Department of Meteorology

University of Reading

SCIENCE OF CLIMATE CHANGE

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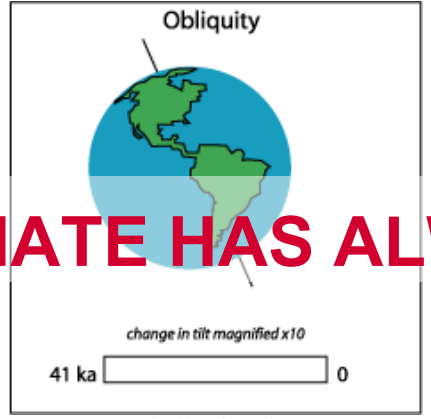
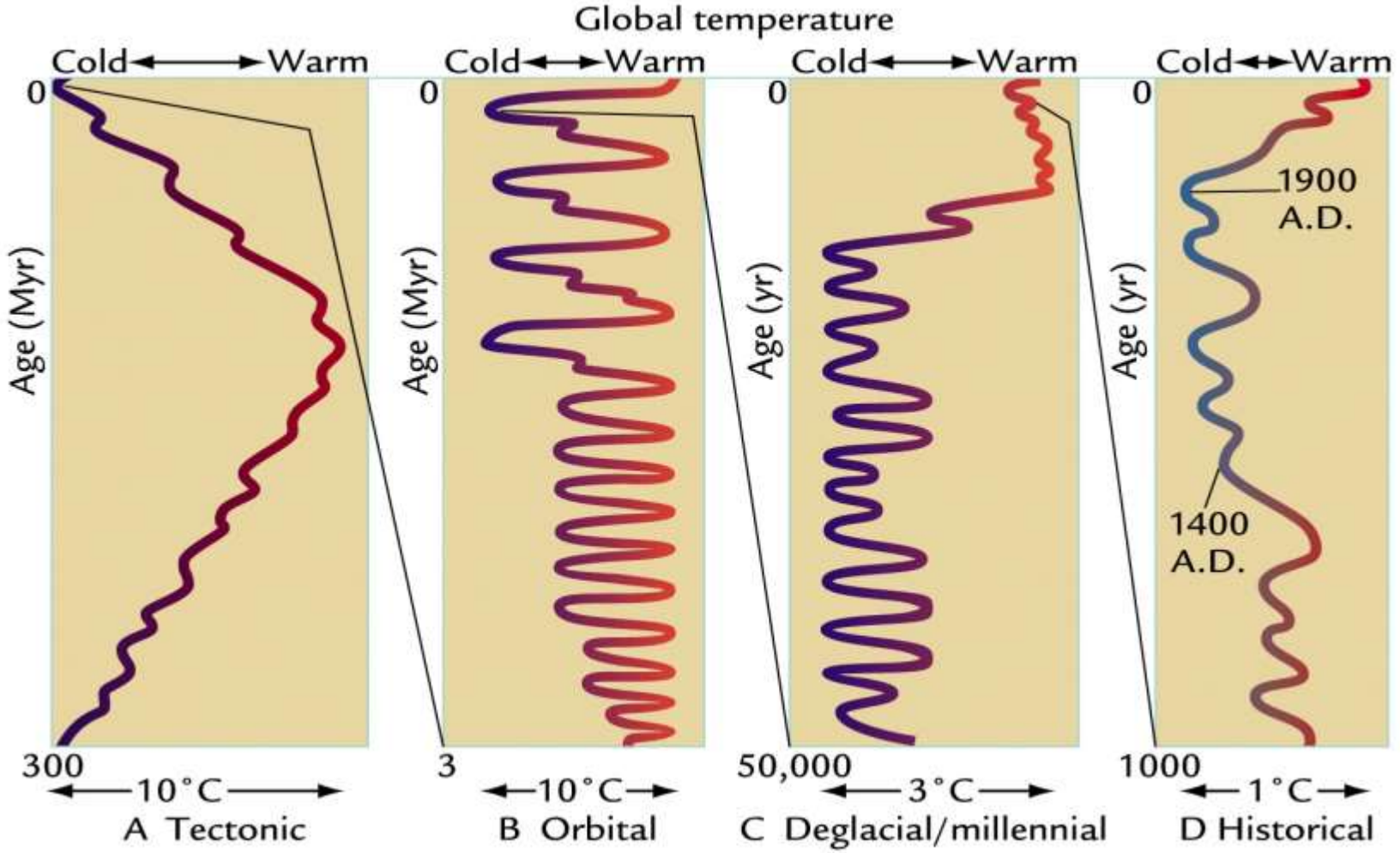
Bohunt School, 7th June 2018

EARTH'S CLIMATE HAS ALWAYS BEEN CHANGING





Ruddiman WF. 2001
Earth's Climate, Past and Future

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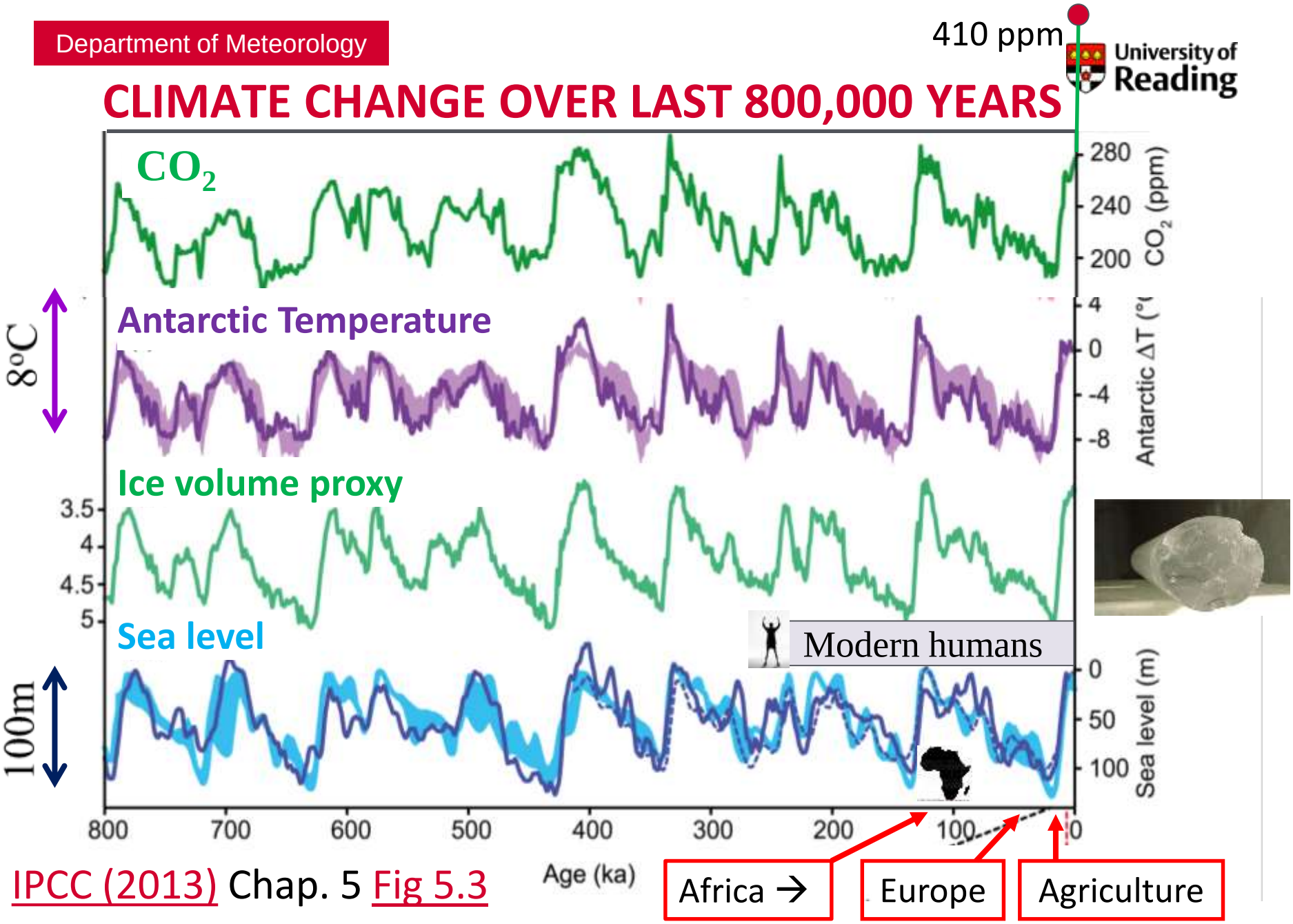
CLIMATE CHANGE OVER LAST 800,000 YEARS



