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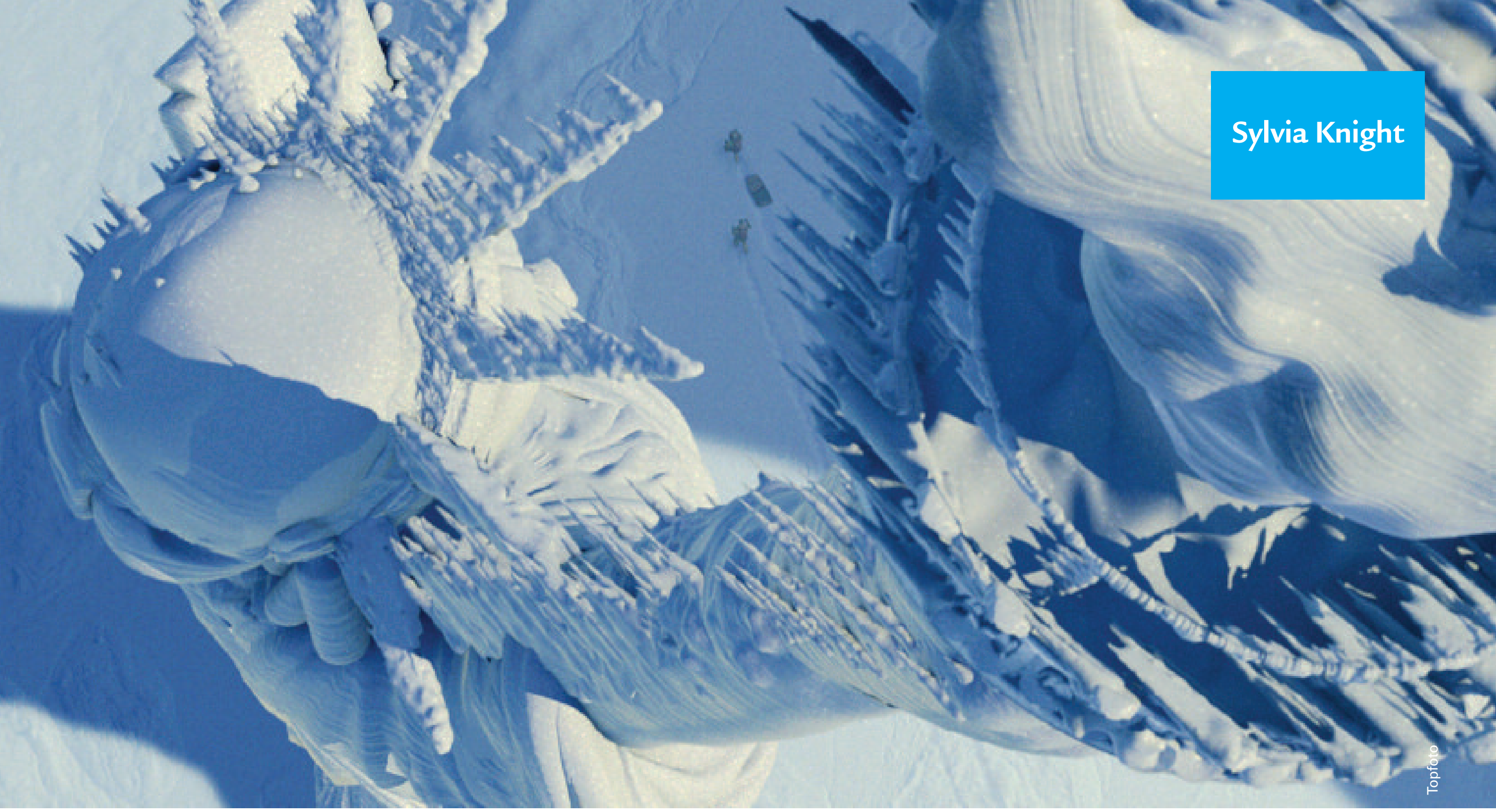

Climate modelling

The disaster film The Day After Tomorrow, *released in May 2004, proved to be hugely popular — it was at the top of the box office list in many countries, and took £69.8 million in the first 10 days of its release. But is the sudden onset of an ice age a scientific likelihood, Hollywood exaggeration or complete and utter rubbish?*

- **Find out how icicles form. Could they ever form in the way they are portrayed in the above scene from *The Day After Tomorrow*?**

GCSE key words
Heat transfer
Convection
Radiation

In the film *The Day After Tomorrow* changes in the circulation of the Atlantic, brought on by man-made climate change, lead to the rapid start of an ice age.

