THE PROSPECTS FOR REMOTE SOUNDING OF TRACE GAS COLUMN AMOUNTS AND PROFILES FROM HIGH SPECTRAL RESOLUTION IR RADIANCE MEASUREMENTS

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1. INTRODUCTION

The design of spaceborne advanced instruments for measurements of IR radiance spectra with high spectral resolution (EOS-AIRS, METOP-IASI missions) promises significant improvements in remote sounding of atmosphere temperature and gas composition (Diebel et al., 1997). The problem under consideration of this paper is the derivation of column amounts (CA) and/or vertical profiles (VP) of some tropospheric minor gas constituents (MGC) especially nitrous oxide (N_2O), methane (CH_4) and carbon monoxide (CO) from forthcoming IASI data, see also (Clerbaux et al., 1998). The developed approach is based on the relevant inverse problem formulation and solution using best linear estimation technique. In the version of inverse problem being considered the unknown target quantities are CAs or functionals of N_2O, CH_4, CO VP; the temperature and water vapour profiles *T(p)*, *H(p)* are treated as interfering parameters. The retrieval accuracy depends largely on the proper selection of IASI measurement channels, which contain if well chosen the maximum information on target quantities. The entropy reduction in Shannon sense have been used as the measure of information content for the selection of appropriate subset of channels. The paper presents the results of retrieval error analysis. The sensitivity of retrieval errors to ancillary data (*T(p)*, *H(p)*) uncertainties is considered. The information content estimates and anticipated retrieval accuracy results are demonstrated for different atmosphere models both for CAs and VPs retrievals.

2. INVERSE PROBLEM FORMULATION

The IASI measurement interpretation, i.e. the retrieval of quantitative characteristics describing the state of the atmosphere (temperature and gas composition distributions) and Earth's surface is based on the solving the inverse problems of the atmospheric optics. The measurement model and relevant inverse problem are stated as a non-linear equation

$$\mathbf{I} = \mathbf{F}(\mathbf{x}, \mathbf{g}) + \varepsilon, \tag{1}$$

where **I** is the ($n_y \times 1$) measurement vector, **x** is the ($n_x \times 1$) vector of unknown parameters (or state vector); **F** is the forward radiative transfer operator, **g** is the ($n_g \times 1$) vector of interfering or disturbing parameters (i.e. those which affect the measured radiance but are not being retrieved); ε is the ($n_y \times 1$)-dimensional vector of instrumental noise. The measurements errors ε are assumed to be random, and have zero mean $<\varepsilon>=0$ and known covariance matrix $\mathbf{S}_\varepsilon$. The state vector **x** includes the N_2O, CH_4 and CO mixing ratios for a set of layers or their CAs. Vector $\mathbf{g} = \|\mathbf{g}_T, \mathbf{g}_H\|^T$ represents a set of functionals of temperature *T(p)* and humidity *H(p)* profiles as principal interfering parameters, *p* - means pressure. Note, that the interfering parameters **g,** such as temperature and humidity profiles, aerosol distribution characteristics, concentrations of selected optically active trace gases, model parameters, etc., being considered as known a priori, enable to evaluate, for given **x**, the operator **F** of the forward model.

To carry out the measurement information content analysis and the retrieval of state vector **x**, equation (1) is linearized regarding the specified value (initial guess) of $\mathbf{x}=\mathbf{x}_0$, $\mathbf{g}=\mathbf{g}_0$. The result is the following linear model:

$$\mathbf{y} = \mathbf{A}\delta\mathbf{x} + \mathbf{A}_T\delta\mathbf{g}_T + \mathbf{A}_H\delta\mathbf{g}_H + \varepsilon, \tag{2}$$

where $\mathbf{y} = \mathbf{I} - \mathbf{I}_0, \delta\mathbf{x} = \mathbf{x} - \mathbf{x}_0, \delta\mathbf{g}_T = \mathbf{g}_T - \mathbf{g}_{T_0}$, $\delta\mathbf{g}_H = \mathbf{g}_H - \mathbf{g}_{H_0}$ and **A**, $\mathbf{A}_T$, $\mathbf{A}_H$ are the respective $(n_y \times n_{g_T})$, $(n_y \times n_{g_H})$ jacobian matrices. As a rule the vector **g** is imperfectly known and (2) should be treated as multicomponent inverse problem with respect to $(\delta\mathbf{x}, \delta\mathbf{g})$ aggregate.

The maximum information content on unknown vectors $\delta\mathbf{x}$, $\delta\mathbf{g}$, is extracted from (2) using the methods of optimal statistical estimation (Uspensky&Fedorov, 1975; Rodgers, 1976, 1996). If we know the first two moments of a probability density functions $\psi(\mathbf{x})$, $\psi(\mathbf{g})$ (e.g. the climatological means $\langle\delta\mathbf{x}\rangle$, $\langle\delta\mathbf{g}_T\rangle$, $\langle\delta\mathbf{g}_H\rangle$ and their covariance matrices $\mathbf{S}_0$, $\mathbf{S}_T$, $\mathbf{S}_H$) then the minimum variance method or the best linear estimators (b.l.e.) may be applied for solution of (2).

