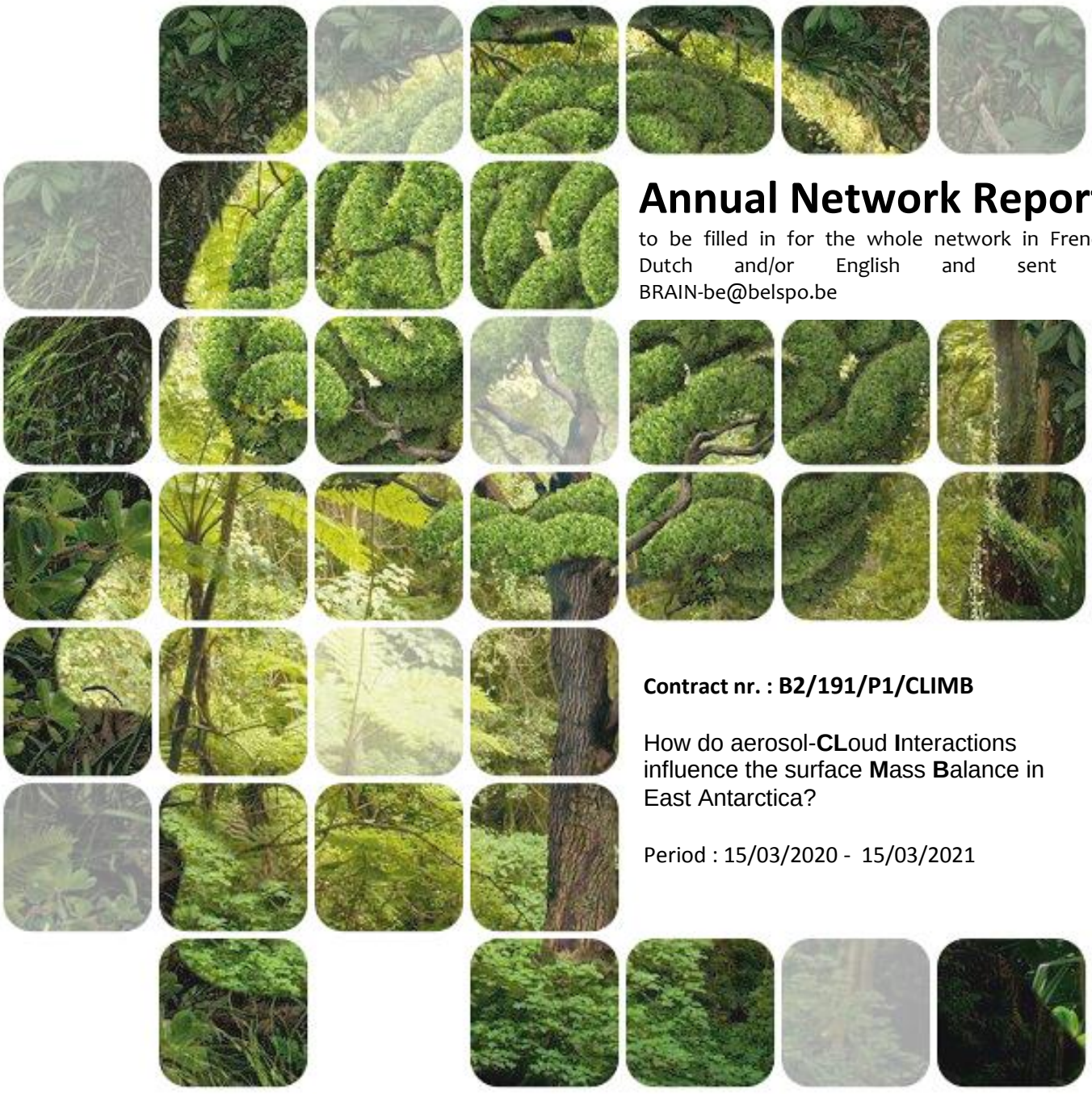
# BRAIN-be

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 : 15/03/2020 - 15/03/2021

## NETWORK

### COORDINATOR

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2. Prof. Dr. Nicole van Lipzig, Katholieke Universiteit Leuven, (KUL)
3. Dr. Michel Van Roozendael, Royal Belgian Institute for Space Aeronomy (IASB-BIRA)
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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.

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## 1. EXECUTIVE SUMMARY OF THE REPORT

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

The CLIMB project conducts 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 possible) 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 S-VOCs in the mountains: this will result in valuable insights which S-VOCs are present at this altitude and in-cloud.

The work is subdivided in several 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 the 15/12/2019. In the table below, the submission date is counted from April 2020 (24 months until end of project in contract 15/03/2022.

| No. | Description | Partner | Subm. date | Status |
|---|---|---|---|---|
| D1.1 | Database with cloud and precipitation properties ready for comparison with model comparison | KUL | M16 | PROG |
| D2.1 | Physical aerosol properties characterised for boundary layer and for the cloud level | RMI | M12, M236 | PROG |
| D2.2 | Total column and vertically resolved aerosol properties | IASB-BIRA | M12M23 | PROG |
| D2.3 | Improved radiative transfer modelling for aerosol composition retrieval | IASB-BIRA | M24 | PROG |
| D2.4 | INP analysis done and measured IN concentrations available | TROPOS | M15, M248 | PROG |
| D3.1 | Assembly of automated sampler for VOCs | UGent | M6 | FIN |
| D3.2 | Quality-checked data for (S-)VOCs measured at cloud level | UGent | M24 | NOT |
| D4.1 | Vertically resolved meteorological analysis of the region around PES | RMI | M12, M23 | PROG |
| D4.2 | Source regions and atmospheric transport pathways of moisture, particles and S-VOCs into Antarctica | RMI | M12, M23 | PROG |
| D5.1 | Improved COSMO-CLM2 model | KUL | M17 | PROG |
| D5.2 | Estimated effect of aerosols on the East Antarctic Climate | KUL | M24 . | NOT |
| D6.1 | Management of project and network | RMI | Cont. | PROG |
| D6.2 | An operational atmospheric observatory at PES | RMI, KUL, UGent, IASB-BIRA | Cont. | PROG |
| D6.3 | Quality-controlled data and accessible data base | RMI | Cont. . | PROG |
| D6.4 | Results published to scientific community, policy stakeholders and public | RMI, KUL, UGent, IASB-BIRA, Tropos | Cont. | PROG |
| D6.5 | Scientific workshop organised | RMI, KUL, UGent, IASB-BIRA, Tropos | M24 | NOT |

**Table 1: List of intermediate and final deliverables and their dissemination. The first three columns give the number, the description and the partner responsible for the deliverable, the fourth column gives the submission date, counted from April 2020, and the fifth column gives the status (finished (FIN), in progress (PROG), or not started (NOT)).**

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 and takes automatic measurements during the austral winter. 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

Two automated sample systems for semi-volatile organics are now installed at and nearby PEA: one in the southern science shelter, and one at the CLIMB remote site. From the first one, samples from the austral winter 2020 could successfully be collected.

