Has a new pathway to the Atlantic been opened?

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Abstract

In May 1999, during a routine continuous plankton recorder survey of the Atlantic Ocean, large numbers of a diatom species were found drifting in the ocean currents. Ordinarily, this would not be an unusual observation for a plankton survey, except that the species, *Neodenticula seminae*, was in the wrong ocean. Rather than thriving in its northern Pacific Ocean home, *N. seminae* was instead blanketing the north-west Atlantic for the first time in 800,000 years (Figure 1).

In Reid *et al.* (2007) it was noted that this event coincided with increased flows of Pacific water into the north-west Atlantic due to the, then-unusual, occurrence of ice-free water to the north of Canada. The authors hypothesised that the diatom had been carried in a pulse of Pacific water from late-1998 or early-1999 into the Atlantic Ocean via the Canadian Arctic Archipelago or via the Fram Strait. Has such a fast transport of Pacific waters become possible under the reduced sea-ice conditions that are typical of the last two decades?

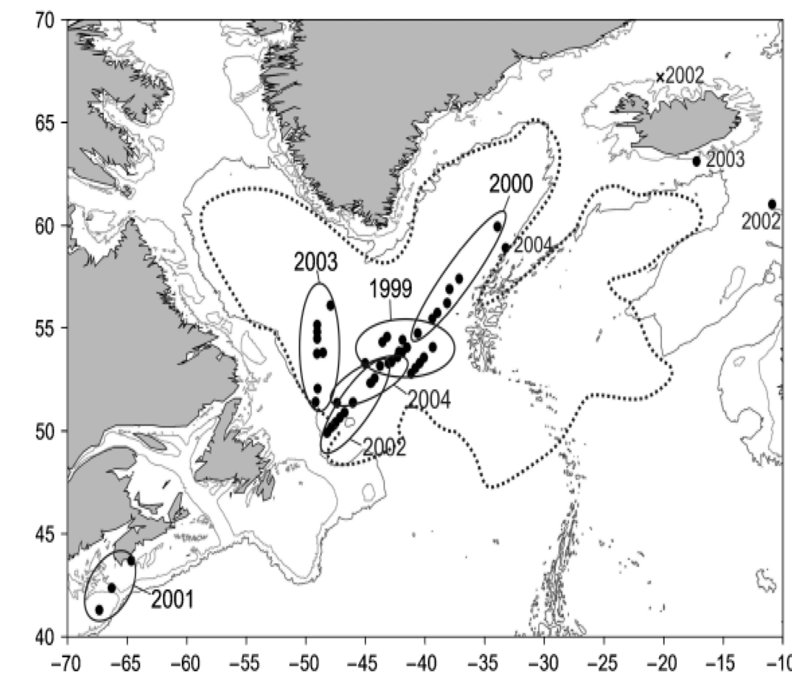


Figure 1

Method

Using velocity data from the 1/12° resolution NEMO ocean model alongside Ariane particle tracking software, 1000 particles were released in the Bering Strait and their trajectories tracked across the Arctic for a 10 year period. This experiment was repeated for releases in every summer from 1980 to 2000. The trajectories were then analysed to investigate the time-scales and transit routes taken to reach the North Atlantic.

As Reid *et al.* hypothesised that changing ice cover facilitated the diatom's transit, we also looked at how Arctic sea-ice concentration varied across the period of interest. The film strip below shows annual minimum ice cover data from our model (left) compared to the Met Office HadISST1 ice data (right).

Trajectory Routes

Trajectories of Lagrangian particles released in the Bering Strait in July 1998. Color denotes the age (in years) of the trajectories. The quickest particles take 3-4 years to reach the Atlantic. Note the quick route through the Canadian Archipelago via the coast of Alaska.

