical properties of aerosols in the troposphere and lower stratosphere over urban areas. Since, the WOS/RS-Lab expertise in measurements by remote sensing of the atmosphere provided an excellent exchange of knowledge and research development around the project's objectives.

In addition, we had an opportunity to formalize pre-conceptual collaboration between TNA requesting researchers (Brazil) and host researchers (Poland) in atmospheric physics and meteorological research (projects and publications), for the reason that we have been in contact with prof. Iwona Stachlewska since 2021 using remote access mode.

5. Activities during the TNA (research, training, events, ...)

During the physical access TNA both teams, the provider, Prof. Iwona Stachlewska and Prof. Dr. Szymon P. Malinowski Director Institute of Geophysics (IGF), and the visitors, Dr. Rayonil Carneiro and Dr. Camilla Borges were undergoing wide expertise exchange related to both observations and modeling. The proponents were acquainted with the operations and roles of various ACTRIS instruments and ACTRIS principles for data provision, evaluation, etc. This was provided by the WOS/RS-Lab members (Dr. Lucja Janicka, Mgr. Patryk Poczta, Dr. Wojciech Kumala, and Dr. Dominika Szczepanik).

Through these facilities, we processed and analyzed data to make simulations by PALM and retrieve turbulence variables within PBL in Warsaw urban environment. We also evaluated the feasibility and the environmental characterization to deploy an EC system in Warsaw's urban ecosystem.

6. Method and set-up of research

The WOS/RS-Lab at the Institute of Geophysics, Faculty of Physics, University of Warsaw (FUW) at an urban station of Warsaw (52.21°N, 20.98°E, 110 m a.s.l.; www.igf.fuw.edu.pl), Figure 1, comprises research platforms installed on the roof of the university building.

The location of this station, close to several main roads but also to a large park (Pole Mokotowskie), is typical for the agglomeration of Warsaw (2,000,000 population). This site has continuous measurements of standard meteorological parameters, radiation fluxes, *in situ* and columnar aerosol optical and microphysical properties, and vertical profiles from lidar (Wang et al., 2020).

Warsaw is characterized by mainly flat topography and that has, according to the Köppen-Geiger climate classification, a humid continental climate (Dfb), with long cold winters, and short hot summers. The annual average temperature varies between -1.8 °C in January and 19.2 °C in July, the average precipitation is 529 mm and the average relative humidity is 79% (Żmudzka, 2019; Weather-Atlas, 2020).

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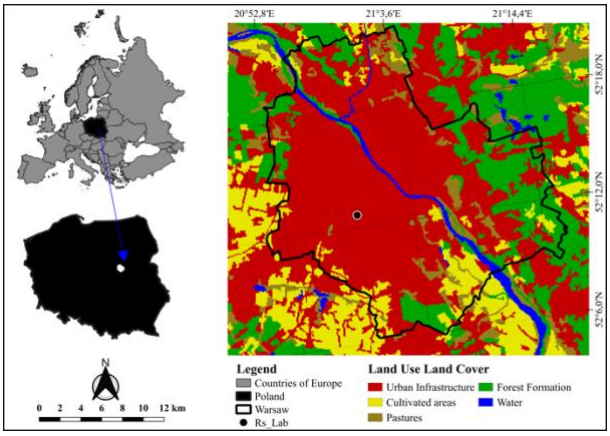

Figure 1. *Localizations of Warsaw city.*

Instruments and measurements

During the BOLAUR TNA we used data from remote sensing observations installed on the WOS/RS-Lab terrestrial platform. The turbulent fluxes and the height of the PBL in Warsaw were calculated. These instruments are described below:

- Doppler lidar Stream Line (METEK GmbH, Halo Photonics Ltd) consists of a pulsed solid-state laser that emits infrared radiation and a heterodyne detector with fiber optic technology, capable of detecting the variation in the frequency of the received radiation due to the movement of particles in the aerosol with the wind. it is possible to obtain vertical profiles of three-dimensional wind vectors at different altitudes within the entire PBL.

