B3

ATMOSPHERIC TURBULENCE INVESTIGATION USING TDLS

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МФТИ
SAPERE AUDE

DLS
LAB

РОСГИДРОМЕТ
ЦАО

Introduction

Russian state program to develop airplane-laboratory started some time ago. It contains TDLS complex [1] to measure H_2O, CO_2, CH_4, and CO. The complex water channel was developed to measure atmosphere humidity and isotopes ratios (see A3).
Atmosphere turbulence is important parameter of atmosphere monitoring. Atmosphere turbulence module development and testing is subject of present paper.
Part of DL radiation of TDLS complex water channel is directed to turbulence module under consideration. This radiation passes airplane window, is reflected by mirror located at some distance from window, and detected by PD inside airplane. Recorded signal processing gives humidity in open atmosphere out of airplane. Humidity variation during airplane flight gives information about atmosphere turbulence.

[1] V.Galaktionov, V.Khattatov, A.Nadezhdinskii, Ya.Ponurovskiy, D.Stavrovskii, I.Vyazov, V.Zaslavskii, TDLS complex development for airplane-laboratory “Atmosphere”, Abstracts of TDLS 2009, Zermatt, Switzerland, p.44.

Airplane - laboratory

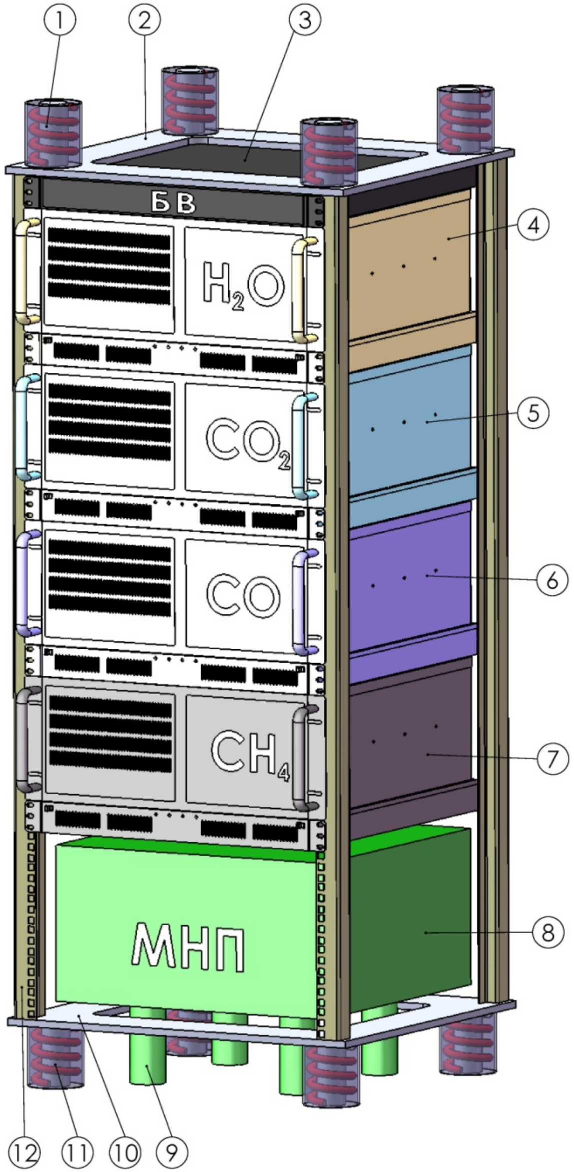
Due to Russian state program airplane-laboratory is under development.

Parameters of Jak-42d [2] airplane considered as carrier for the laboratory.

[2] http://www.aviaport.ru/directory/aviation/jak42d/

Jak-42d	
Speed	730 km/h
Distance	4100 km
Altitude	9.1 km

TDLS complex for airplane - laboratory



TDLS complex front view

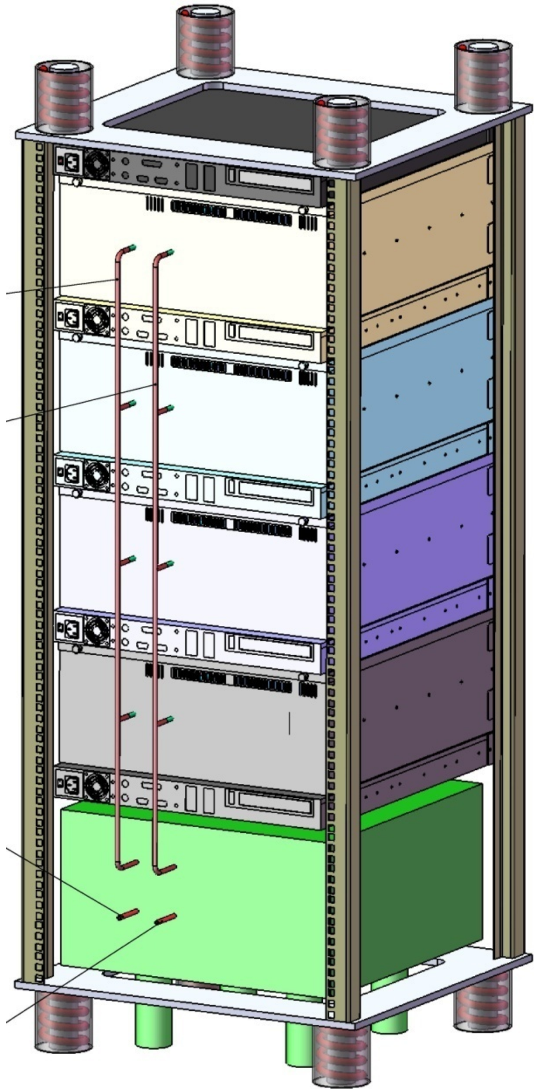
TDLS complex consists of several modules.

4 identical modules to measure concentration of H_2O (4), CO_2 (5), CO (6), and CH_4 (7). These modules are installed in vibro-isolated hardware bay.

Module with pumps to provide air under investigation flow trough the system (8) and its preparation for measurements.

Gas connections: air in (A), air out (B), income line to TDLS modules (C), outcome line from TDLS modules.

