COST
EUROPEAN COOPERATION
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Title: **European network for harmonizing high-latitude dust monitoring, modeling and satellite approaches**

Acronym: **HARMO-HLD**

Summary

COST HARMO-HLD (**Harmo**nizing **H**igh **L**atitude **D**ust), is European Concerted Research Action designated as COST Action of “European network for harmonizing high-latitude dust monitoring, modeling and satellite approaches, for the benefit of weather services, air and water quality, and climate change assessment”.

It focuses on **natural dust (resuspended dust and ash originating from high latitudes (≥50°N and ≥40°S) or transported from elsewhere)**, yet it includes anthropogenic aerosols when required for harmonizing and inter-comparing the techniques in measurements, modelling, remote sensing and effects of dust**. Volcanic eruptions are excluded.** The **time scale** includes both contemporary (monitoring and satellite techniques) and historical (climate modelling, historical dust).

HLD aerosol is an essential climate variable directly affecting the Earth energy balance. **The sources, characteristics and processes related to HLD differ essentially from those characteristics to lower or mid-latitude dust aerosols.** This Action will co-ordinate the European efforts to establish harmonized monitoring practices, modeling and satellite approaches on HLD, and will focus on:

- **harmonizing HLD** monitoring and analysis techniques of dust in air and in the cryosphere; modeling of emission, transport and deposition processes; field and remote sensing of HLD aerosols;

- air quality and operational responses to dust events;

- HLD for climate change and historical dust, hydrology, and cryosphere;

- assessment of HLD including sources and characteristics and effects;

This will be achieved through networking, including intercomparison work, workshops, short-term scientific missions, exchange and training, and linking them to activities in international agencies and global networks, e.g., WMO SDS WAS.

Key Expertise needed for evaluation

Earth and related Environmental sciences
Climatology and climate change
Earth and related Environmental sciences
Meteorology, atmospheric physics and dynamics
Environmental engineering

Remote sensing
Environmental engineering
Risk assessment, prevention and mitigation
Environmental engineering
Databases, data mining, data curation, computational modelling

Keywords
Air quality

Climate change

High latitude dust measurements

Remote sensing

High-latitude dust in models

TECHNICAL ANNEX

COST HARMO-HLD (**Harmo**nizing **H**igh **L**atitude **D**ust) is a European Concerted Research Action designated as COST Action of the **"European network for harmonizing high-latitude dust monitoring, modelling and satellite approaches, for the benefit of weather services, air and water quality and climate change assessment"**

1. S&T EXCELLENCE

1.1. Challenge

1.1.1. Description of the Challenge (Main Aim)

Description of the challenge. Air quality in Europe has improved steadily over the past two decades (Colette et al. 2011; Guerreiro et al. 2014), however air pollution remains the **single largest environmental health hazard responsible for more than 430,000 premature deaths in Europe (**European Environment Agency 2016). Anthropogenic (industrial pollution) and natural dust affects a wide range of **biophysical, biochemical and biological processes on Earth**, including soil formation, ice melt-rates, lake and marine productivity, and air quality. Apart from *changes in natural environments*, people are most affected by illnesses associated with reduced **air quality** as well as by natural disasters, such as **sand or dust storms***,* that negatively affect both **health** and the **economy**. Emissions of particulate matter originate from both *anthropogenic* activities and natural processes with the latter accounting for the highest proportion of total particulate matter (around 90%) but the former having greater impact on some processes such as radiative absorption. Less industrialized and inhabited regions, such as deserts, can contribute remarkably to air pollution. The largest desert in Europe, for example, is located at a high latitude, in Iceland, and it is the largest desert in the northern polar regions. Dust in this desert is mainly from glacial sediments and volcanic material. Similar high latitude (≥50°N and ≥40°S) dust sources cover over 500,000 km^2 area and produce tremendous amounts of particulate matter (about 100 $Tg\,yr^{-1}$) which is poorly monitored and predicted. Pristine polar regions are influenced by long-range transported **anthropogenic pollutants (including heavy metals) and natural particulate matter such as dust,** both of which can negatively influence humans, plants and animals**.** Furthermore, it has been shown that temperatures in these fragile areas have been increasing at twice the global average, causing melting of glaciers and a consequent increase in potential dust source areas which in turn, if blown on to glacier surfaces, decrease ice albedo and consequently influence glacier melt rates and biogeochemical processes on Earth in a positive feedback mechanism. The European high latitude areas also include active volcanoes which produce large amounts of volcanic material. Some of this eruptive material is immediately transported long distances, but much is deposited locally following an eruption and then resuspended to form dust plumes. During recent years, several separated research groups have put efforts into monitoring and modelling the large HLD sources at latitudes ≥50°N and ≥40°S and came together for **the first at the International Conference on High Latitude Dust (HLD) in Iceland in May 2017**. This event showed the large scale of produced air pollution and climatic impacts of high latitude dust, but foremost, it showed the urgent need to synchronize the diverse methods for better investigation of such poorly understood phenomena.

Main aim. The main aim of the COST HARMO-HLD Action (Harmonizing High Latitude Dust) is to establish a European network for **harmonizing high-latitude dust monitoring, modelling and satellite approaches, for the benefit of weather services, air and water quality, and climate change assessment (Fig. 1)**. COST HARMO-HLD focuses on **natural dust (resuspended mineral dust and ash)**, as well as including anthropogenic aerosols when required for harmonizing and inter-comparing the techniques in measurements, modelling, remote sensing and their effects. **The direct emissions from volcanic eruptions are excluded from the scope of COST HARMO-HLD Action, but volcanic ash deposited on the ground and~~or~~ re-mobilized by wind ~~in volcanic regions~~ (such as Iceland, for instance) are included. Deposited ash has been shown to be an important dust source months/years after the original eruption. The time scale includes both contemporary (monitoring and satellite techniques) and historical (climate modelling and historical dust detection techniques). High latitude dust (HLD) in this Action refers to resuspended soil dust or ash either originating from high latitudes, or transported there from elsewhere.** HARMO-HLD will establish an international co-operation network involving research institutions, national agencies, commercial service providers, and potential end users, regarding the detection and assessment of HLD**.** Coupled with regionally specific atmospheric-ground interaction processes (regional variability), HARMO-HLD puts most effort on latitudes of ≥50°N in Europe. Outside Europe, the northern and southern latitudes, e.g., Antarctica, are included, as many European countries are actively working and co-operating on HLD issues there. HARMO-HLD emphasizes that Europe has its own significantly contributing deserts and volcanoes as sources for HLD.

