UPPER TROPOSPHERIC WATER VAPOUR AND ITS INTERACTION WITH CIRRUS CLOUDS

INSIGHTS FROM TWO DECADES OF IAGOS IN-SITU OBSERVATIONS

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AND THE IAGOS – TEAM

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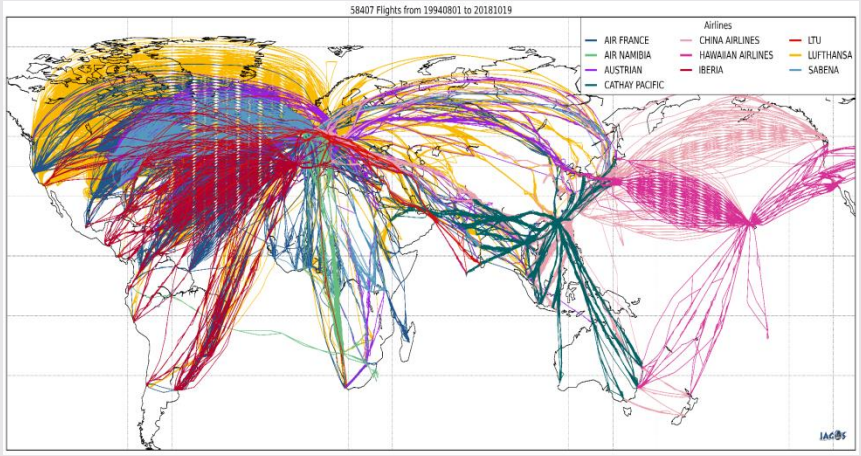
GEWEX UTCC-PROES Workshop | UPMC Sorbonne University Paris | 22 - 23 Oct 2018

IN-SERVICE AIRCRAFT FOR A GLOBAL OBSERVING SYSTEM

Association Internationale sans but lucratif

www.iagos.org

- European Research Infrastructure for Earth observation by passenger aircraft since 2014
- Regular *in situ* global-scale monitoring of essential climate variables H_2O, O_3, CO, NO_x, CO_2, CH_4, aerosols, clouds
- Long-term deployment envisaged (> 20yrs)
- Today, 8 long-haul aircraft (IAGOS-CORE) and one flying laboratory (IAGOS-CARIBIC)



- Open data policy; visit www.iagos.org
- Provision of data in near real time for Copernicus and other services
- Long time series from available for

  - tropopause temperature (> 20 yrs)
  - O_3 , H_2O, RH_{ice} (> 20 yrs)
  - CO (> 15 yrs)
  - NO_x (2 yrs)

THE IAGOS – CORE SYSTEM

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Pump

Instrument:
NO_x or NO_y
CO_2 , CH_4
or Aerosol

Ventilation
Smoke Det.

H_2O
Cloud Det.

O_3
CO
DAS/Modem

O_2
Synth. Air

Safety Panel
Breaker

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IAGOS Capacitive Hygrometer (ICH)

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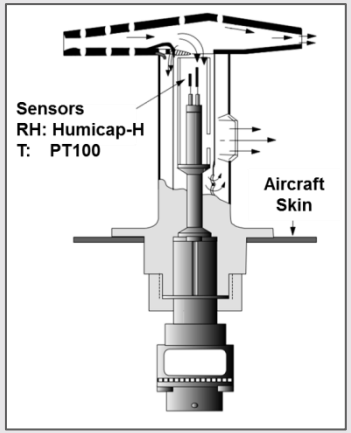
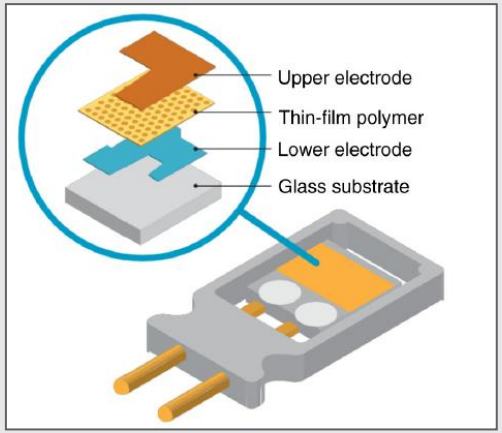
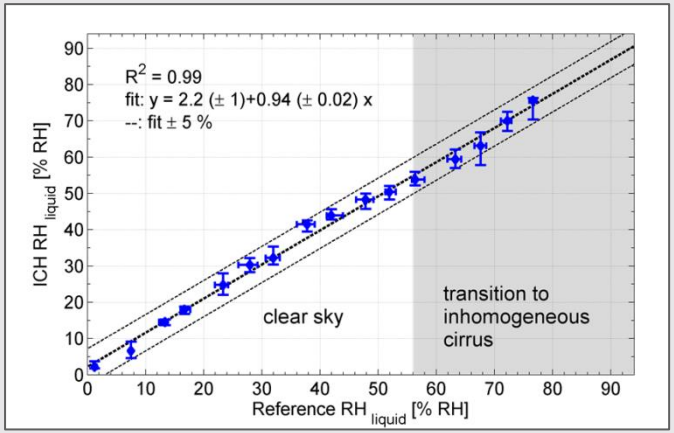