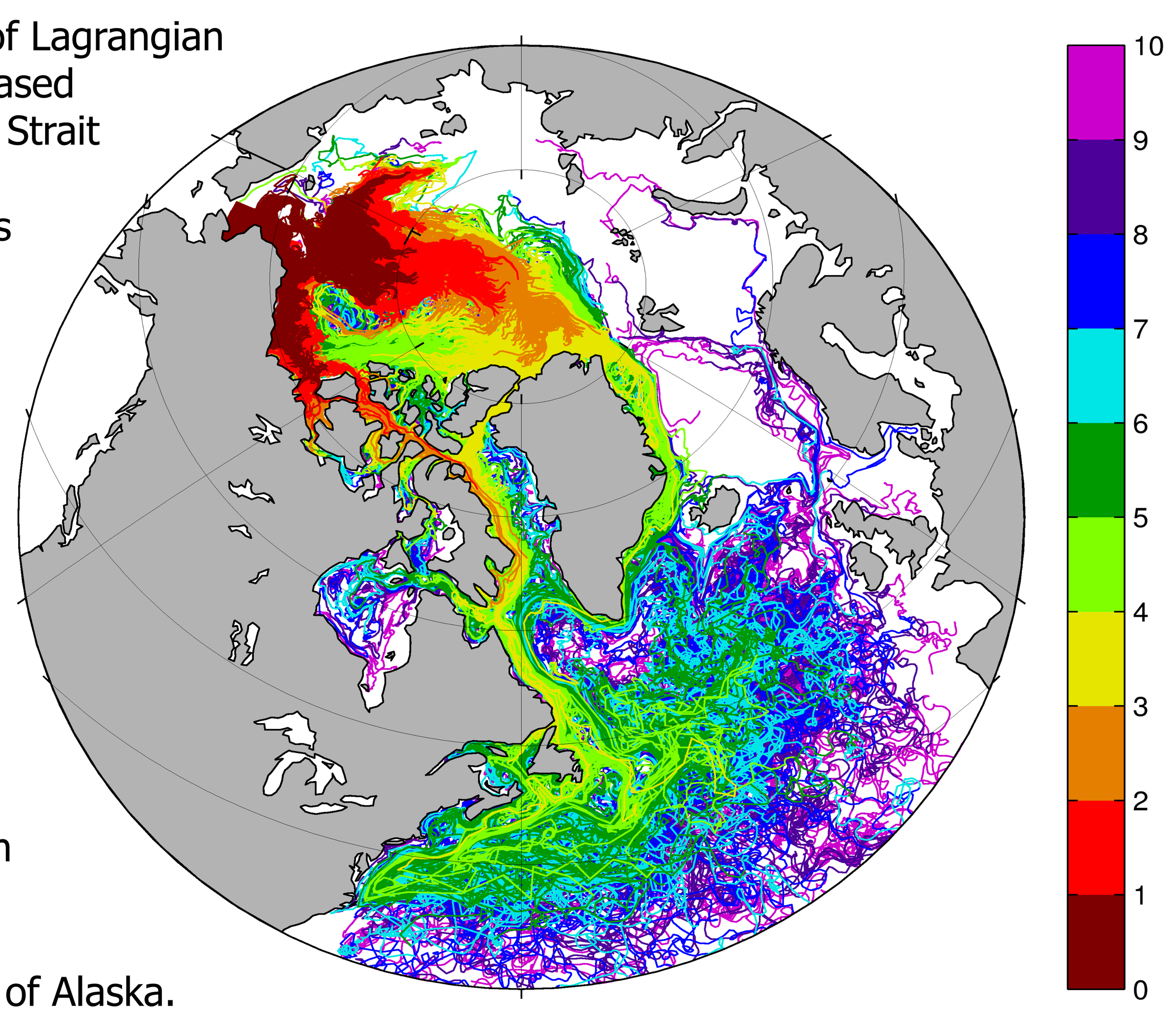
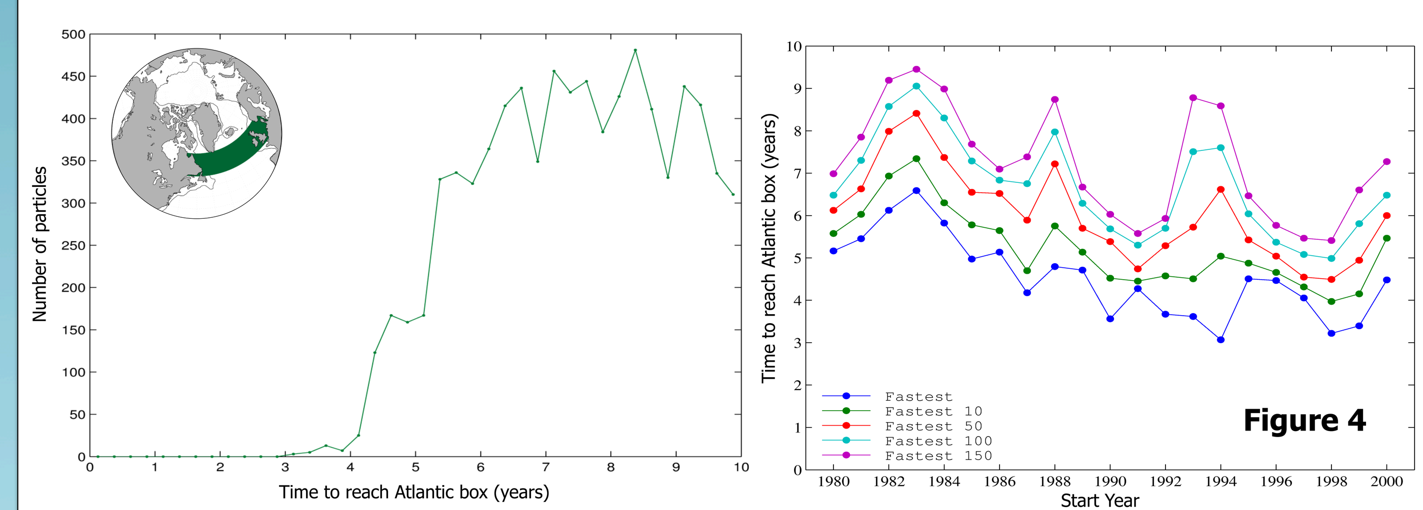


