

The extraction of sea temperature in Barents and Norwegian Sea by a scale space multiresolution method – Results and prospects

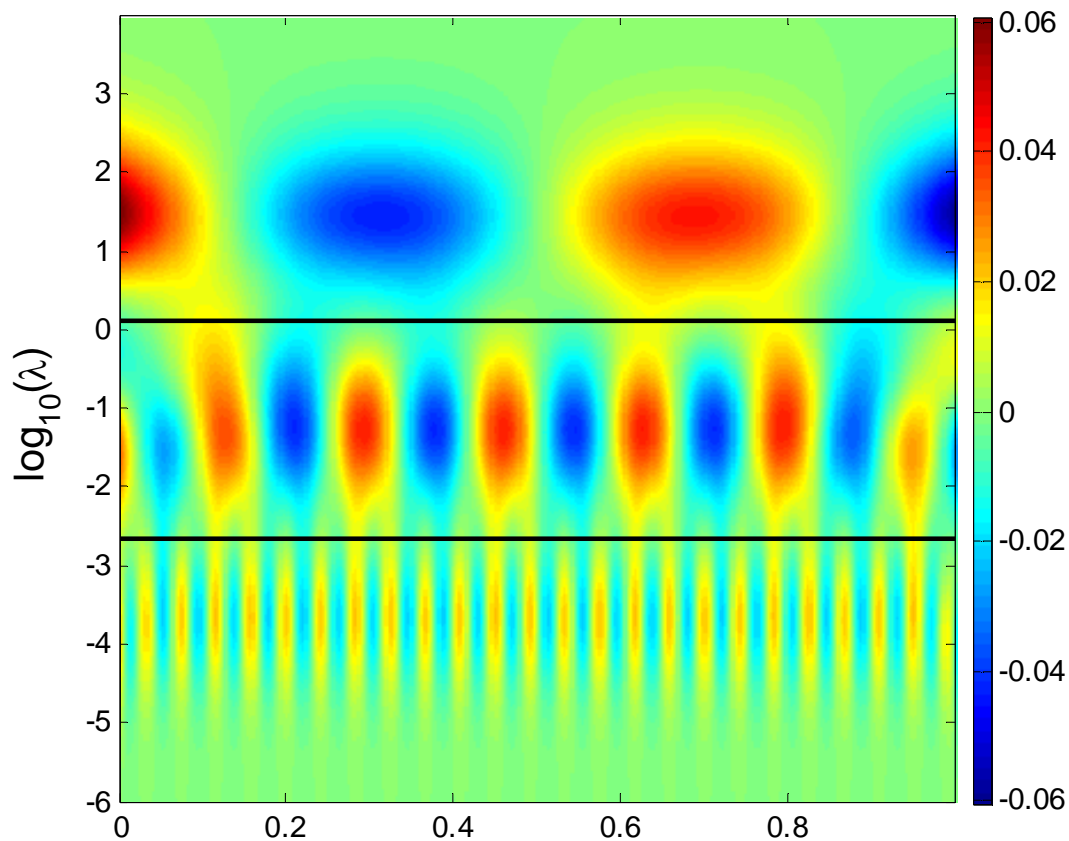
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Cover figure: The scale-derivative map of the example curve (Obs in Figure 1).

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Abstract

The new scale space multiresolution method, published in November 2013, was applied for the extraction of sea temperatures in Barents and Norwegian sea. The observed series of sea temperatures in Ingøy, Laksefjord, Varangerfjord and Kola section were extracted. All series showed an increasing linear trend. Additionally, the long term component showed some increase in Ingøy and Kola section, but a decrease in Laksefjord and no change in Varangerfjord. The extraction of sea temperatures in different locations could be applied to other models. For example, the credibility analysis reveals cool and warm periods which could give more information about the factors affecting the median date of capture.

1. Results

1.1 A scale space multiresolution method

The new method has developed for extraction of time series features. It was published in November 2013 (<http://onlinelibrary.wiley.com/doi/10.1002/sta4.35/pdf>). The traditional time series decomposition includes a random, a seasonal and a trend component, which still might include long scale cyclical components. The seasonal component of the sea temperatures is already known, thus the effect of seasonal variation is not interesting. However, the changes of the sea temperatures in a long scale are interesting, but the traditional time series decomposition does not give any answers to that. An example of the traditional time series decomposition is shown in Figure 1.

