UK Arctic and Antarctic Partnership (UKAAP) summary report

Horizon scan

Report assembled by Viv Jones (UCL) November 2019

The horizon scan, facilitated by the UKAAP took place at the UK Arctic Conference September 12th 2019, Loughborough UK

UKAAP would like to thank to Richard Hodgkins and colleagues from Loughborough for organising the conference, workshop convenors for producing this text and conference participants for their contributions. Contributions from the wider community were obtained through an online 'pin-up' system set up by Richard. The authors would like to thank all who contributed to the pin-boards and workshops.

Contents

1. Priorities for Arctic Terrestrial Research

(Mary Edwards and Clay Prater)

Researchers highlighted points that could be related to a set of six fields: terrestrial ecosystems (including carbon and microbes), cryosphere, pollutants and infrastructural plus two cross-cutting themes.

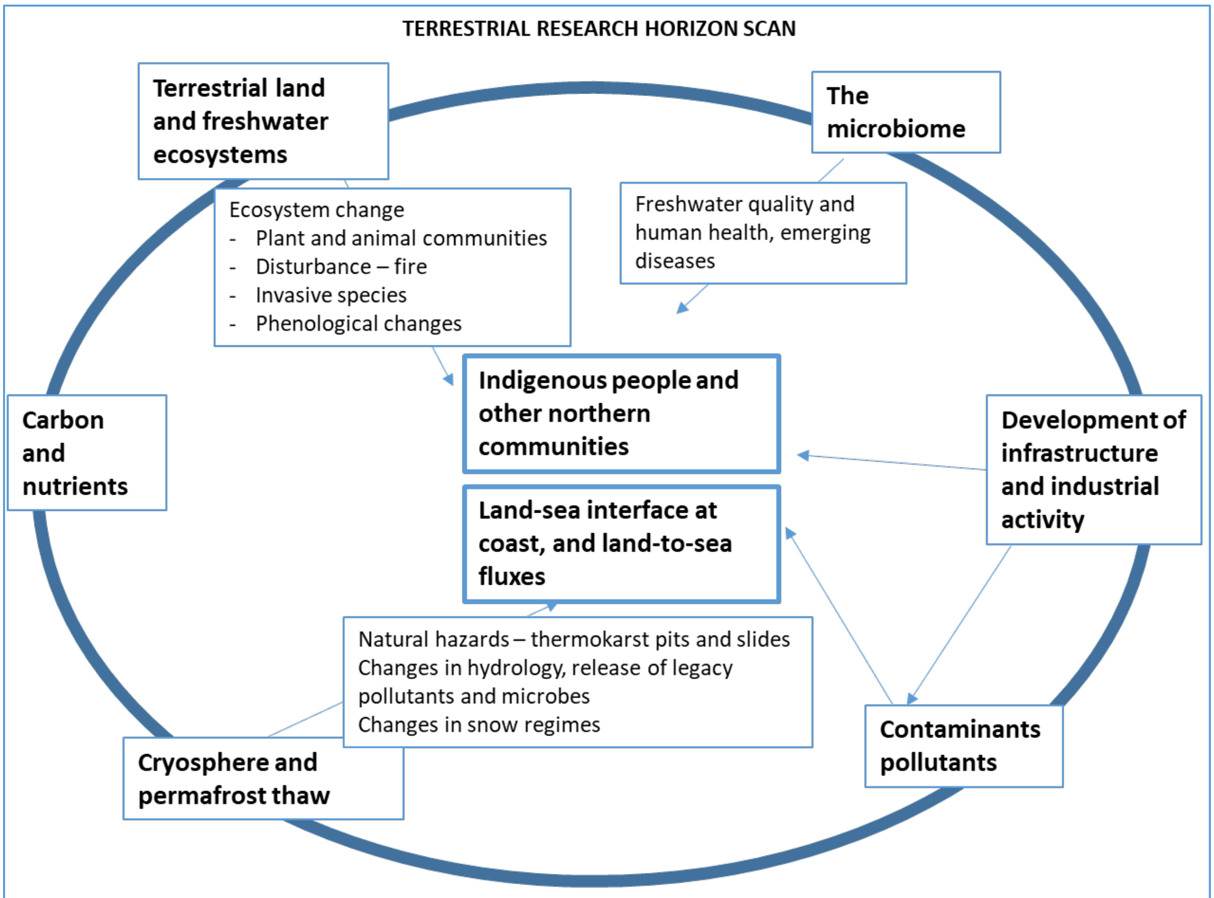
Cross-cutting themes

1) Socio-ecosystems– almost all aspects of physical and biological change are likely to affect indigenous peoples and other northern communities, thus providing a powerful theme for interdisciplinary work.

