

**Consiglio Nazionale delle Ricerche**  
**Dipartimento Scienze del Sistema Terra e Tecnologie**  
**per l'Ambiente**

**Istituto Nazionale di Oceanografia e di**  
**Geofisica Sperimentale**

**Istituto Nazionale di Geofisica e Vulcanologia**



**ARtico: cambiamento Climatico Attuale ed**  
**eventi estremi del passato (ARCA)**

**ARctic: present Climatic change and pAst**  
**extreme events**

**LINE OF ACTION 2:**

*Interdisciplinary project aiming to cross-different areas of intervention, submitted by several Institutions together.*

**MAIN AREA OF INTERVENTION:**

*Actions for Climate, resource efficiency and raw materials*

**OTHER AREAS OF INTERVENTION:**

*Crosswise with **ICT and sensory devices** as regarding the development of distributed system, based on web technology, to store, manage, distribute multidisciplinary environmental data sets.*

*Crosswise with technological areas concerning the development and improvement of integrate meteomarine measurement systems and surface unmanned boats (USV) for the study of processes at interfaces (air-sea-ice).*

**PROJECT COORDINATOR:** *Vito Vitale*

**SCIENTIFIC COORDINATOR:** *Stefano Aliani*

**SCIENTIFIC BOARD:** *Stefano Aliani, Giorgiana De Franceschi, Michele Rebesco*

**Key words:**

*fluxes of heat, mass and energy  
Tidewater glaciers and air -sea interactions,  
C and CO<sub>2</sub> fluxes and biological pump,  
Sediment and deposition,  
Marine technology,  
Melt waters, runoff,  
Kongsfjorden and Storfjorden,  
Underwater drilling,  
Ice caps,  
Distributed data management system,  
Brokering approach*

# State of the art, motivation, project summary

The Arctic is warming faster than anywhere else on Earth, resulting in a rapid environmental change. The community of Arctic research is trying cope with these changes and with the complexity of the interactions, processes and responses that are the basis of these changes. The interactions between the atmosphere, ocean, cryosphere and biosphere, are largely responsible for the phenomenon that is named "arctic amplification"(Serreze and Barry, 2011).. In recent years, signals of an acceleration of the changes are increasingly evident in the observations of many geophysical and biological properties. The possibility of extreme events, especially the collapse of the ice sheets no longer appears as the remote and is assumed by many scientists Hansen, 2007).. The complexity that generates this instability induces large uncertainties and errors in climate models, especially at regional scale.

In the Arctic Ocean two aspects of the interactions with the global climate are important: the first involves mass balances and heat in the water column and the exchanges with atmosphere, the second involves the water cycle of the planet, both in its liquid form, both as vapor and solid (Schmitt 1995).

The budgets of mass, heat and momentum are poorly studied in the Arctic. Their complexity, the different role and weight of atmospheric factors such as wind and temperature, the role of atmospheric and ocean circulation in the process of "export" from the Arctic sea ice, generate a very complex scene (Vinje et al. 1998 , Morison et al, 2012). All the "salinity anomalies" recorded in the past had serious consequences for the European climate. (Dickson et al., 1988, Zhang et Vallis, 2006), but to date we are not able to fully understand this phenomenon and even less to predict them. Ice is considered as a material with important geophysical properties but only some aspects of the thermodynamics of the ice are known. The process of melting continental ice depends on the energy balance at the surface of the glacier, and air temperature is only one of many factors. The balance of all positive and negative flows of energy to the surface, is controlled both by weather conditions (temperature, radiation, turbidity, etc.) and the properties of ice surface. At the local level, interactions between the atmosphere and the surface of the glacier are complex with many feedbacks. Atmosphere affects the energy balance, and in turn is influenced by the glacier. The hydrology of the glacier, which is a set of processes and systems that carry water in and to the base of the ice sheets and glaciers, controls the speed of the ice masses, with their impact on the dynamics of a cycle glacial / interglacial.

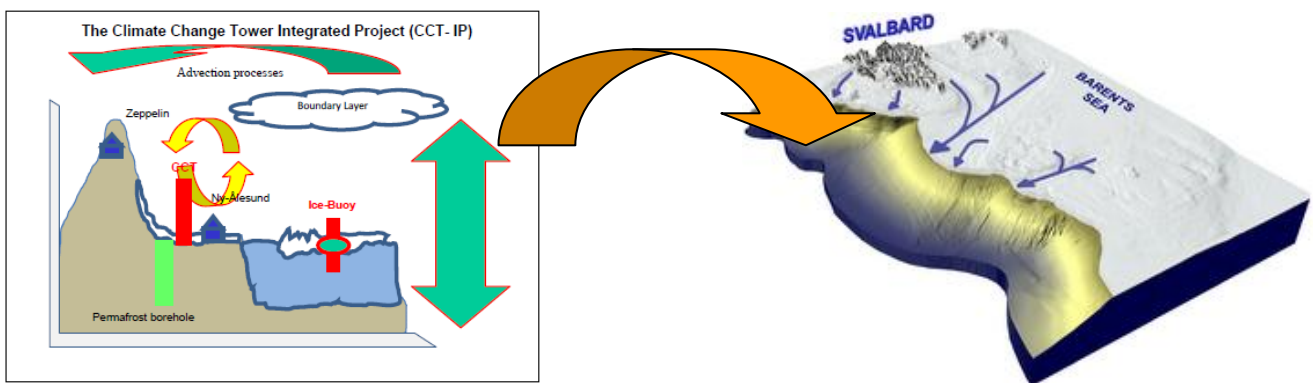
The interactions between the ocean and the tongues of ice immersed in water (tidewater glaciers), contribute to the budget of the terrestrial water cycle, but has been little studied. Only recently in Greenland processes of interaction between sea and ice below the mean sea level have been described (Straneo et al., 2010). Indirect measurements have been made through studies of the reduction in thickness of glaciers or ice transported estimates, but direct measurements are very critical. In Kongsfjorden (Svalbard) this have been done previously since 2000 (Aliani, 2004), but now technology is available with autonomous vehicles to go near the front of the glaciers where no one has ever sampled before.

The retreat of the glacier front has been particularly pronounced in recent decades and has led to the accumulation of sediments in the depressions inter-moraine near the sea-ice interfaces with high sedimentation rates > 1.8 cm y<sup>-1</sup> (Aliani et al ., 2003), mainly in Kongsfiord. The warming has also led to a substantial reduction of ice cover in the surrounding areas and changes in the state of permafrost with increased coastal erosion and sediment transfer at sea as a result of changes in the hydrological regime.. The high erodibility deiced permafrost moves huge amounts of particulate organic matter that enters the carbon cycle with consequences not yet adequately assessed. So far attention has been put on the release of greenhouse gases trapped in the permafrost. The melting of the marine ice cap (meltwaters) during periods of global warming induced inputs of salinity anomalies into the oceans with large volumes of fresh water that cause sudden changes in the thermohaline properties with possible consequences on the global thermohaline circulation (Clark et al. 2001). The data suggest that these changes in ocean circulation have caused the cooling phases of northern Europe during the last glaciation, from 20,000 years ago (IPCC, 2007). Changes in the North Atlantic ocean circulation have been, and may, in the future, be affected by the disintegration of the Greenland ice cap, induced by anthropogenic global warming. The fusion of arctic and sub-Arctic glaciers, involves the transfer at sea of large amounts of suspended sediment (turbid meltwater plumes), with changes of chemical and physical characteristics of coastal and oceanic waters.

The mechanisms controlling the dynamics of the ice sheets and the flow of fresh water and sediment into the ocean are included in a drilling project (CORIBAR) developed to reconstruct the history of extreme events of sub-glacial melting over the last 20,000 years along the southern margin of the continental shelf of Svalbard through long cores.

Activities of ARCA project include (a) an international oceanographic campaign (CORIBAR), (b) intensive campaigns aimed to study the energy balance at the surface interaction processes and air-sea-ice (along the edge of the tidewater glaciers that overlook the Kongsfjorden), and (c) the acquisition / data sharing networks for

monitoring the dynamics of large outlet glaciers of Greenland. The study of the dynamics of outlet glaciers and snow accumulation assessment will be joined for further studies to determine the state (wet / dry) ice-bedrock interface and the determination of the rate of events detachment of icebergs in the fjords. The creation of maps of dry and wet areas, along with the tomography of the rocky bottom, allow an interpretation in terms of thermal and hydrological conditions of the outlet glaciers and ice at the base of the shell. This to add information to the knowledge of local dynamics of outlet glaciers, in fact, the flow of meltwater at the base of glaciers, glacial erosion and affect the speed of the ice. Speed of the ice that also affect the "rate" of events of posting iceberg. In addition, the extension of these maps will help you understand the connections of the masses of fresh water on the rocky bottom with improvements in knowledge of the subglacial hydrological networks of the shell. The work of analysis and synthesis of data will allow to correlate the main events of meltwaters climatic conditions and build some conceptual models. These models will be used to identify the variables and the key processes that regulate the flow of fresh water and sediments, describe the dispersion of sediments in the ocean polar quantify / evaluate sediment transport and the influence on ocean circulation. The possible anthropogenic influence on these processes will be investigated by reconstructing the recent history of the last 150 years through the analysis of sediments and ice cores collected in the area of Kongsfjorden. The figure below provides a schematic representation of the set of activities' observation and research under the project ARCA.



