NDACC Working Group on Water Vapor

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Raman Lidar activities at Rome - Tor Vergata

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Water Vapor retrieving methodology

We record two signals @ Raman λ of H_2O and N_2 (or O_2)

$$S_H(z) = k_H \ \sigma_H \ n_H(z) / z^2$$

$$S_N(z) = k_N \ \sigma_N \ n_N(z) / z^2$$

From the definition of Mixing Ratio and from the ratio of the signals

$$W_H(z) = \frac{n_H(z) M_H}{n_d(z) M_d}$$

$$\frac{S_H(z)}{S_N(z)} = \frac{k_H}{k_N} \frac{\sigma_H}{\sigma_N} \frac{n_H(z)}{n_N(z)}$$

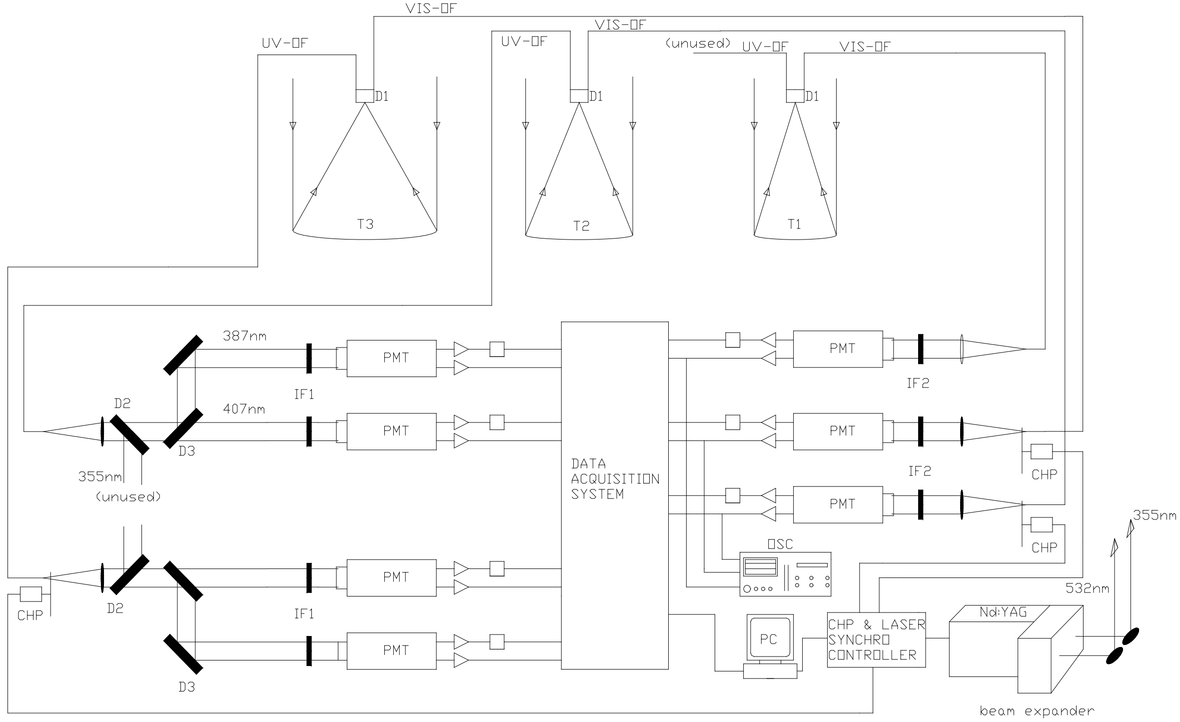
we obtain the measurement of the Mixing Ratio

$$W_H(z) = \frac{k_N}{k_H} \frac{\sigma_N}{\sigma_H} \frac{n_N(z) M_H}{n_d(z) M_d} \frac{S_H(z)}{S_N(z)} = C \frac{S_H(z)}{S_N(z)}$$

The constant C is estimated through calibration using, e.g., co-located radiosoundings at a selected altitude z_c

$$C = \frac{k_N}{k_H} \frac{\sigma_N}{\sigma_H} \frac{n_N(z_c) M_H}{n_d(z_c) M_d}$$

System design



System design

TRANSMITTER

Laser Nd:YAG Continuum Powerlite 8010

Energy: 400 mJ @ 355 nm, 180 mJ @ 532 nm,

Pulse repetition rate: 10 Hz Pulse duration: 7 ns

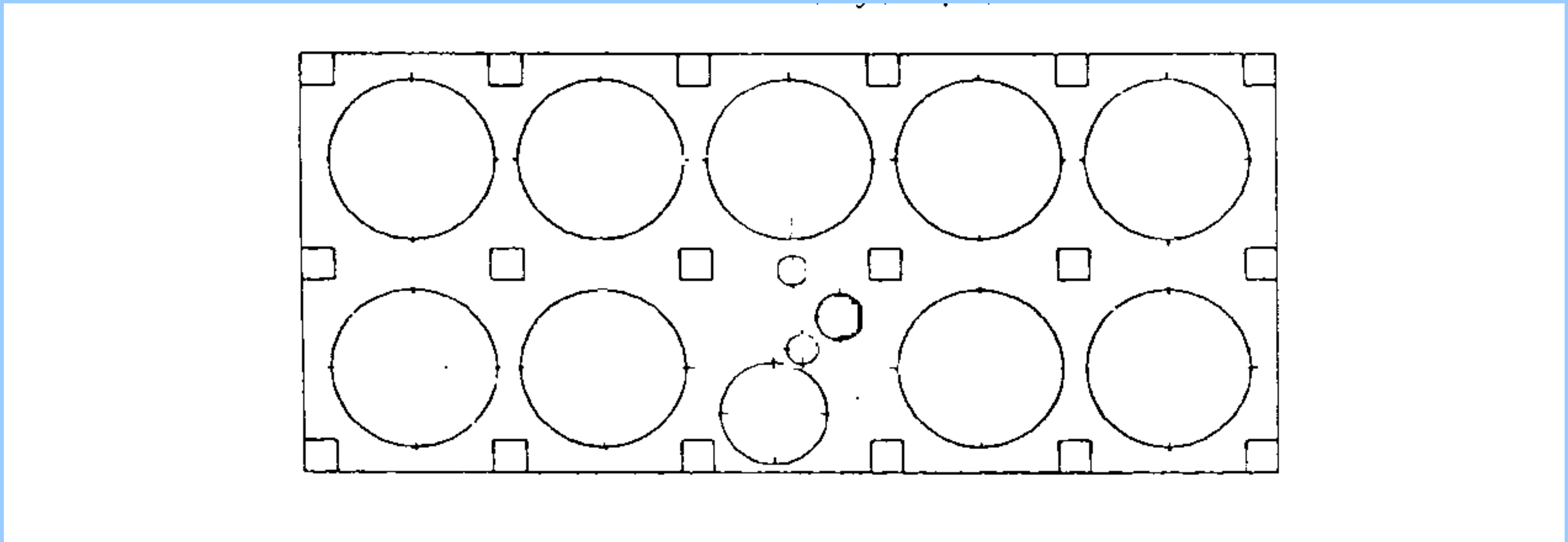
Beam divergences: 0.2 mrad (with 4× beam expanders)

RECEIVER

- Collector 1: Single newtonian F/3 telescope (**nighttime & daytime**)
  Diameter: 0.15 m
  Field of view: 1.8 mrad
  for lower range elastic baksc.
- Collector 2: Single newtonian F/3 telescope
  Diameter: 0.3 m
  Field of view: 0.9 mrad (**nighttime**), 0.45 mrad (**daytime**)
  for lower range Raman backsc. and middle range elastic backsc.
- Collector 3: Array of 9 newtonian F/3 telescopes (**nighttime**)
  Diameter: 0.5 m each (total collection area ~1.75 m^2)
  Field of view: 0.6 mrad
  for upper range Raman backsc. and upper range elastic backsc.

