CYMS2 – ASS

Service evaluation, potential evolution and recommendations

CLS-ENV-NT-23-0045

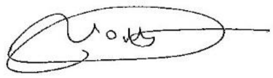
1.1 – 13/04/2023

Open/Public/Público

CHRONOLOGY ISSUES/HISTORIQUE DES VERSIONS

Issue/ Version	Date	Object/Objet	Written by/ Rédigé par	Checked by / Vérifié par	Approved by/ Approuvé par
1.0	11/04/ 2023	Creation	R. Husson	F. Soulat	
1.1	14/04/ 2023	Iteration on recommendations	A. Mouche, R. Husson		

DISTRIBUTION/LISTE DE DIFFUSION

Company/Organisme	Means of distribution/ Format de diffusion	Names/Destinataires
CLS, IFREMER, ESA, METNO	Pdf and Word via Electronic	Consortium members
ESA		Approved by Marie-Helene Rio on May 29th 2023 

LIST OF CONTENTS/SOMMAIRE

1 Introduction 5
2 Service evaluation of the data processing 6
2.1 TC coverage 6
2.2 TC acquisitions evolution with time 9
2.3 TC tasking efficiency 10
2.4 TC vortex products 11
2.5 European Extreme Winds 12
2.6 Timeliness 14
3 Communication 16
3.1 CYMS Webinar 16
3.2 CyclObs 16
3.3 ESA-CYMS 17
3.3.1 Updates 17
3.3.2 Analytics 17
3.4 SeeWater-CYMS 18
3.5 Twitter 19
4 Potential evolutions and recommendations 21
4.1 S1 acquisitions over TC 21
4.2 SAR acquisitions over European waters 21
4.3 SAR inter-calibration 22
4.4 S1 radiometric calibration 23
4.5 CYMS products geophysical content 24
4.5.1 Rain contamination and data quality 24
4.5.2 Wind field estimation 25
4.6 Service timeliness 25
4.7 Tutorials/discussions with end-users 25
4.8 Assimilation studies 26
Appendix A - Acronyms 27
Appendix B - References 28
Appendix C - S1 and RS-2 acquisitions 30
Appendix D - Associated delivered documents 32
Appendix E - Website analytics 33
Appendix E 1 - ESA-CYMS Website 33
Appendix E 2 - CyclObs Website 36
Appendix F - CYMS listing 38

APPLICABLE DOCUMENTS/LISTE DES DOCUMENTS APPLICABLES

[SOP] - CLS-ENV-NT-20-0226 - Standard Operating Procedure (SOP) for SHOC in 2020-2021 - v1.2 - 30/11/2020

[ASM] - Assimilation of CYMS products by MET Norway - v1.0 – 20/09/2022

[EUR] - Collected end-user requirements - CLS-ENV-NT-22-0499 - v1.0 - 18/09/2022

[AR] - Assessment report - CLS-ENV-NT-23-0046 - v1.0 - 11/04/2023

[PUM] - Product User Manual - CLS-ENV-NT-20-0228 – v2.0 - 01/09/2022

[VAL1] - CyclObs Database - Validation report - Part 1: Main report – v1.0 – 21/05/2022

[VAL2] - CyclObs Database - Validation report - Part 2: Case study – v1.0 – 21/05/2022

[VAL3] - CyclObs Database - TC Vortex Analysis Product - v1.0 – 19/09/2022

[ASS] - Presentation of service evaluation, potential evolution, recommendations - CLS-ENV-NT-23-0045 - v1.1 - 14/04/2023

[FR] - Final Report – CLS-ENV-RP-23-0215 - v1.0 – 11/04/2023

1 Introduction

This document aims at presenting the CYMS-2 project assessment. Performed at the end of this one-year project, this document is split into three sections:

- The service evaluation section provides an overview of the service in terms of latency, product availability and communications (sections 2- and 3-). It is based on the analysis of the service performed within work package 400: “Service operation and assessment”.
- The communication section provides an overview of the various platforms and initiatives performed throughout the project to motivate the increasing data uptake by a growing number of end-users. It is based on the analysis of the service performed within work packages 200 (“Engaging end-users”) and 400 (“Service operation and assessment”)
- The recommendations section proposes to analyze the gap between the current service and improvements that could benefit either on a technical or scientific point of view to CYMS end-users community. It is based on the analysis of the service performed within work packages 200 (“Engaging end-users”), 300 (“Technical development”) and 400 (“Service operation and assessment”)

The Appendix contains complementary information such as acronyms and on the S1 ground segment activations to monitor TC of interest.

2 Service evaluation of the data processing

In the first sub-section, an assessment of the TC coverage with the C-band SAR acquisitions is performed and compared to that of the previous years. The coverage of the other European Extreme phenomena is also given in a specific sub-section.

The second sub-section evaluates the timeliness with which CYMS data was acquired and processed in NRT.

2.1 TC coverage

The following figures show all the SAR acquisitions that have been processed from the Level-1 within CYMS for the NRT monitoring between the July 1st 2021 and December 31st 2022 over the various ocean basins into the CYMS Level-2P products.

This coverage involves all the SAR acquisitions (RS-2, S1-A and S1-B) that were co-located with the TC forecast tracks even if they do not match exactly with the actual TC eye at acquisition time. This is due to the fact that, for NRT processing, neither the operational best-Track nor the International Best Track Archive for Climate Stewardship (IBTrACS) are available and we need to rely on a less accurate source of information for the TC position, a forecast provided by ECMWF.

As can be seen on Figure 1, the number of processed products reaches its maximum values during the 2 summer seasons (Q3 2021 and Q3 2022) and the winter season (Q2 2022). For the Q3 2021 season, the number of processed products was particularly high because the space and time criteria used to select SAR data of interest on the ESA Hubs based on the TC forecast tracks was quite rough. The criteria were constrained after this period to select the most relevant products and avoid unnecessary data download and processing. The space/time criteria now use only the 36-hour oldest TC forecast tracks and a 300 km distance from the expected TC center.

In total, 2631 SAR L1 slices were processed in NRT for TC monitoring.

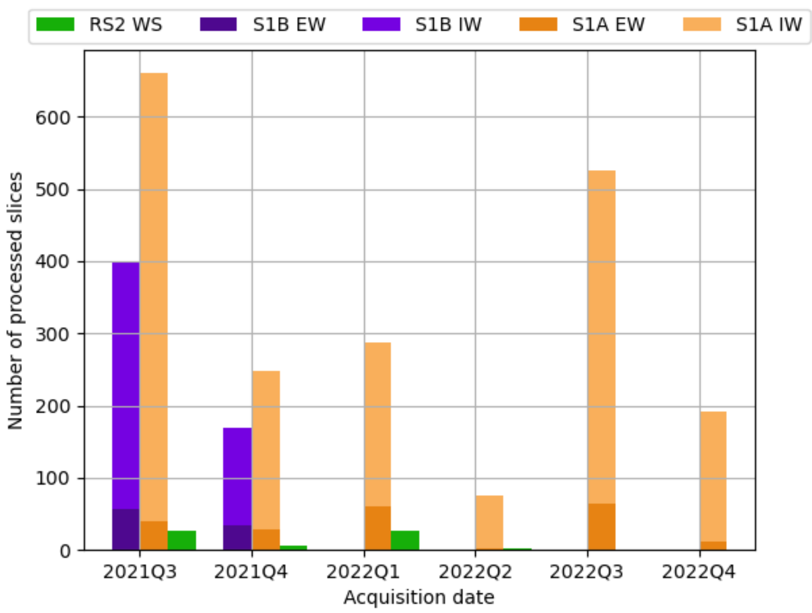


Figure 1: Time distribution of the SAR Level-1 products processed for NRT TC monitoring during the project.

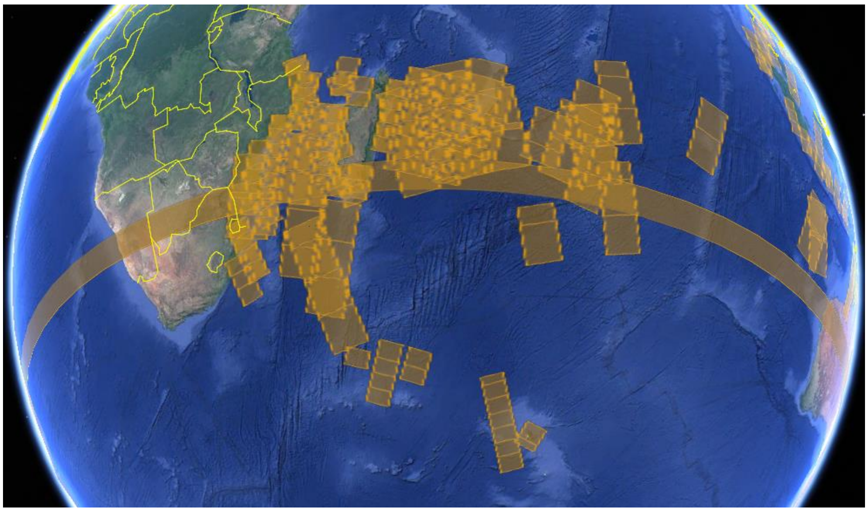


Figure 2: South-West Indian Ocean (SWIO) - meteorological region of responsibility of Météo-France (MF) la Réunion

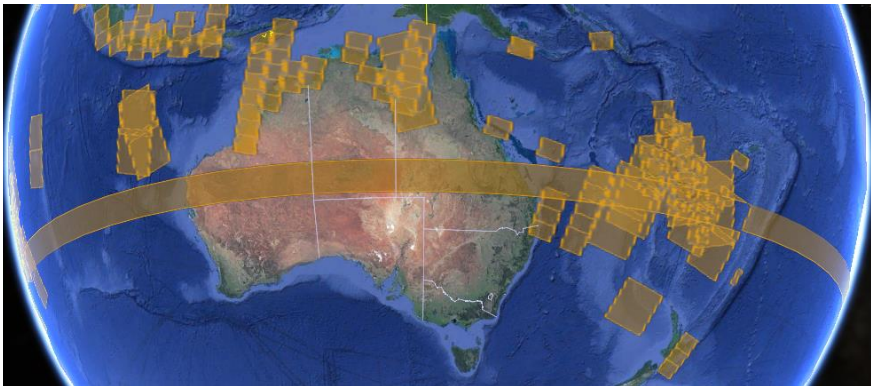


Figure 3: Australian region - meteorological region of responsibility of Australian Bureau Of Meteorology (BOM), Badan Meteorologi, Klimatologi, dan Geofisika and Papua New Guinea National Weather Service

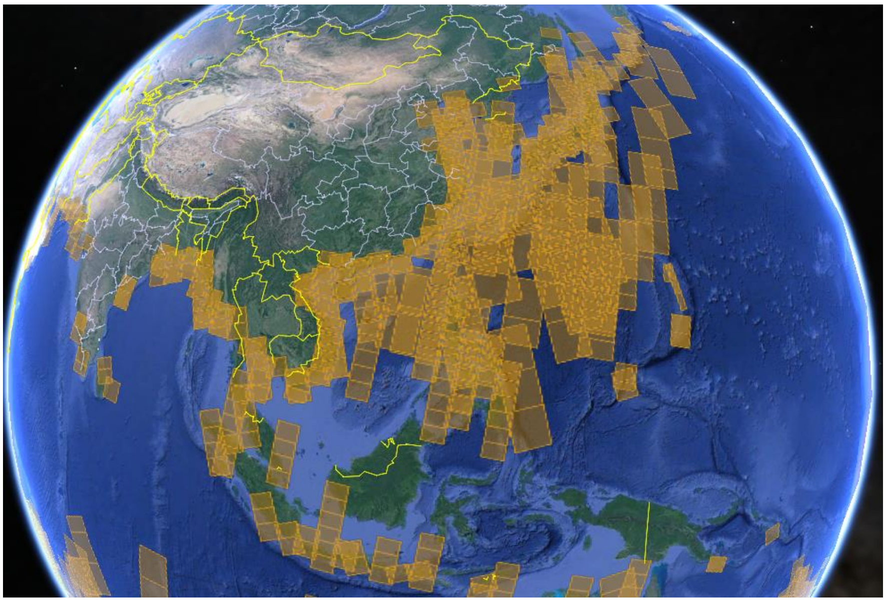


Figure 4: Western Pacific - meteorological region of responsibility of Japan Meteorological Agency (JMA)

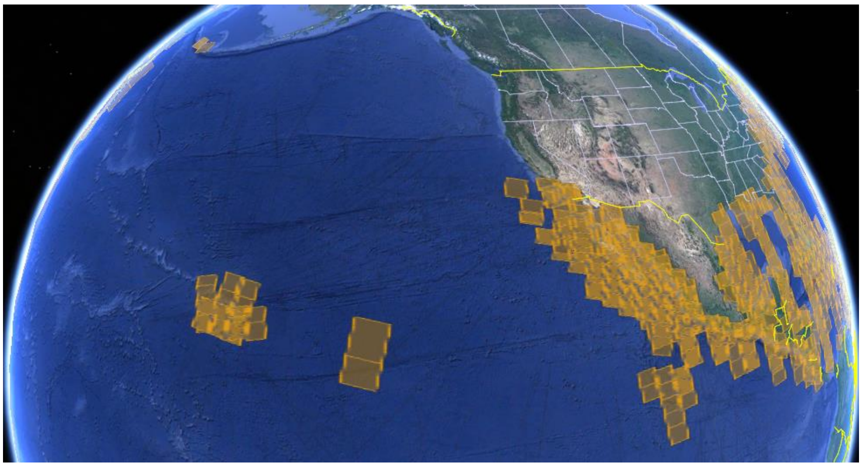


Figure 5: Central and Eastern Pacific - meteorological region of responsibility of Central Pacific Hurricane Center (CPHC) and NOAA's National Hurricane Center (NHC)

