# A Topography of Climate Change Research

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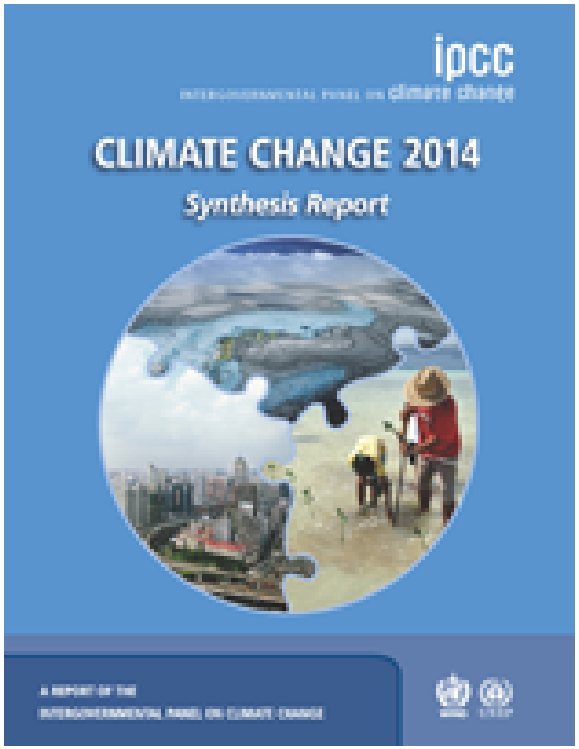
January 29, 2018

# Context




- To contribute evidence-based policy-making on climate change, the IPCC aims to *comprehensively* assess
- These assessments should be aim to balance legitimacy, credibility and relevance (Cash and Clark, 2001)

# Motivation

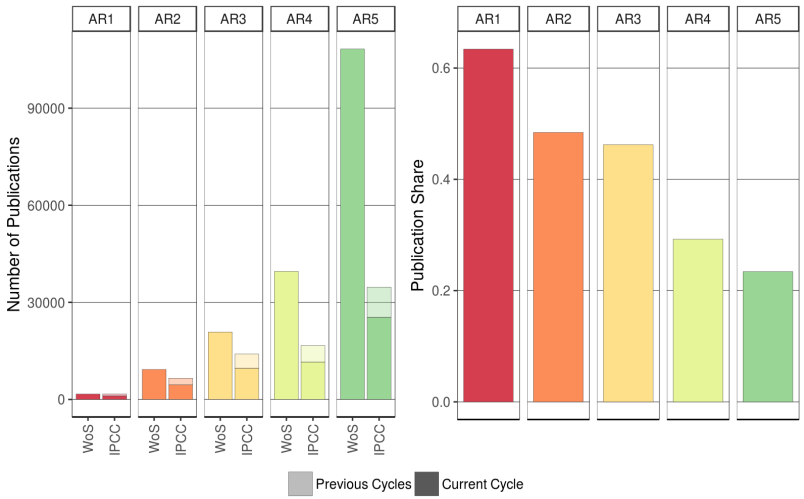



Figure: Source: Minx et al. (2017)

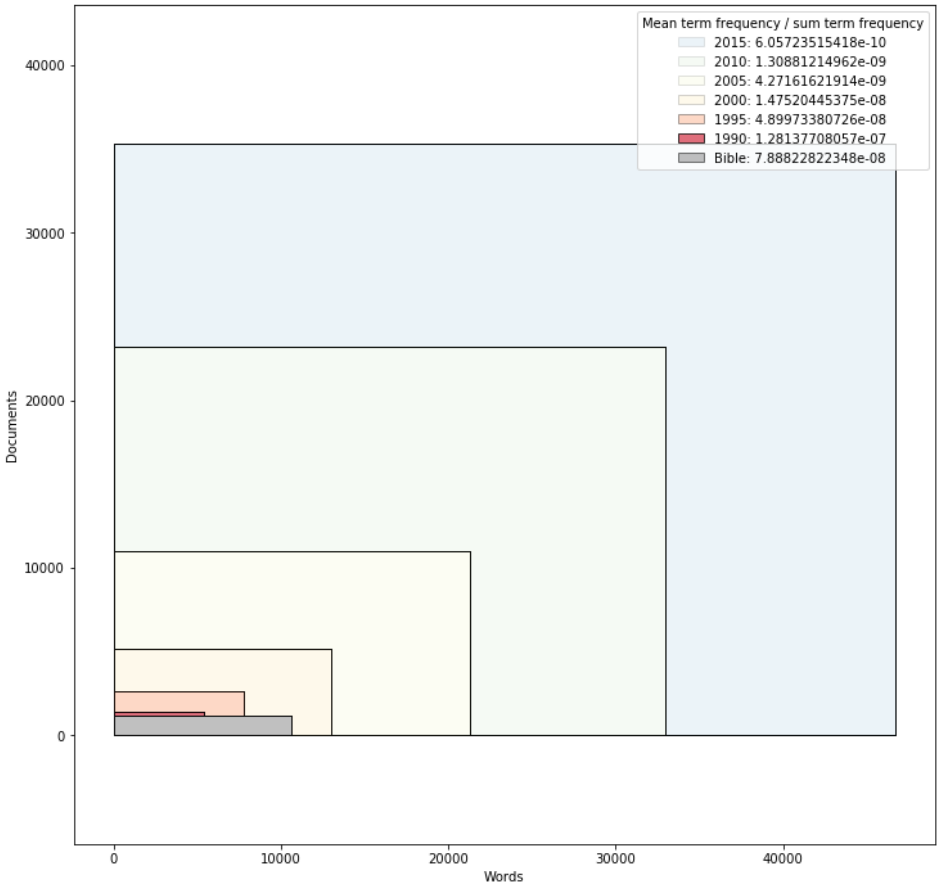
- Comprehensive, credible and relevant assessments become more challenging as the literature grows

*To understand, and to aid, scientific assessments of climate change, we need to machine read the literature*

# Motivation - Update 2018

Now that 2017 has ended, I have update the query to include papers from 2017 as well.

# Approach - Words, words, words




- Topic modelling is a way of reducing the dimensionality of a corpus of documents
- A large matrix of documents x words is factorised by a matrix of topics x words and a matrix of topics x documents (Lee and Seung, 1999)
- Topics describe the latent structure of the document corpus

# Approach - Words, words, words

$$V_{i\mu}$$

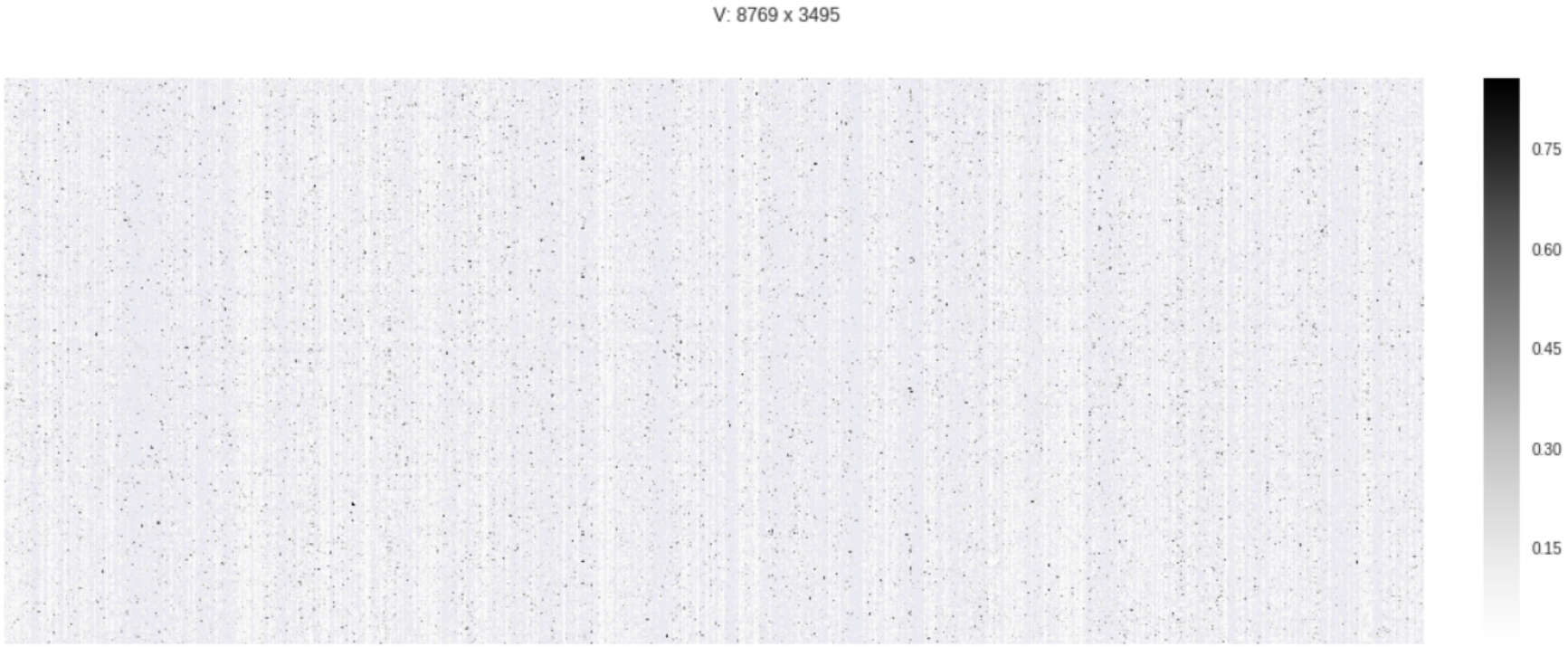



Figure: A topic model of 3495 documents on climate change from the year 2000

# Approach - Words, words, words

$$V_{i\mu} \approx (WH)_{i\mu} = \sum_{a=1}^{r} W_{ia} H_{a\mu}$$

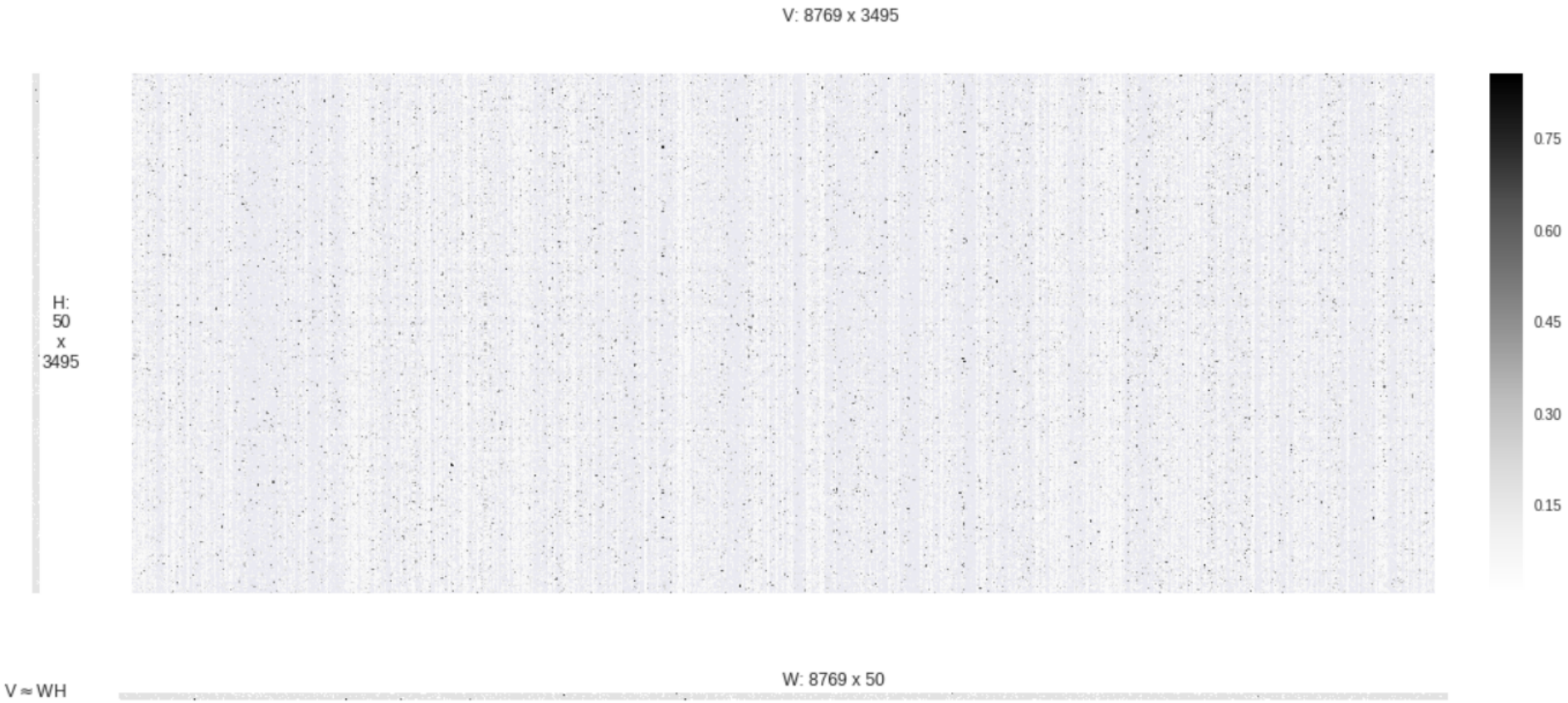



Figure: A topic model of 3495 documents on climate change from the year 2000

# Research Questions

- What is the thematic structure of the literature on climate change, and how has this changed over the five assessment periods of the IPCC
- Which topics have had greater or less representation in the IPCC assessment reports?

