

USING AI TO FIGHT CLIMATE CHANGE

Ian Hawker

AI is a powerful tool to help us MITIGATE & ADAPT to climate change:

Resource Management
x3 sustainable rate

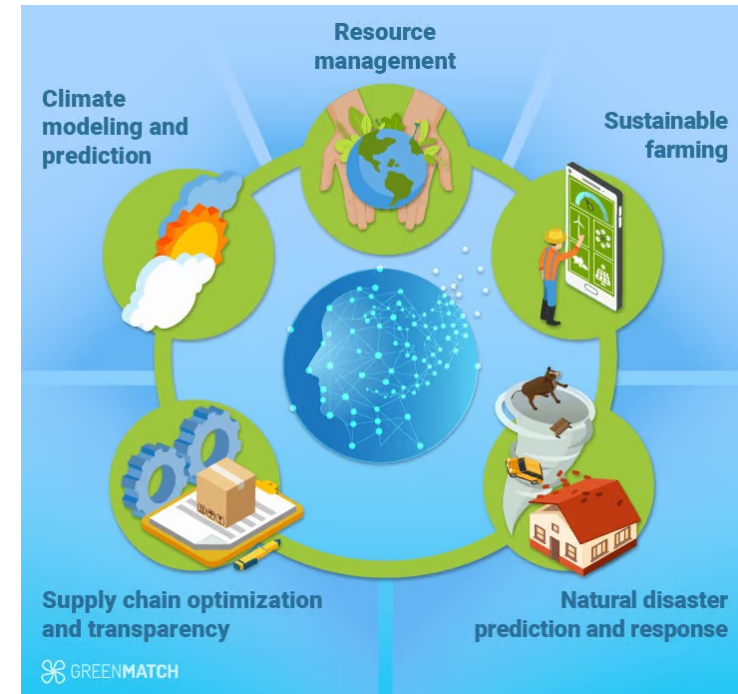
Reduce Emissions Across Market Sectors

Lower Carbon Footprint

Climate Change Forecasting

Extreme Weather Events

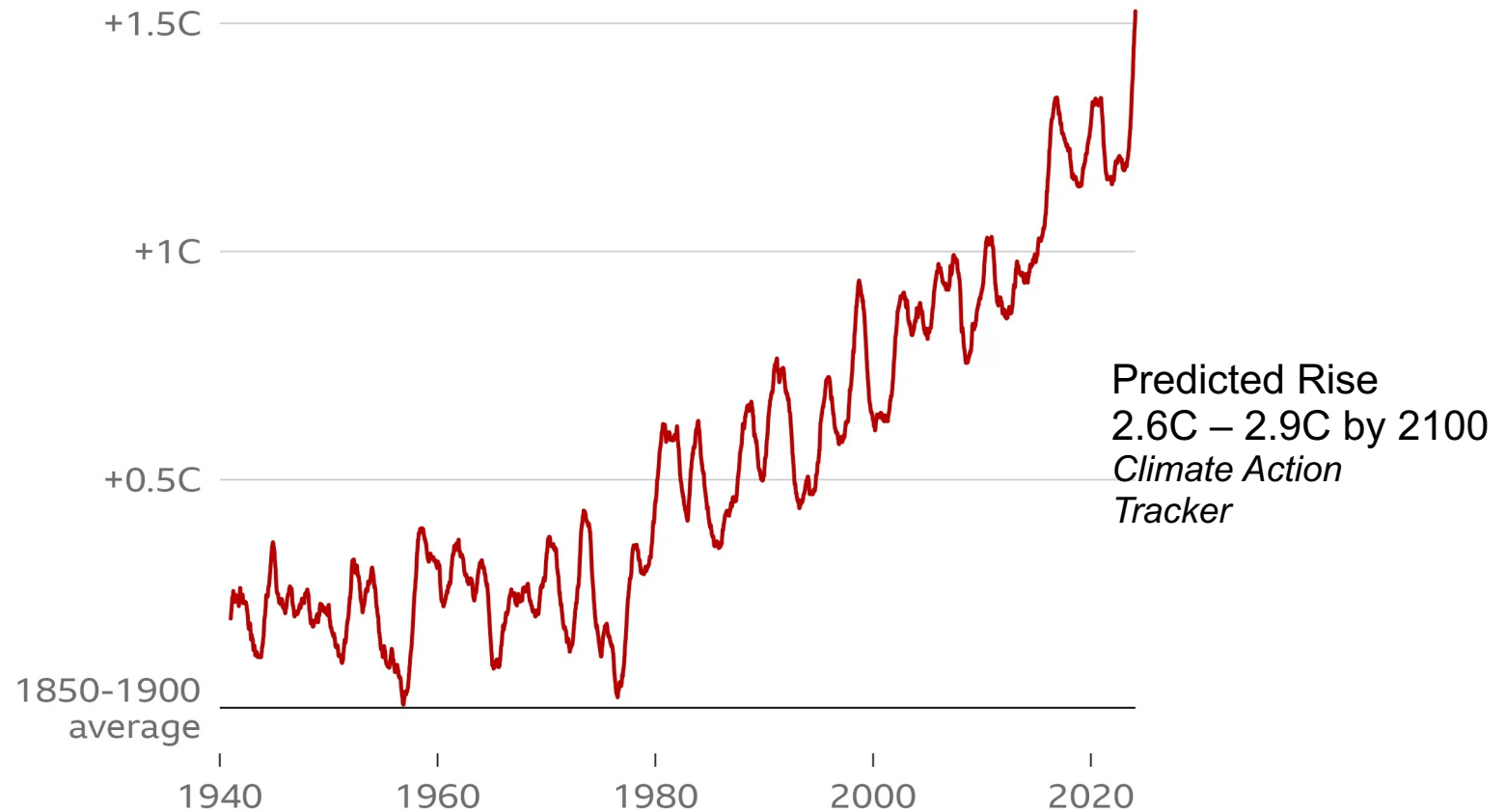
Geoengineering Future Climate



GLOBAL AVERAGE TEMPERATURE

Temperature rises pass 1.5C for full year

Average global air temperature compared with pre-industrial levels, running average of 365 days

