




Copernicus Sentinels contribute to scientific research

Analysis of trends and patterns in academic publications from the Scopus database

Sentinels Benefits Study (SeBS)



Free and open Copernicus Sentinel data are being exploited by scientists from all over the world, contributing to human advances in technology and scientific understanding across a wide range of disciplines, even beyond the space sector.

Clarification on the limits of the analysis and the interpretation of results

This study relies on an analysis of the number and types of academic publications indexed in Elsevier Scopus® database. Often described as “the largest abstract and citation database of peer-reviewed literature”, Scopus® contains some 70 million records, representing scientific journals, books, and conference proceedings from over 5000 publishers. The queries used to find relevant publications in the Scopus database searched for the word “Sentinel-X” or their relevant sensors (MSI, TROPOMI, etc.) within the title, abstract and keywords of listed publications. Throughout our analysis, several iterations and refinements to our search queries were needed as false positives were found to be an issue.

It must be highlighted that Scopus only contains publication meta-data and not the full article text. Consequently, articles where Sentinel data are used but not explicitly mentioned in the article’s metadata (i.e. title, abstract or keywords list) are not picked up by our queries and would require examination of the full text at the publishers’ sites. We did some preliminary analyses using the online search functions of notable journals such as Nature and Science and found that this frequently happens when Sentinel data are used in conjunction with other data sources. Although we cannot quantify the impact of this limitation, we conclude that **the current findings from the Scopus database should be taken as a conservative estimate of the extent to which Sentinel data is being used by the academic community and that the “true” Sentinel-related publication figures might be considerably higher.**

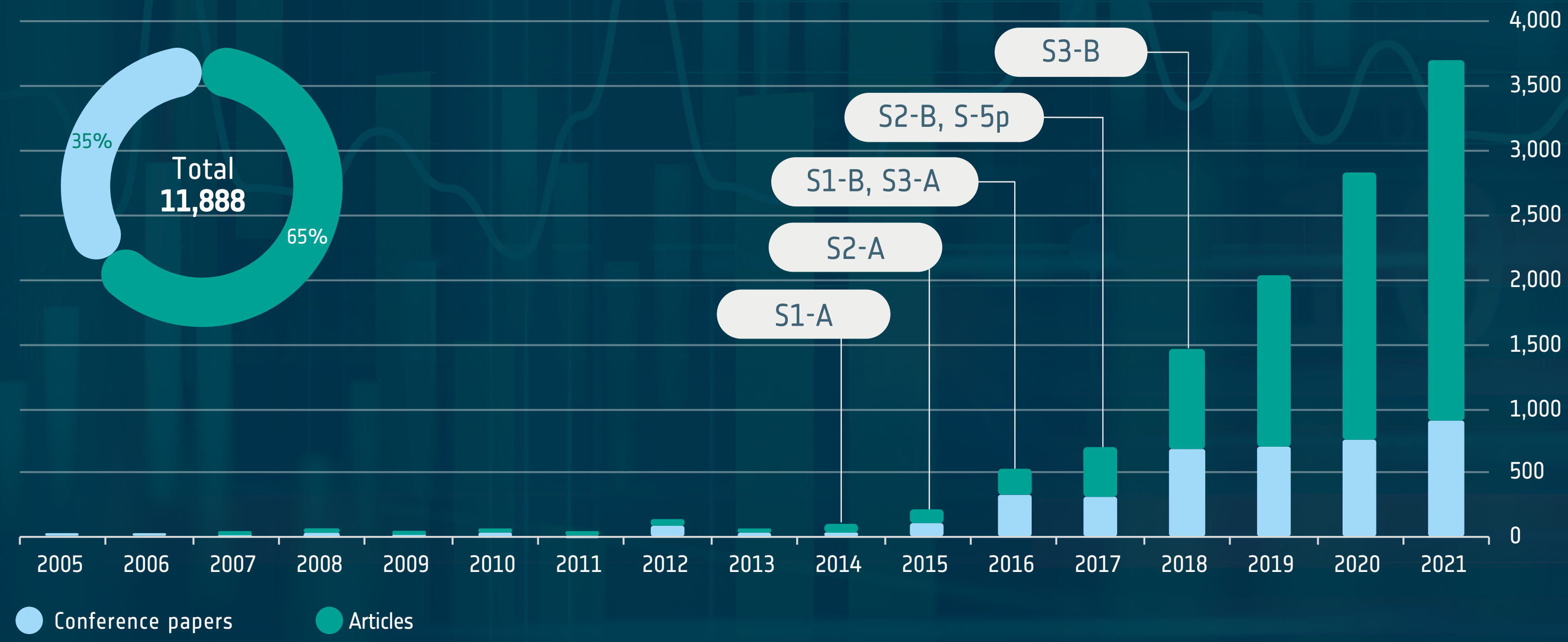
Acknowledgments

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General trends in publication volumes

Overall, up to and including 2021, there have been **11,888** unique publications from over 150 countries relating to Sentinels-1, -2, -3 and -5p. This figure comprises of 4,194 conference papers presented at 475 conferences and 7,694 journal articles published in 890 journals. Year on year, we continue to see significant increases in the volume of publications: of the 11,888 overall publications so far, 3,684 (31%) of these

were published in 2021 alone. Among the Sentinels, Sentinel-2 has the overall largest total publication volume, accounting for 6,187 publications up to and including 2021. Sentinel-1 accounts for the second highest overall publication volume, with 5,505 publications in total up to and including 2021. Statistics for 2022 are not yet included in the analysis, but it is anticipated that well over 3,000 journal articles will be published in 2022 alone.



Journal Articles
7694
in 890 journals

+56%
compared to 2020 totals

Conference Papers
4194
in 475 conferences

+28%
compared to 2020 totals

Figure 1: The 11,888 overall publication figures here constitute unique publications across the Sentinels. However, some publications use data from two or more Sentinels, for example, Sentinel-1 and Sentinel-2 data are often used together for the likes of vegetation/soil monitoring applications. In the individual Sentinel sections, such publications are accounted for under both the Sentinel-1 total figures and the Sentinel-2 total figures.

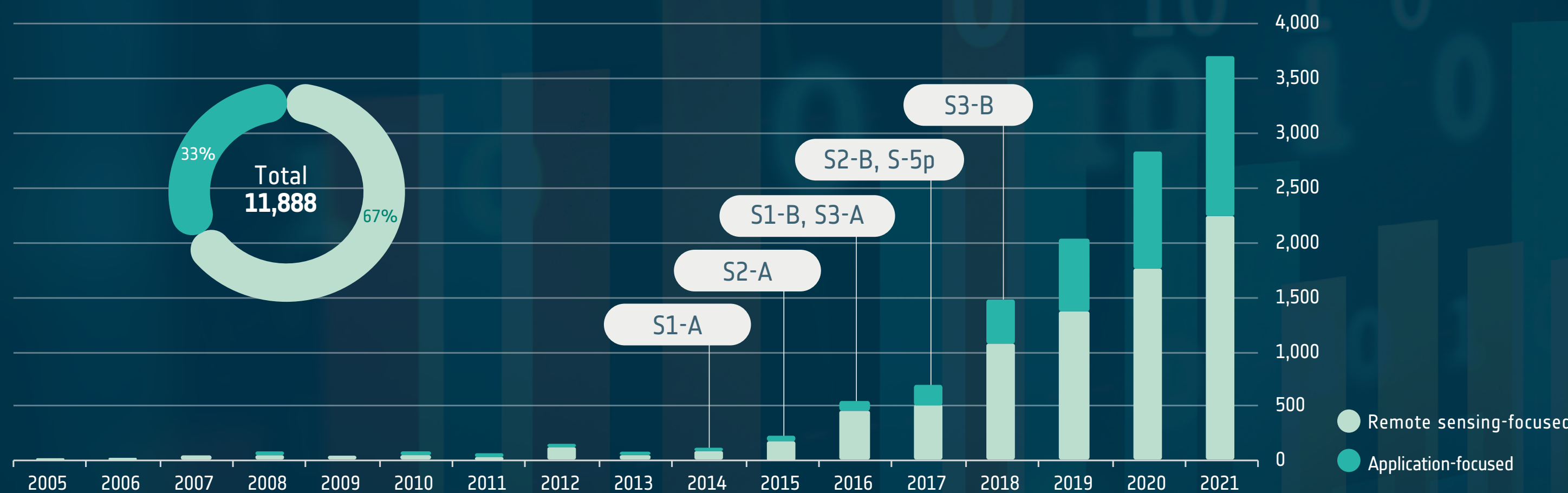
Diffusion into “application-focused” journals

