# 冬季赤道西太平洋环流状况与后期亚洲季风*

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**摘 要** 基于月平均 NCEP 再分析资料（1958～1997 年）以及中国 336 个台站月降水总量（1951～1994 年），通过合成、相关以及统计显著性检验方法，研究了赤道西太平洋区域冬季环流状况与后期春夏季亚洲（东亚和南亚）季风环流变化的关系。研究结果表明，冬季赤道西太平洋环流状况对后期南亚季风和东亚季风以及我国夏季降水均有显著的滞后影响。冬季赤道西太平洋海域海平面气压偏高（低），对应反气旋（气旋）性环流异常，致使后期东亚和南亚夏季风均偏弱（强）以及我国长江流域夏季降水偏多（少），揭示了实施这种滞后影响的一般特征。

**关键词**：冬季；赤道西太平洋；环流；滞后影响；季风

## 1 引言

在 19 世纪 80 年代，Blanford[1]首次研究指出：喜玛拉雅山冬季积雪与后期印度季风降水呈反相关，这种关系被 Walker[2]进一步证实。1976 年，Hahn 和 Shukla[3]应用卫星观测资料研究证实 52°N 以南的欧亚雪盖（冬季）与后期印度夏季降水是反向变化的，因此，积雪的存在和异常可以作为后期气候状况的预测因子。但不可否认，积雪的异常也是特定大气环流的产物，只不过大气环流的持续性偏短而已。ENSO 事件是气候系统中最显著的年际变化信号，它对全球气候变化的影响也最为显著，通常 ENSO 事件的盛期也都发生在冬季，因此，研究冬季环流的滞后影响，不仅可以使我们对气候系统的演变有更进一步的认识，而且可以了解产生灾害性天气的可能机理，为长期气候预测提供有物理意义的预测信息。

热带西太平洋地区对气候变化的影响主要集中在以下几个方面：（1）热带西太平洋的热力状况及其上空对流活动对东亚夏季风环流（包括遥相关型）及降水年际变化有重要作用[4～6]。（2）在 ENSO 循环中起着重要作用。1988 年，李崇银就指出 El Niño 事件发生的前期征兆出现在赤道西太平洋[7]，后来又进一步指出，赤道西太平洋地区西风和积云对流的持续异常将分别引起海洋 Kelvin 波和大气季节内振荡的异常活动，通过海–气耦合作用导致 ENSO 事件的发生[8]。此外，在 ENSO 循环的位相转换期，西北太平洋（5～15°N，130～170°E）风场变化对斜温层调整及其传播起着重要作用[9]。

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(3) 在 ENSO 事件对东亚气候变化的影响中，冬季西北太平洋的反气旋环流是连结赤道中、东太平洋增暖和东亚冬季风的关键系统[10]。

这些工作清楚地表明，热带西太平洋是影响全球气候变化的关键区，然而，这些工作都没有涉及冬季该区域气候变化对后期夏季亚洲季风的影响。本文中，我们主要讨论冬季赤道西太平洋地区环流对亚洲季风的滞后影响。

## 2　资料和方法

本研究用到的大气资料是 NCEP 再分析资料中的月平均海平面气压、风场，时间是 1958～1997 年、1951～1994 年中国 336 个站月降水总量。

本研究所用方法主要是合成分析、相关分析以及两个场差异的显著性检验。为了提高高低纬度环流变化的可比性，我们对任意变量 $X$ 进行如下处理：

$$X'(i,j,t)=\frac{[X(i,j,t)-\overline{X}(i,j)]}{\sigma(j)},$$

其中，$\sigma(j)=\frac{1}{M}\sum_{i=1}^{M}\sigma(i,j)$，表示总体均方差的纬向平均值。

为了描述冬季（12～2 月）赤道西太平洋区域气候的年际变化，本研究以冬季赤道西太平洋（10°S～10°N，130～160°E）区域平均的海平面气压为指标，简称 WP 指数。选择这个区域为研究对象主要有两点考虑：(1) 从年平均海表温度分布来看，该区域温度最高[11]；(2) 该区域斜温层深度的标准差为最大[9]。

