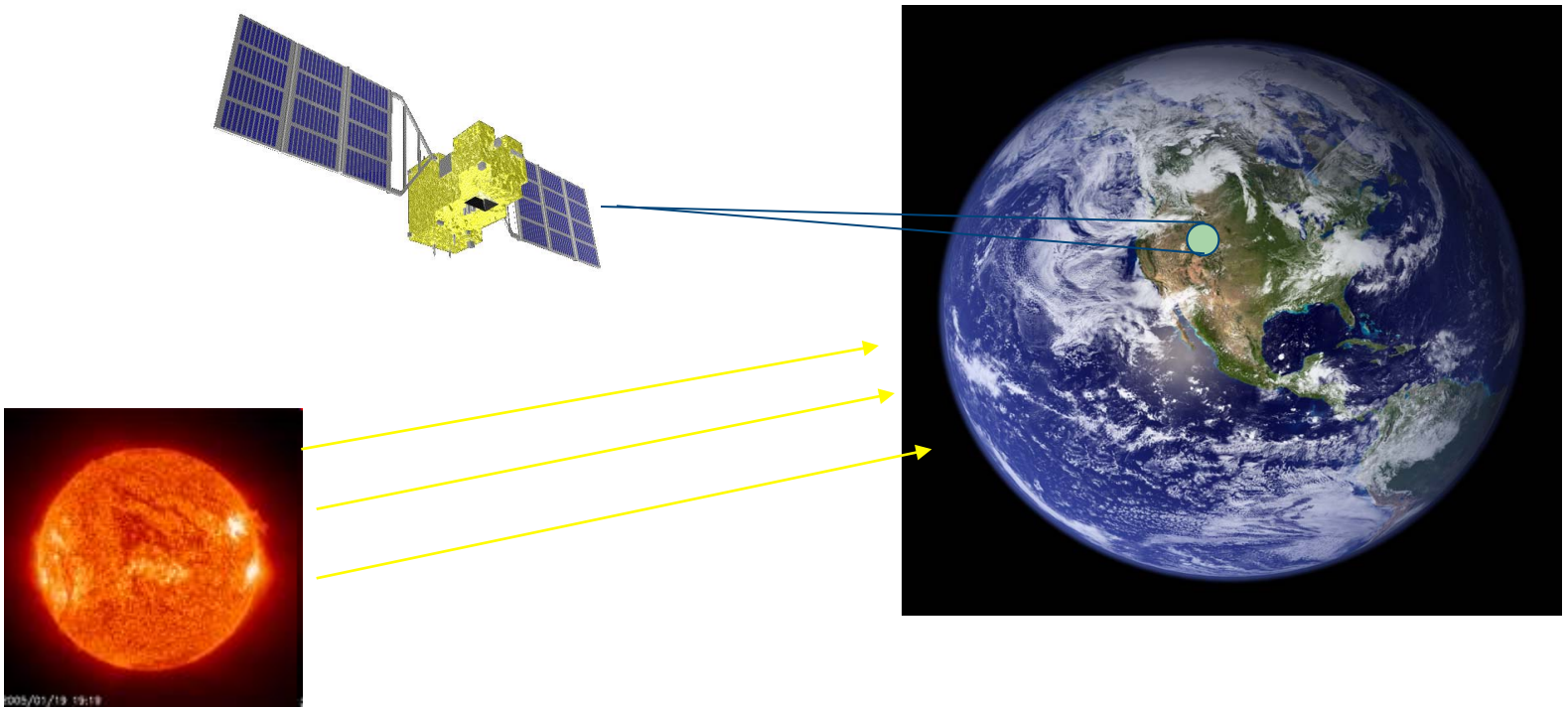
Technique of CO2 concentration profile retrieving from satellite data by means of neural network approach

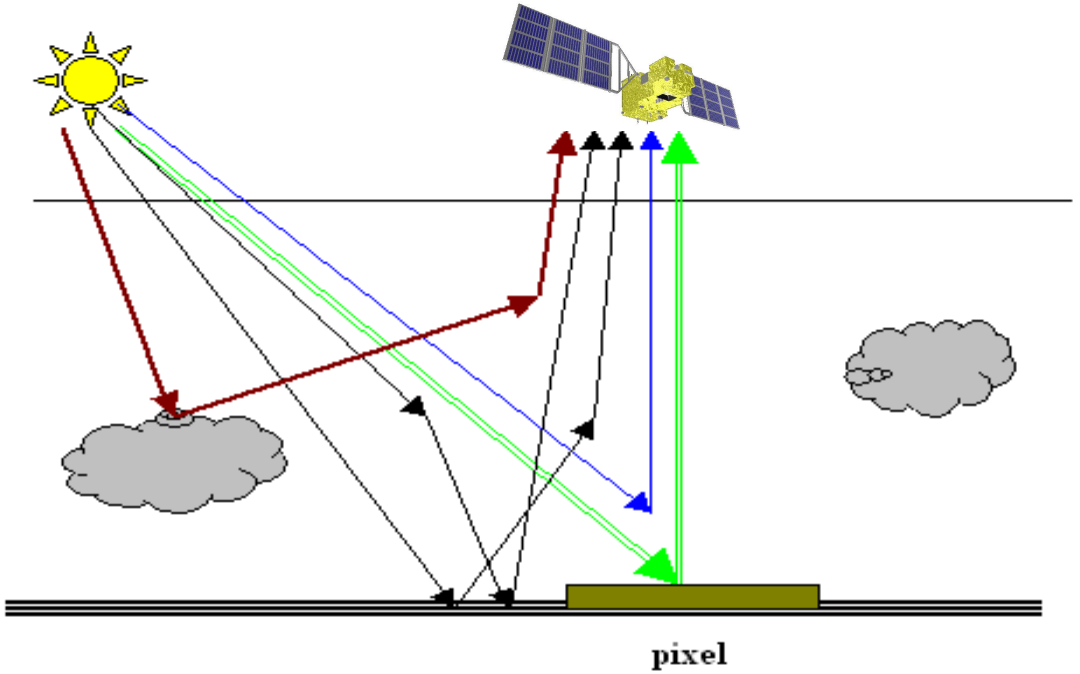
Kataev M.Yu., Andreev A.G.



Goals of work:

To develop the scientific computer program for modeling GOSAT NIR spectrums and their processing for the purpose of retrieving of the CO2 concentration profile by neural-networks method and total content by the differential absorption method.