One of the focal points of our approach is to reduce crucially the dimension of inverse problem (2) treating vector $\mathbf{g}$ as the set of interfering factors (IF). The IF are supposed to be "small" in the following sense: the terms $|\mathbf{A}_T\delta\mathbf{g}_T|$, $|\mathbf{A}_H\delta\mathbf{g}_H|$ have the order of $|\varepsilon|$, $\langle\delta\mathbf{g}_T\rangle=0$, $\langle\delta\mathbf{g}_H\rangle=0$, where $\langle\cdot\rangle$ stands for expectation in the IF space. For such situation with known covariance matrices $\mathbf{S}_T$, $\mathbf{S}_g$ the original inverse problem (2) is reduced to

$$\mathbf{y} = \mathbf{A}\delta\mathbf{x} + \mathbf{e},\ \ \mathbf{e} = \mathbf{A}_T\delta\mathbf{g}_T + \mathbf{A}_H\delta\mathbf{g}_H + \varepsilon,\ \ \langle\mathbf{e}\rangle = \mathbf{0},\ \ \mathbf{S}_e = \mathbf{S}_\varepsilon + \mathbf{A}_T\mathbf{S}_T\mathbf{A}_T^* + \mathbf{A}_H\mathbf{S}_H\mathbf{A}_H^* \quad (3)$$

The superscript "*" stands for transposing, $\langle\cdot\rangle$ stands for expectation both in the measurement and the IF spaces.

For the CH_4, N_2O retrieval the vector $\mathbf{I}$ from equation (1) is formed by the measured radiances in IASI R5 band (1210-1650 cm^{-1}), where the fundamental ν_4 absorption band (centered at 1306.2 cm^{-1}, 7.6 μm) of CH_4 and ν_1 band (centered at 1285.6 cm^{-1}, 7.8 μm) of N_2O are located. For CO retrieval the vector $\mathbf{I}$ is associated with the IASI measurements from the R6 band (2100-2150 cm^{-1}), where the CO absorption band at 2143 cm^{-1} (4.7 μm) is located. This provides for a formal "separation" of the initial inverse problem. The first problem concerns with the retrieval of CH_4, N_2O characteristics (with the temperature and humidity as principal IFs) from measurements in R5 band; the second one deals with the retrieval of CO characteristics within R6 band. This concept allows to decrease the dimension of each particular inverse problem and to alleviate their solution in frame of unified retrieval strategy.

In what follows the model (3) will be the basis for study the IASI data information content and for understanding its potential to infer CH_4, N_2O, CO CAs and/or VPs estimates.

3. INFORMATION CONTENT ANALYSIS AND CHOICE OF A SUBSET OF CHANNELS

An efficient remote sensing of the atmosphere parameters (in particular, the MGC column amount or profile derivation) requires (along with using the b.l.e. for the solution of the inverse problem (3)) to optimize the scheme of measurements. For the IASI instrument, with a considerable number of spectral channels, it is necessary to carry out the analysis of the information content with respect to the unknown parameters $\delta\mathbf{x}$, and to select the optimal subset of channels. Here the optimality of the subset is defined as a possibility of its use to provide the estimate of unknown vector $\delta\mathbf{x}$ (or its components) with accuracy better than 10%.

The b.l.e. for solution $\delta\mathbf{x}$ of (3) has the error covariance matrix $\mathbf{S}_x = (\mathbf{M} + \mathbf{S}_0^{-1})^{-1}$, where $\mathbf{M} = \mathbf{A}^*\mathbf{S}_e^{-1}\mathbf{A}$. The matrix $\mathbf{M}$ as well as covariance matrix $\mathbf{S}_x$ do not depend upon the "observations" $\mathbf{y}$. It allows to select a priori a set of channels which is "better" than others in terms of $\mathbf{S}_x$ (or $\mathbf{M}$). It should be outlined that these optimization problems may be successfully solved using the methods of the design of experiments (Uspensky&Fedorov,1975; Fedorov&Hackl, 1997). The information content analysis and the selection of the optimal channel subset are based on the maximization of the following criterion (Shannon's information content), see e.g. (Rodgers, 1996):

$$H(\mathbf{y}|\delta\mathbf{x}) = 0.5\cdot\log_2\{\det(\mathbf{S}_0)/\det(\mathbf{S}_x)\} = 0.5\cdot\sum_\alpha \log_2(1+\lambda_\alpha), \quad (4)$$

where λ_α are the eigenvalues of matrix $\mathbf{W}=\mathbf{S}_0\cdot\mathbf{M}$.

