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Via Galileo Galilei
Casella Postale 64
00044 Frascati
Italy
T +39 06 9418 01
F +39 06 9418 0280
www.esa.int

Support to Science Element (STSE)
Arctic+

- An ESA-CliC initiative -

Statement of Work

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1 INTRODUCTION

1.1 Scope

This activity is part of ESA's [URL1] Support To Science Element (STSE) [URL2], a component of the Earth Observation Envelope Program (EOEP-4), aiming to reinforce the scientific component of the ESA Living Planet programme. STSE covers scientific support for both future and on-going missions, by taking a pro-active role in the formulation of new mission concepts and by offering a multi-mission support to the scientific use of ESA Earth Observation (EO) mission data and to the promotion of the achieved results. This Statement of Work (SoW) establishes the tasks to be performed within the Arctic+ projects.

This document will be part of the contract and shall serve as an applicable document throughout the execution of the work. It presents the background and objectives of the project, the tasks to be undertaken by the Contractor, the deliverables to be produced and the schedule of milestones to be achieved. During execution of the project, the Contractor shall comply with the requirements and tasks set out in this document.

This activity is a direct response to some of the major discussion points gathered during the ESA/CliC scientific consultation meeting on Earth Observation and Arctic Research Priorities held on 20 January 2015 at the Fram Centre in Tromsø, Norway.

The meeting aimed at reviewing and discussing the existing scientific knowledge gaps and research priorities areas for the Arctic where EO may contribute for the next decade.

The outcome of this workshop was reported in a document [URL4], which will contribute to guide ESA's scientific activities on Arctic research for the time frame 2017-2021.

This Activity aims at contributing to the development of a strong Arctic component in upcoming ESA EO programmes, with the ultimate goal to foster a coordinated European approach to Arctic science and research through a strong collaboration with EC DG-RTD and national programmes, aligning programming and developing a coherent work plan of complementary investments.

Arctic+ will focus on five separate Themes:

- Theme 1: Snow on sea ice;
- Theme 2: Sea ice mass intercomparison;
- Theme 3: Freshwater fluxes;
- Theme 4: The Arctic ocean-atmosphere-sea-ice interactions;
- Theme 5: Contributions to the Year of Polar Prediction (YOPP).

Within this Activity, ESA plans to support five independent studies (one for each of the above themes).

In this context, Arctic+ aims at supporting the scientific community and to value-adding companies of ESA Member States to carry out leading edge research activities to advance the use of ESA and non-ESA EO missions towards the achievement of major scientific challenges identified by the CliC and Cryosphere community for the next decade.

The Arctic+ studies aim at setting up a solid basis for larger actions in the time frame 2017-2021.

1.2 Structure

The document is organized in five sections:

- Section 1: introduces the project. It outlines the scope of the procurement and the structure of the document; this section also lists the common reference documents as well as the web sites that are relevant for this procurement;
- Section 2: presents the problems faced and establishes the objectives of the project;
- Section 3: provides a generic description of the project tasks;
- Section 4: contains management and reporting activities;
- Section 5: includes the schedule and milestones.

1.3 **Reference Documents (RDs)**

The following documents can be consulted by the Contractor as they contain relevant information:

[REF1] Yoo, J., and D'Odorico, P. (2002). Trends and fluctuations in the dates of ice break-up of lakes and rivers in northern Europe: The effect of the North Atlantic Oscillation. J. Hydrol., 268(1-4), 100-112.

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1.4 Relevant Websites

[URL1] ESA web site: www.esa.int

[URL2] STSE web site: www.esa.int/stse

[URL3] CryoSat web site: https://earth.esa.int/cryosat

[URL4] http://due.esrin.esa.int/stse/files/document/Arctic_Agenda_2015_v8.pdf

1.5 Acronyms and Abbreviations

AD	Applicable document
ADB	Actions database
AMOC	Atlantic Meridional Overturning Circulation
ATBD	Algorithm theoretical basis documents
BRO	Brochure
CliC	Climate and Cryosphere
DIR	Directory
DS	Dataset availability
DS-UM	Dataset user manual
DVP	Development and validation plan
EDS	Experimental dataset
EMI	Electromagnetic Interference
EO	Earth Observation
EOEP	Earth Observation Envelope Program
ESA	European Space Agency
FR	Final review
FWF	Freshwater fluxes
GCOS	Global Climate Observing System
IAR	Impact assessment report
ITT	Invitation to tender
IPP	Year of Polar Prediction
KO	Kick-off
MR	Monthly report
MTR	Mid-term review
MV-TN	Modelling and validation technical note
PAR	Preliminary analysis report
PGICs	Peripheral glaciers and ice caps