- Lidar PollyXT & NARLa This lidar emits laser pulses at three wavelengths (UV, VIS and IR) with frequency of 20Hz, measurements are performed on 8 channels using the large telescope (far-field) and on 4 channels using the small telescope (near-field). The measurements can be evaluated to obtain the PBLH using different methods.

- Microwave radiometer HATPRO-G2 (Radiometer Physics GmbH) consists of two working bands 22–31 and 51–58 GHz, each with seven channels. Taking a tier 1 products are glow temperatures. Tier 2 products are integrated water vapor, liquid water path and vertical profiles of absolute humidity, relative humidity, water vapor, temperature and PBLH.

In addition to the remote sensors, WOS/RS-Lab measurements of meteorological variables were also used for analyzing the surface condition (air temperature, specific and relative humidity, sensible heat flux and radiation), wind regime (wind speed and direction). These data were also used to input model.

Methodologies for Lidar Measurement of PBLH

In partnership with the WOS/RS-Lab group (mgr Maciej Karasewicz and prof. Iwona Stachlewska), the PollyXT lidar data in Warsaw were used to estimate the height of the PBLH using three different methods: (1) gradient methods, (2) the wavelet covariance transform (WCT), and (3) Graphic Analysis Method (AG). The results of the observations were compared among themselves and with the simulations of the PALM model.

The Parallelized LES Model (PALM)

Numerical simulations of the Parallelized LES Model (PALM) were performed to obtain greater detail of the turbulence within the PBL. The PALM model has a computational structure capable of optimizing performance and high scalability to calculate massively parallel architectures (Raasch and Schröter, 2001; Maronga et al. 2015 and 2020).

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During the BOLAUR TNA the simulations were carried out in different seasons for the city of Warsaw. The simulations were generated with a horizontal (x, y) domain of 5.0 km × 5.0 km and a vertical (z) domain of 5.0 km, with a grid spacing of 5.0 m for horizontal scales (Δx, Δy) and vertical (Δz).

The performance of PALM model over Warsaw urban area was quantified against observed data using four model efficiency scores, coefficient of determination (r^2), bias, root-mean-square error (RMSE) and the correlation coefficient (CC).

7. Preliminary project results and conclusions

The preliminary results obtained during BOLAUR TNA in relation PALM simulations are showed below. The PBL heights obtained by PALM, together with three methos of Lidar estimate during the daily cycle for the representative days of winter (January 15), springer (May 09), summer (June 18) and autumn (October 03) of 2021 are shown in Figure 2.

