KEPLER Deliverable Report

Report on Deliverable D7.4

Deliverable name	Report on end of project meeting			
Scheduled delivery	**month:**	30	**date:**	June 2021
Actual delivery	**month:**	30	**date:**	June 2021
Report type	Internal Report			
Lead author	Emma Armitage, UKRI - BAS			

Contributing authors

Elaina Ford (UKRI-BAS)

Nick Hughes (Met.No)

Marcin Pierechod (Met.No)

WP leaders, project participants, and PAB.

Context of deliverable within Work Package

This is the final KEPLER meeting report, one of three whole-project annual meetings. The first was the kick-off, D7.2, at the start of the project in Oslo. The mid-term meeting was held at the end of the first year, in November 2019 at CSIC in Barcelona. This Final General Assembly Meeting was held online using ZOOM conferencing software on 21st-22nd June 2021.

Explanation of delays

This meeting was held on time, although virtually via ZOOM due to ongoing travel restrictions due to the COVID-19 pandemic.

Co-funded by the Horizon 2020 programme of the European Union

KEPLER

Final Meeting Report

21st-22nd June 2021

Meeting Report

Co-funded by the Horizon 2020 programme of the European Union

SEVENTH FRAMEWORK PROGRAMME

KEPLER Final General Assembly Meeting Report

21st -22nd June 2021

Overview

The KEPLER Final General Assembly meeting was held online on 21st-22nd June 2021 using ZOOM conferencing software. Due to the ongoing travel restrictions caused by COVID-19, KEPLER has adapted to hosting regular virtual meetings. We split the GA across two days, consisting of presentations & discussions from all work packages. Day 1 was an open event, with invites extended to external stakeholders and the public. Day 2 of the meeting was reserved for internal KEPLER project participants only, to discuss remaining deliverables and end of project reporting. Splitting the meeting allowed for shorter days and sufficient breaks to avoid ZOOM fatigue. We also utilised the online networking platform- wonder.me to host an evening networking event on the first day of the General Assembly.

This event was advertised via the KEPLER website, social media, and mailing lists. It was also promoted by the EU Polar Cluster and distributed to stakeholders and the Project Advisory Board. Over 57 participants registered for this event.

46 attendees from 17 European institutes discussed the output of the KEPLER project and feedback on the current draft roadmap for Copernicus to deliver an improved European capacity for monitoring and forecasting the Polar Regions.

More information can be found on the project website at http://kepler-polar.eu/ and via Twitter @KeplerEU.

All presentations from the KEPLER Final GA Meeting can be found here: Final GA Meeting Presentations

Contents

Timetable

Overview timetable

Monday 21st June: - Open to all - invitations to EU Polar Cluster and ESA Polar Cluster:

*Timings in **BST (GMT+1)***

08:50 – 09:00	Coffee & Joining.
09:00 – 09:10	Welcome and debrief.
09:10 – 09:30	WP1 Task presentations
09:30 – 09:45	WP1 Questions/ Open discussion
09:45 – 10:05	WP2 Task presentations
10:05 – 10:25	WP2 Questions/ Open discussion
10:25 – 10:35	Tea Break
10:35 – 11:05	WP3 Task presentations
11:05 – 11:25	WP3 Questions/ Open discussion
11:25 – 11:40	WP4 Task presentations
11:40 – 12:05	WP4 Questions/ Open discussion
12:05 – 13:05	Lunch
13:05 – 13:25	WP5 Task presentations
13:25 – 14:05	WP5 Questions/ Road map Open discussion
14:05 – 14:15	Copernicus update
14:15 – 14:30	WP6 Dissemination: KEPLER Video
14:30 – 14:40	Tea Break
14:40 – 15:00	WP6 KEPLER Glossy brochures and feedback
15:00 – 15:30	Open session for further discussion
15:30	End of Day 1
15:30 – 17:00	Extended open session time can be arranged if required.
18:00	Virtual drinks

Overview Timetable

Tuesday 22nd June -KEPLER participants only

09:50 – 10:00	Coffee & Joining.
10:00 – 10:20	KEPLER Finance reporting overview.
10:20 – 10:40	KEPLER Final reporting overview.
10:40	**Remaining deliverables review:**
10:40 – 11:00	**Deliverable 6.4**- group input/review on Dissemination and Exploitation report
11:00 – 11:10	**Deliverable 6.5** -any input required.
11:10 – 11:20	Break
11:20 – 11:40	**Deliverable 5.2**- further input/ review time
11:40 – 12:00	End of Project Dissemination feedback: Glossy brochure & Video % Map.
12:00 – 12:30	Optional time for further discussion
12:30	End of Final KEPLER GA.

Programme

Copies of the presentations are available through ADD LINK

Monday 21st June

Monday 21st June			
Topic	Time - EST	Presentation	Speaker
	08:50 – 09:00	**Joining**	
	09:00 – 09:10	Welcome and debrief	Nick Hughes
WP1	**Work Package 1** Stakeholder Needs and Network Coordination		
	09:10 – 09:15	T1.1: Maritime and Research Sector Needs	Penelope Wagner
	09:15 – 09:20	T1.2 Community-based Observing and Societal	Tero Mustonen
	09:20 – 09:25	T1.3 Climate and Weather Forecasting Needs	Helge Goessling
	09:25 – 09:30	T1.4: Overall assessment of stakeholder needs	Penelope Wagner
	09:30 – 09:45	WP1 Questions/ Open discussion	
WP2	**Work Package 2**- Polar Regions provision in Copernicus Services		
	09:45 – 09:55	T2.1 Copernicus Land Monitoring Service (CLMS)	Gilles Garric
	09:55 – 10:05	T2.2 Copernicus Marine Environment Monitoring Service (CMEMS).	Marko Scholze
	10:05 – 10:25	WP2 Questions/ Open discussion	
	10:25 – 10:35	**Tea Break**	
WP3	**Work Package 3** -Identification of research and capacity gaps		
	10:35 – 10:40	T3.1 In situ observing systems.	Jeremy Wilkinson

	10:40 – 10:45	T3.2 New and novel in-situ and airborne observation sensors and techniques.	Nick Hughes
	10:45 – 10:50	T3.3 Space-based capability	Carolina Gabarro
	10:50 – 10:55	T3.4 Integration and assimilation through Quantitative Network Design (QND).	Thomas Kaminski
	10:55 – 11:05	Deliverable 3.5 Executive Summary	Carolina Gabarro
	11:05 – 11:25	WP3 Questions/ Open discussion	
Work Package 4 - Improved sea-ice mapping and forecasting.			
WP4	11:25 – 11:30	T4.1 Sea-ice mapping for maritime purposes.	Antti Kangas
	11:30 – 11:35	T4.2 Monitoring sea-ice as an essential climate variable (ECV).	Thomas Lavergne
	11:35 – 11:40	T4.3 Assess the scope for sea-ice forecast products.	Steffen Tietsche
	11:40 – 12:05	WP4 Questions and discussion	
12:05 – 13:05 Lunch Break			
Work Package 5 - End-to-end operational system			
WP5	13:05 – 13:15	T5.1 Synthesis on the visions of the evolution of the Copernicus services.	Laurent Bertino
	13:15 – 13:25	T5.2 End-to-end operational system roadmap.	Frank Kauker
	13:25 – 14:05	WP5 Questions and discussion	
	14:05 – 14:15	Copernicus update	tbc
	14:15 – 14:30	WP6 Dissemination: KEPLER Video	Nick Hughes
14:30 – 14:40 Tea Break			
Work Package 6 -			

WP6	14:40 – 15:00	WP6 KEPLER Glossy brochures and feedback	Emma Armitage
	15:00 – 15:30	Open sessions for discussion	Emma Armitage
15:30 Day 1 end (Extended open session time available if required)			
	18:00 –	Virtual drinks	All welcome

Tuesday 22nd June

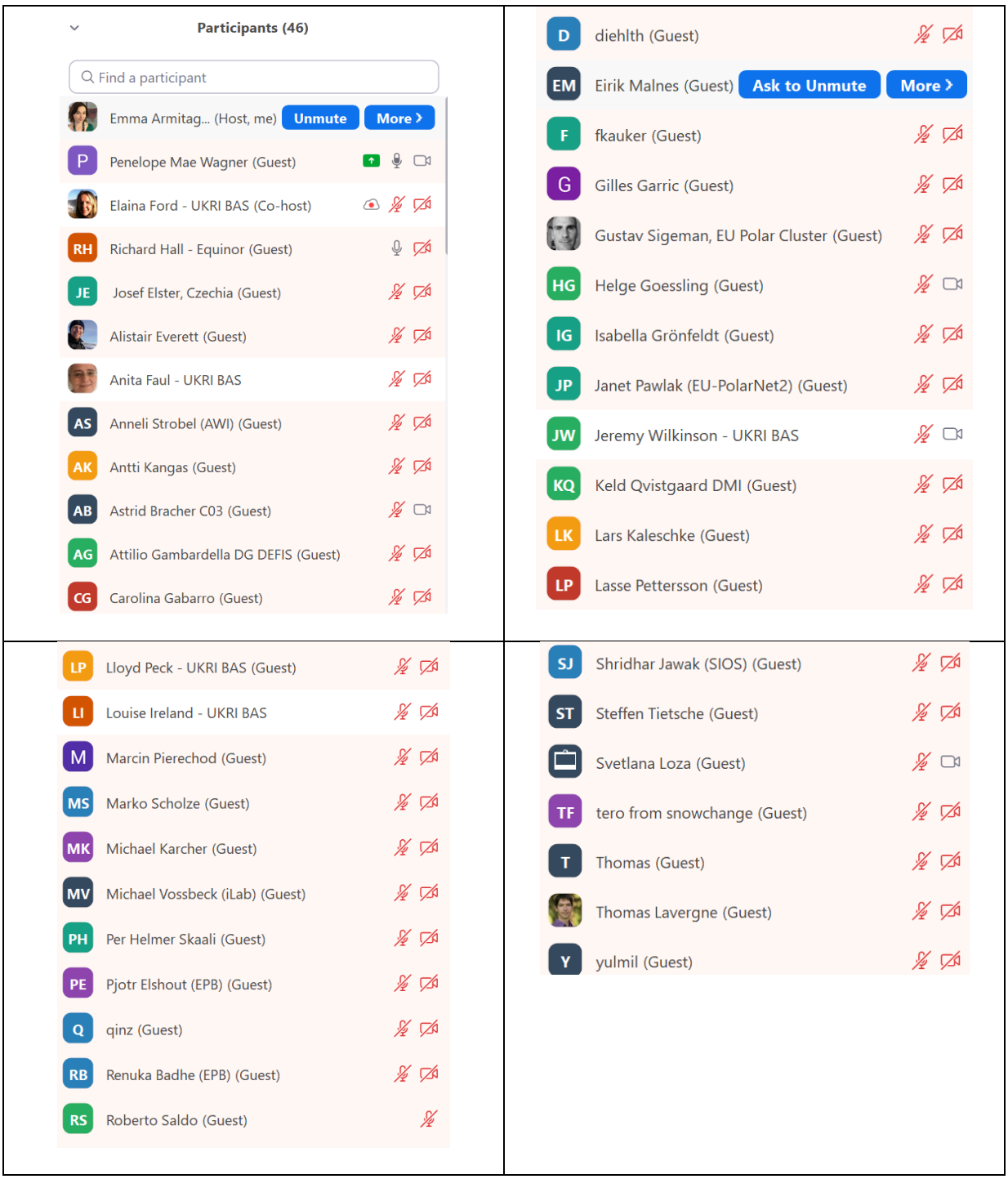
Tuesday 22nd June *(KEPLER participants only)*			
Topic	Time	Presentation	Speaker
09:50 – 10:00 Joining			
	KEPLER Reporting/Management		
	10:00 – 10:20	KEPLER Finance reporting- overview	Elaina Ford
	10:20 – 10:40	KEPLER Final report- overview	Elaina Ford
	10:40 – 11:00	Deliverable 6.4- group input/review on Dissemination and Exploitation report	Elaina Ford
	11:00 – 11:10	Deliverable 6.5- group input/	Elaina Ford
11:10 – 11:20 Break			
	11:20 – 11:40	Deliverable 5.2- further input/ review time	Frank Kauker
	11:40 – 12:00	End of Project Dissemination feedback: Glossy brochure & Video	Elaina Ford
	12:00 – 12:30	Optional time for further discussion	
12:30 End of Final KEPLER GA			

Registered attendees

First Name	Surname	Institute/organisation
Emma	Armitage	British Antarctic Survey
Beena	Balan-Sarojini	ECMWF
Anna	Belcher	BAS
Laurent	Bertino	NERSC
Ed	Blockley	Met Office
Astrid	Bracher	AWI
James	Byrne	British Antarctic Survey
Thomas	Diehl	JRC
Wolfgang	Dierking	Alfred-Wegner-Institut
Mark	Drinkwater	European Space Agency
Pjotr	Elshout	European Polar Board
Josef	Elster	Centre for Polar Ecology, University of South Bohemia
Alistair	Everett	Norwegian Meteorological Institute
Anita	Faul	British Antarctic Survey
Elaina	Ford	British Antarctic Survey
Carolina	Gabarro Prats	ICM/CSIC
Attilio	Gambardella	European Commission
Gilles	Garric	Mercator Ocean International
Helge	Goessling	Alfred Wegener Institute
Isabella	Grönfeldt	SMHI
Richard	Hall	Equinor
Knut	Holba	NERSC
Nick	Hughes	Norwegian Meteorological Institute
Louise	Ireland	British Antarctic Survey
Shridhar	Jawak	Svalbard Integrated Arctic Earth Observing System (SIOS)
Lars	Kaleschke	Alfred-wegener-institut Helmholtz-zentrum Für Polar Und Meeresforschung
Thomas	Kaminski	The Inversion Lab
Antti	Kangas	Finnish Meteorological Institute

First Name	Surname	Institute/organisation
Michael	Karcher	Alfred Wegener Institute for Polar and Marine Research
Frank	Kauker	OASYS
Thomas	Lavergne	Norwegian Meteorological Institute
Amelie	Lecornec	Sorbonne Université
Risto	Makkonen	Finnish Meteorological Institute
Eirik	Malnes	NORCE
Yulia	Milova	Nansen Environmental and Remote Sensing Center (NERSC)
Øyvind	Paasche	Bjerknes Centre for Climate Research/ Climate Futures
Janet	Pawlak	Arctic Monitoring and Assessment Programme Secretariat
Lloyd	Peck	British Antarctic survey
Leif Toudal	Pedersen	eolab.dk
Lasse	Pettersson	Nansen Center (NERSC)
Marcin	Pierechod	Norwegian Meteorological Institute
Tahnee	Prior	Women of the Arctic
Christine	Provost	LOCEAN/CNRS
Keld	Qvistgaard	Danish Meteorological Institute
Roberto	Saldo	Technical University of Denmark, DTU Space
Marko	Scholze	Lund University
Gustav	Sigeman	Nord Universitet
Per Helmer	Skaali	MET Norway
Anneli	Strobel	AWI
Jennie	Thomas	IGE/CNRS
Steffen	Tietsche	ECMWF
Michael	Vossbeck	The Inversion Lab
Penelope	Wagner	Norwegian Meteorological Institute
Penelope	Wagner	Norwegian Meteorological Institute, Norwegian Ice Service
Jeremy	Wilkinson	BAS
Qin	Zhang	Norwegian Meteorological Institute

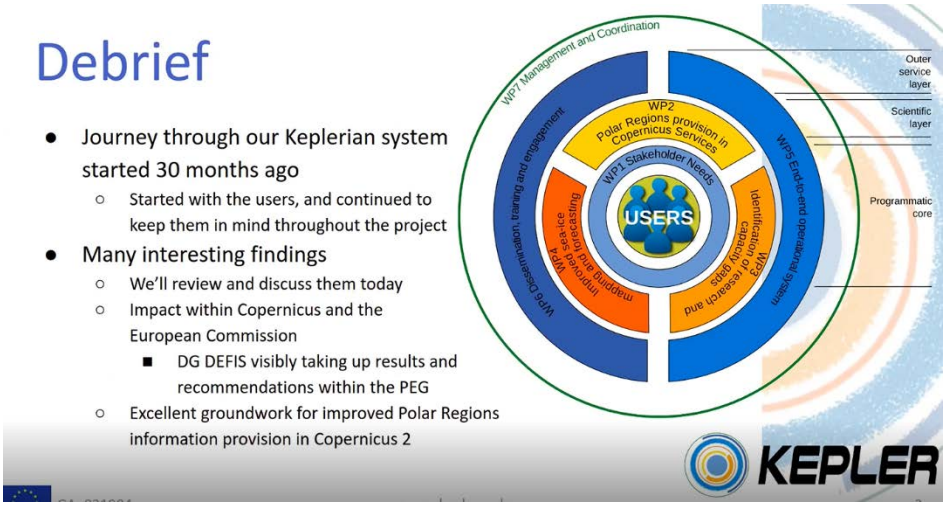
Participants


Participants (46)
Find a participant
Emma Armitag... (Host, me) Unmute More
Penelope Mae Wagner (Guest)
Elaina Ford - UKRI BAS (Co-host)
Richard Hall - Equinor (Guest)
Josef Elster, Czechia (Guest)
Alistair Everett (Guest)
Anita Faul - UKRI BAS
Anneli Strobel (AWI) (Guest)
Antti Kangas (Guest)
Astrid Bracher C03 (Guest)
Attilio Gambardella DG DEFIS (Guest)
Carolina Gabarro (Guest)
diehlth (Guest)
Eirik Malnes (Guest) Ask to Unmute More
fkauker (Guest)
Gilles Garric (Guest)
Gustav Sigeman, EU Polar Cluster (Guest)
Helge Goessling (Guest)
Isabella Grönfeldt (Guest)
Janet Pawlak (EU-PolarNet2) (Guest)
Jeremy Wilkinson - UKRI BAS
Keld Qvistgaard DMI (Guest)
Lars Kaleschke (Guest)
Lasse Pettersson (Guest)
Lloyd Peck - UKRI BAS (Guest)
Louise Ireland - UKRI BAS
Marcin Pierechod (Guest)
Marko Scholze (Guest)
Michael Karcher (Guest)
Michael Vossbeck (iLab) (Guest)
Per Helmer Skaali (Guest)
Pjotr Elshout (EPB) (Guest)
qinz (Guest)
Renuka Badhe (EPB) (Guest)
Roberto Saldo (Guest)
Shridhar Jawak (SIOS) (Guest)
Steffen Tietsche (Guest)
Svetlana Loza (Guest)
tero from snowchange (Guest)
Thomas (Guest)
Thomas Lavergne (Guest)
yulmil (Guest)

Day 1

Co-ordinator's Welcome and Overview of KEPLER - Nick Hughes

The third and final GA kicked off with a welcome and introduction from Nick Hughes, Project Co-ordinator. Attendees were informed of the times for both days and given an overview of the agenda that was shared via email. Day 1 focused on work packages 1-5, with overview presentations on each subtask and plenty of time for questions and discussions. Participants were also invited to view some of the WP6 dissemination activities such as the KEPLER video and brochures.



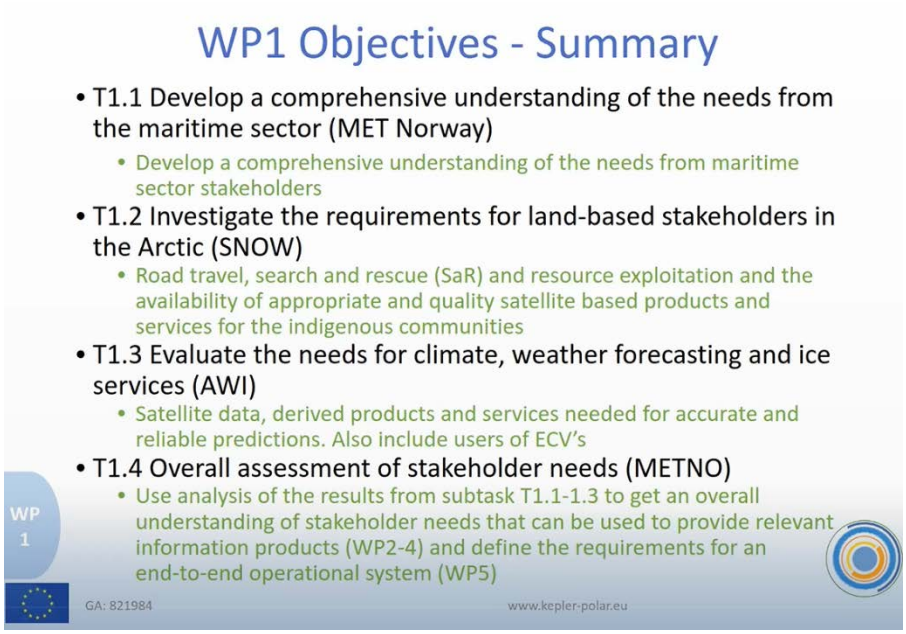
A quick project debrief was given, summarising the activities of the past 30 months. Starting with user requirements and keeping them in mind throughout the project. Based on the feedback gathered so far KEPLER consortium members are confident to already have some impact on Copernicus, specifically DG DEFIS taking up KEPLER results and recommendations within the PEG report.

The project timeline was modified to account for delays due to COVID. A three-month extension was granted by the EC to assist with the completion of deliverables and to hold meetings virtually due to travel restrictions. To date, most deliverables and milestones are complete, or near completion - the three remaining deliverable draft reports have been sent for review by the board/consortium and will be finalised later this week. Nick Hughes stresses that the presentations and feedback from this meeting will aid finalising the end-to-end operational system roadmap.

