The Reliability of Cloud Representation in Climate Models

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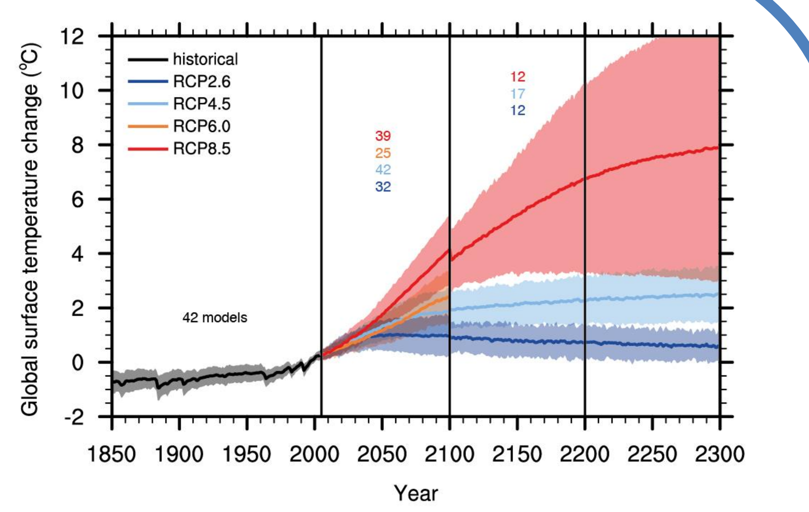
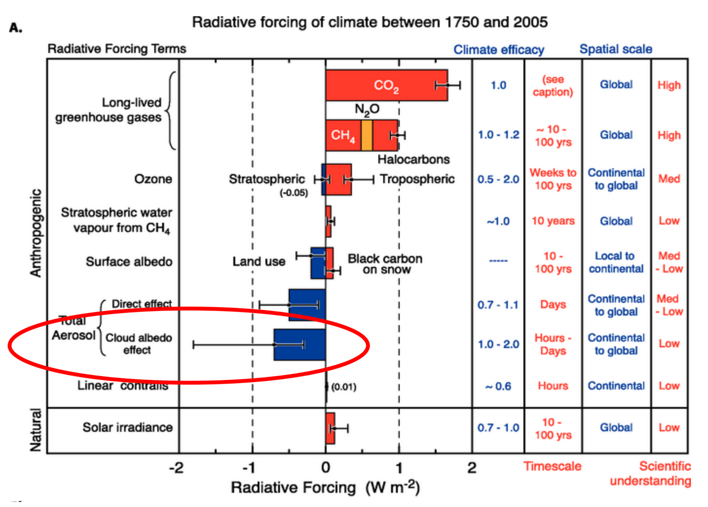
Climate Change

- There is much uncertainty in the future of our planet's climate.
- Uncertainties in both scenarios and models.
- Model uncertainty predominantly due to clouds.



Time series of annual global mean surface air temperature anomalies (relative to 1986-2005). Multi-model mean (solid lines) across distribution of individual models (shading) Taken from IPCC (2013).

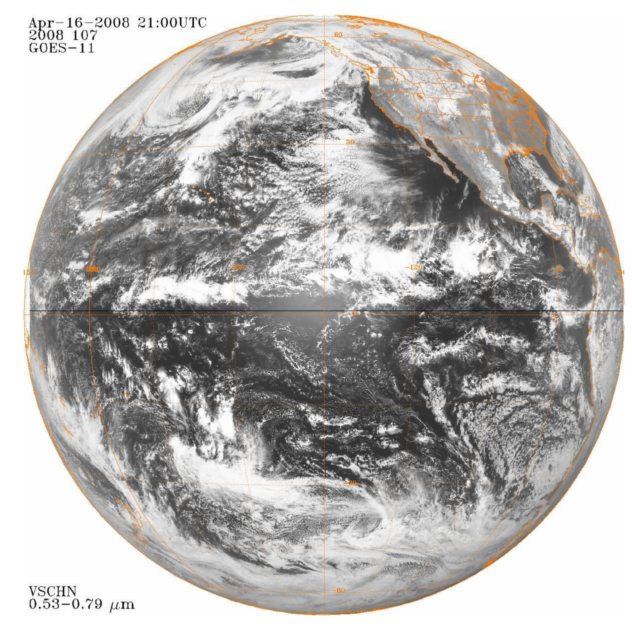


Global mean Radiative Forcings. Taken from IPCC (2007).

