Policy Update on 2°C Warming

Analysis of early IMPACT2C climate modelling results

ecosystems infrastructure Small Islands Africa water forestry energy costs Bangladesh risks air pollution vulnerability cross sector assessments impact health adaptive capacity

Quantifying projected impacts under 2 C warming

decision making transport tourism Europe agriculture adaptation

SEVENTH FRAMEWORK PROGRAMME

Summary

The IMPACT2C project provides information and evidence on the impacts of 2°C global warming for Europe and other key vulnerable global regions.

To summarise and disseminate the results and information from the project, a series of Policy Briefing Notes are being produced.

This note – Policy Briefing Note 1 – provides a summary of the initial findings of the project, reporting key lessons from the climate modelling analysis. The note provides discussion around five key questions that are relevant in the context of the 2°C goal.

When might we hit 2°C?

An analysis of climate model projections in the IMPACT2C project, looking at the A1B Special Report on Emissions Scenarios (SRES) scenario (a medium-high scenario with no mitigation) indicates that the 2°C goal could be exceeded in the next 30 years, just after 2040.

However, there is a considerable range around the timing, as projected by different climate models. Under the worst case scenario, the results indicate the 2°C goal could be exceeded by 2030 (for the A1B scenario) and even under the most optimistic case, they indicate we are likely to pass the 2°C goal before 2050.

What does 2°C of global change mean for Europe?

The project has looked at the regional climate model information for Europe, in the context of the 2°C goal. This provides information on the relative change in Europe versus the global average, including for individual EU countries.

On average, Europe warms at a slightly higher level compared to the global average, i.e. Europe will experience more than 2°C of change even if the global goal is achieved.

Moreover, some parts of Europe will have much higher levels of warming, with potentially 3°C of warming in the Iberian Peninsula and other parts of the Mediterranean in the summer. This will increase the relative level of heat related impacts in these countries.

There are also projected increases in extreme events, notably summer heat extremes in the South of Europe – and increased heavy precipitation in winter across most of Europe – which will increase the current impacts of climate variability.

A key finding is that even if the 2°C goal is achieved, Europe will experience significant impacts, particularly in some vulnerable areas. A 2°C world for Europe is therefore not benign.

How do the new RCP scenarios change our understanding of when 2°C occurs?

The IMPACT2C project has compared the new RCP (Representative Concentration Pathways) model runs to the SRES, looking at the implications of the timing and probability of global average temperatures.

The analysis shows that regardless of the emission scenario assumed, it is expected that +1.5°C of warming (relative to pre-industrial levels) will be exceeded around or before 2040. In addition, all scenarios except B1 and RCP2.6 indicate that +2°C will be exceeded around or earlier than 2060.

The analysis also indicates the likelihood of exceeding the 1.5°C or 2°C goals earlier is slightly higher in the RCP analysis (for non-mitigation scenarios) compared to the previous SRES.

SEVENTH FRAMEWORK PROGRAMME

What is the rate of climate change, and the speed and possible limits of adaptation?

As well as the absolute level of change, it is becoming clear that the rate of climate change is important in relation to impacts, not least because this affects the ability of natural, physical and economic sectors to adapt.

Historical rates of change have averaged just over 0.1°C per decade. However, these rates are likely to increase in the near future, potentially doubling to 0.3°C to 0.7°C per decade over the next few decades.

As much of Europe warms at a faster rate than the global average, this will translate into even higher rates of change for some regions of Europe. These high rates of changes are likely to be very important in relation to the level of impacts and raise earlier concerns in relation to the limits of adaptation.

What does 2°C mean for global and European vulnerability hot-spots and tipping points

The 2°C goal is critical in the consideration of potential tipping points and global or European vulnerability hot spots, because it is seen as a possible precautionary level, which is likely to avoid the occurrence of most major events.

The project is investigating a number of key global and European hot spots to investigate these issues, with case studies in Europe, Bangladesh, the Maldives and Africa.

Introduction

In Europe and internationally, there is an ambition to limit global warming to 2°C relative to pre-industrial levels, in broad alignment with the objective of the United Nations Framework Convention on Climate Change (UNFCCC) to prevent dangerous anthropogenic interference with the climate system.

The IMPACT2C project (see box) aims to provide information and evidence on the impacts of 2°C global warming for Europe and other key vulnerable global regions, and thus provide policy relevant evidence. This includes detailed analysis using regional climate models and impact assessment models.

To help summarise and disseminate the results and information from the project, a series of Policy Briefing Notes are being produced.

This Policy Brief (Number 1) provides a summary of the initial findings of the project, addressing key lessons from the climate modelling analysis. The note provides discussion around five key questions that are relevant in the context of the 2°C goal. These are:

The IMPACT2C project

Political discussions on the European goal to limit global warming to 2°C need to be informed by the best available science on projected impacts and possible benefits. IMPACT2C enhances knowledge by quantifying climate change vulnerability and impacts, using a clear and logical structure. It also considers the economic costs of these impacts, as well as potential responses, within a pan-European sector-based analysis. The multi-disciplinary international project uses a range of models to assess effects on water, energy, infrastructure, coasts, tourism, forestry, agriculture, ecosystems services, and health and air quality-climate interactions. IMPACT2C introduces a number of key innovations.

First, harmonised socio-economic assumptions/scenarios are being developed, using the new RCP and SSPs (Representative Concentration Pathways and Shared Socio-economic Pathways), to ensure that both individual and cross-sector assessments are aligned to the 2°C scenario for both impacts and adaptation.

Second, a core theme of uncertainty has been developed across the climate projections, socio-economic scenarios and impact models within and across sectors. In so doing, analysis of adaptation responses under uncertainty will be enhanced.

Finally, a cross-sectoral perspective is adopted to look at linkages between sectors, to capture direct and indirect effects and to look at areas of Europe that are particularly vulnerable (hot-spots) even to 2°C of warming.

While the focus is on Europe, a number of case studies are being developed to investigate some of the world's most vulnerable regions, i.e. those most at risk under 2°C of warming, with analysis in Bangladesh, Africa (Nile and Niger basins) and the Maldives.

The IMPACT2C aims to integrate and synthesize the findings for awareness-raising and to communicate to a wide audience, relevant for policy.

- When might we hit 2°C?
- What does 2°C of global change mean for Europe?
- How do the new RCP scenarios change understanding of when 2°C might occur?
- What is the rate of climate change, and the speed and possible limits of adaptation?
- What does 2°C mean for global and European vulnerability hot-spots and tipping points?

When might we hit 2°C?

The European Union (CEU, 1996: 2004; CEC, 2005; 2007) has set a goal for limiting global warming to 2°C relative to pre-industrial levels, recognising that the failure to do so could put the world at substantial risk of dangerous climate change. These concerns have been recognised by the G8 (G8, 2007), and at the UNFCCC Conference of the Parties in Cancun (UNFCCC, 2010). At the latter, the Parties agreed to a goal to reduce global greenhouse gas emissions so as to hold the increase in global average temperature below 2°C above pre-industrial levels, and to consider lowering the goal to 1.5°C in the near future. However, there has already been an increase of about 0.85°C over the period 1880–2012 (IPCC, 2013), and at the current time, international negotiations have had modest success: current commitments and pledges are therefore not on track to achieve the 2°C goal (IEA, 2012).

Against this background, a question is <u>when is the world likely to exceed the 2°C goal?</u> The answer is informative in highlighting the further implications of inaction.

However, this question is actually quite difficult to answer, because it depends on socio-economic futures and associated emission pathways over the next few decades, and how the climate responds to changes in these emissions (i.e. to the forcing from alternative emissions).

