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Title: **Integrating Sea, Land, and Atmosphere in Subtropical Islands**

Acronym: **ISLAS**

Summary

The main objective of the ISLAS (Integrating Sea, Land, and Atmosphere in Subtropical Islands) Action is to build synergic bridges between diverse Earth Science disciplines to develop, together with stakeholders, an interdisciplinary network for an improved understanding of the risks and impacts of natural hazards and climate variability in Subtropical North-Eastern Atlantic (SNEA) Islands. It will foster ground-breaking research and, at the same time, it will provide much-needed dissemination and action opportunities for the new climate scenarios of our changing world.

SNEA islands are viewed by the Action as natural laboratories to study the interplay between the physical components of the Earth System, i.e., the solid Earth, the ocean and the atmosphere. This unique platform will involve young and experienced researchers from diverse scientific disciplines such as meteorology and climate, oceanography, geodesy, geology, geophysics and environmental sciences, among others. The outcome of this Action will help stakeholders and policy makers to develop and improve policies and programs that can effectively reduce climatic and geological risks and their impacts.

Key Expertise needed for evaluation

Earth and related Environmental sciences
Climatology and climate change
Earth and related Environmental sciences
Geology, tectonics, volcanology
Earth and related Environmental sciences
Physical oceanography
Earth and related Environmental sciences
Meteorology, atmospheric physics and dynamics
Earth and related Environmental sciences
Paleoclimatology, paleoecology

Keywords

Solid Earth-Ocean-Atmosphere interactions

Climate Change

Geo-hazards

Climate-related impacts

Subtropical Island

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TECHNICAL ANNEX

1. S&T EXCELLENCE

1.1. Challenge

1.1.1. Description of the Challenge (Main Aim)

The main objective of the ISLAS (Integrating Sea, Land, and Atmosphere in Subtropical Islands) Action is to build synergic bridges between diverse Earth Science disciplines to develop, together with stakeholders, an interdisciplinary network for an improved understanding of the risks and impacts of natural hazards and climate variability in Subtropical North-Eastern Atlantic (hereafter SNEA) Islands. It will foster ground-breaking research and, at the same time, provide much-needed dissemination and action opportunities for the new climate scenarios of our changing world. The Action challenge is to create a network of Earth and environment scientists focusing on measuring, modeling and predicting the present evolution of Macaronesia Islands. These islands are located in the SNEA and are viewed by the Action as natural laboratories to study the interplay between the physical components of the Earth System, i.e., the solid Earth, the ocean and the atmosphere. These islands (a) are geologically active, (b) are located in a key region for world marine resources that is very sensitive to climate change, (c) have a high influence on the climate of surrounding areas (including continental Europe), and (d) have experienced (and still now suffer) a rapid social and economic development mainly related to tourism.

1.1.2. Relevance and timeliness

European islands represent a major but often poorly represented part of the EU. These islands face very specific risks as a result of sea level rise, increasing temperatures, altered ocean conditions, decreased rainfall and extreme weather events. Rising sea level increases coastal flooding and erosion, damaging coastal ecosystems and infrastructure and affecting tourism, agriculture and other industries. Changes in sea surface temperature (SST) affect the subtropical Atlantic high pressure system, altering weather regimes and the occurrence of extreme events, and influencing European climate variability. Changes in wind modify coastal upwelling, impacting the supply of nutrients to the photic ocean, with large consequences for primary production and fisheries. Increased ocean acidification due to Saharan dust incursions and changing ocean chemistry have negative consequences for the entire marine ecosystem. Warm and dry conditions mean an overall decrease of freshwater supply. Rising land temperatures, in some areas combined with reduced rainfall, stress native plant and animal populations and species, especially in high-elevation ecosystems, thus increasing the risk of extinctions. All these factors add to mounting threats to food and water security, infrastructure, and public health and safety, leading to human migration to continental mainlands. A prominent example of dramatic consequences of extreme weather events is the flooding and intensive rainfalls in February 2010 in Madeira causing damages over €1,400 million. Additionally, upwelling off NW Africa, among the largest of the world, is experiencing significant changes as a result of both a decadal increase in the wind intensity and the warming of surface offshore waters. Observations, experiments and models have all shown that climate change will result in changes in primary productivity, shifts in the distribution of commercial marine species, and changes in their potential yield, resulting in important impacts on the economics of fisheries.

In addition to climate change, the correct assessment of natural hazards in this region requires taking into account risks related to volcanic activity, a major process controlling global change in these islands. Past and recent volcanic activity has shaped the impressive landscape of the four main archipelagos forming the Macaronesia region within this area: Azores, Madeira, Canary Islands and Cape Verde. Recent examples of societal and economic impact of such geological hazards are: the April 1995 eruption of Fogo volcano (Cape Verde Islands), which produced large lava flows, destroyed one of the most fertile agricultural grounds in Cape Verde and displaced about 2,000 people and the October 2011 submarine eruption following unrest episodes to the south of El Hierro Island (western Canary Islands), which motivated the evacuation of residents, with a negative impacts on the main economic sectors: fishing and tourism.

Observing climate change and natural hazards in the SNEA is not only important because of their local impacts but also as a way to detect and assess global climate changes. This is due to their strategic location in the subtropical belt, where they experience the North Atlantic Oscillation (NAO), the Atlantic Multidecadal Oscillation (AMO), the Atlantic Meridional Overturning Circulation (AMOC), coastal upwelling variability, Saharan dust incursions and extreme cyclones. Setting an adequate climate observing system in the region would help monitoring of these oscillations and events, as well as global teleconnections such as El Niño Southern Oscillation. The SNEA region represents a unique opportunity to carry an integrative study, transversal and interdisciplinary, of a limited-size region which holds the major characteristics of the Earth system - an ideal circumstance for a holistic scientific study of a model Earth system.