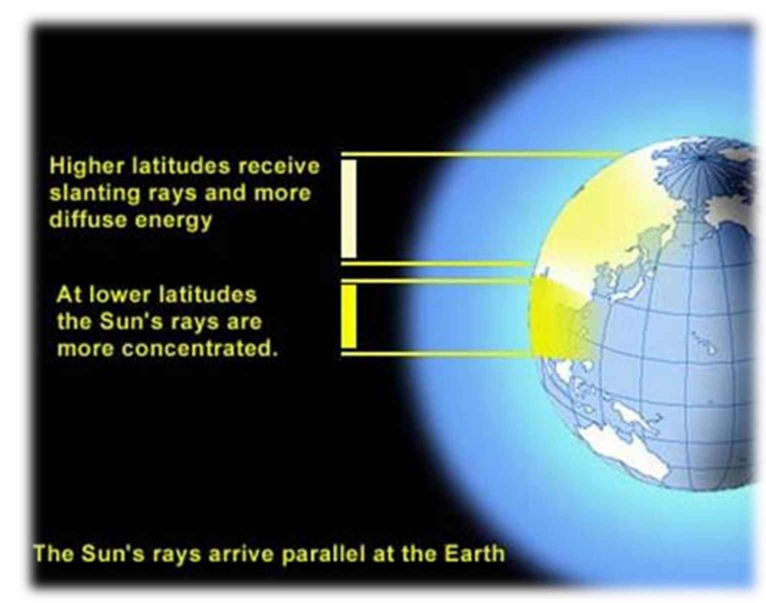
- Clouds very difficult to model as processes occur on scales smaller than models are able to capture.
- Different models include different parameterisation schemes to account for such processes therefore representing clouds differently.

Cloud Effect on Climate

- Clouds have the ability to naturally cool the climate by reflecting some of the incoming solar radiation back out to space.
- Solar radiation received by Earth is not evenly distributed.
- The amount of radiation reflected by clouds depends on their location.



Satellite Image from GOES-11. Taken from National Climatic Data Centre



Distribution of solar radiation at different latitudes. Adapted from Christopherson (2009).

Research Objectives

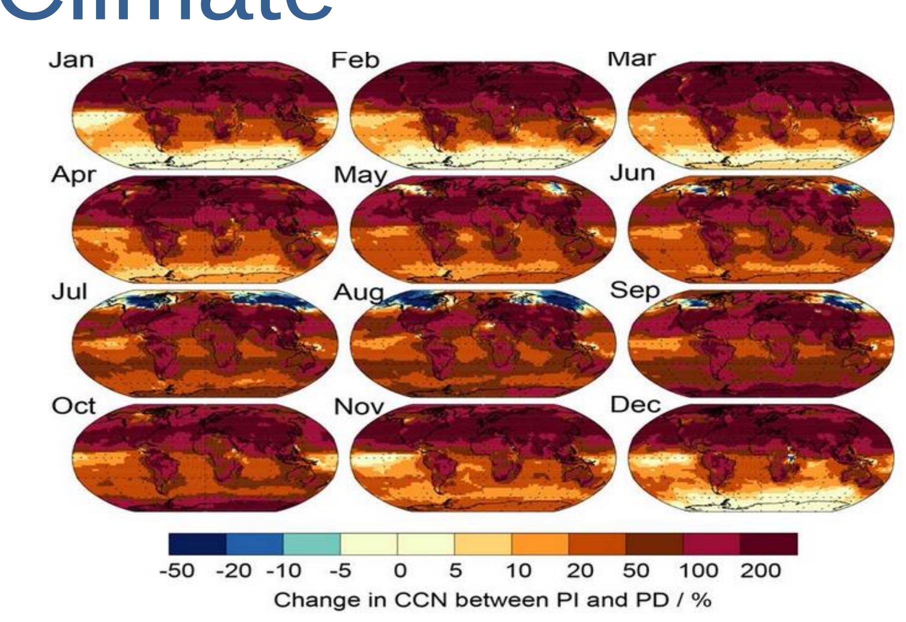
Using the cloud outputs from a selection of the latest generation climate models used in the Coupled Model Intercomparison Project (CMIP), Phase 5, to:

- Quantify the range of inter-model variability and divergence from satellite observations, and
- Evaluate the uncertainty in the Radiative forcing due to clouds.

Use aerosol data from the Global Model of Aerosol Processes to:

- Analyse how a change in aerosol concentrations can change clouds and their forcing effects on climate.