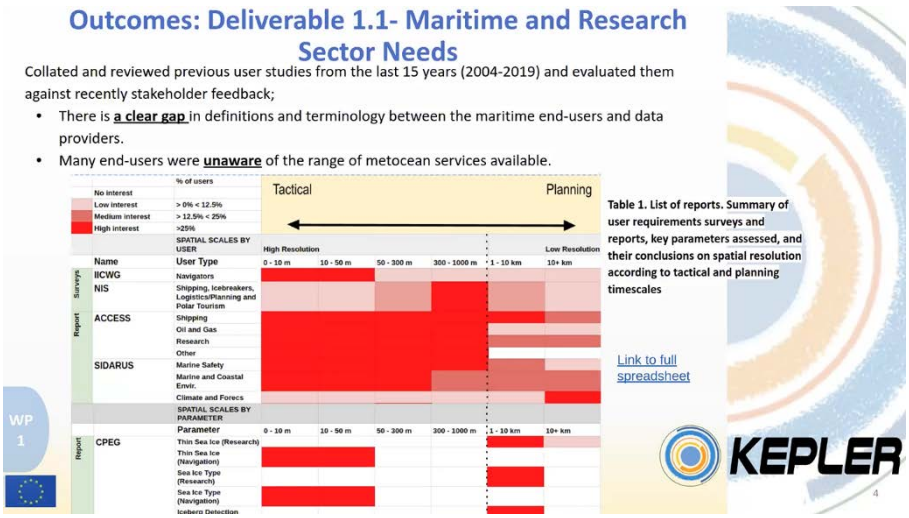
- The roadmap stresses that: Improved Polar Regions information provision.
  - Services become more user relevant.
  - Greater attention to quality control at all levels.
  - Increased use of observation data for validation.

WORK PACKAGE 1: Stakeholder Needs and Network Coordination - Penelope Wagner

Work Package Leader, Penny Wagner, welcomed all to the GA and introduced the WP1 presentations for the day. The four tasks & objectives in WP1 were summarised as below:



T1.1 Maritime and Research Sector Needs - Penelope Wagner



Task 1.1 reviewed end user needs from the last 10 years, based on funded projects from the EC, ESA, internal surveys, reports and feedback from ice services and the international ice charting community. a comparison of what users have previously requested to their current needs today.

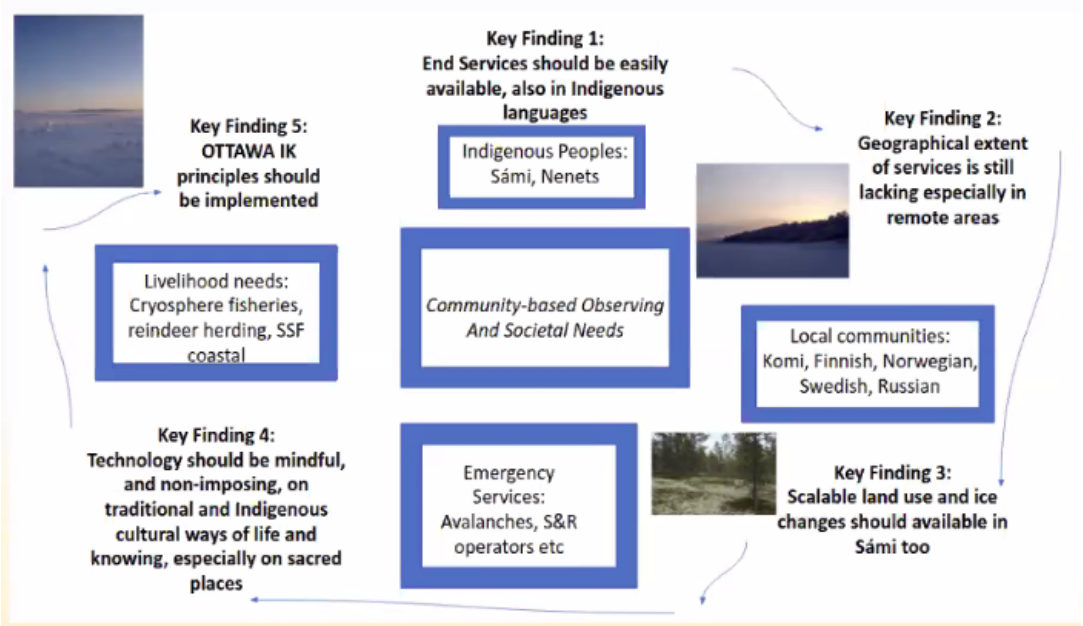
1.1 have identified a clear gap in the available services vs what users need. There is also a requirement for consistent well-defined terminology. In addition to this, many users are unaware of the range of services that are available, perhaps because the products are not being utilised fully by downstream services/intermediate users. Task 1.1 summarised their recommendations in the slide below:

Deliverable 1.1: Maritime and Research Sector Needs Recommendations

1. **User needs have been consistent over the last approximate 10 years** with regards to requiring improved higher spatial and temporal resolution satellite and derived products for maritime activities. Current limitations, particularly during the spring and summer seasons.
    - **Improved spatial resolution of satellite-derived sea ice products** and sea ice forecasts (sub kilometer but preferably <= 300 m)
2. Additional parameters in routine ice information for navigational support (i.e. **sea ice type, deformation and ridging, accurate ice edge mapping and coastal zones and detection of leads**)
3. Sea ice derived products that include information on accuracy and uncertainty
4. Expected greater **requirement for short and medium-term sea ice forecasts with better uncertainty estimates** over the next 5-10 years.
5. Future communication challenges at high latitudes and areas with topography (i.e. fjords and mountain regions) are expected to continue. **Products should be understandable, accessible and low bandwidth formats** such as .jpg or .png, more advanced could use GEOtiff with data format in S-411 and SIGRID-3,.
6. **Consistent and well-defined terminology** (i.e. high resolution, NRT, operational, short/long term)
7. **Iceberg products** that can display individual icebergs, ideally with all false targets filtered out
8. **The dissemination and intended uses of products** for the maritime community should be more transparent and easily understood by all users.

T1.2 Community-based Observing and Societal Needs - Tero Mustonen

Task leader, Tero Mustonen, presented five outcomes of community-based observing and societal needs. The community workshop held as milestone 6.7, and subsequent report for milestone 1.2, gathered evidence from local communities to inform the findings below:



The key high-level outcomes for task 1.2 are summarised below:

Key high-level outcomes:

1. Indigenous and traditional communities are still maintaining unique, even semi-nomadic lifestyles in the region but lack direct access to many services due to non- availability and costs.
2. A need for real-time, certified monitoring of industrial land uses, such as north boreal forestry would be in need to assess speed and scope of change.
3. Avalanche services could be increased and expanded.
4. Documentation of traditional land uses, such as lake fisheries and reindeer herding territories is a sensitive and careful process, and post-documentation of key areas and changes does not feed into changes in land use decisions or zoning.
5. SaR operator capacity to respond lacks in remote national parks and cell services are not still available in all locations.

A key point from work in task 1.2 is to stress to Copernicus that as we continue to explore community-based needs in the Arctic region, that these will form some relationship to growing geopolitical interests in that region. (For example, China's interest in building space centres in northern Sweden/Finland).

Therefore, it is critical to continue to explore and respect community needs and be mindful of these diverse land users (and their societies and culture) when creating recommendations for future services.

Tero Mustonen shared the following website to inform stakeholders of the Ottawa Principles of Indigenous Knowledge- see slide below.

The Komi, Saami and other villages have voiced their appreciation for KEPLER's efforts in fact-finding and enabling them to be heard on their terms.

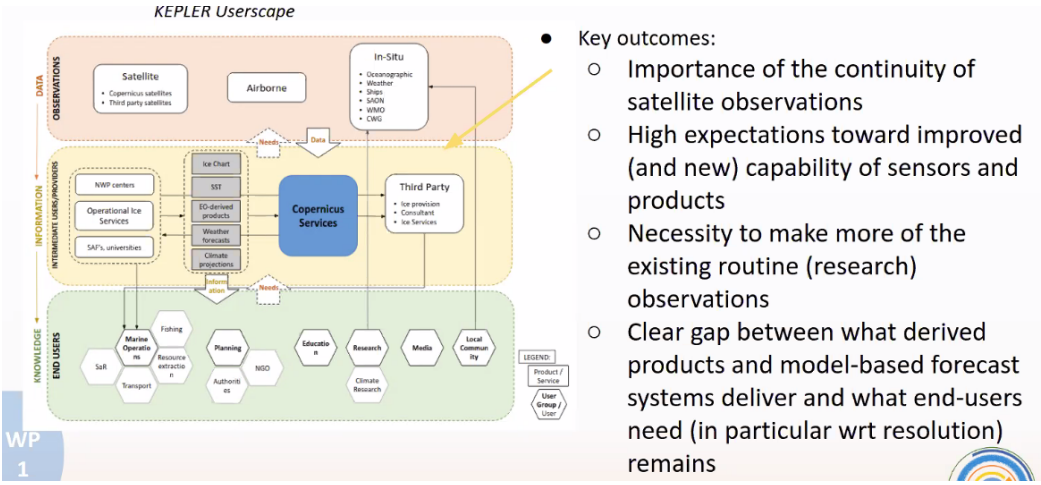
Deliverable 1.2: Community-based observing and societal needs Recommendations

1. **End-user services should be easily available**, also in Indigenous languages, such as the Saami, on hand-held portals and devices
2. **The coverage and affordability of services should cover all areas** of the Indigenous home areas, especially in the context of emergency services.
3. **Portals that portray real-time scalable land use and ice changes should be easily available**, also in Indigenous languages, such as the Saami, on hand-held portals and devices.
4. **Advancement of technological solutions should be mindful of the "slow culture" of Indigenous communities** and traditions. Data is not openly accessible always and intellectual property rights, Indigenous sacred engagement with their landscapes and places, harvest locations and other cultural aspects should be followed.
5. **All stakeholders are to be made aware of the Ottawa Principles of Indigenous Knowledge,** available at: http://www.saamicouncil.net/fileadmin/user_upload/Documents/Eara_dokumeantat/Ottawa_IK_Principles.pdf

T1.3 Climate and Weather Forecasting Needs - Helge Goessling

Task 1.3 developed a user-scape for KEPLER early in the project, to assist with mapping outcomes for this task. They also created a questionnaire that received input from ice and marine, weather services, research groups, satellite production groups and Copernicus services.
The key outcomes were presented below:

Outcomes from Deliverable 1.3- Climate, Weather Forecasting, and Ice service needs



Identifying these outcomes enabled T1.3 to create the following recommendations:

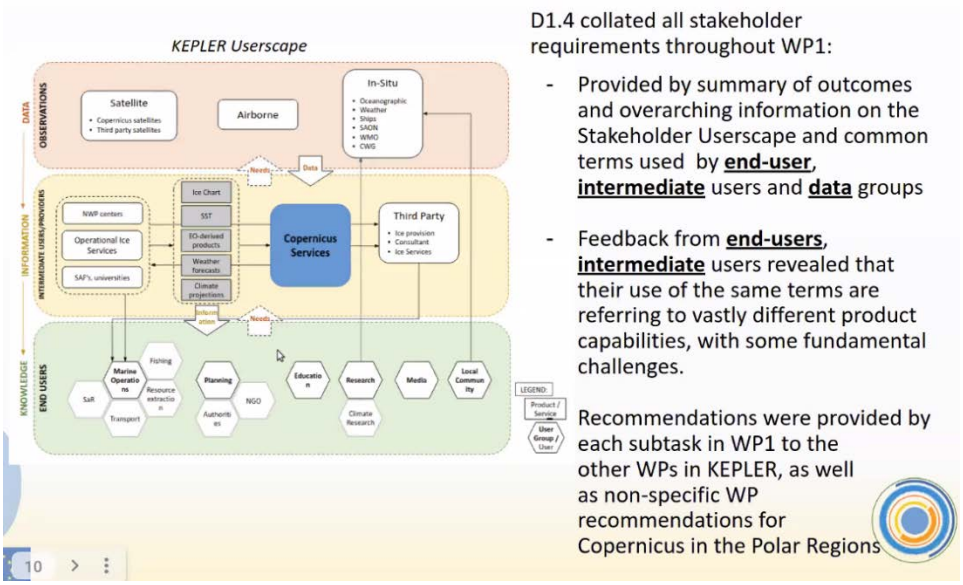
Deliverable 1.3: Climate, weather forecasting and ice service Recommendations

1. **The importance of the continuity of satellite observations from certain sensor types** is stressed, particularly synthetic aperture radar, multi-frequency microwave radiometry, and radar altimetry in high-latitude orbits.
2. **Making more of the existing routine (research) observations available for NRT applications** should have high priority. Aspects include more research on observational impacts, development of appropriate observation operators, and intensification of calibration/validation with appropriate In situ data.
3. Requirement for the **Southern Hemisphere and Sub-Arctic and Canadian side to have a detection of icebergs smaller than 100m** or at the very least, an ability to separate false targets with the current state of satellites.
4. **Exploration of new methods on data compression and communication** when working with highly resolved observational information (i.e overcome high-lat bandwidth limitations).
5. Short term sea ice **forecasts should assimilate sea ice products developed at matching spatial resolutions** to user needs.
6. **Further investment into the development of high-resolution forecast systems, observations and data assimilation techniques** to generate more user-relevant services.

T1.4: Overall assessment of stakeholder needs - Penelope Wagner

Task 1.4 collates all the user needs from the above tasks. The user-scape above helped build the recommendations for T1.4.

Outcomes from Deliverable 1.4- Stakeholder requirements synthesis



Penny Wagner also stressed that intermediate and end-users can be the same, highlighting that the line between users is not always well defined. This should be considered when approaching product dissemination and development of future projects. Recommendations for 1.4 are summarised below:

Deliverable 1.4: General stakeholder requirements synthesis recommendations

1. **Technological improvements within the scope of satellite capabilities to develop products with "higher spatial and temporal resolution", suitable for NRT data assimilation** into models and forecasts
2. **Integration of higher resolution sensors such as SAR, optical, lidar, altimetry** and consider the different sensor-combinations in order to provide relevant operational monitoring on local scales that most end-users require on a daily basis.
3. **Consistent and well-defined terminology** that is in line with how end-users understand this information. (i.e. "high resolution," "NRT," "operational," "short/long term").
4. Until the language and terminology consistency issue is resolved, **descriptions for products developed for Copernicus** are recommended to be explicit about their intended use, and transparent about their limitations
5. There should be a **provision of improved dissemination, tools and training of different data products** for non-specialists. Issues with end-users' understanding of multiple products have been a critical challenge of user uptake with new products.
6. **Better access to high bandwidth communications at high latitudes**
7. **Data and information provided in easily accessible and understandable** and available in familiar and standard data formats for end-users (i.e. graphics and text formats)

Questions/Key Points raised for Work Package 1:

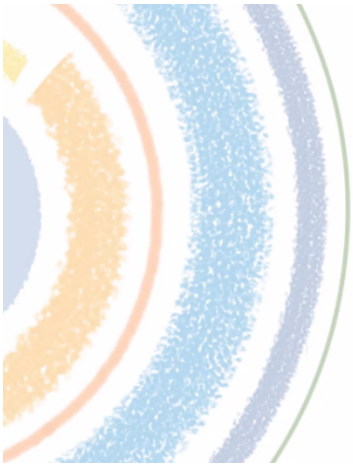
- **Mark Drinkwater (ESA)** Is the message to consider how to retain the ability to provide routine coverage with augmentation of the spatial resolution? Bearing in mind that spatial and temporal resolution comes at the expense of each other?
  PW: Yes, a lot of these products that do provide a more synoptic view of monitoring are useful, but a lot of users work on a tactical level, whether marine or terrestrial, and we would like to offer more types of products based on these types of resolutions.
  MD: Of course, the trade-off is restrictions re: data volume and current capabilities satellite transmission, bandwidth etc.
  PW: Definitely, this is something that we expanded on in WP3 and WP4, and something this project does address is what the capabilities are when creating recommendations.

- *Via Chat:* **Gustav Sigeman (Nord University)** Do you have any recommendations related to the EU Arctic Policy?
  Penny Wagner (WPL): The recommendations would come from the whole project not just WP1, as to answer that we need to consider what the capabilities are now, and for the future. We also should consider how we link in with different bodies concerning Arctic Policies. We hope that once the other work packages have presented, that recommendations related to EU Arctic Policy become clearer.
  Tero Mustonen, (Snowchange): On the Eu recommendations, I would keep hammering the message of a need to appreciate and celebrate the diverse local and Indigenous communities in the region, including fly-in communities on Ponoi. Services need to respond to equity issues too.

WORK PACKAGE 2: Polar Regions provision in Copernicus Services - Gilles Garric

WP2 is the smallest Work Package in the KEPLER project, Gilles Garric provided a brief overview of WP2 objectives, the contributing partners, and a summary of available Copernicus services. Noted Copernicus is currently preparing the next phase of services, and the completion of the KEPLER project now is intentionally timed to inform his development.

Work Package 2 Objectives



Provide ways to improve the ability of Copernicus to describe the changing Polar Regions in the light of different scenarios of availability of additional complementary data from space (CIMR, CRISTAL and ROSE-L).

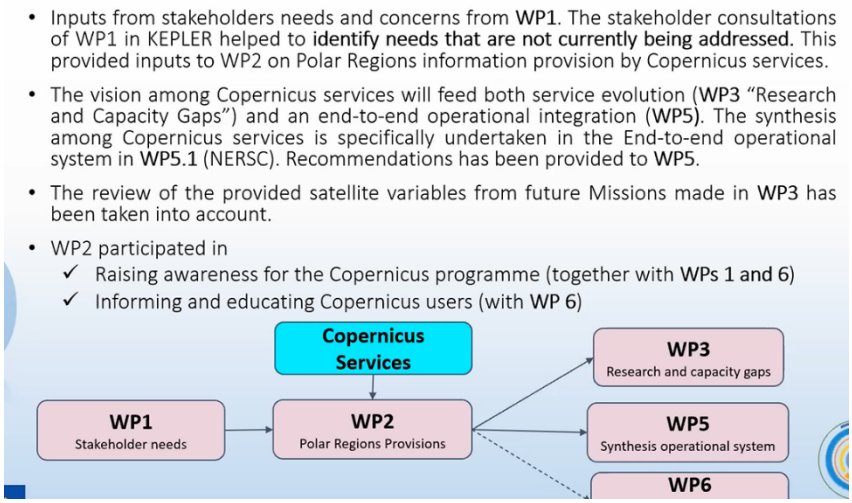
1) Give a status of present and already planned activities led by Copernicus services.
2) Present a vision for complementing the existing services; in other words what future Copernicus services should have in their portfolio in regard to users requirement, to the continuity of the service and space capabilities.

A key starting point for WP2 was the User Requirements for a Copernicus Polar Mission- JRC Technical Report- Phase 2, published in 2018.

WP2 prioritised requirements based on the Arctic Policy document with a panel composed of Copernicus core user, representing national services, Copernicus services and the scientific community. Work was also based also informed by meeting with entrusted entities in charge of the Copernicus Space Component, i.e., ESA and EUMETSAT. A prioritised list of monitoring requirements and high-priority geophysical parameters have been provided.

This year, with the Polar Expert Group, KEPLER contributed to 'User requirements for a Copernicus Polar Mission'- PEG III report. Our participation was as a representative of Copernicus service (CMEMS) and KEPLER provided 10 recommendations to this report.

https://kepler-polar.eu/2021/04/15/peg-3-report/*Interactions with other work packages*



The objectives of work package, and collaborative links with other work packages were presented to meeting participants. A summary of activities such as surveys and events carried out for this work were also provided.

WP2 Achievements

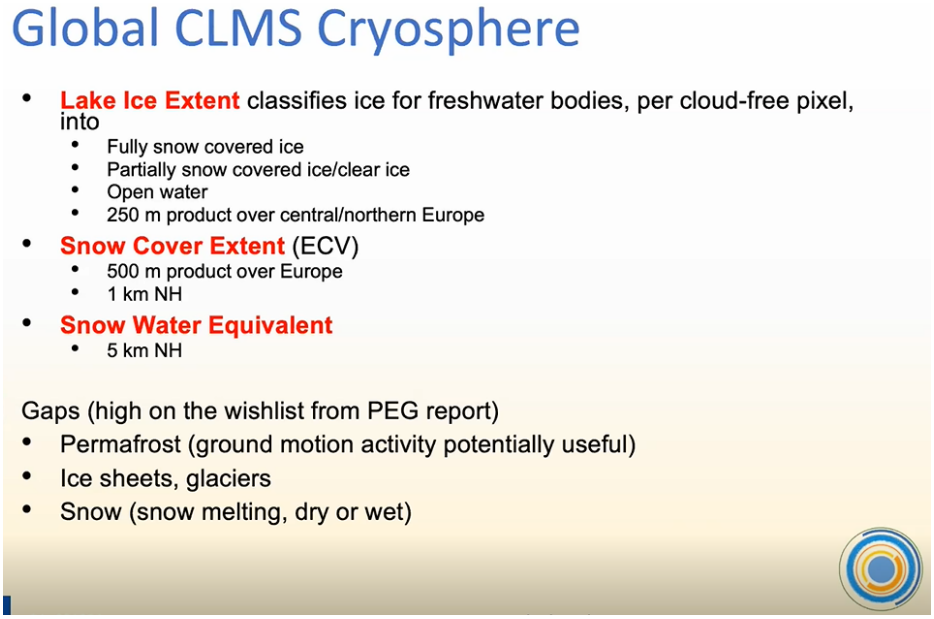
- A **comprehensive and detailed description** of the two Land and Marine Copernicus services is assessed in two distinct tasks. This description takes into account all the components of what is meant by "service".
  - Comprehensive description of the current and planned service given by CMEMS to monitor polar oceans.
  - Assessment of existing and planned products within the global Copernicus Land Monitoring System (CLMS) to monitor polar terrestrial environments together with assessment of relevant products within the Copernicus Climate Change Service and the ESA Climate Change Initiative (CCI)
- **Detailed list of parameters** is given in the CLMS and CMEMS catalogue. When possible, these listings have been completed with other relevant sources and with other Copernicus services such as C3S and CEMS. The description introduced planned developments for new products and services.
- Copernicus services are **user-driven** and, as such, users' feedback and needs have been monitored by questionnaire or regular surveys. A current state of CLMS and CMEMS polar product users has then been established. From these feedbacks, a **gap analysis** from users' survey and feedbacks has been established and highlights a recurrent need of very high spatial resolution (< 100m) and of a more complete portfolio of parameters.
- Together with WP3 findings, observations capacities from the **HPCM** are assessed against Copernicus services commitments. The possibility of having these 3 HPCMs in synergy brings tremendous opportunities for Copernicus services in terms of continuity and extension of the service with important improved capacities.
- **Recommendations** for the end-to-end operational system (WP5) and Copernicus services provision in light of HPCMs polar missions have been done.