System design

(Arrangement of the 11 collectors and 2 beam holes)



System design

Signal modulation system 3 synchronized choppers to prevent blinding of :

- upper and middle range elastic backsc. channels
- upper range Raman backsc. channels

Raman wavelength Interferential Filter bandwidth (FWHM)

- WV Raman: 0.38 nm (**daytime/nighttime**)
- N2 Raman: 5 nm (**nighttime**)
  0.33 nm (**daytime**)

Transportable system (installed in 2 containers transportable by trucks)

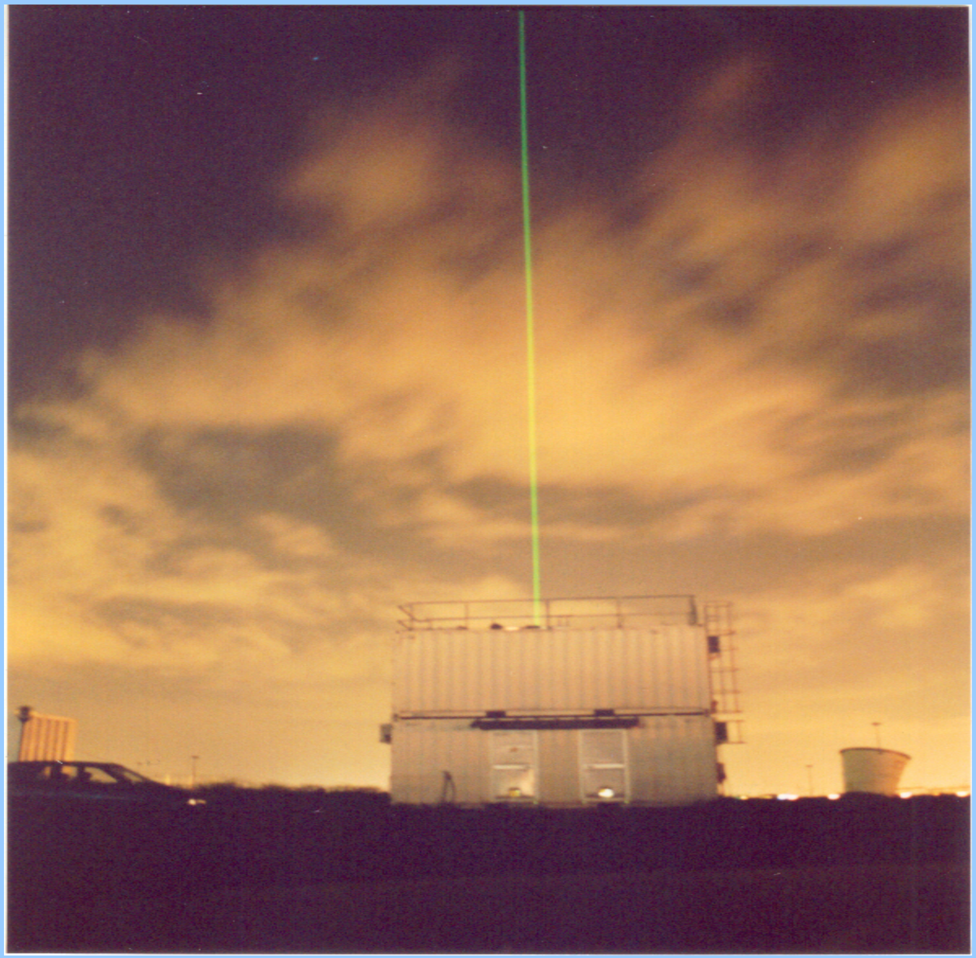
Acquisition resolution	Usual data elaboration resolution
• **in altitude:** 75 m	• **in altitude:** 75 m up to 6 km 525 m above 6 km (7-point smooth.)
• **in time:** 1 min	• **in time:** 10 – 30 min (mostly 20 min)

Calibration / validation through radiosonde of Meteorological Service of Italian M.A. in Pratica di Mare, 25 km S.W. of lidar station

Atmospheric Quantities

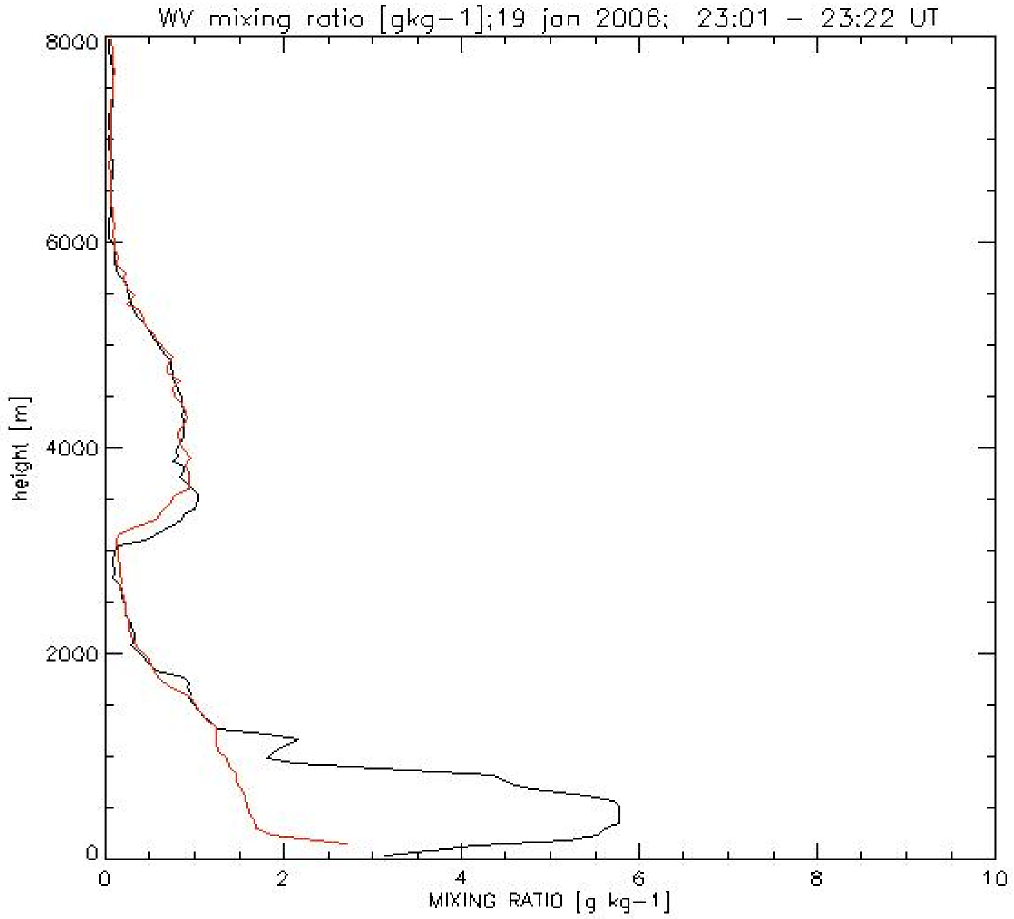
- Vertical profiles of water vapor from ~75 m up to the upper troposphere
- Vertical profiles of temperature in the upper stratosphere and mesosphere
- Vertical profiles of aerosol from ~200 m up to the stratosphere
- Cloud location
- Boundary Layer structure and top

