Climate change risks illustrated by the IPCC "burning embers": Supplementary information

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S1 Data description

S1.1 Embers database fields

The database stores information about 'burning embers' diagrams and the related metadata (see Embers below). The general structure of the tables/models is the following (see Fig. 2 of the main paper):
BiblioReferences (as a rule, IPCC reports) contain figures, which contain EmberGroups (groups of embers), which contain Embers, which are described through (risk) Transitions, which contain Levels. Scenarios are linked to Embers, and Axis are linked to EmberGroups.
In the documentation fields, 'Links to' means that the database field is a foreign key. The database is managed by PostgreSQL and currently accessed trough Django's ORM.

Ember

Embers, short for 'burning embers', are the fundamental elements stored in this database, a synthetic illustration of how risks and impacts increase with a given metric of climate change (for example Zommers et al. 2020, NREE, https://www.nature.com/articles/s43017-020-0088-0).

id	(primary key for this data table/model)
maingroup_id	Links to the 'main group', which is typically a group included in a 'basis figure' in the chapter which is the most important source for assessing this ember. The maingroup is used as default group for embers included in several groups (used when the context does not indicate a specific group).
scenariogroup_id	Links to a group containing a set of embers describing the same risks in the context of different vulnerability/adaptation scenarios (optional).
scenario_id	Links to a scenario. In this database, a 'scenario' is a set of elements defining a 'context' wrt. impacts of climate change, such a shared socio-economic pathway (SSP) or a level of adaptation (capacity).
name	The name of this ember, usually shown under the ember in diagrams.
haz_name	A default 'descriptive' name for the hazard variable, which may be used on the vertical axis if this ember is drawn alone, with no figure/panel axis.
haz_name_std	The standard name of the variable used to define hazard levels.
haz_unit	The unit of the variable used to define hazard levels.
haz_valid_bottom	The bottom of the assessed range, in the same unit as hazard levels.

haz_valid_top	The top of the assessed range, in the same unit as hazard levels.
longname	A name that fully indicates which risk is assessed. This name is specific to this database; unlike some original ember names, which need a specific context, the longer name is sufficient to define the topic, without group name or figure title.
description	A short description of the scope of this ember, explaining which risk is assessed.
sup_information	Additional information (that does not fit in other categories).
internal_notes	Notes containing information for database editors (restricted).
keywords	Keywords may help in defining groups of 'related' embers for identification, illustration, or aggregated analysis.
inclusion_level	Inclusion level relates to API access: it advises on how far an ember could be 'adequate' for use in analyses, in particular to list some embers as superseded by a newer assessment. -3 is the lowest 'adequacy/inclusion' level, +2 is the highest. In JSON output the levels are defined in the general metadata for the key 'ember_inclusion_levels'.
publication_status	Access to an ember may be restricted to editors while the data is being prepared. Visitors can only view embers which include PUB(lic) in publication_status. Three public access levels are defined, depending on how far the data is finalised: NUM (numeric assessment of hazard/risk levels), DESC (ember description), FULL (all fields except for internal ones).
spec_references	Specific references: indicates the sections within the chapter or supplementary material (indicated by the bibliographic reference for the main figure containing these embers), and additional references if needed.
update_ts	The date+time of the last update; this field may be removed in the future, as it could be included in update_log.
update_log_id	Links to a log entry for the last change.

Transition

A risk transition is a change in risk from one level to the next. It is defined through a set of 'levels' of risk for which the climate change metric is assessed, from min to max.

id	(primary key for this data table/model)
ember_id	The ember which contains this transition.
name	The name of the transition (<name of the first risk level> to <name of the second risk level>, such as 'undetectable to moderate').
confidence	A list of one, or exceptionally two, confidence level(s). Two levels would relate to two nested transition ranges. At the date of 1 May 2024, using two confidence levels has only been suggested for AR6 RFC4 but not actually used to draw embers in IPCC reports.
explanation_short	A summary of the elements explaining the assessment of the levels of climate change in this risk transition.
explanation_ipcc	Draft and/or longer text; currently restricted to database editors.
internal_notes	(restricted).

Level

A Level is a risk level for which hazard is assessed. Within a transition, levels are distinguished by their 'phase', such as 'min', 'median', 'max' or percentiles (pXX).

id	(primary key for this data table/model)
trans_id	The transition in which this level is included.
phase	Phases are 'steps' within transitions. The combination of a transition and phase defines a level within an ember.
phase_index	Intended as sorting criteria.

hazard_level	The hazard level assessed for this risk level.