The IMPACT2C project set out to investigate this question – and to examine uncertainty – using existing climate scenario data and climate model results (Vautard et al. 2014). This allows an analysis of when the world might exceed the 2°C goal (global average surface warming).

The analysis has first considered a medium-high emission scenario (SRES A1B). This scenario is a non-mitigation scenario. This scenario is broadly consistent with recent global emissions (observed). Eight major models used in the European Union FP6 project ENSEMBLES (van der Linden and Mitchell, 2009) were considered and Figure 1 below plots the year when the models project exceedance of the 2°C goal. The analysis looks at the central year (in a 30–year time window) when the goal is exceeded.

The results are striking. The mean of the model simulation indicates that the 2°C goal could be exceeded by around 2043 – only thirty years away. However, there is a considerable spread across the models. Importantly, models that have faster warming indicate the 2°C goal could be exceeded before 2030, less than twenty years

Key message. An analysis of climate model projections for the A1B SRES scenario (a medium-high scenario with no mitigation) indicates that the 2°C goal could be exceeded in the next 30 years, just after 2040. However, there is a considerable range around this, as projected from different climate models. Under the worst case scenario, the 2°C goal could be exceeded for this scenario by 2030 and even under the most optimistic case, it is projected we will exceed the 2°C goal before 2050.

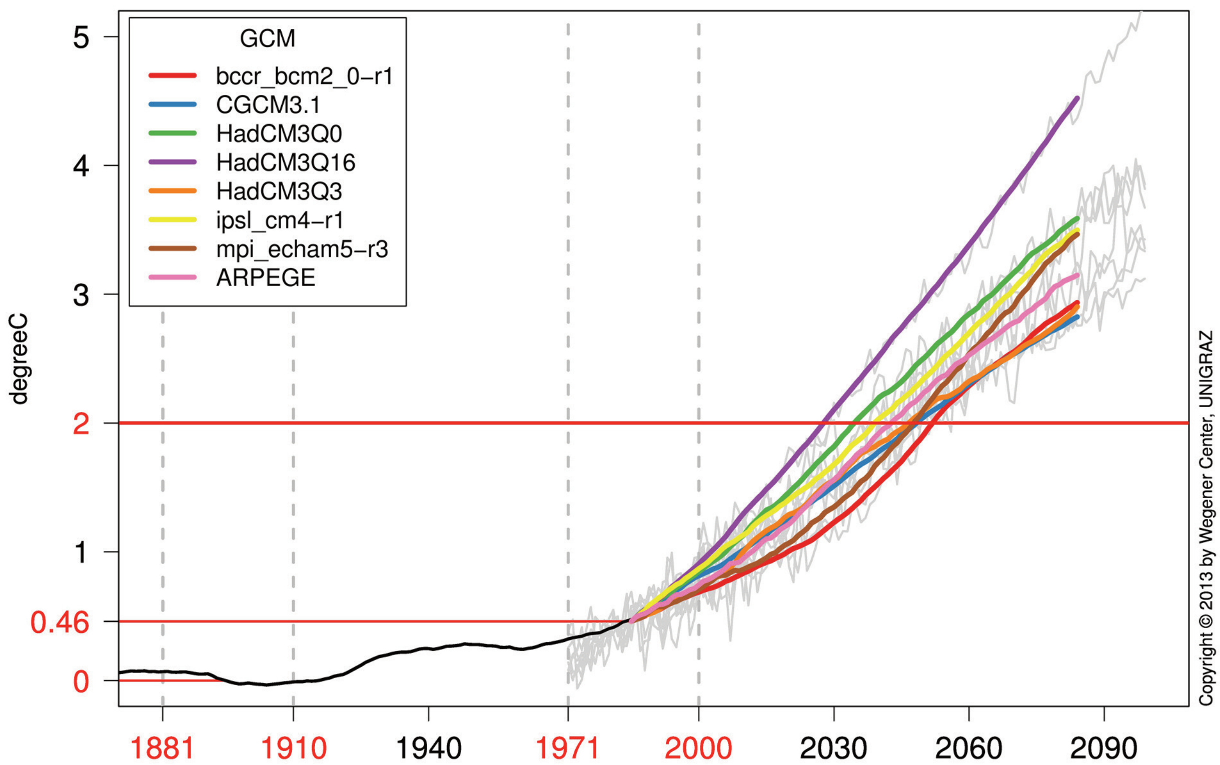


Figure 1. When might we hit 2°C?

Analysis of global temperature change and the 2°C goal. Observed historical (black line) and future projections from different Global Climate Models (GCMs) based on the A1B emission scenario. Time series are smoothed using a 30-year running mean. The 2°C threshold is marked in red. Source: Vautard et al. 2014.

away. Conversely, even the model simulation with the slowest rate of warming projects that the 2°C goal will be exceeded by around 2050.

This has major implications for the speed and urgency of the current policy discussions. It also indicates that early adaptation is likely to be needed.

What does 2°C of global warming mean for Europe?

Climate change does not happen equally across the world. In terms of temperature, 2°C of average warming at the global level translates into different levels of warming for Europe, and also different levels of warming across Europe. A critical question is therefore how much Europe warms under a global 2 degrees scenario, and whether individual countries will experience more or less warming. Similar issues also arise with respect to other key climate metrics, notably precipitation.

To answer this question, the IMPACT2C project (Vautard et al. 2014) considered a large number of European regional climate model simulations, including 15 combinations of GCM and RCMs for the medium-high emission scenario A1B (without mitigation). The analysis looked at the 30-year interval when the global mean temperature reaches 2°C in the driving GCM relative to 1881–1910 (the period taken to represent the pre-industrial conditions), noting this varies for each GCM.

The first finding is that in general Europe warms at a higher level compared to the global average. This is important because it means that a global average temperature rise of 2°C will lead, on average, to higher levels of warming in Europe: EU countries are therefore likely to experience more than 2°C of warming even if the global goal is achieved.

Figure 2 shows the increase in temperature in different regions of Europe at the time when a global increase of 2°C relative to pre-industrial levels occurs. The temperature change in the Figure shows the increase from the present day climate (represented by the reference period 1971-2000, which already includes 0.5°C of warming since pre-industrial).

This shows that many regions of Europe will experience more warming than the global average, noting the exception of the British Isles (which has a median value below the global value) and France and Mid-Europe (which have a median value similar to the global value). This also means that much of Europe will exceed 2°C of warming before the global goal is exceeded, i.e. earlier than the time period shown in Figure 1 above.

