Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft + Universität Karlsruhe (TH) = KIT Karlsruhe Institute of Technology

About the quality of water vapour profiles retrieved from ground-based FTIR measurements

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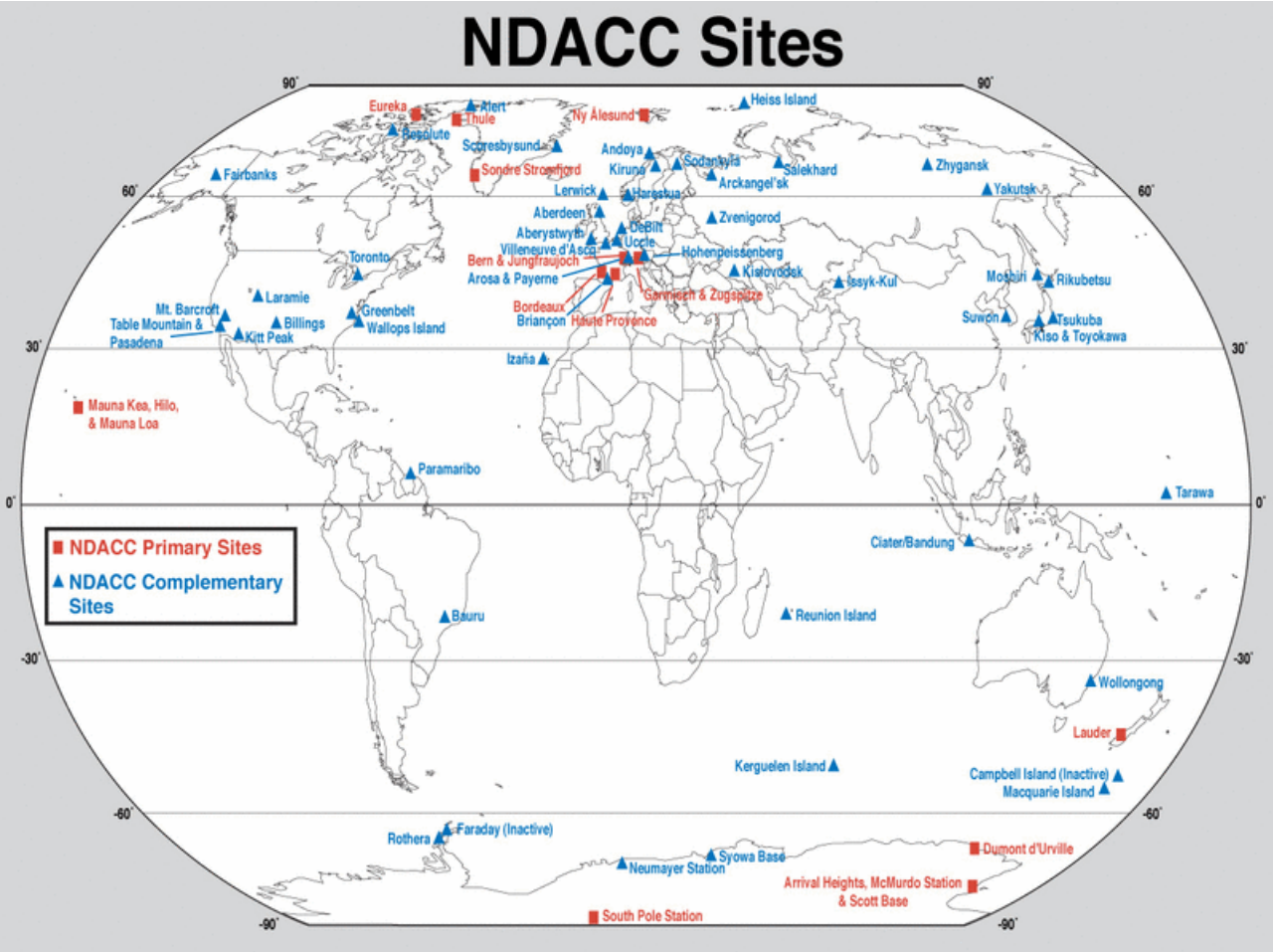
Our group operates currently two FTIR spectrometers within NDACC

Since several years we are working on ground based FTIR H_2O profile retrieval, first results were published in:

ACP, 6, 811-830, 2006

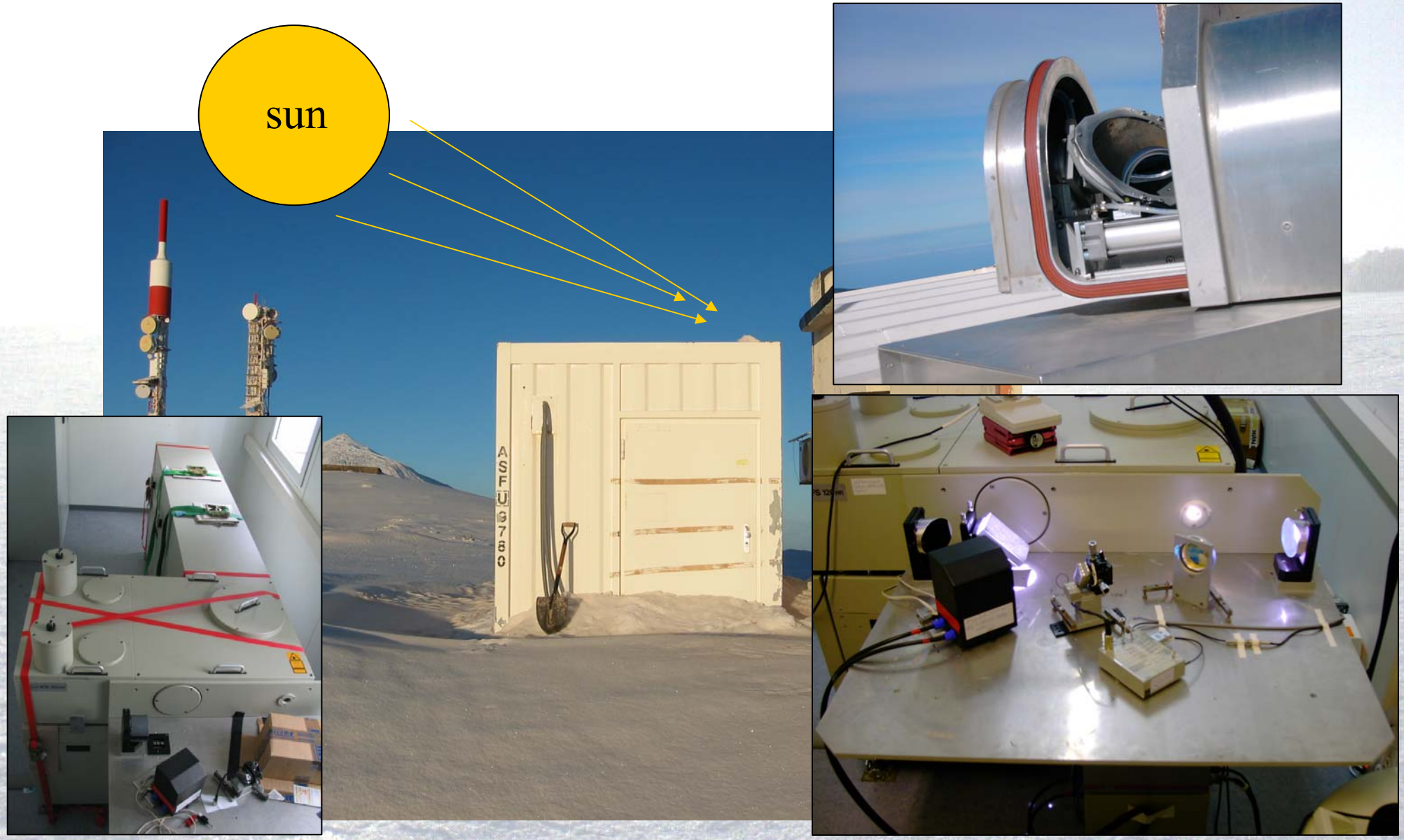
ACP, 6, 4705-4722, 2006

Ground-based FTIR measurements within NDACC for long term validation of IASI H_2O products

