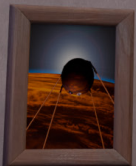


Annual report

Royal Belgian Institute for Space Aeronomy (BIRA-IASB)

2023-2024



Colophon

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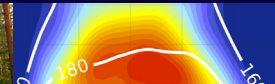
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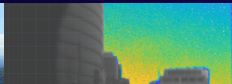
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Foreword

The period 2023-2024 was marked by significant changes at our Institute. No fewer than three Executive Directors succeeded one another during this short period. I would like to express my sincere gratitude to Martine De Mazière, who served as interim director of BIRA-IASB for 12 years without ever being appointed or officially recognised for her commitment and constant support throughout those years. I am sure that all the Institute's collaborators join me in expressing their appreciation. I would also like to thank Ronald Van der Linden for ensuring a smooth transition, allowing for the serene appointment and establishment of the new management.

Over the past two years, BIRA-IASB has confirmed its international recognition and involvement in numerous

research projects, as evidenced by this report and its more extensive version, which can be consulted on our website www.aeronomie.be. Our research projects cover many areas, such as Earth observation from space, analysis of the impact of pollution on air quality and climate, exchanges between the biosphere and the atmosphere, changes in the composition of the stratosphere and their consequences on climate, space physics and meteorology, the development of space missions and the analysis of their observations, and the development of reference laboratories.

BIRA-IASB can be proud of its recognised expertise in the development of observation instruments, particularly space-based ones. IASB researchers and engineers are involved in two of the three missions selected by ESA in 2023 to move

into Phase A. One of these missions will then be chosen to become ESA's next M-class mission. Development of the VenSpec-H instrument aboard ESA's future EnVision mission is continuing. The Institute is also contributing to the Comet Interceptor mission. But instrument development is not limited to space: our ground-based activities also require specific instrumentation. Examples include the progress made by SEMPAS in observing emissions from ships off our coasts, the various instruments developed for observing auroras, and measurements of volatile organic compounds at various sites in Belgium.

BIRA-IASB has continued to contribute to the European Copernicus program through its participation in numerous Earth observation, satellite data analysis, and atmospheric

modeling projects. The Institute is thus continuing its mission to collect, produce, and disseminate high-quality data and information on changes in our planet's atmosphere, in line with its commitment to combat fake news with reliable, verifiable, and indisputable facts.

BIRA-IASB plays a key role in the European research infrastructures ICOS and ACTRIS, coordinating the Belgian consortium for the latter, as well as the component dedicated to remote sensing of reactive trace gases.

To ensure consistency with the scientific message conveyed regarding climate change and its causes linked to human activities, BIRA-IASB participated in an initial exercise to determine its ecological footprint. This initiative will be

continued and will enable us to analyse the effect of future recommendations on, for example, the number of missions or the use of public transportation.

In parallel with its scientific activities, BIRA-IASB continued its dissemination and awareness-raising activities aimed at a variety of audiences by preparing exhibitions, developing educational materials, and welcoming students at different stages of their studies.

The success of BIRA-IASB's activities depends entirely on its staff, their individual talents and skills, and their willingness to work as a team. All the results achieved over the past two years are the fruit of the labour and dedication of the entire BIRA-IASB staff, whom I would like to thank warmly.

Ann Carine Vandaele
General Director
September 2025



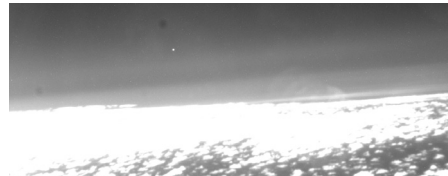
BIRA-IASB involvement





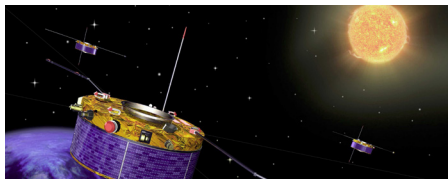
Space physics

Cluster mission ends with controlled re-entry of the satellite Salsa-C2



After more than 24 years in orbit, the Cluster mission is coming to an end. On Sunday 8 September 2024, a first satellite of this ESA mission, Salsa-C2, re-entered the Earth's atmosphere over the South Pacific Ocean, ending a very long space adventure. Launched in 2000, the four identical satellites of the Cluster mission have been studying the interaction between the solar wind and the magnetic bubble surrounding the Earth, the magnetosphere.

GRMB dataset: 22 years of Cluster satellite geolocalisation



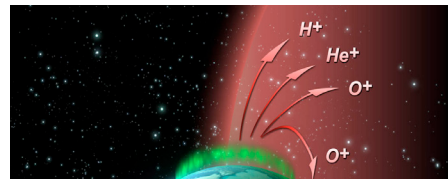
The GRMB (Geospace Region and Magnetospheric Boundary Identification) dataset provides for the first time a classification of the four ESA Cluster satellites' location in geospace regions from 2001 to 2022. Beyond advancing current research, this dataset could pave the way for AI-based classification tools. The GRMB dataset is now publicly available in the ESA Cluster Science Archive.

The Rosetta/ROSINA legacy



Even ten years after Rosetta's historic rendezvous with Comet 67P, Rosetta's ROSINA discoveries continue to (re)shape cometary science. ROSINA detected a wealth of organic molecules, including the simplest amino acid glycine. It also detected phosphorus, a key element in DNA and cell membranes. Its findings reveal new insights into the origins of water on Earth, life's building blocks, and the early solar system.

Deciphering atmospheric escape to model Earth's oxygen loss



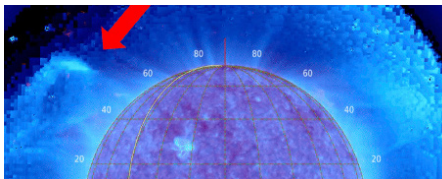
Atmospheric escape plays a significant role in the long-term evolution of planetary atmospheres, thus in the sustainability of habitable conditions. There are different mechanisms that energise atmospheric particles, in particular oxygen neutrals and ions, and lead them to escape from the planet. Using satellite observations and physical scaling, we extrapolated the current oxygen escape rate to Earth's past conditions, considering solar and planetary evolution, to determine the oxygen loss from Earth.

Providing access to data, tools and models with PITHIA



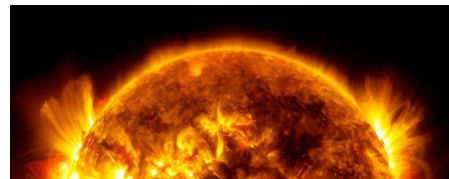
The PITHIA-NRF project stands for Plasmasphere Ionsphere Thermosphere Integrated Research Environment and Access services: a Network of Research Facilities (<https://pithia-nrf.eu>). After 4 years of work, its e-Science Centre (<https://esc.pithia.eu>) provides formalised open access to experimental facilities, data and models, standardised data products, and training services, to support scientific research on the plasmasphere - ionosphere - thermosphere system.

Turbulent impact of interplanetary CMEs on planetary plasma environments



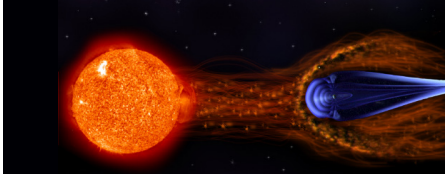
The Venus Express and Cluster space probes are studying the plasma environment of Venus and Earth in situ; data analysis reveals how a Coronal Mass Ejection (CME) erupted on the Sun on 14/01/2009, inducing (1) increased magnetic fluctuations in Venus's outer plasma layers and (2) strong electromagnetic waves in Earth's magnetosheath. Another study with Maven orbiting Mars showed that a CME on 5 March 2018 induces turbulent magnetic noise in Mars' electromagnetic environment. Such turbulence may threaten technologies on board planetary orbiters.

Effects of the Mother's Day superstorm event of 11 May 2024



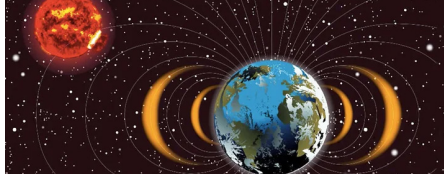
The strongest geomagnetic storm for the last 20 years appeared during the night of 10 to 11 May 2024, caused by a big solar eruption that generated nice auroras visible in many European countries at unusual lower latitudes. It has been called the Mother's Day event due to its date. This geomagnetic storm had important consequences on the radiation belts, with the first observation of four electron belts and the exceptional injection of protons in the South Atlantic Anomaly, a region with a weak magnetic field.

