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Indice

AT1

CLIMATE CHANGE AND ANTHROPOGENIC FORCINGS IN POLAR SYSTEMS: FROM EMERGING POLLUTANTS TO THE RESPONSES OF ECOSYSTEMS. PRESENT POTENTIAL AND A LOOK TO THE FUTURE

How and to what extent contamination of polar marine ecosystems can be affected by global change and vice versa: a tool for preserving and recovering Antarctic marine ecosystems

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KEYWORDS: Southern Ocean; climate change, trophic web; emerging POPs

Introduction

Antarctica is the coldest place on Earth, it plays a crucial role in the global climate system, acting as the largest heat sink in the Southern Hemisphere. The importance of preserving Antarctica and the Southern Ocean is based on its influence on the global balance and the fact that ecosystems are particularly sensitive to global changes and multiple stressors including contamination by anthropogenic chemicals from local and remote sources (Gonzalez-Alonso et al., 2017). Climate-change is occurring most rapidly in the Polar Regions affecting both physico-chemical conditions (e.g. sea temperature, snow, ice distribution, age and thickness) and structure and function of the food-web. Antarctica and the Southern Ocean play a key role in Earth and Living Systems, thus understanding how much climate change along with the increased influence of human activities is damaging this already vulnerable ecosystem is very important. Despite the known long range transport mechanisms in Antarctica, the responses of Antarctic ecosystem to climate change and pollution occurrence are mostly unknown. The direct and indirect responses induced by climate change can moderate or intensify the effects of environmental pollution and other anthropogenic and biological stressors (e.g., ocean acidification, decreased food availability, increased predation, trophic web shift). The good environmental status of this polar marine ecosystem is a priority and a prerequisite for the sustainable developments of our planet (13 and 14 Sustainable Development Goals, https://www.un.org/sustainabledevelopment/) (Corsolini S., 2021).

Activities

A key outcome of this work is to establish a comprehensive toolbox for evaluating the distribution and accumulation of inorganic and organic pollutants in different Antarctic ecosystems, focusing on both the role of the criopelagic community and bioaccumulation in predators to support resilience and adaptation of these ecosystems to changes, starting point for a sustainable development.
This goal is possible trough:

- long-term monitoring of legacy, emerging persistent organic contaminants and trace metals, from abiotic compartments (snow, seawater-ice, marine sediments) to marine communities (benthic and pelagic communities, resident and migrant seabirds)
- the study of the contaminants transfer from the pelagic to the benthic community for investigating the contaminant sink in the deep marine environment
- the correlation between contaminant levels and transfer in the ecosystem to climate and atmospheric parameters with modern chemical transport models
- the comparison of contaminant levels, profile and distribution in different sectors of Antarctic coasts with possible different remote and local contaminant sources.

Future developments

Such understanding will become increasingly important in environmental management in the future, as global change affects the trophic web by identifying hotspots where species ranges need to be most sensitive to climatic variability. A bipolar approach will also improve our knowledge capacity, as the data will be compared to those from Arctic to see how the two Polar Regions are reacting to the effect of climate change on contamination. The integrative work between experts in meteorology, hydrology, oceanography, pollution and climate change is fundamental to assess the link between all environmental factors potentially affecting contaminants accumulation in biota.
An important achievement is to provide strategies for managing new and legacy pollutants as a part of a realistic, integrated, ecosystem-based approach, which represents a major challenge for the scientific community, stakeholders and decision makers.

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Corsolini S., Antarctica and NE Greenland: Marine Pollution in a Changing World https://doi.org/10.1007/978-3-319-71064-8_150-1

Climate-induced changes on contaminant fate and biodiversity in a rapidly changing Euro-Arctic marine ecosystem

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KEYWORDS: arctic marine trophic web; climate change; biodiversity; emerging POPs

Introduction

Climate-change (CC) driven transport of contaminants to the Arctic can lead to their increase in trophic webs. The warming speed in the Arctic is more than twice the global mean and its variation will be reflected in impacts on marine life. The Arctic Monitoring and Assessment Programme (AMAP) indicated that the risk due to the presence of legacy persistent organic pollutants (POPs), mercury and chemicals of emerging Arctic concern (CEAC) is still very high in the Arctic (AMAP, 2016). Thus, the study of contaminant behaviour and fate in the Arctic is a key to investigate ecosystem integrity and associated services. The role of the microbial community in transferring pollutants from abiotic to biotic levels is still mostly unknown, despite their key role in ocean ecology and response to global changes. In the marine trophic webs of NE Greenland many species spend their early life stage under the pack ice and are part of the cryopelagic community, which includes organisms of different trophic levels and plays a key role in the contaminant transfer. In fact, those contaminants trapped in the ice are released into the water column during summer melting and are then available to be bioaccumulated by cryopelagic organisms and then in their consumers. Information on consumers, which influence structure and function of ecosystems, are scarce; among them, fishes play a major role in the wasp-waist polar ecosystems as linkage from lower to upper trophic levels, transferring energy, nutrients and, in the case, contaminants. In the ongoing changing scenario, the trophic relationship between species will likely change influencing the transfer of contaminants too. The preservation of Polar ecosystem is intrinsic to Goals nos. 12, 13, 14 of the United Nations' Sustainable Development Goals (Corsolini, 2021).

Activities

Main aims are to study the fate of CEAC in the poorly studied NE Greenland marine ecosystem in abiotic and biotic (from microbial level to consumers) compartments under a climate change scenario trough an approach able to include different environmental components (water column, benthic environments) and different scales of observations (remote sensing, ecology, ecotoxicology, physiology, genetic, environmental chemistry) by:

- evaluation of CEAC occurrence, distribution and bioaccumulation factors from sediments and seawater to biotic levels
- identification of changes in autochthonous microbial communities in terms of diversity and functioning
- assessment of the genotoxic impact of contaminants on fish
- correlate contaminant levels and transfer in the ecosystem to climate parameters
- promote the synoptic monitoring of the Arctic marine sphere, using remote sensing data and services in synergy with other measurements to assimilate the knowledge on contaminant fate into a broader scale (e.g. climate modelling scale).

Future developments

These studies will help to fill knowledge gaps concerning the effects of global change on marine organism exposure to contaminants and their distribution in polar ecosystems. This is crucial because processes occurring in polar areas may have unpredictable repercussions at global scale. Understanding the interactions between ecological effects of climate change and anthropic pressures is of priority interest for identifying possible alterations and long-term effects in these vulnerable ecosystems. The integration of the results achieved will be tying the ecological changes and the contaminant environmental fate in the Arctic marine ecosystem under a climate change scenario.

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Water soluble compounds in the Arctic and Antarctic aerosol

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KEYWORDS: aerosol, water soluble compounds, Arctic, Antarctica

Introduction

The atmospheric aerosol is an important pathway by which chemical compounds are transported both locally and on a global scale. It is extremely important to know the origin, geochemical composition and effects that the aerosol composition could have on very sensitive environments such as the Arctic and the Antarctic. Due to their distance from the principal emission sources, Polar Regions represent an important natural laboratory to study the atmospheric aerosol. Chemical markers provide unique information on the sources of aerosol and the chemical processes that took place during atmospheric transport.

Activities

Sampling campaigns were performed at Gruvebadet observatory close to Ny-Alesund in the Svalbard Islands (78°55''N, 11°53'E). It is an atmospheric laboratory dedicated to the chemical and physical monitoring of atmospheric aerosol begun in 2010 and is still ongoing; the sampling was normally performed from March to October for each year, but since winter 2018/2019, all-year-round samplings have started.
Several sampling campaigns were performed also in the Antarctica from two continental bases: Mario Zucchelli Station (MZS, 74° 42'S, 164°06'E) on the coast of the Ross Sea and Concordia Station (75°06'S, 123° 20'E) at Dome C on the Antarctic Plateau. Aerosol samples were collected at MZS during austral summer 2010-11, 2014-15, 2018-19 and 2019-20 while samples from Dome C were collected during austral summer 2010-11, 2011-2012, and from 2016-17 to 2020-2021.
Aerosol samples were collected with a high-volume cascade impactor. This sampler allows the collection of airborne particles in six size classes with aerodynamic diameter ranges of 10-7.2 μm, 7.2-3.0 μm, 3.0-1.5 μm, 1.5-0.95 μm, 0.95-0.49 μm and <0.49 μm. The Arctic and Antarctic aerosol samples are analysed to determine trace elements, rare earth elements (Turetta et al., 2021) and water-soluble-organic compounds (WSOC), such as ionic species, carboxylic acids, sugars (monosaccharides, disaccharides, alcohol sugars and anhydrosugars), free and combined amino acids and phenolic compounds (Barbaro et al., 2015; Zangrando et al., 2016; Feltracco et al., 2020). The main aims are to better understand: (1) the distribution of each species among different particulate sizes, (2) the transport processes of aerosol and 3) the inter-annual patterns of each species, using these compounds as specific markers for sources or processes.

Future developments

At the moment, several samples were collected but the completion of all analysis are needed to obtain a complete a dataset of long-term measurements. The dataset will be analyzed using source apportionment techniques to identify and quantify the contribution of natural and anthropogenic sources to PM10, and their source regions.

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First evidence of plastic pollution in the permafrost of Svalbard Islands: characterization of additives, plasticizers, small microplastics (<100 µ) using Micro-FTIR

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KEYWORDS: microplastics, permafrost, plasticizers, Micro-FTIR

Introduction

According to the European Chemical Agency (ECHA), microplastic particles are solid polymer-containing particles, with particle dimensions ranging from 1 nm to 5 mm, fiber lengths ranging from 3 nm to 15 mm, and a length-to-diameter ratio of >3, and which may contain additives as well (ECHA report, 2019). Chemical additives and plasticizers are under scrutiny for the possible toxic effects they cause on organisms (Beiras et al., 2021; Jeong and Choi, 2020). Microplastics have been reported in sediments, in oceans, in seawater, in freshwater, and recently in soil, as well (Wang et al., 2019). permafrost and glaciers in Arctic regions can become sinks of airborne MPs. However, permafrost can turn from a sink into a source of MPs due to permafrost degradation caused by climate-changing.

Activities

A novel method for quantitative analysis and simultaneous identification via Micro-FTIR for additives, plasticizers, small microplastics (< 100 µm), and other components of micro-litter was developed. The method for the oleo-extraction and purification of these particles (Corami et al., 2021) was optimized for permafrost analysis. Permafrost samples were collected in different sites in the Svalbard archipelago (e.g., Airport Bayelva, coal mine area). They were carried refrigerated in Italy. All the operations were carried out in a plastic-free cleanroom ISO to minimize contamination. Samples were analyzed in at least triplicate. Quantification (abundance and weight) and chemical identification of these emerging contaminants were carried out via MicroFTIR.

Future developments

These first results are encouraging and of extreme interest; through the method developed, it is possible to simultaneously evaluate microplastics and coatings, additives, and plasticizers, which can exert toxic effects. The next step is to evaluate seasonal trends and accumulation phenomena related to short and long-range transport. This study can help comprehend different dynamic processes (AT3) and ecosystem performances in a changing climate (AT6). Besides, this study can be in synergy with other important scientific questions such as Arctic amplification (AT4) and the carbon cycle (AT7).

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Occurrence and fate of pesticides in different environmental matrixes

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KEYWORDS: pesticides, neonicotinoids, glyphosate, Venice Lagoon

Introduction

A 'pesticide' is something that prevents, destroys, or controls a harmful organism ('pest') or disease, or protects plants or plant products during production, storage, and transport. The term includes, amongst others: herbicides, fungicides, insecticides, acaricides, nematicides, molluscicides, rodenticides, growth regulators, repellents, rodenticides, and biocides. Neonicotinoids (e.g., acetamiprid, clothianidin, imidacloprid, and thiamethoxam) are frequently used as seed treatments on major agricultural crops across North America and Europe, while glyphosate and its derivates are used mainly in conventional crops, which represent about 55% of 2015 total volume. Among users, the Asian-Pacific countries utilize most of the product (31%), followed by Latin America (20%), and Europe (16%). Given the widespread use of these pesticides and concerns regarding its environmental fate and potential effects in aquatic ecosystems, we aim to develop the analytical method and to determine such compounds in representative dissolved and sedimentary phases in the Lagoon of Venice from spring 2019 to winter 2021, as well as to assess potential spatial distributions and seasonal trends in concentrations. A wide range of pesticides also accumulate in soils over time and are expected to persist longer in colder regions at mid to higher latitudes due to lower temperatures and lower sunlight intensity (Main et al., 2016). While a constant research in urban and rural environments is mandatory to assess their environmental diffusion and their possible toxic effects to humans and other organisms, further studies are crucial to understand the impact of such compounds in the polar areas.

Activities

Seawater and sediment samples were collected in 2018 and early 2019, also considering the application period of pesticides indicatively between May and September from six different stations distributed along the Lagoon of Venice. Sampling sites were chosen to investigate specific emission sources and to obtain an overview of the lagoon area. About 20 L of water were collected at each site by immersing a decontaminated steel bottles. A 10 cm layer of sediment was sampled by using a Van Veen grab. The impacts of deposition and resuspension of neonicotinoids and herbicides on these environment water bodies were determined by Morabito et al. (under review) and Feltracco et al. (under review). In addition, a suspect screening analysis using HPLC/HRMS was performed in order to evaluate if other unknown pesticides and their metabolites may be present in the sample.

Future developments

According to the pesticides measured in Lagoon water, immediate contributions for the investigation of polar atmospheric aerosols and seawater of pesticides should come from studies oriented to the development of innovative method for assessing these compounds in polar matrixes.

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Temporal dynamics of anthropogenic pollutants in the sediment of Kongsfjorden-Krossfjorden system (Svalbard, Norway)

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KEYWORDS: Marine particle fluxes, Persistent Organic Pollutants (POPs), Contaminants of Emerging Concern (CECs), biogeochemical processes.

Introduction

The Arctic system is an environmentally sensitive region where climate change is occurring much faster than elsewhere on our planet. Multiple drivers influenced the chain of events called "Arctic amplification", reflecting in ecosystem impacts. The Kongsfjorden-Krossfjorden system (KKS) is located on the northwest coast of Spitsbergen (Svalbard Archipelago, Norway). The Kongsfjorden is close to the research stations at Ny-Ålesund and is likely contaminated by local sources. Pollution research in the Arctic has usually focused on the long-range transport (LRT) of pollutants (atmospheric and oceanic currents, sea ice drift, and rivers) [2]. However, information on the relative importance of local sources (where there are or have been human activities) vs LRT are lacking. Assessments on levels and effects of Persistent Organic Pollutants (POPs) in Arctic sediments and biota have been extensively carried out, but the same can no longer be said about studies including assessments on Contaminants of Emerging Concern (CECs). These latter include a wide group of compounds (e.g. pharmaceuticals, drugs of abuse, personal care products (PCPs)), partially or not yet regulated. Despite having shorter lifespans than POPs, their continuous release from northern communities and slow degradation due to the colder temperatures and reduced sunlight conditions unique to the Arctic, along with chronic exposure thereto, could have consequences for local ecosystems and populations [1]. Hence, understanding the natural variability ranges (e.g. spatial, seasonal, and inter-annual) is necessary to predict and interpret climate change effects on contaminant concentrations and fluxes in the Arctic ecosystem.

Activities

The quantification of selected organic pollutants, including POPs (e.g. PCBs), PAHs and several CECs (e.g. PBBs, PBDEs) on a marine sediment core from the Kongsfjorden (NYA11-09) was carried out at the University of Cádiz (Spain), from February to June 2020. Parameters such as total organic C and N (TOC, TN), stable isotopes ($\partial^{13}C$, $\partial^{15}N$), and short lives radionuclides (^{210}Pb, ^{137}Cs), have been investigated, to understand both the variation of biogeochemical conditions (organic matter flux) in modulating primary productivity and carbon sequestration, and the chronostratigraphy of the sediment columns and sediment accumulation rates.

Future developments

This study will investigate seasonal to large-scale (ca. 100 yr) variations in pollutants concentrations and fluxes in bottom sediments and of particulate organic matter fluxes in the Kongsfjorden–Krossfjorden system (KKS). Areas of particular interest will be the inner and outer part of the Krossfjorden which will be used as a comparison area without local anthropogenic inputs.
Specifically, this study will aim to provide more information about: i) how much the contribution of suspended material (nutrients and organic matter) released by the glaciers in the inner fjord area affects the sediment characteristics and accumulation rates; ii) the effects of Atlantification on the Arctic fjord environment, particularly on contaminant fluxes; iii) the contamination trends, focusing on selected POPs and CECs, comparing local sources due to human activities with LRT and secondary emissions in summer season, to figure out their impact on marine life and ecosystem; iv) the evolution of the contaminant concentrations over the last century.

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Long-term measurements of carbonaceous aerosols in the Arctic: current activities and future directions

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KEYWORDS: Black carbon, organic carbon, long-term measurements, machine learning

Introduction

Atmospheric aerosol affects Arctic climate through several pathways. Aerosols can scatter/absorb incoming radiation and cool/warm the atmosphere. After deposition, absorbing aerosol species alter snow and ice albedo, modifying the surface energy budget. Acting as cloud condensation (CCN) and ice nuclei (IN), aerosol particles change cloud formation and cloud optical properties, contributing to scattering and absorption of short-wave and long-wave radiation. Finally, aerosols outside the Arctic region can alter heat transfer from lower to higher latitudes [1].

Among the aerosol components, the activities here presented focus on carbonaceous aerosols, and in particular on black carbon (BC) and organic carbon (OC). BC is the strongest warming species after CO_2 [2]. Although ground-based observations indicate that surface BC concentration in the Arctic has decreased over the last 30 years, modeling results suggest that the total BC column burden has increased, mainly driven by the increase of East Asia emissions after 2000s [3]. Recent studies highlight that OC is an under-represented climate-relevant component of atmospheric aerosol. Long-term records of OC in the Arctic are limited nevertheless, the rapid loss of sea ice and the increasing frequency of wildfires are expected to increase the Arctic OC burden in the next few years.

Within the Arctic Council, the Expert Group on Black Carbon and Methane (EGBCM) assesses the progresses on the implementation of BC action plans within and outside the Arctic, while the impacts of BC and OC on Arctic climate, environment, and health are examined by the Arctic Monitoring and Assessment Programme (AMAP).

Activities

Long-term aerosol optical properties and equivalent black carbon (eBC) measurements have been performed since summer 2011 at the Gruvebadet Observatory (78.918°N, 11.895°E) [4]. Aerosol absorption is measured at three wavelengths with a Radiance Research Particle Soot Absorption Photometer (PSAP), while aerosol scattering is measured with a Radiance Research Nephelometer. International collaboration within the Svalbard Integrated Observing System (SIOS) during the last two years allowed us to optimize and validate the correction algorithm required to derive equivalent black carbon (eBC) concentration from light absorption coefficient measurements [5].

At the same site, organic (OC) and elemental carbon (EC) are measured by thermal-optical analysis at 4-day and 1-day time resolution, from 2011 to 2014, and from 2014 to present, respectively. OC and EC time series is illustrated and discussed by Caiazzo et al. [6].

Long term measurements are analysed to understand how the concentrations of short term climate forcers/pollutants in the European Arctic are affected by changes in atmospheric transport pathways, decrease of anthropogenic aerosol emissions at lower latitudes due decarbonization of the energy and transport sectors, and increase of high latitude emissions due to sea-ice loss, shipping, oil industry, and wildfires. Interpretable machine learning techniques, such as Global Additive Models, are used to investigate the impact of change in synoptic scale circulation, local meteorology, and natural and anthropogenic emissions on the observed eBC concentrations.

Future developments

The acquisition of state-of-the-art instruments will allow us to continue the carbonaceous aerosol data series at Gruvebadet in the following years. The research activities within the SIOS framework, together with the integration of Gruvebadet observations with Zeppelin in-situ and Svalbard remote sensing data, will support the analysis of the Arctic boundary layer properties and evolution (ReHearsol project funded by SSF and BETA-NyA project funded by PRA).

