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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Retrieval of atmospheric profiles and cloud properties from IASI spectra using super-channels" *by* X. Liu et al.

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Reply to reviewers' comments on "Retrieval of atmospheric profiles and cloud properties from IASI spectra using super-channels" by X. Liu et al.

Thanks for the reviewers' comments on the manuscript "Retrieval of atmospheric profiles and cloud properties from IASI spectra using super-channels" by X. Liu et al. (Atmos. Chem. Phys. Discuss., 9, 8683-8736, 2009).

Here are specific answers to referee #1:

[General: The paper presents a new method for the retrieval of atmospheric parameters from IASI spectra by use of EOF decomposition. In general, the retrieval of temperature and water vapour is described well and the presented examples for val-

idation are convincing. However, the simultaneously retrieval of cloud products, first, needs some more explanation and, second, the material presented is not sufficient to allow any judgment on the accuracy of the derived cloud parameters. Further, it is claimed that the method is computationally optimized. To judge on this item a rough comparison of computation time with standard schemes and at least a relative breakdown of the CPU times for various sub-tasks (e.g. forward-modeling, retrieval) would be required.]

The authors agree that the cloud parameter retrievals have no quantitative validations due to the lack of the co-incident cloud truth measurements. The retrieval methodology for cloud parameter retrieval has been discussed in our previous papers (Zhou et al. GRL, 2005 and Zhou et al. JAS. 2007).

The inversion computational efficiency depends on the size of K matrix and how fast a forward model can calculate the y vector. Since we only need 100 super channels (as compared to 200-8461 channels for the standard channel-based method), the K matrix is much smaller in our case. Therefore the inversion portion of the retrieval system must be faster and more stable. The authors have not done a rigorous speed comparison between the PCRTM and other channel-based forward models. A test shows that the PCRTM takes much less than 0.05 seconds to calculate both the super channel values and associated Jacobian, while a channel-based radiative transfer model such as RTIASI takes about 2 seconds to calculate 8461 channel radiances (no Jacobian calculation included) on the same computer. It's obvious that the PCRTM retrieval method is computationally optimized as compared to the standard scheme if all 8461 channels are used. We estimate that even if the channel-based method uses 200 channels, the PCRTM retrieval efficiency would be slightly faster in computational speed, represent information from the entire spectral extent.

[Specific p. 8689, Eq. 2 Could you shortly explain how ak is determined?]

The coefficients ak is determined by a regression process. Thousands of monochromatic and channel radiance spectra are calculated using a line-by-line radiative transfer code under various atmospheric and surface conditions. Super channels are calculated by projecting the calculated channel spectra onto a set of EOFs. ak is obtained by solving for thousands of linear equations according to equation 2.

[p. 8690, l. 21: Figure 3 . . . Could you explain in more detail how the error analysis has been done? Which differences are plotted: between PCRTM and the training spectra or an independent dataset? How many spectra have been used to determine the error spectra? Please define the quantities RMS-error and bias-error.]

The differences are between PCRTM and an independent dataset. One hundred spectra have been used to determine the error spectra. The RMS error and the bias-error are defined as the root-mean-sqaure and mean differences between the PCRTM generated spectra and the LBLRTM generated spectra, respectively.

[p. 8692, l. 11: Figures 4 and 5 . . . How have the reflectances and transmittances been calculated? Mie? T-matrix? Which refractive indices have been used? Single particles or particle distribution? Which distribution (width. . .)? What is used for the following retrievals?]

The reflectances and transmittances have been calculated using DISORT (Stammes et al 1988) and single scattering properties calculated by Yang et al (Yang et al. 2001, Wei et al 2007, Huang et al 2006, Niu et al 2007). The single-scattering properties of individual non-spherical ice particles are derived from the composite method (finite-difference time domain method, improved geometric optics method, and Lorenz–Mie theory). A gamma size distribution is assumed for water clouds. A population of droxtals, pristine hexagonal ice columns and aggregates is assumed in the particle size distributions for the ice clouds.

