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Decadal change of January and July persistence of monthly mean 500 hPa geopotential height anomalies

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[1] The decadal variations of January and July persistence of monthly mean 500 hPa geopotential height (GHT) anomalies and associated persistence changes of sea surface temperature anomalies (SSTA) in the tropical oceans are investigated. January persistence of GHT anomalies in the most tropical regions exhibits a decadal change, with a sharp increase after the mid-1970s. This increase has been found to be closely associated with the enhanced persistence of SSTA in the equatorial central-eastern Pacific. July persistence of GHT anomalies in the most tropical regions and Asian regions shows significant decreasing trends between the 1950s and 1990s. The weakened effect of the ENSO on the Indian summer monsoon (ISM) circulation may be a possible reason why July persistence of GHT anomalies in the ISM region has been persistently decreased. The decreased persistence of SSTA in the tropical Indian Ocean, tropical North Pacific and tropical Atlantic possibly contributes to the decrease of July persistence of GHT anomalies in the tropical regions and Asian regions. **Citation:** Ding, R., J. Li, and K.-J. Ha (2008), Decadal change of January and July persistence of monthly mean 500 hPa geopotential height anomalies, *Geophys. Res. Lett.*, *35*, L15702, doi:10.1029/2008GL034137.

1. Indroduction

[2] Under the global warming, obvious changes of atmospheric general circulation and the external forcings, such as sea surface temperature (SST), sea ice extent, etc. have been observed in the recent two decades. Tropical ocean SSTs increased by approximately 0.5°C between 1970 and 2004 [*Agudelo and Curry*, 2004]. Arctic sea ice extent continues to decline as temperatures rise [*Lindsay and Zhang*, 2005]. Geopotential heights get higher in the low latitude and lower in the high latitudes, so the mid-latitude westerlies strengthen since the late 1970s [*Zhu et al.*, 2003]. The changes of atmospheric general circulation and the external forcings could modulate the dynamics of atmospheric internal variability, and in turn may change the atmospheric persistence and predictability. *Tsonis and Elsner* [1997] inferred that the global temperature may be a regulator of climate predictability. They found that higher temperature can result in intensification of the extremes of the hydrological cycle, in enhanced convective activity and other changes that can alter the spatial variability of the climate system and thus its predictability. Recent studies have found that extreme weather and climate events occur more frequently with the continuing global warming [*Zhai and Pan*, 2003; *Schär et al.*, 2004; *Webster et al.*, 2005]. To a certain extent, this will cause the weather and climate forecasting to become more difficult. But on the other hand, the increase of SST variability over the tropical Pacific can enhance the atmospheric seasonal predictability [*Gu and Philander*, 1997; *Knutson et al.*, 1997; *Kang et al.*, 2006]. Due to the differences between the responses of the internal climate variability and external forcings to the global warming in different seasons and different regions, decadal change of climate predictability shows different seasonal and regional characteristics [*Goswami*, 2004; *Nakaegawa et al.*, 2004]. However, up to now, few investigations have been performed investigating the decadal change of climate predictability in different seasons from a global perspective. The persistence of monthly mean circulation anomalies is closely related to the monthly mean predictability. High persistence is favorable for high predictability. The aim of this study is to investigate the decadal-scale variations of the persistence of monthly mean 500 hPa geopotential height (GHT) anomalies in January (winter) and July (summer) and to shed light on possible relationships with the persistence changes of SST anomalies (SSTA) in the tropical oceans.

2. Data Used and Methodology

[3] The datasets used in this study include monthly mean 500 hPa GHT fields from NCEP/NCAR reanalysis data (1948–2005), monthly mean SST fields from version 2 of NOAA Extended Reconstructed SST data (1854–2005), the East Asian summer monsoon index (EASMI) and the South China Sea summer monsoon index (SCSSMI) (1948–2007) [*Li and Zeng*, 2002, 2005]. Prior to the analysis, the annual cycle and linear trend have been removed from all data to obtain the monthly mean 500 hPa GHT anomalies, SSTA and summer monsoon indices anomalies. Lagged correlation analysis is used to measure the persistence of monthly mean 500 hPa GHT anomalies and SSTA, which is defined as the number of lagged months of a significant correlation at the 0.05 level between the time series of the current month (January/July) and the time series of a succeeding lag month in a given length of period. Because January and July persistence are possibly beyond one month, we have to test the significance of persistence correlation many times. This will result in a multiple testing problem. To reduce the problem of falsely positive results due to multiple testing, the Bonferroni corrections for multiple testing is applied, which is a method to adjust the level of significance when

