Vol. 75: 111–115, 2018
https://doi.org/10.3354/cr01511

CLIMATE RESEARCH
Clim Res

Published online May 17

NOTE

Empirical test of the ClimateWNA model for local accuracy in the Kluane Lake area of the southern Yukon, Canada

Charles J. Krebs[1,*], J. David Henry[2], Alice J. Kenney[1], Elizabeth J. Hofer[1]

[1]Department of Zoology, University of British Columbia, 6270 University Blvd., Vancouver BC V6T 1Z4, Canada
[2]Kluane National Park and Reserve, Parks Canada, Haines Junction YT Y0B 1L0, Canada

ABSTRACT: Ecological studies related to climate typically require data on temperature and rainfall. If local climate data are not available, the only recourse is to rely on data from the closest meteorological station or interpolated data from regional models of climate. In the southwestern Yukon, we have for the past 25 yr gathered ecological information such as counts of cones on white spruce trees and attempted to relate these biological variables to weather variables, thus requiring accurate climate information. From 2001 to 2014, we measured local summer temperature and rainfall during the growing season at 7 local sites along 250 km of the Alaska Highway and tested the accuracy of the ClimateWNA model estimates for these 7 sites as well as for the Haines Junction Environment Canada meteorological station. Monthly summer temperatures were reasonably well correlated with the predicted ClimateWNA values ($r = 0.90$, $n = 299$ mo), but summer rainfall was not ($r = 0.37$, $n = 218$ mo). We repeated this analysis with the Daymet climate model and got similar results. We caution the use of ClimateWNA or Daymet rainfall estimates for local areas in this part of the southwestern Yukon for the prediction of ecological measurements.

KEY WORDS: ClimateWNA · Daymet · Temperature · Rainfall · Kluane · Yukon · Accuracy

1. INTRODUCTION

The growing interest in the impacts of climatic warming on ecological processes requires the gathering of accurate data on climate as well as accurate data on the ecological processes under study. One example is tree or shrub growth rings that might correlate with temperature or rainfall in the growing season. In northern Canada, there are relatively few government meteorological stations recording detailed weather data that ecologists can use as predictors of ecological measurements. Hamann et al. (2013) provided a comprehensive high-resolution database that provides interpolated climate data for historical as well as the projected future for western Canada (ClimateWNA, version 4.62, available at http://tinyurl.com/ClimateWNA). A large array of bioclimatic variables is available for any site with specified longitude, latitude, and elevation in western North America. A second high-resolution weather database with daily temperature and rainfall predictions for 1 km^2 pixels is available from NASA for comparison with ClimateWNA (Daymet; Thornton et al. 2017, available at https://doi.org/10.3334/ORNLDAAC/1328).

Our interest in climate models like ClimateWNA and Daymet arose because we have been studying changes in the productivity of trees, shrubs, ground

*Corresponding author: krebs@zoology.ubc.ca

berries, and mushrooms in the Kluane Lake area of the southwestern Yukon since 1986. We became convinced that local variation in temperature and/or rainfall during the growing season might affect local primary production, and that this demanded local rather than distant weather data. Both ClimateWNA and Daymet are scaled to 1 km^2, which is close to the scale of our measurement areas. Beginning in 2000, we installed local weather stations at 7 of our sites along the Alaska Highway to gather rainfall and temperature data in the hope that we might gain more accurate and precise data at the monthly scale to determine how weather affects primary production in the boreal forests near Kluane Lake. Prior to this time, we were forced to use the weather data gathered by the Environment Canada weather station at Haines Junction, Yukon, which is up to 150 km distant from some of our field sites.

We report here on a small-scale evaluation of how modelled climate variables relate to local weather measurements in the Kluane region of the southwestern Yukon during the 2001 to 2014 time period, when both ClimateWNA and Daymet predictions could be fitted to the exact sites of our local weather stations. The hypothesis we wished to test was that the ClimateWNA and Daymet predictions for historical weather are an accurate representation of actual weather measured on site for rainfall and temperature in this part of North America.

2. METHODS

We measured local temperature and rainfall in the summer months from 1 May to 31 August with 2 different measurement systems. From 2000 to 2008, we used automatic weather stations (Campbell Model 150) set up in small clearings in the forest that we downloaded at the end of summer. Temperature probes were 60 and 80 cm above ground level and were programmed to record temperature every 90 min. These data were averaged to give mean monthly temperatures. Rainfall was recorded in tipping bucket rain gauges calibrated to tip every 0.254 mm of precipitation. Rainfall was summed over the monthly periods for the growing season (May to August inclusive). Problems with these Campbell weather stations caused us to change after 2008 to Spectrum Watchdog Model 115 and later Model 1120 tipping bucket rain gauges (www.specmeters.com/weather-monitoring/environmental-meters/rain-gauges/). We doubled up rain gauges at each of the 7 sites to eliminate as much as possible any problems with animal damage (bears) and to have a measure of possible errors in recording. We do not have temperature and rainfall data for all months. These failures were largely due to battery failures and partly due to animal disturbance of weather stations.

