Article ID: 1006-8775(2008) 01-033-04

INTERANNUAL AND INTERDECADAL VARIATIONS OF LARGE-SCALE MOISTURE SINKS OVER GUANGDONG

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Abstract: The interannual and interdecadal variations of moisture sinks over Guangdong are discussed with the NCEP/NCAR reanalysis data and observed precipitation data from 1958 to 2004. The results indicate that climatically, the amount of precipitation is larger than that of evaporation in spring and summer. Precipitation and evaporation almost balance each other in autumn and the amount of evaporation is larger than that of precipitation in winter. The interannual signal dominates the variations of moisture sinks in all seasons in Guangdong with a period of three-year oscillation in autumn and winter. Remarkable interdecadal signal characterized by a period of three-decade oscillation can be identified for winter and spring from seasonally averaged moisture sink data and from annually moisture data, with variance percentage larger than 40%. This result indicates that Guangdong is at a transitional stage from positive anomalies to negative anomalies. The moisture sink anomalies in winter and following spring over Guangdong are usually in-phase. Besides, there exist periodic oscillations with periods of 10 to 15 years in summer and autumn. The positive (negative) anomalies of moisture sinks over Guangdong are due to the intensified (weakened) moisture from the tropical areas being transported to the Southern China, accompanied by an intensified (weakened) moisture convergence.

Key words: moisture sinks; interannual and interdecadal variations; Guangdong

CLC number: P434 **Document code:** A

1 INTRODUCTION

In Guangdong, natural disasters, especially those caused by drought and flood, are especially serious. According to statistics, floods and droughts have taken place in more than 90% and 80% of the years respectively since the 17th century. They differed only in coverage and extent of damage [1]. In recent years, damage and potential threat brought about by droughts and floods are still serious and extremes of such cases include sustained dry spans in autumn and winter in 2004-05 and 2005-06. It is therefore an issue of emergency and social implication to study the budget of water vapor over the area of Guangdong. Up till now, there have been many works on the temporal and spatial distribution of droughts and floods in the province and possible factors responsible for them [2-8]. Most of the works, however, base on rainfall analysis. It should be pointed out that the exchange of water resources between the atmosphere and land include water vapor that evaporates into the atmosphere from ground surface in addition to the amount of water precipitating to it from the atmosphere, and the difference between them is the real net amount of water vapor exchange between land and atmosphere. It is then more accurate to study the variations of large-scale water resources in Guangdong using the difference between precipitation and evaporation, i.e. the atmospheric moisture sink.

Up till now, research on the interannual and interdecadal variations of atmospheric moisture sinks is rarely documented for individual seasons of the province. It is the purpose of this work to study temporal and spatial variations of large scale atmospheric moisture sinks and water vapor flux transports relating to the anomalies of the atmospheric moisture sinks using multi-year data.

2 DATA AND METHODS

Received date: 2006-10-19; **revised date:** 2008-02-04

Foundation item: Natural Science Foundation of Guangdong Province (05003339)

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The data used in this work include daily values of u, v, ω and q from the reanalysis data of NCEP/NCAR for 1958 – 2004, which has a horizontal resolution of 2.5°×2.5° and 12 vertical layers of mandatory isobaric surfaces. The specific humidity q is zero above the level of 300 hPa. On the basis of daily data for the isobaric surfaces above, the moisture sink Q_2 can be determined from the water vapor equation through reverse calculation [9] and the following can be obtained through vertical integration:

$$\langle Q_2 \rangle = \frac{1}{g}\int_{300}^{P_s} Q_2 dp \approx L(P-E) \qquad (1)$$

Specifically, P is rainfall and E the turbulent vapor flux from surface (evaporation), P_s the surface pressure, and g the gravity acceleration. It is known from Eq.(1) that $\langle Q_2 \rangle$, which is integrated through the whole column of the atmosphere, shows the net exchange of moisture between the atmosphere and underlying surface.

As shown in the calculation, $\langle Q_2 \rangle$ in seven of the gridpoints in and around Guangdong (Fig.1) are in significant positive correlation for the four seasons and the whole year (table omitted), which pass the test of the 0.05 significance level, revealing in-phase variations for all of these gridpoints. The mean values of $\langle Q_2 \rangle$ for the seven gridpoints can then be used to represent the average of moisture sink amount of Guangdong. In addition, the mean rainfall amounts from seven weather stations within the province for 1958 – 2004 are used to represent the large-scale mean rainfall amount of Guangdong. Spring is the months of MAM, summer JJA, autumn SON, and winter DJF.

