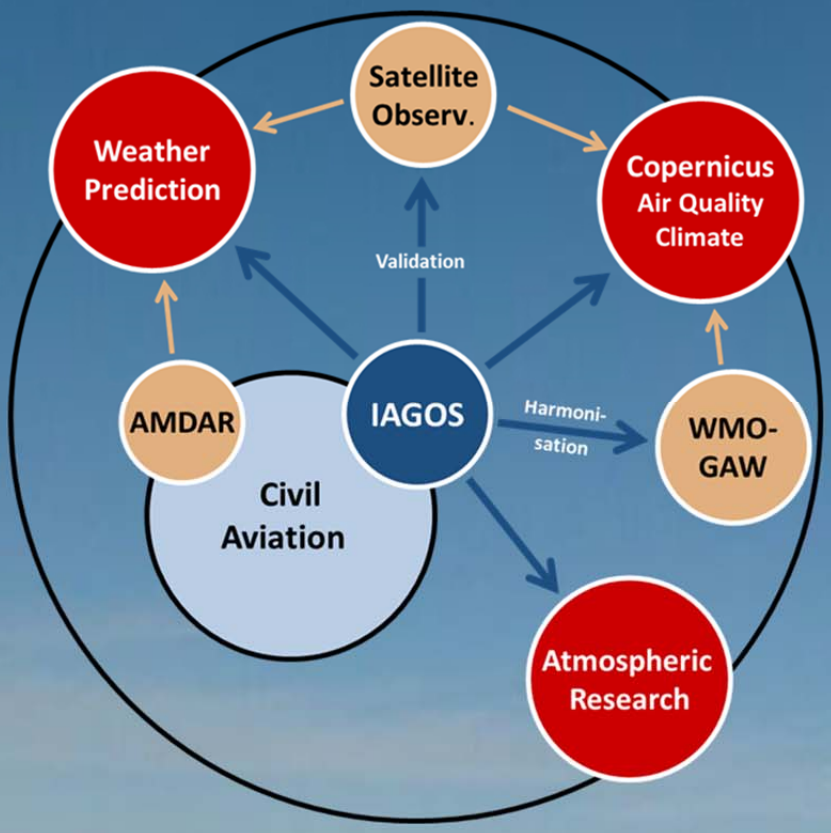
In-Service Aircraft for a Global Observing System
— Association Internationale Sans But Lucratif
IAGOS-AISBL



Annual Report 2016

IAGOS
www.iagos.org

Content

Highlights

IAGOS as a Landmark on the ESFRI Roadmap 2016

In 2016 IAGOS was selected for the ESFRI Roadmap 2016 as one of the landmarks in the Environment domain. For more information see: http://www.esfri.eu/roadmap-2016

Expanding the IAGOS-CORE Fleet

In July 2016, the IAGOS-CORE rack was installed for continuous operation on an AIRBUS A330-300 operated by China Airlines. The modification was made by China Airlines with support of the National Central University of Taiwan, Sabena Technics and the IAGOS team during a scheduled layover of the aircraft. B-18317 is the second aircraft of China Airlines which carries IAGOS-CORE equipment for making atmospheric measurements.

Group photo from PGGM event celebrating the 2nd IAGOS aircraft of China Airlines (from left: A. Petzold (treasurer of IAGOS); C. Gerbig (Max-Planck-Society); J.-M. Flaud (President of IAGOS), P. Nedelec (Chair of IAGOS-TPG); Y.-Z. Hsieh (Chief Secretary of EPA, Taiwan); Pontus von Schoenberg (FOI, Sweden); J.-Y. Jou (President of National Central University); A. Wahner (Vice-President of IAGOS); Kuoying Wang (Director of PGGM), H.-C. Jien (Executive Secretary of Taiwan EPA), Marcel Vanderschoot (CSIRO, Australia), Hiroshi Tanimoto (NIES, Japan), H.-H. Kao (Senior Vice President of China Airlines).

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

Negotiations have been completed with Air France, China Airlines and Hawaiian Airlines for installation of IAGOS equipment on their aircraft in the first half of 2017.

IAGOS-CORE Instrument for Greenhouse Gases Certified

On December 16th, IAGOS reached an important Milestone when the European Aviation Safety Agency (EASA) issued the Supplemental Type Certificate (STC) for IAGOS Package 2d, which is designed for measurements of greenhouse gases, i.e., CO_2 and CH_4. The Package has been developed by the Max-Planck-Institute for Biogeochemistry, Jena, together with enviscope GmbH. The instrument is based on cavity ring-down spectroscopy (CRDS) and will also measure H2O and carbon monoxide. The Design Organisation in charge of the STC application is Gomolzig Flugzeug- und Maschinenbau GmbH. It is planned to install and operate the instrument on IAGOS-CORE aircraft in 2017.

IAGOS-CARIBIC Flying Laboratory Received Major Upgrade

A major effort in 2016 was the complete renovation of the IAGOS-CARIBIC laboratory. During this process, 5 new instruments and 3 newly built-up instruments were integrated:

1. **WIBS**: An instrument for biological aerosol particles such as bacteria, pollen and fungi, developed by MPI-C
2. **AMS**: A mass spectrometer for the chemical composition of aerosol particles, jointly developed by MPI-C and TROPOS
3. **CARDINO**: A 4-channel cavity-ring-down spectrometer for reactive gases, i.e., NO_2, NO_3, N_2O_5 and O_3, jointly developed by University of Cork, NOAA and KIT
4. **Picarro**: A cavity ring down spectrometer for CO_2 and CH_4, developed by MPI-BGC
5. **Core-Slot:** A provision for the flexible deployment of IAGOS-CORE Package-2 instruments, prepared by FZJ
6. **PTRMS-2**: A strongly improved chemical mass spectrometer for diverse organic compounds, developed by KIT
7. **ISOWAT-2**: An improved laser spectrometer for the H2O isotope composition, developed by KIT
8. **DOAS-2**: An improved optical absorption spectrometer for CH2O, NO2, and O3, developed by University Heidelberg

EASA certification of the container is foreseen to be obtained in July 2017 with the re-start of measurements directly thereafter.

