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EVALUATION OF DAILY PRECIPITATION IN CHINA FROM ECMWF AND NCEP REANALYSES*

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Abstract Correlation analysis, hidden period analysis and complex Morlet wavelet transform were used with daily rainfall in China from observation, ECMWF(European Centre for Medium-Range Weather Forecast)and NCEP (National Center for Environmental Prediction) reanalyses to evaluate the validation of precipitation estimates. The results showed that Fisher's test and wavelet analysis, specially the latter, are useful tools for statistical analysis of daily precipitation datasets. Daily rainfall data obtained from ECMWF reanalysis are obviously better than those from NCEP reanalysis in terms of long period daily mean, local correlation, variation amplitude, fluctuation pattern and frequency. Although there is still room for improvement, ECMWF reanalysis is the best available dataset with global coverage and daily variability. In both of the reanalyzed daily mean precipitation fields, the higher estimations of Sichuan Basin rainfall are most likely caused by the topography of the basin, where small scale mountains in the southeast could not be represented by the reanalysis grid points, the typhoon and summer monsoon rainbelt could reach this region.

Key words: daily precipitation, ECMWF and NCEP reanalyses, wavelet transform

INTRODUCTION

Weather forecasting as a major subject in atmospheric science has developed since the 1950's into a modern science. Numerical weather forecast models are extensively and frequently used to check the theories, rule out the old incorrect ones and present new ideas, and suggest methods and projects for study. Precipitation is the most difficult climate component for models to forecast, because it involves microcosmic and macroscopic physical processes; and so, is closely related to both large and small scale weather systems; and is influenced by the atmospheric thermodynamics and local topography. Precipitation also has strong economic impacts and extraordinary importance in climate (specially monsoon) study. Recent studies showed that ocean and atmosphere reinforce each other, so that perturbation can grow to climatological importance (Latif, 1997) and precipitation most likely plays a major role in formation of midlatitudinal interdecadal climate cycles in the North Pacific (Cui et al., 1998).

Operational analyses are often not suitable for the detection of climate variability because of numer-

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ous changes in the analysis/forecasting schemes. These changes may lead to variations of some sensitive variables which are larger than the signal of climate variability itself. Several centers are therefore creating analyses with frozen schemes for application to historical data. However, the precipitation is not analyzed but is obtained from an atmospheric forecast model which provides the first guess field or which is run every day. A key question is how realistic are precipitation estimates created with the analysis scheme. Arpe et al.(1997)[1)] studied this problem and concluded that ECMWF reanalysis(ERA) data set is the best available if global coverage and daily variability is required, although there is room for improvement. The wavelet transform technique introduced and formulated by Morlet et al. (1982) is applied widely in signal and image processing using various wavelets or "mother wavelet" functions. In meteorology, Marhrt (1991), Kumar and Foufoula-Georgiou (1993), and Gamage and Blumen (1993) applied orthogonal (or Haar) wavelet analysis to research of boundary layer meteorology, rainfall processes, and cold fronts, respectively. They maintained that wavelet analysis shows structures on different time (or spatial) scales at different time (or spatial) locations.

China is situated in the active East Asian monsoon region vulnerable and sensitive to global climate variations, so evaluation of rainfall estimates in this region is of special importance for reanalysis validation. In the present paper, correlation analysis, hidden period analysis and complex Morlet wavelet transform (Spedding et al. 1993) are used to study data on observed daily rainfall in China, and ECMWF and NCEP reanalyses are used to evaluate validation of their precipitation estimates.

DATA AND PROCESSING

In this study, we evaluate the daily precipitation in China by ECMWF and NCEP schemes. The datasets used and processed were as follows:

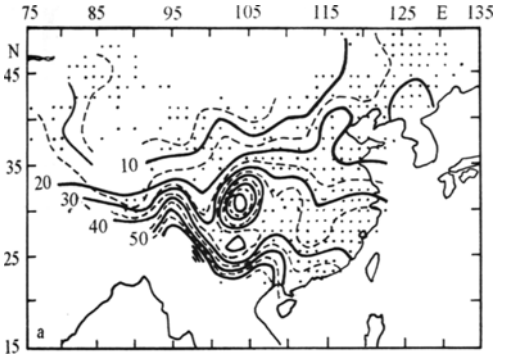
The observed local daily precipitations at about 600 stations over China for the period of 1980 through 1993 (1 May to 31 December, 245 d/a) were supplied by the China National Meteorology Bureau. Fields of daily precipitation estimates in the Asian monsoon region on $1.125° \times 1.125°$ and $1.825° \times 1.825°$ grids from ECMWF and NCEP reanalyses, respectively, for the same period were processed and supplied by Dr. Arpe of the German Max-Planck Institute for Meteorology. As simple space correlation analysis with observed daily precipitations showed that over most positions in China, local daily precipitations nearby are more closely correlated than those far away from each other(not shown); as grid daily precipitation estimates from weather forecast models can only be treated as a kind of space average of possible local rainfall; and as the rainfall observatories are partly changed year by year, the datasets were processed this way: we selected 475 and 220 grid points with local rainfall observatories nearby (marked in Fig.1 and Fig.2) for two kinds of grids, and then calculated the inverse squared distance-weighted averages of observed precipitation at these grid points, respectively.

