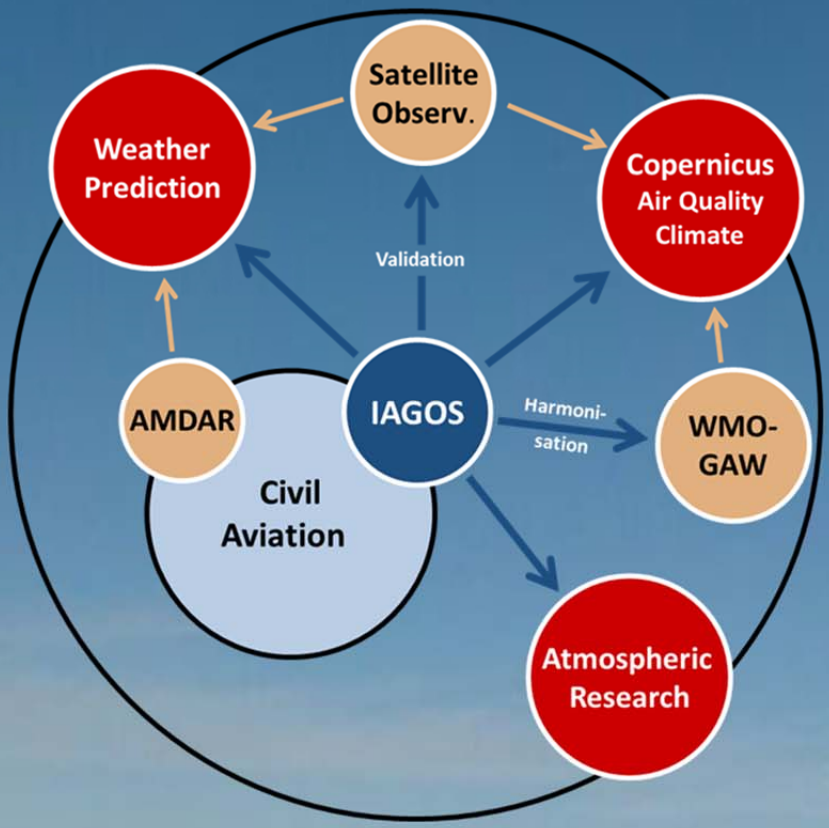
In-Service Aircraft for a Global Observing System
— Association Internationale Sans But Lucratif
IAGOS-AISBL



Annual Report 2017

IAGOS
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Members

Andreas Volz-Thomas becomes an Honorary Member of IAGOS

Andreas is offered Honorary Membership of IAGOS at the General Assembly in November 2017.

In September 2017, Andreas Volz-Thomas retired from his position as Executive Secretary of IAGOS. The EB members are grateful to Andreas for his crucial contribution in the foundation of the AISBL and its management. In order to retain his expertise for the benefit of IAGOS, he was offered Honorary Membership of the organisation. Andreas remains active at the heart of IAGOS, providing consulting services to the new executive secretary Hannah Clark and managing the future installations of P2d on non-European airlines.

Highlights

Hawaiian Airlines: First U.S. Airline joins IAGOS

In February 2017, the IAGOS-CORE rack was installed for continuous operation on an AIRBUS A330-300 operated by Hawaiian Airlines. The modification was made by Hawaiian Airlines on aircraft N384HA with support of Sabena Technics and the IAGOS team during a scheduled layover of the aircraft. Hawaiian Airlines became the first US airline to take part in IAGOS. The location of Hawaii in the central Pacific is extremely important for IAGOS to improve geographical coverage in part of the world where in situ measurements are lacking. A press-event was organised in November 2017 to mark the occasion.

Group photo from the Hawaiian Airlines press event (from left: J. Bienhaus (Hawaiian Airlines), A. Petzold (coordinator of IAGOS-Germany); B. Chun (Hawaiian Airlines); J.-M. Flaud (President of IAGOS), Jim Butler (Chair of IAGOS Advisory Board); A. Wahner (Vice-President of IAGOS); H. Clark (Executive Secretary of IAGOS-AISBL); J.Snook (Hawaiian Airlines CEO).

In April 2017, the installation IAGOS on a second Air France aircraft (Registration F-GZCO) was successfully completed. The new installation, on an A330, joins the A340 aircraft, which has been operating since 2013.

The installation of IAGOS on an Airbus A330 of China Airlines (Registration B-18316) was successfully completed in July 2017, this being the third China Airlines aircraft to be equipped. The A330 aircraft replaces the old A340 aircraft, which was retired at about the same time, after five years of flying with IAGOS equipment.

With the new aircraft, the IAGOS-CORE fleet now comprises eight longhaul aircraft of the type AIRBUS A330 or A340. Flying regularly between Hawaii, Taiwan, North America, Australia and New Zealand, the new aircraft further increase the spatial coverage of IAGOS data.

New IAGOS-CARIBIC Flying Laboratory Operational

IAGOS-CARIBIC is operational again after obtaining the EASA certification on 1st December 2017. The first flight sequence Munich – Seoul – Munich and Munich – Capetown – Munich took place from 11 to 13 December 2017. It has taken more than 20 months to rebuild the container, implement new and revised instruments (see Annual Report 2016) and finally certify this significantly improved laboratory. This work was conducted by Lufthansa Technics and *enviscope* GmbH, coordinated by KIT with help from all the partners across the different institutes and Lufthansa Environmental Concepts.

