

Supplementary Material

Long-Term Dynamic of Cold Stress during Heading and Flowering Stage and Its Effects on Rice Growth in China

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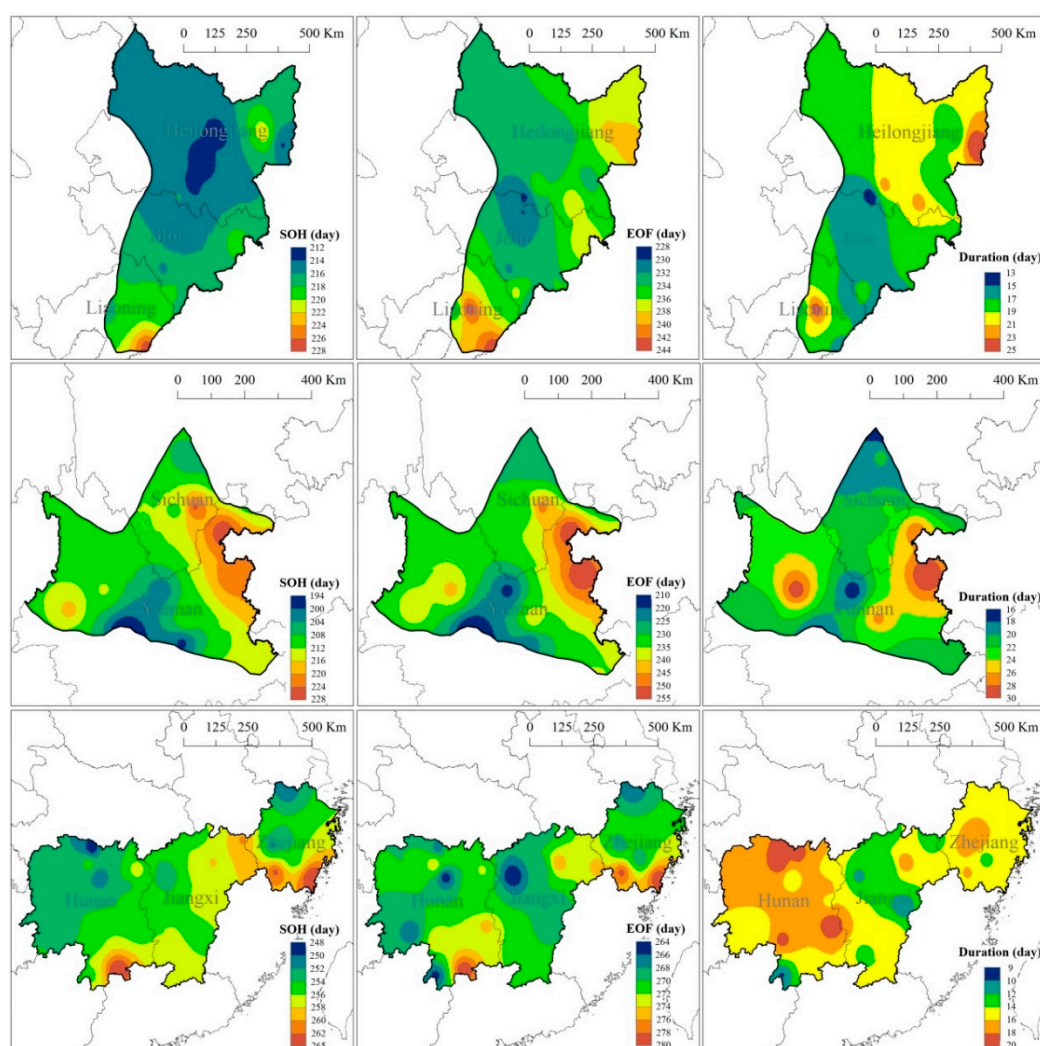


Figure S1. Spatial variation of average values of phenological dates during 1960–2019 across three ecoregions of China: (upper) North Eastern Plain; (middle) Yunnan Plateau; (bottom) South of Middle and Lower reaches of Yangtze River. SOH, start of heading data; EOF, End of flowering data.