While it would be natural for “upstream” journals like Remote Sensing to publish articles relating to the Sentinels, the same cannot be said for venues such as the International Journal on Advances in Precision Agriculture, Ocean Science or Geophysical Research Letters: yet, an increasing number of publications related to the Sentinels can be found in such journals, which we take as an indicator of the increasing uptake of Sentinel data within an enlarged scientific and academic community. To analyse these trends, we separated academic sources focused on Earth Observation or remote sensing (i.e., “remote sensing-focused”) from those focusing on earth sciences or other thematic application areas (“application-focused”). In this analysis we focus mainly on journal articles rather than conference papers, as journal articles tend to require more thoroughness and rigour, thus representing more consolidated contributions to the scientific corpus. As expected, overall, the number of publications in “application-focused” sources is less than the “remote sensing-focused” ones, both for journals (41% of the total) and for conference

papers (17% of the total). Of the 11,888 overall publications (journal articles and conference papers), 3,872, or 33% have been published in venues of an “application-focused” nature. The larger volumes of remote sensing-focused publications are especially pronounced in the early stages of the programme when, for example, official announcements are made, sensors are tested and calibrated, and products are refined. However, in recent years, “application focused” articles have begun to make up an increasingly large proportion of the total, accounting for 44% of journal articles in 2021 alone. When looking at the keywords suggested by authors, we found major differences among the various Sentinels, as can be seen in the “word clouds” in the specific chapters. The most represented keywords are associated with the different sensors or types of derived products (e.g., SAR, TROPOMI, OLCI, NDVI) but also to some core applications (e.g., ocean colour, forest, air quality, COVID-19) and processing techniques (e.g., machine learning, deep cloud).

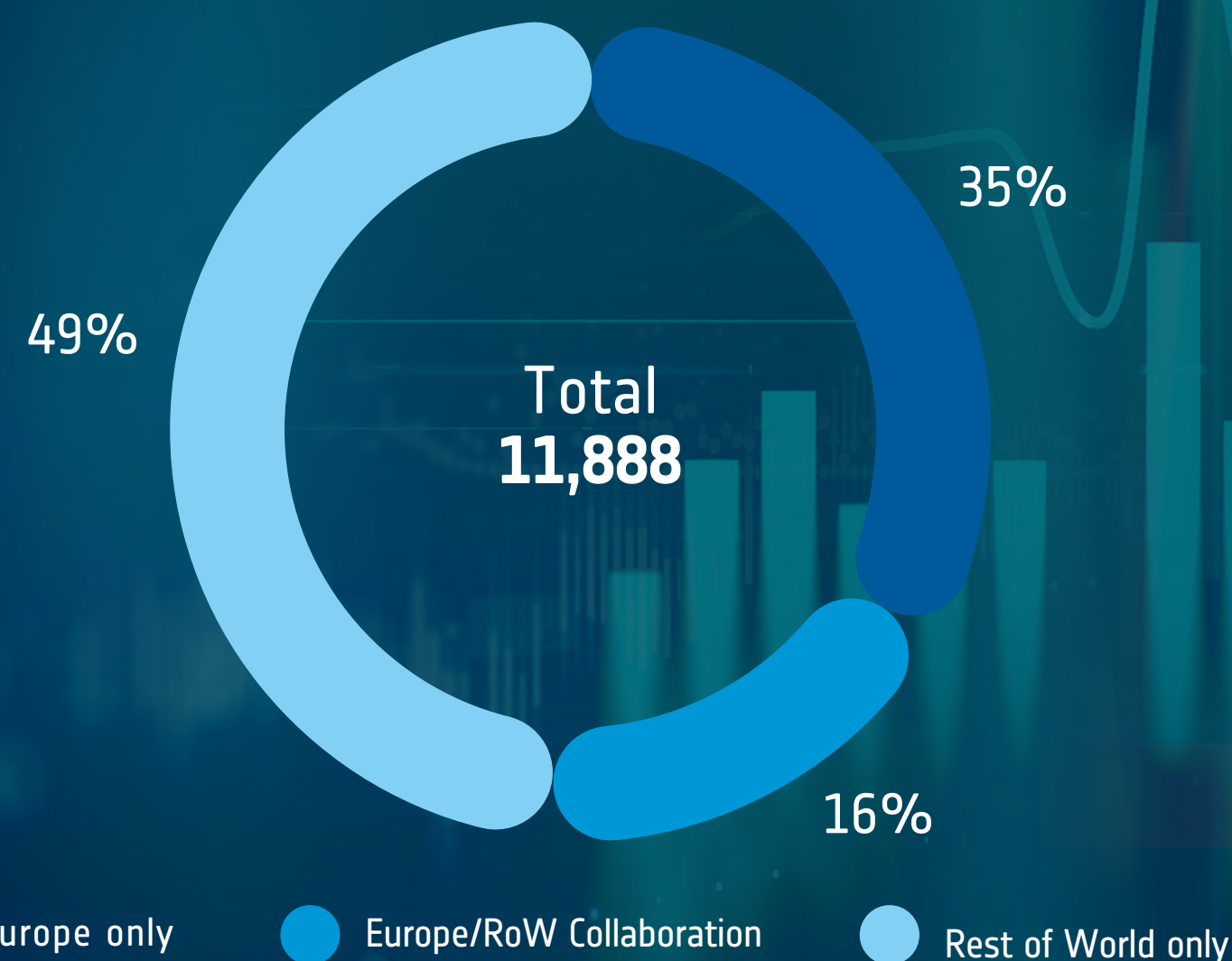
Application-focused journal articles
41%
of all journal publications up to 2021

Application-focused articles
39%
of all journal publications up to 2020



Geographic spread of authorships

Scientists from over 150 countries all over the world are using Sentinel data. Of the 11,888 publications, European authors (i.e., EU27+Norway+Iceland+UK) have either led or contributed to 6,108 in total, accounting for 51% of all publications. Among these, Italian, German, French, Dutch and Spanish authors are the leading contributors. Outside from Europe, China accounts for most publications, with over 2,300 (19%) having had a contribution from at least one Chinese author, followed by the USA with over 1,500 contributions (13%). The emergence of China as a global leader in terms of publication volumes began in 2019 and has sustained ever since. 95% of all publications were written in English, with the remaining 5% divided between Chinese (3%), Russian (1%) and others.



Quality of articles and publication sources

Researchers and scientists aspire to publish their findings in prestigious, high-quality journals. The editors and peer-reviewers of these journals are a guarantee that the published articles are original, accurate, and reliable. The “prestige” or “quality” of the publishers is routinely scrutinized through different indexes. We assessed the quality of the publication sources using the H-index metric and found that many Sentinel-related articles are featured in high-quality publication venues. With regards to non-space, application-focused sources, we found a promising spread amongst highly-ranked and reputable sources overall, including the likes of “Geophysical Research Letters” and “Science of the Total Environment”, the “Journal of Hydrology” and “Atmospheric Chemistry and Physics”. However, we noticed that for Sentinel-1 and Sentinel-2 there are also large numbers of articles with lower H-Index rankings, which seems to reflect the popularity of the data. In the following individual Sentinel sections, bubble graphs showing the top 10 journals by publication volumes versus H-Index provide an idea of what are the highest quality sources hosting Sentinel-related articles. Some notable and prestigious journals represented amongst the publications are also listed on this page.