C
D
A
B

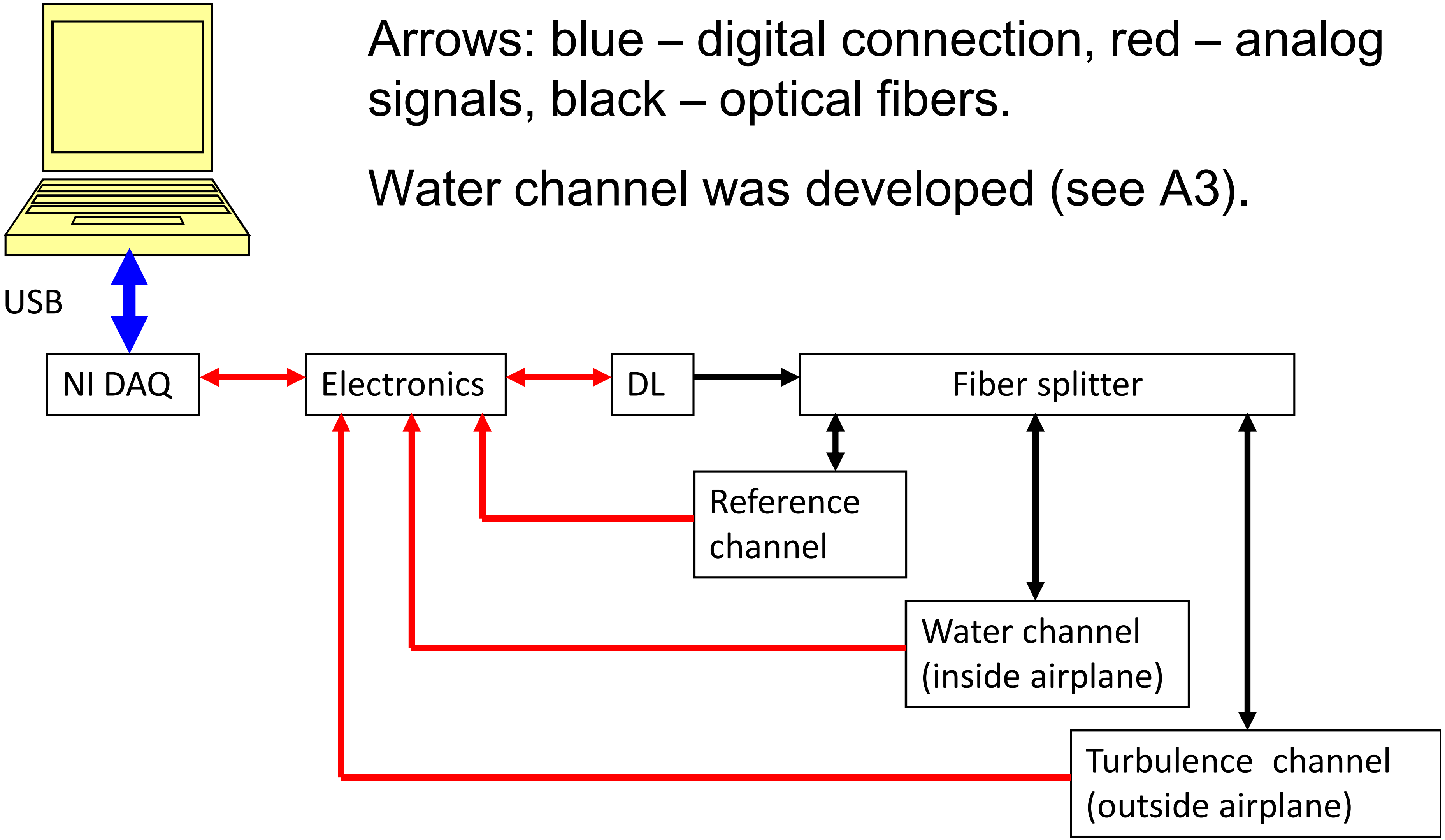


TDLS complex back view

Block scheme of water channel

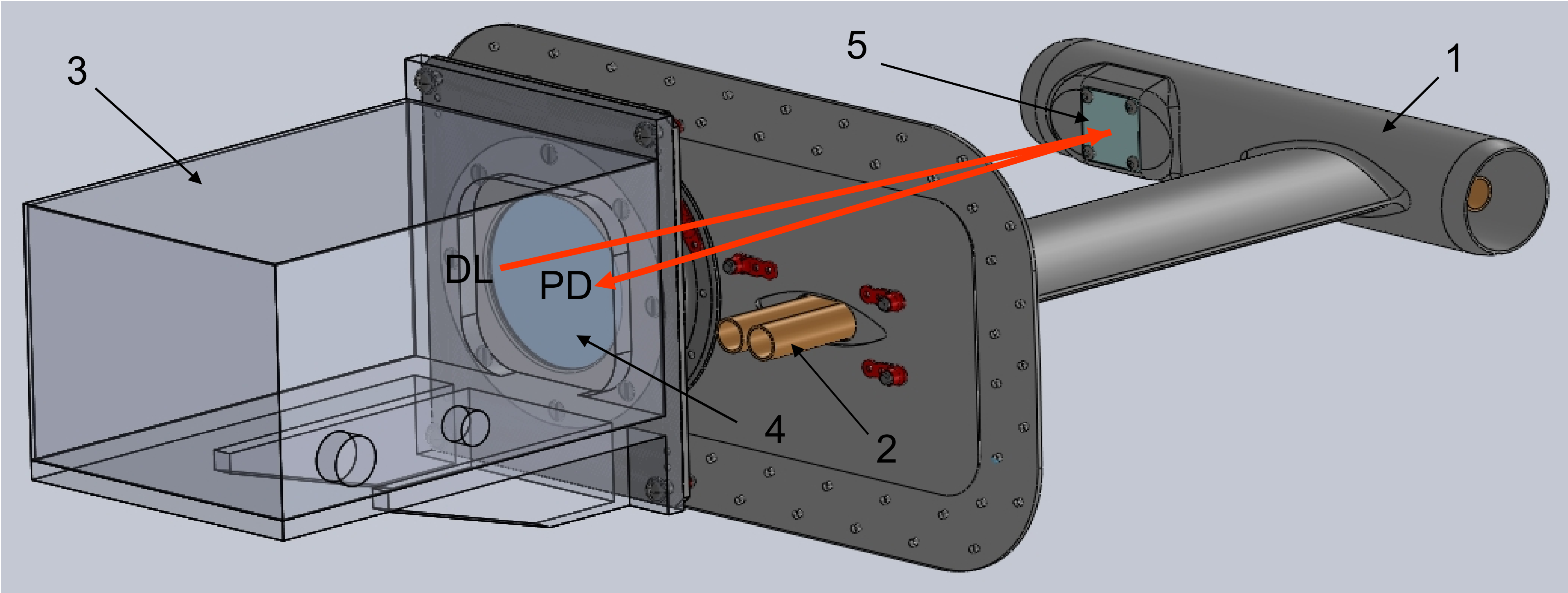
Arrows: blue – digital connection, red – analog signals, black – optical fibers.