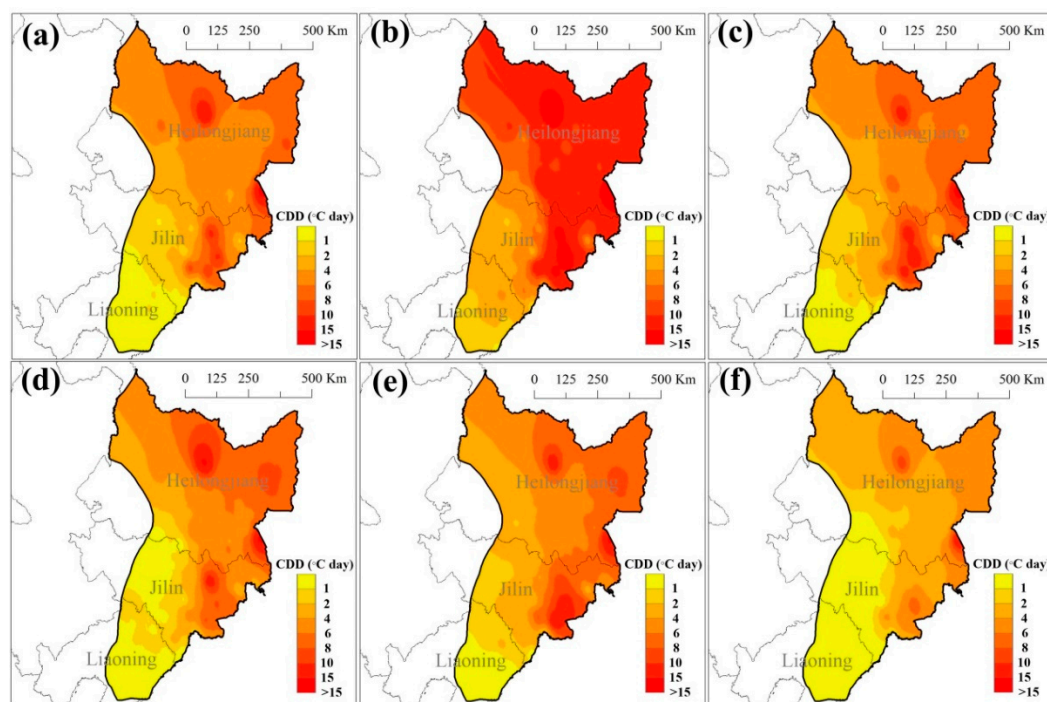


Figure S2. Changes in cold stress between different decades in North Eastern Plain. (a) 1960s; (b) 1970s; (c) 1980s; (d) 1990s; (e) 2000s; (f) 2010s. CDD: cold degree days.

