Reply to “No evidence for iris”

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A number of points put forth by Hartmann and Michelsen (2002) (henceforth HM) are, in fact, irrelevant to the iris effect (i.e., their discussion of the meteorological origin of various systems). We shall discuss this in greater detail later. Some are quantitatively insignificant (the effect of spreading cloud cover near the equator); we shall also return to this later. Others are simply wrong (such as the assertion that we assume cloud cover over latitudes around 20˚ originates from cumulus convection over a thousand kilometers away). Digging through such items that basically amount to ‘red herrings,’ we find that their primary assertion is that cloud cover variations in the region between about 15˚ and 30˚ latitude are not primarily convective in origin, but rather occur because of the penetration of extratropical systems into the tropics. Allegedly the appearance of such clouds reduces the cloud-weighted sea surface temperature (CWT) as well as the ratio of cloud cover to cumulus activity, and spuriously produces the iris effect in Lindzen, Chou and Hou (2001) (henceforth LCH). It is on this assertion that we will focus. Although the Bulletin chose to refer to HM as “a more careful analysis,” HM’s arguments are fundamentally dependent on ignoring important caveats in LCH.

Distribution of brightness temperatures of cloudy regions. Stratiform clouds associated with lifting of air (as opposed to detrainment from cumulus towers) tend to have smooth linear patterns of brightness temperature. Cirrus originating from convective towers tend to have more concentric patterns with identifiable cores. High resolution images from Japan’s Geostationary Meteorological Satellite–5 (henceforth referred to as GMS) clearly show dominance of the latter – even at latitudes beyond 20˚. This is evident in Figure 1 which shows contours for 11-μm brightness temperatures (T_{11}) for the whole region considered by LCH (0502 UT on 10 August, 1998). One cannot display the full available resolution in this figure. Nonetheless, it is evident that cores with $T_{11} < 220$K are generally found in all cloud patches. However, there appear to be some exceptions. Figure 2 shows higher resolution blowups of regions A and B in Figure 1. In region B there are clear convective cores, but they are mostly characterized by 220K < T_{11} < 230K. This region has a cooler sea surface temperature (SST) as shown in Fig. 3, which is the weekly SST for 9-15 August, 1998 taken from the NCEP data archive (Reynolds and Smith, 1994). This is not surprising since cumulus towers over cooler oceans are generally not as tall as those over warmer oceans. Figure 2A shows a broad region with $T_{11} < 220$K, and cores for which $T_{11} < 210$K. As LCH emphasized, the $T_{11} < 220$K criterion is rough at best, and was used only for initial estimates. However, this does not alter the conclusion from Figures 1 and 2 that large-scale cloud systems are convective in origin. As shown in Fig. 4, the precise choice of threshold for the rough cumulus criterion is by no means critical. Results for the dependence of $A_c(260)$-$A_c(220)/A_c(220)$ and $A_c(260)$-$A_c(230)/A_c(230)$ on CWT are both similar and statistically highly significant (correlation coefficient is -0.479 ± 0.140 for the first and -0.458 ± 0.136 for the second, both at the 95% confidence level). That said, the main use of the criterion (i.e., area of $T_{11} < 220$K for cumulus activity) in LCH was to assess the iris effect in the region near the equator. Note that while $A_c(260)$ is largely based on the anvil region, LCH take the area of all upper level stratiform clouds to be proportional to this.

Intrusion of extratropical systems versus latitude. If the iris effect depended primarily on intrusion of extratropical non-convective systems, we would expect a noticeable reduction of the effect when the poleward limit of the region considered was reduced – even if the extratropical systems penetrated beyond 25˚ latitude. This is not what we find. This is illustrated in Figure 5, which shows the cloud-sea surface temperature (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 (not shown in the figures) and –0.348 for the region 25˚S-25˚N (Fig. 5). If the effect suggested by HM were of primary importance, we would expect the correlation to decrease. Rather, the opposite is observed. This supports the view that we are looking at cirrus associated with convection rather than stratiform clouds associated with penetrating mid latitude systems. Incidentally, statistical analyses show that the negative correlation is highly significant (Bell et al., 2002).

