CLIMATE CHANGE: BASIC MECHANISMS AND CAUSE-EFFECT RELATIONSHIPS

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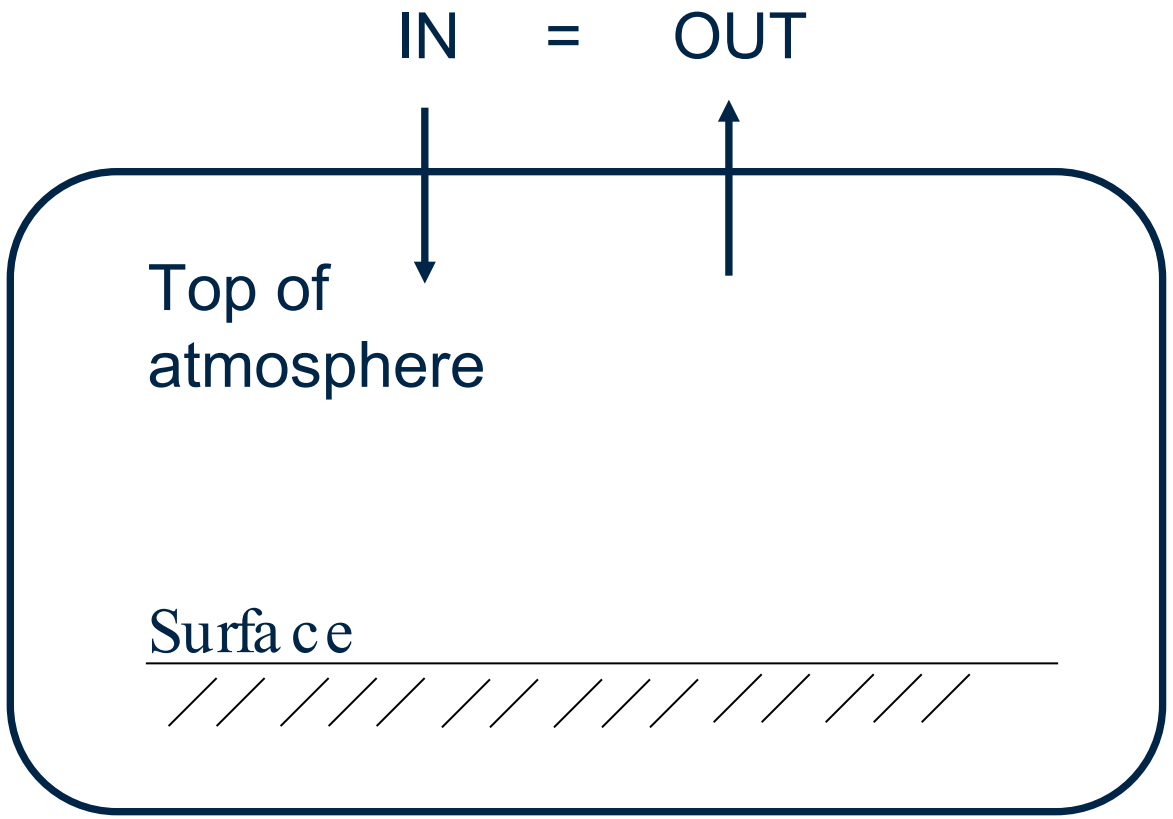
ENERGY BALANCE

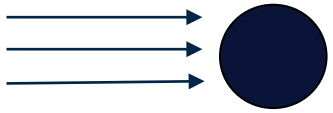


The simplest view:
Heating from sunlight is balanced by cooling from thermal radiation.

EARTH'S EMISSION TEMPERATURE

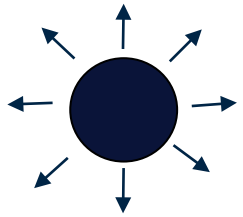
Incoming (shortwave)

$(1-\alpha)S\pi a^2$



Outgoing (longwave)

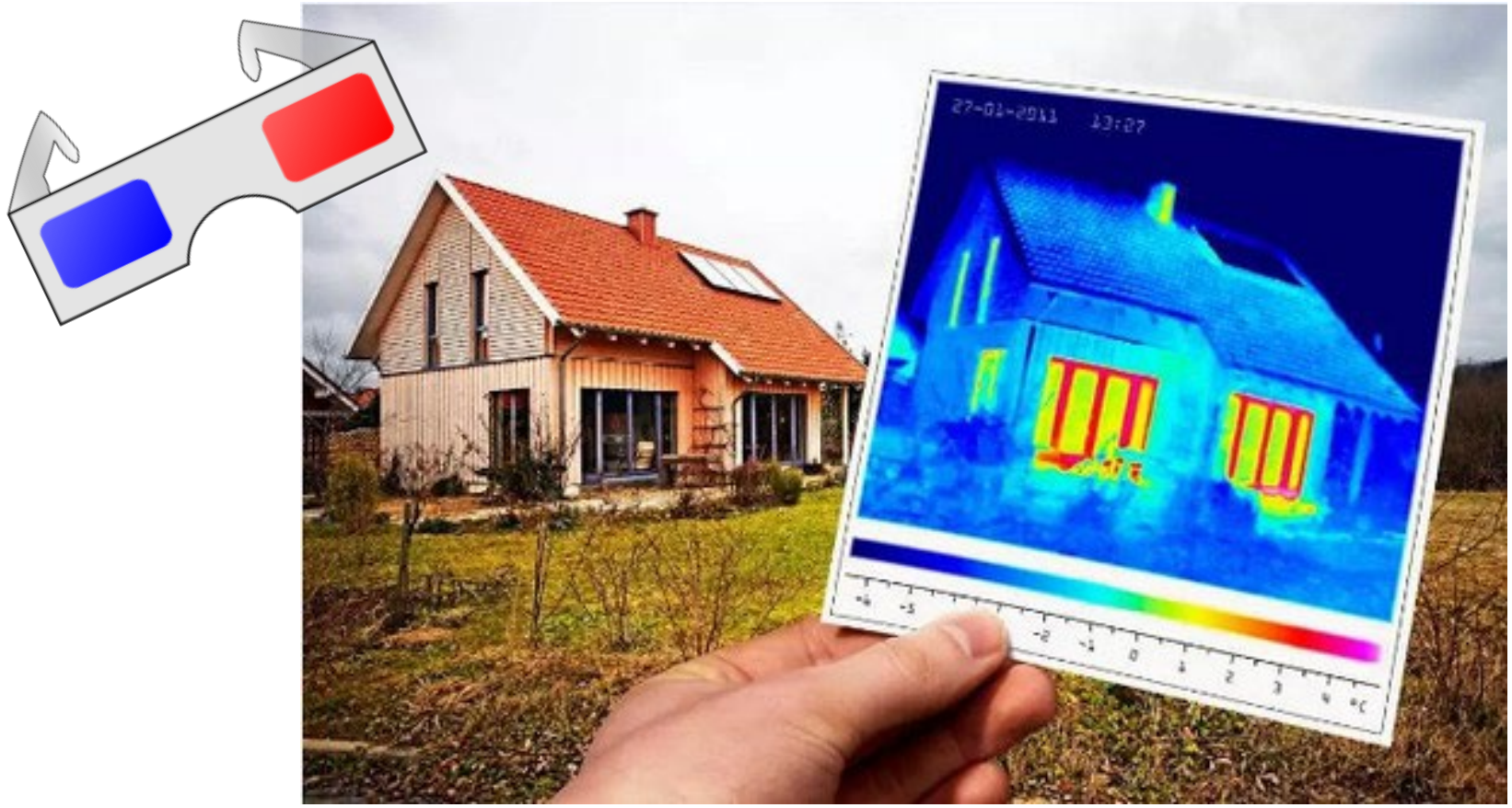
$4\pi a^2 \sigma T^4$



Energy balance:

$$T_E = \sqrt[4]{\frac{S}{4}\frac{1-\alpha}{\sigma}} = 255\ \mathrm{K} = -18\ ^\circ\mathrm{C}$$

PUT ON YOUR INFRARED GOGGLES!



