COST
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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 European weather services, air quality, and climate change assessment".

HARMO-HLD responses to the needs rising from the operational weather services and climate research and focuses on **light absorbing natural dust aerosols (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/inter-comparing measurement, modelling or remote sensing techniques and effects of dust**. Volcanic eruptions are excluded.** The **time scale** includes both contemporary (monitoring and satellite observations) and historical (climate modelling, historical dust).

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

- **harmonizing HLD** monitoring and analysis techniques of dust in air and cryosphere; modeling of emission, transport and deposition processes; field and remote sensing; air quality and operational responses to dust events;

- **assessment of HLD** including sources, characteristic, effects and contributions of various HLD emissions to the global dust load.

This will be achieved through networking, including intercomparison work, workshops, STSMs, exchange and training, and linking them to activities in international agencies and established global networks.

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
Databases, data mining, data curation, computational modelling

Environmental engineering
Risk assessment, prevention and mitigation

Keywords

High-latitude dust

Weather services and air quality

Climate and global dust load

Light absorbing aerosols

Remote sensing of aerosols

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 European weather services, air quality and climate change assessment"**

Keywords: High Latitude Dust, HLD

1. S&T EXCELLENCE

1.1. CHALLENGE

1.1.1. DESCRIPTION OF THE CHALLENGE (MAIN AIM)

Anthropogenic and natural dust, as major constituent of air pollution, affect a wide range of **geophysical, biochemical and biological processes on Earth** including soil formation, ice melt-rates, lake and marine productivity, as well as air quality. Reduced air quality, and sand or dust storms, affect both **health and economy**.

Natural dust is often associated with hot, subtropical deserts, but a mostly forgotten source of dust originating from **cold high latitudes (≥ 50 °N and ≥ 40 °S)** has recently started to receive more and more attention. In a recent *Reviews of Geophysics* -paper, it has been recognized that dust produced in high latitude and cold environments can have **regional and global significance** (Bullard et al. 2016). These natural **High Latitude Dust (HLD)** sources cover over 500 000 km^2 and produce tremendous amounts of **particulate matter (about 100 Tg/yr) which is poorly monitored and predicted, and not included in the current modelling approaches. The main identified sources** in the Northern Hemisphere include Iceland, Greenland, Svalbard, Alaska, and Canada, and Southern sources of Antarctica, New Zealand, and Patagonia, for example (Figure 1). The very first modelling studies show that **Europe's and Greenland's dust production** and **main transport pathways are clearly affecting both the High Arctic and the European mainland**.

Several studies have shown that **HLD has different physical, chemical and optical properties compared to crustal dust as known from the Sahara or American deserts.** The **highly light absorbing HLD aerosol particles**, up to *as black as black carbon*, can induce **significant direct and indirect effects on solar radiation fluxes and snow optical characteristics, strongly impacting Arctic amplification via radiative feedbacks**. Moreover, the World Meteorological Organization **WMO Sand and Dust Storm Warning Advisory and Assessment System SDS-WAS is focusing only on desert dust and HLD is not considered at the moment.**

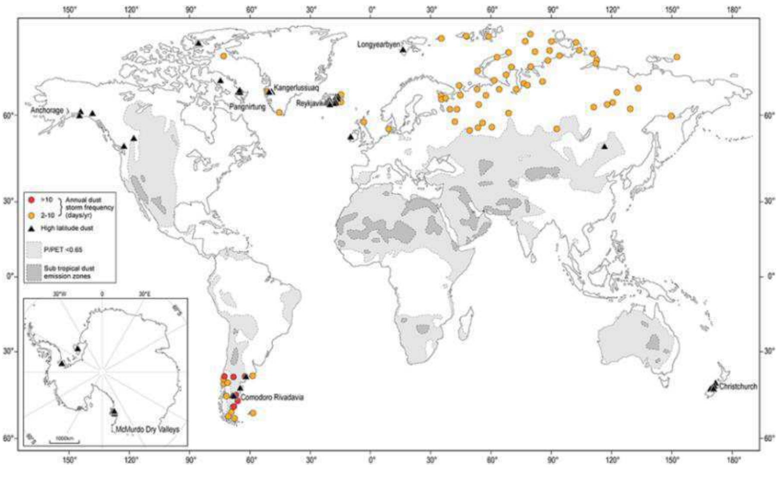

Figure 1. Global observations of high-latitude dust, where filled circles indicate dust storm frequency based on visibility data, and black triangles indicate georeferenced published observations of dust storms. Areas with potential evapotranspiration ratio <0.65 (aridity index) [*United Nations Environment Programme*, 1997] are indicated with light grey and subtropical dust emission zones with dark grey. From *Bullard et al. 2016, Reviews Geophysics*.

The largest desert **in Europe** is located at high latitude in **Iceland** and it is also the largest desert in the northern polar region with the size of Denmark or Slovakia. The resuspension of Icelandic volcanic ash and dust transport over the North Atlantic was first described by Prospero et al. (2012) (Figure 2).

