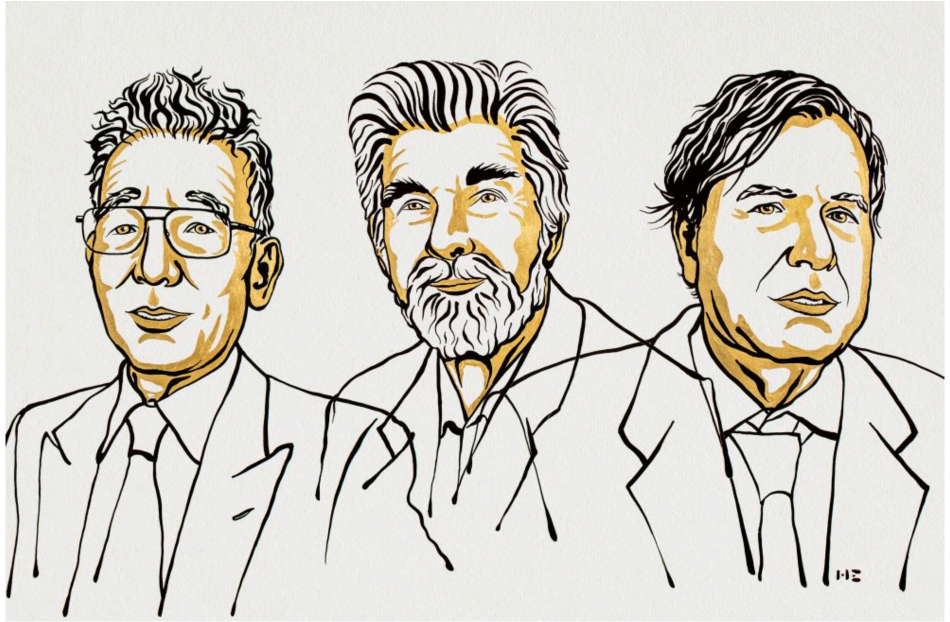
Nobel Prize in Physics 2021



The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2021

"for groundbreaking contributions to our understanding of complex physical systems"

with one half jointly to

Syukuro Manabe
Princeton University, USA

Klaus Hasselmann
Max Planck Institute for Meteorology, Hamburg, Germany

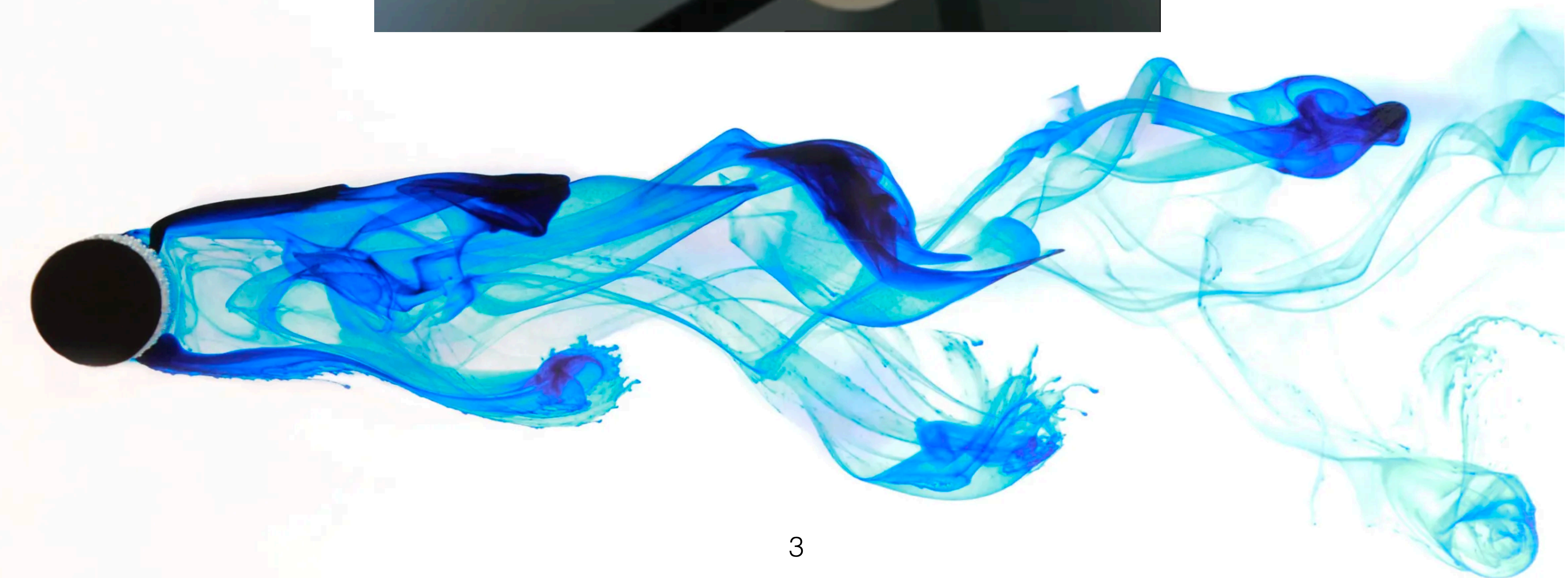
"for the physical modelling of Earth's climate, quantifying variability and reliably predicting global warming"