T2.1 Copernicus Land Monitoring Service (CLMS) - Marko Scholze

Marko Scholze again provided an overview of T2.1 objectives, and the team members working on this task. Marko also confirmed that the deliverable and two milestones for this task were submitted last year.

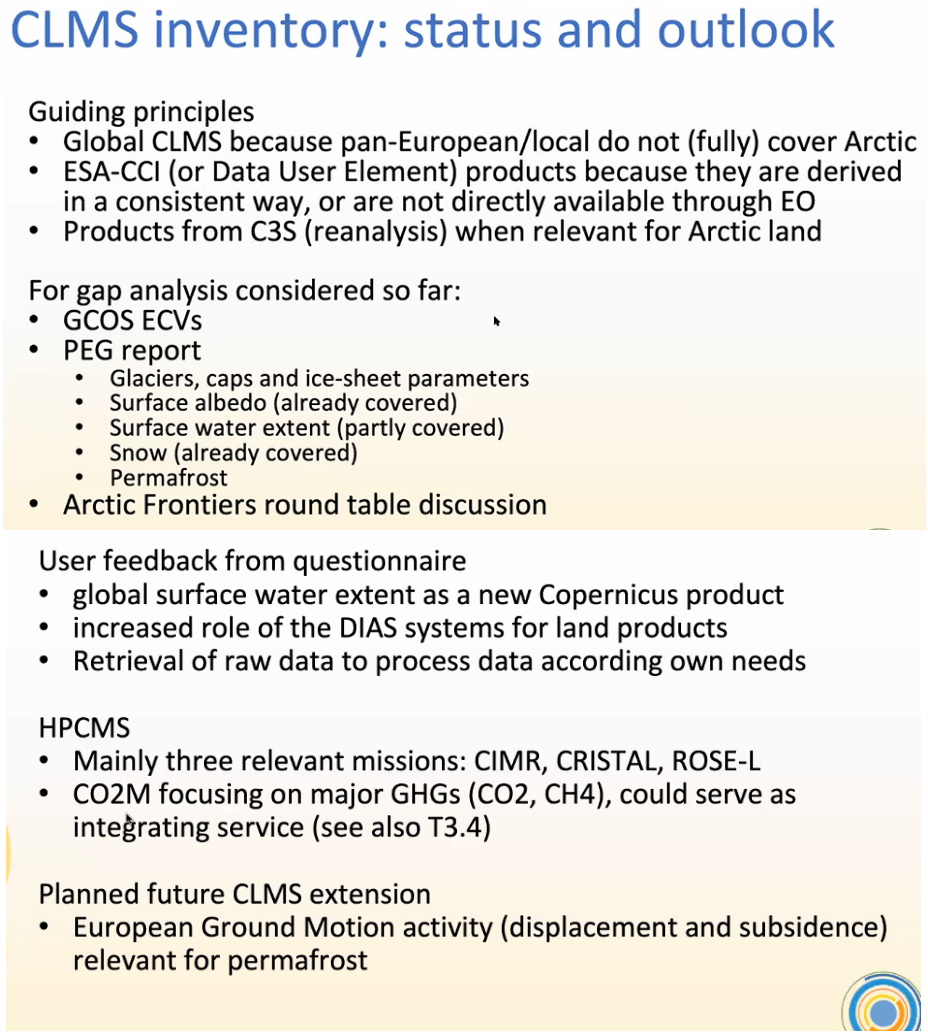
The four main components of the Copernicus land monitoring service were presented to the group- Global, Pan-European, Local and Imagery and reference data. Also highlighted were ongoing activities to develop a fifth component: European ground motion activity (ground displacements, including landslides and subsidence, as well as deformation of infrastructure.) This is something that could be of interest to KEPLER, in regard to permafrost.

The current CLMS services are limited, so Task 2.1 set about identifying gaps in these services below:

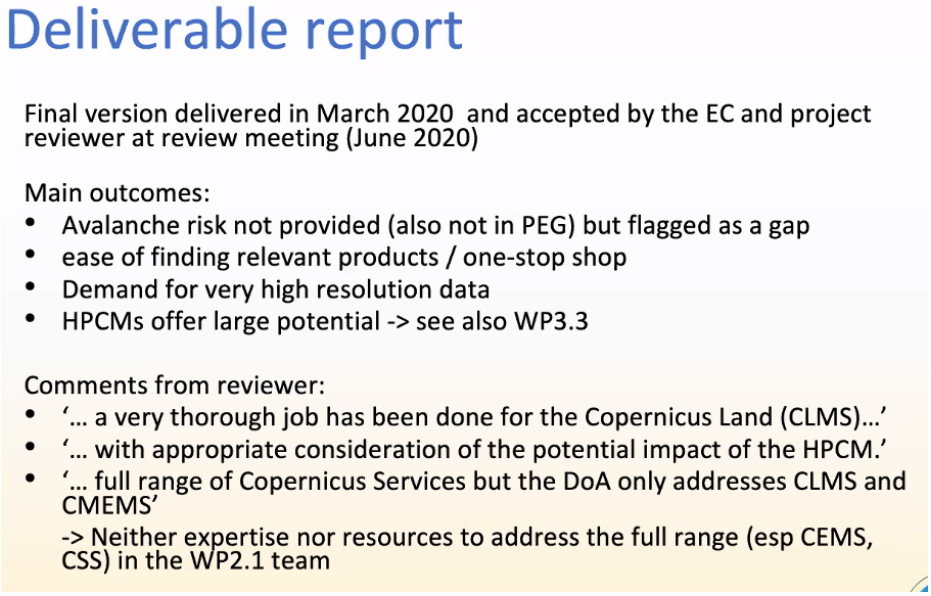


Task 2.1 also reviewed the themes available in the Global land service, identifying products that are relevant for the Arctic:

The CLMS inventory, its guiding principles, and the sources of data that informed this, were presented below:

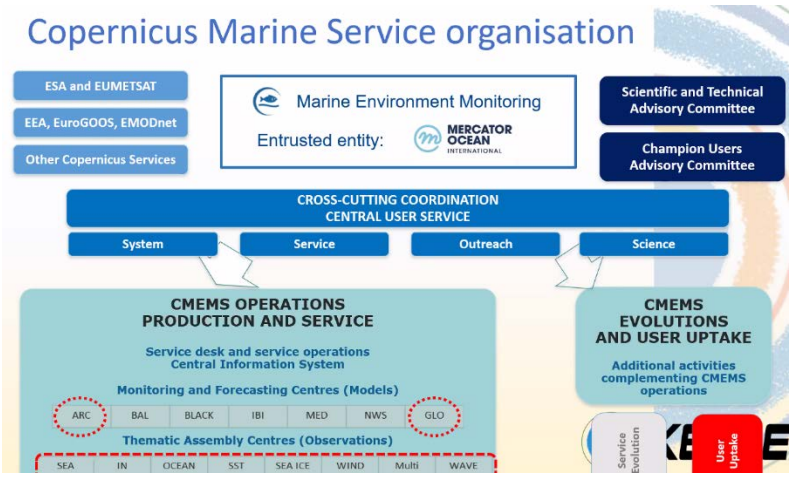


A table of selected land variables not included in global CLMS is also available to view in the full presentation. In summary, the following points were highlighted about the deliverable report:

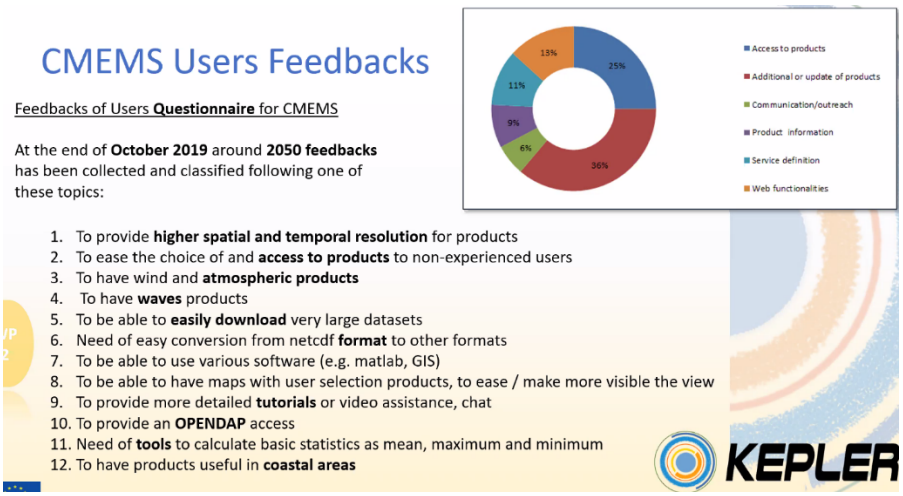


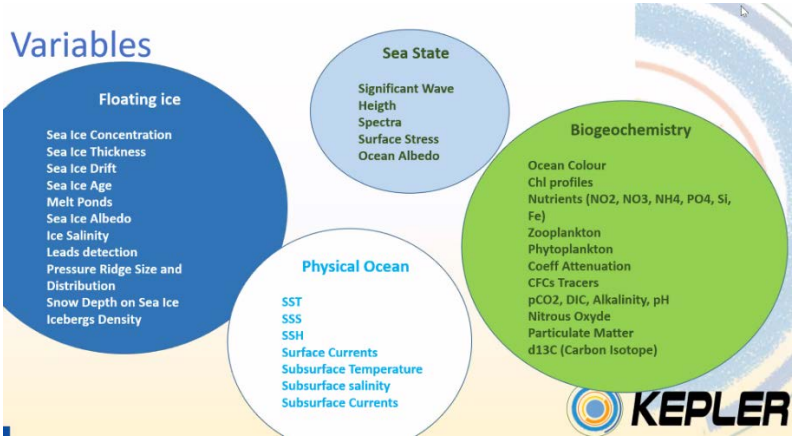
T2.2 Copernicus Marine Environment Monitoring Service (CMEMS) – Gilles Garric

Gilles provided an overview of the objectives of T2.2, and the Copernicus Marine Service organisation. Links in with various agencies were highlighted in the slide below:

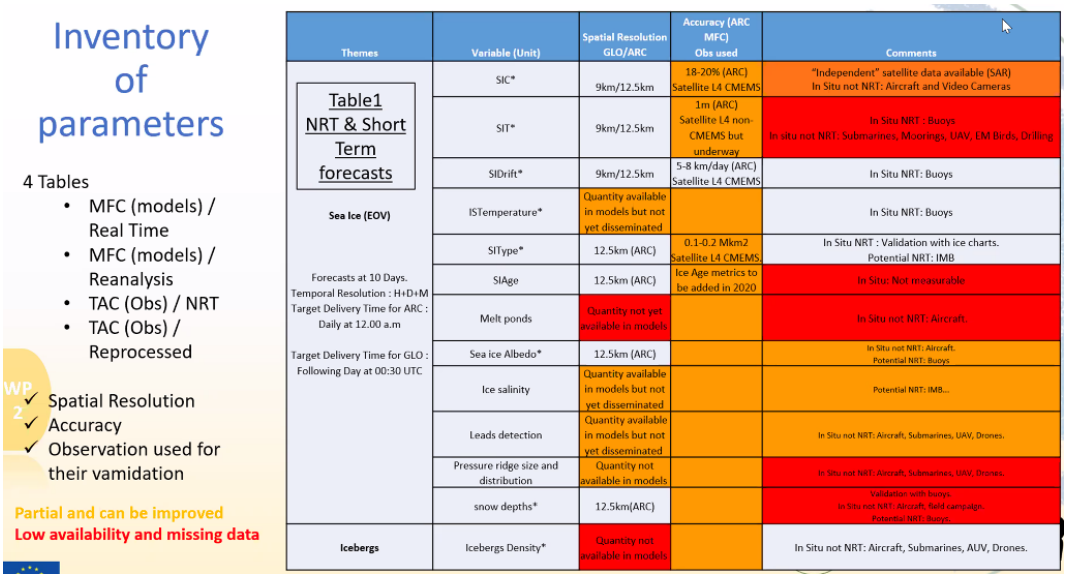


Task 2.2 identified the data policy and access for Copernicus services and data quality provided by production centres. In July 2019, CMEMS provided statistics on the use of CMEMS Arctic products. Noting that a large redistribution of data in terms is predominantly by intermediate users. Feedback questionnaires for CMEMS have been utilised by task 2.2, these and selected variables were presented:





Gilles also presented an inventory of parameters and identified gaps (low availability/missing data) As seen in red below. Future/ planned developments were also identified and shared with the participants. For full details please refer to the Task 2.2 presentation.



Inventory of parameters

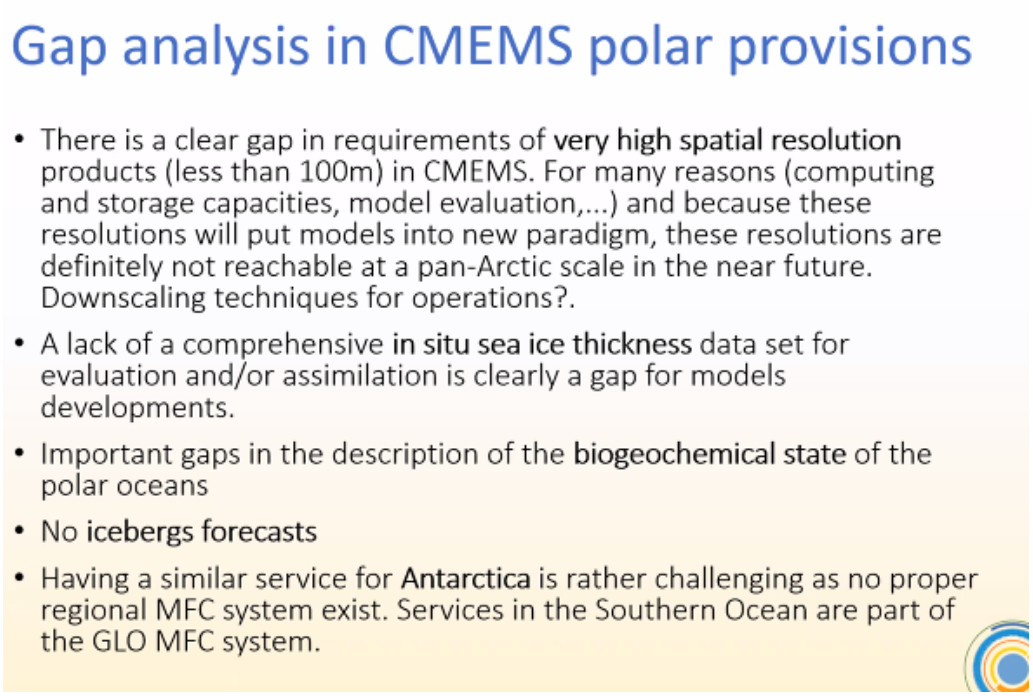
4 Tables
- MFC (models) / Real Time
- MFC (models) / Reanalysis
- TAC (Obs) / NRT
- TAC (Obs) / Reprocessed

WP 2
- ✓ Spatial Resolution
- ✓ Accuracy
- ✓ Observation used for their vamidation

Partial and can be improved
Low availability and missing data

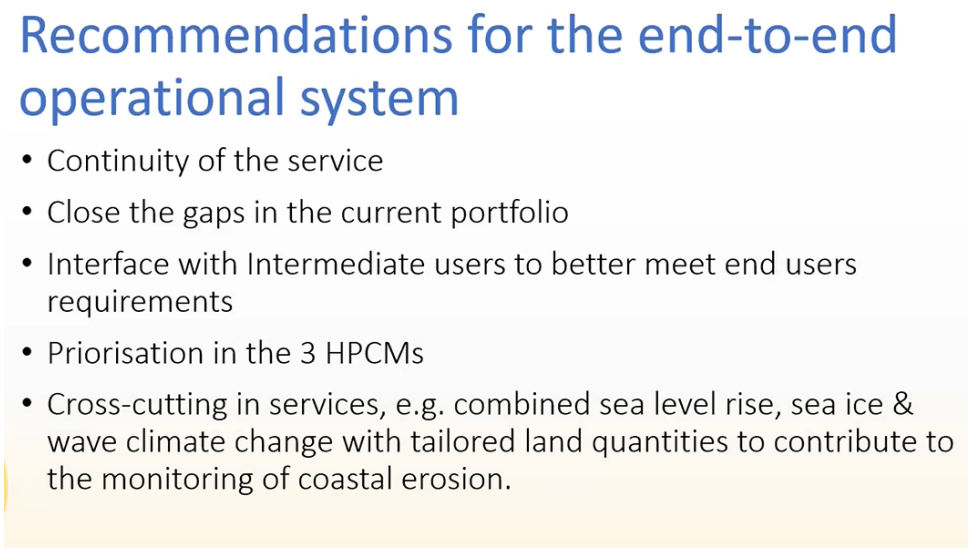
Themes	Variable (Unit)	Spatial Resolution GLO/ARC	Accuracy (ARC MFC) Obs used	Comments
Table1 NRT & Short Term forecasts	SIC*	9km/12.5km	18-20% (ARC) Satellite L4 CMEMS	"Independent" satellite data available (SAR) In Situ not NRT: Aircraft and Video Cameras
	SIT*	9km/12.5km	1m (ARC) Satellite L4 non-CMEMS but underway	In Situ NRT : Buoys In situ not NRT: Submarines, Moorings, UAV, EM Birds, Drilling
	SIDrift*	9km/12.5km	5-8 km/day (ARC) Satellite L4 CMEMS	In Situ NRT: Buoys
Sea Ice (EOV)	ISTemperature*	Quantity available in models but not yet disseminated		In Situ NRT: Buoys
	SIType*	12.5km (ARC)	0.1-0.2 Mkm2 Satellite L4 CMEMS	In Situ NRT : Validation with ice charts. Potential NRT: IMB
Forecasts at 10 Days. Temporal Resolution : H+D+M Target Delivery Time for ARC : Daily at 12.00 a.m	SIAge	12.5km (ARC)	Ice Age metrics to be added in 2020	In Situ: Not measurable
	Melt ponds	Quantity not yet available in models		In Situ not NRT: Aircraft.
Target Delivery Time for GLO : Following Day at 00:30 UTC	Sea ice Albedo*	12.5km (ARC)		In Situ not NRT: Aircraft. Potential NRT: Buoys
	Ice salinity	Quantity available in models but not yet disseminated		Potential NRT: IMB...
	Leads detection	Quantity available in models but not yet disseminated		In Situ not NRT: Aircraft, Submarines, UAV, Drones.
	Pressure ridge size and distribution	Quantity not available in models		In Situ not NRT: Aircraft, Submarines, UAV, Drones.
	snow depths*	12.5km(ARC)		Validation with buoys In Situ not NRT: Aircraft, field campaign. Potential NRT: Buoys.
Icebergs	Icebergs Density*	Quantity not available in models		In Situ not NRT: Aircraft, Submarines, AUV, Drones.

This presentation concluded with a summary of the gap analysis in CMEMS polar provisions, HPCMs of interest for CMEMS and HPCMs Synergy. Recommendations from T2.2 for the end-to-end operational system were also summarised- see below.



Gap analysis in CMEMS polar provisions

- There is a clear gap in requirements of **very high spatial resolution** products (less than 100m) in CMEMS. For many reasons (computing and storage capacities, model evaluation,...) and because these resolutions will put models into new paradigm, these resolutions are definitely not reachable at a pan-Arctic scale in the near future. Downscaling techniques for operations?.
- A lack of a comprehensive **in situ sea ice thickness** data set for evaluation and/or assimilation is clearly a gap for models developments.
- Important gaps in the description of the **biogeochemical state** of the polar oceans
- No **icebergs forecasts**
- Having a similar service for **Antarctica** is rather challenging as no proper regional MFC system exist. Services in the Southern Ocean are part of the GLO MFC system.



Questions/Key Points raised for Work Package 2:

- ***Via Chat*** **Mark Drinkwater (ESA)** – The 10th-anniversary CryoSat Workshop (last week) highlighted the concern and urgency needed in ensuring continuity in Service for Sea ice thickness (SIT) and preserving the climate record. CryoSat is 11 years old and well beyond nominal mission and is estimated to have only 5 years fuel left (with concerns about the gap looming between End of lifetime and launch of CRISTAL in '27/28). Various solutions are proposed including an airborne CryoBridge campaign, to cross-calibrate CryoSat-2 and CRISTAL, and to bridge the gap in the continuous C3S SIT climate record. Have the Services expressed recommendations about this potential gap, and what does KEPLER recommend, given that systematic airborne cal/val capability using airborne instruments remains a requirement in the future?

  Gilles Garric (WP2 Lead)– Copernicus services are strongly recommending the continuity of the service, and this considers all the upstream data which are currently used, e.g., Cryosat-2. As far as I know, no specific recommendation for altimetry or airborne capabilities have been expressed or in the pipes, but I must double-check.

  Mark Drinkwater (ESA)- Thanks. Of course, we cannot accelerate CRISTAL, nor extend CryoSat-2 beyond its fuel-limited End of Life. Thus, the solution space for securing the SIT climate record needs to be carefully evaluated, and clear recommendations made.