It should be noted that the selected subsets of channels (hereinafter referred to as ξ_{n^*}, where n* is the number of selected channels) may be used as the first guess approximation for other algorithms of the measurement scheme optimization, see also (Clerbaux et al., 1998).

To conclude the short description of methodology applied it is pertinent to note that along with criteria (4) the index r=max{a: $\lambda_a\geq1$} has been calculated, where λ_a are eigenvalues of matrix $\mathbf{W}$. The index r represents the number of independent pieces of information with respect to desired quantities inherent in the IASI measurements and is similar to the index $t = \sum_\alpha \lambda_\alpha(1+\lambda_\alpha)^{-1}$ ("degree of freedom for signal") being a measure of the number of statistically independent quantities in the same measurements (Rodgers, 1996). Table 1 contains the values of r calculated for 5 different atmosphere models with $\mathbf{S}_e=\mathbf{S}_\varepsilon$ for R5 IASI band. The five models, referred to as tropical (TRP), midlatitude summer (MLS) and winter (MLW), subarctic summer (SAS) and winter (SAW), incorporate corresponding latitude-averaged profiles of CH_4 and N_2O as well as ozone and CO distributions from corresponding USAF mean profiles (Uspensky et al., 1998a).

Table 1. The values of $r = \max\{\alpha: \lambda_\alpha \geq 1\}$

SAW	SAS	MLW	MLS	TRP
4	6	5	6	7

It can be seen that it is not reasonable to consider the inverse problem with $n_x > 6$. The value of n_x can be treated as the limit for number of atmospheric layers when MGC profiles retrieval is considered. For example, when N_2O and CH_4 profiles are retrieved in R5 IASI band the number of layers in profiles should not be more than 3 for each gas.

While selecting the appropriate scheme of measurements (subset of IASI channels), it is required to provide the maximum universality and independence of ξ_{n^*} regarding the atmosphere models and the a priori information on **x**, as well as to minimize the number of channels within the ξ_{n^*} subset. This is explained by the desirability to minimize the effort and computational resources in developing relevant fast radiative transfer algorithm, because the last one is actually unique with application to each spectral channel (Trotsenko et al., 1998). Due to the non-linearity of the initial inverse problem and presence of IFs, the information content characteristics and the set of channels ξ_{n^*} should be in general dependent on the atmosphere model involved. Therefore the selection of the IASI channel subset, which provides the 10 % accuracy of the $\delta\mathbf{x}$ retrieval for a wide set of the atmosphere models, is performed on the basis of the following considerations. The accuracy of the $\delta\mathbf{x}$ retrieval is evidently decreased in case of low sensitivity of **y** to $\delta\mathbf{x}$ variation and the deterioration in signal-to-noise ratio. Physically it corresponds to colder atmosphere models. Therefore, while selecting the measurement scheme it is reasonable to begin from the high-latitude winter models. For warmer conditions the selected channels may be expected to be acceptable or small number of another channels should be added. The results of the ξ_{n^*} selection for various atmosphere models have shown the validity of the proposed approach (Uspensky et al., 1998b, 1999).

Let address to the results obtained. Due to virtual "separation" the inverse problems Table 2 contains results for CH_4, N_2O measurement schemes in R5 band. The selection of optimal channel sets has been performed for three different error budget models: for the most favourable case with only instrumental noise being present; for "intermediate" situation with additional noise due to moderate uncertainties in ancillary information on the IF; for the most unfavourable case with "high" efficient noise due to imperfect knowledge of the IF (the climatology for *T, H* is incorporated) see (Uspensky et al., 1998b, 1999).

Table 2 shows the data on one of the selected subsets of the optimal IASI channels ξ_{10} defined for the most unfavourable case. Two left columns of the Table present relative numbers and spectral positions of the channels. Other columns show the values of H information criterion and N_2O, CH_4 standard deviations correspondent to different channel subsets within the ξ_{10}, i.e. ξ_i, $i=1,..,10$. As it may be seen from Table, for all standard models, the ξ_{10} subset has a sufficient information content and provides the 10 % accuracy level of the $\delta\mathbf{x}$ retrieval.

Fig. 1 illustrates the conclusions drawn from the analysis of the data presented in Table 2. It shows the so-called information spectra, i.e. the values of H criterion vs. the spectral channel position within the R5 band. The curve 1 represent the spectral dependence of relevant criterion calculated with respect to the a priori information. In turn the curves 2, 3, 4, 5, 10 correspond to the criterion values after the addition the 1st, 2nd, 3rd, 4th, and 9th channels of subset, respectively. The maximums on the curves correspond to the channels, which have the maximum information content with respect to the target species and are evidently positioned within relevant absorption bands of N_2O and CH_4. Lastly, the curve 10 illustrates the "saturation", i.e. the low increments in the information content and the lack of expressed maximums. Note that the Fig. 1 present results obtained for optimal channel subset for TRP atmosphere model that is why the values of Shannon criterion are higher than in Table 2 where values of H refer to optimal channel subset selected for 5 different atmosphere models.