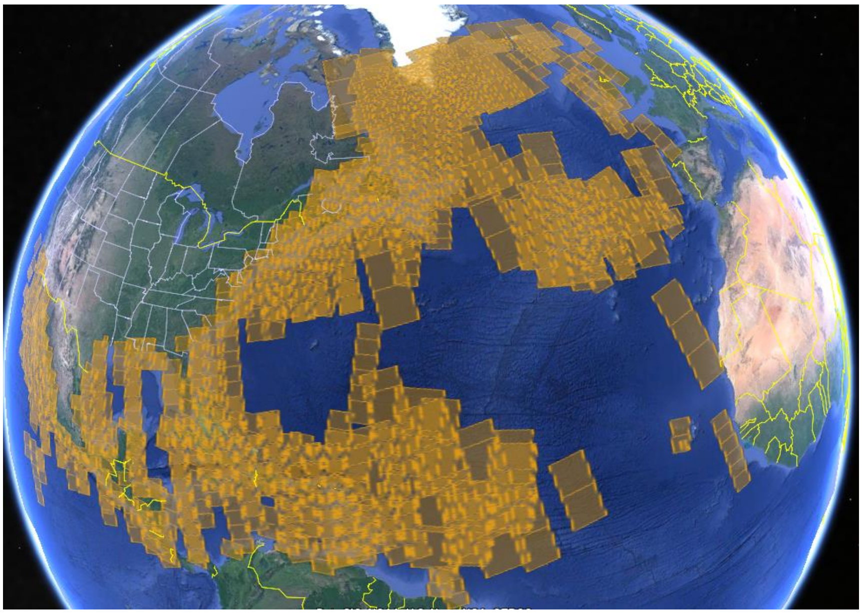


Figure 6: North Atlantic - meteorological region of responsibility of NHC

An associated kml is also delivered as a specific file and specified in Appendix D - (ASS-D1)., giving access to the description of each acquisition as shown in Figure below.

Figure 7: Illustration of the additional information available inside the kml file describing CYMS acquisitions.

2.2 TC acquisitions evolution with time

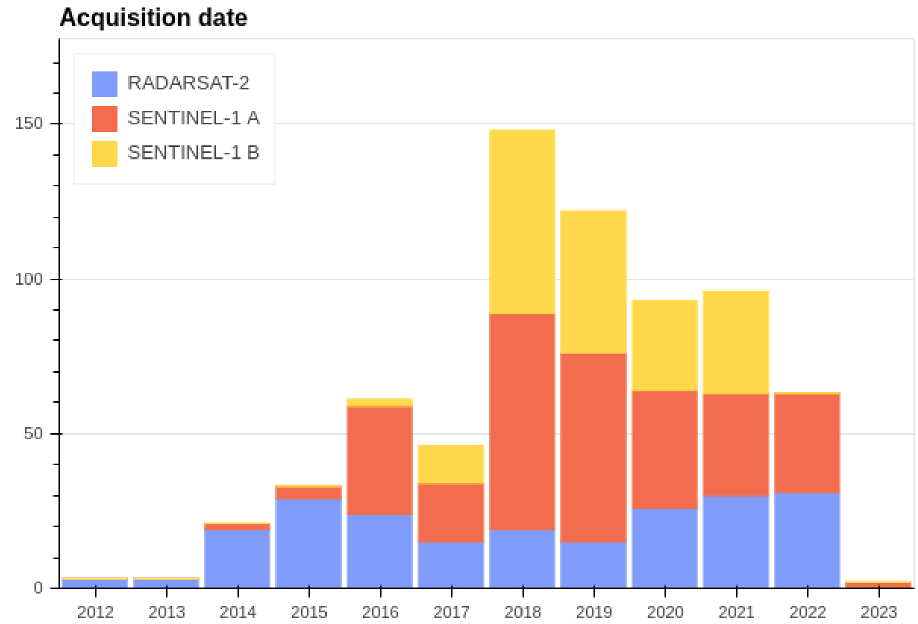


Figure 8: Summary of C-band SAR data acquired over Tropical Cyclones since 2012

Figure 8 recalls the number of C-band SAR acquisitions since 2012. We can see that the number of Sentinel-1 acquisitions is stable in 2020, 2021 and 2022 for all missions (~30 per satellite) with an overall loss of SAR acquisitions since 2022 due to the end of life of Sentinel-1B in December 2021.

The amount of RadarSat-2 (RS-2) data is also stable and has slightly increased since 2020. This improvement can be attributed to the fact that the use of the RS-2 data has been taken over by ESA, RS-2 being a collaborative mission. After the agreement for tasking RS-2 was set up, the total number of RS-2 images that could be tasked over the TC was higher than the quota previously allowed by the GIS-Bretel programme, through the participation of IFREMER and the use of CLS's VIGISAT facility.

Overall, 2018 was the best year in terms of number of acquisitions over TC, even though the number of tropical cyclones worldwide is quite similar: e.g., 151 and 141 for years 2018 and 2020, respectively. Even though 2020 was a very intense TC season for the Atlantic basin, year 2018 was a very intense TC season for the Pacific basin, which explains why the TC counts are similar.

The strong difference of S1 acquisitions (~50% less data in 2020) can mostly be explained by the number of activations sent to ESA S1 ground segment. It was activated 32 times in 2018; 24 times in 2020 and 20 times for this last period (Jul-2021 to Jun-2022 to keep covering a year period). Despite the fact that there were less activations in 2021-2022, the activation process changed slightly in the way that for a single activation, request for monitoring several TCs were sent. This apparent reduced number of 20 activations sent to ESA in 2021-2022 with respect to 2020 is therefore not associated to a reduced number of monitored TC. The maximum number of 4 activations per month was proposed after year 2018 in order not to overwhelm S1 ground segment with TC-related modifications of the acquisition plan.

With respect to 2020 and the Covid context, there was more flexibility to task to S1 ground segment in 2021-2022. Tasking all working days is now possible while it was only possible on Monday and Thursday before. Yet, without additional capabilities to update more regularly the TC tracks due to the limited number of activations, this flexibility has reduced impact on total amount of SAR acquisitions over TC. For instance, the maximum number of 4 activations per month prevents from performing an exhaustive TC monitoring, from early TC stages until end of end-of-life since it would require several activations.

2.3 TC tasking efficiency

Catching TC eyes with SAR acquisitions is key for meteorological forecasters as these observations best describe the TC main characteristics (Vmax, Rmax, eye location and shape…) [1, 2]. It is also of major importance for scientists developing robust algorithms to estimate these parameters [3, 4], and for data assimilation [5, 6].

The ability to catch TC centers greatly depends on the SAR acquisition plan update procedure and more precisely, on the ground segment capability to regularly plan specific SAR acquisitions that are matching with the future TC forecast positions over for the next couple of days. Currently, the identification of potential SAR acquisitions with the TC track is currently manual but the possibility to automate this procedure would make the tasking procedure more efficient. **In particular, the S1 ground segment is sometimes activated while there is no potential S1 acquisition of interest to plan. Possibilities to co-locate the TC tracks with S1 orbit ahead the activation could allow a more efficient use of the activation limitation.**

Besides, each SAR acquisition planned through SHOC over the past 2 years has been analyzed. The exhaustive count of SAR acquisitions triggered through SHOC with hit-or-miss scores and additional characteristics are available in an Excel sheet indicated in Appendix D - (ASS-D3). This is illustrated in Figure 9 and Figure 10. Two categories are distinguished: those for which at least a part of the TC eye is caught located within the SAR scene (in blue) and those for which the entire eye is caught (in orange).

While most of the S1 scenes are planned 2 to 3 days after activation, the number of eye hits are most important with the time after activation is shorter. **We found that chances to catch TC centers reach 70% if planned within one day while they were reduced to 10% if planned within 5 days.**

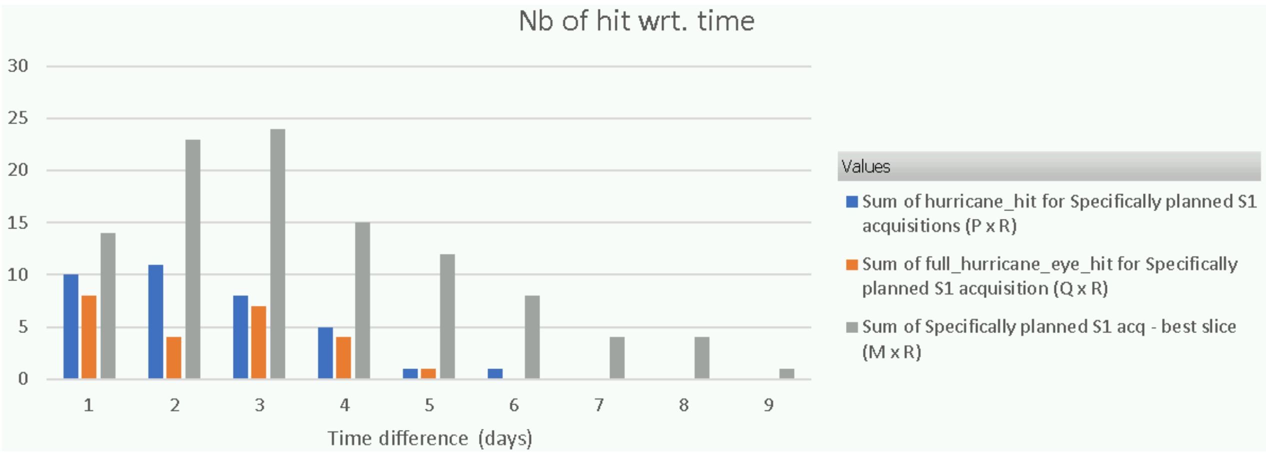


Figure 9: Number of partial (blue), full (orange) eye hits and SAR passes (grey) triggered through SHOC with respect to the time difference between the update of the S1 acquisition plan and the SAR acquisition time.

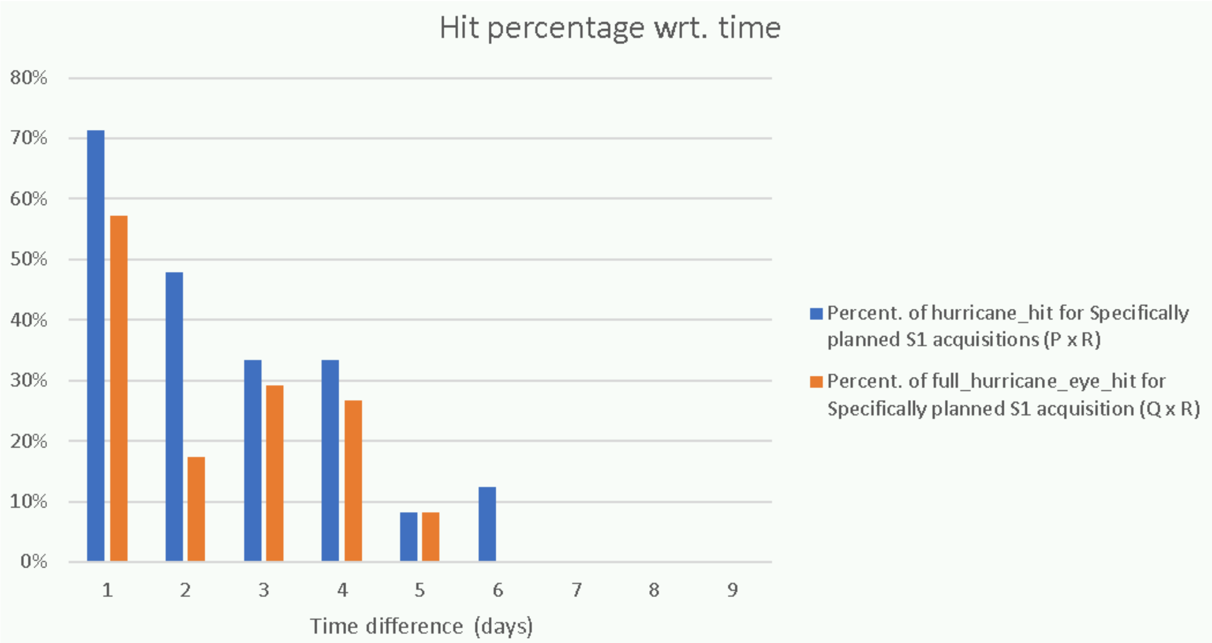


Figure 10: Percentage of partial (blue), full (orange) eye hits triggered through SHOC with respect to the time difference between the update of the S1 acquisition plan and the SAR acquisition time.

However, performing more frequent updates of the satellite acquisition plan is not necessarily feasible as it poses constraints on the instrument planning loop and requires operational capacity to allow for last-minute planning. Comparing the tasking strategies among the different space agencies can certainly help improve SHOC efficiency in the future.

2.4 TC vortex products

In contrast of performing a coverage and latency quality estimate based on TC track and SAR swath limits as done in the previous subsection, here we are directly analyzing the data to find the actual TC eye in the product. When this analysis is successful, we produce a new product (Level-3 TC vortex product) that basically contains the wind profile per quadrant, maximum sustained wind etc…

The following figures show the products that have been processed up to the Level-3 Vortex products over the last 11 years, using the archive data. This report is fully automated. Following numbers are built from these L3 products.

