Importance of Minor-Looking Treatments in GCMs

--- Can satellite observation reduce uncertainty in such treatments? ---

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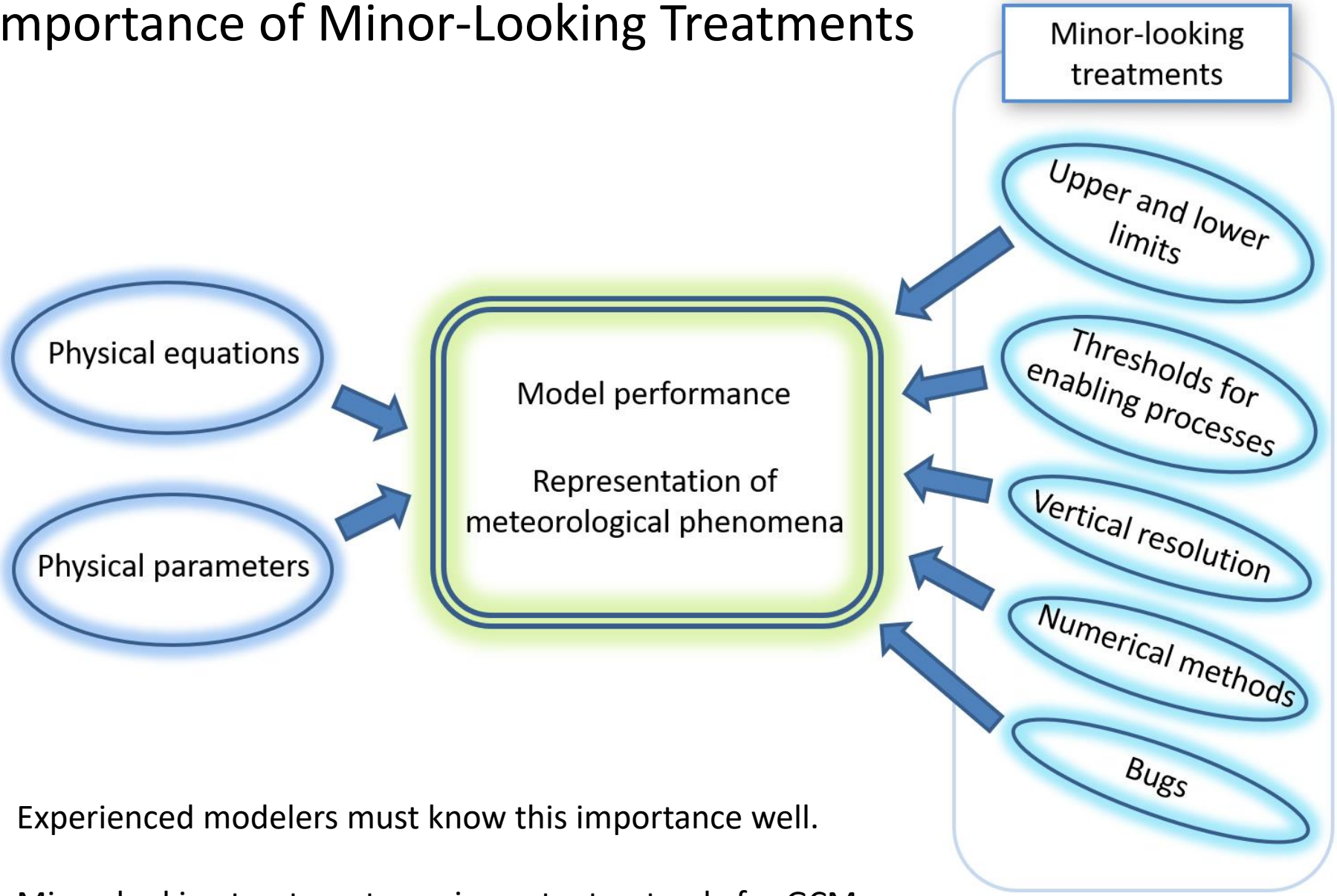
Kawai, H., K. Yoshida, T. Koshiro, and S. Yukimoto, 2022: Importance of Minor-Looking Treatments in Global Climate Models. *J. Adv. Model. Earth Syst.*, 10.1029/2022MS003128.

