

1 The authors wish to thank the editors and reviewers for their effort in reviewing our manuscript. We appreciate the constructive  
2 criticisms, and we hope the changes listed have made the manuscript suitable for publication.

3  
4 **Referee 1:**

5  
6 **General Comments:**

7 ENSO has huge influence on precipitation in east Asia. This paper investigated the impact of different ENSO regimes on rainy-  
8 season precipitation in China at the developing and decaying phases, and it also explored the possible physical mechanism of  
9 precipitation change from the large-scale atmospheric circulation aspect. It will contribute important new knowledge to the study of  
10 the spatiotemporal rainy-season precipitation variability in China under different ENSO types. There are significant opportunities  
11 for improving the paper, which are presented as the following points:

12  
13 **Major comments**

14 **1) Comments:**

15 In study area and data part, how did the authors select the precipitation stations for analysis? How about the data quality? Any  
16 missing data? As far as I know, there might have much more precipitation stations in China Meteorological Data Sharing Service  
17 System. What are the screening conditions for the selected stations?

18 **Response**

19 Thanks for the comment. It is true that more precipitation stations are shown in China Meteorological Data Sharing Service System  
20 as compared to stations selected in this paper. The screening conditions for the selected stations are:

- 21 a) Daily precipitation data at each station is deleted if the missing data is more than 5% per year.  
22 b) Missing data is interpolated by the average value of effective daily precipitation 3 days before and after the missing data.  
23 c) The data period for selected station is no less than 40 years.

24  
25 **2) Comments:**

26 In the methodology part, this paper defined the CPW, EPC and EPW regimes based on the definition proposed by Kim et al. (2009),  
27 and presented the years dominated by CPW, EPC and EPW regimes. However, the determination of conventional ENSO and ENSO  
28 Modoki in this paper is judged by the rainy reason rather than the whole year based on SD values. Could you explain why did do  
29 like this?

30 **Response**

31 Thanks for the comment. The difference is determined by different definitions of CPW, EPC, EPW and ENSO, ENSO Modoki.

- 32 a) The definition of CPW, EPC and EPW  
33 Niño 4 warming exceeding 1 standard deviation (SD), while Niño 3 stays below this range, for CPW; Niño 3 or Niño 3.4 cooler  
34 than 1 SD, for EPC; Niño 3 warming greater than 1 SD, for EPW(Kim et al., 2009). Warming and cooling events are defined based  
35 on the detrended SST anomaly index for August to October (Kim et al., 2009).

36 It can be pointed out that the determination of CPW, EPC and EPW is based on SSTA and SD indices for August to October. Hence,  
37 the three ENSO types can only be determined by years rather than rainy season.

38 b) The definition of ENSO and ENSO Modoki

39 The conventional EN (LN), abbreviated as CEN (CLN), was defined as SSTA above (below) 0.7 SD (-0.7 SD) in the area of 5°N –  
40 5°S, 90°W – 140°W. Similarly, warm (cold) episodes of ENSO Modoki, abbreviated as MEN (MLN), was defined as EMI above  
41 (below) 0.7 SD (-0.7 SD).

42 SD in definitions of ENSO and ENSO Modoki represents the standard deviation of the specific period you select. Therefore, we can  
43 judge the type of ENSO and ENSO Modoki of the rainy season.

44  
45 3) **Comments:**

46 Line 194: the authors need to present a brief introduction why 850-mb vector is selected for the analysis of composites of circulation.

47 **Response**

48 Thanks for the comment. We agree that the reason why choosing 850-mb vector winds to analyze circulation and monsoon is  
49 missing. A brief introduction is presented after the paragraph at *Page 3, Line 67* as:

50 “850hpa wind variability is associated with SSTA in the equatorial Pacific and precipitation anomalies in China (Zhang et al.,  
51 1999;Zhou and Chan, 2007;Wang et al., 2004;Zhang et al., 2016b). Fan et al. (2013) pointed out that 850 hPa vector winds are  
52 related to the moisture transportation from western tropical Pacific to the subtropical region, which determines the precipitation  
53 over the Yangtze-Huai River Valley region. Huang et al. (2004) and Zhang et al. (2014a) presented the atmospheric circulation and  
54 monsoon variability by the composite distribution of wind anomalies at 850 hpa in different phases of El Niño and La Niña to  
55 explain precipitation variation in China. Feng et al. (2011) compared the difference of 850 hPa wind anomalies in decaying ENSO  
56 and ENSO Modoki phases to explain the physical mechanism of seasonal precipitation variation in China. Hence, 850 hpa vector  
57 winds reflecting atmospheric circulation and monsoon variability is used to explore the underlying causes of precipitation anomalies  
58 in this study.”

59  
60 4) **Comments:**

61 In the Results and Discussion part, the climate in China is largely affected by East Asian monsoon, which determines the  
62 spatiotemporal patterns of precipitation. How could you explain the connections between the monsoon effects and precipitation  
63 anomalies under different ENSO types?

64 **Response**

65 Thanks for the comment. We use the spatial patterns of 850-mb vector winds to explain the connections between the monsoon  
66 effects and precipitation anomalies under different ENSO types. The reason why 850-mb vector winds are selected is presented in  
67 comment 3. We have cited more references to further show the teleconnection by revising the paragraph at *Page 10 Line 219* as:

68 “Generally, stronger western and southwestern winds are related to increasing precipitation. It is in agreement with the research of  
69 Zhang et al. (1996) and Wang et al. (2000), who pointed out that southeastern and southwestern winds could substantially enhance

70 the moisture transportation to China. Wu et al. (2003) also found that East Asian monsoon is positively related to precipitation  
71 variations, which is consistent with our result.”

72  
73 The explanation of the teleconnection can also be shown at *Page 10 Lines 194-196* as:

74 “There is a strengthening of westerly and southwesterly wind in the decaying year of CPW (Fig.5b), which brings more moisture to  
75 China, compared to developing CPW (Fig.5a). This may explain the enhanced precipitation in decaying CPW (Fig.2b).”

76  
77 at *Page 10 Lines 205-207* as:

78 “Compared to developing CEN, developing MEN experienced reduced precipitation in western China and generally enhanced  
79 precipitation in eastern parts under the combined influence of stronger monsoon and weakened anti-cyclone (Fig.6a-b).”

80  
81 at *Page 11 Lines 211-213* as:

82 “The difference of wind composites between decaying CLN and MLN indicates similar configuration, with stronger westerly wind  
83 and anti-cyclone causing enhanced precipitation for decaying MLN. ”

#### 84 85 **Minor comments**

##### 86 **1) Comments:**

87 Lines 13-14: higher than normal average precipitation doesn't always mean flooding unless you conduct hydrological modeling. I  
88 would use precipitation anomaly only rather than “flood”. I suggest “the precipitation anomaly can reach up to 30% above average  
89 precipitation during decaying CPW and EPW phase”

##### 90 **Response**

91 Thanks for the comment. We will use precipitation anomaly only rather than “flood” or “drought”.

92 P. 1, it is written: < Results showed that there is a higher probability for flooding during decaying CPW and EPW phases in most  
93 parts of China with a largest precipitation anomaly reaching 30% above average precipitation. >

94 revise the paragraph at *Page 1, Lines 12-14* as:

95 “Results showed that the precipitation anomaly can reach up to 30% above average precipitation during decaying CPW and EPW  
96 phases.”

97  
98 P. 1, it is written: < Developing EPW could trigger droughts over large areas in China with 10-30% lower than average precipitation  
99 in most areas. >

100 revise the paragraph at *Page 1, Lines 14-15* as:

101 “Developing EPW could cause decreasing precipitation over large areas in China with 10-30% lower than average precipitation in  
102 most areas.”

103

104 P. 1, it is written: <Decaying ENSO also showed larger effect on the occurrence of drought and flood, compared to decaying ENSO  
105 Modoki.>

106 revise the paragraph at *Page 1, Lines 16-17* as:

107 “Decaying ENSO also showed larger effect on precipitation anomalies, compared to decaying ENSO Modoki.”

108

109 P. 6, it is written: < In summary, the CPW decaying phase (EPC developing phase) deserves more attention than the developing  
110 (decaying) phase, since it has higher possibility to trigger flooding.>

111 revise the paragraph at *Page 6, Lines 143-144* as:

112 “In summary, the CPW decaying phase (EPC developing phase) deserves more attention than the developing (decaying) phase,  
113 since it show more prominent wet signals.”

114

115 P. 8, it is written: <Flooding or drought is more easily triggered for the warm episodes of conventional ENSO, in comparison to the  
116 other three regimes.>

117 revise the paragraph at *Page 8, Lines 167* as:

118 “Wet or dry signals are more easily shown for the warm episodes of conventional ENSO, in comparison to the other three regimes.”

119

120 P. 8, it is written: < Most parts of China presented increasing precipitation for decaying CEN, with more than 30% above average  
121 precipitation identified in north China, which is more likely to trigger flooding>

122 revise the paragraph at *Page 8, Lines 169-171* as:

123 “Most parts of China presented increasing precipitation for decaying CEN, with more than 30% above average precipitation  
124 identified in north China.”

125 P. 13, it is written: < Conventional ENSO in the decaying phase is more likely to cause flooding and drought in comparison to the  
126 corresponding ENSO Modoki regimes.>

127 revise the paragraph at *Page 13, Lines 246-247* as:

128 “Conventional ENSO in the decaying phase is more likely to show wet and dry signals in comparison to the corresponding ENSO  
129 Modoki regimes.”

130

## 131 2) *Comments:*

132 Line 25: what does “rainy season characteristics represent?”

133 P. 1, it is written: < Rainy season characteristics, however, are less considered, which are of immense significance to rain-fed  
134 agriculture in many countries like China. >

135 **Response**

136 Thanks for the comment. Rainy season characteristics represent onset, withdrawal and precipitation of the rainy season mentioned  
137 below. We have now revised the paragraph at *Page 1, Line 25* as:

138 “Rainy season characteristics (e.g., onset, withdrawal and precipitation of rainy season), however, are less considered, which are of  
139 immense significance to rain-fed agriculture in many countries like China.”