2) Terrestrial to marine via coasts and rivers (T-MOSAiC is a research-infrastructure resource): permafrost thaw and transport of nutrients and contaminants from rivers to marine systems; key ecological zone of human activity.

Figure 1 links these fields (the circle indicating their integration and inter-dependence), and it indicates how virtually all also feed into two cross-cutting themes that emerged from the conversation.

Figure 1



The inner boxes represent two foci of cross-cutting research. The items on the circle are areas of research, many of which are linked with each other.

Ecosystems

A priority has to be mapping and monitoring (plant & invertebrates-non charismatic species), an essential prerequisite for benchmarking change and for understanding ecosystem structure and function. It was noted that monitoring tends a dirty word in the UK, whereas NSF and other funders are more likely to cover monitoring. There's a big gap between the UK and US monitoring efforts. And this leads to uncertainties about where the tipping points are likely to occur. But there are some good resources: CAVM, Arctic DEM, and many published *in-situ* measurements.

Changes in vegetation: shifts of key ecotones and changes in community composition – can affect availability of human resources, directly or my affecting foraging/migration of animals

Disruption and disturbance: a point raised by several people was the spread of non-native and/or invasive species. Control and prediction. What native organisms are threatened and how can we protect them? Identify communities of specifically important organisms (important to indigenous communities).

Fire—there is increasing likelihood of fire in forest AND tundra – feeds to permafrost thaw, plant and animal communities, nutrient cycling. An important feature of ecological communities and biogeochemistry, it is also likely to start becoming a hazard. Past and present fire patterns, impacts of fires, modelling fire futures. An important **natural hazard**.

The changing phenology of many species poses challenges within ecosystems (temporally decouple behaviours) and for people (changed migration patterns). Observed widely, is likely to be strongly expressed in Arctic. Affects freshwater systems via changing ice phenology.

Vegetation change, consequences of extreme events and longer-term trends. Overall, trend with warming is greening the Arctic, but extreme events generally cause damage to vegetation resulting in "arctic browning". While greening continues overall, we now recognise a complexity at finer temporal and spatial scales, with some areas greening and some browning. What drives those changes in different regions and how do we predict the future fate of artic vegetation from this complex set of responses?

The long-term perspective of change in the Arctic (via well-dated lake sediment and peat records) can provide a pre-industrial base line from which to assess future change. Previous periods with a warmer climate (e.g. Holocene Thermal Maximum, Medieval warm period) can provide insight in how carbon sequestration, species turnover rates, fire regimes, etc, might be expected to change in future decades. Requires fire modelling.

Are current/historical relationships between key meteorological variables (temperature, precipitation, snow cover, etc) and plant success sufficiently well-defined to enable us to use future IPCC climate projections to tell us something about how future vegetation is likely to change. How much 'added-value' do computationally expensive land-surface models provide?

These last two points feed into questions about process modelling (see below).

The microbiome

The microbiome is increasingly recognized as essential to nutrient cycling and ecosystem health. We currently lack a comprehensive survey of arctic microbiomes. This required in order to understand how microbial communities respond to change and what processes they will affect, such as nutrient cycling. Legacy microbiomes from thawing permafrost, and freshwater and human health are issues. There may be emerging new disease issues in local communities.

Microbiomes in terrestrial ecosystems are linked with T-MOSAiC.

Carbon and nutrients
There is a need to better understand the operation of the very poorly constrained "permafrost carbon feedback", a large source of uncertainty in future projections. This involves the rates, patterns and controls on mobilisation of old (or "legacy") carbon during permafrost thaw. And the subsequent fate of that carbon (in terms of potential release of CO_2 and CH_4.

Transport of C and nutrients from land to sea. Arctic rivers play an important role in net ecosystem carbon balance and greenhouse gas release (in particular from carbon sources which are old). Linked to changes in hydrology related to permafrost thaw (see below)

Cryosphere

Ecosystem protection of permafrost and how future vegetation change may impact the fate of permafrost. This includes impacts of vegetation change on soil moisture, as well as controls on snow cover (trapping), shading etc.

Fate of permafrost in a warmer arctic and how warming impacts will be modified by greater or less precipitation. E.g. will warmer active layers thaw much faster if wetter from increased precipitation?

What's going on under the ground? Permafrost *hydrological models* could be important because permafrost melting affects many processes: plants, lake nutrients, contaminant leaching (see modelling below).

An important **natural hazard** is permafrost thaw, as thermokarst pits, slumps, and ponding**.**

How is snow mass changing in the Arctic? Is there mass loss or is it simply being redistributed? How is the structure (layering, density, microstructure) of the snowpack changing? How do the changes impact the ecosystem / feed back into the atmosphere?

