Climate Science 102: Climate Feedbacks

Ali Ramadhan
Warittha Panasawatwong

Introduction: Ali Ramadhan

- First-year PhD student in climate physics
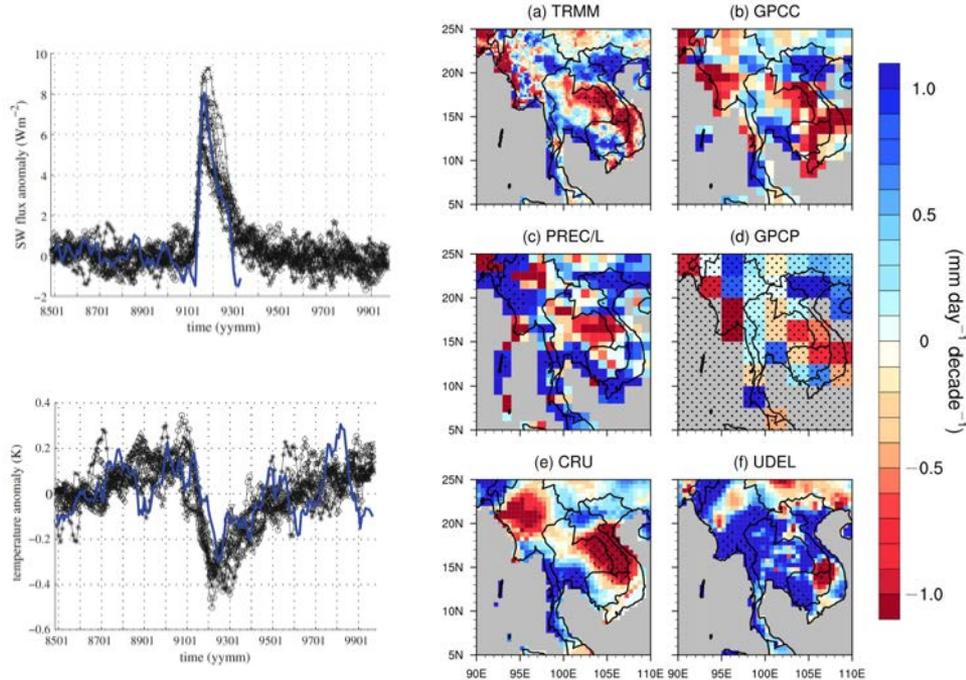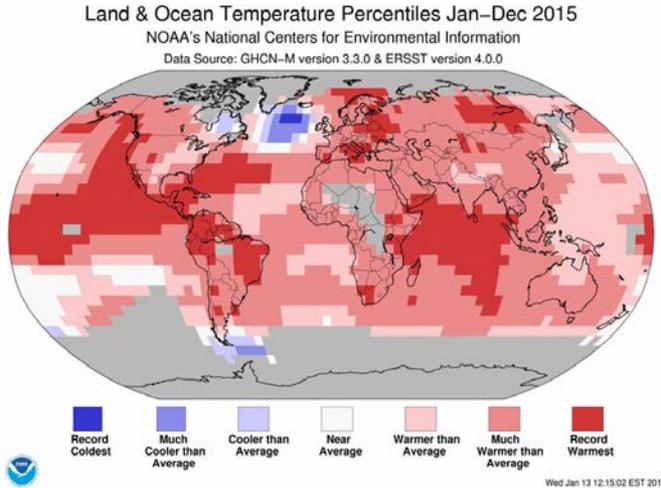
Past life

Current life

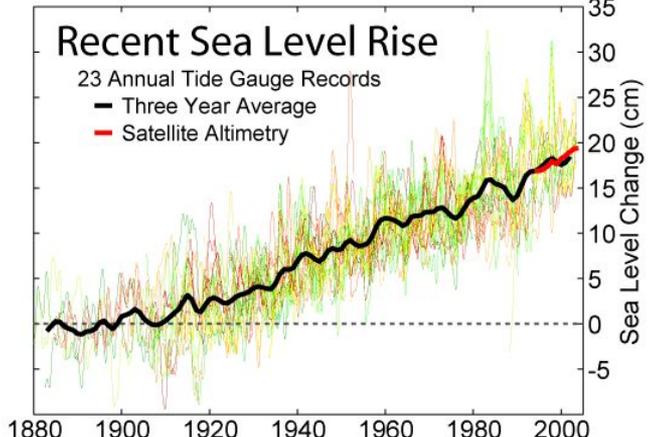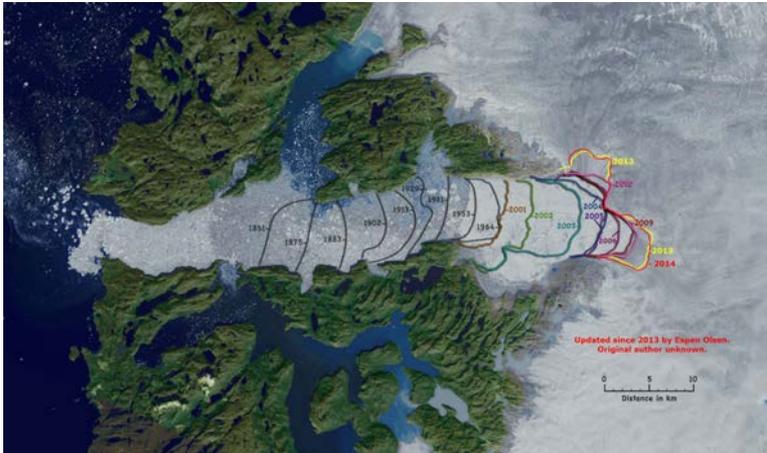# Warittha Panasawatwong

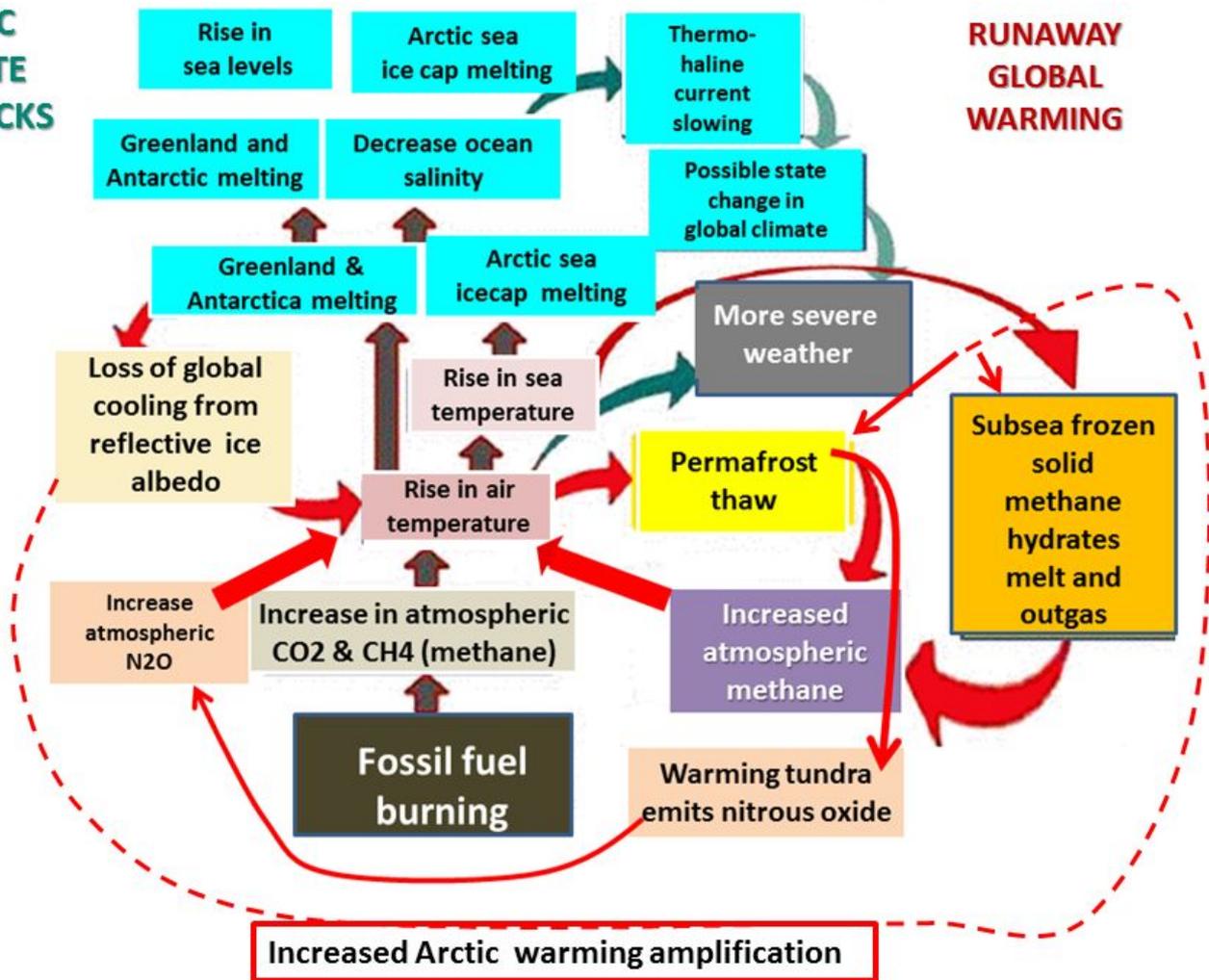- Master's student in atmospheric science

Recap: Climate change impact

Retreat of Jakobshavn Glacier in Greenland

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ARCTIC CLIMATE FFED BACKS

RUNAWAY GLOBAL WARMING

Rise in sea levels

Arctic sea ice cap melting

Thermo-haline current slowing

Greenland and Antarctic melting

Decrease ocean salinity

Possible state change in global climate

Greenland & Antarctica melting

Arctic sea icecap melting

More severe weather

Loss of global cooling from reflective ice albedo

Rise in sea temperature

Subsea frozen solid methane hydrates melt and outgas

Rise in air temperature

Permafrost thaw

Increase atmospheric N2O

Increase in atmospheric CO2 & CH4 (methane)

Increased atmospheric methane

Fossil fuel burning

Warming tundra emits nitrous oxide

Increased Arctic warming amplification

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All the Factors (and other Fs)

