UK-Environmental Observation Framework (UK-EOF) Statement of Need

Cryosphere Observation Requirements

Alongside development of Towards a Statement of Need, the UK-EOF has also developed Observation requirements tables to capture more detailed information to help articulate:

- The UK's requirements for observing the natural environment
- The questions that we need to answer
- How close we are to being able to provide the evidence via a balanced suite of observations.

For ease, information gathering has been split into environmental domains and for each domain, what the specific issues or sub issues that are of importance for the headline issues identified in the UK-EOF Statement of Need.

Information has been gathered from experts in their field via correspondence, a workshop and open consultation. The tables are not final and some gaps exist in the information. The UK-EOF will work to fill these gaps and revise the tables accordingly.

Some of the sub-issues identified fall under several fundamental issues and there are key dependencies with other environmental domains.

Observation requirements captured within the tables have not been prioritised in any way, nor has current capability been identified. Prioritisation will be addressed via a decision support framework which is also being developed under the UK-EOF and capability or current activities are searchable within the UK-EOF Environmental Observation Activity Catalogue (www.ukeof.org.uk).

Other useful sources of information include: The Integrated Global Observing Strategy (IGOS)[1] report which details observation information regarding the large numbers of (mainly physical) variables already being monitored e.g. sea ice, albedo, snow, permafrost. Relevant information may also be found within the Arctic Climate Impact Assessment[2].

Summary of Requirements (under each UK-EOF headline issue)

Pressure on all environments in the light of <u>Population Growth</u> and associated pollution.

Although Antarctica may become habitable, it is unlikely to happen within the next century therefore it is not a question that is of priority to the UK. Indigenous populations within the Arctic are the responsibility of the Arctic Rim Nations and therefore not regarded as an issue for the UK HM Government.

Issues related to pollution have been addressed under Economic Growth and Sustainability and Fisheries, Agriculture, Food Security and Water Supply.

[1] IGOS Integrated Global Observing Strategy (also available for different themes) see http://www.igospartners.org/cryosphere.htm

[2] http://www.acia.uaf.edu/

Supporting economic growth reconciled with sustainable use of natural resources

The melting of sea ice within the Arctic will not only have impacts on the opening of sea routes but could also impact fisheries as species will be able to transfer between the Pacific and Atlantic. There is a need for baseline measurements from which change can be determined and a system to manage an ice free Arctic put in place. This is not limited to the Arctic, long term impacts of melting ice on Krill in the Southern Ocean are unknown but could have large consequences for the surrounding fisheries and ecosystem.

The Protocol on Environmental Protection (to the Antarctic Treaty) forbids any commercial exploitation of geological resources and areas around the Arctic are generally the responsibility of the Arctic Rim Nations. However there could be opportunities for biotechnology (pharmaceuticals, neutraceuticals) or biomining, which would require large scale mapping and survey of potential organisms. Currently the UN Committee for Limitation of Continental shelves is defining the divide between national sovereignty and high seas in the Arctic. The high seas will come under jurisdiction of the UN International Sea Bed Authority, which is likely to develop rules on activities such as biotechnology, biomining and also ownership of the sea floor. If biomining does become a possibility then expert advice will be needed to determine any associated observation requirements.

Pollutant monitoring within the Arctic and Antarctica is limited to a sparse network of stations. To fully understand the baseline levels in the atmosphere, seas and that locked in the permafrost, increased observations from coordinated networks are necessary. It is widely accepted that pollution in the Arctic atmosphere is largely transported from lower latitudes, although this is partly the responsibility of the Arctic rim nations there is a requirement for international coordination to look at the impacts, sources and loads. Other sources of pollution e.g. shipping, nuclear dumping, river run off and oil/mineral exploration require observations.

Understanding future states of the Earth, particularly the Carbon Cycle (but not excluding other element cycles)

There is a need to understand how both the land and sea in polar regions act as carbon sources or sinks. Wide scale continuous measurements are required but are currently under-resourced and there are significant international gaps, both spatially and temporally. Any increase in observations should be made with links to the relevant policy forums, e.g. Arctic Council Working Groups and the United Nations Framework Convention for Climate Change (UNFCCC); this will eliminate any chance of duplicating effort. Questions on the sinks are related to those surrounding carbon sequestration, the role of biological productivity and whether this will change with less or no ice. There is a lack of information to answer these questions and there is therefore a significant gap, which in order to fill requires baseline surveys followed with decadal measurements to assess change.

As well as a requirement for atmospheric carbon dioxide measurements, measurements of methane and other greenhouse gas fluxes are important. There has been limited monitoring in this area to date - The Natural Environment Research Council (NERC) are currently establishing a methane network but international cooperation and coordination are needed to fully address the issues.

There is also a need to understand the distribution and stability of marine clathrates. NERC has established a 2-year programme, however further information regarding

the presence (mapping) of marine clathrates beneath the ice sheets would be beneficial and the information could be fed into climate models.

With a view to the changing environment the stability, cover and distribution of permafrost is an issue, this is especially critical but not limited to the Arctic, which has little mapping or regular measurements. Within the Alps there could be opportunities to join up with other European countries to conduct drilling programmes which are necessary to assess the stability of the warming mountain permafrost.

Acidification is a known effect of the uptake of Carbon Dioxide by the oceans. Several questions surrounding this issue exist such as, understanding the natural variability within the system and therefore being able to identify the rate of anthropogenic change; determining where the hotspots for acidification are and identifying the impacts and the ability of the system to cope with subsequent changes. NERC, the Department of Environment, Food and Rural Affairs (Defra) and the Department of Energy and Climate Change (DECC) have recently launched a Living With Environmental Change (LWEC) endorsed research programme into the impacts of ocean acidification, however to answer some of the remaining questions routine time series data is needed. The European Union also funded some observations however these programmes have either ended or are coming to an end.

Fisheries, Agriculture, Food Security and Water Supply

There is no agriculture in the Antarctic. However questions around the sustainability of fishing and stock numbers need answering for Southern Ocean fisheries, (which are currently managed by the Commission for the Conservation of Antarctic Marine Living Resource (CCAMLR) - using underpinning science from the British Antarctic Survey). In the Arctic and surrounding seas, there are concerns over how fisheries and other marine bioresources may change as the ice melts and seas warm. To gain a full insight into this issue, measurements to enhance our understanding of ecosystem structure and functioning as well as assessing stock levels of fish and other edible organisms are necessary.

The Arctic Monitoring and Assessment Programme (AMAP) has recently released a report on pollution in the Arctic[3]. Although the concentration of historical pollution is decreasing questions remain around the presence of new and emerging persistent organic pollutants which can accumulate in the food chain. Initial surveys could be taken to understand the extent and impact of these pollutants. Repeat surveys, at 2-3 year intervals, could be used to assess changes within the food chain and also to determine whether the occurrence of pollution is increasing with a rapidly changing environment.

