**Remember this movie, from 2004, called ‘The Day After Tomorrow’?**

**It was a great action movie starring Dennis Quaid and a very young Jake Gyllenhaal, which in the best traditions of Hollywood blockbusters provided 2 hours of fabulous entertainment but bore very little resemblance to real world events or possibilities.**

**It portrayed the Atlantic Ocean’s circulatory system, known as AMOC, collapsing within days, resulting in an instant ice age across most of the northern hemisphere.**

**The films overly exaggerated dramatic depiction earnt it the less than complimentary nickname of The Towering Inferno of the climate change era.**

**But the basic premise of the storyline was based, albeit very loosely, on real scientific observations of changes that have been happening in our oceans since the middle of the last century.**

**Changes that look like they may be slowing down the global currents that distribute heat and energy around the entire planet.**

**So how close to the mark did Hollywood get? Is this circulatory system at any real risk of grinding to a halt? And if it does, will the Northern Hemisphere really be plunged into a new ice age?**

**Hello and welcome to Just Have a Think**

**The Gulf Stream here, is an extraordinary force of nature. As it passes the southern tip of Florida, its waters are very warm indeed, averaging more than 24 degrees Celsius. They’re also very wide: about a hundred kilometres or so. And very deep: up to 1000 metres or more than 3000 feet.**

**And all that water is travelling at something like 6 miles an hour.**

**That movement transports about four billion cubic feet of water per second, which for us metric types is about 113 million cubic metres.**

**Now to most people I imagine both of those sound like very large…and completely abstract numbers.**

**So, let’s try this…**

**113 million cubic metres of water per second is more than the amount of water carried by all of the rivers in the world combined.**

**So, you know, it’s pretty epic.**

**But as mind bogglingly immense as that is, the Gulf Stream forms only part of a wider system called the Atlantic Meridional Overturning Circulation or AMOC.**

**And it was an abruptly collapsing AMOC that formed the basis of the plot in the Day After Tomorrow.**

**Meridional means southerly, and overturning refers to different bodies of water rising and sinking above and below each other depending mainly on their temperature and salinity.**

**Cold dense water travels southwards in a very deep ocean layer all the way from the North Atlantic right down to Antarctica and across to the Indian and Pacific Oceans until a phenomenon known as upwelling brings the deep water back into the warm top layer of the oceans where it travels northwards again to re-join the Gulf Stream.**

**The result is a completely interlinked and interdependent system called the Thermohaline Circulation or Global Ocean Conveyor Belt. We looked at the whole system in detail last year and you can click up there somewhere if you want to jump back to that program.**

**Essentially though the process ensures the world’s oceans are continually mixed, and heat and energy are distributed around the earth.**

**And just to give you an idea of the staggering scale of the system, a full circuit can take up to a thousand years to complete.**

**Anyway, back up here at about North Carolina, the Gulf Stream takes a right turn and starts crossing the Atlantic. As it moves North East it loses heat as a result of evaporation of the very warm surface water caused by the ocean winds.**

**That heat energy transferred into the atmosphere is enough to make a difference to the local climate. Temperatures in my part of the world are on average about ten degrees Celsius warmer than areas at the same latitudes over in North America, and many studies have attributed that differential in large part to the bonus heat our atmosphere receives over here from the Gulf Stream.**

**But evaporation only removes water from the ocean flow. It leaves behind the salt. And salt molecules are small enough to get trapped in the gaps between water molecules. All those filled up gaps create a fuller, or denser structure.**

**So now we’ve got very dense cold salty water combining with the much fresher waters towards the arctic circle. As the two bodies of water meet the denser water inevitably sinks, as Bill Nye is so ably demonstrating for us here.**

**Those sinking waters get caught up in the very deep currents of the AMOC and off they go on their millennial trek around the globe.**

**All that clever stuff was mostly worked out by this guy. He’s called Henry Stommel and in 1961, while he was at Harvard University, he published this research paper outlining the principles that have since become the foundation of quite a lot of modern oceanography.**

**In April 2018, a new research paper was published by Levke Caesar and Stefan Rahmstorf from the Potsdam Institute for Climate Impact Research in Germany.**

**They used a very high definition computer modelling program called CM2.6 to analyse sea surface temperatures around the entire circulatory system.**

**This simulation of the model outlines the city of New York to give us an idea of the size of each square, or pixel on the model’s grid. That high level of definition makes this one of the most sensitive and accurate modelling programs available.**

**The research team set up two simulations in the CM2.6 modeller. Firstly a control simulation showing what happens over 80 years if atmospheric CO2 concentrations were fixed at the level they were at in 1860, and a second simulation where CO2 levels were increased by 1% each year for 70 years, until they doubled, and then kept at that level for another 10 years.**

**Areas turning red indicate a surface temperature increase above the control model and areas turning blue indicate a decrease below the control**

**The CO2 doubling simulation predicted a very pronounced cooling of the area of ocean just below Greenland and a noticeable warming in the Gulf Stream close to the eastern coastline of the United States, strongly indicating a big slow-down in heat being transferred across the Atlantic.**

**And then they compared that CO2 simulation with actual real-world observations of changes in seas surface temperatures between 1870 and 2016.**

 **And it looked like this.**

**So, what’s going on?**

**Well, most people already know that the increased levels of atmospheric CO2 are causing the warming of our planet, but the science bods tell us that the warming is happening at least twice as rapidly up in the arctic.**