While the quantity of generated vortex products varies similarly to the quantity of L2P products, the percentage remains stable over time.

The first 2 figures show that about 80% of the Level-2 SAR data are processed up to Level-3 TC vortex products. However, once this product is processed, only about 60% of the Level-2 gives good Level-3 (meaning the center is well located and thus most probably included in the acquisition limit). We go up to 85% if you consider "good" and "warning" flags. See the pie chart.

Finally, when comparing the Level-3 product quality obtained with each of the 3 SARs, the rate of RS2 Level-3 products flagged as good is higher reaching 70% while S1 is about 50%.

The main explanation for this difference in terms of flagging performances is related to the tasking strategy and the fact that RS-2 products are catching more frequently TC eyes than S1. Two main reasons can be identified:

- while Sentinel-1 acquisitions are selected by S1 mission planners, RS-2 acquisitions are directly selected by CLS/IFREMER team. The differences in the planning process are the following:

- The S1-scene can sometimes be made many days after S1 mission planners are updating the acquisition plan. As Figure 10 indicates, there is clearly a loss of performance with increasing delay between ground segment activation and S1 observation.
- The RS-2 acquisition can sometimes be made within 24hours after activation while such delays cannot be met by S1 mission planners.

- RS-2 ScanSAR Wide acquisition mode provides 500 km wide SAR images, which are therefore much more extended spatially and offer greater changes to catch the TC eye.

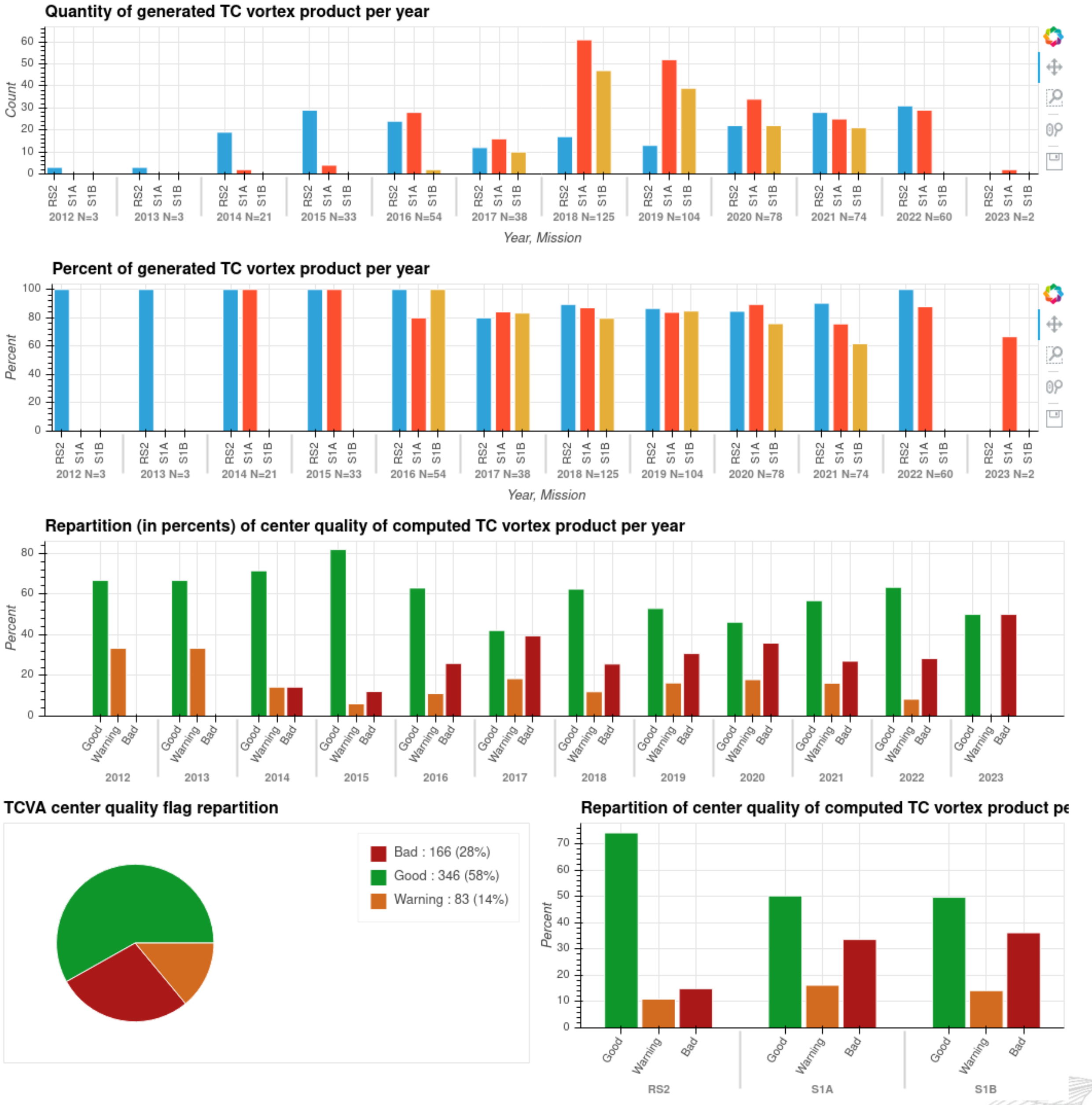


Figure 11: TC vortex products processed by CYMS and their quality over the last 11 years.

2.5 European Extreme Winds

Three different experiments have been performed to address the extreme winds over European waters:

- Reprocessed data: The polar lows from [Rojo et al. 2019] were co-located with Sentinel-1 products to process all the identified products. They are available at: https://cyclobs.ifremer.fr/app/polar
- Reprocessed and NRT data: Storms identified by the group in charge of the COST action: “European network for Mediterranean cyclones in weather and climate (MEDCYCLONES) https://www.cost.eu/actions/CA19109/. They were co-localized with Sentinel-1 and RS-2 and are available at: https://cyclobs.ifremer.fr/app/extra_tropical and on the NRT platforms (EODA and ftp).
- NRT data: In order to provide CYMS products from S1 acquisitions over Europe in a NRT process, a dedicated processing chain was developed:
    - A processing mask, shown in Figure 12 is used to select the S1 data of interest,
    - The maximum wind speed provided by ECMWF model over selected S1 slices is used as a threshold to process all S1 products with high winds, for which the CYMS processing is particularly well suited,w
    - Detected slices are extended if a single slice is selected in order to provide longer S1 acquisitions, with more contextual information.

The Figure 13 shows all the SAR acquisitions processed from the Level-1 within CYMS for the NRT monitoring between 2017 and December 31st 2022 for the two last experiments.

Figure 14 indicates the processing activity over the last months for the last experiment. The increase of processed products in Q4 2022 coincides with the optimization of the NRT processing chain in terms of computing time. This optimization enabled to process more S1 acquisitions by setting a lower threshold on the maximum wind speed given by ECMWF model over the SAR coverage. This threshold now reaches 12 m/s. In total, 1732 SAR L1 slices were processed.

Figure 12: Mask, in white, used to process SAR data in the NRT European Extreme Wind processing chain

An associated kml is also delivered as a specific file and specified in Appendix D - (ASS-D2)., giving access to the description of each acquisition.

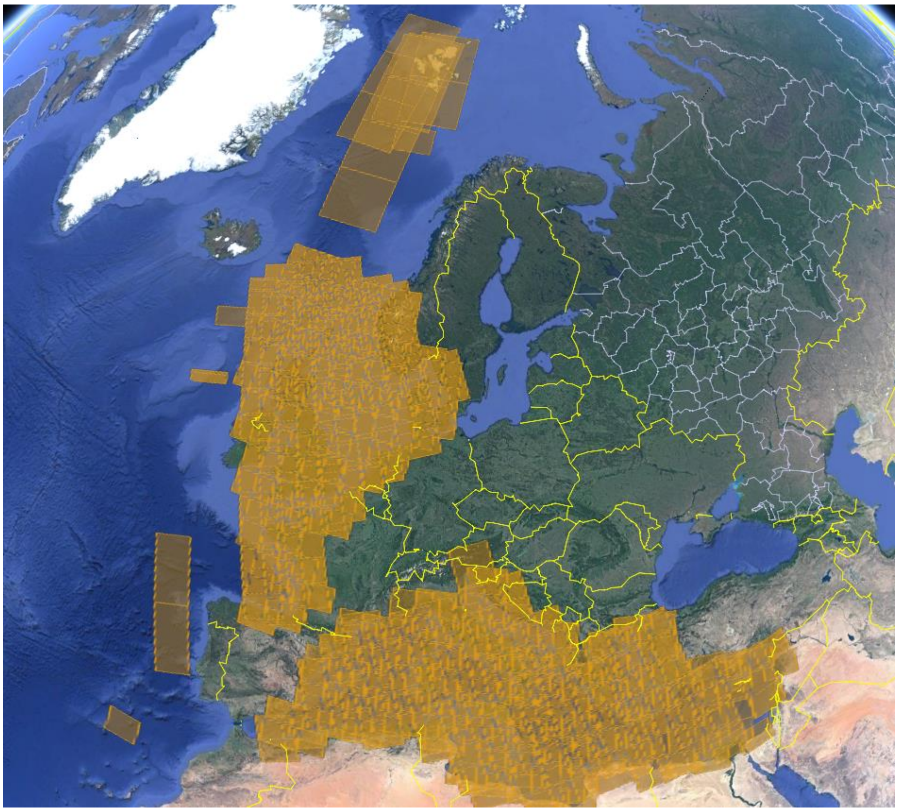


Figure 13: Coverage of the 1731 Level-1 Sentinel-1 products processed over European Seas during the CYMS project. This covers both archive and NRT data over Winter Storms. S1 data processed over polar lows from [Rojo et al. 2019] are not included in this map.

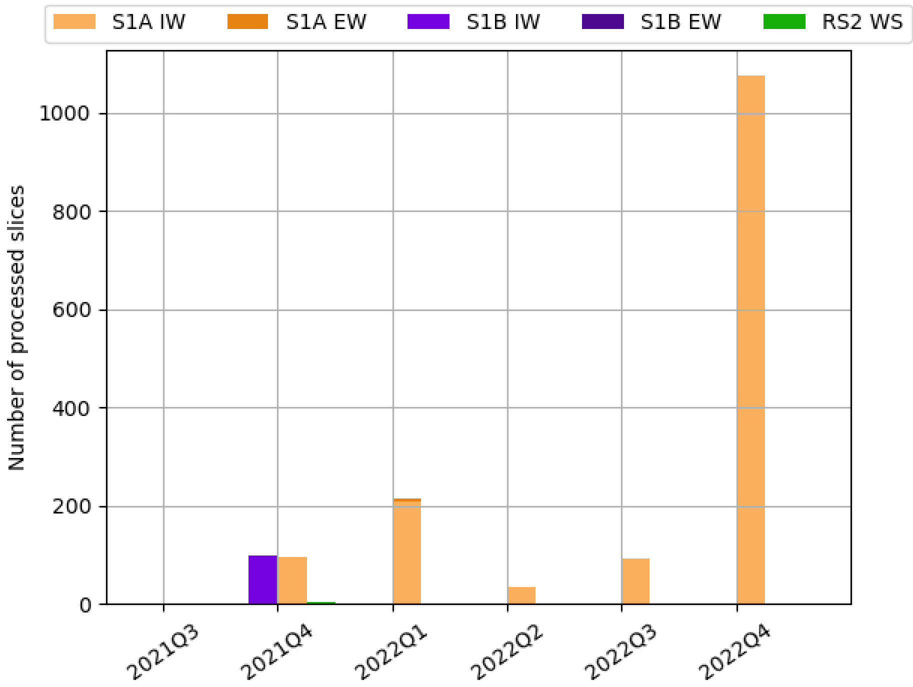


Figure 14: Histogram of S1 products processed with the NRT chain over European water since October 2021.

2.6 Timeliness

This section evaluates the timeliness performances from the SAR acquisition time to the end of the NRT processing.

Metrics

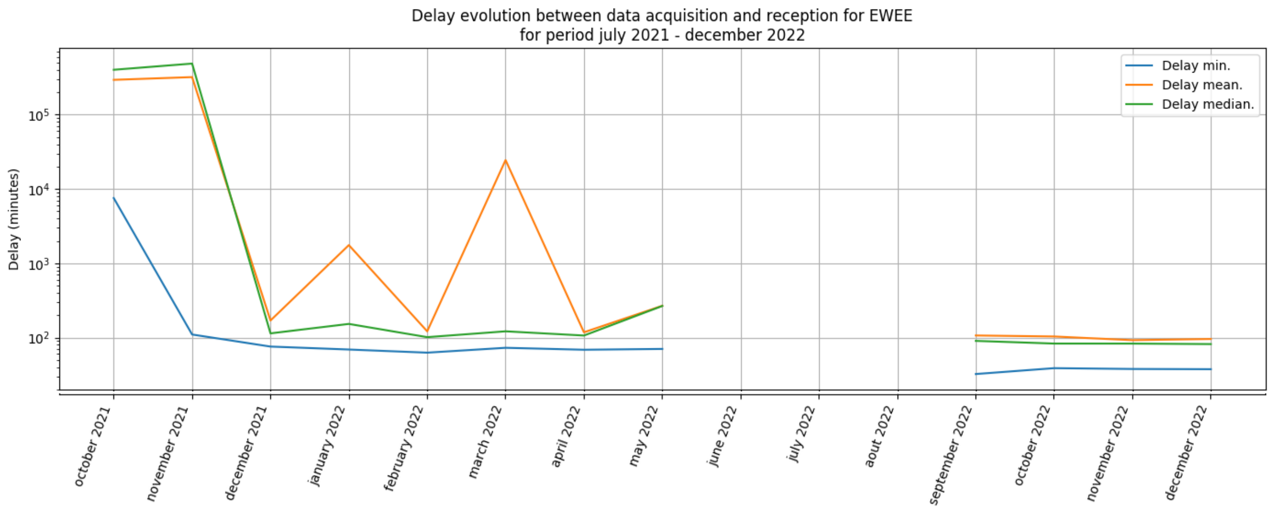
In the sub-section, the "*availability time*" refers to the time difference between the SAR acquisition and the SAR data availability on the ESA CopHub. Only Sentinel-1 data is investigated for this metric. The "*processing time*" refers to the time required to process the CYMS winds starting from the L1 SAR data, once received.

