Evaluation of model differences in the cloud forcing response of the southeastern Pacific marine subsidence region

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Background

- Marine subsidence regions have been suggested as the largest contributor to climate model uncertainties in cloud response to climate change
- The southeastern Pacific subsidence region is dominated by marine boundary layer clouds and is large source of negative cloud radiative forcing

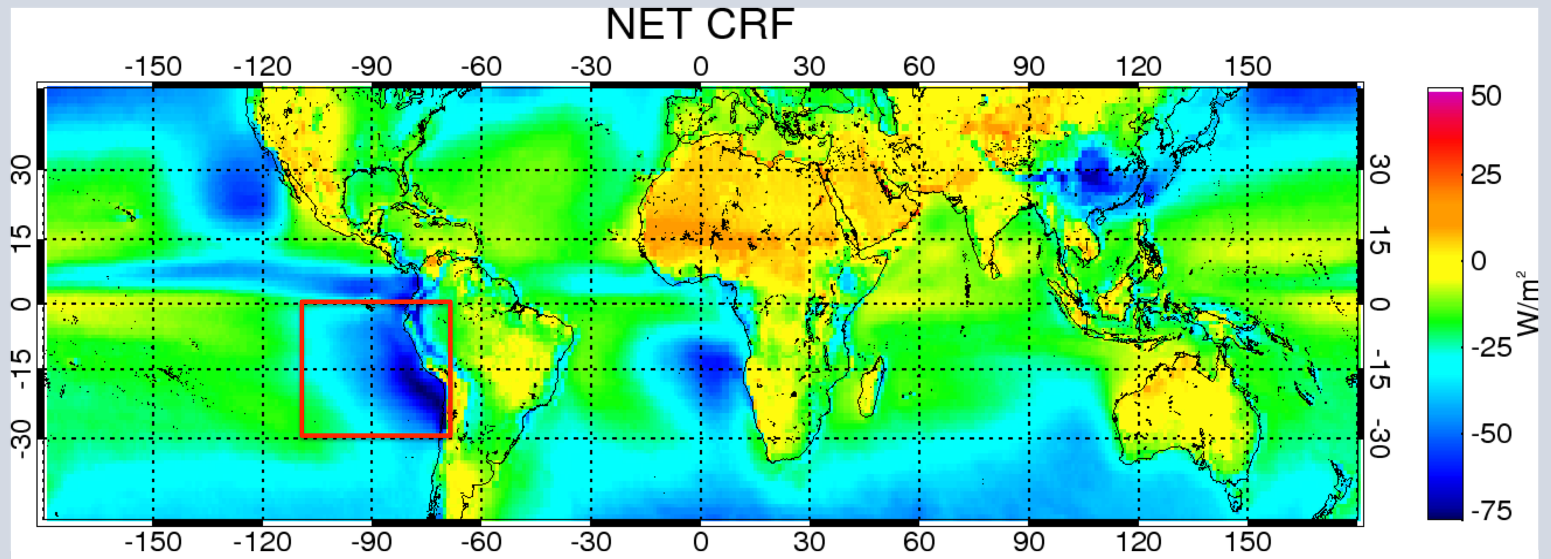


Figure 1. CERES net cloud radiative forcing.

Data/Methods

- Cloud radiative forcing (CRF) in the southeastern Pacific marine subsidence region is compared for all AMIP simulations currently available in the CMIP5 PCMDI archive
- The cloud forcing response to temperature is calculated following the methods of Bony and Dufresne (2005) for all climate models and observations

$$S = \partial\delta C / \partial\delta T \quad \text{where}$$

S = CRF sensitivity to SST

δC = monthly anomaly in CRF

δT = monthly anomaly in surface temperature

- Cloud forcing is compared to CERES measurements
- Regional cloud properties are compared to A-Train measurements

