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2C or Not 2C?

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Summary
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Keywords: Feasibility of 2°C Target, Climate Change Negotiations

JEL Classification: Q5, Q58

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2C or Not 2C?

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Abstract

Political attention has increasingly focused on limiting warming to 2°C. However, to date the only mitigation commitments accompanying this target are the so-called Copenhagen pledges, and these pledges appear to be inconsistent with the 2°C objective. Diverging opinions on whether this inconsistency can or should be resolved have been expressed. This paper clarifies the alternative assumptions underlying these diverging view points and explicits their implications. It first gives simple visualizations of the challenge posed by the 2°C target. It then proposes a "decision tree", linking different beliefs on climate change, the achievability of different policies, and current international policy dynamics to various options to move forward on climate change.

Keywords : feasibility of 2°C target, climate change negotiations

Introduction

According to the United Nations Framework Convention on Climate Change (UNFCCC), the ultimate goal of international climate policy is to "avoid dangerous anthropogenic interference with the climate system" (article 2). Defining a dangerous level implies making subjective choices and value judgments and any such choice cannot be based on scientific and technical evidence only; it has to be a political choice. Following the European Union's position, political attention has increasingly focused on limiting warming to 2°C. This target was recognized by the Major Economies Forum on Energy and Climate in L'Aquila, Italy, in July 2009; was explicitly included in the Copenhagen Accord; and is present in the final text adopted in Cancun in December 2010.

However, to date the only mitigation commitments accompanying this target are the so-called Copenhagen pledges, and these pledges appear to be inconsistent with the 2°C objective (Rogelj *et al*., 2010; UNEP, 2010; Meinshausen *et al., 2009*). Diverging opinions on whether this inconsistency can or should be resolved have been expressed. Some believe that the 2°C target is still reachable, and that the gap between this target and the sum of countries commitments can be bridged with more ambitious policies. Others think that the 2°C target has little chance to be reached but that it plays the important role of stating what is desirable, and should be kept as a symbolic target. Finally, others believe that the 2°C target is losing its credibility, and that the international community should set a new—higher—target.

The aim of this paper is to clarify the alternative assumptions underlying these diverging view points and to explicit their implications.

The first section gives simple visualizations of the challenge posed by the 2°C target. Reckoning that there is some subjectivity in how one defines what is achievable, it aims at providing simple elements for the reader to judge by himself or herself. To do so, it uses stylized emissions trajectories and a simple carbon cycle and climate model to show the link between the peaking year of global emissions and the stringency of emissions reductions that are necessary after the peak to achieve a given target. It further gives several points of references to judge these required emissions reductions. These points of reference correspond to alternative estimates of what is achievable: (i) historical experience (what has already been done in terms of emissions reduction), (ii) committed emissions (what emissions are "locked-in" if existing infrastructure is operated until the end of its lifetime), (iii) emissions pledges (what emissions reductions are already enacted by countries). The reader can chose which point of reference corresponds best, in his or her views, to a limit to what emissions reductions are achievable in the future; hence deduce how challenging the 2°C target is.

The second section proposes a "decision tree", linking different beliefs on climate change, the achievability of different policies, and current international policy dynamics to various options to move forward on climate change. This "decision tree" investigates what to do with a 2°C target that becomes increasingly difficult to achieve. It leads to two unsettled issues. First, we do not know if the inconsistency between the sum of countries' emissions reductions pledges and the global 2°C target is damaging the UNFCCC process and ultimately the success of climate mitigation. Second, there is no consensus on the status of this target: Is it a binding commitment from the international community to the world population? Or is it a non-binding symbolic goal to help international negotiations move forward? There is no scientific evidence or consensus to settle these issues; however the policy options strongly depend on the answers. This article cannot conclude on a scientific basis and only aims at providing the reader with some new elements to make his or her own opinion.

1. Visualizing the challenge

1.1. How much time do we have left?

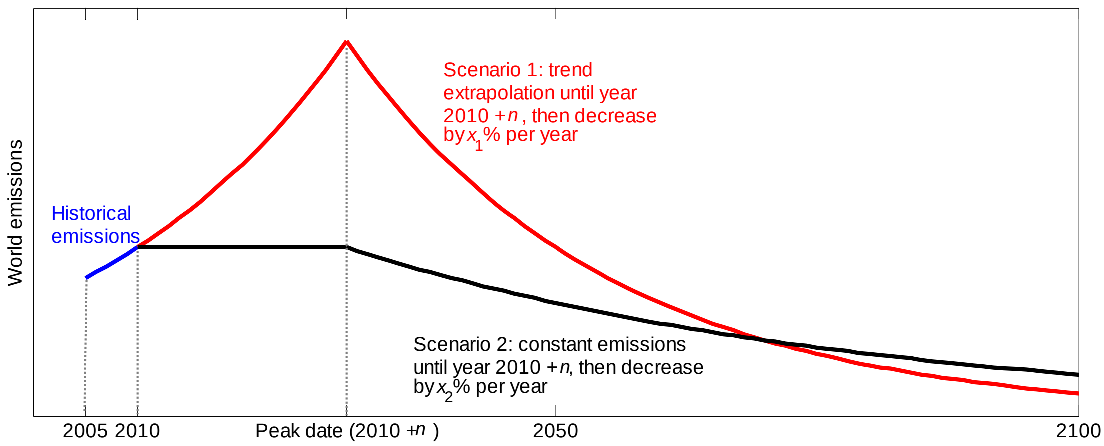
To visualize the mitigation challenge, we explore the issue of global peaking of CO_2 emissions in light of the 2°C mitigation goal. The aim is to give the reader a sense of the stringency of mitigation actions required to reach the 2°C target depending on the peaking year, and to compare with historical emission trajectories, "committed" emissions from existing infrastructure and mitigation pledges. We use a simple carbon cycle and climate model to evaluate the global average temperature increase above pre-industrial levels implied by a family of alternative, idealized CO_2 emissions trajectories, combined with a fixed scenario for non-CO_2 gases; see the Annex, and Figure 1. The trajectories are constructed so that global CO_2 emissions peak *n* years from 2010. Until then, emissions are assumed either (a) to grow at the mean annual rate of emissions growth observed during 2005–10[1] (Scenario 1); or (b) to be fixed at their 2010 level (Scenario 2), which already represents emissions reduction efforts. After emissions peak, the model assumes that ambitious mitigation action reduces global CO_2 emissions at a mean annual rate of *x* percent per year until 2100, which is taken as the end of the study horizon.

To assess how realistic the 2°C objective is, Figure 2A shows the rate of global CO_2 emissions decrease (*x*) after the peak that is necessary to stay below a given temperature increase objective (here + 2°C and + 2.5°C) during the 21st century, assuming a climate sensitivity of 3°C. The figure shows that the required rate of CO_2 emission decrease is increasing

[1] Note that emissions growth increased over the last decade except in 2009, when global emissions stabilized mainly because of the economic slowdown in countries of the Organisation for Economic Co-operation and Development. Considering a continued trend of emissions acceleration before they peak would lead to even more stringent requirement in terms of early peak date and emissions reductions after the peak.

nonlinearly with the peak year, underscoring the urgent need for action if the 2°C target is to be achieved.

