Analysis of the WGI contribution to the Sixth Assessment Report:
Review of the WGI AR6 references

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Introduction

The objective of this study is to investigate the references used in the WGI contribution to AR6, Climate Change 2021: *The Physical Science Basis.*

The first part gives an overview of the references and describes the use, sources, dates and languages of the citations. A second part is dedicated to the geographical aspects of the references and presents their countries and institutions of origin. A third part deals with the themes addressed by the references and finally, a last part focuses on the variety of authors and their links with the references.

This analysis is based on the data associated with the references in the report, some fields of which are supplemented by data collected online. Details of the data used are given in each section with a reference to the supplementary materials where necessary.

1. Analysis of references

A. Use of references

The report consists of 13 chapters containing over 18,000 citations including over 13,000 unique references. The number of references used per chapter is given in the graph below, and completed in the following table.

Number of references in the chapters
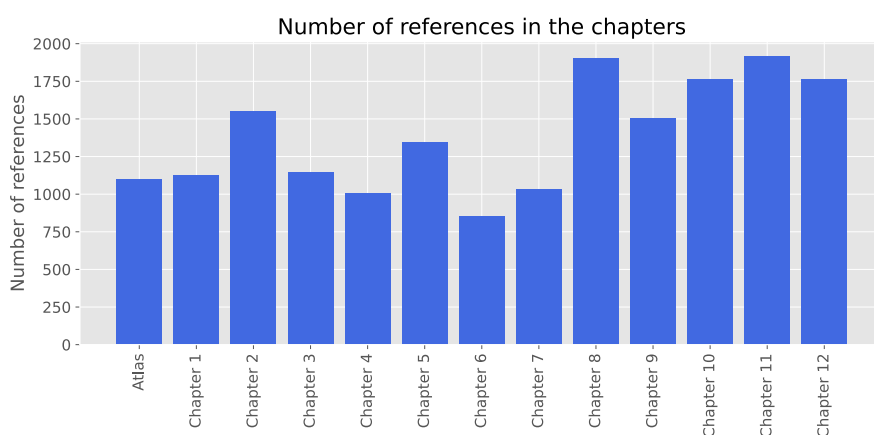
	Min	Max	Average	Std	Total	Total unique
Amount of references	858	1918	1387	354	18030	13487

The number of references varies from one chapter to another. Chapters 8 and 11 contain more than 1900, while chapter 6 contains only 858.

The following graph slightly moderates these disparities by normalising by chapter size. The *reference rate* given on the ordinate corresponds to the number of references used divided by the number of words in the chapters (excluding references).

Number of references normalized by chapter sizes
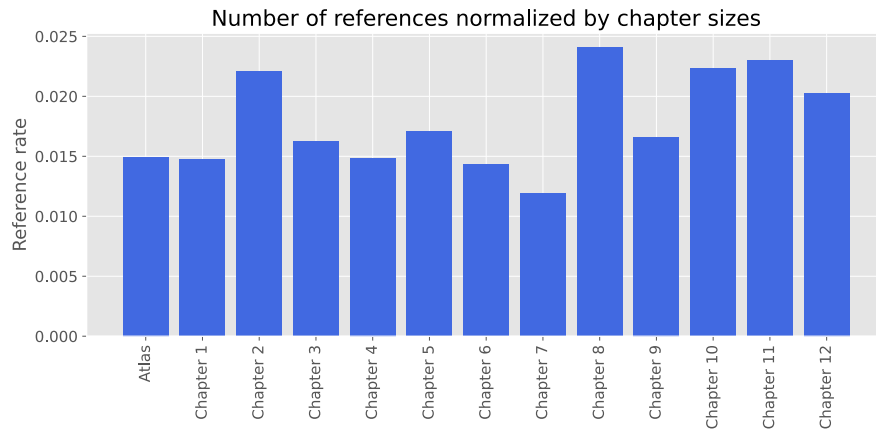
Chapter 8 remains the most referenced chapter relative to its size, while Chapter 6 is now closer to the average. Chapter 7 contains the fewest references relative to its size.

B. Duplicates

About 4500 references are cited in several chapters. About 2000 references are cited in 2 chapters, over 500 appear in 3 chapters and just over 200 are cited in 4 or more chapters. Some chapters of the AR5 are even cited in 8 to 10 chapters.

Some chapters share references, which are presented in the chart below (Chapter 0 corresponding to the Atlas). This is particularly the case for chapters 8 (*Water cycle changes)* and 11 (*Weather and climate extreme events in a changing climate*), chapters 11 and 12 (*Climate change information for regional impact and for risk assessment*) and chapters 8 and 10 (*Linking global to regional climate change).*

Number of references shared between chapters

C. Sources

Of the 13487 references, 96% are articles, the remaining references being technical reports or books. These articles are from different journals. The number of different journals from which the articles were taken is shown below for each chapter.
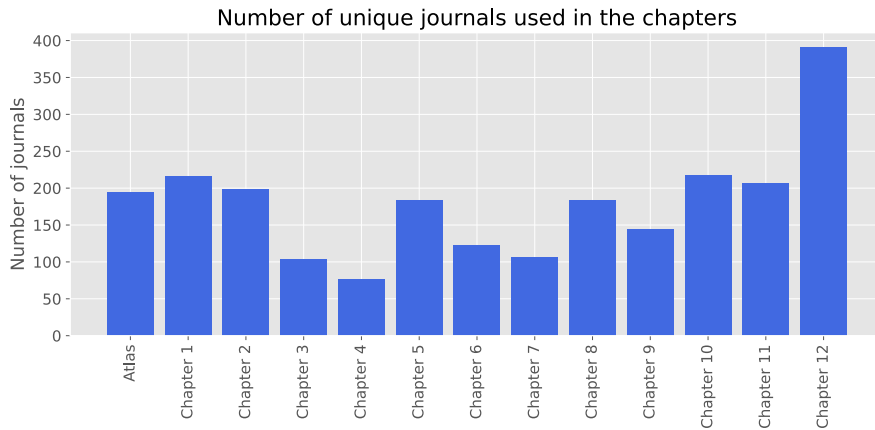
The number of journals from which the references are drawn varies by chapter. Chapter 12 has the greatest diversity of journals being cited; chapter 4 has the least. The number of different journals being cited in these two chapters vary by a factor of 5, while the number of references used varies by a factor of 2. The number of references in chapter 12 is similar to the number in chapter 10 (previous figure), but the number of journals from which the references are drawn is almost twice as high.