"Infrared Thermography Inspection - Thermo Élite Inc" by thermoeliteinc is licensed under CC PDM 1.0

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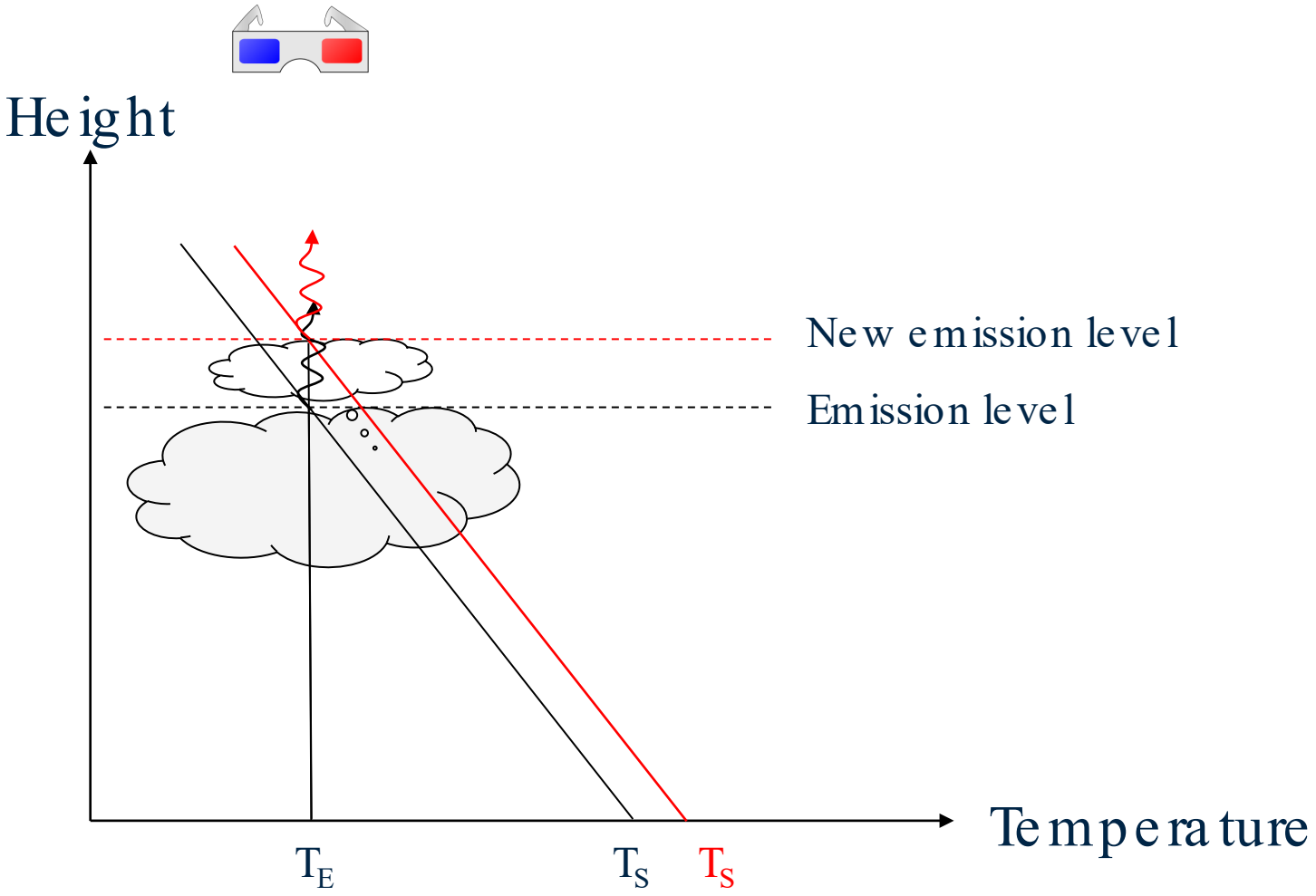
GREENHOUSE EFFECT



CLIMATE MODELS

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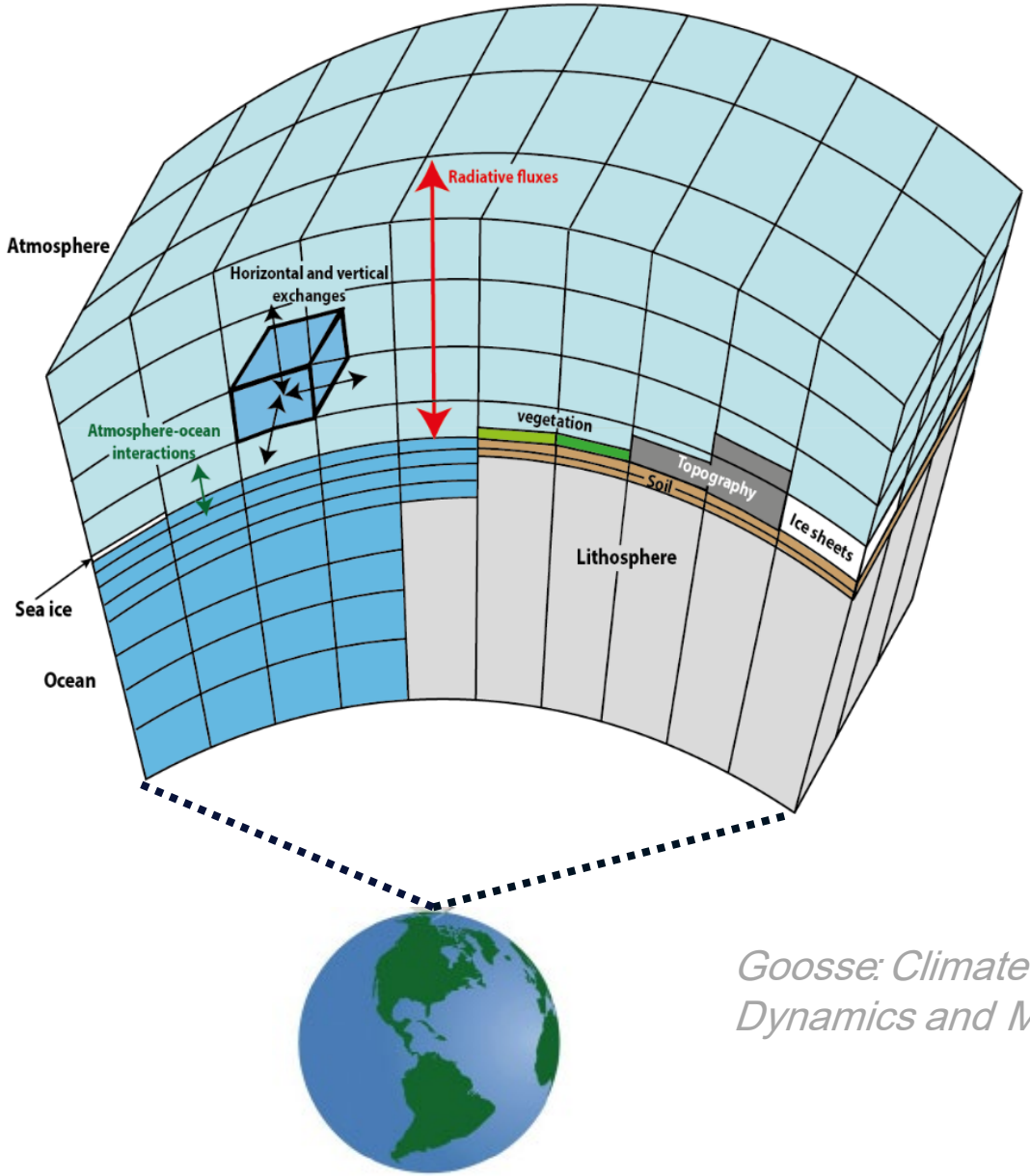
BASIC PRINCIPLES

Fundamental conservation principles:

- Conservation of energy
- Conservation of mass (air, water, etc)
- Conservation of momentum

Ideal gas law (and equation of state for sea water)