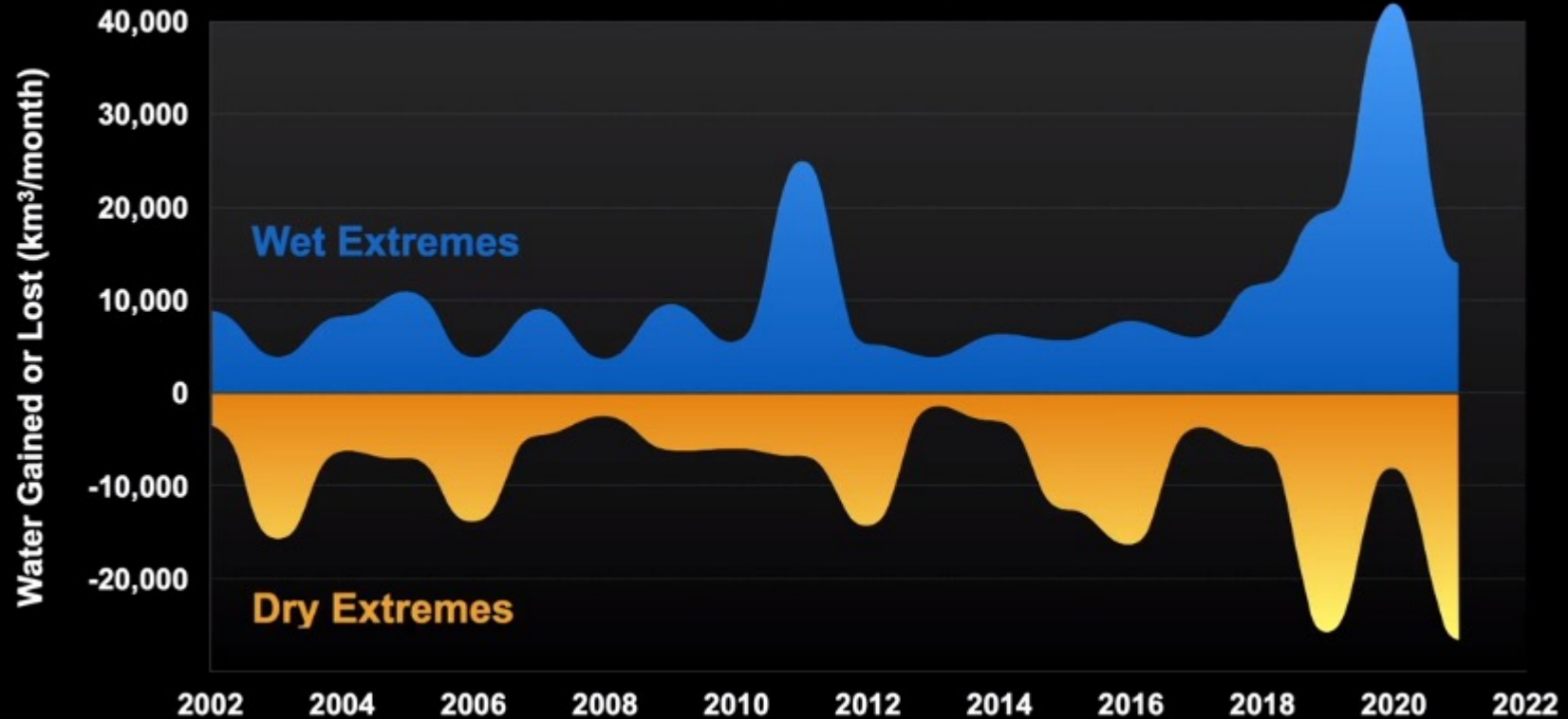


Source: ERA5, C3S/ECMWF

EXTREME WEATHER - RAINFALL & DROUGHTS

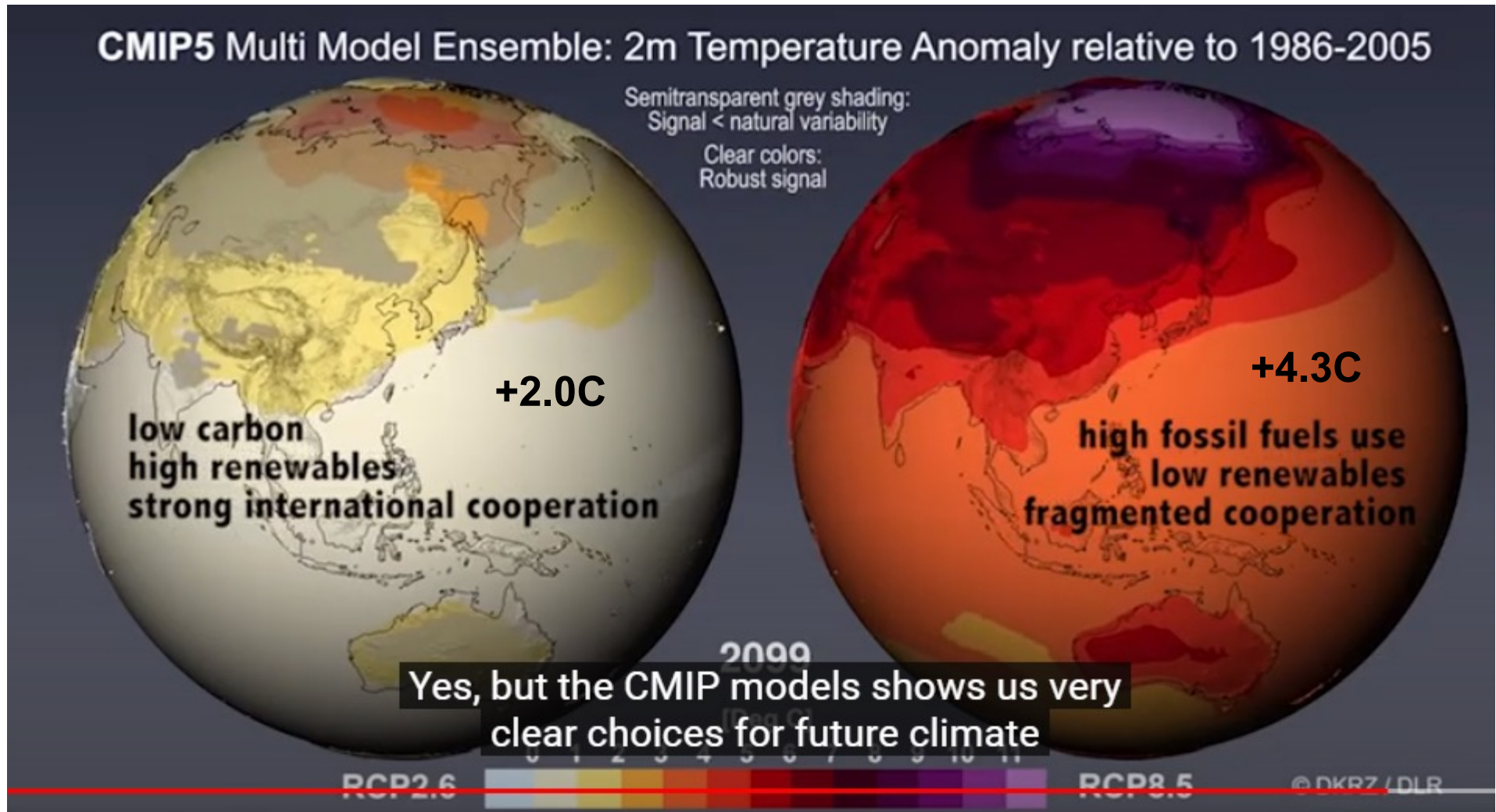
Global Intensity of Extreme Rainfall And Droughts

2002 – 2021



Data: Rodell, M., Li, B. "Changing intensity of hydroclimatic extreme events revealed by GRACE and GRACE-FO." *Nature Water* 1, 241–248 (2023)