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 10 year period. A k-means cluster analysis has been done and four clusters of air mass origin were found. The cluster analysis has been done for the whole period and also for each season separately. Some distinct features can be seen in the air mass origin clustering. Within the constraints of this analysis, 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.

Project partner KUL 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 currently under review in The Cryosphere (Mottram et al., 2020).

The following preparations were undertaken for the 2020/21 field campaign at Princess Elisabeth Antarctica (PEA) station:

- Virtual meetings and email-exchanges with the Station Operator in order to discuss the practical topics for the sampling campaign; Preben Van Overmeiren participated also at a pre-field training in the French Alpes;
- Preparation of the necessary air cargo boxes and shipment forms;
- Administrative organization of the campaign in cooperation with the polar secretariat and the station operator;
- Preparation and testing of the automatic remote sampler for (S-)VOCs;
- Preparation of the aethalometer instrument for re-installation at PEA after repair in Belgium

Alexis Merlaud and Preben Van Overmeiren participated on the CLIMB project in the BELARE 2020/2021 field campaign to PEA station. Alexis Merlaud stayed at PEA from end of November to 20 December 2020 and Preben Van Overmeiren stayed from end of November 2020 to mid-January 2021 at PEA. The scientists installed successfully CLIMB-related instrumentation at the station (MAX-DOAS, CIMEL sunphotometer, aethalometer) and at the remote site (automated sampler for S-VOCs). This included also exploring potential sites, preparation of infrastructure (poles, fixations, power supply) and final installation of the remote site. Alexis Merlaud and Preben Van Overmeiren helped in addition to supervise and maintain the instrumentation for cloud and precipitation monitoring (ceilometer, micro-rain radar), aerosol monitoring (TEOM, nephelometer), helped with launching radio sondes, and took care also of tasks of the CHASE project.

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

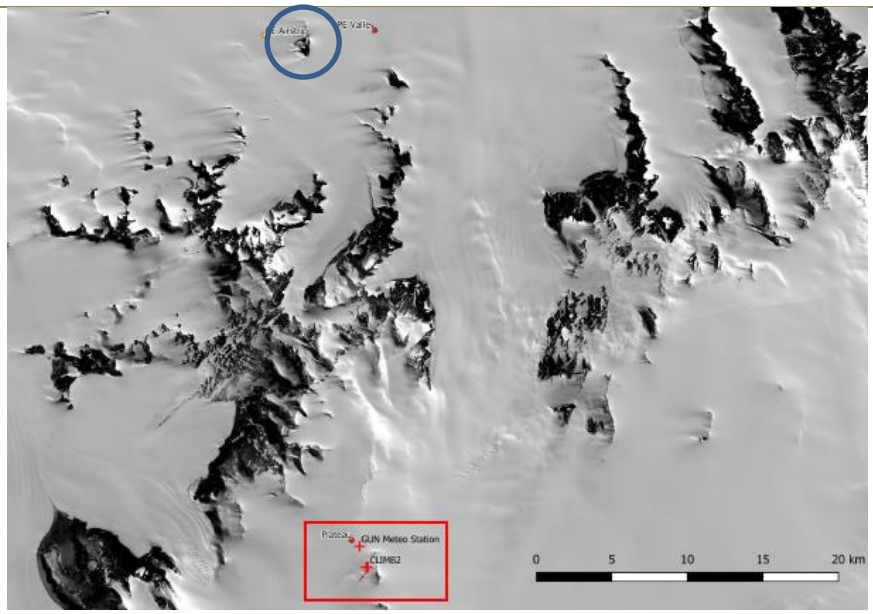

Figure 1: Location of the CLIMB remote site (red box); PEA station in blue circle

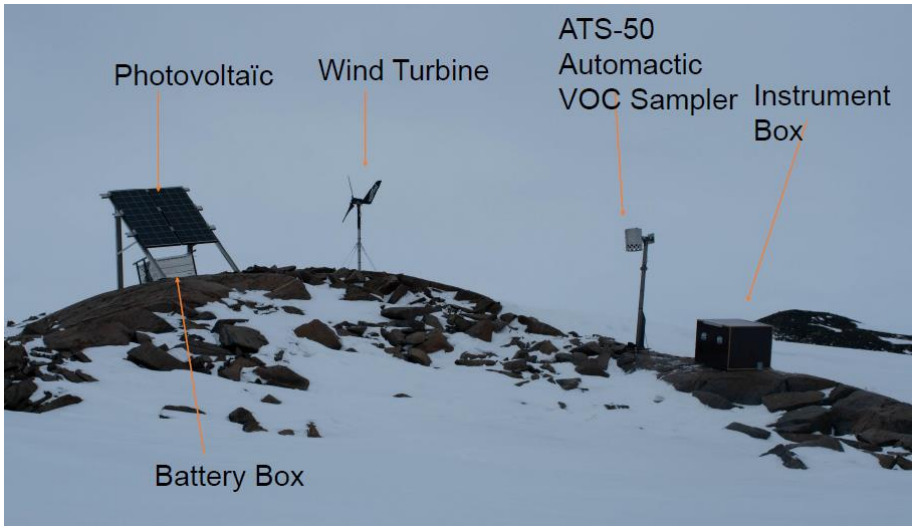

Figure 2: View of the installation at the CLIMB remote

## 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**

The work during the first year of the project for KUL concentrated on continuity of the cloud observatory in Antarctica. The majority of the work was done as preparation and during the field campaign of 2020/2021. The ceilometer was found to be still in good shape when arriving at PE, and could easily be switched on to work properly again. For the precipitation radar, this was a different story: The instrument was heavily damaged. Together with the help from the manufacturer and with the kind help of scientists from UGent that where at PE, we managed to get the instrument

operational again by the end of the season. However substantial maintenance is necessary during next season. The disdrometers were not yet ready for installation during season 2020/21 (see also section 8). During the first year of CLIMB, no staff was recruited on KU Leuven side yet as planned, so the data that have been gathered from ceilometer and precipitation radar will be processed during the second year of the project.