**Figure1** – Sketch of the field of work and research activities in ARCA

## Objectives of the project

- To determine the characteristics of the coupling processes between atmosphere-hydrosphere.cryosphere that control the energy budget and masses fluxes ( fresh water, sediments) heat and momentum at the interfaces and in the water column . To asses the the role played in such processes by meteorological factors and other aspects of the atmospheric phenomenology.
- To describe the oceanic processes occurring at the interface between the glaciers fronts and the sea inside the arctic fjords. To evaluate the flow exchange between fjord waters and the Ocean and develop new paramaterization and models. Define the actual sedimentary processes and the relationship with past events using high resolution geophysical and morphological measurements , by analysing the ice and sediment cores collected in the inner part of the fjord
- Estimate the dynamics of the Greenland great outlet glaciers by the analysis of the sismic data collected by the GLISN network. Theoretical modelling of the signal generated by iceberg production events , finalized to estimate the ice masses involved. Realization of wet/dry maps for the interface ice-sea bed of some outlet glaciers in Greenland
- Quantify the transport of suspended sediment in the glacial melting waters generated during deglaciation of the Barents sea ice sheet, define the mechanisms of dispersal and the age of occurrence of extreme events

(meltwater sediment plumes) in the last 20,000 years, to investigate the influence of such processes on the ocean circulation and the biosphere.

- Provide joint and coordinated data analysis. Develop conceptual models to integrate data and to enable comparisons on a regional scale.

- Design, develop and implement an operational structure ITC for the data management based on the use of the brokering approach concepts.

- To encourage the sharing of expertise currently distributed between various Institution, and establish a multidisciplinary team with extensive experience in the Arctic polar areas as well as strong international links.

### **3.-Activities already done for the implementation of the project**

In Kongsfiord is operating an array of oceanographic instruments at 100 m depth in the channel between the moraine and the front of the sea glaciers. The station is acquiring series of oceanographic data and particle fluxes for biogeochemical studies since 2010.

The hydrology of the Kongsfiord has already been described by both foreign research groups that have focused on the outer part (Svendsen et al. 2002) and by Italian researchers (Aliani et al., 2004) that concentrated in the inner part up the limit of safe navigability, out of the area where sudden collapse of parts of the front of the glaciers may cause very high waves dangerous for boats. An autonomous vehicle surface already available at CNR ISSIA GE will be implemented to work remotely with oceanographic instruments close to the glacier reducing the risk for the activities.

In 2010, in the innermost part of the Kongsfiord seismic survey has been carried out with high-resolution digital capture of about 140 nautical miles CHIRP profiles from which it was obtained a preliminary map of the geomorphological characteristics of the seabed, and which will be used here to reconstruct the stratigraphy of the so far unexplored part of the fjord. In 2011, in the same area were collected cores of surficial sediments undisturbed in 12 points that will be used for the analysis of sedimentary facies, dating of sedimentary sequences, and characterization of sediments biogeochemistry. They are also available cores taken in the 90's to use as a comparison. Models for oceanographic circulation and process are available, that has been developed for arctic areas and will be adapted to Kongsfiord.

At the Italian station Dirigibile Italia, several instruments are installed to investigate the physical and chemical properties of the atmosphere, the fluxes, of heat radiation and chemicals within the interface atmosphere-ice-snow-ground ([www.isac.cnr.it](http://www.isac.cnr.it) / ~ radiclim / CCTower). The scientific platform continuously operational can provide data of all the components of the energy balance at the surface, and all information on weather, cloudiness and turbulence. A key element of this station is the 32 m height Admundsen-Nobile Climate Change Tower (CCT), that has the capability to host and manage many sensors, allowing to carry out measurements and research in an optimal way. The measurements started in 2009 and further implemented in 2010. There are also parametric models to study the processes of the Arctic ABL and the complex interactions between the atmosphere-hydrosphere-cryosphere.

Both in 2010 and 2011 measurement campaigns were carried out aiming to investigate the snow reflectivity characteristics that were added to those collected since the late 90's.

For what concern the atmospheric measurements at Thule (76.5 ° N, 68.8 ° W), in Greenland, long term observations of composition and thermal structure of the atmosphere have been carried out since 1990 by several Italian groups in the frame of the Network for Detection of Atmospheric Composition Change (NDACC; <http://www.ndsc.ncep.noaa.gov/>). Existing activities involving INGV, ENEA and the University of Rome "La Sapienza", in collaboration with the Danish Meteorological Institute, the National Center for Atmospheric Research (USA), and the U.S. Air Force. In last years the activity extended to study of the balance of radiation and energy in the troposphere and stratosphere and the factors that influence them (Muscari et al., 2007; Di Biagio et al., 2011; Muscari et al., 2012, Di Biagio et al., 2012).

During the 2012 Arctic field campaign, extensive nivological and Glaciological measurements were carried out on several glaciers in the area Kongsfjorden. Stratigraphic and bulk snow samples, , have been collected from 20 snow pits at different locations. Moreover, on the top of the glacier Holtedhalfonna (79 ° 09 'N, 13 ° 23' E), at an altitude of 1150 m asl, 11 m long core has been drilled. The samples were analyzed for inorganic species as trace elements, heavy metals, rare earth elements and halogens, and stable isotopic ratios were determined. Aim of project was to provide preliminary information on the source, distribution and end of several trace elements and halogens in Svalbard glaciers. A relationship between the halogens deposition (bromine monoxide (BrO) and iodine oxide (IO)) and extent of sea-ice during the last decade and was highlighted (Spolaor et al. IPICS 2012)

The seismic network GLISN (Greenland Ice Sheet monitoring Network, <http://www.glisn.info/>) was founded in 2009 by a consortium of scientific institutions in Europe and the U.S. with the aim of improving the seismic monitoring of Greenland. The specific location of some of the seismic stations (ILULI, NUUG and Kullo) at the mouth of three fjords of the south-west of Greenland are also able to detect seismic signal, a long period, generated by the formation of icebergs and their floating in fjord. As demonstrated by several published works, the calving icebergs produce signal in a wide range of frequencies and this makes possible to use the seismic signal for its the recognition. (Walter et al. 2013 ). The peculiarity of this type of approach, compared to other techniques of observation, such as satellite, is that this is independent from the weather conditions and from the hours of light / dark. The quality of the recorded data and its spectral content can provide a useful tool for determining the mass of ice released into the sea and the determination of the number of events in time. The measures of Radio Echo Sounding (RES) are also used for the identification of the physical characteristics of the interface ice rocky bottom (Zirizzotti et al, 2010). The analysis method uses a linear model of the absorption of electromagnetic ice. This model, together with other known electromagnetic characteristics, contributes to an assessment of the power variation of the reflectivity of the ice to determine the areas of wet / dry ice-bedrock interface of the polar caps.

In the frame of the International Polar Year 2007-2009, there was a participation to IPY no. 367 NICE STREAMS (Neogene Ice Streams And Sedimentary Processes On High-Latitude Continental Margins, <http://sites.google.com/site/ipynicestreams/ipy>) an oceanographic cruise with R/V OGS-Explora (EGLACOM) was made to define the architecture and evolution of the southern margin of Svalbard. The cruise and the subsequent research activities were supported principally by OGS, with the participation of research groups INGV. The data acquired during the Italian cruise EGLACOM include a multi-channel seismic survey (over 1,000 km) and sub-bottom (over 4,000 km), multibeam data (over 7,100 km<sup>2</sup>), physical and chemical parameters of the water (532 water samples), oceanographic measurements (60 XBT and CTD 6) and 4 cores. Data were analyzed during the PNRA project MELTSTORM in collaboration with other research institutes and Italian universities and European for the study of paleoclimate and stability of the underwater slopes. These data and subsequent results (Lucchi et al., 2010; Rebesco et al., 2011; Pedrosa et al., 2011; Lucchi et al., 2012; Rebesco et al., 2012; Sagnotti et al., 2012; Lucchi et al., submitted; Rebesco et al, submitted-a and-b ) are the basis of the international project CORIBAR (<https://sites.google.com/site/ipynicestreams/coribar>) whose activities 2013 are integral part of ARCA.

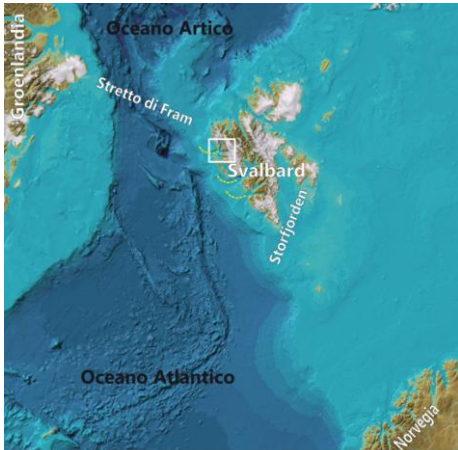
Regarding the ICT technologies as proposed in the project, CNR has developed in recent years developed in collaboration with the European Research Centre in Ispra (EU-JRC) mediation services based on the Brokering approach. The development of these services brought the CNR and EC-JRC to get the leadership on this issue in the framework of GEOSS at the European level. The recently introduced EuroGEOSS brokering architecture is based on three basic principles:

- (a) Construct a "system of systems" based on existing information systems not asking them to give up their autonomy or changing objectives and technologies of implementation.
- (b) To supply features that has not been "brokerated" and are necessary for the effective interoperability.
- (c) Lower the current technological barriers for entry of users and data providers.

The ICT infrascrutre that will be implemented in ARCA will make full use of these consolidated experience adapting them to the specificity of polar research and to information systems already developed by the project partners.

## 4. - Project overview

An overview of the proposed activity, and how it will be organized and carried out through different workpackages (WPs), tasks, and activities is given in the table below. The last column summarizes the results. Specific actions and timing are given in the Gantt Chart.