Remote sensing-focused journals

- **Remote Sensing of Environment**
H-Index: 303, Publications across all Sentinels: 437
- **IEEE Transactions on Geoscience and Remote Sensing**
H-Index: 269, Publications across all Sentinels: 141
- **International Journal of Remote Sensing**
H-Index: 185, Publications across all Sentinels: 138
- **ISPRS Journal of Photogrammetry and Remote Sensing**
H-Index: 155, Publications across all Sentinels: 123
- **Remote Sensing**
H-Index: 144, Publications across all Sentinels: 1911

Application-focused journals

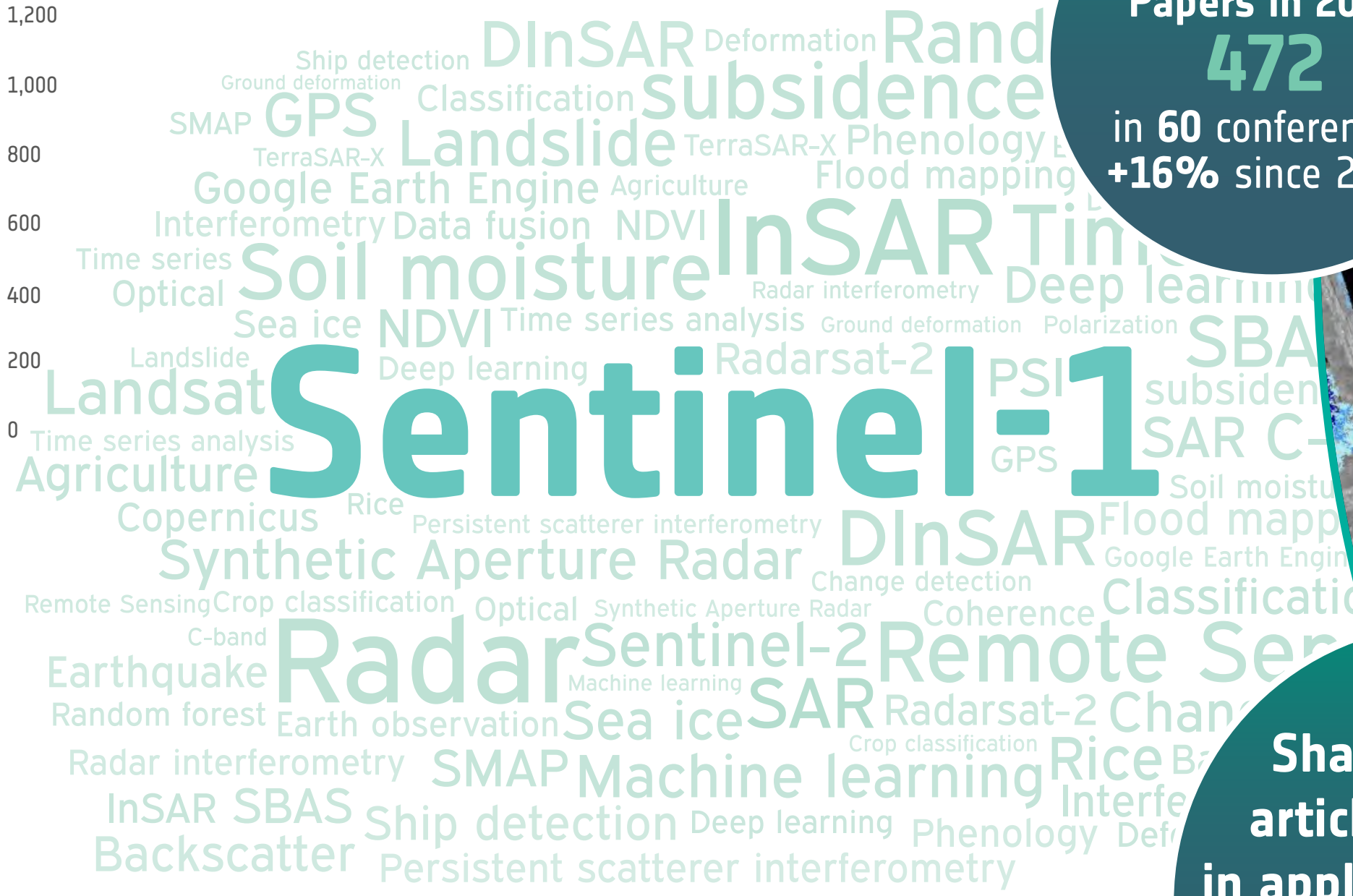
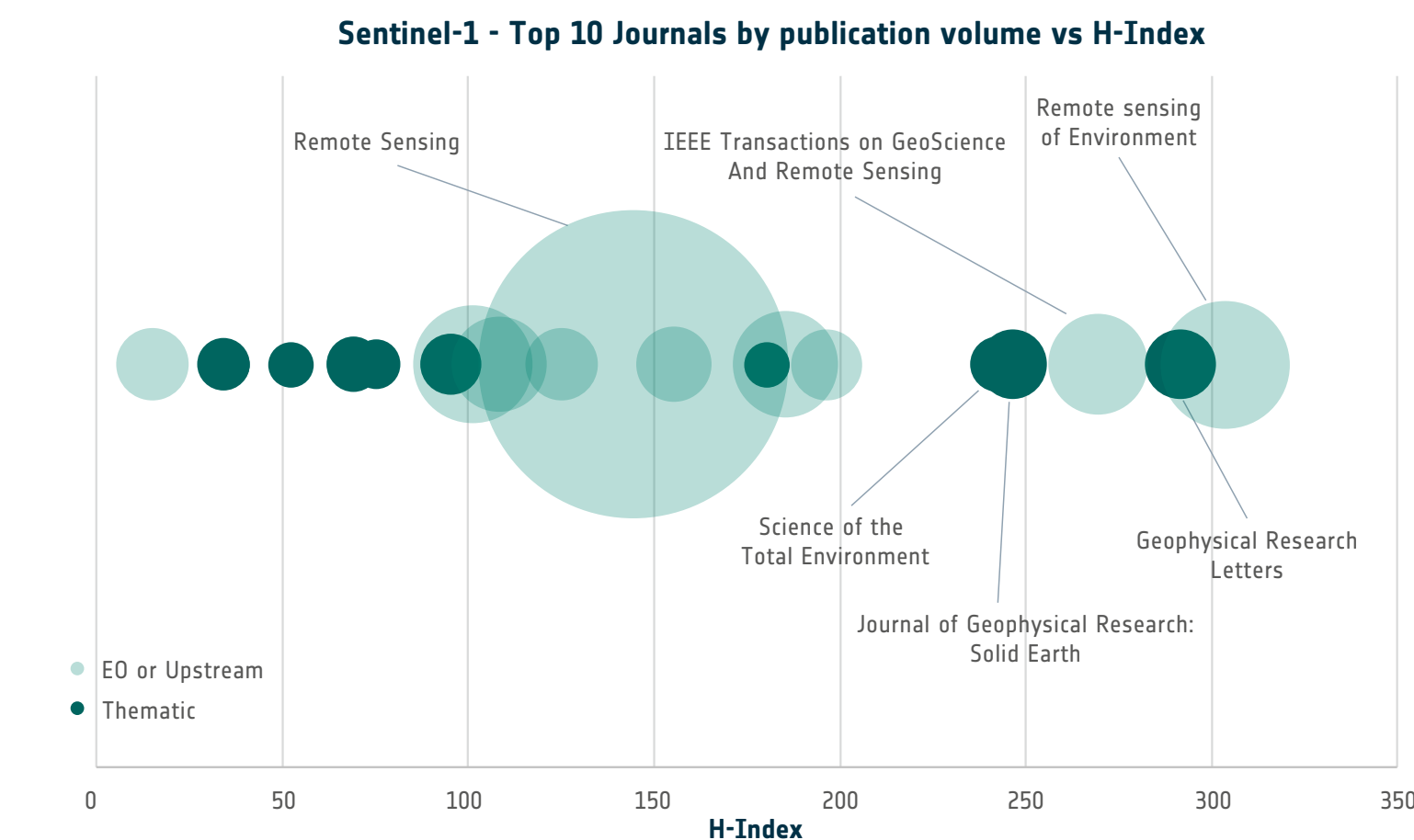
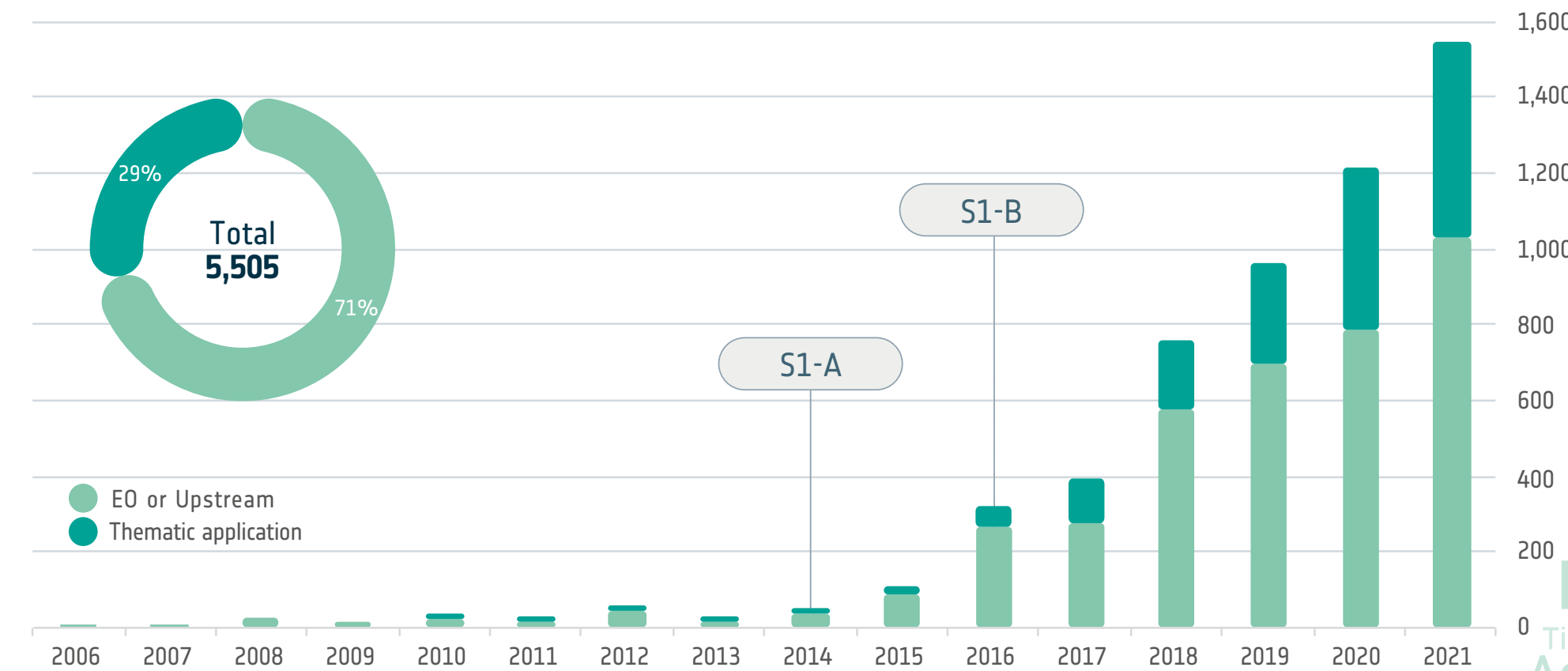
- **Nature Communications**
H-Index: 410, Publications across all Sentinels: 4
- **Science of the Total Environment**
H-Index: 275, Publications across all Sentinels: 74
- **Geophysical Research Letters**
H-Index: 291, Publications across all Sentinels: 70
- **Scientific Reports**
H-Index: 242, Publications across all Sentinels: 48
- **Atmospheric Chemistry and Physics**
H-Index: 221, Publications across all Sentinels: 42