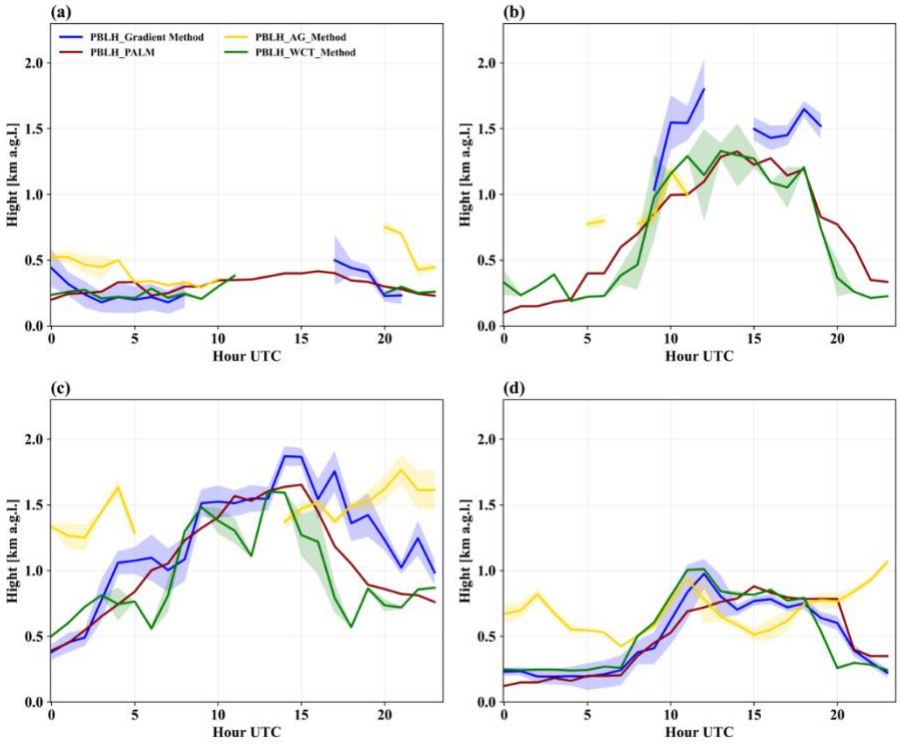

Figure 2. *Heights of the PBL over WOS/RS-Lab in Warsaw (a) winter (January 15), (b) springer (May 09), (c) summer (June 18) and (d) autumn (October 03).*

The PBLH daily cycle from PALM for the representative dates for all seasons were satisfactory in relation the observational data and the PBLH average of ten years results obtained from Wang et al. (2020). During the rainy season (Figure 2a) PALM and analytical methods from Lidar data showed the height below 500 m. For other seasons, PALM had a small underestimated PBLH at beginning of the daily cycle (Figures 2b and d) and overestimated at the end of the day (Figures 2b and c). As we can observe in the results of the statistical methods applied (Table 1).

Generally, the Gradient and WTC methods showed suitable results in relation the regular PBLH daily cycle. However, AG method showed elevated heights during stable PBL phase, which is not the regular pattern, showing higher RMSE (ranging from 0.22 to 1.60 m) compared to PALM and low correlation (ranging from 0.10 to 0.40). Hence this method needs to be improved for futures applications.

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Table 1. *Comparison of r², BIAS, RMSE and CC between PALM and Lidar Methods.*

	PALM X GRADIENT METHOD				PALM X WTC METHOD				PALM X AG METHOD			
	Jan	May	Jun	Oct	Jan	May	Jun	Oct	Jan	May	Jun	Oct
r²	0.13	0.71	0.80	0.87	0.10	0.84	0.71	0.66	0.10	0.60	0.40	0.30
BIAS	0.01	-0.35	-0.16	0.01	0.02	0.03	0.10	-0.03	-0.17	-0.15	-0.55	-0.20
RMSE	0.10	0.43	0.25	0.10	0.06	0.18	0.22	0.17	0.22	1.23	1.60	1.30
CC	0.35	0.85	0.88	0.93	0.25	0.91	0.83	0.80	-0.10	0.40	0.40	0.40

EC system feasibility

The instructions about the technical implementation of all data to be acquired are available via the Ecosystem Thematic Centre (www.icos-etc.eu/documents/instructions). According to the assumptions in the EC theory (Burba et al., 2022), the site selection should minimize systematic biases that may be caused by changing land cover within the flux source area, by topography, and by obstacles that can cause flow distortion. Measurements at a point are assumed to represent an upwind area, and they are done inside the boundary layer where the flux is constant (located approximately 1.5-2 canopy heights above the soil surface, or at least 2.0-3.0 m above the top of the canopy) (Rebmann et al., 2018; ICOS ETC, 2022). In this way, the average height of the buildings was estimated (Figure 3a) using the "Building Height" product from remote sensors obtained on the Copernicus platform (https://land.copernicus.eu/local/urban-atlas/building-height-2012?tab=metadata). Since this average height can be considered as the average height of the urban canopy (Aubinet et al, 2012), therefore, the average height of buildings around the WOS/RS-Lab with a radius of 1,000 m was 12.2 m ± 6.9 m.