## 3　冬季赤道西太平洋环流的极端变化

为了讨论与冬季赤道西太平洋海平面气压相一致的气候异常。首先，从 WP 指数时间序列中分别选出前 5 个数值为最大和最小的冬季，WP 指数为最大的 5 个冬季依次为 1982／1983、1991／1992、1972／1973、1994／1995、1977／1978 年；WP 指数为最小的 5 个冬季依次为 1970／1971、1984／1985、1971／1972、1964／1965、1960／1961 年。然后基于选出的冬季对气象要素场采用合成分析方法，并对两种极端状况差异（高指数状态减低指数状态）的空间场作显著性检验。

基于 WP 指数异常的合成分析以及显著性检验如图 1 所示。图 1a 显示，当冬季赤道西太平洋海平面气压极端偏高时，（0～180°E，30°S～30°N）区域内均是正的气压异常，最大正异常中心刚好位于关键区偏北，即菲律宾东南部海域。赤道东太平洋主要是负异常，此外，在北半球高纬度地区以及东北太平洋海域也是负异常区，并且有两个负距平中心：一个位于巴伦支海，另一个位于 30°N 以北的东北太平洋上。亚洲大陆 40°N 以北都是负距平区，表明冬季西伯利亚高压偏弱。当赤道西太平洋海平面气压极端偏低时，情况正相反（见图 1b）。负距平最大中心仍然位于该关键区略偏北位置，整个热带地区都是气压负距平区。而两个半球的高纬度地区则出现正距平、北半球最大正距平中心仍然位于巴伦支海附近和东北太平洋海域，此时，西伯利亚高压偏强。从显著性检验的空间分布（图 1c）来看，两种极端状态的显著差异主要是热带（30°S～

纬向辐散特征。王斌等[9]在研究西北太平洋风场变化对斜温层调整以及 ENSO 位相转换时也指出，西北太平洋反气旋在斜温层加深过程中起重要作用，他所指的西北太平洋区域是（5～15°N，130～170°E）。当赤道西太平洋海平面气压异常偏低时（图 2b），强大的气旋性环流异常取代了图 2a 中的反气旋性环流异常，受其影响南中国海出现异常偏东北气流，在（10°S～10°N，140～180°E）之间风场异常表现为纬向辐合而经向辐散的特征。

## 4　冬季环流对亚洲季风的滞后影响

### 4.1　对海平面气压的影响

为了讨论冬季赤道西太平洋气候变化对后期亚洲季风的影响，把其后期分为三个时段，即春季 3～5 月、5～6 月和 6～8 月，讨论方法与前一部分完全相同。当前冬 WP 指数异常偏高时，后期春季 30°S～30°N 之间除去东太平洋和美洲外，均是气压正距平（图 3a），与冬季（图 1 a）相比正距平明显减弱（最大正距平等值线由冬季的 14 减弱至 8），虽然最大正距平中心几乎没有移动，但 0 等值线比冬季更接近 120°W，而东太平洋的负距平则加深东移。从整体上看气压距平在由西向东传，这一点与 Barnett 的结论[12]是一致的。此外，亚洲大陆北部已出现大面积正距平区，并且已经与低纬度地区的正距平区相连通。当冬季 WP 指数异常偏小时，后期春季，负气压距平中心仍然位于西北太平洋，并且比冬季明显减弱，90°E 以西的欧亚大陆北部由冬季的正距平转变为负距平（图 3b），显著性检验结果（图 3c）表明，热带西太平洋、非洲地区和欧洲南部的海平面气压差异是显著的，我国南部的气压差异也是显著的，但不论是范围还是强度均明显比冬季的弱（图 2c）。

