Science and Technology Infusion Climate Bulletin
NOAA's National Weather Service
40th NOAA Annual Climate Diagnostics and Prediction Workshop
Denver, CO, 26-29 October 2015

A Downscaling Approach of Relating the Large-scale Patterns to the Extreme Rainfall Frequency in Taiwan Mei-yu Season for Climate Change Projection and S2S Prediction

Mong-Ming Lu, Yin-Ming Cho, Meng-Shih Chen
Central Weather Bureau, Taipei, Taiwan

1. Introduction

May and June is the Mei-yu season in Taiwan. It marks the end of the dry half-year (November-April) and the beginning of the high-risk period with disastrous rainfall events. The period with intense rainfall events during the Mei-yu season is usually located in a narrow time window of about one-month. Therefore, forecast the beginning and duration of the intense period and its extremity is of particular importance to Taiwan (Wang et al. 2015, Yim et al. 2015). A conceptual downscaling method is presented in this paper to show how it can be applied to the global climate forecast model output to generate the frequency information of Taiwan Mei-yu season extreme rainfall events for seasonal outlook and climate change assessment.

2. Data and method

2.1. Data

Taiwan station and global gridded data are used in this study. The station data includes 65 years (1951-2015) of the hourly rainfall data at 10 meteorological stations maintained by Central Weather Bureau (CWB). All of the 10 stations are near the coast located to the west of the Central Mountain Range (CMR). The stations to the east of the CMR are not selected because the causal factors of the extreme events there are different from the stations in the west. To the east of CMR the extreme events are often caused by sporadic convective disturbances from the tropics, while to the west of CMR the extreme events are often associated with strong southwest winds of the monsoonal flow.

The global gridded data used for large-scale index design and seasonal prediction experiment are the daily data of the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) Reanalysis (Kalnay et al. 1996) and the NCEP CFSv2 Reanalysis (Saha et al. 2010). The formal is used to design the large-scale index and the latter is used as a perfect model to test the usefulness of the seasonal prediction concept.

The CMIP5data and extended range weather forecast data generated by CWB forecast system TCWB2T2 are used to explore the feasibility of using the proposed concept to project or predict the extreme rainfall frequency.

2.2. Method

Taiwan Mei-yu season extreme rainfall events are often associated with organized meso-scale convective systems (MCSs) embedded in the cloud band along the Mei-yu front. The southwesterly low-level jet (LLJ) located on the equatorward side of the Mei-yu front is an essential factor to MCS development. In order to objectively describe the LLJ an index based on the common large-scale features of the extreme rainfall events is proposed and tested with a perfect prediction framework for the period of from 2001-2015.

a. Define the extreme rainfall events

The extreme rainfall events are identified on the station basis. At each station a threshold value of extreme event is determined as the median of the annual maximum daily rainfall during the Mey-yu season (May 1st - June 30th) in 50 years (1951-2000). For the 10 stations of study the threshold values range from 88.6mm/day

---

Correspondence to: Mong-Ming Lu, Central Weather Bureau, Taipei, Taiwan; E-mail: lu@rdc.cwb.gov.tw.

to 118.2 mm/day, which is above CWB's official definition of the heavy rain (80mm/day) event and exceeds the 95th percentile value (R95) of the rainfall events with the rainfall amount R > 1.0 mm/day. During the 50 Mei-yu seasons 179 days are identified with rainfall extremes, which means at least one in ten stations received above-threshold daily rainfall amount.

The composite daily anomalies of the 850-hPa winds and vorticity of the 179 days of the rainfall extremes is presented in Fig.1a. A clear positive vorticity anomaly pattern stretching from southern China northeastwardly through Taiwan and Ryukyu Islands to the south of Japan is observed. To the north of the positive vorticity anomaly is the negative vorticity anomalies over central China along the Yangtze River and to the south is the negative vorticity stretching from the South China Sea through the Luzon Island to the Philippine Sea. Between the positive anomaly over Taiwan and the negative anomaly over the South China Sea are the anomalously strong southwesterly winds. The composite wind and vorticity patterns are consistent with a prior knowledge of the raining mechanism associated with LLJ from the South China Sea to the western North Pacific through Taiwan. For the low-level southwesterly flow to last for few days, it often requires an anticyclone to the south of Taiwan and a cyclone to the north of Taiwan.

b. Define the large-scale circulation index SWFI

The large-scale circulation index for the extreme rainfall events is determined by two criteria. The 850-hPa vorticity criterion requires positive vorticity over S. China and Taiwan (red grid in Fig. 1b) and negative vorticity over the SCS and Philippine Sea (blue grid in Fig. 1b). The southwesterly flow criterion (green grid in Fig. 1b) requires the mean value of the 850hPa u component of the wind (U850), termed as SWU, exceed a critical value SWUc. For the application of real time forecast, the SWUc is the median value of SWU in 50 years (1951-2000), while for the application of climate change assessment the SWUc is the median value of SWU in 20 years (1986-2005) simulated by each CMIP5 model. The large-scale circulation index SWFI is determined as the count of the days in May and June that both vorticity and southwesterly flow criteria are satisfied.

