ResearchGate

See discussions, stats, and author profiles for this publication at: https://www.researchgate.net/publication/385410851

SASAS 2024 - BIANKA : A balloon field campaign to study climate change uncertainties

Conference Paper · October 2024

CITATIONS
0

18 authors, including:

Markus Geldenhuys
South African Weather Service
24 PUBLICATIONS **122** CITATIONS
SEE PROFILE

Casper Labuschagne
South African Weather Service
90 PUBLICATIONS **4,222** CITATIONS
SEE PROFILE

All content following this page was uploaded by Markus Geldenhuys on 31 October 2024.

The user has requested enhancement of the downloaded file.

38TH ANNUAL CONFERENCE OF THE SOUTH AFRICAN SOCIETY FOR ATMOSPHERIC SCIENCES

Exploring the novel integration of tools to understand our changing environment

Annual Conference Proceedings
29-30 October 2024

Conference Proceedings ISBN: 978-1-0370-1666-0

PROCEEDINGS OF THE
38th ANNUAL CONFERENCE OF THE
SOUTH AFRICAN SOCIETY FOR
ATMOSPHERIC SCIENCES

29 – 30 October 2024

Hosted by the North-West University
Potchefstroom, South Africa

First Edition Copyright: October 2024
Conference Proceedings ISBN: 978-1-0370-1666-0
Conference Secretariat
South African Society for Atmospheric Sciences
https://www.sasas.org/

BIANKA : A Balloon Field Campaign to Study Climate Change Uncertainties

Markus Geldenhuys 1,2, Kyriaki Blazaki 2, Armin Afchine 2, Francisco Cereceda 5, Jens-Uwe Grooß 2, Michaela I. Hegglin 2, Corinna Kloss 2, Thomas Kuhn 3, Casper Labuschagne 1, Pieter Labuschagne 1, Johannes C. Laube 2, Tshidi Machinini 1, Thumeka Mkololo 1, Jean-Baptiste Renard 4, Christian Rolf 2,, Wilhelm Steffes 2, Chris Stopford 6, Martin Riese 2

1 South African Weather Service, 1263 Heuwel Road, Centurion
2 Institute of Climate and Energy Systems - Stratosphere (ICE-4), Forschungszentrum Jülich GmbH, Germany
3 Division of Space Technology, Luleå University of Technology, Kiruna, Sweden
4 LPC2E-CNRS/Université d'Orléans, 3A avenue de la recherche scientifique, 45071 Orléans, France
5 Universidad Technica Federico Santa Maria, Chile
6 Centre for Atmospheric and Climate Physics, University of Hertfordshire, Hatfield, Hertfordshire, AL10 9AB, UK

Abstract

Climate change affects our everyday lives and despite a lot of research, many climate uncertainties exist. This work aims to help address some of these uncertainties via the BIANKA (**BI**modal **AN**des **KA**roo) campaign; a first of its kind for South Africa. The campaign collected observations in the data sparse southern hemisphere and was a tri-lateral campaign between Chile, Germany and South Africa. The BIANKA campaign aimed at observing atmospheric composition, aerosols and cirrus clouds over South Africa as well as South America, with a special focus on the upper troposphere and stratosphere. This work summarises the aims and outlines the observations of the campaign. Moreover, initial results are showcased alongside plans for future work.

Keywords: Aerosols, cirrus, ozone, atmospheric composition, experiment

Introduction

Climate and weather are driven by incoming solar radiation (Trenberth et al., 2009). The incoming shortwave radiation should balance the outgoing longwave radiation for the system to be in equilibrium. Anthropogenic emissions of greenhouse gasses into the atmosphere have caused an imbalance of the incoming and outgoing radiation resulting in climate change. State-of-the-art observations cannot yet fully account for the imbalance (Trenberth and Fasullo, 2010) and more observations are required; especially in the Southern Hemisphere (Lucas et al., 2012).