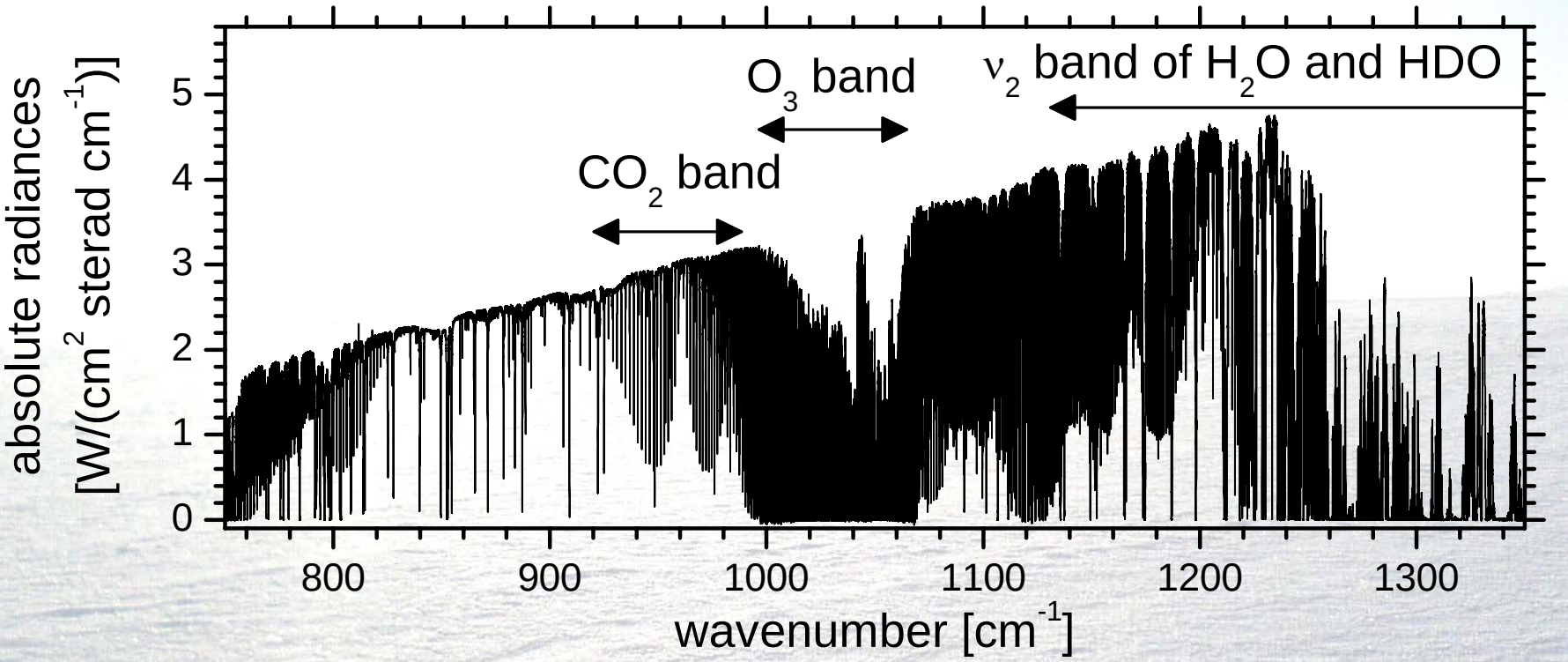


<u>BUT: First we have to prove the quality of the ground based FTIR data!!!</u>

A ground-based FTIR experiment



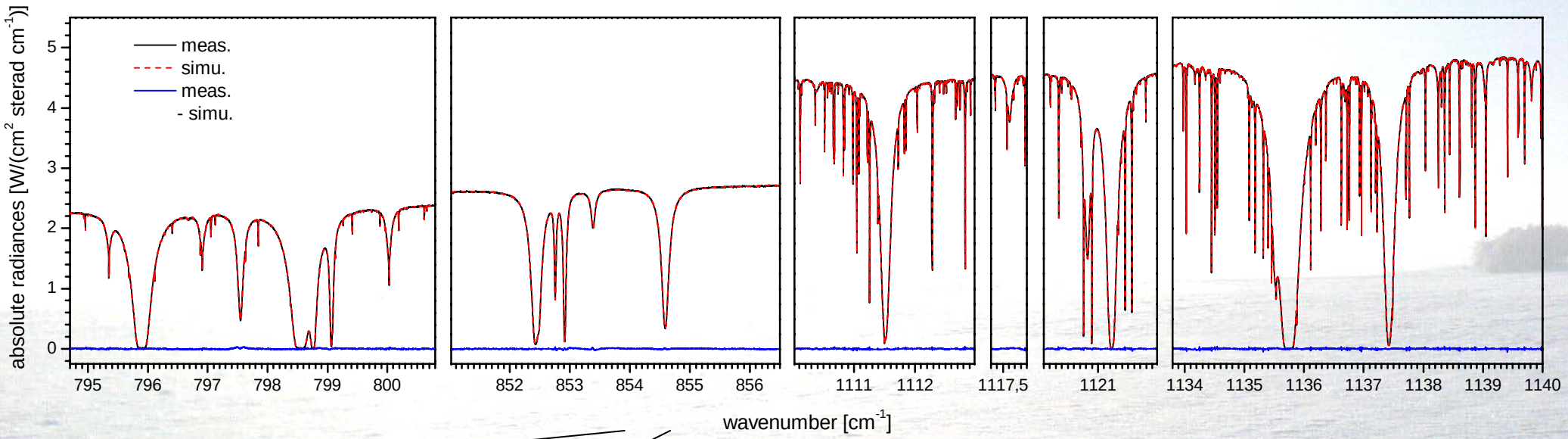
A typical mid-infrared measurement

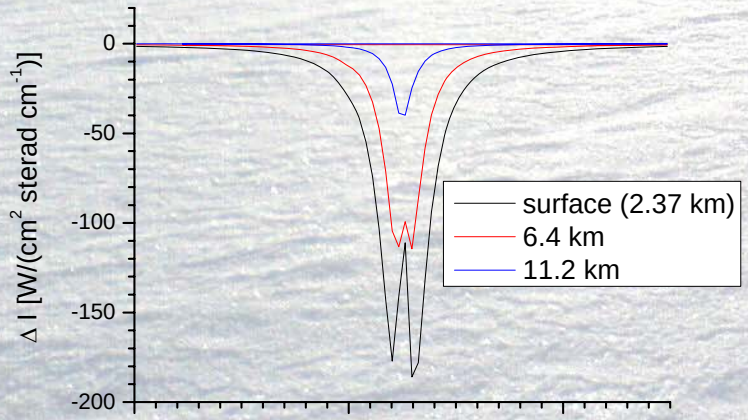


Information content of solar absorption spectra:

1. Envelope of the calibrated spectrum: aerosols (PSCs, mineral dust, cirrus, …)
2. Line area: column amounts
3. Line shape: profiles

Example of H_2O signatures





2. Line area: column amounts

3. Line shape: profiles:
the Jacobian is a singular matrix, so we cannot determine the profile unambiguously …

Optimal Estimation (OE) of vertical profiles

… but estimate the most probable state for the given measurement (OE).

This leads to a minimisation problem of the cost function:

$$\sigma^{-2}(y-\frac{\partial y}{\partial x}x)^{\mathrm{T}}(y-\frac{\partial y}{\partial x}x)+(x-x_a)^{\mathrm{T}}\mathrm{S}_{\mathrm{a}}^{-1}(x-x_a)$$

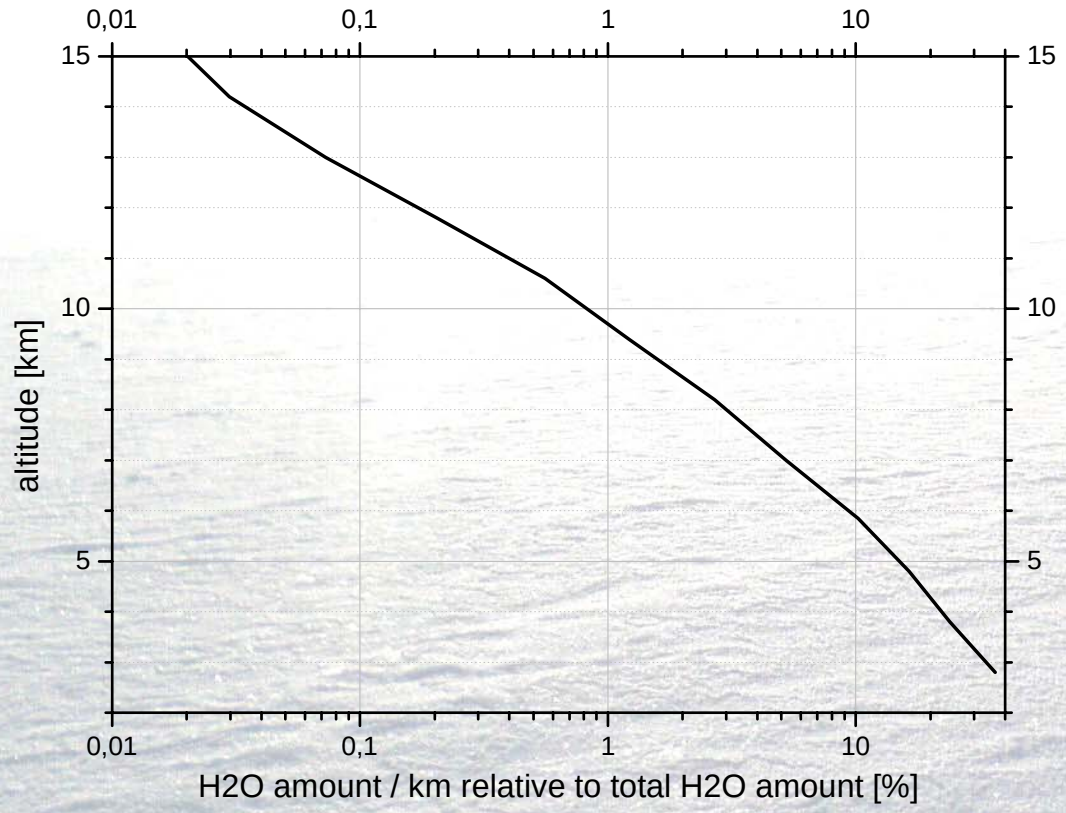
$y, x, x_a, \mathrm{S}_{\mathrm{a}}$: spectral-, state-, *a priori* state-vectors, *a priori* covariance-matrix

$\frac{\partial y}{\partial x}$: Jacobians (sensitivity of spectra wrt absorber)

Advantages of FTIR technique:
- measures many trace gases
- for extended time periods, nearly continuously
- good precision
- provides information about vertical distribution
- different isotopologues produce different absorption signatures
-> enables to measure the isotopic composition of the atmosphere

H_2O
HDO
O_3 (I)
N_2O
CH_4
HNO_3
CCl_2F_2
CCl_3F
$CHClF_2$
COF_2
$ClONO_2$
ClO
NO
NO_2
HCl (I)
C_2H_6
HF
HCN
C_2H_2
CO
CO_2
OCS
NH_3
$COCl_2$
N_2

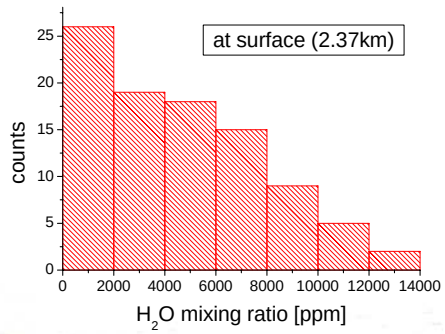
Ground-based remote sensing of vertical H_2O distributions: a real challenge

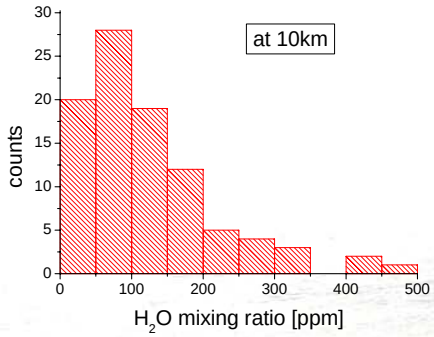


- the first 2 km contain already 60% of all atmospheric H_2O
- the first 5 km more than 90%
- above 10 km there is only 1% of all atmospheric H_2O

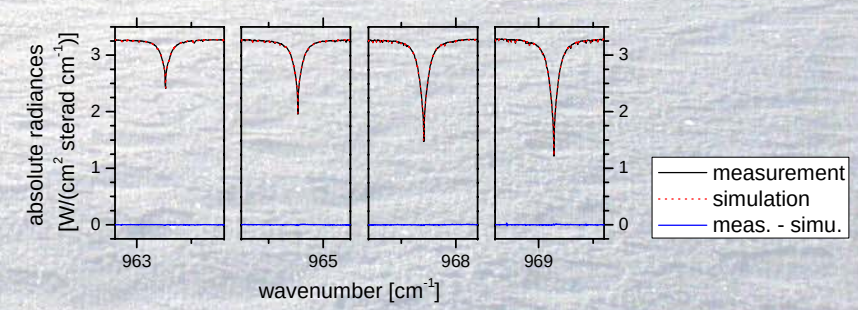
Optimising the H_2O retrieval

(1) retrieval on a logarithmic scale (Hase et al., 2004; Schneider et al. 2006; Deeter et al., 2007):