‘’ No single prediction of anything can be taken as unassailable truth, and without understanding the origins of variability we cannot understand the behavior of any system. ‘’

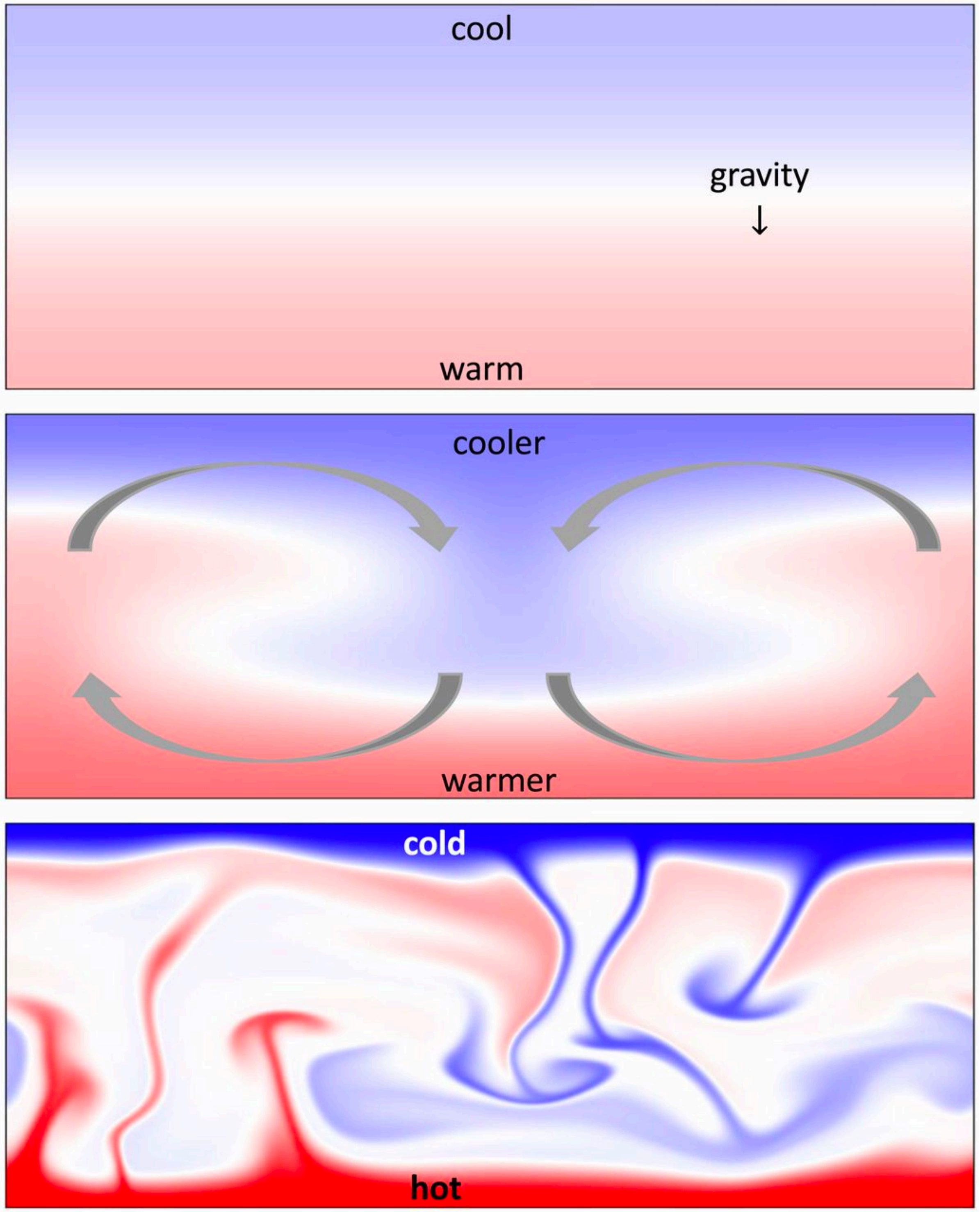
‘’ The emergence of disorder from order, and with it multiple scales in space and time, is a characteristic of complex systems. ‘’

