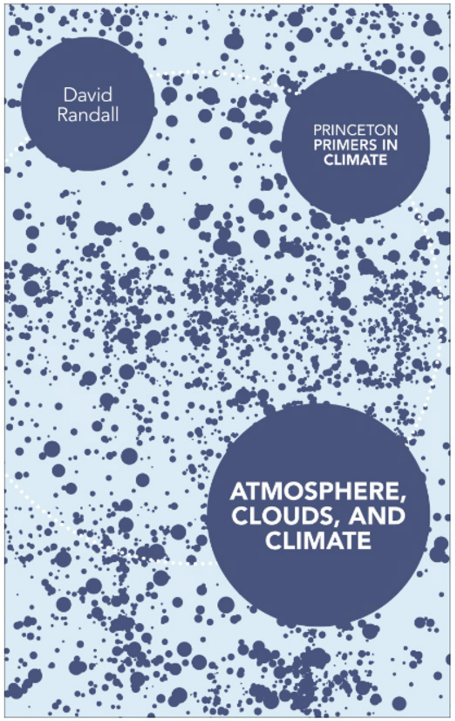
Atmosphere, Clouds, and Climate: Energy Flows & Feedback

AOSC 680

Ross Salawitch

Class Web Sites:
http://www2.atmos.umd.edu/~rjs/class/fall2022
https://umd.instructure.com/courses/1327017



Lecture 14

25 October 2022

Cloud Feedback

Cloud feedbacks are infamous. Their potential importance has been recognized at least since the 1970s (Schneider, 1972; Arakawa, 1975; Charney, 1979). For decades, they have been highlighted as a major source of uncertainty in predictions of future climate change. Why is the problem taking so long to solve?

Although cloud processes are among the most important for climate, they are also among the most difficult to understand and predict. As discussed in Chapter 3, clouds usually form in rising air, which expands and cools until condensation occurs. Cloud processes can be grouped into five categories, all of which are important for the climate system:

Cloud microphysical processes, involving cloud drops, ice crystals, and aerosols, with scales on the order of microns

Cloud dynamical processes associated with the motion of the air in cumulus clouds, with scales on the order of a few kilometers

Cloud radiative processes, involving the flows of both solar and terrestrial radiation through the cloud field

Cloud turbulence processes, which include boundary-layer (near-surface) turbulence, the entrainment of environmental air into the clouds, and the formation of small clouds

Cloud chemical processes, which, among other things, are important for the annual formation of the ozone hole through the destruction of ozone in polar stratospheric clouds

Cloud Feedback

These various processes interact with each other on space scales of a few kilometers and time scales of a few minutes, and they also jointly interact with larger-scale weather systems, up to the size of the Earth itself.

Clouds also couple climate processes together. For example, they cast shadows on the land and ocean, which tend to reduce the surface temperature and evaporation rate.

Each cloud process has the potential to feed back as the climate state evolves due to externally forced variability. As a result, there are many different kinds of cloud feedbacks. Broadly speaking, they occur through changes in cloud amount, cloud top height, and cloud optical properties. In a climate change, there can be many different changes in the geographical patterns and seasonal distributions of both high and low clouds. The net cloud feedback results from the combined effect of these various changes.

IPCC AR5 “downgraded” warming forecast by CMIP5 models

Lecture 8

Chapter 11 of IPCC (2013) suggested *CMIP5 GCMs warm too quickly* compared to observations, resulting in “likely range” (red trapezoid) for rise in GMST relative to pre-industrial baseline (ΔT) being considerably less than actual archived ΔT from the CMIP5 GCM runs