Importance of winter vs summer processes and climate change to ecosystems and biogeochemical cycling. Most terrestrial ecosystem research to date has focussed on summer, but climate change in the arctic is happening much faster in the winter (and the arctic winter is longer than summer). So, for instance, how do snow regime changes, extreme or unusual events (winter rainfall, rain on snow, unusual warmth) impacts ecosystems and biogeochemical cycling?

Pollutants

Role of emerging pollutants and interactions between them, and climate change. How are pollutants stored in permafrost and subsequently mobilised? Concerns both organic and inorganic pollutants. Do they enter food chains and water supplies to impact local communities?

Impacts of development (as infrastructure) is cross cutting with ecology, permafrost and indigenous people. This will be a growing feature of arctic life. Requires reaching out to engineering, industry and other non-traditional sectors for terrestrial science.

Socioecosystems and indigenous knowledge

Terrestrial scientists should consider how well they incorporate indigenous knowledge and local concerns into ongoing and future research. This was a broadly supported theme at the conference, and there was discussion of making it a priority wherever possible, but there appears to be a lack of general mechanism/infrastructure for identifying these issues beyond small-scale interactions between local researchers and populations. Ecosystems, ice and plant phenology and infrastructure are areas where these ideas might be best developed. It was noted that the IASC project RATIC (Rapid Arctic Transitions due to Infrastructure and Climate) is aimed at the intersection of climate change, permafrost dynamics and human activity.

TOOLKITS

- **Various people raised questions about links to modelling. There is need for a survey of process modeling, who is doing it, what models are available—is this a short post-doc project (e.g. 1-2 months), could NERC/Arctic Office Fund?**
- **Bringing together REMOTE SENSING with other aspects of arctic terrestrial science – perhaps some kind of workshop to be organized?**

2. Priorities for Arctic Research in the Oceans

Katharine Hendry (Bristol), Murk Memon (Sheffield) and Finlo Cottier (SAMS)

Represented disciplines:

Oceanography (physics, chemistry, biology); Atmosphere-cryosphere-ocean interactions (including model validation/satellite ground-truthing); Marine geology; Marine pollution; Microbial and benthic biology.

Overarching priority questions:

One of the greatest concerns surrounds the impact of climate change on the Arctic system and the wider global impacts. This requires multi-discipline projects to further understanding of the current situation, in the context of past change, and to allow more robust predictions of the future.

In this context, key marine science highlight topics - largely focussing on interfaces within the marine system - were suggested:

- The influence of meltwater on the oceans around Greenland throughout different timescales;
- Atmosphere-ocean interactions in the Arctic Ocean;
- Ocean fluxes (heat, nutrients including carbon, biology – including non-native species, pollutants – persistent and mobile contaminants) at ocean gateways, over the continental shelves and at the increasingly ice-free shelf-break in the Arctic Ocean.

Additional suggestions for infrastructure funding were centered around the critical need for long-term time series on which Discovery Science can be framed.

Challenges:

A number of general challenges and specific issues predicted to arise with the SDA (and associated planning and logistics changes):

General challenges of working in Arctic waters largely centre around:

1) The geopolitics of Arctic science, and the inaccessibility of some regions either throughout the year or during winter (e.g. Central Arctic Ocean, which is currently an understudied component in the Earth system). The collection of data and samples requires the appropriate diplomatic clearance;
2) The capability of capturing variability over different temporal and spatial scales.

Specific challenges associated with the long duration of SDA cruises were identified including:

- Occupation of scientists on long expeditions
- Data management and standardisation of data processing;
- Logistics of equipment storage off-ship, potentially on a fairly long term basis (>months);

- Conflicting disciplines (e.g. echosounder frequencies, clean sampling, etc.).

It was noted that a number of solutions to some concerns have already been identified to these specific issues, including the incorporation of generous laboratory space and equipment for sample processing, internet capabilities, and the planned hire of data managers for each expedition.

Synergies and opportunities:

- UK collaboration across disciplines will be critical in the future, especially given the logistical changes associated with the SDA coming online. UKAAP are ideally situated to catalyse the necessary networking and cohort building. Working on the same samples in a coherent way will allow UK scientists to obtain the most out of samples that are challenging to retrieve.
- International collaboration is going to be essential to address logistical issues. Multi-national efforts will also benefit science, for example in the form of multi-ship expeditions and improved spatial and temporal coverage of data acquisition.
- The UK marine community needs to emphasise their strengths, including world-leading expertise in robotics, developing the SDA as a “Smart Arctic Observatory”.
- The SDA should additionally be used to promote outreach, both public and in the academic community, and training and research opportunities for Early Career Researchers (ECRs)