## 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)

Two instruments of the permanent aerosol observatory were operational during the reporting period: the nephelometer (continuously) and the aethalometer. The aethalometer was shipped in during the field season after repair in Belgium and started operation in the beginning of December 2020. Two other instruments (condensation particle counter and Laser Aerosol Spectrometer) are currently in Belgium for repair. However, due to pending budget questions, their repair is delayed.
Unfortunately, the particle number size distribution sensor for the CLIMB remote site could not be purchased in time for field season 2020/21. This was due to the Covid-19 imposed restrictions.

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

We have installed two remote sensing instruments dedicated to aerosols on the roof of PEA: a CIMEL sunphotometer and a MAX-DOAS (see Fig. 3). The measurements started for both instruments on 30 November 2020. The CIMEL was dismounted at the end of the season (last measurement on 13 February 2021) and shipped back as every year for calibration. As for the previous years, the CIMEL data (see an example in Fig. 4) are publicly available on the AERONET website (https://aeronet.gsfc.nasa.gov/cgi-bin/draw_map_display_aod_v3). The MAX-DOAS is still operational and taking automatic measurements at the time of writing this report.

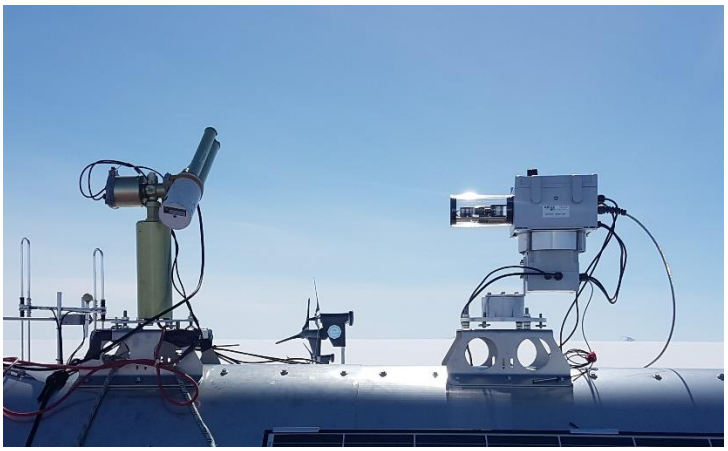

Figure 3: CIMEL (left) and MAX-DOAS (right) instruments on the roof of PEA station (December 2020)

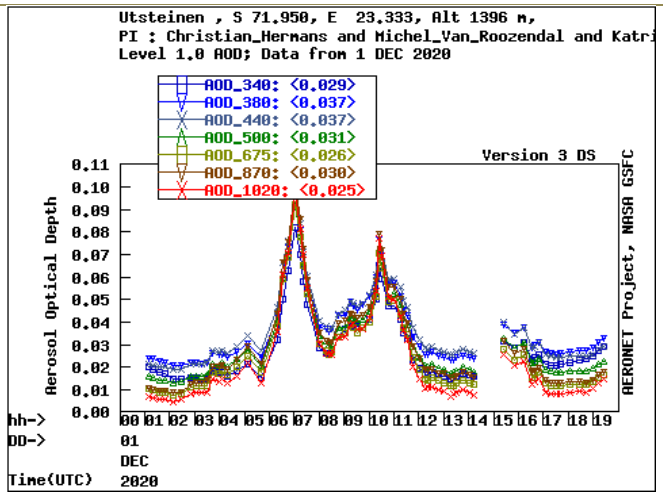


Figure 4: CIMEL measurement of the aerosol optical depth at several wavelengths on 1 December 2020

**Task 2.3: Improved estimation of aerosol properties by radiative transport modeling (BIRA)**
We have integrated the MAX-DOAS data in the analysis chain FRM4DOAS developed at BIRA-IASB. It retrieves in particular the profile of aerosol extinction, using a radiative transfer model and an optimal estimation method (see Fig. 5). The data are processed automatically in near real-time.

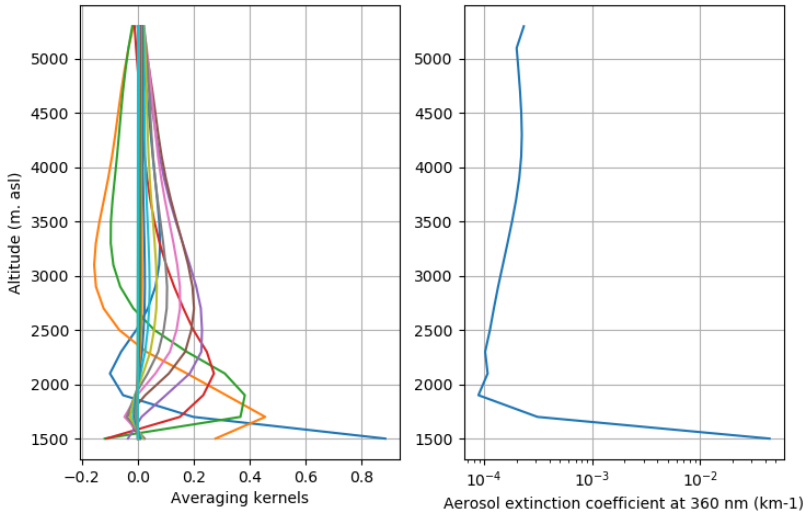


Figure 5: example of a retrieval of the aerosol extinction profile (1 December 2020)

**Task 2.4: INP analysis (RMI, TROPOS)**
In the beginning of December 2020, the sampling line for the collection of ice nucleating particles (INP) was installed in the Northern science 'Atmos' shelter of PEA. Based on the INP samples of seasons 2017/18 and 2018/19, the sample time for INP filter collection was kept to 10 days for the campaign 2020/21. A total of 6 samples, plus blank samples, could be collected. At the time of writing this report, these samples are about to arrive by sea cargo (reefer container at -25°C) at the port of Antwerp. 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**

The prototype automated sampler which was deployed on the Atmos-shelter near the station since December 2019 ran unassisted until its scheduled program ending in mid-October 2020. Sampling continued despite several short power outages and loss of station communication at the start of Q4 2020, taking bi-weekly samples. A few smaller bugs caused the loss of 2 samples. These bugs were addressed by the employed CLIMB personnel at the station. All samples were removed and shipped back to Belgium. A new sample series was installed, and the instrument was reset to run for another year. A second automated sampler was installed at cloud level on the remote CLIMB site. This is the first instrument using the remote power infrastructure which was also installed this year, on the southern side of the Sør Rondane mountains. Both samplers will be renewed and receive a small upgrade during the next expedition in season 2021/22.

