Reply to "Comments on 'Interdecadal Change of the South China Sea Summer Monsoon Onset'"*

BIN WANG

Department of Atmospheric Sciences and Atmosphere–Ocean Research Center, University of Hawai'i at Mānoa, Honolulu, Hawaii

YOSHIYUKI KAJIKAWA

RIKEN Advanced Institute for Computational Science, Kobe, Japan

(Manuscript received 8 March 2015, in final form 27 August 2015)

Understanding the variability and change of monsoon onset is of the utmost importance for agriculture planning and water management. The sudden onset of the South China Sea summer monsoon (SCSSM) is one of the most spectacular phenomena and has a profound societal impact.

Kajikawa and Wang (2012, hereinafter KW12) detected a significant change in the mean onset date of the SCSSM around 1993/94: the epochal mean onset date is 30 May for 1979–93 and 14 May for 1994–2008, so the onset date in the post-1994 epoch has advanced by 16 days. Chen (2015, hereinafter C15) has carefully checked the KW12 finding by using a different reanalysis dataset and extending the analysis period from 1979–2008 to 1979–2012. The result of C15 confirms that the KW12 finding is robust even during the extended period after 2008. We appreciate this contribution from C15.

The fundamental science issue here is why the SCSSM onset date advanced remarkably after 1993/94. The comment of C15 states in its abstract that Kajikawa and Wang (2012) "attributed this [onset] change to enhanced tropical cyclone (TC) activity and intraseasonal variability (ISV) related to 30–80-day and 10–25-day anomalies in the second epoch." This misleading statement motivated C15 to assess the individual impact of TCs and ISV on the change of the SCSSM onset. We would like to start our reply by correcting C15's misunderstanding of the work of KW12.

The fact is that KW12 attributed the root cause of the interdecadal change of the SCSSM onset to decadal changes in the lower boundary anomalies. They pointed out in their abstract that "the advanced SCSSM onset is rooted in the decadal change of the SST over the equatorial western Pacific." KW12 further indicated that "the advanced onset during the second epoch *is affected* by the *enhanced* activity of *northwestward-moving tropical disturbances from the equatorial western Pacific*" (italics added for emphasis). Here they highlighted the *processes* by which the western Pacific SST anomalies may cause the interdecadal change in the SCSSM onset. C15 missed these points.

The major work of C15 is to assess the individual impacts of the TCs and ISV on the SCSSM onset. For that purpose, C15 applied bandpass filters to the SCSSM circulation index in an attempt to remove anomalies associated with TCs and ISV. The SCSSM circulation index (hereafter SCS index for brevity) is measured by the 850-hPa zonal wind averaged over the central South China Sea (5°–15°N, 110°–120°E). This index is a key variable that was used to determine the SCSSM onset date. C15 showed that the SCSSM onset dates were not affected by removing the TCs and the 10–25-day ISV component, but were significantly affected by the removal of the 30–80-day ISV (Fig. 1 of C15). Thus, C15 claimed, "TCs have no significant impact on the SCSSM onset in all years, except 2006," "the 10–25-day anomaly has an insignificant contribution to the interdecadal

---

* Earth System Modelling Center Publication No. 063.

Corresponding author address: Yoshiyuki Kajikawa, RIKEN Advanced Institute for Computational Science, 7-1-26 Minatojima-minami-machi, Chuo-ku, Kobe, 650-0047, Japan.
E-mail: ykaji@riken.jp

DOI: 10.1175/JCLI-D-15-0173.1

shift of the SCSSM onset,'' ''the 30–80-day anomaly can, in part, play a role in the interdecadal shift of the SCSSM onset.'' These are the main results of C15's comment.

