

# OCEANS AND CLIMATE CHANGE

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## Oceans moderate climate change

71% of the world's surface is covered by oceans

Absorb 1/3 excess greenhouse gas emissions from the atmosphere

Capture 90% excess heat from the atmosphere

## But the oceans are warming

Ocean temperature increased by 0.9°C since 1970

Arctic Ice Disintegration, Antarctic Melting, Sea Level Rise &

Ocean Acidification

## Ocean food production

Warmer oceans support less fish stock (oxygen depletion)

Overfishing using 'factory ships'

Sustainable sea farming needed

## Sea Mining of minerals

Seabed contains significant deposits of cobalt, manganese, nickel, copper, and rare earth elements

Deep sea mining produces ocean pollution through disturbance of the sea floor

Growing international support for an embargo & regulation of sea mining

## Energy from the oceans

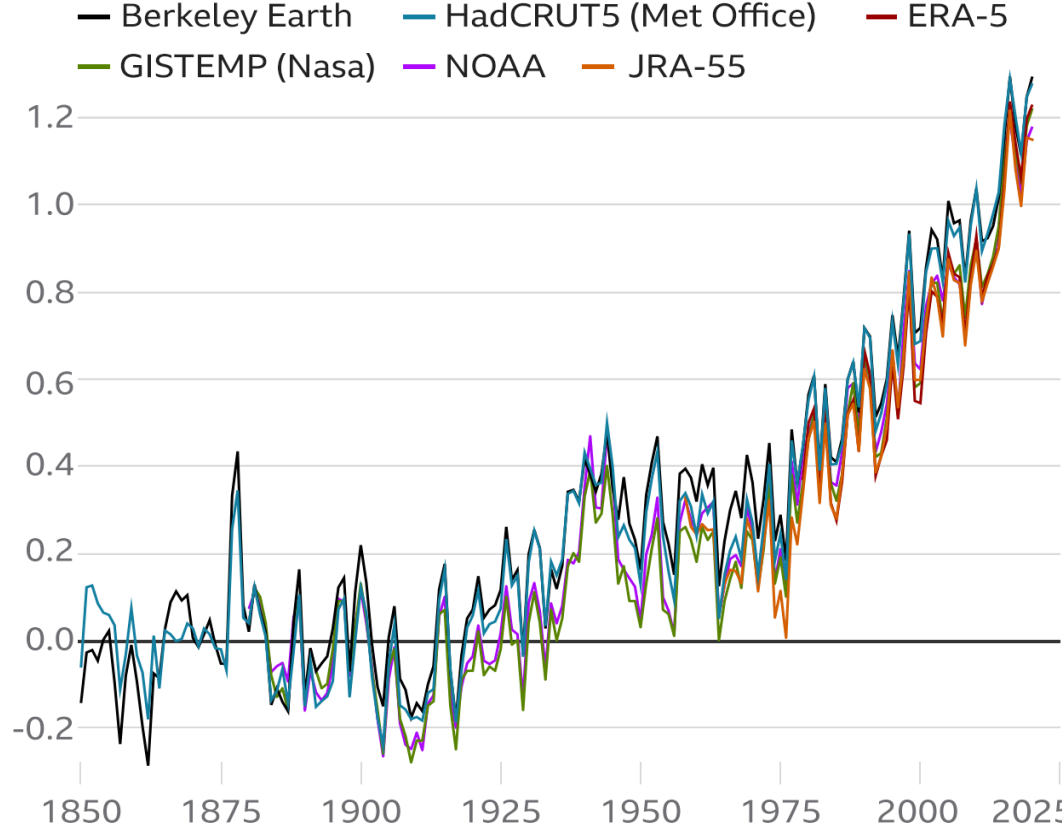
Energy from the tides

Tidal streaming with incremental cost growth

# AVERAGE GLOBAL AIR TEMPERATURE RISE

## Temperature rise since 1850

Global mean temperature change from pre-industrial levels, °C



Industrialisation of Developing countries

Source: Met Office

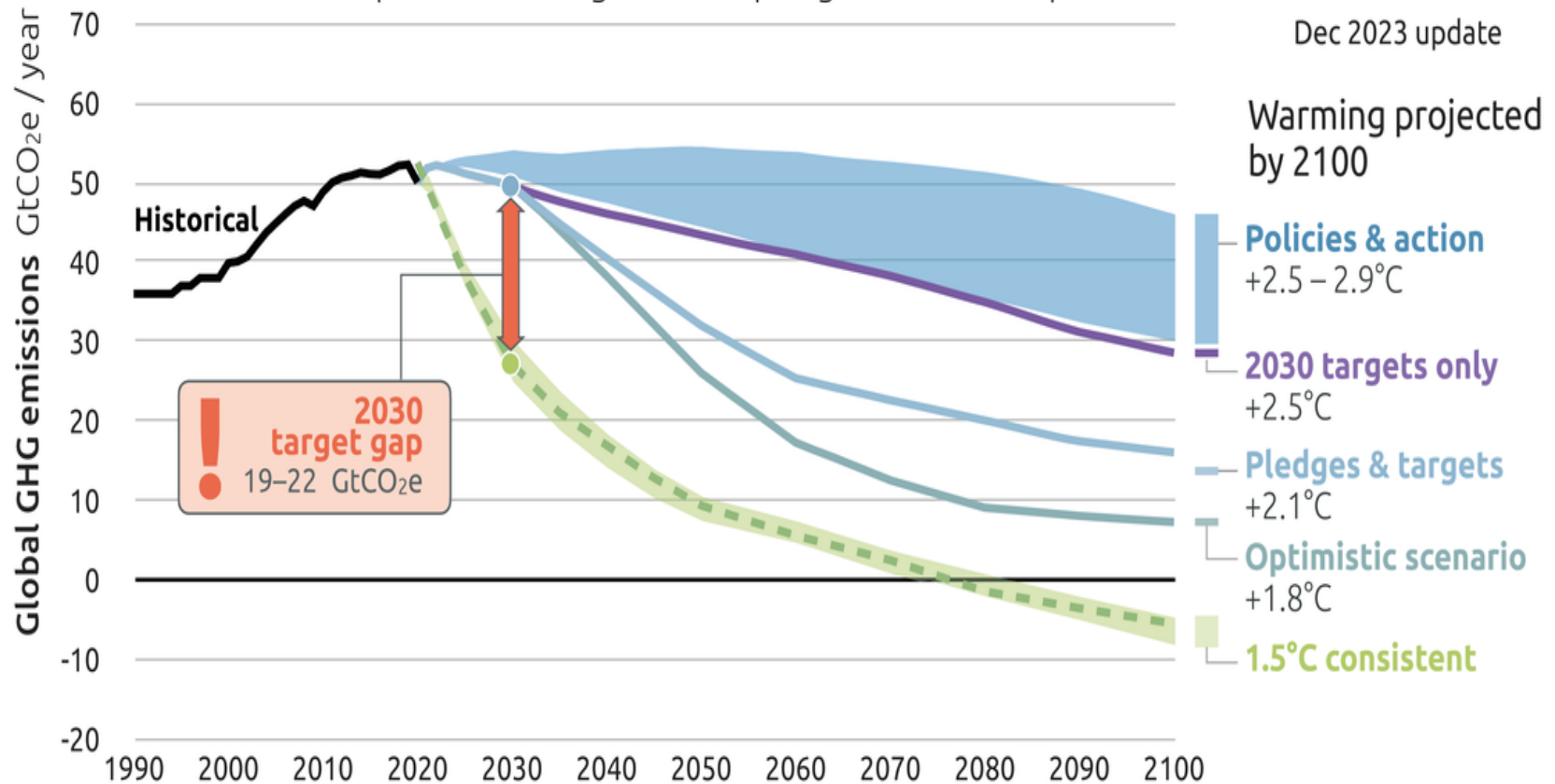
BBC

# 2100 WARMING PROJECTIONS

Emissions and expected warming based on pledges and current policies



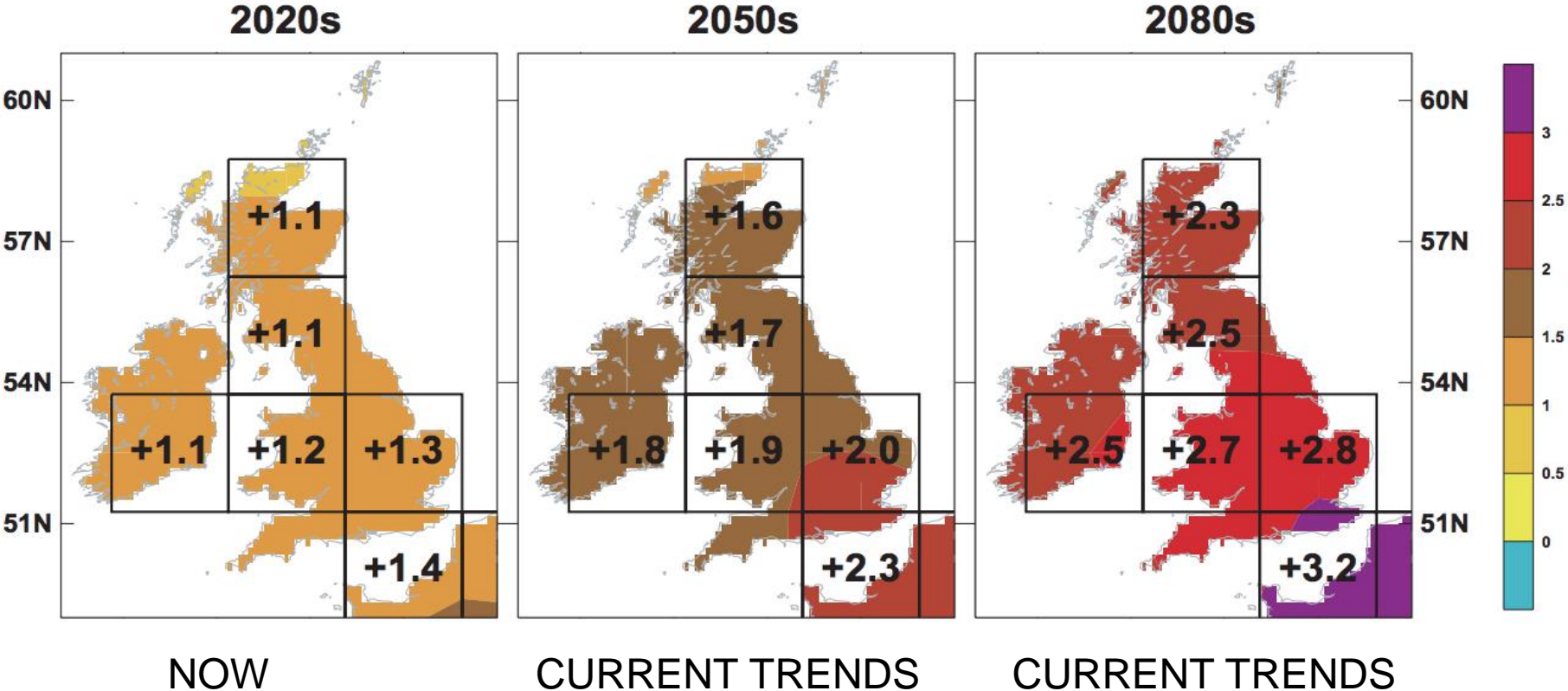
Dec 2023 update



+1.5C requires all countries to cut emissions & achieve zero emissions by 2050

Current policies across all countries predict 2.5-2.9°C warming by 2100

# UK PREDICTED TEMPERATURE RISE



# OCEAN WARMING

Oceans are a climate regulator.