When querying separately on prominent Journals such as Nature and Science, additional articles were found in which Sentinels data are used but not picked up in the Scopus queries because they are not mentioned in the abstract, title or keywords.

Sentinel-1

The total volume of all Sentinel-1 related publications up to and including 2021 amounts to 5,505. In 2021, there was a total of 1,544 Sentinel-1 related publications, comprising of 1072 journal articles and 472 conference papers, each marking a 28% and 16% increase on the previous year respectively. Unsurprisingly, “SAR” and “InSAR” appear as some of the most frequent keywords. Interestingly, the likes of “land subsidence”, “soil moisture” and

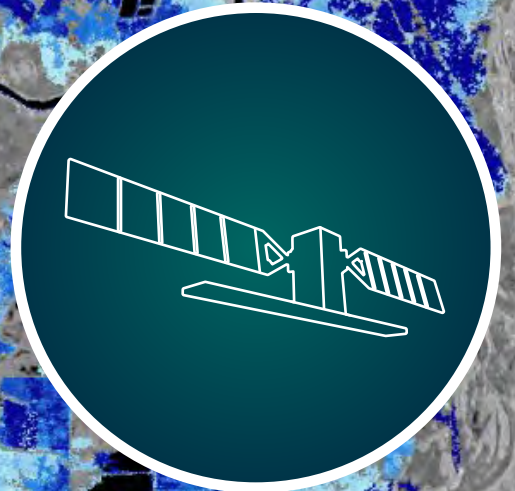
“earthquake” are represented heavily, illustrating the utility of Sentinel-1 data in both geological and agricultural monitoring applications. Up to and including 2021, European-only authorship is noted for some 1898 publications with Europe/Rest of World collaborations accounting for 875, meaning publications either led or contributed to by European authors make up 50% of all Sentinel-1 publications.