GRID CELLS



Climate models

Also known as ***General Circulation Models*** or ***Earth System models***

Physics (energy balance, hydrology, flow of air and water, etc) is solved grid box by grid box

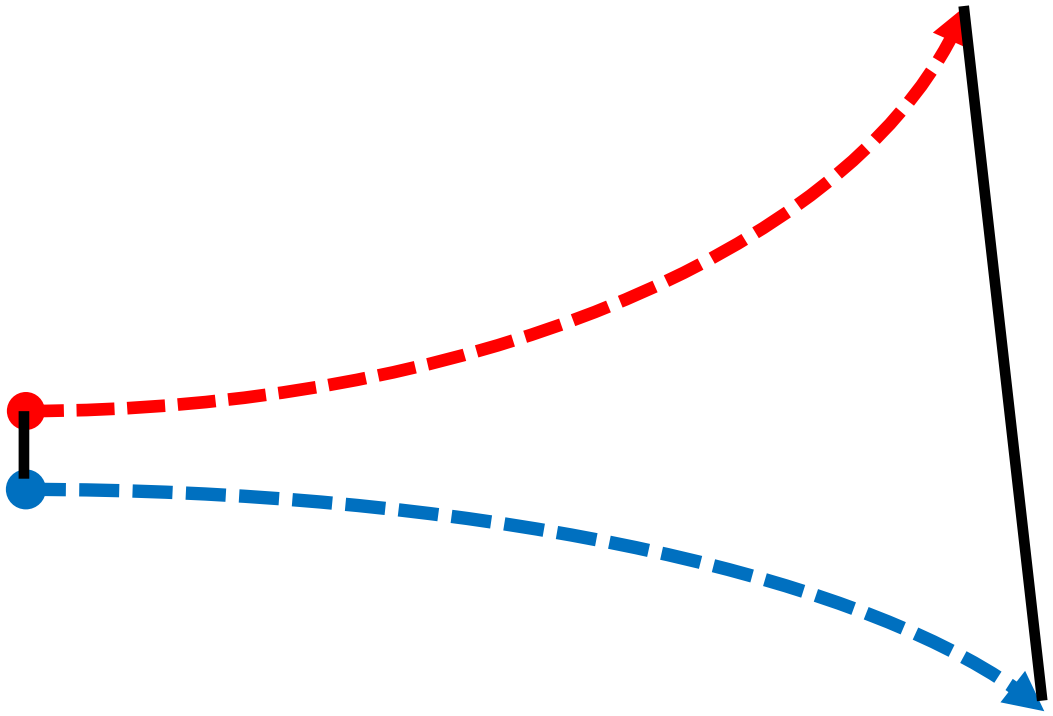
Goosse: Climate System Dynamics and Modelling

PARAMETERIZATIONS

Mathematical formulas that give the net effect of many small-scale effects that cannot be directly included :

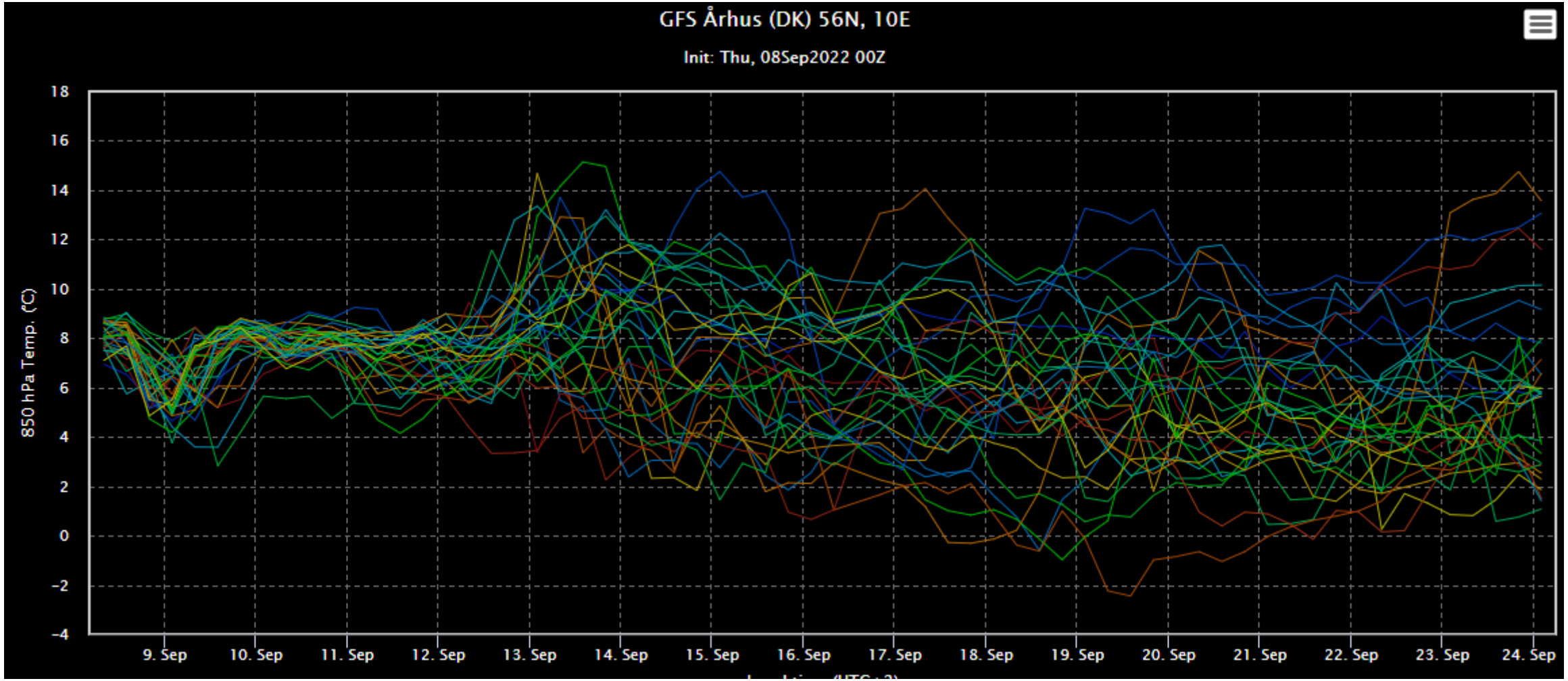
For example
- Clouds
- Turbulence

CHAOS AND PREDICTABILITY



A Trajectory Through Phase Space in a Lorenz Attractor by Dan Quinn (CC BY-SA 3.0)

