IAGOS, IGAS, ADAM, and others: Efforts to make aircraft data available to the community

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Andreas Petzold, A. Volz-Thomas, M. Schultz et al., (JÜLICH)
Carl Breinninkmeijer et al., (MPI-C)
Christoph Gerbig et al., (MPI-B)
Ann Kean et al., (NOAA)
Gao Chen et al., (NASA)
In-service Aircraft for a Global Observing System

www.iagos.org

IAGOS-CORE
- Equipping 20 long-haul aircraft with scientific instruments for:
  - atmospheric chemical composition (H₂O, O₃, CO, NOₓ, NO₉, CO₂, CH₄)
  - aerosol number conc. and size
  - cloud particle number conc. and size
- Long-term deployment (20 yrs)
- Global coverage
- Open data policy (GMES/GEO/GEOSS)
- Near real time data provision

IAGOS-CARIBIC
- Deploy the CARIBIC Container
  Large number of species, including those above plus VOCs, CFCs, aerosol chem. composition, H₂ isotopes, SO₂

Lufthansa; Air France; China Airlines; Iberia; Cathay Pacific
Permanent installations in the avionic bay of A340/A330

First flight of LH D-AIGT on 8 July 2011

Weight: 120 kg  Operation: Continuous

Photograph by courtesy of Alexander Karmazin

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Automated laboratory in the cargo bay
Weight: 1.5 t    Deployment: monthly
Partners: MPI-C, KIT, DLR, TROPOS, U-HD, HZG, UEA, U-Lund, KNMI, ..... permanently installed air inlet system
<table>
<thead>
<tr>
<th>Partner, 1st IAGOS a/c</th>
<th>2 MOZAIC since 1994</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deutsche Lufthansa AG</td>
<td>MoU signed</td>
</tr>
<tr>
<td>AIRBUS, Bristol, UK</td>
<td>MoU in prep.</td>
</tr>
<tr>
<td>British Airways plc</td>
<td>MOZAIC -2004</td>
</tr>
<tr>
<td>IAGOS Partners and Associated airlines</td>
<td></td>
</tr>
</tbody>
</table>

| University of Cambridge, U.K. |
| University of Manchester, U.K. |
| Max-Planck-Gesellschaft, D |
| Karlsruhe Institute of Technology, D |
| Leibniz-Institut für Troposphärenforschung, Leipzig, D |
| Deutsches Zentrum für Luft- und Raumfahrt, Oberpfaffenhofen, D |
| Forschungszentrum Jülich, D |
| Laboratoire d’Aérologie, CNRS, Toulouse, F |
| Météo France, Toulouse, F |
| World Meteorological Organization, Geneva, CH |
| World Meteorological Organization, Geneva, CH |
| Partner |
| MoU |
| Interest in collaboration |
| Interest in collaboration |
| Interest in collaboration |
# Objectives

## IAGOS-CORE
- Equipping 20 long-haul aircraft with scientific instruments for:
  - atmospheric chemical composition ($H_2O$, $O_3$, $CO$, $NO_x$, $NO_y$, $CO_2$, $CH_4$)
  - aerosol number conc. and size
  - cloud particle number conc. and size
- Long-term deployment (20 yrs)
- Global coverage
- Open data policy (**GMES/GEO/GEOSS**)
- Near real time data provision

## IAGOS-CARIBIC
- Deploy the CARIBIC Container
  - Large number of species, including those above plus VOCs, CFCs, aerosol chem. composition, $H_2$ isotopes, $SO_2$

## Scientific issues:
- Changes in the Tropopause Region
- Validation of Atmospheric Models and Satellite Retrievals
- Global Air Quality
  - Biomass burning, long-range transport
- International Transfer Standards
  - Same systems everywhere, regular QA

## Essential information for:
- Climate Change (IPCC)
- Air Quality (UNECE-CLRTAP)
- Carbon Cycle (Kyoto Protocol)
- Ozone layer (Montreal Protocol)
- Atmospheric Impact of Aviation
  - emission trading
  - climate-optimized routing

## Support to Aviation Industry
- volcanic ash and mineral dust
- optimized fuel consumption

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### Unpredicted Findings from MOZAIC, one of the precursors of IAGOS

<table>
<thead>
<tr>
<th>Compound</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{O}_3$</td>
<td>Persistent layering of the atmosphere <em>(Newell et al., Nature, 1999)</em></td>
</tr>
<tr>
<td>$\text{H}_2\text{O}$</td>
<td>Large abundance of ice supersaturated regions in the UT <em>(Gierens et al., An. Geo., 1999; Luo et al., J. Climate, 2008)</em></td>
</tr>
<tr>
<td>$\text{CO}$</td>
<td>Extremely high values in the UTLS due to Biomass Burning <em>(Nédélec et al., GRL, 2005)</em></td>
</tr>
<tr>
<td>$\text{NO}_y$</td>
<td>High values in the UTLS due to convection and lightning <em>(Thomas et al., in prep.)</em></td>
</tr>
</tbody>
</table>

