Response to "No evidence for iris"

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Hartmann and Michelsen's (2001) comment on Lindzen et al. (2001) are strongly based on their assertion that we are assuming that cumulus activity is almost entirely equatorial, and that high-level clouds far from the equator are assumed to originate in detrainment from cumulus towers thousands of kilometers away. HM further assume that clouds associated with migrating storms cannot be associated with convection. Neither their assertion as to what we allegedly assumed nor their own assumption is at all correct. Their assertion that the observed relation between high-level clouds and the sea surface temperature (SST) is due to the tendency of clouds to concentrate near regions of maximum SST and the intrusion of midlatitude cloud systems into the tropics is also incorrect.

Cumulus convection is hardly restricted to the equator – nor did we assume that it was. Figure 1 shows the brightness temperature of Japan's Geostationary Meteorological Satellite–5 11-µm channel (T_{11}) at 5:00 UTC on 10 August 1998. The white regions enclosed by thin solid lines are the regions with $T_{11} < 220$ K. Deep convective clouds tend to form large clusters and spread over the tropics, primarily in the summer hemisphere. These cloud clusters have their distinctive convection cores. The various cloud clusters shown in the figure are over oceanic regions with varying SST. In particular, the cloud clusters around the dateline and 10°N-20°N are over a cool ocean with SST in the range 26-28°C (see Fig. 2), and there is very small area with $T_{11} < 220$K. Nevertheless, those cloud clusters are deep convective clouds. As opposed to what HM suggested, most cloud clusters do not occur near the equator. The largest change in the cloud amount associated with variations in the cloud-weighted SST occurs in the off-equatorial region with varying SST. The result shown in Fig. 2 of HM is consistent with

our conclusion. The claim by HM that deep convective cores are separated by more than 1000 km from the clouds that are associated with most of the variation in cloud-weighted SST is unfounded.

The mobile meteorological systems serve to organize convection. As they move through regions with spatially varying SST, they permit us to examine the effect of SST on detrainment from cumulus. Note that clouds are organized by wave disturbances, but are too short-lived to move with the systems. What we observe is that this detrainment decreases when the convection occurs over regions of warmer SST. Further evidence that is consistent with the negative correlation is given in Fig. 3. It shows the relation between the cloud-weighted SST and the ratio of the area of the anvil clouds to the area of the convection cores. We have assumed that convection cores have a brightness temperature T_{11} <220K in Fig. 3a and <230K in Fig. 3b, whereas the anvil clouds are assumed to have a brightness temperature of <260K outside convection cores. The results show that the detrained cirrus anvils decrease relative to the increase in deep convection. At the 95% confidence level, the correlation coefficient is -0.479 ± 0.140 for the case shown in Fig. 3a and is -0.458 ± 0.136 for the Fig. 3b case. Thus, the correlation is highly significant.

Because the large-scale SST distribution changes slowly with time, we are investigating the local effect of SST on clouds, but not vice versa. Figure 2 shows the weekly SST for 9-15 August, 1998 taken from the NCEP data archive (Reynolds and Smith, 1994). It can be seen that the SST has a significant east-west gradient in the summer hemisphere where the inter-tropical convergence zone (ITCZ) is located. Forced by large-scale thermal and dynamical conditions, disturbances, such as easterly waves

and the Madden-Julian Oscillation, propagate in latitude zones which coincide with the ITCZ. Thus, our premise is consistent with the statement by HM that "These latitude and longitude shifts are associated with meteorological forcing and not with SST forcing".

HM noted that the propagation of cloud systems from mid-latitudes into the tropics had an effect of increasing the cloud amount and decreasing the cloud-weighted SST. This negative correlation was due to the low SST in the subtropical regions and was irrelevant to the response of clouds to SST. To address the concern of HM on this matter, we show in Fig. 4 the cloud-SST relation as in Fig. 5a of LCH, except the domain is confined to the latitudes lower than 25°. The result is similar to that of LCH. The correlation coefficient is –0.301 for the region 30°S-30°N and –0.313 for the region 25°S-25°N. If the effect suggested by HM were of primary importance, we would expect the correlation to decrease sharply. Rather, the opposite is observed. Because the mid-latitude storm systems do not significantly penetrate into the tropics equatorward of 25° latitude, the results shown in Fig. 4 and in Fig 5a of LCH indicate that the intrusion of mid-latitude storm systems has only a small effect on the negative correlation. Statistical analyses show that the negative correlation is highly significant (Bell et al., 2001).