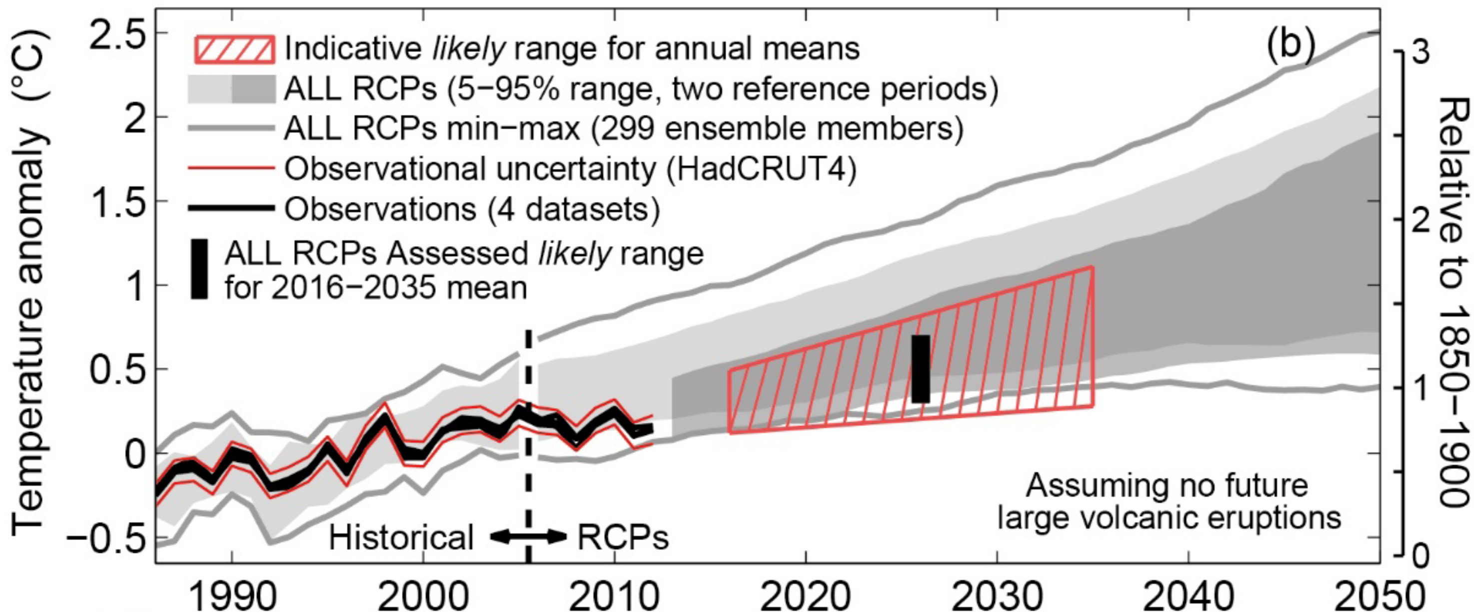
