Guide to the Science of Climate Change in the 21st Century

Chapter 21
Sixth Assessment Report – AR6 WGI Climate Change 2021: The Physical Science Basis

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Eco-print, "Tree of Life", Nora Manz 2020

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Chapter 21.0 Sixth Assessment Report – AR6 WGI Climate Change 2021: The Physical Science Basis

21.1 Introduction

The reports from the different working groups of the IPCC Sixth Assessment Report, AR6, https://www.ipcc.ch/assessment-report/ar6/ are as follows:

- AR6 WGI Climate Change 2021: The Physical Science Basis was published August 9, 2021 https://www.ipcc.ch/report/ar6/wg1/#FullReport.
- AR6 WGII Climate Change 2021: Impacts, Adaptation and Vulnerability was published February 28, 2022 https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/.
- AR6 WGIII Climate Change 2021: Mitigation of Climate Change was published April 4, 2022 https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf.
- AR6 Synthesis Report: Climate Change 2022 is expected to be available September 2022.

Four other reports that have been published since AR5 are:

- Special Report Global Warming of 1.5°C was approved by the IPCC on October 8, 2018 https://www.ipcc.ch/sr15/.
- Special Report Climate Change and Land was published August 8, 2019 https://www.ipcc.ch/srccl/.
- Special Report Ocean and the Cryosphere was published September 24, 2019, https://www.ipcc.ch/srocc/.
- 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories was published May 2019 https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/ .

A fifth report that is currently in preparation is 'Methodology Report on Short-lived Climate Forcers' https://www.ipcc.ch/report/methodology-report-on-short-lived-climate-forcers/.

Preparation of the Sixth Assessment Report began immediately, if not before, the AR5 was published in 2013. The recommendations from AR5 were clear as to the global temperature targets for 2100 – between 1-2°C above pre-industrial. If current emission rates continue it is considered likely that 1.5°C will be reached between 2030 and 2050 – much sooner than 2100.

At the 21st Conference of the Parties (COP21) in December 2015, 195 nations adopted the Paris Agreement (https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-

December 12, 2020 – Fifth Anniversary of the Paris Agreement
August 9, 2021 – Publication of IPCC AR6 WGI, Climate Change: The Physical Science Basis, February 28, 2022 IPCC AR6 WGII, Climate Change: Impacts, Adaptability and Vulnerability and April 4, 2022 IPCC AR6 WGIII, Climate Change: Mitigation

agreement). The first instrument of its kind, the landmark agreement includes the aim to strengthen the global response to the threat of climate change by 'holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels'.

In 2016 the IPCC accepted an invitation from the United Nations Framework on Climate Change to prepare a 'Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty; Special Report on greenhouse gas (GHG) fluxes in land-based ecosystems, land use and sustainable land management in relation to climate change adaptation and mitigation, desertification , land degradation and food security; and, on Special Report on the ocean and the cryosphere in a changing climate.' The Special Reports are intended to provide guidance as to which mitigation strategy to choose (possible) to achieve the emission objective.

The Special Report Global Warming of 1.5°C was approved by the IPCC on October 8, 2018 https://www.ipcc.ch/sr15/. The special report uses shared socioeconomic pathways, SSPs, described in Tables 21.1 and 21.2, used to select workable representative concentration pathways, RCPs, (original four plus three as shown in Figure 21.1). CMIP5 models were used to perform simulations.

The Special Report Climate Change and Land was published August 8, 2019 https://www.ipcc.ch/srccl/. The special report also uses shared socioeconomic pathways, SSPs, described in Tables 21.1 and 21.2 used to select workable representative concentration pathways, RCPs, (original four plus three) as shown in Figure 21.1. CMIP5 models were used to perform simulations. The report was prepared by the Working Groups 1, 2 and 3 in collaboration with the Task Force on National Greenhouse Gas Inventories.

The Special Report Ocean and the Cryosphere was published September 24, 2019, https://www.ipcc.ch/srocc/. The special report uses RCP2.6 and RCP8.5. CMIP5 models were used to perform simulations.

21.2 Outcomes of note from Special Reports

1. Achieving a temperature increase of 1.5°C or less above pre-industrial levels in 2100, carbon neutrality or net zero emissions must be realized by 2050.
2. A decrease in CO_2 emissions of about 45% from 2010 levels (9.995 GtC see https://www.co2.earth/global-co2-emissions) is required by 2030.
3. Some form of carbon dioxide removal will be required.

In order to meet their commitments to the Paris Agreement countries must declare their 'nationally determined contributions' (NDCs). These are likely similar to decreases in CO_2 emissions of about 45% from 2010 levels by 2030 and carbon neutrality by 2050. Progress toward meeting these commitments is reviewed every five years.

Net zero emissions by 2050 is the global objective for carbon dioxide emissions. Net zero emissions by 2050 is in effect another pathway. It is discussed in detail Section 21.

21.3 Shared socio-economic pathways, SSPs

Tables 20.1 and 20.2 explain what is meant by the five SSPs. These are combined with the representative concentration pathways (RCPs) that will work with the desired SSPs as shown in Figure 20.1.

SSPs are developed in a similar manner to RCPs using Integrated Assessment Models (IAMs) as described in Sections 17.12 and 18.2.

An important discussion on emission scenarios may be found in a guest post in Carbon Brief 30 March 2022 which describes how not to interpret the emissions scenarios in the IPCC report, https://www.carbonbrief.org/guest-post-how-not-to-interpret-the-emissions-scenarios-in-the-ipcc-report?utm_campaign=Daily%20Briefing&utm_content=20220331&utm_medium=email&utm_source=Revue%20newsletter.

Box SPM. 1 | Shared Socio-economic Pathways (SSPs)

In this report the implications of future socio-economic development on climate change mitigation, adaptation and land-use are explored using shared socio-economic pathways (SSPs). The SSPs span a range of challenges to climate change mitigation and adaptation.

- SSP1 includes a peak and decline in population (~7 billion in 2100), high income and reduced inequalities, effective land-use regulation, less resource intensive consumption, including food produced in low-GHG emission systems and lower food waste, free trade and environmentally-friendly technologies and lifestyles. Relative to other pathways, SSP1 has low challenges to mitigation and low challenges to adaptation (i.e., high adaptive capacity)

- SSP2 includes medium population growth (~9 billion in 2100), medium income, technological progress, production and consumption patterns are a continuation of past trends, and only a gradual reduction in inequality occurs. Relative to other pathways, SSP2 has medium challenges to mitigation and medium challenges to adaptation (i.e., medium adaptive capacity).

- SSP3 includes high population growth (~13 billion in 2100), low income and continued inequalities, material-intensive consumption and production, barriers to trade, and slow rates of technological change. Relative to other pathways, SSP3 has high challenges to mitigation and high challenges to adaptation (i.e., low adaptive capacity).

- SSP4 includes medium population growth (~9 billion in 2100), medium income, but significant inequality within and across regions. Relative to other pathways, SSP4 has low challenges to mitigation, but high challenges to adaptation (i.e., low adaptive capacity).

- SSP5 includes a peak and decline in population (~7 billion in 2100), high income, reduced inequalities, and free trade. This pathway includes resource-intensive production, consumption and lifestyles. Relative to other pathways, SSP5 has high challenges to mitigation, but low challenges to adaptation (i.e., high adaptive capacity).

- The SSPs can be combined with Representative Concentration Pathways (RCPs) which imply different levels of mitigation, with implications for adaptation. Therefore, SSPs can be consistent with different levels of global mean surface temperature rise as projected by different SSP-RCP combinations. However, some SSP-RCP combinations are not possible; for instance RCP2.6 and lower levels of future global mean surface temperature rise (e.g., 1.5°C) are not possible in SSP3 in modelled pathways. {1.2.2, 6.1.4, Cross-Chapter Box 1 in Chapter 1, Cross-Chapter Box 9 in Chapter 6}

Table 21.1 Description of Shared Socio-economic Pathways (SSPs) taken from Summary for Policymakers, Special Report Climate Change and Land. https://www.ipcc.ch/srccl/

Socio-Economic Challenges to Mitigation	Socio-Economic Challenges to Adaptation		
	Low	Medium	High
High	**SSP5: Fossil-fuelled development** • low population • very high economic growth per capita • high human development • high technological progress • ample fossil fuel resources • very resource intensive lifestyles • high energy and food demand per capita • economic convergence and global cooperation		**SSP3: Regional rivalry** • high population • low economic growth per capita • low human development • low technological progress • resource-intensive lifestyles • resource-constrained energy and food demand per capita • focus on regional food and energy security • regionalization and lack of global cooperation
Medium		**SSP2: Middle of the road** • medium population • medium and uneven economic growth • medium and uneven human development • medium and uneven technological progress • resource-intensive lifestyles • medium and uneven energy and food demand per capita • limited global cooperation and economic convergence	
Low	**SSP1: Sustainable development** • low population • high economic growth per capita • high human development • high technological progress • environmentally oriented technological and behavioural change • resource-efficient lifestyles • low energy and food demand per capita • economic convergence and global cooperation		**SSP4: Inequality** • Medium to high population • Unequal low to medium economic growth per capita • Unequal low to medium human development • unequal technological progress: high in globalized high-tech sectors, slow in domestic sectors • unequal lifestyles and energy /food consumption: resource intensity depending on income • Globally connected elite, disconnected domestic work forces