What is the thermohaline circulation?

Ocean waters circulate because surface waters are heated in the tropics and cooled at the poles (see Figure 1). Cold water is more dense than warm water, so polar water sinks, and warmer water flows in to take its place. In its simplest form, the circulation of the oceans therefore consists of water sinking at the poles and rising in the tropics. Surface and deep currents flow to complete the circulation.

The Gulf Stream is a warm surface current. It is caused partly by this convection, and partly by the winds blowing across the ocean surface. It flows from the coast of North America, keeping northwestern Europe a few degrees warmer than it would otherwise be. As the current flows across the Atlantic, water evaporates from it. The process of evaporation leaves the Gulf Stream water comparatively salty (see Box 1).

In the Arctic, the surface water radiates heat to the atmosphere. This cools the water down, and sea ice forms — again leaving the surface water colder and saltier than the surrounding water. When the Gulf Stream meets the Arctic waters in the Greenland Sea,

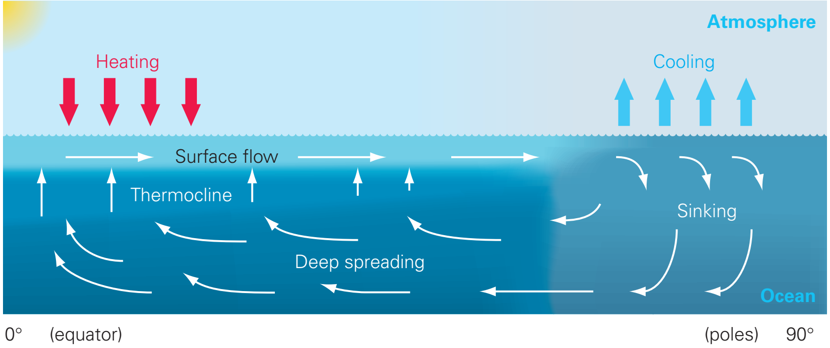

Figure 1 *Simplified model of the thermohaline circulation in the oceans. The Sun's radiation heats the surface ocean in the tropics. At the poles, the surface ocean loses radiation to the atmosphere, cools and sinks. This partly drives the circulation of the oceans*

