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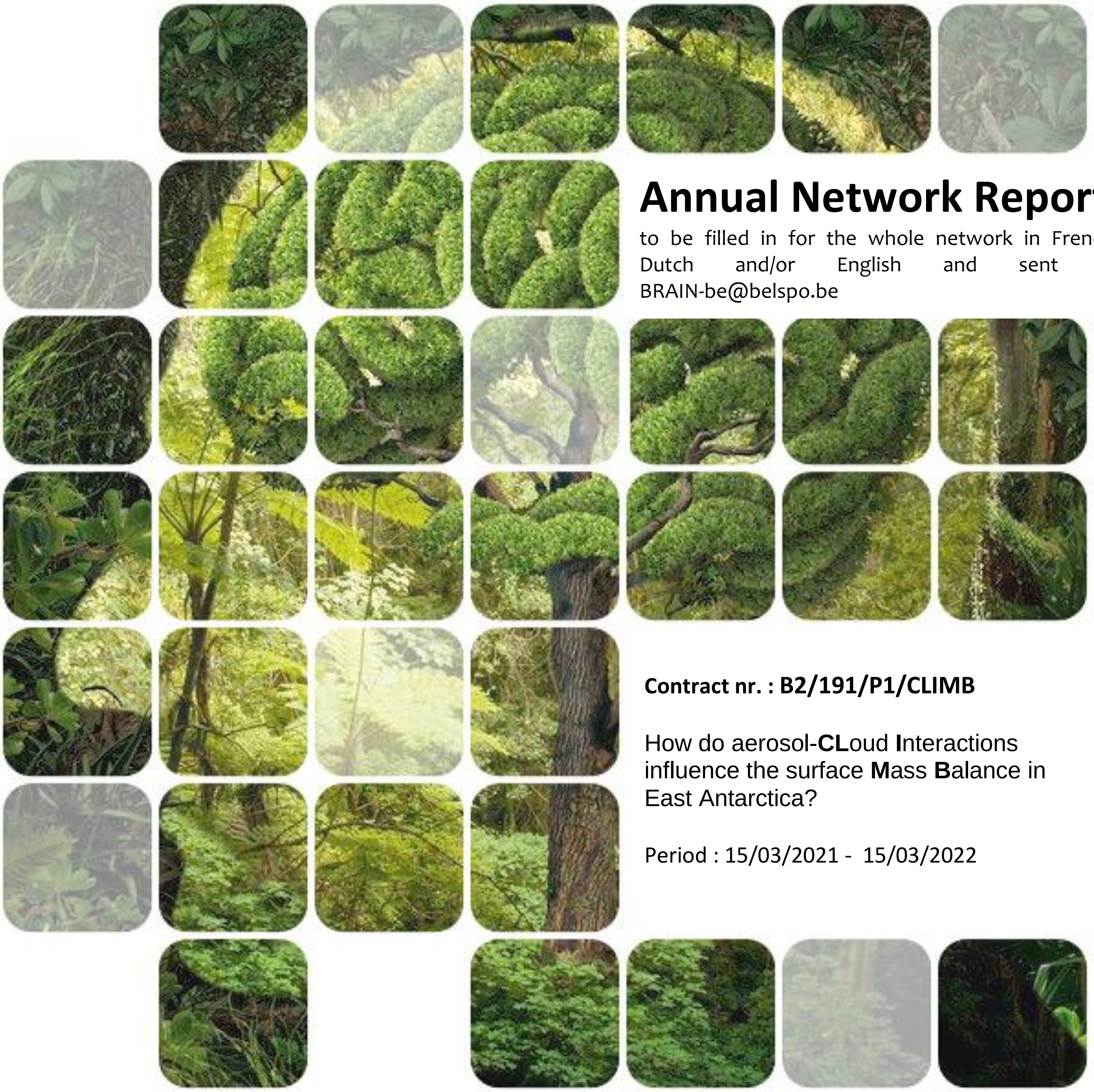
# BRAIN-be

BELGIAN RESEARCH ACTION THROUGH INTERDISCIPLINARY NETWORKS



## Annual Network Report

to be filled in for the whole network in French, Dutch and/or English and sent to BRAIN-be@belspo.be

**Contract nr. : B2/191/P1/CLIMB**

How do aerosol-**CL**oud **I**nteractions influence the surface **M**ass **B**alance in East Antarctica?

Period : 15/03/2021 - 15/03/2022

.be

## NETWORK

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2. Prof. Dr. Nicole van Lipzig, Katholieke Universiteit Leuven, (KUL)
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### PROJECT WEBSITE:

https://ozone.meteo.be/projects/climb

Yearly, one report (max. 15-20 pages) should be filled in for the whole network in French, Dutch or English and sent to BRAIN-be@belspo.be.

## ABLE OF CONTENTS

## 1. EXECUTIVE SUMMARY OF THE REPORT

**How do aerosol-cloud-interactions influence the surface mass balance in Antarctica ?**

CLIMB performs measurements of meteorological, aerosol, cloud and precipitation characteristics at Princess Elisabeth Antarctica station (PEA) and directly at the cloud level, with cost- and logistics-efficient small-sized instrumentation, continuously at least during austral summer. In addition to extended Ice Nuclei filter sampling at PEA, there will be (i) a vertically resolved, continuous (year-round) profile of temperature, relative humidity and pressure for three heights: at PEA (1390 m asl), on the Utsteinen nunatak summit (around 1600 m asl) and in the Vikinghogda mountains; (ii) Measurements of precipitation type, intensity and droplet/crystal size by two disdrometers; one will be placed in the mountain and one at PEA, in order to be able to compare the data with the existing micro-rain radar at PEA; (iii) cloud-level measurements of aerosol particle number distribution; (iv) an automated sampling system for VOCs in the mountains.

The work is subdivided in tasks and deliverables, executed by the different partners of this project. Their progress regarding the different deliverables is listed in table 1. The start date of the project was 15/12/2019. The project has been prolonged until 15/03/2023. With this prolongation, the data time series are distinctly extended – two years and three austral summers for the instruments installed during season 2020/21 and one year with two austral summers for the instruments installed during this season 2021/22. In the table below, an updated timeline for the deliverables, extended until 15/03/2023 is given. Month 1 is April 2020 and month 36 is March 2023.

| No. / Partner | Description | | Subm. date | Status |
|---|---|---|---|---|
| D1.1 / KUL | Database with cloud and precipitation properties ready for comparison with model comparison | original | M24 | |
| | | updated | M36 | PROG |
| D2.1 / RMI | Physical aerosol properties characterised for boundary layer and for the cloud level | original | M23 | |
| | | updated | M34 | PROG |
| D2.2 / IASB-BIRA | Total column and vertically resolved aerosol properties | original | M23 | |
| | | updated | M35 | PROG |
| D2.3 / IASB-BIRA | Improved radiative transfer modelling for aerosol composition retrieval | original | M24 | |
| | | updated | M35 | PROG |
| D2.4 / Tropos | INP analysis done and measured IN concentrations available | original | M24 | |
| | | updated | M36 | PROG |
| D3.1 / UGent | Assembly of automated sampler for VOCs | original | M6 | |
| | | updated | M18 | FIN |
| D3.2 / UGent | Quality-checked data for (S-) VOCs measured at cloud level | original | M24 | |
| | | updated | M36 | PROG |
| D4.1 / RMI | Vertically resolved meteorological analysis of the region around PES | original | M23 | |
| | | updated | M36 | PROG |
| D4.2 / RMI | Source regions and atmospheric transport pathways of moisture, particles and VOCs into Antarctica | original | M23 | |
| | | updated | M32 | PROG |
| D5.1 / KUL | Improved COSMO-CLM2 model | original | M17 | |
| | | updated | M30 | PROG |
| D5.2 / KUL | Estimated effect of aerosols on the East Antarctic Climate | original | M24 | |
| | | updated | M36 | PROG |
| D6.1 / RMI | Management of project and network | original | | |
| | | updated | | CONT |
| D6.2 / ALL | An operational atmospheric observatory at PES | original | | |
| | | updated | | CONT |
| D6.3 / ALL | Quality-controlled data and accessible data base | original | | |
| | | updated | | CONT |
| D6.4 / ALL | Results published to scientific community, policy stakeholders | original | | |
| | | updated | | CONT |
| D6.5 / ALL | Scientific workshop organised | original | M24 | |
| | | updated | M31 | PROG |

**Table 1: List of intermediate and final deliverables with deliverable date, counted from April 2020: finished (FIN), in progress (PROG), or continuous (CONT).**

Two remote sensing instruments dedicated to aerosols have been installed and operated successfully on the roof of PEA: a CIMEL sunphotometer and a MAX-DOAS. The MAX-DOAS is still operational (with a data gap during winter due to the station power outage, see section 8). The MAX-DOAS data has been integrated in the analysis chain FRM4DOAS developed at BIRA-IASB. The data are processed automatically in near real-time. The Cimel was installed during the Belare campaign (December 2021 to February 2022) and its data are sent to the AERONET data base (https://aeronet.gsfc.nasa.gov/cgi-bin/data_display_aod_v3?site=Utsteinen&nachal=2&level=1&place_code=10 ).

Aerosol light scattering and absorption properties have been continuously measured (with the above-mentioned time gap during winter 2021). One disdrometer has successfully been installed end of December 2021 on the southern roof of PEA station and is still operational. The Optical Particle Sizer (OPS) for the remote Climb site has been successfully tested and installed during the Belare 2021/22 expedition. Also, the robust small meteo data loggers have been tested and successfully installed at the foreseen three sites. Also during Belare 2021/22 season, another set of six samples for the analysis on ice nuclei particle concentration could be collected:

One sample set on the automated sample system has been analysed and data will be made available. It was investigated with an in-situ experiment if breakthrough could be an issue for the used sample volume. For compounds which are reported to be active in photo-oxidation processes a seasonal variation can be observed. When the current measurement on the remote sites terminates and is collected successfully the final dataset for VOCs will consist of 2 years of data from the station with a 13-day resolution and 1 year of data from the plateau with a 6-day resolution, all analysed with 2 advanced instruments, using fully developed and optimised novel methods.

The FLEXTRA trajectory model has been applied in order to investigate possible source regions and transport pathways into Antarctica of atmospheric particles and S-VOCs. 10-days backward trajectories, starting from PEA, were calculated for a the period 2010 – 2020. A cluster analysis has been done for the whole period and also for each season separately. In addition, the backward trajectories have been combined with distinct parameters like particle number concentration, aerosol absorption exponent, potential vorticity, exposure to sunshine duration. Some distinct differences between seasons and clusters can be seen. Further, the FLEXPART dispersion model has been applied in order to identify potential source regions, e.g., for the individual sample periods of the active sampling during seasons 2017/18 up to 2020/21.

The ceilometer and precipitation radar are currently operational at the Princess Elizabeth station. An extensive maintenance on the precipitation radar, including replacement of the antenna, were done during the last campaign. These data are currently processed and used for model evaluation (COSMO-CLM2) with respect to the aerosol cloud interactions.

The following preparations were undertaken for the 2021/22 field campaign at PEA station:
- Virtual meetings and email-exchanges with the Station Operator in order to discuss the practical topics for the sampling campaign;
- Administrative organization of the campaign in cooperation with the polar secretariat and the station operator;
- Preparation of the necessary air cargo boxes and shipment forms;
- Florian Sauerland and Nicole van Lipzig (KU Leuven) prepared the maintenance protocols for the cloud observatory and coordinated the replacement of the MRR antenna;
- Preparation and testing of an upgraded version of the automatic remote sampler for VOCs;
- Preparation and testing of the Optical Particle Sizer, of the disdrometer and the small meteo data loggers
- A pre-campaign online briefing meeting on 9 November 2021

Preben Van Overmeiren (UGent) and Andy Delcloo (RMI) participated on the CLIMB project in the Belare 2021/2022 field campaign to Princess Elisabeth station. Both stayed from 9 December 2021 to 14 January 2022 at PEA.