140

141 **3) Comments:**

142 Line 29: Provide references for the statement “china is an ENSO-sensitive country”

143 P. 2, it is written: < China is an ENSO-sensitive country and prone to flood and drought occurrence. >

144 **Response**

145 Thanks for the comment. We agree that the statement needs to be expanded to be made more clearly. We have now revised the  
146 paragraph at *Page 2, Line 29* as:

147 “China is an ENSO-sensitive country and prone to flood and drought occurrence (Zhang et al., 2016a;Feng et al., 2011;Feng et al.,  
148 2010;Wang and Wang, 2013;Zhang et al., 2014b;Feng and Li, 2011)”

149

150 **4) Comments:**

151 Line 30: delete “Chinese”

152 P. 2, it is written: < Thus, it is significant to investigate Chinese rainy-season precipitation under ENSO regimes.>

153 **Response**

154 Thanks for reading thoroughly. We have now revised the paragraph at *Page 2, Line 30* as:

155 “Thus, it is significant to investigate rainy-season precipitation under ENSO regimes.”

156

157 **5) Comments:**

158 Line 31: Nino3 → Niño 3. Global check over the manuscript.

159 **Response**

160 Thanks for reading thoroughly. This point has been corrected.

161

162 **6) Comments:**

163 Line 53: suggest revise “in different parts of China” to “among locations in China”

164 P. 2, it is written: < It can be seen that the influence of ENSO regimes on precipitation varies in different parts of China.>

165 **Response**

166 Again, thanks for reading thoroughly. We have now revised the paragraph at *Page 2, Line 53* as:

167 “It can be seen that the influence of ENSO regimes on precipitation varies among locations in china.”

168

169 **7) Comments:**

170 Lines 74-78: Suggest delete the introduction of paper structure. It is more like the statement in a report.

171 **Response**

172 Thanks for the comment, we agree that it may be not appropriate to include the introduction of paper structure in a research article  
173 and we have corrected it.

174

175 **8) Comments:**

176 Line 81: delete "Climate of"

177 P. 3, it is written: <Climate of China is mainly dominated by monsoon climate and mountain plateau climate, which lead to  
178 pronounced rainfall differences among different seasons and regions.>

179 **Response**

180 Again, thanks for reading thoroughly. We have now revised the paragraph at *Page 3, Line 81* as:

181 "China is mainly dominated by monsoon climate and mountain plateau climate, which lead to pronounced rainfall differences among  
182 different seasons and regions."

183

184 **9) Comments:**

185 Line 106: "Mann-Kendall test at 0.05 confidence level". Do you mean significance level?

186 P. 5, it is written: < at 0.05 confidence level.>

187 **Response**

188 Thanks for the comment. We have now revised the paragraph at *Page 5, Line 106* as:

189 "at 0.05 significance level."

190

191 **10) Comments:**

192 Line 130: delete "It is seen that"

193 **Response**

194 Again, thanks for reading thoroughly. It has been corrected.

195

196 **11) Comments:**

197 Line 226: try not to use vague words like "seems to"

198 P. 11, it is written: <As a consequence, WNP anti-cyclone seems to have larger effect on East Asia precipitation on the inter-annual  
199 or inter-decadal scale,>

200

201 **Response**

202 Again, thanks for reading thoroughly. We have now revised the paragraph at *Page 11, Line 226* as:

203 "As a consequence, WNP anti-cyclone has larger effect on East Asia precipitation on the inter-annual or inter-decadal scale,"

204

205 **12) Comments:**

206 Line 240: “most parts of China”: this statement should be more specific at which part. It is not good to use vague words like “most”  
207 in research paper.

208 P. 13, it is written: <It was found that most parts of China experience increasing precipitation for decaying CPW and EPW,>

209 **Response**

210 Thanks for the comment. We agree that it is not appropriate to use vague words in research paper, and “most parts of china” has  
211 been replaced by specific regions and locations in China. We have now revised the paragraph at *Page 13, Line 240* as:

212 “It was found that northwestern, central and southeastern China experience increasing precipitation for decaying CPW and EPW,”

213

214 **13) Comments:**

215 Lines 241-242: “the positive and negative anomaly ranges from 0 to 30%...”, Is this change significant at a certain confidence level?

216 **Response**

217 Thanks for the comment. The significance level of precipitation anomaly of each precipitation station is truly considered. However,  
218 the paper has induced station data into grid data with a resolution of  $0.2^\circ \times 0.2^\circ$  by Kriging interpolation, because the stations are  
219 distributed unevenly. Hence, the spatial patterns of precipitation anomaly shown in this paper do not present the significance level.

220 The significance level of stations are shown as Table. 1. It can be seen that the precipitation anomalies in most of selected stations  
221 are statistically significant at the 0.05 significance level.

222

223 **Table 1. Number of stations which are statistically significant or insignificant at the 0.05 significance level during various**

224

**ENSO regimes.**

Phase	The developing phase		The decaying phases		
	Number of stations	Statistically significant stations	Insignificant stations	Statistically significant stations	Insignificant stations
CPW		480	56	484	52
EPC		475	61	454	82
EPW		429	107	487	49
CEN		435	101	475	61
CLN		439	97	409	127
MEN		464	72	476	60
MLN		451	85	459	77

225

226

227 **Referee 2:**

228  
229 **General Comments:**

230 This paper attempts to investigate the impact of ENSO regimes (CPW, EPC, EPW, conventional ENSO, and ENSO Modoki) on  
231 precipitation in China through studying PARS (precipitation anomaly index during rainy season).  
232

233 **Major comments**

234 1) *Comments:*

235 First of all, why authors have only focused on precipitation anomaly in their approach? The description is not  
236 convincing. What about composite wind vectors at 850 mb? Is it a common approach to use these two measures to  
237 evaluate ENSO intensity and direction? I think this part of the paper needs more description and the current shape is  
238 not convincing. Also, what was the advantage of using NOAA extended reconstructed

239 Thanks for the comment.

240 a) It is true that the reason why we have only focused on precipitation anomaly in our approach is unclear. A brief introduction is  
241 presented after the paragraph at *Page 5, Line 122* as:

242 “Precipitation anomaly can present the difference of precipitation between ENSO years and normal years and demonstrate the  
243 influence of ENSO regimes on precipitation more directly. Zhang et al. (2013a) used precipitation anomaly index to explore the  
244 effect of ENSO on precipitation in the East River Basin, South China. Zhang et al. (2016a) investigated the influence of ENSO and  
245 ENSO Modoki on seasonal precipitation over the Huaihe River Basin by using precipitation anomaly index. ”

246 b) We agree that the reason why choosing 850-mb vector winds to analyze circulation and monsoon is missing. A brief  
247 introduction is presented after the paragraph at *Page 3, Line 67* as:

248 “850hpa wind variability is associated with SSTA in the equatorial Pacific and precipitation anomalies in China (Zhang et al.,  
249 1999;Zhou and Chan, 2007;Wang et al., 2004;Zhang et al., 2016b). Fan et al. (2013) pointed out that 850 hPa vector winds are  
250 related to the moisture transportation from western tropical Pacific to the subtropical region, which determines the precipitation  
251 over the Yangtze-Huai River Valley region. Huang et al. (2004) and Zhang et al. (2014a) presented the atmospheric circulation and  
252 monsoon variability by the composite distribution of wind anomalies at 850 hpa in different phases of El Niño and La Niña to  
253 explain precipitation variation in China. Feng et al. (2011) compared the difference of 850 hPa wind anomalies in decaying ENSO  
254 and ENSO Modoki phases to explain the physical mechanism of seasonal precipitation variation in China. Hence, 850 hpa vector  
255 winds reflecting atmospheric circulation and monsoon variability is used to explore the underlying causes of precipitation anomalies  
256 in this study. ”

257 Therefore, it is a common approach to use these two measures to evaluate ENSO intensity and direction.

258 c) The advantage of using NOAA extended reconstructed data

259 The Extended Reconstructed Sea Surface Temperature (ERSST) dataset is a global monthly sea surface temperature dataset derived  
260 from the International Comprehensive Ocean–Atmosphere Dataset (ICOADS). It is produced on a  $2^\circ \times 2^\circ$  grid with spatial  
261 completeness enhanced using statistical methods. The newest version of ERSST, version 4, used in this study, is based on optimally

262 tuned parameters using the latest datasets and improved analysis methods (Liu et al., 2015;Huang et al., 2016). ERSST is suitable  
263 for long-term global and basin-wide studies, and smoothed local and short-term variations are used in the dataset.

264  
265 **Minor comments**

266 **1) Comments:**

267 Figures 5, 6, and 7 are not blue shaded but gray shaded.

268 **Response**

269 Thanks for reading thoroughly. It has been corrected.

270  
271 **2) Comments:**

272 Line 29, “China is an ENSO-sensitive country and prone : : .”, how so? a reference will help. As it is in introduction, it should be  
273 more convincing.

274 **Response**

275 Thanks for the comment. We agree that the statement needs to be expanded to be made more clearly. We have now revised the  
276 paragraph at *Page 2, Line 29* as:

277 “China is an ENSO-sensitive country and prone to flood and drought occurrence (Zhang et al., 2016a;Feng et al., 2011;Feng et al.,  
278 2010;Wang and Wang, 2013;Zhang et al., 2014b;Feng and Li, 2011)”

279  
280 **3) Comments:**

281 Line 66, “As a consequence, the investigation of : : .” there is a missing piece that can connect using composite wind vectors at 850  
282 mb to the investigation of atmospheric circulation.

283 **Response**

284 Thanks for the comment. We have added a piece after the paragraph at *Page 3, Line 67* as to connect using composite wind vectors  
285 at 850 mb to the investigation of atmospheric circulation.