PM	Progress meeting
PMP	Projetc management plan
RD	Reference document
RB	Requirements baseline
SAR	Synthetic Aperture Radar
SIAR	Scientific and impact assessment report
SMOS	Soil Moisture and Ocean Salinity
SoW	Statement of work
SR	Scientific roadmap
STSE	Support to Science Element
TDP	Technical data package
TN	Technical note
VIR	Validation and intercomparison report
VR	Validation report
WCRP	World Climate Research Programme
WP	Work package
WS	Workshop minutes
WWRP	World Weather Research Programme

2 PROJECT BACKGROUND AND OBJECTIVES

2.1. Background

ESA and EC RTD have recently put in place a strategic partnership on the Arctic. The scope of the strategic partnership is to coordinate activities, align work programmes in fields of common interest and to have a coherent work plan and activities to be carried out with the objectives of supporting the definition and implementation of the future EU Arctic Policy, contributing to the creation of an integrated observation system for the Arctic, establishing a European Arctic science programme, and enabling the development of Arctic climate services.

In this context, Arctic+ is an ESA-CliC collaboration that makes part of the ESA-EC partnership for the Arctic.

The Arctic is a complex region, encompassing different physical and biogeochemical processes and interactions among several components of the Earth system (e.g., sea ice, ocean, glaciers, ice caps, the Greenland Ice Sheet, snow, lakes and river ice, permafrost, vegetation, complex interactions with the atmosphere, people, etc.). Changes in the Arctic have a strong impact on the Earth's climate system, the global energy budget, the ocean circulation, the water cycle, gas exchanges, sea level, and biodiversity (AMAP, 2011). Considering that all of Earth's inter-connected components respond to changes in air temperature, the Arctic is a sensitive indicator of climate variability and change.

The global climate system is revealing evidence of rapid change, largely amplified over recent decades [REF1; REF2; REF3]. Possible explanations exist, with several stating that current changes complement one another and lead to cascading effects on a global scale; other changes may function individually and act as local or regional climatic contributing factors. In both situations, the explanations may refer to either natural variability of the climate system or to anthropogenic-related drivers. In this context, the Arctic region, highly sensitive to climate variations and extremely responsive to external forcings, is experimenting rapid changes. Understanding the different processes, its variability and the different feedback mechanisms within the Arctic system, (i.e. interactions between ocean, sea ice, atmosphere and land) represents a mandatory step towards better predictions, EO being a critical tool to provide part of the required observations.

As reported [REF3], observed changes in the Arctic show that over the last three decades (1979-2015) the Arctic sea ice has continued to decrease in extent at a rate of 3.5-4.1 % per decade, with loss of perennial ice extent occurring at a rate of 11.5% (±2.1%) per decade. At the same time, average winter ice thickness has decreased by 1.3-2.3 m (1980-2008), this being consistent with the decrease in perennial and multi-year ice extent. Satellites have revealed that peripheral glaciers and ice caps (PGICs) have continue to shrink worldwide, with most of the ice loss occurring for glaciers in Alaska, the Canadian Arctic and the periphery of the Greenland ice sheet [REF4; REF5]. Satellite data, complemented by climate modelling, also suggests that mass loss from the Greenland Ice Sheet has been accelerating since mid-1990s [REF6; REF7] and is now one of the largest mass contributor to sea level rise. Satellite records (1967-2012) also show that the annual mean snow-cover extent in the Northern Hemisphere has decreased significantly, with the greatest change occurring in June (-40% to -66%) [REF3]. Satellite records of NDVI since 1982 have shown increasing greenness over large parts of the Arctic where summer warmth has increased [REF8], consistent with ground-based and airborne observations of increases in forest-type vegetation. The limited observations of freshwater ice in lakes and rivers indicate that due to later freeze-up and earlier break-up, the duration of the lake-ice season has shortened. For example, model simulations and satellite synthetic aperture radar (SAR) observations for over 400 lakes near Barrow, North Slope of Alaska indicate that between 1991-2011, lake-ice season duration decreased by ~1 day per year, lake ice thickness declined by a total of 18-22 cm, and fewer lakes froze to the bed (grounded ice), with an overall reduction in grounded ice of 22% [REF9]. Following an increase in permafrost temperatures in most regions during the last decades, general ice-rich permafrost degradation has been observed from both *in situ* and satellite observations, with significant changes in the Russian European North. There, warm permafrost up to 15 km thick completely thawed and the southern boundary of the discontinuous permafrost moved northwards by 80 km, while that of the continuous permafrost advanced northwards by 50 km [REF3].