Water channel was developed (see A3).



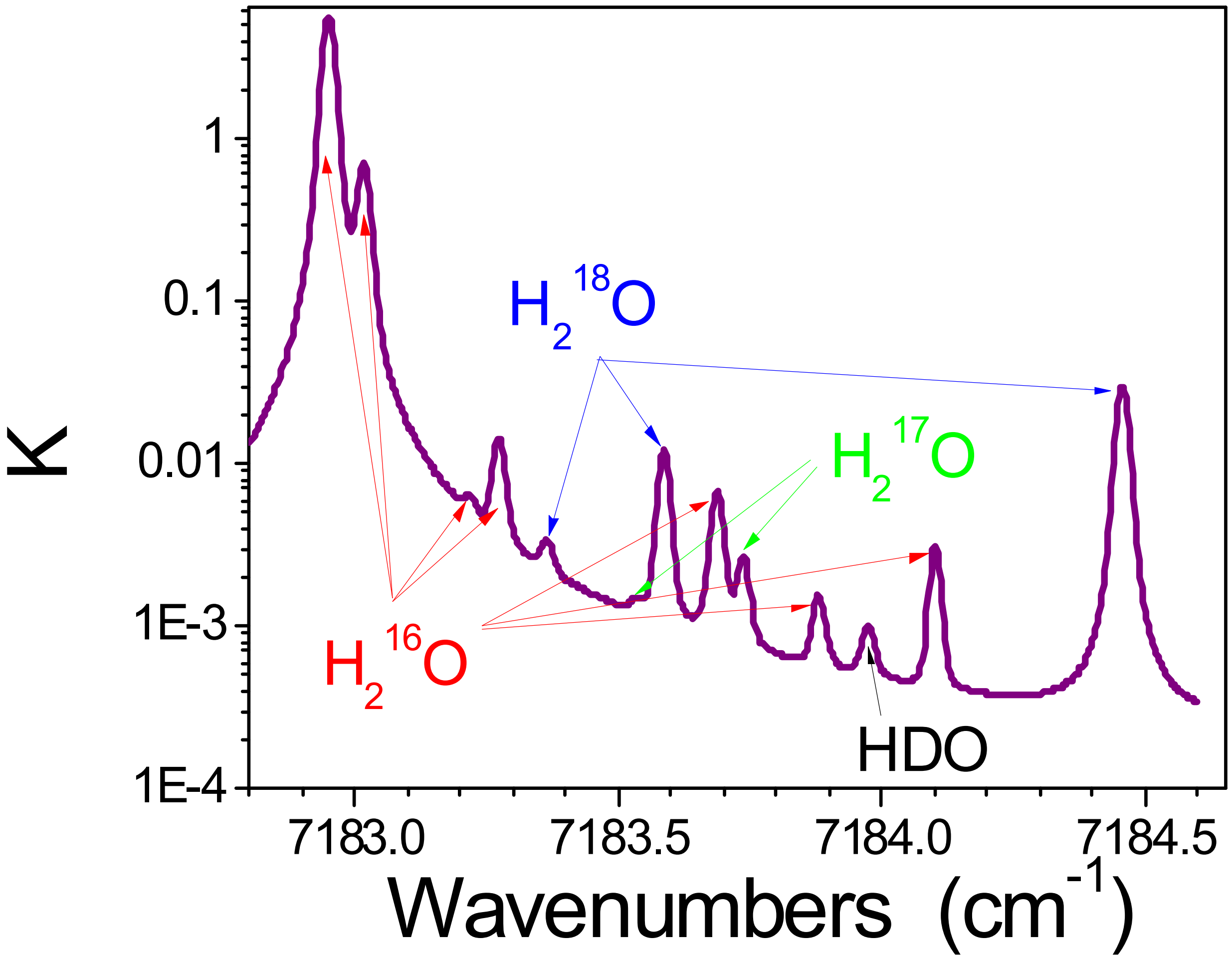
Part of water channel DL radiation by fiber splitter is directed to turbulence channel.

Design of turbulence channel



1, 2, 4 belongs to TDLS complex air receiving module.
Part of water channel DL radiation is directed to turbulence channel. Turbulence channel contains part located in box 3. Fiber output (DL) is located close to illuminator (4). DL radiation is reflected by mirror (5) and detected by PD located close to illuminator. Optical length of atmosphere under investigation (out of airplane) is L = 40 cm.