Simulations of proton-driven instabilities in the solar wind



The solar wind is the continuous stream of electrons and ions outflowing from the Sun and filling the interplanetary space. Recent observations from NASA's spacecraft Parker Solar Probe (PSP) have identified a new population of protons traveling at very high speeds in comparison to the "quiet" solar wind. This population is significantly hotter in the direction perpendicular to the magnetic field that stretches out from the Sun and permeates the heliosphere. This feature drives instabilities which we study with numerical simulations.

Prediction of terrestrial radiation belts using deep learning



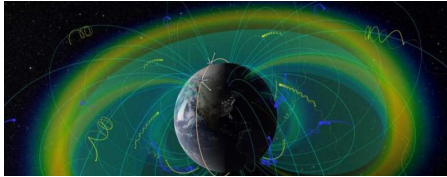
A prototype model based on an artificial neural network has been developed at BIRA-IASB to investigate and forecast the near-Earth high-energy particles' behavior trapped in the Earth magnetic field. This space radiation is the result of sudden solar eruptions and continuous cosmic rays' showers. Monitoring the evolution of this radiation environment is crucial due to its dangerous effects on human activities and on health.

Effects of cosmic rays on the Earth's atmosphere



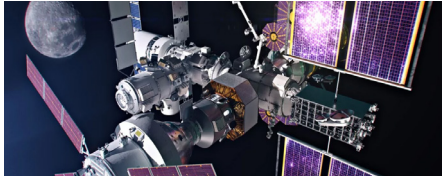
The Earth is drenched in a bath of radiation (highly energetic particles) that constantly interacts with its geomagnetic field and its atmosphere. With the Atmospheric Radiation Interaction Simulator (AtRIS), we can simulate the ionisation and dose rates induced by cosmic rays in different conditions. Understanding the effect of space radiations in the atmosphere is very important due to the role they play on health and on atmospheric chemistry.

Killer electrons and spacecraft charging



At geostationary orbit (~36 000 km altitude) satellites can suffer from operational anomalies caused by electric charging effects due to high energetic (>1 MeV) electrons known as killer electrons. Within the frame of ESA's Space Weather Service Network, BIRA-IASB's Space weather group has developed a prototype service that provides now- & forecasts on the risk for charging during magnetic storms. Warnings ahead of time may support operators to consider taking risk-reduction activities and increasing the alert status of the satellite operator.

Radiation environment & effects nowcasts for the Moon



The Space weather group coordinates one of the four International Science Teams that have been granted early access to data from the European Radiation Sensor Array and the Internal Dosimetry Array instruments on the Lunar Gateway, in the framework of the international Gateway Heliophysics and Space Radiation Working Group. The REENOM team focuses on improving the understanding of the lunar radiation environment and its impacts on both hardware and humans. A service will be developed to provide timely and accurate space weather information.

Five years of space weather operation for civil aviation



As one of the four ICAO Council-designated global space weather centres, PECASUS monitors space weather phenomena and provides advisory information on their expected impact on high-frequency radio communications, GNSS-based navigation and surveillance systems, and radiation exposure risks for aircrew and passengers. In November 2024, PECASUS marked five years of 24/7 operations in support of aviation safety.



Impact of pollutants on air quality and climate

Observations in the Amazon rainforest to quantify emissions



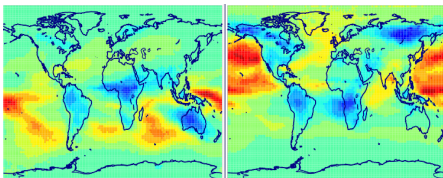
The Amazon rainforest is a major source of volatile organic compounds that influence air quality and climate. To monitor these species, as well as certain greenhouse gases, BIRA-IASB installed a Fourier transform infrared spectrometer in Porto Velho, Brazil, in 2016. This ground-based remote sensing technique measures a similar quantity to that seen by satellite (an integrated column of the atmosphere), making it perfectly suited to verify the quality of satellite measurements.

Satellites reveal trade route shifts due to Red Sea crisis



The Israel-Hamas conflict triggered attacks on commercial vessels in the Gulf of Aden by the Yemen-based Houthi faction, disrupting trade operations and leading to the re-routing of vessels away from the Red Sea through the Cape of Good Hope. We developed a method to isolate the contribution of ship emissions in the satellite observations of NO_2 from the TROPOMI satellite sensor. This method is used to assess the impact of the Red Sea shipping crisis on NO_2 levels along major shipping routes between Asia, Middle East and Europe.

Does cloud-processing of HCHO explain the missing formic acid



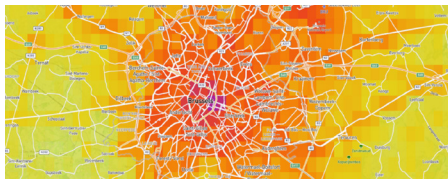
Previous studies revealed a large, unidentified source of formic acid in the Earth's atmosphere. Liquid cloud processing of formaldehyde was recently proposed as a major contributor. However, a new international study using theoretical and modelling tools demonstrated that this process accounts for less than 10% of the missing source. Model simulations performed at BIRA-IASB showed that the mechanism is especially inefficient over forests, which is precisely where the missing source is expected to be the largest.

Nitrous acid (HONO) retrievals from space



Wildfires emit large quantities of trace gases and aerosols, which can degrade air quality and affect climate. Among the constituents emitted by fires, nitrous acid (HONO) is an important precursor of atmospheric oxidants, such as OH and O_3 . Building upon the first detection of HONO from space using TROPOMI, BIRA-IASB has continued to develop and interpret improved HONO retrievals from satellites, including from the geostationary instrument GEMS.

Sentinel-5P products in Terrascope



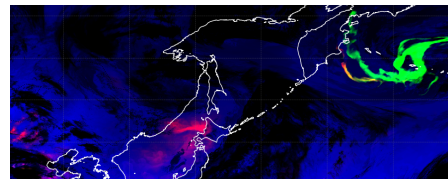
In recent years, the number of data products from satellite measurements of the Earth's atmosphere has been growing rapidly. However, not all data is always easily accessible to non-expert users. The Terrascope ecosystem, hosted at VITO, solves this by allowing users to browse satellite data and tailor them to their specific needs. BIRA-IASB has teamed-up with VITO to add products based on Sentinel-5P data. Among these is an AI-based product of the nitrogen dioxide surface concentration, an indicator of air quality.

Monitoring North Sea ship emissions with a UV-Vis and IR spectrometer



SEMPAS combines two spectrometers, one UV-Visible and one infrared, to measure emissions of nearby ships by remote-sensing. Ship emissions have an impact on health, air quality and climate in coastal areas. SEMPAS aims at quantifying and monitoring these emissions in the Belgian North Sea. The marine environment and the large distance to ships make this a challenging application. The UV-Vis component was first tested in Zeebrugge and will be transferred to an off-shore wind turbine platform in 2025. The infrared component is under development at BIRA-IASB.

Global monitoring of airborne hazards using GEO-constellation



Geostationary sensors offer high temporal and spatial resolution observations of the Earth's atmosphere in the thermal infrared. Using discrimination techniques, BIRA-IASB is developing a system to monitor natural hazards (volcanic plumes and sandstorms) at the global scale from a geostationary constellation. This capability will help to deliver timely alerts in case of events potentially threatening the safety of population and aviation.

The third Cabauw Intercomparison of UV-visible DOAS instruments



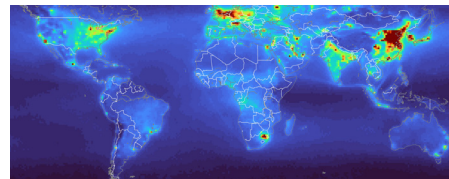
In May-June 2024, BIRA-IASB participated in the third "Cabauw Intercomparison of UV-visible DOAS Instruments" (CINDI-3). The main purpose of this campaign was to intercompare various remote-sensing instruments measuring pollutants such as NO₂ and ozone, and contribute to further develop the reference systems needed for satellite validation. Together with the 100 persons from 18 countries involved in the deployments, BIRA-IASB scientists operated several instruments and were strongly involved in the coordination of field activities.

TROPOMI NO₂ evaluation based on recurrent airborne campaigns



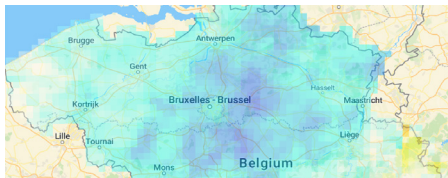
The ESA SVANTE project evaluates the TROPOMI tropospheric NO₂ product through recurrent airborne campaigns using the SWING hyperspectral imager. Conducted over Berlin and Bucharest since 2021, these validation flights map the NO₂ distribution, aligned with TROPOMI overpasses. The data captures various conditions, aiding in the assessment of TROPOMI's accuracy. The project also develops harmonised tools and data formats for processing airborne data, ensuring consistent results and supporting future atmospheric missions like Sentinel-5 and Sentinel-4.

