

Annual Report 2018



In-service Aircraft for a Global Observing System

Association Internationale Sans But Lucratif

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IAGOS-AISBL

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Awards

Andreas Volz-Thomas and Valérie Thouret awarded a medal from the Academy of Air and Space

Andreas Volz Thomas and Valérie Thouret received medals for their contribution to the development of the IAGOS research infrastructure over the past 20 years. The medals were awarded by the Air and Space Academy (<http://www.academie-air-espace.com/>) in a special ceremony in the Salle des Illustres in Toulouse.

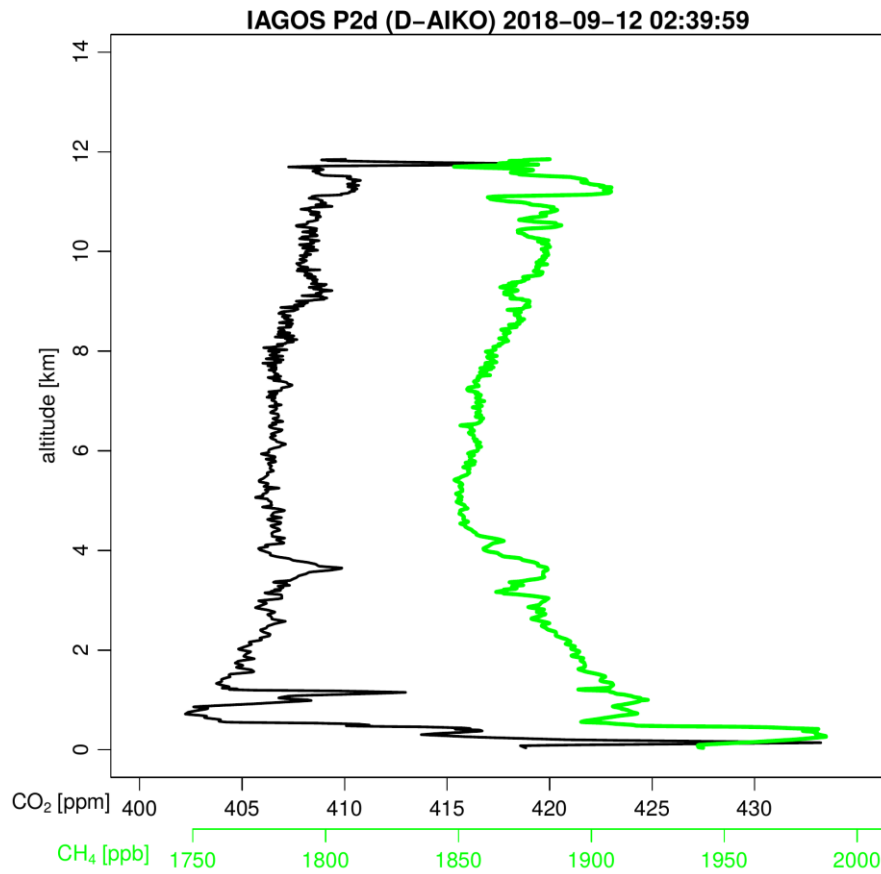


Andreas Volz-Thomas and Valérie Thouret with their medals.

Highlights

Installation of P2d (for CO₂, CH₄, CO, H₂O) on Lufthansa AIKO

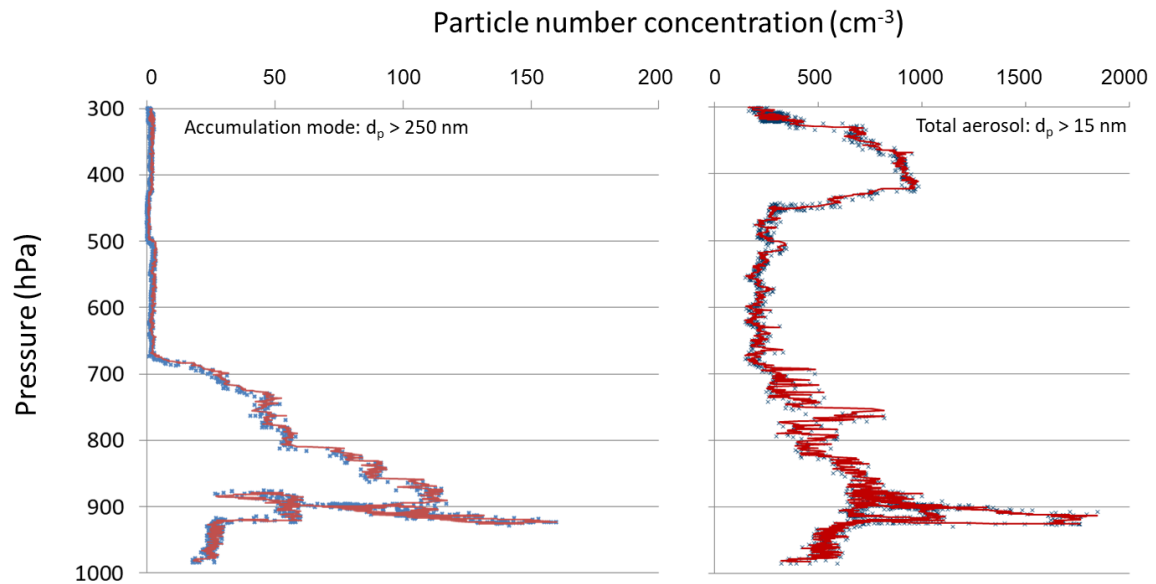
IAGOS P2D-SN01 was successfully installed and operated for its first deployment period during September and October 2018 on board the Lufthansa Airbus A330 (tail sign D-AIKO). Due to a colder than expected temperature in the avionics bay, further adjustments had to be made to ensure proper temperature stabilisation of P2D, a prerequisite for accurate measurements of greenhouse gases. Nevertheless, first data have been collected for CO₂ and CH₄ on several flights. P2D-SN01 has now undergone a minor change to address the temperature control and is ready for its next deployment on board D-AIKO.