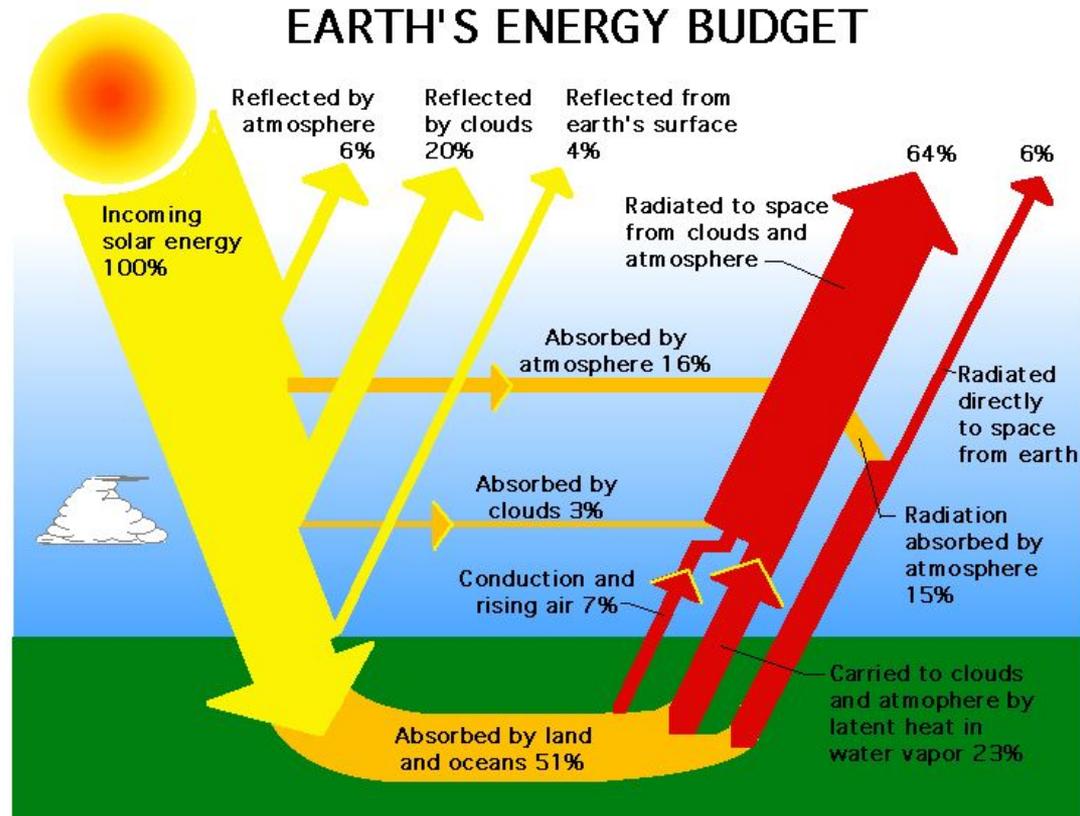Radiative forcing

Effective radiative forcing

Forcings

Feedback

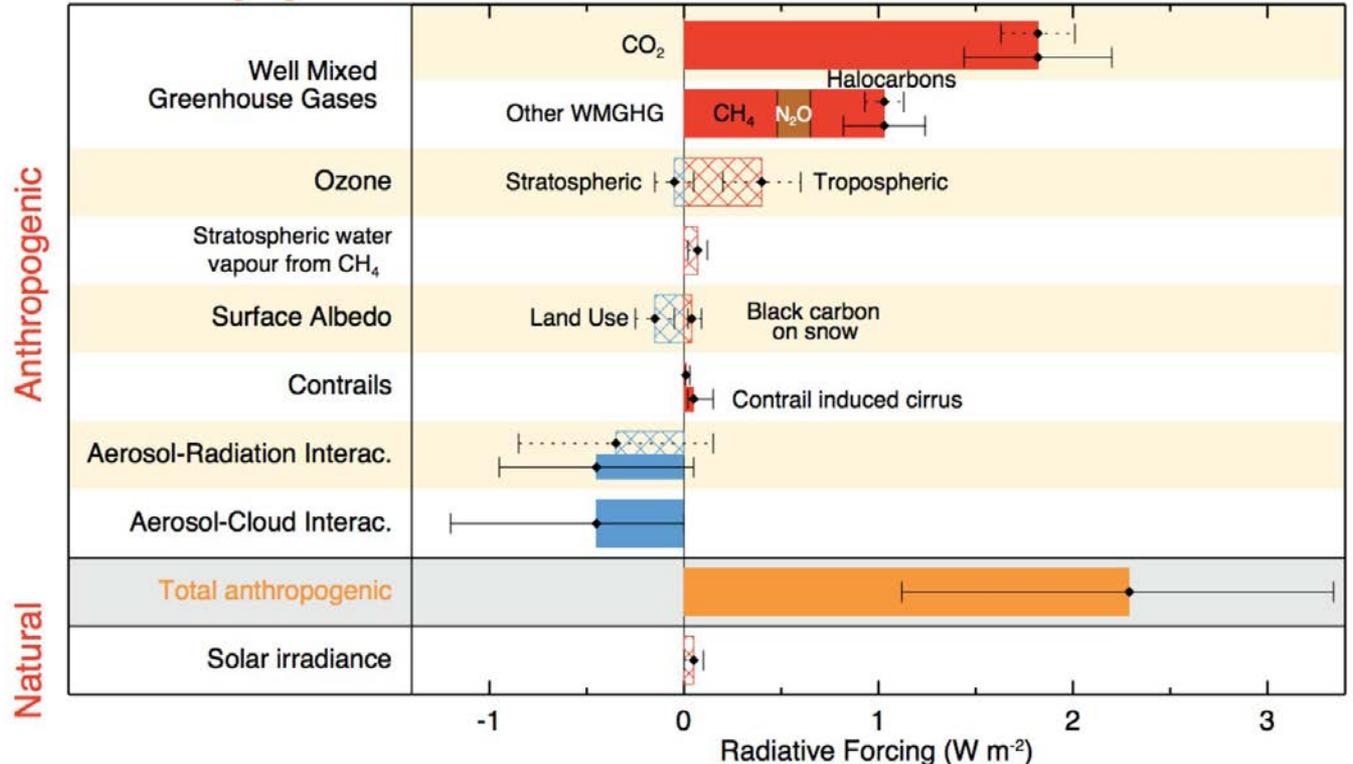# Radiative Forcing (RF)

RF = Change of net downward energy to Earth

If the system is in balance, the radiative forcing would be zero.

Effective radiative forcing
    Realistic RF with feedbacks

EARTH'S ENERGY BUDGET

Reflected by atmosphere 6%

Reflected by clouds 20%

Reflected from earth's surface 4%

Incoming solar energy 100%

64%   6%

Radiated to space from clouds and atmosphere

Absorbed by atmosphere 16%

Radiated directly to space from earth

Absorbed by clouds 3%

Radiation absorbed by atmosphere 15%

Conduction and rising air 7%

Carried to clouds and atmophere by latent heat in water vapor 23%

Absorbed by land and oceans 51%
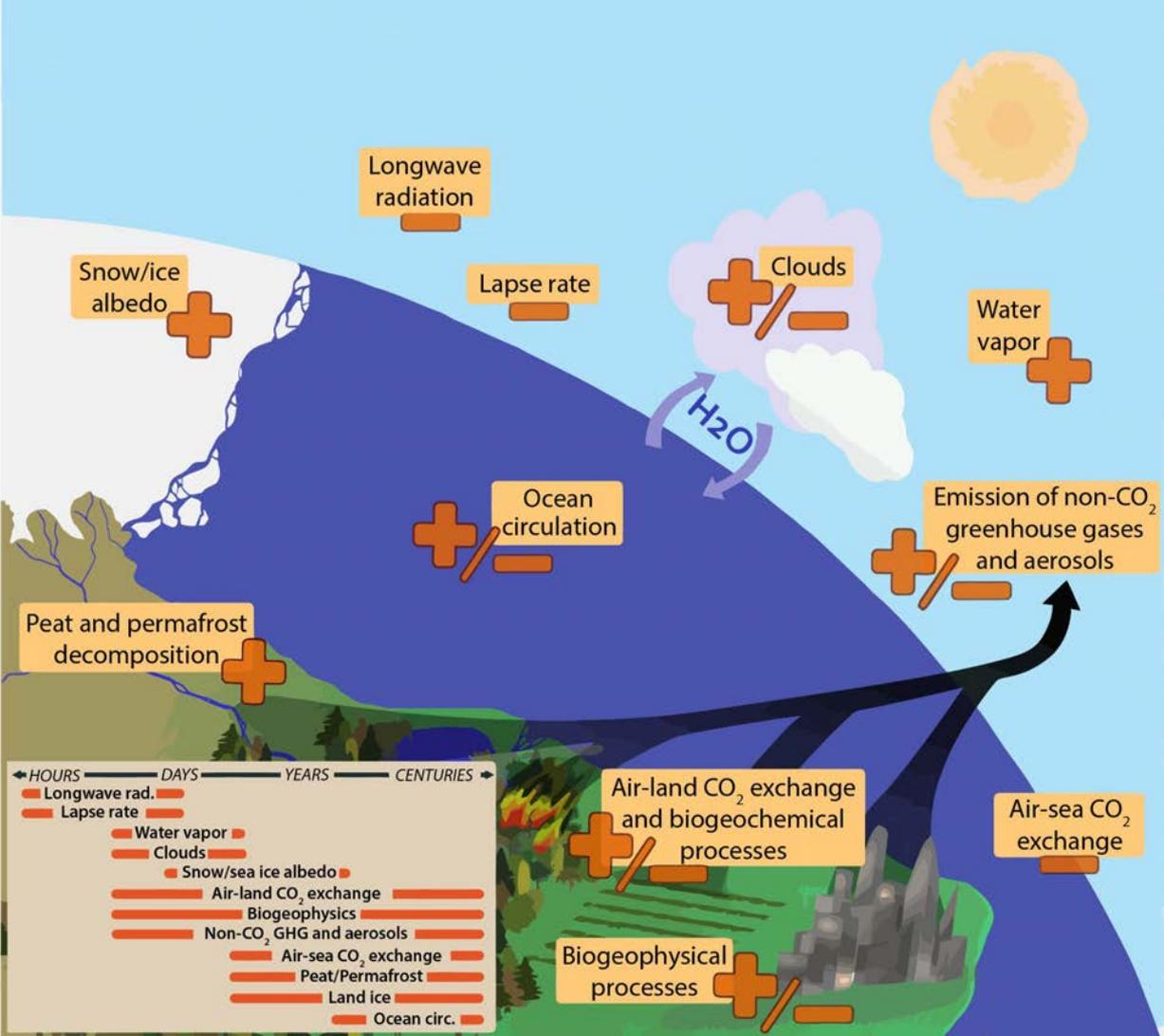
Forcings: Factors impacting radiative forcing

