Development of a Mean Annual Temperature Value for the Continued Calculation of the Pacific Northwest Climate Index

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The Pacific Northwest Index (PNI), developed by Ebbesmeyer and Strickland (1995), is a climate index useful for studying broad climate effects on juvenile salmon. It is a composite index that characterizes Pacific Northwest climate patterns in both coastal waters and freshwater habitats using temperature and water availability. The original PNI incorporates specific parameters at three locations: 1) air temperature at Olga in the San Juan Islands; 2) precipitation at Cedar Lake in the Cascade Mountains; and 3) snowpack depth at Paradise Ranger Station on Mount Rainier. The PNI record is updated annually on the Data Access in Real Time (DART) website maintained by the University of Washington's Columbia Basin Research group.

In April 2016, air temperature readings at the Olga 2 SE station ceased. This jeopardized the continuation of the PNI past 2015. To develop a surrogate mean annual air temperature for the Olga station, we examined the long-term minimum and maximum daily air temperature values from 11 currently active weather station sites around Orcas Island (Table 1). These sites were chosen for their active status, proximity to Olga (Fig 1.), and their long-term record keeping.

Station Name	Station ID	Year Range
BELLINGHAM INTERNATIONAL AIRPORT, WA US	USW00024217	1949- 2020
BLAINE, WA US	USC00450729	1893- 2020
COUPEVILLE 1 S, WA US	USC00451783	1895- 2020
DELTA TSAWWASSEN BEACH, BC CA	CA001102425	1987- 2020
FRIDAY HARBOR AIRPORT, WA US	USW00094276	1998- 2020
OLGA 2 SE, WA US (Original data source)	USC00456096	1891- 2016
SAANICHTON CDA, BC CA	CA001016940	1914- 2020
SATURNA ISLANDS CS, BC CA	CA001017101	1980- 2020
SEQUIM 2 E, WA US	USC00457544	1980- 2020
VICTORIA GONZALES HTS, BC CA	CA001018610	1898- 2020
VICTORIA UNIVERSITY CS, BC CA	CA001018598	1992- 2020
WHIDBEY ISLAND NAS, WA US	USW00024255	1945- 2020

Table 1. Weather stations near Olga 2 E on Orcas Island with current daily minimum and maximum air temperature records.