ANALYSIS METHODS AND RESULTS

In the present paper, time field correlation analysis, frequency field spectrum analysis, Fisher's test and wavelet analysis are used for all of these grid points or some typical points to evaluate daily precipitation estimates in China from the ECMWF and NCEP reanalyses.

1) Arpe, K., Stendel, M., Behr, H., 1997. Evaluation of the ECMWF re-analysis with emphasis on the precipitation. (Manuscript)

Figs 1 and 2 show the estimated and observed daily mean rainfall in unit of 0.1 mm/d at ECMWF and NCEP grids, respectively. We can see that although there is a higher daily mean region centered at Sichuan Basin (31°44' N, 103°30' E) in both of the reanalysis daily mean precipitation fields(Figs 1b, 2b), which do not appear in the observed daily mean precipitation field (Figs 1a, 2a), in other regions, especially in the East Asian monsoon region, the mean field from the ECMWF reanalysis is roughly consistent with observation but that from NCEP reanalysis is rather higher than observation, specially in the Southern Coast zone. Calculation of the field of correlation between the NCEP or ECMWF estimate and observation showed that the latter were 5 – 10 percent higher than the former almost everywhere (not shown).



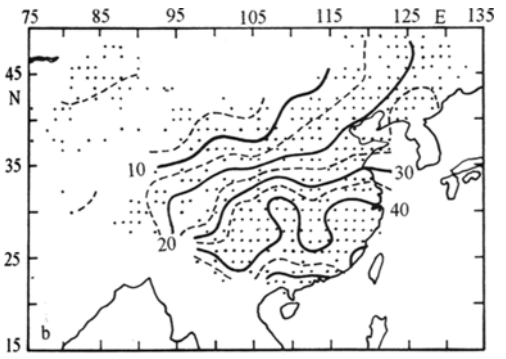
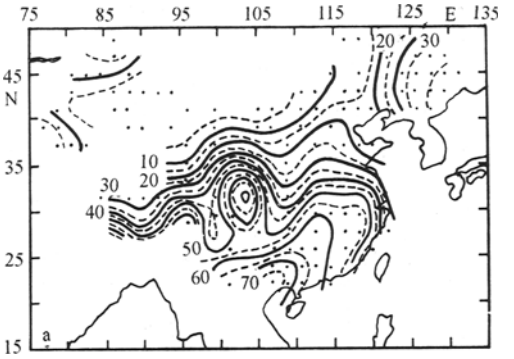


Fig.1 Daily mean rainfall in China during 1980 – 1993 (May – Dec.)
a. ECMWF reanalyzed; b. observed



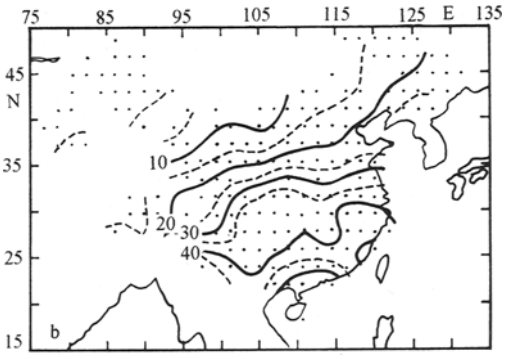


Fig.2 Daily mean rainfall in China during 1980 – 1993 (May – Dec.)
a. NCFF reanalyzed; b. observed

To evaluate how realistic are the different periods precipitation fluctuations created by reanalysis schemes, we selected three typical points, located at the southern coast zone(112.505°E and 21.94°N), Changjiang Valley(113.63°E and 30.94°N) and Bohai Coast zone(118.13°E and 39.94°N) respectively, for hidden period calculation and wavelet transform.

We used a SR. STIEHP program from SASD statistical software provided by the Calculation Center of the Chinese Academy of Sciences for hidden period analysis with Fisher's test. The results

are listed in Table 1.