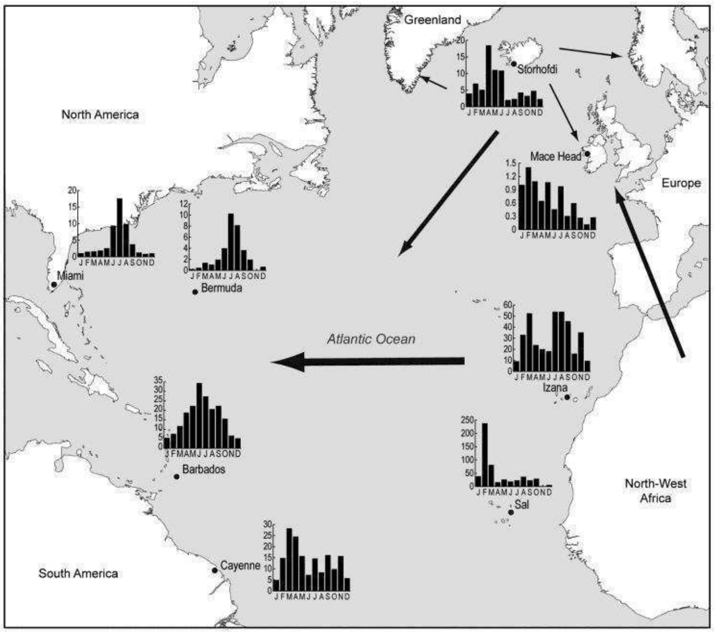

Figure 2. Mean monthly dust concentrations recorded at eight stations around the Atlantic Ocean. Arrows indicate main directions and relative magnitude of dust transported over the North Atlantic. From *Prospero et al. 2012, Science*.

It has been shown that temperatures in fragile areas, such as the pristine polar regions, have been increasing at twice the global average, causing an accelerated melting of the glaciers. Consequently, potential HLD sources such as glacial sediments are increasing. When dust is blown to the glacier surface, ice albedo decreases and influences glacier melt rates via the 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 transported over long distances, but much is deposited locally and then resuspended to form dust plumes. Also deposited ash has been shown to be an important dust source after the original eruption.

HLD is not limited to “dry deserts" at high latitudes. For example, the Southern coast of Alaska has a very wet, maritime climate but cooling and drying events lasting 1-30 days create conditions that encourage dust emission. Similar processes take place in New Zealand or southern coast of Iceland with dust sources in very wet places.

The proposed COST HARMO-HLD Action will focus on **natural HLD dust (resuspended mineral dust and ash either originating from high latitudes, or transported there from elsewhere)** for harmonizing and inter-comparing the techniques for monitoring and modelling of HLD to quantify 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 re-mobilized by wind in volcanic regions (such as Iceland, for instance) is carefully considered.**

Deposited ash has been shown to be an important dust source months/years after the original eruption. During recent years, several research groups have put efforts into monitoring and modelling HLD sources and came together for the first time at the International Conference on High Latitude Dust in Iceland in May 2017 (Gassó et al. 2018). This event showed the large scale of produced air pollution due to HLD and its climatic impacts as well as the urgent need to synchronize and harmonize the diverse research methods and aims for a better understanding of such a poorly investigated phenomena.

The main aim of the proposed COST HARMO-HLD Action is to establish a **European network for harmonizing the HLD monitoring, modelling and satellite approaches for the benefit of weather services as well as air quality and climate change assessments (Fig. 3).** HARMO-HLD will establish an international cooperation network involving research institutions, national agencies, commercial service providers and potential end users regarding the monitoring and assessment of HLD.