TODAY'S MENU*SPAGHETTI*



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MY DOG *LORENZ* ON A LEASH

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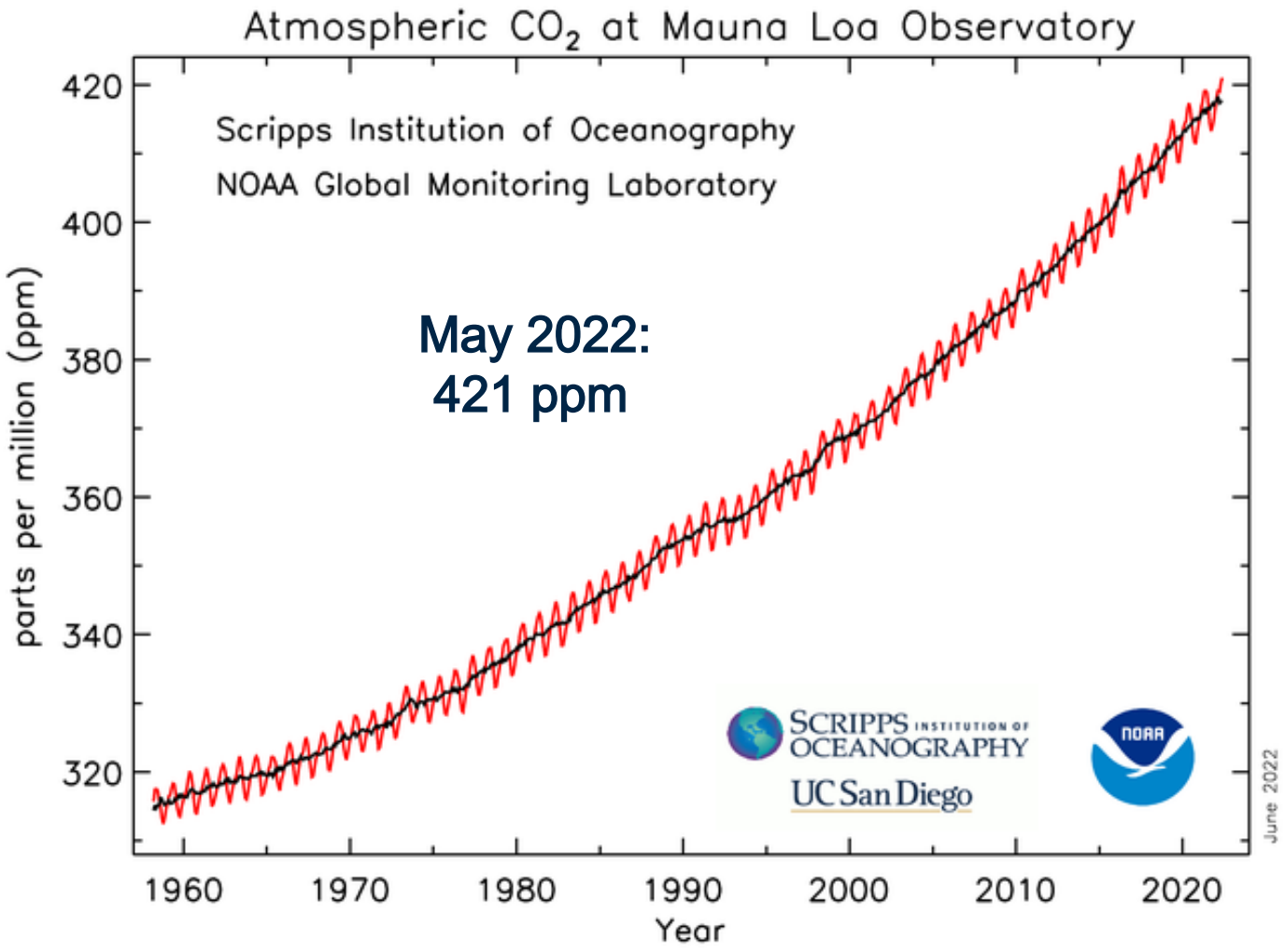
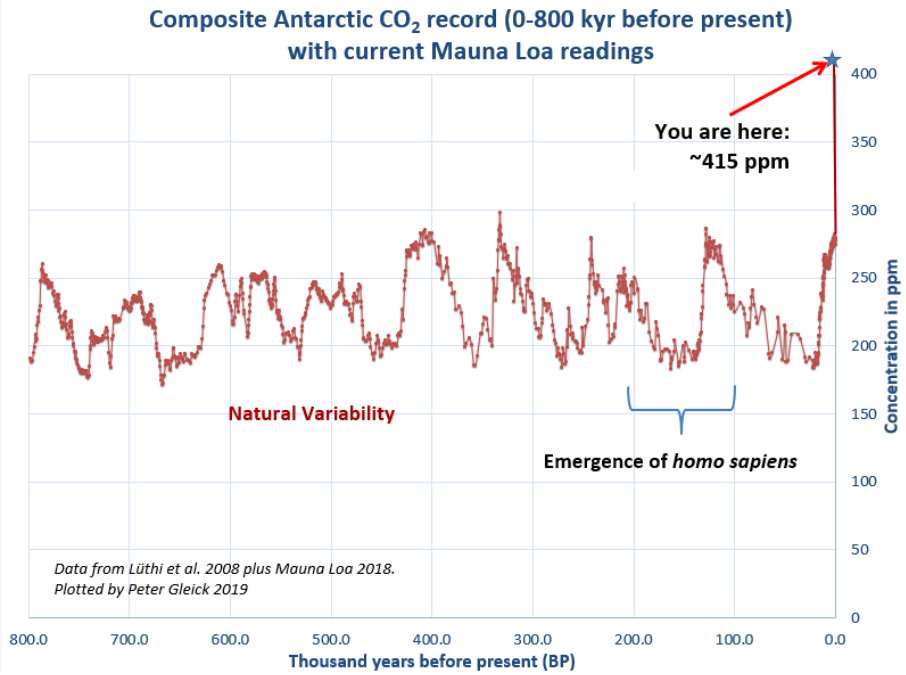
Skeptical Science /
Jacob Bock Axelsen

OBSERVED CHANGES

OBSERVED CHANGES: CO_2

950 ppm ★





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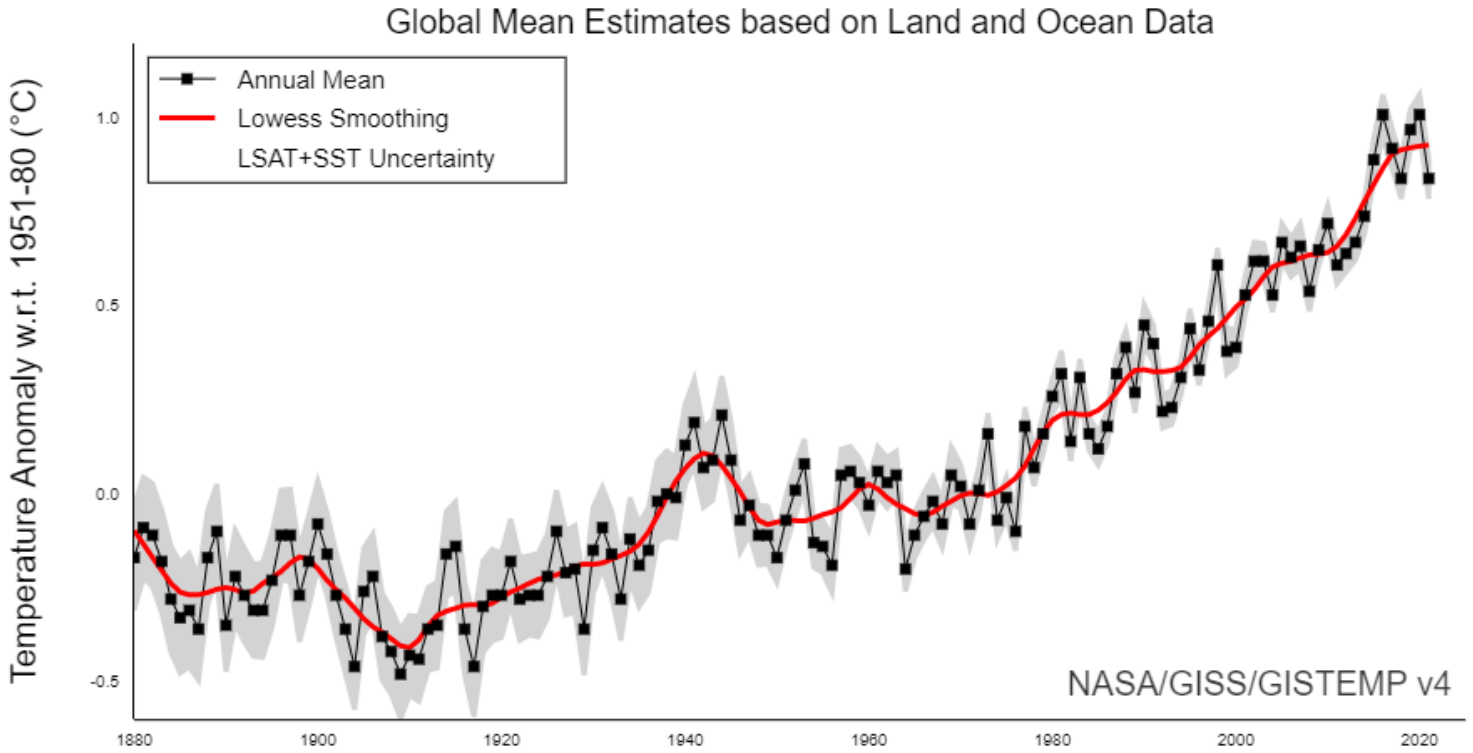
OBSERVED CHANGES: TEMPERATURE



2010's warmer than
2000's warmer than
1990's, warmer than
1980's, warmer than
1970's.