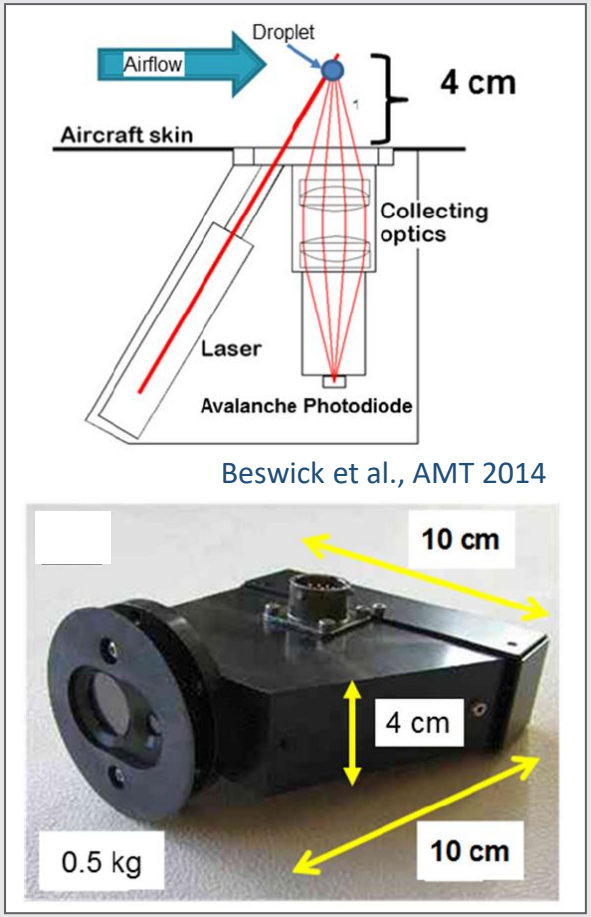


- Hydroactive Polymer Film which adsorbes H_2O molecules
- Capacitance depends on relative humidity (RH); C= 180-220 pF
- Strong temperature dependence
- Measured Signal = RH_{LIQUID}

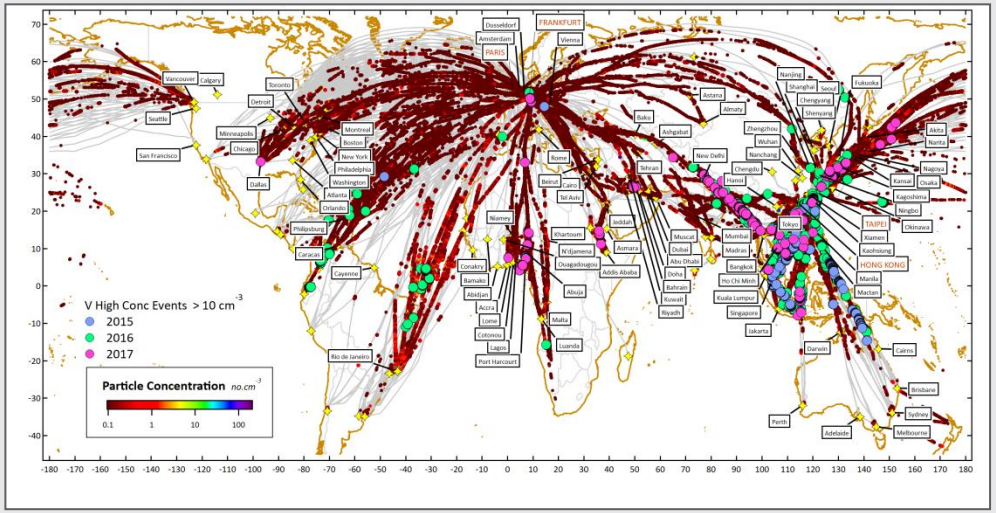
- In operation since 1995
- Established technique for balloon soundings
- Low maintenance requirements
- Calibrations traceable to frost point mirror
- In-flight blind intercomparison: 5% RH_{liquid} uncertainty, LOD approx. 20 ppmv

Helten et al., JGR 1998; Neis et al., Tellus B 2015

BACKSCATTER CLOUD PROBE (BC)



- Particles pass through open laser beam and backscattered light is collected by a photodiode
- Size range: d_p = 5 – 75 µm
- $N_{ice,\ min}$ = 0.015 cm^{-3} with 50% uncertainty
- No size distribution information provided
- In operation since 2011



THE IAGOS DATA SET - COVERAGE

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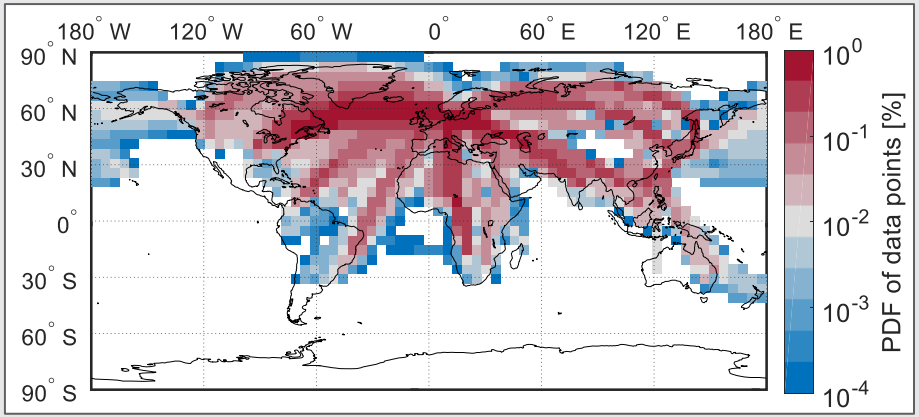
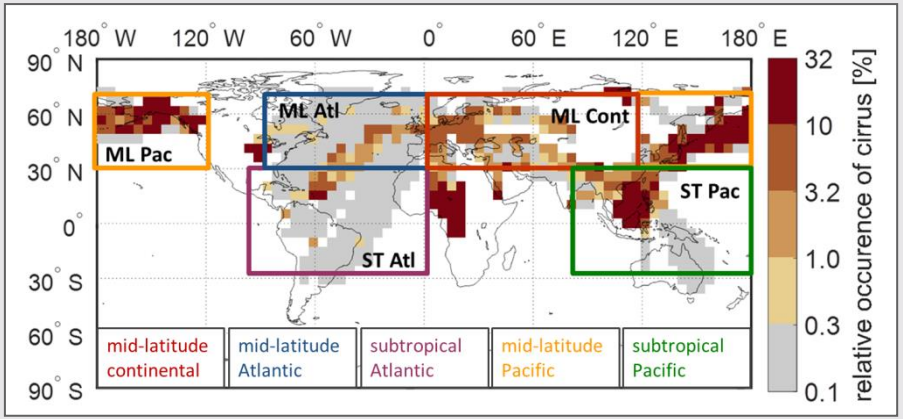
IAGOS - MOZAIC UTH / RH_{ice} data