The top 15 journals used in the report are shown in the graph below
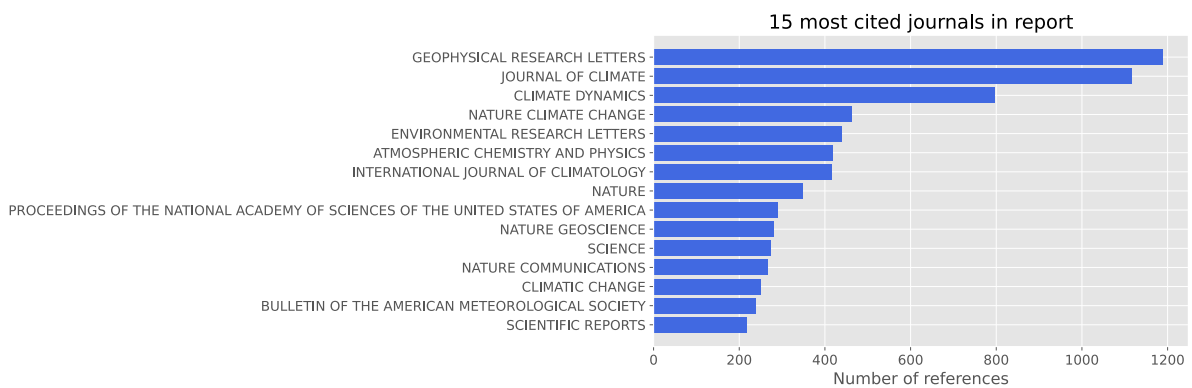
It is possible to compare the journals cited in the report with the journals most involved in certain areas. The following graph shows the journals with the most articles about CMIP, based on 7144 references about CMIP in literature between 2011 and 2020.
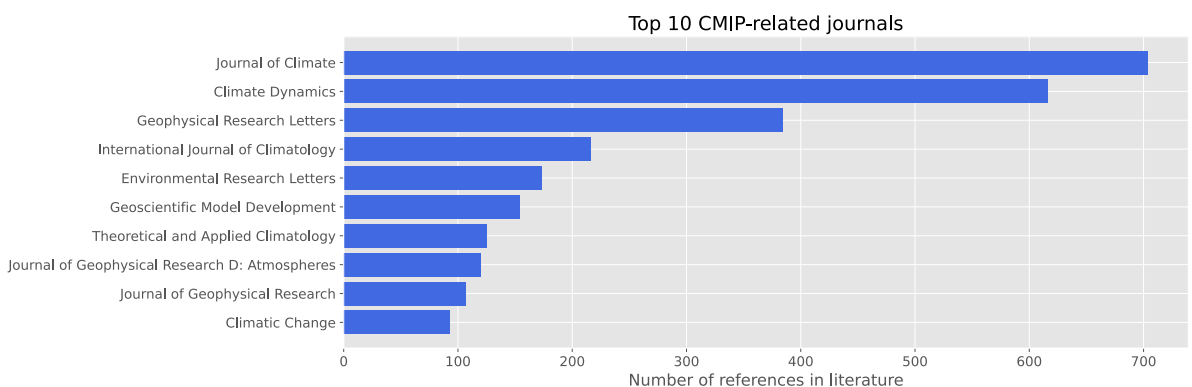
The top three journals associated with CMIP in the literature (Journals of Climate, Climate Dynamics, Geophysical Research Letters) are also the most cited in the report. The next two (International Journal of Climatology and Environmental Research Letters) also appear in the main journals cited in the report. The following journals, with the exception of Climatic Change, are different.

The graph below compares the most cited journals in Chapter 4: *Future Global Climate: Scenario-based Projections* and Chapter 12: *Near-term Climate Change Information for Regional Impact and for Risk Assessment,* chapters with the smallest and largest number of journals respectively.
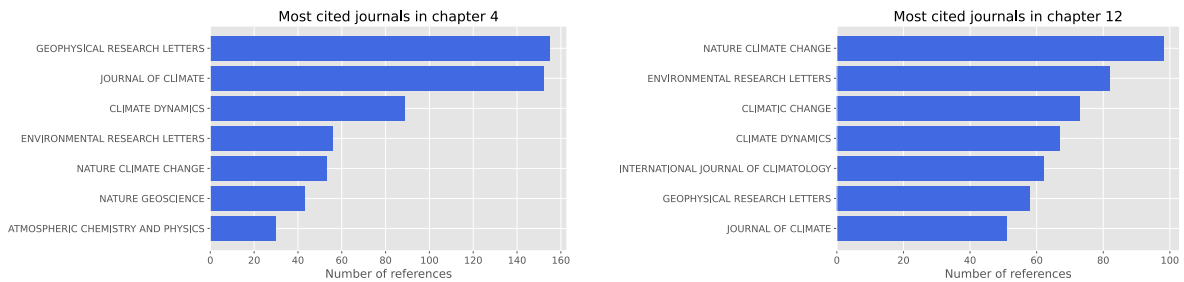
Although there is a greater diversity of journals cited in Chapter 12, the most common journals in both chapters are similar, with 5 of the 7 most common journals being the same in both chapters (although this order changes).

The most cited journals per chapter are given in Supplementary materials.

D. Dates

The number of references per year of publication used in the report is presented in the following graph. The vast majority of references (99% of them) are from after 2000.
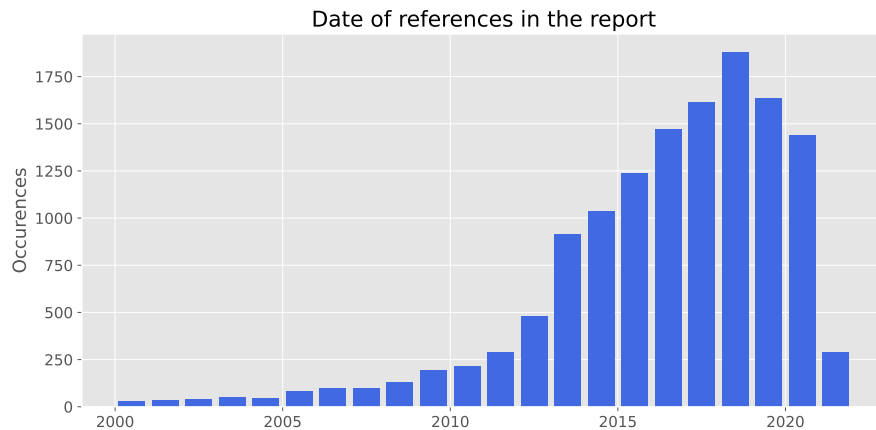
A large part of the report (AR6) is based on new references compared to the last report (AR5), with 85% of the references being post-2013. Only 200 references are before 2000, and 290 (2%) are from 2021, with the last references to be accepted for publication before 31 January 2021.

The earliest reference dates from 1686: *An historical account of the trade winds, and monsoons, observable in the seas between and near the Tropicks, with an attempt to assign the physical cause of the said winds*, by Edmond Halley.

E. Languages

93% of the references cited in the WGI AR6 are tagged with what language it is written in. For references that were missing this tag, a translation tool was applied to the title of the papers to identify the language it was written in. The vast majority of cited references were in English (99,95%). Other languages that were used were: French (4 references), Spanish (4 references), German (2 references), and Portuguese (1 reference).

Not all references assessed in IPCC reports end up being cited in the final product, however this analysis shows how dominating the English language is in the cited references of the WGI AR6.

F. Number of citations

The number of citations of references (outside the report) were retrieved from SciVal[1], as of 11 January 2022. Their number varies widely, from a few to several thousand depending on the reference.

Of the 100 references with the highest number of citations:

- More than half are from 5 journals: 20 from Nature, 15 from Science, 7 from Bulletin of the American Meteorological Society, 6 from Journal of Climate and 5 from AR5.
- The United States is involved in 63 of them, United Kingdom in 28, Germany in 22. Switzerland, Japan, the Netherlands and France are involved in more than 10 of them.
- Only 10 are from after 2013

2. Geographical aspects

A. Data

The following section has been produced using data from SciVal. As some references are not available, the study is conducted on only 86% of the original reference (11664 references, between 2011 and 2020). Missing references have an unknown DOI or a publication date not taken into account.

