In-Service Aircraft for a Global Observing System

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Global climate change and air quality represent one of the most serious environmental challenges facing humanity today. Climate and air quality issues require (i) a good knowledge of the state of the atmosphere and (ii) a long-term monitoring strategy for addressing the changes and their causes. Reliable predictions of the future climate and air quality using climate or chemistry-transport models are central and fundamental requirements for determining future mitigation strategies. For several decades, networks of measurements have been deployed from the surface, mostly over the continental areas of the northern hemisphere. In the 1980s, satellites began providing a global view for few variables, mostly integrative data (i.e.,columns), but they lack the vertical sensitivity which is required for certain regions of the atmosphere.

Thirty years ago, a collaboration was initiated by the scientific research community, aircraft manufacturers and commercial airlines to respond to concerns about the impact of aviation on the climate and particularly on ozone chemistry and on the emissions of water vapour at cruise altitude from a continually growing number of aircraft. The project 'MOZAIC' (measurement of ozone and water vapor by Airbus in-service aircraft) was set-up to measure water vapour and ozone using commercial aircraft as a platform. Its aims were to build a database of measurements for studying chemical and physical processes in the atmosphere rather than to focus solely on the direct effects of aircraft emissions on the budget of ozone which was a key issue in the years following the Montreal Protocol.

MOZAIC has evolved into 'IAGOS' (In-service Aircraft for a Global Observing System) which is a European Research Infrastructure using commercial aircraft to carry scientific instruments for automatic and routine measurements of atmospheric composition including reactive gases (ozone, carbon monoxide, nitrogen oxides, volatile organic compounds), greenhouse gases (water vapour, carbon dioxide, methane), aerosols, and cloud particles along with essential meteorological parameters. The core IAGOS instrumentation consists of two packages, Package1(P1) and Package 2(P2).

- P1 is installed on every equipped aircraft and is the basic instrument containing ozone and carbon monoxide analyzers and the data acquisition system for the IAGOS Humidity Sensor (ICH) and the Backscatter Cloud Probe (BCP). It also records the position of the aircraft and provides data transmission for all IAGOS instruments via the mobile phone network. P1 consists of the instrument unit and the pump box, which contains membrane pumps that compress the sample air from ambient pressure to cabin pressure. The ambient air is sampled via a pitot tube on the IAGOS inlet plate (Figure 1).

FIGURE 1: The inlet plate used on IAGOS-CORE aircraft.

- P2 is available as five different options: nitrogen oxides (P2a and P2b), aerosols (P2c), greenhouse gases (P2d), and the so-called "air quality package" (or P2e) for NO_2 aerosol extinction. Before and after each deployment period (3–6 months), the instruments are shipped to the different European laboratories for detailed quality assurance. Details of operating procedures, data analysis, and quality assurance are described in the Standard Operating procedures (SOP) available from the website[1].

The IAGOS system is currently certified for A340 and A330 aircraft, with the A350 planned in the near future. The measurements are taken throughout the flight, providing data along flight routes at cruise altitude and as quasi-vertical profiles during landing at take-off at worldwide airports (Figure 2). Through cooperation with airline partners, IAGOS is able to build-up a good geographical coverage of data for the benefits of the scientific community and for the operational services in charge of air quality and climate change issues. Currently 10 aircraft are equipped, contributing about 500 flights per aircraft per year.

Commercial long-range aircraft such as A330s spend on average 80% of their time at cruise altitude in a region of the atmosphere known as the upper-troposphere and lower stratosphere (UTLS). Small changes to atmospheric composition from the gases and particles emitted there, have relatively larger impacts on the radiative forcing of climate.

Through various chemical interactions, the emissions of NO_X, CO_2 and H_2O perturb the concentrations of the radiatively active gases CO_2, O_3, and methane and they may also trigger the formation of contrails and contrail induced cirrus. Other gases and particles emitted by aircraft such as SO_X, hydrocarbons and soot interact through microphysical processes leading to increased cloudiness or modify the composition of aerosols with further effects on climate. Lee et al. (2021), estimated that aviation represented about 3.5% of the net anthropogenic effective radiative forcing in 2018 with non-CO_2 emissions comprising about two-thirds. However, of the radiative forcing components due to aviation, contrails and aircraft induced cloudiness are one of the more uncertain (Lee et al., 2021).