C15's comments partially confirm the importance of the 30–80-day ISV; however, unfortunately, these results do not reveal new facts. Why? Let us look at how the SCSSM onset date is defined. Defining the SCSSM onset date in an individual year involves three criteria (Wang et al. 2004), which C15 followed: 1) on the onset day and during the subsequent 5 days, the SCSSM index must be positive (turning from easterly to westerly), 2) the number of days with a positive index during the subsequent 20 days reaches at least 15; and 3) the 20-day mean index after the onset day must be larger than $1\,\mathrm{m\,s^{-1}}$. Criteria 2 and 3 ensure that the onset date represents a ''persistent'' wind regime transition from the preonset easterly to the postonset westerly without being affected by high-frequency weather fluctuations. Therefore, the effects of the individual TCs and the 10–25-day ISV are already ''smoothed out'' by the two 20-day averaged criteria in the determination of the onset dates. As such, it is fully expected that the linear removal of high-frequency TCs and 10–25-day anomalies again will have minimal impact on the determination of the onset data. Therefore, the results shown in Figs. 1a and 1b of C15 are trivial, as are the conclusions regarding the roles of the individual TCs and 10–25-day anomaly in SCSSM onset change.

The results of Fig. 3 in C15 repeated that the TCs and 10–25-day components have little effects while the 30–80-day ISV has significant effects on the composite onset dates, which is again trivial. Note that these composite diagrams were made with respect to two different epoch-mean onset dates; therefore, they are irrelevant to an explanation of the interdecadal change of the mean onset. In fact, the composite amplitudes of the 30–80-day ISV are nearly the same for the two epochs; as such, the 30–80-day ISV could not account for the interdecadal change of the onset date. KW12, on the other hand, tied the early onset in the second epoch to *enhanced* ISV activity compared to the first epoch. They stated in their abstract that ''during 1994–2008, the intraseasonal variability (ISV) over the western Pacific was *enhanced during the period from mid-April to mid-May*'' (italics added for emphasis). It is the enhancement of the ISV active phase in a specific period prior to the seasonal transition (from mid-April to mid-May) that contributed to the advanced SCSSM onset in the second epoch.

We believe that the roles of ISV, TCs, and the biweekly anomaly should not be assessed separately using linear decomposition because they are highly interactive. We consider that the 30–80-day ISV and the associated high-frequency disturbances together contribute to the change in the SCSSM onset (see also Zhou and Chan 2005). Our results, shown in Fig. 1 herein, indicate that there would be no significant interdecadal change of SCSSM onset date provided all transient anomalies with a period less than 80 days were removed. As can be seen from Fig. 1, after the 80-day low-pass filter is applied, the SCSSM mean onset date during 1979–93 becomes earlier whereas the mean onset date during 1994–2008 becomes later. As a result, the difference in the SCSSM onset date between the two epochs is substantially shortened from 16 days to 6 days. Therefore, without the synoptic to 30–80-day variability the interdecadal change of SCSSM onset date between the two epochs is no longer statistically significant even at the 90% of confident level by a Student's t test. The result in Fig. 1 demonstrates that the ISV and associated higher-frequency disturbances together contribute to the interdecadal change of the SCSSM onset.

C15's results deny the roles of individual TCs and 10–25-day anomaly based on a linear decomposition analysis. We would like to point out that the intrinsic interplay between the 30–80-day ISV and the embedded high-frequency disturbances are essentially nonlinear, and so analysis of individually filtered indices (i.e., remove 30–80-day ISV and TC separately) cannot adequately assess the nonlinear effects. This point is further elaborated in the following two paragraphs.

The TCs and 10–25-day anomaly in the western Pacific do not occur independently; rather they are embedded in and regulated by the 30–80-day ISV. It is well known that the westward moving 2-day cloud clusters, 3–10-day northwestward propagating disturbances, and westward propagating quasi-biweekly disturbances are all often embedded in and regulated by the 30–80-day ISV (Nakazawa 1988; Murakami 1980; Lau and Lau 1990; Straub and Kiladis 2003; Kikuchi and Takayabu 2004; Moncrieff 2004; Wang et al. 2006; Biello et al. 2007; Kikuchi and Wang 2009; Wang et al. 2009). The SCSSM onset is also often accompanied by the ISV with embedded synoptic disturbances. For instance, during the second epoch, TCs were generated with the arrival of active phases of ISV during the SCSSM onset periods in 1996 (TC#199603 Bart), 2000 (TC#200001 Damrey), 2002 (TC#200203 Hagibis), 2004 (TC#200403 Omaiss), and 2008 (TC#200802 Rammasun).