Aerosol Forcing on Climate

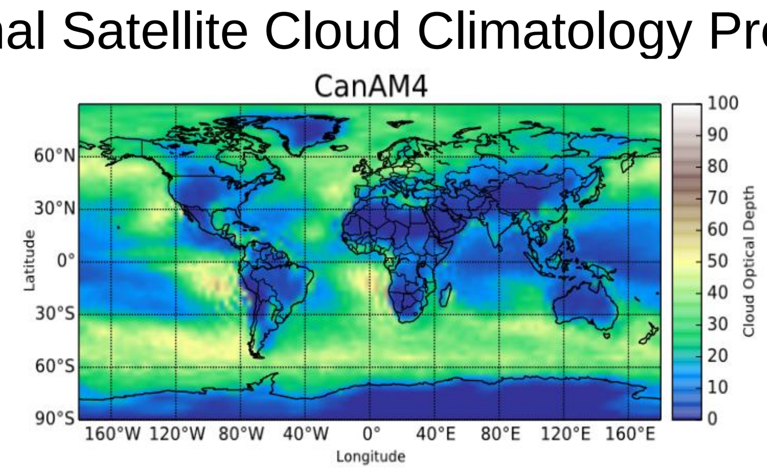


Change in aerosols between the pre-industrial period and the present day. Courtesy of D. Hamilton, Leeds.

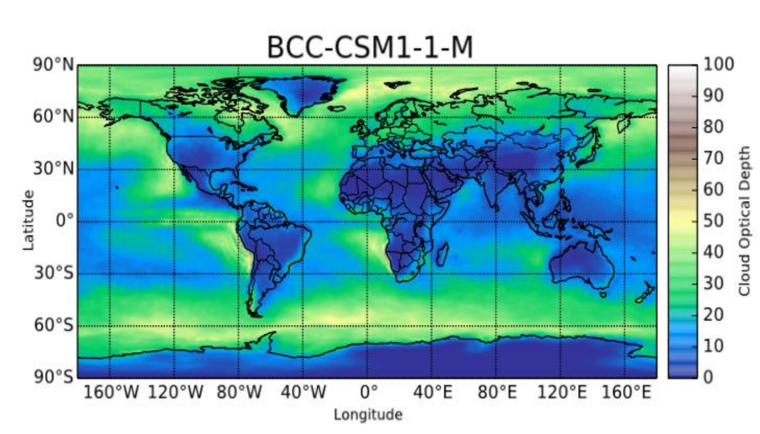
- Some aerosols can serve as a base for cloud droplets.
- More cloud droplets mean clouds are more reflective, having a negative forcing on the climate.
- Marine clouds are more susceptible to changes in aerosol than continental clouds.
- The magnitude of this forcing is dependant on the cloud fields.

Models vs. Observations

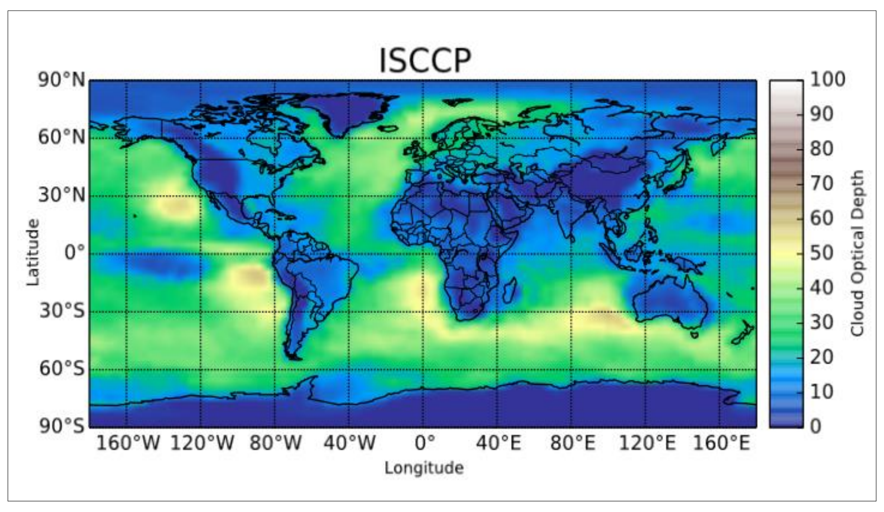
Models used in CMIP5 show very different outputs of cloud fields. The plots below show the global cloud optical depths for low-levels clouds, between pressure levels of 900mb and 740mb, as a yearly average for 2008. The centre plot is the 2008 yearly average of low-level cloud satellite observations from the International Satellite Cloud Climatology Project (ISCCP).

