Long-term IAGOS/MOZAIC-H2O Measurements in the UTH at Cruise Altitude (10-12 km) : In-Service Aircraft For Global Observing Platform

www.iagos.org

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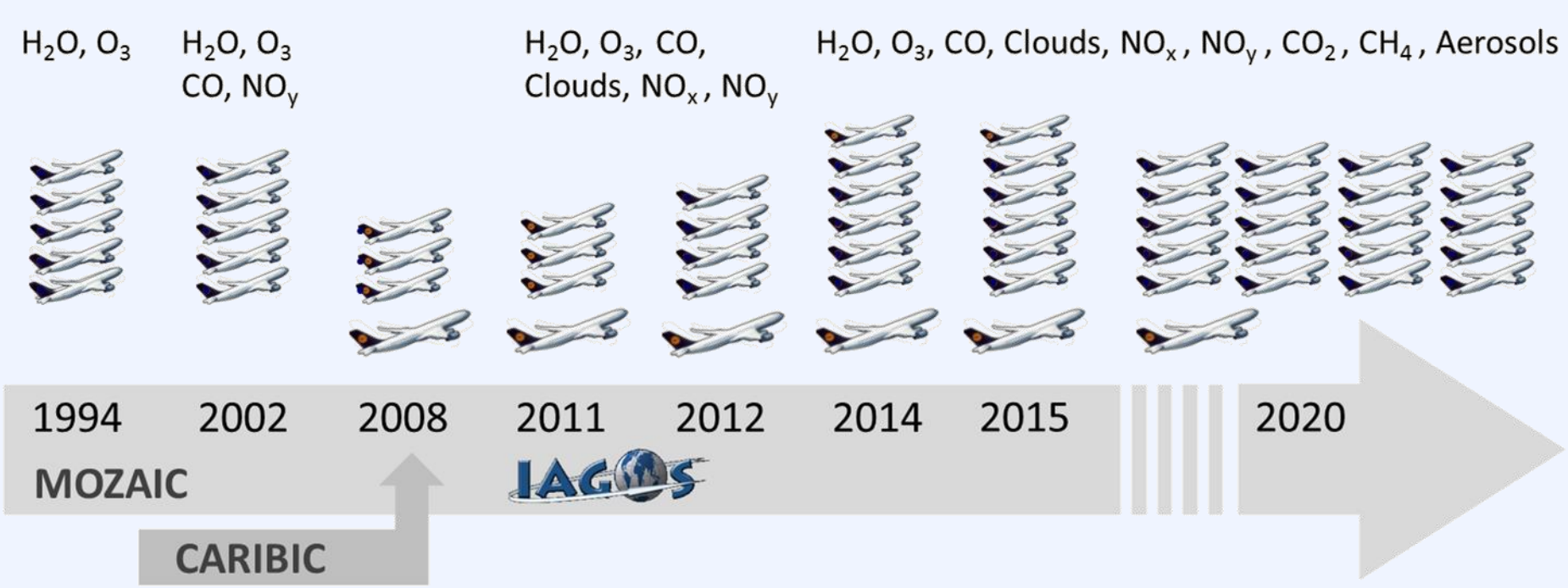
IAGOS Team

IAGOS/MOZAIC-H2O : GRUAN/ICM-8 , Boulder, 25 April 2016

In-service Aircraft for a Global Observing System

European Research Infrastructure

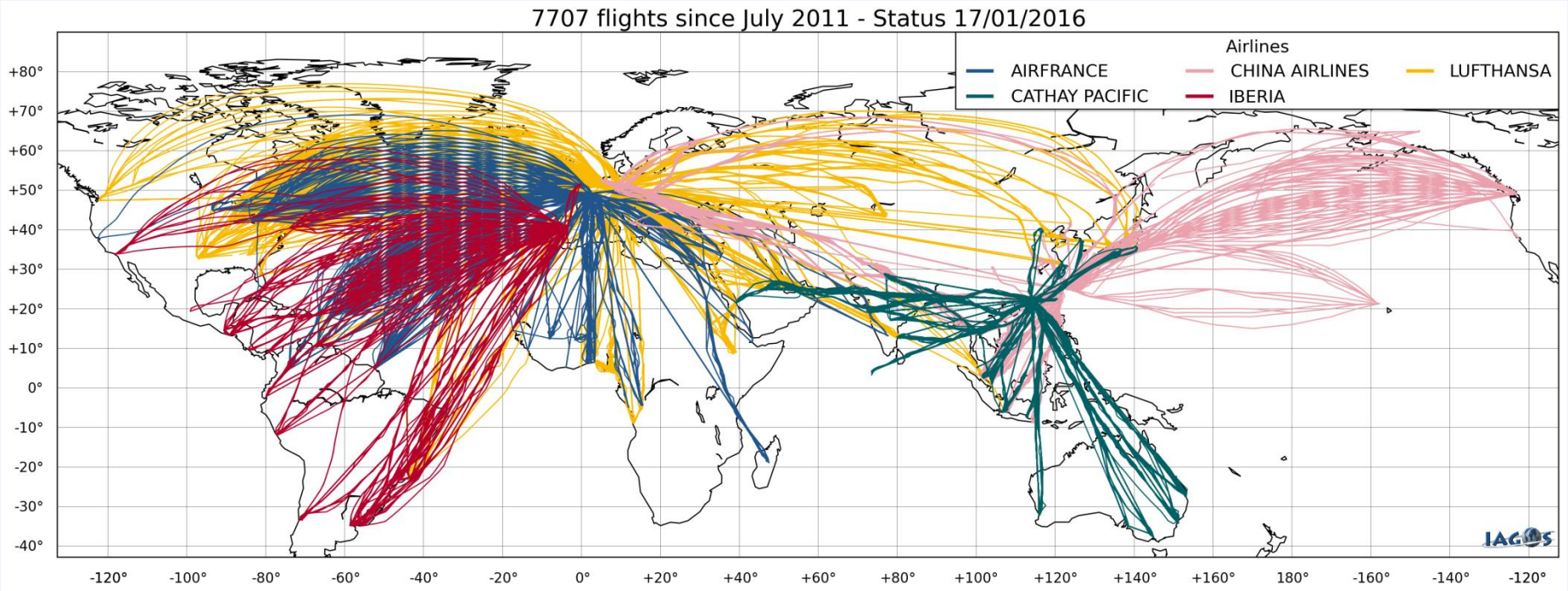
- 20 equipped long-haul aircraft : CORE (former MOZAIC)
- 1 flying laboratory: CARIBIC



