Summary of the Final Report of Research Results

1) Title of the proposed research

Development of methods and software for retrieval of CO_2 and CH_4 spatial distributions fromTANSO-FTS and TANSO-CAI sensors data and application of these methods for atmosphere over Western Siberia

2) Principal Investigator (PI) and Co-Investigators (Co-Is)

PI:

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4) Summary of the Final Report of Research Results

To acquire GOSAT spectra measured in thermal infrared for retrieval of methane and water isotopologue HDO distributions in the atmosphere of Western Siberia we modified FIRE-ARMS (Fine Infrared Explorer for Atmospheric Radiation MeasurementS) software package for massive processing of GOSAT Level 1B standard products. We developed separate codes and modules for the following tasks:

- single thermal infrared spectrum extraction from HDF5 file of GOSAT Level 1B standard product;
- atmospheric temperature, humidity, surface pressure extraction from NCEP/NCAR reanalysis data (in NetCDF format) for given time and coordinates;
- creation of input files for FIRE-ARMS main code;
- selection of spectra from HDF5 directory corresponding to given conditions (coordinate range, time range, cloudiness, quality flags,...);
- scripting for total retrieval job;
- Levenberg-Maquardt solution as suggested in the paper Changfeng Ma, and Lihua Jiang, Some research on Levenberg-Marquardt method for nonlinear equations. Applied Mathematics and Computation, 184 (2007) 1032-1040, doi:10.1016/j.amc.2006.07.004.

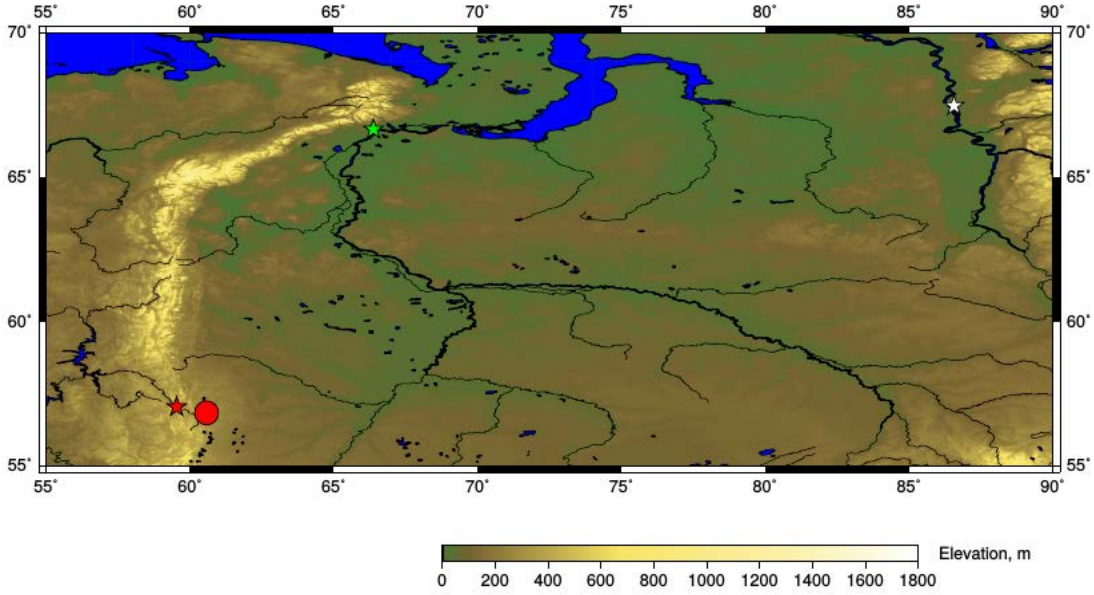

Fig.1. Western Siberia area, red and green stars are existing observation sites at Kourovka and Labytnangi respectively, white star is planned observation site at Igarka, and red circle is Yekaterinburg city.

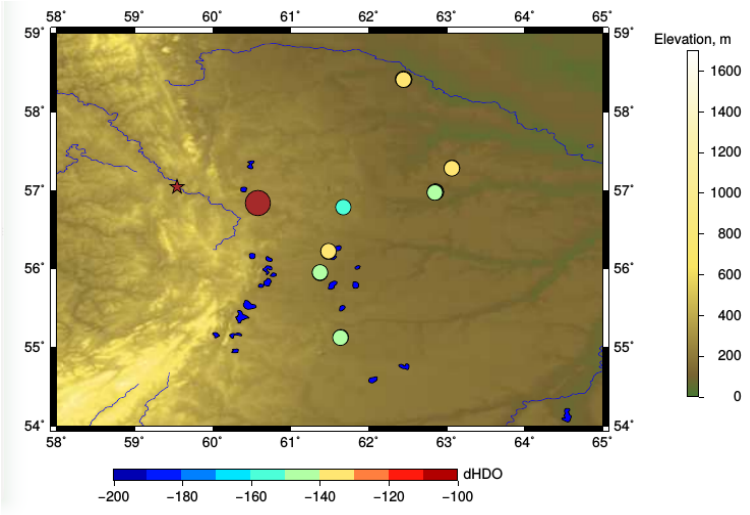

Fig.2. GOSAT cloudless spots closest to Kourovka (red star) for which observation time was synchronous with FTIR ground based observations in Kourovka.