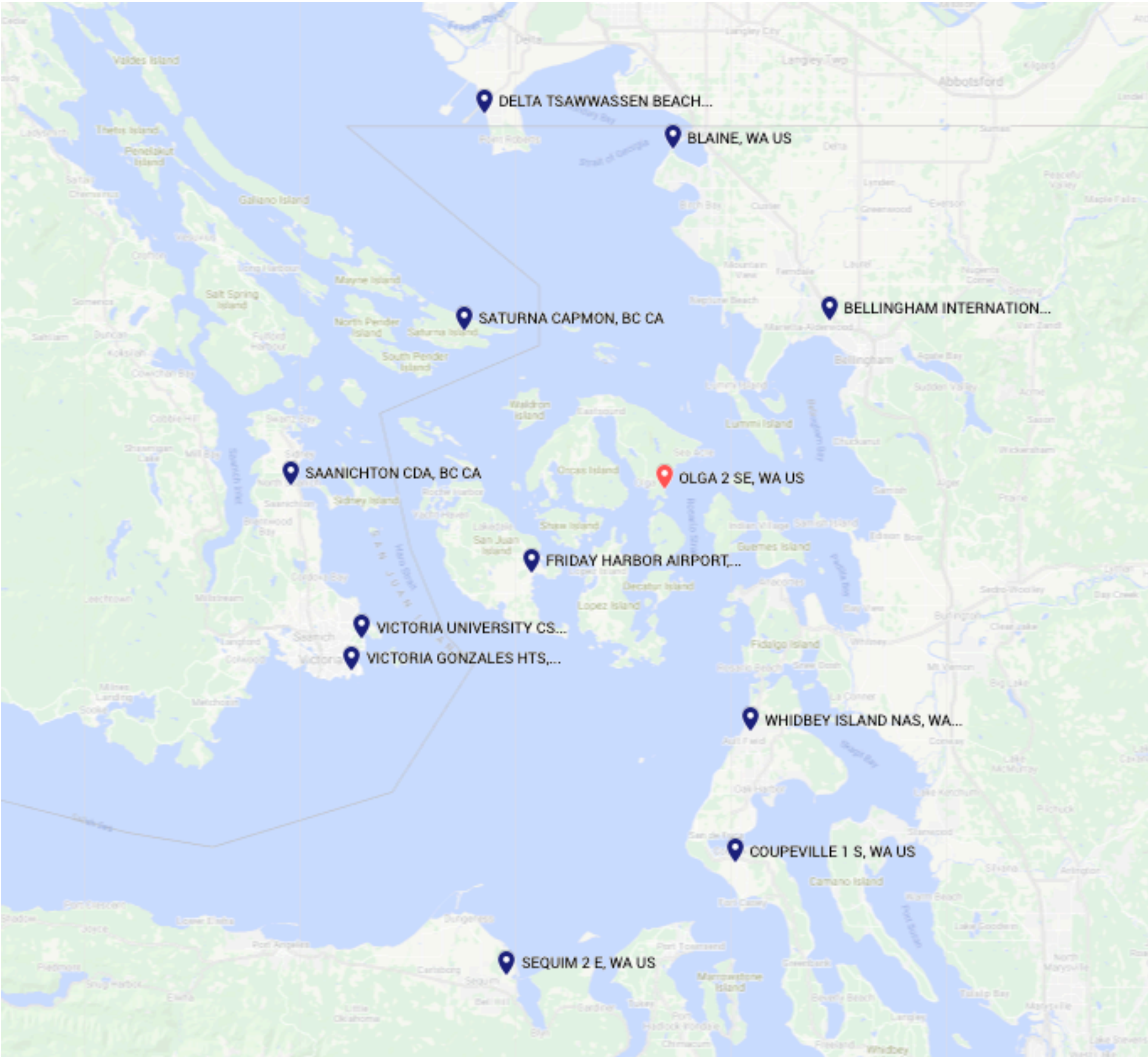

Figure 1. Location of alternative sites for air temperature records relative to the original OLGA site.

We modeled the annual average T_{min} and T_{max} for Olga 2 SE independently, using dynamic factor analysis (DFA) of the annual average T_{min} and T_{max} from these 11 sites. We chose to use dynamic factor analysis because it can analyze short, non-stationary time series containing missing values (Zuur et al 2003). The modeled average annual temperatures for Olga 2 SE to be used in the PNI calculations were then determined by the formula

$$T_{avg} = (T_{min} + T_{max})/2$$

Figure 2 shows the close correspondence of the DFA modeled air temperature measures to the reported temperatures. The R^2 for actual vs modeled T_{avg} is 0.98 (Figure 3).