Photo of the new modified CARIBIC container

An interface was designed and built for housing IAGOS-CORE instruments in the IAGOS-CARIBIC Flying Laboratory. The interface is designed to host one of the IAGOS CORE (Package2) instruments. Available are currently: P2a and P2b, measuring NO_y and NO_x; P2c, measuring aerosol microphysical properties; P2d, measuring greenhouse gases CO_2,CO, H_2O and CH_4; in the future P2e, measuring aerosol optical properties and NO_2 mixing ratio as key air quality parameters. The interface has provisions for gas supply, butanol working liquid, connections to the chemical- and an aerosol inlet line as well as provides the connectivity to the CARIBIC master computer defining the different measurement phases.

Real Real Time Data Transmission on first IAGOS-CORE Aircraft

The Real-Time Transmission Unit (RTTU) was developed by Météo-France with the support of Atmosphere to transmit the IAGOS data via satellite link in real-time to weather services on the ground. The unit connects IAGOS Package 1 with the Satcom Data unit on the aircraft and data are transmitted to the E-ADAS center, a facility operated by Eumetnet, extended to IAGOS data

through a contract with Météo-France for AMDAR and IAGOS data. It will therefore be possible to insert the data onto the WMO Global Telecommunication system (WIS). This will make the IAGOS Ozone and Carbon monoxide profiles available to any user though a connection to the WIS, and namely by Meteorological services and ECMWF for the CAMS service. Reduced vertical profiles are currently transmitted within three hours. Météo-France, subcontracted with Sabena Technics and Lufthansa Technik and installed the RTTU on the first IAGOS-CORE aircraft in February 2017, the A340 Lufthansa D-AIGT.

IAGOS Data Portal Provides New Services to Users

A new tool has been developed to quantify source receptor links for all the observations in the IAGOS database (Sauvage et al. 2017). The tool helps users to analyse the observations and understand the processes driving the observed concentrations, distribution and variability. Based on the FLEXPART particle dispersion model (Stohl et al., 2005), SOFT-IO simulates the contributions of anthropogenic and biomass burning emissions from the ECCAD emission inventory database for all locations and times corresponding to the measured carbon monoxide mixing ratios along each IAGOS flight. Contributions are -simulated from emissions occurring during the last 20 days before an observation, separating individual contributions from the different source regions. The tool has been used to create added-value products for the IAGOS database which are available in the IAGOS database via http://www.iagos.org.

IAGOS Strategy Meeting

Participants of the IAGOS Strategy Meeting, Burg Obbendorf, Germany

The strategy meeting took place at Burg Obbendorf near Jülich from 30.05.2017 to 01.06.2017. The isolated location of the meeting was conducive to improving the dialogue among the

different contributors. The meeting was especially useful in identifying challenges and developing a roadmap toward better integrating CORE and CARIBIC within the single research infrastructure. A useful outcome of the meeting was identification of a pathway forward for ensuring a sustainable CARIBIC effort, and achieving overall goals. It was suggested that the strategy meetings should be repeated every two years, possibly with an expansion on the discussion of scientific topics.

Nature Comm. Article on Methane Emissions over India

IAGOS-CARIBIC methane data collected since 2010 have been used to quantify the methane source of the Indian subcontinent, together with data from satellite and ground stations (Ganesan et al., 2017). We inferred an average emission of 22.0 Tg yr^{-1}, which is consistent with the emission rate reported by India to the United Framework Convention on Climate Change. China on the other hand was found to show a significant increase of the CH_4 source strength over the last years, primarily due to increasing fossil fuel emissions.

Ganesan et al., Atmospheric observations show accurate reporting and little growth in India's methane emissions, Nature Communications 8, Article number:836, doi:10.1038/s41467-017-00994-7, 2017.

IAGOS Participation in the first ENVRI^{PLUS} booth at EGU Vienna

The ENVRI^{PLUS} booth at EGU Vienna

In 2017, for the first time, 15 Research Infrastructures collaborating in ENVRI^{PLUS}, decided to join forces and organize a joint booth for the entire Environmental Research Infrastructure (ENVRI) Community at the General Assembly of the European Geophysical Union (EGU). EGU

is one of the most important events for all the Environmental Research Infrastructures in Europe. The conference brings together yearly 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 have therefore decided to join their forces in promoting the environmental RIs, organizing a joint booth together, to get visibility, share the costs as well as to demonstrate the strong collaboration among them. IAGOS joint the booth and was part of the big success.

IAGOS Listed as a Research Infrastructure of Global Interest

In the Progress Report 2017 of the Group of Senior Officials, IAGOS has entered the List of Research Infrastructures of Global Interest.

