Monitoring and Prediction of the Global Monsoon Systems at the NOAA Climate Prediction Center

Song Yang and CPC Global Monsoons Team
NOAA Climate Prediction Center, 5200 Auth Road, Camp Springs, Maryland 20746, USA

Abstract

The NOAA Climate Prediction Center provides information about monitoring and prediction of regional tropical-subtropical monsoon systems worldwide. Real-time products are provided for monitoring the variations of monsoons over Asian-Australian region, North America, South America, and Africa using various fields of the atmosphere, ocean, and land. The NCEP Global Forecast System and Climate Forecast System are also used to predict the various regional monsoons.

Key words: global monsoon systems, monitoring, prediction, and NCEP models

1. Introduction

Monsoons are important weather and climate systems that affect billions of people worldwide. Monsoon variability is often related to floods, drought, and other hazardous extreme weather and climate events. Excessive monsoon rainfall causes floods and mud slides and hence considerable social and economic impacts. Alternately, insufficient monsoon rainfall leads to drought, hence scarcer fresh water supplies. Monsoon depressions and tropical storms with high winds and tidal surges are often embedded within the large-scale monsoon circulation, posing threats to human lives and property. Monsoon behavior, such as the intensity and duration, influences economic planning and development, water resource management, agriculture (planting and harvesting), and emergency response.

The Asian summer monsoon, which affects about half of the world's population, is the strongest monsoon component. However, monsoons are also found in other tropical-subtropical land areas, including Australia, Africa, South America, and North America. Monsoons usually have certain well-defined atmospheric characteristics such as a life cycle characterized by distinct onset, maintenance, and demise phases. They feature abundant rainfall during summer and dry conditions during winter. However, the discernable features of monsoons vary from region to region. The monsoon climate over many Asian countries is characterized by wet and hot conditions in summer but dry and cold conditions in winter, corresponding to a pronounced seasonal reversal of surface winds. However, regions close to the equator usually experiences two rainy seasons. Over eastern Africa, the monsoon rainfall is characterized by "long rain" in March-May and "short rain" in October-December. The North American monsoon is characterized by distinct rainfall maxima over western Mexico and the southwestern United States and by an accompanying upper-level anticyclone over the higher terrain of northwestern Mexico. The South American monsoon features a pronounced wet season (November-March) and a dry season (April-September) over central Brazil. An intense upper-tropospheric anticyclonic circulation, located over eastern Bolivia, appears during the wet season.

Because of the significant societal and economic impacts of monsoons, improvement in understanding and predicting the variations of monsoons is vital for mitigating losses caused by hazardous weather and climate events and maximizing economic gains. For this sake, monitoring the current conditions and evolutions of monsoons using real-time and historical data and predicting the monsoons using advanced statistical tools and numerical models are equally important.

2. Products of monsoon monitoring

The Global Monsoons Team of the NOAA Climate Prediction Center (CPC) monitors the global monsoon patterns and various regional monsoons on weekly, monthly, and seasonal time scales, with daily-updated information. Most of the Team's products can be founded at http://www.cpc.ncep.noaa.gov/products/Global_Monsoons/Global-Monsoon.shtml. The website contains global total and anomalous patterns of various variables on weekly, monthly, and seasonal time scales. The information, most updated daily, is provided for accumulated precipitation, surface air temperature, 200-mb and

850-mb winds, sea surface temperature, soil moisture, outgoing longwave radiation, and 200-mb velocity potential.

Similar information for regional monsoon systems including the Asian-Australian monsoons, the American monsoons, and the African monsoons an be found respectively at: http://www.cpc.noaa.gov/products/Global_Monsoons/Asian_Monsoons/Asian_Monsoons.shtml, http://www.cpc.noaa.gov/products/Global_Monsoons/African_Monsoons/African_Monsoons.shtml, and http://www.cpc.noaa.gov/products/Global_Monsoons/African_Monsoons/African_Monsoons.shtml. For these regional monsoons, information of additional variables such as sea level pressure, vertically-integrated water vapor flux and divergence, and others is also presented. However, the information is not necessarily identical among the different monsoon components. Useful information at the CPC monsoon website includes the accumulated amounts and their anomalies of precipitation averaged over different space domains. Figure 1 illustrates an example of the accumulated and anomalous precipitation averaged over particular 5x5 latitude-longitude grids (land only) for the past 30 days, 90 days, and 180 days. Useful information also includes the current condition and evolution of precipitation over some river basins such as the La Plata Basin in South America (http://www.cpc.noaa.gov/products/Global_Monsoons/American_Monsoons/Hydro/LPB/LPB.shtml).

