ICSF/CLINTEL Lecture

What does IPCC AR6 say on Scenarios and Extreme Weather?

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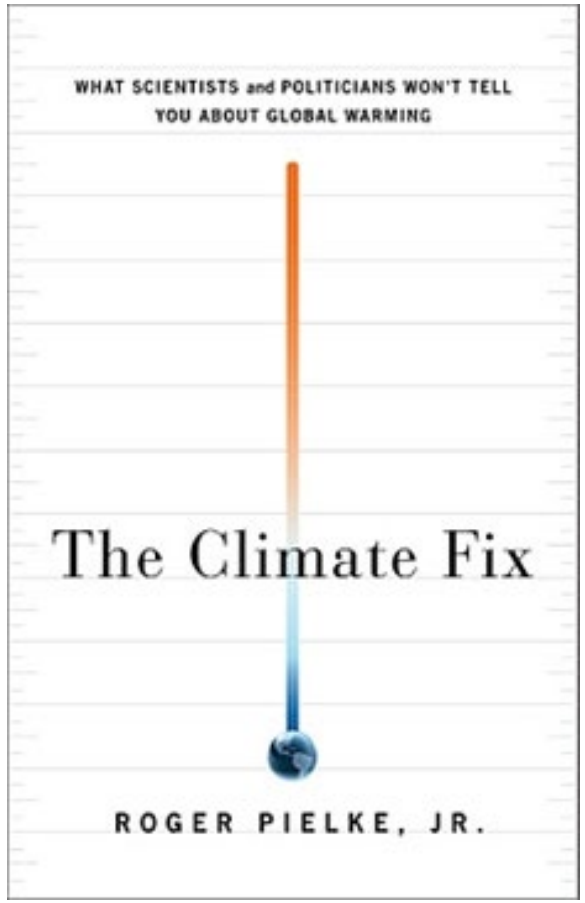
27 October 2021
Dublin, Ireland

Before diving in … let's make this clear



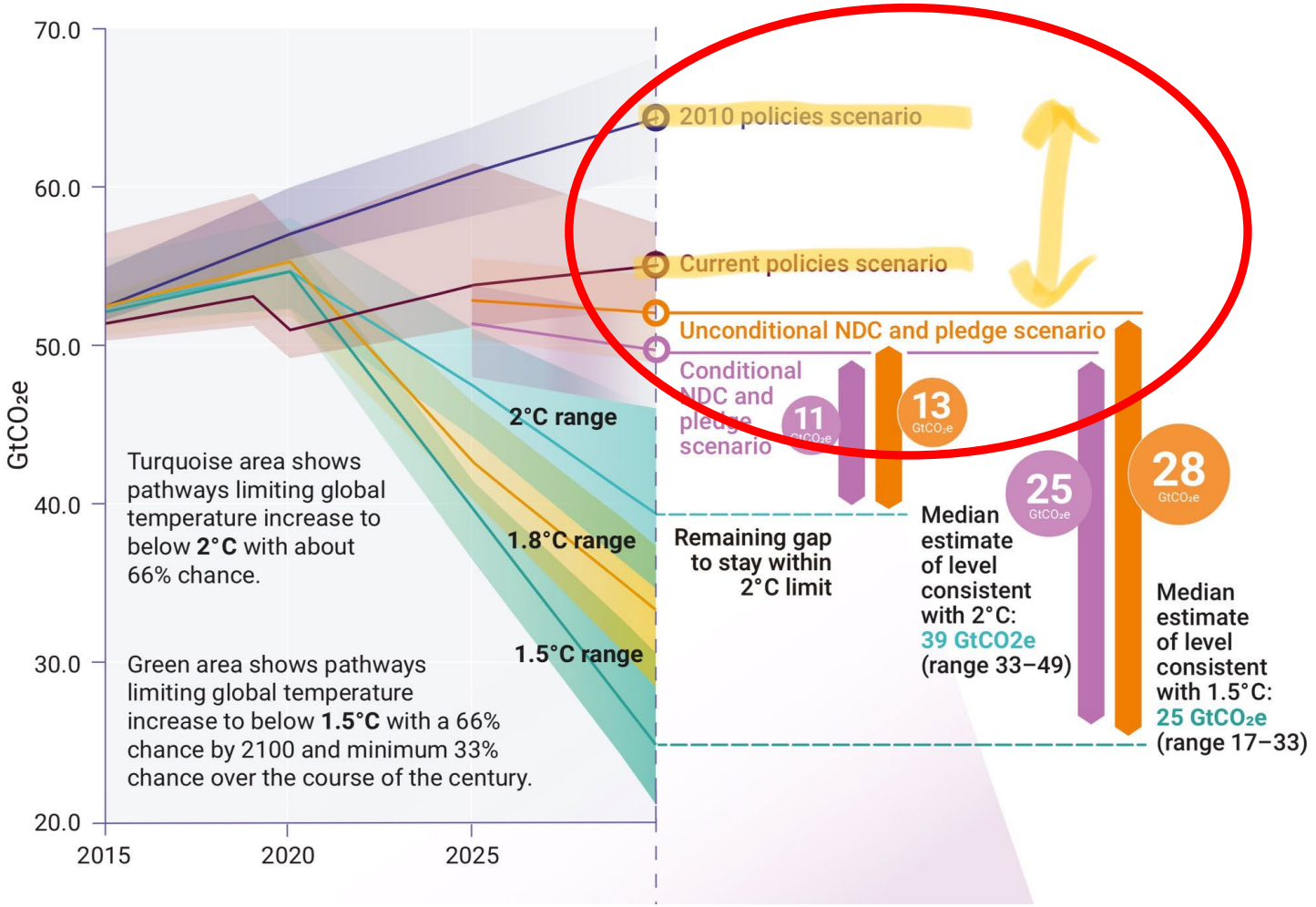
Climate change is

- **Real**
- **Serious**
- **And deserving of serious attention to both mitigation and adaptation policies**

My views on climate science, policy and politics

Makes a great gift for that special someone

Fresh Good News on Climate Policy



UN Emissions Gap Report 2021


WARNS OF CHANGE...
Can UK lead world back from brink?
SEE PAGES 6-9
foreign breaks
ESTS
'Can we have two golds?'
Our writers' best moments of Tokyo 2020
Sport
The Guardian
For 200 years
Global climate crisis: inevitable, unprecedented and irreversible
CODE RED FOR HUMANITY
EXTREME WEATHER DOWN TO GLOBAL WARMING, SAYS DOOMSDAY REPORT FROM UN
WORLD WILL HEAT UP AT LEAST 1.5C BY 2040.. A DECADE EARLIER THAN WAS FORECAST
CODE RED FOR HUMANI
DAILY EXPRESS
FREE Brilliant puzzles pullout
David Cameron denies £7m Greensill pay packet
QUEEN'S BREAK WITH TRADITION
Next decade 'pivotal' to secure planet's future after alarming scientific repo
PM: WAKE UP TO RED ALERT ON CLIMATE CRISIS
WELCOME HOME
Let the party begin for our Olympic heroes
FINANCIAL TIMES
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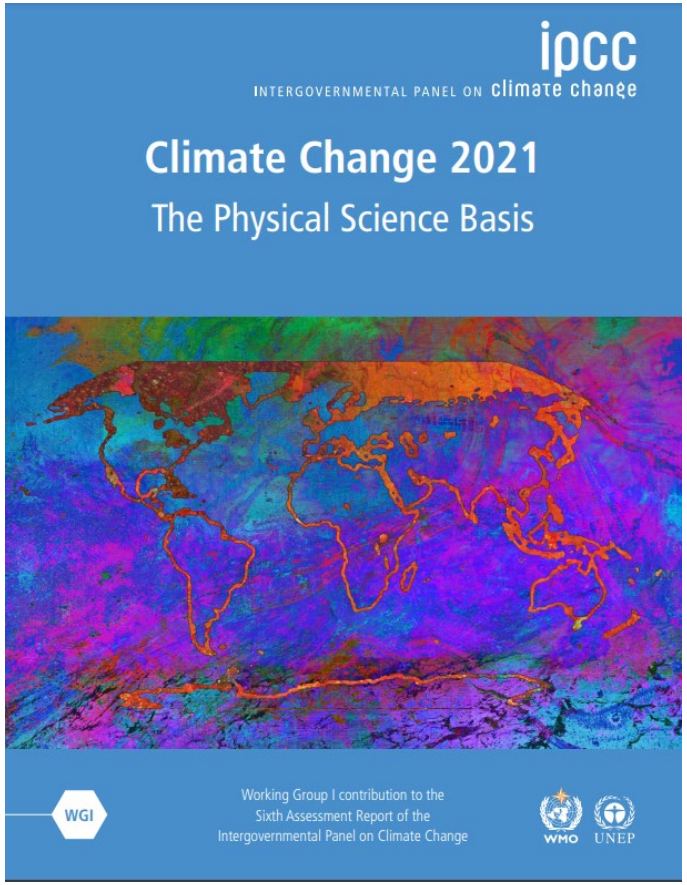
Inside Kim's regime
Why sanctions against North Korea are failing
Silencing staff
NDAs are damaging in the workplace
In China's debt
African nations' risks in borrowing from Beijing
World likely to be 1.5C warmer by 2040, UN's science panel warns
'Code red for humanity'
More extreme weather expected
Call for urgent
CODE RED
shocking verdict on future of humanity
scientists urge PM to create UK climate
Climate change caused by humans is already causing extreme w
every region across world, with global warming set to breach the
10 years early - in 2040 - even in best-case scenario where world
Climate experts call for Johnson and Sunak to 'ramp up' British
Lord Stern tells I: 'We need the Prime Minister and Chancellor to
Scientific report most authoritative ever - and backed by 195 go
Severe floods, heatwaves, droughts and storms becoming mor
Briefling
TUESDAY AUGUST 2021

PART I
Extremes

Summary of IPCC 2021 AR6 WG1 on Extremes



	Detection	Attribution
heat waves	yes	yes
heavy precipitation	yes	yes
flooding	no	no
meteorological drought	no	no
hydrological drought	no	no
ecological drought	yes	yes
agricultural drought	yes	yes
tropical cyclones	no	no
winter storms	no	no
thunderstorms	no	no
tornadoes	no	no
hail	no	no
lightning	no	no
extreme winds	no	no
fire weather	yes	yes

Climate and climate change

Climate
Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

Climate change
Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes.

IPCC Glossary

Detection

Here is how the IPCC defines detection:

> Detection of change is defined as the process of demonstrating that climate or a system affected by climate has changed in some defined statistical sense, without providing a reason for that change. An identified change is detected in observations if its likelihood of occurrence by chance due to internal variability alone is determined to be small, for example, <10%.

IPCC Glossary

Attribution

And here is how the IPCC defines attribution:

> Attribution is defined as the process of evaluating the relative contributions of multiple causal factors to a change or event with an assessment of confidence.

IPCC Glossary

	Detection	Attribution
heat waves	yes	yes
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flooding	no	no
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lightning	no	no
extreme winds	no	no
fire weather	yes	yes

Heat Waves

- Heat Waves: "It is virtually certain that there has been increases in the intensity and duration of heat waves and in the number of heat wave days at the global scale"

In summary, it is *virtually certain* that there has been an increase in the number of warm days and nights and a decrease in the number of cold days and nights on the global scale since 1950. Both the coldest extremes and hottest extremes display increasing temperatures. It is *very likely* that these changes have also occurred at the regional scale in Europe, Australasia, Asia, and North America. It is *virtually certain* that there has been increases in the intensity and duration of heat waves and in the number of heat wave days at the global scale. These trends *likely* occur in Europe, Asia, and Australia. There is *medium confidence* in similar changes in temperature extremes in Africa and *high confidence* in South America; the lower confidence is due to reduced data availability and fewer studies. Annual minimum temperatures on land have increased about three times more than global surface temperature since the 1960s, with particularly strong warming in the Arctic (*high confidence*).

Screenshots from IPCC AR6 WG1 unless otherwise noted

Heavy Precipitation

- Heavy precipitation: "the frequency and intensity of heavy precipitation have likely increased at the global scale over a majority of land regions with good observational coverage"

In summary, the frequency and intensity of heavy precipitation have *likely* increased at the global scale over a majority of land regions with good observational coverage. Since 1950, the annual maximum amount of precipitation falling in a day or over five consecutive days has *likely* increased over land regions with sufficient observational coverage for assessment, with increases in more regions than there are decreases. Heavy precipitation has *likely* increased on the continental scale over three continents, including North America, Europe, and Asia where observational data are more abundant. There is *very low confidence* about

Heavy Precipitation does not always lead to greater flooding

- The IPCC (in its accompanying FAQ) recognizes that "heavier rainfall does not always lead to greater flooding." This is something that we first argued more than two decades ago (here and here), and it is great to see it explicitly acknowledged in the IPCC report. To make claims about trends in flooding, one should look at trends in flooding and not precipitation. The conflation of the two is a common error.

expected to be greater in the future, contributing to more severe flooding.

However, heavier rainfall does not always lead to greater flooding. This is because flooding also depends upon the type of river basin, the surface landscape, the extent and duration of the rainfall, and how wet the ground is before the rainfall event (FAQ 8.2, Figure 1) Some regions will experience a drying in the soil as the climate warms, particularly in sub-tropical climates, which could make floods from a rainfall event less probable because the ground can potentially soak up more of the rain. On the other hand, less frequent but more intense downpours can lead to dry, hard ground that is less able to soak up heavy rainfall when it does occur, resulting in more runoff into lakes, rivers and hollows. Earlier spring snowmelt combined with more precipitation falling as rain rather than snow can trigger flood events in cold regions. Reduced winter snow cover can, in contrast, decrease the chance of flooding arising from the combination of rainfall and rapid snowmelt. Rapid melting of glaciers and snow in a warming climate is already increasing river flow in some regions, but as the volumes of ice diminish, flows will peak and then decline in the future. Flooding is also affected by changes in the management of the land and river systems. For example, clearing forests for agriculture or building cities can make rain water flow more rapidly into rivers or low lying areas. On the other hand, increased extraction of water from rivers can reduce water levels and the likelihood of flooding.

Flooding

- Flooding (detection): "Confidence about peak flow trends over past decades on the global scale is low, but there are regions experiencing increases, including parts of Asia, southern South America, the northeast USA, northwestern Europe, and the Amazon, and regions experiencing decreases, including parts of the Mediterranean, Australia, Africa, and the southwestern USA."

> In summary, the seasonality of floods has changed in cold regions where snowmelt dominates the flow regime in response to warming (*high confidence*). *Confidence* about peak flow trends over past decades on the global scale is *low*, but there are regions experiencing increases, including parts of Asia, southern South America, the northeast USA, northwestern Europe, and the Amazon, and regions experiencing decreases, including parts of the Mediterranean, Australia, Africa, and the southwestern USA.

- Flooding (attribution): "there is low confidence in the human influence on the changes in high river flows on the global scale"

> In summary there is *low confidence* in the human influence on the changes in high river flows on the global scale. *Confidence* is in general *low* in attributing changes in the probability or magnitude of flood events to human influence because of a limited number of studies and differences in the results of these studies, and large modelling uncertainties.

Drought

Box 3-3 | The Definition of Drought

IPCC SREX

Though a commonly used term, drought is defined in various ways, and these definitional issues make the analysis of changes in drought characteristics difficult. This explains why assessments of (past or projected) changes in drought can substantially differ between published studies or chosen indices (see Section 3.5.1). Some of these difficulties and their causes are highlighted in this box.

What is Drought or Dryness?

