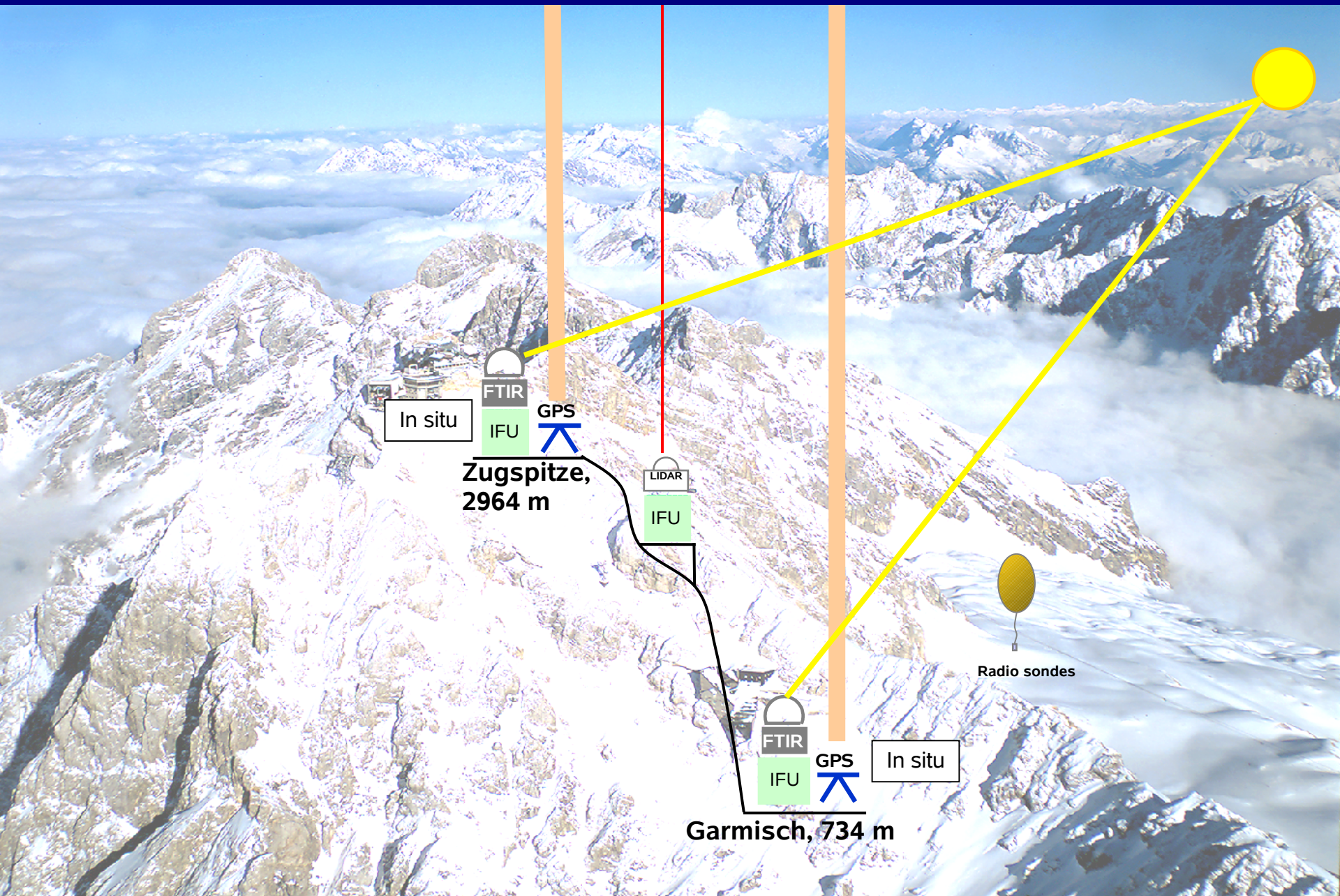
Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

Institut für atmosphärische Umweltforschung IMK-IFU, Garmisch-Partenkirchen

Water-vapor activities at Mt. Zugspitze / Garmisch-Partenkirchen

R. Knoche, H. Kunstmann, H. Scheel, R. Sussmann, T. Trickl, H. Vogelmann

Zugspitze/Garmisch instrumentation for water vapor columns, profiles and in-situ measurements



Water vapor DIAL

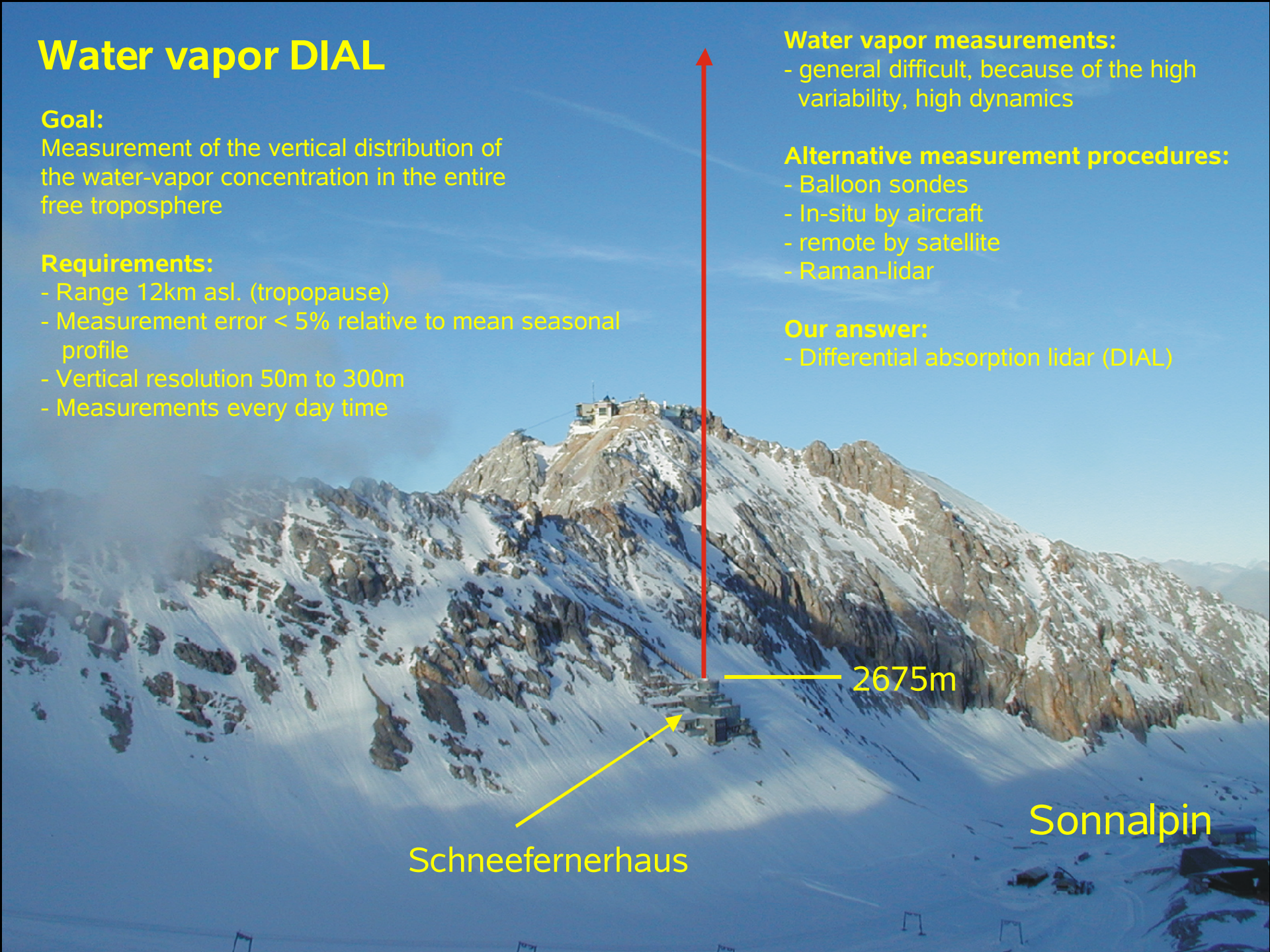
Goal:
Measurement of the vertical distribution of the water-vapor concentration in the entire free troposphere