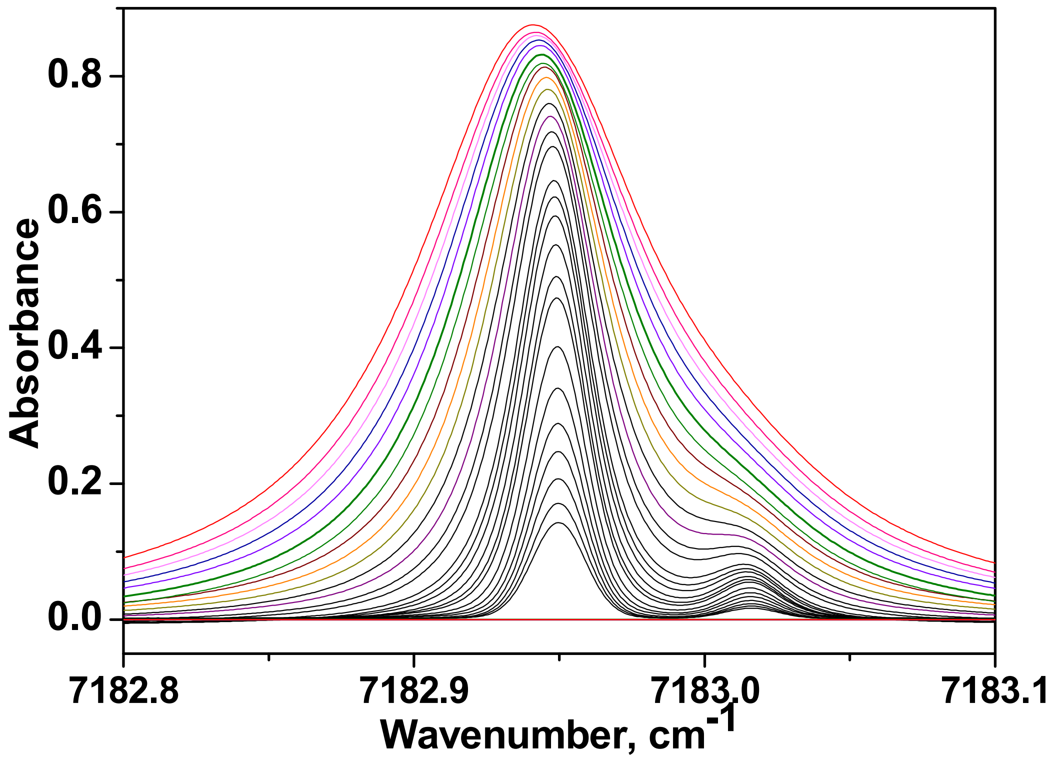
Spectral range of water channel DL



Model water vapor spectrum and lines identification (see C3).
Parameters: L = 40 m, P = 100 mBar, natural abundance.

Turbulence channel analytical line

Water vapor line 7182.9496 cm^{-1} (see previous slide) was selected as analytical one for turbulence channel.

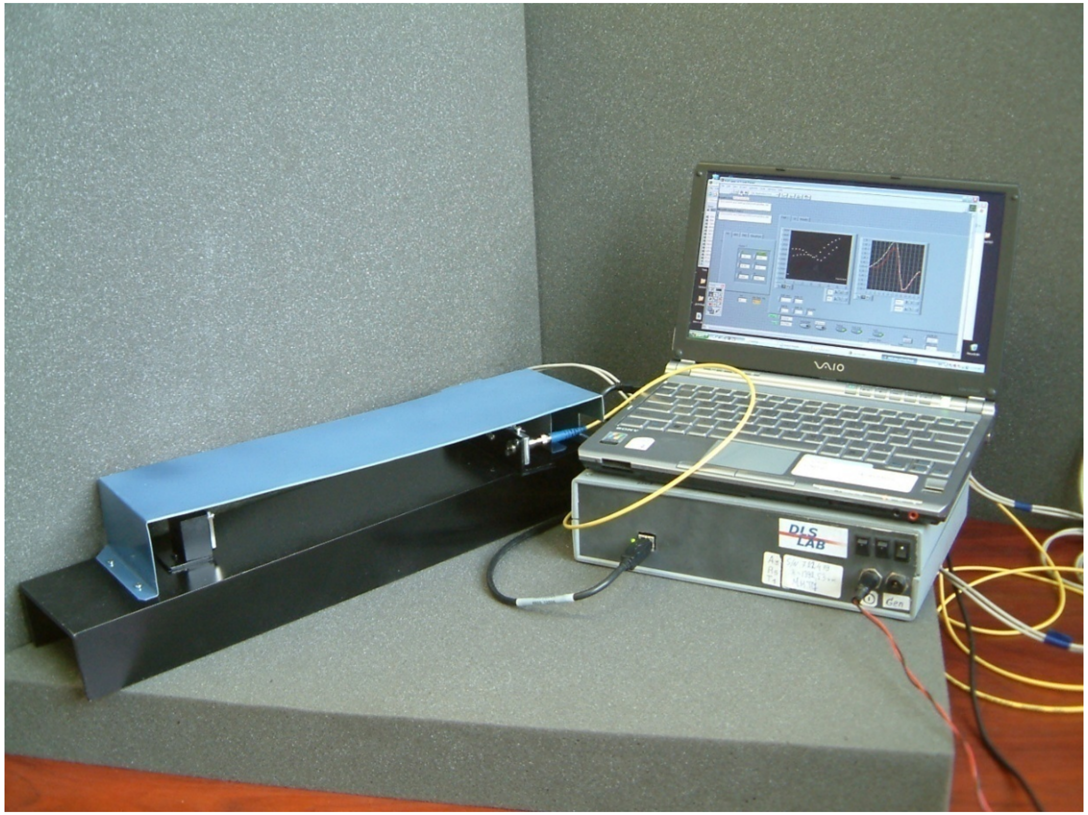


Analytical line shapes for different sample gas pressures.

L = 200 cm, P = 3 – 600 mBar, C_{H2O} = 2.54 %.

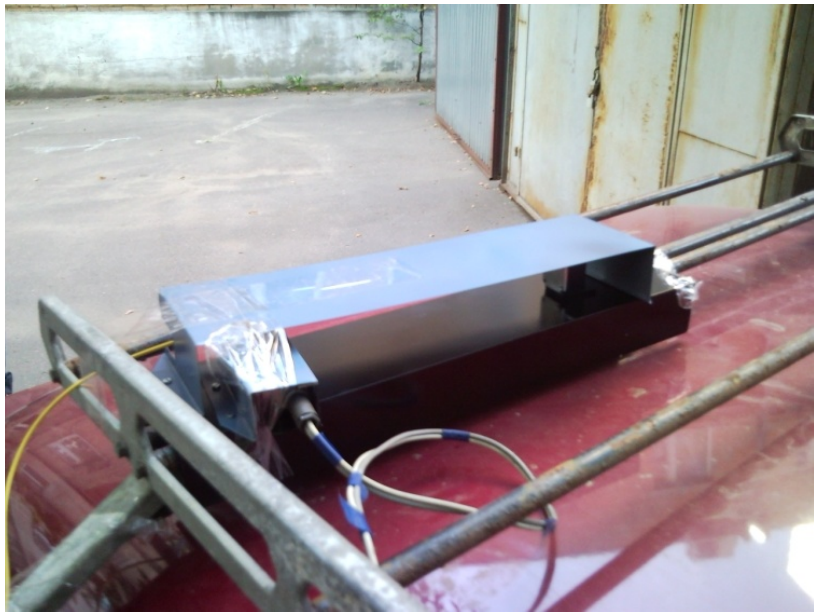
<u>Conclusion: Analytical spectral line shape was measured and its parameters were determined.</u>