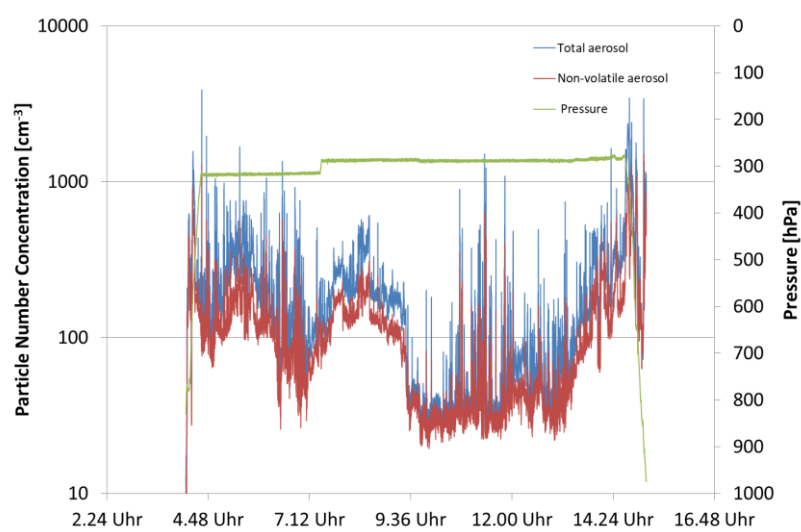
First data provided by P2D-SN01 during the ascent out of Boston Logan airport on September 12, 2018. A clear enhancement of the greenhouse gases CO₂ and CH₄ can be seen near the surface, and around 11.5 km altitude.

First Year of Operation of P2c (aerosol) on IAGOS-CARIBIC

After 12 months of continuous operation on board the IAGOS-CARIBIC container, the IAGOS Aerosol instrument P2c provided observational data of high scientific relevance. The instrument measures particle number concentrations for three types of aerosol particles: (1) the total aerosol with particle diameters from 15 nm; (2) non-volatile particles of the same size range, which are composed of refractory material such as mineral dust, sea salt, volcanic ash, or black carbon; (3) and particles larger than 250 nm in diameter, which contribute to the accumulation mode of the atmospheric aerosol population.



First vertical profiles of aerosol number concentration over Munich airport, measured during the descent into the airport on 11 October 2018; the left panels shows particles larger than 250 nm in diameter (accumulation mode aerosol), whereas the right panel shows the total aerosol for particles larger than 15 nm. The altitude is given in units of pressure (hPa).



Time series of aerosol number concentration measured at cruise altitude during the flight from San Francisco to Munich at 11 October 2018; the blue line shows the total aerosol while the red line refers to the non-volatile particles; the altitude is given in units of pressure (hPa).

Above, the first vertical profiles of accumulation mode (left panel) and total aerosol (right panel) are shown for an approach into Munich airport on 11 October 2018. It is clearly visible that larger particles of the accumulation mode are confined to altitudes below 700 hPa pressure altitude (approx. 2.2 km above ground for Munich conditions) and thus are restricted to the planetary boundary layer. On the other hand, the layer of enhanced aerosol number concentration at 400 hPa contains particles smaller than 250 nm. This type of measurement will permit the investigation of aerosol transport mechanisms and distribution properties.

The observation of aerosol number concentrations at cruise altitude (pressure below 350 hPa) and in particular of that for non-volatile particles as shown above, points directly at the

particulate matter emission of cruising passenger aircraft. This type of observation was not possible in IAGOS before. The high and short-duration peaks in aerosol number concentration are caused most likely by aircraft whereas the variable background concentrations are influenced by the transport of large-scale airmasses. Detailed scientific analyses of the evolved aerosol data set have just started.

First Measurements by the Aerosol Mass Spectrometer on IAGOS-CARIBIC

The newly developed, fully automated aerosol mass spectrometer (CARIBIC-AMS) started its operation in the IAGOS-CARIBIC container in 2018. After several technical test flights which were used to test and improve the automation procedures, first successful measurement flights were conducted in October 2018. The CARIBIC-AMS operated during two long-range flights between Munich and Shanghai, measuring mass concentration of aerosol components like sulfate, nitrate, ammonium and organics. The nominal time resolution of the instrument is 30 seconds, although for low concentrations longer averaging cycles (e.g. 5 min) may be necessary. First data analysis of the sulfate mass concentration showed variations along with ozone concentration in the upper troposphere and lowermost stratosphere, indicating the influence of the Junge aerosol layer on the lowermost stratosphere. Final quantification of the data still requires a more detailed laboratory characterization and validation, but first results show good agreement with co-located instruments during ground-based measurements. However, these calibrations still have to be repeated for pressure conditions relevant to the Upper troposphere- lower stratosphere (UTLS). It is now intended to operate the CARIBIC-AMS in all upcoming IAGOS-CARIBIC flights. Such regular aerosol composition measurements in the UTLS will significantly increase our knowledge and understanding of UTLS aerosol.

Funding of ENVRI-FAIR accepted and co-ordinated by FZ Juelich / Andreas Petzold

The proposal to the European Union for the ENVRI-Fair project was accepted. The project will begin in 2019 and will be co-ordinated by Andreas Petzold. ENVRI-FAIR is the connection of the Cluster of Environmental Research Infrastructures (ENVRI) to the European Open Science Cloud (EOSC). The overarching goal of the project is to have the participating research infrastructures providing data services that conform to the 'FAIR' principles, those being 'Findable', 'Accessible', 'Interoperable' and 'Reusable'; see envri-fair.eu for details. The project is financed for 4 years and will allow 4 personnel to be employed at FZJ and 3 personnel to be employed at CNRS.

CAMS 84-phase 2 launched in October 2018

The proposal for the extension to the Copernicus Atmosphere Monitoring Service (CAMS-84) was accepted by the European Union. The new phase of the service kicked-off in October. The daily validation of real time global and regional forecasts using IAGOS ozone and carbon monoxide that was part of phase 1 continues but will expand in the second phase to include the additional IAGOS products, water vapour, carbon dioxide, methane and nitrogen oxides.

IAGOS Annual Meeting in June 2018

The Annual Meeting of IAGOS took place at Météo France from 18.06.2018 to 19.06.2018. The meeting was conducive to improving the dialogue among the different contributors including Airbus, the Airlines and the subcontractors as well as representatives from the funding agencies, other research infrastructures and the end users of IAGOS products.



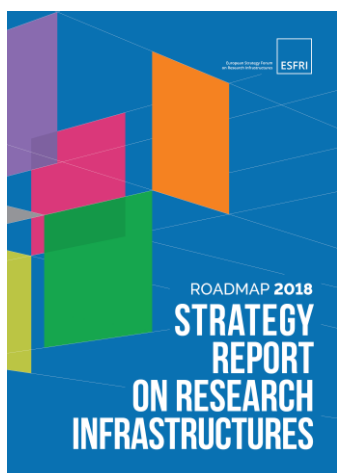
Participants of the IAGOS Annual Meeting at Météo France, Toulouse, June 18/19 2018.

