

THE NOBEL PRIZE IN PHYSICS 2021

Illustrations: Niklas Elmehed



**Syukuro
Manabe**

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

**Klaus
Hasselmann**

**Giorgio
Parisi**

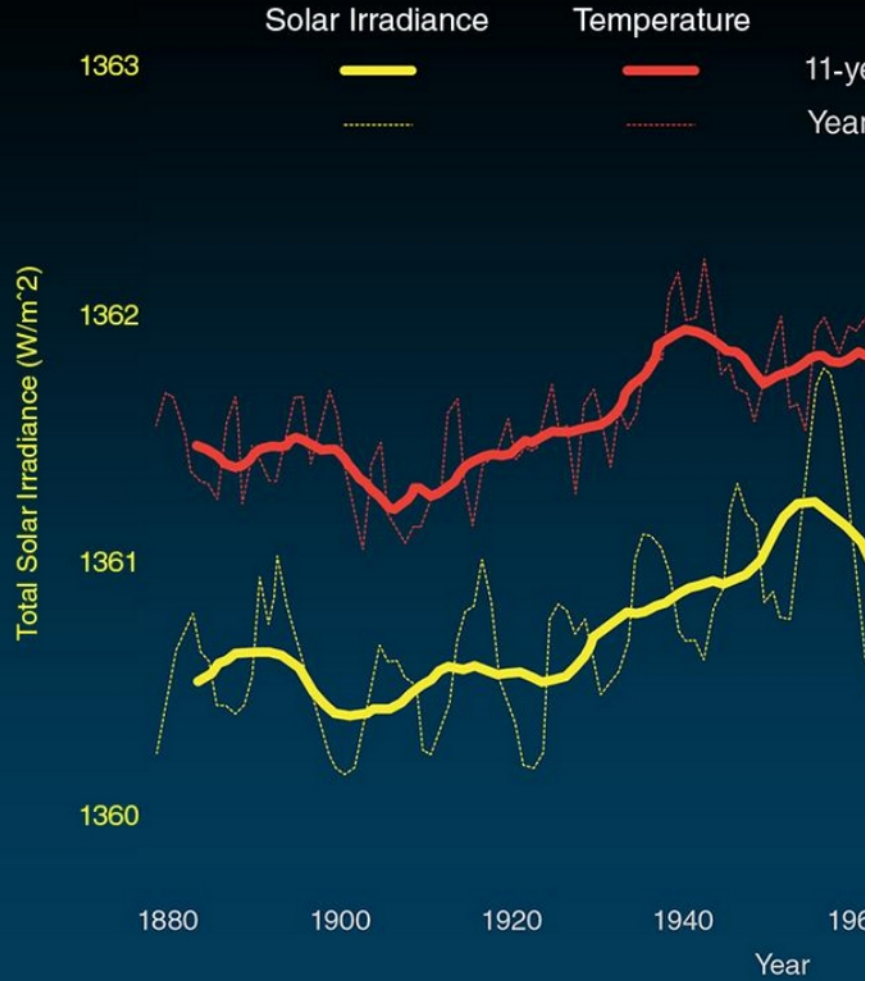
"for the discovery of the
interplay of disorder and
fluctuations in physical
systems from atomic
to planetary scales"