3. UKAAP Workshop Report: Priorities for Arctic Research in the Social Sciences

Duncan Depledge (Loughborough University) and Ingrid Medby (Oxford Brookes University)

Our workshop participants were drawn from UK-based institutions and beyond, with a particularly strong presence from the Russian social science community. In total 11 social scientists took part in UKAAP's HorizScan on Thursday 12th September 2019. Research interests among the participants were wide-ranging, covering mining and resource-related issues as well as other socio-economic concerns effecting local Arctic communities; the relationship between art and science; soft security challenges; Arctic geopolitics, military activity and strategy; Arctic and non-Arctic youth engagement and education; the politics of researching indigenous peoples; the representation of scientific knowledge in maps and models; and Arctic identities.

This is reflective of the breadth of Arctic social science as well as humanities within the UK. As was highlighted during discussions, the UK has a strong scientific reputation in the Arctic, but more connections and multidisciplinary collaborations between the natural and social sciences would be of benefit. This includes but is not limited to questions of scientific and knowledge practices from research design to dissemination.

The ensuing discussion brought out **three priorities f**or future Arctic social science research:

1. The need for a new *critical* geopolitics of the Arctic to balance the resurgence of political attention to the Arctic as a space of state-centric/great power competition. Research would focus on bringing the geopolitical of experiences of indigenous and local peoples to the fore as the basis for challenging dominant assumptions about Arctic actors, issues, knowledges, identities and borders, with a view to writing an Arctic geopolitics that includes (rather than appropriates) indigenous peoples' perspectives. This also includes challenging reductive images of the Arctic as (only) a space of climate change, focusing also on lived realities and day-to-day socio-political concerns.

2. The need for deeper knowledge of youth participation in Arctic geopolitics/governance. With Arctic indigenous youth looking to reclaim their Arctic identity, and non-Arctic 'Western' youth increasingly prominent in the global debate about climate change, there is a need to understand commonalities and differences between Arctic/Non-Arctic youth perspectives (not limited to the study of Western youth either). Are there potential divisions, for example over how best to protect/develop/steward the Arctic, that risk reproducing past conflicts between Arctic and non-Arctic peoples? Would greater interaction between Arctic/non-Arctic youths increase understanding between them? What is the role of education? Broadly put: what do the youth of today think about the Arctic and how should that be factored into geopolitics, governance and policy-making?

3. The need to further enhance UK-Russia cooperation in the social sciences. Such cooperation has tended to focus on sub-national issues, relating for example to indigenous peoples/local communities/production of scientific knowledge. There has been far less emphasis on matters relating, for example, to political science and geopolitics. There are good reasons for this, mainly relating to problems of national security or political sensitivity. Nevertheless, with Russia's upcoming chairmanship of the Arctic Council (2021-2023), there may be scope/opportunity to facilitate an early career dialogue around Arctic governance and security challenges.

There was only limited engagement with the Social and Human pinboard, but the research interests raised can be summarised broadly as follows: (1) the need to find new ways of diffusing tensions between the West and Russia in the Arctic (i.e. through peace promoting initiatives); (2) the need to assess the resilience of Arctic governance as the region continues to undergo profound environmental change; (3) the need to keep developing our understanding of the importance of the Arctic to the UK; (4) the need to better understand issues in the Arctic relating to food, water and health security.

4. Priorities for the Cryosphere

James Lea (University of Liverpool) and Jessica Cartwright (NOCS)

Within this session 18 people contributed to discussions around the state of UK Cryospheric research, with attendees representing primarily glacier and sea ice researchers. Within the workshop a full range of career stages were represented from PhD to professor level, while online pinboards allowed comments to be submitted anonymously and by those not attending the conference. Comments from the wider UK Cryosphere community were solicited through a message to Cryolist on 9th September. Below is a synthesis of these discussions, though the pinboard submissions includes topics that there was not space to cover below.

What large unresolved questions exist in cryospheric research?
Snow – both glacier and snow ice researchers identified snow as a major source of uncertainty within cryospheric research. Priorities identified included: (1) future projections and phase of precipitation; (2) how models are capable of dealing with significant relief; (3) ground truthing of both remote sensing observations and modelling results, with a requirement for geographic coverage and regular sampling; and (4) ascertaining timing and magnitude of melt, how this modifies the snowpack, and how antecedent conditions impact subsequent melt.

