中国沿海省区极端气温栅格数据集

王晓利[1,2]，侯西勇[1,2*]

1. 中国科学院烟台海岸带研究所，烟台 264003；
2. 中国科学院海岸带环境过程与生态修复重点实验室，烟台 264003

摘　要：中国沿海地区人口密集、城市化进程快、经济发达，同时，该地区自然灾害频发、生态环境脆弱，极易受气候变化的影响。基于1961–2014年中国156个地面气象站点日尺度的最高气温和最低气温，采用RClimDex模型计算了中国沿海省区（包括14个省、自治区、直辖市、特别行政区；台湾、南海诸岛和海域的数据暂缺）极端气温指数数据。极端气温指数包括16项内容：冷昼日数（TX10p）、冷夜日数（TN10p）、暖昼日数（TX90p）、暖夜日数（TN90p）、霜冻日数（FD0）、冰冻日数（ID0）、夏季日数（SU25）、热夜日数（TR20）、日最高气温的极高值（TXx）、日最低气温的极高值（TNx）、日最高气温的极低值（TXn）、日最低气温的极低值（TNn）、暖持续日数（WSDI）、冷持续日数（CSDI）、生长季长度（GSL）以及气温日较差（DTR）。根据这些指数数据，利用反距离权重插值方法研发出中国沿海省区1961–2014年极端气温栅格数据集。该数据集包括：（1）中国沿海省区16个极端气温1961–2014年多年平均值的栅格数据；（2）中国沿海省区16个极端气温1961–2014年间年际倾向率的栅格数据。该数据集的空间分辨率为8.934 km，数据集存储为.tif格式，32组文件，数据量为12.5 MB （压缩为1个文件，2.15 MB）。该数据集的分析研究成果发表在《生态学报》2017年第37卷第21期。

关键词：中国沿海；极端气温指数；多年均值；年际倾向率；1961–2014年；生态学报
DOI: 10.3974/geodp.2019.01.08

1　前言

在全球气候变暖的大背景下，中国沿海地区高温热浪、低温冰冻等极端气温事件频发，对区域生态环境保护、社会经济发展以及人们的生命财产等造成了严重影响[1–4]。基于中国气象局气象数据中心提供的中国沿海地区156个地面气象站的日最高（低）气温资料，利用RClimDex模型[5]计算并构建了1961–2014年16个极端气温指数（表1）的时间序列，在气象站点尺度上采用算术平均法和线性倾向估计法计算了各极端气温指数的多年平均值和年际倾向率[6]，并采用反距离权重插值法在ArcGIS软件中生成1961–2014年中国沿海省区极端气温栅格数据集[7]。本数据集有益于提高人们对中国沿海地区极端气温事件时间变化和空间格局的认识。

收稿日期：2018-12-01；**修订日期**：2018-12-29；**出版日期**：2019-03-25
基金项目：中国科学院（XDA11020205，XDA19060205）；国家自然科学基金（31461143032）
***通讯作者**：侯西勇 L-6506-2016，中国科学院烟台海岸带研究所，xyhou@yic.ac.cn
数据引用方式：[1] 王晓利，侯西勇．中国沿海省区极端气温栅格数据集[J]．全球变化数据学报，2019，3(1)：54–58. DOI: 10.3974/geodp.2019.01.08.
[2] 王晓利，侯西勇．中国沿海省区极端气温栅格数据集[DB/OL]．全球变化科学研究数据出版系统，2018. DOI: 10.3974/geodb.2018.08.12.V1.

表 1　极端气温指数的定义与分类[5]