Temperature recording with the Campbell weather stations became problematic due to software malfunctions and bear damage, and we began in 2006 to use Maxim Thermochron iButtons (DS 1921G-F5) mounted on wooden poles to record temperatures every 4 h at both 60 and 80 cm above ground level. These temperature poles were in forested plots, and the buttons faced north to avoid direct sunlight. Duplicate buttons were placed on a second wooden pole to guard against animal disturbance or button failure. For the summer months of May through August, we could detect no significant difference between the 60 cm temperatures and the 80 cm temperatures (paired *t*-test, $p > 0.67$ for all comparisons), so we combined these as 4 replicate measurements to estimate monthly mean temperatures at each of the 7 sites for the summer months.

There is always a concern that temperature and precipitation data might be unreliable. We did not have enough funding to duplicate measurements at all stations in all years to obtain a robust measure of repeatability at each site. We overlapped for 3 yr the Campbell weather stations and the iButtons, and at 6 sites we used 2 rainfall gauges mounted within 1.5 m of each other. There was never more than a 1 to 2% difference in these duplicate measurements, so we are convinced that our local weather data for the summer months are accurate.

ClimateWNA predicted monthly temperature and rainfall can be obtained directly from the web (http://tinyurl.com/ClimateWNA) for each site in our study area by specifying the latitude, longitude, and elevation of the location. Daymet daily temperature and rainfall data are available for 1 km^2 pixels by specifying latitude and longitude of our study plots.

3. RESULTS

The map in Fig. 1 shows the locations of the sites in the southwestern Yukon at which temperature and rainfall were measured from 2001 to 2014. In general, the more southerly sites are warmer and wetter and the more northerly sites colder and dryer, but there is much variation in weather from year to year. Haines Junction weather is recorded by Environment Canada as a registered standardized weather station, and the other 7 sites are field sites used for ecological studies.

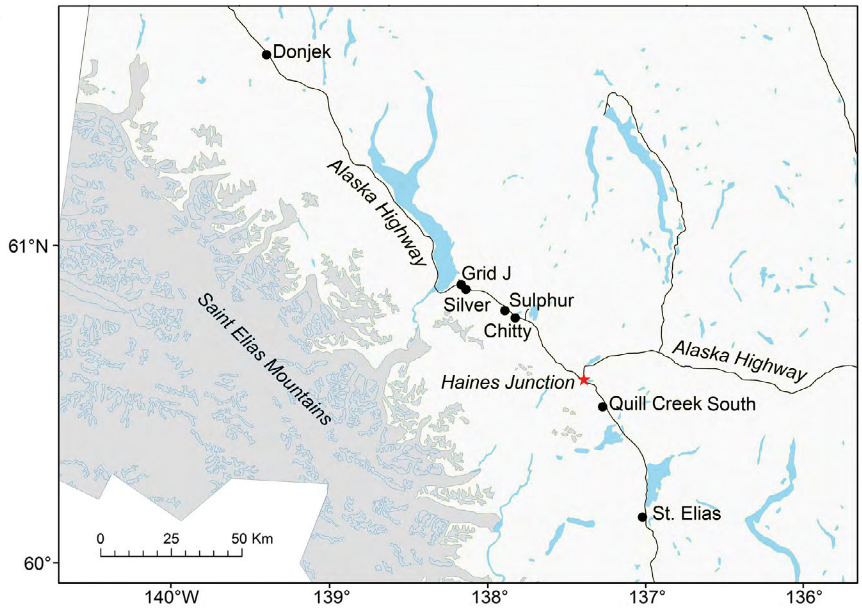

Fig. 1. Kluane region of the southwestern Yukon and the 7 sites at which summer temperature and rainfall were measured on local monitoring areas, as well as the Haines Junction official weather station. Grey areas indicate glaciers in the St. Elias Mountains (lines are 3000 m contours)

