LAWRENCE LIVERMORE NATIONAL LABORATORY

LLNL-JRNL-422752

Comment on "Observational and model evidence for positive low-level cloud feedback"

A. J. Broccoli, S. A. Klein

January 22, 2010

Science

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

Anthony J. Broccoli[1*] and Stephen A. Klein[2]

Clement et al. (Reports, 24 July 2009, p. 460) provided observational evidence for systematic relationships of decadal time scale variations in marine low cloudiness and other climatic variables and found that most current-generation climate models were deficient in reproducing the observed relationships. Our analysis of one of these models (GFDL-CM2.1), using more complete model output, indicates much better agreement with observations, suggesting that more detailed analysis of climate model simulations is necessary.

Clement et al. (1) found that decadal variations in low cloudiness in the subtropical northeast Pacific (NEP) were strongly correlated with several climatic variables. They noted that the negative correlation between low cloud amount and sea surface temperature (SST) in this region was suggestive of a positive low-cloud feedback on decadal time scales and proposed that the ability to reproduce the observed relationship

[1] Department of Environmental Sciences, Rutgers University, 14 College Farm Road, New Brunswick, NJ 08901-8551, USA.

[2] Program for Climate Model Diagnosis and Intercomparison, Lawrence Livermore National Laboratory, P.O. Box 808, L-103, Livermore, CA 94551-0808, USA.

[*]To whom correspondence should be addressed. E-mail: broccoli@envsci.rutgers.edu.

would constitute a useful test of low cloud-climate relationships in climate models. Using output archived by the Coupled Model Intercomparison Project (CMIP3), they examined a set of current-generation climate models and found that most models did not reproduce the observed relationships.

We suggest that the assessment of Clement et al. (hereafter CBN09) regarding one such model, the GFDL-CM2.1 model (2), are too pessimistic because they did not directly examine the relationship between low cloudiness and regional climate variables. Because low cloud amount was not archived in the CMIP3 database, total cloud amount was used instead, a choice that was presumably based on the similarity of the total cloud-climate and low cloud-climate relationships in the observed data. (Low cloud amount could have been approximated from the three-dimensional monthly mean cloud amount distributions archived by CMIP3, but they were not used in CBN09.)

Using output from a GFDL-CM2.1 20th century climate simulation (GFDL-CM2.1 20C3M run 1), we first computed the correlations between total cloud amount and regional climate variables and compared them with the results of CBN09 as a quality check. Both sets of correlations agree to within 0.03 (Table 1), which is an acceptable deviation given that different software and analysis periods were likely used.

Using low cloud amount (defined as the cloud fraction in the layer below the 680 hPa pressure level) from GFDL-CM2.1, correlations with all of the regional climatic variables become much closer to the observed values. The model simulates correlations with the correct sign for all four variables, suggesting that the feedback process identified by CBN09 also operates in this model.

Teleconnections between SST in the NEP and other climate variables provide further evidence of the similarity of the simulated and observed feedback processes. In both the model and observations, the regression of local SST on the time series of NEP SST is positive over a triangular region with vertices on the California coast, near New Guinea, and on the coast of southern Chile (Fig. 1A). Maxima are centered over the NEP and in the equatorial Pacific just east of the dateline. Relative minima are simulated by the model from east of the Philippines northeast to the central North Pacific and from New Guinea east-southeastward, but they are weaker than their observed counterparts (CBN09 Fig. 2A).

Teleconnections with atmospheric circulation (Fig. 1B) are also quite similar, with a negative SLP anomaly and accompanying cyclonic circulation in the central North Pacific and a weakening of the Walker circulation with westerly wind anomalies in the western equatorial Pacific. Southerly wind anomalies in the NEP stratocumulus region represent a weakening of the climatological trade winds, as in observations (CBN09 Fig. 2B). The teleconnections of NEP SST with midtropospheric vertical motion (Fig S1) and lower tropospheric stability (Fig. S2) also resemble the corresponding observed patterns.