New climate data records of ozone and aerosol precursor gases



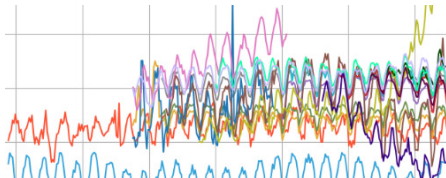
As part of ESA's Climate Change Initiative programme, BIRA-IASB is leading a new project aiming to develop harmonised long-term data records of six atmospheric trace gases (NO₂, HCHO, SO₂, CHOCHO, CO and NH₃) that are precursors of ozone and aerosol Essential Climate Variables (ECVs). The development of HCHO, SO₂ and CHOCHO products as well as the overall validation activities are under BIRA-IASB responsibility. Our tropospheric modelling team also performs an in-depth assessment, demonstrating the value of the new data for climate studies.

LEGO-4-AQ: Monitoring Belgian air quality from space



The LEGO-4-AQ system integrates Sentinel-5P satellite observations with *in-situ* reference measurements to track how NO₂ concentrations near the surface respond to local, regional, and (inter)national air quality policies. For the past 5 years LEGO-4-AQ reports marked decreases of NO₂ over Belgium, from 5% per year in rural areas to 10% per year and more in polluted urban areas. In the Low Emission Zones enforced in Brussels, Antwerp, and Ghent, LEGO-4-AQ does not see stronger NO₂ reductions than in the suburban parts of central Belgium.

Satellite data revisited for Tropospheric Ozone Assessment Report-II



The first international Tropospheric Ozone Assessment Report (TOAR-I) revealed discrepancies between satellite observations of the distribution and long-term changes of ozone in the troposphere, likely due to differences in vertical sensitivity among the various satellite sounding techniques. To improve mutual consistency of the satellite data for the second TOAR assessment, BIRA-IASB has undertaken the vertical harmonisation of 16 key satellite global datasets. Thanks to this harmonisation, the dispersion between datasets is reduced by 10-40%.

Unravelling greenhouse gas variations in Xianghe, China



New research reveals the main sources of greenhouse gases at the Xianghe site, near Beijing. Using advanced ground-based measurements and an atmospheric transport model (WRF-GHG), the key contributing sectors to CO₂ and CH₄ at Xianghe could be identified: industrial activities, agriculture, and energy production, but also the biosphere. Further, weather patterns also significantly influence concentration levels by, for example, transporting pollution from the North China Plain. These findings improve our understanding of regional GHG dynamics and support more accurate climate assessments.



Biosphere troposphere exchanges

Reactive trace gas exchanges at a mixed forest site



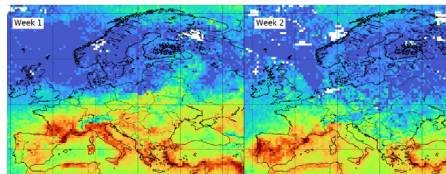
On a global scale, forests are the largest source of volatile organic compounds (VOC). How the exchange of these compounds between ecosystems and the atmosphere will adapt in a world prone to more extreme weather condition is not well known. In order to obtain a more holistic view of the bi-directional exchange between the forest (and its components) and the atmosphere, 3 years of extensive VOC measurements in and above a forest in the Belgian Ardennes have been performed.

Volatile organic compounds in Europe

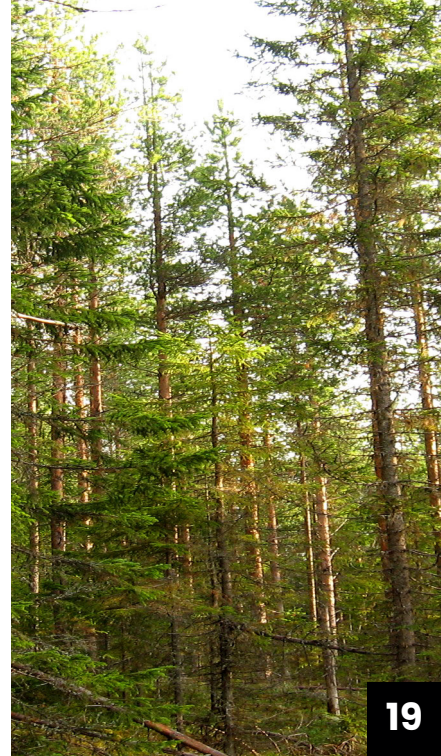


In September 2024, the EUROVOC (EUROpe-wide intensive campaign on Volatile Organic Compounds) pan-European campaign was held to gain insights in volatile organic compounds (VOC) and their emissions. BIRA-IASB contributed high temporal resolution data from a mobile laboratory located at the Space Pole in Uccle and a fixed site located in Vielsalm in the Belgian Ardennes.

Improved estimation of biogenic fluxes over Europe



Volatile organic compounds (VOC) are key precursors of particulate matter and tropospheric ozone. The terrestrial biosphere is by far the largest VOC source, yet its emissions remain poorly constrained. Using weekly TROPOMI formaldehyde data, we estimate that biogenic VOC emissions over Europe are about twice higher than in current inventories. This increase is driven by the high HCHO levels observed in southern Europe. The weekly top-down emissions better capture large emission fluctuations than an inversion based on monthly observations.





Research infrastructures & services

BIRA-IASB is a key actor in the ACTRIS
Research Infrastructure



On April 25, 2023, the European Commission officially established the Aerosol, Clouds and TRace gases (ACTRIS) European Research Infrastructure Consortium (ERIC). ACTRIS provides high-quality data, services, and expertise to facilitate research on short-lived climate pollutants and their variability in both natural and controlled environments. BIRA-IASB plays a key role in this infrastructure, coordinating the Belgian ACTRIS consortium and leading the ACTRIS component dealing with remote sensing of reactive trace gases, along with the associated Central Facility.

Celebrating 35 years of atmospheric composition monitoring with the NDACC



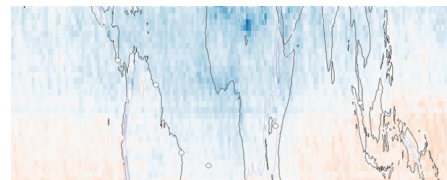
Since the official inception of the Network for the Detection of Atmospheric Composition Change (NDACC) in 1991, BIRA-IASB has contributed to it as a member of its Steering Committee and as provider of high-quality ground-based measurements of ozone, climate variables and other trace gases. NDACC will celebrate its 35th anniversary in 2025 with an international scientific symposium and the publication of a Special Issue to highlight the network's achievements relative to its key objectives and outline its strategy for the next decade.

Atmospheric composition data procurement to Climate Services



As part of the European Copernicus Climate Change Service (C3S), BIRA-IASB operationally feeds the Climate Data Store (CDS) with various atmospheric composition data records derived from satellite and ground-based observations: multiple satellite ozone data sets developed within ESA's Climate Change Initiative programme, dust aerosol products from IASI, stratospheric aerosols climatologies from GOMOS, and a list of trace gases data series (CO, CH₄, O₃, NO₂, HCHO) assembled from the NDACC ground-based reference network.

A tiered approach to the validation of satellite constellations

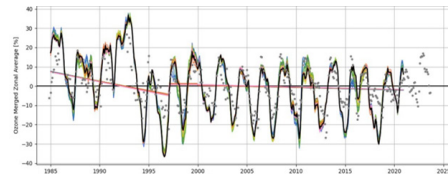


Geophysical validation of satellite observations is essential to establish confidence in the data on the global scale and in the long term. This activity has typically focused on comparisons with ground-based reference measurements providing traceable quality metrics, but with a limited view on regional and global quality features. The advent of satellite sounders coordinated in constellations requires the development of a tiered approach to their validation, addressing also the mutual consistency of multi-orbit, multi-scale data.