Human Health, Wealth and Wellbeing

The risk to human health from pollutants has recently been reviewed in the Arctic[4]. The resulting report provides recommendations for the continuation and expansion of the monitoring for persistent organic pollutants, mercury and leads in the environment and accumulated within the food chain.

[3] Arctic Monitoring and Assessment Programme (AMAP) (2009). Arctic Pollution pp.97. http://www.amap.no/

[4] AMAP Assessment (2009): Human Health in the Arctic. pp274. http://www.amap.no/

With a changing climate, there is a possibility of the emergence and transmission of disease. Such issues are the responsibility of the Arctic Rim Nations and would only be of concern to the UK for vaccination and public protection purposes.

Understanding, avoiding and mitigating the effects of Extreme Events and Disasters

As the globe warms there could be an increasing risk of ice shelf collapse or rapid deglaciation. Measurements on the impacts, and assessment of the probability of collapse, can be used to quantify the risk. Measurements could also be used to determine the rate and extent of ice sheet melt & their corresponding contribution to sea level rise. Satellite imagery, such as that from Cryosat, can provide some information on ice thickness and extent, as can Envisat and Polarview for sea ice and icebergs, which can also be used for shipping forecasts. However due to flight duration the continuation of measurements from satellites is not guaranteed into the future and there is concern over longer term measurements. Most of the information currently gathered in this area is via research rather than long term observations. The same can be said for ice stream stability, which in order to answer relevant questions requires an understanding of the processes.

Several issues, such as tsunamis (from submarine landslides), earthquakes and volcanoes could have catastrophic effects in Antarctica. Information is lacking and that available has been gathered as research; although the risk is thought to be low, surveys to fully assess the risks would require international coordination and continuous monitoring.

There is some evidence that ocean circulation may be changing; this could have large impacts on the climate of the UK, it is however an area that is under sampled. Further measurements would enhance our understanding of what is happening and allow us to assess (with the help of models), future implications and impacts.

Understanding and reducing the impacts of environmental change on marine and terrestrial biological diversity, ecosystems & services

Both terrestrial and marine biodiversity are areas which are not well observed within the Antarctic. Some observations have been undertaken by various initiatives but the coverage is not comprehensive. To be able to answer questions regarding whether & how biodiversity is changing, a network of high frequency biodiversity monitoring sites are required. Information on Arctic biodiversity is more readily available due to the efforts of the Conservation of Arctic Flora and Fauna (CAFF), however there are still gaps in information for long term primary production under the ice and in deep water - these are areas where satellites cannot observe.

In order to be able to respond to impacts on biodiversity, there is a need to understand how change may affect species ranges and abundance. For some species, such as Albatross and Petrels observation activities are supported by the need to fulfil Conservation Treaties. These programmes are however narrowly focused and could be extended to include other key species and those that are highly adapted to living within cold regions. This information is paramount if we are to understand how they are being impacted by environmental change. Abundance and range may also be affected by increased competition from non-native species. Monitoring their appearance, interaction with endemic species and ecological succession studies would provide the necessary information to inform management and biosecurity measures. Although various initiatives and organisations are undertaking some observations there is a need for better coordination and

international cooperation. Any measurements that are taken need to be of a suitable frequency to enable the detection and assessment of change. Linked to this is the sensitivity of species at both the genetic and physical level. Long term surveys of sensitivity could be related to genomic analysis and gene banks could be set up for disappearing species.

Measurements to assess the effects on ecosystem functioning are also important. Biological feedbacks on the climate system are not well quantified and information on multiple species and their interactions could be fed into models to allow effects to be predicted and change monitored.

Understanding climate variability and climate change within Earth System Science.

The Polar Regions play a large role in climate control and are therefore linked to many of the associated issues. Continuous spatially distributed measurements of temperature, salinity and ocean current are required to assess the strength of the Meridional Overturning Circulation (MOC), which is responsible for distributing heat to the Polar Regions. Potential slowing of the circulation is linked to freshening of both the Arctic and Antarctic, measurements for which are thought to be too sparse to address the key issues. The melting of sea ice and glaciers may themselves contribute to the freshening and issues surrounding the effects of climate change and the rates at which their volumes are changing need addressing. Linked to this are measurements required to fully understand the interactions of the Arctic Ocean and sea ice, these include not only parameters for the sea ice such as thickness, distribution, ridges and lead distribution, but also boundary currents, horizontal and vertical mixing. Changing glacier dynamics also plays a role, along with glacial lake drainage. There is little active research in this area and no long term monitoring.

Changes in the volume of sea ice and glaciers are linked to sea level rise. However issues surrounding other impacts, for example in alpine regions – recreational skiing, water resources & supply, power generation and also flooding should not be overlooked. In these regions, in addition to the monitoring of glaciers, understanding the snow distribution and thickness is necessary. Satellites can provide some snow cover information however data may not be routinely available in all areas.

Parameters required to feed into numerical weather prediction models and climatology are needed to assess what meteorological changes are occurring and what extremes could be expected with varying climate. This is also relevant for mountainous areas, but is likely to be covered by national organisations in the appropriate countries. The World Meteorological Organisation (WMO) provides recommendations on measurements and spatial coverage, however the current distribution of surface and upper atmosphere measurements taken by the UK is thought to be below these recommendations.

Scientific & Technological Advancement/Innovation

Development of new technology, specific for use in cold environments, is essential for the cryosphere, this could include multiplatform technology (in which the UK has known expertise).

Measurements using long range Autonomous Underwater Vehicles (AUV) are required for observations under ice sheets and icebergs. These measurements can provide information to answer questions regarding sub ice-ocean interactions and could help with understanding more about past ice extent and the response to climate

change. With further investment in such remote technologies, it is possible that data collection may become more cost effective and efficient.

Development of remote sensing techniques that allow the up-scaling of information to answer a variety of questions (such as inferring volume from extent), would be beneficial and could be used when surveying glacier depth.

Continuity of measurements is an issue. This is to some extent linked to the funding of satellites and remotely sensed data collection - due to the flight duration these are often limited to a few years in length. There is a need to ensure that any new satellites carry instruments that will permit the continuity of measurements when old ones cease to function. Continuity also applies when new technologies are used to take measurements – it would be useful if new could be compared directly to old measurements to establish whether considerations/adjustments have to be taken into account.

It should not be forgotten that new technology is not always the best solution, for example some of the best information on glacier change comes from Icelandic farmers - simple measurements are sometimes better than high tech ones.

Other requirements and General Comments

Important issues related to the improvement of data exchange, interoperability, Virtual Research Environments, storage and management will be considered and taken forward under the UK-EOF Data Initiative.