Importance of Minor-Looking Treatments



- Experienced modelers must know this importance well.
- Minor-looking treatments are important not only for GCMs but also for NWP models and regional climate models.

Minor-looking treatments in various schemes & processes

Kawai et al. (2022, *JAMES*)

- Cloud macrophysics
- Cloud top turbulence
- Cloud microphysics (mass concentration)
- Cloud microphysics (number concentration)
- Convection
- Turbulence
- Vertical Resolution
- Numerical methods
- Bugs

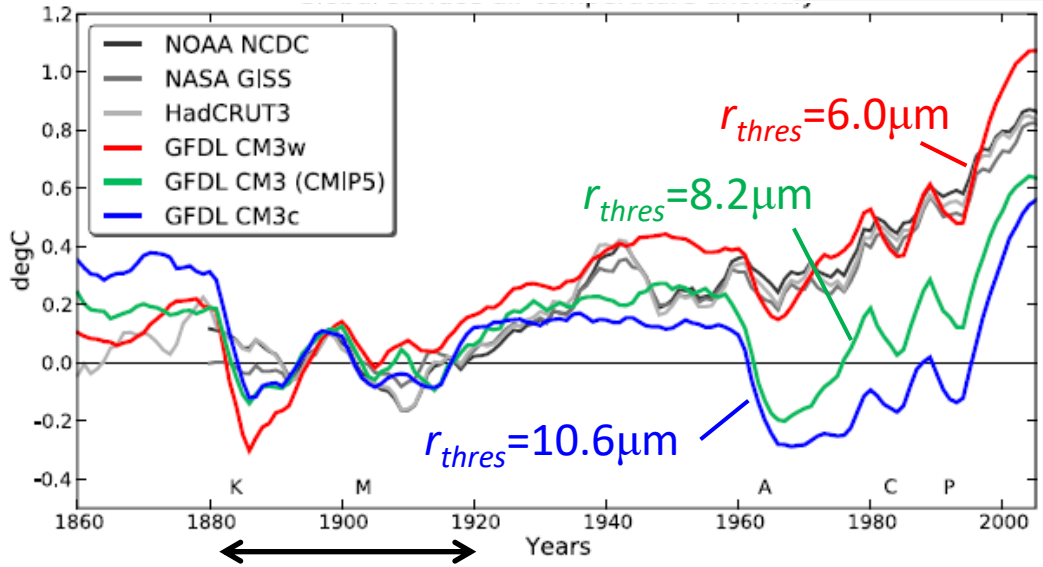
Cloud droplet radius threshold for autoconversion

$$\left(\frac{\partial q_l}{\partial t}\right)_{AU} = -a\frac{0.104 g E_{AU}\rho_{air}^{4/3}}{\mu(N_d\rho_l)^{1/3}}\left(\frac{q_l}{a}\right)^{7/3} H\left(\frac{q_l}{a} - q_{crit}\right)$$ Manton & Cotton (1977)

$$q_{crit} = \frac{4}{3}\pi\rho_l r_{crit}^{\ 3} N_d / \rho_{air}\ \text{[kg/kg]}$$

2m Temperature Anomaly

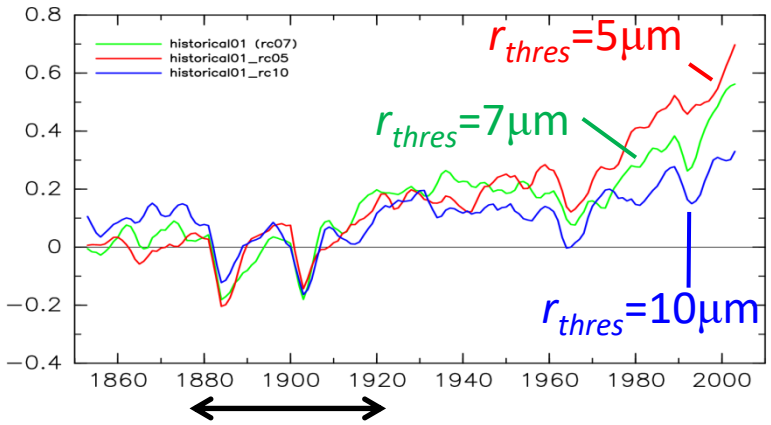
GFDL CM3



Golaz et al. (2013, GRL)