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Mixing state of carbonaceous aerosols in the Arctic

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KEYWORDS: Black carbon, organic aerosol, aerosol mixing state

Introduction

The Arctic is warming at about twice the global rate, with the Arctic environment experiencing dramatic changes. Reduction of the sea ice extent, together with the increase of wildfire frequency and severity, are leading to larger aerosol emissions at high latitudes [1]. These aerosol particles might trigger climate feedback mechanisms, that particularly affect the Arctic region.
The climatic properties of the atmospheric aerosol, such as optical properties and the ability to act as Cloud Condensation (CCN) and Ice Nuclei (IN), are controlled by the particle mixing state. Similarly, the mixing state affects atmospheric lifetime, scavenging efficiency, and wet and dry particle deposition on snow and ice [2]. Despite its climatic relevance, most current climate models are not able to correctly reproduce the extent and variability of the mixing state of atmospheric aerosol particles.

Activities

Within the Mixing State of Carbonaceous Aerosol in the Arctic (MIST-CA2) project, and in collaboration with Stockholm University, we will investigate the mixing state of carbonaceous aerosol particles at the Zeppelin Observatory, in the European Arctic. We will also investigate the impact of organic functional group composition on aerosol cloud activation properties.
The Zeppelin Observatory is located at the top of a mountain at about 500 m a.s.l. Due to its elevation, the site is often surrounded by ice and mixed-phase clouds. The observatory is equipped with a total inlet and a Ground-based Counter-flow Virtual Impactor (GCVI). The total inlet collects activated and non-activated aerosols, while the GCVI is able to collect cloud droplets and crystals, separating them from the cloud interstitial aerosol (Figure 1).

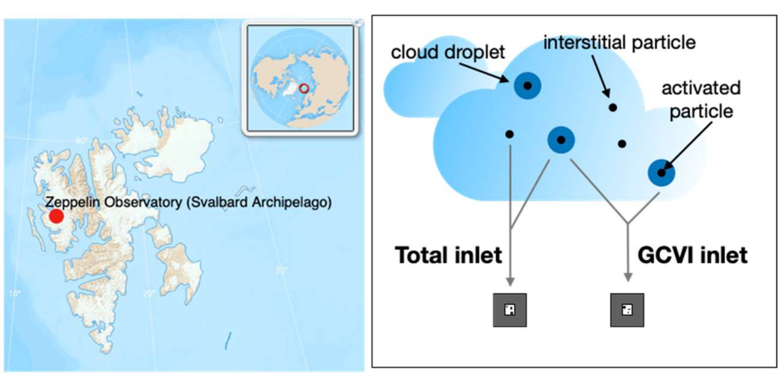

Figure 1. Sampling site location (courtesy of the Norwegian Polar Institute, left panel), and a schematic representation of particle cloud activation (right panel).

We will analyzed cloud activated and non-activated particles by Scanning Transmission X-Ray Microscopy and Near Edge X-Ray Absorption Fine Structure (STXM-NEXAFS). Through the analysis of STXM images we will be able to identify and classify the morphology of particles with a diameter down to 100 nm, while NEXAFS will allow us to identify inorganic salts and carbonaceous chemical functional groups [3].
The mixing state of particles will be investigated in the light of air mass origin (using back-trajectory analysis) and potential aerosol sources (based on chemical and micro-physical information from in-situ measurements). We will compare the mixing state results of particles collected inside the cloud with the spectra of particles collected above or below cloud. Since the GCVI collects particles that acted as CCN, IN, or have been scavenged by cloud droplets and crystals, the comparison will allow us to study the effect of cloud processing on particle composition and morphology, as well as the mixing state of CCN and IN.
In addition, in collaboration with the Pacific Northwest National Laboratory we will characterize the mixing state of aerosol particles collected simultaneously at the Gruvebadet Observatory, located at sea level and at about 1 km distance from the Zeppelin Observatory.

Future developments

Improved knowledge of microphysical properties of carbonaceous aerosol will help us to investigate atmospheric processing of carbonaceous aerosol, and to quantify wet and dry deposition mechanisms, and the consequent impact of light absorbing particles on the cryosphere in the Arctic.

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Py-GC/MS as a complementary technique for the chemical characterization of small microplastics (<100 µm) in polar samples

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KEYWORDS: microplastics identification, Py-GC/MS, µ-FTIR, microplastics quantification

Introduction

Microplastics are a class of emerging pollutants of great concern, since they are widely distributed in the environment and biota, and have also been found in polar regions (Iannilli et al., 2019). Currently there are no standard methods for the identification and quantification of microplastics in environmental samples. Micro-FTIR is a non-destructive spectroscopic technique, that allows polymer identification and quantification in abundance and weight (Corami et al. 2020 and 2021); thanks to the instrument's imaging, particle morphology and size can be evaluated. Mass-based analytical methods – like pyrolysis gas chromatography-mass spectrometry (Pyr-GC/MS) - lack the information on particle size and morphology, but they are time efficient and permit a successful identification of polymer types and quantification of plastic weight (Müller et al., 2020). The cross-validation among techniques allows the standardization of pretreatment and analytical methods. In this abstract, we describe the state of the art of our work, whose aim is a cross-validation of two different techniques: quantification (i.e., abundance and weight) and simultaneous identification of microplastic particles (MPs) and small MPs (SMPs) using Micro-FTIR, and identification and quantification of MPs and SMPs using Pyr-GC/MS. These techniques will be employed for the analysis of polar samples.

Activities

The first phase of the work was dedicated to recognizing the characteristic pyrolysis products necessary to identify some standard polymers plastic materials. Preliminary results were obtained from different environmental matrices. Few water samples from Venice Lagoon and few permafrost samples collected in Svalbard Islands were analyzed via Micro-FTIR and Pyr/GC-MS. The identification of the single peaks in chromatograms was carried out using the NIST 05 library and based on the information available in the literature. The presence of PE was confirmed in all the samples with both techniques. Our data suggest that Pyr-GC/MS could be successfully used for the identification and quantification of MPs, combined with Micro-FTIR.

Future developments

We are going to create a comprehensive library of characteristic pyrolysis products, to increase the chance of recognising plastic materials in polar samples. In addition, the use of Pyr-GC/MS allows the recognition of smaller molecules used as additives in plastics, that can be released in environment and create a serious threat. This work could help in reporting the occurrence of emerging contaminants in polar regions, but could also give an additional point of view in other topics, such as contaminant transport to the Poles, the ecosystem response to contaminants exposure, the interaction between various environmental domains.

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New and existing organic contaminants in the arctic marine ecosystem in a climate change scenario: the Kongsfjorden-Krossfjorden system (Svalbard, Norway) as study model

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Keywords: Arctic fjords, global change, emerging organic pollutants, trophic chain.

Introduction

Arctic fjord ecosystems are linked intimately to the dynamics of sea/ice, input of glacial melting water and it is reasonable that these complex interactions may be perturbed by global warming, ocean acidification, loss of sea-ice, and human impact on local and global scale. The impact of human activities on the marine ecosystems involves the continuous release of hundreds of thousands of old and emerging contaminants, and despite of several studies, there is only little knowledge on new threats related to their dynamics in the Arctic ecosystems. Kongsfjorden and Krossfjorden (KKS) are two open fjords affected by the inflow of warm Atlantic Waters and controlled by run-off processes from tidal glaciers and sediment input. This area has undergone an anthropic pressure in the past up to now (mining, fishing, human settlements) with consequent pollution increase [1-2]. Physico-chemical variations in KKS linked to the overall climate changes can cause an increase of contaminant inputs in the abiotic (seawater, sediment) and biotic (bioaccumulation and biomagnification) marine compartments [2]. Investigations on the long-range transport of persistent organic pollutants (POPs) from lower latitudes by the atmosphere and sea currents are cornerstones of pollution research in the Arctic. Nevertheless, recent studies have also recognized that the human settlements are local sources of emerging contaminants (ECs). Despite having shorter persistence than POPs, ECs continuous release and their slow degradation rates in Arctic areas could have consequences for marine ecosystems [1-2]. Also, the rapid warming in Arctic can enhance the spread and deposition of particle-bound-pollutants, "old POPs" trapped in glaciers can be re-mobilized during melting and released into the sea, acting as a secondary source of contamination [1]. Such widespread changes may induce specie-specific responses from marine communities, altering the predator/prey relationships with repercussions on the complex food web, affecting both species compositions (biodiversity) and functioning in ecosystems. The overall effect of these multiple stressors on Arctic ecosystem is really little known and the rapidity of the environmental changes requires a prompt response from the scientific community.

Activities

Multidisciplinary skills are involved including remotes sensing observation, biogeochemistry, oceanography and biology, based on the available historical dataset and integrated by new monitoring data on the evolution of water masses and marine particles, on old and emerging pollutants distribution in water, sediment, particulate matter and organisms and their potential threat for the Arctic life. These studies aim at improving our knowledge of short and long-term interactions and feedbacks among climate driven changes and anthropogenic pressures in the KKS.

Future developments

This study aligns with goals of the main international projects and scientific community operating in the area, strengthening national and international collaborations. Outcomes will provide an integrated and updated evaluation of the KKS status, focusing on the linking among the changes in particle inputs and water circulation, the current pollution status of the marine environment and the biological response at different scales, from the microbial community to the upper levels of the trophic web (e.g. fishes). The integration of multidisciplinary expertise will allow to evaluate the effects of old and new organic contaminants on the marine ecosystem and trophic web, evaluating how contamination spread and remobilization of ice-trapped pollutants can affect the adaptation and survey of organisms at different levels. Such aspects are crucial to understand how Arctic ecosystem will cope with global change and the impact of current pollution on marine food chain, in view of a sustainable management of these vulnerable environments in the next future (e.g. new shipping routes or more ice-free areas for the development of human settlements).

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Fragrances: iconic emerging contaminants in remote environments

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Keywords: Fragrances, Personal Care Products, Snow, LRAT.

Introduction

The impact of the anthropic activities in polar and remote regions is an in-depth scrutinized issue, however, little is known about the role of the emerging contaminants in such environments. In this context, long-lasting and stable Fragrances, widely used in household and personal care products, due to their volatility are emerging contaminants recently recognized to be atmospherically transported over long distances (Vecchiato et al., 2018, 2020), but their environmental fate is still largely unknown.

Activities

Fragrances, namely Amyl Salicylate, Oranger Crystals, Hexyl Salicylate, Ambrofix, Peonile and Benzyl Salicylate, were found in the coastal seawater of the Ross Sea, Antarctica (Vecchiato et al., 2017) and in seawater and snow samples of the Svalbard Islands (Vecchiato et al., 2018). Local emissions from both the Arctic and Antarctic research bases were revealed, together with the evidence of Long-Range Atmospheric Transport (LRAT) of these substances. Moreover, an ice core retrieved on Elbrus, Caucasus, showed a 20-fold increase of the deposition fluxes of fragrances (Vecchiato et al., 2020), accounting for the deep changes in their usage from 1950s onwards. In each of the investigated environments the allergenic and oestrogenic Salicylates resulted in general the most abundant and widespread components, reflecting their large global consumption. On-going and planned sampling campaigns both in the Arctic and Antarctica are focusing on the distribution of fragrances on inland and coastal snow, to identify the sources, the cold-condensation drivers and finally their environmental fate.

Future developments

The ecotoxicological effects of these substances are very little known, but preliminary studies showed developmental toxicity for copepods at levels close to the environmental concentrations (10-100 ng L^{-1}) (Picone et al., 2021), indicating a possible threat for marine ecosystems. Therefore, it is fundamental for future studies in polar environments to investigate the local sources, as well as the fluxes during the seasonal snowmelt, considering possible amplification phenomena. On the other hand, a better understanding of the atmospheric processes is needed, to increase the knowledge on the transport patterns and dynamics.

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AT2
PALEOCLIMATE AND PALEOENVIRONMENTS

Speleothem paleoenviromental reconstructions: novel proxies and applications

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KEYWORDS: speleothems; paleofires; PAHs; trace elements

Introduction

Speleothems are widely used paleoclimate archives given that they can grow continuously for thousands of years, resist alteration, be precisely dated, and provide high resolution paleoenvironmental information. Stable isotopes of oxygen and carbon, along with select major and trace elements, are the primary chemical markers used in speleothems for paleoclimate reconstruction. Organic compounds hold the potential to preserve paleoenvironmental signals unattainable by inorganic species, but their study in speleothems is still underdeveloped (Wynn and Brocks, 2014; Blyth et al., 2016). The aim of this research is to combine all these proxies within an integrated approach for the analysis of speleothems to achieve a comprehensive reconstruction of paleoenvironmental and paleoclimatic processes.

Current activities

Stalagmites from cave KNI-51 (tropical northwestern Australia) are well suited for the investigation of biogeochemical processes and paleofires, thanks to their unusually high accumulation rate (1-2 mm yr^{-1}) and the typical high frequency of bushfires in the region. Previous studies focused on dating, characterization of flood layers and determination of oxygen isotopes (Denniston et al., 2016). Recently, we presented a method for the determination of trace polycyclic aromatic hydrocarbons (PAHs) and *n*-alkanes in stalagmites through GC-MS (Argiriadis et al., 2019). PAHs are primary tracers biomass combustion events while the pattern of *n*-alkanes is related to the type of vegetation (Bush and McInerney, 2013), thus providing information on fuel availability and composition. So far, two stalagmite slabs were processed for organic compounds, reconstructing the fire-climate-vegetation dynamics during the last millennium (~AD 1100-2008) with unprecedented temporal resolution (2-4 yr). Preliminary micro-destructive multi-elemental analysis by laser ablation-ICP-MS has the potential to complement this information with a complete reconstruction of biogeochemical processes at sub-seasonal resolution. Elemental imaging using this technique is currently under application to an additional slab covering the ~AD 1160-1360 period.

Future developments

The determination of organic and inorganic proxies will be completed on the full set of four stalagmites currently available from cave KNI-51 to replicate results on selected time frames and thus evaluate the variability of the signal within the cave. Field and laboratory tests on pyrogenic compounds are in program for further understanding sources and transport dynamics of these proxies.

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Theoretical and experimental analysis for cleaning ice cores from Estisol^{tm} 140 drill liquid

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KEYWORDS: ice cores; drilling; Estisol; Beyond EPICA

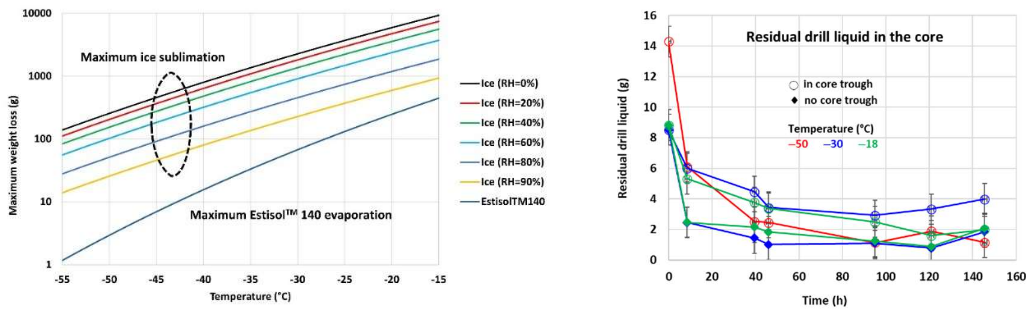
Introduction

To reconstruct climate history of the past 1.5 Million years, the project Beyond EPICA Oldest Ice (BEOI) will drill about 2700 m of ice core in East Antarctica (2021-2025). As drilling fluid, an aliphatic ester fluid, Estisol^{TM} 140, will be used. Newly drilled ice cores will be retrieved from the drill soaked in fluid, and this fluid should be removed from the cores. Most of it will be vacuum cleaned off in a Fluid Extraction Device and wiped off with paper towels. Based on our experiences in Greenland deep ice coring, most of the residual fluid can be removed by storing the cores openly on shelves in a ventilated room. After a week of "drying", the cores have a dry feel, handling them do not give wet gloves and they can easily be marked with lead pencils. In order to speed up the drying process by evaporation of drilling fluid, a ventilation air flux of 40 m^3/h has been suggested. The aim of this work [1] was to discuss both theoretically and experimentally how storage time, degree of ventilation and temperature influence the removal of residual fluid from the cores, i.e. the "drying" process.

Activities

Evaporation and sublimation processes were theoretically investigated, based on the analysis of the particular properties of ice and the chosen drilling fluid under the planned ventilation conditions for different temperatures. The evaluation of ice losses and fluid evaporation were then compared with specific tests on real ice cores, in order to get an evaluation of the theoretical findings. The overall aim is to provide input to the logistical planning and engineering of the drill site under development for the BEOI.
The calculations show that sublimation of the ice core should not occur, and that also the evaporation of fluid should be almost negligible (left figure). Experimental results support these calculations, but revealed significant fluid run-off and dripping, resulting in the removal of most of the fluid in a couple of days, independent of temperature and ventilation conditions (right figure). Based on this, we recommend that cores and core troughs in the drying room at BEOI site are stored with a slight inclination along core axes. We do not recommend ventilation as a means to speed up the drying process as ventilation both in calculations and in our tests has very little effect. Heating up the

storage room to speed up the drying process is also not recommended, as the effects of temperature are small and potential consequences for ice core quality large.



LEFT. Maximum theoretical ice sublimation and Estisol^{TM} 140 evaporation after one week ven-tilation at 40 m3/h as a function of the temperature and relative humidity of the inlet air. If, as assumed, the air is collected from a hole in the ice the relative humidity is 100% and the ice loss goes to zero.
RIGHT. Experimental measurements of the amount of drilling liquid in the ice cores as a function of time.

Future developments

This study supported the logistic organization of the core cleaning and conservation that will be adopted in the incoming Beyond EPICA Oldest Ice project. Additional experimental data will be provided and updated during the project itself for further comparison with theoretical calculations.

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10 years of oceanic observation in the Kongsfjorden

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KEYWORDS: Oceanic Mooring, Atlantification, Particles fluxes, Kongsfjorden

Introduction

The Kongsfjorden is affected by inflow of Atlantic water as well as glacier melt water runoff from 5 glacial termination flowing in the inner part of the fjord. The density and stratification of local waters and so the carbon exchange between the different waters masses, is significantly affected by the meltwater discharge systems. The Arctic water masses differ each other especially in terms of temperature, salinity and stable isotope compositions. Moreover, the increased freshwater supply from sea-ice melt and river runoff have shown to decrease calcium saturation state and provide a positive feedback on ocean acidification processes. Since 2010, the ISP research team get oceanographic parameters in a mooring site (MDI - mooring Dirigibile Italia) and acquires temperature and salinity data in Kongsfjorden (Fig 1) through repeated CTD probes surveys. One of the main goal of this research is the study of the interactions between the different water masses in the fjord and in particular between the cold surface freshwater from melting of the large glacial terminations present and the warmer intermediate water intruding in the fjord. These interactions are very important because contribute to cooling processes of the northernmost branch of the Gulf Stream (West Spitsbergen Current - WSC) and so of the entire global thermohaline circulation.

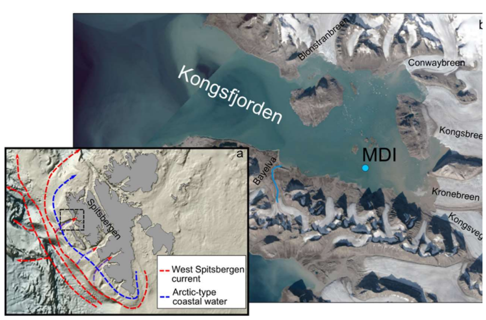

FIG 1: MDI Mooring Location

Activities

The atlantification proces in this fjord has emerged as an increasing heat and salinity of the water column, resulting from enhanced advection of Atlantic waters (AW). The temperature series, spanning the whole decade, show a positive trend during observed period (0.13 °C/yr and 0.06 °C/yr at 35 m and 85 m depth, respectively; Fig.2). Depth-averaged temperatures in the inner fjord have increased by 1 °C in 2010-2020 and more significantly in the warmest months of the year by 0.26 °C/yr, whereas they appear relatively stable in the coolest months. Salinity at 85 m has increased at a rate of 0.03 °C/yr but a decrise trend is found in starting from January 2017. Highly diluted AW are found at the beginning of the decade, which give way to more and more pure AW in later years, culminating in extensive intrusions in 2016 and 2017. Accordingly, the period between autumn 2016 and winter 2017 features the warmest and most saline conditions of the entire decade in inner Kongsfjorden. Our particles time series points towards the subglacial run-off driven by air temperature being the dominant process affecting the glacier fjord discharge of lithogenic material. Water column stratification modulated by the inflow of warm Atlantic waters, especially in winter, will progressively hamper the exchange of nutrients from the bottom waters. This, in turn, will severely reduce the biological production and in particular the primary productivity in the fjord.