System design



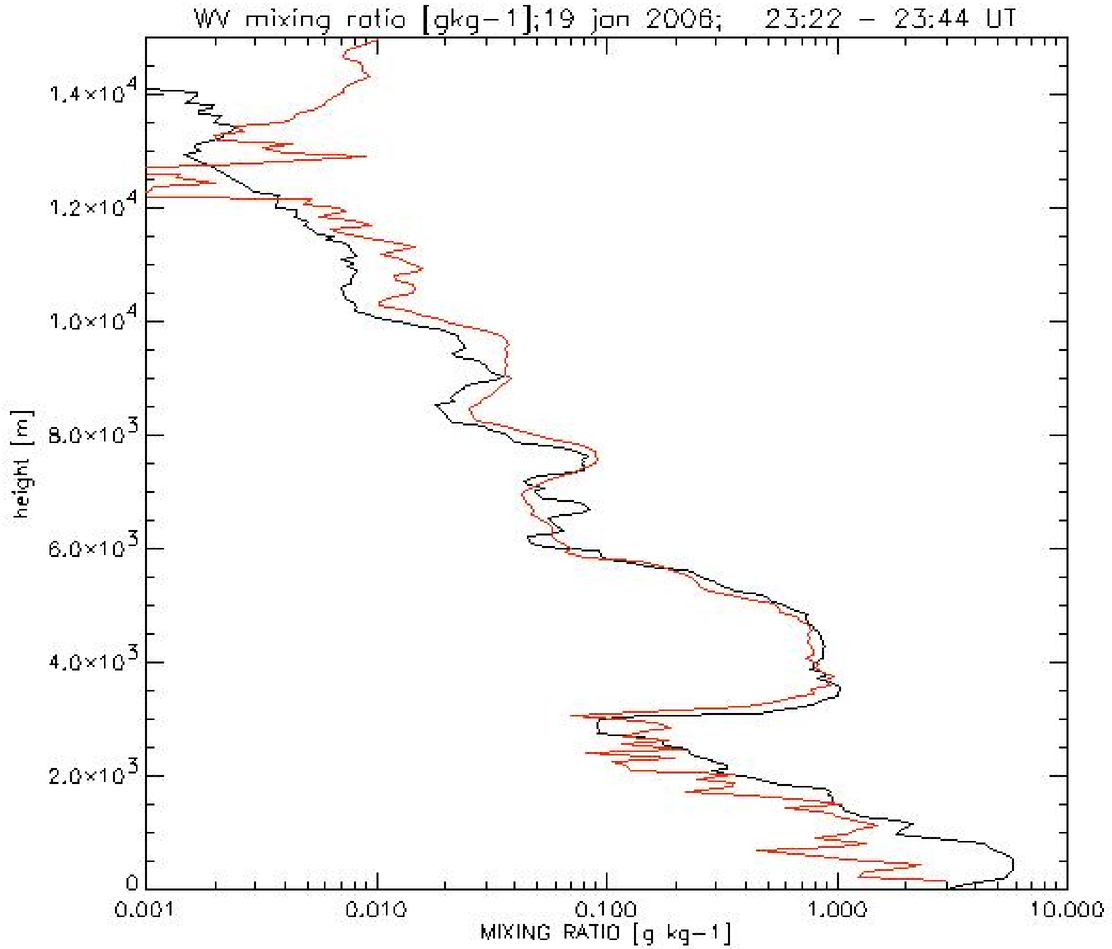
WV profiles in the lower troposphere

RDS of Pratica di Mare, 25 km S.W. of the lidar station (23:02 UT)
Lidar, lower channels (20-min integration)