Coordination: A.Petzold@fz-juelich.de

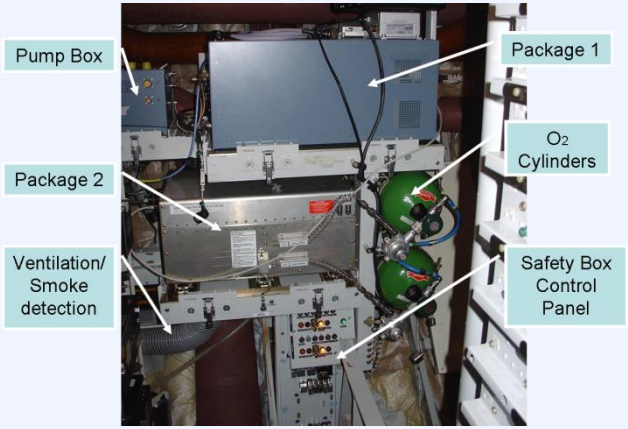
IAGOS - CORE Flight Map

http://www.iagos.fr

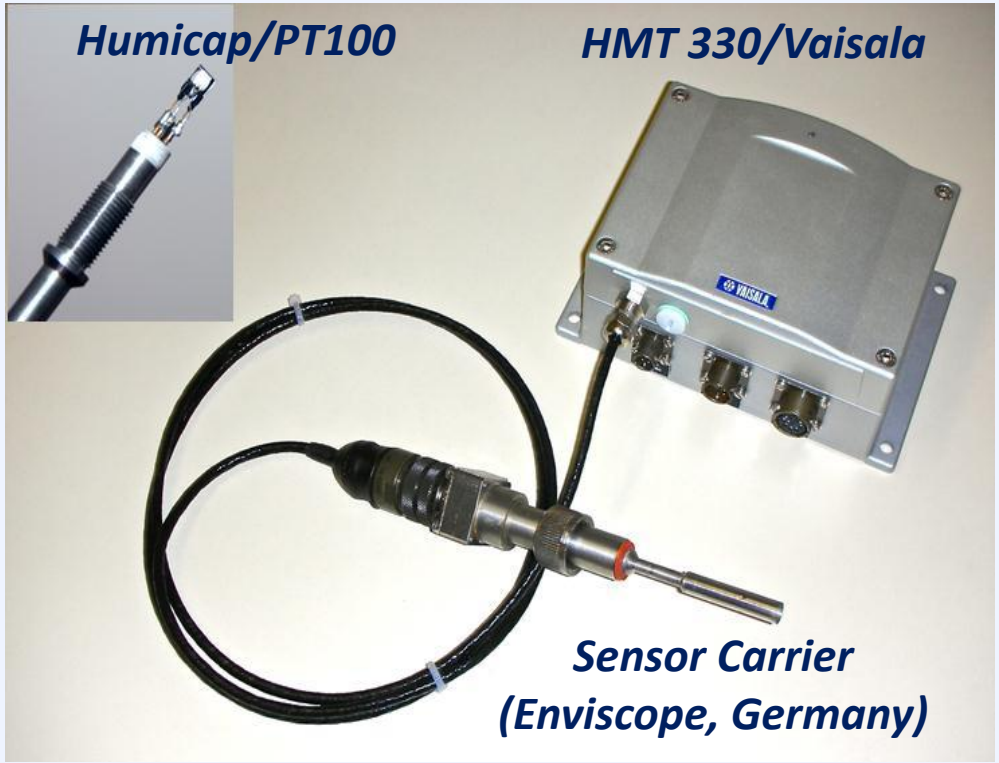


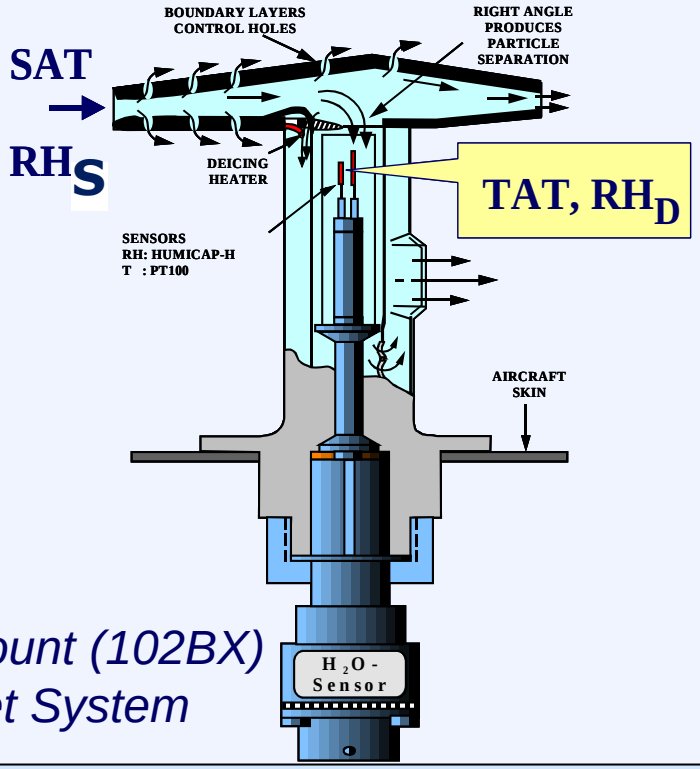
IAGOS-CORE aircraft schedule:

- In 2015, 6 equipped aircraft in regular operation
- Approx. 500 flights per aircraft per year
- More than 200 airports worldwide visited regularly



IAGOS & MOZAIC: RH,T Sensor in TAT-Inlet



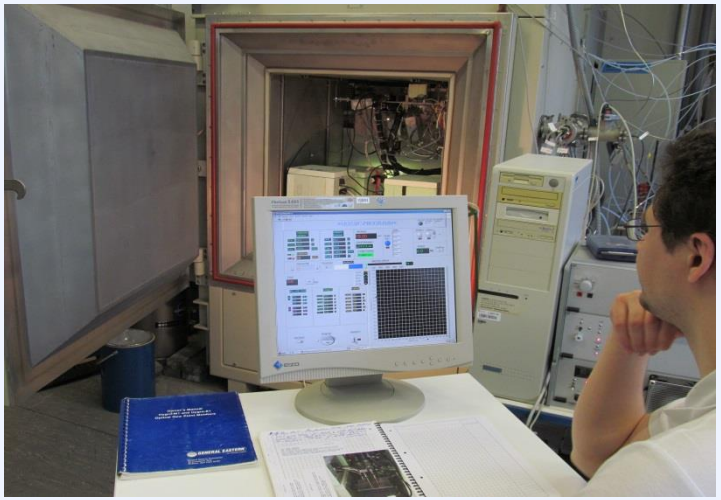


Rosemount (102BX) TAT-Inlet System

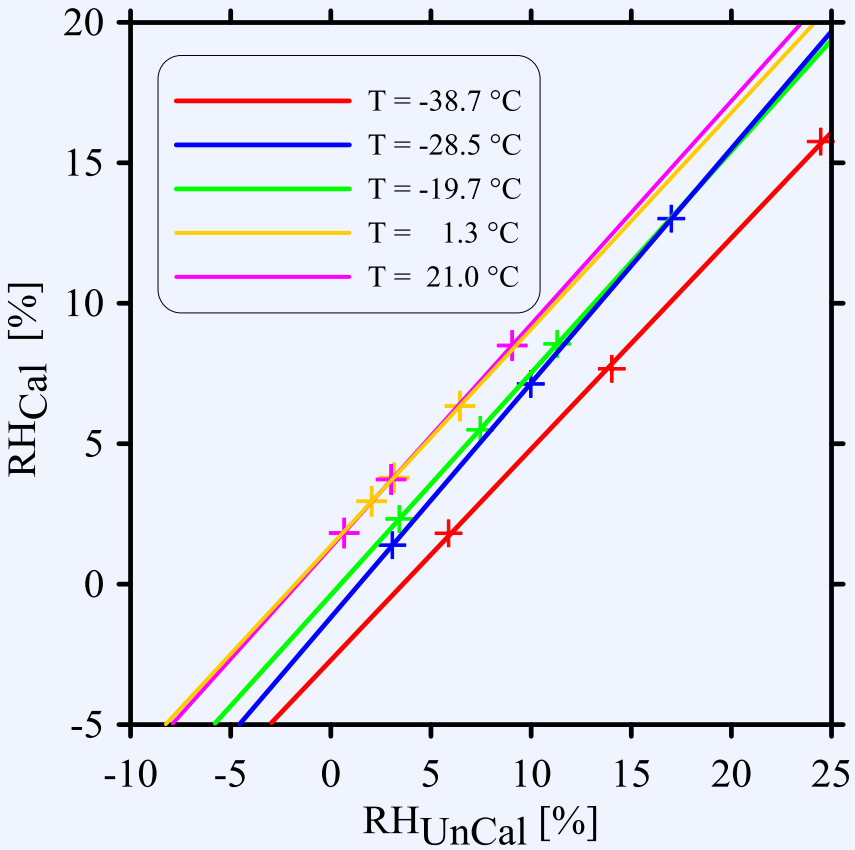
In inlet strong speed reduction (Mach≈0.8 to 0) with adiabatic conversion:

- Heating (SAT to TAT) : in UT ≈ 30°C
- Compression (P_S to P_D): in UT ≈ Factor 1.6
- **RH at detector (RH_D) more than factor 10 smaller than RH sampled air (RH_S)**

IAGOS & MOZAIC Capacitive Hygrometer (MCH & ICH): Pre- & Post-Flight Calibration



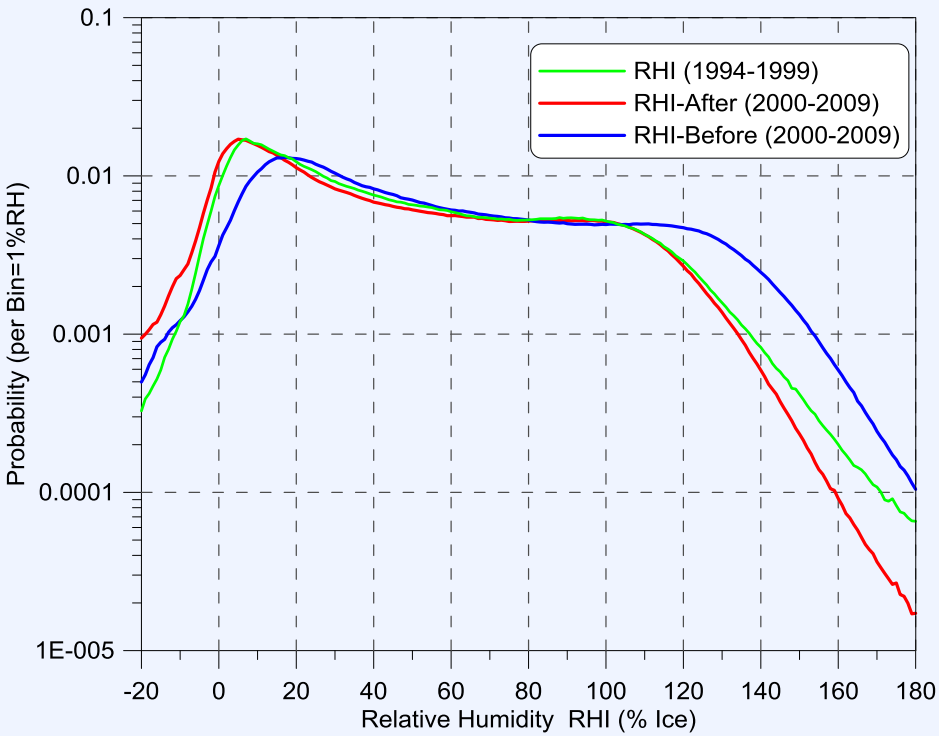
$$RH_{Cal}(T_i) = a(T_i) + b(T_i) \times RH_{UnCal}(T_i)$$



- Regular calibration (every 500-1000 flight hours in the environmental simulation chamber at Juelich, Germany
- Against Lyman(α)-fluorescence hygrometer at T_{Air} <-10 °C and Frost-point hygrometer at T_{Air}>-10 °C with relative uncertainty better than 5%
- Under realistic „flight“ conditions of humidity, temperature and pressure

MOZAIC: Reanalysis of Rel.Humidity Data 2000-2009

- Problem: RHI-data since 2000 systematic about 10-15% too high compared to 1994-1999 data
- Cause: Systematic temperature offset of about -2°C in the pre-&post- flight calibrations made at the laboratory (ESF)



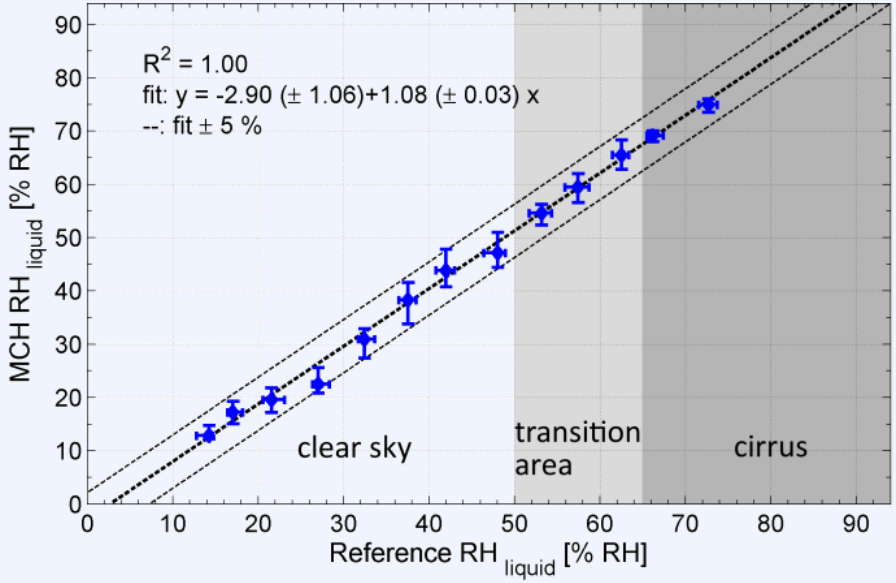
Solution:

1. Reprocessing & Validation of
   - All calibrations since 2000
   - All flight data since 2000
2. Documented in peer reviewed article in ACP by end of 2014 (*)
3. Submission of revised data into IAGOS-data base at CNRS in Toulouse, France in Summer 2016

(*) Smit, H.G.J., Rohs, S., Neis, P., Boulanger, D., Krämer, M., Wahner A., Petzold, A., Reanalysis of upper troposphere humidity data from the MOZAIC programme for the period 1994 to 2009 Atmos. Chem. Phys., 14, 13241–13255, 2014 (doi:10.5194/acp-14-13241-2014)

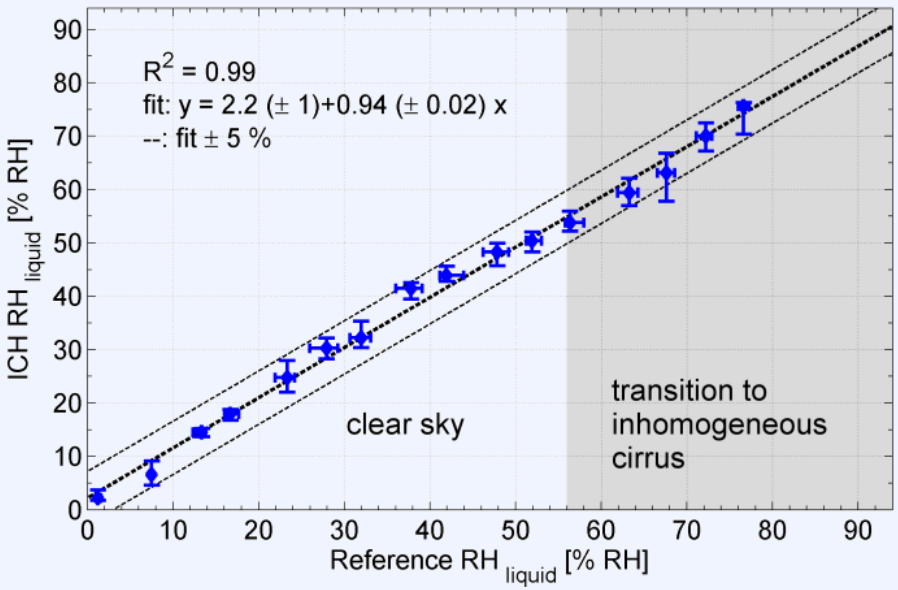
Transition MOZAIC-H2O (MCH) into IAGOS-H2O (ICH): In-Flight Intercomparisons with FISH as Reference Onboard Research Aircraft (Learjet)

CIRRUS-2006: MCH versus FISH



Neis et al., AMT 2015

AIRTOSS-2013: ICH versus FISH

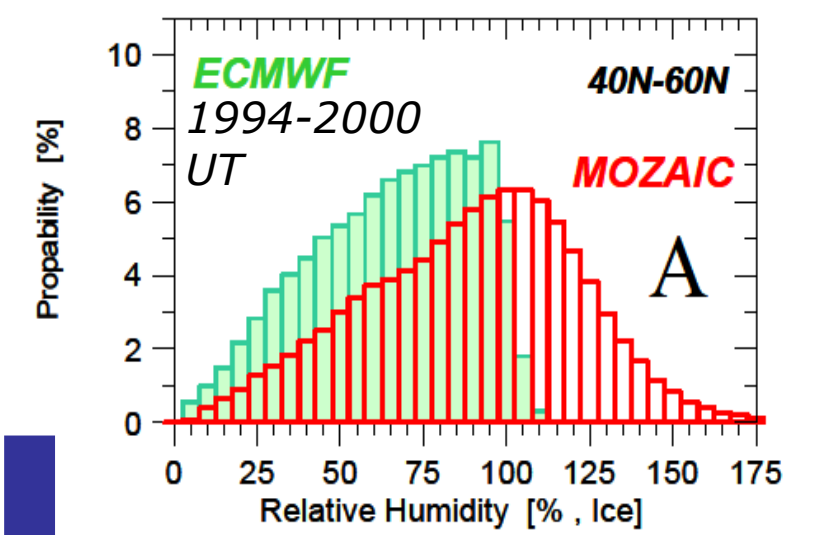


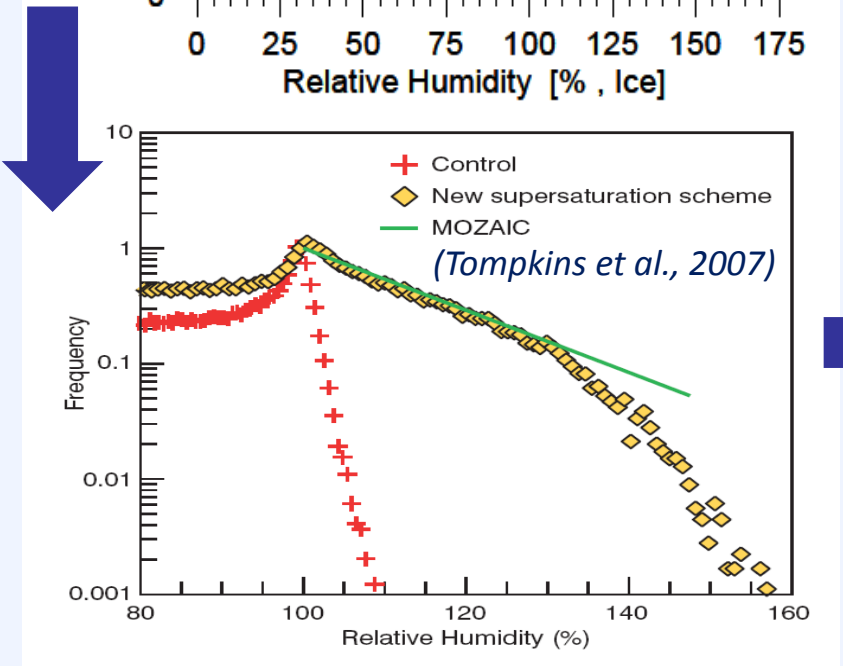
Neis et al., Tellus 2015

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

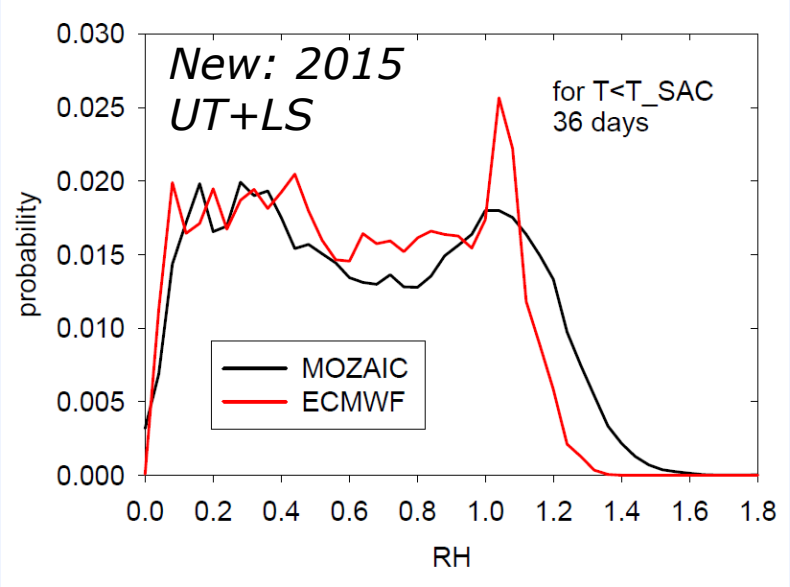
FISH= Fast In-situ Stratospheric Hygrometer (Ly(a) Fluorescence Detection)

MOZAIC: RH_{ice} in UT (Z=9-12 km, PV≤2.0) Over North Atlantic: Observations against ECMWF