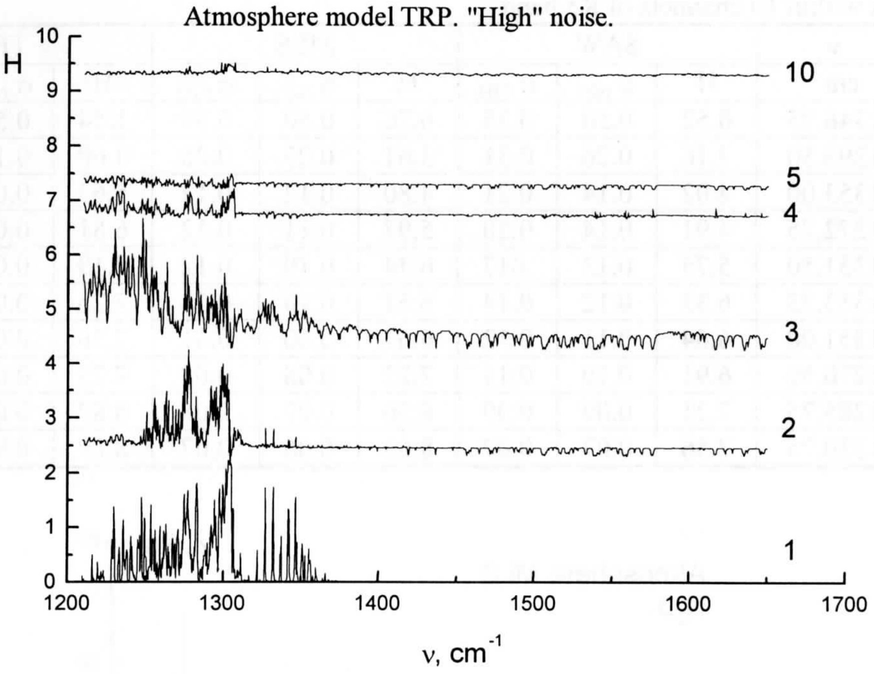

Fig. 1 Shannon information spectra within R5 band. Maximum on each curve corresponds to optimal channel location.

Considering the above the following conclusion may be drawn: the theoretical assessment of the IASI performances demonstrates that if ancillary data have moderate level of uncertainty, than IASI measurements in properly chosen channel subset (with overall number of channels less than 10) provide the information required for the retrieval of CH_4, N_2O, CO column amounts at accuracy better than 10%.
The similar technique has been applied for the analysis of the IASI data information content with respect to vertical distribution of CH_4, N_2O. The vector **x** in this case comprises the N_2O, CH_4 mixing ratios for 3 atmospheric layers (n_x=6). Two types of atmosphere layering were considered: 0-5 km; 5-10 km; 10 km-Top of the atmosphere (TOA) and 0-5 km; 5-15 km; 15 km-TOA.
The optimal subset consists of 40 IASI R5 band channels. Fig.2 presents N_2O jacobians for several channels from optimal subset for MLS atmospheric model. Qualitatively jacobians for CH_4 are similar to those presented at the Fig. 2. It can be seen that the extremums are located approximately at the same altitude. Such shape of jacobians induces evident difficulties in N_2O and CH_4 profiles retrieval from IASI measurements.
The information content analysis shows that IASI data in properly chosen channel subset provide the retrieval of CH_4, N_2O amount in three layers (2 tropospheric layers) at accuracy 10 - 20% for CH_4 and 16 - 30% for N_2O for different atmospheric models (excluding SAW) if the ancillary data on interfering parameters are known with low level of uncertainty.

4. APPLICATION TO SIMULATED IASI DATA

The standard approach to the non-linear inverse problem solution is based on a numerical minimization of the respective functional or cost function (functional of least square regularized method etc.). One of rather efficient iterative algorithms (provided that (1) is "moderately" non-linear) is well-known Gauss-Newton iteration procedure (Uspensky&Fedorov, 1975; Rodgers, 1976):

$$\delta\mathbf{x}(i+1) = \mathbf{S}_{\mathbf{x}(i)}\mathbf{A}^*(i)\mathbf{S}_{\mathbf{e}}^{-1}\left(\mathbf{y}(i) + \mathbf{A}(i)\delta\mathbf{x}(i)\right). \quad (5)$$

Here i is the order of iterations,
$\delta\mathbf{x}(i) = \mathbf{x}(i) - \mathbf{x}_0$, $\mathbf{y}(i) = \mathbf{I} - \mathbf{F}(\mathbf{x}(i), \mathbf{g}_0)$, $\mathbf{A}(i) = \mathbf{A}(\mathbf{x}(i), \mathbf{g}_0)$,
$\mathbf{S}_{\mathbf{x}(i)} = \left(\mathbf{M}(i) + \mathbf{S}_0^{-1}\right)^{-1}$, $\mathbf{M}(i) = \mathbf{A}^*(i)\mathbf{S}_{\mathbf{e}}^{-1}\mathbf{A}(i)$.