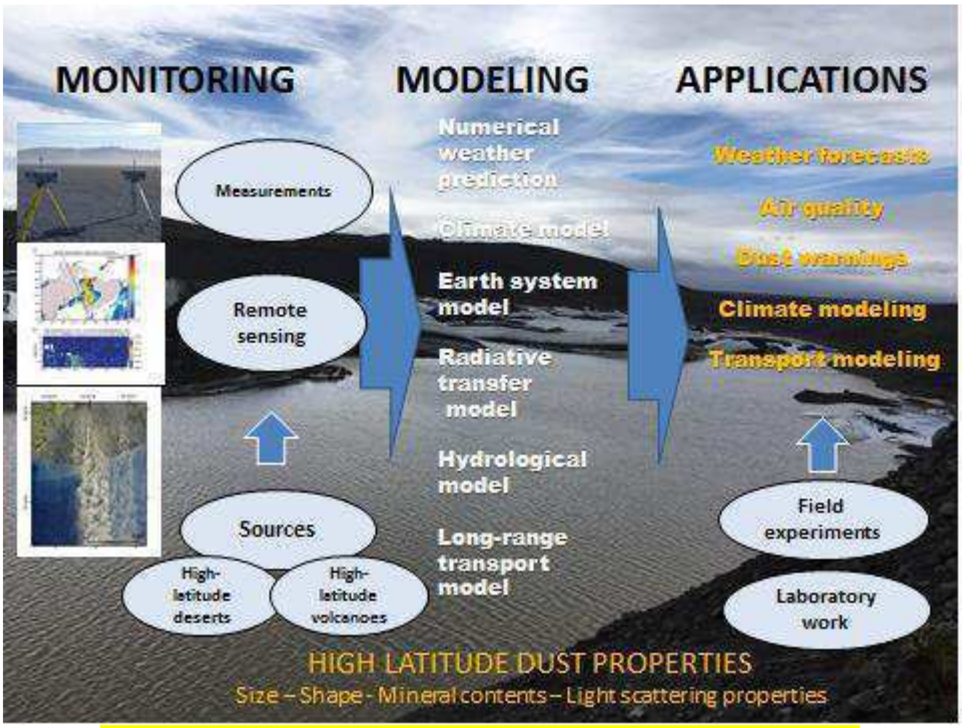


Figure 1. An overview of the COST Action HARMO-HLD project.

This action will coordinate the current research of diverse groups **to enhance the scientific understanding of high latitude dust** (including geology, biology, glaciology, hydrology, meteorology, climate, and remote and in-situ observations) and **to assess impacts on diverse socio-economic sectors**, including, e.g., **tourism and public health**. It will also **improve forecasting** methods to give **warnings** to the general public in advance of dust storm events which are not fully available at the moment. The Action ensures that, where applicable, the best practices and quality of the measurements on the European level can be adapted to polar regions worldwide, and will be evaluated outside polar regions as part of working group (WG) work of the Action.

1.1.2. Relevance and timeliness

HLD is a **poorly understood risk to the human health and to the environment**. The fundamental processes controlling aeolian dust emissions in high latitudes are essentially the same as in temperate regions, but there are **additional processes specific to or enhanced in cold regions**. These include low temperatures, humidity, strong winds, permafrost and niveo-aeolian processes all of which can affect the efficiency of dust emission and distribution of sediments. Dust is an essential and relevant environmental variable with multiple **socio-economical effects**, such as air quality/health and weather/climate. Natural dust is often associated with hot, subtropical deserts, but recently dust originating from cold, high latitudes (≥50°N and ≥40°S), has received attention. HARMO-HLD will launch for the first time a European level COST Action co-operative network to harmonize the relevant measurement, modelling and remote sensing practises in the field of high-latitude dust. Air quality and dust warnings are on-going meteorological services relevant to HLD. Arctic and Antarctic climate change are tied with dust, and historical dust (palaeodust) is not only a contributor to climate change but it also forms a record of previous dust and climate conditions. I**n desert countries over 80% of total air pollution mortalities are caused by suspended dust.** Several hundred thousand mortalities are caused annually due to air pollution in Europe, but more research is needed on health impacts of natural dust. Deposition at high latitudes **can provide nutrients to the marine system**, specifically by contributing iron to high-nutrient, low-chlorophyll oceans. Mineral and organic matter on glaciers, including natural and anthropogenic dust, can form **cryoconite** granules. Granules, dust, and ice algae can reduce surface albedo and accelerate melting of glaciers. **Glaciers constitute important natural hazards as a main contributors to sea level rise, but also water from glacier surfaces may be a source of potential pathogens, black carbon, persistent organic pollutants even antibiotic resistance bacteria which all are transported with dust on glacier surface**. Therefore monitoring of dust in high latitude remote areas has crucial value for climate change assessment and understanding the impacts of global warming for both natural systems as well as socio-economic sectors.

1.2. Objectives

1.2.1. Research Coordination Objectives

1. Establish the first European-wide integrative and multidisciplinary science network on HLD measurements and their optimum use and applications, by direct inclusion and interactions across disciplines and expertise.
2. Assess and harmonize practices, standards and retrieval algorithms applied to ground, airborne and space-borne dust measurements and foster for their acceptance by key HLD network operators at the international level including in temperate regions by coordination of experimentation and developing, testing and inter-comparison of new methods and techniques.
3. Develop a rationale and long-term strategy for HLD measurements in the atmosphere, inputs to soil and oceans, and in the cryosphere, including their dissemination and archiving.
4. Advance the application of dust data assimilation in European weather, climate and hydrological models and show its benefit for weather forecasting, climate and Earth system modeling, and air quality warnings as well as other applications.

5. Establish a validation strategy for weather, hydrological and climate models and remote sensing approaches against dust observations to advance its implementation in the European modeling communities.
6. Involve outside Europe HLD areas such as South America, Antarctica, Canada, USA, and Russia in the European-driven network and practices.
7. Maintain and expand a network of experts, researchers, early career investigators, and University students that allows the achievement of the previous objectives.
8. Utilize all the tools provided by the COST action policy to achieve and sustain this top-level research initiative and network.
9. Parametrization of HL dust and volcanic ash particles for the Positive Matrix Factorization database (currently all HLD particle characteristics are missing) as well as for the Dust Particle Atlas
10. Deliver the Assessments on European Arctic risks and protection from HLD sources for **AMAP,** (Arctic Monitoring and Assessment Programme of the **Arctic Council)**; and for **SCAR (**Scientific Committee on Antarctic Research of the International Council for Science **ICSU**).
11. To produce **a joint peer-reviewed HARMO-HLD review-publication** on HLD, in addition to publications written by smaller focus groups in international journals listed in **JCR (**Journal Citation Reports).

1.2.2. Capacity-building Objectives

HARMO-HLD emphasises **capacity building via its objectives to**: **Foster knowledge exchange** between separated research units on HLD; Scientists and groups dealing with HLD aerosol particle physical characteristics, monitoring and measurements, dust data assimilation **(DA)** and its description in models, biological processes on glaciers affected by dust are often working separately in individual institutes, projects and countries. Therefore, this Action will build a network between the various issues from local-scale characteristics to remote-sensed broad areas, from micro-scale modelling to NWP, climatic and hydrological parameters and from instrumental capabilities to DA, which is likely to boost these communities towards advances in solving some of the multidisciplinary scientific and application issues. **Train new generations** of young scientists and existing experts (STSM, ECI, training schools, laboratory staff exchange); **engage trainees and give guidelines** for the policy makers and educational institutions; **Engage national stakeholder:** Governmental stakeholders (National and/or Regional, e.g. National weather services, Environmental Agencies, National Parks and UNESCO Heritages, and in general EU policy makers and decision-making bodies at national and/or regional levels, health institutions), and Non-governmental organisations (NGOs) in the sector (municipalities, tourist boards, aviation authorities, road administrations, farmers, ski areas).**Encourage Citizen-Science projects,** as dust and ash transported from high latitudes to municipalities or regions elsewhere is difficult to recognize by naked eye, people need to be educated and informed by the municipalities to distinguish when they should take measures to protect their health, e.g. volunteers to collect pictures and videos of the HLD events (dust storms, dirty glaciers) and create a catalogue of such reports using standardised quality controls; **Promotion to media** (newspapers, radios, television); **Transfer of knowledge** to the HLD community globally,including to stakeholders such as policy-makers, regulators, and giving input for future commercial applications, including co-operation with private enterprises; **Workshops and presentations** in primary and high schools. **Dissemination** of research results, best measurement practices and new climate change connections together with mitigation/adaptation strategies to the general public or to stakeholders. The **STSM** from **PhD students, ECI** and participants from **Inclusiveness Target Countries** will have priority, and **gender balance** will be preserved. The Action will involve and liaise with major coordinating and implementing agencies such as the World Meteorological Organization WMO and its relevant Commissions and projects (especially **WMO Sand and Dust Storm Warning Advisory and Assessment System - SDS-WAS)** for taking stock of the Action's achievements with respect to measurement practices and parameters recommendations, the European space bodies (**ESA** and **EUMETSAT**) regarding the production and application of space-borne dust data. Training and harmonizing the methods will be achieved by training schools, workshops and meetings. Students and experts from the different scientific fields must be linked together and must perfectly communicate together in order to get the overall understanding of such complicated phenomenon such as HLD and its effects on climate or anthroposphere. The newest findings from the following scientific topics will be assessed, harmonized, checked for quality and improved during **capacity-building events:** Geochemical, mineralogical and morphological analyses of dust particles; field collection of the samples and instrumentation in harsh conditions; remote sensing; modelling and dust forecasting; climate adaptation/mitigation, understanding the atmosphere-cryosphere interactions and climate effects.

