# Quality Assurance & Quality Control of IAGOS (*) In Service Aircraft Measurements: Concept & Experiences Made

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**And**
**The IAGOS Instrument PI's-Team**

**(*) IAGOS = In-service Aircraft for a Global Observing System**
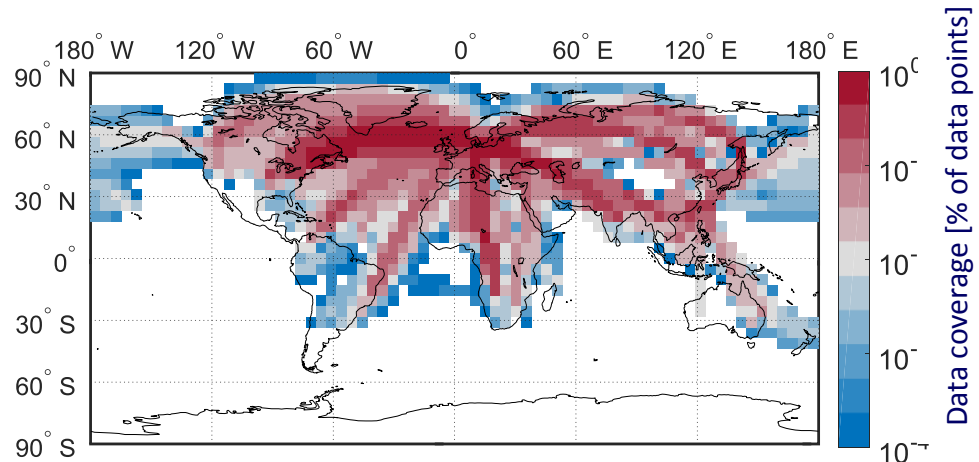
# https://www.iagos.org

Part of IGAS = IAGOS for Copernicus (former GMES) Atmospheric Service, an EU funded project (2013-2016)

CIMO-TECO

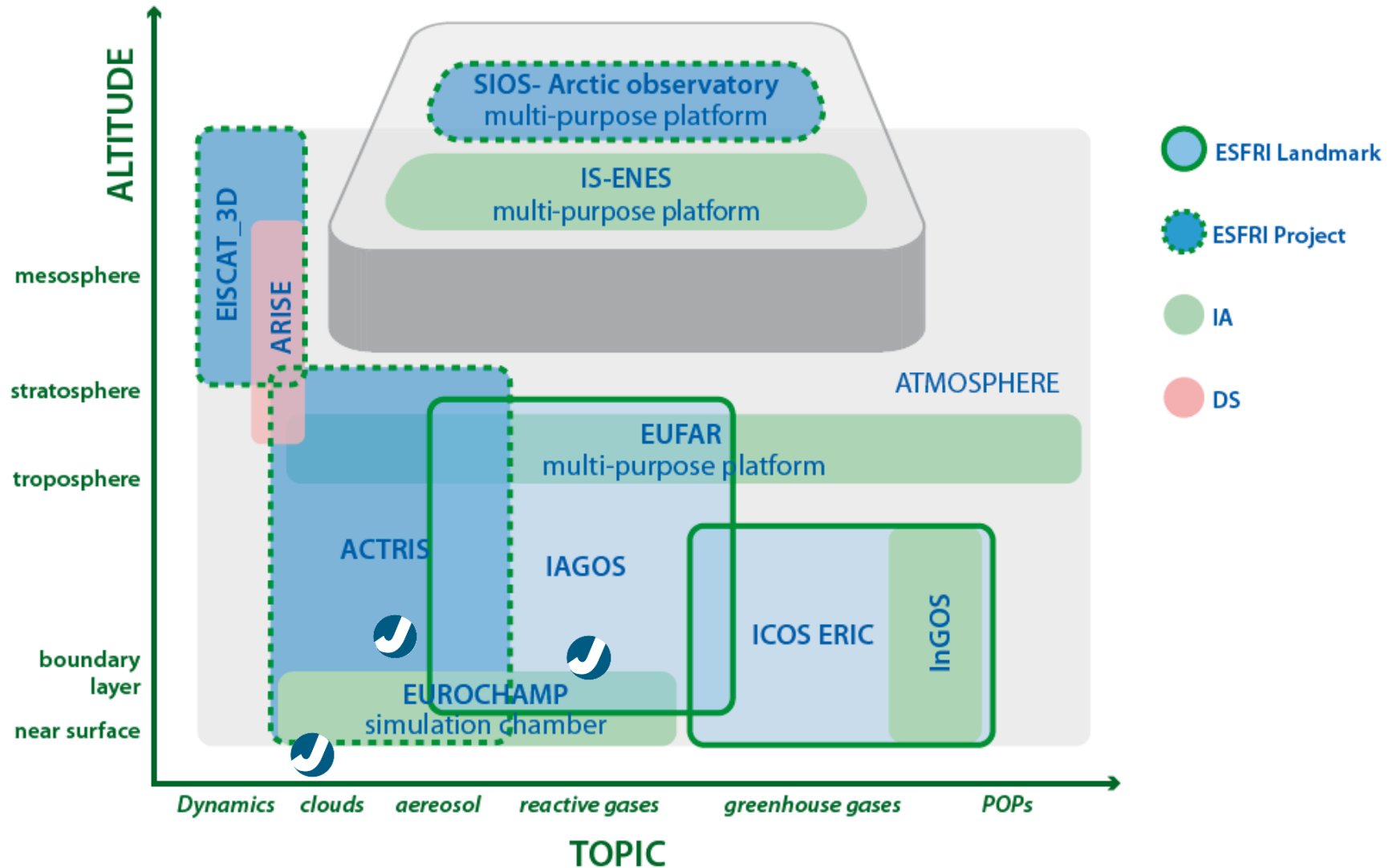08-11 October 2018, Amsterdam, The Netherlands

## European Research Infrastructure for Earth Observation using Passenger Aircraft



- **Regular in-situ global-scale monitoring of essential climate variables $H_2O$, $O_3$, CO, $NO_x$, $CO_2$, $CH_4$, aerosols, clouds.**

- Int. consortium of partners from science, industry and meteorological services.

- Infrastructure operational since 2014.

- Today, 8 long-haul aircraft (IAGOS-CORE) and 1 flying laboratory (IAGOS-CARIBIC).

- **Near real time data for Copernicus services (e.g. air quality).**

- Open data policy (CAMS/GEO/GEOSS).