Further details are described below within the progress per task section.

Coordinates of the CLIMB remote site:
72.27101 S / 23.25238 E / 2350 m asl

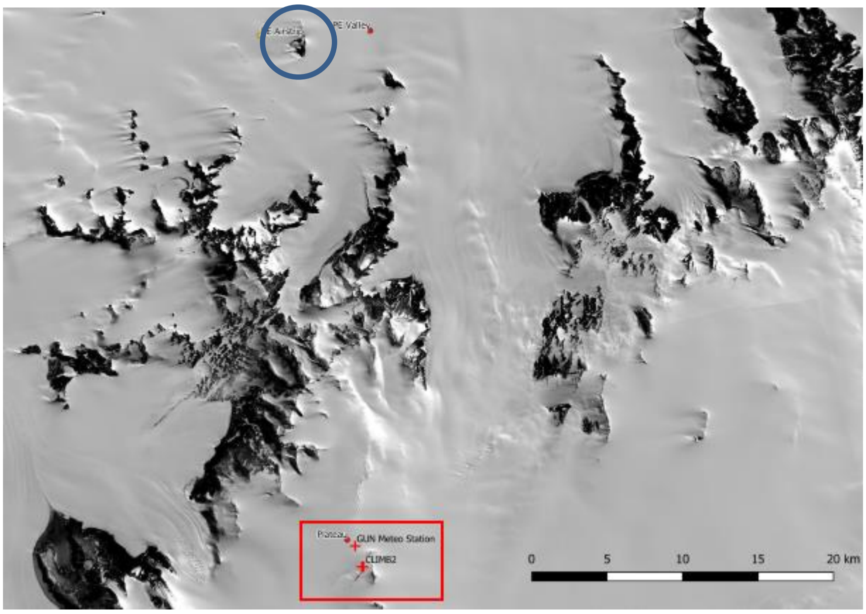

Figure 1: Location of the CLIMB remote site (red box);  PEA station in blue circle

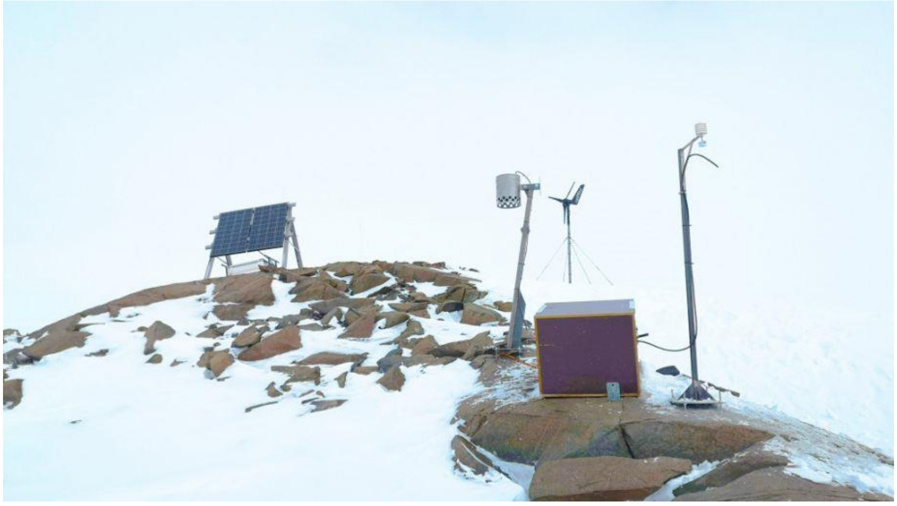
Figure 2: View of the installation at the CLIMB remote

## 2. ACHIEVED WORK

*Detailed description of the achieved work and tasks of the past reporting year*

**WP 1 : Cloud and precipitation properties (KUL)**

**Task 1.1 Deriving cloud and precipitation properties from existing instruments combined with new disdrometer data**

A database has been compiled of all available measurements from the Ceilometer and MRR instruments since the day of their first installation. This database will be updated with new measurements as they are taken by the instruments at the station. It will be used to identify periods of interest for further model runs and serves as the basis for making the data accessible to externals as well (see also Task 6.3). All the recordings have been backed up.

Among the available data, several data gaps have become apparent, which can be attributed to the power cuts at the station, as well as errors regarding the pre-processing. For the ceilometer, the pre-processing procedure has thus been revised and updated to deliver more reliable results with less manual work required in the future. For the MRR, incorrect instrument settings were identified and subsequently fixed after consulting with the manufacturer. Previously recorded data have been re-processed with correct instrument settings.

One disdrometer has been shipped to PEA, tested there and finally installed end of December 2021 on the southern roof of PEA. Since then it operates continuously. The second disdrometer, for installation at the remote Climb site has not been shipped because there was not enough time to test it for the remote conditions (power source, connection to data logging).

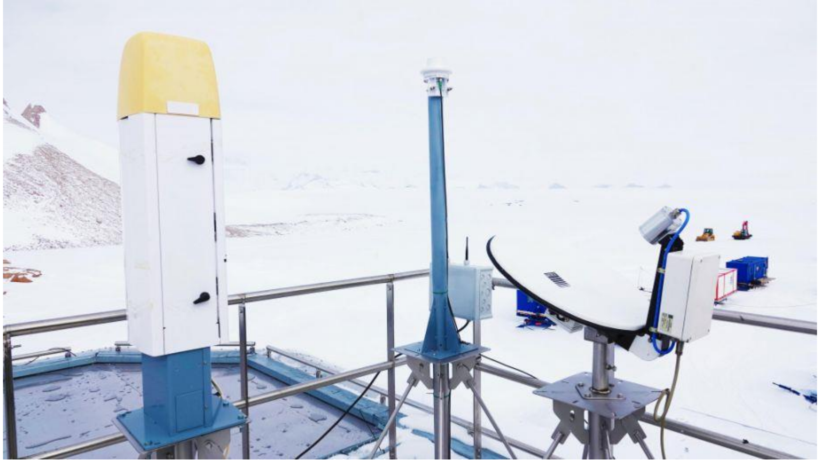

Figure 3:ceilometer (left), disdrometer (middle) and micro-rain radar right) on the southern roof of PEA station

**WP 2 : Characterisation of physical properties of atmospheric aerosol (RMI, BIRA, TROPOS)**

**Task 2.1: Physical aerosol properties characterization for boundary-layer aerosol and for the cloud level (RMI)**

Three instruments of the permanent aerosol observatory were operational during the reporting period: the TEOM, the nephelometer and the aethalometer. All three instruments measured continuously until the general power outage of PEA station beginning of June 2021. The aethalometer and nephelometer were restarted mid-November 2021 and are still operational. The TEOM, however, did not restart due to a defect in the control unit. The control unit had to be shipped back to Belgium and is currently at the supplier for repair. The Optical Particle Sizer (OPS) was tested in Belgium and at PEA before installation at the Climb remote site beginning of January 2022. With a mini-pc (raspberry pi), it was possible to solve the issue of the OPS that it loses its measurement settings after a power interruption. During a check visit at the Climb remote site after a strong storm improvements were done (inlet tubing protection against snow drift; power supply improvements for remote instrumentation).

**Task 2.2: Retrieval of total column and vertically resolved aerosol properties with remote sensing instrumentation (BIRA)**

After its installation during the first CLIMB season on 30 November 2020, The MAX-DOAS operated continuously until the power cut on 25 May 2021. We corrected an initially bad alignment of the MAX-DOAS on 26 February 2021, which prevented the measurements for telescope elevation below 8°. This improved the information content of the aerosol measurements.

The MAX-DOAS optical head was frozen when the first team arrived at PEA in November 2021. The station team dismounted the MAX-DOAS and dried it inside the station before restarting the measurements on 22 November 2021. The MAX-DOAS is still measuring at the time of writing this report. During the 2021-2022 season, we calibrated the elevation angle of the telescope (Fig 4.).

Figure 4: MAX-DOAS calibration of the horizon elevation (23 December 2021)

The CLIMB scientific team reinstalled the CIMEL sunphotometer on PEA's roof at arrival and the data acquisition started on 17 December 2021, until 13 February 2022 when it was dismounted for the regular shipping back for calibration.

**Task 2.3: Improved estimation of aerosol properties by radiative transport modeling (BIRA)**

We initiated a work to investigate the consistency between $O_4$ DOAS measurements and simulations using radiative transfer. In MAX-DOAS measurements, the $O_4$ slant column absorption is a proxy for the aerosol extinction and several studies indicate the need to introduce an ad hoc corrective factor to match observations and simulations. In principle, the pristine area (low aerosol scattering) of PEA renders it a particularly interesting place for such studies.

**Task 2.4: INP analysis (RMI, TROPOS)**

The sampling line for the collection of ice nucleating particles (INP) was installed in the Northern science 'Atmos' shelter of PEA. The sample time for INP filter collection was kept to 10 days for the campaign 2021/22, as for the seasons before. A total of 6 samples, plus blank samples, could be collected between end of November 2021 and mid-February 2022. Tropos has analysed the INP samples of season 2020/21 and results will be presented at the EGU2022 meeting in Vienna. At the time of writing this report, the new samples are still stored in Cape Town, South Africa, waiting for shipment by sea cargo (reefer container at -25°C; ship capacity issues due to Covid-19 and war in Ukraine). Once arrived in Belgium, the samples will then be sent (by keeping the cold chain) to our collaborators of TROPOS in Leipzig, Germany.

## WP 3 : Characterisation of (semi-)volatile organic compounds at the cloud level (UGent)

**Task 3.1: Assembly of the automated sampler for (S-)VOCs**

One of the auto-samplers (the in-house designed ATS-50) used to sample volatile organic compounds was tested under controlled conditions in Belgium to evaluate if it would be possible to employ the sampler (with 50 sample positions for sorbent tubes) in Antarctica to obtain weekly time resolved VOC concentrations levels year-round. The samplers which were installed during the 20-21 and 19-20 expeditions are sampling on a 13-day time interval. The instrument tested in Belgium is an exact copy of the one installed on the CLIMB remote site during the 20-21 season. During testing a few vulnerabilities were discovered which could result a malfunctioning of the sampler, not solvable until human intervention. The main concerns were flaws in the optical sensor responsible for positioning and the motor driving the mechanism not being strong enough to switch samples in all weather conditions. To resolve these issues, among several smaller ones, a large upgrade of the auto-sampler was done:

- Replacement of the motor with a stronger one (more torque, double the current)
- Replacement of the motor mounting bracket with a more rigid version
- Optical sensor replaced with a custom made mechanically actuated switch
- Rotary encoder with an angular resolution of 0.23° installed on the sample switching mechanism to accurately determining if the correct sample is loaded
- Silicone rubber sealing O rings replaced with custom made PTFE covered silicone O-rings to lower background and mechanical friction
- Changes in electronic design to accommodate rotary encoder and position switch (new PCB and cabling)
- 50 sampling positions installed
- Software upgrade to accommodate upgrade and improve power efficiency

During the 2021-22 expedition, collected samples and metadata from the samplers installed at the station (South shelter) and CLIMB remote site were recovered. The sampler at the station operated without interruption until power from the station was lost early June. The instrument was restarted upon arrival of the crew and continued sampling until the CLIMB team left, early January 2022. As we wanted to focus on the CLIMB remote site and deploy all 50 sampling positions to obtain a higher temporal resolution, the instrument on the south shelter was de-installed and shipped back after 2 seasons of operation. The auto-sampler on the remote site became stuck after the first sample. It did continue to draw power from the battery (25 watt continuous) which did prove the feasibility of operating the instrumentation using an autonomous power supply. The auto-sampler was de-installed and replaced with the upgraded version. A software update on the battery management system caused a problem later in the season and required the solar charger to be replaced.