7 warmest years are the 7 latest

21 of the 22 warmest years after 2000

Fewer cold days and nights
More warm days and nights
More frequent heat waves

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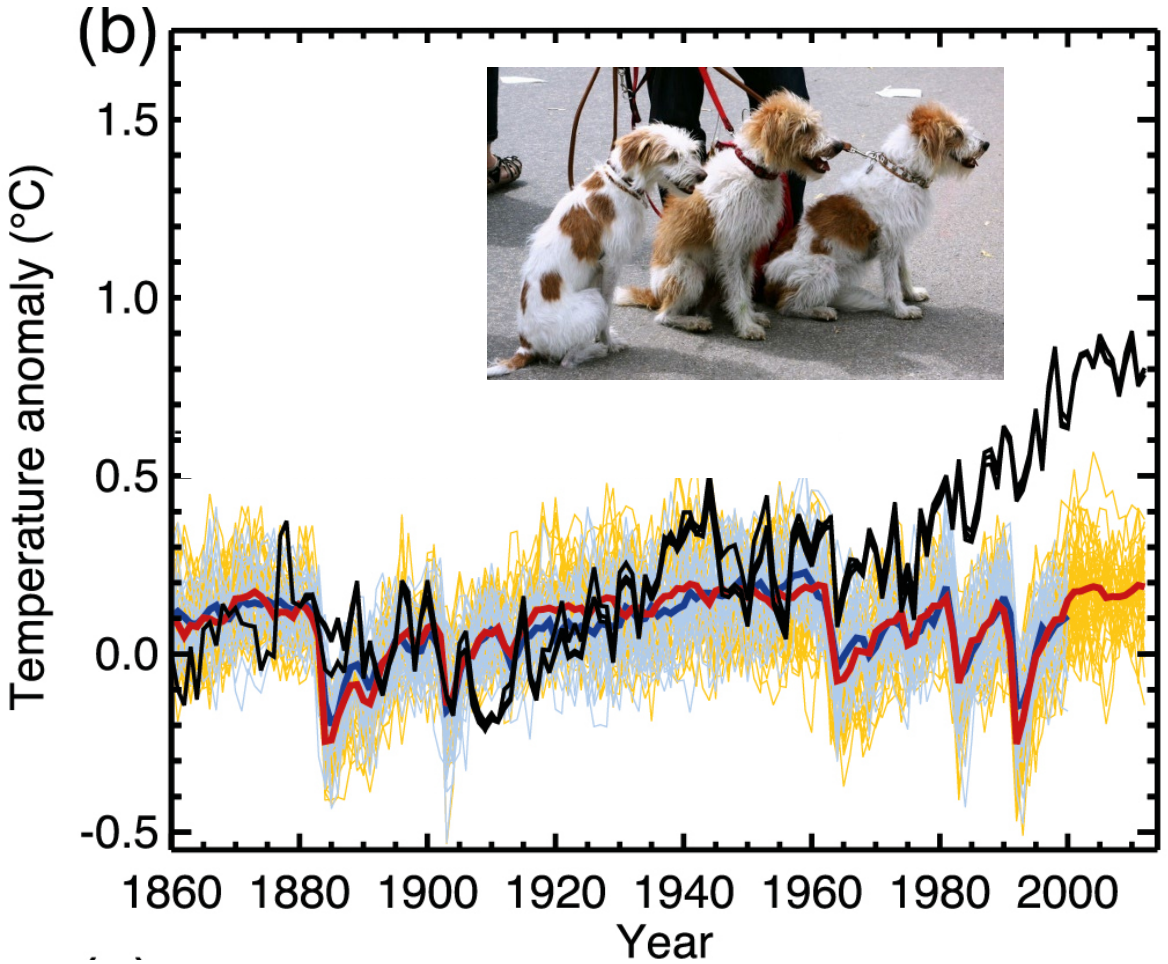
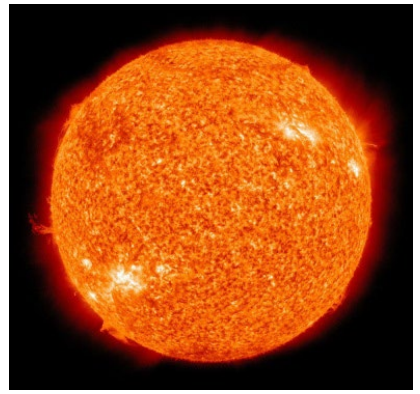
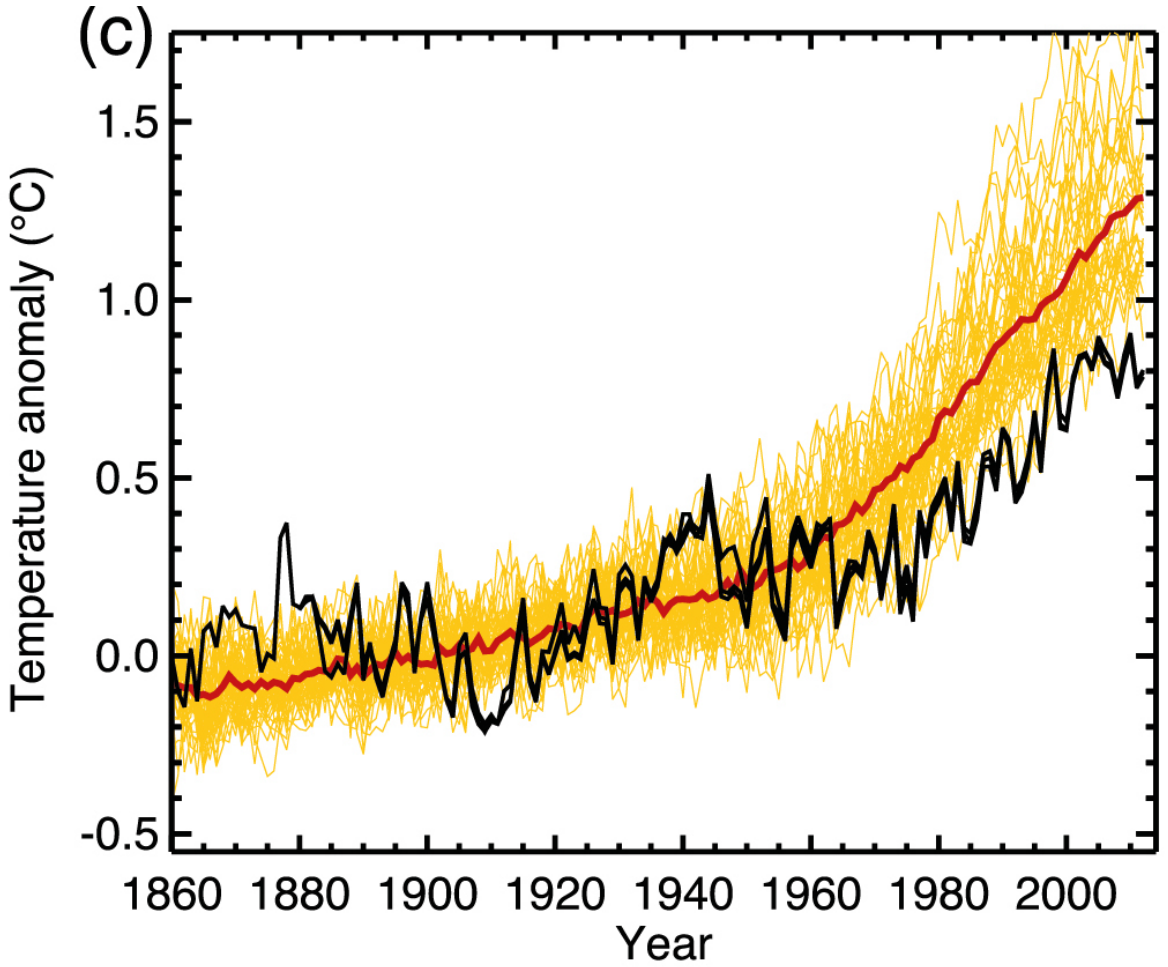
NATURALCHANGES?