1.3. Progress beyond the state-of-the-art and Innovation Potential

1.3.1. Description of the state-of-the-art

Attempts have been made to quantify the expanse, characteristics, or dynamics of high-latitude dust sources at **regional scale** (Iceland, Greenland, Alaska, Canada, Antarctica, New Zealand, and Patagonia). A review on HLD is available in Bullard et al. in 2016 (Fig. 2). For the European Arctic, several **important sources were not included** and long-term research studies from the European research groups maintaining aerosol stations in the Europe's high latitude were not discussed. Both the land area of HLD sources as well as the contribution of HLD dust sources to global dust budget are projected to increase under future climate change scenarios. The important fact is that Europe's largest desert is located in HL, in **Iceland** in vicinity of glaciers. The long-term frequency of dusty days from Iceland was reported as 135 days/year. The scarcity of year-round observations and limitations of satellite remote sensing data at high latitudes are an important scientific issue to be discussed. First modelling studies have calculated estimates on the amounts of **Europe's and Greenland's dust production** and **main transportation pathways are clearly affecting both the High Arctic and European mainland**. Several studies have shown that HLD has different physical, chemical and optical properties compared to crustal dust as known from Sahara or American deserts. HLD has, therefore, different effects on climate and human health. For example, Icelandic dust is of volcanic origin, it is dark, extremely fine (often submicron particles) and consists of higher proportions of heavy metals than crustal dust. The HLD needs to be, therefore, investigated together with fresh volcanic ash inputs (there is one eruption per 3-4 years on average in Iceland). HLD is strongly linked with cryosphere as well.

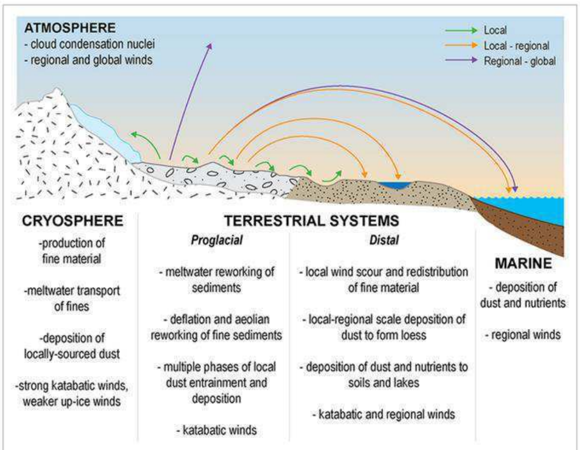


Figure 2. **The current understanding on HLD.** *From Bullard et al. 2016, copyright@authors 2016, published with open access CC BY-NC-ND 4.0.*

HARMO-HLD will be the first European level HLD initiative. HLD has been investigated independently under several European projects: **High Latitude and Cold Climate Dust Network (HLCCD, http://www.hlccd.org/)**, **Nordic Centre of Excellence Top-level Research Initiative on Cryosphere-Atmosphere Interactions in Changing Arctic NCoE CRAICC** (https://www.atm.helsinki.fi/craicc/index.php), and other regional networks, such as **Icelandic Aerosol and Dust Association (https://icedustblog.wordpress.com/)**. On the national level, several aerosol stations have been established and successfully run in European Arctic and in the Antarctic stations of the European countries or their collaborator stations, including outside their home countries (e.g., Polish Svalbard Station, Italian Svalbard Station, Greenland Station, Swedish and Finnish Aerosol Station, Italy-France Antarctic station "Concordia" (Dome C, East Antarctica), Finnish co-operation at the Antarctic Marambio Station of Argentina). These stations generate important records on HLD and other important aerosol. The most successful mineral dust forecast platform World Meteorological Organization Sand and Dust Storm Advisory and Assessment System (WMO WAS-SDS, https://sds-was.aemet.es/) is operating mainly for the dust sources outside Europe (Sahara and Middle-East). The HARMO-HLD action will have cooperation with the WAS-SDS network as well as with the recently granted COST action International Network to Encourage the Use of Monitoring and Forecasting Dust Products (InDust, CA16202) for mutual benefits.

1.3.2. PROGRESS BEYOND THE STATE-OF-THE-ART

The present Action will create a synergy among European HLD researchers from different scientific fields, but also among the HLD and common aerosol researchers. The first attempt have been made to create a network of HLD researchers, HLCCD. For the European Arctic, HLD and aerosol researches network has not been established. Researchers are using different methods to quantify their aerosol or dust inputs, some researchers are **not aware of large dust sources in the European Arctic**l. HARMO-HLD will give guidelines to the outside-Europe HLD researches, but it will also build research cooperation on dust in the Antarctica where aerosol researchers from many European countries conduct their research next to each other. HARMO-HLD is determined to foster the knowledge transfer between the academic bodies, *European directive*, *Arctic protection institutions*, national stakeholders, municipalities, tourist boards and other interested stakeholders. **HARMO-HLD work will contribute significantly beyond the state-of-art with its focus on collecting and providing information on the geographical distribution of dust-productive soils, which is one of the most important information currently lacking and necessary to perform successful modelling. Morphology and mineralogy determine types of direct (optical properties, radiation) and indirect (HLD-clouds-cryosphere interactions) effects to the atmosphere.**

1.3.3. INNOVATION IN TACKLING THE CHALLENGE

COST HARMO-HLD Action innovations are: Emphasizing the importance of climate changes on HLD sources and feedbacks; Influence of dust on glacier melting; Detection and control of new specific aerosol, HLD and ash, in Europe; Synergy of fragmented HLD researchers in the EU Arctic; Obtaining and harmonizing missing characterisation for the PMF and mineralogical databases; Knowledge transfer to educational institutions (primary and high schools, universities) and stakeholders; Incorporating the knowledge to existing dust platforms; Utilizing the knowledge during the sudden events such as volcanic eruptions of HLD volcanoes; Synergy of scientists from different scientific fields, Advance and guide state-of-the-art research on HL and volcanic dust; Innovation to both institutions and commercial organisations to improve the efficiency of work processes (e.g. air traffic management, aircraft maintenance issues, and air quality assessment); This unification is essential to ensure comparability of the different results obtained across Europe by different research groups, allowing for an improved assessment of the variability of fine atmospheric aerosols in Europe; Potential technological or socioeconomic innovation and scientific breakthrough; Awareness raising, innovative research; Protection in tourist areas and ski areas, aviation and road administration protection; Attractivity of such regions for tourists, but contrarily nature protection needed; Implementation of Citizen Science tools on dust storm and dirty glacier and snow monitoring; Close co-operation and coordination with the WMO SDS WAS activities and COST Action InDust are essential parts of HARMO-HLD.

