Methodology of probabilistic climate projections for the assessment of climate change mitigation pathways

*Junichi Tsutsui[1]

1. Central Research Institute of Electric Power Industry

Pathways of climate change mitigation are assessed for their consistency with a given temperature goal from probabilistic climate projections that reflect an ensemble of complex climate models and other lines of evidence. The author have been developing a climate model emulator for such probabilistic assessment and here describes and discusses its methodology.
The emulator consists of a thermal response module and a carbon cycle module. These are basically represented by impulse response functions to anthropogenic carbon input that alters the effective radiative forcing of the atmospheric CO_2 and natural processes in the ocean and terrestrial carbon cycle. The parameters of the thermal response module are calibrated for individual complex models from the latest and previous phases of Coupled Model Intercomparison Project (CMIP6 and CMIP5). The parameters of the carbon cycle module are currently fixed to their default values, which are calibrated to historical carbon balance assessed in the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change and the mean properties of CO_2 increase experiments with CMIP5 Earth system models.
The thermal response parameters are characterized by the two climate sensitivity metrics, equilibrium climate sensitivity (ECS) and transient climate response (TCR). Figure 1 shows the relationship between the TCR and ECS for the individual CMIP models as well as the reference line representing the variation of the models. The reference line is built from principal component analysis for the variation, reflecting that the ratio of TCR to ECS generally decreases with increase in climate sensitivity. The probabilistic projection uses five parameter sets selected along the reference line so that resulting values of transient climate response to cumulative CO_2 emissions (TCRE) match nominal quantiles of 0.17, 0.33, 0.5, 0.67, and 0.83 based on the likely range of the TCRE assessed in the AR5.
Preliminary analysis of the current probabilistic projections compared with other approaches shows similar medians but large variation in ranges. It appears that the current method produces larger ranges than the others constrained by observed temperature changes. This difference implies that the assessed likely range is rather conservative and can be reduced with advanced constrain approaches and emerging observations. Figure 1 also shows that the 66% range of TCR diagnosed from the response parameters is comparable to the AR5-assessed likely range of 1 to 2.5 K despite the fixed carbon cycle parameters. This result implies that the AR5-assessed likely ranges are not necessarily consistent between TCR and TCRE, and that a consistent TCR range can be smaller by the contribution of the carbon-cycle uncertainties to the TCRE range.

Figure 1: Relationship between the TCR and the ECS from the CMIP5 and CMIP6 multi-model ensembles, as of October 2019. The dashed line is drawn to guide a proportional relation with a ratio of 0.6, representing an approximate multi-model mean. The color lines with plumes show regression estimates with a 95% confidence interval. The triangle markers in the marginal box plots indicates means. The dash-dotted line shows a reference line representing the variation of the models, and the five diamond markers along the reference line show reference parameters adjusted to nominal quantiles of 0.17, 0.33, 0.5, 0.67, and 0.83 in terms of the AR5-assessed TCRE range.

Keywords: transient climate response, climate model emulator, multi-model ensemble, cumulative CO2 emissions