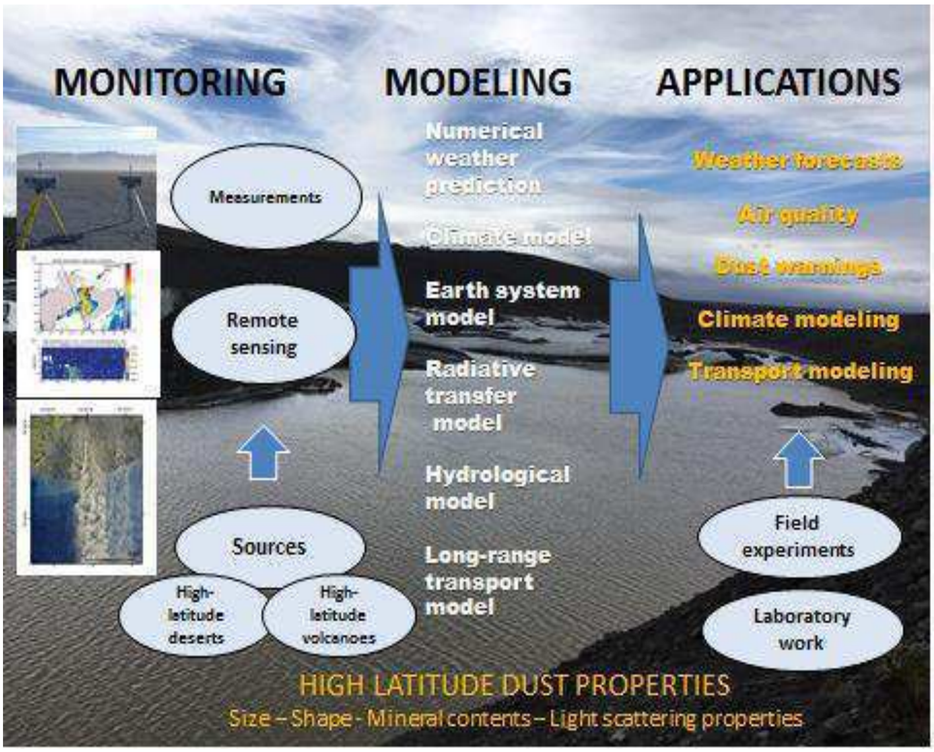

Figure 3. Schematic structure of HARMO-HLD with the focus on natural dust either originating from high-latitudes (≥ 50 °N and ≥ 40 °S) or transported from elsewhere, including deposited re-mobilized ash, but excluding direct emissions of volcanic eruptions. **Highly light-absorbing HLD aerosols have different physical and chemical properties than crustal dust, with strong implications on health, environment and climate**.

This action will coordinate the current multi-disciplinary research of diverse groups **to enhance the scientific understanding of HLD** (including geology, biology, ecology, glaciology, hydrology, meteorology, climate, as well as remote and in-situ observations) and to **assess impacts on diverse socio-economic sectors** including **tourism, transportation and public health**. The coordinated efforts and networking will **improve dust forecasting** methods and **warnings** through weather services, municipalities, road administration or environmental agencies to the general public on expected dust storms, not sufficiently available at the moment. The Action ensures that the best practices and quality of the measurements on the European level can be adapted.

1.1.2. RELEVANCE AND TIMELINESS

HLD is a **<u>poorly understood risk to the human health, to the environment, and to the climate</u>**. The fundamental processes controlling aeolian dust emissions in high latitudes are essentially the same as in temperate regions, but there are additional specific factors influencing the processes in cold regions. These factors include low temperatures and low humidity, strong winds, permafrost and niveo-aeolian processes, all of which can affect the efficiency of HLD emission and distribution. **HLD has different physical and chemical properties than crustal dust with strong implications on health, environment and climate**. Dust in general is an essential and relevant environmental variable with multiple effects.

Firstly, dust plays an important role for **socio-economical effects** such as air quality and public health. It can negatively affect daily societal activities in both densely inhibited regions as well as remote communities, such as in Iceland or Greenland. Air quality and dust warnings are on-going activities in several meteorological services of relevance to HLD as well. In 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 (*European Environment Agency 2016*), but more research is needed on health impacts of natural HLD.

Secondly, dust is an important **weather and climate** variable. HLD has similiar properties as anthropogenic aerosols and can be as absorbing as black carbon. Radiative feedbacks can therefore contribute to Arctic amplification. Also, Arctic and Antarctic climate change both lead to dust production and are enhanced by dust via feedbacks. For example, changes in dust emission patterns can be expected due to changing Arctic conditions, like retreating glaciers, but also extension of vegetated areas in Greenland. Moreover, historical dust (palaeodust) is not only a contributor to climate change but also forms a record of previous dust and climate conditions.

Thirdly, dust deposition can provide **nutrients to marine ecosystems** by contributing specifically iron.

Fourthly, mineral and organic matter deposited on glaciers, including natural and anthropogenic dust, can form cryoconite granules. Granules, dust and ice algae can reduce surface albedo and accelerate the melting of the glaciers. Consequently, **glacier melting constitutes an important natural hazard as a main contributor to sea level rise.** Also, glacier surface water run-off can be a potential source for pathogens, black carbon, persistent organic pollutants and antibiotic resistance bacteria, which were deposited on the glacier together with dust.

These effects reveal that monitoring of dust and especially of HLD in 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

Overall research coordination objectives: Establish a first European-wide integrative and multidisciplinary science network on light absorbing aerosols of HLD to create an understanding and quantification on high-latitude dust, *different from warm desert dust,* and identify and exploit observations for HLD monitoring from ground-based and satellite platforms, and forecast products to be transferred and tailored to the needs of end users, coordinate collaboration between data producers and users, build capacity of end-users to promote the use of delivered products, with the focus on HLD impacting Europe's and global climate (including remote regions in the European Arctic as well as non-EU Arctic dust sources such as Alaska, Canada, Siberia, and southern HLD sources in Antarctica, New Zealand or Patagonia.)

Specified scientific and operational objectives:

1. Establish a first European-wide integrative and multidisciplinary science network on HLD measurements and modelling, and optimum use of corresponding products in applications by direct inclusion and interaction across disciplines.
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 an international level. Temperate regions are used for testing and inter-comparisons of new methods and measurement techniques. Networking of project partners with expertise in numerical dust modelling is encouraged to implement their forecasting and climate models to HL regions.
3. Advance the application of HLD data assimilation in European weather, climate and hydrological models and show its benefit for weather forecasting and climate and Earth system modelling to improve, air quality warnings as well as other applications.
4. Parametrization of HLD and volcanic ash particles for the existing dust particle data basis, and other relevant data bases, where currently all HLD particle characteristics as light absorbing aerosols are missing.
5. Develop a rationale and long-term strategy for HLD-related measurements and modelling products as inputs to soils, oceans and cryosphere, including their dissemination and archiving.