1.2. Objectives

1.2.1. Research Coordination Objectives

The core-action encompasses and entangles the three main spheres of the Earth (atmosphere, hydrosphere, and lithosphere) and their mutually interrelated and interacting processes. SNEA provides an excellent natural laboratory to effectively study these three spheres and their interactions, from local to regional and to large-scale teleconnections. The main objectives are:

1. Interdisciplinary pooling of methods and resources in order to identify the main problems related to climate change, geohazards, and social change in the SNEA.
2. Creating longer and more complete records of the past events and phenomena, at different timescales, from interannual to millennial, in order to broaden the time perspective of climatic and non-climatic changes and events in the SNEA.
3. Integrating data and models to improve the knowledge on how atmospheric patterns and global teleconnections influence the SNEA, in the framework of climate change, including local winds, impact on SST, fisheries, and the NAO.
4. Analyzing and evaluating risks of climate hazards in the SNEA islands, particularly extreme events, whose intensity or frequency will likely be modified with climate change, with strong influence on natural hazards as landslides.
5. Broadening the knowledge on Saharan dust variability at different timescales for better performing a correct assessment of its impact on solar radiation, atmospheric convection, large-scale ocean circulation, ocean temperatures, ocean fertilization and health.
6. Detecting and characterizing the impacts of climate change on the ocean's physical, biological and chemical properties through the integration of data and models.
7. Integrating instrumental (in-situ to satellital) and sedimentological data with geophysical models to improve the characterization of relative sea level changes and related impacts, including those on marine ecosystems.
8. Introducing standards for geohazards and associated risks analyses in Atlantic insular settings for their homogenized and improve assessment, prevention and mitigation.
9. Exploring the relevance of the islands and archipelagos, and their effect on the surface wind patterns, on the large-scale circulation, including the related impacts on climate, and the potential alterations associated to climate change.
10. Enhancing societal awareness and implication through results' dissemination and outreach.

1.2.2. Capacity-building Objectives

1. Establishing new scientific links among ocean, atmosphere, and solid Earth research by merging and integrating different approaches which are specific of each discipline and defining strategies to overcome model and data limitations and to improve the assessments of climate related impacts and geological hazards.
2. Analyzing the possible impacts derived from the temporal and spatial coexistence of hazards of different nature, which can be genetically related or not, with emphasis in the interaction and feedbacks of climatic and geological events.
3. Broadening the knowledge of past natural hazards and climate variability in order to better assess the recent observations and model projections related to climate change.
4. Promoting data literacy and sharing expertise among scientists, observatories, agencies and institutions responsible for monitoring and surveying climate change impacts and natural hazards.
5. Fostering communication with stakeholders and policy makers to improve the design of policies and programs that can effectively reduce the risks and impacts of climate change and geohazards in SNEA and other areas subject to similar impacts.
6. Providing feedbacks to current SNEA observatories, setting forward the needs for future measurements and methodologies.
7. Involving Early Stage Researchers (ESR) and teams from countries with less capacity, in order to improve their training on climate change and geohazards research, with emphasis on coordinated interdisciplinary work.

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

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

From a climatic point of view, the atmospheric circulation over the SNEA region is dominated by the subtropical high-pressure atmospheric system (or Azores high), with strong divergent circulation in the surface central Atlantic, the trade winds over the coastal West African upwelling region, and the Sahara desert inland. The crossing of the subtropical jet stream is responsible for moisture and energy exchange, with local eddies that lead to the formation of tropical cyclones bringing occasionally extreme weather to the region. At interannual timescales, the subtropical Atlantic atmospheric variability is dominated by changes in the Azores high, one of the centres of action of the NAO, defined as a see-saw of atmospheric mass between subpolar and subtropical latitudes. NAO and ENSO affect the trades and the subtropical Atlantic SST variability, mainly through thermodynamical processes, by changing the large-scale atmospheric circulation (i.e.the intensity and location of the Azores high), a response that is furthermore modulated by tropical North Atlantic SSTs (Alexander et al. 2002; Wang 2005). At decadal and longer timescales, SSTs are affected by the AMO, being responsible for prolonged impacts in rainfall and ecosystems. AMO also impacts on the atmospheric general circulation, modulating teleconnections in the region. Because of their proximity, the Sahara Desert has a large influence on the climate in the SNEA, with exposure to high Saharan dust loads that strongly affect radiation, SST and ocean fertilization, with environmental, health and socioeconomic impacts.

The climate-controlling role of the ocean at different timescales is greatly accentuated in ocean islands, such as SNEA islands. The ocean circulation in the northeastern tropical Atlantic is dominated by the Canary Current, a broad and weak southward eastern boundary that constitutes the eastern limb of the North Atlantic subtropical gyre, and by the strong upwelling dynamics triggered by the northeasterly winds. Upwelling varies seasonally in response to winds, being strongest in boreal winter and spring, when the Intertropical Convergence Zone (ITCZ) shifts south. It also varies in response to long-period changes in the surface winds, possibly linked to ENSO and other large-scale oscillations, with important consequences for fisheries in the region.

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Wind-induced coastal upwelling controls the physical and biological pumps of the marine carbon system and provides for the rich fisheries of the region. The supply of nutrients to the subtropical gyre is the outcome of the opposing effects of increased stratification as a result of surface heating and evaporation, and the increasing coastal winds that lead to upwelling. The sharp gradients in sea surface temperature imply heat exchange within the ocean and through the atmospheric bridge, via evaporative cooling in the warm oceanic side and condensation on the cool side, in what becomes a source of energy in driving the atmosphere. The upper and deep ocean are connected through deep water formation at high latitudes of the Atlantic Ocean and large-scale upwelling in what constitutes the Global Overturning Circulation (GOC). This connection drives the amount of energy incorporated into the deep ocean, the dissolved inorganic carbon in the surface layers, and the amount of inorganic nutrients available in the photic zone. The flow of upper and intermediate waters in eastern boundary ocean regions rules, to a great extent, the seasonal (and likely the interannual and interdecadal) variability in the AMOC, the Atlantic component of the GOC. The AMOC is a key player in the Earth's climate. It exerts a strong control of northward heat transport in the Atlantic, in particular toward northwestern Europe, and thereby controls the phase of the AMO. A future reduction in the AMOC is likely to have strong implications for subtropical Atlantic temperatures and the position of the ITCZ, encouraging Sahelian droughts.

