Response to Comment on "Observational and Model Evidence for Positive Low-Level Cloud Feedback"

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Response to Comment on "Observational and Model Evidence for Positive Low-Level Cloud Feedback"

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Broccoli and Klein argue for additional diagnostics to better assess the simulation of cloud feedbacks in climate models. We agree, and here provide additional analysis of two climate models that reveals where model deficiencies in cloud simulation in the Northeast Pacific may occur. Cloud diagnostics from the forthcoming Climate Model Intercomparison Project 5 should make such additional analyses possible for a large number of climate models.

Based on an analysis of the available diagnostics in the Climate Model Intercomparison Project, phase 3 (CMIP3) archive, we argued in Clement *et al*. (*1*) that HadGEM1 was the only model to simulate realistic cloud-meteorology relationships in the Northeast (NE) Pacific. We found that the GFDL CM2.1 model did not simulate the observed relationships between total cloud and both lower tropospheric static stability and mid-tropospheric vertical velocity. Using additional diagnostics that were not available in that archive, Broccoli and Klein (*2*) argue that the GFDL CM2.1 model does in fact simulate the observed signs of correlations between low-level cloud variability and local meteorology in the NE Pacific. We are in agreement with this finding. Furthermore, the GFDL model appears to simulate a vertical structure in the cloud response to local SST in a manner that is qualitatively similar to the HadGEM1 model (Fig. 1), with reduced cloud amount in lower levels and increased cloud amount at upper levels when the SST is high.

The findings in (*1*) and those of Broccoli and Klein (*2*) can be reconciled by the fact that total cloud variability in the GFDL model appears to be dominated by upper-level clouds, as illustrated in Fig. 2, whereas total cloud variability in HadGEM1 is dominated by lower-level clouds. Unfortunately, it is not possible with the model diagnostics currently available through CMIP3 to determine whether the details of the vertical structure of cloud response in either model are quantitatively consistent with satellite or surface-based observations of cloud fraction at different levels in the atmosphere. The only diagnostic available with which the models participating in CMIP3 and observations can be directly compared is total cloud amount. Based on this quantity, the HadGEM1 model is in better agreement with observations than the GFDL model [as we argued in (*1*)], even if the low-level cloud responses are qualitatively similar between the two models. Furthermore, although International Satellite Cloud Climatology Project (ISCCP) cloud amounts cannot be directly compared with the profiles shown in Fig. 2 because those quantities represent an average over pressure levels in which cloud overlap is taken into account, we note that the annual variance in ISCCP high cloud (above 440 mb) is ~5%-squared. This does not appear to be consistent with the GFDL simulation of high cloud variability in the region.

From the forthcoming Climate Model Intercomparison Project 5, there will be a large number of cloud diagnostics that can be used to intercompare both models and observations in much greater detail. Thus, the realism of the low-level cloud simulation in the next generation of climate models can be put to a more complete test.

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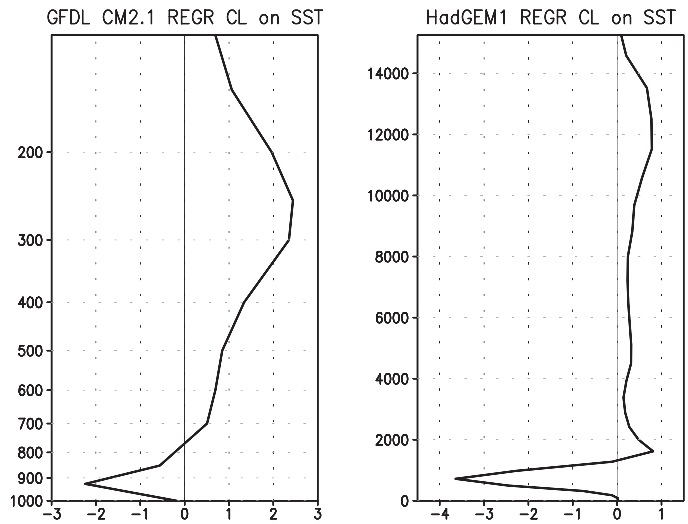

Fig. 1. Regression (REGR) of cloud amount (CL) in the NE Pacific (15° to 25°N, 145° to 115°W) on NE Pacific SST (% per K) in (**left**) GFDL CM2.1 (plotted as a function on a log pressure scale) and (**right**) HadGEM1 (plotted as a function of height). We note that the three-dimensional cloud amount for the HadGEM model was not available in the CMIP3 archive and thank M. Ringer for making this data available to us.

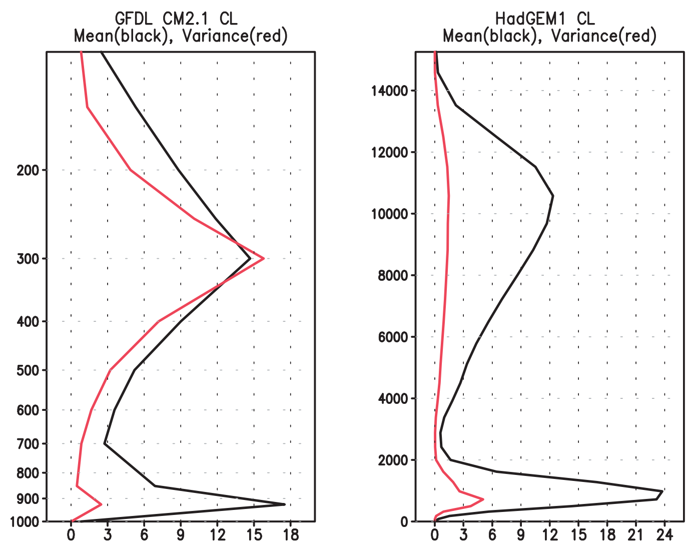

Fig. 2. Mean (%, black line) and variance (%-squared, red line) of cloud amount in (**left**) GFDL CM2.1 (plotted as a function of ln pressure), and (**right**) HadGEM (plotted as a function of height).

References and Notes

1. A. C. Clement, R. Burgman, J. R. Norris, *Science* **325**, 460 (2009).
2. A. J. Broccoli, S. A. Klein, *Science* **329**, 277 (2010); www.sciencemag.org/cgi/content/full/329/5989/277-a.
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