Despite considerable research progress in understanding the Arctic region over the last decades, many gaps remain in observational capabilities and scientific knowledge. These gaps limit present ability to understand and interpret on-going processes, prediction capabilities and forecasting in the Arctic region, thereby hampering evidence-based decision making. Addressing these gaps represents a key priority in order to establish a solid scientific basis for the development of future information services for the Arctic.

In this context, on the 20th January 2015, ESA and the Cryosphere project of the World Climate Research Programme (CliC-WCRP) organised a scientific consultation meeting in Tromsø with the main objective of gathering recommendations from the scientific community on the most pressing priorities for Arctic research, where EO may contribute in the coming decade. The workshop resulted in a report [REF10] listing a number of different priority areas that will contribute to establish a strong focus on Arctic research in the next components of ESA EO programmes for the period 2017-2021.

In order to put words in actions, this ITT aims at addressing some of these priorities as an starting point for future larger activities. In particular, with this ITT, five priority areas will be addressed at feasibility and demonstration level with the ultimate target of establishing a solid scientific basis to initiate larger research actions from 2017.

It is worth mentioning that ESA is at present time supporting a number of research and application projects addressing different priority areas that complement the selected priorities of this ITT. In addition, further actions will follow in the future to address other topics.

2.1 **Objectives**

Arctic+ aims at advancing towards the achievement of some of the most pressing priorities in Arctic science, where EO and ESA data may contribute. In particular, the main overarching project objective is threefold:

1) Supporting the development of novel EO-based products and enhanced data sets responding to the needs of the Arctic science community;

2) Fostering new Earth system scientific results addressing the main priority areas of Arctic research, where space technology may provide a valuable input;
3) Preparing a solid scientific basis for stating larger development activities addressing the priorities of the Arctic science community in the timeframe 2017-2021.

This shall involve the collaboration among the different scientific communities involved in Arctic process studies, modellers and EO experts, as well as coordinating with existing EC and national projects addressing Arctic science and the GEO cold region initiative. Coordination with the projects of the future calls on the Arctic under the Horizon 2020 WP 2016-17 – expected to be published in October 2015 – shall be considered as well.

In this context, in the medium and long-term, the objectives of the project include:

- To foster the scientific exploitation of EO-based geo-information products (maximising the use of ESA data) to respond directly to the needs of the Arctic scientific community in the context of five selected thematic areas;

- To support existing international and national efforts to improve the observation, understanding and prediction of ocean-sea-ice-atmosphere processes at different spatial and time scales demonstrating the capability of EO and ESA data to respond to the needs of the Arctic research community;

- To support the establishment of a solid scientific basis for the development of potential future operational services for the Arctic;

- To develop a Scientific Roadmap as a basis for further ESA activities in support of the Arctic research and applications to be further developed and consolidated within future actions in the context of the ESA-EC partnership for the Arctic.

2.2 Brief Description of the *Arctic*+ Themes

2.3 Theme 1: Snow on Sea Ice

Snow on sea ice was identified by the Global Climate Observing System (GCOS) as a major source of uncertainty in both ice thickness and ice concentration retrieval from satellite data. As such, a much larger effort should be put into using all available data (active/passive microwave, optical, *in situ*/airborne observations) to quantify key snow parameters (e.g., thickness, density). Snow parameters are not only important for processing of remote sensing data but also for thermodynamic (and even some dynamic) processes. Due to its low thermal conductivity, the presence of snow on sea ice greatly modifies its thermodynamics, affecting seasonal accretion and ablation rates [REF11]. Because of its high albedo compared with that of sea ice, snow dominates the surface shortwave energy exchange. Also, by smoothing the ice surface, snow greatly modifies the ice-air drag coefficient and the bulk transfer coefficients for latent and sensible heat. It also has a first-order effect on the microwave properties of the surface, leading to ambiguity in retrievals of sea-ice type and concentration from satellite data. Snow thickness on sea ice is still poorly known and current thickness estimation with satellite passive microwave radiometer data has poor accuracy due to the sensitivity of the microwave wavelengths to ice surface roughness [REF12]. Activities towards improved estimation of snow thickness over sea ice (e.g., based on dual-frequency SAR, combined laser and radar altimetry) are needed. The availability of complementary data from CryoSat-2 and AltiKa (35.75 GHz) and also from the forthcoming Sentinel-3 (13.57 GHz altimeter) along with scatterometers may offer a starting point to explore this capability. In addition, the availability of ICESat-2 mission from 2017 in combination with CryoSat-2 may allow snow depth retrieval in cold conditions.