From a geological point of view, SNEA islands are generally thought to be created by hot-spot volcanism related to the presence of mantle plumes beneath the Nubia plate in the case of the Madeira, Canary and Cape Verde archipelagos, and beneath the triple junction where the American, Eurasian and Nubian plates meet for the Azores Plateau. The latter plate boundary location is responsible for the high seismicity in the Azores, where more than 30 earthquakes since the XVIth century have caused thousands of deaths and severe damages. Large volcanic eruptions recorded in the geological, historical and instrumental periods have covered productive soils, entire villages and motivated massive migrations. For example 4,000 people moved to the US after the submarine Capelinhos Volcano (Faial Island, Azores) submarine eruption in 1957-1958. Much of the Lanzarote Island (eastern Canary Islands) population emigrated to the Americas in 1768 after the drought that affected the island, previously deforested by the 1730-1736 series of eruptions. Lava covered a quarter of the island's surface, including the most fertile soil and 11 villages.

These volcanic islands are particularly vulnerable to slope instability because volcanic edifices rise hundreds to thousand of meters above surrounding areas. Landslide occurrence is apparently closely controlled by volcanic activity at the trends of dyke intrusion (rift zones). Nevertheless, the growth of large volcanoes is commonly interrupted by episodes of flank collapse that may be accompanied by catastrophic debris avalanches, explosive eruptions, and tsunamis. Giant landslides and erosion during the past million years have removed more than half of the total subaerial volume of La Palma and El Hierro. Nowadays, the extremely active Pico do Fogo volcano shows possible signs of renewed flank stability. Failure of the eastern flank of Fogo would pose a serious tsunami threat to the adjacent island of Santiago and possibly to the densely populated West African coast, including the city of Dakar with a population of about 2.5 million (Masson et al., 2008).

Landslides represent a major threat to human life, property and constructed facilities, infrastructure and natural environment in most SNEA islands, as exemplified in the disastrous debris flow events of 20th February 2010 in Madeira. The socio-economic impact of landslides is, however, underestimated because landslides are usually not separated from other natural hazard triggers, such as extreme precipitation, earthquakes or floods. This underestimation contributes to reducing the awareness and concern of both authorities and general public about landslide risk. Large landslides in coastal areas and on the continental shelf can in turn trigger tsunamis, with potentially catastrophic consequences (Lira et al., 2013).

1.3.2. Progress beyond the state-of-the-art

Climatic and geological risks are strongly intertwined in SNEA islands, which hence constitute unique Earth System laboratories to investigate their interaction. An integral study requires addressing all factors mentioned above, with the potential of leading towards an improved understanding of the connections between atmosphere, ocean and lithosphere. This requires assessing a number of open questions.

One prime ocean-atmosphere connection takes place through the coastal upwelling region. Changes in sea-surface alongshore winds influence coastal upwelling variability, and therefore primary production and fisheries. However, these winds also increase the connections between coastal and surface offshore waters, leading to their net warming. Decadal changes and trends in surface water temperature associated with multidecadal internal variability and anthropogenic climate change modulate the way these winds affect coastal upwelling. Thus, investigating the link of these winds with their driving sources - such as ENSO and NAO - could enhance predictability in the region. Winds are also responsible for Saharan dust incursions, with important impacts on the radiative balance and thereby cloudiness and SSTs (Kishcha et al.,, 2015). A compilation of proxy records in the area could help to understand the relation between winds, Saharan dust and SST changes, and the way decadal to millennial-scale ocean circulation variability can modulate these relations.

There is a need to better understand and characterize the links between ENSO and climate variability in the SNEA region, including Saharan dust incursions (Wang, 2005; Alexander et al., 2002, DeFlorio et al., 2015). In particular, several studies have pointed that the teleconnection between ENSO and atmospheric variability in the north Atlantic seems to be non-stationary in time, with this modulation controlled by multidecadal variability of the ocean. In turn, the origin of multidecadal variability of the ocean in this region is not clear, with a strong natural component but also with a significant contribution from aerosols (Ting et al., 2014).

Observations, experiments and models show that climate change would result in changes in primary productivity, shifts in distribution and changes in the potential yield of exploited marine species, resulting in impacts on the economics of fisheries worldwide. A better understanding of the upwelling variability and trend over SNEA will enhance the need to implement climate change mitigation and adaptation policies to minimize impacts on fisheries (Sumaila et al., 2011).

Regional sea level changes are detected in the region and, although they appear to be caused primarily by natural climate variability, the imprint of anthropogenic effects—whether due to changes in the atmospheric forcing or to mass variations in the system—will grow with time as climate change progresses. Towards the end of the 21st century, regional sea level patterns will result from a superposition of climate variability modes and natural and anthropogenically induced static sea level patterns. Attribution and prediction of ongoing and future sea level changes require an expanded and sustained climate observing system (Sauter et al., 2013; Stammer et al. 2013).

Direct in-situ AMOC measurements show evidence of a downward trend (Smeed et al. 2014), although it is still too soon to determine whether this is a response to climate change or is associated to natural multidecadal fluctuations (McCarthy et al, 2012). Investigating old and new tide gauge data and paleoceanographic records from the region could help to put recent changes into context, and thus shed light on the evolution of the AMOC and the role played by the SNEA. This, in turn, will depend on a subtle interplay between the competing effects of a decrease in the AMOC and the direct effect of global warming. It is thus essential to reduce uncertainty in future climate projections in the subtropical Atlantic in relation to these two competing effects.

Mechanisms driving AMOC transport variations in the subtropics are far from clear, in particular the role of the eastern boundary. At 26N, density variability in the western boundary is relevant at many time-scales, but subtropical east Atlantic anomalies are thought to be also partly responsible for seasonal to interannual changes (e.g. Srokosz and Bryden 2015). Yet again, the observational record is too short, and models disagree as to the mechanisms responsible (e.g. Yang 2015). In addition, decadal-scale density anomalies can be felt in the eastern boundary through oceanic adjustments to variations in North Atlantic buoyancy fluxes via coastally-trapped and equatorial waves. Forecasting AMOC variations thus requires observing larger and remote regions, with crucial areas including the Canary Basin.

Buoyancy changes in this region could be useful to detect early warning signals of an AMOC decrease. In response to a freshwater input in the North Atlantic, models show a pattern of fresh surface anomalies following the Canary Current path, denoted "freshwater leakage". This constitutes an important path for salinity anomalies to escape from the subpolar region (Swingedouw et al. 2013). Differences among models may partly be explained by this freshwater leakage; hence, it is crucial to quantify its relevance in the real world.