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

No samples received yet. Sampler has been installed (see task 3.1).

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

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

Similar to the particle sizer for the remote CLIMB site, also the robust small meteodata loggers could not be purchased in time for field season 2020/21.

The automatic weather station (AWS) of IMAU, Utrecht, installed 500 m to the East of PEA, had to be de-installed because of empty power supplies and end of lifetime of some components. It stopped recording already in July 2020. The de-installation went without issues and the AWS was sent back to Belgium and IMAU in March 2021. IMAU is at the moment processing the data and will send then the final AWS data to us.

The data of the radio sounding of seasons 2019/20 and 2020/21 have been sent to the GTS system. The data have been preliminarily analysed (data quality, quicklooks).

**4.2: Back trajectory and dispersion modelling**

The FLEXTRA trajectory model has been applied in order to investigate possible air mass source regions and transport pathways into Antarctica of atmospheric particles and (S-)VOCs. The model was driven with ECMWF meteorological fields. 10-days backward trajectories, starting from PEA, were calculated for the period 01/01/2010 to 31/12/2019, in 6-hour-intervals (the period will be prolonged to include also 2020). 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 are found.

**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 currently under review in The Cryosphere (Mottram et al., 2020). As planned, the improvement of the model will be done during the second year of the project. During the first year of the project no staff was recruited at KUL for the CLIMB project.

**Task 5.2: Assessing the effect of aerosols on clouds and the climate of East Antarctica**
As planned, this task will be performed during the second year of the project. During the first year of the project no staff was recruited at KUL for the CLIMB project.

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

**Task 6.1: Project and network management (RMI)**
Project coordination is led by the Royal Meteorological Institute. A general meeting of all CLIMB partners took place virtually (due to Covid-19 travel and gathering restrictions) on 2 September 2020. Further virtual meetings of partners took place before the BELARE 2020/21 campaign, in order to prepare the campaign and to discuss analysis progress. A general meeting of CLIMB partners took place on 26 October 2020 via an online meeting. During the campaign, several online meetings were held to discuss practical issues. On 9 March 2021, there has been a campaign debriefing online meeting.

**Task 6.2: Maintenance of the observatory at PES (RMI, KUL, BIRA, UGent)**
Alexis Merlaud and Preben Van Overmeiren participated on the CLIMB project in the BELARE 2020/2021 field campaign to PEA station. Alexis Merlaud stayed at PEA from end of November to 20 December 2020 and Preben Van Overmeiren stayed from end of November 2020 to mid-January 2021 at PEA. The scientists installed successfully CLIMB-related instrumentation at the station (MAXDOAS, CIMEL sunphotometer, aethalometer) and at the remote site (automated sampler for (S-)VOCs). Alexis Merlaud and Preben Van Overmeiren helped also to supervise and maintain the instrumentation for cloud and precipitation monitoring (ceilometer, micro-rain radar), aerosol monitoring (TEOM, nephelometer), helped with launching radio sondes, and took care also of tasks of the CHASE project. Further, the BIRA Pyranometer has been restarted and its time issue has been corrected by updating the NTP server. The maintenance protocols for the micro-rain radar and the ceilometer were updated. The micro-rain radar could be repaired and put back into operation with the help of the scientists at the station and the manufacturer.
Together with the station operator, the final remote CLIMB site was explored and determined. A lot of work was done, with help of the technical team of the station, to successfully assemble the power supply for the instrumentation and to finally install and starting the automated (S-)VOC measurements on 2 January 2021.

**Task 6.3: Management of the CLIMB data base (RMI)**
The database has not started yet. It is more reasonable to wait for a more complete dataset and to wait that results got published The 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, BRIA, UGent, TROPOS)**
For a detailed list of publications, please see section 7

**Task 6.5: Scientific workshop (RMI, KUL, BRIA, UGent, TROPOS)**
Not started yet.

## 3. INTERMEDIARY RESULTS

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

The ceilometer and precipitation radar are currently operational at the Princess Elisabeth station. Processing of the data will be done during the second project year.

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

The nephelometer data for 2020 have been preliminary processed (quality checks, corrections, application of calibration results). The aethalometer data since December 2020 have also been preliminary processed. These preliminary results fall in line with the respective values of previous seasons, see Fig. 6 below.

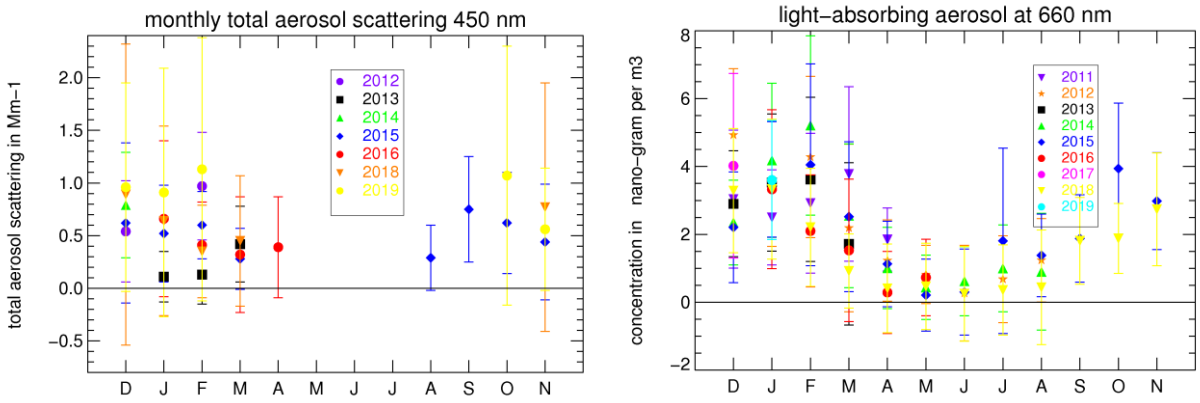


Figure 6: left: aerosol scattering coefficient at PEA, for 450 nm; right: mass concentration of light-absorbing aerosol at PEA, measured at 660 nm; both for monthly averaged values over several years

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

See section 2.