1.4. ADDED VALUE OF NETWORKING

1.4.1. IN RELATION TO THE CHALLENGE

HARMO-HLD Action will focus on harmonizing monitoring, analysis modeling, **field and remote sensing** of HLD aerosols in air and cryosphere for **climate change and historical dust**, **threats** to aviation, **operational responses** to dust events, optical properties of dust, **air quality**; **assessment** of high-latitude dust including sources and mineral and physical features of HLD particles, and modeling of atmospheric dust life-cycle. **This will be achieved through** networking, including intercomparison work, workshops, short-term scientific missions, exchange and training, and linking them to activities in international agencies and global networks. **Emphasis is given** on implementation of Action's outcomes (models, guidelines, assessments) into current observational practices at the national weather services and space agencies in EU, and assure that missing information on HLD will be added to future climate projections and IPCC report to produce more accurate predictions. Main target is the development of air quality related policies and public awareness of new climatic factors – HL are part of Europe, HL produce high amount of climate forcing dust. All these developments are based on cross-border cooperation in EU, but also in HL areas.

1.4.2. IN RELATION TO EXISTING EFFORTS AT EUROPEAN AND/OR INTERNATIONAL LEVEL

Some relevant current European research projects complementary to this Action are listed below. Most of them involved proposers for this Action. Several of the partners have already direct contact/joint projects/involvement/sitting together in committees dealing with meteorological and/or snow observations as well as DA for operation prediction models, which will ensure joint coordination/collaboration/planning of future initiatives. The Action partners include representatives of NWP consortia and modelling communities to directly work in WG2. **The Action will cooperate with: World Meteorological Organization WMO SDS WAS.** WMO has always favourably considered COST Actions (and is observer in the ESSEM DC).**CA COST Action CA16202 "**International Network to Encourage the Use of Monitoring and Forecasting Dust Products" **ESSEM COST Action ES1404 HARMOSNOW; hlccd.org,** High Latitude-Cold Climate Dust Network: focusing on natural dust emissions from contemporary cold climates and including proglacial and paraglacial regions.; **Nordic Centre of Excellence CRAICC,** Cryosphere-atmosphere interactions in a changing Arctic climate (CRAICC), a Nordic Centre of Excellence project investigating the interactions between ice and the atmosphere; Laboratory of excellence: **Labex CaPPA** (http://www.labex-cappa.fr/en); **ESA and EUMETSAT,** regarding the production and application of **space-borne dust data**; **AMAP** (Arctic Monitoring and Assessment Program); **NOAA** - Boulder, **http://bigskyearth.eu/, Arctic SDI, https://arctic-sdi.org/**; **EuroPICS - European Partnerships in Ice Core Sciences. ESF** network. (http://www.esf.org/research-areas/polar-sciences/europics.html); Scattering and Absorption of Electromagnetic Waves in Particulate Media (SAEMPL),**ERC** Advanced Grant; **EUROVOLC H2020** on production of services to initialize volcanic ash transport and dispersal models during eruptions.;**ITASE - International Trans Antarctic Scientific Expedition network** (http://www2.umaine.edu/itase/). and multiple international and national projects, including, e.g., ;ChArMEx (Chemistry-Aerosol Mediterranean Experiment) International.

http://charmex.lsce.ipsl.fr/index.php/charmex-partners.html. 2009-2017. **PNRA** (Progetto Nazionale di Ricerca in Antartide) 2016, **SIDDARTA** Source IDentification of mineral Dust to AntaRcTicA. Groups involved: INFN-Firenze, Florence University, Genoa University and Perugia University.Arctic Climate Across spatial and temporal Scales (**ACAS**)" - *The Knut and Alice Wallenberg Foundation*; 'The Earth spherical albedo from space geodesy', *Acad. Finland project*, 2016-2020; "Dynamical downscaling for Svalbard – application of WRF model", Real Time Analyzer of Carbonaceous Aerosols, Eurostars E!8296, 2013-2016; Source apportionment of PM10 in the Arve Valley (France) and evolution of the contribution of biomass burning emissions, **ADEME**, France, 2013-2016. Progetto Nazionale di Ricerca in Antartide PNRA 2016 - **BioAPRoS**: Correlation between Biogenic Aerosol and Primary production in the Ross Sea (Antarctica); **SAMEECA** – Surface-Atmosphere Mass and Energy Exchanges in Coastal Antarctica (Jang Bogo). Principal Investigator: CNR-ISAC. PNRA Progetto Nazionale di Ricerca in Antartide 2016 - Labex-VOLTAIRE, French funding project on the study of aerosols in the atmosphere, including volcanic aerosols.LOAC-VOLTAIRE, project funded by the French National Space Agency CNES, for the launch of the LOAC instrument from the Aire sur l'Adour base, south- west of France; **PNRA A3 PdR14 00091** project: Long Term Measurements of the chemical and physical properties of the atmospheric aerosol at Dome C, East Antarctica. **An Italian project** with collaboration of Finnish, French, American and Australian research groups. Strateole, CNES (France) and NSF (USA) project,LOAC for the detection of cirrus and aerosols.

2. IMPACT

2.1. EXPECTED IMPACT

2.1.1. SHORT-TERM AND LONG-TERM SCIENTIFIC, TECHNOLOGICAL, AND/OR SOCIOECONOMIC IMPACTS

Short term - establishing a network and ensuring collaboration: coordination and harmonization of current HLD methods and research and sustainability in top-level science for the benefit of measurements, modeling and forecasts and warnings and distributing to stakeholders. **Long term:** Contribution to dust forecasts, dust monitoring control, Arctic protection, aviation control, health community, tourist boards, environmental and air quality agencies; The Network created in the framework of the present Action will continue beyond the present Action. In short, all the EU states and partners from abroad should together monitor, provide observed data, prognose the future behaviours, assess risk and mitigation plan to preserve the European Arctic and HL worldwide. **Technological:** Harmonization and development of the measurement methods and technologies. **Socioeconomic:** the aviation, remote sensing community, forecasts, assessments, health/dust warnings and tourism will benefit from the HARMO-HLS results directly.

2.2. MEASURES TO MAXIMISE IMPACT

2.2.1. PLAN FOR INVOLVING THE MOST RELEVANT STAKEHOLDERS

The target groups/end users are identified and engaged to this Action. Members from the stakeholders of National Weather Services, National environmental authorities and policy makers, remote sensing and climate modeling groups are already part of HARMO-HLD proposal. After the acceptance of the Action, the HARMO-HLD members will further contact their stakeholders and arrange face-to-face conversations and change of information on HARMO-HLD objectives and stakeholder demands. **The most relevant stakeholders are: National Weather Services:** to assimilate dust observations in NWP models and validate models. For guidance in dust observation networks and training of operators. **Hydrological Services:** to assimilate and calibrate hydrological models using improved dust observations. For guidance in hydrological observations related to dust. **National environmental authorities and policy makers (nationally, EU-wide and internationally)**: to have better, sounder and more representative information on dust sources, particle variability and impacts on air quality, health, cryosphere, aviation, etc. **Climate modelling groups in Europe, North America, Asia, and IPCC:** to use improved dust observations for evaluating and developing models that produce climate change scenarios. **Entities responsible for dust warnings:** to enhance their monitoring and warning capacities.**Instrument manufacturers and practitioners**: to have access to state-of the art scientific information about dust physical properties and the usage of measurement data.**European remote-sensing community via ESA and EUMETSAT**: to harmonise ground-based and space-borne observation techniques on dust and their application.**International organisations (WMO, EUMETNET, AMAP):** to set improved harmonised guidelines in a coordinated manner.

