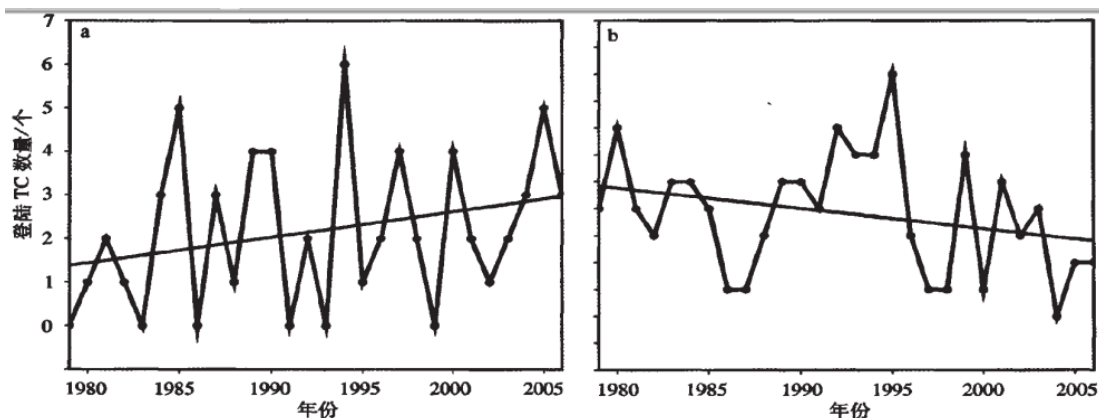


## 近50年热带气旋在我国的登陆位置的变化趋势 及其与西太平洋暖池的可能联系

周群，魏立新

国家海洋环境预报中心，北京

# 1.引言

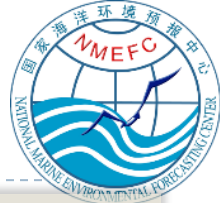


Interannual variations in the number of TCs landfalling (a) north and (b) south of Xiamen over the Northwest Pacific during 1979—2006

(Wang et al., 2009)

◆西北太平洋 (WNP) 是全球热带气旋 (TC) 生成最为频繁的地区, 全球约 1/3 的 TC 在此海域形成。在西北太平洋副热带高压的作用下, 平均每年有 7-8 个 TC 登陆我国, 给沿海地区造成严重的经济损失和人员伤亡 (Guan et al., 2018)。

◆早期的研究发现 TC 在我国登陆位置存在向东北方向偏移的趋势, 然而并未揭示造成该现象的外强迫因子及相关的物理过程 (e.g. Wang et al., 2009)。



# 1.引言

- ◆ The western Pacific warm pool (**WPWP**), containing the warmest water in the world. The thermal state of the WPWP sea surface temperature (SST) has profound influences on the landfall behaviors of TCs over the WNP region (Gray, 1968; Chen and Huang, 2008).
- ◆ 观测表明近年来西太平洋暖池强度显著增强、范围明显扩大 (around late-1970s, Gan and Wu, 2012 ; late-1990s, Huangfu et al., 2015) .
- ◆ In recent years, it causes **increasing attention** from meteorologists to study the WPWP thermal state together with the related regional climatic effects **under the global climate**.

冬季西太平洋暖池与华南降水关系的年代际变化

Possible Origins of the Western Pacific Warm Pool Decadal Variability

GAN Bolan\*

Physical Oceanography Laboratory

(Received 4 Nov 2014)

摘要: 利用 1951—2010 年 NCEP/NCAR 再分析月数据, 西太平洋暖池与我 70 年代前两者弱的负担; 显示, 70 年代前, 暖池

In this study, the impacts of the Pacific Decadal Oscillation (PDO) on the western Pacific

