Net Zero Oceanographic Capability - Journal and cruise analysis

Summary

Analysis of scientific publications and cruise metadata are used to provide an overview of oceanographic observations and emerging trends globally and in the UK. There has been a **rapid move** to lower carbon observing platforms such as **autonomous vehicles and floats**. There is, however, more scope for use of these platforms as together they still account for a much smaller proportion of research than measurements made directly from ships. There have also been **changes** in the **regions** were observations are carried out. The Southern Ocean has been growing in importance since the 1990s, but the **largest recent growth** has been in studies of the **Arctic Ocean**. Cruise metadata analysis also shows the emergence of new cruise activities in recent years such as observations of marine plastics and tracking marine geochemical tracers.

Introduction

This analysis provides context for decision-making about the development of a net zero oceanographic capability. It does so by analysing scientific journals and BODC cruise data to understand the overall distribution of cruise activities as well as the fastest emerging trends in cruise activities. For the analysis I use both scientific journals and cruise metadata to capture both what was measured and what was eventually published.

This report sets out a summary of the main findings. In addition, the full set of analysis has been deployed to a web-based app that can be accessed at https://nzoc-app.herokuapp.com.

Data and methodology

Journal analysis

I ingest research articles from the most popular journals for authors with a National Oceanography Centre affiliation. These journals cover physical oceanography, marine biology, biogeochemistry and geology. In addition, articles in Nature relating to marine topics are also selected as a proxy for “high impact” research.

For each article the data include the abstract text and the author addresses. Articles that have at least one author with a UK affiliation are included in the comparison analysis of UK research. I manually inspected a subset of the articles to ensure this provides a fair picture of UK activities.

Cruise metadata

The cruise metadata were provided by the British Oceanographic Data Centre (BODC). The data includes fields such as the cruise name, location and ship. The description of cruise location and activities are free text fields and so required standardisation.

I have standardised the location by mapping the given cruise location to a region (e.g. North Atlantic) and sub-region (e.g. Porcupine Abyssal Plain). As some cruises cover long distances across multiple regions (e.g. the Atlantic Meridional Transect) I have mapped these to the end furthest from the UK to better characterise their carbon emissions impact.

I have carried out text analysis of the cruise activities to establish what activities took place on each cruise. The text on each cruise varies in the amount of detail provided, however, in most cruises there is sufficient data to characterise the cruise activities.

Text analysis

The text analysis is carried out by developing classification hierarchies that map keywords to topics. For example, an article or a cruise can be classified as relating to the Atlantic if the Sargasso Sea is mentioned in the text. As the volume of data for the journal analysis is substantial, a pre-processing step is carried out to identify which words appear in which articles.

For the journal analysis all time series plots are shown with a 5-year running mean smoothing applied.

Limitations

The primary limitation of the journal analysis is that it requires topics to be referred to in an unambiguous manner in the article abstract. I have reviewed many of the abstracts and concluded that the overall picture that emerges in the charts is representative of the underlying articles.

Another limitation is that new technologies are more likely to be mentioned explicitly in an abstract than established technologies. For example, recent papers that use data from gliders are more likely to make a clear reference to this than a recent paper that uses a tethered CTD.

A related limitation is that a given observation - such as a hydrographic section with a tethered CTD - may primarily be used as part of large-scale data aggregations in a hydrographic atlas or state estimate. It is not possible to link these data aggregations to the original observations in the journal analysis.

The BODC cruise metadata does not cover all of the cruises carried out in the last 20 years but should be sufficient to gain an overview of requirements and emerging trends.

Results

Journal analysis

Regional trends

The Atlantic and Pacific have long been the most common regions for ocean research to be carried out. In recent decades, however, the proportion of research carried out in the Atantic has been falling (Figure 1).