It is stressed that the ISV and the embedded higher-frequency disturbances consist of an integrated two-way interactive system. It has been shown that synoptic eddies can extract (transfer) kinetic energy from the ISV during the ISV active (suppressed) phase through barotropic energy conversion (Sobel and Maloney 2000;

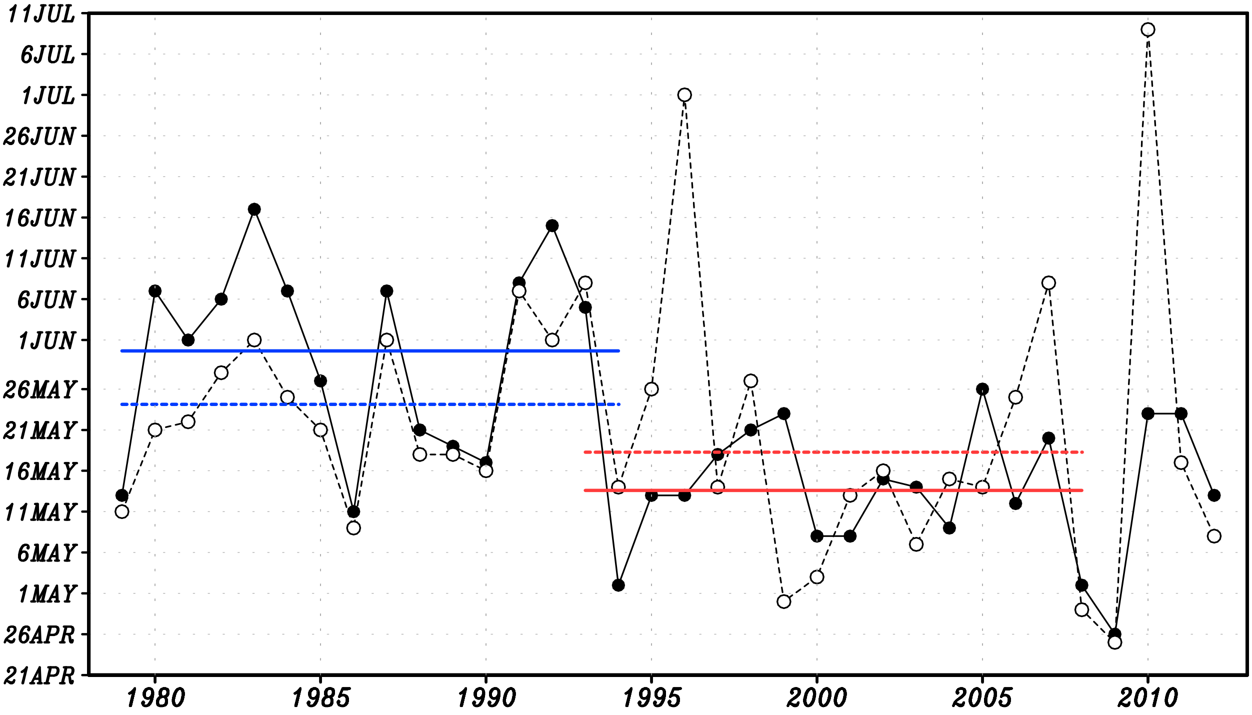

FIG. 1. Time series of the SCSSM onset date based on the original SCSSM index (closed circle with solid line) in KW12 and the low-pass filtered SCSSM index (open circle with dashed line). The blue (red) line denotes the mean onset date during the period of 1979–93 (1994–2008). The low-pass filtered SCSSM index is reconstructed by applying a 80-day low-pass Lanczos filter (Duchon 1979) with 121 weights. The definition of SCSSM onset date with the low-pass filtered data is the same as that with the original index except that the "persistent seasonal transition" criterion (the cumulative 20-day mean SCSSM index must be greater than 1 m s^{-1}) is removed because the low-pass filtered data already assure the persistent seasonal transition.