6. Establish a validation strategy for weather, hydrological and climate models and remote sensing approaches using dust observations.
7. Involve outside Europe HLD areas such as South America, Antarctica, Canada, USA, and Russia in the European-driven network and practices.
8. Maintain and expand a network of experts, researchers, early career investigators, and University students that allows the achievement of the previous objectives. European polar region research including atmosphere and cryosphere observations gather many young researchers from the ITC (Inclusiveness Target Countries) which will be emphasized in our network, including Czech Republic, Poland, Hungary, Serbia, and other.
9. Disseminate according to the implementation of the work plan (GANTT diagram 3.1.2).

1.2.2. CAPACITY-BUILDING OBJECTIVES

HARMO-HLD will focus on harmonizing monitoring, modelling, field and remote sensing, and this will be achieved through networking. The STSMs from PhD students, ECI and participants from Inclusiveness Target Countries will have priority, and the Action focuses on preserving gender balance (responding to the general gender imbalance in physical/natural sciences). HARMO-HLD emphasizes capacity building via its objectives to:

- **Foster knowledge exchange** between separated research units on HLD. Scientists and groups dealing with HLD, such as the physical characteristics of aerosol particles, dust monitoring and measurements, its description in models, HLD mineralogy and its impact to the environment and health (including, e.g., iron (Fe) effects) and biological processes on glaciers affected by dust, are often working separately in individual institutes, projects and countries. Therefore, this Action will build a linkage between the various issues from local-scale characteristics to remote-sensed broad areas, from micro-scale modelling to climatic and hydrological parameters and from instrumental capabilities to data assimilation (DA). This 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), with focus on polar researchers from the ITC countries encouraging them to present their work at topical conferences.
- **Engage trainees and give guidelines** for the policy makers and educational institutions.
- **Engage national stakeholders:** Governmental stakeholders (National and/or Regional, e.g. National weather services, Environmental Agencies, National Parks and UNESCO Heritages, WMO SDS-WAS dust programme, 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.
- **Collect and disseminate** research results of the project partners, including best measurement and modelling practises and new climate change connections together with mitigation/adaptation strategies, to the general public and stakeholders.

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 and WMO SAG-Aerosols and the GAW programme)** for taking stock of the Action’s achievements with respect to measurement and model prediction 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.

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 HLD sources at **regional scales for** Iceland, Greenland, Alaska, Canada, Antarctica, New Zealand, and Patagonia. A review on HLD is available in Bullard et al. (2016). **For the European Arctic, several important sources were not included** and long-term research studies from European research groups maintaining aerosol stations in Europe's high latitude were not discussed. Both the land area of HLD sources and the contribution of HLD sources to global dust budget are predicted to increase under future climate change scenarios. The important fact is that Europe's largest desert is located at HL, in Iceland in the vicinity of glaciers. The long-term evidence on dust days from Iceland shows a frequency of about 135 days/year. The scarcity of year-round observations and limitations of satellite remote sensing data are an important scientific issue to be discussed and improved.

First modelling studies have estimated the amounts of **Europe's and Greenland's dust production** and **main transport pathways are clearly affecting both the High Arctic and the 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 therefore has 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, and it is also linked with the cryosphere.

On national level, several aerosol monitoring stations have been established and run successfully in European Arctic and Antarctic stations, and investigated under European projects. HLD has, however, never been investigated or focused on EU or EU Arctic level.

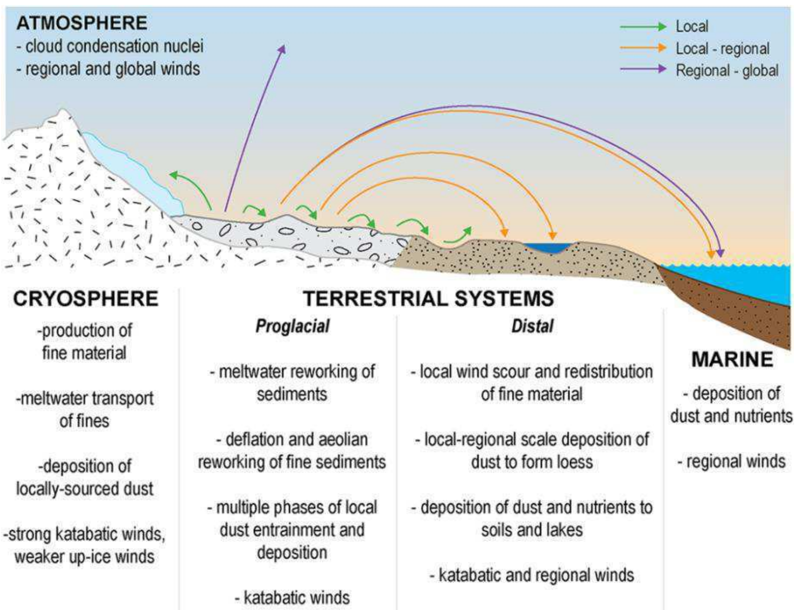

Figure 4. The current understanding of HLD. From *Bullard et al. 2016, Reviews Geophysics*.

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

COST Action HARMO-HLD Network will be the first European level HLD initiative. It is a network connecting all the HL researchers in EU and elsewhere with the main goal TO TARGET A POORLY UNDERSTOOD AEROSOL FORCER AFFECTING BOTH THE ARCTIC AND EUROPE.