COMPUTER MODEL TEMPERATURE RISE PREDICTIONS 2100



CLEAR CHOICES FOR FUTURE CLIMATE

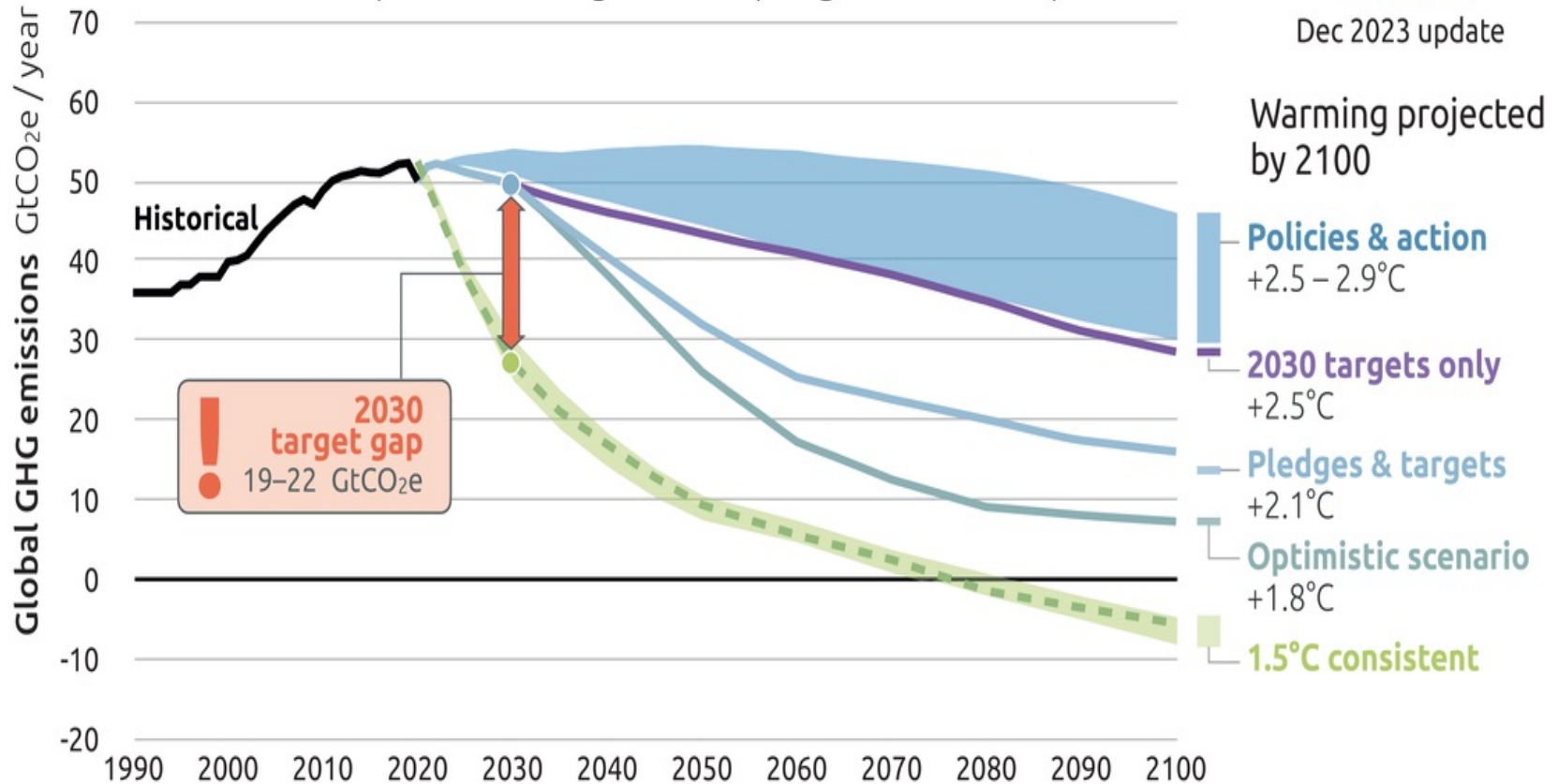
GLOBAL WARMING

2100 WARMING PROJECTIONS

Emissions and expected warming based on pledges and current policies



Dec 2023 update



GLOBAL CLIMATE MODEL PREDICTION 2100+

Predicted global average temperature rise ~3C



Increased desertification

Water Supply

Food Production

Mass migration

Extreme weather

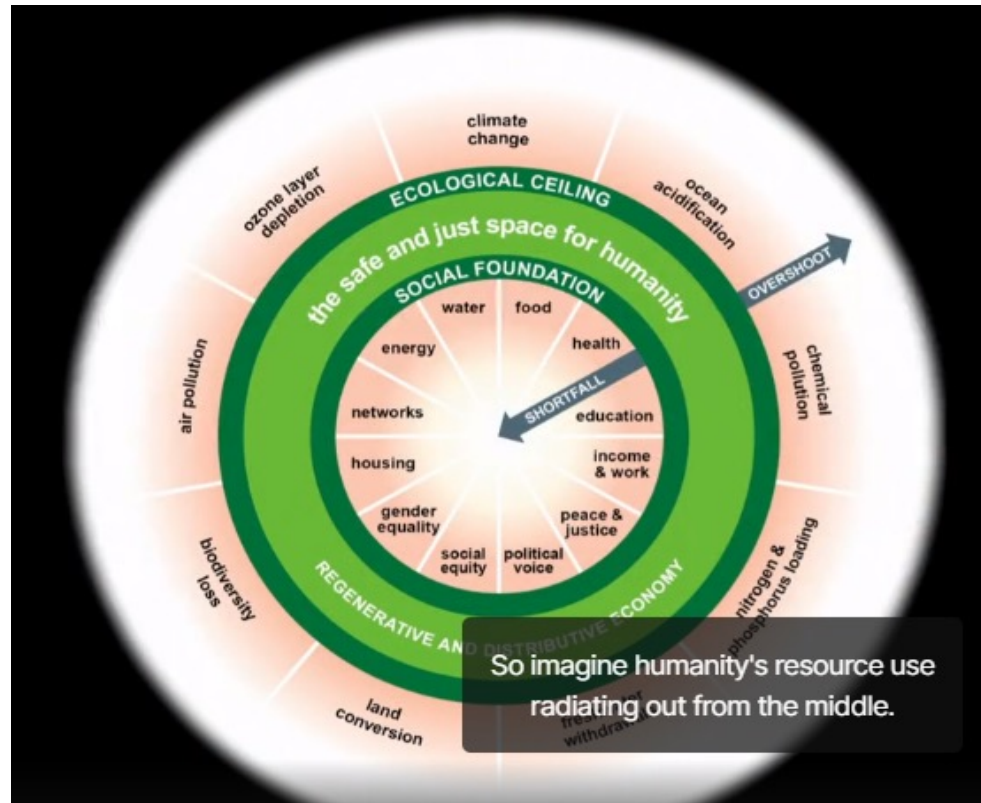
Coastal Flooding

Coastal cities move inland

USE OF EARTHS RESOURCES

Current use of resources is about x3 sustainable limits

Producing climate change, pollution & loss of biodiversity



Better resource management using AI will help keep us below our sustainability limits

COLLECT & ANALYSE THE DATA

Satellite Image Analysis:

Satellite imagery tracks trends in deforestation, melting ice caps, changing land cover *Aqua, Aura, Terra, Copernicus, Sentinel*

Land/Ocean Sensor Networks:

Analyse sensor data from oceans, forests, and urban environments to identify underlying trends & mechanisms

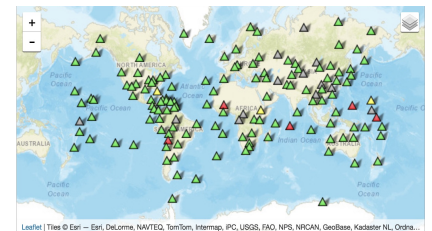
Analysis:

AI recognizes patterns in satellites & ground sensor data
Help understand climate change mechanisms
Improve planning & resource management

Monitor global seismic activity

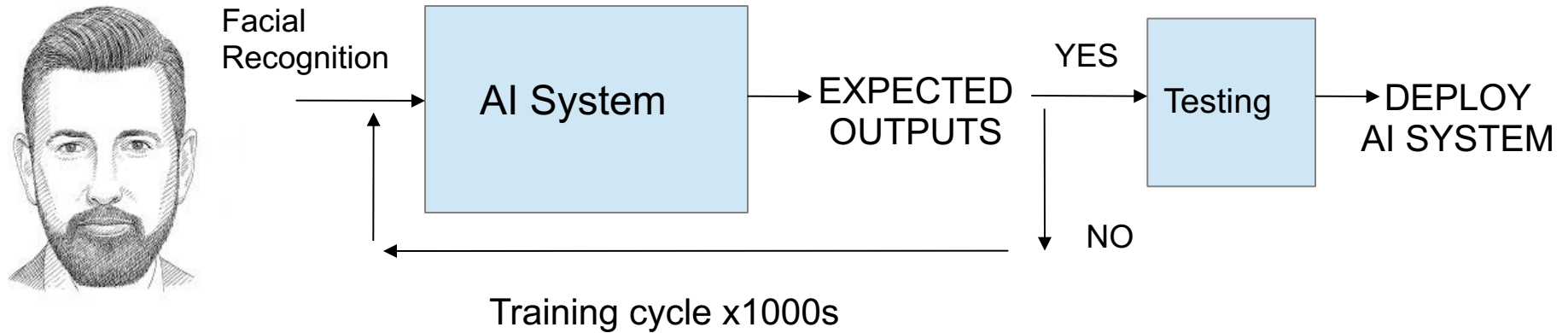
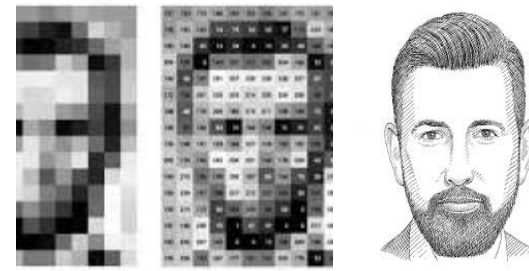
The Global Seismographic Network is made up of over 150 seismic stations

Identify patterns giving early warnings of earthquakes



AI TRAINING

Train the AI on 1000's records (supervised learning)



Compare AI system outputs with expected outputs

Adjust the internal parameters algorithms/neural network to reduce the error

The trained working AI system can now make predictions from similar input data

Add software constraints to ensure the AI systems receive clean data & solutions obey physical laws

AI TECHNOLOGY IS GETTING FASTER

AI is getting better faster

AI capability increasing x2 every 2 years (Moors law)

In 10 years AI Capability x 30

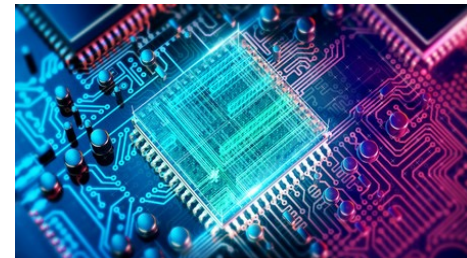
In 20 years AI Capability x1000

In 30 years AI Capability x 10,000 (Quantum Computing)

AI uses algorithms and/or neural networks trained on 'Big Data'

AI algorithms are computer programmes that tell the system how to operate on its own & self improve

Neural networks build interconnections to perform a specific range of task & learn
Resembles the human brain

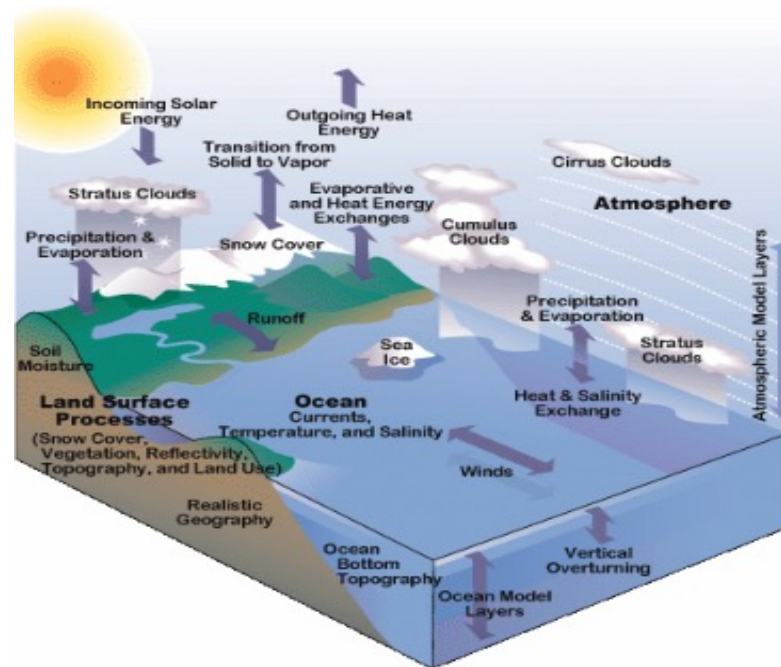


PREDICTING WEATHER & CLIMATE

Weather is short term atmospheric changes

Climate is long term trends

Both involve complex interactions between multiple systems



Predictions made by solving mathematical equations involving energy, ocean, atmosphere & land

This is slow & uses simplifying assumptions

SOLVING THE EQUATIONS

Numerical solution of complex equations on super computers

Basic Equations



Conservation of momentum:

$$\frac{\partial \vec{V}}{\partial t} = -(\vec{V} \cdot \nabla) \vec{V} - \frac{1}{\rho} \nabla p - \vec{g} - 2\vec{\Omega} \times \vec{V} + \nabla \cdot (k \nabla \vec{V}) - \vec{F}_d$$

Conservation of energy:

$$\rho c_p \frac{\partial T}{\partial t} = -\rho c_p (\vec{V} \cdot \nabla) T - \nabla \cdot \vec{R} + \nabla \cdot (k \nabla T) + C + S$$

Conservation of mass:

$$\frac{\partial \rho}{\partial t} = -(\vec{V} \cdot \nabla) \rho - \rho (\nabla \cdot \vec{V})$$

Conservation of H₂O (vapor, liquid, solid):

$$\frac{\partial q}{\partial t} = -(\vec{V} \cdot \nabla) q + \nabla \cdot (k \nabla q) + S_q + E$$