Nature Geoscience Publication on Tropospheric Ozone Change

The authors use a global chemical transport model to simulate the changes in tropospheric ozone observed between 1980 and 2010 from MOZAIC/IAGOS and other platforms and to separate the influences of changes in the spatial distribution of anthropogenic emissions of short-lived pollutants. They conclude that, since 1980, anthropogenic emissions of ozone precursors have shifted from developed to developing regions. Emissions have thereby been redistributed equatorwards, where they are expected to have a stronger effect on the tropospheric ozone burden due to greater convection, reaction rates and NO*x* sensitivity.

The analysis reveals that emission increases in Southeast, East and South Asia may be most important for the observed changes in tropospheric ozone concentrations, suggesting that the future ozone burden will be determined mainly by emissions from low latitudes.

(Zhang et al., Nature Geoscience, 2016, DOI: 10.1038/NGEO2827)

Nature Scientific Report on Atmospheric Chlorine Chemistry

The chlorine radical is a potent atmospheric oxidant. Significantly faster reaction rates allow chlorine radicals to expedite oxidation of hydrocarbons, including methane, and in polluted environments, to enhance ozone production. Using the IAGOS-CARIBIC airborne dataset, the authors provide new evidence of the important role of chlorine chemistry associated with Asian pollution outflow. Oxidant ratios inferred from hydrocarbon relationships show that chlorine radicals were regionally more important than hydroxyl radicals for alkane oxidation and were also important for methane and alkene oxidation (>10%). These observations reveal pollution-related chlorine chemistry that is both widespread and recurrent, and has implications for tropospheric oxidizing capacity, stratospheric composition and ozone chemistry.

(Baker, A. K. et al. Evidence for strong, widespread chlorine radical chemistry associated with pollution outflow from continental Asia. Sci. Rep. 6, 36821; doi: 10.1038/srep36821 (2016))

Special Issue "MOZAIC-IAGOS 20th Anniversary Symposium"

The Special Issue highlighting the scientific achievements using commercial aircraft as measurement platforms was published in *Tellus B*, Vol. 68B, June 2016. Paper copies are available from the IAGOS secretariat. The publications can also be accessed online at http://www.tellusb.net/index.php/tellusb/pages/view/thematic

IAGOS Scientific Symposium

Participants of the IAGOS Scientific Symposium on Atmospheric Composition, Manchester

The IAGOS Scientific Symposium on Atmospheric Composition was held in Manchester University from 17-19 October 2016 with support from NCAS. The goal of the meeting was to discuss new scientific research on atmospheric composition, new insights arising from key chemical and microphysical processes, and analyses of trends using the more than 20 years of IAGOS-CARIBIC and IAGOS-CORE data. Research areas included, aerosol climate interactions, UTLS dynamics, chemical composition and trends in the UTLS; new observations

of reactive trace gases, water vapour and cloud climatology and radiative impacts; new evaluation and validation approaches for satellite and remote sensing; validation of models for long range pollutant transport using IAGOS databases; new technical developments for routine airborne monitoring the atmosphere for climate and pollution including impacts of volcanic eruptions on aviation.

The focus of the meeting was to highlight IAGOS activities and to engage with and expand data users via Copernicus within these specific areas. To enhance IAGOS visibility and promote new end users in the modeling community, a number of key speakers from the global modeling community were invited. The latest technical advances in instrumentation were also highlighted to maintain and encourage feedback on future data product needs that IAGOS can provide for modelling applications across the scientific community.

The breakdown of participants was: Germany 29; UK 13; France 10; USA 2; other 6. Feedback from the meeting participants was very good, with the format lending itself well to off-line discussions and group meetings. Suggestions included increasing the size of the meeting to enhance participation of the modelling community particularly.

IGAS Completed

IGAS (IAGOS for the GMES Atmospheric Service), a project funded under FP7-SPACE (Grant agreement No. 312311) with 2 M€ and coordinated by the Max Planck Institute for Biogeochemistry (MPI-BGC), has been successfully completed after a duration of 42 months (including a 6 month extension). IGAS aimed at enhancing the IAGOS contributions to the European Copernicus programme (previously known as Global Monitoring for Environment and Security (GMES)). To enhance links between data streams of atmospheric measurements from IAGOS and Copernicus, IGAS helped implementing near-real-time data transfer of IAGOS data. Furthermore, the database was enriched with search and retrieval capabilities, making in situ data collected by commercial aircraft easily available to the scientific community. To ensure the high quality of the data, IGAS developed procedures for continuous evaluation and harmonisation of the data. Furthermore, IGAS enhanced IAGOS capabilities through targeted instrument improvements related to the miniature backscatter cloud spectrometer BCPOL (to discriminate between water, ice and dust particles), the proton transfer reaction mass spectrometer (for trace-level detection of volatile organic compounds) and the aerosol extinction monitor PMex.

New IAGOS Website and Data Portal

The IAGOS website has received major improvements, both regarding format and content. Major improvements have also been accomplished for the IAGOS database and its access for users. With support by AERIS (a French data center, funded by CNRS and CNES), a new portal for data access and related information was developed. The IAGOS Data Portal is accessible from the IAGOS web site http://www.iagos.org.