HM claimed that if the SSTs and the near-equatorial clouds remained fixed and constant, any variation in subtropical cloud amount would produce the negative correlation. Observations show that the near-equatorial clouds do not remain fixed and constant, but change rapidly within days. Furthermore, the near-equatorial SST has a significant spatial gradient and does not remain fixed and constant either (see Fig. 2). Even if the assumptions are true, HM's claim is valid only if the SST in the off-equatorial region is constant, so that more clouds in this region will produce a lower cloud-weighted

SST. However, the SST in the off-equatorial region has a significant east-west gradient (also see Fig. 2). When cloud systems propagate from east to west or vise versa (easterly waves, MJO, etc.), the relation between the cloud amount and the cloud-weighted SST is clearly not as trivial as HM claimed.

Cloud systems propagate predominantly in zonal directions, neither just expand from the warmer equatorial region to the cooler off-equatorial region, nor just retreat from the off-equatorial region to the equatorial region, as HM suggested. In fact, the bands with the largest cloud amount, i.e. ITCZ, are in the off-equatorial regions from 5° to 10° latitude in summer hemispheres. In fact, the cloud amount has a local minimum in the equatorial region (see Figs. 4 and 5 of HM). Figure 5 shows the cloud-SST relation as in Fig. 4, except the equatorial region from 5°S to 5°N is excluded. By comparing the two figures, we can conclude that the negative correlation is due to cloud systems propagating in the off-equatorial zones with varying SST, but not due to the tendency of tropical convection to retreat to the region of the highest SST. More importantly, the effect suggested by HM can be shown to be associated with a very small range of temperature changes compared to the dynamic range found in Figs. 4 and 5.

In summary, the assertion made by HM concerning the need for clouds thousands of kilometers away from the equator to be connected to convection at the equator does not seem to have any validity. Nor does their suggestion that the causes of the observational relations shown in LCH do not involve detrainment seem to have any validity. An iris effect associated with detrainment from cumulus towers remains a far more likely possibility – though hardly a certain one.

References

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Lindzen, R. S., M.-D. Chou, A. Y. Hou, 2001: Does the earth have an adaptive infrared iris? . *Bull. Amer. Met. Soc.*, **82**, 417-432.

Reynolds, R. W. and T. M. Smith, 1994: Improved global sea surface temperature analyses. *J. Climate*, **7**, 929-948.

Figure Captions

Figure 1. Image of the GMS-measured brightness temperature in the 11-μm channel, T_{11}. The white regions are the highest clouds with T_{11} <230 K. Units are degrees *Kelvin*.

Figure 2. The weekly sea surface temperature (SST) for 9-15 August, 1998 taken from the NCEP data archive (Reynolds and Smith, 1994). Units are degrees *Celcius*.

Figure 3. Relation between the cloud-weighted SST and the ratio of the area of anvil clouds to the area of the convection cores for the period January 1998-August 1999. The convection cores are assumed to have a brightness temperature T_{11} <220 K in (a) and <230 K in (b). Each data point represents daily mean values averaged over the ocean in the domain 30°S-30°N and 130°E-170°W. The equation represents the regression line, and R is the correlation coefficient.

Figure 4. The relation between high-level clouds and the cloud-weighted SST for the period January 1998-August 1999. Each data point represents daily mean values averaged over the ocean in the domain 25°S-25°N and 130°E-170°W. T_{11} is the brightness temperature as measured in the GMS-5 11-μm channel. The equation represents the regression line, and R is the correlation coefficient.

Figure 5. Same as Fig. 4, except the equatorial region 5°S-5°N is excluded.