Requirements:
- Range 12km asl. (tropopause)
- Measurement error < 5% relative to mean seasonal profile
- Vertical resolution 50m to 300m
- Measurements every day time

Water vapor measurements:
- general difficult, because of the high variability, high dynamics

Alternative measurement procedures:
- Balloon sondes
- In-situ by aircraft
- remote by satellite
- Raman-lidar

Our answer:
- Differential absorption lidar (DIAL)



Rückstreuung
an Luftmolekülen
und Partikeln

Wasserdampf

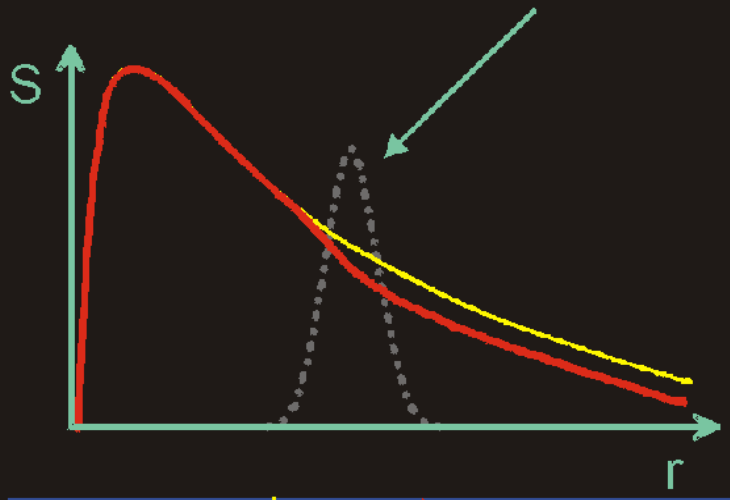
Höheninformation
aus der
Lichtlaufzeit

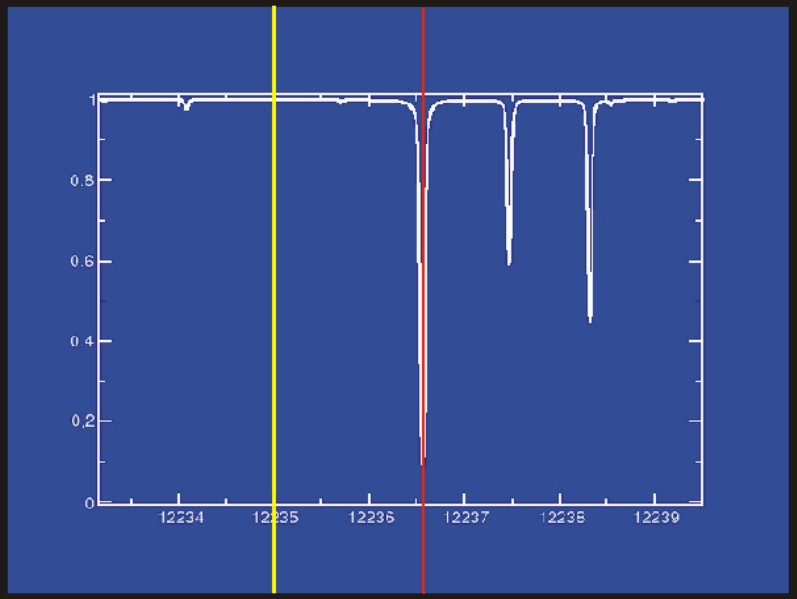
ns-Pulse

LASER

Empfänger

Rayleigh-Streuung und absorbierendes Spurengas





λ_{on} (817.223nm) wird durch Wasserdampf absorbiert

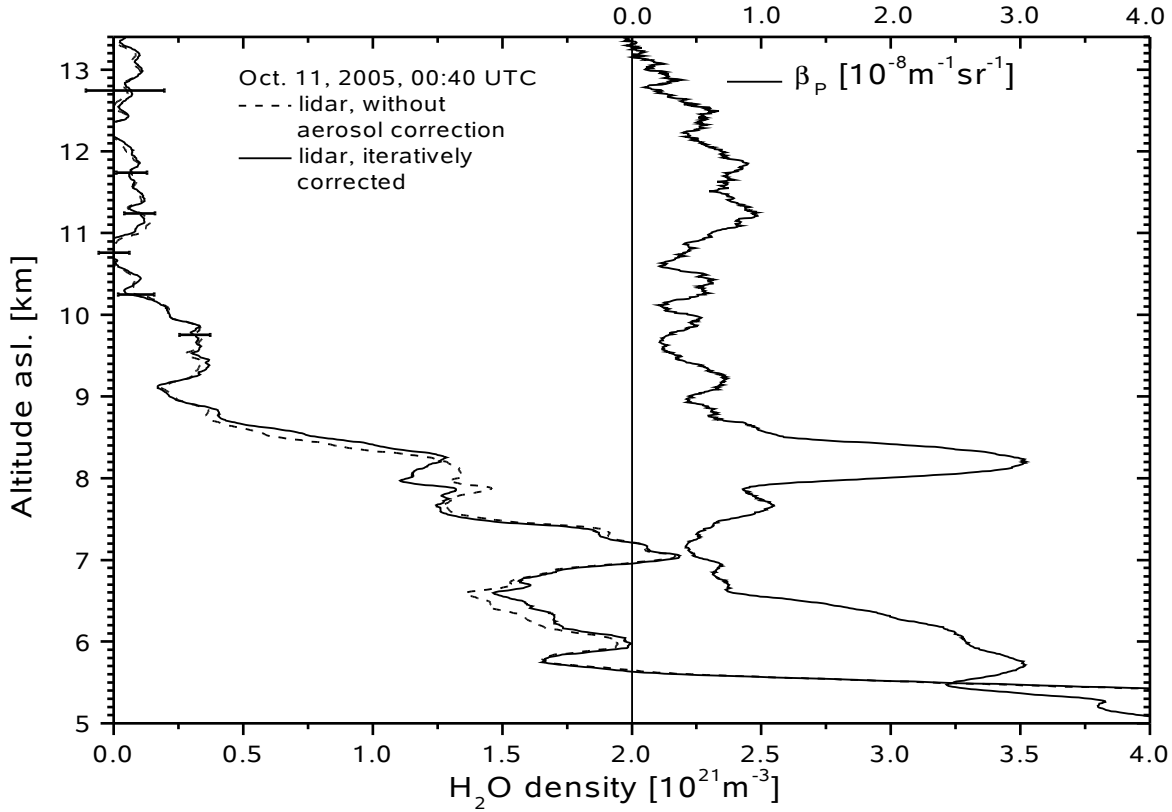
λ_{off} (817.351nm) wird nicht absorbiert

$$N_W(r) = \frac{1}{2\Delta\sigma}\,\frac{d}{dr}\ln\frac{S(\lambda_{\mathrm{on}},r)}{S(\lambda_{\mathrm{off}},r)}$$

DIAL equation

$$N_W(r) = \frac{1}{\Delta\sigma_{\uparrow}(r)+\Delta\sigma_{\downarrow}(r)}\left(G(r)-\frac{d}{dr}\ln\frac{S_{\mathrm{on}}(r)}{S_{\mathrm{off}}(r)}\right)$$