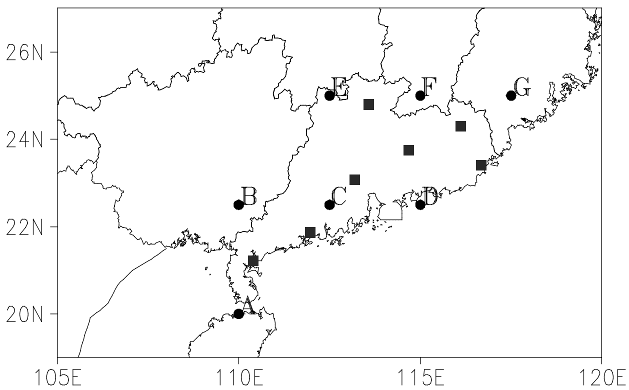

Fig.1 The distribution of gridpoints ('●') and sites of observation ('■') used in the computation.

3 CLIMATOLOGICAL MEAN OF <Q2>, P, AND E FOR THE SEASON AND YEAR

Tab.1 gives the climatological mean of $\langle Q_2 \rangle$, P, and E for the four seasons and the whole year in Guangdong in 1958 – 2004. It can be seen that the underlying surface obtains more water resource than loses in spring and summer. However, the situation is reversed in winter. The precipitation and the evaporation are quite equivalent to each other in autumn. For the mean over the 47 years, about 70% of the annual rainfall in the province is evaporated back to the atmosphere, showing the important role being played by regional evaporation in the inner cycle of atmospheric moisture.

4 INTERANNUAL AND INTERDECADAL VARIATIONS OF MOISTURE SINKS

To study the interannual and interdecadal variations of moisture sinks in Guangdong, the method of harmonic analysis is used in this work to run scale decomposition for the frequency domain of moisture sinks. The compositions with periods shorter than 8 years are the interannual component and those with periods longer than 8 years are the interdecadal component [10].

In spring, the variance of the two components take up 54% and 46% of the total variance, respectively, indicating that the variance of the interannual component is dominant and that of the interdecadal component is also quite remarkable. It is known from the curve of the anomalous variation of the former (Fig.2a) that there are larger amplitudes in the period before the mid-1970s than in recent two decades. On interdecadal scale (Fig.2b), the moisture sink tends to increase over the past few decades though its interdecadal component is currently in a transition from positive phase to negative phase.

In summer, the variance of the interannual and interdecadal components of moisture sinks take up 65% and 35% of the total variance respectively, showing a dominant role of the former component. Its amplitude begins to increase after 1993 (Fig.2c). On the interdecadal variation (Fig.2d), there are significant periods of 10 – 15 years as shown in an analysis of power spectrum. The moisture sink shifts from the negative phase from the late-1970s to early 1990s to the positive phase after early 1990s, making a favorable climatic background for the occurrence of summer floods over the past ten years and more.

In autumn, the variance of the two components take up 73% and 27% of the total variance, respectively, showing that the variation of moisture sinks in the season is mainly dependent on that of the interannual component. There are significant quasi-3-year periods in the curve of the interannual variation (Fig.2e) and its amplitude tends to decrease after mid-

1980s. The component of interdecadal variation (Fig.2f) is dominated by significant periodic change of 10 to 15 years. It is then known that moisture sinks tend to decrease on the long term.

In winter, the variance of the two components take up 53% and 47% of the total variance, respectively, showing that both of them contribute significantly to the variation of moisture sinks. For the interannual variation (Fig.2g), there is a significant variation period of about 2.7 years. For the interdecadal component (Fig.2h), there is obvious long-period variation. If a prediction is to be made following the curve tendency, the period from the present to the time 20 years from now will be in the phase of negative anomalies, which are favorable for drought to appear.

Tab.1 Climatological mean of <Q_2>, P, and E for the four seasons and the whole year in Guangdong in 1958 – 2004 (unit: mm)

	Spring	Summer	Autumn	Winter	Annual value
Moisture sink <Q_2>	204	387	18	-78	531
Rainfall P	555	758	286	147	1746
Evaporation E	351	371	268	225	1215

Note: 1) The unit of <Q_2> has been converted from W/m^2 to mm/season (year), by which 28.9 W/m^2 is equivalent to 1 mm/d. 2) E is determined from P and <Q_2> based on Eq.(1).

In addition, as shown in calculations, there is significant positive correlation between the variations of moisture sinks of winter and spring in Guangdong. The correlation coefficient is 0.6 for the interannual component and 0.56 for the general series without regard to time scales, showing that sustained drought or flood may occur very likely from winter through spring in Guangdong.

