Six parameter water temperature model

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Introduction

Water temperature modeling is performed for two general purposes: prediction and summarization. Predictive models use heat budgets and known mechanisms to anticipate water temperatures at an unmeasured location or time. Summary models concisely describe the temperatures observed in terms of a few parameters and allow comparison of different temperature profiles.

A six parameter model is developed as an extension of a three-parameter sinusoidal fit to temperature data with an explicit effect to account for spring snowmelt water and the creation of a "spring hiatus" that dampens the warming trends during the spring.

The example uses 10 years of flow and temperature data from the Snake River near Anatone, Washington.

Sinusoidal model

The basic sinusoidal model is of the form:

$$T_x = a + b \cdot \sin(\frac{2*\pi}{365} x + c)$$

where a = mean temperature, b = magnitude parameter, and c = phase shift parameter. This model is fit with a non-linear least squares routine though ten years of data and drawn in Figure 1 with the solid line where a = 11.79, b = 8.96, and c =241.

The six parameter model includes the same three parameters as the simpler model but allows for a dip in the temperatures during the hiatus which also has a sinusoidal form

$$H_x = -\frac{d}{2}\left(1 - \sin\left(\frac{2*\pi}{f-e} \cdot \left(x - e + \frac{(f-e)}{4}\right)\right)\right).$$

where e = beginning of snowmelt, f = end of snowmelt and d = maximum change in temperature profile due to snowmelt. The phase terms in this equation shifts the hiatus so that its value is zero at the beginning of the snowmelt season. This has the desired result that the hiatus smoothly increases from 0 to a maximum of d and drops off to 0 again over the snowmelt season that lasts from e until f. Thus:

$T_x = T_x + H_x$ for all days x between e and f.

A simultaneous fit of all six parameters results in: a=13.48, b= -10.76, c= 71.57, d=6.655 e=64.6 f=249 and is plotted with the dashed line in Figure 1.

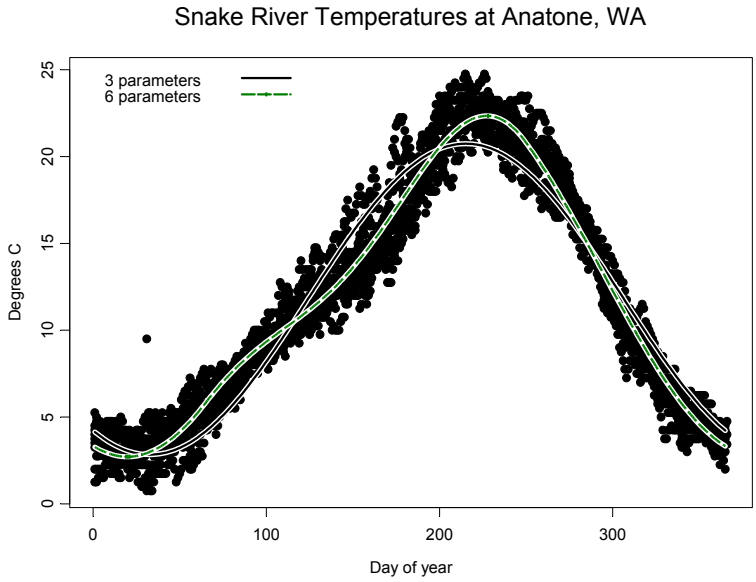
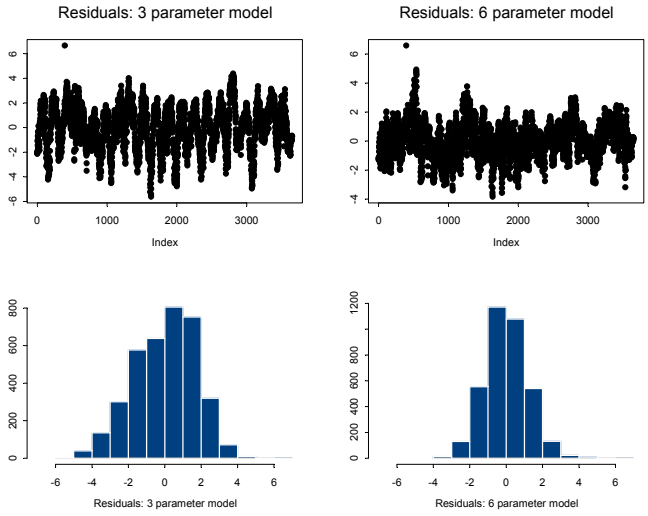


Figure 1 Ten years of Snake River temperature data and two fits through the points using a three and six parameter model.

The six parameter model more accurately portrays the summer high temperatures, the timing of winter lows and the hiatus. All model terms are highly significant for both models.



The additional three terms in the six parameter model have ecological significance: e is the beginning of the snowmelt season, f is the end of the season and d is related to the flow above base flow.