HDO mapping in the atmosphere over Western Siberia from satellite data with validation using ground based measurements.

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HDO is a long existing tool in climate sciences, and concentration distribution retrieval in the atmosphere can be used within general circulation models with embedded isotopes. Retrieval of total columnar value in the atmosphere above the observation site is possible using FTIR spectrometers like Bruker IFS120/125HR series used in TCCON [1] for carbon gases monitoring. Despite of worse spectral resolution and signal to noise ratio, satellite spectrometers can provide better coverage for HDO mapping in the scale of whole planet. First attempt of HDO mapping from satellite data was undertaken with the data from IMG/ADEOS [2]. Lack of information on HDO vertical distribution in satellite spectra (weak spectral features, relatively high level of noise, spectral resolution) conditions the need to develop effective methods for validation and constriction of inverse task solution. This very preliminary study represents the method of vertical profile retrieval from satellite spectra with conservation of columnar value obtained by the ground based measurements performed by FTIR measuring solar radiation transferred through the atmosphere. The method is based on approximation of vertical profiles of H2O and HDO using parametrized probability functions (PDF), so the retrieval of vertical profiles is performed in domain of PDF's parameters. Close measurements in Ural Atmospheric Fourier Station (UAFS, Kourovka, 57.036N, 59.546E) and GOSAT [3] observations were used for this case study. Approximately 30 of ground based and 300 satellite measurements performed in March of 2011 were involved in this study. Vertical profiles of H2O and HDO were represented as

$$n(h) = Total\,\left(k_B T(h)/p(h)\right)\,pdf\,(h,\boldsymbol{\alpha},\boldsymbol{\lambda}).$$

Hyperexponential function $$pdf\,(h,\boldsymbol{\alpha},\boldsymbol{\lambda}) = \sum_{i=1}^{N} \alpha_i \lambda_i \exp(-\lambda_i h)$$

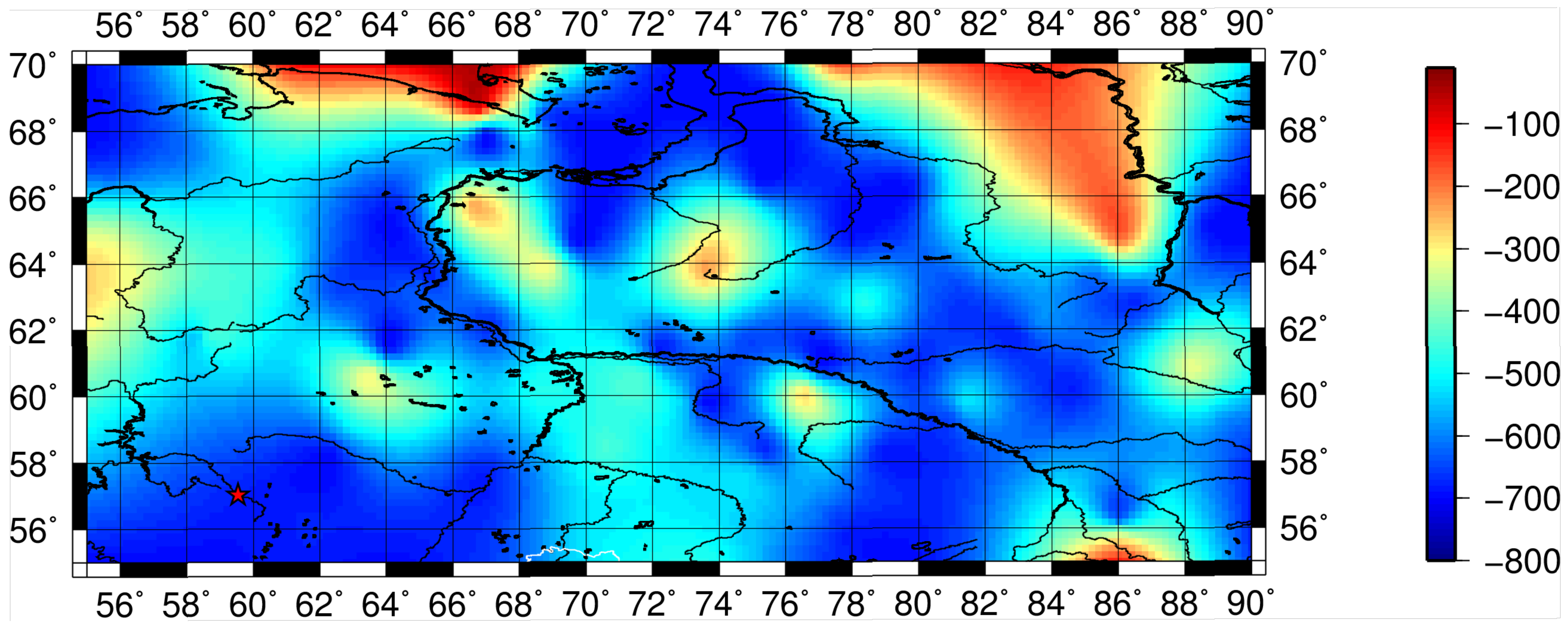
with the condition $\sum_{i=1}^{N} \alpha_i = 1$ and $N=2,3$ was used.

Such representation of vertical profiles allows to vary only shape of vertical profile conserving total column amount of given molecule. Collocated and approximately simultaneous measurements (ground based and satellite) allow to determine approximate ranges of variation of PDF's parameters. Then for the retrieval of wider coverage of HDO distribution, the value of Total become a variable. Denoting calculated and measured radiances as R_c and R_m respectively, retrieval can be represented as the following optimization problem:

$$\min_{Total,\boldsymbol{\alpha},\boldsymbol{\lambda}} \sum_{j=1}^{M} \left(R_c(\nu_j, n(Total,\boldsymbol{\alpha},\boldsymbol{\lambda})) - R_m(\nu_j)\right)^2$$

subject to

$$\sum_{i=1}^{N} \alpha_i = 1;\;\; 0 \le \alpha_i \le i;\;\; \lambda_i^{lower} \le \lambda_i \le \lambda_i^{upper};\;\; Total_{lower} \le Total \le Total_{upper}.$$



Flexible streaming software was developed for the purpose of massive processing of satellite data. Separate routines are developed for the following tasks: extraction of spectra and auxiliary data from HDF5 GOSAT L1B files, extraction of initial guess vertical profiles of temperature and humidity from NCEP/NCAR reanalysis data [4], radiative transfer calculations, cloudless condition selection, sequential quadratic programming on the base of existing *sqp()* routine of Octave [5], etc.

An example of preliminary HDO map is shown in the figure. This map produced from all selected GOSAT spectra measured in March of 2011 over the territory of Western Siberia without any account of air drift. Location of UAFS is marked with the red star in the left bottom corner of the map.

Further validation by direct measurements, exactly collocated observations, error analysis are subject of future study.

References:

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