Modified DIAL equation

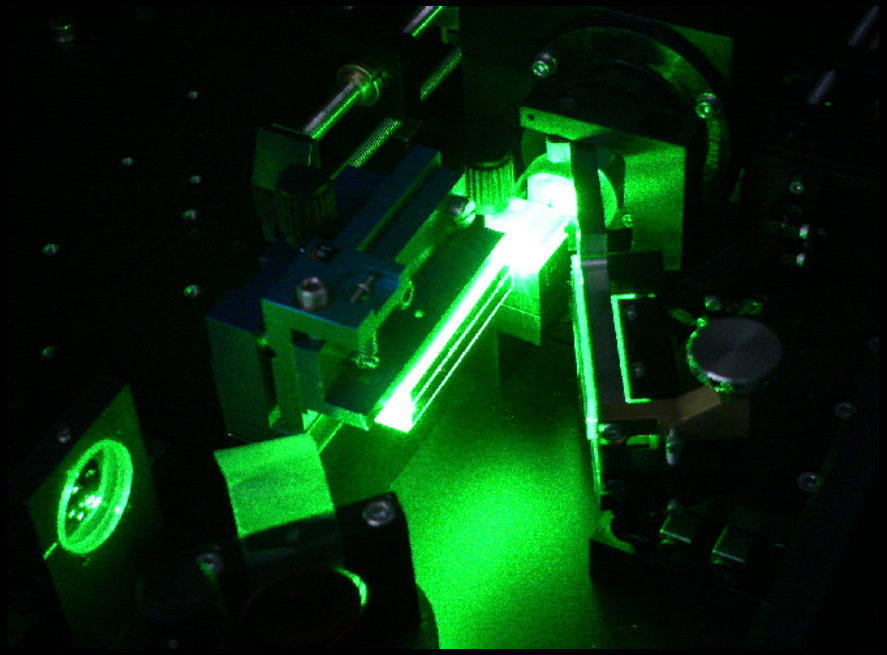


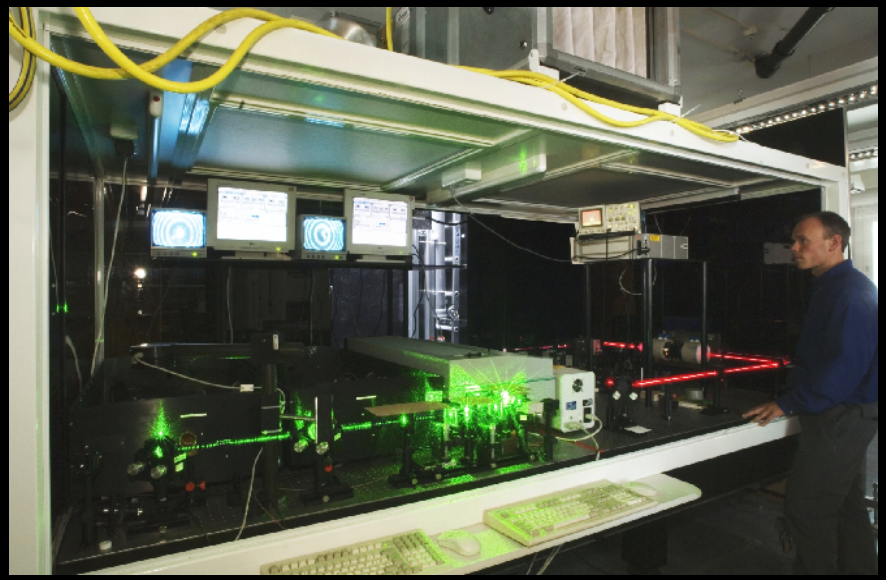
$$N_i = \frac{1}{\Delta\sigma_{\uparrow i}+\Delta\sigma_{\downarrow i}}\left(G_i-\frac{\sum_{j=i-k}^{i+k}(j-i)q_j}{q_i\cdot\delta_i\sum_{j=i-k}^{i+k}(j-i)^2}\right)$$

Numerical modified DIAL equation

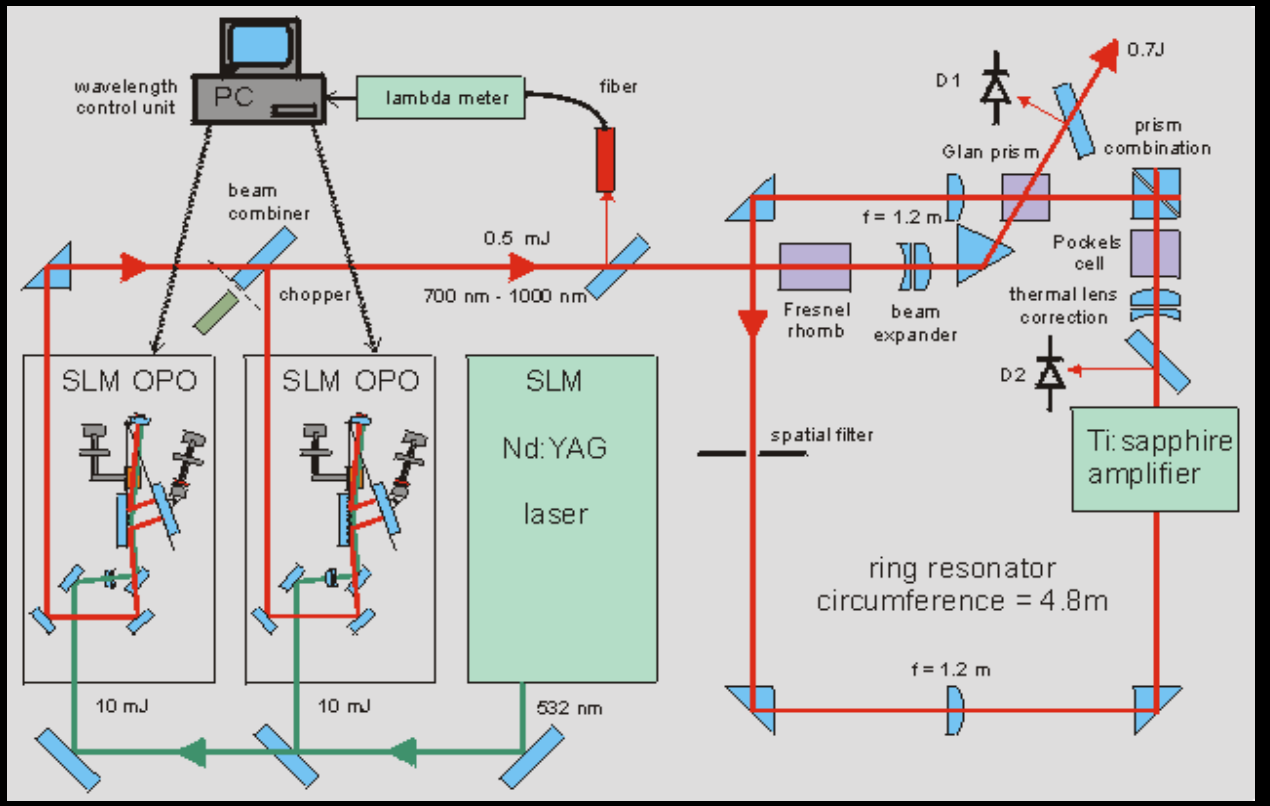
Laser system

- λ = 750nm – 900nm
- Bandwidth = 220 Mhz
- Pulse length = 2ns
- Pulse energy = 250mJ (planned > 500mJ)
- Exceeds common tunable SLM lasers by almost one order of magnitude