The Glossary defines drought as follows: "A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term, therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, shortage of precipitation during the growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed agricultural drought), and during the runoff and percolation season primarily affects water supplies (hydrological drought). Storage changes in soil moisture and groundwater are also affected by increases in actual evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a meteorological drought. A megadrought is a very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more."

As highlighted in the above definition, drought can be defined from different perspectives, depending on the stakeholders involved. The scientific literature commonly distinguishes *meteorological drought*, which refers to a deficit of precipitation, *soil moisture drought* (often called *agricultural drought*), which refers to a deficit of (mostly root zone) soil moisture, and *hydrological drought*, which refers to negative anomalies in streamflow, lake, and/or groundwater levels (e.g., Heim Jr., 2002). We use here the term 'soil moisture drought' instead of 'agricultural drought,' despite the widespread use of the latter term (e.g., Heim Jr., 2002; Wang, 2005), because soil moisture deficits have several additional effects beside those on agroecosystems, most importantly on other natural or managed ecosystems (including both forests and pastures), on building infrastructure through soil mechanical processes (e.g., Corti et al., 2009), and health through impacts on heat waves (Section 3.1.4). Water scarcity (linked to *socioeconomic drought*), which may be caused fully or in part by use from human activities, does not lie within the scope of this chapter (see Section 4.2.2); however, it should be noted that changing pressure on water resources by human uses may itself influence climate and possibly the drought conditions, for example, via declining groundwater levels, or enhanced local evapotranspiration and associated land-atmosphere feedbacks. Drought should not be confused with aridity, which describes the general characteristic of an arid climate (e.g., desert). Indeed, drought is considered a recurring feature of climate occurring in any region and is defined with respect to the average climate of the given region (e.g., Heim Jr., 2002; Dai, 2011). Nonetheless, the effects of droughts are not linear, given the existence of, for example, discrete soil moisture thresholds affecting vegetation and surface fluxes (e.g., Koster et al., 2004b; Seneviratne et al., 2010), which means that the same precipitation deficit or radiation excess relative to normal will not affect different regions equally (e.g., short-term lack of precipitation in a very humid region may not be critical for agriculture because of the ample soil moisture supply). In this chapter we often use the term 'dryness' instead of 'drought' as a more general term.

Continued next page ...

- Drought. The IPCC has distinguished four types of drought: hydrological, meteorological, ecological and agricultural. That means that simply saying "drought" in the context of the IPCC report is incomplete, and potentially confusing. Here is what the report says about each:
  - Hydrological drought: "There is still limited evidence and thus low confidence in assessing these trends at the scale of single regions, with few exceptions"
  - Meteorological drought: "The regional evidence on attribution for single AR6 regions generally shows low confidence for a human contribution to observed trends in meteorological droughts at regional scale, with few exceptions"
  - Ecological and agricultural drought: "There is medium confidence that human influence has contributed to changes in agricultural and ecological droughts and has led to an increase in the overall affected land area"

[15] Agricultural and ecological drought (depending on the affected biome): a period with abnormal soil moisture deficit, which results from combined shortage of precipitation and excess evapotranspiration, and during the growing season impinges on crop production or ecosystem function in general. Observed changes in meteorological droughts (precipitation deficits) and hydrological droughts (streamflow deficits) are distinct from those in agricultural and ecological droughts and addressed in the underlying AR6 material (Chapter 11).

IPCC AR6 WG1

Tropical Cyclones

- Tropical cyclones: "There is low confidence in most reported long-term (multidecadal to centennial) trends in TC frequency- or intensity-based metrics"

Identifying past trends in TC metrics remains a challenge due to the heterogeneous character of the historical instrumental data, which are known as "best-track" data (Schreck et al., 2014). There is *low confidence* in most reported long-term (multidecadal to centennial) trends in TC frequency- or intensity-based metrics due to changes in the technology used to collect the best-track data. This should not be interpreted as implying that no physical (real) trends exist, but rather as indicating that either the quality or the temporal length of the data is not adequate to provide robust trend detection statements, particularly in the presence of multidecadal variability.

IPCC Glossary

Winter Storms

- Winter storms: "There is low confidence in observed recent changes in the total number of extratropical cyclones over both hemispheres. There is also low confidence in past-century trends in the number and intensity of the strongest extratropical cyclones over the Northern Hemisphere…"

11.7.2.1 Observed trends

Chapter 2 (Section 2.3.1.4.3) concluded that there is overall *low confidence* in recent changes in the total number of ETCs over both hemispheres and that there is *medium confidence* in a poleward shift of the storm tracks over both hemispheres since the 1980s. Overall, there is also *low confidence* in past-century trends in the number and intensity of the strongest ETCs due to the large interannual and decadal variability (Feser et al., 2015; Reboita et al., 2015; Wang et al., 2016; Varino et al., 2018) and due to temporal and spatial heterogeneities in the number and type of assimilated data in reanalyses, particularly before the satellite era (Krueger et al., 2013; Tilinina et al., 2013; Befort et al., 2016; Chang and Yau, 2016; Wang et al., 2016).

Thunderstorms, tornadoes, hail, lightning

- Thunderstorms, tornadoes, hail, lightning: "observational trends in tornadoes, hail, and lightning associated with severe convective storms are not robustly detected due to insufficient coverage of the long-term observations"

In summary, because the definition of severe convective storms varies depending on the literature and the region, it is not straightforward to make a synthesizing view of observed trends in severe convective storms in different regions. In particular, observational trends in tornadoes, hail, and lightning associated with severe convective storms are not robustly detected due to insufficient coverage of the long-term observations. There is *medium confidence* that the mean annual number of tornadoes in the United States has remained relatively constant, but their variability of occurrence has increased since the 1970s, particularly over the 2000s, with a decrease in the number of days per year and an increase in the number of tornadoes on these days (*high confidence*). Detected tornadoes have also increased in Europe, but the trend depends on the density of observations.

Extreme winds (between 60S and 60N)

- Extreme winds (between 60S and 60N): "the observed intensity of extreme winds is becoming less severe in the lower to mid-latitudes, while becoming more severe in higher latitudes poleward of 60 degrees (low confidence)"

In summary, the observed intensity of extreme winds is becoming less severe in the lower to mid-latitudes, while becoming more severe in higher latitudes poleward of 60 degrees (*low confidence*). Projected changes in the frequency and intensity of extreme winds are associated with projected changes in the frequency and intensity of TCs and ETCs (*medium confidence*).

Fire Weather

- Fire weather: "There is medium confidence that weather conditions that promote wildfires (fire weather) have become more probable in southern Europe, northern Eurasia, the US, and Australia over the last century"

In summary, there is *high confidence* that concurrent heat waves and droughts have increased in frequency over the last century at the global scale due to human influence. There is *medium confidence* that weather conditions that promote wildfires (fire weather) have become more probable in southern Europe, northern Eurasia, the US, and Australia over the last century. There is *high confidence* that compound hot and dry conditions become more probable in nearly all land regions as global mean temperature increases. There is *high confidence* that fire weather conditions will become more frequent at higher levels of global warming in some regions.

Quality Control in IPCC AR6?

since 1900 is considered to be reliable, and shows no trend in the frequency of U.S. landfall events (Knutson et al., 2019). However, in this period since 1900, an increasing trend in normalized U.S. hurricane damage, which accounts for temporal changes in exposed wealth (Grinsted et al., 2019), and a decreasing trend in TC translation speed over the U.S. (Kossin, 2019) have been identified. A similarly reliable subset of the data

I was of course very happy to see the reference to "normalized" damages in the IPCC, as this methodology and terminology we introduced to the literature in 1998 (Pielke and Landsea 1998) … But …

Quality Control in IPCC AR6?

Table 1. Studies focused on specific phenomena and studies focused on particular regions.

Study (ordered by date of publication)	Phenomenon (region)	Detection claimed to be achieved?	Trend direction	Attribution claimed to be achieved?	Period (*italics* =<30 years)
Studies focused on specific phenomena					
	Tropical cyclones				
Martinez (2020)	United States	No	n/a	No	1900–2018
Grinsted et al. (2019)	United States	Yes	Increase	Yes	1900–2018
Chen et al. (2018)	China	No	n/a	No	1983–2015
Ye and Fang (2018)	China	Yes	Decrease	No	*1985–2010*
Weinkle et al. (2018)	United States	No	n/a	No	1900–2017
Klotzbach et al. (2018)	United States	No	n/a	No	1900–2016
Fischer et al. (2015)	China	No	n/a	No	*1984–2013*
Estrada et al. (2015)	United States	Yes	Increase	No	1900–2005
Bouwer and Wouter Botzen (2011)	United States	No	n/a	No	1900–2005
Nordhaus (2010)	United States	Yes	Increase	No	1900–2005
Zhang et al. (2009)	China	No	n/a	No	*1983–2006*
Schmidt et al. (2009)	United States	No	n/a	No	1950–2005
Pielke et al. (2008)	United States	No	n/a	No	1900–2005
Pielke et al. (2003)	Latin America and Caribbean	No	n/a	No	1944–1999
Raghavan and Rajesh (2003)	India	No	n/a	No	*1977–1998*
Collins and Lowe (2001)	United States	No	n/a	No	1900–1999
Pielke and Landsea (1998)	United States	No	n/a	No	1926–1995
	Floods				
Du et al. (2019)	China	Yes	Decrease	No	1990–2017
Paprotny et al. (2018)	Europe	No	n/a	No	1870–2016
Wei et al. (2018)	China	Yes	Decrease	No	*2000–2015*
Fang et al. (2018)	China (Yangtze River)	Yes	Decrease	No	*1998–2014*
Perez-Morales et al. (2018)	Spain	No	n/a	No	1975–2013
Stevens et al. (2016)	United Kingdom	No	n/a	No	1884–2013
Barredo et al. (2012)	Spain	No	n/a	No	1971–2008
Hilker et al. (2009)	Switzerland	No	n/a	No	1972–2007
Chang et al. (2009)	Korea	No	Increase	No	1971–2005
Barredo (2009)	Europe	No	n/a	No	1970–2006
Downton et al. (2005)	United States	Yes	Decrease	No	1926–2000
Fengqing et al. (2005)	China	No	n/a	No	1950–2001
Pielke and Downton (2000)	United States	No	n/a	No	1932–1997
	Extratropical storms				
Andres and Badoux (2019)	Switzerland	No	n/a	No	1972–2016
Stucki et al. (2014)	Switzerland	No	n/a	No	1859–2011
Barredo (2010)	Europe	No	n/a	No	1970–2008
	Tornadoes				
Simmons et al. (2013)	United States	No	n/a	No	1950–2011
Brooks and Doswell (2001)	United States	No	n/a	No	1890–1999
Boruff et al. (2003)	United States	No	n/a	No	1900–2000
	Convective storms				
Sander et al. (2013)	United States	Yes	Increase	No	1970–2009
	Wildfire				
Crompton et al. (2010)	Australia	No	n/a	No	1925–2009
Studies focused on particular regions					
Study	Region (location & phenomena)	Detection claimed to be achieved?	Trend direction	Attribution claimed to be achieved	Period
	Region				
Choi et al. (2019)	Korea (weather)	Yes	Decrease	No	1965–2015

(*Continued*)

Table 1. Continued.

Study (ordered by date of publication)	Phenomenon (region)	Detection claimed to be achieved?	Trend direction	Attribution claimed to be achieved?	Period (*italics* =<30 years)
Reyes and Elias (2019)	United States (crop loss)	Yes	Mixed	No	*2001–2016*
McAneney et al. (2019)	Australia (weather)	No	n/a	No	1966–2017
Paul and Sharif (2018)	Texas (hydro-meteorological)	No	n/a	No	1960–2016
Bahinipati and Venktachalam (2016)	India (weather)	No	n/a	No	1972–2009
Zhou et al. (2013)	China (natural disasters)	No	n/a	No	*1990–2011*
Crompton and McAneney (2008)	Australia (weather)	No	n/a	No	1967–2006
Choi and Fisher (2003)	United States (weather)	No	n/a	No	1951–1997
	World				
Pielke (2019)	All disasters & weather only	Yes	Decrease	No	*1990–2017*
Watts et al. (2019)	All disasters	No	n/a	No	*1990–2016*
Daniell et al. (2018)	Multi-hazard	Yes	Decrease	No	1950–2015
Mohleji and Pielke (2014)	All-weather related	No	n/a	No	*1980–2008*
Neumayer and Barthel (2011)	All-weather related	No	n/a	No	*1980–2008*
Visser et al. (2014)	All-weather related	No	n/a	No	1980–2010
Miller et al. (2008)	All-weather related	No	n/a	No	1950–2005

Pielke 2021

There are 54 "normalization" studies in the literature, 53 make no claims of attribution. IPCC **AR6 WG1 chose to mention one of 54**

IPCC on Normalized US Hurricane Damage

Lesson: Subject matter experts can readily see when IPCC chooses to deviate from its mission to accurately assess the relevant literature

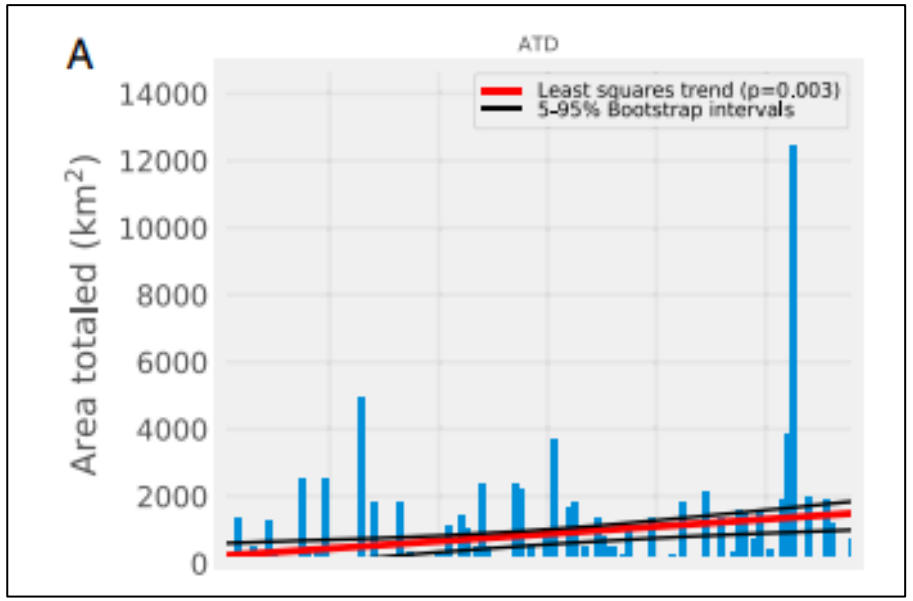
Study highlighted by IPCC (25 citations)

Normalized US **hurricane** damage estimates using area of total destruction, 1900– 2018

A Grinsted, P Ditlevsen… - Proceedings of the …, 2019 - National Acad Sciences

Hurricanes are the most destructive natural disasters in the United States. The record of economic damage from hurricanes shows a steep positive trend dominated by increases in …