指数名称	指数代码	定义	单位
冷昼日数	TX10p	日最高气温<10%分位值的日数	d
冷夜日数	TN10p	日最低气温<10%分位值的日数	d
暖昼日数	TX90p	日最高气温>90%分位值的日数	d
暖夜日数	TN90p	日最低气温>90%分位值的日数	d
霜冻日数	FD0	年内日最低气温<0℃的日数	d
冰冻日数	ID0	年内日最高气温<0℃的日数	d
夏季日数	SU25	年内日最高气温>25℃的日数	d
热夜日数	TR20	年内日最低气温>20℃的日数	d
日最高气温的极高值	TXx	每月内日最高气温的最大值	℃
日最低气温的极高值	TNx	每月内日最低气温的最大值	℃
日最高气温的极低值	TXn	每月内日最高气温的最小值	℃
日最低气温的极低值	TNn	每月内日最低气温的最小值	℃
暖持续日数	WSDI	日最高气温>90%分位值的连续 6 天的日数	d
冷持续日数	CSDI	日最低气温<10%分位值的连续 6 天的日数	d
生长季长度	GSL	日平均气温首先出现至少连续 6 日>5℃，以及首先出现在 7 月 1 日后（指北半球）日平均气温至少连续 6 日<5℃的总日数	d
气温日较差	DTR	年内日最高气温与最低气温的差值	℃

2　数据集元数据简介

《中国沿海省区极端气温栅格数据集》[7]的名称、短名、作者、地理区域、数据年代、数据格式、数据文件个数、数据量、数据集组成、基金项目、数据的出版与共享服务平台和数据政策等信息见表 2。

表 2　《中国沿海省区极端气温栅格数据集》元数据简表

条目	描述
数据库（集）名称	中国沿海省区极端气温栅格数据集
数据库（集）短名	ETI_COAST_CHINA_1961–2014
作者信息	王晓利 Y-7126-2018, 中国科学院烟台海岸带研究所, xlwang@yic.ac.cn
	侯西勇 L-6506-2016, 中国科学院烟台海岸带研究所, xyhou@yic.ac.cn
地理区域	以省级行政区划为界，中国东部临海的 14 个省、市、区（未包括台湾、南海诸岛和海域；北京市也列入研究范围之内以确保研究区在空间上的完整性）。从北至南，依次包括辽宁省、河北省、北京市、天津市、山东省、江苏省、上海市、浙江省、福建省、广东省、香港特区、澳门特区、广西壮族自治区以及海南省
数据年代	1961–2014 年
数据格式	.tif
数据文件个数	32
数据量	12.5 MB
数据集组成	数据集由 32 个.tif 文件组成
基金项目	国家自然科学基金（31461143032）；中国科学院（XDA11020205，XDA19060205）
出版与共享服务平台	全球变化科学研究数据出版系统 http://www.geodoi.ac.cn

续表

条目	描述
地址	北京市朝阳区大屯路甲11号 100101，中国科学院地理科学与资源研究所
数据共享政策	全球变化科学研究数据出版系统的“数据”包括元数据（中英文）、实体数据（中英文）和通过《全球变化数据学报》（中英文）发表的数据论文。其共享政策如下：（1）“数据”以最便利的方式通过互联网系统免费向全社会开放，用户免费浏览、免费下载；（2）最终用户使用“数据”需要按照引用格式在参考文献或适当的位置标注数据来源；（3）增值服务用户或以任何形式散发和传播（包括通过计算机服务器）“数据”的用户需要与《全球变化数据学报》（中英文）编辑部签署书面协议，获得许可；（4）摘取“数据”中的部分记录创作新数据的作者需要遵循10%引用原则，即从本数据集中摘取的数据记录少于新数据集总记录量的10%，同时需要对摘取的数据记录标注数据来源[8]

3 数据研发方法

研发本数据集的基础气象资料来自中国气象局气象数据中心国家气象科学数据共享服务平台（http://data.cma.cn/），主要包括中国沿海地区244个地面气象站点的日最高气温和日最低气温。基于Matlab语言实现气象数据的真实值计算和缺测值处理，并利用双累积曲线法[9]对站点数据的均一性进行检验以完成气象数据质量控制。以资料的长期连续性和历史记录超过50 a为标准，最终共选取156个站点1961–2014年的日最高气温和日最低气温（图1）。