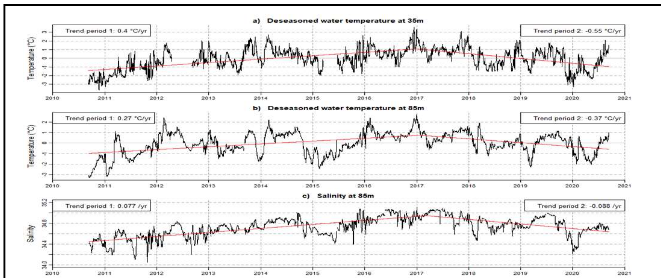

FIG 2. De-seasoned temperature daily medians at different depth (a-b) and (c) Salinity daily medians at 85 m. Predicted regression values are reported with red lines.

Future developments

Long-term oceanographic monitoring systems such as MDI are extremely valuable to detect current modifications in marine polar regions and to help predict their future evolution. The continuous functioning of MDI and other Arctic moorings ensures a data flow of considerable importance for examining climate change impacts on high latitude regions. Improved technologies and instrumentation to study the boundary layer between different reservoir will be the key approach to acquire useful data to develop integrated environmental models in order to predict next future climate scenarios not only in Artic regions. In this sense an instrumental improvement is planned for the next 3 years including pCO2 pH, nitrate, PAR, turbidity and fluorescence sensors; dissolved matter sampler; acoustic recorder; automatic sediment trap for micro and nano plastic.

Ice Memory: an international salvage program

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KEYWORDS: ice-core, glaciology, paleoclimatic reconstruction

Introduction

According to the latest IPCC reports, the average global temperature has increased by about one degree centigrade over the past century and, at the highest altitudes, the value is almost twice. The mountainous areas of our planet are particularly sensitive to climate change, to the extent that they are considered true sentinels of current global warming. Starting from the second half of the 19th century, alpine glaciers have generally been retreating almost continuously, losing on average 60% of their mass at speeds that have increased year by year. In addition to the well-known consequences in terms of both the environment, water resources and mountain ecosystems, the melting of a glacier is the destruction of a veritable natural archive that stores invaluable information on the climate and environment of the past, covering several centuries to tens of millennia depending on the glacier. The history of our Planet and its people is enclosed and preserved in ice crystals; a sort of unique ancient manuscript recorded in a frozen library. And so, just as a fire could destroy the history of our past in a few hours, the disappearance of a glacier is also an incalculable loss of our heritage. The international Ice Memory project, initiated by a consortium of researchers well-known for their contributions in the field of climatic reconstructions from ice cores, aims to recover ice cores from the most important endangered glaciers in order to preserve the information they contain and make it available for use by future generations notably to conduct scientific investigations that are not possible today, due to limits in analytical techniques or in process understanding. Once extracted from the glaciers, the samples will be transported and stored in Antarctica, the coldest place on the planet, thus creating an unique repository for future science. This ambitious project is a real race against time and its importance has been recognized by UNESCO, which has granted its patronage to the initiative and encourages nations to support it.

Activities

The core drilling activities are carried out using an electromechanical drill, powered by solar panels or fuel generators. Once extracted, the ice cores are transported by helicopters and transferred to the ISP laboratories in Venice. In the cold room, each ice section is measured and subjected to a visual analysis to identify the main glaciological parameters before being cut and decontaminated. The samples thus prepared are analyzed through a continuous melting system for the high-resolution simultaneous determination of dust (Abakus laser-counter), trace elements (ICP-QMS) and ionic conductivity. Discrete samples are analyzed for the determination of the isotope ratios of H and O (δD, δ18O;

PICARRO laser-analyzer) and to determine the concentrations of major ions. The ice core dating is carried out using absolute (^{210}Pb, ^{14}C; radiochemical methods) and relative (^{3}H, volcanic tephra and Saharan events) methods.

Future developments

In the framework of international Ice Memory Program, ISP is committed to the conservation of climatic and environmental signals from the Alpine and Apennine environments. The Italian group is planning to take five ice cores representative of the different climatic areas, both continental and maritime. The selection includes two glaciers in the Eastern Alps (Marmolada and Montasio), the last remaining glacial body in the Apennines (Gran Sasso d'Italia) and two high-altitude glaciers in the Western Alps (Grand Combin and Monte Rosa). The sites choice takes into account the current acceleration in the rate of the glacial surfaces reduction. In addition to these sites, a collaboration is underway with colleagues from the University of Innsbruck for the sampling of some Tyrolean glaciers. Furthermore, in collaboration with the French and Swiss colleagues, the core drilling of Kilimanjaro, the last glacier on the African continent, whose extension is now reduced to just a few square kilometers, is also planned. This core, which in importance would be destined to become the icon of the ICE MEMORY project, is not yet confirmed as diplomatic negotiations are underway for the issuance of specific authorizations.

Sea ice dynamics in the north-western Ross Sea during the last 2.6 ka: From seasonal to millennial timescales

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KEYWORDS: Laminated diatomaceous sediments, sea ice dynamics, short-lived climate-driven processes, Edisto Inlet (Ross Sea)

Introduction

Climate reconstructions of the past 2000 years are fundamental for our understanding of human-induced changes into the context of natural climate variability. They also provide opportunities to improve the interpretation of paleoclimate proxy observations, as well as to evaluate the performance of the climate and earth system models that are used to generate projections of future climate change.
Laminated diatom ooze deposits have been documented in different regions of the Antarctic margin. Although the formation of laminated ooze units is dependent on local and regional conditions, collectively, their deposition is generally attributed to spring and summer algal bloom events associated with seasonal sea ice retreat. As such, laminated sediment archives have the potential to provide crucial insights into sea ice dynamics and, more in general, climate variability. On top, laminated records often reflect weak post-depositional processes, which makes them extraordinary archives for resolving short-lived climate-driven processes driven by marked seasonal and sub-seasonal variability. Few modern oceanographic factors favor varve preservation. In general, very high sedimentation rates can overwhelm limited bioturbation and thus additionally foster the preservation of varves, for example in some glacimarine settings.

Activities

Laminated sediments were collected in Edisto Inlet (Ross Sea) during the HOLOFERNE project (PNRA2013) with well-defined dark and light laminae on a mm- to cm-scale, packed like a pan of "lasagne". Tesi et al. (2020) documented that dark laminae contained relatively high concentrations of IPSO25, a biomarker of land-fast ice, whereas low IPSO25 concentrations characterized light laminae and the diatom *Corethron pennatum* became the dominant species.
Satellite images of the inlet reveal marked inter-annual variability of fast ice conditions in summer over the last decade. Three 3 different states of inlet opening were recorded:

a) Full and long-lasting opening. Under these conditions, both dark and light laminae can accumulate;
b) Partial opening: the thawing of fast ice is delayed, and the inlet never completely opens by the end of summer. In this scenario, deposits are dominated by dark laminae;
c) No opening: fast ice persists throughout the summer along the coastal region. These circumstances prevent the accumulation of biogenic material.
Based on these assumptions, fast ice dynamics were reconstructed over the last 2.6 ka for the western part of the Ross Sea. Light laminae became suddenly less frequent starting from ca. 0.7 ka BP, indicating an abrupt shift towards less recurrent ice-free conditions in the inlet. Comparison with ice core data from the region revealed that the abrupt shift in fast ice dynamics was likely the expression of colder climate conditions.

Future developments

The absence of any modern research, based on sediment trap time-series in the study region, which would support the observed seasonality, leaves uncertain the paleoclimatic and paleoceanographic interpretation of these marine laminated sediments. The LASAGNE project, recently funded by PNRA (2021-2023), proposes a multidisciplinary study integrating fast-ice, water column and surface sediment characteristics, supported by biological data collected *in situ* and time-series of satellite images of sea-ice, to gain information on factors influencing the laminated sediment formation, composition and preservation in Edisto Inlet. The project will give new insight into the sub-seasonal formation of laminated sediments providing a backbone for the interpretation of paleoclimate sediment archives.

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Cold-water corals from the polar regions: reliable archives to reconstruct changes of water mass properties in the past

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KEYWORDS: Cold-water corals, geochemical signals, paleoceanographic reconstructions

Introduction

Attempts to decipher the role of the Southern Ocean in modulating past-climate has been particularly difficult due to the paucity of calcium carbonate-precipitating organisms, such as foraminifera, which are commonly used as paleoclimate archives in other oceans. Waters south of the Polar Front become undersaturated with respect to aragonite and calcite, strongly limiting carbonate accumulation and preservation. Cold-water corals (CWC) are one of the few calcifying organisms that can cope with this corrosive and near-freezing environment, so are potential candidates for reconstructing past oceanographic records at high resolution (annual) over centennial timescales. CWC are also part of the intermediate and deep-water benthic communities in the sub-Arctic and Arctic regions and are becoming a prime target for climate-oriented studies and paleoceanographic investigation. CWC have unique advantages compared to other established sedimentary archives: 1) they can be reliably dated using the high precision U-series and ^{14}C techniques, potentially providing century-long records at sub-decadal scale; and 2) they incorporate trace elements, stable and radiogenic isotopes that reflect the environmental conditions of the ambient seawater during skeletal secretion. Specifically, the Li/Mg, P/Ca, B/Ca ratios and boron isotopic composition of the exoskeleton of CWC vary with seawater temperature (Montagna et al., 2014), dissolved inorganic phosphorus concentration (Montagna et al., 2006), ion carbonate concentration (McCulloch et al., 2017) and pH (McCulloch et al., 2012) respectively, providing a new tool to reconstruct the variability of these key parameters in deep water environments.

Activities

Over the last 15 years, several live and fossil specimens of the cold-water coral genera *Flabellum, Javania, Desmophyllum, Lophelia* and *Madrepora* have been collected by the ISP-ISMAR group in the Southern Ocean (Ross Sea and SW Australia) and in the Arctic Ocean (off Iceland and Norway) through dedicated oceanographic cruises and research projects. Most of these samples have been investigated using a combination of novel and established geochemical proxies. The geochemical signals encoded in the coral skeletons have been translated into changes in key seawater parameters using appropriate calibration equations to quantify the natural variability of the most important high-latitude mid to deep-water masses (UCDW, MCDW, AAIW, NADW, ISOW) and improve our understanding on how their physico-chemical parameters (temperature, seawater carbonate chemistry, water mass circulation) have responded to periods of major climate change on decadal-centennial and millennial timescale.

Future developments

A highly complementary and fully integrated suite of geochemical tracers will be applied to precisely-dated coral samples to extract decadal-scale records of intermediate and deep waters from the high-latitudes, overcoming the limitations of sediment cores, including the lower temporal resolution and less accurate age control. Newly-developed geochemical proxies (e.g. carbonate-bound organic nitrogen) will be tested on cold-water corals from the polar regions in collaboration with the Max Planck Institute for Chemistry to reconstruct past changes in the ocean nitrogen cycle since the last glacial period. Finally, a collaboration with climate modellers working with outputs of the Coupled Model Intercomparison Project is foreseen to increase our understanding on the mechanisms and feedbacks of the ocean-atmosphere climate system at decadal and sub-decadal resolution.

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Paleoclimate reconstruction and sea ice variability derived from polar ice archive

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KEYWORDS: ice core, sea ice, impurities, atmosphere

Introduction

Since Willi Dansgaard's demonstrate that oxygen and hydrogen isotope ratios in ice are related to local temperature(Dansgaard et al., 1969), many elements and gases have been studied to understand climate variations in the past from the ice archive. For example, in Antarctica the size of the dust preserved in the ice is used to understand transport pathways, sodium is commonly used to evaluate the influence of sea spray while CO_2 and CH_4 have been used to reconstruct the composition of the ancient atmosphere from the air bubbles trapped in the ice. Analysis of total element concentrations is used to understand the amount of dust deposition and possible changes in the source area occurred during the different past periods of the earth climate while specific organic compounds and particles, such as levoglucosan and black carbon, are now measured for investigating specific natural process and the most recent anthropogenic impact (Barbante et al., 2017).

Activities

In Polar regions, ice core have been recovered mainly from Greenland and Antarctica where most of the Earth ice is stored; however additional places such as Svalbard, Alaska, Canadian Arctic and Sub-Antarctic Island can also be suitable for the recovery of this type of natural climate archive. Different aspects of the past climate have been studied such as the composition of the ancient atmosphere, the role of the iron in fertilizing the ocean (Burgay et al., 2020) and the occurrence of wildfire in the past (Segato et al., 2021). Sea ice is a crucial parameter in the climate system, and in the Arctic it is declining at a faster rate than models predicted. Bromine plays a central role in sea ice chemistry, from where it is released as BrO during springtime, enriching its abundance in the polar atmosphere. Therefore, bromine enrichment in snow, with respect to the sodium ratio in seawater, can be been linked to first year sea ice variability at the Pole (Spolaor et al., 2013). Measurements of Bromine enrichment (Br_{enr}) have been carried out in Greenland (NEEM, EGRIP and Renland), Svalbard, Severnaya Zemlya and Antarctica (Talos Dome, Law Dome and Dome C).

Future developments

The dataset of multi-millennial Br records in Antarctica should be expanded from Talos Dome to other suitable ice core sites, such as WAIS Divide in West Antarctica, EDML in Dronning Maud Land, DSS/Law Dome in East Antarctica. The circum-Arctic ice cores should elucidate a record of Arctic sea-ice variability over the last millennia and possibly as far back as the Holocene Climatic Optimum approximately 8,000 years ago. The records from Central and Southern Greenland should extend well into the last glacial period, providing a detailed record of sea-ice variability and timing related to Atlantic Meridional Ocean Circulation.

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Carbon-climate feedback during last deglaciation: reactivation of frozen-lock permafrost soils

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KEYWORDS: deglaciation, permafrost, green house gasses

Introduction

Permafrost is perennially frozen ground and represents the second largest terrestrial carbon pool on Earth (1300±200 Pg of C). The latest IPCC simulations suggest that, by the end of 2100, over 90% of permafrost will thaw in the RCP8.5 scenario. Microbial decomposition of permafrost carbon (PF-C) following thawing can free Greenhouse Gases (GHGs, CO2/CH4) which, in turn, can amplify climate warming. The latest estimates of GHG emissions from thawing PF-C by 2100 account for 7-25% of the projected fossil fuel emissions which will offset our future effort of reducing emissions of fossil GHGs (Schuur et al., 2015). Altogether, this demonstrates that the anticipated permafrost loss will have a dramatic impact on the Arctic with global consequences (Schleussner et al., 2016). Recent model paleo-simulations have suggested that the release of GHGs from thawing permafrost has already occurred in the past (Crichton et al., 2016). In particular, recent models have hypothesized the reactivation of frozen PF-C during last deglaciation (20-11.5 ky ago). This novel hypothesis has opened new scenarios on the post-glacial carbon history. However, despite the evident implications for climate change, our knowledge about the fate of the glacial PF-C is essentially indirect, largely depending on models (Crichton et al., 2016; Köhler et al., 2014; Simmons et al., 2016; Zeng, 2007).

Activity

In order to fill this critical knowledge gap and investigate this hypothesis, our study exploits sedimentary records from the Arctic Ocean to reconstruct the behavior of the glacial permafrost in response to the last deglaciation. We aim at defining the timing/extent of thawing, the composition of the carbon being released and the processes involved in the reactivation of the glacial permafrost. Overall, our results highlight the role of PF-C buried under the ice-sheets that has been overlooked in the state-of-the-art Earth System Models.

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Trace organic compounds as proxies in ice cores

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KEYWORDS: Ice cores, organic compounds, proxies, paleoclimate.

Introduction

Ice cores constitute environmental archives over time spans of hundreds of thousands of years. Trace concentrations of gases, elements and organic compounds serve as proxies that allow the interpretation of past climatic conditions: temperature, humidity, atmospheric circulation, greenhouse gas concentrations, biological productivity and biomass burning. Biomass burning is one of the principal sources of greenhouse gases and atmospheric aerosols influencing both regional and global climate, yet these records remain one of the least understood aspects of the climate system. Our laboratory has developed analytical techniques to analyze levoglucosan and phenolic compounds, organic biomarkers of fire activity.

Activities

Several ice cores have been analyzed from East Antarctica and Greenland, highlighting that humans may have had a significant impact on the environment in the last 3,000 years, when vast areas of our planet were burned to make room for settlements and agriculture. Trace organic compounds in ice cores supply important paleoclimatic information, and untargeted analyses of dissolved organic matter provide an overview of molecular species in ice samples indicating their sources and past climatic conditions and variations.

The development and improvement of new analytical systems dedicated to highly resolved measurements of chemical markers on samples from climatic archives, such as ice core, is one of the main challenges of the scientific community. We developed an innovative set-up of fast liquid chromatography coupled with tandem mass spectrometry (FLC-MS/MS) to determine organic markers in ice cores in semi-continuous manner. In particular, we developed the analytical set up to quantify vanillic and syringic acids, two specific tracers for biomass burning.

Future developments

The introduction of new molecular tracers will allow to study other aspects of climate evolution. FLC-MS/MS will be applied to any organic compound to investigate in semi-continuous manner other markers in ice cores.

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AT3

DYNAMICAL PROCESSES AND CLIMATE CHANGE: INTERACTIONS BETWEEN DIFFERENT DOMAINS (ATMOSPHERE, CRYOSPHERE, HYDROSPHERE, BIOSPHERE), MULTISCALE OBSERVATION AND MODELING IN A CHANGING CLIMATE

Free amino acids as potential markers of oceanic primary production for paleoclimatic studies

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KEYWORDS: amino acids, Arctic, marine primary production, bloom

Introduction

The role of oceanic primary production on climate variability has long been debated. Defining changes in past oceanic primary production can help understanding of the important role that marine algae have in climate variability. In ice core research, methanesulfonic acid is the chemical marker commonly used for assessing changes in past primary production. However, other organic compounds such as free amino acids, can be produced and emitted into the atmosphere during a phytoplankton bloom. These species can be transported and deposited onto the ice cap in polar regions.

Activities

This first study on the size distribution of L- and D-free amino acids in Antarctica has identified possible sources of marine aerosols in this region and has characterized some chemical and physical transformations that take place during transport to the interior of the Antarctic continent (Barbaro et al. 2015).
The occurrence of free amino acids was evaluated also in the Arctic aerosol, by investigating for the first time the association of chemical markers (major ions, carboxylic acids and free L- and D-amino acids) with biological ones in the Arctic atmosphere. The main aims was clearly correlate them and to better define sources of these tracers (Feltracco et al., 2021). Gly, D-Ala and D-Asp and some C4- organic acids increased during the climax phase of the marine bloom and started to drop at the beginning of the bloom apex. D-amino acids in microorganisms can act as N-sources and be converted to their L-enantiomer form for further use. Thus, D-amino acids could serve as indicators of developing marine blooms and be used to reconstruct past biological activity in marine ecosystems. On the other hand, Polaribacter together with free L-amino acids might constitute a useful marker for the bloom peak and subsequent post-bloom decline (Feltracco et al., 2021).
Free L- and D-amino acids was determined to shallow firn core samples collected on April 2015 from the summit of the Holtedahlfonna glacier, Svalbard (N 79′08.424, E 13′23.639, 1120 m a.s.l.). The main result is that amino acids concentration profiles of three years show a seasonal cycling with the highest concentrations during the spring and

summer time, reflecting changes in oceanic phytoplankton abundance (Barbaro et al., 2017).

Future developments

Future investigations using longer ice core records, and from other locations, must be provided to better assess the applicability of amino acids as possible preserved tracers of oceanic primary production.