Equation of state:

$$p = \rho R_d T$$

$\vec{V}$ = velocity

T = temperature

p = pressure

ρ = density

q = specific humidity

$\vec{g}$ = gravity

$\vec{\Omega}$ = rotation of earth

$\vec{F}_d$ = drag force of earth

$\vec{R}$ = radiation vector

C = conductive heating

c_p = heat capacity, const. p

E = evaporation

S = latent heating

S_q = phase-change source

k = diffusion coefficients

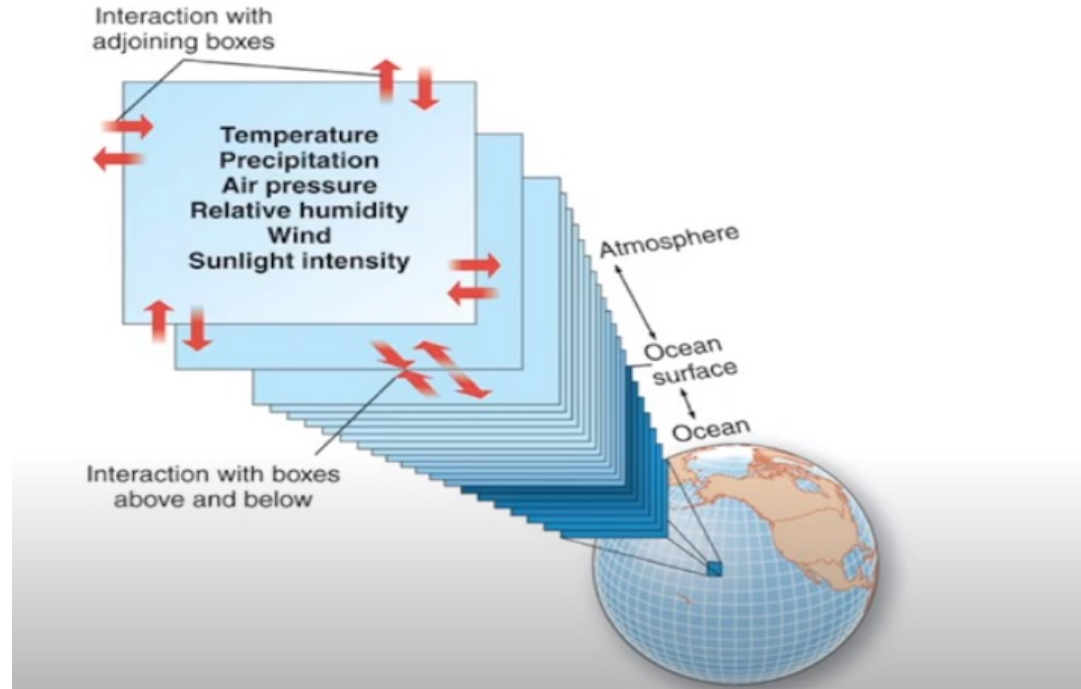
R_d = dry air gas constant

720 x 540

It is slow and complex limiting the number of simulations possible

CLIMATE MODELLING METHOD

Divide the atmosphere into grid boxes extended vertically & horizontally



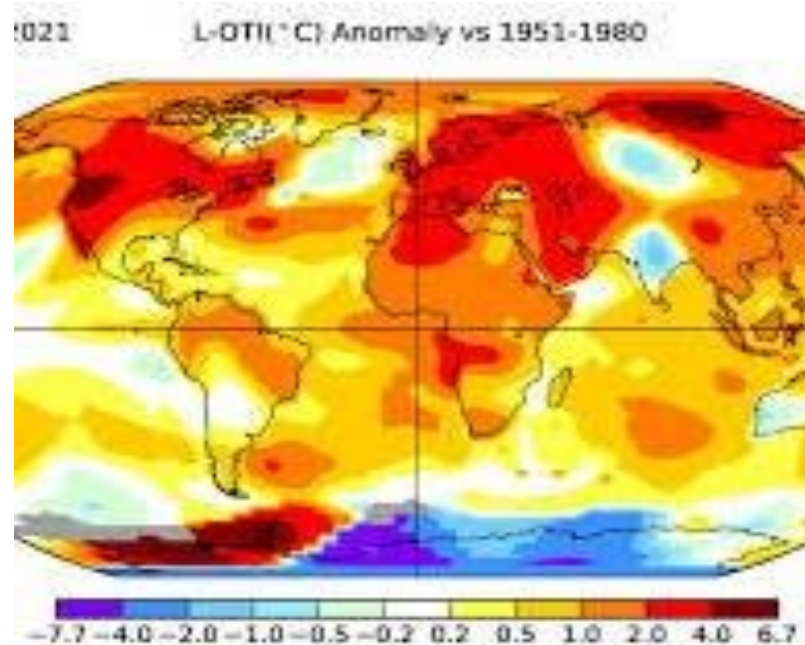
Apply the laws of physics

Compute the variables for each location

Analyse the results

AI SIMPLIFIES THE CLIMATE MODELS

AI enhanced models reduce computation time & produce faster forecasts



The models are trained on data from weather stations, satellites, and radar

AI algorithms/neural nets sift through the data and identifies the patterns

The patterns are used to produce forecasts much faster than traditional methods

Faster simulation times enables multiple scenarios to be explored improving accuracy

AI CLIMATE MODELS

Climate predictions to 2100 using the QuickClim climate emulator

Close match achieved to full physics based climate predictions

QuickClim is one million times faster!

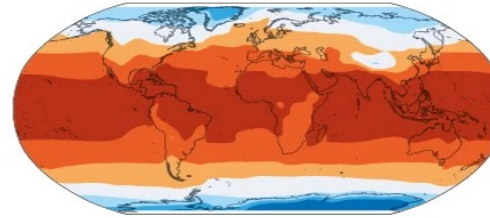
Aim is to create digital models of Earth's systems using AI

Simulate all aspects of the weather and climate down to kilometre scales

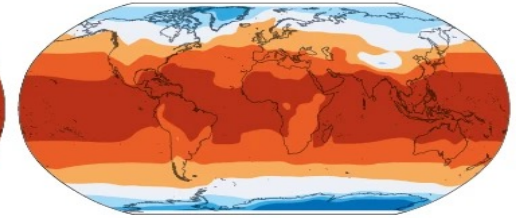
AI CLIMATE MODEL WORKS AT SPEED

In projections of global surface air temperature up to the year 2100, output from the QuickClim climate emulator (right), a machine-learning system, closely matches that of the physics-based climate model it is trained on (left). However, QuickClim generates the output about one million times faster.

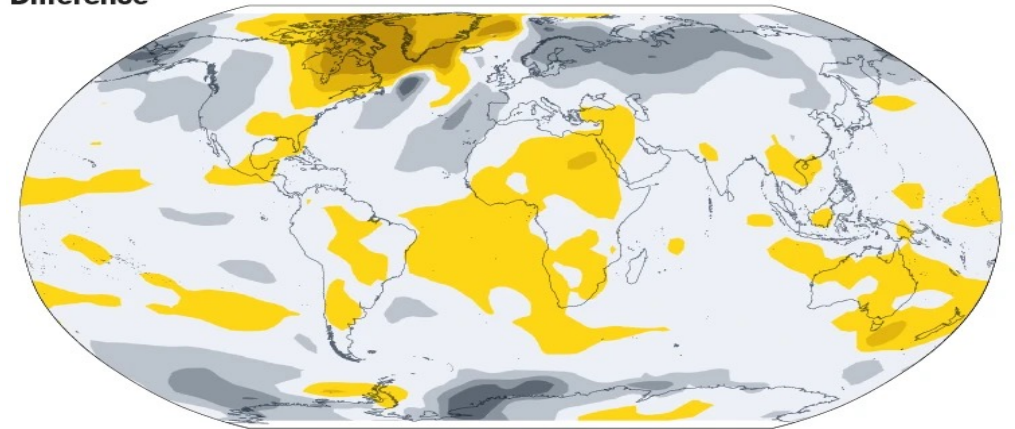
Physics-based model



AI-based emulator



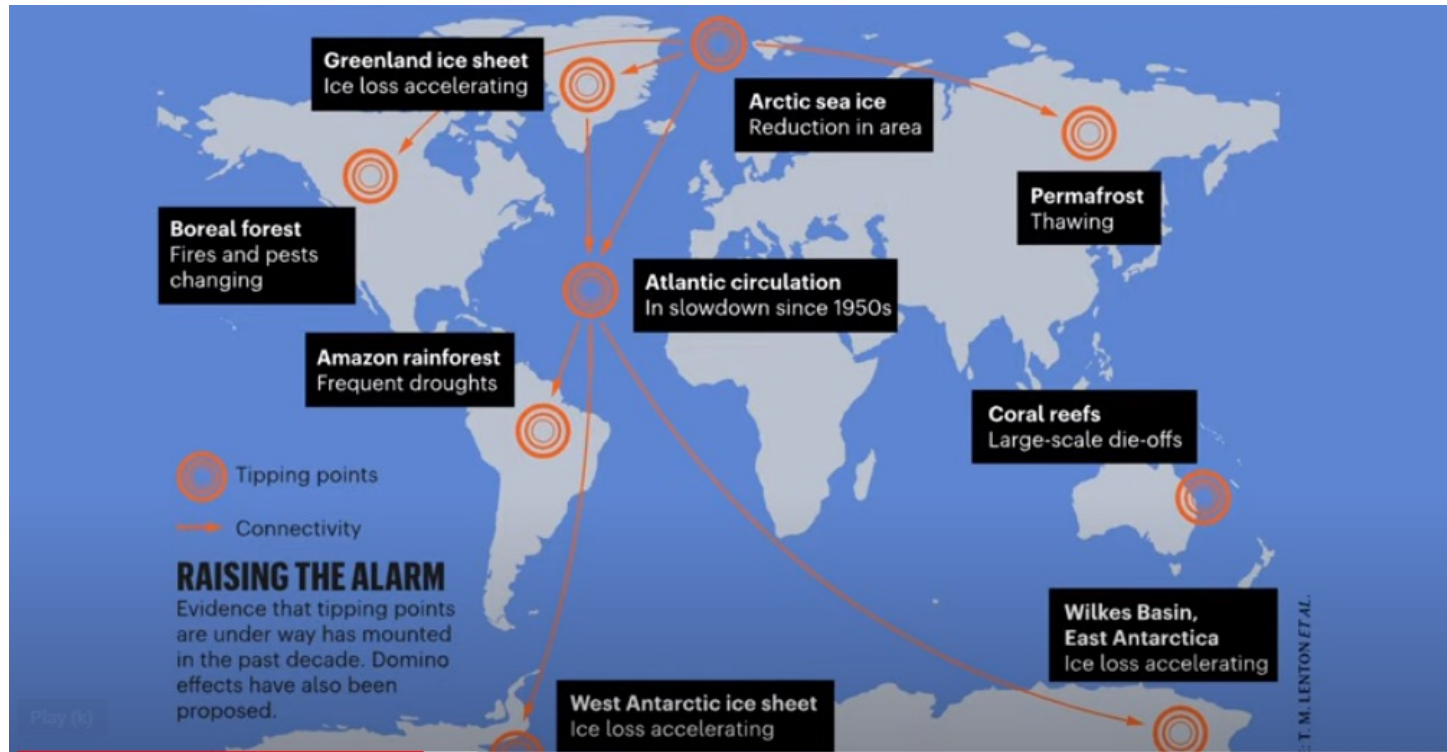
Difference



COMPLEX CLIMATE SYSTEMS

Warming the planet beyond a Tipping Point flips the climate into a new irreversible state