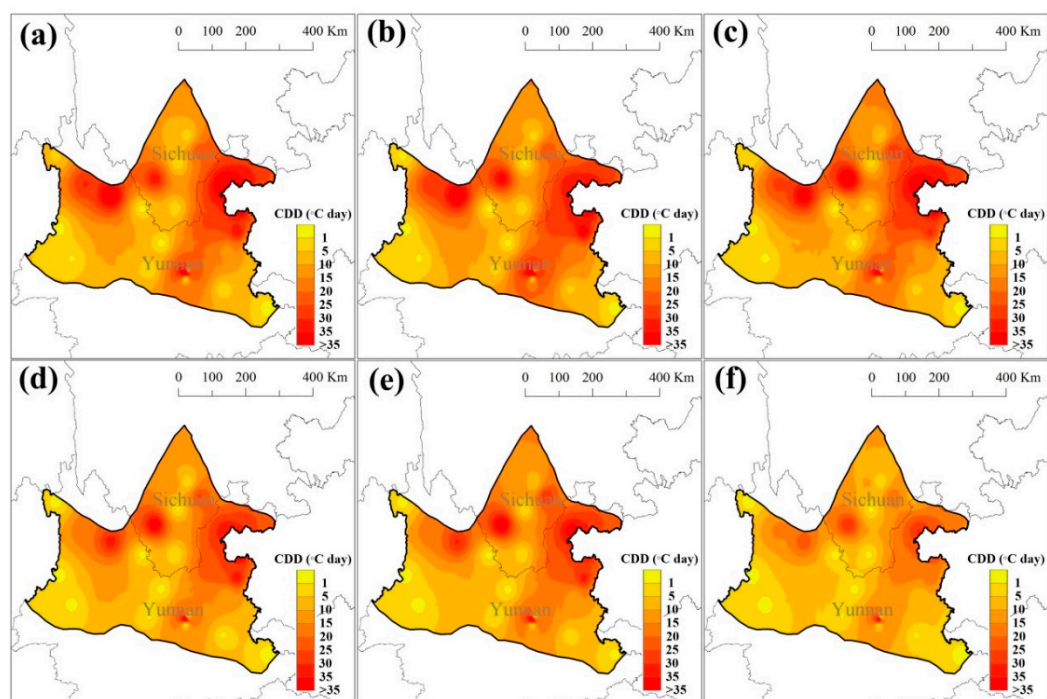


Figure S3. Changes in cold stress between different decades in Yunnan Plateau. (a) 1960s; (b) 1970s; (c) 1980s; (d) 1990s; (e) 2000s; (f) 2010s. CDD: cold degree days.

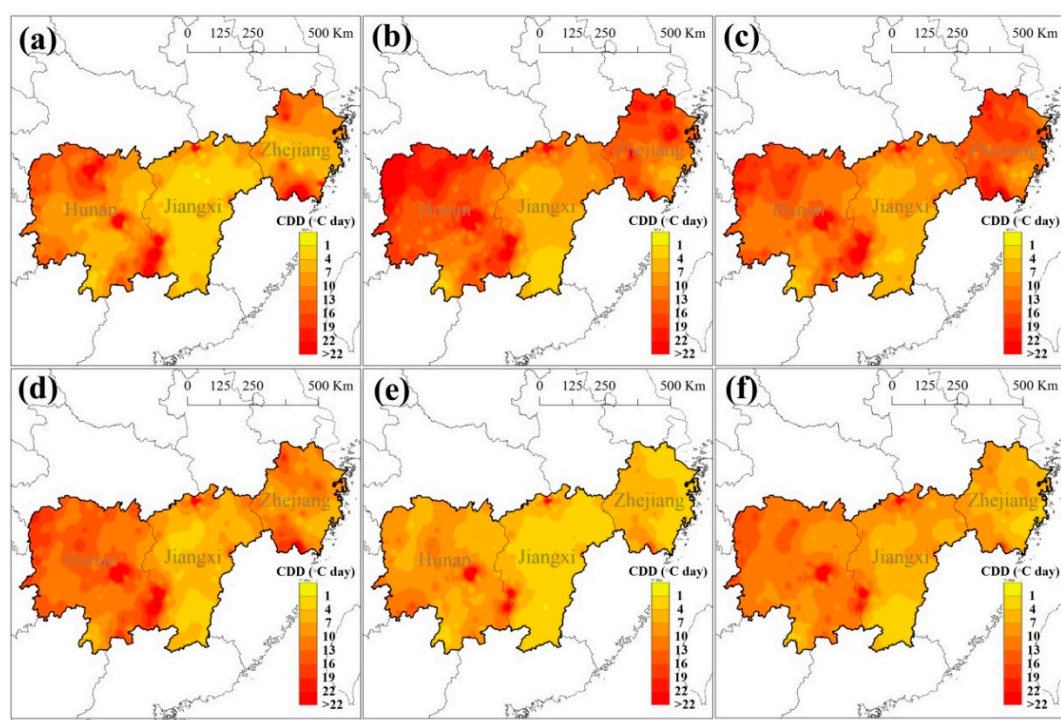


Figure S4. Changes in cold stress between different decades in South of Middle and Lower reaches of Yangtze River. (a) 1960s; (b) 1970s; (c) 1980s; (d) 1990s; (e) 2000s; (f) 2010s. CDD: cold degree days.

Table S1. The multivariate linear and nonlinear equations for yield and related variables as a function of temperature indices during heading and flowering.