- Data available since 1995
- > 20 years of UTH data
- > 57000 flights, 500 flights/year/aircraft

IAGOS Cirrus RH_{ice} - N_{ice} data

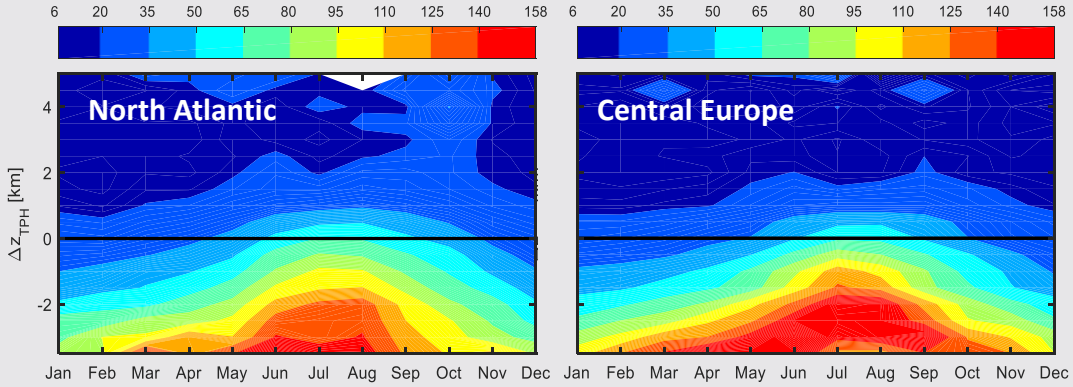


- Data available since 2011
- 360 hours of in-cloud RH_{ice}– N_{ice} data from 2014 to 2015 analysed

Data selection criteria

- Altitude > 8 km, p < 350 hPa
- T_{amb} < 233 K to exclude super-cooled water droplets

UTH Vertical Variability



Seasonal variation of 15 yrs. mean monthly median H_2O VMR [ppmv]

- Distribution relative to the thermal tropopause height z_{TPH}
- clearly visible moistening of the LMS in summer

UTH Vertical Variability

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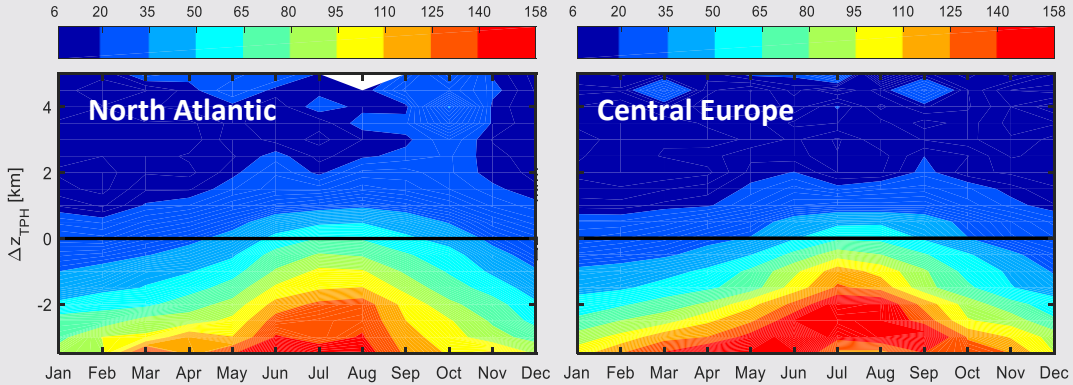

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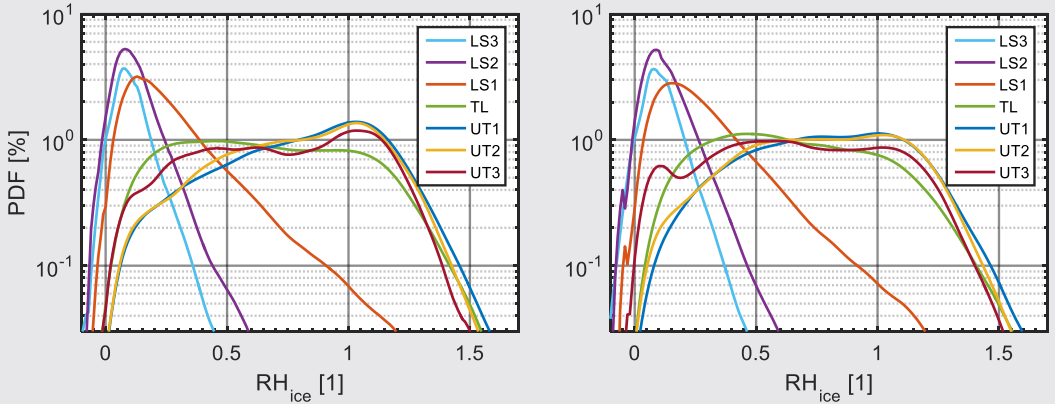

Vertical distribution of RH_{ice} in the vicinity of the thermal tropopause

- Vertical spacing of layers at z_{TPH} is 30 hPa
- PDFs of occurrence indicate frequent supersaturation of UT