Embergroup

An Embergroup is a set of embers in the report (it may be a figure panel).

id	(primary key for this data table/model)
figure_id	The figure in which this group of embers is shown.
name	The name of this group of embers (e.g. the title of a figure panel).
haz_axis_id	The hazard axis for drawing this group of embers (found in database table 'axis' or json field 'axes').
data_references	References for the numerical data in this group of embers (not used so far and thus not included in the JSON output; may change or be removed in the future)

Ember2Embergroup

Intermediate table to link Embers and Embergroups through a many-to-many relationship

id	(primary key for this data table/model)
ember_id	Link to an ember.
embergroup_id	Link to an embergroup.
nameingroup	The name of this ember when shown in this group/figure.
iorder	An index for manual ordering embers within a group, when needed.

Figure

Figures store general information about figures containing embers, such as their title and a link to their source.

id	(primary key for this data table/model)
biblioreference_id	The bibliographic reference (BiblioReference) containing this figure.
number	The number of this figure (as text).
shortname	A short an easily recognisable name used to refer to this figure.
title	A title for this figure (optional).
caption	Figure caption.
sup_information	Additional information relative to the figure (not to an ember).
page	The page number in the source reference.
errata_url	If this figure was subject to an errata, this is a link to the corrected version.
sortkey	An auto-generated sort-key for figures.

Axis

Describes axes (the plural of axis): the primary intended use is for the vertical axis of embers, related to the 'hazard' variable.

id	(primary key for this data table/model)
shortname	A short an easily recognisable name used to refer to this axis for axis selection.
name	Axis 'name', for use as label (axis title) on the diagram.
var_name_std	A standard name for the variable represented in this axis.
var_unit	A unit for the represented variable (may not be needed if there is a 'generic' unit associated to var_name_std).
top	The value of the represented variable at the top of the axis.

bottom	The value of the represented variable at the bottom of the axis.
grid_show	Whether full grid-lines should be shown (All), or just tick marks except for lines defined by the user (User).
lines_num	An indication of the desired axis tick-marks and/or grid lines, which will be rounded to a graph-adapted value by the software.
lines_add	A list of custom grid-lines and/or shaded areas, defined by a set of key/values pairs (corresponding to EmberMaker graphical parameters).For example, a shaded area between 1.4 and 1.6 could be defined as [{line: 1.4, shade_end: 1.6, color: 'blue', label: '2025-2035'}].

Scenario

The term scenario is used here to refer to all elements defining a 'context' wrt. impacts of climate change. Examples are 'shared socio-economic pathways' (SSPs), narratives describing vulnerability and/or exposure, or simply a qualifier for the level of adaptation.

id	(primary key for this data table/model)
name	A short an easily recognisable name used to refer to this scenario.
description	A description of this scenario.
reference	A free-text reference, which may contain a page or section number (it may be transformed into a more structured citation in the future).
adapt_index	An adaptation index used to sort and name adaptation scenarios(1 = low, 2 = medium, 3 = high adaptation).

BiblioReference

Bibliographic references, in particular (but not limited to) an IPCC report

id	(primary key for this data table/model)
cite_key	The citation key.
type	The type of publication: 'article', 'book', or 'incollection'.
author	Authors (separate authors with a comma or 'and').
editor	Editors (separate editors with a comma or 'and').
title	Title of the book or chapter.
volume	Volume of the publication (not used so far).
chapter	Chapter number, required if the type is 'incollection'.
doi	DOI (Digital Object Identifier) for this publication (formatted as in BibTeX, that is, including https://doi.org).
isbn	ISBN (International Standard Book Number), authorised only for books (optional).
url	URL to access this publication; if a DOI is available, this is a secondary link.
sm_url	URL for the Supplemental Material; empty string if this publication has no SM. Note: the SM will appear as a reference in addition to the main document when this field is filled.
journal	Journal of the publication (optional).
publisher	The publisher; inherited if left empty and a parent reference is available.
year	Publication year.
pages	Either the total number of pages, or the page range of this part of a book.
crossref_id	A parent reference, such as a report in which this reference is a chapter.
keywords	Keywords (optional, separate keywords with a comma).

S1.2 JSON data description

This section describes the structure of the JSON data used in archive files or obtained from the online API (S1.3).