- **Long-term mission envisaged (>20 yrs)**

- Longest time series for

  - tropopause temperature (> 20 yrs)
  - $H_2O$, $O_3$ (> 20 yrs)
  - CO (> 12 yrs)

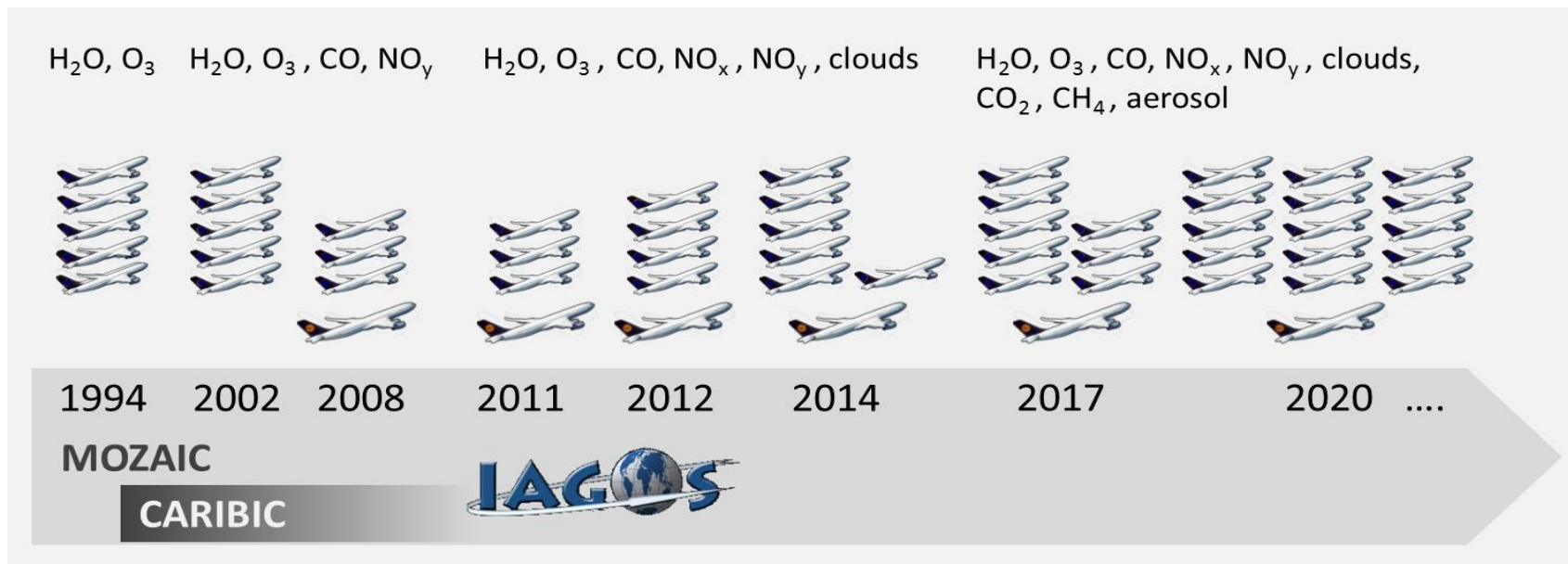# LANDSCAPE OF EUROPEAN RESEARCH INFRASTRUCTURES
## ATMOSPHERIC DOMAIN

ENVRI plus

**ALTITUDE**

- mesosphere
- stratosphere
- troposphere
- boundary layer
- near surface

SIOS- Arctic observatory
multi-purpose platform

IS-ENES
multi-purpose platform

ATMOSPHERE

EISCAT_3D

ARISE

EUFAR
multi-purpose platform

ACTRIS

IAGOS

ICOS ERIC

InGOS

EUROCHAMP
simulation chamber

**TOPIC**

Dynamics · clouds · aereosol · reactive gases · greenhouse gases · POPs

**Legend:**
- ESFRI Landmark
- ESFRI Project
- IA
- DS

# IN-SERVICE AIRCRAFT FOR A GLOBAL OBSERVING SYSTEM

**AISBL-Association Internationale sans but lucratif**

$H_2O$, $O_3$  $H_2O$, $O_3$, CO, $NO_y$  $H_2O$, $O_3$, CO, $NO_x$, $NO_y$, clouds  $H_2O$, $O_3$, CO, $NO_x$, $NO_y$, clouds, $CO_2$, $CH_4$, aerosol

1994   2002   2008   2011   2012   2014   2017   2020   ....

**MOZAIC**

**CARIBIC**

IAGOS

## IAGOS Objectives for next 5 Years:

- Operational provision of data in real real-time for Copernicus services: Validation of numerical forecastings of weather and air-quality

- Fleet implementation of new IAGOS Air Quality Instrument ($NO_2$, aerosol light extinction)

- Extension of aircraft fleet, e.g. to higher latitudes by equipping Finnair aircraft.

- Extension to new members from weather services (e.g. FMI, KNMI)

- However, last but not least: **Implementation QA/QC evaluation plan as operational component!**

# IAGOS-QA/QC:
# Requirements:

## *Requirements:*

Each compound measured by an IAGOS instrument needs

- Standard Operating Procedures (SOP's)
- Transparency and traceability to well established standards
- Guidelines for storage of its measured data in the IAGOS Data Base:

    *Measurement + Uncertainty + QA-Flag + Metadata*

- Regular (≈yearly) documentation of QA/QC protocols on calibration and consistency (internal & external)
- Regular (≈5 years) assessment reports of QA/QC-documentation

# IAGOS-QA/QC Incl. Evaluation Concept: Objectives

**To establish procedures for regular evaluation and documentation of the quality of the IAGOS measurements and their harmonisation through:**

- Development and testing/evaluation of a harmonized **QA/QC-concept**.

- Development and testing/evaluation of QA/QC procedures and their **traceabilitiy**.

- Development and testing/evaluation of tools to evaluate the IAGOS-measurements on **internal and external consistency**.

Essentially thereby is to *obtain a full documentation* of the standard operating procedures (SOPs) and quality control procedures for each instrument, making the measured data transparently *traceable to established standards*.

The goal thereby is that these procedures will be *established as part of the IAGOS-operation* and directly *linked to the QA/QC plan of the WMO/GAW.*

