Reconstructed warm season temperatures for Nome, Seward Peninsula, Alaska

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[1] Understanding of past climate variability in the Bering Strait region and adjacent land areas is limited by a paucity of long instrumental and paleoclimatic records. Here we describe a reconstruction of May–August temperatures for Nome, Seward Peninsula, Alaska based on maximum latewood density data which considerably extends the available climatic information. The reconstruction shows warm conditions in the late 1600s and middle-20th century and cooler conditions in the 1800s. The summer of 1783, coinciding with the Laki, Iceland volcanic event, is among the coldest in the reconstruction. Statistically significant relationships with the North Pacific Index and Bering-Chukchi sea surface temperatures indicate that the Seward tree-ring data are potentially useful as long-term indices of atmosphere-ocean variability in the region. *INDEX TERMS:* 1610 Global Change: Atmosphere (0315, 0325); 4221 Oceanography: General: Dendrochronology; 3344 Meteorology and Atmospheric Dynamics: Paleoclimatology; 3309 Meteorology and Atmospheric Dynamics: Climatology (1620). **Citation:** D'Arrigo, R., E. Mashig, D. Frank, G. Jacoby, and R. Wilson (2004), Reconstructed warm season temperatures for Nome, Seward Peninsula, Alaska, *Geophys. Res. Lett.*, *31*, L09202, doi:10.1029/2004GL019756.

1. Introduction

[2] The Seward Peninsula (SP) in northwestern Alaska separates the Bering and Chukchi Seas and marks the transition between the northern North Pacific and Arctic Oceans. Although the SP is also impacted by features of continental interior climate, the conditions of the Beringia region (including the SP) are distinct due to maritime effects [e.g., *Overland et al.*, 2004]. To help provide extended climatic records for this remote region, we sampled trees of white spruce (*Picea glauca* [*Moench*] *Voss*) from fourteen sites near elevational treeline on the eastern SP in the summer of 2002. To the west there is a longitudinal treeline which may exist because of the cooling influences from the Bering and Chukchi Seas during the summer months. Combined measurements (consisting of 46 cores from 38 trees) from three of the sites were selected to develop a maximum latewood density (MXD, density of the last cells formed in a given season) chronology for the SP, dating from AD 1389 to 2001. The MXD parameter has been shown to provide consistent climatic information about warm-season conditions that is complementary to that derived from ring width [e.g., *Briffa et al.*, 1992; *D'Arrigo et al.*, 1992; *Schweingruber et al.*, 1993]. The ring-width data for these sites and their relation to climate have been described in detail elsewhere [*D'Arrigo et al.*, Temperature variability over the past millennium inferred from northwestern Alaska tree rings, submitted to *Holocene*, 2004].

2. Nome Warm Season Temperature Reconstruction

[3] The SP-MXD chronology was developed using standard dendroclimatological and densitometric techniques [*Fritts*, 1976; *Cook and Kairiukstis*, 1990; *Thetford et al.*, 1991]. The raw density measurements were standardized conservatively using negative-exponential or straight-line curve fits [e.g., *Jacoby and D'Arrigo*, 1989]. Two criteria typically used to evaluate chronology reliability [*Cook and Kairiukstis*, 1990]: the mean series intercorrelation (RBAR) and expressed population signal (EPS), indicate that the SP-MXD chronology is most reliable after ca. 1640, when sample size increases to 7 radii.

[4] Correlations were computed between the SP-MXD chronology and monthly temperatures for the Nome meteorological station, located on Norton Sound on the southern coast of the SP (64.6°N, 165.3°W). Results are plotted in Figure 1 for two time periods: 1910–1950 and 1951–2001. The correlations indicate the strongest density/temperature relationship for the current May–August season, although there is some decrease in positive correlation with density beginning ca. 1950 that becomes most noticeable after ca. 1970.