INTERANNUAL VARIATION IN HEAT CONTENT OF THE WESTERN PACIFIC WARM POOL AND ITS EFFECT ON EASTERN ASIAN CLIMATE ANOMALIES

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**Abstract:** Using the 1980–2010 winter GODAS oceanic assimilations, study is conducted of the winter heat content (HC) established in the subsurface layer (5 to 366 m in depth) over the western Pacific warm pool (WP), followed by investigating the HC spatiotemporal characteristics, persistence and the impacts on the climate anomalies of neighboring regions. Results are as follows: 1) the pattern of integral consistency is uncovered by the leading EOF1 (PC1) mode of HC interannual variability, the year-to-year fluctuation of the time coefficients being well indicative of the interannual anomaly of the WP winter subsurface-layer thermal regime. The HC variation is bound up with El Niño–Southern Oscillation, keeping pronounced autocorrelation during the following two seasons and more, with the persistence being more

Influence of Tropical Western Pacific Warm Pool Thermal State on the Interdecadal Change of the Onset of the South China Sea Summer Monsoon in the Late-1990s

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2015; published 16 March 2015

...a shift around the late 1970s, with a pronounced ... in the warm pool (Huang et al., 2003; Ding and ... 2005; Li et al., 2006; Zhou et al., 2009). Recent ... (Wu et al., 2010; Kajikawa and Wang, 2011; Yuan ... (Chen, 2013) suggest that the SCSSM also underwent ... er shift around 1993. It is argued that the interde- ... warming of the tropical western Pacific is an origi- ... nase (Yuan and Chen, 2013). However, the recent

The SST Gradient between the Southwestern Pacific and the Western Pacific Warm Pool: A New Factor Controlling the Northwestern Pacific Tropical Cyclone Genesis Frequency

RUIFEN ZHAN

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YUQING WANG

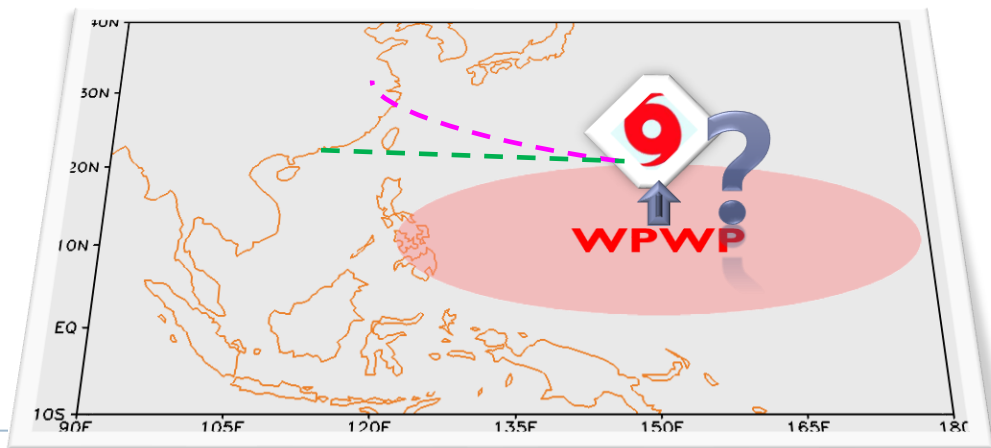
International Pacific Research Center, and Department of Meteorology, School of Ocean and Earth Science and Technology, University of Hawaii at Manoa, Honolulu, Hawaii

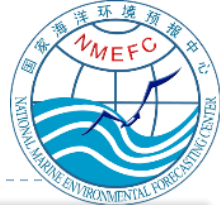
MIN WEN

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# 1.引言

- ◆大量研究揭示了西太平洋暖池的热力状态通过能够影响西北太平洋季风槽 (MT)，从而影响西北太平洋TC生成；还能够通过东亚/太平洋型遥相关型影响西北太平洋副热带高压 (WPSH)，从而影响西北太平洋TC的移动路径。
- ◆那么，西北太平洋TC移动路径特别是在我国登陆位置的长期变化是否与西太平洋暖池的显著增暖有关，这是亟待解决的科学问题。