Neis et al., in preparation

RH_{ICE} Time Series

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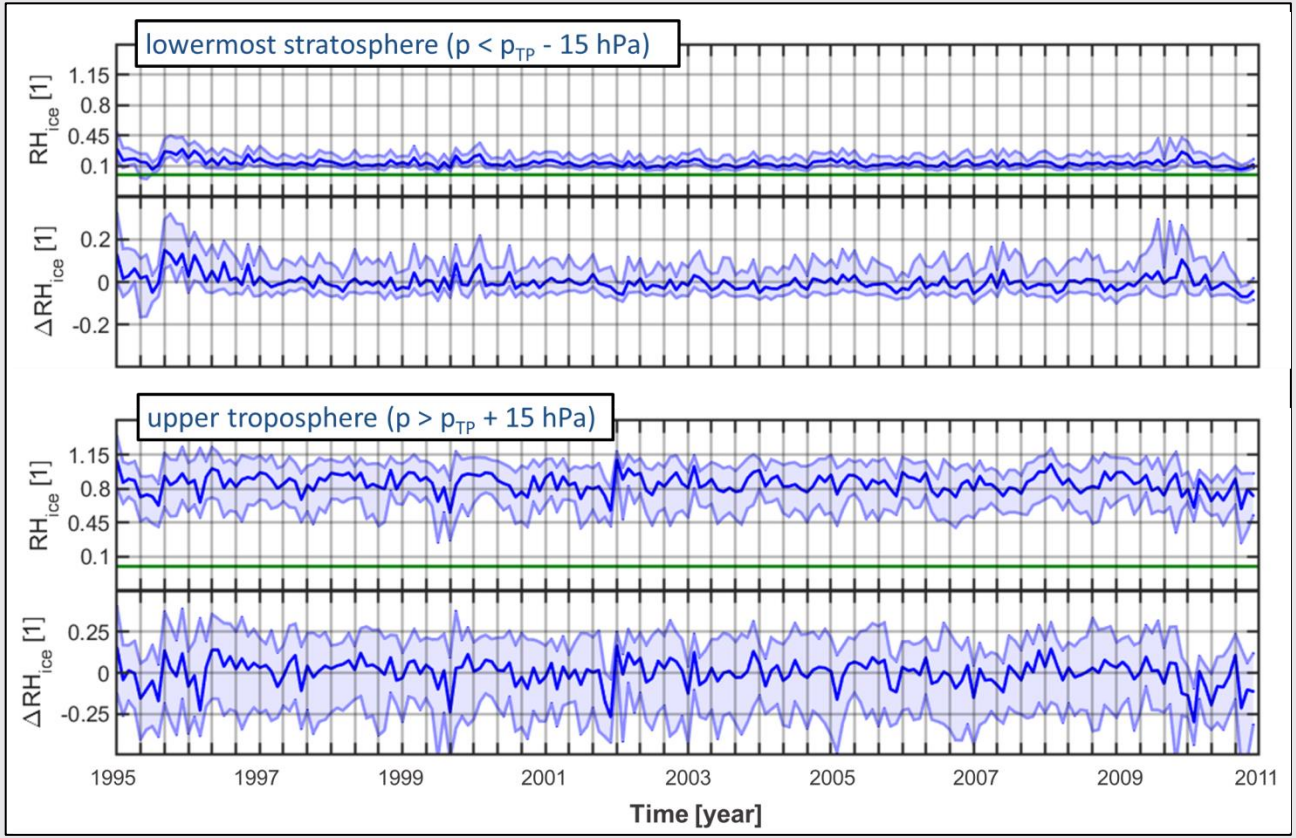

Average RH_{ice} values
LMS: approx. 10%,
close to the LOD of ICH
UT: > 80%

Ice-supersaturation
occurs regularly in the UT
close to the tropopause

No significant trends
of the deviation of monthly RH_{ice} from long-time average (ΔRH_{ice}) are observed

Neis et al., in preparation

CIRRUS CLOUD PROPERTIES

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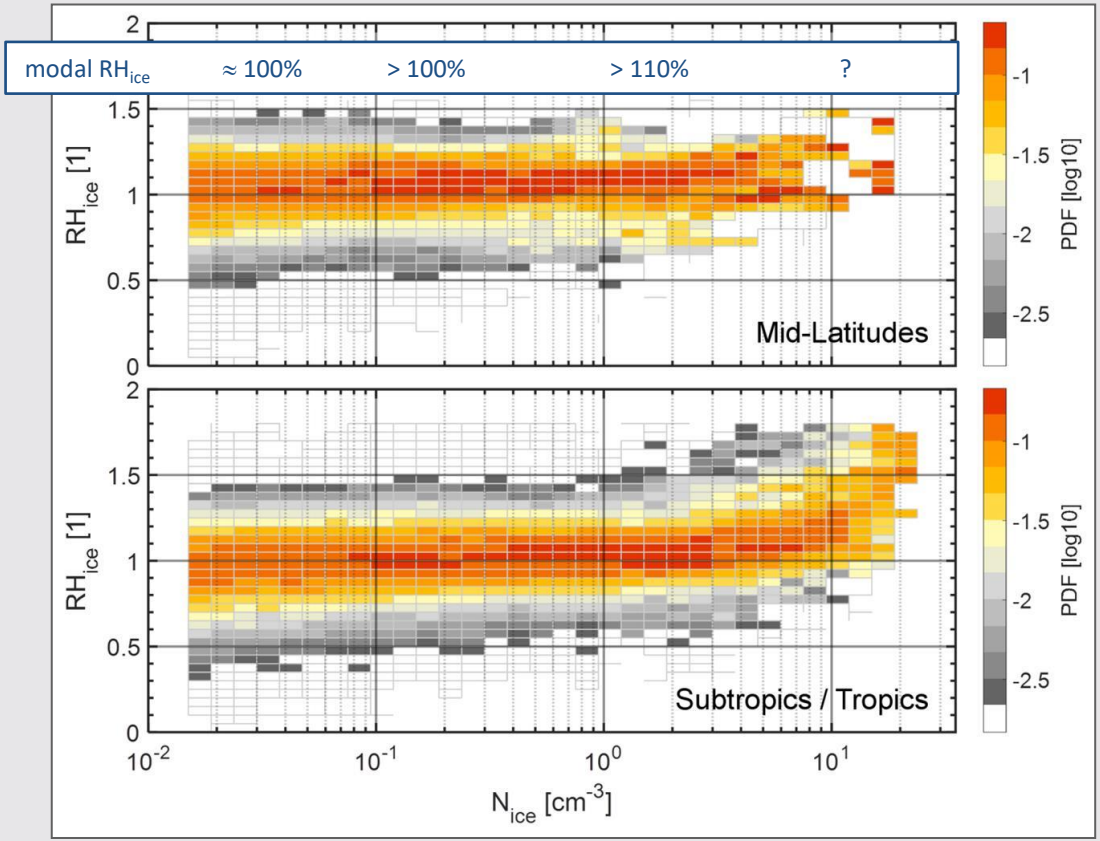