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Aerosol spatial distribution in the arctic troposhere

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KEYWORDS: Aerosol vertical profiles, black carbon,

Introduction

Primary objective of this long-term research activity is to build a climatology of aerosol 3D spatial distribution in the Arctic lower troposphere. To this aim since 2011 an international research team has performed yearly field campaigns at the Ny-Ålesund Research Station (Svalbard- Norway) thanks the support of the Italian CNR Dirigibile Italia and German AWI Koldewey stations. The exploration of 3D aerosol spatial variability makes use of various aerosol payloads deployed on tethered balloons systems (TBS) (1), for vertical profiles, and snowmobiles for horizontal profiles (2). Up to date, more than 500 vertical profiles have been recorded in the first km of the Arctic troposphere, providing detailed information on black carbon concentration, aerosol size distribution, aerosol scattering coefficients and chemical composition. Seasonal trends have been obtained for spring, summer, autumn and winter. Aerosol horizontal profiles in the atmospheric surface layer over the snow surface have been characterized on the major glacier of the Spitzbergen area, including Austre Lowenbreen, Midtre Lowenbreen, Kongswegen, Edithbreen and Holtedahlfonna for four successive years (2016-2019). Case studies has already been reported describing the impact of ship emissions, Arctic haze and new particle formation events on the vertical aerosol structure. In situ TBS activities have been often accompanied by parallel lidar profiling and full chemical aerosol characterization both at bulk level on filter samples and on single particles by scanning electron microscopy (3-5).

Activities

The present activity is focused in the analysis and homogenization of the entire aerosol vertical profiles dataset as obtained in the 2011-2019 period with a suite of lightweight instrumentations (AE51, PSAP), and with different tethered balloon systems. The trends are statistically analyzed, and the results will be compared with ground-based reference monitors at Zeppelin (475 m asl.) and Gruvebadet (70 m asl) observatories. The realization of a new winch for the TBS is also planned which will allow to explore an extended altitude range.

Future developments

On the basis of the robust experience developed we aim at developing a novel tool for aerosol-cloud interaction study, integrating in-cloud observations with ground-based measurements and a suite of models to face key challenges like particle sources, precipitation, biochemical properties in clouds, impacts on snowpack. In particular the goal is to develop a novel in-cloud observational platform to study low-tropospheric clouds, based on the TBS platform and integrating new instrumentation, devoted to bioaerosol and cloud droplet characterization.

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Plastic additives, microplastics and other components of microlitter in the atmospheric compartment of Svalbard Islands: aerosol and snow depositions analysis using Micro-FTIR

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KEYWORDS: Microplastics; Plastic additives, aerosol; snow depositions

Introduction

Plastic pollutants have reached Polar regions, and Arctic waters have been reported to host the highest microplastic concentration despite their being remote; Arctic sediments showed relevant microplastic concentration as well (Bergmann et al., 2019). Comprehending short and long-range transport, sources, and pathways of microplastic pollution in Polar areas is crucial. The scavenging effect is considering an essential pathway that influences the transport of MPs through the atmosphere. The critical role of the combination between aerosol composition and wet and dry deposition that allow precipitate microplastics (MPs) to the terrestrial and aquatic polar environments needs to be investigated (Zhang et al., 2020). Further, small microplastics (< 100 µm; SMPs), additives, and plasticizers are often neglected in polar studies, although these emerging contaminants can be a threat to biota.

Activities

Aerosol and snow samples were collected in Svalbard Islands in April 2021 to study the temporal and spatial variability of additives, plasticizers, microplastics, and other components of microlitter. Snow samples were collected at different remote places, including the summit of surrounding glaciers. Aerosol samples were collected at Gruvebadet. The extraction of these emerging contaminants from the snow was optimized using the pretreatment method (oleo-extraction and purification) developed for seawater samples. (Corami 2021). Aerosol samples were pretreated according to Corami et al. (2020). Quantification (abundance and weight) and simultaneous polymer identification were performed using Micro-FTIR.

Future developments

The quantification and the chemical characterization of additives, plasticizers, MPs, and other microlitter components will allow the investigation of sources and pathways and understand the role of short and long-range transport in the polar atmospheric compartment. Analyses via Micro-Raman of the same polar samples will be considered to evaluate the presence of nanoplastics. This study will advance our understanding of how polar ecosystems are functioning (AT6) and may also be synergistic with other essential topics such as global climate change (AT1), Arctic amplification (AT4).

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Amphipods as bioindicator of microplastics pollution the Svalbard Islands: Characterization of additives, plasticizers, small microplastics (<100 µ) and other microlitter components

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KEYWORDS: microplastics, bioindicators, plasticizers, Micro-FTIR

Introduction

The health of several organisms (e.g., macro-and microinvertebrates, fishes) can be adversely affected by the ingestion of microplastics and fibers, mistaken as food (Rezania et al., 2018; Xu et al., 2020). Microplastics, in particular, small microplastics (< 100 µm), may accelerate the uptake of chemicals by organisms that ingest them (Kwon et al., 2017). Microplastics can be a sink for those highly hydrophobic chemicals; however, microplastics can be a significant source of chemicals because additives and plasticizers are added to polymers to obtain specific characteristics. Plastic additives may exert toxic effects on biota, and they may be multiple stressors for the environment. An increase in temperatures due to climate change will exacerbate the light-induced degradation of plastic (Andrady et al., 2019). Besides, it may affect the availability of microplastics and plastic additives and aggravates their environmental impact. The identification of suitable bioindicators will help understanding impacts and stressors.

Activities

Amphipods were collected in the Svalbard islands (*Gammarus setosus*). Organisms were selected and dissected under a stereomicroscope. Digestive tracts were then pre-treated to dissolve organic matter in a plastic-free cleanroom ISO 7. Quantification and polymer identification of small microplastics (<100 µm), additives, and plasticizers were performed using Micro-FTIR (Iannilli et al., 2019; Corami et al., 2020); hence this group of detritivores can help study the pathways of such contamination throughout the trophic web.

Future developments

These first results are encouraging and of extreme interest. The next step will be to investigate toxic effects and evaluate bioaccumulation and potential biomagnification throughout the food web. This study can be synergistic with other important scientific issues, e.g., anthropogenic stressors and climate change in polar systems (AT1), the local and global effects on communities (AT5), the ecosystem performances in a changing climate (AT6), how the carbon cycle is affected in a changing climate (AT7).

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Albedo feedback in tropical glaciers: a possible role of Light-Absorbing Particles?

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KEYWORDS: tropical glacier; albedo; light-absorbing particles; remote sensing

Introduction

Tropical glaciers in South America supply water to 77 million people, supporting domestic, agricultural, and industrial needs, as well as hydroelectricity production. Tropical glaciers are particularly sensitive to climate change. From 1975 to 2016, the Andes glaciers lost more than 50% of their surface [1]. Glacier surface and mass loss are strictly linked to the increase of surface temperature at high altitudes and change in precipitation pattern [2]. Nevertheless, modeling glacier evolution in the near future is still characterized by elements of uncertainty, such as the impact of light absorbing particles (LAPs) on snow and ice surface albedo and melting [3]. LAPs include: i) black carbon (BC), produced by combustion processes, ii) organic carbon, emitted during low temperature combustion or formed in the atmosphere as secondary aerosol, and iii) mineral dust, re-suspended from disturbed soil. In particular, South American tropical glaciers are potentially threatened by the large BC emissions from the Amazonian open burning and by local agricultural fires, as well as by mineral aerosol re-suspended in the nearby deserts and by the intense mining activities at high altitudes.

Activities

We recently reviewed scientific literature regarding black carbon, organic carbon and mineral dust in South American tropical glacier (Gilardoni et al. *in review).* Just few studies measured the surface concentration of LAPs in south American glaciers [4], and a possible role of atmospheric impurities on snow and ice melting cannot be excluded. We analysed Sentinel-2 satellite images collected in the Cordillera Blanca and Cordillera Vilcanota during the dry season between 2017 and 2020. Cloud-free scenes were selected for each season, and surface reflectance was used to produce maps of broadband albedo (α) and impurity index (I_{imp}). LAGRANTO model simulations were used to characterize the air mass movement in the days preceding the acquisition of the Sentinel-2 data. Furthermore, particulate matter emissions were evaluated using the Global Fire Emissions Database (GFED 4.1). Co-occurrences of glacier darkening and LAPs transport were analysed over the Cordillera Blanca and Cordillera Vilcanota. Preliminary results show that years characterized by strong fire activity in the Amazon basin show also low glacier albedo values.

Future developments

Next steps will regard the analysis of MODIS albedo (MOD10A1) time series in order to understand the possible impact of LAPs transport and deposition on glacier albedo seasonality. Time series analysis of MODIS data will be useful to compare the timing of large aerosol deposition on tropical glaciers and their possible impact on surface melting.

Further back-trajectory analysis will be carried on in order to identify the sources of LAPs on South American tropical glaciers. In this context, a new project (namely Light-Absorbing Particles in the Andes, ALPACA) has been activated on the Cordillera Blanca to promote a measurement campaign for the characterization of LAPs in snow and ice.

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Oxygen and hydrogen isotopic composition of precipitation at Concordia station, East Antarctica

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KEYWORDS: Isotopes, Antarctica, Temperature, Precipitation

Introduction

The atmospheric dynamics determining the isotopic composition of precipitation on the Antarctic plateau are yet to be fully understood, as well as the post-depositional processes altering the pristine isotopic signal of precipitation. Improving the comprehension of these physical processes is of crucial importance for reconstructing past temperature variations using the isotopic records from ice cores drilled in the low accumulation area of Antarctica[1], e.g., the upcoming Beyond EPICA drilling at Little Dome C. Up to now, the spatial relationship between temperature and snow isotopic composition has been used to reconstruct past temperature from ice core isotopic records[2], while very few temporal relationships have been calculated, mostly limited in time or sampling frequency.

Activities

Since 2008, the winter-over personnel at Concordia Station have been continuously collecting daily precipitation: this represents a unique record of the isotopic composition of precipitation from the Antarctic Plateau. Snow is collected every day on a raised platform (height: 1 m) in the clean area of the station. Snow samples are analyzed for $\delta^{18}O$, δD and deuterium excess. A 10-year long (2008-2017) record of the isotopic composition of precipitation at Dome C is now available. A significant positive correlation between $\delta^{18}O$ and δD of precipitation and 2-m air temperature is observed at both seasonal and interannual scale; the lowest temperature and isotopic values are usually observed during winters characterized by a strongly positive Southern Annular Mode index[3]. To improve the understanding of the mechanisms governing the isotopic composition of precipitation and to evaluate the processes modifying the pristine snow isotopic signal, we compare the isotopic data of Concordia samples with on-site observations, meteorological data from the Dome C AWS of the Programma Nazionale di Ricerche in Antartide (PNRA), as well as with high-resolution simulation results from the isotope-enabled atmospheric general circulation models ECHAM5-wiso and ECHAM6-wiso.

Future developments

Daily collection of precipitation at Dome C will continue in the framework of the PNRA project WHETSTONE (P.I.: Dr. Giuliano Dreossi); an already established collaboration with French researchers at Concordia will be strengthen to compare the isotopic data from precipitation with the isotopic composition of surface snow and water vapor, in order to gain a wider comprehension of the mechanisms altering the pristine isotopic signal of precipitation.

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Fate of persistent organic pollutants in arctic permafrost environments

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KEYWORDS: organic pollutants, soil mapping and modelling, permafrost, pollution remobilization

Introduction

The very rapid warming of the Arctic regions raises a concern also in reference to potential changes in glaciers melting and permafrost active layer deepening, enhancing the fact that seawater, snow and soils are becoming important secondary sources remobilizing persistent organic pollutants (POPs), formerly freeze-locked. This cycle of deposition and re-emission gives rise to the global fractionation process that promotes transport of these chemicals to cold polar regions.

Activities

Understanding the factors that determine changes in levels of POPs observed in permafrost environments is essential for a valid interpretation of trends. To achieve the main objective to upscaling the data projections, two specific goals have been identified. 1) Modelling within few sampled areas, simulating processes to better understand how different local conditions affect permafrost/snowmelt-induced contaminant pulses, especially by comparing field and modelling results. 2) Test the sensitivity of the model for the best upscaling on a regional scale.

A field work campaign is ongoing over different areas, chosen considering the age of the permafrost condition, the glacial history, the environmental variables, and the global distribution:

- 2 coastal catchments along Beaufort Sea, Ptarmigan Bay (sampling campaign conduced in summer 2018) and Komakuk Beach (summer 2019);
- 1 area in the permafrost peatlands in Fennoscandia (sampling campaign expected in summer 2022);
- 1 potential area in Svalbard to be scheduled.

An analytical method for the quantification of PAHs, PCBs and HCB has been validated for soil and permafrost sediments analysis. It was performed using Accelerated Solvent Extraction (Thermo Scientific Dionex ASE 350) and Gas Chromatography - Triple Quadrupole Mass Spectrometry (Trace 1310 GC coupled with TSQ9000 TQMS, Thermo Scientific) at CNR-ISP Venice, Italy.

The mechanisms responsible for the transport of POPs into the soil are believed to be gravity drainage and capillary suction into fissures and cracks. Accumulation of PAHs in the permafrost transient layer is probably related to the accumulation and transport of soil organic carbon influence, as well as the changing in hydraulic barriers.

The detailed investigation relies on geostatistical analysis over parameters correlated with the POPs distribution, such as major atmospheric transport and variation; soil properties (classification, stocks of carbon, nitrogen, selected contaminants, soil texture); physical parameters combined with remote sensing products (landforms; drainage; meteorological framework); complementation with digitization of extensive legacy datasets.

Future developments

The research will undertake a series of investigations to create fundamental datasets and process understanding to quantify thawing permafrost and its impact on storage and vulnerability of contaminants. The workflow will include sampling and characterizing representative permafrost catchments, including their thaw-vulnerability and thaw-impacts on lateral fluxes into the aquatic realm.

A great part of this work is possible thanks to the Horizon 2020 Project Nunataryuk EU grant agreement No. 773421.

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Study of the atmospheric ozone content and surface solar ultraviolet radiation in the polar regions

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KEYWORDS: Atmospheric ozone, Solar UV irradiance, Polar environment

Introduction

The ozone is an important atmospheric component that determines the thermal structure of the stratosphere and protects the life on the Earth due to its strong absorption in the ultraviolet (UV) band of the solar radiation. For that reason, the ozone and UV irradiance are jointly studied. The specific atmospheric dynamics over the polar areas is able to affect the air masses in the lower latitudes that makes the study of the polar atmosphere parameters, including ozone and UV radiation an important cross-cutting topic that needs a deeper understanding.

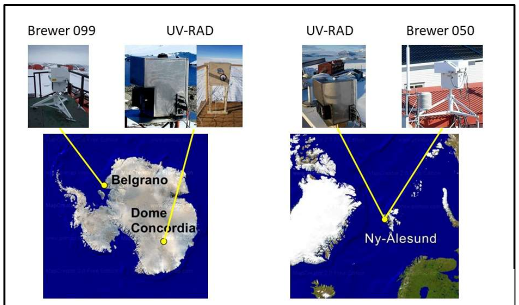

Fig. 1. CNR-ISP instruments for measurement of the ozone column and solar surface UV irradiance, and their locations.

Activities

The measurements of the ozone column and surface solar UV irradiance performed by the team of the Institute of Polar Sciences at the Italian National Research Council (CNR-ISP) in the polar areas started in 2000 with the spectroradiometer Brewer 099 based at the Antarctic station Belgrano (Fig. 1) in collaboration with Argentinian Antarctic Institute (IAA). Two of the own-made narrow-band filter radiometers UV-RAD (Petkov et al., 2006) were established at Dome Concordia (Antarctic) and Ny-Ålesund (Arctic) as Fig. 1 exhibits, in 2007 and 2008 respectively. In addition, Brewer 050 operating at Ny-Ålesund (Fig. 1) was taken under the responsibility of CNR-ISP in 2017. The instruments based in Ny-Ålesund participated in an intercomaprison campaign in 2009 (https://www.researchinsvalbard.no/project/6518). The activity in Ny-Ålesund was developed as a part of the RiS 3305 project (https://www.researchinsvalbard.no/project/6387). International cooperation was sustained inside the Atmospheric Flagship Programme (https://nyalesundresearch.no/research-and-monitoring/atmosphere/) thanks a dedicated workgroup and through the Svalbard Science Forum (SSF) project "UV Intercomparison and Integration in a High Arctic Environment" (UV-ICARE, https://www.researchinsvalbard.no/project/8626).

In addition to organising the monitoring of the ozone column and solar UV irradiance, the CNR-ISP team deals also with their study by analysing both the data collected from the managed instruments as the data provided by other researchers. The variations in the ozone column and UV radiation over large time scale that reveal their evolution and tendency of their changes were analysed (Vitale et al., 2011, Petkov et al., 2012, 2016, 2016(a), 2018). The effect of the strong ozone depletion events occurred in the Arctic in 2011 and 2020 on the ozone column and solar UV irradiance at midd-latitudes were examined by using a large dataset provided by ground-based instruments (Petkov et al., 2014, 2021).

Future developments

Activities in Antarctica were recently included in the frame of BSRN observatory (at Concordia) and RadiCA ("Radiation fluxes and cloud features from surface-based observations in the Antarctic Peninsula and Weddell Sea Region") PNRA project with the aim to expand the cooperation with IAA. It is planned to collect and analyse also data from Brewer 162 at the IAA station S. Martin located in the Antarctic Peninsula.

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Wave climate projections in a semi-enclosed basin combining ERA5 reanalysis and high-resolution climate model wind data

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KEYWORDS: Wind waves; ERA5, Extremes; Climate; Adriatic Sea.

Introduction

In the recent past, model reanalysis data products (e.g. ERA-Interim and ERA5 provided by ECMWF) have found widespread application in many areas of research and have often been used for the assessment of the historical atmospheric and oceanic climate, despite their coarse spatial resolution. On the other hand, regional climate models (RCM) are becoming increasingly popular in climate projection studies due to their accuracy in representing local meteorological features, but often lack adequate temporal resolution for the description of extreme events.

Activities

In this context, we devised a fully relocatable statistical scaling strategy (based on QQ-matching) that combines ERA5 reanalysis and COSMO-CLM RCM sea surface wind data, and produces hourly wind datasets for the historical period (1981-2010) – to represent the present climate condition – and for the future period (2021-2050) under the two IPCC representative greenhouse gas emission scenarios RCP4.5 (intermediate) and RCP8.5 (worst-case). The wind forcing thus derived accounts for the wind speed distribution (historical and future) of the climate model, while retaining the historical sequence of the reanalysis, therefore enabling a direct inter-comparison of historical and future events. The wind datasets are then used to model the past and future wind-wave climate in the Adriatic Sea, with focus on extreme wave crest and crest-to-trough heights. Past observations of wind and waves confirm the validity of the adopted method, whereas both future climate projections seem to show a decreasing trend throughout the basin, especially for stronger events in the northern Adriatic, dominated by Bora storms (Figure 1 and 2).

Further analysis allowed to estimate the return period of the significant wave height H_s over the control and scenario periods in key points close to the three inlets of the Venice lagoon, eventually sorted according to the two prevailing wind regimes Bora and Sirocco, coming, respectively, from the north-east (0 -110° N) and from the south-east (110 –180° N).

Future developments

For a more complete description of the impacts of climate change on the meteo-marine climate of H_s, statistics should be complemented by energy flux considerations. The directional modulation of the climate change effects on wind regimes and on sea states associated with different meteo-marine events is expected to produce not only a spatial variability of the changes of H_s, but also a modification of the associated gradients and of the energy transport towards and along the coast.