Upper level cloud area vs. ratio of upper level cloud area to cumulus activity. In order to make results from a limited region scalable to the entire tropics, one has to consider the ratio of upper level cloud coverage to some measure of cumulus activity. This is discussed and emphasized in LCH. However, when considering a large area symmetric about the equator, such as the total area considered by LCH, there is little change in cumulus activity with cloud-weighted SST (CWT) (largely because seasonal changes in cumulus activity tend to cancel when one considers regions symmetric about the equator), and the behavior of both the upper level cloud area with CWT and the behavior of the ratio of upper level cloud to cumulus activity are similar. However, the former does not depend on the particular definition of cumulus activity. This would not, *per se*, preclude the suggestion of HM that the behavior is due to the intrusion of non-convective clouds into the tropics, except that we have independently established that the upper level clouds are associated with cumulus activity. Where the ratio matters, is when one looks at smaller regions on one side of the equator. In LCH, we considered 15˚S-Equator for longitudes between 130˚E and 170˚W. Here, due to the seasonal migration of the ITCZ, both upper cloud area and cumulus activity increase with CWT, but the ratio decreases in a manner similar to what is found for the larger area, contrary to the claims of HM based on considering a region symmetric about the equator. Note that for the smaller region, $T_{11} < 220$K is a much more reliable measure of convective activity.

The above constitute the main reasons why we regard HM's claims as inappropriate. HM dwell at length on the fact that variations in cloud cover are associated with dynamic systems involving winds. We must confess to failing to understand the relevance of this. Convection certainly will occur without mobile meteorological systems (Emmanuel, 1994) and mobile meteorological systems may have a non-convective origin, but it is also clearly the case that mobile meteorological systems serve to organize the convection. As these disturbances 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. 4.

Because the large-scale SST distribution changes slowly with time, we are investigating the local effect of SST on clouds, but not vice versa. It can be seen from Fig. 3 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".

Finally, HM put forward the suggestion that in near-equatorial regions a negative correlation between $A_c(260)$ and CWT (for fixed convective activity) arises simply from the spreading of cirrus. The point is that the convection is centered on maxima in SST, and spreading automatically reduces CWT. This is, of course, correct in principle. However, for the requisite changes in $A_c(260)$, the changes in CWT would be much smaller than the observed changes. Rather, observations show that the near-equatorial clouds do not remain fixed and constant, but change rapidly from day to day. Furthermore, the near-equatorial SST has a significant spatial gradient and does not remain fixed and constant either (see Fig. 3). Even if the assumptions are true, HM's suggestion 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. 3). 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, and 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. Actually, the cloud amount has a local minimum in the equatorial region (see Figs. 4 and 5 of HM). Figure 6 shows the cloud-SST relation as in Fig. 5, 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.

In summary, the basis for HM's claim that there is no evidence for an iris is that cloud cover variations represents intrusions into the tropics of stratiform clouds not associated with convection. This is clearly not the case for almost all the motion systems they laboriously cite. Nor do observations support their assertion even when one assumes that cumulus activity is uniquely associated with $T_{11} < 220$K – which is patently inadequate in cooler regions. LCH carefully noted the preliminary character of their analysis, and the speculative aspects of the hypothesis. However, the points raised by HM hardly constitute challenges to the hypothesis.

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Figure Captions

Figure 1. Contours of the GMS-measured brightness temperature (K) in the 11-µm channel, T_{11}.