They soak up 90% excess heat, absorb 30% excess CO<sub>2</sub> & drive weather patterns

Warmer waters expand & accelerate melting of glaciers producing sea level rise

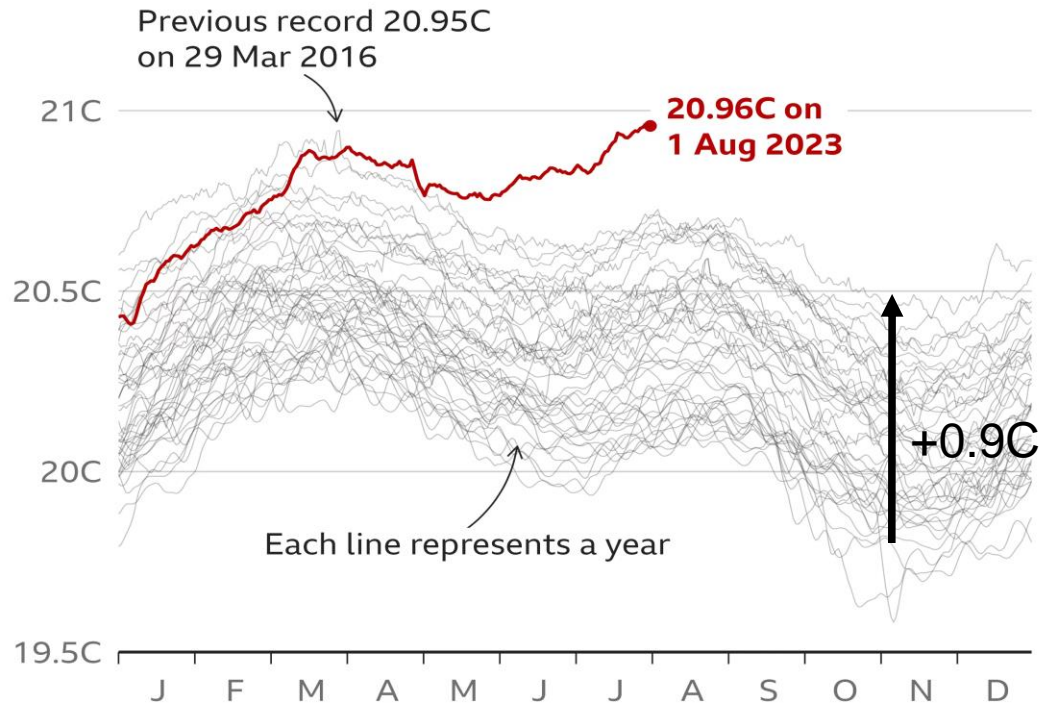
Marine species like fish and whales move in search of cooler waters

Fish stocks reduce due to oxygen depletion & disruption of food chain

Average ocean temperature has increased by 0.9C since 1970

## Ocean temperatures highest on record

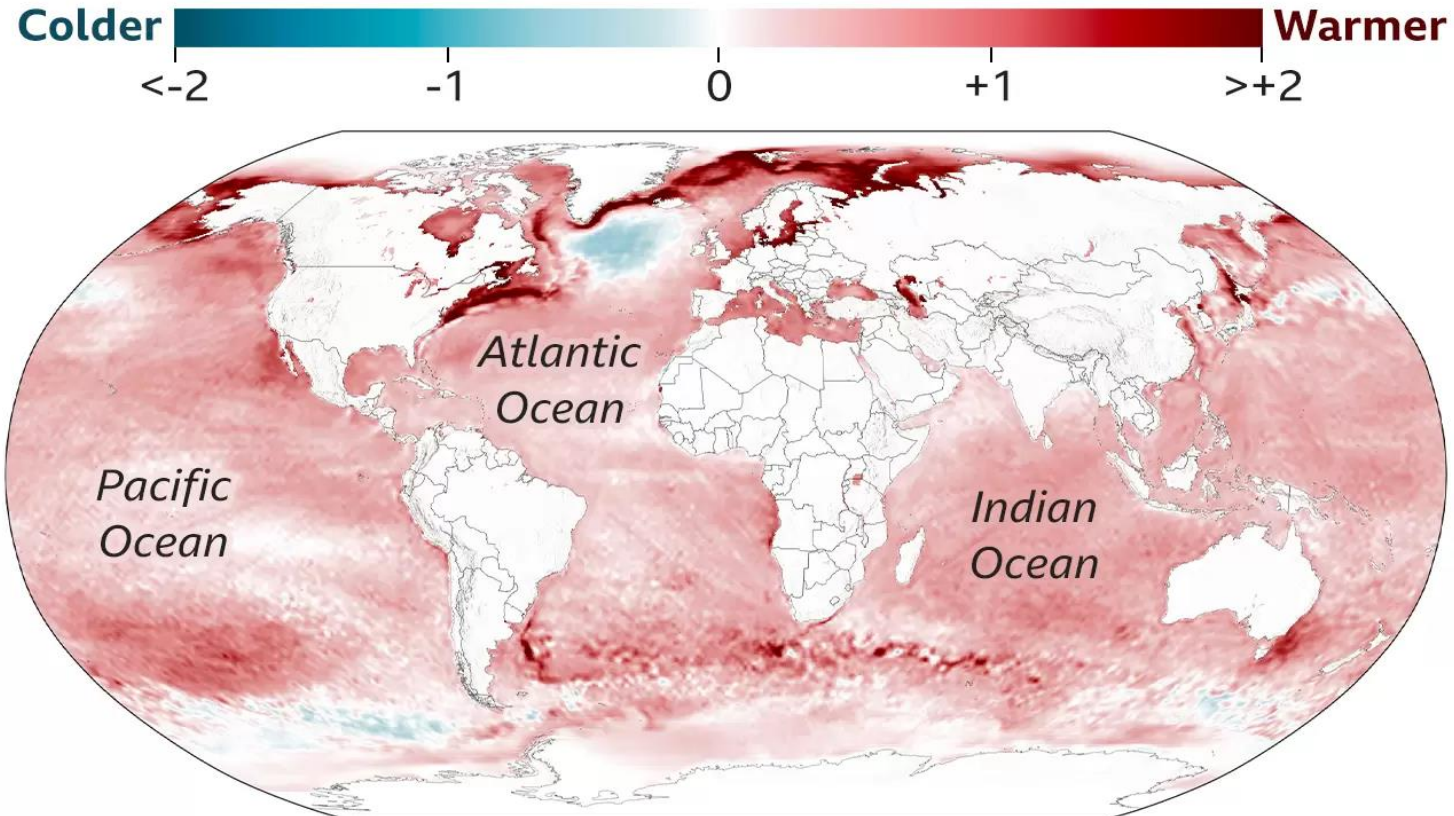
Daily average sea surface temperature between 60° North and 60° South, 1979-2023



Source: ERA5, C3S/ECMWF

# Rising temperatures in the world's oceans

Average sea surface temperature in 2011-2020 (degrees C), compared to 1951-1980



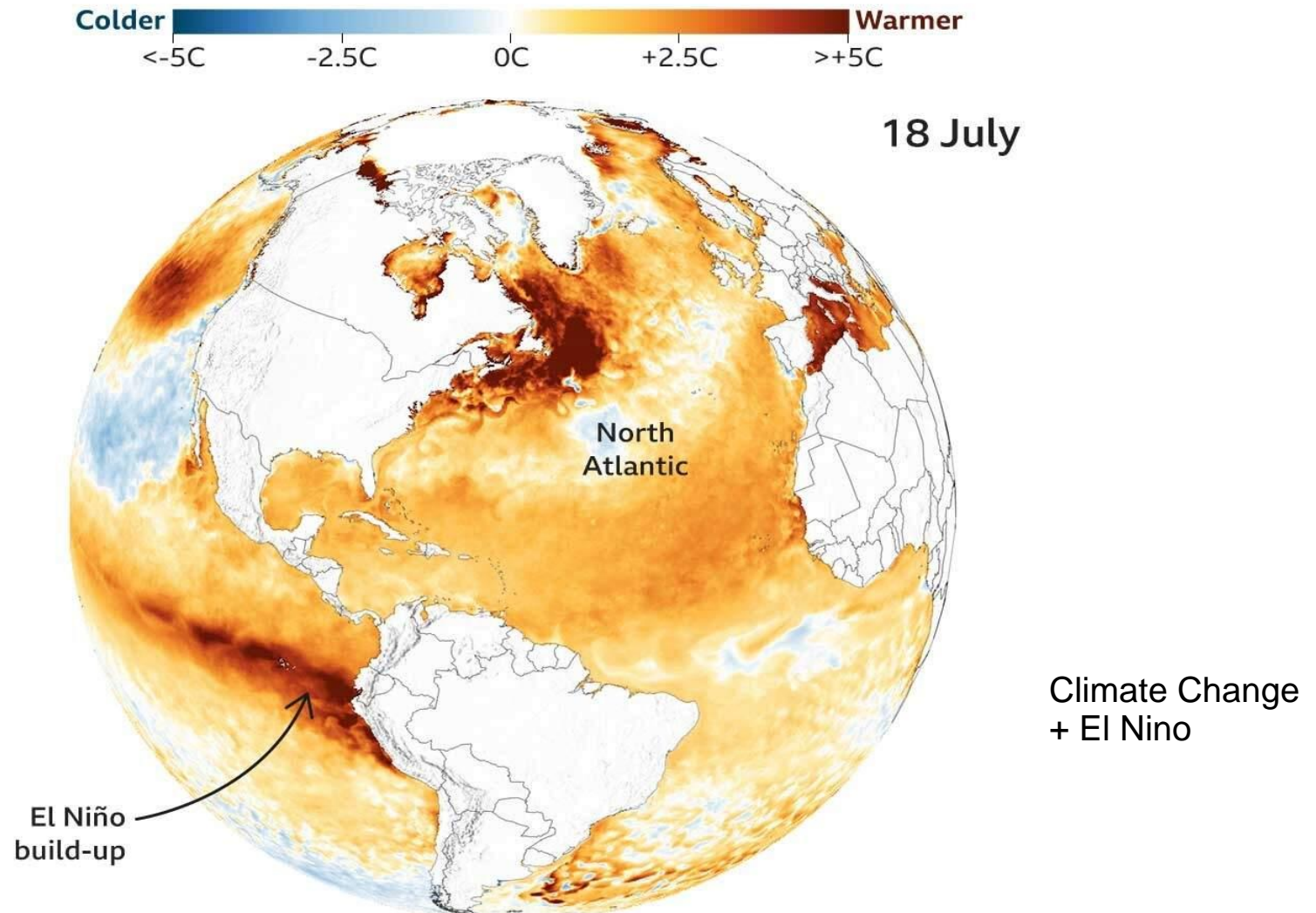
Source: ECMWF ERA5



Arctic is warming faster than the global average due to the albedo effect  
Ice reflects sunlight back into space

# Marine Heatwave In The North Atlantic

Daily sea surface temperature April - July 2023



# EL NINO & LA NINA EVENTS

El Niño & La Niña are natural ocean events occurring every 2-7 years lasting 9-12 months

During 2023/4 El Niño is adding 0.5 C to ocean temperatures

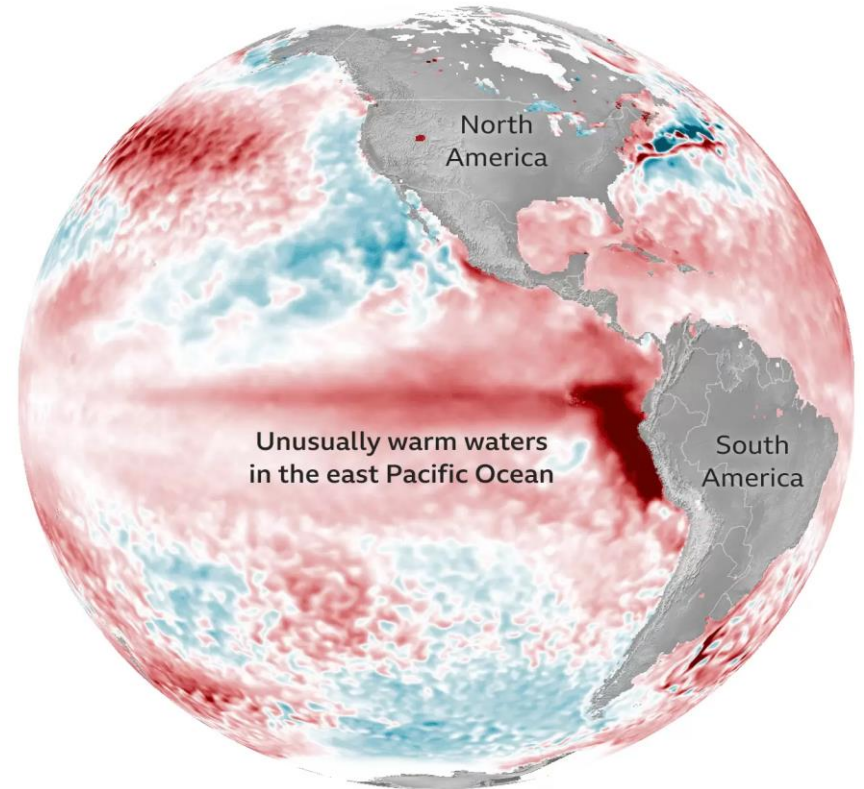
Pacific trade winds usually blow east-to-west warming the waters to the west