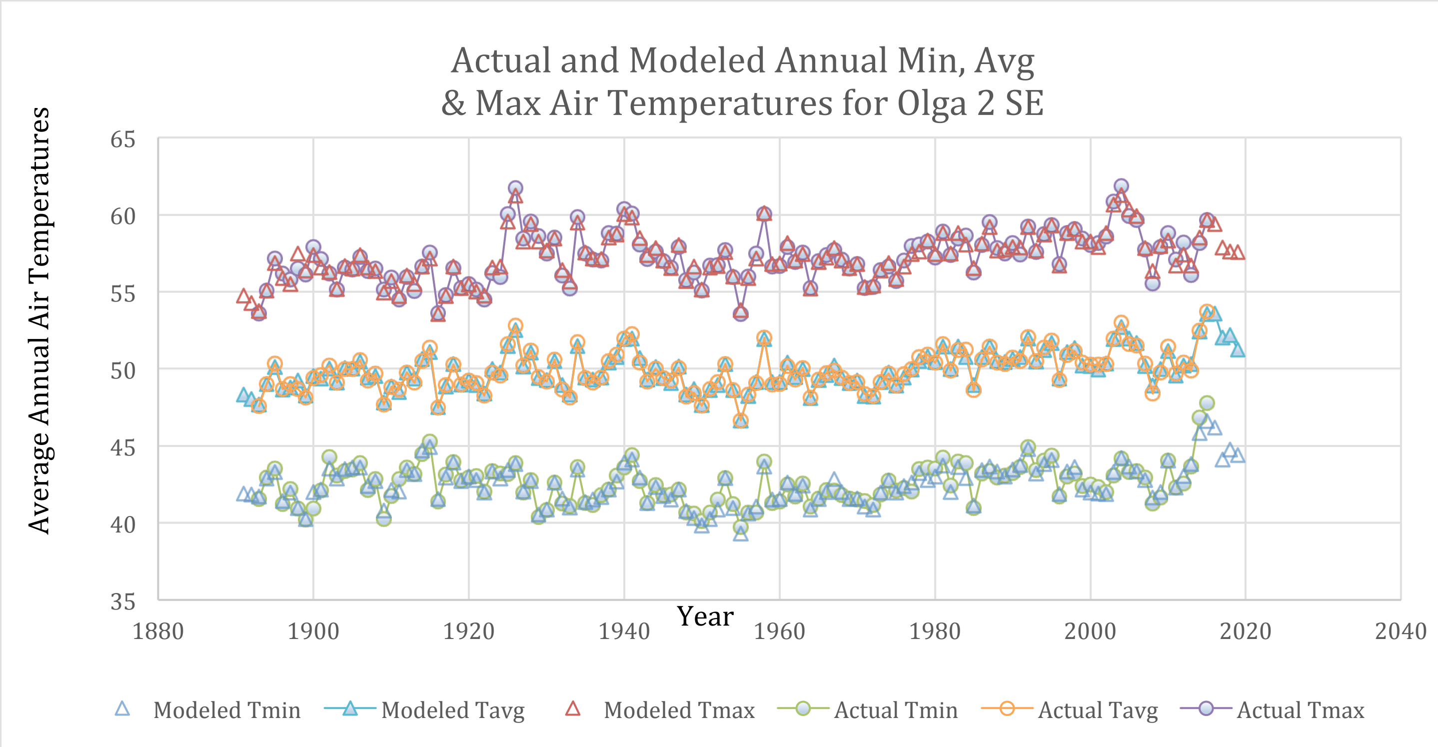

Figure 2. Actual and modeled annual air temperature measures for Olga 2 SE.