An important feature of the Cryosphere is that it has an international dimension. International data and cooperation are paramount in this area. Many research bases that are dedicated to observing the Polar Regions require sustainable international co-funding; currently some mechanisms and organisation are in existence however more action is required. Capturing and considering the international components will be important in any future capability analysis. It should however be remembered that some issues that are not the responsibility of the UK, although they may be of interest to the science community.

Research and observations often cross over and during the collection of information on the observation requirements some research questions rather than questions that require sustained observations were raised, e.g. What could be learned from the paleo-record and what are the basic fundamental parameters and baselines within the polar systems? Identifying the big questions or define what observation activities need to be in place is not always easy, and can often only be defined after the basic research has been undertaken. The remote areas associated with the cryosphere often have governance issues and many basic scientific measurements are still being taken or have not yet been established.

The cryosphere has many cross-linkages to other domains, for example there is connectivity between issues and domains, e.g. Gulf Stream & thermohaline circulation (MOC) - any changes in circulation systems could have dramatic impacts on many issues/sub-issues. Many of the processes could potentially impact issues in other domains but are either not well understood or unknown.

The drivers for observation requirements should not only include the questions that need to be answered but should also consider what may be needed in order to drive climate or predictive models.

Cryosphere Observation Requirements Table

Information captured in the table will help to articulate what the UK's requirements are for observing the natural environment, what the questions are that we need to answer and how close we are to being able to provide that evidence via a balanced suite of environmental observations.

For each environmental domain information has been collected on the specific issues or sub issues that are of importance for the headline issues identified in the UK-EOF Statement of Need.

Consultation with the community has led to the population and validation of the following table. The tables are currently 'work in progress' and will continue to be revised as requirements and priorities change. The requirements captured have not been prioritised in any way.

Specific/Sub issue	**What are the key questions that require answering in order to address the specific/ sub issue?**	**Measurement Type** (variables that would need to be measured to provide evidence to address the specific issues)	**Frequency of collection** e.g. A continuous measurement for 1 week in Spring, repeated every 2 years. Or A spot measurement, once a week, every week throughout the year. Or Irregular measurements as required i.e. extreme event monitoring.	**What geographic coverage do we need?** A) UK B) England C) N. Ireland D) Scotland E) Wales F) Localised UK G) Europe (non UK) H) Global I) Other (please specify) J) Ocean/Sea (please specify	**What is the primary use for the data?** A) Basic Science B) characterising environmental issues/solutions (influencing policy) C) Direct env. Management D) Modelling & Prediction E) Complying with Legislation F) Development & Growth	**Are the current actions / measurements sufficient to provide the evidence needed to address the issue?** If known, please list the current programmes/sensors which are capable of providing the evidence (e.g. for Sea Surface Temperature AATSR, SLSTR. AVHRR, AMSR and Modis satellites are capable of measuring SST).
Population Growth (Pressure on all environments in the light of population growth and associated pollution.)						
Antarctic as habitable land	How quickly will Antarctic become habitable?	Modelling (prediction)		(I) Antarctic	Policy Question (future)?	Sustainable living in Antarctica not likely several centuries (development of cultivable soils)

Indigenous People				(I) Arctic	Policy, C	Arctic rim countries responsibility, not HMG-UK
Economic Growth and Sustainability (Support economic growth whilst reconciling with sustainable use of natural resources)						
Sustainability of fisheries (see also agriculture & food section)	How sustainable are the Southern ocean fisheries?	Routine measurement of marine ecosystems including; Fish populations (species, abundance etc) terrestrial indicators e.g. high predators. phytoplakton mesoplankton	Annual	(I & J) British Antarctic Territory South Georgia South Sandwich Is. Surrounding ocean	A-E	If an ecosystem approach is being adopted for management, the largest unknown is bacteria and viruses in the southern ocean – these assemblages are likely to be very sensitive to climate change, and ocean acidification. Underpinning assessment of fisheries is required for input to the Commission for the Conservation of Antarctic Marine Living Resources Area around South Georgia well sampled in the summer but seasonal information very limited and areas to the South and East poorly sampled. International partners need to make similar measurement in other sectors of Antarctica to ensure a circum-polar assessment is achieved.
	Are there new resource species (e.g. in deep water or on the seabed)?	Identification of potential new resource species	Survey			
	What will be the long term impacts of melting ice and ice shelves on the abundance & distribution of Krill?	Krill abundance & distribution		(I & J) British Antarctic Territory, South Georgia, South Sandwich Is. & Surrounding ocean	A, B, D	Impacts largely unknown
	How do we develop a system to manage the high Arctic as it becomes ice free?	Ecosystem approach? Routine measurement of key species; Plankton assemblages: Mesoplankton top predators	Seasonal measurements	(I & J) Arctic Ocean & surrounding seas/Oceans. (Fish migrate in from Atlantic)	A-D	Fundamental need for baseline measurements from which to determine change

		Measurements of new species e.g. shrimps etc				
	How do we manage Arctic Shelf Seas as main fisheries important for the UK?	As above for ice free Arctic				Interaction between fishing areas: transfer of species between Pacific and Atlantic will become more likely. Arctic Rim countries, relevant Regional Fisheries Management Organisations and other bodies (such as ICES) will take the lead on Arctic Fisheries, Stock Assessments and Management.
Tourism	What are the impacts of tourism? Is tourism sustainable? What is the risk of Transfer of Disease?	Number & size of vessels landing & their location. Impact measurements?	Annual	(I & J) British Antarctic Territory	B, C, E	Basic information on no. of visitors and ships is provided by the tourist industry but there is no large scale monitoring
				(I & J) Arctic		Responsibility of the Arctic Rim Nations
Pharma-ceuticals and nutra-ceuticals (Biotech-nology)	What are the possibilities for novel substances and products from the polar regions?	Wide-scale survey	Regular monitoring until large coverage has been achieved (10-15 years)	(I & J) British Antarctic Territory, Arctic Ocean, High Arctic	A, B, economic benefit	No significant routine screening is carried out at present by the UK but other nations do have programmes (e.g. Germany). The UN Committee for Limitation of Continental Shelves is defining the divide between National Sovereignity and high Seas in the Arctic. High Seas will come under the juridstiction of the (UN) international Sea Bed Authority, which is likely to develop rules on Biotechnology, mining etc.
		Gene bank to ensure future availability of test genetic diversity				
		-Screening?				