# Methodology - Dynamic Topic Modelling

The topic models above assume that the topics, and the words that make them up, are stable over time. Two approaches to better model dynamic topics:

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- Dynamic Non-negative Matrix Factorisation (Greene and Cross, 2016) has varying numbers of topics in each window and allows for topics to emerge and/or disappear.

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Where the size and variety of the literature we want to model has increased exponentially, we need an approach that allows for the emergence of new topics.

# Dynamic NMF

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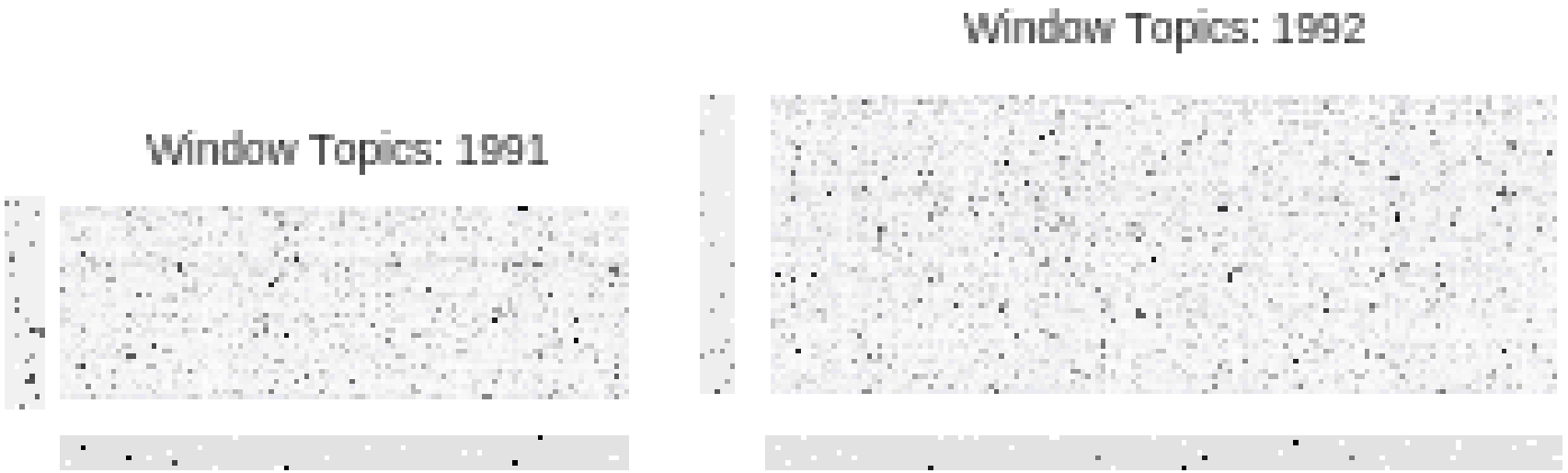

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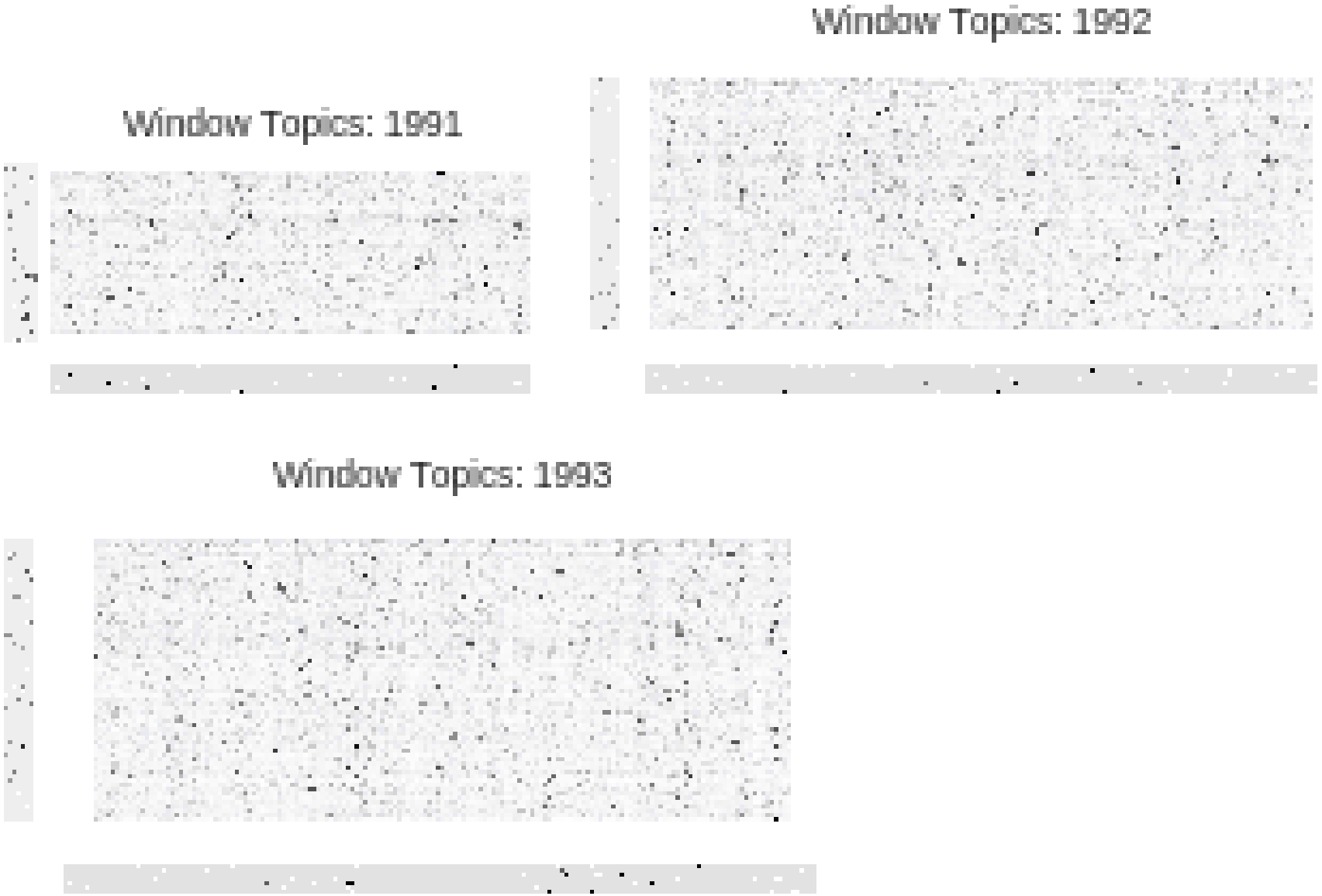
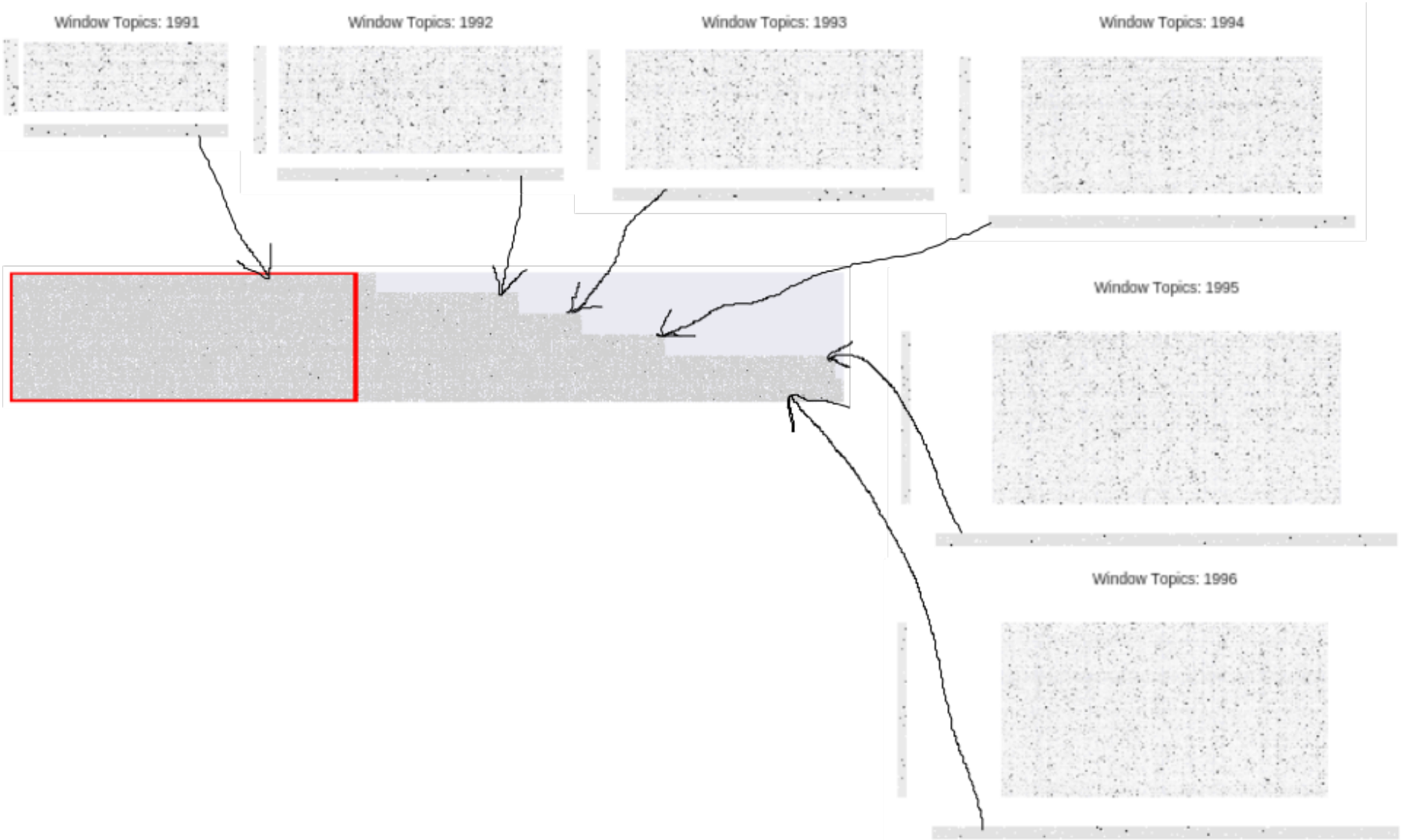