The supporting boom for the sonic anemometer and gas analyzer inlet should be directed into the prevailing wind direction to maximize exposure time for the wind blowing. The boom of the sonic anemometer must face away from the mast structure (Rebmann et al., 2018; ICOS ETC, 2022). In this way, the predominant wind direction and intensity were calculated using the wind data provided by WOS/RS-Lab and the predominant winds (NW), (Figure 3b).

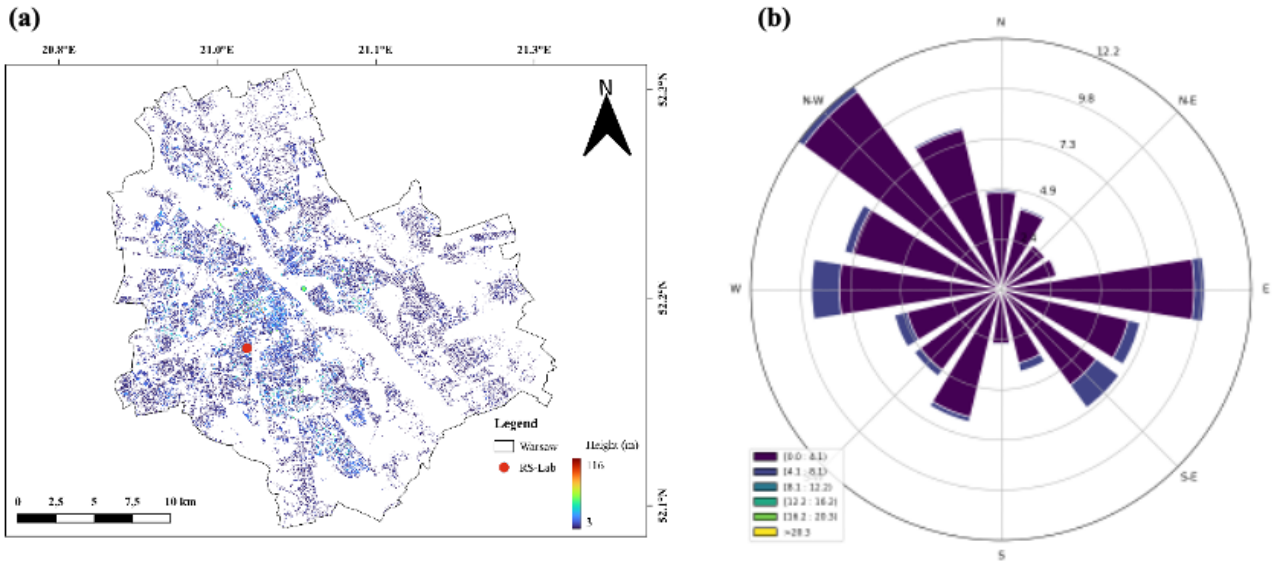

Figure 3. *(a) Building height map of Warsaw and (b) the wind rose derived from wind directions and wind speeds observed between 2018 to 2022.*

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8. Outcomes and future studies

During the BOLAUR TNA we managed to strengthen collaboration between users and host group, specifically in relation to the PBL studies and turbulent fluxes, through the numerical model and observational data use, which provides the deepening and exchange of knowledge for both parts. From this partnership, scientific publications are being developed, and a research project is written to be applied to the National Science Centre of Poland at the end of the year. Concerning the survey on the EC system feasibility, a preliminary budget was made (***note that, as it is concerning certain private companies, this information cannot be made publicly available!***), and application for other scientific projects.

9. Plans for publications

We are preparing a scientific paper about the PALM versus observational data, that probably will be submitted in Atmospheric Chemistry and Physics at the beginning next year. For EC system feasibility in urban ecosystem of Warsaw a technical publication is being prepared to be submitted, likely in Scientific Research Reports.

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