Biomining	***Needs completing by a knowledgeable person***					Arctic: Rules for biomining are likely to be defined by UN International Sea Bed Authority – see above.
Geological resources	What resources are available?	Geological mapping	NA	(I& J) British Antarctic Territory	B	The Protocol on Environmental Protection (to the Antarctic Treaty) bans all mineral-related activities except for Scientific Research.
				(I &J) Arctic		Responsibility of the Arctic Rim Nations except for a few areas in the high Arctic Ocean (mapping for the first time required) and on Svalbard .
Transport	What are the impacts of: - Opening sea routes? - Truckers (on the ice) - Skidoo routes?	Ice thickness & cover		(I) Arctic		Polarview can provide relevant information but see comments below in Shipping.
Migration	What are the impacts of migration by people, flora and fauna?			(I) Arctic		Related to Population growth question and biodiversity
Pollution	What is the baseline pollution levels in a) the Atmosphere & b) Seas? (For comparison if there is a pollution incident)	Pollutant monitoring	Routine - and most continuous	(I) Arctic & Antarctica Present network too sparse and incomplete – need coordinated networks	A, B, C, D	Some international stations distributed in the Arctic, few in the Antarctic with sensitive instrumentation. No consistent POP measurements in Antarctica or surrounding oceans – need for baseline. Stockholm convention lead on POPs. Arctic Council – AMAP (Arctic Monitoring and Assessment Programme)

	What are the sources of pollution and specifically what are the impacts of: a). Airborne transport (i.e. transport of pollutants from lower latitudes)?	Atmospheric pollutants		(I & J) Arctic Ocean, surrounding seas and terrestrial environment (I & J) British Antarctic Territory	A, B, C, D	Needs international coordination, and partly the responsibility of the Arctic rim nations. Pollution in the Arctic atmosphere largely by transport from lower latitudes - need international coordination and partly the responsibility of the Arctic Rim nations.
	b). River run off?	Water pollutants				
	c) Shipping	Flotsam/Jetsam				Pollution to the seas from shipping and flotsam and jetsam
	c). Nuclear dumping?	Nuclear waste (radioactivity)		(I & J) Arctic Ocean, surrounding seas and terrestrial environment	B, C, D, E	International Atomic energy agency?
	d). Oil exploration?	Hydrocarbons			A, B, C, D	
	f). Minerals (Greenland gold)?					
	What pollutants are currently locked in the permafrost and at what concentrations?			- (I & J) Arctic Ocean, surrounding seas and terrestrial environment (I & J) British Antarctic Territory	A, B, C, D	Little knowledge – Arctic more important than the Antarctic at this time
Sovereignty	Who will take ownership of the Arctic Ocean Floor?	Mapping?	Once	(I & J) Arctic Ocean		Some mapping by Canada, Greenland/Denmark, USA but high Arctic largely unmapped. The UN Committee for Limitation of Continental Shelves is defining the divide between National Sovereignty and Arctic high Seas. High Seas will come under the jurisdiction of the (UN) international Sea Bed Authority.

Carbon Cycle (Future States of the Earth and particularly the Carbon Cycle)						
Carbon sources and sinks	What are the sources and sinks of carbon in the polar regions (land and sea) ***Current information is marine focused are there any specific non marine issues/requirements?***	pCO_2, CH4, VOCs, non-methane hydrocarbons (NMHs) Sediment traps Inorganic and organic Carbon pools. Other nutrients (including food web nutrients and carbon) Light etc Cycling: ice-pelagic-benthic Links to Biodiversity & ecosystem structure & function	Continuous, inter-annual monitoring on a wide scale. SO?? Link Remote sensing to Carbon parameters	J- Arctic Ocean and surrounding seas Southern Ocean Land-Ocean interactions (river inputs of carbon) Terrestrial?	A, B, D	Significant International gaps both spatially and temporally. Measurements in both hemisphere vastly under-resourced. Insufficient routine biogeochemistry sampling. Links should be made with relevant policy forums e.g. Arctic Council Working Groups, UNFCCC etc. Link to biodiversity and ocean acidification. Nitrogen? NERC have funded some short term UK work (2 years).
Carbon drawdown	How will biological productivity change with less or no ice?	pCO_2 Sediment traps	Ad hoc at present ***What is required – the ideal?***	(I & J) British Antarctic Territory, and surrounding Ocean. Arctic Ocean and surrounding seas	A, B, D	Significant Gap here. Nitrogen? Sediment traps turned yearly- traps have time interval collections so temporally resolved data e.g. monthly can be collected
Sequestration of Carbon in the Seabed	What percentage of biological productivity is sequestered? What are the links between the pelagic (water column) and benthic (seabed)? What proportion of drawdown is offshore, what is nearshore?	Surveys Surveys Surveys	Need baseline measurements and then decadal?	(I & J) British Antarctic Territory and surrounding Ocean. Arctic Ocean and surrounding seas	A, B, D	Significant gap

Atmospheric CO_2	Is the concentration of atmospheric CO_2 changing and at what rate?	Atmospheric CO_2 measurements -More Flask samples needed (C isotope composition) Same for methane		J- Coordinated Arctic network needed	A, B, D poss. E (after COP15)	International cooperation and coordination is has been accomplished but on a basic level
	How will biological productivity change with increasing CO_2?		Not continuous at present	(I & J) British Antarctic Territory, and surrounding ocean and other ocean islands Arctic Ocean and surrounding seas	A, B, D	Needs a network of measurements (with international coordination)
Atmospheric methane and other GHG	What are the fluxes of methane from the high latitudes, what controls this flux both in space and time?	measurements of key GHGs	Continuous	(I & J) Coordinated Arctic network needed	A, B, D	Need international cooperation and coordination. Limited monitoring. N.B. NERC are establishing a methane network and some work was carried out under IPY – COBRA.
			-Two weekly (CH4) at Halley ***– is this the ideal frequency (or just the current frequency)?***	(I &J) British Antarctic Territory and surrounding ocean	A, B, D	Needs a network of measurements (with International coordination)
Ocean Acidification (links to Carbon Cycle)	Where are the ocean acidification hotspots? What is the natural variability within the system? What is the rate of change outside of the natural variability and how is acidification	pCO_2 (ocean) Nutrients surface temperature Salinity Meterological parameters Atmospheric CO_2 Chemistry (Flask Sampled)	Routine monitoring – time series	(J) Antarctic		NERC-Defra Joint funded programme (need the same observations for ocean acidification as for uptake of CO_2 by the ocean) pCO_2 (ocean), nutrients, surface temperature, salinity, meterological parameters, atmospheric CO_2 (all routinely monitored on ships, from time series stations, buoys etc but coverage

	occurring? What will be the impact of acidification, i.e. to what extent can the system cope with change, at what point will the system not be able to adapt?	Isotopes				could be improved) – other measurements are not routinely taken.
Marine clathrates	Where are there marine clathrates and how stable are they?	Quantification Stability Assessments	Mapping required once	(I & J) Arctic British Antarctic Territory and surrounding ocean – UK but part of international network	A, B, D	Responsibility of the Arctic Rim nations – Coordinated Arctic Network needed. Some UK activity has been funded for 2 years.
	Are there clathrates beneath the ice sheets?	Mapping Drilling (& access) Geophysics (possibly)	Mapping required once	(I &J) British Antarctic Territory and surrounding ocean Greenland and smaller icecaps	A, B, D	International survey needed. Information would feed into modelling.
Permafrost stability	What is the Ground ice cover, distribution and change	Mapping		Arctic - British Antarctic Territory, South Georgia and South Sandwich Islands British Antarctic Territory, South Georgia and South Sandwich Islands	A, B, D	Critical issue for the Arctic - little mapping or regular measurements – less important for the Antarctic and surrounding UK territories at this time. This work should co-ordinate with the IPA
	What is the Carbon Volume and distribution?	Carbon vol/dist.		(I) Arctic - British Antarctic Territory, South Georgia and	A, B, D	As above