During El Niño the winds weaken & the eastern Pacific Ocean warms

During La Niña the normal east-to-west winds become stronger raising cold water from the depths reducing ocean temperatures by 0.5C

## El Niño conditions are now present

Average sea surface temperature in May 2023 (degrees C), compared with May 1991-2020





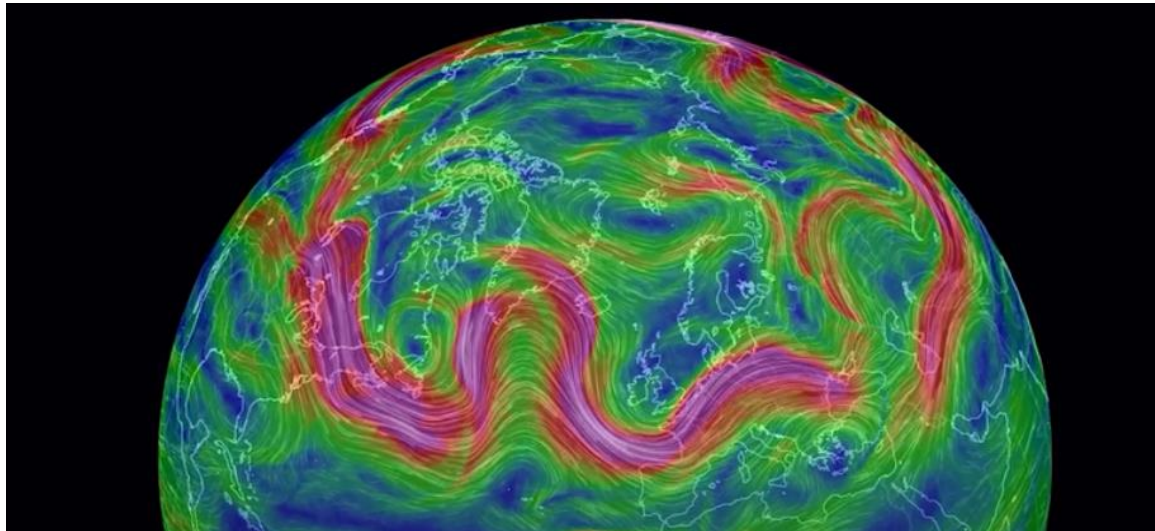
# OCEAN WARMING AFFECTS THE WEATHER

Jet Streams are narrow bands of strong wind in the upper atmosphere

They drive weather patterns controlling the movement cyclones moving west to east

As the Arctic ocean warms the temperature difference between the poles & the equator drops making the Jet Stream less stable

Warm air is dragged further north & cold air is dragged further south for longer



Produces more extreme weather

In June 2020 the town of Koyankst in Siberia hit 100deg F

Snowfall as far south as Texas, US

# ARCTIC SEA ICE SHRINKAGE

Reduced by 50% since 1980

Polar ice cover reflects much of the sun's energy back into space

As the ice melts warming accelerates (albedo effect) x4 compared with lower latitudes

## Arctic sea ice minimum extent

1980

7.5 million sq km



Source: National Snow and Ice Data Center

BBC

## Arctic sea ice minimum extent

2020

3.7 million sq km



Source: National Snow and Ice Data Center

BBC

Russia & Canada plan to exploit exposed regions for new oil & gas development!

# SATELLITES TRACK ARCTIC SEA ICE

Satellites measure the thickness of Arctic sea-ice using lasers/radar/microwaves

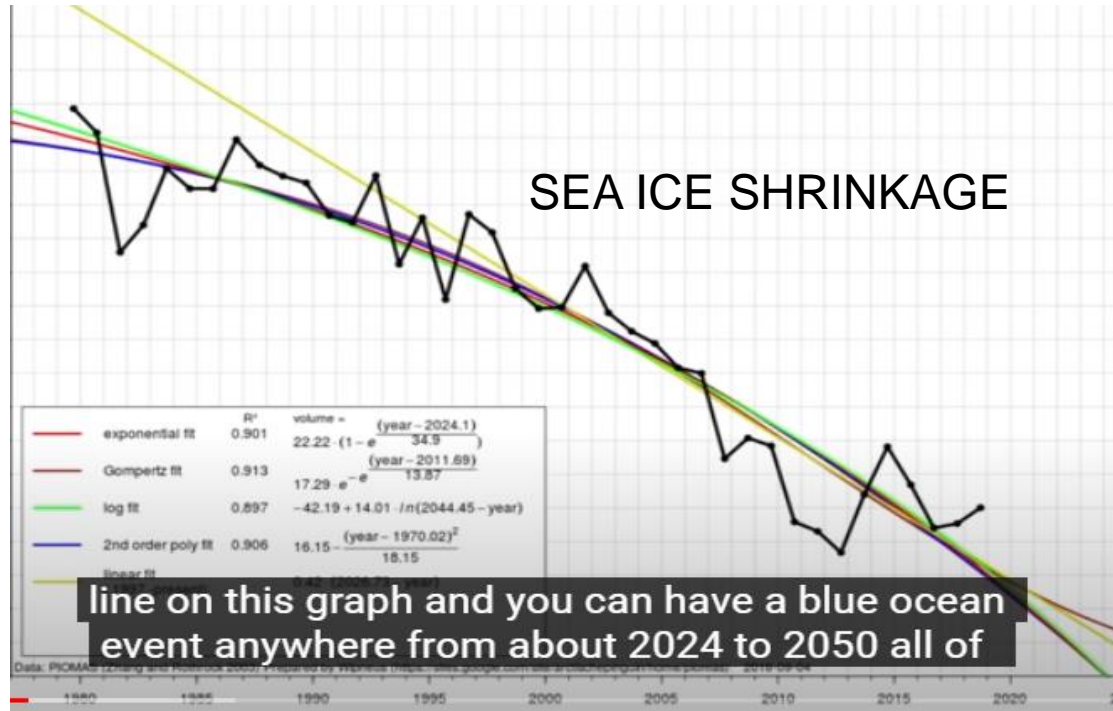
AI is trained on historical data to recognize patterns in ice flow & thickness

Satellites + AI provide improves tracking of changes to Arctic sea ice



# BLUE OCEAN EVENT

No summer Arctic sea ice after 2035



Because the Arctic is warming

Ocean temperature will then rise quickly

Melting 1 gram ice = 80 calories (latent heat)