The invited speaker Michael Prather from the University of Irvine California outlined the importance of IAGOS in the wider scientific community and set IAGOS in a historical context. Oksana Tarasova from the World Meteorological Organisation described the importance of IAGOS measurements to the global observing network and Global Atmosphere Watch. The rest of the presentations on the first day were given by Airbus, the airlines, the research infrastructures and funding agencies and were followed by an evening cruise along the Canal du Midi. The second day was dedicated to the latest scientific results and analysis presented by all Members and their research groups.

Tropospheric Ozone Assessment Report

The Tropospheric Ozone Assessment report (TOAR) is an activity of the International Global Atmospheric Chemistry Project. Gaudel et al., 2018 highlighted the important contribution from IAGOS in establishing the present-day distribution and trends of tropospheric ozone.

Strategy Report on Research Infrastructures 2018



The new Strategy Report on Research Infrastructures 2018 has been published by ESFRI together with the ESFRI Roadmap 2018 and is available for download at roadmap2018.esfri.eu. The report revisits the evolution and growing maturity of the environmental research infrastructures and highlights their evolving role in the European science area. A section on lessons learned during the past ESFRI roadmaps points at the need for focusing on projects of strategic importance, with high added-value and significant potential to develop unique resources and services for European research and innovation.

The role of IAGOS in this environment is highlighted in the Landscape Analyses and in the ESFRI Landmarks descriptions.

Moving IAGOS-CARIBIC to an Airbus A350

The Lufthansa Airbus A340-600 (D-AIHE), on which the CARIBIC laboratory has been deployed since 2004, will be phased out in summer 2020 (based on the current planning). A first assessment considering aircraft specifications, destinations and size of fleet identified an Airbus A350 as most suitable future aircraft. In January 2018, KIT, along with Lufthansa Technik, Airbus, and enviscope launched a feasibility study to assess all certification-relevant issues for the deployment of the CARIBIC laboratory on board an A350. For instance, this included the general certification level of the CARIBIC laboratory (form1 yes or no), the entire safety concept (including smoke detection and the ventilation), EMI issues, the thermal budget (cooling concept), allowed mechanical loads, the air inlet system (including the mount at the fuselage), the possibility to certify rack envelopes (regarding maximum weight and power consumption), and further potentially critical issues such as bird strike or the consequences of engine burst events. Besides two physical meetings in Hamburg (Germany), the technical discussion occurred during 2-weekly telephone and video conferences. During three further telephone conferences, the representatives of Airbus, Lufthansa, Lufthansa Technik, and KIT negotiated the contractual issues. The level of cooperation and the conditions on which Airbus can provide technical data and how these technical data can be used by Lufthansa Technik, have been defined. The feasibility study will finish in March 2019, having found feasible solutions for all issues, including a price tag from Airbus for the provision of data and certain services (e.g. CFD calculations around the air inlet system or the installation of an optical window for a remote-sensing instrument). Based on the present planning, the modification of an A350 is scheduled for December 2020.

Article on hydroxyl and Cl radicals in Nature Partner Journal (npj)

The hydroxyl radical OH is the dominant atmospheric cleansing agent and thus fundamental in atmospheric chemistry. It oxidises most atmospheric pollutants and therefore initiates their removal (e.g. by rainout) from the atmosphere. Li et al. (2018) used IAGOS-CARIBIC measurements of CH₄, CH₃Cl and SF₆ to determine effective OH concentrations in the troposphere and lower stratosphere. Based on the difference in the calculated OH concentrations for CH₄ and CH₃Cl even the average concentration of the Cl radical in the lower stratosphere was inferred. A significant trend of the radical concentrations could not be found for the six years covered by this study.

Article on atmospheric impact of forest fires published in PNAS

Unique information about the abundance and evolution of wildfire-emitted black carbon (BC) in the lowermost part of the stratosphere (LMS) was obtained from long-term airborne measurements made by IAGOS-CARIBIC. Ditas et al. 2018 demonstrate that wildfires can dramatically increase BC mass concentration in the LMS, substantially enhance regional climate forcing, and are a challenge for model simulations. Climate change is expected to increase the frequency and spread of wildfires. Thus, recording a present-day baseline with extensive and long-term measurements should help to constrain model estimations of the climate impact of BC and foster our fundamental understanding of future climate change.

IAGOS Outreach Highlights

IAGOS Movie

The first highlight in this section is the production of the IAGOS movie. All Members were filmed at their respective institutes. The movie was created in two versions of 3 and 9 minutes in duration. It was distributed on USB keys as gifts for attendees at the Annual Meeting, and is also available on the IAGOS website and on youtube.

Video for EUMETSAT MOOC

IAGOS took part in the Massive Online Open Course on Monitoring Atmospheric Composition run by EUMETSAT (The European Organisation for the Exploitation of Meteorological Satellites is Europe's operational satellite agency) and the Copernicus Atmosphere Monitoring Service (CAMS). The course, which is freely accessible after registration, explains how observations of the Earth's atmosphere are collected from all measurement platforms and how these are used for improving forecasts of air quality. Topic 3 was dedicated to IAGOS and included the technical aspects and installation, and use of the data with reference to recent extreme events.

IAGOS Participation in the ENVRI booth at EGU Vienna

The 15 Research Infrastructures collaborating in ENVRI^{PLUS}, joined forces again to organize a joint booth for the Environmental Research Infrastructure (ENVRI) Community at the General Assembly of the European Geophysical Union (EGU). A presentation on the monitoring of 'Healthy Air' using IAGOS data helped to animate the booth.



The ENVRI booth at EGU Vienna 2018.

EGU is one of the most important events for all the Environmental Research Infrastructures in Europe. Every year, the conference brings together around 14000 scientists from more than 100 countries. However, only a fraction of them is aware of the existence of Research Infrastructures, their mission and the benefits they can offer to every single scientist. The

ENVRI^{PLUS} Research Infrastructures therefore join forces in promoting the environmental RIs, organizing a joint booth together, to increase visibility, share costs, and demonstrate the strong collaboration among them.

CAMS Trade Fair in Lisbon

The CAMS trade fair at the kick-off meeting for the CAMS-84 phase 2 was a good opportunity to connect with the users of IAGOS products, and other data providers.



The CAMS Trade Fair in Lisbon.

