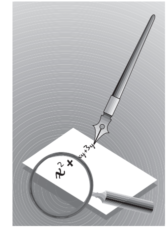
commentary and analysis



Comments on "Choice of South Asian Summer Monsoon Indices"

The choice of an appropriate index for the south Asian summer monsoon has been a subject of some controversy and received considerable attention in recent years (Webster and Yang; Goswami et al. 1999). Two major indices are the zonal wind shear index proposed by Webster and Yang (1992, hereafter referred to WYI) and the meridional shear index defined by Goswami et al. (1999, hereafter referred to as GKA; the index is hereafter referred to as MHI). In their recent article in the *Bulletin*, Wang and Fan (1999, hereafter referred to as WF) attempt to provide a dynamical basis for the discrepancies between different indices. Based on outgoing longwave radiation (OLR) data, they define summer monsoon activity in terms of a convection index, CI1, representing OLR anomalies over the center of convective activity around the northern Bay of Bengal. They try to identify centers of circulation variability that are closely associated with the variation of CI1. Based on such examinations, they show that WYI did not represent the first baroclinic response to CI1 correctly, as they averaged the shear over a region where the anomalies were not largest. They recommended the use of a new zonal wind shear index, MCI, a modified version of WYI in which anomalies are averaged over the region where the zonal wind shear response to CI1 is largest. They also take pains to point out that "the southerly shear [i.e., an index like MHI] should be used with caution because the meridional shears do not represent the first baroclinic mode simulated by convective heating" (p. 636 of their article). Here, we argue that WF are incorrect in making this statement and that no higher objectivity is involved in the choice of a zonal wind shear index over a meridional shear index.

We do not understand how WF arrived at the above-mentioned conclusion. In fact, the first baroclinic response to an off-equatorial heat source (Webster 1972; Gill 1980) would certainly have a meridional wind shear associated with it, which is clearly evident in the regression pattern of WF (their Fig. 4c). This basically was the point made by GKA in their paper. It is true that it may not apply as well to an equatorial heat source.

One criticism of the use of the meridional shear (or southerly shear as they call it) is the fact that the "climatological" mean meridional winds are not homogeneous over the region where MHI is defined (see Figs. 1c and 2c of WF). We agree with that. However, MHI is an index for interannual variations of the monsoon and one has to see whether the meridional shear "anomalies" are coherent over this region and not the climatological mean. The meridional shear anomalies are indeed coherent over this region (cf. Fig. 8a of GKA). This must be so, otherwise WF would not get coherent correlation between meridional wind shear and CI1 over this region (Fig. 4b of WF). The fact that MHI and CI1 are well correlated is duly noted by WF on p. 633. Therefore, we do not think that the criticism for using the meridional wind shear index is well founded.

Coming to the question of exercising caution, one has to exercise it in using any index, including the WY index. Wang and Fan show beautifully that the index originally defined by WY, although based on a sound concept, was incorrect in representing the Asian monsoon as they averaged it over a region where the anomalous response to monsoonal heating is neither uniform nor largest! Even now many researchers are blindly using the WY index as defined by WY to define the strength of the Indian monsoon. While WF show nicely why one should exercise caution even using the WY index, they fail to emphasize this point in the article and unduly stress caution for using the southerly shear index.

Finally, what WF recommend as the MCI1 index is nothing but a corrected WY index. The correlations presented in their Table 2 in no way establish that it is a superior index to MHI, as the correlations with AIRI are 0.68 and 0.64, respectively. The fact that MCI1 and MHl correlate significantly (0.51) indicate that they are two aspects of the same first baroclinic response of the atmosphere to an off-equatorial heat source (CI1). This further reinforces our claim that there is no basis for choosing the zonal wind shear index over the meridional shear index.

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Reply

Dr. Goswami's primary concern is the remarks we made on the "two major indices": the zonal wind shear index proposed by Webster and Yang (1992, hereafter WYI) and the meridional shear index defined by Goswami et al. (1999, hereafter the MHI). He concluded that "while WF (Wang and Fan 1999) show nicely why one would exercise caution even using the WY index, they failed to emphasize this point in the article and unduly stress caution for using the southerly shear index." I appreciate his concern but disagree with his comments on our assessment of the WYI and on our cautious remarks on the use of meridional shear indices. The purpose of this reply is to clarify some misunderstanding in these aspects and to highlight our major points regarding the appropriate choice of the south Asian summer monsoon indices.