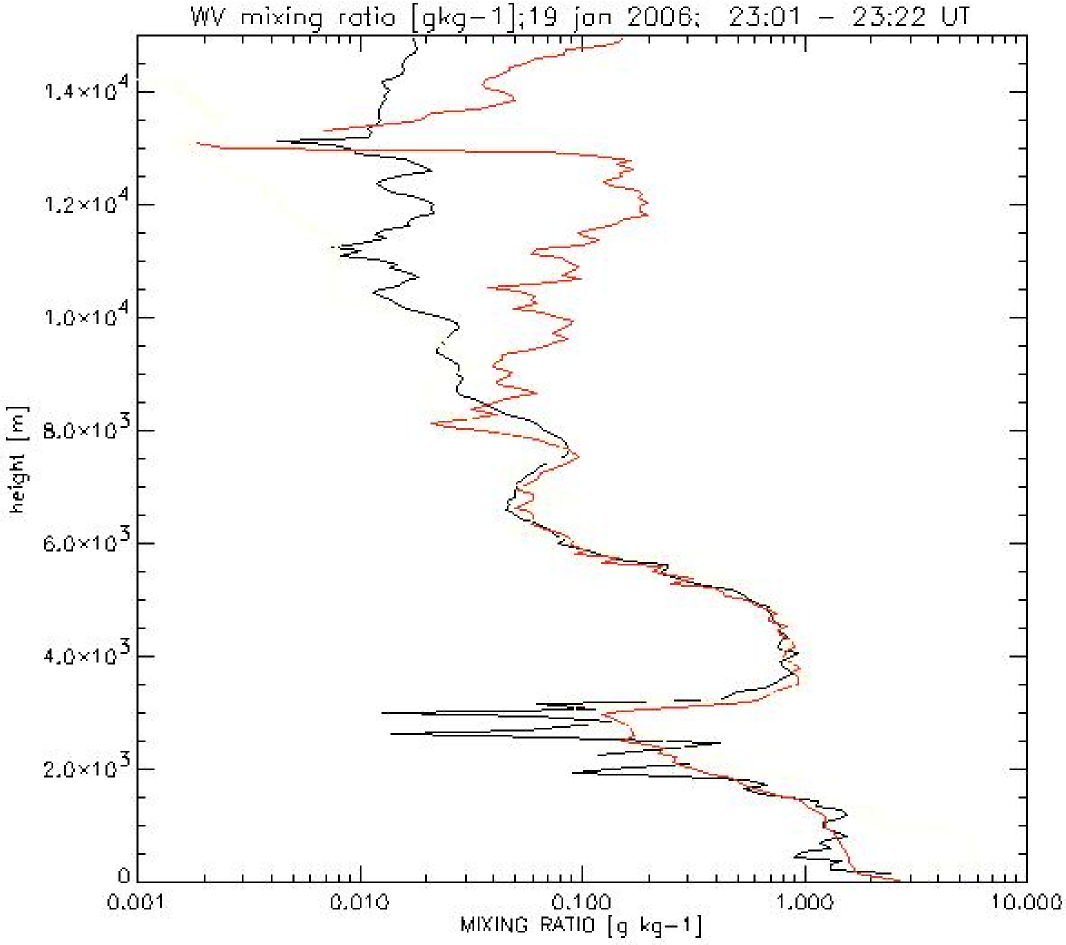
WV profiles in the upper troposphere

RDS of Pratica di Mare (23:02 UT)
Lidar, upper channels (20-min integration)



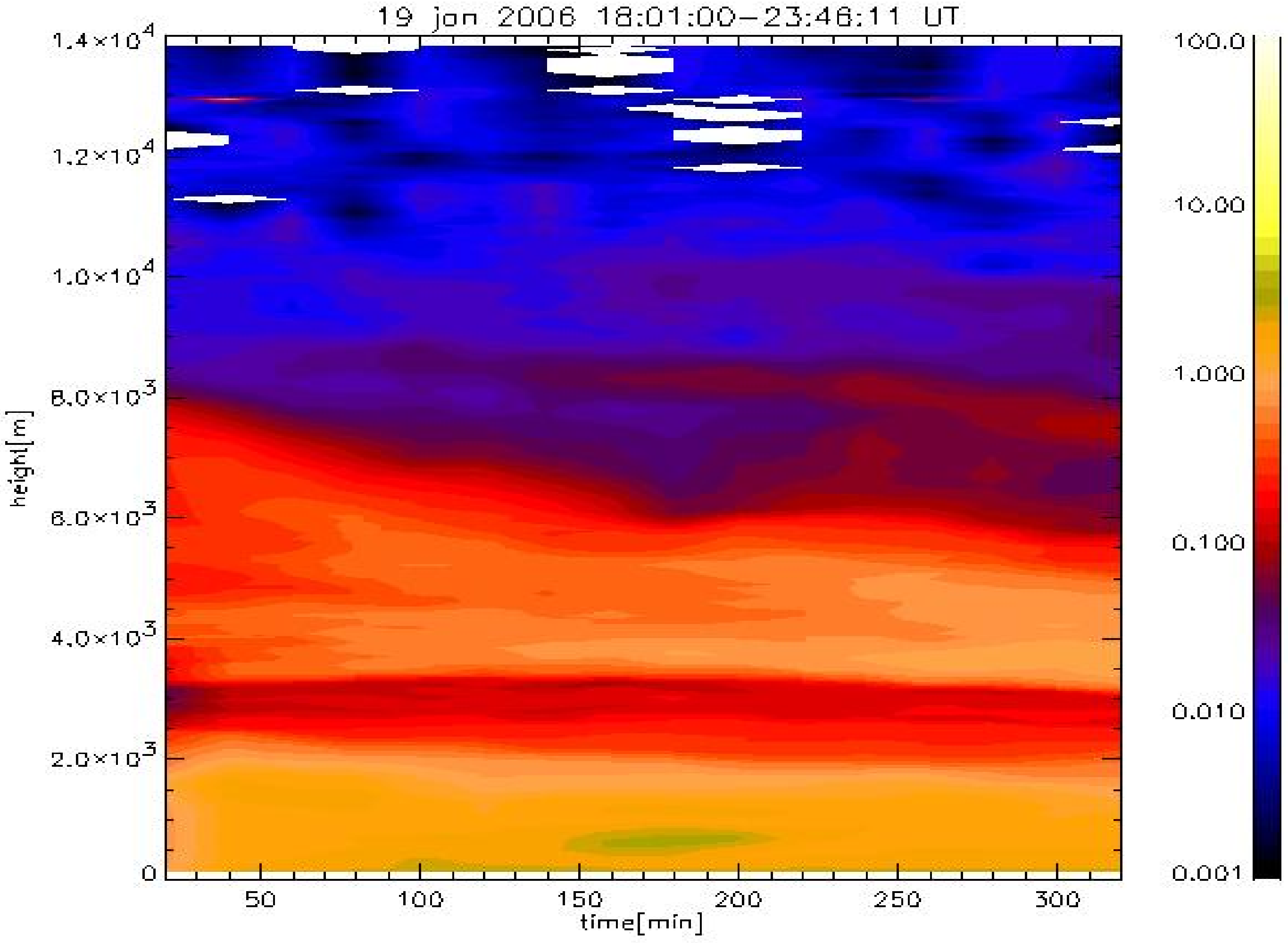
WV profiles in the upper/lower troposphere

Lidar (upper channels)
Lidar (lower channels)



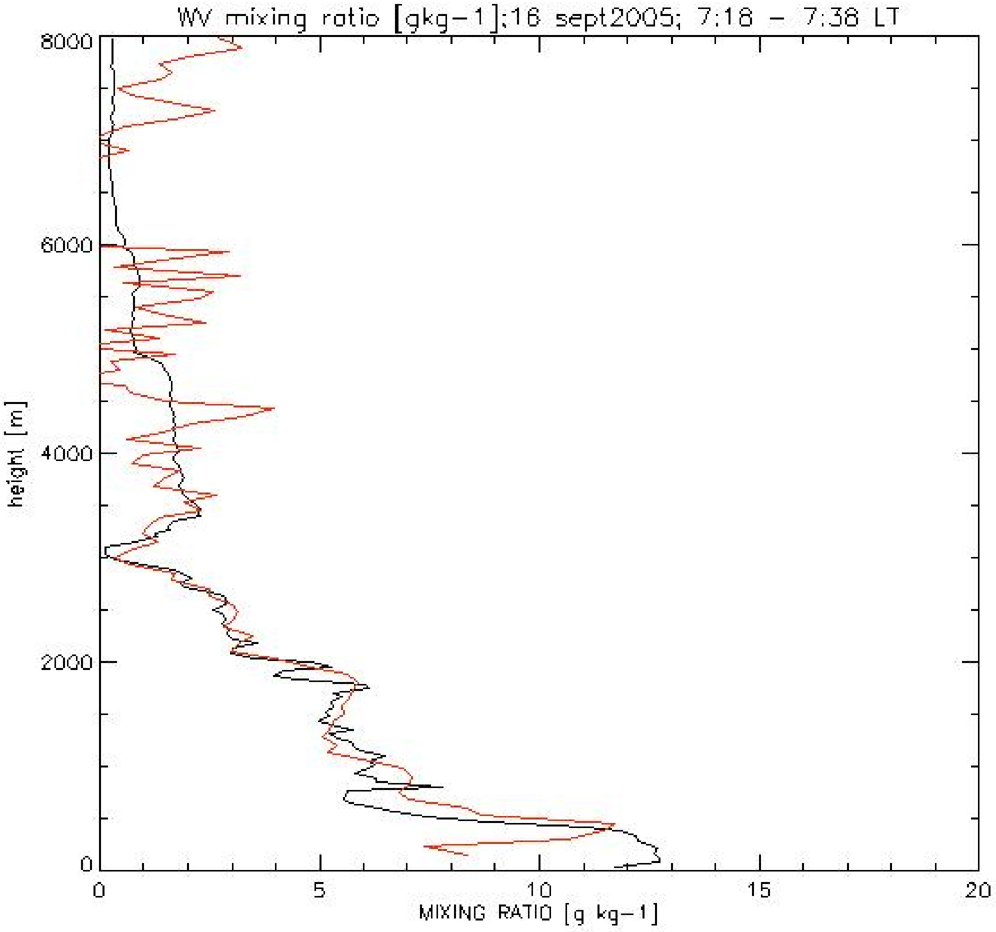
WV measurements in the upper/lower troposphere