In this context the primary objectives of this Theme are:

- Explore, develop and validate different approaches to retrieve snow thickness over sea ice, maximizing the use of ESA data in synergy with additional datasets;
- Based on a thorough experimental analysis, identify the best option and implement a prototype processor;
- Develop an experimental dataset over the Arctic;
- Validate the experimental dataset with *in situ* data and perform an impact assessment on the utility of the data;
- Develop a scientific roadmap for the future evolution of this Theme.

2.4 Theme 2: Sea Ice Mass

Sea-ice mass is an important measure of quantity because it offers the most direct link to environmental changes. In fact, changes in other attributes, such as sea-ice extent or thickness, can arise with no net change in sea-ice mass amount (and vice versa).

Satellite observations have delivered routine assessments of sea-ice extent for decades and historically, relatively sparse airborne or submarine-based observations of sea-ice thickness have been used to develop estimates of sea-ice volume change. Over the past decade, a range of satellite-based estimates of sea-ice thickness has become available from a number of sensors, making systematic assessments of regional and basin-scale volume trends in the Arctic [REF13; REF14; REF20; REF21].

Converting sea-ice volume into sea-ice mass is a rather complex task. Sea ice is often covered by snow of different density and thickness and this complicates retrievals and assessments of the sea-ice mass. To determine with some degree of accuracy the contribution of snow to the observed satellites parameters (e.g. change of elevation) and distinguish between fluctuation of snow and ice mass, climatological models have to be used.

However, given the variety of satellite - and model-based approaches for estimating changes in sea-ice extent, thickness, and snow depth, differences between assessments of sea-ice mass balance are to be expected. A formal inter-comparison exercise to establish the extent to which these various measurements agree is therefore timely, and will lead to improved confidence in assessments of sea-ice mass balance.

In this context, the primary objectives of this Theme are:

- Review and identify all different data products (*in situ*, satellite observations), models, approaches and methods used nowadays to compute sea-ice mass;
- Perform an initial inter-comparison exercise with focus on the accuracies and uncertainties of different approaches;
- Explore and demonstrate possibilities to compute a reconciled estimate (e.g., ensemble approaches, weighted averages, triple collocation) of the sea-ice mass and sea-ice mass multi-decadal evolution based on existing methods, data and models;
- Prepare for a formal inter-comparison exercise aimed at assessing and reconciling different estimates and move towards a community multi-decadal assessment of ice mass evolution and its impacts;
- Develop a scientific roadmap for the future evolution of this Theme.

2.5 Theme 3: Freshwater fluxes

Freshwater fluxes (FWF) play an important role in ocean stratification and circulation. In the Arctic and sub-polar North Atlantic, they are also important for marine productivity. Changes in ocean circulation, in the strength of the Atlantic Meridional Overturning Circulation (AMOC) in particular, can have impacts on the climate system at global scale. As a consequence, oceanographic observational transects have been established to monitor the strength of the AMOC at key latitudes. However, these observations provide limited information on the causes of change. Large fluxes of freshwater are transported out of the Arctic Ocean each spring via sea-ice export through the Fram Strait. Riverine runoff into the Arctic Ocean (the riverine coastal domain) is also a key contributor to the FWF and nutrient balance of the Arctic that can be better estimated by a combination of satellite altimetry, river outline mapping, near-simultaneous space imagery, and *in situ* measurements.

In the last two decades, FWF from the Greenland Ice Sheet and Canadian Arctic have been steadily increasing into both the Arctic and North Atlantic Oceans. Finally, precipitation-evaporation (P-E) also plays a central role in modulating the FWF and, as a consequence, the hydrography of the region. Observational evidence from both satellites and *in situ* data indicates significant changes in the freshwater balance of Arctic seas. Satellite altimetry can provide information on geostrophic flow, ocean circulation and mesoscale variability.

Synthetic Aperture Radar (SAR) data have proved to be invaluable for accurately tracking sea-ice transport, while Soil Moisture and Ocean Salinity (SMOS) might provide measurements of surface salinity changes (despite the fact that L-band radiometry presents problems of sensitivity in high-latitude cold waters). Combined with data on sea-surface temperature, this provides important information about thermohaline flow and mixing of surface waters. The mass imbalance of the Greenland Ice Sheet, and hence its freshwater input into the Arctic Ocean can be determined from satellite altimetry. Thus, a combination of satellite observations can provide key information about FWF into and out of the Arctic seas.