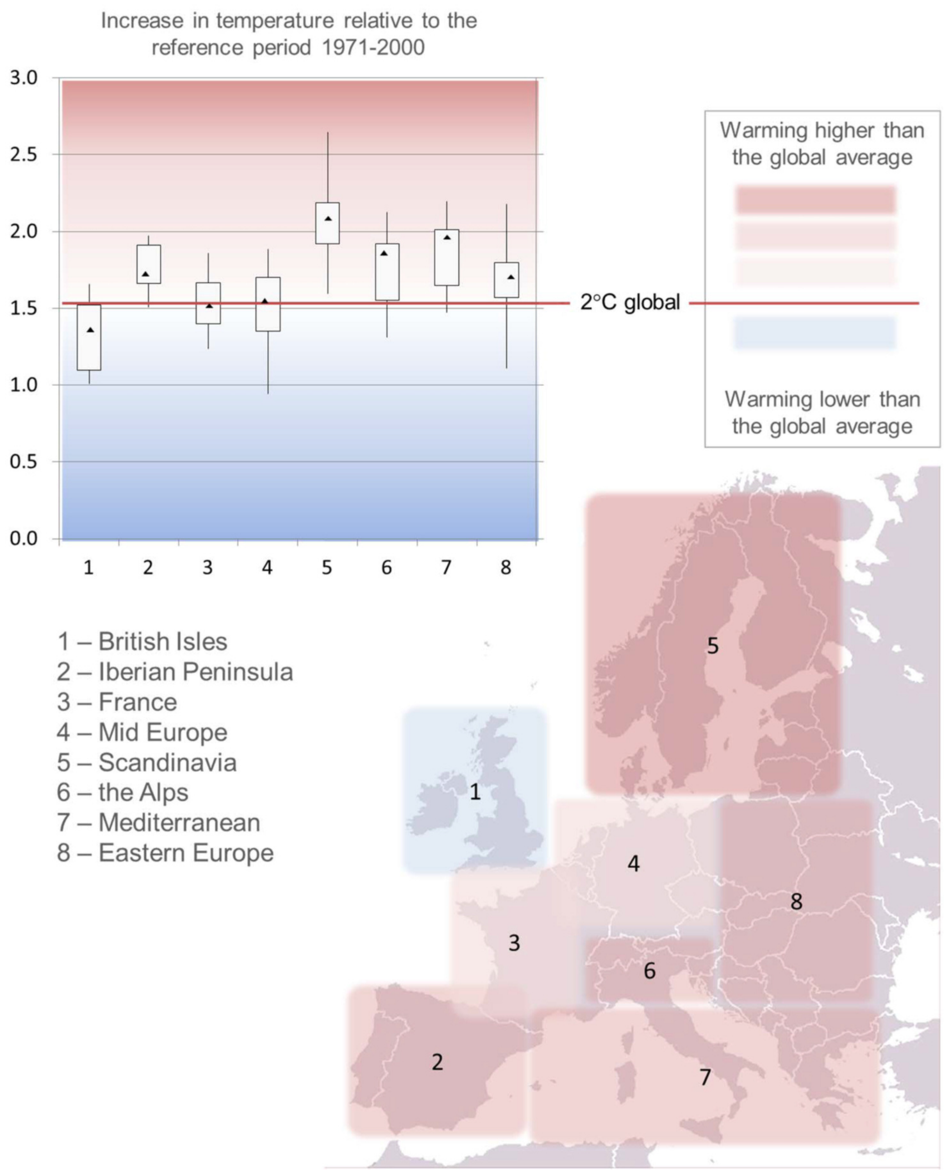


Figure 2. What does 2°C of global warming mean for different regions of Europe?

Change in Temperature in different European regions corresponding to 2°C of global average warming – relative to the reference period 1971–2000. The figure shows the results for 15 Regional Climate Model Simulations for Europe (representing different GCM-RCM combinations) for the A1B scenario. The 2°C period has been estimated as the 30-year interval when the global mean temperature reaches +2°C relative to 1881–1910 (the pre-industrial period). For the RCM runs the 2°C period has been taken from the driving global models (noting this varies with each GCM). The figure shows the range (whiskers), 25/75th percentile (box) and median (triangle) from the simulations. Source: Adapted from Landgren et al. (2013).

The detailed changes for summer (June, July and August, JJA) and winter (December, January and February, DJF) warming are shown in Figure 3. This shows the higher warming trend across Europe, with the exception of the British Isles and Iceland in winter (shown on the right) due to the influence of the North Atlantic, and the same regions and some parts of Southern Scandinavia and the Baltic in summer (shown on the left).

Figure 3 thus shows a very strong distributional pattern of warming across Europe, and highlights some countries experience much greater warming than others. The IMPACT2C project has analysed these regional difference.

On average, we find that a global temperature change of 2°C leads to a similar or slightly lower level warming over coastal areas of North-Western Europe in all seasons, but a more intense warming (of up to +3°C) in Northern and Eastern Europe in Winter and in Southern Europe in Summer.

This relative change – with increased summer warming in the Southern European countries in summer – will increase heat-related impacts in countries that already experience high temperatures, notably heat-related health impacts and energy for cooling demand (EEA, 2012).

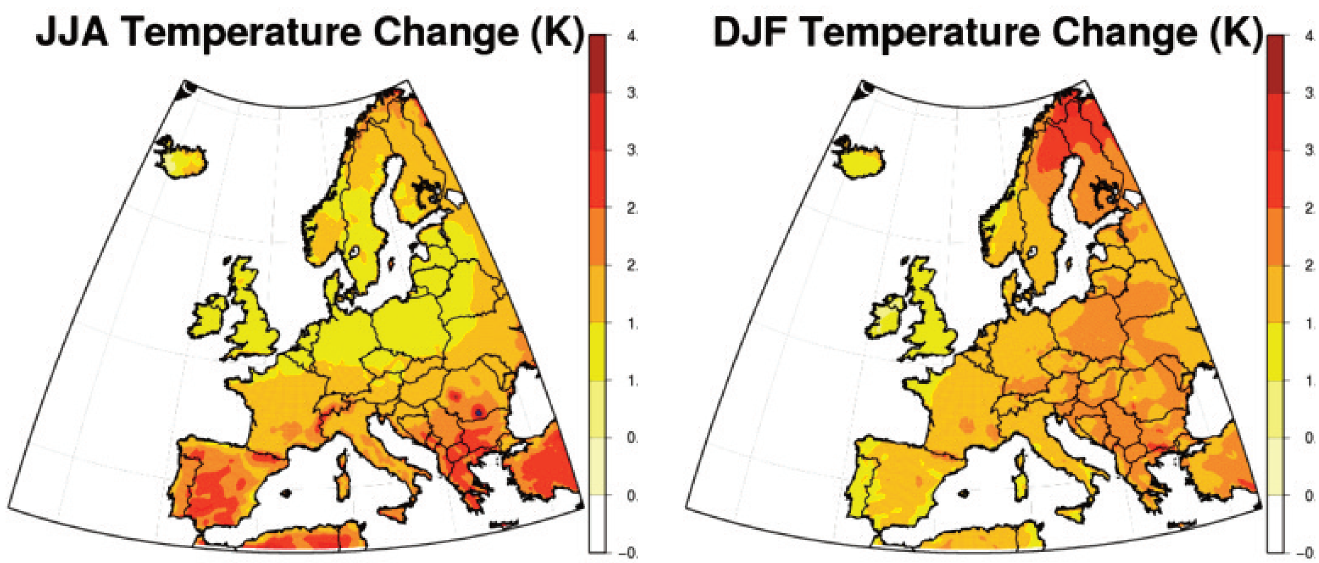


Figure 3. The increase in seasonal temperature (from 1971–2000) across Europe at 2°C of global average warming.

Average RCM simulated temperature (°C) for summer (left) and winter (right) between the reference period (1971–2000) and period corresponding to global temperature difference of 2°C. Note that this takes account of the 0.5°C of warming that has already occurred, and that those areas that are orange or red are warming faster than the global average. Results of 15 GCM-RCM combinations.

Key message. A key finding is Europe warms at a higher level compared to the global average, i.e. much of Europe will experience more than 2°C of change (relative to pre-industrial) even if the global goal is achieved. Moreover, some parts of Europe will experience much higher levels of warming, with potentially 3°C of warming in the Iberian Peninsula and other parts of the Mediterranean in the summer. This will increase the relative level of heat related impacts in these areas.