1. Assessment of the WY index

How should we assess the WYI? Have we failed to emphasize the caution with use of the WYI?

To assess the value of any index, it is essential to first understand the meteorological meaning of the index. One of our major endeavors was to interpret the meaning of the WYI in terms of observed correlation between convection and circulation and based on our theoretical understanding of the tropical atmospheric response to imposed heating. We pointed out that the westerly shear associated with the Indian summer monsoon (ISM) convection is primarily confined to the west of 80°E (Fig. 4 of WF), while the westerly shear associated with the Philippine convection is mainly found east of 80°E (Fig. 6 of WF). Therefore, the WYI defined by the westerly shear from 40° to 110°E in longitude reflects the variability of the convection centers at both the Bay of Bengal (and India) and the vicinity of the Philippines. That also explains in part why the WYI has a relatively low correlation with AIRI (all Indian summer rainfall index). The WYI is, therefore, a measure of the combined convective variability in the two major convection regions in the Asian summer monsoon. It quantifies the variability of the entire tropical Asian monsoon without considering regional differences. The WYI is also adequately defined in the core region of the zonal wind shear (Fig. 1 of WF), thus reflecting well the variability of the large-scale Asian monsoon westerly shear. As long as one understands the meaning of the WYI, one can make good use of it. In this sense, use of WYI need not be cautious unless one decides to use WYI to measure *Indian monsoon rainfall variability,* which, I believe, was not the intention of the original authors.

However, we did point out the limitation of the WYI. We showed that the two convection centers are not significantly correlated in their interannual variations. Therefore, we recommend use of two indices to measure separately the variability of the ISM and the SEASM (southeast Asian summer monsoon). Lau et al. (2000) came up with essentially the same recommendation. This point is one of the primary conclusions of WF, stated in the abstract. Therefore, we did not fail to emphasize the limitation of the WYI.

In summary, the WYI is a useful index that represents the variability of the action center of the Asian monsoon westerly shear and the convective variability of the entire south Asian monsoon region, including both the convection centers located in the Bay of Bengal and the vicinity of the Philippines. It is a meaningful measure of the strength of the broad-scale south Asian summer monsoon. The weakness of WYI is its inability to reflect the regional characteristics. The poor correlation between the two major convection centers suggests the necessity of introducing two regional indices to quantify the ISM and the SEASM. Note that we consider the south Asian summer monsoon to consist of two regional components. The AIRI is a measure of the ISM but not the entire south Asian summer monsoon.

2. Remarks on the meridional shear indices

How have we assessed the adequacy of the meridional shear index such as MHI? In the first place, we helped to interpret the meaning of the meridional shear index such as MHI. The MHI is not merely a measurement of the thermally driven Hadley circulation. It is part of the Rossby wave response to the heat source variability over the ISM region and it reflects primarily the rotational component of the winds. By presenting Figs. 3 and 4 in WF, we made it clear that "the MHI defined by Goswami et al. (1999) using the southerly shear averaged in the region (10°–30°N and 70°–100°E) does correlate well with CI1 [the ISM convection index]" (p. 633). We also concluded in our recommendation section (p. 636) that "the ISM circulation indices corresponding to the convection index CI1 can be defined using either westerly shear averaged over (5°–20°N, 40°–80°E) (hereafter WSI1) or southerly shear averaged over the combined region (15°–30°N, 85°–100°E) and (0°–15°S, 40°–55°E) (hereafter SSI1)." Our meridional shear index SSI1 is averaged over two regions, one located at the head of the Bay of Bengal and the other in the western Indian Ocean cross-equatorial flow region. The former overlaps with the area where MHI is defined. The MHI and SSI1 are highly correlated with a linear correlation coefficient of 0.72. The above two statements clearly indicate that we did not place higher objectivity on the choice of a zonal wind shear over a meridional shear index.

On the other hand, we also noted from Fig. 1 of WF that the region where the MHI is defined "is not located at the action center of the meridional vertical shear" (p. 632). We regard this as an undesirable property. Hence, the southerly shear we defined, SSI1, represents not only the variability center but also the action center of the vertical meridional shear: the vertical shear defined in the western Indian Ocean cross equatorial flows is located very close to the maximum monsoon meridional shear (Fig. 1 in WF).