Radiative forcing of climate between 1750 and 2011

IPCC, 2014

Feedbacks

Feedback agents response to the forcing and may intensify the radiative forcing

- Water vapor
- Ice-albedo
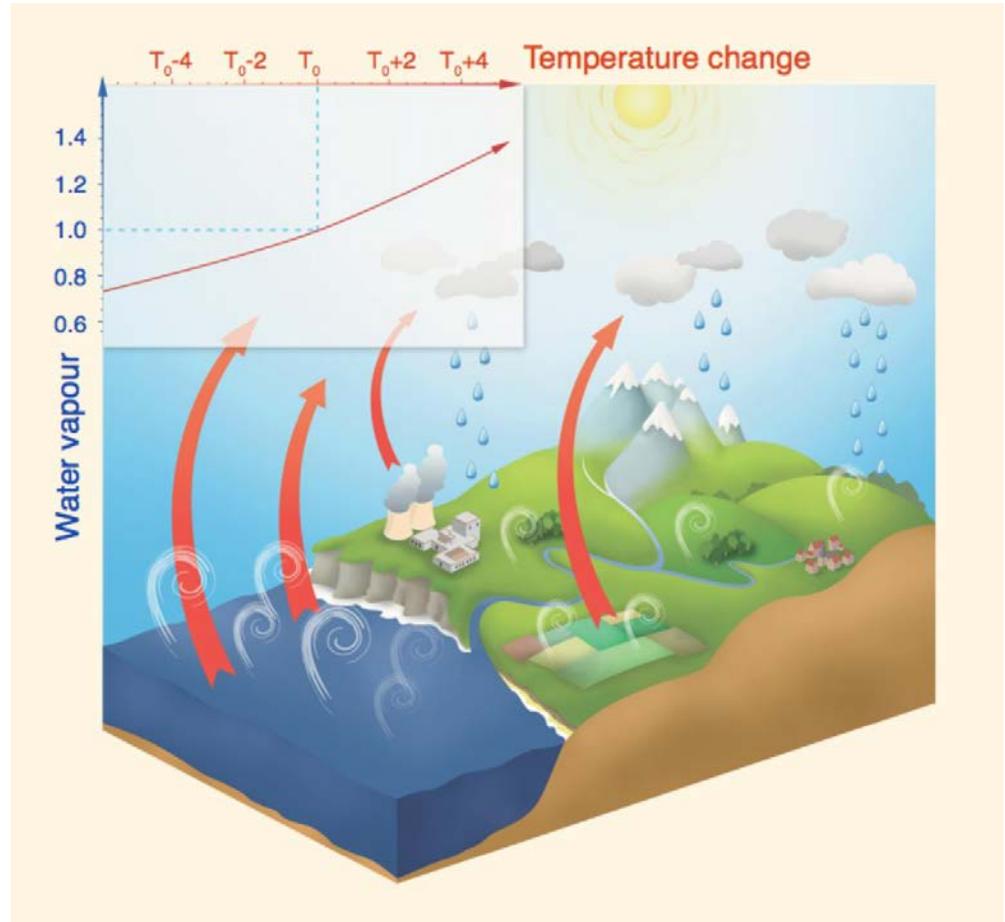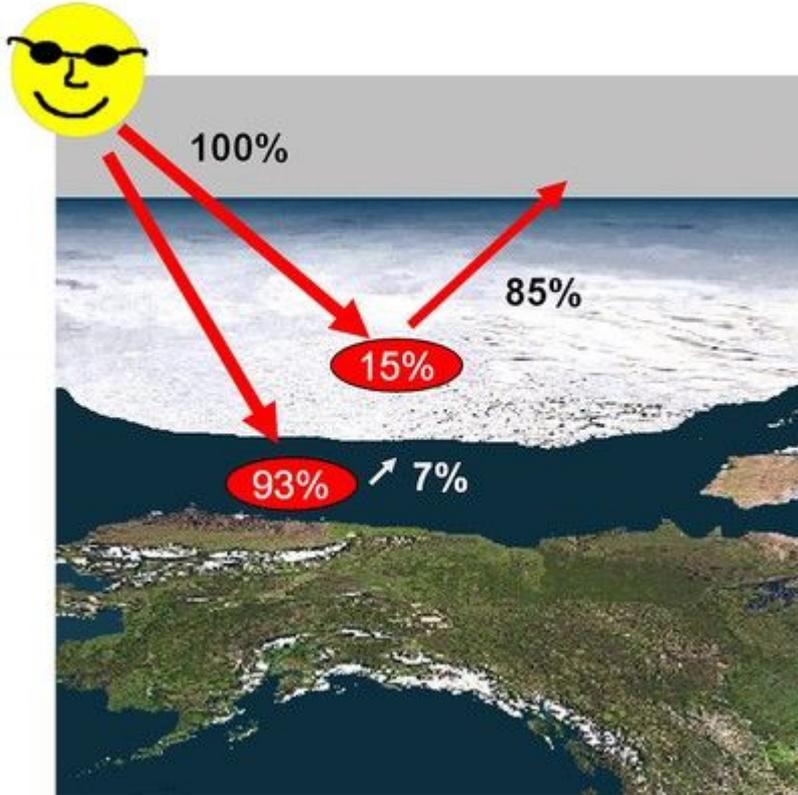- Clouds
- Biogeochemical

Water Vapor

It is a stronger "greenhouse gas" than CO2

However, the vapor amount is not directly controlled by human, so it's a feedback agent and not a forcing
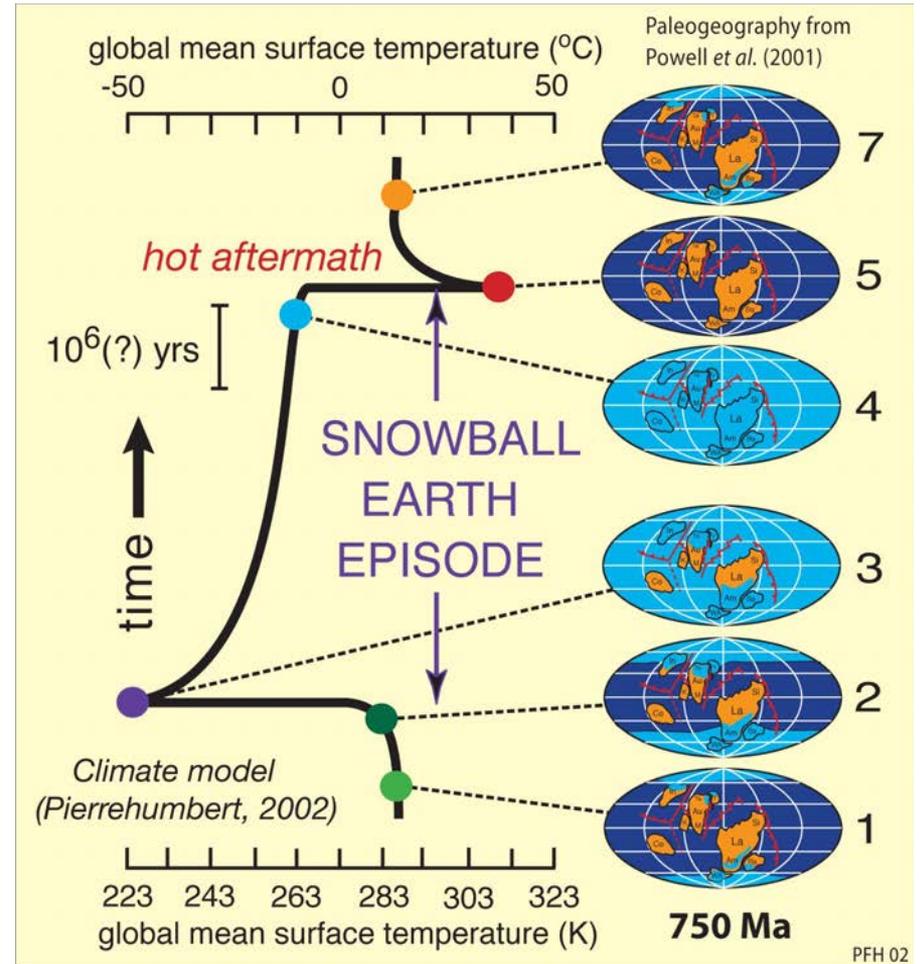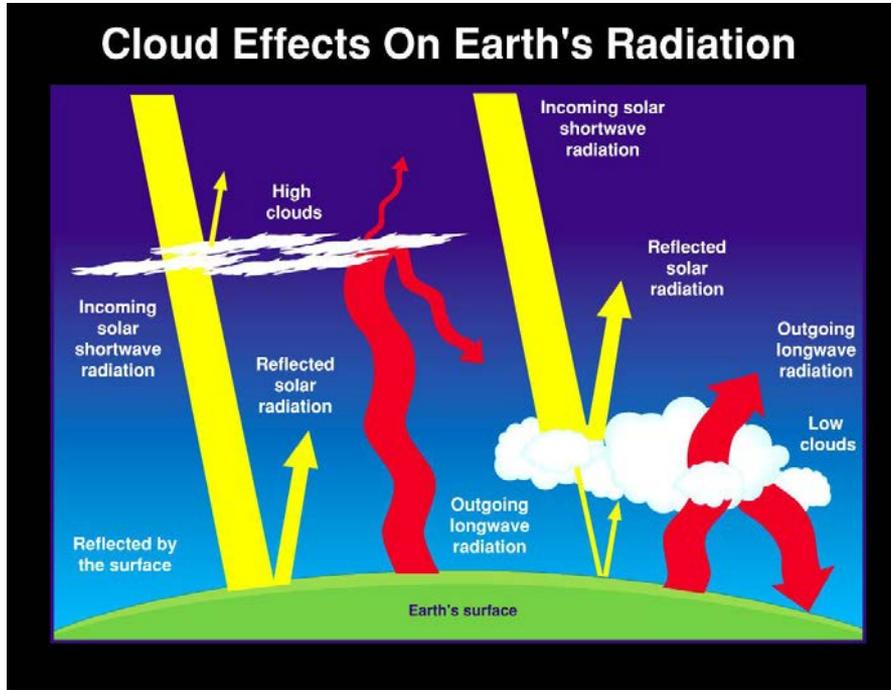
Can multiply the warming by 2-3 times greater
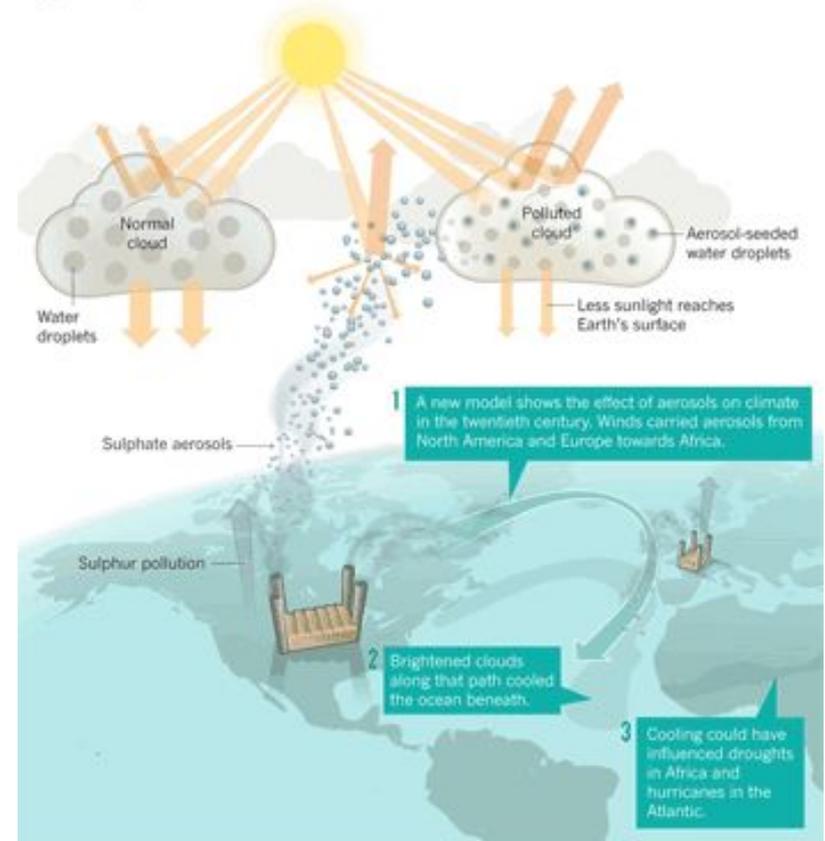