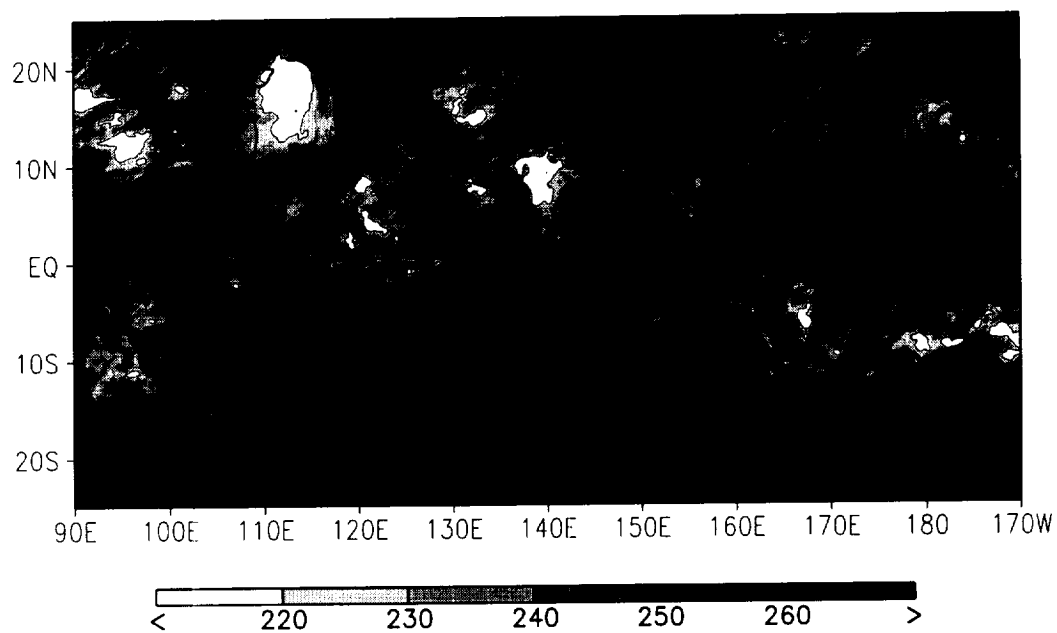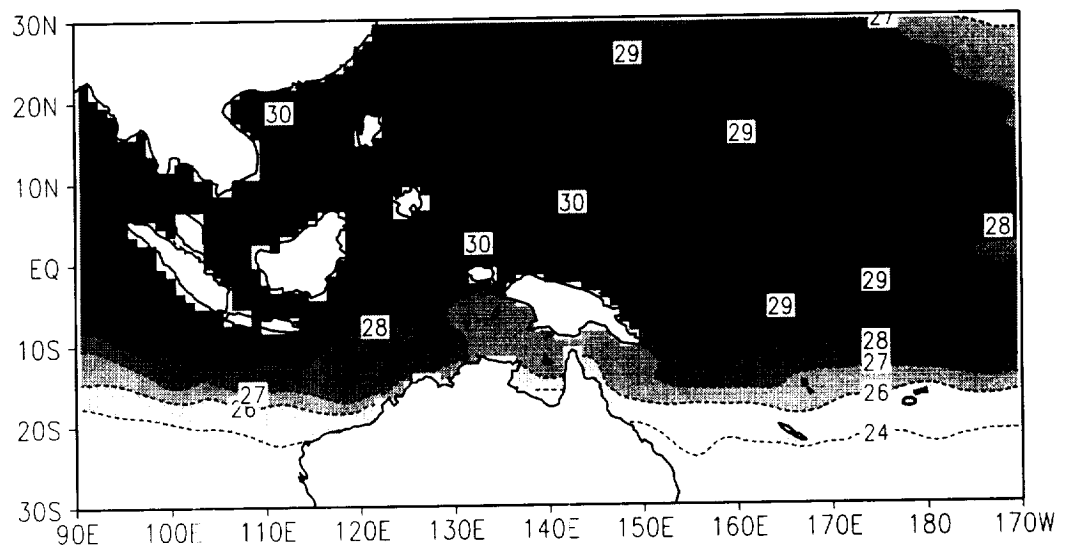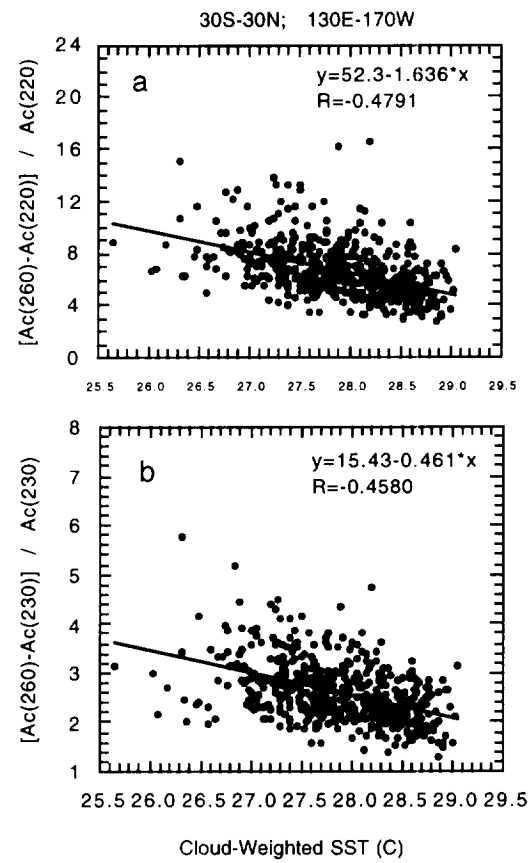GMS5 T$_{11}$ (05:02 UTC Aug. 10, 1998)