**Task 3.2: Data analysis of the samples from the mountain**

Samples from the auto-sampler at the station were analyzed using an innovative analytical method. The sorbent tubes were first desorbed in a Unity 2 thermal desorption system, a fraction of the sample was then introduced and analyzed on a GC-MS using the same method already developed in the CHASE project. The fraction of the sample which wasn't used for GC-MS analysis was recollected on a clean sorbent tube loaded with the same sorbent as the original sample tube. This tube was then desorbed again and analyzed on a high-resolution PTR-TOF-MS instrument using an in-house developed interface between the thermal desorption stage and the PTR-TOF-MS. Both datasets are highly complementary and can facilitate a better interpretation of the results.

**WP 4 : Meteorological analysis (RMI)**

**Task 4.1: Analysis of the data from the meteorological mini-sensors, radio soundings and AWS**

The three robust small meteo data loggers have been installed as foreseen: one at PEA, on the roof of the southern scientific shelter, one on the Utsteinen nunatak, and one at the Climb remote site. Before final installation, they were tested at RMI. On the one hand they were measuring next to each other over several weeks (intra-comparison), and on the other hand all three measured, over one week, together with standard sensors in the calibration laboratory of RMI (cycles of very low to high temperatures, pressure adapted to altitudes of the final installation sites, various levels of relative humidity).

The data of the de-installed automatic weather station (AWS) of IMAU, Utrecht, has been processed by IMAU and is available (up to beginning of July 2020). Alternative, current AWS data is available from the AWS near the Utsteinen air strip (WSL, Switzerland) and from the AWS east of Utsteinen ridge (EPFL, Lausanne, Switzerland). Data from the AWS near the air strip is available up to mid-February 2022.

Radio soundings by weather balloons were performed during season 2021/22 approximately each second day and data have been sent to the GTS system. The data have been preliminarily analysed (data quality, quicklooks). The radio sounding data of seasons 2017/18, 2018/19, 2019/20 and 2020/21 have been analysed with respect to, e.g., tropopause altitude, inversion layers, statistics of temperature, relative humidity, wind, and integrated water vapour.

**4.2: Back trajectory and dispersion modelling**

The FLEXTRA trajectory model has been applied in order to investigate possible source regions and transport pathways into Antarctica of atmospheric particles and S-VOCs. 10-days backward trajectories, starting from PEA, were calculated for a the period 2010 to 2020. A cluster analysis has been done for the whole period and also for each season separately. In addition, the backward trajectories have been combined with distinct parameters like particle number concentration, aerosol absorption exponent, potential vorticity, exposure to sunshine duration. Some distinct differences between seasons and clusters can be seen. Further, the FLEXPART dispersion model has been applied in order to identify potential source regions, e.g., for the individual sample periods of the active sampling during seasons 2017/18 up to 2020/21.

**WP 5 : Regional Climate Modelling (KUL)**

**Task 5.1: Improvement of the surface mass balance and albedo in COSMO-CLM$^2$**

During the first project year, we contributed to an intercomparison study of five regional climate models for Antarctica (COSMO-CLM$^2$, HIRHAM5, MAR3.10, MetUM and RACMO2.3p2). This work is now accepted (The Cryosphere; Mottram et al., 2021). In preparation of further research regarding the impact of the cloud-aerosol effect on the radiative balance, we ported a modified version of COSMO-CLM$^2$ (Souverijns et al., 2019) to the Genius cluster of the Vlaams Supercomputing Center. This modified version differs from the standard version by including an aerosol module (Possner et al., 2017) and a two-moment cloud microphysics scheme (Seifert and Beheng, 2006). For this process experience needed to be gained in (1) the base version of COSMO-CLM, (2) the two mentioned modifications, (3) the OASIS coupler, and (4) the Community Land Model (CLM). All of these components rely on other software installed on the supercomputer, which means that the compilation process had to be adapted to ensure compatibility with the new versions installed on Genius. In addition, several auxiliary scripts, especially those related to downloading and preprocessing input data, were adapted and updated.

**Task 5.2: Assessing the effect of aerosols on clouds and the climate of East Antarctica**
For validation of the model and assessing the impact of Ice Nucleating Particles (INP) on clouds and the radiative balance, we performed integrations with the ported model for a case study. These runs cover a time span of three weeks in February 2011, where both MRR and ceilometer data is available. They differ in the number of INP per volume unit of air, so that the impact of INP becomes visible in the differences in cloud structure and liquid water content. Analyzing existing runs, we concluded that the number of Cloud Condensation Nuclei (CCN) per volume unit does not have a very significant impact on these parameters, hence the focus on different INP contents. We present results at the 2022 general assembly of the European Geosciences Union (EGU). In preparation for the presentation, we created slides and updated and revised our visualization scripts. Furthermore, we identified other time periods for future studies.

*Possner, A., Ekman, A. M., & Lohmann, U. (2017). Cloud response and feedback processes in stratiform mixed-phase clouds perturbed by ship exhaust. Geophysical Research Letters, 44(4), 1964-1972.*
*Seifert, A., & Beheng, K. D. (2006). A two-moment cloud microphysics parameterization for mixed-phase clouds. Part 1: Model description. Meteorology and atmospheric physics, 92(1), 45-66.*
*Souverijns, N., A. Gossart, A. Mangold, Q. Laffineur, P.Herenz, H. Wex, I.Gorodetskaya, G. Eirund, A. Possner, and N. van Lipzig (2019): The impact of aerosols on clouds in the pristine environment of East Antarctica. EGU General Assembly 2019, Vienna, Austria, 7-12 April 2019, EGU2019-9839.*
*Mottram, R., Hansen, N., Kittel, C., van Wessem, J. M., Agosta, C., Amory, C., Boberg, F., van de Berg, W. J., Fettweis, X., Gossart, A., van Lipzig, N. P. M., van Meijgaard, E., Orr, A., Phillips, T., Webster, S., Simonsen, S. B., and Souverijns, N.: What is the surface mass balance of Antarctica? An intercomparison of regional climate model estimates, The Cryosphere, 15, 3751–3784, https://doi.org/10.5194/tc-15-3751-2021, 2021.*

**<u>WP 6 :Project coordination and valorisation, instrument maintenance (RMI, KUL, BIRA, UGENT, TROPOS)</u>**

**Task 6.1: Project and network management (RMI)**
Project coordination is led by the Royal Meteorological Institute. A general – online – meeting of all CLIMB partners took place virtually on 5 July 2021. A general online meeting with all partners took place before start of the field campaign on 9 November 2021. Further (virtual or in-situ) meetings of smaller groups of partners took place before the BELARE 2021/22 campaign (instrument training, research and field work discussion). During the campaign, contact to Preben Van Overmeiren and Andy Delcloo at PEA was held by email and short online meetings. On 30 March 2022, there has been an online meeting, including a campaign debriefing and project progress discussion.

**Task 6.2: Maintenance of the observatory at PES (RMI, KUL, BIRA, UGent)**
Two scientists on the CLIMB project stayed from 9 December 2021 to 14 January 2022 at PEA. They (re-)installed successfully CLIMB-related instrumentation at the station (CIMEL sunphotometer, MAXDOAS, disdrometer, meteo data logger, INP sampling) and at the remote site (automated sampler for VOCs, OPS, meteo data logger). This included also testing of the instruments and its set-up, and final installation at the remote site. They helped in addition to supervise and maintain the instrumentation for cloud and precipitation monitoring (ceilometer, micro-rain radar), aerosol monitoring (TEOM, aethalometer, nephelometer), ozone and uv monitoring (Brewer ozone spectrophotometer, pyranometers), supported the station management with weather forecasts, and took care of tasks of the CHASE project (collecting and exchanging samples at passive sampling sites, removing poles at two sites, de-installation of high-volume sampler of Ghent University).
During the 2020/21 field campaign, a mechanical failure in the mounting system of the antenna dish of the micro rain radar had been detected and provisionally fixed. For a more permanent fix, a replacement part with an enhanced mounting mechanism has been ordered in consultation with the manufacturer of the instrument. This part was checked for completeness and prepared for its shipping to Antarctica at KU Leuven. The maintenance protocol of the MRR for the station personnel has been revised for the new Antenna and new installation instructions were added to

ensure a correct assembly. This mechanical issue was solved by station personnel and the scientists of this project during this season 2021/22 by replacing the antenna dish and enhancing the mounting mechanism. After installation, the micro rain radar was closely monitored remotely, and with the help of station and METEK engineers, it was possible to identify and resolve an issue regarding the calibration constant of the instrument. The model output has been checked for completeness and plausibility, so that the radar can now be seen as fully operational. For the ceilometer, the maintenance protocol was checked as well, but no significant changes were added. At the end of season 2021/22, all instruments for whole-year operation were well running.

**Task 6.3: Management of the CLIMB data base (RMI)**

A general data base has not been started yet. The results of CLIMB will be made available after peer-reviewed publications in respective data bases or repositories. Aerosol data for example will be inserted in the EBAS data base, VOC data in ACTRIS (https://www.actris.eu/).
The CLIMB website can be found at https://ozone.meteo.be/projects/chase

**Task 6.4: Publication of results to scientific community, policy stakeholders and general public (RMI, KUL, BIRA, UGent, TROPOS)**
For a detailed list of publications, please see section 7

**Task 6.5: Scientific workshop (RMI, KUL, BIRA, UGent, TROPOS)**
Work on this task will start soon. Together with the CHASE project, CLIMB partners plan to organize a one-day workshop or mini-symposium in October 2022.

## 3. INTERMEDIARY RESULTS

**Task 1.1 Deriving cloud and precipitation properties from existing instruments combined with new disdrometer data (KUL)**
With the newly revised postprocessing procedure, it is possible to derive cloud properties from ceilometer measurements with limited manual preparations. The measurements contain information on the cloud base and top height as well as a number of microphysical properties through the reflectivity. The new procedure automatically applies a noise reduction filter and creates netCDF files and visualizations for each day of measurements, such as the one below (Fig. 5):

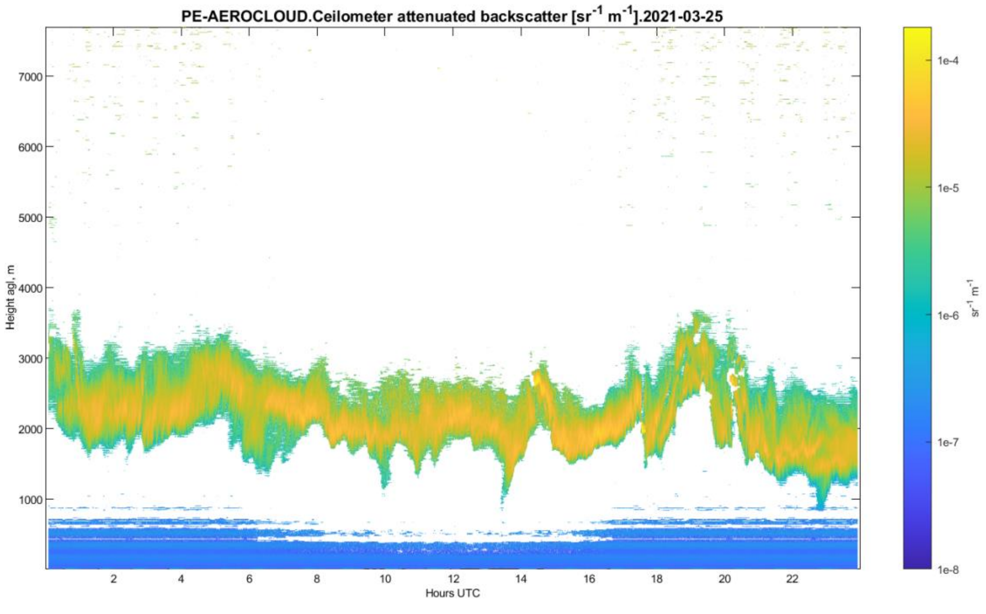


Figure 5: Ceilometer measurement results (reflectivity) on 25 March 2021

The Micro Rain Radar measurements are being postprocessed using the IMProTool software (Maahn and Kollias, 2012). They contain information about the intensity and type of precipitation as well as its fall speed. This processing was previously done with the friendly help of the colleagues at Cologne University, who were also involved in the development of the software, but will be done at KU Leuven in the future. The corresponding protocols are currently being created. Once finished, it will work in a similar way as the ceilometer post-processing software and produce comparable visualizations, as has already been done for measurements up until 2019 (see Fig. 6):