Few places in our planet experience more dramatic and rapid changes in topography and external conditions than hotspot islands, which are subject to volcanic activity, flank collapses and exposure to oceans. As pointed above, the gravitational collapse of volcano flanks (producing the so-called 'giant landslides') is a potentially catastrophic process that strongly shapes the morphology of these islands. Areas prone to submarine landsliding are relatively easy to identify, but we are still away from forecasting individual events with precision. The monitoring of critical areas where landslides might be imminent and the modelling of its consequences, so that appropriate mitigation strategies can be developed, are areas that can experience substantial advances.

One of the major challenges in global geohazards research is to unravel the cause-effect relationships between submarine landslides and climate change. Climate sea-level change appears to influence the distribution and frequency of continental margin landslides by changing the sediment delivery to margins, or more indirectly through changes in the gas hydrate stability zone. Understanding the climatic influence on landslide frequency is particularly important for hazard analysis, since past frequency of landslides that may have occurred under a different climatic regime is often used as an indicator of future hazards. Solid Earth motion in geologically active areas represents an important contribution to sea level changes, therefore requiring proper monitoring and modelling in order to isolate internal and external (climate-related) contributions.

Landslides can trigger eruptions and tsunamis in volcanic islands. They can produce variations in the volcanic and magmatic regimes probably due to the static decompression at depth after surface unloading and its potential influence on magma chamber processes. Furthermore, a volcano flank collapse is likely to set off intense magma mixing at depth, an important and long-recognized eruption triggering mechanism that could result in increased eruption rates (e.g., (Cassidy et al., 2015)). El Golfo landslide (El Hierro, Canary Islands) shows a well-documented case of such fact (Manconi et al., 2009). When assessing volcanic risks, studies are required to show the stress-field perturbations that flank collapse could generate around magma plumbing systems. These are to be complemented with an improved understanding of what determines the rates of magma accumulation and which are the mechanisms making magmas eruptible in such area. Turbidite deposits suggest that some volcanic landslides occur in multiple retrogressive stages (Watt et al., 2014), which significantly reduces the magnitude of potential tsunami relative to models with a single stage emplacement of the landslide. Therefore, understanding landslide emplacement dynamics is a key point for tsunami hazard assessment in the SNEA region.

1.3.3. Innovation in tackling the challenge

The principal innovation of ISLAS is to recognize SNEA islands as a European reference 'Earth System Natural laboratory', overcoming the geographical barriers and the insufficient collaboration among research groups and stakeholders. This view of the SNEA islands is presently missing in Europe, in contrast to the scientific role played, for instance, by the archipelago of Hawaii in the USA. A multidisciplinary integration of atmosphere-ocean-solid Earth connections will enhance the assessment and mitigation plans associated with the impacts of natural hazards and climate change. The methodologies and outputs here developed should be exportable to other regions, of similar and larger scales, characterized by high interaction among the different Earth system components. Also, the results would benefit stakeholders and policymakers to better implement adaptation and mitigation plans.

1.4. Added value of networking

1.4.1. In relation to the Challenge

The assessment of climate change impacts is beyond the individual capabilities of most islands, hence requiring a strengthened cooperation between the different actors: islands, riverine and European countries, and international partners. Despite the climatic and geographical proximity, previous collaborative efforts have been insufficient. Scientists and other stakeholders dealing with climate change and geologic hazards usually work separately in different projects, institutes and countries. Enhanced networking, which enables expertise sharing, is therefore urgently needed.

The proposed Action aims at developing multi- and interdisciplinary networking schemes for a holistic assessment of climate change and natural hazards in the SNEA. The challenge is to bridge the gap between the different disciplines, at different space and time scales, using the SNEA as a paradigmatic Earth-system laboratory. This unique platform will involve young and experienced researchers from diverse scientific disciplines such as meteorology and climate, oceanography, geodesy, geology, geophysics and environmental sciences.

The means to achieve these objectives are:

- Integration of expertise and interdisciplinary groups within and among the different Working Groups (WGs) of the Action;
- Implementing a continuous dissemination of information, methodologies and results, by means of a webpage, conference participations, publications and social media;
- Developing forums for effective dissemination of information and knowledge transfer between basic science and operational systems;
- Training early-stage researchers (ESRs) through their participation in dedicated courses and short-term scientific mission at COST countries' institutions;
- Promoting nationally funded R&D projects focused on related topics;
- Interacting with EU-funded projects and JPI on related topics;
- Collaboration with stakeholders to define mutual needs and in the organization of activities.

1.4.2. In relation to existing efforts at European and/or international level

The Action complements and supports several ongoing activities in Europe with very little overlap. Some of the relevant current research projects and international programs complementary to this Action are listed below.

1. TOPO-EUROPE and EPOS initiatives provide common umbrellas to coordinate national and international geosciences initiatives.
2. GEO (Group on Earth Observation) Supersite initiative provides access to spaceborne and in-situ geophysical data of selected sites prone to geohazards.
3. PREFACE-FP7: EU project combining European and African expertise in observations, modelling, and marine ecosystems to improve the understanding and capabilities to predict Tropical Atlantic climate and its impacts
4. SPECs-FP7: EU project aiming to identify the main problems in climate prediction and investigate a battery of solutions from a seamless perspective
5. RAPID-AMOC: program toward observing system for the meridional overturning circulation (MOC) at 26.5°N in the Atlantic.
6. PIRATA: observational program designed to study ocean-atmosphere interactions in the tropical Atlantic affecting regional climate variability on seasonal, interannual and longer time scales.
7. AtlantOS-H2020: project optimizing and enhancing the Integrated Atlantic Ocean Observing System.

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8. SafeLand-FP7: project “Living with landslide risk in Europe: Assessment, effects of global change, and risk management strategies” is a large, integrating research project on landslide risk management in Europe.
9. DACCIWA: project on interactions of dynamics-aerosol-chemistry-cloud in West Africa and their impact on human and ecosystem health and agricultural productivity.