Organisation

IAGOS is organised as an International not-for-profit Association (AISBL) with its seat in Brussels.

Members of IAGOS-AISBL are:

- | | | |
|---|--|-------------|
|  | Forschungszentrum Jülich GmbH, Jülich, Germany | FZJ |
|  | Centre National de la Recherche Scientifique, Paris, France | CNRS |
|  | Max-Planck Gesellschaft zur Förderung der Wissenschaften e.V., München, Germany | MPG |
|  | Météo France, Toulouse, France | MF |
|  | The University of Manchester, Manchester, United Kingdom | UMAN |
|  | Deutsches Zentrum für Luft- und Raumfahrt e.V., Köln, Germany | DLR |



Leibniz-Institut für Troposphärenforschung e.V.,
Leipzig, Germany

TROPOS



Karlsruher Institut für Technologie,
Karlsruhe, Germany

KIT

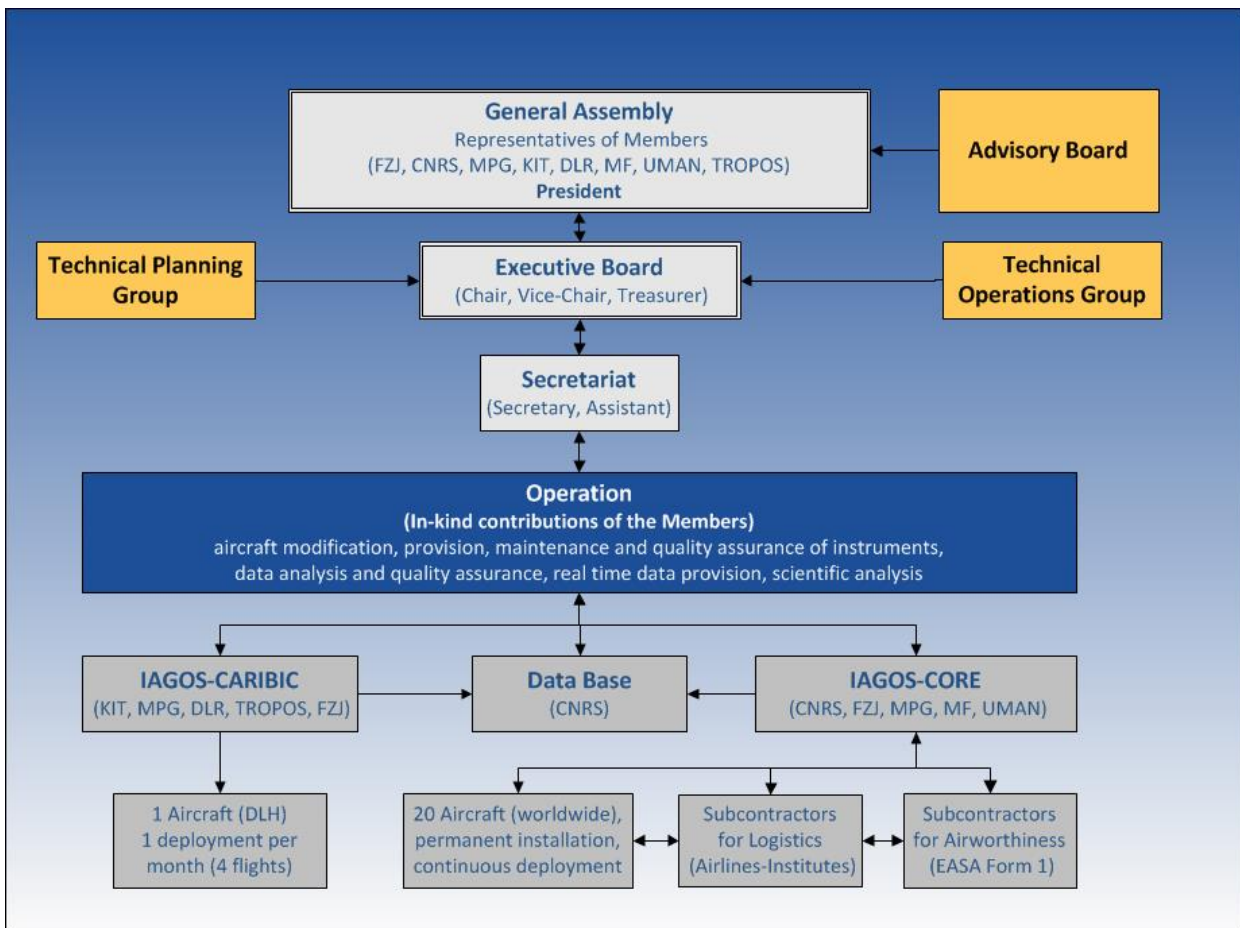
The activities of IAGOS-AISBL are twofold (Statutes are available for download at <http://www.iagos.org>):

1. Activities conducted by the organs of the Association
2. Coordination of the technical and scientific activities carried out by the Members from own resources

The governance structure of the Association is shown below.

The General Assembly (GA) is the highest decision making body. It is composed of the representatives of the Members and is chaired by the President, Andreas Wahner, representative of FZJ. Jean-Marie Flaud, representative of CNRS, serves as Vice-President.

The daily management is conducted by the Executive Board (EB). It is composed of Martin Gallagher, Andreas Petzold (Treasurer), Valerie Thouret (Chair), Andreas Zahn (Vice-Chair) and Hannah Clark (Executive Secretary).



An Advisory Board (AB) regularly reviews the progress made and gives advice to the Members of IAGOS-ASBL for future development and strategic orientation of the IAGOS research infrastructure in the global landscape. The members of the AB are J.H. Butler, NOAA, USA (Chair); J. Haywood, UKMO, U.K.; G. Pappalardo, CNR, Italy; V.-H. Peuch, ECMWF and David Crisp (NASA JPL).

The Technical Planning group and Technical Operations Group oversee the technical operation and development of the infrastructure. The TOG works closely with the aeronautical subcontractors and the associated airlines. In 2018, these were: Lufthansa, Air France, China Airlines, Cathay Pacific, Hawaiian Airlines, and Iberia (see pictures below for details of the aircraft involved). For more information and Statutes see: <http://www.iagos.org>

Activities of the Association

Activities of the Association included five meetings of the Executive Board (2 by Teleconference), two meetings of the General Assembly, one meeting of the Advisory Board, and 2 Meetings of the Technical Planning Group.