Seasonal Shortwave CRF

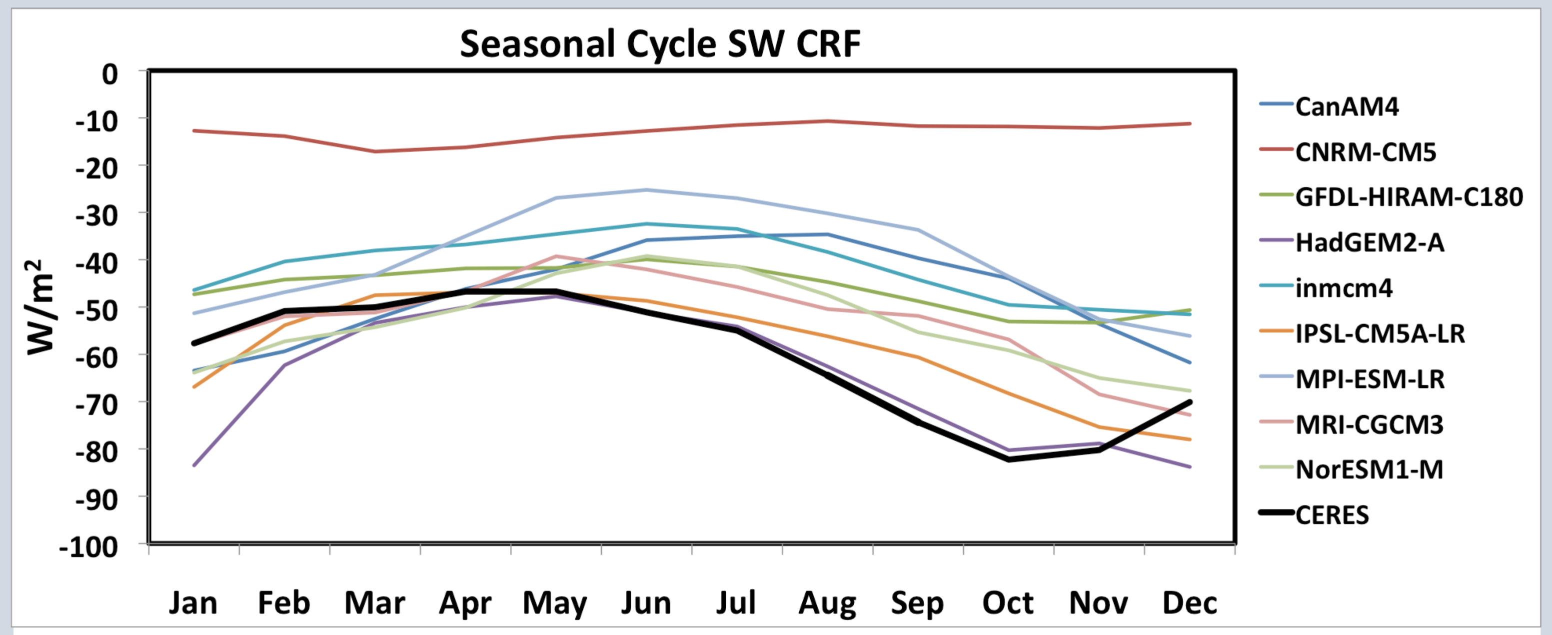
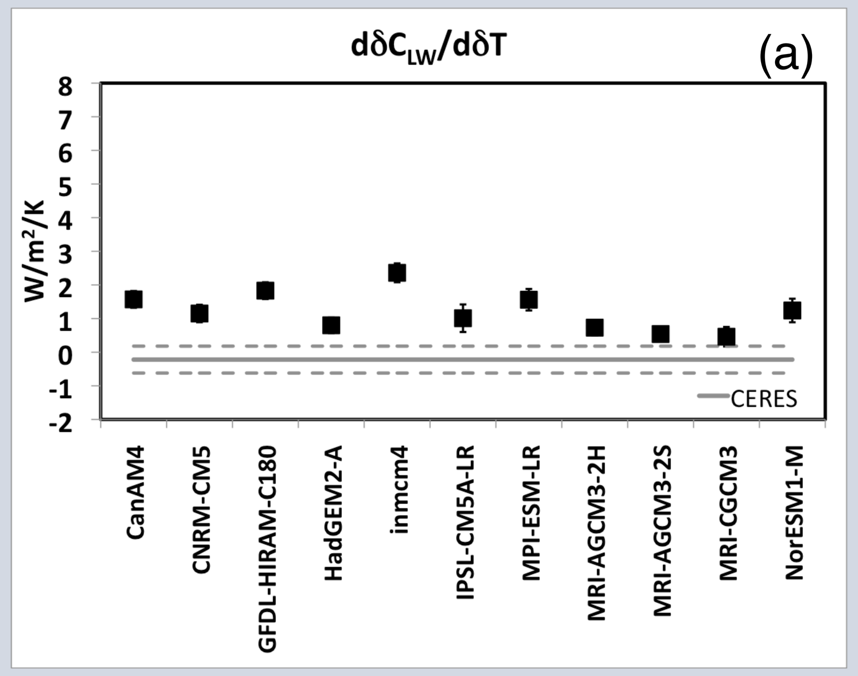
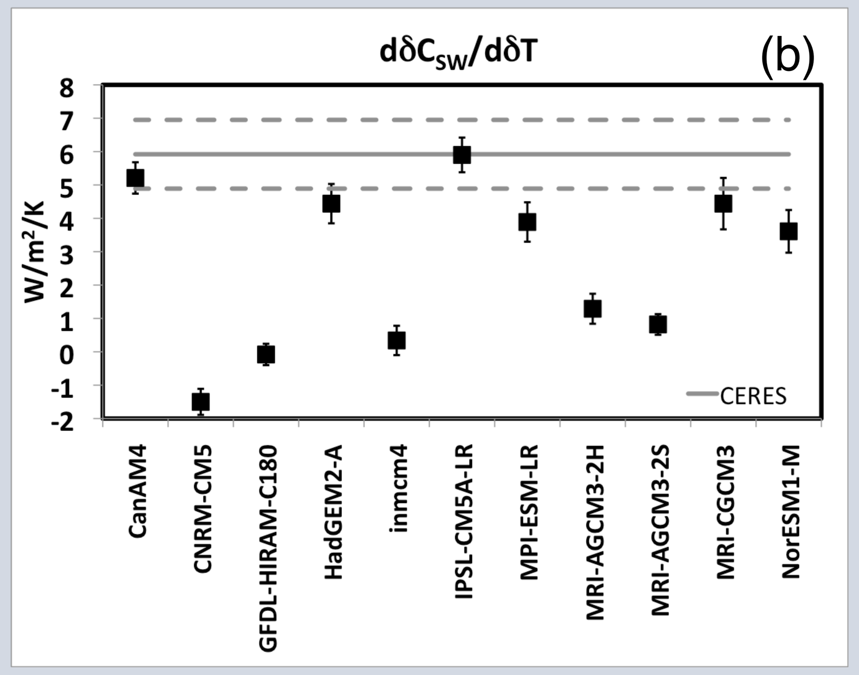