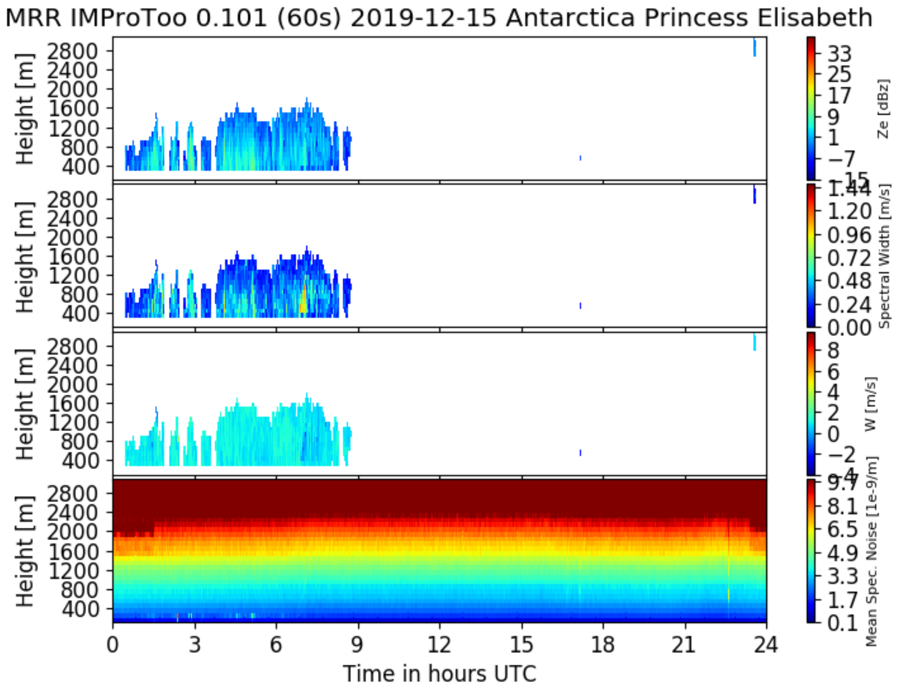


Figure 6: MRR measurement results on 15 December 2019. From top to bottom: Radar Reflectivity, Spectral Width, Fall Velocity, Mean Spectral Noise

The disdrometer has been measuring since end of December 2021. It could detect distinct signals during storms beginning of January 2022, mid-January 2022, 17 March 2022 and 10 April 2022. The instrument categorises the detected particles as snow particles and derives a total precipitation amount (mm eq). The results of the disdrometer will be compared to results of the micro-rain radar.


*Maahn and Kollias: Improved Micro Rain Radar snow measurements using Doppler spectra post-processing, Atmos. Meas. Tech., 5, 2661–2673, 2012.*


**Task 2.1: Physical aerosol properties characterization for boundary-layer aerosol and for the cloud level (RMI)**

The aethalometer and nephelometer data for the last year (with data gap beginning of June to mid-November 2021, as mentioned before) and up to now have been preliminary processed (quality checks, corrections, application of calibration results). These results fall in line with the respective values of previous seasons. The OPS was first installed in the southern scientific shelter of PEA for testing purposes. It measures the particle number size distribution between 300 nm and 10 µm. The measured values agreed well with the respective size distribution measured with the Laser Aerosol Spectrophotometer at PEA (which is currently in Belgium for repair). Particles of sizes below 500 nm showed concentrations between 0.5–2.5 particles/cm$^3$. Concentrations for larger particles decreased distinctly to values < 0.05 particles/cm$^3$. First sample files from the Climb remote site (collected at the check after a strong storm) showed total particle concentrations of around 0.2 cm$^{-3}$, slightly lower than respective particle concentrations at PEA.

**Task 2.2: Retrieval of total column and vertically resolved aerosol properties with remote sensing instrumentation (BIRA)**

We analyzed the 2020-2021 MAX-DOAS measurements with the FRM4DOAS analysis chain, we are currently doing it for the 2021-2022 season.

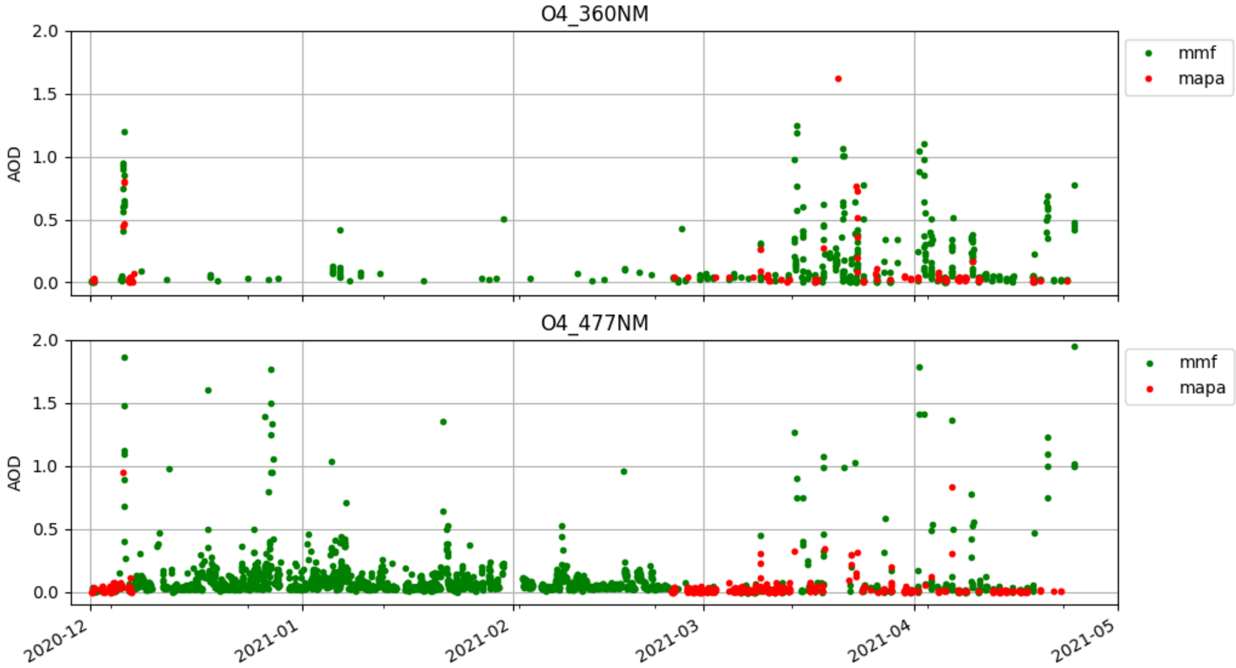


Figure 7: Time series of MAX-DOAS derived AODs at two wavelengths using the two algorithms MAPA (Beirle et al., 2019) and MMF (Friedrich et al., 2019) of the FRM4DOAS (https://frm4doas.aeronomie.be/) processing chain. Note that the period from 4 December 2020 to 26 February 2021 has no valid measurements below a telescope elevation angle of 8°, see text. Therefore, the degree of freedom (dof) of the retrieval is low which leads to a lower retrieval quality and a smaller number of valid retrievals during that period.

We have regularly uploaded the CIMEL data on Aeronet. The whole time series is now available in Level 1.5, and LOA will release Level 2 after the yearly calibration of the CIMEL. The time series is publicly available with the L2 of last season on Aeronet website (https://aeronet.gsfc.nasa.gov/).

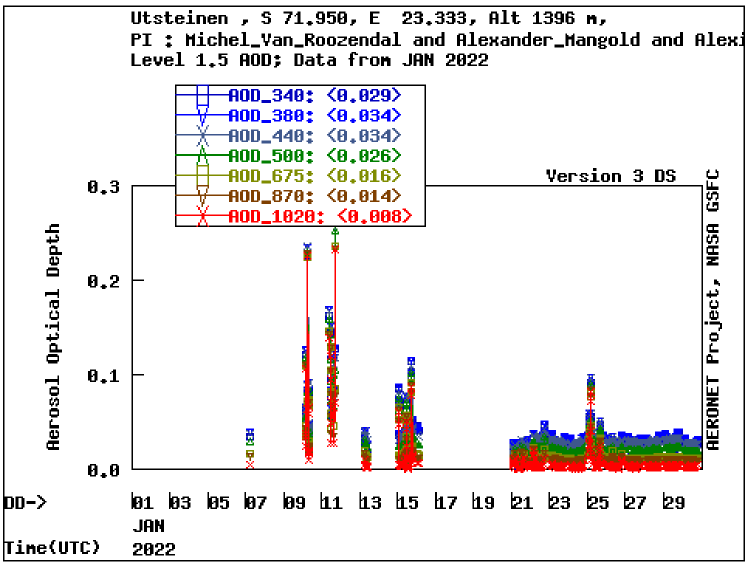


Figure 8: CIMEL measurement of the aerosol optical depth in January 2022

**Task 2.3: Improved estimation of aerosol properties by radiative transport modeling (BIRA)**
In Figure 9, we show measured and simulated O4 slant column densities. For the radiative transfer simulations we use VLIDORT 2.7 (Spurr, 2006). The atmospheric optical property grid is set up to for an total aerosol optical depth (aod) of 0.002 distributed evenly below 15 km above surface with single scattering albedo (ssa) 0.98 and assuming an asymmetry factor of 0.68 for the Henyey Greenstein phase function. The simulations shown here use a surface albedo of 0.98, a fixed temperature pressure profile as measured via balloon sounding from 6 January 2016 22:00 UT. Further tests that we carried out include variations of the surface albedo, using reanalysis data for the temperature pressure profiles, using different distribution of the aerosol content as well as variations of the aerosol parameters within meaningful ranges.

*Spurr, R. J. D. (2006). VLIDORT: A linearized pseudo-spherical vector discrete ordinate radiative transfer code for forward model and retrieval studies in multilayer multiple scattering media. Journal of Quantitative Spectroscopy and Radiative Transfer, 102(2), 316–342. https://doi.org/10.1016/j.jqsrt.2006.05.005*