Cross-disciplinary questions – most questions identified during discussions required cross-disciplinary data collection and/or sharing of already collected samples between groups. For example, unresolved questions linked to topics such as tidewater glacier dynamics or biogeochemistry require collaboration between glaciologists, sea ice researchers, oceanographers and biogeochemists. This raised logistical questions regarding how to facilitate complimentary cross-disciplinary data collection; identification of target sites for sustained interdisciplinary data collection; mechanisms for long-term collection of data beyond the lifespan of individual grants; mechanisms for sharing of samples/material; and information on where currently unanalysed samples exist for.

Where does the UK have strong expertise and potential for capacity building

Snow/surface mass balance – the UK has a strong range of expertise within remote sensing, in situ and modelling of snow processes over glaciers, sea ice and terrestrial environments. A particular strength was identified for the Greenland ice sheet where the UK's significant expertise is currently uncoordinated and fragmented (see pinboard). Other potential for capacity building is to embed the latest advances in climate models within this research (e.g. Hadley Centre) across all parts of the cryosphere. Within these areas and across polar science more generally, formal support of network meetings would allow expertise to be fully capitalised upon for sharing of data, approaches, and development of future grant proposals.

Working across-disciplines – the UK has significant expertise in cryospheric and polar sciences, though barriers to effectively addressing cross-disciplinary questions exist. At the most basic level, improving dissemination of information on funded work across the Arctic would facilitate opportunities for overlap and interdisciplinary collaboration between groups, particularly in relation to the launch of the RRS Sir David Attenborough. Every year different groups also travel to the Arctic for fieldwork, though communication and collaboration between teams is often ad hoc and based on personal networks. Potential therefore exists for formally supported meetings for coordinating logistics between groups within and across disciplines to (1) maximise capacity; (2) realise and enhance potential of fieldwork funds; and (3) foster new interdisciplinary research.

Current UKRI supported strengths and capacity for improvement
It was highlighted that UK Cryospheric research has benefited from UKRI/NERC international collaborations including joint NERC/NSF funds; UK-Canada; UK-Germany; and UK-Russia link programmes, with several present in the workshop being direct beneficiaries. This was identified as a particular strength, especially amongst early career academics.
The NERC Earth Observation and Data Acquisition Service (Plymouth Marine Laboratories) was also highlighted as a facility with potential for significant use by the UK Cryospheric community with respect to the access and generation of near-real time remote sensing datasets. Uptake of this service within the Cryospheric community is currently low, but should be strongly encouraged.
Lastly, while free point of access use of UK supported/partnership infrastructure (e.g. Ny-Ålesund, Cambridge Bay) is excellent, costs of travel to these sites mean that these are not used by the community as much as they might. With the probable cessation of access to the EU-INTERACT programme, it is crucial that similar travel support can be provided to enable researchers to realise the potential that these facilities offer.

5. Priorities for Atmospheric science

Gillian Young (Leeds)

1. Where does the UK have strong expertise and where could UK develop?

- UK expertise: Arctic aerosol sources and characteristics – sources of ice nucleating particles (INP) and cloud condensation nuclei (CCN); aerosol-cloud interactions; mixed-phase boundary layer clouds; short-lived climate forcers; atmosphere-ocean interactions; climate model evaluation and development; small-scale process modelling.
- UK could develop: large-scale teleconnections; mercury (expensive to measure but important to health); no focus in large chemical model intercomparison studies on polar regions; back-trajectory expertise.

2. What are the large unresolved questions in the field/s?

- Interactions between the Arctic and lower latitudes: atmospheric circulation response to a weakening pole-to-equator temperature gradient; **two-way connections** between rapid Arctic change and extreme weather / pollution events in mid-latitudes.
- Arctic boundary layer clouds: two-way coupling with atmospheric boundary layer structure; interaction with aerosol particles (cloud condensation nuclei / INP); poor process and large-scale modelling capability. Need **more measurements** to parametrize associated processes better in numerical models across spatial scales.
- Aerosol sources to the Arctic: INP **sources and associated seasonality poorly understood**; emerging local sources of aerosol and trace gases in the Arctic (local and remote pollution sources, natural sources e.g. dust); climate feedbacks driven by short-lived climate forcers (SLCF)
- Chemistry of sea ice - atmosphere interactions: emission / deposition of trace gases, particles, and precursors; effect of changing Arctic sea ice type (multiyear vs young sea ice) on snowpack chemistry, aerosol formation, and polar boundary layer chemistry (halogens, ozone, and mercury); links between chemical flux and clouds and climate, pollutant processing, GHGs, and productivity.

