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ON STRONG SIGNALS OF MONTHLY PRECIPITATION ANOMALIES IN EARLY RAINING SEASON OF GUANGDONG AND CONCEPTUAL MODELS OF PREDICTION

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ABSTRACT: Reanalysis data from NCEP/NCAR are used to systematically study preceding signals of monthly precipitation anomalies in the early raining season of Guangdong province, from the viewpoints of 500-hPa geopotential height field, outgoing longwave radiation (OLR) field, sea surface temperature (SST) and fourteen indexes of general circulation depicting atmosphere activity at high, middle and low latitutes. Being multiple tools of information, a number of conceptual models are formulated that are useful for prediction of the magnitude of monthly precipitation (drought, flood and normal conditionss).

Key words: early raining season of the year; precipitation anomalies; strong signals; conceptual models

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1 INTRODUCTION

There has been some multiply based research work on predictors appearing before the yearly early season of raining in Guangdong province[1-3]. Almost none of them tackle the study on preceding signals of monthly precipitation anomalies (i.e. of drought or flood) and relevant conceptual models of prediction. The current work used the reanalysis data from NCEP/NCAR to systematically study preceding signals of monthly precipitation anomalies in the early raining season of Guangdong province, from the viewpoints of 500-hPa geopotential height field, outgoing longwave radiation (OLR) field, sea surface temperature (SST) and fourteen indexes of general circulation depicting atmosphere activity at high, middle and low latitudes. Being multiple tools of information, a number of conceptual models are formulated that are useful for prediction of the magnitude of monthly precipitation (drought, flood and normal conditionss).

2 DATA

(1) Monthly mean geopotential height field at 500 hPa (1958 ~ 1997);

(2) Monthly mean field of outgoing longwave radiation (OLR) field (1974 ~ 1997);

(3) Monthly mean SST for the equator and northern Pacific (1982 ~ 1997), which is derived with the method of optimum interpolation (OISST);

(4) 14-month mean circulation index that contains the subtropical high, Indian-Burmese trough, mid-latitude cell and polar vortex (1958 ~ 1997);

(5) Monthly precipitation data from 33 weather stations in Guangdong (1958 ~ 1997). The

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mean precipitation is used to express that of the province.

The above (1), (2) and (3) are reanalysis data from NCEP / NCAR, in which (1) and (2) cover a mesh of 2.5°×2.5° and (3) a mesh of 1°×1°.

3 RESEARCH METHODS AND APPROACHES

Preceding signals are sought among months of anomalous precipitation. Composite analysis and significance verification methods are applied in months with significantly more or less amount of precipitation (which appear by a probability of about 1/4). The followings are the steps taken to determine signals that are higher than average.

3.1 *Composite analysis*

The length of data series is a determining factor for the number of years of anomalous precipitation. As there are 40 years of data describing monthly mean 500-hPa geopotential height field and general circulation, ten years of drought and ten years of flood are selected based on precipitation data and composite analysis is carried out for periods lasting from preceding July to the month just prior to the one to be predicted. For the 22 years of OLR data, five years of drought and five years of flood are selected and for the 16 years of SST, four years of drought and four years of flood are selected.

As the drought or flood years distribute differently in April, May and June, composition of predictor fields have to be done based on the level of drought or flood in individual months.

3.2 *Significance verification of the composite analysis*

Before the relationship and mutual influence are fully revealed from the viewpoint of physical mechanism, the two states of the atmosphere are verified for statistical significance to decide whether they have consequent effect[4]. In the composite analysis undertaken in the work, the degree of confidence is determined following the equation[5] of

$$t = [(M - n) / s]\sqrt{n-1} \tag{1}$$

Here, t is a random variable of t distribution that observes a degree of freedom of $(n-1)$, n is the number of anomalous years, M and s are the mean and standard deviation of n anomalous years and m is the mean of the whole series. The degree of confidence takes $\alpha \leq 0.05$.

Circulation indexes achieving specific levels of significance or domains of physical predictors within definite range are chosen to be preparatory signals, which are subject to more filtration in the following steps.

3.3 *Retrospective filtration of anomalous years*

Signals obtained in the steps above will be studied for actual signs of anomalies (+ or –) in each of the anomalous years. They are then compared with the signs of composite signals to identify those that have the same anomalous signs by a rate higher than 7/10 and perform next-step verification.