Table 21.2 Shared socio-economic pathways explained in Special Report Global Warming of 1.5°C. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_Chapter2_Low_Res.pdf

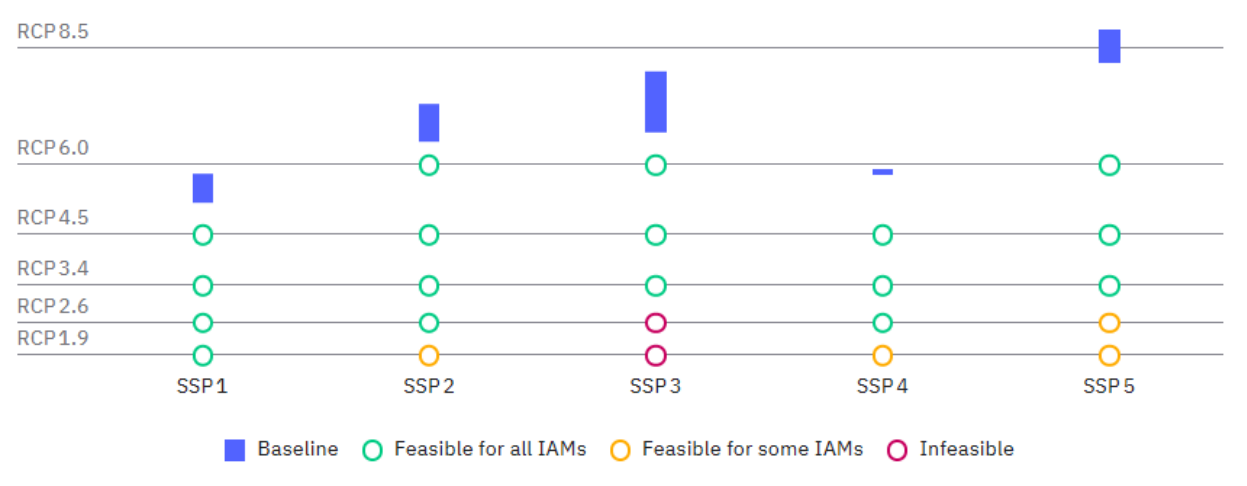

Figure 21.1 Climate change scenarios to be used in AR6.
https://climatescenarios.org/primer/mitigation/

21.4 AR6

A description of the CMIP6 models may be found in Section 17.6.

21.4.1 Validity of AR6 simulations

All AR6 simulations were performed using CMIP6 models. The results of these simulations from the 1850 to 2020 are shown in Figure 21.2 taken from AR6 Summary for Policymakers. Note that the observed and simulated results that include both human and natural factors agree very well in contrast to simulated results that only include natural factors. These results strongly support the validity of the CMIP6 models for predicting climate change and the overwhelming significance of human factors. Climate change, as observed, cannot be explained by natural factors alone.

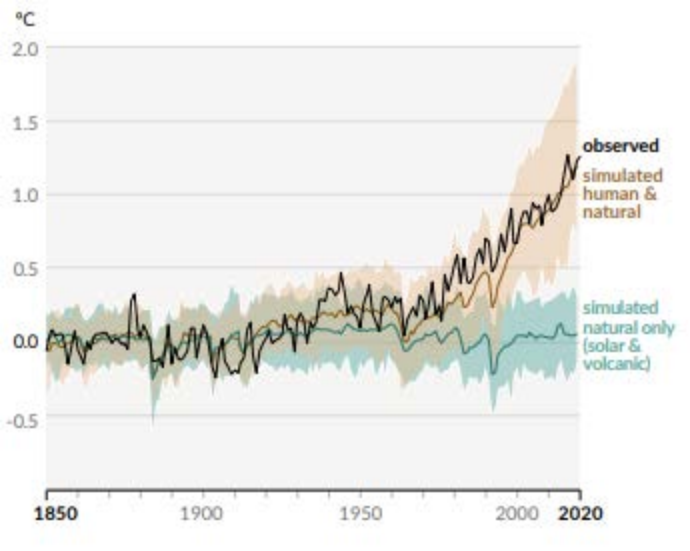

Figure 21.2 Change in global surface temperature (annual average) as observed and simulated using human and natural and only natural factors (both 1850-2020) °C https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

21.4.2 Details of emission scenarios used in AR6 simulations

The future annual emissions of CO_2 across five scenarios are shown in Figure 21.3 (also taken from AR6 WG1 SPM).

They also report emissions of other GHG contributors including methane and nitrous oxide and the aerosol, sulfur dioxide as shown in Figure 21.4.

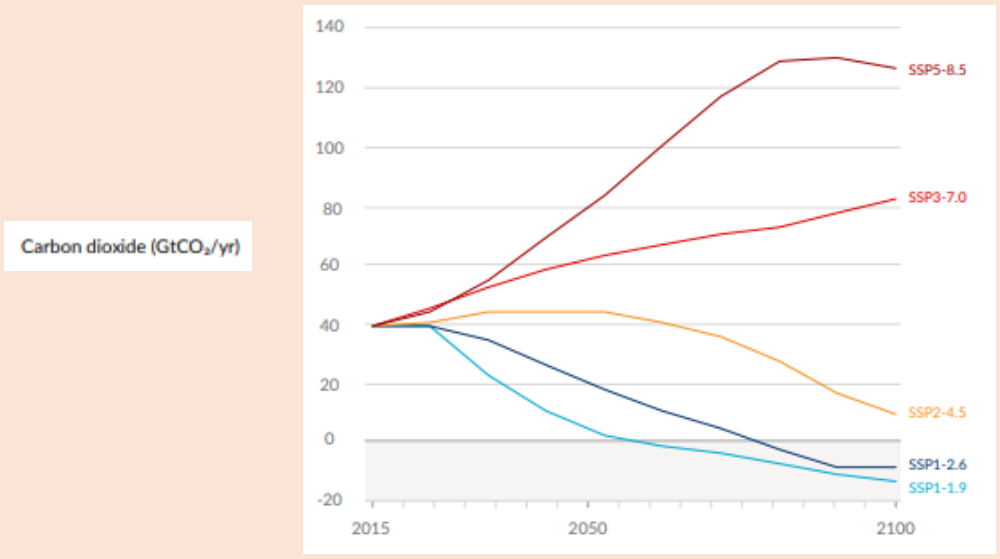

Figure 21.3 Future and annual emissions of CO_2 for five scenarios used in AR6 WG1 simulations https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

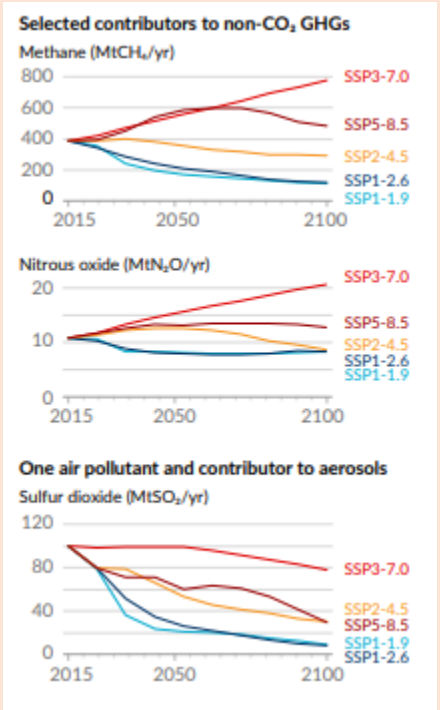

Figure 21.4 Emissions of other GHG contributors including methane and nitrous oxide and the aerosol, sulfur dioxide
https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

21.4.3 Global impact of human activities (also taken from AR6 WG1 SPM)

The global impact of human activities is extensive. The impacts as a function of the selected scenarios and time are particularly descriptive.

The impact of human activities on global surface temperature changes relative to 1850-1900 is shown in Figure 21.5.

The impact of human activities on September Arctic Sea ice area is shown in Figure 21.6.

The impact of human activities on global ocean surface pH is shown in Figure 21.7.

The impact of human activities on global mean sea level change relative to 1900 is shown in Figure 21.8.

It is clear that scenarios SSP1-2.6 and SSP1-1.9 will have the least impacts.