		Formula	R ² _{adj}	Formula	R ² _{adj}
Yield (ton/ha)	NEP	$\Delta Y = -0.032 \times \Delta CDD + 0.075 \times \Delta Tave + 0.106$	0.057**	$\Delta Y = -0.036 \times \Delta CDD + 0.073 \times \Delta Tave - 0.001 \times \Delta CDD \times \Delta CDD - 0.010 \times \Delta Tave \times \Delta Tave - 0.008 \times \Delta CDD \times \Delta Tave + 0.148$	0.046*
	YP	$\Delta Y = -0.060 \times \Delta CDD - 0.102 \times \Delta Tave - 0.047$	0.168**	$\Delta Y = -0.057 \times \Delta CDD - 0.053 \times \Delta Tave - 0.001 \times \Delta CDD \times \Delta CDD - 0.286 \times \Delta Tave \times \Delta Tave - 0.035 \times \Delta CDD \times \Delta Tave + 0.253$	0.141*
	SMLY R	$\Delta Y = -0.136 \times \Delta CDD + 0.221 \times \Delta Tave + 0.066$	0.038**	$\Delta Y = -0.161 \times \Delta CDD + 0.213 \times \Delta Tave + 0.093 \times \Delta CDD \times \Delta CDD + 1.399 \times \Delta Tave \times \Delta Tave + 1.003 \times \Delta CDD \times \Delta Tave + 0.018$	0.058**
	NEP	$\Delta Y = -0.046 \times \Delta CDD - 2.246 \times \Delta Tave + 1.133$	0.047**	$\Delta Y = -0.070 \times \Delta CDD - 2.249 \times \Delta Tave - 0.005 \times \Delta CDD \times \Delta CDD - 0.359 \times \Delta Tave \times \Delta Tave - 0.052 \times \Delta CDD \times \Delta Tave + 1.755$	0.032
NGP	YP	$\Delta Y = -0.246 \times \Delta CDD - 3.572 \times \Delta Tave - 1.197$	-0.023	$\Delta Y = -0.142 \times \Delta CDD - 3.204 \times \Delta Tave + 0.012 \times \Delta CDD \times \Delta CDD + 0.151 \times \Delta Tave \times \Delta Tave + 0.093 \times \Delta CDD \times \Delta Tave - 3.092$	-0.066
	SMLY R	$\Delta Y = -2.747 \times \Delta CDD - 3.579 \times \Delta Tave + 2.362$	0.008	$\Delta Y = -0.161 \times \Delta CDD - 2.778 \times \Delta Tave - 0.444 \times \Delta CDD \times \Delta CDD + 27.523 \times \Delta Tave \times \Delta Tave + 1.116 \times \Delta CDD \times \Delta Tave + 1.655$	0.004
	NEP	$\Delta Y = 0.089 \times \Delta CDD - 0.307 \times \Delta Tave - 0.016$	0.056**	$\Delta Y = 0.076 \times \Delta CDD - 0.328 \times \Delta Tave - 0.001 \times \Delta CDD \times \Delta CDD + 0.181 \times \Delta Tave \times \Delta Tave + 0.034 \times \Delta CDD \times \Delta Tave - 0.187$	0.051*
EGR (%)	YP	$\Delta Y = 0.180 \times \Delta CDD - 1.257 \times \Delta Tave + 0.652$	0.119*	$\Delta Y = 0.234 \times \Delta CDD - 0.850 \times \Delta Tave + 0.016 \times \Delta CDD \times \Delta CDD + 1.336 \times \Delta Tave \times \Delta Tave + 0.256 \times \Delta CDD \times \Delta Tave - 2.067$	0.153*
	SMLY R	$\Delta Y = 1.109 \times \Delta CDD - 2.264 \times \Delta Tave - 0.197$	0.059***	$\Delta Y = 1.139 \times \Delta CDD - 2.472 \times \Delta Tave - 0.201 \times \Delta CDD \times \Delta CDD - 2.343 \times \Delta Tave \times \Delta Tave - 3.210 \times \Delta CDD \times \Delta Tave - 0.393$	0.058**