In this context, the primary objectives of this Theme are:

- Identify the mayor challenges and knowledge gaps in the estimation of the Arctic freshwater budget;
- Explore, develop and validate different approaches to address those challenges and enhance current approaches to compute the freshwater budget of the Arctic maximizing the use of ESA data;
- Compute a multi-year assessment of the Arctic freshwater budget based on the developed methodology;
- Validate the results, compute uncertainty of the estimates and compare the obtained results with existing alternative estimates;
- Develop a scientific roadmap for future research activities in this domain

2.6 Theme 4: Ocean-atmosphere-sea-ice interactions

The Arctic Ocean has been a "serene region" for decades with the sea-ice layer dampening waves. However, this situation is changing as summer sea-ice extent is diminishing. The rapid loss of summer sea-ice cover is changing the way that the sea ice, ocean and atmosphere interact at different levels.

The reduction of sea-ice cover extent fosters the formation of internal waves in Arctic waters that could perhaps accelerate the loss of sea ice. [REF15] report that Arctic waters along continental shelves are becoming more turbulent as the summer sea ice disappears and waves start churning the water as in other oceans. These underwater waves have different impacts on the Arctic Ocean. On one hand, they increase the turbulent behaviour of the ocean, making it more productive and bringing nutrients from deep waters closer to the surface. On the other hand, a more turbulent Arctic Ocean could accelerate the melting of Arctic sea ice. In particular, unlike any other ocean basins, the Arctic is fresh and cold at the surface from melted ice, while it is very salty and slightly warmer below. If turbulence mixes these waters, the warmer surface could accelerate the melting of sea ice.

Furthermore, a reduced sea-ice extent increases the forcing of the atmosphere on the ocean surface augmenting the fetch and surface sea state that interacts with the sea ice and may affect the formation rates. In particular, ice break-up enhances ice melt rate by increasing the area of open water for absorption and providing a larger surface area for lateral melting. Wave conditions also alter the refreezing process [REF16]. If the current trend in sea-ice extent reduction continues, a larger fetch for wave development will be available. This increased fetch will promote the formation of larger waves of lower frequency and higher energy [REF17] waves that were associated with a reduced ice cover in the Arctic Ocean during recent years [REF18]. Since lower-frequency waves propagate farther into the ice pack, there is potential for more wave energy to affect a larger area of sea ice and potentially increase the break-up of the sea ice cover [REF19]. The consequences and magnitude of this feedback mechanism remain an open question.

Storms, characterized by strong winds and high waves, may also play a major role in this process, leading to vertical mixing processes that can affect the cold halocline layer and possibly contribute to a positive feedback that affects sea-ice formation. Understanding the impact of these events on climate is still unknown and needs to be investigated.

In this context, the objectives of this Theme are:

- Identify the major challenges, knowledge gaps and problem areas to better understand, characterise and monitor the sea-ice-ocean interactions in the Arctic;
- Explore the potential of EO technology to understand, characterise and monitor these processes, maximising the use of ESA data;
- Develop and implement a number (at least two) science cases to investigate (at least: 1) the feedback effect of sea-ice and sea-state and 2) the impacts of storms on sea-ice) and explore and demonstrate the potential of EO technology to address and monitor these processes;
- Validate and perform an impact assessment of the test cases results;
- Generate a scientific roadmap for further evolution of this Theme.

2.7 Theme 5: Contributions to Year of Polar Prediction (YOPP)

Over the next several years, attention will be focused on this through the World Weather Research Programme (WWRP) Polar Prediction Initiative, which is stimulating the "Year of Polar Prediction (YOPP) in 2017-18" – with some large Arctic drifting ice camp (Mosaic), icebreaker, and augmented *in situ* measurements. The YOPP will be supported trilaterally by the EU, US and Canada, and the collection of space agencies in the Polar Space Task Group.

The YOPP aims at enabling a significant improvement in environmental prediction capabilities for the Polar Regions and beyond, by coordinating a period of intensive observing, modelling, verification, user-engagement and education activities. The YOPP is one of the key elements of the Polar Prediction Project. YOPP is scheduled to take place from mid-2017 to mid-2019. In particular, YOPP will:

- Cover an extended period of coordinated intensive observational and modelling activities in order to improve polar prediction capabilities on a wide range of time scales in both polar regions;
- Strongly engage in forecast-stakeholder interaction, verification and a strong educational component;
- Foster relationships with partners, provide common focussed objectives, and be held over a bit more than a one-year period in association with a field campaign providing additional observations;
- Coincide with, support, and draw on other related planned activities for polar regions;
- Be implemented in three different stages: a preparation phase (2013-2017), YOPP itself (mid-2017 - mid-2019), and a consolidation phase (2019-2022).