IPCC (2013) Chap. 5 Fig 5.3

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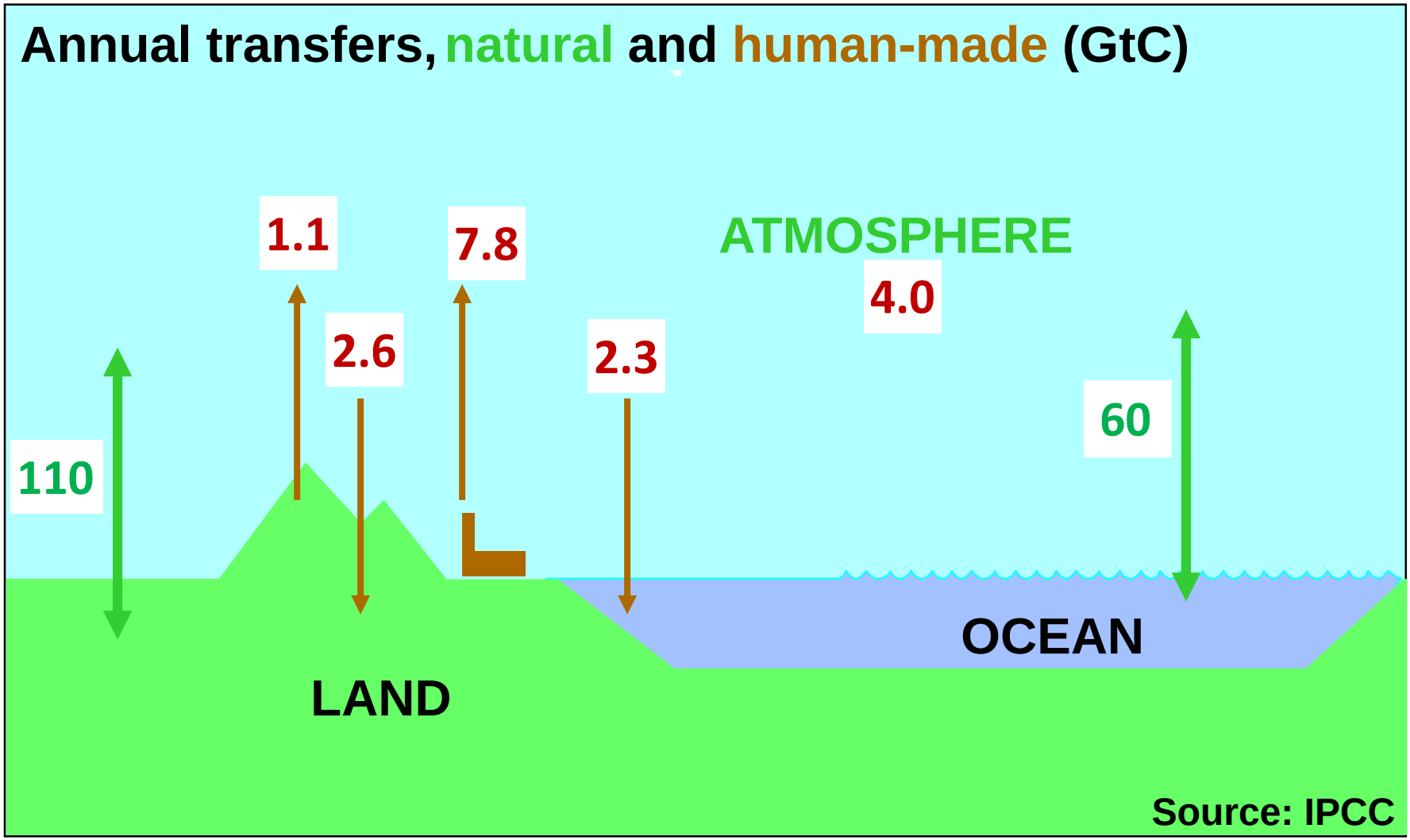
NATURAL & MAN-MADE CARBON CYCLES



Updated values from IPCC (2013) WG1 report Fig. 6.1

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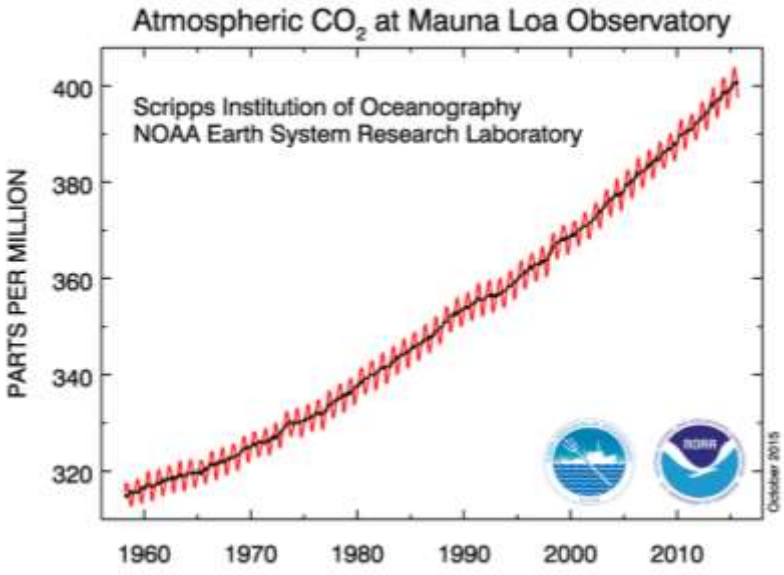
CO_2 EMISSIONS ARE HEATING PLANET

- Increases in greenhouse gases heat the planet by reducing how easily Earth can cool to space through infra-red emission
- More small pollutant "aerosol" particles cool the planet by reflecting sunlight
- More energy is arriving than leaving: Earth is heating up…

Currently energy is accumulating at rate equivalent to every person currently alive using 20 kettles (2kW) each to boil oceans (or about 300 trillion watts) Allan et al. (2014)



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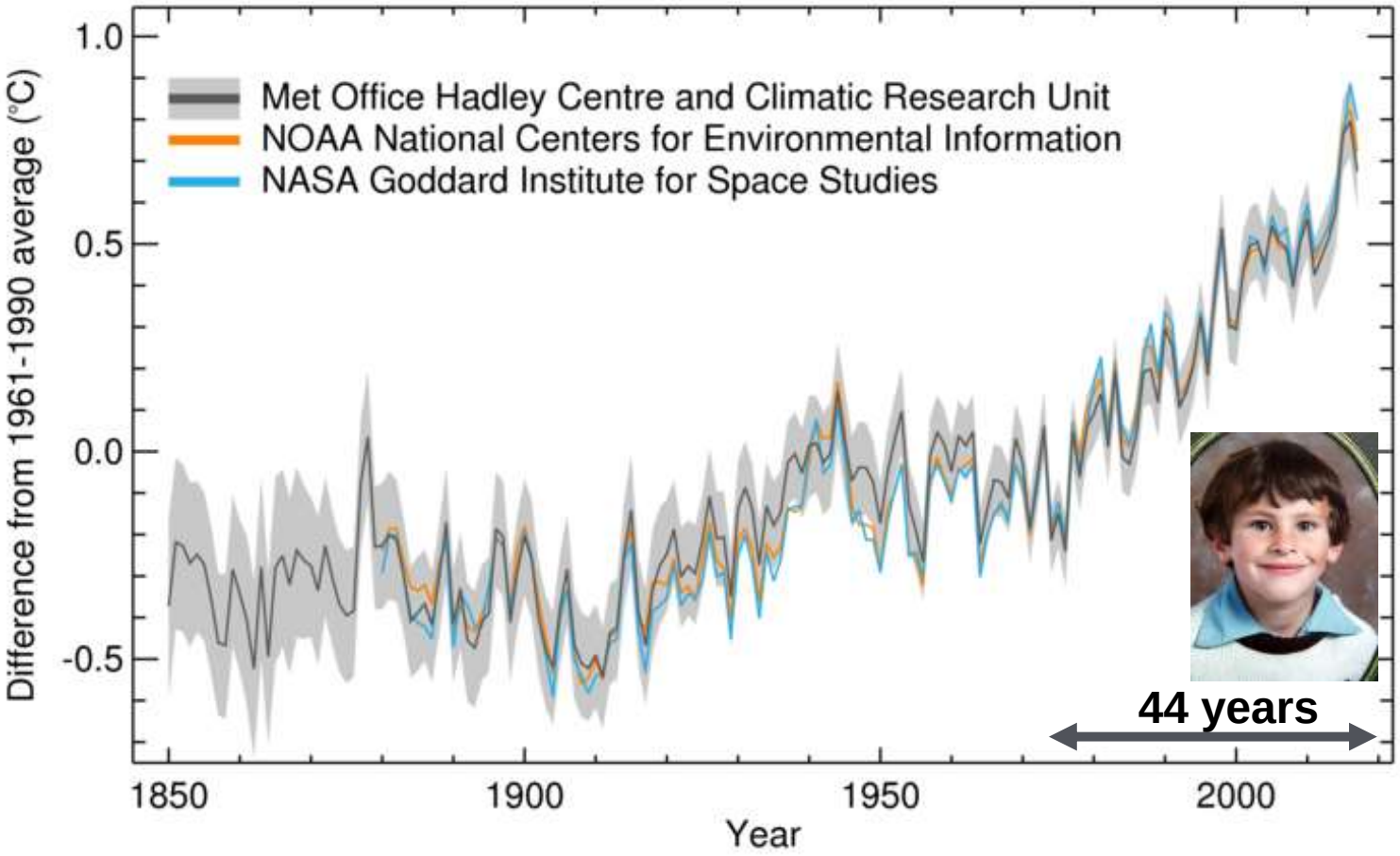
THE PLANET IS WARMING