Once melted 80 calories raises 1 gram water by 80C

# BOREAL FORESTS SHRINKING

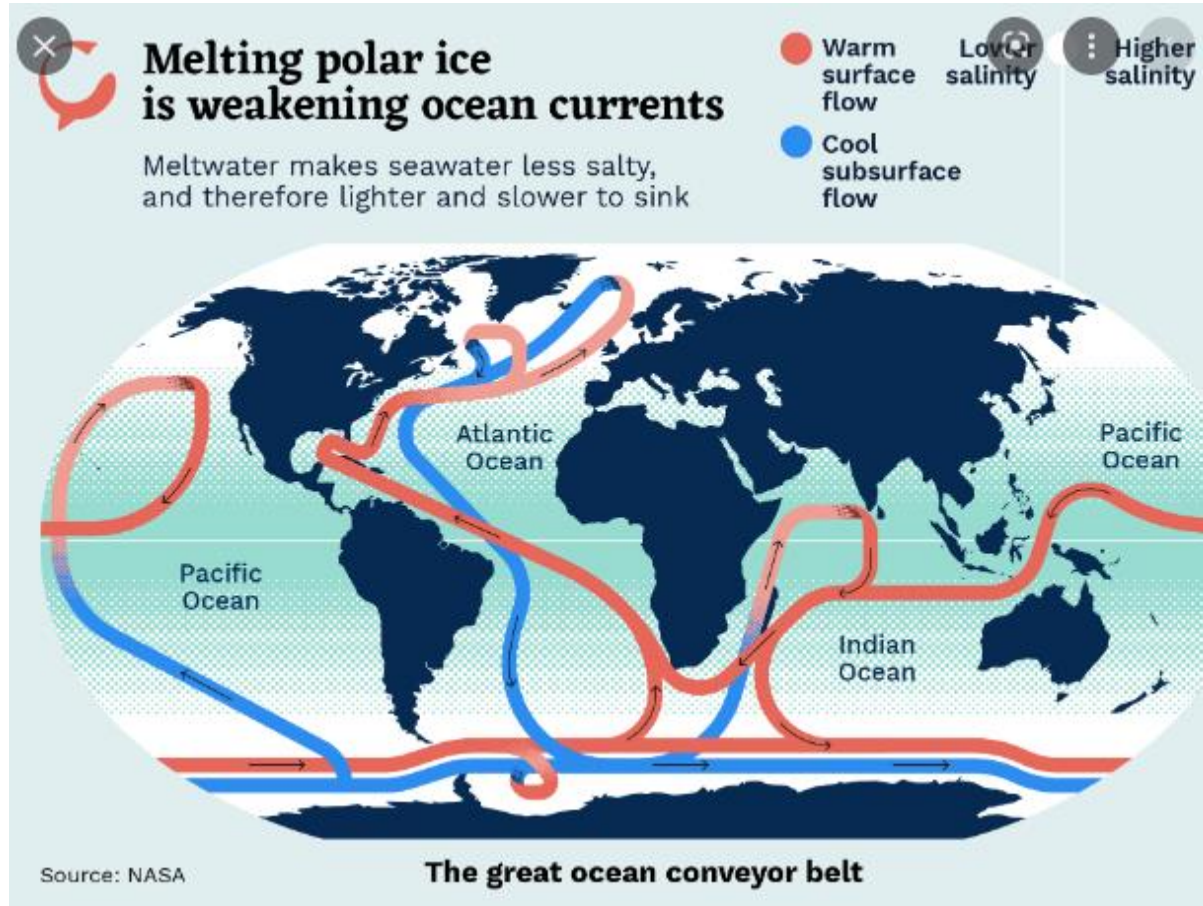


In Canada & Russia the Boreal Forest is moving north

Forest area shrinking by 0.3% per year due to climate change

# MELTING POLAR ICE WEAKENS OCEAN CURRENTS

AMOC – Atlantic Meridional Overturning Circulation



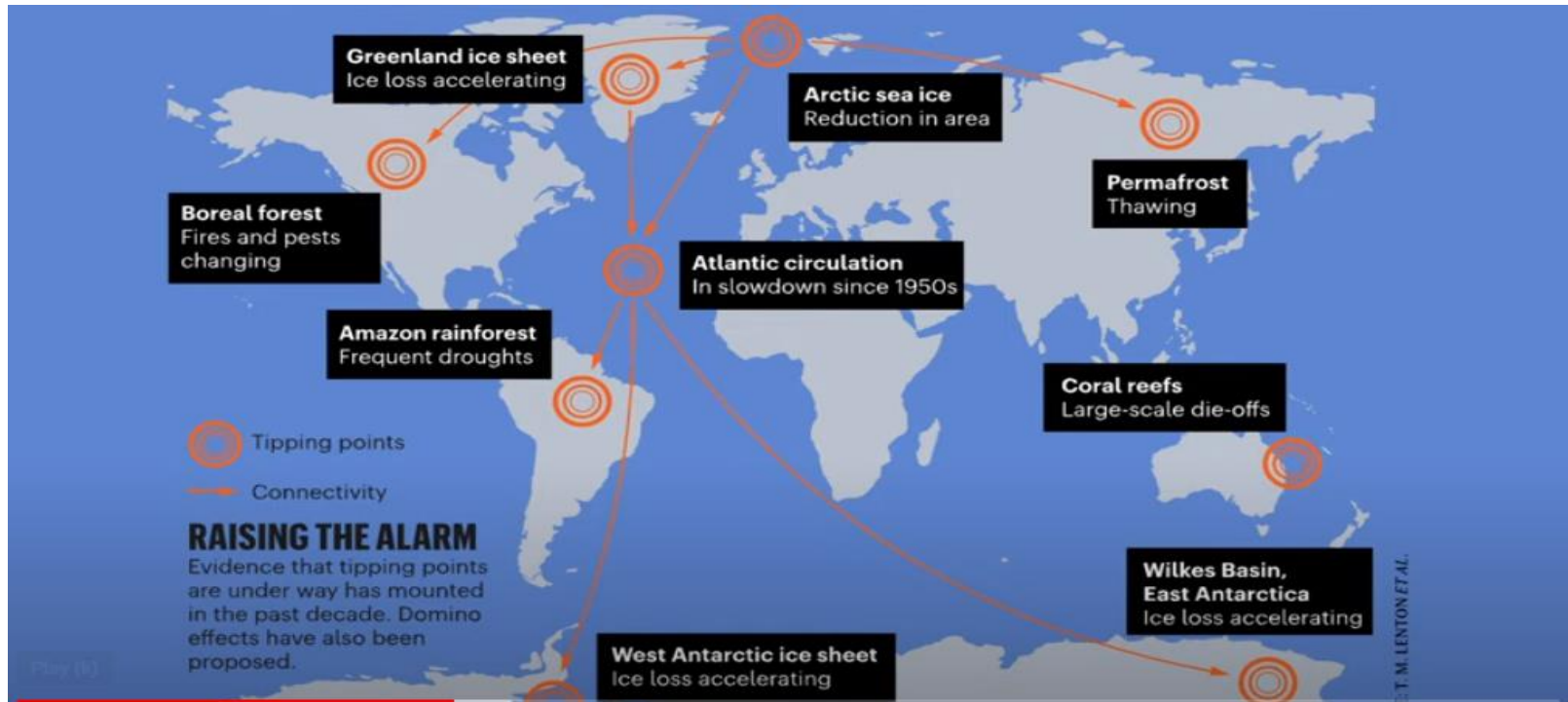
Polar meltwater is lighter & slower to sink

Reduced circulation limits the cooling effect of the oceans

# TEMPERATURE TIPPING POINTS

Trigger irreversible climate change

Warming Arctic melts Greenland Ice sheet & Siberia Permafrost (releasing methane) producing more global warming (domino effect)



Less ocean circulation reduces the cooling influence on the warming the climate

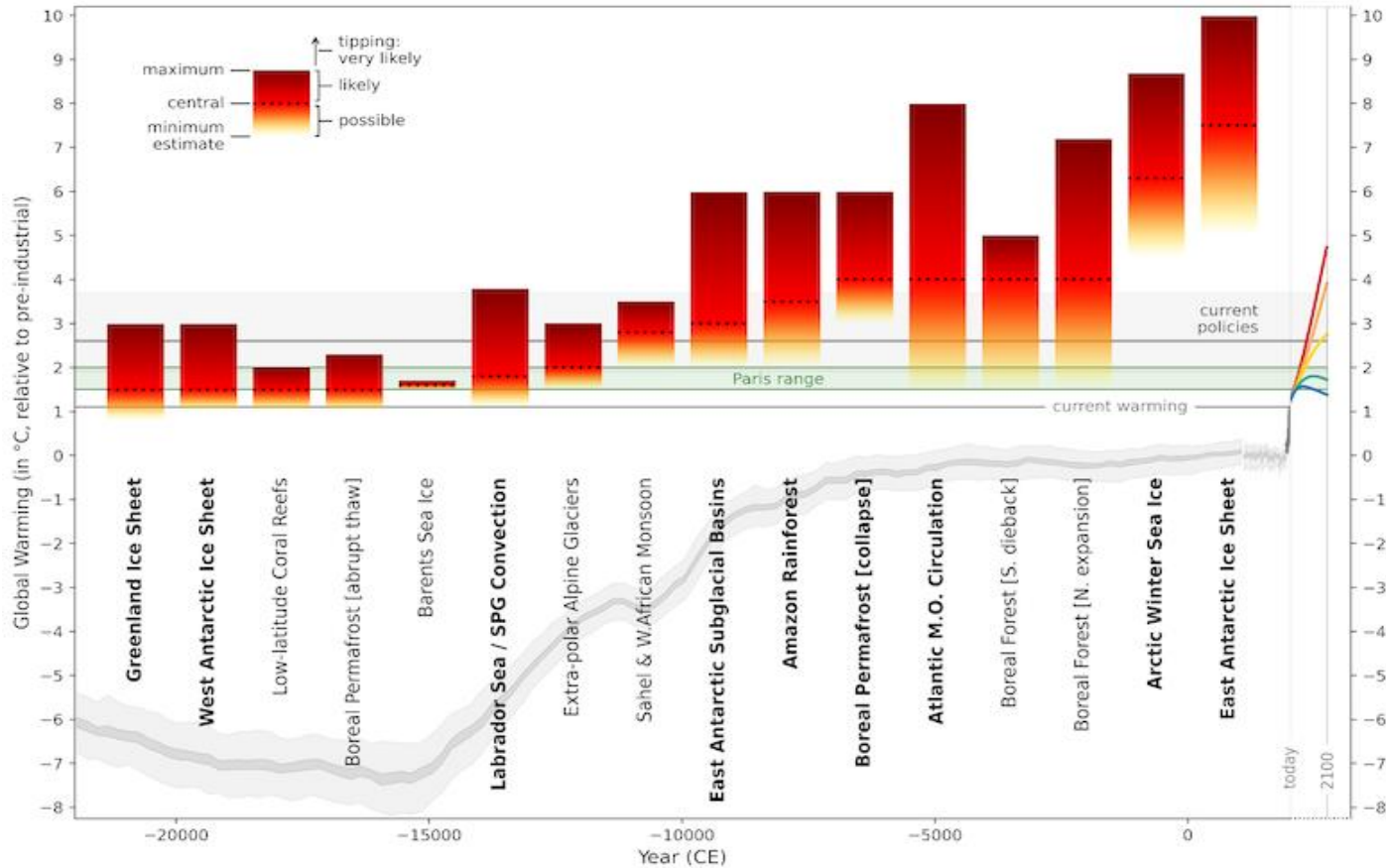
Weather patterns change producing increased desertification (Brazil, Africa, SE Asia)

Melting of Western Antarctic ice sheet

# TIPPING POINTS

16 Tipping Points Identified produce irreversible climate change

↑  
Temp  
Rise



Global warming of 1.2C means 4 tipping points reached

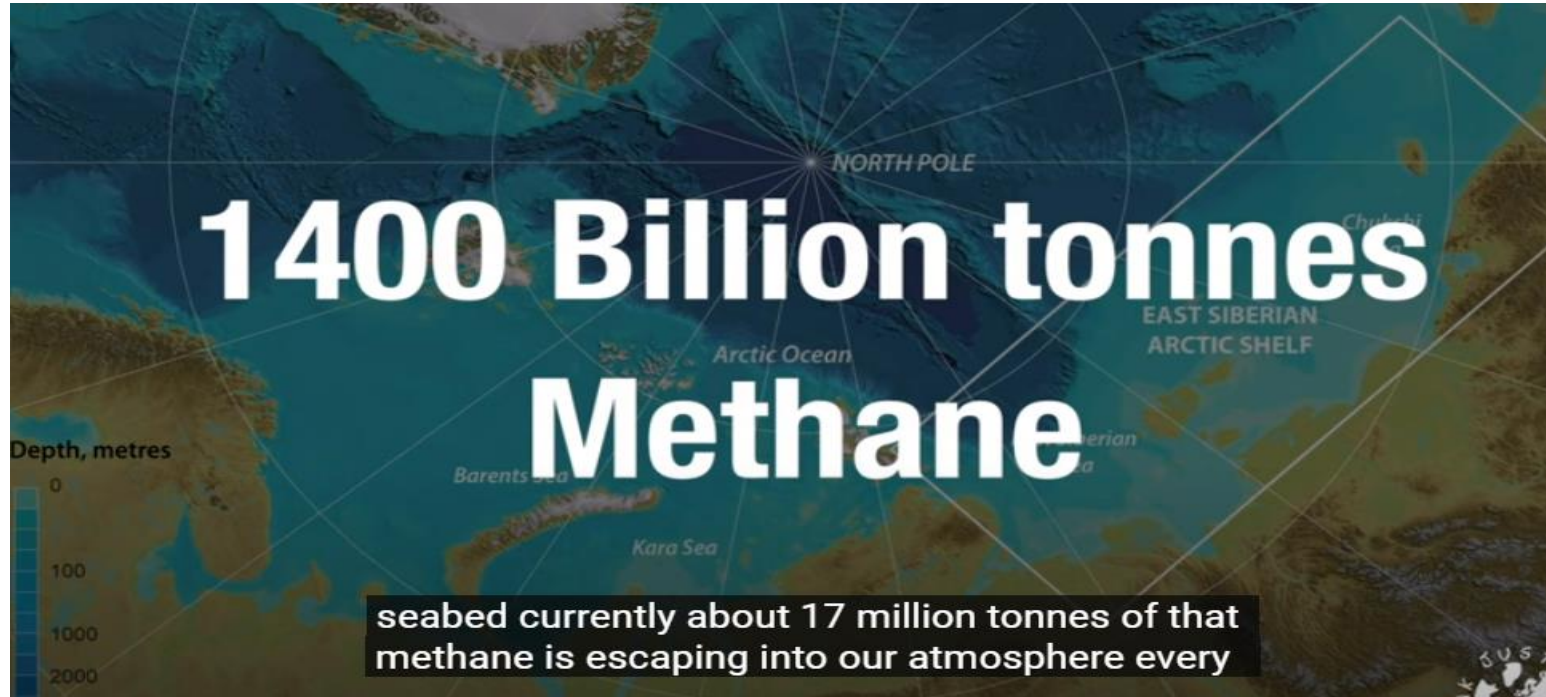
Accelerate global warming



# METHANE RELEASE IN THE ARCTIC

More than 80% of the worlds subsea permafrost exist in the East Siberian Arctic shelf