5 ensemble members

MRI CGCM3



Koshiro et al. (2020, WMO report)

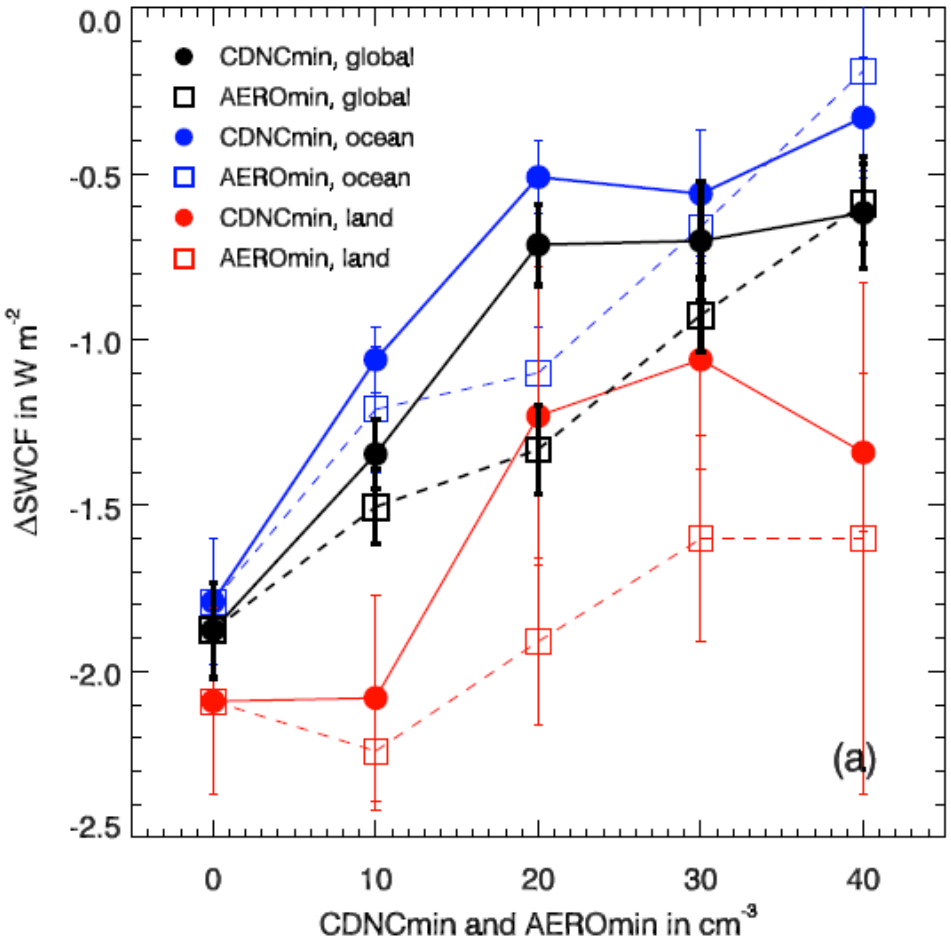
3 members

20C temperature increase drastically changes.

(The results are consistent in the two models.)

Lower limit of number concentration of cloud droplets

Radiative forcing due to anthropogenic aerosols



Hoose et al. (2009)

Radiative forcing due to anthropogenic aerosols is larger for a smaller lower limit of N_{liq} or N_{aer}.

5 years

CDNCmin : Lower limit of N_{liq}
AEROmin : Lower limit of N_{aer}

Radiative forcing due to anthropogenic aerosols changes significantly depending on lower limit of N_{liq} or N_{aer}.