The solar radiation budget is influenced by, amongst others, cirrus clouds (Kramer et al., 2016), aerosols (Kremser et al., 2016), and atmospheric composition (Riese et al., 2012). The BIANKA (**BI**modal **AN**des **KA**roo) campaign was a tri-lateral campaign where the Universidad Technica Federico Santa Maria, Chile; Forschungszentrum Jülich, Germany and South African Weather Service aimed at constraining the distributions of these three factors above South Africa and South America through balloon-borne measurements. Beaufort West (32.354°S 22.583°E) formed the South African base and Portillo (32.836°S 70.129°W) the Chilean base. The campaign took place from 26 February to 9 March 2024 and partly built on the campaign of February/March 2023 in South Africa.

Some objectives of the BIANKA campaign included:
1. Capturing high resolution photos of cirrus ice crystals with the brand new NIXE-Balloon instrument.
2. Detection and characterisation of aerosols within the troposphere and stratosphere.
3. Measuring atmospheric trace gas composition with ozone-sondes, AirCores and the MOSES payload.

The purpose of this work is to provide an overview of the campaign, variety of instruments and initial promising results.

Instrumentation and Method

Four instrument packages were attached in various configurations to balloons during the BIANKA Campaign. These included the MOSES payload, AirCores, LOAC and NIXE-Balloon.

The **MOSES** payload (Khordakova et al., 2022) contains a cryogenic frost-point hygrometer capable of measuring water vapour at its very low stratospheric concentrations, an ozone sonde, and an optional COBALD backscatter instrument for aerosol measurements (Hanumanthu et al., 2020). Given the scientific focus of the campaign, the latter instrument was not flown. In Chile, only a radio- and ozone-sonde was flown to a) enable a higher launch frequency, and b) reduce costs, given that payload recovery in the Andes Mountains is not feasible.

AirCores (Tans, 2022) consist of a ~50-100m stainless steel tube with one end closed. The air inside the AirCore gradually flows out as the payload rises to ~25-35km due to the fact that it is constantly moving to lower pressures. After the balloon bursts, the tube continuously fills during its descent on a parachute as the air flows from the higher pressure outside to the lower pressure inside the tube. Minimal mixing and diffusion take place and are corrected for afterwards. Air samples from AirCores can be analysed for most long-lived species, including; Carbon dioxide, methane, etc.

The Light-weight Optical Aerosol Counter **LOAC** (Renard et al., 2016a) is a miniature spectrometer with a pump. Air is pumped into the payload where it is scanned by a laserbeam. The scattered light at two angles off the aerosol is then measured to determine concentration, size distribution, and some information on the typology of the aerosol/particles, for particles between 200nm to 30µm.

NIXE-Balloon was flown for the first time in February 2024 in South Africa. The instrument comprises a commercially available optical particle counter from Alphasense, modified for use on balloons by the University of Hertfordshire, named OPC-N3. It is capable of measuring aerosol and cloud particles ranging from 0.4 to 40µm. Additionally, an imaging device is also deployed. This instrument is based on Kuhn and Heymsfield (2016) and takes in situ pictures of cloud ice particles collected on an oiled film. The camera can capture particles from 10µm up to 1.5mm.

Flight planning was based on forecasts from the South African Weather Service operational 4km Unified Model, European Centre for Medium-range Weather Forecasting (ECMWF) and the Chemical Lagrangian Model of the Stratosphere (CLaMS). The ECMWF and CLaMS model data was integrated into the Mission Support System (MSS) software (Bauer et al., 2022) to facilitate balloon flight planning.

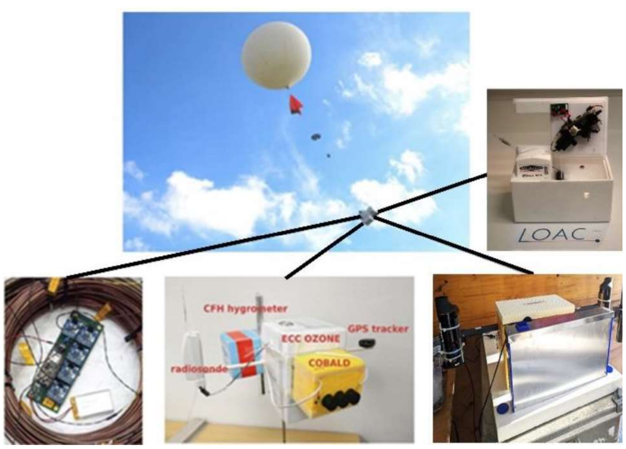

Figure 1: The four instruments can be attached to the balloon in different configurations. Bottom left is an AirCore, bottom middle the MOSES payload, bottom right the NIXE-Balloon prototype, and top right LOAC (LOAC photo from Renard et al., 2016b).