  Richard Hall – (Equinor) the EU will want to know why satellite ice thickness measurements should be continued (and yes, they should be continued) So there needs to be a link to how society (better information to make good decisions) will benefit from the continuation.

- **Thomas Lavergne-** we could touch this again at my presentation of T4.2 focusing on the "Sea Ice ECV", continuity of the satellite data records was of course a topic.

- **Gilles Garric (WP2 Lead)** – I found out what you are looking for in CMEMS recommendations document (https://marine.copernicus.eu/sites/default/files/media/pdf/2020-10/CMEMS-requirements-satellites.pdf): "Continuation and improvement of the sea ice thickness time series from Cryosat-2. This is required both for climate and operational sea ice monitoring activities (including assimilation in sea ice models)" Edited in 2017.

- **Leif Toudal Pedersen**: Remember that while waiting for CRISTAL we also have 2! Sentinel-3 radar altimeters that cover a significant part of the Arctic.
  Thomas Kaminski (iLab): To add to Leif's comment: In task 3.4 we have made the first step and addressed a hypothetical Sentinel 3 radar freeboard product within one of our assessments, see Deliverable 3.4 and Deliverable 5.2- Roadmap.
  Nick Hughes (MET Norway): @Leif IICWG Task Team 12 is on it.

- *Via Chat- in response to the CMEMS user survey about needs/feedback:*
  Nick Hughes (MET Norway): More research should take place to address the routine satellite-derived SIT continuity gap that occurs every summer.

- *Via Chat- in response to the CMEMS Marine Service Organisation overview slide:*
  Richard Hall (Equinor)- Good to see a common iceberg service being recommended.

- *Via Chat* **Laurent Bertino (NERSC):** @Mark Drinkwater (ESA), sorry if we go into the details, but how much more fuel does SMOS have? Airborne campaigns could require a very different span with or without SMOS in 5 years from now.

- *Via Chat* **Mark Drinkwater (ESA)-** @Laurent - fuel is not a limitation for SMOS right now, rather the battery aging. Both the expected lifetimes of SMOS and CryoSat-2 will be fully evaluated as part of a formal "mission extension review" which would be required to secure programme financing for extension of mission beyond 2022 (+3 years until 2025)

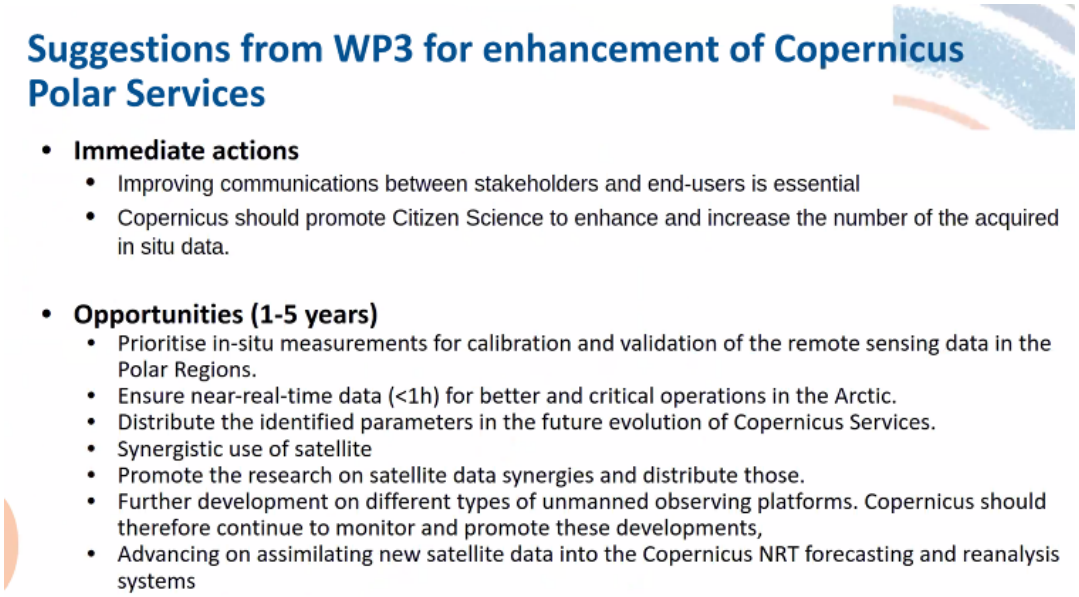
- **Thomas Kaminski (iLAB)-** The last time he spoke Yann Kerr, the SMOS PI, Yann said they were doing extremely well in terms of fuel. However, I do not know how that translates into the expected lifetime of the mission.

- **Mark Drinkwater (ESA)-** *In response to chat about SMOS*: There is no perceived threat to the lifetime of SMOS due to fuel onboard. Rather the degradation of various life-limited items onboard the satellite. Now, battery aging is the most significant threat. But by comparison to CRYOSAT, which has been observed to have a leaky valve on one side of the system, there is a proposed change to mitigate this fuel leak which is thought to be the most significant risk to CRYOSAT. The expected lifetimes and extended performance of both SMOS and CRYOSAT will be evaluated as part of a mission extension review which will take place later this year. That was necessary anyway to secure funding for the continual operation of both satellites beyond 2022. Securing funding is not something I foresee to be a problem, provided of course, that both satellites are in reasonable health to continue operations through the mid-20s. (That does not seem to be at risk at this moment, pending a full evaluation later in the year.) What we need at this time, are the recommendations from the community to be able to provide continuity, with

very specific reasoning, associated of course with continuity of services that rely on the products themselves. I am not looking for that recommendation here, but obviously we would like the services and the projects that are foreseeing a continuation of this type of data to make very explicit recommendations that can only help of course, in asking our member states for the required funding. Thanks very much.

WORK PACKAGE 3: Identification of research and capacity gap – Carolina Gabarró

The overall suggestions for WP3 were presented by Work Package leader, Carolina Gabarro. These recommendations were fed into WP5 Roadmap.



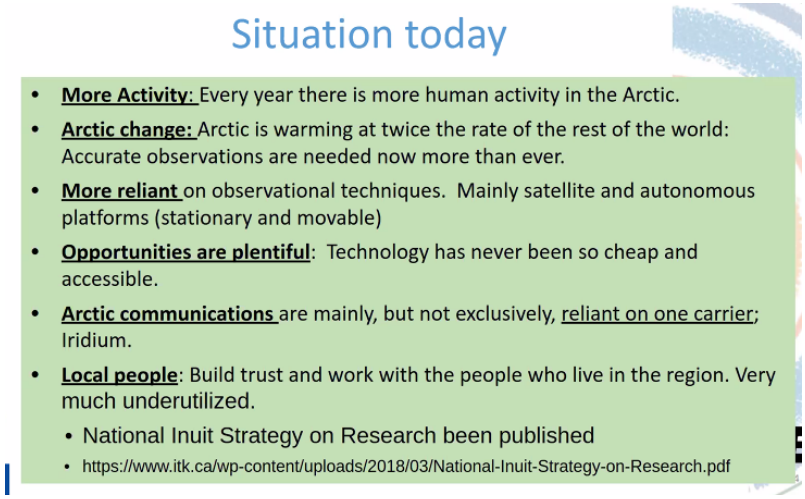
T3.1 In situ observing systems – Jeremy Wilkinson.

Task leader, Jeremy Wilkinson, introduced the partners involved in task 3.1 and reviewed the objectives of task 3.1 and summarised the current situation/challenges faced in the Arctic. This task has two aims:

1. Assess how the observational research community, both marine and terrestrial, can better contribute with in situ monitoring to the aims of Copernicus.
2. Investigate the role citizen science can play in the expansion of Copernicus' in situ monitoring priorities.

Therefore, the resulting deliverable (D1.3) was structure into two parts- Citizen science and the research community needs.

The following slide was viewed at the first KEPLER GA- The Kick-Off Meeting and is still relevant today.



The Role of Citizen Science (part 1 of this task's deliverable) gives a big picture as to where science fits in with society. The suggestions from part 1 of T3.1 are below. (JW has highlighted in red the suggestions that he views as a priority)

T3.1 Citizen science Recommendations and Suggestions

For the Copernicus Services to capitalize on the broad potential of CS we suggest:

- Copernicus Services should make a greater effort to highlight and grow the number of CS projects using their products or validating their products.
- One Copernicus Service, or most likely the presently under-utilised Copernicus In Situ Component, is encouraged to take ownership/stewardship of CS needs and interaction for all Copernicus Services.

The Copernicus lead for CS is encouraged to:

- perform an audit of the interaction between CS and the different Copernicus Services.
- recruit or support a small number of CS experts to develop an achievable strategy that would allow for a more integrated approach to CS by the Copernicus Services.
- develop mechanisms to encourage, support and facilitate more CS projects to be involved in the Cal/Val of the present and future Copernicus products and services.
- pursue channels of communication with the European Citizen Science Association, the H2020 funded EU Citizen. Science project, and other leading CS organisations within Europe. The aim is to support and advance European CS through better communication, coordination, and knowledge sharing with the focus being on strengthening the goals to and maintain the capabilities of the Copernicus Services.

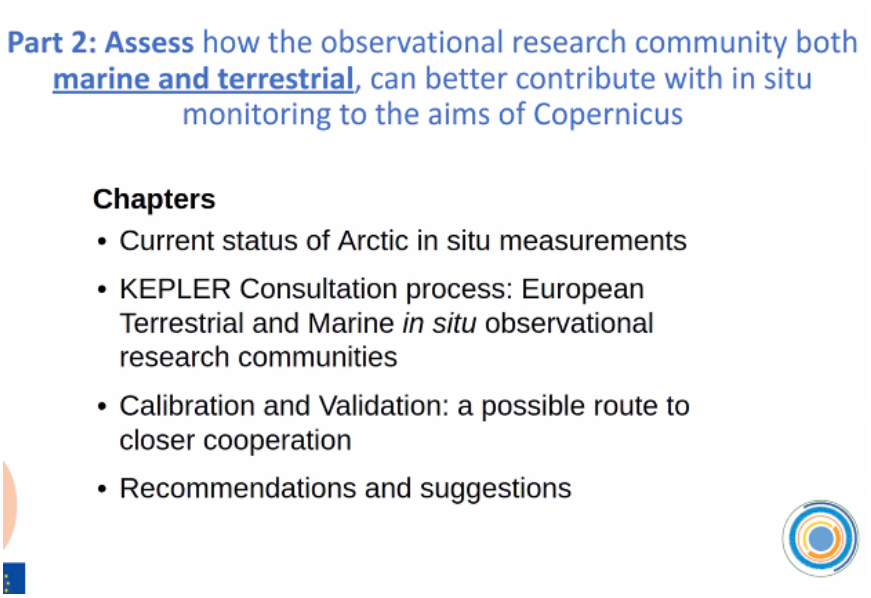
The conclusion of T3.1 Part 1, based on a vast amount of work out from the science community that analyses citizen science projects, is that:

T3.1 Citizen science Conclusion

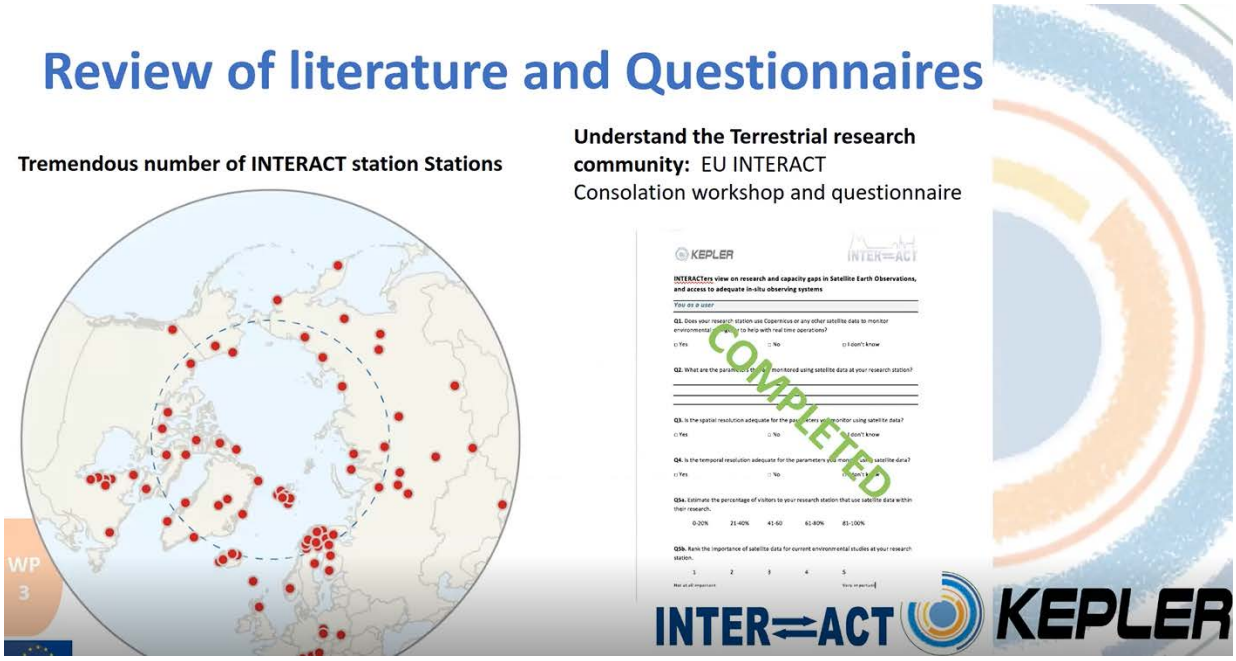
The evidence suggests that CS can make a welcome contribution to enhancing the relevance of the Copernicus Services to European citizens, as well as helping to evaluate and improve the accuracy of Copernicus products themselves.

Addressing the (above-mentioned) suggestions should provide a pathway for the data collected by citizens to become a serious and important part of Copernicus Services in the future, especially the Copernicus In Situ Component.

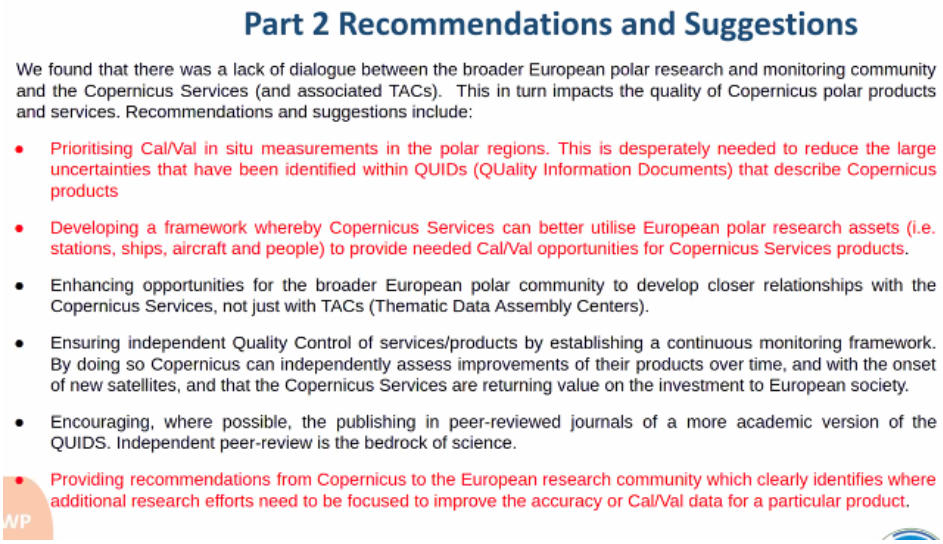
Part 2 of this task, focused on the research community, (/academic- both marine and terrestrial), involved the delivery of the following listed activities:



As part of this task, KEPLER collaborated with the INTERACT project, to deliver milestone 6.4. Producing a report on 'Research and Capacity Gaps in Satellite Earth Observations' and a questionnaire that targeted marine vessel user's views. This questionnaire was distributed at the workshop, online on both projects' websites and social media.



Suggestions from part 2 of T3.1 are below. (JW has highlighted in red the suggestions that he views as a priority)

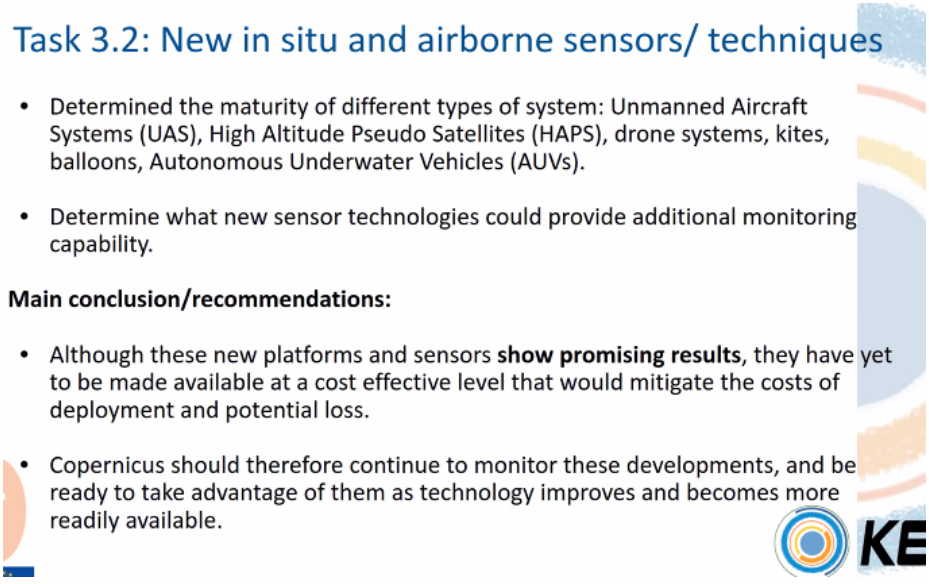


JW encouraged meeting participants to look at the full deliverable report in context, to better understand recommendations. It was also stressed that Europe has a fantastic framework of research assets and that active engagement between the research community and Copernicus should be a priority going forward. One suggestion is that EPB Polar Net 2 could be consulted by Copernicus when there is uncertainty or gaps in products.

Please see the questions for WP3 section for discussion about task 3.1.

T3.2 New and novel in-situ and airborne observation sensors and techniques - Nick Hughes

Task leader, Nick Hughes, provided an overview on both unmanned aircraft systems and autonomous underwater vehicles, and the main conclusions and recommendations from both new in situ and airborne sensors/techniques.



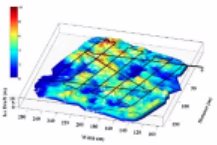
Unmanned Aircraft Systems (UAS)

- Polar use limited, because
  - Lack of experience with the rapidly evolving technology
  - Inability of UAS to comply with international regulations for flight operations
  - Need for operational approval
- Pan-Arctic missions across international Flight Information Regions (FIRs) have been limited
  - Yet to be any attempts to set these up routinely on a basis that can be used for repeat monitoring.
- Recommendations for Arctic use of UAS systems
  - AMAP 2015 Arctic Science Remotely Piloted Aircraft Systems (RPAS) Operator's Handbook
- High Altitude Pseudo Satellites (HAPS)
  - Potential to operate for extreme periods of time (days and months)
  - Technologies more suited for mid- and low- latitudes



KEPLER

Autonomous Underwater Vehicles (AUVs) and Gliders

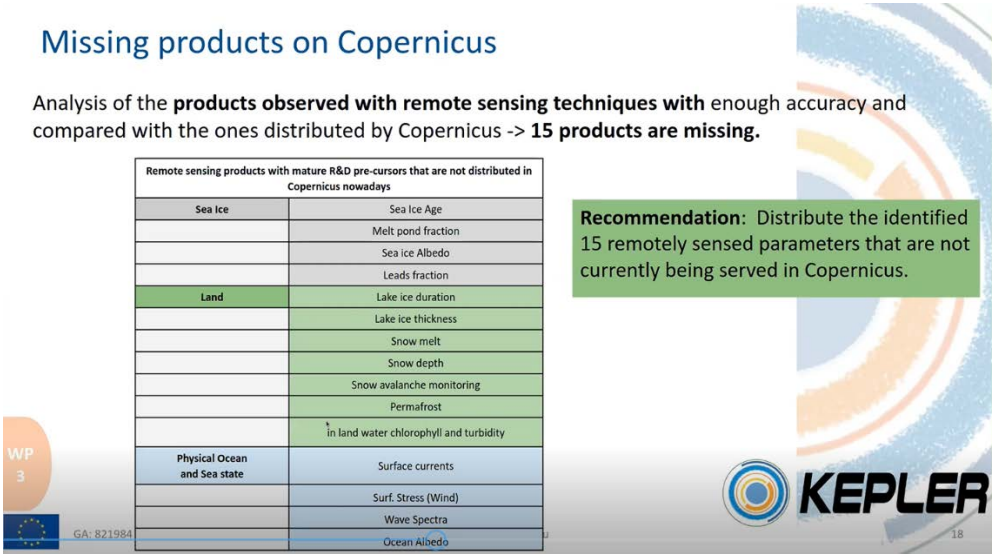



- AUVs
- Used in the polar regions since early 2000's
  - Varying degrees of success
- Key limitations
  - Battery technology limits endurance and sensor load
  - Accurate underwater navigation
  - Smaller AUVs unable to cope in strong current environments
- Gliders
- Very low power, long endurance platforms
  - Wave gliders have potentially infinite endurance, bio-fouling permitting
  - Limited to surface, low ice-risk areas
- Underwater gliders
  - Movement through water column through buoyancy changes

T3.3 Space-based capability - Carolina Gabarró

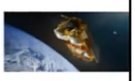
Carolina Gabarro introduced Task 3.3, which was a major task involving a large number of people. This task began with an assessment of state-of-the-art polar parameters acquired with remote sensing. Reviewing characteristics, retrieval methods, validation, errors, and limitations of 22 remote sensing parameters.

These parameters were compared with the remote sensing parameters available in the Copernicus services, which identified 15 products that were missing.



