The comparative analysis of pre-flood season precipitation and water vapor transportation over guangdong before and after "Hiatus"

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Abstract. Relation between pre-flood season precipitation and water vapor transport in Guangdong was analysed by using the monthly observed precipitation data, reanalysis data of ERA, NCEP/NCAR, and OAFlux during 1979-2015, and the differences between before/after global warming "hiatus" were studied. Results showed that, after "hiatus", during the pre-flood season, skin-temperature, evaporation, and the absolute humidity over the ocean near to Southern China was decreasing, and over land was increasing. So, the water cycle over the ocean had slowed down and over land had speed up. The absolute humidity difference between the ocean and the land was reduced. However, at the same time, the total wind speed in Southern China had decreased. So, the water vapor transport from the ocean to the land had reduced. The Eastern Guangdong had an anomalous convergence of meridional water vapor transport, led to increased precipitation; but in Western Guangdong, there was no meridional water vapor transport, so precipitation had a decrease.

1. Introduction
Since the industrial revolution, with the increase in greenhouse gases in the atmosphere, global temperatures continue to rise, however, since 1998, global warming has stagnated (hiatus) [1-4]. The temperature is one of the basic factors of evaporation, so sea/land surface temperature anomaly caused by hiatus will affect the evaporation process, affecting the spatial distribution of the source of water vapor, and precipitation. However, the precipitation over Southern China is very abundant, the pre-flood season (April, May and June) is the main period of droughts and floods in Southern China [5]. The most concentrated and most direct source of water vapor, during the pre-flood season, is the South China Sea [6-8]. Based on Shaohua’s [9-11] study the water vapor mainly comes from the Bay of Bengal, followed by the South China Sea and the Western Pacific.

Then, with the emergence of global warming, the temperature over Southern China and its adjacent waters will change. The water cycle, such as sea / land evaporation will change. The water vapor transport from the Bay of Bengal, the South China Sea and the Western Pacific to Southern China Will change. They will affect the pre-flood season precipitation in Guangdong. This work study the influence of water vapor transport change on the pre-flood season precipitation anomaly in Guangdong and compares the water vapor transport before and after the global warming “hiatus” using precipitation observation data from 86 stations in Guangdong, and reanalysis model output from ERA, NCEP/NCAR and OAFlux from 1979 to 2015.
2. Data
The data used in this article are:
1) the pre-flood seasonal (April, May, June) precipitation data of the 86 stations in Guangdong, provided by the Guangdong Meteorological Bureau;
2) the monthly water vapor divergence and the water vapor flux reanalysis data of ERA-Interim, 0.75°×0.75°, 1979-2015; NCEP/NCAR monthly surface temperature, potential evaporation rate, absolute humidity, full wind speed reanalysis data, 2.5°×2.5°, 1979-2015; OAFlux monthly ocean evaporation reanalysis data, 1.0°×1.0°, 1979-2015; provided by ECMWF, NOAA, WHOI data center.

3. Characteristics of water vapor transport and precipitation before/after "hiatus" over Southern China and its adjacent waters

3.1. Annual average surface temperature variation in Southern China and its adjacent waters
Here we will discuss surface temperature variation. Figure 1 shows the annual average skin temperature of Southern China and adjacent waters during 1979-2015, 1998 is a turning point. Table 1 shows, the average annual skin-temperature of Southern China and adjacent waters showed an increasing trend, the rate of land temperature increase (0.0018°C/year, y=0.0018x+29.349) was greater than that of the ocean (0.0008-0.0013°C/year). From the stage, 1998 was a turning point, temperature rose before it and then decreased. The sea and land were all warming during 1979-1998, and the warming rate in Southern China (0.003 degrees°C/year) was larger than the waters warming rate (0.0008-0.0028°C/year); during 1999-2015, the warming rate of the Bay of Bengal (0.0012°C/year, y=0.0012x+30.041) increased, but in Southern China, the South China Sea and the Western Pacific, the temperature decreased. That is, after 1998, the sea/land warming rate had changed. During 1979-1998, the warming rate of land was greater than that of the waters; during 1999-2015, the warming rate of the Bay of Bengal continued to increase, but Southern China, the South China Sea and the Western Pacific appeared to cool down, that is, the global warming hiatus had shown in Southern China and the adjacent waters.