These metrics have been monitored overall and on a monthly basis over the entire project and are analyzed below. Monitored statistics are the minimum time (in blue), the mean time (in orange) and the median time in green. No statistics are available for the processing over European water during summer 2022 due to the chain maintenance activity.

Results

Overall, the availability time for products over Europe reaches 1h30 for 50% of the data (Figure 15 - top). Higher values at the beginning of the time series (end of 2021) are due to processing of non-NRT products. For data acquired worldwide over Tropical Cyclones, the availability time reaches 3 to 4 hours for 50% of the data (Figure 15 – bottom).

The "*processing time*" reaches 20 min for 50% of the data over Europe and worldwide TC and it has not increased with the large amount of additional data processed by the end of 2022 over Europe (six times more data processed).



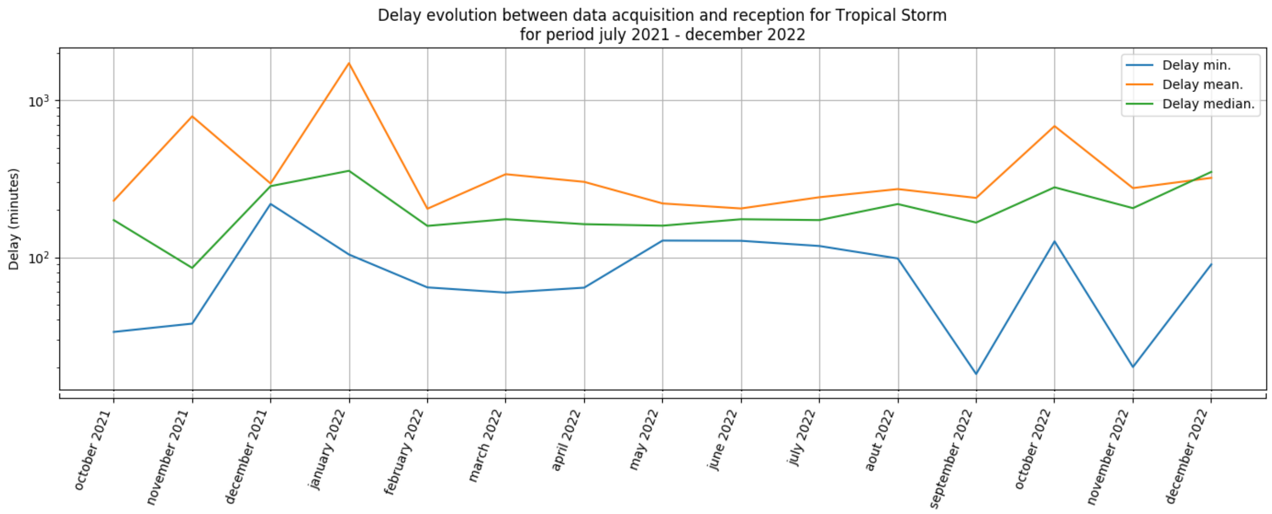


Figure 15: Availability time - Evolutions over the project for S1 products acquired over European waters (top) or worldwide TC (bottom)

3 Communication

This sub-section presents the assessment of the communications media used or developed during the project. It covers the project website, the dissemination platform CyclObs and the CYMS Twitter account.

As for the CYMS NRT platform (EODA), no visitor statistics could be retrieved from it.

3.1 CYMS Webinar

The Webinar was performed in a single session on 5th May 2022 and lasted 2 hours. It totalized 70 registrations and 39 participants on the day of the webinar. After this live event, the whole presentation was distributed together with a Q&A (Questions and Answers) discussed during the webinar.

The webinar content was the following:

- Present the CYMS project: objectives, data processing & perspectives,
- Demonstrate accessing data and visualization tools,
- Present 3 different use cases with different partners (LACy, Météo-France La Réunion and METNO)

Below are the useful links:

- Replay, totalizing 31 views after the webinar session: https://www.youtube.com/watch?v=L-usex2Dbek
- Q&A pdf: https://www.esa-cyms.org/wp-content/uploads/2022/05/Webinar_Questions-Answers.pdf
- Overall presentation: https://www.esa-cyms.org/wp-content/uploads/2022/05/CYMS_Webinar_presentation2022-05-05.pdf
- All CYMS documentation: https://www.esa-cyms.org/documentation/

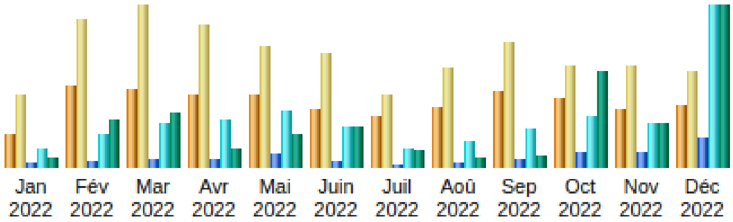
The webinar communication was performed via emails and Twitter (from CLS Group and CYMS accounts), with three mailing sessions for:

- Invitation
- Agenda
- Thank you

3.2 CyclObs

Detailed statistics are provided in Appendix E -.

The website analytics indicate a constantly increasing number of unique visitors with up to 430 visitors per month for February 2023 (unique IP address). Similarly, it shows increased activity during TC seasons.



Mois	Visiteurs différents	Visites	Pages	Hits	Bande passante
Jan 2022	146	317	1 626	7 765	3.62 Go
Fév 2022	356	652	2 643	13 694	18.83 Go
Mar 2022	343	707	3 209	18 546	21.70 Go
Avr 2022	320	622	3 150	19 606	7.83 Go
Mai 2022	320	534	5 655	23 255	13.56 Go
Juin 2022	258	498	2 974	17 112	15.96 Go
Juil 2022	224	320	1 487	7 945	6.56 Go
Aoû 2022	261	433	1 796	10 662	3.86 Go
Sep 2022	336	549	3 387	16 217	4.42 Go
Oct 2022	300	443	6 504	20 959	38.12 Go
Nov 2022	257	447	6 416	18 376	17.59 Go
Déc 2022	271	424	12 411	66 987	64.42 Go
Total	3 392	5 946	51 258	241 124	216.47 Go

Figure 16: Monthly statitics for CyclObs website during year 2022

3.3 ESA-CYMS

3.3.1 Updates

The main updates performed on the esa-cyms website (https://www.esa-cyms.org) are listed below:

- Addition of pages for the announcement and the landing page of the webinar,
- Addition of the link with webinar material,
- Updates of manuals and data accesses,

3.3.2 Analytics

Detailed statistics are provided in Appendix E -. Below are the main comments based on the website analytics:

- The top 10 countries using the website are given by decreasing order of number of users:
    - United States,
    - China,
    - France,
    - United Kingdom,
    - India,
    - Canada,
    - Italy,
    - Germany,
    - Netherlands,
    - Japan

  → These statistics are mainly explained by:
    - the location of the Regional Specialized Meteorological Centres (RSMC) from NOAA, JMA, New-Delhi,
    - the location of ECMWF (Reading, UK),
    - the location of ESA (Frascati, Italy),

    - The Canadian Hurricane Watch initiative, performed in collaboration with NOAA,
    - The collaboration with the MEDCYCLONES project (COST action), many of which are located in Italy,
    - The location of the project partners (IFREMER and CLS, in France),
    - The origin of the activity from Netherlands and Germany is not completely clear but could be related with the location of ESTEC and EUMETSAT and to the three special Netherlands municipalities (Bonaire, Sint Eustatius and Saba) in the Caribbean.
- 1.3 session / user means that users are coming back to the website.
- 1.6 page / session means that, on average, users are reading several pages while ¾ users leave the website immediately ("bounce rate").
- The top 5 pages are: the homepage, Data Access, About, Webinar and Documentation.
- 31% users typed the website address while 31% used a search engine, 13% came from another website and 10% via a link in an email.
- The most visited months are:
    - April 2022: with lot of communication ahead to prepare the Webinar,
    - October 2021 and October 2022: due to the cyclonic season,
    - Reading is within the cities who most visited the website, probably due to the presence of ECMWF headquarters.

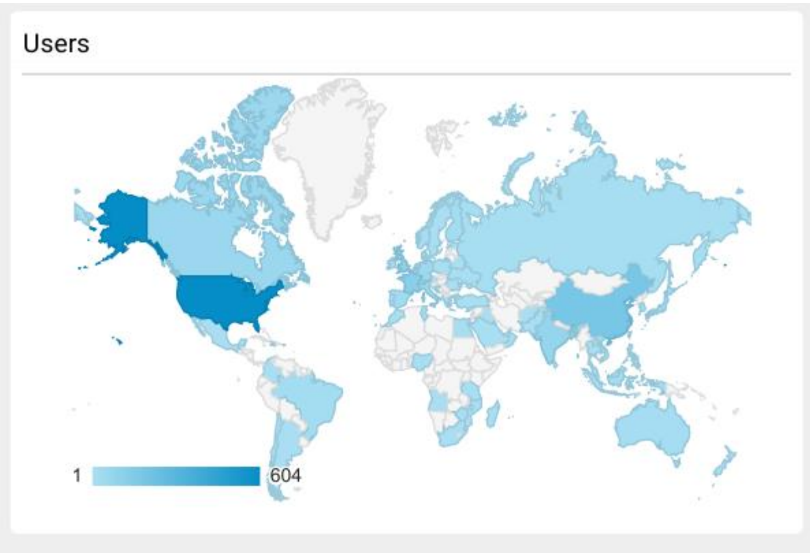


Figure 17: Number of unique users by country between June 2021 et December 2022

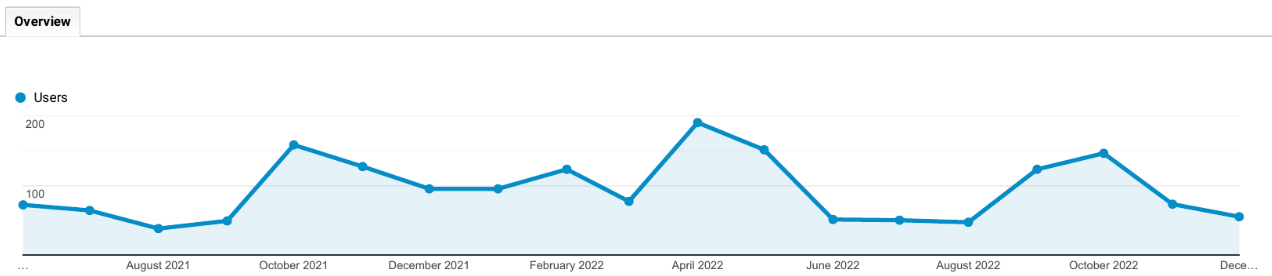


Figure 18: Activity on the esa-cyms.org website along the project

3.4 SeeWater-CYMS

The following figure indicates the number of unique visitors per month since April 2022. It can be seen that the website activity is closely related to the Tropical Cyclone activity with Northern and Southern TC seasons showing higher activity. The May-2022 higher activity is also explained by the Webinar.

The number of visitors is lower than for the other websites. This can be attributed to the fact that the first versions of SeeWater were not completely mature at the beginning of the project. It has significantly improved since to ease the end-user experience.