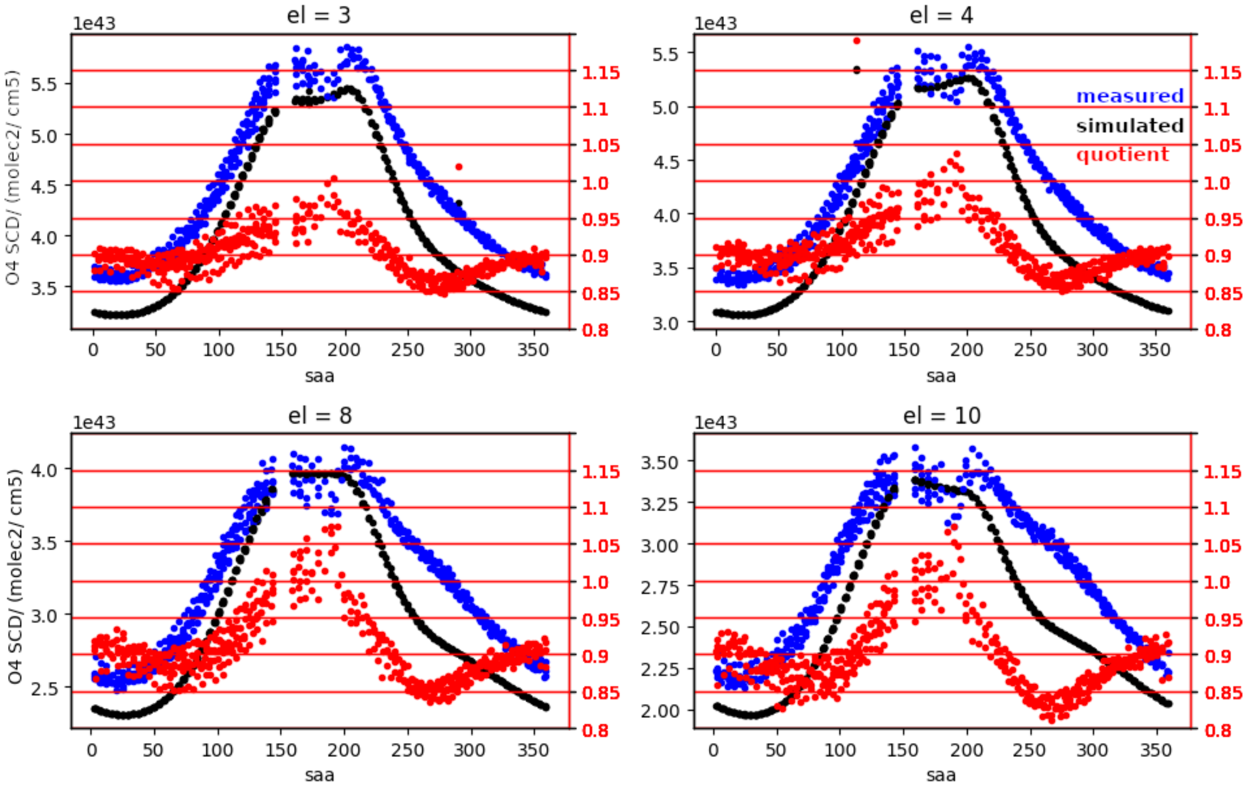


Figure 9: Measured (blue) and simulated (black) O4 slant column densities and their quotient (measured/ simulated, in red, using right axis) as function of solar azimuth angle (saa). Shown is data for clear days in 2016 (1 January 2016 -- 6 January 2016). See text for details of the simulations.

**Task 2.4: INP analysis (RMI, TROPOS)**
At PEA, low INP concentrations were obtained from former samples taken during seasons 2017/18 and 2018/19. The samples of season 2020/21 have been analysed by Tropos and results will be presented at the EGU2022 meeting. Compared to INP samples collected at the German Antarctic research station Neumayer III and also compared to the scarce literature data, the INP numbers for PEA are lower. The new INP samples of season 2021/22 are therefore very important.

**Task 3.1: Assembly of the automated sampler for (S-)VOCs (UGent)**
An upgraded auto-sampler is running on the CLIMB remote site year-round starting from January 2022. Knowledge obtained from the previous campaigns with auto-samplers in Antarctica was used to improve the auto-sampler and make it more robust. The auto-sampler installed for two years at the south-shelter close to the station delivered two sets of samples of which the first set (2019-2020) is analyzed. A final sample set will be delivered and analyzed after the 2022/23 expedition.

**Task 3.2: Data analysis of the samples from the mountain (UGent)**
A unique dataset could be obtained. Reporting for the first time on the presence and concentration levels of a broad range of VOCs compounds in Antarctica. About 70 VOCs were identified in 20 samples taken during the 19-20 season using both GC-MS and PTR-MS data. Data from the same samples analyzed on both instruments was highly correlated indicating both analysis techniques are equivalent and complimentary as the chemical ionization data from TD-PTR-MS directly generates the chemical formula of a compound. TD-PTR-MS creates opportunities for high throughput analysis of VOCs, collected on sample tubes, and obtaining high mass resolution data.
Exact quantification of the compounds is possible when an analytical standard is available and when the specific compound breakthrough volume is not exceeded. Breakthrough is of concern because the sampled volume is particularly large. Therefore, in situ breakthrough experiments were conducted to verify if the compounds measured during the experiment can be quantified. 2/3 of all compounds didn’t suffer from breakthrough, when breakthrough is suspected the VOCs are reported either as minimum concentrations or as “detected”.

A unique dataset of a wide group of (oxygenated) volatile organic compounds is created, providing insight in the behavior of these trace gases in a very remote area and an extreme environment.
The most striking observation possibly being the concentration change of so called primary anthropogenic VOCs such as benzene, toluene, ethylbenzene, and the xylenes (BTEX). These are typically originating from human activities such as fuel combustion and the usage of solvent-based products. During the measurement period when the station is manned a significantly higher mixing ratio, up to a factor 20, of these compounds is found (Fig. 10). When the station is abandoned for the winter, the mixing ratio drops to close to 0. This indicates the impact of the station on the environment is not negligible despite being a zero-emission base.

Another interesting trend is the evolution of OVOCs (oxygenated VOCs) which are formed by the oxidation of primary VOCs and play an important role in the degradation pathway of these trace gases and might play an important role in the cloud formation process and microphysics as they are a precursor for secondary organic aerosols. Furfural is a compound emitted from biomass burning and known to form SOA’s by photooxidation. A negative correlation with the hours of sunshine can be seen in the temporal evolution of furfural (Fig. 11), indicating a lower photooxidative activity during winter.

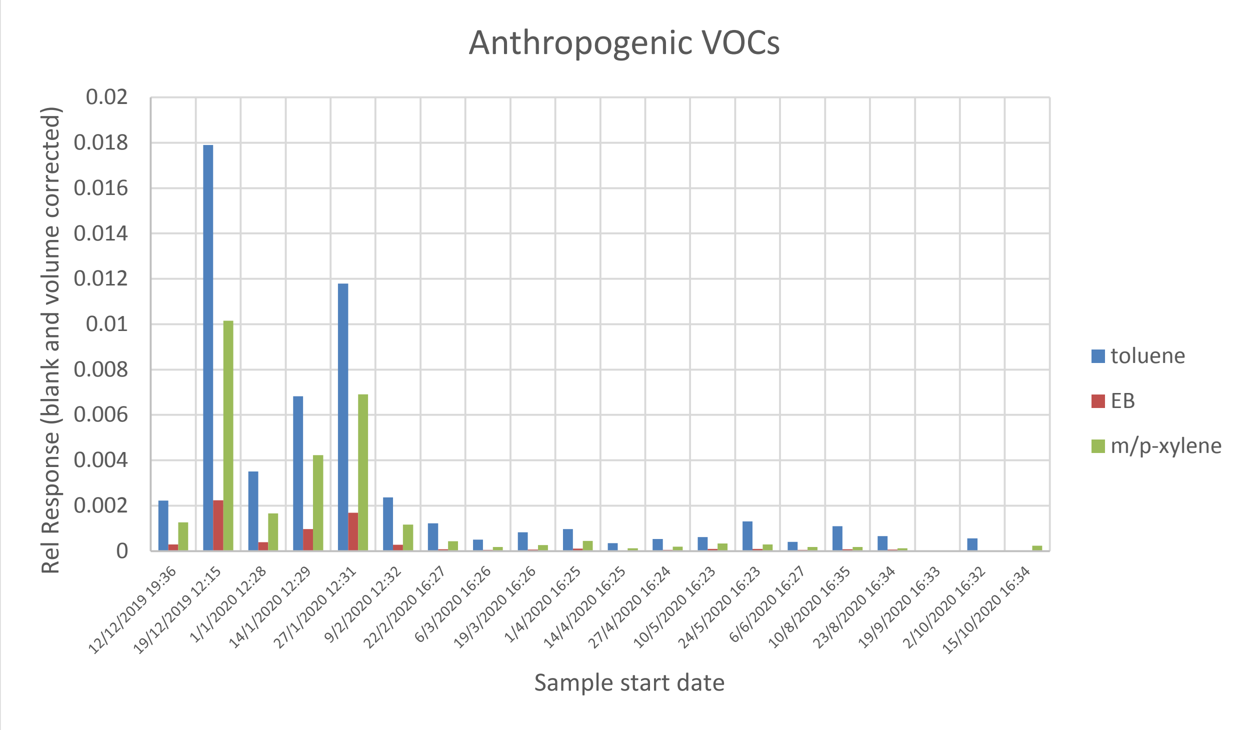


Figure 10: concentration change of so called primary anthropogenic VOCs such as benzene, toluene, ethylbenzene, and the xylenes, measured at PEA.

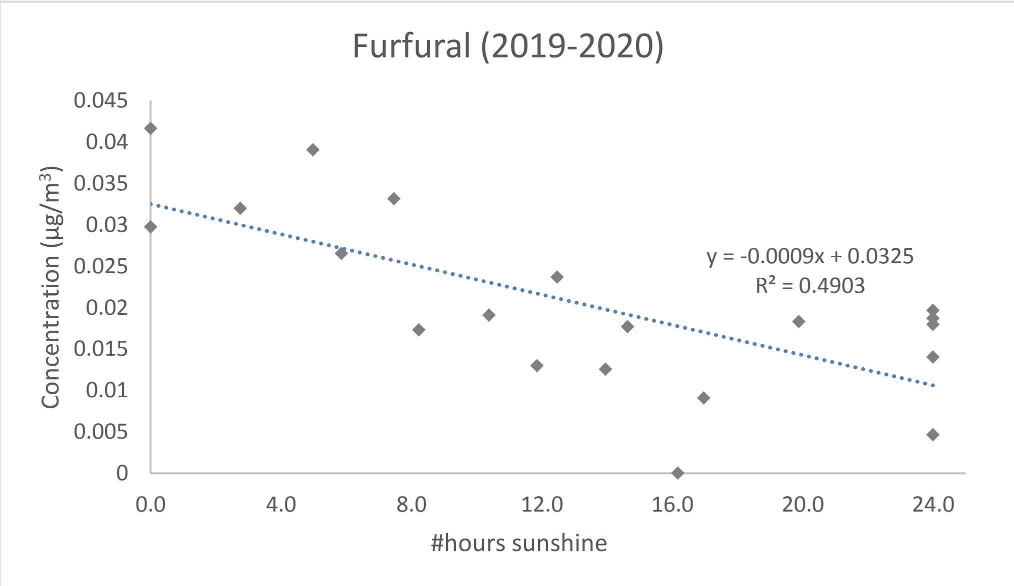


Figure 11: concentration change of the oxygenated VOC Furfural, in relation to sunshine duration during the sampling time.

**Task 4.1: Analysis of the data from the meteorological mini-sensors, radio soundings and AWS (RMI)**

The data of the radio soundings of season 2021/22 have been sent to the GTS system and the data have been preliminarily analysed. The radio soundings of former seasons have been analysed in more detail, with respect to, e.g., tropopause altitude, inversion layers, statistics of temperature, relative humidity, wind, and integrated water vapour (see Fig. 12 for the tropopause during season 2018/19).

Data of the former radio soundings have been used in a paper on the physical habitat characterisation in the Antarctic Sør Rondane Mountains using satellite remote sensing by the Belgian Institute for Natural Sciences (https://doi.org/10.1016/j.rsase.2021.100529).