# QA/QC-Plan of WMO/GAW

QAQC of IAGOS Measurements: IAGOS Scientific Symposium @ University Manchester, UK, 17-19 Oct. 2016
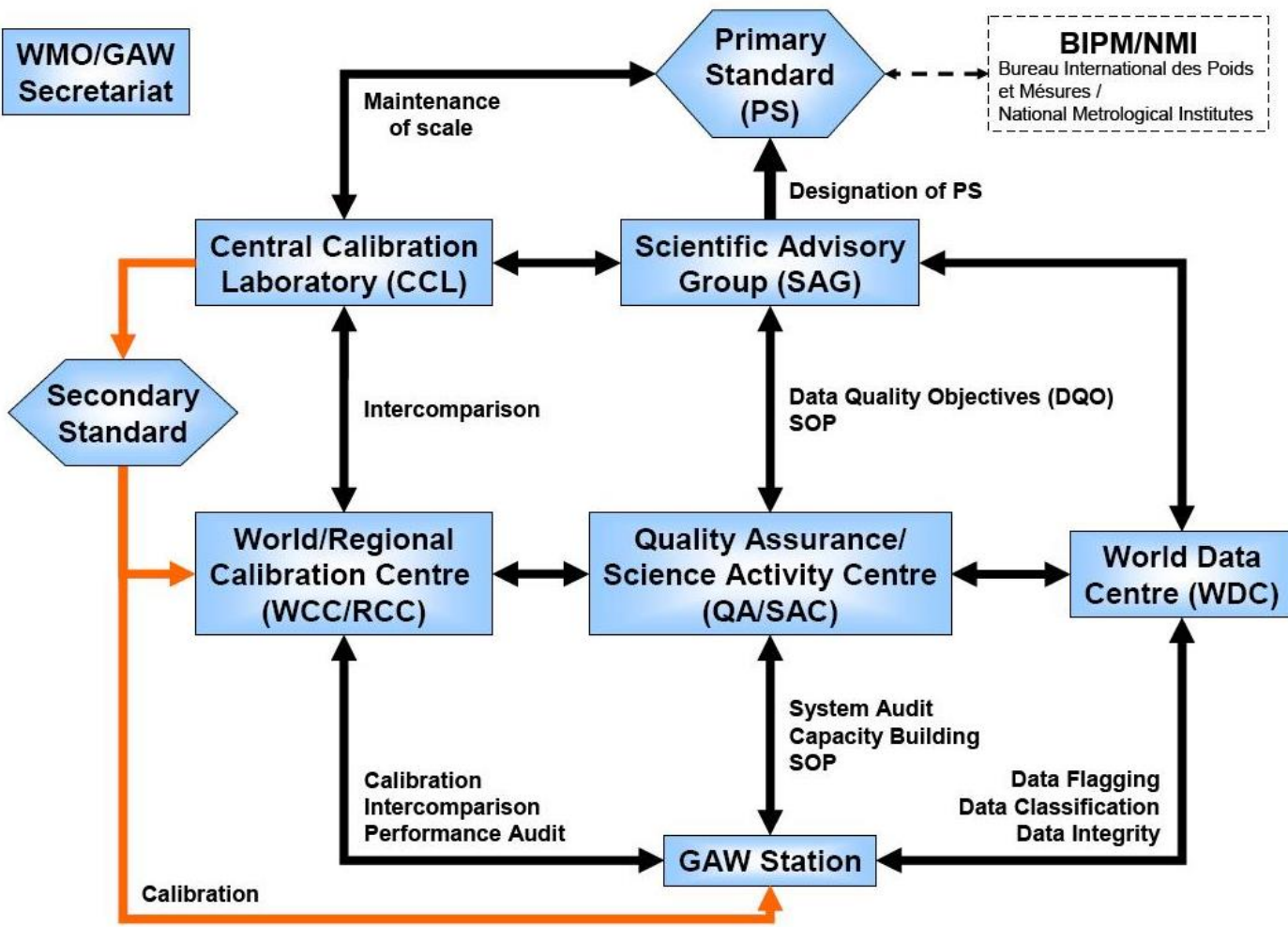
# IAGOS-QA/QC:
## Adapting QA/QC-Concept of WMO/GAW
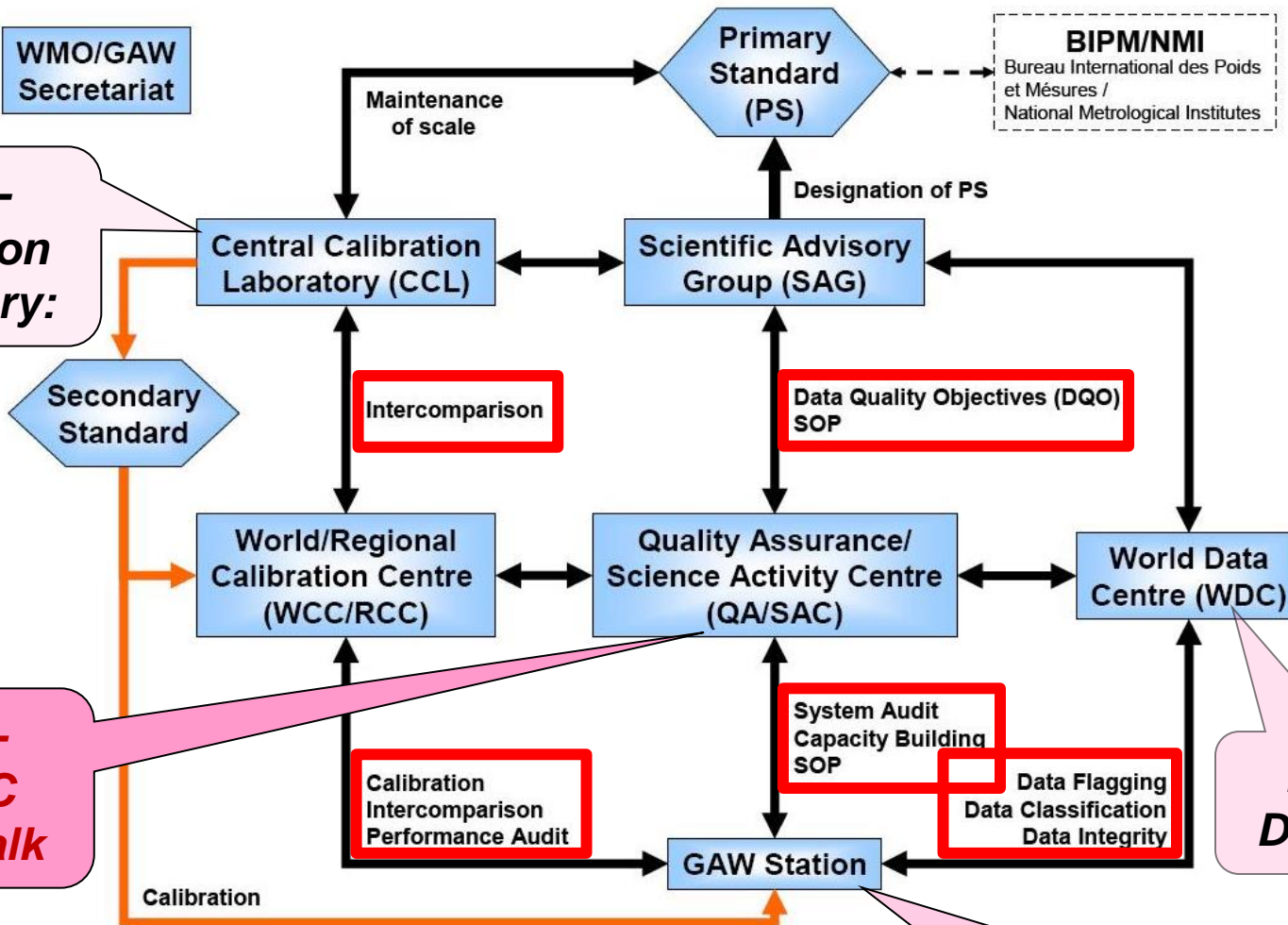
# IAGOS-QA/QC:
## Concept of QA/QC, incl. Evaluation & Harmonisation
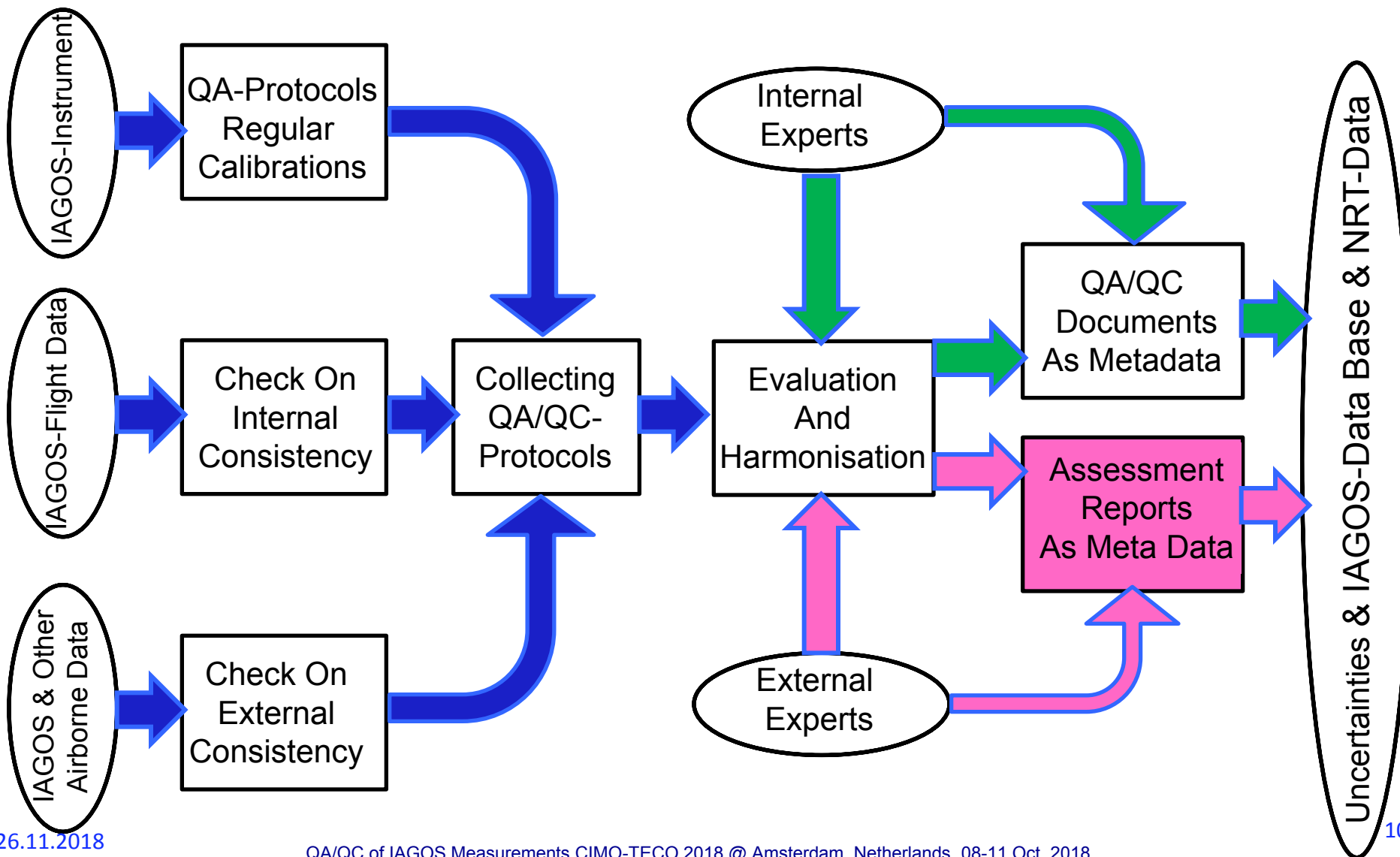
# IAGOS-QA/QC:
## Evaluation and harmonisation of data quality in routine aircraft observations