	What is the temperature? (Cold versus warm permafrost)	Permafrost temperature	Continuous	South Sandwich Islands		
	What are the Geotechnical properties?	Drilling and Geophysics (together)				
	What are the interactions with Groundwater and glaciers?					
	-What are the *stability* thresholds?	- permafrost temperature - ground ice volume & distribution - Shallow drilling programmes		(I) Arctic - British Antarctic Territory, South Georgia and South Sandwich Islands	A, B, D	As above
				(G) European Alps (stability of warming mountain permafrost)	A, B, D	Drilling programmes could be joint within Europe (i.e. with Switzerland, Germany, Norway).
	-How much permafrost thaw is there?	Mapping of thermokarst activity (thaw lakes etc)		(I) Arctic		As above
Changes in Physical Disturbance	How are blooms affected by change in nutrient release from sediment disturbance	Wide Surveys & Local Monitoring: - Drilling - Geo. Physics - Iceberg frequency - Sediment Character		(J) British Antarctic Territory.	A, B, D	Information would feed into models
FISHERIES, AGRICULTURE, FOOD SECURITY & WATER SUPPLY (The effects of environmental change)						
Pollution (See also Economic Growth & Sustainability)	Are there persistent organic pollutants in the food chain (& what is their concentration)?	Routine measurements of concentrations in the atmosphere and some key species	Every five years	(I & J) British Antarctic Territory and surrounding territories and seas	A, B, C, D	No baseline measurements at present (No agriculture in Antarctica)

	Will the occurrence of these pollutants increase with a changing environment?			- (I & J) Arctic Ocean, surrounding seas and terrestrial environment	A, B, C, D	Needs international coordination, and partly the responsibility of the Arctic rim nations.
Fisheries (including Whaling) (See also Economic Growth & Sustainability)	How will the marine bioresources in the Arctic Ocean and surrounding seas change as the Arctic continues to warm?	Basic understanding and quantification of the ecosystem structure and function including stock levels of fish and other edible populations.	Annual	(J) Arctic, shelf seas and North Atlantic.		No UK monitoring activity and little knowledge base; need to be in at the ground level for sustainable use of the Arctic Ocean
	What marine bio-resources can be taken from the Southern Ocean sustainably		Annual	Southern Ocean		Currently managed under CCAMLR; underpinning science undertaken by British Antarctic Survey
Potential/ opportunity	How much land new agricultural land will become available?	Mapping of exposed land and soil	Every decade	(I) Antarctic		Not currently a pressing issue
Human Health, Wealth and Wellbeing (Consequences of environmental change for Human health, wealth and wellbeing)						
Invasive/Infectious Diseases	How will Climate Change affect the occurrence and transmission of diseases etc?			(I & J) Antarctic Arctic	E - Policy (Health and Safety) Science	Human health the responsibility of each nation; no pressing issues for the UK
	What medical or biosecurity measures will be needed (e.g. for the Science Community)?			(I & J) Antarctic	E	Out of scope for the UK-EOF
	Will increasing temperatures see the emergence of diseases in the Arctic region?	Modelling spread of disease e.g. malaria, Lyme disease etc		(I & J) Arctic		Human health outside the scope of the UK-EOF, however environmental factors related to the transmission/emergence are within scope. UK assessment of risks & protection will take place in the UK.
Pollutants – See Economic Growth and Sustainability AND Agriculture, Food Security and Water Supply. Assessment of pollutants required before risk to human health can be determined (also see AMAP 2009 report which deals with Human health).						

Extreme Events and Disasters						
Sea level rise (Extreme sea level rise as a result of shelf collapse /rapid deglaciation)	What controls sea level rise? At what rate will sea level rise? What are the impacts of sea level rise?	Changes in ice sheet (altitude, speed of glacier motion, accumulation, ablation)	Annual	(I) – Entire ice Sheet Arctic & Antarctic	A, B, D	Cryosat will provide critical information but concern over long term measurements; PML run network of tide gauge observations.
		Isostatic recovery	Annual & ongoing			Arctic Limited at present. BGS make measurements in the UK Antarctic: UK makes only a very modest contribution to a limited international effort; significant data gaps.
		Ice cores				
Ice shelf collapse / Rapid deglaciation	What are the impacts of a changing environment on ice shelves/glaciers? What is the probability of collapse?			(I & J) Antarctica		Some research undertaken
	How fast and to what extent will marine based parts of ice sheets melt? What are the controls of deglaciation? What effect will this have on sea level rise? **See Sea level rise above**	Export/transformation monitoring.		(I & J) Arctic and Antarctica	A, B, D	No monitoring, any work is carried out as research.
		Mapping				
		Depth of outlets (Airborne radar, surface radar, seismics)				
		Velocity of outlets (remote sensing)				
		Accumulation/ Ablation (in situ/satellites)				

	What effect will this have on the delivery of particulate and dissolved inorganic materials to surface waters and coastal zone?					
Ice stream Stability	To answer questions surrounding this, there is a need to understand the processes	Velocity		(I & J) Antarctica		No current monitoring funded. Some research undertaken.
		Boundary Conditions(bed/sides & downstream changes)				
		Ice properties				
		Accumulation				
		Drainage Basin changes				
Sea Ice extent – see Climate Change						
Ocean Circulation	How is ocean circulation changing and what are the implications and impacts?	CTD locations currents processes Freshwater delivery – changes in salinity	Multi-annual	(J) Southern Ocean High Arctic Ocean	A, B, D	Seriously under-sampled
Tsunamis (caused by submarine landslides)	Where would they occur? What areas would be affected? What would the extent of impact be?	Mapping of ocean floor (swath bathymetry)	Continuous	(I & J) British Antarctic Territory and overseas territorial waters	B, D	Needs international coordination; risk assessment would probably show <u>low probability</u> but needs to be undertaken. (Some work funded as research – not a systematic survey)
			(Needs to be done for the 1st time)	(J) High Arctic Ocean (limited measurements to date)	B, D	Risk Assessment would probably show <u>low probability</u> but needs to be undertaken.
Earthquakes	Will any of the earthquakes cause loss of infrastructure or human life?	Seismometry	Continuous	(I & J) British Antarctic Territory and overseas territorial waters	B, D	Needs international coordination; risk assessment would probably show low risk and low impact but needs to be undertaken.