☆ 99 Cited by 25 Related articles All 12 versions



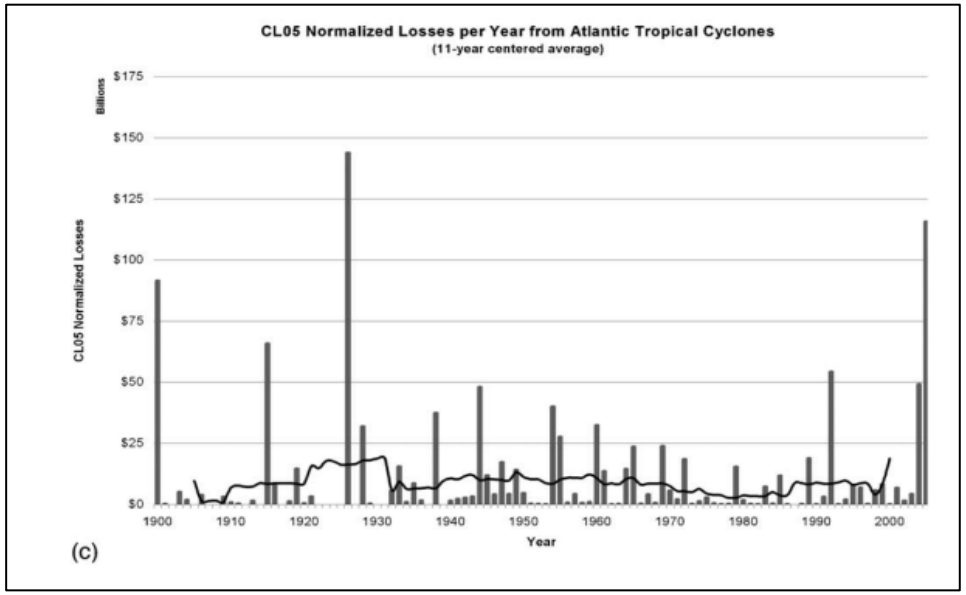
Study ignored by IPCC (1,216 citations)

Normalized hurricane damage in the United States: 1900–2005

RA Pielke Jr, J Gratz, CW Landsea, D Collins… - Natural Hazards …, 2008 - ascelibrary.org

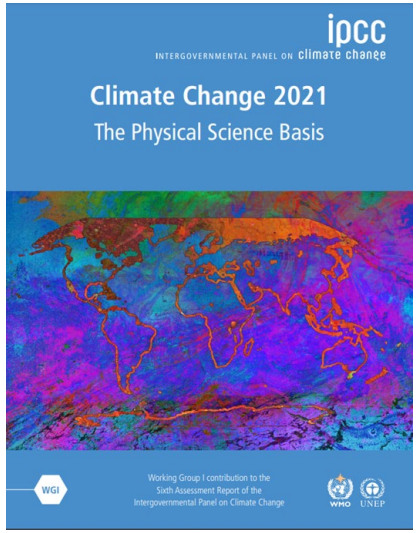
After more than two decades of relatively little Atlantic hurricane activity, the past decade saw heightened hurricane activity and more than 150billionindamagein2004and2005.Thispapernormalizesmainland USHurricane …

☆ 99 Cited by 1216 Related articles All 59 versions



In summary:

Overall, the IPCC WG I did an excellent job representing the literature on extreme events



	Detection	Attribution	
heat waves	yes	yes	
heavy precipitation	yes	yes	
flooding	no	no	
meteorological drought	no	no	
hydrological drought	no	no	
ecological drought	yes	yes	**Medium Confidence**
agricultural drought	yes	yes	**Medium Confidence**
tropical cyclones	no	no	
winter storms	no	no	
thunderstorms	no	no	
tornadoes	no	no	
hail	no	no	
lightning	no	no	
extreme winds	no	no	
fire weather	yes	yes	**Medium Confidence**

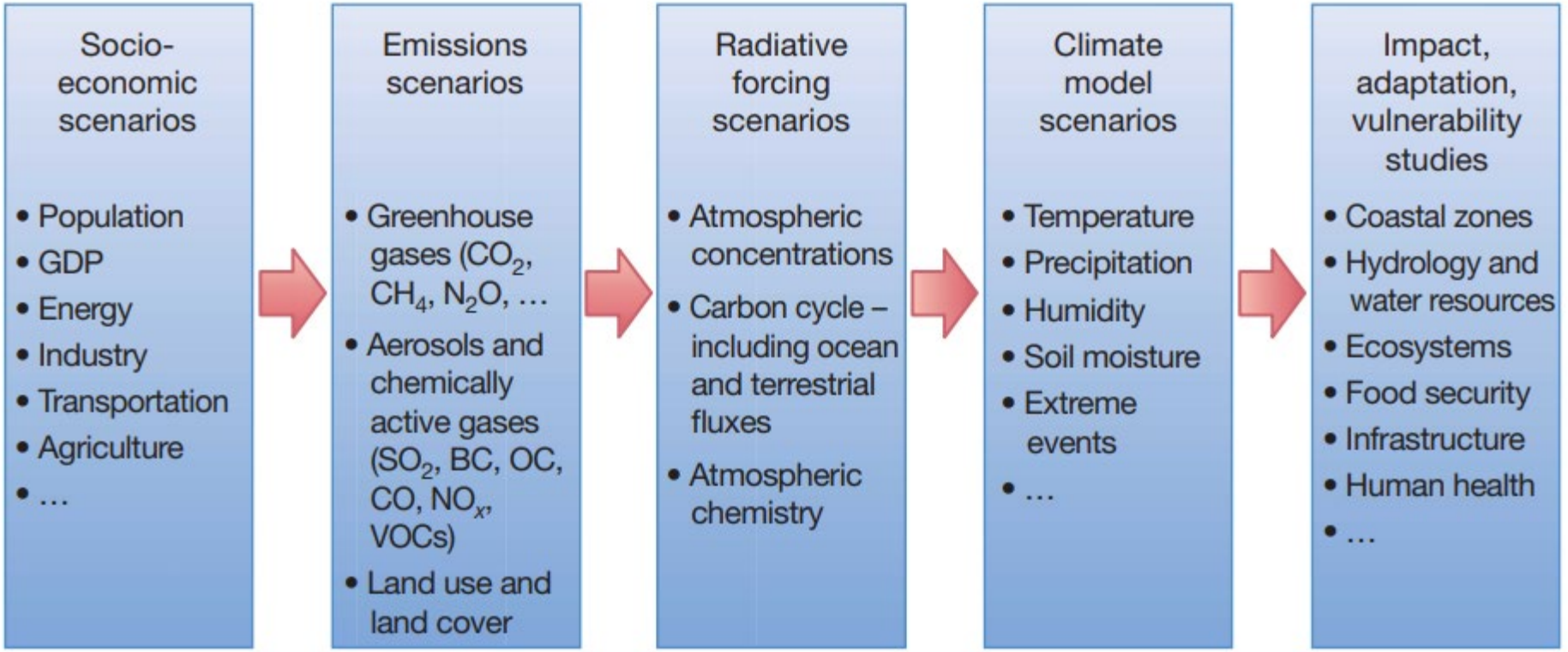
Perhaps more accurately called "soil moisture drought" as in IPCC SREX

Confidence Terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

PART 2
Scenarios

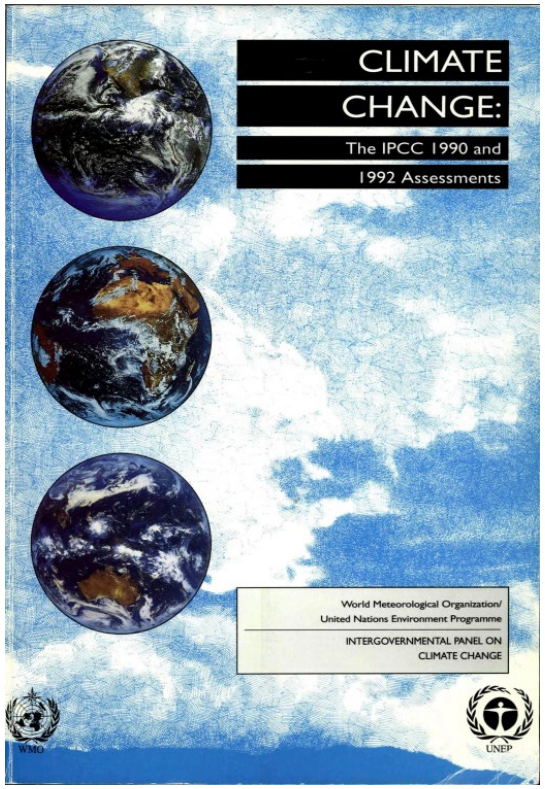
There is quite a story here!
See Pielke and Ritchie (2021) for an in-depth discussion
Please email me for a PDF

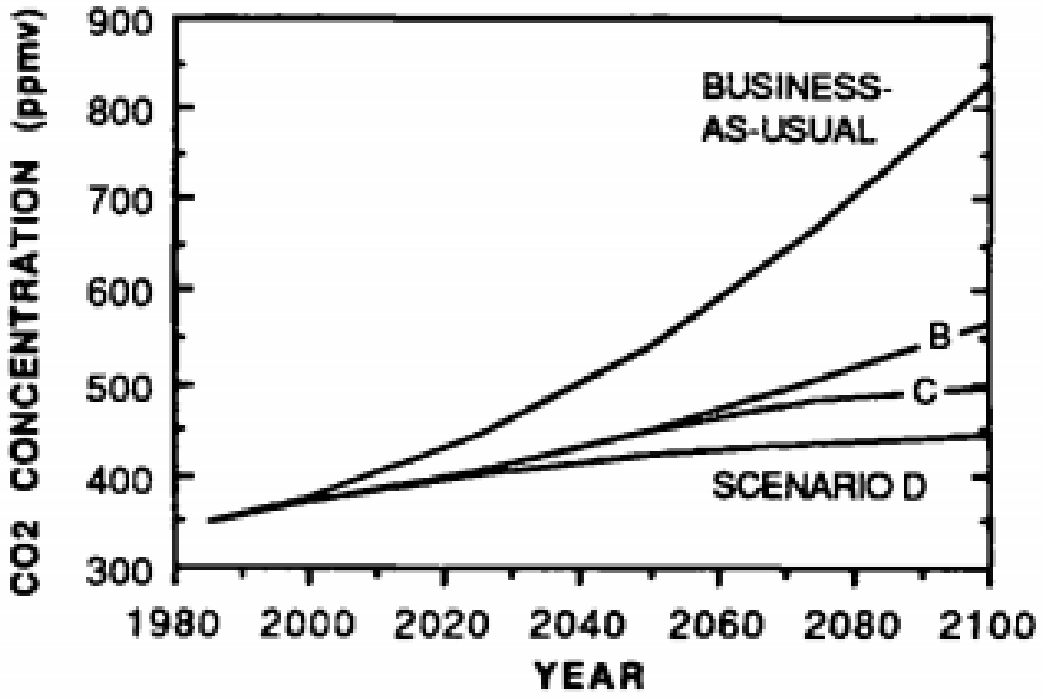
Scenarios are fundamental to climate research and policy



Moss et al. 2010

IPCC First Assessment Report 1990
Scenarios ("Task A") as plausible projections of the future
BAU as a "reference scenario"
Scenarios B, C, D as "policy scenarios"

