A METHOD FOR RETRIEVING COLUMNAR CO_2 CONCENTRATION FROM THERMAL INFRARED RADIATION SPECTRUM

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1. Introduction

The most difficult problem in retrieving atmospheric CO_2 concentration from the thermal infrared radiance spectra observed from space is separation of temperature and CO_2 information. Recently, some attempts to retrieve CO_2 concentration profile have been made (e.g., Chedin et al., 2003; Engelen et al., 2001). In these studies, CO_2 information was extracted by combining some strong CO_2 absorption bands (15ìm and 4ìm) or taking spatial and temporal average of retrieved concentration. However, most of these studies focused on the usage of IASI data and spectral resolution was assumed to be in the order of 1cm^{-1}.

In this study, we present a retrieval method that would be more effective for sensors such as IMG and TES whose spectral resolution is higher than that of IASI and each absorption line can be separated more clearly (Fig.1).

2. Method

In the solar occultation method, atmospheric gas concentration can be obtained assuming that absorption process is dominant in the radiation transfer process and thermal emission from the atmosphere can be negligible. It made data analysis method very simple and temperature information is not so important in retrieving gas concentrations.

On the other hand, both of absorption and emission processes of radiation have to be considered in the data analysis of thermal infrared radiation measured by the nadir looking observation (Fig.2). It means that temperature information have to be retrieved simultaneously with gas concentrations or obtained independently from the spectrum measurement.

However, radiance data of week absorption bands such as shown in Fig.1 ("C" band) can be treated like in the solar absorption analysis because temperature effects relatively smaller than that in the strong absorption bands.

Based on this fact we would propose a data analysis procedure to estimate atmospheric columnar CO_2 concentration as follows:

(1)Retrieve atmospheric temperature profile, water vapor concentration profile, and the surface temperature using strong absorption band data (indicated as "A" and "D" regions in Fig.1)
(2)Synthesize the atmospheric radiance spectrum based on the retrieved profiles.
(3)Subtract the radiance bias due to retrieval errors in the week absorption band ("C" in Fig.1). This bias can be estimated from the difference between observed and synthesized radiances in the window region ("B" in Fig.1).
(4)Calculate the radiance difference (observed - synthesized) in the week absorption bands (This information contains CO_2 concentration information).
(5)Calculate Jacobian matrix or look up table of CO2 columnar concentration-radiance difference relation.
(6)Evaluate CO_2 concentration information (columnar concentration) from radiance difference obtained in (4) using Jacobian matrices of the look up table calculated in (5).

Examples of Jacobian matrices for CO2, temperature, and water vapor, and CO_2 look up table are shown in Fig.3 and Fig.4, respectively.

Figure 5 (left) shows the comparison of equivalent black body temperature (Tbb) change due to CO_2 concentration changes and temperature changes. It should be noted that temperature retrieval error can be reduced by one order of magnitude in the week CO_2 band region through the process (3).

LBLRTM Ver.7.02 provided by Dr. Clough was used in all calculations shown above.

3. Example of data analysis

The data analysis procedure shown above was applied to the IMG data. One IMG data observed under clear sky condition in the middle latitude was selected. Temperature and water vapor retrievals were carried out as shown in Fig.6. The final "Tbb difference" obtained through the procedure shown in the previous section is superimposed over the lookup table as shown in Fig.5 (right). As easily seen, the signal to noise ratio (S/N) of the IMG data is not enough to estimate CO_2 concentration precisely only from single shot spectrum. However, it can be expected that averaging of data over some time period or spatial region would reduce the noise level as to be able to evaluate CO_2 concentration with some useful accuracy.

4. CONCLUSION

In this study we proposed a data analytical method to estimate atmospheric columnar CO_2 concentration from the thermal radiance spectrum observed from space. In this method, strong absorption bands are used to retrieve temperature and water vapor profiles and a week CO_2 absorption bands is used to estimate CO_2 concentration. It is pointed out that this method is effective to reduce the effects due to temperature retrieval error in the estimation of CO_2 concentration. It also shown that noise level of radiance data should be smaller than about 0.1K in order to evaluate columnar CO_2 concentration with accuracy of 1%. In this study, we assumed uniform change of CO_2 concentration in the atmosphere. Improving this method to be applicable to various types of vertical profile of CO_2 concentration change is the next step of our study.

Acknowledgement

This study has been partially supported by Japan Science and Technology Corporation (JST) and Global Environment Research Fund (GERF) of Ministry of the Environment (ME).