Executive Board

Brussels, 9 February 2018 (4 EB members, P, VP, AVT)

- Annual Report 2017
- Activity plan 2018
- Preparation Annual Meeting
- Status of Operations
- Membership of UHEL and FMI
- IAGOS and ENVRI-Fair

Teleconference, 9 March 2018 (3 EB members, VP, ES)

- Check documents for GA
- Status of P2d
- Participation in conferences
- Modification to statutes
- Annual Meeting
- IAGOS video

Teleconference, 6 April 2018 (All members, VP, ES)

- Annual Meeting Planning

Toulouse, 20 June 2018 (4 EB Members, ES, P and VP)

- Review of Annual Meeting
- Revision of IAGOS-CORE Framework Agreement
- News Items
- Future meetings

Brussels, 6 September 2018 (4 EB members, ES, P and VP)

- Preparation of GA on 30 May 2017 (7th GA)
 - Discussion on IAGOS operations
 - Status of CAMS-IAGOS contract
 - Preparation of next GA
 - Preparation of next AB meeting
- Revision of IAGOS-Core Framework
- Update on submitted proposals ENVRI-Fair and CLIMATO

General Assembly

Brussels, 26/27.03.2018

- Approval of the Activity Plan for 2018 and implementation plan
- Decision on threshold for voting rights
- Approval of the Budget for 2018
- Approval of the Annual Report for 2017
- Approval of ToR for TOG and TPG
- Annual Meeting
- Signature of modifications to statutes
- Election of president and vice-president

Burg Obbendorf, 28.11.2018

- Approval of the Budget for 2018
- Approval of the Activity Plan for 2019, pending availability of Members' resources (to be confirmed in spring 2019)
- Approval of the long-term Implementation Plan

Advisory Board

Burg Obbendorf, 27.11.2018

- Review of actions in response to recommendations made at last meeting
- Managing change – aircraft type, personnel changes, instrument and technical
- Partnerships
- Communications –visibility and PR

Technical Planning Group

Frankfurt, 14.09.2018 – TPG Meeting

- New TPG organisation
- Planning and coordination of aircraft installations, including costs estimates
- Planning and coordination of aircraft equipment with Package 2 options
- Planning of further instrumentation development
- Evaluation of new technologies for real real time data transmission
- Assessment of the requirements for IAGOS on new aircraft types
- Actions, next meeting

IAGOS-TPG-Info, 19.10.2018 – P2d Taiwan

- New Memorandum of Understanding (MoU) between IAGOS and National Central University Taiwan (NCU) requested.
- Report on P2d operations on LH A330 is requested by NCU Taiwan before signing a contract with China Airlines (CAL), necessary to start formal process for P2d installation on CAL
- A risk of further delay is identified concerning P2d documentation to be provided to CAL
- P2d installation on CAL seems unlikely before mid-2019.

Technical Operations Group

Teleconferences

(25.01.2018, 08.03.2018, 02.05.2018, 14.06.2018, 09.07.2018, 21.09.2018, 20.11.2018)

The teleconferences cover the same 4 topics with additional points discussed when necessary.

- 1 Status of IAGOS-CORE Operations P1, ICH, BCP, P2b, P2d on A/C core
 - 2 Status of CARIBIC operation
 - 3 Status of Maintenance Centre Operations
 - 4 Status of aircraft installations
- status CARIBIC A350 feasibility study
 - status new Part 145 MO for P1
 - status of the ICH digital cable retrofit for LTH aircraft
 - status discussions with Finnair for new A330
 - status RTTU
 - status LGM supervised by Sabena as MO for P1
 - status FAA agreement for GFM
 - report meeting Sabena, Enviscope, CNRS for the BCP hermetic version
 - P2c successful flight on IAGOS CARIBIC
 - status first p2d operation on D-AIKO
 - status GSM network at Frankfurt Airport
 - status P2 USB stick for all P2 versions
 - status P2c, P2e

Communication and Outreach

- IAGOS Annual Meeting (18-19th June 2018), Toulouse, France
- Participation in ENVRI^{PLUS} booth at EGU
- Participation in the EUMETSAT's Massive online open course (MOOC)
- Release of the IAGOS Movie
- Creation of Twitter account
- Presentations at International Conferences (*see Presentations*)
 - SPARC-UTLS (Mainz 5-8 February 2018)
 - EGU General Assembly (Vienna, 23 – 28 April 2018)
 - GMAC conference NOAA, (Boulder, 22-23 May)
 - IGAC conference (Takamatsu, 25-29 September 2018)
 - GAW 2018 Symposium (Osaka, 1-3 October 2018)
 - CAMS General Assembly (Lisbon, 16 – 18 October 2018)
 - ENVRI^{PLUS} Weeks (Zandvoort 15 – 18 May, Riga, 5 – 19 Nov. 2018)
 - OCTAV-UTLS (Mainz, 7-9 November 2018)
 - AGU Fall Meeting (Washington D.C., 11 – 15 Dec. 2018)

Activities of the Members under Coordination of IAGOS-AISBL

IAGOS-CARIBIC

One AIRBUS A340-600 by Lufthansa (shown below) carries provisions for operating the IAGOS-CARIBIC Flying Laboratory, a modified cargo container with state-of-the-art instrumentation for in-situ and remote sensing measurements, and for the collection of whole



air and aerosol samples. The latter are analysed in different European laboratories for a detailed view of the atmospheric composition at flight altitude. The aircraft carries a special inlet probe, which is connected to the instruments inside the laboratory. Operation of the CARIBIC laboratory is discontinuous with 10-12 sequences per year, each for 4 consecutive flights.

Activities 2018

The current IAGOS-CARIBIC payload of altogether 19 instruments is provided by twelve institutes, eleven from Europe (Germany, UK, Ireland, Sweden, Netherlands) and 1 (NOAA) from the US. Five institutes are members of the AISBL: Karlsruhe Institute of Technology (**KIT**), Max-Planck society (**MPG**), German Aerospace Center (**DLR**), Leibniz Institute for Tropospheric Research (**TROPOS**), and Forschungszentrum Jülich (**FZJ**).

KIT coordinates IAGOS-CARIBIC and operates the CARIBIC laboratory since April 2015. KIT is also responsible for the operation of four in-situ instruments for the analysis of H₂O, cloud water/ice, ISOWAT for H₂O isotopic composition, and a PTR mass spectrometer for selected volatile organic compounds (VOCs) such as acetone, acetonitrile, and methanol.