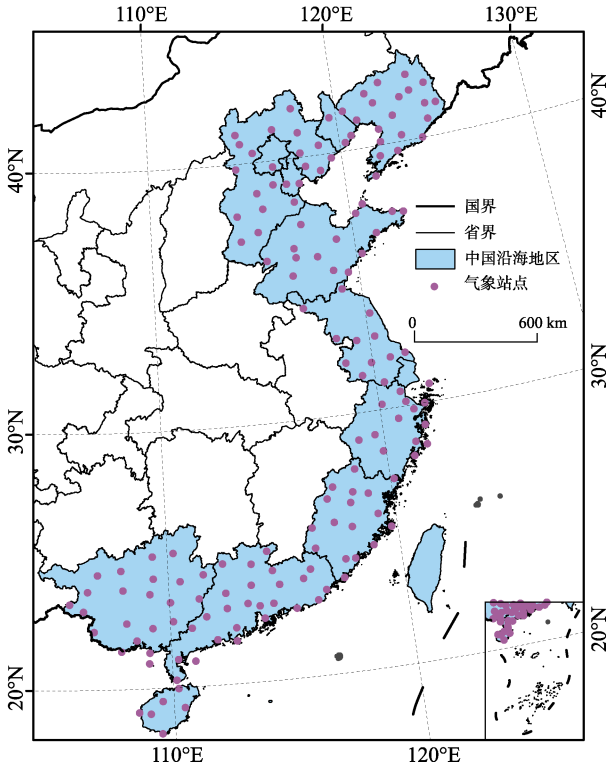

图1 中国沿海地区156个地面气象站点的空间分布图

在 R 语言环境中加载 RClimDex 模型，逐站点导入气象数据，进一步对数据质量进行检验和控制，设定基准期、阈值等参数，计算 16 个极端气温指数。在此基础之上，利用 Matlab 语言对模型输出的计算结果进行归并、整理，构建中国沿海地区 1961–2014 年 156 个气象站点 16 个极端气温指数的时间序列数据。

分别利用算术平均值法和线性倾向估计法计算获得各气象站点 16 个极端气温指数的多年均值和年际倾向率，其中，采用一次线性方程表示极端气温指数的历史变化趋势，即：

$$Y(t) = at + b \tag{1}$$

式中，Y 为极端气温指数值；t 为时间（a）；a 为线性趋势项；b 为常数项；$a\times10$ 表示极端气温指数每 10 a 的变化量，即年际倾向率，单位为℃/10a。

利用 ArcGIS 软件制备中国沿海地区 156 个站点各极端气温指数多年均值和年际倾向率的矢量数据，以.shp 格式存储。进一步利用反距离权重插值法对各极端气温指数的 shp 矢量数据进行插值，生成.tif 格式的栅格数据。