Figure 1. Examples of Emission Trajectories, 2005–2100

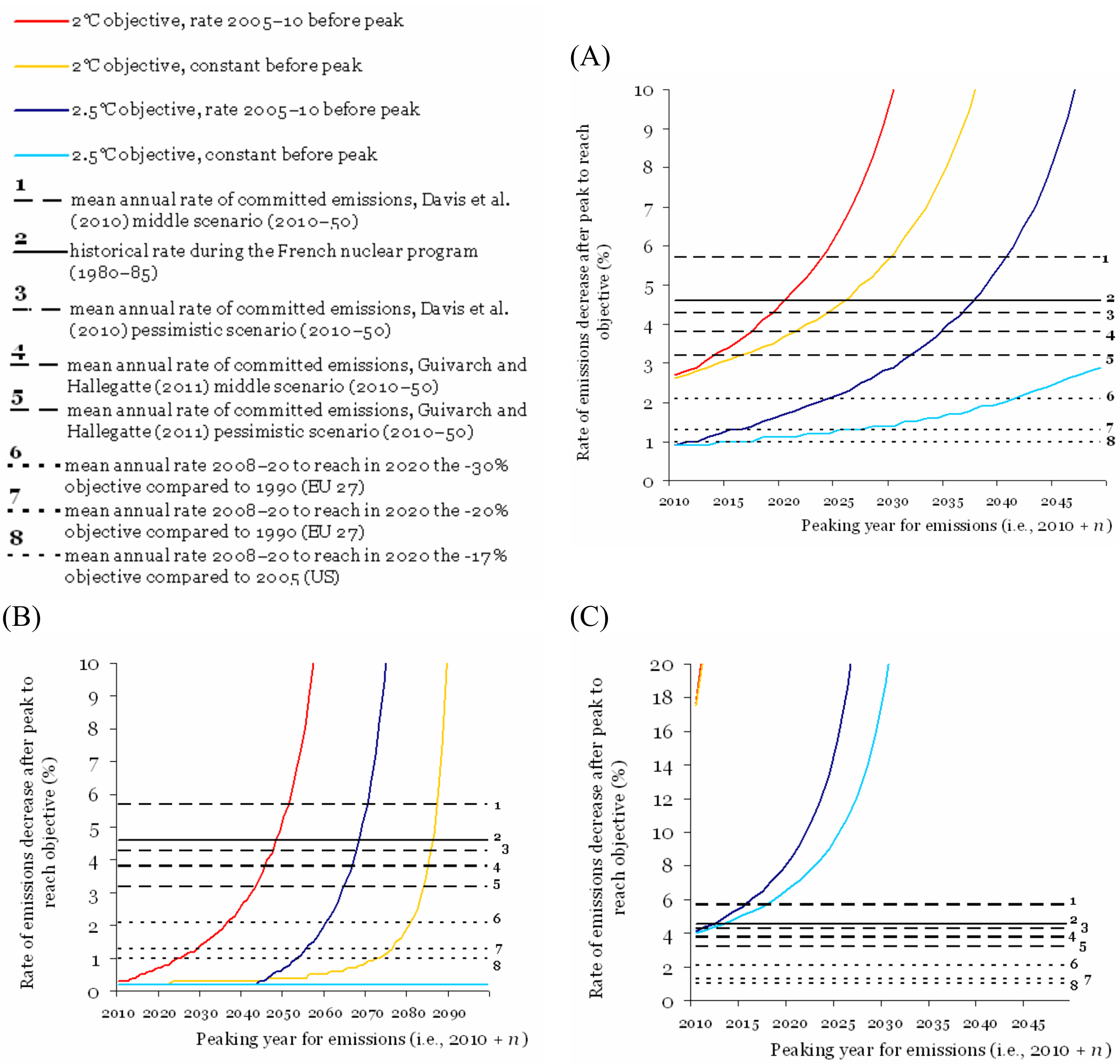


For comparison purposes, the figure also reports as horizontal lines several points of reference. The 1.0 percent per year rate corresponds to the mean annual CO_2 emissions decrease from 2008 to 2020 necessary to achieve the target of -20% emissions in 2020 compared to 1990 level, announced by the European Union. This rate becomes 2.1 percent per year to reach the -30% target. The US pledge to reduce emissions by -17% in 2020 compared to 2005 corresponds to a 1.3 percent per year mean annual emissions decrease rate. With world emission peaking after 2020, reaching the 2°C target would thus require – at the global level – CO_2 emission reduction efforts that are much larger than existing commitments by developed countries alone.

Historical experience also provides useful references. For instance, the 4.6 percent per year rate of mean annual CO_2 emissions reductions from 1980 to 1985 in France corresponds to the country's most rapid phase of nuclear plant deployment. According to WRI-CAIT data, it is the highest rate of CO_2 emissions reductions historically observed in any industrialized country over a five-year period, excluding the countries of the Commonwealth of Independent States during the years of economic recession that followed the collapse of the former Soviet Union. The French example is informative because it represents an important effort to shift away from fossil fuel energy and to decarbonize electricity production through the introduction of carbon-free technologies (in this case, the nuclear energy) and of energy efficiency measures. Even though motivations were different – reducing energy costs vs. reducing GHG emissions – and if future climate policies will likely be based on newer technologies and different economic instruments, this period provides an illustration of an energy transition similar in nature to what is needed to reduce GHG emissions.

From Davis *et al.* (2010), it can be calculated that committed emissions from existing energy infrastructure lead to a mean emission reduction pace of 5.7 percent per year during 2010–50 (middle scenario) and 4.3 percent (pessimistic scenario) if early capital retirement is avoided. In a comparable analysis that also takes the inertia in transport demand into account, Guivarch and Hallegatte (2011) find a mean decrease in committed emissions of 3.8 percent per year during 2010–50 (middle scenario) and 3.2 percent (pessimistic scenario). To go beyond this emission reduction rate, policies affecting new capital would not be sufficient, and early capital retirement or retrofitting would be necessary. Doing so would increase the cost of climate policy. Moreover, the limits to what is achievable in terms of emission reduction do not only depend on technical or economic criteria; political and social acceptability – linked in particular to the redistributive effects of climate policies – will also play a major role (Parry et al., 2005; Fullerton, 2008).

Figure 2. Rate of Emissions Reduction Necessary to Achieve the 2°C Target or a 2.5°C Target as a Function of the Peaking Year for Emissions, with different climate sensitivities (A) 3°C, (B) 2°C and (C) 4.5°C.



Note: Only CO_2 emissions, including emissions from land-use, land-use change and forestry, are considered; the trajectory of radiative forcing from other gases is forced in this simple modelling experiment (see Annex). Historical emissions data are from CITEPA, WRI-CAIT and UNFCCC.

These results are obviously affected by the uncertain climate sensitivity parameter. Figure 2A is based on the IPCC "best guess" (IPCC, 2007) for climate sensitivity, i.e. 3°C. Figures 2B and 2C shows the same result with climate sensitivities of 2°C and 4.5°C. These two alternative sensitivities are chosen to give contrasted visions within the range of published estimates of the climate sensitivity probability distribution function[2]. The figure shows that 2°C is probably achievable with an emission peak after 2030 if climate sensitivity is around 2°C. But if climate change sensitivity is 4.5°C, the 2°C target already appears to be unreachable, at least if extremely large economic costs are to be avoided.

It appears that there is no definite answer to the initial question of this section "how much time do we have left?", or in other terms "when should global emissions peak?", since there is uncertainty on the climate sensitivity and subjectivity in defining what is technically – but also economically, socially and politically - achievable. For example, if one believe the climate sensitivity is close to 3°C, and that it is possible (technically possible but also economically, socially and politically acceptable) to reproduce at the global scale and over several decades the historical experience of emissions decreasing at 4.6%/ year in France over 1980-85, then we still have 10-15 years before global emissions have to peak to reach the 2°C target. If one believes that the emissions reductions given in Copenhagen pledges are close to the highest achievable rate of global emissions decrease, then the 2°C target may already be out of reach, at least with a constant relative decrease in emissions after the peak.

To investigate more rapid emission decreases, or even negative emissions, the next subsection explores another family of emission scenarios, with a linear decrease in emissions (and thus possibly negative emissions).