MPI-C maintains the operation of the whole air sampling systems, a CO instrument, and a single particle soot photometer. In the laboratory, three GC systems for greenhouse gases, non-methane-hydrocarbons and further N- and S-containing species are used for measuring the altogether 118 air samples collected during one flight sequence. In 2017, a bio-aerosol analyser (Wideband Integrated Bioaerosol Sensor, WIBS-NEO) and an aerosol mass spectrometer (together with TROPOS) were integrated.

DLR is responsible for operation of an instrument for measurements of nitrogen oxides (NO and NO₂) and total odd nitrogen (NO_y) aboard the CARIBIC container. Following the container modification the regular measurements of NO and NO_y have been successfully resumed.

TROPOS is responsible for operation of instruments for the measurement of particle concentrations aboard the IAGOS-CARIBIC container. These include an Optical Particle Size Spectrometer (OPSS) for the larger particles (0.14-1.05 μm diameter) and three Condensation Particle Counters (CPC) for the smaller particles (0.004 - 2 μm ; 0.012 - 2 μm ; 0.018 - 2 μm diameter). In parallel, a new aerosol mass spectrometer (AMS) was developed in close collaboration with MPI-C and successfully flew for the first in 2018.

FZJ is responsible for the IAGOS-core package 2 instrument slot in the CARIBIC laboratory. Currently the aerosol package is installed which contains two CPCs and an OPSS. This newly installed instrument worked fine and reliable in 2018.

In 2018, a reduced number of 21 measurement flights have been conducted. Considerable manpower and energy have been devoted for a feasibility study on the move of the CARIBIC laboratory to an Airbus A350. The current planning assumes a phase-out of the current CARIBIC Airbus (A340-600) in spring/summer 2019 and the modification of a new A350 in December 2020. This will guarantee the operation of IAGOS-CARIBIC for the subsequent at least 10-15 years.

IAGOS-CORE

IAGOS cooperates with several airlines for quasi-continuous measurements of trace gases, aerosol and cloud particles from a fleet of long-haul passenger aircraft. Each aircraft carries the IAGOS-CORE rack with provisions for installing fully automated instruments measuring ozone, carbon monoxide, humidity and cloud particles (denoted P1), and provisions for installing a second instrument package (denoted P2) for measurements of either total odd nitrogen (P2a) or nitrogen oxides (P2b) or aerosol (P2c) or greenhouse gases (P2d). A special plate with dedicated inlet probes for the different instruments is mounted on the fuselage in the vicinity of the rack. The eight aircraft shown below are currently equipped with the IAGOS-CORE Rack and P1. Package 2a and 2b are intermittently flown on Lufthansa D-AIGT. The Installation of Package 2d was completed in September 2018 on D-AIGT. Some further modifications were made to the instrument and it is awaiting a slot for re-installation.

Instrumentation

Installation and operation on commercial aircraft requires that IAGOS instruments are fully compliant with design standards, safety regulations, and quality management of civil aviation. The aircraft modification has been approved by the European Aviation Safety Agency (EASA) as a Supplemental Type Certificate (STC), which was issued in 2011 for A340 and in 2013 for A330 aircraft. For installation in countries outside the EU, the EASA-STC has to be adopted by the national authorities responsible for the airline of concern. This process had been successfully completed in 2012 for Taiwan (China Airlines) and in 2013 for Hong Kong (Cathay Pacific). Each new aircraft to be equipped with the IAGOS modification must be investigated for compliance with the technical requirements of the IAGOS installation in terms of structure, electrical load and safety.

The set of P2 instruments is still under certification. One aircraft (Lufthansa D-AIGT) is certified to carry P2a or P2b. With the EASA certification of the P2d instrument obtained in December 2016, it is planned to install the new instrument for measurements of greenhouse gases (P2d) successively on IAGOS-CORE aircraft.



IAGOS-CORE Fleet 2018.

One RTTU is installed on the aircraft D-AIGT operated by Lufthansa. It was installed in 2017 and for few months, transmitted data via SATCOM to the EUMETNET E-ADAS facility which was established to receive and forward AMDAR data to the WMO Information System (WIS). The telecom provider was changed by Lufthansa in 2018. Some modifications to the RTTU are required before it can transmit data via the new operator. Studies have been carried out to

explore the best approach to continue the transmission of data in real time with the RTTU. A certification of the new system is underway.

Activities 2018

The Members involved in IAGOS-CORE, Forschungszentrum Jülich (**FZJ**), Centre National de la Recherche Scientifique (**CNRS**), Max-Planck Gesellschaft zur Förderung der Wissenschaften (**MPG**), Météo France (**MF**), and The University of Manchester (**UMAN**), concluded the following tasks:

FZJ maintains its strong engagement in the scientific analysis of the data set from own resources. As in the past for MOZAIC, this is achieved through own modelling activities and in collaboration with data users worldwide. FZJ is also engaged in the Copernicus Atmosphere Monitoring Service.

In the reporting period 2018, FZJ focused on the operation of the existing infrastructure. From German resources, no additional hardware was purchased but the certification of the various Package 2 types was promoted. In addition major progress was achieved in the field of instrument development, near real time data transmission, and data analysis:

- The implemented automated data inversion algorithm for water vapour permits provision of water vapour data in NRT mode to the IAGOS data base; these data are now used by Copernicus.
- The novel Package 2 instrument of type P2e for the simultaneous detection of aerosol and NO₂ passed successfully the Preliminary Design Review step and will go for certification in 2019.
- The first full 12 months deployment period of Package 2 type P2c - Aerosol in IAGOS – CARIBIC provided excellent data which will be analysed and published in 2019.
- Two decades of upper tropospheric temperature observations by MOZAIC and IAGOS were analysed and compared to temperature data from ERA-Interim. The results will be published in Atmospheric Chemistry and Physics in 2019.

FZJ represents IAGOS in the European project ENVRI^{PLUS}, a cluster of European Research Infrastructures; see <http://www.envriplus.eu/>. FZJ is in charge of developing new technologies with respect to future applications for satellite validation activities. Furthermore, FZJ serves as the Atmospheric Domain Leader in ENVRI^{PLUS}.

FZJ also serves as the coordinator for the EU H2020 project ENVRI-FAIR (Environmental Research Infrastructures building FAIR services accessible for society, innovation and research) which is funded under Grant Agreement No 824068. ENVRI-FAIR is the connection of the Cluster of Environmental Research Infrastructures (ENVRI) to the European Open Science Cloud (EOSC). The overarching goal is that at the end of the proposed project, all participating RIs have built a set of FAIR data services which enhances the efficiency and productivity of researchers, supports innovation, enables data- and knowledge-based decisions and connects the ENVRI Cluster to the EOSC.

