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IAGOS at the Paris Air Show

IAGOS was invited by the Paris Air Lab to participate in a stand entitled Understanding Climate Change at the Paris air show (17-23 June 2019). The stand was shared with representatives from the satellite IASI and the research aircraft group SAFIRE to illustrate the importance of IAGOS in the Global Observing System with the three observing systems being necessary and complementary. The stand attracted delegates from European and national governments, the aviation industry and the general public. Due to the success of the stand at the Paris Air Show, IAGOS will be present at the Farnborough Air Show in July 2020.

The measurements from the backscatter cloud probe (BCP) installed on each IAGOS aircraft allow us to monitor both seasonal and long term global trends in cirrus clouds. This activity is of great importance to Rolls Royce in understanding the impact of ice crystals and supercooled water ingestion into aircraft engines and the effect on engine performance and aircraft safety. The approach of using commercial aircraft to provide routine in situ measurements of cloud properties is important due to the volume of flights undertaken, which is vital in capturing relatively rare atmospheric conditions which can lead to engine damage. This work is contributing to improvements in design of engine intakes, as well as engine service schedules in collaboration with Satavia as part of the UK DEICER programme reflecting the passage of the aircraft through specific regions where damage is more likely to occur.

Partnerships with Rolls Royce & Satavia

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Since 2018, aerosol properties such as number concentration and fraction of non-volatile particles for the size range $d_p > 15$ nm and size distributions of particles larger than 250 nm have been measured by the aerosol package installed in the IAGOS-CARIBIC container. The chemical composition of the aerosols have also been sampled. On 22 June 2019, the Raikoke Volcano on the Kuril Islands erupted and transported vast amounts of gaseous and particulate matter into the Upper Troposphere-Lower Stratosphere (UTLS). IAGOS-CARIBIC conducted several flight series in the Northern Hemisphere before and shortly after the eruption. Several flights signalled the impact of the Raikoke eruption on the UTLS aerosol, including statistical analyses of aerosol properties in the pre- and post-eruption periods. The figure (right) shows the change in the aerosol load of the tropopause region from two flights from Munich to San Francisco before and after the eruption. After the eruption, we saw a pronounced increase in the number concentration of small particles larger than 15 nm in diameter (left panel). Even more pronounced was the increase in the number of large particles with a size greater than 250nm (right panel). This increase was apparent over the sampled range (350-250hPa) in the upper troposphere.

**Highlights**

**The Raikoke eruption seen by the Aerosol Package on IAGOS-CARBIC**

Profiles of aerosol number concentrations of small particles (Left: diameter larger than 15 nm) and large particles (Right: diameter larger than 250 nm) before and after the Raikoke eruption.

**First Year of ENVRI-FAIR**

The European ENVRI-FAIR project started in January 2019 under the co-ordination of Andreas Petzold (Forschungszentrum Jülich / IAGOS). ENVRI-FAIR will connect the Environmental Research Infrastructure (ENVRI) community to the European Open Science Cloud (EOSC). ENVRI-FAIR builds on the heritage of the previous projects of the ENVRI cluster, namely ENVRI and ENVRIPLUS. IAGOS as one of the most mature research infrastructures in the atmospheric domain will play a key role in the implementation of the ENVRI-FAIR results. At the end of the project (in December 2022), all participating Research Infrastructures will have built a set of FAIR data services (FAIR being ‘Findable’, ‘Accessible’, ‘Interoperable’ and ‘Reusable’).

Activities in 2019 have been focused on FAIRness assessment within the IAGOS Data Centre. It has allowed us to identify the weaknesses and strengths of IAGOS for the application of the FAIR principles. Following this assessment, IAGOS is now defining an implementation plan for the next years of the project, in accordance with the others Research Infrastructures in the atmospheric domain.

