Towards the Climate Prediction of Mei-Yu Rainfall for Taiwan

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1. Introduction

Climate prediction is vital to many human activities and drought has been a recurrent and troublesome problem for Taiwan. Water resource managers need to know rainfall forecasts well before the season so that they could make a scientifically based decision regarding whether to issue water conservation or water rationing for the regions expected to be affected. This would in turn effectively minimize the hardship incurred to customers (e.g., farmers, industry users) and/or residents during periods of drought. By incorporating the forecast information into long-range resources planning and management, decision-makers can take more pro-active instead of reactive action.

Climatologically, Mei-Yu rainfall in Taiwan occurs from the mid-May to mid-June, one month earlier than its counterpart over central and eastern China (Tao and Chen, 1987; Ding, 1994). In the central and southern part of the western Taiwan where population is dense, Mei-Yu rainfall makes up more than 30% of the annual rainfall totals. Because of the large percentage of rainfall being produced in a short time period, there is considerable interest in Mei-Yu rainfall prediction. This situation became critical when the Mei-Yu season was heralded by a prolonged drought, as exemplified by the dry summer and fall of 1995 and the successive, dry winter of 1996. Whether the dry condition would have persisted into the Mei-Yu season of 1996 posed a great challenge to decision makers during the first few months of 1996. In this study, we attempt to forecast Taiwan Mei-Yu (May/June) rainfall using the antecedent November/December Pacific sea surface temperatures (SSTs) and the 500 hpa geopotential height over East Asia with an advanced technique called the canonical correlation analysis (CCA). CCA has been used as a major methodology to operationally forecast the surface climate in the continental United States (Barnston, 1994) and to forecast winter rainfall in Hawaii (Chu and He, 1994; Barnston and He, 1996) and seasonal precipitation in other tropical Pacific islands (He and Barnston, 1996; Yu et al. 1996).

2. Data and data processing

The monthly mean SST data over the Pacific (50°N-40°S, 120°E-90°W) from 1955 to 1995 are used. This data set has a horizontal resolution of 10° latitude by 10° longitude, yielding 125 grids over the Pacific. A second predictor variable, the monthly mean 500 hpa height over East Asia, is obtained from the Central Weather Bureau. The domain covers from 20°N to 60°N and 60°E to 160°E, and the data period spans from 1955 to 1995. Long-term monthly rainfall totals for eight first-order stations (Keelung, Taipei, Hsinchu, Taichung, Tainan, Kaohsiung, Hualien, and Taitung) are also supplied by the Central Weather Bureau. To be consistent with SST and height data, we extract May/June rainfall records from these eight stations for the period from 1956 to 1995.

The November/December data from the two predictor variables and May/June rainfall are first summed to produce a bi-monthly total. The bi-monthly data are then normalized by taking the difference between the individual bi-monthly value and the long-term average of the bi-monthly value, and dividing this difference by the standard deviation of the bi-monthly series. This normalization method is applied to each grid point of the SST and height field and to each rainfall station.

3. Results

To reduce the large dimensionality of the SST and height fields, an empirical orthogonal function analysis is first performed to each field and the leading 7 eigenmodes of SST and 5 eigenmodes of height are retained as predictor variables. They account for 65% and 74% of the total variance in the SST and height field, respectively.

A dependent dataset is used for the model development and an independent dataset for the period 1986-95 is reserved for prediction. Two types of forecasts are made; the first one is based on the Pacific SST as the only predictor variable and the second one uses the Pacific SST and East Asian 500 hpa height as predictor variables. All forecasts are made four months in advance.

The root-mean-square error and the correlation coefficient between the forecast and observation serve as a yardstick for the forecasting accuracy. Although forecast skills vary from station to station, Mei-Yu rainfall in Taiwan is generally predictable from the antecedent large-scale atmosphere/ocean circulation. Specifically, when the Pacific SST is used as a predictor, there is more predictability in southern Taiwan where Mei-Yu rainfall accounts for a large percentage of annual rainfall (Table 1). Keelung also shows a good skill. However, forecast skills are the least for Hualien and Taichung. A real-time forecast made in February 1996 called for a wetter condition for most stations during the 1996 Mei-Yu season and this forecast appeared to be consistent with the actual observation.

When both the Pacific SST and 500 hpa height over East Asia are used as predictors, the forecast skill generally improves relative to that based on the SST alone, particularly for Taipei and Hualien (Table 1). The improvement for Taipei is about 25% and for Hualien is 15%. Nevertheless, there is also a slight decrease of forecast skill for Hsinchu and Tainan.

Table 1. Forecasting skill of Taiwan Mei-Yu rainfall (1986-95) in terms of root-mean-square error by CCA. All predictor variables are antecedent November/December conditions.

	Predictor variables	
	SST	SST + 500 hpa height
Keelung	1.079	0.971
Taipei	1.498	1.192
Hsinchu	1.267	1.364
Taichung	1.537	1.444
Tainan	1.373	1.398
Kaohsiung	1.230	1.127
Hualien	1.527	1.328
Taitung	1.328	1.215

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