References

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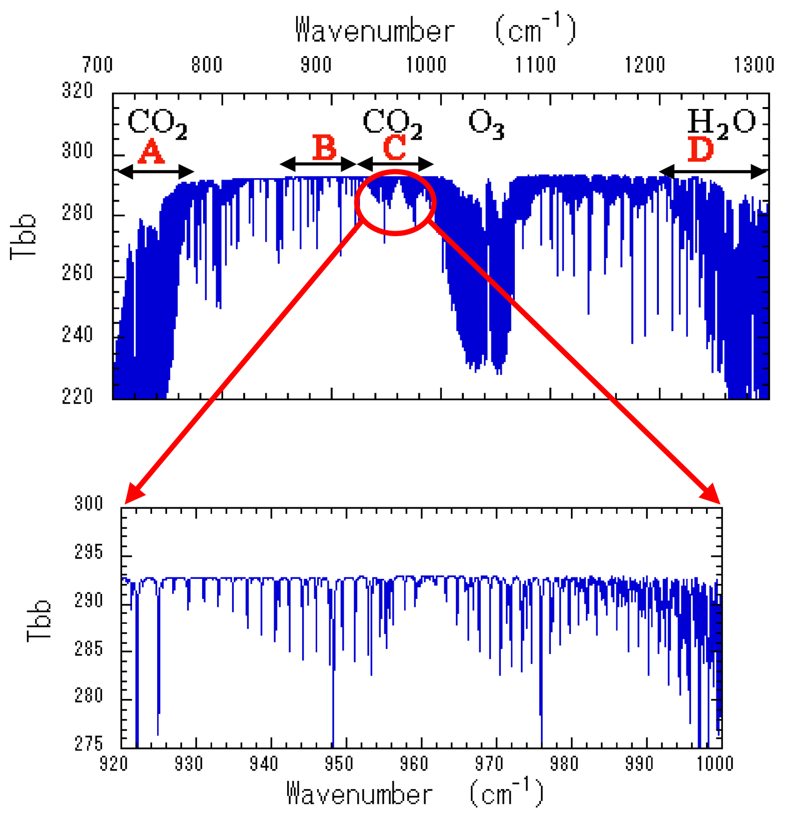


Fig.1. Thermal infrared radiance (equivalent black body temperature: Tbb) observed by IMG sensor whose spectral resolution is about 0.1 cm^{-1}.

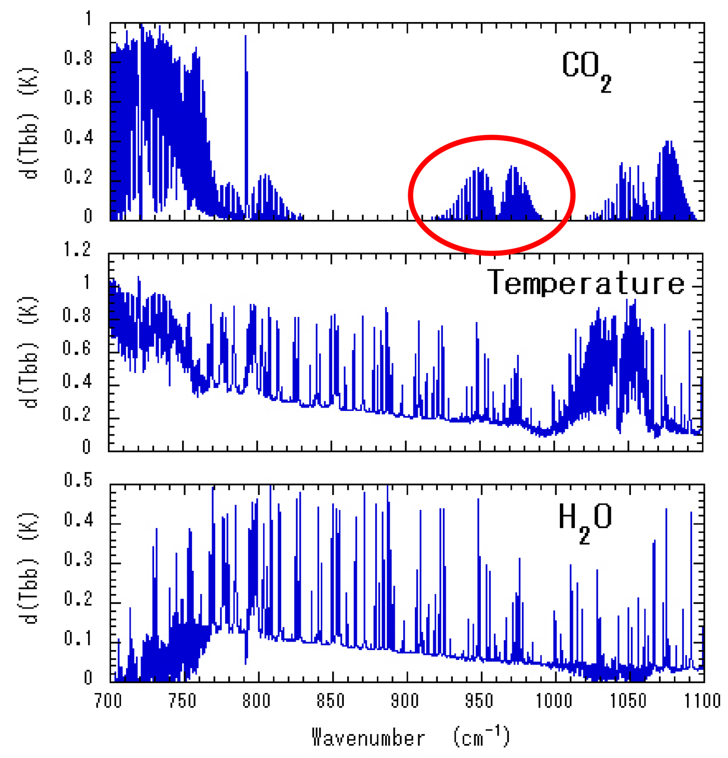


Fig.2. Tbb differences due to changes in CO2 concentration (+5%), temperature (+1K), and water vapor concentration (+5%). In all cases concentration and temperature were changed uniformly at all height revels.