We undertook an attempt to retrieve columnar values of δHDO for atmospheric water vapor from thermal infrared measurements of TANSO-FTS for whole area of Western Siberia (see Fig.1) and for smaller area in surroundings of our observation site at Kourovka (57.048N, 59.545W). We had an intention to compare direct measurements at surface and retrievals from GOSAT spectra. However, our efforts were not successful. We noticed that some spectra have too strong HDO signal (near 1204 cm^{-1}) for cold northern observation points with relatively small H_2O signal. Our retrieval procedure gave close to zero or even positive values for δHDO in these cases which were considered as implausible. Also we tried to compare retrievals with ECHAM5-wiso output for whole area of Western Siberia, we did not find good correlation. We obtained some weak result (only

7 cloudless observations in the vicinity of Kourovka and at given time, see Fig.2) and tried to represent them in publication (2 in the list below), this part was removed due to reasonable criticism from referees. So, final publication (3 in the list below) does not contain mentioning of retrieval from GOSAT spectra. The problem was understood better after 5th GOSAT PI Meeting (May 27, 2013, Yokohama, Japan) where J.Gero et al. presented their report "GOSAT TIR Band Inter-calibration with Satellite Infrared Sensors" and showed that radiometric calibration of TASNO-FTS in thermal infrared band was not perfect for given period of time. So, since this moment we decided to postpone using of TIR GOSAT measurements and to focus our efforts on using ready SWIR Level 2 products (as in 1 in the publication list) and development of code applicable for the acquisition of SWIR band of GOSAT measurements. To continue our research on water isotopologues in the atmosphere of Western Siberia we had to develop the same package for massive processing of IASI/METOP data. Our current activity (related to GOSAT project) is focused on the following directions:

- continuing development of methods for ground based FTIR measurements for methane and water isotopologues using constraints obtained from our direct measurements from our observation sites (using Picarro L2130-i and G2401 instruments);
- inclusion of VLIDORT software package into our FIRE-ARMS code to become able to retrieve required constituents from satellite measured spectra of near infrared band (including SWIR band of GOSAT);
- installation of new observation site for water isotopologues in Igarka (eastern boundary of Western Siberia, 67.467N, 86.567E)

5) List of publications relating to the proposed research

1. Rokotyan, N.V., Imasu, R., Zakharov, V.I., Gribanov, K.G., Khamatnurova, M.Yu. Seasonal cycle amplitude of CO_2 for the atmosphere of Ural region as measured by ground-based and satellite remote sensing. Atmospheric and Oceanic Optics, in press (in Russian).
2. K. Gribanov, J. Jouzel, V. Bastrikov, J.-L. Bonne, F.-M. Breon, M. Butzin, O. Cattani, V. Masson-Delmotte, N. Rokotyan, M. Werner, and V. Zakharov. ECHAM5-wiso water vapour isotopologues simulation and its comparison with WS-CRDS measurements and retrievals from GOSAT and ground-based FTIR spectra in the atmosphere of Western Siberia. Atmos. Chem. Phys. Discuss., 13, 2599-2640, 2013.
3. K. Gribanov, J. Jouzel, V. Bastrikov, J.-L. Bonne, F.-M. Breon, M. Butzin, O. Cattani, V. Masson-Delmotte, N. Rokotyan, M. Werner, and V. Zakharov. Developing a western Siberia reference site for tropospheric water vapour isotopologue observations obtained by different techniques (in situ and remote sensing), Atmos. Chem. Phys., 14, 5943-5957, doi:10.5194/acp-14-5943-2014, 2014.
4. Pommier, M., Lacour, J.-L., Risi, C., Bréon, F. M., Clerbaux, C., Coheur, P.-F., Gribanov, K., Hurtmans, D., Jouzel, J., and Zakharov, V.: Observation of tropospheric δD by IASI over western Siberia: comparison with a general circulation model, Atmos. Meas. Tech., 7, 1581-1595, doi:10.5194/amt-7-1581-2014, 2014.
5. Rokotyan N.V., Gribanov K.G., Zakharov V.I. Effect of temperature-independent absorption and its use in remote sensing of atmospheric carbon gases. // Atmospheric and oceanic optics. 2011. V. 24. No. 06. P. 510-515 [in Russian].
6. Gribanov K.G., Imasu R., Zakharov V.I. Neural networks for CO_2 profile retrieval from data of GOSAT/TANSO-FTS. // Atmospheric and oceanic optics. 2009. V. 22. No. 09. P. 890-895 [in Russian].

7. K. Gribanov, N. Rokotyan, V. Bastrikov, V. Zakharov. Series of measurements from new possible validation site at Kourovka. Abstract Collection, The 9th International Workshop on Greenhouse Gas Measurements from Space (IWGGMS-9), May 29th — 31st, 2013, Yokohama Symposia, Japan, p.51.
8. N. Rokotyan, R. Imasu, M. Khamatnurova, V. Zakharov, K. Gribanov and C. Petri: Ground-based remote sensing of XCO2 and XCH4 in the atmosphere of Ural and comparison with GOSAT L2 retrievals, IRWG/TCCON Meeting, Bad Sulza, Germany, 2014