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**

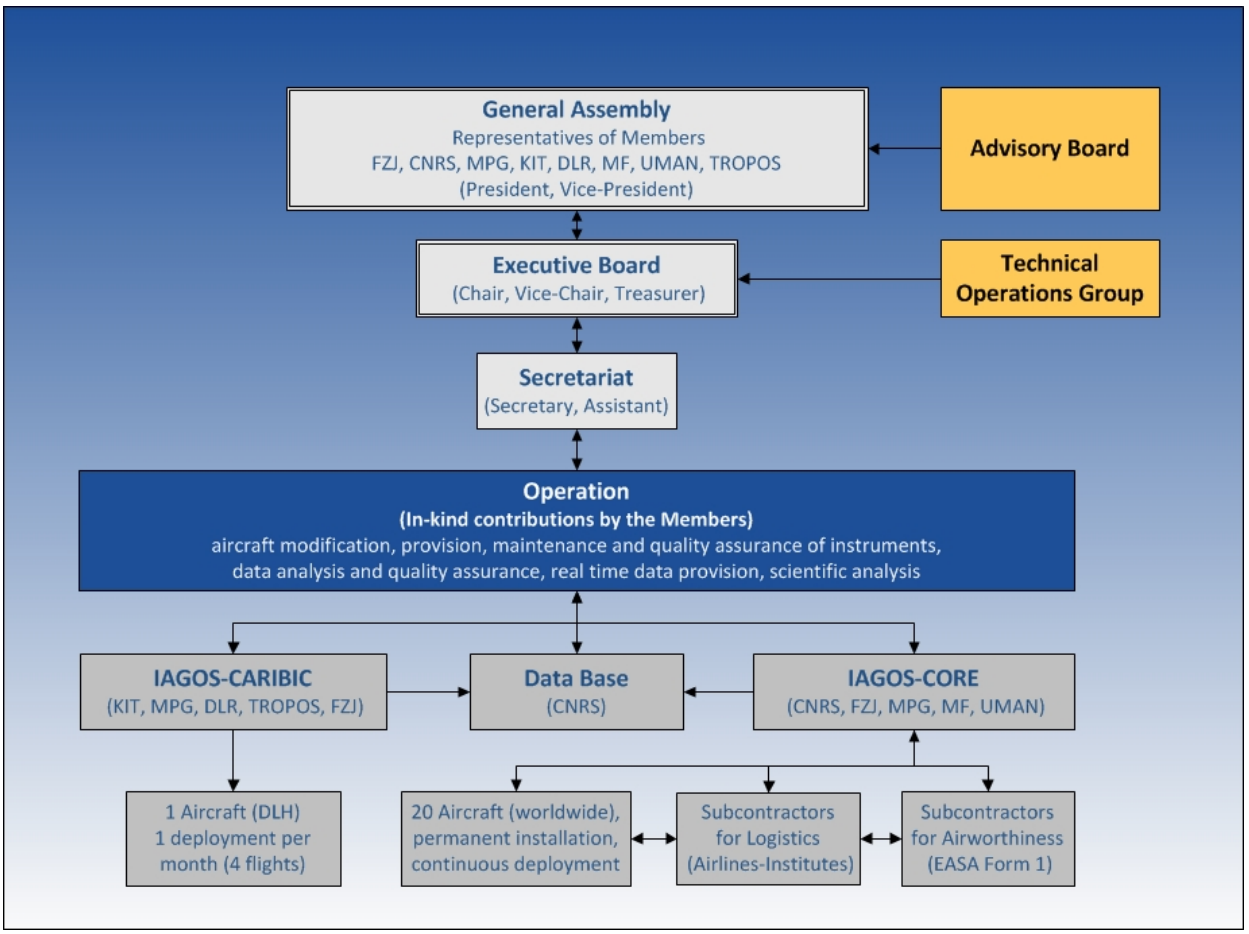
The activities of IAGOS-AISBL are twofold (Statutes are available for download at http://www.iagos.org):

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, Jean-Marie Flaud, representative of CNRS. Andreas Wahner, representative of FZJ, 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), and Andreas Zahn (Vice-Chair). The EB was assisted by Andreas Volz-Thomas and now Hannah Clark (since September) as Executive Secretary (ES).



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. In order to enhance IAGOS' links with the satellite community, it was decided at the strategy meeting in June, to invite a new member to the AB. 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 has been reorganised as the technical operations group with the main objective of overseeing the technical operation and development of the infrastructure. The TOG works closely with the aeronautical subcontractors and the associated airlines. In 2017, 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 eight meetings of the Executive Board (5 by Teleconference), two meetings of the General Assembly, one meeting of the Advisory Board, and 3 Meetings of the Technical Operations Group.

Executive Board

Meetings

Teleconference 19 January 2017 (4 EB members, P, VP)

- Annual Report 2016
- Final review of Activities 2016
- Approval of final Budget 2016
- Schedule for Preparation of report
- Activity Plan 2017 and Implementation Plan
- Budget 2017
- Job offer and revised ToR for ES (EB)
- Preparation of 7th GA Meeting (week 22, starting 29th May 2017)

Brussels, 22 February 2017 (4 EB members, P, VP)

- Annual Report 2016
- Budget 2017
- Activity plan 2017
- Preparation Strategy Meeting
- Decision on AUDIMAX video
- Publication of ES job offer

Teleconference, 21 April 2017 (3 EB members, VP, ES)

- Selection of ES candidate

Brussels, 4 May 2017 (4 EB Members, ES, VP)

- Proposal for ES candidate and ToR
- Preparation for 7th GA
- Member resources in 2016
- AB-report from 3 AB meeting
- Annual report 2016
- Activities 2017
- Implementation Plan 2017
- Budget 2017
- IAGOS movie
- Planning for Strategy meeting

Teleconference, 11 May 2017 (3 EB members, ES)