5～7 月，与春季相比正气压距平中心发生了跳跃性变化（图 4a），正距平中心由菲律宾东部（春季）突然跃入亚洲大陆中部，强度仍然在减弱。此外，菲律宾东北还保留一个强度为 4 的正距平中心，从下文分析会看到，该处的气压正距平对产生东风异常有非常重要的作用。此外，在赤道东太平洋和 30°S 附近，气压正距平与春季相比明显向东传播，并形成了从欧亚大陆至东南太平洋的气压正距平带。图 4b 中的负气压距平也出现了类似的变化，即负距平中心由菲律宾以东海区移至亚洲大陆上，但气压负距平并没有明显向东传播。与春季相比，海平面气压差异显著的区域已明显向西北移置（图 4c，亚洲大陆的中北部、东部、南部以及南中国海区域均为差异显著的区域，而北非和欧洲的差异显著区域则是由春季的显著区北移造成的。亚洲大陆中北部的阴影区则很可能是受到高纬度地区影响所致。

6～8 月，整体特点与 5～7 月类似，不同之处是位于亚洲大陆的正、负距平中心进一步加强（图 5a、b），南北半球中纬度地区的正距平区进一步向东扩展（图 5a），阴影区进一步向亚洲大陆收缩（图 5c）。对照图 3c、图 4c、图 5c，阴影区不断向西北移动的现象清晰可见。

此外，从时间–纬度（经度）剖面图上也可以看到，超过统计显著性的海平面气压的异常传播，如图 6 所示。在经向剖面上（沿 112.5°E），阴影区从 4 月中后期开始从 10°N 向北传播到 40°N 附近，整个夏季（6～8 月）30～40°N 附近都为阴影区所覆盖。