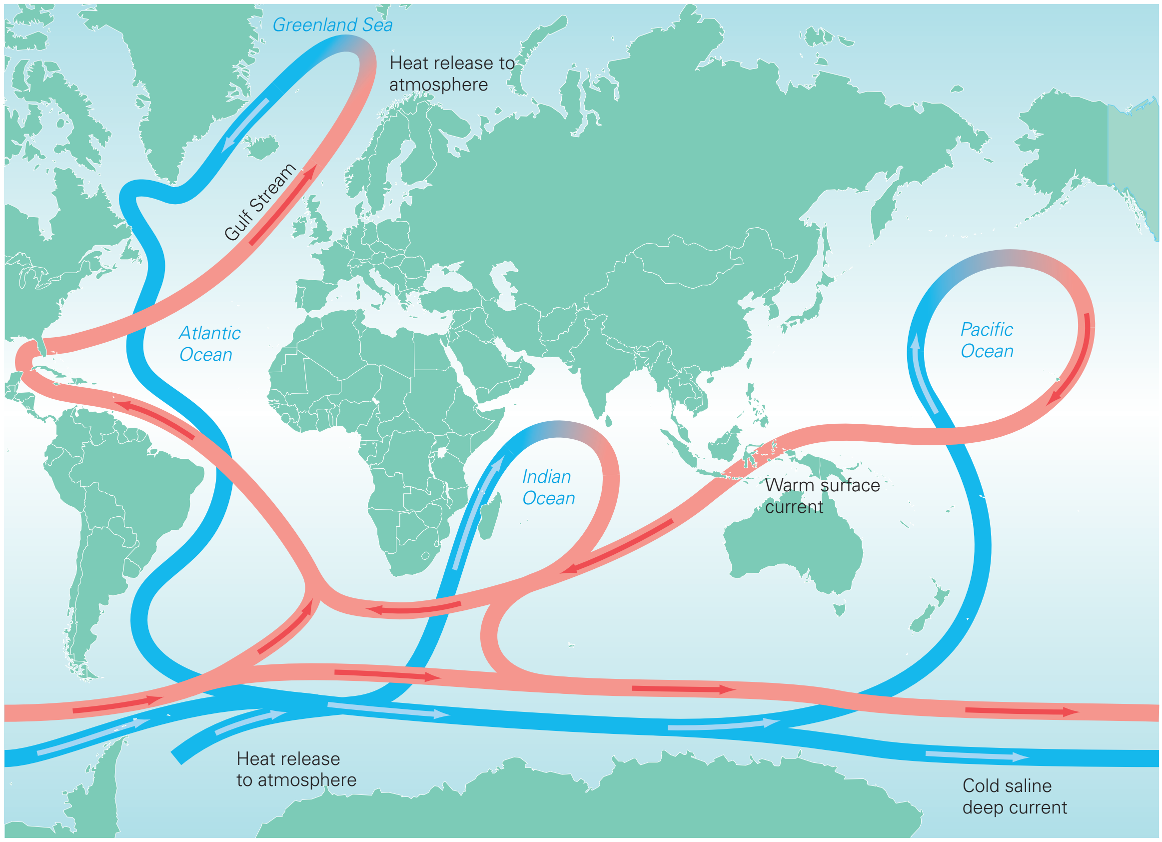

Figure 2 *Simplified model of the global oceanic circulation. The red arrows represent the transport of warm surface water, and the blue arrows represent the transport of cold water below the thermocline*

An individual water molecule takes about 1000 years to do a complete circuit of the oceans.

Box 1 Evaporation

Within a liquid some molecules have more energy than others, and may have sufficient energy to escape from the surface of the liquid as vapour. This process is called **evaporation**. If the liquid is warmer, more molecules will have enough energy to escape and so the liquid evaporates more rapidly. Evaporation is also assisted by windy conditions which help to remove the vapour particles from above the liquid so that more can escape. If the liquid is a solution, the solvent (e.g. water) can evaporate leaving the solute (e.g. salt) behind.

Box 2 The greenhouse effect

Some gases in the Earth's atmosphere (e.g. carbon dioxide, water vapour) act as an insulating blanket for the Earth — they keep the Earth's surface and the lower atmosphere warmer than it would otherwise be. If there were no greenhouse gases, the surface of the Earth would be about 33 °C colder than it is now (so Britain would be about the temperature of the inside of a freezer). Most scientists now think that the gradual increase in greenhouse gases over the past 200 years is having a noticeable effect on the Earth's climate.

The North Pole is in the Arctic Ocean, which is frozen over, though the ice is never very thick. Sea ice also develops around Antarctica.

the combination is so much more dense than the water around it that these salty waters sink and flow towards the equator.

The full, large-scale, three-dimensional circulation pattern of the ocean is called the **thermohaline circulation**, because it is driven by differences in both temperature and salt concentrations in the water (see Figure 2). As yet, scientists know relatively little about it.

● The word *thermohaline* is constructed from two parts: *thermo* means *related to heat*, and *haline* means *related to salt*. What other words can you think of that are related to either *thermo* or *haline*?

How could the circulation 'switch off'?

Floating ice shelves fringe much of the Antarctic ice sheet which is 3000 m thick in places. These ice shelves form where glaciers, flowing from the main ice sheet through gaps in coastal mountains, reach the sea. Huge tabular icebergs regularly break off as part of the normal life cycle of an ice shelf.