# Dynamic NMF


Window Topics: 1991
Window Topics: 1992
Window Topics: 1993
Window Topics: 1994
Window Topics: 1995
Window Topics: 1996

# Dynamic NMF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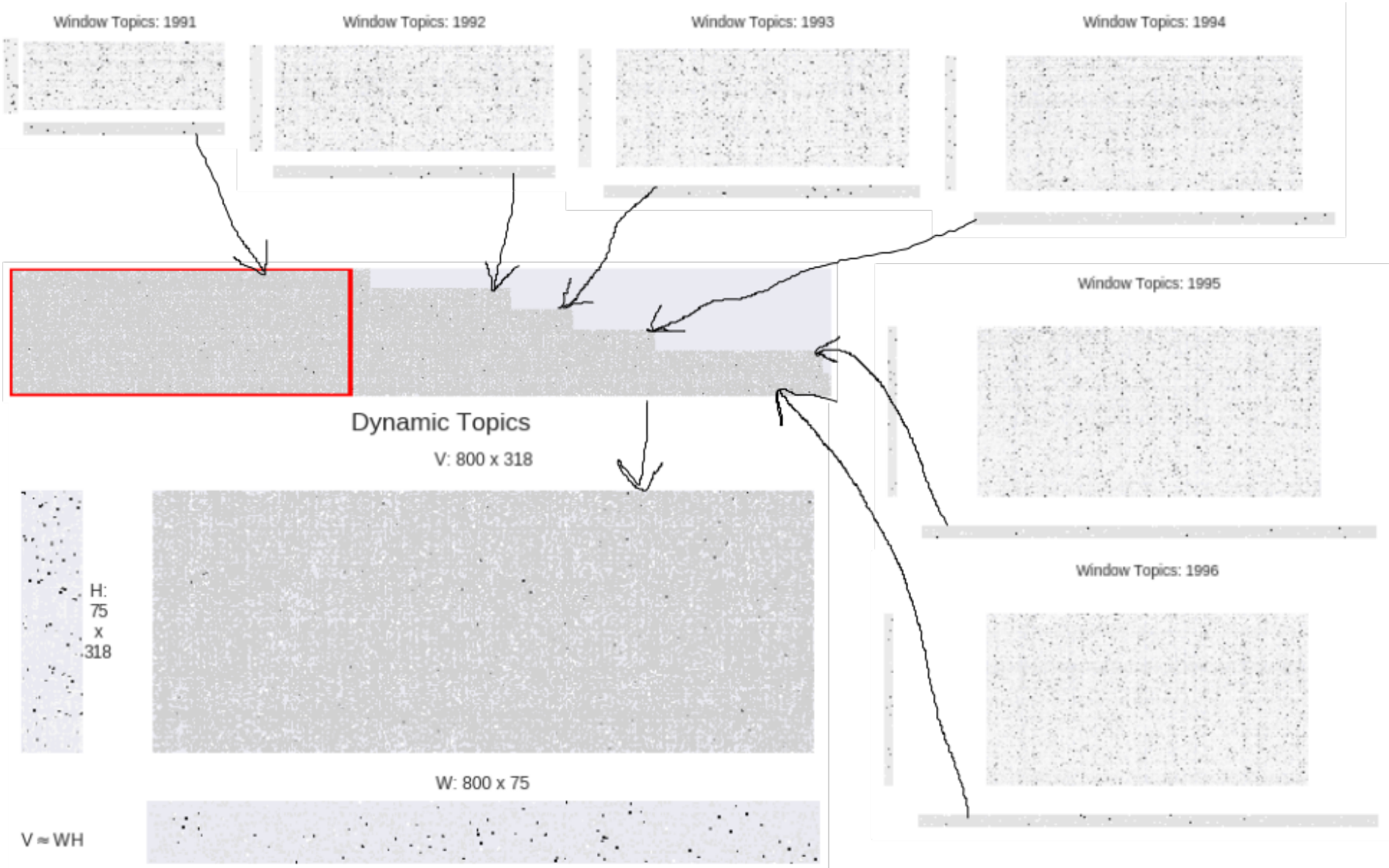

Window Topics: 1991
Window Topics: 1992
Window Topics: 1993
Window Topics: 1994
Window Topics: 1995
Window Topics: 1996
Dynamic Topics
V: 800 x 318
H: 75 x 318
W: 800 x 75
V ≈ WH

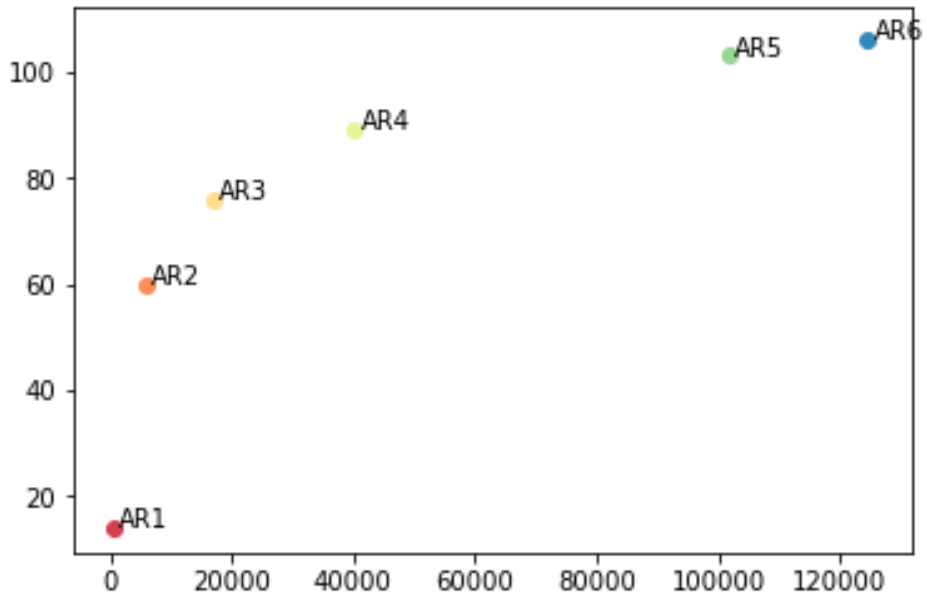
# Dynamic NMF - application to climate change

- Choosing the number of window topics is non-trivial. Data-driven approaches are limited (see below), and human selection is time consuming.
- To facilitate the description of trends over the assessment periods of the IPCC, and to minimize the number of modelling decisions, I consider each IPCC assessment period as a time window.

# Dynamic NMF - application to climate change

- Choosing the number of window topics is non-trivial. Data-driven approaches are limited (see below), and human selection is time consuming.
- To facilitate the description of trends over the assessment periods of the IPCC, and to minimize the number of modelling decisions, I consider each IPCC assessment period as a time window.

- Starting from a logarithmic relationship between the number of documents and the ideal topic number, I compare 5 runs with varying numbers of topics for each window



# Dynamic NMF - number of topics

**Human topic number criteria**

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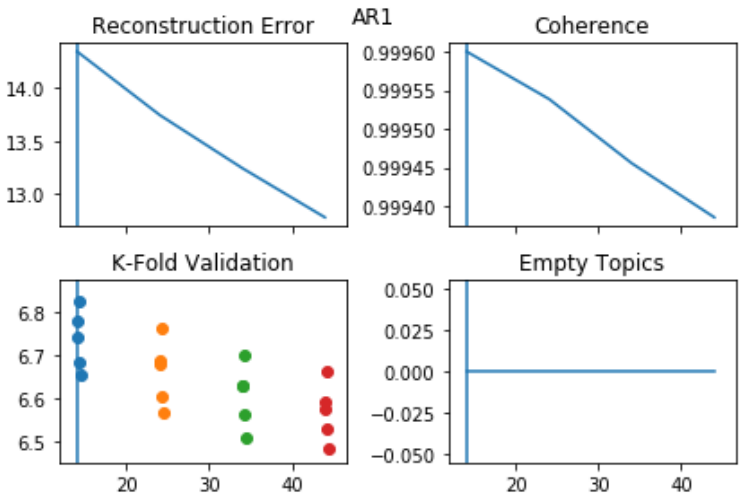
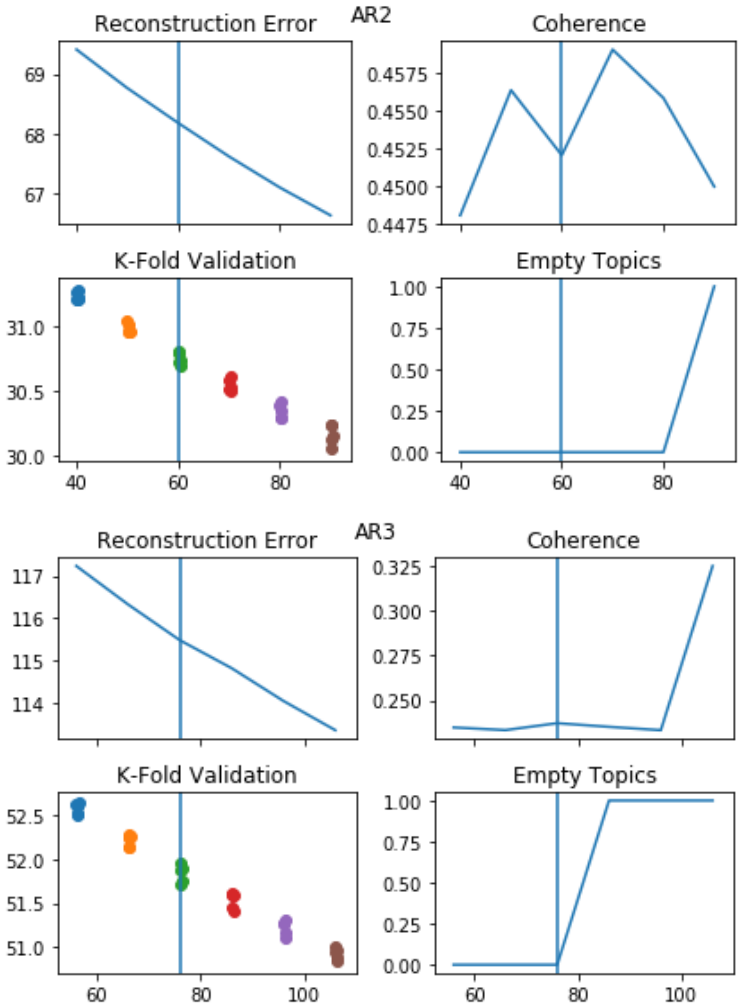
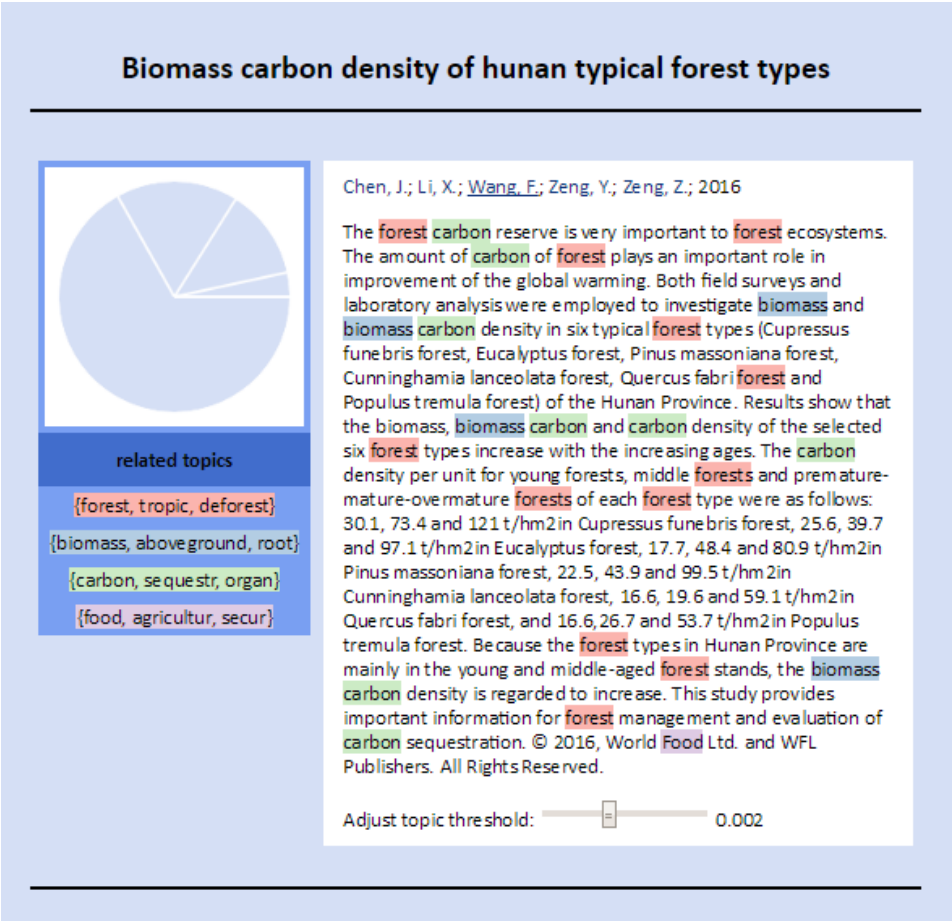