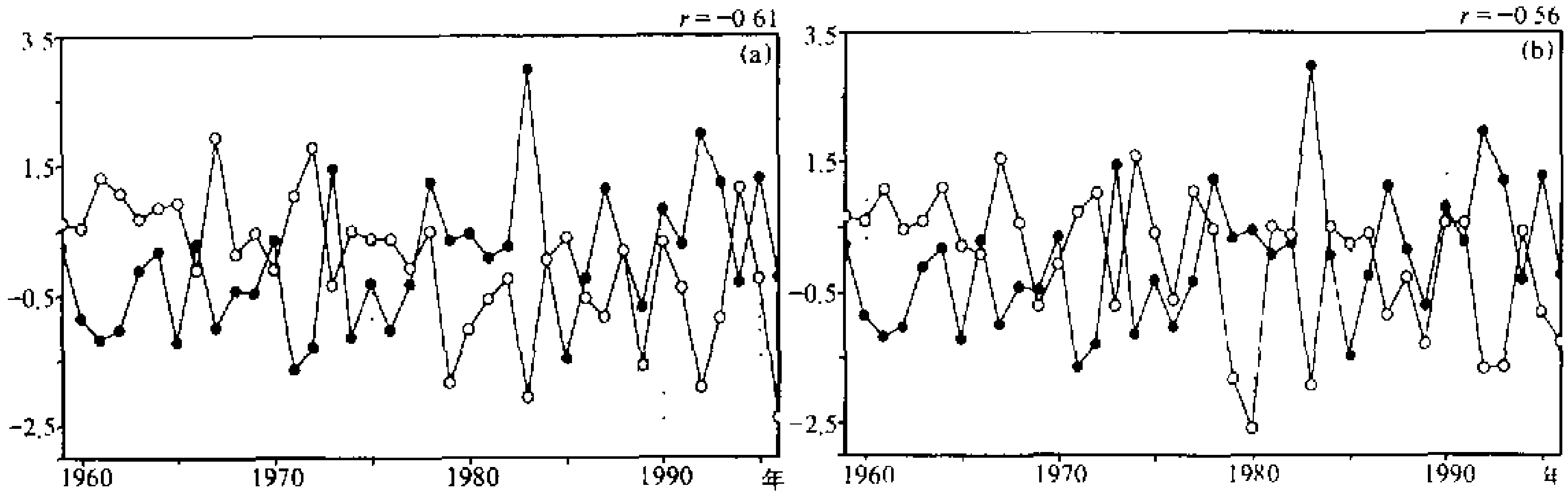


图 8　冬季 WP 指数（黑点）与后期亚洲大陆热低压范围指数的年际变化
所有数据均经过标准化处理过，纵坐标为无量纲单位
(a) 5～7 月；(b) 6～8 月

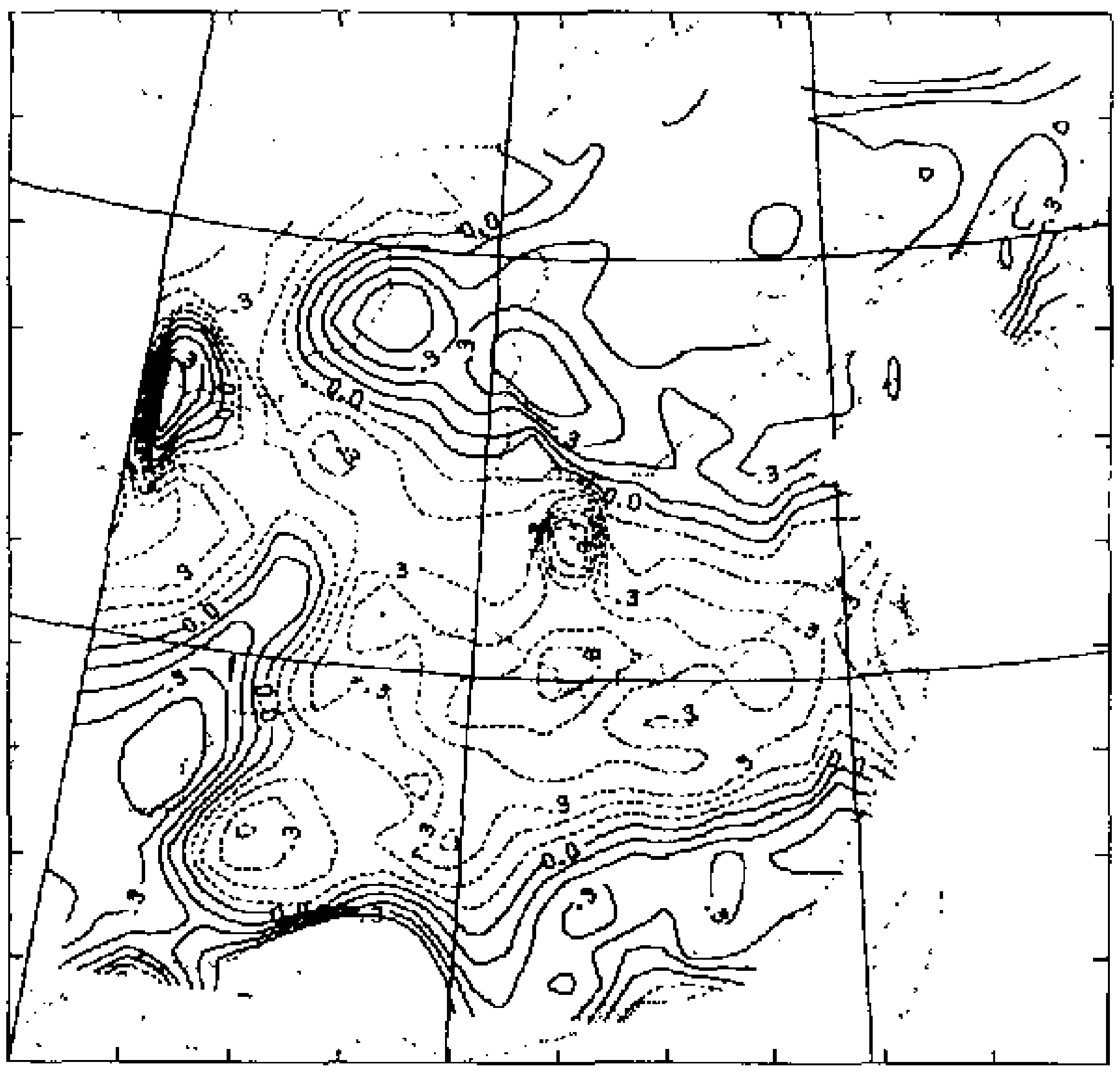

图 9　亚洲大陆热低压范围指数 HL（6～8 月）与夏季
我国 130 个台站降水量的相关系数空间分布
($|R|_{0.05}=0.325$，$|R|_{0.01}=0.418$)