Dynamical equilibrium RH_{ice} in clouds > 100% is driven by vertical velocity

cooling during air mass updraft

$\Rightarrow$ decrease of $e_{sat,ice\ ice}$

$\Rightarrow$ RH_{ice} ↑

deposition of excess water vapour on existing ice crystals

$\Rightarrow$ RH_{ice} ↓

RH_{ice} – N_{ice} correlations indicate: dynamic equilibrium $RH_{ice} \propto N_{ice}$

Petzold et al., Faraday Discuss. doi: 10.1039/c7fd00006e, 2017

CIRRUS CLOUD PROPERTIES

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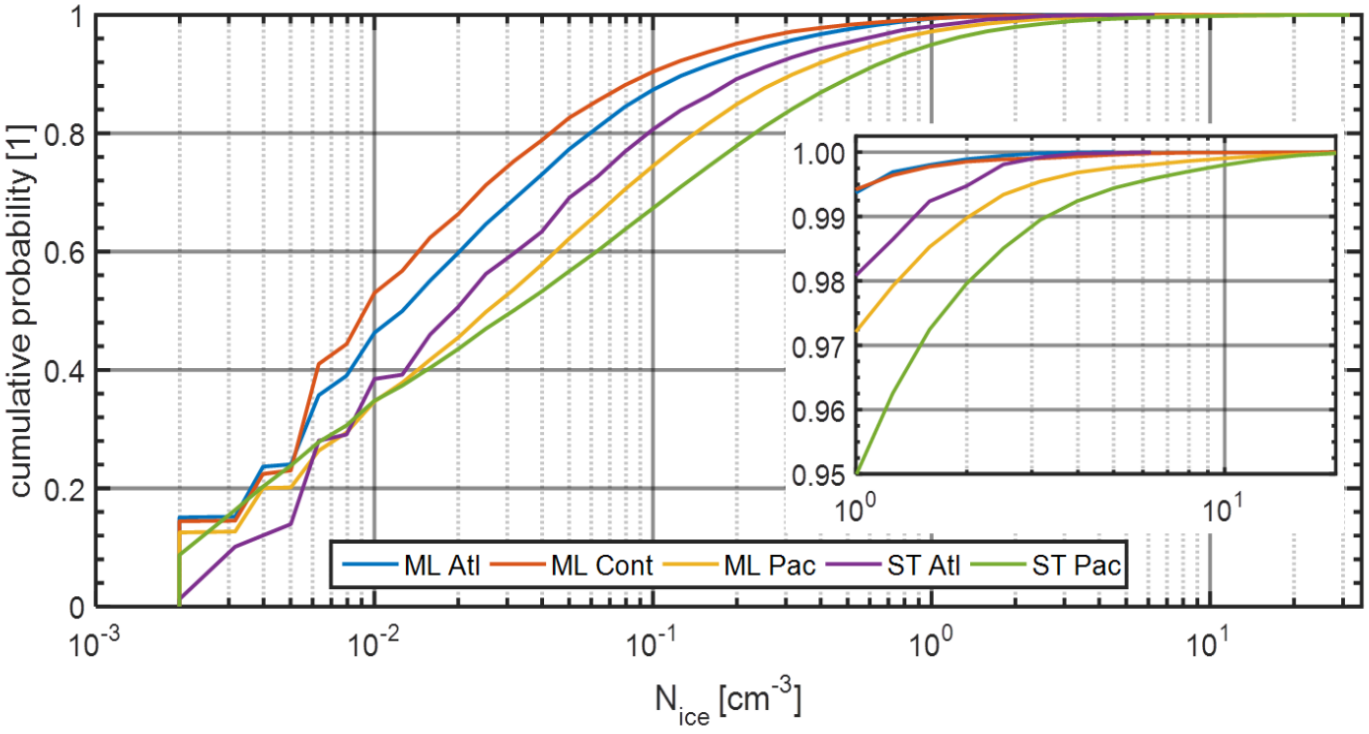
Cirrus type:	Equilibrium	higher updraft	convectively induced
	$RH_{ice, mod} \approx 100\%$	$RH_{ice, mod} > 100\%$	$RH_{ice, mod} > 110\%$



