Proposal for a very low emissions scenario for CMIP6 ScenarioMIP

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Proposal

Two candidate scenarios are available for inclusion as a *very low emissions scenario* in the Scenario Modelling Intercomparison Project[1] (ScenarioMIP) exercise of the Sixth Phase of the Coupled Model Intercomparison Project[2] (CMIP6). Here we provide a description and comparison of both candidate scenarios that were developed by the Integrated Assessment Modeling (IAM) community. The purpose of this material is to support ScenarioMIP in its selection process of the most desirable very low emissions scenario. The two available candidate scenarios are based on the marker implementations of SSP1 and SSP2, respectively, and reach an end-of-century total anthropogenic radiative forcing level of 1.9 W/m^2 after peaking at a higher level earlier in the century[3]. They are referred to as SSP1-1.9 and SSP2-1.9, respectively. The radiative forcing evolution over the 21st century of these two candidate scenarios is very similar. However, potentially important differences exist between the candidate scenarios, particularly between their projected land-use evolutions. These differences have implications for their further use and applicability, which have to be taken into account during the selection process.

For example, land-use conversion for energy crops of SSP1-1.9 represents the low end of SSPx-1.9 scenarios, and does not differ much from the land-use development in the already selected SSP1-2.6 scenario for the 2.6 W/m^2 row of the SSP-RCP matrix. SSP1-1.9 sees virtually no reductions in cropland for cereal production compared to its no-climate-policy baseline. SSP2-1.9, on the other hand, includes a large expansion of land for energy crops compared to SSP1-1.9, and also includes afforestation as a mitigation measure. This leads to a clear decline in cropland for cereal production in SSP2-1.9. Where SSP1-1.9 thus shows relatively little land-use variation, SSP2-1.9 allows to explore the potential trade-off between food and energy crop production.

These differences lead to divergent sets of incentives for selecting either SSP1-1.9 or SSP2-1.9 as the very low emissions scenarios for CMIP6 ScenarioMIP. The following table provides an overview of these incentives.

Overview of key incentives for selecting either SSP1-1.9 or SSP2-1.9 for inclusion in ScenarioMIP

SSP1-1.9	SSP2-1.9
A) Similarity between adjacent scenarios in ScenarioMIP: minimization of differences with the next nearest ScenarioMIP scenario by eliminating intermodel uncertainty.*	**A) Representation of potential trade-offs of very low emissions scenarios between adjacent scenarios in ScenarioMIP:** one of the key dynamics in very low emissions scenarios is competition over land and water between mitigation options and food production. SSP2-1.9 expresses these dynamics and thus enables subsequent exploration of climate impacts on sustainability and food security issues by the impact, adaptation and vulnerability communities
B) Sustainability storyline: selection of a scenario developed under SSP1 which represents a world reigned by sustainability concerns, a story line most consistent with the very stringent mitigation being considered.	**B) Storyline in line with historical experience:** selection of a scenario developed under SSP2 which represents a world which follows a middle-of-the-road development. This shows how a 1.9 W/m^2 radiative forcing target can be modelled in a world assuming a continuation of the historical experience, and represents the trade-offs in such a world.
C) Elimination of IAM model diversity/variation in low emissions scenarios for climate research: selection of SSP1-1.9 leads to all low emissions scenarios with 2.6 W/m^2 or lower radiative forcing since CMIP5 to be derived from the same IAM framework. This effectively eliminates IAM model diversity/variation and uncertainty in the climate assessment of very low emissions scenarios. Local climate effects between 2.6 and 1.9 scenarios are mainly driven by greenhouse gas and small aerosol forcing differences, and particularly the potentially large influence of land-use uncertainty is eliminated.	**C) Inclusion of IAM model diversity/variation in low emissions scenarios for climate research:** selection of SSP2-1.9 allows to reflect model diversity/variation prevalent among very low emissions scenarios in the IAM literature, and to avoid that analyses of 2.6 W/m^2 and lower radiative forcing by the climate, impact, adaptation and vulnerability (IAV) communities continue to depend on scenario data that is derived from the same single IAM framework for the past 10 years (i.e. for RCP2.6 in CMIP5 and RCP2.6 & RCP1.9 in CMIP6). This increases variations between IAM scenarios assessed by other communities and reduces the potential of persistent IAM model fingerprint bias in the assessment of local climate effects and land-use or other trade-offs.