Syukuro Manabe (真鍋 淑郎) *1931,
Princeton, USA



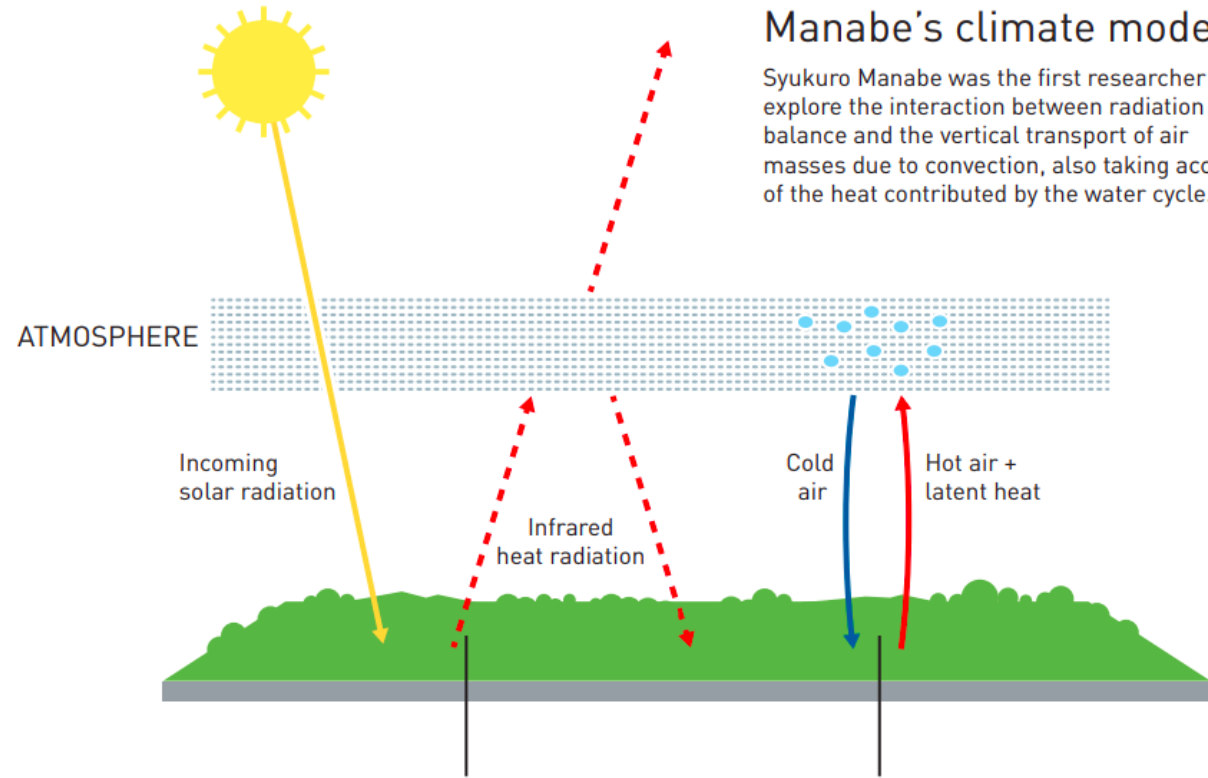
Temperature vs Solar Activity





Manabe's climate model

Syukuro Manabe was the first researcher to explore the interaction between radiation balance and the vertical transport of air masses due to convection, also taking account of the heat contributed by the water cycle.

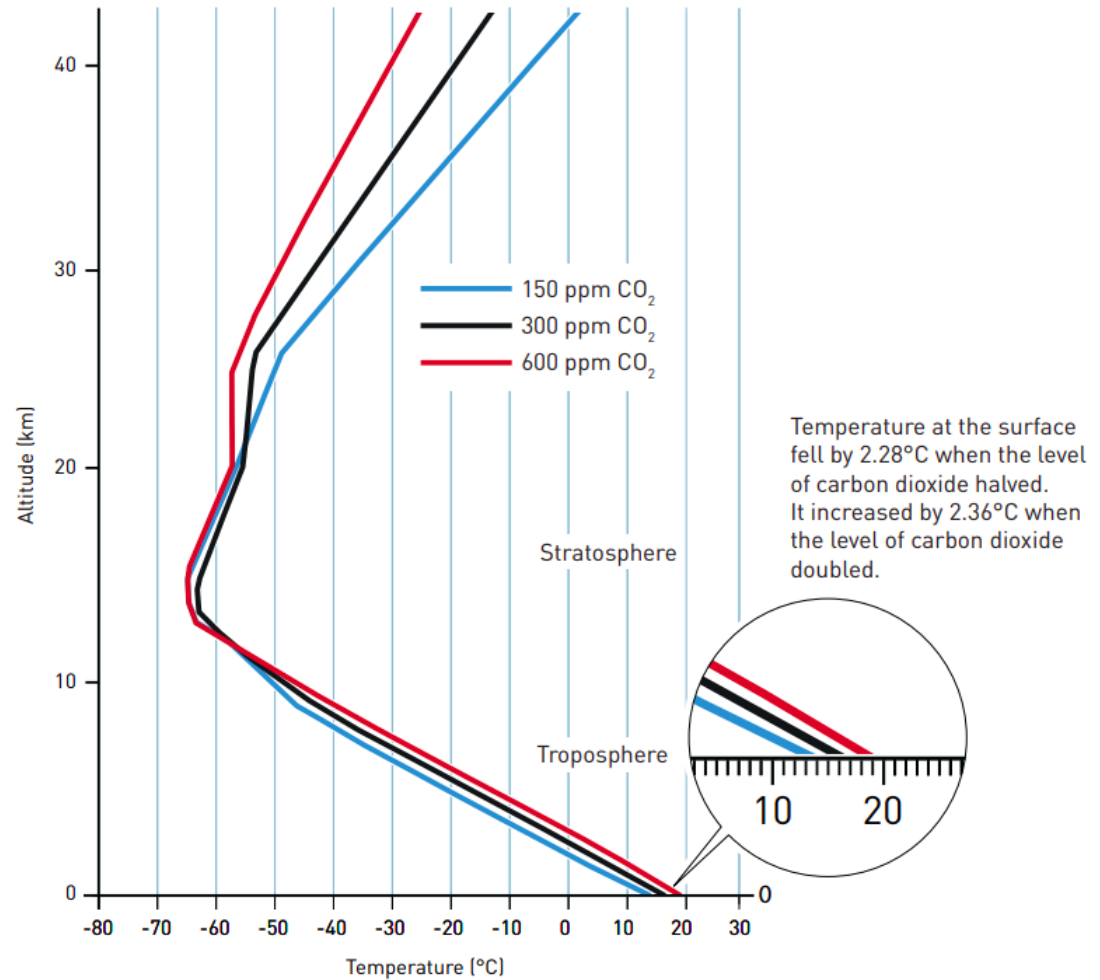


Infrared heat radiation from the ground is partially absorbed in the atmosphere, warming the air and the ground, while some radiates out into space.