Climatological patterns and certain statistical relationships about the global monsoons are also important because they yield useful information for monitoring and predicting monsoons. At the CPC, the monsoon team also determines the climatological dates of onset and withdrawal of the various regional monsoons. Figure 2 shows the dates of monsoon onsets over Asia and Africa. It is clearly seen that the onset of Asian summer monsoon is characterized by a southeast-to-northwest orientation over much of the monsoon region and the most rapid process of monsoon onset appears over the South China Sea. In contrast, the onset of West African summer monsoon is characterized by an organized northward propagation, reflected by the shift of the Intertropical Convergence Zone. The team also presents the monthly and seasonal climatological patterns of precipitation and atmospheric circulation and depicts the time-latitude evolution of monsoon precipitation along different longitude bands.

Monsoon indices are convenient tools for depicting the intensity of monsoons and comparing monsoon intensity during different periods of time. Many dynamical monsoon indices have been developed during the past decades. However, a dynamical index is useful for climate forecast operations only if it is clearly linked to well-defined features in the patterns of precipitation, atmospheric circulation, and/or other variables. At the CPC, the monsoon team also provides information about the relationships of several commonly-used monsoon indices with precipitation and wind patterns at the different time of the year. This information is used to understand and interpret the results from predictions of these indices by operational models (see next section). For example, Fig. 3 shows that, in May, when the Webster-Yang (Webster and Yang 1992) monsoon index is large, the lower-tropospheric flow over southern Asia and the adjacent tropical oceans is strong. Correspondingly, precipitation increases over these regions and decreases over tropical western Indian Ocean and the equatorial Pacific.

3. Products of monsoon prediction

Predictions of monsoons at the CPC are mainly based on the NCEP Global Forecast System (GFS) and the NCEP Climate Forecast System (CFS). In particular, the CFS has demonstrated noticeable skills in simulating and predicting the variations of monsoons on different timescales in various monsoon regions (e.g., Mo et al. 2005; Thiaw and Mo 2005; Misra and Zhang 2007; Higgins et al. 2008; Liang et al. 2009; Yang et al. 2008a-b; Yang et al. 2009). It has also demonstrated skills in simulating and predicting the variations of East Asian winter monsoon (Li and Yang 2010) and East Asian mid-summer Mei-yu climate (Gao et al. 2010).

Figure 4 shows the bias-corrected week-1 prediction of precipitation anomaly for Asian-Australian monsoons by the GFS. Predictions of accumulated and anomalous precipitations, updated daily, are also available for week 2 and for other regional monsoon systems. Figure 5 shows the 15-day predictions of daily Webster-Yang monsoon index by the GFS. Monthly variations of different monsoon indices are also predicted by the NCEP CFS at different lead months. Anomalous patterns of monthly precipitation, surface temperature, and atmospheric circulation by the NCEP CFS at different leads are made by the CPC monsoon team as well.

Finally, one can find the North American Monsoon Forecast Forum at http://www.cpc.ncep.noaa.gov/products/Global_Monsoons/American_Monsoons/NAME/index.shtml, which provides an accessible online forum for the posting, distribution, monitoring, and synthesis of intra-seasonal and seasonal precipitation forecasts of the North American monsoon. Here, several models including the NCEP CFS, the NASA/GSFC Coupled General Circulation Model, and Experimental Climate Prediction Center (University of California, San Diego) models are used to predict the spatial patterns and area averages of precipitation for summer from June to September. The spatial patterns include monthly and seasonal means of predicted precipitation and the area-averaged time series are for the daily accumulated precipitation over eight spatial domains in Southwest United States and Mexico.

4. References

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Contact information:

Muthuvel Chelliah (Muthuvel.Chelliah@noaa.gov) for Asian-Australian monsoons

Wei Shi (Wei.Shi@noaa.gov) for the North American monsoon

Viviane Silva (Viviane.Silva@noaa.gov) for the South American monsoon

Wassila Thiaw (Wassila.Thiaw@noaa.gov) for African monsoons

Song Yang (Song.Yang@noaa.gov) for general issues about the CPC Global Monsoons products

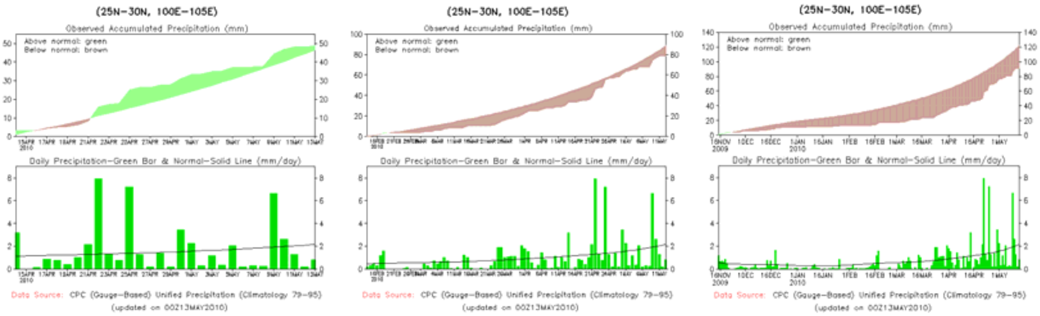

Fig. 1. Time series of accumulated and anomalous precipitation averaged over southwestern China (25º-30ºN/100º-105ºE) for the past 30, 90, and 180 days.

