Preface

Weather extremes such as heat waves, cold surges, heavy rains, severe drought and forest wildfire, unusual storm tracks, and tornadoes frequently hit humankind. Climatic anomalies like the Arctic warming and sea ice decline have become a hot topic of climate change in recent years. Can we find early signals or methods to predict these weather extremes? And how can we explain these climatic anomalies? Some questions have been raised by meteorological researchers and weather forecasters. Since more data from satellite observations and mathematical model simulations have become accessible, we feel that atmospheric motion is more complex and full of chaos. We worry about if we are still standing on a mound while more data are filled like a high mountain. We need to stand on a higher platform to inspect the general circulation and anomalous atmospheric motion. Finally, we can physically achieve to build a connection between the surface weather extremes and atmospheric variable anomalies.

To quantitatively describe an extreme weather event, we first need a common reference in measuring the event's intensity, coverage, and duration. The common reference is a precise climatic clock (or climatic cycle), which is divided into 365-day $\times$ 24-hour = 8760 terms in a year. This climatic cycle or temporal climatology should be identified and studied, but does not need to be predicted. On the contrary, the hourly and daily departures from the temporal climatology need to be predicted. However, researchers nowadays directly apply reanalysis products and model simulations to study the historical weather episodes, and forecasters are still employing the traditional synoptic chart drawn by current observations and medium-range model outputs to predict the future weather extremes. This book demonstrates that the temporal climatology is useful to understand the climatic state and improve the forecast of weather extremes.

As a teacher at Peking University, I think we need an innovative concept and method to re-identify: What is weather? What are climate and general circulation? What are their differences? These three questions have been confusing teachers and students. We hope to cultivate the new generation of researchers and forecasters using this new concept and method. To achieve this goal, I have published a book titled "Principles of Medium to Extended Range Weather Forecasts" in Chinese in 2012.

In that book, all cases of weather extremes have been published in Chinese journals by analyzing the NCEP/NCAR reanalysis products with the four-term decomposition, namely zonally averaged climatology, its zonal departure, the zonally averaged anomaly, and its zonal departure. In this book, the cases have been published by 20 papers in international journals by use of the ERA-Interim product using the two-term decomposition, including the temporal climatology and anomaly. Ten chapters supported by the National Natural Science Foundation of China (41375073) and the two patents of China (201110061438.7 & ZL201210134358.4) are presented to readers as follows.

This book tells the readers a story from the universal dynamics of the Newton's single particles to Laplace's all particles in the Universe. Dynamics for each system, such as the Milky Way galaxy, the Solar and Earth systems, and a tropical cyclone with their similarity are described by decomposing total field into a basic state and anomaly in Chap. 1, "Weather and Climate." Wind is the oriented motion of air particles. The general circulation is a climatic representation of wind state. Therefore, multi-scale general circulations with diurnal and seasonal cycles are summarized in Chap. 2, "Wind and General Circulation." In this chapter, we will also introduce two new meridional mean circulations, the Arctic cell and the Antarctic cell, besides the Hadley, Ferrel, and Polar cells. Spatial patterns of climatic state are responses of the solar forcing and surface condition, so the four meridional cells in each hemisphere, the zonal Walker cells in boreal summer, and the atmospheric active centers are illustrated in Chap. 3, "Spatial Patterns and Time Scales of Climatic State," including annual, semiannual, and biweekly cycles. Monsoon has been an archaic topic since BD 23–22 centuries. The study of global monsoon started in the 1950s but the keyword of "global monsoon" describing dry–wet alternation was not proposed until the late 1990s. There are lots of monsoon definitions from regional to planetary scales and from precipitation variation to wind reversal. Therefore, the literature for monsoon is abundant. Chapter 4 has not only summarized previous monsoon results but also given a reasonable definition for the global monsoon domain with dry–wet alternation and low-level prevailing wind reversal associated with the cross-equatorial flow. Based on the global monsoon definition, division of the global monsoon, outer edge active zones of the global monsoon, and millennium monsoon dry–wet modes are also summarized in Chap. 4, "Global Monsoon."