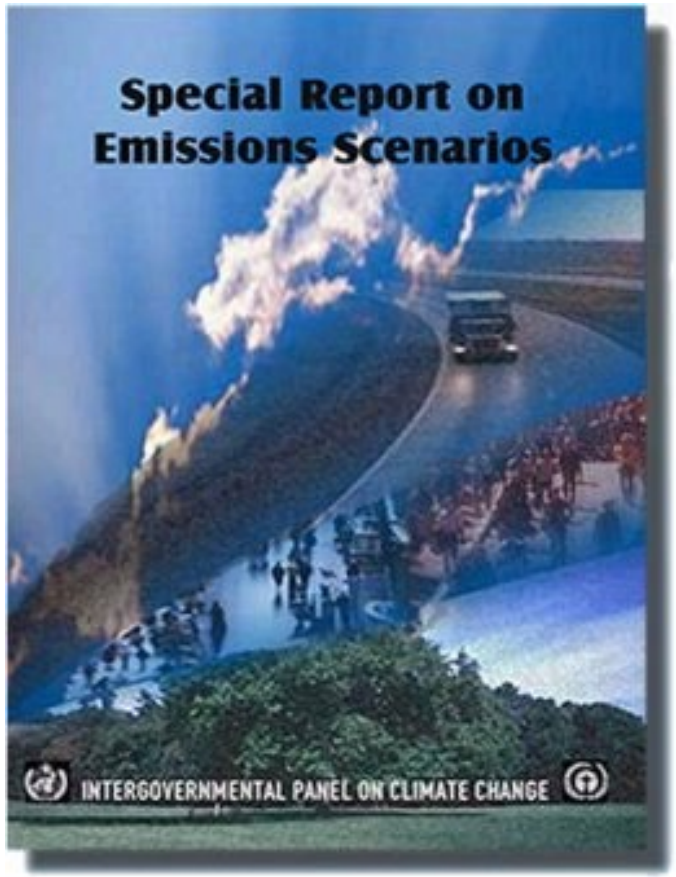


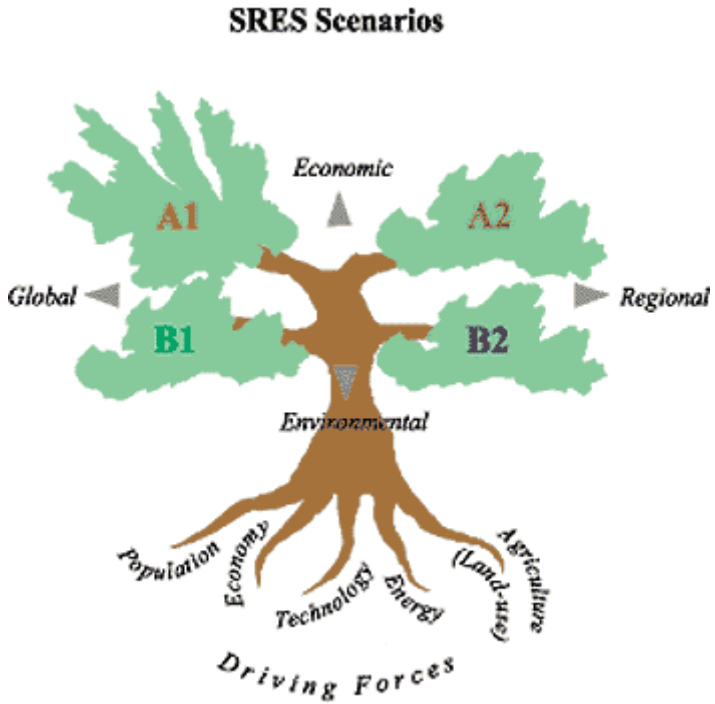


IPCC 2000: SRES Scenarios

Adopted an approach to scenarios with no reference/policy distinction

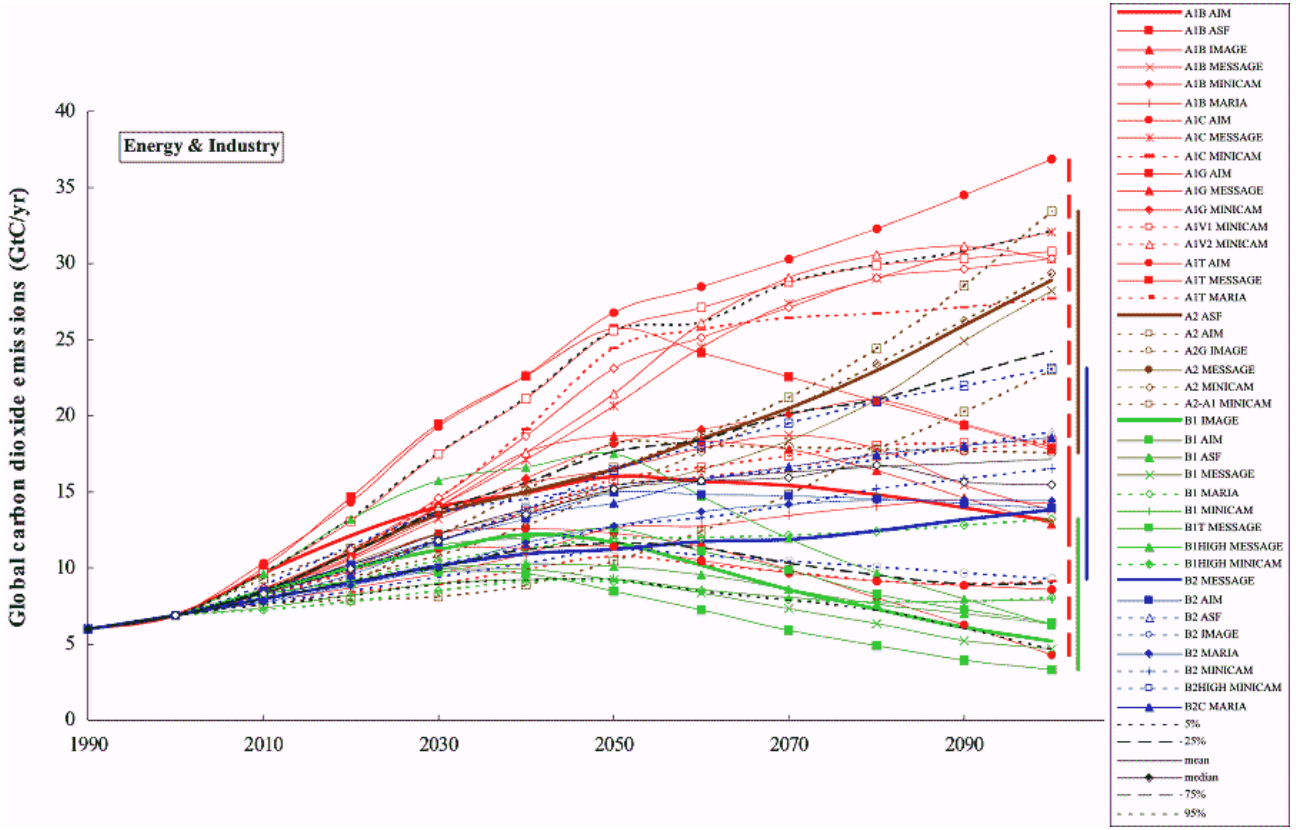
Informed IPCC TAR & FAR





IPCC 2000 SRES scenario range

No "reference scenario" & all were plausible futures



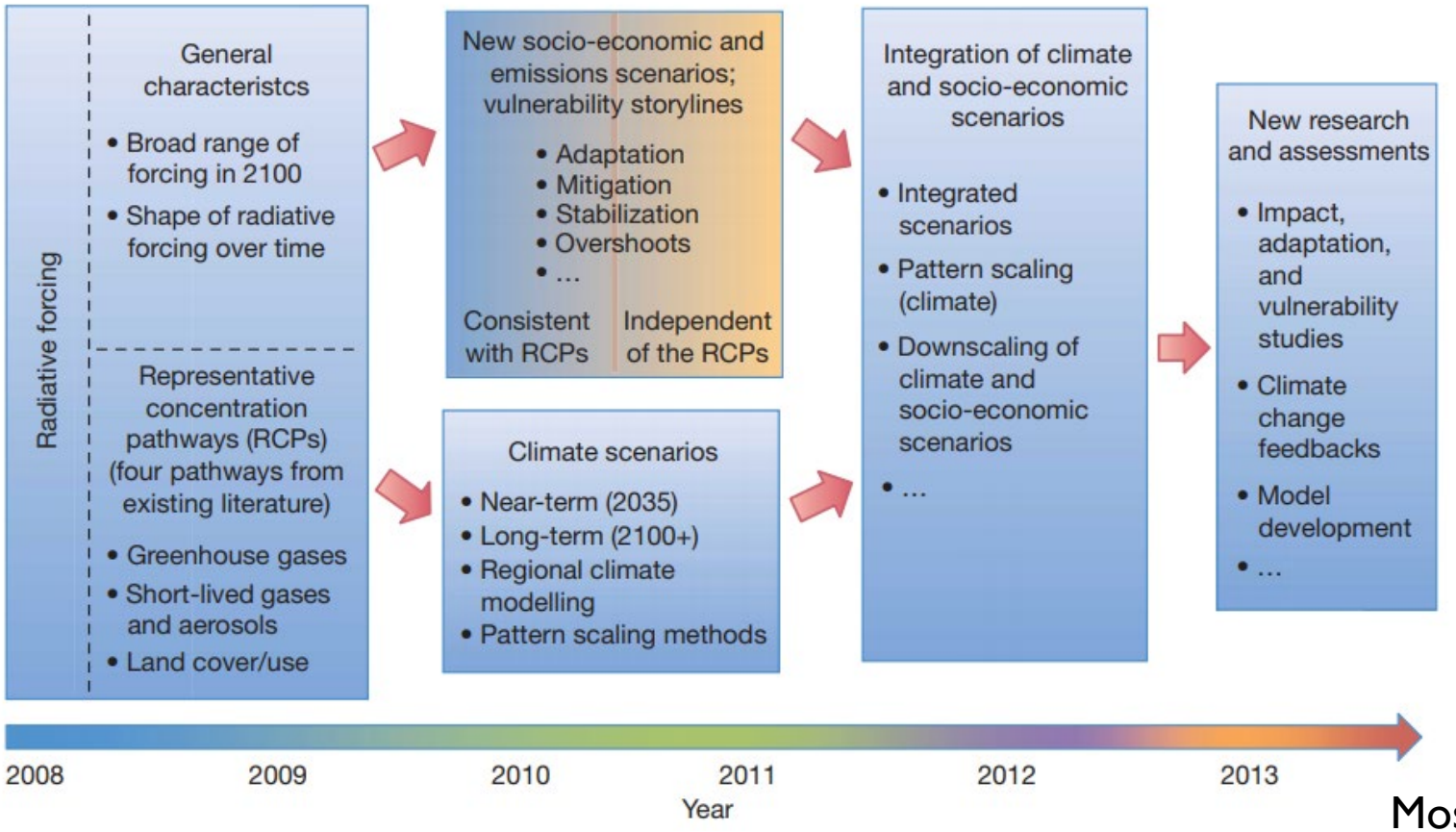
"there was no objective basis on which to assign likelihood to any of the scenarios"

IPCC 2000

Post-SRES scenarios ~2005 to present

Representative Concentration Pathways (RCPs)

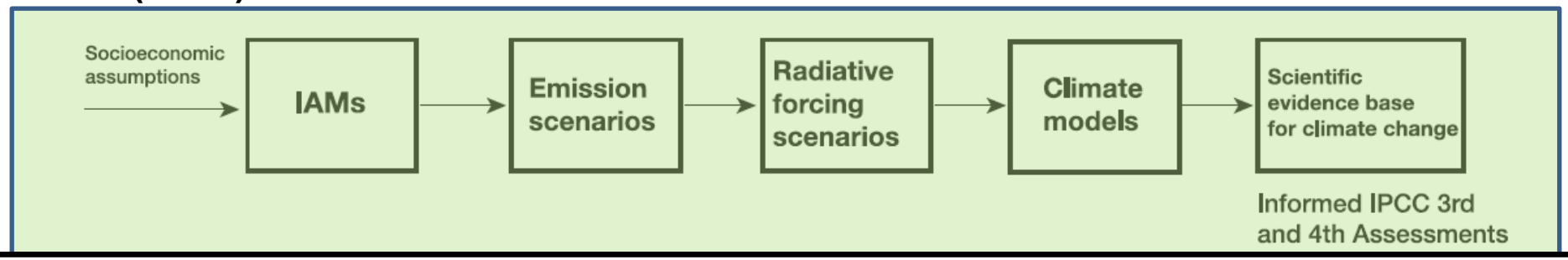
Informed the IPCC AR5, SR15, SROCC, AR6

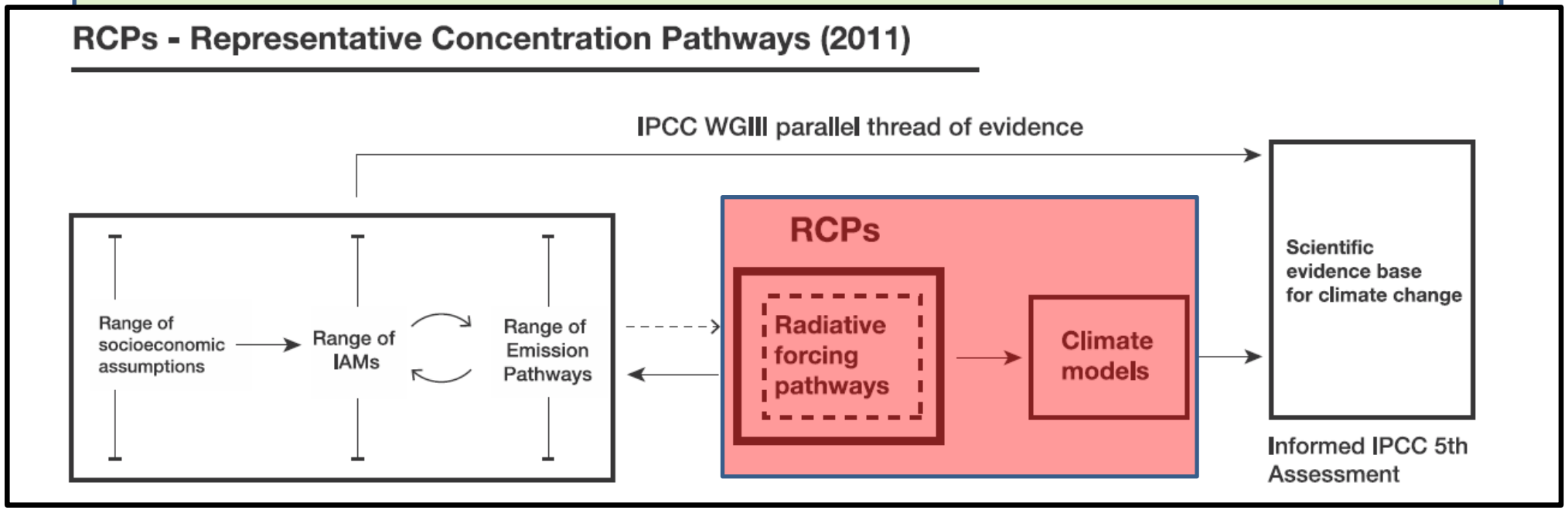


Moss et al. 2010

How the IPCC detached climate modeling from socio-economic plausibility

SRES (2000)