2. IMPACT

2.1. Expected Impact

2.1.1. Short-term and long-term scientific, technological, and/or socioeconomic impacts

Relevant scientific and socio-economic impacts envisaged by the ISLAS Action are:

- Enhanced scientific relevance of the SNEA, an ultra peripheral European zone, both at European and international level. The networking of research laboratories at the different SNEA islands, together with centres from the riverine and European institutions, will represent an urgently needed projection of European research into the North Atlantic.
- Enhanced visibility of European climate-related research. The Action will collaborate with international research networks, thereby improving the visibility of European research groups in the field.
- Improved use of models and datasets. The ISLAS Action will provide complementary feedback to current monitoring carried out by observatories in the SNEA islands, setting the needs for future measurements and methodologies.
- Education of a new generation of scientists, enhancing the interdisciplinary perspective that is necessary to carry out future significant developments: ISLAS will ensure training ESRs through workshops, scientific missions, training schools and an ESR forum.
- Improved communication with stakeholders and policy makers, aimed at developing and boosting policies and programs that can effectively reduce climatic and geological risks and their impacts.
- Scientific background for entities linked to the energetic sector, in particular aeolian, solar and geothermal energy.
- Improved scientific/environmental culture of residents and tourists, by means of close collaboration with museums, educational and tourism institutions, as well as through different dissemination and outreach activities.

2.2. Measures to Maximise Impact

2.2.1. Plan for involving the most relevant stakeholders

Main stakeholders related to ISLAS Action range from transeuropean agencies and initiatives (ESA, EUMETSAT, EUMETNET, WMO, ECMWF) to local governments and institutions (civil protection, property and constructed facilities, civil engineering, agronomical institutions, meteorological and oceanographical agencies, fisheries, tourist agencies, energy, public health, sociologists, economics) and NGOs. ISLAS aims at fostering the synergies between researchers and these stakeholders by:

- Providing science-based guidelines to improve preparedness and mitigation.
- Fostering the exchange of data and information between stakeholders and the scientific community.
- Providing an assessment of impacts of climate change and natural hazards in the SNEA islands for improving mitigation and adaptation plans.
- Inviting stakeholders as experts to the topical workshops organized by the Action, to some of the Management Committee and Working Group meetings to deal with questions of common interest as well as to the final conference.

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- Transferring information to stakeholders and policy makers through the distribution of fact sheets and policy briefs, as well as follow up inquires about the project.

2.2.2. Dissemination and/or Exploitation Plan

A high-level dissemination plan is designed for ISLAS at European as well as international level aiming at the wider international community, including policy makers and stakeholders. A fact-sheet will be prepared for the ISLAS Kick-Off (KO) meeting, as well as at each stage of the project, following the working plan. These fact-sheets will be distributed to the members of the action to be disseminated through the stakeholders of the different countries. Also, a website will be created and updated regularly. In this webpage activities related to the aim of the action will be reported, enhancing the participation in workshops and exchange of researchers. A wiki page of ISLAS will be created and ISLAS-related topics regularly updated in Wikipedia.To inform the broader scientific community, a long review paper in an international high-impact journal envisaged.

Visibility of the ISLAS action in Macaronesian observatories will be fostered by involving these in the dissemination activities, including training schools, workshops, and regular meetings, which could be held in the observatories. Two training schools are planned, to be determined by the MC. The final project meeting will be hosted by one of the Macaronesian islands. The meeting will include a special session targeting policy makers and stakeholders, inviting stakeholders and decision makers from neighbour countries and NGOs.

In addition, policy briefs will be prepared to help stakeholders and policymakers to design mitigation and adaptation plans, as well as material for a broad audience, including a documentary, handbooks, and a booklet of the project. Close collaboration will be maintained with local museums, educational and tourism institutions in outreach activities with the aim of improving the scientific/environmental culture of inhabitants and tourists.

2.3. Potential for Innovation versus Risk Level

2.3.1. Potential for scientific, technological and/or socioeconomic innovation breakthroughs

The potential for innovation is based on the integrative approach planned in this Action, which has no precedent in Earth Sciences. Securing the society against disasters is one of the central elements of the functioning of any society. There is barely any societal sector which is not to some extent concerned by disasters and related resilience and security issues. Among this, particularly in this region, the geological patrimony constitutes an important part of the cultural heritage that fuels tourism in SNEA islands, a significant economic sector on which many communities depend. Given the relevance of the scientific challenge and the socioeconomic dimension of the Action, it is expected that a large number of researchers will be willing to join the Action during the implementation stage. This will increase the critical mass that will ensure that all the objectives can be achieved or even expanded. In addition, the Action risks have been analysed and a contingency plan to reduce them has been described in section 3.4.1. The coordination and the clustering of research and innovation activities proposed by this Action in relation to climate change and natural hazards impacts will be useful for improving support to decisions related to risk management and development of environmental policies in the context of climate change. Furthermore, the Action approach will help to develop an efficient networking, promoting effective mechanisms and interactions with the stakeholders in order to contribute to a new strategic vision on climate change and risk reduction.

3. IMPLEMENTATION

3.1. Description of the Work Plan

3.1.1. Description of Working Groups

Three Working Groups are proposed with the following objectives and tasks. Their main milestones and deliverables are detailed in a table below.

WG.1 Extreme events / Atmospheric variability and predictability

The principal objective of this working group will be to understand changes in the atmospheric components of the region, sources of variability and impacts in past and present in order to understand future climate change scenarios from a multidisciplinary perspective.

Task 1.1 Extreme events

- Identify extreme events in the region and their main sources of predictability;
- Evaluate how changes in SST, moisture availability and related effects on weather regimes will influence the occurrence of extreme events (e.g. intense cyclones);
- Assess the variation of extreme events, including their past evolution, trends and interannual to decadal variability;
- Assess their evolution in future projections:
- Investigate the impact of extreme events on landslides.