## 2. 数据与方法

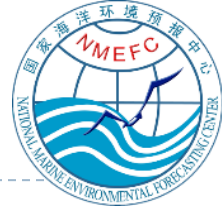
大气: NCEP/NCAR 再分析资料, 包括海平面气压、位势高度、垂直速度、经向风及纬向风

海温: Hadley 中心提供的海温资料

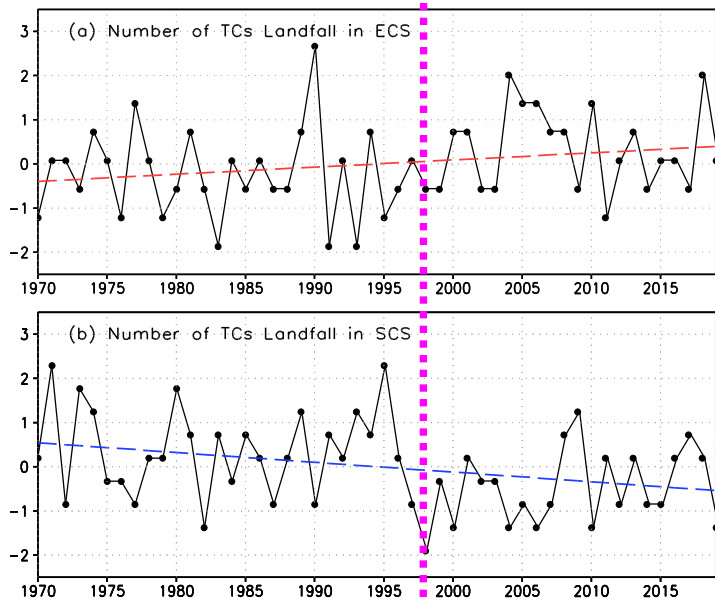
热带气旋: 西北太平洋TC最佳路径数据集, 来自中国气象局热带气旋数据中心

- ◆ TC生成定义: maximum wind speed reaches 18 m/s
- ◆ 路径密度定义: the number of TCs passing through grid boxes of  $2.5^\circ$  divided by the number of years
- ◆ 登陆东海/南海沿岸TC: north of Zhangzhou City/south of Chaozhou City in Fujian/Guangdong
- ◆ 研究时段及范围: 1970-2019年, 赤道以北、日界线以西的WNP区域
- ◆ 研究方法: 相关/回归分析、合成分析 + Student's two-sided t-tests