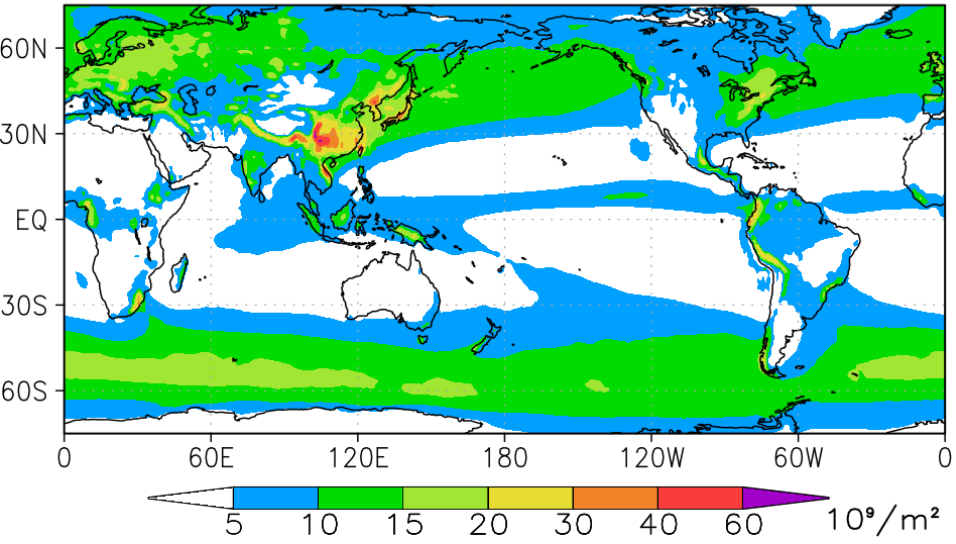
Lower limit of updraft speed for aerosol activation calculation

w for activation calculation — grid-scale w — turbulence fluctuation w — lower limit for w_{act}

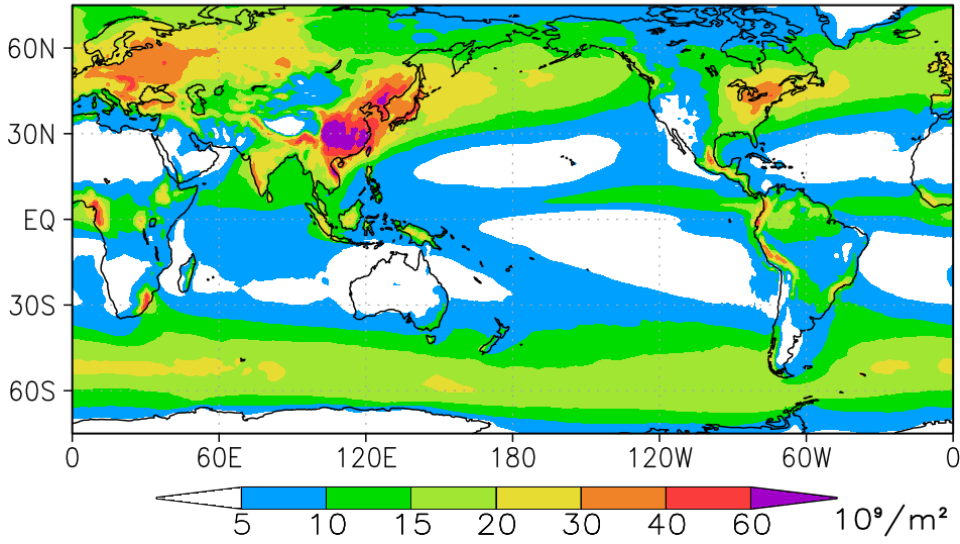
$$w_{act} = \max (w_{grid} + w_{turb} , w_{min})$$