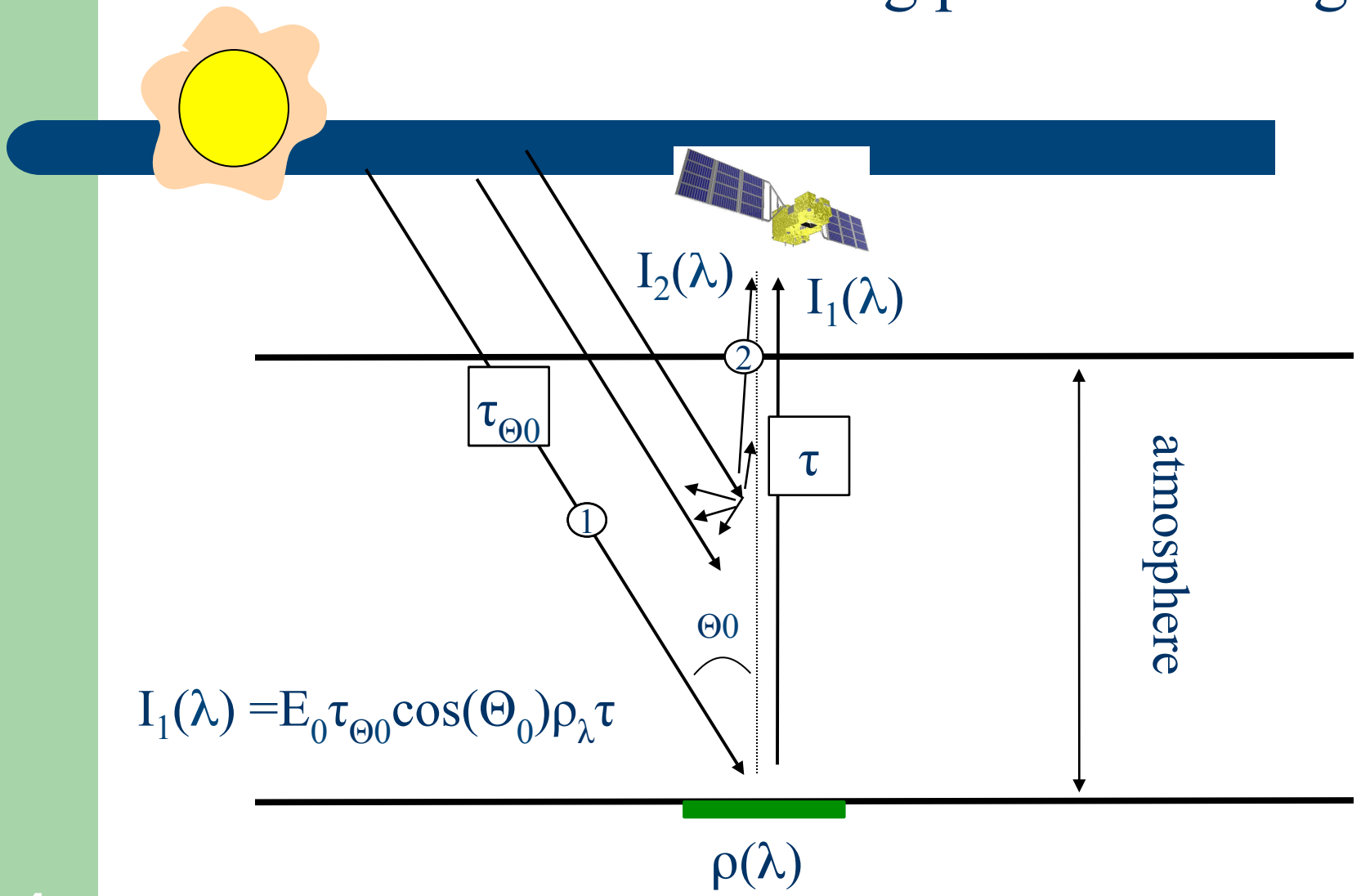
The main trajectories of the solar beams in the system « earth + atmosphere ».



Green is the reflected from surface solar radiation

Blue is the scattering in atmosphere solar radiation

Reflected and scattering parts of the signal



Radiative transfer (RT)

(F-M. Breon, S. Boffies J.Appl.meteorol., 1996, Jan, pp. 69-76)

$$T(\lambda,\mu,P_1,P_2)=\exp\left\{-\frac{1}{\mu}\int_{P_1}^{P_2}(\alpha_{gas}(\lambda,p)+\alpha_{aer}(\lambda,p)+\alpha_{mol}(\lambda,p))dp\right\}$$

$$I_1(\lambda)=\frac{S_0(\lambda)}{\pi}\cdot R_{surf}(\lambda)T(\lambda,\mu_{sun},0,P_{surf})T(\lambda,1,0,P_{surf})$$

$$I_2(\lambda)=\frac{S_0(\lambda)}{\pi}\cdot\frac{1}{\mu_{sun}}\int_0^{P_{surf}}(\alpha_{mol}(\lambda,p)F_{mol}(\gamma)+\psi_{aer}\alpha_{aer}(\lambda,p)F_{aer}(\gamma))\cdot$$