286 “850hpa wind variability is associated with SSTA in the equatorial Pacific and precipitation anomalies in China (Zhang et al.,  
287 1999;Zhou and Chan, 2007;Wang et al., 2004;Zhang et al., 2016b). Fan et al. (2013) pointed out that 850 hPa vector winds are  
288 related to the moisture transportation from western tropical Pacific to the subtropical region, which determines the precipitation  
289 over the Yangtze-Huai River Valley region. Huang et al. (2004) and Zhang et al. (2014a) presented the atmospheric circulation and  
290 monsoon variability by the composite distribution of wind anomalies at 850 hpa in different phases of El Niño and La Niña to  
291 explain precipitation variation in China. Feng et al. (2011) compared the difference of 850 hPa wind anomalies in decaying ENSO  
292 and ENSO Modoki phases to explain the physical mechanism of seasonal precipitation variation in China. Hence, 850 hpa vector  
293 winds reflecting atmospheric circulation and monsoon variability is used to explore the underlying causes of precipitation anomalies  
294 in this study.”

296 **4) Comments:**

297 Line 115, “The definition of ENSO Modoki and conventional ENSO was demonstrated.” Not clear to me what authors wanted to  
298 highlight by this.

299 **Response**

300 Thanks for the comment. The purposes to demonstrate the definition of ENSO and ENSO Modoki is:

- 301 a) Show the difference of ENSO and ENSO Modoki.  
302 b) Facilitate readers and other researchers to have a better knowledge of the research process, and the judgment of ENSO and  
303 normal years is based on their definitions.

305 **5) Comments:**

306 Line 186, authors stated that “spatial patterns of PARS under ENSO regimes may not only be determined by ENSO but also by the  
307 combination of various drivers” is it a result/finding of this study? Is there any other study that supports the idea?

308 **Response**

309 Thanks for the comment. It is not a result of this study, there are other studies to support the idea, which has been presented at *Page*  
310 *8*, Lines *181-185*.

311 “Xu et al. (2016) revealed that increasing autumn precipitation in southern China is due to the combined ENSO and Indian Ocean  
312 Dipole (IOD) events. Other researchers also concluded that IOD and ENSO have mutual impact on precipitation anomalies in China  
313 (Weng et al., 2011; Liu et al., 2009; Wu et al., 2012). Moreover, Pacific Decadal Oscillation, subtropical high, also influence the  
314 distribution of Chinese precipitation (Chan, 2005; Wang et al., 2008; Chang et al., 2000; Niu and Li, 2008; Ouyang et al., 2014).”

316 Reference

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# Impact of ENSO regimes on developing and decaying phase precipitation during rainy season in China

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**Abstract.** This study investigated the influence of five El Niño-Southern Oscillation (ENSO) types (*i.e.*, Central Pacific Warming (CPW), Eastern Pacific Cooling (EPC), Eastern Pacific Warming (EPW), conventional ENSO, and ENSO Modoki) on rainy-season precipitation in China. The multi-scale moving t-test was applied to determine the onset and withdrawal of rainy season. [Results showed that the precipitation anomaly can reach up to 30% above average precipitation during decaying CPW and EPW phases. Developing EPW could cause decreasing precipitation over large areas in China with 10-30% lower than average precipitation in most areas. Results showed that there is a higher probability for flooding during decaying CPW and EPW phases in most parts of China with a largest precipitation anomaly reaching 30% above average precipitation. Developing EPW could trigger droughts over large areas in China with 10-30% lower than average precipitation in most areas.](#) Conventional El Niño in the developing phase had the largest influence on ENSO-related precipitation among developing ENSO and ENSO Modoki regimes. [Decaying ENSO also showed larger effect on precipitation anomalies, compared to decaying ENSO Modoki. Decaying ENSO also showed larger effect on the occurrence of drought and flood, compared to decaying ENSO Modoki.](#) The difference between rainy-season precipitation under various ENSO regimes may be attributed to the combined influence of anti-cyclone in the western North Pacific and the Indian monsoon. Stronger monsoon and anti-cyclone are associated with enhanced rainy-season precipitation. The results suggest a certain predictability of rainy-season precipitation related to ENSO regimes.

## 1. Introduction

El Niño-Southern Oscillation (ENSO) is one of the most important factors affecting precipitation, which has been achieved urgent attention worldwide (Li et al., 2016; Wang et al., 2006; Preethi et al., 2015; Yuan et al., 2016a; Yuan et al., 2016b; Zaroug et al., 2014; Brigode et al., 2013). Many researchers have studied various aspects of ENSO-based precipitation, such as seasonal precipitation and extreme precipitation. [Rainy season characteristics \(e.g., onset, withdrawal and precipitation of rainy season\).](#)

30 [however, are less considered, which are of immense significance to rain-fed agriculture in many countries like China. Rainy season](#)  
31 [characteristics, however, are less considered, which are of immense significance to rain-fed agriculture in many countries like China.](#)  
32 Reliable prediction of onset and withdrawal of rainy season will assist on-time preparation of farmlands and is significant to  
33 ecosystem (Omotosho et al., 2000; Marteau et al., 2011). In addition, rainy season is a period when it is easier for flooding and rainy-  
34 season precipitation could provide certain predictability for flood occurrence. [China is an ENSO-sensitive country and prone to](#)  
35 [flood and drought occurrence \(Zhang et al., 2016a; Feng et al., 2011; Feng et al., 2010; Wang and Wang, 2013; Zhang et al.,](#)  
36 [2014b; Feng and Li, 2011\).](#) ~~China is an ENSO-sensitive country and prone to flood and drought occurrence.~~ Thus, it is significant  
37 to investigate ~~Chinese~~ rainy-season precipitation under ENSO regimes. Cai (2003) observed similar inter-decadal oscillation and  
38 abrupt variations between rainfall of rainy season in Fujian and [Niño Niño](#)<sup>3</sup> SST. Lu (2005) pointed out that rainfall in the rainy  
39 season in North China is related to sea surface temperature anomalies (SSTA) in the equatorial eastern Pacific and negative (positive)  
40 SSTA could trigger heavier (lighter) rainy-season precipitation. However, such studies mainly concentrated on regional scales and  
41 single ENSO mode, rather than continental scale and various ENSO regimes, which is important for overall understanding of  
42 relationship between ENSO and Chinese rainy-season precipitation. In order to decipher this, it is necessary to explore the spatial  
43 pattern of precipitation during the rainy season under various ENSO regimes at the continental scale in China.

44 Different types of ENSO regimes have been demonstrated based on the Pacific spatial pattern SSTA (Kao and Yu, 2009; Larkin  
45 and Harrison, 2005; Ashok et al., 2007; Trenberth, 1997; Tedeschi et al., 2013; Kim et al., 2009). Conventional ENSO episodes,  
46 including El Niño (EN) and La Niña (LN), are defined based on SST anomalies in the [Niño Niño](#)<sup>3.4</sup> region, and El Niño is mainly  
47 characterized by East Pacific warming in the cold tongue of the East Pacific ocean (Kim et al., 2009). Several researchers have  
48 identified different episodes of SST in the Pacific, such as the central Pacific warming and east Pacific cooling (Larkin and Harrison,  
49 2005; Weng et al., 2007; Kao and Yu, 2009). Kim et al. (2009) divided ENSO into three types, i.e., Central Pacific Warming (CPW),  
50 Eastern Pacific Cooling (EPC), and Eastern Pacific Warming (EPW). The division of ENSO is also based on SSTA in [Niño Niño](#)<sup>3</sup>  
51 [Niño Niño](#)<sup>3.4</sup>, and [Niño Niño](#)<sup>4</sup> regions. Ashok et al. (2007) introduced a new type of ENSO event, ENSO Modoki, which is  
52 different from conventional ENSO. ENSO Modoki is characterized by positive SSTA in the central Pacific, bounded by negative  
53 SSTA in the western and eastern Pacific.

54 ENSO and ENSO Modoki have different influence on precipitation (Ashok et al., 2007; Ashok et al., 2009; Weng et al.,  
55 2007; Taschetto and England, 2009). Zhang et al. (2016a) pointed out that CPW, EPC, and EPW regimes showed various  
56 performance on seasonal precipitation over the Huaihe River Basin. Precipitation below average usually occurs in southern China  
57 in ENSO Modoki years, whereas the conventional ENSO tends to imply precipitation above average (Zhang et al., 2014b). In  
58 contrast, enhanced precipitation over the Huaihe River Basin often occurs during decaying El Niño Modoki events in summer,  
59 whilst reduced precipitation signals are found in the corresponding season in the decaying year of El Niño (Feng et al., 2011). [It can](#)  
60 [be seen that the influence of ENSO regimes on precipitation varies among locations in China. It can be seen that the influence of](#)

~~ENSO regimes on precipitation varies in different parts of China.~~ The National Climate Center (NCC) succeeded in predicting the severe flood over the Yangtze River basin in the typical El Niño year of 1997-1998. Nonetheless, NCC failed to predict the enhanced precipitation in the Huaihe River basin in 2002-2003, since it was an El Niño Modoki year rather than a conventional El Niño. This highlights the significance of correct distinguishing between ENSO and ENSO Modoki.

Different performance of precipitation under various ENSO regimes is associated with atmospheric circulation and monsoon (Tedeschi et al., 2013;Feng et al., 2010;Cai et al., 2010;Black et al., 2003;Chang et al., 2001;Zhang et al., 2014a;Onyutha and Willems, 2015). Wu et al. (2003) explained the physical mechanism of links between precipitation and SSTs through features of atmospheric circulation. Wang et al. (2004) pointed out that the local onset of rainy season in the South China Sea is related to mean summer monsoon onset. Cai et al. (2010) argued that a rainfall reduction in southeast Queensland in Australia is related to an eastward shift in the Walker circulation. Feng et al. (2011) pointed out that China rainfall anomalies were mainly due to anomalous anti-cyclonic flow in the western North Pacific associated with El Niño Modoki and El Niño events. Gerlitz et al. (2016) argued that ENSO-induced precipitation variability in tropical regions is directly associated with the atmospheric circulation. The atmospheric circulation and monsoon have different influence on two types of ENSO (Feng and Li, 2013;Zhang et al., 2011;Zhou and Chan, 2007). As a consequence, the investigation of atmospheric circulation and monsoon is used to explain different performance of rainy-season precipitation anomalies under various ENSO regimes in this study.