[2] Note that no higher bound has been proposed for climate sensitivity, and published estimates of the climate sensitivity probability distribution function have a long right tail. 4.5°C thus cannot be seen as a higher bound for climate sensitivity.

1.2. Negative emissions to save the day?

To include net negative global emissions in our "idealized" emissions trajectories, we reiterate the same simple exercise with a second set of emissions trajectories (Figure 3). They are identical to the first set until the peaking year for emissions, *n*, i.e. two scenarios are considered before peak, either with emissions (a) growing at the mean annual rate of emissions growth observed during 2005–10; or (b) fixed at their 2010 level. After emissions peak, however, they decrease linearly until 2100, by the amount *X* per year (expressed as a share of 2010 emissions).

Figure 3. Examples of the second set of Emission Trajectories, 2005–2100

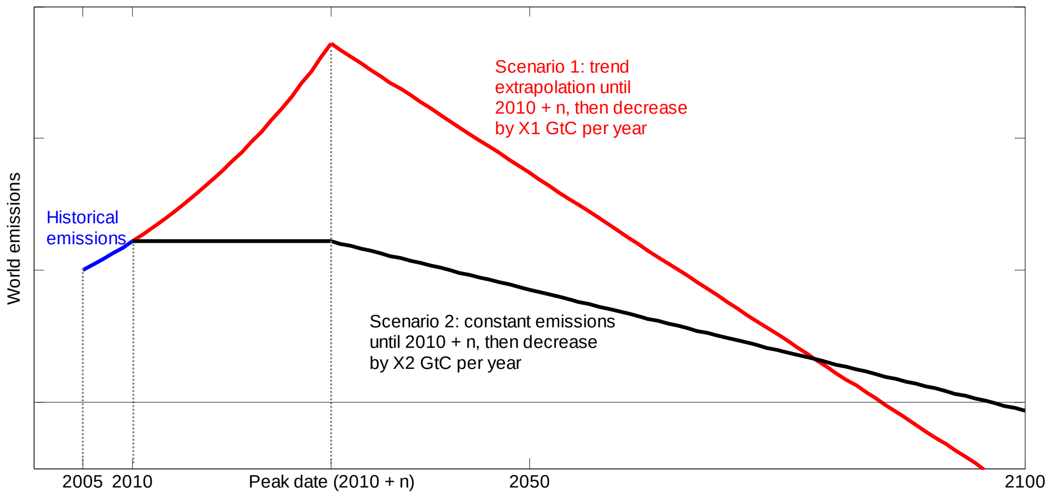
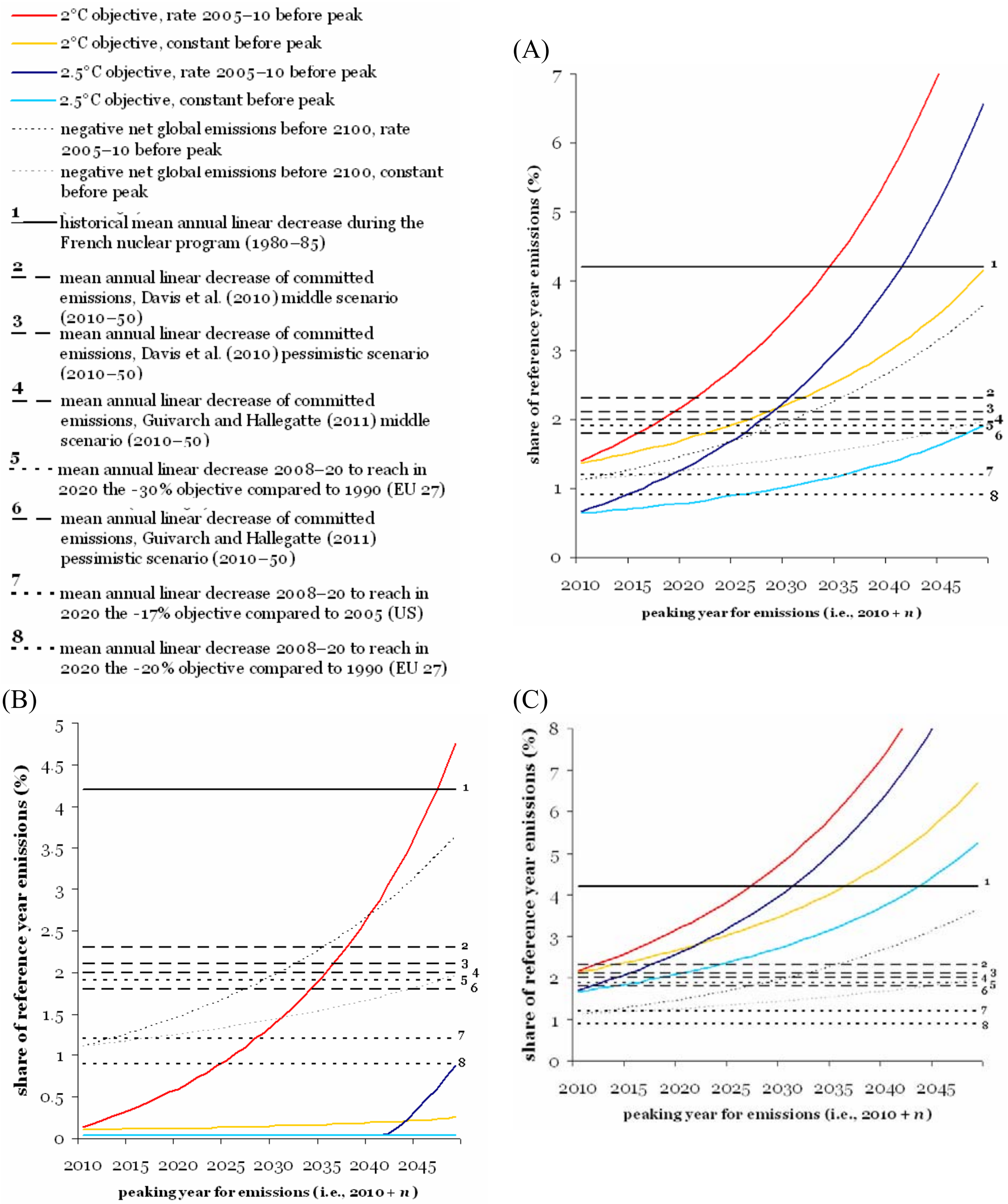


Figure 4 shows the linear annual decrease of emissions necessary to reach a 2°C target or a 2.5°C target as a function of the peaking year for emissions. The figure also reports as horizontal lines the same points of reference as in previous exercise, converted to mean linear annual decreases as a share of reference years' emissions (1980 for the historical French data, 2010 for committed emissions from Davis et al. and Guivarch and Hallegatte (2011) analyses, 2008 for pledges). Additionally, the figure delimits the regions for which the combination of the peaking year and the linear annual decrease implies negative global emissions before the end of the 21st century. In particular it shows that - with climate sensitivity equal to 3°C - negative global emissions are necessary to reach the 2°C target, even if emissions peak today. Also, it shows that a *global* annual decrease of the same order than EU high pledge may achieve the 2°C target, if the peak date is between 2017 and 2026, depending on trajectory up to peaking year.

Of course, results are dependent on the climate sensitivity. For a 2°C sensitivity, the 2°C target appears easier to reach: negative global emissions are required only if emissions peak after 2040 and continue to increase from today to peaking year. But if climate sensitivity is higher (4.5°C), the room for maneuver is very limited and even a 2.5°C target would require negative global emissions before 2100.

Figure 4. Linear Annual Decrease of Emissions, as a Share of 2010 Emissions, Necessary to Achieve the 2°C Target or a 2.5°C Target as a Function of the Peaking Year for Emissions, with different climate sensitivities (A) 3°C, (B) 2°C and (C) 4.5°C.