Log contour of merged profiles (20-min integration; matching at 4 km)



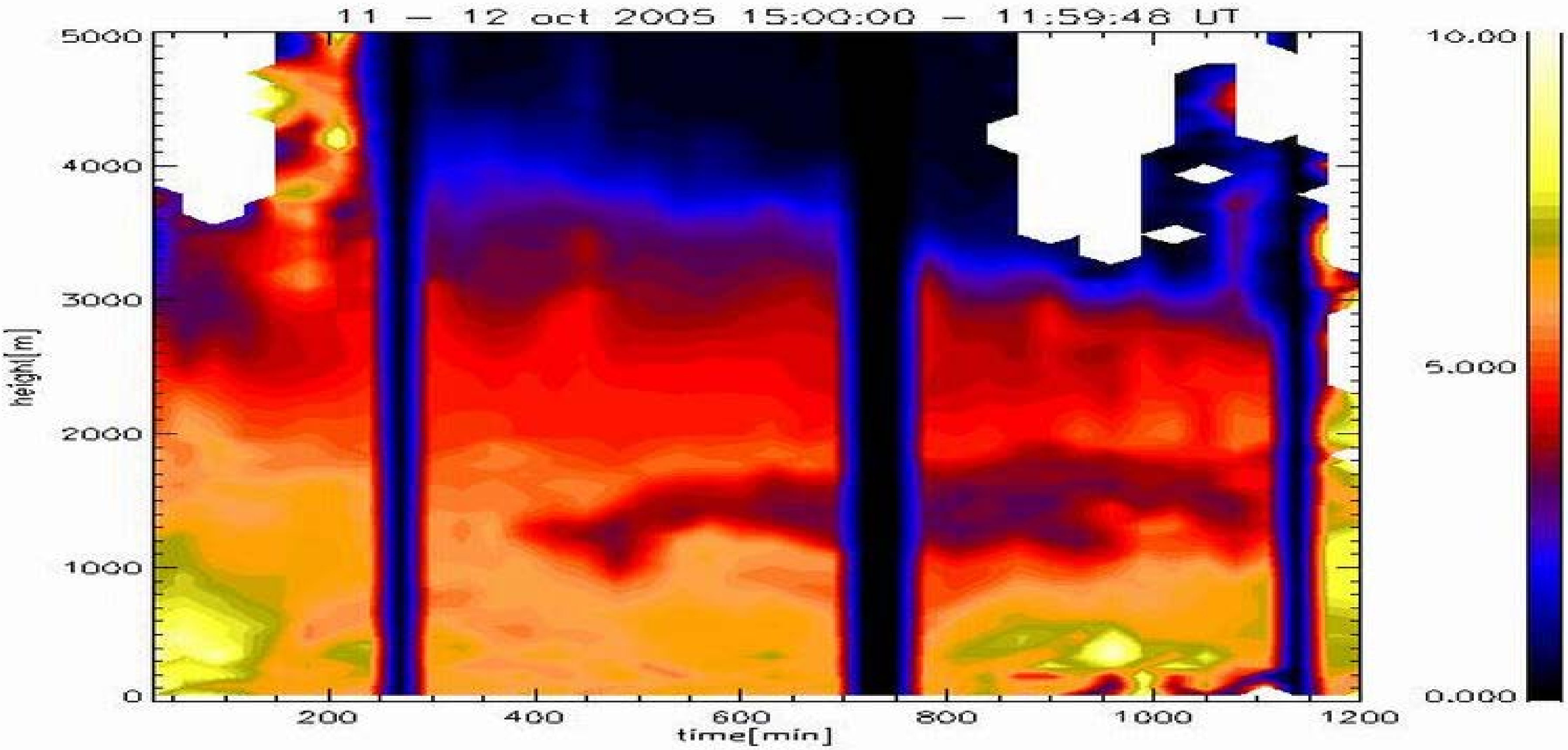
Daytime profiles

RDS of Pratica di Mare, (7:00 LT)
Lidar lower channels (20-min integration)