- Preparation of GA on 30 May 2017 (7th GA)

    - Activity Plan for 2017, (and Draft Service Agreement with enviscope GmbH
    - implementation plan
    - Annual Report 2016 (activity report and financial report)
    - Updated Budget 2017
- Outreach and Communication (storyline for movie)
- ES Mandate

Teleconference, 26 June 2017 (4 EB members, ES)

- Status of document from strategy meeting
- Call for TPG meeting
- Status of Finland
- IAGOS movie
- ES contract

Brussels, 14 September 2017 (4 EB Members, ES, P, VP, future ES)

- Preparation of 8th GA on Nov 15 and AB of Nov 14 2017
- Summary of Strategy Meeting 2017
- Activity Plan 2017/2018
- Status of fleet
- Status of database
- Update on IAGOS as Global RI
- Review of recommendations from 3rd AB meeting
- Communications strategy, IAGOS movie, publications

Teleconference, 23 Oct 2017 (3 EB members, ES, AVT)

- Final check and approval of preparatory material for GA and AB Meetings
- Report on TOG implementation
- Update on video
- H2020 infrastructure

General Assembly

Burg Obbendorf, 29/30.05.2017

- Approval of the Activity Plan for 2017 and implementation plan
- Approval of the Budget for 2017
- Approval of the Annual Report for 2016
- Approval of applicant and ToR for ES position from 15th Sept 2017
- Exoneration of EB members

Brussels, 15.11.2017

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

Advisory Board

Brussels, 14.11.2017

- Review of actions in response to recommendations made at last meeting
- IAGOS doing a great job at maintaining and growing the network, but SH remains a challenge
- Discussions on smaller aircraft
- Discussion on user-oriented level-3 products
- Big improvements on communications noted since last year

Technical Operations Group

Meetings

Teleconference (subgroup Jülich), 17.01.2017

- Status of P2d amendment of STC
- P2d installation planning on LTH Aircraft
- Planning for P2ab STC application

Teleconference, 01.08.2017

- P2d actions
- P2b STC application status
- status of IAGOS CORE operations
- A330 China airline installation status
- A330 Hawaiian final activation status
- status CARIBIC
- Planning for new installations (IBE,FIN)

Frankfurt, 06.09.2017

- Status of IAGOS CORE operation
- Status of IAGOS CARIBIC certification and operation
- Accreditation of enviscope
- Status of P2d implementation on Lufthansa
- Status of STC applications for P2b
- Planning for retrofit of digital cable for ICH
- Instrument updates
- Planning for new installations (timeline, status)

Teleconference, 10.10.2017

- New telecon meeting procedure
- The use of Redmine to improve group communication
- Reporting status of iagos-core operation
- Organisation of the iagos maintenance centre

Teleconference, 07.11.2017

- Status of A/C core operations
- Review of instrument status
- Status ICH serial cable installation
- Status of CARIBIC operation
- Report on IAGOS maintenance centre
- Status of the BCP neo design/qualification
- Status P2d installation on CAL

Teleconference, 07.12.2017

- Status of A/C core operation
- Review of instrument status
- Status of CARIBIC operation
- Report on IAGOS maintenance centre
- Status of P2d implementation
- visit at HAL and enviscope
- TOG subgroups on planning/certification and data base
- status of installation on Finnair

Communication and Outreach

- Distribution of an Information Package (Flyer, Annual Report,) to stakeholders
- Participation in ENVRI^{PLUS} booth at EGU
- Hawaiian Airlines press event
- Preparation of a IAGOS Movie
- Presentations at International Conferences (*see Presentations*)
    - 3rd ACTRIS-2 General and MTR Meeting (Granada, 30 Jan. - 03 Feb. 2017)
    - GAW 2017 Symposium (Geneva, 10 – 13 April 2017)
    - EGU General Assembly (Vienna, 23 – 28 April)
    - CAMS General Assembly (Warsaw, 16 – 18 May 2017)
    - Faraday Discussion: Atmospheric chemistry in the Anthropocene (York, 22 – 24 May 2017)
    - GRUAN ICM-9 Annual Meeting (Helsinki, 12-16 June 2017)
    - CCMI (Toulouse, June)
    - SPARC UTLS Workshop (Boulder, 18 – 20 July 2017)
    - European Aerosol Conference 2017 (Zürich, 27 Aug. - 01 Sep. 2017)
    - ENVRI^{PLUS} Weeks (Grenoble 15 – 18 May, Malaga, 6 – 10 Nov. 2017)
    - AGU Fall Meeting (San Francisco, 11 – 15 Dec. 2017)

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 dis-continuous with 10-12 sequences per year, each for 4 consecutive flights.

CARIBIC, since May 2005

Activities 2017

Twelve institutes are involved in IAGOS-CARIBIC, eleven from Europe (Germany, England, Ireland, Sweden, Netherlands) and 1 (NOAA) from the US. Four institutes are members of the AISBL: Karlsruhe Institute of Technology (**KIT**), Max-Planck society (**MPG**), German Aerospace Center (**DLR**), and Leibniz Institute for Tropospheric Research (**TROPOS**) who concluded the following tasks:

A new container was built-up in 2016 (by Gomolzig Flugzeug- und Maschinenbau GmbH and *enviscope* GmbH) and delivered to the KIT in October 2016. Thereafter, the entire cabling, tubing and smoke detection system was renewed and integrated and the new/modified/updated (altogether 19) instruments installed. From October 2016 to November 2017 an elaborate EASA certification followed and finished 1th December 2017. The first flight sequence to Seoul and Capetown occurred in mid-December.