Both sites in Chile and South Africa are situated in the tropospheric westerly belt (Wallace and Hobbs, 2006). Over South Africa these westerly winds were periodically disturbed by a mid-tropospheric high-pressure system. The high pressure resulted in hot, clear days with slow tropospheric winds. The slow winds translated into the balloon drifting shorter distances and ultimately into easier payload recoveries. During the same time, the Chilean campaign region was being influenced by a series of shallow tropopause folds associated with passing Rossby waves in the westerly belt. For both sites the tropospheric westerly belt slowly changed to an easterly belt in the stratosphere. This further helps to bring the balloon back closer to the landing site.

Results and Discussion

Ozone is a key stratospheric trace gas and can also be used to study tropospheric and stratospheric exchange processes. Figure 2 shows two ozone profiles that illustrate stratospheric intrusions. The flight on 28 February shows a large peak at 10km surrounded by lower ozone values. Both days show another peak at 12.5km. The dip at 13-14km is not as sharp as lower down, most likely caused by more pronounced mixing of tropospheric and stratospheric air. These peaks indicate that the stratospheric air is surrounded by tropospheric air and a tropospheric-stratospheric exchange is taking place. No intrusion is observed below ~10km which indicates a shallow intrusion into the troposphere. This is more likely than a deep intrusion during this time of year (Akritidis et al., 2021).

The aim was to sample the same intrusions again over South Africa, but these never came close to the campaign site. This finding is consistent with the December-to-February climatology (Figure 2(a) in Akritidis et al., 2021) showing a disconnect in tropopause folds between South America and South Africa.

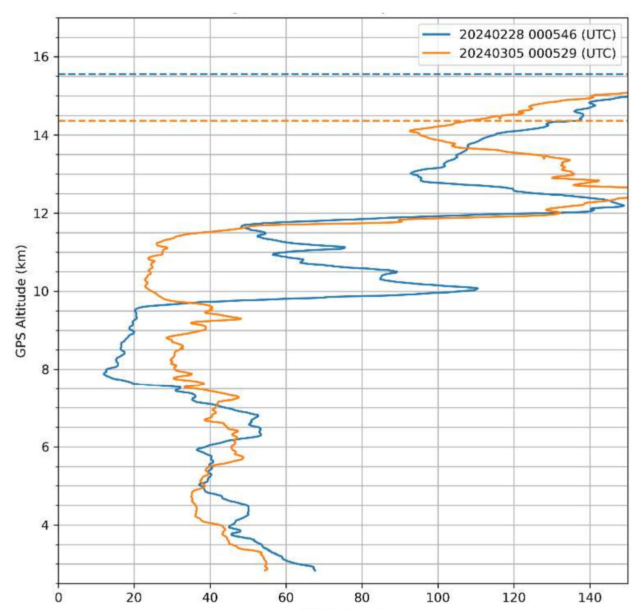

Figure 2: Two ozone profiles launched from Portillo, Chile on 28 February (blue) and 5 March 2024 (orange) at ~05:00UTC.

On March 3, 2023, air samples were captured by an AirCore over South Africa to create an atmospheric profile.

The upper tropospheric and stratospheric portions of these air samples were subsampled into a specialized container (a more robust, leak-tight tubing called a subsampler) for transportation to Germany for analysis. The subsampler consisted of 15 independent loops of tubing, which reduced the dataset to 15 points. Transferring the air from the AirCore to the subsampler induced some mixing, resulting in the smoothing of the profiles shown in Figure 3. Figure 3 shows concentrations of Sulfur Hexafluoride (SF6) and Chlorofluorocarbon-11 (CFC-11, CCl3F) between 9 and 24km. The tropospheric and stratospheric regions are clearly distinguishable on either side of the cold point tropopause. No major concentration gradients are observable in the troposphere contrasted by a rapid decrease with increasing altitude in the stratosphere. The main causes of this structure are much faster mixing times and complete chemical inertness of the two molecules in the troposphere, whereas in the stratosphere the vertical mixing takes years and is, in the case of CFC-11, accompanied by significant chemical decomposition. The lower end of the profiles at about 10km agrees reasonably well with the publicly available data from the NOAA Global Monitoring Lab ground-based network (https://gml.noaa.gov/) data for the southern hemisphere in March 2023 (CFC-11: 217.5 ± 0.1ppt, SF6: 11.25 ± 0.15ppt). This data set successfully demonstrates the feasibility of deriving in situ profiles at high altitudes in the southern hemisphere for such trace gases for the first time. Further investigations are underway to use these values to determine the mean age of the air as a constraint to evaluating the speed of the Brewer-Dobson circulation.