In addition, the MAX-DOAS measurements allowed also the measurement of the total ozone column amount. In Fig. 7 a comparison with the Brewer ozone spectrophotometer (also installed at PEA) and with satellite data is shown.

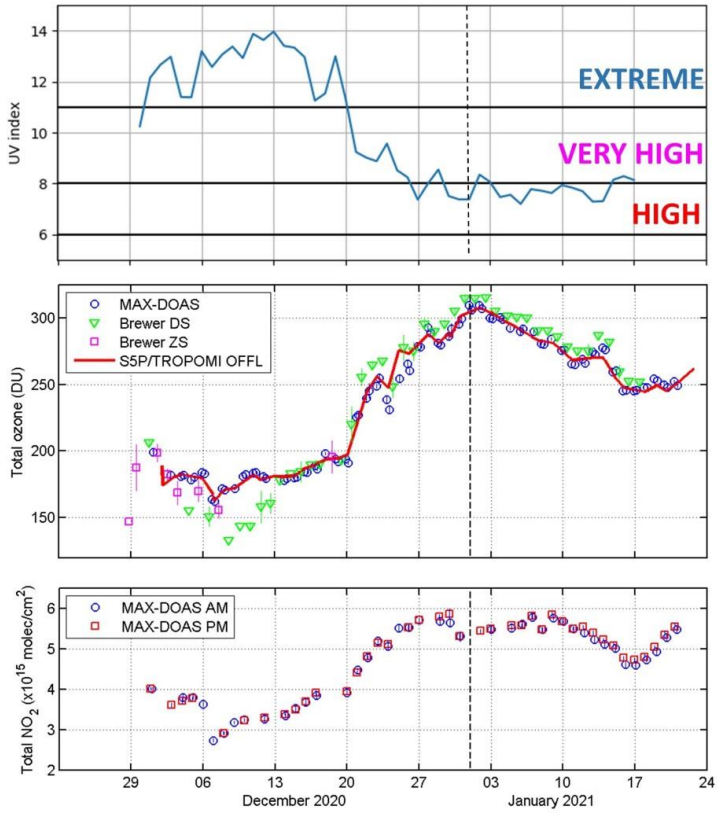


Figure 7: UV index, total ozone column and NO2, measured at PEA (and additional total ozone by TROPOMI satellite observations)

**Task 2.3: Improved estimation of aerosol properties by radiative transport modeling (BIRA)**
See section 2.

**Task 2.4: INP analysis (RMI, TROPOS)**
At PEA, low INP concentrations (see Fig. 8) were obtained from former samples. Compared to the scarce literature data, the INP numbers for PES are at the lower limit. This shows the clear need to obtain more measurements, particularly as INP play an important role in ice formation in clouds and hence in precipitation formation. The new INP samples of season 2020/21 are therefore very important.

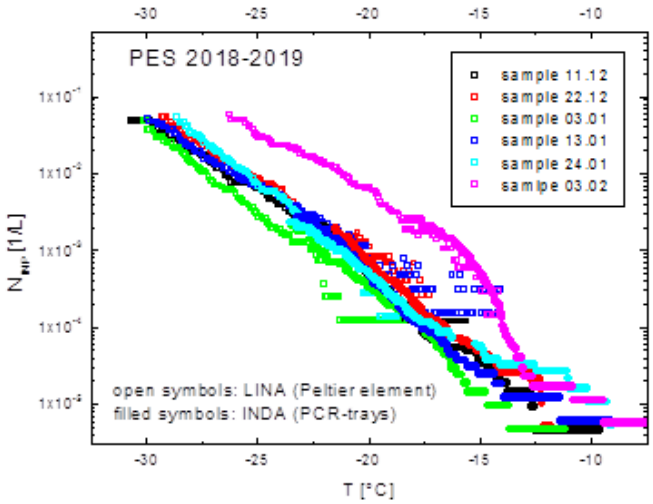


Figure 8: Number concentration of ice nucleating particles as function of freezing temperature

**Task 3.1: Assembly of the automated sampler for (S-)VOCs (UGent)**
Both autosamplers which were scheduled to be deployed are currently active. They will be maintained and receive minor updates when deemed necessary during the length of the project.

**Task 3.2: Data analysis of the samples from the mountain (UGent)**
See section 2.

**Task 4.1: Analysis of the data from the meteorological mini-sensors, radio soundings and AWS (RMI)**
The data of the radio sounding of seasons 2019/20 and 2020/21 have been sent to the GTS system. The data have been preliminarily analysed (data quality, quicklooks, see Fig. 9). Data of the radio soundings have been used, e.g., in a paper on gravity waves (Moffat-Griffin, GRL (https://doi.org/10.1029/2020GL089740) and will be used for analyses on the physical habitat characterisation in the Antarctic Sør Rondane Mountains using satellite remote sensing by the Belgian Institute for Natural Sciences.

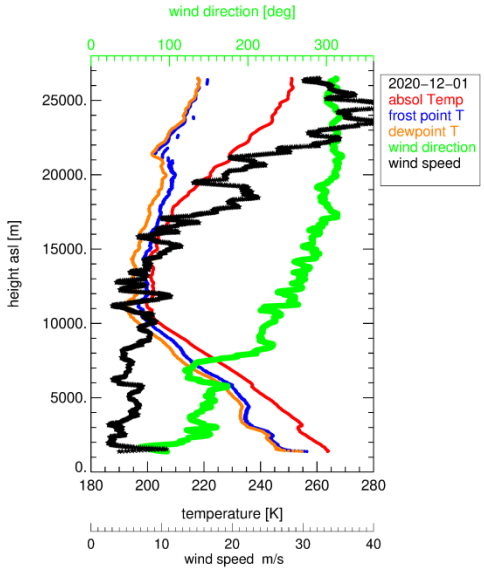


Figure 9: data of the radio sounding on 1 December 2020, showing very low temperatures in the upper troposphere and lower stratosphere. PEA was in the polar vortex then, with the Antarctic ozone hole still very significant at that time.