Met Office

Global average temperature anomaly (1850-2017)



www.metoffice.gov.uk/research/monitoring/climate/surface-temperature

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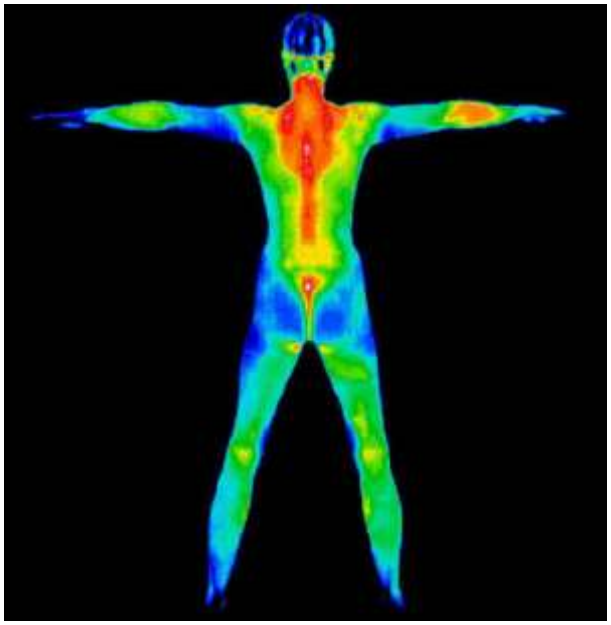
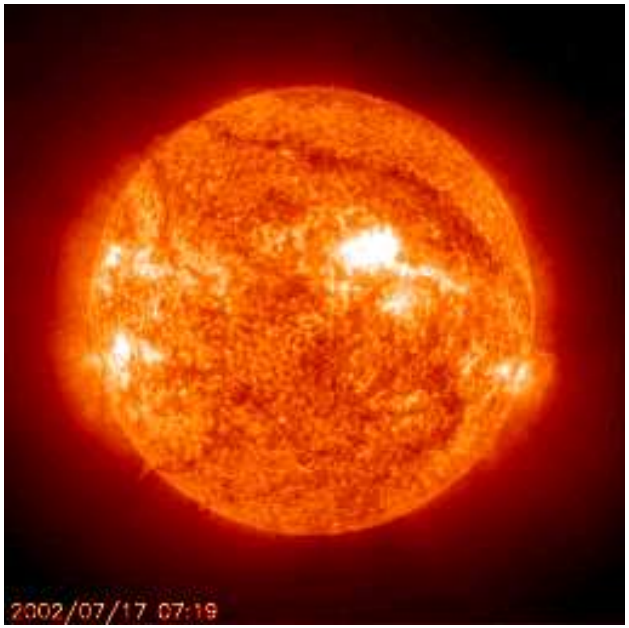
EVERYTHING EMITS RADIATION ENERGY UNITS: WATTS PER SQUARE METRE (Wm^{-2})



Cool things: long wave-length/thermal infrared radiation, e.g. us ~300 K



Hot things: short wave-length radiation, e.g. the sun ~6000 K

Temperature in Kelvin = Temperature in ^{o}C + 273.15

IR thermometer activity

EARTH'S RADIATIVE ENERGY BALANCE IN SPACE

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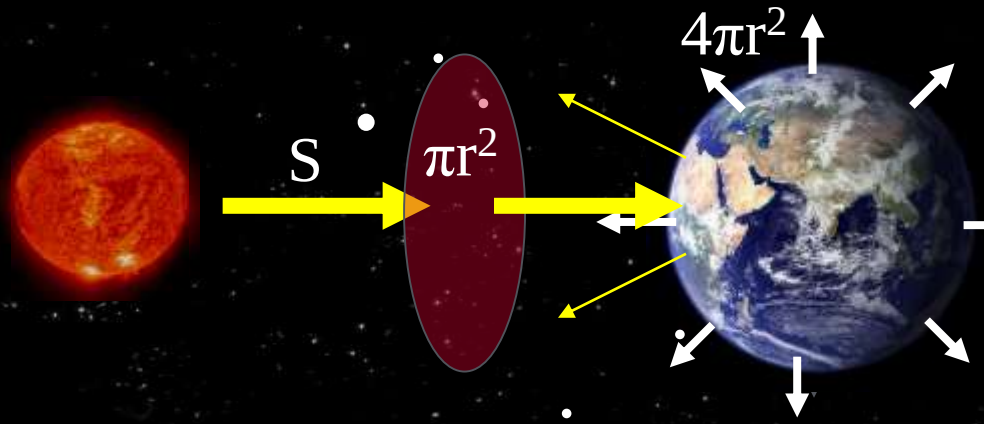

Absorbed Solar or Shortwave Radiation $\frac{S}{4}X(1-\alpha)$

α is "albedo" – the proportion of incoming solar radiation reflected back

- There is a balance between heating from absorbed sunlight and cooling to space through thermal/longwave radiative energy
- $\frac{S}{4}(1-\alpha) = OLR$ S ≈ 1361 Wm^{-2}, α ≈ 0.3, OLR ≈ 239 Wm^{-2}
- How does it balance? Why is Earth's average temperature ~15°C?
- Scratch Energy Balance Activity

Earth's annual mean energy balance

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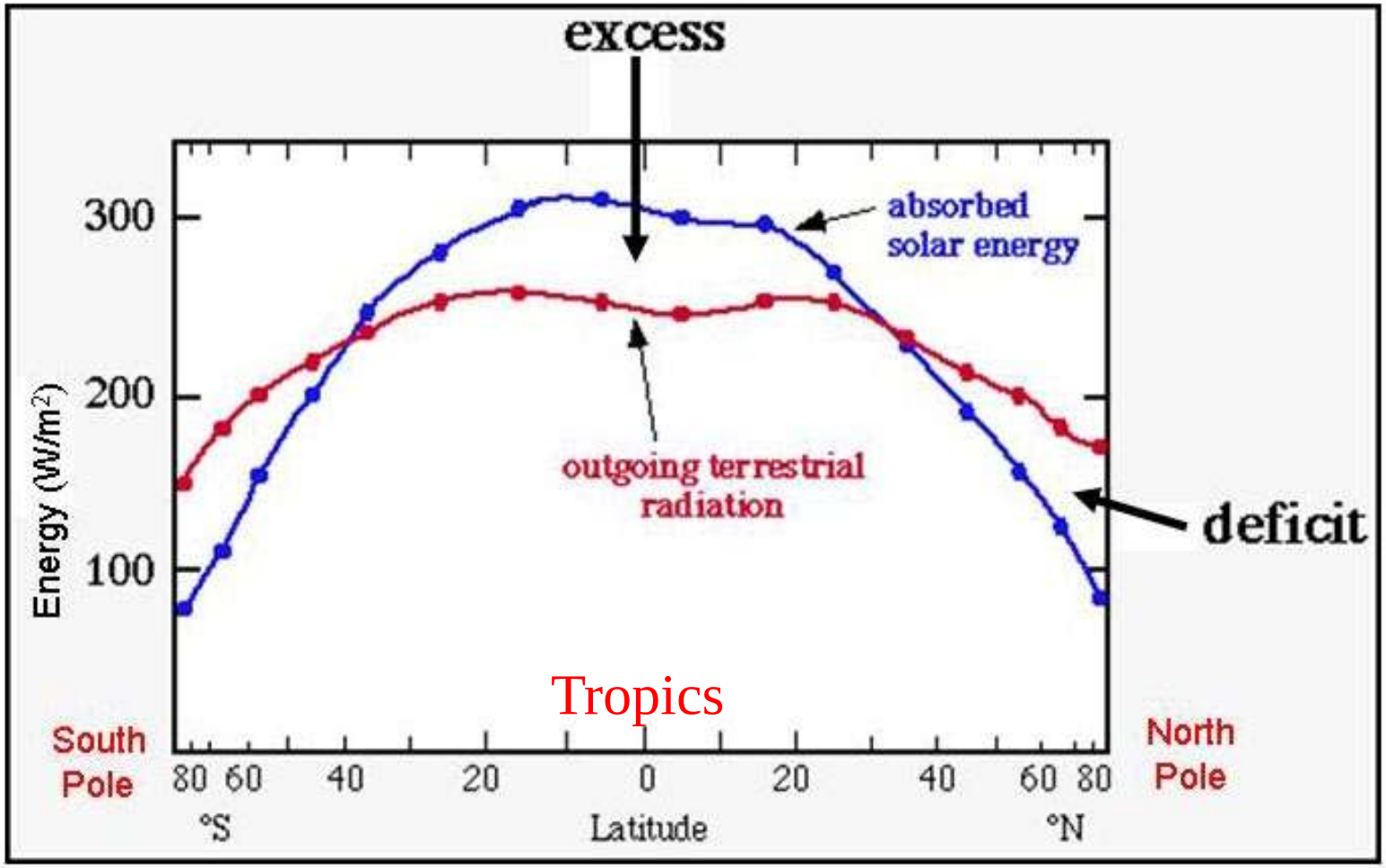
EARTH'S RADIATIVE ENERGY BALANCE