**That means accelerated melting of the Greenland Ice Sheet and a rapidly decreasing volume of sea ice sitting in the Arctic Ocean.**

**All that melting is releasing huge quantities of pure water into the salty ocean, which has the effect of freshening the water. Fresher water is less dense than salty water so less of it sinks. And that SLOWS DOWN the ENGINE of the great global Thermohaline Circulation.**

**The Potsdam team showed a decline in the AMOC of about 15% since the mid-twentieth century. In fact, in recent years it looks like the AMOC has reached its lowest point since records began back in 1880.**

**Those findings tallied with other research in THIS paper, ALSO published in April 2018, that found the AMOC was the weakest it’s been for around 1600 years.**

**The Special Report published by The Intergovernmental Panel on Climate Change in October 2018 reviewed all the available scientific evidence and concluded that the AMOC was indeed very likely to weaken more over the course of this century.**

**The report stated**

 **“Such a weakening would have a cooling effect on climate around the North Atlantic region, as the northward heat supply is slowed down. This effect is included in the climate projections, but the direct warming effect from rising concentrations of greenhouse gases is stronger, so the net result is still warming over land regions.”**

**That cold blob under Greenland is indeed causing cooler North Atlantic weather, but meteorologists have found that it also tends to cause an air-pressure distribution that channels warm air northwards over Europe, and that’s making European summertime heatwaves more likely and increasing levels of storminess across the continent.**

**Back across the other side of the pond, the slowdown of the Gulf Stream means above average sea level rises on the eastern seaboard and that extra energy from the ocean surface is getting scooped up into the local atmosphere causing more powerful hurricanes across the southern states.**

**Even further south, on the warm water return leg of the global circulation, the slowing conveyor belt means greater heat retention along the western side of Africa bringing the likelihood of worsening droughts across the Sahel region.**

**As long as we continue to pump greenhouse gases into our atmosphere, all of those climatic consequences will most likely continue to worsen as the AMOC continues to weaken.**

**Eventually, if our emission levels don’t change, the system could slow down so much that its ability to maintain momentum will grind to a halt and we’ll reach a catastrophic tipping point.**

**Thankfully, all the existing scientific evidence suggests we’re not approaching that point anytime soon.**

**But that doesn’t mean there’s any room for complacency. Arctic sea ice volumes have been reducing very dramatically in recent years. The lowest extent on record occurred in 2012, a year that was unusually warm as a result of a very strong El Nino event.**

**Most of the years since then have hovered around record low levels.**

**And then we come to 2020.**

**Here’s what the plot looked like at the start of the year. The red dotted line is the 2012 record low year and the dark grey line is the 1981 to 2010 median.**

**Our 2020 blue line starts off fairly predictably, but right around the end of February it takes a very noticeable dip downward, well below the dotted red line of the record 2012 year.**

**That drop does of course coincide with the start of the global shutdown and a massive drop in atmospheric levels of reflective sulphate and nitrate particles.**

**We looked at the debate around global dimming a couple of weeks ago, and some commentators have pointed to this dip in the graph line as evidence of global brightening causing abrupt global warming.**

**It remains to be seen whether that downward movement is a blip or a true reflection of a significant increase in arctic temperatures, but if that trendline continues all the way to the annual sea ice minimum in September then we may well be heading for a new record low that would most likely exert a noticeable influence on AMOC slowdown.**

**This article published in February 2020 at Carbon Brief by Dr Richard Wood and Dr Laura Jackson from the UK Met Office Hadley Centre, includes this simple graph taken from Henry Stommel’s original 1961 research papers.**

**The units of measurement by the way, are apparently called Sverdrups.**

**‘Cos you know, why not!**

**One Sverdrup denotes one million cubic metres of water transported per second.**

**Stommel had identified that if enough fresh water from ice melt got into the circulation then eventually a tipping point would be reached which would cause a very rapid collapse of the AMOC.**

**Doctors Wood and Jackson point out that under scenarios of**[**continued high greenhouse gas concentrations**](https://www.carbonbrief.org/explainer-the-high-emissions-rcp8-5-global-warming-scenario)**, a number of models project an**[**effective AMOC shutdown by 2300**](https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL070457)**.**

**And when the whole system shuts down, the models do indeed suggest a widespread cooling across the Northern Hemisphere that could outweigh the effects of global warming.**

**Not that anyone should take any comfort from that either. Other consequences are likely to include major shifts in rainfall patterns causing huge storms over Europe and a sea level rise of half a metre around the North Atlantic basin, in many cases actually worsening the already terrible effects of our already rapidly changing climate.**

**The entire world would experience major socioeconomic consequences with catastrophic impacts on agriculture, wildlife, transport, energy demand and coastal infrastructure resulting in the likely loss of hundreds of millions of lives.**

**Unsurprisingly a great deal of time and money is being spent researching ways to develop early warning monitoring systems at various pints around the AMOC circulation. Scientists hope that by tracking medium term variations in salinity levels in subtropical and subpolar waters they might be able to forewarn an AMOC collapse decades in advance.**

**Of course, the easiest and most blindingly obvious solution to this future calamity is to rapidly reduce our use of fossil fuels in transport and industry, embrace renewable energy and regenerate our land and forests back to the sustainable levels that existed in pre-industrial times.**

 **I wonder if we will?**

**No doubt you’ve got your views on the subject, so get scribbling down there in the comments section and I’ll be keen to read your feedback.**

**That’s it for this week though.**

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**As always, thanks very much for watching,**

**Have a great week and remember to just have a think**

**See you next week.**