IPCC, 2014

Ice-albedo

OSS foundation

Snowball Earth

Clouds

NASA

Nature group

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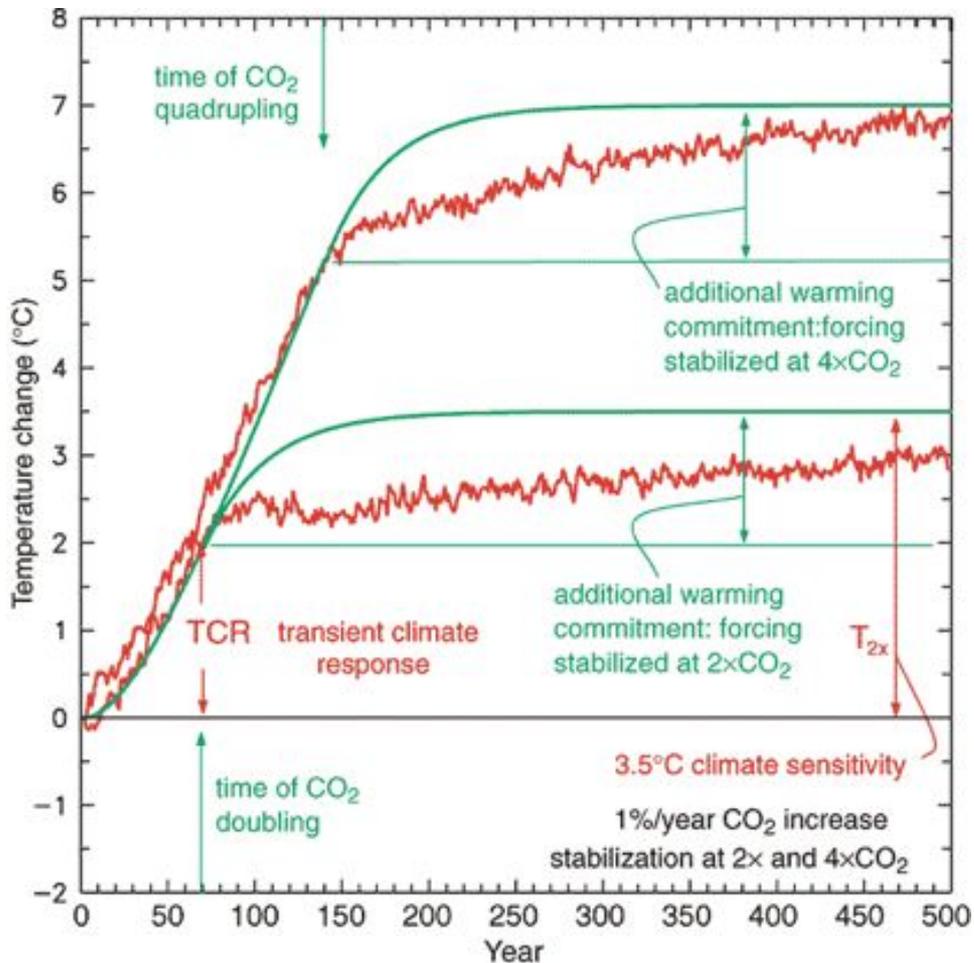
Biogeochemical feedback
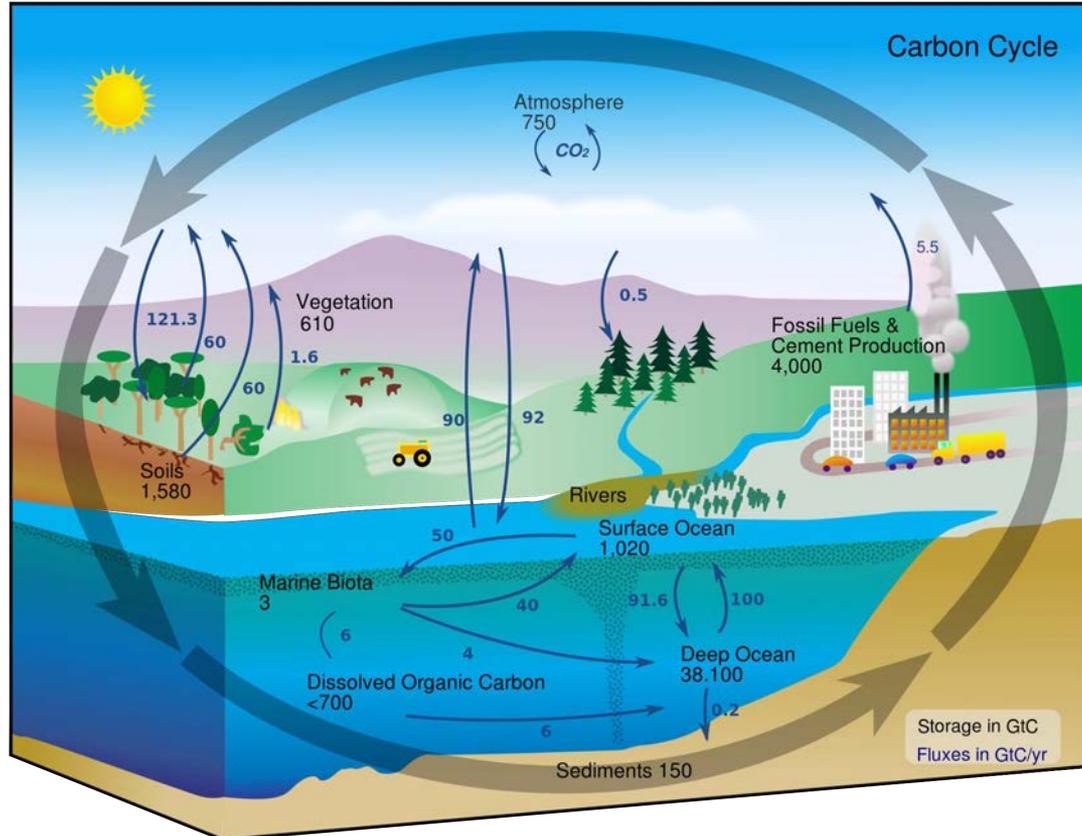
Climate Sensitivity