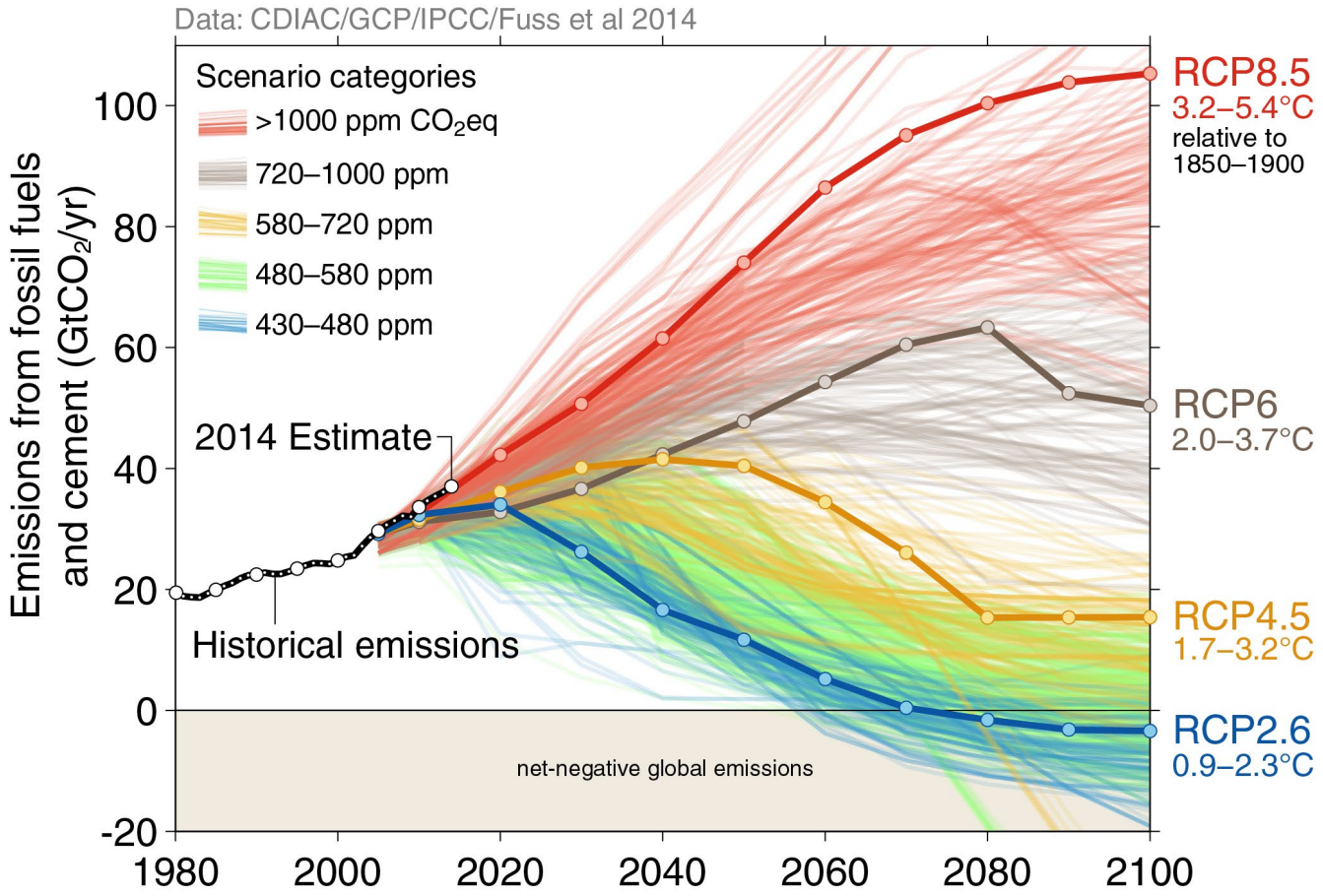




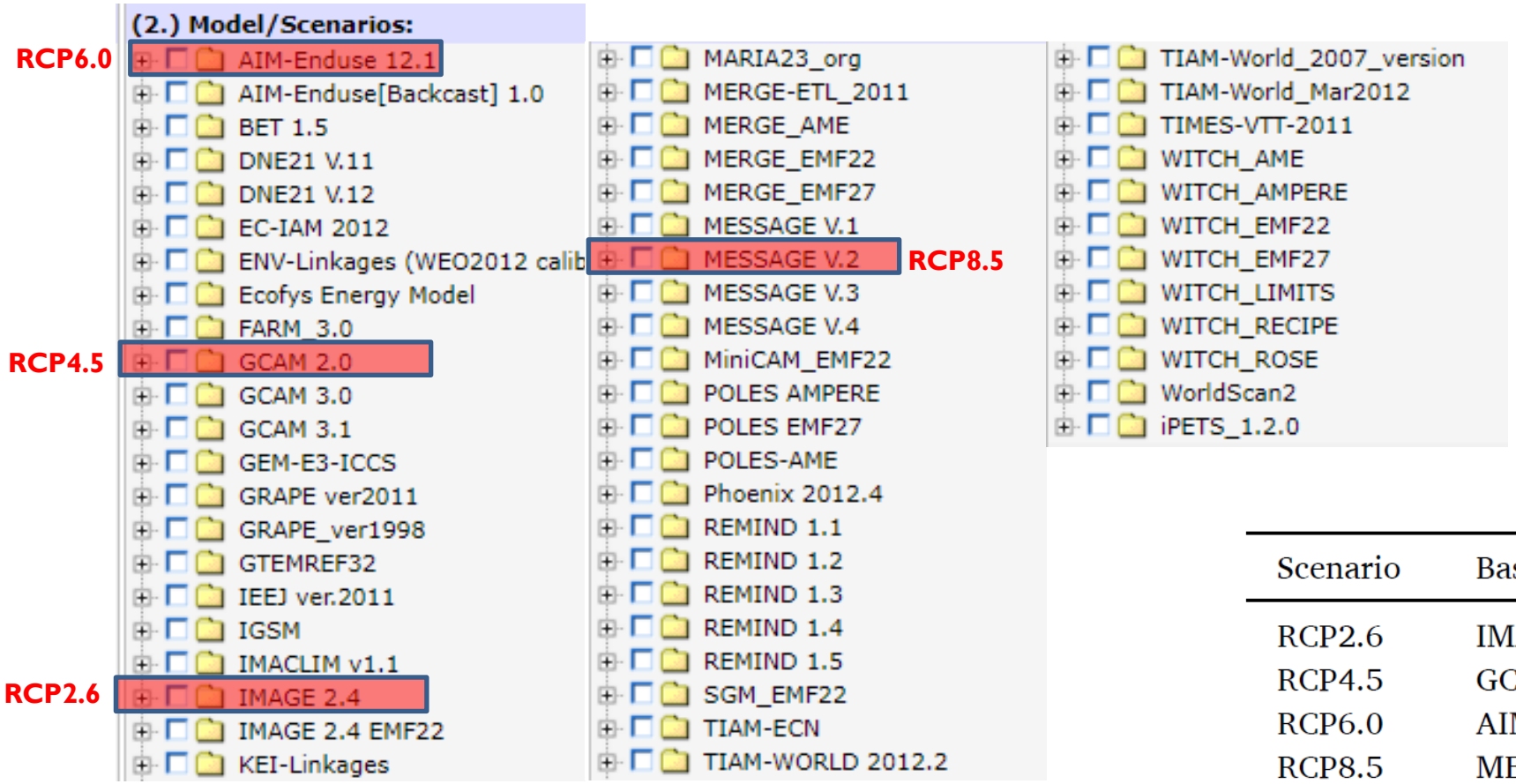
See Pielke and Ritchie (2021) for discussion

Representative Concentration Pathway Scenarios

4 of the 1,184 AR5 Scenarios



IPCC AR5 Integrated Assessment Models
(producing 1184 scenarios in AR5 IIASA database)



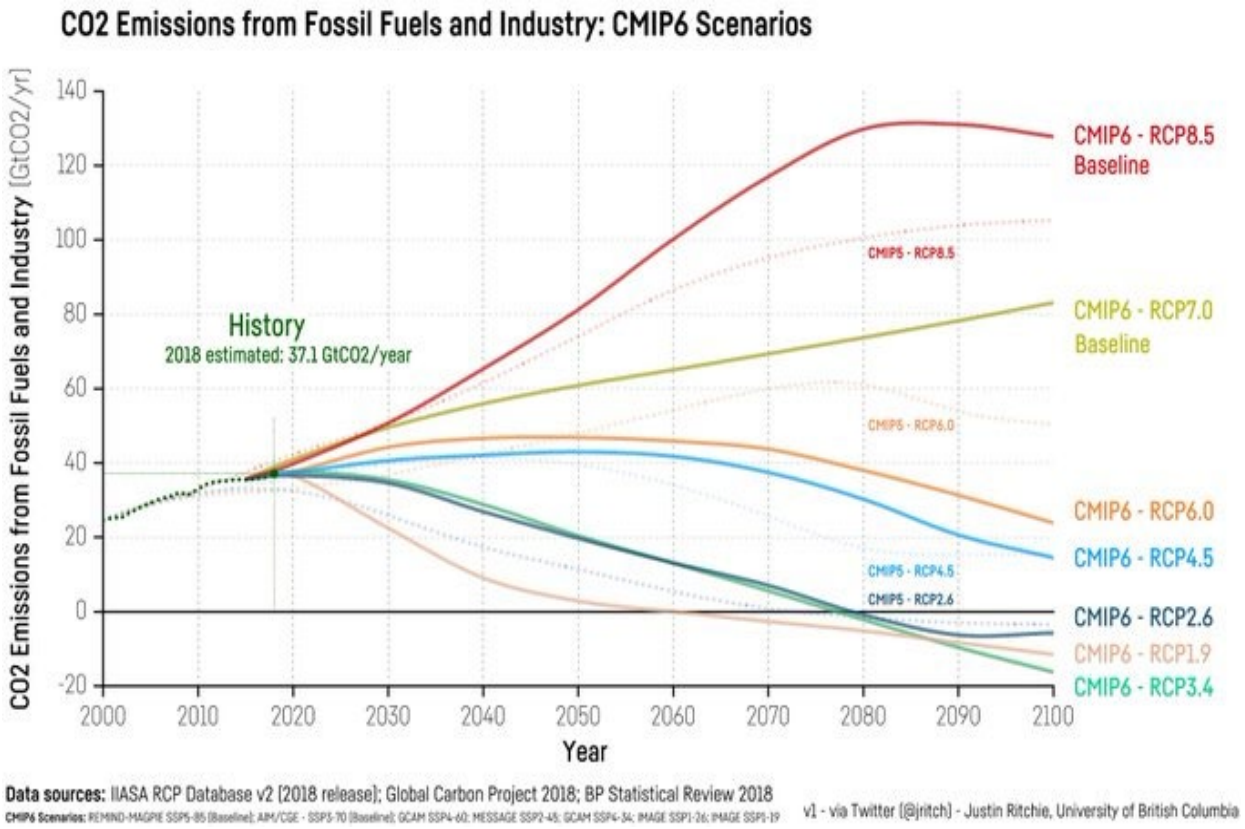
IIASA 2016

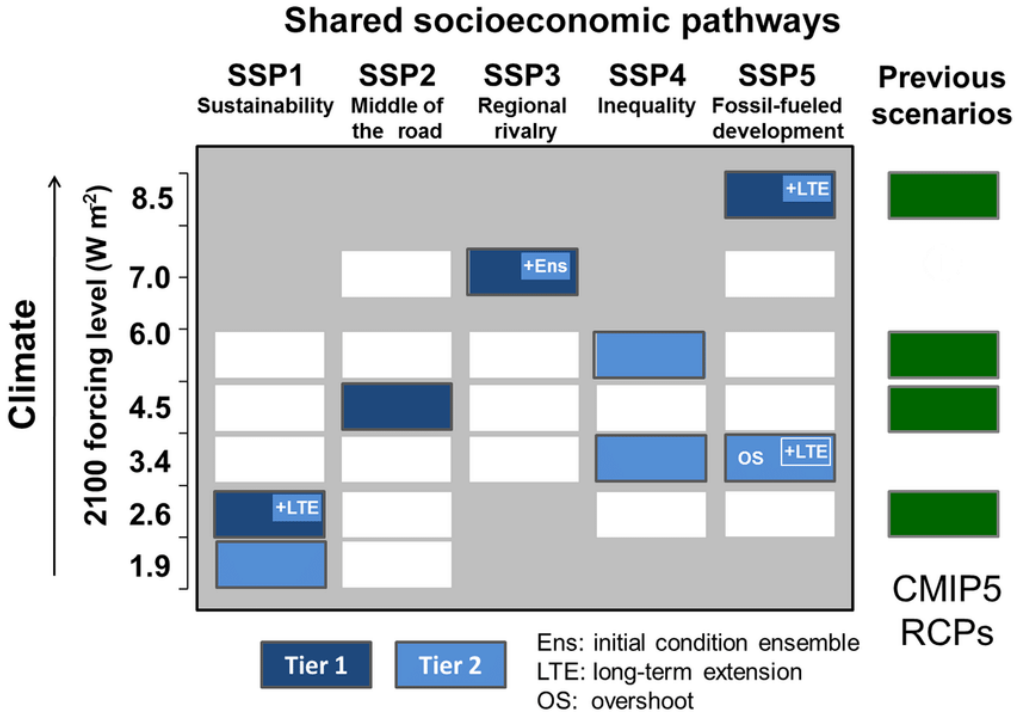
Scenario	Baseline IAM
RCP2.6	IMAGE 2.4 B2
RCP4.5	GCAM 2.0
RCP6.0	AIM SRES B2
RCP8.5	MESSAGE V.2 SRES A2r

See Pielke and Ritchie (2021) for discussion

There are 1000s of climate scenarios

But only 8-12 are presently available for climate research





Justin Ritchie - @jritch
https://twitter.com/jritch/status/1073611322401513474?s=20

See Pielke and Ritchie (2021) for discussion

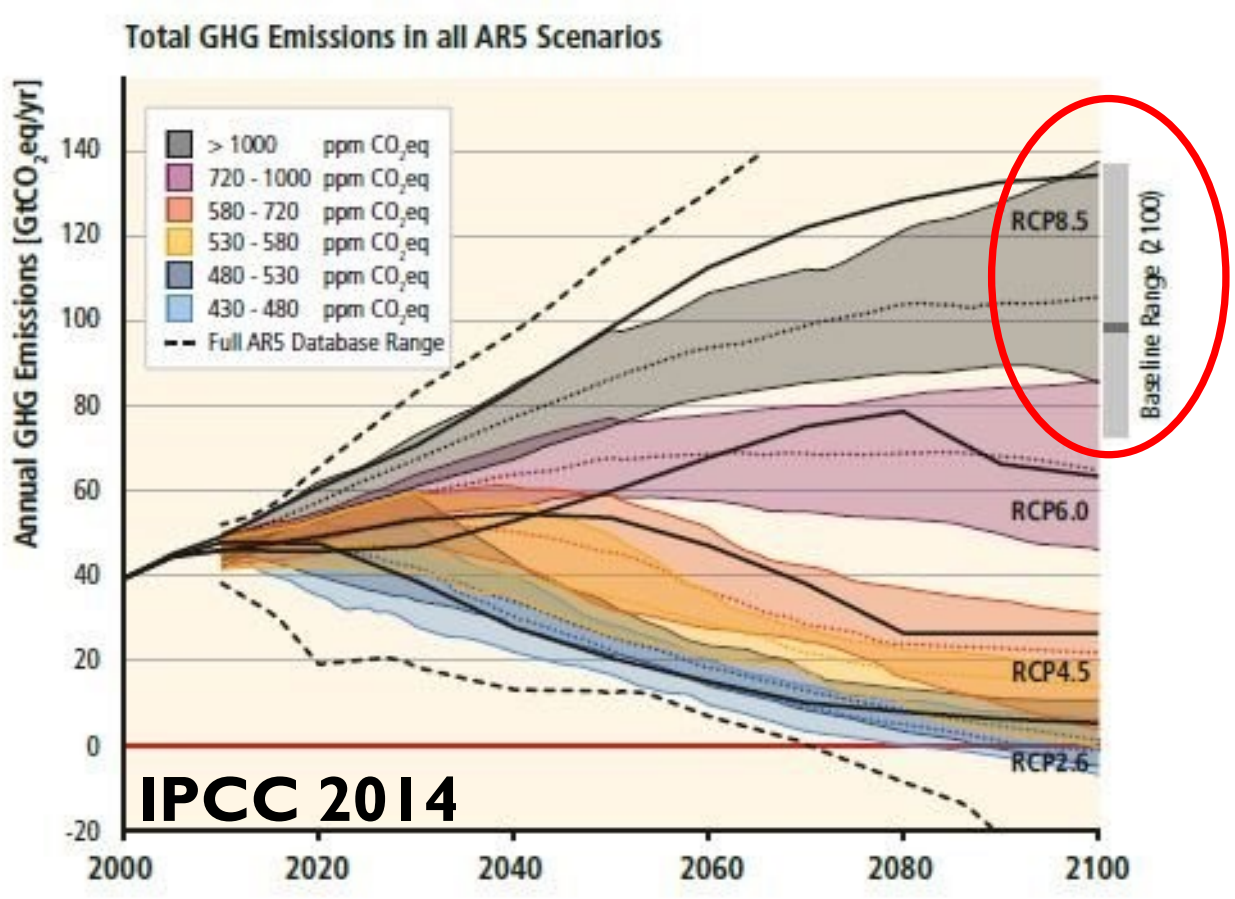
IPCC AR6 gives mixed messages on scenarios

48 *1.6.1.4 The likelihood of reference scenarios, scenario uncertainty and storylines*
49
50 In general, no likelihood is attached to the scenarios assessed in this Report. The use of different scenarios

But at the same time

14 uncertainties in underlying long-term projections of economic drivers (Christensen et al., 2018). However,
15 the likelihood of high emission scenarios such as RCP8.5 or SSP5-8.5 is considered low in light of recent
16 developments in the energy sector (Hausfather and Peters, 2020a, 2020b). Studies that consider possible
17 future emission trends in the absence of additional climate policies, such as the recent IEA 2020 World
18 Energy Outlook 'stated policy' scenario (International Energy Agency, 2020), project approximately
19 constant fossil and industrial CO_2 emissions out to 2070, approximately in line with the medium RCP4.5,
20 RCP6.0 and SSP2-4.5 scenarios (Hausfather and Peters, 2020b) and the 2030 global emission levels that are
21 pledged as part of the Nationally Determined Contributions (NDCs) under the Paris Agreement (Section
22 1.2.2; (Fawcett et al., 2015; Rogelj et al., 2016; UNFCCC, 2016; IPCC, 2018). On the other hand, the default

IPCC AR5, CMIP5, CMIP6
RCP8.5 as "baseline" (i.e., "business as usual")



See Pielke and Ritchie (2021) for discussion

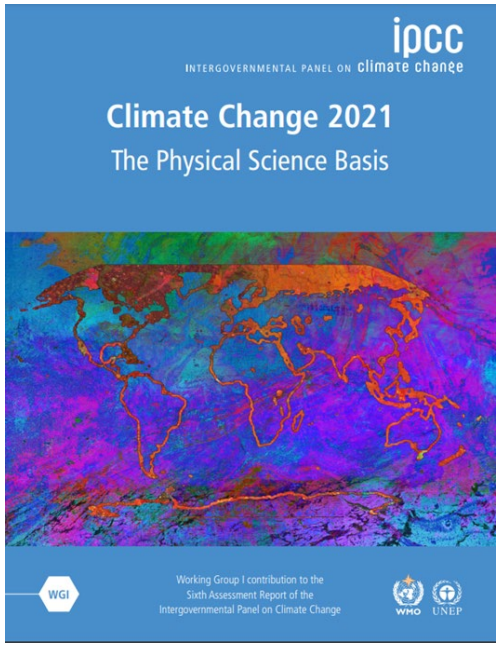
More than half of scenario mentions in IPCC AR6 WG1 are to those judged low likelihood by IPCC AR6 and generally viewed as implausible (8.5 and 7.0, specifically)

To be clear, there are many legitimate scientific uses for implausible, extreme scenarios, such as in exploratory research

But such research should not be conflated with projections of plausible futures or for use in impact, economic or policy studies