Stratospheric composition & climate

The impact of El Niño on ozone trend assessments

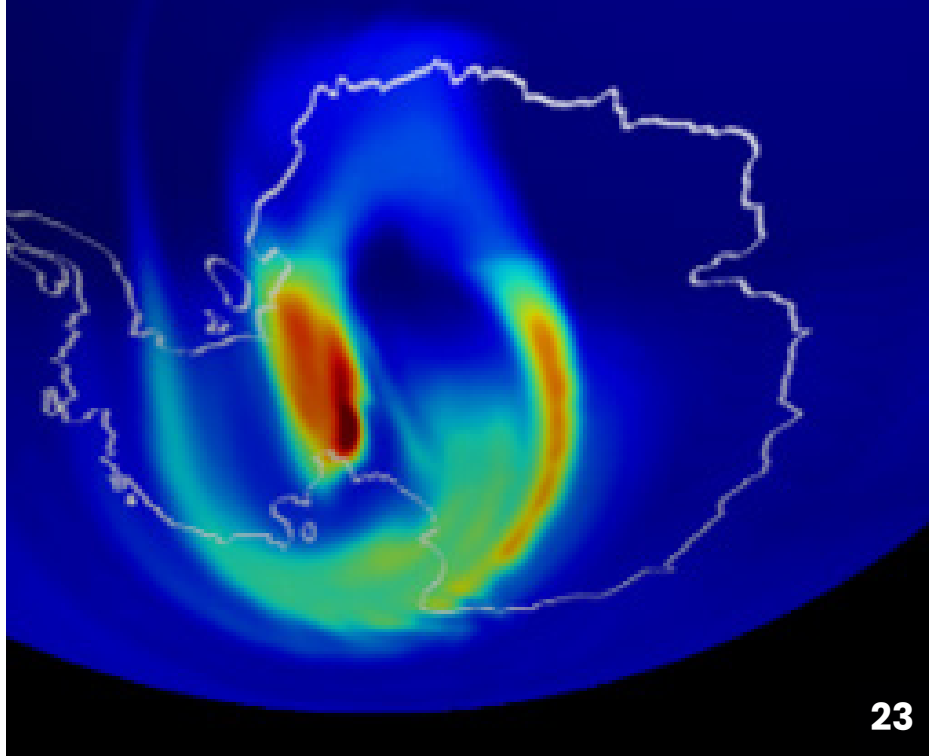


Since 1987, the Montreal Protocol bans chemicals that led to severe stratospheric ozone loss in the 1970s and 1980s. The international ozone assessment LOTUS, coordinated by BIRA-IASB, found conclusive evidence that the ozone layer has started its recovery in the upper stratosphere, but also that its evolution in the lower stratosphere remains highly uncertain. A team at BIRA-IASB recently demonstrated that this uncertainty is not related to a confounding interplay with the El Niño climate pattern.

Forecasting Stratospheric Chemistry for Copernicus



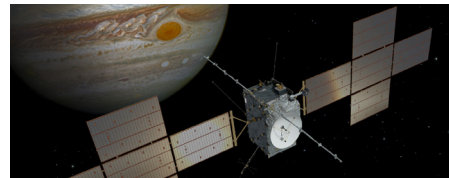
Since 27 June 2023, Europe's Copernicus Atmosphere Monitoring Service's (CAMS) forecasts the detailed chemical processes not only in the troposphere (lower 10 km of the atmosphere) but also in the stratospheric ozone layer, thanks to BIRA-IASB's contribution to the Integrated Forecasting System (IFS) of the European Centre for Medium Range Weather Forecasts (ECMWF). We extended IFS with stratospheric chemistry modules from our own modelling and assimilation system (BASCOE) and validated the improved operational forecasts of stratospheric composition.





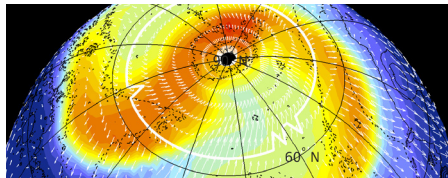
Planetary aeronomy

Contributions to MAJIS with ASIMUT-ALVL



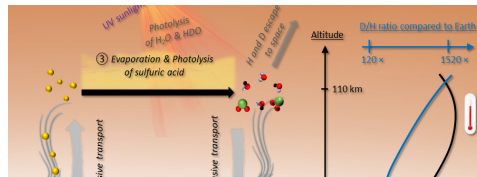
The Moons And Jupiter Imaging Spectrometer (MAJIS) is one of the key instruments on board ESA's JUICE mission, designed for a detailed study of Jupiter and its icy moons. BIRA-IASB is supporting the science team by assessing the capabilities of the MAJIS' visible and near-infrared (VIS-NIR) channel for the study of Jupiter's atmosphere. This is possible through the new version of ASIMUT-ALVL, a radiative transfer code developed in house, which is now able to simulate observation scenarios of Jupiter, besides those of Earth, Mars and Venus.

GEM-Mars model explores fundamental Mars chemistry problem

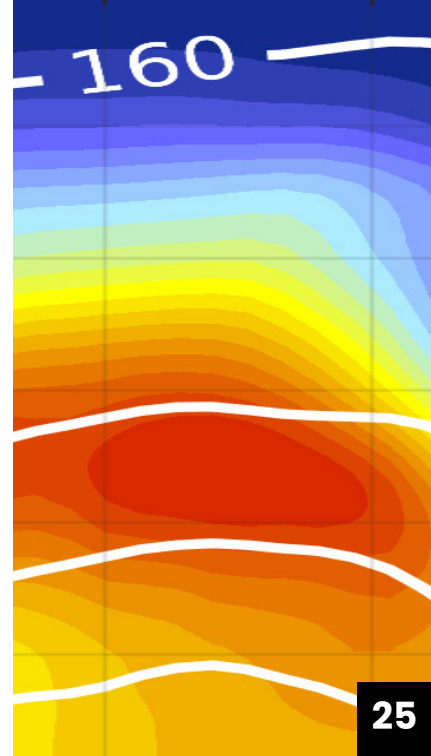


The persistent underestimation by models of the highest ozone abundances on Mars may be indicative of a fundamental problem with our understanding of the Martian atmospheric chemistry. It was suggested before that heterogeneous reactions on water ice clouds could solve this, but there remain important issues at stake. Using BIRA-IASB's Mars climate model GEM-Mars, a wide range of processes were explored that can contribute to solving the puzzle. This study helped to provide recommendations to guide the research community in finding solutions.

Spectacular increase in the D/H ratio in Venus' atmosphere



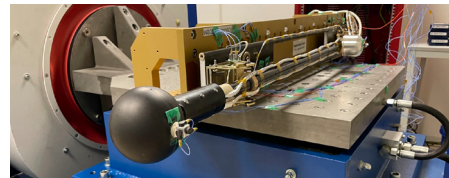
Thanks to observations made by the Solar Occultation in the Infrared (SOIR) instrument on board ESA's Venus Express space probe, BIRA-IASB researchers have revealed an unanticipated increase in the abundances of two variants of water molecules – H₂O and HDO – along with their ratio in the Venus mesosphere. This unexpected phenomenon questions our current knowledge of the history of water on Venus and the factors that may or may not have favoured planetary habitability in the past. This breakthrough is based on the identification of a possible mechanism for deuterium enrichment in the upper mesosphere.





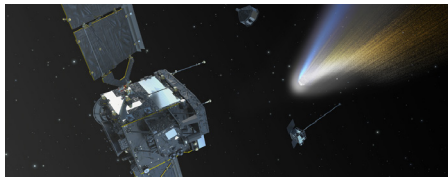
Space missions development: science & technology

Building the electric probes for Comet Interceptor



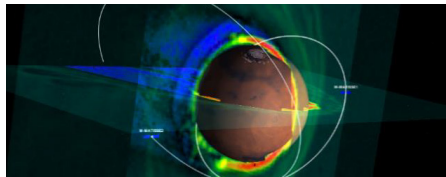
Comet Interceptor is the European Space Agency's next mission to a comet. Aiming for a flyby of a dynamically new comet, it consists of a mother spacecraft and two daughters, one of which is offered by the Japanese Aerospace Exploration Agency. BIRA-IASB is responsible for building the electric probe assemblies on the mother spacecraft.

Designing the Comet Interceptor comet flyby



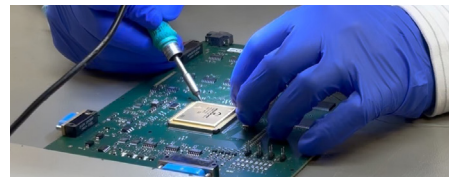
How do you plan a comet flyby when the target is unknown until after launch? Many target properties remain unknown until shortly before the comet encounter. Comet Interceptor faces this challenge by staying flexible. An international team of planetary scientists led by BIRA-IASB developed a technique to adjust the closest approach distance - one parameter that can be changed up to a week before flyby. This helps the Science Operations Working Group to plan the science observations during the encounter.

Preparing a space weather science mission at Mars



The European Space Agency's call for the medium-scale M7 science mission slot came out in 2021. From the 27 initial proposals, 10 were invited to submit a detailed proposal. Out of these, 5 were selected at the end of 2022 for a Phase 0 pre-study. End 2023, only 3 of them continued into Phase A. BIRA-IASB scientists were involved in several proposals from the very beginning, in particular one targeting space weather science at Mars.

