Introduction
The Arctic region is experiencing rapid climate change. The ability to predict the future state of Arctic sea ice on seasonal to inter-annual timescales would be of great value to a wide range of policymakers and stakeholders, with consequences for adaptation in the Arctic and beyond.

The Arctic Sea Routes (ASRs)
- The Northern Sea Route (NSR), illustrated in red, is the route currently open most regularly, this is expected to remain so in the future.
- The historic North West Passage (NWP), green, is more unreliable due to the influence from the islands of the Canadian Archipelago.
- The Transpolar Sea Route (TSR), blue, is the shortest route whereby a ship will attempt to set a course along a great circle route between the Ierling Strait and Atlantic.

Recent Trends
Figure 3. Observed September mean Arctic sea ice extent from the HadISST dataset.

Arctic sea ice observations
- The minimum sea ice areaintent occurs in September.
- The lowest recorded sea ice extent was in 2012.
- There appears to have been an increase in the rate of sea ice loss around the year 2000.
- The green bars show the relative magnitude of each years minimum extent (the extent if there was no background climate change).

Aim
- To both predict and quantify the predictability of the opening of the ASRs on monthly to inter-annual time scales.

Motivation
- Arctic sea ice is a significant factor in the global climate.
- The rapid retreat of Arctic sea ice is one of the most obvious signs of climate change.
- The current generation of Global Climate Models (GCMs) poorly capture the recent decline. There is large disparity between the seasonal sea ice predictions of different forecast groups.
- The sequence of extreme sea ice minima over recent years suggests a transition to a seasonally open Arctic Ocean.
- Future shipping activity may take advantage of this opportunity using the ASRs as a short-cut between Atlantic and Pacific basins cutting some journey times by 40%.
- How such reductions in sea ice will correspond to increased opportunities for marine traffic is not well quantified.

Project Details
Hierarchy
- This project is part of the wider Arctic Predictability and Prediction on Seasonal to Inter-annual Timescales (APPPOSITE) project.

Current Activity
Traffic increase on the NSR
- In 2012 46 vessels transited the route, compared to 34 in 2011 and only four in 2010.
- In Summer 2013 at least 500 permits to sail on the route have been granted, although not all vessels will be sailing the whole route between Europe and Asia.

Methodology
- Future access to the Arctic Ocean was evaluated using the UK Met Office GCM HadGEM2-ES which is a fully coupled Earth System Model used in the IPCC AR5.
- The prospects of two vessel classes with differing ice thickness restrictions were evaluated. The Open Water class of vessel was selected for study as it constitutes the vast majority of the worlds shipping fleet. The Polar Class 6 vessel was chosen as the ice-breaker representative due to potential accessibility gains from operating in medium first year ice.
- The ice thickness restrictions of each vessel class were used to determine the region of the Arctic that is accessible to that class. This was applied to every month of the year for all four ensemble members to give the frequency of accessibility for each decade (Figure 5).

Future Work
- The next phase of this project will examine the recent transits on the ASRs to establish the present constraints and trends, with a view to applying this knowledge to future projections of Arctic sea ice.

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Decadal Projections
Figure 5. Decadal frequency of vessel accessibility in HadGEM2-ES for the Representative Concentration Pathway of 4.5 RCP4.5 (medium mitigation emissions scenarios). Polar Class 6 vessels can navigate through ice up to 1.2 m thick. Open Water vessels can navigate through ice up to 0.15 m thick.

Figure 2. The "Yamal", one of the Russian nuclear-powered icebreakers.