Figure 2. Mean seasonal cycle in shortwave cloud radiative forcing.

➡ *Shortwave CRF is generally weaker in all models than CERES – especially in the months with the greatest cloud fraction.*

CRF Sensitivity to Temperature





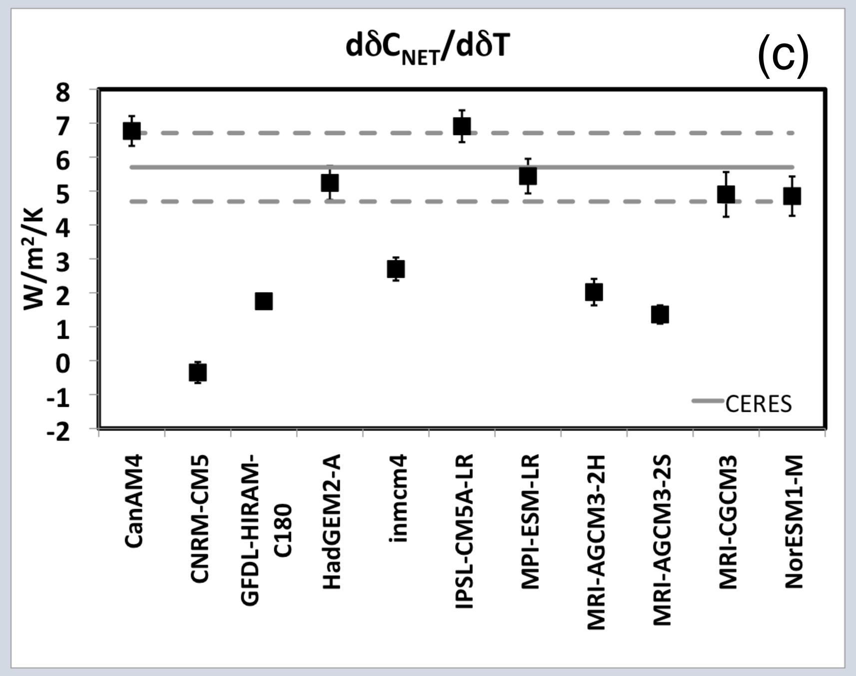


Figure 3. (a) Longwave, (b) shortwave, and (c) net CRF sensitivity to temperature for models and CERES observations.