4　数据结果

以气温日较差为例，作者分析了 1961–2014 年在中国沿海地区的多年均值和年际倾向率的空间分布特征，结果如图 2 所示。

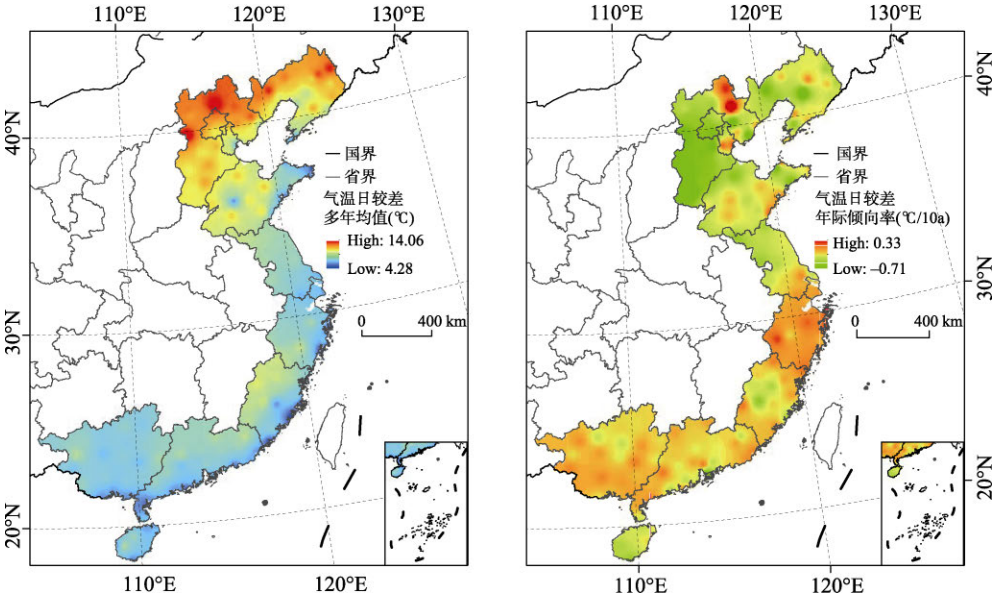

图 2　1961–2014 年中国沿海地区气温日较差的多年均值和年际倾向率数据可视化图

研究时段内，中国沿海地区气温日较差的多年均值和年际倾向率分别介于 4.28–14.06 ℃和−0.71 至 0.33 ℃/10a 之间。空间分布上，气温日较差的多年均值基本呈北高南低的格局特征，年际倾向率的空间分布与之相反，总体上表现为南高北低。

综合所有极端气温指数可知[10]，中国沿海地区冷昼日数、冷夜日数、暖昼日数、暖夜

日数、日最高（低）气温的极高值以及冷（暖）持续日数的多年均值总体相差较小，而夏季日数、热夜日数、日最高（低）气温的极低值以及生长季长度的多年均值从北至南依次增加；与之相反，霜冻日数、冰冻日数以及气温日较差的多年均值从北至南依次递减，其中，广东、广西部分临海地区的冰冻日数均为0。

从年际倾向率的结果来看，1961–2014年期间，中国沿海地区的暖昼日数、暖夜日数、夏季日数、热夜日数、日最高（低）气温的极高（低）值、暖持续日数以及生长季长度总体呈上升趋势，而冷昼日数、冷夜日数、霜冻日数、冰冻日数、冷持续日数以及气温日较差基本呈下降趋势。进一步分析可发现，沿海地区极端气温夜指数（冷夜日数、暖夜日数）变化幅度的绝对值要大于昼指数（冷昼日数、暖昼日数）。

5 结论

地面气象站点的气象观测资料是评估历史时期气候变化特征的数据源之一，但气象站点建站时间不一、站点迁址、共享数据的站点有限等均会对构建中国沿海地区气象要素及其极端态的高时空分辨率数据集产生一定的影响。然而，本数据集历史记录时长已超50 a，极端气温指数种类多，可以较全面地评估中国沿海地区极端气温的历史变化特征。

作者分工：侯西勇负责设计数据集生产的总体思路与技术框架；王晓利完成气象数据的下载和预处理，极端气温指数的计算以及数据集的制备。

参考文献

[1] 陈特固, 时小军, 余克服. 华南沿海近 100 年来 2 月份的极端气温事件[J]. 热带地理, 2008, 28(3): 199–202.

[2] 董锁成, 陶澍, 杨旺舟等. 气候变化对中国沿海地区城市群的影响[J]. 气候变化研究进展, 2010, 6(4): 284–289.

[3] Jiao, N. Z., Chen, D. K., Luo, Y. M., *et al*. Climate change and anthropogenic impacts on marine ecosystems and countermeasures in China [J]. *Advances in Climate Change Research*, 2015, 6(2): 118–125.

[4] 王米雪, 延军平, 李双双. 1960–2013年中国东南沿海地区旱涝时空变化特征及其趋势分析[J]. 资源科学, 2014, 36(11): 2307–2315.

[5] Zhang, X., Yang, F. RClimDex (1.0), User Manual [Z]. Climate Research Branch, Environment Canada, 2004.

[6] 王琼, 张明军, 王圣杰等. 1962–2011 年长江流域极端气温事件分析[J]. 地理学报, 2013, 68(5): 611–625.

[7] 王晓利, 侯西勇. 中国沿海省区极端气温栅格数据集[DB/OL]. 全球变化科学研究数据出版系统, 2018. DOI: 10.3974/geodb.2018.08.12.V1.

[8] 全球变化科学研究数据出版系统. 全球变化科学研究数据共享政策[OL]. DOI: 10.3974/dp.policy.2014.05 (2017 年更新).

[9] 穆兴民, 张绣勤, 高鹏等. 双累积曲线方法理论及在水文气象领域应用中注意的问题[J]. 水文, 2010, 30(4): 47–51.