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**

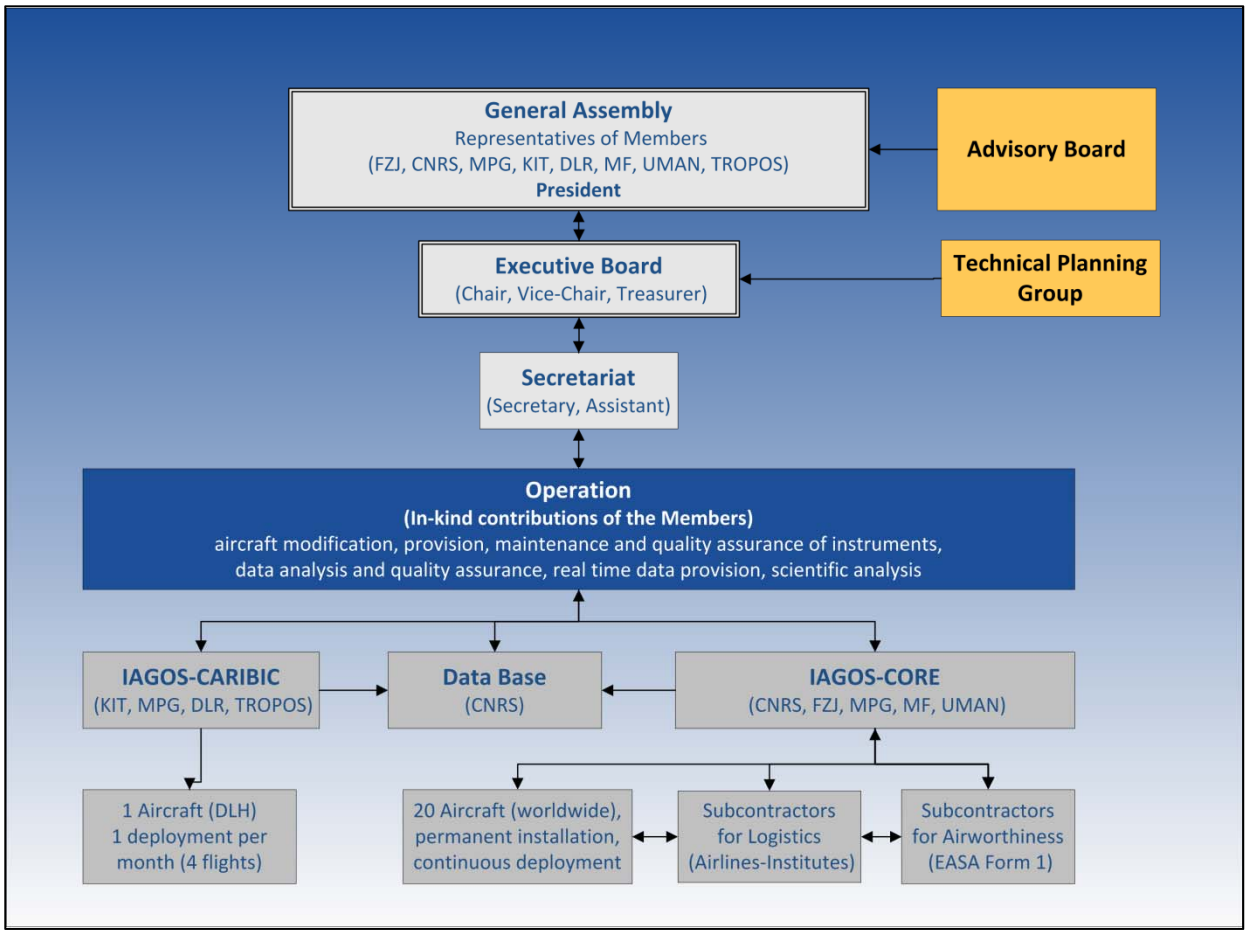
The activities of IAGOS-AISBL are twofold (Statutes are available for download at http://www.iagos.org):

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 is assisted by Andreas Volz-Thomas 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. Members of the AB are J.H. Butler, NOAA, USA (Chair); J. Haywood, UKMO, U.K.; G. Pappalardo, CNR, Italy; V.-H. Peuch, ECMWF.

A Technical Planning Group has been established for the technical planning in relation to construction and operation of IAGOS in cooperation with the associated airlines. In 2016, these were: Lufthansa, Air France, China Airlines, Cathay Pacific, and Iberia (see pictures below for details on aircraft involved).

For more information and Statutes see: http://www.iagos.org

Activities of the Association

Activities of the Association included six meetings of the Executive Board (3 by Teleconference), two meetings of the General Assembly, one meeting of the Advisory Board, and 3 Meetings of the Technical Planning Group.

Executive Board

Meetings

Brussels, 20 January 2016 (4 EB members, ES, P, VP)

- Annual Report 2015
- Budget 2016
- Activity plan 2016
- ES Mandate
- IAGOS proposal for data provision to CAMS
- IAGOS Symposium 2016

Teleconference, 23 February 2016 (3 EB members, ES)

- Preparation of GA on 2nd March 2016
    - Activity Plan for 2016 and long-term implementation plan
    - Annual Report 2015 (activity report and financial report)
    - Updated Budget 2016
- Outreach and Communication (Flyer, website)
- IAGOS Symposium 2016
- ES Mandate

Brussels, 31 May 2016 (4 EB Members, ES, P, VP)

- Discussion on the IAGOS proposal for data provision to CAMS
- MoU with WMO/GAW
- Preparation of IAGOS Symposium 2016
- Review of TPG report and of Activity Plan 2016
- Review of Budget 2016
- Communication strategy

Teleconference, 24 June 2016 (4 EB members, ES)

- Preparation of the IAGOS Symposium 2016
- Delegation to PGGM Workshop
- IAGOS website structure

Brussels, 15 September 2016 (4 EB members, ES, P)

- Preparation of GA on 02. Dec 2016 and AB on 01 Dec 2016
- Implementation Plan and Activities 2017, Annual Report
- Re-structuring of IAGOS Website
- IAGOS Symposium, Oct 2016
- Communication with Airlines

Teleconference, 03 Nov 2016 (3 EB members, ES)

- Final check and approval of preparatory material for GA and AB Meetings
- Approval of letter to ECMWF for CAMS-IAGOS

General Assembly

Brussels, 02.03.2016

- Approval of the Activity Plan for 2016, including confirmation of foreseen in-kind contributions of the Members
- Approval of the Budget for 2016
- Approval of the Annual Report for 2015

Brussels, 02.12.2016

- Approval of the Budget for 2017
- Approval of the Activity Plan for 2017, pending availability of Members' resources (to be confirmed in spring 2017)
- Approval of the long-term Implementation Plan
- Approval of a selection procedure for the Executive Secretary

Advisory Board

Brussels, 01.12.2016

- Review of actions in response to recommendations made at last meeting
- MoU with WMO/GAW
- Discussion of IAGOS approach to realtime data transmission
- Discussion of the role of IAGOS for CAMS
- Discussion on the expansion of IAGOS,
    - Involving a US airline, i.e., Hawaiian Airlines
    - Coordination with Mauna Loa Observatory
    - Communication strategy

Technical Planning Group

Teleconference, 19.02.2016

- Current IAGOS operations - Approval of new revised equipment (P1, Pump Box, BCP)
- Maintenance Center Operations
- Package2 STC status
- RS232 data transmission of ICH with Package 1
- Planning for new aircraft installations and new airlines - Contracts with airlines
- Status of CARIBIC
- Budget issues : BCP, installation kits
- RTTU