The main objectives for YOPP are to:

- Improve the polar observing system to provide good coverage of high-quality observations in a cost effective manner;
- Gather additional observations through field programmes aimed at improving understanding of polar key processes;
- Develop improved representation of polar key processes in uncoupled and coupled models used for prediction, including those which are a particular hindrance to high-quality prediction for the polar regions, such as stable boundary layer representation, surface exchange, and steep orography;
- Develop improved data assimilation systems that account for challenges in the Polar Regions such as sparseness of observational data, steep orography, model error and the importance of coupled processes (e.g., atmosphere-sea ice interaction);
- Explore the predictability of sea ice on time scales from days to a season;
- Improve understanding of linkages between Polar Regions and lower latitudes and assess skill of models representing these.
- Improve verification of polar weather and environmental predictions to obtain quantitative knowledge on model performance and on the skill of operational forecasting systems for user-relevant parameters, and efficiently monitor progress;
- Improve understanding of the benefits of using existing prediction information and services in the polar regions, differentiated across the spectrum of user types and benefit areas;
- Provide training opportunities to generate a sound knowledge base on polar prediction related issues.

There is a significant potential to link existing ESA efforts and planned R&D activities to this initiative (e.g., assimilation of CryoSat-2/SMOS NRT thickness) and newly tailored Sentinel products (e.g., albedo or ice surface temperature products from Sentinel-3 and Sentinel-2).

In this context, the objectives of this Theme are:

- Study the potential contribution of ESA data to the objectives of the YOPP;
- In particular, explore and demonstrate the potential offered by:
    - Archived (ERS-1, ERS-2, ENVISAT) and new data (e.g., from CryoSat, SMOS, ADM-Aeolus) and related product as part of the potenetial core datasets for improving regional and global prediction within the objectives of YOPP.
    - Long-term data records generated as part of the ESA Climate Change Initiative.
    - The Sentinel data that will be available in the YOPP timeframe;
- Demonstrate through a number of test cases the validity of the proposed contributions;
- Establish eventually new user requirements and recommendations for new datasets and novel products.
- Generate a roadmap to start dedicated activities in support of the YOPP in 2017.

3 GENERIC DESCRIPTION OF THE PROJECT TASKS

In the following, a generic description for each of the tasks to be carried out in the context of *Arctic+* is provided. The proposed tasks are common to all Themes. Any possible departure from the presented structure shall be properly justified by the Contractor.

The projects shall be completed within a maximum of 18 months from kick-off.

- Task 1: Scientific Requirement Consolidation;
- Task 2: Dataset collection;
- Task 3: Development and Validation;
- Task 4: Prototype Demonstration and Impact Assessment;
- Task 5: Scientific Roadmap.

Task 1: Scientific Requirements Consolidation
Description: In this task, the Contractor shall consolidate the preliminary scientific requirements for the investigated Theme. This shall include: • A detailed review, assessment and analysis of the main scientific challenges, knowledge gaps and scientific problems to be addressed in the project. • A survey of all accessible associated datasets (space, airborne and *in situ*) to be used for development and validation (problems such as the lack of sufficient datasets shall be investigated and practical solutions identified); • A survey of current and on-going initiatives (e.g., CliC activities) and projects (e.g., EC, national) related to the investigated Theme and a clear description of the added value of the work to be carried out with respect to existing activities; • An analysis and identification of the best candidate test areas to be used in successive tasks for development and validation of the prototype products. This shall include a complete analysis and description of the available data over those test areas. This Task shall be complemented by a consolidated risk analysis pointing out which risk areas could affect the final success of the project (as concerns the considered Theme) and the proposed solutions. On the basis of such analysis, the Contractor shall then derive a consolidated, coherent and complete view of the scientific and operational requirements associated with the topic in consideration. Moreover, the Contractor shall describe in detail the technical and scientific constraints for the methods and models to be developed.

Deliverables:

- Requirement Baseline (RB): This document shall capture the outcome of the above tasks and preliminary analysis, and include a complete and detailed description of the information requirements concerning the investigated Theme. The RB will represent the basis for all the activities to be carried out during the project.

Task 2: Dataset Collection

Description:

A database of suitable products based on Earth Observation (EO), airborne, *in situ* data and relevant ancillary information shall be collected over the areas of interest in order to perform the required work. The database shall be made accessible on a project webpage and described in detail in a user manual.

Any restrictions in the use of any type of datasets (e.g., proprietary campaign data) shall be communicated to ESA in due time.

The datasets shall be used in later tasks for development and validation purposes.