Petzold et al., Faraday Discuss. doi: 10.1039/c7fd00006e, 2017

Occurrence of Ice Supersaturation

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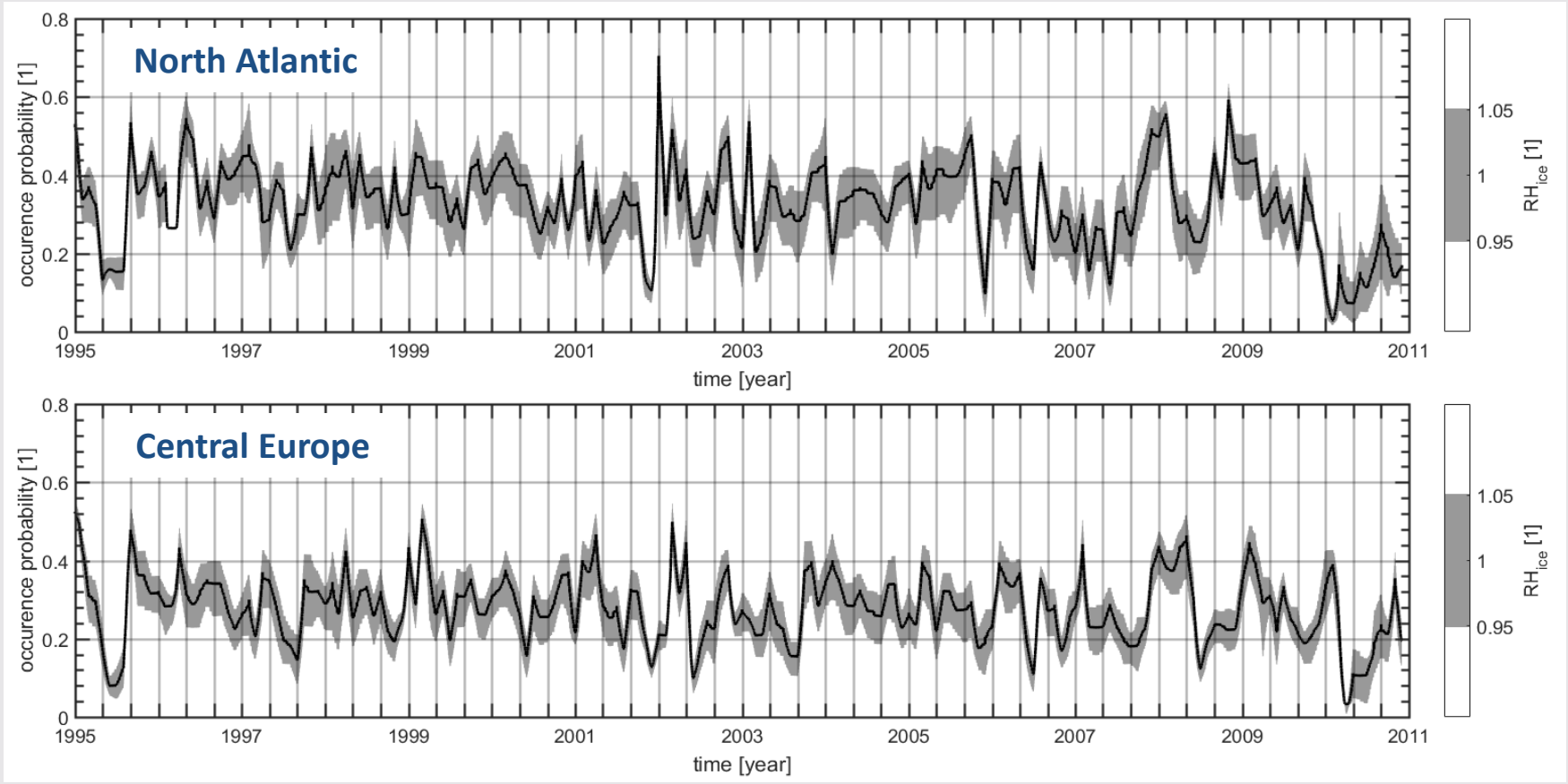

Neis et al., in preparation

Occurrence of Ice Supersaturation

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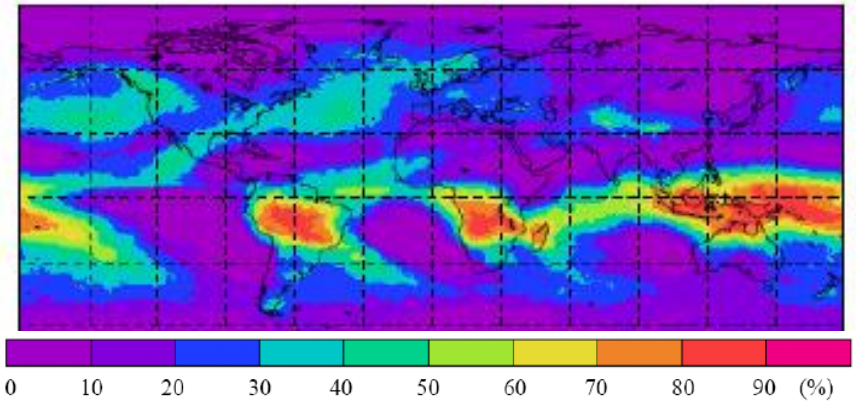
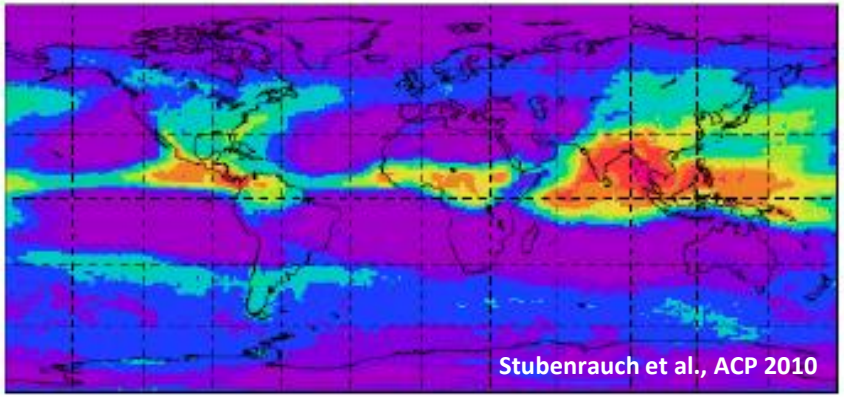
January 2003 – 2008 AIRS High Cloud Amount July 2003 - 2008