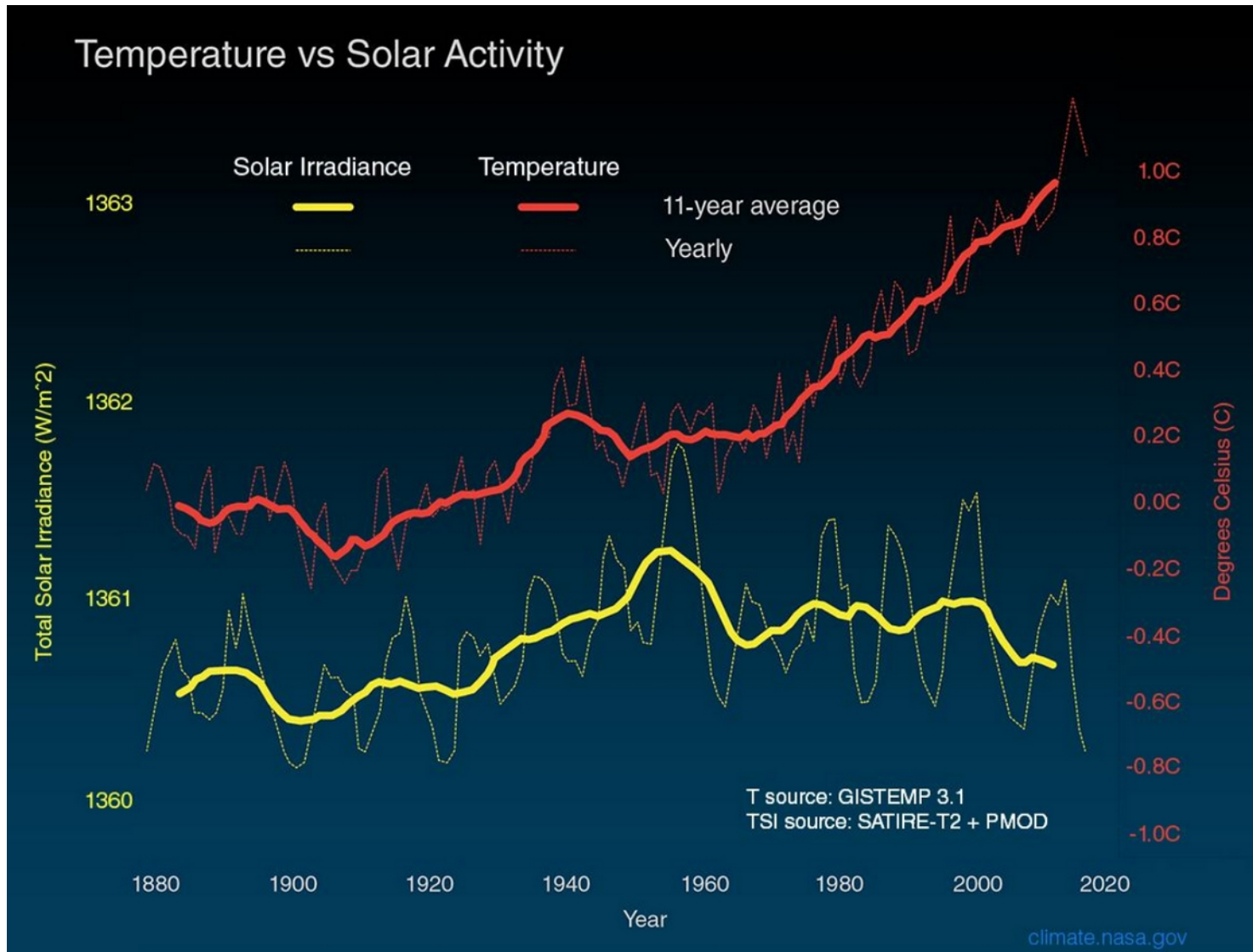
Hot air is lighter than cold air, so it rises through convection. It also carries water vapour, which is a powerful greenhouse gas. The warmer the air, the higher the concentration of water vapour. Further up, where the atmosphere is colder, cloud drops form, releasing the latent heat stored in the water vapour.



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.

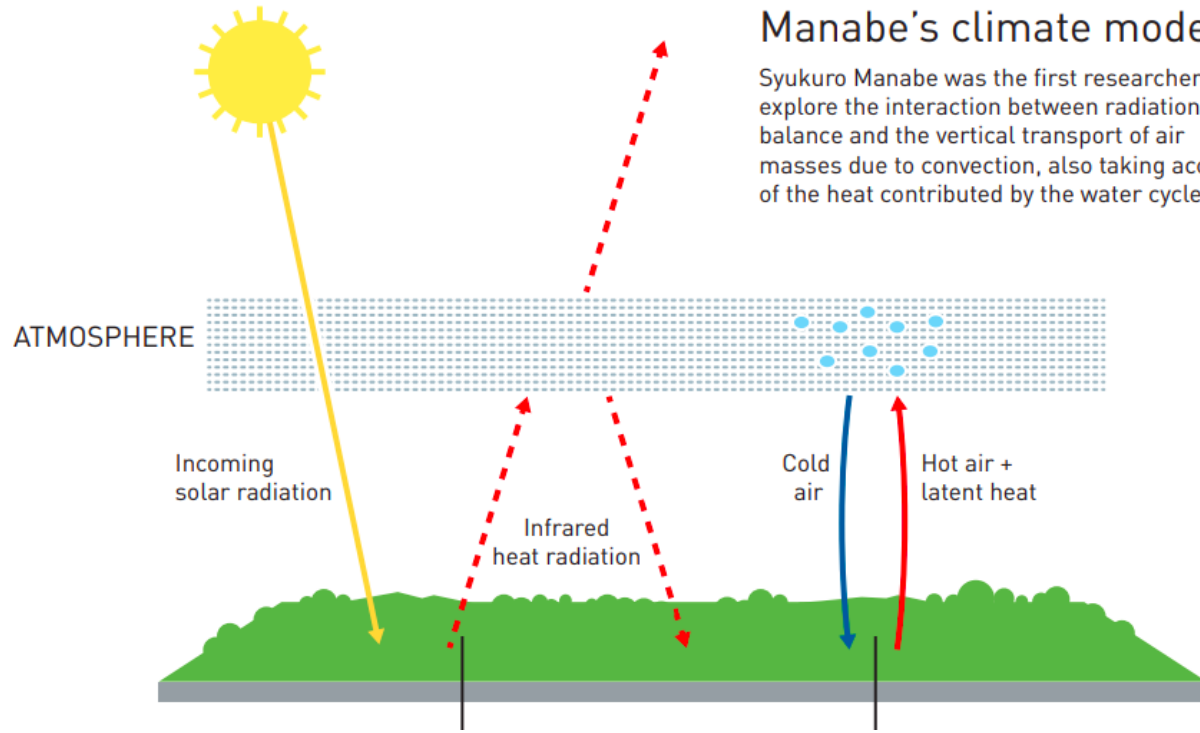


Source: Manabe and Wetherald (1967) Thermal equilibrium of the atmosphere with a given distribution of relative humidity, *Journal of the atmospheric sciences*, Vol. 24, Nr 3, May.