Task 1.2 Atmospheric variability and teleconnections

- Better characterize the role of the subtropics in the NAO at different time scales.
- Identify ENSO teleconnections with tropical North Atlantic from past records up to present and future projections. Determine decadal changes in ENSO teleconnections
- Investigate the role of tropical North Atlantic multidecadal variability in time-varying ocean mean state, and in modulating remote teleconnections to upwelling/SST variability;
- Obtain paleo-records of interannual to multidecadal climate variability in the subtropics and of the influence of ENSO;
- Assess the variability of local winds in SNEA and its impact on the SST variability, Saharan dust incursions, and upwelling variability;
- Identify observational needs and available sources of measurements of key chemical compounds and meteorological variables in the subtropical upper atmosphere to monitor the stratosphere-troposphere exchange variability on a wide range of timescales (from synoptic to long-term trends);
- Bring together scientists to explore the dynamics of the influence of oceanic and atmospheric variability (e.g. ENSO, NAO) on the stratosphere-troposphere transport processes leading to composition changes in this region.

Task 1.3 Saharan dust and other aerosols

- Determine sources of Saharan dust incursions into the SNEA and explore the links with synoptic-scale weather patterns. This information can later be used to determine their connections with climate variability on interannual and longer time scales.
- Identify cases of mixed aerosol types, especially dust from North Africa and pollution aerosols from Europe.
- Study the effect of Saharan dust on ocean decadal variability and coupled (ocean-atmosphere) processes.
- Evaluate the Impact of Saharan dust on terrestrial nutrient budgets and ocean fertilization.
- Evaluate the effect Saharan dust outbreaks and pollution aerosols from Europe on air quality and human health.

This WG is connected to WG.2 in terms of geologic paleowinds reconstructions and atmospheric impact on landslides and sea level. This group will provide WG.2 with appropriated meteorological datasets for a more accurate correction of atmospheric effects on geodetic observations and for the analysis of the relation between landslides and extreme meteorological events. In relation to WG.3, is connected to the impact of winds on sea surface temperature variability, upwelling and

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wind-induced ocean circulation. The role of Saharan dust on ocean fertilization and on the ocean circulation, to the multidecadal variability of sea surface temperature in the subtropics provides additional connection to WG.3 .

WG.2 Geohazards and geologic indicators of past changes

The objectives related to landslides research are twofold. First, to provide a better understanding of the risk posed by debris flows in SNEA islands, how this risk will evolve in the future as a result of climate change and changes in demography, and how the risk can be effectively mitigated. Second, to gain a better understanding of the dynamics of mass movements for large landslides in coastal areas, which is a key point for tsunami hazard assessment. Concerning research on volcanic activity, the overall objective is the achievement of an improved knowledge on the volcanic subsurface or surface processes in SNEA in order to improve the monitoring strategy.

Task 2.1. Landslides research

- Hazard zonation for debris flows triggered by extreme precipitation and strong earthquakes. The techniques and methodologies developed in the FP7 Project SafeLand will be adopted for this purpose;
- Mapping of debris flow risk, considering the vulnerability of the population and infrastructure exposed to debris flow hazard. The model for landslide risk will be calibrated against historical events. Once a calibrated model is developed, the changes in the risk pattern for future climate and development scenarios will be assessed;
- Development of a toolbox of physical and nonphysical risk reduction measures;
- Pooling of data and methods to investigate possible correlations between the timing of past large landslides, major climatic events and changes in sea level;
- Modelling of tsunamis generated by scenarios for large mass movements into the Atlantic, including landslide events and volcano sector collapse.

Task 2.2 Volcanic activity

- Include magmatic processes in the kinematic models actually used to integrate geophysical, geological and geodetic observations which can be very important in periods between eruptions at moderately active volcanoes as the ones in SNEA islands;
- Characterize the interactions of magma with surrounding host rock in numerical models for advanced deformation interpretation;
- Integrate different space and time scales in the numerical modelling for the establishment of stress and deformation background levels in geodetic data interpretation;
- Collaborative benchmarking of numerical models for quantitative interpretation (pressure/volume, location, source geometry) of different geodetic data streams provided by the volcano monitoring systems at SNEA islands;
- Characterize stress perturbations caused by landslides that could alter feeding system process through petrological data and numerical simulations;
- Compile observations for the SNEA region of satellite and ground-based remote sensing observations for all phases of eruptive processes and unrest episodes.
- Dating the Holocene volcanic activity.

Task 2.3 Geo-indicators of climate change:

- Constrain past and present-day sea level variations by means of compilation of geologic and geodetic observations;
- Paleoclimatic reconstructions and detection of climatic and non-climatic signals related to sea-level variations and solid-Earth deformation/motion.

This WG will interact with WG1 and WG3 with regards to discussion of the contributions (climatic and geodynamic) to past and present sea-level changes. Interaction with WG1 is needed to

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improve the correction of atmospheric propagation effects for microwave-based geodetic techniques (VLBI, GNSS, DORIS, ecc) as well as altimeter satellite.

WG.3 Oceanic changes

Task 3.1 Upwelling

- Identify the current state of knowledge and open questions on the physical environment, biogeochemistry and biodiversity of the Canary Current upwelling system, with emphasis on its variability at different temporal and spatial scales, from submesoscale to large-scale processes and from daily to decadal;
- Assess temporal variability, including interannual variability and long-term trends, in coastal winds, sea surface temperature, and ocean productivity. This is to be done by placing together scientists working on this topic, identifying relevant questions and knowledge gaps, and analysing available in situ and satellite data;
- Collaborate with surrounding African countries (Morocco, Mauritania and Senegal), particularly in terms of training and calibration efforts, in setting a coherent and coordinated ensemble of island and coastal oceanographic and meteorological stations.

Task 3.2 Eastern boundary currents

- Identify the current state of knowledge and open questions on processes of lateral exchange between the coastal and deep oceans (including carbon export) and vertical exchange within the deep ocean (including relevance on primary production);
- Encourage and support the collection of time series of physical (currents and structure of the water column), chemical (atmospheric CO_2 and oceanic pH and pCO_2) and biological (primary production and organic matter) properties;
- Collaborate with African countries in the design of a limited number of continuous stations and tide (sea-level high) gauges in African countries.