850hpa wind variability is associated with SSTA in the equatorial Pacific and precipitation anomalies in China (Zhang et al., 1999;Zhou and Chan, 2007;Wang et al., 2004;Zhang et al., 2016b). Fan et al. (2013) pointed out that 850 hPa vector winds are related to the moisture transportation from western tropical Pacific to the subtropical region, which determines the precipitation over the Yangtze-Huai River Valley region. Huang et al. (2004) and Zhang et al. (2014a) presented the atmospheric circulation and monsoon variability by the composite distribution of wind anomalies at 850 hpa in different phases of El Niño and La Niña to explain precipitation variation in China. Feng et al. (2011) compared the difference of 850 hPa wind anomalies in decaying ENSO and ENSO Modoki phases to explain the physical mechanism of seasonal precipitation variation in China. Hence, 850 hpa vector winds reflecting atmospheric circulation and monsoon variability is used to explore the underlying causes of precipitation anomalies in this study.

The influence of ENSO and ENSO Modoki regimes on Chinese precipitation has been studied intensively. However, research has been limited to the comparison of impacts of developing (decaying) ENSO and ENSO Modoki on precipitation at the regional scale in China. Therefore, this study aims to improve our understanding of ENSO-induced precipitation during rainy season and to explore the effect of five important ENSO types (i.e., CPW, EPC, EPW, ENSO and ENSO Modoki) in the developing and decaying phase on the continental scale precipitation. The multi-scale moving t-test method was applied to determine the onset and withdrawal of the rainy season. The underlying causes of the spatial patterns of rainy-season precipitation were analyzed by the variability of atmospheric circulation in the western North Pacific (WNP) together with monsoon. ~~Consequently, the paper is organized as follows.~~

92 ~~Section 2 describes the study area and used data. Section 3 shows the methodology for determining the rainy season and the~~  
93 ~~definition of ENSO and ENSO Modoki. In Sect.4, we investigate and discuss the spatial distribution of rainy season precipitation~~  
94 ~~under different ENSO regimes in the developing and decaying phase and their underlying causes. The final section summaries the~~  
95 ~~main findings.~~

## 96 **2. Study area and data**

97 China, located in middle latitude in East Asia (18°N-54°N, 73°E- 135°E) , is the most populous country in the world (Fig. 1), with  
98 a population of over 1.381 billion and an area of approximately 9.6 million km<sup>2</sup>. ~~Climate of~~ China is mainly dominated by monsoon  
99 climate and mountain plateau climate, which lead to pronounced rainfall differences among different seasons and regions.

100 Daily precipitation data from 1960 to 2015 at 536 observation stations in China were selected for this study. The data were  
101 obtained from China Meteorological Data Sharing Service System, and the data quality has been regularly checked. The locations  
102 of the observation stations are shown in Fig.1. The stations are distributed unevenly, with fewer stations in the northwestern part of  
103 China. Hence, we applied Kriging interpolation to induce a resolution of  $0.2^{\circ} \times 0.2^{\circ}$ .

104 The dataset of National Oceanic and Atmospheric Administration (NOAA) extended reconstructed SST was used to identify  
105 different types of conventional ENSO. ENSO Modoki index (EMI) was obtained from the Japan Agency for Marine Science and  
106 Technology. In addition, the National Centres for Environmental Prediction (NCEP)/ National Centres for Atmospheric Research  
107 (NCAR) reanalysis data were used to investigate underlying causes of the spatial pattern of precipitation under different ENSO  
108 regimes (Kalnay et al., 1996).

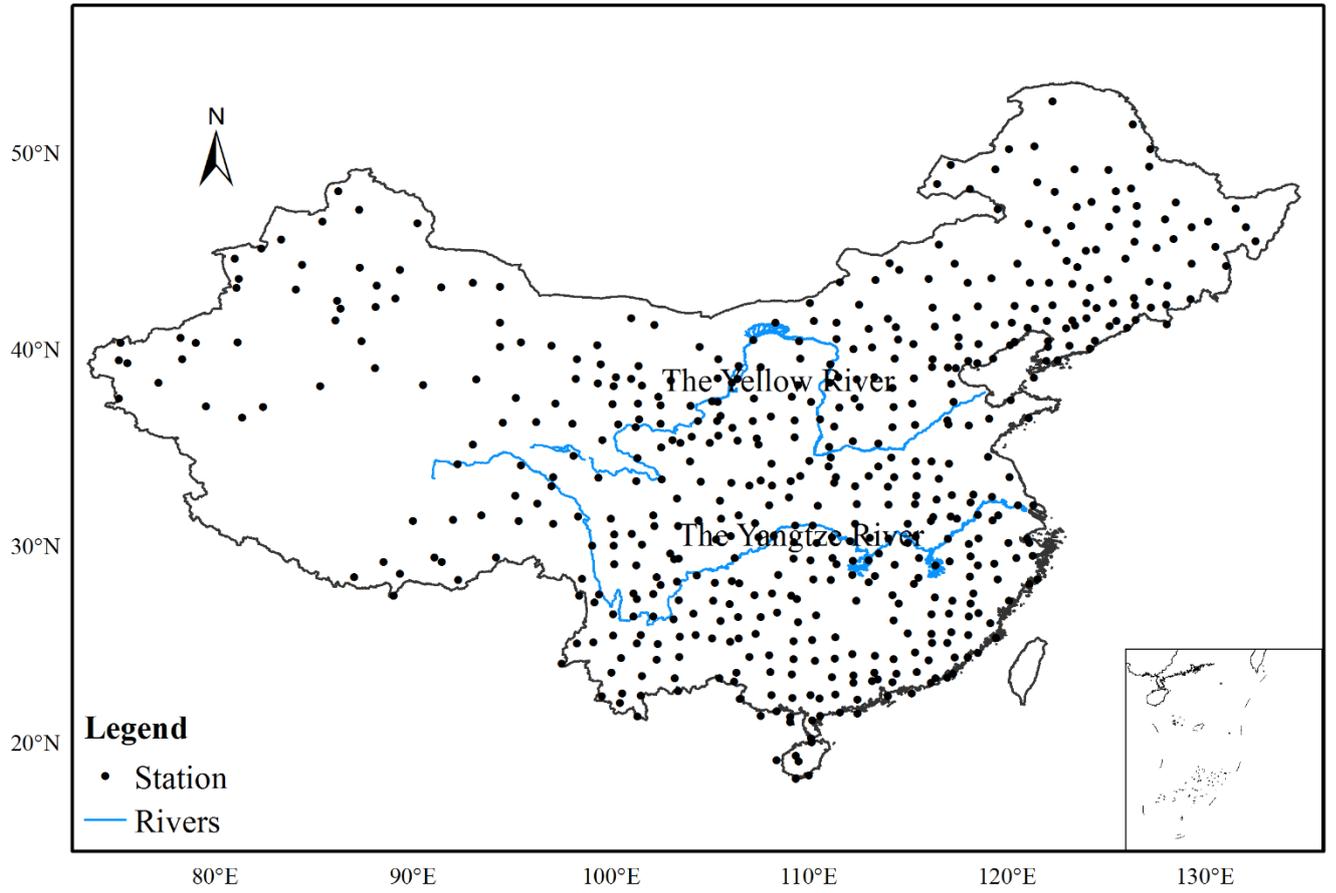


Figure 1: The spatial distribution of precipitation stations used in this study.

### 3. Methodology

#### 3.1 Determination of rainy season

The onset and withdrawal of rainy season was determined by the multi-scale moving t-test method. This method is characterized by the detection of mutation points between two subsamples with equal size  $n$ , where  $n$  is the length of the subsample, ( $n=30, 31, \dots, 182/183$ ;  $182/183$  corresponds to half the value of length of one year  $365/366$ ). Theoretically, the length of subsamples in this study ranged between 1 and  $182/183$ . However, as the onset or withdrawal of the rainy season, it will not be considered if the length of the subsample is one day or just several days when the abrupt point is prominent. As a result, the length of the subsample is limited between 30 and  $182/183$ . The determination of the mutation point can be described as (Fraedrich et al., 1997)

$$t(n, i) = (\bar{x}_{i2} - \bar{x}_{i1})n^{1/2}(s_{i2}^2 + s_{i1}^2)^{-1/2}, \quad (1)$$

where  $\bar{x}_{i1}$  and  $\bar{x}_{i2}$  defined as,

$$\bar{x}_{i1} = \sum_{j=i-n}^{i-1} \frac{x_j}{n}; s_{i1}^2 = \sum_{j=i-n}^{i-1} (x_j - \bar{x}_{i1})^2 / (n-1), \quad (2)$$

$$\bar{x}_{i2} = \sum_{j=i}^{i+n-1} \frac{x_j}{n}; s_{i2}^2 = \sum_{j=i}^{i+n-1} (x_j - \bar{x}_{i2})^2 / (n-1), \quad (3)$$

and  $x_i$  is daily precipitation for Julian day  $i$  within one year and for one station.  $\bar{x}_{i1}$  and  $\bar{x}_{i2}$  are the mean values of the subsamples before and after the Julian day  $i$ , respectively.

The t-value calculated above was normalized by the 0.01 test value showing in Eq. (4), which is equal to the result of Mann-Kendall test at 0.05 ~~significance~~~~confidence~~ level.

$$t_r(n, i) = t(n, i)/t_{0.01}(n), \quad (4)$$

where  $t_r(n, i)$  can be taken as the threshold to detect mutations.  $t_r(n, i) > 1.0$  represents an increasing trend while  $t_r(n, i) < 1.0$  is a decreasing trend. The onset of rainy season in this study was defined as the mutation point corresponding to a maximum  $t_r(n, i)$  value. For this case, precipitation changes from a smaller to a higher value. Likewise, the withdrawal is defined as the changing point corresponding to a minimum  $t_r(n, i)$  value.