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 H_2O, cloud water/ice, ISOWAT for H_2O isotopic composition, and a PTRMS for selected volatile organic compounds (VOCs) such as acetone, acetonitrile, and methanol. In 2017, strongly improved versions of ISOWAT and PTRMS were installed.

MPI-C maintained 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 NO_2) and total odd nitrogen (NO_y) aboard the CARIBIC container.

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.

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. Installation of Package 2d is in preparation after having received the EASA STC in December 2016.

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. Certification of the other P2 instruments is expected to be realised in 2018.

Real-time data transmission of the IAGOS-CORE data via SATCOM to the WMO Information System (WIS) is currently being developed for operational users such as the Copernicus Atmospheric Monitoring Service. Installation of the first unit on the first aircraft has been completed and data are now transmitted to the EUMETNET E-ADAS facility, established to receive and forward AMDAR data to the WIS.

IAGOS-CORE fleet 2017

Activities 2017

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 2017, from German resources, FZJ financed the installation of the IAGOS kit on board of the Hawaiian Airlines A330-200 with the call sign N384HA. Operation started in February 2017. The technical part of the installation was conducted in close collaboration with, Hawaiian Airlines, CNRS and Sabena Technics. FZJ further provided the installation kit for the installation of IAGOS on China Airlines A330-300 with the call sign B-18316. Operation started in July 2017.

Hardware acquisition concerned one unit of P2b for continuous operation of NO_x measurements on board of Deutsche Lufthansa A340-400 D-AIGT.

Major progress was achieved in the field of instrument development, near real time data transmission, and data analysis:

- The automated data inversion algorithm for water vapour was implemented. Data are provided in NRT mode to the IAGOS data base on an operational basis.
- The analysis of combined water vapour and cloud data of IAGOS was successfully conducted for 15 month of operation and presented at the Faraday Discussion from 22-24 May 2017 and the EGU 2017.
- Two decades of upper tropospheric temperature observations by MOZAIC and IAGOS were analysed and compared to temperature data from ERA-Interim. The results were published in Atmospheric Chemistry and Physics.
- The first field deployment of the prototype of the Package 2 instrument of type P2e for the simultaneous detection of aerosol and NO_2 was analysed and published in Aerosol Science and Technology.

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}.

CNRS acts as one leading institution in operating the research infrastructure and provides the President of the Association.

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 post-calibration procedures in its laboratory. CNRS also ensures the coordination of the IAGOS Data Base 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 own resources. As in the past for MOZAIC, this is achieved through own modelling activities and in collaboration with data users worldwide. CNRS is also engaged in the Copernicus Atmosphere Monitoring Service.

In the reporting period 2017, from French resources, CNRS financed and provided engineering support for installation of the IAGOS kits on Air France (F-GZCO) in March 2017 in Xiamen, and partially financed installations on Hawaiian Airlines (N384HA) in February 2017 in Brisbane and on China Airlines (B-18316) in July in Taipei. Acquisition of hardware for development of the RI included 1 unit of Package 1 (O3, CO), and 1 installation kit for future aircraft modifications. Further work included technical improvements and associated modifications of the STC for Package 1.

A major part of the activities concerned the operation of the equipment aboard the eight IAGOS-CORE aircraft. This included logistics, maintenance and re-certification, quality assurance of the data for O_3 and CO, and provision of the data and metadata to the IAGOS data base, as well as data transmission in near real time (NRT) to ECMWF for the CAMS., Related activities concerned the development of software for data analysis, quality assurance and near-realtime provision for faster validation and availability of NRT data for CAMS. This work was supported by ECMWF under the CAMS-84 contract, which focuses on the evaluation of regional and global models with ozone and CO data from IAGOS.

Development of the data base included the provision of added-value products using SOFT-IO (see highlights section), such as meteorological information and air-mass history, and inclusion of the data from the former CARIBIC project into the IAGOS data base.

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. It was decided that IAGOS represented by FZJ and CNRS will co-ordinate the follow-on project ENVRI-FAIR which will be submitted in 2018 to start in 2019.

The Institute for Biogeochemistry (MPI-BGC) of **MPG** is responsible for implementation and operation of an instrument for the measurement of greenhouse gases (GHGs), namely carbon dioxide (CO_2) and methane (CH_4), as well as carbon monoxide (CO) and water vapour (H_2O). 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 (SN001) was installed on the Lufthansa A330 aircraft (tail sign D-AIKO) on October 17, 2017. A full functional test of P2d was successfully performed on the ground.

Due to a damaged ventilation duct required for cooling P2d and for smoke detection however, P2d had to be deactivated and removed from the aircraft. The system is now at Lufthansa Technik, ready for re-installation as soon as the replacement part for the ventilation duct is available (expected early February 2018).

In preparation of the first deployment period of P2d, the software for communication between P1 and P2d required for regular automated data transmission was adapted and tested. Furthermore, data transfer via USB storage medium was implemented and tested as fall-back option.

A complete maintenance and calibration cycle was performed with P2d SN001 also in preparation of the first deployment. This, in combination with the post-deployment calibration, will ensure the traceability of the GHG observations to WMO global standards.