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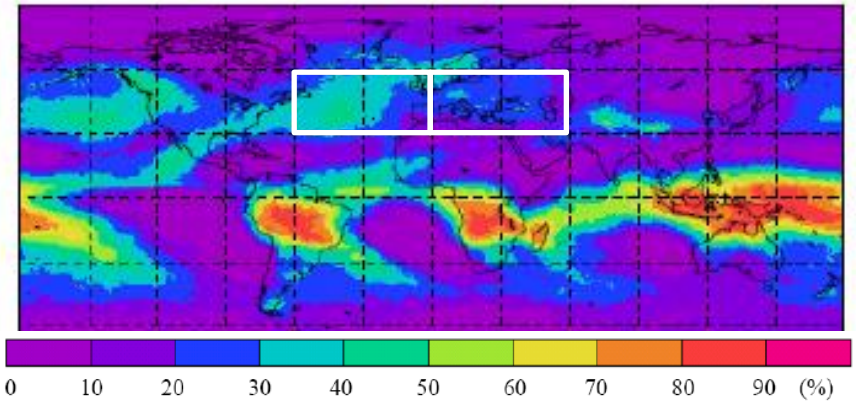
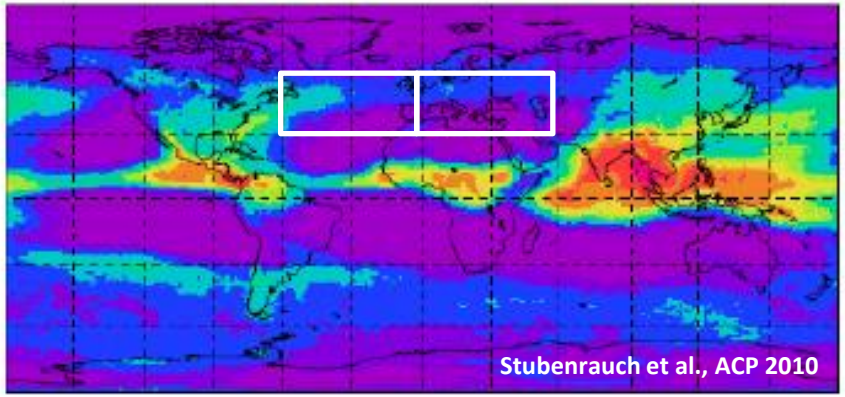
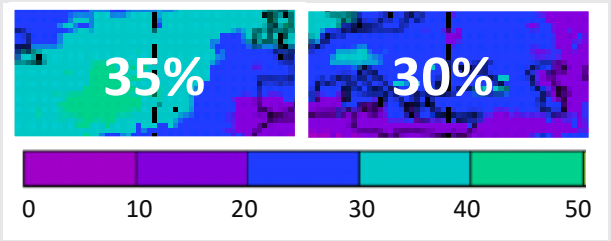
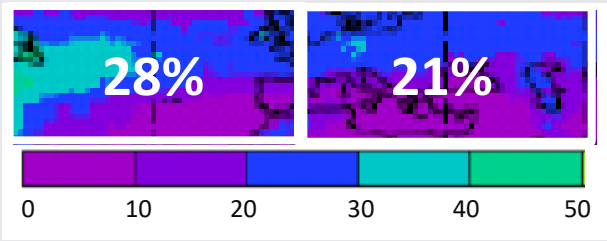




IAGOS Occurrence of $RH_{ice} \geq 100\%$





SUMMARY & NEXT STEPS

www.iagos.org

- Regular global-scale *in situ* data from MOZAIC / IAGOS are available for open access
- RH_{ice} data since 1995 and RH_{ice} – N_{ice} data since 2011 provide a highly valuable basis for research on upper tropospheric humidity and cirrus clouds
- IAGOS water vapour data will be used for SPARC OCTAV-UTLS (Observed Composition Trends and Variability in the UTLS)
- IAGOS water vapour – cirrus data may be of value for GEWEX UTCC-PROES purposes

□ □ □

- Investigate long-term evolution of cirrus coverage over regions sampled by IAGOS
- Link IAGOS RH_{ice} - cirrus observations to satellite observations of cirrus coverage

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IAGOS Data Services

Available: O_3, CO, H_2O (CORE NRT)
O_3, CO (CARIBIC L1)

In preparation: Cloud Index (CORE NRT)
NO_x/NO_2 (CORE L1)