IPCC unfortunately engages in and legitimizes such conflation

SCENARIO	MENTIONS	PCT of MENTIONS
SSP5-8.5 & RCP8.5	1359	41.5%
SSP1-2.6 & RCP2.6	733	22.4%
SSP2-4.5 & RCP4.5	571	17.4%
SSP3-7.0	378	11.5%
SSP1-1.9	200	6.1%
RCP6.0	32	1.0%



Dominance of RCP8.5 Across Recent Climate Assessments

Table 3

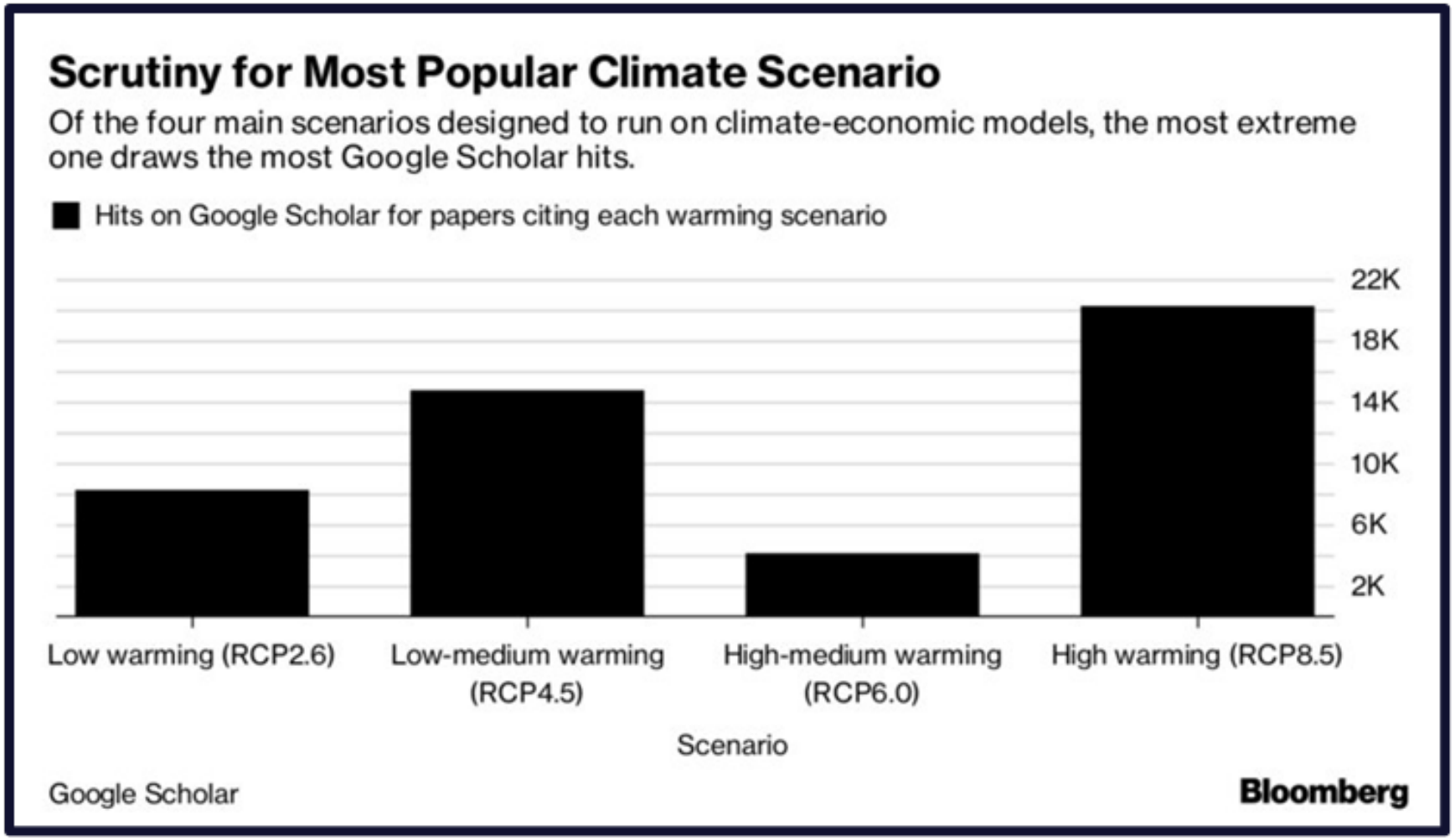
Prevalence of mentions of the RCPs in the IPCC Fifth Assessment Report and the U.S. National Climate Assessment.

Scenario	AR5 WG1	AR5 WG2a	AR5 WG2b	AR5 WG3	SUM
RCP2.6	629 (24.1%)	111 (28.6%)	62 (23.5% 0	18 (30.5%)	820 (24.7%)
RCP4.5	715 (27.4%)	62 (16.0%)	52 (19.7%)	14 (23.7%)	843 (25.4%)
RCP6.0	446 (17.1%)	56 (14.4%)	15 (5.7%)	12 (20.3%)	529 (15.9%)
RCP8.5	821 (31.4%)	159 (41.0%)	135 (51.1%)	15 (25.4%)	1130 (34.0%)
TOTAL	2,611	388	264	59	3,322

Scenario	USNCA (2017, part 1)	USNCA (2018, part 2)	SUM
RCP2.6	47 (15.4%)	35 (6.6%)	82 (9.8%)
RCP4.5	82 (26.8%)	182 (34.4%)	264 (31.6%)
RCP6.0	11 (3.6%)	6 (1.1%)	17 (2.0%)
RCP8.5	166 (54.2%)	306 (57.8%)	472 (56.5%)
TOTAL	306	529	835

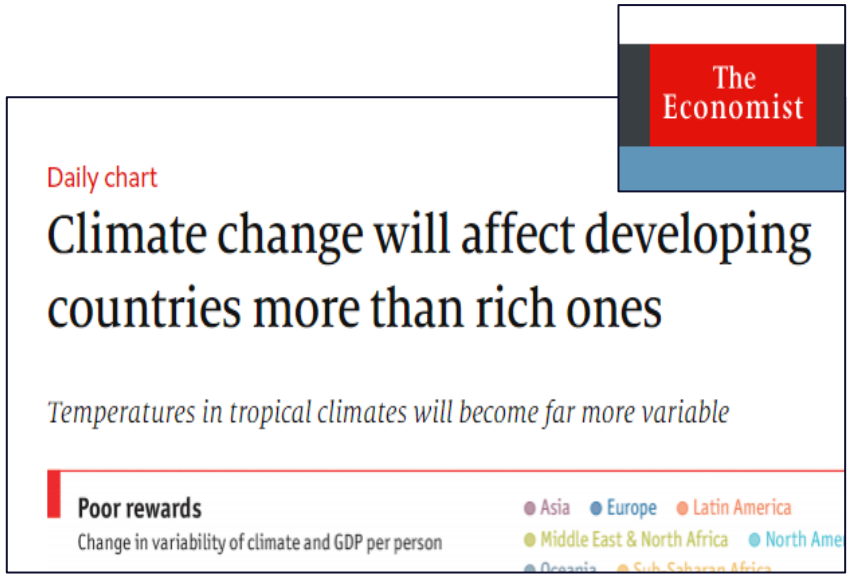
See Pielke and Ritchie (2021) for discussion

Research emphasizes an implausible scenario



See Pielke and Ritchie (2021) for discussion

If you read a media report about climate impacts, it is likely that the story is based on RCP 8.5



See Pielke and Ritchie (2021) for discussion

Massive Confusion!
Scenarios as exploratory for climate modeling vs. projections for informing policy

"Given that the **primary goal of this [RCP] exercise is to provide input data for climate models**, the core products will be global emissions and concentrations of long-lived greenhouse gases, gridded emissions of shorter-lived species, and gridded land-use and land-use change information."

Van Vuuren 2008

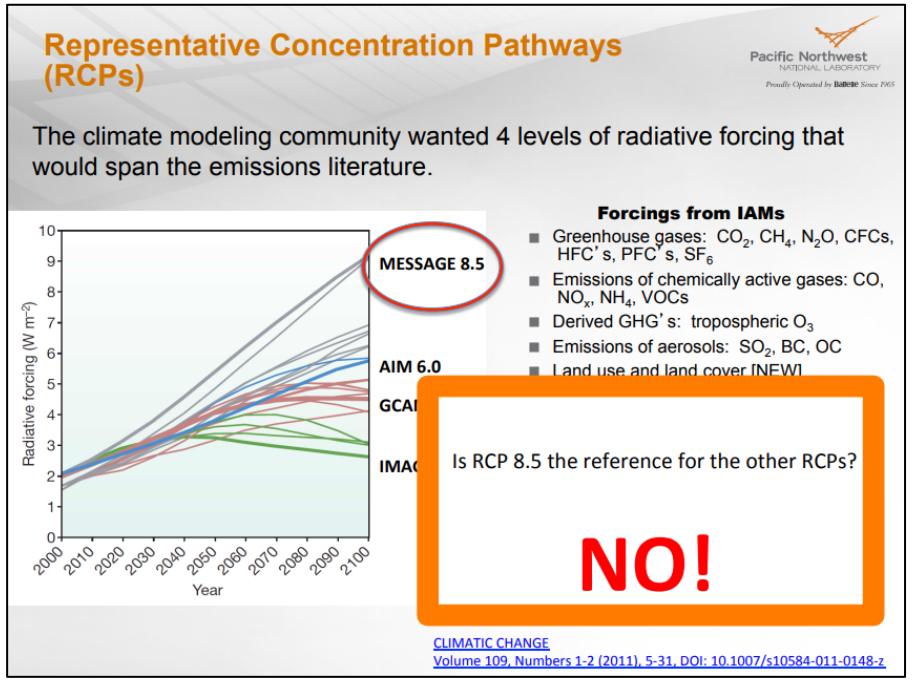
"**RCPs are mainly intended to facilitate the development of integrated scenarios by jump-starting the [climate modeling] process** through the provision of data on emissions, concentrations, and land use/land cover needed by [climate models]."

Moss et al. 2008

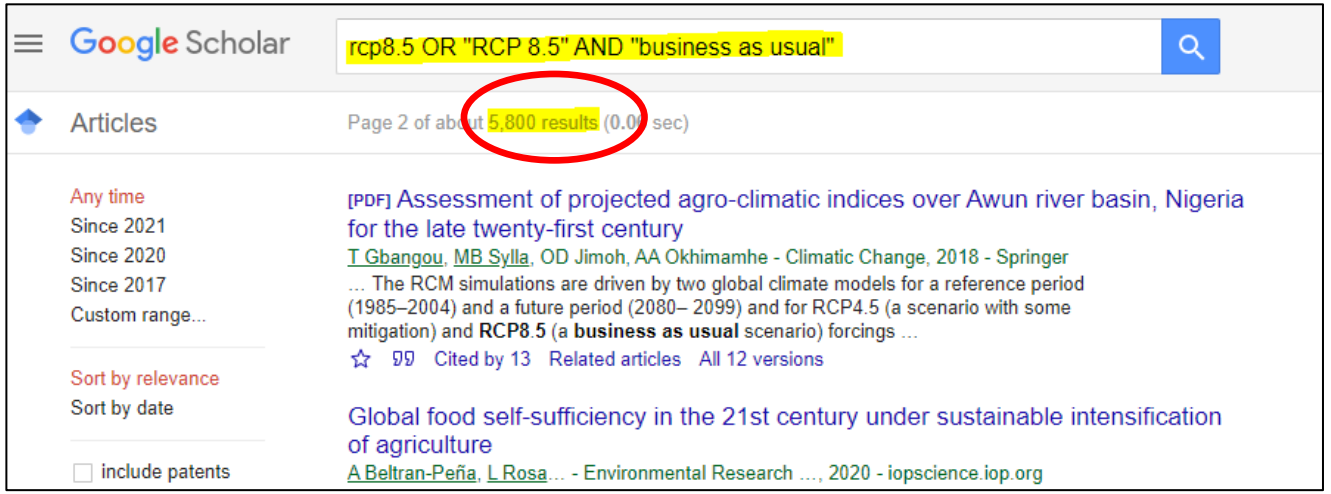
See Pielke and Ritchie (2021) for discussion

Despite warnings by RCP creators RCP8.5 is systemically misused as a reference scenario for the other RCPs

Warning!



Ignored!



Search of 13 Mar 2021

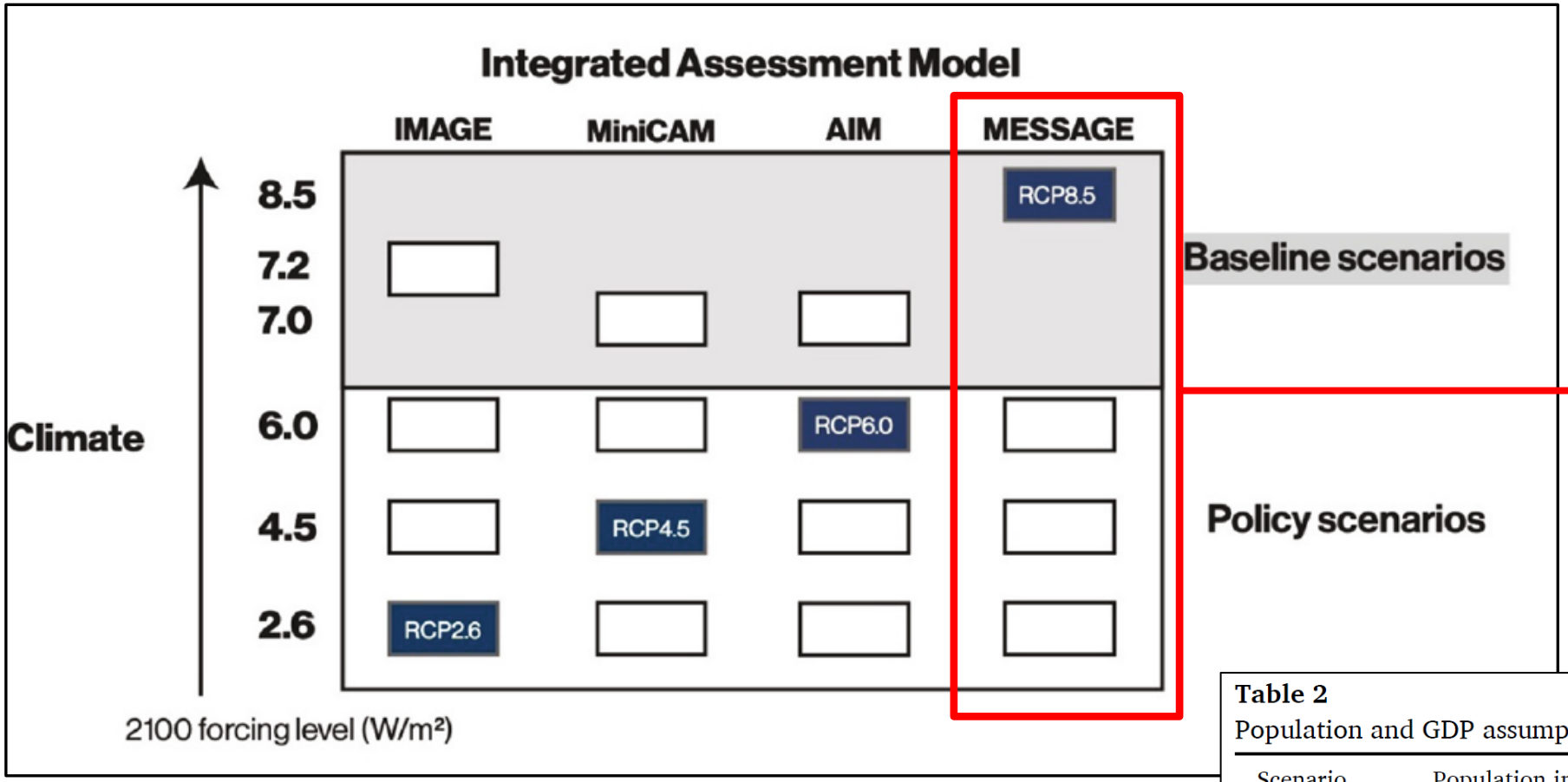
From a presentation by Richard Moss in 2014

http://www.globalchange.umd.edu/data/annual-meetings/2014/Moss-GCAM_scenarios_v1.pdf

See Pielke and Ritchie (2021) for discussion

RCPs are not in fact RCPs

They are re-named from pre-existing scenarios, which come with fully characterized socio-economic inputs (e.g., population, GDP, etc.)