The release of large volumes of cold and fresh water from melting of ice caps will be studied both from paleoclimatic and from processes of interaction air-sea-ice point of view. The story of the last deglaciation will be investigated (through the field cruise CORIBAR) in a very important region for significant flows to and from the Arctic Ocean and for great relevance to the climate in Europe (WP3). Observation activities and analysis in Greenland will collect information on the present contribution to freshwater flows from the largest mass of continental ice (WP2). Even if located in two specific locations (Greenland and Svalbard, in the northwest part of the Svalbard), the activities referring to WP1 will aim to study the physical processes controlling the supply of marine and continental ice into the ocean. WP4 will have the specific task to summarize

the results in one or more conceptual models that may help in assessing future scenarios. Integral part of the synthesis work will be the design of an ICT tool that will help in synthesis and represents an important legacy for future activities in other areas of the Arctic.

Below is a detailed description of the activities' in the individual workpackages

### WP1 – Atmosphere-hydrosphere and cryosphere integrated system

Workpackage 1 will aim to study the interaction between the atmosphere-hydrosphere and cryosphere. The radiation balance and its variability is a function of several factors, so the complex processes of interaction at ice-atmosphere interface, will be treated separately from the processes at the more complex air-sea-ice interface. The diversity of observational systems, and especially the great difference in operational issues fully justify this division.

#### **1.1 - Radiation and energy balances, mass, heat and momentum fluxes in the troposphere and at the air-snow-land interface**

Activities in this task are designed to identify the variables that most influence the radiation balance and energy on iced surfaces, and the breakdown between the various components. The study of seasonal variations in relation to meteorological conditions, cloud cover, stability of the arctic atmospheric boundary layer (ABL), the reflectivity and the morphology of surfaces will allow to define some new simple parameterizations for the processes controlling the melting of snow in spring and of glaciers in summer. Experimental activities will be held in Ny Alesund (Kongsfjorden) in Svalbard and Thule in Greenland.

At Ny Alesund, the Climatic Change Tower (CCT) will be central in the activities related to this task as it can provide continuous measurements throughout the year. Currently on CCT traditional meteorological sensors are installed at 4-level and fast response to 3 intermediate levels. Temperature, wind and humidity data are continuously recorded and averaged over a minute. The fast response sensors are used in the study of the processes of turbulent exchange between the surface and the atmospheric boundary layer (2 sonic anemometers and two hygrometers) and collect data at the frequency of 20 Hz in the same time with another sonic anemometer coupled, at 20 m heights on the CCT, with sensors to measure continuously fluxes of heat, CO<sub>2</sub> and CH<sub>4</sub> and water vapor. A set of radiometers at 30 meters height provides components and radiation balance at 1 minute resolution, as well as surface albedo information. With proper analysis algorithms one can obtain information on cloudiness, with a resolution of 15 minutes (Long and Ackermann, 2000)

The peculiar characteristics of weather conditions in the area of Kongsfjord will be statistically defined to identify the components that contribute most to the development of processes in the stable atmospheric boundary layer (SABL), to define the the averaged and turbulent thermodynamic state of ABL, and to study the local atmospheric circulation in relation to the large-scale dynamics.

Measuring in two sites the structure and composition of the atmosphere (troposphere and stratosphere), the vertical distribution of clouds, and the longwave and shortwave radiation fluxes the evolution during winter and winter- spring transition phase , will provide the information to understand the influence of clouds, water vapor and ozone on the radiative balance at the surface in the Arctic. On glaciers in Kongsfjorden, spectral measurements of surface reflectivity and morphology (grain size, roughness, stratigraphy) will be performed. Where possible, simultaneously to radiometric nivologica and glaciological sampling, along altitudinal gradients and away from the sea will be carried out on the stratigraphic layer of yearly snow layer. One or two surface cores (depth 10 - 12 m) will be extracted in the northern part of Spitsbergen, in order to integrate the data from the core Holtedhalfonna and to evaluate the spatial variability of halogens and trace elements deposition in the last ten years. Near the village of Ny Alesund, at a particular site and in collaboration with Università di Firenze, stratigraphic snow samples will be collected every 2-3 days to study the post-depositional processes of the halogens and trace elements as a function of meteorological parameters and physical processes. This to improve the interpretation of the results extracted from the core surface.

From data collected during ARCA will be integrated with those already collected and may improve the historical data set acquired by other ten stations operating at Ny Alesund. In the context of ARCA, datasets of glacial mass balance Lovenbreen, Broggerbreen, (about 50 years), Kongsvegen (about 30 years) and Holtedahlfonna (about 15 years) will be of great importance, that thanks to established international collaborations, may be made available to the ARCA project.

### **1.2 - Oceanographic processes and at atmosphere-hydrosphere-cryosphere interfaces**

The activity of this task will mainly concern the study of the interactions and relationships between the oceanographic processes, the atmosphere and the sea ice with particular reference to the exchange processes at the interface between the different components. Observative activities in Kongsfjorden will be used as a case study, and in spite of the limitations of spatial representativeness, may be a useful test to build conceptual models (WP4) of the processes of melting and supply of fresh water and sediment from the ice sheets to the Arctic Ocean.

It will be collected data on fluxes of water and particles at the sea-ice interface, ocean circulation and sediment dispersion, mass exchange with the ocean, the thermodynamic fluxes at the air-sea in the fjord and in the open ocean, with the aim to reconstruct the impact of climate change from modern sedimentary deposits (100-200 years). To do this it will carried out a measurement campaign in collaboration with NPI (Norway), AWI (Germany), under the auspices of the activity coordinator in the Kongsfjorden (NySMAC). The campaign will include CTD and ADCP measurements, water sampling with Niskin bottles, collection of suspended matter and surface sediments, that will be analysed for C and N contents and stable isotopes, grain size, dissolved O<sub>2</sub>,  $\delta^{18}O$ . The underwater measurement platform Mooring Dirigibile Italia by CNR ([www.dta.cnr.it](http://www.dta.cnr.it)) will be available and implemented with additional sensors for the measurement of CO<sub>2</sub>, and adapted to accommodate experiments related to variations in alkalinity of the sea and to the biological pump. More data on recent paleoclimate and sedimentation processes will be attained by analyzing sediment cores already collected in the past in CNR and other European projects.

An important contribution to the data interpretation will be given to the measurements at the air-sea interface through autonomous buoy equipped to monitor meteo-marine parameters and from the integration of bathymetric mapping already performed. For the first time in Kongsfjorden, the air-sea-ice interface will be studied at minimum distance from glacier front by using an autonomous surface vessel with remotely-controlled instrumentation (<http://www.issia.cnr.it/htdocs%20nuovo/home.html>) from a vessel with personnel at a safe distance from the collapse of the ice walls. The USV (Unmanned Surface Vehicle, boat central) Charlie will make measurements with integrated systems and automatic deployments of mobile platforms and/or multi-parametric probes. The measurements at the air-sea interface may be compared with those made at the air-snow or air-to-ground instruments installed on CCT. The data provided by CCT will allow to close the energy balance at the surface by providing information on the structure of the upper atmospheric surface layer. The chemical water analyses will be compared with those acquired on the mainland at the laboratory Gruvenbadet.

### **WP2 - Dynamics of large outlet glaciers in Greenland**

The work of this WP, dedicated to acquire information about the current dynamic of the Greenland ice cap and the discharge of ice from the outlet glaciers into the Arctic Sea, will be develop in two lines of research: (i) the first focused on the acquisition and analysis of RES (Radio Echo Sounding) data finalized to the production of a wet/dry map for the interface ice-bedrock of some of the outlet glaciers plus different areas of the Greenland ice cap; (ii) the second, dedicated to the analysis of seismic data from the GLISN stations (Greenland Ice Sheet



Network) located at the entrance of the fiords where the most active glaciers exit to the open water with the final goal to model the seismic signal generated by iceberg's calving and its interaction with the fiord.

The RES measure campaign will benefit of new data analysis methodology. The original technique will allow a better electromagnetic characterization of the bedrock by means of the analysis of the radar reflection power. The power of the reflected signal is correlated with the bedrock reflectivity and to its specific physical conditions and this allows to use a linear model for the ice electromagnetic absorption that, coupled with hypothesis or measures of the ice nature, will permit to reconstruct the power of the signal reflected at the bedrock interface and then its wet/dry status. This technique will be applied on data acquired by previous campaigns of measure plus those data that will be produced by the specific campaign that is part of the ARCA project. The target area will be selected on the base of the results from previous data with a particular attention to the Southwestern sector of Greenland, target region of the seismological branch of this WP. The analysis of previous data will also allow to evaluate and model the time dependent evolution, to compare different data analysis techniques, and to investigate the impact of the wet/dry characteristic of the bedrock interface on the velocity of the outlet glaciers and on their rate of mass discharge into the sea.

To study the seismic signal produced by the iceberg calving into the Greenland fiords we will use those broadband seismic stations located in the vicinity of the active outlet glaciers, mainly located in the Southwestern sector of Greenland. These high-sensitivity seismometers can record the signal produced by those large icebergs that calve from the glacier tip, and then capsize and collide with the fiord bottom. These phenomena produce seismic signal that mainly covers three frequency bands: 1-10Hz, 0.1 – 0.03 Hz e 0.005 – 0.001 Hz. The analysis and modelization of such data will contribute to the determination of the ice mass discharged into the fiords, its seasonality and the eventual fluctuation in time. For this purpose we will use standard techniques used in seismology for earthquake's detection as the unmanned recognition of changes in frequency and amplitude in the long period continuous signal. The discrimination of iceberg calving from large earthquakes occurring worldwide is a more complex task and it is tackled by the characterization of the recorded seismic signal in terms of duration, frequency content and H/V (horizontal/vertical) ratio, given the recognizable differences between the two types of long period signal. The first part can be done automatically in the framework of the acquisition system called SeisComp3 (<http://www.seiscomp3.org>) that is, currently one of the standards for earthquake monitoring at regional and global scale, while the second will require the development of some specific software whose preliminar version is already under test with encouraging results.