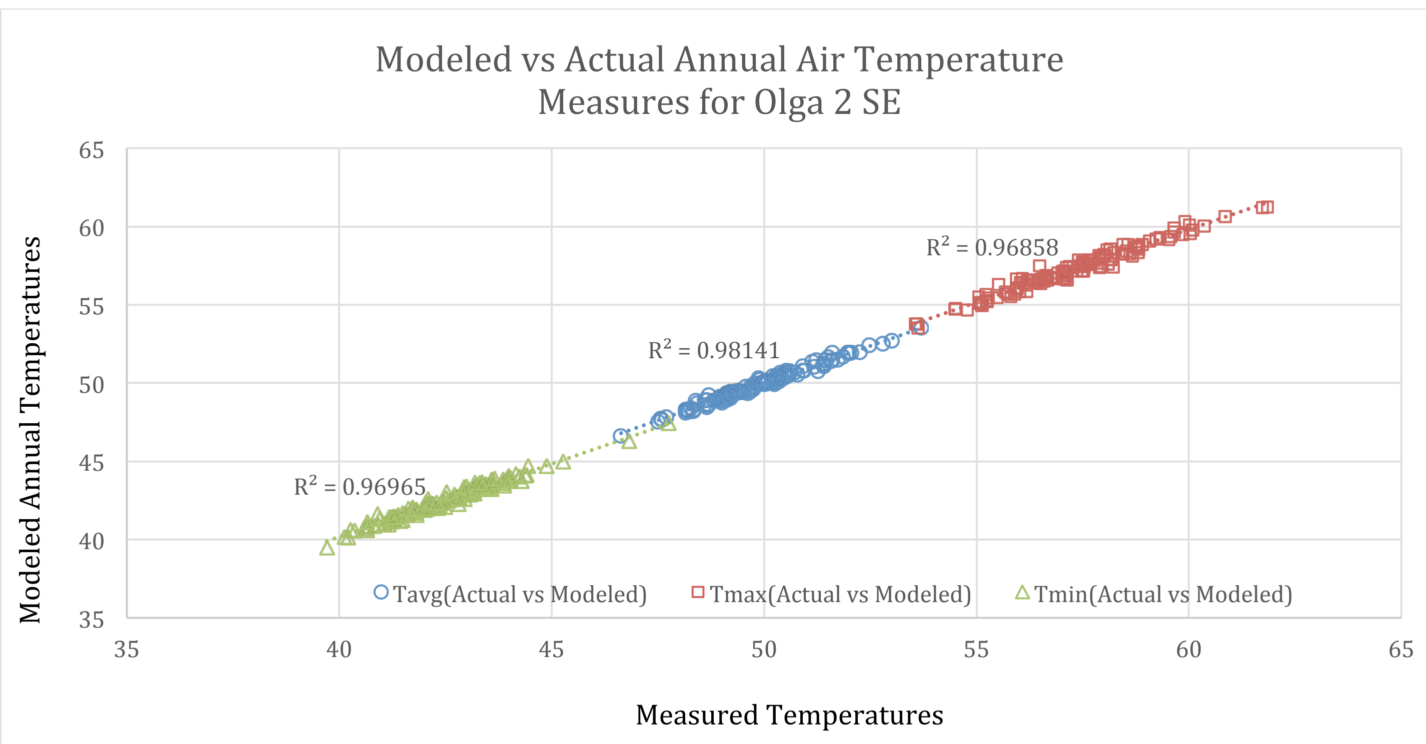

Figure 3. *Modeled vs actual Olga 2 SE average annual temperatures (1893-2015).*

Figure 3 shows the large R^2 values of the actual and modeled temperatures. 1881 and 1882 are omitted due to the large number of missing daily data points for those years.

The results of using the DFA modeled temperatures as the basis for the alternative PNI (aPNI) are shown in Figure 4 with the original PNI values.

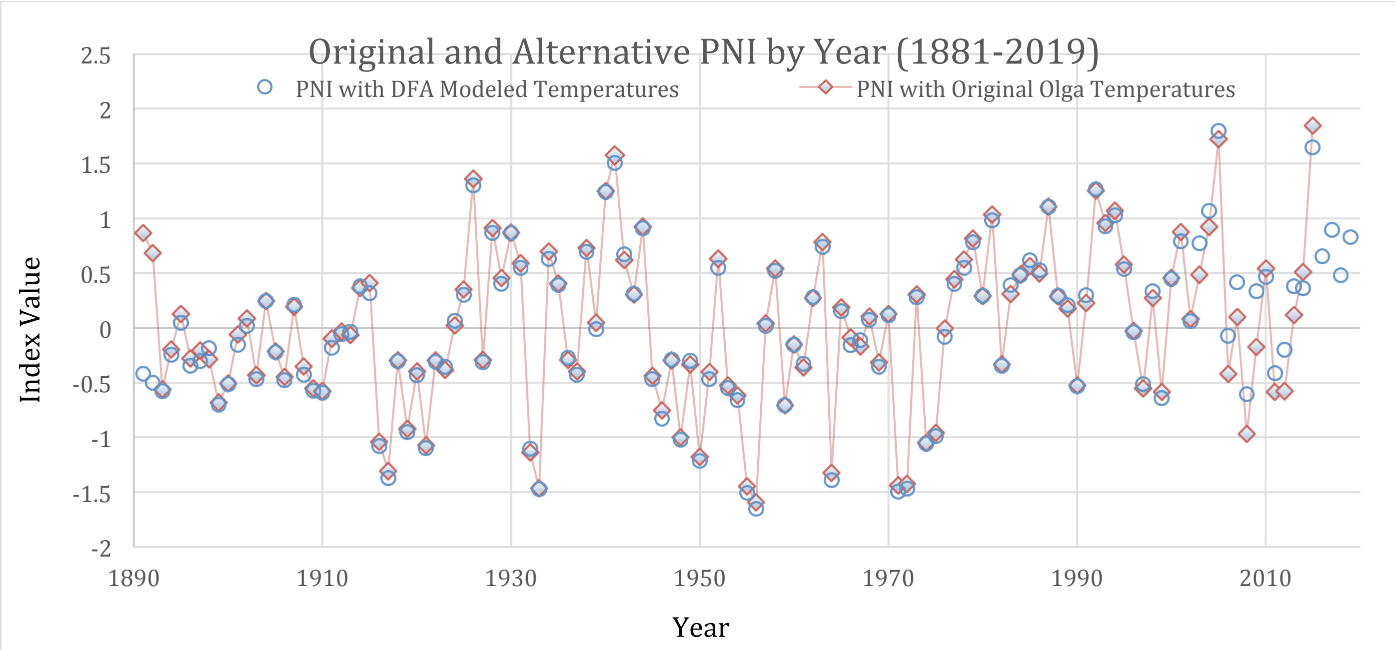

Figure 4. PNI plotted with aPNI.