There are 16+ tipping points and 5 are already passed

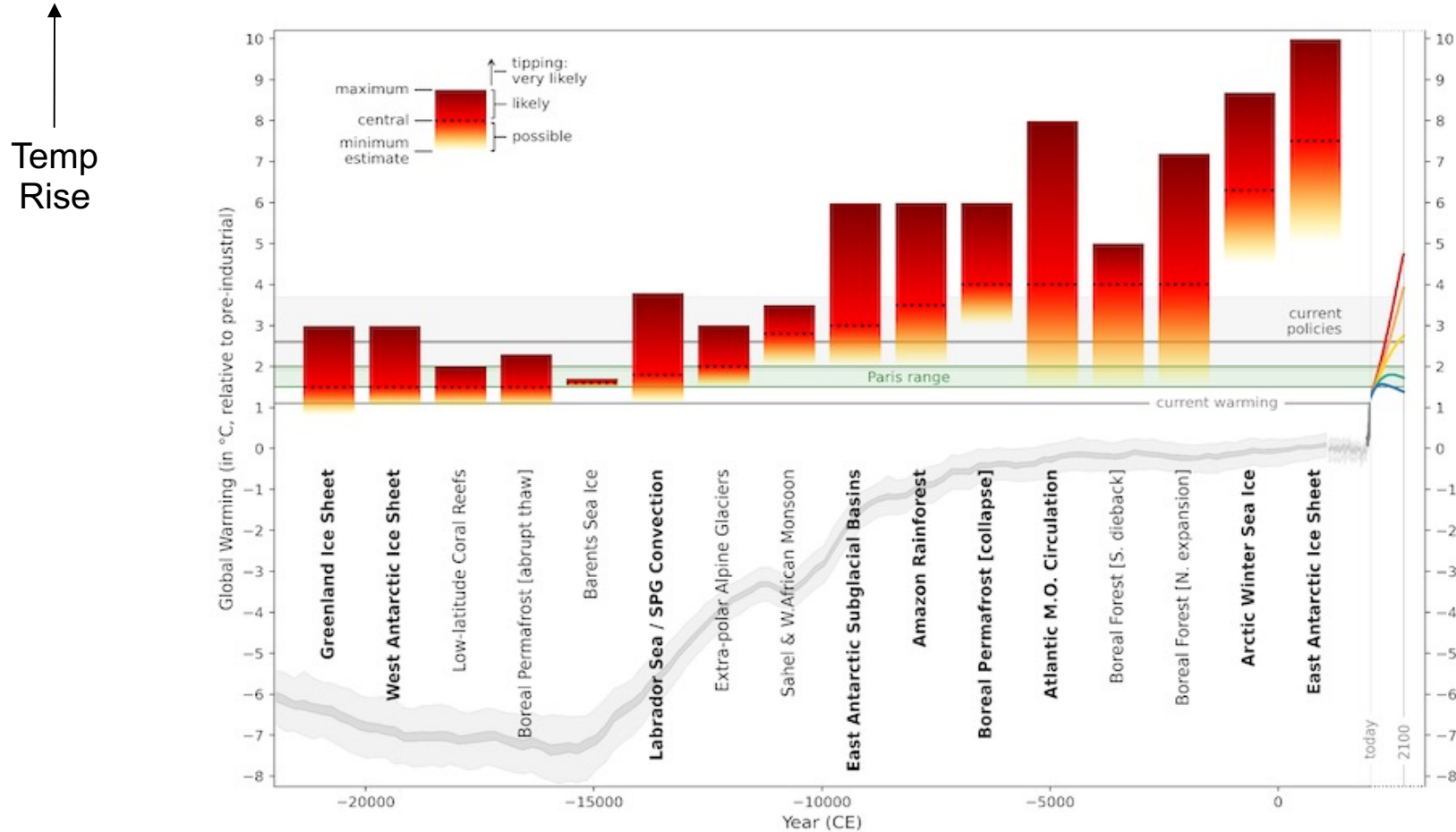


AI enhanced climate models help us understand tipping points

Predict when tipping points will be reached

CLIMATE TIPPING POINTS

16 Tipping Points



Human-caused warming of 1.3°C means 4 tipping points already reached

Climate modelling indicates a 3°C rise would trigger most of the remaining tipping points

THE MET OFFICE IS USING AI

The Met Office is actively using AI to improve its climate modelling.

Collaboration:

The Met Office has partnered with research institutions including *The Alan Turing Institute* to develop AI models for weather forecasting & understanding & predicting extreme weather events

New Techniques:

They're exploring the use of neural networks to analyse weather patterns and improve the accuracy of forecasts

Data Expertise:

The Met Office has a rich archive of meteorological data and expertise in weather science. This data is crucial for training and developing AI models for climate modelling.

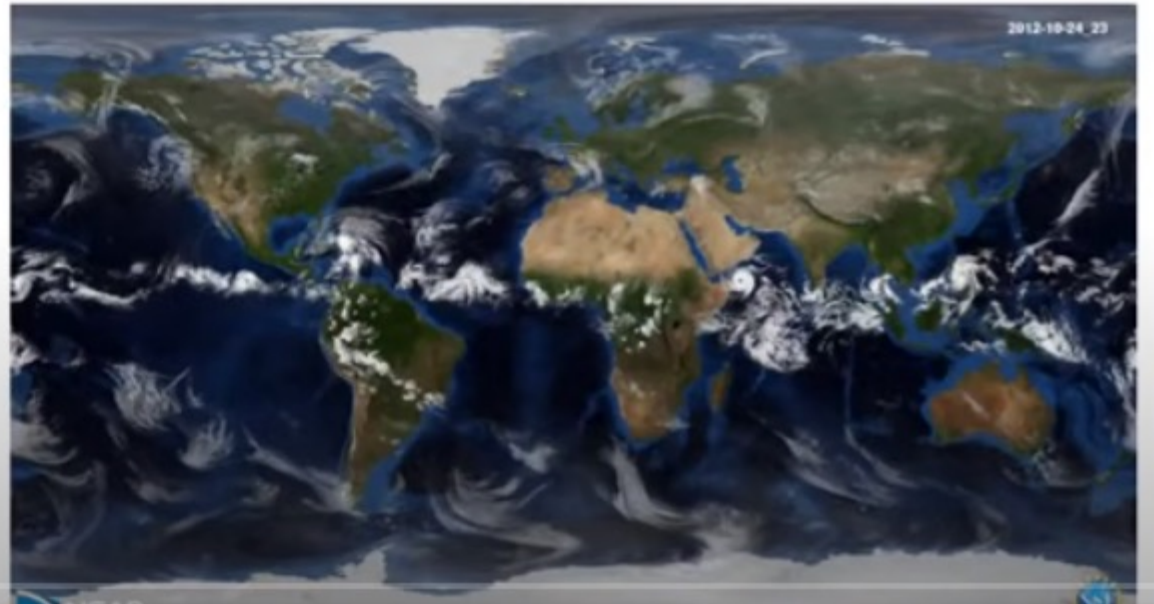
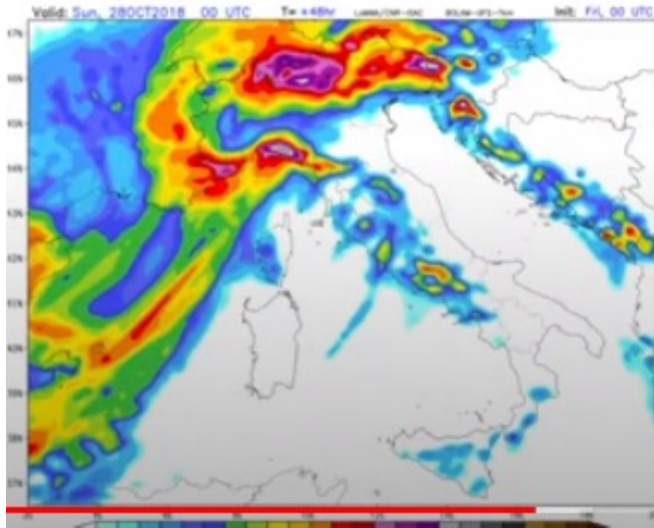
EXTREME EVENT MODELLING USING AI

AI enhanced modelling enables faster & more accurate prediction of extreme climate events

What are the signs? When will they occur? How often will they occur?

How intense will they be? What is their extent?