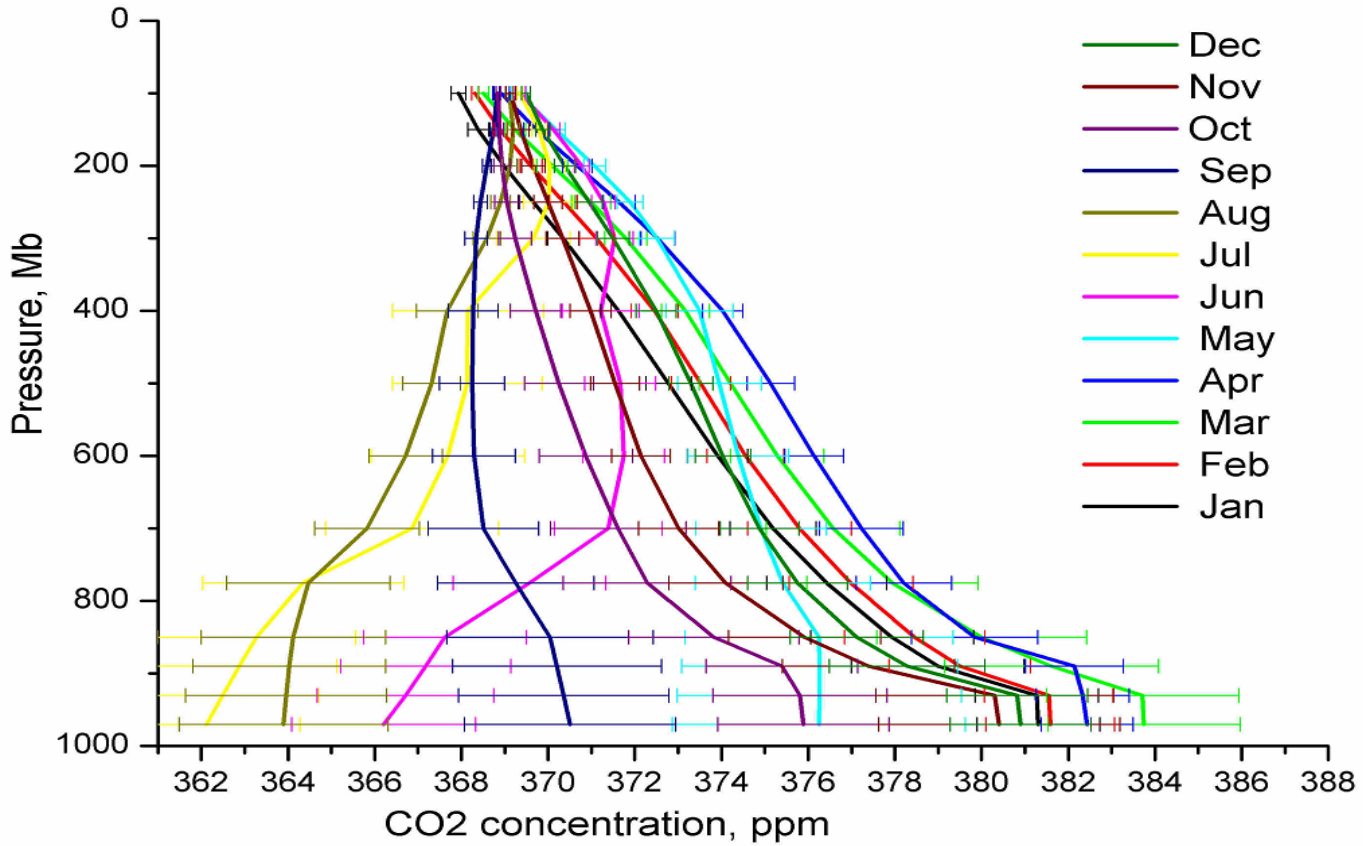
$$T(\lambda,\mu_{sun},p,P_{surf})\cdot T(\lambda,1,p,P_{surf})dp$$

$$\cos(\gamma)=-\mu_{sun}\mu_{sat}-[(1-\mu_{sun})(1-\mu_{sat})]^{1/2}\cos(\varphi)$$

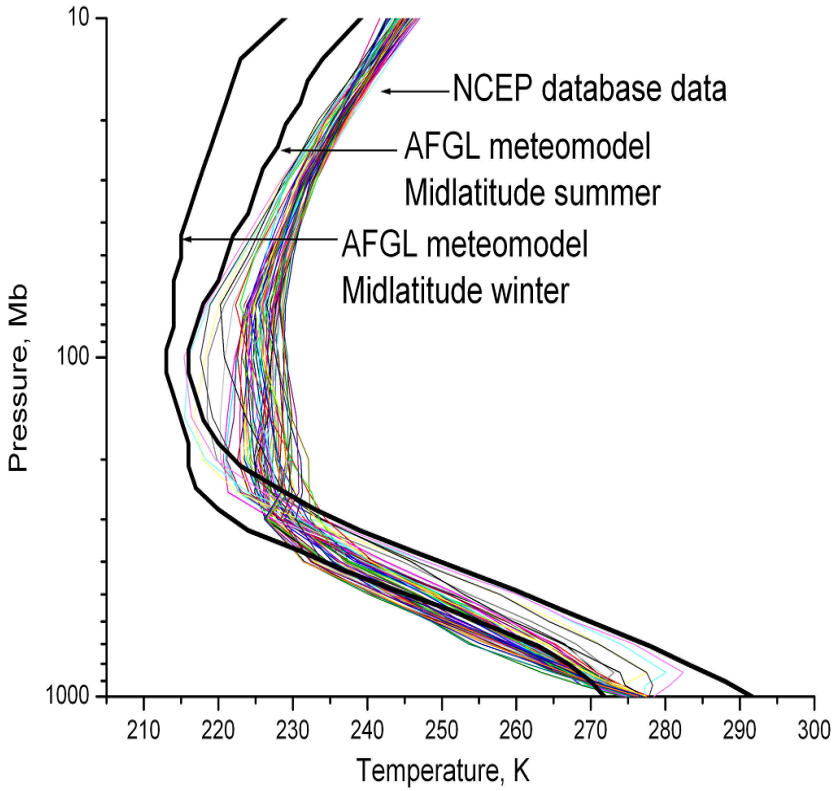
Databases for spectra calculation in global world

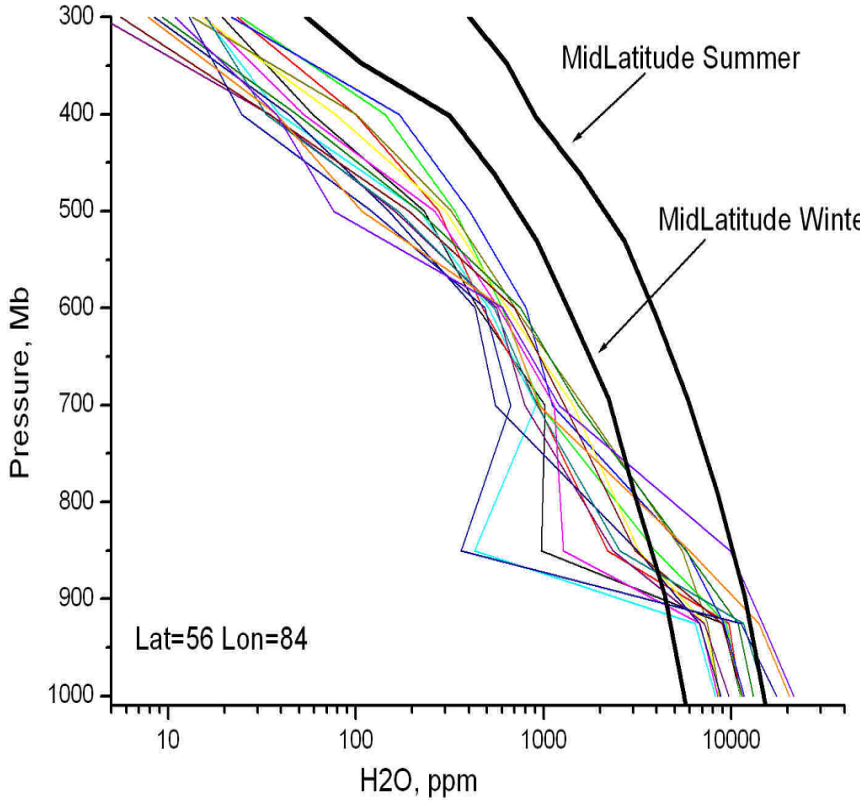
- 1 Solar spectra, Kurucz spectral resolution 1 cm-1,
- 2 Spectroscopic information HITRAN2004 spectral parameters database,
- 3 Meteorological parameters – NCEP Reanalysis data 6 hours 2.5x2.5 grad,
- 4 Gases concentration profiles H2O – NCEP data, CO2 – NIES (S.Maksyutov) data
- 5 Aerosol extinction – SPRINTARS (Toshihiko Takemura,RIAM,Kyushu Univ.)