**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 and also for each season separately.
An example is shown in Figure 10 below. It shows the four air mass origin clusters (calculated over the whole period 2010-2019) for the austral summer season (December-January-February). All 10 days of the back trajectory calculation have been used for the clustering and all 10 days are included in the graphs.

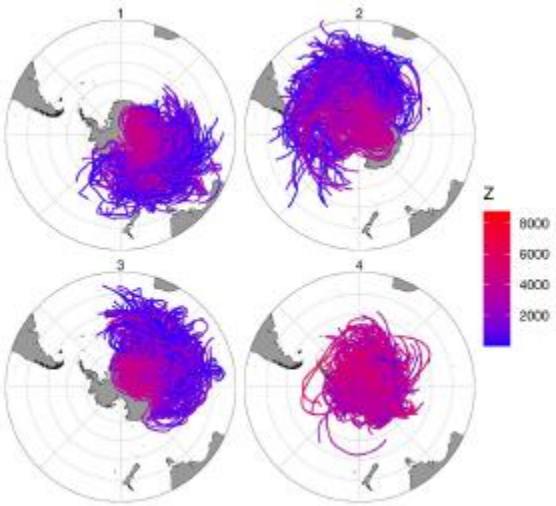


Figure 10: clusters of air mass origin, for austral summer, for 10 years of back trajectories starting at PEA station; Z is height in m asl

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. This cluster also has a lower specific humidity compared to the other clusters.

**Task 5.1: Improvement of the surface mass balance and albedo in COSMO-CLM$^2$ (KUL)**
An intercomparison study was performed between five regional climate models for Antarctica (COSMO-CLM2, HIRHAM5, MAR3.10, MetUM and RACMO2.3p2). The ensemble average of the surface mass balance of these five models is 2329 ± 94 Gigatonnes (Gt) year$^{-1}$ over the common 1987 to 2015 period, with individual model results varying from 1961 ± 70 to 2519 ± 118 Gt year$^{-1}$. Most of these differences occur in West Antarctica, the Peninsula and the transantarctic mountains. Such large differences are caused by different ice masks and different model resolution. Additionally, large differences for the integrated surface mass balance over the continent could be attributed to large differences in model precipitation at relatively few grid points in coastal areas. No systematic consistent trend was found in the surface mass balance over the ERA-Interim period.

Daily observed temperature and pressure were found to be well represented by the models. For the surface mass balance it was found that models share common biases. Inclusion of drifting snow improves model performance for the areas where katabatic winds are active in especially between one and two kilometer height. Regions with high precipitation lack observations needed for a sound evaluation. Targeting coastal areas for observational campaigns is necessary to improve and refine estimates of the integrated surface mass balance over the Antarctic ice sheet. This work is currently under review in The Cryosphere (Mottram et al., 2020).

**Task 5.2: Assessing the effect of aerosols on clouds and the climate of East Antarctica (KUL)**
No results yet.

**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 Elisabeth station. It is recommended that and extensive maintenance on the precipitation radar will be done during the next campaign.

**WP 2 : Characterisation of physical properties of atmospheric aerosol (RMI, BIRA, TROPOS)**
Data of the nephelometer and aethalometer have been preliminarily analysed and show results in line with previous seasons. Two remote sensing instruments dedicated to aerosols have been installed and operated successfully on the roof of PEA: a CIMEL sunphotometer (during austral summer) and a MAX-DOAS. The MAX-DOAS is still operational and takes automatic measurements during the austral winter. The MAX-DOAS data has been integrated in the analysis chain FRM4DOAS developed at BIRA-IASB and the data are processed automatically in near real-time. Six filter samples for analysis on ice nucleating particles (INP) have been collected during the field campaign 2020/21.

**WP 4 : Meteorological analysis (RMI)**
The radio soundings in the beginning of December 2020 showed very low temperatures in the upper troposphere and lower stratosphere, connected to the then still large ozone hole region with record low temperatures.
10-day backward trajectories have been calculated with FLEXTRA over a period of 10 years. A k-means cluster analysis has been performed for the trajectories, based on the whole period as well as for each season separately, and four clusters have been identified (see Fig. 10). One of the clusters has its air mass origin almost completely above the Antarctic continent, corresponding to air subsiding from aloft. The other clusters show rather oceanic origins and reach lower altitudes. The Southern Ocean and the Antarctic continent are the main source regions. Within the constraints of this analysis, source regions from South America, Australia and Southern Africa are very limited.

**WP 5 : Regional Climate Modelling (KUL)**
Using an ensemble of regional climate models is a strong added value when studying the surface mass balance. Not only do the estimates become more robust by using more members, in addition uncertainties can be assessed. Given the importance of coastal areas in the estimates of the

integrated surface mass balance over the ice sheet and given the large observational uncertainties in these areas it is recommended that targeting observational campaigns are planned in coastal areas. More information can be found in the paper that is currently under review in The Cryosphere (Mottram et al., 2020).

**WP 6 Project coordination and valorisation, instrument maintenance :**
See section 2, achieved work.

**General recommendations:**
In December 2020, the ozone hole lasted longer than usual above Antarctica and the station team was inside the ozone hole area during the first three weeks of the expedition. The Brewer and MAX-DOAS could very well detect the depletion. The Brewer has to be dismounted each end of the season, but the MAX-DOAS remained and should be operational before the team arrives. The MAXDOAS data could be used to warn the crew if the ozone column is low again when they arrive at PEA.
The role of changes in INP for clouds dominates over the role of changes in CCN. Little is known about INP in the Antarctic region and there is a clear need to obtain more measurements, particularly as INP play an important role in ice formation in clouds.

## 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)**
Substantial maintenance on the precipitation radar will be necessary during the next campaign. The disdrometers will be installed during the next campaign.