2.2.2. DISSEMINATION AND/OR EXPLOITATION PLAN

HARMO-HLD responds to the needs rising from the air quality and meteorological services, high-latitude climate change assessment and remote sensing and modeling communities, as HLD differs from non-HLD aerosols by sources, properties and effects. **None of existing networks on monitoring the European Arctic consider the HLD as an environmental issue, although since 2010 over 40 peer reviewed publications have been published by the partners of this proposal**. Assessments based on reliable data and dispersion modelling will be elaborated for the climate scenario projection (currently without HLD calculations) in future **IPCC (Intergovernmental Panel on Climate Change)** report. Dissemination of research results to health authorities to give warnings during extreme events. Health science representative will be selected to disseminate the Action's achievements to the community and targeted health institutions. ***HARMO-HLD generates new knowledge on*** obtaining the reliable information on Arctic deserts, glaciers, atmospheric composition and standardize and harmonize the practices. Handbook on the best practices will be introduced recommending for the practices at the polar stations and to *The European Monitoring and Evaluation Programme **(EMEP)** and particularly contribute to **EBAS database** (http://ebas.nilu.no/).* Data sharing leading to European database on parameters of HLD and aerosol and adding the currently missing HLD parameters to the the Positive Matrix Factorization for models and dust weather forecasts and geological databases. This will affect and likely change the results of high number of published studies on origins of aerosols in the Arctic and elsewhere. Special attention will be given to the remote sensing techniques in High Latitudes with limited amount of daylight in winter. This transfer of the knowledge will be through the representatives of the databases - mainly weather services. ***HARMO-HLD benefits and results used will come for*** stakeholders including standardization bodies, policy-makers, regulators, existing organizations and associations, AMAP (Arctic Monitoring and Assessment Program, meteorological institutes. Awareness rising is the key to outreach the gained knowledge on the European Arctic. HARMO-HLD will coordinate the fragmented research groups under one network, spread maximally the generated innovative results to the public (*media, social media, popular geographical journals, wikipedia, newsletters, websites of aerosol and dust associations)*,the *scientific community* (members participating in this Action (from different scientific fields) and other scientific communities and research bodies interested in dust and its atmospheric impacts/feedbacks, the *Governmental stakeholders* (**National and/or Regional, e.g. National weather services, Environmental Agencies, National Parks and Unesco Heritages, and in general EU policy makers and decision-making bodies at national and/or regional levels, health institutions**), and Non-governmental organisations (NGOs) in the sector **(municipalities, tourist boards, aviation authorities, road administrations, ski areas**). The HARMO-HLD action plan consists of all the elements required to meet its objectives, covering benefits in: Establishing European-wide top-level science network on HLD and volcanic ash control and improved coordination between existing research bodies to provide opportunities and promote innovation and sustainability of the Network and Standardisation for the best practices through guidelines, training schools, STSM to ensure the preservation strategies for existing and future HLD network. ***The end users will be informed about***

<u>the generated results as follows</u>**:** Scientific communities will be engaged through the international conferences (EGU, AGU, DUST), mail list, workshops, training schools, and STSMs. A special effort from the experiences requires to communicate with the NGOs and Governmental stakeholders - the Action's representatives give an undertaking to disseminate the results personally to selected institutions, lead a dialog on this issue and implement the information and dust warnings in their action plans. ***<u>Awareness-raising and communication between scientists from different science fields, aerosol scientists, outside Europe HLD experts and aerosol scientists:</u>*** Engagement of new generation of young scientists already working in HLD through training schools and STSM; Elaborate the first European joint review open access publication on HLD and European Arctic impacts as well as a depository and overview of scientific papers including the main output of the Action regarding both methods and results at a European scale: A **webpage** of the Action will be created and kept updated; **online channels (facebook, twitter, blogs, wikipedia);** press releases; newsletters to participants and to further distribution. Presentation of results from the Action to competent European institutions, such as Environment and the European Environmental Agency, by inviting them to one of the Action's meetings or through a specific meeting for this purpose. Contact with the European institutions will be maintained during the course of the Action. Majority of the Action representatives are in collaboration with the media and authorities on a regular basis. Hence the relevant results from the Action will be disseminated in the media, and in meetings with concerned parties and policy makers at the municipality and regional authorities level. An important consideration for the project is that its outcomes are sustainable into the future after the project's funding has ceased. Part of the sustainability strategy will be the focus on public body, environmental agency and scientific end-user engagement.

2.3. POTENTIAL FOR INNOVATION VERSUS RISK LEVEL

2.3.1. POTENTIAL FOR SCIENTIFIC, TECHNOLOGICAL AND/OR SOCIOECONOMIC INNOVATION BREAKTHROUGHS

The potential of HARMO-HLD for **innovation is high** compared to risks identified in 3.1.4. Potential **<u>scientific breakthroughs include</u>**: identification of new aerosol types with high impacts on climate; Understanding of the role of European Arctic in the climate changes and on the European air quality including health impacts;- predicting ice surface melting affected by dust; understanding relation between dust and air quality and human health problems; discovering interaction feedback mechanisms between Arctic biota and dust **(including possible phytoplanktonic fertilization effects);** - new knowledge to **AMAP, IPCC**, Arctic protection; better understanding risk mitigation for future eruptions,- transfer knowledge to the world's HLD community, develop guidelines. **<u>Technological breakthroughs:</u>** standardization and best practices for measurements in Arctic conditions,new information to geological databases, new parametrization for models, dust modelling and forecasting including HLD; aviation and eruptions, **<u>Socioeconomic innovation;</u>** Awareness-raising, innovative research; protection in tourist areas and ski areas, aviation and road administration protection; attractivity of such regions for tourists, but contrarily nature protection needed. **<u>The overall breakthrough:-</u>** setting Europe as the excellence science leader in European Arctic monitoring and protection while adoption of the EU Arctic monitoring strategy by other Arctic areas with expansion to the Antarctic and other HL aeras.

3. IMPLEMENTATION

3.1. DESCRIPTION OF THE WORK PLAN

The Action is based on four Working Groups (WG). The WGs are closely linked and need to share the deliverables between each other. The WG1 “Dust Sources” provides outcome to WG2 “Measurements on Dust” and WG3 “Modeling of dust”, while WG2 will inform WG1 if new sources are identified through satellite images. WG2 obtained data will be validated and harmonized to support the WG3. WG3 needs to validate outcomes from the WG1 to understand properly the surface processes of HLD suspension. Based on systematic task solution of the WG1-3, the WG4 can elaborate assessments on impacts of HLD and aerosol on cryosphere, Arctic region, Europe’s air quality and health impacts to be disseminated to stakeholders. WG4 takes, however, the responsibility of continuous dissemination of partial deliverables of all WGs to the stakeholders and via media and ECI trainees. Additionally, WG meetings, sessions at non-COST conferences and STSMs will be organised to improve the networking.