Table 1 Hidden periods (day, in order of precision) calculated by SR. STIEHP

Position	Data type	Period # 1	Period # 2	Period # 3
Southern Coast	Observed	241	251	234
	ECMWF	241	251	234
	NCEP	241	237	233
Changjiang Valley	Observed	244	236	98
	ECMWF	245	237	122
	NCEP	238	242	233
Bohai Coast	Observed	233	238	91
	ECMWF	239	234	244
	NCEP	122	233	239

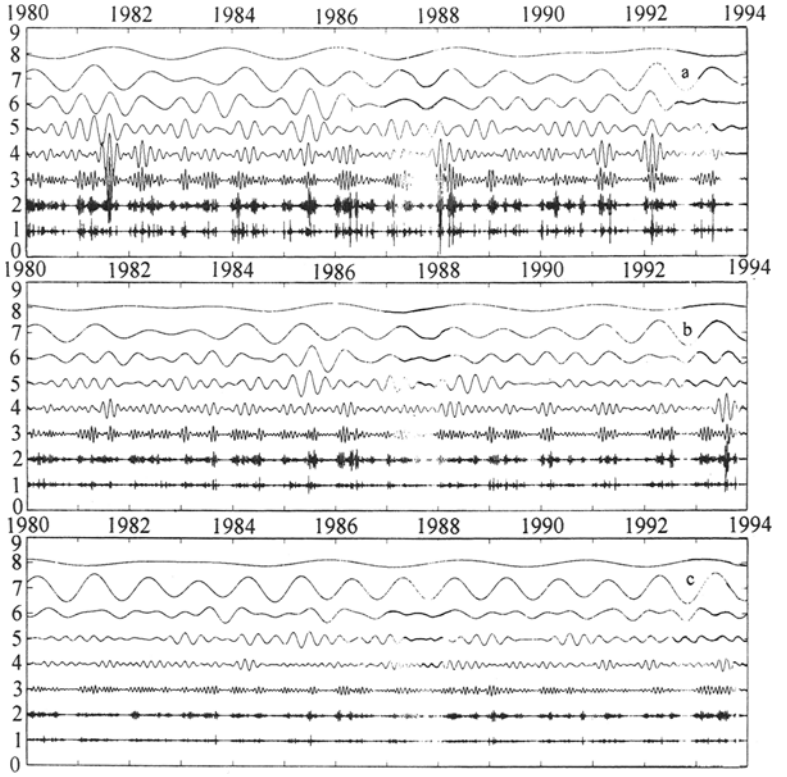


Fig.3 Wavelet transform for the southern coast daily rainfall with 8 periods
a. observed; b. ECMWF reanalyzed; c. NCEP reanalyzed

As only 8 months (245 days) data were used per year, Table 1 shows that in the southern coast, while only quasi-annual cycle is identified by Fisher's test from observation, which is exactly and well estimated by ECMWF and NCEP schemes, respectively; in the Changjiang Valley, both quasi-annual and semi-annual cycles were identified by Fisher's test from observation, and were

well estimated by ECMWF scheme but only the quasi-annual cycle was well estimated by the NCEP scheme; in the Bohai coast zone, both quasi-annual and semi-annual cycles were identified by Fisher's test from observation, and were well estimated by the NCEP scheme but only the quasi-annual cycle was well estimated by the ECMWF scheme. Therefore, from the viewpoint of hidden period analysis, the daily precipitation data set from ECMWF reanalysis was also better than that from NCEP reanalysis.

Wavelet analyses at the selected 3 points showed that in the southern coastal zone, the amplitude of wavelet transform anomalous precipitation was large(- 80—160 mm/d) from observation, small(- 70—100 mm/d) in ECMWF estimate and rather small (- 80—80 mm/d) in NCEP estimate. The expansion time series with 8 periods(2, 7, 14, 30, 60, 122.5, 245 and 490 days) from observation and ECMWF estimate were similar to each other, specially for interannual and interseasonal variations(Figs 3a: 5-7 and b: 5-7), and even some strong or weak monsoon years could be represented by ECMWF scheme; but the interannual variation from NCEP estimate appeared too regular to be true(Fig. 3c: 7). In Changjiang Valley, the amplitude of wavelet transform anomalous precipitation was small (- 70—100 mm/d) in observation, rather small (- 30—45 mm/d) in ECMWF estimate and small (- 80—80 mm/d) in NCEP estimate; but the wavelet transform anomalies from observation and ECMWF estimate were still similar to each other and even some strong or weak monsoon years could be represented by the ECMWF scheme also (but not by NCEP estimate) (not shown); in the Bohai Coast zone, the amplitude of wavelet transform anomalous precipitation was small(- 40—90 mm/d) in observation, smaller(- 45—55 mm/d) in ECMWF estimate and very small (- 35—40 mm/d) in NCEP estimate. However the three wavelet transform anomalies from observation and ECMWF and NCEP estimates were somehow similar and even some strong or weak monsoon years could be represented by both ECMWF and NCEP schemes (not shown). Therefore generally speaking, the wavelet analysis results also showed that the daily precipitation from ECMWF reanalysis was usually better than that from NCEP reanalysis in terms of variation amplitude, fluctuation pattern and frequency in Chinese regions.