The second section of Task 3.3 was to identify and assess the potential for HPCM missions- improving the monitoring of Polar Regions. Task 3.3 tried to synthesis how these three missions- (CIMR, CRISTAL and ROSE-L) using four priority parameters- 1. Floating Ice, 2. Glaciers and Ice Caps, 3. Ice Sheets and 4. Snow. Evaluating these has highlighted that it is critical that all 3 missions are carried out to cover the identified high priority environmental parameters.

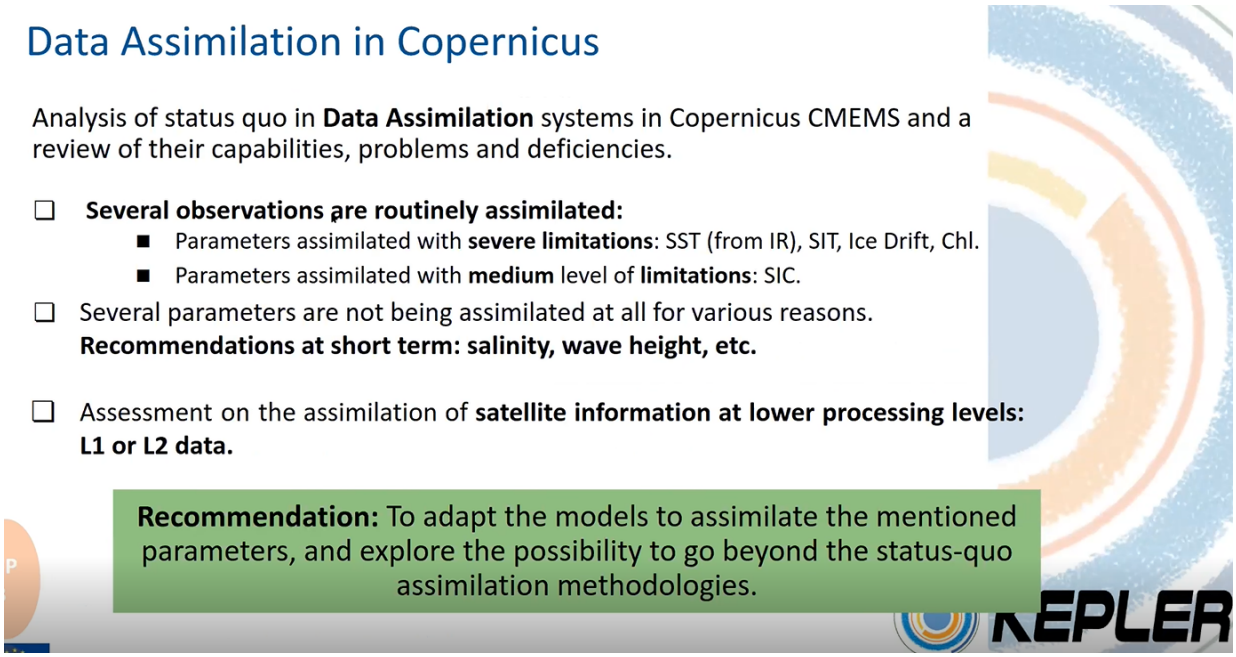
The third section of work package 3 was to evaluate the current and potential synergies to improve the qualities and resolution of remote sensing products.

Sensors	PMR (e.g. CIMR) 	RA (e.g. CRISTAL) 	IR (e.g.LSTM) 	Optical (e.g. CHIME) 	SAR (e.g. ROSE-L) 
PMR (e.g. CIMR)		lake ice thickness		**Soil moisture downscaling**	Snow Water Equivalent **Soil moisture**
RA (e.g. CRISTAL)	SIT[1], ice type, snow depth			Phytoplankton groups	
IR (e.g.LSTM)	SIT, ice surface temperature, sea surface temp	SIT, ice type			
Optical (e.g. CHIME)	SIC, ice type	ice type MPF		**Phytoplankton groups, phytoplankton dynamics** *	snow extent snow wetness **snow avalanche** lake ice extent
SAR (e.g. ROSE-L)	SIC, SIDrift	sea ice deformation evolution **iceberg properties,** snow depths on sea ice	ice type	SIC, ice type	

Assessment of these synergies has illustrated there are 18 potential synergies of different types of sensors that are presented for land, ocean, and ice; most of them published in scientific literature. However, only 4 will be operational in Copernicus by the end of phase 1, the rest are experimental. Task 3.3 therefore recommends the following action:

Recommendation: to promote the production and distribution of new products resulting from the synergies between sensors.

Another important part of this task was presented- data assimilation in Copernicus. Task 3.3 undertook an analysis of the status quo in the Copernicus system- specifically CMEMs, looking at data assimilation and a review of their capabilities, problems, and deficiencies. Working with 5.1, this task identified which parameters were recommended, which lead to the following conclusions:

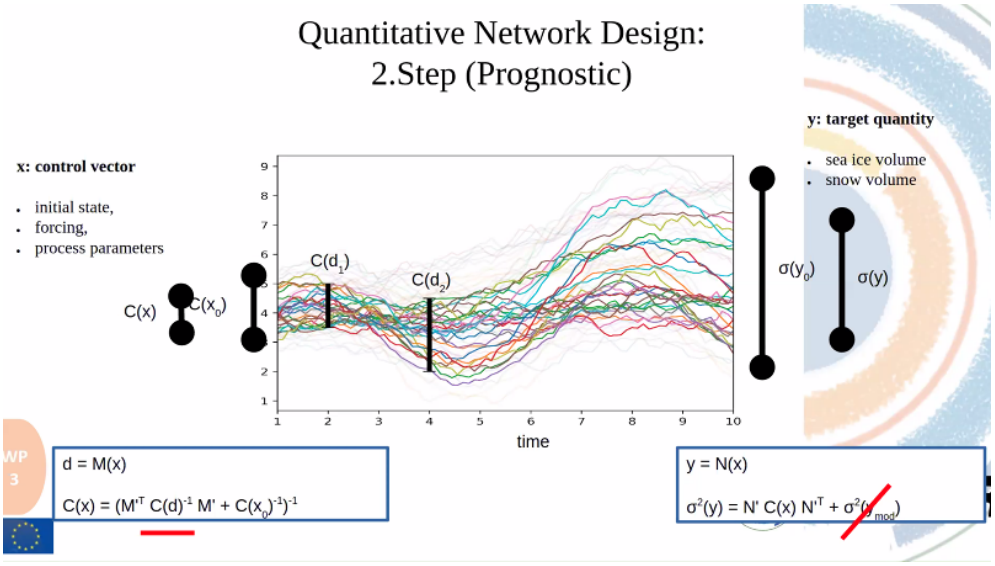


T3.4 Integration and assimilation through Quantitative Network Design (QND) - Thomas Kaminski

Thomas Kaminski (iLab) presented work carried out by T3.4, another large task within the KEPLER project. This task has constructed two sets of observations and scenarios, one targeting land-based fossil fuel emissions, one targeting predictions of sea ice.

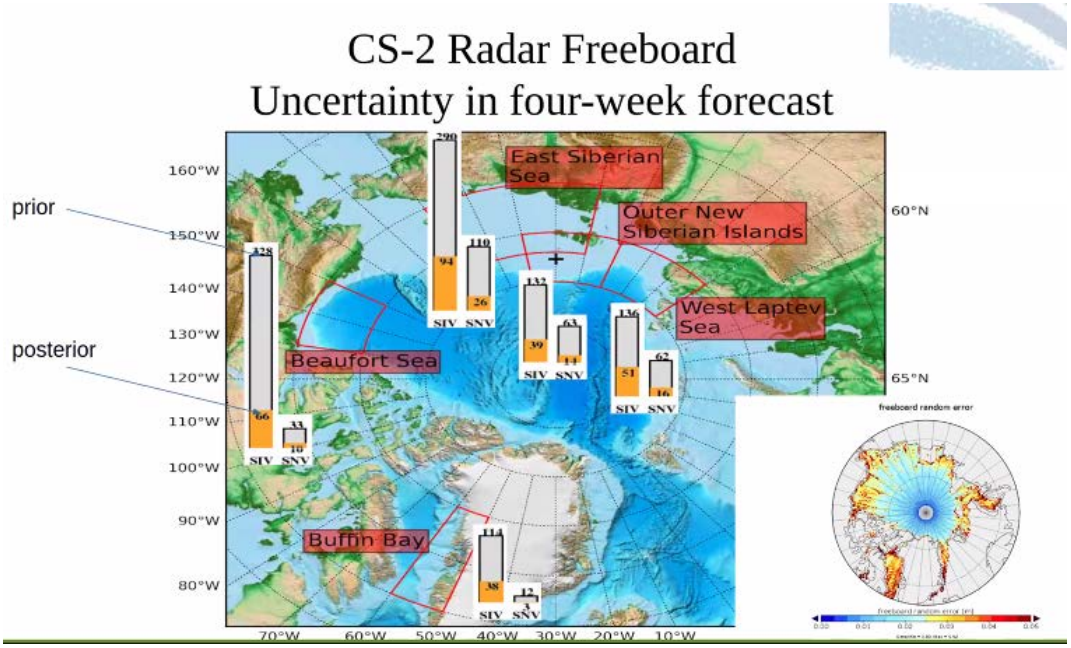
The schematics for the setup of these experiments, and assimilated data and utilised models- such as the Max-Planck Institute Ocean Model.

The formula that was applied for the network design approach was illustrated in the slide below. The uncertainty ranges in the observation coupled with additional parameters e.g. ice nucleation and time allow the design of the hypothetical data products.



An example of utilising lower processing level of sea ice thickness provider was also presented – CS-2 Radar Freeboard Uncertainty in a four-week forecast, showing how multiple observations affect the strength of the constraints the model is using.

TK also provided an example of Radar Freeboard + CRISTAL snow uncertainty in a four-week forecast.



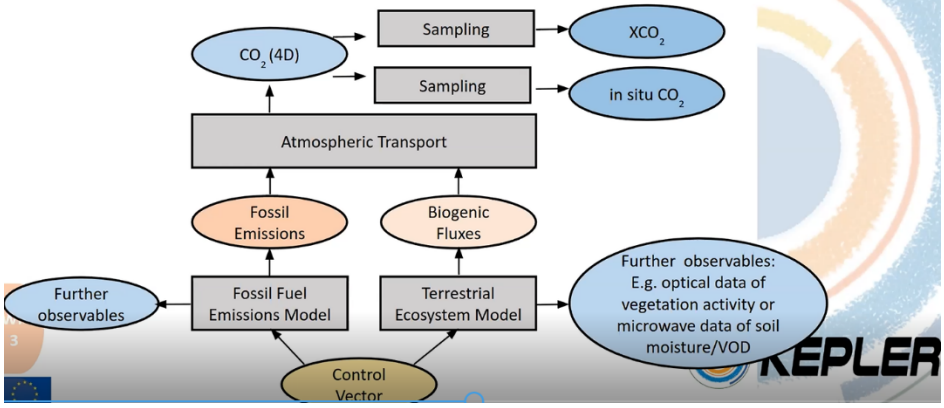
Another aspect of this task was to create hypothetical scenarios for In-Situ snow buoy networks, producing a tabular form of results to show the forecast uncertainty ranges per region.

Forecast Uncertainty per Region

		Sea ice volume [km³]					Snow volume [km³]				
Product	Product	BAB	BFS	WLS	ONSI	ESS	BAB	BFS	WLS	ONSI	ESS
prior	-	113.7	327.9	136.5	131.6	289.6	12.2	33.5	62.3	63.3	110.1
RFB CS-2	-	37.9	65.5	51.3	39.2	93.8	2.8	9.7	16.4	14.2	26.0
RFB S3	-	23.1	44.1	34.0	28.1	65.2	1.7	6.5	11.3	10.6	19.5
RFB CS-2	SND CIMR	11.8	27.4	4.3	5.9	19.7	0.6	2.5	4.0	4.1	7.9
RFB CS-2	SND CRISTAL	15.7	37.8	6.4	8.5	27.8	1.0	4.2	6.2	6.4	12.5
RFB CS-2	SND Reanalysis	14.6	36.1	6.2	8.0	25.9	0.9	3.9	6.0	6.2	11.9
RFB CS-2	LFB ICESat	5.7	13.1	2.1	2.7	9.1	0.4	1.5	1.6	1.7	3.3
RFB CS-2	13 Buoys 10 cm	37.9	64.2	51.3	39.2	93.0	2.8	9.7	16.4	14.1	26.0
RFB CS-2	13 Buoys 2 cm	37.8	55.9	51.3	38.7	84.2	2.8	9.6	16.4	14.0	25.7
RFB CS-2	20 Buoys 10 cm	37.9	64.2	43.7	35.4	87.2	2.8	9.7	14.8	13.5	25.6
RFB CS-2	20 Buoys 2 cm	37.8	55.8	17.9	18.6	52.7	2.8	9.6	10.5	11.2	23.6
RFB CS-2	88 Buoys 10 cm	37.8	59.4	43.5	35.4	86.0	2.8	9.6	14.8	13.4	25.5
RFB CS-2	88 Buoys 2 cm	37.8	51.1	17.5	19.1	53.8	2.8	9.5	10.5	11.2	23.7
RFB CS-2	123 Buoys 10 cm	37.8	59.4	31.9	27.6	71.5	2.8	9.6	12.6	12.2	24.6
RFB CS-2	123 Buoys 2 cm	37.7	51.0	11.3	12.9	41.6	2.8	9.5	9.7	10.6	23.0

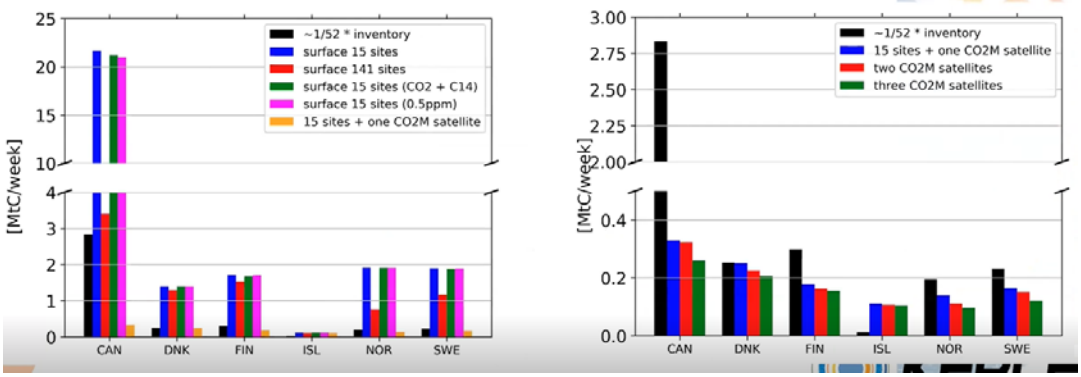
The following processing chain for the land-based fossil fuel emissions scenario was presented:

Carbon Cycle Fossil Fuel Data Assimilation System: Constraint on land based fossil fuel emissions



The posterior uncertainties for the country scale fossil fuel emissions (excluding electricity generation) for a week in June and for several in-situ and remote sensing scenarios are presented in the following slide and contrasted to an average value for the weekly (non-electricity generation) emissions derived from national inventories:

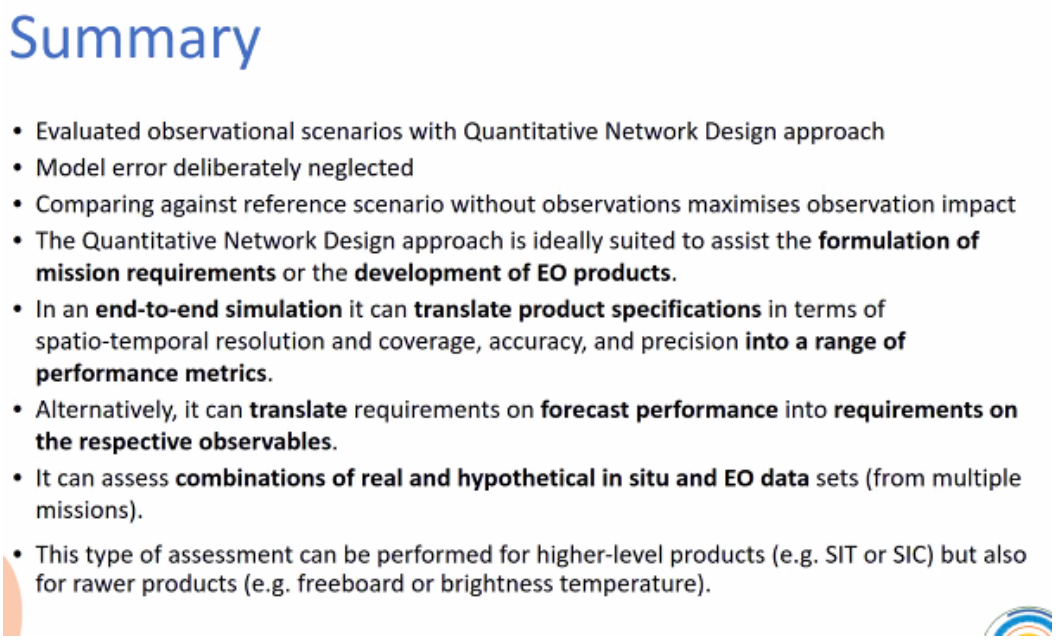
Impact of observational scenarios on uncertainty in fossil fuel emissions (1st week of June)



Specific recommendations gathered from these scenarios (see below) were fed into the roadmap, deliverable 5.2.

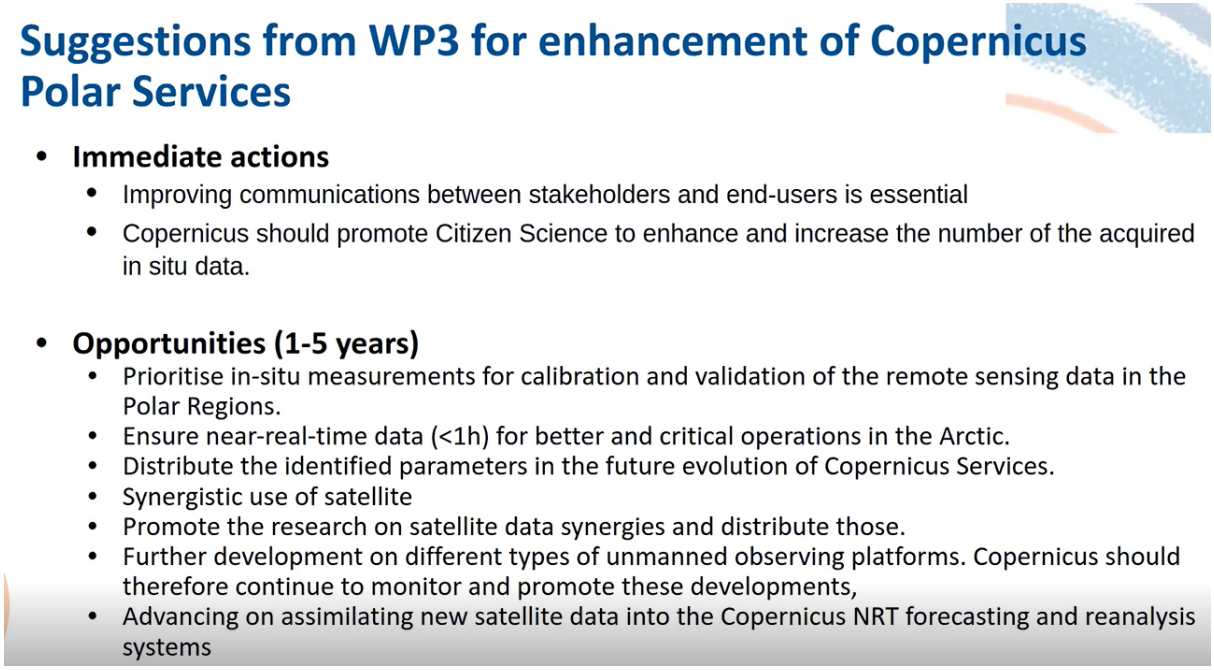
- All deliverables and milestones for this task have been achieved.

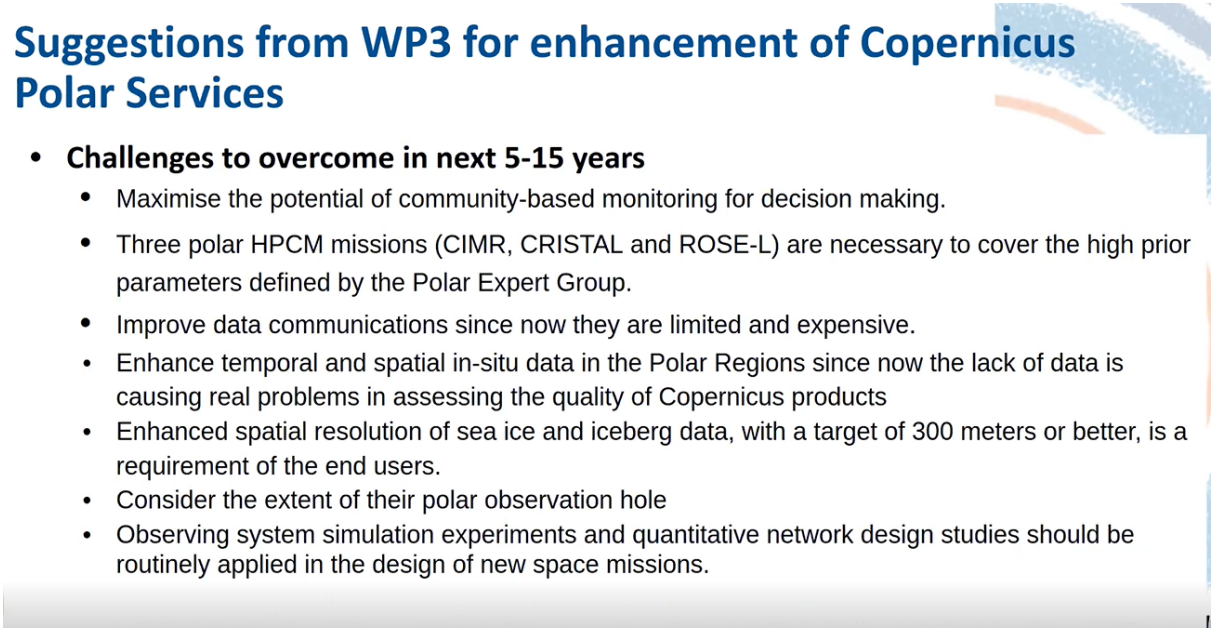
The team is preparing a paper for a peer reviewed journal and an extended abstract for the 16th AMS conference on Polar Meteorology and Oceanography that took place earlier this month.



