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A COMPREHENSIVE, HIGH-RESOLUTION DATABASE OF HISTORICAL AND PROJECTED CLIMATE SURFACES FOR WESTERN NORTH AMERICA

BY ANDREAS HAMANN, TONGLI WANG, DAVID L. SPITTLEHOUSE, AND TREVOR Q. MURDOCK

With growing concern over global climate change, interpolated climate data have become increasingly important for biological research, natural resource management, and infrastructure planning. Virtually every study in the field of climate change impact and adaptation requires a variety of data that may include long-term reference data, historical time series, climate change projections, or information about recent climate trends. Such data are usually not easily accessible at the appropriate resolution, in a consistent format, and for a comprehensive set of relevant climate variables. Several comprehensive efforts exist to provide researchers as well as nonspecialists with such databases, typically in the format of gridded spatial data (E. H. Girvetz et al. reviewed such databases in their 2009 *PLoS One* article). However, gridded climate data with high resolution, many climate variables, long historical time series, and comprehensive future projections can become very large and difficult to use for researchers and resource managers.

We address this need for climatically characterizing sample data, extracting custom time series, and generating high-resolution gridded data with a software solution that allows for custom queries and downscaling of historical and future climate data for western North America. We use climate data for the 1961–90 normal period, developed with the Parameter-elevation Regressions on Independent Slopes Model (PRISM). PRISM is an expert interpolation approach (described by C. Daly et al. in a 2008 *International Journal of Climatology* article), which uses physiographic information to better predict climate patterns in mountainous terrain. For example, leeward-facing slopes can indicate rain shadows, or valley bottoms may imply temperature inversions in winter that are difficult to model with standard interpolation approaches. Our software algorithms use flexible temperature lapse rates to downscale PRISM data, and derive historical data and future projections using the "delta method" described in the work of T. Mitchell and P. Jones in 2005. This approach interpolates differences (also referred to as "delta" or "anomaly") observed in an individual year from a common reference time period (the 1961–90 normal period), and subsequently adds the resulting surfaces onto the high-resolution baseline dataset. Previous research by M. Mbogga et al. in 2009 and T. Wang et al. in 2006 and 2012 has shown that software estimates based on the above downscaling and delta methods considerably improve the statistical accuracy over the original climate surfaces.

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THE CLIMATEWNA SOFTWARE PACKAGE. The software package we provide has a simple graphical user-interface (Fig. 1) and can handle interactive queries, generation of time series, and multilocation processing, using comma separated text files for input and output. The so-called ClimateWNA software can calculate monthly, seasonal, and annual climate variables for specific locations in western North America based on latitude, longitude, and elevation. The program provides easy access to more than 20,000 climate surfaces, which have been widely used to generate climate data for the region. Our software is primarily meant to improve climate estimates for sample locations with known elevation, and to generate high-resolution climate data

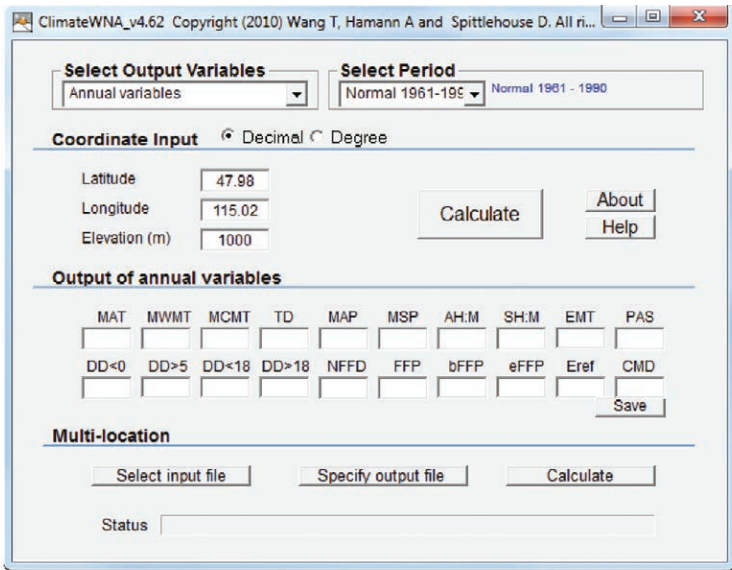

FIG. 1. Interface of the ClimateWNA software package.