In parallel, assembly of three further P2d SN002 – SN004 was started, with the aim to have the next systems ready for exchange with SN001 and for integration onboard CAL and HAL aircraft.

The contribution of **MF** focuses on the RTTU project, 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. During the year 2017, the first RTTU has been installed on the Lufthansa D-AIGT aircraft, and data were transmitted to the Eumetnet E-ADAS center.

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 and to improve and extend the operational characteristics and lifetime of the BCP. Some of these improvements are now included in the most recently procured instruments for which certification has been completed.

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 have been fostered and joint laboratory experiments were carried out in mid-2017. Further upgrades to the system have been made since and the system is provided for student training (MSc and PhD projects). A further significant upgrade is underway to improve ice particle calibration response data to investigate provision of improved higher level ice-cloud data products.

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).

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 iBCP 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 sut

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 will start continuous operation in Jan 2018 as part of the UK PICASSO and MOCCA projects. This agreement with FAAM will provide routine data as part of on-going strategic projects with FAAM and the UK Met Office. 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.

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, including the organisation of meetings.

Table 1: *Shipments of instruments and auxiliary parts for IAGOS-CORE operation in 2017*

Item	Member					Airline				
	FZJ	CNRS	UMAN	MPG	other	DLH	CAL	CPA	AFR	HAL
Package 1		4					1	4	1	2
Package 2ab	3					2				
O_2 Cylinders	22					10				
Pump Box		5					1	4	1	
BCP		2	13		1	2	1	3		
ICH	47	2				11	5	5	2	1
Package 2d				10		5				
Auxiliary parts	4	11		1	2	8	3	4		

Financial Information

Balance 2017

Income	
Membership Fees	130,000 €
Total Income	**130,000 €**
Expenditure	
Personnel incl. overheads	€55,210
Services and other expenses	€92,230
Total Expenditure	**€147,440**
Amount carried forward from 2016	**€ 94,211**
Total Balance 31.12. 2017	**€76,771**

Resources dedicated to IAGOS by the Members

In 2017, the Members contributed in total approximately 5.7 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 funding[1]

Member	*Operation and Hardware (k€)*	*Personnel (k€)*	*Total (k€)*
FZJ	828	973	1801
CNRS	521	924	1444
MPG	267	627	895
MF	38	74	112
UMAN	27	105	131
DLR	41	87	128
TROPOS	90	113	203
KIT	238	843	1081
Total	**2049**	**3745**	**5794**

[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 2017 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