Variations of the CO2 concentration profile for West Siberia region

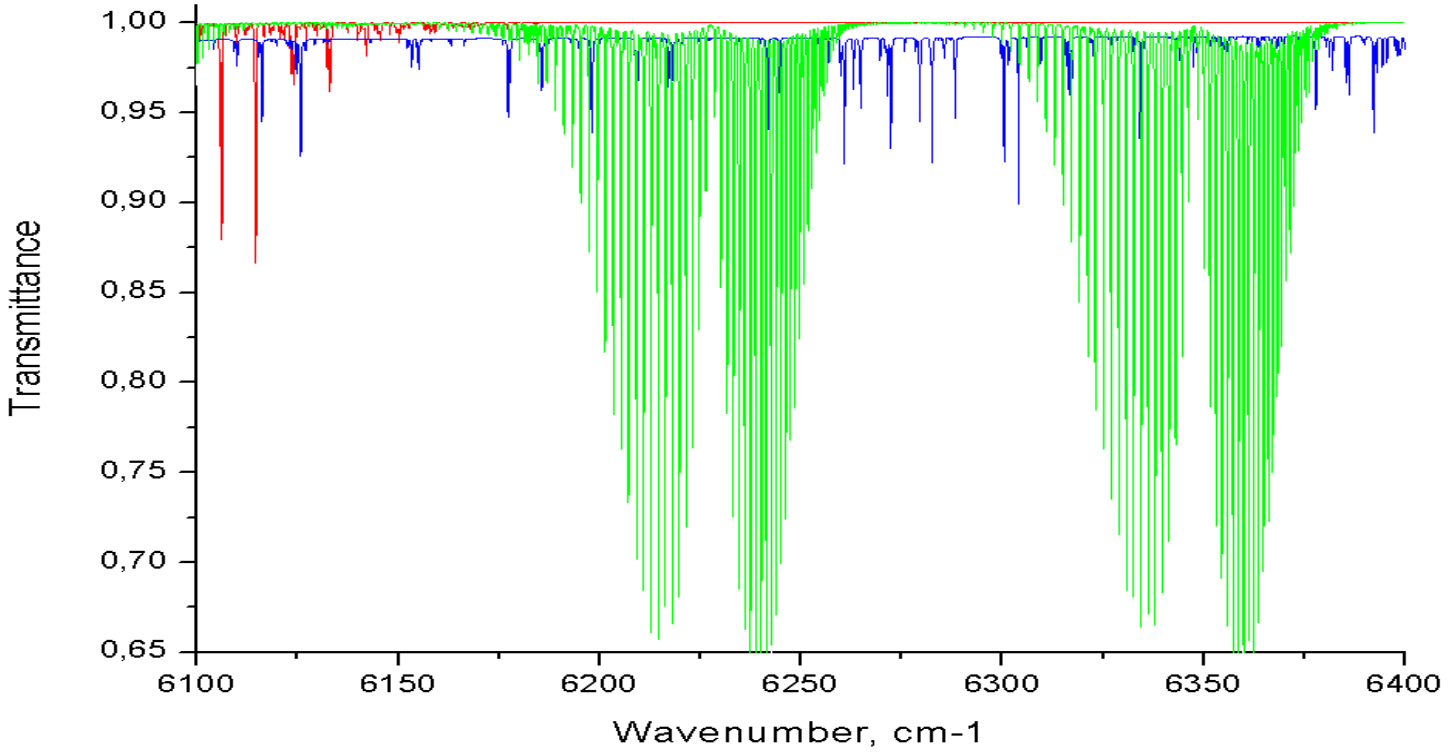


Data from NCEP with comparison of AFGL climatological model





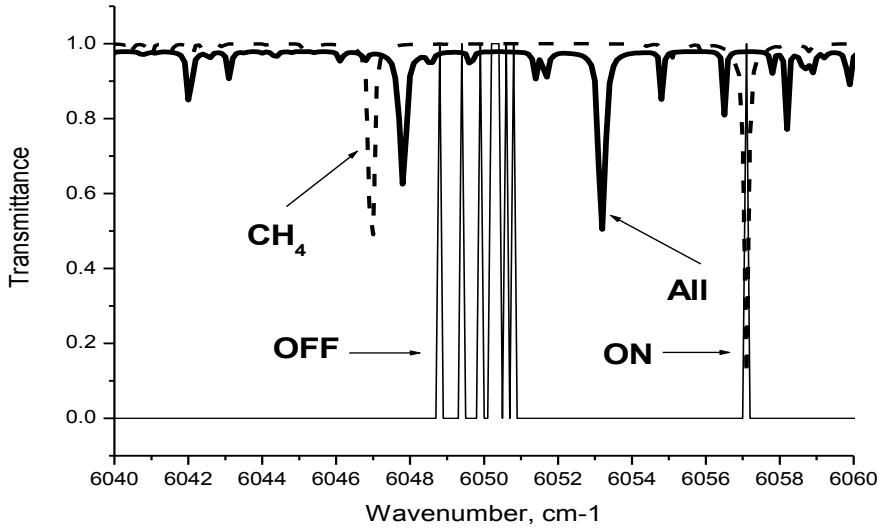
Example of transmittance calculation for Channel 2 of GOSAT



