

## Proposals funded as part of the first funding round of the Arctic Research Programme.

### Arctic Predictability and Prediction On Seasonal to Inter-annual Timescales (APPOSITE)

PI	Co-I	Institution	Total Costs
Dr Edward Hawkins	Professor Keith Haines Dr Daniel Hodson Dr Sarah Keeley	University of Reading	£551,340
Professor Matthew Collins		University of Exeter	£13,554
			<b>£564,894</b>

#### Objectives

The scientific goals of Arctic Predictability and Prediction On Seasonal to Inter-annual Timescales (APPOSITE) are to:

1. quantify the predictability of the Arctic environment on seasonal to inter-annual timescales
2. determine the physical processes and mechanisms that determine Arctic predictability
3. establish to what extent, and through what mechanisms, the Arctic influences the predictability of the wider climate system
4. provide recommendations on required developments in operational prediction systems

This proposal directly targets the overarching aim of NERC's Arctic Programme - "To improve the capability to predict changes in the Arctic, particularly over timescales of months to decades, including regional impacts", with a focus on the physical atmosphere-ocean-ice system.

An additional component of APPOSITE is a PhD studentship, "Predictability of the opening of Arctic Sea Routes", which answers a highly relevant scientific question for policymakers and industry.

## Aerosol-Cloud Coupling And Climate Interactions in the Arctic (ACCACIA)

PI	Co-I	Institution	Total Costs
Dr Ian Brooks	Professor Ken Carslaw Dr Steven Dobbie Dr Barbara Brooks	University of Leeds	£670,139
Professor Lucy Carpenter	Dr Jacqui Hamilton Dr James Hopkins	University of York	£315,040
Professor Tom Choulaton	Dr Paul Connolly Professor Martin Gallagher Dr Keith Bower Dr James Dorsey Dr Paul Williams Professor Gordon McFiggans Dr James Allan Dr Jonathan Crosier	The University of Manchester	£623,283
Dr Thomas Lachlan-Cope	Dr John King Dr Alexandra Weiss	BAS	£548,445
Professor Ian Renfrew		UEA	£252,244
			<b>£2,409,151</b>

### Objectives

The overarching objective of this study is to reduce the currently large uncertainty in the representation of Arctic climate. The largest single source of this uncertainty arises from the poor understanding and representation of cloud and aerosol processes in climate models in general and in the Arctic in particular. We focus on cloud microphysical and boundary processes directly affecting the surface energy budget, and the sources of aerosol that control cloud microphysical properties. This work will provide a sound foundation for making improved predictions of future Arctic climate. Specific objectives are to:

1.1 Understand the microphysical properties of Arctic clouds and their dependence upon aerosol properties.

1.2 Develop new parameterizations of cloud properties specifically tuned to Arctic condition

2.1 Quantify the surface sources of aerosol and precursor gases as a function of season and sea ice conditions from open ocean through marginal ice zone and in to dense pack ice conditions. We will include both direct aerosol production (i.e. sea spray) and secondary production via gas to particle conversion.

2.2 Estimate the entrainment flux of aerosol from the free troposphere into the boundary layer.

2.3 Develop parameterizations of aerosol surface sources that can be scaled up to Arctic Ocean basin scale and included within large scale models of aerosol processes (here GLOMAP/UKCA).

3.1 Determine the relationships between the vertical structure and turbulent mixing properties of the boundary layer, surface fluxes, and radiatively driven turbulence in cloud.

3.2 Develop and test new parameterizations of turbulent dynamics for shallow/stable Arctic boundary layers.

4.1 Quantify the feedbacks between clouds, aerosol, sea ice, and the wider Arctic climate system. Parameterizations developed under the objectives above will be incorporated into the MetOffice HadGEM climate model for evaluation and assessment of the impact on future climate of the processes they represent.

## The Environment of the Arctic: Climate, Ocean and Sea Ice (TEA-COSI)

PI	Co-I	Institution	Total Costs
Dr Sheldon Bacon		NOC	£426,970
Dr Helen Johnson	Professor David Marshall	University of Oxford	£333,657
Dr Seymour Laxon	Dr Daniel Feltham	UCL	£436,256
Dr Thomas Rippeth		Bangor University	£253,844
Dr Emily Shuckburgh		BAS	£175,398
Dr Alberto Naveira Garabato		University of Southampton	£102,263
Dr Leonard Shaffrey	Professor Rowan Sutton	University of Reading	£243,327
Dr Jonathan Jackson	Mr David Meldrum	SAMS	£401,526
			<b>£2,373,241</b>

### Objectives

- O1: Identification & quantification of critical present-day Arctic ocean & sea ice processes;
- O2: Diagnosis of present & prognosis of future Arctic ocean and sea ice circulation, fluxes, & dynamics;
- O3: Evaluation of future Arctic regional climate & wider consequences of change.