1. Berkes, F; Neis, P; Schultz, MG; Bundke; Rohs, S; Smit, HGJ; Wahner, A; Konopka, P; Boulanger, D; Nedelec, P; In situ temperature measurements in the upper troposphere and lowermost stratosphere from 2 decades of IAGOS long-term routine observation, Atmospheric Chemistry and Physics, 17 (20) pp. 12495-12508, 2017.
2. Bieser, J.; Slemr, F.; Ambrose, J.; Brenninkmeijer, C.; Brooks, S.; Dastoor, A.; DeSimone, F.; Ebinghaus, R.; Gencarelli, C. N.; Geyer, B.; Gratz, L. E.; Hedgecock, I. M.; Jaffe, D.; Kelley, P.; Lin, C.-J.; Jaegle, L.; Matthias, V.; Ryjkov, A.; Selin, N. E.; Song, S.; Travnikov, O.; Weigelt, A.; Luke, W.; Ren, X.; Zahn, A.; Yang, X.; Zhu, Y.; Pirrone, N.: Multi-model study of mercury dispersion in the atmosphere: vertical and interhemispheric distribution of mercury species. Atmospheric Chemistry and Physics, 17 (11), pp. 6925-6955, 2017.
3. Borsdorff, T.; aan de Brugh, J.; Hu, H.; Nedelec, P.; Aben, I.; Landgraf, J.: Carbon monoxide column retrieval for clear-sky and cloudy atmospheres: a full-mission data set from SCIAMACHY 2.3,unitmum reflectance measurements. Atmospheric Measurement Techniques, 10 (5), pp. 1769-1782, 2017.
4. Eckstein, J.; Ruhnke, R.; Zahn, A.; Neumaier, M.; Kirner, O.; Braesicke, P.: An assessment of the climatological representativeness of IAGOS-CARIBIC trace gas measurements using EMAC model simulations. Atmospheric Chemistry and Physics, 17 , pp. 2775-2794, 2017.
5. Feng, L.; Palmer, P. I.; Bösch, H.; Parker, R. J.; Webb, A. J.; Correia, C. S. C.; Deutscher, N. M.; Domingues, L. G.; Feist, D. G.; Gatti, L. V.; Gloor, E.; Hase, F.; Kivi, R.; Liu, Y.; Miller, J. B.; Morino, I.; Sussmann, R.; Strong, K.; Uchino, O.; Wang, J.; Zahn, A.: Consistent regional fluxes of CH4 and CO2 inferred from GOSAT proxy XCH4: XCO2 retrievals, 2010-2014. Atmospheric Chemistry and Physics, 17 (7), pp. 4781-4797, 2017.
6. Fischbeck, G.; Bönisch, H.; Neumaier, M.; Brenninkmeijer, C. A. M.; Orphal, J.; Brito, J.; Becker, J.; Sprung, D.; van Velthoven, P. F. J.; Zahn, A.: Acetone CO enhancement ratios in the upper troposphere based on 7 years of CARIBIC data: new insights and estimates of regional acetone fluxes. Atmospheric Chemistry and Physics, 17 (3), pp. 1985-2008, 2017.
7. Ganesan, A. L.; Rigby, M.; Lunt, M. F.; Parker, R. J.; Boesch, H.; Goulding, N.; Umezawa, T.; Zahn, A.; Chatterjee, A.; Prinn, R. G.; Tiwari, Y. K.; van der Schoot, M.; Krummel, P. B.: Atmospheric observations show accurate reporting and little growth in India's methane emissions. Nature Communications, 8 (1), pp. 836, 2017.
8. Martinsson, B. G.; Friberg, J.; Sandvik, O. S.; Hermann, M.; van Velthoven, P. F. J.; Zahn, A.: Particulate sulfur in the upper troposphere and lowermost stratosphere - sources and climate forcing. Atmospheric Chemistry and Physics, 17 (18), pp. 10937-10953, 2017.
9. Perim de Faria, J.; Bundke. U.; Berg, M.; Freedman. A.; Onasch, T. B.; Petzold, A.: Airborne and laboratory studies of an IAGOS instrumentation package containing a modified CAPS particle extinction monitor. Aerosol Science and Technology, 51, pp. 1240-1253, 2017.
10. Petzold, A.; Kramer, M.; Neis, P.; Rolf, C.; Rohs, S.; Berkes, F.; Smit, H. G. J.; Gallagher, M.; Beswick, K.; Lloyd, G.; Baumgardner, D.; Spichtinger, P.; Nedelec, P.; Ebert, V.; Buchholz, B.; Riese, M.; Wahner, A.: Upper tropospheric water vapour and its interaction with cirrus clouds as seen from IAGOS long-term routine in-situ observations. Faraday Discussions, 200, pp. 229-249, 2017.
11. Sahu, L. K.; Sheel, V.; Kajino, M.; Deushi, M.; Gunthe, S. S.; Sinha, P. R.; Yadav, R.; Pal, D.; Nedelec, P.; Thouret, V.; Smit, H. G.: Impact of tropical convection and ENSO variability in vertical distributions of CO and O3 over an urban site of India. Climate Dynamics, 49 (1-2), pp. 449-469, 2017.
12. Sauvage, B., Fontaine, A., Eckhardt, S., Auby, A., Boulanger, D., Petetin, H., Paugam, R., Athier, G., Cousin, J.-M., Darras, S., Nédélec, P., Stohl, A., Turquety, S., Cammas, J.-P., and Thouret, V.: Source attribution using FLEXPART and carbon monoxide emission inventories: SOFT-IO version 1.0, Atmos. Chem. Phys., 17, 15271-15292, 2017.

13. Thorenz, U. R.; Baker, A. K.; Leedham Elvidge, E. C.; Sauvage, C.; Riede, H.; van Velthoven, P. F. J.; Hermann, M.; Weigelt, A.; Oram, D. E.; Brenninkmeijer, C. A. M.; Zahn, A.; Williams, J.: Investigating African trace gas sources, vertical transport, and oxidation using IAGOS-CARIBIC measurements between Germany and South Africa between 2009 and 2011. Atmospheric Environment, 158, pp. 11-26, 2017.
14. Verma, S.; Marshall, J.; Gerbig, C.; Rödenbeck, C.; Totsche, K. U.: The constraint of CO2 measurements made onboard passenger aircraft on surface-atmosphere fluxes: the impact of transport model errors in vertical mixing. Atmospheric Chemistry and Physics, 17 (9), pp. 5665-5675, 2017.
15. Verma, S.; Marshall, J.; Parrington, M.; Agusti-Panareda, A.; Massart, S.; Chipperfield, M. P.; Wilson, C.; Gerbig, C.: Extending methane profiles from aircraft into the stratosphere for satellite total column validation using the ECMWF C-IFS and TOMCAT/SLIMCAT 3-D model. Atmospheric Chemistry and Physics, 17 (11), pp. 6663-6678, 2017.
16. Weimer, M., Schröter, J., Eckstein, J., Deetz, K., Neumaier, M., Fischbeck G., Hu, L., Millet, D.B. Rieger, D., Vogel, H., Vogel, B., Reddmann, T., Kirner, O., Ruhnke R., and Braesicke, P., An emission module for ICON-ART 2.0: implementation and simulations of acetone, Geoscientific Model Development, 10, 2471–2494, 2017.