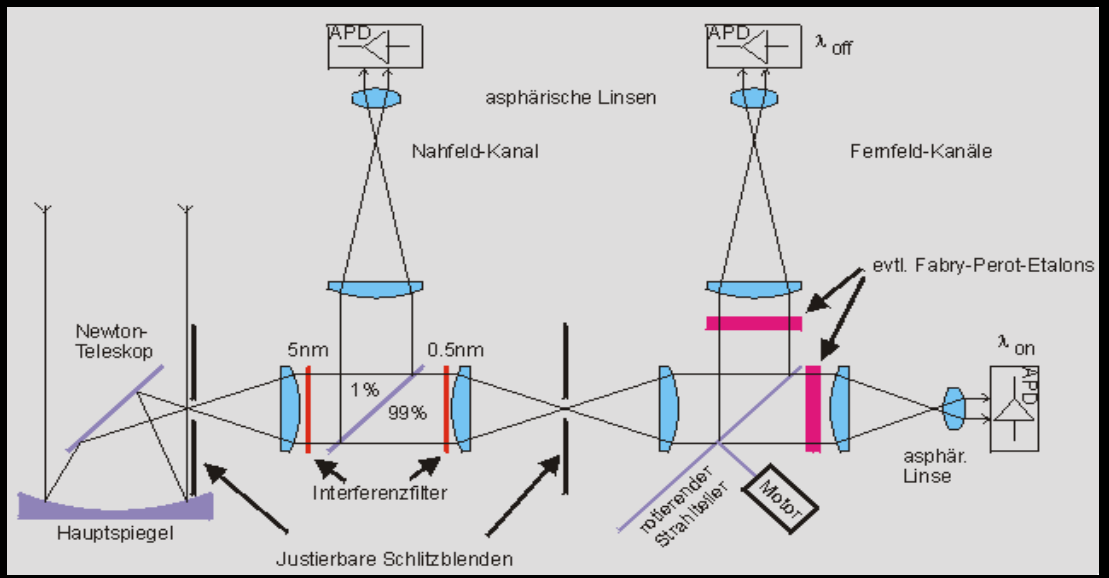




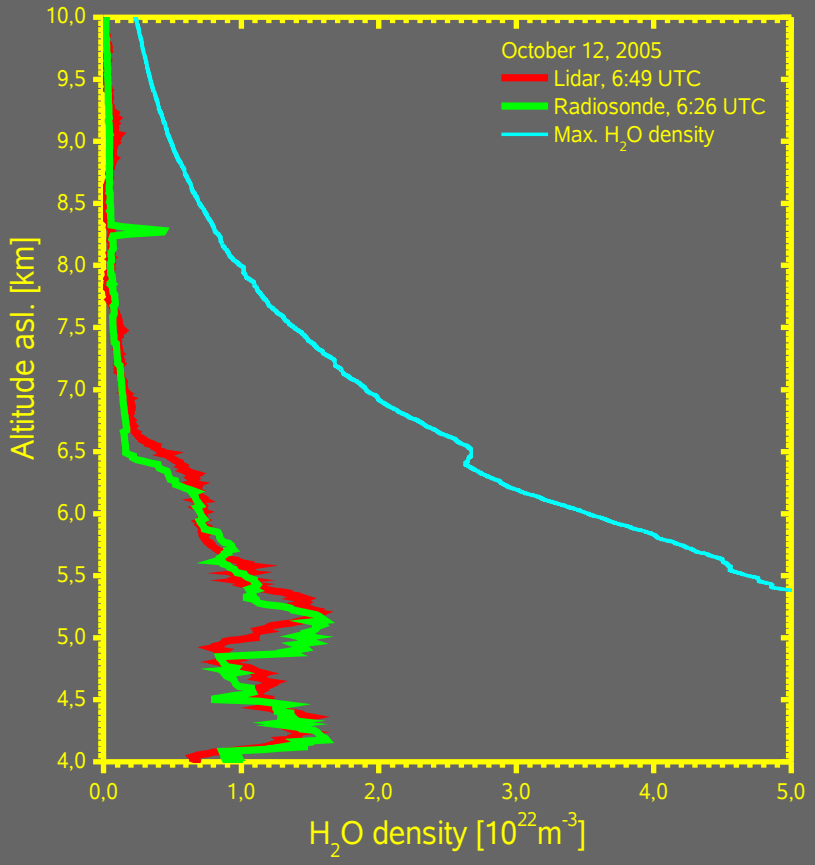
Laser system

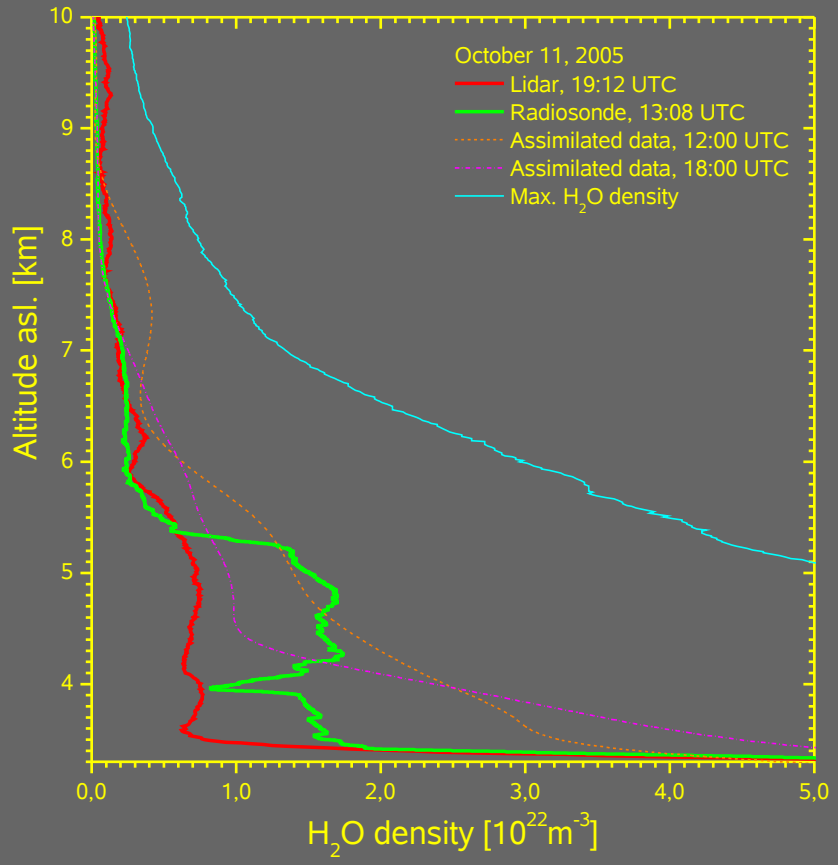


Receiver

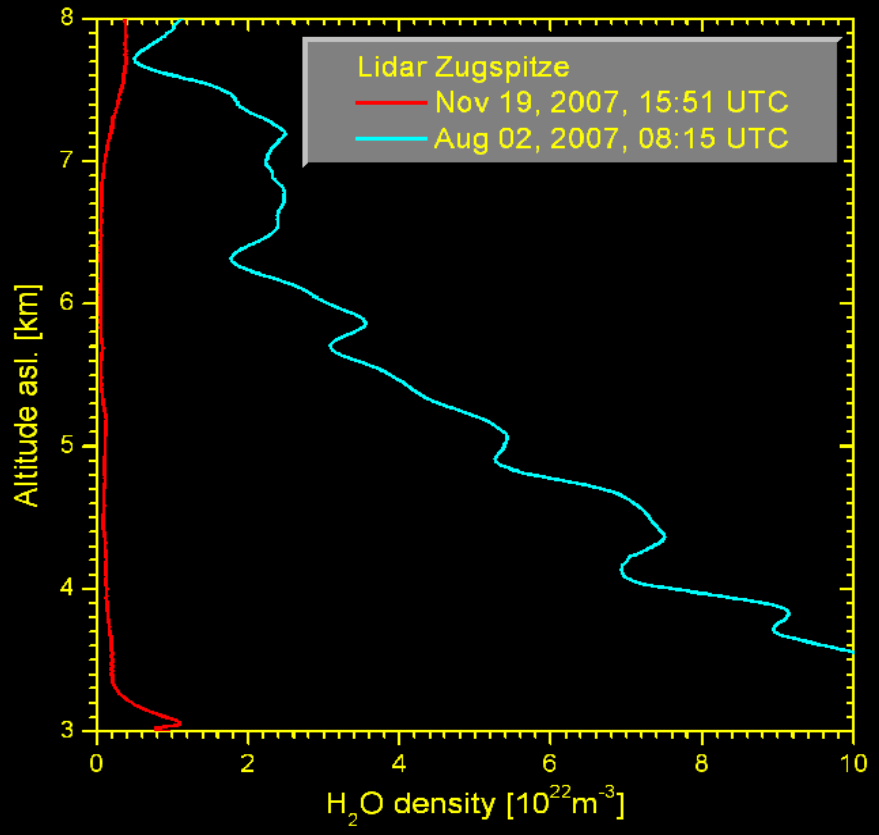


Intercomparison with radiosondes