B. Collaboration

The numerous references in the report are produced by authors and institutions from around the world. The following graph shows the international collaboration within the references. About half (+6000 publications) are from international collaboration, 28% are from national collaboration, and 14% are from institutional collaboration (i.e. authors from the same affiliation) only.

Metric	
■ International collaboration	53.9%
■ Only national collaboration	27.9%
■ Only institutional collaboration	14.4%
■ Single authorship (no collaboration)	3.8%

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[1] https://www.scival.com
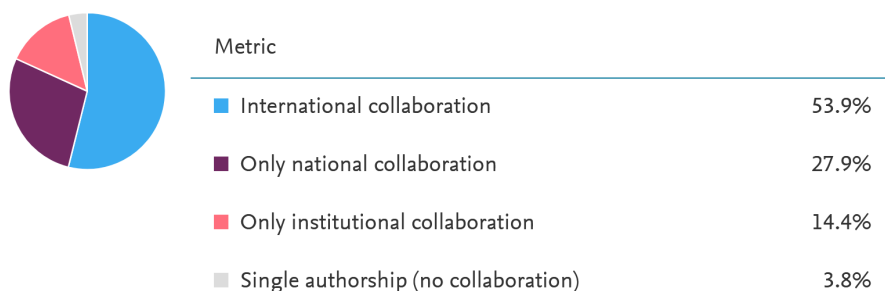
C. Countries

The map below shows the top 100 countries (among 185) from which the references come. The bubbles indicates the number of references given by the colour scale.

The most represented countries are, in order, the United States, involved in 5871 references (about 50% of the total number of references available), the United Kingdom with 3039 references (26%), Germany (2118 references), France and China (over 1500 references).

Figure 1 : Data : SciVal (2011-2020)

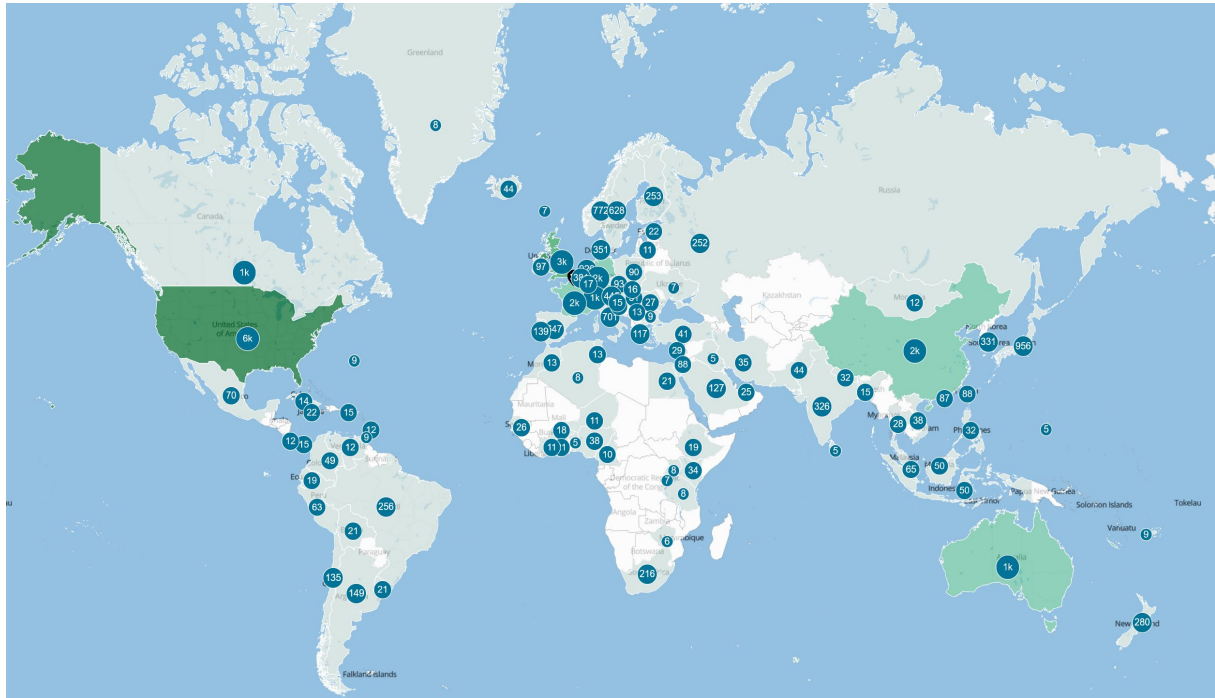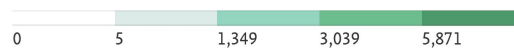| 0 | 5 | 1,349 | 3,039 | 5,871 |

It appears that the most developed countries are also the most represented (USA, Europe), with most African countries not appearing.

The following graph specifies the number of references for the top 15 countries:
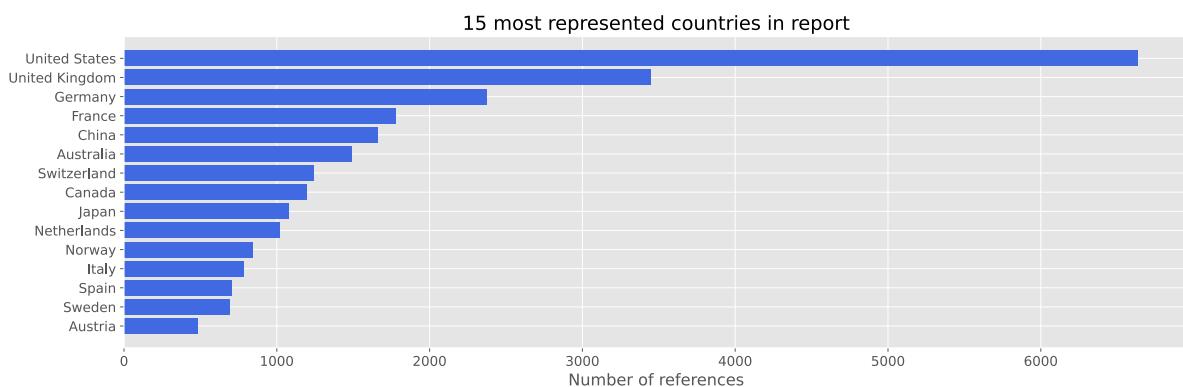
Figure 2 : Most represented countries. Data : SciVal

The United States is by far the most involved. European countries follow, as well as China, Canada and Japan.

The United States thus has a prominent place, being involved in about 50% of the references in the report, while the UK is involved in about a quarter of the references. However, this gap is less pronounced among all articles in the main climate science journals. Geophysical Research Letters, Journal Of Climate, and Climate Dynamics, are the top 3 journals cited in the report and account for about 20% of references (see Sources). Of the articles in these journals, over the period 2011-2020, (resp. 34083, 10684 and 6762 articles - note that not all of these articles are solely dedicated to climate science), only 25-30% have US involvement, and 5-10% have UK involvement. China also appears in the top 3 countries involved in these three journals whereas it only appears in 5th position in the report references.

It is possible to look more closely at the regional diversities within each continent.