[10] 王晓利, 侯西勇. 1961–2014 年中国沿海极端气温事件变化及区域差异分析[J]. 生态学报, 2017, 37(21): 7098–7113.

Journal of Global Change Data & Discovery. 2019, 3(1): 54-58
DOI:10.3974/geodp.2019.01.08
www.geodoi.ac.cn

Raster Dataset of Extreme Temperature in the Coastal Area of China

Wang, X. L.[1,2] Hou, X. Y.[1,2*]

1. Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences, Yantai 264003, China;
2. Key Laboratory of Coastal Environmental Processes and Ecological Remediation, Chinese Academy of Sciences, Yantai 264003, China

Abstract: With large population density, rapid urbanization process and high-speed economic development, the coastal area of China is prone to vulnerable to climate change because of the frequently nature disasters and fragile eco-environment. Based on daily maximum and minimum temperature of 156 meteorological station records from 1961 to 2014, 16 extreme temperature indices including cool days (TX10p), cool nights (TN10p), warm days (TX90p), warm nights (TN90p), frost days (FD0), ice days (ID0), summer days (SU25), tropical nights (TR20), maximum value of daily maximum temperature (TXx), maximum value of daily minimum temperature (TNx), minimum value of daily maximum temperature (TXn), minimum value of daily minimum temperature (TNn), warm spell duration index (WSDI), cold spell duration index (CSDI), growing season length (GSL) and diurnal temperature range (DTR) were calculated by RClimDex model, respectively. And Inverse Distance Weight interpolation method was employed to produce the extreme temperature raster dataset, which includes two types of raster data, the first of which refers to the multi-year average, and the other is the inter-annual magnitude in 16 extreme temperature indices in the coastal area of China during 1961–2014. With an 8.934 km spatial resolution, the dataset is archived in .tif format, including 32 sets of data files, with the data size of 12.5 MB (compressed to 1 .zip file, 2.15 MB). Related research results of this dataset were published in the *Acta Ecologica Sinica*, 2017, Volume 37, Issue 21.

Keywords: coastal area of China; extreme temperature; multi-year average; inter-annual magnitude; 1961–2014; Acta Ecologica Sinica

1 Introduction

Within the context of global warming, extreme temperature events such as heatwaves and cryogenic freezing have occurred frequently in the coastal area of China, which have caused serious impacts on regional ecological environment protection, socio-economic sustainable development as well as people's properties and lives[1-4]. Based on daily maximum and minimum temperature dataset of 156 meteorological station records from 1961 to 2014 in

Received: 01-12-2018; **Accepted:** 29-12-2018; **Published:** 25-03-2019
Foundations: Chinese Academy of Sciences (XDA19060205, XDA11020205); National Natural Science Foundation of China (31461143032)
***Corresponding Author:** Hou, X. Y. L-6506-2016, Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences, xyhou@yic.ac.cn
Data Citation: [1] Wang, X. L., Hou, X. Y. Raster dataset of extreme temperature in the coastal area of China [J]. *Journal of Global Change Data & Discovery*, 2019, 3(1): 54–58. DOI: 10.3974/geodp.2019.01.08.
[2] Wang, X. L., Hou, X. Y. Extreme temperature grid dataset in coastal area of China [DB/OL].Global Change Research Data Publishing & Repository, 2018. DOI: 10.3974/geodb.2018.08.12.V1.

the coastal area of China, time series of 16 extreme temperature indices (Table 1) were performed by the software RClimDex[5], and then the multi-year average and inter-annual magnitude[6] in all extreme temperature indices were worked out on the meteorological site scale during the considering period. Furthermore, raster dataset of multi-year average and inter-annual magnitude in extreme temperature indices in the coastal area of China from 1961 to 2014[7] were produced using Inverse Distance Weight interpolation method in ArcGIS software. Raster dataset of extreme temperature is expected to raise awareness of the temporal and spatial patterns of extreme temperature events in the coastal area of China.