CNRS acts as one leading institution in operating the Research Infrastructure.

Laboratoire d'Aérodologie, UMR5560, of CNRS coordinates the technical and legal work in France and with the main partners from other countries, particularly FZJ in Germany, assumes

responsibility for establishing contracts with airlines and maintenance organisations in order to ensure the timely progression of the work.

CNRS acts as the leading French partner in the cooperation with partners in Germany and U.K. on aircraft modification, including the acquisition of the IAGOS modification kits. CNRS ensures the performance, sustainable operation and data quality of the ozone and CO instruments by pre- and post-calibration procedures in its laboratory. CNRS also ensures the coordination of the IAGOS Data Centre in close collaboration with the French data centre AERIS (<http://www.aeris-data.fr>).

CNRS coordinates IAGOS-F (CNRS and MF), the national Research Infrastructure of the French Ministry for Research and Education (MESR), which is the French contribution to IAGOS.

CNRS maintains its strong engagement in the scientific analysis of the data set from its own resources. As in the past for MOZAIC, this is achieved through modelling activities and in collaboration with data users worldwide. CNRS is also engaged in the Copernicus Atmosphere Monitoring Service.

In the reporting period 2018, CNRS did not finance any units of Package 1 (O₃, CO) or installation kits, unlike in previous years. Instead, priority was put on the acquisition of two calibration benches and calibration instruments including software studies, along with the payment of aeronautical studies and audits to set up the new maintenance process in France which is now performed by LGM and Sabena.

A major part of the activities concerned the operation of the equipment (including the acquisition system and transmissions) aboard the eight IAGOS-CORE aircraft. This includes logistics, maintenance, quality assurance of the O₃ and CO data, and provision of the data and metadata to the IAGOS data base. Activities by CNRS also aim at data delivery in near real time (NRT) to ECMWF for the CAMS thanks to the development of software for data analysis, quality assurance for faster validation, and availability. This service is required by ECMWF under the CAMS-84 contract, which focuses on the evaluation of regional and global models with ozone and CO data from IAGOS. In 2018, CNRS renewed its engagement in CAMS-84 phase 2 (as sub-contractor of KNMI) from October 2018 for a duration of 33 months.

Development of the data base in 2018 included the replacement and improvement of the database and reception servers in Toulouse. The provision of added-value products produced with SOFT-IO, such as meteorological information and air-mass history are continuous efforts as well as the improvement of the data work flow with automation, integration of new QA/QC metadata, and flight comparisons. In 2018, web services for IAGOS PI (status of the data reception, etc.) have been implemented, and the improvement of the metadata for the IAGOS datasets has allowed creation of the associated DOIs.

CNRS, together with FZJ, represents IAGOS in the European project ENVRI^{PLUS}, a cluster of European Research Infrastructures. CNRS is in charge of data base developments that aim at promotion and implementation of common practices and harmonization of the data bases operated within the different infrastructures. In 2018, the proposal for the follow-on project ENVRI-FAIR (coordinated by FZJ, with the Atmospheric domain being co-lead by CNRS as IAGOS Members) was accepted by the European Commission for a start in January 2019.

The institute for Biogeochemistry (MPI-BGC) of MPG is responsible for operation of an instrument for the measurement of greenhouse gases (GHGs), namely carbon dioxide (CO₂) and methane (CH₄), as well as carbon monoxide (CO) and water vapour (H₂O). The instrument is referred to as Package 2d (P2d). It has obtained approval by the European Aviation Safety Agency (EASA) for deployment aboard passenger aircraft as part of the IAGOS CORE installation.

The first Package 2d (SN01) was installed and activated on the Lufthansa A330 aircraft (tail sign D-AIKO) on September 7, 2018. Operation was successful, with good data quality for CO₂ and CH₄ in the first few hours of each flight. Data transmission via P1 and the GSM network was not successful, but data could be transferred via USB storage medium (the fall-back option). A colder than expected avionics bay temperature however lead to insufficient temperature control, resulting in a severe loss of data quality for the rest of each flight. The deployment period lasted about six weeks, as scheduled based on expected calibration gas usage during the initial phase with frequent calibrations. Subsequent to the first deployment, P2d-SN01 has undergone a minor change to address the temperature control, and is ready for its next deployment on board D-AIKO.

The assembly of three further P2d SN02 – SN04 was continued, and completion is expected in early 2019. As SN02-SN04 differ slightly from SN01, a further change of the STC is required before those packages can be deployed onboard CAL and HAL aircraft. This is expected in the second half of 2019.

Météo-France is responsible for the RTTU, i.e. the real real-time data transmission of the IAGOS-CORE data to the WMO Information System (WIS) for operational users, particularly the Copernicus Atmosphere Monitoring Service. After the SATCOM system was changed by Lufthansa in 2018 the RRTU stopped transmitting real time data. In 2018, Météo-France has co-ordinated discussions with Lufthansa Technik and the subcontractor ATMOSPHERE, as well as Lufthansa and its new satellite telecommunications provider, in order to define best way to proceed with the operation of the RTTU already installed, and to ensure the delivery of real time data from additional aircraft in the future. Several options have been explored. The telecommunications provider can now deliver the data, with a protocol agreed amongst all the actors. New software, which will require a new certification, is necessary before being able to switch to the new version of the RTTU.

UMAN is responsible for operation of the Backscatter Cloud Probe (BCP) aboard all IAGOS-CORE aircraft. The BCP is a new instrument, originally designed as simple cloud detector, which still requires substantial work for characterisation of its performance with regard to analysing the size distribution of cloud particles.

UMAN have worked with the supplier (DMT) to deliver improvements to BCP integrity and to improve and extend the operational characteristics and lifetime of the BCP. It is becoming apparent that the older BCP's are now starting to show deterioration, exposed as they are to extreme conditions on the outer fuselage. We have been working with enviscope to improve care and maintenance of these older instruments until the newer BCP (version BCP-H). Certification for the newer BCP-H versions has been completed and we will start gradual replacement as the older instruments undergo refurbishment.

The droplet gun/laser mapping calibration facility at UMAN was rebuilt and new personnel (supported by NCAS) have been trained to speed up calibration and data delivery. Links with NCAS research scientists to make use of the droplet/ice generation facility. Further upgrades to the system have been made since and the system is provided for student training (MSc and

PhD projects). Ongoing work includes upgrades to investigate ice particle calibration response to provide improved higher level cirrus-cloud data products (i.e. effective diameter).