Table 2. Information content analysis of the IASI measurements and retrieval accuracy of N_2O, CH_4 column amounts within 10 channels of R5 band

#	ν	SAW			MLS			TRP		
Channel	cm^{-1}	H	σ_{N20}	σ_{CH4}	H	σ_{N20}	σ_{CH4}	H	σ_{N20}	σ_{CH4}
548	1346.75	0.52	0.50	0.35	0.76	0.50	0.30	1.54	0.50	0.17
343	1295.50	3.16	0.26	0.31	3.61	0.23	0.26	4.60	0.15	0.16
573	1353.00	4.02	0.14	0.21	4.80	0.12	0.12	5.63	0.08	0.08
252	1272.75	4.91	0.14	0.20	5.97	0.11	0.12	6.81	0.07	0.08
567	1351.50	5.75	0.13	.017	6.44	0.10	0.12	7.19	0.07	0.08
574	1353.25	6.33	0.12	0.14	6.51	0.10	0.11	7.25	0.07	0.08
565	1351.00	6.64	0.11	0.12	6.61	0.10	0.11	7.36	0.07	0.07
243	1270.50	6.91	0.10	0.11	7.22	0.08	0.08	7.73	0.06	0.06
304	1285.75	7.21	0.09	0.09	8.36	0.07	0.08	8.87	0.05	0.06
484	1330.75	7.56	0.07	0.07	8.63	0.06	0.07	8.89	0.05	0.06

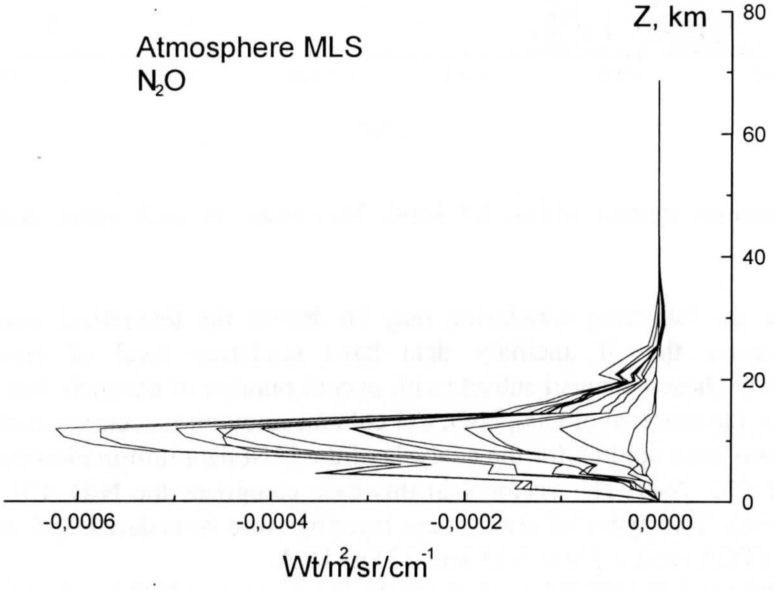

Fig. 2 N_2O jacobians calculated for optimal channels in R5 IASI band.

Let address the algorithm (5) and its application in more detail. First of all it is rather easy to show that the iteration process (5) converges as fast as geometric progression to the solution of problem (1) if the original problem is not grossly non-linear with respect to **x**. Secondary in terms of practical needs it is very crucial to examine a degree of the non-linearity of problem (1). The results of numerical estimates practically confirmed the commonly recognized fact, that the inverse problem is weakly non-linear concerning temperature, and moderately non-linear regarding the absorbing gas constituents. Therefore, the matrix $\mathbf{A}(i)$ in the (5) is nearly constant (in the vicinity of the solution) and depends very weakly on the order i of iteration

Along with the theoretical analysis of sounding accuracy the set of numerical experiments has been carried out to retrieve CAs of N_2O, CH_4 on the basis of simulated IASI data.

The random measurement errors have been generated in accordance with given matrix $\mathbf{S}_e$ and added to measurements. Errors are supposed to be independent, centered and distributed according the normal low.

The iteration procedure have been executed for i=1 only, $\delta\mathbf{x}=\delta\mathbf{x}_{(1)}$. The accuracy characteristics include mean biases Δ and standard deviations σ.

All the executed experiments can be separated on three groups according to their goals:

Experiment #1 - numerical solution of the inverse problem in absence of the measurement errors (using the fully adequate measurement model). The experiment allows to assess the limit theoretical potential of the proposed method of the indirect MGC CAs derivation as well as to estimate the instrument smoothing.