### 3.2 Classification of ENSO and ENSO Modoki regimes

Three types of ENSO were classified based on the definition proposed by Kim et al. (2009). The years dominated by CPW, EPC, and EPW are listed in Table 1.

**Table 1. Years dominated by CPW, EPC, and EPW regimes during 1960-2015.**

EPW	EPC	CPW
1965,1972,1976,1982,1987,1997,2015	1964,1970,1973,1975,1988,1998,1999, 2007,2010,2011	1963,1969,1991,1994,2002,2004,2009

The definition of ENSO Modoki and conventional ENSO was demonstrated. Specifically, warm (cold) episodes of ENSO Modoki, abbreviated as MEN (MLN), was defined as EMI above (below) 0.7 SD (-0.7 SD), where SD is the standard deviation (Ashok et al., 2007).  $EMI = [SSTA]A - 0.5 \times [SSTA]B - 0.5 \times [SSTA]C$ , where [SSTA]A, [SSTA]B, [SSTA]C represents the SSTA in region A(10°S – 10°N, 165°E – 140°W), region B(15°S – 5°N, 110°W – 70°W) and region C(10°S – 20°N, 125°E – 145°E), respectively. Likewise, the conventional EN (LN), abbreviated as CEN (CLN), was defined as SSTA above (below) 0.7 SD (-0.7 SD) in the area of 5°N – 5°S, 90°W – 140°W (Tedeschi et al., 2013). This definition gives an opportunity to judge the ENSO type of the rainy season rather than the whole year, which is greater than definition proposed by Trenberth (1997).

### 3.3 Precipitation anomaly index during rainy season (PARS)

—Precipitation anomaly can present the difference of precipitation between ENSO years and normal years and demonstrate the influence of ENSO regimes on precipitation more directly. Zhang et al. (2013a) used precipitation anomaly index to explore the effect of ENSO on precipitation in the East River Basin, South China. Zhang et al. (2016a) investigated the influence of ENSO and ENSO Modoki on seasonal precipitation over the Huaihe River Basin by using precipitation anomaly index.

Precipitation anomaly index ~~is was used to investigate the difference in precipitation between ENSO and normal years~~ defined as:

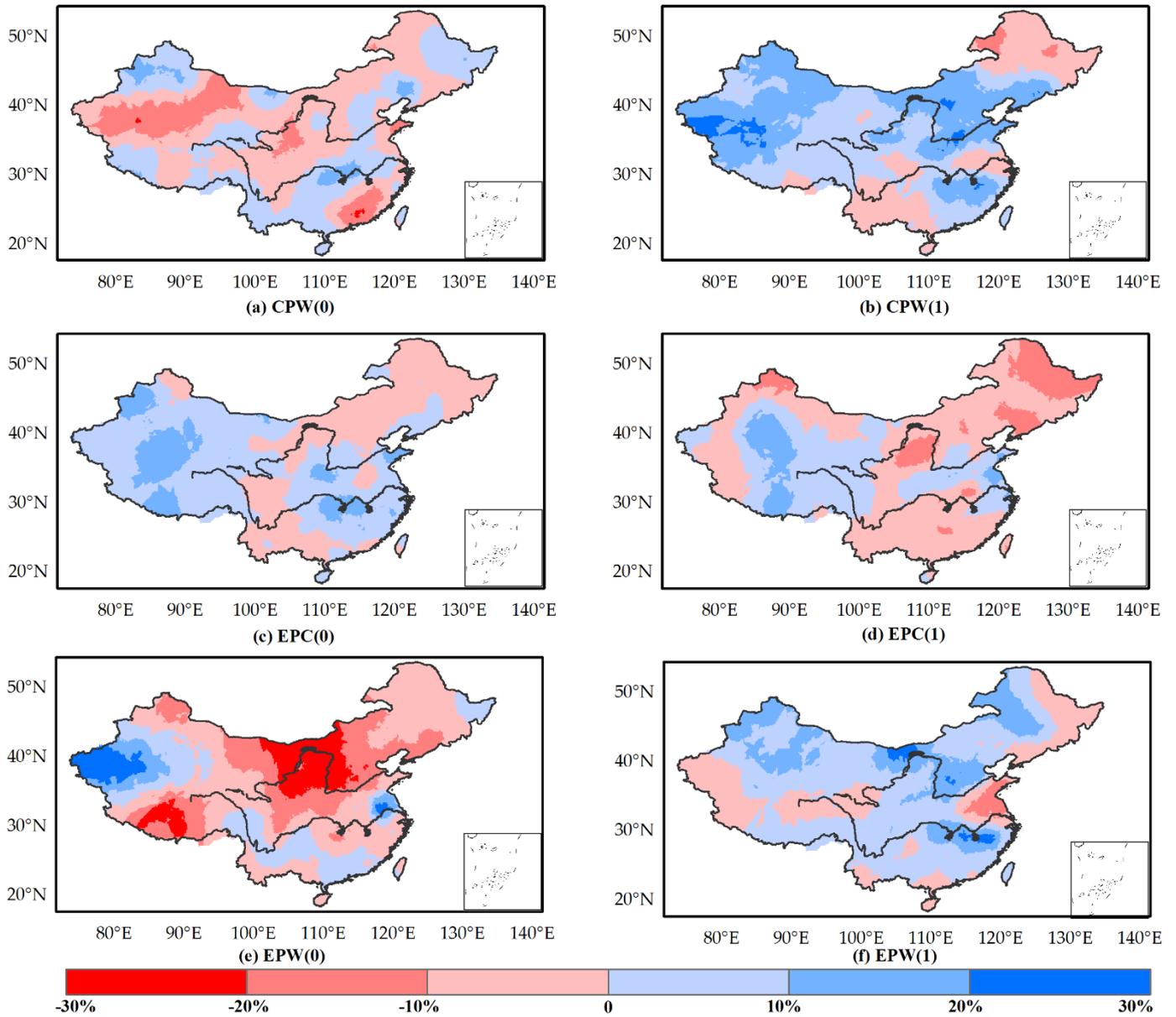
$$PARS_{ij} = \left( \frac{\overline{PRS_{ij}}}{\overline{PRSN_{ij}}} - 1 \right) \times 100\%, \quad (5)$$

where  $PARS_{ij}$  denotes precipitation anomaly during rainy season at  $i_{th}$  station in  $j_{th}$  year;  $\overline{PRS_{ij}}$  denotes mean daily precipitation during rainy season at  $i_{th}$  station in  $j_{th}$  year, and  $\overline{PRSN_{ij}}$  denotes mean daily precipitation during rainy season at  $i_{th}$  station in  $j_{th}$  normal year. The normal year refers to a year without ENSO event occurring.

## 4. Results and Discussion

### 4.1 Precipitation anomaly during rainy season (PARS) influenced by CPW, EPC, and EPW regimes

The spatial variability of PARS under CPW, EPC and EPW regimes in the phase of developing and decaying years is presented in Fig.2. ~~It is seen that~~ the distribution of precipitation anomaly is irregular over the whole area in the developing phase of CPW. The coastal regions in southeastern China that had the largest amount of rainy-season precipitation presented the largest decreasing trend, with the precipitation anomaly reaching 30% below average precipitation. The upper and middle reaches of the Yangtze River and the Yellow River showed decreasing precipitation, whereas the lower reaches had the opposite trend. The decaying CPW regime had relatively regular spatial pattern. More specifically, most parts of China presented increasing precipitation during rainy season, with the largest PARS being 20% above average precipitation. The distribution of PARS influenced by the decaying CPW is similar to that by the developing EPC, with shrinking extent of enhanced precipitation in central China for developing EPC. The distribution of PARS is similar as well in the two phases of EPC (Fig.2, second row), with precipitation above average in northwestern China and precipitation below average in northeastern China. The difference between the two phases lies in the increasing (decreasing) precipitation in southeastern China in the developing (decaying) phase. Nonetheless, developing and decaying EPW (Fig.2, third row) showed opposite spatial precipitation pattern. Most parts of China presented dry signals in the phase of developing EPW, which became stronger northwards, and more than 30% below average precipitation can be identified in north China. However, there is above average precipitation in most regions of China in the case of decaying EPW, with PARS values ranging between 0 and 30%. ~~In summary, the CPW decaying phase (EPC developing phase) deserves more attention than the developing (decaying) phase, since it show more prominent wet signals. In summary, the CPW decaying phase (EPC developing phase) deserves more attention than the developing (decaying) phase, since it has higher possibility to trigger flooding.~~ Both phases are significant for the EPW regimes, due to the obvious dry (wet) signals shown in the developing (decaying) phase.