3. Are there some common challenges between sub-disciplines / What are the synergies?

- Need to **improve communication and collaboration between the observing and modelling communities** to facilitate knowledge transfer to high-resolution atmospheric models and up-scaling parametrizations to general circulation models. Would be beneficial to start communication early in projects to know what measurements are helpful for model development / use models to identify which measurements are needed and where.
- E.g. introduce **flexibility in projects** to allow changing campaign plans to adjust measurement set up: e.g. 5 year project, observations project could run on longer time scale (e.g. 3 years) after some modelling done before the measurements (e.g. 2 years). Same money, more time.
- Scale issues: **gap between localised measurements and large-scale modelling**, global models not able to capture the small processes. Lots of work done at small-scale process

level and large-scale global scale, often miss upscaling through the regional scale. Need to develop mechanisms to do this.

4. What are cross-cutting themes between the (IASC) working groups?

- TWG: dust transport; forest fires (smoke plumes); net ecosystem GHG exchange
- MWG: climate change / teleconnection studies; atmosphere-ocean interactions (surface exchange processes)
- CWG: glacier surface mass balance (cloud cover affecting melt / accumulation and surface fluxes)
- SHWG: air quality studies (can link with TWG with e.g. dust transport) and impacts on human health

5. General recommendations / issues.

- Need to encourage to come to these interdisciplinary meetings – UK atmosphere community underrepresented.
- Dundee Satellite Station closed down. **Need satellite data for field campaigns**, relying on outside sources.

Observations required:

- **Long term monitoring**; PM measurements (good measure to constrain models); particle number and size distributions; aerosol sources and chemistry; **vertical structure of aerosols, clouds, and boundary layer.**

Resource issues:

- Hard to get funding for pure modelling projects, mostly get funding for modelling linked to measurements.
- **Data rescue is underfunded** – historical data very important, but hard to get resources.
- Satellites under represented: e.g. removing surface contributions from microwave satellite observations could potentially unlock millions of observations for improving weather forecasts.
- Eager to be involved with multi-disciplinary Arctic training courses often by other WGs. Repeated measurements (by students) at such events would be very beneficial for community and student development

Appendix 1 notes from Pin Boards

A series of pin boards were used to engage with conference participants and also the wider community who were invited to comment before and during the conference

These boards were 'harvested' for their text content after the end of the conference

Terrestrial PIN BOARD

- How is snow mass changing in the Arctic? Is there mass loss or is it simply being redistributed? How is the structure (layering, density, microstructure) of the snowpack changing? How do the changes impact the ecosystem / feed back into the atmosphere?
- The long-term perspective of change in the arctic (via well-dated lake sediment and peat records). Previous periods with a warmer climate (e.g. Holocene Thermal Maximum, Medieval warm period) can provide insight in how carbon sequestration, species turnover rates, fire regimes etc, might be expected to change in future decades and/or provide a pre-industrial base line from which to assess future change
- Microbiomes in terrestrial ecosystems linked with T-MOSAiC: role of microbiomes in permafrost, freshwater and human health in the Arctic using multidisciplinary approach ranging from genomics, biogeochemical measurements, and laboratory experimentation: coastal transition, what is happening in winter, impact of warming to greenhouse gas production, emerging diseases, toxins and invasive species, sentinels of change, nutrient cycling (ADJungblut)
- The rates, patterns and controls on mobilisation of old (or "legacy") carbon during permafrost thaw. And the subsequent fate of that carbon (in terms of potential release of CO_2 and CH_4). This in the context of better constraining the operation of the very poorly constrained "permafrost carbon feedback
- Arctic rivers and their role in net ecosystem carbon balance and greenhouse gas release (in particular from carbon sources which are old)
- Importance of winter vs summer processes and climate change to ecosystems and biogeochemical cycling. Most terrestrial ecosystem research to date has focussed on summer, but climate change in the arctic is happening much faster in the winter (and the arctic winter is longer than summer). So, for instance, how do snow regime changes, extreme or unusual events (winter rainfall, rain on snow, unusual warmth) impacts ecosystems and biogeochemical cycling.
- Role of emerging pollutants and interactions between them, and climate change. How are pollutants stored in permafrost mobilised? Both organic and inorganic. Do they enter foodchains and water supplies?
- Ecosystem protection of permafrost and how future vegetation change may impact the fate of permafrost. This includes impacts of vegetation change on soil moisture (see comment about warming/precipitation interactions), as well as controls on snow cover (trapping), shading etc.
- How does changing phenology of individual ecosystem components affect interactions within and across aquatic-terrestrial ecosystems?