3.1.1. DESCRIPTION OF WORKING GROUPS

WG1 DUST SOURCES. Task 1.1–To determine a single approach for high and low latitude dust sources for-mapping and classification of actual and potential dust sources. To establish a method for applying the classification at an agreed range of spatial scales to enable mapping of the dominant source type. **Task 1.2** The geomorphological context for dust sources, seasonal or long-term hydrology-connected sediment exposure due to ephemeral lakes,-vegetation cover, glacier retreat to constrain dust source dynamics. **Task 1.3** To agree a method for characterising dust source persistence at a range of temporal scales, for example seasonality, decadal cycles.
Deliverable 1.1 A map and classification of the HLD sources to be implemented to the global dust source maps.
Deliverable 1.2 A harmonized guidelines for dust researchers to identify the dust sources and use the correct classification for the dust sources based on dust source dynamics
Milestone 1 Dissemination of D1.1 and 1.2 at conferences and workshop and open access availability of the data for the stakeholders (modellers, weather services, governmental bodies).
WG2 MEASUREMENTS ON DUST. Task 2.1 Instrument and method evaluation-intercomparison of different instrumentation to measure different dust properties and evaluate the different approaches to separate the dust from other aerosols. **Task 2.2 Chemical properties of dust**, including various methods for atmospheric particulate matter, e.g., (MC)ICP-MS measurements of Rare Earth Elements (REEs) and Nd-Hf isotopes (as markers of dust source areas) and Ion Bean Analysis (elemental composition). **Task 2.3 Physical and optical properties of dust in air and snow,** including albedo, extinction, scattering, absorption, polarisation, spectrum, laser backscattering in laboratory, field, and aerial measurements. This will be linked with other dust morphology, interaction and evolution studies. One to two measurement campaigns will be conducted to obtain maximum of data to modellers. Emphasis is given on the differences between HLD and the most powerful light absorbing aerosol, black carbon, both directly and indirectly affecting Arctic warming. **Task 2.4 Remote sensing of dust aerosols** to review existing space-borne sensors and-algorithms applied for retrievals of aerosol dust, to find improvements in MODIS including Bayesian Dark Target (BDT)-algorithm for selected events of HLD. Aerosol retrieval algorithms applied at high latitudes have currently problems with non-homogenous surfaces, low aerosol concentrations and low viewing and solar zenith angles.
Deliverable 2.1 Handbook on the best practices for methods and measurements
Deliverable 2.2 Assessment on the chemical properties of HLD for the PMF and global geochemical databases
Deliverable 2.3.1 Assessment on morphological properties of HLD for mineralogical databases
Deliverable 2.3.2 Assessment on optical properties of HLD using a simplistic optical two-component model to discriminate between the black carbon and dust aerosol.
Deliverable 2.4 Assessment on improvements on detecting HLD in MODIS including BDT more suitable for HL regions (Lipponen et al. 2017).
Milestone 2.1 Field campaign
Milestone 2.2 Handbook ‘How to measure HLD - the best practices’

Milestone 2.3 Joint assessment based on D2.2, D2.3.1 and D2.3.2

WG3 MODELLING OF DUST. WPs on different aspects contributing to a successful dust model system are consolidated. **Task 3.1 Numerical modelling of the atmospheric dust life-cycle** aims at improving the representation of the HLD life-cycle (dust emission, transport, and deposition processes) in state of the art atmosphere-dust aerosol models, the intensification of the exchange between modelling and field & lab experiments, and ultimately providing an additional dimension to measurement and observational data allowing for a holistic interpretation.**Task 3.2 Climate modelling** for dust emission parameterizations adjustments (developed for transport modeling approaches), and treatment of emissions and optical properties of dust, and effects of absorbing aerosols in snow, in both land surface and sea ice modules, for climate models. **Task 3.3 Dynamical downscaling for Svalbard – application of WRF model.** Optimizing the WRF model to indicate spatial and temporal variability of meteorological elements, first for Svalbard archipelago, including testing of boundary layer, microphysics and radiation parameterization schemes and evaluation of their impact on modeling results. Simulations in high resolution will be prepared (3 km x 3 km) in reanalysis mode and with future climate change. **Task 3.4 HLD feedback mechanisms with environment (HLD-atmosphere direct and indirect interactions; HLD-ocean interactions).** Dust emission parameterizations adjustments (developed for transport modeling approaches), treatment of emissions and optical properties of dust, as well as the effects of absorbing aerosols in snow in both land surface and sea ice modules for climate models.
Deliverable 3.1 HLD Model - from the Model development to provide a platform for exchange on model parameterizations/schemes through the validation against measurement data.
Deliverable 3.2 HLD Climate Model
Deliverable 3.3 HLD WRF Model
Deliverable 3.4 Assessment on the HLD feedback mechanisms with environment and future projections
Milestone 3.1 Model intercomparison of different modelling approaches and parameterizations and final method exchange with field & lab groups (WG1,2) to improve dust model with physical properties and dynamical processes.
Milestone 3.2 Dissemination of D3.1-D3.4 at conferences, to global forecasting centers, governmental stakeholders (Dissemination twice during the Action = mid term and end term)

WG4 IMPACTS AND DISSEMINATION.
Task 4.1 Air quality and health impacts. Development of methods to implement HLD Model, observations and laboratory analyses to provide timely warnings to the public.**Task 4.2 Dust and cryosphere interactions** to predict ice melting affected by HLD, to indicate the most endangered glaciers and ice caps by HLD,to understand the role of organisms in affected glaciers (cryoconite, algae, pathogens (bacteria) and assess the effects of dust/BC/OC aerosols, and landscape changes on ice sheets and ice caps affected by HLD transport. Glaciers constitute important natural hazards as a main contributors to sea level rise, but also water from glacier surfaces may be a source of potential pathogens, black carbon, persistent organic pollutants even antibiotic resistance bacteria which all are transported with dust on glacier surface. **Task 4.3 Historical record of dust preserved within glaciers** to link the data on today dust distribution with past dust variations in the Arctic. The pivot area is in Svalbard and Iceland with dust and other light-absorbing impurity concentrations and deposition in ice cores for the last ca. 300 years. Analytical methods relying on both chemical proxies (linked with Task 2.2) and measurements of the light-absorbance of mineral particles and BC (linked with Task 3.4) will be compared. Historical record of dust will be used for statistical linkages between HLD and climate parameters in the Arctic.
Task 4.4 Threats to aviation to assess the risk of reduced visibility, and in extreme cases engine flame out in flight, to provide well characterized and standardized data on dispersion of the airborne HLD to Aviation safety authorities. Current airborne dust predictions for aviation safety in Europe include only the dust outbreaks from temperate region deserts (mainly Sahara and Arabian peninsula)

while based on observations from geostationary satellites only. **Task 4.5 Best practices regarding communication and dissemination of the Action´s results.** The Action will elect a HARMO-HLD dissemination director, Health Science representative and Climate impacts dissemination representative at the Kick-off MC meeting. Dissemination responsibilities are divided to subtasks: Each country dissemination representative, website, social media+wikipedia, media, communication plan with the stakeholders, and dissemination plan of the main Action´s outcomes (Handbook, guidelines, geochemical and mineralogical databases, Health and Climate Impact assessments, Dust/Ash warning plan, publications coordination, Citizen Science guidelines and promotion, workshop and conferences promotion).