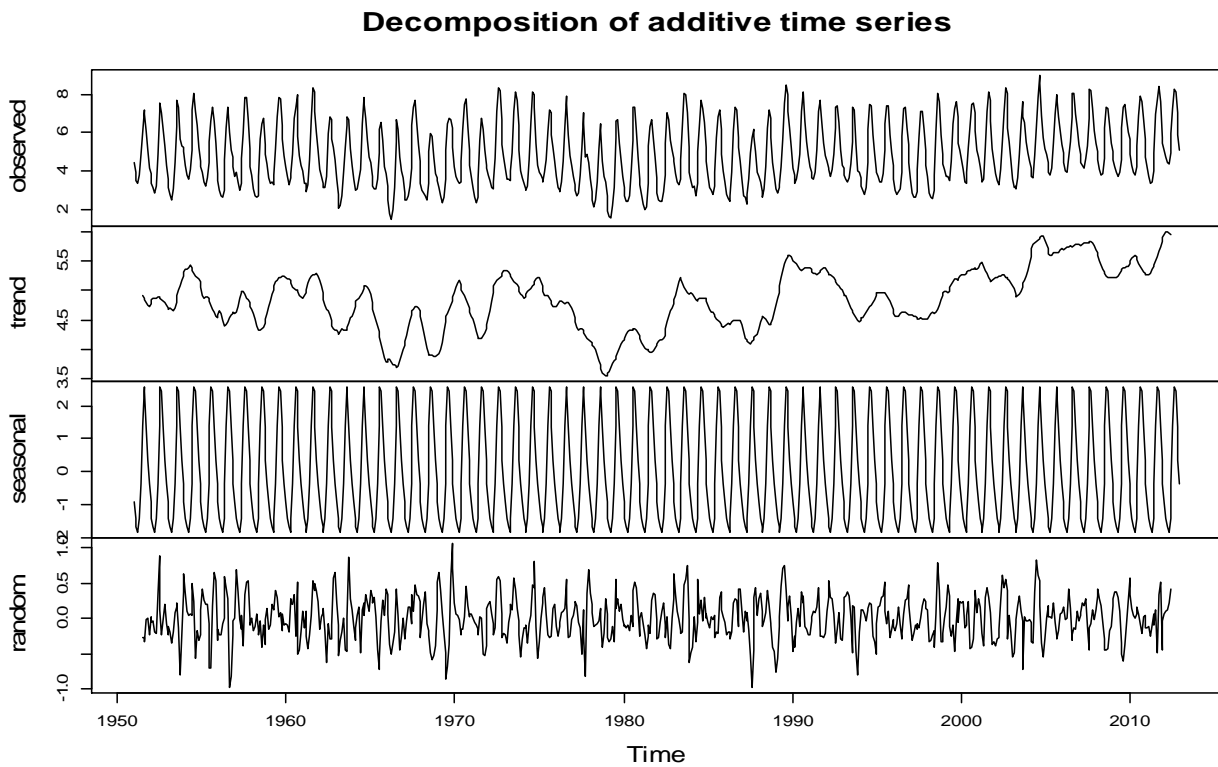


Figure 1. The traditional time series decomposition of the sea temperatures in Kola section (depth 0-50 m).

In the next example of the scale space multiresolution method, the starting point is a time series shown in Figure 2. In reality, time series are noisy, but for the simplicity of demonstration the noise has been removed. Most time series contain features at various different time scales. They have fine local detail at short time scales and smooth average detail at long time scales. The curve of the example is a sum of three components with different wave lengths (Figure 3). The first component has a high frequency and describes the fine short time scale detail of the series. The second component describes the medium time scale detail and the third the long time scale detail.