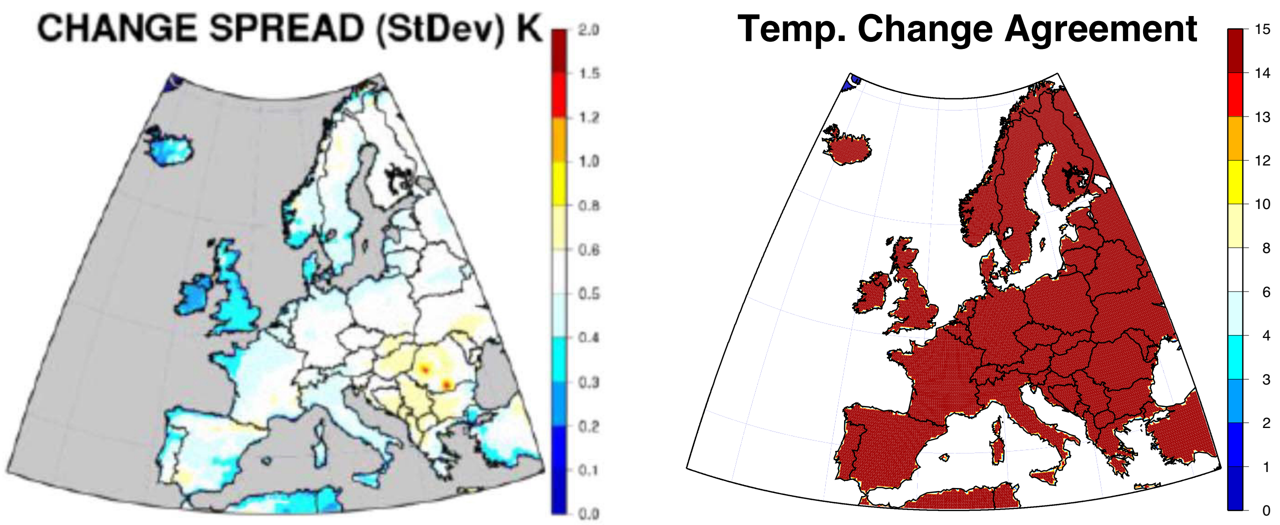


Figure 4. Do the models agree?

Left. Standard deviation of the climate change signal. Right Number of models agreeing on an increase in summer temperature. Analysis of RCM simulated temperature (°C) between the reference period (1971–2000) and period corresponding to global temperature difference of 2°C for 15 GCM-RCM combined simulations.

There is an even stronger relative increase in the Artic, which is important in relation to impacts on ecosystems. However, it is also noted that the higher warming in Northern and Eastern Europe in winter will have a mix of positive as well as negative effects. While there will be benefits in reducing current cold-related mortality as well as winter heating costs (EEA, 2012), there would also be negative impacts, such as on winter tourism and ecosystems. These differences will get larger in later years after 2050. Indeed the Iberian Peninsula has a mean projected increase of up to 5°C by 2071–2100 for this scenario.

The IMPACT2C project has also investigated the robustness of these findings (see Figure 4) (based on Kjellström et al. 2013). This is important in understanding the confidence in the results. Figure 4 shows the standard deviation (left) across the models of mean temperature change (over all seasons), a measure of the ‘spread of uncertainty’ and number of models agreeing on warming, measuring the ‘agreement across the models’ for summer temperature (right). This illustrates two key findings. First, all of the models agree (universally) on the warming signal for Europe, and they also show high agreement on the distributional pattern of warming across Europe. Second, the uncertainty is much smaller than the amplitude of changes.

Temperature extremes

While changes in seasonal averages are important, the change in the frequency and/or intensity of extreme events may have early and potentially more significant consequences to society (see IPCC, 2012). One of the key concerns for Europe is the potential increase in summer extreme heat, which is linked to health impacts and temperature related mortality (Baccini et al. 2008). To investigate these issues, the IMPACT2C project has looked at the changes in extremely hot days (shown in Figure 5), using the metric of the 20-year return values (i.e. the peak event that happens on average once every 20 years).

Under the 2°C scenario, the largest summertime changes in daily maximum temperature (3-4°C) are found over South-Eastern Europe and the Iberian Peninsula (Figure 5, left). In areas where this value is highest (Iberian Peninsula, France, the Balkans) the 20-year return value is expected to rise in many areas in the range 42°C to 45°C and above in some areas (see Figure 5, right).

This pattern of change – with a higher relative change in the South of Europe – is likely to exacerbate existing distributional impacts, i.e. to further increase the high levels of heat related

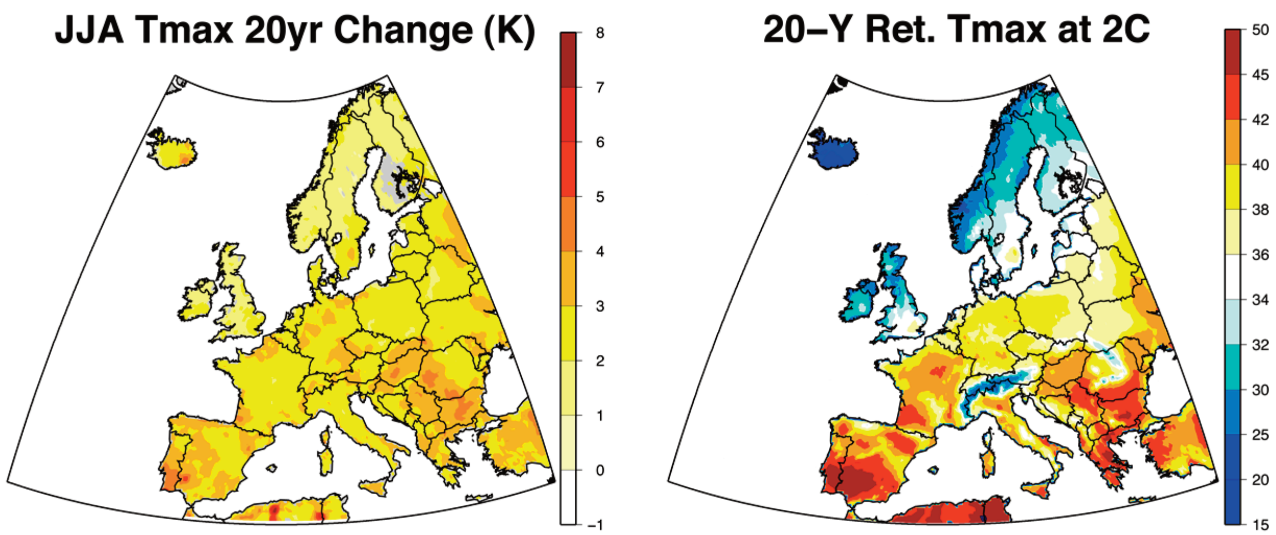


Figure 5. Left: The change in 20 year return value for European daily maximum temperature (Tmax). Right: The mean absolute 20-year return value for the +2°C climate.

Left. Analysis between the reference period (1971–2000) and period corresponding to global temperature difference of 2°C period corresponding to global temperature difference for 15 GCM-RCM combined simulations.

mortality and energy for cooling in these regions (though higher heat extremes will also be important in other countries that are not used to high temperatures). However, lower extremes of daily minimum temperatures occur in some Northern areas of Europe, which will have benefits, for example in reducing winter cold extremes and cold related mortality.

Precipitation

The IMPACT2C project has also analysed the changes in precipitation in Europe for a 2°C world. The change in precipitation projected across Europe from different climate models is much greater than for temperature and the distributional patterns are more pronounced. Part of this difference is caused by the fact that the climate is variable, even in the absence of changes in greenhouse gas concentrations. Nonetheless, there are robust patterns of change. The changes are shown in Figure 6.

For 2°C of global average warming, robust increases in winter precipitation (Figure 6, right) are projected on average over Central and Northern Europe, of the order of +10-15%, and robust increases in summer precipitation are also projected (Figure 6, left) for Northern Europe.

At the same time, robust decreases in summer precipitation, of the order of –10-15%, are projected for Central/Southern Europe. These changes exacerbate existing water management issues in these areas of Europe, i.e. potentially increasing water deficits in the South during summer. There are also robust increases in summer precipitation over Scandinavia).