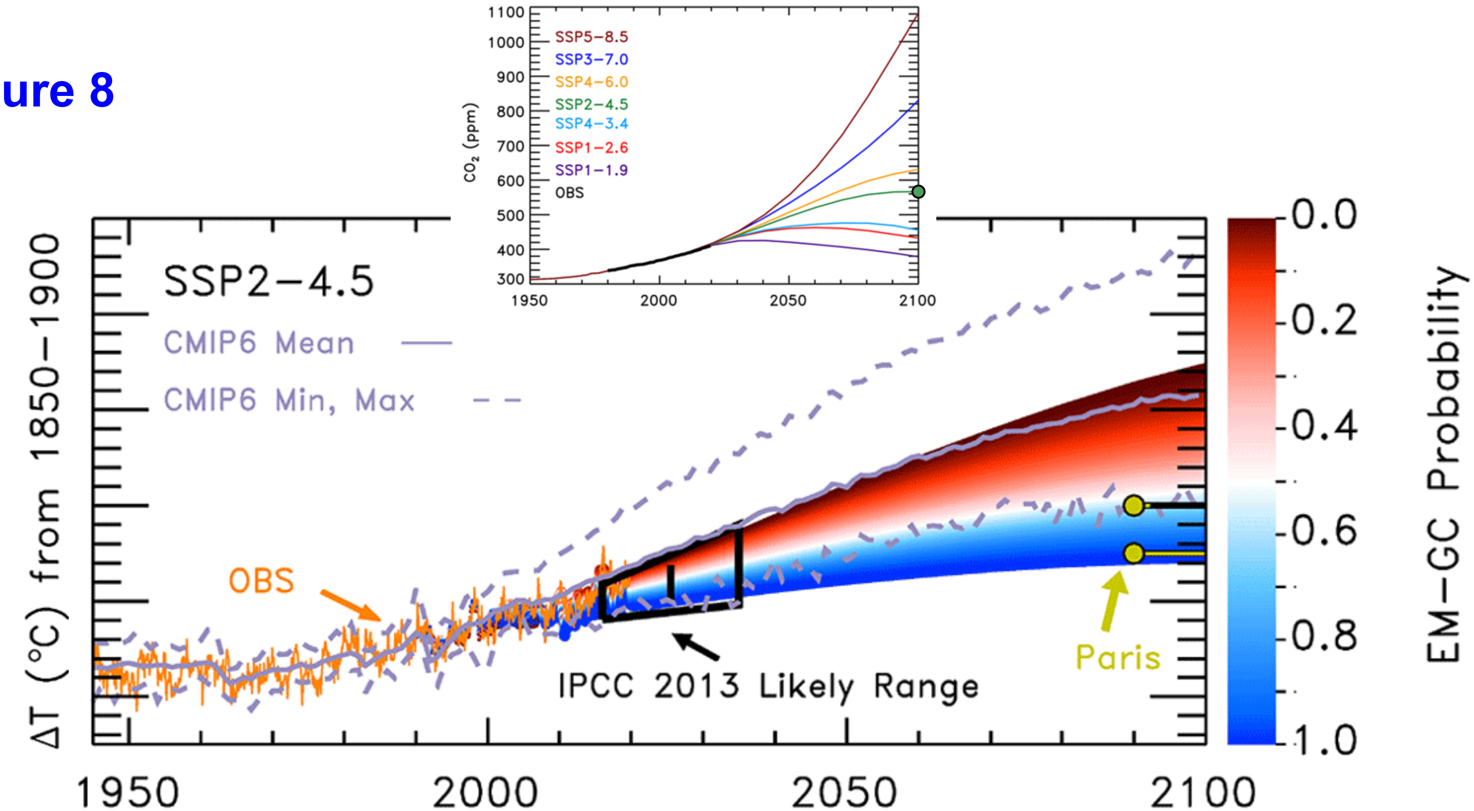


