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学 位 論 文 内 容 の 要 旨

博士 (環境科学)

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学 位 論 文 題 名

Transport model diagnosis of stratospheric transport field
using boundary impulse evolving response method

(境界パルス応答法を用いた輸送モデルによる成層圏輸送場の診断)

Atmospheric transport plays an important role on the distribution of stratospheric trace gases. Changes in their concentrations potentially have a strong impact on global climate. Since the tropospheric air mostly enters the stratosphere through the tropical tropopause layer (TTL), the age of air, the transit time since stratospheric air parcel last had contact with the troposphere, is used as a common proxy of the transport. The mean age of air provides understanding in the strength of stratospheric circulation. Because of the irreversible mixing, any air parcel is composed of many elements that have taken different pathways. Thus, mean age cannot be characterized by a single transit time, but by a distribution of transit times. This distribution is the age spectrum, which provides full information about transport histories of air parcels. It is not directly observable, but can be obtained by applying boundary impulse evolving response (BIER) method that uses simulated distribution of inert tracers released as a series of pulses at a source region.

This study applies the BIER method with the aid of an atmospheric general circulation model-based chemistry transport model (ACTM) nudged to ERA-Interim fields to investigate stratospheric transport field. Multi-year averaged transport field is examined by comparing the evolution and distribution of tracers with the source region at tropical surface and at the TTL. The results show a rapid transport toward high-latitude lowermost stratosphere due to the eddy mixing around the tropopause. Stratospheric transport features are also shown through the variations of age spectrum. Multi-peaks of age spectrum reflect the seasonal variations of stratospheric circulation and isentropic mixing. The results are also applied to assess the mean age estimated from CO₂ and SF₆ samples acquired during a field campaign over Indonesia. Comparisons are also made with those estimated from Lagrangian backward trajectories calculated by using ACTM transport field. The mean age derived from the BIER method is noticeably older than that estimated by the Lagrangian method and stratospheric air samples, implying high diffusivity in the transport model. In contrast, observed SF₆ age is only reproducible in lower stratosphere, and far exceeds the estimates from Lagrangian method above 25 km.

This study confirms the capability of BIER method in capturing all transport features including unresolved diffusive processes. Mean age estimation by this method with the source region at the TTL does not work well due to its wide coverage in latitude and height. The study also highlights the difficulty in estimating mean age from air samples assuming a ratio between the first and the second moments of the age spectrum. The transport field simulated by the ACTM indicates height dependency of this ratio in the tropical lower stratosphere.