3.4 *Retrospective filtration of historical years*

The signals filtrated in Section 3.3 are used in retrospective forecasting of historical years for fine fixation of strong signals. The significant regional mean or composite circulation indexes, obtained through composite analysis, are used as critical values. Regional mean for all areas of historical annual signals are calculated for a ratio of flood, normal and drought years that possibly appear in years when the critical values are acquired. If a specific anomaly (like floods) appears by a much higher rate or another anomaly is always absent (like drought), strong signals are then set.

The strong signals (or preceding signals) presented below (Figs.1 ~ 6) are available with filtration through the 4 steps.

4 RESULTS OF STUDY

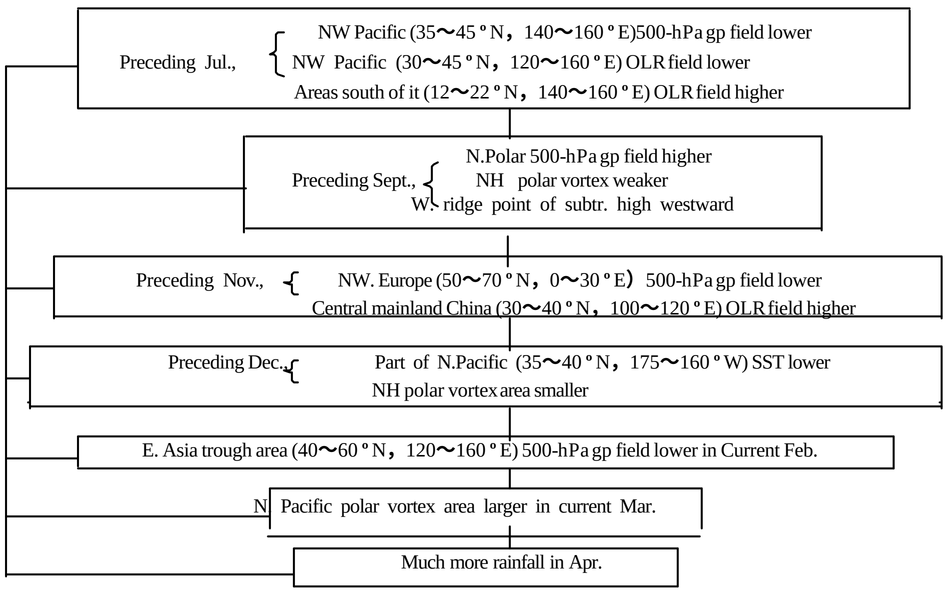

Fig.1 Physical concept model for significantly more precipitation in April.

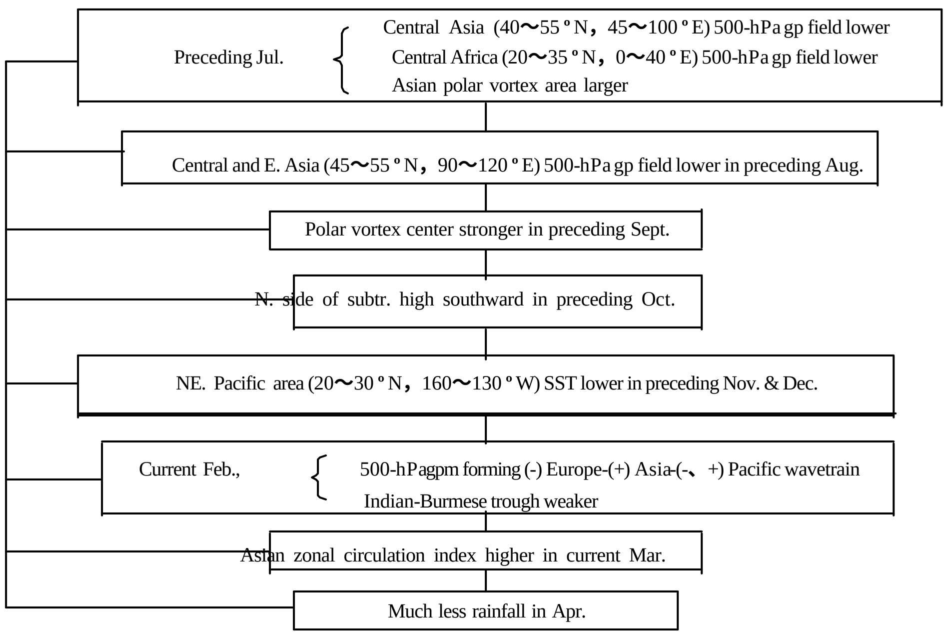

Fig.2 Same as Fig.1 but for significantly less precipitation.

