論文内容の要旨

CO_2 Concentration Retrieval from Satellite-based Observation of Thermal Infrared Radiation

（衛星からの熱赤外放射観測による CO_2 濃度解析）

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Atmospheric carbon dioxide (CO_2) is a prevalent greenhouse gas whose atmospheric concentration has been increasing concomitant with industrial growth by anthropogenic emissions that accompany the consumption of fossil fuels. The current knowledge of its spatial distribution and temporal variation has been accumulated over several decades using flask sample monitoring from a global network of ground-based stations. However, more spatially and temporally dense observations have been required from a community studying the sources and sinks of CO_2 using so called inversion analysis. Satellite measurements of CO_2 have been expected to be able to provide such observational data. However, it has not been realized for a long time mainly because of the problem that CO_2 signals are too weak to be extracted from satellite-measured radiance data, which also include several error factors. The most important tasks to solve them is developing a method to remove or decrease the error factor.

The objective of this study is to develop a new method to retrieve CO_2 concentration from thermal infrared data for yielding at a desired precision level. The method of this study mainly consists of optimization of ILS function and procedures to decrease errors that prevent detecting CO_2 signals from the thermal infrared radiation. Those methods have been applied to real thermal infrared radiation spectrum as measured by Interferometric Monitor for Greenhouse gases (IMG) onboard the ADEOS satellite, whose spectral resolution and data quality are much higher than those of other instruments.

The ILS function of FTS has potential for becoming an important error factor in CO_2 retrieval procedure. In practice, ILS of the IMG instrument has been unknown, and a quantitative estimation of ILS function has been required for IMG to retrieve trace gas concentrations. Based on this fact, a procedure for optimizing the ILS function of IMG instrument was presented at first in this study. Applying the method to real radiance spectrum data of IMG, the spectral resolution of IMG has been estimated as about 0.060 cm^{-1} (HWHM) at 750 cm^{-1} (15-□m band).

On the other hand, temperature estimation error is another significant error factor for retrieving CO_2 concentration from thermal infrared radiation data. The European Center for Mid-Range Weather Forecasting (ECMWF) re-analysis data named as “ERA40” data are employed for the analysis of each IMG spectrum in this study. Furthermore, the method of selecting effective channels for CO_2 retrieval is employed. This method has shown that CO_2 signal and temperature error can be separated in some extent and it also confirms that the errors due to water vapor, ozone, and surface temperature are avoidable. As a result, it has been concluded that the main error factors in CO_2 retrieval from IMG data are temperature estimation error and ILS function error.

It is difficult to completely remove the temperature error and the ILS error in retrieving CO_2. In order to introduce those errors into retrieval procedure appropriately, a method is proposed that the errors are regarded as components of forward model parameter errors and are included in the measurement error covariance matrix. Using this method, it has been shown that IMG can resolve a CO_2 vertical profile with a resolution of about 4.0 km between mid and upper troposphere. The final retrieval accuracy was estimated to be 2.5 % and 2.0 % at pressure levels of 500 hPa and 300 hPa, respectively.

Those methods have been applied to cloud-free IMG data. Comparison with aircraft measurements have shown that CO_2 concentrations retrieved from IMG data fairly good agreed with them without any large systematic biases. Furthermore, a global distribution of CO_2 mixing ratio for April 1997 has been obtained for both sea and land areas from the equator to mid-latitude. This is the first CO_2 global map observed by a satellite-based instrument. It also showed some regional characteristics of high CO_2 concentration in some area from the east of India to the Southeast Asia. The latitudinal distributions of zonal mean CO_2 concentration were obtained for the same observational period. The results show the latitudinal gradient of CO_2 mixing ratio and its difference between the pressure revels of 300 hPa and 500 hPa.

Considering the results from comparison of retrieved individual CO_2 concentration with aircraft measurements and that of global distribution feature with our current knowledge of atmospheric CO_2, it can be concluded that satellite-based measurement of atmospheric CO_2 using the analysis method presented in this study is effective and CO_2 profiles retrieved even from the thermal infrared radiation data have a certain precision to be used for the CO_2 source/sink inversion analysis.