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**Figure 2: Spatial pattern for rainy-season precipitation anomaly (PARS) during the CPW (first row), EPC (second row), and EPW (third row) episodes in the phase of ENSO developing year (0) and decaying year (1). The sign “0” in the parentheses denotes ENSO developing year and “1” denotes decaying year.**

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#### **4.2 Precipitation anomaly during rainy season (PARS) impacted by ENSO and ENSO Modoki regime**

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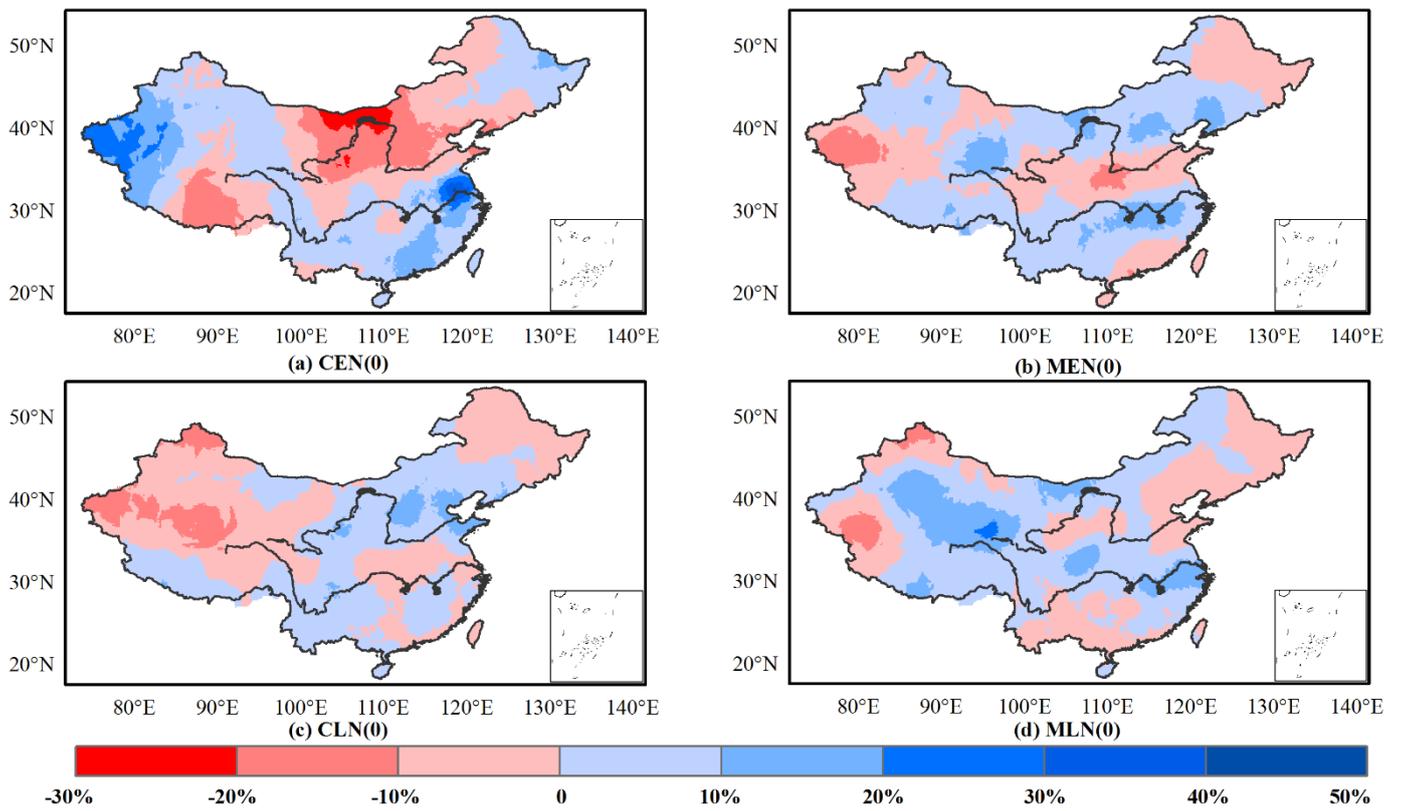
Figure 3 and 4 present precipitation anomalies during rainy season (PARS) for warm and cold episodes of conventional ENSO and ENSO Modoki in a developing phase, and a decaying phase, respectively. Precipitation increased in a band stretching from northwestern China to the coastal region in the southeast, with the largest precipitation anomaly (40%) occurring in southeast China under a developing CEN regime (Fig.3a). The dry condition is more severe northwards in central China, with PARS equal to about -30% in the northern parts of central China. Zhang et al. (2016b) concluded that strong El Niño events are associated with summer monsoon flooding over the Yangtze River, which is consistent with our results. The distribution of rainy-season precipitation for developing El Niño is also in agreement with the research by Zhang et al. (2011). Northern China had opposite PARS pattern for

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181 developing El Niño Modoki, in comparison to developing CEN (Fig.3b). Nonetheless, the two phases showed similar precipitation  
182 distribution, with reduced precipitation in central China (approximately -10%) and enhanced precipitation in southern China.  
183 Typically, developing CEN demonstrated more obvious wet or dry signals compared to MEN. Moreover, the wet and dry condition  
184 for developing CEN is the most serious among all ENSO and ENSO Modoki regimes in both developing and decaying phases, with  
185 the largest precipitation anomaly reaching 50% above average precipitation amount and lowest 30% below. This means that  
186 developing CEN should be paid urgent attention for flooding and drought monitoring. The spatial pattern of PARS for developing  
187 CLN presented similar signals with developing MEN, with a shorter wet precipitation band in northern China for developing CLN  
188 (Fig.3c). The increased precipitation was shifted westwards for the developing MLN, compared to cold episodes of conventional  
189 ENSO (Fig.3d). ENSO and ENSO Modoki regimes in the developing phase presented various distribution of precipitation anomalies.  
190 Wet or dry signals are more easily shown for the warm episodes of conventional ENSO, in comparison to the other three regimes.  
191 Flooding or drought is more easily triggered for the warm episodes of conventional ENSO, in comparison to the other three regimes.  
192 Similar patterns of PARS for developing CLN and MEN is suggested to be further studied.

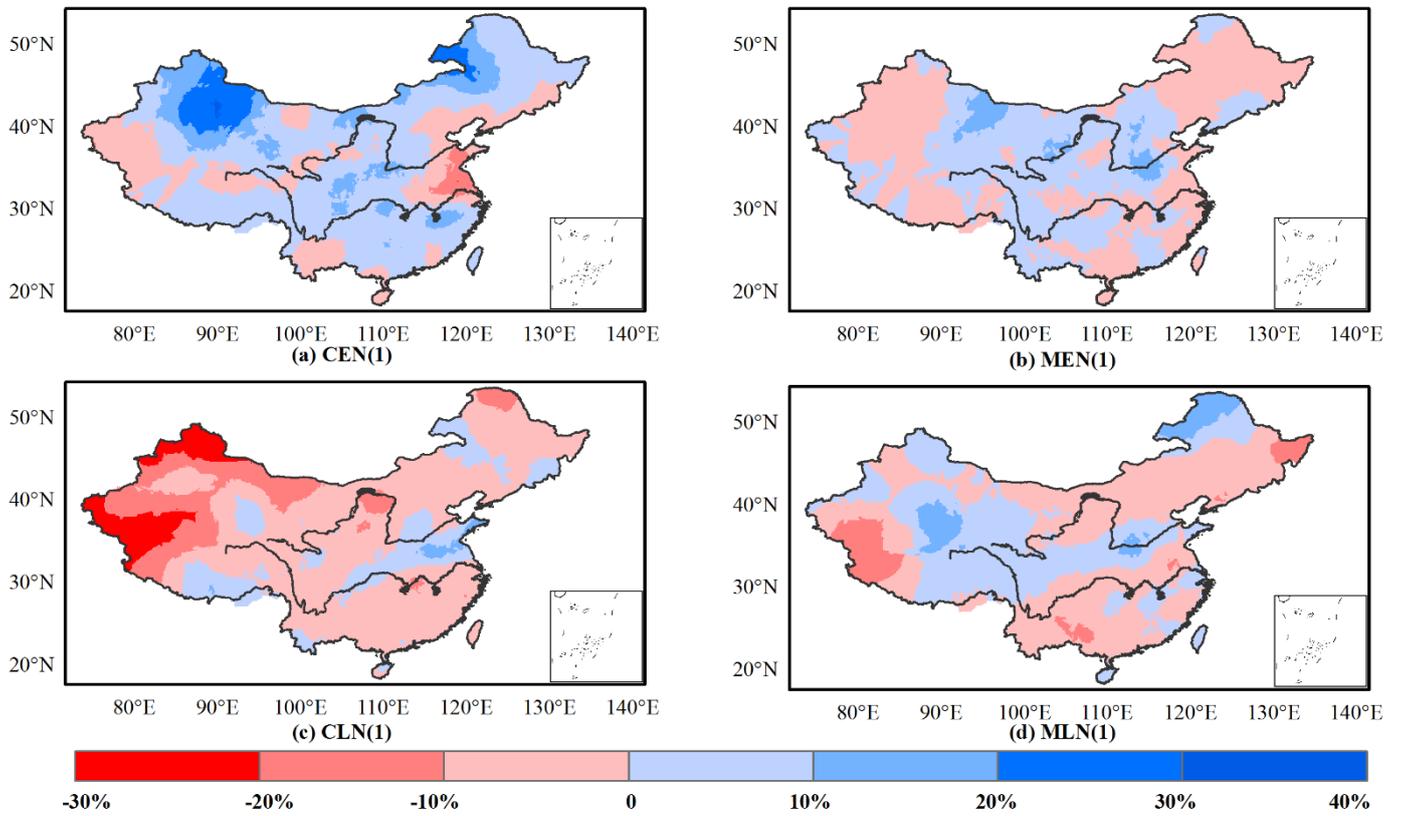
193 Decaying ENSO and ENSO Modoki years showed different features of PARS (Fig.4). Most parts of China presented increasing  
194 precipitation for decaying CEN, with more than 30% above average precipitation identified in north China ~~Most parts of China~~  
195 ~~presented increasing precipitation for decaying CEN, with more than 30% above average precipitation identified in north China,~~  
196 which is more likely to trigger flooding (Fig.4a). The decaying phase of MEN (Fig.4b) presented shrinking extent of enhanced  
197 precipitation, which was condensed in the central parts of China, ranging between 0 and 10%. The result is consistent with  
198 conclusions from Feng et al. (2011), who found obvious rainfall anomalies in southern China for decaying El Niño and no prominent  
199 rainfall variations in the corresponding phase of El Niño Modoki. In terms of the cold episodes of ENSO (Fig.4c), approximately  
200 95% of China showed dry signals, and the condition was more serious eastwards, being 30% below average precipitation amount.  
201 We can see that the spatial pattern of PARS for the decaying CLN is opposite to that of CEN. Decaying MLN (Fig.4d) showed  
202 larger extent of enhanced precipitation in a band stretching from western China to parts of the Yellow River Basin, in comparison  
203 to CLN. In conclusion, the decaying phases of conventional ENSO showed more obvious wet or dry signals compared to ENSO  
204 Modoki, with most parts of China displaying increasing (decreasing) precipitation for the CEN (CLN).