Frankfurt, 25.05.2016

- Welcome to new TPG members : U. Bundke and P. Dandin
- Current IAGOS operations
- Maintenance Center Operations - Website

- Package2 STC status
- RTTU
- Technical issues on ICH (bonding cable and Serial acquisition) and BCP (Hermetic)
- Planning for new aircraft installations and new airlines - Contracts with airlines
- Status of CARIBIC
- Budget issues

Frankfurt, 26.10.2016

- Proposal for new TPG members
- Preparation of Activity Plan 2017
- Planning of new installations (HAL, AFR, CAL)
- RTTU
- Technical issues on ICH (analogue and serial data acquisition) and BCP (evolution report on hermetic version)
- Status of STC for P2
- Planning for new airlines / Contracts with airlines
- Status of CARIBIC
- Budget issues
- Maintenance Centre

Communication and Outreach

- Distribution of an Information Package (Flyer, Annual Report, Tellus-B special issue) to stakeholders
- Exhibition at the ICCP and participation to ENVRIplus exhibition at EGU
- Presentations at International Conferences (*see Presentations*)
    - GRUAN ICM-8 Meeting (Boulder, April)
    - EGU General Assembly (Vienna, April)
    - SPARC SSiRC Workshop (Potsdam, April)
    - SPARC UTLS Workshop (Geneva, May)
    - Global Monitoring Conference (Boulder, May)
    - RMetS/NCAS Conference (Manchester, July)
    - International Conference on Clouds and Precipitation (Manchester, July)
    - PGGM Workshop (Taipei, Sept)
    - Quadrennial Ozone Symposium (Edinburgh, Sept)
    - IGAC Conference (Breckenridge, Sept)
    - ENVRI^{PLUS} Week (Prague, Nov)
    - AGU Fall Meeting (San Francisco, Dec)
- Preparation and organisation of the Scientific Symposium 2016 (*see Presentations*)
- Distribution of information material to colleagues (USA, Japan, Canada, Italy, UK, France) for reaching support from the G7+ Group of Senior Officials (GSO) for recognition as Global RI.
- Interviews on the project IAGOS-ERI for evaluation of the European FP7 programme

Activities of the Members under Coordination of IAGOS-AISBL

IAGOS-CARIBIC

One AIRBUS A340-600 operated by Lufthansa (shown below) carries provisions for operation of 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 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 container during preparation of the deployment. Operation of the CARIBIC container is discontinuous with 10 to 12 deployments per year, each for 4 consecutive flights.

Activities 2016

The Members involved in IAGOS-CARIBIC, Karlsruher Institut für Technologie (**KIT**), Max-Planck Gesellschaft zur Förderung der Wissenschaften (**MPG**), Deutsches Zentrum für Luft- und Raumfahrt (**DLR**), and Leibniz-Institut für Troposphärenforschung (**TROPOS**), concluded the following tasks:

In 2016, the CARIBIC observatory was deployed on only 2 flight sequences for a total of 8 flights. In March 2016 the container was damaged during installation at the airport Munich. The instruments survived without failure. It was decided to build-up a new laboratory, also to catch up with the actual technical demands of the flight authorities. A new container was built-up by Gomolzig Flugzeug- und Maschinenbau GmbH and delivered to the KIT in October 2016 for re-integration of the container infrastructure and of the old/new instruments.

KIT coordinates IAGOS-CARIBIC and operates the CARIBIC laboratory since April 2015. KIT is also responsible for the operation of five in-situ instruments for the analysis of H_2O, cloud water/ice, H_2O isotopic composition, CH_4, and selected volatile organic compounds (VOCs) such as acetone, acetonitrile, and methanol. Work in 2016 included maintenance of the instruments, data quality assurance and transfer of the data to the database, as well as improvement of the software for instrument data analysis in order to speed up data availability. Major work was the finalization of the new instruments for the container upgrade (see above) and re-integration of the infrastructure and the instruments in the new CARIBIC container.

MPI-C maintained the operation of the whole air sampling systems and a single particle soot photometer. A new detector for the GHG analysis system has been ordered and will be installed in early 2017. This will restore the GHG analysis to again include CO_2, CH_4, N_2O and SF_6. Analysis of flask samples for organic compounds was continued routinely, including analyses for halocarbons made at the University of East Anglia, Norwich. The SP2 soot particle

data analyses are ongoing and were supported by additional laboratory studies to improve the calibration of the SP2 instrument.

All MPI-C instruments survived the container accident without damage. They were thoroughly checked and then sent to KIT for integration into the new container. In the meantime, efforts were made to work up all data for inclusion into the IAGOS-CARIBIC database.

MPI-C has completed the development and implementation of an innovative bio-aerosol analyser (Wideband Integrated Bioaerosol Sensor, WIBS-NEO) in cooperation with Droplet Measurement Technologies (DMT, Boulder, USA). The instrument is ready for integration into the new CARIBIC container. The need for further instrument characterization and adaption for the high-altitude application is envisaged after the first long-distance flights.

In collaboration with TROPOS, MPI-C developed the CARIBIC-AMS up to point where it is ready for installation. This development included a rearrangement of the instruments components, the automation of the instrument, and the development of instrument control software for communication with the master computer in the container.

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. In 2016 a major modification of the NO/NO_y-instrument was performed. First, the instrument was rebuilt to reduce size and weight in order to allow integration of the new aerosol mass-spectrometer of MPG/TROPOS in the same rack. In a second step, the detector of the NO/NOy-instrument was modified. The so far used photomultiplier are not produced anymore, so that the detector system including electronics had to be adapted and exchanged. This modification has been completed and is awaiting a final test of the new detector system.

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). Work in 2016 was dominated by the container accident. The TROPOS instruments were checked thoroughly. No physical damage was found and all internal checks were successful. 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 seven 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.

IAGOS-CORE fleet 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 2017.

Real-time data transmission of the IAGOS-CORE data via SATCOM to the WMO Information System (WIS) has been developed for operational users such as the Copernicus Atmospheric Monitoring Service. Planning for Installation of the first unit on Lufthansa D-AIGT has been completed and will be achieved as soon as a suitable layover of the aircraft becomes available.

Activities 2016

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

FZJ coordinates the technical and legal work in Germany and with the main partners from other countries, particularly CNRS in France, assumes responsibility for establishing contracts with airlines and maintenance organisations in order to ensure the timely progression of the work.