Journal Articles in 2021
1072
 in 271 journals
 +28% since 2020

Conference Papers in 2021
472
 in 60 conferences
 +16% since 2020

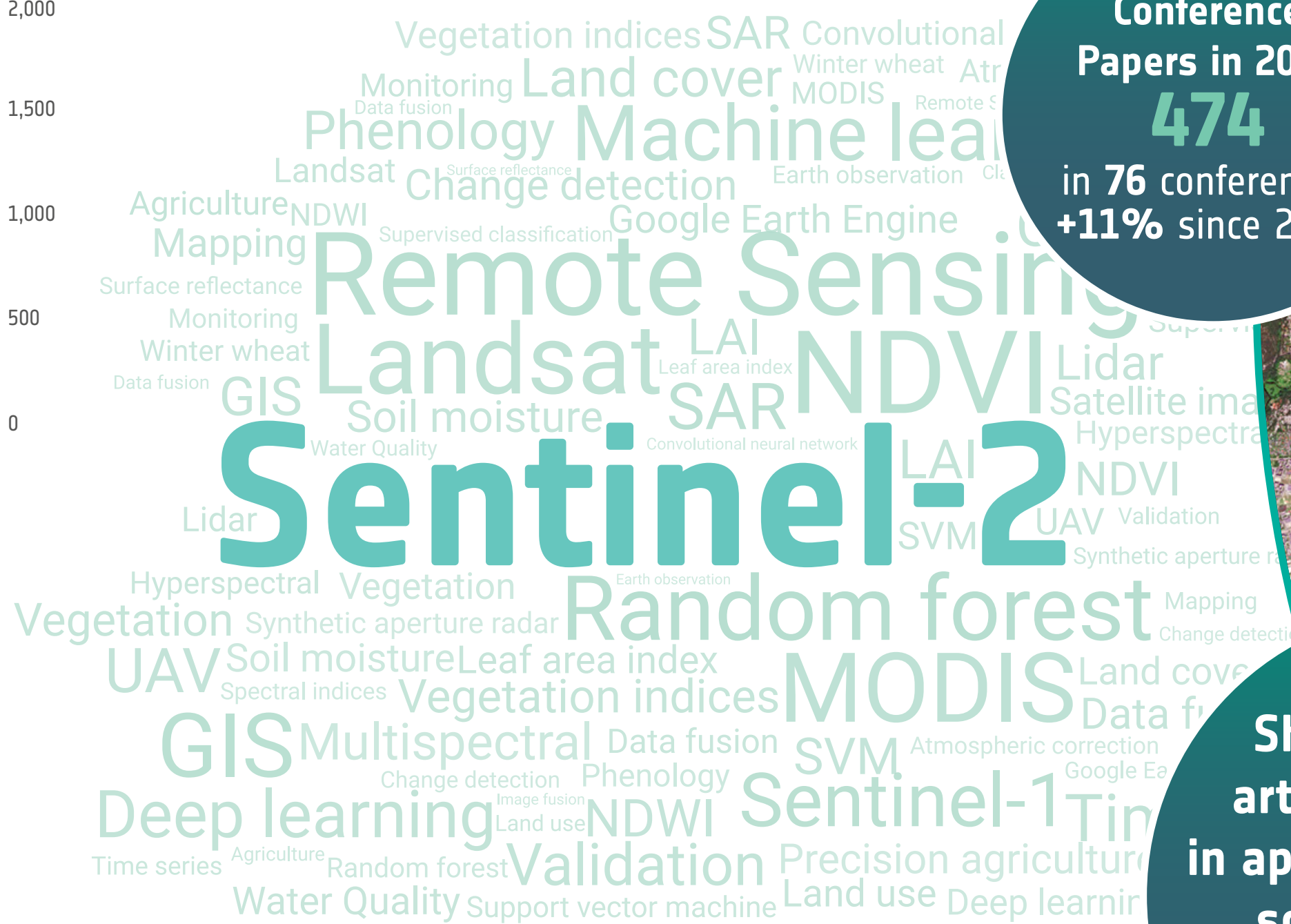
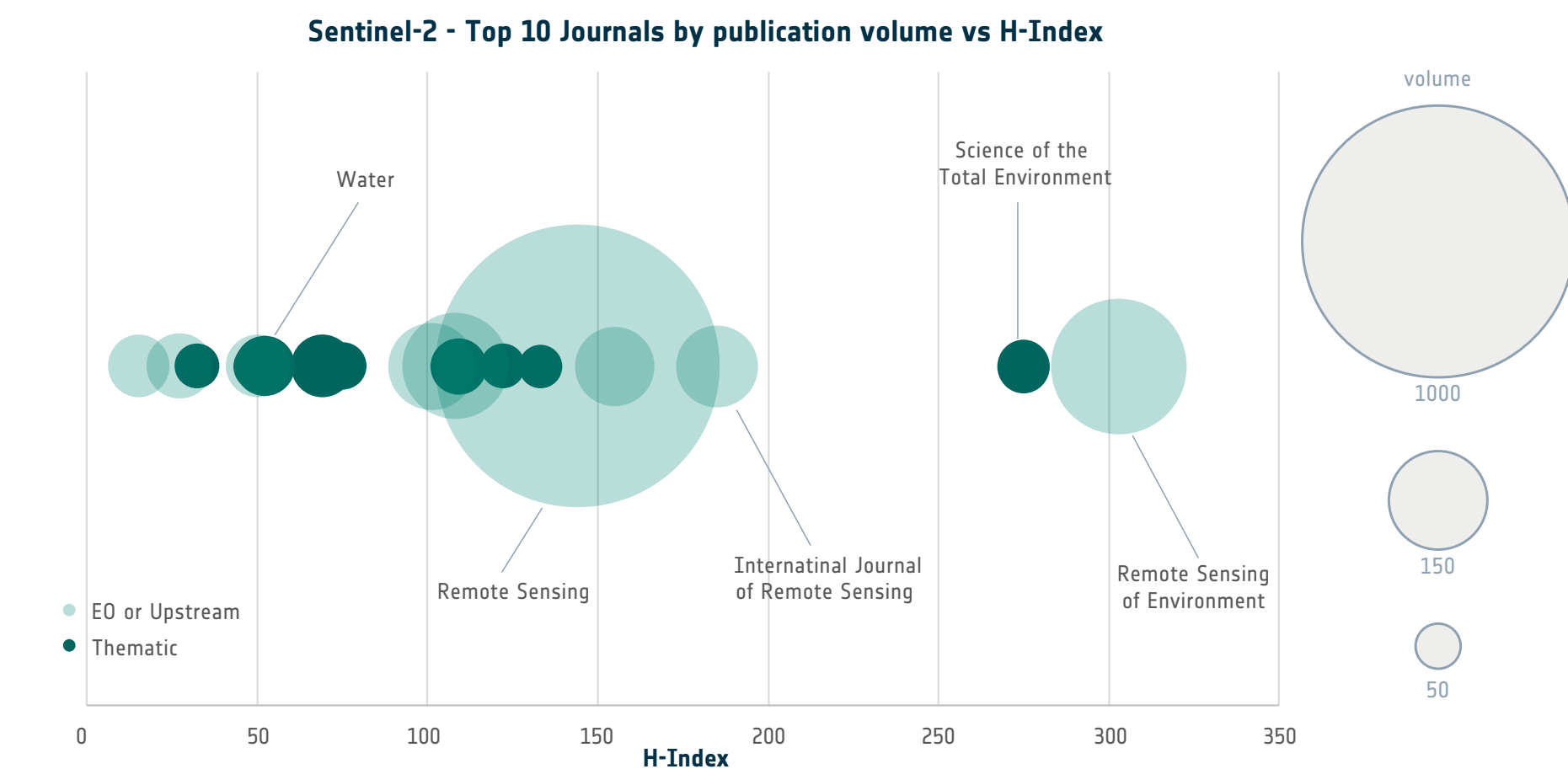
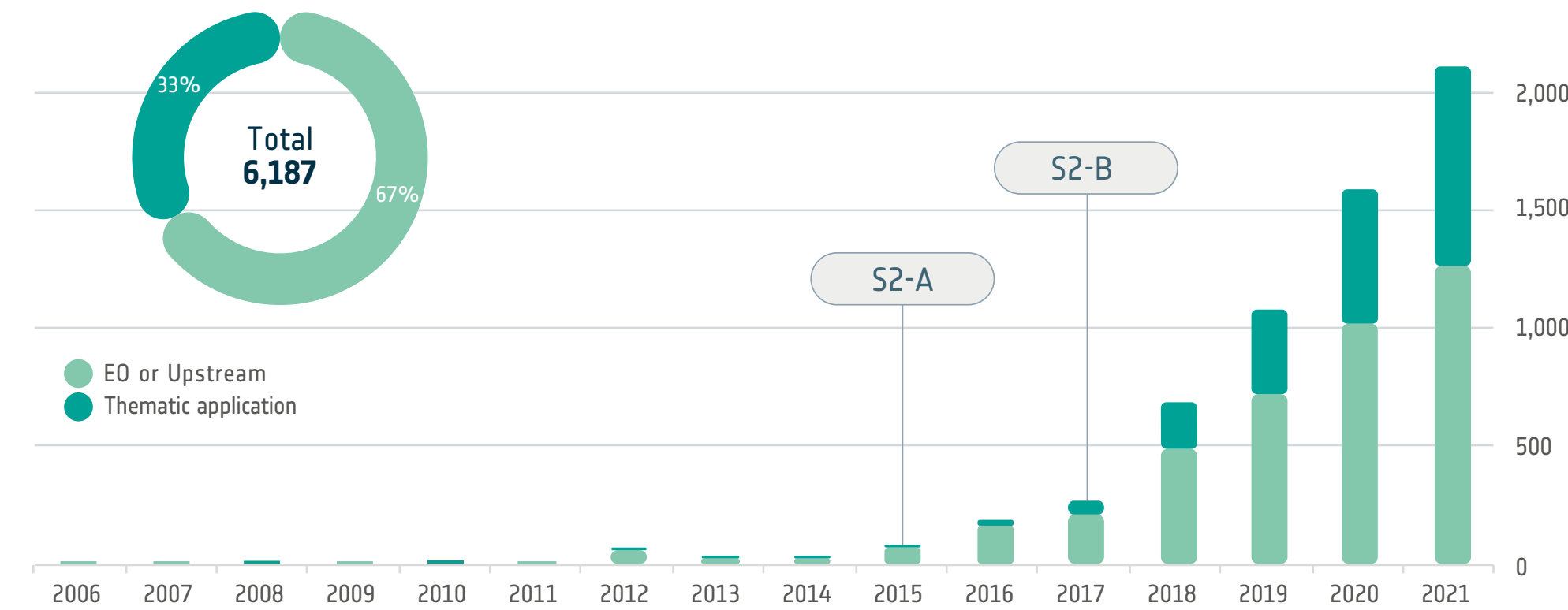
Share of journal articles published in application-focused sources in 2021
40%



Sentinel-2

Sentinel-2 has the overall largest total publication volume, amounting to 6,187 up to and including 2021. In 2021, there was a total of 2,116 Sentinel-2 related publications, comprising of 1642 journal articles and 474 conference papers published and presented in 370 journals and 76 conferences throughout the year. The uptake in “application-focused” venues is high, with 43% of journal articles in 2021 published in downstream, application-

focused journals such as “Science of the Total Environment” and “Forests”. Keywords tend to be more related to processing technologies and data sources (e.g., “NDVI”, “classification”, etc.). For Sentinel-2, European only authorship accounts for 2,114 publications and Europe/Rest of World collaborations account for 944, meaning publications either led or contributed to by European authors make up 49% of all publications.