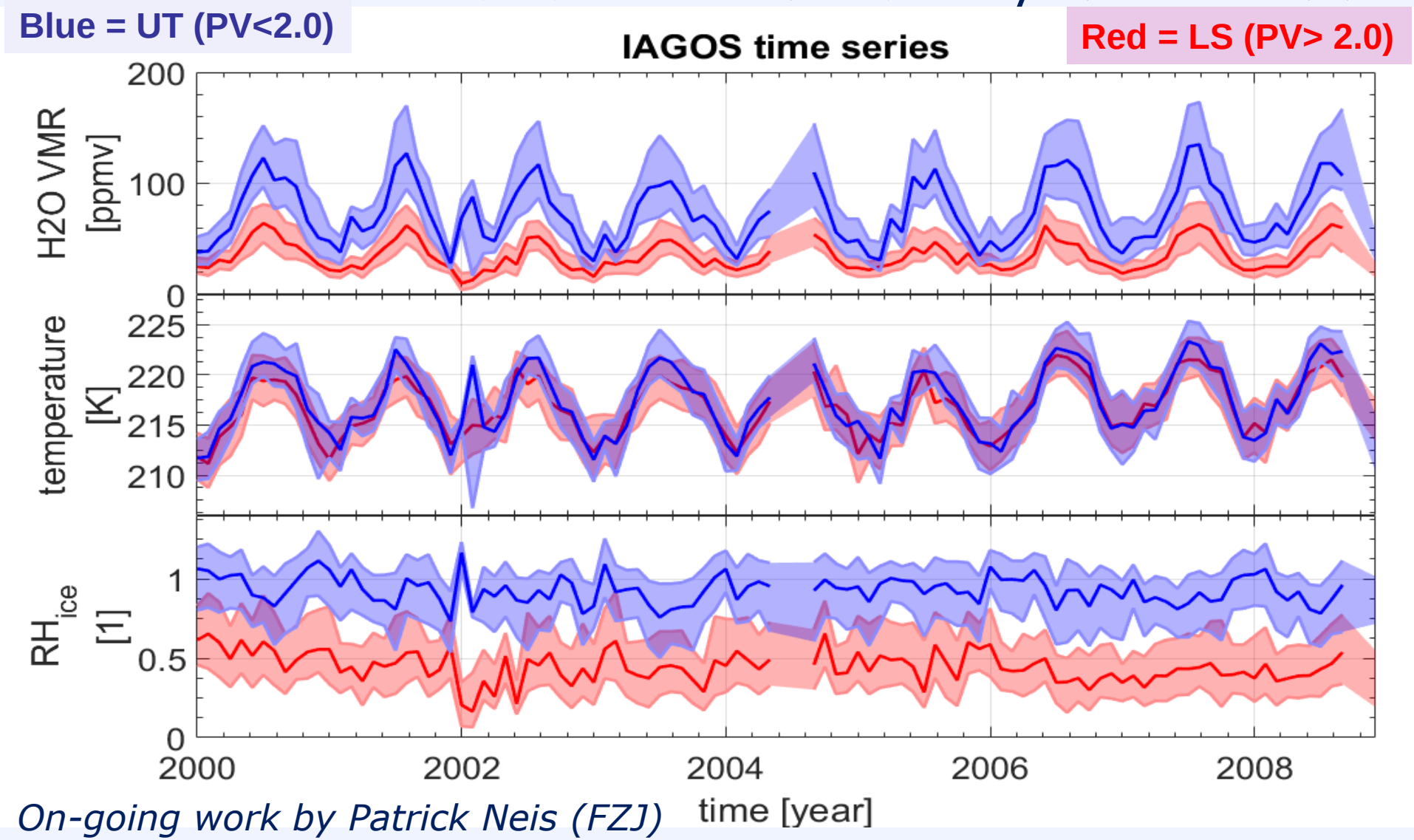


- UTH show large variability in time and space
- UT considerably more wet (up to factor 2)
- Significant part of MOZAIC-UTH (20-30%) show ice super saturation
- Ice super saturation associated with cirrus (sub-visible)



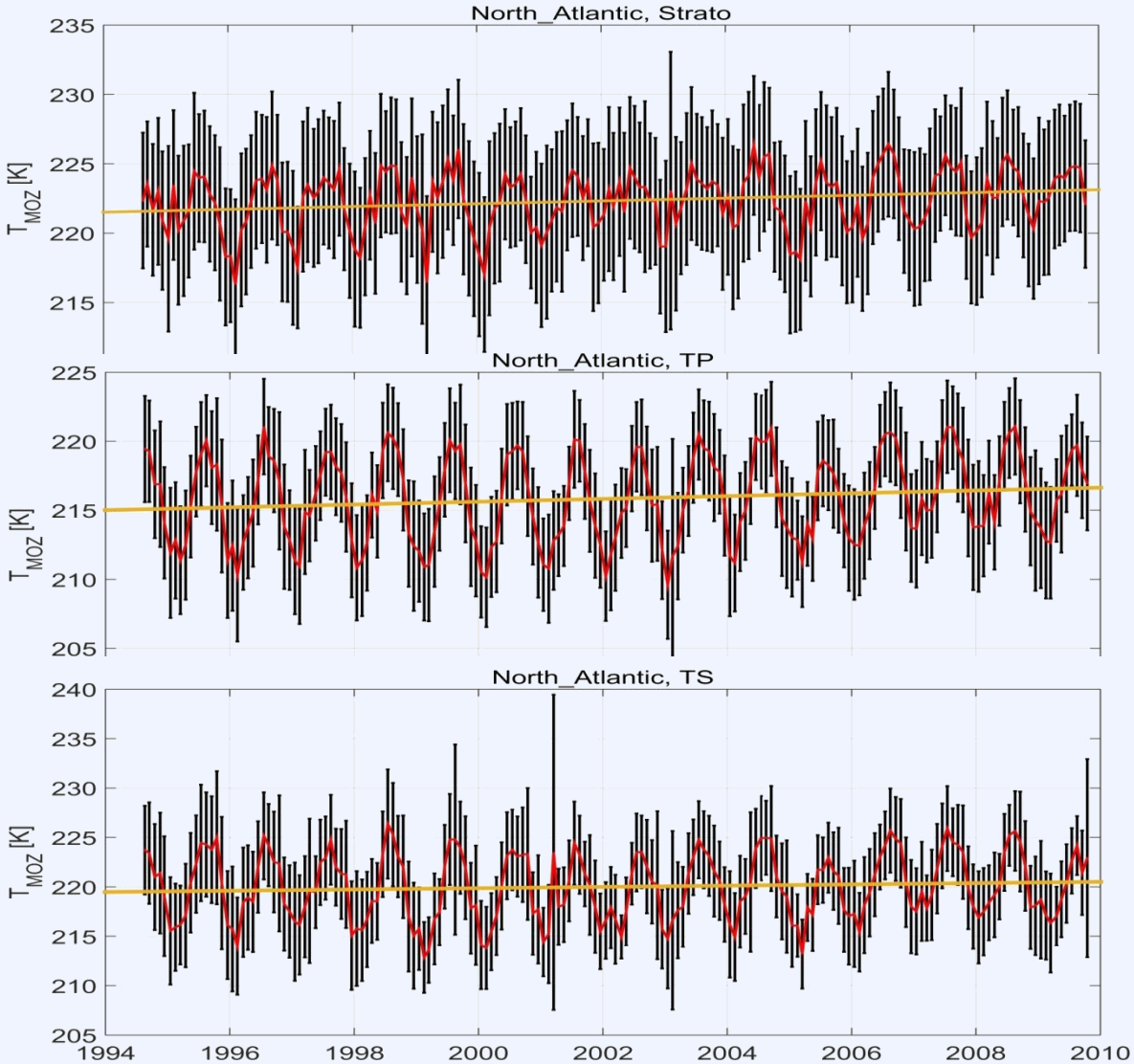
All RH over Ice!

UTLS-Humidity and Temperature over North Atlantic: Seasonal-Inter Annual Variation Measured by MOZAIC-MCH



On-going work by Patrick Neis (FZJ)

MOZAIC: Temperature



Intercomparison of 15 years of air temperature data from MOZAIC / IAGOS data.

Reference temperature for trend analysis was calculated as monthly average over the full period.

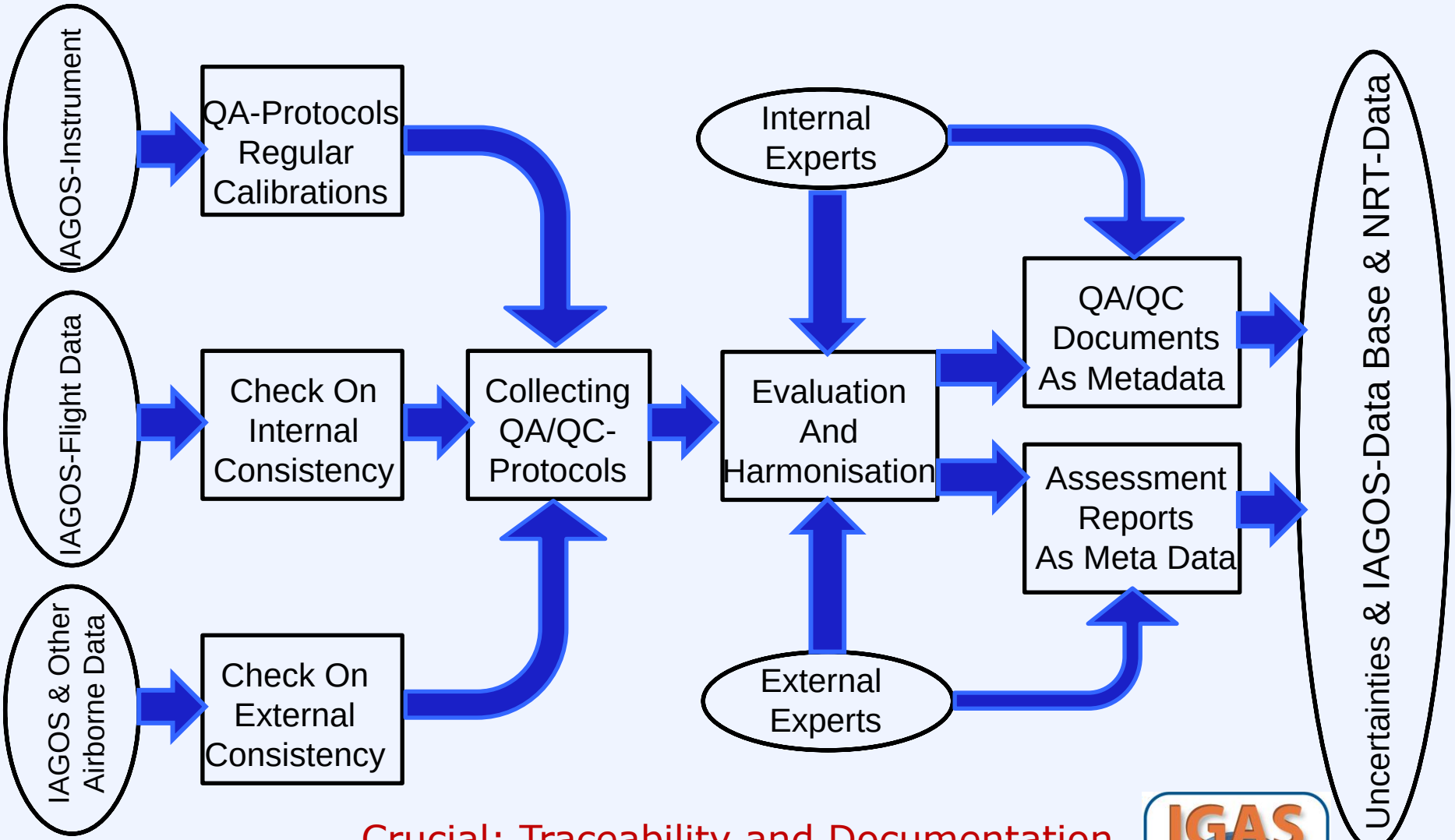
Observed temperature trends:

LMS	1.5K/15 yr
TP	1.5K/15 yr
UT	1.0K/15 yr

Work in progress
by Florian Berkes, FZ Juelich

IAGOS Concept QA/QC Evaluation & Harmonisation

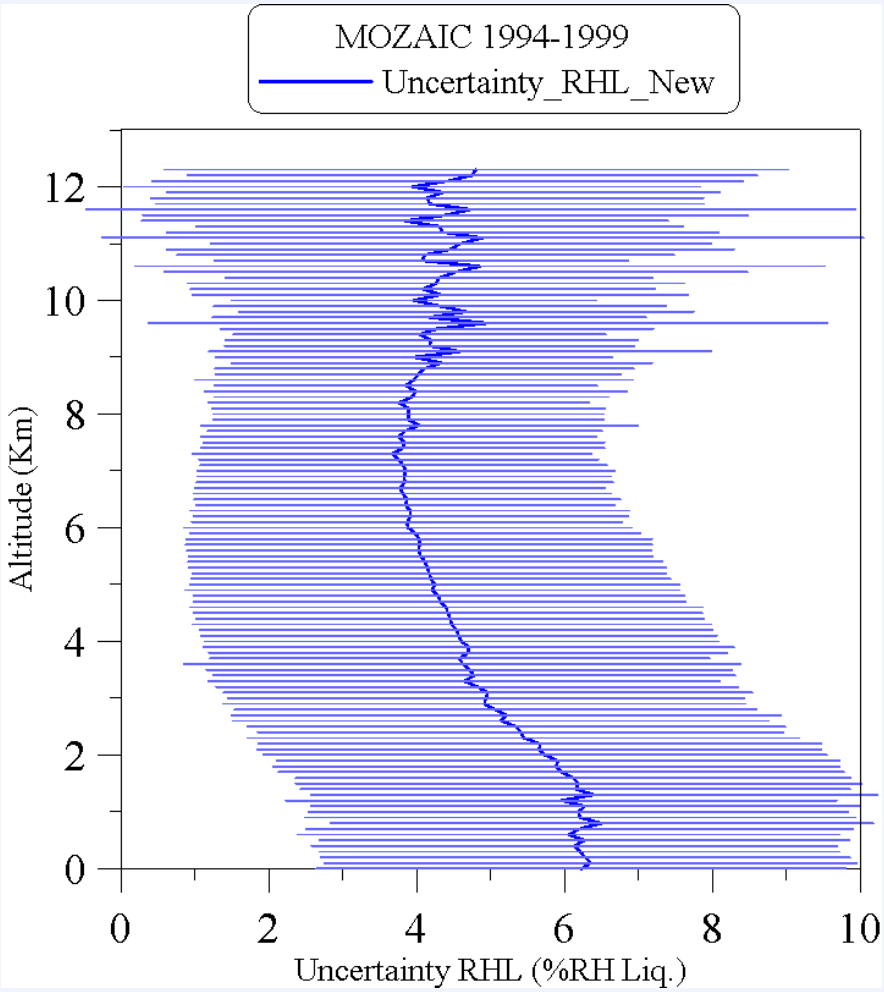
(Adapting QA-Concept of GAW (IGACO))

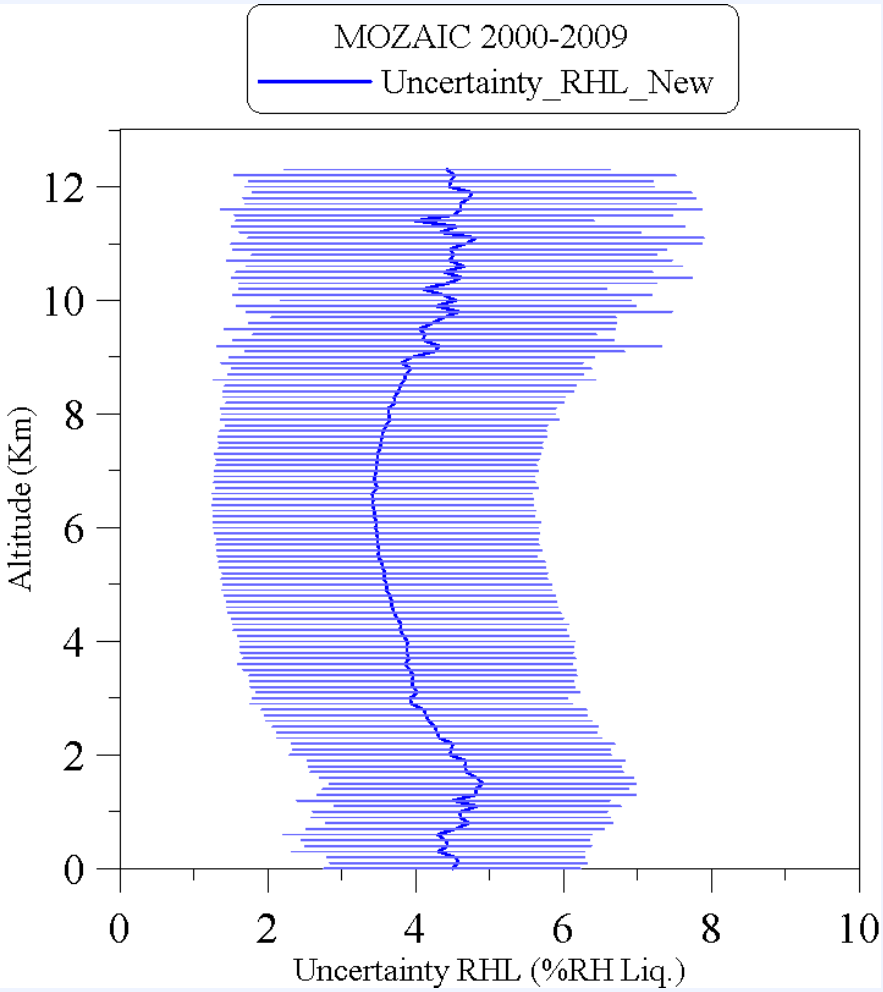


Crucial: Traceability and Documentation

Reserve Slides

MOZAIC-Capacitive Hygrometer (MCH): Average Uncertainty RHL (Z) For 1994-1999 & 2000-2009