It is very important to note the starting year for the implementation of the various scenarios is 2015 and the concentration of GHGs and aerosols in the Earth's atmosphere at that time. If the composition of the starting value increases the predicted results will shift upward (not illustrated).

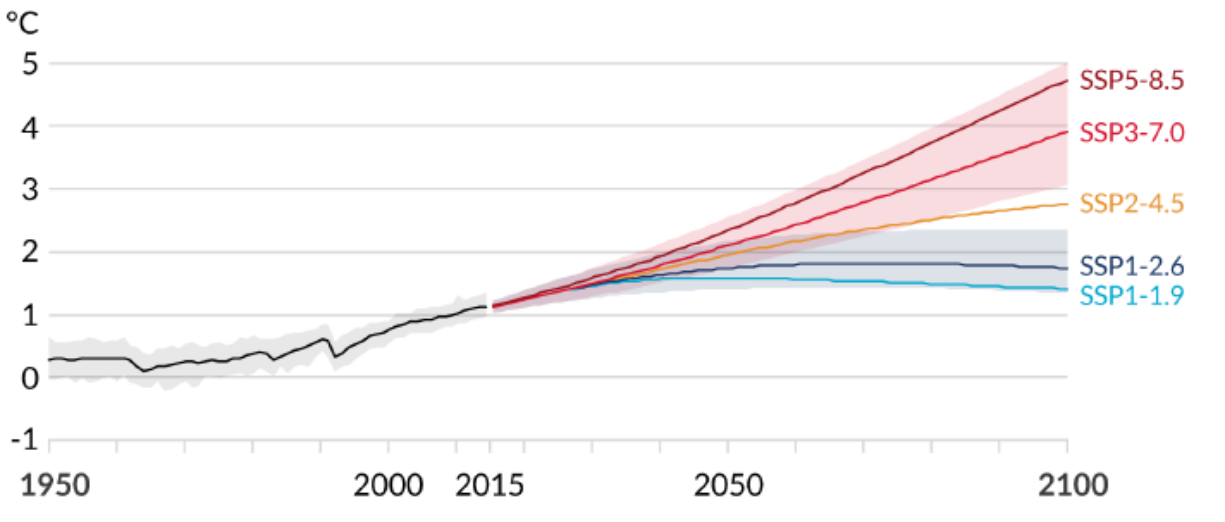

Figure 21.5 Global surface temperature change relative to 1850-1900 also from AR6 WG1 simulations https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

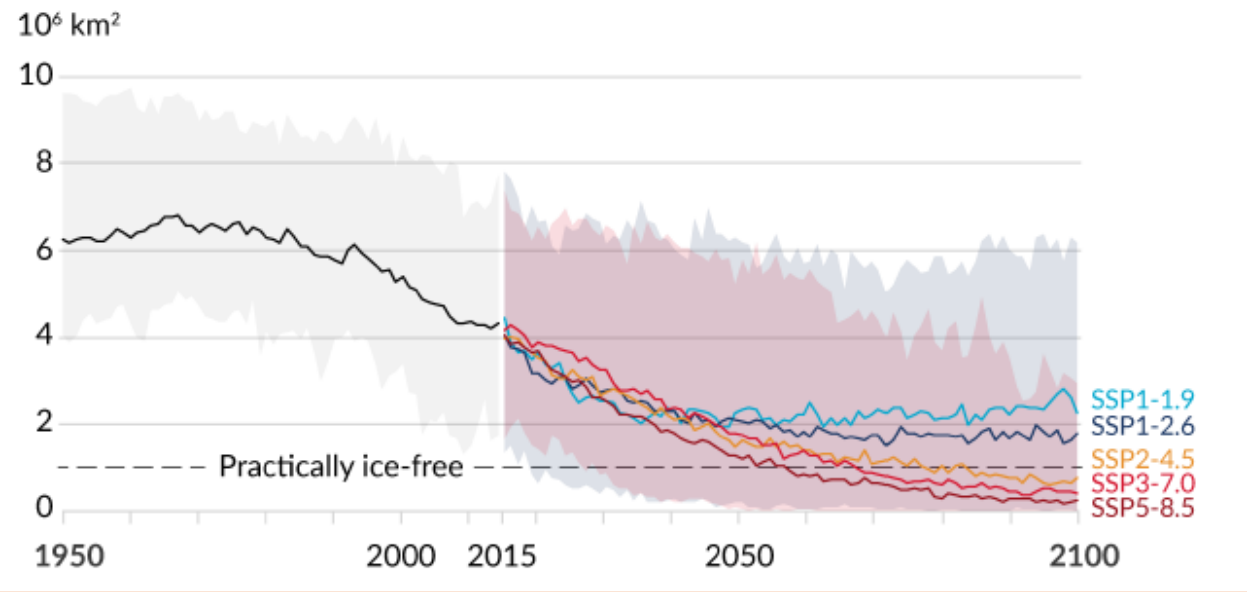

Figure 21.6 September Arctic Sea ice area also from AR6 WG1 simulations https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

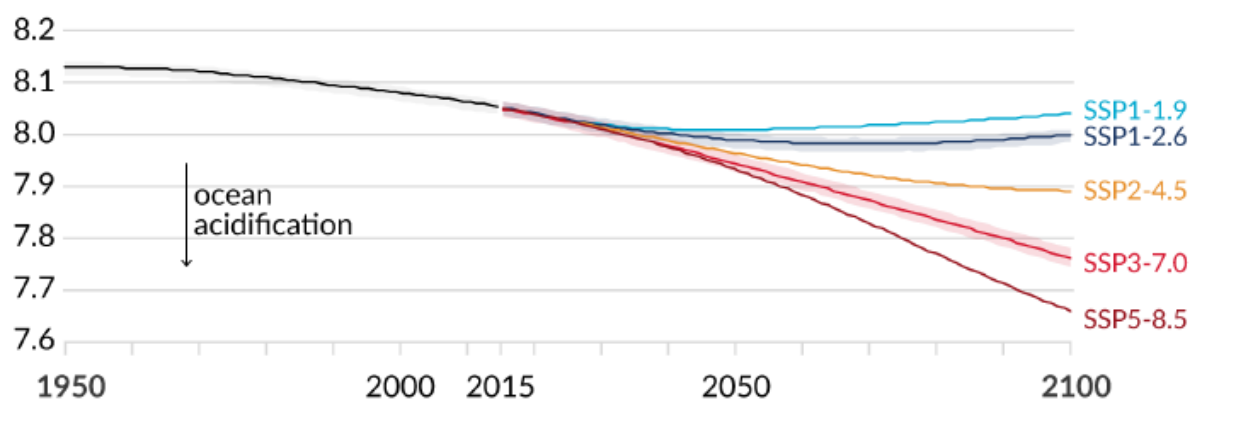

Figure 21.7 Global Ocean surface pH also from AR6 WG1 simulations https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

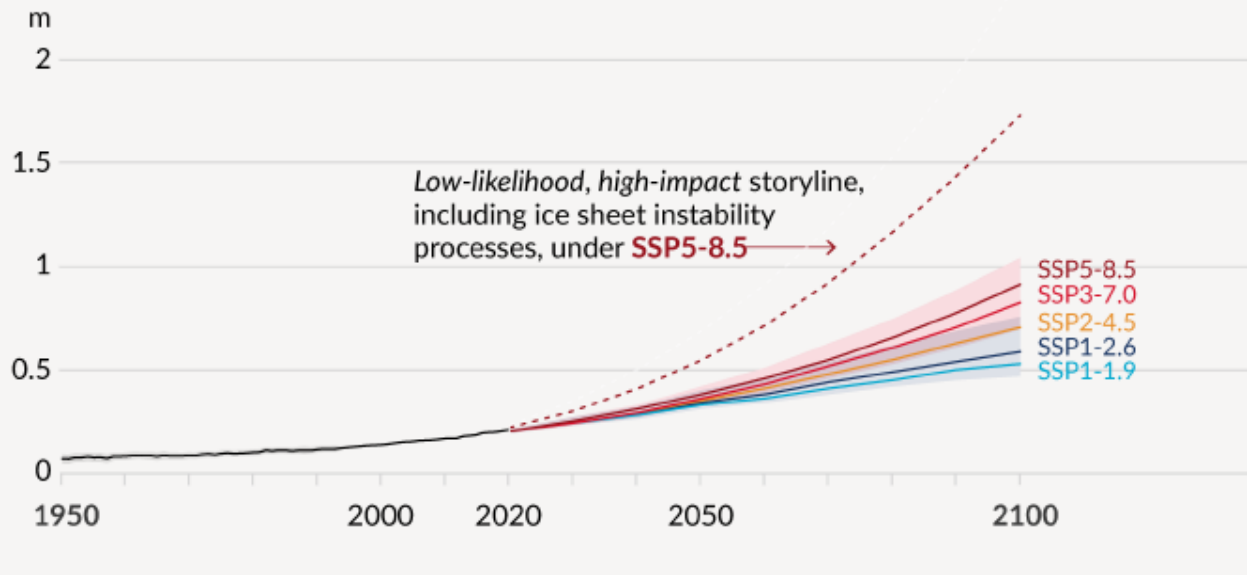

Figure 21.8 Global mean sea level change relative to 1900 also from AR6 WG1 simulations https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

2.4.4 Climatic impact-drivers

The concept of 'climatic impact-driver' is introduced. IPCC defines climatic impact drivers as follows: 'Climatic impact-drivers (CIDs) are physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems. Depending on system tolerance, CIDs and their changes can be detrimental, beneficial, neutral, or a mixture of each across interacting system elements and regions. CID types include heat and cold, wet and dry, wind, snow and ice, coastal and open ocean. Table 21.3, taken from AR6 WG1 SPM https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf identifies and describes climatic impact-drivers on land and coastal regions of the world assuming they are a consequence of 1.5°C increase in global warming by 2100. Temperature increases greater than 1.5°C would be more widespread and/ or pronounced.