The present Action will create a synergy among European HLD researchers from different scientific fields including also aerosol researchers from other research fields, including measurement, modelling and remote sensing of atmosphere, cryosphere, hydrosphere and biosphere. Aerosol researchers of different fields are using different methods to quantify their aerosol or dust inputs. Some researchers are **not aware of large dust sources in the European Arctic** at all. HARMO-HLD will give guidelines to the outside-Europe HLD researches, but it will also build research cooperation on dust among the aerosol research community not only working in the Antarctica, where aerosol researchers from many European countries conduct their research next to each other, but in Europe generally. HARMO-HLD is determined to foster the knowledge transfer between the academic bodies, the *European directive*, *Arctic protection institutions*, national stakeholders, municipalities, tourist boards and other interested stakeholders.

Currently HLD is not, nor has previously been, investigated or focused on EU or EU Arctic level. HLD has different physical, chemical and optical properties compared to crustal dust as known from Sahara or American deserts, and HLD is also linked with the cryosphere. **The optical properties and effects of HLD can even be closer to those of black carbon than to Saharan dust. Therefore, HLD is to be considered as its own type of aerosol, with unique properties in some respect close to black carbon and in some respect close to Saharan dust.** HARMO-HLD's objectives are aligned and complemented to the mineral dust forecast platform of the **World Meteorological Organization Sand and Dust Storm Advisory and Assessment System** (WMO WAS-SDS, https://sds-was.aemet.es/) which is operating for the dust sources outside Europe (Sahara and Middle-East), and the related recently granted COST action International Network to Encourage the Use of Monitoring and Forecasting Dust Products (InDust, CA16202, www.cost-indust.eu), and with the European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases ACTRIS (https://www.actris.eu/*)*, and the International Convention for the Safety of Life at Sea SOLAS (http://www.imo.org).

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 **atmospheric direct (radiation) and indirect (clouds) effects**, as well as environmental, health and climate impacts.

1.3.3. INNOVATION IN TACKLING THE CHALLENGE

The innovations and added value of this COST network will be due to its HLD focus complementary (and beyond) the existing and previous networks of aerosol monitoring in Europe. None of the previous networks focus on HLD. The innovations of this Action are:

- In order to improve the accuracy and precision the use of the receptor models, a chemical approach is required to determine exact fingerprints of dusts from their natural emission sources. Also, specific chemical forms of elements originating from emission sources can help following long-range atmospheric transport of dusts. This information in combination with receptor models will help to evaluate the contributions of various natural emissions sources to the global dust load.
- Exploring mineralogy effects of transported dust to marine biochemistry, health and climate.
- Assessing climate change and HLD, with a particular focus on HLD role in modifying snow and ice optical characteristics and impact on seasonal snow melting process as well as radiative feedbacks and influence of dust on glacier melt.
- Detection and control of the specific aerosol, HLD and ash, in Europe for EU Arctic protection and awareness.
- Obtaining and harmonizing missing characterisation for the geological databases.
- Incorporating HLD knowledge to existing dust platforms.

- Utilizing the knowledge during the sudden events such as volcanic eruptions of HLD volcanoes.
- Advancing and guiding state-of-the-art research on HL and volcanic dust.
- Involving commercial partners to specify user-tailored products.
- Potential technological or socioeconomic innovation.

1.4. ADDED VALUE OF NETWORKING

1.4.1. IN RELATION TO THE CHALLENGE

HARMO-HLD will focus on characteristics of HLD, different from warm desert dust, and contribution of HLD to the global dust load. The network will focus on harmonizing monitoring, modelling, 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 modelling of atmospheric dust life-cycle.

This will be achieved through networking, including inter-comparison work, workshops, short-term scientific missions, exchange and training, and linking them to activities in international agencies and global networks. All parties of the network will benefit from the cooperation – the observers provide source data to modellers as well as to remote sensing experts. Modellers and forecasters can provide products to stakeholders. Stakeholders are needed to participate on the evaluation of the products during the progress as well as express their needs to be implemented in the products. The main goal is the awareness of general public about this specific phenomenon from all points of view – health, property protection, preparedness and awareness, as achieved through the dissemination of the Action. Scientific network will bring innovative break-through results, which can be further investigated from the various scientific disciplines point of view. Natural habitat is what the Europe should be protecting the most. To gain this, first step is the scientific understanding of the inner mechanisms in such environments, to be able to provide the best protection of such environments and people living in their vicinity. The scientific core of this action will provide such needed information. The EU air quality monitoring will get new aerosol information from our Action, and climate assessments will gain reduction in uncertainties on factors related to Arctic Amplification. Special attention in this Action will be given to the remote sensing techniques at high latitudes with limited amount of daylight in winter.