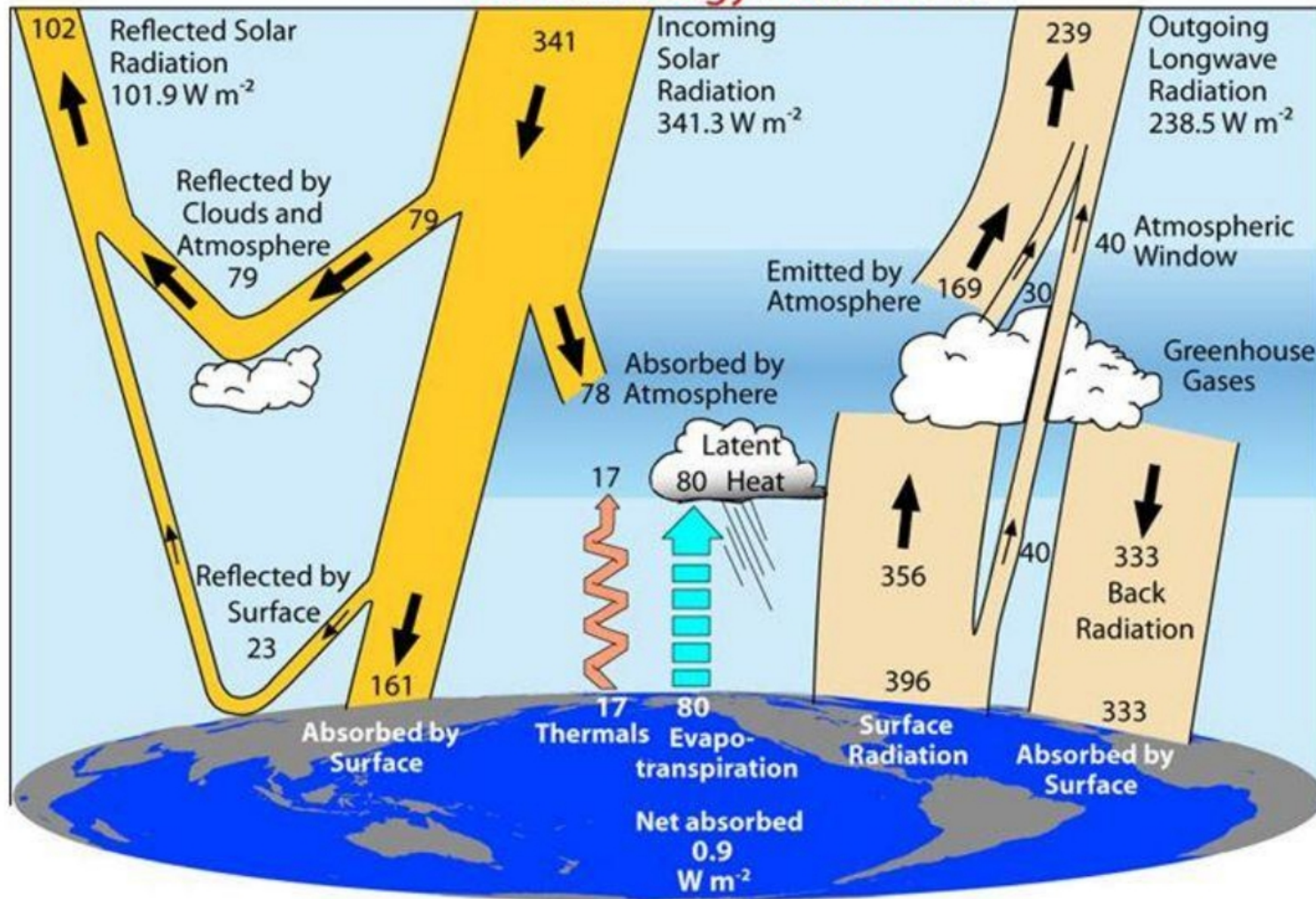


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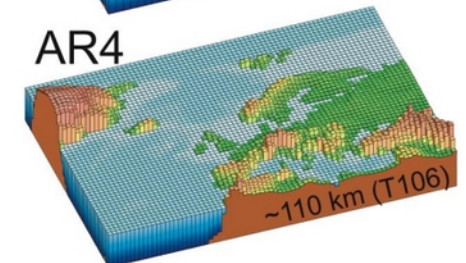
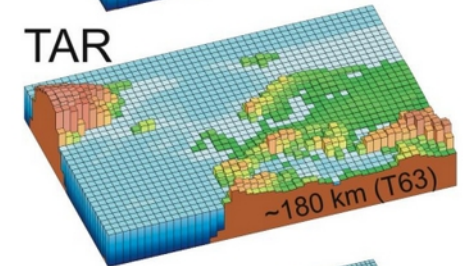
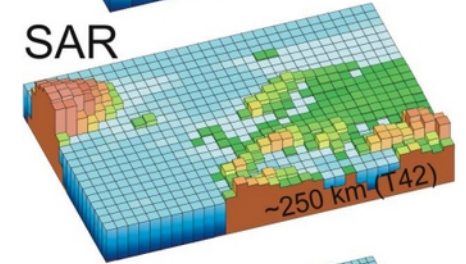