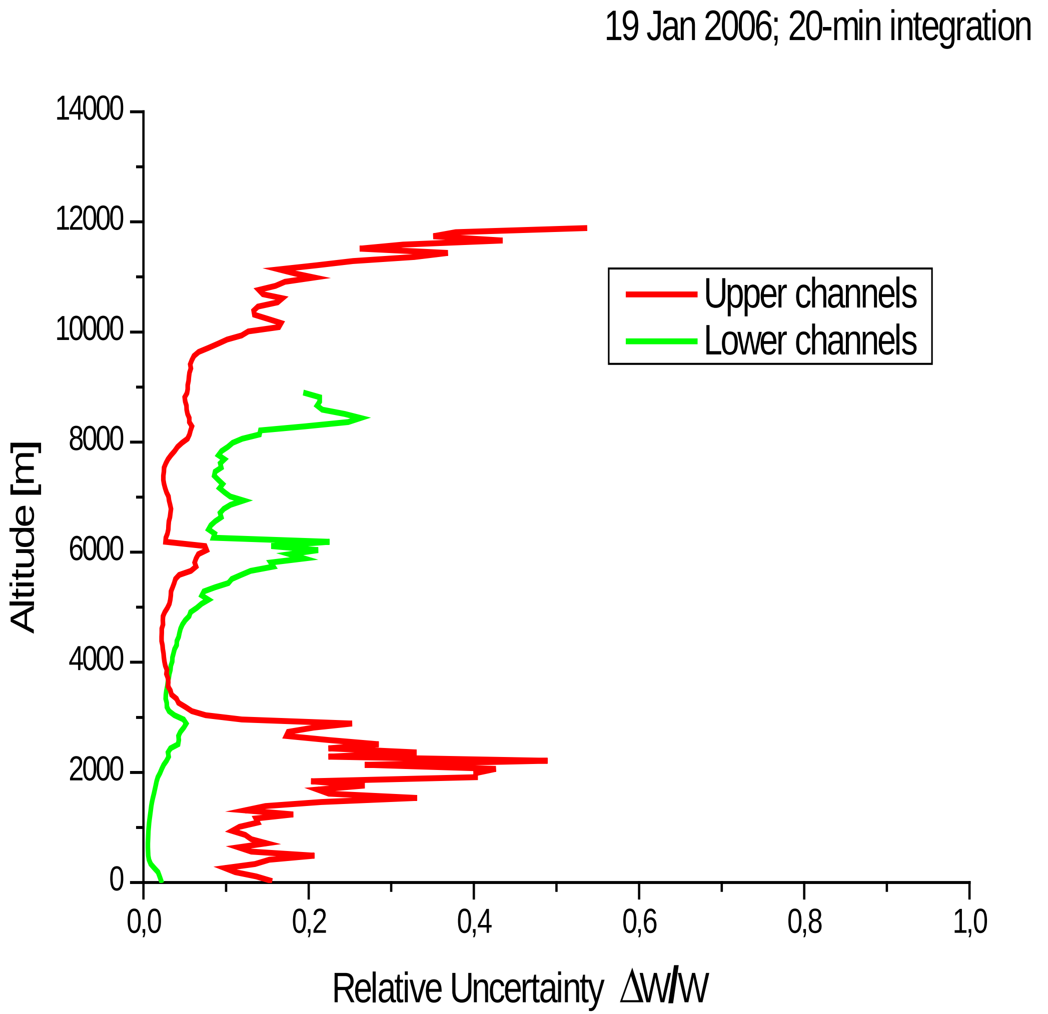


Daytime-nigthtime measurements

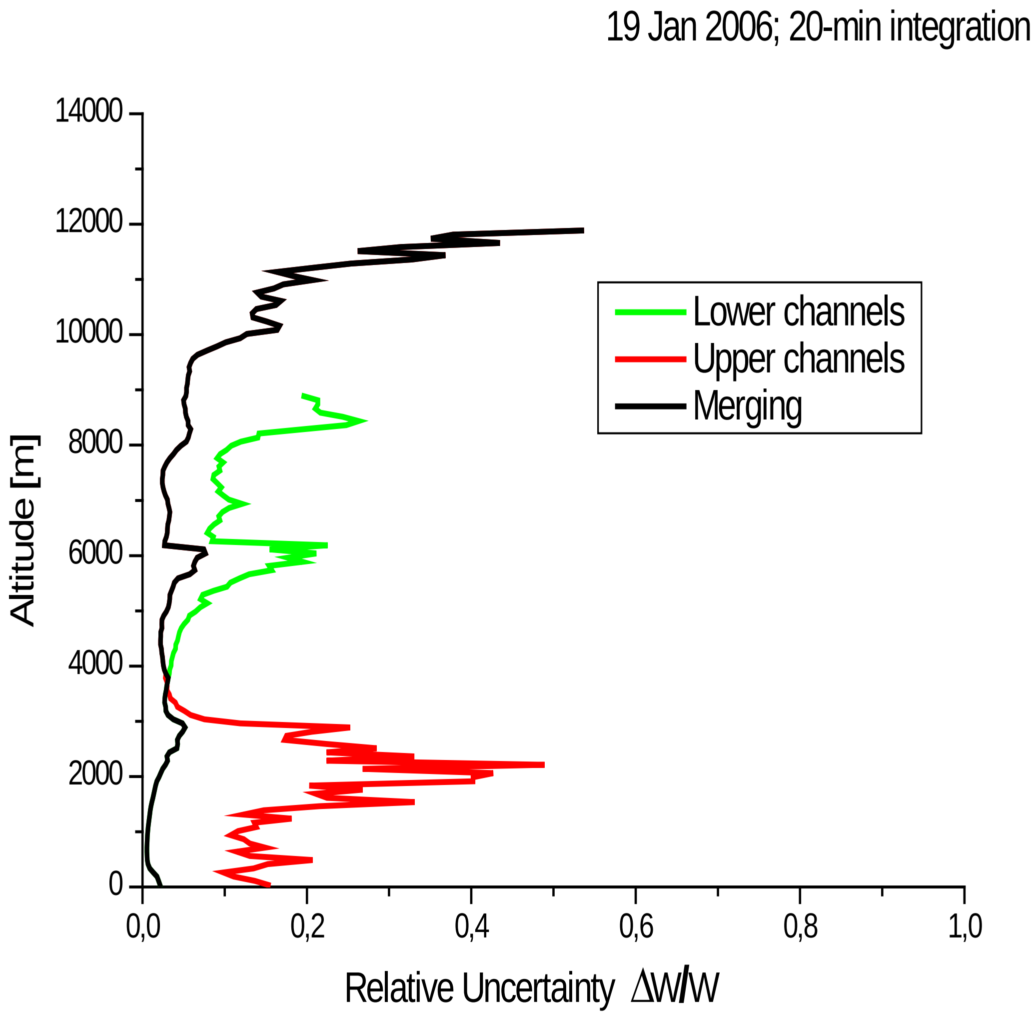
Lower range channels; Clouds above 4-3 km
(30 min integration; 525-m smoothing above 2 km)