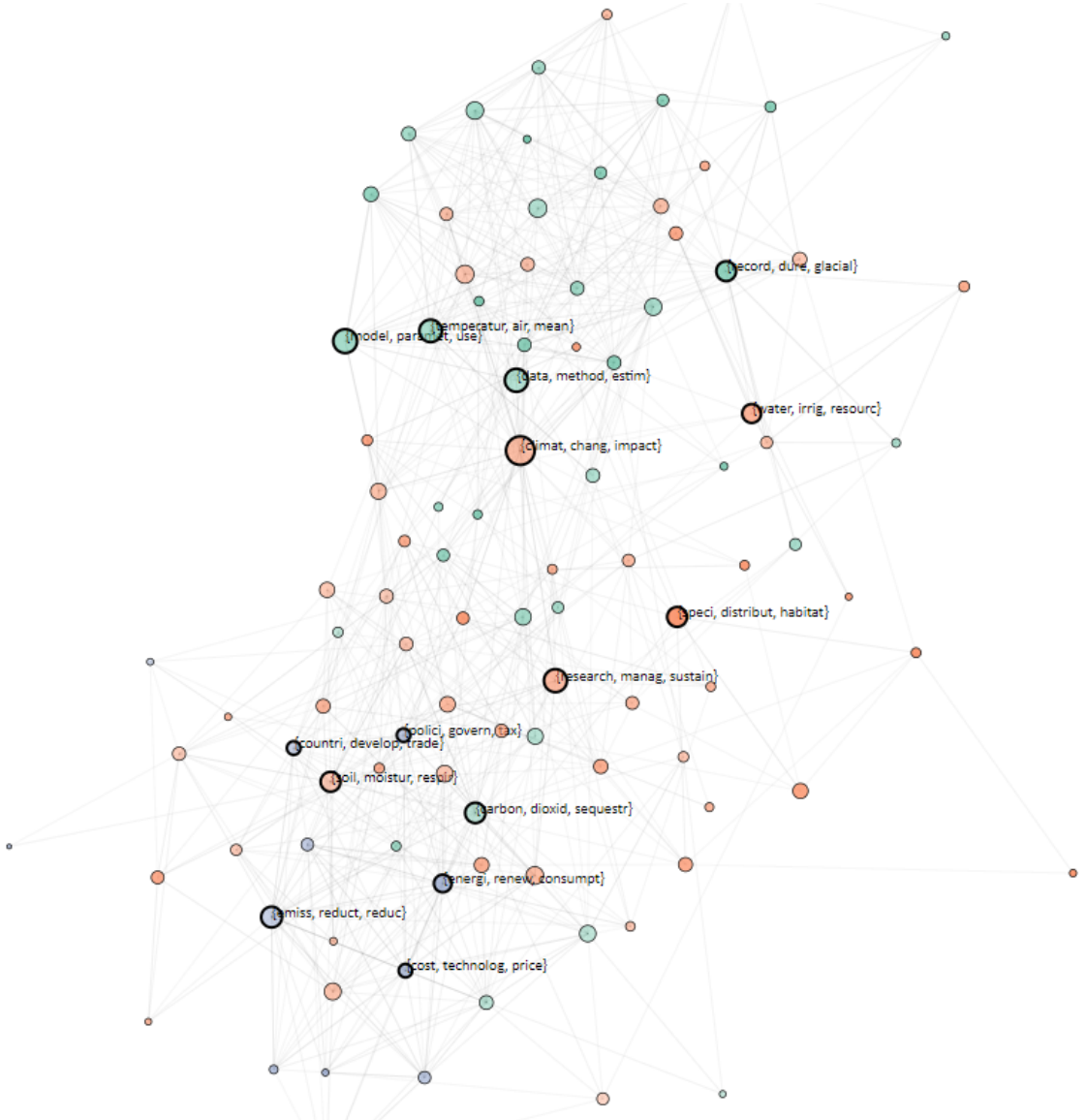



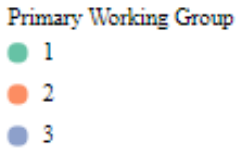
# Preliminary results - explanation




- Documents are mixtures of topics, based on the words which occur in them

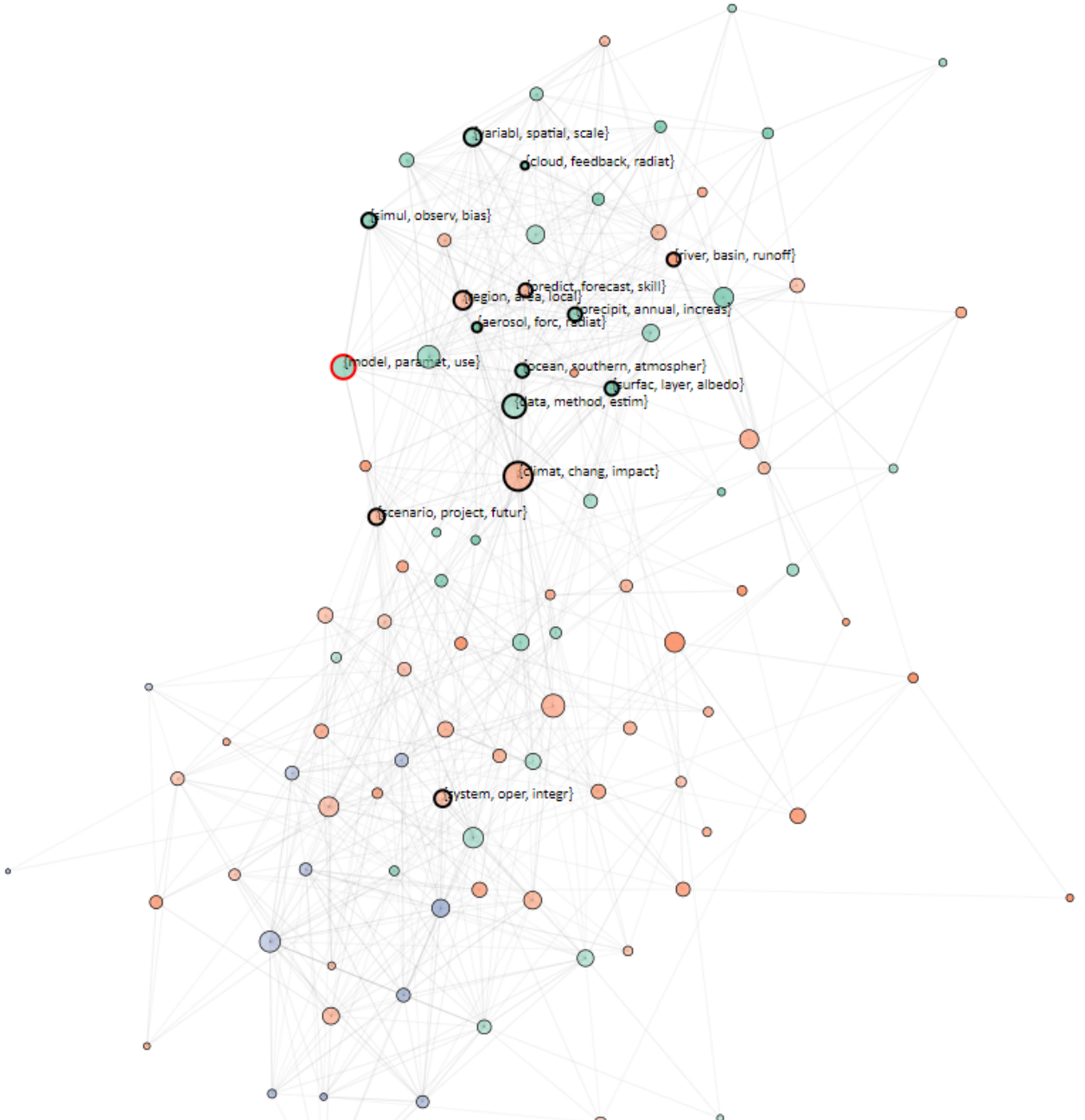
# Preliminary results - structure



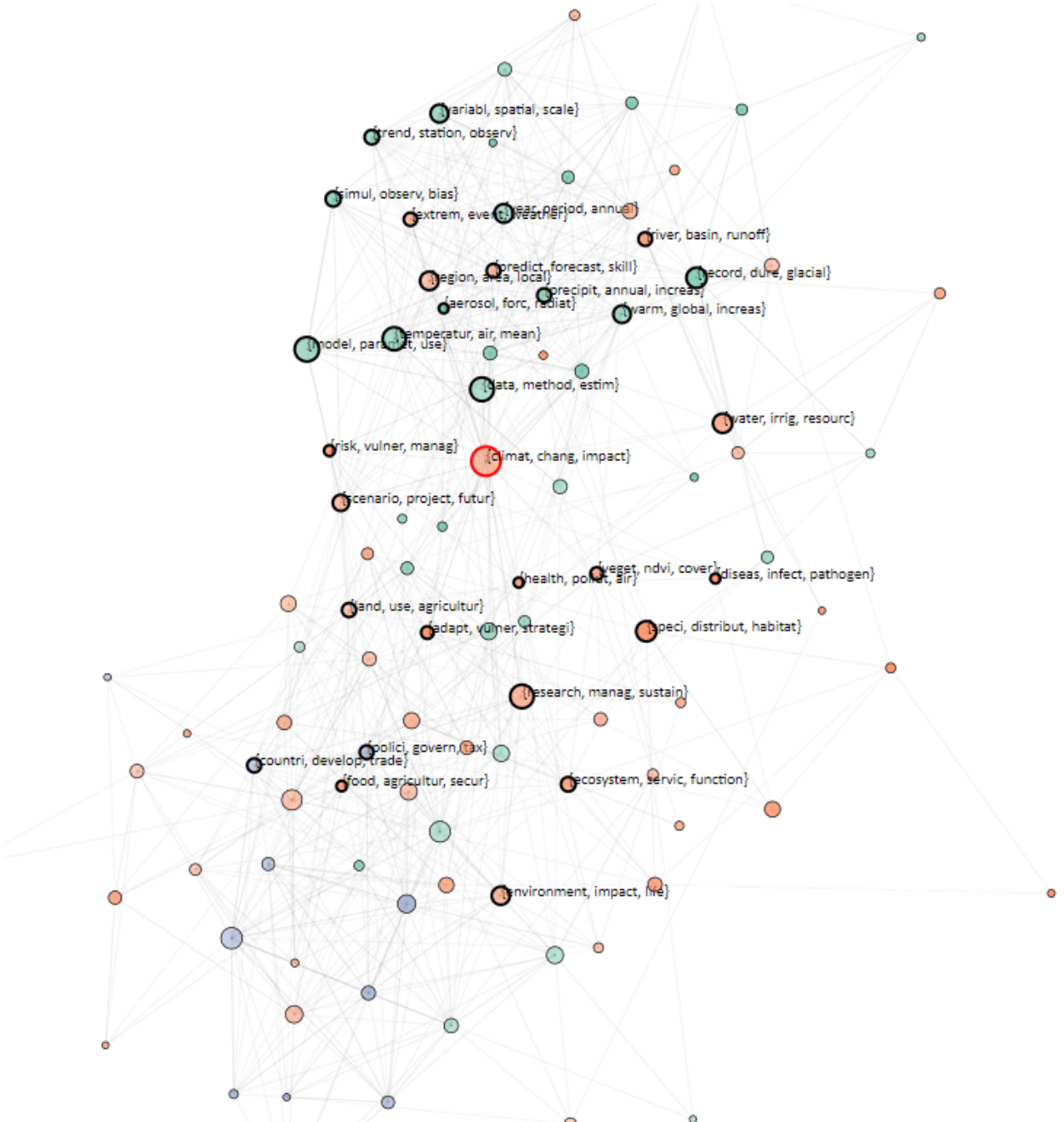

- A network of comprehensible topics is generated with 100 topics
- Topics can be matched to the IPCC working group from which the majority of the topic documents are referenced in
- Topics from the same working group are **significantly** more likely to be correlated with each other than those which are not