Dr. Andreas Petzold (ENVRI-FAIR / FZJ) introduces ENVRI-FAIR at the EOSC Symposium 2019 in Budapest, see also https://mailchi.mp/3c37516d2040/envri-fair-news-5779691?e=d829591d7.
The main activities of ENVRI-FAIR identified are:

- the consolidation of consistent use of Persistent Identifiers (PID) throughout the data production workflow
- the consistent documentation of provenance throughout the data production workflow
- the development of common standard interfaces for metadata and data access for all the RI
- the definition of common Atmosphere domain vocabulary in order to improve data discovery and interoperability
- the common use of authentication systems
- the harmonization of the licenses on metadata and data
- the improvement of the Data Portal (new services, semantic search, etc.)

Three people have been employed at CNRS in Toulouse on web development (since April 2019), data management (since September 2019) and added value products (since September 2019), and one person at FZJ in Jülich on data workflow design scheduled to start in 2020.

In this second phase of the CAMS project, the daily validation of real time global and regional forecasts using IAGOS ozone and carbon monoxide has been expanded to include water vapour. The daily profiles of water vapour compared with the CAMS model are now operational on the www.iagos.fr/CAMS website.

Example of a profile of water vapour on a descent into Kuwait City on 10 December 2019.
The Helmholtz Association of German Research Centres, home of the major German IAGOS partners Forschungszentrum Jülich and Karlsruhe Institute of Technology, organised on 26 November 2019 in Brussels their autumn event on “Understanding tomorrow’s climate: What science can tell us”. The event highlighted the huge influence our climate has on our lives, and the major contributions of Helmholtz research centres on decoding the mechanisms of climate change and its consequences. The aim of Helmholtz scientists is to gain a better understanding of the causes and to improve forecasts and models that allow us to predict future climate development.

The event focused on climate research – and the stories behind. Two landmark research projects of the Helmholtz association were presented to the audience: The largest polar expedition in history in MOSAiC (Multidisciplinary drifting Observatory for the Study of Arctic Climate) and IAGOS as leading European Research Infrastructure for atmospheric observation.

IAGOS with its history dating back to the MOZAIC project in 1994, convinced the audience and the representatives of the European Commission of its invaluable and long-lasting contributions to climate science. Notably, the provision of essential data on climate change and air quality by open access to the global scientific community and the created value from the coordinated data analysis was very much appreciated by the audience.

IAGOS visits the Finnish Meteorological Institute

The General Assembly was held at the Finnish Meteorological Institute (FMI) in Helsinki. It was a good opportunity to strengthen the links between IAGOS and FMI, and the other research infrastructures based in Helsinki.

Helmholtz Autumn Event on Climate Science

Prof. Astrid Kiendler-Scharr (Forschungszentrum Jülich) presents IAGOS to the interested public at the Helmholtz autumn event on “Understanding tomorrow’s climate: What science can tell us” in Brussels.
Aerosol composition has been measured by the IAGOS-CARIBIC laboratory since 1997 by collecting aerosol samples at flight altitude and then by measuring their elemental composition in the laboratory by two accelerator-based methods (Particle-Induced X-ray Emission and Particle Elastic Scattering Analysis). The long time-series has allowed us to study the seasonal variation and vertical profile of carbon, oxygen and sulphur in the aerosol particles found in the upper troposphere-lower stratosphere. Martinsson et al. (2019) showed that the chemical composition of tropospheric aerosol in the tropics (at 10-12 km altitude) differs markedly from that at NH mid-latitudes, and that the carbonaceous aerosol is oxygen-poor in the stratosphere compared with the upper troposphere. Together with the considerable increase of the carbonaceous and sulfurous components of the stratospheric aerosol in springtime (associated with the springtime subsidence from higher altitudes), the IAGOS-CARIBIC data helped to improve the partitioning of the different pathways of aerosol and its precursors around the mid-latitude tropopause. In a further study by Sandvik et al. (2019) these data or the inferred aerosol backscattering have been compared with measurements of the satellite-based CALIOP Lidar system. During high-aerosol loading of the UTLS caused by volcanic eruptions and at higher altitudes above the mid-latitude tropopause the in-situ IAGOS-CARIBIC data compared well with satellite observations. In the upper troposphere and around the tropopause, at low aerosol concentrations, the discrepancy strongly increased, with the CALIOP Lidar system measuring backscatter ratios up to a factor of four higher.