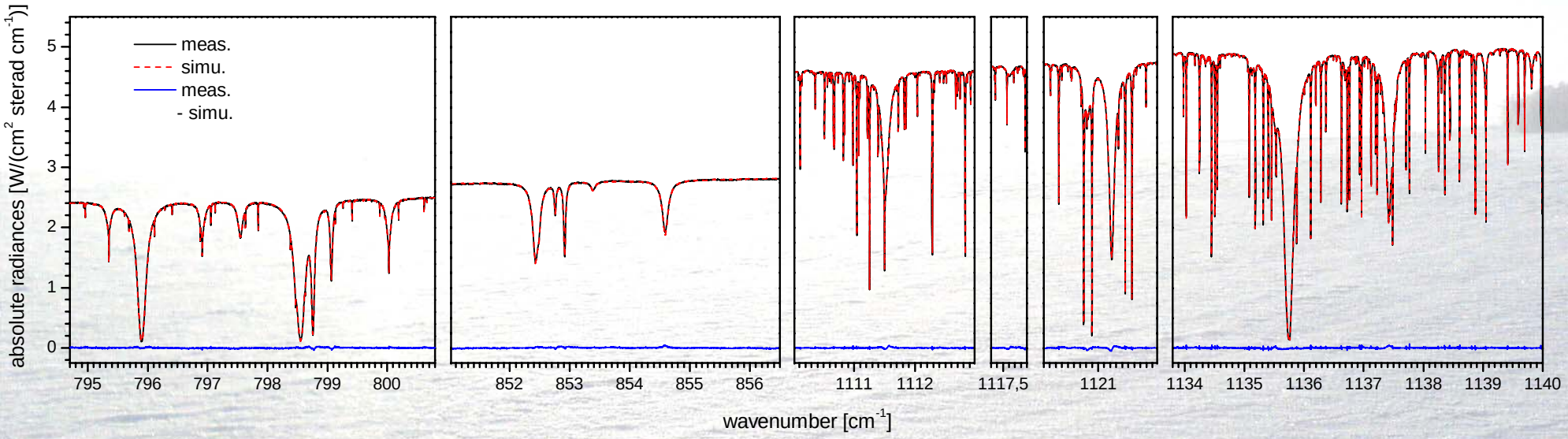
(2) simultaneous retrieval of temperature profile (Schneider et al. 2006; 2007):



temperature from CO_2 lines

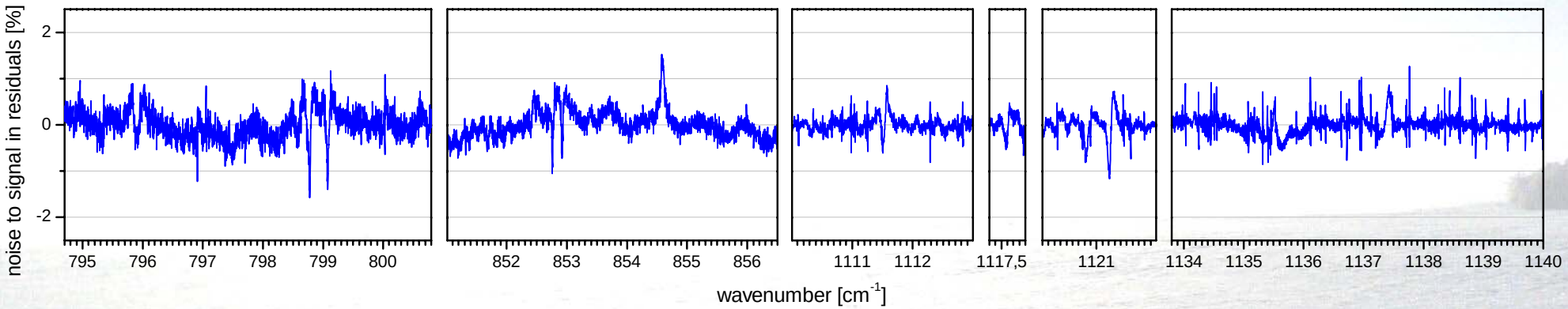
Optimising the H_2O retrieval

(3) reduce inconsistencies in spectroscopic line parameters:



Optimising the H_2O retrieval

Investigating inconsistencies between HITRAN parameters and our FTIR measurements:

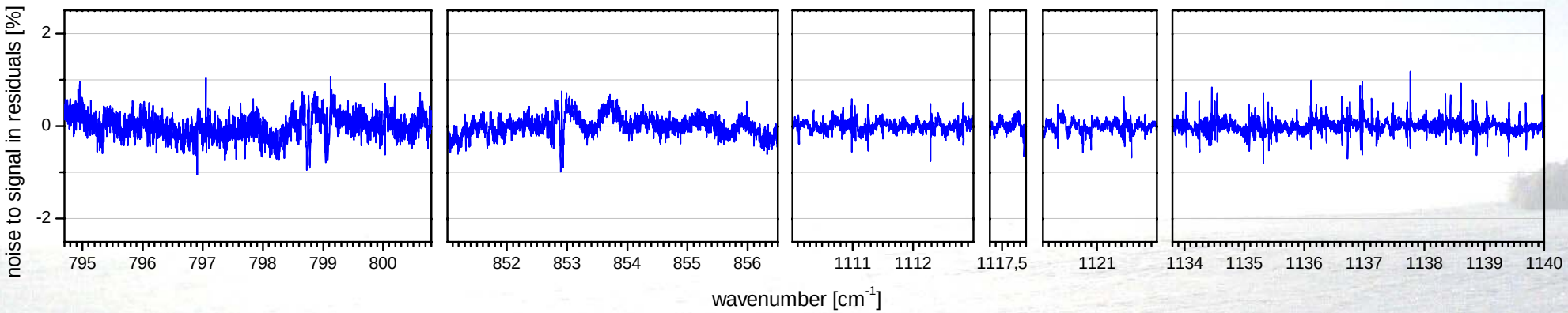


Idea: use the residuals to 'remove' inconsistencies in HITRAN parameters.

→ we make an optimal estimation of the HITRAN parameters taking the residuals as measurement.

Optimising the H_2O retrieval

Adapting HITRAN parameters to our measurements:



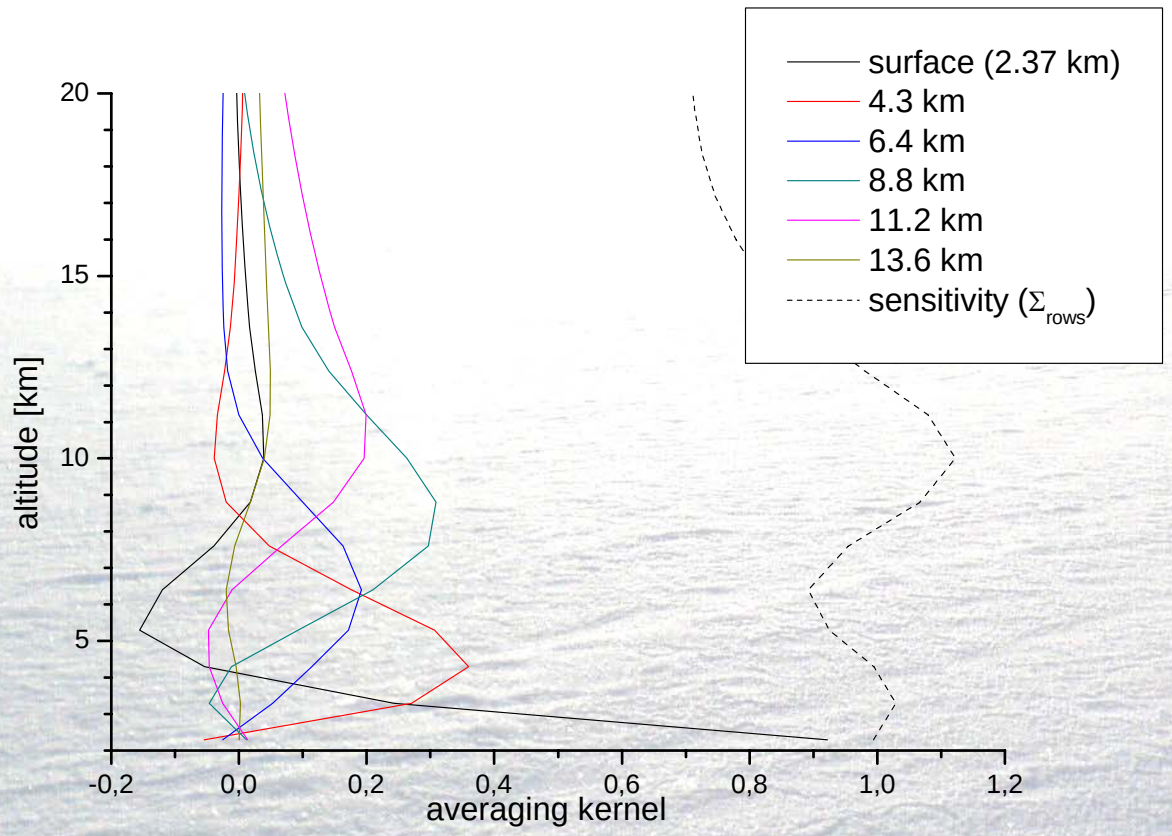
the required changes are within the given HITRAN uncertainties:

< 0.002 cm^{-1} for line positions

< 3 % for line intensities

< 4 % for pressure broadening coefficients

Averaging kernels for ground based FTIR H_2O mixing ratios



DOF: 2.8 – 3.5

→ we can retrieve between 3 and 4 independent layers:

surface layer: 1st km

mid troposphere: e.g. 3.3 km-5.3 km

upper troposphere: e.g. 5.3 km-10 km

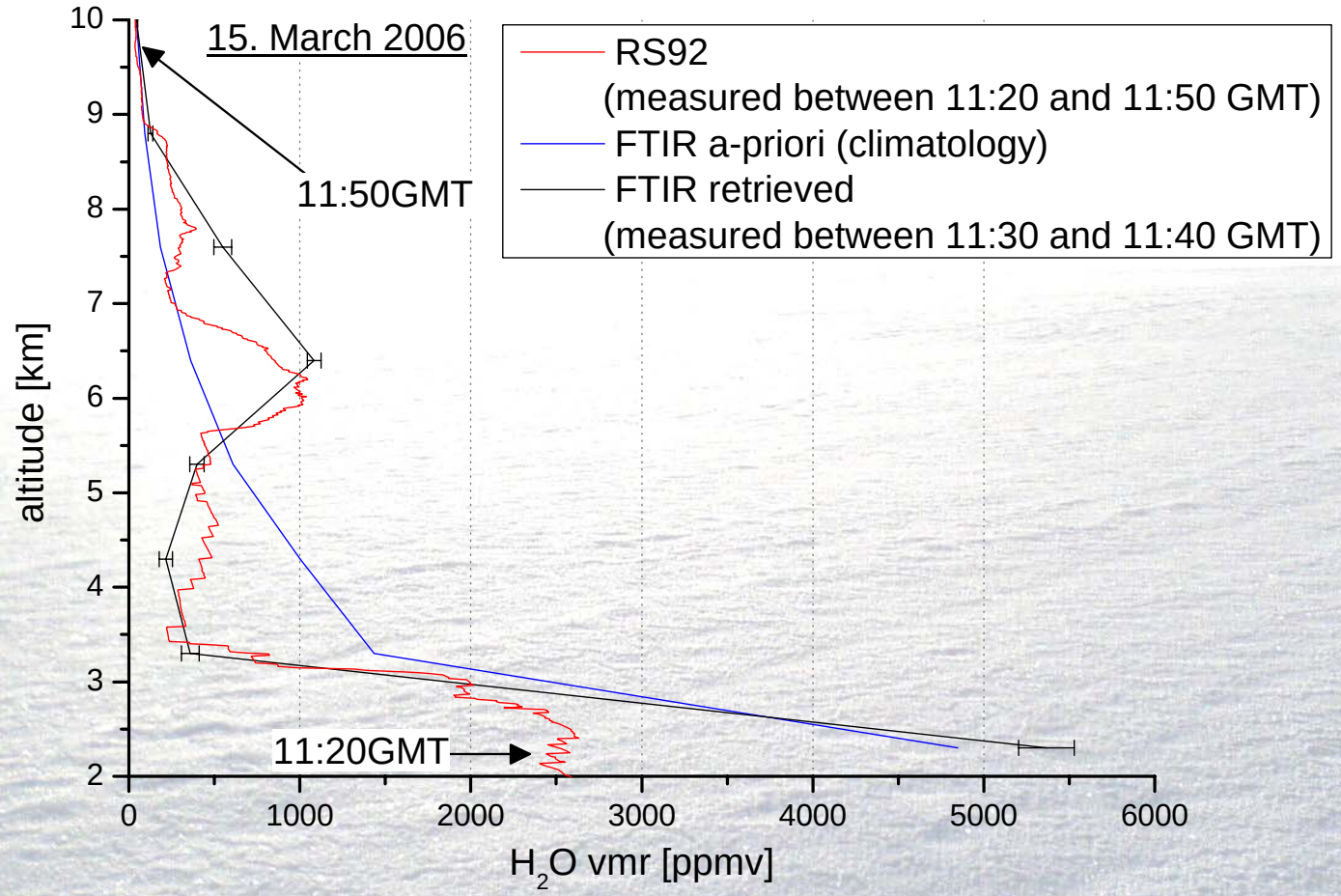
tropopause: above 10 km

Estimated FTIR H_2O errors

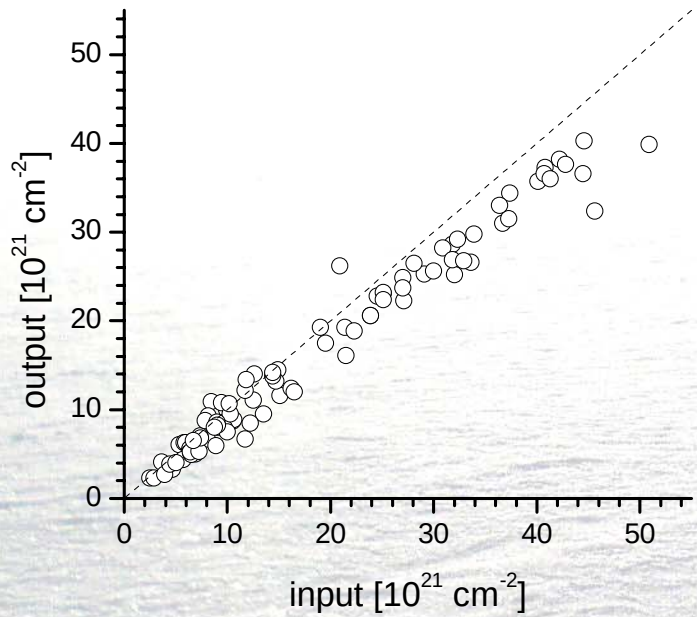
error source	total	2.3–3.3 km	4.3–6.4 km	7.6–10.0 km	8.8–11.2 km
smoothing	2	10	21	44	36
meas. noise	1	4	2	7	8
pha. err.	2	19	10	33	18
mod eff.	<1	1	<1	<1	<1
T. profile	1	8	6	7	3
solar angle	1	<1	<1	<1	<1
line int.	<1	1	1	1	1
pres. coef.	1	11	6	5	4
total	**4**	**22**	**24**	**49**	**42**

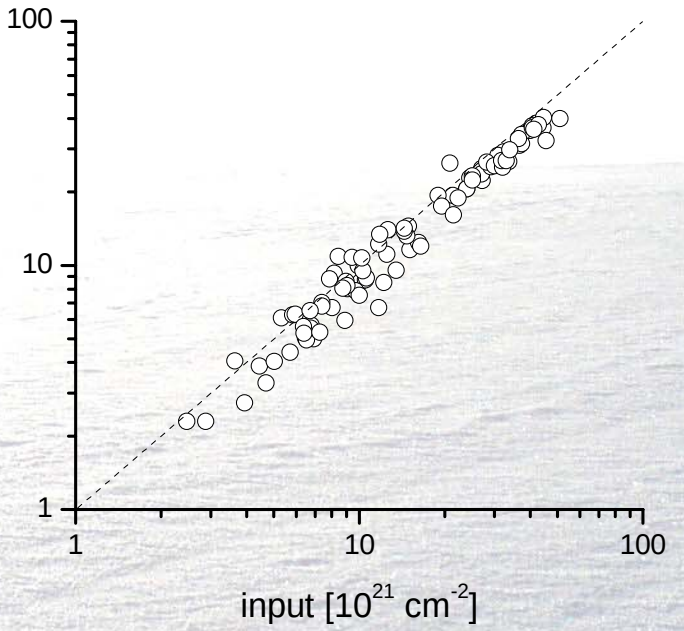
from ACP, 6, 811-830, 2006

Example of Vaisala RS92 vs. FTIR profiles



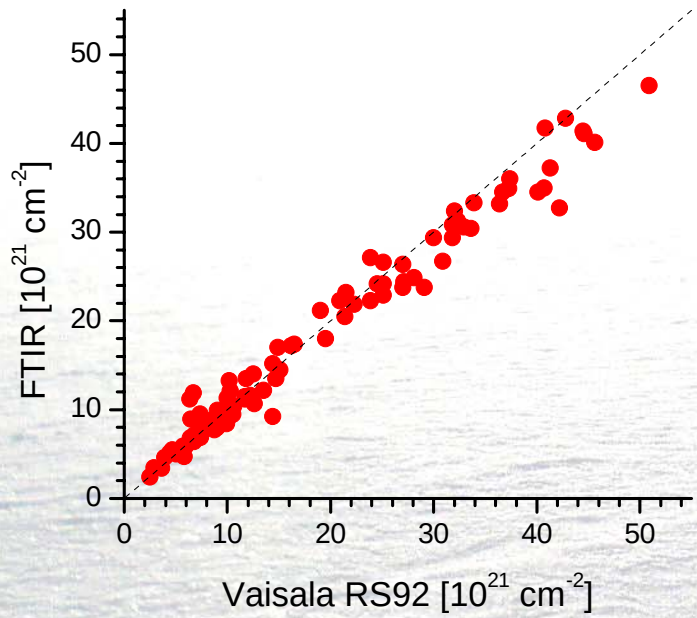
Theoretical FTIR performance (2.37 km-15 km+)

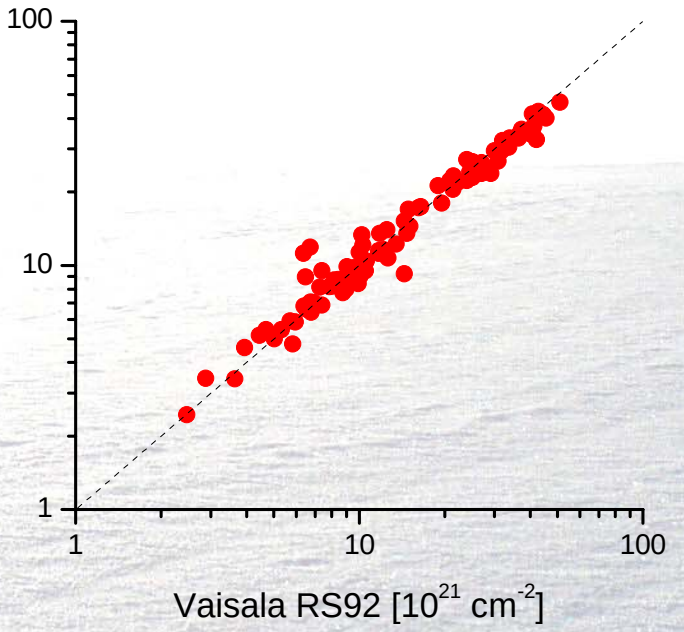




+ more than 99.9% of total column amount

RS92* vs. FTIR (2.37 km-15 km+)

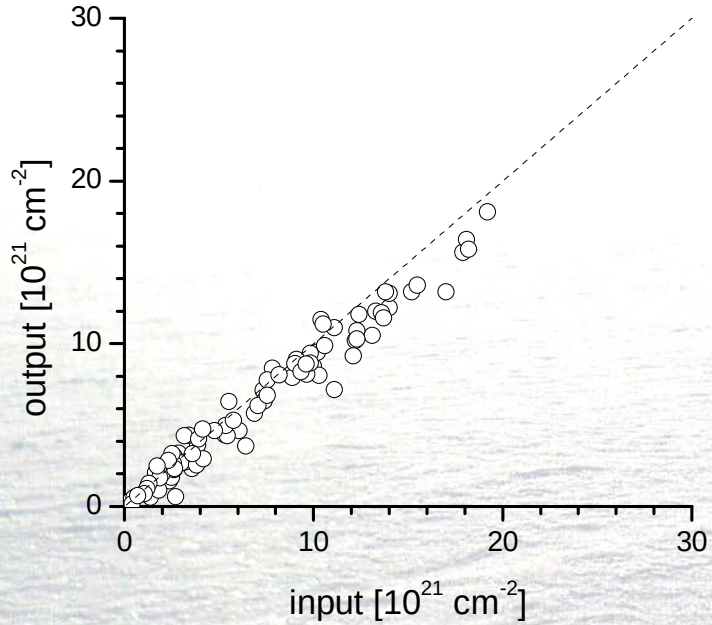


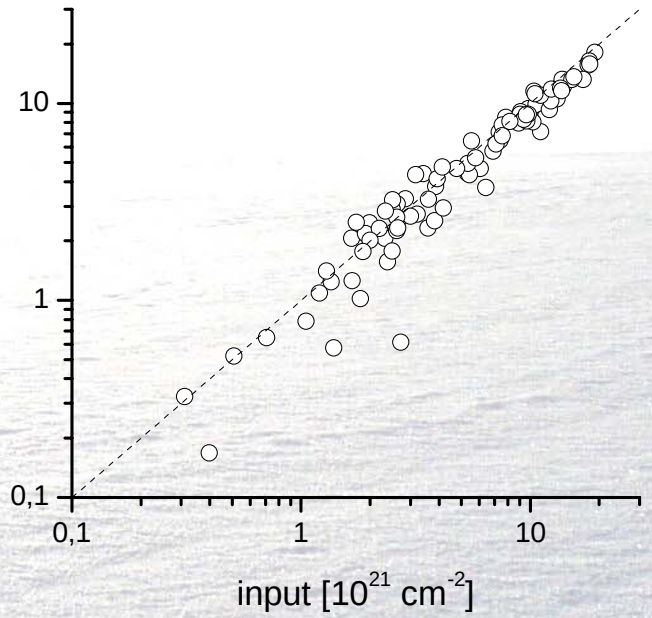


*corrected according to Vömel et al. (2006)

+ more than 99.9% of total column amount

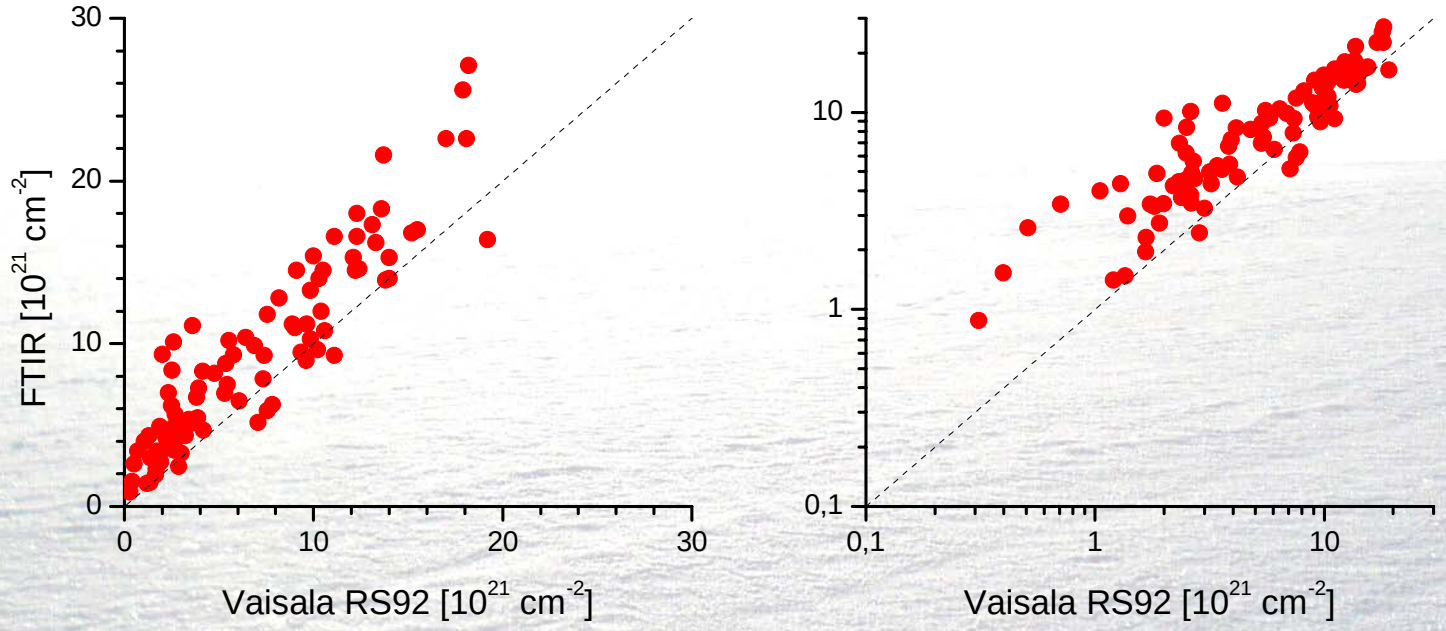
Theoretical FTIR performance (1st km; 2.37 km-3.3 km+)