205 This study analyzed spatial patterns of precipitation under different ENSO regimes, since ENSO is the leading driver of  
206 precipitation anomaly in China (Xiao et al., 2015). Xu et al. (2016) revealed that increasing autumn precipitation in southern China  
207 is due to the combined ENSO and Indian Ocean Dipole (IOD) events. Other researchers also concluded that IOD and ENSO have  
208 mutual impact on precipitation anomalies in China (Weng et al., 2011; Liu et al., 2009; Wu et al., 2012). Moreover, Pacific Decadal  
209 Oscillation, subtropical high, also influence the distribution of Chinese precipitation (Chan, 2005; Wang et al., 2008; Chang et al.,  
210 2000; Niu and Li, 2008; Ouyang et al., 2014). As a result, the spatial patterns of PARS under ENSO regimes may not only be  
211 determined by ENSO, but also by the combination of various drivers, which ought to be studied further.



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**Figure 3: Spatial pattern of precipitation anomalies during rainy season (PARS) during developing (0) conventional ENSO and ENSO Modoki events.**



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**Figure 4: Spatial pattern of precipitation anomalies during rainy season (PARS) for decaying (1) conventional ENSO and ENSO Modoki events.**

### 4.3 Composites of circulation

Figure 5 presents the composites of 850-mb vector wind for three types of ENSO. There is a strengthening of westerly and southwesterly wind in the decaying year of CPW (Fig.5b), which brings more moisture to China, compared to developing CPW (Fig.5a). This may explain the enhanced precipitation in decaying CPW (Fig.2b). The difference between developing and decaying EPC (Fig.5c-d) lies in the shift of anti-cyclonic flow in the western part of North Pacific (WNP). The eastward anti-cyclone for the decaying EPC weakened the transportation of moisture in eastern China and caused reduced precipitation (Fig.2d). The decaying EPW (Fig.5f) experienced stronger western and southwestern wind but weakened anti-cyclone compared to the developing phase (Fig.5e). The WNP anti-cyclone could bring plentiful moisture to China, so weakened anti-cyclonic flow will cause reduced precipitation (Feng et al., 2011). However, most parts of China presented wetter signals in the phase of decaying EPW in comparison to developing EPW. Therefore, it can be pointed out that the India monsoon plays a more significant role in the formation of rainy-season precipitation during EPW phases compared to the atmospheric circulation.

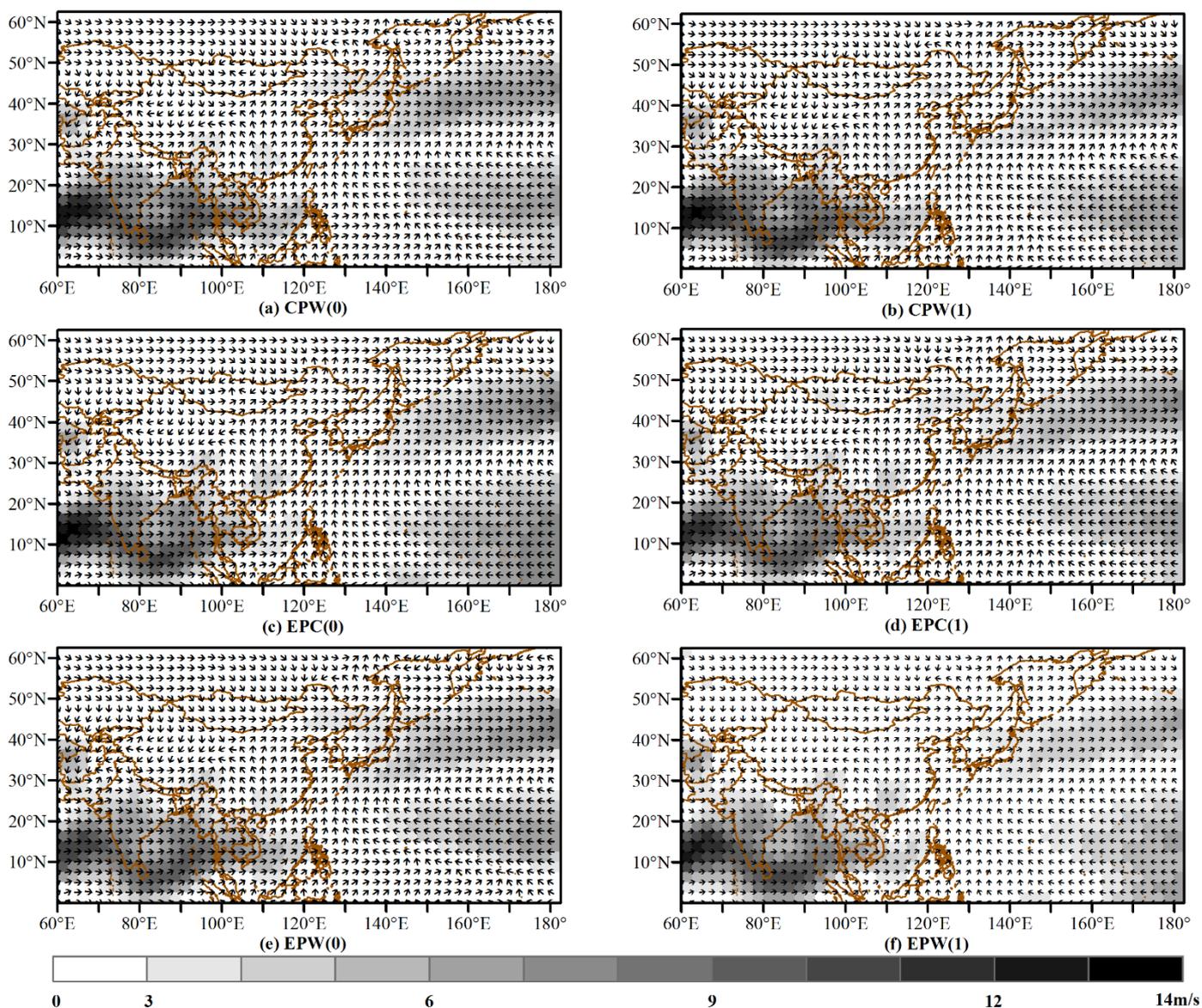
Figure 6 shows the underlying causes of different performance of conventional ENSO and ENSO Modoki in the developing phase by analysis of the 850-hp wind. Compared to developing CEN, developing MEN experienced reduced precipitation in western China and generally enhanced precipitation in eastern parts under the combined influence of stronger monsoon and weakened anti-cyclone (Fig.6a-b). Stronger anti-cyclonic flow in the phase of developing La Niña Modoki (Fig.6d) may cause the enhanced precipitation in western parts of China compared to conventional La Niña regime in developing years (Fig.6c).

The wind composites of warm and cold episodes of decaying ENSO and ENSO Modoki are presented in Fig.7. Compared to decaying CEN, the wet signal of precipitation is weaker in the decaying year of MEN, which may be attributed to the weakened anti-cyclonic flow in WNP and western winds for the decaying MEN. The difference of wind composites between decaying CLN and MLN indicates similar configuration, with stronger westerly wind and anti-cyclone causing enhanced precipitation for decaying MLN.

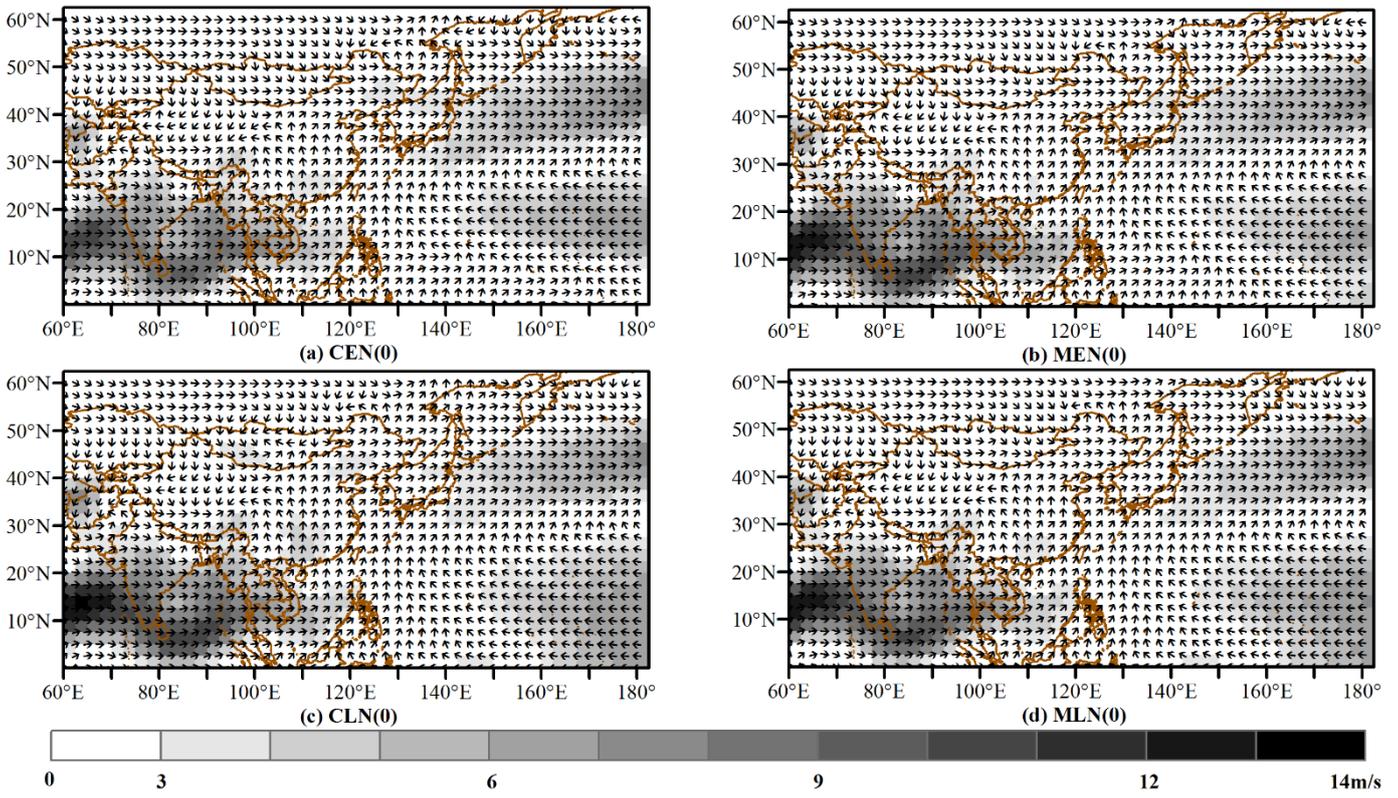
In summary, westerly winds seem to play more significant role in the phase of CPW and EPW, while developing La Niña and La Niña Modoki are dominated by the anti-cyclone. The spatial pattern of PARS is the reflection of combined influence of westerly winds and anti-cyclonic flow for the EPC and decaying ENSO and ENSO Modoki regimes.