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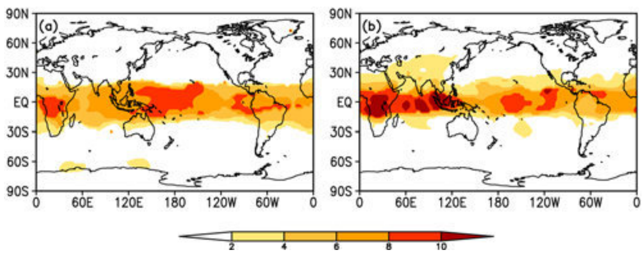

Figure 1. The average (a) January and (b) July persistence (in month) of monthly mean 500 hPa GHT anomalies during 1948–2005.

multiple testing is made [*Benjamini and Hochberg*, 1995]. To examine the decadal variation of the persistence, we perform a moving lagged correlation analysis (MLCA) with time series of 500 hPa GHT anomalies and SSTA. With this analysis, January and July persistence are determined within a 19-year window that is shifted gradually (by 1 year) from 1948 to 2005. The time axis indicates the middle year of the 19-year moving window. As an example of MLCA, the persistence of "January in year $(a + b)/2$" means the lagged correlation between Januaries and succeeding Februaries, Marches, etc until the significance disappears during a 19-year period from year a to year b. Besides, the moving t-test technique (MTT) is employed to detect possible decadal change in a time series [*Xiao and Li*, 2007].

3. Results

[4] Figures 1a and 1b show the global distributions of the average January and July persistence of 500 hPa GHT anomalies during 1948–2005, respectively. It is shown that January and July persistence both are largest in the tropics, and decrease quickly from the tropics to middle-high latitudes of Southern and Northern hemispheres. January persistence in the tropics is beyond 4 months with the maximum value exceeding 8 months. However, January persistence in the mid-high latitudes is only 1~2 months. July persistence in the tropics is higher than January one with the maximum value exceeding 10 months. Besides the tropics, July persistence in the West and Central Asia as well as China is beyond 2 months, and is also higher than January one. In the high latitudes of two hemispheres, July persistence has no obvious change compared with January one. The following analysis will mainly focus on investigating the variations of January and July persistence over the regions with high persistence.

[5] To investigate the long-term trends of January and July persistence of 500 hPa GHT anomalies, Figures 2a and 2b show the linear trend coefficients of January and July persistence, respectively. It is shown that there exist obvious differences between the distributions of linear trend coefficients of January and July persistence. January persistence increases significantly in the most tropical regions, but decreases significantly in Antarctic (Figures 2a). However, with the exception of equatorial eastern Pacific, July persistence decreases significantly in the most tropical regions including the tropical Atlantic, tropical Africa, and tropical western Pacific. In addition, July persistence in the most Asian regions including India also shows significant decreasing trends (Figures 2b). This result is in agreement with the studies of *Goswami* [2004], who found that the potential predictability of the Indian summer monsoon (ISM) during 1980s and 1990s has decreased by a factor of two compared to its values during 1950s and 1960s.

[6] We choose two regions, the tropical Eastern Hemisphere (0°E~180°E, 10°S~10°N) and tropical Western Hemisphere (140°W~0°W, 10°S~10°N), with significant increasing trends in Figure 2a. Figure 3a illustrates the variations of area-averaged January persistence in these two regions. It is found that January persistence in the tropical Eastern Hemisphere displays nearly consistent temporal variations with that in the tropical Western Hemisphere. By employing the MTT, we found that January persistence in both regions undergoes a distinct decadal change during the mid-1970s. Compared with earlier period (1957–1975), January persistence in both regions in the period 1980 to 1996 is significantly higher. Consistent