[5] A reconstruction was developed for Nome May–August temperatures (NTR) from the SP-MXD series using linear regression analysis [*Cook and Kairiukstis*, 1990]. 42% of the variance (ar^2, adjusted for degrees of freedom) was accounted for in the regression model based on the 1909–1950 calibration period (Figure 2). This model verifies over the 1951–1970 interval using several statistics, including a positive Reduction of Error (RE = 0.25). The RE is a measure of verification period variance, for which any positive value indicates predictive skill [*Cook and Kairiukstis*, 1990]. Statistically significant sign test (14+ 6−; p = 0.06 level) and Pearson coefficient results (0.547; p = 0.06 level) are also indications of the reconstruction's validity [*Cook and Kairiukstis*, 1990]. Calibration trials including the SP ring-width data for modeling temperature did not improve these results.

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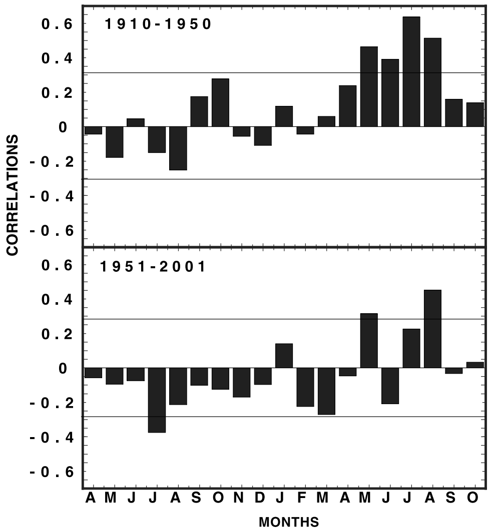

Figure 1. Correlation of SP-MXD chronology with Nome, SP mean monthly temperatures for prior and current growth year. Top: 1910–1950; bottom: 1951–2001. Horizontal lines denote 95% confidence levels. Nome temperature data from Global Historical Climate Network (vol. 2) [*Peterson and Vose*, 1997] and A. Lloyd (personal communication, 2003).

[6] As was found for the SP ring-width data (SRW; Figure 3) [*D'Arrigo et al.*, submitted to *Holocene*, 2004], there is some decrease in positive temperature correlation with density (particularly after 1970), and the temperature model weakens in the post-1970 period (Figure 2). Similar decline in temperature sensitivity has been noted for other northern forest sites in Alaska [e.g., *Jacoby and D'Arrigo*, 1995; *Barber et al.*, 2000], including the SP [*Lloyd and Fastie*, 2002]; and other locations [e.g., *Briffa et al.*, 1998a]. On the SP this decline in sensitivity is possibly related to drought stress or other factors but not to differences in trends (there are none) between nighttime and daytime temperatures that may bias mean temperatures [*Wilson and Luckman*, 2003].

[7] The NTR (Figure 3) indicates annual to multidecadal variability in May–August temperatures, including a warm period in the late 1600s, near-average conditions in the 1700s, and cooler 1800s. Although the signal strength is weak prior to 1640, the reconstruction also suggests warm conditions in the 1500s. The middle 20th century (1949–1968) is the warmest 20-year interval reconstructed since 1640. The SRW series (Figure 3) shows generally similar trends but with more pronounced low-frequency variability. The closest other such record available for comparison is a May–August temperature reconstruction for northern Alaska based on MXD data (NAR) [*Jacoby et al.*, 1999]. The two reconstructions are similar with a correlation of r = 0.67 over the 1680–1990 common period (Figure 3). Differences may partly reflect more maritime influences on the SP. Analyses of Arctic instrumental data indicate that the climate of the Beringia region has distinct differences from that of interior Alaska [*Overland et al.*, 2004].