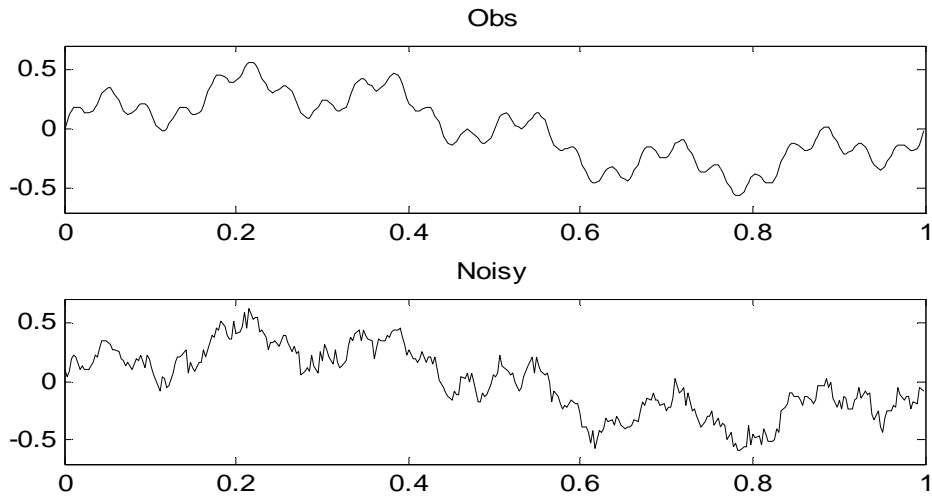


Figure 2. A simple time series (Obs) for demonstration the scale space multiresolution method. In reality, the observed time series are noisy, more like lower curve which is the example curve with added noise.

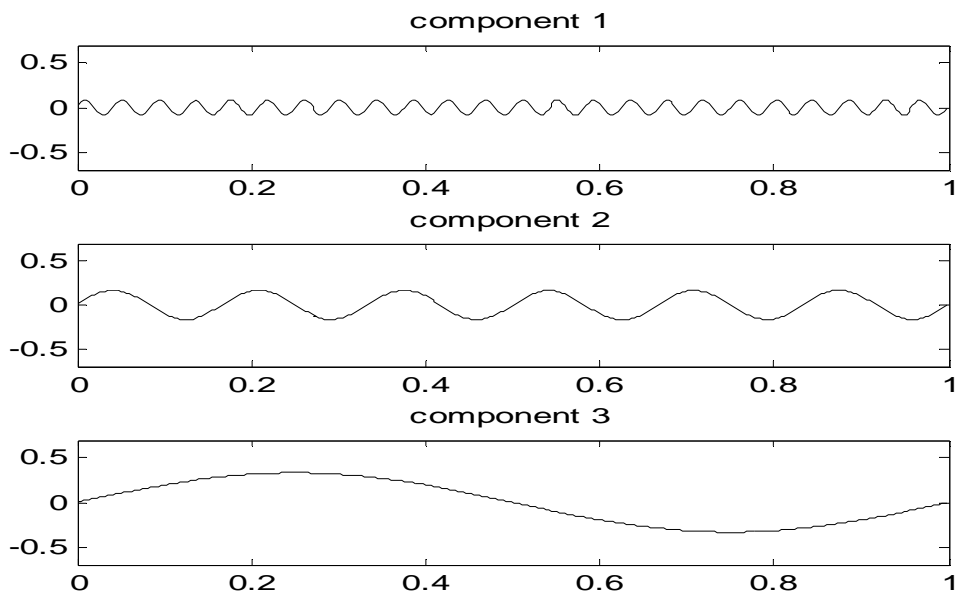


Figure 3. The three components of the example curve (Obs in Figure 1).

The purpose of the recently developed method is to reveal all scale-dependent components. This is done by applying a smoother (here a spline smoother was used) to the time series and then calculating the differences of such smoothed versions of the series. In fact, the number of possible smooths is infinite for the series. Thus, some guiding principle is needed to choose only a few of these possible smoothing levels if we wish to capture any true details of the time series. For this purpose, the method uses a scale-derivative map.