The two values are highly correlated with an R^2 of 0 .98 (Fig 5). However, the aPNI deviations from PNI show a change in pattern starting in 2003 (Fig.6), where deviations tend to be larger and the aPNI tends to underestimate the measured PNI value. We suspect the longer term temperature modeling is obscuring the increased variability in actual temperatures in recent years.

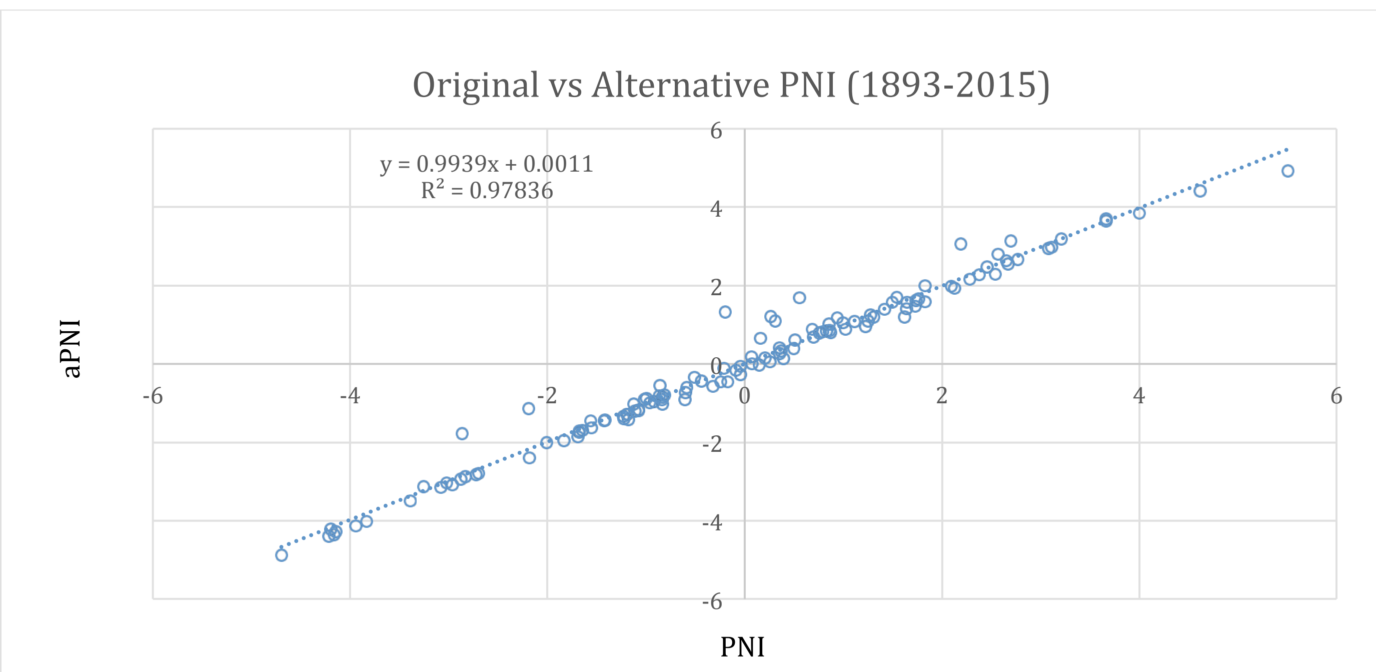

Figure 5. aPNI vs PNI for 1893-2015.