Plasma Observatory: Preparing a Multi-Satellite and Multi-Scale Mission to the Earth's Magnetosphere



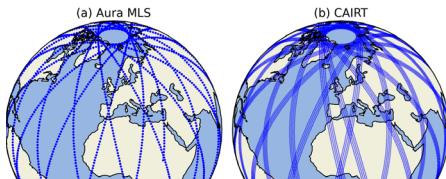
Plasma Observatory is another mission selected for entering the Phase A study for ESA's medium science missions. Plasma Observatory consists of 1 mother spacecraft and 6 daughter spacecraft orbiting the Earth to study multiscale plasma energization processes in the Earth's magnetosphere. BIRA-IASB is responsible for the development of the control unit of the IMS-M ion mass spectrometer.

Dusting the Moon



Charged dust particles are present on the Moon, Mars, comets and asteroids, and can be a threat for both human and robotic exploration missions. To tackle this issue, BIRA-IASB is coordinating DUSTER, an EU-funded project aiming at characterising the properties of the dust particles present on the exploration sites and their transportation mechanisms, driven by electrostatic forces. In this framework, a Langmuir probe, E-field probe and active Dust probe are being developed. BIRA-IASB is developing the first two sensors as well as the electronics front-ends for all three.

CAIRT, a proposed satellite mission to chart the middle atmosphere



CAIRT is a satellite instrument project to observe the Earth's middle atmosphere, to diagnose how climate change may increase ozone transport from the stratosphere to the troposphere, where ozone has its largest warming potential. Proposed for ESA's flagship satellite Earth Explorer 11, we simulated CAIRT ozone data and estimated how they could constrain a model of the middle atmospheric composition. Compared with NASA MLS instrument, results confirm that CAIRT will be a step forward for upper tropospheric ozone observations.

Expanding the ALTIUS ozone mission to more climate variables



The ALTIUS satellite mission, initially designed to retrieve stratospheric ozone and deliver near-real-time data to the scientific community, is now evolving to significantly broaden its scope. Equipped with an innovative three-channel instrument that detects across a wide range of wavelengths and operates in three distinct observation modes, ALTIUS will be capable of retrieving a diverse array of key atmospheric molecules through up to 21 independent processing chains.

VenSpec-H – From concept to breadboard



VenSpec-H is a high-resolution infrared spectrometer set to fly on ESA's EnVision mission to Venus, launching in 2031. It will analyse Venus' atmosphere above and below the planet's cloud deck to better understand its climate and chemistry. The instrument is led by the Planetary Atmospheres division of BIRA-IASB and benefits from key contributions by the institute's Engineering department for its design and building. In 2023-2024, the VenSpec-H concept was refined, leading to the construction of the first full breadboard model.



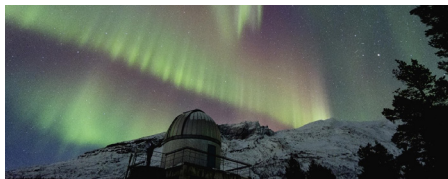
Groundbased & airborne instrument development: science & technology

A new window for auroral observations



The observatory in Skibotn, Norway, is a prime location for monitoring the auroral activity. Installed in October 2024, the Polar Light Imager (PLI) can be remotely controlled from Belgium to capture high-resolution images of the aurora. Equipped with multiple narrow-band filters targeting key auroral spectral lines, PLI plays a crucial role in studying the dynamics of the aurora. Analysing these images provides valuable insights about the properties of the precipitating electrons, responsible for these captivating northern lights.

ASIS : the Auroral Spectrograph In Skibotn, 1.5 years of observations



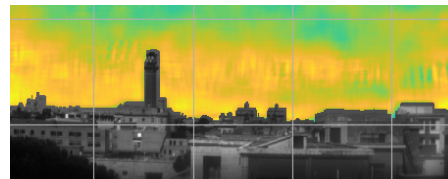
ASIS (Auroral Spectrograph In Skibotn) is an auroral spectrograph installed at the Skibotn observatory in Norway, as a collaboration between BIRA-IASB, IPAG and UiT. Using a small astronomical lens and an optical fibre to capture auroral light in a 4° field-of-view, it records an auroral spectrum every 30 seconds on a CCD camera. Since its installation in October 2023, ASIS has run continuously in Arctic conditions, in a fully automated and remote manner. With only a few similar instruments worldwide, and being just 2km from the future EISCAT_3D radar facility, it provides valuable and complementary data enabling many collaborations.

Autonomous mobile FTIR experiment



Rising greenhouse gas concentrations are driving climate change. To monitor emission reduction efforts, and improve our understanding of the global carbon cycle, BIRA-IASB developed a mobile measurement platform that uses infrared remote sensing to monitor atmospheric greenhouse gas concentrations. The compact system captures sunlight using a solar tracker and analyses it with a spectrometer to determine gas concentrations. This system will be deployed in remote regions and used to measure emissions from cities and industrial areas in Europe.

Capturing the skies with the NO₂ Camera



The NO₂ camera project returns to the annual report for a second time, highlighting its progress and recent measurement campaigns. Originally inspired by the space technology of ALTIUS, this ground-based instrument has evolved significantly, demonstrating its capabilities in air quality monitoring over the past two years.

SEMPAS – Engineering an instrument for operation at the North Sea



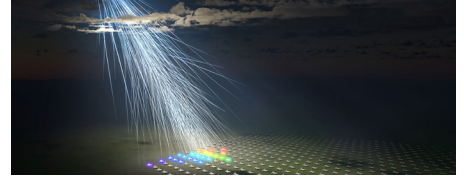
SEMPAS (for “Ship Emission Monitoring by Passive Absorption Spectroscopy”) is an instrument designed to detect emissions from ships in the North Sea, including CO₂, SO₂ and NO_x. The instrument is designed, manufactured and assembled under the responsibility of the Engineering department of BIRA-IASB. Operating in a maritime environment, the instrument has been specifically adapted to withstand significant technical challenges linked to the harsh environmental conditions, including corrosion resistance and protection against extreme weather.





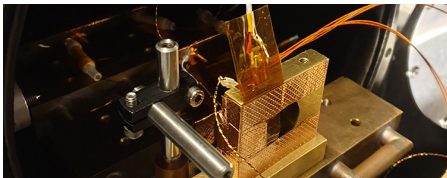
Belgian Radiometric Characterization Laboratory

Tracking the effects of cosmic radiation on the biosphere



The BIOSPHERE project aims to identify and quantify the impact of cosmic rays and solar activity on the atmospheric chemistry and Earth's biosphere. It will contribute to improve policies on climate research and human health. Since 2023, campaigns for simultaneous satellite measurements combined with ground-based monitoring are conducted at different places in Europe, including Brussels. The objectives are to detect solar events inducing atmospheric ionisation, effects on ozone chemistry at high altitude and biologically active solar UV irradiance at ground level.

B.RCLab, the key stopover for optical instruments



The B.RCLab continues to advance its expertise by expanding its capabilities with new equipment, increasing its potential for radiometric characterisation. A major breakthrough now enables UV radiometric characterization down to 90 nm. The lab remains at the forefront of ground and space instrumentation, contributing to major projects including the UVSQ-SAT NG NIR spectrograph, the GRASS gravimeter, SEMPAS, and more. With upcoming work on VenSpec-H, the B.RCLab continues pushing the boundaries of ground and space instrument characterisations.





Belgian User Support and Operations Centre

20 Years of operations onboard the International Space Station



Founded by BELSPO, the Belgian User Support and Operations Centre was integrated into ESA's ground segment for decentralised European payload operations onboard the International Space Station (ISS) in 1999. It oversaw Frank De Winne's 2002 Odissea mission, managed pressurised and external facilities, and supported educational and technical validation projects. Through this experience, B.USOC excels in preparing and executing space operations, serving as a key interface between payload developers, science teams, and stakeholders of the ISS programme.

Realignment of the Belgian User Support and Operations Centre



In anticipation of the planned phase-out of the ISS payload operations, the role and governance of the Belgian User Support and Operations Centre (BUSOC) have been reassessed in 2023 in agreement with BELSPO. Transformed into a Scientific Programme of BIRA-IASB, BUSOC objectives now align more closely with the Institute's interests and are reflected by BUSOC contributions to space projects involving other BIRA-IASB teams, such as the ESA Space Weather Service Network, the ALTIUS mission, Comet Interceptor, and the VenSpec-H instrument.





Citizen Science, knowledge dissemination, communication and education

Auroras under the lens: citizen scientists change the game!