4.1 *Influence on temperature fields*

Fig.7 gives one of the strong signals for significantly less precipitation in April —there is a wavetrain of Europe (–), Asia (+) and Pacific (–, +) in current February. The wavetrain appears for 12 times in Februaries over the period of 40 years. Consequently, droughts occur for 8 times, normal conditions for 3 times and floods for 1 time, in April. In other words, if the wavetrain appears in February, it is more likely for drought than for flood to appear in the coming April.

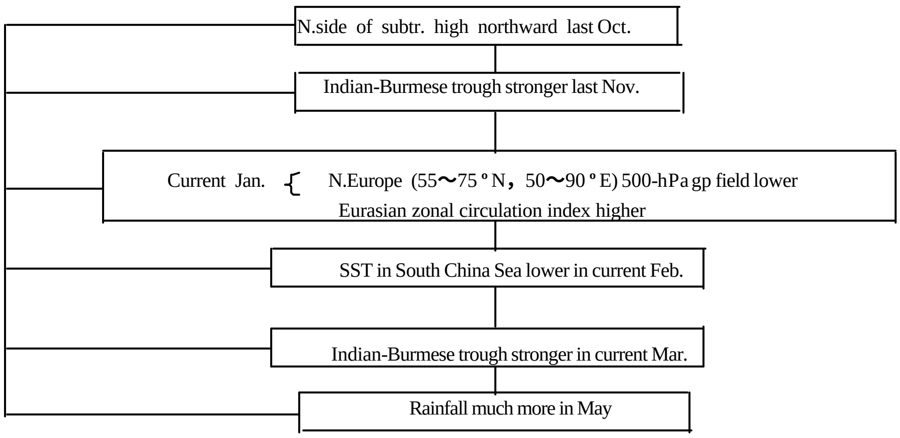

Fig.3 Same as Fig.1 but for May.

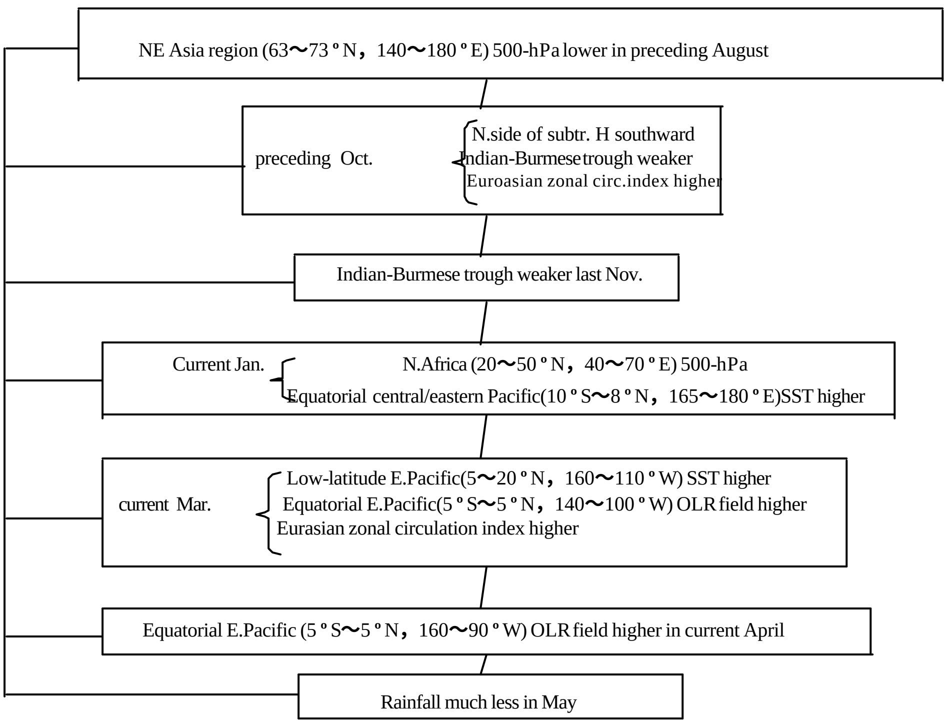

Fig.4 Same as Fig.2 but for May.