**SOP's**
**Standard Operating Procedures**

1. Instrument layout and operation
2. Calibration procedure and traceability
3. Calculation of results from raw (L0) to final (L2)
4. Uncertainty Analysis
5. Maintenance
6. Validation and flagging scheme
7. Storage of data

**QA/QC**
**Protocolls**

1. Performance over flight period
2. Regular Calibration
3. Internal Consistency: IAGOS A/C by A/C
4. External Consistency: IAGOS A/C with other platforms
5. Development and use of automatic tools to match in time and space (incl. use of trajectory analysis)

# IAGOS-QA/QC:
## Evaluation and harmonisation of data quality in routine aircraft observations

**Regular QA/QC & Assessment Reports**

For each measured compound:
- Collecting all QA/QC-protocols over a period of 1-2 years
- Prepare regular (every 1-2 years) QA/QC-report.
- Internal review of QA/QC-report by IAGOS-PI's
- Prepare regular (every 5 years) QA/QC-assessment report
- Review by panel of external experts
- Feedback to IAGOS Data Base on impact of archived data

**Implemen-tation QA/QC Into IAGOS & WMO/GAW**

**Migration of IAGOS-QA/QC-Concept into IAGOS-Operation and established at WMO/GAW, i.e. as QA/SAC (SAC= Scientific Activity Center), which means:**
I. Establishment of IAGOS-QA/QC concept into operation as part of IAGOS-AISBL
II. Link to WMO-GAW QA/QC infrastructure with a IAGOS-QA/SAC; incl. link to its SAG's (Scientific Advisory Groups)

# IAGOS-QA/QC Concept Development:
## Team of External Experts to Coach and Review IAGOS-QA/QC Procedures during two Evaluation Rounds in November 2014 & 2015

| Name | Affiliation | Expertise | E-Mail |
|---|---|---|---|
| Hurst, Dale | NOAA/GM | H2O | Dale.Hurst@noaa.gov |
| Zellweger, Christoph | EMPA | O3 & CO | Christoph.Zellweger@empa.ch |
| Andrews, Arlyn | NOAA | GHG (CO2 & CH4) | Arlyn.Andrews@noaa.gov |
| Baumgardner, Darrel | DMT | Aerosol | Darrel.Baumgardner@gmail.com |
| Nott, Graeme | Cranfield University | Cloud | Graeme.Nott@faam.gov.uk |
| Brunner, Dominik | EMPA | NOX & NOY | Dominik.Brunner@empa.ch |