AI finds patterns in the data & predicts the outcome



Google DeepMind AI tool predicted where hurricane Lee would make landfall in Canada three days ahead of existing methods

AI MODELLING TO OPTIMISE USE OF AGRICULTURAL LAND

AI enhanced modelling improves our understanding of the complex relationships between agriculture, land use & environment.

Helps develop sustainable agricultural practices & improved food security against climate change



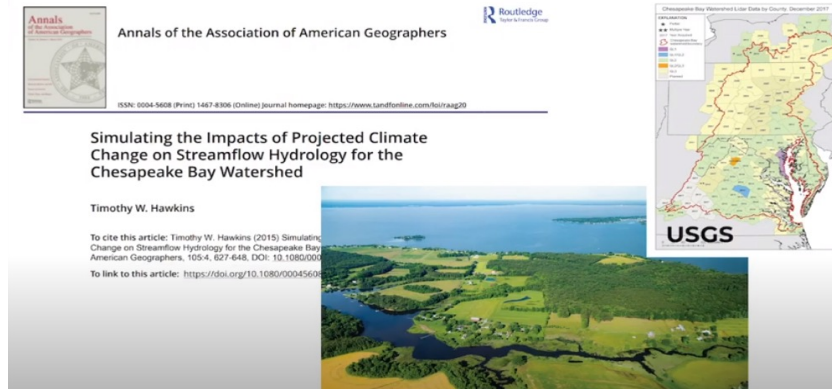
Optimize Crop Yields: Model agricultural practices, soil conditions & climate change to identify optimal planting times, irrigation levels & fertilization strategies

Predict Food Shortages: Analyse land degradation, extreme weather events, pest outbreaks & supply chains & enable proactive interventions

Reduce Greenhouse Gas Emissions: Evaluate the carbon footprint of different agricultural practices and identify strategies for reducing emissions

AI MODELLING OF WATER SUPPLY, ENVIRONMENT & INFRASTRUCTURE - Impact of climate change

Impact on Water Supply



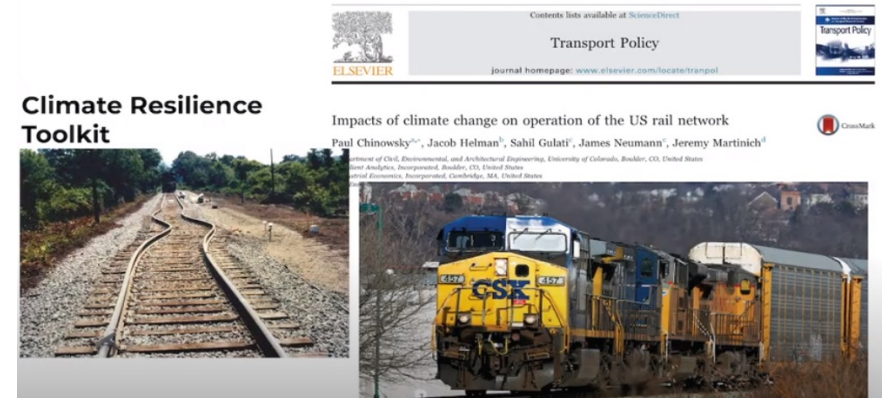
Impact On Agriculture



Impact On Environment



Impact On Infrastructure

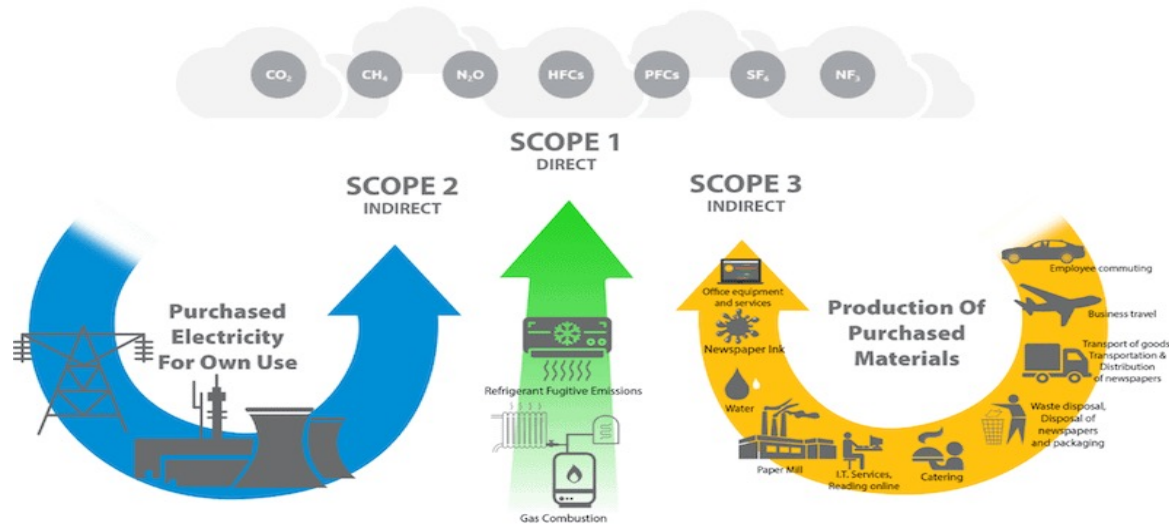


REDUCING EMISSIONS USING AI

Type 1 Direct emissions from sources that are owned or controlled by an organization

Type 2 Indirect emissions associated with the purchase of electricity, heat, or cooling

Type 3 Indirect emissions along the entire value chain of a company's operations

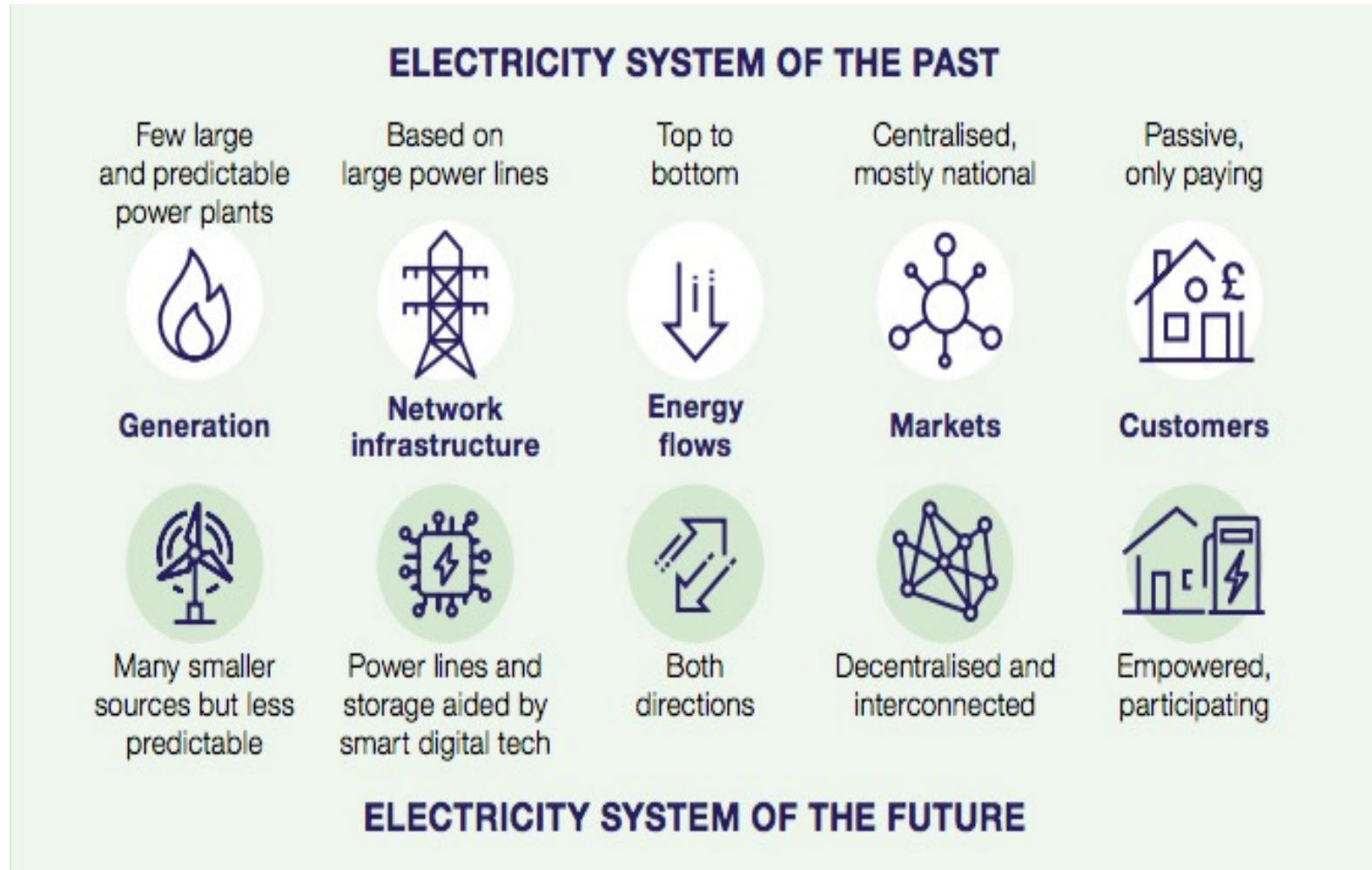


By understanding all 3 types of emissions governments & companies can develop strategies to reduce their overall environmental impact