The first four chapters introduce the temporal climatology of the atmospheric motion. Chapter 5, "Waves and Vortices," is a transition from temporal climatology to anomaly and their applications. A total atmospheric variable can be decomposed into temporal climatic state and anomaly. Spatial structures of climatic state show wave features with propagations while the anomalous component shows transient vortices with different spatiotemporal scales. As an example, the climatic states and anomalies of geopotential height, temperature, and wind at 0000 UTC 2 July 1998 are plotted from the troposphere to the stratosphere to illustrate those waves and vortices as well as their connections with surface climate and extremes in Chap. 5.

To let readers and forecasters understand the connection between anomalous vortices aloft and surface weather extremes, Chapter 6, "Regional Convective

Events," introduces the application of regional heavy rains and tornado-producing systems while Chap. 7, "Heat Waves and Cold Events," illustrates the applications on heat waves and cold surges. The intensity of a tropical cyclone (TC) can be well evaluated following its center by the vertical profile of height and temperature anomalies. The explanation and prediction of most TC unusual tracks are still difficult from direct observations and complex model outputs. Chapter 8, "Unusual Tropical Cyclones," introduces an optimal-level dynamical model, showing its application in the prediction of most unusual TC tracks which affected China in the past 30 years. This model is also used in the explanation of the left turning of Hurricane Sandy (2012) and the binary interaction of two typhoons in the Northwest Pacific. Chapter 9, "Circulation and Climatic Anomalies," gives the explanation of the Arctic warming and sea ice decline associated with the anomalies of meridional Polar and Arctic cells from seasonal, interannual, and interdecadal scales. The intraseasonal activity of the South Asian high and the western Pacific subtropical high is also illustrated in Chap. 9 to describe their connection with anomalous weather patterns in Eurasia-Pacific region. Finally, standing low-frequency oscillations and moving intraseasonal oscillations are described in Chap. 10, "Low-frequency Oscillations." There is no special chapter to describe the regional drought events and forest wildfires because they are usually accompanied with heat waves or warm anomalies.

Shortly, several important innovations are demonstrated in the book. It presents an approach, decomposing the atmospheric variable into temporal climatology and anomaly. It helps students, teachers, researchers, and forecasters understand weather, climate, and general circulation as well as their anomalies. It confirms the fourth meridional circulation (the Antarctic cell and the Arctic cell) in each hemisphere. The Arctic cell is directly linked to the warming in the high latitudes. It proposes the anomaly-based synoptic chart that can locate weather extremes. It develops an optimal-level dynamical model which can predict most unusual TC tracks. These points are the background to develop an anomalous nonhydrostatic atmospheric model in the future.

Observations of the Milky Way galaxy system, the Earth system, and even a TC show the feature of chaos. This book introduces a method to identify the large-scale structure (climatic state) from observations and to extract vortex signals to indicate weather extremes. Although observations are chaos and headache for forecasters, the decomposed climatic chart and anomalous chart can illustrate many beautiful spatial structures and temporal evolution from basic atmospheric variables.

When we enjoy these beautiful pictures from anomalous synoptic charts, forecasters need to remember their duty to send information of weather extremes to the public. I had been working as a forecaster at Yancheng station for 9 years. Whenever there were weather extremes, I usually collected data and then published papers to Chinese journals. In the afternoon of 23 June 2016, a tornado hit the villages of Yancheng and caused 99 fatalities. This is a new case that we have studied using the basic method introduced in this book.

In 1976, all faculties in the meteorological group of Peking University wrote a textbook titled “Weather Analysis and Forecast” for undergraduate students. Forty years later, the book, “Temporal Climatology and Anomalous Weather Analysis” is written for graduate students as an introductory course. The course of “Medium to Extended Range Weather Forecast” has employed this book draft in the first term of 2016.

Beijing, China Weihong Qian
October 2016

http://www.springer.com/978-981-10-3640-8

Temporal Climatology and Anomalous Weather Analysis
Qian, W.
2017, XVI, 687 p. 489 illus., Hardcover
ISBN: 978-981-10-3640-8