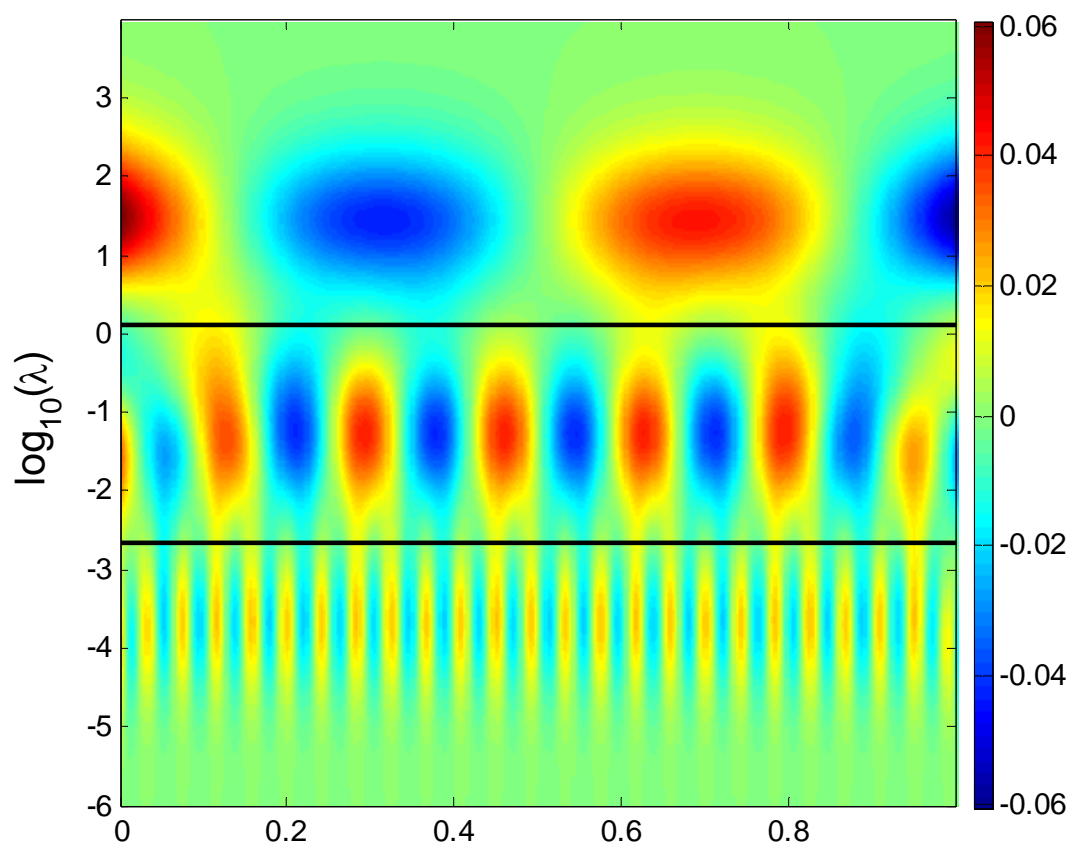


Figure 4. The scale-derivative map of the example curve (Obs in Figure 1).

In Figure 4, the horizontal axis relates to the time points of the series and the vertical axis relates to the smoothing parameter value. The depth of the color signifies the value of derivative of the series' smooth at a certain time point and smoothing level. Deep red signifies large positive value of the derivative, deep blue large negative value and green value near zero.

The three waves of the example curve come up in the derivative map by three oscillating bands of red and blue. The correct smoothing parameter values are found at the intersections of these bands, where the norm of the derivative has a local minimum and which are marked by black lines in the derivative map.