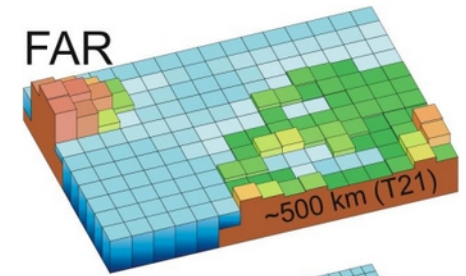
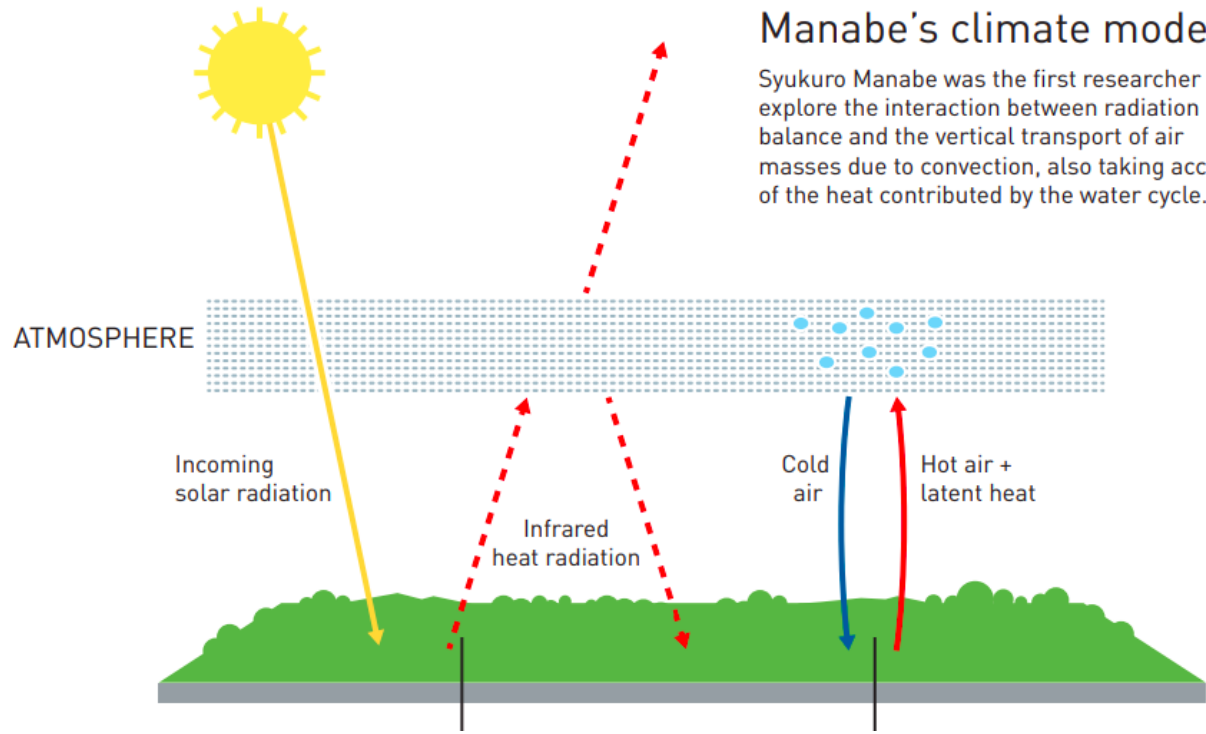
Global Energy Flows $W m^{-2}$

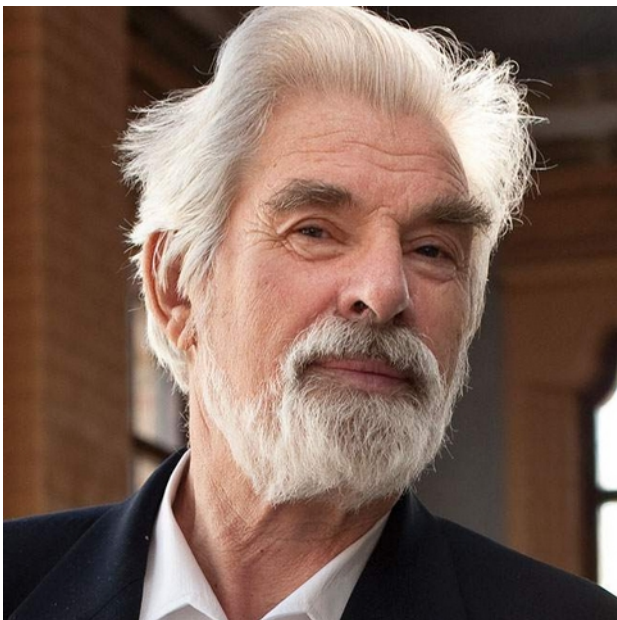


From K. Trenberth, J. Fasullo, and J. Kiehl, EARTH'S GLOBAL ENERGY BUDGET BAMS 2009