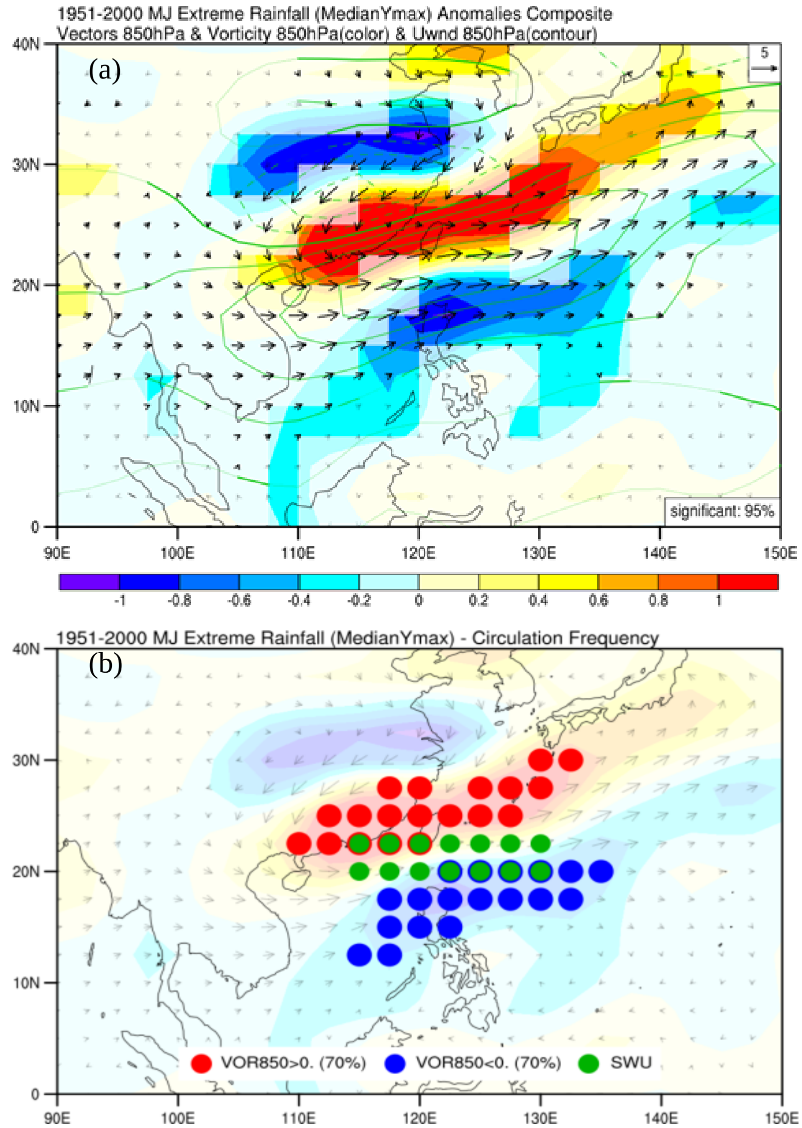

Fig. 1 (a) The composite daily anomalies of the 850-hPa winds and vorticity (colors) of the 179 days of the rainfall extremes. The vectors (contours) mark the composite wind (vorticity) anomalies are significant at the 95% confidence level. (b) The key grid points selected for identifying the favorable large-scale conditions represented by 850-hPa vorticity (red dots: positive, blue dots: negative) and U (green dots: mean value exceed the critical value SWUc) for Taiwan Mei-yu extreme rainfall events.

3. Results

3.1 The forecast potential estimated from the perfect global forecast

The relationship between SWFI and the observed seasonal frequency of the extreme events is presented in Fig. 2. Here the frequency of the extreme events is counted as the sum of the daily rainfall extreme events over the 10 stations during the entire Mei-yu season of May and June, excluding the extremes associated with tropical cyclones. The tropical cyclone event means the extreme event occurred concurrently with a tropical cyclone of which the center is located within the boundary of less than 300km away from Taiwan coastline.