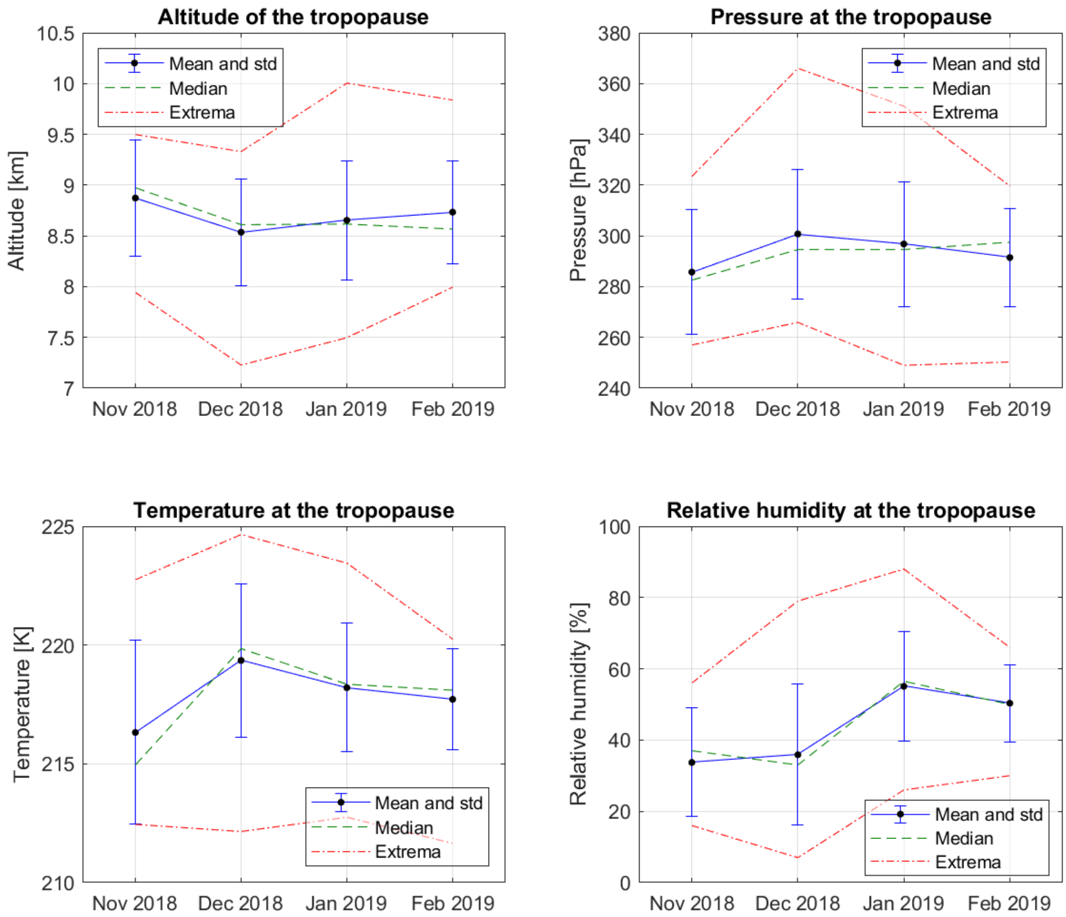


Figure 12: tropopause characteristics for season 2018/19 at PEA

The three small meteo data loggers were tested during several weeks at RMI, measuring simultaneously at the same location. Relative differences for temperature and relative humidity were between ± 1 % (with differences up to ± 4 % during distinct changes in T and rH). For atmospheric pressure, the relative differences were between -0.06 and +0.06%. The small meteo data loggers were also compared to standard sensors in the calibration laboratory of RMI (cycles of very low to high temperatures, pressure adapted to altitudes of the final installation sites, various levels of relative humidity). This comparison will be analysed in the coming months. Further, a comparison of one-week data between the meteo data logger at the southern scientific shelter with data of the AWS at Utsteinen air strip showed strong pressure differences (around 5 hPa) and a high bias for temperature and relative humidity. Results of the laboratory comparison and of the whole-year data set (which will be collected during coming season 2022/23) will give more insights.

**4.2: Back trajectory and dispersion modeling (RMI)**

The FLEXTRA model has been successfully applied to calculate air mass trajectories and a k-means cluster analysis has been done based on several parameters. When the clustering is performed relying on the normalised latitude, longitude and altitude, four clusters of air mass origin were found. The cluster analysis has been done for the whole period (2010 – 2020) and also for each season separately.

An example is shown in Figure 13 below. It shows the four air mass origin clusters (calculated over the whole period) for the austral winter season (June-July-August). All 10 days of the back trajectory calculation have been used for the clustering and all 10 days are included in the graphs.

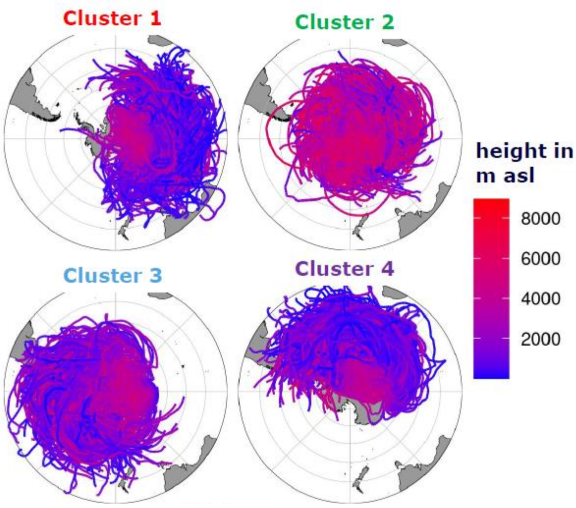


Figure 13: clusters of air mass origin, for austral winter, for 10 years of back trajectories starting at PEA station; Z is height in m asl

Some distinct features can be seen in the air mass origin clustering. Source regions from South America, Southern Africa and Australia were very limited. The Southern Ocean was a main source region, as was the Antarctic continent itself. For one of the clusters, the source region is mostly restricted to the region above the Antarctic continent. The average altitude along the trajectories in this cluster is higher compared to the average altitude of air coming from source regions over the Southern Ocean, indicating that this cluster corresponds to air subsiding from aloft.
Figure 14 shows the probability density of the measured particle number concentration within the four clusters, for the four seasons. Again, some distinct differences among the seasons and among the clusters can be seen. For example, for the winter season, cluster 1 showed the highest concentrations and cluster 3 the lowest.

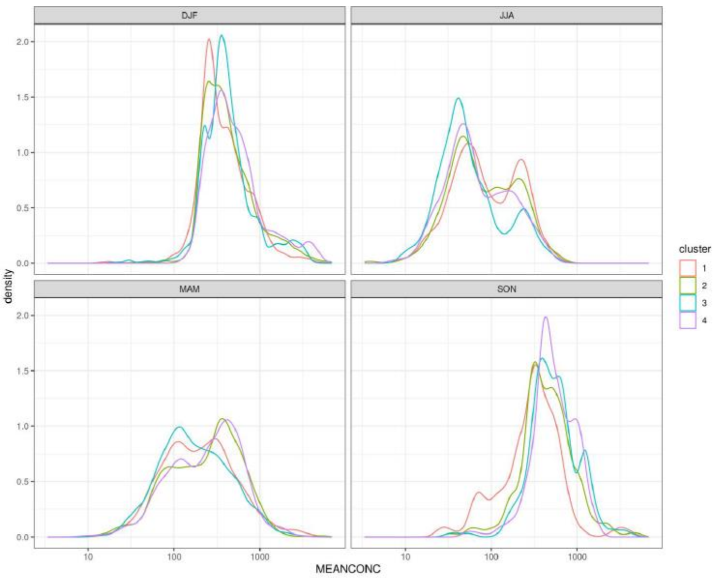


Figure 14: probability density distribution for measured particle number concentration, for the four seasons and the four air mass clusters

Further, the FLEXPART dispersion model has been applied in order to identify potential source regions, e.g., for the individual sample periods of the active sampling during seasons 2017/18 up to 2020/21. Fig. 15 shows as an example the source regions for two measurement periods of the active sampling To create the figures, FLEXPART was run 30 days back in time starting from the end of each measurement period. Wet or dry deposition was not taken into account to make these figures.

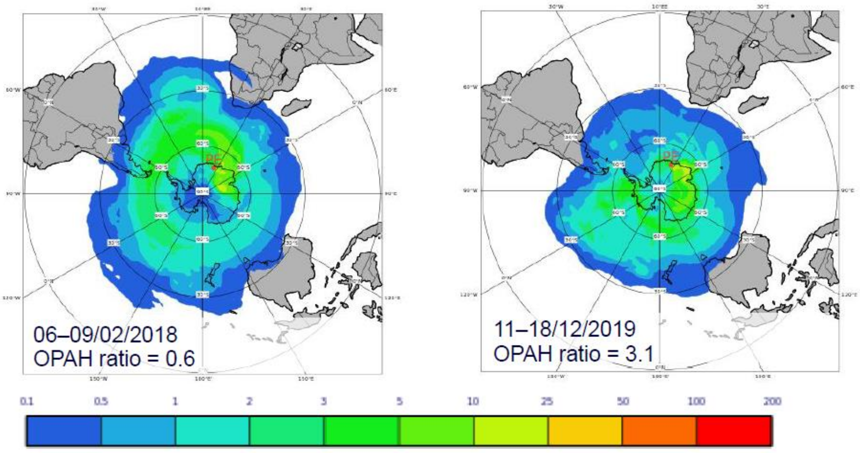


Figure 15: source regions for two periods of active filter sampling; the color code gives the probability that the air mass has passed through that region

**Task 5.1: Improvement of the surface mass balance and albedo in COSMO-CLM$^2$ (KUL)**

An intercomparison study was performed during the first project year between five regional climate models for Antarctica (COSMO-CLM2, HIRHAM5, MAR3.10, MetUM and RACMO2.3p2), which was reported last year. This work is now published (Mottram et al., 2021).

Case studies are currently being performed with the COSMO-CLM model for the region around the Princess Elisabeth Station which will be compared with observations in the next project year. Preliminary results indicate that a low number of Ice Nucleating Particles coincide with more liquid and mixed phase clouds, which tend to have a higher Cloud Radiative Effect (CRE) in Antarctica. The higher CRE causes an increased surface energy balance, which may result in higher ice melt rates. Furthermore, the model results suggest that precipitation rates are lower when there is a limited number of INPs, which could impact the accumulation.

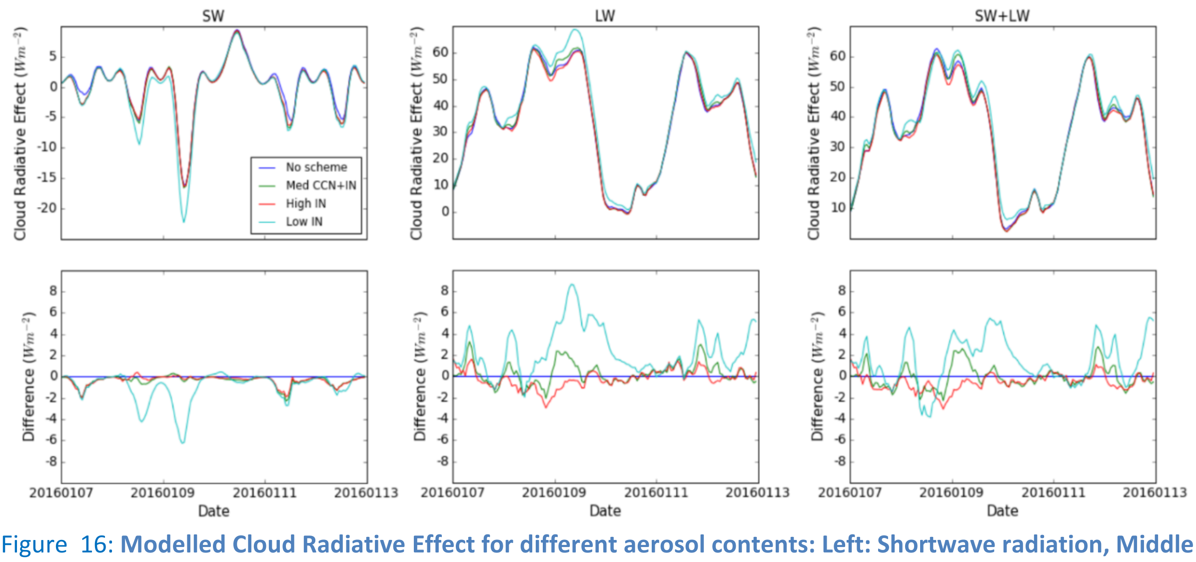


**Figure 16: Modelled Cloud Radiative Effect for different aerosol contents: Left: Shortwave radiation, Middle: Longwave radiation, Right: Shortwave and Longwave radiation; Top: Total CRE modelled; Bottom: difference compared to the model without aerosol module. Souverijns et al., 2019**

**Task 5.2: Assessing the effect of aerosols on clouds and the climate of East Antarctica (KUL)**

We have performed a number of model runs over a short period of time using different settings for our modified version of COSMO-CLM². These indicate a high sensitivity of the liquid water content of clouds to the amount of Ice Nucleating Particles (see Fig. 17). While the number of Cloud Condensation Nuclei only has little impact on cloud structures, a high number of INPs removes almost all liquid water and turns it into ice. With a medium number, the amount of liquid water is also very small. These results will be presented at the EGU General Assembly 2022.