Journal Articles in 2021
1642
 in 370 journals
 +40% since 2020

Conference Papers in 2021
474
 in 76 conferences
 +11% since 2020

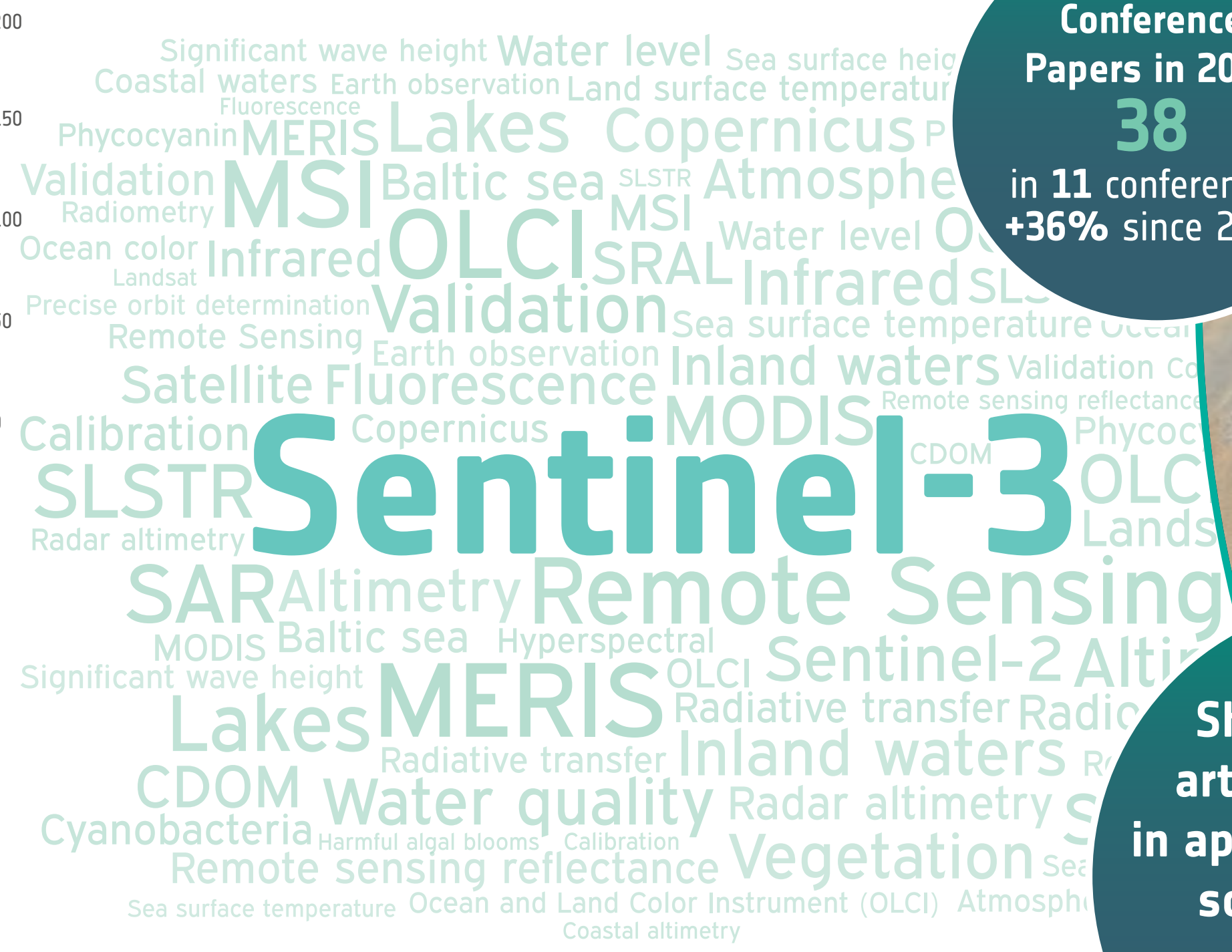
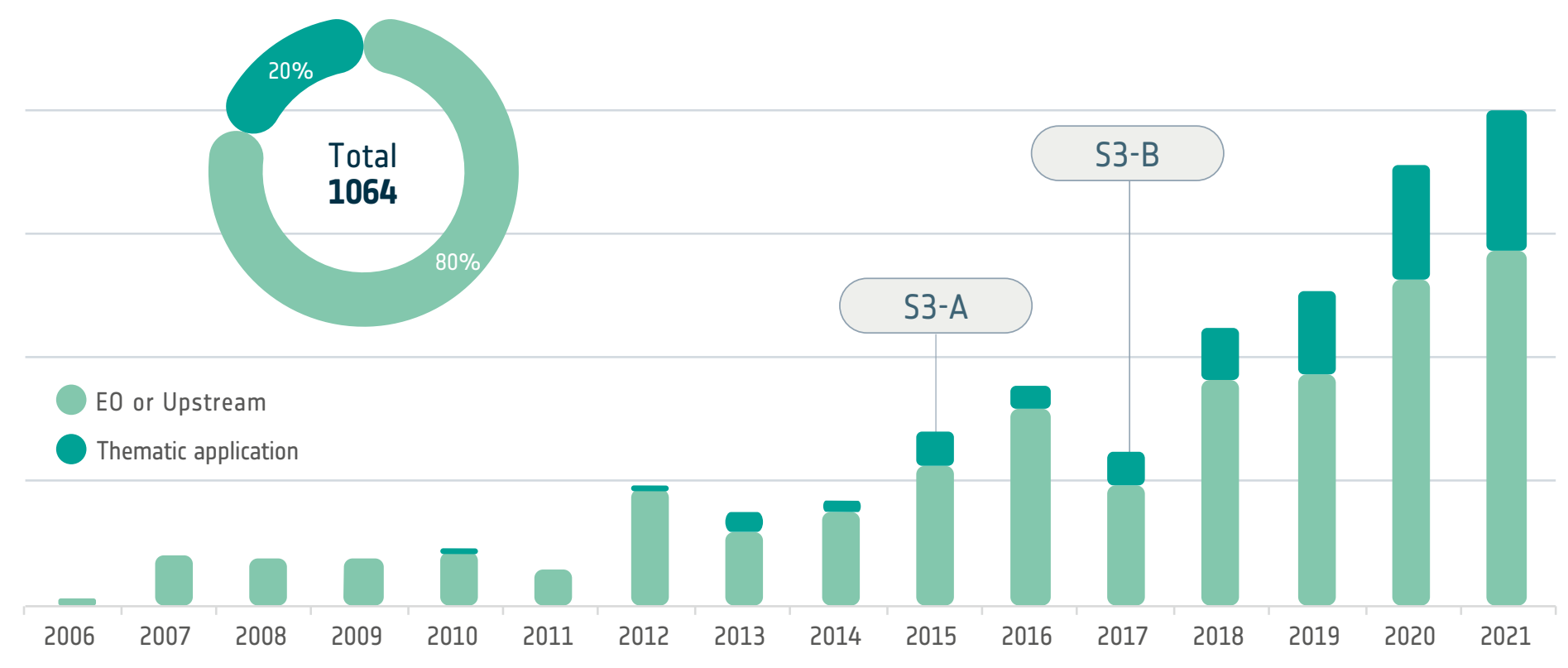
Share of journal articles published in application-focused sources in 2021
43%



Sentinel-3

Sentinel-3, with 1,064 publications in total up to and including 2021 shows a much lower publication volume compared to Sentinel-1 or Sentinel-2, possibly due to the more niche applications associated with the use of Sentinel-3 data. In 2021, there was a total of 200 Sentinel-3 related publications, comprising of 162 journal articles