Estimated 1400 Billion tonnes methane stored



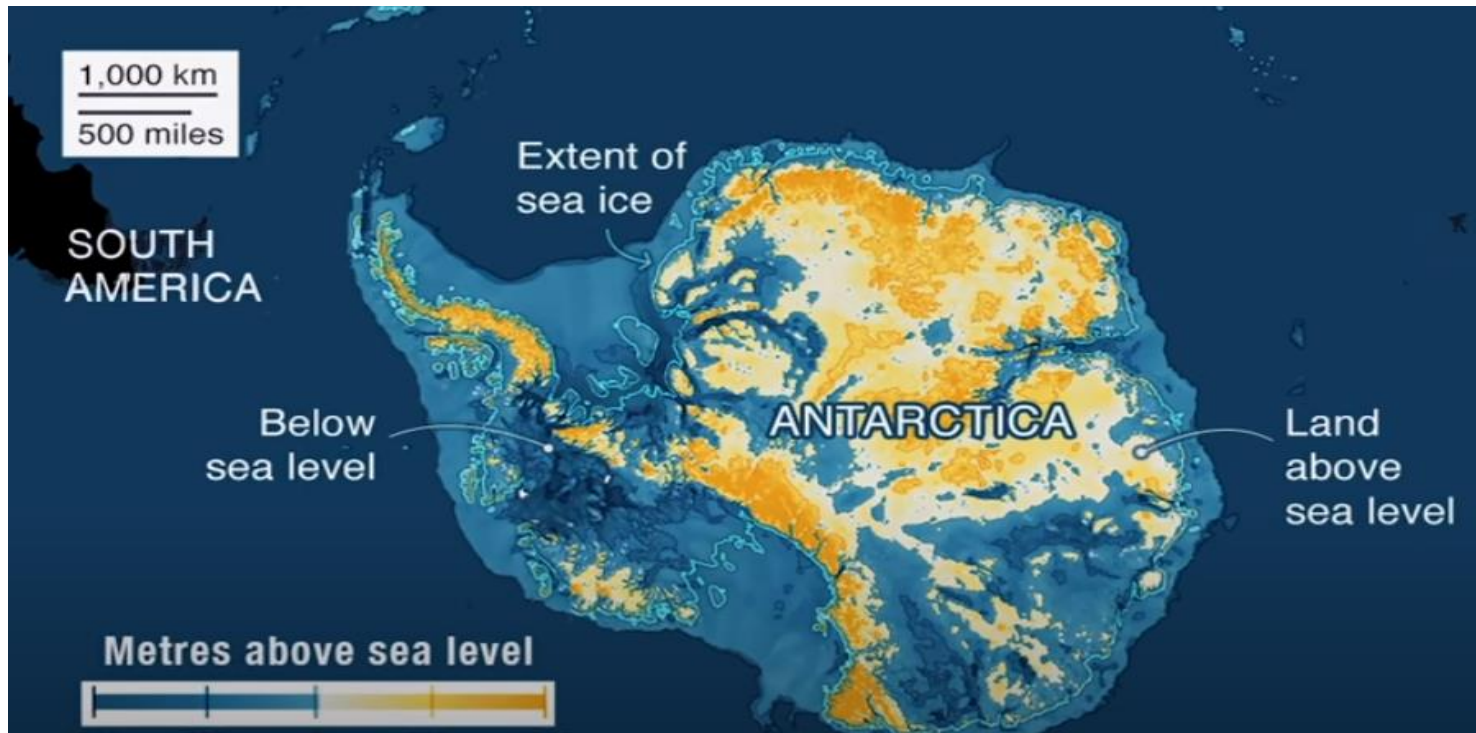
Methane emissions escaping ~ 17 million tons each year accelerate as temperatures rise

Over 5-10 years methane is 80x more potent than CO2 (methane burp)

# ANTARCTIC ICE

The Antarctic ice sheet contains 70% world's fresh water

Eastern Antarctic ice is a mile thick & sits on solid bedrock



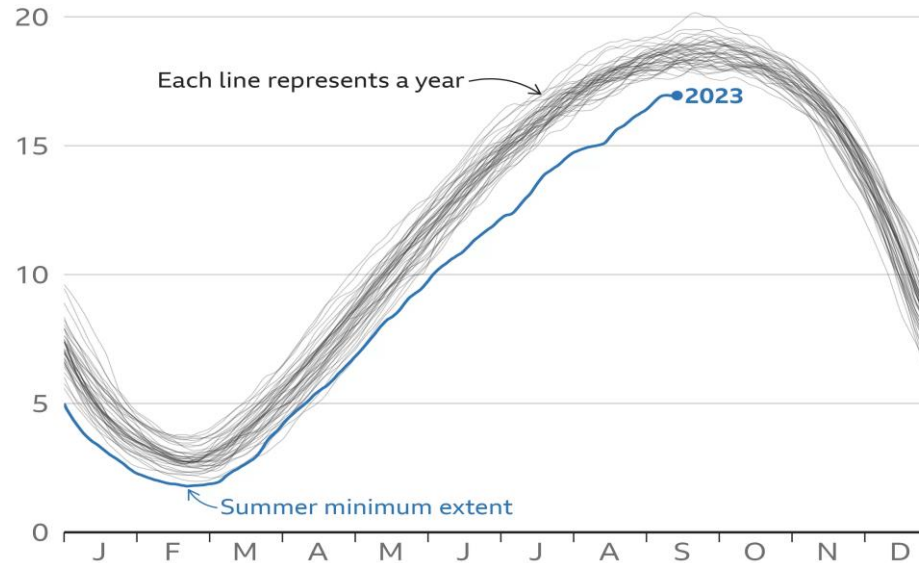
Western Antarctica ice sits on a series of islands and is receding

# ANTARCTIC SEA ICE REDUCTION

Antarctica sea ice at lowest recorded winter level (satellite data) in 2023

## Antarctica sea-ice far lower than usual

Daily sea-ice extent in million sq km, 1979-2023



Five-day rolling average of sea-ice extent

Source: National Snow and Ice Data Center (NSIDC), data to 14 Sep 2023



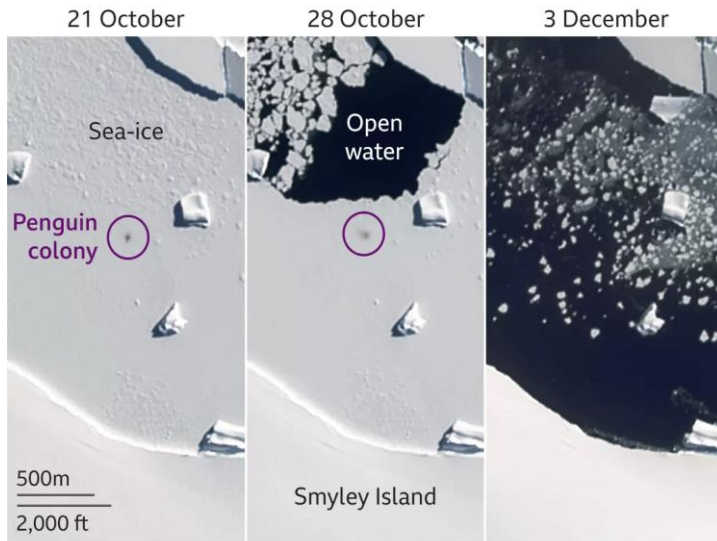
Antarctica's ice expanse regulates the planet's temperature as the white surface reflects the Sun's energy back into space

# EARLY BREAKUP OF ANTARCTIC ICE

2022 a loss of 10,000 emperor penguin chicks

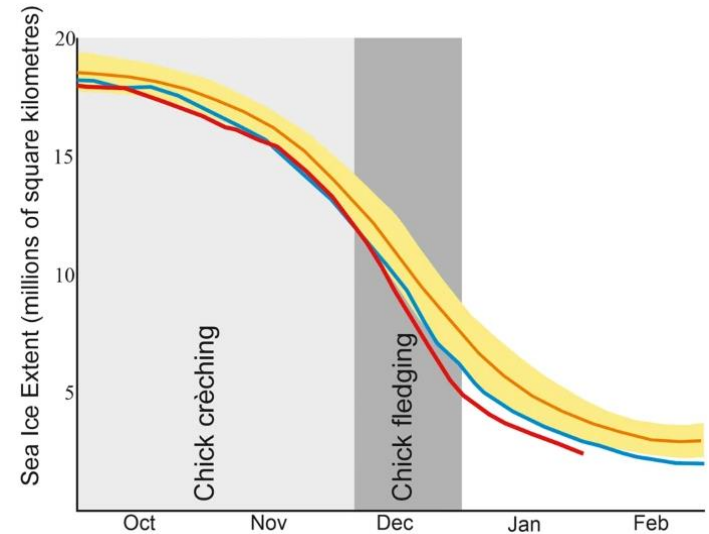
Sea-ice melted and broke apart before the chicks could develop the waterproof feathers needed to swim in the ocean

## Loss of Smyley Island emperor colony in 2022



Source: Copernicus Sentinel-2

BBC



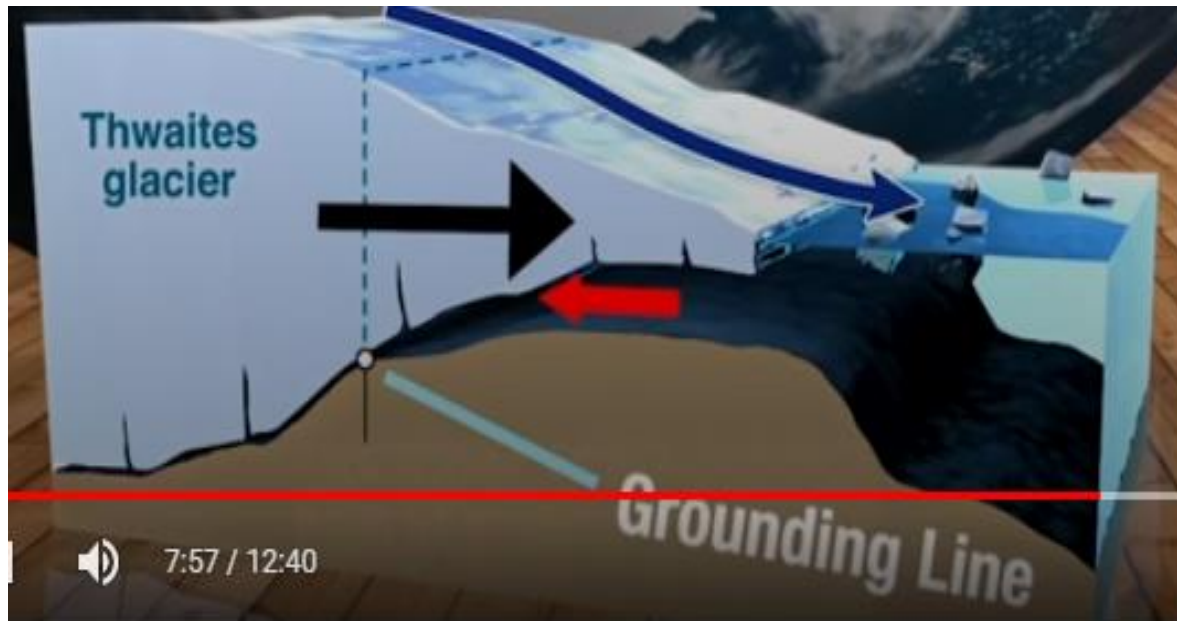
The birds drowned or froze to death.

More than 90% of emperor penguin colonies are predicted to be extinct by 2100

# ANTARCTIC ICE INSTABILITY

Due to climate change warm waters from the Pacific move south & meet the edge of the Antarctic continental shelf

Warm water gets beneath the glaciers



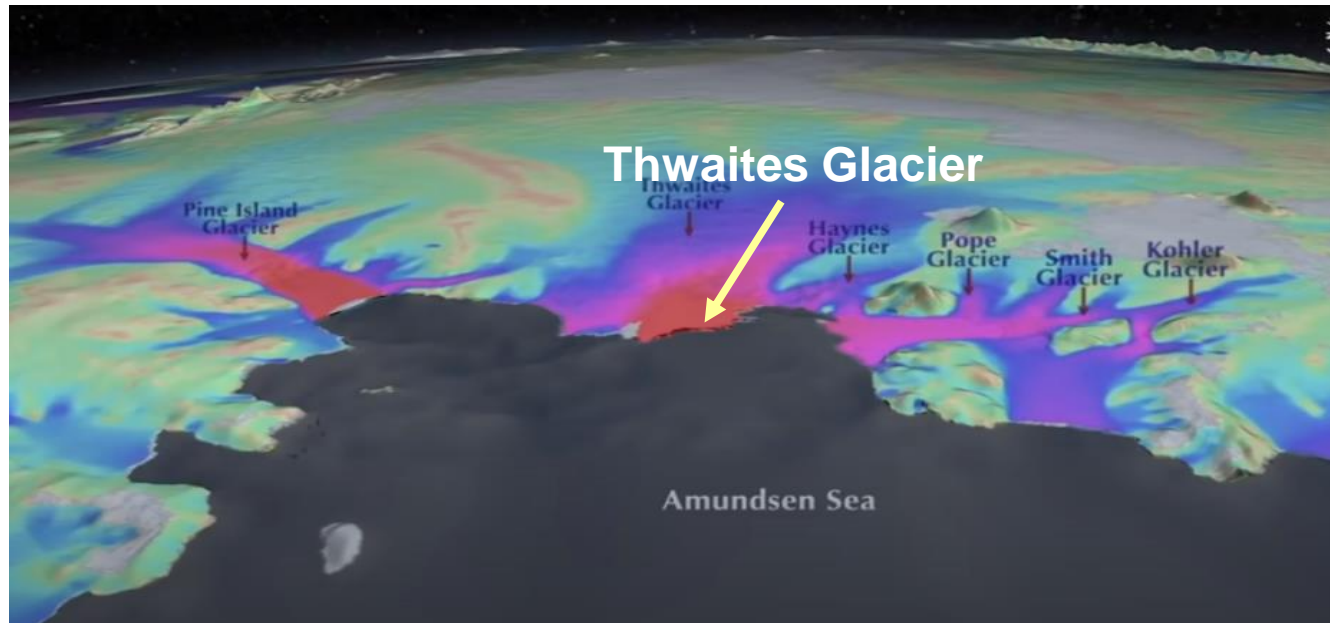
The temperature of the water beneath the glacier is 2C above freezing