Experiment #2 - numerical solution of the inverse problem with "noisy" measurements and with accurate knowledge of the IF. The experiment allows investigating the simultaneous influence of measurement errors and initial inverse problem nonlinearity on the method accuracy.
Experiment #3 - numerical solution of the inverse problem with simulated "real" conditions, i.e. with measurement errors and IF uncertainties. A priori information about the IF have been simulated with different accuracy levels: 3a) $\mathbf{S}_T = \mathbf{S}_{T(f)}$, $\mathbf{S}_H = \mathbf{S}_{H(min)}$; 3b) $\mathbf{S}_T = \mathbf{S}_{T(r)}$, $\mathbf{S}_H = \mathbf{S}_{H(min)}$; 3c) $\mathbf{S}_T$, $\mathbf{S}_H$ - for SAW, TRP models.
Here $\mathbf{S}_{T(f)}$ is the error covariance matrix for the numerical short-term weather forecast scheme; $\mathbf{S}_{T(r)}$ is the error covariance matrix for temperature sounding with simulated IASI data in 15 μm absorption band; $\mathbf{S}_{H(min)}$ - diagonal matrix, σ_H=0.15 (standard deviation at all levels equal to 15%).
The described experiments have been conducted for $\delta\mathbf{x}_{(1)} = \| 0.1, 0.1 \|^T$, $\delta\mathbf{x}_{(2)} = \| 0.2, 0.2 \|^T$, $\delta\mathbf{x}_{(3)} = \|0.3, 0.3\|^T$, $\delta\mathbf{x}_{(4)} = \| 0.4, 0.4 \|^T$ and for SAW and TRP atmospheric models. The set of 30 realizations of measurement errors have been generated for experiments #2, 3. The results of experiments are summarized in Table 3.
The experiment #1 confirms the high potential of the IASI data with respect to troposphere MGC CAs indirect measurements. The systematic bias Δ component gives the main contribution in resulting error (in full agreement with theory).
The experiment #2 gives the results qualitatively similar to theoretical accuracy assessments (see Table 2). They actually confirm the hypothesis on the inverse problem moderate nonlinearity with respect to **x** and as consequence the possibility of using the one-step iteration procedure (5). The systematic bias contribution in CAs retrieval error (negative bias Δ, especially for CH_4) becomes prevailing with $\delta\mathbf{x}$ increase. It is explained evidently by the nonlinearity of inverse problem.
The experiments #3a, 3b provide results qualitatively similar to theoretical analysis (see Table 2), although the retrieval accuracy characteristics are noticeably worse than theoretical assessments. Again (as in the experiment #2) the systematic bias becomes prevailing (with $\delta\mathbf{x}$ increase).
The improvement in MGC CAs retrieval accuracy can be provided (in frame of approach involved) by using more accurate a priori information about IF, although the possibility to obtain such information is limited. The evident alternative approach is to solve the multicomponent inverse problem with respect to the set of **x**, **g** parameters.
The results of experiment #3c don't confirm (at least for SAW model) the theoretical analysis conclusions on the possibility of using the "climatological" information (T^0=<T>, H^0=<H>, $\mathbf{S}_T$, $\mathbf{S}_H$) for indirect MGC CAs measurements with required accuracy level. Effective noise components due to uncertainties in *T(p)*, *H(p)* knowledge (actual realizations $\mathbf{A}_T\delta\mathbf{g}_T$, $\mathbf{A}_H\delta\mathbf{g}_H$ at sounding points) become comparable with $|\varepsilon|$.
Hence the results of the retrieval experiments can be summarized as following: if the ancillary data on interfering parameters are known with moderate level of uncertainty (experiments #2, 3a, 3b) the IASI measurements in properly chosen channel subset (with the number of channels less or equal 10) provide the information for the retrieval of MGC CAs with the accuracy of 10%.
Similar numerical experiments have been conducted to assess the accuracy of N_2O and CH_4 profiles retrieval. Retrieval accuracy characteristics for simulated IASI data are presented in the Table 4. The set of 30 realizations of noncorrelated measurement errors has been generated for each atmosphere model. The set of experiments has been carried out for 4 simulated vectors of trace gases profiles. The nondimensional values of content variations are the following: 0.1, 0.2, 0.3 and 0.4. The simulated vectors of profile variations are $\delta\mathbf{x}_i=\|i/10, i/10, i/10, i/10, i/10, i/10\|^T$, i=1,2,3,4. The last row of Table 4 contains theoretical assessment of profiles retrieval accuracy.
For the most favourable conditions of tropic atmosphere the experiments have been conducted with "realistic" conditions i.e. with account for measurement errors and IF uncertainties. The error covariance matrix in these experiments was $\mathbf{S}_e = \mathbf{S}_{\varepsilon/2} + \mathbf{S}_{T(f)} + \mathbf{S}_{H(min)}$. Results are summarized in Table 5a for 0-5 km, 5-15 km, 15 km -TOA and in Table 5b for 0-5 km, 5-10 km, 10 km -TOA layering. In the last rows of Table 5a,b theoretical assessments of standard deviations obtained at the same conditions are shown.
Data in Table 5a,b demonstrate that the retrieval of N_2O and CH_4 tropospheric layer amounts is possible only in the layer higher than 5 km if the content variation doesn't exceed 20%.