# IAGOS-QA/QC:Internal consistency

Objective : Automatic detection of « coincident » profiles within 1-3 hours
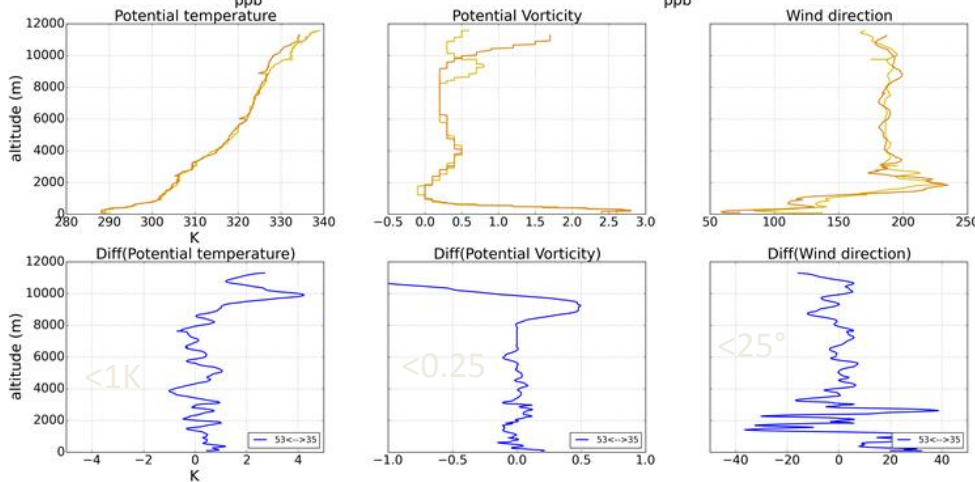➔ Individual Quicklooks for comparisons between 2 profiles (O3 and CO)
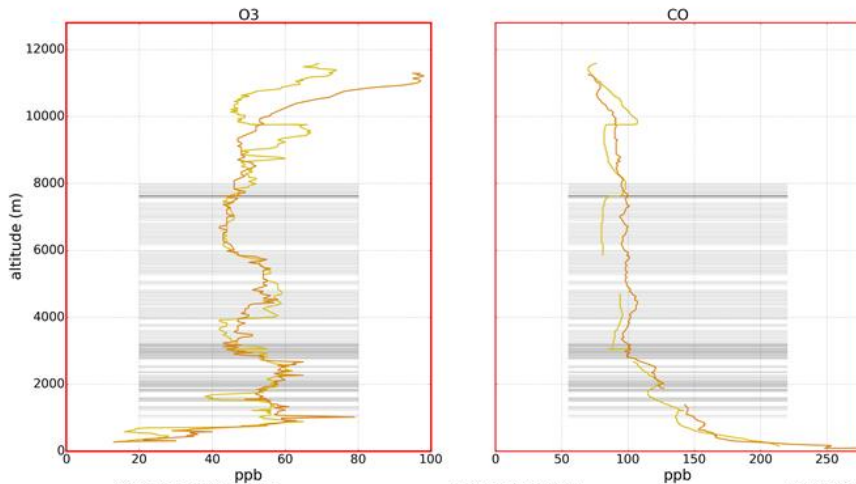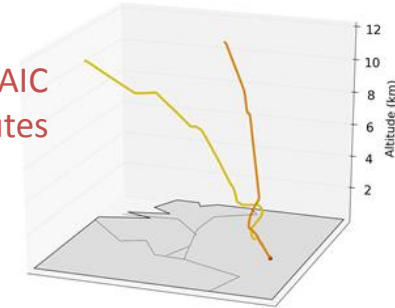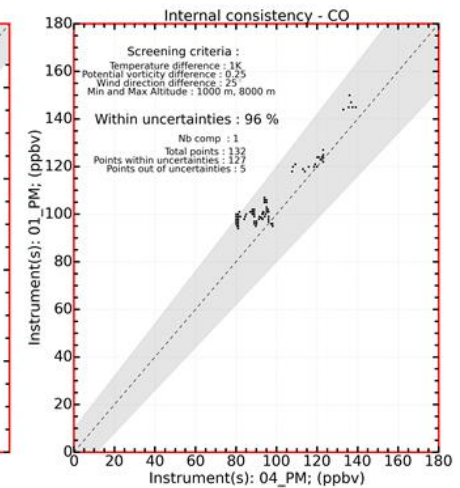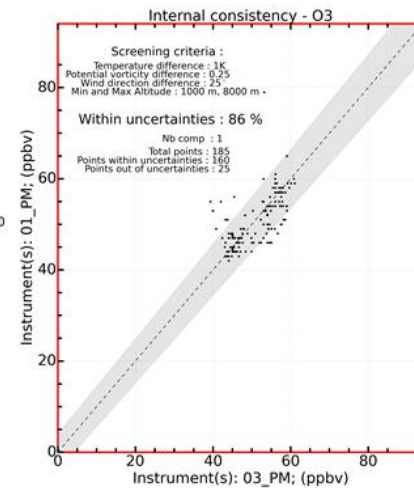


The grey shading represents the « comparable » records.

Dashed line is the 1:1 line and the grey shading represents the total instrument uncertainties
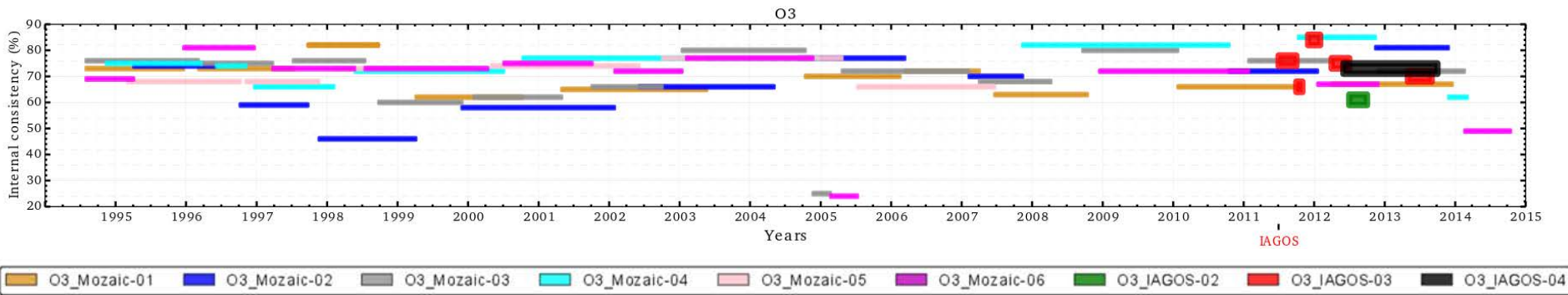
# MOZAIC-IAGOS consistency
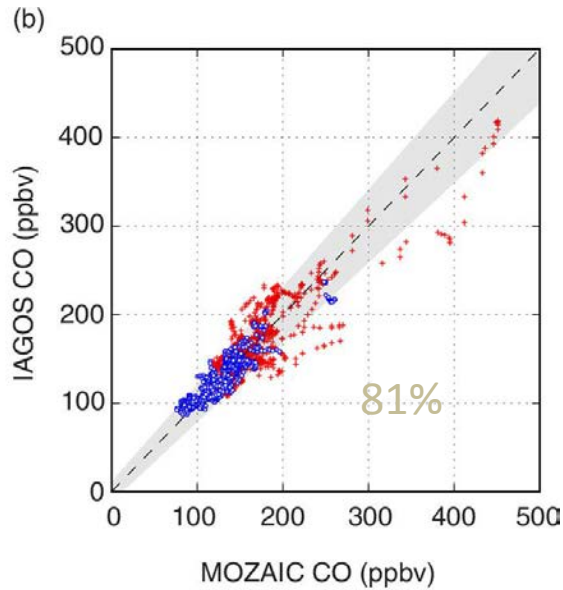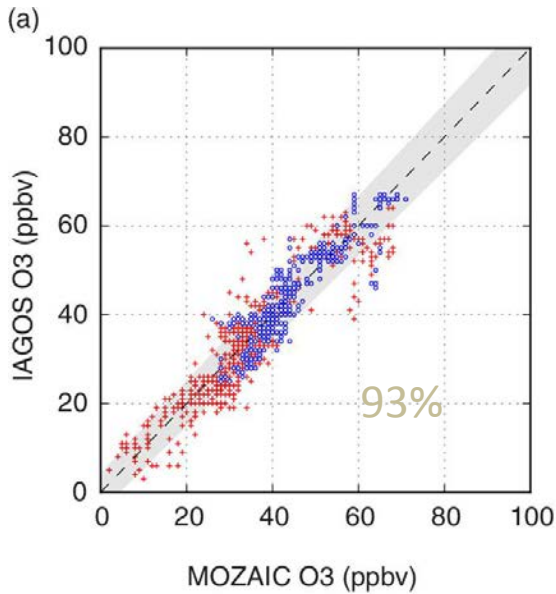
delta_t < 3 hours ➔