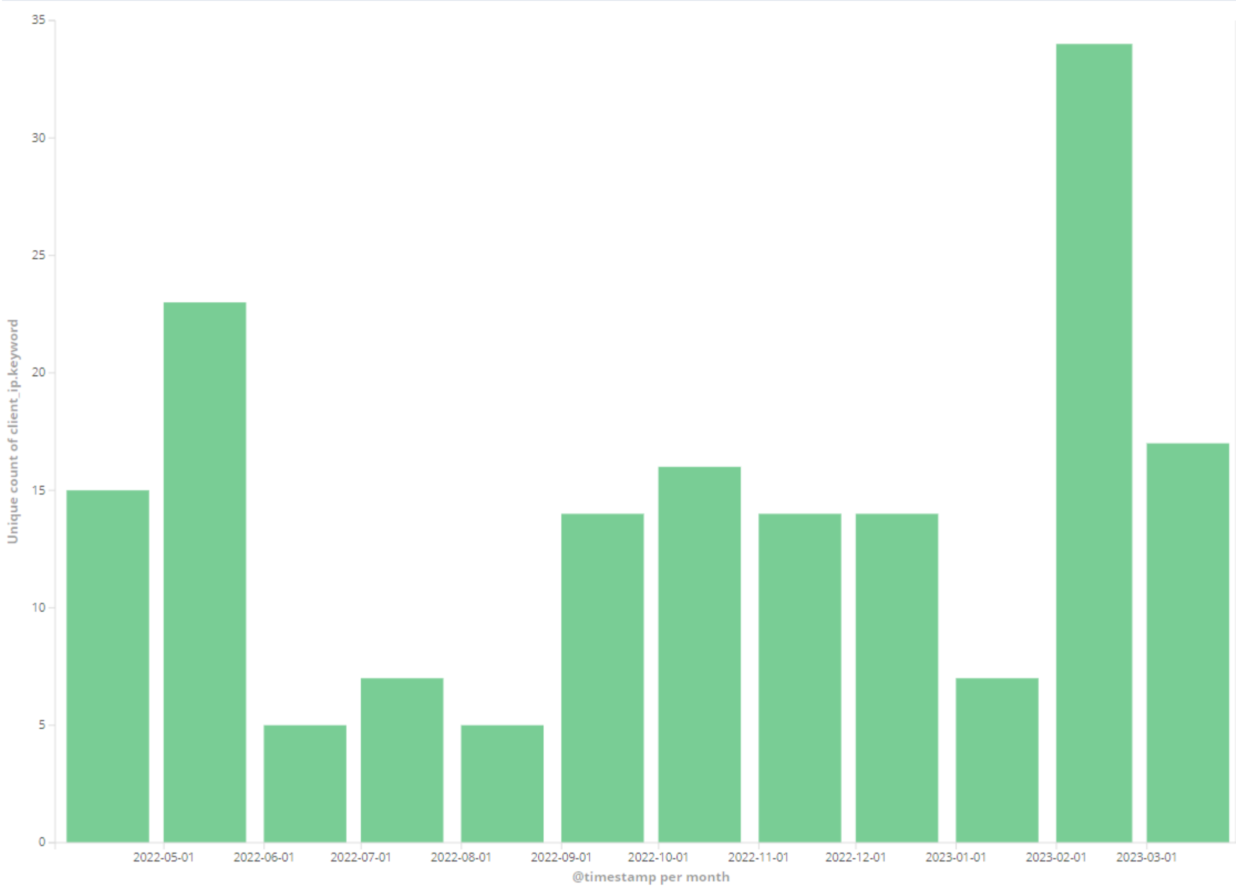


Figure 19: Number of unique visitors per month over the last year.

3.5 Twitter

The twitter activity aims at providing short news in direct link with current or very recent TC activities. The twitter activity along the CYMS projects is summarized hereafter:

- 169 followers (as of Sept. 21, 2022) with at least two systematically retweet our tweets. The audience covers a mix of organizations (Copernicus, CEMS, Eumetsat…) and individuals, either interested in meteorology as field of knowledge (personally or professionally) or directly impacted by cyclones.

  As a comparison, there were 78 followers at the end of the CYMS first phase (2020-2021),

- 28 tweets since July 2021 (this summer has been very calm) + 5 retweets,

  As a comparison, there were 40 tweets during the CYMS first phase (2020-2021),

- Best "impression" (~views): around 13200 for a tweet on Ida (Aug. 2021 – it is cumulative) while the latest tweets (Innamnor, Danielle) reached about 400 – 500 views.

  This is higher than the most seen tweet during CYMS first phase which reached 11,000 views.

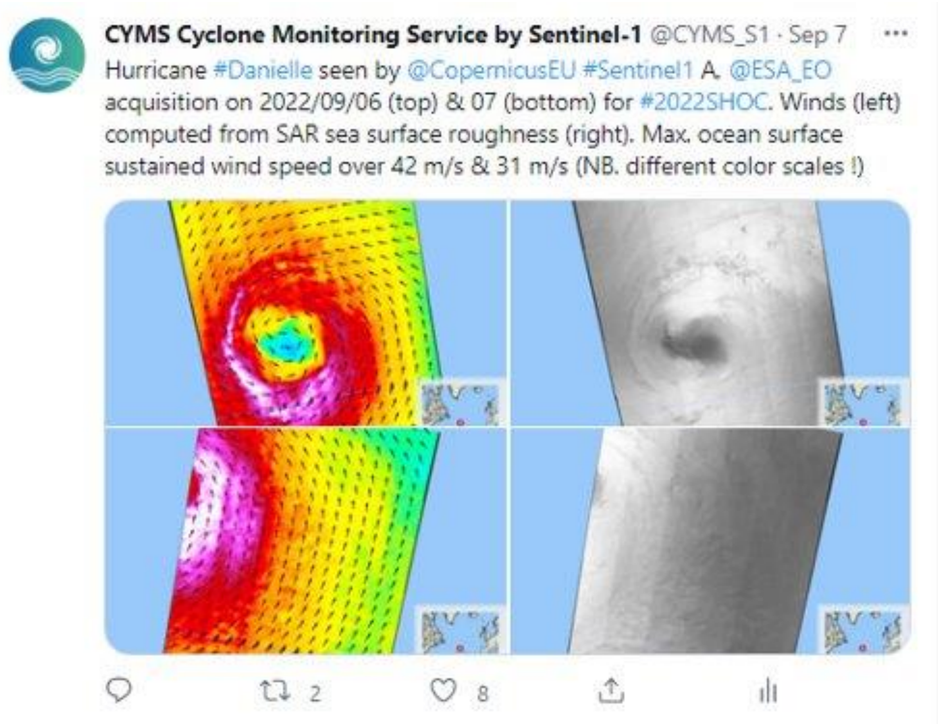


Figure 20: Illustration of the tweet about Danielle TC posted on Sept 7th, 2022, with high impact on Twitter.

Individually contacted end-users

On top of this general presentation, several individual CYMS presentations were performed throughout the 2nd phase. The following entities were contacted individually and a full CYMS presentation and demonstration was performed:

4 Potential evolutions and recommendations

This section summarizes the recommendations from the CYMS consortium based on the analysis of CYMS service as a whole. This also takes into account feedbacks gathered from the [AR] document. As a reminder, feedbacks from end-users and WMO and other Regional Specialized Meteorological Centers (RSMC) are provided in the [AR] document.

The main identified recommendations are the following and are further detailed in the next sub-sections:

1. S1 acquisitions over TC: Review and automatize the overall procedure for updating S1 acquisition plan over TC,
2. SAR acquisitions over European waters: Increase the monitoring of extreme winds over European waters using Copernicus contributing missions,
3. SAR inter-calibration: Monitor and ensure the inter-calibration among SAR-derived geophysical products from the various sensors.
4. S1 radiometric calibration: Monitor with new metrics and improve S1 radiometric calibration,
5. CYMS products geophysical content: Improve the geophysical content of the current CYMS products and enrich them with additional parameters on data quality,
6. Service timeliness: Increase the overall processing efficiency so that all CYMS products can be made available within 3h after acquisition.
7. Tutorials/discussions with end-users: Organize regular meetings with end-users in order to present the content, possibilities and limitations of CYMS products, discuss use-cases with end-users and identify requirements to drive future evolutions.
8. Assimilation studies: The assimilation exercise performed by MetNo has enabled identifying many points to improve the assimilation impact in the NWP model.

4.1 S1 acquisitions over TC

Extensive analysis of SHOC efficiency, i.e., Sentinel-1 performances in catching TC eye were performed. They reveal that the use of Sentinel-1 datatake could be improved by reducing the time between the release of ECMWF forecast track and the update of S1 acquisition plan.

Several discussions have been (and are) performed with S1 mission planning team and are expected to lead to a revision of the CYMS Standard Operation Procedure [SOP] setup with ESA. **The objective is to review and improve the overall process with more automatized procedures** including automated identification of potential S1 passes of interest before modifying S1 acquisition plan and automatized distribution of information to the mission planners.

4.2 SAR acquisitions over European waters

Despite the global effort from the various space agencies to monitor TC worldwide, extreme winds phenomena met over European waters are not as well captured. Even though Europe is systematically imaged by Sentinel-1, it is composed of only 1 satellite (or 2 with the full S1 constellation). In comparison, 5 times more satellites are used for TC monitoring to capture extreme winds. **This results in seldom acquisitions over mid-latitudes phenomena** such as medicanes or extra-tropical storms. Polar lows would also greatly benefit from additional acquisitions as these systems have a small spatial extent and are short-lasting.

In that matter**, the ability to use contributing missions within the framework of Copernicus services would greatly benefit to the monitoring of extreme winds over Europe**, otherwise poorly sampled.

On top of this, the possibility to access to storms database over Europe for both Archive data or NRT is currently being discussed with various entities. It is of high interest for various purposes:

- For NRT activities, it would enable scheduling other SAR missions such as RS-2 using forecast tracks, similarly to what is being done today with Sentinel-1 over TC. Identified sources are:
  - ECMWF: Some sample internal products have been identified in previous meetings with ECMWF. They consist in forecast tracks of cyclonic features that could be shared in order to feed potential SAR satellites acquisition plan updates.

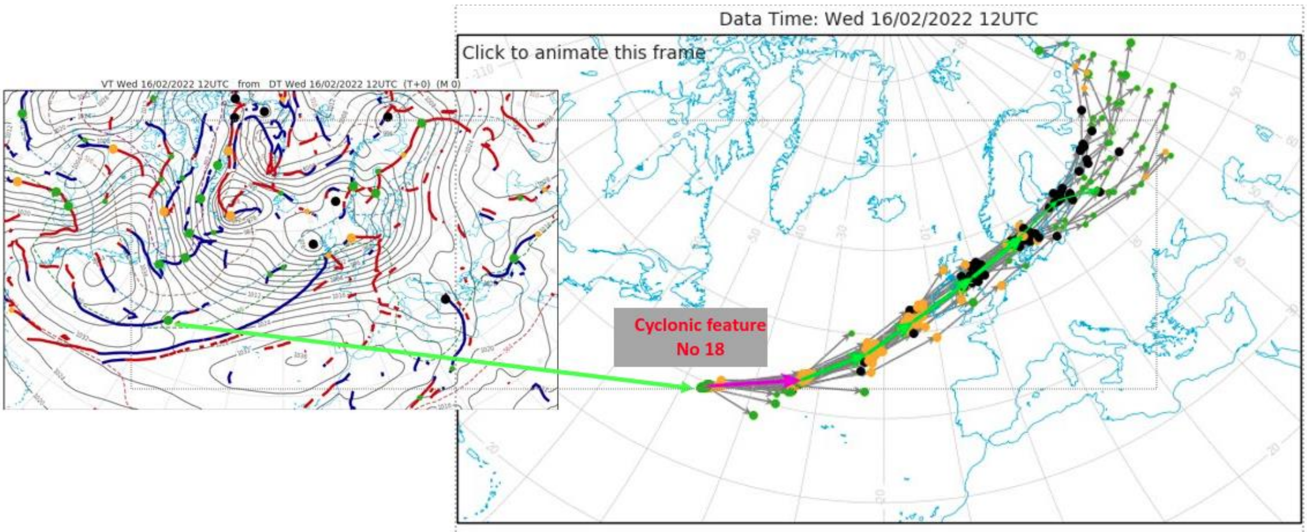


Figure 21: Caption of ECMWF Extra-tropical Cyclone Database (CDB) products illustrated over storm Eunice based on a forecast started on 16th Feb 12Z

  - MedCyclone COST Action: [Flaounas et al. 2023]: This article presents a composite approach to produce reference datasets for extratropical cyclone tracks. It is applied over the Mediterranean cyclones and provides a dataset over time period 1979–2020 but a NRT capability should be made available by the end of 2023.

- For archive activities: They enable better assessing storm events for validation purposes (Bidlot et al. 2023 - MAXSS international workshop, 3rd-5th May 2023) and for their overall effect, at a larger scale that just for a single SAR observation. They also provide possibilities to characterize the event using other sensors and parameters (e.g., SST, SSS anomalies):
  - ECMWF presentation from Jean Bidlot at MAXSS show the usefulness of CYMS products for the validation of ECMWF model research versions able to better represent extreme winds.
  - Extreme windstorms catalogue (over Europe): The XWS (eXtreme Wind Storms) catalogue is a freely available database of storm tracks and model-generated maximum 3 second gust storm footprints (both raw and re-calibrated) at ~25km resolution for 50 of the most extreme windstorms to hit Europe in recent times. The catalogue currently covers the period October 1979 - March 2013. An estimate of the uncertainty of the gusts for each re-calibrated storm footprint is also provided. http://www.europeanwindstorms.org/
  - MedCyclone COST Action: [Flaounas et al. 2023]: Similarly to the archive dataset presented in the paper, a NRT capability should be made available by the end of 2023.

4.3 SAR inter-calibration

Today, several initiatives from ESA, CSA, MDA Space and JAXA are contributing to the monitoring of TC worldwide with SAR acquisitions from S1, RS-2, RCM-1, -2, and -3 and ALOS-2.

This leads to an unprecedent frequency of TC acquisitions with SAR:

- Over the past years: S1A, S1B and RS-2 each contribute approximately equally to nearly 30 acquisitions over TC eyes per year, each satellite bringing new co-location opportunities with the TC track.
- Recently with TC Freddy, the impact of the additional 3 RCM satellites in the TC monitoring has particularly well illustrated the new capabilities with more than two SAR acquisitions over TC eyes per day.

Despite this wealth of TC SAR acquisitions, significant differences exist between 1- the acquisition strategy (e.g. the ocean basins monitored for acquisitions over TC) and 2- the SAR sensors' calibration.

- For the first point, it is relevant to ensure that, at global scale, the TC monitoring requirements from all regional centers are met. Therefore, it is first important identify, for each SAR mission, which ocean basins are TC-monitored and how, and then to possibly adapt it, if not satisfactory. For instance, in the past years, TC occurring in the North Indian Ocean were not as frequently monitored with S1 and RS-2 as in the Southern Indian Ocean.