Table 3. N_2O and CH_4 CAs retrieval accuracy in different experiments with simulated IASI data

EXPERIMENT #		TRP N_2O σ	TRP N_2O Δ	TRP CH_4 σ	TRP CH_4 Δ	SAW N_2O σ	SAW N_2O Δ	SAW CH_4 σ	SAW CH_4 Δ
1		0.03	-0.02	0.04	-0.03	0.02	-0.02	0.04	-0.03
2	$\delta x_{(1)}$	0.02	<0.01	0.02	-0.01	0.05	0.01	0.04	-0.01
	$\delta x_{(2)}$	0.02	-0.01	0.03	-0.02	0.05	<0.01	0.04	-0.02
	$\delta x_{(3)}$	0.03	-0.02	0.04	-0.04	0.05	-0.02	0.06	-0.04
	$\delta x_{(4)}$	0.05	-0.04	0.07	-0.06	0.06	-0.04	0.08	-0.07
3a	$\delta x_{(1)}$	0.02	<0.01	0.03	<0.01	0.05	0.03	0.05	-0.02
	$\delta x_{(2)}$	0.03	-0.01	0.03	-0.02	0.05	0.01	0.06	-0.04
	$\delta x_{(3)}$	0.04	-0.03	0.05	-0.04	0.04	<0.01	0.07	-0.06
	$\delta x_{(4)}$	0.06	-0.05	0.08	-0.07	0.05	-0.03	0.10	-0.09
3b	$\delta x_{(1)}$	0.02	<0.01	0.02	-0.01	0.05	0.03	0.06	-0.04
	$\delta x_{(2)}$	0.03	-0.02	0.03	-0.03	0.05	0.01	0.08	-0.06
	$\delta x_{(3)}$	0.04	-0.03	0.05	-0.05	0.05	-0.01	0.10	-0.08
	$\delta x_{(4)}$	0.06	-0.05	0.08	-0.08	0.06	-0.04	0.12	-0.12
3c	$\delta x_{(1)}$	0.02	<0.01	0.03	<0.01	0.09	-0.07	0.23	-0.22
	$\delta x_{(2)}$	0.02	-0.01	0.03	-0.01	0.11	-0.09	0.25	-0.24
	$\delta x_{(3)}$	0.04	-0.03	0.04	-0.04	0.14	-0.12	0.28	-0.27
	$\delta x_{(4)}$	0.06	-0.06	0.07	-0.06	0.17	-0.16	0.32	-0.31

5. SUMMARY AND CONCLUSIONS

The most important results obtained may be summarized as following:

1. The mathematical formalism for the information content analysis of the IASI data has been developed. The optimal IASI channel subsets within the R5 and R6 spectral bands has been selected which provide for the CH_4, N_2O and CO column amount retrievals with required level of accuracy (10%)
2. The pilot inversion algorithm has been developed and tested using the IASI measurements simulated at different noise levels. Based on the iteration scheme it provides the retrieval of the CH_4, N_2O and CO column amount in conditions of imperfect knowledge of the temperature/humidity vertical distribution. The performed experiments have approved the validity of theoretical estimates of the IASI potential to retrieve the CAs of above gases. The IASI radiances processing within a range of corresponding measurement scheme, the utilization of a priori information on the temperature and humidity profiles of a definite-level accuracy guarantees as a rule the determination of the CH_4, N_2O and CO column amounts with required degree of accuracy. However, in a set of conditions (primarily, in high latitudes) the use of the climatological ancillary information does not enable to attain the issued accuracy of the CA retrieval. The suitable level of a priori information accuracy may be reliably provided by the data output of the numerical short-term weather forecast models or directly by the available IASI temperature and humidity soundings.
3. The estimates of the IASI information content regarding the MGC VP have been performed. They have shown a possibility to extract more than one piece of information on the vertical distribution of target species. The IASI data information content analysis shows that the MGC profile retrieval is principally possible. To improve the VP retrieval accuracy it is required to develop the corresponding climatological database on the MGC vertical distributions. According to the preliminary assessments the utilization of such database (Pan et al., 1997) will provide an efficient retrieval of the profiles under consideration and, in turn, may promote an improvement of the MGC column amount determination.

6. ACKNOWLEDGMENTS

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Table 4. Numerical assessment of profile (0-5 km, 5-15 km, 15 km -TOA) retrievals with simulated IASI data.