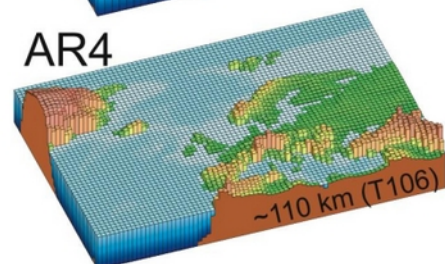
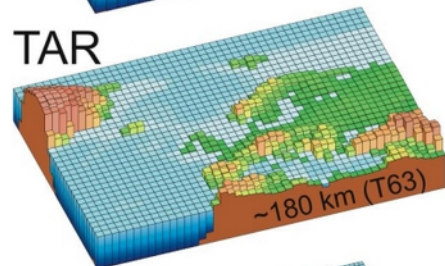
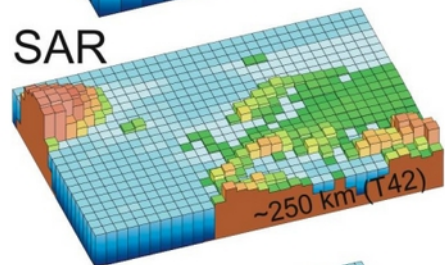
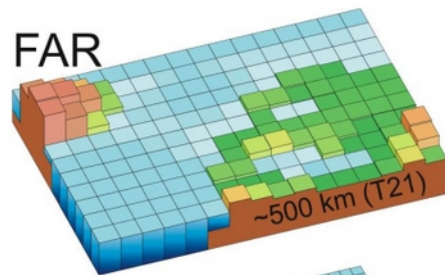
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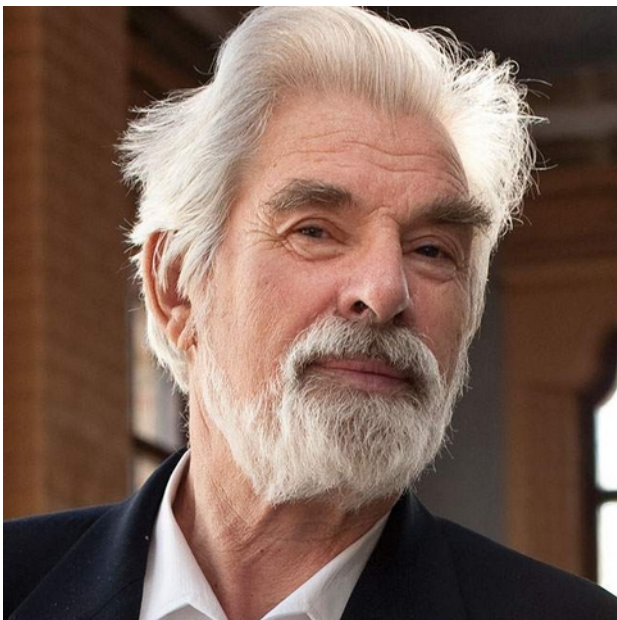
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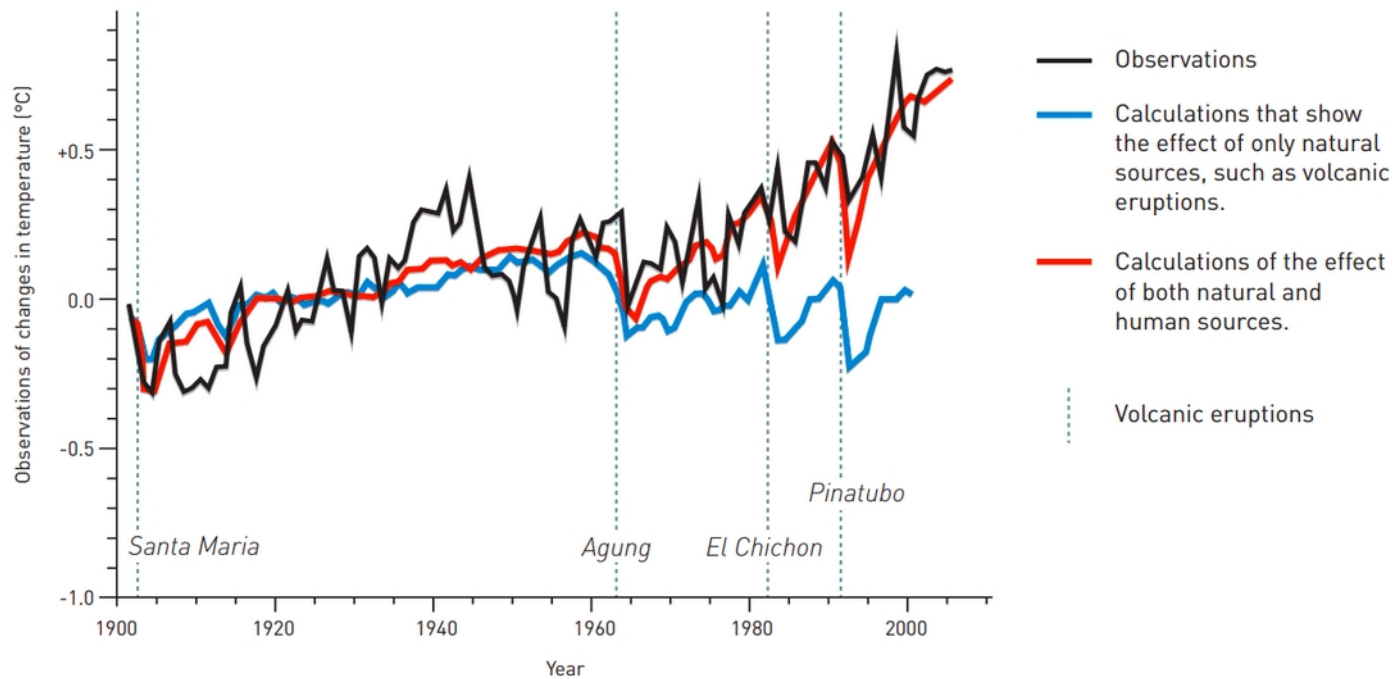
Klaus Hasselmann, *1931
MPI Met., DE





