TAKING THE TEMPERATURE OF THE COMMON ERA: STATISTICS, PATTERNS AND DYNAMICAL INSIGHTS

by

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Dedication

To my parents, for making me who I am.
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Abstract

The Common Era is essential for our understanding of natural climate variability. It places current climate change into a context broad enough to study decadal to centennial-scale climate variability. Published temperature reconstructions, however, show large discrepancies amongst themselves and with simulations from global climate models (GCMs). In this thesis, we explore the causes of these discrepancies, propose some remedies, and present a new global surface temperature reconstruction, from which we draw new dynamical insights.

Chapter 1 reviews the current state of climate field reconstructions (CFRs). We show that reconstructions are subject to both uncertainties tied to input data and methodology, whose contributions are poorly separated. We therefore start by exploring methodological in Chapter 2, where we evaluate the spatial performance of four different CFR methods (RegEM-TTLS, M09-TTLS, CCA, GraphEM) using synthetic data that mimic various characteristics of real-world proxies. We show that spatial skill varies considerably between CFR techniques, with GraphEM and CCA displaying better overall spatial performance than the other two methods. Chapter 3 then applies these CFR methods to two real-world datasets. We find reconstructed spatial patterns to be highly sensitive to the choice of CFR methods and proxy datasets, and caution against drawing dynamical interpretations based on a single reconstruction. Nevertheless, more inter-method similarity can be reached when high-quality data are used. This motivates the use of an expanded,
quality-controlled dataset of temperature-sensitive proxies (PAGES2k, phase 2) from which we derive a new global temperature reconstruction in Chapter 4, via GraphEM. We find a globally warm Medieval period, which was colder than the late twentieth-century by 0.5°C. With a probability of 87%, the 1961 – 1990 period was the warmest in the past 2000 years in most regions, especially in the high latitudes of the Northern Hemisphere. We show that surface temperature has a robust large-scale cooling pattern shortly after an eruption; in particular, over the North Atlantic Ocean, the cooling can persist up to 3 years after an eruption. Solar irradiance forcing is found to be an important modulator of multidecadal climate variability. These key features are echoed in GCM simulations of the past millennium, though we find notable differences, in particular regarding the timing of the post-volcanic ENSO response, and the magnitude of the temperature response to solar irradiance forcing.

Overall, the thesis demonstrates the utility of CFRs to quantify contributions of external forcings to climate variability and constrain the behavior of predictive climate models.