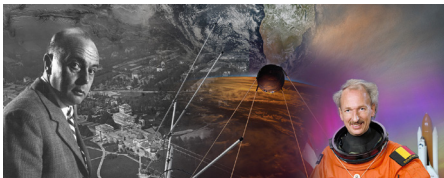
With solar activity at its peak, intense auroras are reaching lower latitudes, as seen on May 10, 2024. Amateur photographers, equipped with highly sensitive cameras, are capturing these displays. Their widespread presence enables large-scale auroral monitoring, providing crucial data to scientists. Citizen contributions have led to discoveries like STEVE, SARs, and recent N_2^+ upflows. By helping classify new auroral types, they prove that public participation is key to advancing auroral research.

European Space Weather and Space Climate Association



In 2022 the European Space Weather and Space Climate Association (E-SWAN) was established in Belgium as a result of a community effort to unite forces of various entities in order to sustain and further develop activities of the space weather and space climate communities. The BIRA-IASB Space weather group is among the founders of E-SWAN. The group has been part of the Executive Board, is chairing the Council and the Education and Outreach Committee, is contributing to many committees and working groups, and provides technical support.

60 Years of aeronomy: Reflecting, sharing and prospects



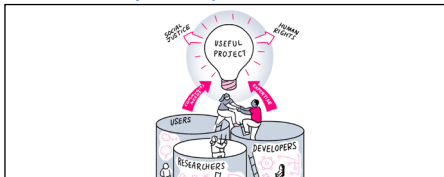
On 25 November 2024, our Institute celebrated its 60th anniversary. The anniversary was an opportunity to highlight our past achievements, current research and future prospects. An open-access exhibition was set up, while specific events for our Uccle neighbours, including an inauguration and visits to secondary schools, strengthened our link with the community. At the Planetarium, an event dedicated to our future colleagues was a great success, testifying to the commitment and enthusiasm of our staff, as well as the interest of the public.

Science Outreach and Education takes on many forms



The communication team has worked hard on online content – from maintenance and renewal of existing webpages, new animations and interviews, magazine articles about science projects, to student-made educational interactive aeronomy tools. A few exhibitions travelled outside our borders with the RoadMap exhibition in Madrid, as well as the “Shine through Mars” exhibition in Edinburgh. Not to forget the visits from schools all over the world for the 12th and 13th editions of ASGARD. These years were marked by inspiring exchanges, crowned on 31 January 2024 with the visit of His Majesty King Philippe of Belgium.

New data repository tool



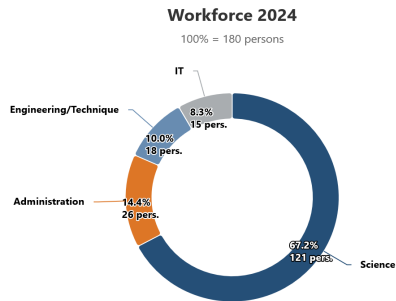
BIRA-IASB teams have created countless datasets (observations & models) that are freely available on corresponding project sites. Nevertheless, modernisation required BIRA-IASB to host its own data repository tool. In 2024, an outdated tool gave way to a new system that offers many more possibilities in terms of findability in the context of open data and FAIR principles. All this was visually overlaid with elements of the corporate identity.



BIRA-IASB in numbers

Staff 2024

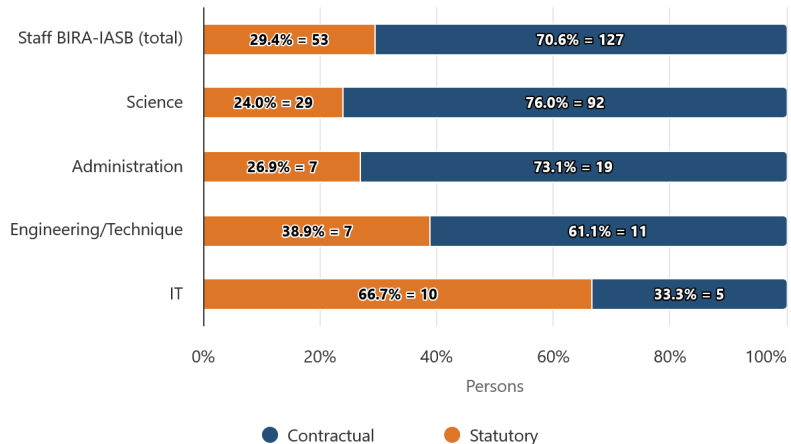
Breakdown of staff by category



On 31 December 2024, 180 employees were working at the Royal Belgian Institute for Space Aeronomy. However, many other people have contributed to the work performed at the Institute during the period 2023-2024. It concerns people with

an external contract, such as 3 IT persons with an Egov contract, persons with an FNRS contract and visiting scientists, or people that have left the institute in the course of this 2-year period. You will find their names at the end of this paper report. They were not included in our graphs. Between 2023 and 2024, the Institute has continued to grow. Especially the number of PhD candidates has increased.

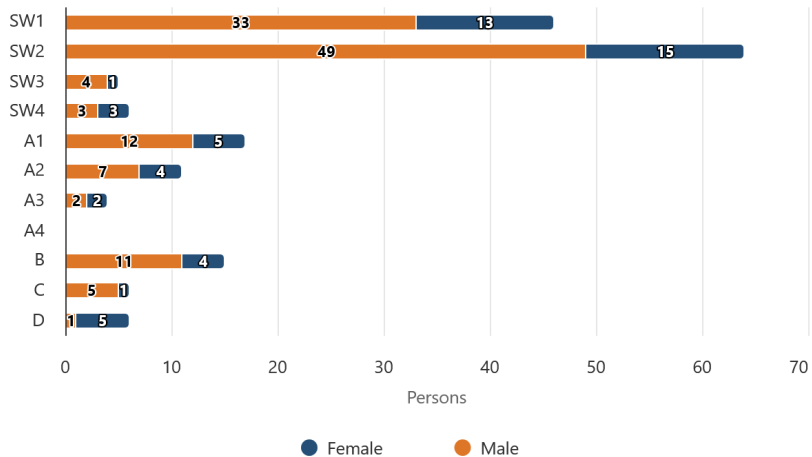
Statute per category (31/12/2024)



Ratio of contractual staff among the different categories

The ratio of contractual personnel to the total number of personnel is slightly rising. The share of contractual employees is especially large among scientists and reached almost 76% of the scientists. This reflects the high number of scientific projects in which BIRA-IASB is involved.

Distribution by pay level

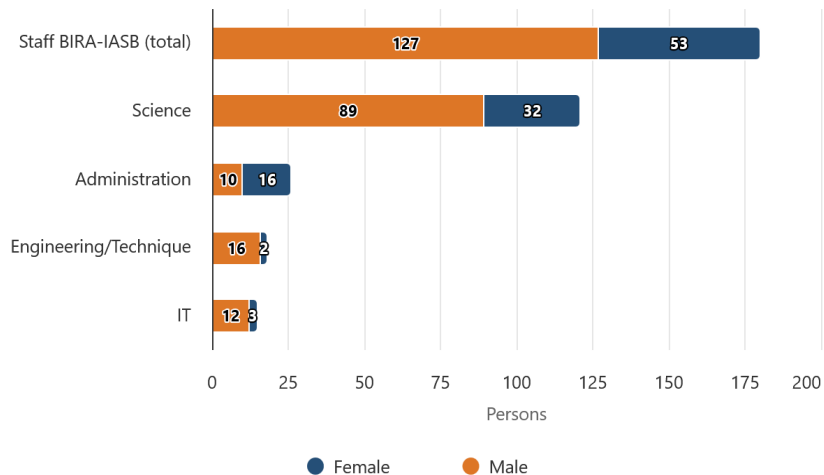


Breakdown of staff by level

The workforce within BIRA-IASB consists of 85% levels A and SW (master level or higher), only 9% level B (bachelor level) and 6% lower levels (C and D). This is directly related to BIRA-IASB's basic missions, which are essentially focused on Research and Development.

Diversity

Gender distribution by category in 2024

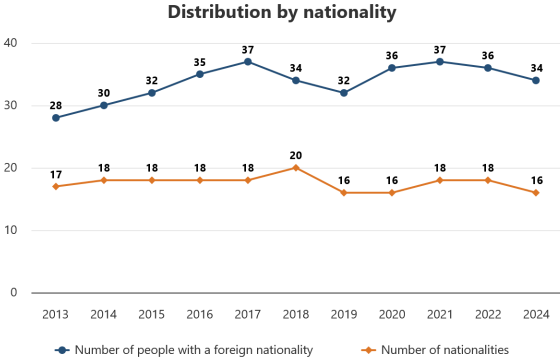


At BIRA-IASB, we want to promote awareness of diversity and encourage measures to make all of us feel comfortable with and respectful of diversity of all kinds.

Gender

In response to recent European and Federal rules, BIRA-IASB published a Gender Equality Plan (GEP) with an action plan addressing aspects of work-life balance, leadership, career progression, research and teaching, and possible gender-based violence internally. A Gender & Diversity Team was created at BIRA-IASB to implement this GEP, but also to address other aspects of diversity.