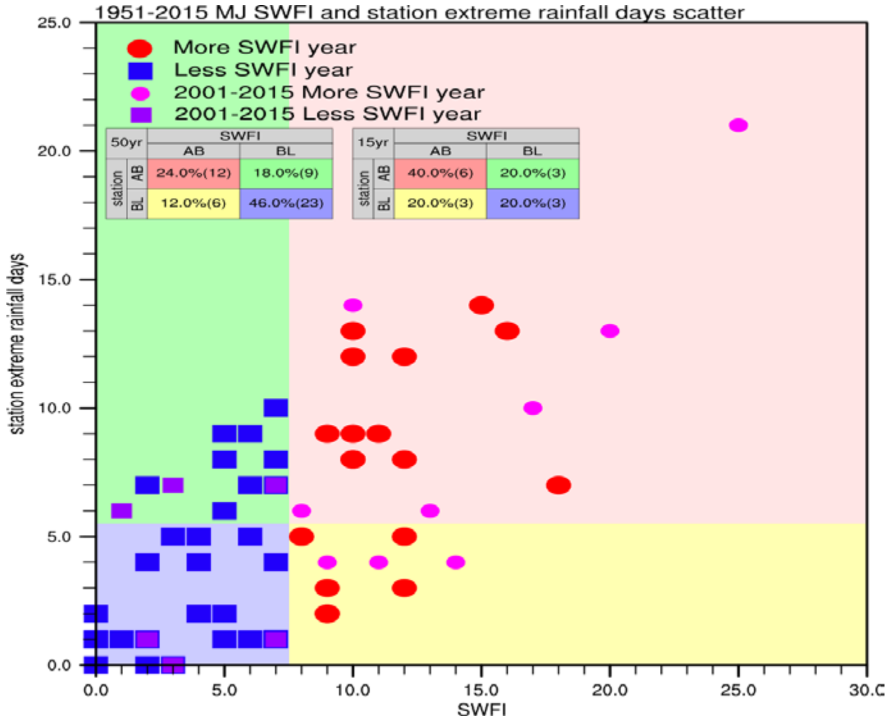

Fig. 2 The scatter diagram of the predictor: SWFI and the predictand: frequency of the extreme events. The colors in the rectangular boxes symbolize the hit (red, blue) and miss (green, yellow) domain of two-category forecast.

Fig. 2 shows significant correlation of SWFI and the frequency of the extreme events. The correlation coefficient during the training period from 1951-2000 reaches 0.62, which is significant at the confidence level of 99%. For the forecast period from 2001-2015 the correlation 0.74 also reaches the 99% confidence level. The hit rate during the training period of two-category forecast is 70%, while during the prediction period is 60%.

3.2 Project the future changes of the frequency of the extreme events

The proposed downscaling concept can also be applied to assess the influence of global climate change on the frequency of extreme events of Taiwan Mei-yu. After the method is applied to six CMIP3 and ten CMIP5 models whose daily U850 data are available at PCMDI web site (http://cmip-pcmdi.llnl.gov/cmip5/data_portal.html) under the A1B for CMIP3 and RCP8.5 for CMIP5 climate scenarios, it turns out that 75% of the models shows in the near-term future (2046-2065) the frequency is less than the frequency in the historical climate (1986-2005). For the long-term future (2081-2100), the percentage of the decreased frequency model drops to 56%. It suggests in the long-term future the occurrence probability of extreme events is larger than that in the near-term future. However, the relation has very weak statistical significance.

4. Ongoing/future work

The proposed method of applying the global climate model product to predict the frequency of Mei-yu season extreme rainfall events in Taiwan is proved skillful in terms of two-category forecast. It can also be applied to assess the climate change influence on Taiwan Mei-yu. An on-going research is to apply the method to the forecast product of CWB’s S2S prediction system that updates the forecasts of 1-90 days on daily basis. It is hoped that the downscaled information can be useful for bettering disaster preparedness in Taiwan.

References

Kalnay, E., and Coauthors, 1996: The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, **77**, 437–471.

Saha, S. and Coauthors, 2010: The NCEP climate forecast system reanalysis. *Bull. Amer. Meteor. Soc.*, **91**, 1015-1057.

Wang, S.-Y., Y.-H. Lin, and C.-H. Wu, 2015: Interdecadal shift of the active-phase East Asian summer monsoon (Meiyu). *Atmospheric Science Letters*, doi: 10.1002/asl.603.

Yim, S.-Y., B. Wang, W. Xing, and M.-M. Lu, 2015: Prediction of Meiyu rainfall in Taiwan by multi-lead physical-empirical models. *Clim. Dyn.*, **44**, 3033-3042. doi:10.1007/s00382-014-2340-0.