# 3.结果与讨论



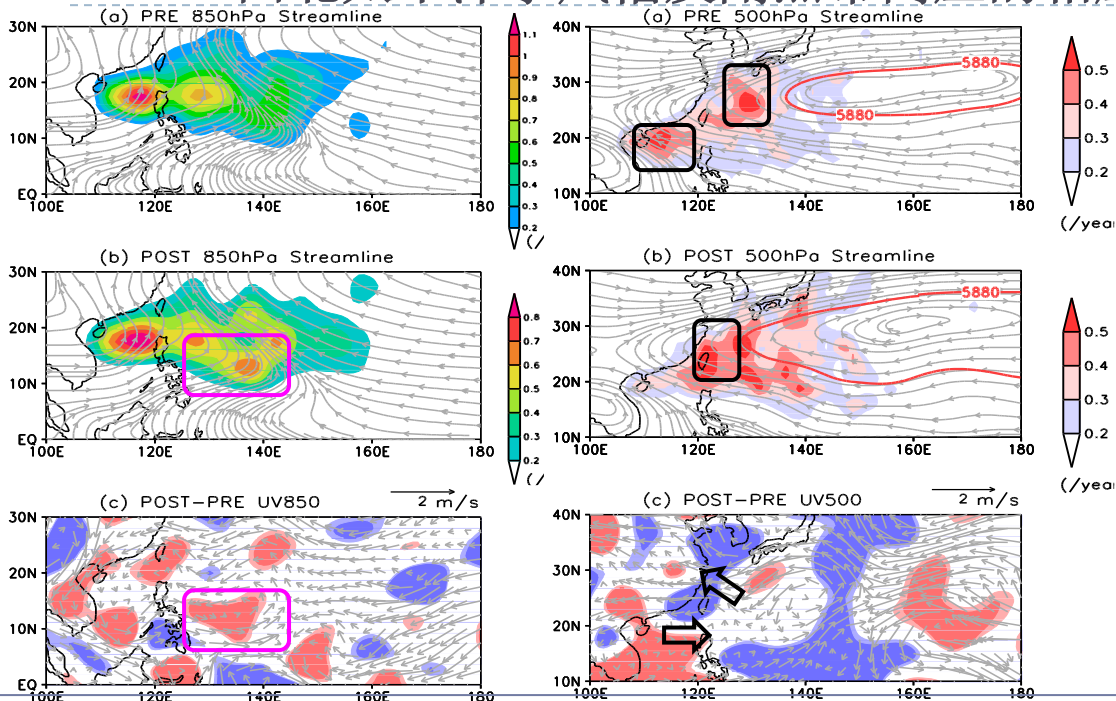
## 3.1 TC在我国登陆位置的长期趋势变化



- ◆均呈明显的年际变化和年代际变化；
- ◆二者相关系数（原始： $-0.35$ ；去线性趋势后： $-0.30$ ）均能通过95%信度检验；
- ◆TC在我国登陆位置存在北移趋势，与前人研究结果一致。
- ◆PRE/POST：1970-1999/2000-2019
- ◆7-9月：超过75%的登陆台风在此间发生

Normalized time series of the number of the TCs landfall in the coast of the (a) ECS and (b) SCS (solid lines) and its linear trends (dashed line) during 1970-2019.

## 3.2 西北太平洋季风槽及副热带高压的相应变化



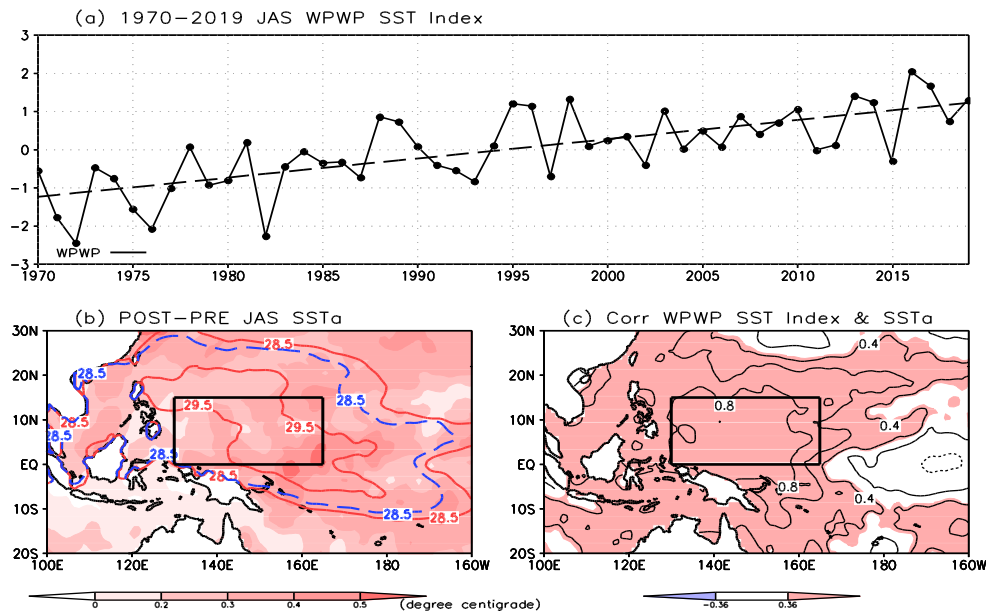
◆ **POST**: MT增强; WPSH强度偏强、面积偏大(脊线 $30^{\circ}\text{N}$ 以北) TC track density is much higher over the ECS.