DISCUSSION AND CONCLUSION

Of special interest is that the amplitudes and patterns provided by wavelet transform from observational rainfall data sets of 1.125° × 1.125° and 1.825° × 1.825° resolutions were almost the same (not shown). It means that rainfall fluctuations at different time scales were of large scale characteristics and independent from the space resolution, on which the analyzed rainfall data sets were space-averaged from observations.

Both of the reanalyzed daily mean precipitation fields had a special region located at the Sichuan Basin with higher rainfall estimated by reanalysis schemes. To get an insight into this problem, we carried out wavelet analysis of this region and the results showed that although the estimated and observed amplitudes of transformed anomalous precipitation were close to each other, the interseasonal variation of observed rainfall had no obvious two peak structure indicating that the summer monsoon and typhoon rainbelt could hardly reach this region (Fig.4a: 6) but the ones estimated by ECMWF and NCEP schemes, specially the latter, had clear two peak structures as a result of the summer monsoon onset and typhoon activity rainfall (Fig.4b: 6 and Fig.4c: 6). Therefore this exception was most likely caused by the basin topography, where small scale mountains in the south-

east could not be represented by both of the reanalysis grid points, so that the basin appeared to be a land gulf monsoon and typhoon rain belts could go deep into this region.

The observed daily precipitation data were processed by weighted average in the present paper. It is reasonable because in most positions in China local daily precipitation nearby are 40% – 70% correlated. It is necessary also since weather forecast model output can only be understood as a kind of space average of possible local variables and the rainfall observatories are partly changed year by year.

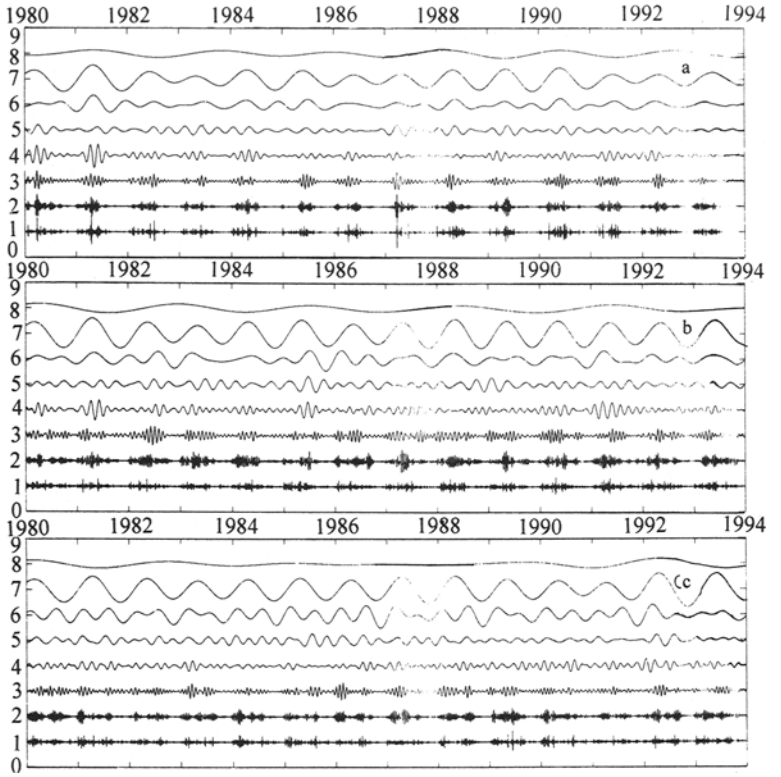


Fig.4 Wavelet transform for the Sichuan Basin with 8 periods
a. observed; b. ECMWF reanalyzed; c. NCEP reanalyzed

Our results showed that Fisher's test and wavelet analysis are useful tools for statistical analysis of daily precipitation datasets. The latter is very powerful for showing rainfall structures on different time scales at different time locations. The traditional Fourier transform provides information only on the frequency, without its variation in time (or position) on a single frequency in the signal series analyzed. The wavelet transform provides localized time and frequency information without requiring the time series to be stationary. It transforms a one-dimensional function of time into a two-dimensional function of time and frequency or, equivalently, scale.

Up to now, there are still many places, such as the regions over seas, high mountains and pla-

teaus, in which there are hardly any rainfall observations available. However these regions may be important for climatological studies, so that reanalysis datasets came into use in recent years. Our results showed that in Chinese regions the daily rainfall from ECMWF reanalysis were obviously better than that from NCEP reanalysis in the aspects of long period daily mean, variation amplitude, fluctuation frequency and pattern. Although there is still room for improvement, ECMWF reanalysis is the best available data with global coverage and daily variability.

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