32 & 55 vertical profiles, over Frankfurt between July 2011 and December 2012

Nedelec et al., Tellus-B 2015

Blot et al., in prep.

➔ 70% for O3 on average, 90 % for CO ; Same consistency over the 20 (12) years period.
➔ IAGOS can be considered as the continuation of MOZAIC with the same data quality of O3 and CO measurements. A single data set to calculate trends from 1994 (2002).

# Internal Consistency of RH by MCH & ICH: Direct Matching in Space and Time







Source: Offermann et al., JGR, 2002
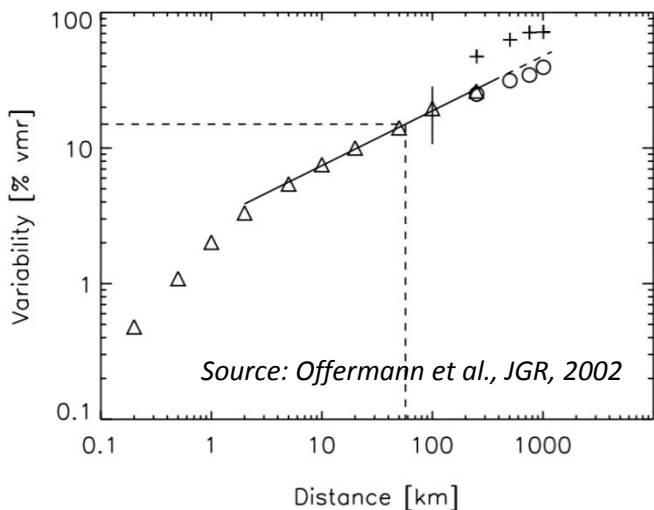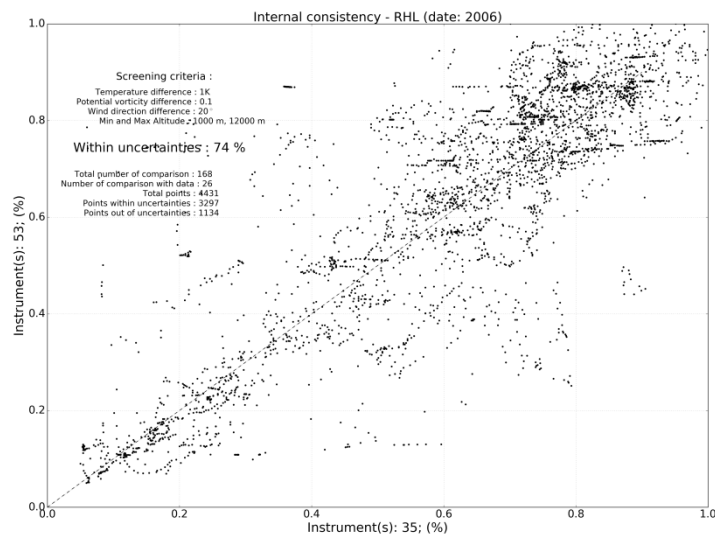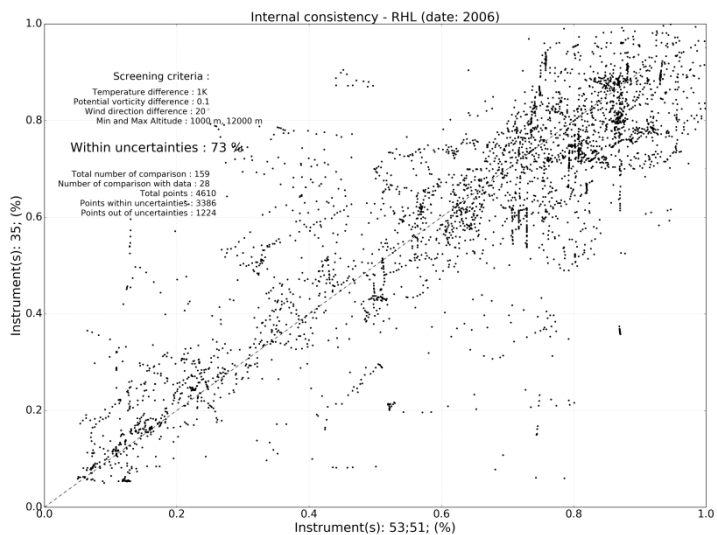
1. Natural variability of H2O already:
   - > 20 %  over radius = 100 km
   - > 10 %  over radius = 20 km
   - < 1% over radius < 1 km

2. When matching in time and space H2O internal consistency cannot be done on statistical base but only by careful flight by flight and by use of trajectory analysis