Climate sensitivity measures temperature response to doubling of atmospheric CO2
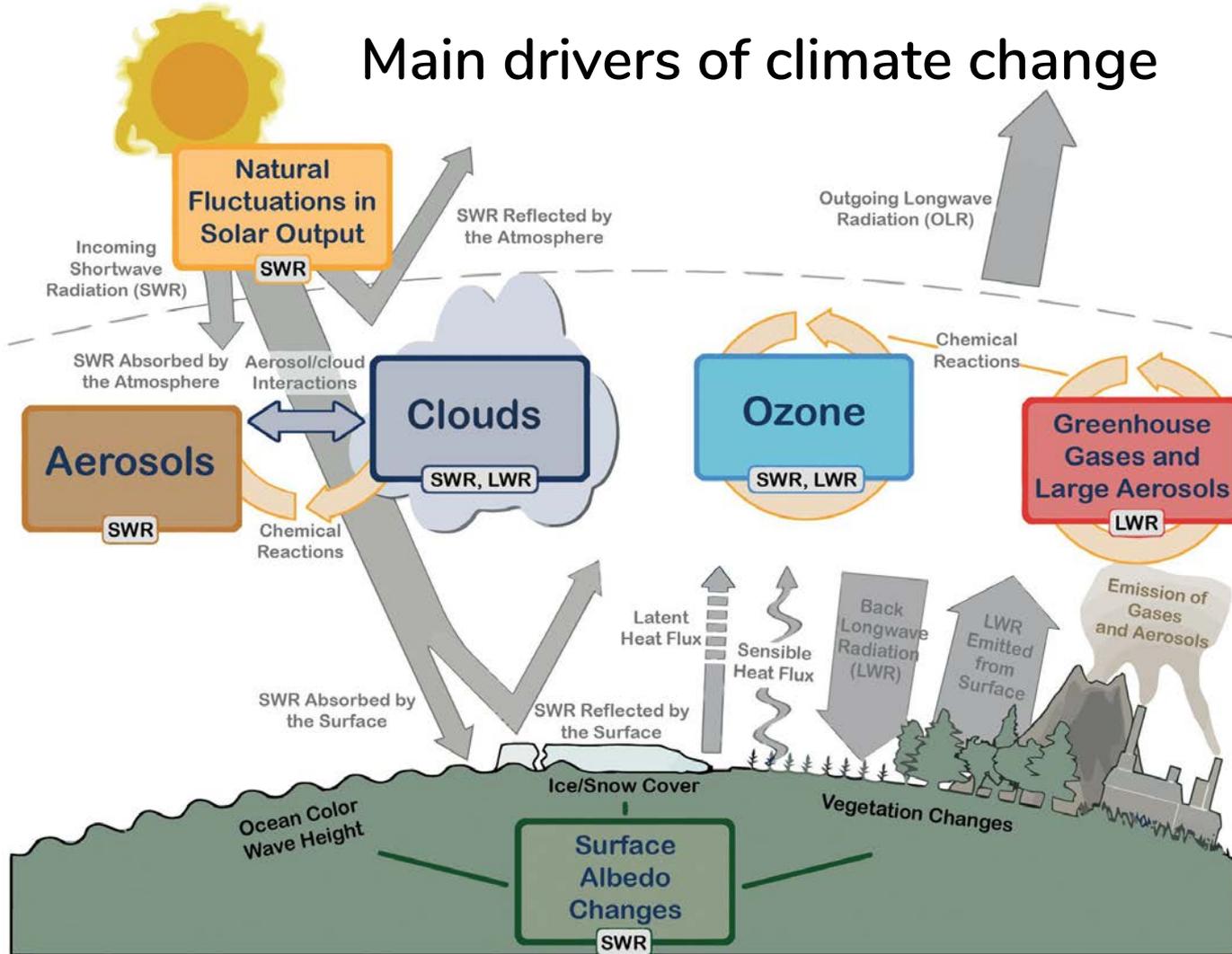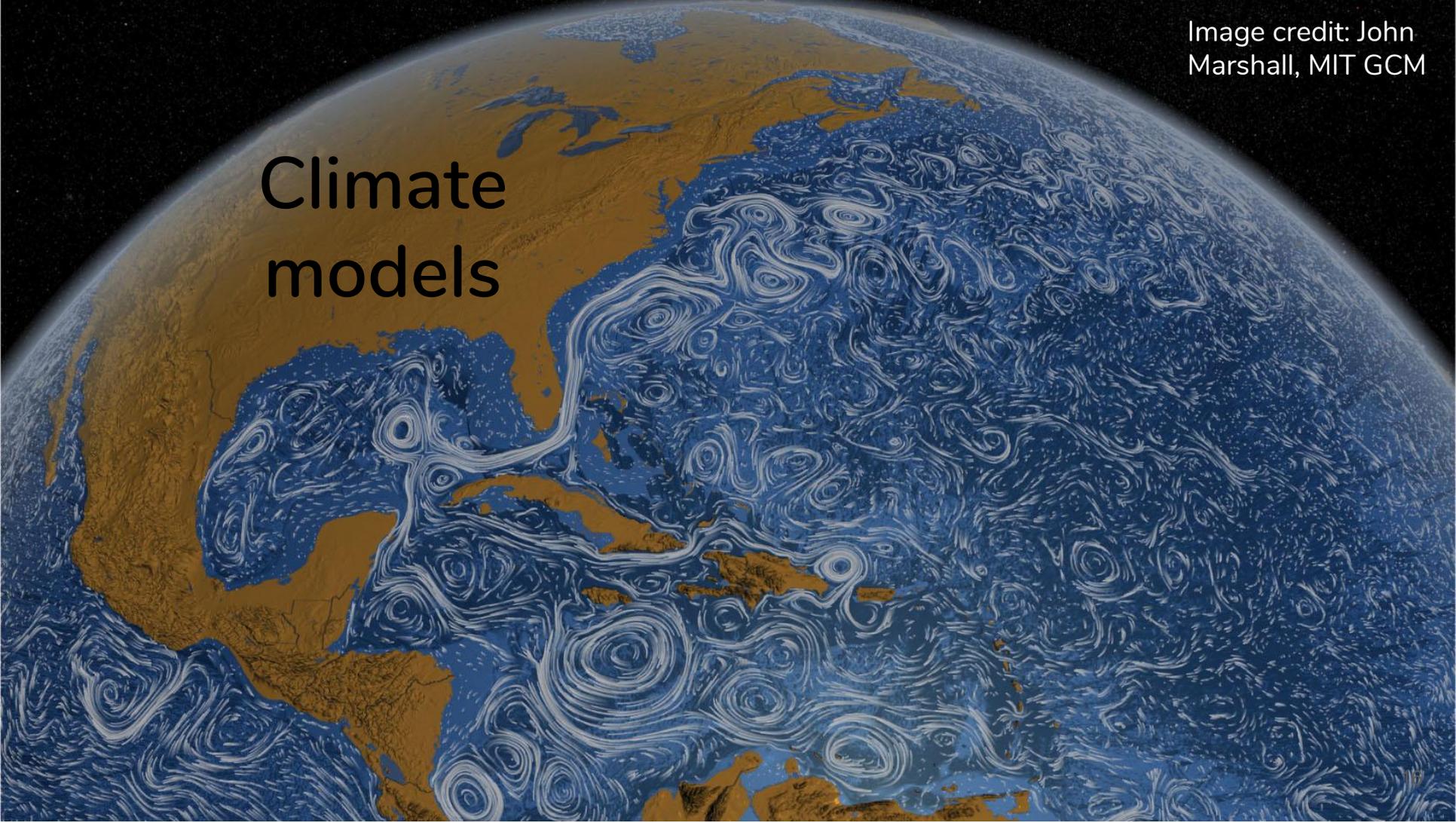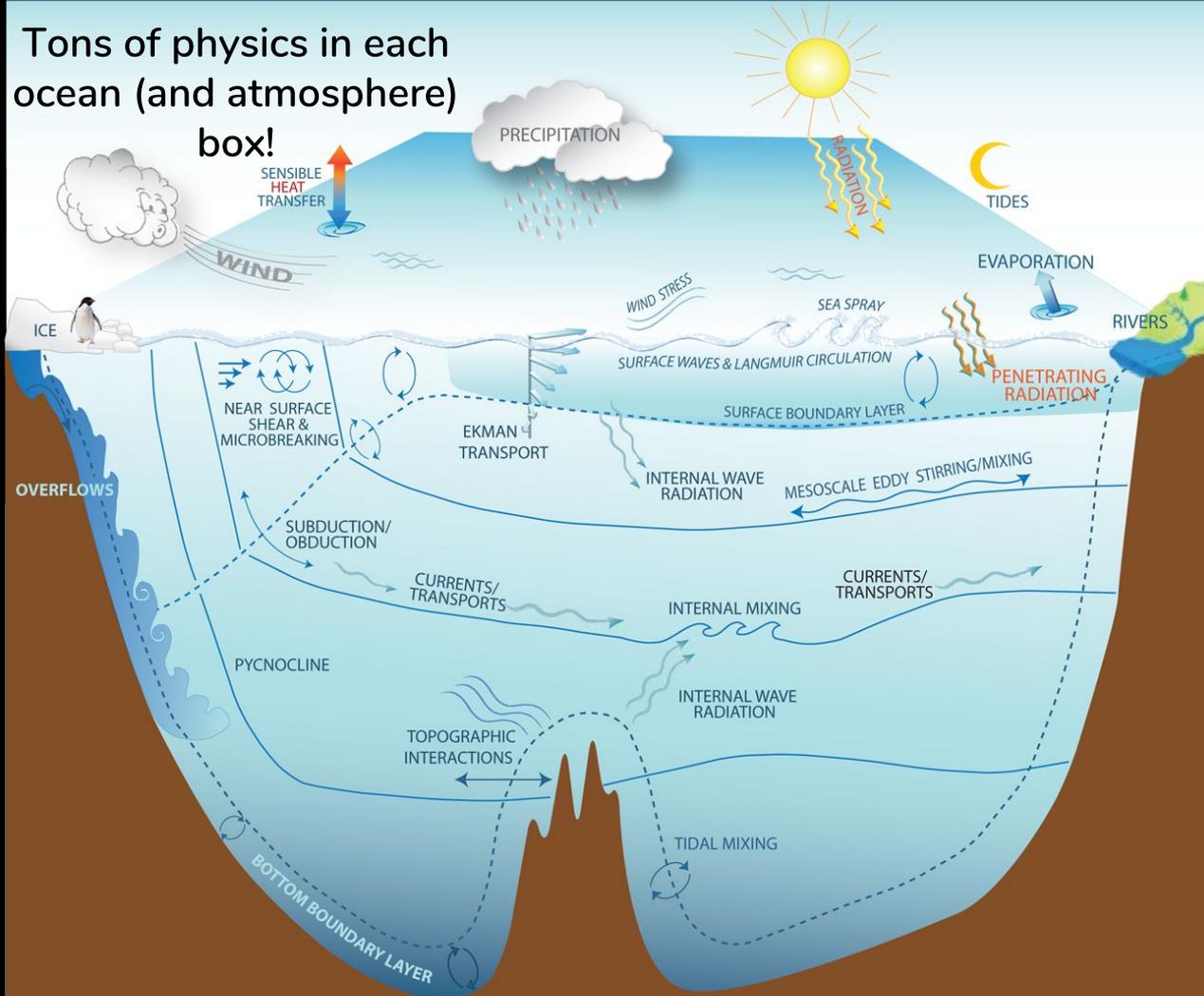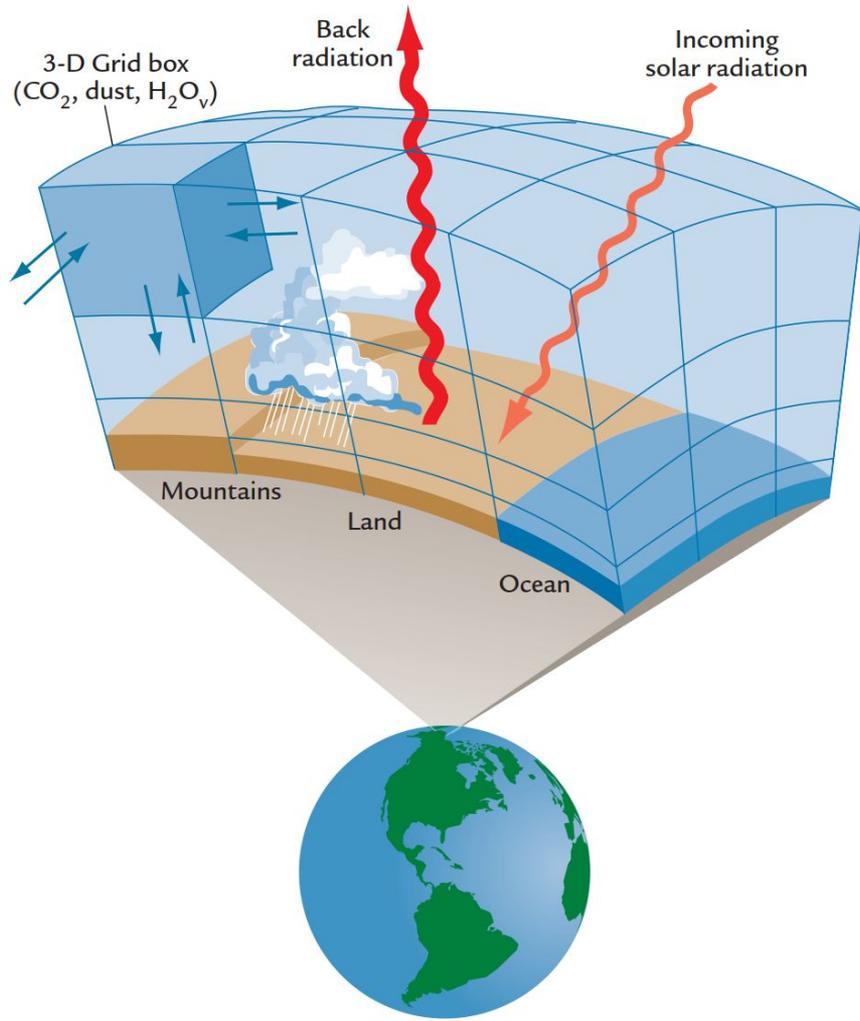
Main drivers of climate change

Climate models

Tons of physics in each ocean (and atmosphere) box!

NOAA GFDL

a)

87.5 km x 87.5 km

b)

30.0 km x 30.0 km

IPCC AR5

3-D Grid box
(CO$_2$, dust, H$_2$O$_v$)