In other parts of Europe, the changes are more uncertain, and the models sometimes even project differences in the direction of change (i.e. whether increases or decreases will occur).

The level of agreement between models translates through to a higher standard deviation. The only area where all models agree on the sign of change is Scandinavia (increase in both seasons) and some areas in South-Eastern Europe and the West coast (decrease in summer), as shown in Figure 7.

Heavy precipitation extremes

Floods are among the most important weather-related loss events in Europe and can have large economic consequences: ABI (2005) reported average annual losses are €6 to 7 billion in Europe and the EEA (2010) reports total losses of over €50 billion have occurred over the past

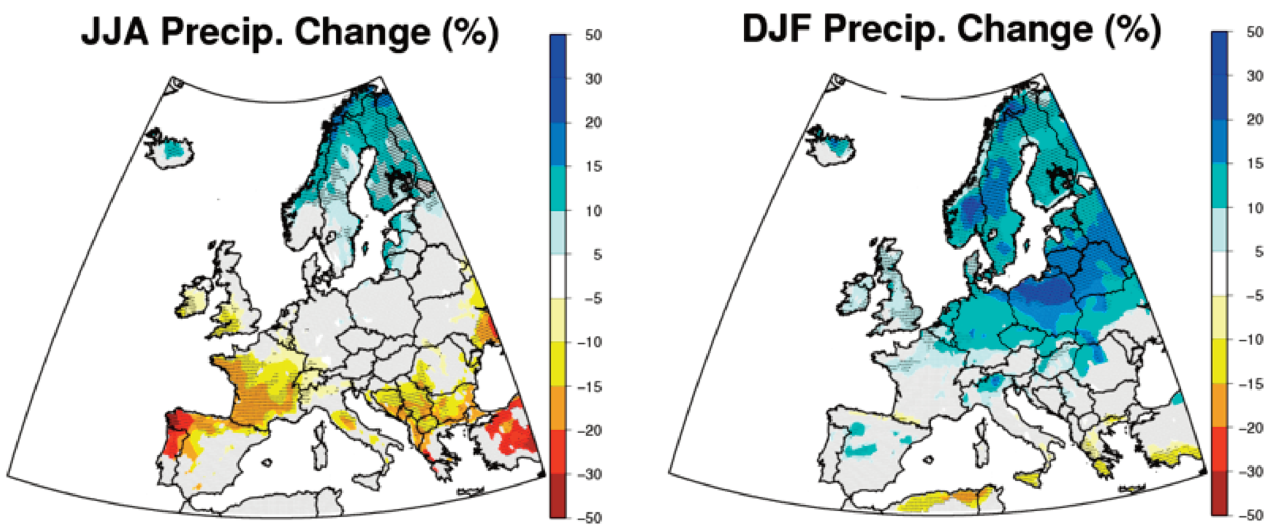


Figure 6. The change in seasonal European precipitation (%) (from 1971–2000) with 2°C global average warming. Left (summer). Right (winter).

Average RCM simulated precipitation between the reference period (1971–2000) and period corresponding to global temperature difference of 2°C. Results of 15 GCM-RCM combinations. Only areas where at least 12 models agree are coloured and areas where at least 14 models agree are dotted areas.

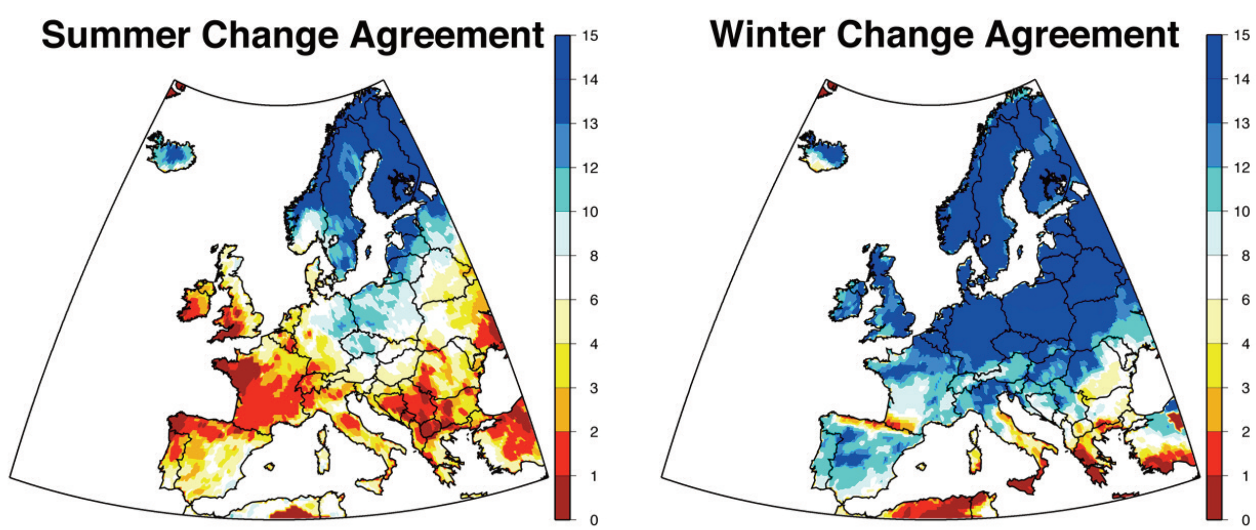


Figure 7. Do the models agree?

Number of models agreeing on an increase in summer (left) and winter (right) precipitation (15 GCM-RCM combined simulations).

decade. The analysis has therefore considered changes in heavy precipitation, associated with higher flood risks, again looking at the 20-year return value.

The model simulations (Figure 8) show increases across much of Europe in both summer and winter, with (ensemble mean) intensity increasing by +5% to 15% (and in some areas, even more). The increase in heavy precipitation found under the 2°C scenario therefore has the potential to increase flood risks. The increase is marked over Eastern Europe and Scandinavia in summer and over Southern Europe in winter. The increase in Eastern Europe is a particular concern because this is one of the existing flood hot-spots in Europe. These increases are found in a majority of models in most areas, but not all.

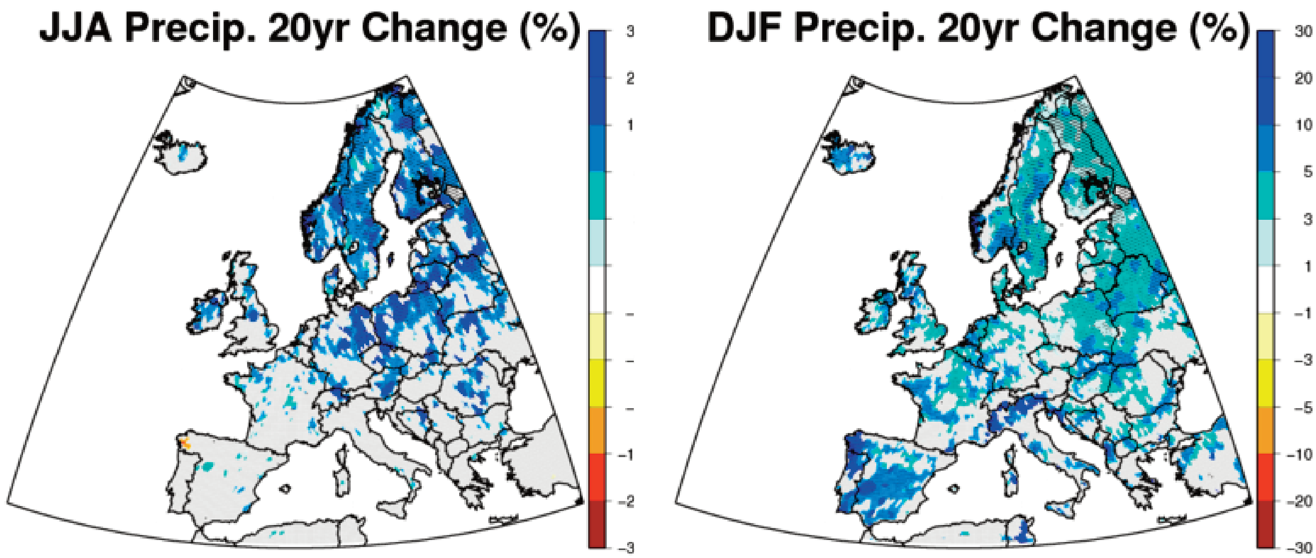


Figure 8. The increase in heavy precipitation events with a return period of 20 years.