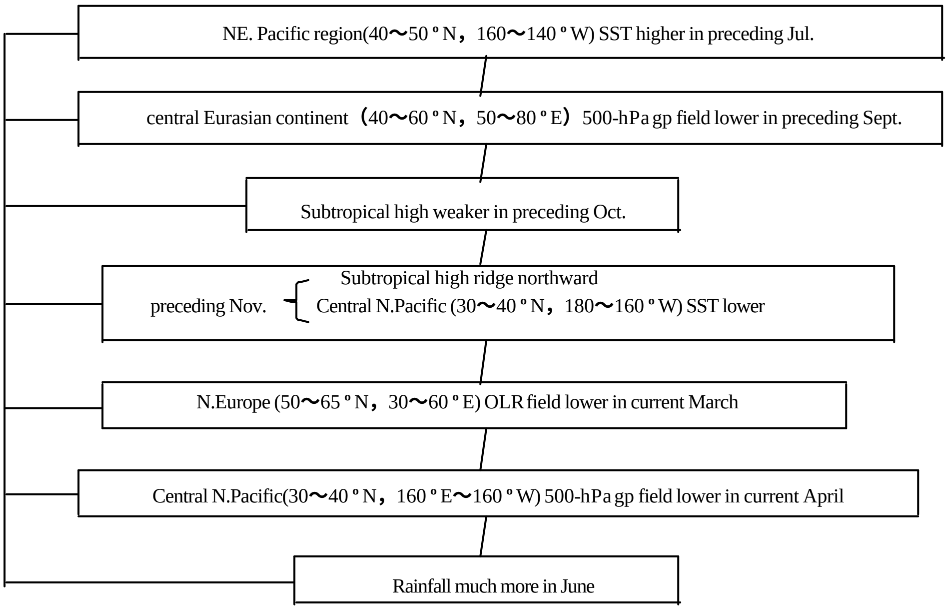

Fig.5 Same as Fig.1 but for June.

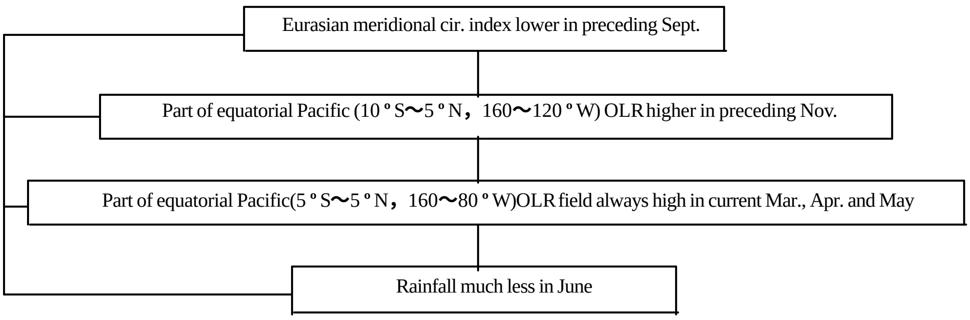

Fig.6 Same as Fig.2 but for June.

Due to text limitation, distribution figures for other strong signals are omitted.

From comparisons of strong signals between Figs.1, 3 and 5 and Figs.2, 4 and 6, we learn that preceding signals do not necessarily have linear effect on precipitation. For one of the preceding predictors for April precipitation, if the vortex center is weak (strong) last September with less (more) precipitation, it is considered linear (or approximately linear) while others are without such relationship. For instance, a low SST may be the strong signal for flood later but a high SST may not be the strong signal for drought afterwards, over the same area of waters. In other words, the SST is non-linearly related with precipitation over that part of the ocean. There are two linear or approximately linear preceding predictors of precipitation in May, i.e. northern boundary of the subtropical high and the intensity of the Indian-Burmese trough in preceding October and November, respectively while there are non-linear predictors only in June. Here in the work, strong signals are not sought with the correlation coefficient method that is generally used. It can only help in identifying linear predictors at the expense of non-linear ones. Application of composite analysis for months of drought and flood makes up the deficit to some degree.