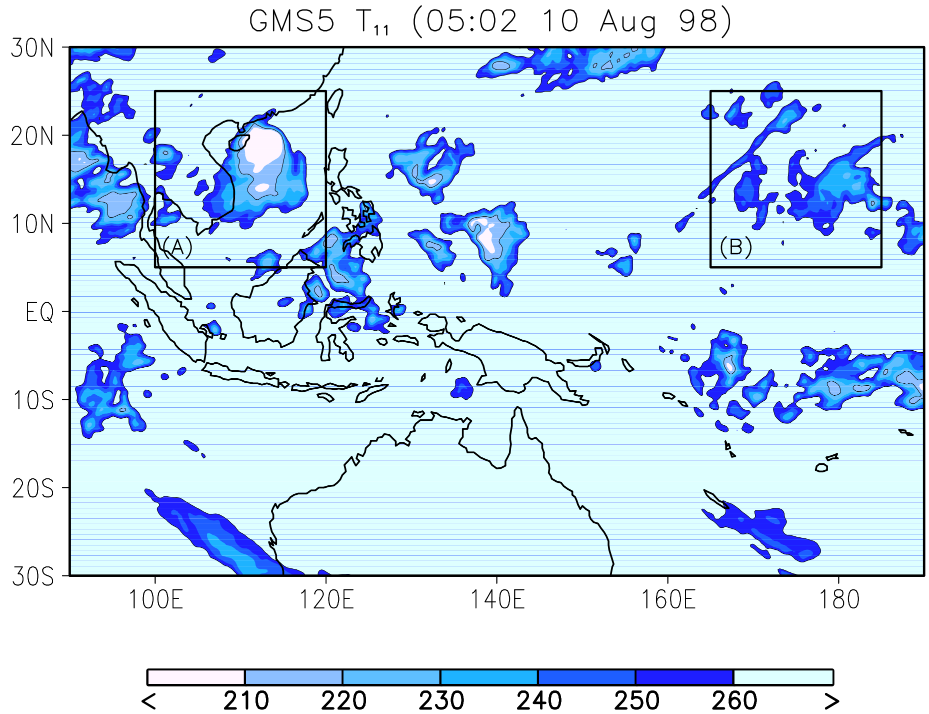
Figure 2. Closeups of regions A and B in Figure 1. The thin solid lines represent temperature T_{11} = 220 K.

Figure 3. The weekly sea surface temperature (SST) for 9-15 August, 1998 taken from the NCEP data archive (Reynolds and Smith, 1994). Units are ˚C.

Figure 4. Relation between the cloud-weighted sea surface temperature (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 5. 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 6. Same as Fig. 5, except the equatorial region 5˚S-5˚N is excluded.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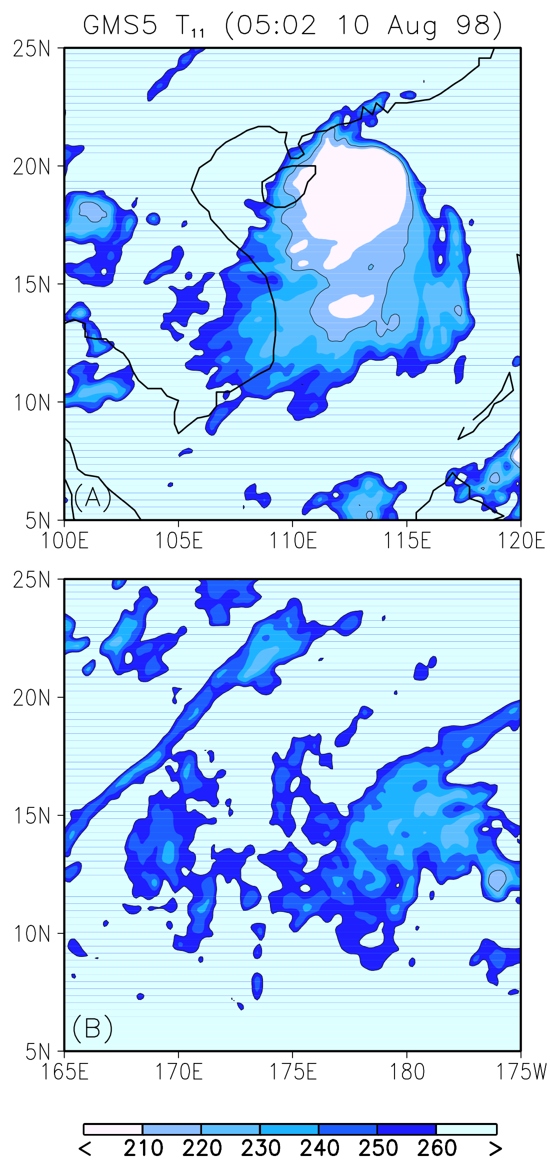
30N
20N
10N
EQ
10S
20S
30S
100E
120E
140E
160E
180
(A)
(B)
<
210
220
230
240
250
260
>