![Figure 1. The trend of annual mean skin-temperature in southern China and adjacent waters during 1979-2015](image-url)
Table 1. The increase rate of annual mean skin-temperature in Southern China and adjacent waters during 1979-2015.

| Areas                           | Linear trend coefficient 1979-1998 | Linear trend coefficient 1999-2015 |
|---------------------------------|-------------------------------------|-------------------------------------|
| Bay of Bengal (sea, 85-95°E, 4-18°N) | 0.0008°C/year                      | 0.0012°C/year                      |
| South China Sea (sea, 109-118°E, 4-18°N) | 0.0028°C/year                      | -0.0004°C/year                     |
| Western Pacific (sea, 120-160°E, 4-30°N) | 0.0016°C/year                      | -0.0014°C/year                     |
| Southern China (land, 105-120°E, 18-30°N) | 0.003°C/year                       | -0.0002°C/year                     |

3.2. The pre-flood season skin temperature variation in Southern China and its adjacent waters

The main factor affecting the water cycle rate of the pre-flood season is the surface temperature of that season.

Analyzing the variation of the pre-flood season skin temperature in Southern China and its adjacent waters, 1998 was also a turning point (figure, table omitted). During 1979-1998, the warming rate of land was greater than that of the waters, and during 1999-2015, the warming rate of the Bay of Bengal was greater than that of the Southern China area, while the South China Sea and the Western Pacific appeared to be cooler.

3.3. The pre-flood season evaporation variation over Southern China and its adjacent waters

The skin temperature directly affects the evaporation. Analyzing the variation of the pre-flood season evaporation over Southern China and its adjacent waters, 1998 was also a turning point (figure, table omitted). Compared with 1979-1998, during 1999-2015, the evaporation of the adjacent seas had decreased, the evaporation of the Southern China area had increased, the water cycle of land had accelerated, and that of the seas had slowed down.

3.4. The pre-flood season absolute humidity variation over Southern China and its adjacent waters

Evaporation is closely related to the amount of moisture in the air. The transport of water from ocean to land depends on the comparison of their absolute humidity. Analyzing the variation of the pre-flood season absolute humidity difference between southern China and adjacent waters during 1979-2015, 1998 is also a turning point (figure, table omitted). After 1998, the absolute humidity difference between Southern China and the Bay of Bengal, South China Sea, or West Pacific were all decreasing. The absolute humidity of the Bay of Bengal decreased and the absolute humidity increased in Southern China, which led to the decrease of the absolute humidity difference between them. A greater increasing rate of absolute humidity in Southern China led to a decrease in the absolute humidity difference between Southern China and the South China Sea, or the Western Pacific.

3.5. The pre-flood season wind speed variation over Southern China and its adjacent waters

The size of wind speed determines the diffusion ability of water vapor, and it is also the key factor that affects the evaporation directly. Figure 2 shows the difference of first rainy season wind speed over Southern China and adjacent waters between 1999-2015 and 1979-1998. After 1998, the wind speed in the Bay of Bengal increased, the other three regions total wind speed was significantly reduced. The increase of wind speed is conducive to the diffusion of water vapor, while the wind speed decreases, water vapor diffusion ability was reduced.
3.6. The pre-flood season water vapor transmission variation over Southern China and its adjacent waters

The water vapor transport over Southern China before/after "hiatus" was analysed and compared. Compared with 1979-1998, during 1999-2015 (Figure 3a), in Southern China and the northern part of South China Sea, there was abnormal eastward water vapor input, the southern part of the South China Sea had abnormal westward water vapor input. The east wind transport was strengthened, that near southern side of the subtropical high, and then turned, over north of the South China Sea and the west of Guangdong had a northward anomalous water vapor output, over eastern Guangdong, there was a southward anomalous water vapor input (Figure 3b). The divergence field (Figure 3c) of the water vapor flux was calculated, there were all abnormal water vapor divergence over Southern China and the South China Sea.