The fields are mostly identical to the fields in the database, but there are some differences: the structure of the JSON data includes a few additional fields which provide related information with no or less need to follow links between data tables. This benefits from the fact that the JSON data is a « frozen output » intended to be read but not modified, by contrast to the database. In particular, each ember contains a field named « transitions » (plural) which contains the list of transitions for that ember. By contrast, the Ember table in the database does not contain a transition field; transitions are obtained from the Transition table by the database management software (PostgreSQL) through the foreign key for embers; thanks to a different structure, made for data consultation, this is not needed here. The fields which are specific to the JSON output are **marked in blue**.

embers	Embers, short for 'burning embers', are the fundamental elements stored in this database, a synthetic illustration of how risks and impacts increase with a given metric of climate change (for example Zommers et al. 2020, NREE, https://www.nature.com/articles/s43017-020-0088-0). This field contains a list of 'embers'.	
	id	Unique identifier (primary key) of an ember
	group_ids	Unique identifiers (list of foreign keys): related groups, containing the given ember
	maingroup_id	Unique identifier (foreign key): links to the 'main group', which is typically a group included in a 'basis figure' in the chapter which is the most important source for assessing this ember. The maingroup is used as default group for embers included in several groups (used when the context does not indicate a specific group)
	mainfigure_id	Unique identifier (foreign key): links to the figure which contains the main (=defaut) group which contains this ember
	scenariogroup_id	Unique identifier (foreign key): links to a group containing a set of embers describing the same risks in the context of different vulnerability/adaptation scenarios (optional)
	scenario_id	Unique identifier (foreign key): links to a scenario. In this database, a 'scenario' is a set of elements defining a 'context' wrt. impacts of climate change, such a shared socio-economic pathway (SSP) or a level of adaptation (capacity)
	name	The name of this ember, usually shown under the ember in diagrams
	longname	A name that fully indicates which risk is assessed. This name is specific to this database; unlike some original ember names, which need a specific context, the longer name is sufficient to define the topic, without group name or figure title
	haz_name	A default 'descriptive' name for the hazard variable, which may be used on the vertical axis if this ember is drawn alone, with no figure/panel axis
	haz_name_std	The standard name of the variable used to define hazard levels
	haz_unit	The unit of the variable used to define hazard levels
	haz_valid	The range of hazard values over which risk was assessed, a list of 2 elements [haz_valid_bottom, haz_valid_top]
	description	A short description of the scope of this ember, explaining which risk is assessed
	sup_information	Additional information (that does not fit in other categories)
	keywords	Keywords may help in defining groups of 'related' embers for identification, illustration, or aggregated analysis
	spec_references	Specific references: indicates the sections within the chapter or supplementary material (indicated by the bibliographic reference for the main figure containing these embers), and additional references if needed

	inclusion_level	Inclusion level relates to API access: it advises on how far an ember could be 'adequate' for use in analyses, in particular to list some embers as superseded by a newer assessment. -3 is the lowest 'adequacy/inclusion' level, +2 is the highest. In JSON output the levels are defined in the general metadata for the key 'ember_inclusion_levels'		
	transitions	A risk transition is a change in risk from one level to the next. It is defined through a set of 'levels' of risk for which the climate change metric is assessed, from min to max. This field contains a list of ‘transitions’.		
		id	Unique identifier (primary key) of a transition	
		name	The name of the transition (<name of the first risk level> to <name of the second risk level>, such as 'undetectable to moderate')	
		confidence	A list of one, or exceptionally two, confidence level(s). Two levels would relate to two nested transition ranges. At the date of 1 May 2024, using two confidence levels has only been suggested for AR6 RFC4 but not actually used to draw embers in IPCC reports	
		explanation_short	A summary of the elements explaining the assessment of the levels of climate change in this risk transition	
		levels	Assessed hazard levels within the transition,provided as key:value pairs where the key is the level's 'phase' (such as 'min', 'median') and the value is the level's 'hazard'	
embergroups	An Embergroup is a set of embers in the report (it may be a figure panel). This field contains a list of ‘embergroups’.			
	id	Unique identifier (primary key) of an embergroup		
	name	The name of this group of emberse.g. the title of a figure panel		
	figure_id	Unique identifier (foreign key): the figure in which this group of embers is shown		
	ember_ids	Unique identifiers (list of foreign keys): related embers, containing the given embergroup		
	haz_axis_id	Unique identifier (foreign key): the hazard axis for drawing this group of embers (found in database table 'axis' or json field 'axes')		
figures	Figures store general information about figures containing embers, such as their title and a link to their source. This field contains a list of ‘figures’.			
	id	Unique identifier (primary key) of a figure		
	shortname	A short an easily recognizable name used to refer to this figure		
	number	The number of this figure (as text)		
	title	A title for this figure (optional)		
	sup_information	Additional information relative to the figure (not to an ember)		
	biblioreference_id	Unique identifier (foreign key): the bibliographic reference (BiblioReference) containing this figure		
	biblioreference.cite_key	The citation key		
	biblioreference	The full text of the reference for this publication, in Markdown format		
Axes	Describes axes (the plural of axis): the primary intended use is for the vertical axis of embers, related to the 'hazard' variable. This field contains a list of ‘axes’.			
	id	Unique identifier (primary key) of an axis		
	shortname	A short an easily recognizable name used to refer to this axis for axis selection		
	name	Axis 'name', for use as label (axis title) on the diagram		