AI can analyse the data, optimize & improve the solutions over time

AI CONTROLLED ENERGY NETWORK

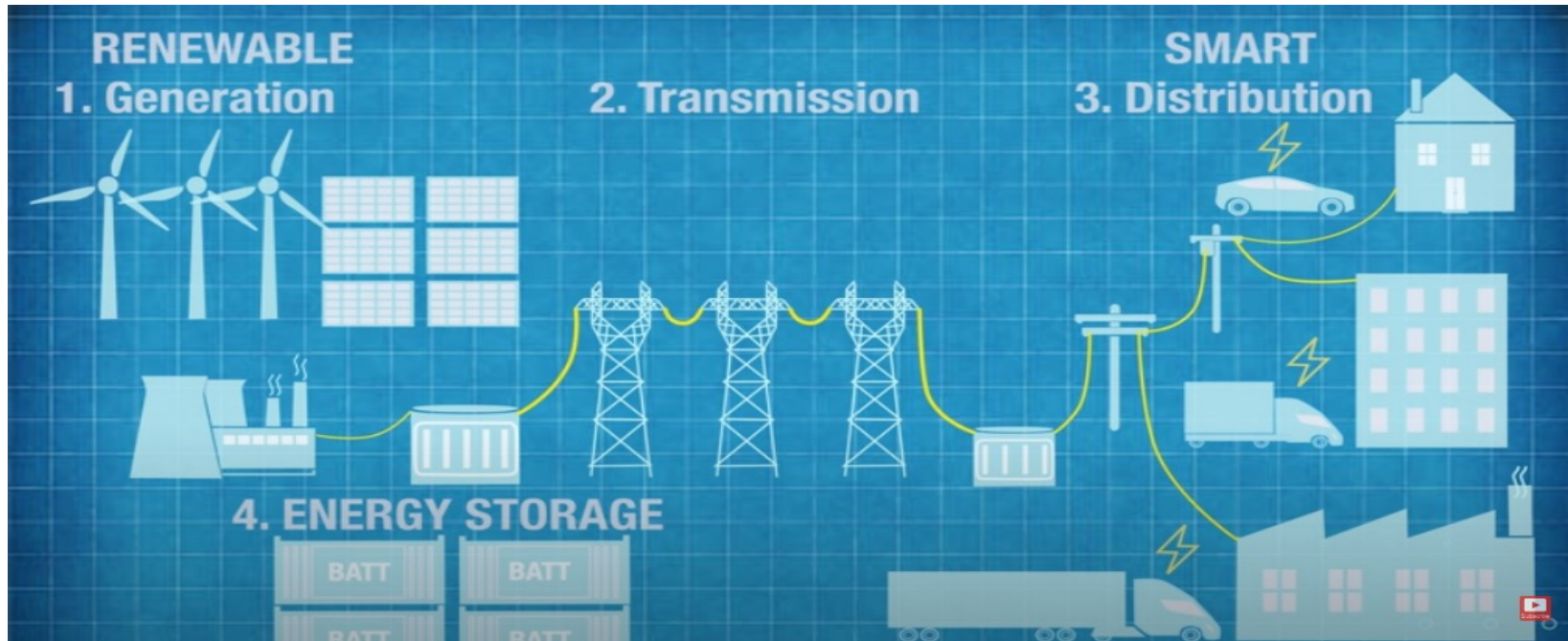
Optimise Use Of Energy Resources & Reduce Emissions



Upgrade cost >£50 billion

AI ENHANCED ENERGY NETWORK

Smart energy distribution & storage



Multiple energy sources
Organic growth

Energy storage
Bi-directional flow

Decentralised control
Resilience

AI analysis of real-time energy demand & forecasting

AI balanced power grids to optimize use of renewable energy

AI ENHANCED TRANSPORT NETWORK

Traffic Management Systems:

AI algorithms analyse traffic patterns and optimize traffic flow,
Reduce congestion, fuel consumption & emissions

Self Drive vehicles:

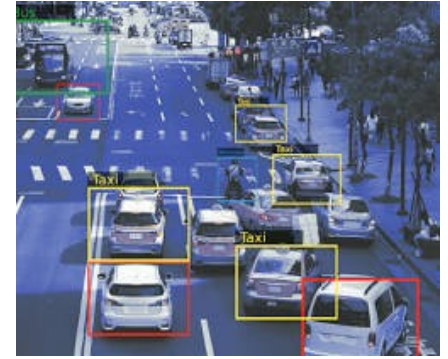
AI plan routes on passenger request
AI uses radar & laser sensors to avoid obstacles
AI vehicles learn & pool experiences
AI control systems updated remotely

Challenges:

Comms Infrastructure
Road & weather conditions
Minor road comms
New situations
Accident liability

Benefits:

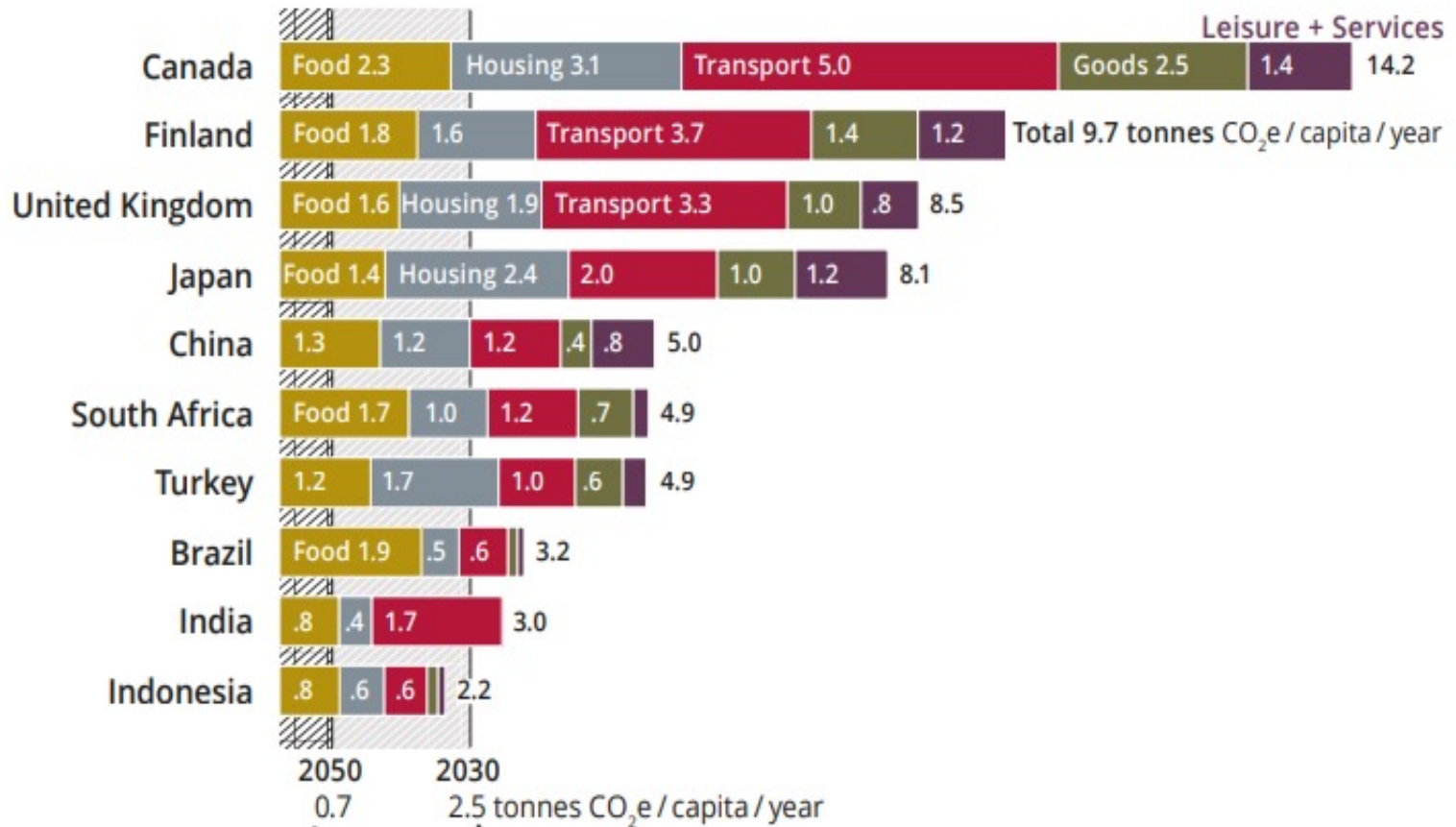
Reduced accidents
Zero driving skill required
Mobility for all
Real time vehicle monitoring of road surfaces



INDIVIDUAL CARBON FOOTPRINT

CO₂e/capita/year

Average annual carbon footprint tonnes CO₂e per year by sector



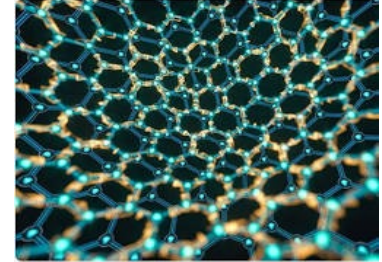
Target 3 tonnes by 2030 & 0.7 tonnes by 2050
Embedded AI in systems helps reduce emissions

AI & GREEN TECHNOLOGIES

Material Science

AI can predict the properties of new materials, reducing the need for physical testing and enabling faster development.

AI can streamline manufacturing processes to minimize waste and energy consumption



Regenerative Agriculture

AI to optimise use of energy, water & natural fertiliser

Maintain cover crop to keep carbon & moisture in the ground

AI analysis of images & sensor data to identify crop diseases & pests,

Enable targeted interventions reducing reliance on harmful pesticides.