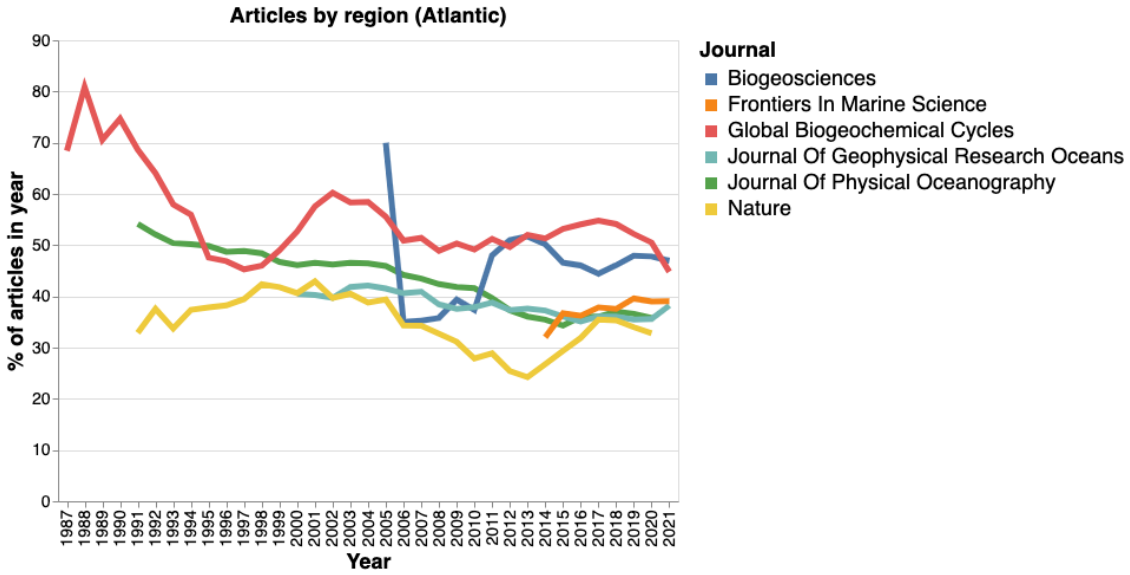


Figure 1: Reduced emphasis on Atantic Ocean in recent decades across a range of journals.

The Southern Ocean and Antarctic margins have been a greater focus of activities in ocean research in the last 20 years. However, in many journals the proportion of articles referring to this region has plateaued in the last 5 years. The proportion of articles referring to the Southern Ocean is now similar to the proportion of articles referring to the Atantic or Pacific in many journals (Figure 2).