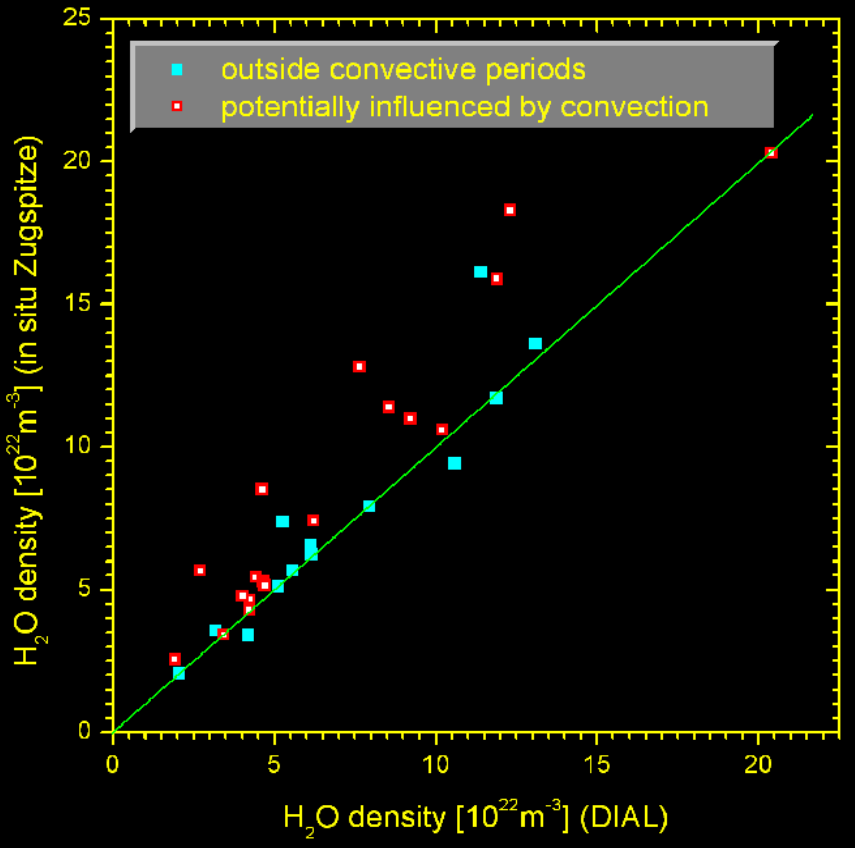




Variability and In-situ correlation

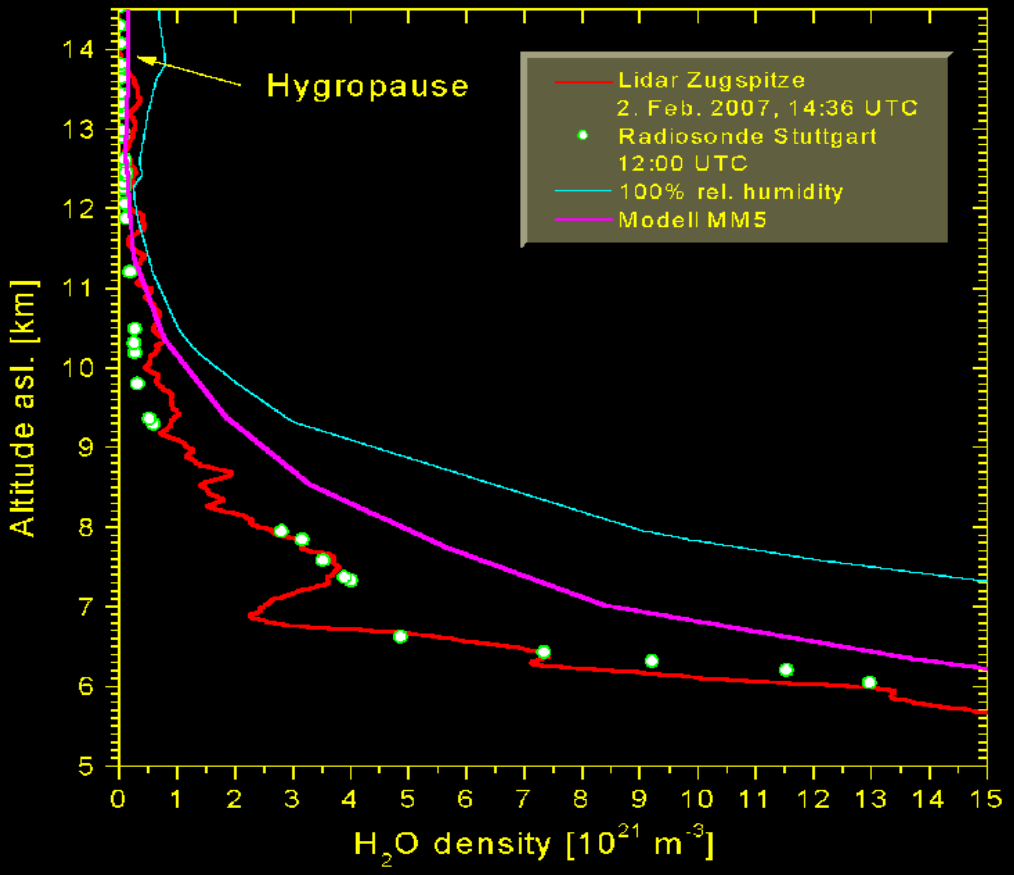


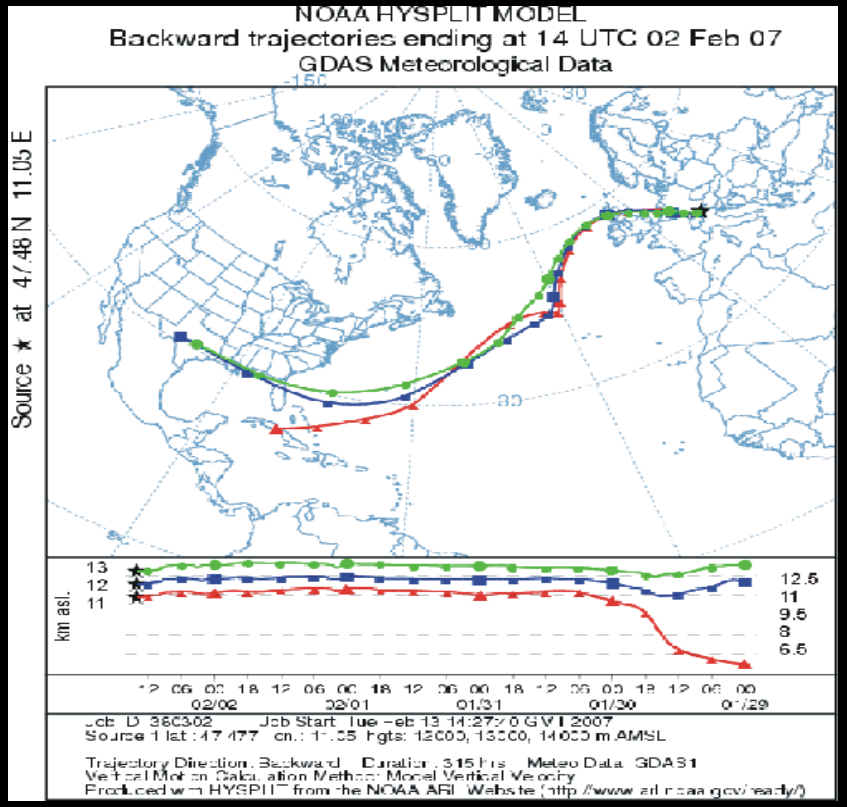
On the moistest day there was 30 times more water than on the driest day.