# Preliminary results - structure - WGI



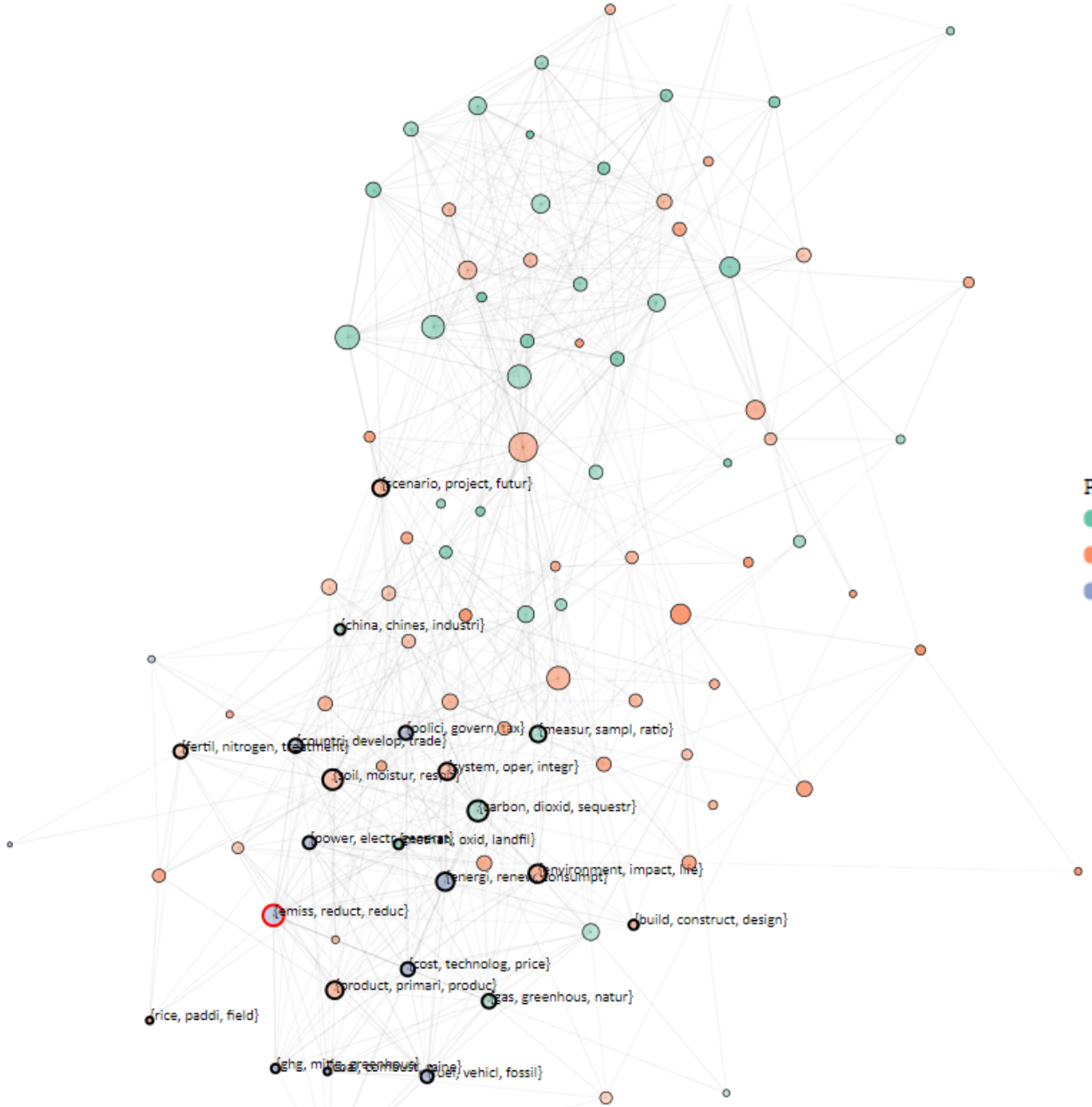

- The largest topic in WGI is on models.

# Preliminary results - structure - WGII




- The largest primarily WGII topic is on climate change impacts

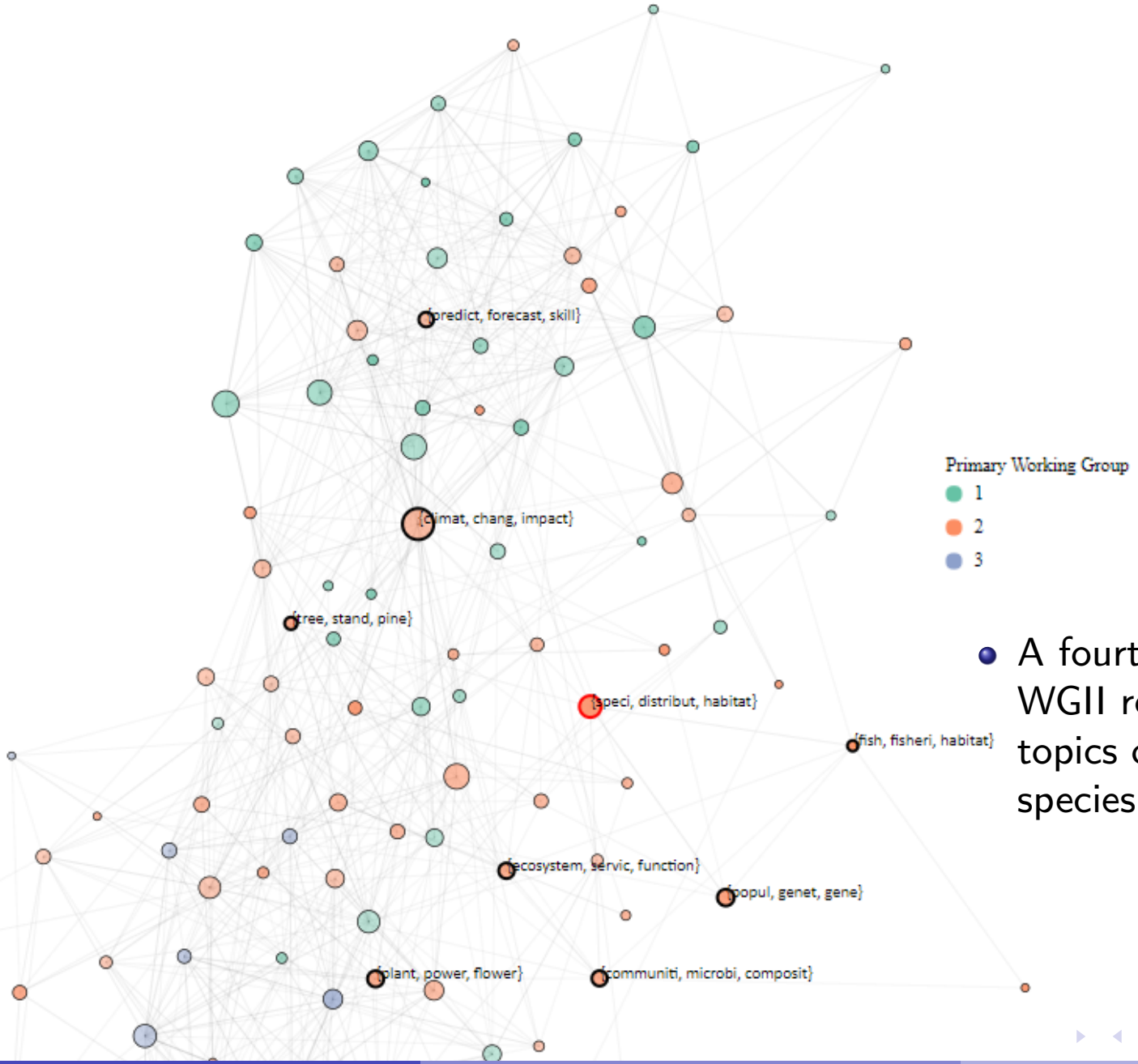
# Preliminary results - structure - WGIII




Primary Working Group
- 1
- 2
- 3

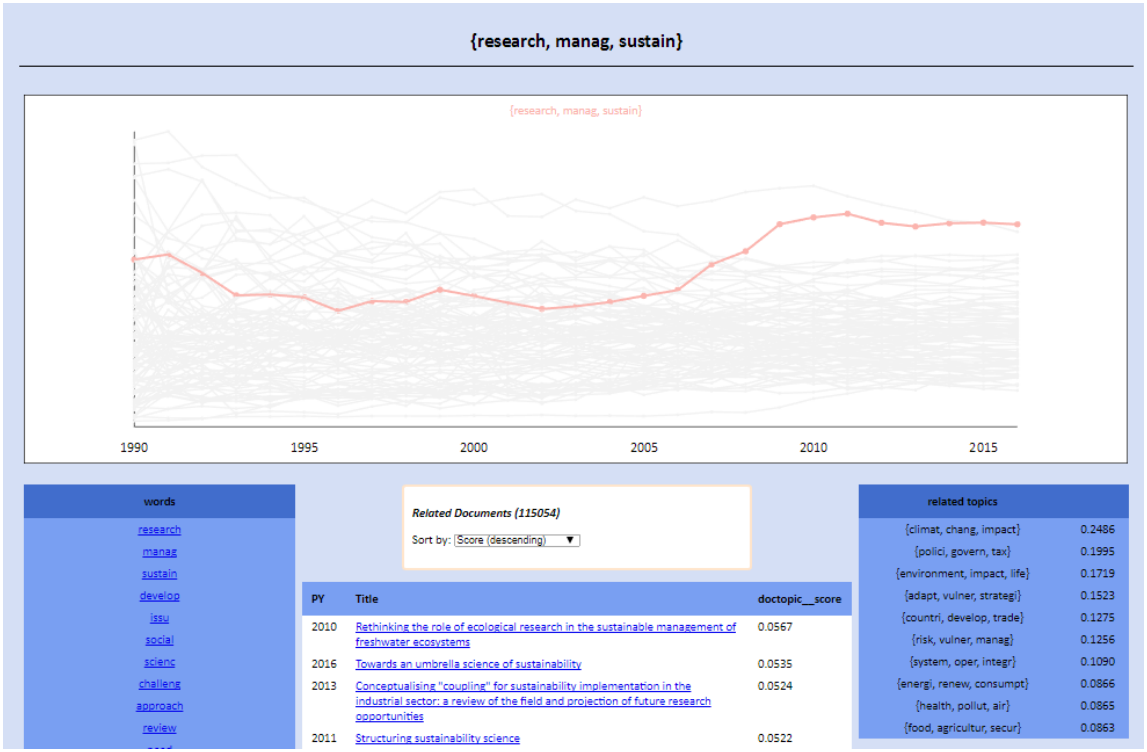
- The largest WGIII topic is on emissions reductions.