Back radiation

Incoming solar radiation

Mountains

Land

Ocean
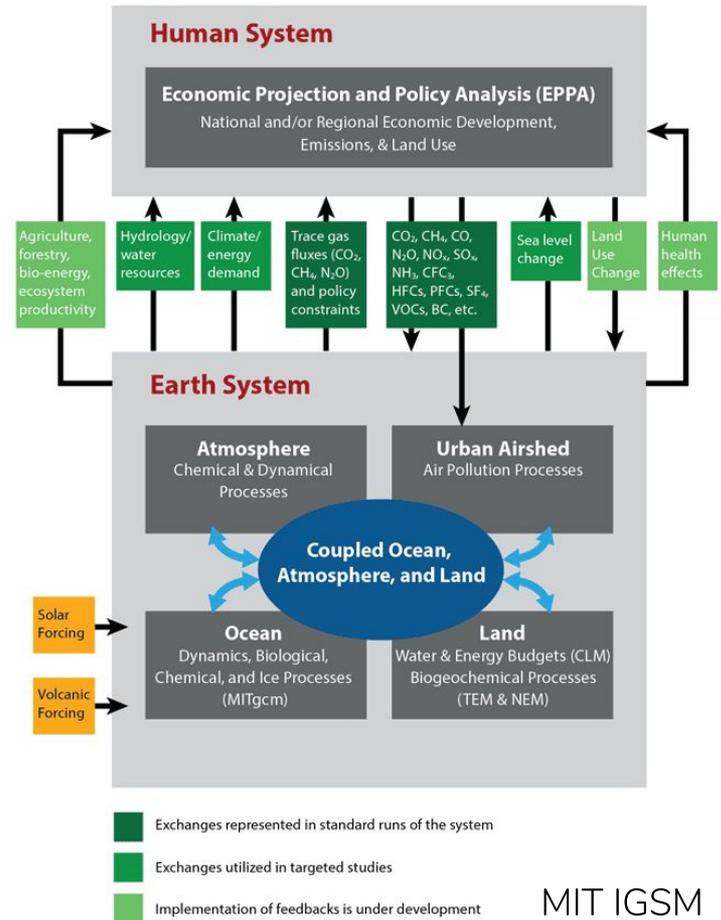
Ruddiman (2014)
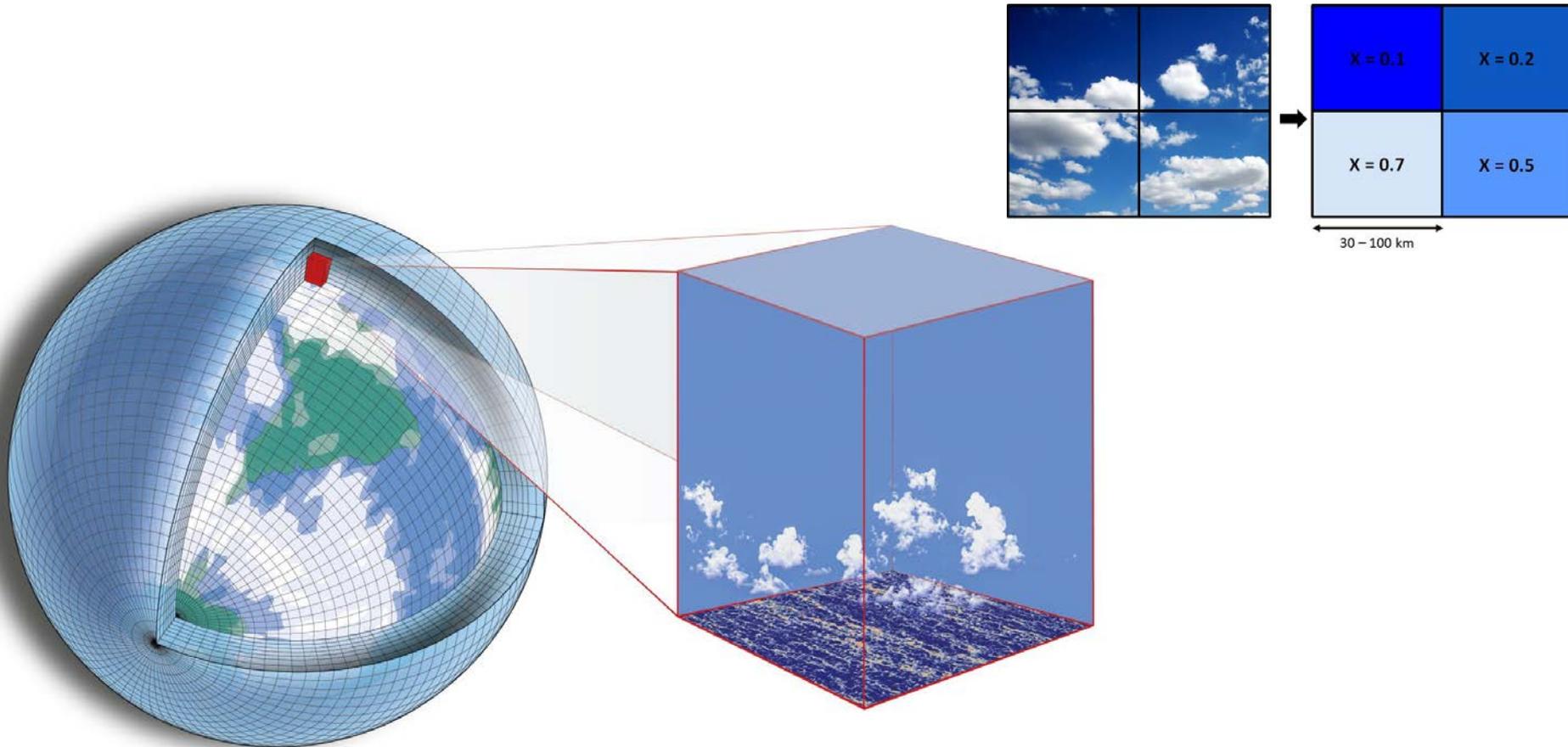
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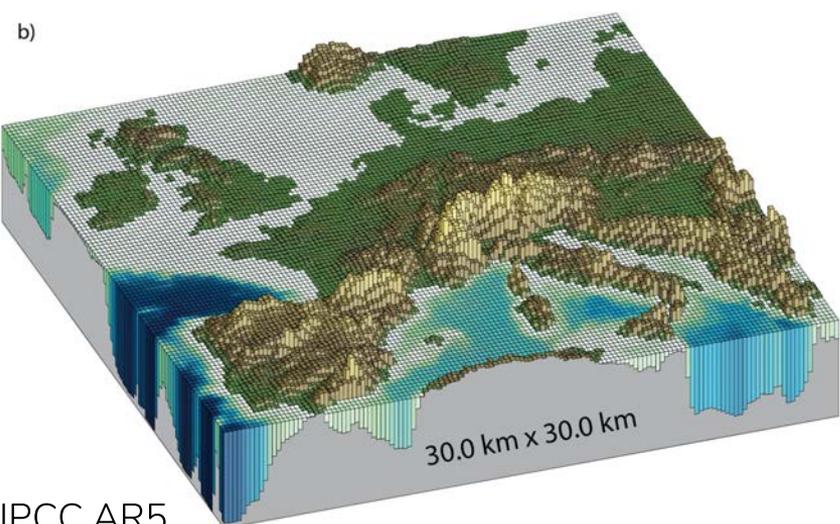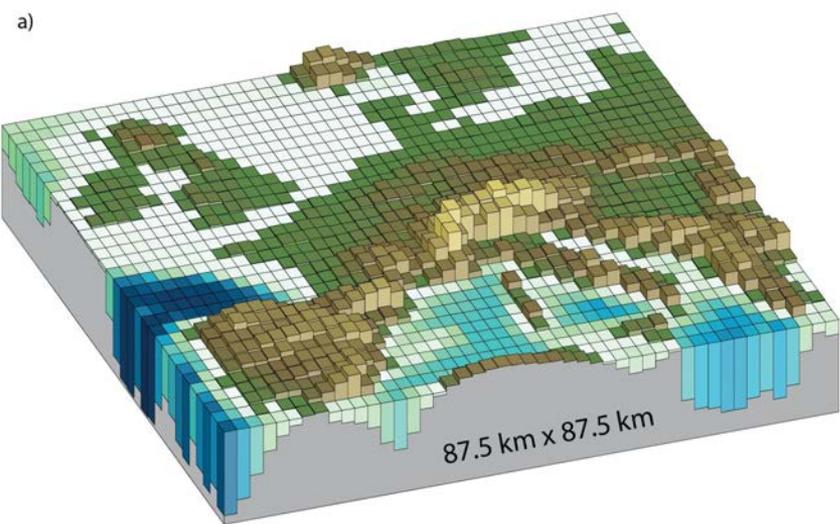
Today's climate models have many components

IPCC AR5
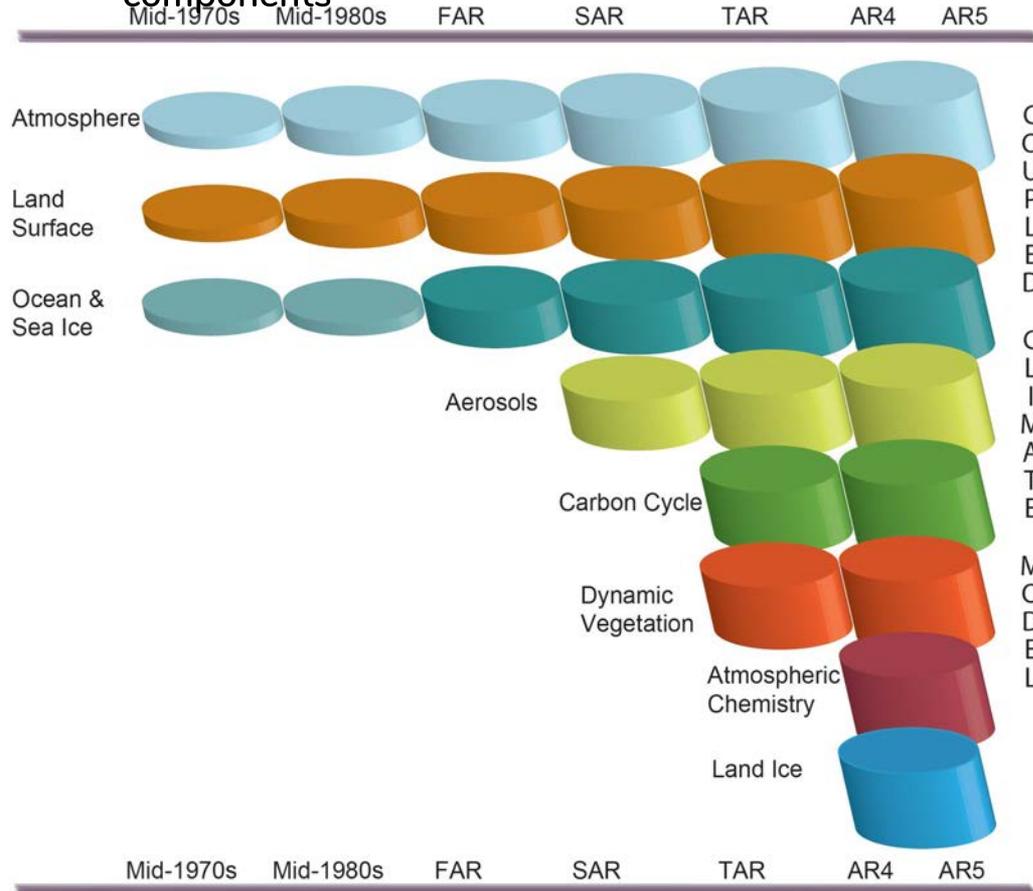
To make future predictions, must also predict what humans will do!