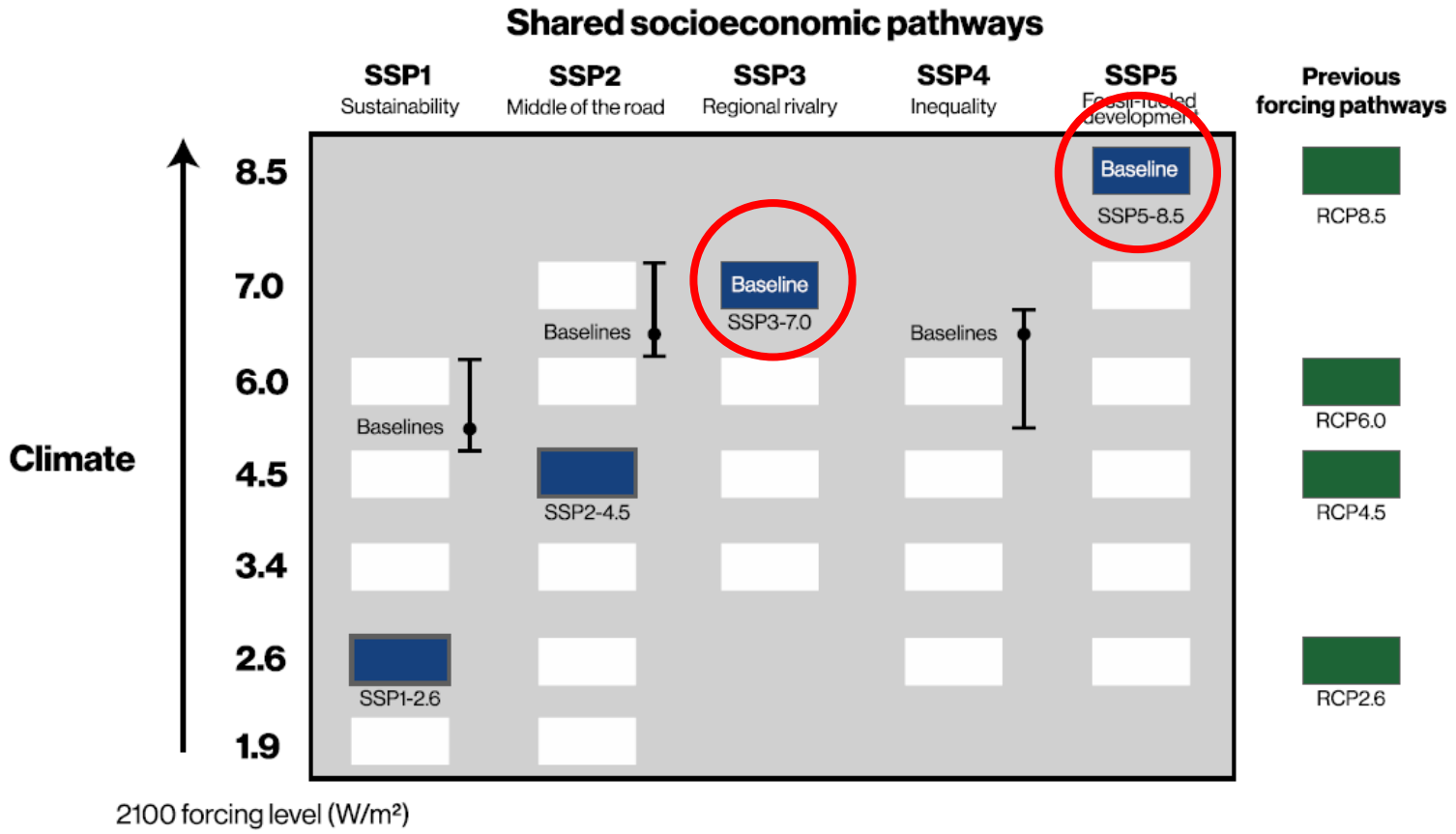
To evaluate climate policy using an IAM, it would be necessary to compare scenarios within a column. Comparing across columns is meaningless.

See Pielke and Ritchie (2021) for discussion

Table 2
Population and GDP assumptions of the baseline scenarios of the RCPs.

Scenario	Population in 2100	GDP in 2100	References
RCP2.6	9.1 billion	$329 trillion (1995$)	[46]
RCP4.5	8.7 billion	$340 trillion (2005$)	[44]
RCP6.0	9.8 billion	$225 trillion (2005$)	[47]
RCP8.5	12 billion	$250 trillion (2005$)	[34]

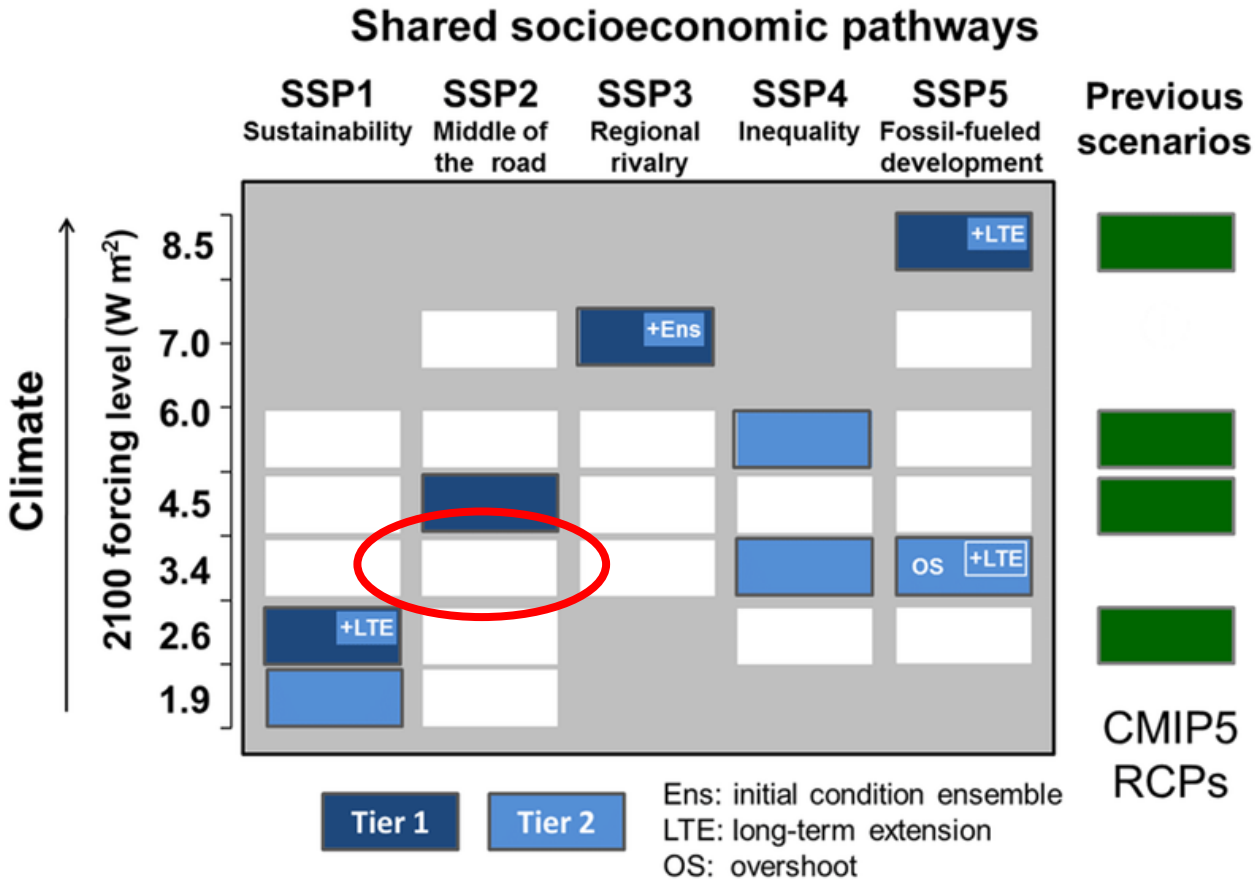
SSPs are repeating problems of the RCPs



See Pielke and Ritchie (2021) for discussion

An arguably most plausible SSP scenario – SSP2-3.4 is not even being studied! While implausible scenarios (SSP3-7.0 & SSP5-8.5) are the highest priority

Scenarios as prioritized by the climate modeling (CMIP6) community



See Pielke et al. (2021, in review) for discussion

So What?

What is wrong with using RCP8.5, SSP5-85 and SSP3-70 as baselines?

- These scenarios are fine for exploratory modeling and investigation
- However, as we will see next – they are implausible – they have no connection to the real world
- They should play no role in climate research to inform plausible projections of climate, impacts or policy
- And the problems are not limited to these 3 scenarios
- Nor is misuse limited to misdefined baselines, the issues are much deeper (Pielke and Ritchie 2021)

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COMMENT · 29 JANUARY 2020

Emissions – the 'business as usual' story is misleading

Stop using the worst-case scenario for climate warming as the most likely outcome – more-realistic baselines make for better policy.

Zeke Hausfather & Glen P. Peters

Falling costs for generating clean electricity have led to a proliferation of wind farms, such as this one near Palm Springs, California. Credit: David McNew/Getty

More than a decade ago, climate scientists and energy modellers made a choice about how to describe the effects of emissions on Earth's future climate. That choice has had unintended consequences which today are hotly debated. With the Sixth Assessment Report (AR6) from the Intergovernmental Panel on Climate Change (IPCC) moving into its final stages in 2020, there is now a rare opportunity to reboot.

PDF version

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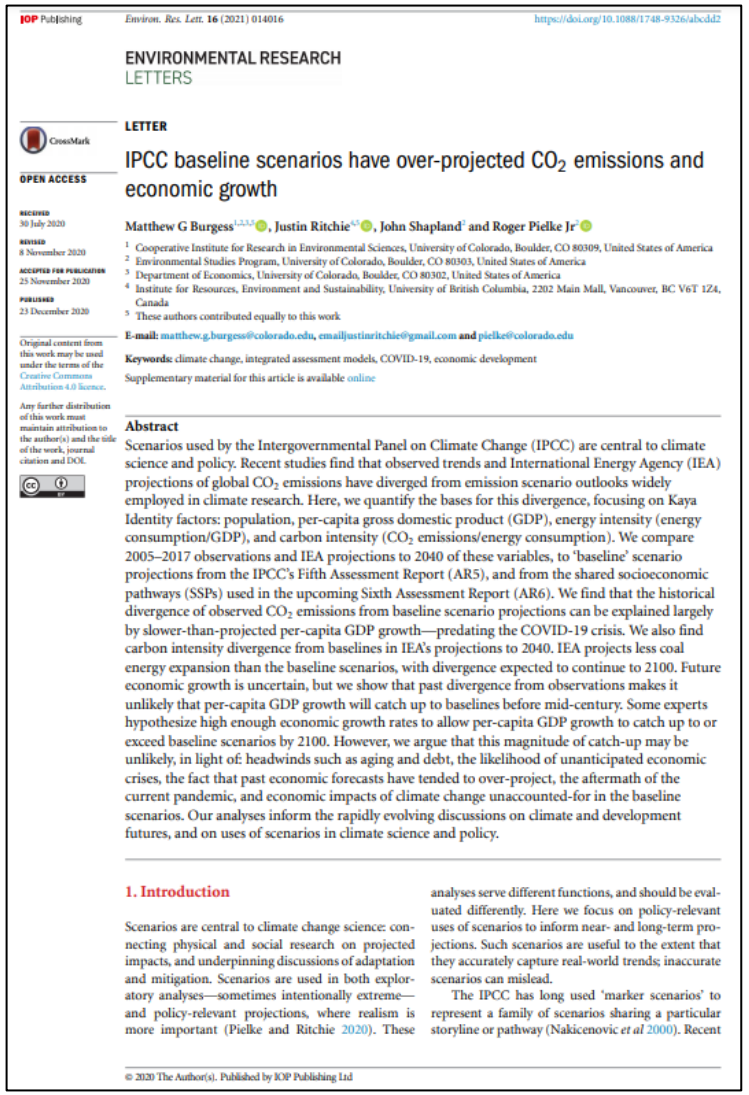
The hard truths of climate change – by the numbers



IOP Publishing Environ. Res. Lett. 16 (2021) 014016 https://doi.org/10.1088/1748-9326/abcdd2

ENVIRONMENTAL RESEARCH LETTERS

LETTER

OPEN ACCESS

IPCC baseline scenarios have over-projected CO_2 emissions and economic growth

Matthew G Burgess, Justin Ritchie, John Shapland and Roger Pielke Jr

Abstract

Scenarios used by the Intergovernmental Panel on Climate Change (IPCC) are central to climate science and policy. Recent studies find that observed trends and International Energy Agency (IEA) projections of global CO_2 emissions have diverged from emission scenario outlooks widely employed in climate research. Here, we quantify the bases for this divergence, focusing on Kaya Identity factors: population, per-capita gross domestic product (GDP), energy intensity (energy consumption/GDP), and carbon intensity (CO_2 emissions/energy consumption). We compare 2005–2017 observations and IEA projections to 2040 of these variables, to 'baseline' scenario projections from the IPCC's Fifth Assessment Report (AR5), and from the shared socioeconomic pathways (SSPs) used in the upcoming Sixth Assessment Report (AR6). We find that the historical divergence of observed CO_2 emissions from baseline scenario projections can be explained largely by slower-than-projected per-capita GDP growth—predating the COVID-19 crisis. We also find carbon intensity divergence from baselines in IEA's projections to 2040. IEA projects less coal energy expansion than the baseline scenarios, with divergence expected to continue to 2100. Future economic growth is uncertain, but we show that past divergence from observations makes it unlikely that per-capita GDP growth will catch up to baselines before mid-century. Some experts hypothesize high enough economic growth rates to allow per-capita GDP growth to catch up to or exceed baseline scenarios by 2100. However, we argue that this magnitude of catch-up may be unlikely, in light of: headwinds such as aging and debt, the likelihood of unanticipated economic crises, the fact that past economic forecasts have tended to over-project, the aftermath of the current pandemic, and economic impacts of climate change unaccounted-for in the baseline scenarios. Our analyses inform the rapidly evolving discussions on climate and development futures, and on uses of scenarios in climate science and policy.

1. Introduction

Scenarios are central to climate change science: connecting physical and social research on projected impacts, and underpinning discussions of adaptation and mitigation. Scenarios are used in both exploratory analyses—sometimes intentionally extreme—and policy-relevant projections, where realism is more important (Pielke and Ritchie 2020). These analyses serve different functions, and should be evaluated differently. Here we focus on policy-relevant uses of scenarios to inform near- and long-term projections. Such scenarios are useful to the extent that they accurately capture real-world trends; inaccurate scenarios can mislead.