Turbulence channel prototype

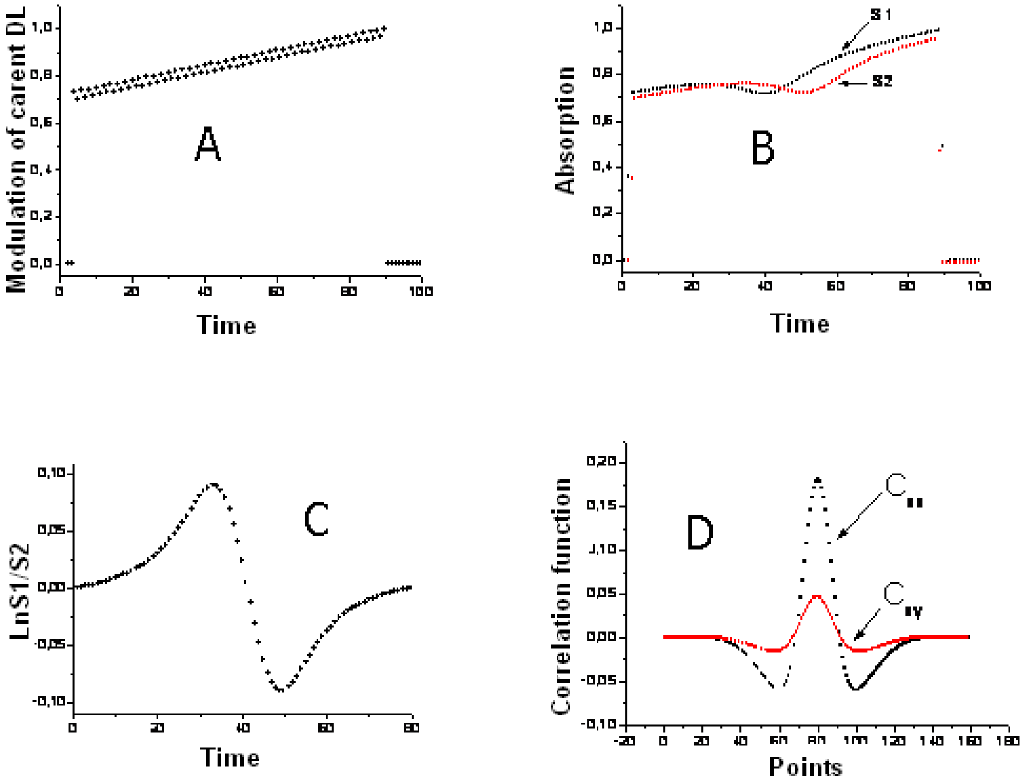


Turbulence channel prototype was developed for field tests. For this prototype the same components and dimensions were used as for airplane turbulence channel.

Turbulence channel prototype was installed on vehicle. It measures water vapor concentration in air passing through prototype optical path (L = 40 cm).



System operation



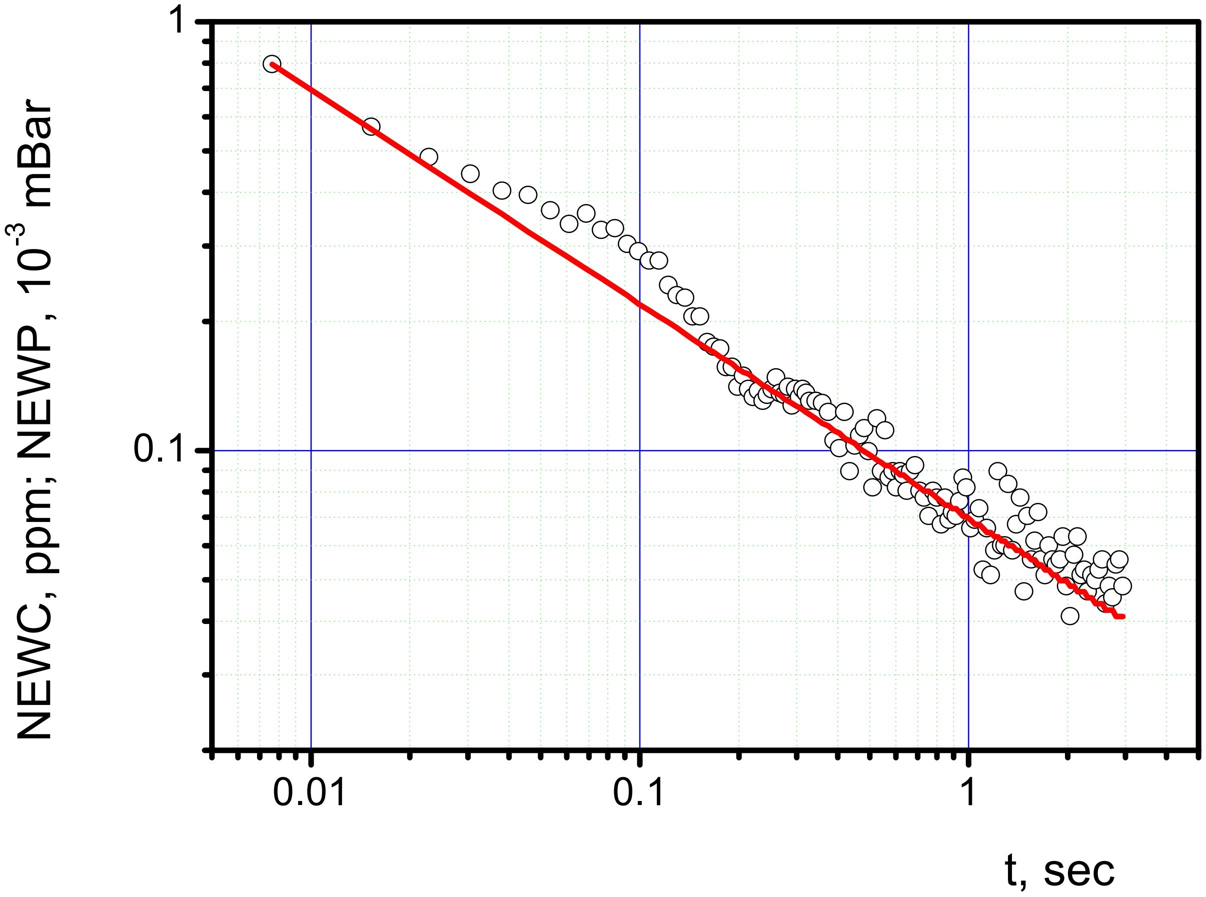
DL is excited by trapezoidal current pulse with modulation (A). In presence of resonant molecular absorption two lines can be observed due to modulation (B). Using these data computer calculates signal looking like line first derivative (C). Two cannels are using in system - analytical and reference ones. Using reference channel both autocorrelation function of reference and correlation function of analytical and reference channels were determined – black and red in Fig.D, respectively