+ typically 36% of total column amount

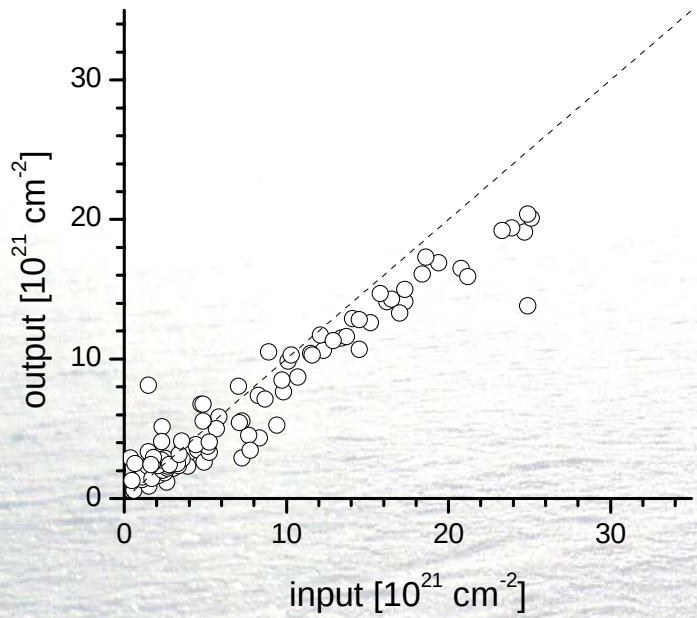
Vaisala RS92* vs. FTIR (1st km; 2.37 km-3.3 km+)

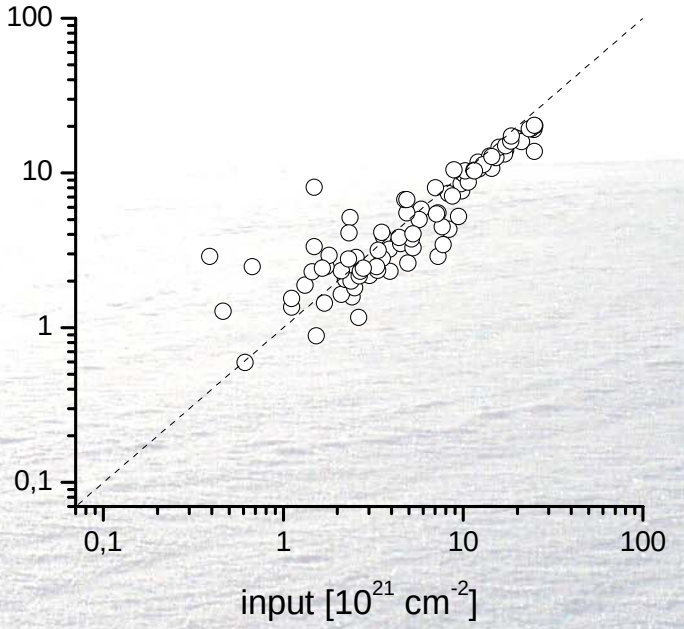


*corrected as in Vömel et al (2006)

+ typically 36% of total column amount

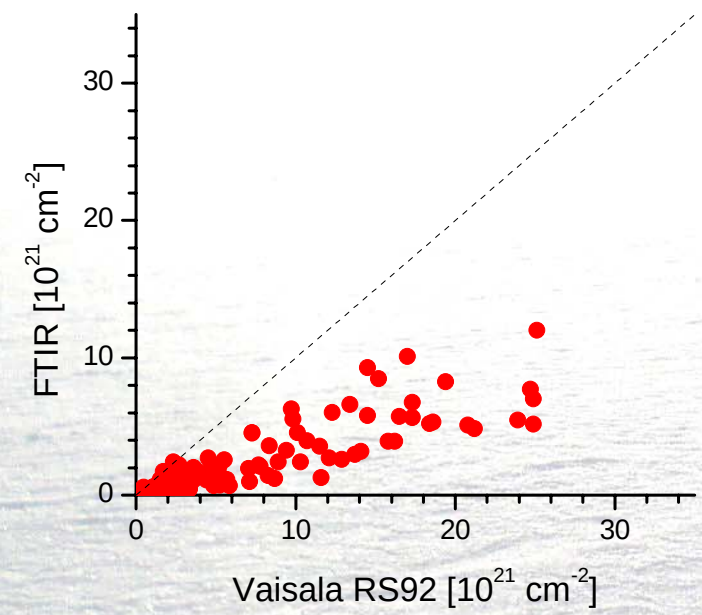
Theoretical FTIR performance (3.3 km-5.3 km+)

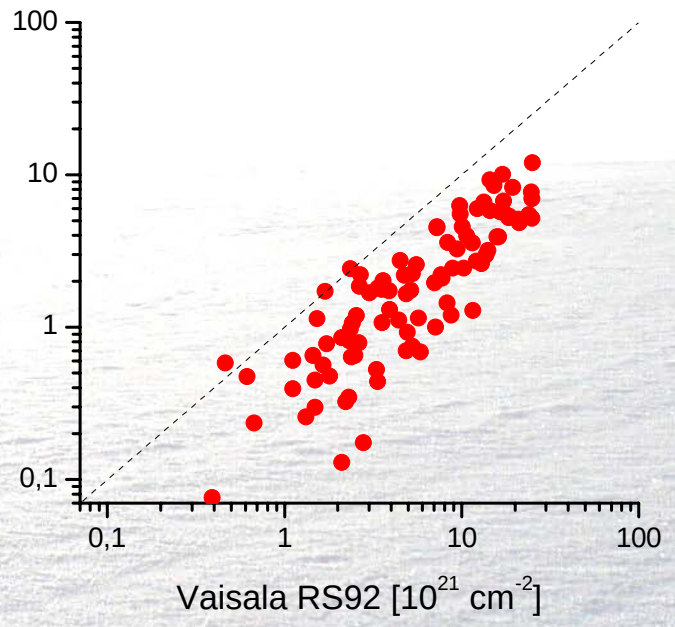




+ typically 40% of total column amount

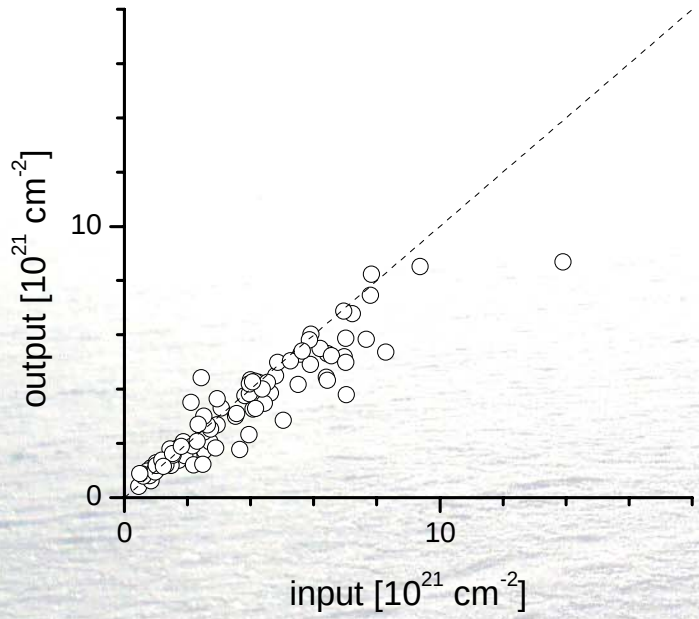
Vaisala RS92* vs. FTIR (3.3 km-5.3 km)

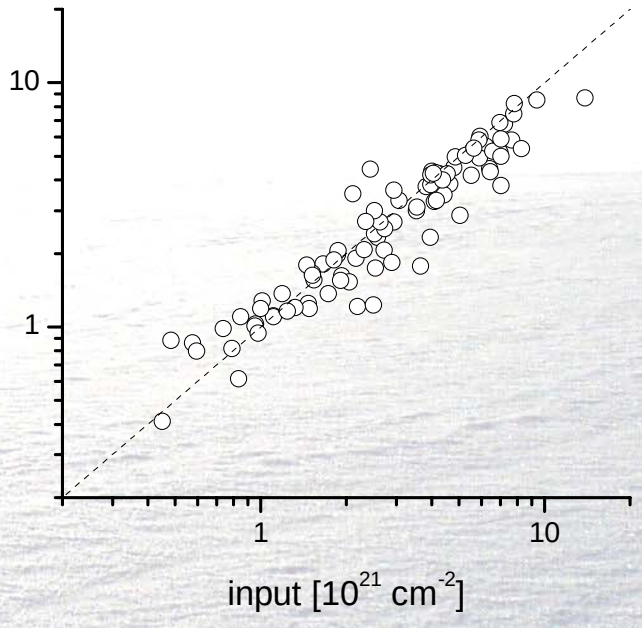




*corrected as in Vömel et al (2006)

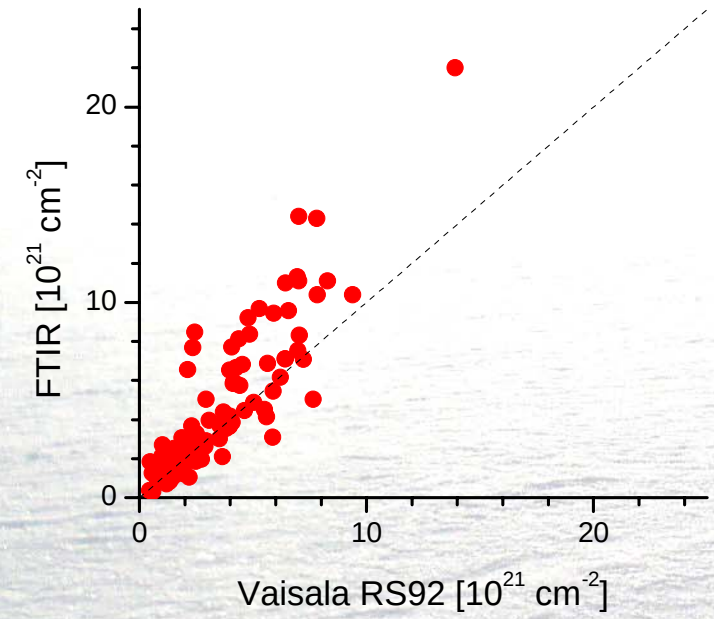
Theoretical FTIR performance (5.3 km-10 km+)