As a primary dispute, Dr. Goswami said that "they (WF) take pains to point out that 'the southerly shear (i.e., index like MHI) should be used with caution because meridional shears do not represent the first baroclinic mode simulated by convective heating.'" Unfortunately, this is a distorted and incomplete quote. The original sentence is stated as follows: "The southerly shear should be used with caution because the meridional shears do not represent *well* the first baroclinic mode stimulated by the convective heating, *especially* since *the SSI2* is dominated by upper-tropospheric circulation anomalies and strongly influenced by the south Asian subtropical high" (emphasis added).

Here, we emphasized that the meridional shears do not represent *well* the heating-induced baroclinic mode but did not say they *do not represent* the first baroclinic mode. Furthermore, we particularly refer in this problem to the SSI2, which is the southerly shear index defined over the Philippine Sea, not the MHI defined over the Bay of Bengal. We do not see anything wrong with the above statement given the fact that we have already clearly interpreted the meaning of MHI in section 3 of WF.

The reasons we said that the meridional shears do not represent well the convective heating-induced lowest baroclinic mode follow. The vertical shear between 850 and 200 hPa observed in the Asian monsoon region is not only stimulated by latent heat released in convection but also by other heat sources such as strong sensible heat over the Plateau of Tibet (Li and Yanai 1996), which contributes to the upper-tropospheric circulation but has little effect on the low-level circulation. The vertical shear is, therefore, stimulated not only by the convective heating. In this sense, the vertical shear does not always represent the first baroclinic mode stimulated solely by the convective heating. Figure 2 of WF indicates that for the mean monsoon, the low-level and upper-level meridional winds are far from the structure of the first baroclinic mode. In the correlation maps (Figs. 3 and 5 of WF), the 180° out-of-phase relationship between 850 and 200 hPa is better for zonal wind than meridional wind component, especially for the Philippine Sea heat source. Our cautious comment particularly refers to the weakness of the meridional shear response to the Philippine convection heat source.

3. Appropriate choice of the south Asian summer monsoon indices

After he mentioned two major indices for the south Asian summer monsoon, Dr. Goswami stated, "WF attempts to provide a dynamical basis for the *discrepancies* between different indices" (emphasis added). In fact, we were not interested in comparing the discrepancy between the WYI and the MHI. As stated in our paper (p. 630), "Our focus is placed on understanding the dynamical basis for adequate choice of meaningful indices." Our results, shown in section 3, "provide a basis for defining dynamically coherent monsoon indices [between convection and circulation]" (p. 630).

Our major conclusion reflect our purposes. One of our major conclusions is that the variability in convection exhibits a high degree of coherency with circulation variability. This can be understood, in the lowest order, as a Rossby wave response to heat source. This provides a physical basis for choice of circulation indices dynamically consistent with convection and for understanding of the meanings of various indices. In this sense, the south Asian monsoon can be described by either circulation index or convective index. However, as we discussed in our paper, discrepancies can exist between the indices defined using circulation and convection. We have speculated on three possible sources for the discrepancies and pointed out that it is important to understand their physical cause.

After we unravel the meaning of the WYI and MHI, it is obvious that they are not comparable, because they represent variability in different domains. If one subjectively uses AIRI as a test base to judge the usefulness of a proposed index, the MHI is perhaps better than WYI, because the MHI–AIRI correlation appears to be significantly higher than the WYI–AIRI correlation (Goswami et al. 1999). But, as mentioned earlier, the use of AIRI as an index for the south Asian summer monsoon is inadequate. Furthermore, if one finds an index (such as MHI) that is highly correlated with AIRI, why do we need two for the same ISM? The indices of AIRI and MHI belong to the same set of indices that measures the variability of the Indian summer monsoon, whereas the WYI represents a broader-scale south Asian summer monsoon.

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A New Minimum Temperature Record for Illinois

A recent article in the *Bulletin* (Schmidlin 1997) described state minimum temperature records that were tied or broken in six Midwestern states in January 1994 and February 1996. Among those records was –35°F (–37.2°C) at Elizabeth 5S, Illinois, on 3 February 1996, which tied the Illinois cold record set on 22 January 1930 at Mount Carroll. A temperature of –36°F (–37.8°C) was reported at Congerville 2NW, Illinois, on 5 January 1999, thus establishing a new