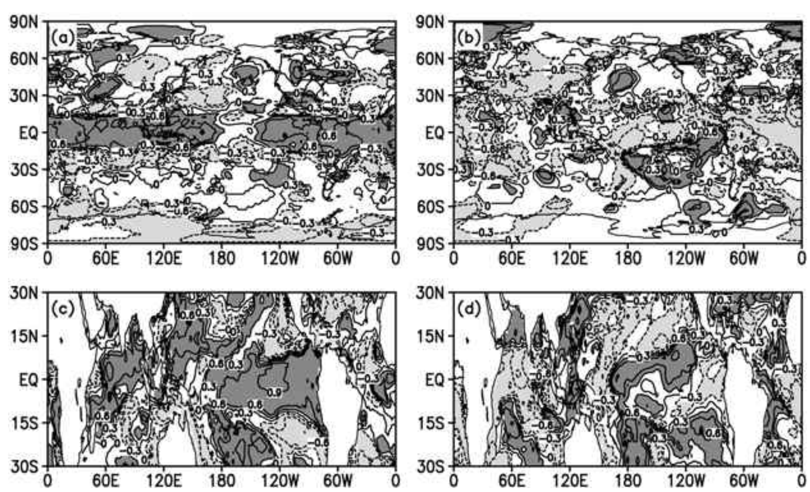

Figure 2. (a) Linear trend coefficients of January persistence of 500 hPa GHT anomalies for the period of 1957–1996. (b) Linear trend coefficients of July persistence of 500 hPa GHT anomalies. (c) Same as Figure 2a, but for SSTA in the tropical regions. (d) Same as Figure 2b, but for SSTA in the tropical regions. The values in the shaded areas are significant at the 0.05 level.

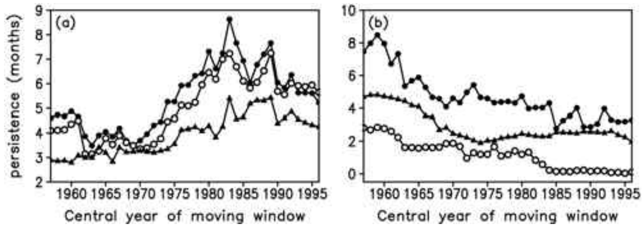

Figure 3. (a) Area-averaged January persistence of GHT anomalies in the tropical Eastern Hemisphere (0°E ~180°E, 10°S~10°N) (closed circle line) and the tropical Western Hemisphere (140°W~0°W, 10°S~10°N) (open circle line), and area-averaged January persistence of SSTA in the equatorial eastern Pacific (180°W~80°W, 10°S~6°N) (closed triangle line). (b) Area-averaged July persistence of GHT anomalies in the tropical Atlantic-Africa region (30°W~20°E, 15°S~10°N) (closed circle line) and central-eastern Asia (60°E~110°E, 30°N~45°N) (open circle line), and area-averaged July persistence of SSTA in the equatorial Indian Ocean (40°E~80°E, 6°S~10°N) (closed triangle line).

variations in both regions indicate that the mechanisms determining the decadal variation of January persistence in the whole tropical regions might be the same. Similarly, we choose two regions, the tropical Atlantic-Africa region (30°W~20°E, 15°S~10°N) and central-eastern Asia (60°E~110°E, 30°N~45°N), with significant decreasing trends in Figure 2b. It can be seen from Figure 3b that July persistence in the tropical Atlantic-Africa region has been persistently decreasing from the 1960s to the early 1980s, and shows no clear trend from the mid-1980s to the late 1990s. July persistence in central-eastern Asia has also been persistently decreasing from the 1960s to the early 1980s and maintains at a very low level from the mid-1980s to the late 1990s.

[7] Because anomalous SST forcing in the tropics has a great influence on the formation and maintenance of the persistent anomalies of global and especially tropical atmospheric circulation [*Namias*, 1965], the persistence variations of SSTA are then examined to explore possible relationships with the decadal change of persistence of GHT anomalies. January persistence of SSTA shows a significantly increasing trend over the most tropical oceans, especially in the equatorial central-eastern Pacific (Figure 2c). The area-averaged January persistence of SSTA in the equatorial central-eastern Pacific exhibits a decadal change with a sharp increase after the mid-1970s (Figure 3a), which is concurrent with the variations of January persistence of GHT anomalies in the most tropical regions. The correlation coefficient between January persistence of SSTA in the equatorial central-eastern Pacific and that of GHT anomalies in the tropical regions of Eastern Hemisphere (Western Hemisphere) is 0.85 (0.88). It is implied that the increase of January persistence of GHT anomalies in the tropical regions is closely associated with the enhanced persistence of SSTA in the equatorial central-eastern Pacific.