3. Nome Temperature Reconstruction and Volcanism

[8] The NTR, one of the longest density-based records for northern latitudes (albeit with low sample size prior to 1640), can be used to evaluate the climatic impact of past volcanic events in the region [*Jones et al.*, 1995; *Briffa et al.*, 1998b; *D'Arrigo and Jacoby*, 1999]. The year 1783, for example, which coincided with the eruption of Laki in

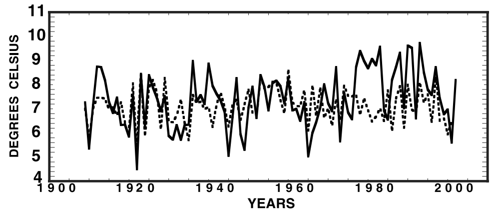

Figure 2. Actual (solid line) and estimated (dashed line) Nome May–August temperatures from 1909–2001 based on SP-MXD chronology, including both calibration (1909–1950) and verification (1951–1970) periods. Note that estimates after ca. 1970 tend to underpredict actual values (calibration ar^2 declines from 42% for 1909–1950 to 38% for 1909–70 and 23.2% for 1909–2001). The ar^2 for the verification period is 26%, with a positive RE of 0.20 in verification. Additional tests: calibration 1909–1920: ar^2 67%, verification 1921–1950: RE = 0.31; calibration 1921–1950: ar^2 38%; verification 1909–1920: RE = 0.40.

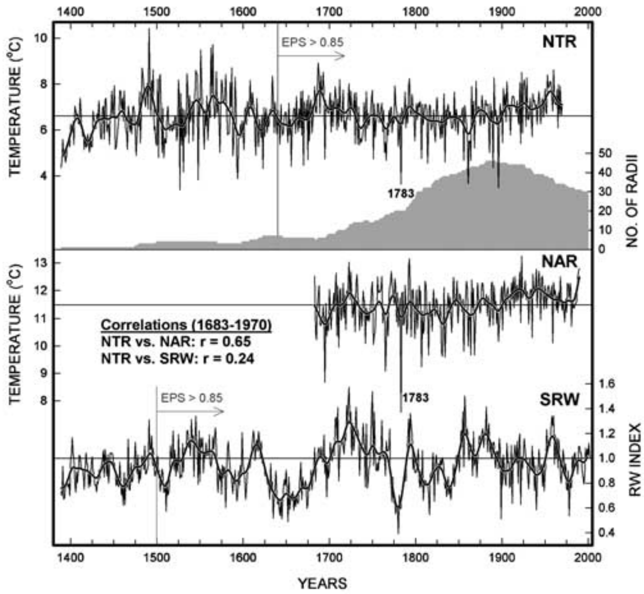

Figure 3. Top line: May–August NTR extending from 1389–1970 (recent decades truncated, see text), based on 1909–1950 model. Thick lines shows smoothed values. Horizontal lines indicate mean values. Chronology based on 3 SP sites: Death Valley (65.19°N, 162.27°W, 239m), Alpine View (65.11°N, 162.18°W, 282m) and Hey Bear (65.22°N, 162.22°W, 229m) [*D'Arrigo et al.*, submitted to *Holocene*, 2004]. Gray shading shows changing sample size over time, which ranges from 1–7 radii prior to 1640. Inferences of past climate prior to ca. 1640 should be interpreted with caution. Low value in 1783 is labeled. Middle line: May–August NAR [*Jacoby et al.*, 1999]. Bottom line: SRW series [*D'Arrigo et al.*, submitted to *Holocene*, 2004]. Vertical lines in SP records indicate acceptable EPS cutoff of 0.85 [*Cook and Kairiukstis*, 1990].