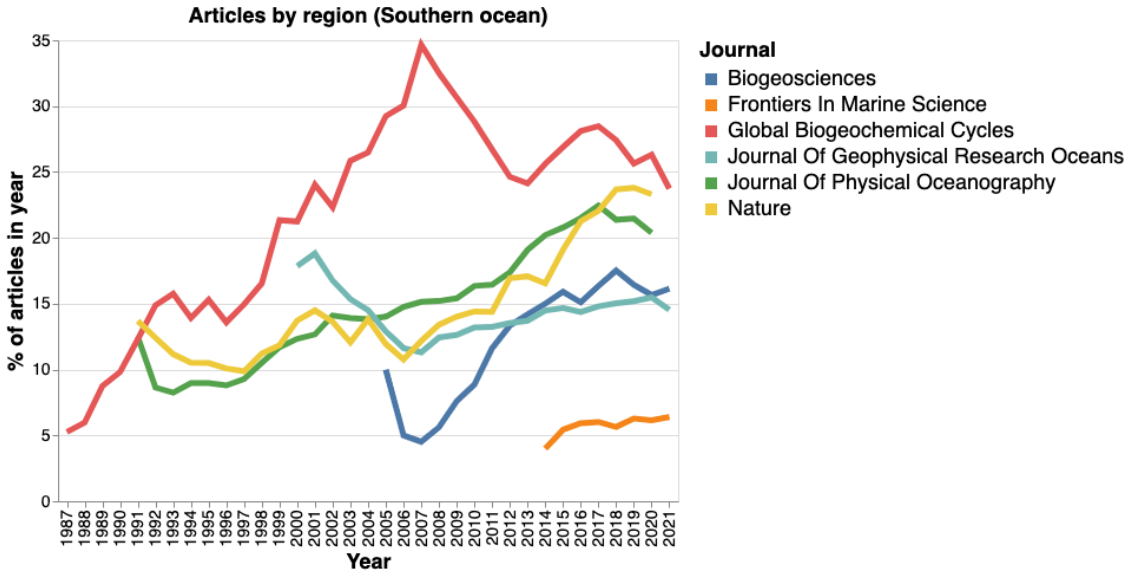


Figure 2: Increased emphasis on Southern Ocean in recent decades though with a plateau in recent years across a range of journals.

In the last decade the region with the fastest growing proportion of ocean research has been the Arctic. In some physical and biogeochemical journals the proportion of articles referring to the Arctic has grown from near 0% to almost 20% of articles (Figure 3). There has been no comparable change in the proportion of articles referring to the Indian Ocean.

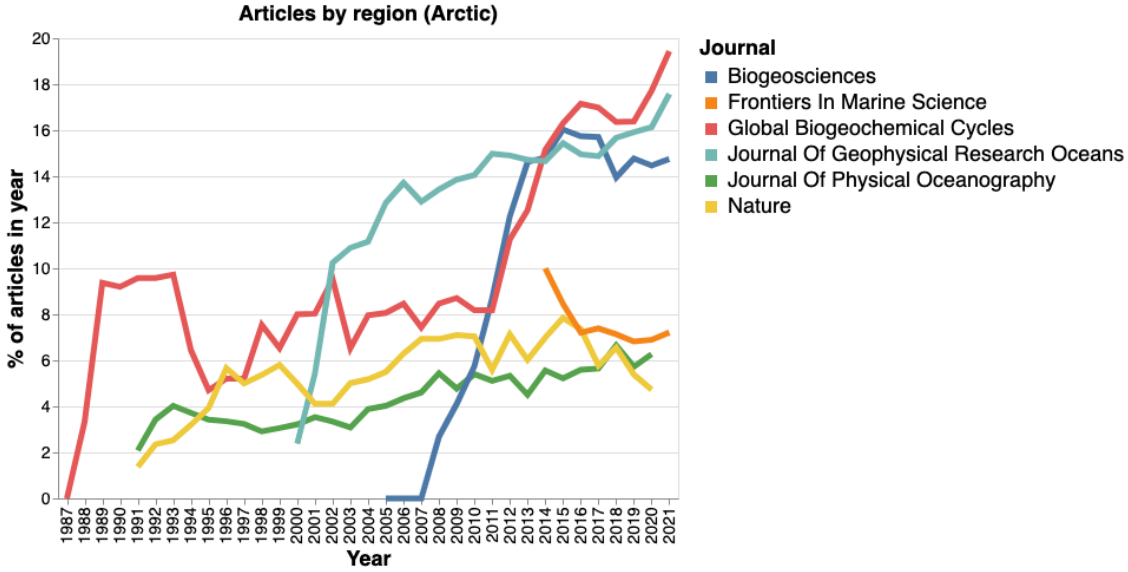


Figure 3: The Arctic Ocean has the region with the fastest growing proportion of research in the last decade across a range of journals.

These trends of growing interest in the Southern and Arctic Oceans have been particularly strong in the UK. For example, more than 30% of articles in the Journal of Physical Oceanography that included a UK author referred to the Southern Ocean compared to

about 20% for the global average (Figure 4). The Arctic has also been referred to about twice as often by papers with a UK author as the global average.