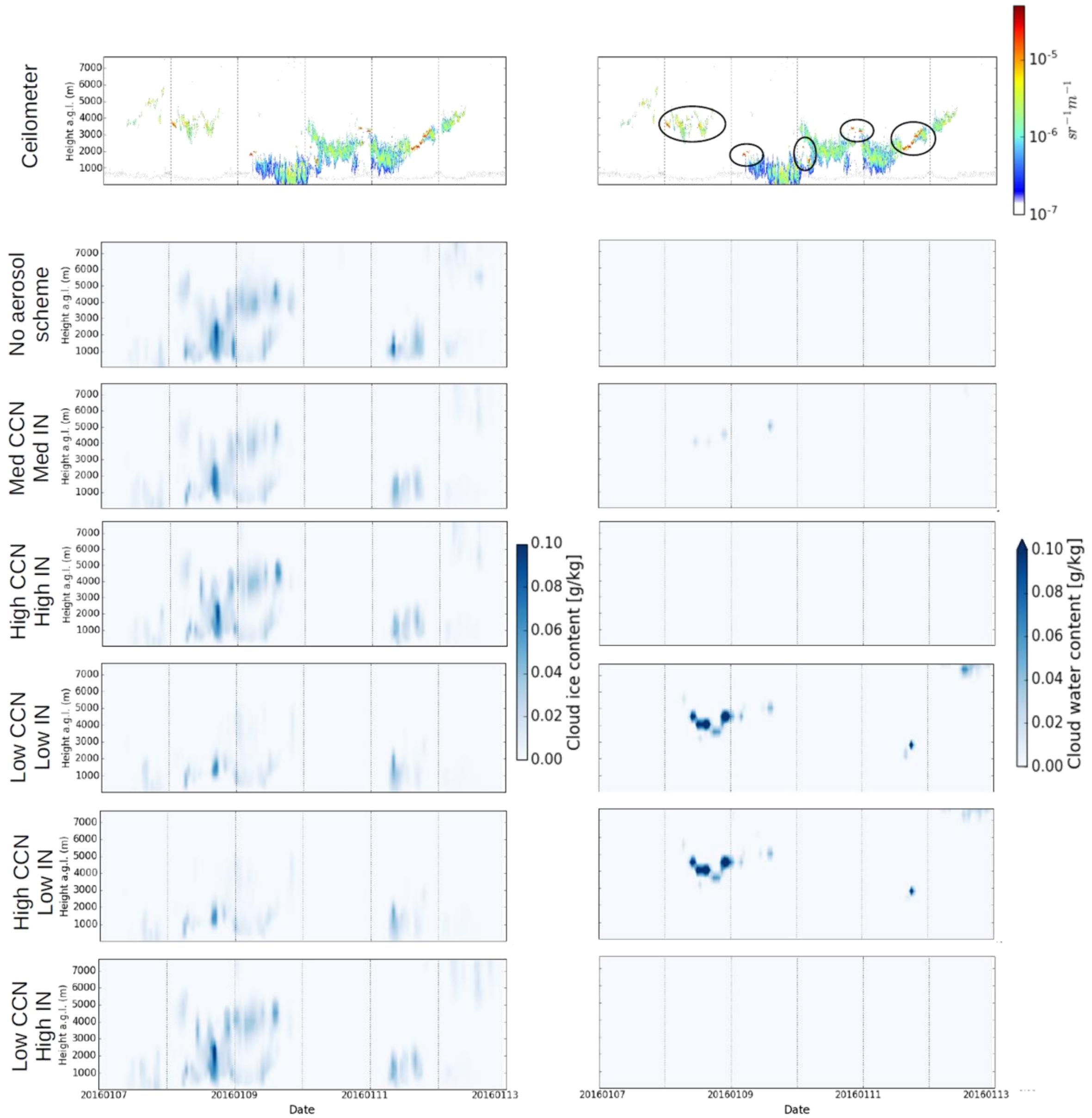


Figure 17: **Modelled cloud ice and cloud water content for different aerosol settings, compared to ceilometer observation results. Souverijns et al., 2019**

**Task 6.1: Project and network management (RMI)**
See section 2.

**Task 6.2: Maintenance of the observatory at PES (RMI, KUL, BIRA, UGent)**
See section 2.

**Task 6.3: Management of the CLIMB data base (RMI)**
See section 2.

**Task 6.4: Publication of results to scientific community, policy stakeholders and general public (RMI, KUL, BIRA, UGent, TROPOS)**
For a detailed list of publications, please see section 7.

## 4. PRELIMINARY CONCLUSIONS AND RECOMMANDATIONS

**WP 1 : Cloud and precipitation properties (KUL)**
The ceilometer and precipitation radar are currently operational at the Princess Elizabeth station. An extensive maintenance on the precipitation radar, including replacement of the antenna, were done during the last campaign. These data are currently processed and used for model evaluation. The cloud observatory has been operational since 2009 so it would be recommended to keep this operational for the years to come to have a unique long-term climatological dataset on cloud and precipitation properties. However, substantial maintenance especially on the MRR would be needed.
The disdrometer has successfully been installed at PEA. It detected distinct precipitation signals during several storms. It will be interesting, but also important to compare the disdrometer results with simultaneous observations of the micro-rain radar. Also, the observations of the ceilometer will help to detect periods of blowing snow (rather than precipitation), which will also be detected as signals by the disdrometer.

**WP 2 : Characterisation of physical properties of atmospheric aerosol (RMI, BIRA, TROPOS)**
The data of the aethalometer and nephelometer for the aerosol absorption and scattering coefficient, as well as for the mass concentration of light-absorbing aerosol, fall in line with the respective values of previous seasons. First preliminary results for the particle size distribution, measured with the new optical particle sizer and installed at the Climb remote site showed total particle concentrations of around 0.2 $cm^{-3}$, slightly lower than respective particle concentrations at PEA. Results for the concentration of ice nuclei particles showed values lower than for samples collected at Neumayer III and over the Southern Ocean. During season 2021/22, six new INP samples could be collected.

**WP 3 : Characterisation of (semi-)volatile organic compounds at the cloud level (UGent)**
As mentioned in section 3, 1 sample set is analysed and data will be made available. It was investigated with an in-situ experiment if breakthrough could be an issue for the used sample volume. For compounds which are reported to be active in photo-oxidation processes a seasonal variation can be observed. When the current measurement on the remote sites terminates and is collected successfully the final dataset for VOCs will consist of 2 years of data from the station with a 13-day resolution and 1 year of data from the plateau with a 6-day resolution, all analysed with 2 advanced instruments, using fully developed and optimised novel methods. For future iterations of similar experiments it is recommended to monitor ground-level ozone as it is reported by (Hwan

Lee et al., 2006) as a possible interferent. Since tropospheric concentrations are a factor 5 to 100 lower than those used in the mentioned report, and no significant signal of ozone products is found, interferences are currently not considered as of concern.

**WP 4 : Meteorological analysis (RMI)**

The data of the radio soundings of season 2021/22 have been sent to the GTS system and the data have been preliminarily analysed. The radio soundings of former seasons have been analysed in more detail, with respect to, e.g., tropopause altitude, inversion layers, statistics of temperature, relative humidity, wind, and integrated water vapour.

The FLEXTRA trajectory model has been applied in order to investigate possible source regions and transport pathways into Antarctica and 10-day backward trajectories, starting from PEA, were calculated for a the period 2010 – 2020. A cluster analysis has been done for the whole period and also for each season separately. In addition, the backward trajectories have been combined with distinct parameters like particle number concentration, aerosol absorption exponent, potential vorticity, exposure to sunshine duration. Some distinct differences between seasons and clusters can be seen. Further, the FLEXPART dispersion model has been applied in order to identify potential source regions, e.g., for the individual sample periods of the active sampling during seasons 2017/18 up to 2020/21.

**WP 5 : Regional Climate Modelling (KUL)**

Especially the number of INPs has a significant impact on the microphysical properties of the clouds, which in turn impact precipitation and radiative balance. A low number of INPs increases the amount of liquid water in clouds as in the absence of an INP, liquid water will stay in a supercooled state. This effect has become apparent in the case studies we performed, and as ceilometer measurements indicate the presence of liquid water in clouds and INP numbers are expected to be low – due to the remote location – this conclusion seems realistic. We also saw lower precipitation rates when the number of INPs is set to be low, presumably due to the lower residence time of ice particles. However, the modelled precipitation rate could not be confirmed by MRR measurements. To see if this is a result of the selected case and to confirm our other findings, additional time periods should be investigated, and the number of INPs, which are now being measured at the station, should be included in further analyses of our results. Finally, a longer model integration should be performed to uncover potential climatological effects that these effects may have.

**WP 6 Project coordination and valorisation, instrument maintenance :**

See section 2, achieved work.

**General recommendations:**

The results for measured time series for the atmospheric aerosol, for the cloud and precipitation properties, for the remote sensing instruments and the vertical meteorological profile demonstrate that long time series are of great benefit, not only for the CLIMB project, but also for the scientific community. It is therefore very good news that with respectively low effort (cost, logistics), new complementary measurements could be started (observations at Climb remote site, disdrometer) or could be prolonged (INP filter sampling). It is important that these observatories can be maintained also beyond the CLIMB project.

## 5. FUTURE PROSPECTS AND PLANNING

*Overview of the foreseen activities and planning for next reporting year, taking into account the actual state of the work and the intermediary results*

**WP 1 : Cloud and precipitation properties (KUL)**

Our plans include doing a statistical analysis relating large-scale weather regimes to cloud and precipitation properties. We will use ERA-5 reanalysis data to identify recurring atmospheric patterns and combine these results with observations taken at the station. This way, we will be able to uncover possible relations between cloud and precipitation properties with large-scale and regional atmospheric dynamics without having to rely on a custom-made model.

The data of the disdrometer installed at PEA will be analysed and compared to the measurements of the micro-rain radar and ceilometer. In addition, a second disdrometer will be installed next austral season 2022/23 at the Climb remote site.

**WP 2 : Characterisation of physical properties of atmospheric aerosol (RMI, BIRA, TROPOS)**

The analyses of the existing aerosol instrumentation at PEA will go on. The INP filter samples will be analysed and another set of INP filter samples will be collected during season 2022/23 at PEA. At the beginning of austral season 2022/23 at PEA, first data of the OPS from the Climb remote site will be available and will be analysed. Also, the TEOM, the condensation particle counter and the Laser Aerosol Spectrometer will be re-installed at PEA if they are ready in time after repair and calibration.

For season 2022/2023, it is planned to ship in the CIMEL already with the first team arriving at PEA, to ensure the longest possible time series. In addition, it is envisaged, to upgrade the software of the CIMEL, in order to operate it also during austral winter when the station in not inhabited (remote switch on/off of idle mode during storms, moon observations…).

**WP 3 : Characterisation of (semi-)volatile organic compounds at the cloud level (UGent)**

The second sample set retrieved from the sampler at the station is currently stored in the lab in Ghent. Sample analysis will take place later this year using the same methodology as was used for the first dataset. The final sample set currently deployed will be collected during the 2022-2023 season by non-CLIMB personnel and can be analyzed upon arrival in the lab.

Data will be made available via a data repository.