[p. 8692, Eq. 7 Can you really exclude solar scattering even for the highest wavenumbers?]

Currently, the solar component is excluded in the forward model, which introduces an error for channels with frequencies higher than 1800 cm-1. We account for this error source during the inversion process by adding an error term in the Sy matrix when the solar zenith angle is between 0-89 degrees.

[p. 8693: cloud parameter retrievals Could you specify which parameters have been retrieved in addition to the cloud parameters? How has the decision on the cloud type been done by the retrieval model? Performing two retrievals, one for ice and one for liquid water and using the result of the better fit? (This information is missing in the flow diagram of the retrieval process of Fig. 12 and should be added.) How much do the fits in case of liquid water and of ice differ?]

Other retrieved parameters are atmospheric temperature, moisture, ozone and carbon monoxide vertical profiles, surface skin temperature and surface emissivity. The cloud phase is determined from a regression-retrieval (Zhou et al 2008). For small cloud particle sizes, the fits using liquid water and ice differ significantly due to different spectral features of the two cloud types. As the particle size increases, the difference becomes smaller.

[p. 8693, l. 24 45 μm seem to be quite large for a liquid cloud. Can you comment on this? This leads to the following major comment: In contrast to the temperature and H2Oretrieval, the cloud-parameter retrieval is not compared to any external dataset. This is quite a large drawback of the study and it would be helpful if the authors could at least add some arguments/data to be able to estimate on the reliability of the cloud connected data products.]

Yes, the retrieved water cloud effective diameter seems large. This could be caused by the crosstalk between the cloud parameters and other parameters such as surface emissivity during the retrieval process. It is also possible that the algorithm incorrectly identifies the ice cloud as water cloud giving large cloud size. Validation of retrieved cloud parameter products is an ongoing effort and, with the availability of coincident truth data, will be the subject of studies to be reported on in the future.

[p. 8696, Eq. 9 Could you define the matrix U?]

U is defined in equation 3. It is a matrix that contains the radiance eigenvectors. More explanations of the U are added to the paper.

[p. 8697, l. 7 Could you indicate here if this has been derived from pure simulations or within a retrieval on real data?]

The averaging kernel is derived within a retrieval on real data.

[p. 8698, l. 7 Could you show by e.g. relaxing the side-conditions that this is not an effect of the retrieval scheme but really due to the a-priori?]

By using a covariance matrix derived from ECMWF profiles without including any raw radiosonde data, the integrated areas of the averaging kernels above 300 hPa have larger values, indicating that the a-priori does affect the averaging kernels.

[p. 8699, l. 27 – p. 8700, l. 5 Skip this paragraph. It does not add any useful information related to the subject of the manuscript.]

Done

P[. 8701, l. 9 and Tab. 2 Are these all co-incidences between IASI and ARIES? Which co-incidence criterium has been applied?]

For each day, only those IASI fields of view, which are co-incident with ARIES within +/- 0.1 degree in latitude and longitude, are chosen.

[Technical: p. 8692, l. 4 size -> sizes]

Done

[Figs. 2 and 3 x-axis title: should read 'wavenumber (cm−1)' y-axis title: missing bracket: (T -> (T)]

Done

[p. 8697, l. 29 pHa -> hPa]

Done

[p. 8692, l. 5 Please explain 'ARIES'.]

Done

[Fig. 12 Inside formula it must read ym-yn.]

Changed

Here are specific answers to referee #2:

[a. The authors provide little, if any, quantitative evidence that their approach is "better" than a physical retrieval with a subset (100-200, say) of hand-picked IASI channels. Sensor noise could be effectively reduced with a linear filter operating on all IASI channels prior to downselection of the relevant channels. A linear regression (also operating on all or most IASI channels) could be used as a first guess to further exploit "broadband" information content in the IASI spectrum, prior to the use of a physical retrieval on a reduced channel set. Why does the PCRTM offer any advantages to this approach, which is currently used in practice (NASA AIRS/AMSU "Level 2" retrieval, for example)? Simple, quantitative investigation of this issue should be included in the paper. For example, what happens if you simply use one of the Collard (ECMWF) IASI channel sets in a physical retrieval? Some statistical comparisons over an ensemble would greatly augment the "case-study" analysis presented in the paper – both types of analysis are required to fully evaluate high-performance retrieval systems over a variety of atmospheric conditions.]