➡ *Large intermodel differences in shortwave CRF.*

➡ *Compared with CERES, many models underestimate the sensitivity of CRF to temperature.*

Regional Shortwave CRF

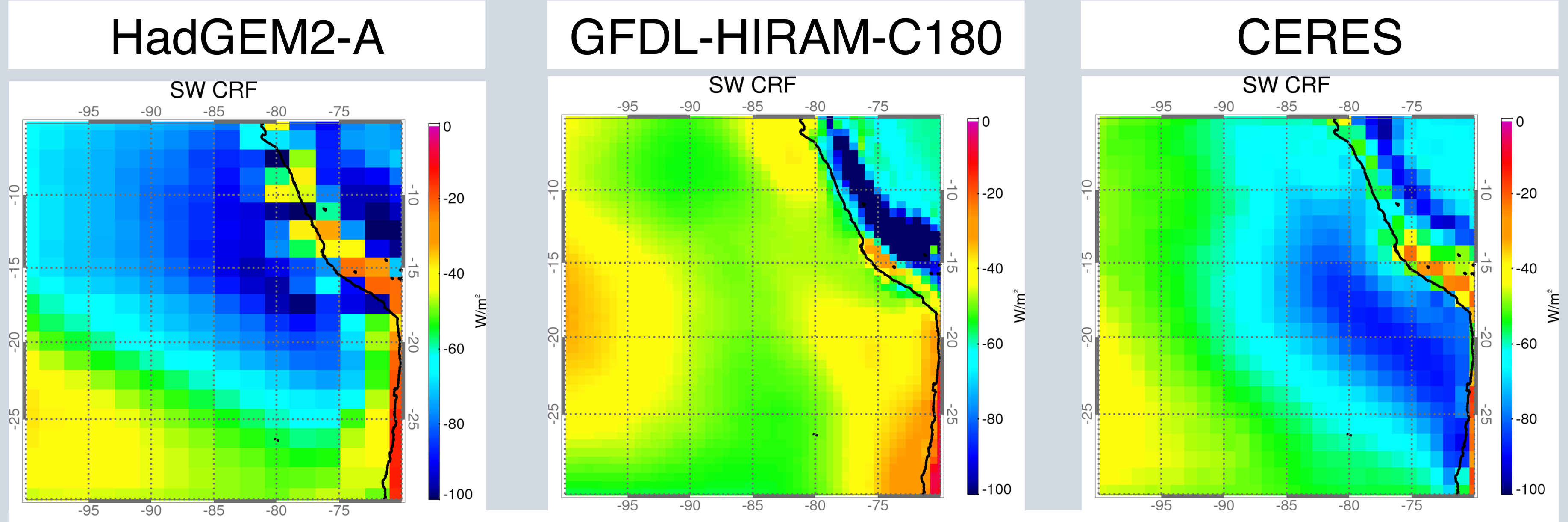


Figure 4. Mean shortwave CRF for (a) HadGEM2-A, (b) GFDL-HIRAM-C180, and (c) CERES.

➡ *The spatial distribution of shortwave CRF is similar to CERES in some models, but varies from model to model.*