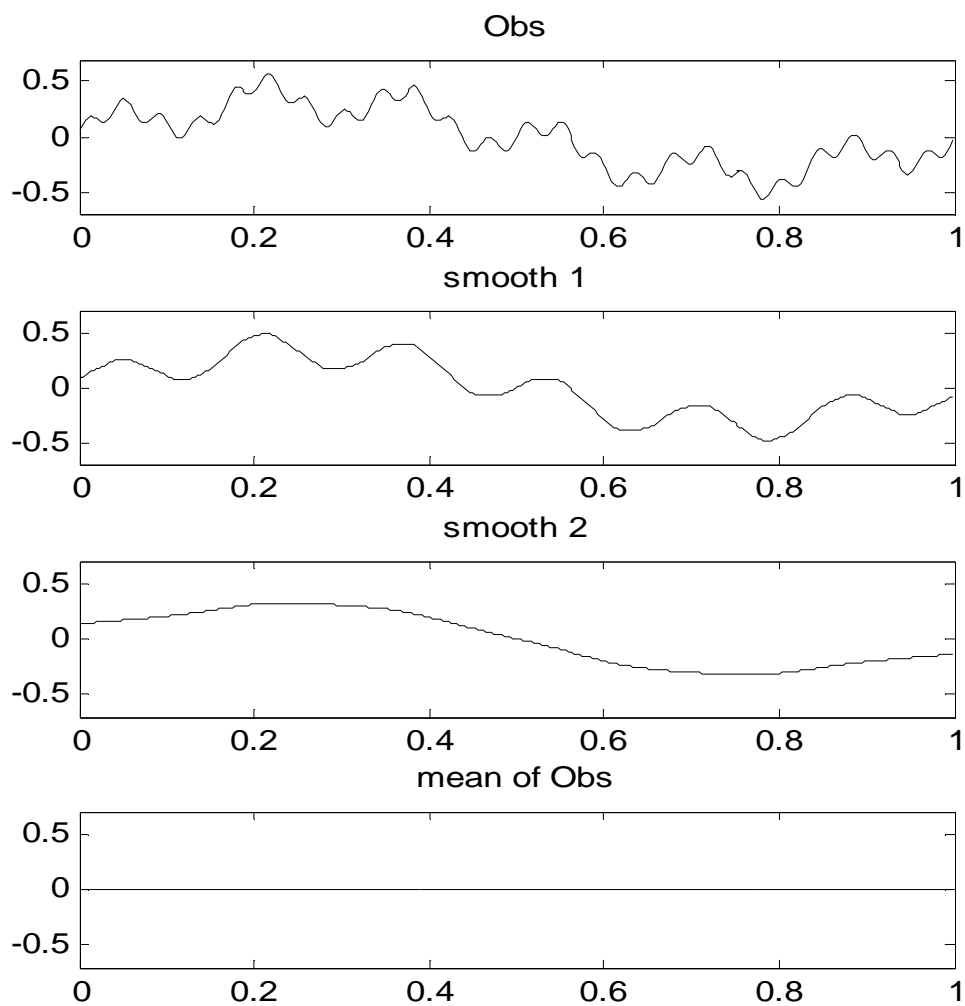


Figure 5. The example curve (Obs), two smooths and mean of example curve.

Based on the derivative map and found number of smooths, two smooths are observed (Figure 5). The first smooth is obtained by smoothing the example curve with the smoothing parameter value indicated by lower black line and the second smooth is obtained from the smoothing level indicated by the upper black line.

Next step is to calculate the differences of smooths (Figure 6). The first difference is the example curve minus the first smooth. The second difference is the first smooth minus the second, and the third difference is the second smooth minus the mean of example curve (which is equal to the second smooth).

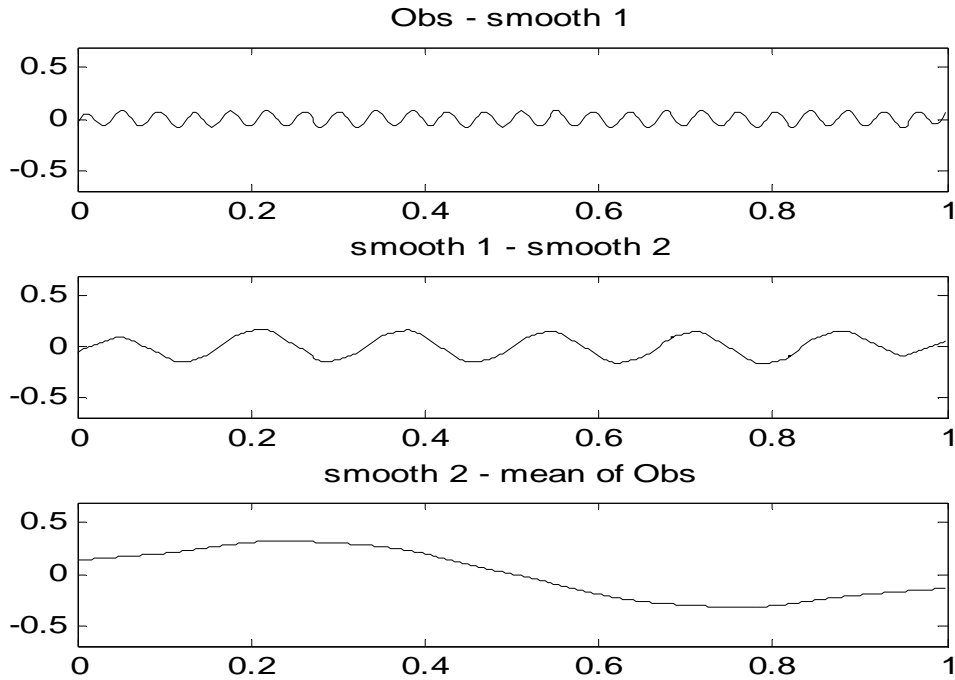


Figure 6. The differences of smooths.

