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Integrated assessment model structure and linkage with climate model

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1. History and basic structure of integrated assessment model

Integrated assessment model (IAM) has been developed as a tool to analyze climate change countermeasures. Edmonds-Reilly model in 1980s was the one of initial trials to indicate the importance of the relationship between climate change and energy issues, through explicit analysis of energy CO_2 and global warming. Since 1990s, model development has been active to evaluate comprehensive measures from interdisciplinary knowledge in climate change, energy system, land use, etc. The new keywords of the models developed are 'interdisciplinary', 'large scale', 'very long-term dynamics', 'scale integration'. These models are called IAMs because their scope is very wide in time, space and disciplines. For example, GRAPE model, developed by the GRAPE development team, consists of modules dealing with energy, climate, land use, macroeconomics and environmental impacts. Intergovernmental Panel on Climate Change (IPCC) working group III reviewed IAM intercomparison results such as economic impacts of Kyoto Protocol, multiple GHGs mitigation including non-CO_2 gases mitigation potential and its effects in the past assessment reports.

2. Linkage with climate model

There are various types of linkage of climate model in IAMs. Major categories are 'hard-link' and 'soft-link'. The former includes all equations and variables of climate module in the entire model structure, while the latter exchanges the information (e.g. GHG emissions) between climate module and other parts of the model.

DICE model, one region global model, is the one of initial famous IAMs. It uses hard-link optimization methodology and simple one-dimension climate model with two ocean layers and one atmospheric layer. Radiative forcing of CO_2 is calculated endogenously but other aggregated forcing values are exogenously provided. After obtaining the global mean temperature, macroeconomic damage feedback is assessed as the function of temperature rise.

It is great challenge to include large scale climate model in the hard-link type IAMs. Because of climate system nonlinearity and many constraints including inequalities, it is quite difficult to get solutions especially under dynamic climate constraints such as long-term forcing stabilization. Climate module of GRAPE includes carbon cycle representation of one-dimensional version of the ISAM, one of the reference model in IPCC WG I third assessment report. Global carbon stock is distributed to the atmosphere, ocean, and terrestrial biospheres. The ocean part has 40 deep layers and terrestrial biosphere has six boxes. Energy exchange among atmosphere and ocean layers are also modeled.

Recently, coupled analyses combining earth system model and IAMs are in progress in the area of climate impact assessment with fine mesh-scale, or climate feedback of energy consumption level, etc. Climate information is quite useful and essential in these assessments.

3.Future issues and summary

GHG reduction would not be on the track to avoid potential dangerous impacts to global climate change because it is difficult to get consensus in global climate policy. Adjustment to climate condition (i.e. 'adaptation') could be the realistic solution in the short to medium term. Vulnerability to climate change varies by region and economic condition, and climate information in the future is important to design regional adaptation policies.

'Geoengineering', such as solar radiation management (SRM) and carbon dioxide removal (CDR), is included in the IPCC working group I fifth assessment report sentences. Negative emission feasibility through implementation of CDR needs further considerations with low GHG emissions scenarios with assistance of climate models.

IAM has close and essential linkage with climate model from initial development stage, and more interaction are crucial to resolve global and regional agenda in the future.

Keywords: Integrated Assessment Model, Climate Model