Volcanoes	Are any of the volcanoes in Antarctic and the surrounding seas likely to have a major eruption (threat to shipping, tsunami source)	Observations from satellite	Continuous	(I & J) British Antarctic Territory and overseas territorial waters Arctic	B, D	No routine monitoring at present; needs international coordination; risk assessment would probably show low risk and low impact but needs to be undertaken.
Shipping **Also relevant to tourist ships**	Will risk to shipping increase?	Sea and iceberg monitoring Mapping Need for bathymetry measurements	Annual/ Austral summer	(J) Oceans south of polar front Arctic Ocean and surrounding seas, especially around Greenland for icebergs	C (economic?)	Envisat UKHO and MoD play an important role; Polarview provides sea ice and ice berg information in both hemispheres but no long term sustainable funding in place – will help to avoid disaster and pollution
Tundra fires	Will the frequency of fires in tundra areas increase?					
Extreme Weather	How will heat waves, storms, droughts etc occur and how frequently? What level is extreme?	Meteorological measurements				

Biological Diversity, Ecosystem & Services (Impacts of environmental change on biological diversity, ecosystems and ecosystem services)						
Marine Biological Diversity	How will biodiversity be affected by change?	Biodiversity surveys (there are currently no biodiversity monitors in the Antarctic – therefore these need setting up). Primary Production (Need to link to Remote Sensing to primary production) -Indicator species Phytoplankton and zooplankton (sensitive to temperatures)	Annual (& one off) at present More frequent required - Annual surveys may miss migration periods of certain species	J- British Antarctic territory and surrounding ocean south of polar front (where rapid change is occurring). South Georgia and South Sandwich Islands (SGSSI) Along with International partners	A, B,C, D, E	Limited biodiversity surveying is undertaken – Some observations have been taken under CCAMLR (CEMP Programme, Sentinel Programme (Australian Initiative in the S. Ocean) & ICE (BAS) however coverage is not comprehensive and more could be done. There is limited investment in critical experiments; International coordination important. [Potential for greater use of satellite data and monitoring?] South Georgia mammals, Seabirds & pelagic system
			Annual and one off at present Need continuous interannual for detecting regime shift. surveys need to be carried out in correct season to account for migrations	(J) Arctic Ocean and Surrounding Seas	A, B, D	CAFF (Conservation of Arctic Flora and Fauna) has much in place for monitoring - Circumpolar Biodiversity Monitoring Programme, CAFF sea bird programme. Data are limited (both spatially and scientifically) Need long term primary production (spatially and temporally resolved) especially under the ice & in deep water where satellites cannot observe. Cross linkages with Marine.

	How 'sensitive' will species become at: a. genetic level? b. physiological level?	Genomic and physical responses to change & stress. Setting up of gene banks for disappearing species.	- Survey – multiple species: short term (annual) and longer term (3-5 years)	(J) British Antarctic territory and surrounding ocean south of polar front (where rapid change is occurring). Along with International partners Arctic Ocean and surrounding seas		Limited research only – no systematic or comprehensive approach
	What are the effects on ecosystem functioning[5]?	Need multiple species analysis & interactions to allow ecosystem level effects to be predicted and change monitored. (If possible conduct ecosystem level analysis).	Surveys	(J) British Antarctic Territory and surrounding ocean south of polar front (where rapid change is occurring). Along with International partners Arctic Ocean and Surrounding Seas	A, B, D	Biological feedbacks on the climate system not well quantified. Information will feed into modelling Currently fragmented eddy-flux measurements of CO2, energy and water vapour could be better integrated. Network of LTER-type research platforms needs to established to cover a broader spectrum of environmental variability. High Arctic poorly covered at present

[5] Ecosystem Function needs to be defined. Would it include C and N turnover? Net Primary Production, Biomass, Population Dynamics?

	What will be the impact of Invasive species?	Monitoring of invasive species (surveys needed to see first invasives) Monitoring what disappears as a result (therefore need all species monitoring) - CPR type surveys	Annual monitoring of biodiversity	(J) British Antarctic Territory and surrounding ocean south of polar front (where rapid change is occurring). Along with International partners Arctic Ocean and surrounding seas		Limited monitoring occurring within British Antarctic Territory and some work on South Georgia
Terrestrial biodiversity	How will biodiversity be affected?	Biodiversity surveys (no current biodiversity monitors in the Antarctic)	Annual and one off at present	(I) Arctic	A, B, D	Much done by Arctic nations/Arctic Council Remote Sensing ***of what?***
				(I) British Antarctic Territory & in collaboration with International partners	A, B, C, D, E	Need to move to a more structured and systematic survey – perhaps decadal once the baselines have been established Remote Sensing ***of what?***
	What are the effects on ecosystem functioning[5]?	Multispecies surveys and analysis of the interactions and how they change (or if possible ecosystem level analysis)		I - Arctic		.
			Surveys	(I) British Antarctic Territory		Biological feedbacks on the climate system not well quantified.
	What will be the impact of Invasive species,	Monitoring of invasive species (surveys needed	Annual monitoring of	(I) Arctic		Responsibility of the Arctic Rim Nations

	including pests and pathogens?	to see 1st invasives); rates of dispersal/colonisation of different ecosystem components Loss of original (endemic) species (plants and animals) Ecological succession studies Thresholds in ecosystem structure	biodiversity	(I) British Antarctic Territory and elsewhere in Antarctica in collaboration from international partners		This is a key priority for the Antarctic Treaty's Committee on Environmental Protection. (It is likely that there will be recommendation for significant observation and monitoring to underpin strengthened biosecurity measures).
	How 'sensitive' will species become at: a. genetic level? b. physiological level?	Surveys of sensitivity across species and ecosystems (responses to change). - Genomic Analysis & gene banks	Short term (annual) & long term (3-5 years)	I - Arctic		
				(J) British Antarctic Territory and surrounding ocean S. of Polar front. Collaboration with international partners	A, B, C, D, E	
Ecosystem Structure and Functioning	How will environmental change affect ecosystem structure and functioning. (Biodiversity is coupled to this).			(J) British Antarctic Territory and surrounding seas		Biological feedbacks on the climate system not well quantified.
				(J) Arctic Region		Biological feedbacks on the climate system not well quantified.
Bird populations	What is the likely extent Albatross/Petrel loss (red list species)?	Counting, tagging Behavioural studies	Annual	J - British Antarctic territory and overseas territories	A, B, C, D, E	UK contribution to agreement on the Conservation of Albatrosses and Petrels and Antarctic Treaty System