For known parameters of analytical and reference channels concentration of molecule under investigation can be obtained straightforward.

$$C = \frac{\alpha \cdot P_r \cdot L_r}{P_a \cdot L_a} \cdot 10^9, [ppb]$$

$$C_{xy} = \alpha \cdot C_{xx}$$

Turbulence channel Detectivity

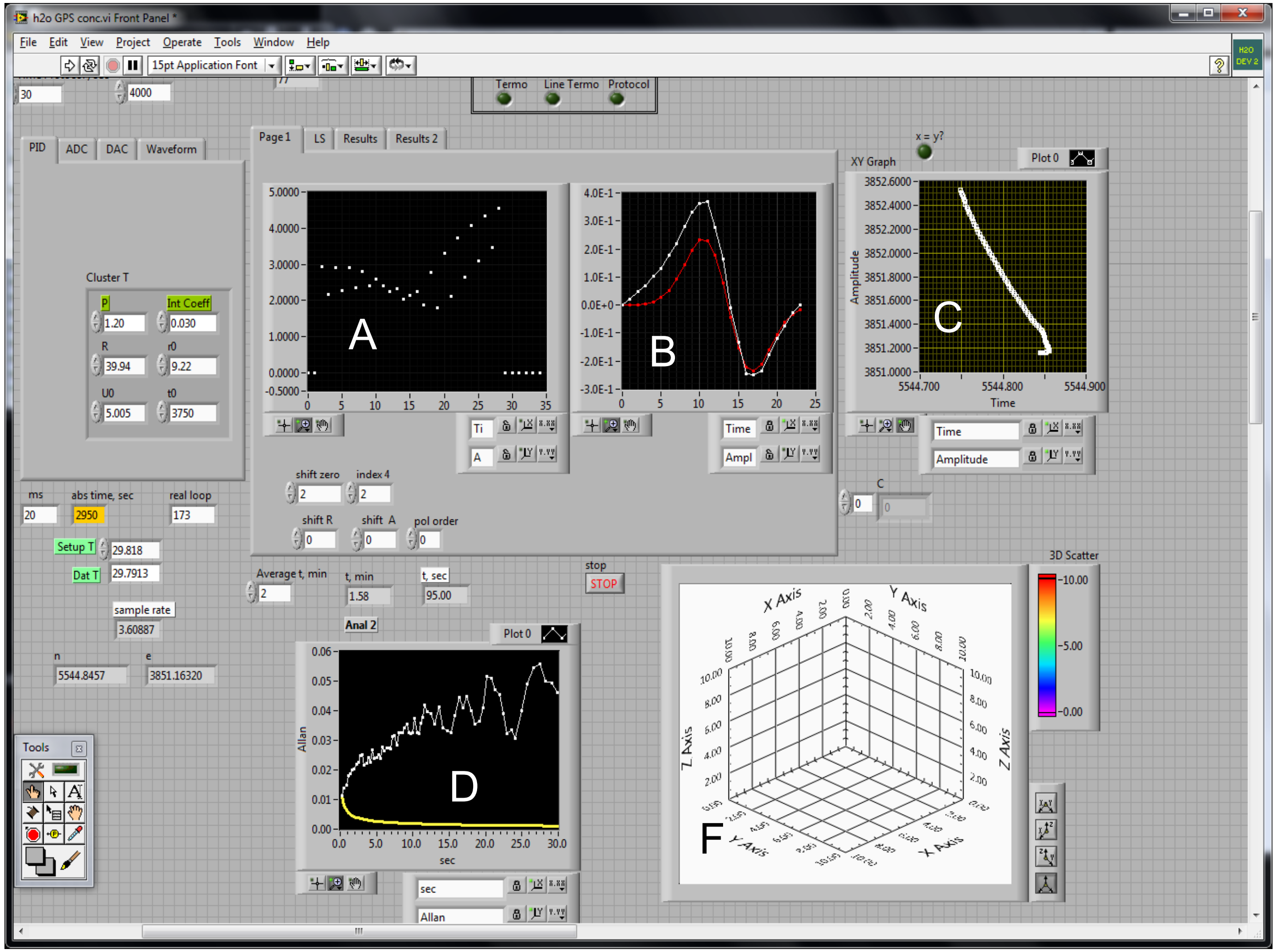


To analyze data time series and to determine instrument Detectivity Allan plots are using.
NEWC – Noise Equivalent Water Concentration and NEWP – Noise Equivalent Water Pressure for turbulence channel as function of averaging time.

<u>Conclusion: using turbulence channel both humidity in open atmosphere and its turbulence can be measured during airplane-laboratory flight.</u>

Turbulence channel software

Special software was developed to support turbulence channel operation.