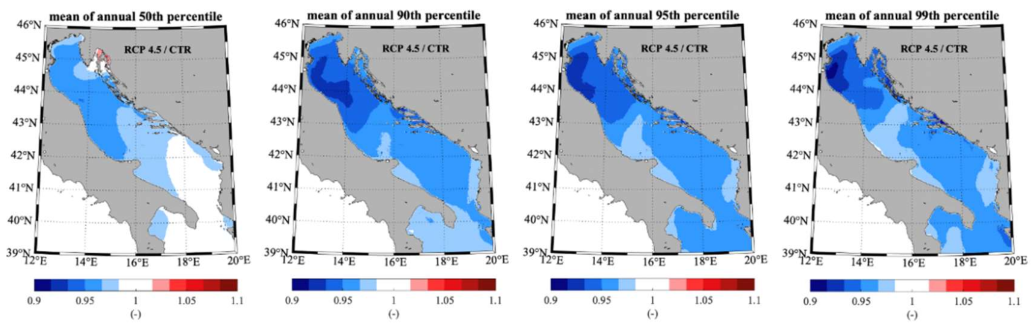

Figure 1. Scenario RCP4.5 impact (2021-2050), expressed as ratio with respect to the present-day climate (CTR, 1981-2010), on the mean annual 50th, 90th, 95th and 99th percentiles of the significant wave height *H*

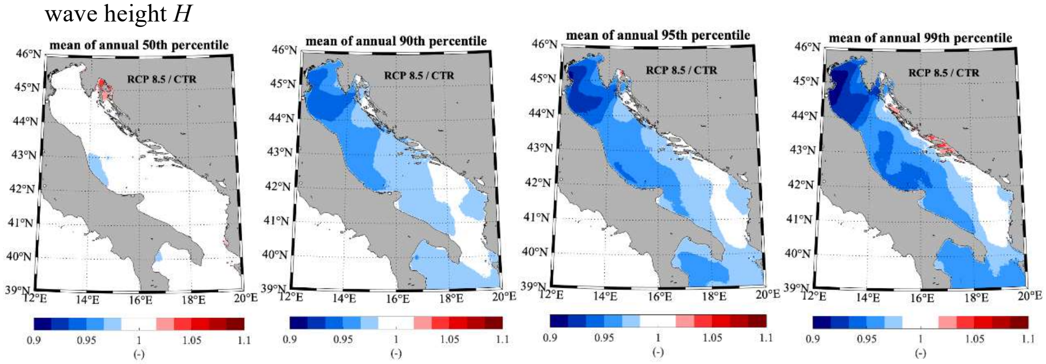

Figure 2. Scenario RCP8.5 impact (2021-2050), expressed as ratio with respect to the present-day climate (CTR, 1981-2010), on the mean annual 50th, 90th, 95th and 99th percentiles of the significant wave height H_s.

Worth noting, for a complete assessment of climate change scenarios in coastal regions it would be crucial to quantify the uncertainty associated with the choice of the climate model. This would require running sets of similar wave model simulations forced by wind fields produced by different climate models, allowing to evaluate the inter-model spread and assign a level of confidence to the results. It will be an increasingly urging goal for future studies, as progress in numerical modelling and new frontiers set by big data and artificial intelligence may provide increasingly powerful tools for more extensive climate analysis.

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Long term mass balance monitoring and evolution of ice in caves through Structure from Motion – Multi View Stereo and Ground Penetrating Radar techniques

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KEYWORDS: Ice Caves, Photogrammetry, GPR, Structure from Motion

Introduction

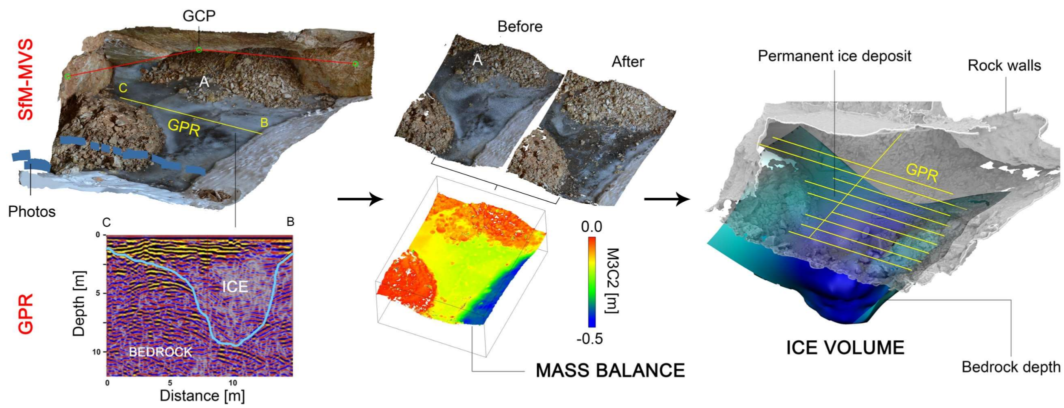
This study investigates the application of a terrestrial structure from motion – multi view stereo (SfM-MVS) approach combined with ground penetrating radar (GPR) surveys for monitoring the surface topographic change of two permanent ice deposits in caves located in the Julian Alps (south-eastern European Alps).
Long-term mass balance measurements are rather common on glaciers both in mountains and polar environments and in the last decades new methodologies such as LiDAR, terrestrial/aerial photogrammetry and pseudo 3D ground penetrating radar improved the reliability of the surveys (Berenguer et al., 2014; Forte et al., 2014; Piermattei et al., 2016). This is not the case for permanent ice deposits in caves where only scattered and short-term mass balance records exist (Obleitner and Spötl, 2011; Perşoiu, 2018; Colucci and Guglielmin, 2019). Moreover, in all such cases, mass balance measures refer to specific discrete locations as for instance in the Eisriesenvelt ice cave (Austrian Alps) where an ultrasonic ranger continuously monitored ice thickness changes (Obleitner and Spötl, 2011) or in the Leupa ice cave (Julian Alps) where surface topography changes have been monitored by using 2 fixed benchmarks since 2011 (Colucci and Guglielmin, 2019). The proposed workflow allows accurate calculation of both seasonal and annual mass balance, estimating the amount of ice inside caves with very high accuracy. The ground based SfM approach represents a low-cost workflow with very limited logistical problems of transportation and human resources and a fast acquisition time, all key factors in such extreme environments. Under optimal conditions SfM-MVS allows sub-centimetric resolution results, comparable to more expensive and logistically demanding surveys such as terrestrial laser scanning (TLS).

Activities

Fourteen SfM acquisitions were made between the 2017-2020 ablation seasons (i.e. July-October) while 2 GPR surveys were acquired in 2012. The obtained dense point clouds and digital terrain models (DTMs) made possible a reliable calculation of topographic changes and mass balance rates during the analyzed period. The integration of SfM-MVS products with GPR surveys provided comprehensive imaging of the ice thickness and the total ice volume present in each of the caves, proving to be a reliable, low cost and multipurpose methodology ideal for long-term monitoring.

Future developments

The proposed combined surveying technique offers a versatile, fast-to-acquire and relatively inexpensive approach for analysing underground cryospheric environments. The excellent resolution and fast acquisition times obtained makes this methodology ideal for investigating any variable geometry in remote underground environments, where light and space-saving instruments are mandatory.



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The chemical composition of the annual snow pack and the snow-atmosphere interaction polar regions

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KEYWORDS: snow, chemistry, interaction, contamination

Introduction

The annual snow layer is an extremely dynamic player of the Cryosphere and can be defined as the snow accumulated on the ground during the year (Barbaro et al., 2021). The Physicochemical characteristics of the annual snow strata are strongly dependent on climate conditions and can influence the access to food, particularly for animals that rely on food sources below the snow strata. Snow depositions during the winter are a sink for an impressive variety of chemical compounds, natural and anthropogenic (Vecchiato et al., 2018), and elements trapped in the snow layers. Particularly, photoactive compounds can accumulate during the winter and be re-emitted in the atmosphere during springtime (Spolaor et al., 2019), taking part in numerous geochemical and biological cycles. Upon thawing, elements and compounds present in the snow can be released in the melting water, thereby accumulate in the ground or be discharged into the sea, consequently affecting biological productivity or, in the case of anthropogenic compounds, causing a contamination in the surrounding environment.

Activities

The snow studies conducted so far in the Arctic (Svalbard and Greenland) and Antarctica (at Concordia station, in the inland Antarctic plateau during Traverse and at Mario

Zucchelli station) are/have been directed to the surface snow layer and on the chemical composition (trace elements, mercury, ionic compounds, organic compounds including anthropogenic contaminants, radionuclide and elemental isotopic abundances) of the entire annual snow pack. By simultaneously investigating both the snow pack and the superficial snow have provided us data on how the chemical composition of the snow changes with climate changes. High temporal resolution experiments have provided precious information of the timescales at which chemical processes take place under climate change forcing.

Future developments

The snow research is crucial and complementary to the other research activities to improve our comprehension of the rapidly changes that are affecting the high latitudes. Specific snow sampling campaign and experiment should be planned in the close future to: i) better investigate photo-activation and re-emission processes of specific photoactive elements that play key roles in crucial atmospheric processes (such as the cloud condensation nuclei formation(Sipilä et al., 2016)); ii) evaluate the chemical composition of the annual snow layer to better understand to which extent different atmospheric, transport and climate processes can affect its chemical composition; iii) evaluate the effect of specific meteorological events, such as rain, snow melting events or rapid temperature excursions, to the observed chemical and physical structure of the annual snow layer; iv) evaluate the presence of new emerging contaminant such as microplastic in the snow strata.

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Atmopheric measurements over the sea
Using fixed and/or mobile platforms

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KEYWORDS: marine boundary layer; essential climate variables; radiation, aerosol

Introduction

To represent and predict realistically climate system behavior and climate change needs good representation and coupling of different domains and spheres. The importance of accurate fluxes of radiation, heat and momentum in the coupled ocean/atmosphere system has been acknowledged since the mid-1980s. Observing programs and process studies indicated accuracy goals for the measurement of net heat exchange across the ocean-atmosphere interface of ±10 Wm^{-2} over short to medium time scales. Despite a so clear evidence, nowadays the status of atmospheric measurements over the sea has not made sufficient progress. Shawn et al., 2019, presented the status of ship measurements: extended observations of atmospheric Essential Climate Variables (ECVs) are limited to standard meteo-parameters, while radiation and precipitation are less frequently measured, cloud observation carried out only manually, aerosol and flux measurements performed only on research vessels. The status of buoys observations, derived by OceanSITES database, in not different. If we add that sampling from research vessels often suffers from a lack of regularity, inducing seasonal biases in repeated sampling at given locations, and that, in contrast, commercial ships tend to traverse the ocean along traditional shipping routes, the gap appearsN very clearly and can't be covered by satellite observations. The urgent need to fill this gap has been clearly recognized by GCOS and SCOR, that endorsed an Observing Air-Sea Interactions Strategy (OASIS) working group (#162). Also Baseline Surface Radiation Network (BSRN) implemented a WG focused on observations over sea. A better knowledge of the processes involving aerosols in the marine boundary layer (MBL) would be very important for the impact they can have on cloud formation and properties. Nowadays, necessary developments are made possible by the potentiality that new technologies offer to implement more automatic measurements on both ships and buoy, also reducing dimension and weight, and need for maintenance. At the same time, improvements in communication would increase the possibility for near real time (NRT) data, with larger use in weather forecast operational models.

Activities

We started to consider these issues some years ago, focusing on the technological aspects of improving radiation measurements and to make automatic sun photometric observations of aerosol optical depth (AOD) over a ship. Prototypes have been developed, and at least for radiation a test campaign was performed during High North cruise in 2017. The new research vessel Laura Bassi offer us new possibility to plan permanent instruments installation and elaborate more ambitious projects, enlarging the topics of interest to MBL aerosol characterization and processes (including ice nuclei and biological matter) and to MBL dynamics. Radiation instruments as well as a sonic anemometer were acquired in the frame of a ship refitting, and installed in early summer 2021 for the first Arctic cruise of Laura Bassi and to collect data then in Antarctica during next austral summer PNRA campaign. A system to collect observations and transfer them in NRT was implemented and data are now flowing daily in Bologna. An all sky camera provides information on cloudiness. Images are acquired every 10 minute and stored on a NAS system on-board. Actual connectivity constraints prevent the possibility that these images are acquired in NRT. In addition to field activities and plans, in the frame of the EU project ARICE, our research group is promoting this topic of atmospheric measurements: April 2021 a workshop were organized to discuss gaps, challenge and opportunities for radiation, aerosol and boundary layer dynamic structure measurements on ships. We are also actively participating to the WG on sea measurements in the frame of BSRN.

Future developments

- fully develop the PNRA project and move forward cooperative activities in the Antarctic Ross Sea with KOPRI
- better connect activities focused on the atmosphere with the plan for synoptic arctic survey (SAS) and promote cooperation field activities in connection with OceanSITES network and BSRN WG on sea measurements
- complete the development of both the gyroscopic platform for accurate radiation and cloud measurements and the Mobile Platform Photometer (MPP) for automatic AOD observation on a ship.

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AT4

ARCTIC AMPLIFICATION: PROCESSES AND IMPACTS ON THE GLOBAL CLIMATE, THE ATMOSPHERIC CIRCULATION AND THE CARBON CYCLE

AdvanCing knowledge on the present Arctic Ocean by chemical-phySical, biogeochemical and biological obServAtioNs to preDict the futuRe chAnges (CASSANDRA)

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KEYWORDS: Arctic Amplification; Carbon Cycle; Greenland Sea Gyre

Introduction

The Arctic and sub-Arctic regions have been warming more than twice as rapidly as the rest of the world for the past 50 years. The Arctic climate has undergone tremendous changes, such as Arctic wetting, reduction of Arctic sea-ice thickness and coverage, decrease of snow cover extent and duration, thawing of permafrost and melting of Greenland ice sheet. The changes in sea-ice conditions in turn accelerate warming, by reduced summer albedo and through the additional heat flux from the ocean as more open water areas are maintained later into the Autumn. This positive feedback effect is among the main processes responsible for the "Arctic Amplification", which is likely to strengthen in the years to come. Arctic and sub-Arctic ecosystems are environmentally sensitive regions, where the impact of global climate change is expected to make marked changes over the next decades and more rapidly than elsewhere. However, many of its consequences have yet to be understood. In this context, the Arctic Ocean and its marginal seas remain profoundly understudied and among the least-known basins in the world ocean, due to their remoteness, hostile weather and the multi-year or seasonal ice-cover. Indeed, the Arctic Ocean plays a major role in the global climate system for the aforementioned changes in the extent and thickness of its iconic sea-ice but also because i) it is a crossroads of water masses advected and modified from the Pacific and the Atlantic oceans and ii) absorbs the excess of heat and salt provided by the Atlantic Water (AW) carried northward by the West Spitsbergen Current (WSC) along the Eastern Fram Strait (FS) and generates a returning cold and fresh flow transported by the East Greenland Current (EGC) along the western side of the FS. The exchanges and interactions between the two main currents of the FS, as well as the variability of the AW temperature flowing into the Arctic Ocean, are largely controlled by the response of the Greenland Sea Gyre (GSG) circulation to the overlying atmospheric forcing. The Greenland Sea is one of the key regions of deep ocean convection, an important process

for carbon sequestration and global ocean ventilation, and its dense waters feed the lower limb of the Atlantic Meridional Overturning Circulation (AMOC).
CASSANDRA aims at contributing to the Synoptic Arctic Survey (SAS; https://synopticarcticsurvey.w.uib.no) effort by studying in the summer 2021 a historical transect to 75°N crossing the GSG, and provides a temporal integration for a complete characterization of the Pan-Arctic hydrography and circulation, ocean acidification, and biological and ecosystem functioning and productivity.

Activities

SAS, to which CASSANDRA contributes, is a bottom-up initiative aiming to develop synoptic scale observations across the Arctic Ocean. SAS consists of regional shelf-to-basin ship-based coordinated surveys (2020/21) to generate a comprehensive dataset of essential ocean variables (atmospheric, chemical-physical, biogeochemical and biological) on a quasi-synoptic, spatially distributed basis. SAS aims to take a "picture" of the Arctic Ocean in as much detail as possible and to answer the main scientific question: what is the current state and major ongoing changes in the Arctic marine system? CASSANDRA project will carry out an oceanographic cruise from 29 August to 14 September 2021 in the GSG and the work plan has been designed to contribute to answer this question. The selected transect (75°N) is coincident with one included in the GO-Ship programme to take profit of historical records and plan future synergies. The multidisciplinary approach will be enlarged including a significant atmospheric component providing important "ancillary" measurements. Another important novelty is the great attention to common procedures in generating an unmatched dataset that allows a complete characterization of the Arctic Ocean hydrography and circulation, organismal and ecosystem functioning and productivity, carbon uptake and ocean acidification.

Future developments

SAS dataset will provide a unique and critically needed baseline for future studies and, at the same time, will inform and better constrain biogeochemical models.

The possible influence of Arctic Amplification in providing resilience to very small glaciers in the Julian Alps due to increase winter snowfalls

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KEYWORDS: Resilience, Cryosphere, Climate, Very small glaciers

Introduction

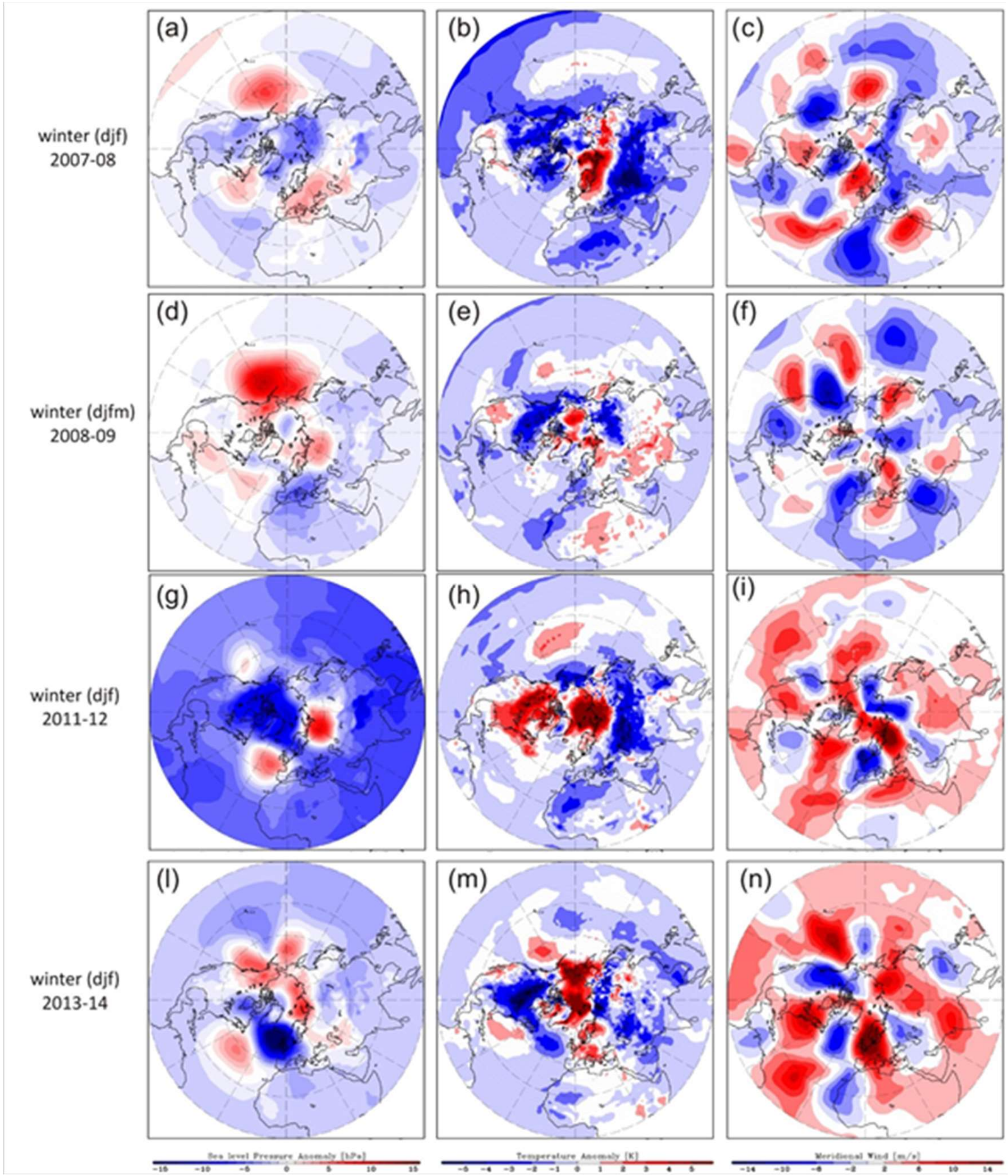
Very small glaciers (<0.5 km2) account for more than 80% of the total number of glaciers and more than 15% of the total glacier area in the European Alps. This study seeks to better understand the impact of extreme snowfall events on the resilience of very small glaciers and ice patches in the. southeastern European Alps, an area with the highest mean annual precipitation in the entire Alpine chain. Mean Annual precipitation here is up to 3300 mm water equivalent and the winter snow accumulation is approximately 6.80 m at 1800 m.a.s.l. averaged over the period 1979-2018. As a consequence, very small glaciers and ice/firn patches are still present in this area at rather low altitudes (1830-2340 m). The long-term evolution of these very small glaciers and ice bodies matches well with changes in mean temperature of the ablation season linked to variability of Atlantic Multidecadal Oscillation. Nevertheless, the recent behaviour of such residual ice masses in this area where orographic precipitation represents an important component of weather amplification, is somehow different to most of the Alps. We analysed synoptic meteorological conditions leading to the exceptional snowy winters in the 2000s, which appear to be related to the influence and modification of atmospheric planetary waves and Arctic Amplification, with further positive feedbacks due to changes in local sea surface temperature and its interactions with low level flows and the orography. Although further summer warming is expected in the next decades, we conclude that modification of storm tracks and more frequent occurrence of extreme snowfall events during winter are crucial in ensuring the resilience of small glacial remnants in maritime alpine sectors.