Click for movie

Why doesn't the tropics keep getting hotter and hotter?

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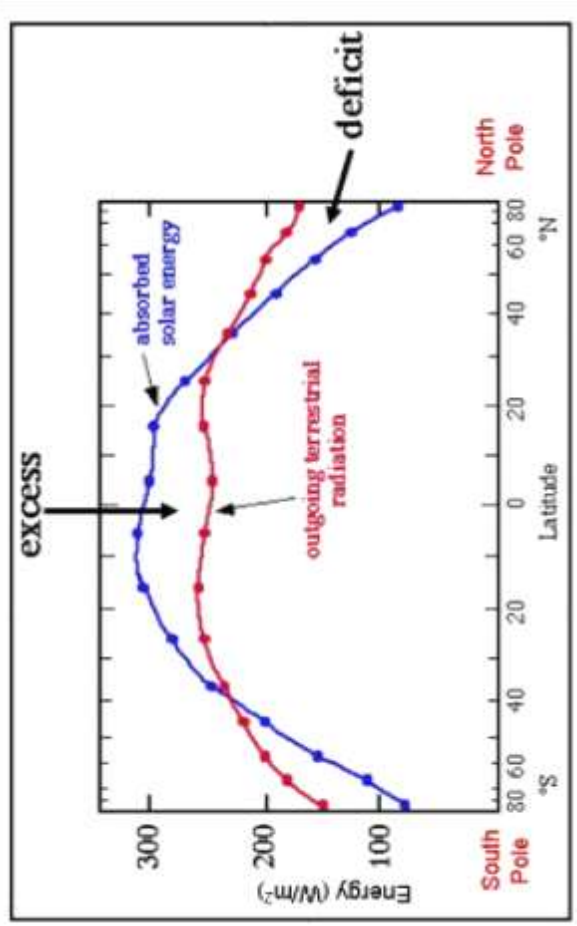
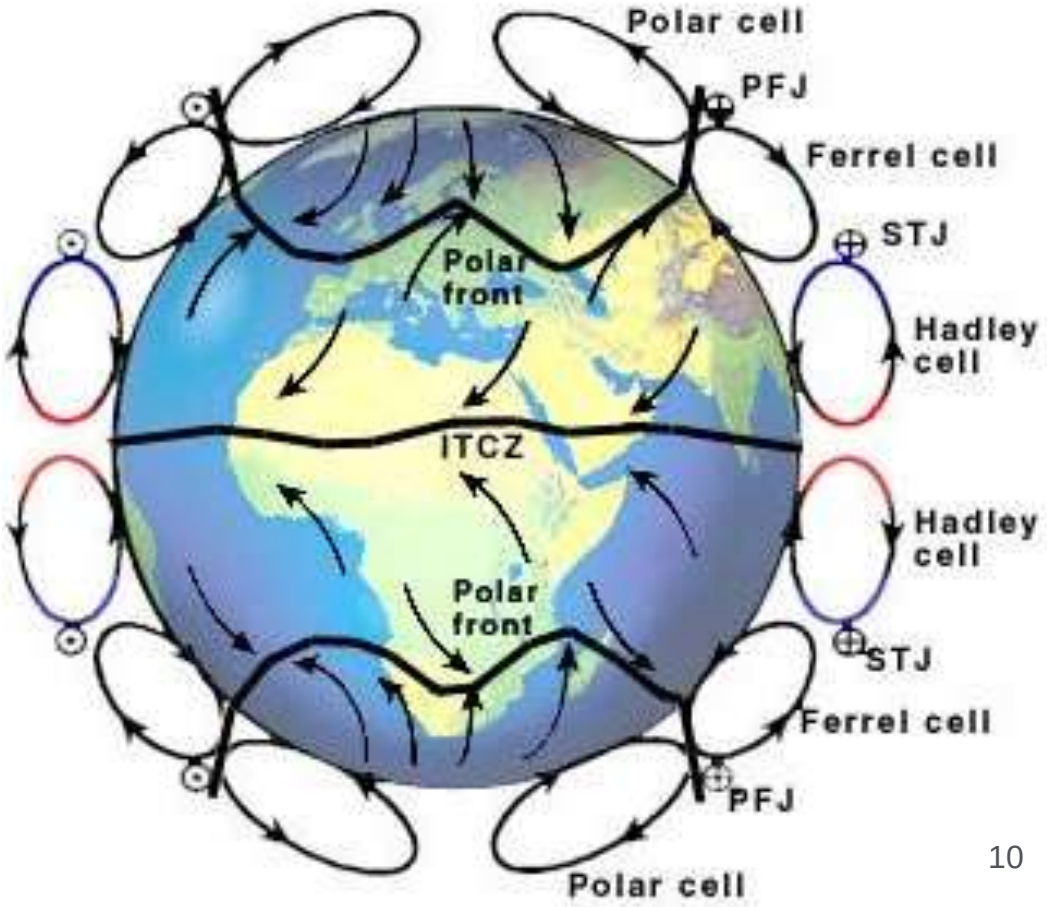
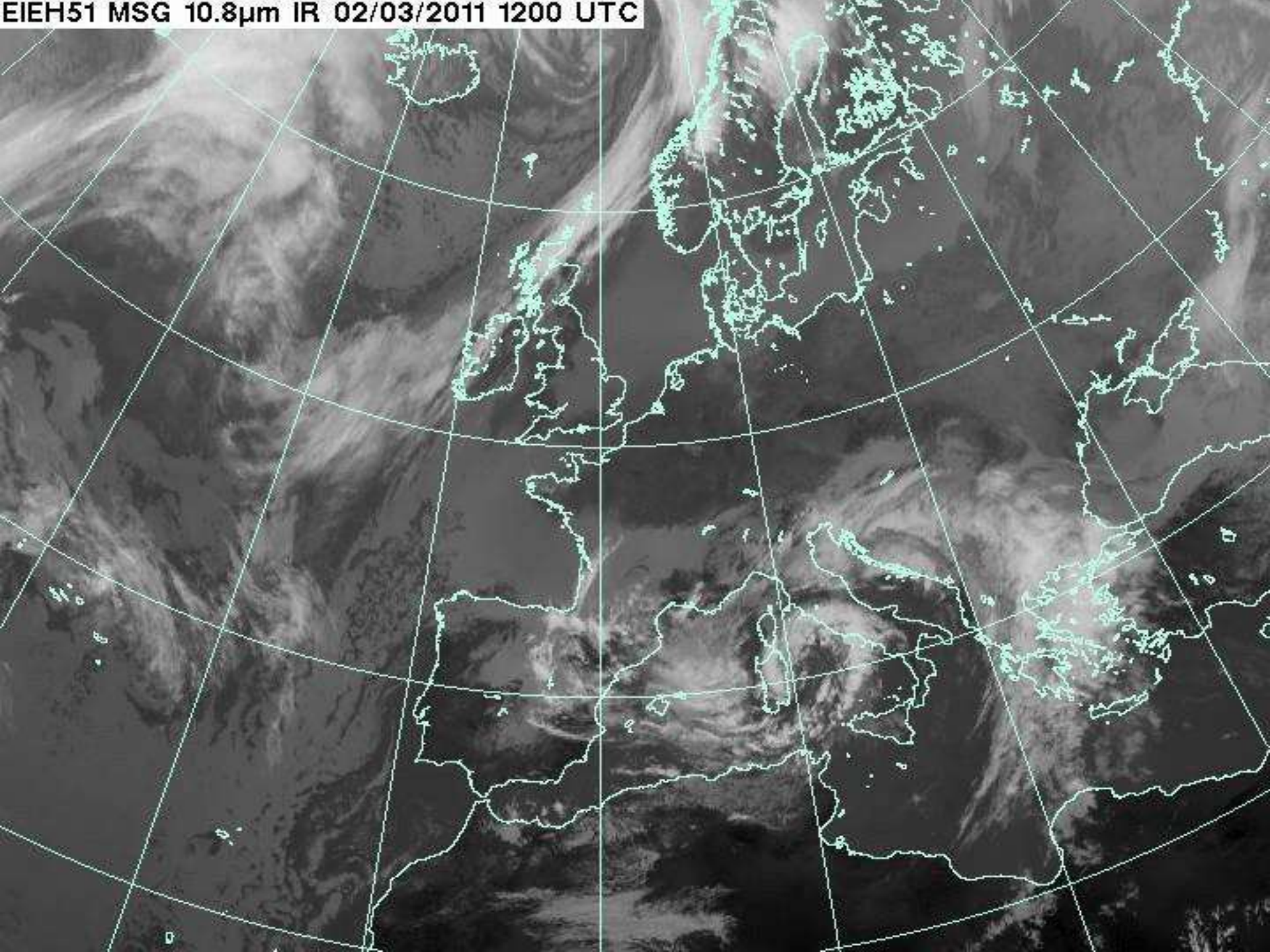
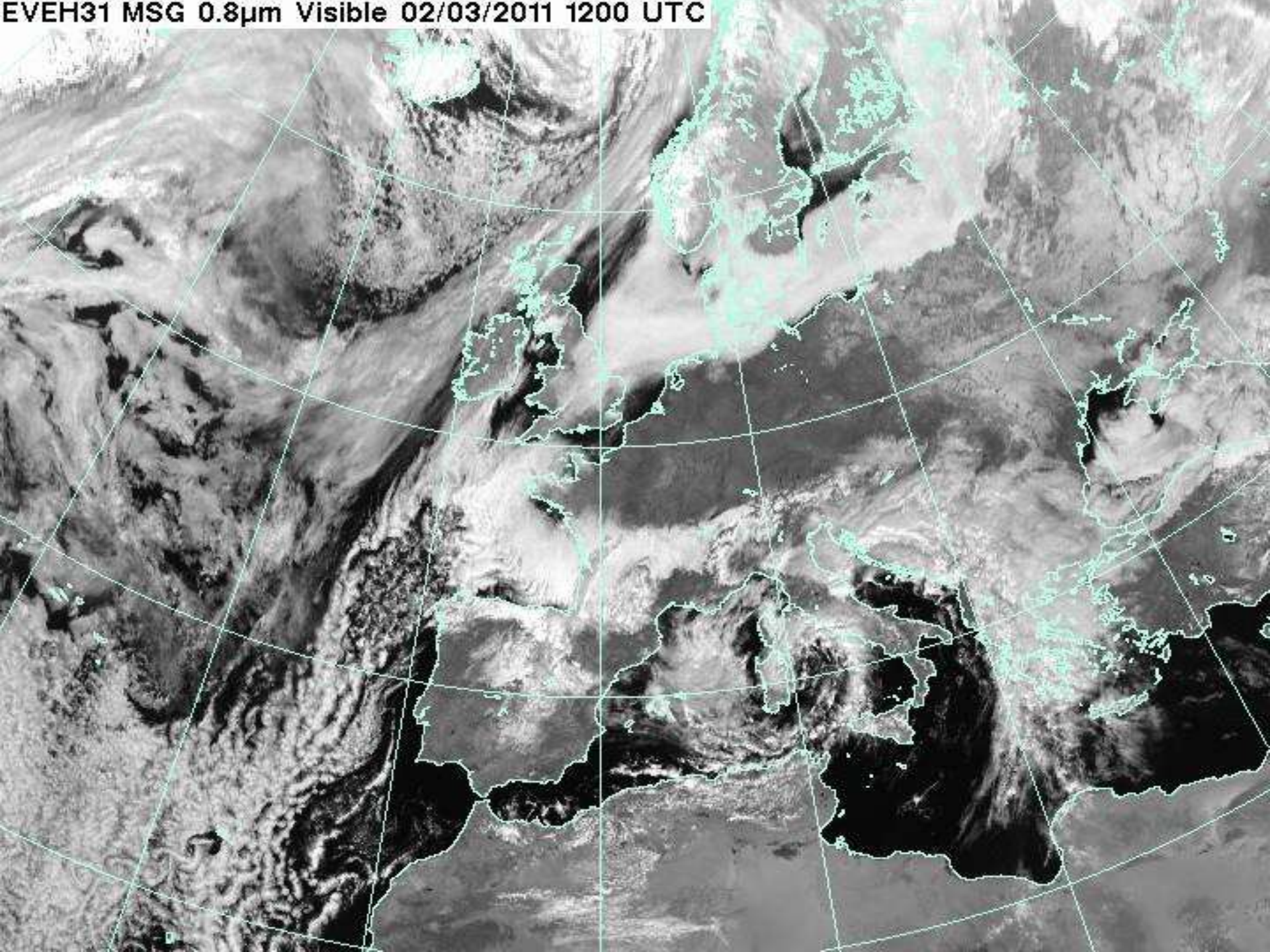
EARTH'S RADIATIVE ENERGY BALANCE