- Fate of permafrost in a warmer arctic and how warming impacts will be modified by greater or less precipitation. E.g. will warmer active layers thaw much faster if wetter from increased precipitation?
- Vegetation change, and consequences of extreme events vs trend climate change. Overall, trend warming is greening the arctic, but extreme events generally cause damage to vegetation resulting in "arctic browning". While greening continues overall, we now recognise a complexity at finer temporal and spatial scales, with some areas greening and some browning. What drives those changes in different regions and how do we predict the future fate of artic vegetation from this complex set of responses.
- The impact of climate change on broad-scale plant success i.e. changes in the spatial distribution of different ecotones. Are current/historical relationships between key meteorological variables (temperature, precipitation, snow cover etc) and plant success sufficiently well-defined to enable us to use future IPCC climate projections to tell us something about how future ecotone distributions are likely to change. How much 'added-value' do computationally expensive land-surface models provide?

Sir David Attenborough use (SDA)/Ocean PIN BOARD

- To establish changes in the Arctic on seasonal timescales, we need coordination between the UK and other nations to gather comparable data sets from key locations during all seasons. This is crucial if we want to get more than snapshots of the seasonal dynamics.
- temperature sensitivities of FIELD metabolic rates -instrument ship with suite of respirometry equipment to determine metabolic performances minimising laboratory effect...
- How about a multi-ship cruise close to the shelf-break to encircle the Antarctic with oceanographic measurements, as a baseline measurement. Three ships (SDA, Araon, NBP, Nuyina, Oden, etc) could do it in a season. Addresses question around heat carbon and freshwater flux, ocean temperature... (please add here?)
- Investigate the inner circle north of 85 degrees, rather than focus on the edge of arctic.
- Establish long term series of locations to monitor, and use this commitment to take Masters' students out to sea to intensively train next generation.
- Research regarding persistent and mobile contaminants in the Arctic Ocean.
- Identify source regions (long-range transport vs. sources within the Arctic).
- Use Attenborough as a platform to send aerial and subsurface autonomous vehicles, or field parties into areas never investigated. e.g. get to ice edge, then helicopter in further. Seek novelty rather than use the ship to do measurements routinely done elsewhere.
- A UK-wide proposal to NERC to form a programme of Arctic research - UKAAP can lead this.
- Make SDA available as mission-specific platform to enable IOPD expeditions to the Arctic and recovery of long climate records using RockDrill or MeBo
- temperature sensitivies of FIELD metabolic rates -instrument ship with suite of respirometry equipment to determine metabolic performances minimising laboratory effect...
- Opportunities for piggybacking of novel, passive sensors on existing cruises
- Make the most of two research platform availability in 2020 Antarctic season:
    - for example, in the last season of use of the Sir James Clark Ross deploy it as a floating/frozen in research station in the Weddell or Ross Sea over winter and deploy Sir David Attenborough in support.
    - do comparative science and performance trials of Sir James Clark Ross and Sir David Attenborough to establish reference data of ship performance for the future successor of Sir David Attenborough (no one has done this!)

- Use the SDA to support a smart Arctic observatory (i.e. repeat long-term mooring deployment, Autosub Long Range, gliders, repeat CTD transects). A possible location would be the northern Barents Sea region. This region would fit in well to research done upstream in Fram Srait and West Svalbard, and downstream in Laptev Sea. Annual or biennial cruises with standard observing and multidisciplinary science projects.

Social Sciences PIN BOARD

Research is urgently needed to investigate whether several provisions stated in the United Nations Declaration on the Rights of Indigenous Peoples – particularly in articles 7 and 8 – are not de facto violated by

1. Not sufficiently reducing emission-reducing activities of other players which lead to an accelerated warming in the Arctic,
2. Not sufficiently addressing long-range pollutants,
3. Not sufficiently reducing ecosystem impacts,
4. Not abstaining from further exploitation of resources and increased future shipping traffic.

This poses also the question of potential liabilities for impacts on – under the Declaration protected – rights to life, integrity and culture.

- Water resource - in terms of link to modified hydrological pathways and cryosphere water waters, but also in terms of potential pollutants and conti [sic]
- Improving cooperation and good governance for the Future of the Arctic
- Microbiome diversity and function for human health and country food under climate (ADJungblut)
- Take advantage of UK expertise to work with Indigenous Communities to deliver useful forecast information (weather, trail navigability), provide better weather and sea ice information for shipping.
- Research on how to facilitate full participation of Arctic inhabitants in decision-making structures, governance, and future planning priorities.
- Research on youth perspectives on Arctic futures.
- Research on peace-promoting and/or cooperation initiatives, especially between Russia and NATO states in the Arctic.
- defining why the changing Arctic is important to people in the UK

Cryosphere PIN BOARD

- Impact of changing seasonal snow cover on terrestrial environments and sea ice. Synergies are very strong with other UKAAP themes: transport and herding (social sciences), snow-albedo feedbacks (climate modelling), snow emissivity (Numerical weather prediction), thermal conductivity (active layer/permafrost), ecology (Carbon fluxes, Arctic greening/browning), hydrology (runoff timing and magnitude), boreal forests (energy fluxes and fire risk), measurement uncertainties in sea ice thickness from airborne and satellite platforms.