John Wettlaufer,
Member of the Nobel committee, and Professor at Nordita, Stockholm University and Yale University.

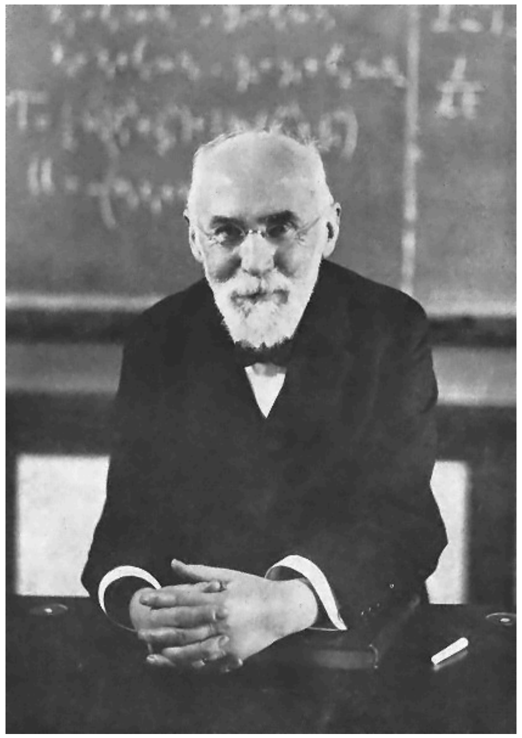
Flow past a cylinder: transition from laminar to turbulence



Turbulent thermal convection



Loren(t)z disambiguation



Hendrik Lorentz (Dutch): 1902 Nobel
Laureate with Zeeman, for the Zeeman effect.

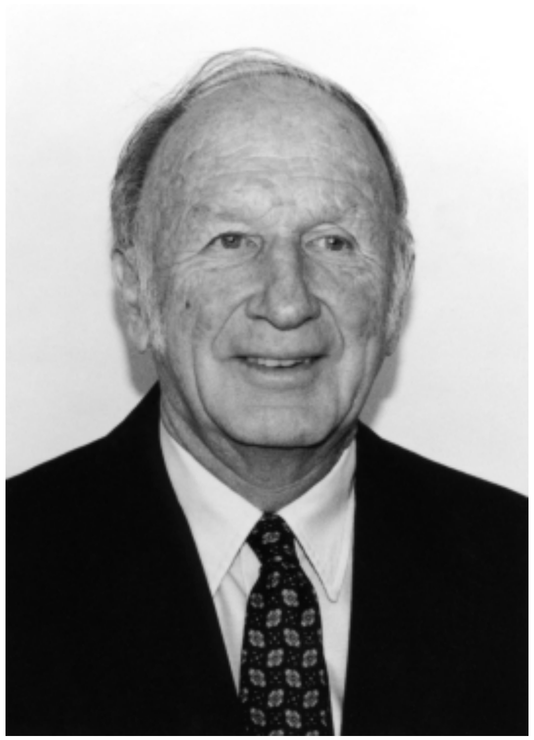
Lorentz transformation in special relativity
Lorentz force in electromagnetism

$$\vec{F} = q\big(\vec{E} + \vec{v} \times \vec{B}\big)$$

Ludvig Lorenz (Danish), contemporary of Lorentz.
Known for the Lorenz gauge condition

$$\vec{\nabla} \cdot \vec{A} + \frac{1}{c^2}\frac{\partial \varphi}{\partial t} = 0$$

Loren(t)z disambiguation



Edward Lorenz (American, died in 2008): mathematician and meteorologist. Known for the discovery of CHAOS = sensitivity to initial condition.