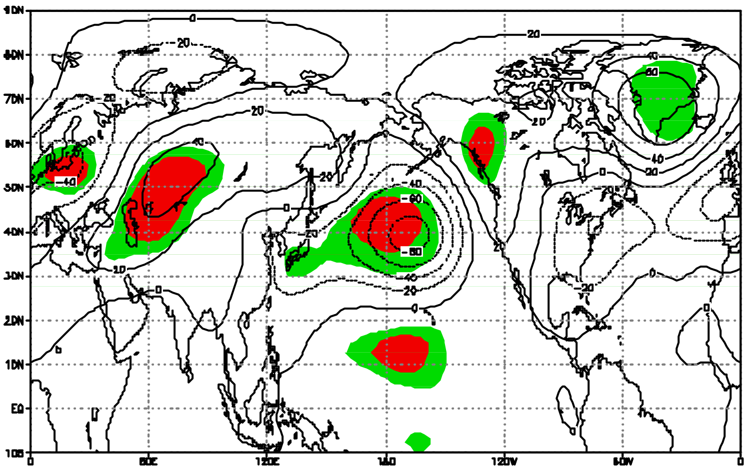

Fig.7 500-hPa composite geopotential height field of preceding February for much less raining April.

4.2 *Classification of preceding signals*

Depending on the results of retrospective forecast of historical years, the preceding signals can be divided into three groups. Group One: When the signal reaches or surpasses the critical value, some kind of anomalous precipitation month is certain to appear afterwards. Group Two: When it reaches or surpasses the critical value, there may be a kind of anomalous precipitation (like floods) or normal conditions afterwards while it is highly unlikely that another anomalous conditions (like droughts) would appear. Group Three: When it reaches or surpasses the critical value, it is very probable that an anomalous precipitation month would appear later while it is also likely that normal conditions or another anomalous state would occur, though with low probability.

Tabs.1 & 2 give the groups of strong signals and rates of retrospective forecast for obviously more or less rainfall in April (ratio of floods, normal conditions and droughts). From the tables, we know that the preceding signals for April anomalous precipitation are Groups Two and Three. For May (table omitted), preceding signals for obviously more rainfall concentrate in Groups Two and Three and those for obviously less rainfall spread in all of the three groups. For June (table omitted), preceding signals are of all groups whether it is anomalously more or less. Of course, the classification of strong signals may change with the accumulation of data and verification of actual forecast.

4.3 *Application of strong signals of monthly anomalous precipitation in real forecast*

Examining the classified strong signals, one can find that with the appearance of Group One, months of precipitation anomalies (drought or flood) can then be forecast for a later period. The problem now is that even for anomalous months, it is seldom for the Group One signal to appear. When signals in Groups Two or Three appear, one cannot be sure of later appearance of months of precipitation anomalies. In addition, strong signals are not necessarily at or above the critical level for historical months of precipitation anomalies. In contrast, a limited number of strong signals (of Group Two or Three) may be at or above it for historical months of normal precipitation. How should we cope with such variability in real forecasting?

With investigation and verification, we have summarized forecasting tools for individual months.

4.3.1 Forecast conditions for April precipitation anomalies and results of retrospective forecast for the 40 years

If there are 5 or more than 5 signals indicating flood, a flood month is forecast. The result: one false alarm and one miss. If there are 4 or more than 4 signals indicating drought, a drought month is forecast. The result: one false alarm but no miss.

4.3.2 Forecast conditions for May precipitation anomalies and results of retrospective forecast for the 40 years

If there are 2 or more than 2 Group Two signals indicating flood, a flood month is forecast. If there are 3 or more than 3 Group Two signals indicating flood but less than 3 signals indicating drought, a flood month is forecast. The result: four false alarms and two misses. If there are 4 or more than 4 signals indicating drought, a drought month is forecast. The result: no false alarm and no miss.

4.3.3 Forecast conditions for June precipitation anomalies and results of retrospective forecast for the 40 years

If there are 2 or more than 2 signals indicating flood, or there is 1 or more than 1 Group One signals indicating flood, a flood month is forecast. The result: no false alarm and no miss. If there are 2 or more than 2 signals indicating drought, or there is 1 or more than 1 Group One signals indicating drought, a drought month is forecast. The result: two false alarms and one miss.