### **WP3 - Extreme melt-water's events reconstruction**

Planned activity within this WP is largely focused on the CORIBAR campaign and the analysis of data collected. CORIBAR aims to collect over 500 m of sediment in 7 drilling sites on the Storfjorden and Kveithola continental shelf and slope. Coring sediments consist of thick and high- stratigraphic resolution Holocenic deposits, melt waters deposits with high accumulation rate (3.4 cm y<sup>-1</sup>, Lucchi et al., 2010; 2012; submitted) builded during extreme events of deglaciation, glacial sediments deposited at the front of ice stream during episodic glacial retreat and subglacial moraines produced during ice streams advances. The overall target is the reconstruction of the glacial ice caps response to climate changes, with particular attention to defining the mechanisms of dispersion and the age of pluvial processes (meltwater sediment plumes) occurrence, quantifying the sedimentary input associated with subglacial meltwater and assessing the influence of deposition of these sediments on the polar continental margins stability. The ARCA project and more specifically the activities of this WP will contribute to CORIBAR through sharing data and knowledge already acquired during previous activities, especially those developed in the PNRA project/MELSTORM, the participation of researchers on board and to the analysis at the core repository in Bremen, the fine-tuning of OGS sedimentological analysis laboratory, the data analysis in Italy and the collaboration to interpretation and publication of the results.

Geophysical analyses will include the correlation between sedimentary sequences sampled by the wells through geophysical data.

Sediments study include detailed facies analysis through the application of automated and non-invasive type new technologies (high resolution x-rays through TAC, multi-sensor core logger for the physical properties of sediments, XRF core scan for chemical composition) and traditional investigation methods applied on individual samples extracted from sediment cores (water content, grain size, geochemical analysis, CHN isotopic analyses). The results will be integrated with the data obtained by the partners (clay minerals, biostratigraphical and paleoenvironmental study) to reconstruct the sedimentary processes and the evolution of the margin by using detailed morfo-bathymetric and acoustic data acquired in previous campaigns (Italian EGLACOM and Spanish campaign SVAIS). Study on the type and quantity of gas in sediments and their possible association with landslides.

The biogeochemical analysis on sediment layers considered representative of paleoclimatic events will include the characterization of the total organic matter and its bioavailable fraction. Will be assessed the rates of

hydrolysis of the major oligomers fundamental for life along with the general description of the metabolism of microbial associations. Portions of sediment will be preserved for possible investigations on biodiversity and genetic pool of possible use in biotechnological and industrial applications.

Paleoclimatic comparing data derived from the study of speleothems will also be used to identify extreme weather events on global scale, contributing to the reconstruction of climatic variations over the past 20,000 years.

Analysis on cores and sediments will be put next to (1) paleomagnetic analysis: through high-resolution paleointensity stacking measurements will be possible to reconstruct the dynamics of Earth's magnetic field at high latitudes and the cores correlation through the development of an age model; and (2) measures of environmental magnetism, in order to detect changes in a set of magnetic parameters for a high-resolution reconstruction of climatic and environmental changes of the area.

In addition, the review of literature data concerning the tephrostratigraphy and tephrochronology of the Arctic area and preliminary study (grainsize, components and geochemistry) of tephra layers in the sampled sequences, will allow a comparison of literature data and preliminary results and to identify possible tephrochronological markers.

The analyses of stable isotopes (carbon and oxygen) in the foraminifera shells will allow to 1) provide an absolute time control through correlation with the astronomical scale calibrated on orbital parameters; 2) reconstruct important properties of water masses including temperature,  $\delta^{18}O$  of seawater (which includes a global glacio-eustatic signal) and the  $\delta^{13}C$  of dissolved inorganic carbon.

The complex analytical work will be carried out on schedule thanks to the collaboration with several universities. In detail: (a) University of Trieste will carry out biostratigraphical and paleoenvironmental study using foraminifera; (b) University of Siena will carry out clay minerals analysis and provenance of sedimentary clasts; (c) University of Parma will carry out biostratigraphical and paleoenvironmental study using calcareous nanofossils. (d) University of Naples will study the Diatoms distribution by electromicroscopy (SEM). (e) Università Politecnica delle Marche: study of biocenosis in benthic foraminifera. (f) University of Florence: inorganic geochemistry of major and in trace elements and metals, including rare earth elements. (g) University of Pisa: biostratigraphical and paleoenvironmental study using planktonic foraminifera, (h) University of Melbourne (Australia) for the study and dating of speleothems.

## **WP4 - Conceptual model and distributed system for the management, use and dissemination of data**

The overall objective of this WP is to merge all project results in an integrated approach to provide insight on the budget of fresh water in the Arctic, on the mechanisms that can trigger extreme events of collapse of the ice, to use ICT techniques to help synthesis and ensure that the ARCA project provides a concrete and solid data legacy for future activities.

The two activities of this WP are closely linked with each other and include: a) a summary of the results of the observation and analysis carried out in the previous WPs aiming to build conceptual models; b) the development of ICT platform to support the synthesis work and to offer a repository of data for possible future use.

The synthesis work aims to integrate the results that emerged during the project using the different components of observation, and benefit from the interdisciplinary nature of the ARCA activities and the research team. The challenge, difficult (high risk / high gain), is to define a conceptual model for the interpretation as a single integrated system and not as an aggregation (summation) of individual results. Aggregate, integrate and synthesize are the key words of this action from "rescaling" of space-time scales of the processes put in evidence, albeit largely qualitative relationships between the various components of the Arctic atmosphere, hydrosphere, cryosphere and geosphere.

The synthesis and development of the conceptual model will have several stages:

i) the results of analyzes carried out in the different workpackages team work will be harmonized and integrated: from the interdisciplinary framework that will emerge, the fundamental processes that regulate the balance of fresh water and sediments will be identified and extracted also identifying and supporting small additional research, technological development or acquisition of information instrumental to the holistic view. For example development of models, also for numeric extend the results to areas similar to those measured (p.e.s. Irminger Sea), and comparison with data from other polar areas.

The indications and conclusions of the model and / or conceptual will describe the process of collapse of ice and massive inputs of fresh water, sedimentary processes at small and large-scale, the effects on ocean circulation at regional scale and on thermohaline properties and compared with paleoclimate data at different time scales.

ii) A phase of document research for the integration of information on the processes from the past to the present, including any comparisons also at bipolar scale with other glaciers (ice streams, outlet glaciers) will be also performed. The task will have the objective to show how the past and present of different processes and different types of observations and analysis should be integrated: from processes in the atmosphere (radiation budget, albedo, vertical flows of mass and momentum, atmospheric circulation, air-interaction) to those of deglaciation, ocean processes and sedimentation. Issues to focus on will be the processes and parameters that regulate the flow of fresh water and sediment into the sea, the definition of the influence of deglaciation of the ice sheets and anomalies of fresh water and suspended sediment, global ocean circulation, biogeochemical cycles, alkalinity and marine biomass.

### ITALIAN ARCTIC METADATA SYSTEM



Data from the project ARCA will be interoperable and integrated through a set of information systems. These systems in spite of heterogeneous domain, type of data and technologies will be interconnected leaving maximum flexibility. It will operate using Web technologies to achieve a multidisciplinary and distributed digital infrastructure, that is based on the concept of "system of systems" approach using Brokering to resolve these differences in a transparent way. The ITC designed and implemented will be able in the near future be used to catalog and store historical data and to maintain the continuity of the series.

Brokering services that will be developed will allow the pooling of resources and capabilities, resulting in a more complex system that offers more functionality and performance than simply the sum of the existing systems. This "bottom-up" approach will guarantee autonomy and technological diversity of individual systems, and full interoperability of resources through the development of appropriate mediation services.

The architecture of the ITC infrastructure developed in the field of ARCA will be based on two general points:

- The interconnection capacity of existing systems - operated by different organizations for different purposes.
- An infrastructure central (brokering) to facilitate the interconnection of capacity / existing systems.

It involves the activation of four "nodes" federated together and listed below: Arctic Node, Node INGV, OGS Node, Node CNR. The following diagram represents the logical architecture

The basic structure of each node will consist of a server, preferably in the LINUX OS where the tools for creating and managing catalogs metadata standards will be installed.



Each node will be able 'to represent the center of another "system of systems" who collect information based on a defined criteria (type, discipline, property ...) and can be seen as consistent with each other. In particular, the node INGV (simplified in the figure), will contribute 'to the realization of the structure through the observations arising from measurement campaigns and monitoring of the different geophysical parameters made during the entire duration of the project. Nodes will pass even the continuous monitoring already carried out in Arctic that may contribute to the scientific results of the project.

Node Arctic, will introduce the testing of innovative technologies such as technology SOS (Sensor Observation Service), the operability of real time data and instrumentation installed at fixed observing platforms (CCT, Gruvebadet, Mooring) in Ny Alesund. For the measurements currently under way data are collected locally and transmitted at regular intervals (typically every 24 hours) over the network to their corresponding Italian nodes CNR and INGV. The infrastructure of metadata will constitute the basis for access to information on the data and the status of the measures.