Figure 1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25N
20N
15N
10N
5N
(A)
100E
105E
110E
115E
120E
25N
20N
15N
10N
5N
(B)
165E
170E
175E
180
175W
<
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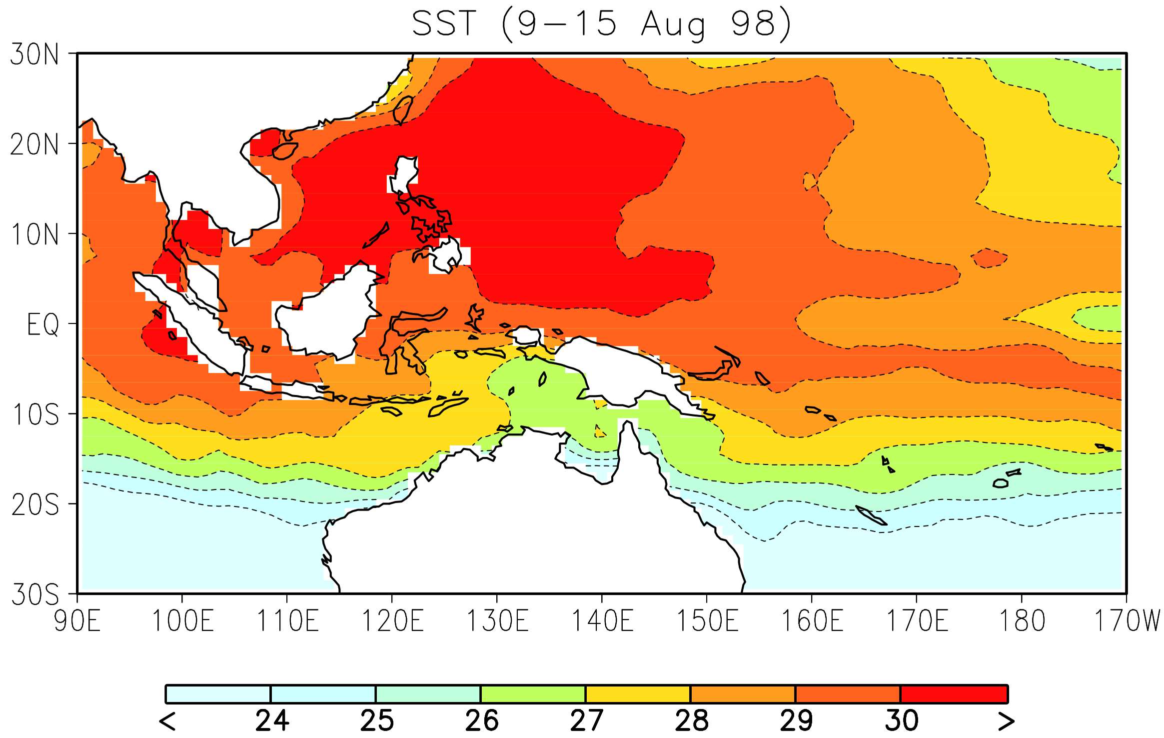
220
230
240
250
260
>

Figure 2


SST (9–15 Aug 98)
30N
20N
10N
EQ
10S
20S
30S
90E
100E
110E
120E
130E
140E
150E
160E
170E
180
170W
<
24
25
26
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28
29
30
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Figure 3