Except for May in which poor forecast performance results from obviously more precipitation, the result is generally good, especially for drought spells in May and flood processes in June when there are neither false alarms nor misses. To add to the success, the method never gives rise to a possibility in which one kind of anomaly (drought or flood) is forecast as the other kind (flood or drought).

Table 1 Strong signals for significantly more rainfall in April and their critical values and rate of retrospective forecast

Classification	Strong signals	Critical anomalies	flood : normal : drought
Group 2 Signals (in preceding years)	polar vortex intensity, September	+3.0	4:6:0
	NW.Pacific 500-hPa field, July	–20.5	6:2:0
	European 500-hPa field, November	–45.8	4:4:0
	Central China OLR field, November	+6.2	2:1:1
	+ N vs. – S in NW.Pacific OLR, July		5:3:0
	N.Pacific SST, December	–0.49	1:3:0
Group 3 Signals (in preceding years, unless noted otherwise)	Pacific polar vortex area, current March	+7.4	6:5:2
	Subtr. high W.ridge point, September	–8.4	7:6:3
	NH polar vortex area, December	–14.3	6:5:2
	NW.Pacific 500-hPa field, current Feb.	–33.8	6:4:1
	North Pole 500-hPa field, September	+39.4	7:2:2

Table 2 Same as Table 1 but for significantly less rainfall

Classification	Strong signals	Critical anomalies	flood : normal : drought
Group 2 Signals (in preceding years)	Asian zonal circulation index, March	+24.5	0:2:5
	Polar vortex intensity, September	–3.6	0:4:6
	Eastern N.Pacific SST, Nov.	–0.40	0:1:1
	Eastern N.Pacific SST, Dec.	–0.50	0:1:1
Group 3 Signals (in current years, unless otherwise noted)	Indian-Burmese trough intensity, Feb.	+3.8	2:5:8
	Asian polar vortex area, last July	+12.9	2:0:6
	N. boundary of subtr. high, last Oct.	–1.6	2:2:6
	500-hPa Europe(–)-Asia(+)-Pacific(–,+) wavetrain, February		1:3:8
	Central Asian 500-hPa field, last July	–26.5	1:3:5
	N.African 500-hPa field, last July	–11.1	1:1:5
	Central/E.Asia 500-hPa field, last Aug.	–24.1	1:0:5

5 CONCLUDING REMARKS

a. When the composite analysis method is used to locate preceding predictors, statistical verification of confidence level and retrospective forecast historical cases are two procedures desirably required. For example, the absolute value of composite anomalies of SST can be very large for waters of eastern equatorial Pacific but fall short of some level of confidence in statistical verification and with low rate of retrospective forecast. It is not useless if used as strong signal.

b. It is not safe to rely on a single strong signal in forecasting. When Group One strong signals appear, forecast will be made that a month of anomalous precipitation occurs at a later time. As it is rare for the signal to appear, we generally have to integrate multiple signals in the prediction.

c. Next is a list of preceding signals for precipitation anomalies in the first raining season of the year: (a) intensity and area of the boreal polar vortex, index of mid-latitude circulation, intensity of Indian-Burmese trough, ridge line, northern boundary and western ridge point of the subtropical high; (b) 500-hPa geopotential height field and OLR field where the East Asian trough locates; (c) geopotential height field and OLR field over the Eurasian continent; (d) European-Asian-Pacific wavetrain in the 500-hPa geopotential height field; (e) OLR field over equatorial eastern Pacific and central North Pacific; (f) SST over the South China Sea, equatorial central Pacific, central / eastern North Pacific.

For waters from key El Niño areas to equatorial eastern Pacific, SST is not a strong signal for precipitation anomalies in Guangdong province but its spring OLR value can be a reliable indicator for obviously less rainfall in May and June.

d. The strong signals summarized here as forecasting tools are used in retrospective prediction of historical cases. Except for poor May results caused by much more precipitation than normal, the work has been successful, especially for the drought in May and flood in June when there is not a single false alarm or miss. It is particularly noted that the forecast does not mistake one kind of conditions (flood or drought) for another (drought or flood).

e. It is necessary to have more verification of the strong signals in future routine forecast and to adjust critical values based on forecast results so that forecast can be improved.

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