The metadata can be generated in situ for each node in the "system" through a specific software interface according to the instructions of the INSPIRE Directive. Infrastructure for data access in distributed systems will be developed to support the activities providing basic services as discovery, selection, viewing, downloading.

The search for information on the data and the data itself is through a system that can query existing catalogs and major database engines. The goal is 'to go beyond the mere publication of metadata and make it "accessible" "data", on the basis of specific data policy independently established by each node. Through the concept of brokering, forming a 'system of systems' different operating systems and different modes of data management, allowing each entity to maintain its specificity can exist.

In practical terms, the implementation of the ITC will take place 'in the following stages: (1) Documentation capacity / system to be interconnected, (2) development and online publication of Brokering infrastructure, (3) Online publication capacity / system to be interconnected, (4 ) test interoperability, (5) Release of System of Systems

For this purpose we will proceed to a) design and integration of a metadata structure for cataloging and discovery of data; b) implementation of facilities for automatic real-time data collected in the database; c) creation of a web portal for public access for graphical display of the data available and can access with authentication to download data.

It is the task of this WP, in a close exchange with other partners and any other national and international collaborations to organize, workshops, meetings, training and dissemination.

Finally the guidelines for the publication of a thematic volume, dedicated to the project of scientific journal interactional, in addition to the normal production of scientific results, to the end of the project will be defined.

## Project structure and activity plan

WPs	Tasks	SPECIFIC ACTIVITIES	INSTITUTION	EXPECTED RESULTS
<b>WP1 - The integrated atmosphere-hydrosphere-cryosphere system</b>	<i>1.1 – <u>Radiation and energy budgets and fluxes of mass, heat and momentum at the air-snow-ground interface</u></i>	<i>Radiation energy budgets, Arctic ABL dynamics, role of clouds, water vapor, aerosols and albedo, influence of the chemical composition on the radiative balance in the strato-mesosphere, fluxes of C, N and O at the air-snow-ice-ground interface, reconstruction of the recent history by glaciological measurements, development of parameterizations for climate models at the regional scale</i>	<b>CNR - INGV</b>	Meteo-climate peculiarities of Kongsfjorden, in particular in periods of seasonal transition: characterization, cataloguing. Parameterization of the exchange processes between the surface and the atmosphere, especially in reference to radiation and energy budgets Integration of information and data acquired from the scientific platforms in the information system. Construction of the catalogue of measures
	<i>1.2 – <u>Oceanographic observations and processes at atmosphere-hydrosphere-cryosphere interfaces</u></i>	<i>Water and particle exchanges at the sea-ice interface, ocean circulation, dispersion and sedimentation processes, ocean exchanges, , at air-sea fluxes in the fjord and in open ocean, reconstruction of recent history by sedimentary deposits (100-200 years)</i>	<b>CNR</b>	Hydrological survey and oceanographic observing site maintenance Water and carbon fluxes at the interfaces of the Kongsfjorden Map of the thicknesses of modern sediment in the inner fjord Assessment of human impact on the recent sedimentary dynamics, pollution and the sedimentary carbon cycle Development of integrated systems of meteo-marine measurements and unmanned surface vehicles (USV)
<b>WP2 Dynamics of large outlet glaciers in Greenland</b>		<i>Greenland ice cap study by determining the ice-bedrock interface conditions with RES techniques and monitoring of the ice discharge into the sea by seismic data, detecting and modeling the so-called calving events (iceberg formation)</i>	<b>INGV - OGS</b>	Maps of wet/dry bedrock-ice interface in some areas of Groenlandia Catalogue of the most significant calving events for some of major glaciers Theoretical model of the seismic signal produced by the iceberg-fjord interaction
<b>WP3 - Reconstruction of extreme meltwater events</b>		<i>Dispersal mechanisms, age and recurrence of meltwater processes, quantification of sediment supplied based on lithological and geophysical data in Storffjorden and Kveithola; studies of magnetic and paleomagnetic properties of sediment cores, speleothem-based paleoclimate</i>	<b>OGS - INGV CNR</b>	CORIBAR drilling campaign in Storffjorden and data analysis. High-resolution reference paleoclimate record based on speleothems
<b>WP4 - Conceptual model and distributed system for the management, use and dissemination of data</b>		<i>Study of processes and parameters driving fresh water and sediment supply, definition of influence of ice sheet deglaciation on global ocean circulation and marine biomass, transport of suspended sediment in glacial melting waters, comparisons on a regional scale with other glacial systems (ice streams, outlet glaciers), definition of the distributed network architecture, deployment nodes, tools development for managing individual nodes and interconnection capacity/existing systems, functional testing, implementation of the operational phase</i>	<b>CNR - OGS - INGV</b>	Summary obtained through the results of WPs 1-3 and development of conceptual models for the study of various phenomena and processes Integration of complementary expertizes by participant institutions, establishment of an interdisciplinary multi-institution team Collaboration with international partners involved in the CORIBAR experiment Implementation of a distributed structure based on the brokering approach concept, with nodes managed by different participants and a central infrastructure at the CNR

## Gantt Chart with specific actions in each WP and their timing

Activity	Month	1	2	3	4	5	6	7	8	9	10	11	12
<b>WP 1</b>													
Instrument and material preparation		■	■										
Measurement campaigns and mooring servicing Sensor and technological testing			■	■	■	■						■	■
Development of sensors and USV system		■	■	■	■						■	■	■
Data analysis					■	■	■	■	■	■	■	■	■
<b>WP 2</b>													
RES measurement campaigns			■	■									
RES data processing (past and new-acquired in ARCA)					■	■	■	■	■	■	■	■	■
Analysis of GLISN seismic data		■	■	■	■	■							
Development of theoretical models								■	■	■	■	■	■
<b>WP 3</b>													
CORIBAR cruise and non-destructive core logging at Bremen core repository		■	■	■	■	■	■						
Grain size lab implementation at OGS						■	■	■					
Geological and geophysical data analysis in Italy						■	■	■	■	■	■		
Integrated data interpretation and publications									■	■	■	■	■
<b>WP 4</b>													
Analysis and synthesis of results									■	■	■	■	■
Development of conceptual models											■	■	■
Design and implementation of a distributed data management			■	■	■	■	■	■					
Off-line testing and on-line version of the running system									■	■	■	■	■

## 5. - Duration and cost of the project

The ARCA project will be 12 months long. Observational activities obviously will be concentrated in the first part, with mode and timing strictly dependent on operational and logistical constraints. The oceanographic campaign will be carried out during the late spring and summer, with decisive contribution from infrastructures resulting from international collaboration. At Ny Alesund (NYA), the experimental activity will concentrate in the spring (monitoring glaciers, monitoring was CCT and other observational platforms) and summer (activity in the fjord between June and September). A second campaign in NYA at least limited to atmospheric measurements, should be possible in the following spring. Atmospheric activities at Thule will take place in coordination with similar activities to NYA. The RES measurement campaign they will always take place during spring and summer, when conditions allow it to operate on the cap and glaciers of Greenland.

The second part of the project will be dedicated to the processing and analysis of large amounts of data acquired, the integration of results, development of parameterizations and models.

The complex activity 'first observational and intense activity' of integration and the following summary, together with a large interdisciplinary team of researchers and technicians, require proper governance and scientific management. The scientific governance of ARCA, the necessary internal coordination between the EPR participants, and the external connection to the many public and private actors, will be secured by a scientific board of three members, who will meet every 4 months. Meetings will also be web based whenever possible. Meetings will make an accurate assessment of the status of the project, both in its scientific and administrative part and the project

coordinators will always participate to the meeting. The presence of different expertizes from atmosphere to marine sciences in the governance structure of the project will help to strengthen / develop the multidisciplinary nature of the ARCA project.

The total value of the proposal is about 6.9 Meuro, 5.2 Meuro about (75%) of which provided by Ministry of Education as a contribution to FOE 7%.

In detail, 3.5 Meuro of contribution required by the CNR, 1.2 Meuro by OGS and 0.5 Meuro by INGV.

The ARCA project will co-fund almost 25 % of total cost. This support is provided as 1.2 Meuro by the CORIBAR international consortium where OGS participates, for 0.20 Meuro by CNR, 0.35 Meuro by OGS and finally by 0.25 Meuro by INGV.

In the table at the end of this section, details on the cost of ARCA are included into different captions. The wide observational and experimental activities, the need to have a team that includes all the skills necessary to look at the problem with the necessary multidisciplinary approach, the burden imposed from operating in polar area away from Italy, make staff costs, infrastructure costs and overheads definitely most important voice around 78% of the total costs.

Size, quality and roles of the research team (see final section) justify the figure inserted in the first digit of the table, which accounts for 38 % of the total cost. 5% of this cost will be co-funded by EPR.

Infrastructure costs include facilities that will be used in the Arctic for observation and measurement campaigns as well as laboratory facilities for the analysis of marine samples and the computer systems to realize the distributed ICT department. Almost all of these expenses (85%) will be co-funded by the participants either directly or through the international collaboration established (see letter of support from the consortium CORIBAR).

General and administrative expenses in Italy will cover the operating costs associated with the project, and also costs related to the observation activities at NYA and Thule, mission costs in Italy and abroad, the cost of transportation of materials and equipment, costs for safety in the field, etc. A percentage of 14% for overheads are justified by the addition of standard research expenses and special projects costs related to activity in the Arctic.

Personnel costs, thanks to the funds FOE7%, will cover seven research grants. These young researchers will benefit for their training of the multidisciplinary and international environment that characterizes' the ARCA project.