Activities

We perform repeated geodetic mass balance measurements on 14 ice bodies starting from 2006 and the results show more than 10% increase in ice volume over the period 20016-2018. This is in accordance with several extreme winter snow accumulations in the 2000s, promoting a positive mass balance in the following years. Development of new techniques and methodologies to improve the resolution and accuracy of mass balance measurements is also a target.

Future developments

In order to understand the key elements responsible of the observed winter precipitation increase, we need to develop new models taking in account both the changed weather patterns due to Arctic Amplification and global circulation, as well as the influence of local parameters such as the increased SST in the Mediterranean. This will be possible modelling the behavior of the low level jet below and above the boundary layer interacting with the alpine orography in maritime areas.



Northern Hemisphere sea level pressure anomalies, temperature anomalies and stationary Rossby wave pattern. (a) (d) (g) and (d) sea level pressure anomalies (from 1981 to 2010 climatology; 15 day mean, centered on January 2009 and 2014 respectively); (b) (e) (h) and (m) as (a) (d) (g) and (d) but for surface temperature anomaly (K), while (c) (f) (i) and (n) as the previous ones but for meridional (ms-1) in the upper troposphere (300 hPa) based on NCEP/NCAR data (Kalnay et al., 1996). Winters 2008-09 (DJFM) is based on longer period representative of most intense snow precipitation.

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Onset of Atlantification along the Fram Strait at the beginning of the 20th century

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KEYWORDS: Atlantification, Svalbard, AMOC, Subpolar Gyre

Introduction

Sea ice loss and expansion of Atlantic waters into the Arctic Ocean are considered as the preeminent examples of the recent changes occurring in the Arctic. This phenomenon, generally known as "*Atlantification*", is however poorly investigated in pre-industrial times.

Activity

Here, we combined a robust geochronology with biomarkers and microfaunal data to reconstruct the Atlantification at the gate of the Arctic Ocean (Kongsfjordern, Svalbard; Fram Strait) using a sediment record. We found that the Atlantification began in the early XX century, much earlier than the modern documented changes. Our results suggest that the heat transport to the Fram Strait suddenly increased in the early XX century because of reduced surface heat loss at subpolar latitudes which, eventually, initiated the Atlantification. Overall, our study provides the first historical perspective on the Atlantification and reveals Subpolar-Polar connections, much stronger than previously thought, which are capable of shaping the Arctic climate variability. The signs of Atlantification documented in this study are currently not reproduced in climate simulations participating in the Climate Model Intercomparison Project Phase 6 (MIROC-ES2L and MRI-ESM2.0). Overall, this implies an incomplete process understanding of climate forcing during the industrial era.

AT5

BIOMES (FROM MICRO- TO MACRO-) IN A CHANGING CLIMATE: LOCAL AND GLOBAL EFFECTS

The microbiology of Antarctic briny systems read in an astrobiological key

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KEYWORDS: cold-adapted prokaryotes; liquid brines; microbial activities; microbial abundances

Introduction

In continental Antarctica, lakes are often characterized by the presence of icing blisters, which develop annually on their surface. Differently from their Arctic counterparts, Antarctic icing blisters mostly derive from the generation of hydrostatic pressures by the progressive freezing of high salt-content water beneath the lake-ice cover during winter. In fact, even if the lake ice cover never melts, heating by direct insolation or enhanced thaw and seepage at the permafrost table probably allow free water, in the form of liquid and saline brine lenses, to accumulate beneath the lake-ice cover in warmer periods. Studying briny ecosystems is multifaceted. It assumes particular relevance not only for geological aspects, but also for unravelling the functional potential and roles in biogeo-chemical cycling of the psychrophilic lifeforms. Microorganisms inhabit such extreme environments on Earth, which are also intriguingly similar to other worlds within our Solar system. Current knowledge about the drivers of prokaryotic diversity, distribution and metabolism in Antarctic briny systems is patchy and therefore deserves to be deepened. Since 2014, we are focusing our attention on the microbiology of brine pockets from lakes in the Northern Victoria Land (NVL), lying in the Tarn Flat (TF) and Boulder Clay (BC) areas. Overall, the prokaryotic community included methanogens, strictly anaerobes, halophiles and (hy-per)thermophiles. Diversification in terms of abundance, metabolic potentials and enzymatic activities of the prokaryotic assemblages among the examined brines was highlighted. In Tarn Flat brines, previous analyses found the presence of proteolytic activity, as well as a comparatively lower alkaline phosphatase activity than in Boulder Clay. Enzymes able to degrade polysaccharides were also detected, whose hydrolytic activity rates were quantitatively different between the studied samples. Conversely, in Boulder Clay, microbial community was mostly active in the decomposition of organic phosphates and lower proteolytic and glycolytic activity rates were recorded. Moreover, decreasing patterns of aminopeptidase and phosphatase activities were observed with increasing depth of the collection site. These peculiar features were ascribed to a lot of factors including brines' historical origin, depth horizon, time of segregation. The prediction of metabolic functions highlighted that prokaryotic communities are presumably involved in methane metabolism, aromatic compounds biodegradation and organic compounds (proteins, polysaccharides, phosphates) decomposition.

Activities

Activities are part of different PNRA projects (e.g. IPECA). Brines are analysed for the prokaryotic component by culture-dependent and -independent approaches, including microbial activities, abundance and biomass, bacterial isolation and characterization (both phenotypic and genotypic), bioprospecting on cold-adapted bacterial isolates (screening for the production of biotechnologically relevant biomolecules), bacterial ability to degrade organic pollutants, prokaryotic diversity by next-generation sequencing.

Future developments

Some authors have speculated on the possible existence of Northern Victoria Land environments with similar chemical and physical features on the Martian surface, while subsurface origin of brines resembles physical conditions on the icy moons Enceladus and Europa, both characterized by a high habitability potential. In an astrobiological key, analyzed brines could represent a second-order terrestrial analogue environment giving us the opportunity to investigate planetary habitability by the exploration of diversity and activity of extremophilic microorganisms. The exploration of terrestrial analogues represents a unique opportunity to gain a "*critical ground-truthing for astrobiological studies*" also in terms of detectability of biosignatures and potential for the long-term preservation of signs of past life. As potential astrobiological targets, the exploration of brines, and their psychrophilic microbial inhabitants (both in terms of diversity and activities), on Earth becomes incredibly sounding for our comprehension of the boundaries of life on Earth and the development of scenarios for planetary habitability.

Benthic filter-feeders at the Poles: searching for factors shaping the associated prokaryotic communities

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KEYWORDS: diversity; co-evolution; cold-adapted bacteria; metabolic activities

Introduction

Studies of bacterial communities living in association with benthic invertebrates from temperate and tropical climates have largely reported. The associated communities generally differ from those in the water column, thus displaying host-specificity, and they often vary between habitats and seasons. Several factors, both environmental and biological (including the age and health state of the host, the production of organic metabolites and extracellular polymers), may influence the colonization of living surfaces, both inner and outer portions. Bacterial epi- and endobiotic associations play an important role in the development and evolution of an organism interactions. These associations require the establishment of complex signal communication systems and fine regulating processes between the host and its symbionts, as well as within the symbiotic community itself. This is particularly true in extreme and isolated environments where the host and the symbionts often evolve together establishing peculiar and strict interactions. One would imagine that at low temperatures life is sporadic or somewhat static, remaining in a suspended state. However, this is not the case in polar environments. Despite the incredibly harsh conditions in extremely cold habitats preclude life in most of its forms, microorganisms become dominant in terms of biodiversity and biomass by adopting peculiar survival strategies. Not only microbes, but even invertebrates can also reproduce and complete their life cycle at low temperatures.
The ecological function of bacteria-invertebrate interactions in Polar areas remains poorly understood, despite increasing evidence that microbial metabolites may play pivotal roles in host-associated chemical defence and in shaping the symbiotic community structure. An additional factor to be considered is the contaminant accumulation in the organism tissues, even in remote areas. In fact, filtering large volumes of water, filter-feeders accumulate contaminants (both legacy and emerging) in their tissues, and the associated prokaryotic communities may be particularly responsive against them.

Activities

As part of different research projects (e.g. PNRA, INTERACT and ASSEMBLE plus), experiments are carried out on benthic filter-feeding invertebrates (mainly Porifera) collected from: *Terra Nova Bay* (Ross Sea, Antarctica), *Adelaide Island* (Rothera, Antarctic Peninsula), *Isfjorden* (Svalbard Islands, High Arctic Norway) and *Pasvik River* (Arctic Norway). In the case of sponges, particular attention is given to the Antarctic species *Mycale acerata* Kirkpatrick, 1907, *Dendrilla antarctica* Topsent, 1905 and a new species in the genus *Haliclona* (taxonomic classification is in progress). In the Arctic, a focal point is the riverine sponge *Spongilla lacustris* (Linnaeus, 1759). Main aims are: *a)* assessing if the associated prokaryotic communities are environment- or sponge species-driven, by comparing results deriving from abiotic matrices (water and sediment) and (when applicable) the same species but collected from different areas (biogeographic purposes), thus extending the investigation across different, and differently human-affected, regions; *b)* exploring the chemical contamination (both legacy and emerging contaminants) in organism tissues in comparison to sediment and seawater; assessing if pollutants can induce alteration in the prokaryotic community composition; *c)* investigating the response of the prokaryotic communities to selected contaminants in enrichment cultures, evaluating the population dynamics; *d)* searching for biomolecules or activities (e.g. antibiotic activities and extracellular polymeric substances) that could be involved in bacterial colonization of organism surfaces,

Future developments

Projects will benefit of the integrated collaboration of BAS (UK), INACH (Chile), GEMA (Chile), Universidad de Concepción (Chile), IOPAN (Poland), and NIBIO (Norway) partners for sampling (where requested) and data elaboration process. This will enable strengthening international network, and a more efficient coordination, sharing and utilization of resources and data.

The biotechnological relevance of cold-adapted bacteria

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KEYWORDS: biotechnological potential; cold-adapted bacteria; biomolecules; biodegradation

Introduction

Bioprospecting is an emerging and fascinating branch of the marine research, which aims at exploring biological matrices as sources of new natural compounds with biological activity and possible commercial exploitation. The search for new molecules with biocompatibility and safety features has been strongly encouraged to avoid the use of synthetic compounds that could be very deleterious for the ecosystems. In comparison to land resources, aquatic environments remain still largely underexplored for bioprospecting aims, despite their undisputed ecological value as harbouring system of highly diversified communities of living being. Moreover, the possibility to find new biologically active molecules with thermal stability and specificity is higher in (micro)organisms from extreme environments, such as cold habitats, due to the development of unusual metabolic and physiological adaptations. The exploration of such biologically diverse resources can lead to the identification of novel natural products or chemical scaffold(s) with biotechnologically relevant bioactivity. Cold-adapted bacteria can proliferate in biotic and abiotic matrices of Arctic and Antarctic aquatic environments, including seawater, rivers and lakes. They are subjected to restrictive environmental conditions on a long timescale. To surmount the negative effects of low temperature (alone or in concomitance with further environmental constraints), cold-adapted bacteria have successfully evolved a variety of structural and physiological modifications. Most of their phenotypic changes may be permanent and genetically regulated, and not merely driven by a short-term acclimatization. Recently, the application of novel "multi-omic" approaches (including metagenomic, metatranscriptomic, and metaproteomic analyses) evidenced the presence of a highly diverse set of metabolic features to thrive in the cold, by the acquisition of information related to the functionality of genotypic traits. As a general conclusion, cold-adapted bacteria downregulate primary metabolism under cold conditions and activate non-classical metabolisms for a cold lifestyle. All these complex and sophisticated survival strategies and unusual features can often rely on the synthesis of still undisclosed natural biomolecules with unique properties for adapting to extreme environmental constrains, thus making cold-adapted bacteria valuable resources for biotechnological purposes. Beside the production of biomolecules, cold-adapted bacteria could find possible application also in the removal of organic contaminants (e.g. hydrocarbons, polychlorinated biphenyls) from cold environments under *in situ* conditions.

Activities

As part of different research projects (e.g. within PNRA, INTERACT and ASSEMBLE plus programs), experiments are carried out on cold-adapted bacteria mainly isolated from *Terra Nova Bay* (Ross Sea, Antarctica), *Adelaide Island* (Rothera, Antarctic Peninsula), *Byers Peninsula* (Antarctic Peninsula), *Isfjorden* and *Kongsfjorden* (Svalbard Islands, High Arctic Norway) and *Pasvik River* (Arctic Norway). Different environmental matrices (e.g., seawater, freshwater, hypersaline brines, sediment, glacier ice) are taken into consideration, but particular attention is given to bacteria associated with benthic filter-feeding invertebrates. In fact, the versatility of their natural products remains virtually unexplored, even if they could represent a new attractive frontier in the search for novel natural compounds. Bacteria are screened under laboratory conditions to test some ecological aspects with relapses on biotechnological applications, such as biological surface colonization (production of exopolysaccharides, antibiofilm and antimicrobial activities), adaptation to the cold (e.g., production of extracellular polymeric substances), utilization of organic contaminants (e.g., biodegradation capabilities at low temperature, production of biosurfactants eventually enhancing the biodegradation efficiency). More interesting isolates are fully characterized (genotypically and phenotypically), also for possible pathways responsible for detected activities.

Future developments

Projects will benefit of the integrated collaboration of IOPAN (Poland), NIBIO (Norway) and University of Valencia (Spain) partners for sampling (where requested) and data elaboration process, thus it will enable strengthening international network, and a more efficient coordination, sharing and utilization of resources and data. Next steps will deepen the structural properties of produced biomolecules and their applicability in the biotechnological field.

Microbiological and environmental surveys in rivers at the Arctic cap of Europe: ongoing INTERACT projects

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KEYWORDS: prokaryotic diversity; microbial abundance; metabolic activities; environmental contamination

Introduction

As a consequence of local and global human activities, Arctic environments are not exempt from anthropogenic contamination. Since many years, in the framework of the Transnational Access Program INTERACT, we have been dealing with the environmental microbiology and chemistry of the Pasvik River, in the northern Fennoscandia (Arctic Norway), aiming at contributing to the assessment of the environmental status of this human-impacted Arctic system. First activities (as part of three past INTERACT projects, i.e. *MicroRem*, *SedMicro* and *SpongePOP*) were focused on the response of the bacterial communities in water and sediment to heavy metal (HM), polycyclic aromatic hydrocarbon (PAH) and polychlorobiphenyl (PCB) contaminations, and on a preliminary characterization of the chemical-physical features of the river. In 2014, within the project *SpongePOP* a two-season campaign was carried out to survey sessile benthic filter-feeding invertebrates (suitable biomonitoring systems and sentinel species) for further developments. The choice to analyse such organisms was based on their trophic strategy. Filtering large volumes of seawater, filter feeders capture suspended particles, including prokaryotes, and accumulate contaminants in their tissues. In cold environments, the reduced metabolic and growth rates of organisms, due to the low water temperature, promote high concentrations of contaminants in the biota. The fate of pollutants is strictly linked to bacteria, representing the first step in the transfer of toxic compounds to higher trophic levels. Thus, there is the increasing possibility to retrieve symbiotic prokaryotes able to degrade or tolerate such compounds, with important relapses in the biotechnological field. The individuation of *Spongilla lacustris* (Linnaeus, 1759) specimens in the Pasvik River paved the way for future analyses. During summer 2021, within the recently granted INTERACT project "*Benthic filter-feeding Invertebrates from the Arctic as accumulators of Pollutants and tolerant bacterial communities* – **BIP**", *S. lacustris* was collected along the Pasvik River, together with sediment and water samples. Differently to previous projects, the chemical survey will be extended also to emerging contaminants of particular concern, including antibiotics.

Activities

The main objective of BIP will be putting in relation the amounts of the selected pollutants detected in biotic and abiotic riverine matrices to the occurrence of HM-tolerant, PCB/PAH-degrading bacteria, and antibiotic resistant bacteria. A preliminary survey will be done to determine the occurrence of microplastics in the analysed samples, and adsorbed contaminants and bacteria (including pathogens). The following steps are envisaged: *a)* chemical analyses of *S. lacustris* and the bulk environment (water and sediment) to determine HM, PHA, selected pharmaceutical product, antibiotic and PCB concentrations; preliminary search for the occurrence of microplastics in the analysed matrices; *b)* phylogenetic characterization of the prokaryotic communities associated with sponges, water and sediment, and microplastics; *c)* exploring the pollution level and the spread of antibiotic resistance in sponges and abiotic matrices, as well as linking such data with the self-depuration feature of the environment due to the occurrence of bacteria able to cope with contamination; *d)* enrichment cultures with selected contaminants for the isolation of bacteria with biodegradation capabilities at low temperature; *e)* screening of bacterial isolates for determining their susceptibility to the main categories of antibiotics; *f)* characterization of promising bacterial strains by standard phenotypic assays and biomolecular techniques; g) comparison with results previously obtained from the same area to achieve advanced knowledge.

Future developments

Further information on the issue will be gained by extending the analyses reported above to a second River in the Northern Fennoscandia, the Teno River in Finland, within the INTERACT project "*SearChIng for EmeRging Contaminants in Sub-Arctic rivErs* – **CIRCE**", whose sampling activities are programmed for Summer 2022. This will allow a comparison with results from previously granted INTERACT TA projects on the Pasvik River.

Ecosystem indicators from cumulative biomass curves in the Barents Sea

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KEYWORDS: Ecosystem Approach, fish assemblages, emergent properties, food-web

Introduction

Trophodynamic indicators derived from biomass accumulation across trophic levels (CumB-TL) combine important emergent ecosystem properties (i.e. energy flows and biomass accumulation), and respond to changes in environmental conditions and ecosystem perturbation[1]. In the Barents Sea, food-web structure and complexity varies across environmental gradients and habitat heterogeneity[2].

Activities

In this work, data of fish assemblages from the bottom trawl surveys[3] carried out by the Norwegian Institute of Marine Research (IMR) were used to compute indicators derived from the CumB-TL curves (steepness, biomass and TL at the inflection point) to perform a preliminary comparison with the main food web types in the Barents Sea.
The simpler, more modular food-web, typical of the northeast Arctic, seems to be associated with less steep curves with inflection at relative low biomass and TL (Fig. 1), while the Svalbard Archipelago and southeast-shallow food-webs, with a relatively high number of species and link density show higher steepness in the cumB-TL curves, even with different inflection points.