Maloney and Hartmann 2001; Maloney and Dickinson 2003; Zhou and Li 2010; Hsu et al. 2011). On the other hand, the high-frequency disturbances embedded in the ISV can strongly feed back to the ISV (Krishnamurti et al. 2003; Hsu and Li 2011; Hsu et al. 2011). In addition, numerical experiments with AGCMs have shown that the existence of high-frequency weather perturbations in the initial conditions can generally extend the ISV prediction skill by about 5 days compared to those in which the high-frequency disturbances are filtered out (Fu et al. 2009).

In summary, during the post-1994 epoch the process that contributed to the early onset of the SCSSM is the enhanced ISV and the embedded synoptic-biweekly activity in a specific period prior to the seasonal transition (from mid-April to mid-May). However, the fundamental cause of the interdecadal changes in the ISV and transient activity is rooted in the SST changes in the western Pacific (KW12). While KW12 has tied the change of SCSSM onset to the SST changes, it remains a challenging issue to elucidate how the SST anomalies-induced mean state change affected the ISV and tropical disturbances in the late spring of the post-1994 epoch. The numerical experiments with a coupled climate model made by Xiang and Wang (2013) demonstrate that, indeed, the advanced SCSSM onset is primarily determined by the abrupt SST warming near the Philippine Sea after the mid-1990s. They also found that the SST anomalies affected the monsoon onset through westward propagation of Rossby waves (the model counterparts of TCs, 3–10-day and biweekly anomalies) and their interaction with the spring asymmetric background states, which intensifies the Northern Hemispheric perturbations and westerly winds in May. Further numerical experiments and diagnostic studies are requested to deepen our dynamical understanding of the causes of the Asian summer monsoon onset variability.

Acknowledgments. The authors are grateful to Dr. John Chiang, the editor of the *Journal of Climate*, and the associate editor for their useful comments. This work is supported by the Atmosphere–Ocean Research Center at the University of Hawai'i at Mānoa funded by Nanjing University of Information Science and Technology and RIKEN Incentive Research Projects 2014.

REFERENCES

Biello, J. A., A. J. Majda, and M. W. Moncrieff, 2007: Meridional momentum flux and superrotation in the multiscale IPESD MJO model. *J. Atmos. Sci.*, **64**, 1636–1651, doi:10.1175/JAS3908.1.

Chen, G., 2015: Comments on ‘‘Interdecadal change of the South China Sea summer monsoon onset.’’ *J. Climate*, **28**, 9029–9035, doi:10.1175/JCLI-D-14-00732.1.

Duchon, C. E., 1979: Lanczos filtering in one and two dimensions. *J. Appl. Meteor.*, **18**, 1016–1022, doi:10.1175/1520-0450(1979)018<1016:LFIOAT>2.0.CO;2.

Fu, X., B. Wang, Q. Bao, P. Liu, and J.-Y. Lee, 2009: Impacts of initial conditions on monsoon intraseasonal forecasting. *Geophys. Res. Lett.*, **36**, L08801, doi:10.1029/2009GL037166.

Hsu, P.-C., and T. Li, 2011: Interactions between boreal summer intraseasonal oscillations and synoptic-scale disturbances over the western North Pacific. Part II: Apparent heat and moisture sources and eddy momentum transport. *J. Climate*, **24**, 942–961, doi:10.1175/2010JCLI3834.1.

——, ——, and C. H. Tsou, 2011: Interactions between boreal summer intraseasonal oscillations and synoptic-scale disturbances over the western North Pacific. Part I: Energetics diagnosis. *J. Climate*, **24**, 927–941, doi:10.1175/2010JCLI3833.1.

Kajikawa, Y., and B. Wang, 2012: Interdecadal change of the South China Sea summer monsoon onset. *J. Climate*, **25**, 3207–3218, doi:10.1175/JCLI-D-11-00207.1.

Kikuchi, K., and Y. N. Takayabu, 2004: The development of organized convection associated with the MJO during TOGA COARE IOP: Trimodal characteristics. *Geophys. Res. Lett.*, **31**, L10101, doi:10.1029/2004GL019601.

——, and B. Wang, 2009: Global perspective of the quasi-biweekly oscillation. *J. Climate*, **22**, 1340–1359, doi:10.1175/2008JCLI2368.1.