### Summary

Look at a map of the world and find the Shetland Islands. Follow the 60 degrees north latitude circle eastwards. You pass through St. Petersburg, the Ural Mountains, Siberia, the Bering Sea, Alaska, northern Canada, the southern tip of Greenland, then back to the Shetlands. All these places are cold, harsh environments, particularly in winter, except the Shetlands, which is wet and windy but quite mild all year. This is because in the UK we benefit from heat brought northwards by the Atlantic Ocean in a current called the Conveyor Belt. This current is driven by surface water being made to sink by the extreme cold in and around the Arctic. It returns southwards through the Atlantic at great depths. Scientists think it is possible that the Conveyor Belt could slow down or stop, and if it did, the UK would get much colder.

We know the planet has been warming for the last century or more, and we think this is due to the Greenhouse Effect. Burning fossil fuels puts a lot of carbon dioxide into the atmosphere, which stops heat from leaving the Earth, like the glass in a greenhouse. In a warming world, ice melts faster, and there is a lot of ice on the Earth: ice caps on Greenland and Antarctica, sea ice in the Arctic and Antarctic Oceans, glaciers in high mountains. And we know that the Arctic is the fastest-warming part of the planet. This causes extra amounts of fresh water to flow into the oceans. Now this fresh water can affect the Conveyor Belt by acting like a lid of water too light to sink, so the Conveyor Belt stops.

What is the chance of this happening? We do not know, because there is much we do not understand about how the Arctic Ocean works. You need a powerful icebreaker to get into the Arctic Ocean, and that's only really possible in the summer, because in winter the sea ice thickens and the weather is bad. Scientists all over the world agree that the Arctic Ocean is important because it contains a lot of freshwater, which is why, although it is difficult to make measurements in the Arctic, the UK's Natural Environment Research Council has decided to fund a programme of scientific research in the Arctic.

We want to be able to make better predictions of how the Arctic climate will change during the 21st century, so this project will help improve our ability to make these predictions. We will do this by improving the way that computer models of the Earth's climate represent the Arctic. We are going to treat the Arctic Ocean as a box, with a top, a bottom, sides and an interior, and we're going to examine all these parts of the box using measurements from space, from ships, from instruments moored to the sea bed, and from robotic sensors attached to drifting sea ice. We'll use all these measurements together to improve the scientific equations within the computer models, and then we'll run the models into the future to create better predictions not just of the Arctic, but of how changes in the Arctic might influence UK, European and global climate. With better predictions, we can make better plans for the future.

## Methane and Other Greenhouse Gases in the Arctic - Measurements, Process Studies and Modelling (MAMM)

PI	Co-I	Institution	Total Costs
Professor John Pyle	Dr Glenn Carver Dr Nicola Warwick	University of Cambridge	£530,375
Dr Andrew Manning		UEA	£318,397
Professor Hugh Coe	Professor Martin Gallagher Dr Keith Bower Dr Carl Percival Dr Grant Allen Dr James Whitehead Dr James Dorsey	The University of Manchester	£440,432
Professor Euan Nisbet	Dr David Lowry Dr Rebecca Fisher	RHUL	£467,992
Dr Ute Skiba	Dr Garry Hayman Dr Peter Levy Dr Jonathan Evans	CEH	£447,072
			<b>£2,204,268</b>

### Objectives

MAMM addresses directly Objective 2 (Quantifying processes leading to Arctic methane and carbon dioxide release) of the Arctic Research Programme and makes important contributions to Objectives 1 and 3 (Understanding and attributing the current rapid changes in the Arctic; reducing uncertainty in Arctic climate and associated regional biogeochemistry predictions). Our specific aims are: to improve quantitative knowledge of Arctic methane and other gases from various sources (wetlands, natural gas, clathrates [Arctic Research Programme Science Plan Objectives 2.4, 2.2, 2.1]), to determine magnitudes and spatial distributions, and to develop process understanding (e.g. dependence of flux on temperature) [2.4, 2.3]. Our programme will collect new datasets and knowledge about N<sub>2</sub>O, CO<sub>2</sub>, H<sub>2</sub>, CO, O<sub>2</sub>, SF<sub>6</sub> and other gases relevant to global change [2.2, 2.4].

