Mapping Change in the Science of Ocean Change

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Abstract

Using bibliometric analysis techniques, we trace the evolution of climate and climate-change related articles in major oceanographic journals, 1987-2017. We use these bibliometric tools (network mapping, cluster analysis, alluvial analysis, corpus keyword detection) to document trends in growth, integration and centralization of climate-related research within ocean sciences over the past three decades. Such analysis methods offer an objective and complementary methodology, in contrast to the traditional "expert panel" approach, for guiding long-term strategic science planning. But how does the macro trend compare to scientific outputs supported by large ocean observatory facilities? Have scientists making use of these facilities followed, led or diverged from the general trend? We compare the macro trend to corpora of published science from two such facilities, Australia's Integrated Marine Observing System (IMOS) and Ocean Networks Canada (ONC). The goal is to discern the extent to which these "big science" ocean observatories have been able to support or lead research that helps inform policy, management and the public about critical societal issues such as long term ocean change.

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WORLD-LEADING DISCOVERIES AT A CRITICAL TIME

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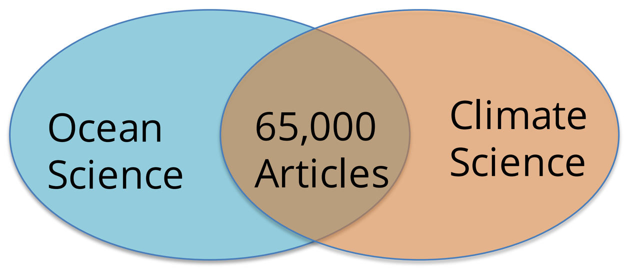
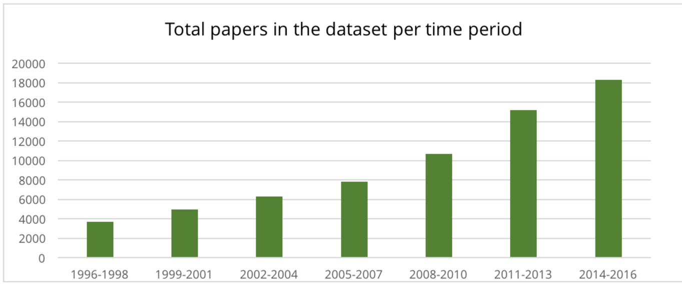
Introduction

Using bibliometric analysis techniques, we trace the evolution of ocean science research related to climate science, over the period 1996-2016. Resulting diagrams illustrate trends in growth, divergence and merging of topic clusters over time. We relate these trends to the publicaton output of Ocean Networks Canada (ONC) and the Australian Integrated Marine Observing System (IMOS).

Data Selection

Starting with papers in specialist journals in the fields of oceanography and climate change, the dataset was expanded using keyword-based queries in titles, author keywords, and abstracts. The relevant terms were identified by computing the TF-IDF* of each term. The final corpus of 65,000 papers on ocean-climate change research was created from the intersection between the two datasets. **TF-IDF, or term frequency-inverse document frequency is a statistical measure used to evaluate how important a word is to a document in a collection or corpus.*





Methodology

To identify themes, terms (keywords) were detected using co-occurrence patterns of word pairs and expressions within the corpus. Two distinct words or expressions co-occur if they are present in the same document. The corpus consisted of titles, abstracts, author keywords, and titles of references collated into seven 3-year subsets between 1996-2016. Co-occurences within these subsets were determined by converting text into noun phrases after merging variants of the same words[1]. Relevance scores for each noun phrase were assigned according to the distribution of co-occurrences[1].

Filtered keywords were then ranked by relevance scores, with 10% of papers filtered out due to insufficient terms. Clustering was then performed in VOSviewer using total link strength for weighting. This generated a set of 10-18 clusters per time period. The evolution of these clusters over the 3-year time periods is visualized by the large Sankey diagram, with groups of terms merging into and diverging out from the various clusters over time along the X axis.