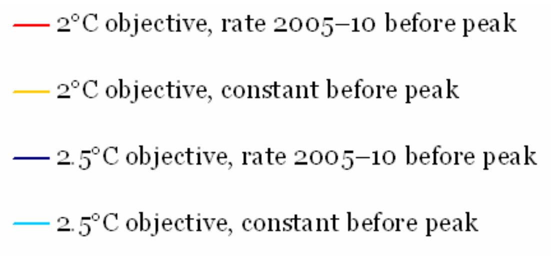
At this point, it is interesting to assess the quantitative role played by negative global emissions in reaching the climate target. Figure 5 gives the year when global emissions become negative as a function of the peaking year (right panel) and the level of emissions in

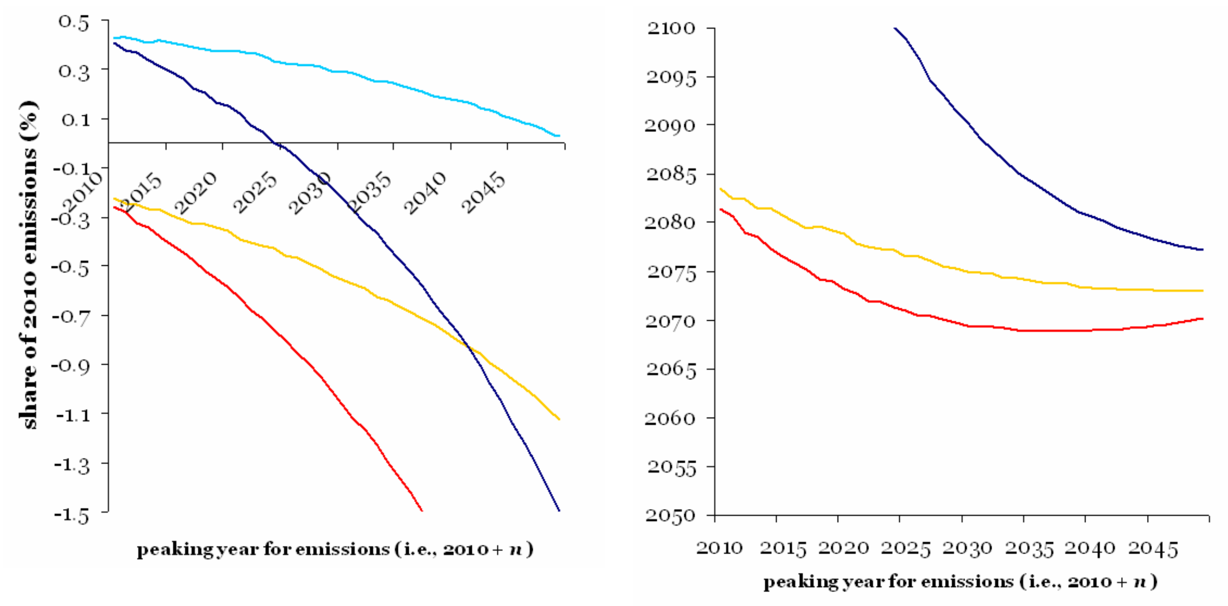
2100 (left panel). It shows that negative emissions occur relatively late in the century (never before 2070), which may appear as good news since it gives some time for research, development and diffusion of technologies enabling such negative emissions.

But it also highlights that dramatically high levels of negative emissions may be needed. For instance, emissions need to reach -100% of current emission levels, i.e. around -35GtCO2, if peaking year is after 2025 and if emissions before peak continue to increase. These levels may seem unrealistically high, but they are partly due to the oversimplified form (linear) of emissions trajectories considered.

To account for possible limitations of the potential for net negative global emissions, a third set of idealized emissions trajectories is considered. Using the set of scenarios reviewed by van Vuuren and Riahi (2011), we assume that the earliest date of net global emissions becoming negative is 2060, and that the maximum negative emissions attained in 2100 is -5GtC. From these assumptions we delimit a linear maximum envelope for negative global emissions. Trajectories are then forced to remain within this maximum 2060-2100 envelope, and are assumed to follow a linear decrease from peak to 2060.

Figure 5. (A) Level of emissions in 2100 , and (B) Year when global emissions become negative as a function of the peaking year in linear emissions trajectories achieving the 2°C Target or a 2.5°C Target with a 3°C climate sensitivity.





The graphs (Figure 6) are identical to those from previous experiment for the closest dates of peaking year for emissions. But when the peak is delayed, the maximum envelope for negative emissions becomes bounding, hence emissions reductions between the peaking year and 2060 have to be more significant. The linear reduction required to reach the 2°C target therefore increases more steeply with the peaking year than in the case without constraints on negative emissions.

Figure 6. (A) Linear Annual Decrease of Emissions from peaking year to 2060, as a Share of 2010 Emissions, Necessary to Achieve the 2°C Target or a 2.5°C Target as a Function of the Peaking Year for Emissions, with a 3°C climate sensitivity, when a maximum envelope for global negative emissions is taken into account; and (B) Level of emissions in 2100 , and (C) Year when global emissions become negative as a function of the peaking year in linear emissions trajectories achieving the 2°C Target or a 2.5°C Target with a 3°C climate sensitivity.