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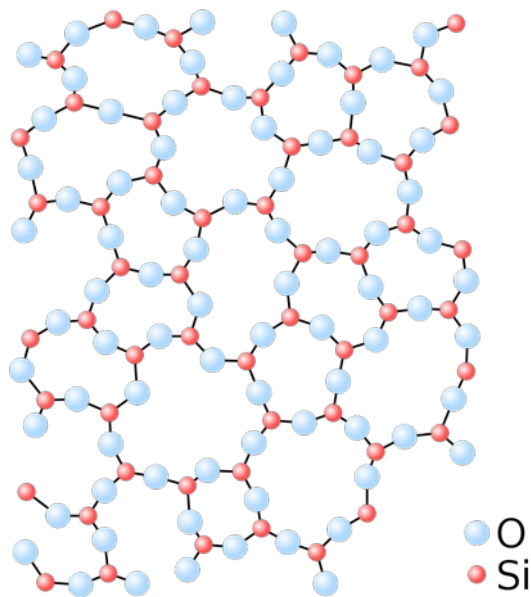
Klaus Hasselmann developed methods for distinguishing between natural and human causes (fingerprints) of atmospheric heating. Comparison between changes in the mean temperature in relation to the average for 1901–1950 (°C).



Source: Hegerl and Zweirs (2011) Use of models in detection & attribution of climate change, *WIREs Climate Change*.

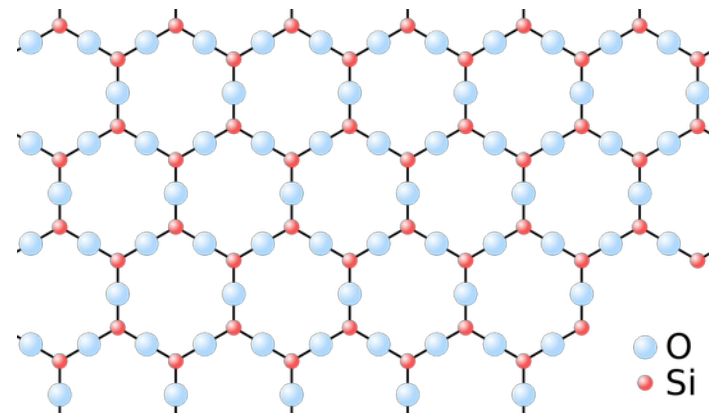
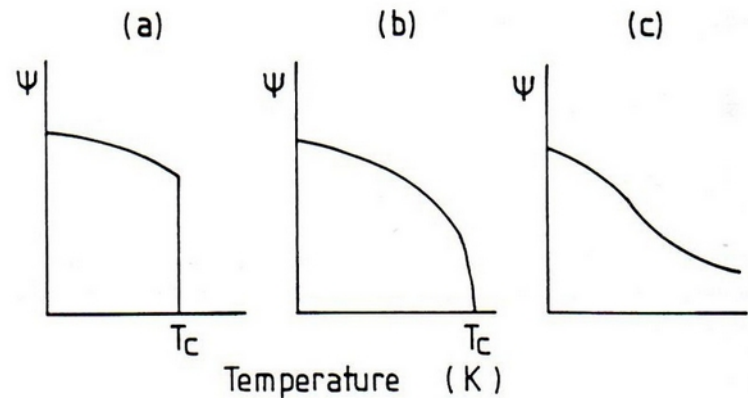
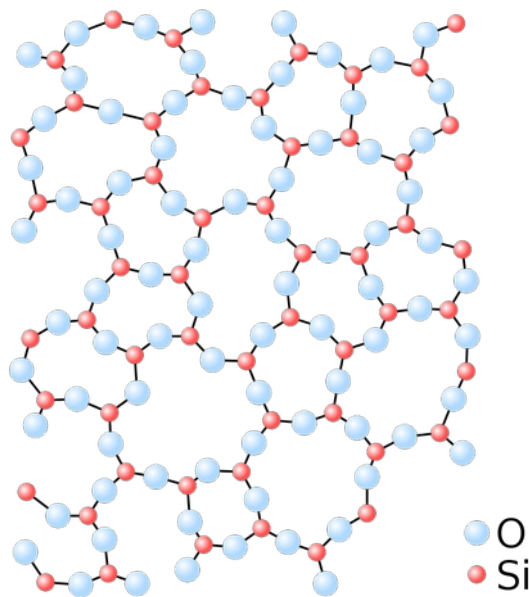