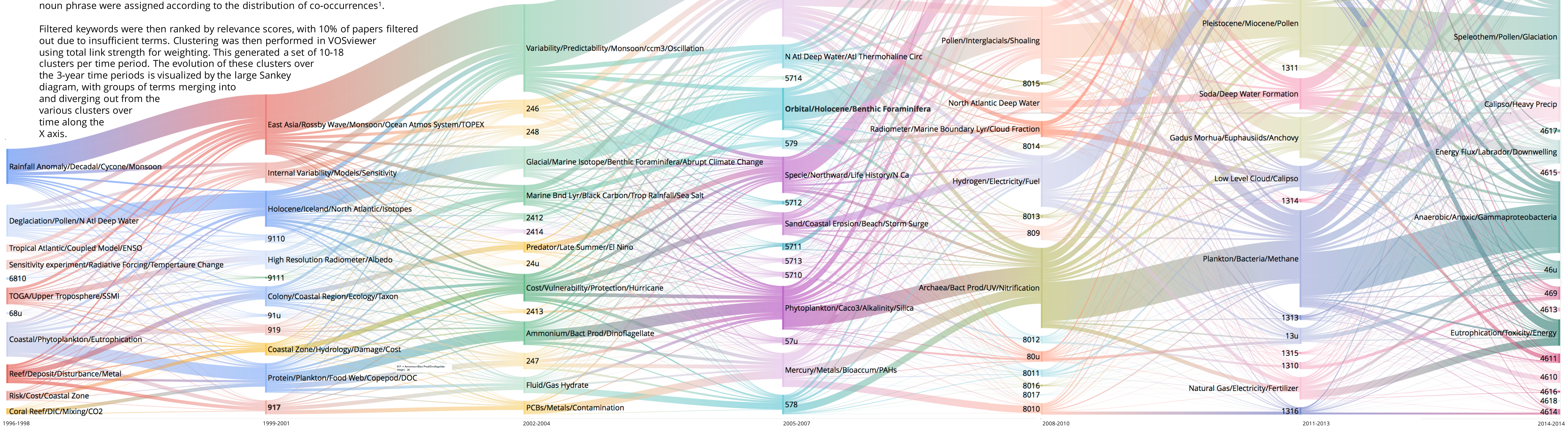
Influence of Large Experiments

Names of several large experiments and infrastructure or numerical modeling platforms appear as significant terms in the corpus. AVHRR, Calipso, CCM3, CFS, GPCP, Grace, HADCM, HyMeX, ISCCP, SODA, TOGA, TOPEX Poseidon, and SSMI all occurred within the top 100 terms for a time period. ***This approach enables major developments and science investments to measure and trace their impact on the corpus of scientific literature.***

Expanding Research

Ocean-climate change research has expanded significantly over the past two decades:

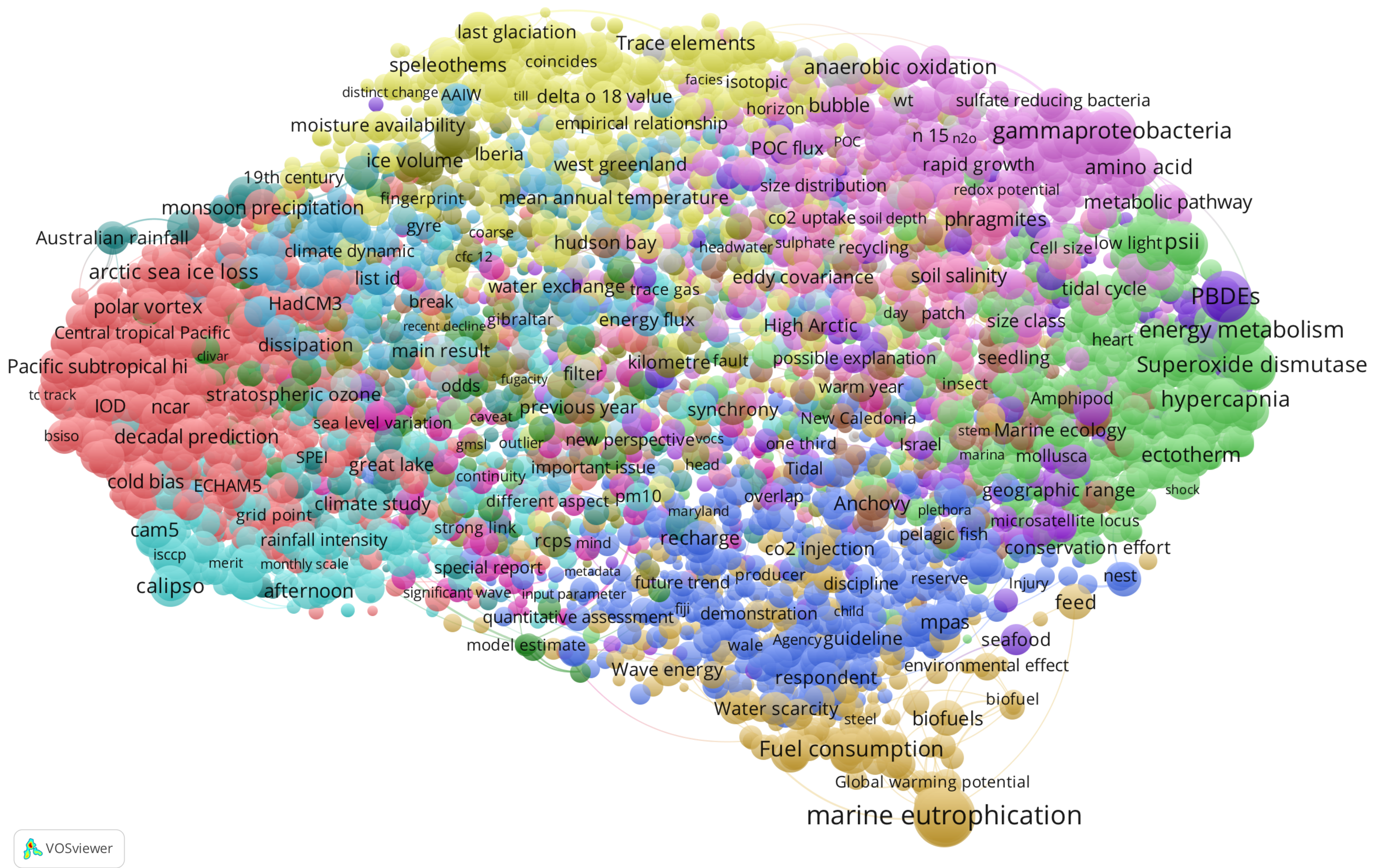
- Total paper counts grew from 1160 in 1996 to 6490 in 2016 (**560%** increase)
- In 1996-1998, the dominant thematic cluster, *Rainfall Anomaly /Decadal/Cyclone/Monsoon,* included **156** terms.
- In 2014-2016, the dominant thematic cluster, *Arctic Ice/Polar Vortex/Monsoon Precip,* included **904** terms.



Shape of the Science

When mapped as clustered topics by VOSviewer, major topical areas are indicated by colour. Some clusters, such as the red, yellow, magenta, green and blue ones below, are displayed as distinct, tightly connected groupings around the edges of the map. These clusters could be characterized as having greater coherence. Others, such as the dark green, pink and purple clusters, are more diffuse and centrally located, indicating that terms in these clusters have weaker coherence and stonger affinities across cluster boundaries.

Major clusters in the 2014-2016 period include « Arctic Sea Ice Loss/Polar Vortex/Monsoon Precipitation » (904 terms), « Energy Metabolism/Superoxide dismutase/Hypercapnia » (621 terms), « MPAs/Guideline/Recharge » (535 terms), « Speleothems/Last Glaciation/Trace Elements » (505 terms), « Anaerobic oxidation/Gammaproteobacteria/Amino Acid » (457 terms).