Additional Deliverable: D3.5- Conclusions and recommendations of WP3- Carolina Gabarró

This deliverable gathered all conclusions from the four tasks in work package 3. It also explained what WP3 considers to be important action points to be undertaken as soon as possible, and opportunities that could improve Copernicus services that should be taken up in the next 1-5 years. This deliverable also highlighted the challenges that Copernicus face in the next 5-15 years. These recommendations have provided constructive recommendations to Copernicus with reasonable timescales.





Questions/Key Points raised for Work Package 3:

T.3.1:

- *Via chat* **Anita Faul, (UKRI BAS)**: How is quality monitored in Citizen Science?
  Tero Mustonen (Snowchange): Quality in citizen science needs to be understood also in the context of agency. CS processes are led by a scientist. Indigenous and traditional knowledge has to do with agency also in defining the spatiotemporal and interpretable frames of observations. When divergence with science and ILK happens, we should embrace why and how rather than dismiss them. CS is closer to classical data sets.
  Oral histories and cultural indicators are a part of ILK systems So there needs to be a link to how society (better information to make good decisions) will benefit from the continuation.
  So, quality can be determined also using cultural integrity as well as science criteria.
  Richard Hall, (Equinor): It is important to understand the quality of reliability of data, whether its official or unofficial (community data). If you understand the quality, then you can include mitigations even for amateur data.
  In Norway NMI are using private, amateur weather observations to improve temperature forecasts. In the future, I think we will see this expanded to include air quality - but this is still an idea: https://www.met.no/en/archive/private-weather-observations-improve-temperature-forecasts-on-yr.
  There is also a lot to be gained if local cultural classifications (citizen science) can be employed to improve scientific classification schemes - technology could unlock the potential if, for example, geo-located smartphone pictures of a particular snow cover could be collected to be used in a machine learning program to re-classify satellite images in Norway.
- In response to a question on the accuracy of citizen science measurements. **Jeremy Wilkinson, (UKRI-BAS)** shared the following figure from Deliverable 3.1. This highlighted that the co-production and co-design of science projects are important. Citizen science projects will have varying error bars and constraints depending on the activity that they are addressing.

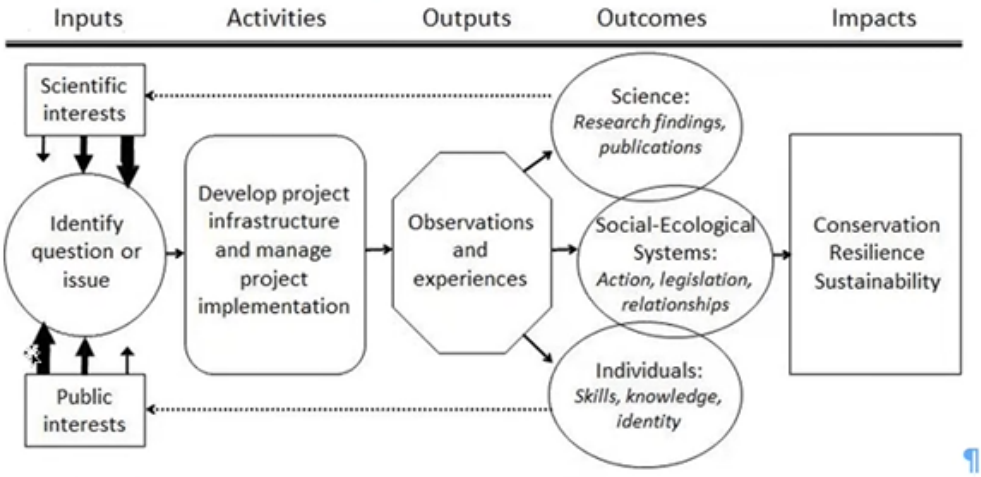
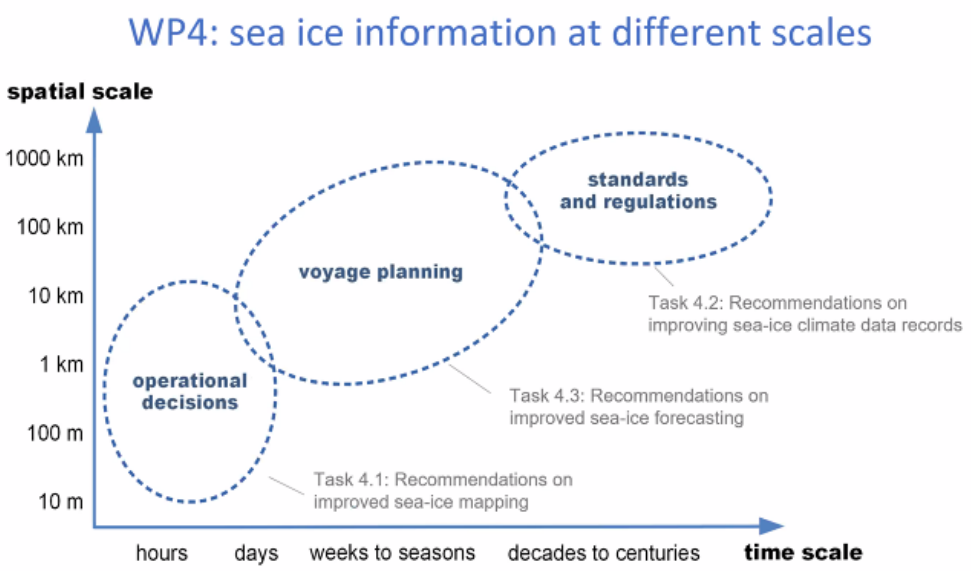


Fig. 1. Framework for public participation in scientific research projects involved in studying an ecological system (from Shirk et al, 2012).

WORK PACKAGE 4: Improved sea-ice mapping and forecasting - Steffen Tietsche



Steffen Tietsche introduced WP4 looks closer at sea ice information both currently and how we can approach this in the future.

An overview as to how sea-ice information is relevant at different timescales was illustrated using the slide above:

Ice services are in the lower-left corner, where operational decisions are made in real-time. This area is where task 4.1 is focused.

The opposite end of the spectrum on the graph above are climate change, climate modellers, and the research community. They are focused further ahead in the future, are working on larger spatial scales. This is where task 4.2 is focused.

In between these, are those that are trying to predict ice movements in the days/weeks/seasons ahead. Creating forecasts with numerical models, is where task 4.3 is focused.

T4.1 Sea-ice mapping for maritime purposes - Antti Kangas

Task leader, Antti Kangas presented this task which was undertaken by a team of European Ice services. The objectives of task 4.1 are in summary, to provide recommendations on how to provide better services for mariners. T4.1 utilised the gap analysis in T1.1, these user requirements were analysed against existing CMEMS services and current ice services capacities and potentials. This led to 25 recommendations for improving Copernicus services.

Outcomes

- The gap analysis is based on the user needs/requirements for the services provided in the Kepler T1.1.
- The user requirements were analyzed against existing CMEMS services and current ice services capacities and potential.
- Based on the gap analysis and projected future challenges, 25 recommendations for improving the services were reported.
- Recommendations were given in five categories:
  - User needs
  - Geographical gap analysis
  - Future challenges
  - Copernicus in general
  - Concerning satellite missions.

Table 1: Common desired parameters from EC and ESA project reports.

	CMEMS			
	Resolution	Update frequency	Timeliness	Product ID
Ice Concentration (Baltic)	1km	daily		011_004
Ice Concentration (Arctic)	1km	daily		011_002
Ice Type	10km	daily		011_001
Ice Edge (Baltic)	1km	daily		011_004
Ice Edge (Arctic)	1km	daily		011_002
Ice Thickness (Baltic)	500m	daily		011_004
Ice Thickness (Arctic)	25km	weekly		011_014
Ice Drift (Baltic)	800m	depends on SAR data		011_004
Ice Drift (Global)	10km	depends on SAR data		011_006
Deformation (Baltic)	1km	daily		011_004
Snow on Sea ice	12.5 km	daily	Forecast	002_001_a
Icebergs	10 km	Weekly		011_007
Ice surface temperature	5km	daily		011_008
Detailed Ice Charts				
Waves at ice edge	10km	daily	Forecast	011_001

Table 2: Color coding based on IICWG, ASF and AECO Polar Tourism Survey: Dark red: not met at all/missing product, Very poor: satisfies less than 25% of the users, Poor less than 50%, Moderate at least 50% and Good 75%.

User satisfaction	Resolution	Update frequency	Timeliness
No service	-	-	-
Very poor	1 - 10km	weekly	48h
Poor	500m - 1km	two days	24h
Moderate	50 - 500m	daily	12h
Good	0 - 50m	sub-daily	7h

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3

Highlights of the recommendations are:

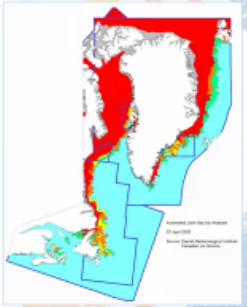
Highlights of the recommendations

In general, mariners want more timely information at higher resolutions.

#4 - For several products, **spatial resolution can already be increased** within limitations of SAR data (10-100m) and manual ice analysis spatial resolution.

#8 - **Improve service timeliness**, aim towards frequent or continuous updates in near real-time, preferably instantly. The demand for real-time services is expected to strengthen in the future.

#22-25 – To obtain high-quality daily sea ice and iceberg products for maritime needs, it is recommended to have **more satellite data** (geographically) with higher spatial resolution and **maintain continuity** of existing frequencies and acquisition types to preserve the climatological time series.



13 - Provide resources to **fill the geographical gaps** of ice chart coverage over the eastern parts of the Arctic (Northern sea route, NW Passage) and the Antarctic. Potentially open services for new areas, such as central Arctic (trans-Arctic route).

#14 - Establish a common platform that integrates information from combined ice chart products and merges regional ice charts from relevant ice services to a **pan-Arctic chart**.

#3 - CMEMS is recommended to offer an option for a **SIGRID-3** Shapefile format in its services for transferring and archiving ice information.

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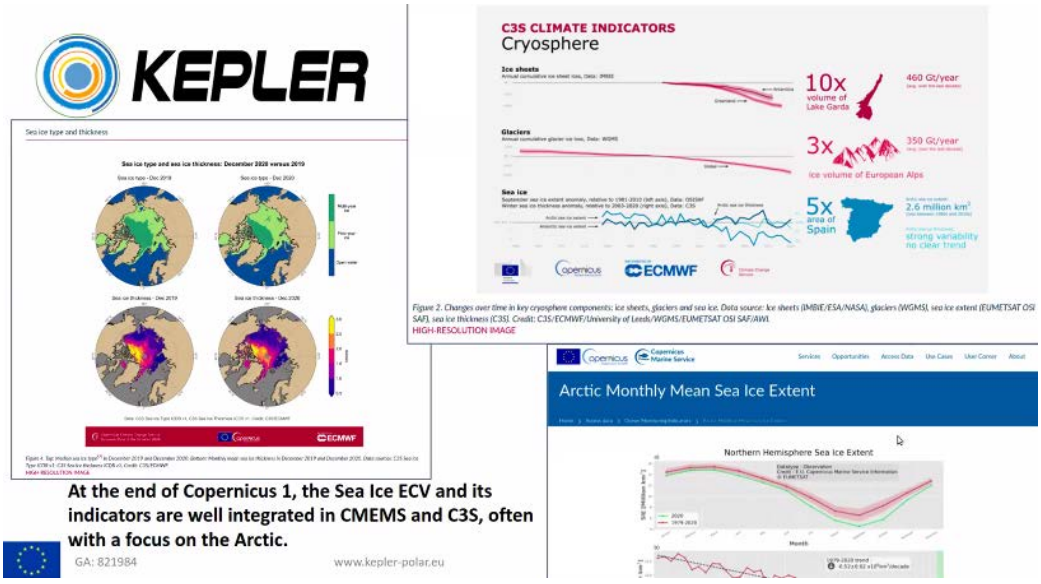
T4.2 Monitoring sea-ice as an essential climate variable (ECV) - Thomas Lavergne

The task Leader, Thomas Lavergne presented this task, which is focused on monitoring sea ice as an essential climate variable (ECV). The focus here was less on user requirements from WP1, and the recommendations for what should be done for improving ECVs were covered in WP3. Instead, this task looked at what sea ice ECV is currently available in Europe, both from Copernicus and other various initiatives. This task then considered how best to organise these services in the future- to facilitate an improved range of ECV services and products.

A note to highlight, that at the end of Copernicus 1, the sea ice ECV and its indicators are well integrated into CMEMS and C3S, often with a focus on the Arctic.



The status of sea ice ECV, and resulting recommendations were presented using the slides below:

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Focus on Sea Ice ECV as defined by WMO GCOS

- The status of the **Sea Ice Essential Climate Variable** (ECV) and its current implementation in Europe is analysed with the requirements for multi-decadal, error-characterized and time-consistent satellite-based Climate Data Records. The focus is on the **Copernicus Services** (CMEMS and C3S) and other contributing agencies (incl. **EUMETSAT SAFs** and **ESA CCI**).

- We polled the community of sea-ice climate data producers (not data users) to try and understand the **factors that impede or slow down** the development of sea ice CDRs, with a focus on Europe.

- **Deliverable report D4.2** "Recommendations for improved sea ice ECV records" with recommendations (some of them outlined next).

- **The GCOS ECV is over-crowded.** GCOS defines a single ECV for all the sea-ice variables (concentration, drift, extent, thickness, supported by age/type, albedo, melt ponds, surface temperature, snow depth,...). As a result, units of funding (1 ECV = 1 unit of funding) spread too thin over many variables.

- Recommendation #1: "**The Sea Ice ECV is more than Concentration and Thickness**": Recognize that the Sea Ice ECV is multivariate and allocate enough funding to its development so that all ECV products, and all EO technologies, can mature. All ECV products need repeated cycles of R&D.

- **A follow-up from KEPLER (initiated in WMO GCW):** The sea-ice EO community to liase with GCOS and outline the consequences of the over-crowded Sea Ice ECV (and potential solutions) .

- Recommendation #2: Some key missing products are: **melt-pond fraction**, **age/type**, **snow-depth** (in particular to support thickness retrievals), **albedo**, and **lead fraction**. Climate data records of **drift, concentration, thickness, type** exist but new R&D cycles are needed to further mature them.

- Importantly, the European EO R&D community **is ready to tackle the challenge (ref our survey)**, but they lack the large-scale, coordinated initiative to transfer their R&D products into mature, sustained CDR productions.

- The funders (EUMETSAT SAFs, ESA CCI, CMEMS, C3S) are seemingly not coordinated in their development agendas. Recommendation #3: **Coordinate the R&D and production agendas**.

- **A potential follow-up from KEPLER:** A multi-party workshop on "monitoring the Sea Ice ECV in Europe" with the funders, to synchronize the development and gain visibility.

- Other recommendations include:
  - During Copernicus 2: **Synchronize the Sea Ice ECV catalogues of CMEMS and C3S** (including if possible the Climate Indicators).
  - Expansion missions **CRISTAL (⚠ gap polar altimetry)** and **CIMR** (⚠ gap L-band radiometry) will directly input the Sea Ice ECV, likewise the Sentinel-NGs.
  - **Satellite data rescue** should be conducted as an international endeavour (CEOS/WCG-Climate) to extend ECV time-series back in time (pre 1978).
  - When a coordinated service for in-situ sea-ice data is started, one of its focus should be to ingest **past in-situ data**, to serve the validation of climate data records.

- **In Conclusion:** We can be happy about the state of the Sea Ice ECV in Europe during Copernicus 1. **The situation can be improved during Copernicus 2**, starting with a better coordination of the actors, and appropiate level of R&D funding (Horizon Europe?) to close the existing gaps. **Importantly:** we have the strong EO community in Europe, but must put it to work towards the ambitious goal.

T4.3 Assess the scope for sea-ice forecast products - Steffen Tietsche.

Steffen Tietsche, summarised the structure of work and subsequent report for task 4.3 in 4 key areas:

1. Synthesis of sea-ice specific user requirements
2. Assessment of current forecasting capabilities
3. Gap analysis
   - Forecast resolution and coverage
   - Ice properties being forecast
   - Forecast quality
   - Forecast presentation and communication
4. Recommendations for improvements along parallel work streams
   - Improved understanding and utilization of existing forecasts
   - Evolution of existing forecasting systems
   - Improved provision of observations for forecast validation and calibration
   - Nowcasting and short-range forecasting using sub-kilometer scale sea-ice observations
   - Develop new class of physics-based sea-ice forecast models

An assessment of currently available sea-ice forecasts leads this task to question if we are utilising existing forecasts to their full potential and are there existing forecasts or products that can be improved for users. There is a need to approach service providers and encourage co-development, and sustained dialogue between Copernicus and users to create products that are fit for purpose.

Currently available sea-ice forecasts

Forecasting system	Provider (producer)	Forecast range	Compo-nents	Spatial coverage	Update frequency	Spatial resolution
Seasonal multi-system	C3S (several)	6 months (LR)	IOA	global	monthly	1°
ENS-extended	ECMWF	7 weeks (ER)	IOA	global	twice-weekly	36 km
GLO-CPL	CMEMS (UKMO)	10 days (SMR)	IOA	global	daily	1/4 °
GLO-HR	CMEMS (MERCATOR)	10 days (SMR)	IO	global	daily	1/12 °
ARC-MFC TOPAZ	CMEMS (METNO)	10 days (SMR)	IO	Arctic	daily	12.5 km
ARC-MFC neXtSIM-F	CMEMS (NERSC)	7 days (SMR)	I	Arctic	daily	3 km
BAL-MFC	CMEMS (DMI/BSH)	6 days (SMR)	IO	Baltic	twice-daily	2 km

With **increasing**
time range and spatial coverage,
there is a **decrease** of
spatial resolution and update frequency.

This is because
1. supercomputers have limited resources
2. at long time ranges, we expect forecast to have skill only at large scales

This **trade-off** is unavoidable.

Key recommendations from Task 4.3 were presented in the slide below:

Key recommendations from Task 4.3

1. Main gaps between user requirement and current service provision are

- Spatial resolution (~100m needed but ~10km provided)
- Deficiencies in forecast quality and presentation (reliable uncertainties)
- Lack of user-relevant sea-ice parameters (e.g. compression, stage of development)

2. Therefore, research and development is needed on:

- Increasing spatial resolution of sea-ice forecasts
- Reliable forecast uncertainty quantification using *re-forecasts and ensembles*
- New and improved sea-ice models to better capture relevant features
- Better use of in-situ as well as novel and high-resolution satellite observations

Co-development of information products with users is key!

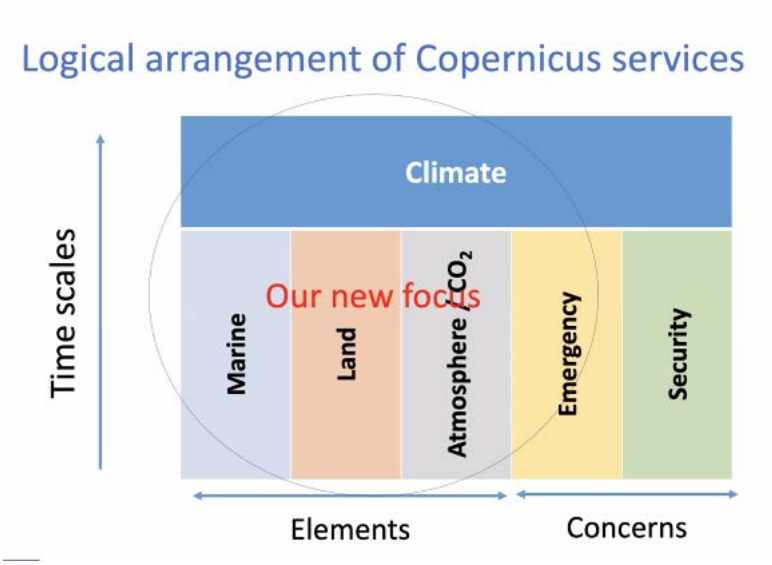
Questions/Key Points raised for Work Package 4:

- No questions raised for work package 4.