In-situ correlation of Mt. Zugspitze sumit and DIAL measurement

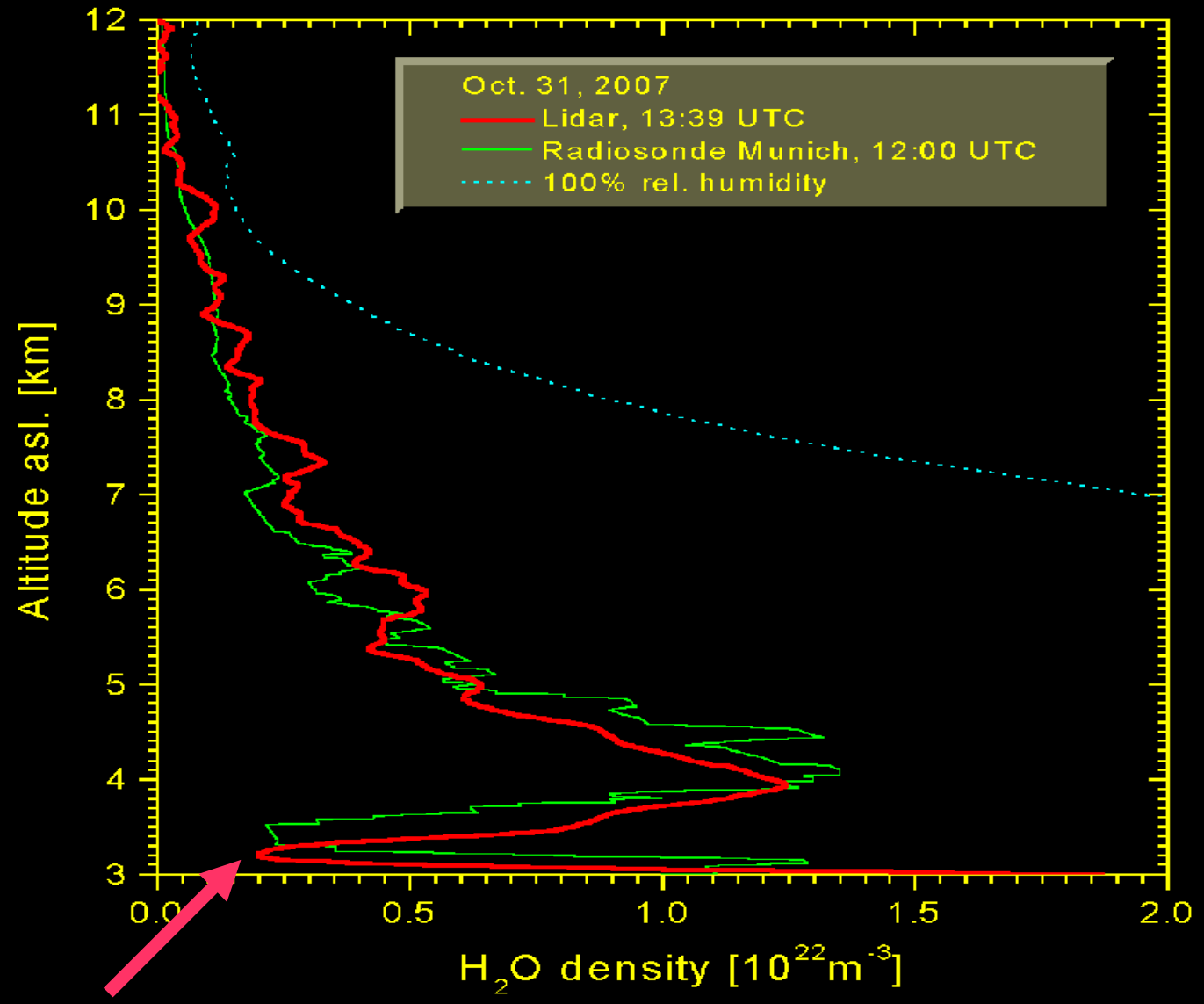
Extreme warm period Feb 2007 with extraordinary humidity in high altitudes





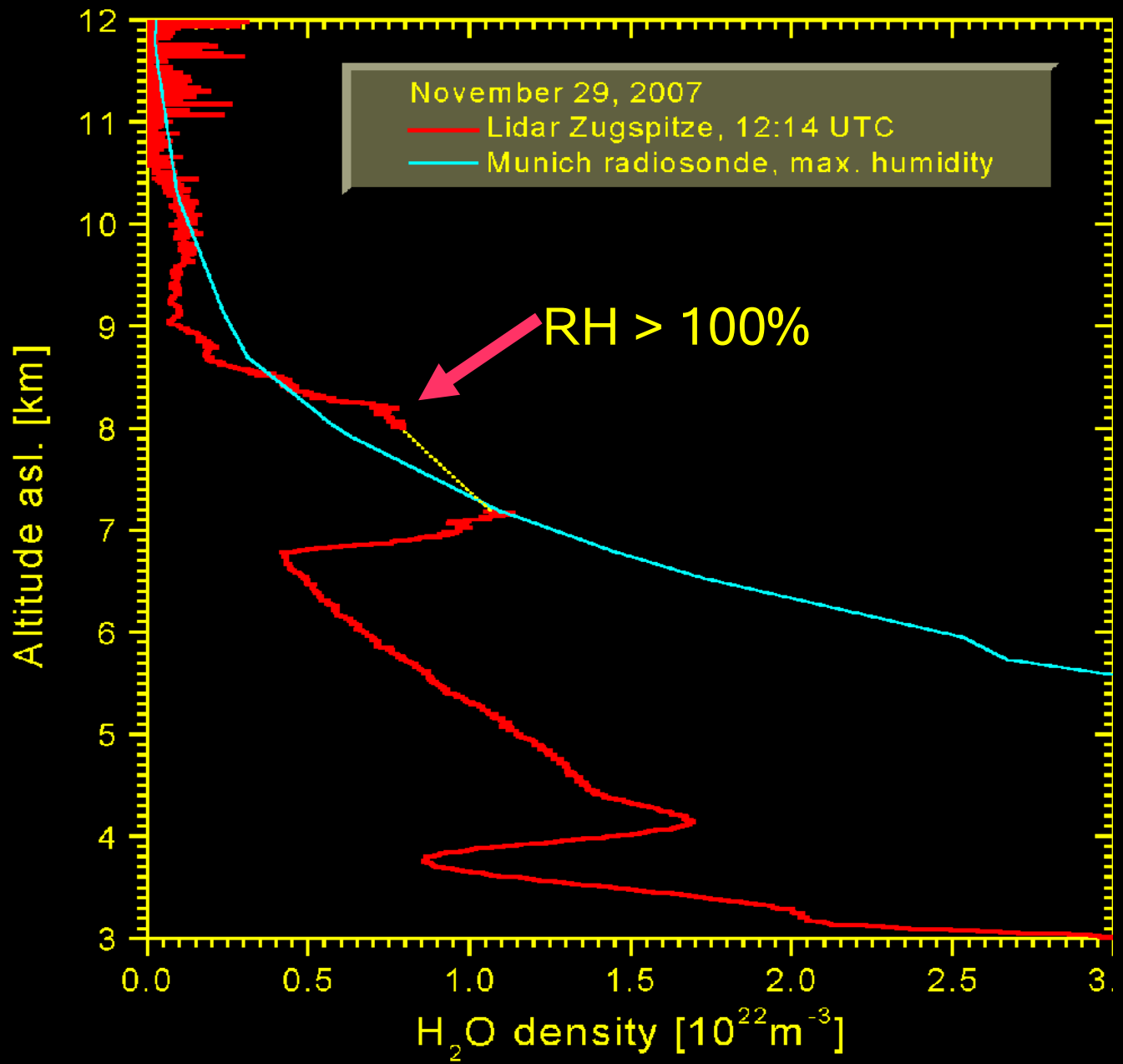
Numerical simulation: H. Kunstmann, R. Knoche