FZJ acts as the leading German partner in the cooperation with partners in France and U.K. on aircraft modification, including the acquisition of the IAGOS modification kits. FZJ ensures the performance, sustainable operation and data quality of the H_2O, NO_x, NO_y and aerosol instruments by pre- and post-operational tests in its laboratory.

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 2016, from German resources, FZJ financed the installation of the IAGOS kit on board of the China Airlines A330-300 MSN 0861 with the call sign B-18317. Operation started in June 2016. The technical part of the installation was conducted in close collaboration with the Taiwanese PGGM project, China Airlines, CNRS and Sabena Technics. FZJ further prepared the installation of new aircraft in 2017 by ordering the required installation

kit and services. Hardware acquisition concerned mainly 10 water vapour sensor systems (part of P1) for equipping the growing fleet and for continuous sensor exchange and maintenance in order to ensure data quality. Further hardware was not ordered in 2016 since FZJ decided to wait for the EASA STC for the IAGOS instruments P2a, P2b, and P2c.

Major progress was achieved in the field of instrument testing, data quality and data analysis:

- The automated data inversion algorithm for water vapour was successfully implemented. Data are provided in NRT mode to the IAGOS data base.
- The data inversion algorithm for IAGOS package P2b (nitrogen oxides NO_x) was successfully developed and tested for deployment periods aboard Deutsche Lufthansa D-AIGT. The implementation started in 2016. NO_x are available on the data base since mid-2015.
- The IAGOS package P2b participated successfully in an instrument intercomparison campaign of ACTRIS in October 2016 at the observatory Hohenpeissenberg of German Weather Service.
- The analysis of combined water vapour cloud data of IAGOS was initialized in September 2016. This activity will provide input for the first large-scale study of water vapour cirrus properties globally.

FZJ represents IAGOS in the European project ENVRI^{PLUS}, a cluster of European Research Infrastructures. 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 2016, from French resources, CNRS financed partially and provided engineering support for installation of the IAGOS kit aboard the B-18317 of China Airlines in

June-July 2016 in Taipei. Acquisition of hardware for development of the RI included 1 unit of Package 1 (O3, CO), 1 Pump box, and 1 installation kit for future aircraft modifications. Further work included technical improvements and associated modifications of the STC for Package 1. Negotiations with Hawaiian Airlines, who had been contacted in 2105, were continued in order to explore the possibilities for installation of IAGOS equipment on their A330 aircraft. Upon their agreement, the installation, which is scheduled for February 2017, was prepared including transfer of the STC to the US Federal Aviation Administration (FAA) together with the STC holder Sabena Technics. .

A major part of the activities concerned the operation of the equipment aboard the seven 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 development of a new web interface and a new data access form for users, the provision of added-value products, 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.

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.

Final modifications to the design of P2d were implemented in 2016 in conjunction with the certification procedure. The production of further packages has been prepared by stocking the associated components.

The software for processing and quality assurance of GHG data was tested using data collected during the deployment of P2d on board of the German research aircraft HALO during a test campaign for CHARM-F (an airborne CH4 and CO2 lidar developed at DLR). Results for traceability of CO2 and CH4 observations to WMO standards using the calibration approach developed for P2d were fully satisfactory.

Furthermore, MPI-BGC has successfully completed the coordination of the FP7 project IGAS.

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 2016, the main actions were:

- The final contribution to the FP7 project IGAS. The project was closed and validated by the EC after explanation (the final objective which was to install the RTTU could not be reached during the project's duration) and in depth evaluation.
- MF committed to finish the installation of the RTTU aboard the AIRBUS A340 D-AIGT on its own financial resources. With its subcontractors Sabena Technics and Atmosphere, and CNRS, MF prepared the necessary documentation and delivered it to Lufthansa Technik for preparation of the installation. A window for the installation was foreseen at the end of the year for the first trimester of 2017.
- MF proposed and initiated the preparation of a similar RTTU installation for an AIRBUS A330, but the project had to be postponed.
- MF participated in the TPG.

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 was 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 have been planned for mid-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 BCP-D for improved size resolution and particle phase discrimination have been investigated.

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 7 operational IAGOS-aircraft (see Table 1), and handling of instrument exchange intervals; (iii) instrument maintenance, repair and parts production; (iv) re-design 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 Planning Group, including the organisation of meetings.

Table 1: *Shipments of instruments and auxiliary parts for IAGOS-CORE operation in 2016*

Item	Member				Airline					
	FZJ	CNRS	UMAN	other	DLH	CAL	CPA	AFR	IBE	HAL
Package 1		9		2	4	4	1		2	1
Package 2ab	6				4					
O_2 Cylinders	33			1	18					
Pump Box		6		2	2	2	1		2	1
BCP	6	4	13	2	1	1		1	2	1
ICH	60	4		2	14	12	1	1	2	1
Regulators	4			4	4					
Other parts	1	6								

Financial Information

Balance 2016

Income	
Membership Fees	130,000 €
Total Income	**130,000 €**
Expenditure	
Personnel incl. overheads	54,966 €
Services and other expenses	70,831 €
Total Expenditure	**125,797 €**
Amount carried forward from 2015	**90,008 €**
Total Balance 31.12. 2016	**94,211 €**

Resources dedicated to IAGOS by the Members

In 2016, the Members contributed in total approximately 5.6 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	722	892	1614
CNRS	448	929	1377
MPG	246	816	1062
MF	1	72	73
UMAN	25	66	92
DLR	71	87	158
TROPOS	71	213	284
KIT	160	827	988
Total	**1744**	**3903**	**5647**

[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 MS fees, funding from European projects and work related to scientific activities.*