Figure 2

Time taken to reach Atlantic



Integrating over all experiments, Figure 3 shows the distribution of times taken to reach the Atlantic (green box on inset map). Note that all trajectories take at least 3 years to reach the Atlantic.

Figure 4 shows the time taken by the fastest particle from each annual release, and then the average time taken by the fastest 10, 50, 100 and 150 particles. There is significant inter-annual variability, and although particles released in 1998 are quick compared to other years, they are not quick enough to satisfy Reid's hypothesis. We also note that the years where trajectories take less time to finish coincide with the years that have a lot of trajectories taking the Canadian Archipelago shortcut.

'Shortcut' Route?

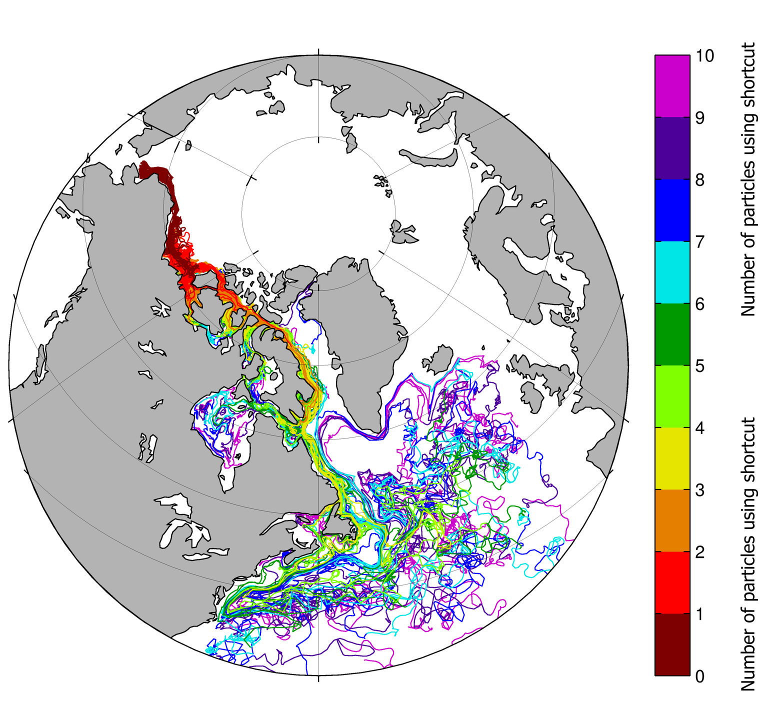
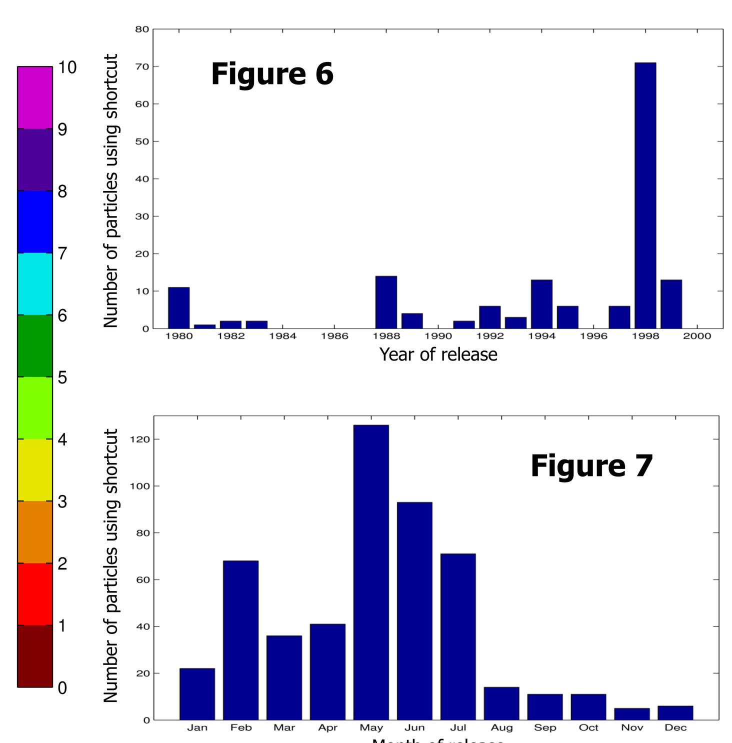