UGR (%)	NEP	$\Delta Y = 0.253 \times \Delta CDD + 0.065 \times \Delta Tave$	0.188***	$\Delta Y = 0.280 \times \Delta CDD + 0.198 \times \Delta Tave - 0.022 \times \Delta CDD \times \Delta CDD - 0.212 \times \Delta Tave \times \Delta Tave - 0.141 \times \Delta CDD \times \Delta Tave + 0.367$	0.257** *
	YP	$\Delta Y = -0.041 \times \Delta CDD + 0.260 \times \Delta Tave - 0.373$	-0.022	$\Delta Y = -0.025 \times \Delta CDD + 0.379 \times \Delta Tave + 0.003 \times \Delta CDD \times \Delta CDD + 0.051 \times \Delta Tave \times \Delta Tave + 0.046 \times \Delta CDD \times \Delta Tave - 0.611$	-0.080
	SMLY R	$\Delta Y = 0.232 \times \Delta CDD + 4.682 \times \Delta Tave + 0.365$	0.035**	$\Delta Y = 0.236 \times \Delta CDD + 4.548 \times \Delta Tave - 0.068 \times \Delta CDD \times \Delta CDD - 5.084 \times \Delta Tave \times \Delta Tave - 1.623 \times \Delta CDD \times \Delta Tave + 0.471$	0.028*
1000-GW (g)	NEP	$\Delta Y = 0.001 \times \Delta CDD + 0.245 \times \Delta Tave - 0.079$	0.027*	$\Delta Y = 0.006 \times \Delta CDD + 0.256 \times \Delta Tave + 0.003 \times \Delta CDD \times \Delta CDD - 0.042 \times \Delta Tave \times \Delta Tave + 0.011 \times \Delta CDD \times \Delta Tave - 0.038$	0.028
	YP	$\Delta Y = 0.044 \times \Delta CDD + 0.164 \times \Delta Tave + 0.248$	0.11*	$\Delta Y = -0.061 \times \Delta CDD + 0.055 \times \Delta Tave - 0.003 \times \Delta CDD \times \Delta CDD - 0.150 \times \Delta Tave \times \Delta Tave - 0.053 \times \Delta CDD \times \Delta Tave + 0.600$	0.134
	SMLY R	$\Delta Y = 0.120 \times \Delta CDD + 2.277 \times \Delta Tave - 0.084$	0.043**	$\Delta Y = 0.116 \times \Delta CDD + 2.186 \times \Delta Tave - 0.027 \times \Delta CDD \times \Delta CDD - 1.766 \times \Delta Tave \times \Delta Tave - 0.843 \times \Delta CDD \times \Delta Tave - 0.106$	0.041**
GDL (day)	NEP	$\Delta Y = 0.149 + 0.550 \times \Delta Tave + 0.004$	0.057***	$\Delta Y = 0.145 \times \Delta CDD + 0.576 \times \Delta Tave - 0.005 \times \Delta CDD \times \Delta CDD - 0.158 \times \Delta Tave \times \Delta Tave - 0.089 \times \Delta CDD \times \Delta Tave + 0.019$	0.086** *
	YP	$\Delta Y = 0.152 \times \Delta CDD + 0.141 \times \Delta Tave + 0.499$	0.129***	$\Delta Y = 0.067 \times \Delta CDD + 0.133 \times \Delta Tave + 0.097 \times \Delta CDD \times \Delta CDD - 0.003 \times \Delta Tave \times \Delta Tave - 0.0415 \times \Delta CDD \times \Delta Tave + 0.411$	0.114** *
	SMLY R	$\Delta Y = 1.166 \times \Delta CDD - 1.321 \times \Delta Tave + 0.284$	0.213***	$\Delta Y = 1.120 \times \Delta CDD - 1.438 \times \Delta Tave + 0.157 \times \Delta CDD \times \Delta CDD - 1.127 \times \Delta Tave \times \Delta Tave + 1.026 \times \Delta CDD \times \Delta Tave - 0.106$	0.21***

NGP, number of grains per panicle; PUG, percentage of undeveloped grain; PPDG, percentage of partially developed grain; 1000-GW, 1000-grain weight. GDL, growth duration length during the heading and flowering stages. The correlation significant at 0.05 level were marked by *, significant at 0.01 level were marked by ** and significant at 0.001 level were marked by ***.