Glacier melting rate can increase by x10

# THE 'DOOMSDAY GLACIER'

Thwaites glacier is about the size of the UK

Melting of Thwaites glacier would raise world sea levels 0.65 metres



Thwaites sits as giant plug holding back the Western Antarctic ice sheet

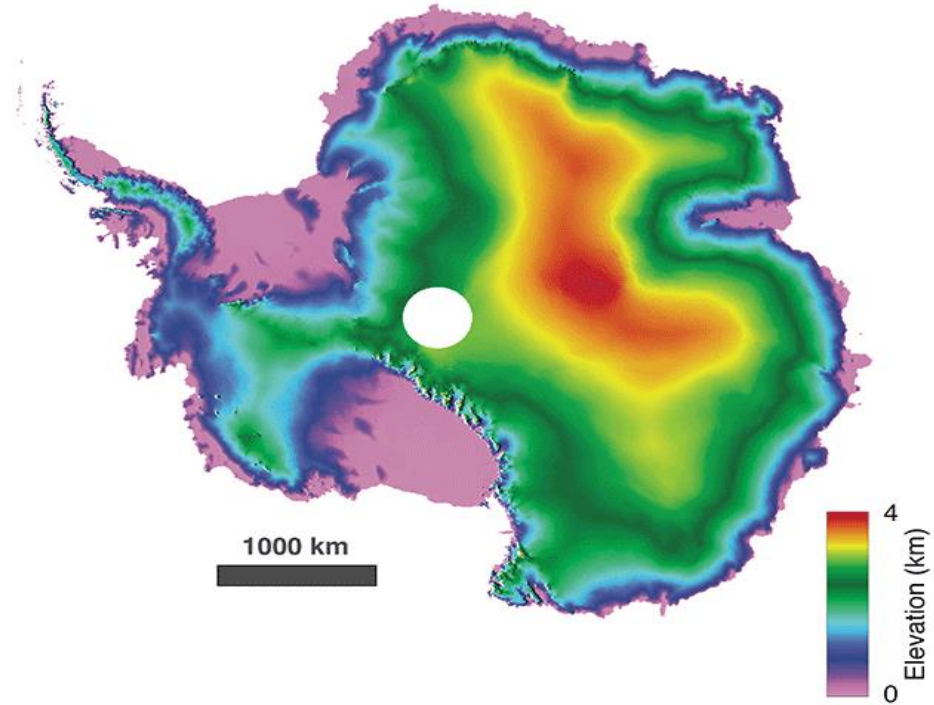
The rate of ice loss from the glacier has doubled in last 20 years

# SEA LEVEL RISE

**2100**

0.5 – 2.0 metres sea level rise

Displaces 150-200M people from coastal



**Future**

Greenland Ice Sheet Melted + Western Antarctic = 13 Metre Rise

Displaces 2 billion people from coastal towns & cities

**Future**

Eastern Antarctic Ice Sheet Melted = 70-80 Metre Rise

Displaces 4 billion people

The rate of sea level increase depends on the ocean temperature rise

# FUTURE WORLD: 3C Temperature Rise



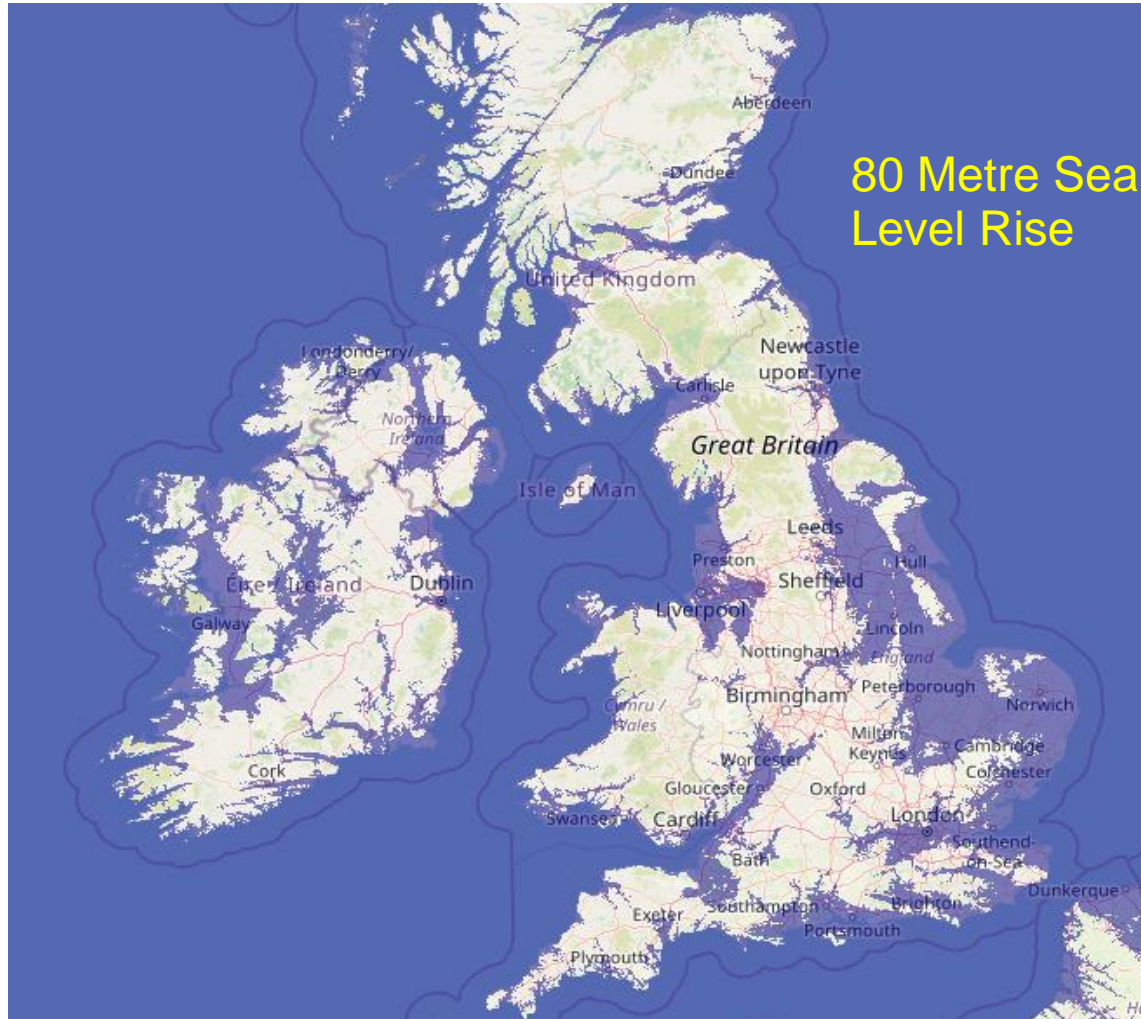
80 Metre Sea Level Rise  
Land Area Reduction ~10% worldwide  
Coastal Cities Relocated  
Reduced Population?

Uninhabitable Equatorial Zone  
Tropics Move Towards Poles  
Wild Weather  
90% Species Loss



# FUTURE UK

30% reduction in land area

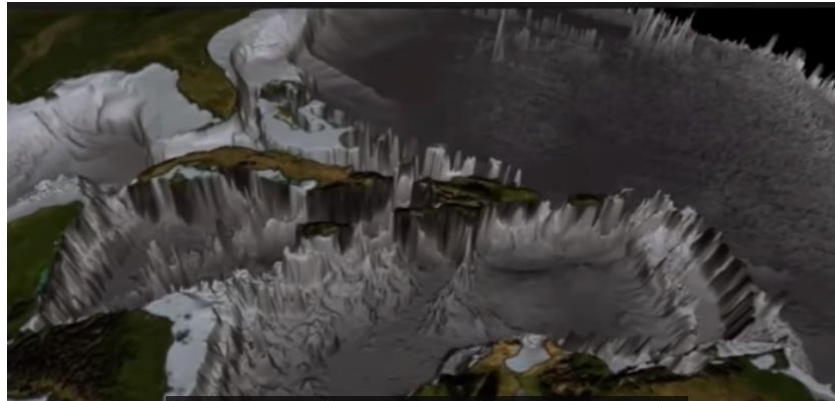


# OCEAN ACIDIFICATION

Oceans absorb about 1/3 excess CO<sub>2</sub> emissions

A natural vault of stored solid CO<sub>2</sub> already exists on the ocean floor  
Oceans hold x150 the CO<sub>2</sub> in the air

Warming oceans dissolve stored CO<sub>2</sub> increasing ocean acidification  
Less alkalinity endangers sea life



Oceans emit CO<sub>2</sub> back into the atmosphere when warmed

A warm surface layer can also build up preventing oxygen absorption

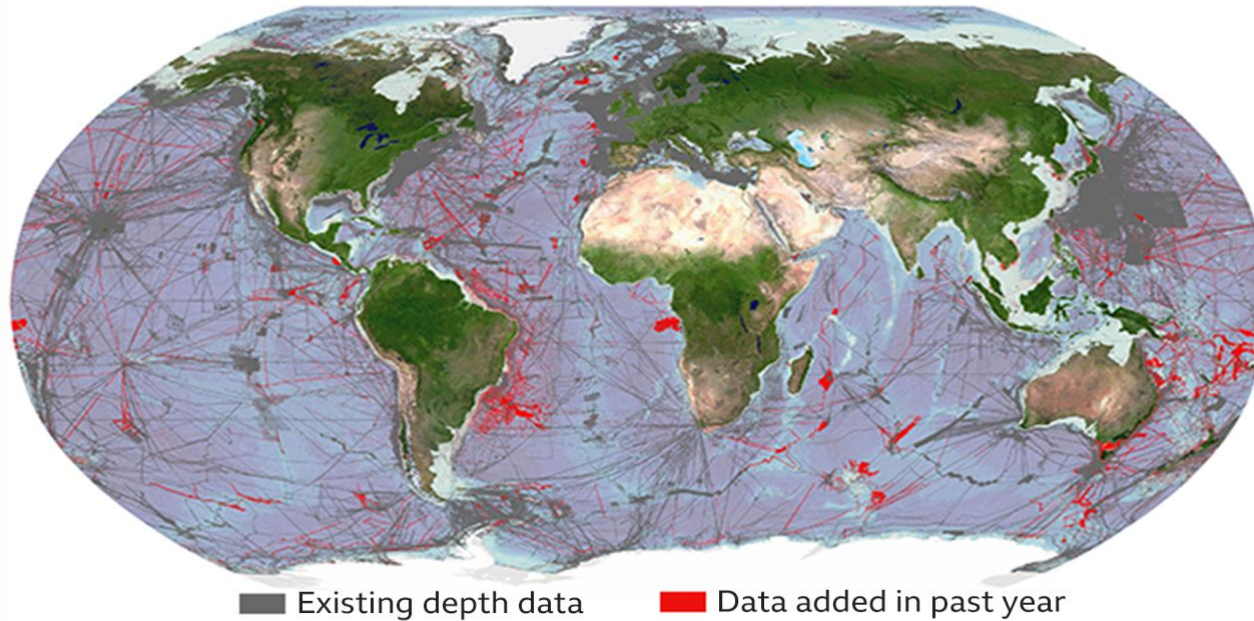
# OCEAN MAPPING

Ocean mapping improves climate models predicting how oceans move heat around the planet