Task 3.3 Atlantic meridional overturning

- Analyse current climate simulation ensembles to assess the uncertainty in future climate projections in the subtropical Atlantic in relation to the competing effects between future climate change and a future likely reduction of the AMOC;
- Explore the paleoceanographic records of past AMOC variability, to put recent observations into context and to determine if the AMOC decrease predicted by models in response to global warming is already at play;
- Use available (from the past and planned in WG.2) tide-gauge data and models to estimate geostrophic transports at 26N by means of covariances with satellite/RAPID data to detect fingerprints of AMOC interannual to decadal variability at the eastern boundary;
- Use simulations to identify early warning signals to anticipate a future AMOC decrease;
- Combine modeling and observational data to investigate the link between local versus remote forcing and eastern boundary densities to constrain the mechanisms that control the AMOC transport variability in the subtropics and reconstruct AMOC variations based on surface wind observations.

Task 3.4 Deep-ocean oceanographic measurements and indices

- Determine which deep-ocean oceanographic data, both in situ and remote, are necessary for a better understanding of the eastern Atlantic Ocean;
- Propose regional and large scale indices that can characterize the regional and large-scale behaviours of the eastern tropical and subtropical Atlantic Ocean;
- Identify and coordinate the European research vessels to and from to Antarctica to arrange for standard measurements during their transit through the eastern Atlantic Ocean.

Narrow collaboration with WG.1 is required for a joint assessment of the sources of sea-surface winds. The reported increase in sea-surface winds should boost coastal upwelling, and therefore primary productions, fisheries and even rainfall. However, these winds also increase the connections between coastal and the warming surface offshore waters, hence leading to a net temperature increase in the coastal waters. The sources of these winds should be determined for predictability issues, as those related to ENSO and NAO. These winds in turn are responsible for saharan dust incursions which impact on the radiative balance is very important.

The main activities/milestones and deliverables of the Action are listed below:

Milestones	Deliverables
M1 Kick-off Meeting Construction of management structure: nomination of MC, CG, ESRF and its chair. Nomination of website manager. Nomination of EG leaders. Schedule date, title and invited speakers of first annual workshop. **M2 Webpage launch** **M3 Calls for WGs workshop** **M4 call for STSM** **M5 MC meetings** Evaluation and recommendations for WGs workshop and STSM **M6 WG workshops** **M7 Summer Schools** **M8 call for STSM** **M9 Annual international workshops** Schedule date, title venue and invited speakers of annual workshops and summer schools Design of dissemination plan. Plan for position papers. Design of plan for international conferences. Design strategy for database sharing facilities. **M10 Design of final report**	D1.1 Report on extreme events and teleconnections impacting atmosphere-ocean-land in SNEA. D1.2 Compilation of interannual to multidecadal climate variability and natural hazard time records. D1.3 Summary of oceanic, atmospheric and health impacts of dust on SNEA. D2.1 Comparison of numerical models for near real-time interpretation of geodetic data during volcanic crises. D3.1-2 Design network of island and coastal oceanographic and meteorological stations, together with continuous global positioning stations and tide gauges. D3.3 Review of impacts of AMOC in future projections in subtropics. D3.4 Summary of paleoceanographic records of past AMOC variability. *All WGs:* DA1 Creation of a Website , including a wikipage, and creation of accounts in social networks: instagram, twitter, facebook DA2 Creation of factsheet of ISLAS for stakeholders and policymakers DA3 Public database with outcome of experiments and analyses and software packages DA4 Handbook on integrative assessment of climate change in SNEA DA5 Report of STSMs DA6 Report of Summer school on WG1-WG2-WG3 DA7 Report compiling recommendations for defining climate variability indices and available proxies *DA8* Final report to, promote and disseminate the Action's achievements, involving users, policymakers and stakeholders

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3.1.2. GANTT Diagram

Milestone	Year 1				Year 2				Year 3				Year 4			
Meetings																
Kick-off meeting	X															
MC meeting	X		X		X		X		X		X		X		X	
ESR meetings			X				X				X				X	
CG online meetings	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WG online meetings	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Workshops																
Call deadline			X				X				X				X	
WG workshops	X			X				X				X				X
International workshop				X				X				X				X
Training School						X				X						
STSM																
Call deadline	X		X		X		X		X		X		X		X	
Website																
Launch	X															
Update		X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Legacy website														X	X	X
Reports																
Annual reports				X				X				X				X
Summer school reports						X					X					
Final report														X	X	X

3.1.3. PERT Chart (optional)

3.1.4. Risk and Contingency Plans

To foresee a good contingency plan for all the risks in ISLAS, a study of risk assessment and management is needed. There are a number of foreseen risks that could impede ISLAS completing some goals. The following are the Action contingency plans to address them. The main risk is that networking around a particular WG is insufficient. This could be avoided because all the WGs are defined to tackle the objectives in coordination with other WGs. In addition, all the proposers expertises fit with the main tasks of the WG. Many of the Action proposers have substantial experience in the coordination of large National and EU projects. In addition, the composition of WGs will be open and flexible in order to allow for the inclusion, at the implementation stage, of perspectives and activities not foreseen during the preparation of the proposal. Another risk is that related to personnel involved in ISLAS: The action is committed to promote the participation of ESRs, and actually there are many ESR as proposers of the action. Also, there are ongoing PhD students that are already working around the main topics of ISLAS. Regarding Reports, there is a risk of not having enough consensus. In this case, an assessment report about the disagreement and a list of additional research activities will be presented. There is also that the number of STSMs carried out is not satisfactory. To prevent this risk, frequent calls of flexible deadlines have been planned in order to be adequately publicised. Regarding meetings, there is a risk of not being adequately designed. Nevertheless, the contingency plan makes them achievable using videoconference or other online applications.

3.2. Management structures and procedures

The following management structures will help the Action meet the proposed challenge:

- *Management Committee (MC):* The MC will be responsible for the overall organisation and will comply with COST rules (doc. COST 4159/10).
- *Working groups (WG):* Three WGs form the basis of the Action. A WG leader, elected by participants, and vice-leader will be responsible for the WG specific activities. The different WGs will be formed during the first meeting.
- *Core Group (CG):* The CG (Chair, Vice Chair, WG leaders, and Early Stage Researchers Forum ESRF chair) will be help the MC for executive "daily" management and to improve communication within the Action.
- *Early Stage Researchers Forum (ESRF):* An informal forum of young scientists will be formed based on the ESR participants in the Action. The ESRF will nominate a chair.