Average RCM simulated heavy precipitation for summer (left) and winter (right). between the reference period (1971–2000) and period corresponding to global temperature difference of 2°C for Results of 15 GCM-RCM combinations. Only areas with at least 12 models agreeing on sign are coloured. Areas where at least 14 models agree on sign are highlighted with dots.

Wind Storms

The analysis has also looked at the potential changes in wind storms, which are among the most damaging extreme events in Europe (ABI, 2005). The analysis has considered the change in the 99th percentile of the daily maximum 10-meter wind speed for each season (I99), with results shown in Figure 9.

There are increases of extreme winds (more than 12 models out of 15 agree in sign) of up to 10% seen over some areas of Central and Eastern Europe in winter. Over other regions the change is generally positive but modest.

Key message. Under the 2°C of global change, there are large increases in extreme events for Europe, with much larger increases in daily maximum temperature over parts of Southern and South-Eastern, as well as increases in heavy precipitation across all of Europe. These will cause more frequent and severe high impact events.

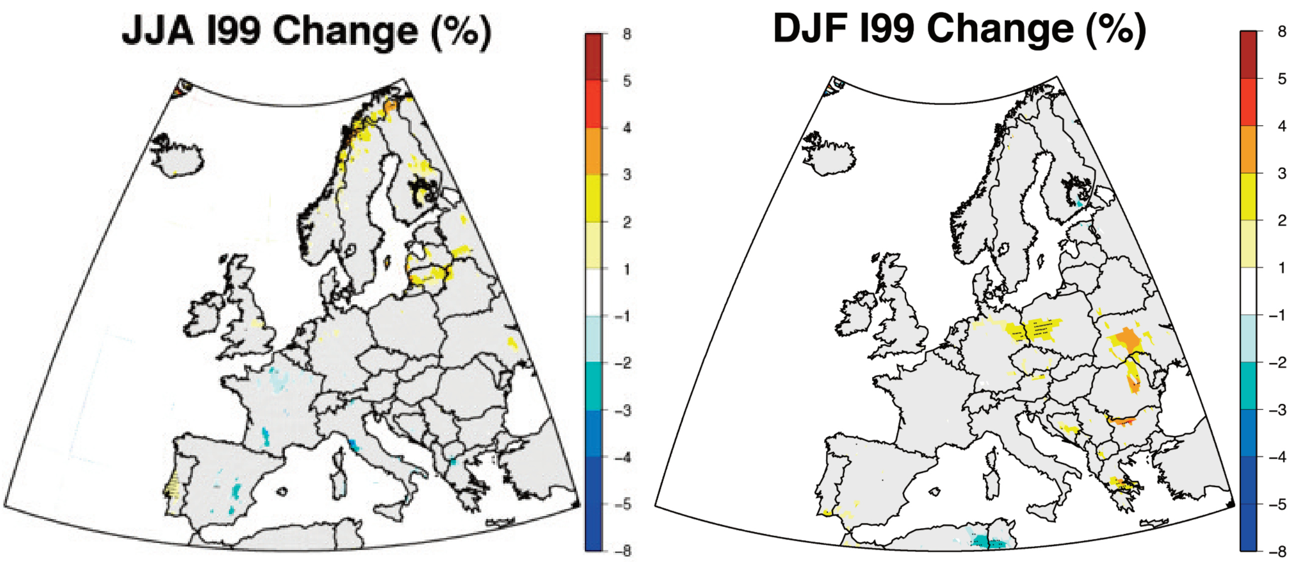


Figure 9. The increase in extreme winds.

Average RCM simulated extreme winds (I99) for summer (left) and winter (right) between the reference period (1971–2000) and period corresponding to global temperature difference of 2°C. Only areas where at least 12 models agree are coloured and areas where at least 14 models agree are dotted areas.

Summary

Overall, there is also a strong distributional pattern of warming seen across Europe (and thus different countries) under 2°C of global change. Many of the changes – in terms of the sign and magnitude as well as the spatial location and distributional pattern – will exacerbate impacts across Europe.

As an example, there is higher relative warming and greater relative increases in heat extremes in southern Europe in summertime, which will drive heat related impacts such as cooling and mortality. Similarly, there are higher relative (and more robust) signals for increased precipitation and heavy precipitation events in Eastern Europe along existing flood risk corridors, but lower projected summer rainfall in the Mediterranean which will increase pressures on water and drought management.

While there are some exceptions (e.g. higher winter warming in the north, which will have the benefit of reduced winter mortality and reduced winter heating demand, noting that winter warming will also lead to negative impacts on winter tourism and natural ecosystems), the general finding is that the distributional pattern of changes across Europe increase relative risks compared to a scenario where Europe warms equally. This is of high policy relevance: even if the 2°C goal is achieved, Europe will experience strong distributional impacts: a 2°C world in Europe is therefore not benign and further work to explore these key hotspots and advance adaptation is needed.

How do the new RCP scenarios change our understanding of when 2°C occurs?

Many existing climate model projections are based on the emission scenarios of the IPCC Special Report on Emission Scenarios, i.e. the SRES (Nakićenović et al. 2000).

More recently, these have been replaced by the Representative Concentration Pathways (RCPs), which includes four RCPs (van Vuuren et al. 2011). These are used in the new Fifth Assessment Report of the IPCC (IPCC, 2013) and apply a different approach to the previous SRES scenarios.

There are four RCPs which span a range of possible future emission trajectories over the next century, with each scenario corresponding approximately to a level of total radiative forcing (W/m^2) in the year 2100.

The first RCP is a deep mitigation scenario that leads to a very low forcing level of 2.6 W/m^2 (RCP2.6), only marginally higher compared to today's situation (2.29 W/m^2, IPCC, 2013) and this scenario achieves the 2°C goal. There are also two stabilization scenarios (RCP4.5 and RCP6)). Finally, there is one scenario with very high greenhouse gas emissions (RCP8.5). These corresponds to CO_2 concentrations reaching 421 ppm (RCP2.6), 538 ppm (RCP4.5), 670 ppm (RCP6.0), and 936 ppm (RCP 8.5) by the year 2100 (IPCC, 2013).

These scenarios therefore cover the range from high emission futures to scenarios consistent with the 2°C goal.

A key question is whether the new RCPs vary when compared to the SRES, i.e. do they indicate whether we will hit the 2°C goal earlier or later.

The IMPACT2C project has investigated this issue by comparing the SRES and RCP scenarios with regard to the time when key global average temperature thresholds are exceeded. This spans a range from +1.5°C to +4.5°C compared to pre-industrial values.

A summary of the findings is shown below in Figure 10.

Along the horizontal x-axis are increasing temperature thresholds for global average surface temperature.

For each temperature threshold, the columns compare three of the SRES scenario on the left (B1, A1B, A2 – reflecting low, medium-high and high emission scenarios) against the four new RCP scenarios on the right.

The vertical y-axis shows the likelihood that a certain threshold will be reached at a certain year in the 21st century using a colour scale linked to the IPCC likelihood scale.