Shortwave CRF Sensitivity to Temperature

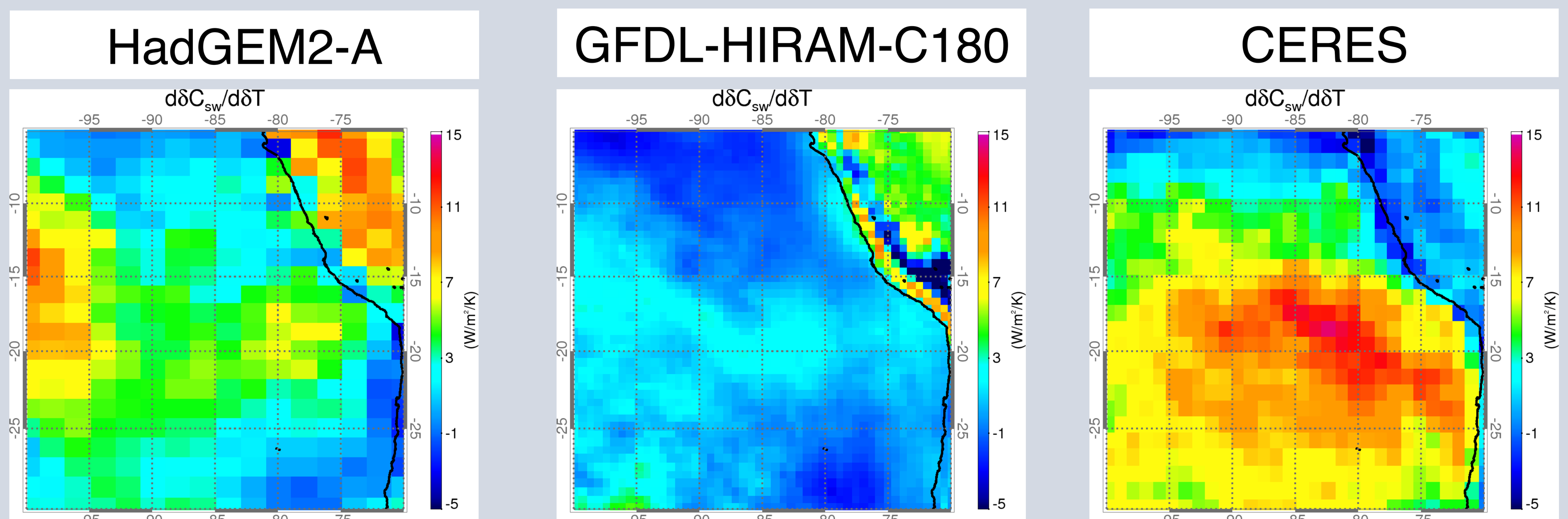


Figure 5. Mean shortwave CRF sensitivity to temperature for (a) HadGEM2-A, (b) GFDL-HIRAM-C180, and (c) CERES.

➡ *Even though some models realistically simulate the mean regional behavior, the spatial distribution of the CRF sensitivity differs from CERES observations.*