North America
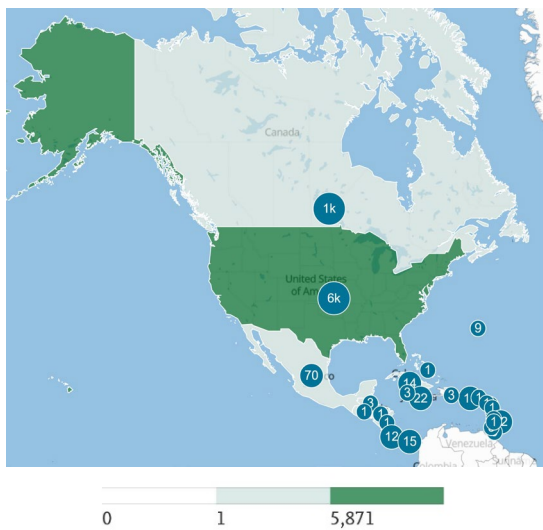
Europe
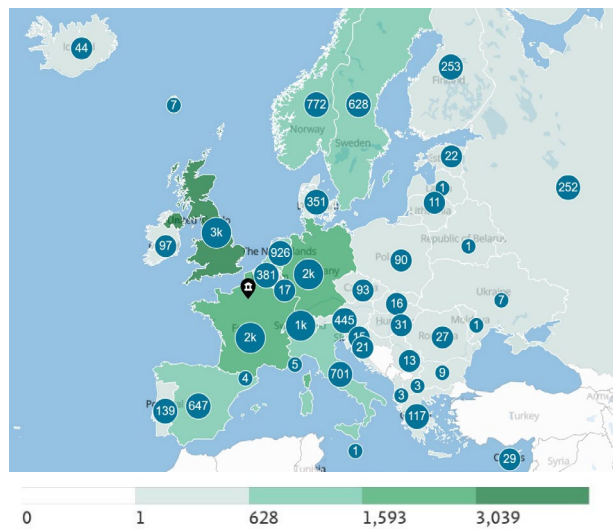
Middle-East

Asia-Pacific

South-America

Africa

There are obvious imbalances across the different continents. With North America and Europe dominating. But it is also very clear that there is a real diversity within each continent. Although the citations are usually dominated by 1 or 2 countries, there are many countries represented.

The figure below show the correlation between number of countries represented by the chapter author team (CLAs, LAs, CAs) and the number of countries represented by the number of countries represented in the chapter citations (this is done using the institutional location of the authors as authors nationality data is not available). There seems to be a week positive correlation ($R^2 = 0,69$) between the number of countries represented in the chapter's author team and the number of countries in the chapter's citation list.
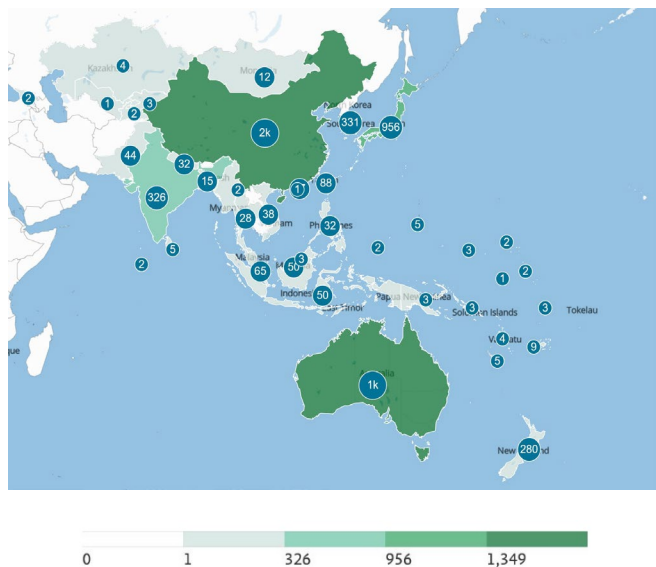
D. Institutions

The institutions from which the references come are shown in the map below. The references are from 2596 institutions (with an average of 5.2 institutions per reference). Again, only the first 100 are shown, with the number of associated references in the orange bubbles.

Of the top 100 most cited institutions in the WGI AR6, all are found in North America, Europe, Asia and Oceania. None of the top 100 are located in South America or Africa.

The following graph shows the top 15 institutions with the proportion of references in which they are involved. Half are French, led by the CNRS, involved in 1478 references (almost 11% of the total).

15 most involved institutions in report
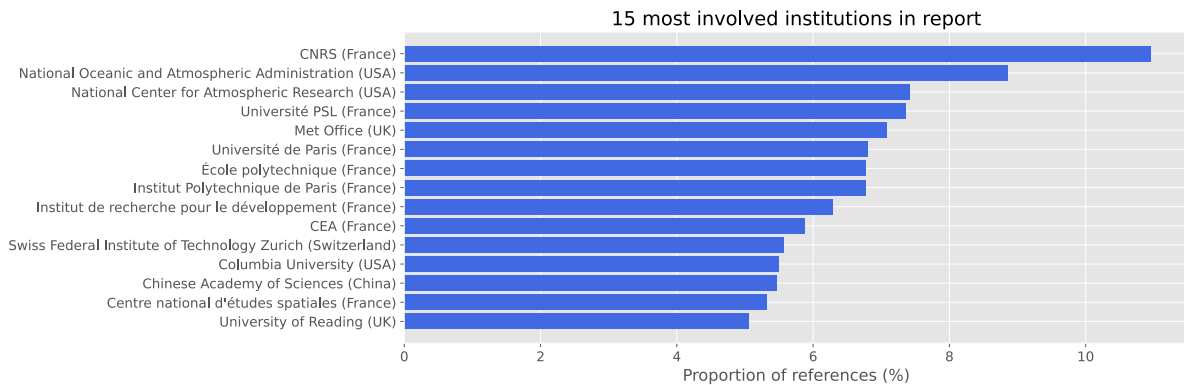
3. Topics & keywords

For each citation, key words can be provided by authors to improve searchability functions. In addition, Scival[2] assign key word topics to each citation. It is therefore possible to do an analysis of these assigned themes across the WGI AR6 references and in the literature. There is a hierarchy of the assigned themes that ranges from more general/broad to more specific/unique. The table below gives an overview of the different classifications and their number of elements.
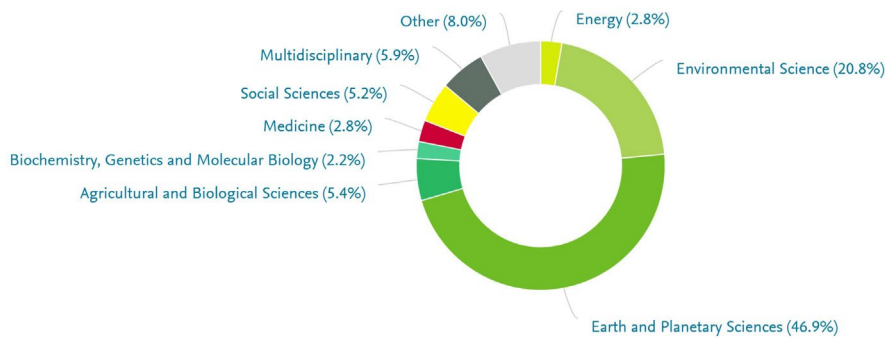

Subject Areas (e.g. Earth & Planetary Sciences)	Subjects (e.g. Atmospheric Science)	Topic Clusters (e.g. Climate Models)	Topics (e.g. Regional Climate)
27	188	251	941

More general ⟶ More specific

A. Subject Areas & Subjects

The main topics covered by the references are presented in the diagram below. Just under half (about 8000 references) are in *Earth & Planetary Sciences*, and 20% are in *Environmental Sciences*. A fraction of the references are in other fields such as *Social Sciences* (5.2%) i.e. about a thousand references, or *Medicine* (2.8%), i.e. about 500 references (mainly in public health).