The Pacific cloud pattern also covaries with NEP SST in the model. When this region is warm, low cloud anomalies are negative *in situ* and west of the South American coast and positive in a band extending east-southeastward from the west central Pacific (Fig 1C). These features are broadly similar to those diagnosed by CBN09, although a region of simulated positive cloud anomalies just west of Baja California is not consistent with observations. The simulated total cloud anomaly pattern (Fig. 1D) is very similar to the simulated low cloud pattern and in broad agreement with the observed pattern, although there are regional discrepancies in the eastern portion of the basin. These discrepancies may be associated with the tendency for convection to be displaced to the west in GFDL-CM2.1as a result of a cold bias in equatorial SST (3).

The most noteworthy discrepancy between the observed feedback processes and the GFDL-CM2.1 simulation involves the sensitivity of the *in situ* correlations to the metric of cloud amount that is used. In the model, the correlations with vertical velocity and lower tropospheric stability change sign when total clouds are used instead of low clouds, and the correlation with SLP essentially vanishes. This does not happen in the real climate system, although the correlations with total clouds are weaker, especially for LTS and vertical velocity (Table 1). Using total cloud amount as a surrogate for low cloud amount apparently makes a larger difference in the model because the simulated variability of high clouds over the NEP is larger than in observations.

Models are imperfect representations of the real climate system and simulating the relationships between clouds and climate is particularly challenging. We readily acknowledge that much work remains if models are to represent such interactions with greater fidelity. Nonetheless we find that the representation by GFDL-CM2.1 of decadal variations in NEP low-level clouds, when analyzed with the method of CBN09, is considerably more realistic than their analysis would suggest. We also note that GFDL-CM2.1 and HadGEM1 (the only model found by CBN09 to successfully represent these relationships) share a common formulation of boundary layer turbulent mixing (4), suggesting that this parameterization may contain the necessary ingredients to successfully simulate these variations.

It remains to be determined if other models would have appeared more realistic if low cloud amount had been available for all of the CMIP3 models. With the more complete cloud diagnostics that will soon be available through the next CMIP intercomparison it will be possible to better analyze decadal cloud variability in model-simulated marine low cloudiness.

References and Notes

1. A. C. Clement, R. Burgman, J. R. Norris, *Science*, **325**, 460 (2009).
2. T. L. Delworth et al., *J. Clim.*, **19**, 643 (2006).
3. A. T. Wittenberg et al., *J. Clim.*, **19**, 698 (2006).
4. A. P. Lock, A. R. Brown, M. R. Bush, G. M. Martin, R. N. B. Smith, *Mon. Wea. Rev.*, **128**, 3187 (2000).
5. The authors acknowledge the support of the New Jersey Agricultural Experiment Station. The contribution of Stephen A. Klein to this work was funded through the

Climate Change Prediction and Atmospheric Radiation Measurement Programs of the Office of Science in the U. S. Department of Energy and was performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Table 1. Correlations between cloud quantities and other climatic variables in the northeast Pacific (NEP) for observations and the GFDL CM2.1 climate model. Observed correlations are taken from CBN09. Cloud variables are correlated with SST (first column), lower tropospheric stability (LTS, second column), sea-level pressure (SLP, third column), and mid-tropospheric pressure vertical velocity (ω500, fourth column).

	SST	**LTS**	**SLP**	**ω500**
Observations (from Clement et al. 2009)				
ISSCP corrected total	-0.75	0.44	0.80	0.30
ISSCP corrected low+mid	-0.91	0.81	0.89	0.70
COADS total	-0.74	0.35	0.72	0.53
COADS MSC	-0.82	0.42	0.74	0.70
GFDL CM2.1 Model				
Clement et al. (2009)	-0.31	-0.38	0.05	-0.56
This paper (total cloud)	-0.30	-0.41	0.04	-0.55
This paper (low cloud)	-0.78	0.39	0.52	0.37