Green colours indicate that it is exceptionally unlikely (0-1%) or very unlikely (0–10%) that the threshold will be exceeded. As an example, the colour scale for the 4.5°C threshold (far right) show dark green colours, showing that this temperature threshold is unlikely to be exceeded this century.

The yellow and orange colours indicate that it is as likely as not (33–66%) or likely (66–100%) that the threshold will be exceeded for given years.

The red and dark red colours indicate that it is very likely (90–100%) or virtually certain (99–100%) that the threshold will be exceeded for given years.

Looking at the 1.5°C ambition threshold level (far left) – it can be seen that it is virtually certain or very likely it will be exceeded before the end of the century, even with the ambitious RCP2.6 scenario. It can be expected (as likely as not) that the threshold will be exceeded around or before 2040.

For the 2°C goal, the likelihood varies with the scenario – but, with the exception of the B1 and

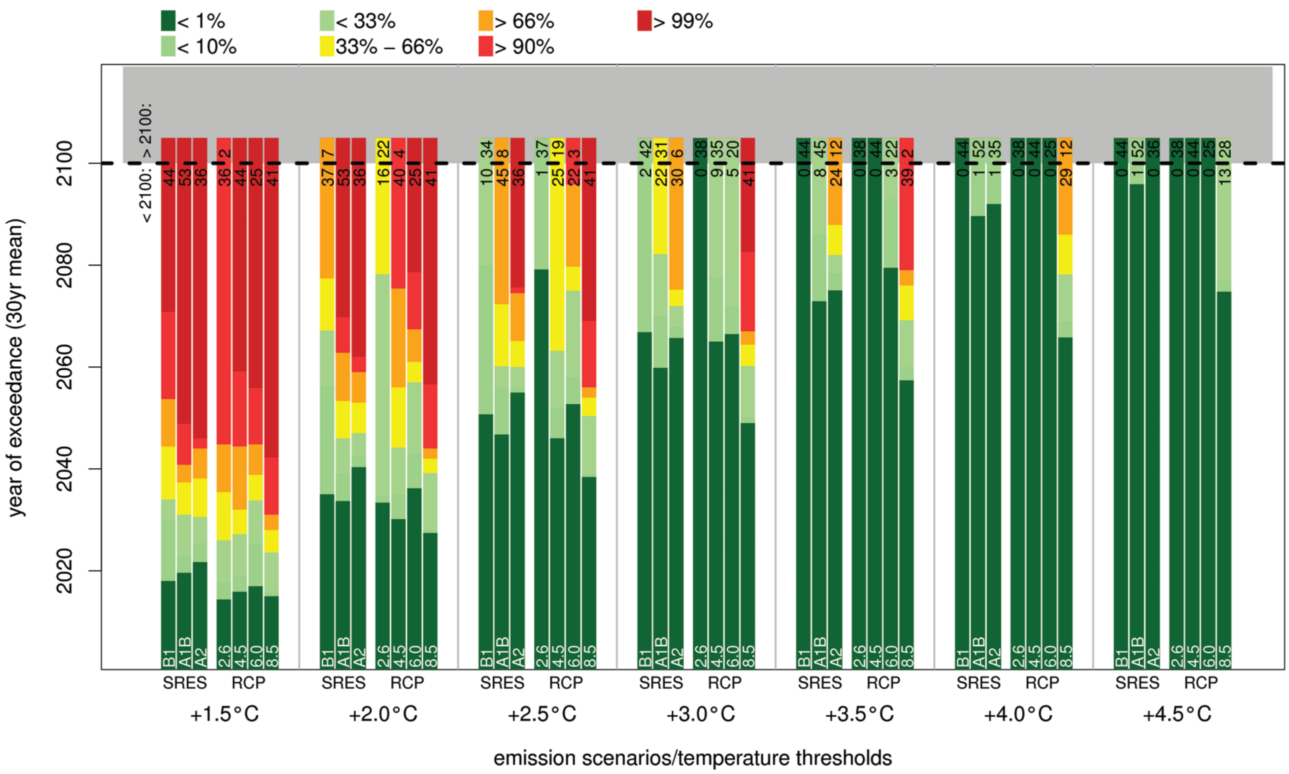


Figure 10. Likelihood of exceeding global average temperature thresholds in different years

The figure shows the likelihood level (colour scale) of the global temperature exceeding temperature thresholds (x-axis) in different time periods (y-axis). The number of model runs is shown in numbers, showing numbers that stay below (above dotted line) or exceed (above dotted lines) for SRES and RCP runs. Source: Andreas Gobiet and Martin Suklitsch, University of Graz,

RCP2.6 scenarios, it is virtually certain or very likely, that the threshold is exceeded before the end of the 21st century and it can be expected (as likely as not) to be exceeded around or earlier than 2060.

It is also highlighted that the likelihood of exceeding the 1.5°C or 2°C goals earlier in time are slightly higher than in the RCP (non-mitigation) scenarios compared to the previous SRES analysis.

For temperature thresholds of 3.5°C or higher, only the A2 and RCP8.5 scenarios indicate a considerable probability to be reached within this century.

Key message. The analysis shows that regardless of the emission scenario assumed, it is expected that +1.5°C of warming (relative to pre-industrial levels) will be exceeded around or before 2040. In addition, all scenarios except B1 and RCP2.6 indicate that +2°C is expected to be exceeded around or earlier than 2060. It is also highlighted that the likelihood of exceeding the 1.5°C or 2°C goals earlier is slightly higher than in the RCP analysis (non-mitigation) scenarios compared to the previous SRES.

The IMPACT2C project has also compared how the earlier analysis of when we might hit 2°C (Figure 1) changes with the new RCPs. The comparison is shown in Figure 11, showing the central year (in a 30 year time window) when the 2°C goal is exceeded.

The new deep mitigation scenario (RCP2.6) largely avoids 2°C of warming (relative to pre-industrial), though even under this scenario, some warmer models exceed the goal. For the RCP4.5 scenario, the time period when the 2°C goal is exceeded is similar to the previous A1B analysis, even though the temperature increase in the later part of the century (for RCP4.5) is much lower. Finally, for the high emission scenario (RCP8.5), the 2°C goal is exceeded sooner than the previous A1B analysis, and continues to rise much more sharply thereafter.