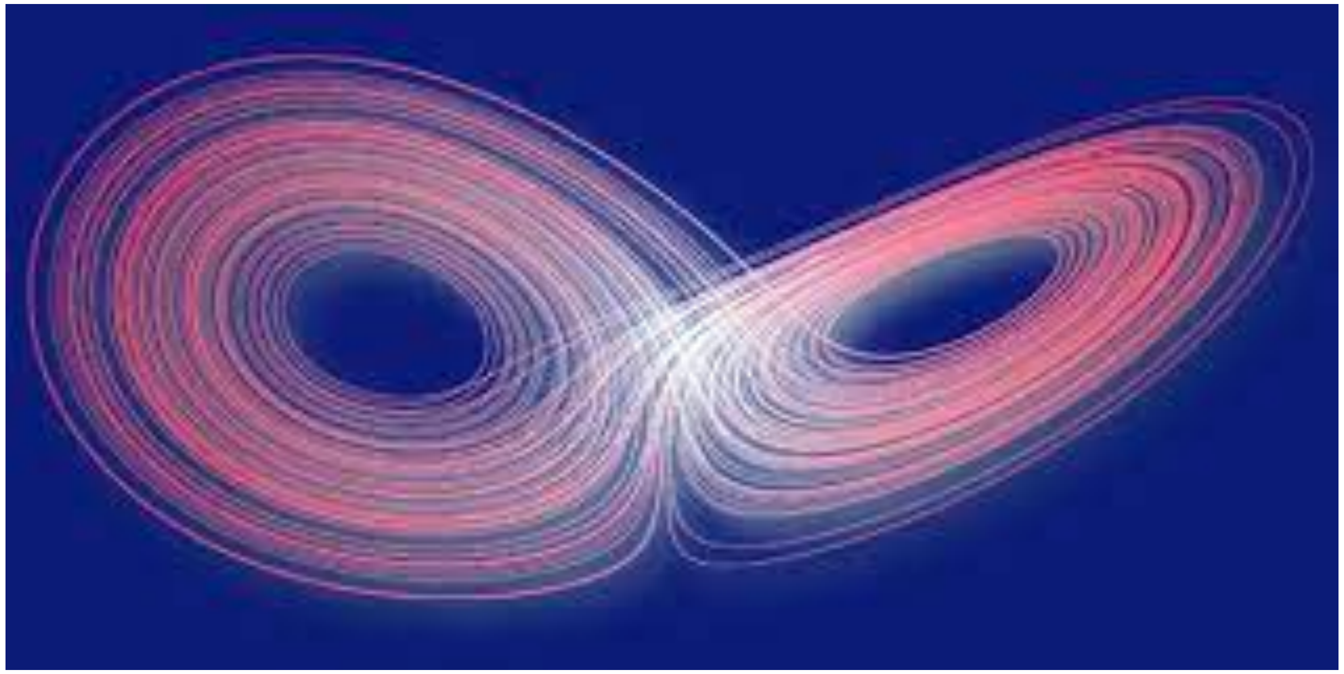
Toy model for convection in atmosphere:

$$\frac{dx}{dt} = \sigma(y - x)$$
$$\frac{dy}{dt} = x(Ra - z) - y$$
$$\frac{dz}{dt} = xy - \beta z$$

Lorenz Strange attractor

In the phase space (x, y, z) trajectories are confined in a fractal set:

- It is bounded.
- Two neighboring trajectories separate exponentially fast.
- It has zero volume.
- It has dimension 2.05.