Table 1 Definitions of extreme temperature indices

Indicator name	ID	Definitions	Unit
Cool days	TX10p	Days when daily maximum temperature <0.1 fractiles	d
Cool nights	TN10p	Days when daily minimum temperature <0.1 fractiles	d
Warm days	TX90p	Days when daily maximum temperature >0.9 fractiles	d
Warm nights	TN90p	Days when daily minimum temperature >0.9 fractiles	d
Frost days	FD0	Annual days when daily minimum temperature <0 ºC	d
Ice days	ID0	Annual days when daily maximum temperature <0 ºC	d
Summer days	U25	Annual days when daily maximum temperature >25 ºC	d
Tropical nights	TR20	Annual days when daily minimum temperature >20 ºC	d
Max Tmax	TXx	Monthly maximum value of daily maximum temperature	ºC
Max Tmin	TNx	Monthly maximum value of daily minimum temperature	ºC
Min Tmax	TXn	Monthly minimum value of daily maximum temperature	ºC
Min Tmin	TNn	Monthly minimum value of daily minimum temperature	ºC
Warm spell duration index	WSDI	Annual days with at least 6 consecutive days when daily maximum temperature >0.9 fractiles	d
Cold spell duration index	CSDI	Annual days with at least 6 consecutive days when daily minimum temperature <0.1 fractiles	d
Growing season length	GSL	Annual days between first span of at least 6 days with daily mean temperature >5 ºC after winter and first span after 1st July of 6 days with daily mean temperature <5 ºC	d
Diurnal temperature range	DTR	Monthly mean difference between daily maximum temperature and daily minimum temperature	ºC

2 Metadata of Dataset

The metadata of "Extreme temperature grid dataset in coastal area of China"[7] is summarized in Table 2, which includes the dataset full name, short name, authors, geographical region, data period, data format, data files, data size, foundation, data publisher, and data sharing policy, etc.

3 Methods

The meteorological records, including daily maximum and minimum temperature of 244 meteorological stations in the coastal area of China, provided by the National Meteorological Information Center, China Meteorological Administration (http://data.cma.cn/), was used to produce the raster dataset of extreme temperature. Based on the meteorological records, daily temperature data series were built using Matlab programming language, and then were through quality control by homogeneity assessment using the double-mass curve method[9].

Be founded on the principle of that the historical records were continuous and the duration was longer than 50 years, 156 meteorological stations (Figure 1) with daily maximum and minimum temperature from 1961 to 2014 were finally selected in the coastal area of China.

Table 2 Metadata summary of "Extreme temperature grid dataset in coastal area of China"

Items	Description
Dataset full name	Extreme temperature grid dataset in coastal area of China
Dataset short name	ExtremeTem_CoastalAreaChina
Authors	Wang, X. L. Y-7126-2018, Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences, xlwang@yic.ac.cn Hou, X. Y. L-6506-2016, Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences, xyhou@yic.ac.cn
Geographical region	$ ˝˝ɪrding to the division boundary of Chinese provincial administrative, the 14 provinces, municipalities and autonomous regions located in the eastern coast are identified (data is absent in Taiwan, the South China Sea islands and waters; and Beijing is included for ensuring the spatial integrity), including Liaoning, Hebei, Beijing, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hongkong, Macao, Guangxi, and Hainan.
Year	1961–2014 Data format .tif
Data size	12.5 MB Data files 32 .tif data files
Foundations	Chinese Academy of Sciences (XDA19060205, XDA11020205); National Nature Science Foundation of China (31461143032)
Data publisher	Global Change Research Data Publishing and Repository, http://www.geodoi.ac.cn
Address	No.11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (data products), and publications (in this case, in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be freely downloaded from the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten percent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[8]

Importing the meteorological data into RClimDex in the R software station by station, 16 extreme temperature indices were calculated out after data verification and parameter settings. And then time series of 16 extreme temperature indices at each meteorological station in the coastal area of China from 1961 to 2014 were all constructed by application of Matlab programming.