Expenses for contracts to third parties include costs for the rental of the aviation infrastructure for RES campaign on Greenland, the cost to perform special tests on the samples and cores when required by external laboratories, the coverage of logistics services of local facilities at NYA and Thule, the costs for the development of technological systems (embedded systems climatic measures, unmanned surface vehicles UPS, etc.).

The cost of materials will be largely needed to buy the materials for the different laboratories (paleomagnetic, environmental geophysics, electronics), the materials to carry out specific analyzes (radiocarbon dating, gas chromatography), supplies for the activities in the field (paleoclimate sampling etc.), spare parts for instrumentation and electronic systems, consumer products for the business ITC.

6.4% of resources will be used to the purchase dedicated equipment. In detail, we will update the Multi Sensor Core Logger (colorscanner, imaging, X-ray fluorescence, resistivity), purchase of a Coulter counter, purchase all the systems to set up the ITC department for the management and data distribution, data storage and processing equipment for ion local, buy a capture card (RES) and a spectrometer, acquisition of sensors for meteo-marine electronics and for unmanned boat.

Under other expenses, were put expenses for the organization of a thematic workshop, the cost of the spread and dissemination of results (publications, participation in meetings), any expenses to attend international meetings and for management of campaigns, general costs for the campaign RES, costs to sustain invitations of foreign experts, expenses to adjust and maintain the core repository.

## PROJECT COSTS ESTIMATE (keuro)

<b>Macro voci di spesa</b>	<b>Ammontare previsto</b>	<b>Fonte FOE 7%</b>	<b>Cofinanziamento Altre forme di Copertura</b>	<b>Incidenza percentuale</b>
Staff Personnel and contract personnel	<b>2.607,9</b>	<b>2.468,7</b>	<b>139,2</b>	<b>37,8%</b>
Student grant	<b>170</b>	<b>170</b>	<b>0</b>	<b>2,5%</b>
External services	<b>335</b>	<b>325</b>	<b>10</b>	<b>4,8%</b>
Materials	<b>350</b>	<b>330</b>	<b>20</b>	<b>5,1%</b>
Equipments and tools	<b>440</b>	<b>440</b>	<b>0</b>	<b>6,4%</b>
Infrastructures ( upgrade and management)	<b>1.768</b>	<b>268</b>	<b>1.500</b>	<b>25,6%</b>
General expenses	<b>970</b>	<b>960</b>	<b>10</b>	<b>14,0%</b>
Other expenses ( field campaign, workshops, participation to meetings, publications, travel expenses)	<b>263</b>	<b>220</b>	<b>43</b>	<b>3,8%</b>
<b>TOTALE</b>	<b>6.903,9</b>	<b>5.181,7</b>	<b>1.722,2</b>	<b>100%</b>

### POTENZIALI ULTERIORI COPERTURE FINANZIARIE:

Progetti FIRB

Sostegno MIUR alla iniziativa ESFRI SIOS

Possibile partecipazione a bandi europei in ambito Horizon 2020.

Risorse ulteriori da inserire nelle azioni di trasferimento Tecnologico di questo progetto possono provenire da azioni di sviluppo tecnologico già finanziate con fondi FESR e exL.297 attraverso il Distretto Ligure delle Tecnologie Marine: strumenti e tecnologie sviluppate per i mari italiani nell'ambito di questi progetti saranno impiegati anche in Artico, offrendo in questo modo alle aziende italiane l'opportunità di aumentare i loro potenziali mercati verso le nazioni del Nord Europa e del Canada



## 6.- Expected results

The table in section 4 (page 13), which summarises the structure and the activities of the project, presents the main expected results of the research (last column). Such results, sorted per work packages, correspond in some cases to the general objectives listed in section 2, but they often indicate specific results which aim to contribute to fulfil the general objectives.

ARCA project aims to pursue not only scientific objectives/results dedicated to the improvement of our knowledge of the climate system in polar regions and in Arctic in particular, but also to achieve strategic, technological and infrastructural (mainly ICT) results.

Strategically ARCA project will allow to systematize skills and knowledge actually distributed among the 3 participant bodies. In this context such a wide multidisciplinary team of researchers and technicians will collaborate and work in frontier research in a wide and stimulating international framework. Such cutting edge research will favour high level training of young researchers involved in the project. ARCA will contribute significantly to the birth of a new generation of motivated and highly trained polar researchers at national level. Within the ARCA's activities a big number of private and public bodies will be involved (see full list in the summary sheets), in order to ensure the full involvement of the working team in the national context of the research. Moreover such activity will allow to consolidate the Italian presence in the international context of the Arctic research.

In a vision across the different areas of intervention, ARCA project aims to achieve important technological and infrastructural (ICT) results. For what concerns technological objectives, the development of integrated systems aimed to meteo-marine measurements in the air-sea interface will be carried out. The improvement and the expansion of the currently available autonomous surface systems (USV) will allow to drive such instrumentation below glacier tongue on the Kongsfjorden, allowing to study the interface air-sea-ice. Both from research and application point of view there is a great difficulty in having such autonomous surface systems able to reach so dangerous areas and instruments able to integrate dedicated to marine and atmospheric parameters measurements. The results achieved in ARCA will have a wide range of potential applications and capabilities in attracting more resources. This put CNR-INGV-OGS team at the cutting edge in the field. Such consideration can be extended also to the ICT infrastructure proposed in ARCA. Research team has top level expertise in the field of such a new field of research devoted to distributed and multidisciplinary database (brokering approach). This will guarantee the timing and the quality of the realized system. The ARCA activities will allow to develop new tools and routines suitable to the peculiarities of the polar research and to manage efficiently such heterogeneous data ensemble. The system, once implemented, will be among the few to experiment the multidisciplinary, interdisciplinarity, integration and interoperability. At now, both at NSIDC (National Snow and Ice Data Center) and at MET-NO (Meteorological Norwegian Service) similar systems addressed to the polar areas are under development, but they work on a smaller variety of data kind.

Finally, for what concerns the objectives and the scientific results, whose details are described in section 2 and reported in the table of section 4, they will aim to:

- a) Consolidate the observational activities already in operation before ARCA and ensure their continuity and maintenance, at Ny Alesund as well as at Thule;
- b) Acquire new data and sample series by means of measurement campaigns addressed to the achievement of the ARCA project's final objectives. In particular, concerning the samples, sediments cores, biological and sediment samples, snow and ice cores will be collected either during terrestrial as well as during marine activities.
- c) Realize specific products and analysis such as wet/dry maps of the contact surface between ice and rock layer, characterization and classification of the meteo peculiarities over Ny Alesund, bathymetric and paleomagnetic relief maps, etc...
- d) Tune modelling tools (processes parametrization, theoretical and conceptual models) able to contribute to the understanding of fresh water production process and possibly to predict its future evolution and the occurrence of extreme events.

## 7. - Proposed criteria for verifying the achieved results

Useful elements for the verification of achieved results include:

- (i) The large data set of atmospheric, environmental, geophysical, biological and paleoclimatic parameters collected during the planned extensive and well-structured experimental activity;

- (ii) Scientific products elaborated jointly by the project team (maps, models, climatologies, paleoclimatic sequences, even at short time scale);
- (iii) Consolidation of the Ny Alesund and Thule observational structures, upgrading of available instrumentation, through new focused purchases and implementation of laboratory facilities in Italy;
- (iv) The integration and optimization level of scientific, infrastructural and technological resources fielded by CNR, OGS INGV national in order to expand the exploratory capability;
- (v) The advancements achieved in the marine technology and environmental observation fields, with the improvement of the autonomous surface vessels (USV) control system and the integrated meteomarine measuring systems realised specifically for the ARCA project;
- (vi) Design and implementation of ICT system deployed for the efficient management of multidisciplinary Databases, based on brokering approach with 1 main node and 3 satellites nodes;
- (vii) Creating a project web page and periodic task progress by the governance structure;
- (viii) The strengthening of many international collaborations that applicants have already underway at different levels and from several years;
- (ix) The educational degree and level of young researchers;
- (x) Amount and quality of thematic meetings (workshops) organized in Italy and the level of national and international attendance;
- (xi) Amount and quality of communications (oral, poster, invitation) at national and international conferences, and number of publications produced in the first year after the project closure;
- (xii) The governance level and the periodic reports produced by the Scientific Board.

The collection of items indicated above will represent a substantial legacy able to “act as flywheel” for future initiatives, the continuation of the activities, and especially for inclusion within the infrastructure networks and thematic networks, which will form the framework of the future pan-Arctic Observing System SAON.

***Governance will be ensured by the Coordinator and a Scientific Committee of 3 members. Coordinator and Scientific board will meet at least once every 4 months, and finally prepare a short report of the work progress, in which report the status of the activities, the results achieved, possible issues and the solutions adopted to solve them.***

Obviously, scientific publications in peer-reviewed journals, will constitute the most relevant scientific product, which impact within the national and international scientific community will be measured in terms of normal Bibliometric indexes. Maximum integration in publication of the results will be encouraged.

## 8. – List of project participants

The TEAM of scientist participating to ARCA project includes 86 staff and contract scientist and technician 14 of which are scientist less than 35 years old and 28 female scientist. They contribute with the to 16% and 32% respectively of presence in the team to the activities within the Project ARCA. To these 7 more yearly contract will be assigned by the FOE7% financial support. The young scientist that contribute to the project will in this way increase up to 23%.

The following table lists the participants to the Project ARCA, including some details on the role within their own Institution, bibliographic indexes and the activity and competences provided within the project. An asterisk close to the name indicate the age of the scientist younger than 35 (highlighted in yellow). The female scientist names are highlighted in pink. Also responsibility and chair and governance roles are highlighted.