The subject area *Earth & Planetary Sciences* presented above is broken down into different subjects: just over a third (+4500 references) are associated with *Atmospheric Science*, and around 15% (about 2000 publications) are attributed to *General Earth and Planetary Sciences* and *Geophysics*.
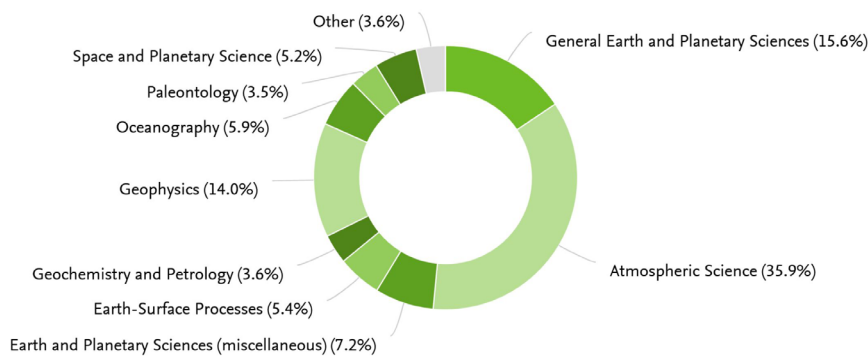
The second largest subject area, *Environmental Science*, is detailed below, grouping the subjects *Global & Planetary Change* (about 1200 references) followed by *Water Science & Technology* and *General Environmental Science*.
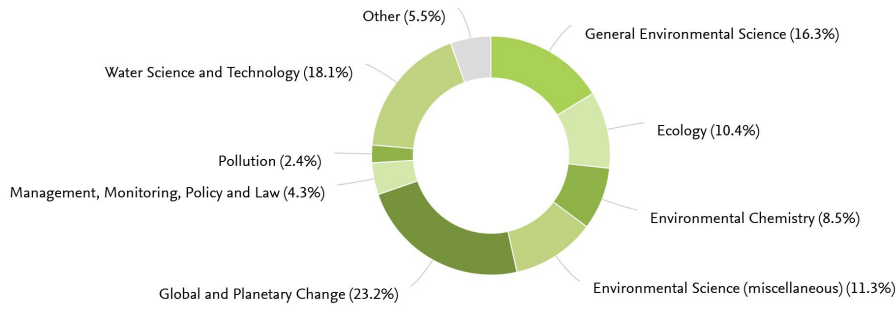
B. Topic Clusters

The main themes extracted from the references (251 in total) are presented in the wheel below. The position of the bubbles characterises the discipline of a group of references, and the size indicates the number of associated references. The large green bubble corresponds to the main topic cluster *Climate models; Model; Rain*. It is noticeable that there are many other topic clusters focusing on various disciplines (represented by different colours), associated with a limited number of references. *Climate models; Model; Rain* is however largely dominant, representing almost half of the references. The other topic clusters account for less than 10% of the references.

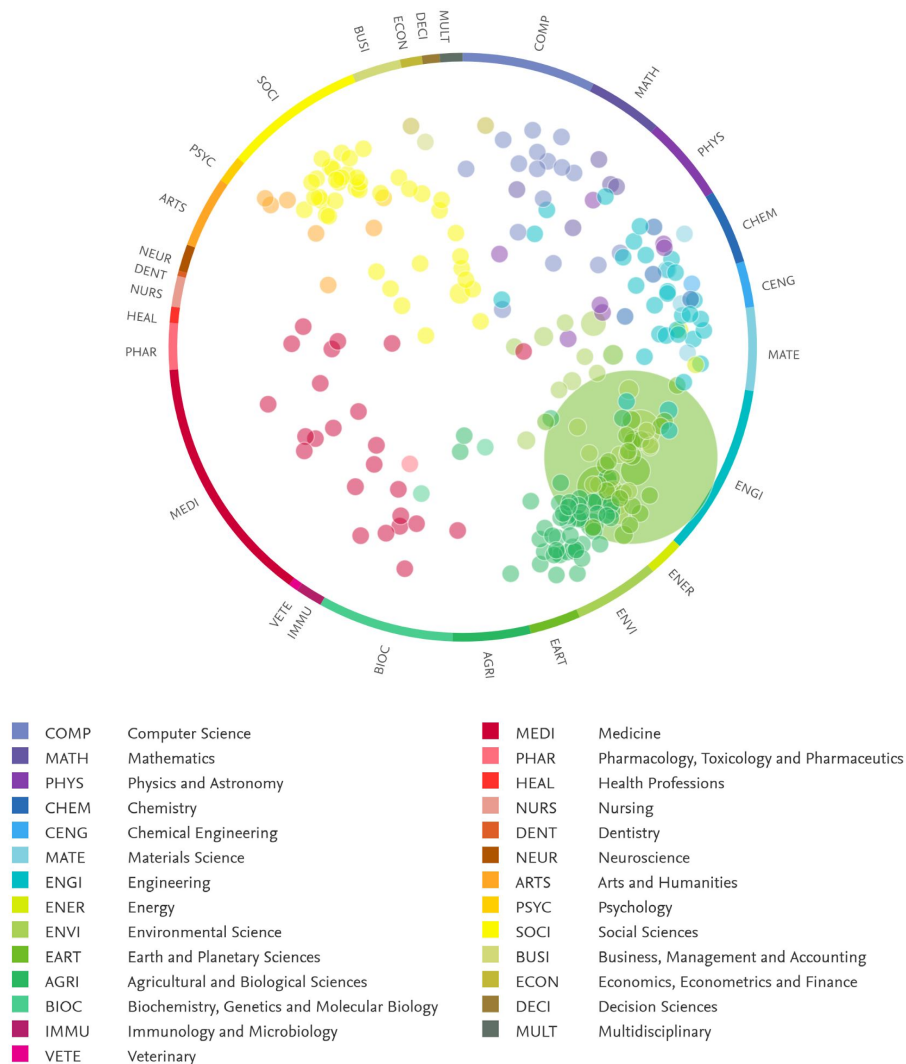|				
COMP	Computer Science	MEDI	Medicine
MATH	Mathematics	PHAR	Pharmacology, Toxicology and Pharmaceutics
PHYS	Physics and Astronomy	HEAL	Health Professions
CHEM	Chemistry	NURS	Nursing
CENG	Chemical Engineering	DENT	Dentistry
MATE	Materials Science	NEUR	Neuroscience
ENGI	Engineering	ARTS	Arts and Humanities
ENER	Energy	PSYC	Psychology
ENVI	Environmental Science	SOCI	Social Sciences
EART	Earth and Planetary Sciences	BUSI	Business, Management and Accounting
AGRI	Agricultural and Biological Sciences	ECON	Economics, Econometrics and Finance
BIOC	Biochemistry, Genetics and Molecular Biology	DECI	Decision Sciences
IMMU	Immunology and Microbiology	MULT	Multidisciplinary
VETE	Veterinary		

C. Topics

The topic clusters are made up of different topics. 941 topics are extracted from the references and specify the topic clusters at a finer scale. The following graph shows the 10 most used topics in the report. Most of them are included in the topic cluster *Climate models; Model; Rain*.