We propose the following Measurement campaigns [21, 2.2]:

1. Determination of mixing ratios of methane and other gases across the Arctic by time and location, using in situ measurements, in conjunction with high resolution measurement on the BAe146.
2. Mapping delta<sup>13</sup>C(CH<sub>4</sub>) in the Arctic troposphere, with in situ sampling for delta<sup>13</sup>C(CH<sub>4</sub>) at selected sites on land (Zeppelin, Pallas, Alert). High altitude BAe146 flights will sample downward transport of Arctic stratosphere over Svalbard for delta<sup>13</sup>C(CH<sub>4</sub>) and D/H [CH<sub>3</sub>D], to assess the impact on the methane isotope budget from the polar vortex.
3. Flights that target particular sources at the landscape scale will allow calculation of fluxes of CH<sub>4</sub> and N<sub>2</sub>O based on a combination of ground based eddy covariance and chamber measurements; aircraft based measurements, and a landscape scale box approach flying up and downwind of a source region.
4. Use of the AIRE spectrometer on the BAe146 will determine methane column profiles and comparison with satellite to investigate methane 'hot spots'.
5. Assessment of the overall Arctic increment to the methane budget.

Data from the measurements will then be studied by Modelling projects:

1. Detailed back-trajectory analysis of the measurements, especially the isotopic data, to identify sources of methane by location, nature (e.g. gasfield, wetland, biomass fire, clathrate), and seasonality / event.
2. Improved understanding of methane fluxes will be incorporated into the JULES land surface model [3.2].
3. Regional source analysis will be performed using the NAME particle dispersion model.
4. Global implications, using chemistry/climate models to assess the role of the Arctic in recent changes in atmospheric methane and to perform projections for future change, including changes in atmospheric composition and radiative forcing [1.2; 3.3].

## Submarine Estimates of Arctic Turbulence Spectra (SEATS)

PI	Co-I	Institution	Total Costs
Dr John Allen	Dr Adrian Martin	NOC	£212,457

### Objectives

(1) SEATS primary objective is to provide insight into how the close links between fluid dynamic scales and biogeochemical cycles will change under conditions of an increasingly ice-free arctic. 'The overarching aim of the NERC Arctic programme is to improve capability to predict changes in the Arctic, particularly over timescales of months to decades'. The SEATS project will work with perhaps the only source of existing data which covers these timescales and significant spatial scales over the Arctic Ocean.

(2) SEATS will deliver on the following 2 NERC Arctic deliverable targets:

(a) improved parameterisation of Arctic processes;

the project will use a previously untapped submarine collected data resource to produce the first cross correlation spectra for the Arctic Ocean, against which model parameterisations can be tested.

(b) improved capabilities for predicting changes in the Arctic;

submarine data include several biogeochemical parameters and the project will significantly enhance our understanding of the relationship between biogeochemical and physical length scales in the Arctic ocean. More specifically, the data-set spans significant variation in sea-ice extent, and a period that has seen large changes to the seasonality of this extent, and thus these correlation spectra will be valuable for prediction of the consequences of future change in sea-ice cover.

(3) SEATS, will directly address Objectives 1.1, 1.4 and 1.7 of the NERC Arctic RP by seeking to differentiate between ice-covered waters and ice free waters using spectra of cross correlation coefficients for hydrographic data:

(RP 1.1): Understanding large scale variations in the energy and water budgets of the Arctic region.

(RP 1.4): Understanding the role of physical processes in recent Arctic change.

(RP 1.7): Identifying key processes driving Arctic marine biogeochemistry, biodiversity and carbon cycle change.

A difference in spectra in the variability of physical parameters for the two regions will imply a fundamental difference in pathways for energy exchange at the meso- and submeso-scale. Spectra in biogeochemical sensor data will show how these differences may impact on primary production, and through it the arctic marine ecosystem.

(4) SEATS will contribute to the NERC Arctic RP Objective 3.1 by establishing the first observation based cross correlation spectra for the Arctic ocean against which Arctic ocean models, coupled or otherwise, can be compared:

(RP 3.1): Identifying and quantifying key physical ocean, atmosphere and sea-ice processes for improving models for large scale Arctic prediction.

(5) To achieve the above over-arching objectives, the specific methodological objectives of SEATS are:

(a) To identify cross correlation scales in the arctic ocean, both for physical properties and biological patchiness.

(b) To investigate how relationships between physical and biological scales change between ice covered and ice-free regions.

(c) To investigate the length scales most affected by isolation from direct atmospheric forcing.

(d) To extract valuable scientific research and environmental information from a large extant data source with traditionally severely restricted access.