Name	Position	Institute	Papers	Citation	H	Activity and expertise
ACHILLE ZIRIZZOTTI	Contract scientist	INGV	28	159	7	Polar geophysical research
<b>ALIANI STEFANO</b>	<b>Scientist Staff</b>	<b>CNR-ISMAR</b>	<b>39</b>	<b>289</b>	<b>10</b>	<b>Biophysics and oceanography Resp. WP4 - Chair Scientific Board</b>
ALVISI FRANCESCA	Scientist Staff	CNR-ISMAR	12	160	7	Sediment analysis
AUGUSTI ANGELA	Scientist staff	CNR-IBAF	1	30	1	Stable isotopes
AZZARO FILIPPO	Scientist Staff	CNR-IAMC	21	133	6	Marine microbiology
AZZARO MAURIZIO	Scientist Staff	CNR-IAMC	21	168	8	Marine ecology and biogeochemistry

BARBANTE CARLO	Institute Director	CNR-IDPA	150	3282	26	Paleoclimate, global change
BASKARADAS, JAMES AROKIASAMY	Contract scientist	INGV	9	139	2	Technologist geophysical research
BIBULI MARCO*	Scientist Staff	CNR-ISSIA	27	64	4	Unmanned vehicles
BOLDRINI ENRICO*	Contract scientist	CNR-IIA	4	3	1	Heterogeneous data access
BORGHINI MIRENO	Scientist Staff	CNR-ISMAR	21	169	7	Oceanography
BRUZZONE GABRIELE	Scientist Staff	CNR-ISSIA	43	153	6	Unmanned vehicles
CABURLOTTO ANDREA	Contract Scientist	OGS	15	74	5	Responsible for Core logger
CACCIA MASSIMO	Senior scientist	CNR-ISSIA	84	454	13	Ocean engineering
CALFAPIETRA CARLO	Scientist staff	CNR-IBAF	52	1415	23	Vegetation ecology
CAMERLENGHI ANGELO	contract scientist	OGS	84	1431	20	Sediment analysis
CAPOTONDI LUCILLA	Scientist Staff	CNR-ISMAR	45	702	16	Biostratigraphy paleoreconstruction
CARDILLO FRANCESCO	Technician	CNR-ISAC	7	30	4	Field measurements
CAROPPO CARMELA	Scientist Staff	CNR	21	190	8	Phytoplankton eco-physiology
CARUSO GABRIELLA	Scientist Staff	CNR-IAMC	46	295	9	Microbic ecology
CELUSSI MAURO*	Contract Scientist	OGS	19	93	5	Biochemical and biological analysis
CONESE ILARIA	Contract scientist	CNR-ISMAR				Oceanographer
CONIDI ALESSANDRO	Technician	CNR-ISAC				Field measurements
CORRADO LEONE	Technologist staff	CNR- DTA				Data service management
COZZI GIULIO	Scientist staff	CNR-IDPA	50	899	20	Paleoclimate, global change
<b>DE FRANCESCHI GIORGIANA</b>	<b>Research Director</b>	<b>INGV</b>	<b>45</b>		<b>9</b>	<b>High atmophere physics modelling Member Scientific Board</b>
DE SANTIS LAURA	Scientist staff	OGS	39	477	14	Data analysis and intepretation
DECEMBRINI FRANCO	Scientist Staff	CNR	24	224	7	Phytoplankton ecophysiology
Del Caro PAOLA	Scientist staff	INGV	26	617	11	Physic vulcanology and petrology
DEL BIANCO FABRIZIO*	Contract scientist	CNR-ISMAR	4	3	1	Seimic profile interpretation
DONDA FEDERICA	Scientist staff	OGS	20	139	7	Geological data interpretation
DROFA OXANA	Scientist staff	CNR-ISAC	7	16	3	Atmosphere dynamics modelling
ELEFANTE COSIMO	Associate research	CNR-ISAC	4	6	1	Data management infrastructure
Esposito GIULIO	Technician	CNR-IIA	9	82	6	Field experiments
FERRETTI PATRIZIA	Contract Scientist	CNR-IDPA	10	203	5	Paleoclimate, paleoceanography
FLORINDO FABIO	Research Director	INGV	117	1648	22	geophysical research in polar areas
GABRIELI JACOPO*	Scientist staff	CNR-IDPA	14	33	4	Paleoclimate, global change
GASPERINI LUCA	Senior Scientist	CNR-ISMAR	62	543	12	Seismic profile interpretation
GAVRICHKOVA OLGA*	Contract scientist	CNR-IBAF	8	103	4	C fluxes
GIACOPELLI MAURO	Scientist Staff	CNR-ISSIA				Unmanned vehicles
GIGLIO FEDERICO	Scientist staff	CNR-ISMAR	15	63	5	Biogeochemical polar research
GOVONI ALADINO	Scientist staff	OGS	15	283	7	Seismic data analysis in Greenland
IANNIELLO ANTONIETTA	Scientist staff	CNR-IIA	16	229	9	Snow chemistry and deposition
ISOLA ILARIA	Contract scientist	INGV	26	327	9	Technologist paleoclimatic research
LA FERLA ROSABRUNA	Scientist Staff	CNR-IAMC	31	235	8	marine biogeochemistry
Lanconelli CHRISTIAN	Contract Scientist	CNR-ISAC	13	21	3	Radiation measurements
<b>LANGONE LEONARDO</b>	<b>Senior Scientist</b>	<b>CNR-ISMAR</b>	<b>63</b>	<b>1035</b>	<b>19</b>	<b>Polar marine research Resp. WP1 and task 1.2</b>
LEONARDI MARCELLA	Scientist Staff	CNR-IAMC	12	93	7	Marine biogeochemistry
LONGO SIMONA	Technologist staff	CNR- DTA				Data service management
LUCCHI RENATA GIULIA	Scientist staff	OGS	21	204	10	Sediment analysis
MACRI PATRIZIA	Contract scientist	INGV	17	154	7	Stratigraphy geochronolgy
MAGALDI MARCELLO	Scientist Staff	CNR-ISMAR	25	110	4	Oceanographic modelling
MAIMONE GIOVANNA	Contract scientist	CNR-IAMC	18	163	7	Microscopy cellular counting
<b>MARCO OLIVIERI</b>	<b>Scientist staff</b>	<b>INGV</b>	<b>10</b>	<b>177</b>	<b>6</b>	<b>Seismic data analysis Resp. WP2</b>
MARGHERITI LUCIA	Scientist staff	INGV	51	1070		Seismic data analysis
MARINI SIMONE	Scientist Staff	CNR-ISMAR	13	122	6	Genetic data analysis
Mazzetti PAOLO	Scientist staff	CNR-IIA	28	61	5	Web services

MAZZOLA MAURO	Contract Scientist	CNR-ISAC	11	30	3	Aerosol measurement
MISEROCCHI STEFANO	Scientist staff	CNR-ISMAR	41	573	15	Biogeochemical analysis
MONTAGNA PAOLO	Scientist Staff	CNR-ISMAR	27	170	9	Paleoclimatology
MONTICELLI L. SALVADOR	Scientist Staff	CNR-IAMC	21	238	8	Microbic ecology
MUSCARI GIOVANNI	Scientist staff	INGV	21	116	7	Atmospheric physics
NATIVI STEFANO	Scientist staff	CNR-IIA	61	135	7	Brokering architecture - Resp. WP4
PANIERI GIULIANA	Scientist Staff	CNR-ISMAR	16	99	6	Sediments and paleoclimatology
POLANSKI LUKASZ*	Technician	CNR				Data management
Pondrelli SILVIA	Senior scientist	INGV	35	1256	16	Seismic data analysis
<b>REBESCO MICHELE</b>	<b>Scientist staff</b>	<b>OGS</b>	<b>55</b>	<b>876</b>	<b>18</b>	<b>Polar geophysical research Resp WP3-Member Scientific Board</b>
ROMANO VINCENZO	Contract scientist	INGV	26	152	7	Electronic geophysical research
SAGGINI ELEONORA*	Contract scientist	CNR-ISSIA				Unmanned vehicles
SAGNOTTI LEONARDO	Research Director	INGV	88	1830	24	Paleomagnetism and polar research
SALVATORI ROSAMARIA	Scientist staff	CNR-IIA	23	106	5	Snow and ice reflectivity
SANTORO MATTIA*	Contract scientist	CNR-IIA	4	4	1	Interoperability services
SCIPIONI SILVIO*	Technologist	CNR	8	10	2	Computer sciences
SILVIA PONDRELLI	Senior scientist	INGV	35	1256	16	Seismic data analysis
SPATARO FRANCESCA*	Contract scientist	CNR-IIA	2	16	2	Snow chemistry and deposition
SPIRANDELLI EDOARDO	Scientist Staff	CNR-ISSIA	13	58	3	Coastal water monitoring
SPOLAOR ANDREA*	Contract Scientist	CNR-IDPA	5	3	1	Paleoclimate, global change
TAMPIERI FRANCESCO	Research director	CNR-ISAC	73	365	7	ABL and turbulent fluxes
TAVIANI MARCO	Scientist Staff	CNR-ISMAR	122	1455	21	Paleoclimatology
TESI TOMMASO*	Associate research	CNR-ISMAR	18	190	9	Organic matter geochemistry
TURETTA CLARA	Scientist staff	CNR-IDPA	33	3423	12	Atmospheric chemistry
URBINI STEFANO	Contract scientist	INGV	23		8	Glaciology, geophysics
<b>VIOLA ANGELO PIETRO</b>	<b>Senior Scientist</b>	<b>CNR-ISAC</b>	<b>29</b>	<b>200</b>	<b>7</b>	<b>ABL thermodynamics at CCT Resp. task 1.1</b>
<b>VITALE VITO</b>	<b>Senior Scientist</b>	<b>CNR-ISAC</b>	<b>54</b>	<b>332</b>	<b>10</b>	<b>Energy and radiative budget Project Leader</b>
ZACCONE RENATA	Scientist Staff	CNR-IAMC	36	206	8	Microbic ecology
ZEREIK ENRICA*	Contract scientist	CNR-ISSIA				Unmanned vehicles