A piece of Climate Science

- Stefan-Boltzmann law
- Solar constant
- Albedo
- Green-house effect

Earth's climate: a complex system

- The albedo depends on cloud cover and the amount of ice/snow.
- Radiation is latitude and day/night dependent.
- There are seasonal variations because the axis of rotation is tilted and the orbit around the Sun is elliptic.
- Effect of convection: temperature is altitude dependent.
- Evaporation of oceans and lakes, condensation of water vapor in clouds. Latent heat affects the temperature gradient (lapse rate).
- Horizontal gradients: winds, ocean currents

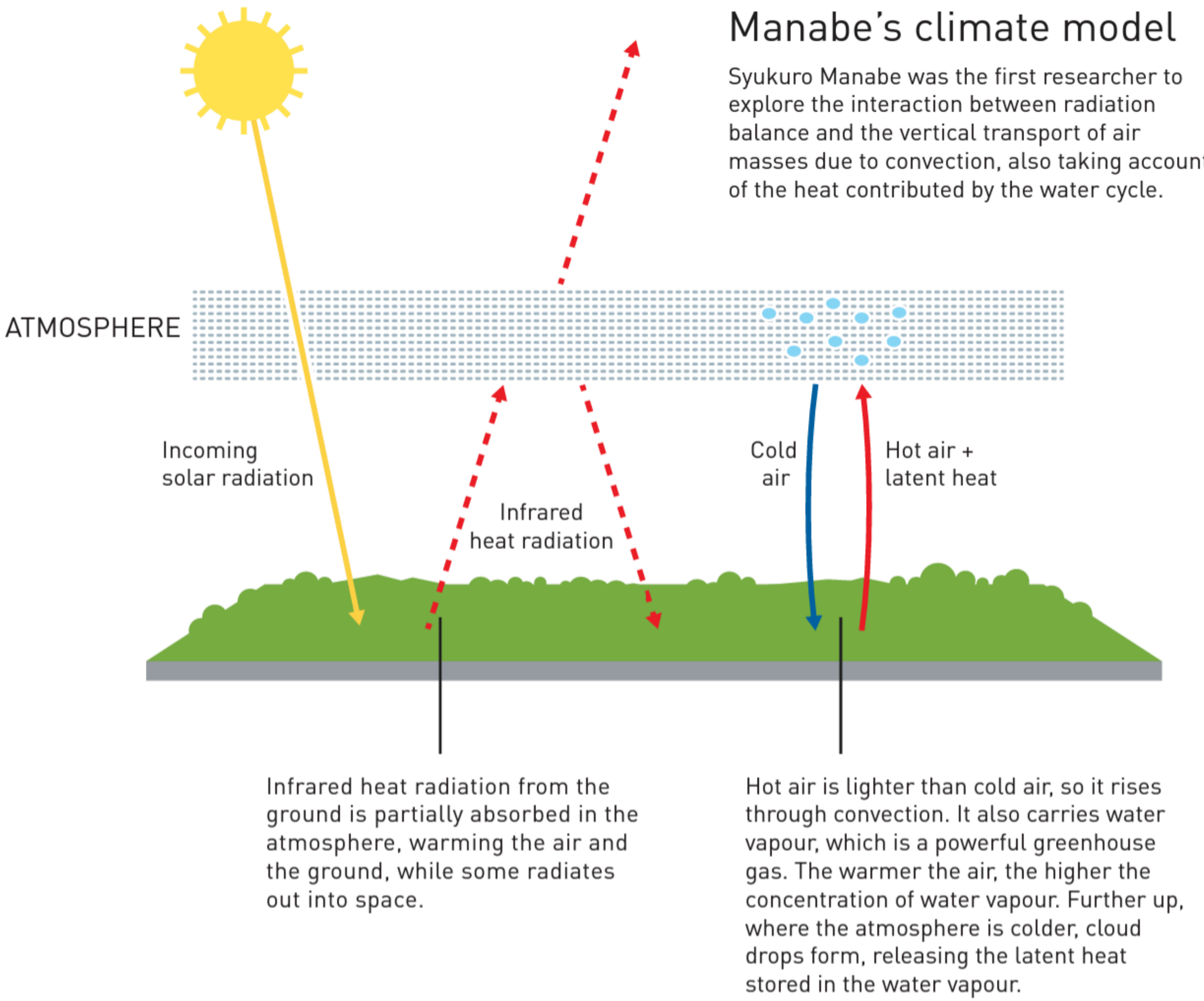
How to understand its variability ?

Climate sensitivity

How much does the surface temperature increase when the concentration of C02 is doubled ?

Water vapor is the most powerful greenhouse gas, but we don’t control the hydrological cycle. However, we can regulate CO2 emissions !