	var_name_std	A standard name for the variable represented in this axis
	var_unit	A unit for the represented variable (may not be needed if there is a 'generic' unit associated to var_name_std)
	bottom	The value of the represented variable at the bottom of the axis
	top	The value of the represented variable at the top of the axis
	grid_show	Whether full grid-lines should be shown (All), or just tick marks except for lines defined by the user (User)
	lines_num	An indication of the desired axis tick-marks and/or grid lines, which will be rounded to a graph-adapted value by the software
	lines_add	A list of custom grid-lines and/or shaded areas, defined by a set of key/values pairs (corresponding to EmberMaker graphical parameters). For example, a shaded area between 1.4 and 1.6 could be defined as [{line: 1.4, shade_end: 1.6, color: 'blue', label: '2025-2035'}]
scenarios	The term scenario is used here to refer to all elements defining a 'context' wrt. impacts of climate change. Examples are 'shared socio-economic pathways' (SSPs), narratives describing vulnerability and/or exposure, or simply a qualifier for the level of adaptation. This field contains a list of ‘scenarios’.	
	id	Unique identifier (primary key) of a scenario
	name	A short an easily recognizable name used to refer to this scenario
	description	A description of this scenario
	reference	A free-text reference, which may contain a page or section number (it may be transformed into a more structured citation in the future)
	adapt_index	An adaptation index used to sort and name adaptation scenarios(1 = low, 2 = medium, 3 = high adaptation)
biblioreferences	A bibliographic reference, in particular (but not limited to) an IPCC report. This field contains a list of ‘biblioreferences’.	
	id	Unique identifier (primary key) of a biblioreference
	cite_key	The citation key
	title	Title of the book or chapter
	year	Publication year
	author	Authors (separate authors with a comma or 'and')
	editor	Editors (separate editors with a comma or 'and')
	type	The type of publication: 'article', 'book', or 'incollection'
	chapter	Chapter number, required if the type is 'incollection'
	volume	Volume of the publication (not used so far)
	doi	DOI (Digital Object Identifier) for this publication (formatted as in BibTeX, that is, including)
	url	URL to access this publication; if a DOI is available, this is a secondary link
	sm_url	URL for the Supplemental Material; empty string if this publication has no SM Note: the SM will appear as a reference in addition to the main document when this field is filled",
	publisher	The publisher; inherited if left empty and a parent reference is available
	pages	Either the total number of pages, or the page range of this part of a book
	crossref_id	Unique identifier (foreign key): a parent reference, such as a report in which this reference is a chapter
	fullref	The full text of the reference for this publication, in Markdown format
	sm_fullref	The full text of the reference of the supplementary material for this publication, in Markdown format
embers_count	178	
ember_inclusion_levels		

	-3	Not in any IPCC figure			
	-2	Excluded: see sup. info.			
	-1	Excluded: superseded			
	0	Undefined			
	1	Included with remarks			
	2	Included			
format_version	1.0				
license	CC BY 4.0				
license_url	https://creativecommons.org/licenses/by/4.0/				
cite_as	https://doi.org/10.5281/zenodo.12626977				
disclaimer	This file is not an IPCC product. The IPCC does not assume any responsibility for the accuracy of its content. For any use of the data, please refer to the information provided through the link under 'cite_as' and provide the sources shown in the 'biblioreferences' fields.				

S1.3. Remote API Access point & token

There is a single access point to request data: https://climrisk.org/edb/api/combined_data

The data initially provided through the access point does not differ from the data provided in version 1.0.0 of the archive file presented above and in the main paper (https://doi.org/10.5281/zenodo.12626977). In the future, the remote API will continue to provide the same data as the user interface (climrisk.org/cree), and could therefore provide access to updates before these are made available as new versions on Zenodo. The date of the last update of the data for a given ember is shown at the bottom of the page in the Climate Risks Embers Explorer. We regard the remote API as a tool that may help in conducting future research using updated data, while publications based on updates will likely continue to rely on the archive files published on Zenodo with versioning and explanations about the changes.