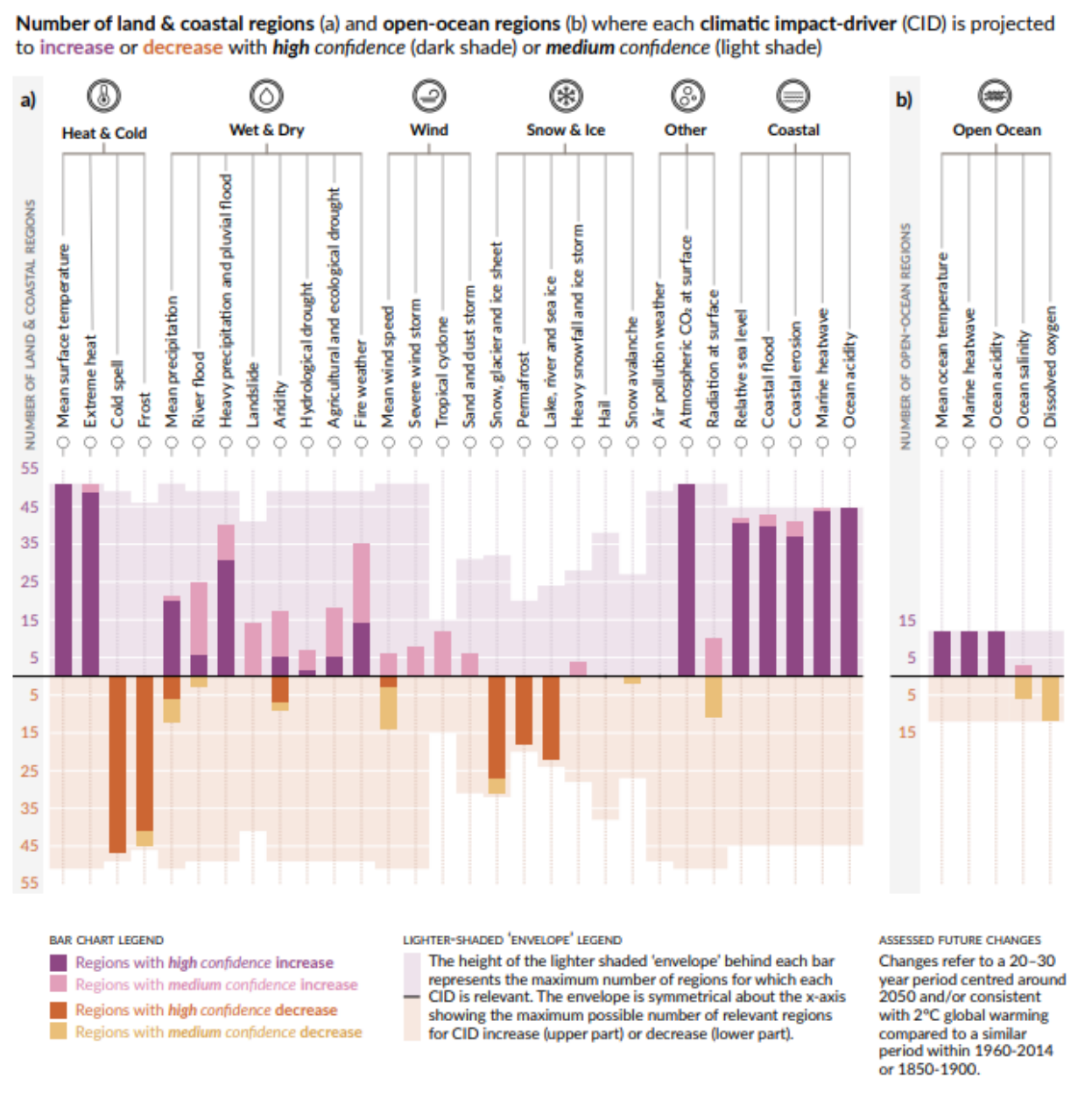

Table 21.3 Number of land and coastal regions (a) and open-ocean regions (b) where each climatic impact-driver is projected to increase or decrease with high confidence or medium confidence from AR6 WG1 simulations https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

21.4.5 Limiting future climate change to 1.5°C

It has been established by SR1.5 (https://www.ipcc.ch/sr15/) that 'there is a near-linear relationship between cumulative anthropogenic CO_2 emissions and the global warming they cause. Each 1000 $GtCO_2$ of cumulative CO_2 emissions is assessed to likely cause a 0.27°C to 0.63 increase in global surface temperature with a best estimate of 0.45°C.' This relationship is known as the transient climate response to cumulative CO_2 emissions or TCRE.

In order to stop global warming at any level net-zero emissions are required (cumulative emissions do not increase). It is clear scenario SSP1.9 is most desirable. From Figure 21.9 holding global surface temperature increases of 1.5 °C by the end of the century requires that cumulative CO_2 emissions not exceed 2900 $GtCO_2$. The pathway for achieving this is shown is Figure 21.3 which indicates net-zero by 2050 and negative emissions thereafter. The area below the curve associated with SSP1.9 is the amount of CO_2 emissions that can occur before achieving net-zero. Note that the SSP1.9 curve is the most achievable of the many possible.

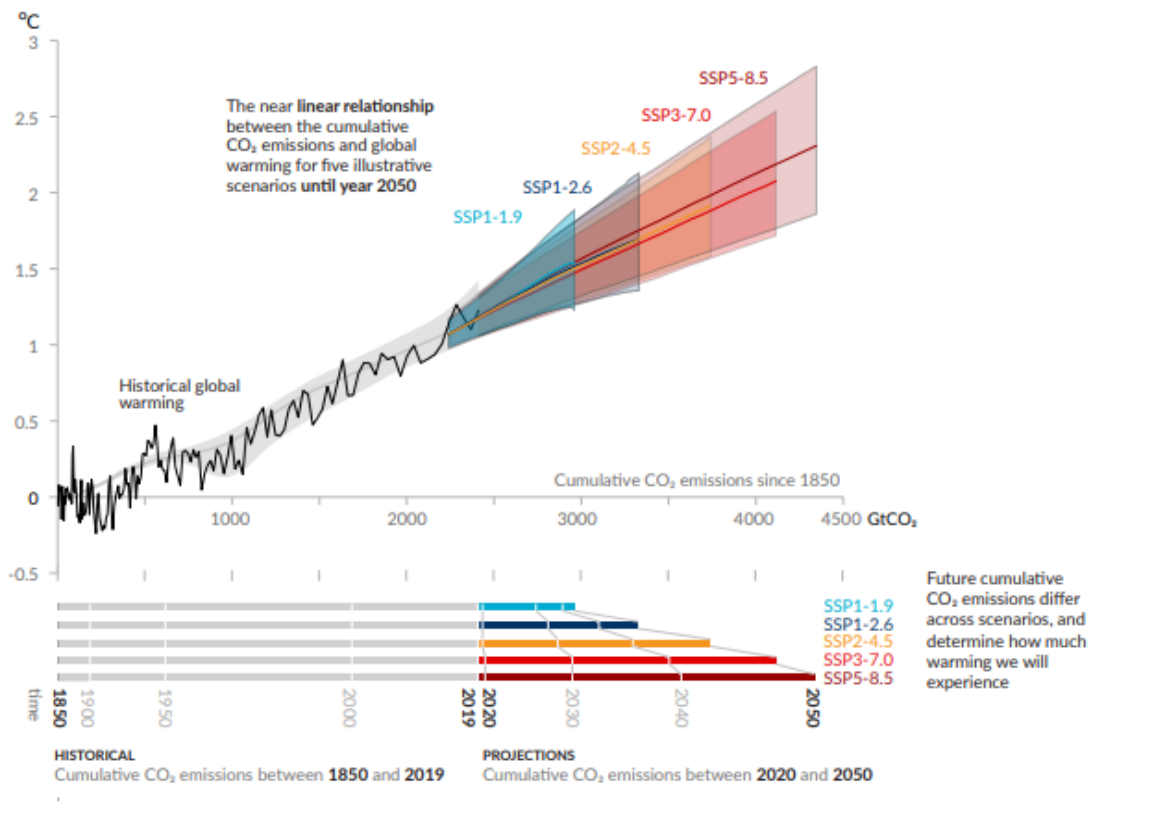

Figure 21.9 Global surface temperature increase since 1850-1900 °C as a function of cumulative CO_2 emissions ($GtCO_2$) from https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