IAGOS Dissemination Event Brussels

The final event for ENVRplus was the dissemination event at the Royal Belgian Institute of Natural Science, Brussels at the beginning of June. The aim of the event was to showcase the contribution from the European environmental research infrastructures to global earth observations, discuss the ENVRplus results and look ahead to the future of the ENVRI community. IAGOS had the opportunity to present the infrastructure to European and national decision-makers, the European Commission, national representatives in Brussels, European Environment Agency, and the other European research infrastructures.

International Symposium on Digital Earth

IAGOS was invited by the research infrastructure ACTRIS to take part in a special session on the “Impact of digital transformation on monitoring of atmospheric composition for environmental and human welfare”. The event was hosted by the Institute of Atmospheric Pollution Research of the National Research Council of Italy to focus on the advances in the science, technology and applications for the Digital Earth.
Organisation

IAGOS-AISBL

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)
Activities of IAGOS-AISBL

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). In order to strengthen the link between IAGOS and Airbus, IAGOS was delighted that Rainer Von Wrede accepted to join the advisory board in 2019. Rainer has been closely involved with IAGOS since the early days of MOZAIC. Rainer's knowledge of the aviation industry will be important to IAGOS in the coming years, particularly with the move to the A350.

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 www.iagos.org
Activities of the Association

Executive Board
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.

Brussels, 12 February 2019
(3 EB members, P, VP)
• Annual Report 2018
• Activity plan 2019
• Preparation Annual Meeting/Workshop in Jena
• Status of Operations
• Strategy Planning

Teleconference, 14 May 2019
(All members, VP, ES)
• Status of operations
• Planning of the GA in Helsinki
• Update on Paris Airshow
• Update on CAMS-IAGOS contract
• Annual Meeting Planning

Brussels, 12 September 2019
(4 EB members, VP, ES)
• Preparation of GA on 19th November in Helsinki
  ○ Discussion on IAGOS operations
  ○ Implementation Plan 2020
  ○ Aircraft installations 2020-2022
• Preparation of the AB meeting 19th November in Helsinki
• Adoption of ToR for the QA/QC committee
• Status of CAMS-IAGOS contract
• Annual Meeting in Toulouse 2020
• Report of ES

Teleconference, 21 October 2019
(All members, VP, ES)
• Review of documents for 10th GA
• Preparation of 6th Advisory Board meeting
• Update on logistics for the AB/GA in Helsinki

General Assembly

Brussels, 18/19.03.2019
• Approval of the Activity Plan for 2019 and implementation plan
• Decision on threshold for voting rights
• Approval of the Budget for 2019
• Approval of the Annual Report for 2018
• Planning for Annual Meeting/Workshop Jena

Helsinki, 18/19.11.2019
• Report on Operations and Planning
• Approval of the Budget for 2019
• Approval of the Activity Plan for 2020, pending availability of Members’ resources (to be confirmed in spring 2020)
• Report on activities on EU projects
• Annual Meeting 2020 Toulouse

Advisory Board

Helsinki, 18.11.2019
• Welcome to new Advisory Board member Rainer Von Wrede
• 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, 09.05.2019 – TPG Meeting
- Status of Package1 replacements and BCP-H
- Package2: certification and plans for equipment on aircraft
- Planning and coordination of IAGOS-CORE aircraft installations – New DLH A330
- CARIBIC – Change to A350
- Planning of further development in mid-term perspective (5 – 10 years)
  - Plans for the definition of scientific needs - How IAGOS answers scientific needs and how to improve in mid-term
  - Plans for evaluation of technical feasibility for new sensors for commercial aircraft
  - Available sensors technologies review (Core, Caribic, bibliography on research aircraft ...).
  - Work to be done by institutes - Sub-contract feasibility studies.
  - Plans for evaluation of technical feasibility on different aircraft - (A330neo, A350, A320...). Work to be done by institutes - Subcontract feasibility studies
- Plans for definition of the mid-term perspective
- Midterm improvements of equipment, documents and procedures based on the gained experiences