Presentations at International Conferences

1. Berkes, F. In-situ NO and NO_2 profiles measured onboard passenger aircraft over Frankfurt airport in Germany, EGU General Assembly, Vienna, Austria, 23. - 28. April, 2017.
2. Blot, R., et al., The Use of In-service Passenger Aircraft for Measuring Atmospheric Composition on a Global Scale: the European Research Infrastructure IAGOS, AGU Fall AGU Fall Meeting, New Orleans, USA, 11. - 15. December, 2017.
3. Boenisch, H., et al, Revisiting the IAGOS-CARIBIC CO and O3 observations and their correlation in the UT/LS, EGU2017-7363, EGU General Assembly, Vienna, Austria, 23. - 28. April, 2017.
4. Bundke, U. Setup of an interface for operation of IAGOS (In-service Aircraft Global Observing System) CORE instruments onboard the IAGOS CARIBIC platform, EGU General Assembly, Vienna, Austria, 23. - 28. April, 2017.
5. Bundke, U., et al: Setup of an Interface for operation of IAGOS (In-service Aircraft Global Observing System) CORE Instruments onboard the IAGOS CARIBIC platform, EAC, Zürich, 2017.
6. Bundke, U., et al., Common methodologies for inter-comparisons and joint field tests: IAGOS – ACTRIS sensors, ENVRI^{PLUS} Midterm Review Meeting, Grenoble, 17 May 2017.
7. Clark, H., et al., Evaluation of regional and global CAMS products with IAGOS aircraft observations of ozone and CO, CAMS 2nd General Assembly, Warsaw, 16-18 May 2017.
8. Cohen, Y., et al., Climatologies and long-term evolution of O3 and CO over northern midlatitudes in the UTLS as seen by IAGOS, SPARC OCTAV-UTLS, Boulder, 18-20 July, 2017.
9. Denise, A., et al., Spatio-temporal aerosol particle distributions in the UT/LMS measured by the IAGOS-CARIBIC Observatory, EGU2017-2727, EGU General Assembly, Vienna, Austria, 23. - 28. April, 2017.
10. Ditas, J., et al., Biomass burning events insert impact on the aging of black carbon in the tropopause region and lowermost stratosphere, AGU Fall AGU Fall Meeting, New Orleans, USA, 11. - 15. December, 2017.
11. Forster, C., et al., Validation of a satellite-based thunderstorm detection and nowcasting system with IAGOS data, ENVRI^{PLUS} Industry Forum, Grenoble, 18 May 2017.
12. Friberg, J., et al., Climate impact of volcanic aerosol in the stratosphere and upper troposphere – CALIPSO observations from 2006-2015, EGU2017-10217, EGU General Assembly, Vienna, Austria, 23. - 28. April, 2017.
13. Ganesan, A., et al., Quantifying India's methane emissions using satellite, aircraft and surface data, EGU2017-15494, EGU General Assembly, Vienna, Austria, 23. - 28. April, 2017.
14. Holla, R., et al.: European NOx-intercomparison at the observatory Hohenpeißenberg 10.-20. October 2016, 3rd ACTRIS-2 General and MTR Meeting, Granada, 2017.

15. Marais, E.A., et al., Nitrogen oxides in the global upper troposphere interpreted with cloud-sliced NO_2 from the Ozone Monitoring Instrument, EGU General Assembly, Vienna, Austria, 23. - 28. April, 2017.
16. Neumaier, M., et al., Biomass Burning observed during IAGOS – CARIBIC, EGU2017-15013, EGU General Assembly, Vienna, Austria, 23. - 28. April, 2017.
17. Penth, L., et al., A new DOAS instrument on long-distance IAGOS-CARIBIC flights and airborne DOAS applications, EGU2017-7603, EGU General Assembly, Vienna, Austria, 23. - 28. April, 2017.
18. Petetin, H., et al., A climatological view of the PBL heights and the vertical distribution of O_3, CO and RH within the PBL and at the interface with free troposphere as seen by MOZAIC-IAGOS aircraft and ozonesondes, AGU Fall AGU Fall Meeting, New Orleans, USA, 11. - 15. December, 2017.
19. Petzold, A., Upper tropospheric water vapour and its interaction with cirrus clouds as seen from IAGOS long-term routine in-situ observations, EGU General Assembly, Vienna, Austria, 23. - 28. April, 2017.
20. Petzold, A., et al., Upper tropospheric water vapour and its interaction with cirrus clouds as seen from IAGOS long-term routine in situ observations, Faraday Discussion: Atmospheric chemistry in the Anthropocene 22 – 24 May 2017, York, UK.
21. Petzold, A., et al., IAGOS Team, Water and Clouds Team at FZJ, IAGOS UTLS Water Vapour at SPARC OCTAV, SPARC OCTAV-UTLS, Boulder, 18-20 July, 2017. Ganesan, A., et al., Quantifying India's methane emissions using satellite, aircraft and surface data, EGU2017-15494, EGU General Assembly, Vienna, Austria, 23. - 28. April, 2017.
22. Sandvik, O.S., et al., Intercomparison of in situ and remote sensing aerosol measurements in the lowermost stratosphere during varying volcanic influence, EGU2017-8007, EGU General Assembly, Vienna, Austria, 23. - 28. April, 2017.
23. Smit, H.G.J., et al., Update of the IAGOS-H2O On-Going Aircraft Measurements and its QA-Efforts, GRUAN ICM-9 Annual Meeting ,12-16 June 2017, Helsinki, Finland.
24. Thouret, V., IAGOS: 20 years of in situ observations in the UTLS, CCMI Workshop, Toulouse, 13-15 June, 2017
25. Zahn, A., et al., Research Infrastructure IAGOS-CARIBIC: laboratory on board passenger aircraft, SPARC OCTAV-UTLS, Boulder, 18-20 July, 2017.
26. Zahn, A., et al., The European research infrastructure IAGOS-CARIBIC: a chemical laboratory on board passenger aircraft and what we have learned since 2005, NOAA seminar, 17 July 2017.

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