21.4.5 IPCC WG1 Interactive Atlas https://interactive-atlas.ipcc.ch/

The IPCC WG1 Interactive Atlas summarizes the results of the modelling of the science in such way that the user may examine the global and regional effects of global warming to 2100. A description of the Interactive Atlas, taken from the web site, is provided here:

'A significant innovation in the AR6 WGI report is the inclusion of the Interactive Atlas, allowing flexible spatial and temporal analyses of much of the observed and projected climate change information underpinning the WGI assessment. The Interactive Atlas has two components. The first (**regional information**) includes the ability to generate global maps and a number of regionally aggregated products (time series, scatter plots, tables, climate stripes, etc.) for observed and projected climate change for time periods, emissions scenarios or global warming levels of interest. It integrates a range of

different datasets, including global and regional observations and the three most recent coordinated global and regional climate projection experiments: CMIP5, CORDEX and CMIP6, for different key variables, extreme indices and climatic impact-drivers (CIDs). The second component (**regional synthesis**) provides qualitative information about changes in climatic impact-drivers (CIDs) in several categories such as heat and cold, wet and dry, or coastal and oceanic. Users can select one or several impact-drivers and visualize the regional historical trends and projected changes over the sub-continental reference regions.'

The regional information segment is up and running. The regional synthesis segment is still under development but is expected to be available soon.

The regional information segment allows the user to select the Dataset as shown in Figure 21.10 which allows the selection of global projections using CMIP6, CMIP5 or regional projections using CORDEX. (Note that these models are discussed in Chapter 17.)

The second selection allows the user to choose the Variable of interest as it relates to the atmosphere, ocean or other variables. This is shown in Figure 21.11.

The third selection allows the user to choose the Value and Period as shown in Figure 21.12. The user may select the change in degrees centigrade or actual value. The user then selects the period, scenario and baseline of interest.

The fourth selection allows the user to choose the Season of interest as shown in Figure 21.13.

There are two other selections the user must make: region set and uncertainty as shown in Figure 21.14. This is usually done first.

There are several other controls on the side bar including: zoom in, zoom out, projections, ability to select all regions, access meta data, download/share, lean point information, duplicate the map and adjust to full screen.

The user is encouraged to visit and explore the web site, https://interactive-atlas.ipcc.ch/ . The Interactive Atlas invites and facilitates exploration and the user is encouraged to do this. It is a very important learning experience in itself.

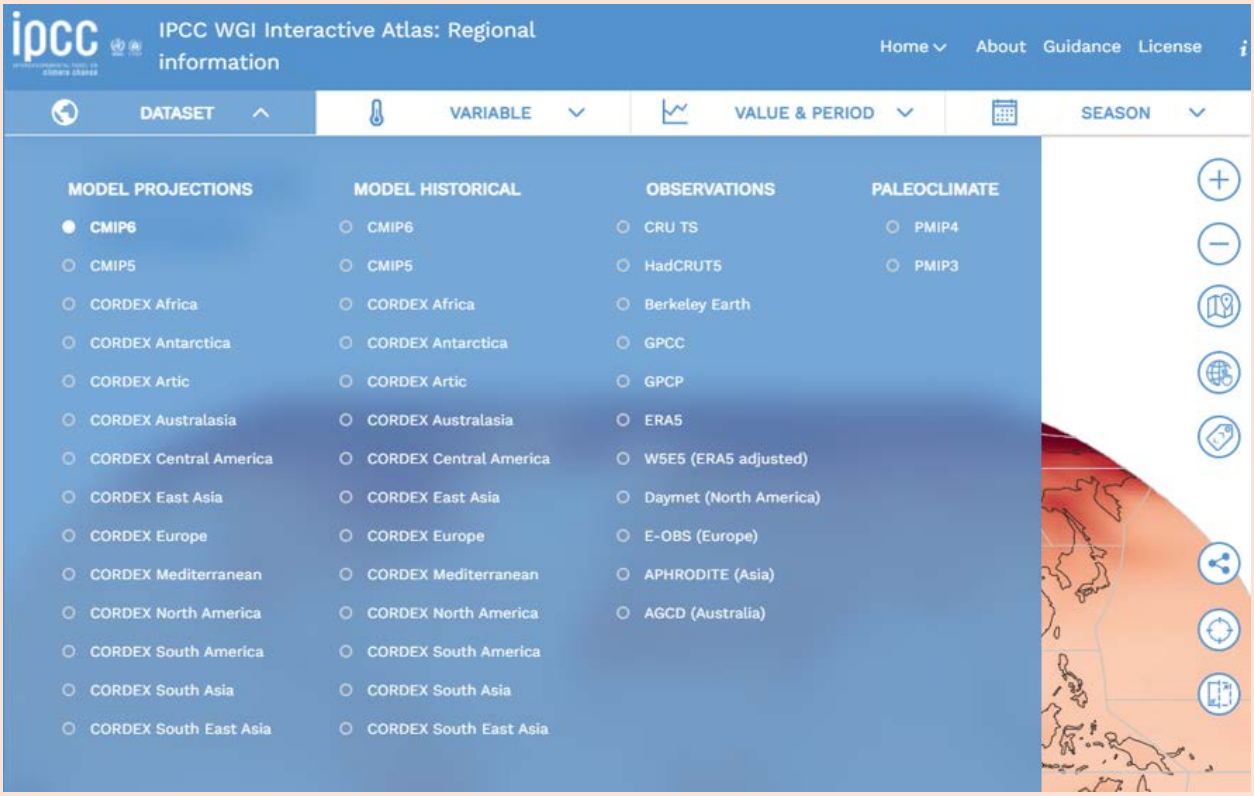

Figure 21.10 Selection of model projections using CMIP6, CMIP5 or regional models, CORDEX.