Statistical uncertainties



Statistical uncertainties

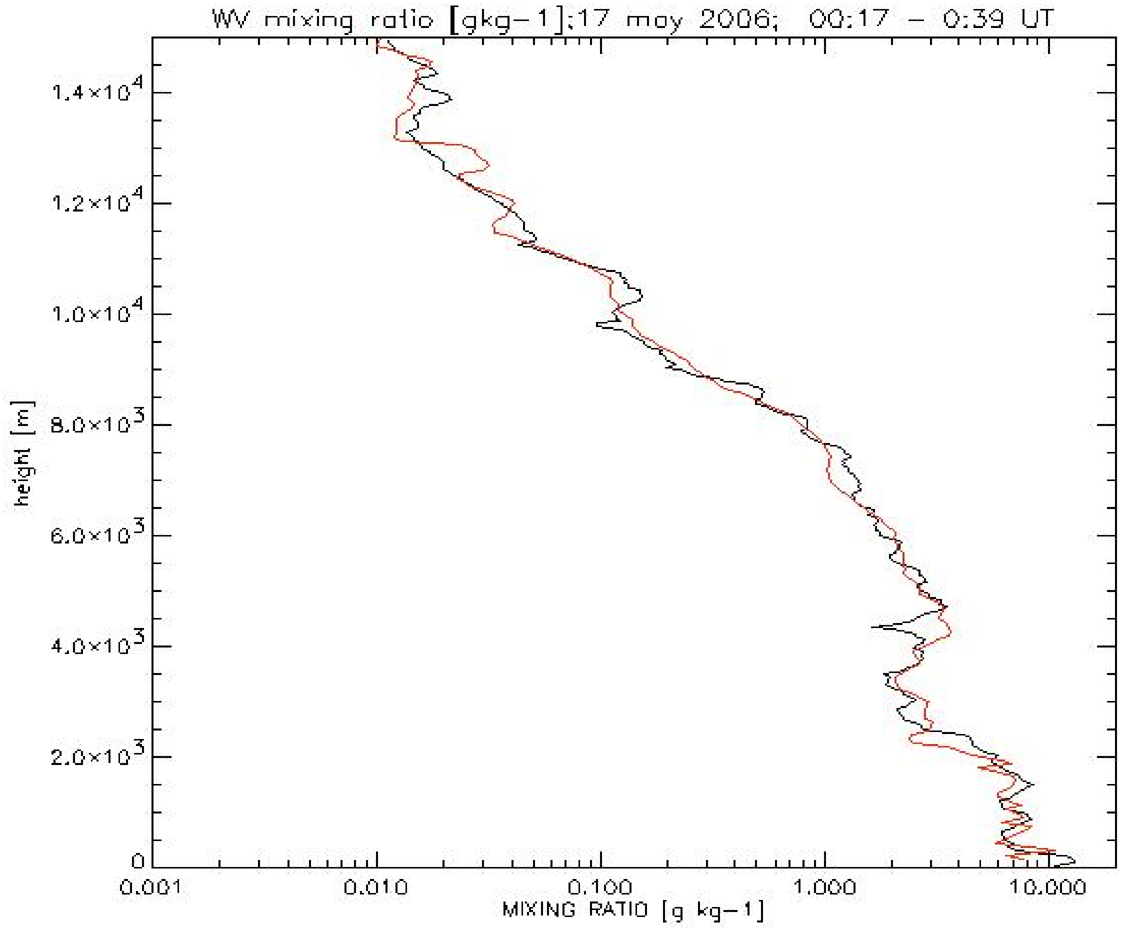


Statistical uncertainties

Performance improvement in high humidity conditions

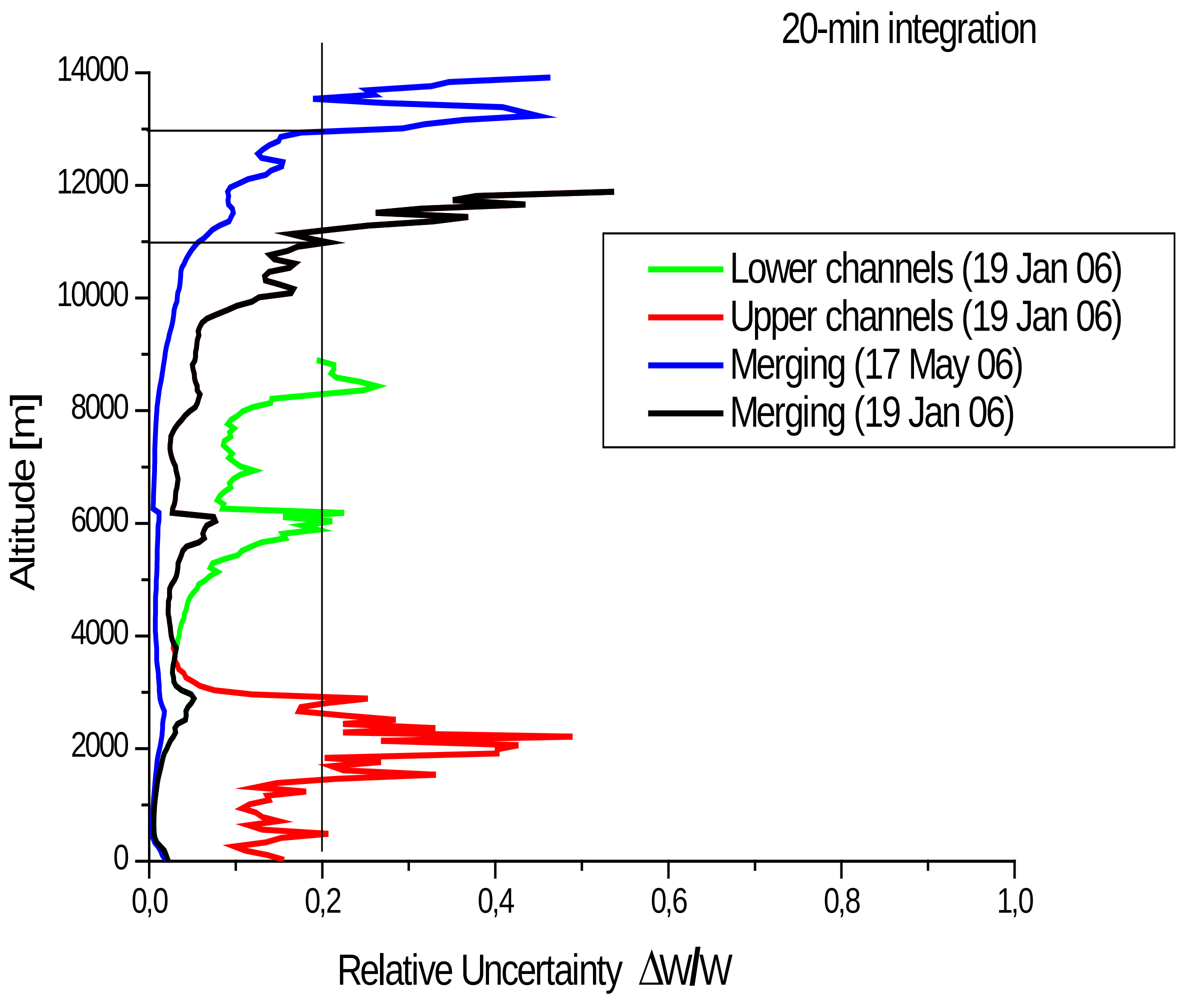
RDS of Pratica di Mare, 25 km S.W. of the lidar station (23:09 UT)

Lidar, lower channels (20-min integration)