Multi-year average and inter-annual magnitude in extreme temperature index were calculated out using the arithmetic mean method and linear trend method on the meteorological station scale during 1961–2014, respectively. And a linear equation was employed to represent the historical trend of the extreme temperature index, namely:

$$Y(t) = at + b \tag{1}$$

where Y represents the extreme temperature index, t is the time, a refers to the linear trend term, b is the constant term, and $a \times 10$ represents the change of the extreme temperature index during every 10 a, namely inter-annual rate of change, in unit of °C/10a or d/10 a. Vector data in .shp format in terms of multi-year average and inter-annual magnitude of 16 extreme temperature indices at 156 meteorological stations in the coastal area of China were produced by ArcGIS software, and then raster data in .tif format was generated by extending the site data of each extreme temperature index at meteorological scale to continuous space using Inverse Distance Weight method.#

4 Results

Take diurnal temperature range as an example, the spatial patterns of multi-year average and inter-annual magnitude presented in Figure 2 are analyzed in detail from 1961 to 2014.

The multi-year average and inter-annual magnitude of DTR varied from 4.28 °C to 14.06 °C and −0.71 °C /10a to 0.33 °C/10a through the coastal area of China, respectively. Spatially, the multi-year average of DTR exhibited a pattern of "south-low and north-high" while the inter-annual magnitude of DTR was characterized by "south-high and north-low" generally.

For all extreme temperature indices[10], a similar spatial pattern of multi-year average was found in cool days, cool nights, warm days, warm nights, maximum value of daily maximum temperature, maximum value of daily minimum temperature, warm spell duration index, and cold spell duration index, and a generally gradient descent of multi-year average was observed in summer days, tropical nights, minimum value of daily maximum temperature, minimum value of daily minimum temperature and growing season length while a gradual increasing tendency in frost days, ice days and diurnal temperature range from south to north in the coastal area of China during 1961 to 2014.

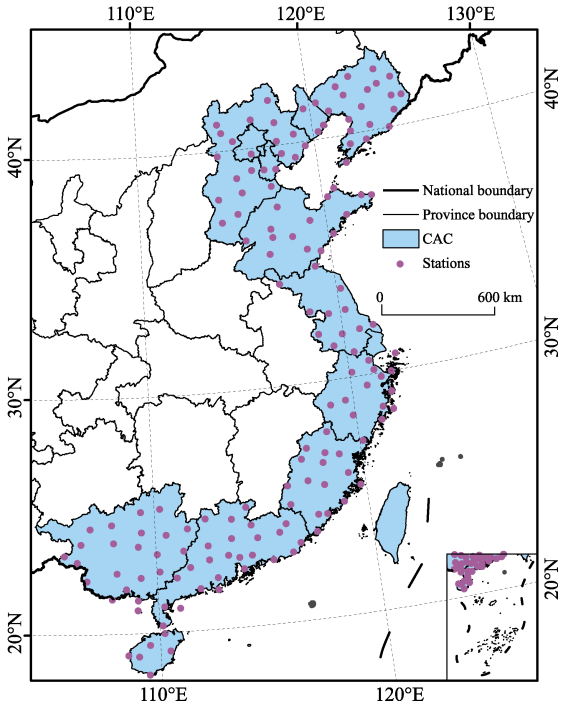

Figure 1 Distribution of 156 meteorological stations in the coastal area of China (CAC)