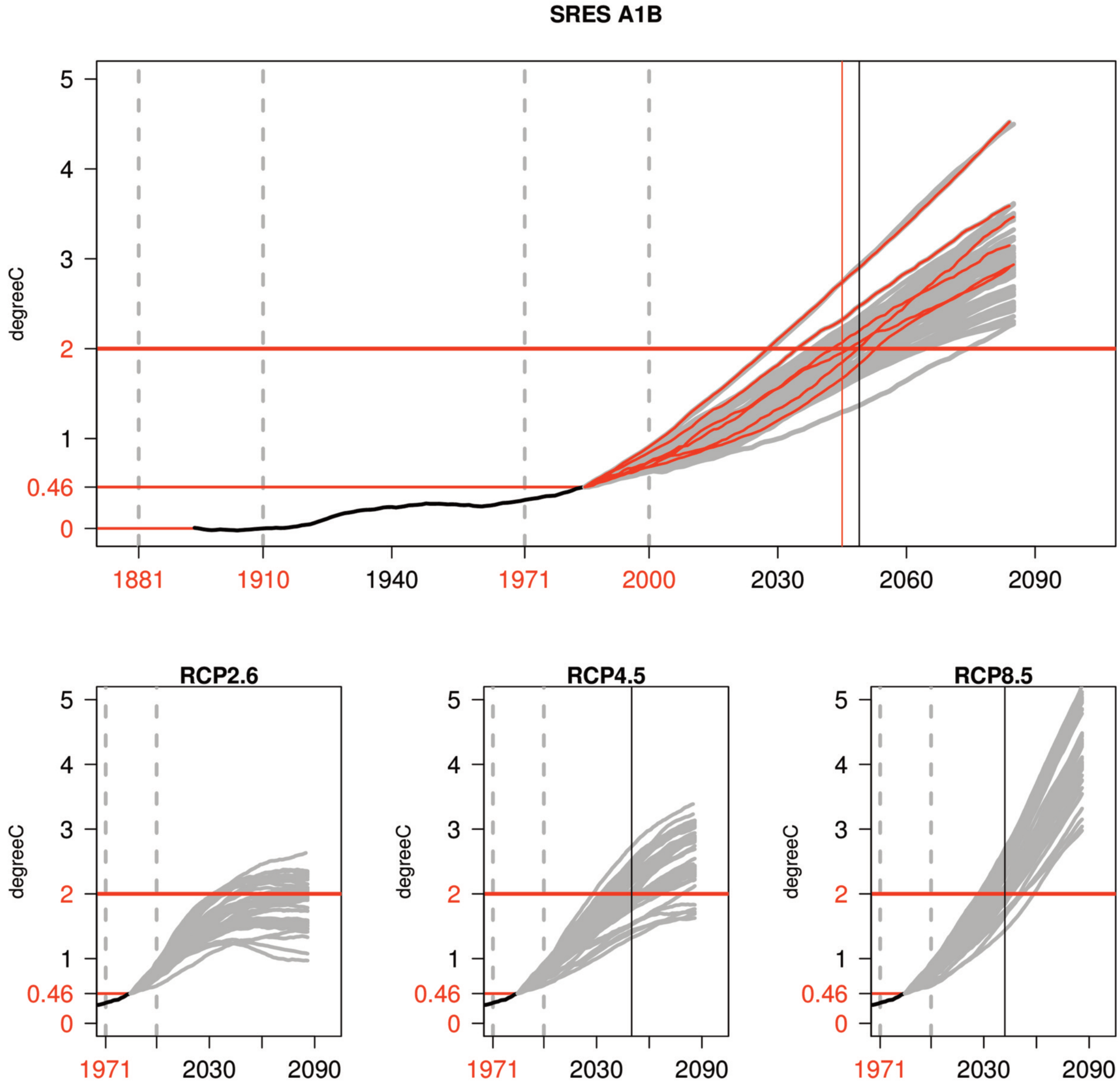


Figure 11. When might we hit 2°C: Comparing the SRES A1B to the RCPs?

Analysis of global temperature change and the 2°C goal. Observed historical (black line) and future projections from different Global Climate Models (GCMs) based on the A1B emission scenario and 2.6, 4.5 and 8.5 RCP scenarios. Time series are smoothed using a 30-year running mean. The 2°C threshold is marked in red. Source: Vautard et al. 2014.

What do the climate projections tell us about the rate of climate change – and the possible limits of adaptation?

Most climate change assessments report on the future level of projected change. While this is extremely important, it is becoming clear that the rate of change, as well as the absolute level of warming, is important.

This is because the speed of change is critical in the ability of natural, physical and economic sectors to adapt. This is also linked to the emerging concept of the limits of adaptation, which may relate to absolute limits, but may also arise due to the speed of change in relation to economic, social or behavioural limits. As an example, at high rates of climate change, species migration rates maybe exceeded. Similarly, the rate of change maybe too fast for standard investment renewal and replacement cycles, significantly increasing the costs of adaptation, and potentially leading to stranded assets.

Historically, the global combined land and ocean temperature data show an increase of about 0.85°C over the period 1880–2012 as a linear trend (IPCC, 2013). Over the last sixty years (1951–2012) the rate of change has been 0.12 [0.08 to 0.14] °C per decade

However, as shown in Figure 11, there is likely to be an acceleration of future climate change in the next few decades – and especially post 2050 under non-mitigation scenarios. This has the potential to significantly increase decadal warming, compared to historially observed rates.

The recent IPCC WGI summary reports that the global mean surface temperature change for the period 2016–2035 relative to 1986–2005 will likely be in the range of 0.3°C to 0.7°C. This implies a much higher decadal change over the next few decades, when compared to historical trends over the last sixty years. The experience of warming – even from recent decades – is therefore not a good indicator of the scale and rate of changes potentially likely in the near future

Moreover, these represent average global rates. As highlighted earlier in this note, Europe is likely to warm faster than the global average, particularly in some regions. This means that much of Europe will experience higher decadal rates of change than the global average. These high rates of change are likely to increase impacts, particularly in the fastest warming regions of Europe, and raise issues of the limits of adaptation much earlier than anticipated.

Recognising this, the IMPACT2C project is investigating the rates of change in Europe, using the downscaled regional climate models, and will analyse the implications on impacts and adaptation.

Key message. The rate of climate change is important in relation to impacts. Historical rates of global change have averaged just over 0.1°C per decade. However, these rates are likely to increase in the near future, potentially to 0.3°C to 0.7°C per decade over the next few decades. As much of Europe warms at a faster rate than the global average, this will mean even higher rates of change for some regions of Europe. These high rates of changes are likely to be very important in relation to the level of impacts and raise earlier concerns in relation to the limits of adaptation.

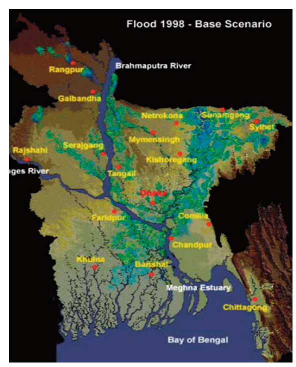
What does 2°C mean for global and European vulnerability hot-spots and tipping points?

The final issue related to the 2°C goal is in relation to the risks of catastrophic events, often know as tipping points or tipping extremes (Lenton et al. 2008). These are large-scale (non-linear) discontinuities that could push the climate system into undesirable states, and could lead to major catastrophic events, or pass thresholds that would trigger changes that would be difficult to control. They include examples such as the abrupt solid ice discharge from the West Antarctic Ice Sheet or the onset of large-scale disintegration of Greenland Ice Sheet.

More recent literature indicates that some of these large-scale discontinuities may emerge at lower warming temperatures than previously thought (e.g. Smith et al. 2008, updating IPCC, 2001). While the critical threshold temperatures that could trigger these events is highly uncertain, elicitation on potential probability intervals (Kriegler et al. 2009) indicates they are low (although not negligible) up to 2°C of warming, as compared to being significant for higher warming scenarios (above 4°C) and far from low for intermediate levels of warming (2 to 4°C). Levermann et al. (2012) considered the potential for some of these tipping elements on Europe, indicating the likelihood of transition emerges above 2°C for a number of major risks.

While the information on the likelihood of such large-scale events remains highly uncertain, especially with regard to the critical threshold temperatures that might trigger them, these studies highlight the concerns in moving above 2°C of warming.

The IMPACT2C project is investigating a number of the key global and European hot spots to investigate these issues with case studies in Europe of highly vulnerable regions, as well as a number of key global hot spots. The latter include Bangladesh (the combined risks of flooding from sea level rise, coastal wind-storms and increased peak river flows), the Maldives (the risks of sea level rise to low-lying developing islands) and Africa with case studies along the major river systems of the Nile and Niger.



Key message. The 2°C goal is critical in the consideration of potential global or European tipping points and vulnerability hot spots, because it is seen as a possible precautionary level that is likely to avoid the occurrence of most major events. The project is investigating a number of key global and European hot spots to investigate these issues, with case studies in Europe, Bangladesh, the Maldives and Africa.

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To find out more about the IMPACT2C project, please visit:
http://www.hzg.de/mw/impact2c/

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