洋海平面气压偏高（低），则后期夏季沿长江流域的广大地区易出现多雨（少雨），尤其是长江中游地区将更为显著。

为了进一步研究长江中游区域降水与夏季亚洲大陆热低压年际变化的关系，选取达县、钟祥、恩施、宜昌、荆州、孝感、武汉、桑植、岳阳、常德和长沙的夏季平均降水代表长江中游区域降水，其年际变化与 HL（6～8）也是反相关的，如图 10a 所示，相关系数为−0.6。由图 10b 可以看到，夏季这 11 个站降水多年平均值在 500～550 mm 之间，在这 37 年降水量时间序列中，有 27 年完全满足与 HL（6～8）指数呈符号相反关系，即 HL(6～8) 指数大于（小于）其平均值时，对应夏季降水量小于（大于）其多

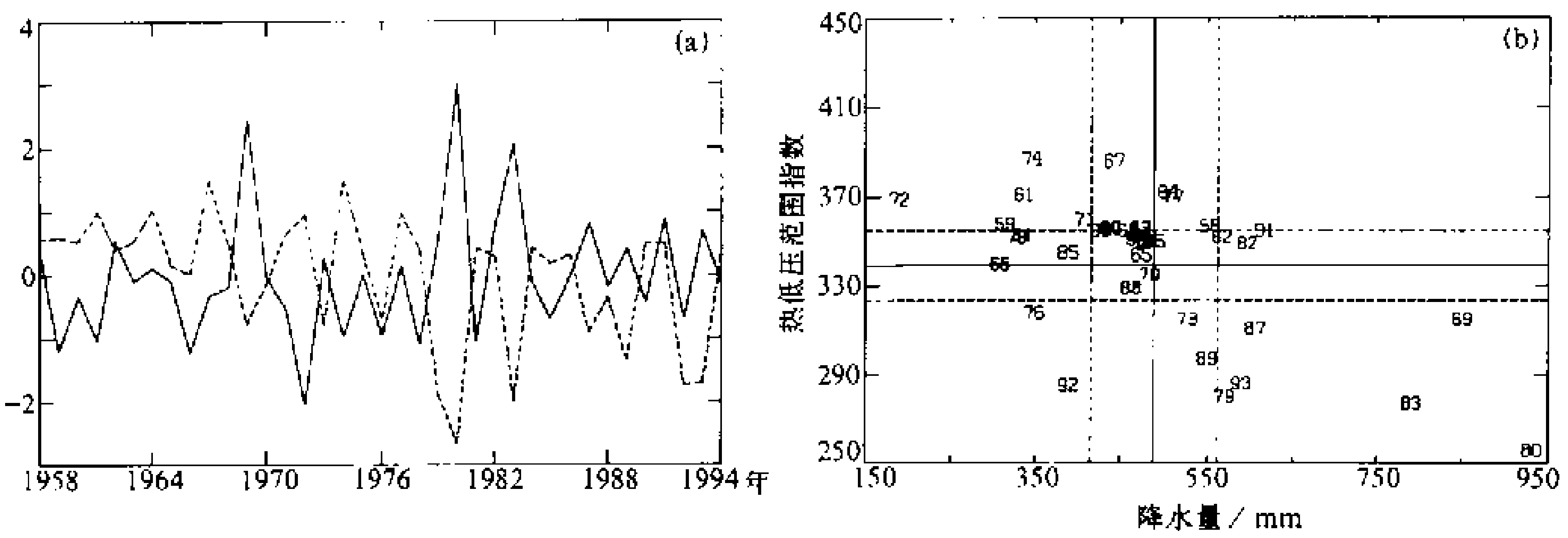


图 10 (a) 冬季 WP 指数与后期夏季长江中游 11 个站平均降水量的年际变化曲线. 所有数据均经过标准化处理过, 纵坐标为无量纲单位; (b) 长江中游 11 个站点 37 年夏季降水量序列, 其中与纵、横坐标平行的实线 (虚线) 表示降水量 (热低压范围指数) 的平均值 (平均值 ± 1 / 2 标准差)