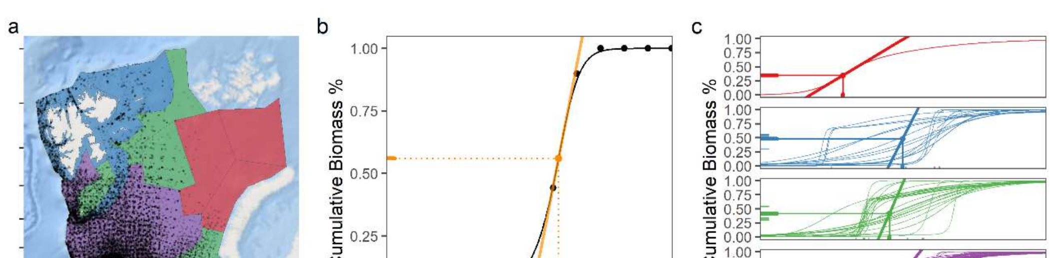

Fig. 1. Map of the 25 sectors in the Barents Sea, classified according to the main food-web regions[2] and distribution of IMR bottom trawl sampling points in the period 2004-2007[3] (a); example of a biomass accumulation curve with the fitted curve (black line) and the estimated steepness (maximum slope; orange line) and the inflection point with its biomass (orange y-axis rug) and TL value (orange x-axis rug) (b); fitted curves (thin lines), average steepness and inflection point biomass and TL for the four regions (bold lines and rugs; c)

Future developments

In the next phases the focus will be on a) quantifying the relationship among cumB-TL curves characteristics and environmental conditions; b) assess the association among curves properties and food-web structure and assemblages composition and functional diversity; c) evaluate the response of cumB-TL curves to anthropogenic impacts, such as presence of pollutants or resources exploitation. This will represent the basis to use trophodynamic indicators to reconstruct the evolution of the ecosystem in the last decades, in order to disentangle the effects of climate change to the ones of other human impacts.

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AT6

AIR-WATER-EARTH-FIRE: INTERCONNECTIONS TO ADVANCE IN THE KNOWLEDGE OF THE FUNCTIONING OF POLAR ECOSYSTEMS

Biogenic aerosol: the ocean/atmosphere interaction

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KEYWORDS: Biogenic aerosol, Chl-a, ocean/atmosphere interaction

Introduction

Quantifying the response of climate to anthropogenic forcing is one the most discussed topic in recent time. It has been postulated that the marine biosphere may induce a feedback through dimethylsulfide (DMS) emissions but there are still large uncertainties in both the sign and the amplitude of this feedback (Quinn and Bates, 2011). A coupled ocean-atmosphere model forced by increasing atmospheric CO_2 suggested a negative feedback with enhanced DMS fluxes up to 30% for a doubling of CO_2 (Bopp et al., 2003). This coupled model predicts reasonably well the oceanic DMS distribution for the present-day situation except very high concentrations due to spring and summer blooms of *Phaeocystis* at high latitudes. Therefore, the response of marine biota to climate change in these regions remains essentially unknown. Besides, increasing attention is given in recent time to the role of the biogenic aerosol arising both from secondary processes (DMS oxidation to methane sulfonic acid: MSA and non-sea salt sulfate: $nssSO_4^{2}$) and primary organic biological aerosol (released from living phytoplankton, either directly or by cellular lysis of senescent algae, bacteria activity and biological degradation) in cloud condensation nuclei (CCNs) and ice nuclei (INs) formation in polar region (Wex et al., 2019; Jang et al., 2019; Ki-Tae et al., 2021). For these reasons to obtain information relative to the role of climatic conditions on oceanic biogenic emissions at high latitudes is of relevance also because data from these regions remains very sparse.

Activities

To understand the processes related to the ocean/atmosphere interaction the activities have to combine in situ marine measurements in the sea with atmospheric measurements. Due to the multidisciplinary of the topic, the activities have to be performed in collaboration with different Italian and International research groups active in polar regions having different expertise. The activities can be summarised as follow:

- Acquisition of phytoplankton biomass time series through both on field and satellite measurements.
- Determination of gaseous DMS in the atmosphere emitted by phytoplankton (in collaboration with KOPRI for the Arctic and with IGE for Antarctica.
- Determination of the ionic composition of the aerosol focusing on compounds of biogenic aerosol arising from DMS oxidation processes in the atmosphere (MSA and $nssSO_4^{2-}$).
- Determination of organic compounds related to the presence of aerosol arising from phytoplankton (carbohydrates and L-amino acids), from bacteria (D-amino acids) and from lignin degradation, phytoplankton and biomass burning (methoxy phenols).

- Determination of the synoptic conditions, and calculation of backward trajectories to be associated with the collected samples, aiming at identifying source regions, transport pathways, and transit times in the atmosphere.

Future developments

The above reported activities were performed in the Antarctic campaign 2018-19 and 2019-20 in the framework of the PNRA_16 BioAPRoS (Correlation between biogenic aerosol and primary production in the Ross Sea) project at the Italian coastal base "Mario Zucchelli Station" in Antarctica and in May-June 2019 in the framework of SIOS_2018 BioAPNEA (Biogenic Aerosol, oceanic Primary production, and Nucleation Events in the Arctic) at Ny Alesund in the Arctic. These campaigns produce a huge amount of data and very good results, and high-quality publications are in progress, but to really understand such a complex interconnection long term monitoring studies are necessary.
Besides, to understand the role of atmospheric deposition of nutrients and oligoelements supply to the ocean primary productivity, the collection and chemical measurements on deposition (snow) and sea water could be achieved for the future.

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Controlled vocabularies for polar activities

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KEYWORDS: cryosphere, terminology, ecology, biodiversity

Introduction

Controlled vocabularies are useful tools for organizing information. They help to correctly use the specific language of a certain discipline for the description, cataloguing and information retrieval of databases and objects produced by research activities. They also help to enhance semantic interoperability. A controlled vocabulary collects variants and synonyms of concepts linked together in a logical order or sorted into categories. The polar sciences and the cryosphere utilise a specific language characterised by cross-disciplinarity that often requires disambiguation of the meanings of terms.

Activities

SnowTerm is an example of a structured reference multilingual scientific and technical vocabulary, covering the terminology of a specific knowledge domain such as the polar and the mountain environment. The thematic areas deal with snow and ice physics, snow and ice morphology, snow and ice radiometry, remote sensing and GIS in cryosphere environment, sea ice, avalanches and glaciers. At present, the SnowTerm database contains around 3,700 terms mainly in English and Italian.

BiodivThes represents a vocabulary of terms covering the field of environment, ecology and biological diversity. It includes both biotic and abiotic concepts. BiodivThes contains around 1,800 terms in English and Italian.

For both vocabularies the identification, acquisition and harmonisation of controlled multilingual terminologies brought to the development of a complete basic reference list of terms in English, partially multilingual which was then expanded and further structured.

The terminology of these sources was analysed concerning the degree of semantic relevance in the field excluding both terms too generic or considered as non-pertinent.

For the vertical structure of the vocabularies, we adopted the Classification Scheme already in use for the development of the CNR EARTh Thesaurus. The hierarchical setup is based on facets (a principle of division of a category or class that guides the activity of grouping and separating -classifying- concepts); according to its intrinsic features, the structure can be used as a semantic reference system, stable and partially independent from the context.

Future developments

The creation and maintenance of terminology tools is a never-ending task that is constantly being updated.

Presently we are implementing a glossary and thematic structure for both vocabularies. The possibility of applying different thematic schemes could allow the exploration of concepts according to different perspectives, which may emphasize particular and contingent aspects.

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An ecological approach to evaluate the fate and effects of organic contaminants in polar ecosystems

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KEYWORDS: microcosm, pollution, multidisciplinary approach, field monitoring program

Introduction

Over the last decades, the increasing population, development of human activities, higher well-being demand and worldwide production of synthetic xenobiotics have reached a level that could result in abrupt and irreversible environmental changes [1]. Xenobiotics can be transported from various emission sources to Arctic regions by sea currents (including sea ice trapping contaminants during the freezing process), rivers, atmospheric currents and migratory animals. Many of these contaminants are persistent and toxic compounds (e.g. persistent organic pollutants), for which have been set environmental concentration limits and/or have been completely banned from the worldwide market (e.g. polychlorinated biphenyls). Other chemicals named “Emerging Compounds” (ECs, including pharmaceuticals and personal care products), which use is not regulated by legislation, need to be more investigated due to the lack of exhaustive knowledge on their ecotoxicological and toxic effects [2-3]. Once released into the environment, chemicals can persist for a long time causing the malfunction of one or more components of ecosystems [2-3]. The environmental impact of organic pollution can be extremely diversified and not easily predictable [1-2]. The polar regions are very sensitive to contamination due to extreme seasonal light variation, low temperatures, short growing seasons. Pollutants can have direct toxic effects on particular taxa or trophic groups (invertebrates, microorganisms, or plants) or indirect ones by changing predator/prey relationships, causing repercussions on the complex food web, affecting ecosystem structure and functioning.
In this context, the study of environmental contamination, especially in polar regions, requires an ecological approach combining several scientific disciplines and according to the “One Health” concept. The latter recognizes that the health of people is closely connected to the health of animals and our shared environment.

Activities

An exhaustive evaluation of environmental issues can be performed by combining integrated field monitoring programs and laboratory-scale experiments. Field experiments are often hampered by high environmental variability and poor reproducibility. In natural environments, different biotic (e.g. living organisms at different trophic levels) and abiotic factors (e.g. natural disturbance, weather events, co-presence of contaminants, acidity, temperature) can affect the degradation of organic pollutants as well as their dynamics and effects on the ecosystem. The combination of laboratory-scale experiments and field monitoring programs is thus crucial for the comprehension of the environmental contamination issue.

In this context, microcosms are ecosystem models in which a portion of the natural environment (soil or water comprehensive of autochthonous biotic communities), is circumscribed and studied under controlled conditions (e.g. light, temperature, presence/absence of microorganisms etc). This site-specific approach makes it possible to assess specific processes such as the persistence of organic contaminants and the eventual formation of hazardous metabolites, their effects (as single compound or in mixtures) on the microbial community and on target organisms (ecotoxicological tests) and so on. Therefore, the interpretation of data obtained by *in-situ* measurements can be integrated with lab-scale microcosms experiments to better understand real environmental processes in a more holistic approach.

Future developments

In the wake of climate change, industrial development and tourism are expected to increase in the Arctic regions, leading to temporal human population increase in these ecologically sensitive areas, where infrastructure such as wastewater treatment plants are general lacking. The determination of the sources and effects of organic contaminants at high and medium latitudes and the estimation of their residence times in polar ecosystem, are key issues that directly affect the ability of environmental managers to assess the ecological effects and mitigate their impact. In this context, the future developments will be addressed to the evaluation of the occurrence of ECs in remote areas, with particular attention to antibiotics, antibiotic resistence genes and personal care products, as indicators of anthropogenic pollution.

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AT7

THE CARBON CYCLE IN POLAR ENVIRONMENTS: GEA AND BIOS IN A CHANGING CLIMATE

The role of the microbial community in the carbon cycle

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KEYWORDS: Carbon Cycle, microorganisms

Introduction

Despite the recent increase in knowledge concerning microorganisms, the processes determining their global distribution and functioning have not been disentangled. Although the individual biomass of microorganisms is quite negligible, they represent a major proportion of Earth's biomass due to their extremely high abundances, becoming therefore key players in the global carbon cycle. The polar environment has traditionally been considered too harsh for significant microbial activity to occur. It has long been considered that any lifeform, if present at all, was either dormant or functioning sub-optimally, as living organisms must be well adapted or highly resistant to extremely cold and desiccation conditions, low nutrient availability and seasonally variable UV radiation levels to survive. However, it is now clear that microbial presence is ubiquitous across the polar regions, and recent insights into the polar aerobiome point toward a potentially dynamic polar microbial community and, therefore, the possibility of significant microbial activity within the snowpack, even in the most remote locations. Research into the aerobiome has also demonstrated that microorganisms in aerial fallout may remain both viable and active. Furthermore, the presence of microbes in remote, low nutrient, low water, very cold environments such as polar glacial surfaces is now well established for several key sites.
Microbial life is ubiquitous in the Earth and if in some remote polar sites it does not exist, we should ask why there is not there!

Activities

At present the authors have several active projects in Antarctica (PNRA: SIGNATURE; IPECA; RESTORE) and the Arctic (PRA: CASSANDARA), also having the study of the carbon cycle among their objectives. These projects (sampling both marine and terrestrial environments) aim at studying and quantifying the carbon metabolized by microorganisms in the marine epi-, meso- and batipelagic areas, in the soil and in the active layer of permafrost, in intrapermafrost liquids and in the atmosphere. The challenges are many but the most difficult one is to look at all the sectors where microbes live in their entirety and not separately.

Future developments

We believe that a transdisciplinary approach is needed to fully disentangle the microbial role on Earth. Future studies should include a collaborative effort that encompasses not only the expertise of environmental microbiologists (atmosphere, oceans, soils), as well as ocean, soil, and atmosphere scientists.

Employing remotely operated devices to study fish communities in Antarctic waters

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KEYWORDS: fish communities, underwater photographic survey, Antarctica

Introduction

There is a long history of employing seabed photography to investigate composition, spatial distribution and habitat preferences of benthic communities, but it was rarely used in the Southern Ocean. It is a nondestructive and effective survey method, allowing a finescale description of benthic assemblages while minimizing the impacts of direct sampling. Using both still and video cameras mounted on remotely operated vehicles (ROV), it is possible to acquire data on species composition, population structure, relative abundance and fish behavior.

Activities

Since 2013, we have applied this methodology opportunistically, by scrutinizing thousands underwater images on macrobenthic benthic fauna collected along transects by means of an ocean floor observation system (OFOS) developed at the Alfred Wegener Institute of Bremerhaven (Fig. 1). We provided useful insights on species composition, behavior, spatial distribution and preferred habitats of local demersal fish assemblages from different Antarctic areas, including the Amundsen Sea (Eastman et al. 2013), the Weddell Sea (La Mesa et al. 2019) and the Antarctic Peninsula (La Mesa et al. 2021).

Future developments

As a future development we would like to extend this kind of methodological approach to other Antarctic areas, focusing our attention especially to marine protected areas, such as the Ross Sea, where the use of low-impacting methods of investigation is particularly advisable.

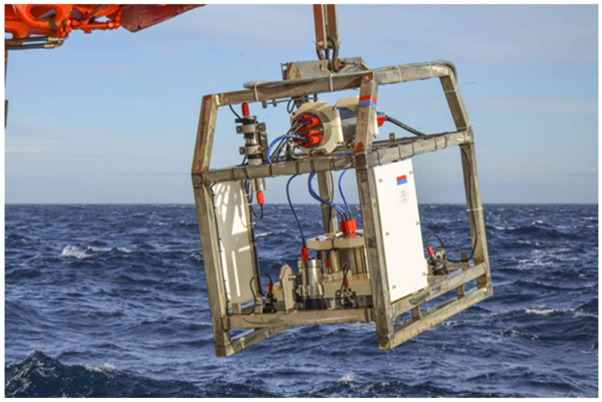

Fig. 1. The Ocean Floor Observation System (OFOS) developped at the Alfred Wegener Institute (AWI).

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Response to changing temperature in soils

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KEYWORDS: Soil organic matter, temperature, climate change

Introduction

Soil Organic Matter (SOM) at the global scale store about 2400 Gt of C, more than plants and atmosphere combined. Numerous studies have shown the warming effects on soil carbon dynamics. The response of SOM degradation to increasing temperature due to climate change is cause of concern for the possible positive feedback triggered by the release of CO_2 by soil respiration. Because soils contain three times as much C as the atmosphere and 240 times the annual emissions from fossil fuel combustion, also small changes in carbon stored in soils if relocated into the atmosphere, could cause positive feedback. Furthermore, soils in alpine areas, as well as other cold ecosystems such as Arctic and Antarctica, store large amount of C due to lower temperature that limit microbial activity and allow the storage of C for long period of time. Climatic conditions, specifically temperature and precipitation are important drivers in carbon storage because they can affect both C input and output.

Activities

To study the SOM response in soils to climate change we analyze organic carbon (OC), total nitrogen (TN), the labile fraction through the dissolved organic carbon (DOC) and the SOM degradation using stable isotope signature ($\delta^{13}C$ and $\delta^{15}N$) in samples from three different alpine sites located within the Stelvio National Park. These sites are three different mountain ecosystems: a bare ground, an alpine grassland, and a pasture. Also in vegetation we determined $\delta^{13}C$ and $\delta^{15}N$ to evaluate their different response, if any, to climate changes.

Future developments

Application of analytical methods to soils and plants in Artic and Antarctic environment. As part of the PNRA2018 BioCyCLeS project, a multidecadal characterization of SOM in Antarctic ice-free areas in response to global and local climate variations will be performed through the study of OC, TN and lipid biomarkers. These areas are very fertile for the development of algal and bacterial communities, being one of the liveliest and most sensitive areas in continental Antarctica. Samples cover a period of about 25 years, from the 1990-91 to the 2013-14 Antarctic campaign.

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AREA TEMATICA: AT8
EARTH OBSERVATION AND MODELING FOR THE ANALYSIS OF THE TERRITORY, POLAR ECOSYSTEMS AND AIR-SEA-ICE INTERACTIONS IN COASTAL AREAS

Deep learning-based ship detection in SAR images for fishing effort estimation in the Barents Sea

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KEYWORDS: Earth Observation; Barents Sea; Sentinel 1; fishing grounds

Introduction

The Barents Sea ecosystem showed a rapid warming trend since the mid-1980s, driving geographic shifts in biological communities, including commercially valuable species, and inducing changes also in the exploitation patterns. In this context, ocean monitoring using earth observation data from various sources allows to better understand the possible evolution of different human activities. In particular, the detection of fishing vessels represents an efficient tool to describe the exploitation pressures occurring on specific marine areas and to support fisheries management.

Activities

A Convolutional Neural Network (CNN) object detection algorithm has been trained to detect ships within Sentinel 1 Synthetic Aperture Radar scenes and compared to the performances of the Constant False Alarm Rate (CFAR) algorithm. A preliminary dataset has been set up combining Sentinel 1 data acquired between September and October 2020, processed as pseudo-RGB images using different polarizations as channels[1], and coupled with available Automatic Identification System (AIS) data. The scenes were split in small tiles and manually inspected to define bounding boxes containing ships. The SSD MobileNet V2 FPNLite 640x640 [2,3] has been trained, showing encouraging performances when evaluated on a small test dataset (not used for training), with an average precision of 0.759 and a recall of 0.459 (Fig. 1).

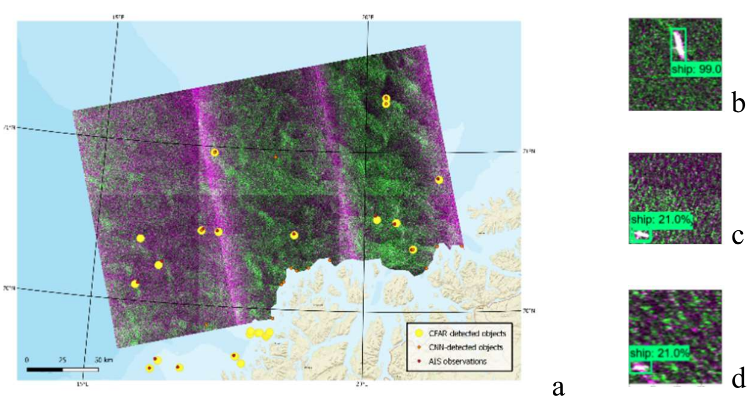

Fig. 1. Example of a processed SAR scene (a; acquired in September 19th 2020), and a focus on a successful identified ship (b), a ship with an inaccurate low score (c), and a non-ship object with an low score (d).

Future developments

The next steps will focus on: 1) building an extensive training dataset (labelling SAR imagery coupled with AIS); 2) test alternative network architectures, evaluating the performances taking into account the potential confounding presence of sea ice and the characteristics of the local fleet[1,4]; 3) systematically process Sentinel 1 archives, to estimate the dynamic of ships distribution in the study area.