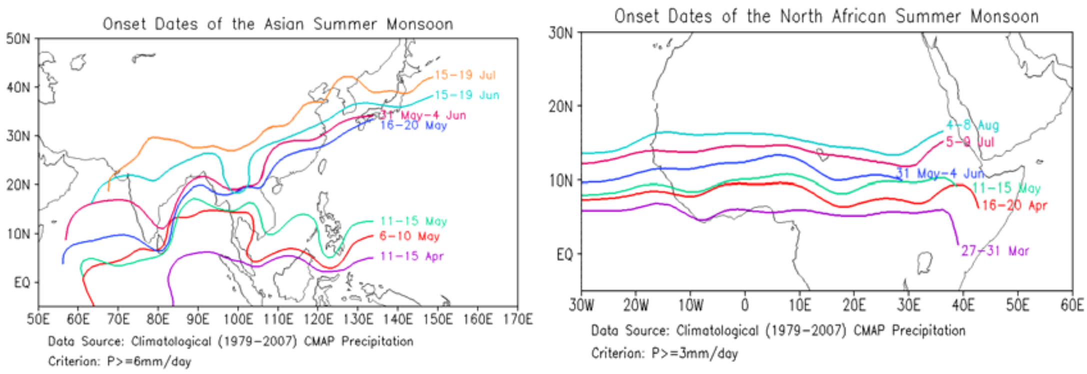

Fig. 2. Climatological dates of summer monsoon onsets over Asia and Africa.

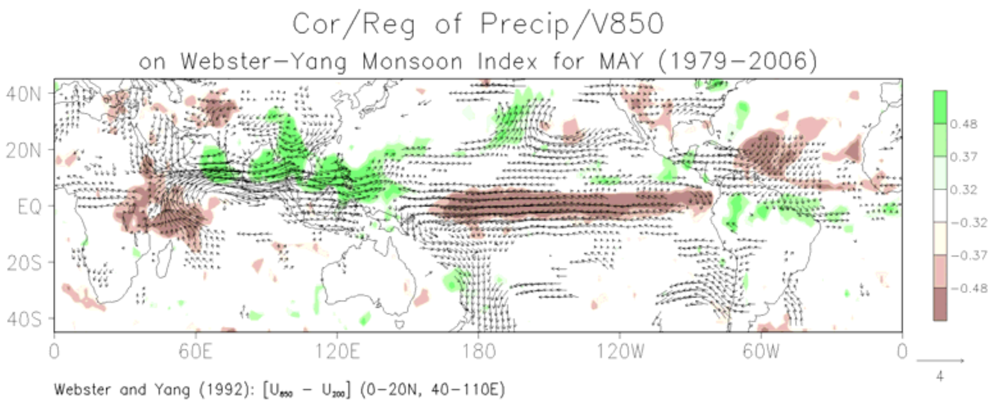

Fig. 3. Correlation (shading) of precipitation with Webster-Yang monsoon index and regression (vectors) of 850-mb winds against the index for May.

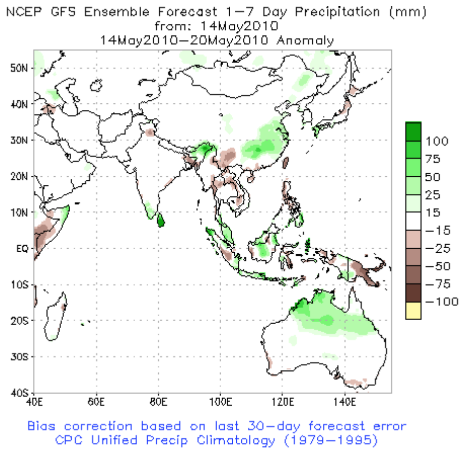

Fig. 4. Week-1 prediction of precipitation anomaly by the NCEP GFS.

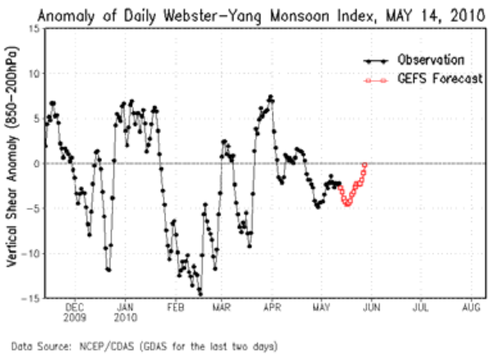

Fig. 5. Prediction of daily Webster-Yang monsoon index by the NCEP GFS.