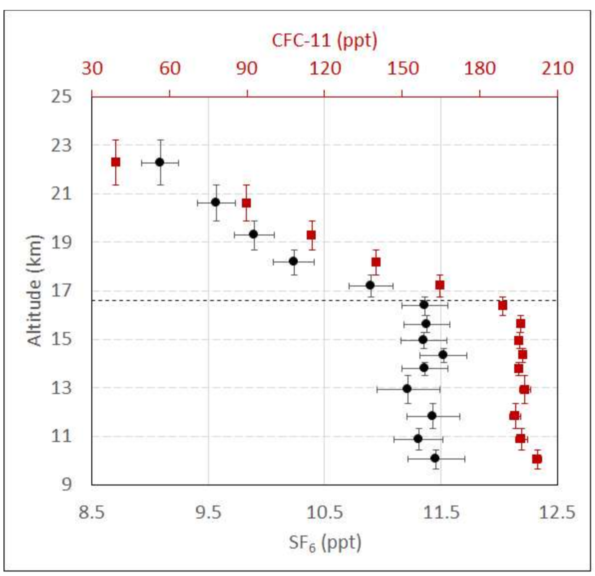

Figure 3: Sulfur hexafluoride (SF_6 – black dots) and Chlorofluorocarbon-11 (CFC-11 – red squares) mixing ratio profiles from air sampled with an AirCore launched on 3 March 2023 from near Beaufort West, South Africa. The dashed black line is the cold point tropopause from radiosonde data. Horizontal error bars represent measurement precisions whereas vertical ones visualize the altitude range over which the samples were collected (average altitude uncertainty: ~1km).

As a brief example for the ice crystal observations, on 29 February 2024 NIXE-Balloon passed through a cirrus cloud and captured the first photo of an ice crystal over South Africa (Figure 4). This type of ice crystal is longer than wide and is called a bullet form (Jarvinen et al., 2018). The full data set is currently being investigated for further insights into these ice crystal measurements with their formation mechanisms.

Figure 4: A photo of an ice crystal from NIXE-Balloon at ~270hPa on 29 February 2024. The first of its kind over South Africa.

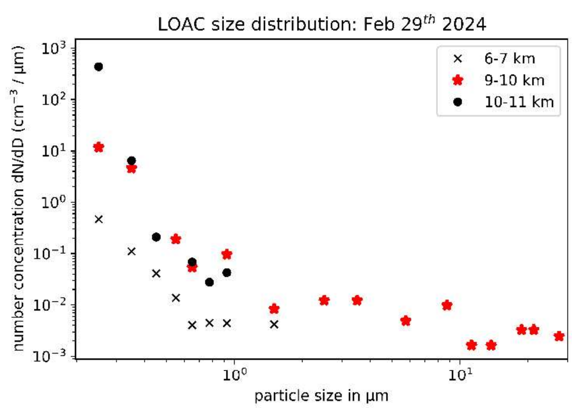

Figure 5: Aerosol size distribution from LOAC on 29 February 2024 from Beaufort West, South Africa. The red stars approximately coincide with the altitude of the ice crystal photo. The black circles and crosses show size distribution at altitudes above and below the NIXE-Balloon picture (Figure 4).

Different diameters of the particles measured during this flight can be seen in Figure 5. The size distribution reaches 30µm, which is the upper limit of what LOAC can measure. Thus, it is likely that larger particles also

View publication stats

existed. The aerosol typology scheme identified ice particles between 0.5 to 30µm and liquid particles between 0.5 and 2µm at 9-10km altitude (see Figure 4). Aerosols above and below this level during the same flight are dominated by liquids. Here NIXE-Balloon is well complemented by LOAC, which measured liquid and ice particles well below the lower size/detection limit of NIXE-Balloon.