The calculated differences in Figure 5 and the wave components in Figure 3 are close to equal. Thus, all the components of the example curve at various scales have been revealed from the differences of its smooths. Importantly, the more alike the waves in the corresponding panels in Figures 3 and 5 are, the better the extraction method is.

As time series are usually noisy, the method uses Bayesian inference to establish the credibility of the components. This is done by firstly drawing a large sample from the posterior distribution of the true time series. Then the difference of smooths transformation is applied to each sampled time series. The transformed sample is used to find the time points where the proportion of positives or negatives exceeds for example 0.95 in the sample. As such pointwise inference is sensitive to false-positives, simultaneous inference was used over all time points by applying the method of the highest pointwise probabilities (HPW), first described by Erästö & Holmström (2005).

A Gaussian distribution was used as the posterior distribution of the true time series. The observed mean and the standard error of sea temperature in each month were used for the parameter values of the Gaussian distribution. In the credibility figures, the background for the time intervals where the component is credibly positive, negative or neither is white, black and gray, respectively.

1.2 The extraction of sea temperatures in Barents and Norwegian Sea

In Figure 7, the observed sea temperatures in Ingøy (depth of 0-50 m) have an obvious seasonal component. The extraction of sea temperatures includes three curves and a linear trend (Figure 8). In Figure 8, two warmer periods are observed from 1970 to 1976 and from 2000 to 2007. One cooler period is seen from 1978 to 1993. Four or five shorter warm periods and five cooler periods are also seen beside the seasonal variation and linear trend.

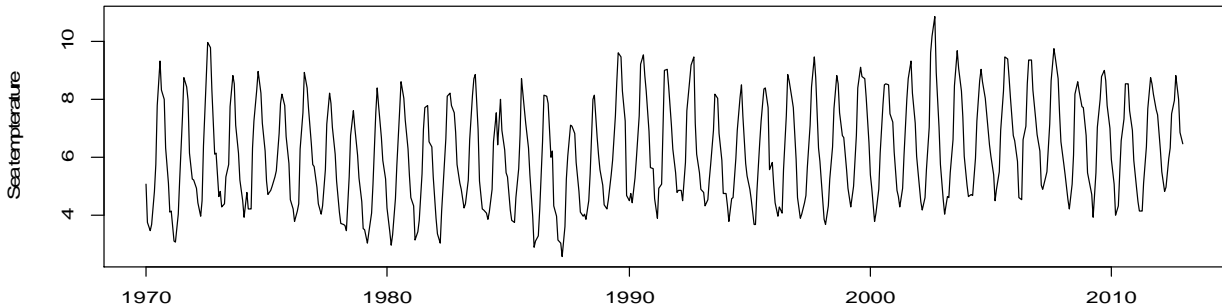


Figure 7. The observed sea temperatures in Ingøy (depth of 0-50 m).