Additional resources of approximately 335 k€ were deployed in 2016 due to co-funding by the European Union for development of the RI (FP7 project IGAS), coordination with other European RIs (H2020 project ENVRI^{plus}), and contributions to the Copernicus Programme (FP7 project 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 data base 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 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. Baker, A.K., C. Sauvage, U.R. Thorenz, P. van Velthoven, D.E. Oram, A. Zahn, C.A.M. Brenninkmeijer, J. Williams, Evidence for strong, widespread chlorine radical chemistry associated with pollution outflow from continental Asia, Nature Scientific Reports, 6, 36821, 2016.
2. Barret B., B. Sauvage, Y. Bennouna, E. Le Flochmoen, Upper-tropospheric CO and O3 budget during the Asian summer monsoon, Atmos. Chem. Phys., 16, 9129-9147, doi:10.5194/acp-16-9129-2016, 2016
3. Hermann, M., A. Weigelt, D. Assmann, S. Pfeifer, T. Müller, T. Conrath, J. Voigtländer, J. Heintzenberg, A. Wiedensohler, B. G. Martinsson, T. Deshler, C. A. M. Brenninkmeijer, and A. Zahn, An optical particle size spectrometer for aircraft-borne measurements in IAGOS-CARIBIC, Atmos. Meas. Tech., 9, 2179-2194, 2016.
4. Jöckel, P., H. Tost, A. Pozzer, M. Kunze, O. Kirner, C.A.M. Brenninkmeijer, S. Brinkop, D.S. Cai, C. Dyroff, J. Eckstein, F. Frank, H. Garny, K.-D. Gottschaldt, P. Graf, V. Grewe, A. Kerkweg, B. Kern, S. Matthes, M. Mertens, S. Meul, M. Neumaier, M. Nützel, S. Oberländer-Hayn, R. Ruhnke, T. Runde, R. Sander, D. Scharffe, A. Zahn, Earth System Chemistry Integrated Modelling (ESCiMo) with the Modular Earth Submodel System (MESSy, version 2.51), Geosci. Model Dev., 9, 1153-1200, 2016.
5. Laube, J. C., N. Mohd Hanif, P. Martinerie, E. Gallacher, P.J. Fraser, R. Langenfelds, C.A.M. Brenninkmeijer, J. Schwander, E. Witrant, J.-L. Wang, C.-F. Ou-Yang, L.J. Gooch, C.E. Reeves, W.T. Sturges, D.E. Oram, Tropospheric observations of CFC-114 and CFC-114a with a focus on long-term trends and emissions, Atmos. Chem. Phys., 16, 15347-15358, doi:10.5194/acp-16-15347-2016, 2016.
6. Ojha, N., A. Pozzer, A. Rauthe-Schöch, A.K. Baker, J. Yoon, C.A.M. Brenninkmeijer, J. Lelieveld, Ozone and carbon monoxide over India during the summer monsoon: regional emissions and transport, Atmos. Chem. Phys., 16, 3013-3032, doi:10.5194/acp-16-3013-2016, 2016.
7. Osman, M., D.W. Tarasick, J. Liu, O. Moeini, V. Thouret, V.E. Fioletov, M. Parrington, P. Nédélec, Carbon monoxide climatology derived from the trajectory mapping of global MOZAIC-IAGOS data, Atmos. Chem. Phys., 16, 10263-10282, doi:10.5194/acp-16-10263-2016, 2016.
8. Petetin, H., V Thouret, G. Athier, R. Blot, D. Boulanger, J.M. Cousin, A. Gaudel, P. Nédélec, and O.R. Cooper, Diurnal cycle of ozone throughout the troposphere over Frankfurt as measured by MOZAIC-IAGOS commercial aircraft, Elementa: Science of the Anthropocene, 4:000129. doi:10.12952/journal.elementa.000129, 2016.
9. Petetin, H., V. Thouret, A. Fontaine, B. Sauvage, G. Athier, R. Blot, D. Boulanger, J.M. Cousin, P. Nédélec, Characterizing tropospheric O3 and CO around Frankfurt over the period 1994-2012 based on MOZAIC-IAGOS aircraft measurements, Atmos. Chem. Phys., 16, 15147-15163, doi:10.5194/acp-16-15147-2016, 2016.
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Presentations at International Conferences

1. Baumgardner, D. et al. Progress in Quantification of Mixed Phase Cloud Properties with Single Particle Light Scattering Polarimetry, 17th International Conference on Clouds and Precipitation, Manchester, U.K., 25-29 July, 2016.
2. Berkes, F. et al., Langzeit-Beobachtung der Atmosphäre mit MOZAIC und IAGOS, Berlin, DACH, Berlin, Germany, 14.-18. March 2016
3. Berkes, F. et al., Measurement of nitrogen oxides (NOx) measurements in the Upper Troposphere and Lowermost Stratosphere within IAGOS – Instrument Performance and First Results, EGU General Assembly, Vienna, Austria, 17. - 22. April, 2016.
4. Berkes, F. et al., Long-term Temperature Measurements of the Upper Troposphere and Lowermost Stratosphere with MOZAIC and IAGOS, EGU General Assembly, Vienna, Austria, 17. - 22. April, 2016.
5. Boschetti, F. et al., Multi-Species Inversion and IAGOS Airborne Data for a Better Constraint of Continental Scale Fluxes, AGU Fall Meeting, San Francisco, USA, 12. - 17. December, 2016.
6. Bundke, U. et al., Setup and first airborne application of an aerosol optical properties package for the In-service Aircraft Global Observing System IAGOS, EGU General Assembly, Vienna, Austria, 17. - 22. April, 2016.
7. Bundke, U. et al., Common methodologies for inter-comparisons and joint field tests – Use-case 2: Common sensors – case of aerosol lidar and in-situ light extinction measurements, 2nd ENVRIplus Week, Zandvoort, The Netherlands, 9. – 13. May, 2016.
8. Deshler, T. et al., The stratospheric sulfur burden: an assessment based on gas and particle phase measurements, SPARC SSiRC workshop, Potsdam, Germany, 25. - 28. April, 2016.
9. Ditas, J. et al, Different emission sources of black carbon in the UTLS (IAGOS-CARIBIC), EGU General Assembly, Vienna, Austria, 17. - 22. April, 2016.
10. Fischbeck, G. et al., A new approach to detect local correlations of tropospheric acetone and carbon monoxide sampled onboard the IAGOS-CARIBIC passenger aircraft, EGU General Assembly, Vienna, Austria, 17. - 22. April, 2016.
11. Fischbeck, G. et al., CARIBIC passenger aircraft measurements in the UT/LMS: Long-term analysis of the correlation between acetone and carbon monoxide, EGU General Assembly, Vienna, Austria, 17. - 22. April, 2016.
12. Flaud, J.-M., GHG monitoring in Europe: COPERNICUS and ICOS, PGGM Workshop, Taipeh, Taiwan, 6. - 7. September, 2016.
13. Gallagher, M. et al. Seasonal trends in cloud vertical properties in the SE Asia region from IAGOS in situ observation, 17th International Conference on Clouds and Precipitation, Manchester, U.K., 25-29 July, 2016.
14. Gallagher, M., et al. Measuring Cirrus, RMetS/NCAS Conference, Manchester, U.K., 6th July 2016.
15. Gerbig, C. et al., IAGOS-GHG Observations and their Potential, PGGM Workshop, Taipeh, Taiwan, 6. - 7. September, 2016.
16. Gerbig, C. et al., On the potential of GHG emissions estimation by multi-species inverse modeling, EGU General Assembly, Vienna, Austria, 17. - 22. April, 2016.
17. Glatt, I., et al., Three-dimensional structure of ice supersaturation and cirrus clouds, 17th International Conference on Clouds and Precipitation, Manchester, U.K., 25-29 July, 2016.
18. Hermann, M. et al., A., Long-term measurements of UT/LMS aerosol particles by the IAGOS-CARIBIC observatory: size distributions, elemental composition, and black carbon, Presentation at the SPARC SSiRC workshop, Potsdam, Germany, 25. - 28. April, 2016.
19. Lloyd, G. et al. In-Situ Ice Cloud Properties using the IAGOS Global Observing System, RMetS/NCAS Conference, Manchester, U.K., 6th July 2016.
20. Nedelec, P., IAGOS operations on the 2 China Airlines aircraft - First scientific results, with focus on strong biomass burning in south-East Asia in summer 2015, PGGM Workshop, Taipeh, Taiwan, 6. - 7. September, 2016.
21. Neis, P. et al., Climatology of 15 years of North Atlantic upper tropospheric relative humidity in-situ measurements by the MOZAIC programme, EGU General Assembly, Vienna, Austria, 17. - 22. April, 2016.
22. Neis, P. et al: Climatology of 15 years of North Atlantic upper tropospheric relative humidity in-situ measurements by the MOZAIC programme, SPARC-GAW-NDACC UTLS Workshop, Geneva, Switzerland, 24.-27. May, 2016.