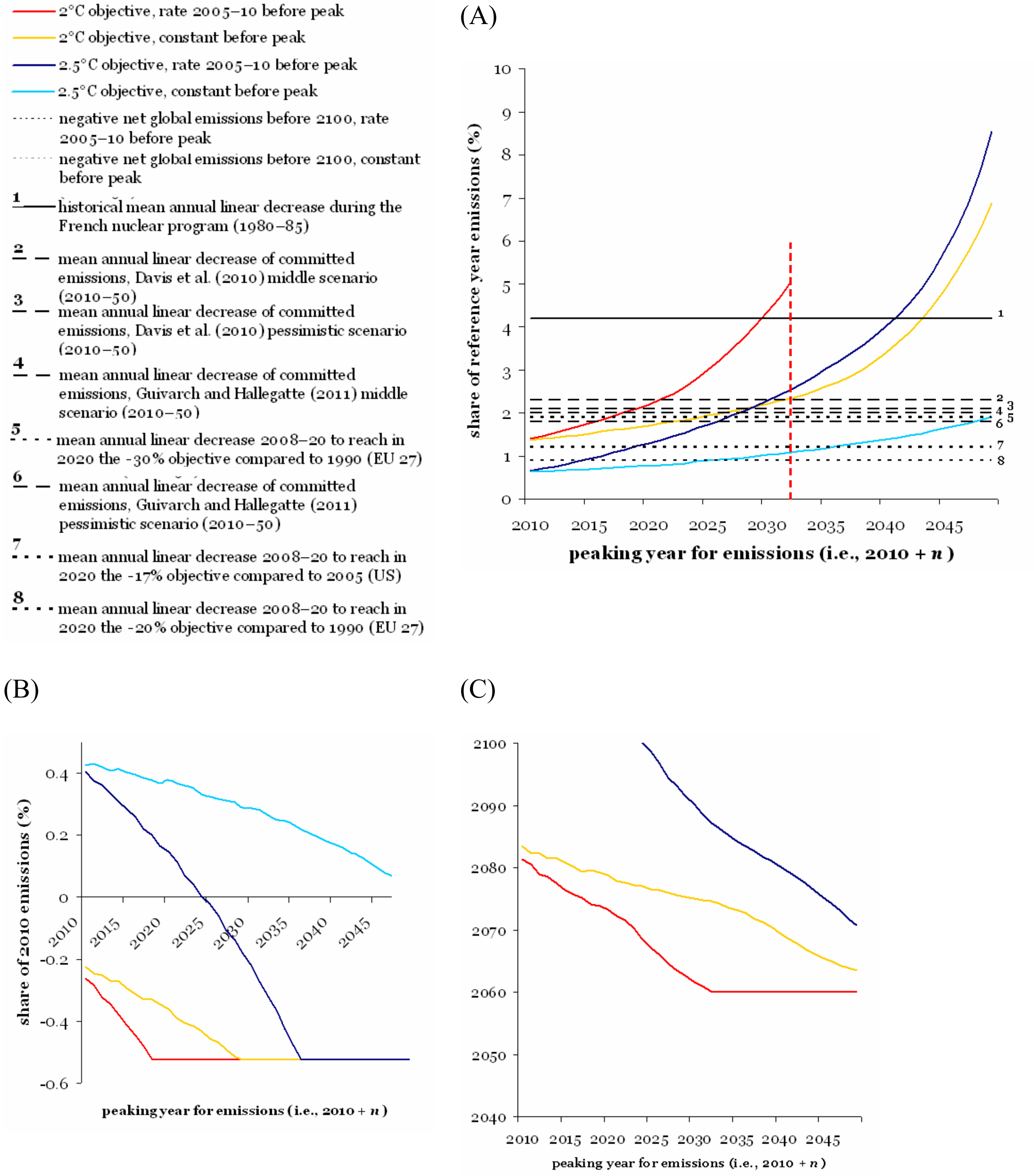
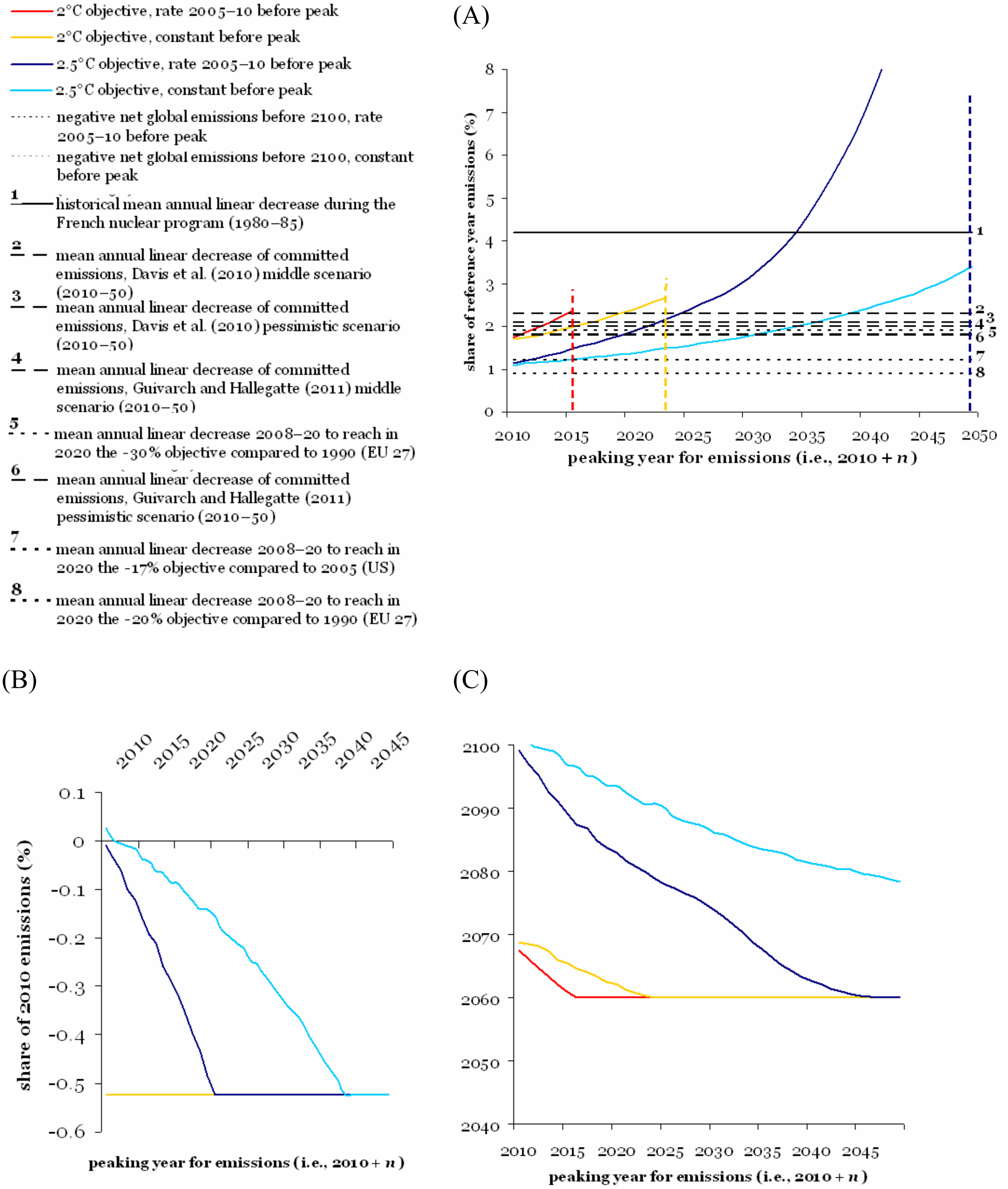


Figure 7. (A) Linear Annual Decrease of Emissions from peaking year to 2060, as a Share of 2010 Emissions, Necessary to Achieve the 2°C Target or a 2.5°C Target as a Function of the Peaking Year for Emissions, with a 3.5°C climate sensitivity, when a maximum envelope for global negative emissions is taken into account; and (B) Level of emissions in 2100 , and (C) Year when global emissions become negative as a function of the peaking year in linear emissions trajectories achieving the 2°C Target or a 2.5°C Target with a 3.5°C climate sensitivity.



If emissions peak occurs after a given date, it may even become impossible to find a trajectory of the form defined that respects the climate objective and the maximum envelope. E.g. for a 3°C climate sensitivity, reaching the 2°C target requires global emissions to peak before 2032 if emissions are assumed to keep growing before the peak. This result is very sensitive to the assumption on climate sensitivity. If only a little more pessimistic, e.g. considering a 3.5°C climate sensitivity, global emissions have to peak before 2016 (still with emissions growing before the peak), or 2023, (if emissions remain at the 2010 level before the peak); see Fig. 7.

Here again, it is not possible to give an unequivocal answer whether the possibility to produce negative net global emissions makes the 2°C target reachable. It depends on the climate sensitivity, the stringency of emissions reductions achievable (technically feasible and economically, socially and politically acceptable) and the extent of negative emissions possible at the end of the century. However, this possibility to produce negative net global emissions in 50 years gives some flexibility in the peaking year and/or in the stringency of emissions reductions after the peak necessary to reach the 2°C target.

1.3. Concluding on the feasibility of the 2°C target?

The conclusion of these simple exercises is that the 2°C target can only be reached if climate sensitivity is not too high, and either under optimistic assumptions about available technologies allowing for negative emissions in 50 years or under the combination of two conditions, namely: (a) an immediate change in mitigation policies with universal participation, leading global emissions to peak extremely rapidly, i.e. in the coming few years, and (b) the possibility − in particular the economical, social and political acceptability − to reproduce at the global scale and over several decades the highest rate of emissions reductions ever observed in a country over a short period.

These results are consistent with published emissions scenarios using high-complexity models. Rogelj et al. (2011) show that in the set of scenarios with a 'likely' (greater than 66%) chance of staying below 2°C, emissions peak between 2010 and 2020. Van Vuuren and Riahi (2011) show that these scenarios, while indicating the absence of a direct relationship between short-term emissions and long-term stabilization targets, suggest that reaching the 2°C target with 2020 emissions above 2000 levels is possible only if negative global emissions are achieved in the second half of the century.