# Preliminary results - structure - other clusters




- A fourth cluster of mostly WGII references contains topics on ecosystems, species and habitats

# Preliminary results - structure - Sustainability




- In later assessment periods, a large meta-topic on research priorities and sustainability emerges

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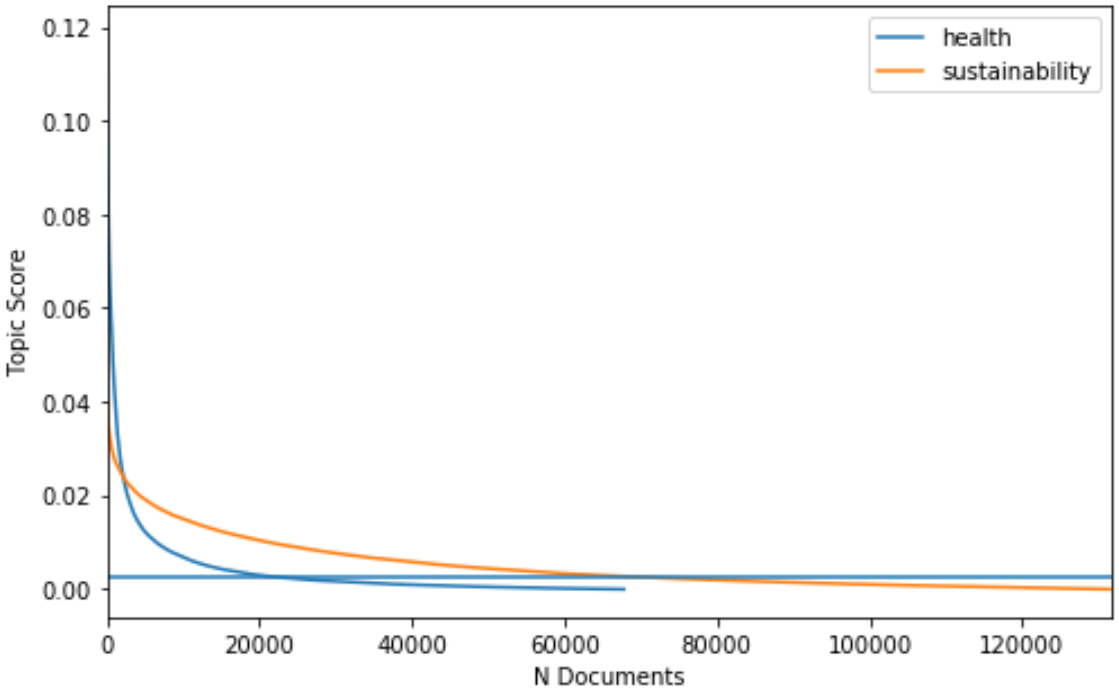
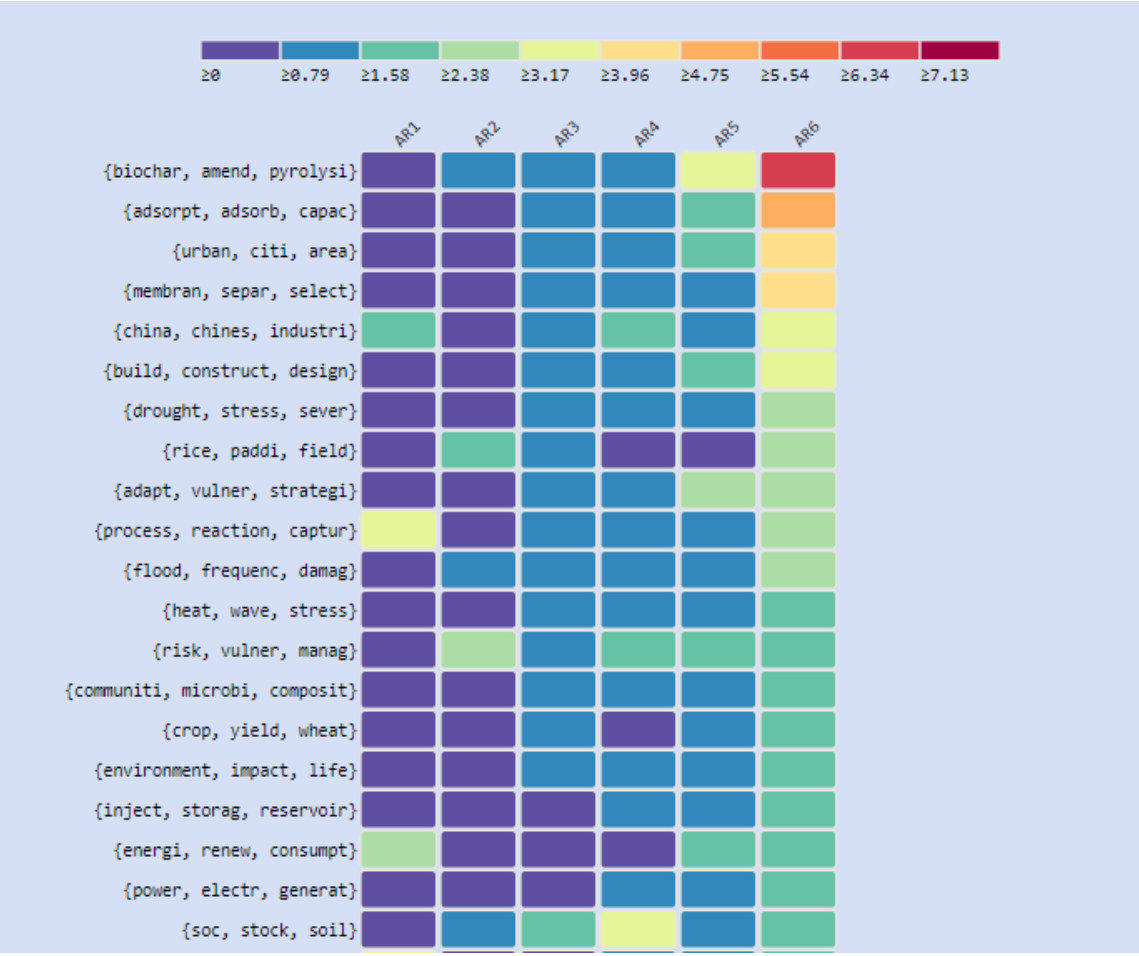



- The flatness of its distribution across documents indicates a topic that occurs

# Preliminary results - structure - Sustainability

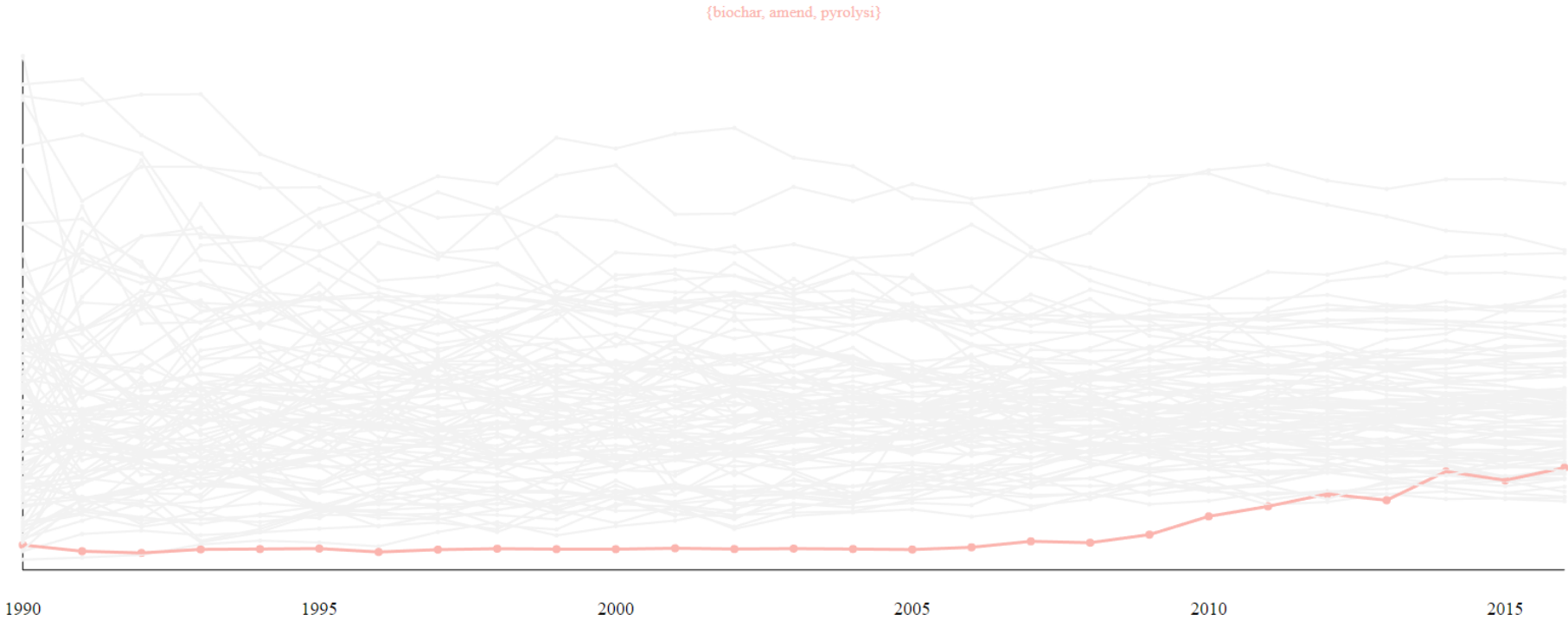
| polici, govern, tax | adapt, vulner, strategi | urban, citi, area |
|---|---|---|
| How Research-Prioritization Exercises Affect Conservation Policy | Methodological choices in solution-oriented adaptation research: a diagnostic framework | A review of urban ecosystem services: six key challenges for future research |
| Role of hydrology and economics in water management policy under increasing uncertainty | When not every response to climate change is a good one: Identifying principles for sustainable adaptation | Lines of Tradition and Recent Approaches to Urban Ecology, Focussing on Germany and the USA |
| Informing food policy: balancing the evidence | Informed adaptation: Ethical considerations for adaptation researchers and decision-makers | Advancing understanding of the complex nature of urban systems |
| The identification of priority policy options for UK nature conservation | Future oriented conservation: knowledge governance, uncertainty and learning | Sustainable urban landscapes: South African perspectives on transdisciplinary possibilities |
| Environmental education policy research challenges and ways research might cope with them | Towards an integrated agenda for adaptation research: theory, practice and policy | A conceptual framework for addressing complexity and unfolding transition dynamics when developing sustainable adaptation strategies in urban water management |

# Preliminary results - growth




- Negative emissions related topics have shown strong growth since the end of AR5
- As have topics on cities and extreme weather events