**WP 2 : Characterisation of physical properties of atmospheric aerosol (RMI, BIRA, TROPOS)**
The analyses of the existing aerosol instrumentation will go on. The condensation particle counter and the Laser Aerosol Spectrometer will be re-installed at PEA after repair. The small particle number size distribution sensor for the remote CLIMB site will also be installed during the field season 2021/22. First data of this sensor will be available at the end of that season. During the field season 2021/22, another set of filter samples of INP analyses will be collected and then sent to Tropos for laboratory analysis.
IASB-BIRA will consolidate the database of aerosol optical depths by modelling the radiative transfer and comparing the simulated $O_4$ slant columns with the MAX-DOAS measurements. IASB-BIRA will also study the phase function with the almucantar scans of the MAX-DOAS instrument.
The MAXDOAS measurements at PES may also be used for the validation of satellite products, in particular stratospheric species measured by TROPOMI. The CIMEL sunphotometer will be re-installed during next austral summer at PEA.

**WP 3 : Characterisation of (semi-)volatile organic compounds at the cloud level (UGent)**
Delivery of the 2019-2020 samples from the first autosampler is scheduled end of April 2021. As soon as they arrive analysis of the samples can be performed using TD-GC-MS. Sample recollection on a clean sorbent tube will be evaluated to be able to re-analyse the sample later using a complimentary technique such as TD-PTR-TOFMS.

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

The small robust loggers for meteorological data have been purchased and will be installed during the coming field season 2021/22. One at the CLIMB remote site, one on the Utsteinen nunatak and one at PEA station. At the end of the season in February 2022, a first set of data can already be analysed.

Radio soundings will also be made during season 2021/22. The analysis of radio sounding data from previous seasons will continue. In particular, during July and August 2021, two 6-weeks-internships at RMI of physics master students of University of Antwerp will work with these radio sounding data.

The gap of the IMAU AWS will be filled with an AWS of EPFL (école polytechnique federal de Lausanne) Lausanne, CH. That AWS has been displaced from the PEA air strip to the East side of the Utsteinen ridge, near PEA. CLIMB project partners have already been collaborating with them and AWS data will be available for the CLIMB analyses.

The FLEXTRA trajectory model will further be applied to identify air mass origin regions, including the cluster analysis. Especially, the properties along the trajectories within each cluster (e.g. meteorological parameters, altitude, time over ocean) will be further investigated, as well as particle properties between the clusters. For specific cases, also the FLEXPART dispersion model will be applied, e.g., to identify potential source regions for specific events (e.g., precipitation events).

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

Model improvements and an assessment of the aerosol effect on clouds and the climate of Antarctica are planned for the second year of the CLIMB project.

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

- The next Belgian Research Expedition to the Princess Elisabeth station (November 2021 – February 2022) will be planned similar to season 2020/21, with 1 or 2 Pax.
- At the remote CLIMB site, the instrumentation will be extended with the particle sizer, the meteo data logger and a disdrometer. Another disdrometer will be installed at the station, as another meteo data logger. A third meteo data logger will be installed on the Utsteinen nunatak. Further, the existing instrumentation and power supply will be maintained.
- Further INP samples will be collected during the field campaign season;
- The maintenance of the ceilometer and hence precipitation radar are needed, in especially for the radar where a replacement of antenna and controller are foreseen;
- The CLIMB website has been created and will be further developed in order to give information on results and availability of data.
- Results of CLIMB will be presented at vEGU 2021 (online meeting, accepted presentation for Karen De Causmaecker), at the European Aerosol Conference (submitted contribution by Alexander Mangold) and other virtual conferences;
- MAXDOAS observations will be used and presented during a dedicated MAXDOAS workshop at Max-Planck Institute for Chemistry, Mainz, Germany, 11-12 May 2021;
- Further outreach activities like lectures at university, public talks, and blogs will be continued, e.g., by Preben Van Overmeiren on 5 May 2021 on the UGent Faculty Research Days and on 18 May 2021 at an event of the UGent Alumni organization;
- The final scientific workshop will be organized, probably as an online event.

## 6. FOLLOW-UP COMMITTEE

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

Project partner KUL 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 currently under review in The Cryosphere (Mottram et al., 2020). In the framework of this research, Nicole van Lipzig was in contact with Dr. Xavier Fettweis of the University of Liège, Belgium.

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 on practical points for the measurements of ice nucleating particles.

Alexander Mangold met online with Prof. Dr. Frank Pattyn (Université Libre de Bruxelles, Belgium), during the meeting of the Belgian National Committee on Antarctic Research (BNCAR) in December 2020. He is president of BNCAR and also delegate to SCAR. Questions on the scientific programme of the field campaign 2020/21 were discussed.

## 7. VALORISATION ACTIVITIES

### 7.1 PUBLICATIONS

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

- Aun, M., Lakkala, K., Sanchez, R., Asmi, E., Nollas, F., Meinander, O., Sogacheva, L., De Bock, V., Arola, A., de Leeuw, G., Aaltonen, V., Bolsée, D., Cizkova, K., Mangold, A., Metelka, L., Jakobson, E., Svendby, T., Gillotay, D., and Van Opstal, B.: Solar UV radiation measurements in Marambio, Antarctica, during years 2017–2019, Atmos. Chem. Phys., 20, 6037–6054, https://doi.org/10.5194/acp-20-6037-2020, 2020.
- Held, A. and A. Mangold, 2021, Measurement of fundamental aerosol physical properties, in: Th. Foken (ed.), Springer Handbook of Atmospheric Measurements, Springer, proofread accepted, in press.
- Mottram, R., Hansen, N., Kittel, C., van Wessem, 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 Discuss, https://doi.org/10.5194/tc-2019-333, in review, 2020.

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

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

**Oral presentations**:

- K. De Causmaecker, A. Mangold, C. Walgraeve, P. Van Overmeiren, N. Mattielli, S. Gili, and A. W. Delcloo, Identifying source regions at the Princes Elisabeth station in Antarctica, using dispersion modelling tools: a case study, European Geosciences Union General Assembly 2020 (online video conference), Abstract EGU2020-9127, 4-8 May 2020, Vienna, Austria, 2020.