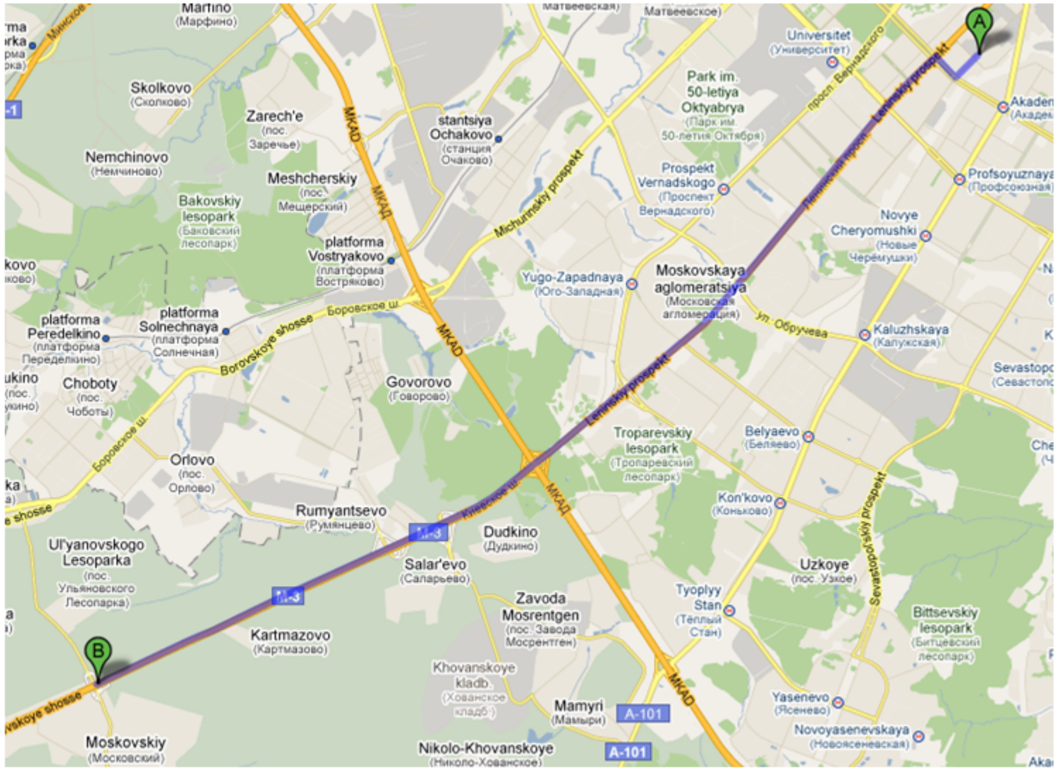


A – signal in analytical channel demonstrating presence of water vapor absorbance.
B – Reference (red) and analytical (white).
Water vapor is measuring continuously and Allan plots (D) for determined time periods.

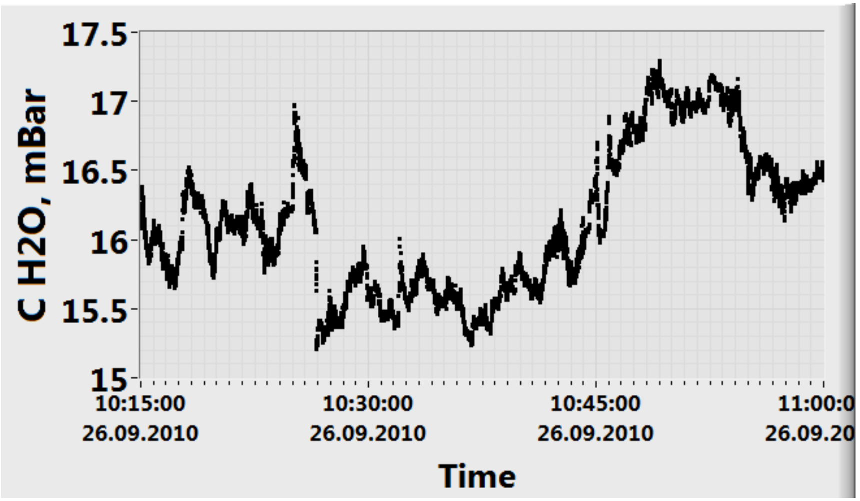
The instrument has GPS.
C – vehicle trajectory.
F – spatial dependence of water concentration measured.

Turbulence channel field tests

Using system developed several field tests were performed during 2010 fall.



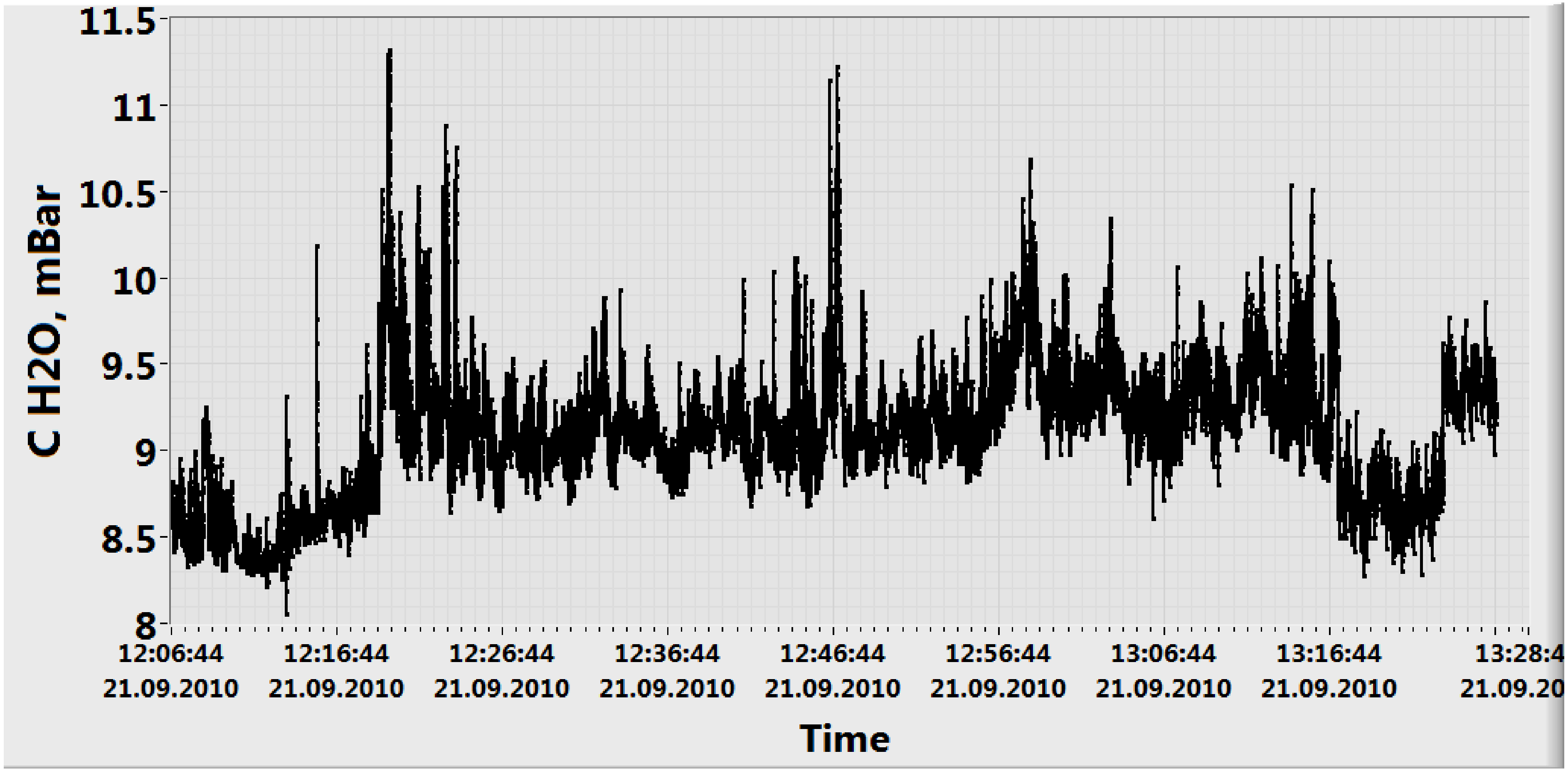
Field test 09/26/2010.
Operator used Leninsky prospect and Kiev highway. A – GPI location, B – final point. Distance between A and B – 40 km.
By blue line trajectory is shown as was measured by GPS.