- For the second point, differences in SAR calibration are partly attributed to varying NRCS calibration strategies among the space agencies (e.g., C-band missions from ESA, CSA and MDA Space). This results in discrepancies between the different missions of the downstream CYMS products (L2P and L3) if they are processed with the same algorithms. **A dedicated activity is therefore needed to make sure that all L2P and L3 products are consistent by proposing a common calibration and validation chain of either the Level-1 or the downstream products.** This work has already started for RS-2 and S1-A and S-1B comparisons, enabling correcting for large wind speed discrepancies, sometimes reaching 20 m/s for RS-2 and 7m/s for S1-A acquisitions. Yet, this work remains to be done for RCM and ALOS-2 before including them into CYMS framework.

4.4 S1 radiometric calibration

Sentinel-1 radiometric calibration is well assessed and known thanks to the joint activities performed as part of the Sentinel-1 Mission Performance Center project (MPC-S1). The Sigma0 quality is regularly improving over time with new IPF releases (Instrument Processing Facility). Yet, some issues can still be mentioned:

- The quality of the newly acquired products or old S1 data provides the best possible S1 data quality whenever processed with the latest IPF version. However, **preparing Cal/Val activities require a homogenous and the highest data quality over the largest possible dataset**. Possible ways to prepare this are:
    - Reprocessing from Level-0 with the IPF via the MPC-S1 facility,
    - Reprocessing from Level-1 with the latest retro-calibration possible (Schmidt et al. 2023) and then a Level-2 Wind processor.

  Depending on the number of products to process, the first solution may not possibly be applied. The second solution can therefore prove particularly useful for a more flexible way to process S1 data to the highest data quality level.

- Even with the latest IPF version, some large radiometric calibration inconsistencies can exist, particularly visible at subswath edges (reaching ~0.5dB) for both co- and cross-pol, including for winds > 20 m/s. This is illustrated in Figure 22 where a Beta0 discontinuity is visible at IW1-IW2 subswath change with differences larger than 0.5dB for both noise-corrected and noise-uncorrected data. Such products are manually detected via the daily processings performed by CYMS over both TC and European extremes. Such detected issues are typically passed to the MPC-S1 and discussed together with the L1 and L2 teams. However, **a more**

systematic monitoring of such inconsistencies should be implemented within the MPC-S1 by adding new metrics S1 radiometric calibration process.

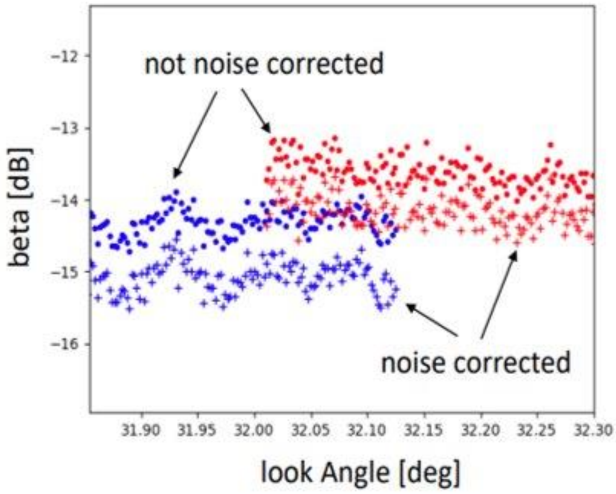


Figure 22: Analysis from Kersten Schmidt (DLR) on a S1 IW SLC data presenting large subswath jumps between IW1-IW2. For the current case, difference between sub-swaths even increases with noise correction (S1A_IW_SLC__1SDV_20220502T172608_20220502T172635_043035_052376_F155.SAFE)

4.5 CYMS products geophysical content

Feedbacks from the end-users, mainly meteorological forecasters, indicate that the currently provided products can be misleading and confusing. On top of the aforementioned issues (S1 radiometric calibration and consistency among SAR sensors), two main issues have been identified and are presented below.

4.5.1 Rain contamination and data quality

As mentioned in the [AR] deliverable, the quality of the SAR data can sometimes be very questionable for isolated situations. E.g., of Freddy on 08/03/2023 at 15:42 UTC indicates largely over-estimated Vmax (reaching 55 m/s) with respect to the Best Track data. This is seen on different sensors (RCM and Sentinel-1) thereby suggesting that this is not sensor-specific but rather attributed to the atmospheric conditions. In the present case, we suspect the rain contamination to be responsible for this overestimation. One issue with the current contamination is that it could not be detected based on the currently implemented heterogeneous filter. Additionally, undergoing research based on the texture analysis using DNN (Deep Neural Network) methodologies are not foreseen to identify such effects due to their rare occurrence and co-location with coastal rain radars. Other methodologies described in the literature based on the agreement between SAR observables are expected to be more promising (Zhao et al. 2023).

In a more general approach, it is a high priority to better identify all non-wind related processes expected to affect the SAR measurements and the downstream wind products. Some specific methodologies, applied as pre-processing modules ahead of the wind-inversion and based on the Sigma0 texture analysis, are already in place to filter bright targets and rain-related signatures inducing large heterogeneous features. Yet, they cannot answer this general issue alone.

To address this issue, it can be useful to take advantage of the wide range of observables provided by SAR measurements:

- Co- and Cross-polarized Sigma0 [Mouche et al. 2017 - Combot et al 2020],
- CCPC (Co- Cross- Polarization Coherence) [Longepe et al 2021],

- Doppler shift [Moiseev et al 2020],
- MACS (MeAn Cross-Spectra) [Li et al. 2019],
- wind streaks direction [Husson et al. 2021 – Zanchetta and Zecchetto 2020],

Their dependency on wind conditions is documented in the literature and their common agreement can be a very good approach to better quantify the SAR-derived wind quality. Besides, this topic is highly related to the following one.

4.5.2 Wind field estimation

The current wind inversion scheme is implemented based on [Mouche et al. 2017]. The downstream L3 (FIX) product is based on this L2P product. **The wind inversion methodology does not take advantage of all the possibilities that S1 can offer and that could greatly improve the quality of SAR-derived wind**:

- The wind direction currently estimated in the Bayesian process is strongly influenced by the model which often differs significantly from the actual situation observed by SAR close to the storm center. Wind streaks information is provided in the product as a separate variable but not included in the Bayesian scheme. Other SAR observables impacted by the wind direction should be included to provide a more model-independent wind retrieval: the Doppler Shift and the CCPC altogether provide a complementary wind vector estimation as shown in [Longepe et al. 2021], the estimated error on the wind direction error based on the wind streaks can facilitate the inclusion of this variable in the Bayesian scheme. Finally, MACS parameter can also be used to further constrain the wind inversion if an associated GMF was also developed and integrated in the Bayesian scheme.

- The current wind inversion is performed from the GRD products and such developments thus involve a re-architecture of the wind inversion process as some of the previously mentioned variables need to be estimated from the SLC products.

- More globally, this evolution of the Level-1 to Level-2 wind processing will also benefit to other geophysical variables which are closely nested with the sea surface wind estimation: the radial sea surface current and the wave parameters such as the total, the wind sea and the swell Hs.

4.6 Service timeliness

Currently, the service analysis in the previous sub-section 2.6 has revealed that about 50% of the data was processed within 3 hours after acquisition time. Yet, in order to be used for forecasting but also potentially for assimilation purposes, it is mandatory to increase the service efficiency so that 100% of the data is made available in the time useful for NRT constraints.

This would require increased processing capabilities to improve the service timeliness and operational processing facilities to ensure a better Service Level Agreement (SLA).

4.7 Tutorials/discussions with end-users

The complexity of certain SAR acquisitions can require in-depth analysis of the situation by meteorological forecasters who are not necessarily well formed to fully understand the reliability, the quality and the content of the SAR-derived measurements. It is therefore important to setup a long-term loop of SAR tutorials and discussions allowing for in-depth discussions on CYMS products content, measurements possibilities and limitations to describe meteorological situations of interest and to keep including end-users needs for the development of future products. The end-users' practices are also a topic of interest as mentioned in the [AR] deliverable and they should be discussed in terms of data format, data access to keep improving end-users experience with CYMS products.

Past meetings with end-users within the framework of various projects (e.g., CYMS, RenovRisk, WMO Tropical Cyclones meetings) have proven very useful in better understanding their needs and identifying their reference sources and their practices.

It is therefore important to maintain a framework to **organize regular meetings with end-users** in order to present the content, possibilities and limitations of CYMS products, discuss use-cases with end-users and identify requirements to drive future evolutions.

4.8 Assimilation studies

The assimilation exercise of CYMS products by MET Norway, further developed in [ASM] document, shows that we can assimilate SAR winds and that the Data Assimilation (DA) system can handle the information as the cost function minimizes smoothly.

A number of quality control problems in the screening were not looked into due to time constraints. The small impact in the storm case is actually quite normal even when established observation types are studied, especially when the reference performance is quite good which was the case here, i.e., the Copernicus Arctic Regional ReAnalysis (CARRA) system performed well in representing this storm. With that in mind, it is a good indicator that the SAR wind assimilation only gave minor impact.

We outline below some points to be further considered:

- Data *selection*: Several impact studies would be needed to better identify the useful of all parameters provided in CYMS products. E.g., the **wind streak orientation** may be better to use for wind direction (mainly model driven) in some cases. This was already illustrated in [Duong et al. 2021]. Additionally, it would be useful to test the impact of using the **heterogeneity mask** to decipher between valid vs. non-valid pixels.
- Aggregating NETCDF files: If SAR data is available from **different satellite passages** withing the same assimilation window then they would be in different NETCDF files. There is already a solution to this. In later HARMONIEAROME versions this can be handled by the system in the BATOR script.
- Quality control: There should be more time spent on developing a more mature handling of SAR winds especially in the screening. E.g., making sure the **first guess check** is done and tuned properly. Also, making sure that SAR winds can be used together with other scatterometer data such as ASCAT.
- Use of ambiguous wind components: Overall, we think that since other scatterometer products are assimilated with the ambiguous wind components that DA methodology is more mature. It would therefore be better if the ambiguities were kept in the data provided to NWP. Then a SAR **DA methodology with ambiguities** can and should be developed.

Appendix A - Acronyms

BOM	Bureau Of Meteorology
BUFR	Binary Universal Form for the Representation of. meteorological data
CEMS	Copernicus Emergency Management Service
CMEMS	Copernicus Marine Environment Monitoring Service
CPHC	Central Pacific Hurricane Center
CYMS	CYclone Monitoring with Sentinel-1
EC	European Commission
ECEPS	ECMWF Global Ensemble Prediction System
ECMWF	European Centre for Medium-Range Weather Forecasts
FTP	File Transfer Protocol
GMS	Geostationary Meteorological Satellite
HK	Hong-Kong
HKO	Hong-Kong Observatory
HNPW	Humanitarian Networks and Partnerships Weeks
IMD	India Meteorological Department
JMA	Japan Meteorological Agency
KMA	Korean Meteorological Administration
LACy	Laboratoire de l'Atmosphere et des CYclones
MF	Météo-France
NASA	National Aeronautics and Space Administration
NCEP	National Center for Environmental Prediction
NetCDF	Network Common Data Form
NMS	National Meteorological Services
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
RSMC	Regional Specialized Meteorological Centres
RMW	Radius of Maximum Wind
SAR	Synthetic Aperture Radar
SWIO	South West Indian Ocean
TCWC	Tropical Cyclone Warning Centres
TC	Tropical Cyclone
UKMO	United Kingdom Meteorological Office
WMO	World Meteorological Organization
WWMIWS	Worldwide Met-Ocean Information and Warning Service

Appendix B - References

Combot, Clement, Alexis Mouche, John Knaff, Yili Zhao, Yuan Zhao, Leo Vinour, Yves Quilfen, and Bertrand Chapron. “Extensive High-Resolution Synthetic Aperture Radar (SAR) Data Analysis of Tropical Cyclones: Comparisons with SFMR Flights and Best Track.” Monthly Weather Review 148, no. 11 (November 10, 2020): 4545–63. https://doi.org/10.1175/MWR-D-20-0005.1.

Duong, Quoc-Phi, Sébastien Langlade, Christophe Payan, Romain Husson, Alexis Mouche, and Sylvie Malardel. “C-Band SAR Winds for Tropical Cyclone Monitoring and Forecast in the South-West Indian Ocean.” Atmosphere 12, no. 5 (May 2021): 576. https://doi.org/10.3390/atmos12050576.

Duan, Boheng, Weimin Zhang, Xiaofeng Yang, Haijin Dai, and Yi Yu. “Assimilation of Tropical Cyclone Wind Field Retrieved from Scatterometer and SAR Based on the Huber Norm Quality Control.” Remote Sensing 9 (September 23, 2017). https://doi.org/10.3390/rs9100987.

Howell, Brian, LT Sean Egan, and LT Caitlin Fine. “Application of Microwave Space-Based Environmental Monitoring (SBEM) Data for Operational Tropical Cyclone Intensity Estimation at the Joint Typhoon Warning Center.” Bulletin of the American Meteorological Society, 2022.

Husson, R., N. Longepe, A. Mouche, H. Berger, C. Lin, O. Archer, and A. Colin. “Wind Direction Estimation and Accuracy Retrieval from Sentinel-1 SAR Images Under Thermal and Dynamical Unstable Conditions.” In 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS, 7588–91, 2021. https://doi.org/10.1109/IGARSS47720.2021.9555045.