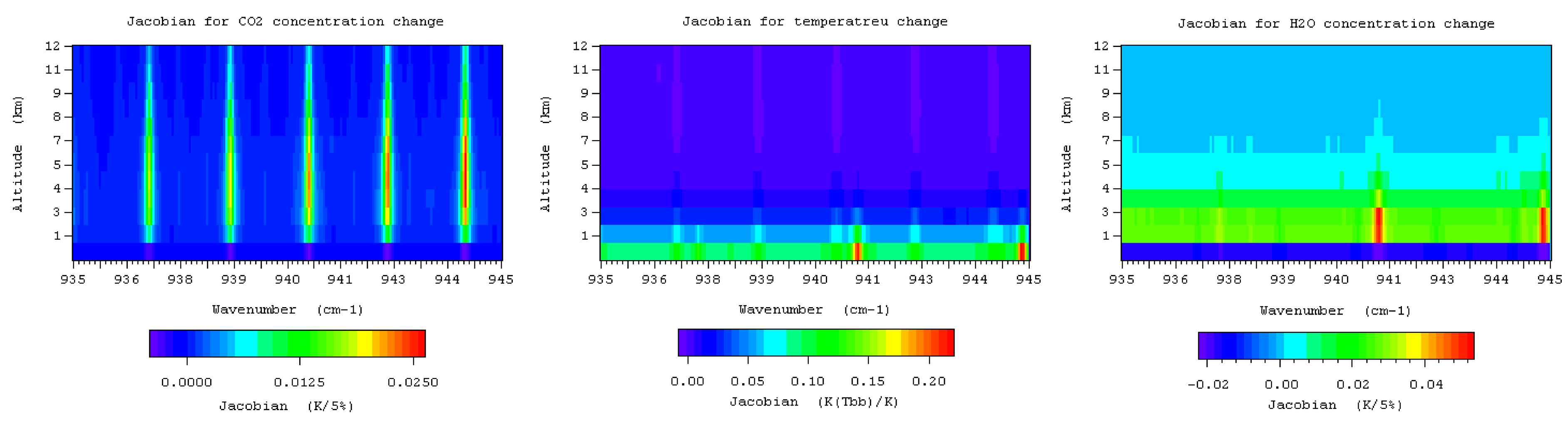


Fig.3. Jacobian matrices for CO_2, temperature and water vapor. All components are expressed in terms of Tbb.

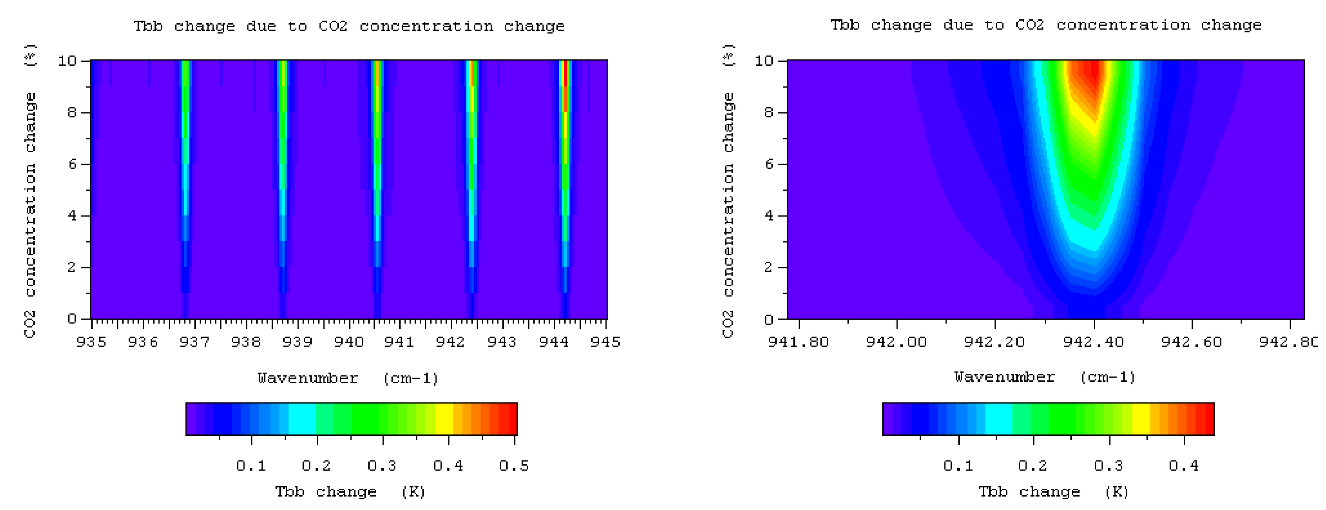


Fig.4. Tbb changes caused by uniform CO_2 concentration changes (columnar concentration changes). Right panel is an expansion around one absorption line of CO_2.