Published modeling experiments exploring low stabilization all reach the first conclusion that stabilization of greenhouse gas concentrations at levels compatible with the 2°C target is feasible (e.g. Edenhofer et al., 2010; van Vuuren et al., 2010).[3] However, their second conclusion, that it is feasible only under a set of optimistic assumptions, should not be ignored. For example, van Vuuren et al. (2010) indicate that the low stabilization levels compatible with the 2°C target are close to the maximum achievable emissions reduction potential in their model. They show that the target is achievable only if optimistic assumptions

[3] It should however be noted that failed experiments tend to not be published, which introduces a bias in the low stabilization literature (Tavoni and Tol, 2010). Indeed, when a stringent target is revealed as infeasible with a given model, it simply does not appear in the literature. Often the policy demand for evaluations of the 2°C target has pushed modelers toward implementing more optimistic assumptions for their mitigation portfolios. The introduction of large-scale BECCS in integrated assessment models has followed this push.

are adopted on (a) the early participation of major sectors and regions in sufficiently stringent mitigation policies from 2013 onward; (b) the expansion of the area needed for food production to allow space for bio-energy; (c) a significant increase in the efficiency of second-generation biofuels; and (d) the carbon neutrality of bio-energy, that is, that large-scale development of bio-energy can be done without an increase in land-related CO_2 emissions (from soil degradation, shifting cultivation, deforestation, or draining of peat lands) and without an increase of nitrous oxide emissions from the application of fertilizer.

Negative emissions scenarios require large-scale combinations of bio-energy and carbon capture and storage (BECCS) (van Vuuren et al., 2010a; Edenhofer *et al., 2010;* van Vuuren et al., 2010b). For instance, Azar et al. (2010) show that two of the three models they consider cannot reach stabilization levels below 400 parts per million of CO_2 equivalent if BECCS is not available. Similarly, Blanford et al. (2009) show that without BECCS or large-scale afforestation, the 2°C target is unreachable and the 2.5°C target is extremely difficult to reach. However, BECCS is not currently a commercially proven technology and its potential remains contentious. Being so dependent on BECCS is a dangerous gamble considering the uncertainty with respect to this technology and the feasibility of its large-scale deployment, and the risks associated with leakage, food security, water scarcity, and biodiversity protection. For instance the low stabilization scenario "Representative Concentration Pathway 3 Peak&Decline" (RCP3-PD), which relies on large development of BECCS, has the second largest primary land area conversion to secondary land (harvested forest), cropland or pasture among the four Representative Concentration Pathways (Hurtt et al., 2011). In that scenario, low stabilization is achieved at the expense of biodiversity protection. And without negative emissions, the only solutions would rely on even more uncertain technologies, such as geoengineering and radiative-forcing management strategies, with their unknown feasibility, risks, and local effects (Schneider, 2008).

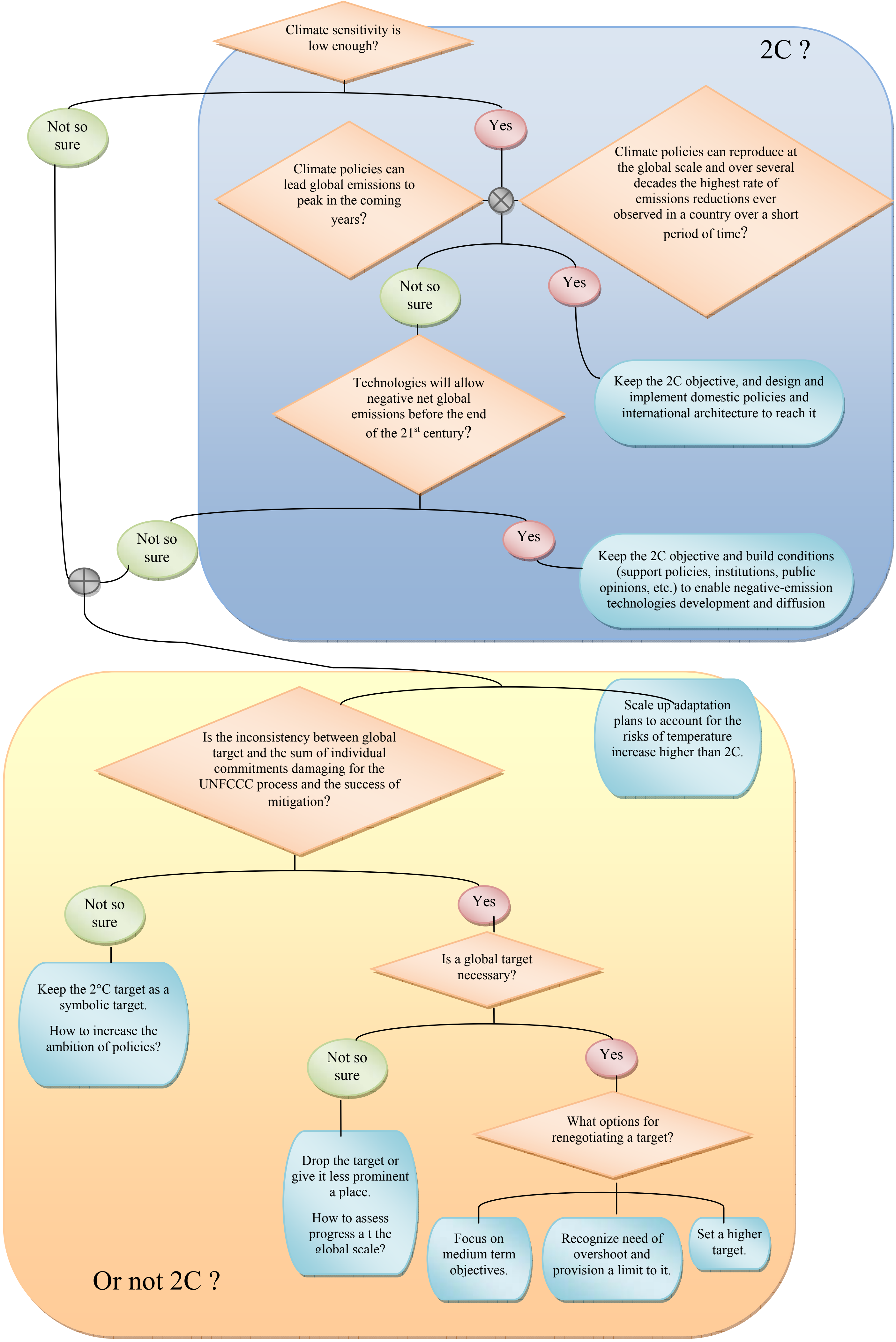
Finally, it should be highlighted that most analyses evaluate the feasibility of the 2°C target on the basis of technical feasibility only. When accounting for possible political, economic, or social constraints, the feasibility appears considerably lower. For instance, the Energy Modeling Forum 22 results showed that delayed participation of non-Annex I countries in mitigation agreements, as an application of the "differentiated responsibilities" and "respective capabilities" principles of the UNFCCC, makes the 450 ppm CO_2-eq target unreachable (Clarke et al., 2009). Anderson and Bows (2011) even conclude that the 2°C target without an overshoot of the target is no longer compatible with economic prosperity.

2. From beliefs to actions

This analysis does not allow to conclude from a scientific point-of-view, as there is always some subjectivity in how one defines what is achievable. It depends for instance on the efforts one is ready to accept to limit climate change. In the same way, the role of the 2C objective can be discussed: Is it a binding commitment from the international community to the world population? Or is it a non-binding symbolic goal to help international negotiations move forward? As a consequence, alternative views can be expressed as a function of one's belief. To illustrate the role of these beliefs, Figure 8 draws an "opinions tree" to explicit the alternative view points and their implications.