** Note: Analysis of differential impacts between 1.5°C and 2°C will not necessarily use SSPx-1.9 and SSP1-2.6, but could also rely on higher emissions scenarios, as SSP1-2.6 is expected to keep warming likely to **below** 2°C and will thus not necessarily reach a 2°C warmer world. The next scenarios in the ScenarioMIP set (SSP4-3.4 in Tier 2 and SSP2-4.5 in Tier 1) are expected to exceed 2°C of warming.*

Detailed background

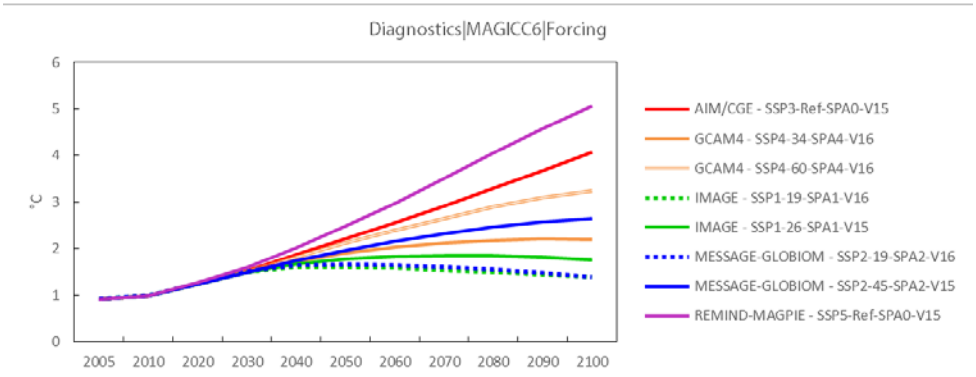
The ScenarioMIP design includes a placeholder for the inclusion of a very low emissions scenario. Guidance on this very low emissions scenarios is given in the ScenarioMIP overview paper[1]:

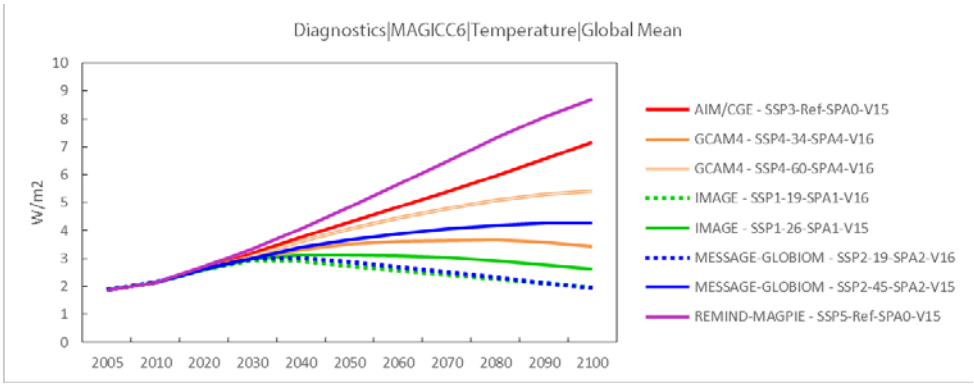
> *"SSPa-b (with b around or below 2.0): this scenario represents the very low end of the range of scenarios in the literature measured by their radiative forcing pathway. […] The final design is subject to additional consideration of specific features of this scenario, including the SSP on which it is based, its 2030 emissions level, the likelihood of peak warming exceeding 1.5 ◦C, and the likelihood of warming being below 1.5 ◦C in 2100. The emission profile will be characterized by a rapid decline to zero and a long period of negative emissions for CO_2."*

The Integrated Assessment Modelling (IAM) community has meanwhile created a set of very low emissions scenarios which limit end-of-century radiative forcing to 1.9 W/m^2, publication of which is forthcoming[3]. All participating models have been able to create such scenarios for both SSP1 and SSP2. That means under the wider socioeconomic assumptions of a green-growth and a middle-of-the-road world, respectively[4,5]. For the other SSPs, significantly fewer scenarios were submitted. This thus results in two candidate scenarios for inclusion in ScenarioMIP: SSP1-1.9 and SSP2-1.9, for each of which its respective marker implementation was selected. Here we provide an overview of their characteristics as input to the selection process for a very low emissions scenario in ScenarioMIP.