MIT IGSM

Sub-grid scale processes must be parameterized

X = 0.1 X = 0.2

X = 0.7 X = 0.5
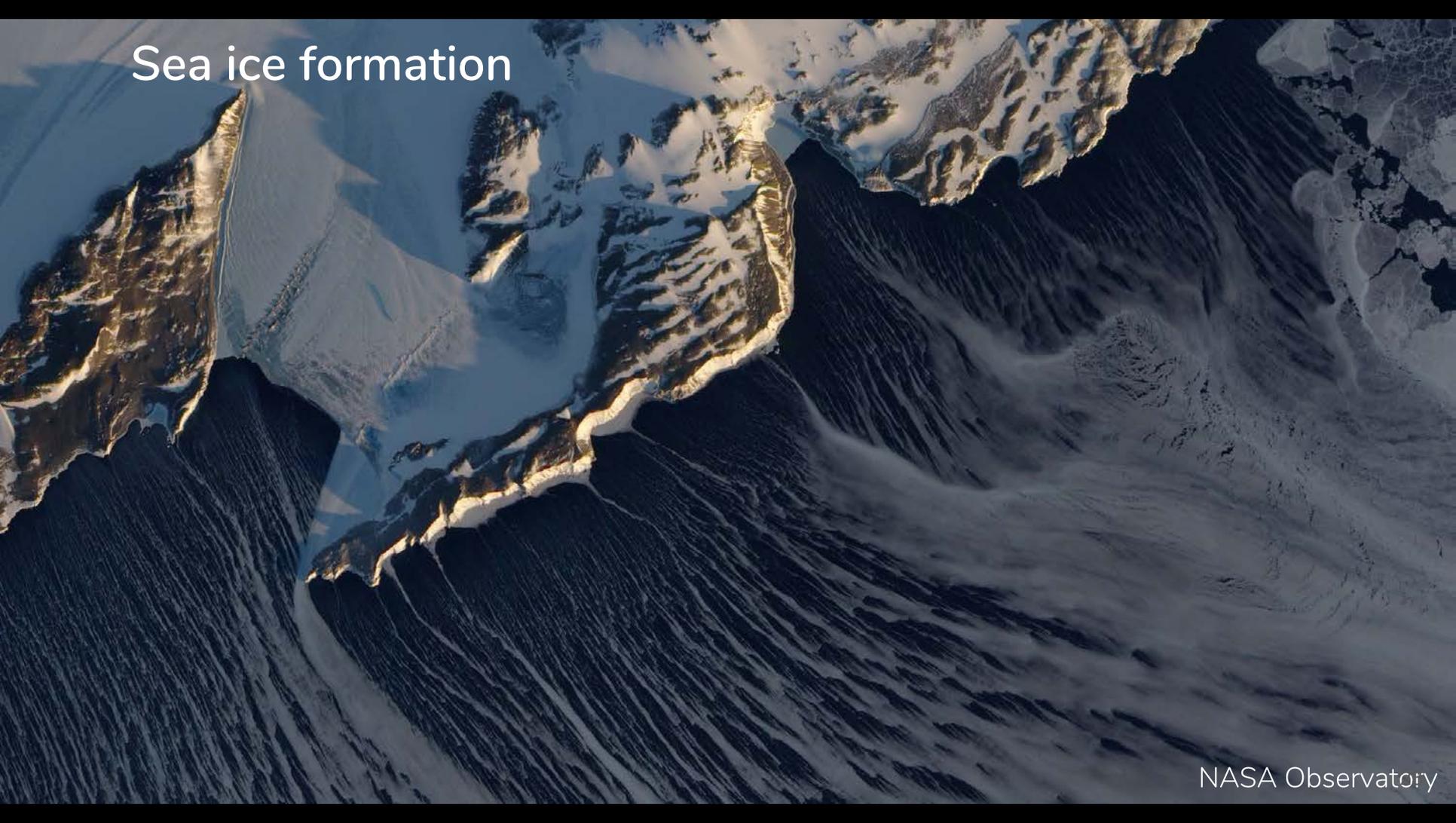
30 – 100 km

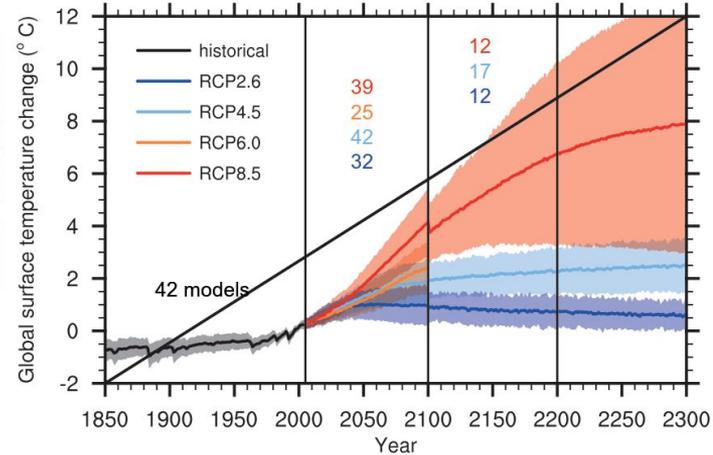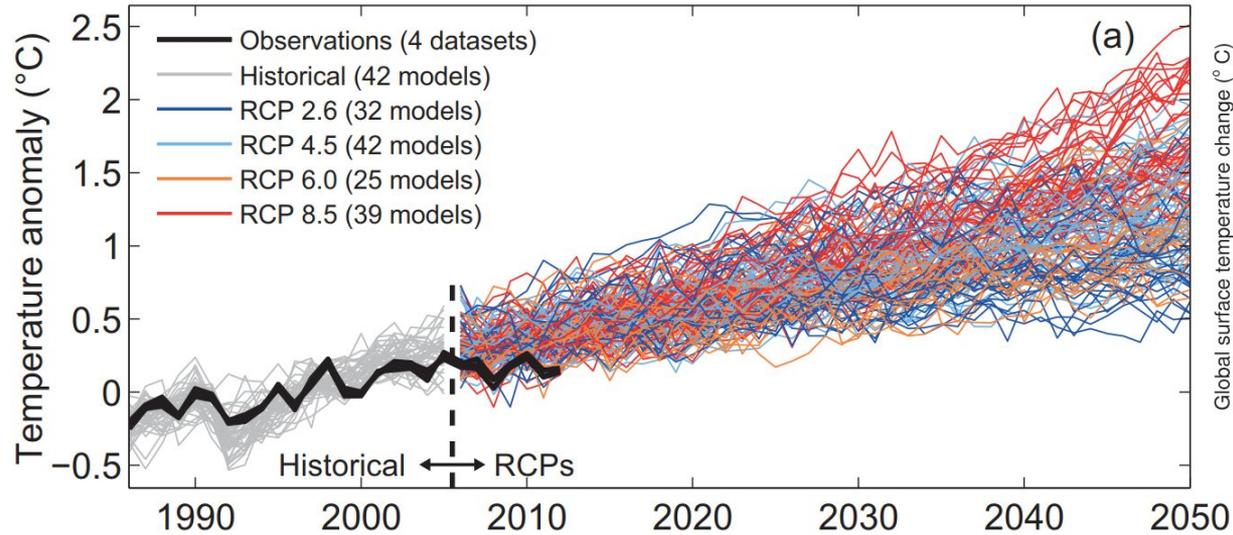Climate dynamics group, Caltech

Thin broken altocumulus clouds

Cloud formation, convection, stratocumulus clouds

Sea ice formation

NASA Observatory

Must tune model due to many parameters → High model spread

Global mean temperature near−term projections relative to 1986−2005

Image credit: IPCC AR5

Extreme weather events in a warmer world

Heavy Precipitation Events

Droughts Mediterranean, West Africa

Droughts Central North America Northwest Australia

Hot Days and Nights; Warm Spells and Heat Waves

Cold Days and Nights

Strongest Tropical Cyclones North Atlantic
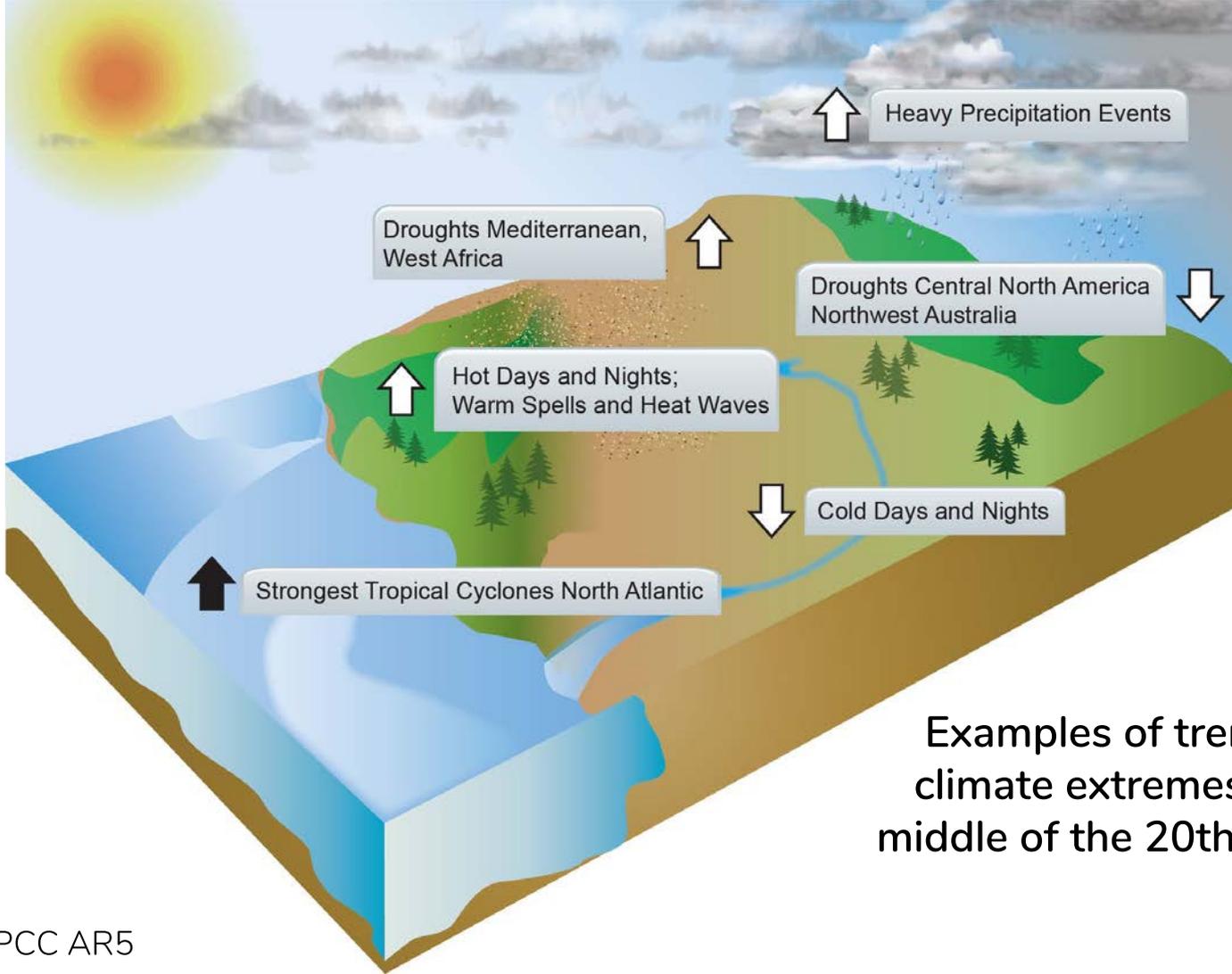
Examples of trends in climate extremes since middle of the 20th century

