Modulation of Internally Generated Radiative Feedbacks and its Application for Global Warming Evaluation

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https://hdl.handle.net/2324/7182308

出版情報：Kyushu University, 2023, 博士（理学）, 課程博士
バージョン：

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論 文 名　：Modulation of Internally Generated Radiative Feedbacks and its Application for Global Warming Evaluation
（気候系内部変動が引き起こす放射フィードバック強度の変調と温暖化予測における不確実性評価への応用）

区　　分　：甲

論　文　内　容　の　要　旨

This study investigated the physical properties of modulation for internally generated radiative feedbacks on interannual timescales based on the coupled model intercomparison project phase 6 (CMIP6) dataset. We demonstrated how the modulation of radiative feedbacks can contribute to the pattern effect evaluation.

Firstly, we clarified the mechanisms of variability on internally generated radiative feedbacks based on pre-industrial control (piControl) simulations. Radiative feedback showed large modulation with a comparable magnitude to the intermodel uncertainty associated with internal changes in the zonal gradient of the ocean thermocline and sea surface temperature (SST) in the equatorial Pacific on interdecadal timescales. When the interdecadal SST anomalies in the eastern and western equatorial Pacific were simulated as positive and negative, respectively, the statistical properties of the interannual variations were also modified with diminished Walker circulation changes per unit of global mean surface temperature rise. Meanwhile, the enhanced local Hadley circulation led to a middle-to upper-level cloud decrease and a low-level cloud increase in the subtropics, causing enhanced negative radiative feedback as a global average. This effect can cause nonnegligible uncertainty directly while the estimation of pattern effect for the forced radiative feedback from a short-term historical record.

Secondly, key physical processes controlling lead–lag relationships were elucidated by categorizing piControl simulations into three groups based on cross correlation values of net radiation flux at the top of the atmosphere (GMTOA) against global mean surface temperature (GMST) at Lag 0 and Lag +1 year. The diversity of the lead–lag relationships in GMST and GMTOA create uncertainty during the estimation of radiative feedbacks. The diversity in the lead–lag relationships was primarily caused by the climatological state difference of the atmosphere over the equatorial Pacific, which modulated the strength of convective activity and sensitivity of low-level clouds. Diminished atmospheric stability caused enhanced convective activity, more efficient energy release, and smaller lags. In addition, enhanced stability in the lower atmosphere rendered the low-level clouds more sensitive to sea surface temperature changes and considerably delayed the radiative response. The climatological state difference of the atmosphere resulted from model-inherent atmospheric conditions. These findings suggest that the diversity of lead–lag relationships of GMST and GMTOA over interannual timescales could represent the characteristics of general atmospheric circulation models and possible solutions of the actual atmosphere, which could also affect long-term feedback features.

Finally, we suggested the potential applicability of internally generated radiative feedbacks for evaluating uncertainty in forced radiative feedbacks. We clarified that the significant relationship between internally generated radiative feedbacks and forced radiative feedbacks can be attributed to the similar intermodel pattern effect: El Niño like surface temperature pattern and enhanced outward net radiation in the subtropics. However, the significant relationship can be contaminated associated with the differences in atmospheric stability. Suppressed convective activity strength and enhanced low-level cloud sensitivity weakened the pattern effect sensitivity, less dominantly controlling radiative feedbacks as a global average, and thus weaker correlation between radiative feedbacks across the models. Our results indicate that sensitivity of the pattern effect is a potential source of uncertainty in global warming estimation, which can be further investigated by elucidating the physical properties of internal variability with its radiative properties.

Our research revealed that the modulation of internally generated radiative feedbacks with its physical mechanism, which can contribute to assessing the sensitivity of both temporal and intermodel pattern effect. These findings will promote the further understanding about the impact of internal variability on global climate as well as global warming evaluation.