Climate forcing and global mean temperatures

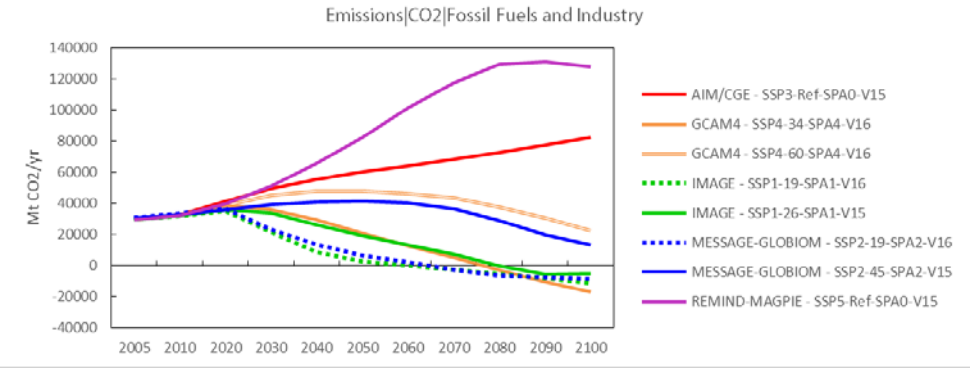
All submitted scenarios have been assessed with the same simple carbon-cycle and climate model[6,7]. Despite large variations between the many submitted SSPx-1.9 scenarios, the total anthropogenic radiative forcing and global mean temperature evolutions of SSP1-1.9 and SSP2-1.9 scenarios selected for consideration by ScenarioMIP are very similar. The figure below shows SSP1-1.9 and SSP2-1.9, together with the already selected ScenarioMIP scenarios as reported in ref. 1. Forcing and global mean temperatures are computed with the reduced complexity carbon-cycle and climate model in a setup up which reflect the median response across the CMIP4 ensemble, consistent with how the Representative Concentration Pathways (RCPs) were derived[8]. When assessed with the same probabilistic setup of the MAGICC model[9,10] as in the Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change[11] the SSP1-1.9 and SSP2-1.9 scenario result in a 30-40% chance of limiting peak warming to below 1.5°C and a 60-70% chance of returning warming to below 1.5°C by 2100. Importantly, this climate model does not resolve land-use induced forcing variations, which are typically assessed with coupled Earth system models.

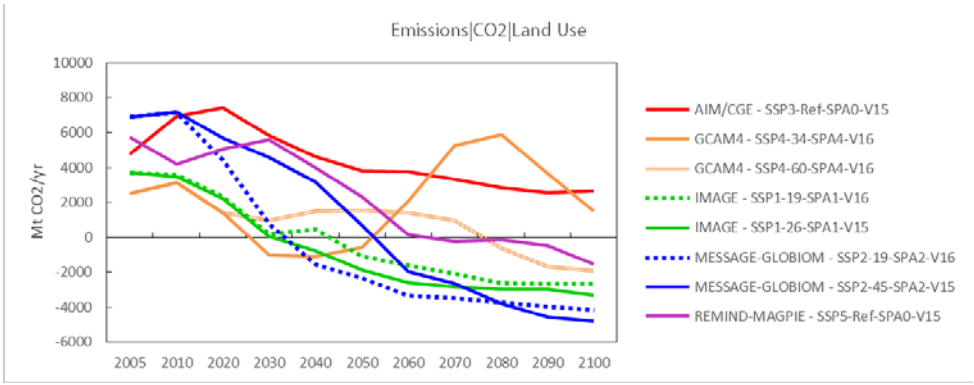


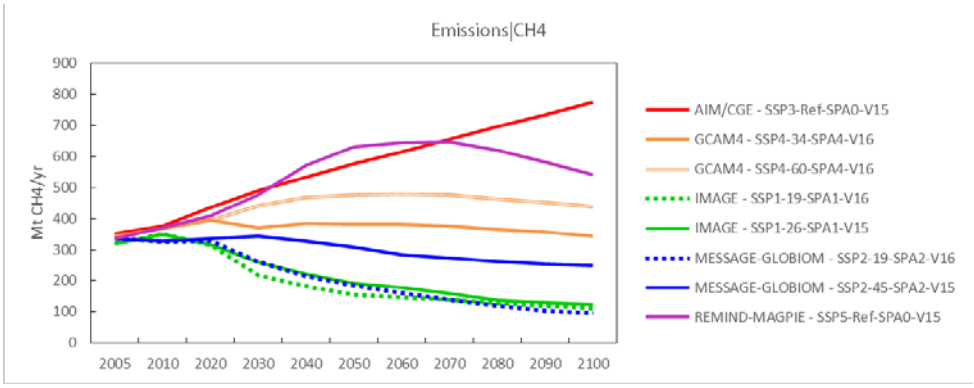


Emissions

Also in terms of emissions of greenhouse gases and other radiatively active species, SSP1-1.9 and SSP2-1.9 show very similar evolutions over the 21st century, including very similar 2030 levels. Here the evolutions for CO_2 from fossil-fuel use and industry, for CO_2 from land use and CH_4 are shown as an illustration. The figures show native emissions as provided by the IAMs. For ScenarioMIP, emissions of all scenarios will be harmonized to historical inventories. This will result in small adjustment. For land-use CO_2, the native differences between SSP1-1.9 and SSP2-1.9 would decrease.