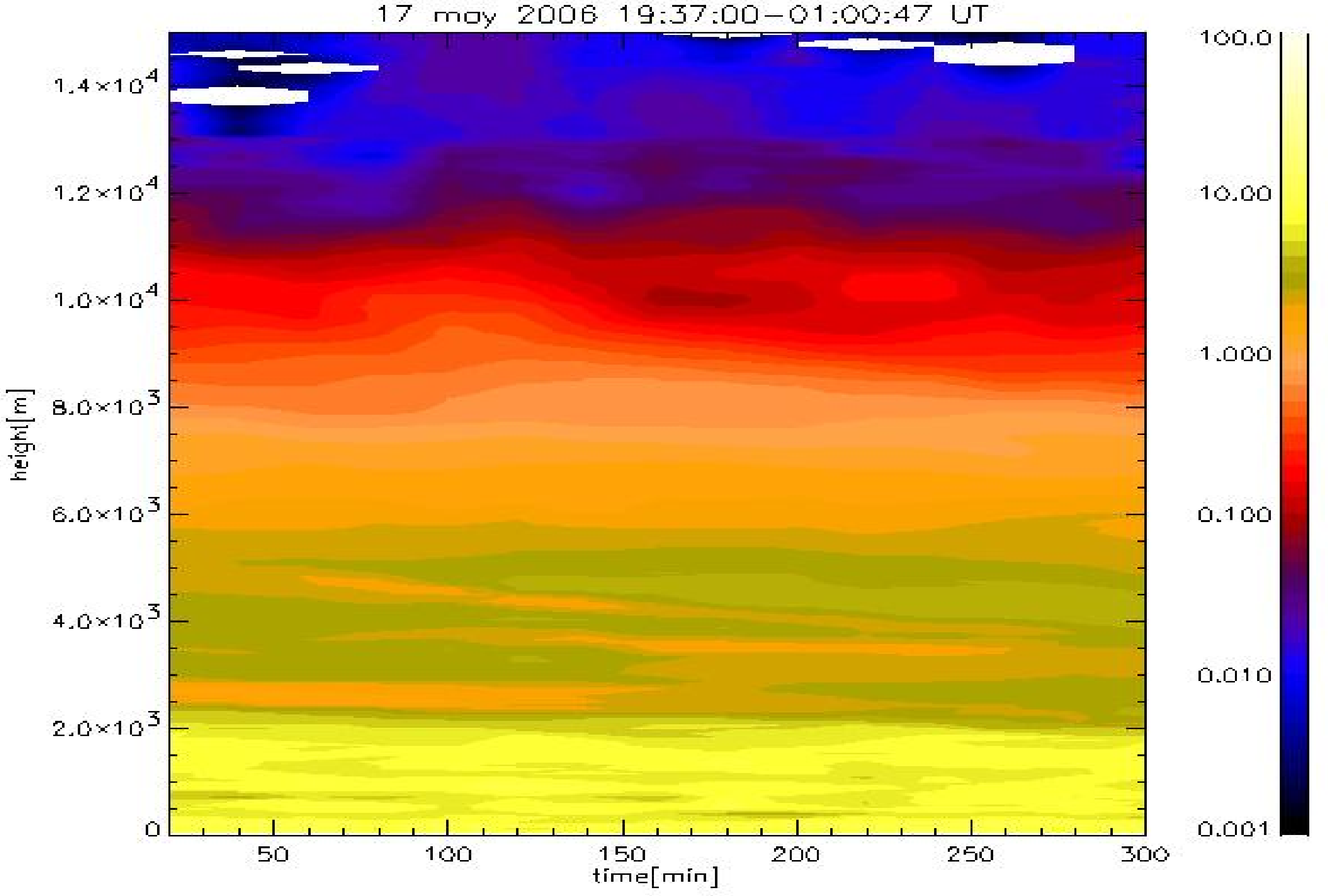
Statistical uncertainties

Performance improvement of in high humidity conditions



Statistical uncertainties

Performance improvement in high humidity conditions



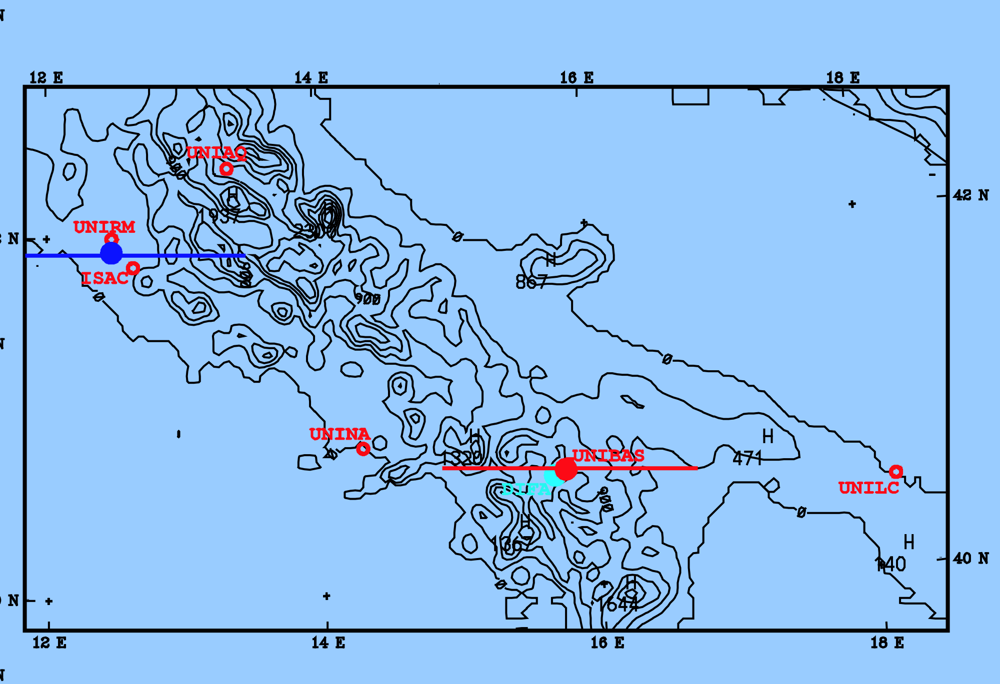
Systematic effects

- Calibration
  - Calibration by fitting lidar profiles to radiosonde profile (Pratica di Mare)
  - Selection of best fitting altitude interval by visual and $\chi 2$ comparison
  - Variation in calibration constant for different lidar profiles, in periods around the rds. launch, are found due to the spatial distance; amount of variation depending on weather conditions
  - Values associated to the apparently best fits are averaged and st.dev. computed
  - Range of calibration uncertainty (= resulting st.dev.) between 2-10%, depending on weather stability

- Cloud effects
  - Clouds presence contaminates WV measurement due to liquid water Raman spectrum partly covering the WV spectrum
    - The effect can be reduced by narrowing filter bandwidth
  - No contamination for ice clouds because of displacement of ice Raman spectrum

Italian participation in LAUNCH campaign

12 Sett- 28 Oct 2005



ITALIAN GROUPS

University of Rome
(WV & aerosol Raman Lidar,Sodar,MFRSR)
CNR-ISAC
(WV & aerosol Raman Lidar, Sodar)
University of L'Aquila
(weather forecast,lidar assimilation)
University of L'Aquila
(WV & aerosol Raman Lidar, soundings)
CNR-IMAA
(WV & aerosol Raman Lidar,soundings)
University of Basilicata
(WV & T & aerosol Raman Lidar)
University of Napoli
(WV & aerosol Raman Lidar)
Univeristy of Lecce
(WV & aerosol Raman Lidar, soundings)
Enea –Lampedusa
(soundings, aereosol Lidar)

Conclusions

- System of Rome-Tor Vergata
  - Resolution
    - **in altitude:** 75 m up to 6 km
      525 m above 6 km
    - **in time:** 20 min
  - Useful range starting from very lower layers of PBL and extending up to upper troposphere
  - Capability of measuring WV MR as low as 0.01 g/kg
  - Errors of 20% in a 11-13 km altitude range
  - Measurements possible in daytime but performance drastically worse