EIEH51 MSG 10.8µm IR 02/03/2011 1200 UTC


EVEH31 MSG 0.8µm Visible 02/03/2011 1200 UTC

FORCING AND RESPONSE: A NATURAL EXPERIMENT


29/3/06 11.05am
© Stuart Webster 2006


© Stuart Webster 2006


29/3/06 12.26pm
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- Clouds affect radiation fluxes
- Radiation fluxes affect clouds

Feedback demonstration

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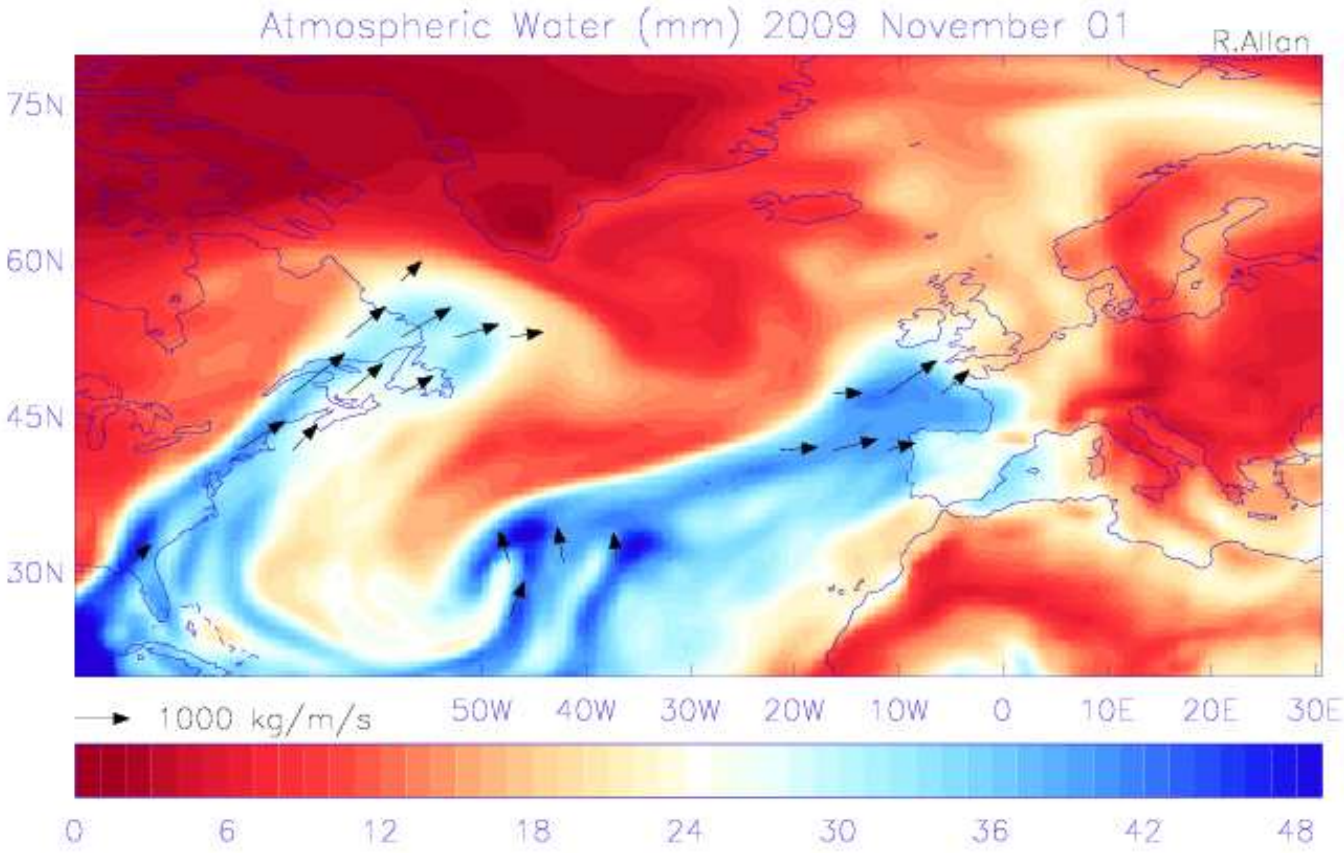
WATER VAPOUR & CLIMATE