	How will other migratory bird populations change?	species surveys, ringing, monitoring programmes	Annual	J- Arctic Oceans and surrounding seas British Antarctic territory and overseas territories	A, B, C. D	Many Arctic birds over-winter in the UK; International cooperation required.
Species Ranges	Are species ranges changing? Are some species ranges declining?	Surveys and species monitoring. ***Indicator species needed.*** ***e.g. arctic cod***		(I) British Antarctic Territory and elsewhere in Antarctica and the Southern Oceans		Key to work of the Antarctic Treaty (CCAMLR & CEP).
Iconic Species	What will be the affect of environmental change on key indicator species/species with conservation value? (e.g. penguins, seals, whales, krill, sea spiders?)	Routine assessment of population size and distribution	Annual	(J) British Antarctic Territory and Surrounding Oceans		Measurements on South Georgia; limited elsewhere
	What will be the affect upon iconic species e.g. Bears, Walruses, Narwhal etc	Routine assessment of population size and distribution of specific species e.g. Bear walruses, Narwhal etc	Annual	(I & J) Arctic Tundra and ocean		may be covered by Arctic Rim Nations
Loss of highly adapted species (incl. Ice associated organisms)	Will the changing environment result in the loss of highly adapted species such as ice fish?	surveys & targeted monitoring of whole and less impacted areas e.g. Arctic fox, specialist birds (Ross gulls)	Frequency which will enable an assessment of change	(I) British Antarctic Territory & surrounding oceans.		Stock assessment around South Georgia only
	What will happen to ice algae?			(I) Arctic		Some work on algae in glaciers but little on sea-ice species.

Effects of ice disturbance on ecosystems, biodiversity & productivity.	How will ecosystems respond to changing levels of physical disturbance?	Surveys of whole and less impacted sites		(I & J) Arctic I & J) British Antarctic territory and surrounding ocean south of polar front (where rapid change is occurring). Along with International partners		Ice disturbance only carried out around Rothera station intermittently
	How will nutrients, for phytoplankton blooms change with less resuspension from ice impacts?	Surveys		(I & J) Arctic		
CLIMATE CHANGE: (Variability & Climate Change: Challenges in Earth System Science).						
Meridional overturning circulation	What is the strength of the MOC and will it turn off?	Spatial distribution of ocean sensor: - Temperature - Salinity - Ocean current	Continuous	J- Arctic Ocean and surrounding seas	A, B, D	Needs international coordination; RAPID an important contribution; Establishment of Arctic Regional Ocean Observing System http://arctic-roos.org/ Arctic – Alaskan Observing System http://ak.aoos.org.arc/ The integrated Arctic Ocean Observing system iAOOS http://wwwaosb.org/programs.html
			Continuous	J- British Antarctic Territory and surrounding ocean south of polar front and linked globally	A, B, D	Needs international coordination; significant gaps in many locations. Satellite play a critical role on all areas. Surface measurements also used for ground-truthing satellite data.

Meteoro-logical changes	What changes are occurring? What are the extremes that could be expected with varying climate?	Standard meteorological parameters including: - precipitation - surface & upper atmosphere	(Continuous) 3 hourly	(J) British Antarctic Territory and British Overseas Territories Arctic Ocean and Surrounding Seas	A, B, C, D	Used for numerical weather prediction and climatology; distribution of surface and upper atmosphere measurements well below the recommendations of the WMO spatial coverage and range of measurements.
	How will mountain weather/climate change and what will will be the impacts (e.g. heatwaves 2003)?	Long term monitoring sites	continuous	(G) Alpine Regions		Best done by national organisations in appropriate countries
Ozone	What changes are occurring in the ozone?	Ozone measurements Vertical profiles (of ozone) from space	- Daily (freq.)	I- Halley and Rothera research stations J-South of Polar front Arctic	B, C, D, E	Vertical profiles of ozone rather than total content would be valuable Atmospheric chemistry undersampled – see also Carbon Cycle.
Sea Ice	What are the effects of climate change on sea ice?	Sea ice extent and thickness (mapping) Areas of ridges and leads Spatial variability across scale measures needed.	Monthly (min.)	(J) South of polar front Arctic	A, B, D	Use of Remote sensing observations is essential for area, thickness measurements. AUV i.e. thickness distribution and related parameters (ridges distribution, lead distribution etc)
	To fully understand Arctic Ocean and Sea ice the following would be required:	Drag coefficients (upper & lower; roughness and keels)		J Arctic Oceans and surrounding seas	A, B, D	Radar, laser, acoustic (via satellite, aircraft and sub).
		Boundary Currents (from moored current meters/drifters).	continuous			Distribution of drifters.and current meters well below the resolution required for the problem; international coordination essential but UK needs to play a role

		Understanding dense water formation. *In situ* observatory. Wide area chemical tracers.				Need to quantify these processes once and then determine where and when to apply the knowledge, and how the locations and fluxes change with time
		Horizontal/Vertical mixing (eddies, instability processes/ turbulent/ convective/ seasonal).	Continuous			As above Can use tracers & downstream monitoring for export transformation
		"Neptune effect" (Topostrophy) Montgomery potential Air sea fluxes		J Arctic Oceans and surrounding seas		As above
		Modal circulation variation and forcing		J Arctic Oceans and surrounding seas (Wide Area Monitoring	A, B, D	Satellite Altimeter –SSM/1, SAR, AATSR Bottom pressure records
		Shelf basin exchanges - Downstream export monitoring?		J Arctic Oceans and surrounding seas		As above
		"Localisation" (what happens where and when).		J Arctic Oceans and surrounding seas (Wide Area Monitoring)		
	What is the interaction of Barotrophic & baroclimatic tides? (cf. mixing, interaction with sea-ice)	Improved bathymetry, land & marine		J Arctic Oceans and surrounding seas		Need mapping for the first time, especially in the Arctic basin. Tide Gauges, Satellite
	What is the effect/occurrence of melt ponds?	(Albedo): changes in absorbion.		J Arctic Oceans and surrounding seas		From space with ground-truthing – research funded outside UK
	Ice interior radiation transfer??	***Need Advice from Sea ice expert***		J Arctic Oceans and surrounding seas		
	Ice Rheology?	***Need Advice from Sea ice expert***		J Arctic Oceans and surrounding seas		