Krishnamurti, T. N., D. R. Chakraborty, N. Cubukcu, L. Stefanova, and T. S. V. Vijaya Kumar, 2003: A mechanism of the Madden–Julian oscillation based on interactions in the frequency domain. *Quart. J. Roy. Meteor. Soc.*, **129**, 2559–2590, doi:10.1256/qj.02.151.

Lau, K.-H., and N.-C. Lau, 1990: Observed structure and propagation characteristics of tropical summertime synoptic scale disturbances. *Mon. Wea. Rev.*, **118**, 1888–1913, doi:10.1175/1520-0493(1990)118<1888:OSAPCO>2.0.CO;2.

Maloney, E. D., and D. L. Hartmann, 2001: The Madden–Julian oscillation, barotropic dynamics, and North Pacific tropical cyclone formation. Part I: Observations. *J. Atmos. Sci.*, **58**, 2545–2558, doi:10.1175/1520-0469(2001)058<2545:TMJOBD>2.0.CO;2.

——, and M. J. Dickinson, 2003: The intraseasonal oscillation and the energetics of summertime tropical western North Pacific synoptic-scale disturbances. *J. Atmos. Sci.*, **60**, 2153–2168, doi:10.1175/1520-0469(2003)060<2153:TIOATE>2.0.CO;2.

Moncrieff, M. W., 2004: Analytic representation of the large-scale organization of tropical convection. *J. Atmos. Sci.*, **61**, 1521–1538, doi:10.1175/1520-0469(2004)061<1521:AROTLO>2.0.CO;2.

Murakami, T., 1980: Empirical orthogonal function-analysis of satellite-observed outgoing longwave radiation during summer. *Mon. Wea. Rev.*, **108**, 205–222, doi:10.1175/1520-0493(1980)108<0205:EOFAOS>2.0.CO;2.

Nakazawa, T., 1988: Tropical super clusters within intraseasonal variations over the western Pacific. *J. Meteor. Soc. Japan*, **66**, 823–839.

Sobel, A. H., and E. D. Maloney, 2000: Effect of ENSO and the MJO on western North Pacific tropical cyclones. *Geophys. Res. Lett.*, **27**, 1739–1742, doi:10.1029/1999GL011043.

Straub, K. H., and G. N. Kiladis, 2003: Interactions between the boreal summer intraseasonal oscillation and higher-frequency tropical wave activity. *Mon. Wea. Rev.*, **131**, 945–960, doi:10.1175/1520-0493(2003)131<0945:IBTBSI>2.0.CO;2.

Wang, B., LinHo, Y. S. Zhang, and M. M. Lu, 2004: Definition of South China Sea monsoon onset and commencement of the East Asia summer monsoon. *J. Climate*, **17**, 699–710, doi:10.1175/2932.1.

——, P. Webster, K. Kikuchi, T. Yasunari, and Y. J. Qi, 2006: Boreal summer quasi-monthly oscillation in the global tropics. *Climate Dyn.*, **27**, 661–675, doi:10.1007/s00382-006-0163-3.

——, F. Huang, Z. W. Wu, J. Yang, X. H. Fu, and K. Kikuchi, 2009: Multi-scale climate variability of the South China Sea monsoon: A review. *Dyn. Atmos. Oceans*, **47**, 15–37, doi:10.1016/j.dynatmoce.2008.09.004.

Xiang, B., and B. Wang, 2013: Mechanisms for the advanced Asian summer monsoon onset since the mid-to-late 1990s. *J. Climate*, **26**, 1993–2009, doi:10.1175/JCLI-D-12-00445.1.

Zhou, C., and T. Li, 2010: Upscale feedback of tropical synoptic variability to intraseasonal oscillations through the nonlinear rectification of the surface latent heat flux. *J. Climate*, **23**, 5738–5754, doi:10.1175/2010JCLI3468.1.

Zhou, W., and J. C. L. Chan, 2005: Intraseasonal oscillations and the South China Sea summer monsoon onset. *Int. J. Climatol.*, **25**, 1585–1609, doi:10.1002/joc.1209.