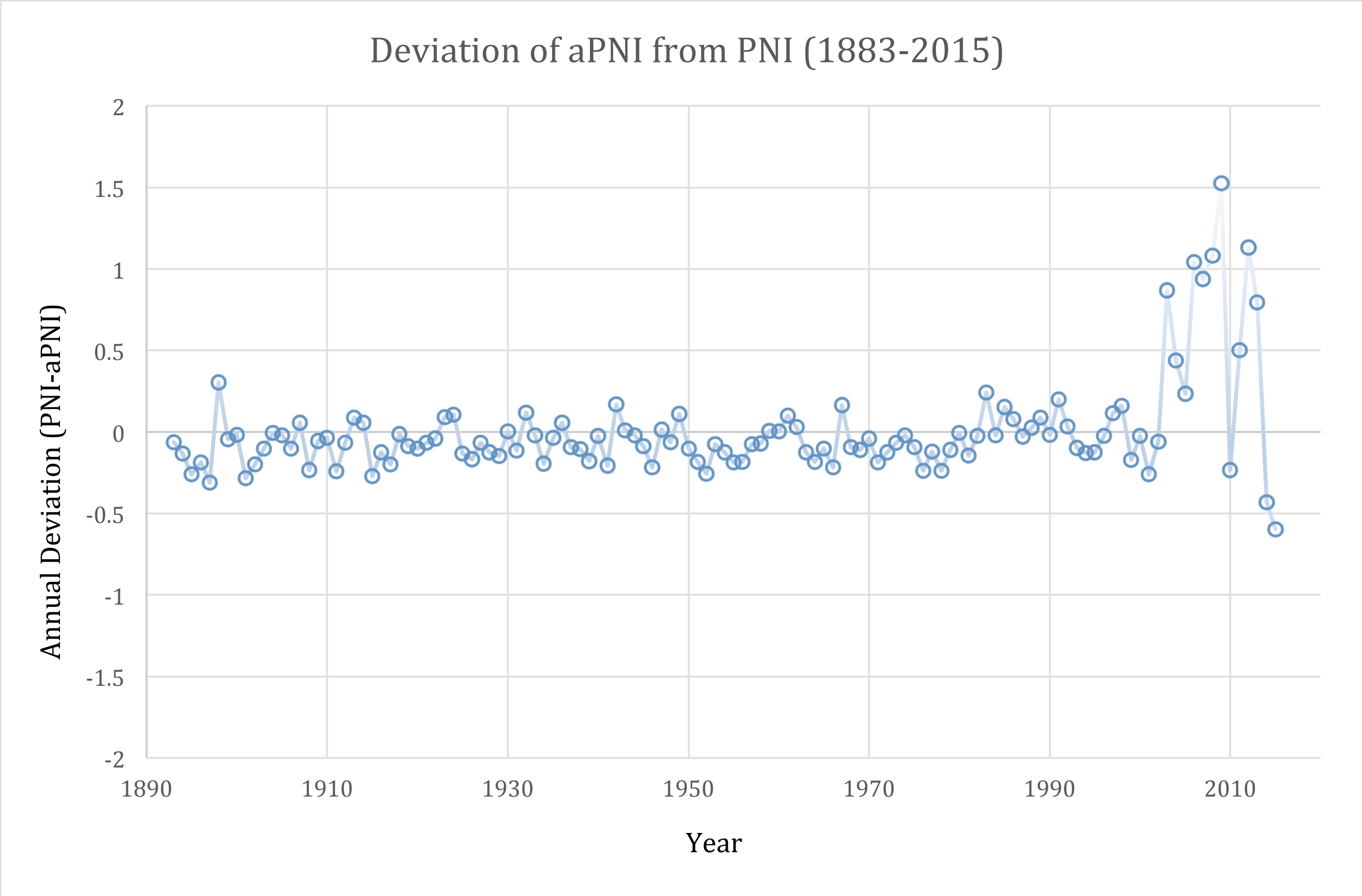

Figure 6. Annual difference between PNI and aPNI.

DART (2020) will use this DFA temperature model as a surrogate for Olga 2 SE mean annual temperatures in an alternative PNI calculation (aPNI) through the available time series and publish the results in parallel with the original PNI. We will continue to explore opportunities in modeling an annual temperature value for the Pacific Northwest that can improve upon this DFA analysis.

References

Columbia River DART, Columbia Basin Research, University of Washington. 2020. Pacific Northwest Index (PNI). Available from http://cbr.washington.edu/status/pni

Ebbesmeyer, C.C. and R.M. Strickland. 1995. Oyster Condition and Climate: Evidence from Willapa Bay. Publication WSG-MR 95-02, Washington Sea Grant Program, University of Washington, Seattle, WA. 11p.

Zuur, A.F., Fryer, R.J., Jolliffe, I.T., Dekker, R. and Beukema, J.J. (2003), Estimating common trends in multivariate time series using dynamic factor analysis. Environmetrics, 14: 665-685.