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

This Action, as a science and technology network, will co-operate with the international efforts and established networks related to its topic and will be open for all participants to join. **As a first European level initiative on HLD**, it will widen the perspective of the existing efforts of, for example, World Meteorological Organization WMO SDS WAS (WMO has always favourably considered COST Actions and is observer in the ESSEM DC), WMO GAW, ESA, EUMETSAT, NOAA, AMAP (Arctic Monitoring and Assessment Program) and SCAR (Scientific Committee on Antarctic Research). HARMO-HLD will be open for all participants to join its activities of workshops, conferences, training schools, short-term scientific missions (STSMs) and dissemination, and it will aim at participation, coordination, collaboration, and planning of future initiatives in its field of science. HARMO-HLD will implement suitable tools and results, evaluate existing tools for HLD, improve or create new tools so existing efforts will clearly benefit from this.

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; Contribution to dust forecasts, dust monitoring control, Arctic protection, transport control (road and aviation), health community, tourist boards, environmental and air quality agencies; understanding and quantifying the effects of HLD on climate and climate change; climate change mitigation; **Coordination and harmonization** of current HLD methods and research and sustainability in top-level science for the benefit of

measurements, remote sensing, modelling and forecasts and warnings and distributing to stakeholders.
<u>**Long term:**</u> 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, predict the future behaviours, assess risk and mitigation plan to preserve the European Arctic and HL worldwide. To attract the next generation of scientists via student training and to create a problem-awareness to promote HLD research at universities.
<u>**Technological:**</u> Harmonization and development of the measurement methods and technologies. <u>**Socioeconomic:**</u> the aviation, remote sensing community, forecasts, assessments, health/dust warnings and tourism will benefit from the HARMO-HLD 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 will be engaged to this Action. 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. <u>**The most relevant stakeholders are:**</u>

- **National Weather Services:** to assimilate dust observations in NWP models and validate models as well as for guidance in dust observation networks and training of operators.
- **Hydrological Services:** to assimilate and calibrate hydrological models using improved dust observations as well as for guidance in hydrological observations related to dust.
- **National environmental authorities and policy makers on a national, EU-wide and international level**: 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 within the IPCC:** to use improved dust observations for evaluating and developing models that produce climate change scenarios.
- **The next generation of scientists:** student training to attract more researchers into this specific field, and to create a problem-awareness, to promote Arctic and Antarctic high latitude dust research at universities.
- **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.
- **Aviation** authorities.
- **Tourism** organizations.

2.2.2. DISSEMINATION AND/OR EXPLOITATION PLAN

<u>***HARMO-HLD responds to the needs***</u> rising from air quality and meteorological services, high-latitude climate change assessment, remote sensing and modelling communities as HLD differs from non-HLD aerosols by sources, properties and effects. **None of existing networks on monitoring the European Arctic consider HLD as an environmental issue although over 100 peer reviewed scientific papers have been published since 2010**. 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)** reports. Research results will be disseminated to health authorities to give warnings during extreme events. Health science representatives will be selected to disseminate the Action's achievements to the community and targeted health institutions.

<u>***HARMO-HLD generates new knowledge on***</u> obtaining the reliable information on Arctic deserts, glaciers, atmospheric composition and standardize and harmonize the practices. A handbook on the best practices will be introduced recommending the practices at polar stations and to *The European Monitoring and Evaluation Programme* ***(EMEP)*** *and contribute to* ***EBAS database***

(http://ebas.nilu.no/). Data will be shared leading to a European database on parameters of HLD and aerosol. Besides currently missing HLD parameters will be added 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. This transfer of the knowledge will be through the representatives of the databases - mainly weather services.

HARMO-HLD benefits and results will be shared with stakeholders including standardization bodies, policy-makers, regulators, existing organizations and associations, AMAP (Arctic Monitoring and Assessment Program) and meteorological institutes. Rising awareness is the key to outreach the gained knowledge on the European Arctic. HARMO-HLD will coordinate the fragmented research groups under one network to successfully spread the generated innovative results to: a) the *public*, and to 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 and feedbacks. b) *Governmental national and/or regional stakeholders* (**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**). c) Non-governmental organisations (NGOs) active in the sector **(municipalities, tourist boards, aviation authorities, road administrations, ski areas**).

HARMO-HLD Action plan comprises all elements required to meet its objectives, covering benefits in establishing a 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 and STSM to ensure the preservation strategies for an existing and future HLD network.

***The end users will be informed about the generated results as follows*:** Scientific communities will be engaged through international conferences (EGU, AGU, DUST), social media, 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. The public community will be informed via *media, social media, popular geographical journals, wikipedia, newsletters and websites of this initiative as well as of aerosol and dust associations.*

Awareness-raising and communication between scientists from different science fields, aerosol scientists, outside Europe HLD experts and aerosol scientists: 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, including a **HLD publication repository**; Actions highlights will be promoted periodically through **'newsroom'** at the Action´s website as well as the **cost.eu website**; **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. 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 **scientific breakthroughs include**: identification of new aerosol types with high impacts on climate; understanding of the role of European Arctic in climate change 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 feedback mechanisms between Arctic biota and dust **including phytoplankton 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. **Technological breakthroughs:** 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. **Socioeconomic innovation;** Awareness-raising, innovative research; protection in tourist areas and ski areas, aviation and road administration protection; attractiveness of such regions for tourists, but contrarily nature protection needed. **The overall breakthrough:** Establishing Europe as the science excellence leader in European Arctic monitoring and protection while adopting the EU Arctic monitoring strategy by other Arctic areas with expansion to the Antarctic and other HL areas.