Deliverables:

- Dataset;
- Dataset Description: this document provides a detailed description of the dataset as well as related metadata.

Task 3: Development and Validation

Description:

In this task, the Contractor shall explore, analyse, develop and test and select the necessary methods and algorithms to derive the required based products and develop the target test cases relevant to the Theme in question.

Major scientific efforts shall be devoted to this task to perform a thorough experimental analysis on different test sites in order to develop the suitable algorithms and novel prototype products.

The final methods and algorithms shall be selected on the basis of a detailed experimental analysis of the potential alternative methods and approaches supported by a sound inter-comparison and validation.

In this context, a detailed experimental error analysis for testing and verifying all the different implementation choices and ultimately evaluate the accuracy and reliability of the developed methods and products shall be carried out under different sites, assumptions or conditions that could affect or influence the performances of the methods and the final accuracy of the products.

A detailed description of the final version of the algorithms (including related data sources, processing steps and output data) shall be reported by the Contractor in the form of an ATBD. This shall also include a scientific analysis of the results driving to specific development choices and trade-offs (including technical considerations justifying the selected methodologies).

In addition, when required by the Theme objectives, a detailed cross-comparison of the resulting products/estimates with existing EO-based equivalent/alternative datasets shall be performed in order to gain a thorough understanding of the range of validity, limits and benefits of the different existing products in the relevant thematic area.

The Contractor shall also report a detailed description of the error and validation analysis as well as the cross-comparison experiment exercise into the Validation Report (VR).

Deliverables:

- ATBD: This document shall describe in detail all the algorithms, methods and models implemented for the selected Theme. The report shall also include all related input data and its sources, processing steps and output data. In addition, this document shall report a scientific analysis of the results driving to specific development choices and trade-offs for all the algorithms implemented for developing the whole suite of target products. Technical considerations justifying the selected methodologies shall be also provided.

- Product VR: This document shall describe all the experimental error analysis and validation activities carried out.

Task 4: Prototype Demonstration and Impact Assessment

Description:

On the basis of the developed methodology, the target prototype products shall be generated (hereinafter called experimental dataset) and the proposed application shall be demonstrated over a number of selected areas and suitable time frames.

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The geographical areas and the time frames to be covered by the dataset shall be representative of the faced scientific problem and application, allowing a complete demonstration of the feasibility of the proposed methodology and its potential value in terms of scientific and operational potential returns.

This experimental dataset shall be integrated into the project dataset generated in Task 3 and the user manual shall be updated accordingly. The experimental dataset shall be publicly available via the project website.

On the basis of the resulting dataset, the Contractor shall interpret, analyze and quantify the impact and benefits of the results obtained in the context of the considered Themes. This shall include:

- Comparison of the results with existing and current state of the art results quantifying the improvement of the development methods and models;
- Analyse the errors/uncertainties;
- Investigate the potential of the derived product to enhance the current knowledge and state-of-the-art in the context of the relevant Theme;
- Determine the benefit and impact of the obtained results on the specific test areas considered in the project in close collaboration with the relevant scientific and user communities;
- Determine the general potential benefit and impact of the results on the scientific and operational areas addressed by the project.

Deliverables:

- Experimental dataset publication on the web;
- Updated dataset user manual;
- Impact Assessment Report (IAR): This document shall collect the final findings and results of the Impact Assessment.

Task 5: Scientific Roadmap

Description:

In this task, the Contractor shall define a Scientific Roadmap for fostering future developments aimed at transferring the outcomes of the *Arctic+* project (as concerns the investigated Theme) into future scientific activities for the time frame 2017-2021 and where applicable, into pre-operational services in the future. In this context, the consultation with scientific and existing operational organisations which operated in the Arctic is considered fundamental. Note that at least the following issues shall be considered:

- Providing a critical analysis of the project results obtained vs. the specific scientific objectives of the project and the chalages associated to the Theme.
- Identifying the required additional scientific work and developments to further advance towards achiving the overarching scientific objectives of the Theme;
- Identify potential observational gaps (satellite, in-situ) that may be addressed in the future by novel products, new datasets, in-situ campaigns and or even future missions;
- Investigate the potential for integrating the project results into existing or planned large scientific initiatives;
- Define a solid scientific agenda and development and evolution plan for the project in the timeframe 2017-2021.
- Identify and coordinate with the relevant projects and teams at international, EC and national level that may be relevant for a potential project evolution in the time frame 2017-2021, ensuring that the proposed roadmap fits within planned projects and initiatives in preparing the future;
- Defining a potential plan for fostering a transition from research to operational activities, when relevant;

Deliverables:

- Scientific Roadmap (SR): This document shall define strategic actions for expand the work done under Arctic+ towards larger scientific activities in the period 2017-2021 in support of Arctic research.