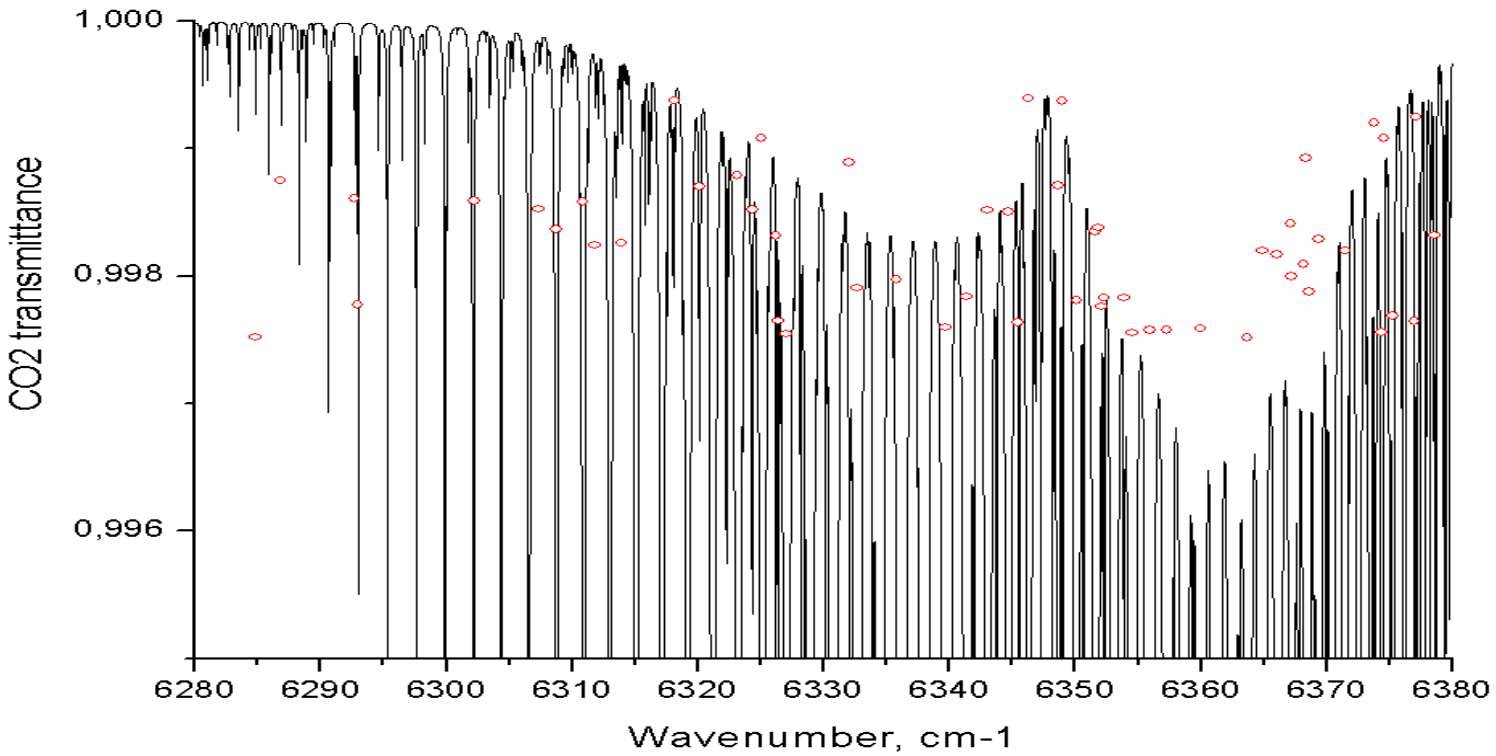
SEARCH OF THE OPTIMAL SPECTRAL CHANNELS

$$L(\nu_1,\nu_2,\mu) = \frac{1}{\sigma}\cdot\frac{T(\nu_1,\mu)}{T(\nu_2,\mu)}\cdot\left[1-\frac{T_o(\nu_2,\mu)}{T_o(\nu_1,\mu)}\right]$$

where σ - dispersion of the measurements, $T(\nu_{1,2},\mu)$ - transmittance for all components of air besides gas under investigation, $T_o(\nu_{1,2},\mu)$ - transmittance (1 – lie in absorption lines of gas under investigation and 2 – very small absorption of gas under investigation).

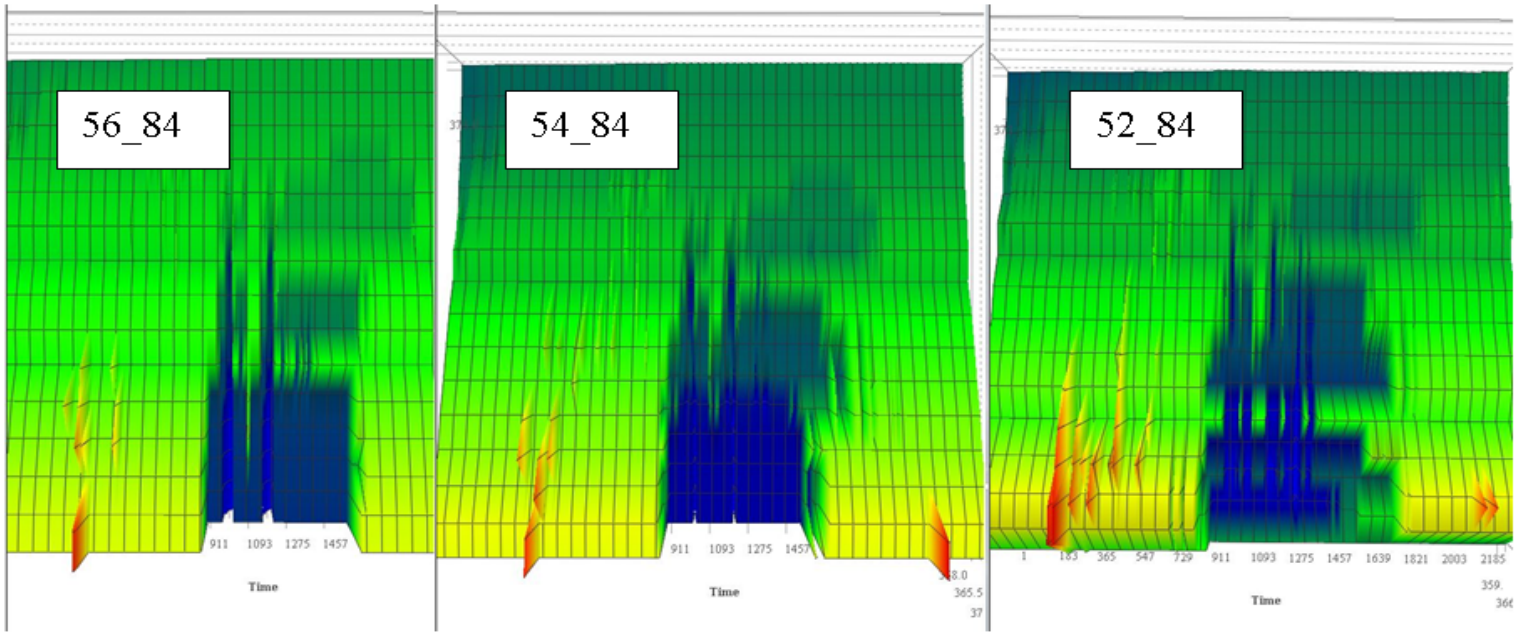


Results of searching of the CO2 spectral channels



The 753 wavenumber with help of algorithm when selection criterion for retrieving error =0.1% was found.