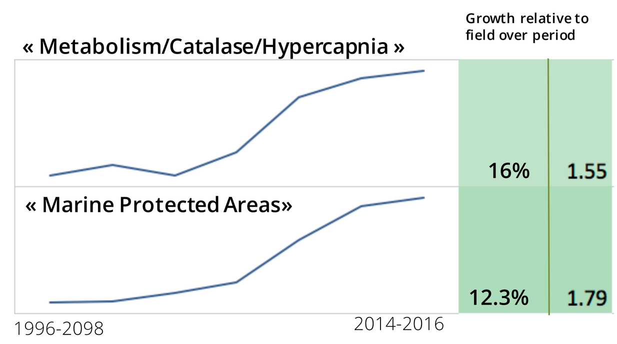


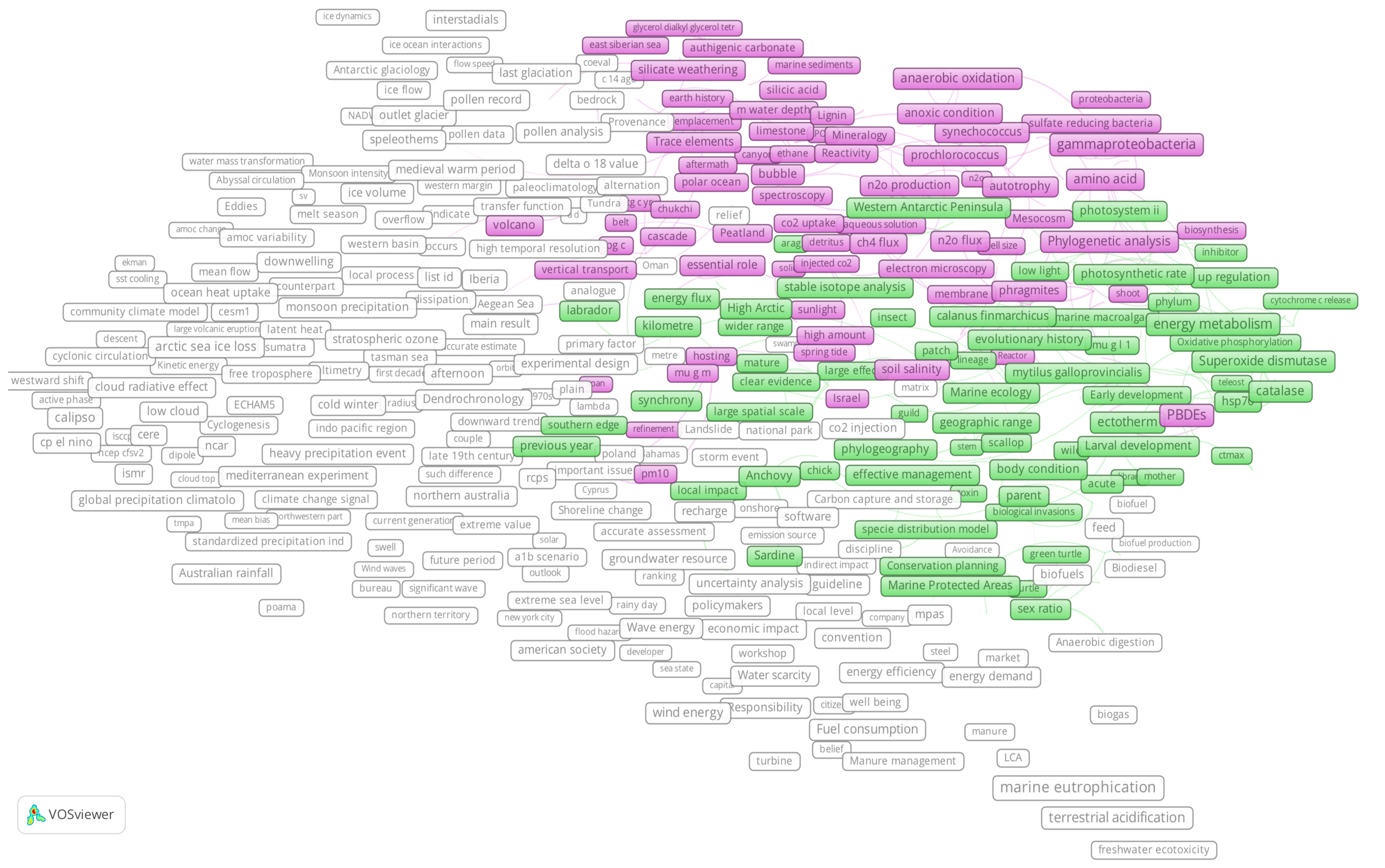
VOSviewer map of 5188 terms in 18 clusters for papers published between 2014-2016.

Areas of Notable Growth

Two topical clusters (highlighted below) stood out as areas with significant growth between 1996-2016. Over 21 years, terms in the « Anaerobic oxidation/Gammaproteobacteria/Amino Acid » cluster grew from 4.6% to 16% of the total share, while terms in the « Energy Metabolism/Superoxide dismutase/Hypercapnia » cluster grew from 1.6% to 12.3% of the total share.

In contrast, the « Arctic Sea Ice Loss/Polar Vortex/Monsoon Precipitation » cluster remained stable and dominant theme, growing slightly from 25% to 29.2% of the total share over the period.