**WP 4 : Meteorological analysis (RMI)**

The radio sounding data of season 2021/22 will be analysed and a new series of radio soundings will be performed during season 2022/23 at PEA. The small robust meteo data logger will be read out in the beginning of austral season 2022/23 and the first data will then be analysed for the three sites (PEA, Utsteinen nunatak and Climb remote site). The available AWS data up to mid-February 2022 will be analysed.

The results of the Flextra trajectory and the Flexpart dispersion model will further be analysed, in particular with respect to specific sample periods, periods with specific aerosol signatures, precipitation events, residence time over ocean or at distinct altitude levels.

**WP 5 : Regional Climate Modelling (KUL)**

We plan to create and evaluate longer model integrations using the modified COSMO-CLM² model and new measurements from the station. Through the results, we will assess the impact of aerosols on the Antarctic climate and improve COSMO-CLM²'s capability of capturing the aerosol effect. Most notably, a long-term high-resolution integration is planned. This run will help identify long-term effects that are not apparent in short-term case studies. We will present these results at the Polar CORDEX meeting in Bergen (Norway)

**WP 6 Project coordination and valorisation, instrument maintenance, workshop (RMI, KUL, BIRA, UGent, TROPOS):**

- The next Belgian Research Expedition to the Princess Elisabeth station (November 2022 – February 2023) will be planned similar to season 2021/22 – however without any personnel of Climb partners (no campaign budget anymore). As station staff is well-trained with the instrumentation, we are confident that the maintenance and installation of instruments will happen without problems.
- At the remote CLIMB site, another disdrometer will be installed, the small meteo data logger and OPS, and power supply will be maintained. The auto-sampler for VOCs will be dismounted and shipped back to Belgium.
- Further INP samples will be collected during the field campaign season.
- Review of the maintenance protocols for the MRR and ceilometer instruments. Maintenance will be performed by station personnel.
- Preben Van Overmeiren and Christophe Walgraeve are working on a publication on the VOC's measured during the 2019-20 season with the auto-sampler on the south shelter
- MSc Preben Van Overmeiren will defend his PhD thesis in autumn 2022.
- Results of CLIMB will be presented at EGU 2022 (accepted presentations by Heike Wex, Tropos, on INP results, by Florian Sauerland on the regional modeling and by Preben Van Overmeiren on results VOC analyses), and at the SCAR Open Science conference 2022.
- Together with the CHASE project, CLIMB partners plan to organize a one-day workshop or mini-symposium around end of September, beginning of October 2022.

## 6. FOLLOW-UP COMMITTEE

*Dates of the meetings and overview of the concrete contributions of the follow-up committee*

Alexander Mangold is in email contact with Dr. Martina Krämer (Research Centre Jülich, Germany and University of Mainz, Germany) who is an expert on cloud physics, in particular on the influence of ice clouds on climate. They discussed about recent findings on the ice nucleating properties of different kinds of aerosol particles.

Colleagues Andy Delcloo and Preben Van Overmeiren met with Prof. Dr. Frank Pattyn (Université Libre de Bruxelles, Belgium), during the field campaign 2021/22, when all three were present at PEA. They discussed their respective scientific projects.

Alexander Mangold contributes to a paper of Jost Heintzenberg (former director of Leibniz institute for tropospheric research, Tropos, Leipzig, Germany), comparing particle number measurements in East Antarctica, including measurements at Neumayer station. Partner in this paper is Dr. Rolf Weller (Alfred Wegener Institute, Bremerhaven, Germany).

# 7. VALORISATION ACTIVITIES

## 7.1 PUBLICATIONS

**Publications in peer-reviewed scientific journals**:

Mottram, R., Hansen, N., Kittel, C., van Wessem, J. M., Agosta, C., Amory, C., Boberg, F., van de Berg, W. J., Fettweis, X., Gossart, A., van Lipzig, N. P. M., van Meijgaard, E., Orr, A., Phillips, T., Webster, S., Simonsen, S. B., and Souverijns, N.: What is the surface mass balance of Antarctica? An intercomparison of regional climate model estimates, The Cryosphere, 15, 3751–3784, https://doi.org/10.5194/tc-15-3751-2021, 2021.

Held, A. and Mangold, A. (2021): Measurement of Fundamental Aerosol Physical Properties, in: Foken, T. (ed.), Handbook of Atmospheric Measurements, Springer Nature, Switzerland, 533-563. https://doi.org/10.1007/978-3-030-52171-4_18

## 7.2 PARTICIPATION/ORGANISATION OF SEMINARS (NATIONAL/INTERNATIONAL)

*Oral presentation, poster… and/or organisation of workshops, symposia etc.*

**Oral presentations**:

De Causmaecker, K., Delcloo, A., and Mangold, A.: Identifying source regions for airborne particles in East Antarctica, Dronning Maud Land, using backward trajectory modelling, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-14524, https://doi.org/10.5194/egusphere-egu21-14524, 2021.

De Causmaecker, K., A. Mangold, C. Walgraeve, P. Van Overmeiren, N. Mattielli, S. Gili and A. W. Delcloo, Validating aerosol plume data using satellite data and dispersion modeling, EUMETSAT Meteorological Satellite Conference, Bucarest, Romania, 20-24 September, 2021.

K. De Causmaecker, A. W. Delcloo, and A. Mangold, Wildfire emissions and atmospheric disperison, ITM 2021, 38th International Technical Meeting on Air Pollution Modelling and its application, Barcelona, Spain, 18-22 October, 2021.

Alexis Merlaud, Martina Friedrich, François Hendrick, Caroline Fayt, Christian Hermans, Alexander Mangold, Michel Van Roozendael, MAX-DOAS O4 measurements under pristine aerosol-free conditions at the Belgian Princess Elisabeth Antarctic station, DOAS Workshop 2021, 11 May 2022, online.

**Poster presentations:**

Mangold, A., K. De Causmaecker, A. Delcloo, Q. Laffineur, P. Van Overmeiren, C. Walgraeve, K. Demeestere H. Van Langehove, S. Gili, A. Vanderstraeten and N. Mattielli, Climatology of air mass origin for Princess Elisabeth Antarctica station: clustering and analysis for atmospheric particle properties and semi-Volatile Organic Compounds, European Aerosol Conference 2021 (online) Abstract 200-AAS-P2, 30 August – 3 September 2021, Manchester, UK, 2021

## 7.3 SUPPORT TO DECISION MAKING (IF APPLICABLE)

The connection between scientific research on Antarctica and policy is largely managed by the Scientific Committee on Antarctic Research (SCAR). Belgium is a Full Member of SCAR, represented by the Belgian National Committee on Antarctic Research (BNCAR, http://www.bncar.be/bncar/). Prof. Nicole van Lipzig, Dr. Michel Van Roozendael and Dr. Alexander Mangold are members of BNCAR and have been following the meetings to ensure that all scientists involved are aware of the on-going research. This is further strengthened via discussions with members of the follow up committee.

## 7.4 OTHER

Presentation of the scientific project to PEA crew by Andy Delcloo and Preben Van Overmeiren (12/01/2022)
Presentation on the UGent faculty research days by Preben Van Overmeiren (1/05/2021)
Presentation to the alumni organisation of the UGent bioscience engineering faculty (18-05-2021)

Blog on RMI's activities at Princess Elisabeth station:
https://belatmos.blogspot.be

News-ticker of RMI at the beginning of the season at PEA:
https://www.meteo.be/fr/infos/actualite/lirm-en-antarctique-nouvelle-campagne-de-mesure
https://www.meteo.be/nl/info/nieuwsoverzicht/het-kmi-op-antarctica-nieuwe-meetcampagne

News-ticker of RMI on award-winning presentation at scientific conference:
https://www.meteo.be/nl/info/nieuwsoverzicht/wetenschapper-van-het-kmi-wint-internationale-prijs-met-werk-rond-bosbranden
https://www.meteo.be/fr/infos/actualite/une-scientifique-de-lirm-remporte-un-prix-international-pour-ses-travaux-sur-les-feux-de-foret

Blog by Andy Delcloo and Preben Van Overmeiren on the research activities during Belare 2021/22:
https://ozone.meteo.be/projects/climb/belare-2021-2022-campaign-v2

Interviews with CLIMB partners on PEA station website or on website of International Polar Foundation :
http://www.antarcticstation.org/news_press/news_detail/andy_delcloo_and_preben_van_overmeiren_discuss_the_belspo_climb_project

## 8. ENCOUNTERED PROBLEMS AND SOLUTIONS

*Encountered problems/obstacles, adopted and/or envisaged solutions, unsolved problems*

Beginning of June 2021, PEA station lost power. Both communication and power boards for science and other station operation were off. Only when the first team of the expedition 2021/22 arrived, the station was put back into full operation. This caused a data gap of around 5 ½ months. Luckily, all instrumentation did restart without issues. Only the Teom-Fdms had an issue to restart.

The control unit of the TEOM-FDMS (measuring the total mass concentration of atmospheric particles) did not start up in November 2021 after the winter power outage. After contacting the supplier, it was decided to ship the control unit back to Belgium for repair. It is currently at the Belgium supplier of this instrument and it will be available in time for coming austral season 2022/23.

The MAXDOAS optical head was frozen after the winter interruption, with ice inside the tube. This was solved thanks by the IPF station team by dismounting the instrument, letting it dry inside the station, and adding tape around the interfaces. This may happen again next season, depending on tape ageing during Antarctic winter conditions. The Cimel and pyranometers were affected by a wrong time (1h offset) during the first days of the season. It was solved by setting a correct time server. It may happen again when the station is connected back to internet after an interruption, applying then the default time server. There were several twists of the data and power cables of the CIMEL during strong winds. A bad cable setup was identified, which will be corrected during the next installation in season 2022/23.

During the 2020/21 field campaign, a mechanical failure in the mounting system of the antenna dish of the micro rain radar had been detected and provisionally fixed. This mechanical issue was solved by replacing the antenna dish and enhancing the mounting mechanism. The replacement dish was ordered alongside the necessary utilities from METEK before this season 2021/22. It was checked at KU Leuven before it was shipped to Antarctica. At the station, the radar dish was installed by the station personnel and the scientists of this project. After installation, the instrument was closely monitored remotely, and with the help of station and METEK engineers, it was possible to identify and resolve an issue regarding the calibration constant of the instrument. The model output has been checked for completeness and plausibility, so that the radar can now be seen as fully operational.

At the Climb remote site, the power supply worked well during winter 2021. An issue was that the automated sampler for VOCs got stuck after its first sample. Therefore, only one sample of winter 2021 is available. During field season 2021/22, the VOC-auto-sampler was replaced with an updated version. At a check visit at the Climb remote site, after installation of the new instrumentation and after a strong storm, some issues had to be solved: the battery control was faulty and had to be replaced; the inlet tubing for the OPS and the VOC-auto-sampler were blocked with snow. The inlet tubing was emptied, flushed with air and the tubing was mounted in a way that blowing snow would not enter the tubing. The VOC-auto-sampler was cleaned.

Due to the Covid-19 restrictions for work on-site at the institute, the testing for several new instruments was delayed. For the installation of the second disdrometer at the remote site, a separate data logging system with its own power supply is needed. This was not possible to set up and test in time. This will be done however in time for installation during field season 2022/23. One disdrometer however has successfully been installed at PEA and is still continuously measuring.

## 9.2 COMPOSITION OF THE FOLLOW-UP COMMITTEE

See section 6.

## 10. REMARKS AND SUGGESTIONS

*Concerning for example: the coordination, the use or valorisation of the results, personnel change …*

KUL:
With the prolongation of CLIMB until March 2023, KUL can use its personnel budget for Florian Sauerland also after March 2022. The employment of FS was delayed and due to the prolongation, FS can be employed until the end of the CLIMB project and he can analyse the data of winter 2021, 2022 and some data of austral summer 2022/23.

UGENT:
With the prolongation of CLIMB until March 2023, UGent can use its personnel budget for Preben Van Overmeiren also after March 2022. It enables Preben Van Overmeiren to analyse the data of winter 2021 and austral summer season 2021/22 and to include it in his PhD thesis.