The rugged seafloor influences the behaviour of ocean currents and the vertical mixing of water

Only 25% of the sea floor is mapped

## 2022: Extent of ocean floor currently mapped



Source: Nippon Foundation / Seabed 2030

BBC

Project 'Seabed 2030' aims to map the oceans 100% by 2030 using dedicated autonomous vehicles

# OCEAN MAPPING & ARTIFICIAL INTELLIGENCE

Researchers are using AI controlled vehicles to investigate ocean areas that cannot be reached by traditional methods

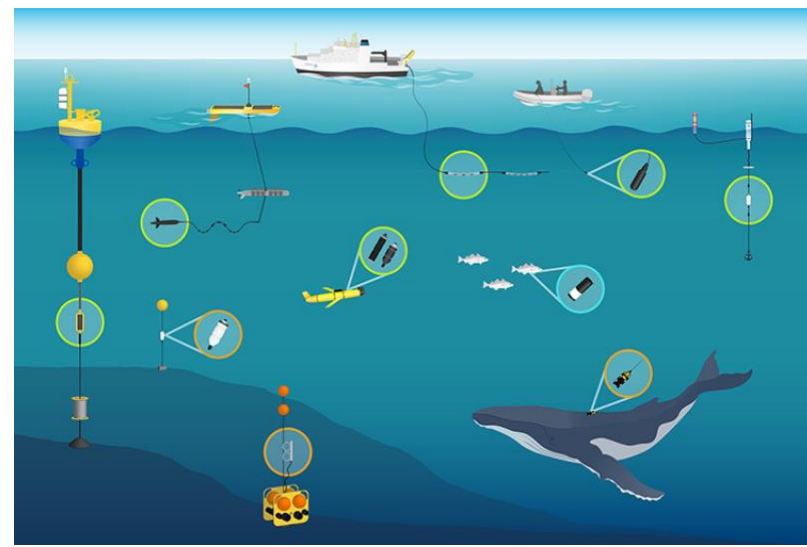
AI is being used to make Remote Operated Vehicles more powerful

Control ROV manipulators to perform complex tasks  
Collecting samples & attaching sensors

AI processes data 24/7 from remote marine vehicles & cameras

AI used to identify and track endangered species, assess the health of coral reefs

Study the effects of climate change on the oceans  
Ocean acidification, sea level rise, and changes in ocean currents.



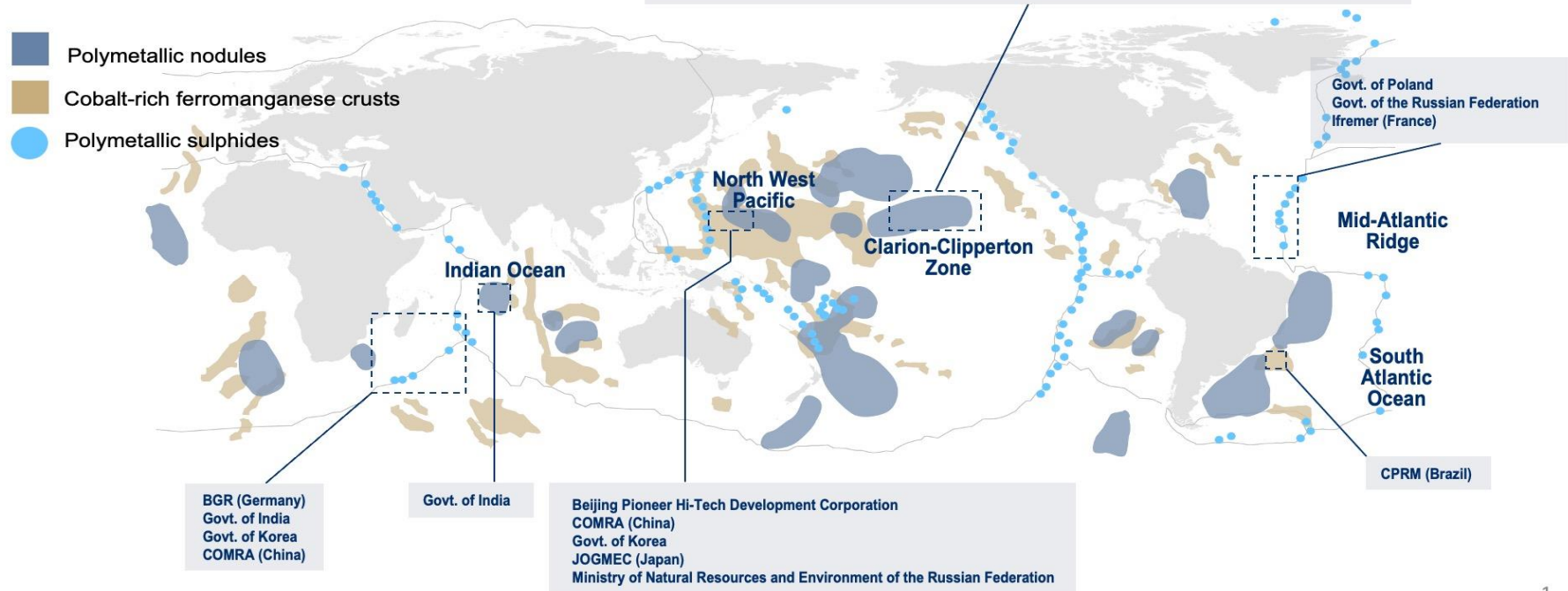
# OCEAN MINING

There is growing interest in the mineral deposits of the seabed.

Metals include copper, nickel, aluminium, manganese, zinc, lithium and cobalt

To produce technologies like smartphones, wind turbines, solar panels and batteries

## Exploration for minerals in the Area



# MINING THE SEA FLOOR

Mining the ocean floor by machines can alter or destroy deep-sea habitats leading to loss of species & ecosystems

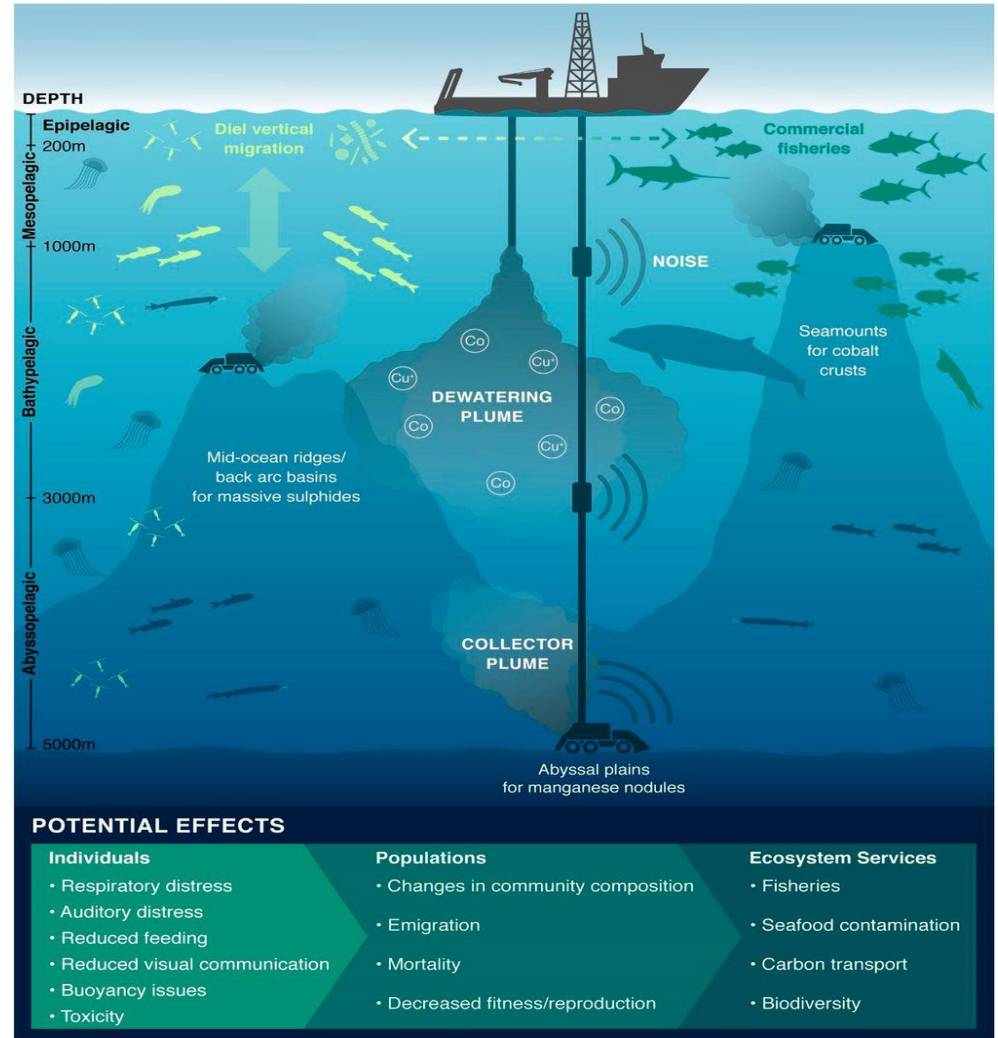
Around six billion tonnes of sand is dredged from the world's oceans every year

**World Conservation Congress Sep 2021**

Adopted Resolution 122 to protect deep-ocean ecosystems and biodiversity

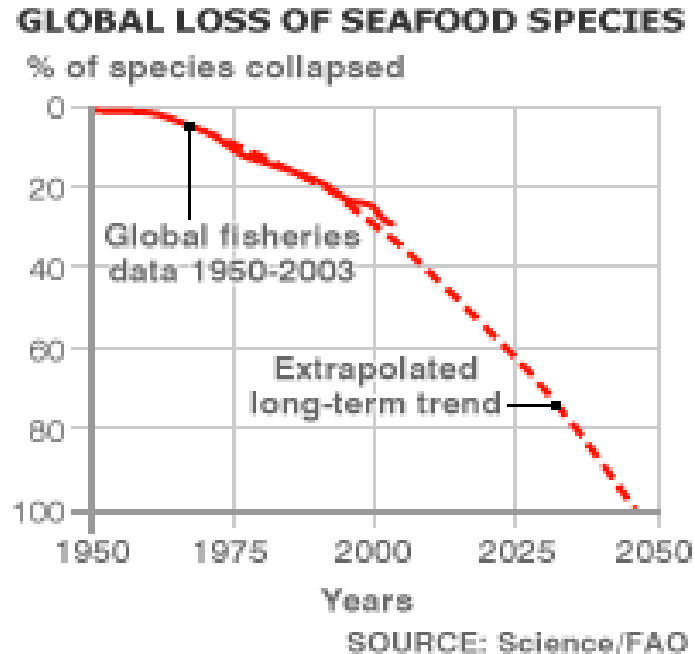
Impact assessments of mining are being conducted

Governance mechanism?



# SEA FISH DECLINE

Stocks reduced in nearly one-third of sea fisheries & the rate of decline is accelerating.



The global catch fell by 13% between 1994 and 2003

A greater use of protected areas could safeguard existing stocks

What about sea farming?