# Preliminary results - growth - biochar



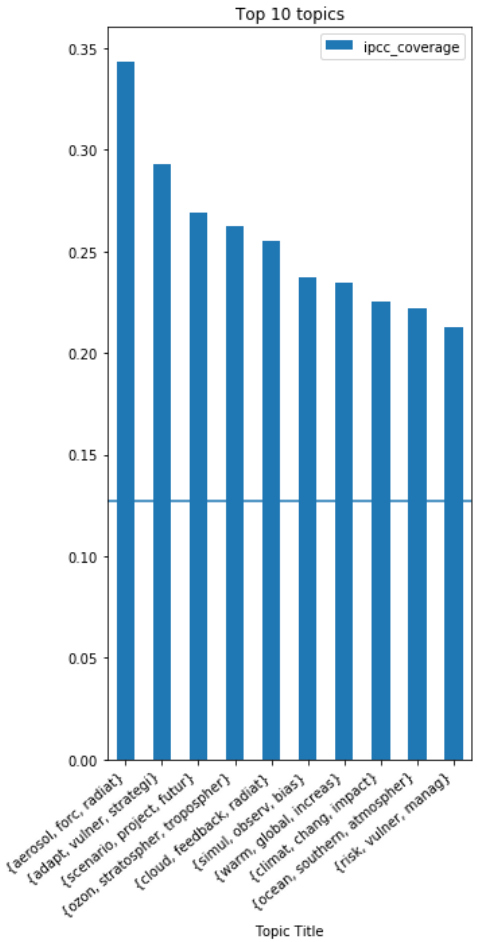

- Biochar has emerged as an entirely new topic in the last 10 years

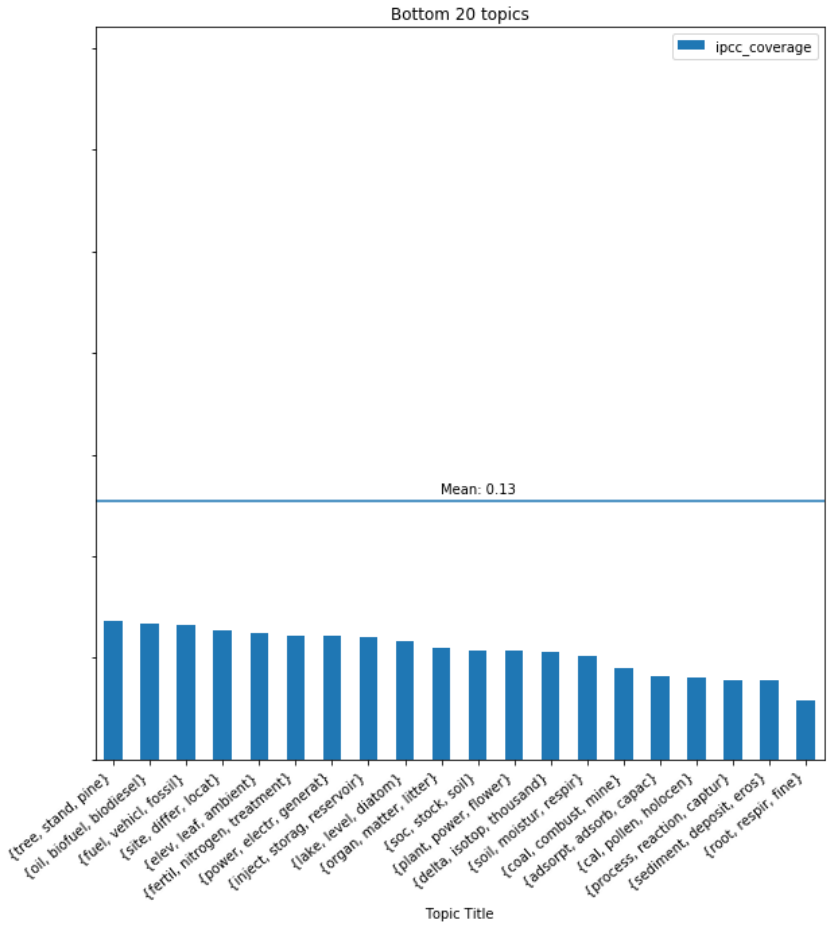
# Preliminary results - gaps in coverage

How can we get a sense of which topics are better covered in IPCC reports?

- Each document $d$ either matches or does not match an IPCC reference
- For each topic $h$, we can sum the scores for each category of document
- The "IPCC proportion" of each topic is the proportion of the sum of the document score accounted for by documents which match IPCC references.

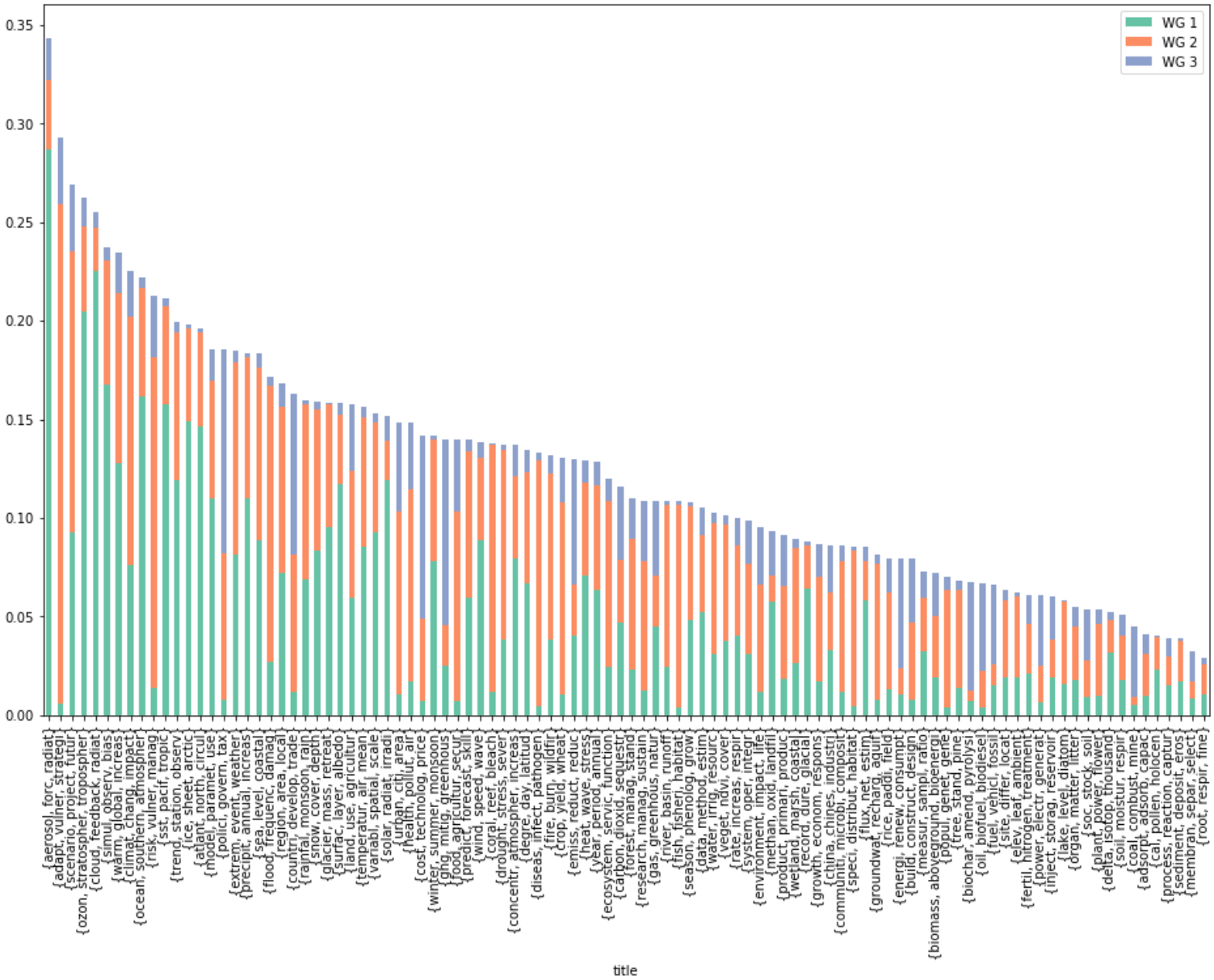
# Preliminary results - gaps in coverage




- The physical science aspects of climate change, as well topics on impacts, adaptation and scenarios are well covered by the IPCC
- Topics on specific technological solutions (particularly NETs), as well as soils, are less well covered

# Preliminary results - gaps in coverage



# Preliminary results - Inter-working Group topics - WG 1 and 3

| IPCC Coverage | Primary WG | Topic Title | WG 1 | WG 2 | WG 3 |
|---|---|---|---|---|---|
| 0.14% | 1 | {winter, summer, monsoon} | 0.55% | 0.44% | 0.01% |
| 0.16% | 2 | {rainfal, monsoon, rain} | 0.43% | 0.56% | 0.01% |
| 0.11% | 2 | {season, phenolog, grow} | 0.45% | 0.53% | 0.02% |
| 0.16% | 1 | {glacier, mass, retreat} | 0.60% | 0.39% | 0.00% |
| 0.04% | 1 | {cal, pollen, holocen} | 0.57% | 0.42% | 0.02% |

# Preliminary results - Inter-working Group topics - WG 1 and 3

| IPCC Coverage | Primary WG | Topic Title | WG 1 | WG 2 | WG 3 |
|---|---|---|---|---|---|
| 0.13% | 3 | {emiss, reduct, reduc} | 0.31% | 0.20% | 0.49% |
| 0.09% | 1 | {methan, oxid, landfil} | 0.61% | 0.14% | 0.24% |
| 0.11% | 1 | {gas, greenhous, natur} | 0.41% | 0.24% | 0.35% |
| 0.07% | 3 | {fuel, vehicl, fossil} | 0.23% | 0.16% | 0.61% |
| 0.12% | 1 | {carbon, dioxid, sequestr} | 0.40% | 0.28% | 0.32% |

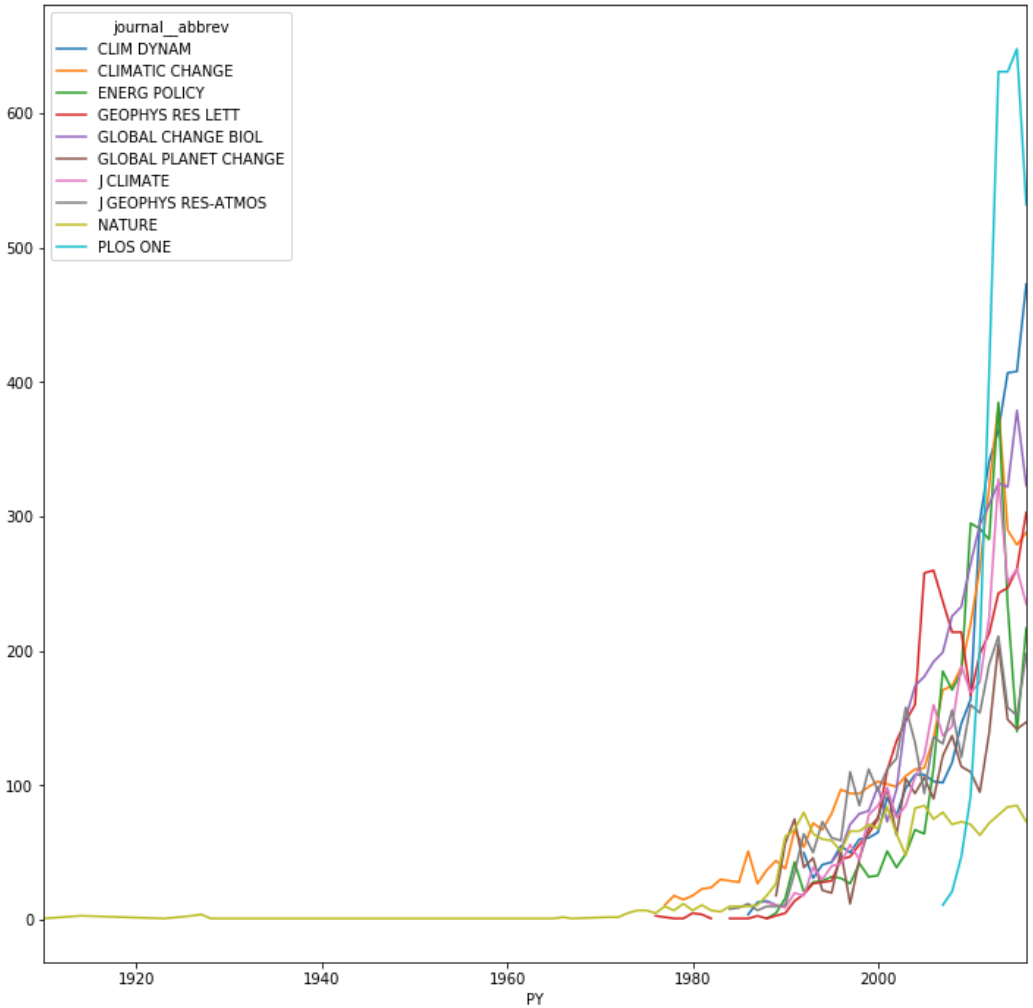
# Preliminary results - Inter-working Group topics - WG 2 and 3

| IPCC Coverage | Primary WG | Topic Title | WG 1 | WG 2 | WG 3 |
|---|---|---|---|---|---|
| 0.19% | 3 | {polici, govern, tax} | 0.04% | 0.40% | 0.56% |
| 0.16% | 3 | {countri, develop, trade} | 0.07% | 0.43% | 0.50% |
| 0.08% | 2 | {build, construct, design} | 0.10% | 0.49% | 0.41% |
| 0.14% | 3 | {cost, technolog, price} | 0.05% | 0.30% | 0.65% |
| 0.15% | 2 | {urban, citi, area} | 0.07% | 0.62% | 0.30% |