Column droplet number concentration

w_{min} = 0.01 m/s



w_{min} = 0.2 m/s



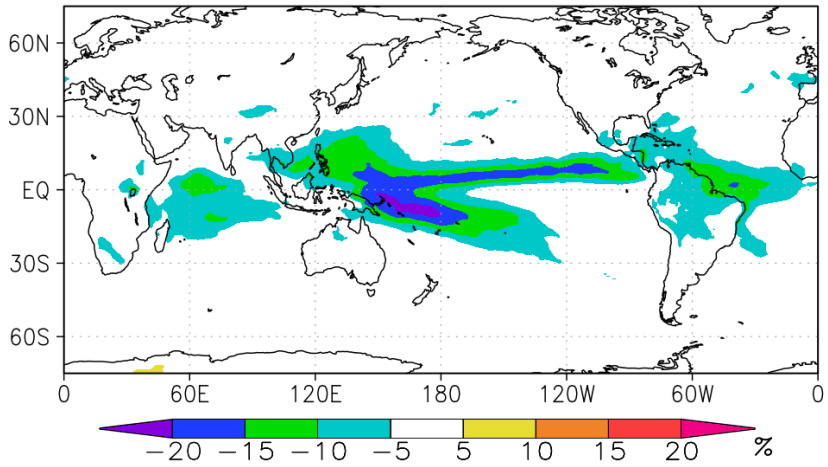
2001-2005年

Column N_{liq} significantly increases for larger w_{min}.

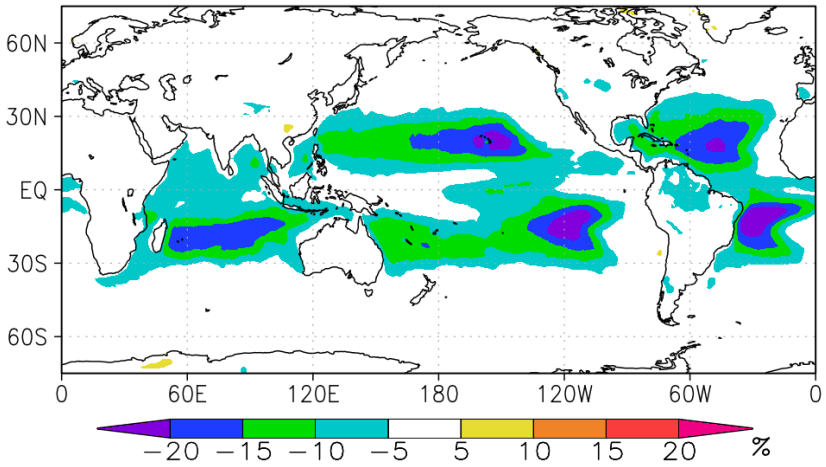
Impact of threshold of RH for instant evaporation of clouds detrained from convection

Instant evp. for RH<80% — No instant evp.

Mid-level Cloud Cover

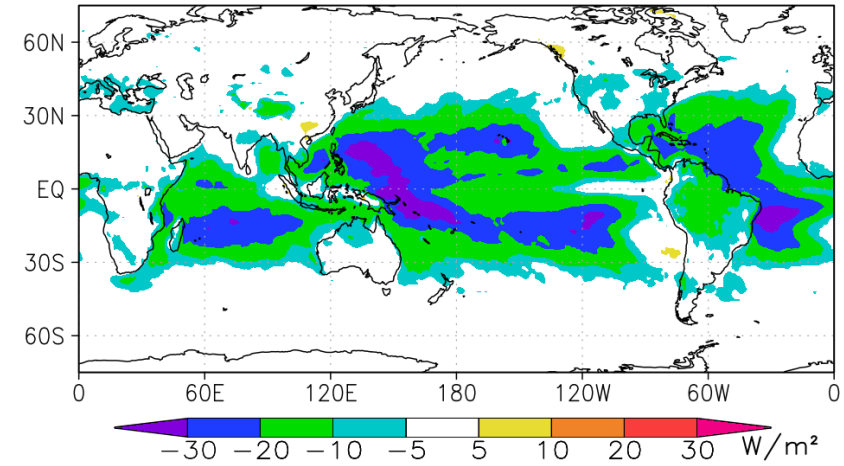


Low Cloud Cover



2001 - 2005

TOA SW radiation (upward)