3. IMPLEMENTATION

3.1. DESCRIPTION OF THE WORK PLAN

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. **Task 1.4.** To coordinate approaches for generating data on gridded soil types and mineralogy of dust sources.

Deliverable 1.1 A map and classification of the HLD sources to be implemented to the global dust source maps.
Deliverable 1.2 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 High Latitude Dust sources assessment Dissemination of D1.1. and 1.2. 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 inter-comparison 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), Ion Beam Analysis (elemental composition, particle size, shape), and SEM-EDS (mineral chemistry). **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. Two measurement campaigns will be conducted to obtain maximum of data for 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. **Task 2.5 Student's training school** on dust measurements.

Deliverable 2.1 Handbook on the best practices for methods and measurements
Deliverable 2.2 Assessment on the chemical properties of HLD for the 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.

Milestone 2.1 Two inter-comparison field campaigns linked to one student's training school on HLD, places to be jointly decided on the basis of suggestions presented in the first MC and WG meetings.
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. WGs on different aspects contributing to successful dust model system to be 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 modelling 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 Weather research and forecasting model, WRF.** 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 modelling 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 modelling 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 New modelling parameterizations/schemes through validation against measurement data.
Deliverable 3.2 HLD in climate models.
Deliverable 3.3 HLD in WRF models.
Deliverable 3.4 Assessment on the HLD feedback mechanisms with environment and future projections.
Deliverable 3.5 Identification of model users.
Milestone 3.1 Inter-comparison of different modelling approaches and parameterizations and final method exchange with field & lab groups (WG1,2) to improve dust models with physical properties and dynamical processes.
Milestone 3.2 Dissemination of D3.1-D3.4 to global forecasting centers, governmental stakeholders (Dissemination twice during the Action = mid-term and end term), including attendance at the EGU special "COST session".
Milestone 3.3 Assessment evaluating dust simulations of severe HLD storms

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 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. **Task 4.4 Threats to transportation and aviation** to assess the risk of reduced visibility, and in extreme cases engine damage, 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 (webpage of the Action including a HLD publication repository and 'newsroom' as well as the cost.eu website**,** 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 cryosphere 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, responsible persons, dissemination reports.
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. **M4.4 Final joint assessment based on the M2.2, M3 and D4.1-5.**

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 “Modelling of dust”, while WG2 will inform WG1 when 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 WG1-3, 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 conferences and STSMs will be organised to improve the networking.

3.1.2. GANTT DIAGRAM

	Year 1				Year 2				Year 3				Year 4			
HARMO-HLD ACTIVITY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
WG1 - Dust Sources																
Task 1.1,1.3,1.4				D1.1												
Task 1.2								D1.2				M1				
WG2 - Measurements on dust																
Task 2.1,2.5				D2.1			M2.1									
Task 2.2										D2.2				M2.3		
Task 2.3										D2.3.1,2						
Task 2.4								D2.4					M2.2			
WG3 - Modelling of dust																
Task 3.1				D3.1			M3.1									
Task 3.2									M3.3		D3.2					
Task 3.3					D3.5						D3.3		M3.2			
Task 3.4													D3.4			
WG4 - Impacts and dissemintaion																
Task 4.1															D4.1	
Task 4.2												D4.2				
Task 4.3							D4.3									
Task 4.4													D4.4		M4.4	
Task 4.5	D4.5		M4.1				M4.3				M4.2					

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 focuses on resuspended dust. The risks are: RISK1: Dissemination of the Action's results to National stakeholders and policy makers. CONTINGENCY PLAN1: 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. RISK2: Low attendance of the MC members for the voting at the MC meetings CONTINGENCY PLAN2: Evaluation of the participants attendance prior the MC meeting by the Action's director. RISK3: Field campaign organization and measurement acquisition CONTINGENCY PLAN3: 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. RISK4: STSM flow - too many or too few applications. CONTINGENCY PLAN4: 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. The risk will be minimized by linking field campaigns, training schools and STSMs. RISK5: Delay in delivery of deliverables or fulfilling milestones on time. CONTINGENCY PLAN5: 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 the selected and most appropriate COST member), and detailed monitoring of tasks progress. RISK6:Ensure high participation of ECI (>current 25%). CONTINGENCY PLAN6: STSM, ITC grants, training school, field campaigns, providing new topics and leadership for theses and publications.