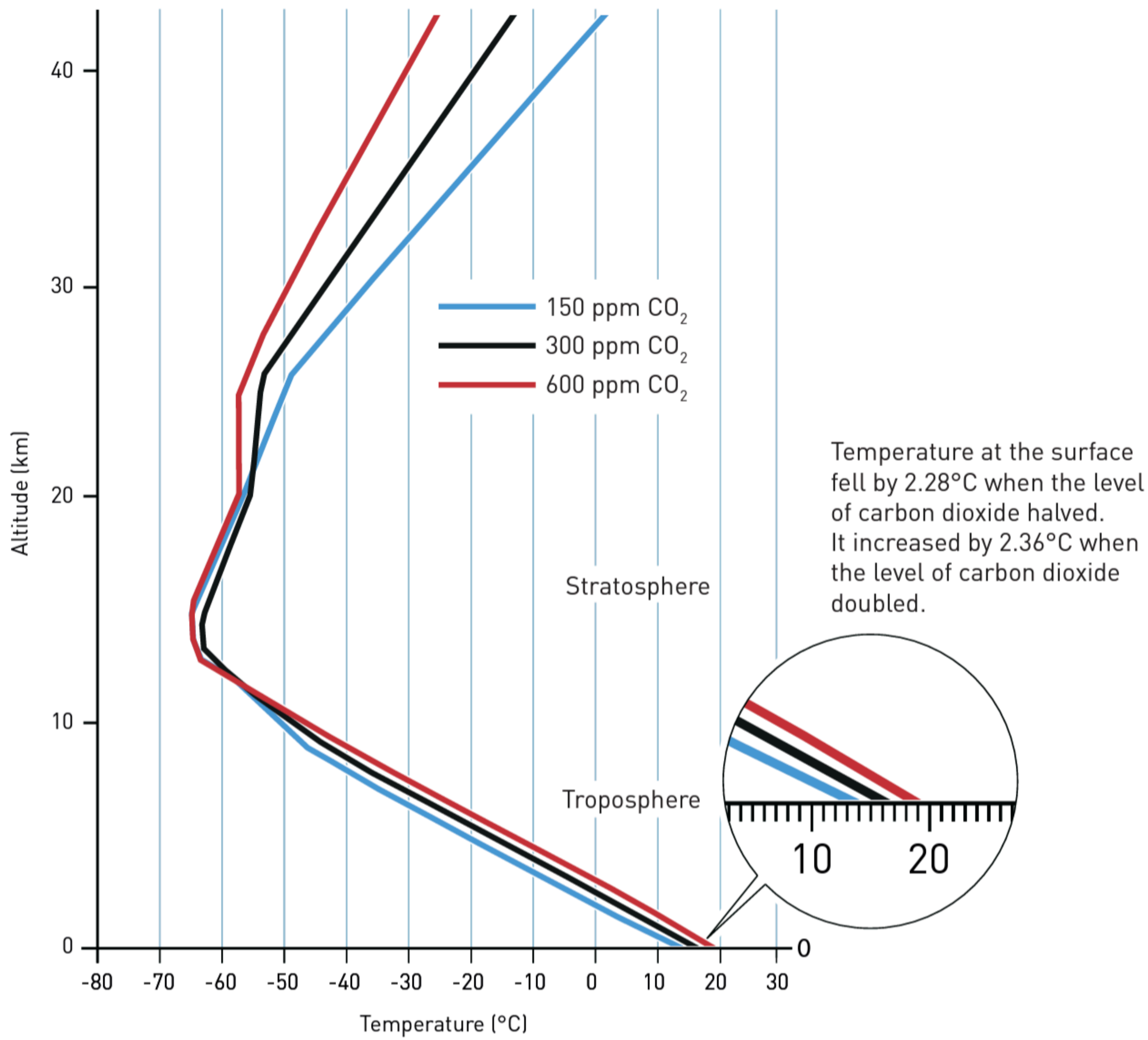
Manabe's solution: numerical climate model



Manabe's solution: numerical climate model

Carbon dioxide heats the atmosphere

Increased levels of carbon dioxide lead to higher temperatures in the lower atmosphere, while the upper atmosphere gets colder. Manabe thus confirmed that the variation in temperature is due to increased levels of carbon dioxide; if it was caused by increased solar radiation, the entire atmosphere should have warmed up.



Hasselmann's solution: Brownian motion

Climate is the signal, weather is the noise!

Walk your dog!

Global warming is due to human activity