Flaounas, Emmanouil, Leonardo Aragão, Lisa Bernini, Stavros Dafis, Benjamin Doiteau, Helena Flocas, Suzanne L. Gray, et al. “A Composite Approach to Produce Reference Datasets for Extratropical Cyclone Tracks: Application to Mediterranean Cyclones.” Weather and Climate Dynamics Discussions, January 12, 2023, 1–32. https://doi.org/10.5194/wcd-2022-63.

Jackson, Christopher, Tyler Ruff, John Knaff, Alexis Mouche, and Charles Sampson. “Chasing Cyclones from Space.” Eos 102 (2021).

Knaff, John A., Charles R. Sampson, Matthew E. Kucas, Christopher J. Slocum, Michael J. Brennan, Thomas Meissner, Lucrezia Ricciardulli, et al. “Estimating Tropical Cyclone Surface Winds: Current Status, Emerging Technologies, Historical Evolution, and a Look to the Future.” Tropical Cyclone Research and Review 10, no. 3 (September 1, 2021): 125–50. https://doi.org/10.1016/j.tcrr.2021.09.002.

Li, Huimin, Bertrand Chapron, Alexis Mouche, and Justin E. Stopa. “A New Ocean SAR Cross-Spectral Parameter: Definition and Directional Property Using the Global Sentinel-1 Measurements.” Journal of Geophysical Research: Oceans 124, no. 3 (2019): 1566–77. https://doi.org/10.1029/2018JC014638.

Longepe, N., A. Mouche, R. Husson, E. Pottier, and O. Archer. “Co-Cross Polarization Coherence Over Sea Surface from Sentinel-1 Data: Perspectives for Mission Calibration and Wind Field Retrieval.” In IGARSS 2019 - 2019 IEEE International Geoscience and Remote Sensing Symposium, 4681–84, 2019. https://doi.org/10.1109/IGARSS.2019.8898803.

Moiseev, A., H. Johnsen, J. A. Johannessen, F. Collard, and G. Guitton. “On Removal of Sea State Contribution to Sentinel-1 Doppler Shift for Retrieving Reliable Ocean Surface Current.” Journal of Geophysical Research: Oceans 125, no. 9 (2020): e2020JC016288. https://doi.org/10.1029/2020JC016288.

Mouche, Alexis A., Bertrand Chapron, Biao Zhang, and Romain Husson. “Combined Co-and Cross-Polarized SAR Measurements under Extreme Wind Conditions.” IEEE Transactions on Geoscience and Remote Sensing 55, no. 12 (2017): 6746–55.

Rojo, M., C. Claud, G. Noer, and A. M. Carleton. “In Situ Measurements of Surface Winds, Waves, and Sea State in Polar Lows Over the North Atlantic.” Journal of Geophysical Research: Atmospheres 124, no. 2 (2019): 700–718. https://doi.org/10.1029/2017JD028079.

Schmidt, Kersten, Marco Schwerdt, Guillaume Hajduch, Pauline Vincent, Andrea Recchia, and Muriel Pinheiro. “Radiometric Re-Compensation of Sentinel-1 SAR Data Products for Artificial Biases Due to Antenna Pattern Changes.” Remote Sensing 15, no. 5 (2023): 1377.

Zanchetta, Andrea, and Stefano Zecchetto. “Wind Direction Retrieval from Sentinel-1 SAR Images Using ResNet.” Remote Sensing of Environment, November 20, 2020, 112178. https://doi.org/10.1016/j.rse.2020.112178.

Appendix C - S1 and RS-2 acquisitions

The following tables counts:

- The S1 activations sent to ESA S1 ground segment to require an update of S1 acquisition plan. Please note that one activation can concern either one or several TC monitoring.
- The number of requests for RS-2 data sent to MDA for NRT data,
- The number of RS-2 data gathered from the RS-2 archive.

Tableau 1 : Table of Activation per month for S1 and RS-2

Month - Year	S-1 activations	RS-2 activations	RS-2 archive
Jul-21	1	1	
Aug-21	3	2	11
Sep-21	4	5	5
Oct-21	2	3	
Nov-21	0	0	
Dec-21	2	2	
Jan-22	3	3	
Feb-22	1	1	
Mar-22	3	4	
Apr-22	2	3	
May-22	0	0	
Jun-22	0	0	
Jul-22	4	0	
Aug-22	2	0	
Sep-22	5	0	
Oct-22	0	0	
Nov-22	1	0	
Dec-22	1	0	

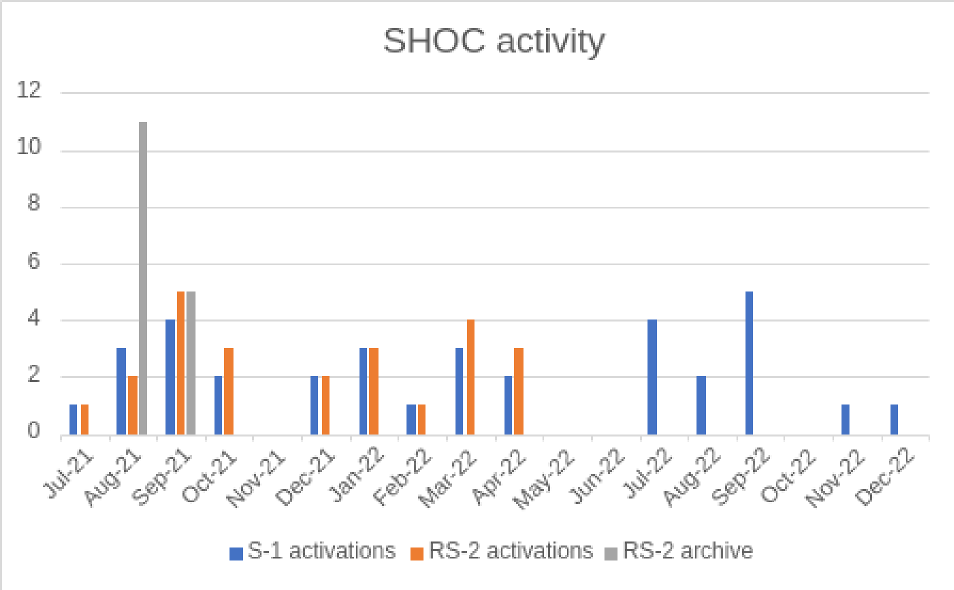


Figure 23: Histogram of number of activations for S-1 (blue), RS-2 (orange) per month

Appendix D - Associated delivered documents

ASS-D1: Kml of all SAR acquisitions performed in NRT over Tropical Cyclones

- sarproducts_20230214134458_NRT_EEW_EODA_until20221231.zip

ASS-D2: Kml of all SAR acquisitions performed in NRT over European Waters

- sarproducts_20230214130916_NRT_TC_EODA_20210701_20221231.zip

ASS-D3: Statistical analysis of SHOC acquisitions

- SHOC - activations - 07-2021 to 12-2022 - STATISTICS v3.xlsx

ASS-D4: Excel file of contacted end-users throughout CYMS 2 phases

- CYMS - End-users Listings V2.xlsx

Appendix E - Website analytics

Appendix E 1 - ESA-CYMS Website

The following statistics are given for the time period: Jun 1st 2021 to Dec 31st 2022

All Users
100.00% Sessions

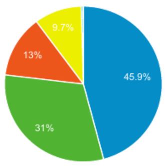
Users
1,682
% of Total: 100.00% (1,682)

New Users
1,678
% of Total: 100.00% (1,678)

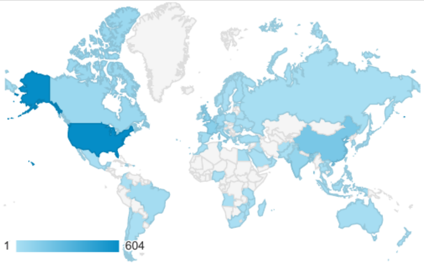
Sessions
2,231
% of Total: 100.00% (2,231)

Number of Sessions per User
1.33
% of Total: 100.00% (1.33)

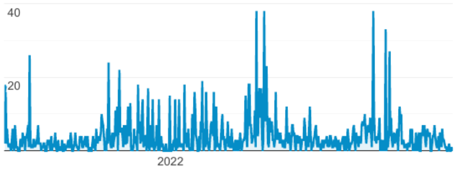
Visits by Traffic Type



Users



Visits



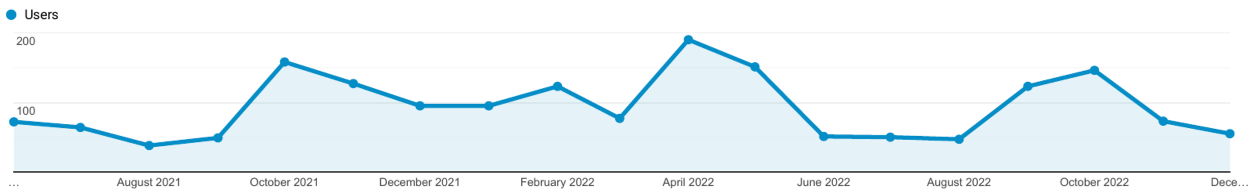
Pageviews and Users by Page Title

Page Title	Pageviews	Users
CYMS - Cyclone Monitoring Service based on Sentinel-1	1,178	899
Data access - Cyclone Monitoring Service based on Sentinel-1	512	179
About CYMS - Cyclone Monitoring Service based on Sentinel-1	295	196
Webinar announcement - Cyclone Monitoring Service based on Sentinel-1	252	177
Documentation - Cyclone Monitoring Service based on Sentinel-1	241	95
Uses cases - Cyclone Monitoring Service based on Sentinel-1	142	115
Webinar - Cyclone Monitoring Service based on Sentinel-1	136	116
Applications - Cyclone Monitoring Service based on Sentinel-1	101	85
News - Cyclone Monitoring Service based on Sentinel-1	90	56
Tropical cyclones' impact on the ocean - Cyclone Monitoring Service based on Sentinel-1	76	59

Visits and Avg. Visit Duration by City

City	Sessions	Avg. Session Duration
(not set)	537	00:01:06
Washington	202	00:00:00
Ashburn	100	00:00:00
Brest	87	00:01:37
Paris	56	00:01:57
Reading	43	00:01:25
Columbus	42	00:00:00
Cardiff	37	00:00:00
London	36	<00:00:01
Toulouse	32	00:00:28

Overview



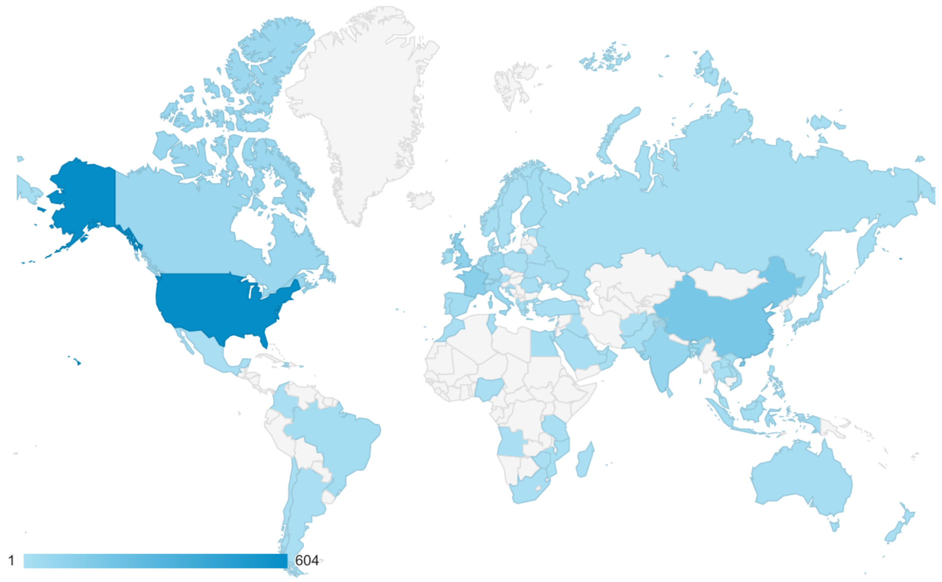
Users	New Users	Sessions	Number of Sessions per User
1,682	1,678	2,231	1.33

Pageviews	Pages / Session	Avg. Session Duration	Bounce Rate
3,545	1.59	00:01:00	74.54%

	Language	Users	% Users
1.	en-us	834	49.58%
2.	c	208	12.37%
3.	zh-cn	180	10.70%
4.	en-gb	103	6.12%
5.	fr	54	3.21%
6.	fr-fr	48	2.85%
7.	en-us.utf-8	30	1.78%
8.	it-it	26	1.55%
9.	es-es	18	1.07%
10.	ja	18	1.07%