Conclusions and Outlook

The BIANKA campaign aimed to address the data sparse gap in the Southern Hemisphere by focusing on uncertainties in climate models. Tropospheric-stratospheric exchanges were observed over Chile, which provides a good dataset for studying atmospheric composition in the upper troposphere and lower stratosphere. Over South Africa and Chile observations were collected of multiple different trace species that is being evaluated against other observations and climate models. Sulfur hexafluoride and CFC-11 were observed in air collected with an AirCore and will be used to perform age-of-air studies to provide information on the stratospheric circulation systems, as well as assessing the continued success of international agreements such as the Montreal Protocol on Substances That Deplete the Ozone Layer.

In the troposphere the first photo of an ice crystal above South Africa was captured by NIXE-Balloon. The LOAC aerosol instrument also detected such ice crystals and provided additional information on much smaller sizes. This illustrates how different instruments can complement each other during balloon campaigns deploying light-weight sensor payloads in a modular way. In addition, the carbon dioxide and methane vertical profiles, which extend from near ground to the middle stratosphere, are currently being investigated further and could help constrain the South African greenhouse gas inventory in the future. Overall, the newly created high quality in situ data sets are well suited to better characterize dynamical and chemical processes in the sparsely sampled southern hemispheric upper troposphere and stratosphere.

Acknowledgements

We would like to thank everyone who supported the campaign to make this work. Especially, we would like to thank all the farmers within the Karoo who always welcomed us with open arms and went out of their way to help us retrieve our payloads. Markus Geldenhuys would like to thank all his forecasting colleagues who always work his forecasting shifts while he is doing fieldwork/research.

References

Akritidis, D. et al., 2021. A global climatology of tropopause folds in CAMS and MERRA-2 reanalyses. Journal of Geophysical Research: Atmospheres, Issue 126, p. e2020JD034115.

Bauer, et al., 2022. The Mission Support System (MSS v7.0.4) and its use in planning for the SouthTRAC aircraft campaign. GMD, 15(24), pp. 8983--8997.

Hanumanthu, S. et al., 2020. Strong day-to-day variability of the Asian Tropopause Aerosol Layer (ATAL) in August 2016 at the Himalayan foothills. acp, Issue 22, pp. 14273-14302.

Jarvinen, et al., 2018. Additional global climate cooling by clouds due to ice crystal complexity. ACP, 18(21), pp. 15767-15781.

Khordakova, D. et al., 2022. A case study on the impact of severe convective storms on the water vapor mixing ratio in the lower mid-latitude stratosphere observed in 2019 over Europe. acp, Issue 22, pp. 1059-1079.

Kuhn, T. & Heymsfield, A., 2016. In Situ Balloon-Borne Ice Particle Imaging in High-Latitude Cirrus. pp. 3065-3084.

Lucas, et al., 2012. An observational analysis of Southern Hemisphere tropical expansion. JGR, p. D17112.

Renard, et al., 2016. LOAC: a small aerosol optical counter/sizer for ground-based and balloon measurements of the size distribution and nature of atmospheric particles - Part 1: Principle of measurements and instrument evaluation. AMT, 9(4), pp. 1721-1742.

Renard, et al., 2016. LOAC: A small aerosol optical counter/sizer for ground-based and balloon measurements of the size distribution and nature of atmospheric particles - Part 2: First results from balloon and unmanned aerial vehicle flights. AMT, 9(8), pp. 3673-3686.

Riese, et al., 2012. Impact of uncertainties in atmospheric mixing on simulated UTLS composition and related radiative effects. JGR, Issue 117, p. D16305.

Tans, P., 2022. Fill dynamics and sample mixing in the AirCore. amt, Issue 15, pp. 1903-1916.

Trenberth, et al., 2009. Earth's global energy budget. BAMS, March.pp. 311-324.

Trenberth, K. & Fasullo, J., 2010. Tracking Earth’s Energy. Science, pp. 316-317.

Wallace, J.M. & Hobbs, P.V., 2006. Atmospheric Science. 2 Hrsg. s.l.:Academic Press.