Extreme dryness in a stratospheric intrusion

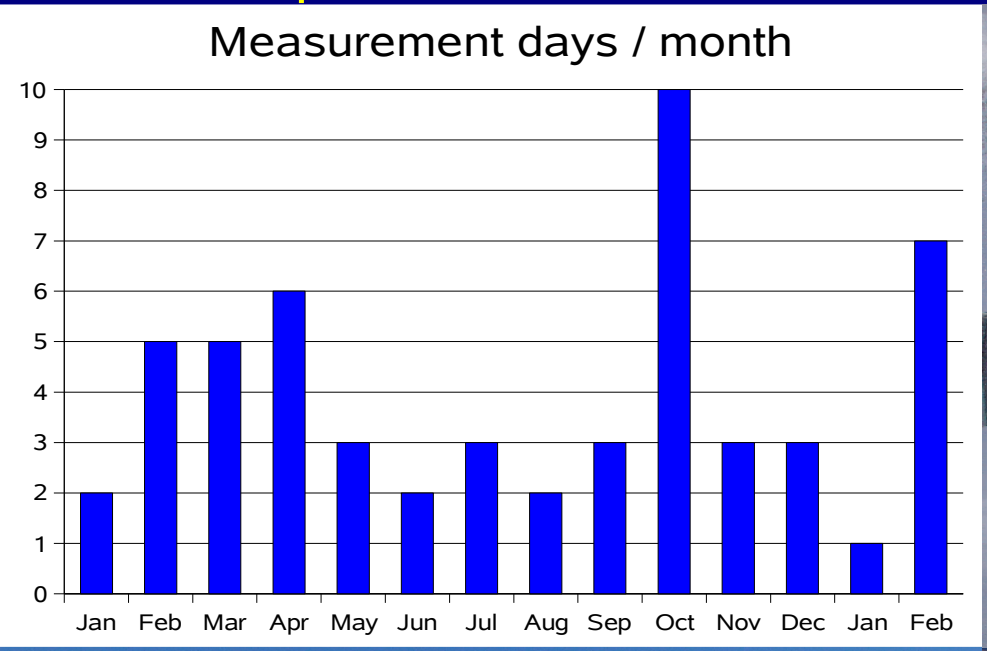


RH < 1%

Oversaturation in a cirrus layer ?



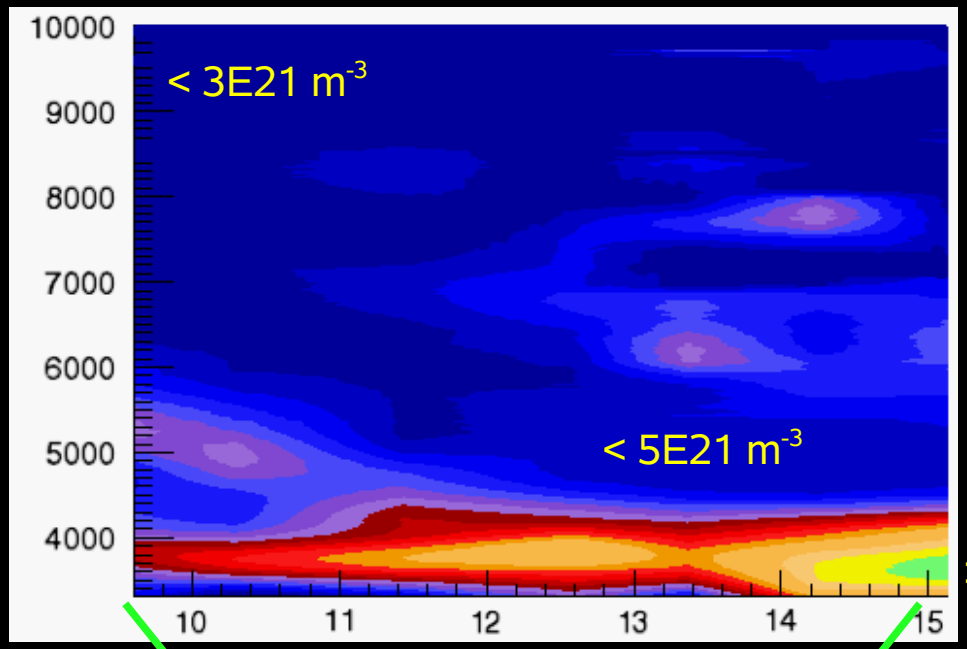
Routine operation since Jan 2007 with about one or two days per week