### Complementary database for further significance:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{O}_3$</td>
<td>Trends in the troposphere: Impact of Asian emission on the increasing springtime ozone in western part of the US <em>(Cooper et al., 2010)</em>; consistency over Europe and recommendations for model evaluation <em>(Logan et al., 2012, Staufer et al., 2013)</em></td>
</tr>
</tbody>
</table>

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IAGOS-CORE Measurements

Option 1:
- Package 1 (CNRS)
  - $\text{O}_3$, CO (CNRS)
  - $\text{H}_2\text{O}$ (FZJ)
  - BCP (UMAN)
  - RTTU (MF)
- Package 2a (FZJ)
  - NOy

Option 2:
- Package 1 (CNRS)
  - $\text{O}_3$, CO (CNRS)
  - $\text{H}_2\text{O}$ (FZJ)
  - BCP (UMAN)
  - RTTU (MF)
- Package 2b (FZJ)
  - NOx

Option 3:
- Package 1 (CNRS)
  - $\text{O}_3$, CO (CNRS)
  - $\text{H}_2\text{O}$ (FZJ)
  - BCP (UMAN)
  - RTTU (MF)
- Package 2c (FZJ)
  - Aerosol

Option 4:
- Package 1 (CNRS)
  - $\text{O}_3$, CO (CNRS)
  - $\text{H}_2\text{O}$ (FZJ)
  - BCP (UMAN)
  - RTTU (MF)
- Package 2d (MPG)
  - $\text{CO}_2$, $\text{CH}_4$

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Essential concern for the program:

- Use of proven technology (field campaigns, intercomparison studies)
- One lab responsible for each type of instrument on all a/c
- Calibration against reference instruments during maintenance (2-6 month)
- In-flight calibration ($O_3$, CO, NO$_x$, GHGs)
- Comparison of measurements from different IAGOS aircraft during regular flights (Internal Consistency)
- IAGOS Partners are strongly involved in international QA/QC activities:
  - FZ Jülich: GAW WCC for $O_3$ sondes and for NO$_x$
  - TROPOS: GAW WCC for Aerosol
  - MPI-BGC: ICOS Central Facility for GHG analysis
- IAGOS data contribute to harmonisation of global networks through data assimilation by, e.g., MACC, GMES, GEOSS
Datasets for GEOSS

What is available? Since when?

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MOZAIC</th>
<th>IAGOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozone</td>
<td>1994</td>
<td>2011</td>
</tr>
<tr>
<td>Water Vapour</td>
<td>1994</td>
<td>2011</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>2002</td>
<td>2011</td>
</tr>
<tr>
<td>Odd Nitrogen (NO₃)</td>
<td>2001-2005</td>
<td>2011</td>
</tr>
<tr>
<td>Nitrogen Oxides (NOₓ)</td>
<td></td>
<td>2011</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td></td>
<td>2013</td>
</tr>
<tr>
<td>Methane</td>
<td></td>
<td>2013</td>
</tr>
<tr>
<td>Aerosol</td>
<td></td>
<td>2013/2014</td>
</tr>
<tr>
<td>Cloud Particles</td>
<td></td>
<td>2011</td>
</tr>
</tbody>
</table>

Plus many more from CARIBIC aircraft at lower frequency
2012 : The first trans-Pacific flights

Details on the poster by Clark et al.

IAGOS Flights – Status September 8th, 2012
LUFTHANSA – CHINA AIRLINES

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The Central IAGOS Data Base

• How is it organized today?
  – historical MOZAIC data + IAGOS-core

• How to get access?
  – Request on the web, abstract required
  – Open data policy

• Who are the users?
  – Scientists (more than 150 groups worldwide)
  – Projects (QUANTIFY, AQMEII, AMMA, etc…)
  – GMES/MACC (In-situ data provision and automatic model validation)

• Current developments:
  – IGAS (metadata standardisation, interoperability, merge IAGOS-core and IAGOS-CARIBIC, etc…)
  – Source/Receptor link (added-values products to attribute the origin of observed CO plumes: coupling IAGOS-FLEXPART-ECCAD)

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IAGOS for GMES/Copernicus
Atmospheric Service

Start in January 2013; A bridge between IAGOS and Copernicus

http://www.igas-project.org
WP2 Enhancing the IAGOS-GMES link

Partners: KNMI (WP-lead), ECMWF, UPS, FZJ, MPI-BGC, MPI-C

- Develop the IAGOS database into a system with full semantic interoperability leading to enhanced search and retrieval capabilities, and inclusion of the complete IAGOS-core and IAGOS-CARIBIC data

- Link the IAGOS database to the GENESI-DEC portal and the GEO Air Quality Community of Practice data catalogue

- Enhance the use of airborne in-situ data for satellite validation activities by provision of standardized complete atmospheric profiles, co-location tools, and representativeness assessment of IAGOS data

- Develop the use of IAGOS greenhouse gas and aerosol data in the MACC-II monitoring/forecasting system
Further development of the Central IAGOS Data Base

**Objective**
Make airborne in-situ data available such that they can be used directly within the GMES/Copernicus atmospheric services, by increasing the accessibility and interoperability and harmonizing the data and metadata formats.