10 most represented topics in report
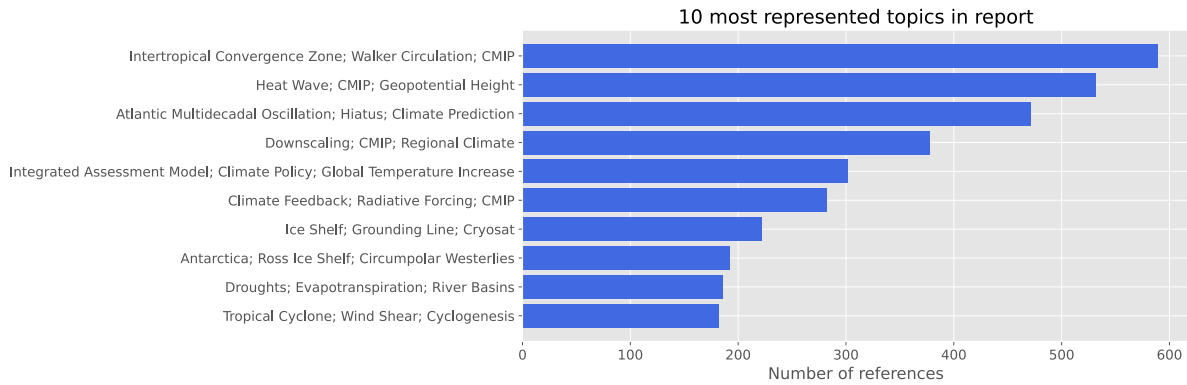
D. Country contributions

The contribution of the main countries to the main topic clusters is given in the following graph. The colour gradient indicates the number of references associated with each topic cluster. Countries are ranked according to their contribution to the main topic cluster *Climate models; Model; Rain*.

Main contributing countries in main reference topic clusters
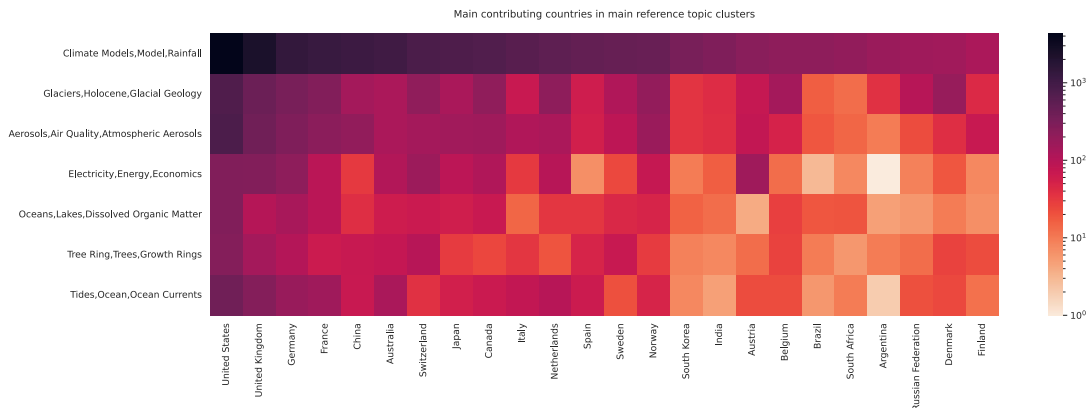
It appears that the United States appears most prominently in all topic clusters and that the *Climate Models, Model, Rainfall* topic cluster concentrates more references than the others, for all countries.

The participation of the main countries in the *Climate Models, Model, Rainfall* topic cluster in the literature, over the period 2011-2020 (gathering 132,761 articles) is presented below.

10 most involved countries in 'Climate Models; Model; Rainfall' Topic Cluster
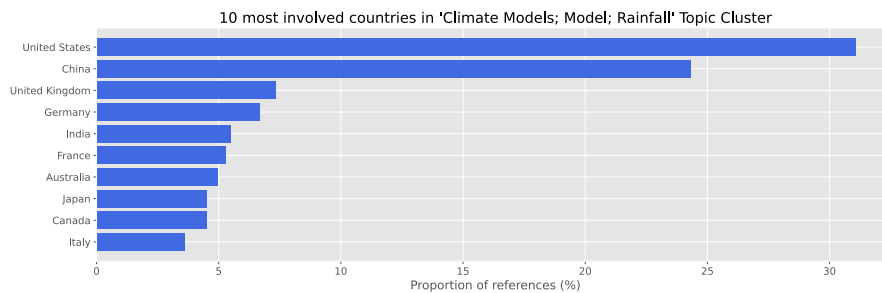
Compared to the previous graph, it appears that the involvement of the different countries in this topic cluster within the report does not exactly reflect the involvement in the literature.

Indeed, in the report, the participation of the United States is similar to that in the literature and amounts to about 33% but the share of some countries is over-represented: 18% for the United Kingdom, 11% for Germany, 9% for France for example, while the share of other countries is under-represented: that of China is only 9%, that of India is 2%.

E. Key phrases

Finally, key phrases can be extracted from the references and used to compare the topics of the chapters. While general key phrases (*Climate Change, Climate, Climate Models*) appear in most chapters, the more specific ones help to identify the topic of each chapter (e.g. for Chapter 6: *Emissions, Aerosols, Air Quality, Ozone, Atmosphere* or for Chapter 9: *Glacier, Oceans and Sea, Ice, Sea Level, Antarctic Regions*). Details of these key phrases are given by chapter in supplementary materials.

4. Authors

A. Citizenship

A.1 CLAs and LAs

The countries of citizenship of the CLAs and LAs in the report are given in the graph below. 81 (41%) are European, 41 (21%) are Asian, 29 (15%) are from North, Central America or the Caribbean. Africa, South America and the South West Pacific region have 15-17 authors each (between 8 and 9%).

Citizenship region of CLAs and LAs in report
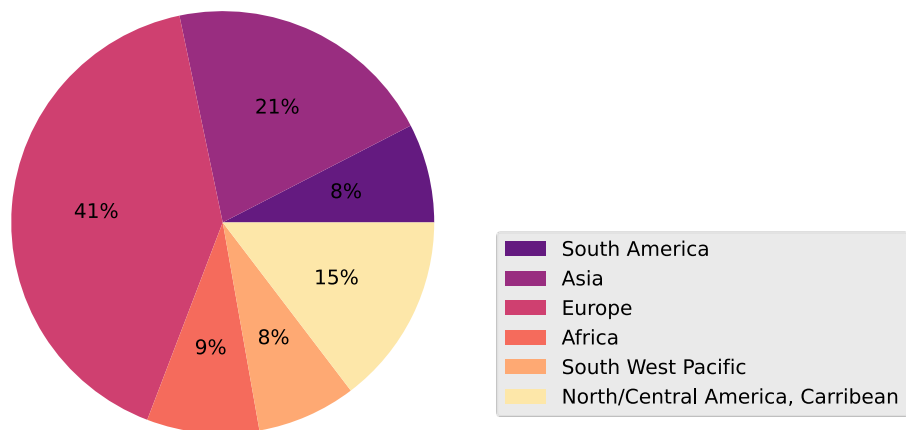
The citizenship regions of the CLAs and LAs in each chapter are presented in the graph below. Chapter 0 corresponds to the Atlas. Europe is an important part of most chapters. Authors from Europe, Asia, North and Central America are present in each chapter, while South America, Africa and the South-West Pacific region do not appear in some chapters.