# FARMING THE SEA 2050

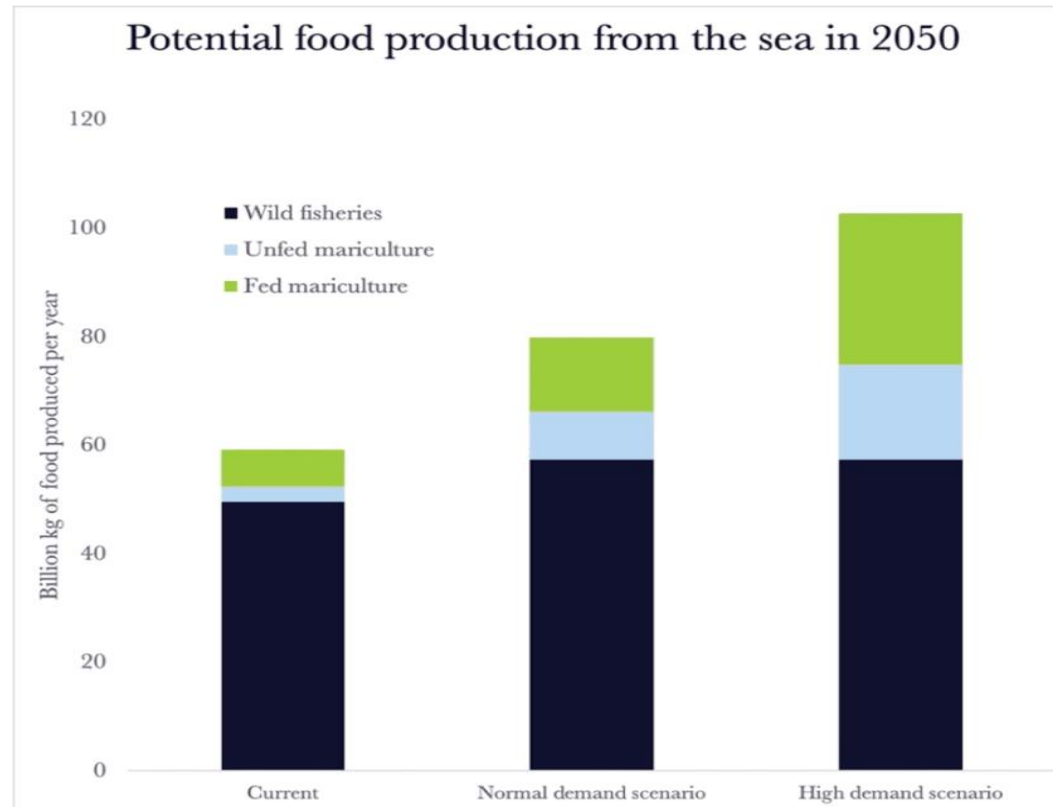
Study about managing sea resources

Improve fishery management

Implement policy reforms

Advance feed technologies

Widen consumer demand



*By 2050 the oceans could provide 36-74% more food*



# OCEAN WILDLIFE PROTECTION

Two-thirds of the world's oceans are international waters where all countries have a right to fish

Only 1.2% is currently protected.

The UN High Seas Treaty has been through 10 years of negotiations but not yet signed

Ensure 30% of land & sea protected against exploitation by 2030

Agreed at 2022 UN Biodiversity COP15

If agreed, it would put 30% of the world's oceans into conservation areas by 2030

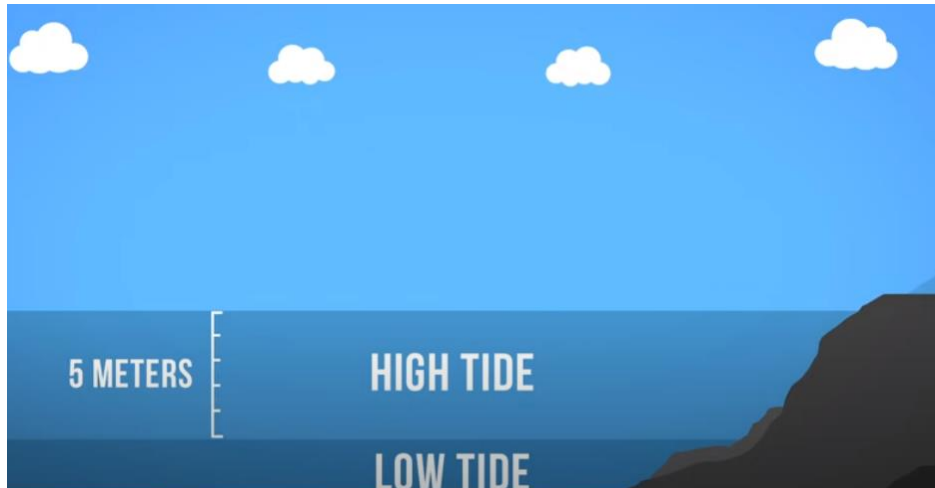
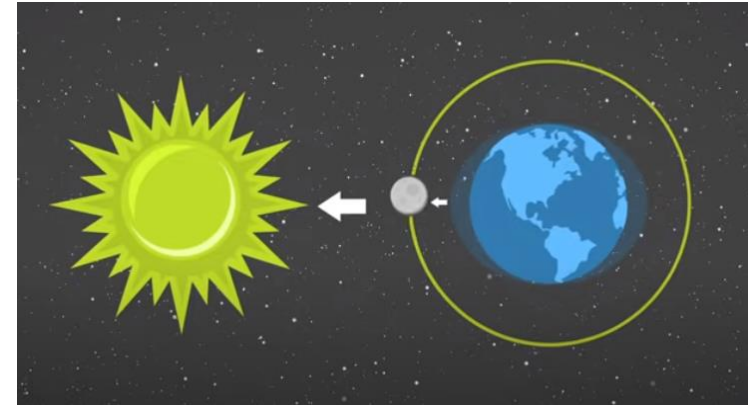
Protect marine life from overfishing and other human activities



# ENERGY FROM THE OCEAN

Tides are formed by gravitational forces from the Moon, the Sun & the rotation of the Earth

The Earth rotates through two tidal “bulges” every day



Tidal Power converts energy from the rise & fall of the tides into electricity

The difference in water levels needs to be ~5 metres to generate electricity efficiently

Mainly around coasts

# TIDAL TECHNOLOGIES

**Tidal barrages** use the potential energy between high & low tides to drive turbines & produce electricity

Reliable: the predictable tides & intrinsic energy storage stabilizes supply

Expensive: Building a barrage is a big undertaking

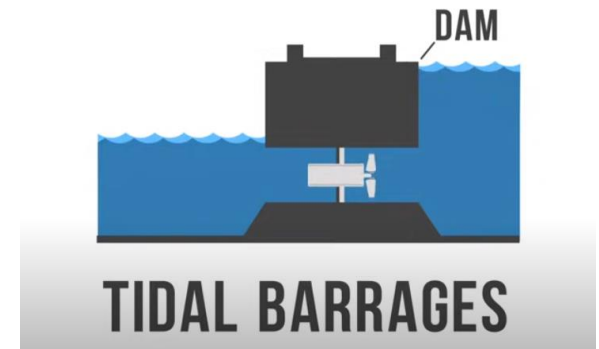
Ecology: Impact on fish movements & wildlife has to be assessed case by case

**Tidal flow schemes** operate like wind turbines better as water is 850 times more dense than air

Tidal turbines added incrementally as required

Energy storage to stabilize supply over a 24 hour period

The UK government invests £20 million per year in tidal stream electricity



# TIDAL BARRAGE SCHEMES

The Woodbridge Tide Mill for grinding grain dates back to 1170

A tidal barrage was built across a basin & filled whilst the tide was rising



The French built the first commercial Tidal plant at St Malo in 1965 to generate Electricity

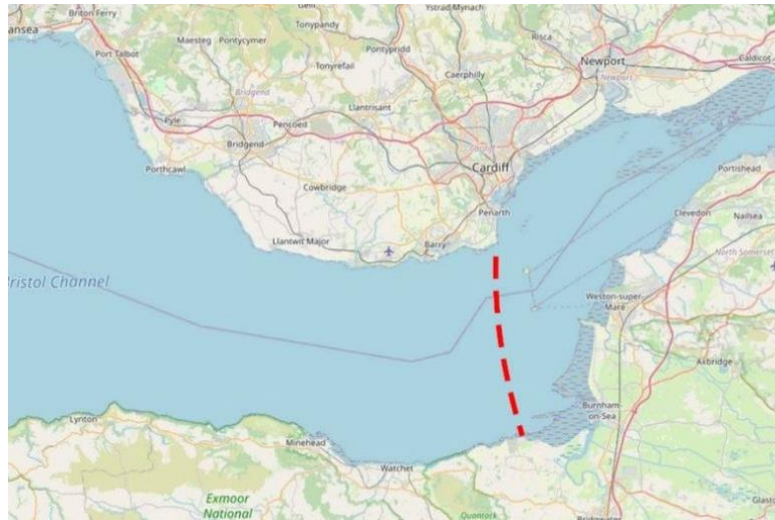
Only 5 barrage projects have been developed commercially to 2012 due to cost & potential impact on the surrounding ecosystem

# THE PROPOSED SEVERN BARRAGE

Mean tidal range 9.8 metres could generate 16.8 TWhr/year ~10% of UK electricity

Estimated cost = £30billion

Previous proposals blocked by environmental groups & the capital cost outlay



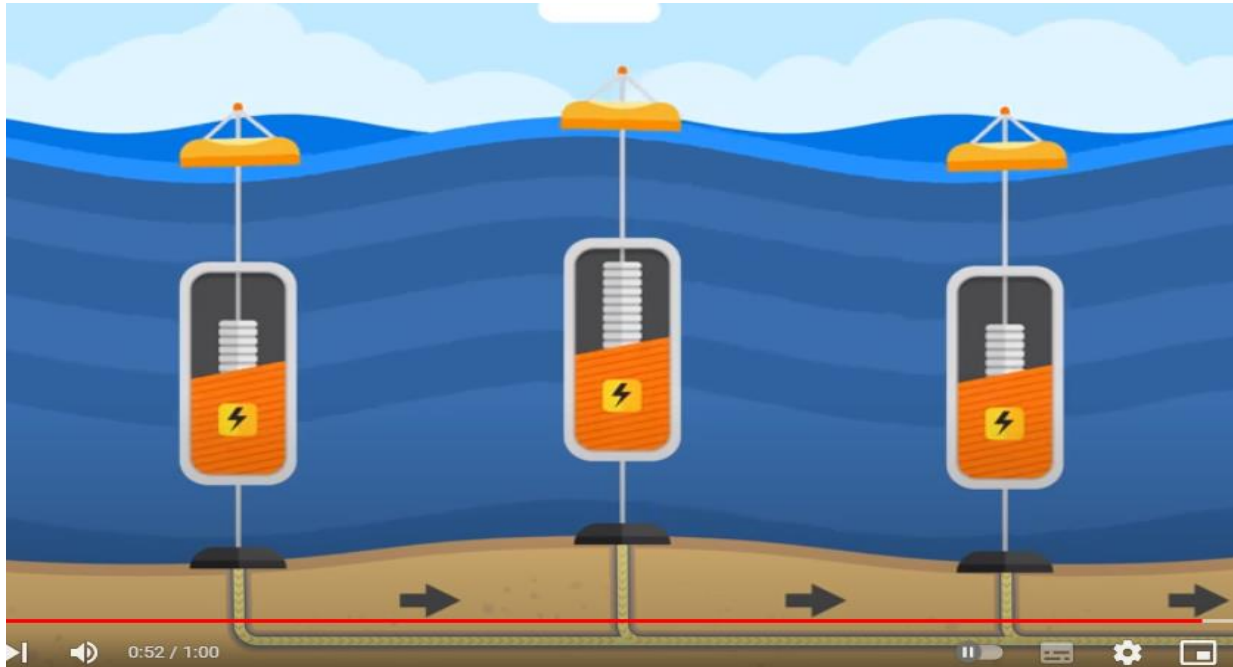
The need to reach Net Zero by 2050 has revised interest in the scheme

The Great Western Power Barrage consortium is raising £10M to develop in-depth plans

A tidal flow scheme would be lower cost!

# WAVE ENERGY

Wave energy can be harvested by the vertical movement of floating units attached to underwater turbines linked to a power cable



Most early wave energy projects failed

The sea is a challenging environment corrosive & rough reducing systems lifetime & increasing operating & maintenance costs

Various technologies are being trialled to find the best way forward

# OFFSHORE HYBRID PLATFORM

## Concept Design

Platform supporting a combination of Wave, Wind, Tidal Streaming & Solar for various sites & application

Quickly installed at remote sites on Lakes, rivers & coastal regions

Based on modular designs allowing expansion as necessary

Incremental cost spend



Lifting rods connected to the main structure allow floats to move up and down

The system is connected to a bi-directional power generator