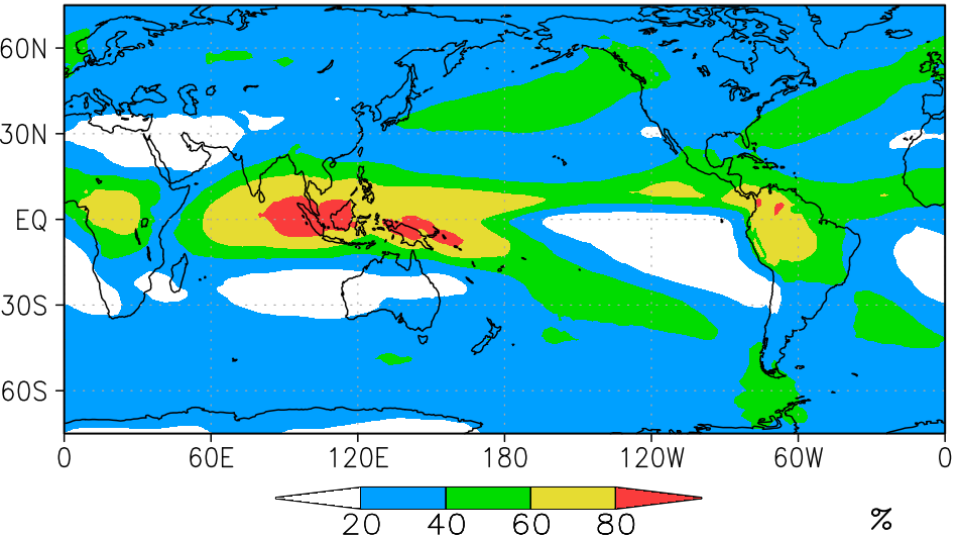
In Tiedtke (1993), CWC and cloud fraction detrained from a convection scheme is passed to a large-scale condensation scheme. However, CWC and cloud fraction is evaporated (without being passed) in MRI-ESM2 when RH is low.

Middle clouds, low clouds & radiation change significantly depending on the instant evaporation.

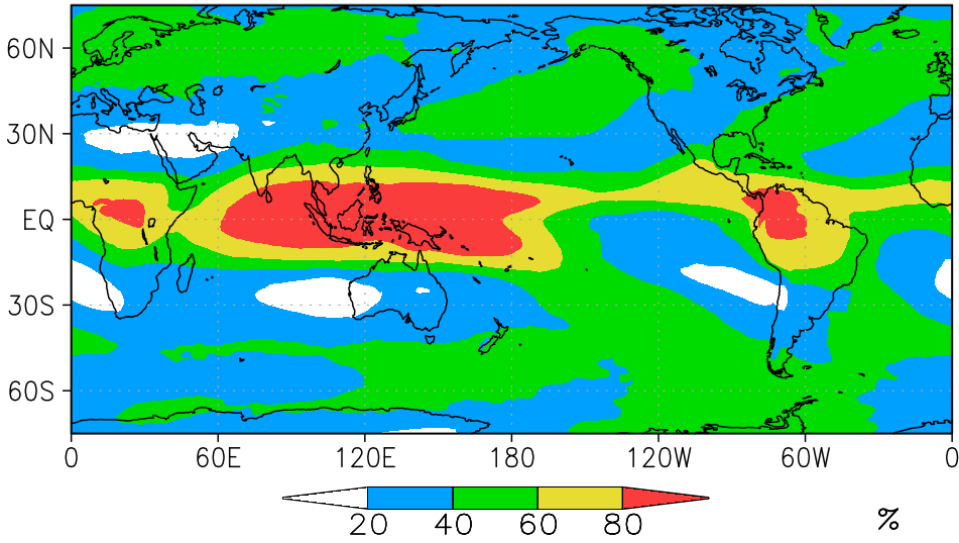
CWC threshold for cloud cover of optically thin clouds

High cloud cover

CWC_{thres} = 0.5 mg/kg



No threshold
(All clouds are counted)



2001 - 2005

High cloud cover significantly changes depending on the threshold for optically thin clouds. (Impact on radiation budget is not significant because they are optically thin)