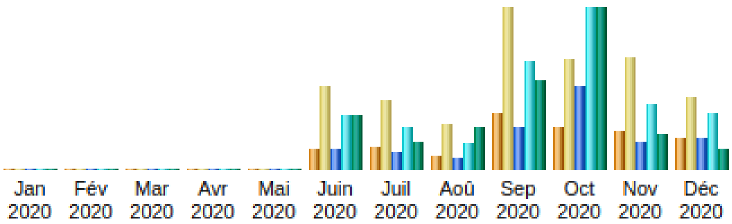
Map Overlay

Summary

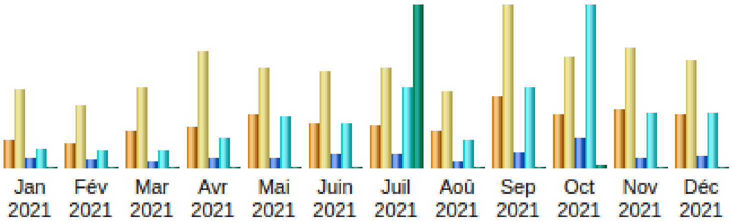


Country	Acquisition			Behavior			Conversions		
	Users	New Users	Sessions	Bounce Rate	Pages / Session	Avg. Session Duration	Goal Conversion Rate	Goal Completions	Goal Value
	1,682 % of Total: 100.00% (1,682)	**1,679** % of Total: 100.06% (1,678)	**2,231** % of Total: 100.00% (2,231)	**74.54%** Avg for View: 74.54% (0.00%)	**1.59** Avg for View: 1.59 (0.00%)	**00:01:00** Avg for View: 00:01:00 (0.00%)	**0.00%** Avg for View: 0.00% (0.00%)	**0** % of Total: 0.00% (0)	**€0.00** % of Total: 0.00% (€0.00)
1. United States	**604** **(35.43%)**	604 (35.97%)	615 (27.57%)	95.61%	1.10	00:00:08	0.00%	0 (0.00%)	€0.00 (0.00%)
2. China	**180** **(10.56%)**	179 (10.66%)	312 (13.98%)	71.47%	1.58	00:01:46	0.00%	0 (0.00%)	€0.00 (0.00%)
3. France	**120** **(7.04%)**	114 (6.79%)	303 (13.58%)	53.14%	2.06	00:01:39	0.00%	0 (0.00%)	€0.00 (0.00%)
4. United Kingdom	**107** **(6.28%)**	103 (6.13%)	139 (6.23%)	69.78%	1.61	00:00:39	0.00%	0 (0.00%)	€0.00 (0.00%)
5. India	**78** **(4.57%)**	77 (4.59%)	85 (3.81%)	80.00%	1.36	00:00:24	0.00%	0 (0.00%)	€0.00 (0.00%)
6. Canada	**56** **(3.28%)**	57 (3.39%)	59 (2.64%)	89.83%	1.24	00:00:36	0.00%	0 (0.00%)	€0.00 (0.00%)
7. Italy	**52** **(3.05%)**	49 (2.92%)	69 (3.09%)	53.62%	2.35	00:02:40	0.00%	0 (0.00%)	€0.00 (0.00%)
8. Germany	**44** **(2.58%)**	41 (2.44%)	55 (2.47%)	70.91%	2.18	00:01:38	0.00%	0 (0.00%)	€0.00 (0.00%)
9. Netherlands	**35** **(2.05%)**	35 (2.08%)	38 (1.70%)	57.89%	2.00	00:01:34	0.00%	0 (0.00%)	€0.00 (0.00%)
10. Japan	**29** **(1.70%)**	28 (1.67%)	32 (1.43%)	75.00%	2.97	00:03:00	0.00%	0 (0.00%)	€0.00 (0.00%)
11. Spain	**26** **(1.52%)**	26 (1.55%)	48 (2.15%)	54.17%	2.06	00:01:04	0.00%	0 (0.00%)	€0.00 (0.00%)
12. Brazil	**24** **(1.41%)**	24 (1.43%)	26 (1.17%)	57.69%	1.50	00:00:10	0.00%	0 (0.00%)	€0.00 (0.00%)
13. Finland	**24** **(1.41%)**	24 (1.43%)	24 (1.08%)	83.33%	1.17	00:00:00	0.00%	0 (0.00%)	€0.00 (0.00%)
14. Hong Kong	**23** **(1.35%)**	22 (1.31%)	30 (1.34%)	83.33%	1.50	00:00:36	0.00%	0 (0.00%)	€0.00 (0.00%)
15. Indonesia	**22** **(1.29%)**	19 (1.13%)	28 (1.26%)	60.71%	1.61	00:02:19	0.00%	0 (0.00%)	€0.00 (0.00%)
16. Australia	**17** **(1.00%)**	17 (1.01%)	18 (0.81%)	66.67%	1.44	00:00:20	0.00%	0 (0.00%)	€0.00 (0.00%)
17. Singapore	**15** **(0.88%)**	15 (0.89%)	25 (1.12%)	64.00%	1.84	00:01:39	0.00%	0 (0.00%)	€0.00 (0.00%)
18. Philippines	**14** **(0.82%)**	14 (0.83%)	15 (0.67%)	80.00%	1.33	00:00:10	0.00%	0 (0.00%)	€0.00 (0.00%)
19. Russia	**12** **(0.70%)**	12 (0.71%)	13 (0.58%)	69.23%	1.69	00:01:28	0.00%	0 (0.00%)	€0.00 (0.00%)

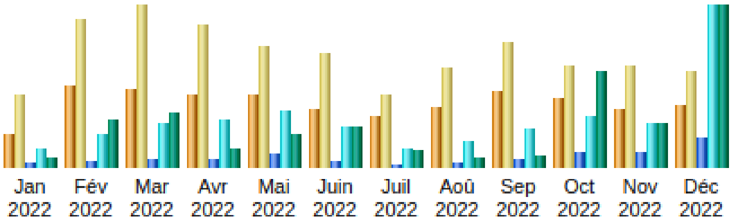
Appendix E 2 - CyclObs Website



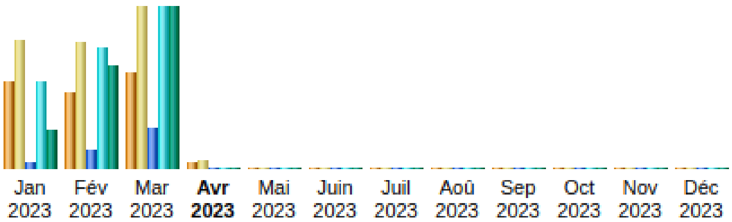
Mois	Visiteurs différents	Visites	Pages	Hits	Bande passante
Jan 2020	0	0	0	0	0
Fév 2020	0	0	0	0	0
Mar 2020	0	0	0	0	0
Avr 2020	0	0	0	0	0
Mai 2020	0	0	0	0	0
Juin 2020	74	285	1 581	4 256	2.57 Go
Juil 2020	77	240	1 276	3 329	1.29 Go
Aoû 2020	46	157	970	1 999	1.98 Go
Sep 2020	192	556	3 296	8 454	4.18 Go
Oct 2020	147	379	6 439	12 516	7.57 Go
Nov 2020	133	387	2 089	5 054	1.62 Go
Déc 2020	106	248	2 446	4 449	976.31 Mo
Total	775	2 252	18 097	40 057	20.18 Go



Mois	Visiteurs différents	Visites	Pages	Hits	Bande passante
Jan 2021	108	305	2 099	4 251	1.21 Go
Fév 2021	95	243	1 669	3 730	4.44 Go
Mar 2021	143	309	1 255	3 532	1.64 Go
Avr 2021	156	448	2 034	6 390	1.32 Go
Mai 2021	204	388	2 105	11 053	1.54 Go
Juin 2021	170	374	2 731	9 518	1.55 Go
Juil 2021	167	390	2 984	17 357	2.53 TB
Aoû 2021	143	296	1 218	6 014	918.39 Mo
Sep 2021	273	629	3 131	17 062	4.09 Go
Oct 2021	209	430	6 228	34 892	48.52 Go
Nov 2021	230	463	2 247	11 999	3.66 Go
Déc 2021	204	417	2 495	11 881	6.31 Go
Total	2 102	4 692	30 196	137 679	2.60 TB



Mois	Visiteurs différents	Visites	Pages	Hits	Bande passante
Jan 2022	146	317	1 626	7 765	3.62 Go
Fév 2022	356	652	2 643	13 694	18.83 Go
Mar 2022	343	707	3 209	18 546	21.70 Go
Avr 2022	320	622	3 150	19 606	7.83 Go
Mai 2022	320	534	5 655	23 255	13.56 Go
Juin 2022	258	498	2 974	17 112	15.96 Go
Juil 2022	224	320	1 487	7 945	6.56 Go
Aoû 2022	261	433	1 796	10 662	3.86 Go
Sep 2022	336	549	3 387	16 217	4.42 Go
Oct 2022	300	443	6 504	20 959	38.12 Go
Nov 2022	257	447	6 416	18 376	17.59 Go
Déc 2022	271	424	12 411	66 987	64.42 Go
Total	3 392	5 946	51 258	241 124	216.47 Go



Mois	Visiteurs différents	Visites	Pages	Hits	Bande passante
Jan 2023	395	573	3 926	58 187	31.97 Go
Fév 2023	343	571	12 759	80 968	87.21 Go
Mar 2023	430	726	26 998	107 294	135.60 Go
Avr 2023	31	36	171	963	316.56 Mo
Mai 2023	0	0	0	0	0
Juin 2023	0	0	0	0	0
Juil 2023	0	0	0	0	0
Aoû 2023	0	0	0	0	0
Sep 2023	0	0	0	0	0
Oct 2023	0	0	0	0	0
Nov 2023	0	0	0	0	0
Déc 2023	0	0	0	0	0
Total	1 199	1 906	43 854	247 412	255.09 Go

Appendix F - CYMS listing

The full listing of end-users identified within the CYMS projects are listing in the document [ASS-D4]. This document is separated in 5 pages:

1-RSMC, TCWC & National TC Centres,

2-European Institutions,

3-New end-users (contacted within CYMS 2nd Phase),

4-Webinar invitation sent to...

5-Webinar inscriptions

The following entities (3-New end-users) were contacted individually and a full CYMS presentation and demonstration was performed for those interested in organizing a visio-conference (indicated below):

Type	Insitution / Company	Contact	Presentation by email	Visio conference	Email
Reinsurance	CCR	Thomas Onfroy	yes	yes - 04/02/2022	tonfroy@ccr.fr
Maritime transport	CMA-CGM	Jocelyn RAPP	yes	yes - 15/12/2020	nav.jrapp@cma-cgm.com
Applicative Coastal Ocean modelling in Europe	CMCC (Italy)	Giovanni Coppini Nadia Pinardi	yes	yes	Giovanni Coppini <giovanni.coppini@cmcc.it> Nadia Pinardi <nadia.pinardi@unibo.it>
Applicative Coastal Ocean modelling in Europe	IMEDEA (spain/ Baléares)	Baptiste Mourre + Joaquin Tintoré	yes	yes	Baptiste Mourre <bmourre@socib.es> Joaquín Tintoré Subirana <jtintore@socib.es>
Coastal Ocean modelling in Europe	Univ de Liège (Belgique)	Alexander Barth	yes	yes	Barth, Alexander <a.barth@uliege.be>
Coastal Ocean modelling in Europe	Tunisie	Slim Gana	yes	yes	slim.gana@sea-gust.com
Modélisation Risques côtiers/ Alerte précoce	BRGM - riscope	Déborah Idier	yes	yes	d.idier@brgm.fr
Research Institute	HCMR	Emmanouil Flaounas, Marcello Miglietta	yes	yes	em.flaounas@hcmr.gr ; m.miglietta@isac.cnr.it

Private company	Dat4Risk	Stavros Dafis	yes	yes	sdafis@noa.gr
Private Meteo	WNI	Hugo Reveney	yes	no	hugo@wni.com
Private Meteo	Tomorrow (https://www.tomorrow.io/)		yes	no	
Insurance	Axa Climate	Melodie Trolliet	yes	no	
Insurance	Descartes Underwriting	Kevin Dedieu	yes	no	kevin.dedieu@descartesunderwriting.com
Caraibes /SAMTool/Meteo + UNESCO	Director Meteorological Department ARUBA + Aruba National Commission for UNESCO	Marck Oduber	yes	no	m.oduber@unesco.aw
Caraibes /SAMTool/Environment	Directorate of Nature and Environment of Aruba (DNM)	Robert Kock	yes	no	robert.kock@dnmaruba.org
Caraibes /SAMTool/Meteo	Caribbean Institute for Meteorology and Hydrology - Barbades	Niles Grahame	yes	no	gniles@cimh.edu.bb
Caraibes /SAMTool/ Environment	STINAPA National Park Bonnaire	Caren Eckrich	yes	no	nature@stinapa.org
Caraibes /SAMTool/Meteo	Meteorological Dpt Curacao /WMO (psdt)	Albert Martis	yes	no	albert.martis@meteo.cw
Caraibes /SAMTool/Aff Maritimes	government agency Maritime Affairs Authority - rep Dominicaine	Omar Shamir	yes	no	Omar_shamir@hotmail.com
Caraibes /SAMTool/Meteo	Head of Meteorological Department - Sint Maarten	Joseph Isaac	yes	no	joseph.isaac@sintmaartengov.org
Caraibes/ Cyclones/ via BRGM CaribCoast	CARICOOS	Julio Morell (directeur) + Juan Gonzalez +Patricia Chardon	yes	no	jmorell55@gmail.com julio.morell@upr.edu

Applicative Coastal Ocean modelling in Europe	Deltares (Netherlands)	Marieke Eleveld	yes	no	Marieke Eleveld <Marieke.Eleveld@deltares.nl>
Coastal Ocean modelling in Europe	COSTT mailing list		yes	no	kirsten.wilmer-becke@metoffice.gov.uk demey-redir@neyak.org Villy Kourafalou <vkourafalou@miami.edu>
CEMS/ prototype system alerte coastal flood	ECFAS	Clara Armaroli	yes	no	clara.armaroli@iusspavia.it
Caraibes /SAMTool/ Recherche	UWI-CERMES - Barbades	Shelly-Ann Cox	yes	no	shellsalc@gmail.com
Applicative Coastal Ocean modelling in Europe	DUTH (Greece)	Georgios Sylaos	yes	no	GEORGIOS SYLAIOS <gsylaios@env.duth.gr>