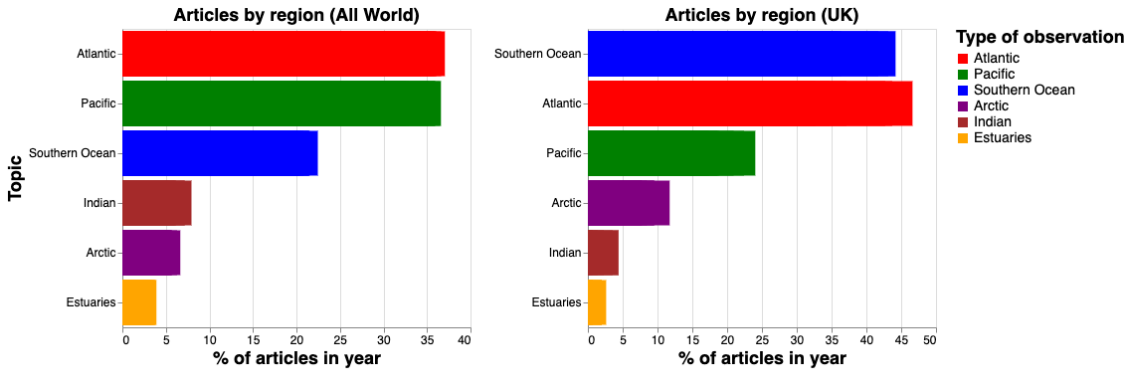


Figure 4: Papers with a UK author have a much higher proportion of research in the Southern and Arctic Oceans in the Journal of Physical Oceanography.

Observing platform trends

The main trend in observing platform in recent years has been the increasing use of remote instruments. We define autonomous vehicles to be piloted instruments including gliders and AUVs while we define floats as drifting instruments such as ARGO.

Use of autonomous vehicles - primarly gliders rather than AUVs - has grown in the last ten years. Gliders have been used about twice as often in physical oceanography research as in biogeochemical research, but usage is growing fast in both areas. The absolute proportion of articles using gliders remains relatively low with less than 3% of articles referring to gliders even in the journals where they are most common (Figure 5).

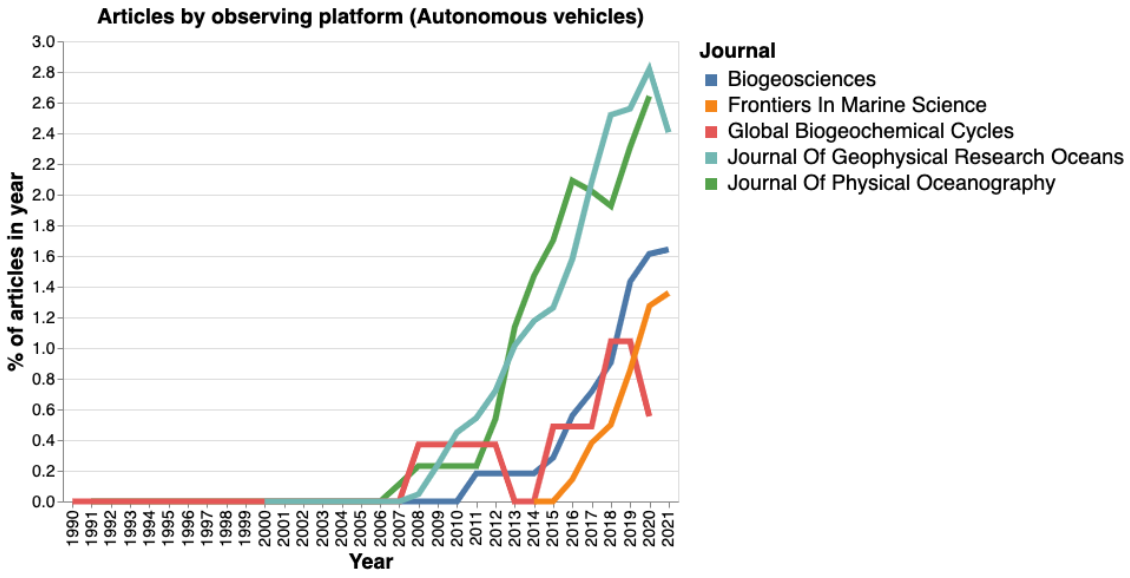
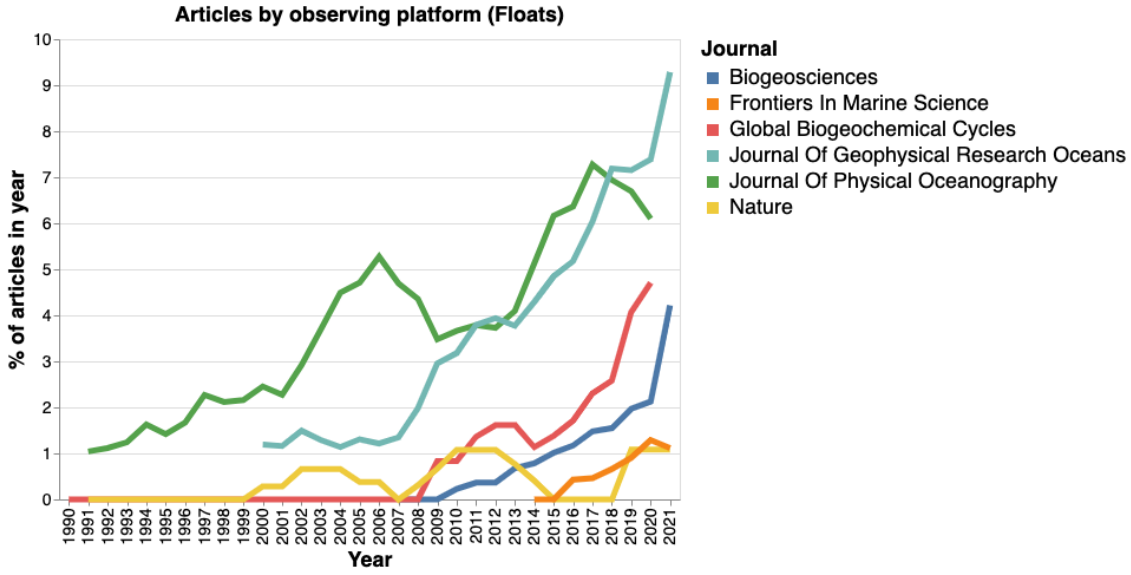