## 9. - References

- Aliani, S. et al., 2004. Multidisciplinary investigations in the marine environment of the inner Kongsfjord, Svalbard Islands (September 2000 and 2001). *Chemistry and Ecology*, 20, S19-S28.
- Caccia M., Bono R., Bruzzone Ga., Bruzzone Gi., Spirandelli E., Veruggio G., Capodaglio G., Stortini A.M.: "Sampling Sea Surfaces with SESAMO," *IEEE Robotics & Automation Magazine*, Volume 12, Issue 3, pp. 95 – 105, Sept. 2005.
- Clark, P.U. et al., 2001. Freshwater forcing of abrupt climate change during the last glaciation. *Science*, 293, 283-287.
- Di Biagio, C., A. di Sarra, P. Eriksen, S.E. Ascanius, G. Muscari, and B. Holben (2012), Effect of surface albedo, water vapour, and atmospheric aerosols on the cloud-free shortwave radiative budget in the Arctic, *Climate Dynamics*, vol. 39, p. 953-969, doi: 10.1007/s00382-011-1280-1.
- Di Biagio, C., G. Muscari, A. di Sarra, R. L. de Zafra, P. Eriksen, G. Fiocco, I. Fiorucci, and D. Fuà (2010), Evolution of temperature, O<sub>3</sub>, CO, and N<sub>2</sub>O profiles during the exceptional 2009 Arctic major stratospheric warming observed by lidar and mm-wave spectroscopy at Thule (76.5°N, 68.8°W), Greenland, *J. Geophys. Res.*, 115, D24315, doi:10.1029/2010JD014070.
- Dickson, R.R., J. Meincke, S.A. Malmberg, and A.J. Lee, 1988: The Great Salinity Anomaly in the Northern North Atlantic 1968-1982. *Prog. Oceanogr.*, 20(2), 103-151.
- Hansen, J.E., 2007, Scientific reticence and sea level rise, *Environ. Res. Lett.* 2, 024002 doi:10.1088/1748-9326/2/2/024002
- IPCC, Intergovernmental Panel on Climate Change, Fourth Assessment Report (FAR), 2007: *Climate Change 2007, The Scientific Basis*, J.T. Houghton et al. Eds., Cambridge University press, 801 pp.
- Long, C.N. and T.P. Ackerman, 2000. Identification of clear skies from broadband pyranometer measurements and calculation of downwelling shortwave cloud effects, *J. Geophys. Res.*, 105, NO. D12, pp.15,609 –15,626.
- Lucchi RG, Camerlenghi A, Colmenero-Hidalgo E, Sierro FJ, Bárcena MA, Flores JA, Urgeles R, Macri P, Sagnotti L, Caburlotto A, 2010. Sedimentary processes on the Storfjorden trough-mouth fan during last deglaciation phase: the role of subglacial meltwater plumes on continental margin sedimentation. *Geophysical Research Abstracts* Vol. 12: EGU2010-5753-2, 2010.
- Lucchi, R.G., Pedrosa, M.T., Camerlenghi, A., Urgeles, R., de Mol, B., and Rebesco, M., 2012. Recent submarine landslides on the continental slope of Storfjorden and Kveitehola Trough-Mouth Fans (Northwestern of Barents Sea), In: Yamada Y et al (Eds.) *Submarine Mass Movements and Their Consequences, Advances in Natural and Technological Hazards Research*, Vol. 31, Pag. 735-745, Springer, The Netherlands. ISBN 978-94-007-2161-6.
- Lucchi, R.G., Camerlenghi, A., Rebesco, M., Urgeles, R., Sagnotti, L., Macri, P., Colmenero-Hidalgo, E., Sierro, F.J., Melis, R., Morigi, C., Barcena, M.A., Giorgetti, G., Villa, G., Persico, D., Flores, J.A., Pedrosa, M.T., Caburlotto, A., submitted, Postglacial sedimentary processes on the Storfjorden and Kveithola trough-mouth fans: impact of extreme glacial marine sedimentation. *Global Planet. Change*.
- Luchetta A., Lipizer M., Socal G. 2000 "Temporal evolution of primary production in the central Barents Sea." *Journal of Marine Systems*, 27 :177-193
- Morison, J. et al, 2012, Changing Arctic Ocean freshwater pathways, *Nature*, 481, 66-70, doi:10.1038/nature10705
- Muscari, G., C. Cesaroni, I. Fiorucci, A. K. Smith, L. Froidevaux, and M. G. Mlynyczak (2012), Strato-Mesospheric ozone measurements using ground-based millimeter-wave spectroscopy at Thule, Greenland, *J. Geophys. Res.*, D07307, doi:10.1029/2011JD 016863.
- Muscari, G., A. di Sarra, R. L. de Zafra, F. Lucci, F. Baordo, F. Angelini, and G. Fiocco (2007), Middle atmospheric O<sub>3</sub>, CO, N<sub>2</sub>O, HNO<sub>3</sub>, and temperature profiles during the warm Arctic winter 2001-2002, *J. Geophys. Res.*, 112, D14304, doi:10.1029/2006JD007849
- Pedrosa M, Camerlenghi A, De Mol B, Urgeles R, Rebesco M, Lucchi RG, SVAIS and EGLACOM Cruises shipboard parties (2011) Seabed Morphology and Shallow Sedimentary Structure of the Storfjorden and Kveitehola Trough-Mouth Fans (north west Barents Sea). *Mar Geol.*, 286 (2011) 65-81.
- Rebesco, M., Liu, Y., Camerlenghi, A., Winsborrow, M., Laberg, J.S., Caburlotto, A., Diviacco, P., Accettella, D., Sauli, C., Tomini, I., and Wardell, N., 2011. Deglaciation of the Barents Sea Ice Sheet - a swath bathymetric and sub-bottom seismic study from the Kveitehola Trough. *Marine Geology*. 279, 141-147

- Rebesco, M., Pedrosa, M.T., Camerlenghi, A., Lucchi, R.G., Sauli, C., De Mol, B., Madrussani, G., Urgeles, R., Rossi, G., Böhm, G., 2012. One million years of climatic generated landslide events on the southern Storfjorden Trough Mouth Fan (western Barents Sea). In: Yamada Y et al (Eds.) *Submarine Mass Movements and Their Consequences, Advances in Natural and Technological Hazards Research*, Vol. 31, Pag. 747-756, Springer, The Netherlands. ISBN 978-94-007-2161-6
- Rebesco M, Wählin A, Laberg JS, Schauer A, Brezcynska-Möller A, Lucchi RG, Noormets R, Accettella D, Zarayskaya Y, Diviacco P (submitted). Contourite drifts of the Western Spitsbergen margin. *Deep-Sea Research Part I*.
- Sagnotti, L., Macrì, P., Lucchi, R., Rebesco, M. & Camerlenghi, A. 2011, A Holocene paleosecular variation record from the northwestern Barents Sea continental margin, *Geochemistry, Geophysics, Geosystems*, vol. 12, no. 11, Q11Z33
- Schmitt, R. W., 1995. The ocean component of the global water cycle. (U.S. National Report to the IUGG), *Reviews of Geophysics*, 33 (Supplement, Pt. 2), 1395-1409.
- Serreze, M.C. and Barry, R.G., 2011. *Processes And Impacts Of Arctic Amplification: A Research Synthesis, Global and Planetary Change*, 77, pp.85-96.
- Spolaor, A., 2012. Bromine and Iodine species: A new proxy for Antarctic sea ice extent. Talk at the First Open Science Conference of the International Partnerships in Ice Core Sciences, 1-5 October 2012, Presqu'île de Giens, Côte d'Azur, France
- Straneo, F. et al. 2010. Rapid circulation of warm subtropical waters in a major glacial fjord in East Greenland, *Nature Geoscience* 3, 182 - 186, doi:10.1038/ngeo764
- Svendsen, H. et al., 2002. The physical environment of Kongsfjorden–Krossfjorden, an Arctic fjord system in Svalbard, *Polar Research*, 21, pp. 133-166.
- Vinje, T., N. Nordlund, and A . Kvambekk, 1998. Monitoring ice thickness in Fram Strait, *J. Geophys. Res.*, 103, 10,437– 10,449, 1998.
- Walter F., M. Olivieri, and J.F. Clinton, 2013. Calving event detection by observation of seiche effects on the Greenland fiords, *Journal of Glaciology*, in press.
- Zirizzotti A., Cafarella L., Baskaradas J. A, Tabacco I. E., Urbini S., Mangialetti M., and Bianchi C., 2010. “Dry-wet bedrock interface detection by radio echo sounding measurements” *IEEE Transactions on Geoscience and Remote Sensing*, Volume 48, Issue 2343-2348 DOI:10.1109/TGRS.2009.2038900.
- Zhang, R. and J.K. Vallis, 2006. Impact of Great Salinity Anomalies on the Low-Frequency Variability of the North Atlantic Climate, *J. Climate*, 19, pp. 470-482.