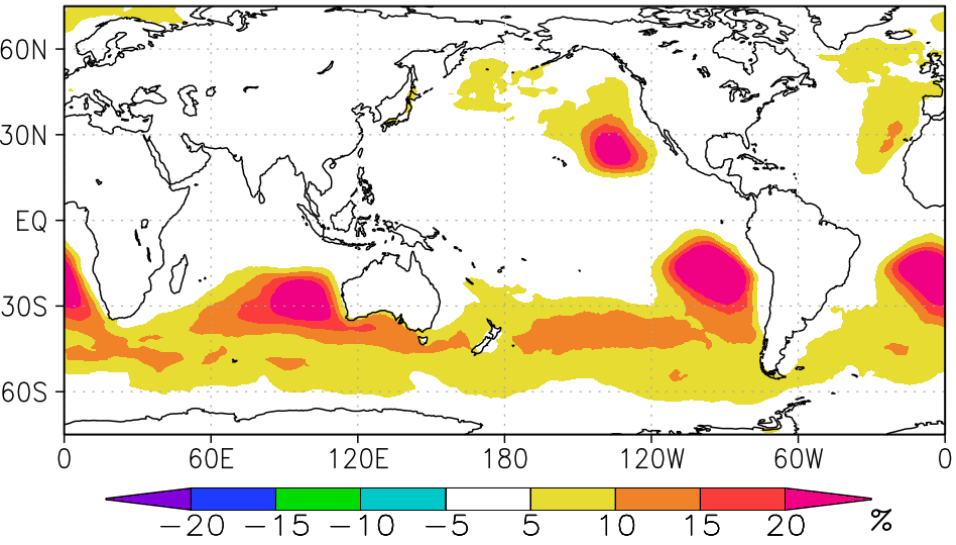
(We don't need to think about this issue if we use a satellite simulator (e.g. COSP).)

Impact of conditionally disabling shallow convection

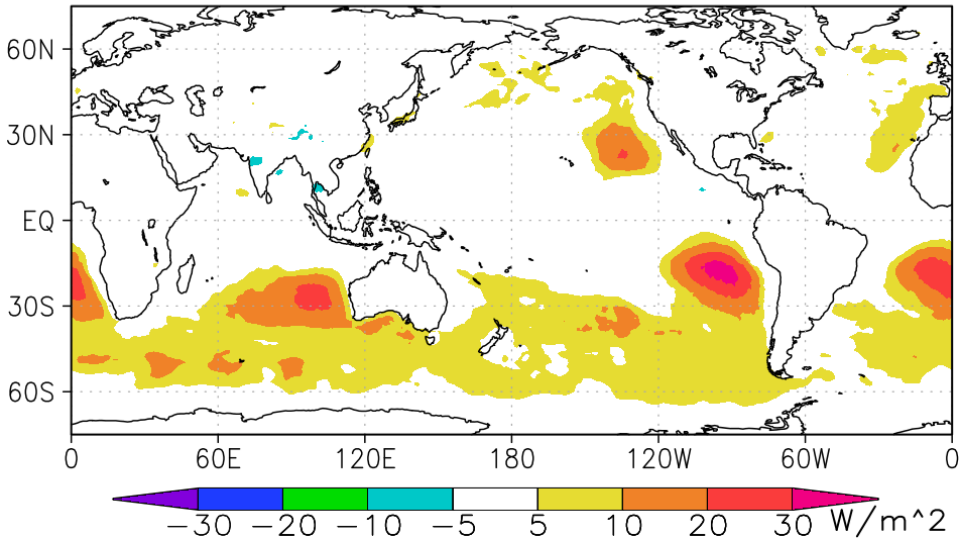
Shallow Cu conditionally Off – Shallow Cu On

(shallow convection is disabled over stable ABL (determined by ECTEI))

Low Cloud Cover



TOA SW radiation (upward)



LCC is increased over the SO and west coast of the continents over subtropics

(Closer to Obs.)