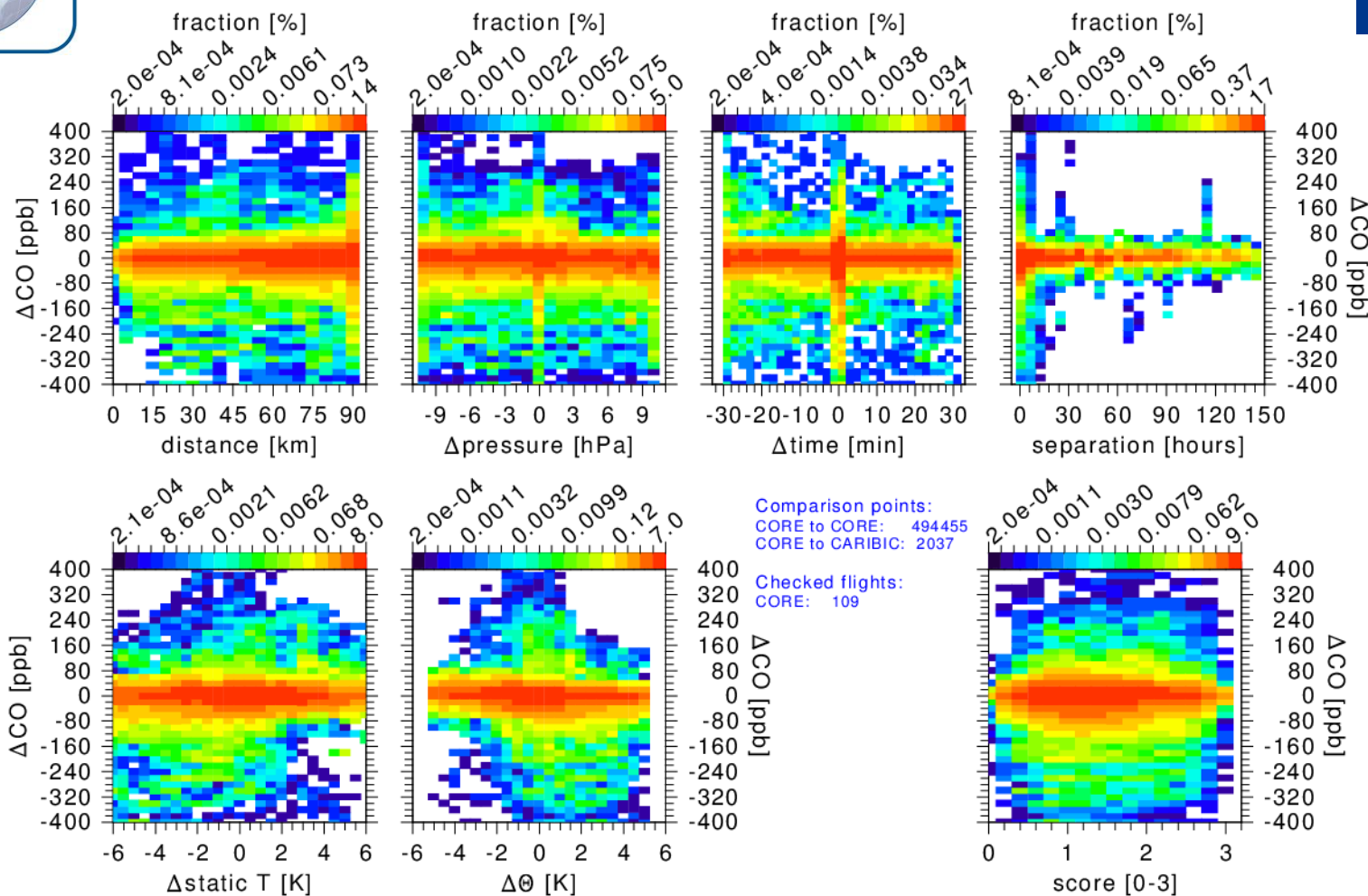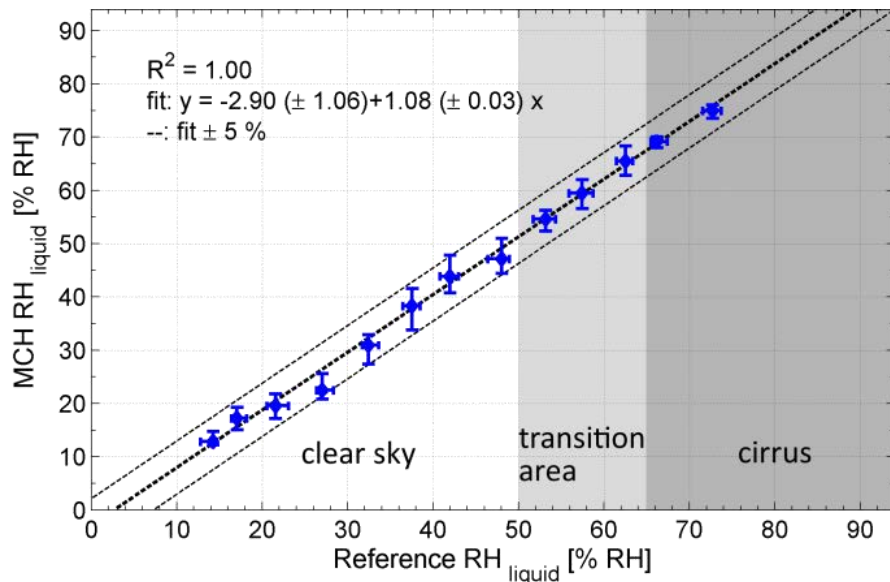# Development Lagrangian Tool for Matches in Time and Space



**Figure 3:** *Coincidence statistics for all flights with CO measurements in January – June 2012 but restricted to coincidences which not only fall within the specified limits for distance, pressure difference and time difference but where the (dry) potential temperature difference ΔΘ between the two measurements is not larger than 5 K. Note that the axis scaling for ΔT and ΔΘ is different than before.*

# External Consistency MCH & ICH:
## Research Flight Inter Comparison Against Ly (a)
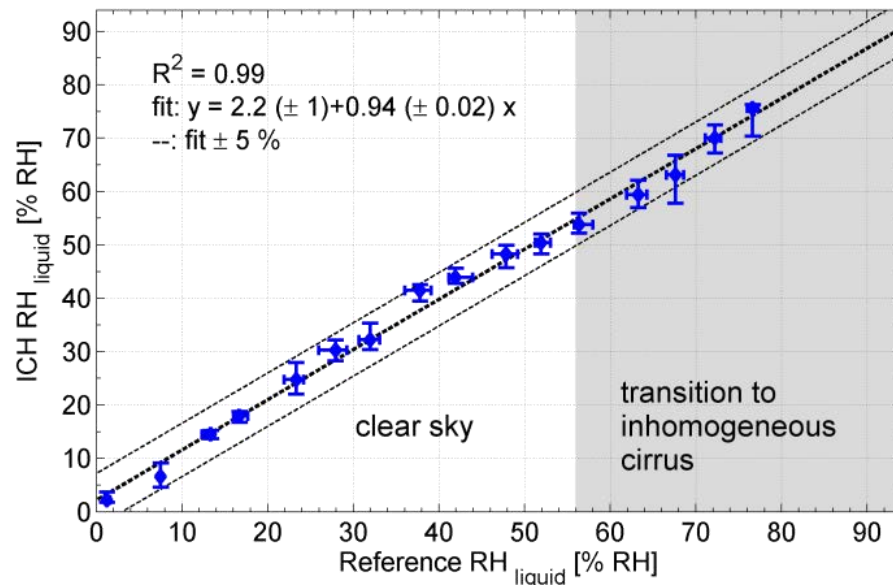## On board of Learjet operated by GFD/Enviscope

### CIRRUS-2006: MCH versus FISH          AIRTOSS-2013: ICH versus FISH



$R^2 = 1.00$
fit: y = -2.90 (± 1.06)+1.08 (± 0.03) x
--: fit ± 5 %

clear sky     transition area     cirrus

*Neis et al., AMT 2015*



$R^2 = 0.99$
fit: y = 2.2 (± 1)+0.94 (± 0.02) x
--: fit ± 5 %

clear sky     transition to inhomogeneous cirrus

*Neis et al., Tellus 2015*

- Agreement MCH and ICH with FISH within 5% RHL-uncertainty
- No bias at transition from MCH- to ICH-instruments