4 MANAGEMENT, PROMOTION AND COORDINATION

4.1 6.1 Promotion and coordination

The Contractor shall:

- Promote the Project(s) results within the relevant scientific and/or operational communities;
- Promote the resulting products, methods and datasets to the user community;
- Represent the project at scientific conferences and other international forums through scientific presentations and exhibitions;
- Based on the results provide multimedia content to be used for communication, educational and promotional purposes, such as image files, animations, presentation slides, etc.;
- Submit at least one paper to an international peer-reviewed journal.

In addition and as a minimum, the following items shall be delivered (the contents and format of all promotional material shall be submitted to ESA for approval):

Project Website: before the end of Task 1 a website for the project shall be developed. The contents of the website shall be submitted to ESA for approval. This website shall also provide a direct access to the different products and datasets developed during the project. This shall include an internal webpage (password protected, accessible to ESA and consortium members) for supporting management and documentary activities.

The project webpage content shall be maintained and updated by the Contractor at least every month to include updated deliverable items and content for the duration of the contract.

The Contractor shall also coordinate with the relevant projects and teams at international (e.g., CliC), EC (e.g., existing projects or project originated from the future calls on the Arctic under the Horizon 2020 WP 2016-17 – expected to be published in October 2015) and national level that may be relevant for the project and in particular for preparing a SR (Task 5) for further developments in this domain, ensuring that the proposed activities are well coordinated with existing projects and initiatives in preparing the future.

4.2 6.2 Management and reporting

The Contractor shall provide at least the following management deliverables:

- Monthly Executive Summary Progress Reports (maximum one page);
- Final Report for public access;
- Executive summary of the project summarising relevant achievements.

The schedule of planned activities shall comply with the milestones reported in the table below. In addition, a Progress Meeting (PM) will take place every three months (by video or teleconference).

The following meetings shall be planned:

Meeting name	ID	Venue	Schedule
Kick Off Meeting	KO	N/A	KO (by teleconference)
Mid-Term Review	MTR	Contractor premises	KO+8 months
Final Review	FR	ESRIN	KO+18 months

The Contractor shall provide electronic versions of all presentations, hand-outs, deliverables, reports and presentations for each progress meeting **at least one week** in advance of the meeting, via the website. All material required to conduct the meeting shall be accessible by all participants of the meeting (ESA and others).

The Contractor shall provide electronic versions of all final presentations and meeting minutes (including presentation slides and word processor documents) made at every meeting at the project website within 2 weeks following each progress meeting.

Electronic copies of the hand-outs used during each progress meeting, including at least the meeting agenda, a contact list for all meeting attendees and minutes from the previous progress meeting, shall be provided by the Contractor.

The following table summarises the deliverables for all the tasks:

Activity	**Deliverable**
Scientific Requirement Consolidation	• Requirement Baseline (RB)
Dataset Collection	• Dataset • Dataset User Manual
Development and Validation	• Algorithm Theoretical Basis Documents (ATBD) • Product Validation Report (VR)
Prototype Demonstration and Impact Assessment	• Experimental Dataset • Updated Dataset User Manual • Impact Assessment Report (IAR)
Scientific Roadmap	• Scientific Roadmap (SR)
Promotion	• Project website • Publications • Presentations • Communication material
Management	• Executive Summary Progress Reports • Final Report • Executive Summary

5 DATA ACCESS

It is the responsibility of the Contractor to secure access to the relevant data sets (i.e. satellite or campaign) required for this activity. Bidders or team members who are not already registered users of ESA data may register by following instructions found on the Earth Observation Data Access portal (https://earth.esa.int/web/guest/pi-community/apply-for-data). Further information may be obtained by sending an e-mail to eohelp@esa.int.

It is worth noting that the work to be performed in *Arctic+* will require the availability of additional data sources (satellite data, ancillary information and airborne or *in situ* measurements) beyond ESA data. Accordingly, the Contractor shall have granted access to the required data sets to perform the project.

All potential restrictions in the use of the non-ESA, or non-ESA third party missions, data used in the project shall be communicated to ESA in due time.

Data procurement can be quoted, but all the procurement with the ESA budget will be property of ESA and will only be put at the disposal of the Contractor in the framework of the project. Terms and conditions from the Data Distributors are to be fully understood and strictly fulfilled.

Due to the Research and Development (R&D) nature of the present activity, the Contractor shall explore the possibility of acquiring non-ESA data required for the project at an R&D compatible price.