Frankfurt, 23.10.2019 – TPG Meeting
- Planning and coordination of IAGOS-CORE aircraft installations
- Operations Status - Package1 Part145 maintenance and replacements planning
- Package2: Certification and plans for equipment on aircraft
- CARIBIC – Operations and change to A350
- Budget : IAGOS-D and IAGOS-F

Technical Operations Group

Teleconferences
The teleconferences cover the same five 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 instrument certifications
5. Status of new aircraft installations
  - integration study of CARIBIC on A350
  - new Part 145 MO for P1
  - stowage plate retrofit for the BCP hermetic version
  - certification for the BCP hermetic version
  - discussions with Finnair for new A330
  - discussions with DLH for new A330
  - discussions with IBERIA for new A330
  - FAA agreement for GFM
  - first p2d operation on D-AIKO
  - GSM network at Frankfurt Airport
  - P2 USB stick for all P2 versions
  - P2b, P2c, P2e, P2d (major changes) certification

Communication and Outreach
- ENVRI Dissemination Event (1 June 2019), Brussels, Belgium
- Participation in ENVRIPLUS booth at EGU, Vienna
- Participation in Paris Airshow, Paris, France
- Presentations at International Conferences (see Presentations)
  - EGU General Assembly (Vienna, 8-12 April 2019)
  - International Symposium on Digital Earth (Florence, 23-27 September 2019)
The current IAGOS-CARIBIC payload of 19 instruments is provided by 12 institutes, 11 from Europe (Germany, UK, Ireland, Sweden, Netherlands) and 1 (NOAA) from the US. Five institutions 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 (NOy) aboard the CARIBIC container. The measurement system operated successfully throughout 2019 and the data have been analysed.

TROPOS is responsible for operation of instruments for the measurement of particle concentrations aboard the 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).

FZJ is responsible for the IAGOS-core package 2 instrument slot in the CARIBIC laboratory, integrated in 2017. Currently the aerosol package is installed which contains two CPCs and an OPSS.

MPI-BGC is responsible for the picarro CRDS CO2 and CH4 measurement system. The instrument provided first data in July 2018, and has provided high quality data for all flights except one during 2019. The cause for the missing data (disk failure) was addressed by implementation of a safer boot sequence in early 2019. Since then the system has been fully reliable.

In 2019, a reduced number of 20 measurement flights were conducted. Considerable manpower and energy were devoted to a feasibility study on the move of the CARIBIC laboratory to an Airbus A350. The results of this feasibility study were presented at a 4-hour meeting at the European Aviation Safety Agency (EASA) on 21st October 2019. The EASA didn’t foresee any major technical objections. The detailed timeline of the technical and organisational implementation until the modification of the A350 (foreseen in 2021) has been defined, together with the involved companies; Lufthansa Technik, Safran, Airbus, and enviscope. The current planning assumes measurement flights using the current CARIBIC Airbus (A340-600) at least until December 2020. In 2021, a new CARIBIC laboratory will be build-up, with a strongly modified payload. Flights with the new A350 can hopefully start still in 2021.
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.

**Instrumentation**

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**Activities of Members**

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** coordinates the joint programme IAGOS – Germany, funded by the German Ministry for Education and Research (BMBF) under Grant Numbers. 01LK1301A-G. IAGOS – Germany terminated end of 2020.