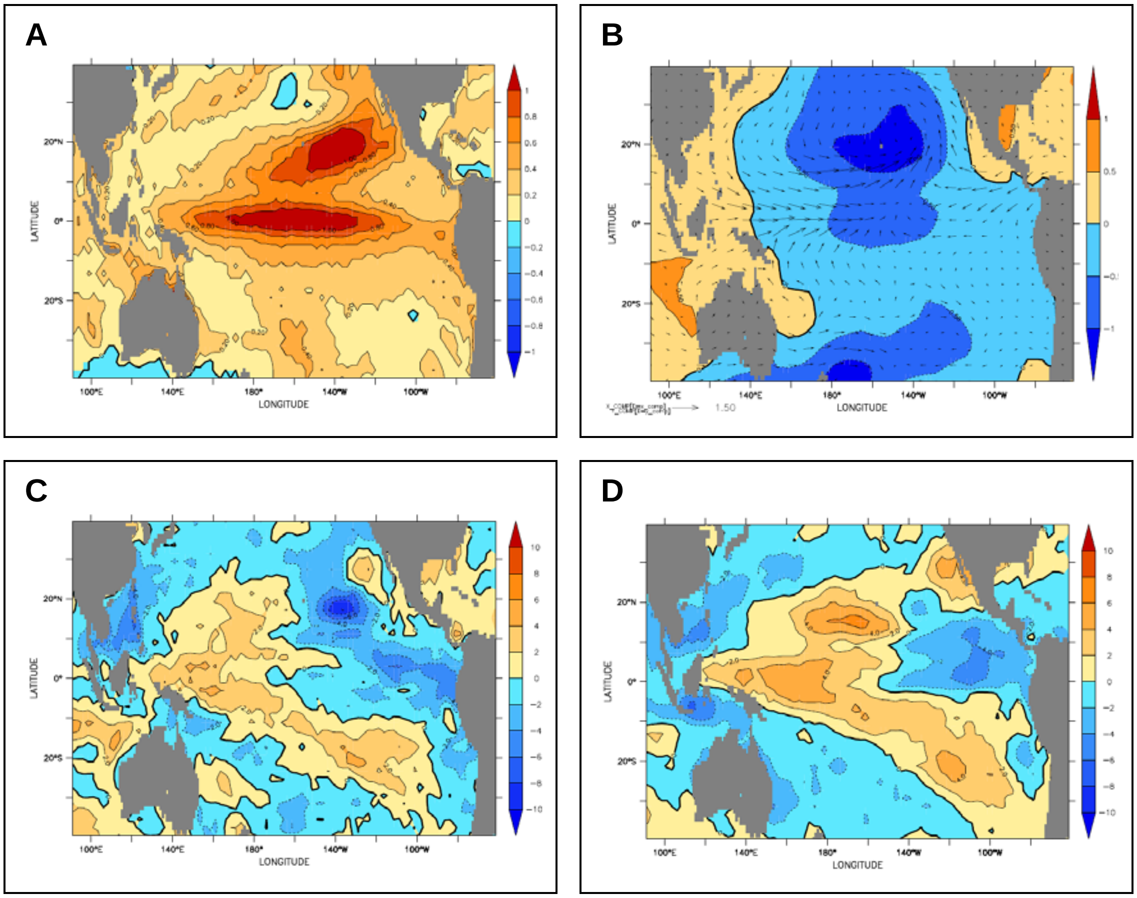

Fig. 1. Regression of climate variables on the time series of SST averaged over the NEP (115° to 145°W, 15° to 25°N). All variables are annual means with a 1-2-1 smoothing applied. Values are shown per degree change in NEP SST. (A) SST (in K). (B) SLP (colors, in hPa) and surface winds (vectors, standard vector length is 1.5 m/s). (C) Low cloud amount (percent). (D) Total cloud amount (percent).

Comment on “Observational and Model Evidence for Positive Low-Level Cloud Feedback”