Fig 11.25b, IPCC (2013)

Probabilistic Forecast of ***Human-Induced Rise in GMST*** for model trained on data acquired until end of 2019 and future GHG levels from SSP2-4.5

Lecture 8



If GHGs follow SSP2-4.5, **2%** chance rise GMST stays below **1.5°C** and **33%** chance stays below **2.0°C**

EM-GC: University of Maryland Empirical Model of Global Climate
ΔT: rise in GMST (Global Mean Surface Temperature) relative to pre-industrial
CRU: Climate Research Unit, Easy Anglia, UK: Premier source of data for ΔT

McBride *et al*., 2021: https://esd.copernicus.org/articles/12/545/2021

What To Do About The “Hot Models”

nature

COMMENT | 04 May 2022

Climate simulations: recognize the ‘hot model’ problem

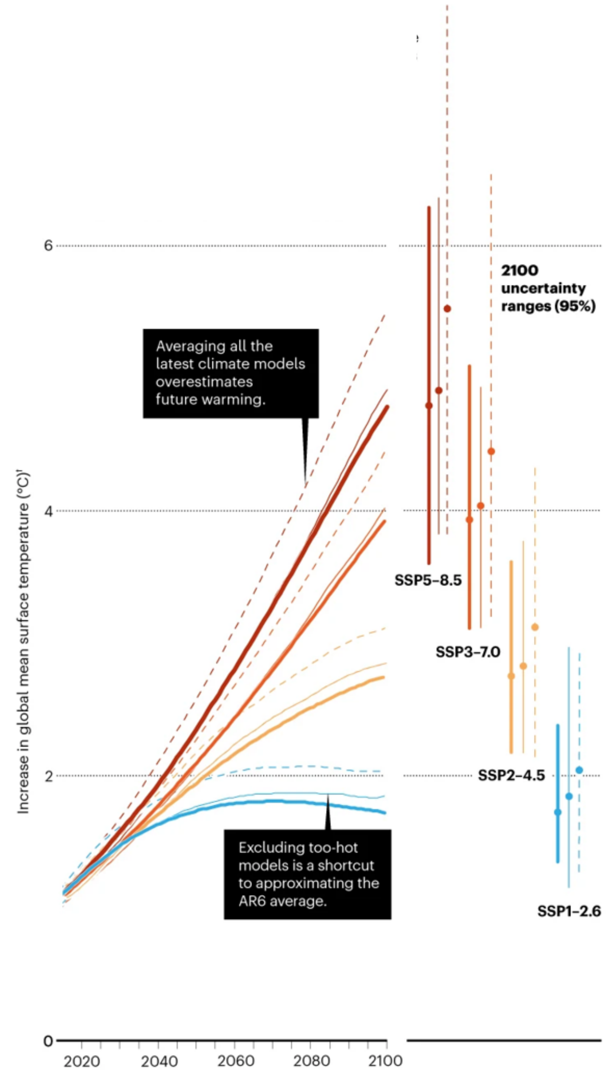
The sixth and latest IPCC assessment weights climate models according to how well they reproduce other evidence. Now the rest of the community should do the same.

Zeke Hausfather, Kate Marvel, Gavin A. Schmidt, John W. Nielsen-Gammon & Mark Zelinka

CLIMATE MODELS: CHOICE MATTERS

The IPCC’s Sixth Assessment Report (AR6) assessed dozens of computer models to project global temperature change (four scenarios shown). Some of these projections were ‘too hot’ when compared with other lines of evidence for climate warming in response to carbon dioxideemissions[8]. Researchers using all these models without the AR6 statistical adjustments could end up overestimating future temperature change.

- – – Mean of all models
- —— Limited range of models, no ‘too hot’ ones*
- ▬▬ Best estimate of warming as assessed in AR6



*Using the transient climate response (TCR) metric in the range 1.4–2.2 °C deemed as “likely” in AR6. (TCR is the amount of global warming in the year in which atmospheric CO_2 concentrations have doubled after having steadily increased by 1% each year.)
†Global mean surface temperatures are relative to a 1850–99 baseline.
IPCC, Intergovernmental Panel on Climate Change; SSP, Shared Socioeconomic Pathway.

https://www.nature.com/articles/d41586-022-01192-2

Recent Attempt to Evaluate the “Hot Models”