Key to the study of contrails, predicting where they will form and avoiding their formation, is an accurate knowledge of upper tropospheric humidity and regions of ice supersaturation (Ice-Supersaturated Regions - ISSR), and an accurate prediction of these regions in meteorological models. The IAGOS Capacitive Hygrometer (ICH) is one of 3 types of instruments used for aircraft-based humidity measurements. It consists of a capacitive sensor and a platinum resistance sensor to measure the temperature. The IAGOS humidity sensor ICH is the only sensor able to provide these measurements with sufficient accuracy in the upper troposphere to detect ISSRs reliably. IAGOS is working with partners within the project CICONIA, a SESAR project funded by the EU which aims to offer strategies for contrail avoidance working through the chain from the prediction of the ISSR to the proposal of the new routing with air traffic management and finally the execution of the flight by the pilots. The avoidance strategy is extremely sensitive to the prediction of ISSRs as an unnecessary avoidance manoeuvre results in more emissions of CO_2.

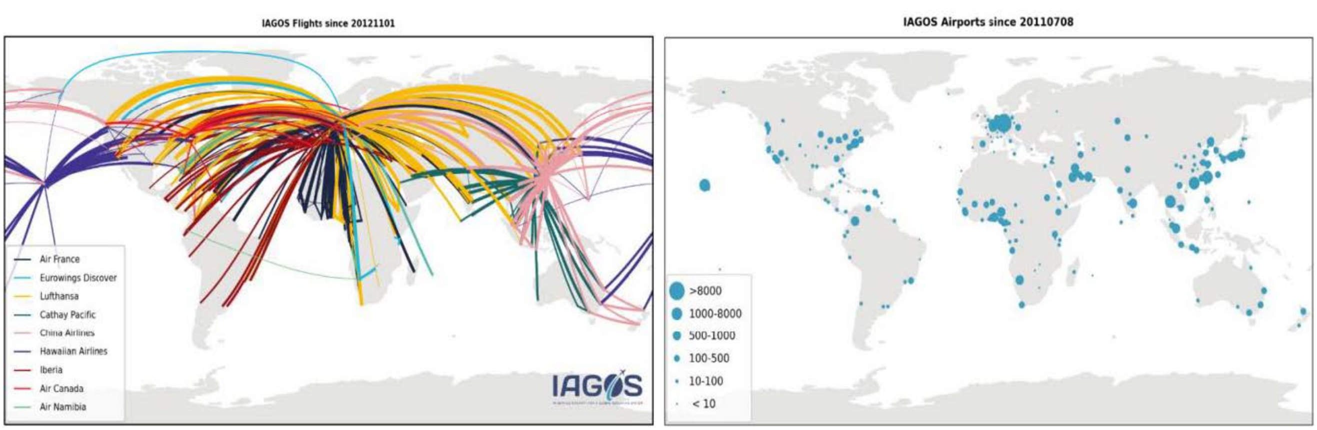

FIGURE 2: (Left) Current flight coverage by the airlines carrying IAGOS equipment. (right) Distribution of airports visited by IAGOS aircraft.

1 www.iagos.org

The continuity of data over the long-term is an important feature of IAGOS. Having been running for 30 years, the time-series is now recognised as a 'climate' dataset by the World Meteorological Organisation. Time-series of ozone in the free troposphere from IAGOS are essential for analysis of trends used in the Tropospheric Ozone Assessment Report (TOAR) which in turn show the impact of mitigation policies. 30 years of water vapour measurements give us the longest time series of upper tropospheric water vapour and ISSRs which serves as a reference dataset with which to compare satellites and models and allows us to understand the vertical distribution and seasonality (Gierens et al. 1999, Petzold et al. 2020). The 30-year time-series is important for detecting any trends or changes in the abundance of upper tropospheric water vapour, which is the most important greenhouse gas, and has a positive feedback role in climate change.

Data collected by IAGOS aircraft are freely available and accessible via the data centre after registration. Also provided are additional products that aid the scientific interpretation of the data. These range from important parameters such as the tropopause height, which is essential to place the aircraft in the upper troposphere or in the lower stratosphere where atmospheric characteristics are very different or information on the source of the pollution through an application that gives a source-receptor link for the observed anomalies in CO. These so-called added-value products enable more thorough analysis and diagnostics that can be used for evaluating the behavior of atmospheric models. Humidity data from the ICH is available in near-real-time (NRT - defined as within 3 days) to the Copernicus Atmosphere Monitoring Service and to partners in the CICONIA project for the purposes of validating global and regional forecasts of humidity and ISSRs.

References

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