Supporting Online Material

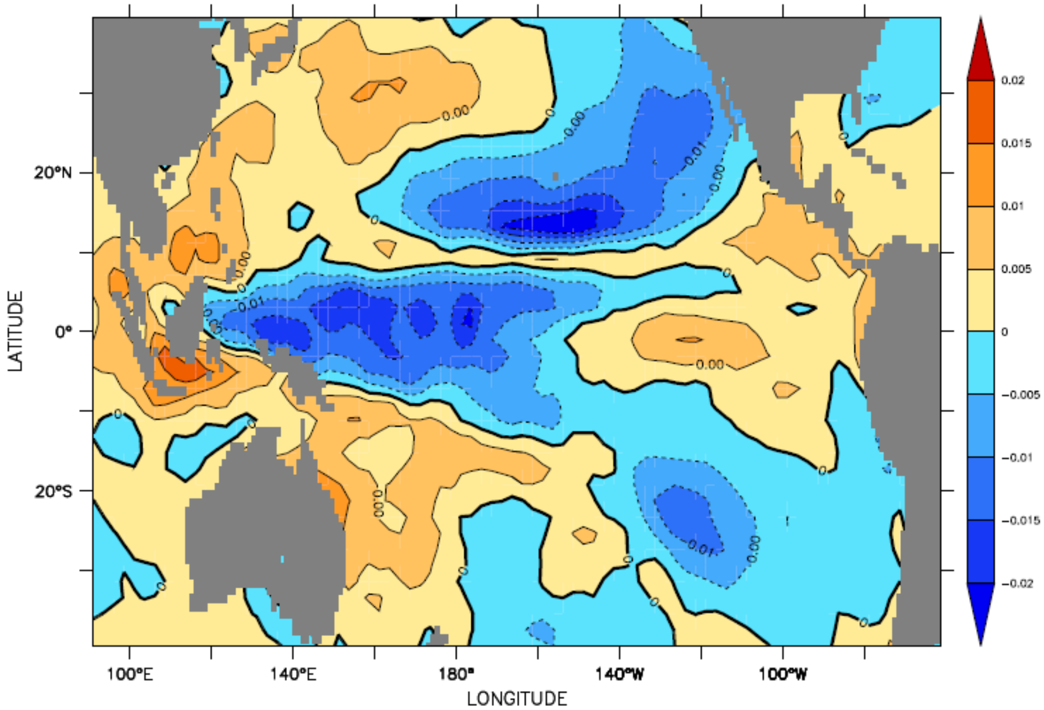

Fig. S1. Regression of 500 hPa vertical velocity on NEP SST. Units are Pa/s per degree.

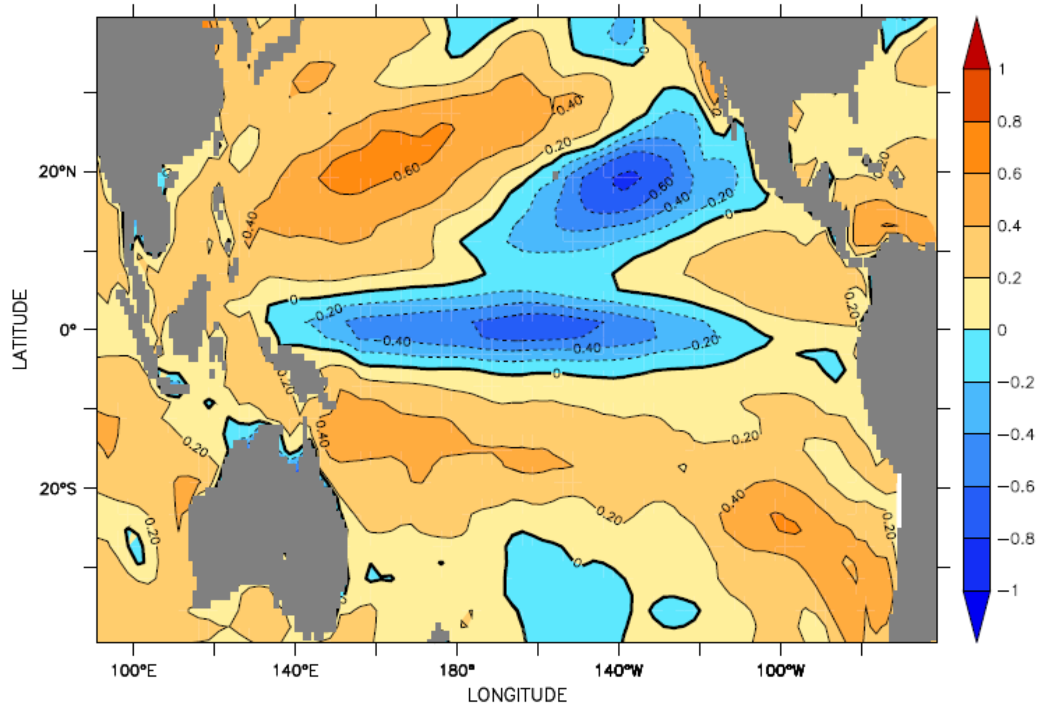

Fig. S2. Regression of lower tropospheric stability (LTS) on NEP SST. LTS is defined as the difference between the potential temperature at 700 hPa and SST. Units are K/K.