Evaluating Climate Models’ Cloud Feedbacks Against Expert Judgment

Mark D. Zelinka, Stephen A. Klein, Yi Qin, Timothy A. Myers

JGR Atmospheres

First published: 11 January 2022 | https://doi.org/10.1029/2021JD035198

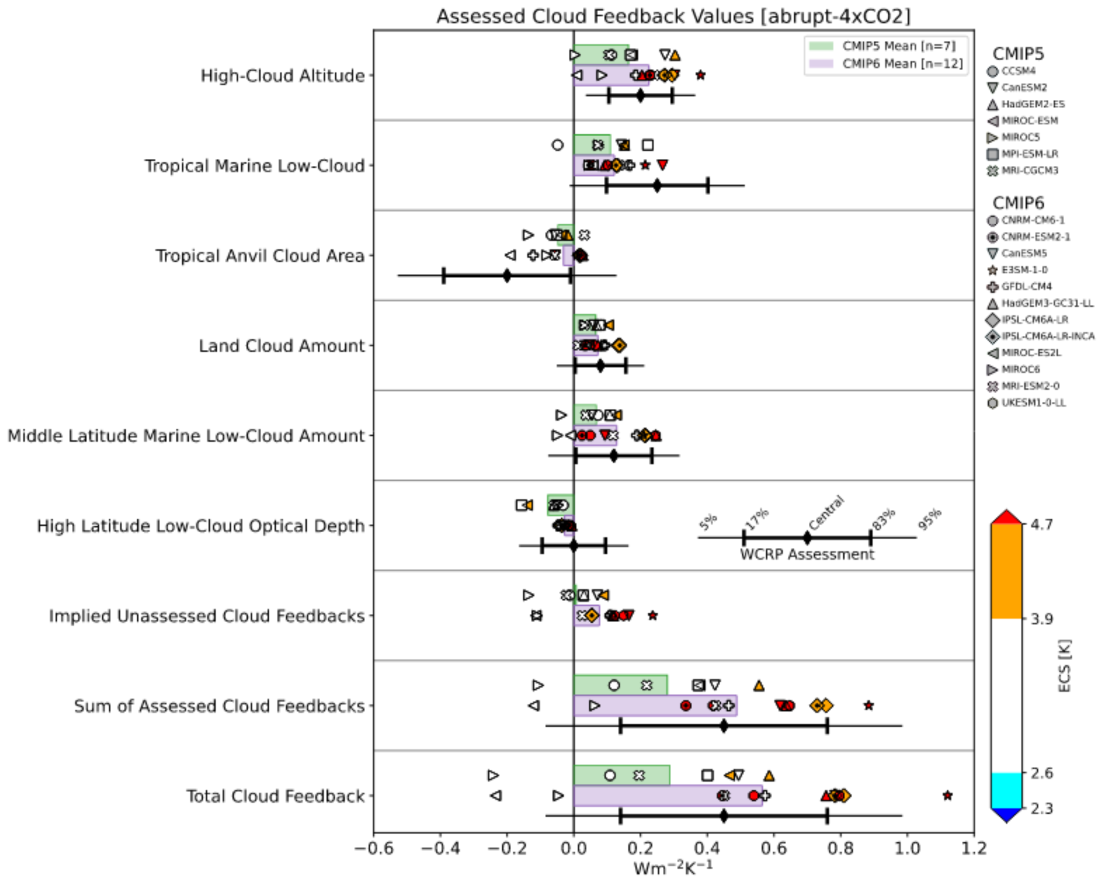


Figure 1. Cloud feedback components estimated from climate model simulations and as assessed in Sherwood et al. (2020). For each component, the individual model values are indicated with symbols, the multimodel means are indicated with green (CMIP5) and purple (CMIP6) bars, and the expert-assessed *likely* and *very likely* confidence intervals are indicated with black errorbars. Model symbols are color-coded by ECS with color boundaries corresponding to the edges of the *likely* and *very likely* ranges of the Baseline posterior PDF of ECS from Sherwood et al. (2020). Identical figures highlighting each individual model are provided in Figures S4–S22 in Supporting Information S1.

https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2021JD035198

Recent Attempt to Evaluate the "Hot Models"

Evaluating Climate Models' Cloud Feedbacks Against Expert Judgment

Mark D. Zelinka, Stephen A. Klein, Yi Qin, Timothy A. Myers

JGR Atmospheres

First published: 11 January 2022 | https://doi.org/10.1029/2021JD035198

Plain Language Summary Climate models strongly disagree with each other regarding how much warming will occur in response to increased greenhouse gases in the atmosphere. This is mainly because they disagree on the response of clouds to warming—a process known as the cloud feedback that can amplify or dampen warming initially caused by carbon dioxide. In this study, we compare many models' cloud feedbacks to those that have been determined by a recent expert assessment of the literature. We find that the models whose cloud feedbacks most strongly disagree with expert assessment tend to have more extreme cloud feedbacks and hence warm too much or too little in response to carbon dioxide. The models with total cloud feedbacks that are too large do not have a single massive feedback component but rather several components that are larger than in other models. Models that simulate current-climate clouds that look more like those in nature also simulate stronger amplifying cloud feedbacks, but doing a better job at simulating current-climate clouds does not, in general, guarantee a better simulation of cloud feedbacks.

Key Points

- Models with smallest feedback errors have moderate total cloud feedbacks and ECS
- Models with large positive total cloud feedbacks have several systematically high-biased feedback components
- Better simulation of mean-state cloud properties leads to stronger but not necessarily better cloud feedbacks

https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2021JD035198