for study areas in complex mountainous landscapes, where climate conditions and ecological communities can change at scales of a few hundred meters. The ClimateWNA software package is available at no charge and can be downloaded anonymously. The latest software versions are available at www.genetics.forestry.ubc.ca/cfcg/climate-models.html, with a secondary download mirror at www.ualberta.ca/~ahamann/climate.html. The data cover North America west of 100° latitude (Fig. 2) and include monthly data for the last century (1901–2009), future projections of the Coupled Model Intercomparison Project phase 3 (CMIP3) of the of the World Climate Research Programme, as well as decadal averages and multiple 30-year climate normals for the last century. For each of these time periods, the software estimates a large set of basic and derived, biologically relevant climate variables, such as growing and chilling degree days, frost-free days, extreme temperatures, growing season precipitation, Hargreaves' climatic moisture deficit, precipitation as snow, etc. The variables are described in more detail by T. Wang et al. in their January 2012 article in the *Journal of Applied Meteorology and Climatology.*

APPLICATIONS AND LIMITATIONS. The software solution that we provide has been gaining rapid adoption and has been used and cited in more than 100 scientific studies conducted in western Canada over the past 5 years. Examples encompass engineering applications, environmental impact assessments, natural resource management, research in historical ecology, conservation biology, tree-ring research, and climate change impact assessments; a selection of these have been reviewed in the 2009 and 2006 publications of M. Mbogga et al. and T. Wang et al., respectively. This database and software package is now available for the whole of western North America, covering montane areas from Mexico to Alaska. Regarding spatial accuracy, climatic features such as rain shadows or temperature inversions are modeled at a scale of kilometers, suitable to broadly represent mountainous terrain. Lapse-rate–driven differences in temperature-related variables along elevation gradients are accurately represented at a much finer scale, informative at a resolution of hundreds of meters. We should note, however, that all interpolated climate

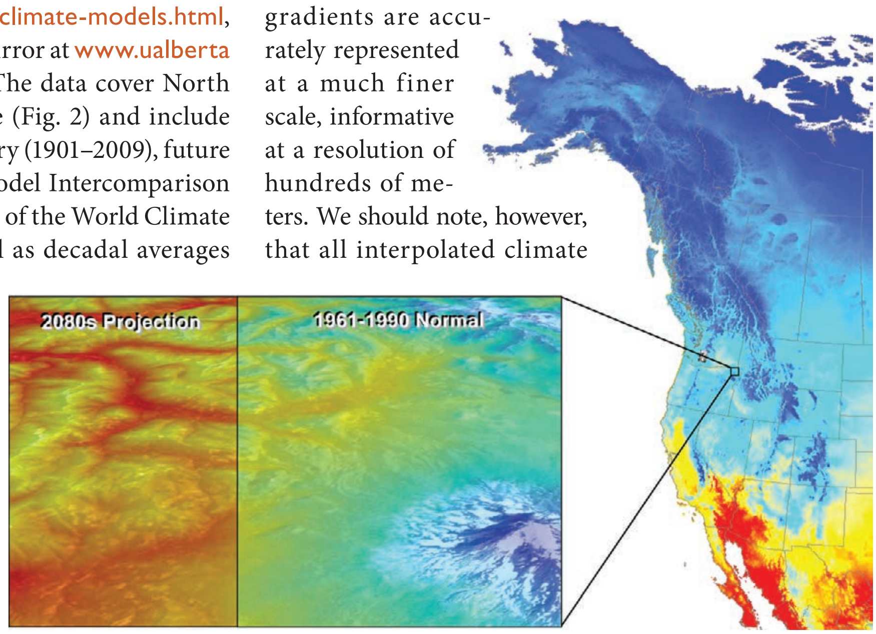

FIG. 2. Map of growing degree days above 5°C created with the ClimateWNA software package (blue indicates low values, red indicates high values, for growing degree days). The insert shows climate change projections for the 2080s, derived from one of the third-generation coupled atmosphere–ocean general circulation models of the World Climate Research Programme.

surfaces of this dataset are ultimately based on standard weather stations and, consequently, microclimates that are driven by vegetation, water bodies, or topography at a scale of tens of meters are not represented.

FOR FURTHER READING

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