◆ **PRE**: MT偏弱; WPSH强度偏弱、面积偏小(脊线 $30^{\circ}\text{N}$ 以南) TC track density is increased over the SCS and the higher latitudes around  $130^{\circ}\text{E}$ .

◆ 850hPa风场合成: 菲东气旋式环流异常; 500hPa风场合成: 东海(南海)沿岸上空为异常的东南(偏西)气流控制

Comparison of JAS mean streamlines at (left) 850hPa (shadings: TC genesis location density) and (right) 500hPa (shadings: TC track density) for (top) PRE and (middle) POST epoch. (bottom) Composite circulations at (left) 850hPa and (right) 500hPa between the two epochs (POST minus PRE).

### 3.3 西太平洋暖池的相应变化



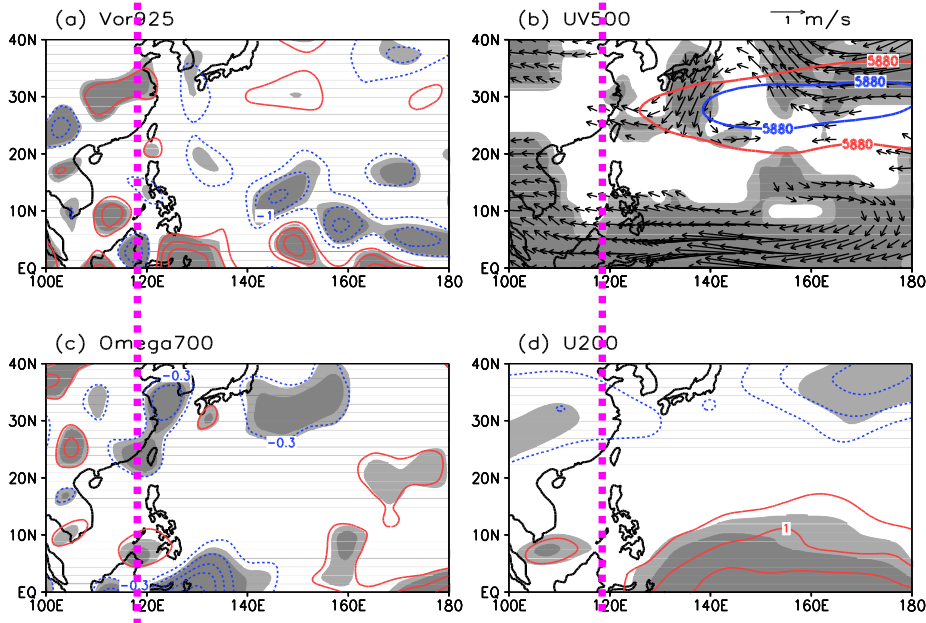
- ◆相较于PRE, POST: 暖池明显东伸、范围增大;
- ◆关键区平均海温作为反映WPWP热力状态的指数, 该指数呈显著的年代际上升趋势;
- ◆Corr. (detrended WPWP SST & annual longitudinal/latitudinal position of TCs genesis)=0.52/-0.37( $\geq 99\%$ 信度检验).

(a) Normalized the JAS mean WPWP SST index (solid line) and its linear trends (dashed line). (b) Composite the JAS mean SST anomalies (shadings) between the two epochs. The red solid (blue dashed) isothermal lines are denoted for the POST (PRE) epoch. (c) Correlations between the WPWP SST index and the SST field.



### 3.4 暖池热力状况对西北太平洋上空大气环流的影响

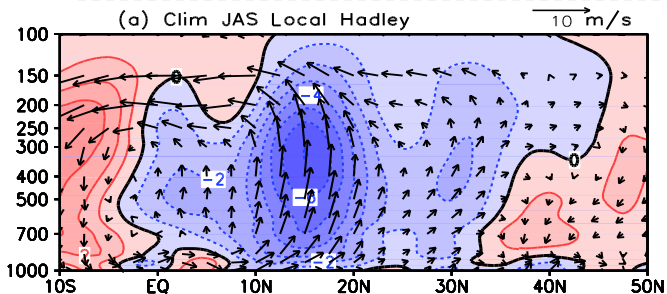
- ◆ **WPWP偏暖**：低层辐合+中层上升运动等的响应；WPSH 偏大偏强，高空引导气流有利于TC趋近东海沿岸。
- ◆ **WPWP偏冷**：情况与上述相反。