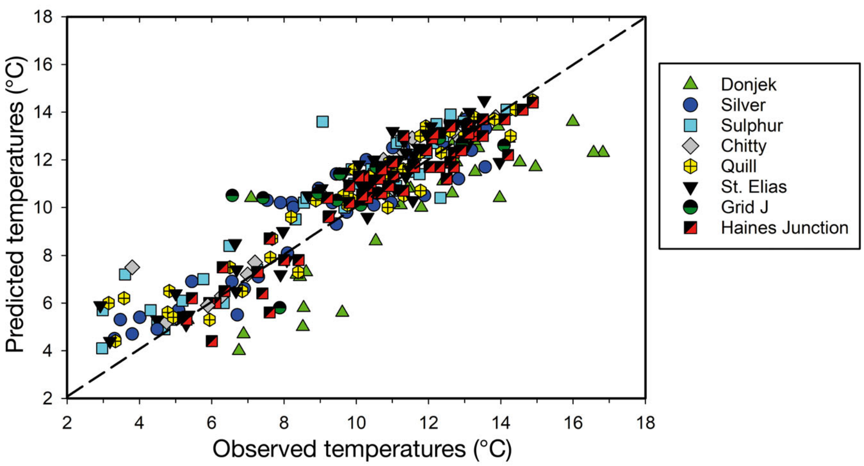

Fig. 2. Relationship between observed and predicted (ClimateWNA) monthly summer temperatures at 8 sites mapped in Fig. 1. The dashed line is the exact 1:1 line between observed and predicted temperatures (*T*). A regression line for the observed data is: predicted *T* = 1.1703 + 0.9138 observed *T* (r = 0.90, R^2 = 0.81

Fig. 2 shows the association between the observed monthly temperatures for May through August for all 8 sites in relation to the monthly temperature predicted by ClimateWNA (data extracted 27 February 2017). There is a clear association (r = 0.90). An analysis of covariance among the regression lines for each of the 8 sites was not significant ($F_{7,283}$ = 1.14, p = 0.34), indicating a common slope for all sites. The orthogonal regression has a slope of 0.914 (SE 0.0233) and an intercept of 2.011 (SE 0.243). There is clearly not a perfect fit, which would require a slope of 1.0 and an intercept of 0.0. In general, however, there is a good relationship between observed and predicted temperatures, such that any ecological analysis would be well served by ClimateWNA-predicted monthly temperature for historical climate. The Donjek site shows systematic underestimation of predicted temperatures, but this could be a local effect, and the underestimation appeared to be constant for all different observed monthly temperatures. Haines Junction, which is an official weather station, shows a very high correlation with ClimateWNA predictions (r = 0.95, n = 56 mo).

Fig. 3 shows the association between the observed monthly rainfall for May to August for all 8 sites (7 local sites plus Haines Junction) in relation to the monthly rainfall predicted by ClimateWNA. The linear regression fits the data poorly (r = 0.37). An analysis of covariance among the regression lines of the 8 sites showed no difference in the slopes for the sites ($F_{7,202}$ = 0.64, p = 0.72), indicating a common slope for all sites. The orthogonal regression has a slope of 0.455 (SE 0.047) and an intercept of 18.74 (SE 1.84). The expected slope for equality of observed and predicted is 1.0 with the *y*-intercept of 0.0. Haines Junction, which is an official weather station, shows a very low association with ClimateWNA predictions of monthly summer rainfall (linear regression, r = 0.26, n = 52 mo). There is a clear inability of the ClimateWNA model to predict actual summer precipitation in this area of the southern Yukon.

We carried out the same analysis with the Daymet climate model, with similar results to those of the ClimateWNA model (see Figs. A1 & A2 in the Appendix). Temperatures could be predicted reasonably well with the Daymet model (r = 0.91, slope 0.98), but summer rainfall was not predictable (r = 0.64, slope 0.62). The Dayment rainfall predictions for the Haines Junction meteorological station were only loosely associated (r = 0.65, n = 52 mo).