IAGOS data products

Calibration Centres

calibration data

meta data

IAGOS Data Centre
hosted by AERIS (CNES-CNRS/INSU)
in Toulouse

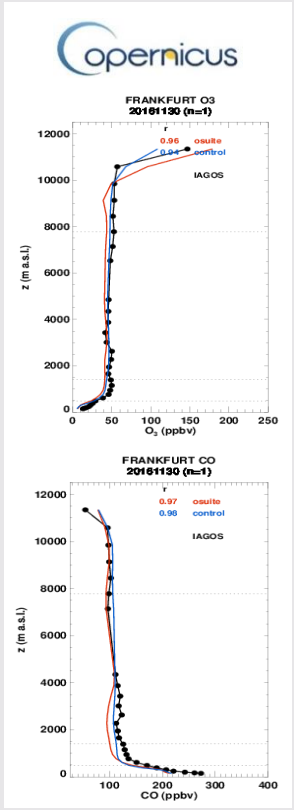
near real time data

for Copernicus model validation

calibration

maintenance

data



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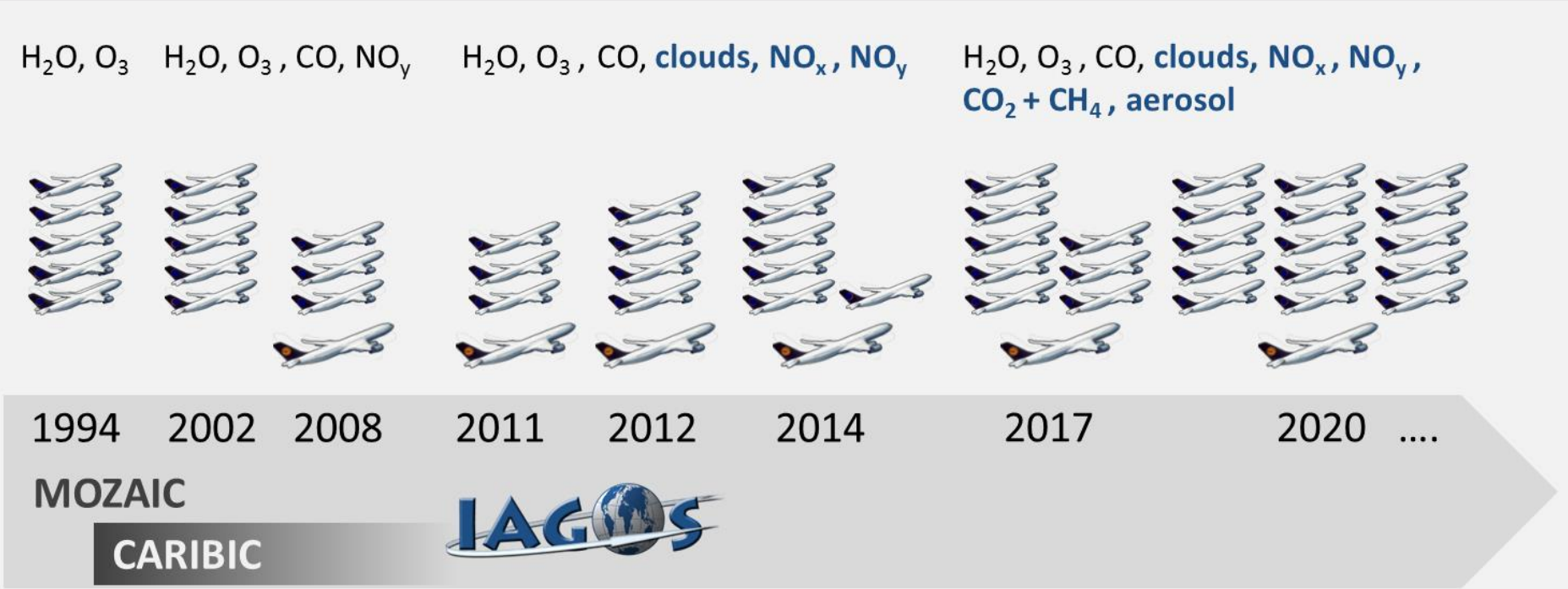

THE IAGOS DATA SET – VERTICAL COORDINATES

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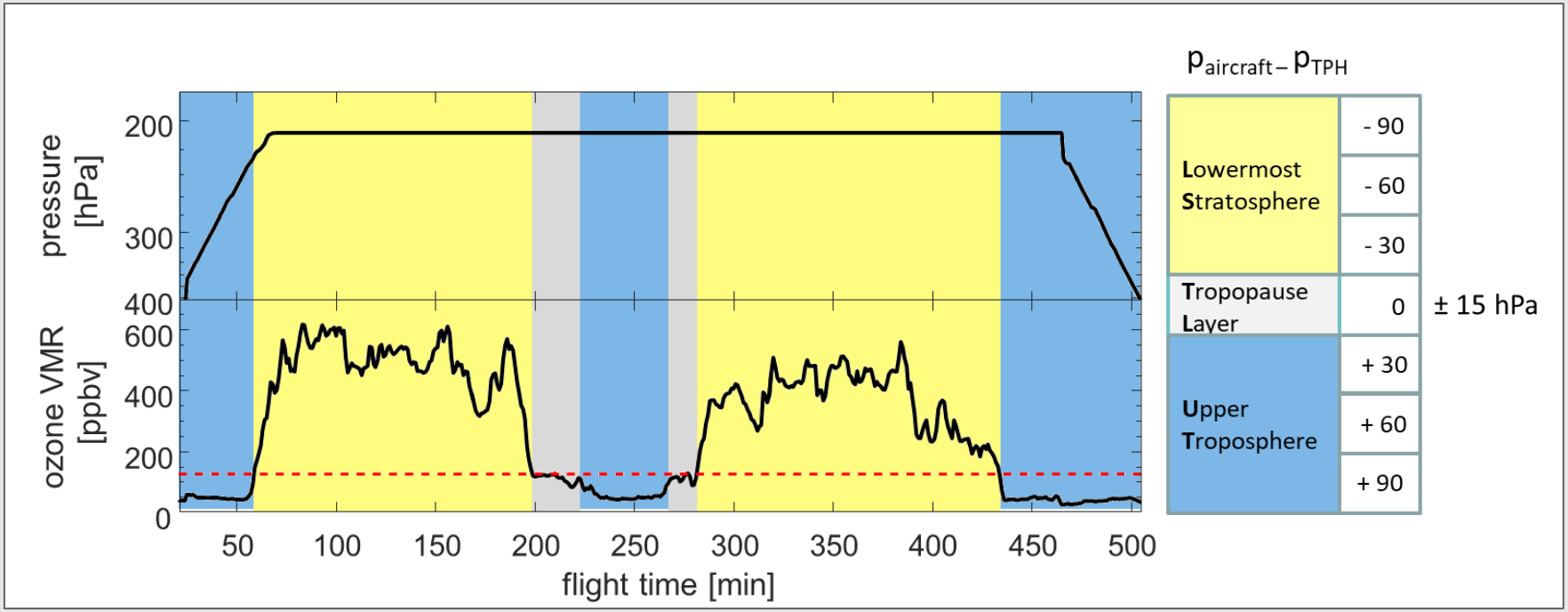

- Seasonal and regional variation of the tropopause height requires relative altitude coordinates.
- Data are grouped relative to the dynamical or thermal tropopause height ($p_{dyn.TPH}$; $p_{therm.TPH}$) according to Thouret et al. (JGR 2006).