Iceland (and Asama, Japan) [*Simkin and Siebert*, 1994], indicates the second coldest summer since 1640 (after 1896) based on the Nome record. The reconstructed temperature value for 1783 is 3.6°C.; more than three standard deviations (SD) below the mean of 6.6°C. MXD records from northern Alaska were used previously to infer that the summer of 1783 was the coldest in the past several centuries (Figure 3) [*Jacoby et al.*, 1999]. Historical accounts and oral history [*Oquilluk*, 1973] described the path of survivors on the SP as they sought shelter following this period known as "the time when summer did not come", linked to widespread cold and famine in northwestern Alaska. The NTR suggests that conditions on the SP in 1783, although intensely cold, were somewhat less severe than in interior Alaska (where the 1783 reconstructed value is over 5 SD below the mean [*Jacoby et al.*, 1999]), possibly due to the moderating effects of oceanic climate. Nevertheless, inspection of the SP-MXD samples still indicates that in the majority of these data, 1783 is the lowest density year since 1640. Cold summers following this event have also been inferred from northwestern Russia and northern Ural density data [*Jones et al.*, 2003]. 1783 shows the highest stratospheric optical depth over the last 500 years based on a sulfate flux record derived from ice core data for 64°N [*Robertson et al.*, 2001], the same general latitude band as the SP and northern Russian density records.

[9] Other noteworthy volcanic events of the past several centuries include the eruption of Huaynaputina, Peru in 1600 [*Simkin and Siebert*, 1994]; 1601 is the lowest value over the past 600 years in a density record averaged over northern land areas [*Briffa et al.*, 1998b]. The reconstructed Nome temperature in 1601 is significantly below average at 5.1°C. The Nome record provides support for a proposed eruption in 1675 (4.7°C) [*Briffa et al.*, 1998b]. 1695, considered a possible eruption year [*Lamb*, 1970; *Briffa et al.*, 1998b], and identified as an 'event' in the *Robertson et al.* [2001] data, is also significantly below average in the NTR (4.7°C). Reconstructed Nome conditions were not unusual in 1809, the year of another proposed volcanic event [*Dai et al.*, 1991]. However, cold is inferred for 1807 (4.7°C), listed as a very cold year by *Lamb* [1970] for some northern areas. The coldest (post-1640) reconstructed value at Nome (1896; 3.5°C) is not associated with a known eruption [*Simkin and Siebert*, 1994]. 1896 did coincide with a significant El Niño-Southern Oscillation (ENSO) episode, rated a "moderate plus" by *Quinn* [1992], although it is not certain how this event may have impacted the climate of the SP. Prior to 1640, although the signal strength in the reconstruction is weak, it is worth noting the extremely cold summer reconstructed for 1527 (3.4°C), which is also a low density year elsewhere in Alaska [*D'Arrigo and Jacoby*, 1999]. We speculate that this year may be an additional candidate for the date of the Billy Mitchell eruption in the southwest Pacific [*Briffa et al.*, 1998b].

4. North Pacific Influences

[10] The Seward tree-ring data are potentially important as long-term indices for decadal-scale atmosphere-ocean conditions in the region. For example, the SP-MXD record correlates with the warm season (April–October) North Pacific Index (NPI, the sea-level pressure average from 30-65°N, 160°E-140°W [*Trenberth and Hurrell*, 1994]) at $r = -0.34$ (1900–2001; $p = 0.001$ level; 1900–70, $r = -0.30$, 0.05 level). Negative NPI values (in the colder months) indicate an intensified Aleutian Low [*Trenberth and Hurrell*, 1994]. The SP-MXD record also correlates with summer Bering-Chukchi sea surface temperatures (SST; $r = 0.34$, $p = 0.01$ level, 1910–70; averaged over 60–67°N, 160–174°W, from the Hadley Centre SST data set).

5. Summary

[11] We have described a reconstruction of warm-season temperatures for Nome, Seward Peninsula, Alaska, which indicates interannual to multidecadal scale variability over the past several centuries. The middle-20th century warming is the warmest 20-year interval since 1640. Evidence for the climatic impact of volcanism includes cold conditions reconstructed for the summer of 1783 following Laki, as well as during several other proposed volcanic events. Efforts to reconstruct features of Bering Strait and North Pacific climate variability using the SP data along with other North Pacific rim tree-ring series will be the subject of a future investigation.

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