23. Neis, P., et al., 15 years of in-situ measurements of upper tropospheric humidity and ice-supersaturated regions by the MOZAIC programme, 17th International Conference on Clouds and Precipitation, Manchester, U.K., 25-29 July, 2016.
24. Neumaier, M. et al., The impact of acetone photolysis to the production of HOx around the tropopause, EGU General Assembly, Vienna, Austria, 17. - 22. April, 2016.
25. Neumaier, M. et al., A. Biomass Burning observed during IAGOS – CARIBIC, EGU General Assembly, Vienna, Austria, 17. - 22. April, 2016.
26. Öström, E. et al. The use of IAGOS BCP observations to evaluate satellite products developed for detecting areas of high ice water content, 17th International Conference on Clouds and Precipitation, Manchester, U.K., 25-29 July, 2016.
27. Oram, D. E., et al., Have we underestimated the role of short-lived chlorine compounds in ozone depletion?, Quadrennial Ozone Symposium, Edinburgh, 4. – 9. September, 2016.
28. Petetin, H. et al., Characterizing tropospheric O3 and CO around Frankfurt over the period 1994-2012 based on MOZAIC-IAGOS aircraft measurements, Quadrennial Ozone Symposium, Edinburgh, 5.-9. September 2016.
29. Petzold, A. et al., Climatology of 15 years of North Atlantic upper tropospheric relative humidity in-situ measurements by the MOZAIC programme, 17th International Conference on Clouds and Precipitation, Manchester, U.K., 25-29 July, 2016.
30. Petzold, A., Global-Scale Atmosphere Monitoring by In-service Aircraft - Current Achievements and Future Prospects of the European Research Infrastructure IAGOS, PGGM Workshop, Taipeh, Taiwan, 6. - 7. September, 2016.
31. Petzold, A., Research Infrastructures – Europe's Way Towards an Integrated Observing System for the Atmosphere, PGGM Workshop, Taipeh, Taiwan, 6. - 7. September, 2016.
32. Raga, G. et al., High Ice Water Content in Cirrus Clouds Linked to Biomass Burning, 17th International Conference on Clouds and Precipitation, Manchester, U.K., 25-29 July, 2016.
33. Sauvage, B. et al., Identification of CO sources and transport processes driving O3 and CO distributions in the upper troposphere over Africa, Quadrennial Ozone Symposium, Edinburgh, 5.-9. September 2016.
34. Smit, H.G.J. et al., Long-term IAGOS/MOZAIC-H2O Measurements in the UTH at Cruise Altitude (10-12 km) : In-Service Aircraft For Global Observing Platform, GRUAN-ICM 8, Boulder, USA, 25.-29. April, 2016.
35. Smit, H.G.J., et al., Global-Scale Atmosphere Monitoring by In-Service Aircraft in the IAGOS-CORE (MOZAIC) Programme: Long Term Measurements of O3, H2O, CO, NO, NO2, NOY, CO2, CH4, Cloud Properties and Aerosols, SPARC-GAW-NDACC UTLS Workshop, Geneva, Switzerland, 24.-27. May, 2016.
36. Tatrai, D. et al., Development of photoacoustic water vapor and total water measuring instrument with a long term objective of becoming part of the IAGOS project, EGU General Assembly, Vienna, Austria, 17. - 22. April, 2016.
37. Thouret, V. et al., In-service Aircraft for Global Monitoring: 20 Years of MOZAIC-IAGOS measurements, IGAC Conference, Breckenridge, 26-30 September 2016.
38. Thouret, V. et al., In-service Aircraft for Global Monitoring: 20 Years of MOZAIC-IAGOS ozone measurements, Quadrennial Ozone Symposium, Edinburgh, 5.-9. September 2016
39. Volz-Thomas, A. et al., IAGOS - Status and Perspective, Global Monitoring Conference, Boulder, USA, 17.-18.05.2016
40. Wang, K.-Y., PGGM Results 2012-2015, PGGM Workshop, Taipeh, Taiwan, 6. - 7. September, 2016.
41. Ziereis, H. et al., Nitrogen oxides at the UTLS: Combining observations from research aircraft and in-service aircraft, EGU General Assembly, Vienna, Austria, 17. - 22. April, 2016.