The first belief that plays a role is about the ability to reach the 2C objective. If one believes that ambitious climate policies will be able to lead global emissions to peak in the coming years and to reproduce at the global scale and over several decades the highest rate of emissions reductions ever observed in a country over a short period of time, it “only” remains to design and implement these “ambitious climate policies” at the local and national scales and the international architecture to support them. In the same way, if one believes that technologies will allow net negative global emissions before the end of the 21st century to a scale that will put the 2°C target within reach, it “only” remains to set the conditions (support policies, institutions, public acceptability…) for the development and diffusion of these technologies, BECCS in particular.

Figure 8. “Opinions tree” to explicit the alternative view points and their implications.


2C ?
Climate sensitivity is low enough?
Not so sure
Yes
Climate policies can lead global emissions to peak in the coming years?
Climate policies can reproduce at the global scale and over several decades the highest rate of emissions reductions ever observed in a country over a short period of time?
Not so sure
Yes
Technologies will allow negative net global emissions before the end of the 21st century?
Keep the 2C objective, and design and implement domestic policies and international architecture to reach it
Not so sure
Yes
Keep the 2C objective and build conditions (support policies, institutions, public opinions, etc.) to enable negative-emission technologies development and diffusion
Is the inconsistency between global target and the sum of individual commitments damaging for the UNFCCC process and the success of mitigation?
Scale up adaptation plans to account for the risks of temperature increase higher than 2C.
Not so sure
Yes
Keep the 2°C target as a symbolic target.
How to increase the ambition of policies?
Is a global target necessary?
Not so sure
Yes
Drop the target or give it less prominent a place.
How to assess progress a t the global scale?
What options for renegotiating a target?
Focus on medium term objectives.
Recognize need of overshoot and provision a limit to it.
Set a higher target.
Or not 2C ?

If one doubts about both assumptions, the 2°C target becomes unreachable, at least without allowing for an overshoot of the target, and may be considered as unrealistic. In that case, the 2°C target does not seem compatible with the sum of individual countries commitments, and an internal inconsistency appears in the Copenhagen and Cancun climate agreements. The first conclusion concerns adaptation: adaptation plans designed assuming a temperature rise of 2°C are likely to be insufficient, and adaptation plans, infrastructure design, and land use and urban plans need to consider the possibility of greater warming.

Then, there is a question on what to do with a 2°C target that becomes increasingly difficult to achieve. Some inconsistency between the target and the commitments is probably unavoidable given the nature of the evolution of international negotiations on climate change. Indeed, such negotiations have been built on two parallel tracks since the Bali Road Map in 2007. The first is a Kyoto-like top-down track that starts from a common global objective, such as the 2°C objective, and tries to derive consistent commitments for all parties (country burden sharing). This approach stems from the public good nature of the climate change issue, for which only global emissions matter. It was adopted from the start of international negotiations on climate change, but gave rise to unsolvable disputes about the burden sharing rules and negotiations deadlocked. This deadlock entailed the creation of a second track of negotiations.

This second track is a bottom-up track based on a pledge-and-control approach, and is the basis of the Copenhagen Accord. This approach corresponds to the political economy of the realities of climate change negotiations: mitigating climate change requires ambitious domestic policies with potentially large economic impacts, which cannot be decided in absence of internal negotiations within each country. Country commitments are thus difficult to set up through a burden sharing negotiations in short UNFCCC sessions. A bottom-up track through which countries announce commitments is thus extremely useful. However, this track cannot be sufficient, since these unilateral commitments need at one point to be added up and assessed on the basis on their aggregated effect on the world climate, compared to an objective in terms of global climate change.

Today, the world is reaching the point when the inconsistency between the global 2°C objective and individual countries' commitments is becoming very obvious. But there is no consensus on whether this inconsistency is damaging the UNFCCC process and ultimately the success of climate mitigation.

An unreachable target may be damaging by creating unrealistic expectations and an impression of failure, obscuring real successes in limiting emissions, creating a demobilizing climate of pessimism. Clemens et al. (2007) warn about this risk for Millennium Development Goals (MDGs). They argue that the growing concern that the MDGs will not be achieved by 2015 is obscuring the bigger picture that development progress has been occurring at unprecedented levels over the past years. Indeed, among the many countries that are likely to miss the MDGs in 2015, many will yet still outperform the historical trajectories of now-developed countries. They conclude that, by labelling many development successes as failures, the MDGs may create an inaccurate climate of pessimism toward aid, which may undermine future constituencies for aid (in donors) and reform (in recipients).

Also, the inconsistency between global target and country commitments may give low emitting and highly vulnerable countries, such as Small Island Developing States or African countries, the impression that high emitting countries behave opportunistically and would lose trust in the process. More generally, trusting interstate relationships can emerge only when states can 'commit' themselves to particular outcomes (e.g., Kydd, 2000; Wendt, 1999), through commitments that are sufficiently costly to violate (Kydd, 2000; Fearon, 1994; Schelling, 1966). And the ability to make binding commitments is essential to the process of international institutionalization (Keohane, 1984). Making unrealistic commitments suggests that violating them is not costly, and weaken all other commitments, and trust in general.

The consequences of a loss of trust in international negotiation can be illustrated by the case of international development aid. Since 1970, developed countries have repeated their commitment to increase aid up to 0.7 percent of their gross national product. Yet in most countries, it has amounted to only 0.4 percent. This target likely played a positive role to obtain public support for foreign aid budget in developed countries. But because of the continued gap between the target and the reality, it also had a negative impact on international discussions, as developing countries now understandably receive all commitments related to development aid by the industrial countries with disappointment, and sometimes skepticism.

Similarly, within countries, citizens and businesses are unlikely to support an international process that appears inconsistent and based on unrealistic commitments. National climate policies thus risk to appear less credible (or acceptable), and citizens and private actors would be less inclined to invest in low-carbon options, which would reinforce the risk of lock-in a carbon-intensive economic model.

But this opinion is not consensual. Alternative points of view consider the 2°C target as a "symbolic target", i.e. a target that is more a mean than an end. In that framework, the 2°C target becomes a tool, a process to generate discussion, focus attention, assign accountability, and measure progress. Along this view of the 2°C target as primarily a mean to drive mitigation efforts worldwide, its inclusion in official texts, in particular the final UNFCCC text adopted in Cancun in December 2010, may be acknowledge as a real success, and renegotiating it would be damaging to the process. The Millennium Development Goals provide an example of such symbolic targets that are not supposed to be binding constraints, but as a commonly-agreed objective guiding the action of many governments, donors, and international organizations. The MDG offered a framework that undoubtedly helped reverse aid decline after end of Cold War, and stimulate the aid community (Hulme, 2007; Hulme and Scott, 2010). With such a target, the increasing difficulty in reaching the target might not be a problem, except if a "literal" interpretation of the target creates a demobilizing impression of failure (as suggested by Clemens et al.,2007).

Depending on what one thinks about this debate, i.e. about the damage from the inconsistency between the global target and individual country commitments, the best approach is different.

If one thinks that the damage is limited, then it is possible to keep the 2°C target as a symbolic target, and focus on improving country commitment to close the gap. If one thinks that the damage is large, then the international community should prevent a widening of the gap between the official global target and the sum of countries' commitments. There are several ways to do so.

First, one can think that such a global target is not necessary. In that case, it might be possible to drop it or give it less prominent a place, without any other changes.

Otherwise, assuming that a realistic long-term global target is useful or even necessary, the international community would have to set a new, more realistic objective. Changing the international target can be done through an increase in the objective (e.g., to 2.5°C), through the recognition that an overshoot will be needed and the provision of a limit to this overshoot (e.g., the objective of a 2°C stabilization with overshoot below 2.5°C), or through a focus on medium-term objectives (e.g. the objective of limiting warming below 1.8°C in 2050).