![Figure 3](image_url)

**Figure 3.** Differences in the distribution of water vapor transmission to east (a) water vapor transmission to north (b) water vapor transmission divergence (c) in the pre-flood season of South China between 1999-2015 and 1979-1998.

The above analysis shows that in the eastern part of Guangdong, there was an anomalous convergence of meridional water vapor transport; but in Western Guangdong, there was no. The whole Guangdong had an eastward water vapor transport anomaly. It can be seen that the change of meridional water vapor transport led to the difference of the spatial distribution of precipitation in Guangdong before/after "hiatus", while the change of zonal moisture transport had little influence on the spatial distribution of precipitation in Guangdong.

3.7. Characteristics of the pre-flood season precipitation before/after "hiatus" in Guangdong

During 1979-2015, the total pre-flood precipitation in Guangdong was on the rise, but not significant (figure omitted). Was there a difference in the spatial distribution of pre-flood precipitation before/after "hiatus" in Guangdong? Figure 4 shows that, compared with 1979-1998, during 1999-2015,
pre-flood season precipitation decreased significantly in Western Guangdong (30-100 mm), precipitation in the Pearl River Delta and Eastern Guangdong (30-150 mm), Qingyuan, Pearl River Delta, Shanwei precipitation increased significantly.

Figure 4. Precipitation difference between 1999-2015 and 1979-1998 in the first rainy season of Guangdong (units: mm)

4. Conclusions:
After global warming "hiatus", after global warming "Hiatus", in the pre-flood season, the skin temperature, evaporation, the absolute humidity over the waters near Southern China was decreasing, the land was opposite, so the water cycle of the ocean had slowed down, the land water cycle was speeding up.

The absolute humidity difference between the waters and land was reduced. At the same time, the total wind speed in Southern China and adjacent sea was decreasing, so the water vapor transport from the sea to the land was reducing.

Eastern Guangdong had an anomalous convergence of meridional water vapor transport, led to increased precipitation; but in Western Guangdong, there was no meridional water vapor transport, led a decrease in precipitation.

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References
[1] Carter B 2014.http://www.telegraph.co.uk/comment/personal-view/3624242/
[2] Franzke C L E 2014 Nature Climate Change 4 423-424
[3] Fyfe J C, Gillett N P 2014 Nature Climate Change 4 150-151
[4] Lovejoy S 2014 Geophys Res Lett 41 4704-4710
[5] "Southern China pre-flood season rainstorm" writing group. Southern China pre-flood season rainstorm. Guangdong science and Technology Press 1986 1-3.
[6] Shen Rugui, Luo Shaohua, Chen Longshun 1980 Proceedings of the tropical weather Conference in 1980 102-111
[7] Zhu Qiangen, Zhou Jun 1982 China Meteorological Press 136-142
[8] Ding Yihui, Hu Guoquan 2003 Acta Meteorologica Sinica 61(2) 129-145
[9] Luo Shaohua 1981 Yunnan people Press **1981** 142-151
[10] Dettinger, M. D R Cayan, H F Diaz, and D M Meko 1998 North–south precipitation patterns in western North America on interannual to decadal timescales *J. Climate* **11** 3095–3111
[11] Najibi, N, N Devineni, and M Lu 2017 Hydroclimate drivers and atmospheric teleconnections of long duration floods: An application to large reservoirs in the Missouri River Basin, *Adv. Water Resour* **100** 153–167 doi:10.1016/j.advwatres.2016.12.004