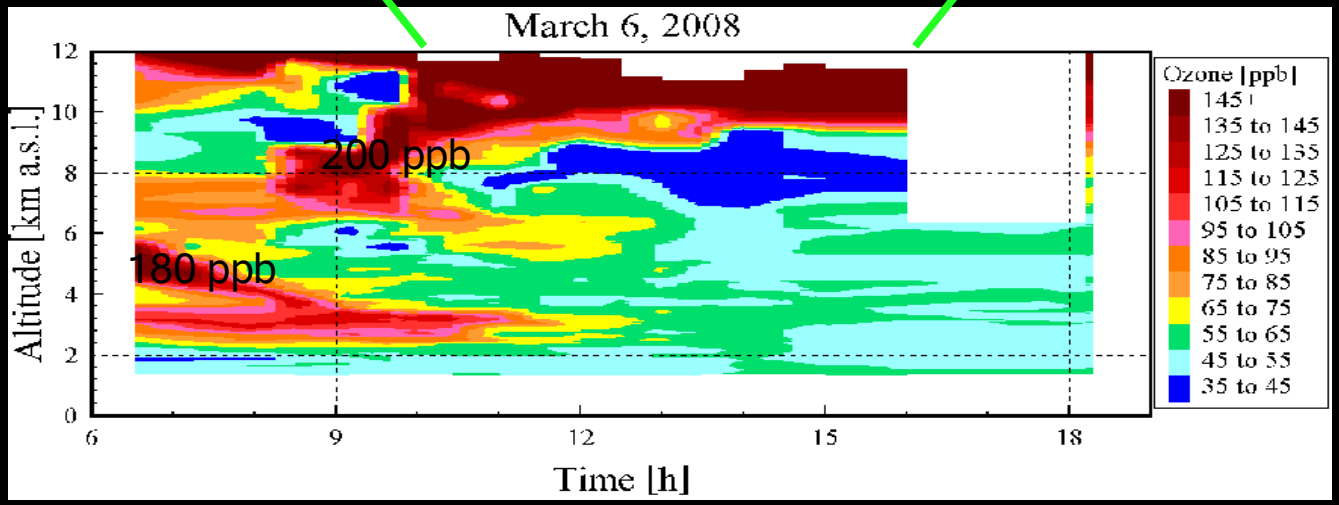
Observatory Schneefernerhaus

Simultaneous lidar-measurement of water vapor and ozone

Water vapor



Ozone



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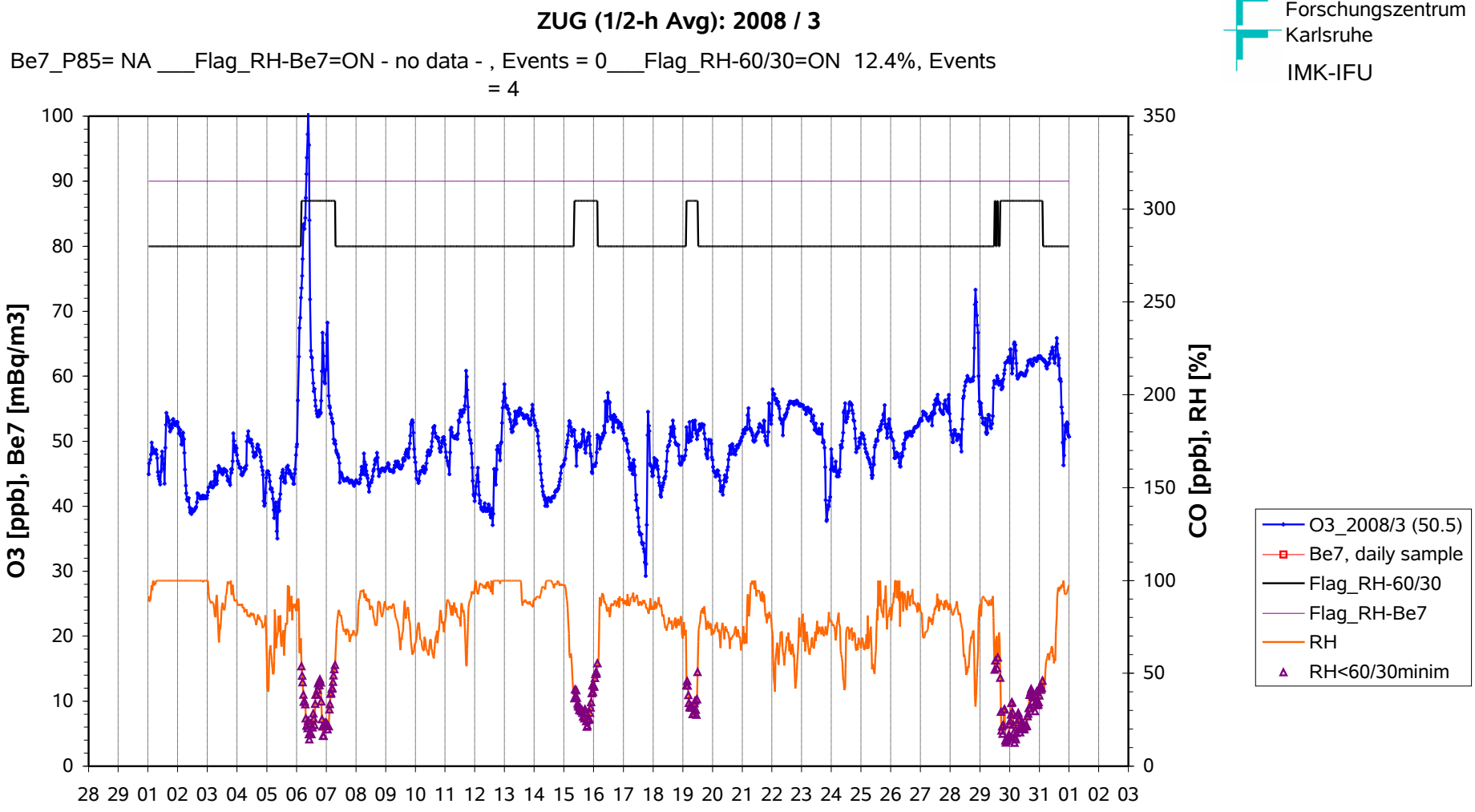
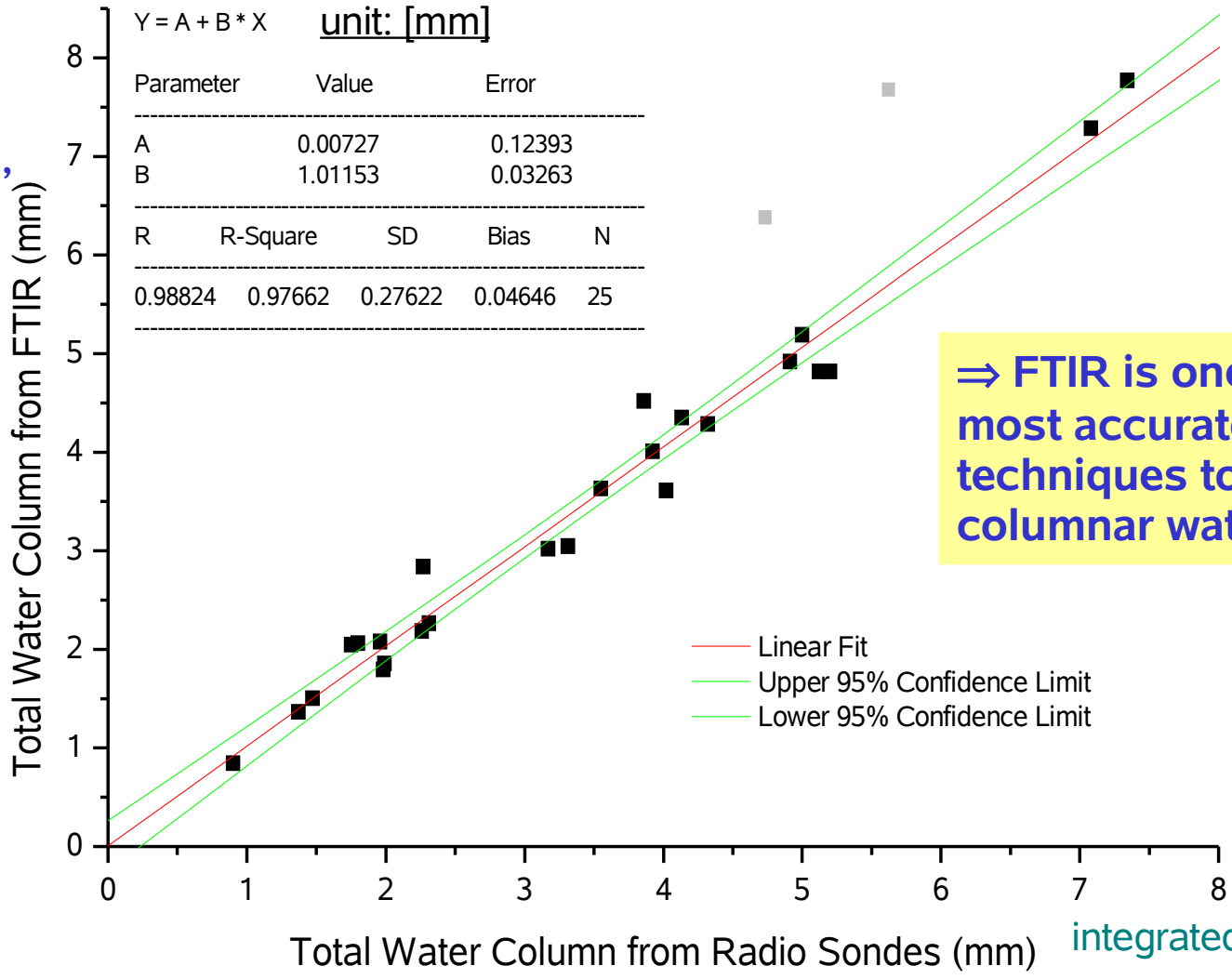


In-Situ measurements: E. Scheel

Optimized FTIR total water vapor column retrieval and its validation

Columns above Zugspitze, 2964 m

2-h-mean values



integrated Tobin-profiles

⇒ FTIR is one of the most accurate techniques to quantify columnar water vapor

FTIR Measurements: R. Sussmann

Strategy for validation of FTIR total water vapor columns by sondes: Tobin-Sondes

Sonde 1 launched 1h before overpass
Sonde 2 launched 5 min before overpass

AIRS validation campaign
19 Aug 2002 - 17 Nov 2002

Vaisala RS 80-30 G sondes
TOTEX-800-g balloons
2 x Digicora III (Marvin 21, SPS220G)

TOBIN-Inter-/Extrapolation between both soundings:

$$q_{Tobin}(z, t_{op}) = q_{sonde}(z, t_0) + (dq(z)/dt)\ (t_{op} - t_0)$$

Tobin, D., W. Feltz, B. Knuteson, H. Revercomb, *"ARM T/q Best Estimate Profiles for AIRS validation"*, 1 March 2000

Thank you for attention!

Reference: [H. Vogelmann and T. Trickl, Appl. Opt., Vol. 47, April 2008]