*MCH = MOZAIC Capacitive Hygrometer*

*ICH   =  IAGOS Capacitive Hygrometer*

*FISH= Fast In-situ Stratospheric Hygrometer (Ly(a) Fluorescence Detection)*

- **Tasks IAGOS-QA/SAC:**
  1. Watch over SOP's
  2. Collecting on regular base (1-2 years) all QA/QC-protocols which should contain all information on performance pre-, in- and post-flight operation, calibration and internal and external consistency)
  3. Every 1-2 year internal review by instrument PI's
  4. Every 5 years preparation of assessment report on the performance of each instrument by its PI.
  5. Review of assessment reports by external experts
- Report to IAGOS-AISBL and alert about eventual impact on archived data at IAGOS-Data Base

**<u>More Info on IAGOS at https://www.iagos.org</u>**

# Reserve Slides

# IAGOS - CORE Data Flow
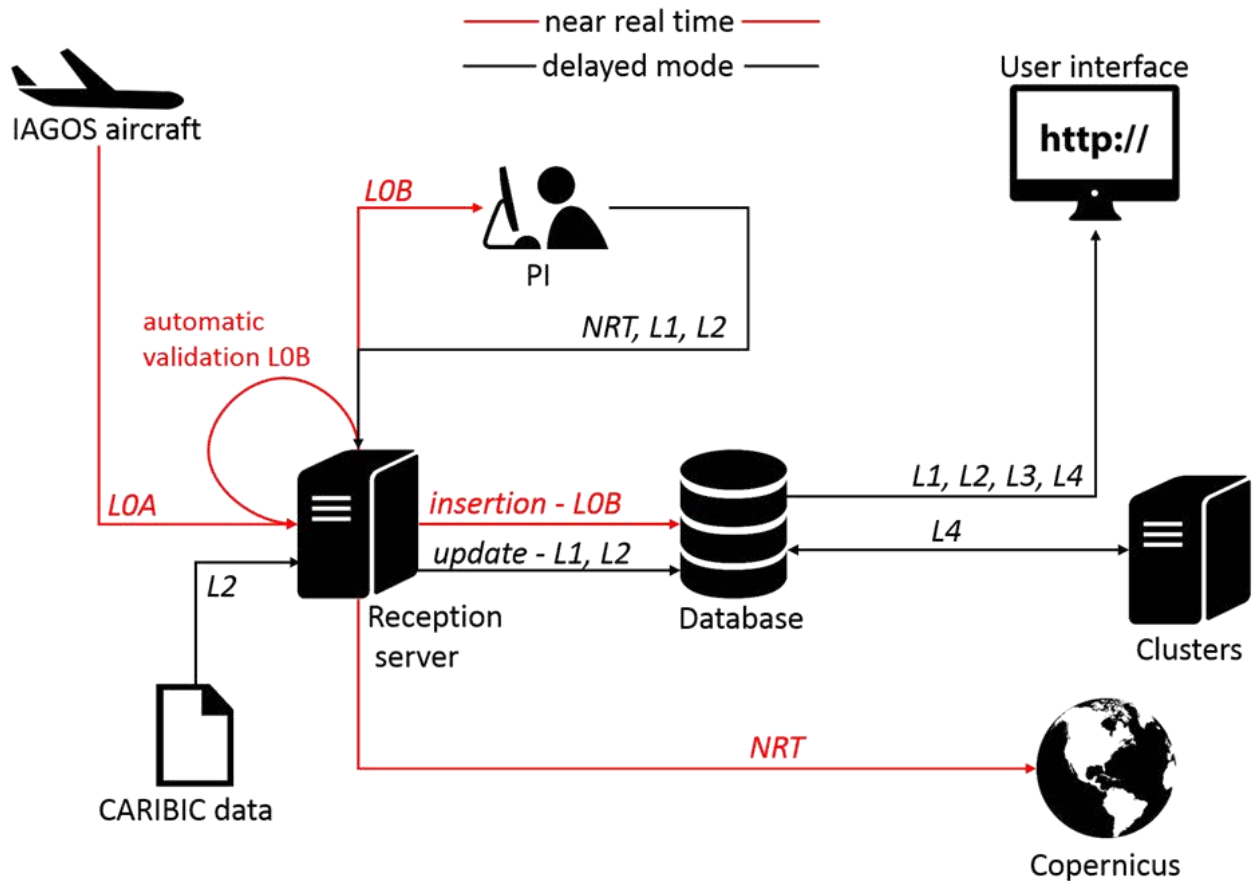


The IAGOS central database is hosted by AERIS (CNES-CNRS/INSU) in Toulouse.
Date access is free and open, the database can be accessed at www.iagos-data.fr

# Implementation IAGOS-QA/QC Concept into Infrastructures of IAGOS & WMO/GAW (1)

**IAGOS-QA/QC concept has been successfully developed and tested its QA/QC Procedures and Tools such that it can now be implemented into IAGOS operational infrastructure.**

- **Available components in IAGOS-AISBL:**
  1. IAGOS-instruments (observations) : installed & operated @ aircraft
  2. IAGOS-calibration & maintenance facilities
  3. IAGOS-Data Base
  4. IAGOS-QA/QC evaluation frame work with tools to test on consistency
- **Next steps**
  I. Establishment of QA/QC evaluation frame work as an additional component of IAGOS-operation
  II. Constitute the IAGOS-QA/SAC as an entity that consists of IAGOS-instrument PI's coordinated by the IAGOS-AISBL secretary
  III. Linkage to WMO-GAW QA/QC infrastructure with a IAGOS-QA/SAC; Incl. link to the GAW-SAG's (Scientific Advisory Groups)

## More Info on IAGOS at https://www.iagos.org

# IAGOS-QA/QC-Preparatory Work: Layout of SOP's

**Table of Content**

1. **Rationale**

   *{Measurement objectives}*

2. **Description of Method**

   *{Measurement principle, Description of instrument, Instrument operation, Data acquisition and*
   *storage}*

3. **Maintenance and Calibration**

   *{Test procedures, Calibration methodology and standards: Traceability}*

4. **Data Analysis and Uncertainty Assessment**

   *{Data Flow, Calculation of results, Uncertainty Analysis, Validation and Flagging}*

5. **Specifications**

   *{Brief overview of technical specifications with table}*

6. **References**

7. **Glossary**

Annexes

Leading principle is that ***each stored IAGOS-measurement*** consists of:

A.  ***Measured value*** as obtained in the SOPs of the measuring IAGOS instrument

B.  ***Overall Uncertainty*** in same physical quantity as measured value. It consists of the sum of all uncertainty contributions of calibration and in-flight performance (Incl. sampling) as described in the SOPs of the measuring IAGOS instrument.

C.  ***Flag Code:*** (i) giving state of processing/validation; (ii) reliability

For more details see the "Guidelines of data storage of IAGOS-measurements" document which is available at:
*http://www.igas-project.org/index.php/Internal/Workpackagedocuments*