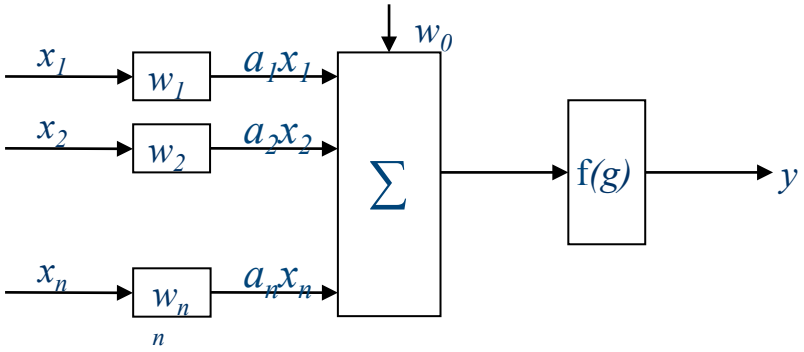
Clusterization of the CO2 data



The clusterization is based on close structure analysis of matrix of the distances between objects. The algorithm is realized using of performance of graph theory.

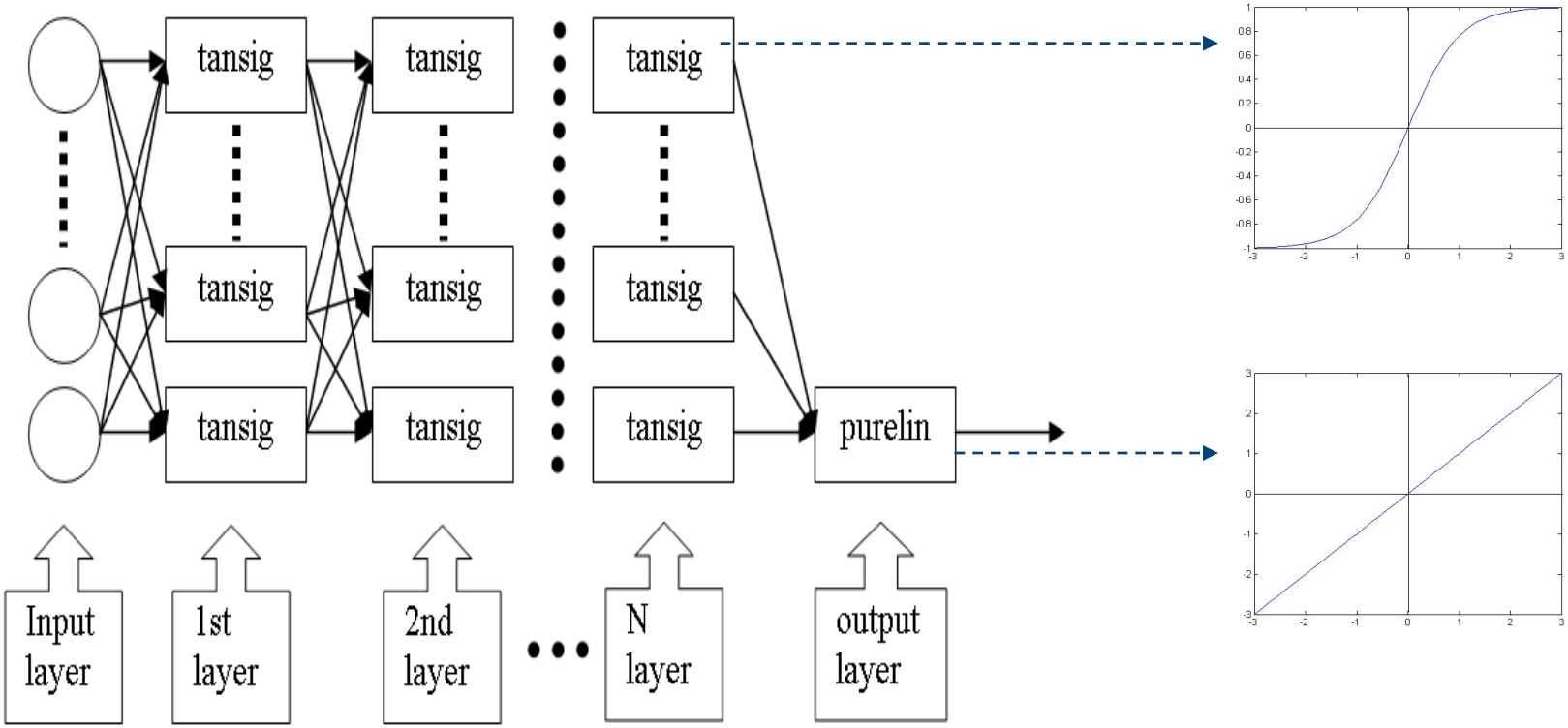
Neural network approach for inverse task solving