Cloud Fraction Sensitivity to Temperature

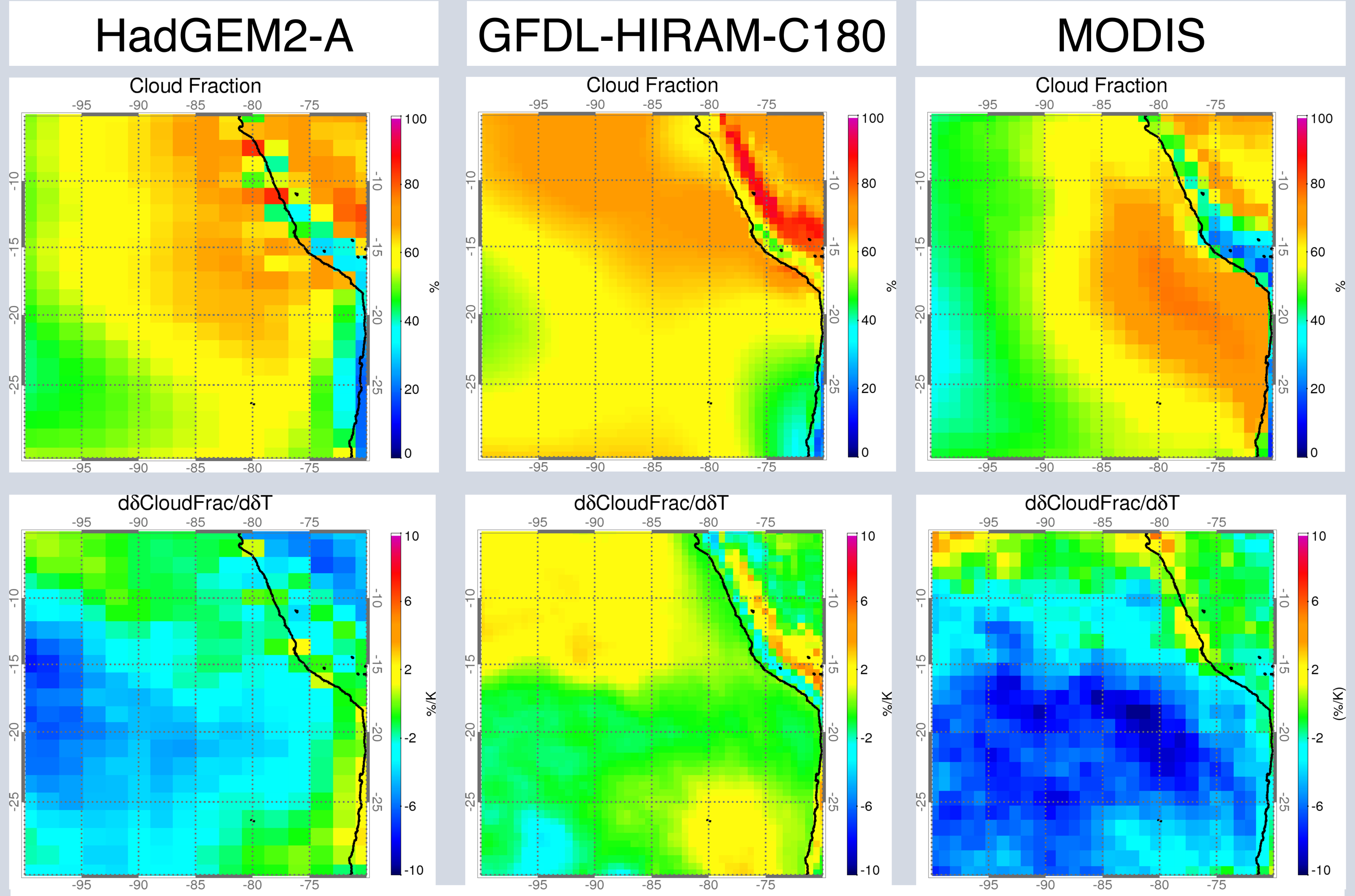


Figure 6. Mean cloud fraction and cloud fraction sensitivity to temperature from (a, d) HadGEM2-A, (b, e) GFDL-HIRAM-C180, and (c, f) MODIS observations.

➡ *Model mean cloud fraction compares favorably with MODIS, however the sensitivity of cloud fraction to temperature varies.*

CloudSat & MODIS Cloud Properties

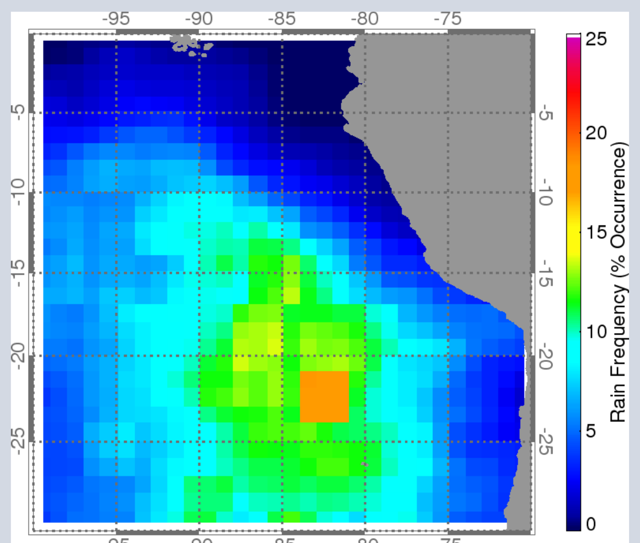


Figure 7. CloudSat precipitation frequency.

Table 1. MODIS cloud properties for precipitating and non-precipitating clouds.

	All Clouds	Non-Precipitating	Precipitating
LWP (g/m²)	113	87	272
Re	16	15	21
Tau	11	9	19
Z_{top} (km)	1.53	1.47	1.79

➡ *Highest CERES CRF sensitivity to temperature corresponds to region with highest CloudSat-estimated precipitation frequency.*

Conclusions

- Still a large spread in model response of shortwave cloud forcing to temperature in southeastern Pacific subsidence region
- Seasonal cycle and mean regional response show that models generally underestimate shortwave cloud forcing – largest differences between observations & models in cloudiest months
- Even for models that accurately simulate the mean regional response, the geographic distribution of the response differs from observations
- Largest CERES CRF sensitivity to temperature in region with the highest CloudSat-estimated precipitation frequency – few models show the highest sensitivity in this region

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