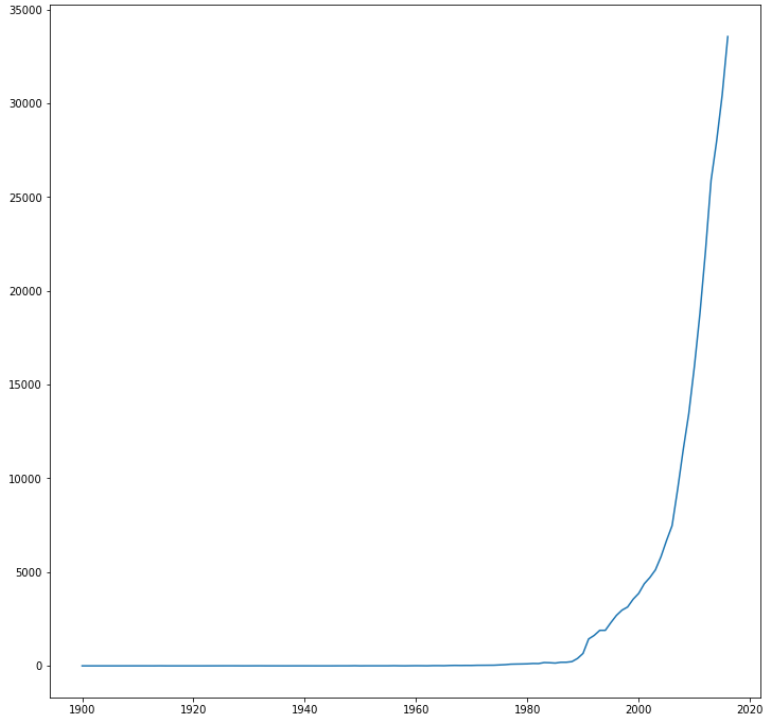
# Conclusions

- Endogenously discovered topics make substantive sense of an unmanageable dataset of climate-relevant literature
- Topic modelling discovers over-arching topics such as that on sustainability and research priorities, as well as individual, fast growing topics such as biochar or CCS
- Matching documents to IPCC references, we can describe topics that belong to or bridge IPCC working groups
- Quantitative evidence is found to support policy makers' dissatisfaction with a lack of 'solution orientation' in IPCC reports (Kowarsch et al., 2017)
- By uncovering the structure at scale of a large collection of documents, and by enabling the discovery of documents relevant to specific topics or combinations of topics, this approach can provide for more comprehensive and salient scientific assessments.

# Extra results - Journals




- Nature has been publishing about climate change for a long time
- Plos One has very recently overtaken all other journals
- The number of journals has risen very steeply



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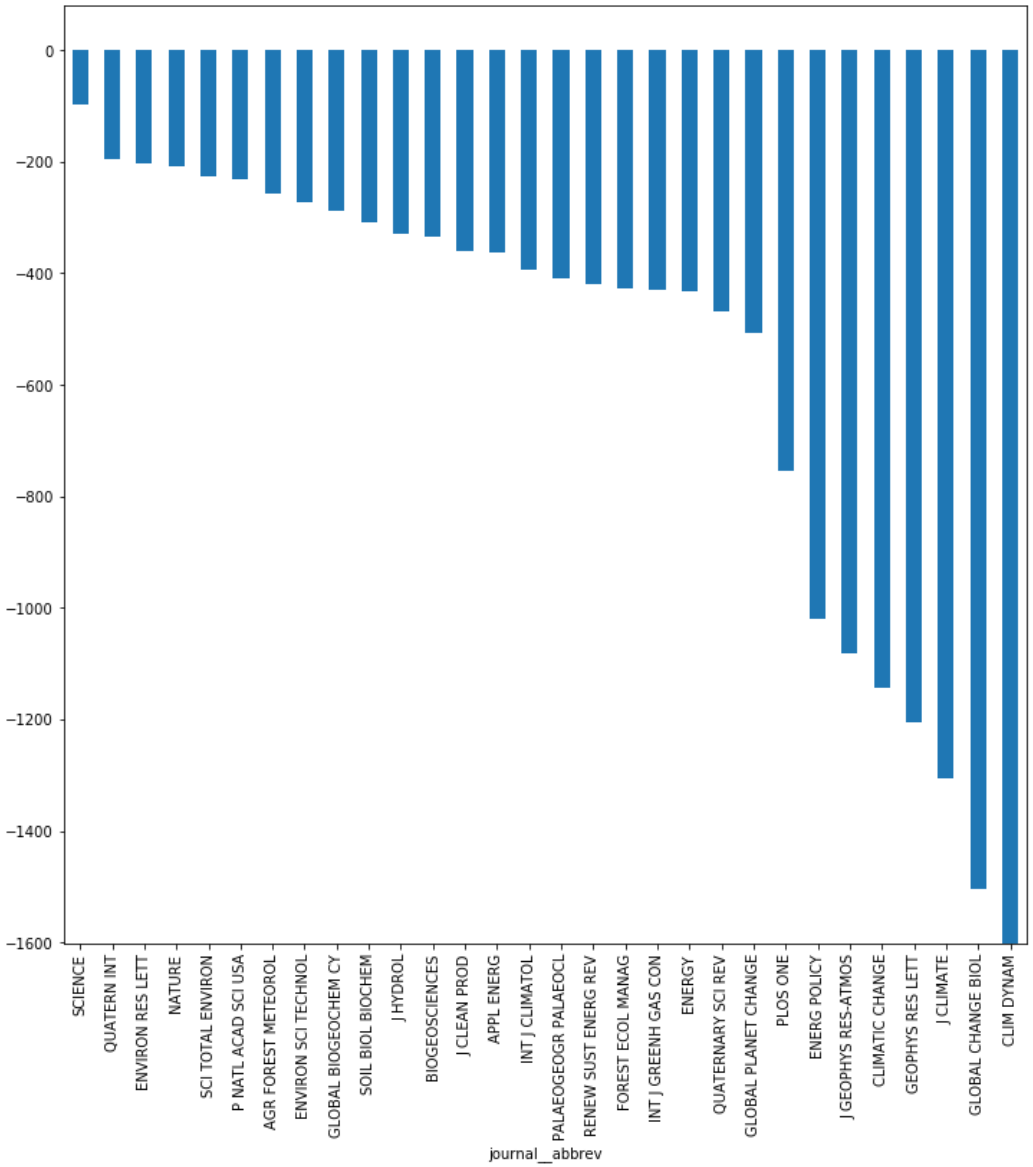
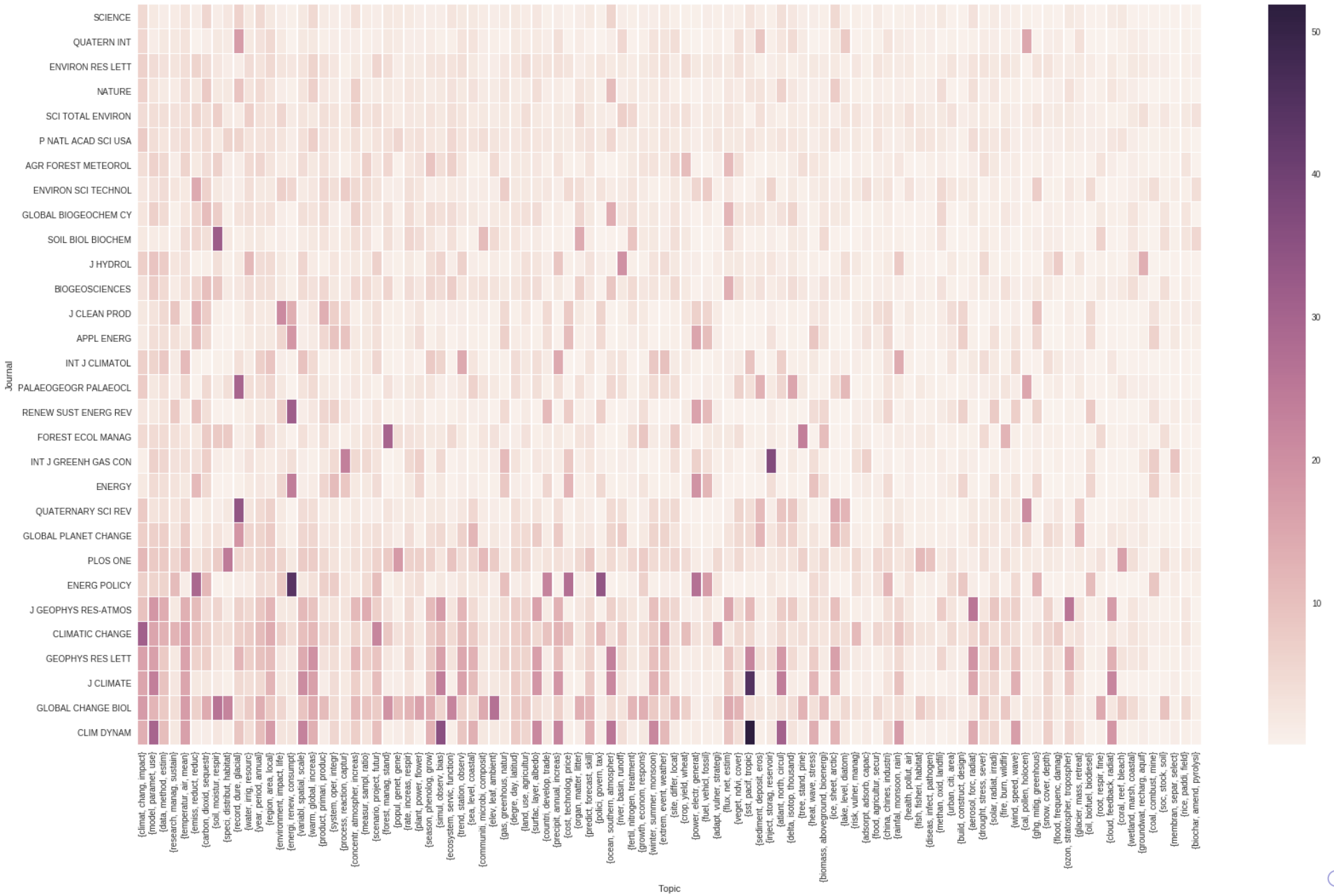



- Journal Entropy describes the distribution of topics in a journal (Hall et al., 2008)
- High values mean the journal deals with a wider range of topics

$$H(z|c,y) = -\sum_{i=1}^{K} \hat{p}(z_i|c,y)\ log\ \hat{p}(z_i|c,y)$$

# Extra results - Journals



MCC

Blei, D. M. and Lafferty, J. D. (2006). Dynamic Topic Models. *International Conference on Machine Learning*, pages 113–120.

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