Temperature

(a) Increase in mean

Fewer cold extremes   More hot extremes

Cold   Average   Hot

Temperature

(b) Increase in variance

More cold extremes   More hot extremes

Cold   Average   Hot

Temperature

(c) Increase in mean and variance

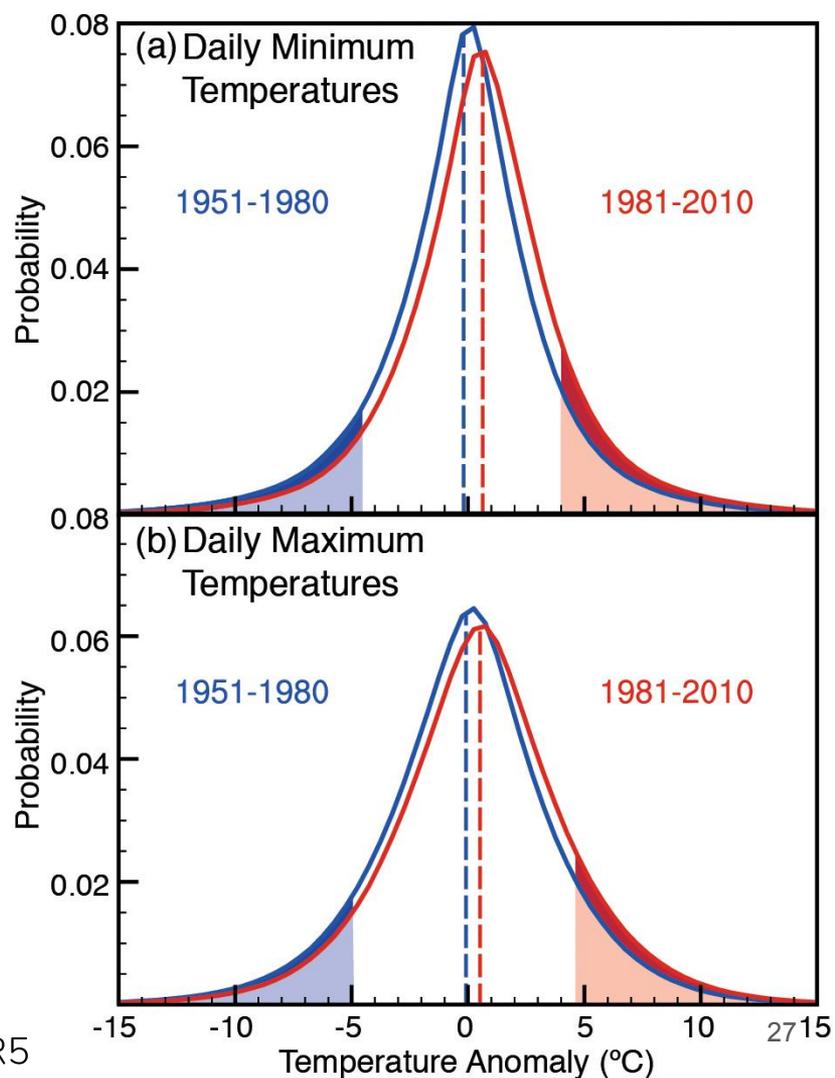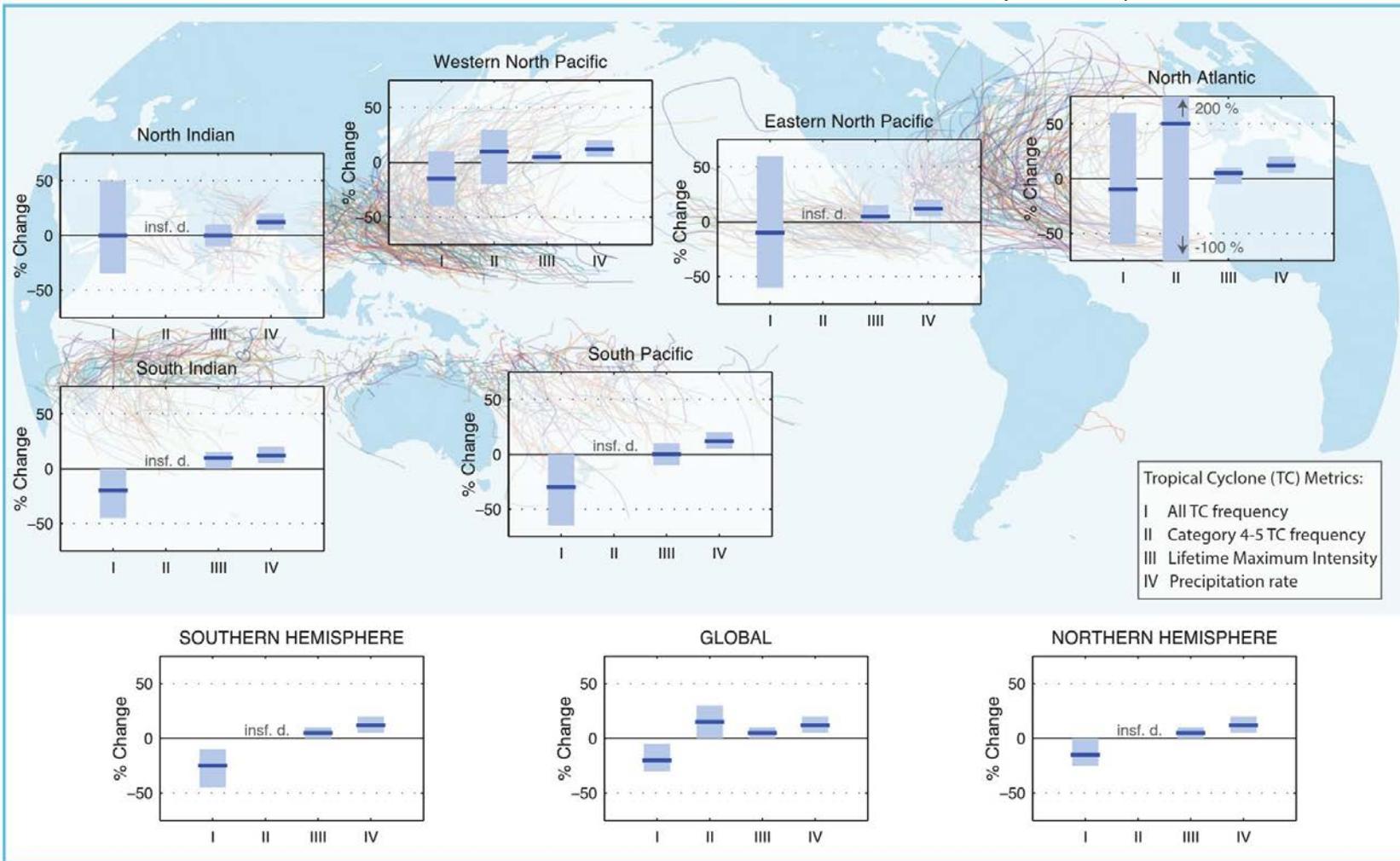More/Fewer cold extremes   More hot extremes

Cold   Average   Hot

More temperature extremes and heat waves
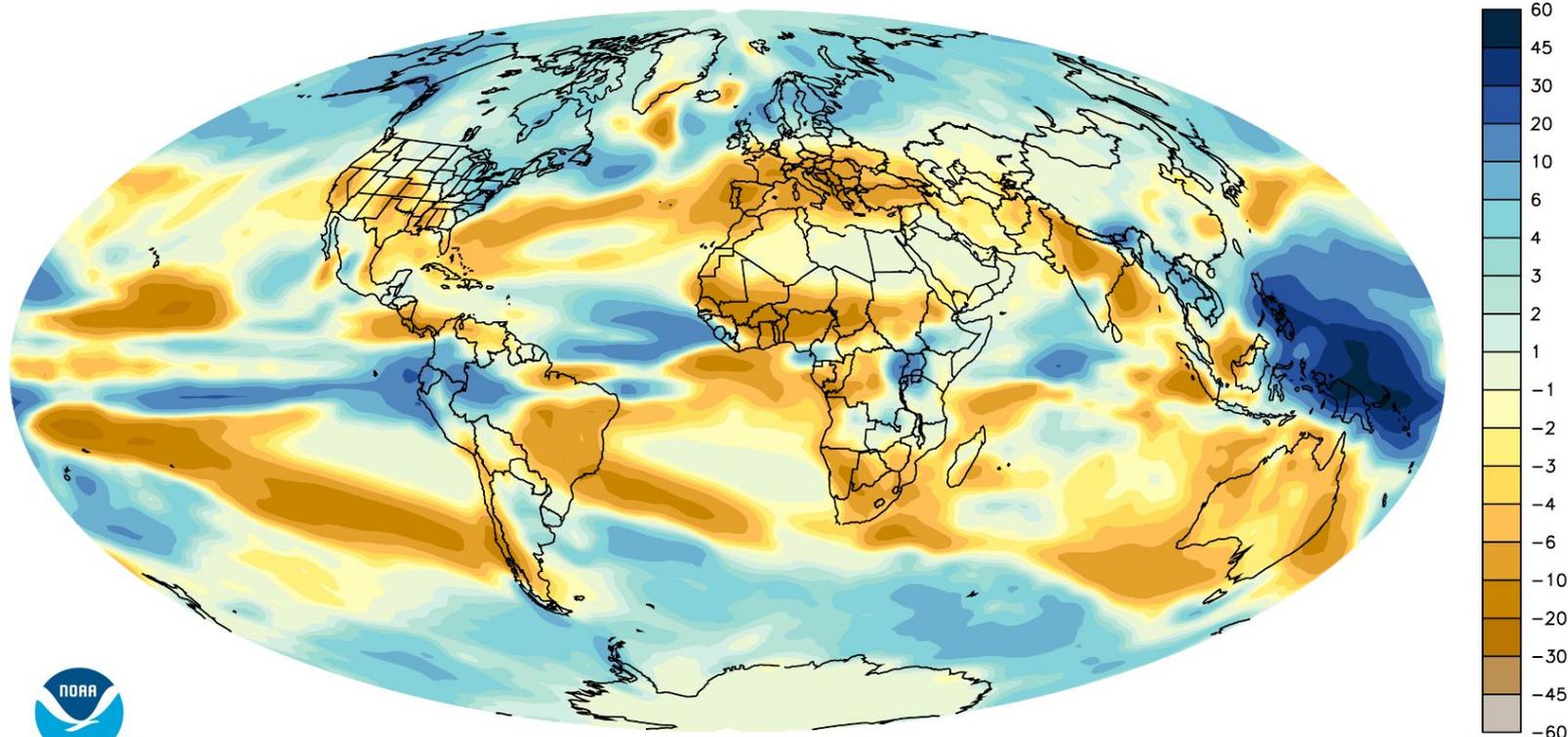
Image credit: IPCC AR5

(a) Daily Minimum Temperatures

1951-1980   1981-2010

(b) Daily Maximum Temperatures

1951-1980   1981-2010

Probability

Temperature Anomaly (ºC)

-15   -10   -5   0   5   10   15

0.08   0.06   0.04   0.02

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Warmer ocean → Fewer but more intense tropical cyclones

Tropical Cyclone (TC) Metrics:
I   All TC frequency
II   Category 4-5 TC frequency
III Lifetime Maximum Intensity
IV   Precipitation rate

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"Dry gets drier, wet gets wetter"
CHANGE IN PRECIPITATION BY END OF 21st CENTURY
inches of liquid water per year

as projected by NOAA/GFDL CM2.1
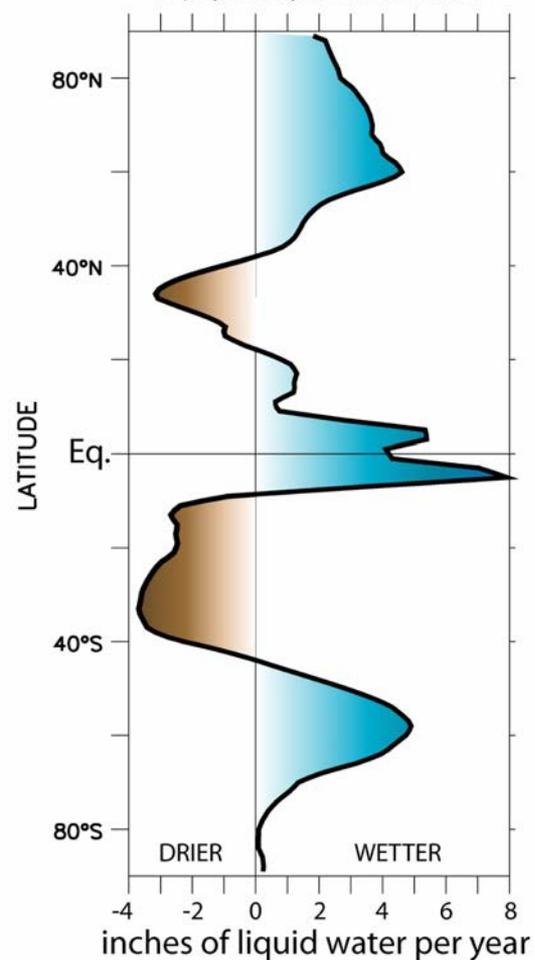
Credit: NOAA Geophysical Fluid Dynamics Laboratory

"Dry gets drier, wet gets wetter"

Credit: NOAA Geophysical Fluid Dynamics Laboratory

Tomorrow!

5:30 PM: Actually making climate predictions
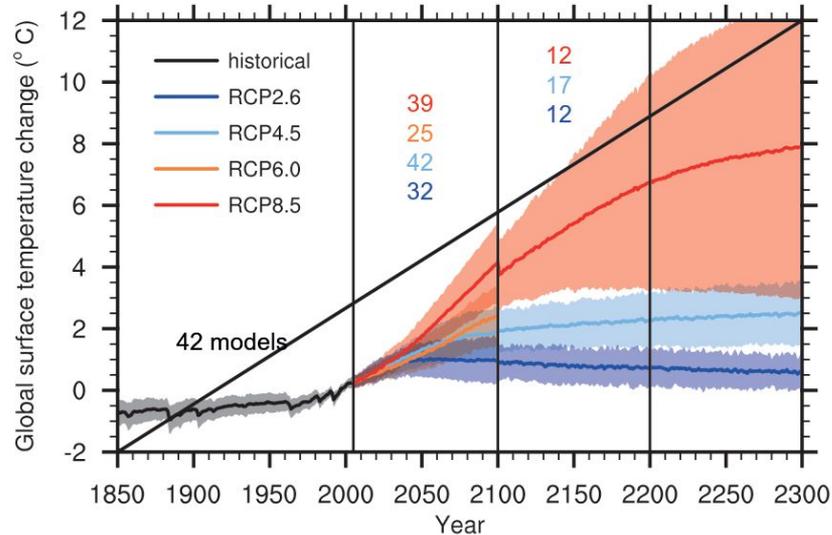
6:30 PM: Climate policy and local initiatives

Questions?