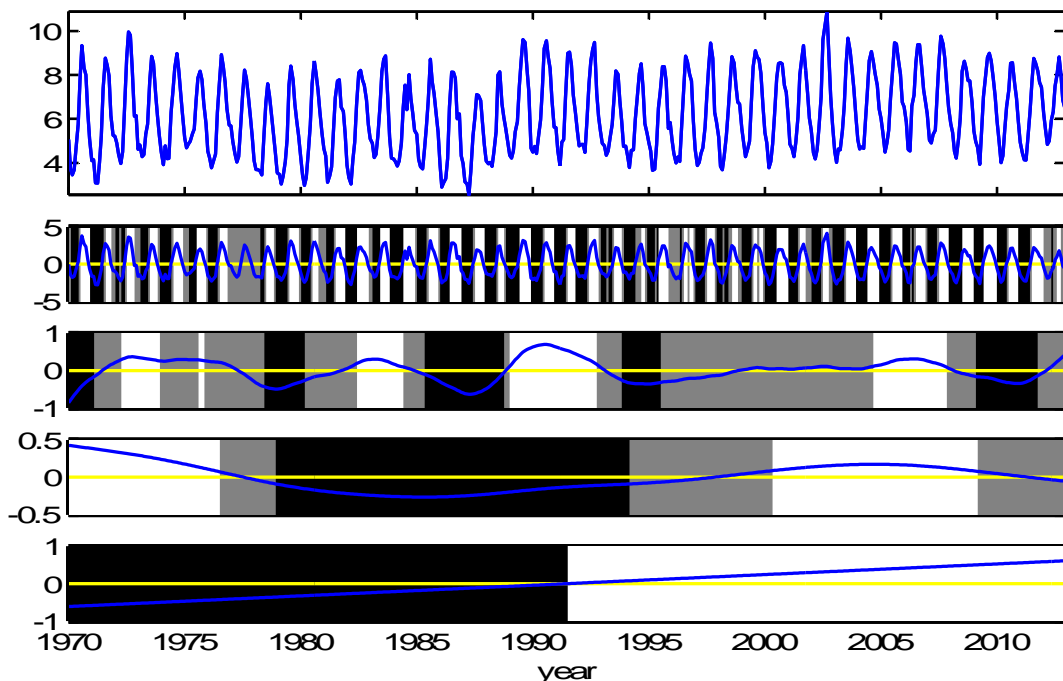


Figure 8. The credibility of the extraction of sea temperatures in Ingøy (depth of 0-50 m). Uppermost panel: the posterior mean of the true time series. Rest of the panels: The extracted components are colored blue. The zero level is highlighted by yellow. The background for the time intervals where the component is credibly positive, negative or neither is white, black and gray, respectively.

The observed sea temperatures in Laksefjord (depth of 4 m) have a seasonal component and since 1984 seem to have a change in the mean level (Figure 9). The extraction of sea temperatures includes two curves and a linear trend (Figure 10). In Figure 9, two warmer periods are observed from 1973 to 1975 and from 1984 to 1993. Three cooler periods are seen from 1976 to 1983, from 1995 to 1997 and from 2003 to 2012. If the observed change in the mean level is not due to changes in measuring technology, the estimated positive linear trend is substantial.

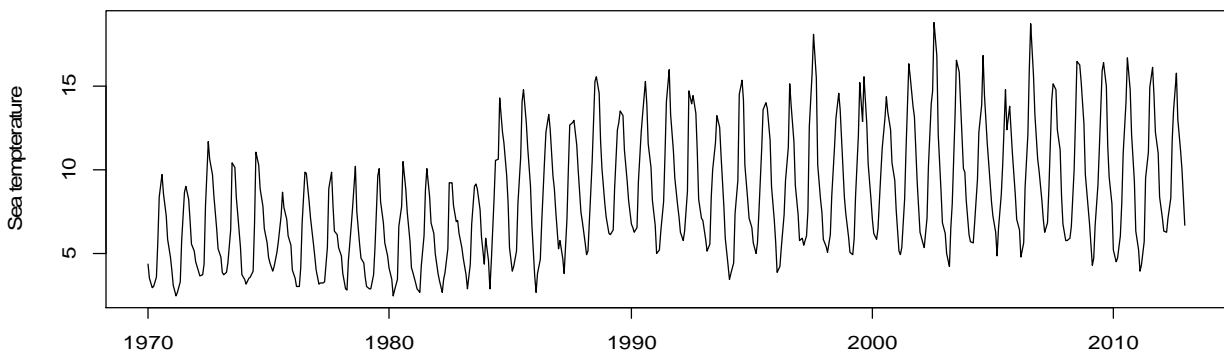


Figure 9. The observed sea temperatures in Laksefjord (depth of 4 m).