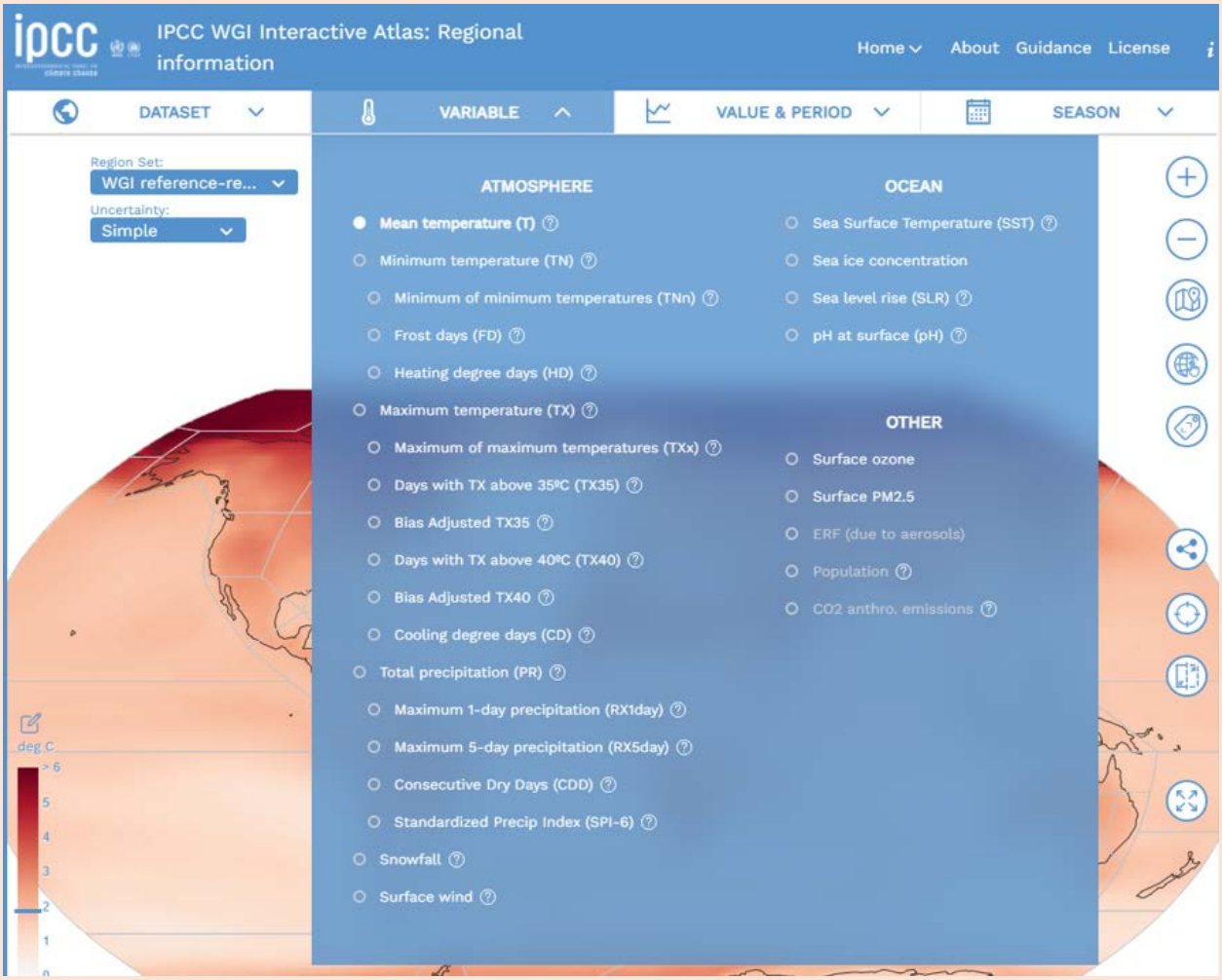

Figure 21.11 Selection of variable of interest as it relates to the atmosphere, ocean or other variables.

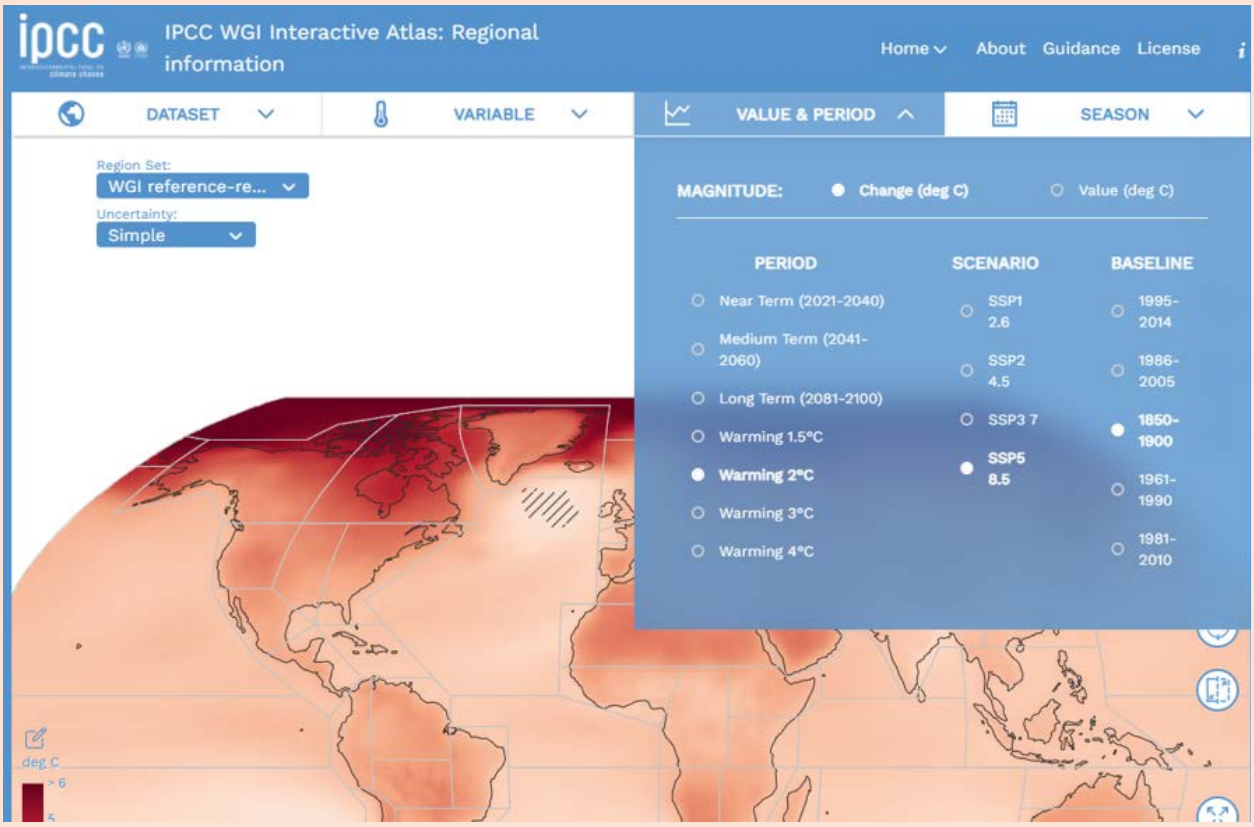

Figure 21.12 Selection of Value and Period – specifically period, scenario and baseline.

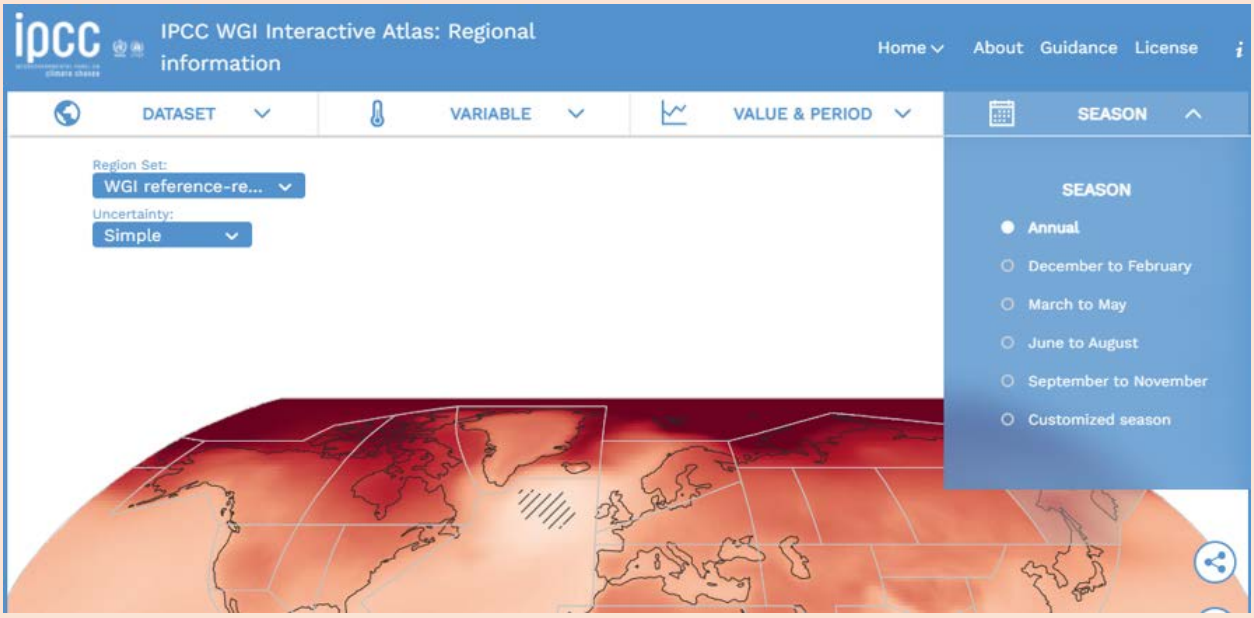

Figure 21.13. Selection of season of interest.

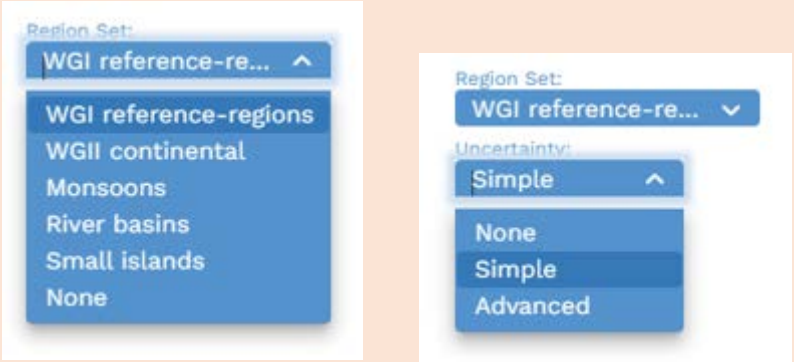

Figure 21.14 Selection of WG1 reference-regions and level of uncertainty.