The IPCC has long used 'marker scenarios' to represent a family of scenarios sharing a particular storyline or pathway (Nakicenovic *et al* 2000). Recent

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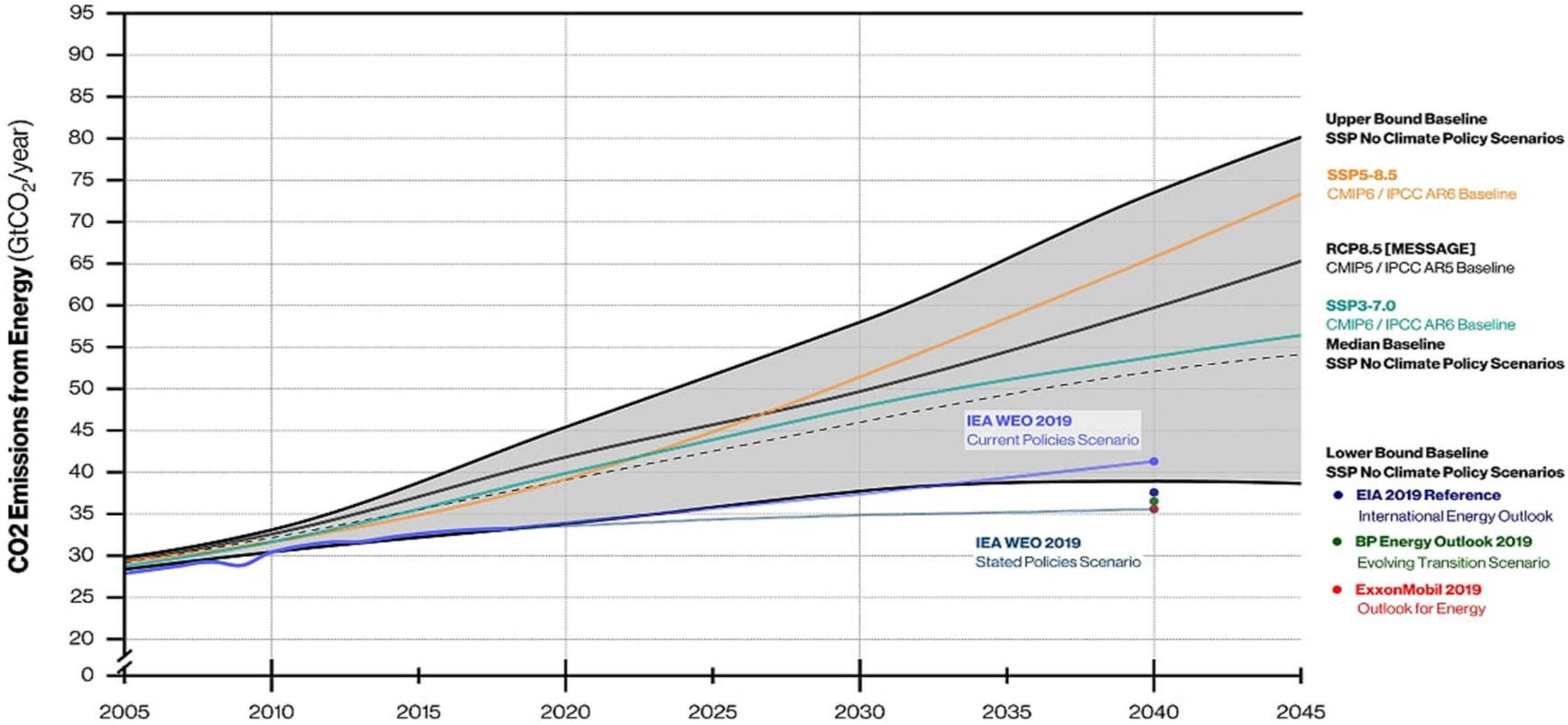
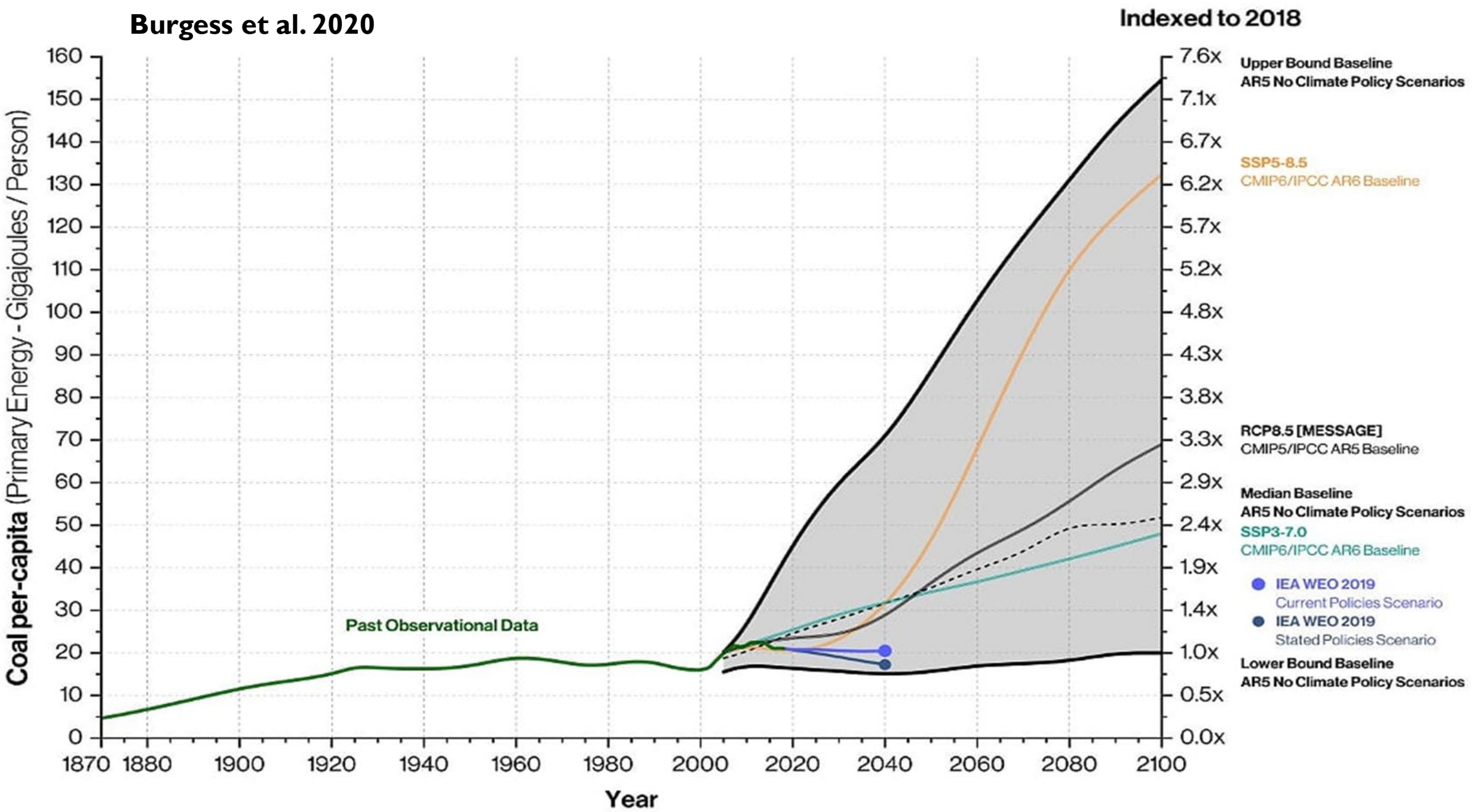
Burgess et al. 2020

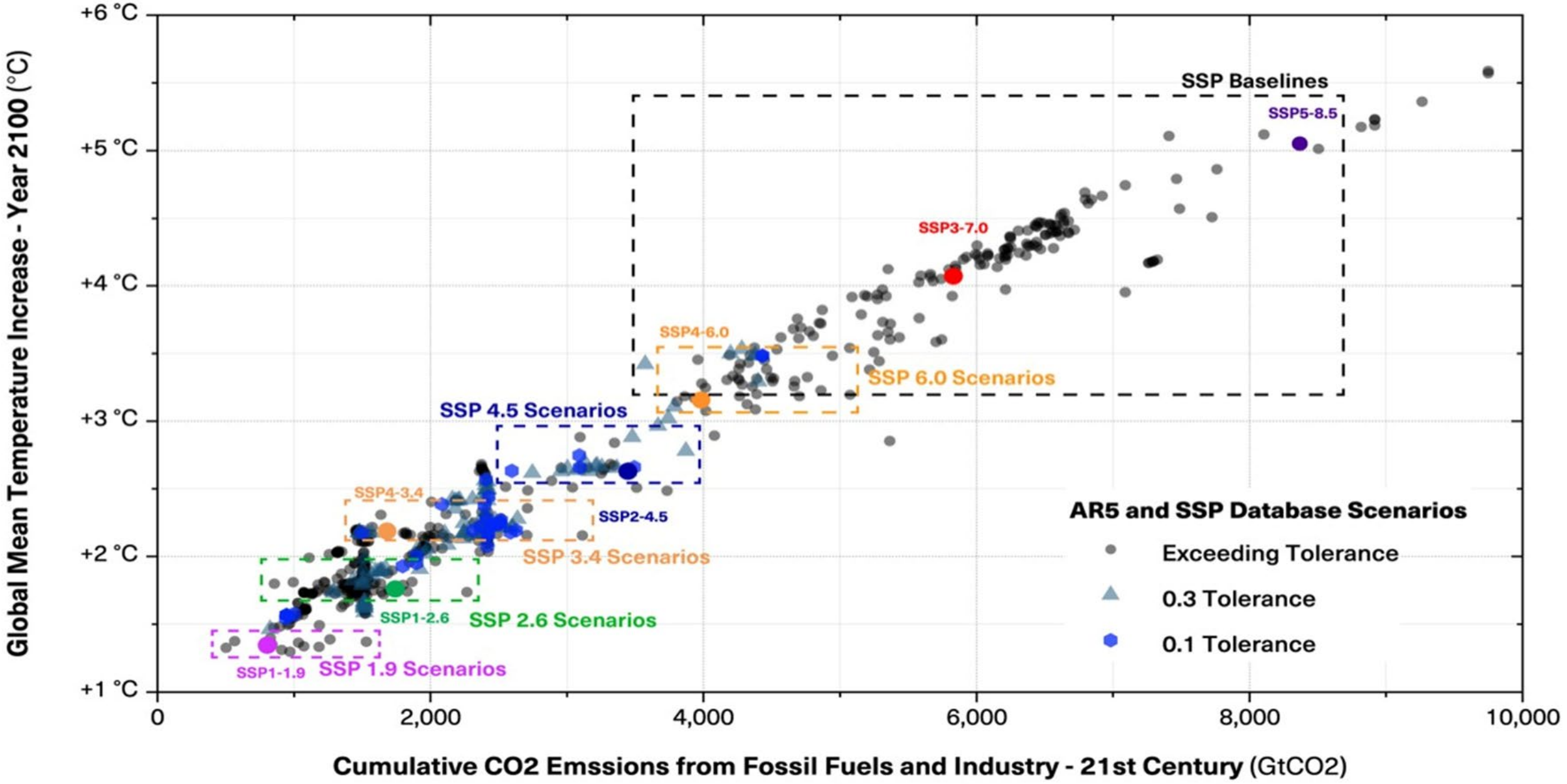


Burgess et al. 2020



From Pre-Industrial Baseline

Viewing the future through plausible AR5 & SSP scenarios (WIP)



Some Closing Observations on Scenarios

- Much of climate science is based on implausible scenarios
- Thousands of studies erroneously project the future as if it were plausible
- Implausible scenario research makes up a significant portion of the research summarized in leading climate assessments
- It also is deeply embedded into policy (including but going well beyond the "social cost of carbon" – such as informing regional and local adaptation planning)
- This is a huge problem
- Climate science has a scientific integrity crisis – not unlike the contamination of literature by misidentified cell lines in cancer research

- What to do?
  - Admit there is a problem
  - Develop new scenarios
  - Even better, develop a much better approach to the use of scenarios
  - Focus climate policy on robust decision making

Special thanks!

- **On scenarios**
  - **Matt Burgess (University of Colorado)**
  - **Justin Ritchie (University of British Columbia)**

Of course, I am solely responsible for all claims and statements made in this presentation!

For further reading:

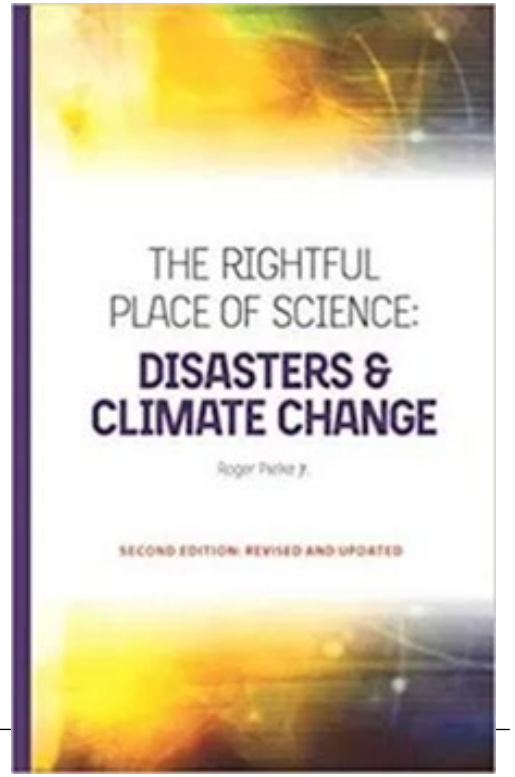
- Ritchie, J., & Dowlatabadi, H. (2017). Why do climate change scenarios return to coal? *Energy*, 140:1276-1291.
- Pielke, Jr., R. (2018). Opening up the climate policy envelope. *Issues in Science and Technology*, 34:30-36.
- Hausfather, Z., & Peters, G. P. (2020). Emissions–the 'business as usual' story is misleading. *Nature*.
- Burgess, M. G., Ritchie, J., Shapland, J., & Pielke, Jr., R. (2020). IPCC baseline scenarios have over-projected CO2 emissions and economic growth. *Environmental Research Letters*, 16(1), 014016.
- Pielke Jr, R., & Ritchie, J. (2021). Distorting the view of our climate future: The misuse and abuse of climate pathways and scenarios. *Energy Research & Social Science*, 72, 101890.
- Pielke, R., & Ritchie, J. (2021). How Climate Scenarios Lost Touch With Reality: A failure of self-correction in science has compromised climate science's ability to provide plausible views of our collective future. *Issues in Science and Technology*, *37*(4), 74-84.
- Pielke, Jr., R., M. Burgess and J. Ritchie, (2021, in review). Most plausible 2005-2040 emissions scenarios project less than 2.5 degrees C of warming by 2100, https://osf.io/preprints/socarxiv/m4fdu

• On extremes

Of course, I am solely responsible for all claims and statements made in this presentation!

For further reading:

- Overview
  - Pielke, R. (2021). Economic 'normalisation' of disaster losses 1998–2020: a literature review and assessment. *Environmental Hazards*, *20*(2), 93-111.
  - Pielke, Jr. R. 2018. **Disasters and Climate Change**, CSPO ASU.
  - For a deeper dive, many dozens of papers here:
    - https://scholar.google.com/citations?user=WtqpmdIAAAAJ&hl=en&oi=ao



Thank You!

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@RogerPielkeJr

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