Nationalities



BIRA-IASB is proud of its international recognition and working environment. The countries of birth of the Institute’s staff give a good indication of the diversity of people we find among our collaborators. Some have been living for a long time in Belgium and even obtained the Belgian nationality. By the end of 2024, 19% of our workforce (34 persons) have a foreign nationality, while 10 years ago

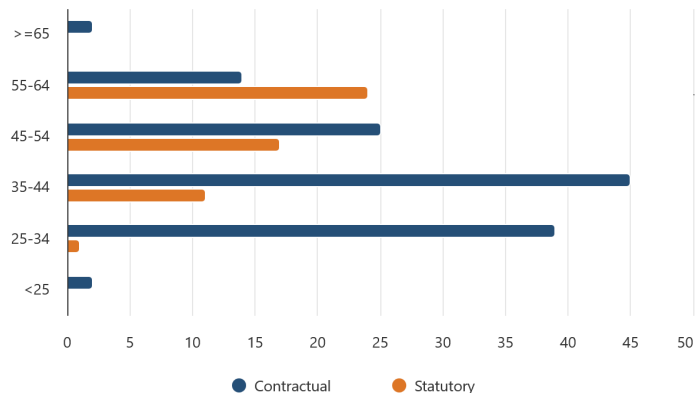
this number was only 30. End 2024, the Institute hosts 16 different nationalities (including Belgian).



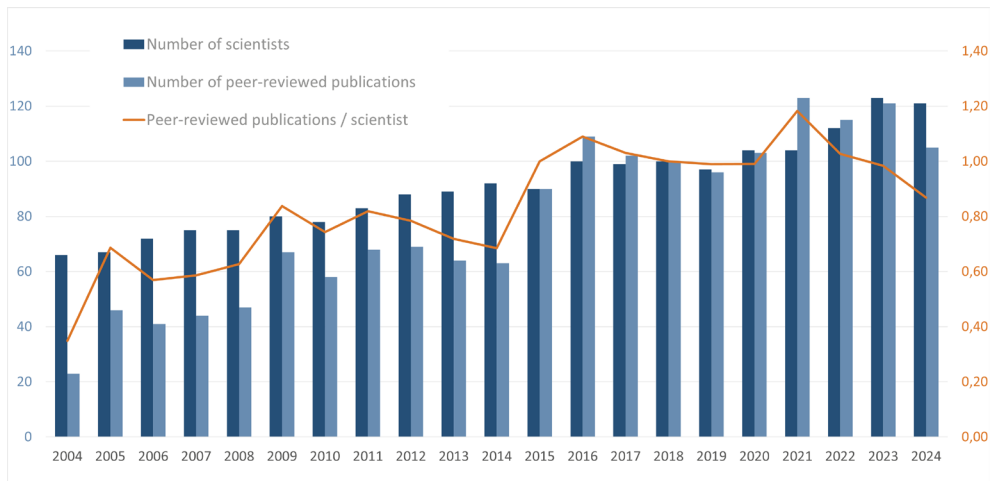
Age

The increasing number of PhD students within BIRA-IASB brings with it a rejuvenation of the population; however, this rejuvenation is limited to contractual staff. The lack of resources to recruit statutory staff causes a predominance in the statutory staff of people above the age of 55. The bulk of staff (statutory and contractual together) are in the 35-44 age group, which includes mainly contractual personnel. Only the 55-64 age group is dominated by statutory staff.

Age Pyramid and Statute



Publications



During the period 2023-2024, BIRA-IASB staff (co-)authored 226 peer-reviewed articles, averaging one publication per year in 2023 followed by a slight decrease in 2024. This graph shows the evolution of the number of publications and the number of scientists since 2004.

All publications are stored in the federal institutional Open Access repository.

Orfeo: <https://orfeo.belnet.be/>.

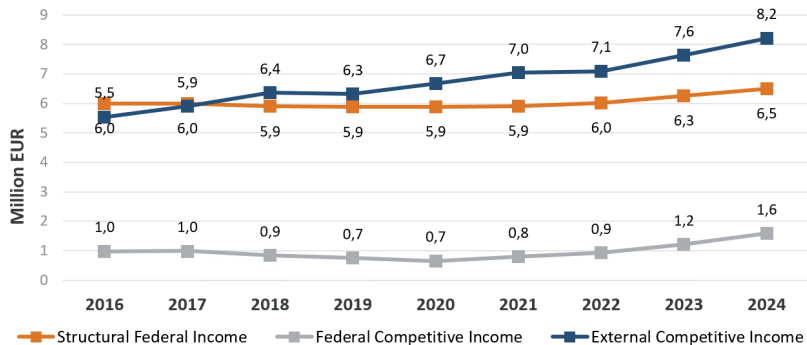
Research projects and budgets

BIRA-IASB reaches a record number of ongoing research projects

As the list of projects shows, the Institute has diversified its sources of funding. However, most of our projects are funded by ESA or Prodex, making us dependent on continued funding for space activities in Belgium.

Source of funding	2021	2022	2023	2024
Endowment	-	-	-	-
Commercial revenue	-	-	-	-
ESA	31	32	36	33
FNRS	2	0	0	0
PRODEX	14	15	13	13
Federal R&D projects	17	15	16	17
EU	11	10	11	10
EUMETSAT	2	3	2	2
ECMWF	8	4	5	6
FED-TWIN	3	5	8	8
FPS VVVL	1	1	1	1
LOTTO	1	1	1	0
EURAMET	0	1	1	1
BIRA-IASB	0	0	0	1
TOTAL	90	87	94	92

Smoothed evolution of income, running means over 4 years

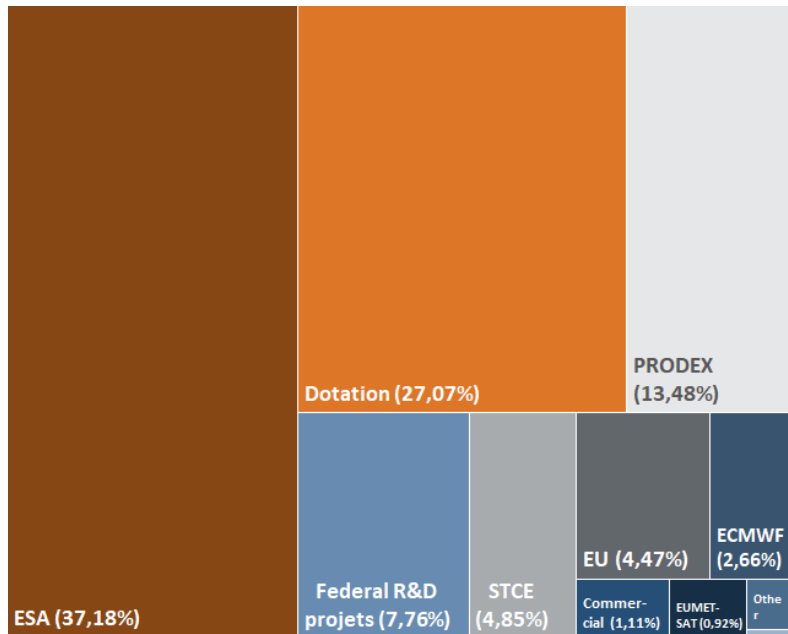


Since we work with multi-annual projects and related expenses and incomes, it is dangerous to compare the evolution of budgets on an annual basis. Hence, we have chosen to show 4-year running averages, with 4 years being the typical duration of a research project, i.e., 2024 represents here the average income over the period 2021-2024, 2023 the average over period 2020-2023, etc.

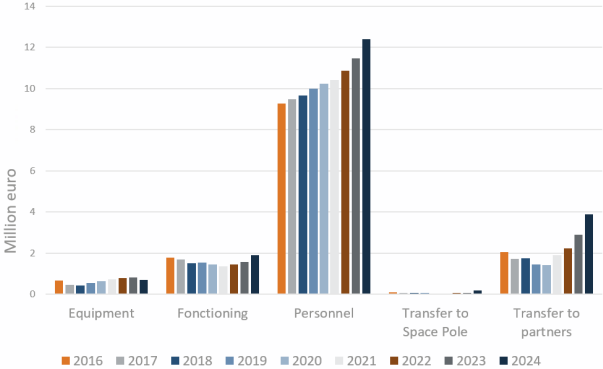
Researchers at BIRA-IASB are pushing very hard to acquire external funding. Research resources are scarce and competition in calls for R&D projects is fierce. Nevertheless, BIRA-IASB researchers managed to secure a record research budget in 2023-2024. The position of our researchers is thus further strengthened and recognised nationally and internationally.