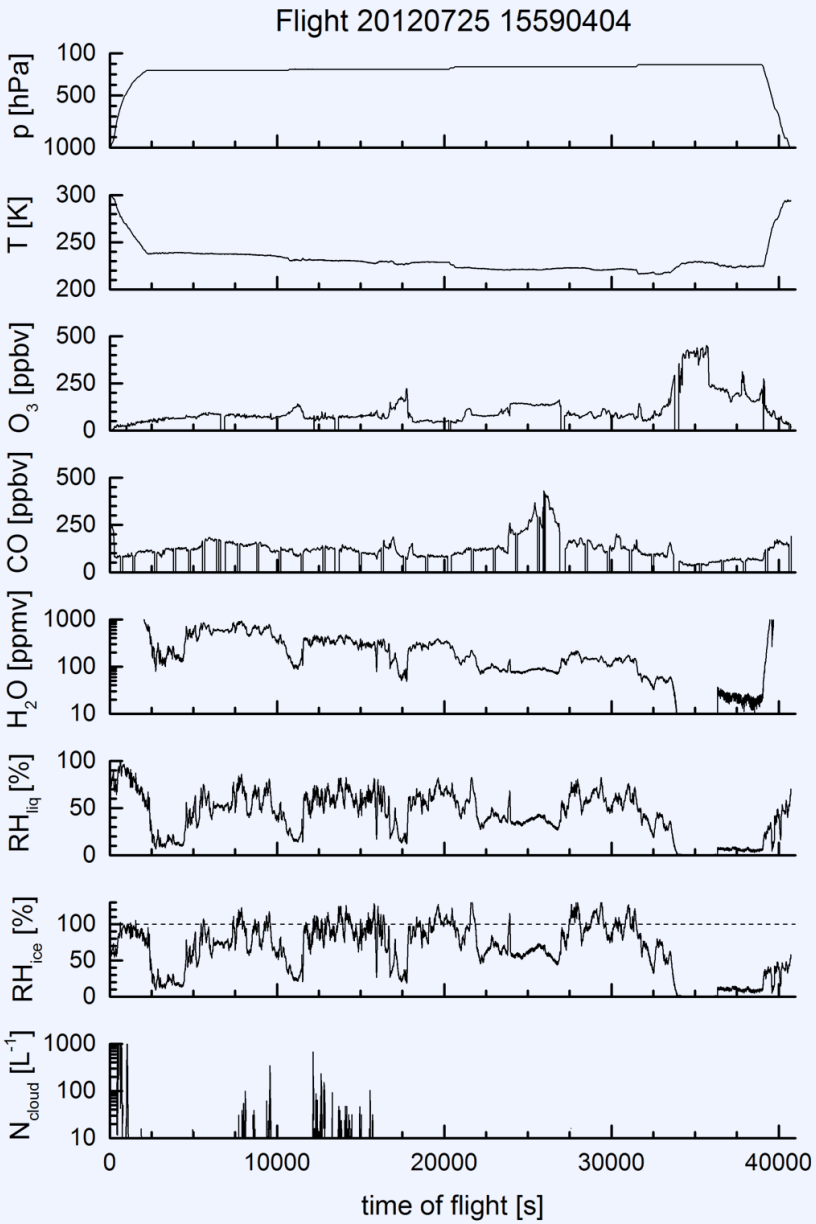


Transition from MOZAIC to IAGOS

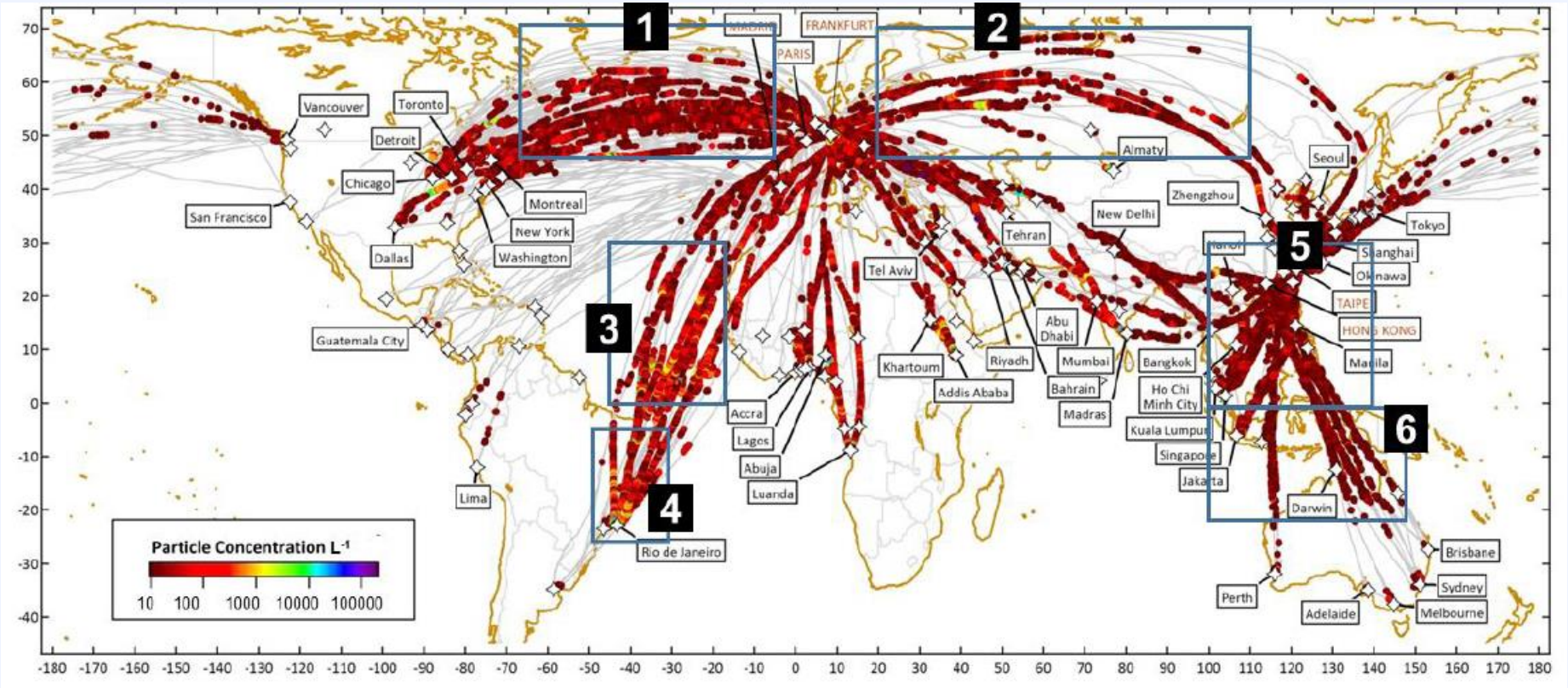
IAGOS add-ons:

- Regular Trans-Pacific flights routes thanks to the participation of China Airlines and Cathay Pacific.
- Detection of clouds; separation of cloud-free and in-cloud data.
- New species and parameters added to the data set (final instrument certification is pending).

Example: Complete data set from one Trans-Pacific flight between Taipei and Vancouver.



Global Observation of Clouds



This map lays out a summary of all the flight trajectories of the five aircraft from 2012 to 2014. The filled circles mark cloud encounters. The color is proportional to the number concentration. The six numbered regions are (1) Extratropical Atlantic, (2) Extratropical Eurasia, (3) Tropical Atlantic, (4) Eastern Brazil, (5) Southeast Asia Maritime/Continental and (6) New Guinea Maritime/Continental. K. Beswick et al., Tellus B 2015

In-service Aircraft for a Global Observing System

European Research Infrastructure

20 equipped long-haul aircraft + 1 flying laboratory

Technical Goals

- **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 and cloud particles
- **Long-term deployment** (20 years)
- **Global coverage**
- **Open data policy** (CAMS/GEO/GEOSS)
- **Near real time data provision**
- **Deploy the CARIBIC Container**

  Large number of species, including those above plus VOCs, CFCs, aerosol chem. composition, H_2 isotopes, SO_2

Scientific Objectives

- **Changes in the Tropopause Region**
  - ozone background and trend
  - water vapour background and trend
- **Validation of Atmospheric Models and Satellite Retrievals**
  - tropospheric profiles of H_2O, O_3, CO, CO_2, CH_4, NO_x, aerosol
- **Global Air Quality**
  - influence of developing regions
  - long-range transport of air pollutants
  - biomass burning, climate change, ...
- **International Transfer Standards**
  - same systems deployed globally

IAGOS - CORE

Permanent installations in the avionics bay of Airbus A340/A330
First flight of LH D-AIGT on 8 July 2011
Weight: 120 kg **Operation:** Continuous
6934 flights of IAGOS-CORE
45443 flight of MOZAIC/IAGOS

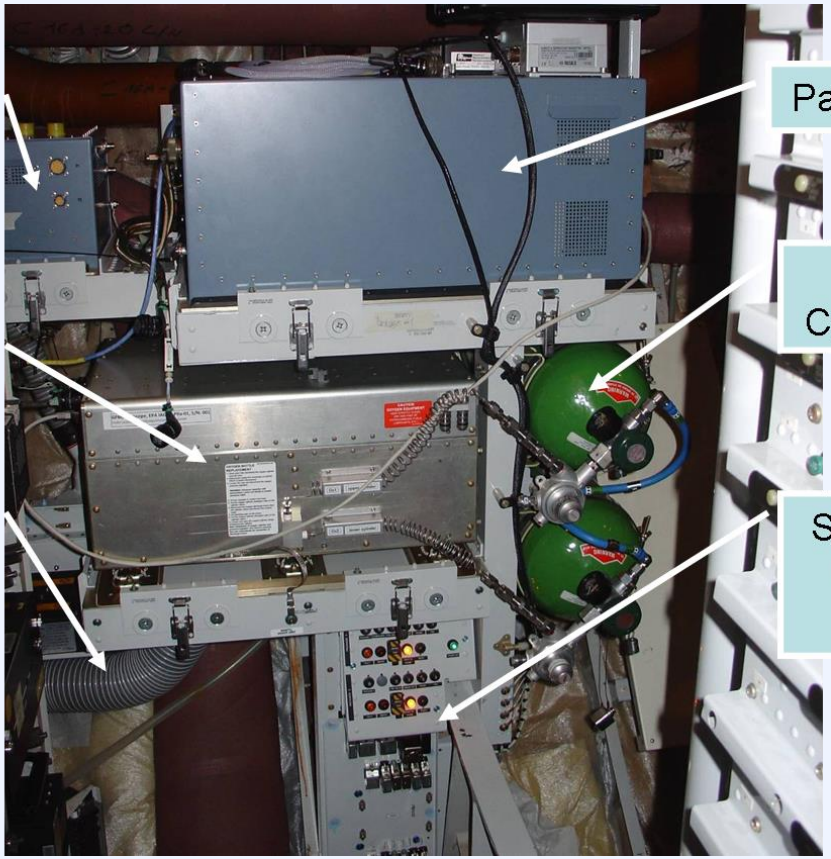
Photograph by courtesy of A. Karmazin

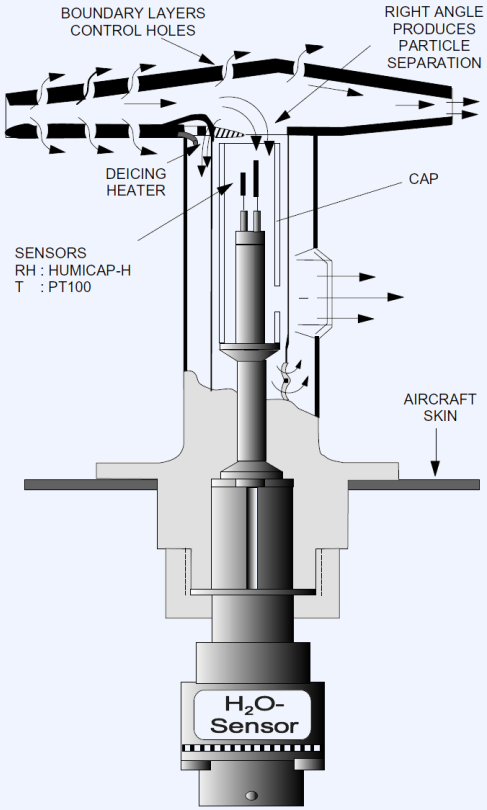
IAGOS CARIBIC

- Lufthansa Airbus A340-600
- Instrumented container 1.6 tons
- 15 instruments
- ~100 trace species and aerosol parameters
- 4 consecutive flights per month
- CARIBIC I: 1997 – 2002
- CARIBIC II: since 2005

CARIBIC flight routes
May 2005 – Sep 2015 (376 flights)

IAGOS - CORE Instrumentation





LEFT: IAGOS-CORE rack installed on an A340-300 a/c (120 kg)