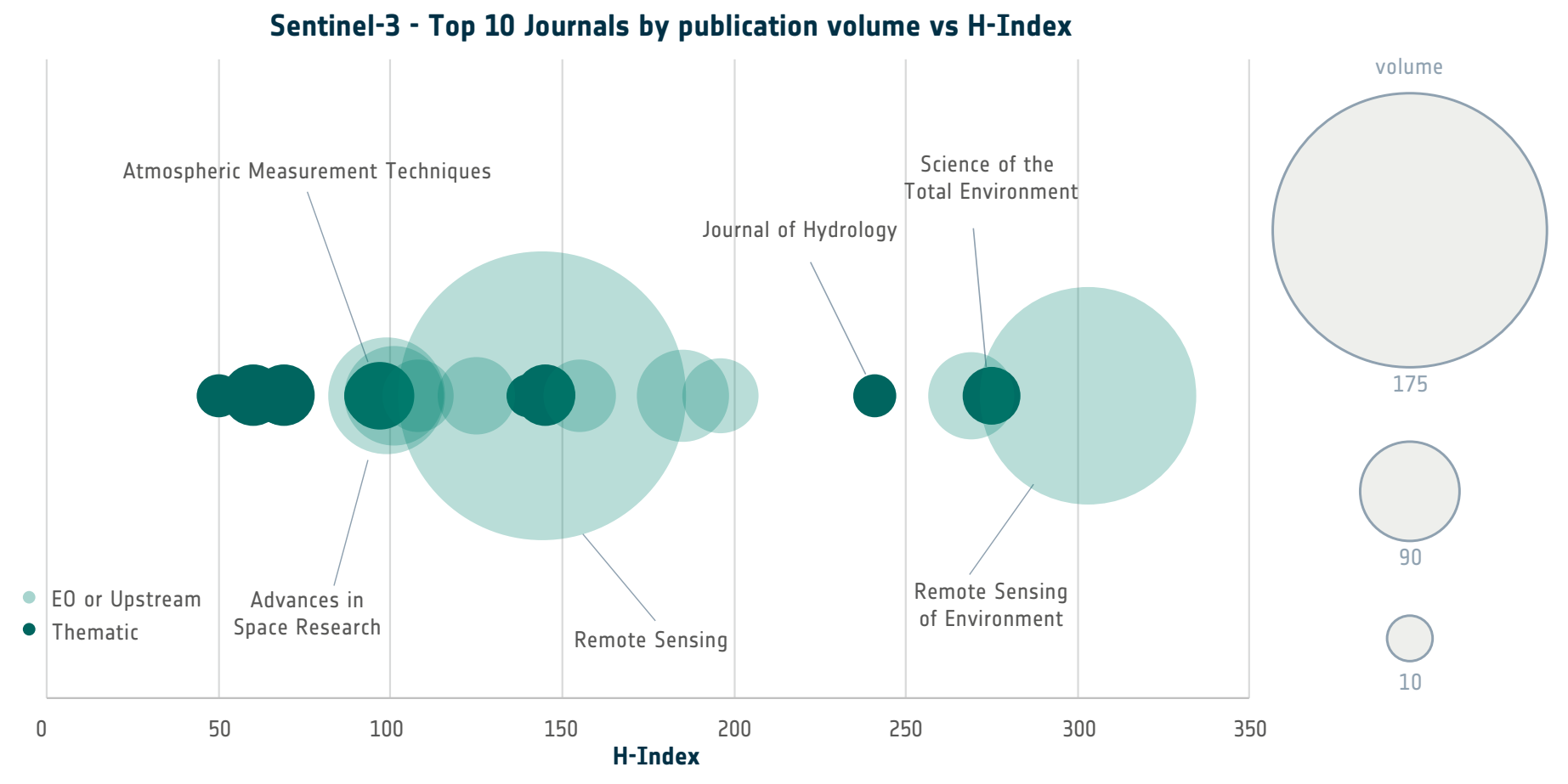
and 38 conference papers. European scientists are the most productive authors for Sentinel-3, contributing 638 alone and 154 further publications in collaboration with non-European authors. This means that European authors have either led or contributed to 74% of all Sentinel-3 publications.