	σ_{N2O}	Δ_{N2O}	σ_{CH4}	Δ_{CH4}
	SAW			
δx_1	>1.0 0.18 0.77	-0.02 <0.01 0.03	0.86 0.08 0.44	-0.05 0.01 -0.19
δx_2	>1.0 0.18 0.78	0.18 -0.03 0.12	0.90 0.09 0.42	0.27 -0.04 -0.13
δx_3	>1.0 0.18 0.75	0.46 -0.07 0.13	>1.0 0.12 0.38	0.68 -0.09 -0.12
δx_4	>1.0 0.22 0.82	0.73 -0.12 0.27	>1.0 0.19 0.40	>1.0 -0.17 -0.07
Theory	0.47 0.06 0.40		0.41 0.04 0.32	
	SAS			
δx_1	0.14 0.05 0.33	<0.01 -0.01 0.07	0.12 0.03 0.22	<0.01 -0.01 -0.03
δx_2	0.14 0.06 0.35	0.02 -0.03 0.13	0.12 0.04 0.22	<0.01 -0.03 0.03
δx_3	0.15 0.08 0.39	0.04 -0.06 0.20	0.12 0.07 0.25	-0.01 -0.06 0.12
δx_4	0.16 0.12 0.47	0.07 -0.11 0.34	0.12 0.11 0.30	-0.01 -0.11 0.21
Theory	0.12 0.04 0.28		0.11 0.02 0.19	
	MLW			
δx_1	0.24 0.07 0.38	0.01 -0.01 0.05	0.15 0.03 0.29	<0.01 <0.01 -0.09
δx_2	0.24 0.07 0.38	0.03 -0.03 0.08	0.16 0.04 0.28	0.05 -0.03 -0.08
δx_3	0.25 0.09 0.39	0.07 -0.05 0.12	0.19 0.07 0.28	0.12 -0.06 -0.07
δx_4	0.27 0.11 0.42	0.11 -0.09 0.18	0.25 0.11 0.28	0.20 -0.11 -0.06
Theory	0.19 0.05 0.29		0.14 0.03 0.26	
	MLS			
δx_1	0.15 0.06 0.25	0.04 -0.02 0.07	0.09 0.03 0.20	-0.01 <0.01 -0.04
δx_2	0.16 0.06 0.25	0.06 -0.03 0.09	0.09 0.04 0.20	0.01 -0.03 0.01
δx_3	0.17 0.08 0.26	0.09 -0.06 0.12	0.10 0.07 0.21	0.04 -0.07 0.06
δx_4	0.20 0.12 0.29	0.14 -0.10 0.18	0.11 0.12 0.24	0.07 -0.12 0.13
Theory	0.13 0.05 0.21		0.08 0.03 0.20	
	TRP			
δx_1	0.12 0.05 0.18	0.04 -0.02 0.04	0.07 0.04 0.17	-0.02 <0.01 -0.04
δx_2	0.13 0.06 0.18	0.04 -0.03 0.05	0.06 0.04 0.18	<0.01 -0.01 -0.06
δx_3	0.13 0.07 0.18	0.05 -0.05 0.05	0.07 0.05 0.21	0.02 -0.03 -0.12
δx_4	0.13 0.09 0.18	0.05 -0.07 0.04	0.08 0.07 0.24	0.04 -0.06 -0.18
Theory	0.11 0.05 0.16		0.06 0.04 0.18	

Table 5. Numerical assessment of profile retrievals with simulated IASI data including "realistic" IF uncertainties

a) Atmosphere layering: 0 - 5km; 5 - 15km ; 15km - TOA

	TRP			
	σ_{N2O}	Δ_{N2O}	σ_{CH4}	Δ_{CH4}
δx_1	0.26 0.06 0.20	0.22 0.03 0.06	0.35 0.09 0.26	0.34 0.08 0.18
δx_2	0.28 0.07 0.21	0.25 0.05 0.09	0.35 0.11 0.26	0.35 0.10 0.18
δx_3	0.33 0.09 0.23	0.30 0.07 0.13	0.37 0.13 0.23	0.36 0.13 0.14
δx_4	0.39 0.12 0.26	0.36 0.11 0.18	0.39 0.17 0.23	0.38 0.17 0.14
Theory	0.16 0.06 0.17		0.08 0.04 0.20	

b) Atmosphere layering: 0 - 5km; 5 - 10km ; 10km - TOA

	TRP			
	σ_{N2O}	Δ_{N2O}	σ_{CH4}	Δ_{CH4}
δx_1	0.30 0.15 0.0.07	0.24 0.05 0.03	0.42 0.14 0.04	0.41 0.11 <0.01
δx_2	0.32 0.15 0.09	0.25 0.05 0.06	0.40 0.14 0.05	0.38 0.10 0.03
δx_3	0.34 0.15 0.12	0.28 0.05 0.10	0.38 0.13 0.08	0.37 0.10 0.07
δx_4	0.38 0.16 0.16	0.32 0.06 0.15	0.37 0.14 0.13	0.35 0.10 0.12
Theory	0.22 0.16 0.07		0.13 0.10 0.05	

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