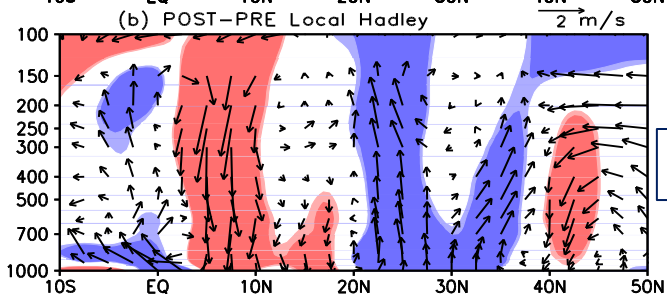
- ◆ **对流层高层**：WPWP **偏暖** (冷) 时，副热带西风急流及热带东风急流的强度均 **减弱** (加强)，表明WNP热带与热带外地区之间存在密切联系。

Regression distributions of the JAS mean (a) 925h-Pa vorticity, (b) 500-hPa wind, (c) 700h-Pa vertical velocity and (d) 200-hPa zonal wind on the WPWP SST Index. The red (blue) 5880gpm line in (b) indicates the distribution of the WPSH during warmer (cooler) WPWP phase.

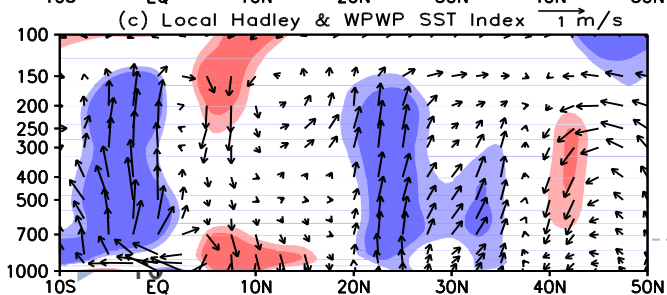
### 3.5 暖池影响下的局地经向环流异常



multi-year  
mean



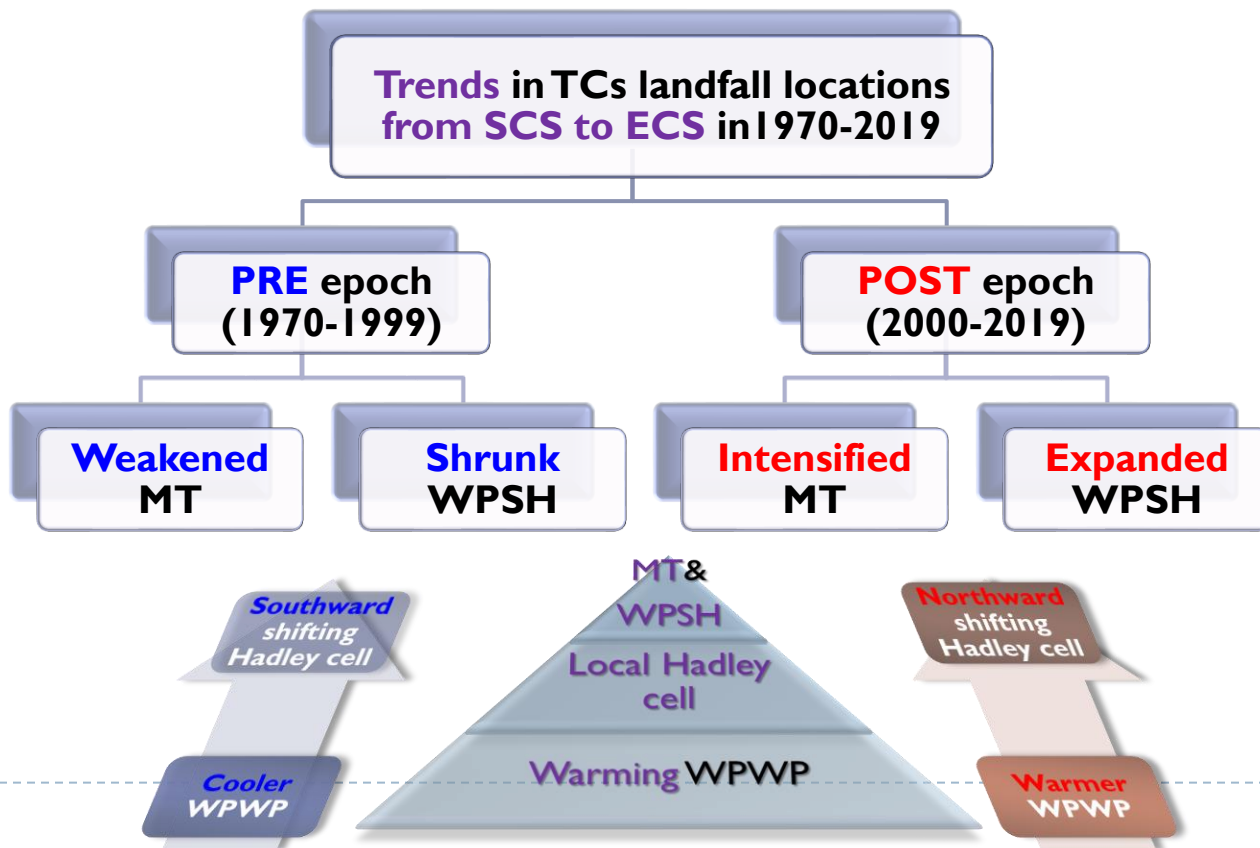
POST minus PRE

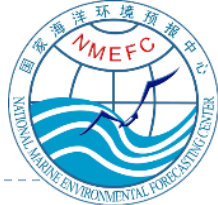


Regression  
with WPWP  
SST

- ◆沿120°E经向环流：热带上升、副热带下沉
- ◆POST-PRE合成场显示：向极移动，异常的上升(下沉)支位于20°N-35°N之间(40°N附近)
- ◆WPWP热力状况对经向环流的影响与此十分类似。

### 3.6 暖池热力状态影响TC登陆位置的物理机制示意图

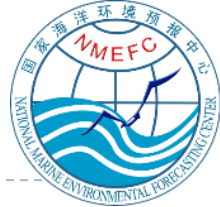