Access currently requires a token which normally identifies the user (we may consider full public access in the future depending on actual use of this function). However, for the review period, it is possible to test this function anonymously by using the following « public token »: 70cae8402eeb7862ffbdc13015c7273dc22aef4d

Requests may include one or more of 'filter' parameters (search criteria). Information on these filters is available in the documentation provided with the code (file 'Embers_retrieve_API.md'), available on Zenodo (Marbaix, 2024) or GitHub: https://github.com/pmarbaix/EDB_paper/blob/main/Embers_retrieve_API.md

You may use cURL to test data retrieval. For example,

```
curl "https://climrisk.org/edb/api/combined_data?source=AR6_WGII_Chapter16" -H
"Authorization: Token {token}"
```

(replace `{token}` with the above public token) would retrieve the data for the "Reasons for concern" embers as assessed in IPCC AR6 (O'Neill et al., 2022). The Climate Risks Embers Explorer uses the same data to reconstruct ember diagrams and provide information in an interactive way: https://climrisk.org/cree/emberfigure?figure=14

More examples and information are available in (Marbaix, P., 2024). The code includes a script to build all the figures and tables in the paper in a single run (or separately), taking input either from the archive file or from the remote API.

S2 Sources and calculations related to the GMT/GMSST ratio

This section provides the background information for table 2 and the box « From sea-surface temperature to global mean temperature change »: the specific source of each value and the calculation of the ratio.

Least-square linear regressions are used to estimate the GMT/GMSST ratio (GSR): this only assumes approximate linearity of global mean temperature change (GMT) with global mean sea surface temperature (GMSST). This assumption is reasonable given the available data, as shown in Fig. S2.1. For each set of estimates, we also provide the mean value of the ratio for each scenario and/or time period, showing that both approaches give almost identical results. As explained in the main paper, estimating the GSR is challenging due to several sources of uncertainty.

1. SROCC projections

Source: table CB1.1 in Abram et al. 2019		GMSST	GMT (=GSAT)	GMT/GMSST
RCP2.6	1986-2005=>2031–2050	0.64	0.9	1.41
RCP8.5		0.95	1.4	1.47
RCP2.6	1986-2005=>2081–2100	0.73	1	1.37
RCP8.5		2.58	3.7	1.43
			Mean:	1.42
			Linear reg.:	1.43

2. AR6 projections / ref. period 1995-2014

Sources: SST: Section 9.2.1.1, p.1223 in Fox-Kemper et al. 2021; GMT(GSAT) and GMAT : Table 4.2 (p572 in Lee et al. 2021). Note: all are 'unconstrained', CMIP6-only values.		GMSST	GMT (=GSAT)	GMT/GMSST	GMAT (marine surface air T)	GMT/GMAT
SSP1-1.9		not avail.	0.7	-	0.6	1.17
SSP1-2.6		0.86	1.2	1.40	1	1.20
SSP2-4.5	1995-2014=>2081-2100	1.51	2	1.32	1.8	1.11
SSP3-7.0		2.19	3.1	1.42	2.7	1.15
SSP5-8.5		2.89	4	1.38	3.4	1.18
			Mean:	1.38	Mean:	1.16
			Linear reg.:	1.39	Linear reg.:	1.16

3. AR6 / 1850-1900 ('pre-ind'; observations from 1850-1900 to 1995-2014 + scenarios)

Sources GMSST: calculated from above (2.) + historical warming below (3., green cell) for GMSST GMT: table 4.2 (p572 in Lee et al. 2021).		GMSST	GMT (GSAT proj.+ GMST historical)	GMT/GMSST
SSP1-2.6		1.53	2	1.31
SSP2-4.5	1850-1900 =>2081-2100	2.18	2.9	1.33
SSP3-7.0		2.86	3.9	1.36
SSP5-8.5		3.56	4.8	1.35
			Mean:	1.34
			Linear reg.:	1.35

4. AR6 - observations

Source : Table 2.4 in Gulev et al. 2021		GMSST	GMST ('blended' air/water T)	GMST/GMSST
	1850-1900 => 1995-2014	0.67	0.85	1.27
	1850-1900 => **2001**-2020	0.79	0.99	1.25
			Mean (obs & proj):	1.31

Table S2.1: Estimates of GMT/GMSST and their sources.