The following meetings and communication activities will be organised:

- *Workshops:* The Action will organise two kind of annual workshops, 1) International workshops, hosted by Action partners, bringing together a wide community of research scientists related to the COST Action area, and 2) Smaller WG specific topical workshops targeted at the deliverables of the WG. All workshops will ensure a minimum of 20% Early Stage Researcher (ESR) participation. The WG workshops will be proposed for approval by the MC 6 months in advance.
- *MC meetings:* The MC will meet separately twice a year to discuss and decide the progress of the Action, deliverables and future activities.
- *ESR meetings*. Early stage researchers will organize meetings in connection to annual workshops to give participants the chance to discuss their experiences within the action,.
- *GC and WG online meetings*. These meetings will be arranged to discuss ongoing progress when needed, with a minimum frequency of 4 times per year.
- *Training Schools*: two schools will be organized aiming at ESR training.
- Short-Term Scientific Missions (STSM): different deadlines will be established by the MC for enhancing the exchange of scientists, mainly ESR.
- *Website:* a website will be created to inform about the Action's activities as well other activities relevant to ISLAS members (meetings, conferences, summer schools, publications, etc.). It will provide datasets and software packages.

3.3. Network as a whole

The network of proposers is composed of 16 researchers belonging to 9 COST countries,one International Partner Country (IPC; USA) and one NNC (Morocco). Their expertise covers all research fields needed to conduct multidisciplinary research proposed herein, and to successfully assess the challenge of advancing in the understanding of the risks and impacts of natural hazards in SNEA region. This area is envisaged in the Action as a natural laboratory representative of areas highly vulnerable to geologic and climate-related hazards. Most of the proposers have former experience in the region, while others will provide their background from other areas to jointly assess common problems. Conversely, the Action aims at exporting the lessons learned to other areas.

The participation of the USA as an IPC in ISLAS is important as this will allow to disseminate news, research findings and opportunities for collaboration within related networks there. This participation will also provide an opportunity to broaden the relevance of this network, since the weather and climate of SNEA has been shown to also affect that of the southeastern US; particularly with regards to hurricane genesis and intensification. Morocco as COST Near Neighbour Countries, the ISLAS core services will be an important contribution for the sustainable development of the region, that greatly depends from marine ecosystem services, and their natural, social and economic value (e.g., tourism, fisheries and aquaculture).

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COST Mission and Policies

The action is focused on the Subtropical North-Eastern Atlantic islands, which are envisaged by the Action as natural laboratories to study the interplay between the physical components of the Earth System. They are scientifically and socioeconomically strategic because (a) are geologically active, (b) are located in a key region for world marine resources that is very sensitive to climate change, (c) have a high influence on the climate of surrounding areas (including continental Europe), and (d) have experienced (and still now suffer) a rapid social and economic development mainly related to tourism. The integrative approach planned in this Action has no precedent in Earth Science, and involves broad international collaboration and cooperation. The network proposers belong to nine COST countries, one International Partner Country (IPC; USA) and one Near Neighbour country (NNC, Morocco).

This COST Action will be strongly committed to involve early-stage researchers (ESR) and to respect an appropriate gender balance in all its activities. Monitoring of both issues will be placed as a standard item on all Management Committee (MC) agendas. The co-chairing positions in the MC and in the working groups will be assigned with a gender and ESR balance approach.

The website will include a page in the public domain outlining the role of women in the Action. Special consideration will be paid to promote female ESR, as it has been observed that there is a significantly higher risk for women than for men to abandon the research career during the few years after the PhD (Gordon et al., 2008, Nature Geosciences, 1, 79-82). Concealing a research career and a young family is a very difficult task, specially because of the traveling often involved for research. Travelling to the Action meetings and workshops is not an exception. To address this issue, local child care options at the workshops will be suggested to the Action members. In addition, participation through net-meeting facilities will be arranged to allow participation of members unable to travel to the meetings, which may particularly benefit researchers with young families.

Additional support will come also from the specific conditions of the individual partner institutions, most of which have developed gender equality strategies specific gender action plans.

ESRs will be supported according to the “COST Strategy towards increased support of early-stage researchers”. As described in the Technical Annex, a significant part of the budget of the Action will be reserved for ESR through required participation in workshops and through funding Short-Term Scientific Missions (STSMs) and training schools, where ESR will have a priority. Furthermore, an informal forum of young scientists will be formed based on the ESR participants in the Action. The ESR forum will nominate a chair, who will belong to the Core Group (CG) of the action.

Network of Proposers - Features

COST Inclusiveness target countries
22.22 %

Number of Proposers
17

Gender Distribution of Proposers
70.6% Males
29.4% Females

Average Number of years elapsed since PhD graduation of Proposers with a doctoral degree
13.2

Number of Early Career Investigators
6

Core Expertise of Proposers: Distribution by Sub-Field of Science
82.4% Earth and related Environmental sciences
5.9% Civil engineering
5.9% Electrical engineering, electronic engineering, Information engineering
5.9% Environmental engineering

Institutional distribution of Network of Proposers

68.8% Higher Education & Associated Organisations
18.8% Government/Intergovernmental Organisations except Higher Education
7.8% Business enterprise
4.7% Private Non-Profit without market revenues, NGO

Government/Intergovernmental Organisations except Higher Education:12

- Number by Level
  Local government:1
  Central and Federal Government:3
- Number by Type
  R&D Funding and/or R&D Performing bodies:2
  Government department or government-run general public services:1
  Non-R&D executive agencies, including sector specific regulatory bodies:1

Higher Education & Associated Organisations:44

- Number by Field of Science of Department/Faculty of Affiliation
  Earth and related Environmental sciences:9
  Other engineering and technologies:1
  Physical Sciences:1
- Number by Type
  Research Oriented:10
  Education Oriented:1
- Number by Ownership
  Fully or mostly public:11

Private Non-Profit without market revenues, NGO:3

- Number by Type
  Other:1
- Number by Level
  National:1

Business enterprise:5

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

COST Country Institutions(9) : France , Germany , Ireland , Italy , Norway , Portugal , Romania , Spain , United Kingdom
Near-Neighbour Country Institutions(1) : Morocco
COST International Partners(1) : United States

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