Citizenship region of CLAs and LAs
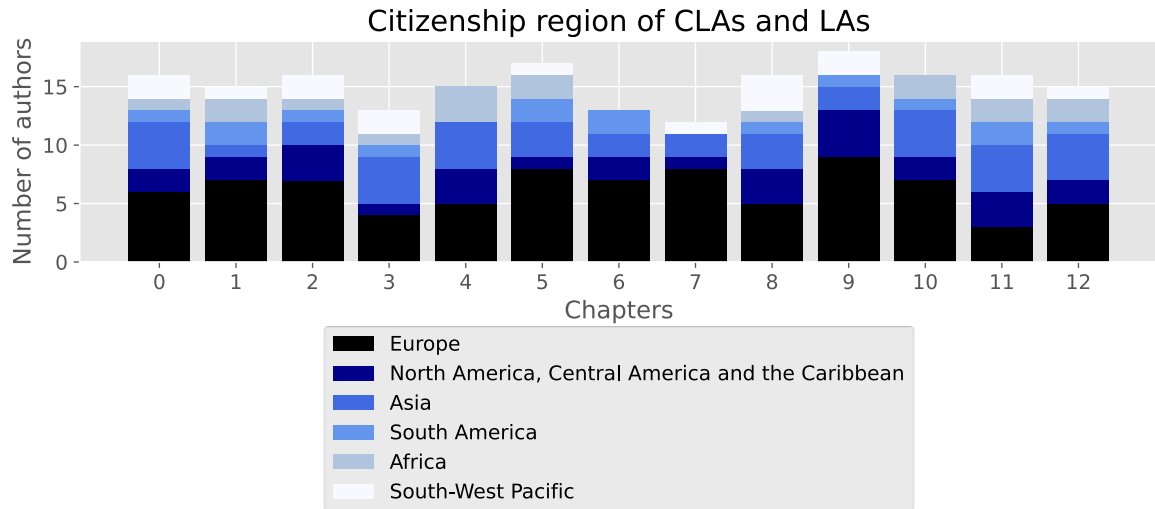
A.2 CLAs, LAs and CAs

The following graph shows the regions of citizenship of CLAs, LAs and CAs. More than half (521 in total) are European. North and Central America has 182 authors, about as many as Africa, South America and the South West Pacific region combined.

Citizenship region of CLAs, LAs and CAs in report
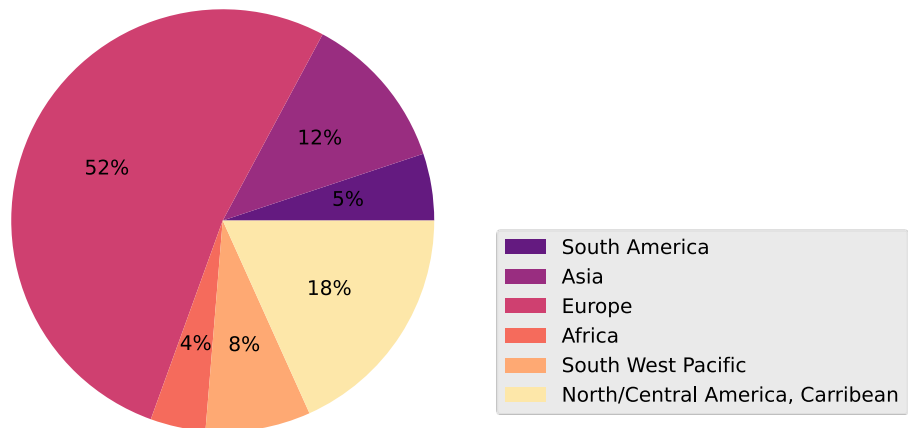
B. Gender

The gender of CLAs, LAs and CAs is given in the table below. The proportions are similar and unbalanced for all three categories of authors, with approximately 70% male.

	Number of authors	Female	Male
CA	876	30%	70%
LA	167	29%	71%
CLA	31	32%	68%

C. Chapter self-citation

C.1 CLAs and LAs

The proportion of each chapter's self-citation is shown in the graph below. Self citation is defined as paper where a CLA or LA of that chapter is listed as first author in any papers in its reference list.

Self-citation of CLAs and LAs in chapter references (1st author only)
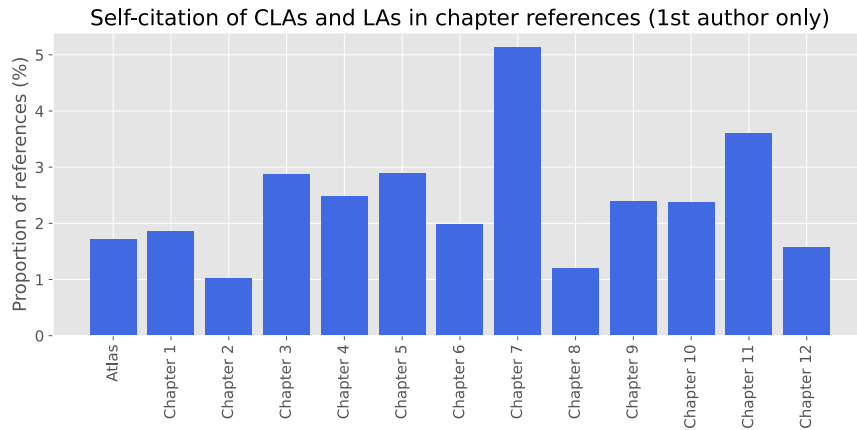
The rate of chapter self-citation varies greatly between chapters : between 1.2% and 5.1% with an average of 2.4%. Chapter 7 has the highest self-citation rate (with 53 references out of 1032 references) possibly reflecting the narrow scope of the chapter. Chapter 11 has a higher number compared to Chapter 7: 69 references found, but the chapter lists almost twice as many references as Chapter 7. Chapters 1, 2, 6, 8 and the Atlas contain about twenty references listed.

Supplementary materials

A. References

The number of references available is given in the table below.

The **references** contain the following data: *DOI, Title, Authors, Type, Journal, Year*. The **references completed** contain the following additional data from SciVal : *Country, Institutions, Citations* (number of times cited)*, Author Keywords, Topics, Topic Clusters, Funding organizations, Language.*

Chapter	References	References completed (SciVal)
Atlas	1103	994
1	1129	883
2	1552	1472
3	1146	1109
4	1007	967
5	1348	1275
6	858	807
7	1032	976
8	1903	1847
9	1504	1442
10	1762	1664
11	1918	1813
12	1768	1604
Total	**18030**	**16853**
Unique	**13487**	**12988**

B. Journals

The main journals associated with each chapter are shown in the following table.