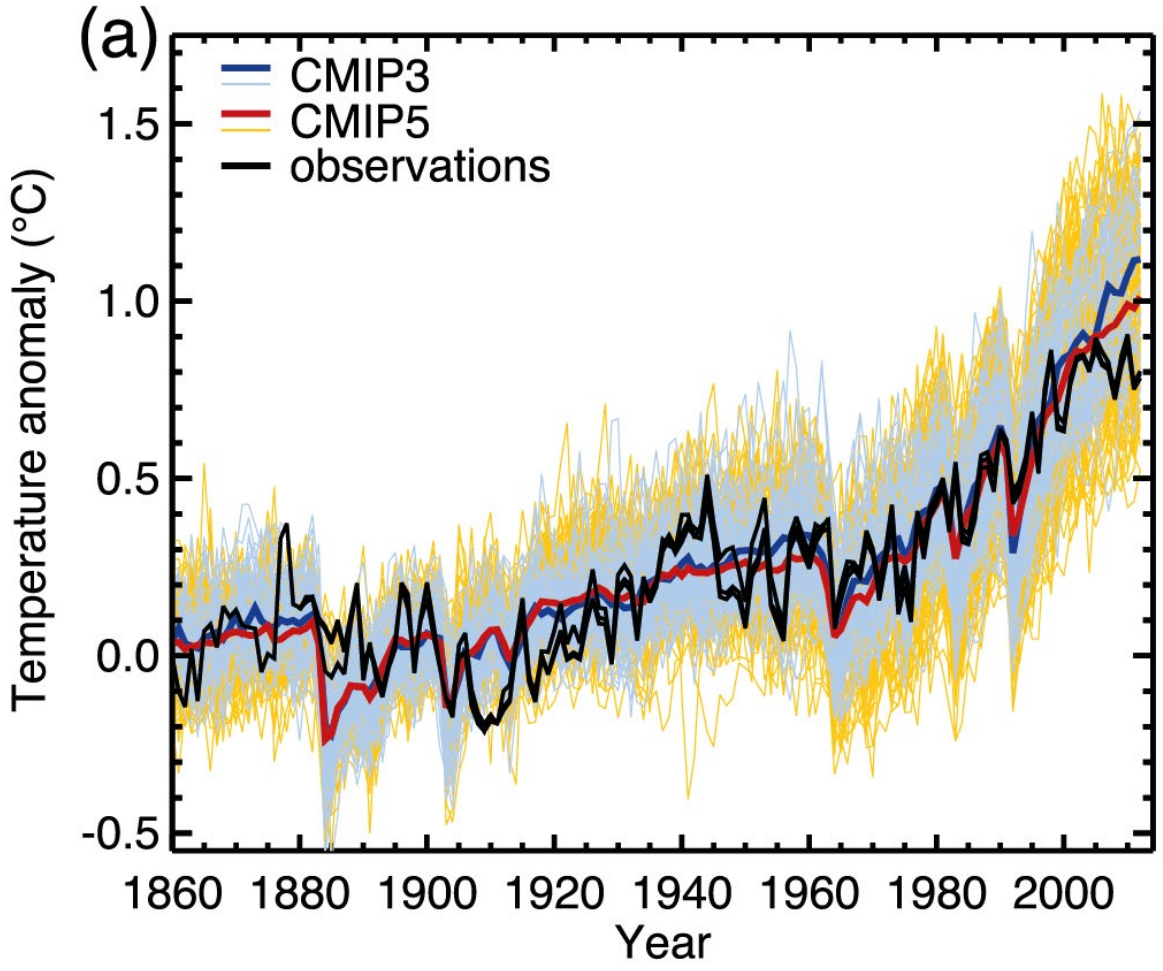


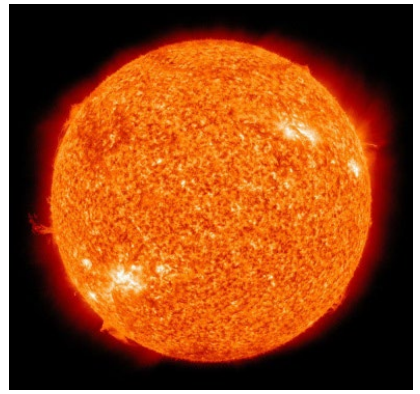


MAN–MADE CHANGES?



BOTH?


(a)
CMIP3
CMIP5
observations
Temperature anomaly (°C)
1.5
1.0
0.5
0.0
-0.5
1860
1880
1900
1920
1940
1960
1980
2000
Year