	What is the mechanical distribution of ice in ridging?	Ridges		J Arctic Oceans and surrounding seas		
	To what extent is sea ice forming on Leads and polynyas (Frazil ice)	Satellite?		J Arctic Oceans and surrounding seas		
	What role do Fjord Processes play in changing sea ice conditions?					
Glaciers (including Glacier Lakes) **See also Rapid Deglaciation under Extreme Events**	To what extent and at what rate are glacier volume/dynamics changing?				D	
	What are the impacts of glacier melt/glacier lakes for: Sea level rise Recreation (skiing) Water resources & supply Power generation Human populations (outburst floods)			(H) Global. Including alpine regions (Himalayas)		**See comments under extreme events concerning sea level rise**
	What is the volume of Glacier lake drainage? What are the drainage mechanisms? What are the impacts?	Geophysics Drilling ICESAT or etc (elevation changes)	Multi-annual	(I & J) Antarctica	A, B, D	Very little active research; no long term monitoring
	What is the depth of Marine based temperate outlet glaciers that are highly cravassed? (This information will be used in overcoming scattering)	Depth		Arctic and Antarctic Peninsula		

Snow distribution, depth and longevity	How will snow distribution, depth and longevity change? What will be the effect on: - River run off? - Albedo? - Plant phenology and Normalised Difference Vegetation Index? - Ecosystem functioning e.g. CO_2 and CH_4 fluxes Herbivore population dynamics and spatial distribution	Distribution, depth, density, chemical composition, longevity and thickness of snow	Monthly (min)	(G) Global: Polar regions, Alpine regions, lower latitudes in winter etc.		Daily maps of snow cover – available from met satellites but added value data to address this questions not routinely available for all areas Snow depth and density measurements on the ground required to supplement satellite remote sensing
Sea level rise – See Extreme events (sea level rise and rapid deglaciation) and Glaciers above						
Permafrost	(See Earth System changes including Carbon Cycle)					
Freshening of the Arctic and the Antarctic	***What are the key questions/issues that need to be answered?***	Salinity Glacier meltwater River input Precipitation/ evaporation Isotopic measurements Net boundary monitoring at heat & freshwater import/export key gateways	Seasonal	(J) Arctic Ocean and surrounding seas (key gateways: Bering straight, Barents, Davis Straight, Fram Straight, Orkney Passage etc) Antarctic, Southern and surrounding oceans	A, B, D	Distribution of measurements too sparse to address the key problems

Ocean Currents	What are the changes in ocean currents? What are the controls? What will the effect of changing currents be on shipping, safety, navigation etc?		Continuous			Distribution of measurements too sparse to address the key problems
Changes in Land Extent	What will be the changes to land extent (ice sheet/glaciers)?					
Scientific & Technological Advancement/Innovation (Stimulation of Scientific & Technological Advance and Innovation)						
Space Weather	How do Sun outputs link to the outer atmosphere?	- Ionosphere - Magnetosphere - Sun outputs (& how it links to the outer atmosphere.	Continuous	(I) Halley and Rothera Research Station (Antarctic) Arctic (various locations currently measure)	A, D	Some sampling at Halley & a modest programme at Rothera. Distribution around the Antarctic continent too limited to address spatial & temporal variations Shortage of information from the Russian Sector
Continuity	How can we increase the continuity of remote sensing measurements, many of which are only a few years in length?			Antarctic Arctic, Global		
	How can we secure more consistency (and longer term) measurements (i.e. GRACE, ICEAST, Cryosat2, SAR – as an example this currently has no interferometry).					

Sub Ice observations (and sub sea ice shelf/ icebergs)	What is happening beneath the icesheets/icebergs? What are the ice-Ocean interactions that occur under the icesheets/icebergs? Can observations under the icesheets help us to understand more about past ice extent and the response to climate change?	long range AUV (Autonomous Underwater Vehicles)		Arctic, Antarctic		
Multi-Platform Technology (e.g. Biology on Physics Moorings)				Arctic, Antarctic, Global		The UK has expertise in this field.
Technology required (specific to cold environ-ments)	Needed to address several issues	Airborne techniques & remote sensing (satellites) - mapping	- As required	(J) British Antarctic Territory and overseas territories (J) Arctic	B, C	
OTHER REQUIREMENTS						
Areas for development	Can we exploit isotope measurements more effectively?	Isotope sampling can be used for a variety of purpose- not fully exploited e.g. diet of higher predators;		Arctic & Antarctic		Current actions not sufficient as isotope analysis general slow, time consuming and expensive

		understanding sources and sink of atmospheric trace gases				
Remote technology	Can data collection be cheaper, faster and more effective with increased use of autonomous and remote instrumentation?			Arctic & Antarctic		Insufficient investment in UAVs, UORs, remote observatories, cabled observatories etc.
Data Handling & Associated information. (NB Arctic/ Antarctic/ Global)	How can we improve: -Data exchange, interoperability, standards etc -Need for Virtual Research Environments (How can we develop interfaces for user communities to develop collaborative online resource outputs/utilities? -What utilities are required? -How to discover/visualise/access data -Facilities for outreach -Would a single data centre be the best solution? -Do the current data centres deliver? -Management of data in the short term is different to long-term management – how can this be incorporated into data policy and managed. -Does the data/data		Data collected from Near real time – continuous to Decadal	Arctic, Antarctic & Global		Need to keep up with technology development and have continual investment Currently far too many data sets are not internationally available – big issue

	storage conform to legislation? -What are the common requirements across the scientific community? How can we secure long term resource commitment? What are the interactions between models and real data.					
International collaboration	How can international collaboration be achieved? How can we ensure/sustain international co-funding of research bases? (e.g. EU or UK – Canada, i.e. UNIS – Svalbard; Russia, Poland, Norway; Toolits Lake, North Alaska).			Arctic and Antarctic		Some mechanisms and organisation exists but a long way to go – needs a champion or two ;
What is the role of snow (visable snow) vs. radar (ice) or remote sensing (aircraft/satellite?)	***Need further explanation***					
Upscaling from Remote sensing and other data sets	How can remote sensing be used to upscale and answer a variety of questions such as inferring volume from extent	Survey of glacier depth is one example		Generic issue to all parts of the environment		

Other issues raised by the community but which relate more to research questions than sustained observations

Past Climate contribution	What can we discover from past climate contributions to climate warming from Permafrost (MIS5e) and last glacial-interglacial transition?	-Cores of ancient permafrost. -V series dating -^{14}C dating -Carbon content & distribution		(I) British Antarctic Territory		
	What can we learn from past climate changes and evidence from the palaeo-record?	- Climate Records		(G) Alpine Regions		
Basic Knowledge of Polar Systems	What are the fundamental parameters and baselines within the Antarctic system?			Antarctic		
	What are the fundamental parameters and Baselines within the Arctic system?	-Survey -First observations of processes		Arctic		
Development of sub-nivean processes and biogeochemistry fields??						
Robust modelling of the system						