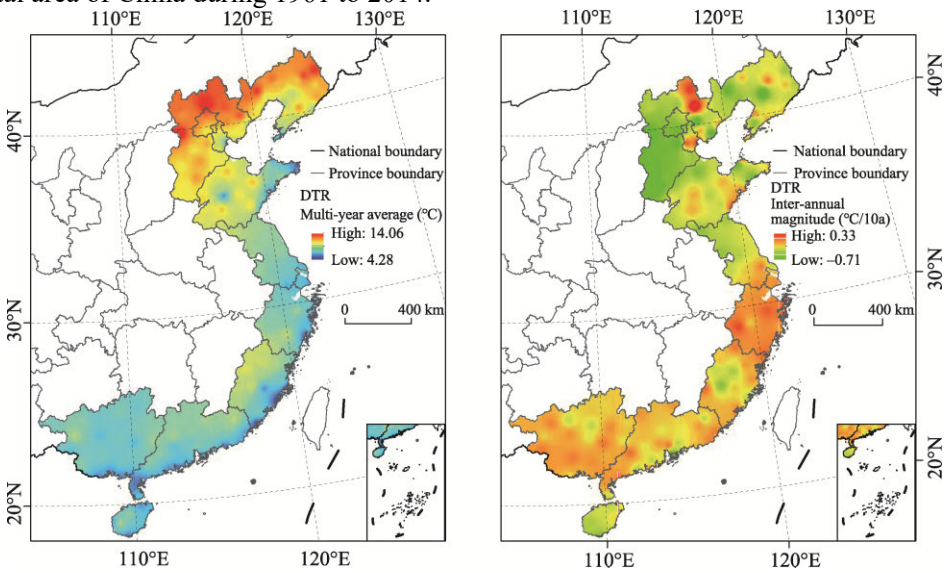

Figure 2 Distribution of multi-year average and inter-annual magnitude in diurnal temperature range (DTR) from 1961 to 2014 in the coastal area of China

Regarding to inter-annual magnitude, an upward trend in warm days, warm nights, summer days, tropical nights, maximum value of daily maximum temperature, maximum value of daily minimum temperature, minimum value of daily maximum temperature, minimum value of daily minimum temperature, warm spell duration index and growing season length, while a downward trend in cool days, cool nights, frost days, ice days cold spell duration index as well as diurnal temperature range were found in the coastal area of China from 1961 to 2014 generally. What's more, the decadal trend rates of the night extremes such as cool nights and warm nights were obviously higher than those of the day extremes like cool days and warm nights.

5 Conclusion

Meteorological observations from surface stations are one of the data sources used to assess the climate change characteristics in historical periods. However, there are some limitations on the production of high spatiotemporal resolution dataset of meteorological elements and their extremes due to the differences of station construction time, station relocation, and sharable policies. In this study, the length of historical records exceeded more than 50 years, and the extreme temperature indices are diversified, which is sufficient for comprehensive evaluations on the spatial-temporal characters of the extreme temperature events in the coastal area of China.

Author Contributions

General idea and technical framework of this dataset production was proposed by Hou, X. Y. Wang, X. L. is responsible for downloading and pre-processing of meteorological data, calculating of extreme temperature indices and producing this dataset.

References

[1] Chen, T. G., Shi, X. J., Yu, K. F. Extreme air temperature events of February in South China area in the past 100 years [J]. *Tropical Geography*, 2008, 28(3): 199–202.

[2] Dong, S. C., Tan, S., Yang, W. Z., *et al*. Impacts of climate change on urban agglomerations in coastal region of China [J]. *Advances in Climate Change Research*, 2010, 6(4): 284–289.

[3] Jiao, N. Z., Chen, D. K., Luo, Y. M., *et al*. Climate change and anthropogenic impacts on marine ecosystems and countermeasures in China [J]. *Advances in Climate Change Research*, 2015, 6(2): 118–125.

[4] Wang, M. X., Yan, J. P., Li, S. S. Spatial-temporal variation and the tendency of droughts and floods on the southeast coast of China over 54 years [J]. *Resources Science*, 2014, 36(11): 2307–2315.

[5] Zhang, X. B., Yang, F. RClimDex (1.0), User Manual [Z]. Climate Research Branch, Environment Canada, 2004.

[6] Wang, Q., Zhang, M. J., Wang, S. J., *et al*. Extreme temperature events in Yangtze River Basin during 1962–2011 [J]. *Acta Geographica Sinica*, 2013, 68(5): 611–625.

[7] Wang, X. L., Hou, X. Y. Extreme temperature grid dataset in coastal area of China [DB/OL]. Global Change Research Data Publishing & Repository, 2018. DOI: 10.3974/geodb.2018.08.12.V1.

[8] GCdataPR Editorial Office. GCdataPR data sharing policy [OL]. DOI: 10.3974/dp.policy.2014.05 (Updated 2017).

[9] Mu, X. M., Zhang, X. Q., Gao, P., *et al*. Theory of Double Curves and Its applications in Hydrology and Meteorology [J]. *Journal of China Hydrology*, 2010, 30(4): 47–51.

[10] Wang, X. L., Hou, X. Y. Analysis of spatiotemporal variations and regional differences in extreme temperature events in the coastal area of China during 1961-2014 [J]. *Acta Ecologica Sinica*, 2017, 37(21): 7098–7113.