CLIMATE SENSITIVITY AND FUTURE PROJECTIONS

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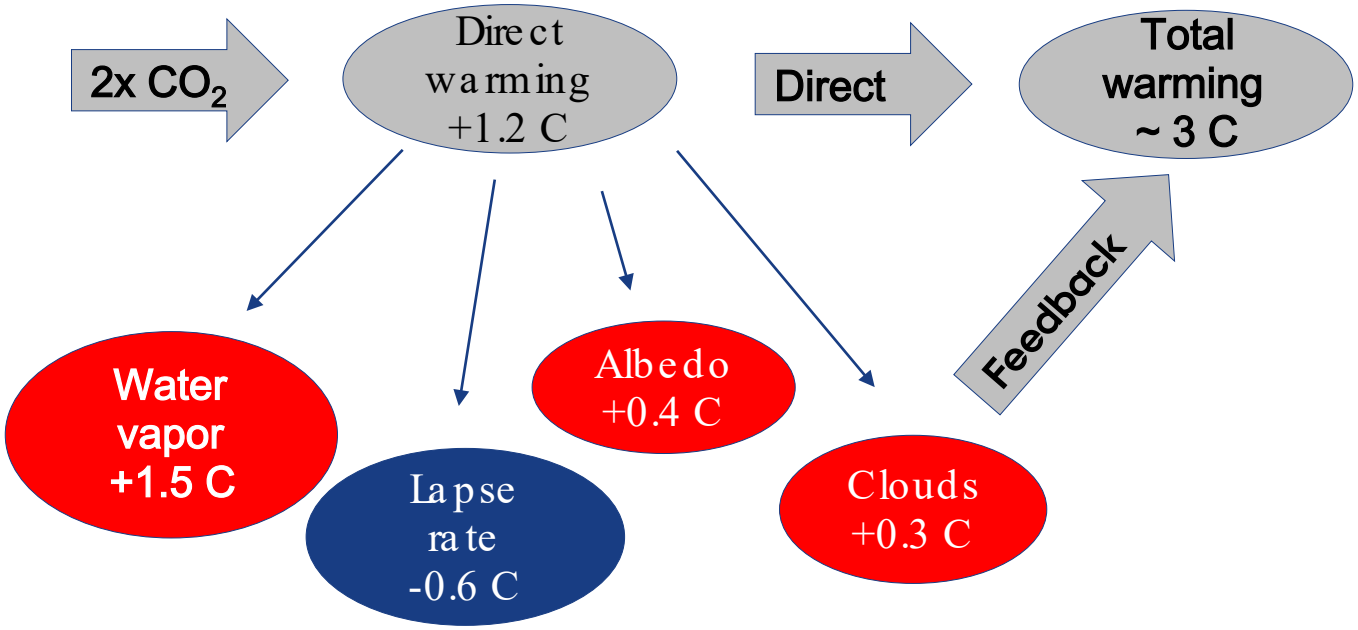
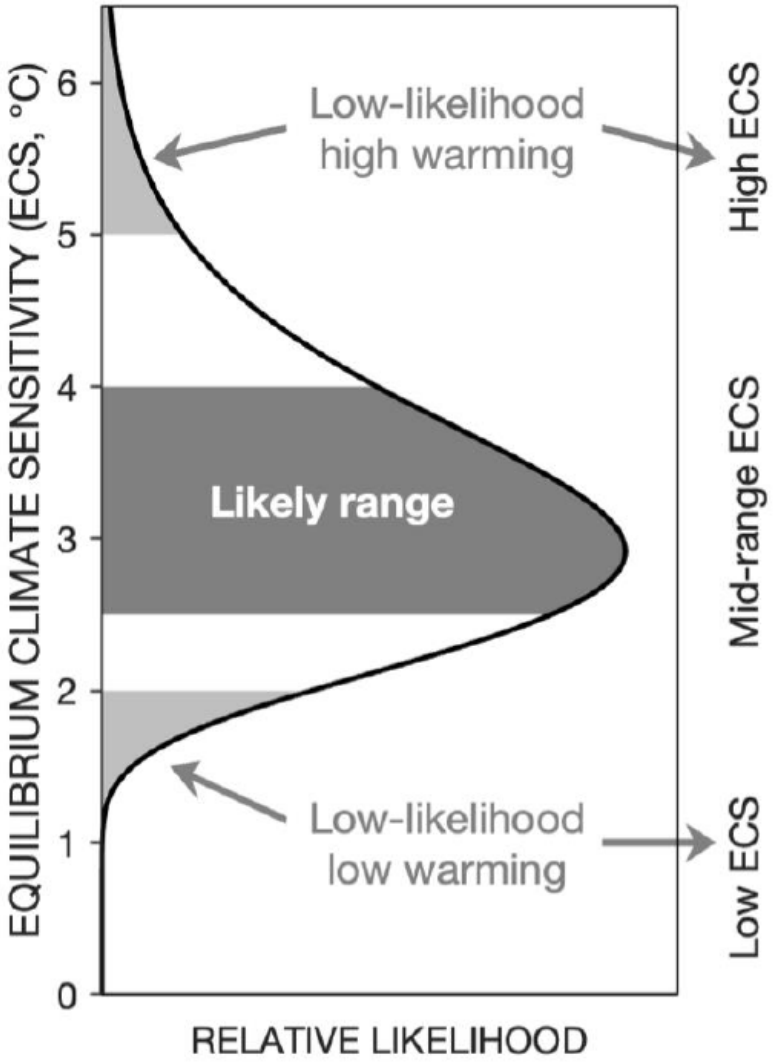
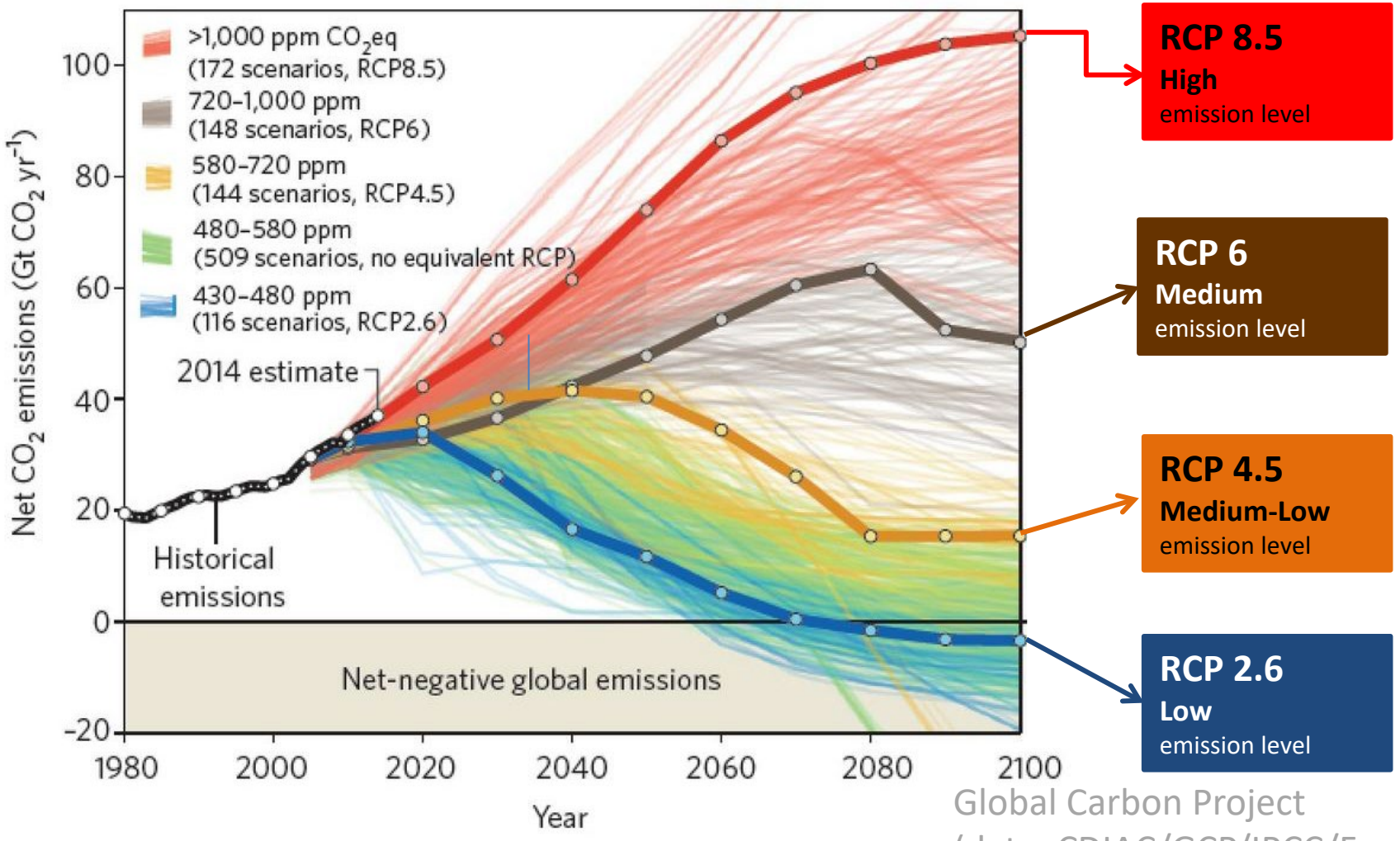
CLIMATESENSITIVITYAND FEEDBACKS