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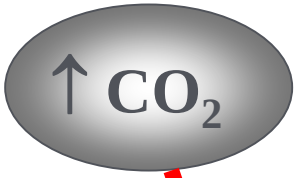
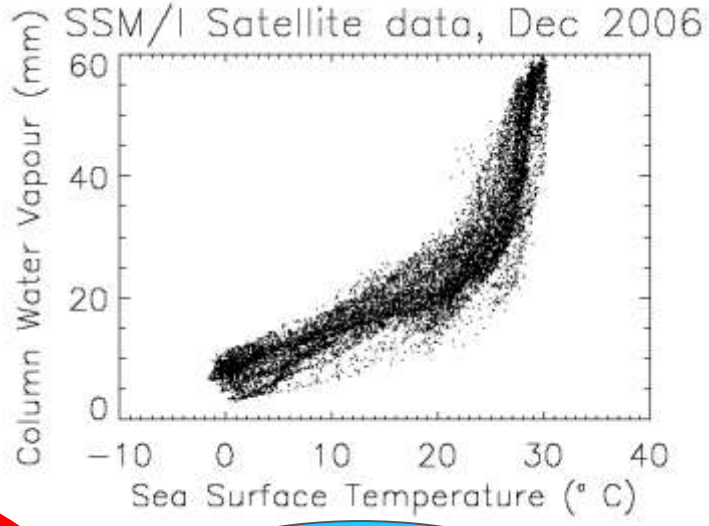
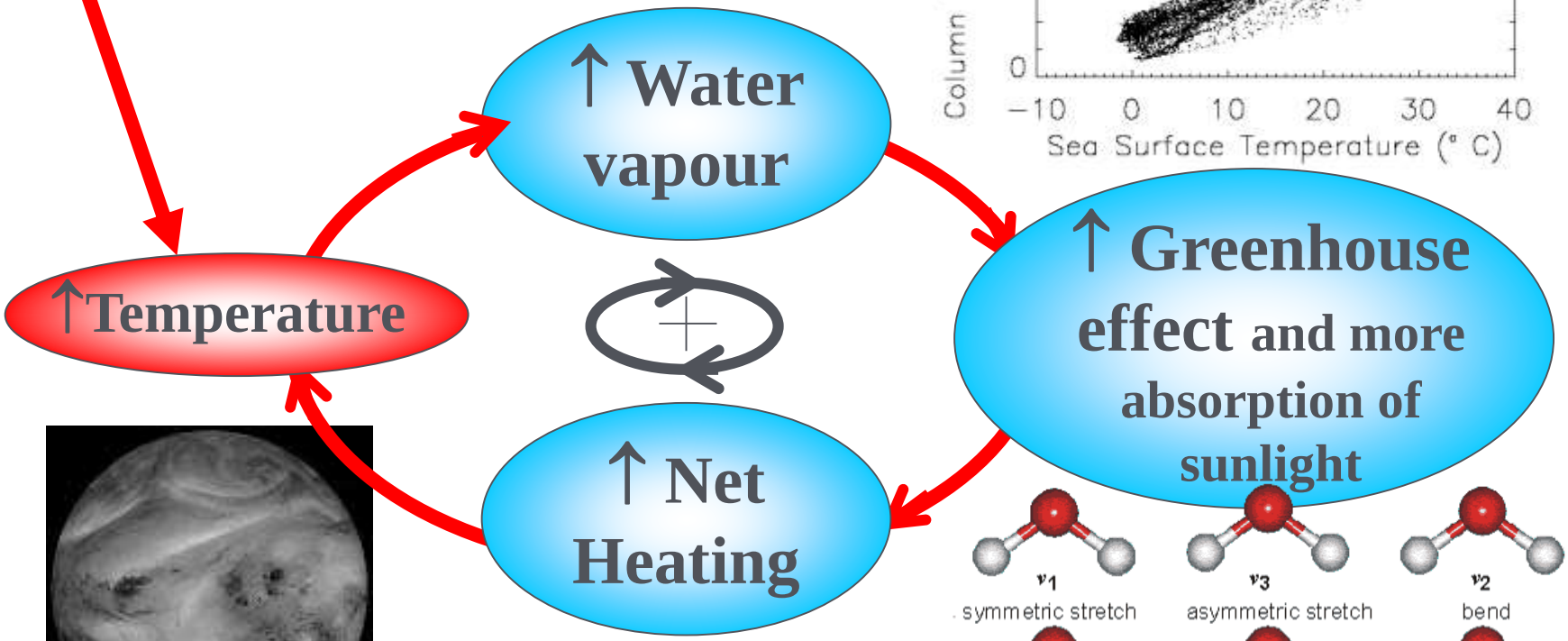
WATER VAPOUR AMPLIFIES CLIMATE CHANGE

An amplifying (positive) feedback loop involving water vapour

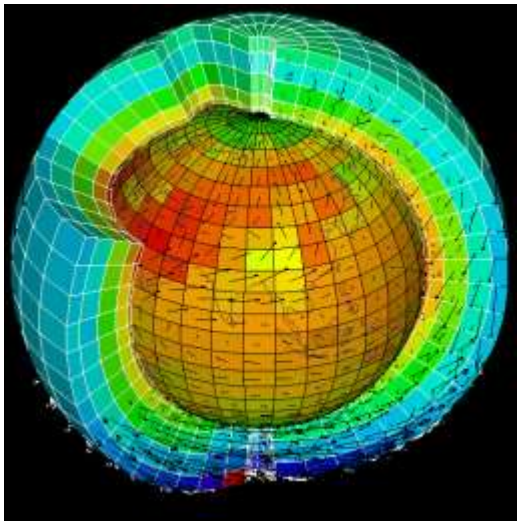


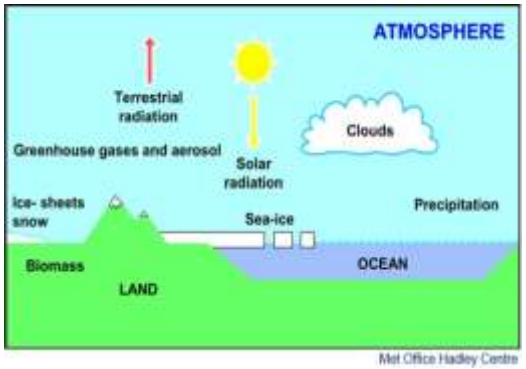




WHAT ARE THE PREDICTIONS?