Deliverable 4.1 Air quality and health assessment for EU and governmental stakeholders, weather services, and municipalities

Deliverable 4.2 Assessment Dust and cryospheric interaction linked with the D2.3.2

Deliverable 4.3 Assessment on comparison of historical and current dust environments

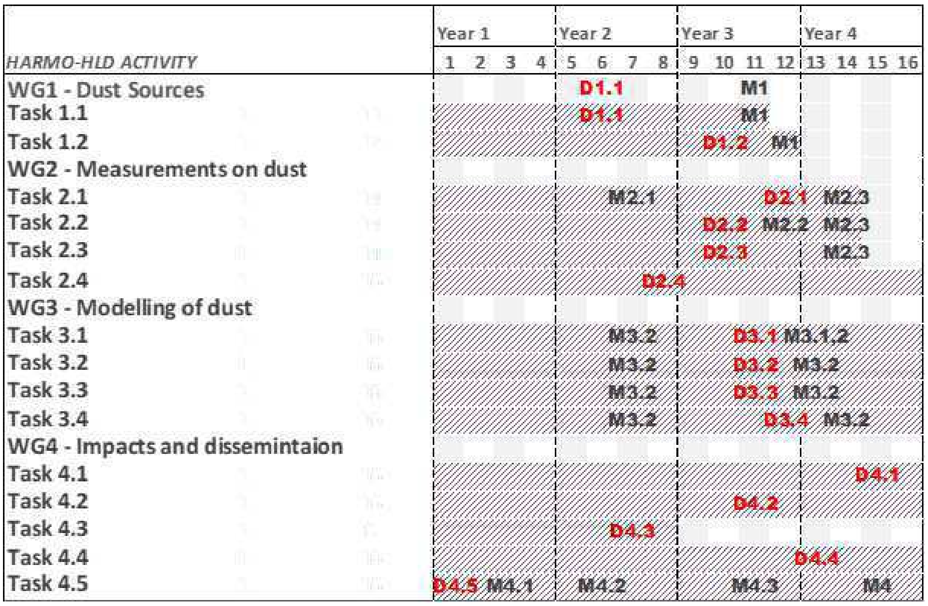
Deliverable 4.4 Implementation of new research techniques of HLD retrieval to operational aviation safety products and harmonization of the research techniques and standardization of the retrieval products.

Deliverable 4.5 Dissemination plan and committee

Milestone 4 Final joint assessment based on the M2.2, M3 and D4.1-5

Partial Milestones M4.1 Deployment of the website of the project and social media profiles. **M4.2** A workshop to build the capacity of scientists, and policymakers to address the risks associated with HLD. **M4.3** Training School on HLD observations and modelling.

3.1.2. GANTT DIAGRAM



3.1.3. PERT CHART (OPTIONAL)

(see 3.1 for different WGs and their inter-relation).

3.1.4. Risk and Contingency Plans

HARMO-HLD excludes volcanic eruptions and therefore no critical risks are expected. Risks include: **RISK:** Dissemination of the Action's results to National stakeholders and policy makers. CONTINGENCY PLAN: The dissemination director and country dissemination representatives will utilise Action's dissemination plan and other measures (workshops, short assessments, trainee if needed) to deliver the results to the National stakeholders. **RISK:** Low attendance of the MC members for the voting at the MC meetings CONTINGENCY PLAN: Evaluation of the participants attendance prior the MC meeting by the Action's director. **RISK**: Field campaign organization and measurement acquisition CONTINGENCY PLAN: There is possibility that there will be no aerosol concentration during the field campaign. The laboratory conditions or indoor environment would have to be used instead or include measurements of anthropogenic pollution in the Arctic areas. **RISK**: STSM flow - too many or too few applications. CONTINGENCY PLAN: The STSM coordinator will assure the STSM flow by promoting the Action's benefits and needs with emphasis on experts and ECI. The STSM committee will be elected if there is high number of STSM to select the most beneficial STSMs for the Action's outcome. **RISK**: Delay in delivery of deliveries or fulfilling milestones on time. CONTINGENCY PLAN: Identification and mitigation of the causes of the delay, creation of smaller working segments of scientist concentrated on the delayed task. Support in networking of all the COST members (skype meetings to ensure that the responsibility of each part of the deliverable is linked to selected and most appropriate COST member). Detailed monitoring of tasks progress.

3.2. Management structures and procedures

The composition of the Action Management Committee (MC) is not defined at the proposal stage. MC members will be nominated by the COST countries and can join the Action anytime during its lifetime. The participation of WG members and ad hoc participants will be decided by the MC. WG and management structure may be changed by the MC at a later stage in compliance with COST rules. Management Committee (MC) meetings will be carried out twice per year with the WG meetings. Open discussion and planning is the most important to maximise the Action's success. The Action is based on four Working Groups (WG). At least one of the key leadership positions in the Action management (e.g. Action Chair, Vice-Chair, Working Group Leader, Grant Holder, STSM Coordinator) shall be reserved to a representative of a COST Inclusiveness Target Country.

3.3. Network as a whole

The Network includes **46** proposers from **24** countries, including **14** ECIs (**36%**). In addition, atmospheric and cryospheric experts from the Non-COST countries will be involved as the International Partner Countries (**5** - Canada, Chile, New Zealand, South Korea, USA) in the Action (more HLD experts from Australia, Japan, South Africa, Russia, and Argentina are expected as representatives of the Antarctic, Greenland, Alaska and Patagonian HLD sources). Each IPC have a specific role in the HARMO-HLD network: Canada and Chile have been an active partner of the HLCCD since the beginning, it has many dust sources and expertise in source dynamics; South Korea is an expert in cryosphere and organisms in dust and cryoconites; USA as the global dust source monitoring expert for inserting HLD in the global context; New Zealand as an expert for the past Antarctic climates and polar aeolian sediment distribution. It is important to emphasize here that HLD research demands high financial standards because the research is usually maintained far from researcher's own home institution. We aim to build a network comparable to global dust or aerosol networks with added HLD, but the novelty of this research topic and limited understanding of HL natural processes, induced by both natural and human activities, allowed us to create this network of smaller amount of COST countries than it is expected to have at the end of the Action. The EU HLD network is the core of the worldwide effort to understand, monitor and create protection strategies for the European Arctic, Arctic, Antarctic and HL areas of our planet. Gender balance is **63**% males and **37**% females at the moment of submission with a resolution to equalize these numbers during the progress of the Action. The main proposer is a female while the main candidates on the working groups leaders (to be voted at the Kick-off meeting) are females and leading experts on HLD as well. The most of the proposers have an extensive experience related to the challenge of the Action, and have participated in previous and/or current European or International projects related to this topic (see section 1.4.2). The Core Expertise is in the Earth and Environmental Sciences (**74%**) with specialists in physical, biological, chemical sciences and civil engineering. NGOs, Business enterprises and Standard Organisations are about **8%** of the proposers. The HLD-Network proposers are about **14** years after their PHD graduation on average, showing the dedication and top-level scientific experience in this young and novel research topic. Summarizing all above, this guarantees the capability of the Network to achieve the Action objectives.

About **41%** of the of the **17** COST Member Countries are COST Inclusiveness Target Countries (**7**). The cooperation is ensured by presence of the HL countries (Iceland, Finland, Sweden, Norway, Denmark, and United Kingdom), and other countries maintaining their research stations in the HL such as Svalbard, Antarctic stations, Alpine stations (Poland, Italy, Czech Republic). Experts from the remaining countries have conducted their research in HL in short term campaigns or developed methods on remote sensing and modelling of the dust. The work and inputs of these members allow the Action to meet the objectives, foremost the establishment of the first EU-wide multidisciplinary science network with a coordination and leadership of the HL monitoring on the EU level. Representatives of international and European organisations, bodies and associations involved in environmental protection issues will be represented and have already expressed their interest in participating in the current Action. The current network consist of minority of involved countries while experts from the past European initiatives are ready to transfer the knowledge and legacy on current climate state of the European Arctic to proposed HARMO-HLD network and disseminate to increasing number of HL researchers and students from Europe and abroad.

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COST Mission and Policies

The COST Action proposal HARMO-HLD on harmonizing high latitude dust will follow the COST Policy and rules. HARMO-HLD shall be governed by legal, ethical, contractual and administrative rules and principles in compliance with best scientific stewardship and the set of COST Rules. The relevant activities planned in the proposal include (pointing out which COST Policy they target and how):

1. HARMO-HLD will be, as all COST Actions are, **open** to researchers, engineers and scholars or other stakeholders from non-COST countries or Specific Organisations.