21.4.6 NASA/ IPCC sea level projection tool

NASA, using IPCC reports developed what is called the sea level projection tool, https://sealevel.nasa.gov/data_tools/17 and https://sealevel.nasa.gov/. NASA's Sea Level Change Team makes extensive use of the IPCC's prediction of future sea level rise. The interactive tool provides maps on which one can pick anywhere on global ocean and

coastlines and any decade between 2020 and 2150 and the IPCC scenario to be considered (IPCC's Sixth Assessment Report WG1, Climate Change 2021: the Physical Science Basis). The tool is hosted on NASA's Sea Level Portal, https://sealevel.nasa.gov/. The tool will provide a detailed report for the location selected based on IPCC information.

21.4.7 Climate Information web site https://climateinformation.org/

The Climate Information platform was developed by World Meteorological Organization, Green Climate Fund, World Climate Research Program, and the Swedish Meteorological and Hydrological Institute to help countries determine their adaptation needs resulting from climate change. This platform is provided free of charge. This information will assist countries develop submissions to the Green Climate Fund to help fund their adaptation needs.

21.4.8 Climate data for a resilient Canada https://climatedata.ca/

The Government of Canada "provides high-resolution climate data to help decision makers build a more resilient Canada". The information is similar in nature to the IPCC Interactive Atlas: Regional but is focused specifically on regions of Canada. It allows investigation by location, variable and sector. Analytical tools are also available. There is a 'Learning Zone' to teach more about the science behind the climate data, choose and access Canadian climate data, and download pre-made materials for continued training.

21.4.9 Carbon Brief In-depth Q&A: The IPCC's sixth assessment report on climate science. https://www.carbonbrief.org/in-depth-qa-the-ipccs-sixth-assessment-report-on-climate-science

Carbon Brief produced an exceptional discussion on the IPCC's Sixth Assessment Report on climate science. Many of the most important questions answered by this report are answered in language that is readily understood. It is a significant complement to the Interactive Atlas. Table 21.4, extracted from their report, lists the questions addressed.

- What is this report?
- How is Earth's temperature changing?
- How much warmer will the world get in future?
- When might global warming reach 1.5C?
- How are rainfall patterns changing?
- What impact is warming having on the world's snow and ice?
- What does the report say about changes to the oceans?
- How have projections of sea level rise changed since AR5?
- What does the report say about the impact humans are having?
- What does the report say about abrupt changes and 'tipping points'?
- How does air pollution affect global temperatures?
- How have climate sensitivity estimates changed since AR5?
- What does the report say about the remaining carbon budget?
- What does the report say about 'net-zero'?
- How are weather extremes changing and what role does climate change play?
- How do climate risks vary across the world?

Table 21.4 List of questions addressed in Carbon Brief In-depth Q&A: The IPCC's sixth assessment report on climate science. https://www.carbonbrief.org/in-depth-qa-the-ipccs-sixth-assessment-report-on-climate-science.

The World Resources Institute, Insights, August 9, 2021, complements the Carbon Brief Q & A with their significant take-aways in their article '5 Big Findings from the IPCC's 2021 Climate Report', https://www.wri.org/insights/ipcc-climate-report.

21.5 Net zero by 2050 objective and committed warming

The concepts of 'net zero' and 'committed warming' are actually part of the discussion of emission scenarios, namely, representative concentration pathways, (RCPs) which may be found in Section 18.2 and shared socio-economic pathways, (SSPs) which may be found in Section 21.3. The outcomes of following these emission scenarios are determined using various

climate change models. The net zero objective is different in that it is simply the emission target for 2050. There is no attempt to describe the emission pathway to achieve this except to note that if this objective is achieved, the global temperature in year 2050 will not increase. (Intermediate emission targets for 2030 are encouraged to help ensure that the 2050 target can be achieved.) This has caused some confusion with all parties, governments at all levels, businesses and all other human activities who seem to be left to their own resources as to how they will achieve this objective (not quite true since governments at all levels are closely involved providing guidelines and incentives). The net zero objective is quite simple though and all parties are expected to achieve the objective independently following their own pathway. All stakeholders (parties) must be conversant in all aspects of greenhouse gas emissions as it relates to their activities and responsibilities. Their progress is reported and collated at a national level and so their success in achieving the 2050 objective can be monitored. A brief discussion of net zero and committed warming follows.

The UNFCC Paris Agreement (https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement), adopted by 196 Parties at COP21 in Paris on December 12 2015 and entered into force on November 4, 2016 committed the Parties (countries) to reducing their GHG emissions sufficiently to limit global warming to well below 2 °C. and preferably 1.5°C.

The IPCC Special Report, Global Warming of 1.5 °C, outlines the impacts of global warming above this temperature and the pathways with which this may be achieved https://www.ipcc.ch/sr15/. The pathways with which the 1.5°C objective for 2100 can be achieved is discussed in the In-depth Q&A article in Carbon Brief 08.10.2018 https://www.carbonbrief.org/in-depth-qa-ipccs-special-report-on-climate-change-at-one-point-five-c . Some involve 'over-shoot' of warming before 2100 but achieve 1.5°C by 2100 and others that do not over-shoot the temperature objective before 2100. Only those scenarios which did not over-shoot were considered acceptable; that is, aligned with the Paris Agreement's real objective of 1.5°C limit for 2100.

The 'net-zero' emission objective is the commitment by all countries to net-zero CO2 emissions by 2050. If this were achieved the global temperature at 2050 would gradually decrease from this year forward. The underlying hope is that the global temperature in 2050 will be less than 2°C and close to 1.5°C.

The 'Explainer article' in the newsletter, Carbon Brief, by Zeke Hausfather, 29.04.2021 that 'The

best available evidence shows that – warming is likely to more or less stop, that is, no over-shoot, once carbon dioxide emissions reach zero', https://www.carbonbrief.org/explainer-will-global-warming-stop-as-soon-as-net-zero-emissions-are-reached?utm_campaign=Daily%20Briefing&utm_content=20220224&utm_medium=email&utm_source=Revue%20newsletter.

The author explains the difference in surface temperature between scenarios which maintain a constant concentration of CO2 and the effect of achieving net-zero. This is illustrated in Figure 21.15. Additional warming would occur, (over-shoot), if the concentration of CO2 was held constant after 2050, that is until the concentrations of CO2 in the atmosphere, land and the ocean achieved equilibrium.

If CO2 emissions decreased as per the net-zero emission scenario, the concentration of CO2 in the atmosphere would decrease as a result of the CO2 loss to the land and oceans.

It is interesting to note that the IPCC 1.5°C objective for 2100, https://www.ipcc.ch/sr15/, can be achieved in a variety of other ways as discussed in the In-depth Q&A article in Carbon Brief 08.10.2018 https://www.carbonbrief.org/in-depth-qa-ipccs-special-report-on-climate-change-at-one-point-five-c that involve 'over-shoot' of warming before 2100 but achieve 1.5°C by 2100 and those that do not over-shoot the temperature objective before 2100. See Figure 21.16. Only those scenarios which did not over-shoot were considered acceptable; that is, aligned with the Paris Agreement's 1.5°C limit for 2100.

It is important to emphasize that net-zero CO2 will likely achieve the IPCC 1.5°C objective for 2100. The success of net-zero was determined using the models discussed in Chapter 17. The ways with which net-zero can be achieved are determined by individual governments.

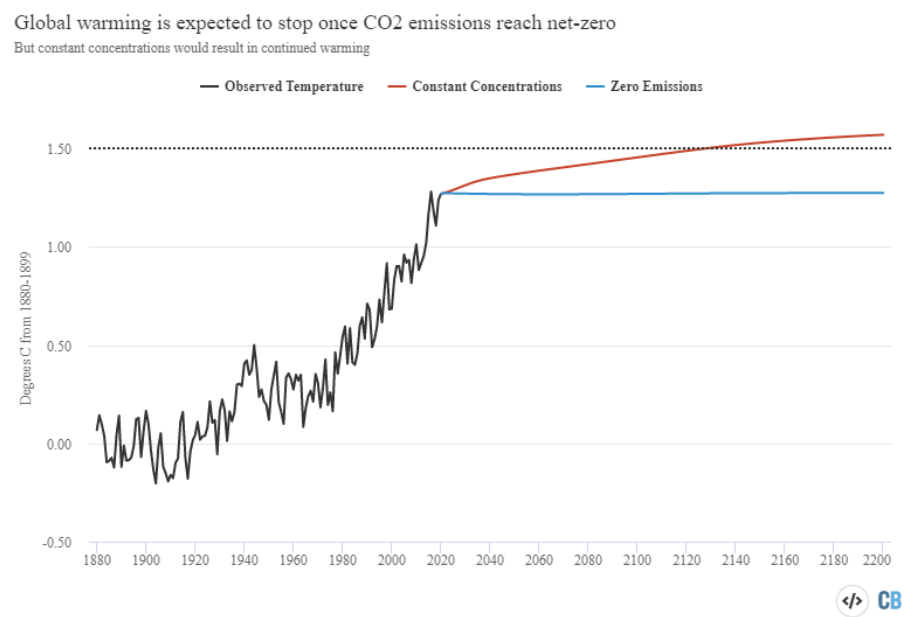

Figure 21.15 Committed temperature increases under the constant concentration scenario of CO2 in the atmosphere and the zero emissions scenario https://www.carbonbrief.org/explainer-will-global-warming-stop-as-soon-as-net-zero-emissions-are-reached?utm_campaign=Daily%20Briefing&utm_content=20220224&utm_medium=email&utm_source=Revue%20newsletter.