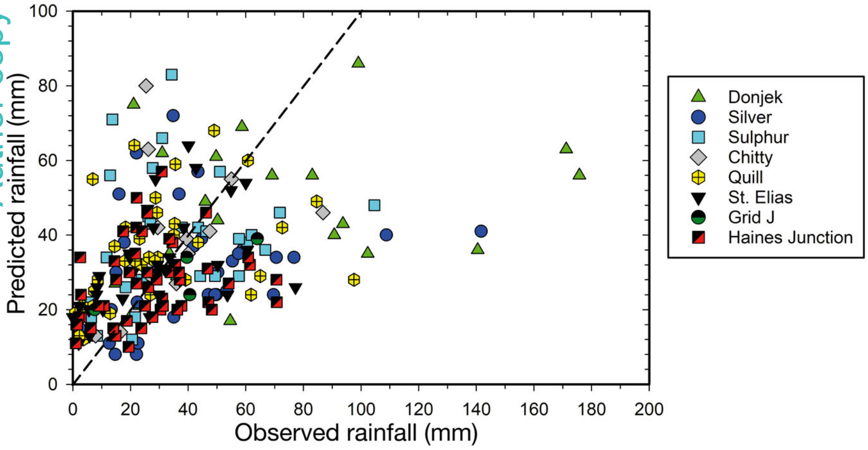

Fig. 3. Relationship between observed and predicted (ClimateWNA) monthly summer rainfall at 8 sites mapped in Fig. 1. The dashed line is the exact 1:1 line between observed and predicted summer rainfall (precipitation, ppt). A regression line for the observed data is: predicted ppt = 18.744 + 0.4545 observed ppt ($r = 0.37$, $R^2 = 0.14$)

4. DISCUSSION

Our first reaction to these results was the consideration that our local rainfall data were in error. To check this, we duplicated rain gauges at all the sites to calculate repeatability of rain measurements (Krebs 1999, p. 554). We had 28 mo of duplicate summer rainfall data, and repeatability was 0.99, so we concluded that our rainfall data was precise for the 7 sites we measured.

Every model has its limits, and here we use the ClimateWNA model and the Daymet model to predict local weather on study sites of approximately 1 km^2 in the southwestern Yukon. The general area is mountainous, but all our sites were located on level valley areas, so there should be minimal slope effects on rainfall. It seems clear that these climate models have a reasonable accuracy for summer temperature in these local areas but a poor accuracy for rainfall. Why might this matter for ecological studies?

If the relevant weather for ecological correlations is temperature, there is no problem with the use of ClimateWNA or Daymet values. For example, in our analysis of the climatic correlates of white spruce cone production (Krebs et al. 2017), July summer temperatures included the key variables for prediction. We found that the best statistical model was the combined measures of degree-days >5°C for 1 to 31 July and the 4 highest daily maximum July temperatures (with $r = 0.81$) with data from 2 yr before cone appearance on trees. Rainfall measured at the Environment Canada station at Haines Junction showed no correlation with spruce cone crops. By contrast, when we searched for a statistical model to predict summer mushroom aboveground biomass, we found that May rainfall of the previous year was the key predictor (Krebs et al. 2008). The question our current analysis raises is whether rainfall would be a better predictor if we had local rainfall data for each site sampled for mushrooms or spruce cones. We can address these questions only by more research and more local weather stations that can capture the local rainfall not captured at present by ClimateWNA or Daymet for this area of the Yukon.

Agricultural applications rely on accurate weather data to estimate crop yields, and agricultural scientists have found similar problems with gridded weather data models. Ramirez-Villegas & Challinor (2012) carried out an extensive analysis of the utility of existing climate models. They found that Daymet was not accurate for estimating crop yields in sub-Saharan Africa and parts of South Asia. Mourtzinis et al. (2017) used the most recent climate models to predict corn and soybean yields in the US Corn Belt and found that in this area with a dense array of weather stations, gridded weather models produced good predictions for temperature-related crop measurements, but poor predictions for rainfall-related crop characteristics like yield. They recommended that high-quality local weather data were required, and that local measurements could not be replaced at the present time by estimates from models that use gridded weather station data (such as Daymet). The recommendation that arises from these studies and our Yukon study suggests that high-quality weather data measured on site are essential for making accurate estimates of plant growth and yield in field sites.

Acknowledgements. We thank Richard Greer and all our summer assistants who have worked over the years to capture these weather measurements. We thank 2 referees for critical reviews of the manuscript. Research funding was provided by Parks Canada and the Natural Science and Engineering Research Council of Canada. The facilities of the Kluane Lake Research Station of the Arctic Institute of North America were essential to this long-term research program, and we thank Andy and Carole Williams, Lance Goodwin, and Sian Williams for their assistance.

LITERATURE CITED

Hamann A, Wang T, Spittlehouse DL, Murdock TQ (2013) A comprehensive, high-resolution database of historical and projected climate surfaces for western North America. Bull Am Meteorol Soc 94:1307–1309

Krebs CJ (1999) Ecological methodology. Addison Wesley Longman, Menlo Park, CA

Krebs CJ, Carrier P, Boutin S, Boonstra R, Hofer EJ (2008) Mushroom crops in relation to weather in the southwestern Yukon. Botany 86:1497–1502

Krebs CJ, O'Donoghue M, Taylor S, Kenney AJ, Hofer EJ, Boutin S (2017) Predicting white spruce cone crops in the boreal forests of the southern and central Yukon. Can J For Res 47:47–52