Figure 5: Increasing use of gliders - first in physical oceanography journals and then in biogeochemical journals.

Floats have also grown in usage in recent years driven by the expansion of the ARGO network. The proportion of articles that refer to floats has typically been about 3 times the proportion referring to gliders (Figure 6).



While the UK has increased use of floats at a similar rate to the rest of the world in recent years, it has adopted gliders much more rapidly (Figure 7). Articles with a UK author have referred to gliders 2-5 times more often than the global average for a number of journals in physical and biogeochemical oceanography.

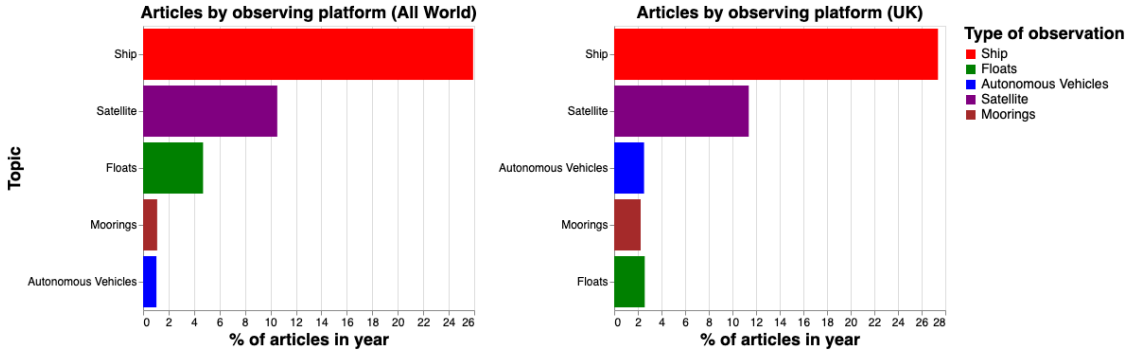


Figure 7: Papers with a UK author (right) have a much higher proportion of research in the Southern and Arctic Oceans in Biogeosciences than the global average (left).