Metadata file information for the BCP has been improved and software tools are available to improve routine data analysis. In collaboration with manufacturers, new data from test flights of the BCP and the updated BCP-D for improved size resolution and particle phase discrimination have been investigated. The BCP-D has now been permanently installed on the UK FAAM BAe146 research aircraft for on-going data collection and comparison with cloud and dust spectrometers operated by FAAM and UK groups. BCP and BCP-D can be swapped/interchanged using this platform for various improvement assessments due to a common mounting template. The BCP-D completed initial operation in Jan 2018 as part of the UK PICASSO and MOCCA projects and will continue further flights as part of PICASSO and UK Met Office PIKnMIX projects. This agreement with FAAM will provide routine data as part of on-going strategic projects with FAAM and the UK Met Office. The data will be analysed alongside FAAM core and Manchester ice spectrometer data to improve understanding and mathematical retrievals of the IAGOS BCP in ice clouds. The FAAM cloud instrument fit has recently been upgraded by Manchester and NCAS to include faster, higher resolution instruments including a 3D holographic particle spectrometer (HaloHolo) provided by the University of Mainz as part of a joint PhD project and supported by PICASSO. Agreement to deliver BCP-D and complementary data products data via the CEDA data portal and beyond will be discussed at upcoming FAAM cloud instrument strategy meetings.

In collaboration with FZJ the power of integrated IAGOS RHice and Nice (BCP) pdf data products was demonstrated in a Royal Society Faraday Discussions publication (Petzold et al. 2017). A grant application to assess impacts of IAGOS BCP data products among commercial end users was submitted August 2018 and we were recently notified that this was successful (start data March 2019, duration 12 months). Visits and interviews will commence 2019 and will include Satavia UK who are working with Rolls Royce. Satavia are using IAGOS data to enable aircraft equipment manufacturers and operators to minimise unscheduled aircraft maintenance caused by the environmental impacts and we are providing expertise on BCP data analysis.

IAGOS Maintenance Centre

The company *enviscope* GmbH is in charge of the maintenance and aeronautical management of the instruments operated on board of civil aircraft. Instrument calibration is conducted at the laboratories of the scientific partners while *enviscope* is responsible for the coordination of the calibration activities and for the quality assurance related to continued airworthiness of the equipment. The company is involved in IAGOS since the beginning with respect to instrument development and aeronautical certification. Hence, in-depth knowledge of deployed techniques and aeronautical procedures is ensured.

Activities in the reporting period covered (i) software development and maintenance such as the revision of Maintenance Centre Website for interactive usability including connection with *enviscope* data base and database development for document management; (ii) logistics like instrument storage and shipment for 8 operational IAGOS-aircraft (see Table 1), and handling of instrument exchange intervals; (iii) instrument maintenance, repair and parts production; (iv) maintenance of the IAGOS website; (v) coordination activities like approving of legal aviation requirements, organisation of agreements between Design Organisations and Manufacturers, and participation in the IAGOS Technical Operations Group and Technical Planning Group, including the organisation of meetings. In addition *enviscope* organizes the shipments of P2c between FZJ and KIT for regular measurements on IAGOS-CARIBIC.

Table 1: Shipments of instruments and auxiliary parts for IAGOS-CORE operation in 2018

| Item | Member | | | | | Airline | | | | |
|--------------------------|--------|------|------|-----|-------|---------|-----|-----|-----|-----|
| | FZJ | CNRS | UMAN | MPG | other | DLH | CAL | CPA | AFR | HAL |
| Package 1 | | 7 | | | | 5 | | | | |
| Package 2ab | 5 | | | | | 3 | | | | |
| O ₂ Cylinders | 16 | | | | 3 | 16 | | | | |
| Pump Box | | 7 | | | | 4 | | | | |
| BCP | | 1 | 8 | | | 2 | 2 | | 1 | |
| ICH | 57 | | | | | 14 | 3 | 3 | 2 | 1 |
| Package 2d | | | | 4 | | 1 | | | | |
| AIR | | | | 25 | 10 | 2 | | | | |
| Auxiliary parts | 3 | 1 | | 1 | 1 | 4 | | | 1 | |

Financial Information

Balance 2018

Income

| | |
|---------------------|------------------|
| Membership Fees | 130,000 € |
| Total Income | 130,000 € |

Expenditure

| | |
|-----------------------------|------------------|
| Personnel incl. overheads | 57,056 € |
| Services and other expenses | 102,027 € |
| Total Expenditure | 159,083 € |

Amount carried forward from 2017 76,771 €

Total Balance 31 December 2018 47,688 €

Resources dedicated to IAGOS by the Members

In 2018, the Members contributed in total approximately 5.9 Million Euro from own resources in the form of personnel, equipment and consumables to construction and operation of the IAGOS Research Infrastructure according to the Statutes of IAGOS-AISBL. The breakdown of costs, calculated according to Article 22 of the Statues, is listed in Table 1.

Table 1: Contributions by the Members to construction and operation of the infrastructure from institutional resources and national funding¹

| <i>Member</i> | <i>Operation and Hardware (k€)</i> | <i>Personnel (k€)</i> | <i>Total (k€)</i> |
|---------------|------------------------------------|-----------------------|-------------------|
| FZJ | 902 | 908 | 1810 |
| CNRS | 573 | 890 | 1463 |
| MPG | 205 | 617 | 823 |
| MF | 47 | 46 | 92 |
| UMAN | 39 | 127 | 167 |
| DLR | 41 | 44 | 86 |
| TROPOS | 90 | 113 | 202 |
| KIT | 602 | 660 | 1261 |
| Total | 2498 | 3406 | 5904 |

¹**NOTES:** Personnel costs are calculated based on the average salaries of FZJ and CNRS, including overheads (82.4%). Acquisition of hardware is included by 10% annual depreciation. Not included are Membership fees, funding from European projects, and work related to scientific activities.

Additional resources of approximately 335 k€ were deployed in 2018 due to co-funding by the European Union for coordination with other European RIs (H2020 project ENVRI^{PLUS}), and contributions to the Copernicus Programme (CAMS-84).

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The participating Airlines contribute significantly to operation of the IAGOS infrastructure by waving the additional fuel costs incurred by carrying the IAGOS-CORE installation and by providing technical expertise during installation and deployment of the equipment.



Publications

Peer-reviewed Publications

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