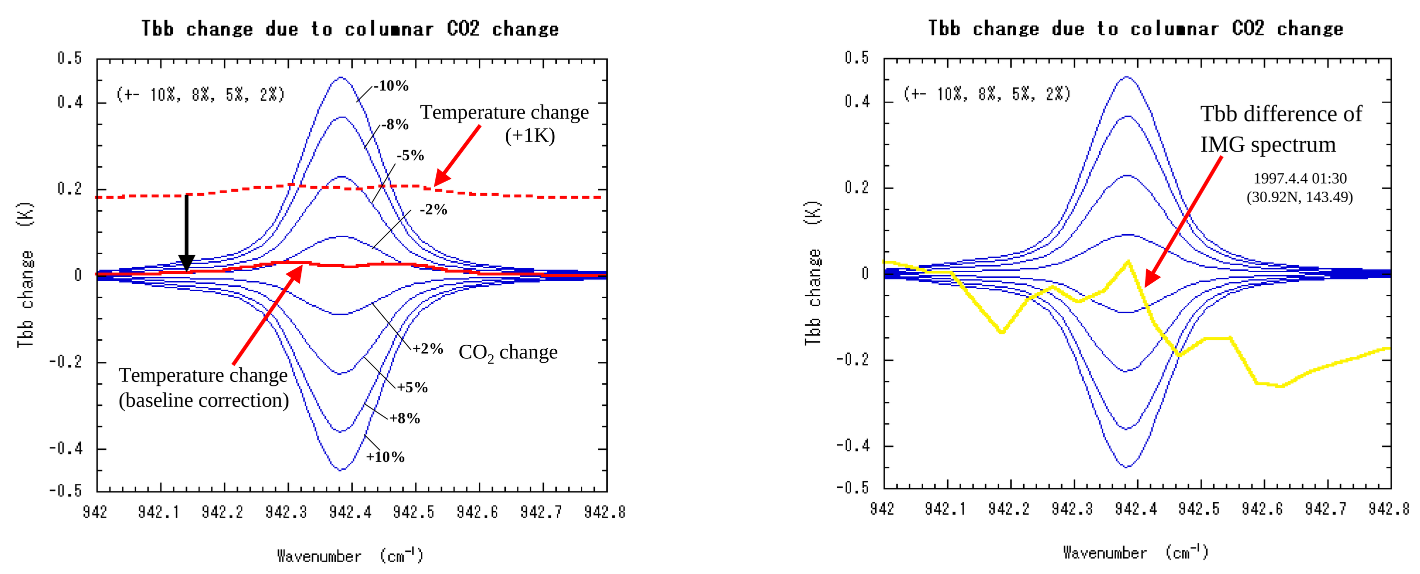


Fig.5. Tbb changes caused by uniform CO_2 concentration changes (blue lines). Solid and broken red line in the left figure represent Tbb changes caused by uniform temperature change and that after baseline correction, respectively. Right figure shows an example of actually observed spectrum data (IMG data) that is superimposed over the Tbb change lines for CO_2.

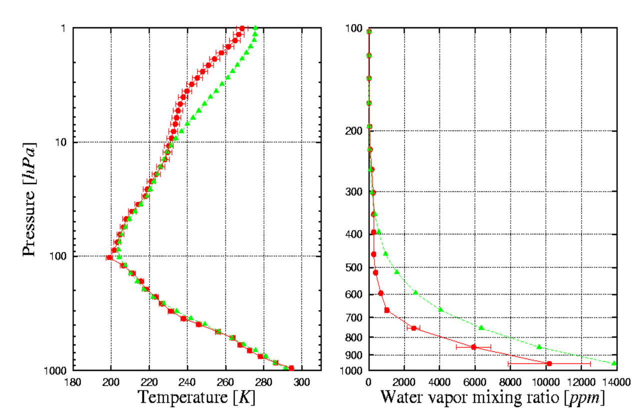
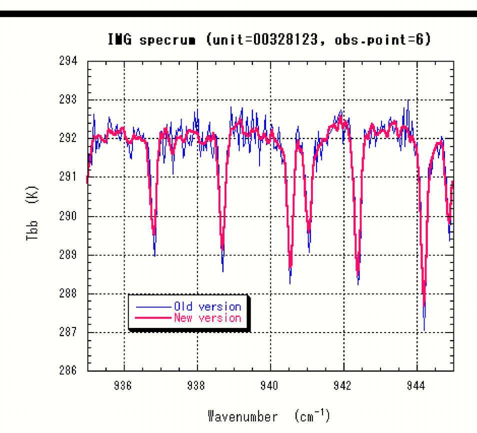


Fig.6. Temperature and water vapor profile retrieved from IMG data that is used for CO2 concentration analysis shown in Fig.5. Red and green lines are retrieved and initial guess profiles, respectively.



IMG Band 2 (1800-2600cm^{-1}) and Band 3 (650-1800cm^{-1}) data provided from National Institute for Environment and Resources (NIRE) have been revised. Particularly, signal to noise ratio was improved by tuning some phase correction and calibration parameters, e.g., optimizing the interferogram region of the deep space data used for the calibration. If you hope to use the new version of IMG data, please make a contact to R. Imasu at imasu@ccsr.u-tokyo.ac.jp .