Sources of income (liquidation credits; 4-year running means)

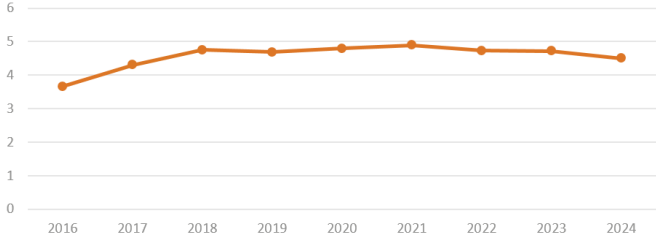
We can state that the structural government funding consisting of dotation and Solar-Terrestrial Centre of Excellence (STCE) represents about 1/3rd of our budget, and ESA funding another third. The remaining third of the budget consists about half of PRODEX funding, and half of various national and European R&D projects-funding. Apart from some annual variations, this partitioning remains rather stable throughout the years.



Expenses



*2016-2024
Ratio payroll to operating equipment costs*

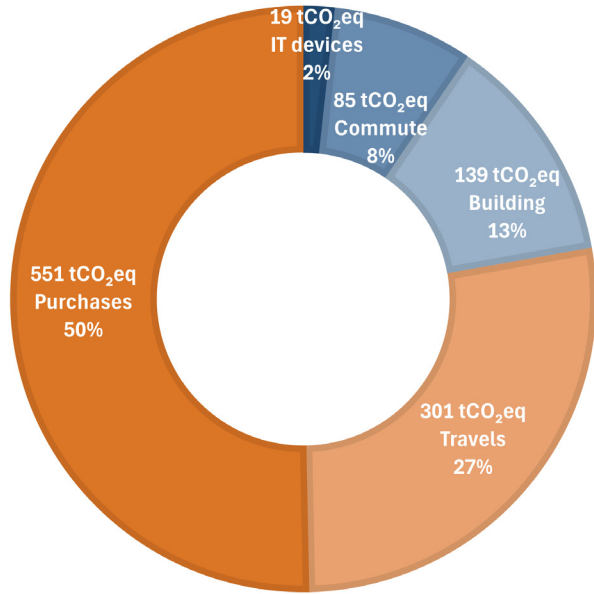


The vast majority of our expenditure is on personnel. This cost rises every year and draws increasingly from our structural federal funding source that, as shown earlier, has not increased accordingly. This leaves less room for hiring statutory personnel and harms the basic functioning of the Institute.

BIRA-IASB Carbon Footprint for 2024

In its commitment to limiting the environmental impact of its activities, BIRA-IASB has developed a greenhouse gas inventory and estimated the Institute's carbon footprint for the year 2024. The footprint is measured in tonnes of CO₂ equivalent (tCO₂eq), a standard unit for measuring greenhouse gases based on their warming effect compared to CO₂.

The total estimated carbon footprint is 1095 tCO₂eq, distributed as follows:



- Purchases (excluding digital devices) : 551 tCO₂eq
- Business travel : 301 tCO₂eq
- Buildings (energy use and water consumption) : 139 tCO₂eq
- Commuting : 85 tCO₂eq
- Digital devices (excluding their electricity consumption) : 19 tCO₂eq

The carbon footprint per staff member is 6.1 tCO₂eq and the carbon intensity is 58 gCO₂eq/€.

These figures are indicative and represent orders of magnitude. They cover only the organisational perimeter —i.e., the facilities directly operated by the Institute, where actionable levers for reduction exist. The estimates were generated using the open source tool GES 1point5 developed by Labos 1point5, an international and interdisciplinary collective of academic researchers.



Thanks!



Albrecht-Marc Michel
Alonso Tagle Luisa
Amelynck Crist
Anciaux Michel
Arijs Yenn
Aubry Aurélien
Bacchini Fabio
Baker Noel
Balis Joachim
Beeckman Bram
Berkenbosch Sophie
Berthelot Antonin
Bevernaegie Jessica
Billot Pierre
Bingen Christine
Bjorklund Robin
Bogaert Pieter
Bogaerts Brigitte
Bolsée David
Bosse Leo
Botek Edith
Brassine Ansje
Brenot Hugues

Brodu Etienne
Brouckmans Kristien
Bulcke Johan
Burssens Siemen
Busschots Cedric
Calders Stijn
Calegaro Antoine
Callewaert Sieglinde
Cardoen Pepijn
Cessateur Gael
Chabanski Sophie
Cierkens Jana
Cisneros Miriam
Cisneros Miriam
Compernelle Steven
Counerotte Frédéric
Crosby Norma
Daerden Frank
Danckaert Thomas
Darrouzet Fabien
De Brouwer Benedicte
De Cock Roderick
De Donder Erwin

De Grave Charlotte
De Harenne Christina
De Keyser Johan
De Mazière Martine
De Pauw Samuel
De Smedt Isabelle
Debosscher Jonas
Dekemper Emmanuel
Demoulin Philippe
Desmet Filip
Dhooghe Frederik
Dierckxsens Mark
Dils Bart
Dohogne Yves
Drochmans Philippe
Ducreux Emile
Echim Marius
Egerickx Tom
Ermakova Anna
Errera Quentin
Erwin Justin
Evenepoel Marie
Fabris Lorenzo

Fayt Caroline
Flimon Zachary
Franssens Ghislain
Fratta Stéphanie
Friedrich Martina
Fussen Didier
Gerard Pierre
Friedrich Martina
Fussen Didier
Gerard Pierre
Geunes Yves
Gramme Pierre
Granville José
Hemerijckx Geert
Hendrick François
Heymans Carine
Hubert Daan
Hufnagel Marco
Iterbeke Philippe
Jacobs Lars
Jonas Caroline
Kalb Nathalie
Keppens Arno

Kindarkhedia Dhiren
Kruglanski Michel
Kumps Nicolas
Lambert Jean-Chritopher
Lamort Lucie
Lamy Hervé
Langerock Bavo
Laur Johannes
Le Carrères Jean-Laurent
Leclere Fabienne
Lefebvre Arnaud
Lefever Karolien
Letocart Vincent
Liber Corentin
Libert Alexis
Litefti Karim
Maes Jeroen
Maggiolo Romain
Mahieux Arnaud
Martinez Ana
Massano Cristina
Mateshvili Nina
Merlaud Alexis

Messios Neophytos
Mettepenningen Gytha
Mezhoud Sami
Michel Alice
Middernacht Michael
Minganti Daniele
Minion Jean Louis
Miron Octavian
Moreau Didier
Muller Alexis
Müller Jean-François
Nath Oindrila
Nay Maïté
Neary Lori
Neefs Eddy
Noel Christian
Nollet Yvan
Oomen Glenn-Michael
Ooms Tim
Op de beeck Marc
Opacka Beata
Pasternak Antoine
Pauwels Dirk

Pereira Nuno
Piccialli Arianna
Pieck Gerry
Pieroux Didier
Pierrard Viviane
Pinardi Gaia
Poraicu Catalina
Queirolo Claudio
Ranvier Sylvain
Rasoanaivo Aina
Rasson Olivier
Ristic Bojan
Robert Charles
Robert Séverine
Rose Kristof
Sall Massamba
Santos Branca Claudia
Sathiyananthan Viththakhan
Sayyed Umar
Schoon Niels
Sfendla Yasmine
Sha Mahesh
Somers Tim

Sotiriadis Sotiris
Soumaré Ablaye
Stavrakou Trissevgeni
Sun Wenfu
Szabo Peter
Tack Frederik
Theys Nicolas
Thomas Ian
Trompet Loïc
Van Asselberghs Tim
Van Damme Martin
Van Doorne Cato
Van Gent Jeroen
Van Laeken Lionel
Van Passel Wouter
Van Roozendael Michel
Vandaele Ann Carine
Vandenbussche Sophie
Vanhamel Jurgen
Vanhellemont Filip
Vasquez Michel
Van der Linden Ronald
Verbracke Fabian

Verhoelst Tijn
Verreyken Bert
Vervalcke Sarah
Vigouroux Corinne
Viscardy Sébastien
Vlietinck Jonas
Wespes Catherine
Willame Yannick
Winant Alexandre
Yu Huan
Zychova Lenka



Sources

Most of the illustrations in this annual report come from the ESA and NASA royalty-free image libraries.

Some photographs (taken by our scientists or the communications team) as well as graphics and visuals were produced in-house.

The fonts used come from Google Fonts.

Ce rapport annuel est aussi disponible en français.

Dit jaarverslag is eveneens beschikbaar in het Nederlands.

This brochure shows at a glance which fascinating projects BIRA-IASB was involved in 2023-2024. We invite you to explore these topics and learn more about the institute on our website:

www.aeronomie.be/annualreport