On the basis of a composite analysis of the anomalous field of moisture flux in both strong and weak years of moisture sinks during different seasons in Guangdong (figure omitted), it is known that anomalously strong (weak) atmospheric moisture sinks are caused by strengthened (weakened) moisture fluxes

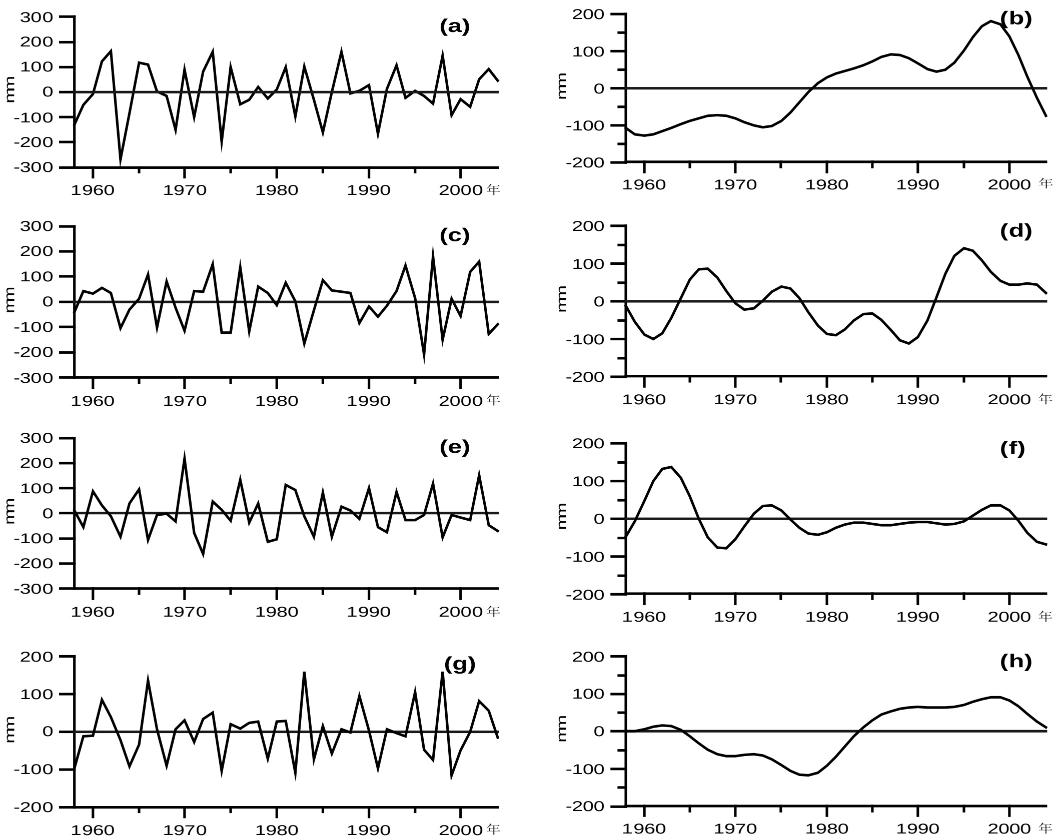

Fig.2 The interannual (left panels) and interdecadal variations of vertically integrated atmospheric moisture sinks averaged over Guangdong. Moisture sinks for spring, summer, autumn and winter are shown from top to bottom panels.

transported from tropical low latitudes to northern South China Sea and South China, in addition to the strengthened (weakened) convergence of the fluxes, though differences exist with the anomalous distribution patterns for each of the seasons.

For analyses of other aspects, refer to the Chinese edition of the journal.

5 SUMMARIES

The following conclusions can be drawn from the analysis of the interannual and interdecadal variations of moisture sinks and the relationships between the anomalies of moisture sinks and changes in moisture fluxes.

(1) From the viewpoint of climatological mean, the atmosphere transports more moisture to the ground surface in spring and summer, rainfall is on comparable magnitude with the amount of evaporation in autumn, and the ground surface transports more moisture to the atmosphere in winter, in Guangdong.

(2) The variance of the interannual component of the moisture sink plays a dominant role in all seasons, though the variance of the interdecadal component has a larger contribution in winter, spring and the whole year and mostly on long scales of more than 30 years. It is now in a transition changing from the positive phase to the negative phase, indicating a dryer tendency in Guangdong in the winter and spring to come. A 10-15-year significant period exists in the interdecadal component of the moisture sink in summer and autumn while a quasi-3-year period is with the interannual component in autumn and winter. In the province, drought and flood are very likely to last continuously from winter to spring.

(3) The anomalously strong (weak) atmospheric moisture sinks for all seasons of Guangdong are resulted from the strengthened (weakened) transport of moisture fluxes from tropical low latitudes to northern South China Sea and South China and their associated strengthened (weakened) convergence, though difference is found in the pattern of anomalous distribution between individual seasons.

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Citation: JIAN M Q, CHEN W X and QIAO Y T et al. Interannual and interdecadal variations of large-scale moisture sinks over Guangdong. *J. Trop. Meteor.*, 2008, 14(1): 33-36.