[8] July persistence of SSTA shows a significantly increasing trend in the equatorial central-eastern Pacific, but shows a significantly decreasing trend in most areas of tropical Indian Ocean, tropical North Pacific and tropical Atlantic (Figure 2d). *Kumar et al.* [1999] found that the inverse relationship between the ENSO and the ISM has weakened in recent two decades. *Wu and Hu* [2000] demonstrated that Nino3 SSTA-related potential predictability of the ISM is lower in 1980s than in 1960s and 1970s. These studies showed that the effect of the ENSO on the ISM circulation has weakened, which may be a possible reason why July persistence of GHT anomalies in the ISM region has been persistently decreased, under the situation of the increased persistence of SSTA in the equatorial central-eastern Pacific. In addition, it is shown that the correlation between the summer SSTA in the equatorial Indian Ocean (40°E~80°E, 6°S~10°N) and EASMI remains significant at the 0.05 level from the 1960s to the mid-1970s. After the mid-1970s, the correlation shows a distinct shift in sign from positive to negative. During the mid-1980s, negative correlation is beyond the 0.05 significance level (Figure 4a). However, the correlation between the summer SSTA in the Niño 3.4 region (170°W~120°W, 5°S~5°N) and EASMI remains below the 0.05 significance level at all times, although it has become enhanced since 1990s (Figure 4b). These results indicate that the summer SSTA in the equatorial Indian Ocean possibly exert greater influences on the East Asian circulation anomalies than the Niño 3.4 SSTA. So it could be inferred that the decreased persistence of SSTA in the equatorial Indian Ocean might be one of the major causes of the decrease of July persistence of GHT anomalies in the East Asia from the 1960s to the mid-1970s. From the mid-1970s to the early 1980s, the relationships of SSTA both in the equatorial Indian Ocean and in the Niño 3.4 region with EASMI become weaker, which may explain the reason for the decrease of July persistence of GHT anomalies in the East Asia during this period. Besides, the decreased persistence of SSTA in the equatorial Indian Ocean possibly also contributes to the decrease of July persistence of GHT anomalies in the tropical Atlantic-Africa regions (Figure 3b). Different from EASMI, the SCSSMI has a much better relationship with the Niño 3.4 SSTA than with the SSTA in the equatorial Indian Ocean in recent decades (not shown). This might be the cause for the increase of July persistence of GHT anomalies around the South China Sea region (100°E~125°E, 10°N~25°N) (Figure 2b).

4. Summary and Discussion

[9] The decadal variations of January and July persistence of 500 hPa GHT anomalies and associated persistence

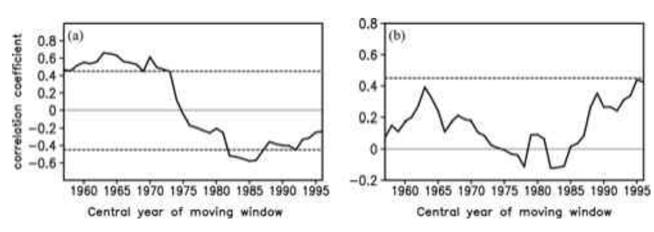

Figure 4. (a) The 19-year moving correlations between the EASMI and SSTA in the equatorial Indian Ocean (40°E~80°E, 6°S~10°N) for JJA during 1948–2005. (b) Same as Figure 4a, but for EASMI and SSTA in the Niño 3.4 region (170°W~120°W, 5°S~5°N). The horizontal dashed lines show the 0.05 significance level.

changes of SSTA in the tropical oceans are investigated in this study. The results show that January persistence of GHT anomalies in the most tropical regions has undergone a distinct increase since the mid-1970s. This increase has been found to be closely associated with the enhanced persistence of SSTA in the equatorial central-eastern Pacific. Contrary to the variations of January persistence, July persistence of GHT anomalies in the most tropical regions shows significant decreasing trends between the 1950s and 1990s. In addition, July persistence in the most Asian regions including ISM region also shows significant decreasing trends. The weakened effect of the ENSO on the ISM circulation may be a possible reason why July persistence of GHT anomalies in the ISM region has been persistently decreased. The decreased persistence of SSTA in the tropical Indian Ocean, tropical North Pacific and tropical Atlantic, has likely also, to some degree, contributed to the decrease of July persistence of GHT anomalies in the tropical Atlantic-Africa region and central-eastern Asia. Besides the influences of external forcing of SST, the changes of the forcing of the monthly mean atmosphere by high-frequency transient eddies might be another reason causing the decadal variations of the persistence of monthly mean circulation anomalies [*Van den Dool*, 1983]. In addition, it is worthwhile to examine whether the decrease of January persistence of GHT anomalies in the southern high latitudes is related to the trend change of Southern Hemisphere annular mode (SAM). These will be open questions and need further exploration in the future.

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