RIGHT: IAGOS Capacitive Hygrometer

IAGOS - CORE Fleet 2015

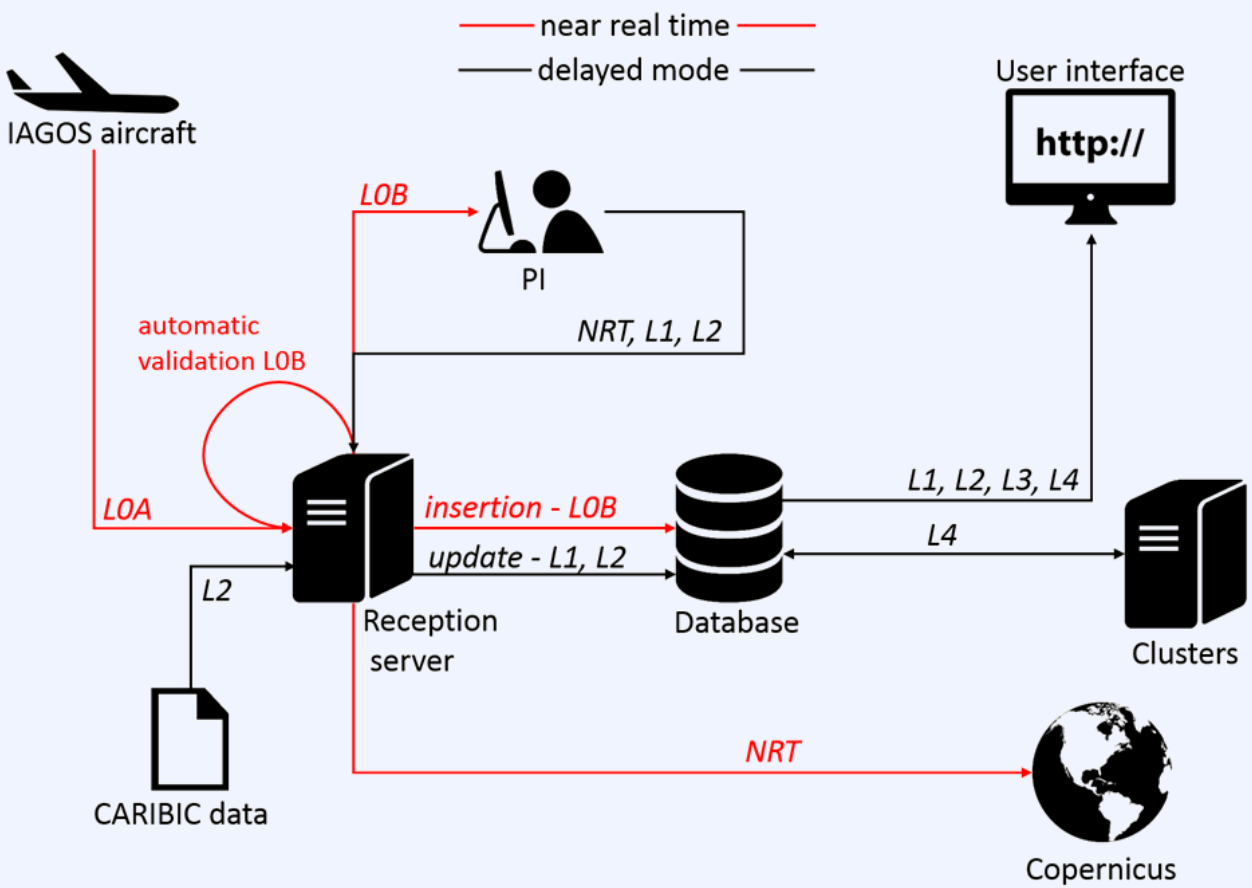
IAGOS - CORE Instrumentation

Configuration a	Configuration b	Configuration c	Configuration d
Package 1 (CNRS)	**Package 1 (CNRS)**	**Package 1 (CNRS)**	**Package 1 (CNRS)**
O_3, CO (CNRS) H_2O (FZJ) BCP (Uni MAN) RTTU (MF)	O_3, CO (CNRS) H_2O (FZJ) BCP (Uni MAN) RTTU (MF)	O_3, CO (CNRS) H_2O (FZJ) BCP (Uni MAN) RTTU (MF)	O_3, CO (CNRS) H_2O (FZJ) BCP (Uni MAN) RTTU (MF)
Package 2a (FZJ)	**Package 2b (FZJ)**	**Package 2c (FZJ)**	**Package 2d (MPG)**
NOy	**NOx**	**Aerosol** number density total, non-vol, acc	**Greenhouse Gases** CO_2 , CH_4 , H_2O, CO
O_2, Air	O_2, Air	Buta-nol, Buta-nol	Cal Gas, Cal Gas

Instrument configurations for IAGOS-CORE aircraft:

- Package 1 operates on all IAGOS-CORE aircraft and builds on the MOZAIC set-up
- Package 2 a-d (one option for one IAGOS-CORE aircraft)
  - Nitrogen-containing compounds (P2a, P2b)
  - Aerosol properties (P2c)
  - Greenhouse gases, mainly CO_2 and CH_4 (P2d)

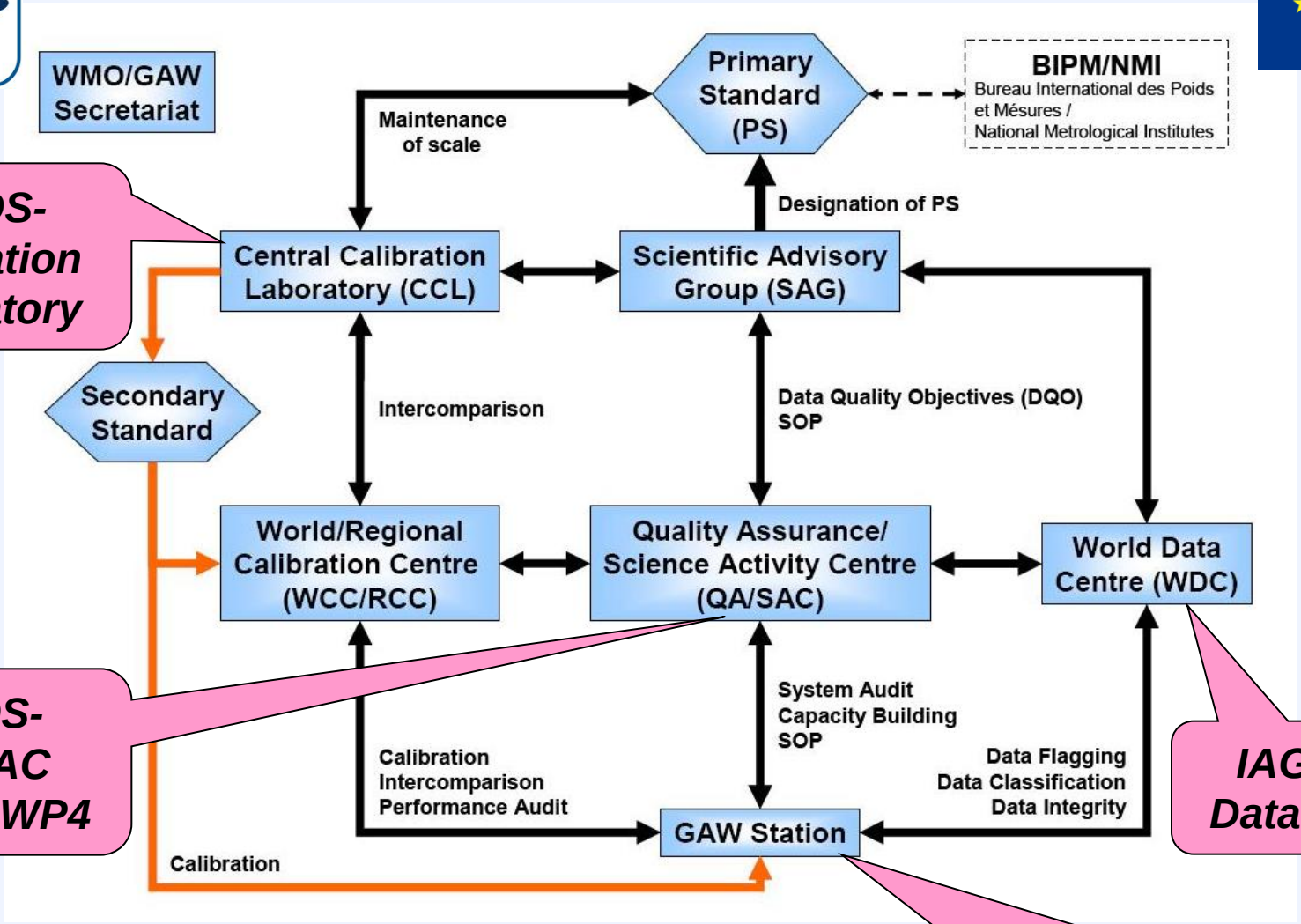
IAGOS - CORE Data Flow



Level	Description
L0A	raw data
L0B	automatically validated data
NRT	NRT for Copernicus use, bad data removed
L1	data validated by PI (preliminary data)
L2	calibrated data (final data)
L3	averaged data and climatologies
L4	added-value products

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

IGAS-WP4:
Adapting QA-Concept of GAW (IGACO)