FUTURE CO_2 SCENARIOS



RCP 8.5
High
emission level

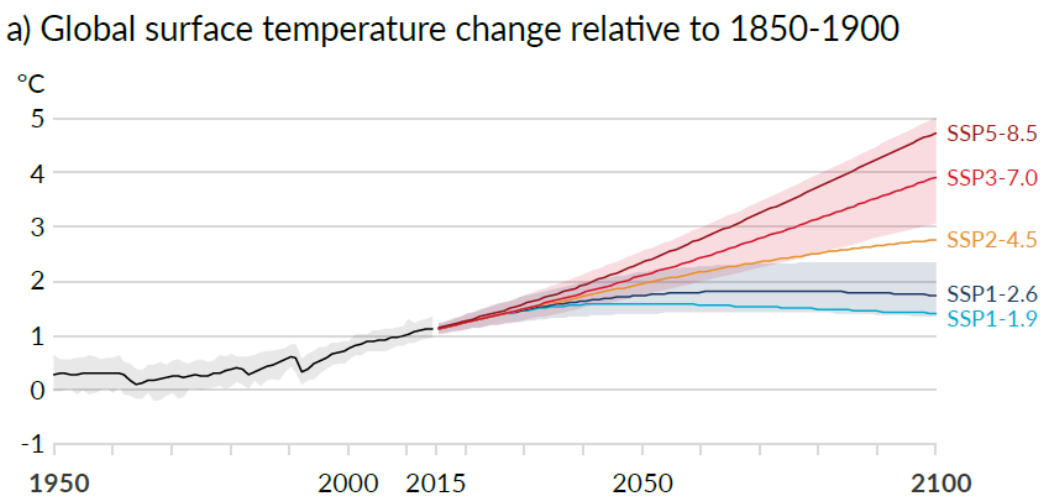
RCP 6
Medium
emission level

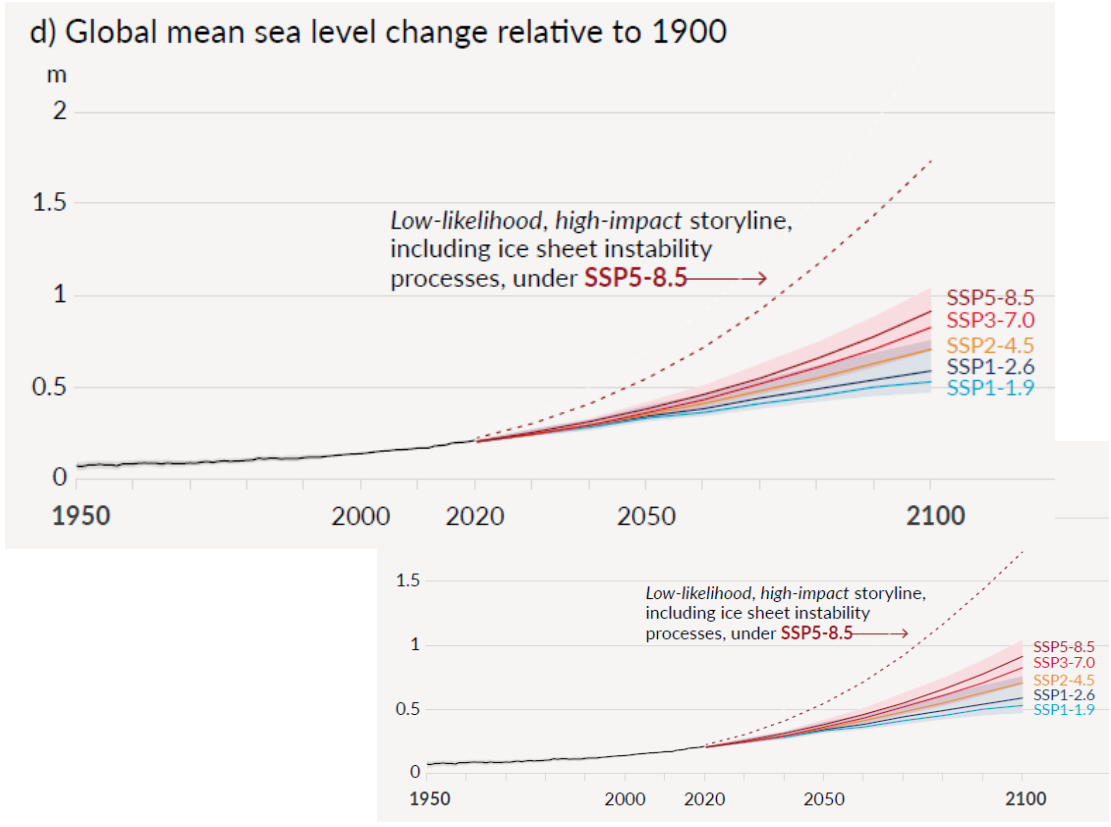
RCP 4.5
Medium-Low
emission level

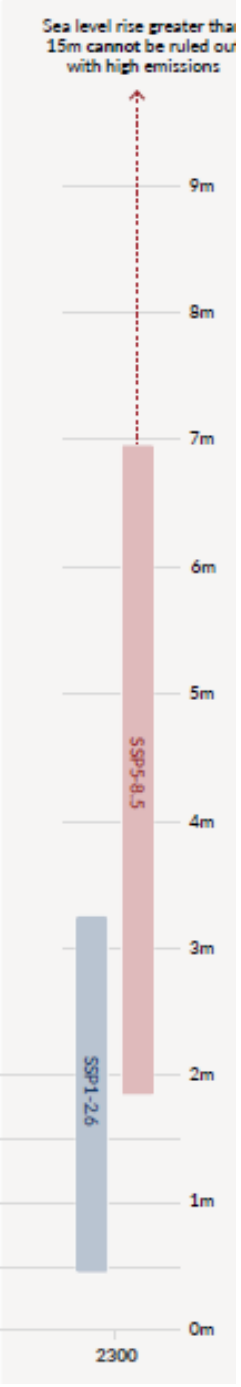
RCP 2.6
Low
emission level

Global Carbon Project
(data: CDIAC/GCP/IPCC/Fuss et al. 2014)

SCENARIOS FOR TEMPERATURE AND SEA LEVEL







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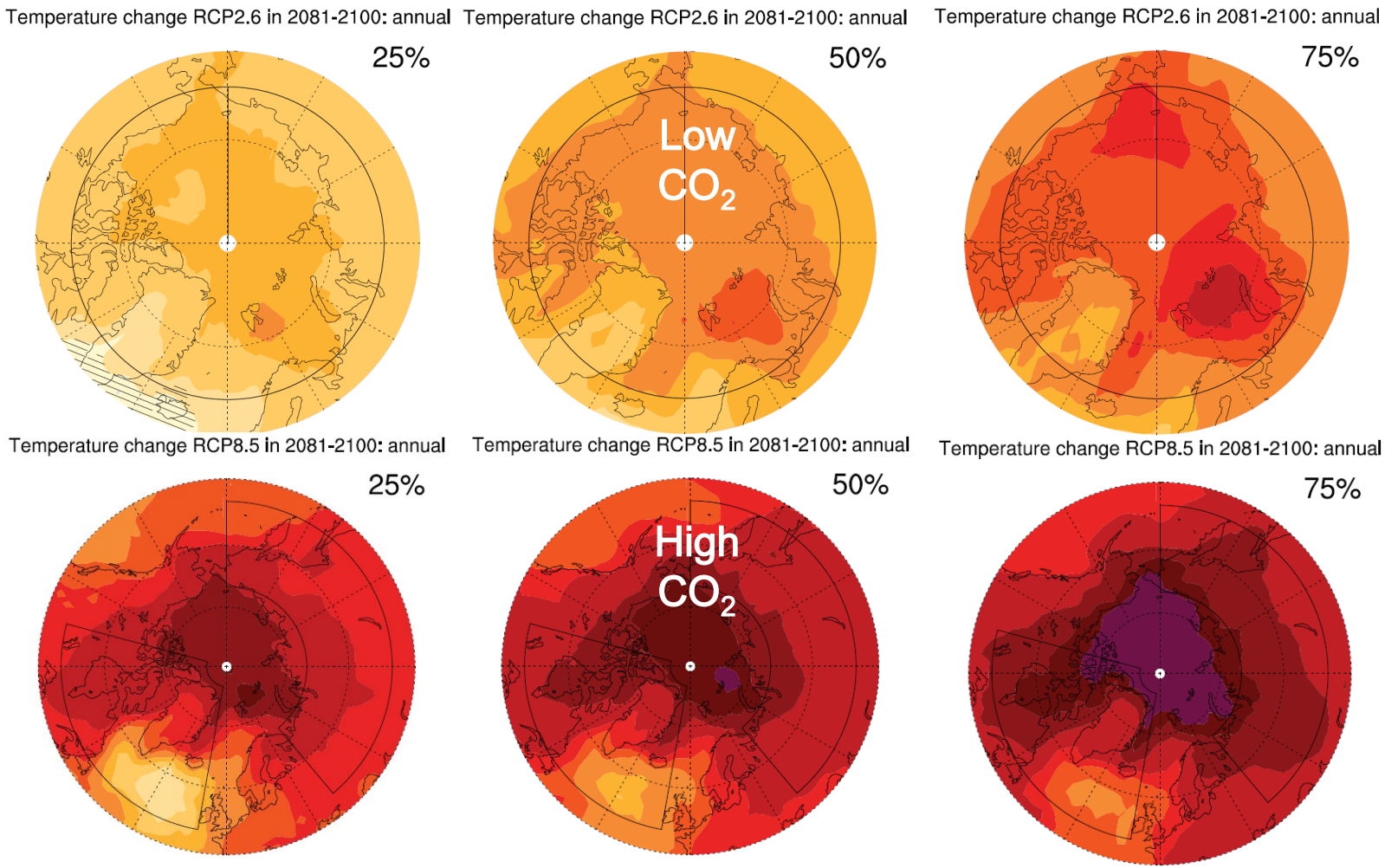
FUTURE ARCTIC WARMING UNCERTAINTY



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