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 2019, FZJ focused on the operation of the existing infrastructure and on its future development. From German resources, additional installation kits were purchased to ensure the extension of the fleet in the coming period. Furthermore, the certification of the package 2 types was promoted, and 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. The certification of this novel Air Quality Package P2e started in 2019.
- The second year of deployment of Package 2 type P2c - Aerosol in IAGOS – CARIBIC provided excellent data which have been analysed and presented at an international conference. The development of an automated data analysis started.

FZJ represented IAGOS in the European project ENVRIPLUS, a cluster of European Research Infrastructures; see http://www.envriplus.eu/. FZJ was in charge of developing new technologies with respect to future applications for satellite validation activities. Furthermore, FZJ served as the Atmospheric Domain Leader in ENVRIPLUS. ENVRIPLUS finished in May 2019.

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 of the leading institution in operating the Research Infrastructure.

Laboratoire d’Aérologie, 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 postcalibration 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, since the beginning of MOZAIC, this is achieved through deep data analysis and modelling activities in collaboration with data users worldwide. CNRS is also engaged in the Copernicus Atmosphere Monitoring Service, in particular for the validation of the regional and global models. Since 2019, this validation also concerns the water vapour distribution, as data are available in NRT. See dedicated pages in http://www.iagos-data.fr/cams and in the highlights section above.

Activities of Members

In the reporting period 2019, CNRS financed one unit of Package 1 (O3, CO) and several maintenance kits to adapt the system to the new maintenance process in France which is now performed by LGM and Sabena. A major part of the activities concerned the finalization of the maintenance process and the operation of the equipment (including the acquisition system and transmissions) aboard the seven to eight IAGOSCORE aircraft. This includes logistics, maintenance, quality assurance of the O3 and CO data, and provision of the data and metadata to the IAGOS database.

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, CO, and water vapour data from IAGOS. In 2018, CNRS renewed its engagement in CAMS-84 phase 2 (as sub-contractor of KNMI) from October 2018 until June 2021 for a duration of 33 months. In 2019, CNRS also started the negotiation with ECMWF for the direct contract between CAMS and IAGOS for the delivery of data in real time.

Development of the database in 2019 included the continuous 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 workflow with automation, integration of new QA/QC metadata, and flight comparisons. In 2019, major improvements have been set up thanks to additional resources through the ENVRI-FAIR project (started in January 2019; coordinated by FZJ, with the Atmospheric domain being co-lead by CNRS as IAGOS Members).

CNRS, together with FZJ, keeps representing IAGOS in the European project ENVRIPLUS, (project ended in May 2019) a cluster of European Research Infrastructures and in the ongoing BEERI (Board of Environment European Research Infrastructures), aiming at building the ENVRI community independently from the different ENVRI projects. Within ENVRI-FAIR, CNRS is in charge of database developments that aim at promotion and implementation of common practices, FAIR principles and harmonization of the databases operated within the different infrastructures.

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 operated onboard the Lufthansa A330 aircraft (tail sign D-AIKO) during two deployment phases during 2019 (Jan. 31 – Mar. 2, Aug 6 – Nov 14).
Activities of Members

Initial temperature problems encountered in 2018 have been fully addressed by the minor change of P2d- SN01. During the first deployment a damaged fibre optic cable prevented GHG measurements, but during the second deployment high quality data have been acquired from a total of 17 flights. In-flight calibration results confirmed excellent traceability of CO2, CH4 and CO data to WMO calibration scales. Subsequent to the last deployment, P2d-SN01 has undergone a maintenance cycle, and is ready for its next deployment on board D-AIKO.

The assembly of one further P2d (SN03) has been completed, two further P2d (SN02 and SN04) are close to completion, and the last two (SN05 and SN06) are expected to be assembled within 2020 (all parts in stock). As SN02-SN06 differ slightly from SN01, the completion of the major change of the STC is required before those packages can be deployed onboard CAL and HAL aircraft.