Figure 5



As figure 2 shows, the very fastest trajectories take a route through the Canadian Archipelago via the coast of Alaska. By isolating these trajectories (figure 5) the number of particles taking this route can be compared between years (figure 6). Significantly more trajectories follow this route in 1998 than in any other year, warranting further investigation into 1998 especially as it was the year that *N. seminae* was proposed to have started its journey.

The experiment was repeated with particles released in every month of 1998. Many particles take this route throughout 1998 (figure 7), especially in the early summer months. This corresponds with unusually ice-free conditions north of Alaska in the summer of 1998 (see film strip far left).

1998 – Further Analysis

As already described, to further examine year 1998, 1000 particles were released every month from the Bering Strait. Figure 8 shows the fastest times, per month, that a particle reached the Atlantic. As with Figure 4, the graph includes the fastest particle, and then also the average time taken by the fastest 10, 50, 100 and 150 particles for each release.

While Figure 8 shows some of the quickest transit times across all of the experiments, the fastest particles still take over 2 years to finish – meaning that they would arrive in the Atlantic too late to explain the appearance of *N. seminae* in May 1999.

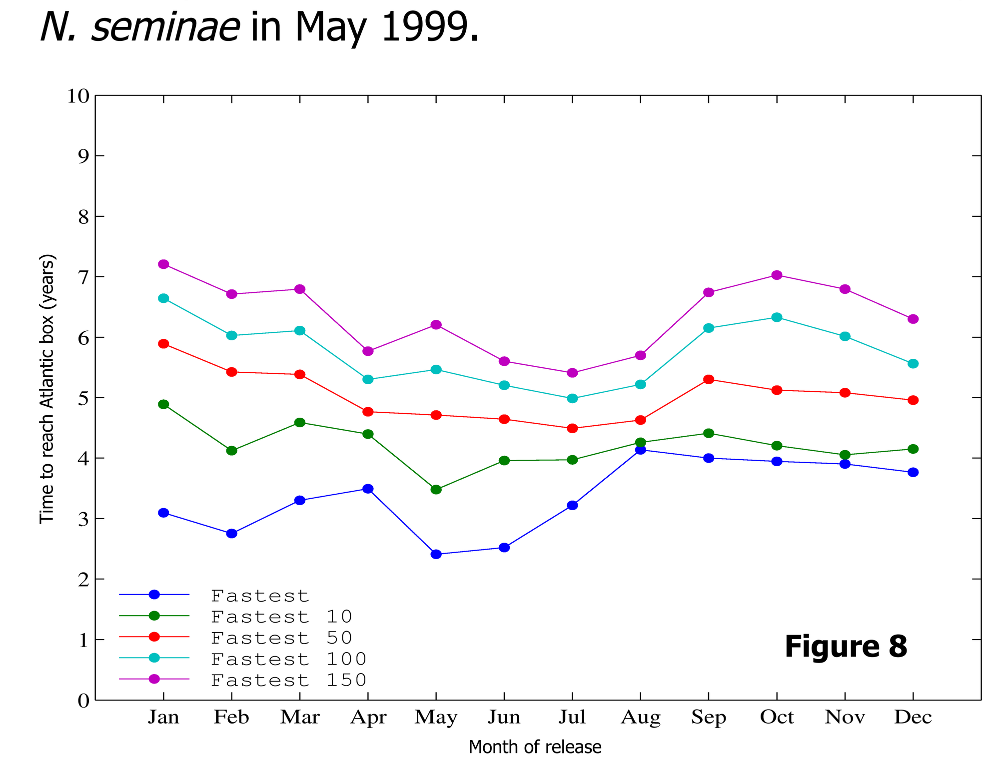


Figure 8

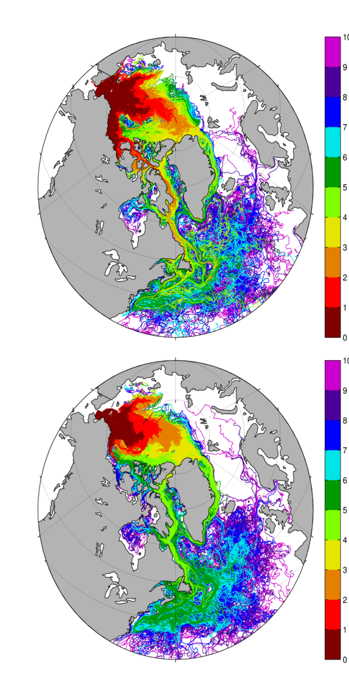
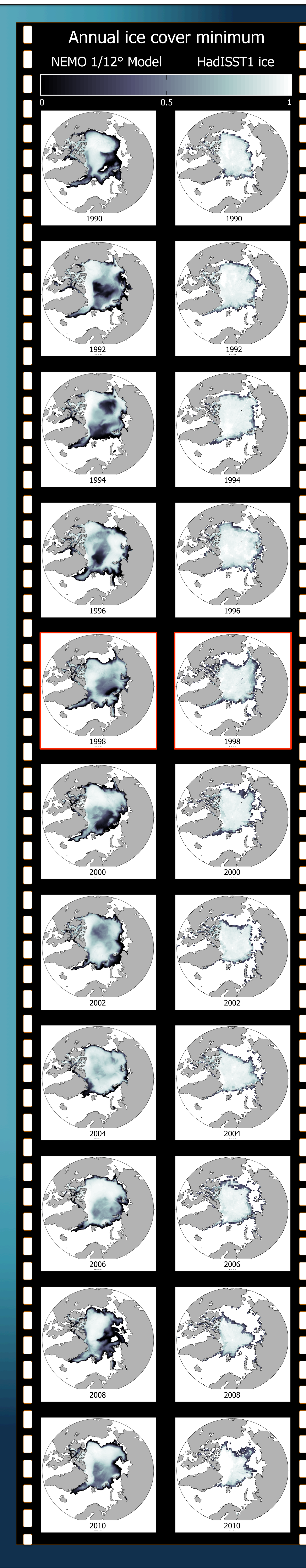


Figure 9

Figure 9 shows trajectories from May 1998 (top) and July 1996 (bottom) releases. These two are shown to demonstrate the difference that the 'shortcut' route makes in 1998.



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Conclusions

- Particles travelling from the Bering Straits can reach the North Atlantic via both the Canadian Archipelago and Fram Strait
- The fastest simulated transit time was 2.4 years (starting in 1998), along the coast of Alaska and via the Canadian Archipelago
- Examining inter-annual variability suggests that this route is not consistently available
- 1998 is remarkable as having the highest number of particles entering the Atlantic via the Canadian Archipelago 'shortcut'
- However the fastest particle transit times are considerably longer than the sub-annual time-scale hypothesised by Reid *et al.*
- This suggests that diatoms crossing the Arctic do so over several years and may need good growing conditions during transit in order to survive and reach the Atlantic
- Future work will examine the conditions (ice, temperature, light) along the trajectories

References

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