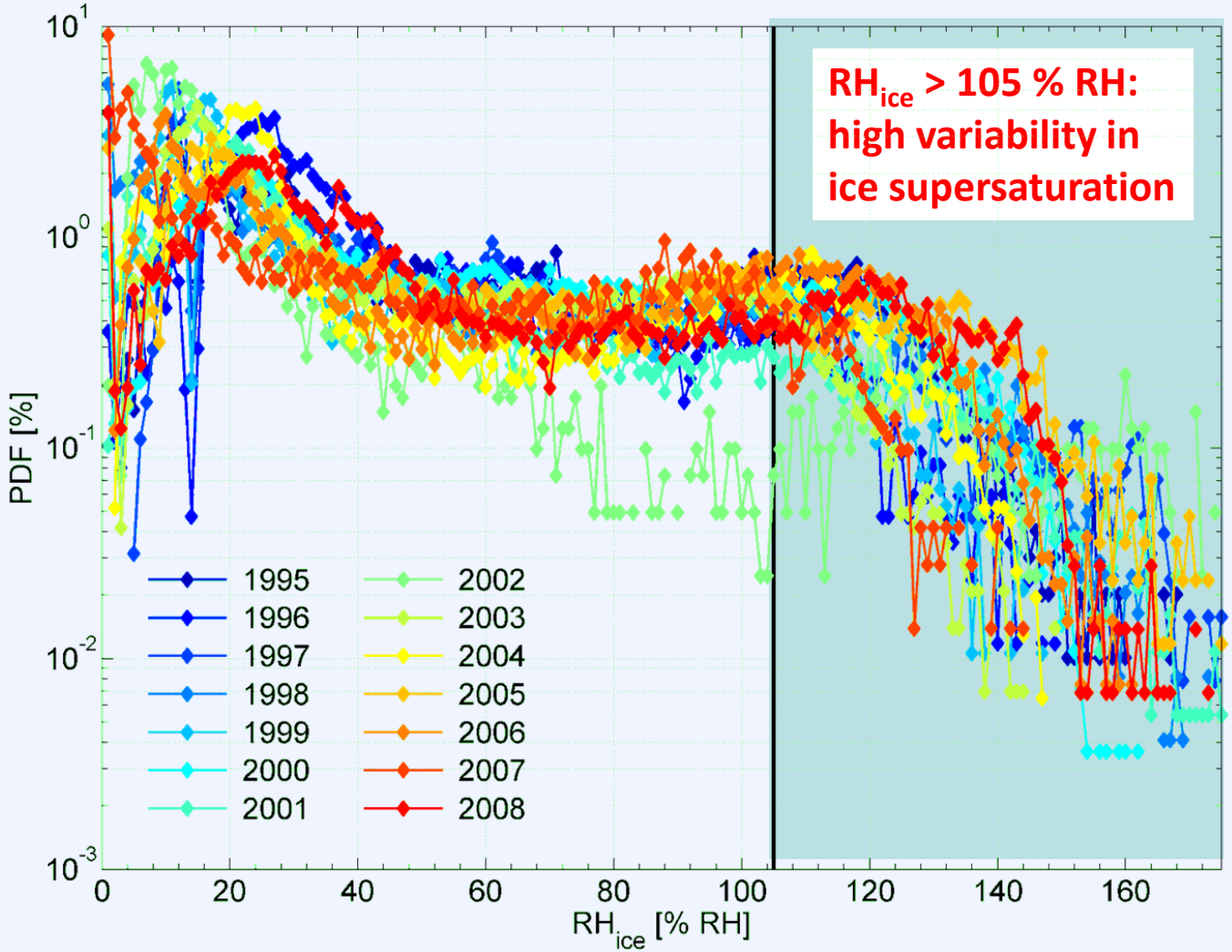
IAGOS-Calibration Laboratory

IAGOS-QA/SAC = IGAS-WP4

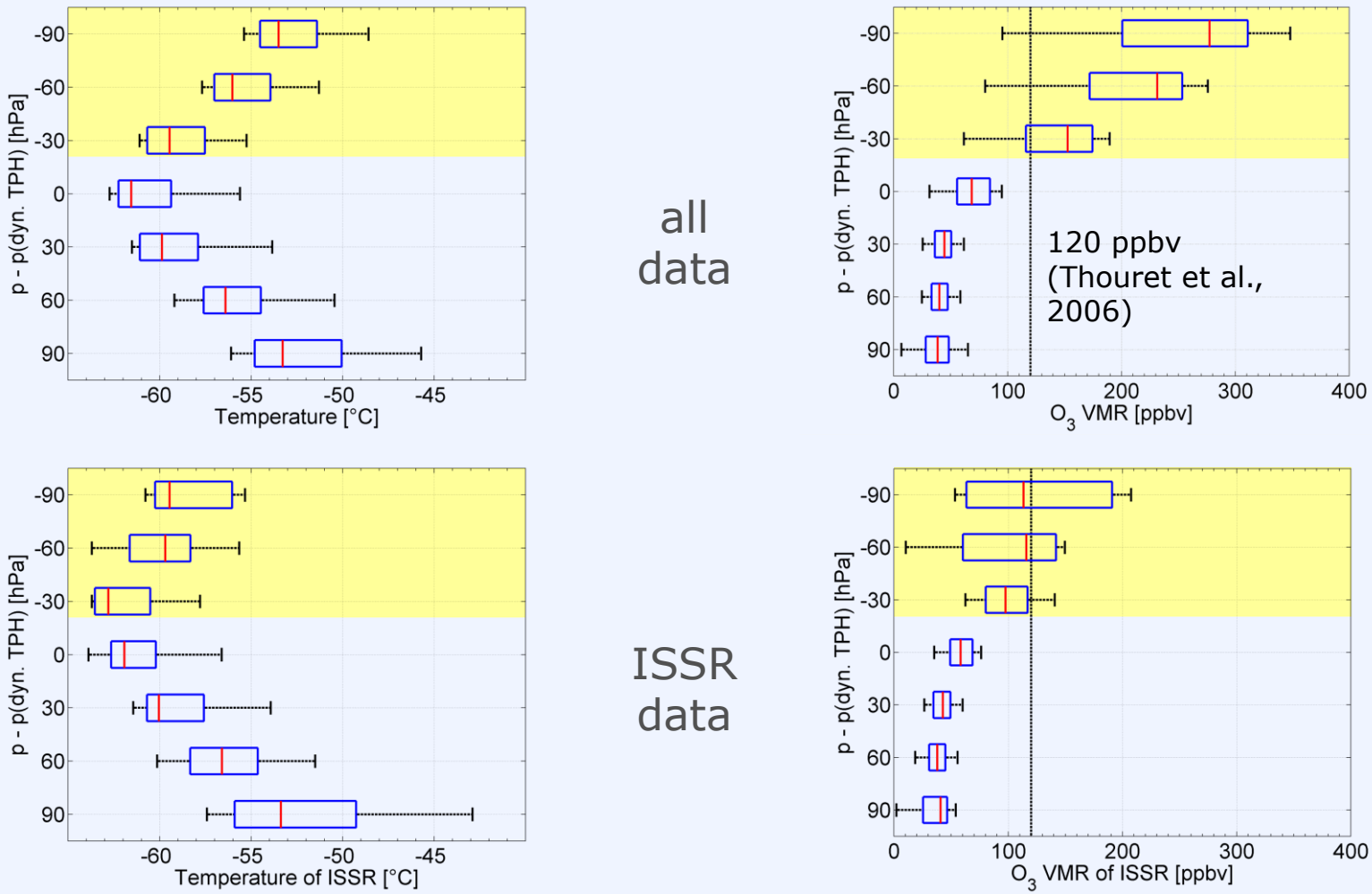
IAGOS-Data Base

IAGOS-Instrument/Observation

Annual UT-LS distribution of RH_{ice}



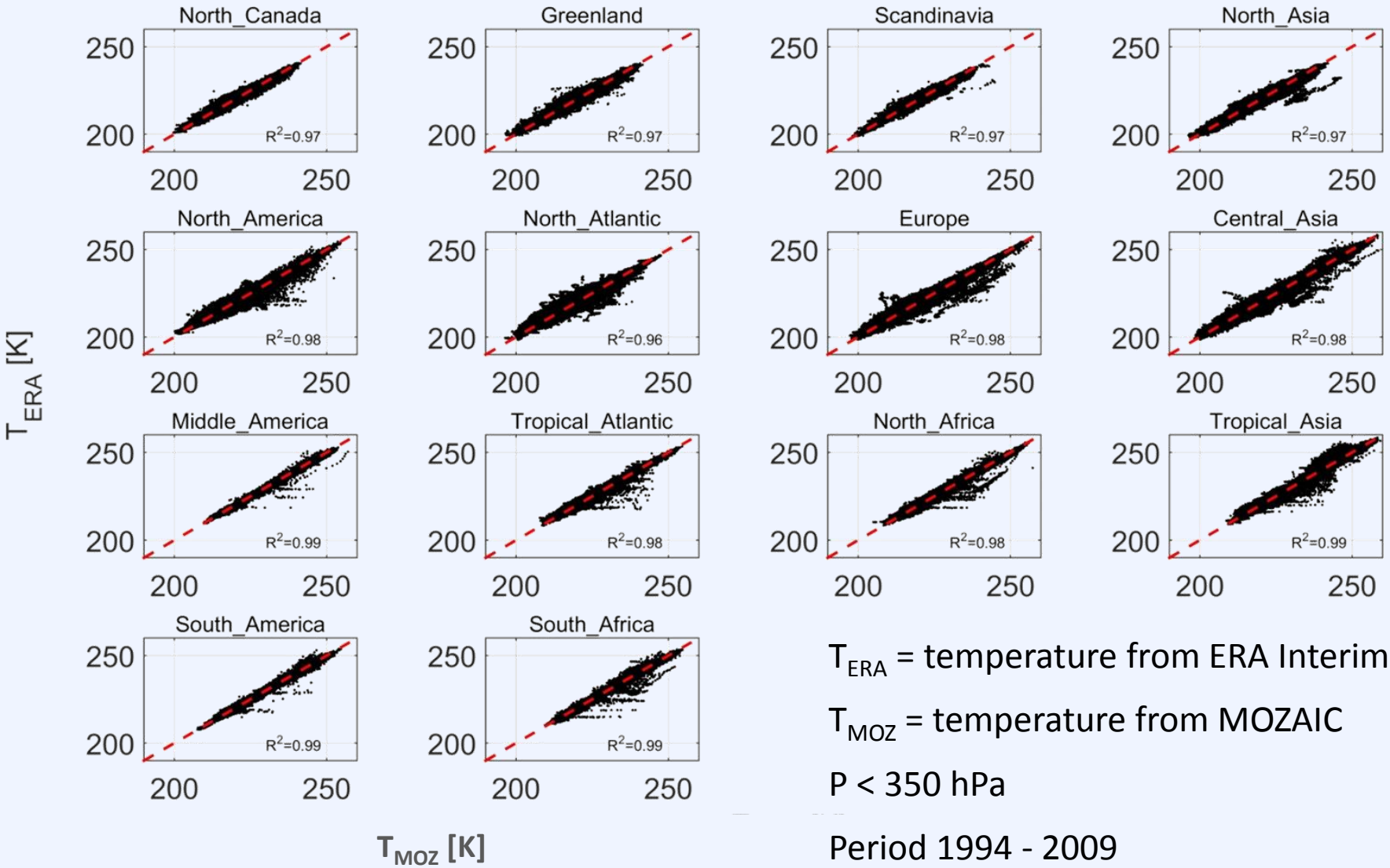
Ice Supersaturated Regions



Lowermost stratosphere ISSR contain UT signatures.
Formation processes are investigated.

Patrick Neis (FZ Juelich), EGU 2015

Temperature



T_{ERA} = temperature from ERA Interim

T_{MOZ} = temperature from MOZAIC

P < 350 hPa

Period 1994 - 2009