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. The Action is based on four Working Groups (WG). Management Committee (MC) meetings will be carried out once a year with the WG meetings, and additional WG meetings will be arranged to implement the work plan. Open discussion and planning is the most important to maximise the Action's success. 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 **56** proposers from **21** COST countries and **2** International Organisations, with **14** ECIs (**25 %**). In addition, atmospheric and cryosphere experts from the Non-COST countries will be involved as International Partner Countries (**7** – Argentina, Canada, Chile, India, Japan, South Korea, United States; more HLD experts from the New Zealand, Australia, South Africa, and Russia are expected as representatives of the Antarctic, Greenland, Alaska and Patagonian HLD sources). Each IPC have a specific role in the HARMO-HLD network: For example, Canada has been an active in High Latitude and Cold Climate Dust investigations, it has many dust sources and expertise in source dynamics; South Korea is an expert in cryosphere and organisms in dust and cryoconite; USA as the global dust source monitoring expert for inserting HLD in the global context. 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 rather smaller amount of the COST countries that 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 **62 %** males and **38 %** 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 group leaders (to be voted at the Kick-off meeting) are females and leading experts on HLD as well. The Core Expertise is in the Earth and Environmental Sciences (**80 %**) with specialists in environmental engineering (~**5 %**), physical, biological and chemical sciences (**9** %), and other (~**5 %**). **64 %** of proposers represent higher education and associated organizations, **30 %** governmental organizations, **4 %** standard organizations and **2 %** private. NGOs, Business enterprises and Standard Organisations are **5 %** of the proposers. The HLD-Network proposers are on average **16** years after their PhD graduation, 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 **43 %** of the **21** COST Member Countries are COST Inclusiveness Target Countries. The cooperation is ensured by presence of the high-latitude countries and countries maintaining their research stations at HL (North and South). 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 EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

COST Mission and Policies

The COST Action proposal HARMO-HLD on harmonizing high latitude dust will carefully 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. HARMO-HLD will work activily to create links between the scientific communities, the enterprises, the policy makers and the society. HARMO-HLD will promote geographical, age and gender balance throughout its activities and operations.

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 and ITC researchers:** 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

42.86 %

Number of Proposers

56

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
Argentina	other	1	1	1.79 %
Austria	non ITC	2	2	3.57 %
Canada	other	1	1	1.79 %
Chile	other	1	1	1.79 %
Cyprus	ITC	1	1	1.79 %
Czech Republic	ITC	2	2	3.57 %
Denmark	non ITC	1	1	1.79 %
Estonia	ITC	2	3	5.36 %
Finland	non ITC	5	7	12.5 %
France	non ITC	1	1	1.79 %
Germany	non ITC	3	3	5.36 %
Hungary	ITC	1	1	1.79 %
Iceland	non ITC	4	4	7.14 %
India	other	1	1	1.79 %
Ireland	non ITC	1	1	1.79 %
Italy	non ITC	4	5	8.93 %
Japan	other	1	1	1.79 %
Norway	non ITC	1	1	1.79 %
Poland	ITC	1	1	1.79 %
Portugal	ITC	1	1	1.79 %
Serbia	ITC	2	2	3.57 %
Slovakia	ITC	1	1	1.79 %
Slovenia	ITC	1	1	1.79 %
South Korea	other	1	1	1.79 %
Spain	non ITC	3	3	5.36 %
Sweden	non ITC	2	2	3.57 %
United Arab Emirates	other	1	1	1.79 %
United Kingdom	non ITC	1	2	3.57 %
United States	other	4	4	7.14 %

Gender Distribution of Proposers
62.5% Males
37.5% Females

Average Number of years elapsed since PhD graduation of Proposers with a doctoral degree
16.4

Number of Early Career Investigators
14

Core Expertise of Proposers: Distribution by Sub-Field of Science
80.4% Earth and related Environmental sciences
5.4% Environmental engineering
5.4% Physical Sciences
1.8% Biological sciences
1.8% Chemical sciences
3.6% Other
1.8% Unspecified

Institutional distribution of Network of Proposers

64.3% Higher Education & Associated Organisations
30.4% Government/Intergovernmental Organisations except Higher Education
3.6% Standards Organisation
1.8% Private Non-Profit without market revenues, NGO

Government/Intergovernmental Organisations except Higher Education:17

- Number by Level
  Local government:1
  Central and Federal Government:14
  International:2
- Number by Type
  Other Public Non-Profit Institution:4
  Government department or government-run general public services:8
  R&D Funding and/or R&D Performing bodies:4
  Non-R&D executive agencies, including sector specific regulatory bodies:1

Higher Education & Associated Organisations:36

- Number by Field of Science of Department/Faculty of Affiliation
  Earth and related Environmental sciences:21
  Other agricultural sciences:1
  Physical Sciences:4
  Chemical sciences:5
  Civil engineering:1
  Agriculture, Forestry, and Fisheries:1
  Biological sciences:1
  Clinical medicine:1
  Environmental engineering:1
- Number by Type
  Education Oriented:12
  Research Oriented:24
- Number by Ownership
  Fully or mostly private:2
  Fully or mostly public:34

Private Non-Profit without market revenues, NGO:1

- Number by Type
  Other:1
- Number by Level
  National: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(21) : Austria , Cyprus , Czech Republic , Denmark , Estonia , Finland , France , Germany , Hungary , Iceland , Ireland , Italy , Norway , Poland , Portugal , Serbia , Slovakia , Slovenia , Spain , Sweden , United Kingdom
Near-Neighbour Country Institutions(0)
COST International Partners(7) : Argentina, Canada, Chile, India, Japan, South Korea, United States
European Commission and EU Agencies(0)
European RTD Organisations(0)
International Organisations(2)

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: 26

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Years from PhD: 9

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Years from PhD: 15

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Years from PhD: 18

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Years from PhD: 15

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Years from PhD: 16

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Years from PhD: 0

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Years from PhD: 6

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Years from PhD: 13

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Years from PhD: 4

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