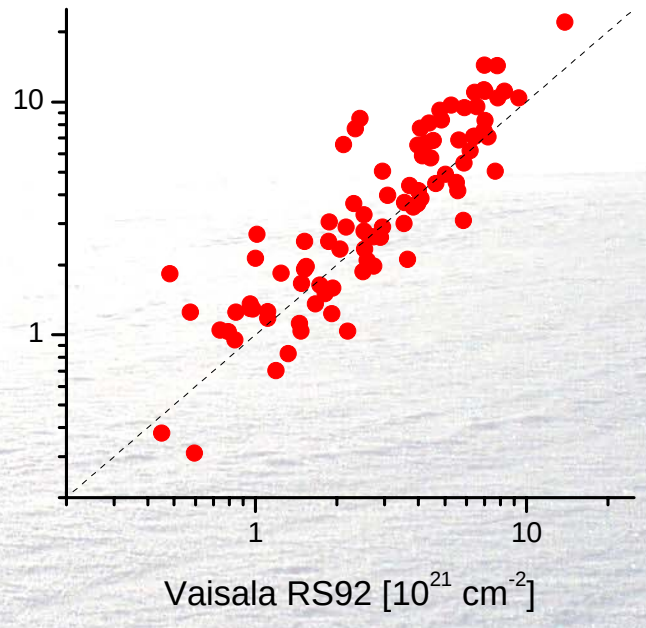




+ typically 22% of total column amount

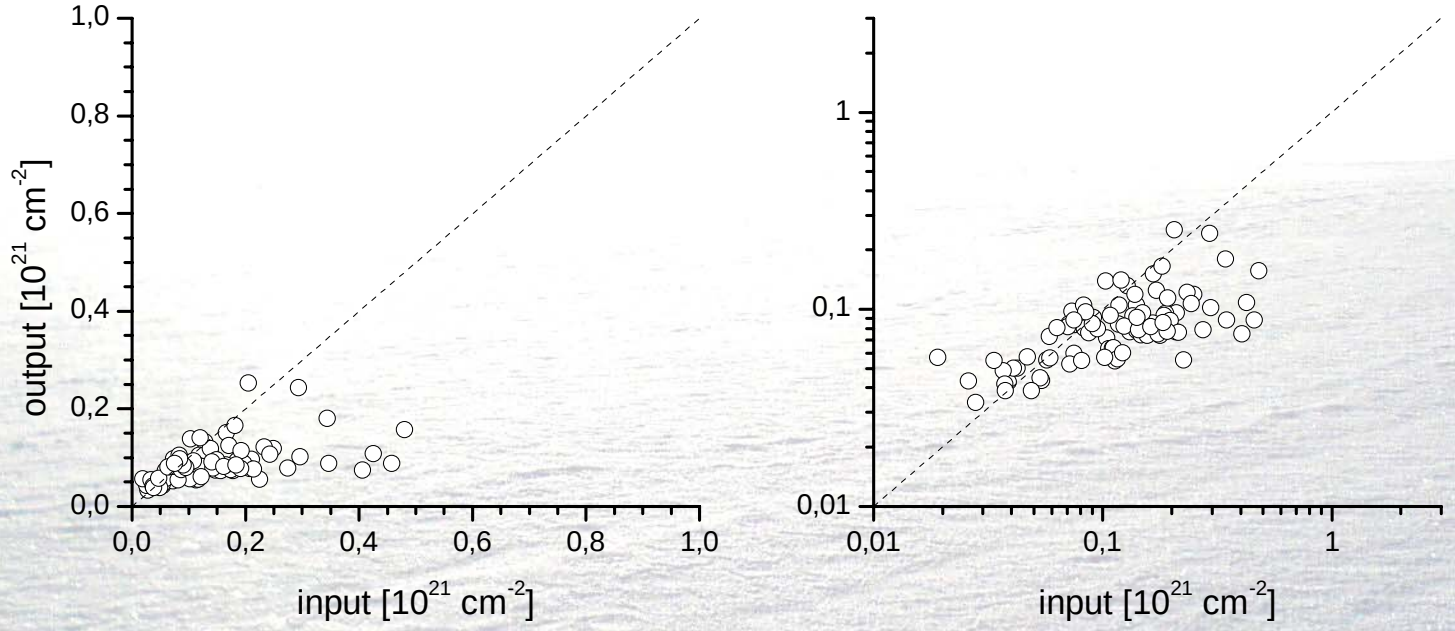
Vaisala RS92* vs. FTIR (5.3 km-10 km)





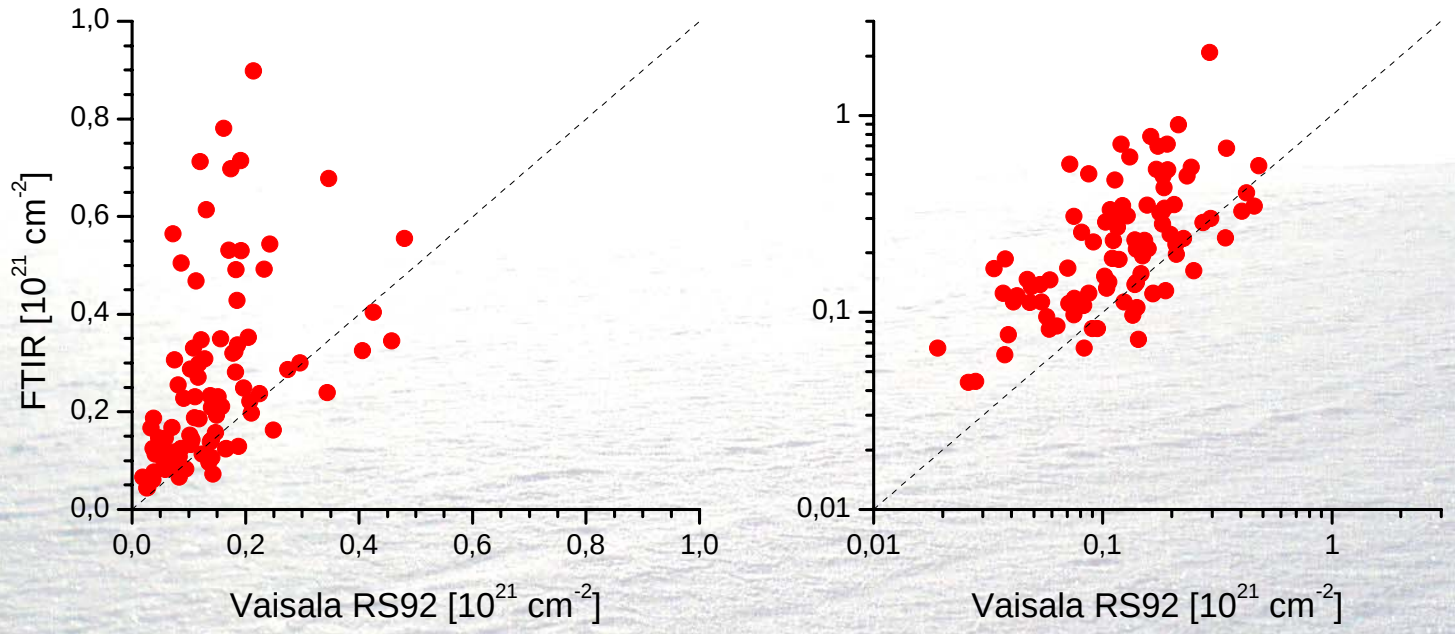
*corrected as in Vömel et al (2006)

Theoretical FTIR performance (10 km-15 km+)



+ typically 1% of total column amount

Vaisala RS92* vs. FTIR (10 km-15 km)

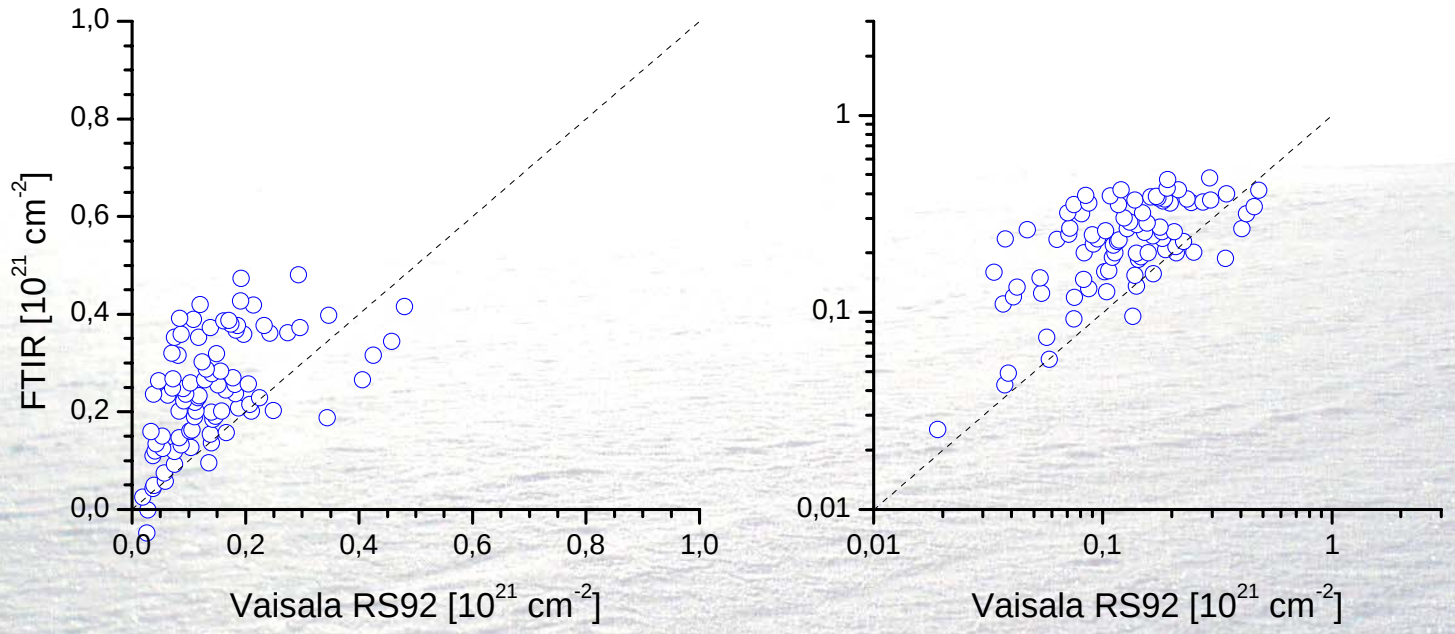


The ground based FTIR system can distinguish the 1% of H_2O above 10 km from the 99% below 10 km !!!