年平均值; 而其余 10 年则是正相关, 它们是 1958、1962、1964、1970、1976、1977、1982、1988、1991、1992。

### 4.3 对 850 hPa 风场的影响

在第 3 节中, 已经讨论了与冬季 WP 指数异常相对应的 850 hPa 风场异常, 不仅如此, 其极端异常还对后期 850 hPa 风场产生显著的影响。在 WP 异常高指数的后期春季 (3～5 月, 见图 11a), 与冬季风场异常相对照 (图 2a), 异常反气旋位置已明显北移并且范围进一步扩大, 东西方向的扩展非常显著。此外, 在亚洲大陆中高纬地区 (40～50°N, 80～110°E) 出现了一个弱的异常反气旋, 在该反气旋的东南方有强的异常偏北气流南下并一直南压至中南半岛地区。5～7 月 (图 11b) 位于亚洲大陆中、高纬度地区的反气旋环流异常进一步加强范围扩大, 东亚地区盛行偏北风异常, 因而东亚夏季风偏弱。同时, 西北太平洋上的异常反气旋继续向东北方向移动, 由于东西方向轴线的进一步拉长, 致使其南部的东风异常持续向西北方向推进, 并在印度北部地区与大陆反气旋的东风异常相会合, 图中清晰表明, 在 (0～20°N, 80～150°E) 范围内出现强大的偏东南气流异常, 该异常气流的存在对南亚季风有着非常重要的影响, 因此印度西南季风将偏弱。前文提到, 5～7 月菲律宾东北部还保留一个强度为 4 的正距平中心 (图 4a), 对照风场异常可以看到, 在 (80～180°E, 0～30°N) 之间的东西风异常 (阴影区) 与气压距平为 2 的等值线走向非常一致, 表明风场异常与大尺度气压梯度密切相关。6～8 月 (图 11c), 整体特征与 5～7 月相似, 不同之处是亚洲大陆的异常反气旋控制范围更大了, 强度进一步加强。

在 WP 指数异常偏低的后期 (见图 12), 春季 (3～5 月) 西太平洋异常气旋的位置明显向东北移动 (图 12a), 15°N 以北区域出现强偏东风气流异常, 亚洲大陆中纬度地区出现异常气旋性环流, 并在我国 (30～40°N, 105～120°E) 范围内出现较强的偏南风异常。此外, 在 50～80°E 之间出现跨赤道偏南风异常, 而印度半岛南部、中南半岛南部已经出现异常偏西风。5～7 月在亚洲大陆边缘出现明显的气旋性环流异常 (图 12b), 东亚夏季风偏强, 尤其在华北和东北南部地区出现异常偏南风。同时, 西太平

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# Winter Circulation Condition of the Tropical Western Pacific and Subsequent Asian Summer Monsoon

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**Abstract** Using monthly mean NCEP reanalysis data and monthly rainfall data of 36 stations in China, by means of composite correlation and statistical significant test, the relationship between winter circulation conditions over the tropical western Pacific and Asian monsoon circulation variations (including South and East Asia) of the following spring and summer is explored. The results clearly indicate that winter circulation condition over the tropical western Pacific predominantly influences the subsequent South and East Asia Monsoon circulations and summer rainfall in China. Having positive SLP anomalies over the tropical western Pacific, corresponding to anticyclone (cyclone) circulation anomalies, results in weaker (stronger) monsoon circulations over South and East Asia and more (less) summer rainfall in the Yangtze River Valley. The research reveals the general feature of the lag influences.

**Key words**: winter; tropical western Pacific; circulation; lag influence; monsoon

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**Key words**: winter; tropical western Pacific; circulation; lag influence; monsoon

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