Presentations at the IAGOS Symposium

1. Assmann, D. et al., Aerosol Particle Distributions in the UT/LMS measured by the IAGOS-CARIBIC Observatory.
2. Baker, A. et al., Evidence for strong, widespread chlorine radical chemistry associated with pollution outflow from continental Asia
3. Barret, B. et al., Origin of pollution in the Asian monsoon upper tropospheric anticyclone from MOZAIC/IAGOS
4. Berkes, F. et al., Two Decades of In-Situ Temperature Measurements within the UTLS by IAGOS
5. Berkes, F. et al., Nitrogen Oxides measurements in the UTLS by IAGOS – Instrument Performance and First Results.
6. Blot, R. et al., Comparing ozone and carbon monoxide measurements from commercial aircraft programs
7. Bönisch, H. et al., Revisiting the IAGOS-CARIBIC CO and O_3 observations and their correlation in the UT/LS
8. Boschetti, F. et al., Using a transport model as a transfer to compare in-situ and column airborne GHG observations
9. Boulanger, D. et al., The new IAGOS Data Portal
10. Brown, S. (invited), Aircraft measurements of nitrogen oxides and ozone by cavity ring-down spectroscopy
11. Bundke, U. et al., 15 years of Aerosol package for IAGOS-core: Setup and first airborne application.
12. Carslaw, K. (invited), Using in situ aerosol measurements to constrain global models
13. Clark, H. et al., The use of IAGOS in the Copernicus Atmosphere Service
14. Cohen Y. et al., Ozone and CO trends (1995-2014) in the UTLS by MOZAIC-IAGOS over northern mid-latitudes
15. Ditas, J. et al., Influence of biomass burning events on the amount and characteristics of black carbon in the atmosphere: in situ measurements by the IAGOS-CARIBIC observatory,
16. Eckstein, J. et al., An assessment of the climatological representativeness of IAGOS-CARIBIC trace gas measurements using EMAC model simulation
17. Fischbeck, G. et al., Estimating acetone emissions using regional correlations with CO observed within IAGOS-CARIBIC
18. Fontaine, A. et al., CO sources and transport processes driving African UT pollution using the SOFT-IO coupling model
19. Gallagher, M. et al., What can IAGOS cloud detectors tell us about the UTLS?
20. Gaudel, A. et al., Long-term trends of tropospheric ozone over North America and Southeast Asia
21. Gerbig, C. et al., On the potential of IAGOS-core GHG observations to constrain regional anthropogenic emissions
22. Gressent, A. et al., Estimation of sulfuryl fluoride emissions on regional and global scales using AGAGE measurements
23. Gromov, S. et al., Understanding CO_2 exchanges in the biosphere-boundary layer-free troposphere system during the South Asian Monsoon using CARIBIC ^{13}C and ^{18}O measurements
24. Haynes, P. (invited), Quantifying dynamics and transport in the extratropical UTLS
25. Haywood, J. (invited), Volcanic Eruptions indicate Aerosol–Cloud lifetime climate impacts are weak.
26. Hoor, P. (invited) Process observations versus global view: Do we understand the UTLS?
27. Karu, E. Fluxes of Airborne Sulphur Compounds IN Atmospheric Troposphere-stratosphere Exchange (FASCINATE)
28. Krämer, M. (invited), Cirrus Clouds & Water Vapour at 25°S to 75°N rom two decades of in-situ aircraft observations
29. Laube, J. et al., Observations of long-lived trace gases in the upper troposphere and stratosphere

30. Maycock, A. (invited), The importance of UTLS water vapour and ozone for climate.
31. Neis, P. et al: 15 years of North Atlantic upper tropospheric relative humidity measurements by MOZAIC.
32. Neumaier, M., et al., Impact of Biomass Burning onto the upper troposphere observed during IAGOS – CARIBIC
33. Oram, D. et al., Have we underestimated the role of short-lived chlorine compounds in ozone depletion?
34. Ostrom, E. et al., IAGOS BCP observations to evaluate satellite products for detecting areas of high ice water content
35. Perim de Faria, J. et al., Multi-instrument Optical Closure Study: laboratory and field approaches.
36. Penth, L. et a., A new DOAS instrument aboard the CARIBIC passenger aircraft
37. Petetin, H. et al., Overview of tropospheric CO distributions by MOZAIC-IAGOS and role of vegetation fires
38. Riede, H. et al., Lagrangian model analysis of CARIBIC observations – quantifying transport, chemistry, and mixing
39. Rohs, S. et al. First experiences from the testing phase of the processing and implementation of Near-Real Time data provision of IAGOS-Humidity data for Atmospheric Services
40. Rubach, F. et al., An Aerodyne mini-AMS for UT/LMS aerosol measurements within IAGOS-CARIBIC.
41. Ruth, A. et al., A new cavity ring-down instrument for airborne monitoring of N_2O_5, NO_3, NO_2 and O_3 in the upper troposphere lower stratosphere
42. Schultz, M. et al., Investigation of low ozone, high water vapour episodes over the Pacific
43. Slemr, F. et al., CARIBIC observations of mercury in the upper troposphere and lower stratosphere.
44. Smit, H. G. J. et al., Quality Assurance & Quality Control of IAGOS Measurements: Concept & First Findings Made in IGAS.
45. Stich, D. et al., Validation of satellite-based thunderstorm detection and Cb nowcasting with IAGOS
46. Thorenz, U. et al., Investigating African trace gas sources, transport and oxidation using measurements made at 10 km between 2009 and 2011 from IAGOS-CARIBIC
47. Verma, S. et al., IAGOS CO_2 measurements for surface-atmosphere fluxes: the impact of transport model errors
48. Zahn, A. (invited), The new IAGOS-CARIBIC payload
49. Zahn, A. et al., Processes controlling water vapor in the upper troposphere/lowermost stratosphere
50. Ziereis, H. et al., Nitrogen oxides in the UTLS: Combining observations from in-service aircraft and research aircraft
51. Zimmermann, P. et al., Global model replication of methane observations by the flying CARIBIC observatory with special focus on the resuming increase in 2007

Revision and Status:

Version	***Published***	***EB approval***	***GA approval***	***Remarks***
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IAGOS-AISBL

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