SW reflection is increased over these regions

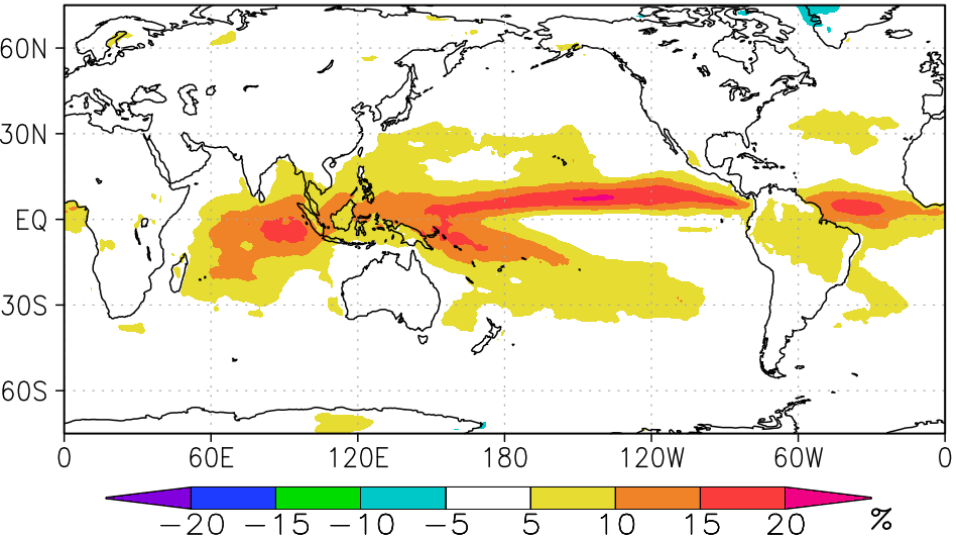
(Closer to obs.)

10-yr mean

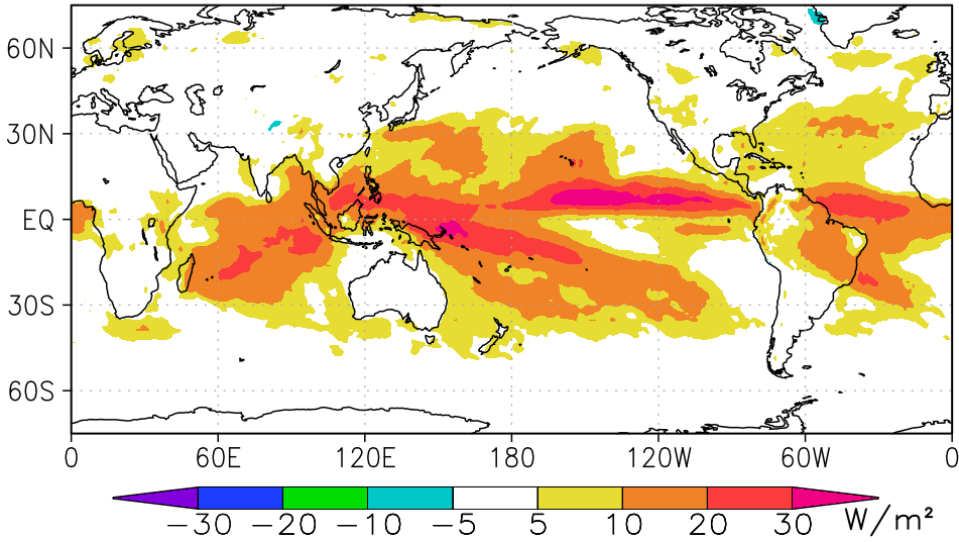
Impact of minimum height of permitting convective precipitation

Minimum height: 2km — 400m

Low Cloud Cover



Upward Shortwave Radiation at TOA



2001-2005

Low clouds (& reflection of solar radiation) over the tropics and subtropics increase significantly for deeper minimum height.

(Because CWC is maintained due to suppression of conversion to precipitation.)

Summary

Mentioned today:

Minor-looking treatments	Sensitive physical variables or phenomena
Threshold of droplet radius for autoconversion	20C temperature increase
Lower limit of number concentration of cloud droplets	Radiative forcing due to anthropogenic aerosols
Lower limit of updraft speed for aerosol activation calculation	Cloud droplet number concentration
Impact of threshold of RH for instant evaporation of clouds detrained from convection	Mid- & Low- level cloud cover
CWC threshold for cloud cover of optically thin clouds	High cloud cover
conditionally disabling shallow convection	Low cloud cover
minimum height of permitting convective precipitation	Low cloud cover

Other examples: See Kawai et al. (2022, *JAMES*)

Can satellite observation reduce uncertainty in these treatments?

References

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Acknowledgements

This work was partly supported by the advanced studies of climate change projection (SENTAN) Grant JPMXD0722680734 from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. It was also supported by the Japan Society for the Promotion of Science (JSPS) KAKENHI Grant Numbers JP19K03977 and JP19H05699, and the Environment Research and Technology Development Fund (2-2003) of the Environmental Restoration and Conservation Agency, Japan.