However, around 8000 km^2 of ice has been lost since the 1950s, and this may well be linked to the changing climate — in the same period, meteorological stations in Antarctica measured an increase in the air temperature of about 2 °C (see Box 2). The final stages of the loss of Larsen Ice Shelf A in 1995 were particularly spectacular: in 50 days an area of ice shelf the size of Surrey broke up into thousands of football-pitch-sized icebergs and floated away. If the warming continues more ice shelves may be threatened.

When ice shelves melt, they release a huge amount of fresh water into the oceans. This may be enough to slow down the thermohaline circulation. There is some evidence that at the end of the last ice age, when the glaciers covering North America melted, the thermohaline circulation may have switched off altogether for a while. However, because the Gulf Stream is

Left: *Tabular icebergs that have broken away from ice shelves in Antarctica. The vertical face can be 15 m high*

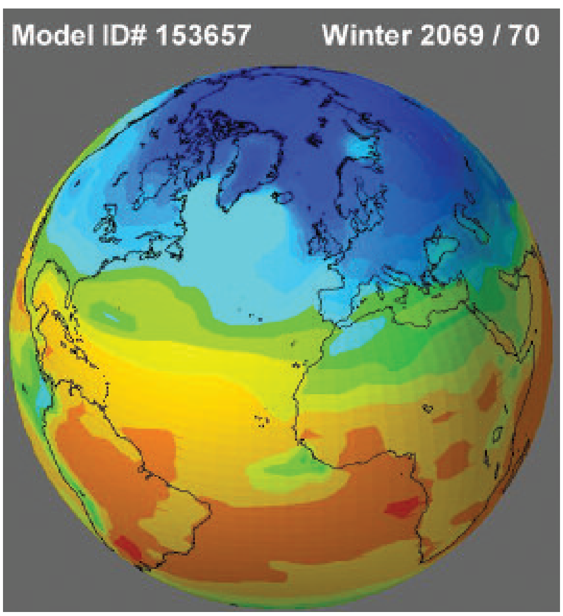

Figure 3 *An example of* **climate*prediction*.net** *results. This model shows a very cold North Atlantic*

driven by both the thermohaline circulation and by the wind, it can never be switched off entirely.

What is a climate model?

In *The Day After Tomorrow*, scientists use computer models to try to predict how the atmosphere will respond to the slowdown of the Gulf Stream. This is the same approach that scientists all over the world are taking — together with using satellites and ocean buoys to try to understand how the oceans work.

Box 3 Climate*prediction*.net website

To find out more about climate*prediction*.net, see the first results, or even join in, go to http://www.climateprediction.net

A climate model consists of sets of equations which represent how scientists think the atmosphere and oceans behave. The conservation of energy, salt, water and momentum are taken into account, as well as factors like how clouds form. These equations have to be solved at many places on the Earth's surface, in the depths of the oceans and the heights of the atmosphere. If the models are only run a few days into the future, scientists can use the data produced as a weather forecast. They have to be run decades into the future to produce a climate forecast.

Are scientists trying to model *The Day After Tomorrow*?

In the film, the scientists struggle to get enough super-computer time to predict how the weather will develop. The **climate*prediction*.net project**, based at Oxford University, is taking an alternative approach (see Box 3). Rather than using super-computers, the project is asking people all over the world to run a climate model on their home, school or work PCs. A new experiment, inspired by *The Day After Tomorrow*, investigates how the atmosphere reacts to both a doubling of the carbon dioxide concentration in the atmosphere and a slowdown of the thermohaline circulation. While the model runs on your computer, you can watch the climate patterns develop (see Figure 3).

The results of the experiment should show how the atmosphere is likely to respond if the thermohaline circulation does slow down. Will the effects counteract global warming? Will the atmosphere change in a way which will tend to increase the thermohaline circulation again? Or are we all doomed to a *Day After Tomorrow* type ice age?

Glaciers in the northern hemisphere do calve off icebergs — the *Titanic* hit one — but on nothing like the scale and extent of Antarctic tabular icebergs.

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