WORK PACKAGE 5: End-to-end operational system - Frank Kauker

T5.1 Synthesis on the visions of the evolution of the Copernicus services - Laurent Bertino

Laurent Bertino introduced task 5.1, noting there have been significant contributions and input from all work packages. This task has been internally referred to as 'the inventory' as it looks at Copernicus services in the Arctic, and establishing what linkages are missing. Reviewing the status of Copernicus services, this task arranged these based on timescales below:



Description of work – Task 5.1

Synthesis on the visions of the evolution of the Copernicus services

Consistency and possible synergies

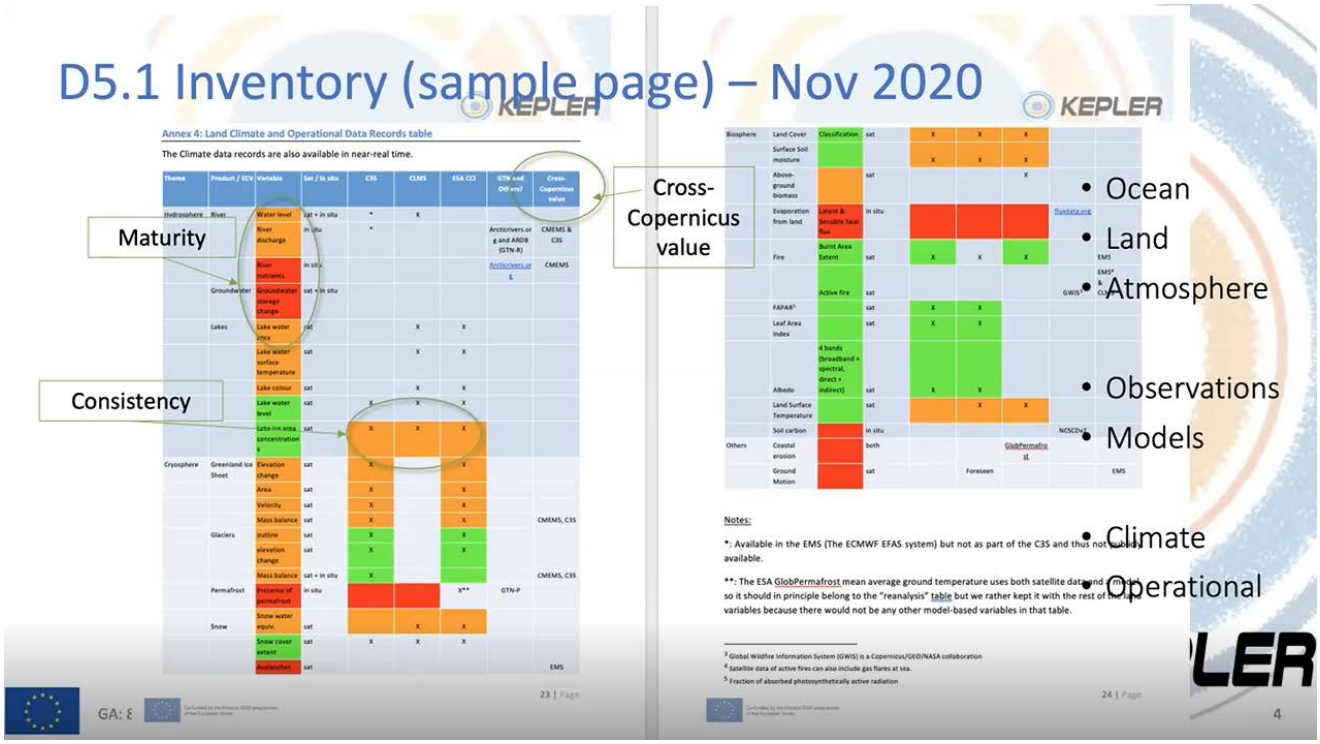
- reporting on the linkages between the terrestrial and marine components
- between the short-term (CMEMS, CLMS, EMS) and climate time scales (C3S),

Gaps in the overall service

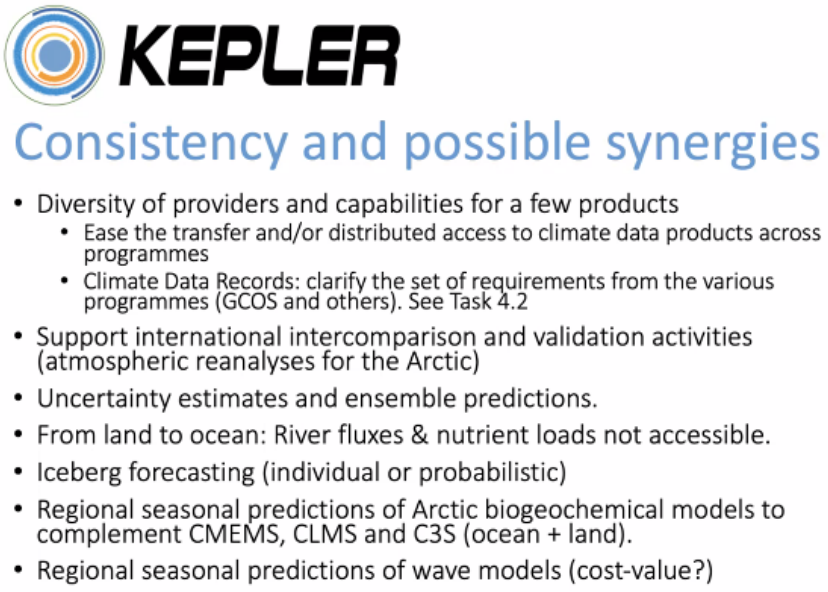
- Present status of variables and services available,
- Possible inconsistencies,
- Evolution of the needs

The above actions informed the deliverable report- 5.1 – the 'inventory', and an example page of this can be viewed in the slide below:

Note that there are tables for ocean, land, atmosphere, observations, models, climate, and operational scales. All follow the same template - a colour for each variable, and the traffic light colours indicate the maturity of the variables (in general), and other columns show different services within Copernicus and external providers. The colours also show how consistent the information is across providers. The Cross-Copernicus value column highlights what other services would benefit from this variable.



The 'inventory' informed the following information and recommendations:



Gaps in the services

- Sea ice in situ observations in CMEMS and C3S
- Additional sea ice variables from satellite in CMEMS and C3S
- Permafrost in the CLMS and C3S data servers.
- Evaporation in the CLMS and C3S data servers.
- River nutrient fluxes to the ocean, either in CMEMS or CLMS
- Observations of avalanches, either in CLMS or EMS
- Out of reach, too complex: Biodiversity ECVs, human pressure.

Evolution of the needs

- Set up a meta-browser that can harvest polar data from CMEMS, CLMS, C3S data stores and other international sources consistently.
- Set up such a cross-Copernicus window with these capabilities:
  - Dataset discovery
  - Subsetting
  - Visualisation
  - Easy handling of polar projections.
  - Cloud computing (including the “invoke” service from INSPIRE)
  - Comparisons between different products
  - Overlays with external validation data

T5.2 End-to-end operational system roadmap - Frank Kauker

Frank Kauker, Work Package 5, and Task 5.2 leader presented on the KEPLER roadmap.

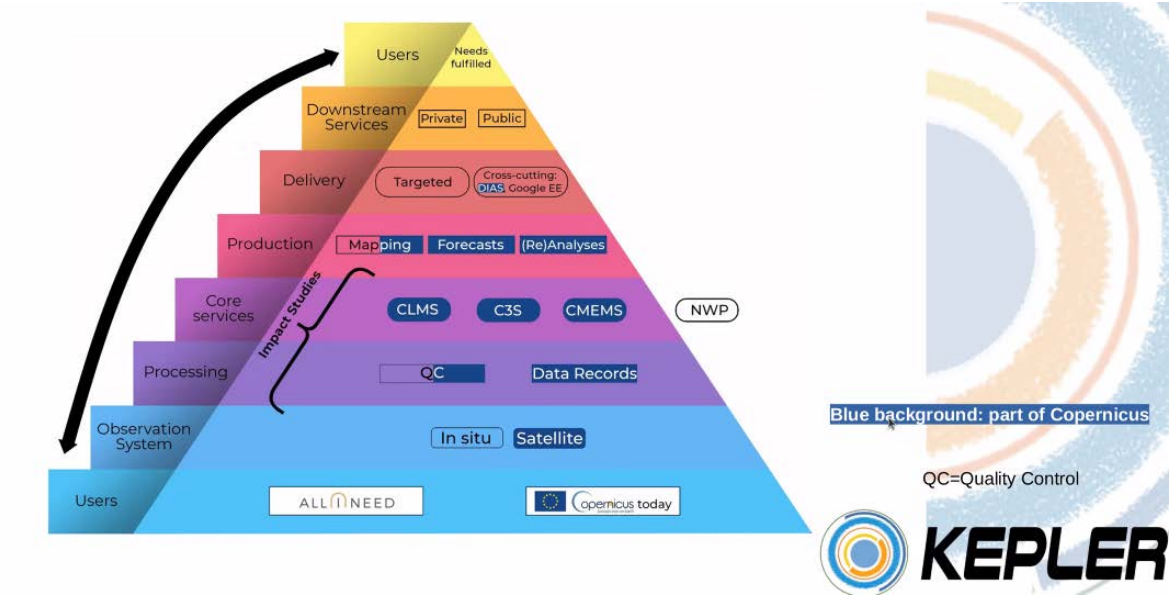
The roadmap produced reflects the specific areas that KEPLER has addressed. This deliverable will pull together the various recommendations of each work package.

There are many recommendations on different levels of the system. The table of contents for the roadmap was displayed, showing how this report is structured. Terminology has also been addressed for this report, and the implications of the terminology. As identified in WP1, conceptual clarity and terminology need to be improved on all levels of Copernicus products.

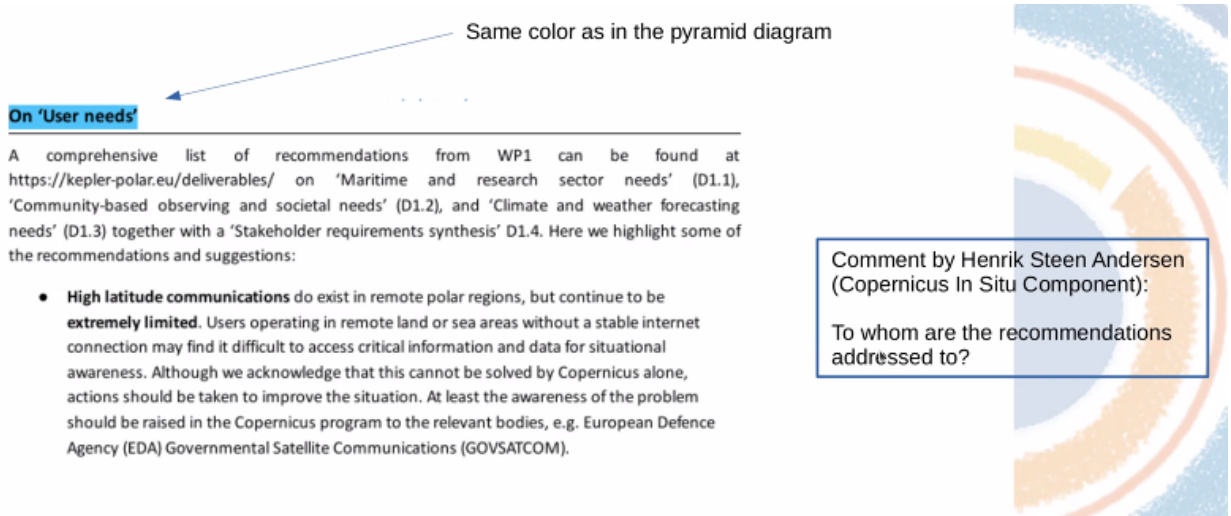
This task draws together the overarching recommendations and suggestions across all work packages:

> **Overarching recommendations and suggestions across all work packages**
>
> Some of the recommendations and suggestions of KEPLER are generic, i.e. have been made in several work packages cross-cutting the core services. Note that for some of the recommendations and suggestions no consensus between the wishes of the stakeholders and, e.g. the scientist performing the forecasts in the KEPLER group, could be reached that the demands could be fulfilled within the next multiannual financial framework for 2021-2027, known as Copernicus 2. These recommendations and requests comprise:
>
> - **Improved spatial and temporal resolution** and latency of model and data: The KEPLER user-uptake has yielded a strong request for high spatial resolution (better than 1 kilometer) for remotely sensed observations and forecast model outputs. **Remark:** It is unlikely that these requests could be fulfilled within Copernicus 2 but it might be possible to fulfil the demand for selected variables. We recommend **fostering new ways to fulfil the demand**s, e.g. by deep learning methods (see as well the more specific recommendations below).

WP5 has produced a diagram of the Copernicus ecosystem to assist with explaining our recommendations and user needs.



This task has considered who are these recommendations for- not just Copernicus, but for the general science community.



FK noted that there is a problem with the delivery of data, DIASES is not free of cost, if you want to create a downstream service, you must pay for this data. You can source it from Copernicus, but we foresee and issue for the DIASES platform- especially for indigenous communities who will not have the funding to access these downstream services/data.

Data delivery - targeted and public

Developing private Downstream services in the Arctic is handicapped due to **non-free of cost** deliverance of atmospheric forecast products. Additionally the cross-cutting delivery of data via DIAS and Google EE, although cost-free at the moment, are intendented (or probably intended in case of Google EE) to be no free-of-charge services. Because a very low to be expected return-of-investment for most Arctic Downstream services, especially if indeginous people (see below the user story on reindeer herders) or local communities are beneficiaries, non-free of cost delivery of data add another handicap.

- It is recommended to **find solutions for free-of-cost delivery of Copernicus and NWP data if Downstream services intended for local communities and local and indeginous people via the DIASES.**
- **The potential role of the DIASes as a cloud solution including cloud computations, as had been under consideration earlier, should be reinforced.** It could be powered for example by a DIAS cloud for assessment of all nominal products (as well as on their source level) across all Copernicus services. Such a cross-Copernicus window should allow cloud computations e.g. dataset discovery, subsetting, visualisation, comparisons between different products, overlays with external validation data.

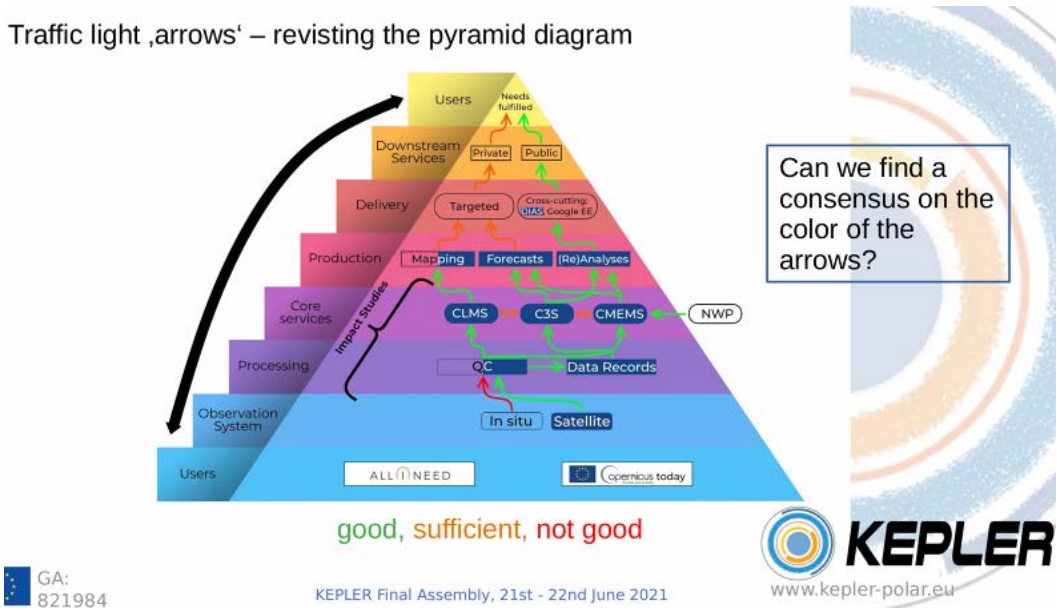
- In 2016, the 'FAIR Guiding Principles for scientific data management and stewardship' were published. The authors intended to provide guidelines to improve the **F**indability, **A**ccessibility, **I**nteroperability, and **R**euse of digital assets. The principles emphasise machine-actionability (i.e., the capacity of computational systems to find, access, interoperate, and reuse data with none or minimal human intervention). Metadata and data should be easy to **find** for both humans and computers. Machine-readable metadata is essential for the automatic discovery of datasets and services. This includes assigning a globally unique and persistent identifier and registering the data in a searchable resource. The data should be **accessible** by their identifier using a standardised open, free, and universally implementable communications protocol. Because the data most likely needs to be integrated with other data, in addition, **interoperability** with applications or workflows for analysis, storage, and processing is essential. The ultimate goal of FAIR is to optimise the reuse of data. To achieve this, metadata and data should be well-described so that they can be replicated and/or combined in different settings. (Meta)data are richly described with a plurality of accurate and relevant attributes and are released with a clear and accessible data usage license. **The European Commission and Copernicus are prompted to request to follow the FAIR principles in all funded projects to facilitate the exchange of data.**

The Roadmap draft has been discussed internally in KEPLER, the following feedback is being addressed and was raised for comment at this general assembly meeting.

Some open issues (internal KEPLER):

- WPL's please check again if all recommedations are suggesting ways to improve the situation
- Comment by Michael: I guess it would be very helpful for a receiver of the output to find all recommendations compiled/listed together, either as a part of the Executive Summary or as a separate chapter.
- Should we be more specific where to find each recommendation in the deliverables of WP1 too WP4 in the roadmap

The pyramid structure was illustrated with a traffic light system:



Questions/Key Points raised for Work Package 5:

- **Jeremy Wilkinson (UKRI-BAS)**- In Situ data issue is due to owners of platforms not putting the data on GTS. Once it is on there it is accessible. There is a bottleneck there.
- **Nick Hughes (METNo)-** The colour of the arrows can vary according to the type of user, and what type of information they are interested in.
- **Jeremy Wilkinson (UKRI-BAS)-** It would be good to have a description of what 'good' 'sufficient' means- so that there is a better interpretation of what those colour arrows mean.
- **Michael Karcher (OASYS)-** The pyramid is a useful mechanism for this report. It will also be very useful to other projects, especially for Arctic Passion they will benefit from this output.
- **Richard Hall, (Equinor)-** Rather than say 'not good' say 'requires improvement' Change the black arrow on left-hand side, have one signal arrow that links the user feeding in the needs and an arrow at the bottom. Good, satisfactory, improvement area might be good category names for this traffic light system.
- **Helge Goessling (AWI)-** Questioned why the users are at the top and bottom. Richard Hall highlighted that this was due to a feedback loop. Users feed into the services, and uptake them.
- **Michael Karcher (OASYS)-** If you would unfold this, you would see many more players in the game between the levels between users and requirements?
- **Leif Toudal Pederson (EOLAB)-** suggested that the black arrow is not ideal- and that user needs flow down through the pyramids, the users do not have needs for observations, they have needs that they will communicate to their downstream service provider.
- **Richard Hall, (Equinor)-** At the bottom is all I need, at the top should be needs fulfilled.
- **Leif Toudal Pederson (EOLAB)-** It is important that we do not just see this as needs for requirements to observation systems, this is also communicating requirements to improving services, models, quality control etc. This does not just always have to come down to where the observations are.
- **Gilles Garric (MERCATOR)-** instead of putting users at the bottom, we could put a box at the side, and have arrows that point to each layer- as users are involved in each layer.
- **Michael Karcher (OASYS)-** Agreed with Gilles, include the side figure that acts as a pipeline figure, informing each layer.
- **Thomas Lavergne (METNO) / Leif Toudal Pederson (EOLAB)-**Questioned if citizen science/ observation could also be added.
- **Frank Kauker (OASYS)**- To confirm, users on the left side, arrows to all layers from users, add citizen science on processing level, and add definitions- change the rating scale.
- **Michael Karcher (OASYS)-** Will there be indications at the end of the roadmap that show Copernicus how to arrive at the recommendations- actions to help those solutions happen.
- **Frank Kauker (OASYS)**- for some, not all recommendations yes.
- **Richard Hall, (Equinor)-** With EU funding, when you buy in-situ data you have an obligation to make it available. From a roadmap perspective, that agreement should be followed up and ensure the data Is made available. That would improve things somewhat.
- **Gilles Garric (MERCATOR**)- KEPLER is for Copernicus, who in the future will help assist fulfil these recommendations? When you recommend these services, you do not want to interrupt them. In terms of research, we will need to help the European Commission to plan these changes and actions- so that projects get what they need. How to help Copernicus focus on which aspects first? Especially in terms of finances.

- **Nick Hughes (METNo):** Danger of the arrows becoming overcomplicated- can we simplify this? The user scape from deliverable 1.3 had a similar issue.
- **Michael Karcher (OASYS)-** There are two versions of this diagram in the document- so that the simpler one is at the start.
- **Frank Kauker (OASYS)**- Another option is to skip the green arrows and focus on the things that need work.
- **Antti Kangas (FMI)** Keep all the colour arrows as it helps pinpoint issues.
- **Frank Kauker (OASYS)**- A good compromise is to make all arrows green from processing to core services, and core services to production, then we can have one arrow to show all in a good state. (The consensus was to use this to simplify the pyramid diagram)

Further feedback was provided by Mark Drinkwater via email after the Final General Assembly:

Please find below some comments for the Roadmap, based largely on the section on General Recommendations and Suggestions.

•Improved spatial and temporal resolution and latency of model and data: The KEPLER user-uptake has yielded the strong request for high spatial resolution for remotely sensed observations and model output forecast model

In order for ESA to act on such recommendations, exact requirements are needed (latency, resolution etc.). It might be that this is provided elsewhere in the specific deliverables of KEPLER, if so need to be cross-referenced. Specifics would have to be provided for us to act on requirements not already covered by the Copernicus User Requirements collection effort. Currently, there are already established user requirements from the mission requirements documents which are being achieved. This recommendation can perhaps be applicable to future missions (HPCMs, continuities etc.), but for us to act on this, would require a strong and clear recommendations/requirements supported by the Copernicus services or from EC.

•Continuity and improved capabilities of satellite observations are crucial. Continuous time series of European satellite based estimates of both sea ice concentration and sea ice thickness are of utmost importance for operational users and climate research. Of the three Polar HPCMs, CRISTAL and CIMR have the highest potential to extend the monitoring of the changing polar sea ice. With the current time line with launch dates at the end of the 2020s, we must expect gaps to current missions (e.g. CryoSat-2, SMOS). The gaps between missions should be made as short as possible.