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Sinergy of satellite altimetry and in-situ observations near Ny-Ålesund

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KEYWORDS: Satellite Altimetry, Sea Level, Arctic Ocean, sea ice

Introduction

The interactions between the ocean, the ice and the atmosphere in the Arctic are deeply influenced by the alternance of open sea and sea ice zones, which therefore contributes to the Arctic climate change. Ice openings can be detected by satellite altimetry [Müller et al., 2017], which also enables the estimate of sea ice freeboard, absolute sea level rise, sea surface wind and sea state. Consistent and long-term satellite-based datasets for climate studies of sea level are available nowadays. Among them, the climate-oriented altimeter sea level product of the European Copernicus Climate Change Service (C3S) extends from 1993 to present over the global ocean at 0.25˚of resolution. It covers the Arctic up to the latitude of 81.5 N (about 950 km from the North Pole), including the coastal area surrounding Ny-Ålesund (Svalbard Islands, Norway). Here, a tide gauge (TG) and several global positioning system (GPS) stations are active since the beginning of the altimetry era. Near coast, the along track surface height observations of the CryoSat-2 mission (CS-2) are also available, through the European Space Agency's Grid Processing on Demand (G-POD) for Earth Observation Applications facility. CS-2 observations cover the global ocean from 2010 to present. The sea region east of Svalbard therefore represents an ideal laboratory, where several aspects of the ocean, ice and atmosphere interaction can be studied with high quality and high frequency in-situ and remotely sensed observations.

Activities

As a starting point, we have compared sea level measurements from the Ny-Ålesund TG with the gridded C3S altimeter sea level data and with the along track observations of the CS-2 mission. We have found that: 1. the absolute sea level trend of C3S and CS-2 data moving from near- to off-shore increases (Fig. 1); 2. the differences between satellite altimetry and TG sea level can be used as a proxy to estimate the vertical land motion (VLM) in Ny- Ålesund, as done in Vignudelli et al. [2019] and De Biasio et al.

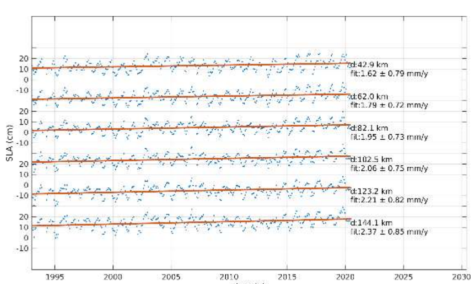

Figure 2. C3S altimetry absolute sea level trend at increasing distance from the Svalbard coast.

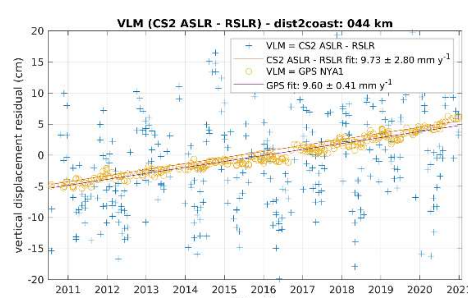

Figure 2. Vertical land motion estimated by differencing CS-2 absolute and TG relative sea level height (blue crosses) and measured by GPS at Ny-Ålesund.

[2020]. VLM estimates obtained by differencing altimetry and TG sea levels has been validated with GPS data at Ny-Ålesund (Fig. 2).

Future developments

The research will be developed in three directions: 1. to explore how the synergy with along-track CS-2 data might help to detail the sea ice impact on the observation of relative and absolute sea level rise around Svalbard; 2. to create an auxiliary dataset of collocated CS-2 and ICESAT-2/SAR/MODIS observations in order to facilitate the classification of leads, sea ice and open sea areas; 3. to identify a suitable approach to discriminate such different zones in the Arctic Ocean with satellite altimetry. The approach can be applied also to the Antarctic region.

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Metadata for a spectral library on snow and ice and FAIR principles

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KEYWORDS: metadata; reflectance spectral libraries; snow surface properties, FAIR principles

Introduction

The cal/val activities on satellite products require ground-truth dataset suitable for assessing the quality of retrieved information and for improving the capacity of observing the snow cover in particular environments such as the Polar areas. From this perspective, the availability of optical, spectrally resolved, field data is an important source of information useful for detecting remotely surface characteristics when field data can not be collected. The first step for preparing a sharable and interoperable spectral library consists of defining the appropriate metadata profile for the description of snowed and iced surface covers.

Different spectral libraries on vegetation, rocks, and soils are already available and described in detail. Science needs data, but is increasingly difficult to share and search them with accuracy and precision now that every action leaves a digital footprint, creating a huge amount of data, the so-called "Big Data". It's not only the volume but also the variety of data that poses a challenge to successfully manage it. The scientific world has decided upon principles to grant "open access" in activities as the FAIR (Findeable, Accessible, Interoperable, Reusable) principles. Metadata are an essential part of these principles but to help data usability they must be well documented and sound.

The standardization process plays as well an important role to provide guidelines and standards for data (and metadata) models and encodings. This effort aims at reducing the present heterogeneity, making data and metadata more manageable and interoperable.

Activities

Having to adopt a set of metadata to describe our spectral library containing snow and ice spectral signatures (SISpec), we searched for a metadata profile, specific to cryosphere properties, but found none. The ISO standards 19115 (Geographic information — Metadata, both parts 1 and 2 - Extensions for acquisition and processing) were chosen as the standard framework for describing the SISpec metadata model. When the available metadata was not sufficient or suitable, metadata extensions or new detailed metadata components were created to be compliant with the ISO 19115 standards. INSPIRE requirements were also taken into account. The result is a metadata model that can be useful to share SISpec metadata both in the European and international contexts.

Particularly detailed metadata sections and elements were created for describing spectral signatures and microphysical snow parameters.

Future developments

Considering the FAIR rules and metadata standards, the spectral data and ancillary information contained in SISpec have been made compatible with the principles illustrated above. The new setup of the library will provide the polar area monitoring community with an effective tool. Documentation is available in a public repository (Zenodo).

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Field and satellite hyperspectral data for cryospheric applications

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KEYWORDS: hyperspectral imaging; reflectance; snow; ice

Introduction

Hyperspectral spectroscopy is a powerful tool for investigating Earth surface properties. It can provide important information on the state and dynamics of the global cryosphere. The optical properties of snow and ice vary both in space and time, and they depend on several variables related both to the observation system (e.g., view zenith angle, diffuse or direct radiation etc.) and the physical properties of the surface [1]. These latter can be summarized as: snow/ice grain size, surface liquid water content, snow density and concentration of light-absorbing particles (e.g. mineral dust, black carbon, cryospheric algae). Therefore, respective parameters can be derived from spectral reflectance measurements obtained both from field spectroscopy, airborne and satellite data, as shown in previous studies [2]. The retrieval of these parameters from remote sensing data is an active field of research and it is useful for assessing the state of snowpack and glaciers for hydrological and climate-related applications.

Activities

Several field spectroscopy campaigns have been conducted in the last years in snow fields and glaciers. Recently, we installed an automatic spectrometer in a high altitude site in Western Alps. We analysed these data in order to monitor melting dynamics of snow and for evaluating the impact of episodic Saharan dust deposition on snow melt-out dates [3]. Retrieved parameters (snow albedo, grain size, and LAPs concentration) have been also compared with Sentinel-2 data with promising results. Furthermore, since the launch of the hyperspectral satellite mission PRISMA in April 2019 [4], we used field spectroscopy data for calibrating and validating those hyperspectral satellite data. Several PRISMA scenes were acquired on demand over snow and ice both in Alpine and polar areas. Data quality was also evaluated for different cryospheric surfaces such as: seasonal snow, glacier ice, ice sheets, and ice shelves.

Future developments

Ad hoc atmospheric and topographic corrections are needed for snow- and ice-covered areas in rugged terrain. Both field and satellite optical data suffer these problems, and future steps will regard the development of dedicated corrections for hyperspectral data both in alpine and polar environment. Retrieval scheme for estimating snow and ice properties will be also developed for corrected hyperspectral data.

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Integrated monitoring of the spectral properties of snow coverings

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KEYWORDS: (snow cover, reflectance, remote sensing, terrestrial photography):

Introduction

The description of the evolution of the snowpack during the accumulation and melting seasons is an important contribution to the study of the impact of climate change in the Arctic and Alpine Regions. The importance of these surfaces derives from including some descriptors in the GCOS list of essential climatic variables: the Snow Cover Area (SCA). Since the 1980s, the SCA has been estimated by using multispectral satellite data (Dozier 1989), observing that the snow reflectance in the visible wavelengths is significantly higher than other natural surfaces and, in the near and medium infrared, it is strictly related to the snow surface microphysical properties, such as shape and size of the snow grains. The description of the snow seasonality in terms of optical behaviour and areal extension will support the gap filling between observations at different spatial scales and the availability of observative time series.

Activities

The research activities are focused on the integration of monitoring methodologies at different spatial and temporal scales. The backbone of this monitoring strategy are data obtained by satellite platforms, including both state-of-the-art optical sensors (MODIS, Landsat OLI, VIIRS and Sentinel-2 OLCI) and recently deployed instruments (Sentinel-3 and PRISMA). This activity is linked to the development of algorithms useful for defining novel snow cover products and for building data services based on them. Ground-truth activities are an additional pillar of this monitoring strategy and the study of the optical properties of surfaces is approached through hyperspectral measurements acquired in different field polar campaigns. In-situ observations provide on one hand information on the relationship between microphysical properties and optical behaviours, on the other hand it supports the development of devices aimed on continuously observing the snow cover such as the Continuous Reflectance Monitor (CReM), that continuously measures reflectance in 3 narrow spectral bands (Salzano et. to 2021). While the CReM 1 and 3 bands overlap the bands used to compute the snow index (NDSI) from satellite images (MODIS, Landsat-8 and Sentinel-2), the CReM 2 band was specifically selected to highlight the microphysical characteristics of the snowpack (Dominè et al 2006). The proposed monitoring strategy is completed by terrestrial photography, which provides useful information for the calibration and validation of remotely sensed data. The development of automatic algorithms to identify the presence of snow guarantees the possibility of estimating the Fractional Snow Cover in long time-series. Finally, this monitoring strategy, which was already applied at the NyAlesund site, made possible to evaluate the SCA with a better spatial and temporal scale than actually feasible with satellite sensors alone (Salzano 2021).

Future developments

The integrated monitoring of the snow cover appears to be reliable tool for understanding the evolution of the climate and ecosystems of the polar areas. CReM is proving to be an effective system for the continuous monitoring of the snow cover in remote regions and for the analysis of the spectral behaviour of the surface snow layer. The curation of the SISPEC spectral library is certainly another fundamental tool for the calibration and validation of remotely sensed data, having in mind the future enforcement of hyperspectral satellite missions. The integration with the description of the snow seasonality obtained by terrestrial photography (in the framework of PASSES2 and Snow CorD projects) is certainly an additional key point. The impact of these studies is not limited only to cryospheric studies, but it is also clearly linked to studies on Arctic ecosystems, such as the Brogger peninsula (PRA-ECOSYSTEM). The use of CReM, associated with terrestrial photography, is the approach currently operational at Ny Alesund close to the Climate Change Tower, and it is going to be deployed in the framework of multidisciplinary activities in Antarctica, at Dome C, as part of the PNRA-CRASI project.

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Biogeographical shifts and climate discontinuities: understanding polar and sub-polar spatial patterns and temporal processes

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KEYWORDS: Earth Observation, ecological modelling, Essential Variables, Copernicus

Introduction

Polar regions are pathways and receptors to climate change effects, especially to the rising temperatures. Warming immediate consequence, can be seen in the annual variability of non-frozen season. For example, Arctic is warming much faster than the rest of the world through a process known as 'Arctic Amplification' [1].

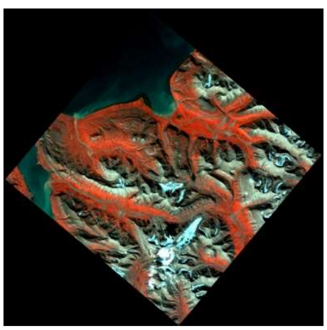

Figure 3. This image was acquired by PRISMA's hyperspectral satellite sensor in July 2020. It is a False Colors composite: RGB = VNIR-42,22,15 on Barentsburg (Svalbard, 78.065041° N, 14.214635° E).

The red color represents the vegetation coverage and the light blue to white color gradient is related to the snow and ice presence. The plumes close to the coastline are sediments that reach the sea through the inland waters network. Credits:

The color composite is provided by Institute of Polar Sciences (CNR-ISP) and the School of Advanced Studies (IUSS) under an ASI License to Use; Original PRISMA Product - © ASI - (2020). All rights reserved.

Understanding the dynamics of the ecosystem structures (i.e., biodiversity) and functions (i.e., carbon cycle) is based on the concept of Essential Variables (EVs). EVs are a tool to support the assessment of the status of, and the changes in, the ecosystems. Knowledge gaps in polar ecosystems and their biodiversity can be filled by using the existing and the new generation of Earth Observation (EO) imagery [2]. Together with *in situ* monitoring data, geospatial analysis, ecosystem modelling, the use of analytics like Artificial Intelligence and Big Data processing on cloud platforms (i.e., Copernicus), EO could strength evidence-based policy making and surface biophysical data sovereignty in polar systems.

Activities

EVs provide indicators to observe, and assess, changes in the environment. Remote sensing and modelling stand out as unprecedented tools for assessing spatial and temporal patterns, trends, and magnitudes of these indicators:

- Microwave (MW) and Infrared (IR) radiometers capture terrestrial and aquatic surface thermal emission. They can be used for measuring and predicting seasonal changes in snow and ice cover.
- Hyperspectral and multispectral satellite imagery (VNIR-SWIR wavelengths) capture changes in absorption and reflectance intensity of terrestrial and aquatic surface

biological and geophysical properties. Thematic maps help understanding the effects on wildlife habitats and to track the gradients across biomes from tundra to polar regions.

- Satellite altimeters (SAR) and radiometers (VNIR-SWIR) can report glacier mass and movement. Monitoring inland and marine water quality parameters, together with the retreating rates of coastal glaciers, are proxies for modelling dynamics and identifying the mechanisms underlying non-polar systems changes.
- Land surface temperature, snow water equivalent and land cover products assimilated into models, can support studies of sub-polar regions, typically characterized by the presence of permafrost [3].

Future developments

Building a new generation of user-driven technology knowledge, means that researchers, the relevant stakeholders and local population need to work together and agree on a uniform set of variables that are essential to evaluate the status of, and changes in: ecosystem functions and structures, ecosystem services, pressures and drivers of changes.

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Biophysical parameters retrieval in Svalbard with the new generation of satellite sensors

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KEYWORDS: Svalbard, Satellite Earth Observation, PRISMA, Essential Variables

Introduction

Polar and sub-polar ecosystems' integrity, functions and processes are currently undergoing pressures caused by various disturbances [1]. The immediate impact of climate change is the extension of the annual non-frozen season, and the consequently melted glaciers, sea-ice, and snow cover variability [2]. The new generation of satellite sensors for Earth Observation supports the identification of key monitoring targets and trends of Essential Variables (EVs) giving insights into the emergent properties of cold biomes, spanning a wide variety of spatial, spectral and temporal scales [3].

Activities

Hyperspectral and multispectral satellite images allow for detecting changes in absorption and reflectance intensity that can be related to Earth surface biological and geophysical properties. The PRISMA hyperspectral sensor (launched in 2019 by Italian Space Agency) has been designed for scientific purposes and currently provides satellite images over 70°N and 70°S latitudes. PRISMA captures images in 239 spectral bands in the Visible Near-InfraRed (VNIR) and in the Short-Wave Infra-Red (SWIR). Its nominal spatial resolution (30 m) can be extended to 5 m thanks to its panchromatic band. Multispectral sensors, i.e., Copernicus Sentinel-2 (S2), provide a higher temporal resolution (5 days of S2 vs. 30 days of PRISMA) and a fair spatial resolution that goes up to 10 m.

The potential of the new generation of satellite sensors is tested in Svalbard islands (Norway), as a first show case of a polar ecosystem. The demonstration includes the use of PRISMA images that capture terrestrial and aquatic domains with different snow cover. The estimation of common radiometric indices (NDVI, NDWI and NDSI) for vegetation, water and snow is improved with the large number of spectral bands with a spectral resolution smaller than 12 nm. Furthermore, biophysical parameters related to vegetation, water and substrates are retrieved through subpixel analysis for a higher reliability in modeling each pixel composition. The unique value offered by hyperspectral data is also given by the integration of image spectra with insitu spectral libraries (e.g. SISPEC) [4].

Future developments

It is foreseen to use PRISMA imagery to enlarge the products and services portfolio for studies in the field of terrestrial and aquatic Polar Sciences. This would contribute to improving the understanding of polar and sub-polar ecosystems as well as to consolidating studies for the future EU Copernicus Hyperspectral Imaging Mission for Environment (CHIME), PRISMA Second Generation and other hyperspectral missions in synergy with other space agencies such as NASA.

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Wind fields in polar coastal areas derived from satellite Synthetic Aperture Radar images

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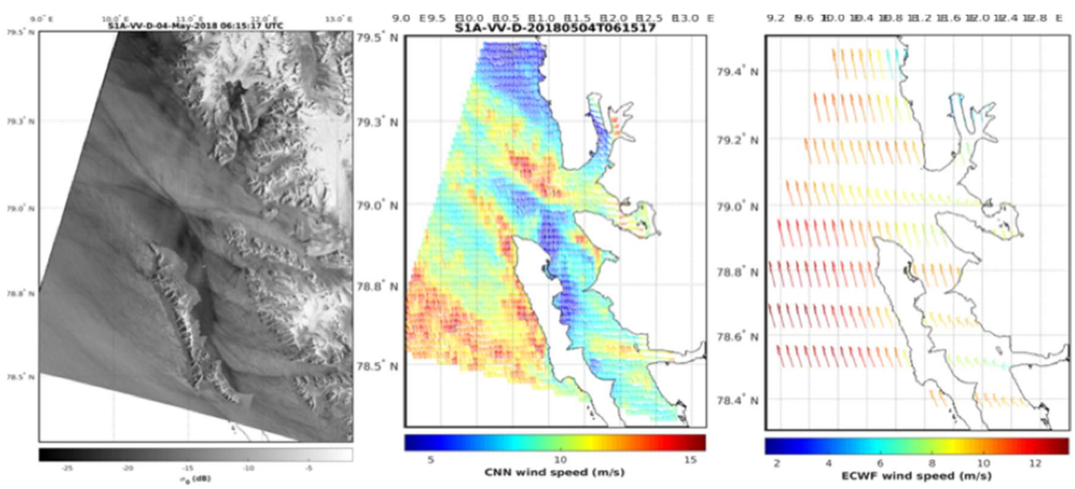
KEYWORDS: Microwave remote sensing; Synthetic Aperture Radar; coastal meteorology; sea wind field

Introduction

The Synthetic Aperture Radar (SAR) is a microwave imaging device providing high resolution (~10 m) radar images of the Earth in all-weather and day-night time . It is extensively used both on ground and on sea. One of the most relevant applications of SAR over the sea is the wind field retrieval at high resolution (up to 500 m) in coastal areas. At present possible only with SAR images.



Left panel: Sentinel-1 SAR image over the Ny-Ålesund area, 4 May 2018 at 06:15 GMT. Middle panel: wind field from CNN at 1 km spatial resolution. Right panel: ECMWF wind at 9 km of spatial resolution.

Activities

To extract the wind field from SAR, methodologies based on two-dimensional Continuous Wavelet Transform (2D-CWT) and Convolutional Neural Network (CNN) have been developed at ISP (*Zecchetto et al, 2016, Zecchetto, 2018, Zanchetta and Zecchetto, 2021*). An example of results is provided in the figure, which shows in the left panel a portion of a Sentinel-1 SAR image over the Ny-Ålesund area. The middle panel reports the wind field extracted using the CNN methodology at 1 km resolution, while the right panel shows the ECMWF wind at 9 km resolution. The comparison between these two fields allows to appreciate the results obtained with CNN which provides with an unprecedented level of details the spatial characteristics of the wind also in the narrow fiords.

Future developments

What distinguish polar coastal areas from others is the possible presence of sea ice which prevents the extraction of the wind from SAR images. To apply the CNN and 2D-CWT methodologies to the polar regions the sea ice areas must be previously detected on the SAR images by available algorithms (see, for instance, *Zakhvatkina et al., 2013*). This will be one of the most important future tasks, along with the continue refinement of the present algorithms to extract the wind field from SAR.

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