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GWP, alternative metrics, and their uncertainties

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Global Warming Potential (GWP) is a metric to convert a non-CO2 greenhouse gas emission to a CO2-equivalent emission that is currently used in the Kyoto Protocol. Given a climatic target (usually in terms of a CO2-equivalent emission), GWP determines the mixture of greenhouse gases in an emissions reduction strategy. GWP is, however, subject to various disputes since its inception (e.g. Fuglestvedt et al., 2003; O'Neill, 2003). Those include the arbitrariness of the time horizon to compute the values of GWP – the choice of time horizon in the Protocol (100 years) is, to our knowledge, not based on any published conclusive discussion. We recognize that other choices are also defensible (Fuglestvedt et al., 2010). The lack of support for the concept of GWP from the scientific community adds a complication to the negotiation in the policy arena.

In view of various criticisms, several alternative indices have been proposed such as Global Temperature change Potential (GTP) (Shine et al., 2005, 2007), Global Cost Potential (GCP) (Manne and Richels, 2001), Cost-Effective Temperature Potential (CETP) (Johansson, 2009), and most recently TEMperature Proxy index (TEMP) (Tanaka et al., 2009a). GTP, a physically-based approximation (i.e., temperature ratio in the target year), was recommended for further analysis by IPCC (2009). GTP is a special case of GCP (Tol et al., 2008), which is a price ratio that leads to a cost effective solution. CETP is proposed as an even better approximation to GCP (Johansson, 2009). TEMP, defined as a multiplier of non-CO2 GHGs emissions which produces the best fit between the reference temperature trajectory and the corresponding trajectory with non-CO2 GHG emissions converted with TEMP, has a unique attribute to follow the behavior of the climate system (Shine, 2009).

The goal of this study is to explore uncertainties surrounding GWP, GTP, and alternative metrics. Characterizing the uncertainties in GHG exchange metrics is a research area strongly recommended by IPCC (2009). The sensitivity of TEMP to uncertain parameters (e.g. atmospheric gas lifetimes) is investigated in Tanaka et al. (2009a). While this previous analysis is conducted for the historical period with the intent to evaluate GWP and TEMP, this study focuses on potential policy applications of the future. We also investigate the relative sensitivity to the background emission scenario used to calculate the different indexes. This work is based on the premise of Berntsen (2009), which establishes the methodology to account for the uncertainties associated with the metrics such as emission trajectiory, climate sensitivity, and the implication for post-target year.

To compute the values of metrics, we use the model ACC2 (Aggregated Carbon Cycle, Atmospheric Chemistry, and Climate model), a reduced-complexity climate and carbon cycle model accompanied by an inverse estimation setup (Tanaka, 2008). The inverse estimation setup for ACC2 will be exploited to investigate the uncertainties in exchange metrics. The inverse estimation setup for model ACC2 is designed to compute best estimates of uncertain parameters based on historical observations during the past 250 years. These parameter estimates are used for subsequent future projections. The model ACC2 is a successor of NICCS (Hooss et al., 2001), ICLIPS Climate Model (Bruckner et al., 2003), and DOECLIM (Kriegler, 2005).

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