Smart Homes

Reduction of household waste and automated recycling

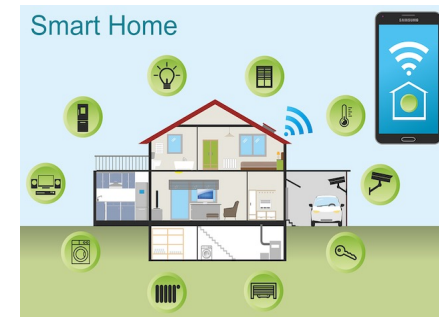
Robotic sensing & cleaning

Solar panel maintenance

Intelligent fridge communicates with the delivery van

Security using facial recognition

Optimize heating, lighting, and cooling systems, minimizing energy consumption



ADAPTING TO CLIMATE CHANGE

AI will help us use our resources more effectively in a hotter climate

<u>Top 8 Risks</u>	2020	2050	2100	<u>Impact</u>
Risks to diversity of land & freshwater habitats				Continued decline in animal & plant biodiversity
Risks to soil health from flooding & drought				Pressure on agriculture especially in SE England
Risks to natural carbon stores bogs & forests				Essential to achieve Net Zero
Risk to crops & live stock due to frequent drought				Reduced food supply & Increased prices
Risks to industry supply chains				Increased cost of goods & services
Risk to power supply due to more extreme weather				Power outages
Risks to human health due to overheating				x3 heat related deaths by 2050 2,000 to 7,000 each year
Risk to imports				Supply of overseas goods become less reliable

FIXING THE CLIMATE?

Having trashed the Earth's atmosphere we may wish to fix it!

Excess carbon dioxide remains in the atmosphere for thousands years

Geoengineering is the deliberate large-scale intervention in the Earth's natural systems

The two principle geoengineering methods are massive CO2 removal & reflection of solar energy back into space

AI enhanced modelling enables benefits & risks of geoengineering interventions to be assessed

Understand how these techniques should be applied

Geoengineering research has expanded significantly over the past 5 years

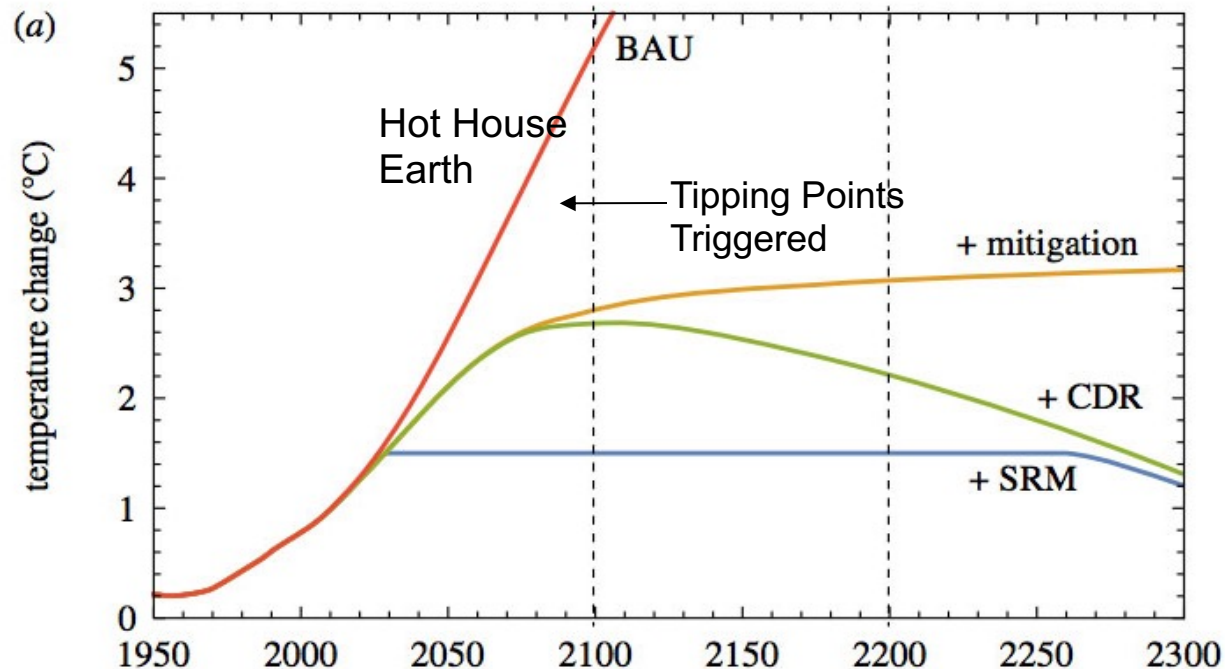
The White House has begun a five-year research programme into “climate interventions”

BENEFITS OF GEOENGINEERING THE CLIMATE

AI enables analysis of climate geoengineering solutions typically CDR and SRM

CDR= Carbon Dioxide Removal

SRM= Solar Radiation Management



The issue is scalability and unexpected consequences

AI analytic methods allow exploration & evaluation of climate fixing scenarios

MASSIVE DEPLOYMENT OF CARBON CAPTURE TECHNOLOGY

x1million

CARBON DIOXIDE REMOVAL METHODS

Direct Air Capture
(DAC)

CO₂



Bioenergy with carbon
capture & storage
(BECCS)

CO₂



Afforestation
Reforestation

CO₂



Biochar
soil carbon

CO₂



Enhanced
Weathering



Ocean
fertilisation

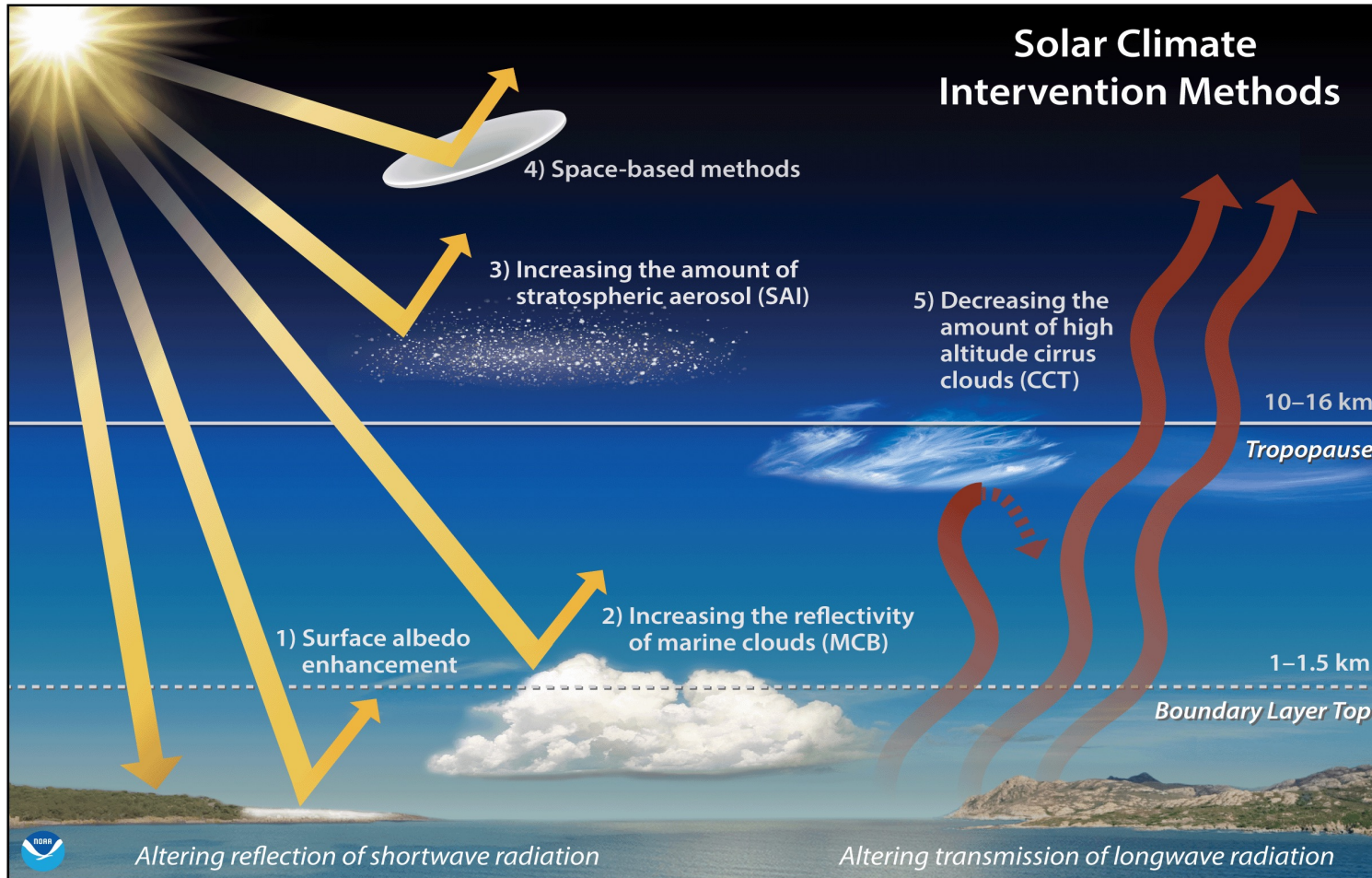


CO₂ STORAGE

dramatic transformations in land use to
draw even more carbon back down into the



SOLAR RADIATION MANAGEMENT



AI enhanced modelling to evaluate the effectiveness of different SRM methods

Explore the risks of SRM on weather patterns & climate (unexpected consequences)



SUMMARY

AI & Climate Change

AI helps us:

Collect & analyse complex climate data

Predict future climate change

Assess methods to mitigate & adapt to climate change

Develop new green technologies

Remember

AI has no understanding - it sees only the data

Erroneous data needs to be filtered

AI comes with its own climate challenges

AI is being used to accelerate oil and gas exploration and extraction

AI power demand increasing carbon footprint 2-3% emissions

Training AI systems needs large quantities of good data (expensive)

But worthwhile!

THE FINAL SOLUTION?