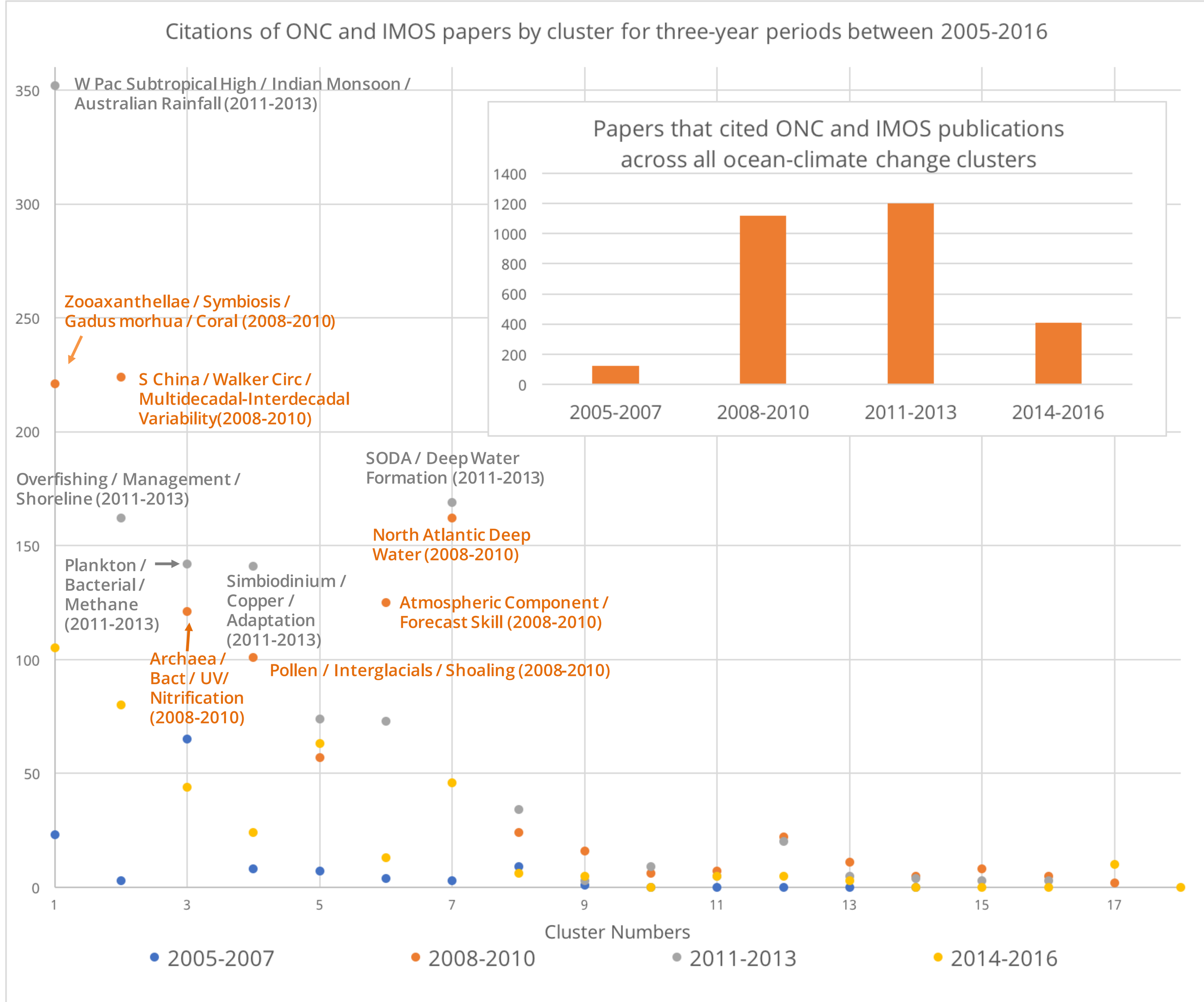


VOSviewer map with the most common terms from two clusters highlighted for the 2014-2016 period.

IMOS & ONC Contributions

We also examined the numbers of papers identified in the dataset, which cited papers that made use of ONC and IMOS data, infrastructure or support. IMOS was established in mid-2006, and ONC in 2007, so citations counts for the 2005-2007 period were minimal. Citation counts crest for the 2011-2013 period because citations generally lag publication year by several years.

Citations within the larger, more robust clusters (generally 1-7) are much more numerous than those in the the smaller, more transient clusters (8-18). Many ONC and IMOS-related



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