*corrected as in Vömel et al (2006)

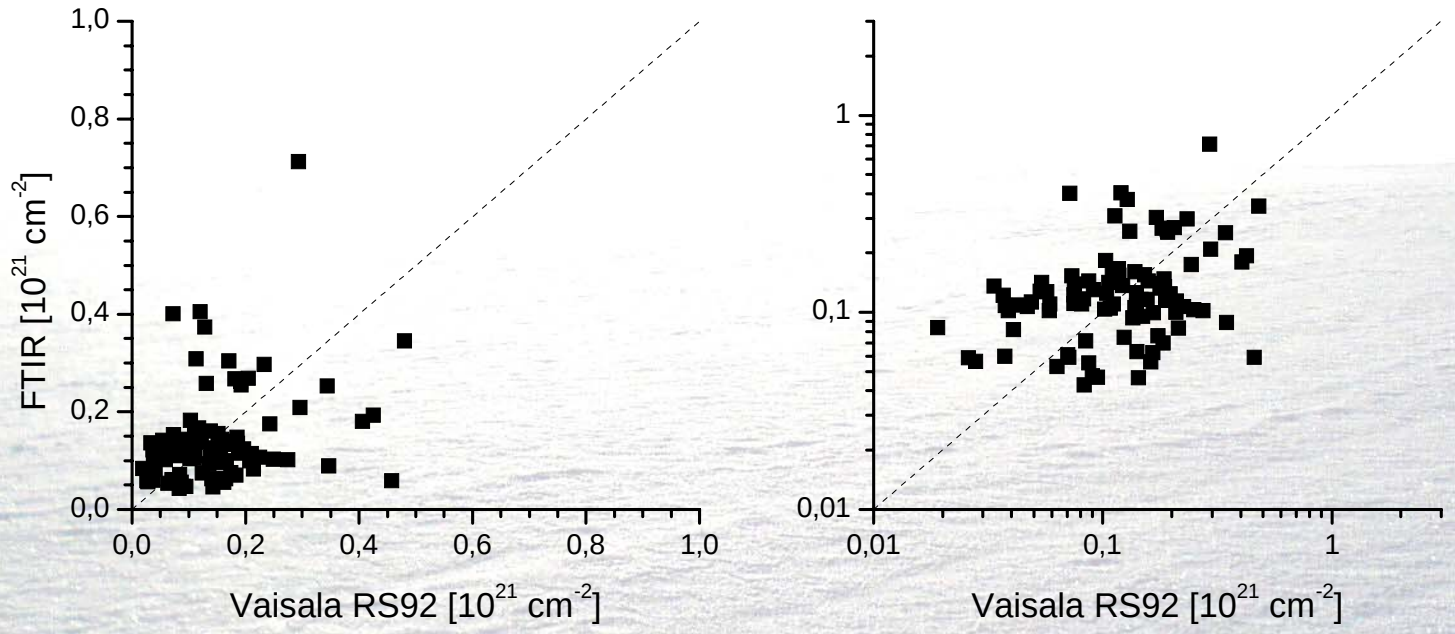
Vaisala RS92* vs. FTIR (10 km-15 km)

for retrieval on a linear scale:

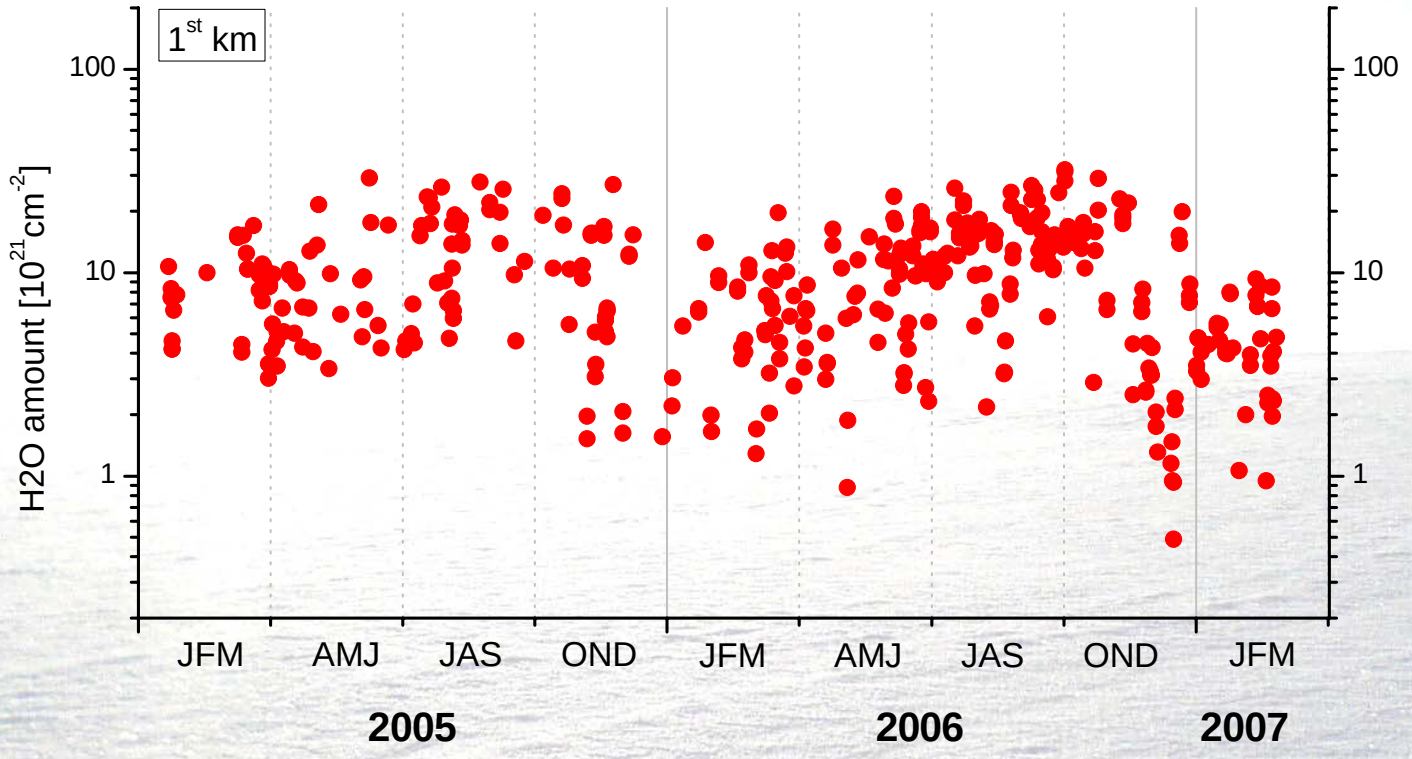


Vaisala RS92* vs. FTIR (10 km-15 km)

with original HITRAN 2006 data:

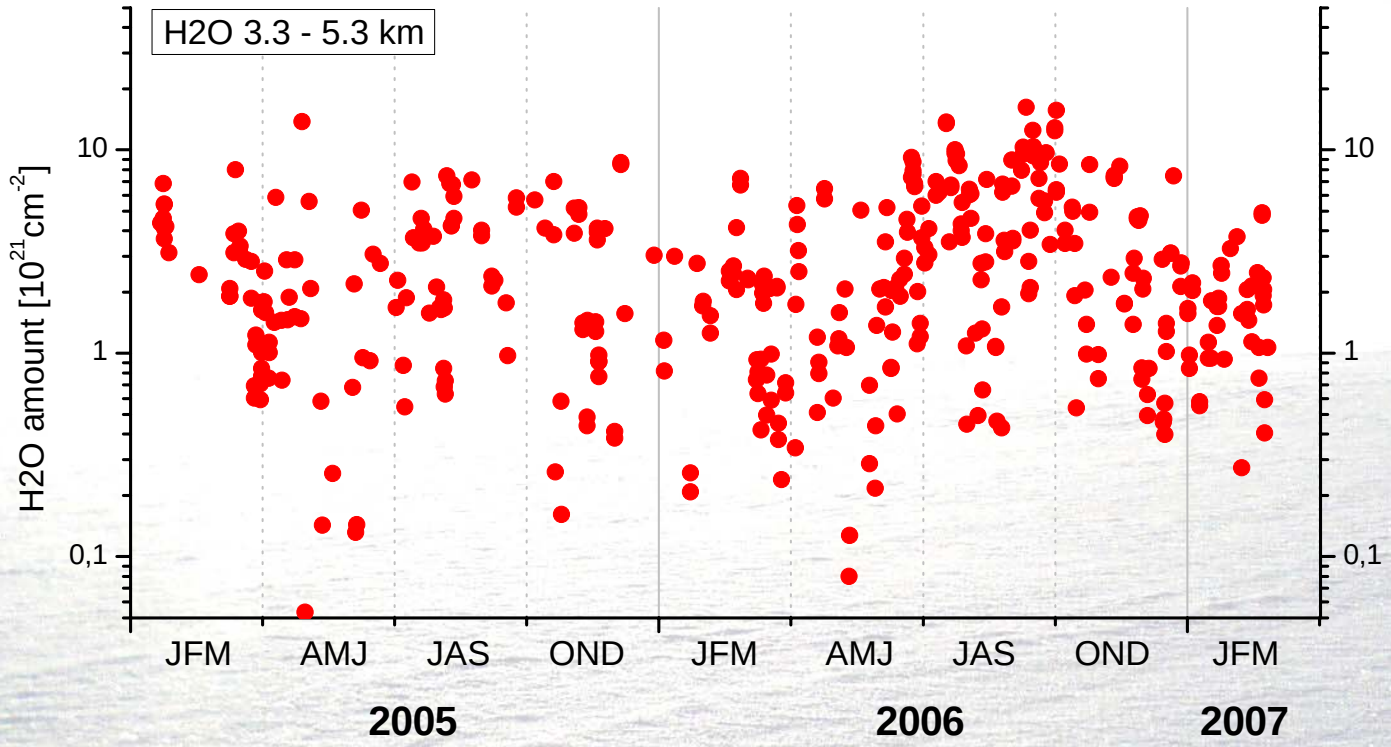


FTIR H_2O* time series above Tenerife (1st km)



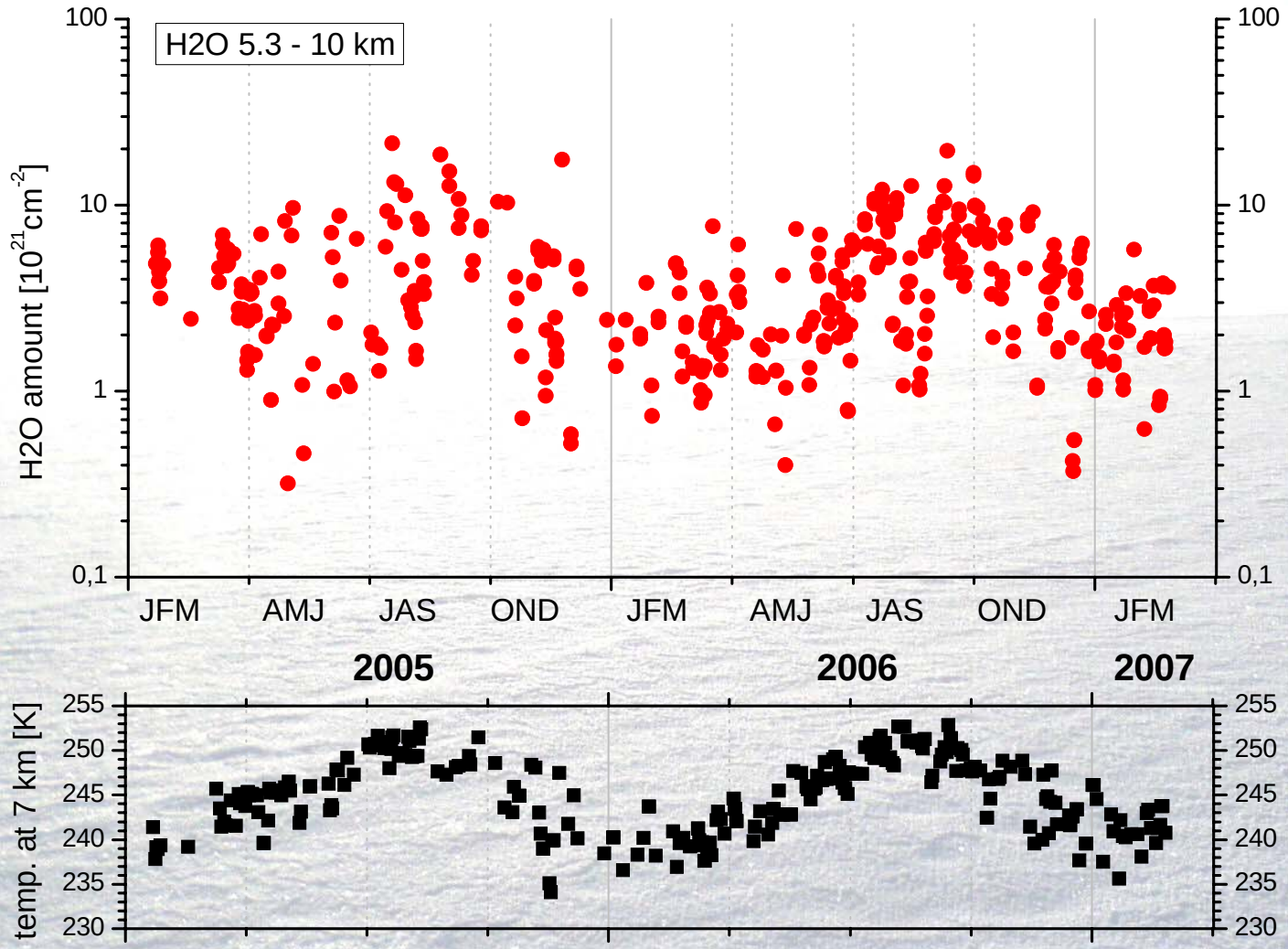
*preliminary (no temperature and phase error fit)