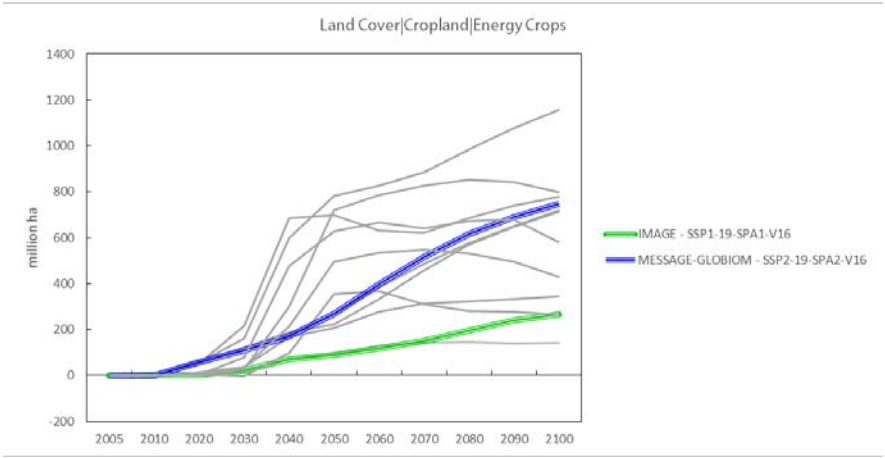


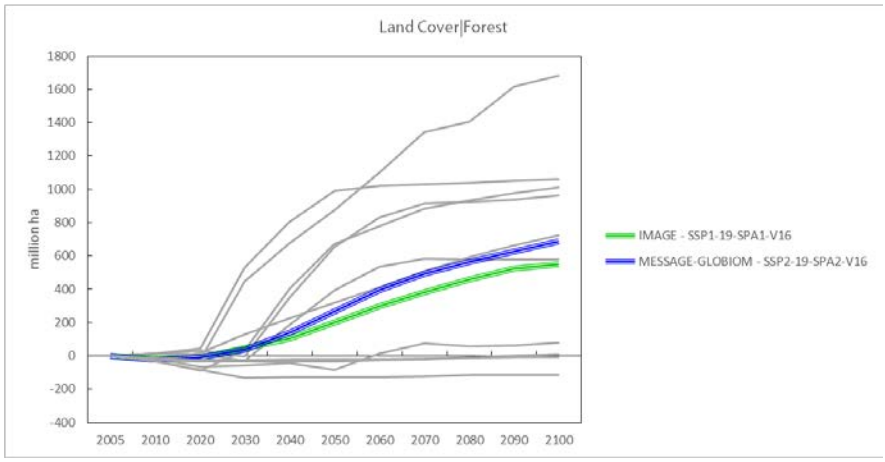


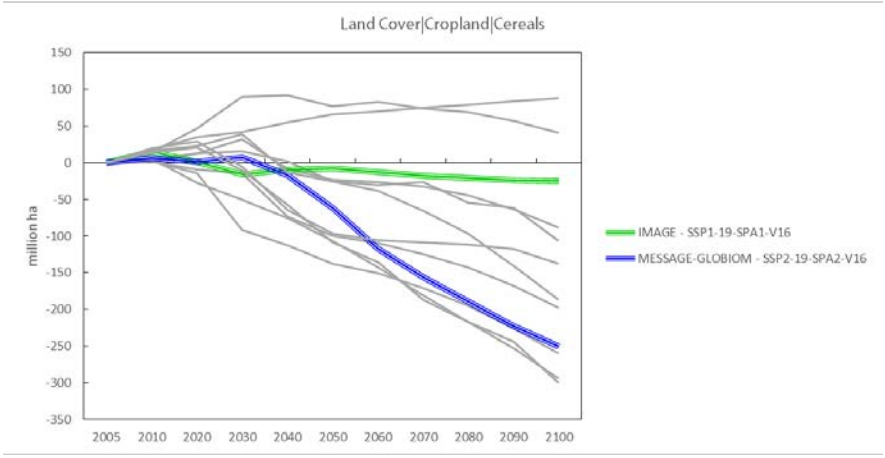


Key differences

The most marked differences between SSP1-1.9 and SSP2-1.9 are found in the land-use sector, where SSP1-1.9 follows a land-use evolution which is very similar to the one in SSP1-2.6, while SSP2-1.9 shows a dynamic of expansion of cropland for energy crops, afforestation, and reduction of cropland for food production. Here the changes in energy crops, forest cover, and cropland for cereals are shown as an illustration of these characteristics. As a point of comparison, all other SSPx-1.9 scenarios are also plotted in the same thin grey lines.







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