Constraining Models’ Response Of Tropical Low Clouds To SST Forcings Using CALIPSO Observations

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The decrease of low cloud cover (LCC) in future climate is in the larger end of the model range if they agreed when constrained by satellite observations (Qu et al., 2014)
• Large uncertainty around the vertical response of low cloud fraction to a uniform SST increase in CMIP models.

Better understanding and constraining the vertical response of low cloud fraction could help us reduce uncertainty on future climate projections

Brient et al. (2015)
Between 35°S and 35°N
Over ocean
15 hPa/day < \( \omega_{500} \) < 35 hPa/day (between the blue and the green lines)
AMIP simulations + lidar simulator for the models (12)
2007-2015 CALIPSO-GOCCP, CERES and for ERAI reanalysis (\( \omega_{500} \)) for the observations
Change In Low Cloud Cover As A Function The Present Day Cloud Cover

- \(\Delta CF/\Delta SST\) is filtered for \(SST_{\text{anomaly}} > 1\)K
- 11/13 models predict a decrease of the LCC
- The larger the present day LCC, the larger the change in LCC per K
- 8/13 models are outside the observation uncertainty
Change In SW CRE

- Filtered for $\text{SST}_{\text{anomaly}} > 1\text{K}$

- Most models fall within the observational uncertainty although a significant part underestimates the $\Delta\text{CRE}$

- The magnitude of the CRE is « overestimated » by all but one models

- The larger the CRE the smaller the $\Delta\text{CRE}$
Filtered for SST anomaly > 1K

- Most models fall within the observational uncertainty although a significant part underestimates the ΔCRE

- The magnitude of the CRE is « overestimated » by all but one models

Too few too bright

- The larger the CRE the smaller the ΔCRE

Change In SW CRE
Change In Cloud Fraction Profiles

- $\Delta CF/\Delta SST$ is filtered for $\text{SST}_{\text{anomaly}}>1\text{K}$
- Deepening of the low cloud top
- Decrease of the Low-level cloud fraction (thinning)
- Model variability quite large but capture the pattern qualitatively (7 models out of 13)
- The overall change is a decrease of the cloud fraction (consistent with the decrease of the LCC)
Change In Cloud Fraction Profiles

3 behaviors:
- Decrease of the low-level CF
- Deepening of the cloud top followed by a decrease of the low-level CF
- No significant change at all
- Seems to be the result of competing effect of the turbulent scheme and shallow convection scheme
Change In Cloud Fraction Profiles: Uniform +4K

- SST is increase uniformly by +4K over the AMIP period
- Two type of behavior In the low-levels: Increase or decrease
- Change in high clouds is larger than that of low clouds
- Overall little positive SW cloud feedback
Change In Cloud Fraction Profiles: Uniform +4K

- Same 8 models in both +4K and interannual modeled $\Delta CF$

- While the variation in SST is smaller in the interannual $\Delta CF$, the change in low clouds is much larger

- The cloud feedbacks are larger in the interannual

$\Rightarrow$ Uniform SST increase does not produce equivalent $\Delta CF$ as a local SST increase due to interannual variations.
Understanding What Control the Low Cloud Change

• Different environmental quantity contributes to changes in the CF (e.g. humidity, dynamic, SST, wind… EDIT e.g. Steve’s talk this morning)

• How well are reproduced these factors may affect the ability of GCMs to reproduce the right cloud feedbacks in future climate.

• CALIPSO-GOCCP and ERAI reanalysis to evaluate the mechanisms in GCMs.

• Controlling factors based on Bretherton et al. (2013)
Understanding What Control the Low Cloud Change

1) Moisture gradient: e.g. larger SST

Bretherton et al., 2013

![Diagram showing Moisture gradient and ΔCF filtered by SST](image)
2) Turbulent driving: e.g. larger q at 700mb

Bretherton et al., 2013
3) Inversion strength: e.g. larger estimated inversion strength

Bretherton et al., 2013
Understanding What Control the Low Cloud Change

4) Dynamic: e.g. reduced subsidence via $\omega_{500}$

Bretherton et al., 2013
Summary

• Based on present day observations, it seems that the models underestimate the change of low cloud cover and fraction (both positive and negative)

• It affects their ability to estimate cloud feedbacks in present day and likely and future climate

• The controlling factors for low cloud changes (e.g. Bretherton et al [2013]) together with CALIPSO/CloudSat/CERES observations may help us constrain the low cloud response to future climate change in GCMs

Next

• Investigate different type of clouds using other regimes

• Check whether the results are equivalent for idealized simulation using GISS single column model

• Modify parameters in the cloud schemes to better match the Obs and analyze the effect on cloud feedbacks