FTIR H_2O* time series (3.3 km-5.3 km)



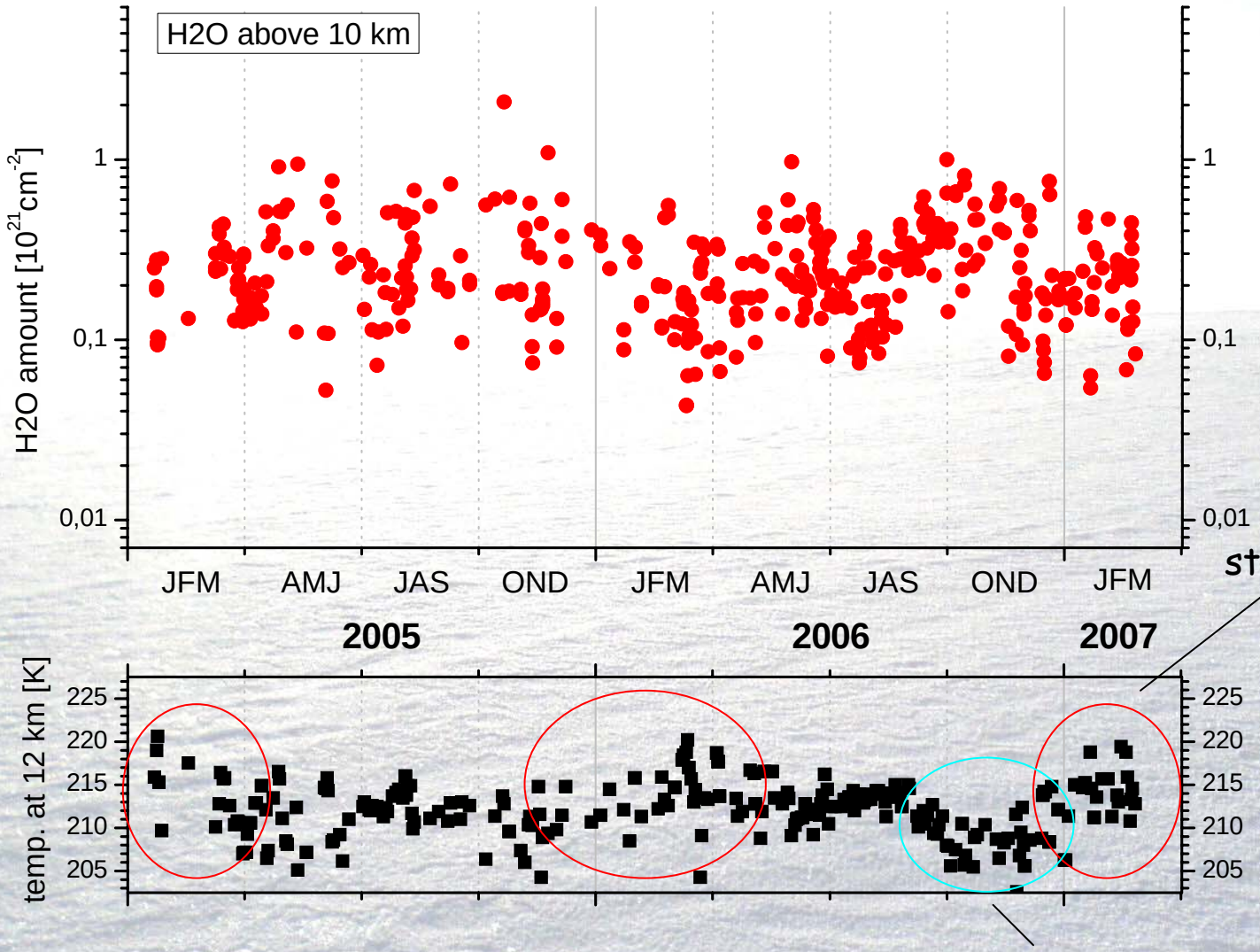
*preliminary (no temperature and phase error fit)

FTIR H_2O* time series (5.3 km-10 km)



*preliminary (no temperature and phase error fit)

FTIR H_2O* time series (above 10 km)

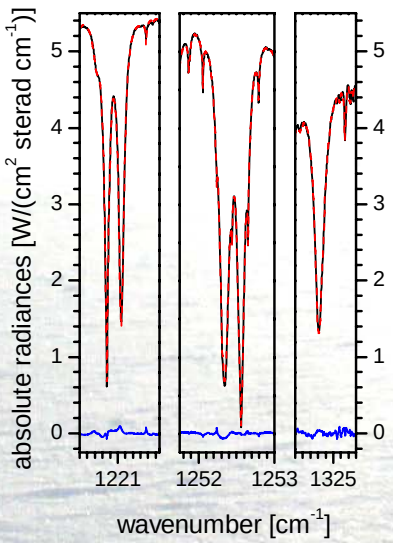


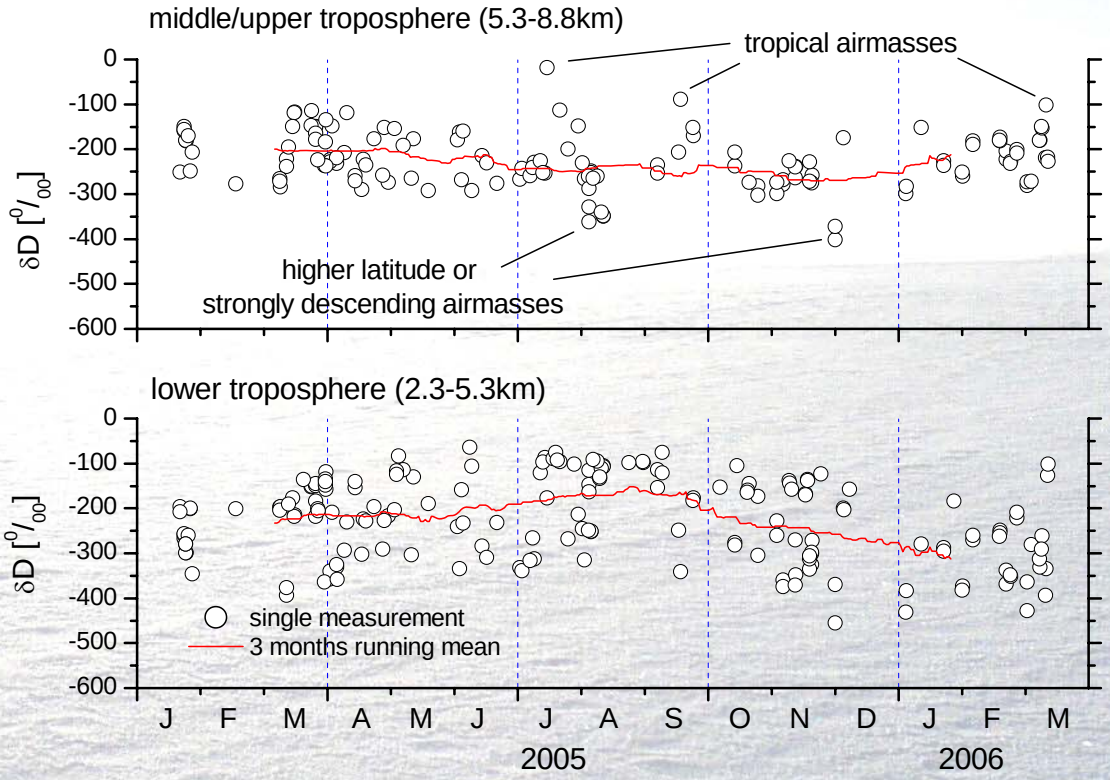
stratosphere ???

upper tropical troposphere ???

*preliminary (no temperature and phase error fit)

FTIR HDO/H_2O time series



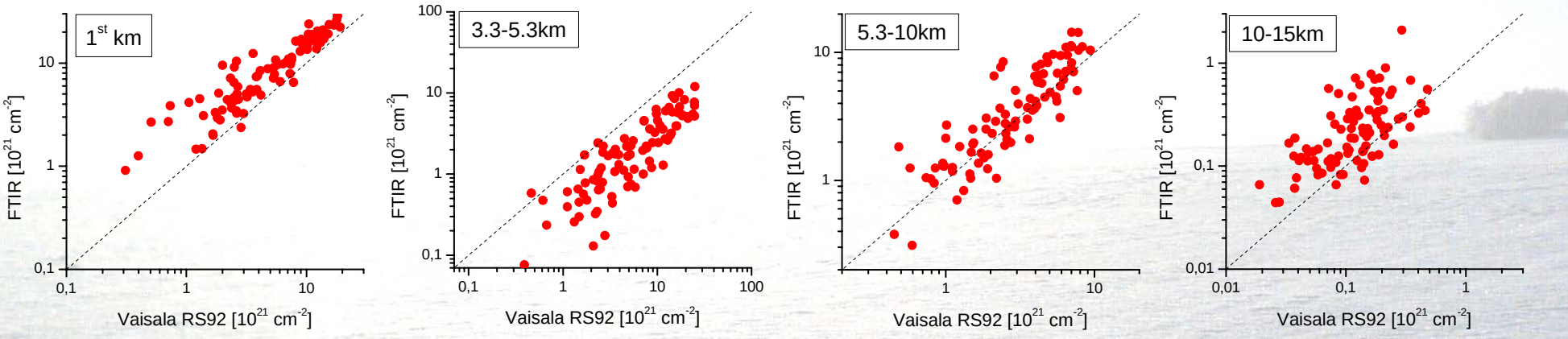


from ACP, 6, 4705, 2006

Summary

(1) We confirm the good performance of the Vaisala RS92 system

(2) NDACC FTIRs are suited to measure the H_2O (and HDO/H_2O) distribution from the ground to 15 km



(3) Our retrieval is 'nearly operational'

→ NDACC FTIRs can contribute to a long term QC of IASI H_2O products

Thank You !