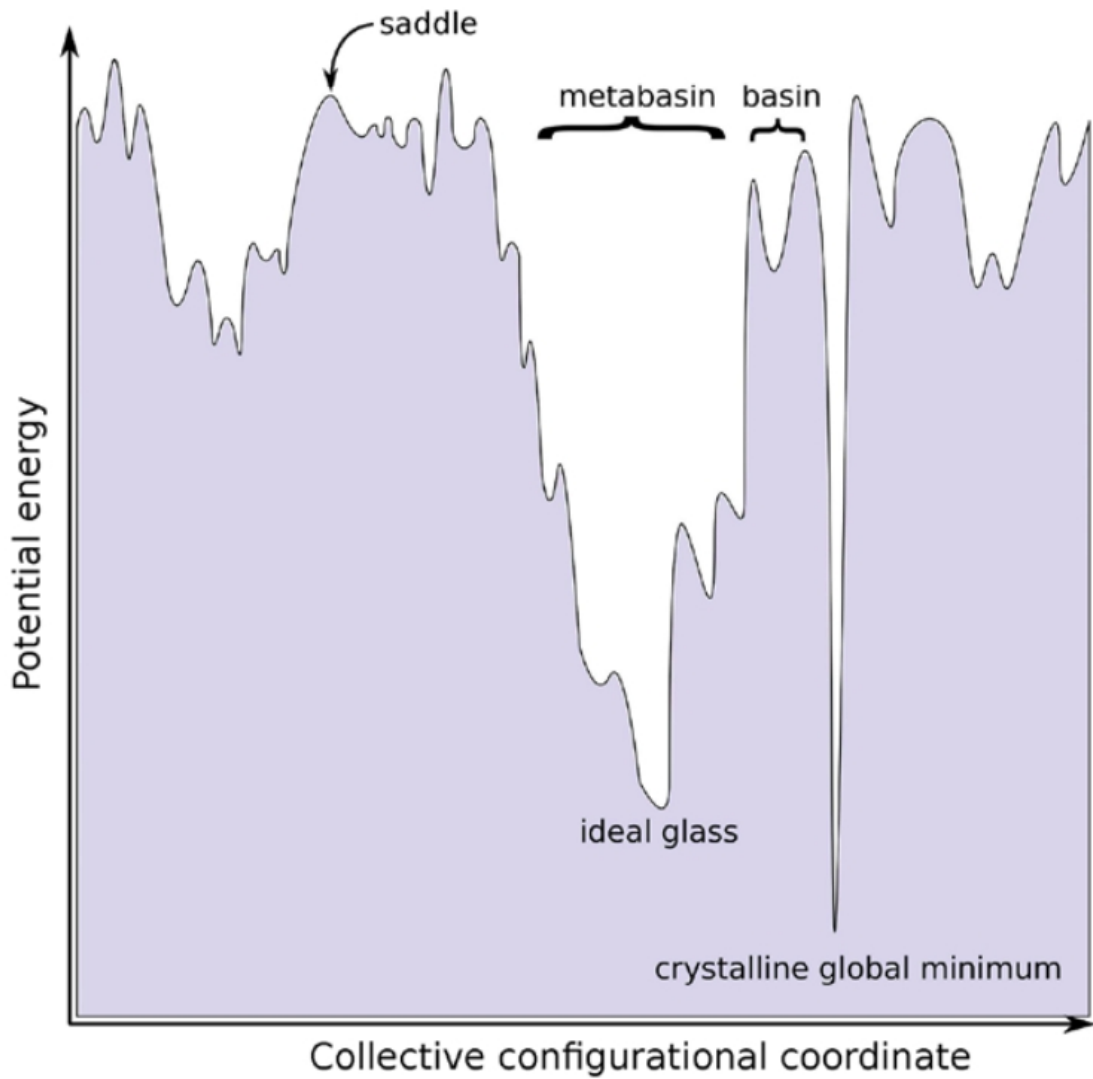
Giorgio Parisi, *1948
Sapienza, IT





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Sapienza, IT



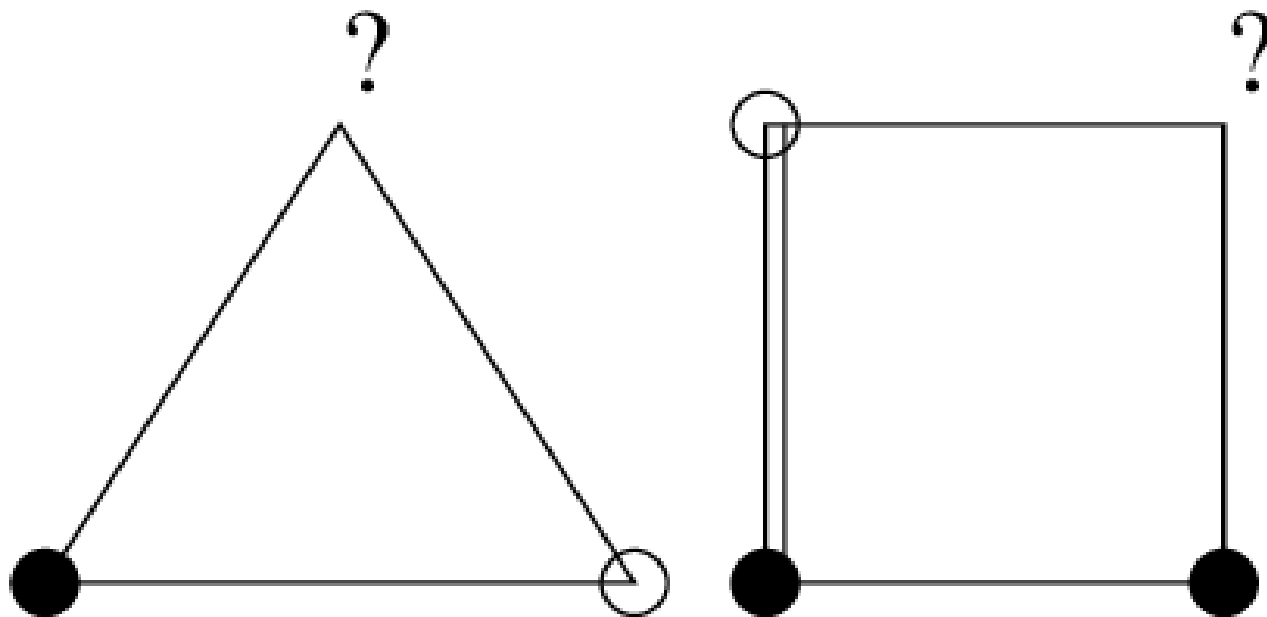




Giorgio Parisi, *1948
Sapienza, IT

Sherrington–Kirkpatrick model

$$H = - \sum_{i < j} J_{ij} S_i S_j$$





Giorgio Parisi, *1948
Sapienza, IT



Sherrington–Kirkpatrick model

$$H = - \sum_{i,j} J_{ij} S_i S_j$$



Giorgio Parisi

Friends

2 mutual friends



Geszti Tamás



Zoltán Zimborás



Giorgio Parisi, *1948
Sapienza, IT

Sherrington–Kirkpatrick model

$$H = - \sum_{i < j} J_{ij} S_i S_j$$