Such a change in target would likely be perceived as a failure, especially by those who have championed the 2°C target for years, but it would issue a useful wake-up call, and would also be a way to communicate an important aspect of the climate change problem: delaying action does not mean we can still achieve the same results. If we delay the construction of a high speed train line by five years, we get the same train line, or an even better one, five years later. By contrast, with climate change mitigation, reachable objectives will become increasingly less attractive over time.

Conclusion: 2C or not 2C?

This paper does not pretend to answer on what should be done with the 2°C target. Indeed, this depends on what is considered achievable from a political and economical perspective, which is and will remain a subjective question (theoretically, one can stop emitting overnight by turning off all emitting devices). It also depends on the status of the 2°C target, and there is no consensus on this point in the scientific community. This is why we aim at providing information to make it possible for the reader to make his or her own opinion. And this is why we let our readers draw their own conclusion from this information…

Write your own conclusion here…

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Annex

This Annex describes the hypotheses and modeling assumptions used to produce Figures 2, and 4 to 7.

Radiative Forcing from Other Gases

The radiative forcing from other gases follows the trajectory from the scenario Representative Concentration Pathway 3 Peak&Decline (RCP3-PD) from the IMAGE model (van Vuuren *et al.*, 2011). This scenario is representative for the scenarios leading to extremely low greenhouse gas concentration levels in the literature. It represents a substantial reduction of greenhouse gases over time and is a best-case scenario with respect to non-carbon dioxide (CO_2) emissions.

Carbon Cycle Model and Climate Model

The carbon cycle is a three-box model, after Nordhaus and Boyer (2010). The model is a linear three-reservoir model (atmosphere, biosphere + ocean mixed layer, and deep ocean). Each reservoir is assumed to be homogenous (well-mixed in the short run) and is characterised by a residence time inside the box and corresponding mixing rates with the two other reservoirs (longer timescales). Carbon flows between reservoirs depend on constant transfer coefficients. GHGs emissions (CO2 solely) accumulate in the atmosphere and they are slowly removed by biospheric and oceanic sinks.

The stocks of carbon (in the form of CO_2) in the atmosphere, in the biomass and upper ocean, and in the deep ocean are, respectively, A, B, and O. The variable E is the CO_2 emissions. The evolution of A, B, and O is given by

$$\frac{dA}{dt} = -\phi_C^{A,B} + E,$$
$$\frac{dB}{dt} = \phi_C^{A,B} - \phi_C^{B,O}, \text{ and}$$
$$\frac{dO}{dt} = \phi_C^{B,O};$$

The fluxes are equal to

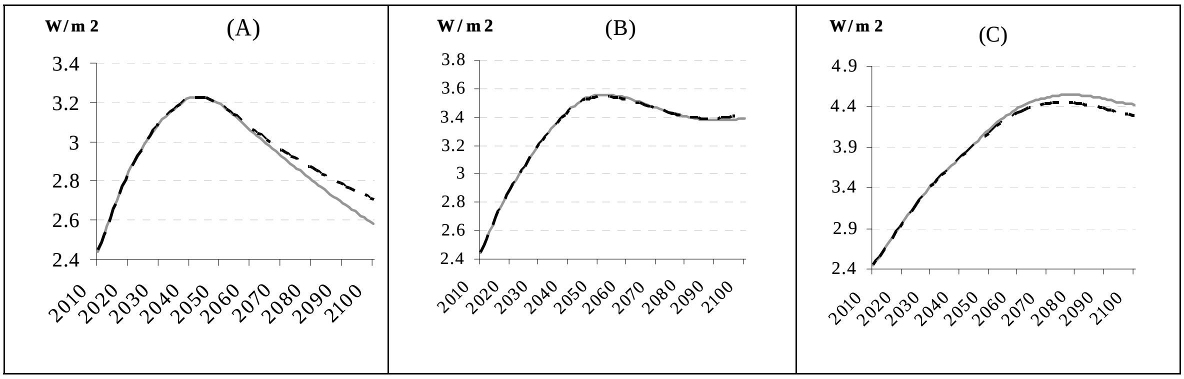
$$\phi_C^{A,B} = a_{21}A - a_{12}B, \text{ and}$$
$$\phi_C^{B,O} = a_{23}B - a_{32}O;$$

The initial values of *A*, *B*, and *O*, and the parameters a_{12}, a_{21}, a_{23}, and a_{32} determine the fluxes between reservoirs. The main criticism which may be addressed to this C-cycle model is that the transfer coefficients are constant. In particular, they do not depend on the carbon content of the reservoir (e.g. deforestation hindering biospheric sinks) nor are they influenced by ongoing climatic change (e.g. positive feedbacks between climate change and carbon cycle).

Nordhaus original calibration has been adapted to reproduce data until 2010 and results from IMAGE model for a given trajectory of CO2 emissions (see below), giving the following results (for a yearly time step): a12= 0.02793, a21=0.03427, a23=0.007863, a32=0.0003552, with the initial conditions: A2010=830 GtC (i.e. 391ppm), B2010=845 GtC and O2010=19254 GtC.

Figure A1, panel B, compares the trajectory of total radiative forcing calculated with the three-box carbon cycle model and the IMAGE model forced with the emissions trajectory used for calibration. This emissions trajectory, from Energy Modeling Forum 24 study, is between those of RCP 3PD and RCP 4.5 from RCP database. Panels A and C compares the three-box carbon cycle model and IMAGE model results for the RCP 3PD and the RCP 4.5 emissions trajectories, respectively. The differences are linked to elements modifying transfer coefficients, such as reforestation or deforestation for instance, not accounted for in the three-box model with constant transfer coefficients. For information the three emissions trajectories A, B and C lead to a temperature increase in 2100, using the simplified carbon-cycle and climate model presented here, of 1.9°C, 2.4°C and 2.9°C, respectively.

Figure A1. Trajectories of total radiative forcing calculated with the three-box carbon cycle model (dashed black lines) and IMAGE model (solid grey line) for three given emissions trajectories: (A) the RCP 3-PD emissions trajectory, (B) the emissions trajectory used for calibration, from EMF24 study, between those of RCP 3-PD and RCP 4.5, and (C) the RCP 4.5 emissions trajectory.



The additional forcing caused by CO_2 and non-CO_2 gases is given by

$$F_A = F_{2X} \frac{\log\left(\frac{A}{A_{PI}}\right)}{\log 2} + F_{non-CO_2},$$

where A_{PI} is the pre-industrial CO_2 concentration (280 ppm), F_{2x} is the additional radiative forcing for a doubling of the CO_2 concentration (3.71 $W.m^{-2}$), and F_{non-CO_2} is the additional radiative forcing of non-CO_2 gases.

The temperature model is a two-box model, after Schneider and Thompson (1981) and Ambrosi *et al.* (2003), with the atmosphere temperature T_A and the ocean temperature T_O as follows:

$$\frac{dT_A}{dt} = \sigma_1 \left(-\frac{F_{2X}}{T_{2X}} T_A - \sigma_2 \phi_T + F_A \right),$$

$$\frac{dT_O}{dt} = \sigma_3 \phi_T, \text{ and}$$

$$\phi_T = T_A - T_O,$$

where T_{2x} is the equilibrium temperature increase at the doubling of the CO_2 concentration, that is, it represents climate sensitivity. All parameters have been calibrated to reproduce observed values and IPSL Global Climate Model scenarios for the 21st century (see Ambrosi *et al.* (2003) for details on calibration), leading to the following parameter values (for a yearly time step): σ_1=0.1396048 $C.W^{-1}.m^2$, σ_2=0.6833236 $C^{-1}.W.m^{-2}$ and σ_3=0.0206022. The climate sensitivity parameter is taken as equal to 3°C, the “best guess” value from the most recent Intergovernmental Panel on Climate Change (2007) report.

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