Journal Articles in 2021
162
 in 162 journals
 +8% since 2020

Conference Papers in 2021
38
 in 11 conferences
 +36% since 2020

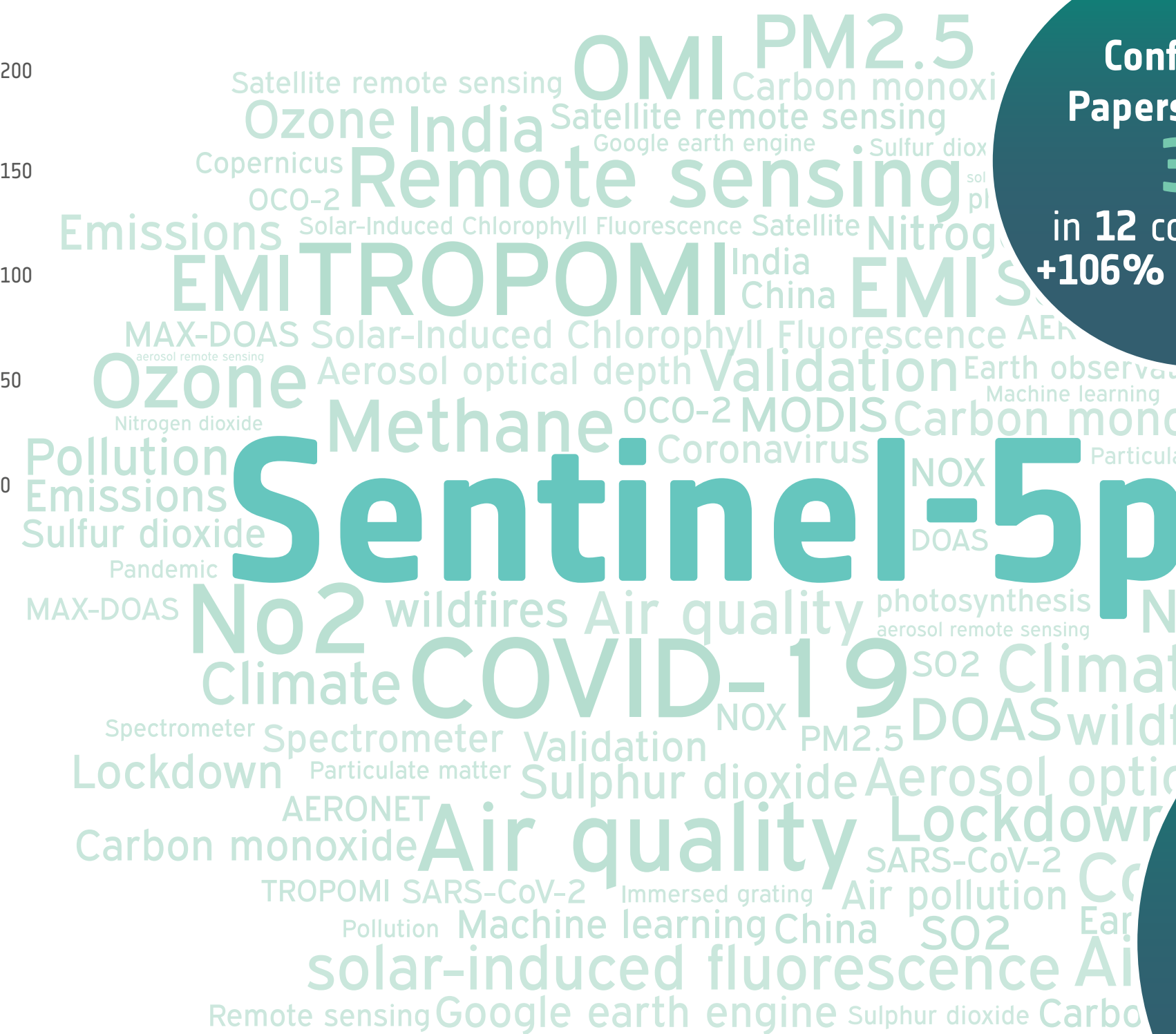
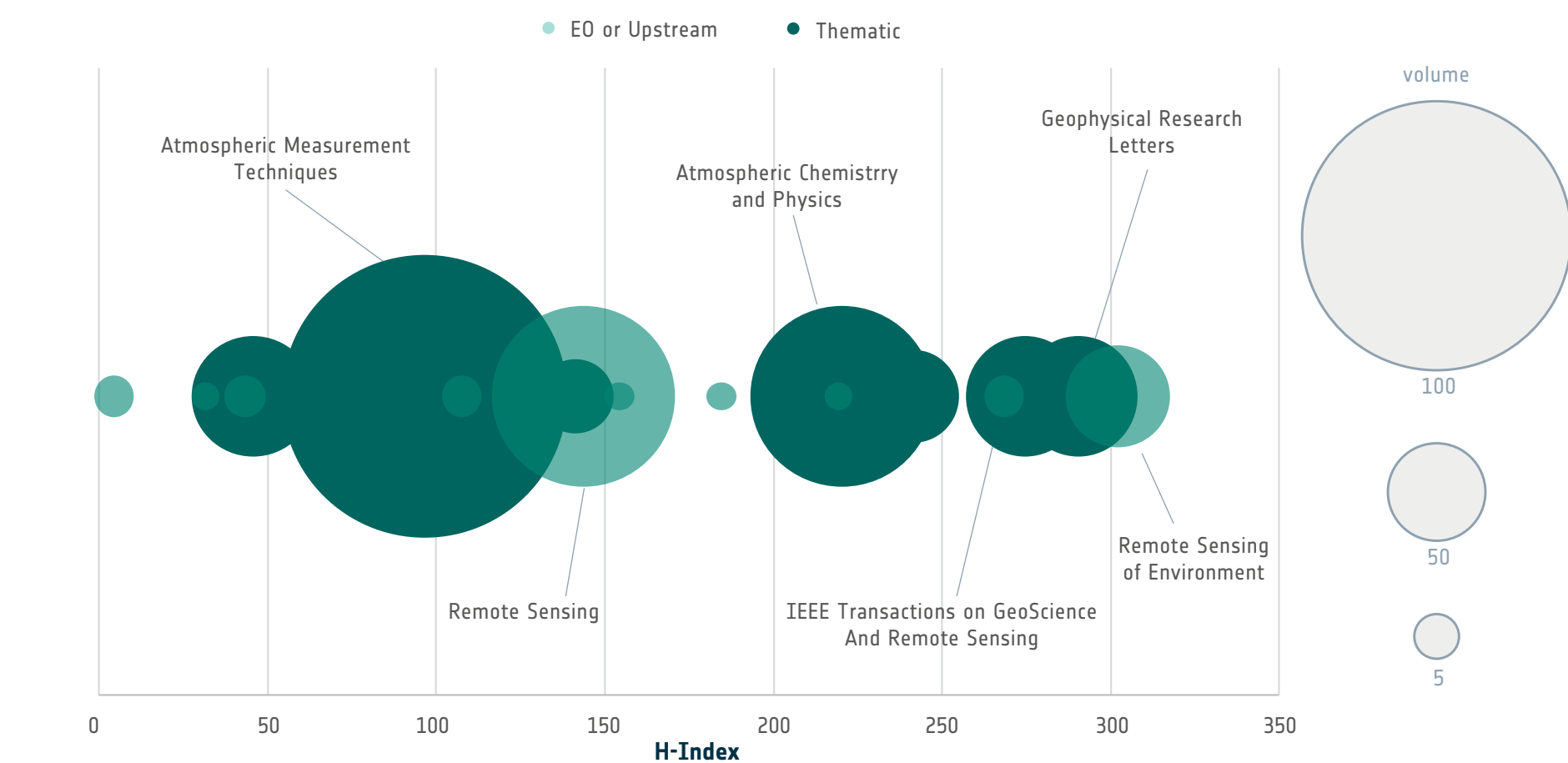
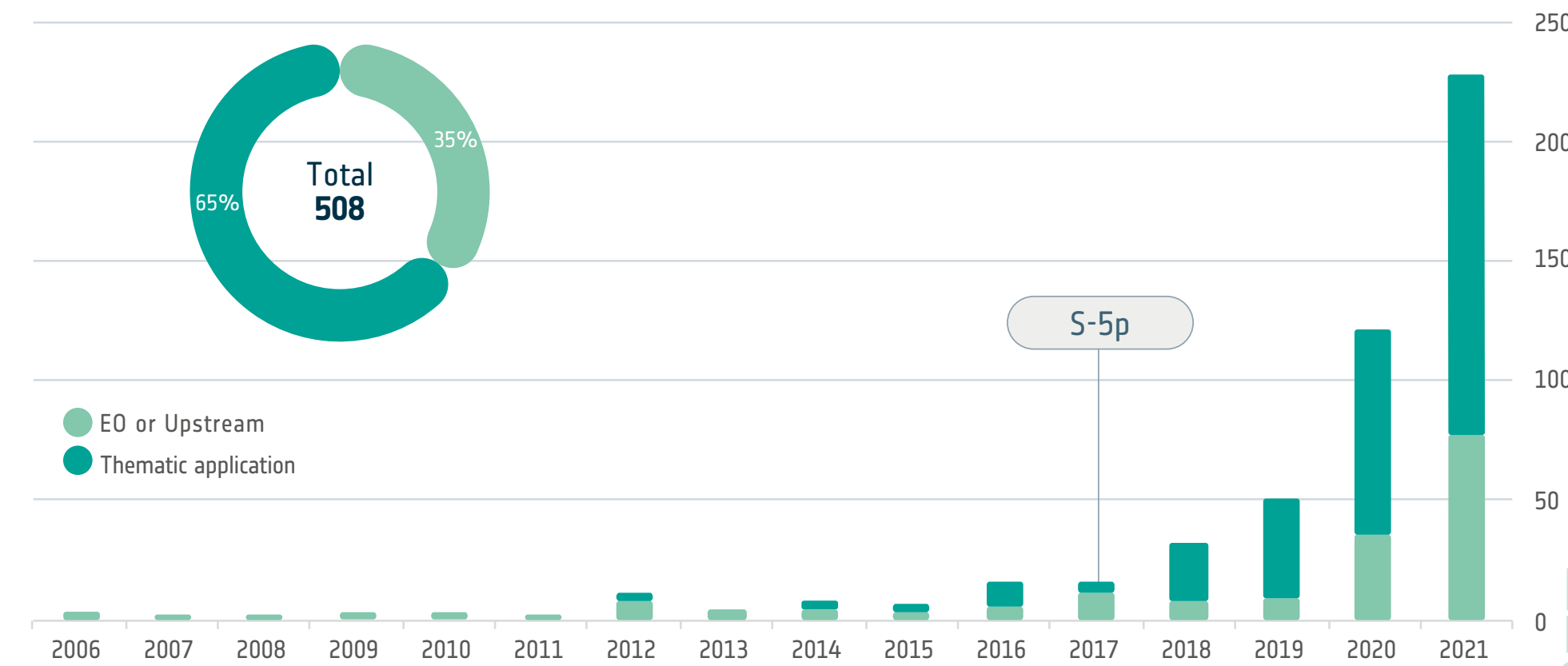
Share of journal articles published in application-focused sources in 2021
33%



Sentinel-5p

Sentinel-5p is the most recent mission to have launched, therefore it is not surprising that it has relatively lower overall publication volumes i.e., 508 in total up to and including 2021. Nevertheless, it has the highest year-on-year growth rate in publication volumes and, contrary to the other Sentinels, the largest share

of “application-focused” publications i.e., 66% of all publications up to and including 2021. Interestingly, “COVID-19” is one of the most frequent keywords cited in the publications, which is taken as an indicator that Sentinel-5p data was called upon frequently by researchers throughout the pandemic in 2020/2021.



Journal Articles in 2021
179
in 67 journals
+87% since 2020

Conference Papers in 2021
31
in 12 conferences
+106% since 2020

Share of journal articles published in application-focused sources in 2021
76%