- What's a prediction?
- Scientists use observations and experiments to understand the physics of the environment
- The physics of the atmosphere/oceans/land are coded in complex computer simulations
- They are used to:
  - understand past climate change
  - project how climate will change over future decades and centuries





climate model animation

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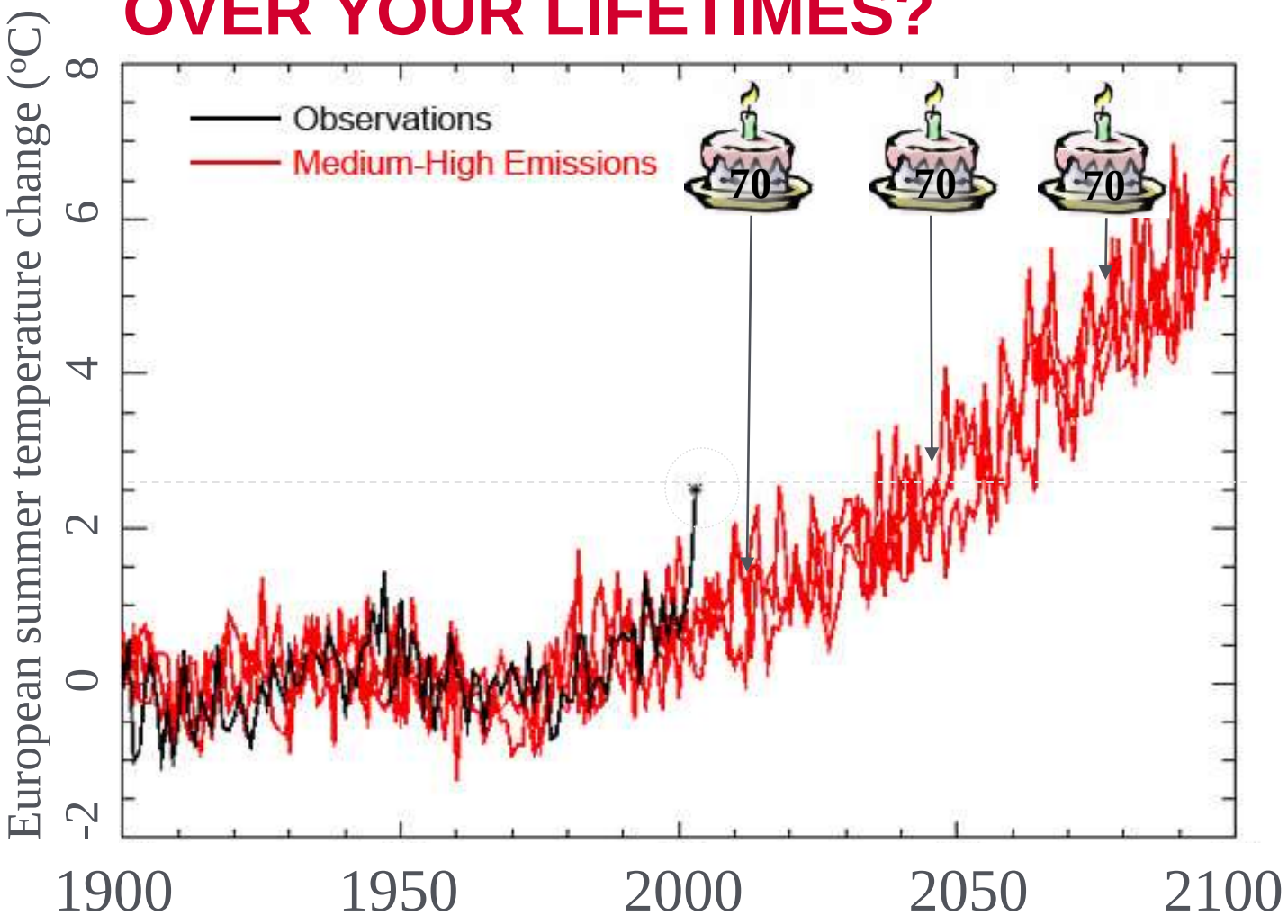
HOW WILL CLIMATE CHANGE OVER YOUR LIFETIMES?



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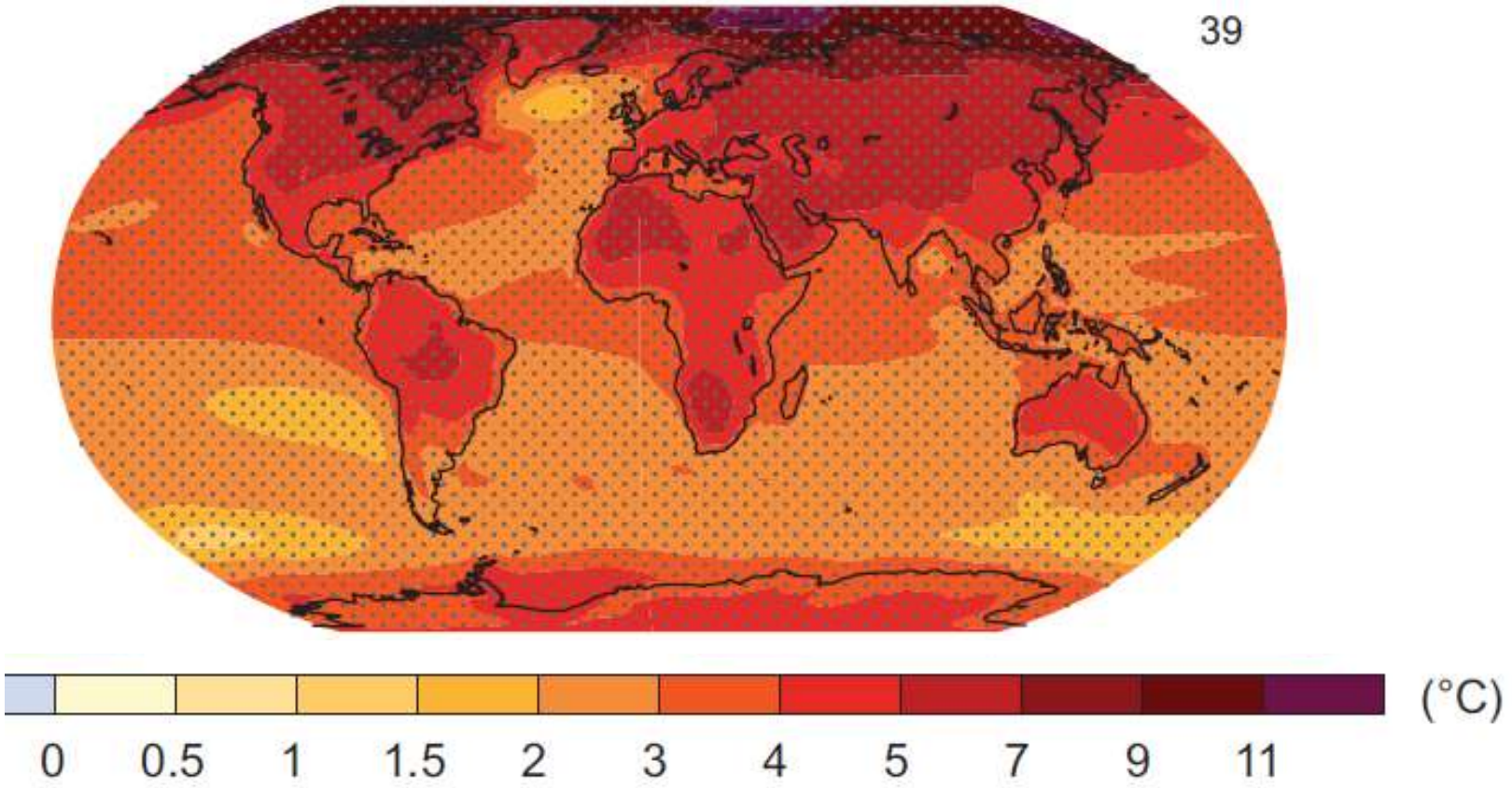
WARMING WILL BE GREATER OVER THE LAND AND GREATEST IN THE ARCTIC