Mathematical model of the neuron $y = f(g) = f(\sum_{i=1}^{n} w_i x_i + w_0)$

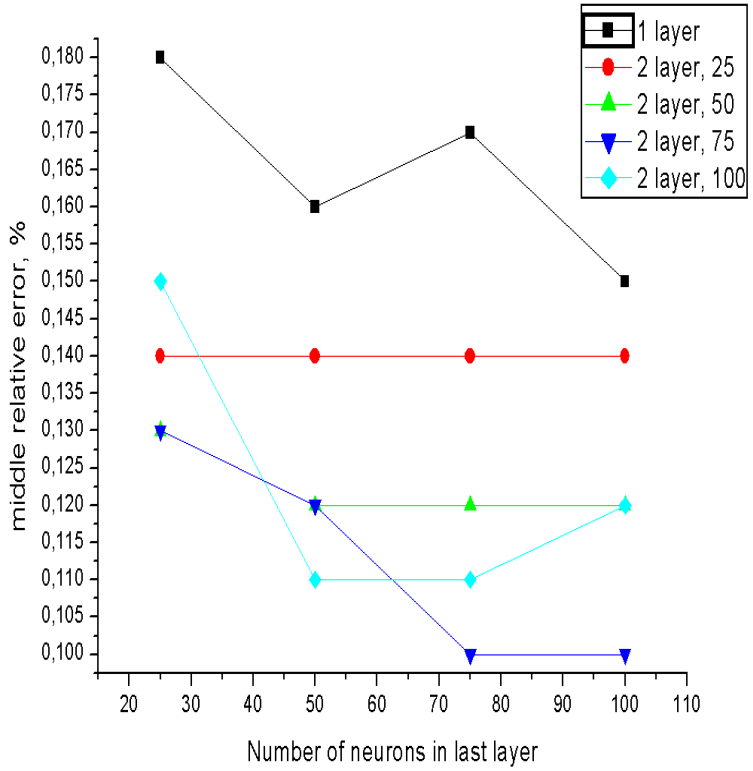


The neural network of one layer; f(g) is the activation function; inputs: x1, x2, ..., xn; weight factors: w11, w12, …, outputs: y

Scheme of Neural network in our work

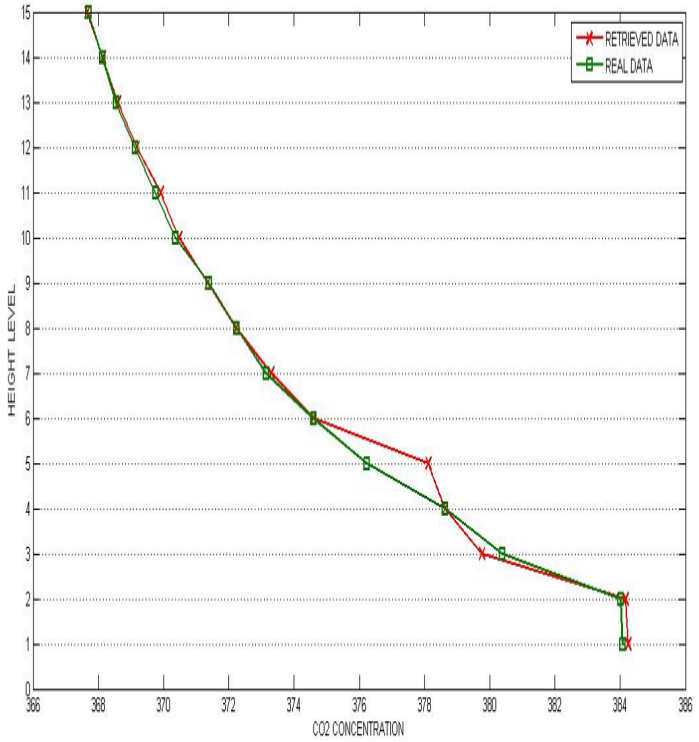


Maximal relative error on training of NN for retrieving of the CO2 concentration profile

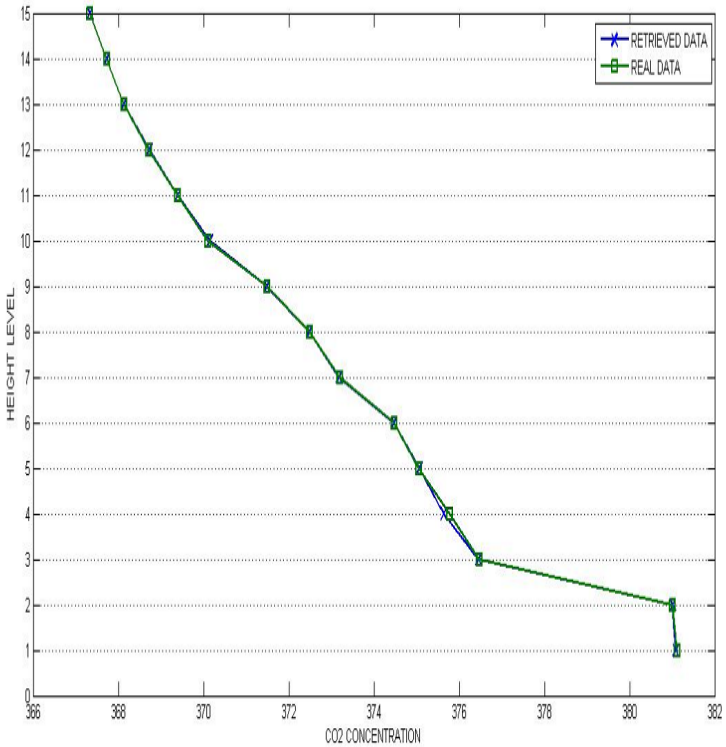


Number of network	Architecture of a network	M1	M2	M3	M4
1	500	0.14%	0.006%	0.12%	0.0059%
2	600	0.073%	0.00896%	0.32%	0.0128%
3	600	0.15%	0.014%	0.14%	0.016%
4	600	0.17%	0.02%	0.16%	0.028%
5	600-200	0.22%	0.03%	1.6%	0.048%
6	600-200	0.24%	0.04%	2.02%	0.058968%
7	800-200-200-200	0.4%	0.06%	2.27%	0.0759%
8	800-400-200	0.56%	0.0597%	1.01%	0.0575%
9	600-200	0.75%	0.088%	1.34%	0.087%
10	600-200-200	0.81%	0.09%	1.88%	0.089%
11	700-200-200	1.36%	0.16%	1.39%	0.13%
12	700-200-200	1.2%	0.21%	1.01%	0.17%
13	600-100-100	1.38%	0.16%	1.3%	0.13%
14	600-100-100	1.08%	0.16%	2.38%	0.15%
15	500-100-100	0.74%	0.15%	1.74%	0.09%

Resuls of retrieving of the CO2 concentration profile from test samples (A) and training samples (B).