2. HARMO-HLD shall be initiated by COST Full or Cooperating Members which, in order to participate in a COST Action, shall formally accept the Action's **Memorandum of Understanding (MoU**). The Action MoU shall be accepted by at least seven (7) different COST Full or Cooperating Members within the six months following the CSO approval of the Action. By accepting the MoU confirm that activities to be covered by the Action shall rely on research funding provided by national authorities or other sources. The adherence to the MoU implies the acceptance the set of COST Implementation Rules.

3. **An Action Management Committee (Action MC**) shall be responsible for the coordination and management of the Action activities. The Action MC shall be composed of representatives of COST Members (maximum two MC Members per COST Member). The Action MC shall elect an Action Chair at its first meeting, which shall be responsible for coordinating the Action MC activities as well as an Action Vice-Chair. Other key leadership positions required for achievement of the Actions' objectives and the implementation of the networking tools shall be elected at the first possible opportunity.

4. HARMO-HLD **MC members** shall be affiliated to a university, research centre, company or other relevant legal
entity and shall adhere to the set of COST Implementation Rules and COST Vademecum. In order to participate in COST Actions, COST Partner Members shall formally accept the Action's Memorandum of Understanding (MoU). **HARMO-HLD will continuously assess achievements against its work plan by setting new steps for implementing MoU.**

5. **Leadership roles in COST Actions:** at least one of the key leadership positions in the Action management (e.g. Action Chair, Vice-Chair, Working Group Leader, Grant Holder, STSM Coordinator) shall be reserved to a representative of a **COST Inclusiveness Target Country** (= Bulgaria, Cyprus, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Luxembourg, Malta, Montenegro, Poland, Portugal, Romania, Slovakia, Slovenia, the former Yugoslav Republic of Macedonia, Republic of Serbia, Turkey, and Bosnia and Herzegovina).

6. **Grant Holder role**: Administering the Action network centered around nationally funded research projects in fields that are of interest to at least seven COST Member States with financial support averages EUR 130 000 per year for a four-year period.

7. **Grant holder/chair/vice-chair roles**: MC Decisions taken by majority vote at approved MC meetings must be recorded in MC Meeting minutes. The MC meeting minutes recording the decision must be filed with the documents that are relevant to why the MC approval was originally sought. The MC can also formally approve the proposed changes by means of a 'written procedure' which involves the Chair (or vice-Chair if the Chair is also based in the Grant Holder institution is able to produce on demand invoices or time sheets which validate the work performed and the amounts paid for the services provided;will be responsible that all activities performed and referred to on any invoice must be performed in their entirety within the respective Grant Period and are relevant to the COST related tasks detailed in the approved Work and Budget Plan.

8. HARMO-HLD, as all COST Actions, shall be **implemented through** a set of networking tools such as meetings (Action MC meetings, Working Groups, workshops, conferences), Short-Term Scientific Missions (STSMs), Training Schools and Dissemination activities.

9. The reimbursement of expenses incurred by Action Participants, other than those incurred by the Action MC Members, depends on the fulfilment of the COST eligibility criteria for reimbursement and shall be
always subject to the availability of COST funds.

10. **HARMO-HLD will put effor in being active in DISSEMINATION OF RESULTS AND OUTCOMES, INTELLECTUAL PROPERTY AND OPEN ACCESS (as described in the Technical Annex)**

Network of Proposers - Features

COST Inclusiveness target countries
42.11 %

Number of Proposers
46

Geographic Distribution of Proposers

Country	ITC/ non ITC/ other	Number of institutions from that country	Number of researchers from that country	Percentage of the proposing network
Austria	non ITC	2	2	4.35 %
Canada	other	1	1	2.17 %
Chile	other	1	1	2.17 %
Cyprus	ITC	2	2	4.35 %
Czech Republic	ITC	2	2	4.35 %
Denmark	non ITC	1	1	2.17 %
Estonia	ITC	2	3	6.52 %
Finland	non ITC	5	7	15.22 %
France	non ITC	1	1	2.17 %
Germany	non ITC	1	1	2.17 %
Hungary	ITC	1	1	2.17 %
Iceland	non ITC	3	4	8.7 %
Italy	non ITC	2	3	6.52 %
New Zealand	other	1	1	2.17 %
Norway	non ITC	1	1	2.17 %
Poland	ITC	2	2	4.35 %
Serbia	ITC	2	2	4.35 %
Slovakia	ITC	1	1	2.17 %
Slovenia	ITC	1	1	2.17 %
South Korea	other	1	1	2.17 %
Spain	non ITC	3	3	6.52 %
Sweden	non ITC	2	2	4.35 %
United Kingdom	non ITC	1	2	4.35 %
United States	other	1	1	2.17 %

Gender Distribution of Proposers
63.0% Males
37.0% Females

Average Number of years elapsed since PhD graduation of Proposers with a doctoral degree
14.0

Number of Early Career Investigators
15

Core Expertise of Proposers: Distribution by Sub-Field of Science
73.9% Earth and related Environmental sciences
6.5% Physical Sciences
4.3% Chemical sciences
4.3% Environmental engineering
2.2% Biological sciences
6.6% Other
2.2% Unspecified

Institutional distribution of Network of Proposers

71.7% Higher Education & Associated Organisations
19.6% Government/Intergovernmental Organisations except Higher Education
4.3% Standards Organisation
2.2% Private Non-Profit without market revenues, NGO
2.2% Business enterprise

Government/Intergovernmental Organisations except Higher Education:9

- Number by Level
  Local government:1
  Central and Federal Government:8
- Number by Type
  Other Public Non-Profit Institution:2
  Government department or government-run general public services:5
  R&D Funding and/or R&D Performing bodies:1
  Non-R&D executive agencies, including sector specific regulatory bodies:1

Higher Education & Associated Organisations:33

- Number by Field of Science of Department/Faculty of Affiliation
  Earth and related Environmental sciences:20
  Other agricultural sciences:1
  Physical Sciences:4
  Civil engineering:2
  Chemical sciences:4
  Biological sciences:1
  Interdisciplinary:1
- Number by Type
  Education Oriented:10
  Research Oriented:23
- Number by Ownership
  Fully or mostly private:1
  Fully or mostly public:32

Private Non-Profit without market revenues, NGO:1

- Number by Type
  Other:1

- Number by Level
  National:1

Business enterprise:1

- Number by Market sector of unit of affiliation
  Professional, Scientific And Technical Activities:1
- Number by Type
  Private enterprises:1
- Number by Ownership and International Status
  Independent Enterprise:1
- Number by Size
  SME (EU Definition provided underneath after selection):1

Standards Organisation:2

- Number by Membership type
  Including at least partial government membership:2
- Number by Level
  National:1
  International:1

COST Country Institutions(19) : Austria , Cyprus , Czech Republic , Denmark , Estonia , Finland , France , Germany , Hungary , Iceland , Italy , Norway , Poland , Serbia , Slovakia , Slovenia , Spain , Sweden , United Kingdom
Near-Neighbour Country Institutions(0) :
COST International Partners(5) : Canada , Chile , New Zealand , South Korea , United States
European Commission and EU Agencies(0)
European RTD Organisations(0)
International Organisations(0)

Network of Proposers - Details

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Sub-field of Science of Department:		**Core Area of Expertise:**	Earth and related Environmental sciences (Climatology and climate change)

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Years from PhD: 4

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Years from PhD: 22

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