Mourtzinis S, Rattalino Edreira JI, Conley SP, Grassini P (2017) From grid to field: assessing quality of gridded weather data for agricultural applications. Eur J Agron 82:163–172

Ramirez-Villegas J, Challinor A (2012) Assessing relevant climate data for agricultural applications. Agric For Meteorol 161:26–45

Thornton PE, Thornton MM, Mayer BW, Wei Y, Devarakonda R, Vose RS, Cook RB (2017) Daymet: daily surface weather data on a 1-km grid for North America. Oak Ridge National Laboratory DAAC, Oak Ridge, TN. https://doi.org/10.3334/ORNLDAAC/1328 (accessed on 19 Jan 2018)

Appendix. A referee made the important suggestion that we check the Daymet model of gridded weather estimates for our particular study sites to determine if it was more accurate than ClimateWNA. We did this analysis and results were essentially the same as those shown in the main study. We include here the 2 relevant figures from the Daymet analysis for our Yukon study area.

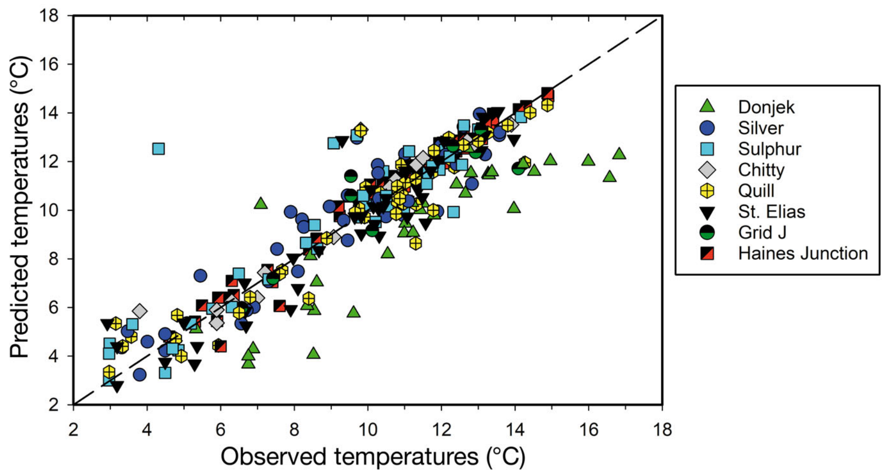

Fig. A1. Relationship between observed and predicted monthly summer temperatures at the 8 sites mapped in Fig. 1. The dashed line is the exact 1:1 line between observed and predicted temperatures (T). A regression line for the observed data is: predicted T = −0.0048 + 0.9844 observed T (r = 0.91, R^2 = 0.82). Predicted temperatures from Daymet (https://doi.org/10.3334/ORNLDAAC/1328)

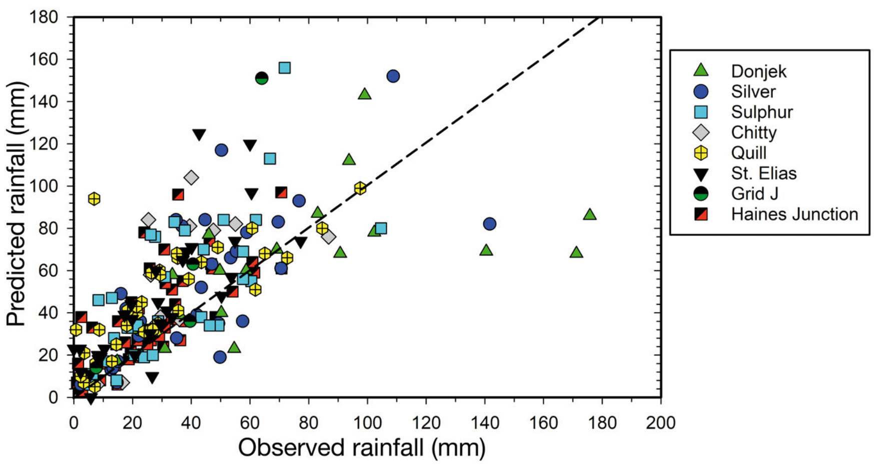

Fig. A2. Relationship between observed and predicted monthly summer rainfall at 8 sites mapped in Fig. 1. The dashed line is the exact 1:1 line between observed and predicted summer rainfall (precipitation, ppt). A regression line for the observed data is: predicted ppt = 13.70 + 0.927 observed ppt (r = 0.65, R^2 = 0.42). Predicted rainfall from Daymet

Editorial responsibility: Tim Sparks, Cambridge, UK

Submitted: November 23, 2017; Accepted: February 7, 2018
Proofs received from author(s): April 23, 2018