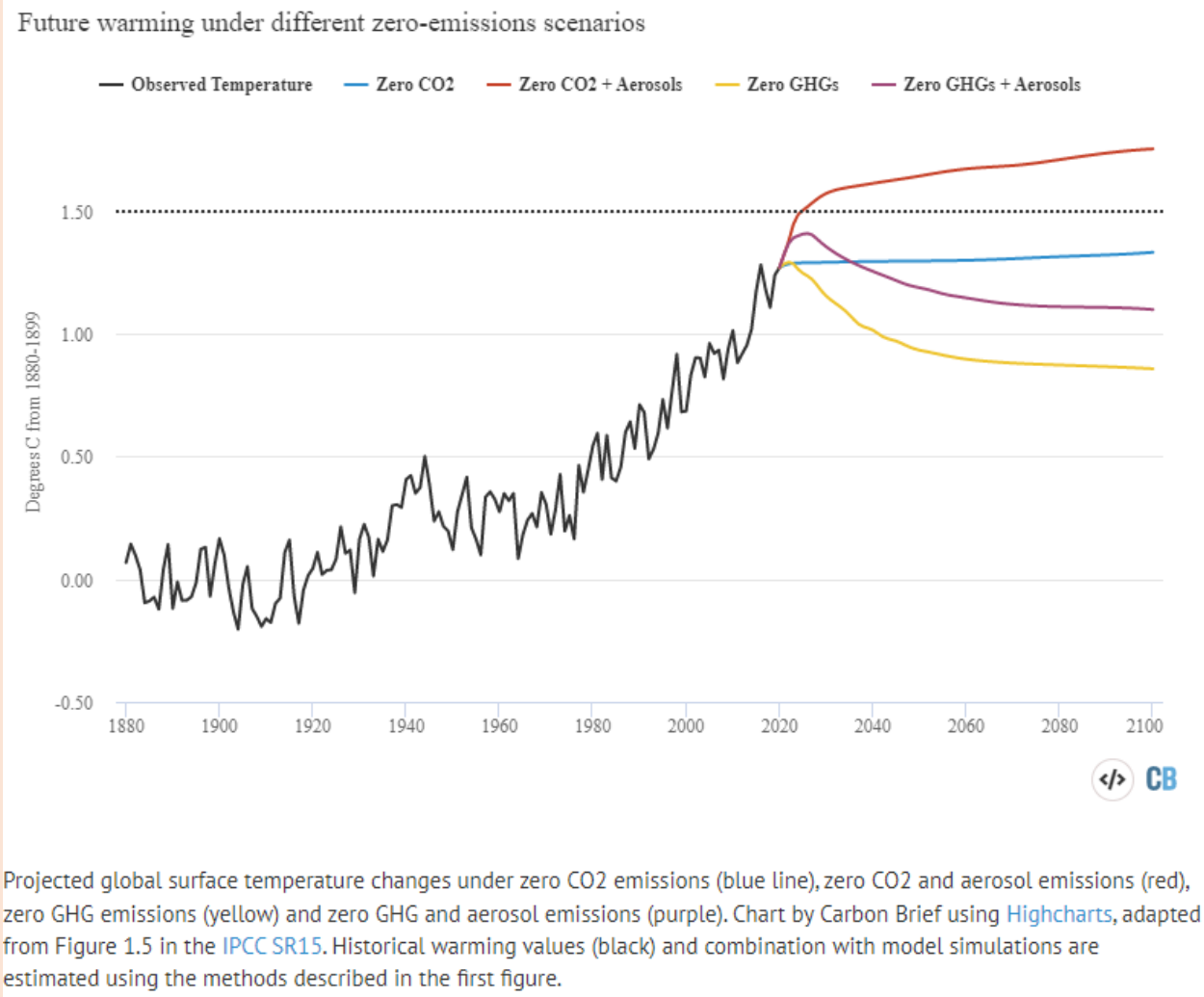

Figure 21.16 Temperature increases under zero emission scenarios: zero CO2 (no change in other GHGs or aerosols), zero CO2 and aerosols, zero GHGs (no change in aerosols) and zero GHGs and aerosols https://www.carbonbrief.org/explainer-will-global-warming-stop-as-soon-as-net-zero-emissions-are-reached?utm_campaign=Daily%20Briefing&utm_content=20220224&utm_medium=email&utm_source=Revue%20newsletter.

21.6 Information support

Key web sites:

1. Paris Agreement, COP21, https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement

2. Global emissions. https://www.co2.earth/global-co2-emissions

3. IPCC Sixth Assessment Report. https://www.ipcc.ch/assessment-report/ar6/.

4. IPCC Sixth Assessment Report, WG1 Climate Change: The Physical Science Basis, https://www.ipcc.ch/report/ar6/wg1/#FullReport.

5. IPCC Sixth Assessment Report WGII Climate Change 2021: Impacts, Adaptation and Vulnerability was published February 28, 2022 https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/.

6. IPCC Sixth Assessment Report, AR6, WGIII Climate Change 2022: Mitigation https://report.ipcc.ch/ar6wg3/pdf/IPCC_AR6_WGIII_FinalDraft_FullReport.pdf.

7. Change in global surface temperature (annual average) as observed and simulated using human and natural and only natural factors (both 1850-2020) °C https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf.

8. IPCC special report, global warming 1.5 degrees C. (https://www.ipcc.ch/s (r15/

9. IPCC special report, climate change and land. https://www.ipcc.ch/srccl/

10. IPCC special report, ocean and the cryosphere in a changing climate. https://www.ipcc.ch/srocc/

11. IPCC special report, ocean and the cryosphere, supplementary material. https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/SROCC_FinalDraft_Chapter1-SM.pdf

12. IPCC special report, 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/.

13. IPCC methodology report, Methodology Report on Short-lived Climate Forcers, in preparation https://www.ipcc.ch/report/methodology-report-on-short-lived-climate-forcers/.

14. A new scenario framework for climate change research: scenario matrix architecture. https://link.springer.com/article/10.1007/s10584-013-0906-1

15. Discussion of representative concentration pathways used in AR6. https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change

16. Climate change scenarios to be used in AR6. https://climatescenarios.org/primer/mitigation/

17. IPCC sea level projection tool. https://sealevel.nasa.gov/data_tools/17

18. NASA Sea Level Portal. https://sealevel.nasa.gov/

19. Carbon Brief In-depth Q&A: The IPCC's sixth assessment report on climate science. https://www.carbonbrief.org/in-depth-qa-the-ipccs-sixth-assessment-report-on-climate-science

20. Climate Information web site, World Meteorological Association, Green Climate Fund, World Climate Research Program, and the Swedish Meteorological and Hydrological Institute https://climateinformation.org/.

21. Climate data for a resilient Canada, Government of Canada, https://climatedata.ca/.

22. In-depth Q&A article in Carbon Brief 08.10.2018. https://www.carbonbrief.org/in-depth-qa-ipccs-special-report-on-climate-change-at-one-point-five-c .

23. 'Explainer article' in the newsletter, Carbon Brief, by Zeke Hausfather, 29.04.2021 https://www.carbonbrief.org/explainer-will-global-warming-stop-as-soon-as-net-zero-emissions-are-reached?utm_campaign=Daily%20Briefing&utm_content=20220224&utm_medium=email&utm_source=Revue%20newsletter.

24. In-depth Q&A article in Carbon Brief 08.10.2018 https://www.carbonbrief.org/in-depth-qa-ipccs-special-report-on-climate-change-at-one-point-five-c.

25. Carbon Brief Explainer, 02.10.2018 Q&A: How integrated assessment models are used to study climate change, https://www.carbonbrief.org/qa-how-integrated-assessment-models-are-used-to-study-climate-change.

26. Carbon Brief Guest post 30 March 2022 Guest post: How not to interpret the emissions scenarios in the IPCC report. https://www.carbonbrief.org/guest-post-how-not-to-interpret-the-emissions-scenarios-in-the-ipcc-report?utm_campaign=Daily%20Briefing&utm_content=20220331&utm_medium=email&utm_source=Revue%20newsletter.

27. World Resources Institute, Insights, August 9, 2021, 5 Big Findings from the IPCC's 2021 Climate Report. https://www.wri.org/insights/ipcc-climate-report.