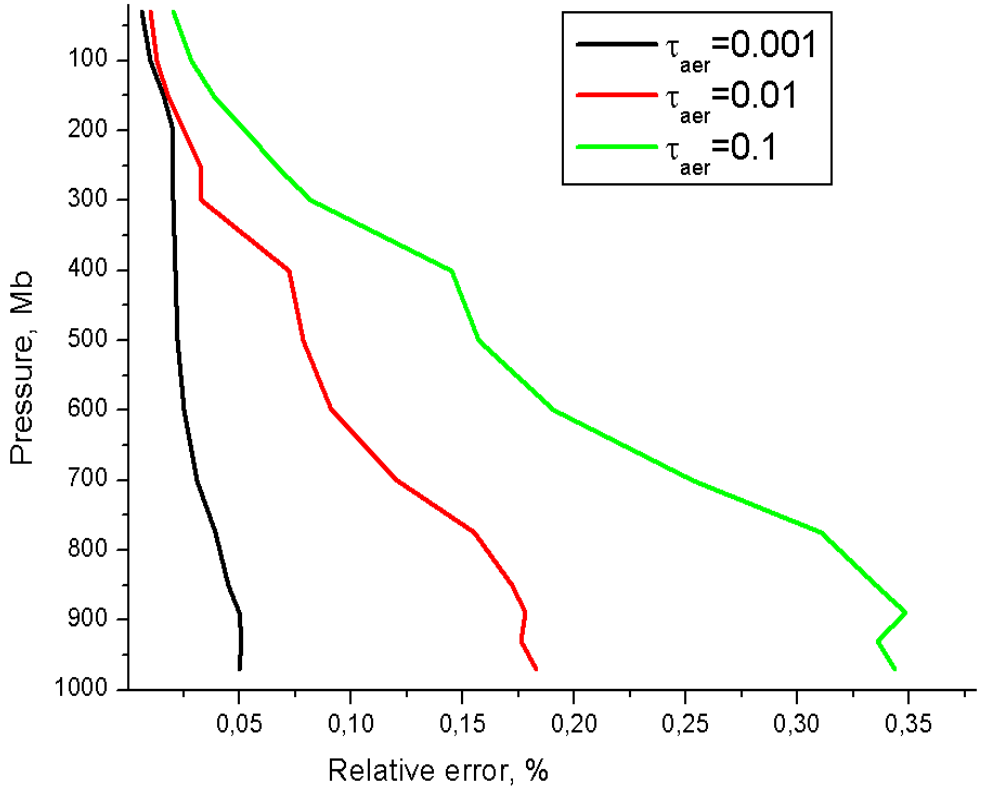


A



B

Relative error of CO2 concentration profile retrieving with changes of the aerosol optical thickness



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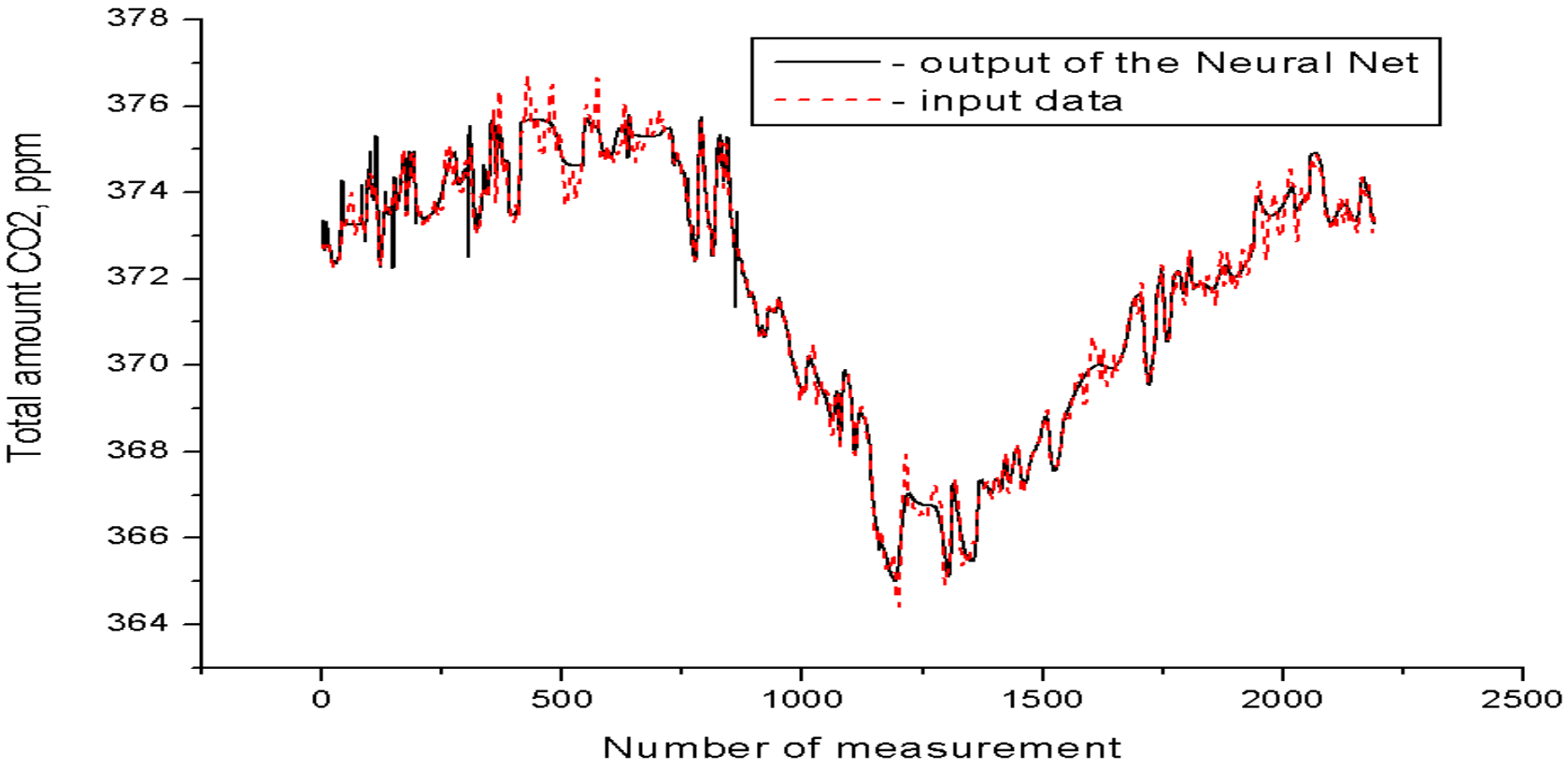
Tomsk state university of control systems and radioelectronics

Result of the CO2 total amount retrieving with help of Neural Net



Number of network1	Architectureof a network	M1	M2	M3	M4
1	200-200-1	0.51%	0.05%	0.42%	0.06%