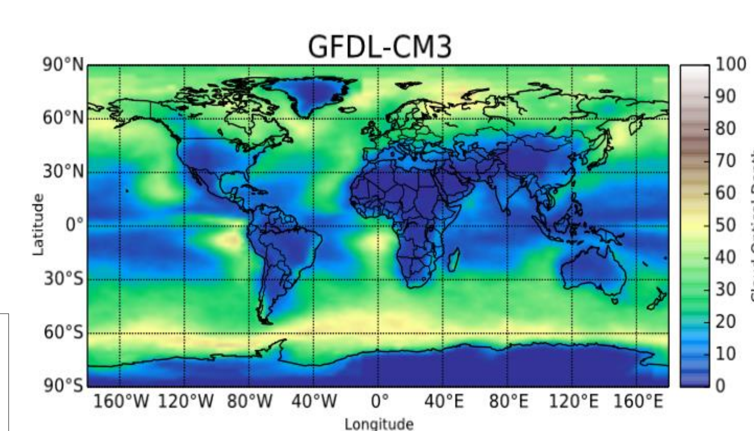


Canadian Centre for Climate Modelling and Analysis

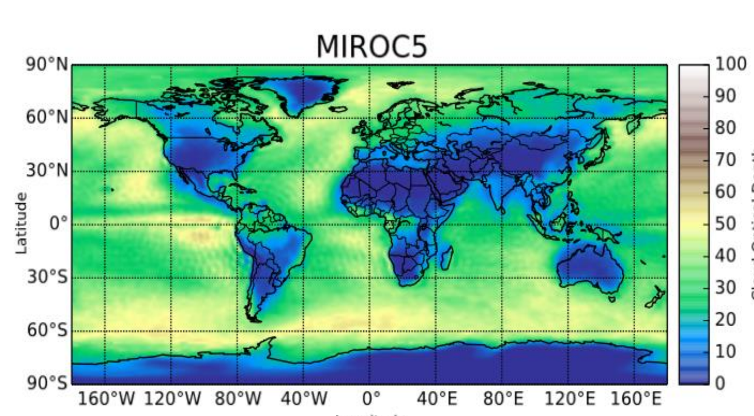


Beijing Climate Centre

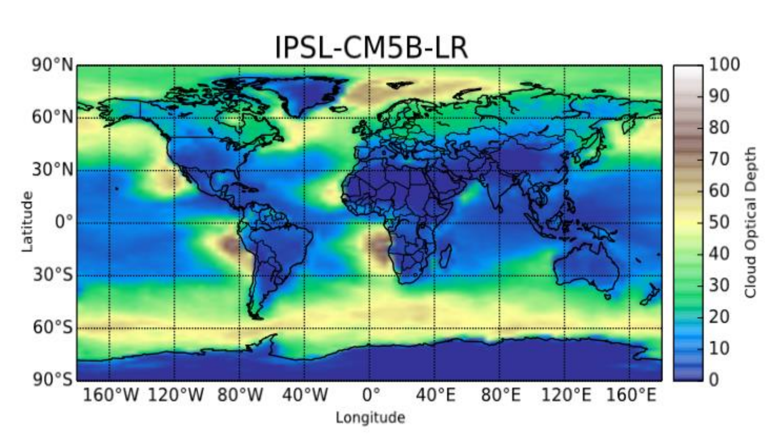




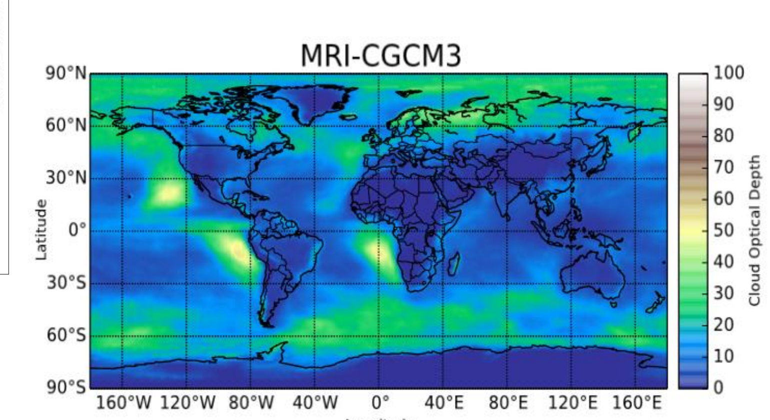
Geophysical Fluid Dynamics Laboratory



Centre for Climate System Research, National Institute for Environmental studies, Japan Agency for Marine-Earth Science and Technology.



Institut Simon Pierre Laplace



Meteorological Research Institute

- MIROC5 has the greatest extent meaning more clouds reflecting solar radiation, hence having a cooling effect on climate.
- Whereas MRI-CGCM3 has the smallest extent, suggesting less clouds to reflect radiation, allowing it to pass through to warm the earth.
- CMIP5 models have different outputs of cloud extent and optical depth, resulting in models having different radiative properties.

Benefits of Research and Future Work

An analysis of the accuracy of cloud representation in climate models could be incredibly beneficial to aid further work in attempting to incorporate these results into climate models and reduce the uncertainty in model projections of future climate. Improvements in the representation of future climate will allow the global community to work together to formulate sustainable adaptation and mitigation strategies.

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