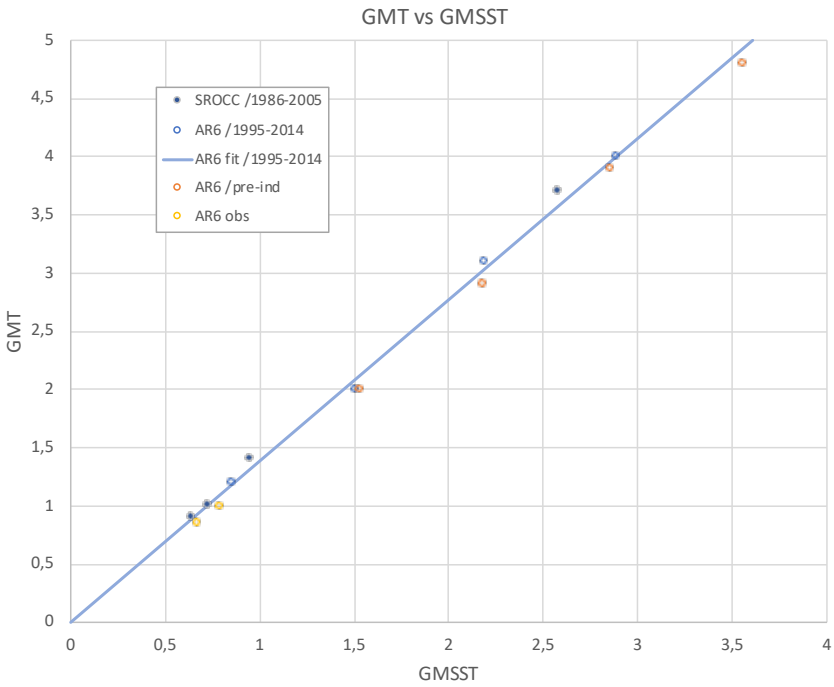


Figure S2.1: Estimates of GMT vs GMSST from recent IPCC reports, following table S2.1

S3 Extraction of risk transition limits from AR5 SYR ember diagrams

For the five embers in figure 2.5 of the Synthesis Report of AR5 (IPCC, 2014), the data was extracted from the original figures using the approach described in Marbaix 2020. The density of each of the colour (red, green, blue) within each ember and the vertical scale are extracted by software, as shown on page 13. This allows a manual determination of each transition, which is largely sufficient to reconstruct the embers without adding significant uncertainty. The values obtained are shown below. To confirm these values, the reconstructed embers are shown next to the original figure on page 13.

Risk for terrestrial and freshwater species impacted by the rate of warming

Name	Risk Transition	Rate of change (°C/year)	
Global averages	Undetectable to Moderate	Min	0.000
		Max	0.003
	Moderate to High	Min	0.033
		Max	0.050
Flat landscapes	Undetectable to Moderate	Min	0.000
		Max	0.001
	Moderate to High	Min	0.009
		Max	0.013
	High to Very High	Min	0.025
		Max	0.080

Risk for marine species impacted by ocean acidification only, or additionally by warming extremes