Change in average surface temperature (1986–2005 to 2081–2100) RCP 8.5 Scenario

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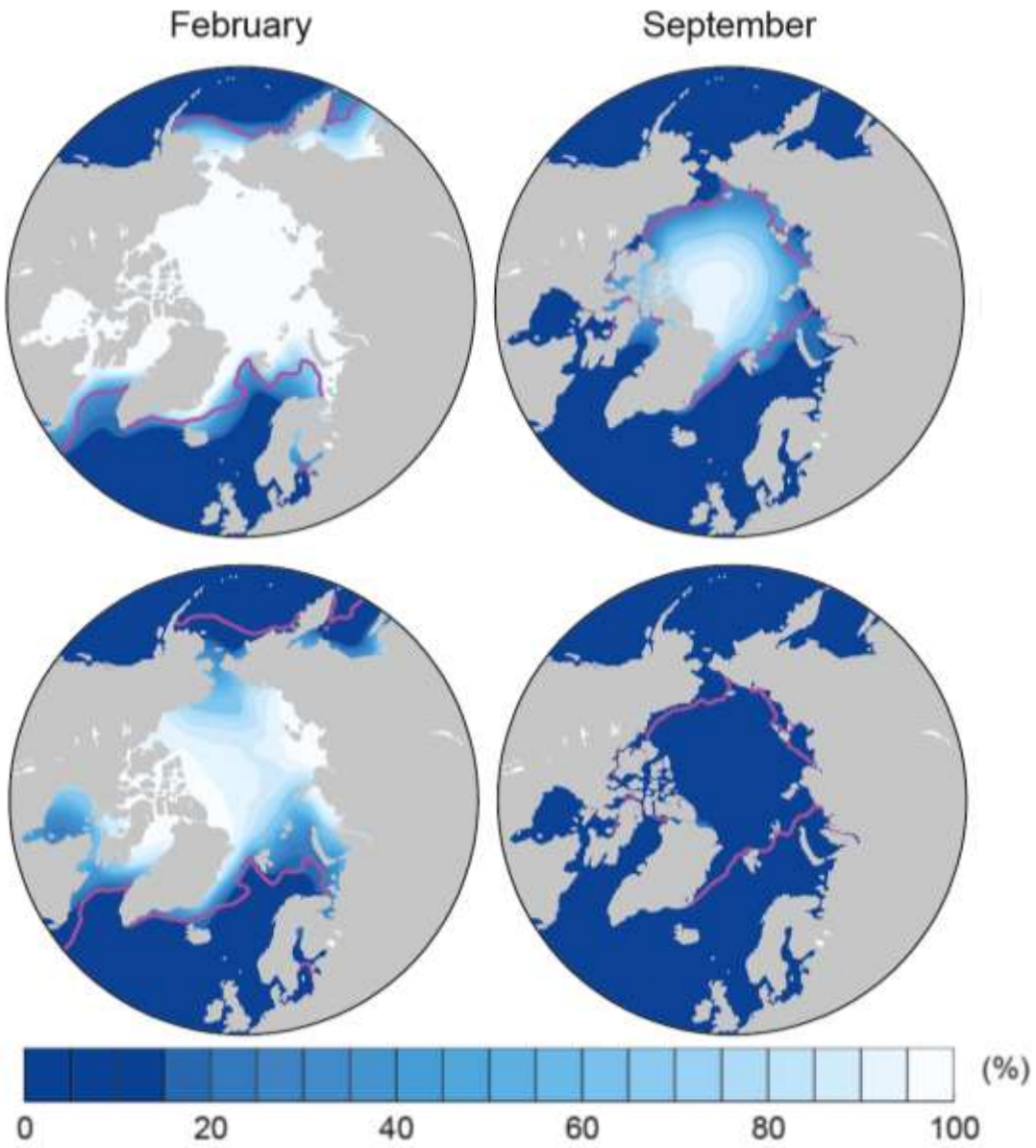
PROJECTIONS: ARCTIC SEA ICE EXTENT DECLINE IN 21ST CENTURY



- **94% decrease in September**
- **34% decrease in February**

high emissions scenario

IPCC (2013)
WG1 Fig. 12.29

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INTENSIFICATION OF HEAVY RAINFALL

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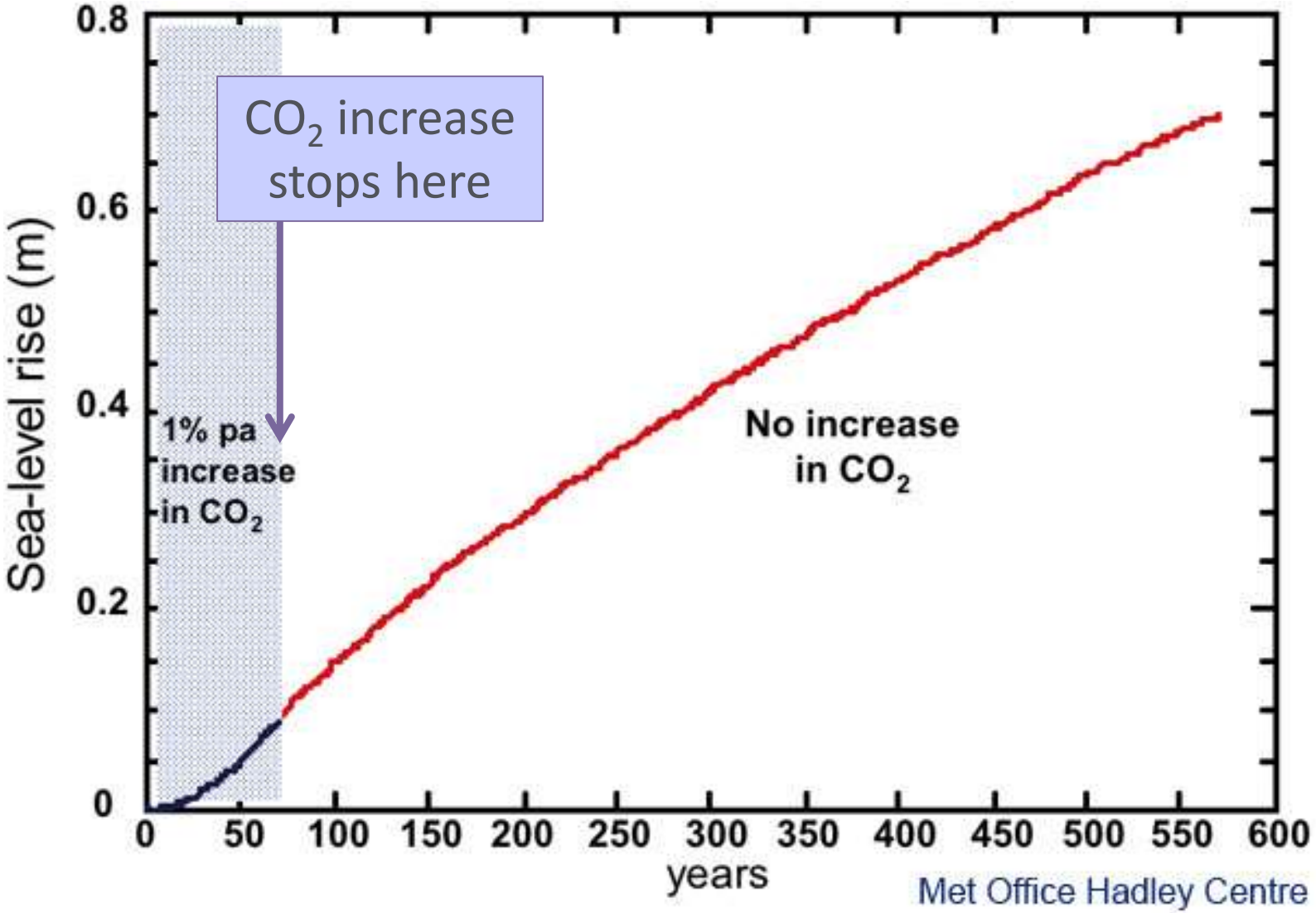
SEA-LEVEL WILL RISE FOR CENTURIES



CLIMATE CHANGE

- Climate has always changed
- Greenhouse gases such as carbon dioxide are at their highest levels for at least the last 800,000 years
- This pollution from human activity is amplifying the natural greenhouse effect
- This is heating the planet by impeding outgoing infrared cooling to space
- Substantial changes in global temperature and rainfall patterns are projected using computer simulations
- Predicting regional climate change is a challenge
- What can we do to avoid dangerous climate change?

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COP21 PARIS CLIMATE DEAL

source: http://www.carbonbrief.org/analysis-the-final-paris-climate-deal

- **Target**: global temperature well below 2°C; efforts to limit to 1.5°C
- **Mitigation**: pursue policies aiming to achieve INDC climate pledges; subsequent pledges progressively more ambitious; global stocktake 2018 & then every 5 years; peak global greenhouse gas emissions “as soon as possible”; “balance” between emissions & sinks 2050-2100
- **Adaptation**: $100bn/yr fund for developing countries: new collective quantified goal by 2025; periodic review of adaptive planning of Loss & damage has its own Article in the agreement — now on par with mitigation & adaptation; liability/compensation excluded.
- **Transparency:** "facilitative, non-intrusive, non-punitive” system of review will track countries’ progress; emissions trading allowed; aviation/shipping not included
- **Treaty:** deal enters force once 55+ parties, covering at least 55% of global emissions have signed up

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DEGREES IN METEOROLOGY AND CLIMATE

- BSc Meteorology & Climate (BB physics and maths)
- MMet Meteorology & Climate with a year in Oklahoma (AA physics and maths)
- BSc Mathematics & Meteorology (AAB-ABB including A in Maths)
- MMath Mathematics & Meteorology (AAB-ABB including A in Maths)
- BSc Physics of the Environment (ABB-AAC from three A levels including Mathematics & Physics, one of which must be at grade A)

Modules: *Atmospheric physics, dynamics, numerical methods, energy exchange, differential equations & calculus, Aran field course, dissertation, boundary layer, optional extra physics, weather forecasting, climate change, remote sensing, oceanography, environmental chemistry, global circulation, atmospheric electricity, …*

- More information at www.reading.ac.uk/met/undergraduate-courses
- Work Experience Programme (February 2019): https://research.reading.ac.uk/meteorology/work-experience/