A recent community letter of concern regarding the imminent gap in satellite polar altimetry, which is likely to occur in the latter half of this decade, was published. An airborne campaign activity is likely required to bridge the records from the two missions. However, since CryoSat is approaching end of lifetime this would require funding from elsewhere (EC etc.), to mitigate the effect of this possible gaps in the climate record (perhaps consider e.g., Something similar to Operation Ice Bridge/airborne campaigns). The gap is not a certainty but can be expected. Meanwhile Sentinel-3 will allow for measurements up to 81.5 degrees, thus we should call on science community to work more with Sentinel-3, especially after an Instrument Processing Facility update in April 2021 (same quality as CS2). It is not feasible to change S-3 inclination/orbit to include near-polar observations. Sea ice (thickness) Fiducial Reference Measurements (FRM) seems prudent in this context – by considering: "how to ensure a long-term record in sea ice thickness, if we cannot compare with precise, high quality reference points?"

•The evolution of the future Copernicus services have to take into account all components. The future service should ensure the continuity of the core service played by Copernicus services on pan-Arctic scale. This concerns the variables already present in the current portfolio but also the monitoring of the data quality and the data policy.

Ensuring data quality is ESA's mandate, and proper characterisation of uncertainty is needed – there is a clear justification for FRM here. Furthermore, best practice/protocol to ensure the quality is the core of projects, to define

good quality/protocol/parameters. The ESA S3TART activity is relevant in this context. Currently, there is no funding for long-term maintenance and deployment of FRM.

It is not ESA's mandate to fund all in-situ data segments for FRM. The S3TART objective is to show the benefit of FRM for Sentinel-3 with the appropriate supporting budget. To ensure data quality, currently we have sporadic campaigns and are still in demonstration phase/developing phase. A similar S3TART like activity is expected in prep for CRISTAL – resulting in defining a roadmap for FRM.

•Especially in-situ data are very scattered among several platforms if present at all at Copernicus. For instance, no sea ice in-situ data are available to date from Copernicus Services. It is suggested by many users to establish a "one-stop-shop" for Polar region under the leadership of Copernicus.

Harmonization of formats and information is often discussed in forums. It would be nice to have, e.g., a platform within ESA (common platform) with the goal to harmonise FRM data and provide ice data access to science community – a place people would go with high confidence in the data, that would be ideal. It is a welcomed initiative.

Such a platform would include sea ice (thickness)-relevant in situ reference data. Furthermore, allow for access to data and tools – an interface allowing users to use existing data. With the target to show examples to the community and build on existing data.

The idea to compile everything is complex and time consuming, so perhaps part of roadmap for higher-level targets.

Highlighted recommendations on 'Stakeholder needs' (WP1)

•A recurring recommendation from users is the need of information that is easily understood and available in familiar and standard data formats. This includes being able to easily access the information from multiple sources without having to encounter bandwidth intensive formats and issues. Standard format usually includes ENC's, ice charts in various standard graphics formats, GIF, PDF and JPEG2000 for raw satellite data when used.

Harmonization of products are often discussed. Often something to discuss in beginning of mission or for every baseline (e.g., CS2 Baseline-D now changed to NetCDF format). Ensure that common formats are used in future missions.

•The increase of sea ice information provision should include better dissemination, tools and training of different data products for non-specialists. Issues with end-user's understanding of multiple products have been a critical challenge regarding the user uptake of new products. For most marine users it can also be difficult to access large data files due to communication limitations in Polar Regions.

It is our aim to provide all relevant information to the users on the product, formats, quality etc. Perhaps showcase how the product maturity matrix can be used, to ensure that the dissemination of the products are of high maturity. CMEMS provides workshops for non-specialists (and also JupyterNotebooks to training) to ensure that they can open/use the data (even non-specialists). ESA Cryo-TEMPO Project is aiming at providing state-of-the-art products for non-altimetry experts.

Highlighted recommendations in 'Polar Regions provision in Copernicus Services' (WP2) – on CLMS improvements

•Include additional products from the following ESA-CCI projects, when available: permafrost, Glaciers, Biomass, Snow, Land cover, Fire (the latter three are already included in CLMS, hence the recommendation is to harmonize with the existing products).

•Include from C3S: snow cover extent, land cover, surface soil moisture, and surface albedo.

Perhaps also outcomes of SnowPEx+ (Snow Product Intercomparison Exercise) could be highlighted or included here, to illustrate the work on going to understand product uncertainties.

- on CMEMS improvements

•Important gaps in the description of the biogeochemical state of the polar oceans are present

E.g. Ocean colour/lead detection has been discussed. Currently, not a lot of information is available in detecting high production in Polar areas due to the difficulties in obtaining ocean colour directly adjacent to bright sea ice. Could be a future activity to be investigated e.g., using S-3 altimetry/optical.

•Having similar services for Antarctica is rather challenging, as no proper regional Marine Forecast Centre exists. Services in the Southern Ocean are part of the GLO MFC system.

Sentinel-3 allows for detecting the entire Antarctic sea-ice region, thus it will be prudent to properly communicate the improvements of the products (new IPF in April 2021) to include the science community and make them act to produce relevant/more work on S-3 Antarctic sea ice. The Sentinel continuations (C+D) will be crucial for Antarctic sea-ice studies as well. We must highlight the importance of this and the products, so that the science community can act on this.

'Identification of research and capacity gaps' – on In-Situ Observations

•Prioritising Cal/Val in situ measurements in the Polar Regions is desperately needed to reduce the identified uncertainties associated with Copernicus Services polar products.

A clear justification of a polar Fiducial Reference Measurement (FRM) system here.

•Developing a framework whereby Copernicus Services can better utilise European polar research assets (e.g. stations, ships, aircraft and people) to provide needed Cal/Val opportunities for Copernicus Services products.

If there is a focus on this – ESA shall join/participate in this? This would facilitate better provide Cal/Val opportunities.

•Ensuring independent Quality Control of services/products by establishing a continuous monitoring framework.

S2I will allow for tools/practices to, in best practice, compare results. Perhaps Copernicus users can leverage from this in future

•Eighteen synergies that could be achieved with the current satellite data and/or with the future HPCM data once flying, are described in D3.3. We strongly recommend to enable the necessary R&D and initiate the production and distribution synergistic products.

Current ESA products of relevance (e.g., Polar+ Snow on SI for CRISTAL/snow depth). Perhaps ESA can make an effort to help investigate these synergies and invest time in an activity that can provide/invest/test these synergies before the HPCMs?

recommendations on 'Improved sea-ice mapping and forecasting' – on Improved Sea Ice ECV Records

•"The Sea Ice ECV is more than Concentration and Thickness": Recognize that the Sea Ice ECV is multi-variate and allocate enough funding to its development so that all ECV products, and all EO technologies, can mature. All ECV products need repeated cycles of R&D. At any given time, some key sea-ice variables (see next item) might not be recognized as official ECV Products by GCOS.

•Some key missing products (or products on which R&D is needed) are: melt-pond fraction, age/type, snow-depth (in particularly to support thickness retrievals), albedo, and lead fraction. Climate data records of drift exist or are being prepared, but new R&D cycles will be needed to further mature them.

Sea ice ECV is clearly more than concentration and thickness. It is necessary to reframe the ECV for it to be possible to allocate time/resources to investigate the other R&Ds and aspects that could be of interest for sea ice ECV, e.g., type, snow depth (Polar+ Snow on SI), lead fraction, albedo (optical/thermal) etc.

•Europe lacks a coordinated collection of in-situ data in sea-ice covered regions

Ensuring of data quality and potential sea ice FRM – can a framework be established that leverages/utilises current polar assets (e.g., ships, or other things), and allocate funding/effort to ensure a coordinated collection of this – potentially storing in a data portal for FRM hosted by ESA.

•Satellite data rescue should be conducted as an international endeavour to extend ECV time-series back in time.

This is the core of ESA CCI+ Activity and is currently being undertaken in the sea ice project (cf T. Lavergne).

Copernicus services- update/discussion- Nick Hughes & Mark Drinkwater

In place of Ola Nordbeck, Nick Hughes gave an overview of the status of the new phase of the Copernicus service.

Mark Drinkwater highlighted there is a delay to the programmatic checkpoint to decide how the blend of funding between space infrastructure commission/ESA funding requires input and sign-off. The decision has been pushed to the end of the year now.

All expansion missions are planned to go ahead. As far as ESA are aware they will proceed with all expansion mission, but there is a need to shoehorn all the budget needs Copernicus 2.0 and ESA funding. Some shortfall that will require development. Some things will be phased over a longer timescale, and the milestones that allow us to recoup some of the later funding 2022, 25 and 28 for covering things that may not be achievable within the current budget envelope,

Problematic waypoint needs to decide what is achievable and have a proper outlook on the development timescale.

Ola Nordbeck is returning to the Norwegian space agency, which is why he was unable to participate today.

There is still some work to be done to determine how the program develops based on the final budget decisions.

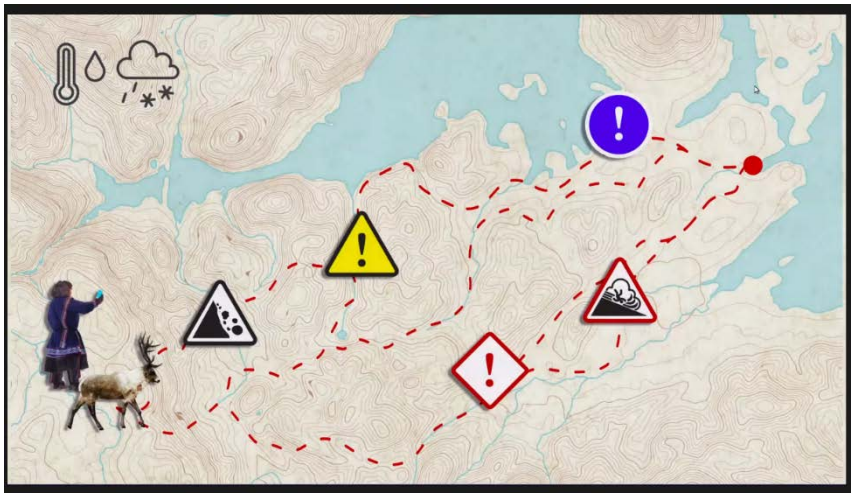
Mark Drinkwater highlighted that there is an important workshop happening tomorrow, with program board member states, that will present the status of all the expansion missions on the table today- there is another discussion scheduled for September, and various ongoing Copernicus committee and user forum related meetings between now and the end of the year. That will lead to a more consolidated picture in terms of the development of satellites, and the services that revolve around these data products.

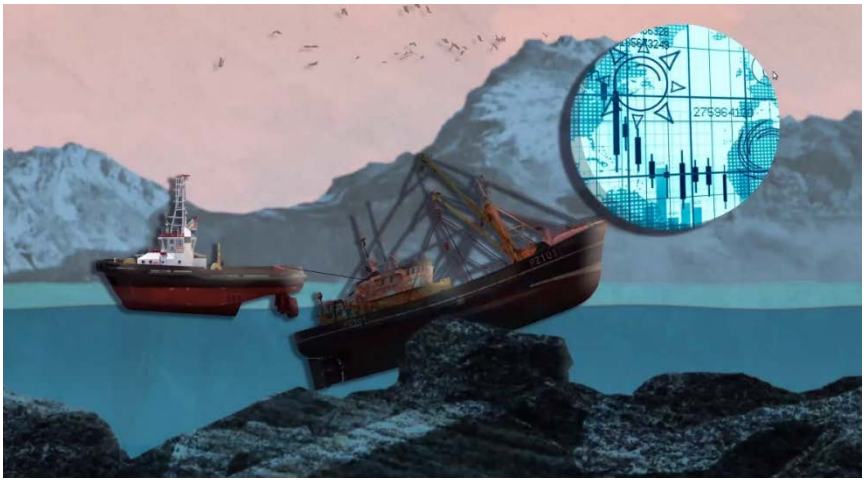
WORK PACKAGE 6: Dissemination, training, and engagement - Nick Hughes

As part of the end of project dissemination, work package 6 developed various dissemination activates to promote the project.

KEPLER Video- Emma Armitage/Nick Hughes

Meeting participants were shown the first draft version of a KEPLER promotional video, that focuses on three key user stories, illustrating how KEPLER's recommendations could help Copernicus' ability to provide improved services, and greater safety to activities in the Arctic regions.





Feedback for the video was provided by meeting participants and collated to send to the KEPLER video animators for development.

- **Richard Hall, (Equinor)-** US coastguard polar ship sinking not a good idea- change name!
- Norwegian words- check pronunciation.
- **Steffen Tietsche (ECMWF)-** note that the fish looks like pikes- please update.
- **Michael Karcher (OASYS)-** Queried the oil retrieval mechanism. Note what is KEPLERs part in this?!
- **Steffen Tietsche (ECMWF)-** should stress that this is hopefully where we want to be.

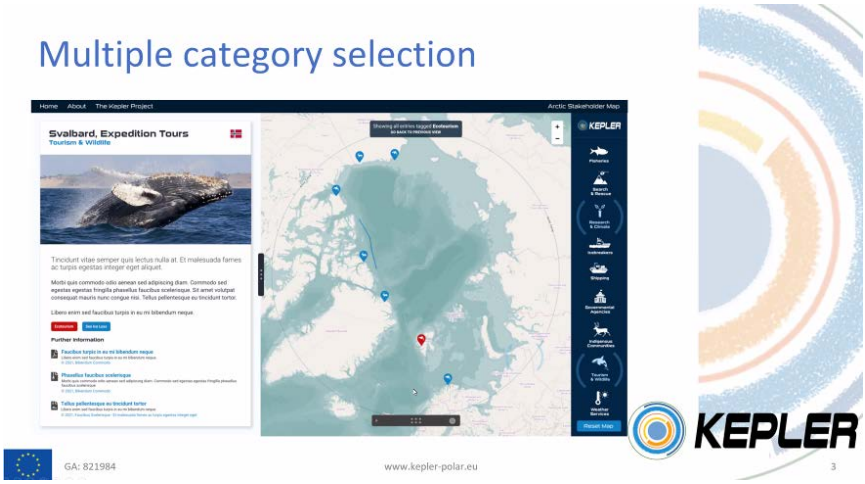
- **Jeremy Wilkinson (UKRI-BAS)-** End on key recommendations of KEPLER there- 2 or 3 taken from us. What is KEPLERs doing? The 3 examples are good. Now that we are moving into the second era of Copernicus the key recommendations are……
- **Richard Hall, (Equinor)-** Near future rather than science fiction. Aim will be that those user stories would be reality. KEPLER is a guideline to EU decision makers on how to spend EU money on services and data collection to ensure a safe society in the Arctic. KEPLER is delivering those guidelines so the EU politician will pay attention. Therefore, I should invest in this…. Help reindeer, ensure safe shipping etc… KEPLER delivers the potential, Copernicus 2 delivers the reality. KEPLER recommends ABC, doing this would deliver it in Copernicus 2.0.
- **Laurent Bertino (NERSC)-** note that the report is full of red lights- do not undermine where things need to be improved.
- **Thomas Lavergne (METNO)- Include** breaks between the stories. For S&R include Galileo for this.
- **Lasse Pettersson (Nansen Center**)- P- Problem is mixing situations with reality. Do not use a real situation- as the comparison is confusing. Have this as fiction. Focus on the recommendations. Do not use American ship!

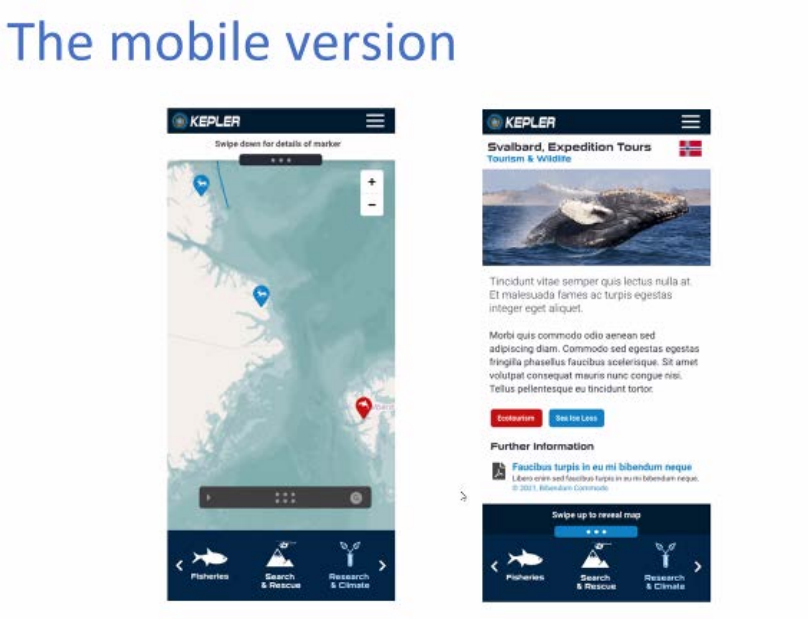
KEPLER Interactive Arctic Region Stakeholder Map- Marcin Pierechod

Marcin presented on KEPLER's interactive stakeholder map. Showing the administration and public-facing functions of this application.

<u>Feedback</u>

- **Michael Karcher (OASYS)-** keen to link this up with Arctic-PASSION. FOLLOW UP. Polar cluster, SAON. Organization that could last longer- and continuously updated map/depository for these things.
- The title- what is the stakeholder? Consider the name- can easily change the name and platform.
- Can base this platform on what the users are doing- how to make these tools much more useful. The current design is quite lean so will function quickly.
- Will need to check the contract as to who the legal owners for this platform are.





KEPLER Brochures- Emma Armitage/Nick Hughes

Participants were shown the available KEPLER brochures, and were informed that they would be sent copies of other brochures as soon as they are complete.

Feedback

- Is ice watch in there? To provide more information to researchers- telling them what is available and having a short easily accessible reference guide.
- Could have a feedback mechanism such as ice watch.
- NORUT logo should be NORCE.

Day 2 - KEPLER internal meeting

Day 2 of the Final General Assembly was an internal meeting for KEPLER participants only. This day was for internal review of WP6 dissemination and WP7 management activities.

KEPLER Reporting/Management- Elaina Ford

Notes

Final review

The final review (within 60 days after the end of the project) will take place on July 12th.

- This will include finance ports & submission of costs for the EC to make the final payment.
- Presentation of work carried out and achievements which an external reviewer will assist in the final review.
- Progress beyond the state of the art, expected results until the end of the project and potential impacts (including the socio-economic impact and the wider societal implications of the project so far)

Finance

Participants were informed of the requirements/ stipulations for eligible and ineligible costs as well as common errors to be aware of i.e.: correct timesheets- signed/ backed up by HR, following company procedure for travel and the restrictions on consultancy and third-party work.

- Underspend with some partners due to COVID-19. If any partners are going over budget, please let us know but will likely not be an issue.
- Please include time on meetings, reports but also preparation for these as well.
- Timesheets are needed for all personnel costs claimed, using your institute's system, and explaining the tasks that time is related to.
- BAS will check through financial reports and highlight any issues.
- Form C will open on July 1st.
- Requested a draft of Form C by 11th July before the review meeting.
- We will request that Form Cs are submitted by the end of July - and will be checked by BAS and METNO.
- METNOs financial reporting will be completed by August 20th.
- When including costs please make sure the explanation text includes – who, what, why, when, and where.
- Note that all personnel time should be accounted for before the 11th of July.
- WPLs may have more time to add after this, but in general partners should have completed all KEPLER activities by them.
- Partners are reminded to submit their periodic report contributions to UKRI-BAS. These are now overdue.

Final Report

- Each summary title for the final report was discussed, the final project brochure is being put together in the same format as the Final Report.
- The publishable summary will be put on the EU's website.
- Sections are:
    - Summary of the context and overall objectives of the project
    - Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far project so far)
- These will be submitted for the reviewer to look through. Please provide these as soon as possible.

Remaining Deliverables - Elaina Ford

WP7

The meeting report (this deliverable) will be drafted asap and circulated for comments by the end of the week, Friday 25th June, for final submission by the end of the month.

WP6

Both deliverable 6.4 and 6.5 draft reports were reviewed, and links were shared. Final feedback should be given by the end of the day, Wednesday 24th June. The final additions to the D6.4 on dissemination include the final website updates and the last newsletter. Once these links are added the deliverables will be submitted.

WP5

Plans to update the pyramid graph, a few comments that have been raised are being checked over now.

Dissemination ideas:

- Discussed using a journal via the commission to publish the results: https://open-research-europe.ec.europa.eu
- Potential of submitting to The Cryosphere journal.
- Work will be on the EU website – open access.
- Per Helmer has raised that could claim time spent turning this document into a journal by the end of the day. If you want to pay for a journal that has green open access- that needs to be decided soon and paid for by the end of this month.
- Suggested that the consortium have a look for available journals to see if this would work.
- EOS- would be a potential, nice to show US colleagues what we have worked on. Should the funding be a problem- could get BAS to cover these costs.
- Jeremy will provide input to the Roadmap by the end of the day.
- Carolina has raised: And what do you think about publishing WP3 in the open research European journals?
- For task 4.2- cryosphere peer-review journal. Same for D3.5
- EA will send out the most recent version of both brochures- some confusion on the version right now.
- The roadmap brochure will be able to be organised from tomorrow when the roadmap is ready.

- Jeremy Wilkinson highlighted a paper that has just been accepted in Nature; it is called 'Seasonal Arctic sea-ice forecasting with probabilistic deep learning". Might be of interest to many with KEPLER. The lead is Tom Andersson as BAS, and you can find the paper here (not the final copy as this is pre-review copy) https://eartharxiv.org/repository/view/2027/
- Partners reviewed the final project brochure text.

Conclusions/Wrap up

All participants were sent links for remaining actions/documents to feedback on for the end of the project.

The KEPLER Management team would like to take the opportunity to thank all who have been involved with input and support throughout the KEPLER project, and commend consortium members for the delivery of this project despite the challenges presented in the past year. The KEPLER project looks forward to presenting their results to the European Commission and reviewer on July 13th, 2021.