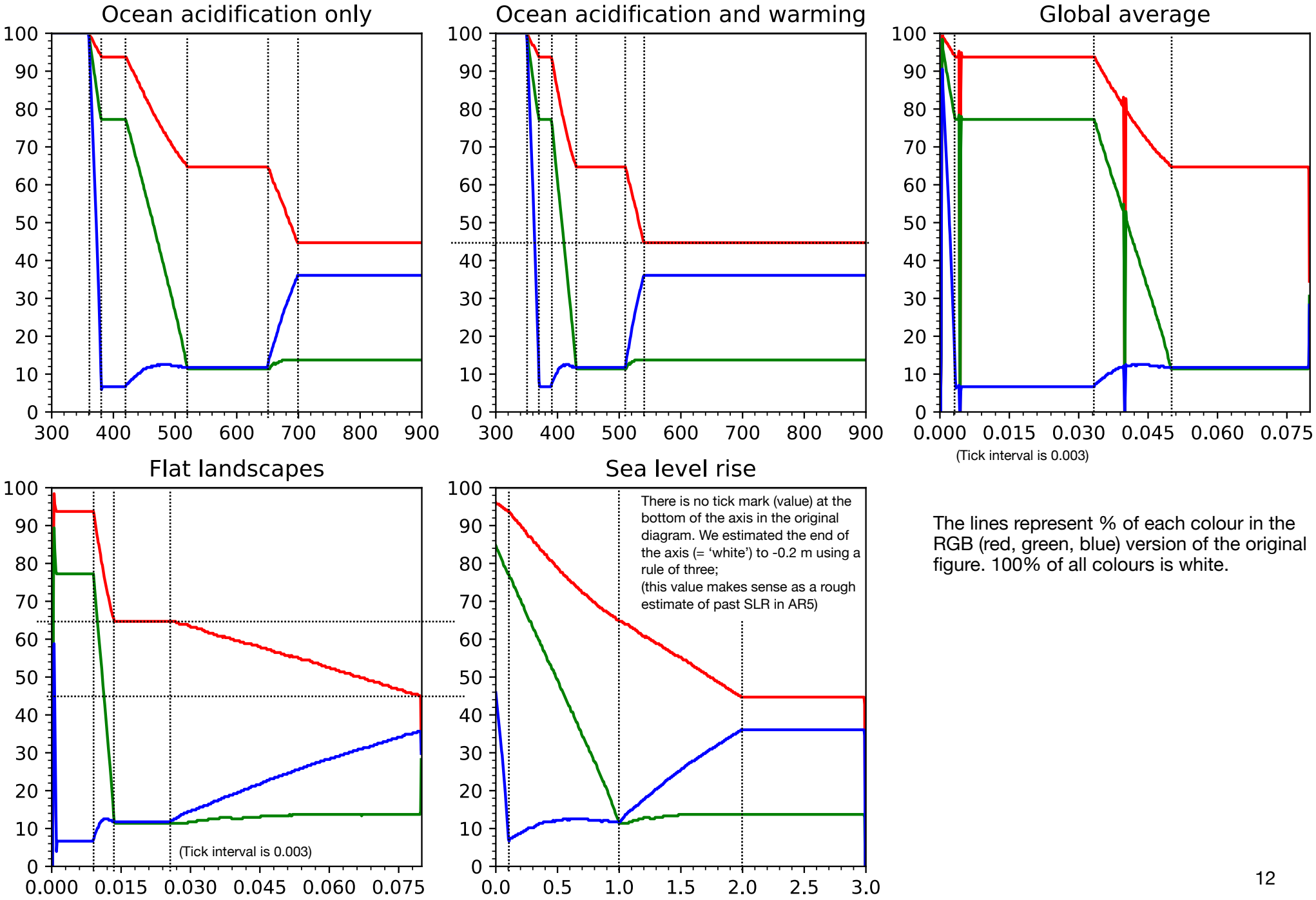
Name	Risk Transition	Atmospheric CO_2 (ppm)	
Ocean acidification only	Undetectable to Moderate	Min	360
		Max	380
	Moderate to High	Min	380
		Max	520
	High to Very High	Min	650
		Max	700
Ocean acidification and warming	Undetectable to Moderate	Min	350
		Max	370
	Moderate to High	Min	390
		Max	430
	High to Very High	Min	510
		Max	540

Risk for coastal human and natural systems impacted by sea level rise

Name	Risk Transition	Sea level rise (m, relative to 1986–2005)	
Sea level rise	Undetectable to Moderate	Min	-0.2
		Max	0.1
	Moderate to High	Min	0.1
		Max	1.0
	High to Very High	Min	1.0
		Max	2.0