## 4. 结论

- ◆本研究利用中国气象局发布的TC最佳路径数据、NCEP/NCAR再分析产品和Hadley中心提供的全球海温资料，揭示了近50年来（1970-2019年）TC在我国登陆位置存在北移趋势，也即TC在我国东海沿岸的登陆频数增加，而在我国南海沿岸的登陆频数减少，这与TC生成位置和中层引导气流的改变密切相关。
- ◆西太平洋暖池能够对西北太平洋季风槽和副热带高压的年代际变化产生重要影响，导致TC生成位置和移动路径的改变，这可以很好地解释TC在我国登陆位置向北移动的长期趋势，这其中暖池热力状况对局地经向环流的调制起到了关键的桥梁作用。
- ◆在全球气候变化背景下，西太平洋暖池区可能是近50年来TC在我国登陆位置北移趋势的敏感区。本研究的结果为局地气候预测奠定基础，也为我国沿海地区应对气候变化、制定西北太平洋TC灾害的防灾减灾规划带来一定帮助。

Zhou Q, Wei LX. Trends in the landfall locations of tropical cyclones in China and its association with the enhancing western Pacific warm pool during recent decades. Proceedings of the Fourteenth (2020) ISOPE Pacific-Asia Offshore Mechanics Symposium, PACOMS-2020, Dalian, China, November 22-25, 2020, Virtual/Online, PP. 65-71, 2020



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