It can be seen that the spatial pattern of precipitation during the rainy season in China is dominated by westerly winds from India and anti-cyclone in WNP, which is equivalent to the results by Dai and Wigley (2000), Feng and Li (2011), Wu et al. (2003). Generally, stronger western and southwestern winds are related to increasing precipitation. [It is in agreement with the research of Zhang et al. \(1996\) and Wang et al. \(2000\), who pointed out that southeastern and southwestern winds could substantially enhance the moisture transportation to China. Wu et al. \(2003\) also found that East Asian monsoon is positively related to precipitation variations, which is consistent with our result.](#) Likewise, the westward and stronger anti-cyclone is related to enhanced PARS. Wu et al. (2003) reported that the anomalous low-level anti-cyclone is determined by large-scale equatorial heating anomalies and local

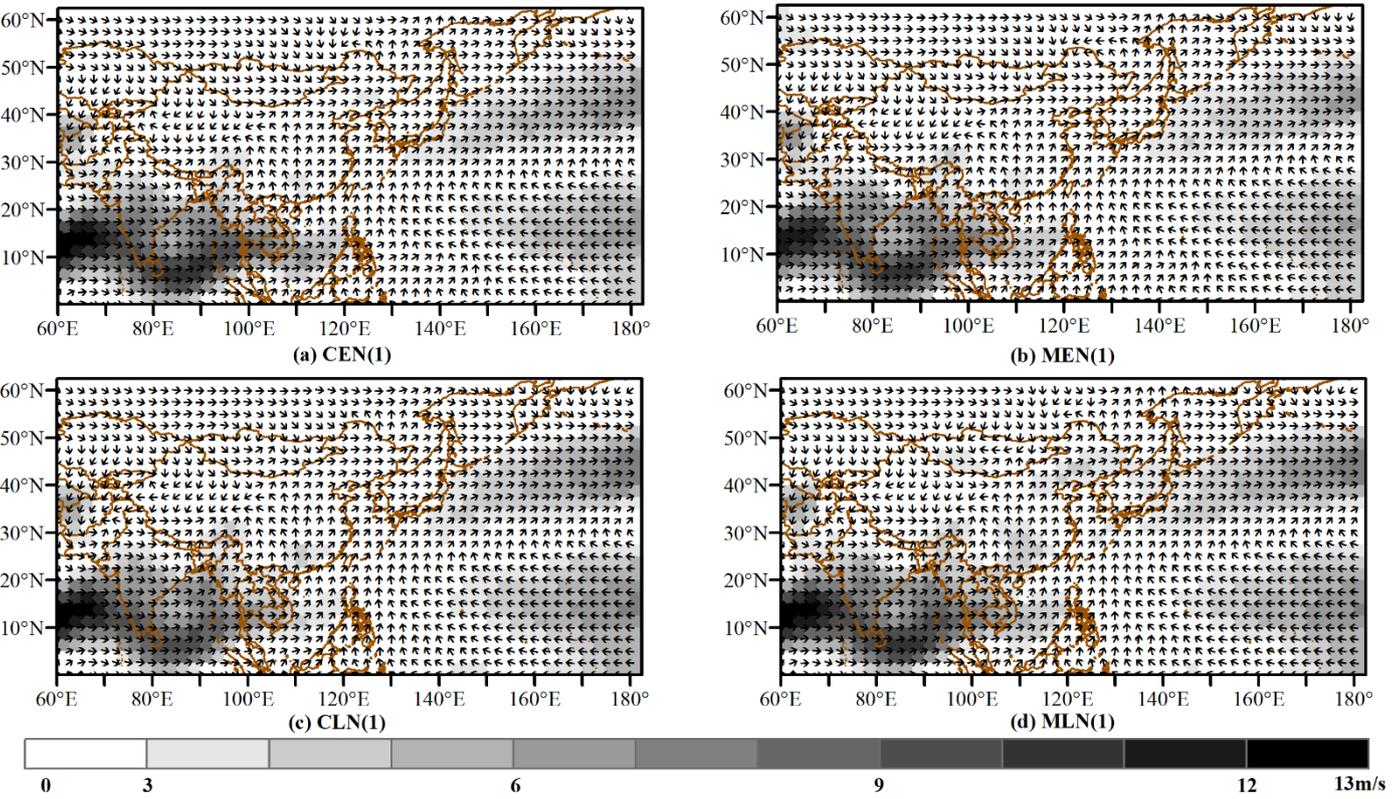
249 air-sea interactions. Westerlies and anti-cyclone are of dominant importance for the ENSO-induced precipitation during the rainy  
 250 season. However, cyclonic flow may have larger influence on Chinese precipitation under certain circumstances. For example, the  
 251 autumn drought in southwest China in 2009 was determined by a strong cyclone in WNP for ENSO Modoki (Zhang et al., 2013b).  
 252 Feng et al. (2011) also revealed that the WNP circulation is cyclonic in winter and then becomes weak in the following spring and  
 253 anti-cyclonic flow in summer for El Niño Modoki. [As a consequence, WNP anti-cyclone has larger effect on East Asia precipitation](#)  
 254 [on the inter-annual or inter-decadal scale.](#) [As a consequence, WNP anti-cyclone seems to have larger effect on East Asia precipitation](#)  
 255 [on the inter-annual or inter-decadal scale,](#) but anti-cyclone and cyclone are both crucial for the determination of precipitation on the  
 256 annual or smaller scale.



257  
 258 **Figure 5: Composites of 850-mb vector wind for mainland China during CPW, EPC and EPW developing (0) and decaying (1) phases.**  
 259 **Arrows show the direction of wind (m/s); [grey-blue](#) shaded areas denote wind speed above 3 m/s.**



260  
261 **Figure 6: Composites of 850-mb vector wind for mainland China during ENSO and ENSO Modoki developing (0) phases. Arrows show**  
262 **the direction of wind (m/s); grey/blue shaded areas denote wind speed above 3 m/s.**  
263



264  
265 **Figure 7: Composites of 850-mb vector wind for mainland China during ENSO and ENSO Modoki decaying (1) phases. Arrows show**

265 the direction of wind (m/s); ~~grey~~blue shaded areas denote wind speed above 3 m/s.

## 267 5. Conclusion

268 This study investigated the distribution of PARS under various ENSO types in developing and decaying phases and their underlying  
269 causes. It was found that northwestern, central and southeastern China experience increasing precipitation for decaying CPW and  
270 EPW~~It was found that most parts of China experience increasing precipitation for decaying CPW and EPW~~, and positive  
271 precipitation anomaly ranges from 0 to 30% due to the stronger westerly and southwesterly winds. The developing phase of EPW  
272 presents overall negative rainy-season precipitation anomalies in China with more than 30% below average precipitation identified  
273 in many parts of the country, which is a result from weak westerly winds. The different spatial distribution of rainy-season  
274 precipitation under developing and decaying ENSO and ENSO Modoki regimes was also examined. Conventional El Niño in  
275 developing years showed larger influence on precipitation during rainy season in China as compared to developing CLN, MEN, and  
276 MLN. Conventional ENSO in the decaying phase is more likely to show wet and dry signals in comparison to the corresponding  
277 ENSO Modoki regimes. ~~Conventional ENSO in the decaying phase is more likely to cause flooding and drought in comparison to~~  
278 ~~the corresponding ENSO Modoki regimes.~~ Different performance of conventional ENSO and ENSO Modoki is a reflection of  
279 combined influence of the India monsoon and the WNP anti-cyclone. This study improved our understanding on the spatial  
280 variability of ENSO-induced precipitation during rainy season in China and the underlying causes. These results suggest that  
281 improved predictability can be achieved for rainy-season precipitation related to ENSO regimes. We suggest that further work  
282 should focus on the influence of interactive ENSO and other drivers on precipitation to evaluate and improve the predictive ability.

## 283 6. Data availability

284 The daily precipitation, NOAA extended reconstructed SST, ENSO Modoki index (EMI) and the NCEP-NCAR reanalysis datasets  
285 used in this study are available for download under the following URLs:

- 286 – Daily precipitation: [http://data.cma.cn/data/detail/dataCode/SURF\\_CLI\\_CHN\\_MUL\\_DAY\\_V3.0.html](http://data.cma.cn/data/detail/dataCode/SURF_CLI_CHN_MUL_DAY_V3.0.html)
- 287 – NOAA extended reconstructed SST: <https://www.ncdc.noaa.gov/data-access/marineocean-data/extended-reconstructed-sea-surface-temperature-ersst-v4>
- 289 – EMI: <http://www.jamstec.go.jp/frsgc/research/d1/iod/DATA/emi.monthly.txt>
- 290 – NCEP/NCAR reanalysis data: <https://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.html>

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296 *Competing interests.* The authors declare no conflict of interest.

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