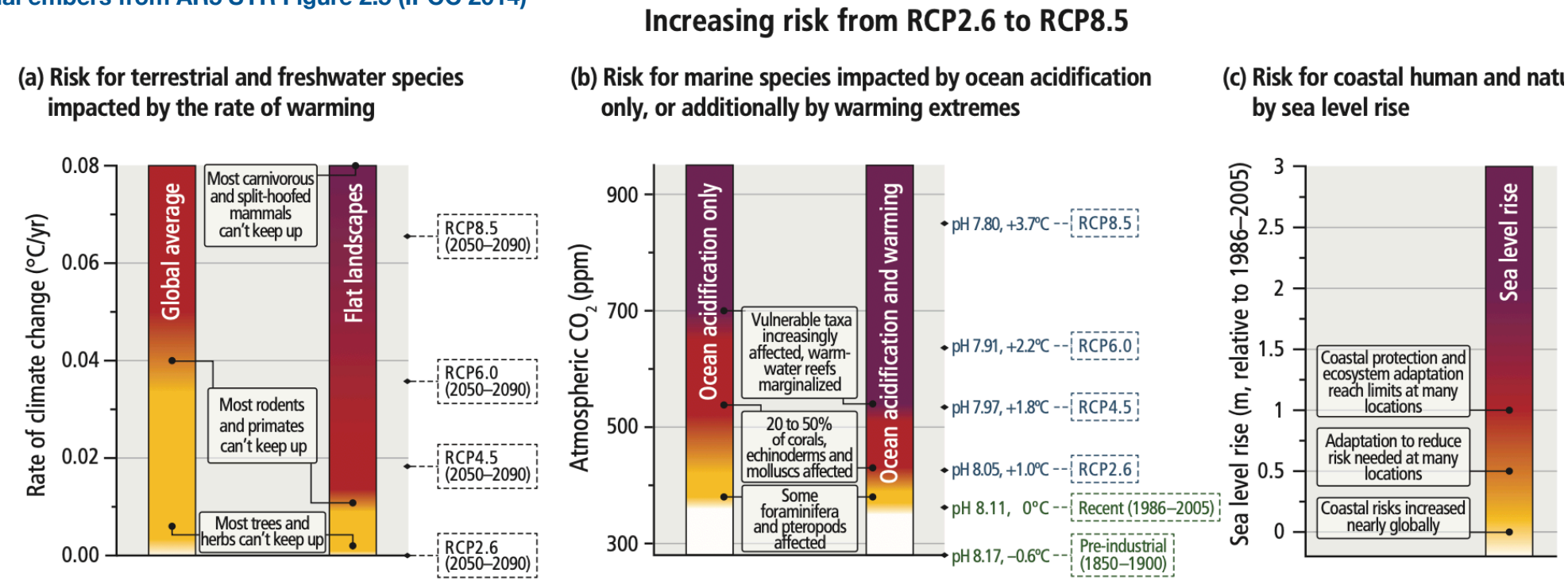
Table S3.1: Limits of the transitions for AR5 SYR embers, obtained from the diagrams.

Risks for terrestrial and freshwater species impacted by the rate of warming

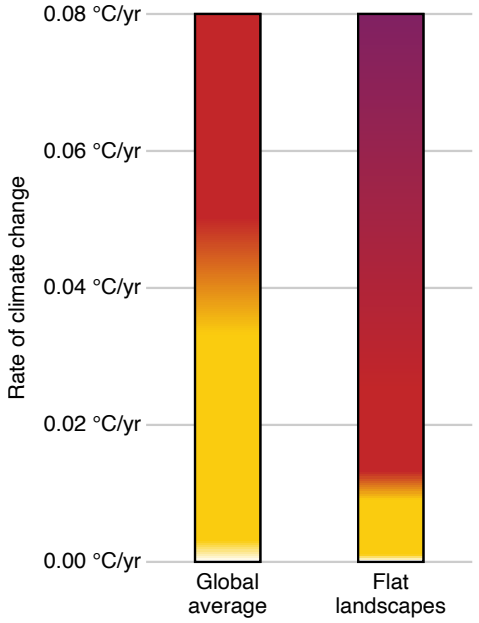


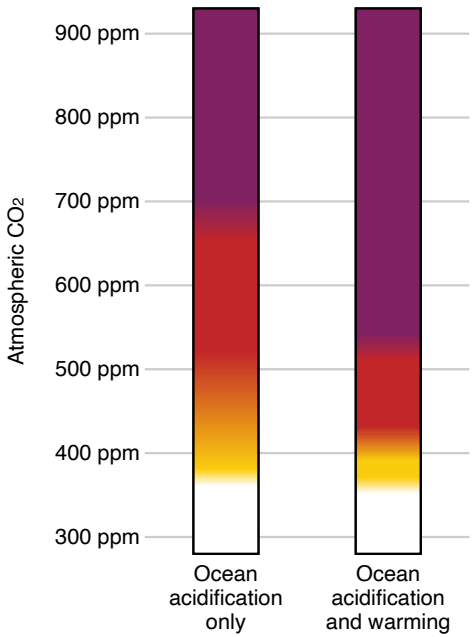
The lines represent % of each colour in the RGB (red, green, blue) version of the original figure. 100% of all colours is white.

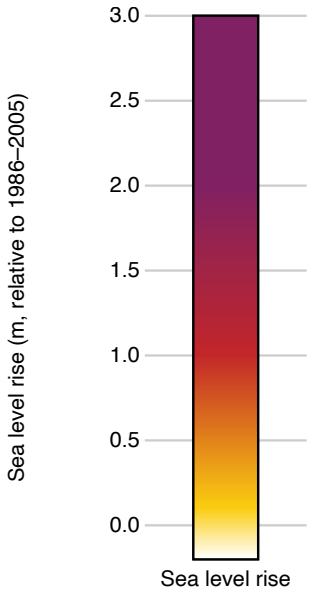
Original embers from AR5 SYR Figure 2.5 (IPCC 2014)



Reconstruction with the database values







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