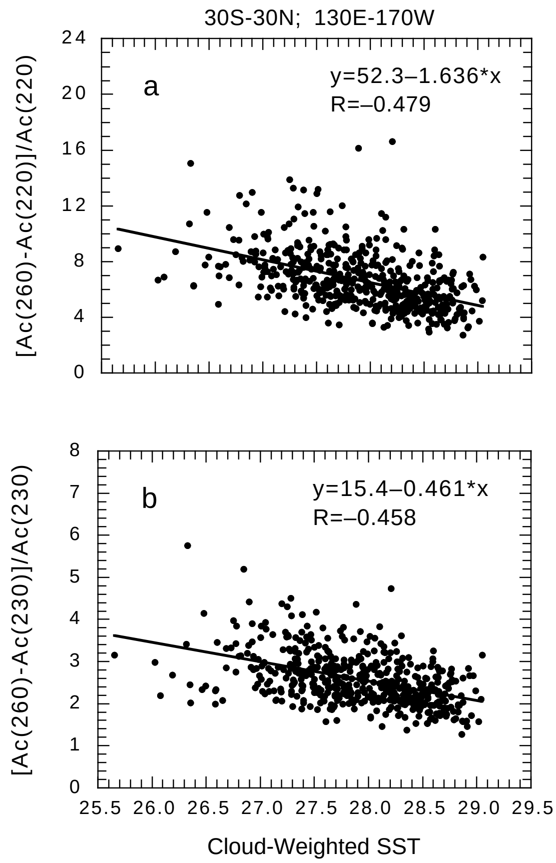
30S-30N; 130E-170W
a
y=52.3–1.636*x
R=–0.479
[Ac(260)-Ac(220)]/Ac(220)
b
y=15.4–0.461*x
R=–0.458
[Ac(260)-Ac(230)]/Ac(230)
Cloud-Weighted SST

Figure 4

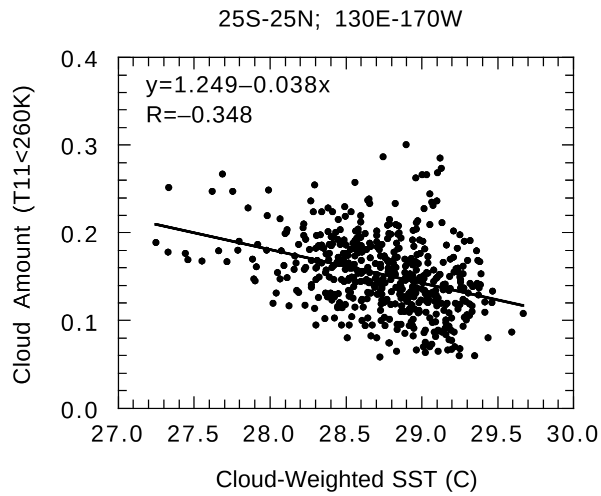

Figure 5

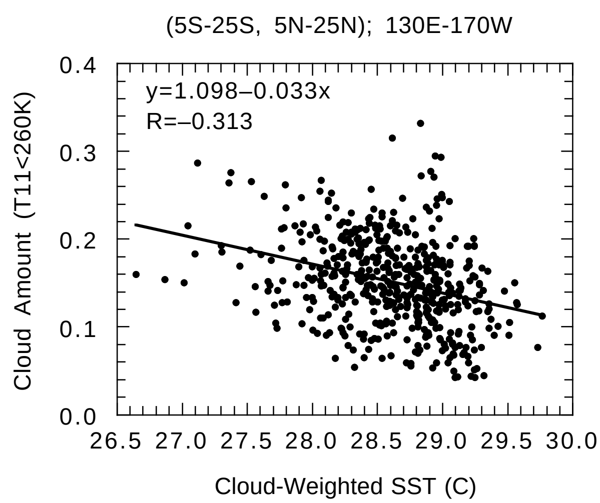

Figure 6