- Microbiomes in terrestrial ecosystems linked with T-MOSAiC: role of microbiomes in cryosphere (sub/ supraglacial ecosystems, mineral-mirobe interactin, bioalbedo, using multidisciplinary approach ranging from genomics, biogeochemical measurementts, and laboratory experimentation; coastal transition, what is happening in winter (ADJungblut)
- UK-wide initiative on the mass balance of the Greenland ice sheet - we have lots of expertise in the UK but it is uncoordinated and fragmented.
  Seconded - we should work together in this respect rather than criticise each other's proposals.
- Better cal-val of snow precipitation in weather models, through better field measurements of snowfall on the regional scale.
- Capabilities for processing, analysing and easily disseminating remote sensing based cryospheric data products (i.e. not just the raw data). Challenges:
  - accessibility of computational resource
  - ensuring data products are regularly updated
  - identification of what data products would be valuable to the research community
  - ensuring the interfaces for data access are easy to navigate
- Atmosphere-surface interactions for numerical weather prediction
- Impact of aerosols deposited on snow, linking to terrestrial and atmosphere themes.
- Control of vegetation on snow, control of snow on vegetation, and control of both on surface energy balance.
- Similar to the Danes, have an annual meeting of all research council funded projects that are doing fieldwork in the Arctic for coordinating logistics and cost sharing
- UK involvement in ice cores from Greenland and Canadian Arctic. Especially urgent to better develop sea ice proxies to establish a better history of Arctic sea ice; the UK has significant atmospheric, modelling and ice core expertise that might make this a reality.
- The mass loss signal into the oceans from ice sheets and tidewater glaciers is still poorly known in terms of the split between water and ice contributions. Knowing more about this split will help ocean modelling, and climate prediction

Atmosphere PIN BOARD

- Interactions between the Arctic and lower latitudes, in particular, but not limited to, the response of large-scale atmospheric circulation to a weakening pole-to-equator temperature gradient (i.e., Arctic amplification). We need to better understand the possible connections between rapid Arctic change and extreme weather in mid-latitudes.
- please forgive me, i am not a scientist, but i have an idea; what if there were a 10yr suspension of commercial fishing globally? would the mass of fish cool the oceans and then would that cool the Atmosphere?
- more measurements to quantify chemical sea ice - atmosphere fluxes (emission/ deposition of trace gases, particles & precursors) in a changing sea ice regime, with more FYI & increase of the marginal sea ice zone. Quantify links between chemical flux and clouds & climate, pollutant processing, greenhouse gases, productivity. Requires strong collaboration with sea ice / snow physicists & sea ice biogeochemists
- Need more measurements of the vertical structure of the boundary layer, clouds, and aerosols, particularly during the winter, to improve our understanding of the Arctic indirect effect and quantify associated processes better in numerical models.

- Arctic boundary layer clouds, two-way coupling with atmospheric boundary layer structure
- We need to work out how to remove surface contributions to microwave satellite observations used for atmosphere soundings. If we could do this, we could potentially unlock millions of observations that could be used to improve weather forecasts, particularly in the Arctic.
- Arctic aerosol sources and characteristics – sources of ice nucleating particles (INP) and cloud condensation nuclei (CCN), aerosol-cloud interactions, mixed-phase clouds
- Ice nucleating particles (INP) are key to determining the properties of Arctic clouds, but the sources of these particles are poorly understood. We need more measurements of INP concentrations and a better understanding of which sources are important at which times of the year.
- Understanding of emerging local sources of aerosol and trace gases in the Arctic (local pollution sources, natural sources)
- Need to know the impact of changes in Arctic sea ice type (multiyear vs young sea ice) and extent on snowpack chemistry (e.g. snow salinity), aerosol formation and polar boundary layer chemistry (halogens, ozone and mercury).
- Arctic climate response to short-lived climate forcers (SLCF); response to local and remote forcing; SLCF-driven climate feedbacks
- net ecosystem greenhouse gas exchange; this crosses between terrestrial and atmosphere theme
- Atmosphere-ocean and atmosphere-ice interactions (surface fluxes, surface exchange parameterisation in models)
- Need a better understanding of the low latitude to high latitude teleconnections and how remote regions can affect the climate of Arctic and their drivers on sea ice.
- Analysis of the changing interplay between the different modes of atmospheric circulation variability that impact Arctic climate.
- Efforts are needed to improve communication and collaboration between the observing and modelling communities to facilitate better knowledge transfer to high-resolution atmospheric models and up-scaling parametrizations to general circulation models