- S. Gili, A. Vanderstraeten, M. Cazaunau, A. Chaput, J.-F. Doussin, C. Di Biagio, P. Formenti, J. S. King, A. Mangold, N. Mattielli, E. Pangui, P. Van Overmeiren and C. Walgraeve, The role of Southern Africa as a dust precursor to East Antarctica, European Geosciences Union General Assembly 2020 (online video conference), Abstract EGU2020-18441, 4-8 May 2020, Vienna, Austria, 2020.
- Merlaud A. A trip to the ozone hole, BIRA seminar, 9 February 2021

**Poster presentations:**

- Mangold, H. De Backer, V. De Bock, K. De Causmaecker, A. Delcloo, Q. Laffineur, F. Hendrick, C. Hermans, P. Herenz, H. Wex, P. Van Overmeiren, C. Walgraeve, S. Gili, and N. Mattielli, Atmospheric aerosol in Dronning Maud Land, East Antarctica: physical and chemical properties and source region analysis, European Aerosol Conference 2020 (online) Abstract P3-036, 30 August – 4 September, Aachen, Germany, 2020.
- P. Van Overmeiren, S. Gili, A. Vanderstraeten, N. Mattielli, A. Delcloo, K. De Causmaecker, A. Mangold, K. Demeestere, H. Van Langehove, C. Walgraeve, Obtaining insight in atmospheric trace organic compound concentrations and trends in Dronning Maud Land, East Antarctica by means of long term passive and active air sampling, SCAR Open Science Conference (only online), Hobart, Australia, 3-7 August 2020.

## 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/). One meeting of BNCAR has been on 18 December 2020. 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

Nicole van Lipzig: Podcast – together with weatherman Frank Deboosere – melting ice sheets, sea level rise and sea ice. https://www.vrt.be/vrtnws/nl/2020/10/15/planeet-frank-7/, 15 October 2020:

Nicole van Lipzig was promoter of the KU Leuven Honorary Doctorate Valerie Masson Delmotte, co-chair of IPCC working group 1 and paleoclimatologist, which raised substantial attention in the Flemish media, 2020;

Mangold, A., Notre l'environnement, le climat et l'Antarctique, Workshop for children of 12-13 years, presentation and experiments, TADA, (http://toekomstatelierdelavenir.com), 24 October 2020, Anderlecht, Belgium;
Merlaud, A., The ozone layer and its measurements at PES, TADA, (http://toekomstatelierdelavenir.com), 6 February 2021;

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

Blog by Preben Van Overmeiren on the research activities during Belare 2020/21 (https://ozone.meteo.be/projects/chase/belare2020-2021-campaign)

News on the IASB-BIRA website, interview with Alexis Merlaud on the campaign 2020/21: https://www.aeronomie.be/en/news/2020/scientific-expedition-antarctica-interview

Zoom-In (News-ticker of RMI) at the beginning of the season at PEA: https://www.meteo.be/fr/infos/actualite/des-scientifiques-belges-suivent-de-pres-le-trou-record-dans-la-couche-dozone-en-antarctique

Interviews with CLIMB partners on PEA station website or on website of International Polar Foundation :
http://www.antarcticstation.org/news_press/news_detail/preben_van_overmeiren_explains_aerosols_and_cloud_formation_in_antarctica ( 9 February 2021); ); short version also on UGent faculty website:
https://www.ugent.be/bw/en/news-events/news/expedition-antarctica-atmospheric-particles-preben-van-overmeiren.htm
http://www.antarcticstation.org/multimedia/picture_gallery/traverse_for_the_chase_and_climb_projects ( 9 February 2021);
http://www.antarcticstation.org/news_press/news_detail/alexis_merlaud_springtime_ozone_hole_over_antarctica_lasting_longer ( 14 December 2020);
http://www.polarfoundation.org/news_press/news/alexander_mangold_contributions_of_research_to_polar_science_yopp_ipcc ( 22 July 2020)

Video call of Preben Van Overmeiren during his stay at PEA, and short lecture on life and science on Antarctica from the PE Station to the 5th and 6th year of the municipal primary school 'de droomwolk' (Beveren-Waas).

## 8. ENCOUNTERED PROBLEMS AND SOLUTIONS

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

Despite the Covid-19 pandemic, the Belare 2020/21 expedition to PEA station could take place. It meant however, a long quarantine period in Cape Town (RSA) for the expedition team, which prolonged from planned two weeks to four weeks due to meteorological conditions and needed quarantine time for other flight passengers or pilots. This shortened the planned (mid-Nov to 20-Dec 2020) time at PEA by two weeks (arrival at PEA by end November 2020 only). In order to be able to do all foreseen field work, Preben Van Overmeiren stayed almost four weeks longer at PEA.

Unfortunately, not all instrumentation for the remote CLIMB site could be purchased in time for the season 2020/21. Due to the Covid-19 imposed restrictions, the time needed to buy equipment and to have it delivered prolonged largely (more time for administrative checks, more time to have quotes, more time to have it delivered). Also, there were less DROMLAN flights to Antarctica and respective delivery times for items to be sent in were much earlier than previous seasons. Therefore, the foreseen disdrometers, small meteorological robust loggers and the particle sizing instrument could not be installed at the remote CLIMB site. However, these instruments are available now and can be installed in season 2021/22. In addition, Preben Van Overmeiren succeeded in installing the automatic sampler for (S-)VOCs at the remote site, including the necessary power supply infrastructure. A solution for meteorological data at the remote site is that there is also an automatic weather station installed nearby, by Swiss colleagues of EPFL Lausanne. It is already agreed that we will have access to these data.

The micro-rain radar appeared to be severely damaged after the last austral winter. Together with the help from the manufacturer and with the kind help of scientists from UGent that where at PE, the instrument could be put into operation again by the end of the season. However substantial maintenance will be necessary during next season.

Due to the Covid-19 crisis, participation at (inter-)national scientific conferences is compromised. E.g., some conferences have been postponed from 2020 to following years and other conferences took place virtually, however, with shortened agenda (e.g., SCAR Open Science Conference 2020). Others kept the whole programme (e.g., EAC 2020). CHASE partners participated however in several virtual conferences, see section 7.

## 9. MODIFICATIONS COMPARED TO THE PREVIOUS REPORT (IF APPLICABLE)

### 9.1 PERSONNEL

KMI hired a new staff member: Karen De Causmaecker

| Partner | Name | Nationality | Gender | Date of birth | Certificate | Year of graduation | Statute | Time implication in the project financed by BELSPO (in FTE) | Type of labour contract | Annual gross salary | Time implication in the project financed by other source(s) (in FTE) | Name(s) of the other funding source(s) | Remarks |
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## 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 …*

KMI:
Dr. Karen De Causmaecker works since December 2020 on the CLIMB project. Before, she worked on the CHASE project. As both projects are closely related, she continues tasks for both projects.