Water partial pressure as measured during this field test.
In present case mane water pressure variations were due to vehicle emission near lights.

Turbulence channel field tests

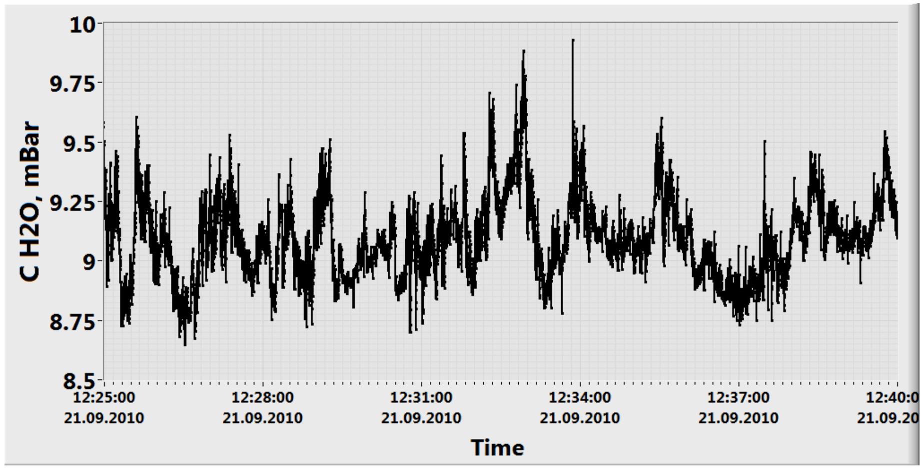
Using system developed several field tests were performed during 2010 fall.



Field test 09/21/2010.

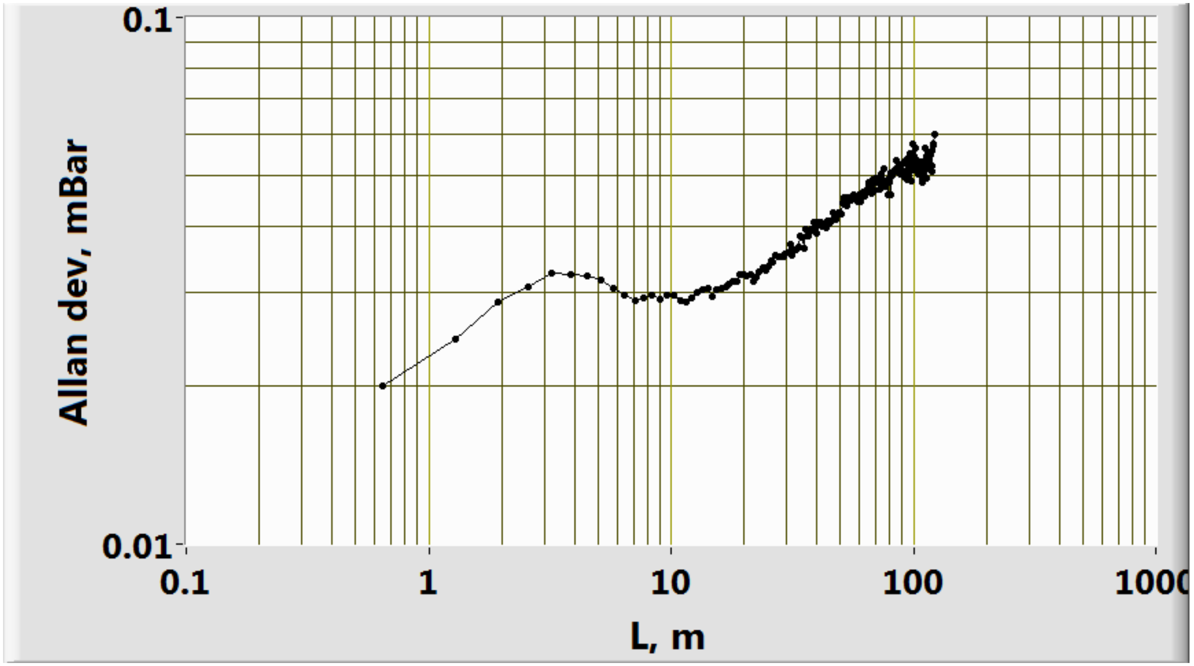
Operator used Moscow ringroad with less trafic and more or less constant driving speed (around 80 – 100 km/h). Stable water concentration can be observed with variations - subject of present paper.

Turbulence channel operation during field test.



Fragment of water detection presented in previous slide used to determine Allan plot.
H_2O pressure is constant with variations due to water spatial inhomogeneity – subject of present paper.

Allan plot of fragment presented above. To obtain this graph GPS data were used to transform time dependence to spatial one.



Smoothed peak can be observed near 3-4 m due to distance between vehicles.
For higher distances water pressure drift can be observed.

Conclusions

1. ***Turbulence channel for airplane-laboratory was developed.***
2. ***Turbulence channel analytical line was selected and calibrated.***
3. ***Algorithms and software to measure atmosphere turbulence were developed.***
4. ***Turbulence channel prototype was developed to be installed on vehicle.***
5. ***Field tests were performed in Moscow.***