The authors agree that a linear filter operation can be done on all IASI channels prior to down selection of the relevant channels to reduce the instrument noise. We have not seen any publications demonstrating the retrieval performance using this approach.

Performing the analysis suggested by the referee requires using different radiative transfer models and consistent retrieval systems and is beyond the scope of the current study. We will perform further study of this kind in our analyses and report results in future papers.

[b. How is scan angle treated? Are the principal components computed at each scan angle?]

The principal components are calculated with all scan angles included. The scan angles are varied from 0 to 66.42 degrees.

[c. How do you know that "about 100 super channels are adequate"?]

The 100 super channels are determined by regenerating the observed IASI spectra using various numbers of principal components, and selecting the minimum number of super channels that adequately represents the radiance spectra information content.

[d. Why did you calculate principal components for each of the three bands instead of the aggregate?]

We have calculated principal components both for each of the three bands and for the aggregate. The results are similar. It is more convenient to use separate PCs for each of the IASI bands if we decided not to use one of the band (or part of the spectral region) in the retrieval.

[e. The paper mentions matching the synthesized radiances "to the noise level." Exactly what noise level – the native noise level or the noise level that can be achieved after spectral filtering? If the former, why not the latter?]

The noise referred in the paper is the original IASI native noise. Although the radiance residuals in many spectral regions (most noticeable in band 3) are much less than the native noise, we decided not to fit the radiance spectrum to the PC-filtered noise level at this stage of study because we have not accounted for many error sources such as spectroscopy and un-retrieved traces gases.

[f. The cloud parameter retrievals were presented with very little validation other than the radiances were well-fit after the retrieval (which is encouraging, but not necessarily conclusive proof of retrieval skill). The paper could be substantially strengthened if minimal quantitative validation of these products is added.]

The authors agree that the cloud parameter retrievals have no quantitative validation due to the lack of co-incident cloud truth measurements. The retrieval methodology for cloud parameter retrieval has been discussed in our previous papers (Zhou et al. GRL, 2005 and Zhou et al. JAS. 2007). The primary focus herein is on clear-air retrievals, and cloud parameter retrievals are included to show corresponding applicability of PCRTM methodology. Validation of cloud parameter retrievals is an ongoing effort and, with the availability of more truth data, will be the subject of other analyses and future reporting.

[g. The black art of physical retrievals is largely contained in the treatment of regularization. This is not discussed in any detail – please add additional discussion. Same comment applies to retrieval non-convergence, that is, what do you mean exactly by "the cost function is too large?"]

More details are added with regards to regularization of the physical retrievals. The magnitude of the cost function has been further defined.

[h. Please provide additional detail on the ARIES instrument. A few sentences would suffice.]

Added in the paper.

[i. Why are 29 April and 4 May not included in the discussion of surface emissivity retrieval?]

We don't have ARIES surface emissivity retrievals for those two days.

[j. For the retrieval comparisons of water vapor mass mixing ratio, why not normalize the error by the truth (or a mean value, etc.) for a more intuitive sense of the magnitude of the error?]

The mass-mixing ratio values for water vapor are so low for the upper troposphere in these cases, expressing the error as normalized by the truth will give very large error. The large error for dry upper troposphere is not the result of the retrieval system; it is limited by the sensitivity of the infrared passive remote sensor towards the dry atmosphere. Normalizing the error by the water saturation mixing ratio results in relative error expressed in relative humidity unit, which is included in the paper.

[k. An additional table summarizing the atmospheric (clear/cloudy, etc.) and viewing conditions (land/ocean, etc.) of each of the four cases would be helpful.]

Table 2 and relevant texts have been modified to incorporate the suggestions of the referree.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 8683, 2009.