BODC cruise analysis

Geographic breakdown

As with the journal analysis there has been an increasing focus on the Southern Ocean over recent decades (Figure 8). The North Atlantic and Southern Ocean have been the most common cruise destinations over the last 20 years. The Arctic and Southern Ocean became more common cruise destinations in the last five years.

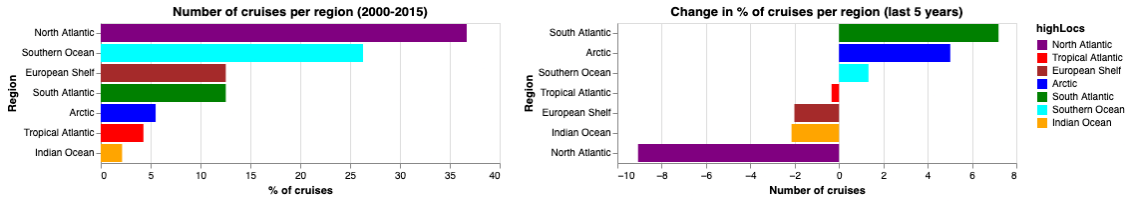


Figure 8: The most common cruise regions (left) and the changes in cruise regions (left) in the last 5 years compared to the previous 15.

Cruise activities

The most common cruise activities over 2000-2020 related to hydrography, bio-physical observations and nutrient sampling (Figure 9). In the 5 year period from 2015 there were some important changes in cruise activities. Measurement of marine tracers such as isopes and dye release experiments were much more common. Observations of marine pollutions - plastics in particular - had been recorded on just a few percent of cruises in before 2000 but were recorded on 16% of cruises in the last 5 years.

Activities related to autonomous vehicles - both gliders and AUVs - were also recorded much more often in the last 5 years than previously (Figure 9). On the other hand observations of turbulence were less common, perhaps because these were supplanted by dye release experiments.

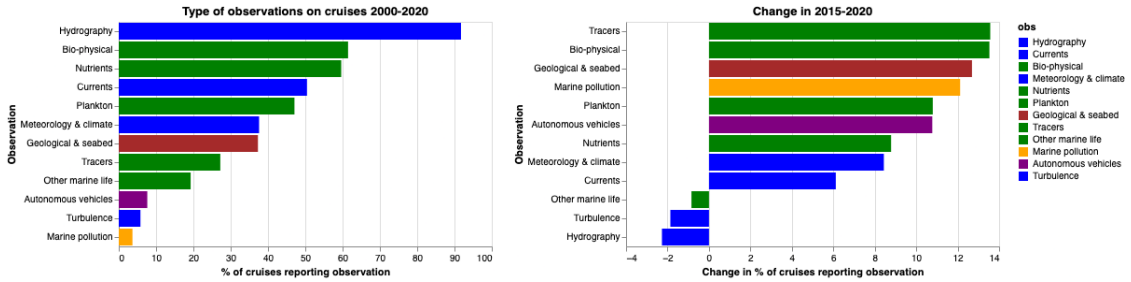


Figure 9: The most common cruise activities (left) and the changes in cruise activities (left) in the last 5 years compared to the previous 15.

Conclusions

The cruise metadata analysis shows that most cruises still carry out a wide variety of observations. From this analysis and my own experience there does not appear to be much scope for reducing carbon emissions simply by making more efficient use of cruise sampling time.

Many cruises are engaged with activities that would be very difficult to replace with autonomous vehicles such as trawling with nets, seabed sampling and advanced chemical analysis such as gas chromatography. The primary avenue for replacing high carbon observations with low carbon observations is likely to remain physical oceanography along with related biogeochemical sampling. In particular, replacing some long-term mooring

deployments with combinations of floats and gliders would appear to be the best route for reductions in emissions in the near-term.