Chapter	Top 10 journals cited in the chapter
Atlas	['CLIMATE DYNAMICS', 'INTERNATIONAL JOURNAL OF CLIMATOLOGY', 'JOURNAL OF CLIMATE', 'GEOPHYSICAL RESEARCH LETTERS', 'ENVIRONMENTAL RESEARCH LETTERS', 'CRYOSPHERE', 'THEORETICAL AND APPLIED CLIMATOLOGY', 'NATURE CLIMATE CHANGE', 'JOURNAL OF GEOPHYSICAL RESEARCH: ATMOSPHERES', 'GEOSCIENTIFIC MODEL DEVELOPMENT']
1	['GEOSCIENTIFIC MODEL DEVELOPMENT', 'NATURE CLIMATE CHANGE', 'JOURNAL OF CLIMATE', 'NATURE', 'GEOPHYSICAL RESEARCH LETTERS', 'CLIMATIC CHANGE', 'SCIENCE', 'BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY', 'CLIMATE DYNAMICS', 'ENVIRONMENTAL RESEARCH LETTERS']
2	['GEOPHYSICAL RESEARCH LETTERS', 'JOURNAL OF CLIMATE', 'NATURE', 'QUATERNARY SCIENCE REVIEWS', 'NATURE GEOSCIENCE', 'SCIENCE', 'CLIMATE OF THE PAST', 'CLIMATE DYNAMICS', 'NATURE CLIMATE CHANGE', 'NATURE COMMUNICATIONS']
3	['JOURNAL OF CLIMATE', 'GEOPHYSICAL RESEARCH LETTERS', 'CLIMATE DYNAMICS', 'NATURE CLIMATE CHANGE', 'NATURE GEOSCIENCE', 'NATURE', 'GEOSCIENTIFIC MODEL DEVELOPMENT', 'ENVIRONMENTAL RESEARCH LETTERS', 'SCIENCE', 'JOURNAL OF ADVANCES IN MODELING EARTH SYSTEMS']
4	['GEOPHYSICAL RESEARCH LETTERS', 'JOURNAL OF CLIMATE', 'CLIMATE DYNAMICS', 'ENVIRONMENTAL RESEARCH LETTERS', 'NATURE CLIMATE CHANGE', 'NATURE GEOSCIENCE', 'ATMOSPHERIC CHEMISTRY AND PHYSICS', 'EARTH SYSTEM DYNAMICS', 'NATURE', 'NATURE COMMUNICATIONS']
5	['BIOGEOSCIENCES', 'NATURE', 'NATURE CLIMATE CHANGE', 'NATURE COMMUNICATIONS', 'PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA', 'GEOPHYSICAL RESEARCH LETTERS', 'NATURE GEOSCIENCE', 'SCIENCE', 'ENVIRONMENTAL RESEARCH LETTERS', 'GLOBAL BIOGEOCHEMICAL CYCLES']
6	['ATMOSPHERIC CHEMISTRY AND PHYSICS', 'ATMOSPHERIC ENVIRONMENT', 'GEOPHYSICAL RESEARCH LETTERS', 'JOURNAL OF GEOPHYSICAL RESEARCH', 'PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA', 'ENVIRONMENTAL RESEARCH LETTERS', 'NATURE CLIMATE CHANGE', 'GEOSCIENTIFIC MODEL DEVELOPMENT', 'JOURNAL OF GEOPHYSICAL RESEARCH ATMOSPHERES', 'NATURE COMMUNICATIONS']
7	['GEOPHYSICAL RESEARCH LETTERS', 'JOURNAL OF CLIMATE', 'CLIMATE DYNAMICS', 'ATMOSPHERIC CHEMISTRY AND PHYSICS', 'NATURE CLIMATE CHANGE', 'NATURE', 'JOURNAL OF GEOPHYSICAL RESEARCH: ATMOSPHERES', 'ENVIRONMENTAL RESEARCH LETTERS', 'JOURNAL OF GEOPHYSICAL RESEARCH', 'PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA']
8	['JOURNAL OF CLIMATE', 'GEOPHYSICAL RESEARCH LETTERS', 'CLIMATE DYNAMICS', 'NATURE CLIMATE CHANGE', 'ENVIRONMENTAL RESEARCH LETTERS', 'PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF THE UNITED STATES OF AMERICA', 'NATURE GEOSCIENCE', 'INTERNATIONAL JOURNAL OF CLIMATOLOGY', 'NATURE', 'SCIENTIFIC REPORTS']
9	['GEOPHYSICAL RESEARCH LETTERS', 'CRYOSPHERE', 'JOURNAL OF CLIMATE', 'JOURNAL OF GEOPHYSICAL RESEARCH: OCEANS', 'NATURE', 'NATURE CLIMATE CHANGE', 'NATURE COMMUNICATIONS', 'QUATERNARY SCIENCE REVIEWS', 'NATURE GEOSCIENCE', 'CLIMATE DYNAMICS']
10	['JOURNAL OF CLIMATE', 'CLIMATE DYNAMICS', 'GEOPHYSICAL RESEARCH LETTERS', 'INTERNATIONAL JOURNAL OF CLIMATOLOGY', 'NATURE CLIMATE CHANGE', 'ENVIRONMENTAL RESEARCH LETTERS', 'BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY', 'JOURNAL OF GEOPHYSICAL RESEARCH', 'CLIMATIC CHANGE', 'HYDROLOGY AND EARTH SYSTEM SCIENCES']
11	['JOURNAL OF CLIMATE', 'GEOPHYSICAL RESEARCH LETTERS', 'CLIMATE DYNAMICS', 'INTERNATIONAL JOURNAL OF CLIMATOLOGY', 'BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY', 'ENVIRONMENTAL RESEARCH LETTERS', 'NATURE CLIMATE CHANGE', 'CLIMATIC CHANGE', 'JOURNAL OF HYDROLOGY', 'HYDROLOGY AND EARTH SYSTEM SCIENCES']
12	['NATURE CLIMATE CHANGE', 'ENVIRONMENTAL RESEARCH LETTERS', 'CLIMATIC CHANGE', 'CLIMATE DYNAMICS', 'INTERNATIONAL JOURNAL OF CLIMATOLOGY', 'GEOPHYSICAL RESEARCH LETTERS', 'JOURNAL OF CLIMATE', 'NATURE', 'SCIENTIFIC REPORTS', 'NATURE COMMUNICATIONS']

C. Key phrases

The main key phrases used in the chapters are listed in the following table

Chapter	Main key phrases (ordered by frequence, data: SciVal)						
Atlas	Climate Models	Climate Change	Climate	Regional Climate	Warming	Summer	Projection	Rain
1 Framing, context	Climate	Climate Change	Global	Climate Models	Statistical Ensemble	Oceans and Seas	Warming	Projection
2 Changing climate	Climate	Climate Change	Global	Variability	Oceans and Seas	Glaciers	Climate Models	Warming
3 Human influence	Climate Models	Climate Change	Variability	Forcing	Oceans and Seas	CMIP	Warming	Sea Surface Temperature
4 Future climate	Climate Models	Climate Change	Climate	Warming	Variability	Forcing	Global Warming	Statistical Ensemble
5 Carbon cycle	Carbon Dioxide	Global	Climate Change	Climate	Atmospheric	Oceans and Seas	Emissions	Carbon Cycle
6 Short-lived forcers	Emissions	Aerosol	Climate	Air Quality	Ozone	Climate Change	Atmospheric	Climate Models
7 Energy budget	Climate Change	Climate Models	Climate	Warming	Clouds	Radiative Forcing	Forcing	Feedback
8 Water cycle	Climate Change	Climate Models	Climate	Rain	Precipitation	Warming	Tropical	Summer
9 Ocean, sea	Glacier	Oceans and Seas	Climate Change	Ice	Climate	Climate Models	Sea Level	Antarctic Regions
10 Global to regional	Climate Models	Climate	Climate Change	Regional Climat	Summer	Statistical Ensemble	Warming	Projection
11 Extremes events	Climate Change	Climate	Extremes	Climate Models	Extreme Events	Trends	Drought	Warming
12 Regional impact	Climate Change	Climate	Climate Models	Projection	Extremes	Warming	Global Warming	Twenty First Century
Report	Climate Change	Climate	Climate Models	Warming	Oceans and Seas	Global Warming	Forcing	Projection