Météo-France is responsible for the RTTU, i.e. the real realtime 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 RTTU stopped transmitting real time data. In 2019, Météo- France 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 has 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 so 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 DMT, 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 2018 as part of the UK PICASSO and MOCCA projects. It will also be deployed as part of recently funded NERC cloud-climate sensitivity projects including: M-Phase (October 2020 in Canada) and DC-MEX (July 2021, USA). The data collected will continue to be used as a reference database for BCP data interpretation and improvement of retrieval algorithms by comparison with state-of-the-art research cloud instruments. There is agreement with FAAM-NCAS to provide support for the BCP/D routine data as part of NCAS support for IAGOS and it is currently offered as part of the FAAM core cloud instrument fit for facility users.

NCAS and NERC have recently funded (Jan 2020) the Manchester MU-HOLO project to develop two new high-resolution holographic spectrometers in collaboration with the University of Mainz, one for the FAAM aircraft and one for use in the Manchester laboratory cloud calibration facility which can be used for validation of BCP ice particle retrievals. Agreement to deliver FAAM BCP/D and complementary data products data via the CEDA data portal will be discussed at upcoming FAAM-NCAS 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 began in 2019. Visits and interviews includes 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.
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>
<thead>
<tr>
<th>ITEMS</th>
<th>MEMBERS</th>
<th>AIRLINES</th>
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<tr>
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Table 1: Shipments of instruments and auxiliary parts for IAGOS-CORE operation in 2019

IAGOS Maintenance Centre
In 2019, the Members contributed in total approximately 6.5 Million Euros 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 Statutes, is listed in Table 1.

### Balance 2019

<table>
<thead>
<tr>
<th>Income</th>
<th>Membership Fees</th>
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<tr>
<td>Total Income</td>
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<td>Expenditure</td>
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<td>Personnel incl. overheads</td>
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<td>Services and other expenses</td>
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<td>Total Expenditure</td>
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<td>Amount carried forward from 2018</td>
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<td>Total Balance December 2019</td>
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<td>79,523€</td>
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</table>

### Resources dedicated to IAGOS by the Members

In 2019, the Members contributed in total approximately 6.5 Million Euros 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 Statutes, is listed in Table 1.

<table>
<thead>
<tr>
<th>Member</th>
<th>Operation &amp; Hardware (k€)</th>
<th>Personnel (k€)</th>
<th>Total (k€)</th>
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<td>FZJ</td>
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<td>804</td>
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<tr>
<td>TOTAL</td>
<td></td>
<td>3719</td>
<td>6564</td>
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</table>

**Table 2:** Contributions by the Members to construction and operation of the infrastructure from institutional resources and national funding.

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 272 k€ were deployed in 2019 due to co-funding by the European Union for coordination with other European RIs (ENVRI-FAIR) and contributions to the Copernicus Programme (CAMS-84).
Acknowledgements

The Members of IAGOS-AISBL acknowledge the funding received from Germany, France and the United Kingdom for the construction phase of the Research Infrastructure and co-funding by the European Commission for development of the infrastructure, coordination with other RIs and for contributions to the Copernicus Atmosphere Monitoring Service. The IAGOS database is cosponsored by the Centre National d’Études Spatiales via the French data centre AERIS.

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

Peer-reviewed Publications

Presentations at International Conferences

1. Boenisch, H., Tracer distribution and transport in the UTLS derived from the IAGOS-CARIBIC observatory using JETPAC, European Geophysical Union, Vienna, 8-12 April, 2019.
2. Boulanger D, Advanced services for the IAGOS user, European Geophysical Union, Vienna, 8-12 April, 2019.
6. Cussac, M., Understanding the origin and composition of air in the upper troposphere from MOCAGE CTM and IAGOS airborne data: a focus on biomass burning, European Geophysical Union, Vienna, 8-12 April, 2019.
7. Gerbig, C., First IAGOS-CORE greenhouse gas observations from commercial airliners European Geophysical Union, Vienna 8-12 April, 2019.
11. Marécal, V., On the use of IAGOS 20-years database for evaluating and analyzing chemistry-climate simulations, European Geophysical Union, Vienna, 8-12 April, 2019.