Figure 1.

Figure 2.
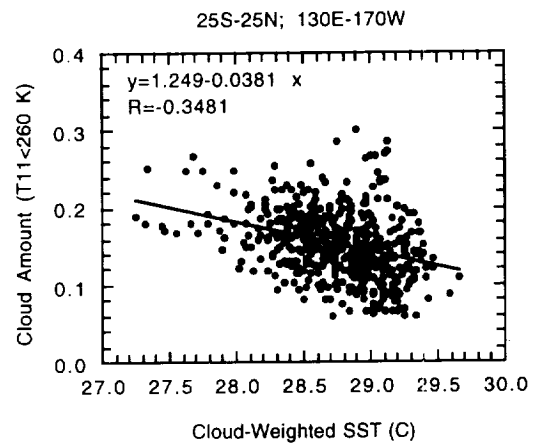
30S-30N; 130E-170W

a y=52.3-1.636*x
   R=-0.4791

b y=15.43-0.461*x
   R=-0.4580

Cloud-Weighted SST (C)

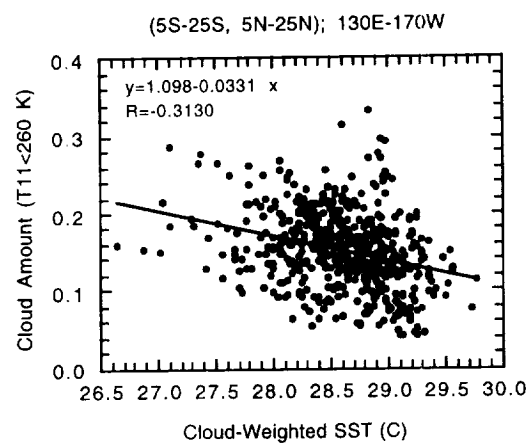Figure 3.

11

25S-25N; 130E-170W

Figure 4.

Figure 5.

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Popular Summary

Hartmann and Michelsen claimed that there was no evidence for the negative relation between the high-level clouds and the sea surface temperature as suggested by Lindzen et al. The assertion made by Hartmann and Michelsen that there is a need for clouds thousands of kilometers away from the equator to be connected to convection at the equator does not seem to have any validity. Nor does their suggestion that the causes of the observational relations shown in Lindzen et al. do not involve detrainment.

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