**Keywords (and our interpretation):**

- **accessibility**: e-solution for data protocol; data readily available on (fast) servers; automated access possible; flexible data selection
- **interoperability**: OGC protocols (WCS); data available through JOIN and GENESI-DEC
- **data formats**: netCDF-CF (and others: ASCII NASA Ames for ex.)
- **metadata formats**: ISO 19115 and INSPIRE compliant XML files; netCDF-CF attributes

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Other Initiatives in the US

Same objective … To make aircraft data available to the (modellers) community:

• NOAA: 7 Fields missions datasets from 1999-2010 located in continental US and Alaska

• NASA: Airborne Data for Assessing Models (ADAM): a web development effort to effectively disseminate airborne data products (from CITE-1B to ARCTAS, and other NOAA, NSF, and EU airborne field campaigns (NARE, ACE, AMMA?, …).

Same willingness … to keep the comm. on, to coordinate our efforts/standards: ➔ enlarge HTAP_WP6.6 objectives.
• 7 field mission datasets from 1999-2010 located in continental US and Alaska
• Data sampling:
  • 1 minute averages of fast-response meteorological, gas-phase, particulate-phase and radiative parameters
  • Fast-response data averaged to Whole Air Sampler (flask) sampling open/close times.
  • Whole Air Sampler hydrocarbons, halocarbons and other trace species.
• ICARTT formatted text data files
  http://www-air.larc.nasa.gov/missions/etc/IcarttDataFormat.htm
Tropospheric Chemistry: Datasets for Modellers

Created to improve the ability to incorporate NOAA WP-3D airborne chemistry data sets into large-scale models. Provided ICARTT-formatted data files from all the major chemically-instrumented NOAA WP-3D aircraft field projects since 1999. There are three data files for each flight day:

1. First file contains one-minute averages of faster-response (typically 1Hz) meteorological, gas-phase, and particulate-phase data for a given flight.
2. Second file contains these faster-response data averaged over the whole air sampler (WAS) open/close times for a given flight.
3. Third file contains the WAS data on hydrocarbons, halocarbons, and other trace species.

http://www.esrl.noaa.gov/csd/groups/csd7/measurements/modellers.html
**Background:**

- ADAM development was supported by NASA’s MEaSUREs program.
- ADAM is designed to provide a set of intuitive web tools for accessing airborne data sets.
- ADAM is considered as a prototype of the toolsets for accessing the airborne data hosted at the Atmospheric Science Data Center at NASA Langley Research Center.

**Current Status:**

- **Implemented Features:**
  - Textual variable search across multiple airborne sets further filtered by mission, platform, and categories.
  - Data merge based on user specified time bases – both continuous and other measurement time bases.
  - Data merge generates standard deviation and is capable of handling column LOD and column uncertainties.

Current data holdings: INTEX-AdQST 2006
Prototype Web Coverage Service for ADAM
A NASA AQAST Tiger Team Project

• Develop a working prototype Web Coverage Service for ADAM – A NASA Air Quality Applied Science Team Tiger Team project in collaboration with the US EPA Remote Sensing Information Gateway (RSIG) – funds pending.

• OGC-Web Coverage Service (WCS) focused on high utility ADAM data over North America: INTEX-A, NEAQS ITCT-2004 INTEX-B, TexAQS-II, ARCTAS, ARCPAC, CalNEX and DSICOVER-AQ.

• Provide data in multiple formats (ASCII, NetCDF-CF, NetCDF-IOAPI, and GEOTIFF) subsetted by variable, longitude-latitude rectangles, and date ranges for field missions as well as re-gridded to model grids.

• Prototype WCS to provide data service to existing data systems, such as NASA Airborne Data for Assessing Models (ADAM), EPA Remote Sensing Information Gateway (RSIG), and interoperable with similar WCS data access and analysis services developed under the auspices of the TF HTAP, the Group on Earth Observations Air Quality Community of Practice.

• Project Team: James Szykman and Rohit Mathur, (US EPA) Gao Chen and Pam Rinsland (NASA/LaRC), Danny Mangosing (NASA/LaRC/SSAI), Todd Plessel and Matt Freeman (USEPA/NCC/L-M), Martin Schultz (Forschungszentrum Juelich), Greg Carmichael (U. Iowa), Pius Lee (NOAA/ARL) and Brad Pierce (NOAA/NESDIS).
The ASDC Toolset for Airborne Data (TAD) is designed to serve the science community needs for aircraft data for scientific researches on climate change and air quality relevant issues, particularly model assessment and evaluation.

- The development of TAD will leverage ADAM design principles and lessons learned and will significantly expand the service capabilities from ADAM.
- TAD will include tools for variable search, spatial/temporal data search, data download, data merge, data browsing, and data subsetting. Relevant tools will be Web Coverage Service capable.
- TAD is designed to handle ASDC airborne data holdings in ICARTT format, e.g., DISCOVER-AQ, ARCTAS, INTEX-B, INTEX-A, with additional later capability to include earlier/other data sets.
- ADAM will be available during the ASDC toolset development effort.