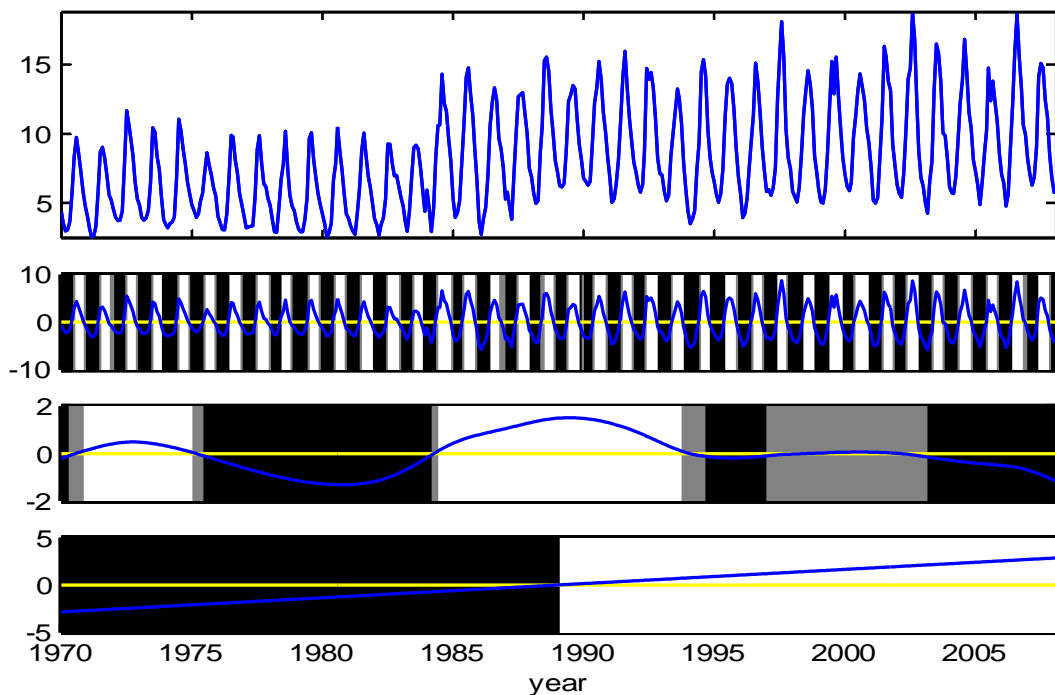


Figure 10. The credibility of the extraction of sea temperatures in Laksefjord (depth of 4 m).

The observed sea temperatures in Varangerfjord (depth of 4 m) have a seasonal component (Figure 11). The extraction of sea temperatures includes two curves and a linear trend (Figure 12). In Figure 12, a warmer period is observed from 1988 to 1992 and the year 2001 seemed to be warmer than the mean of sea temperatures in Varangerfjord. Two cooler periods are seen from 1987 to 1988 and from 1993 to 1999.

During the past decade, no warm or cool periods are seen in the long scale. The seasonal and linear components are enough to explain the variation in the sea temperatures.

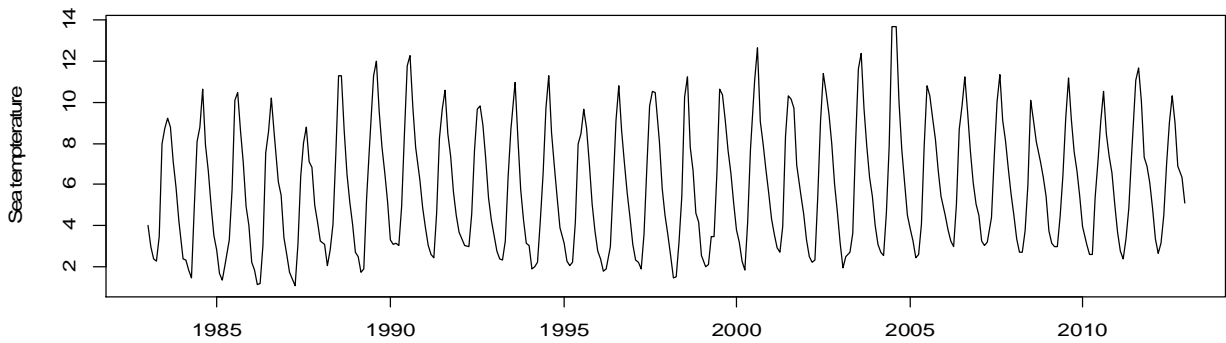


Figure 11. The observed sea temperatures in Varangerfjord (depth of 4 m).

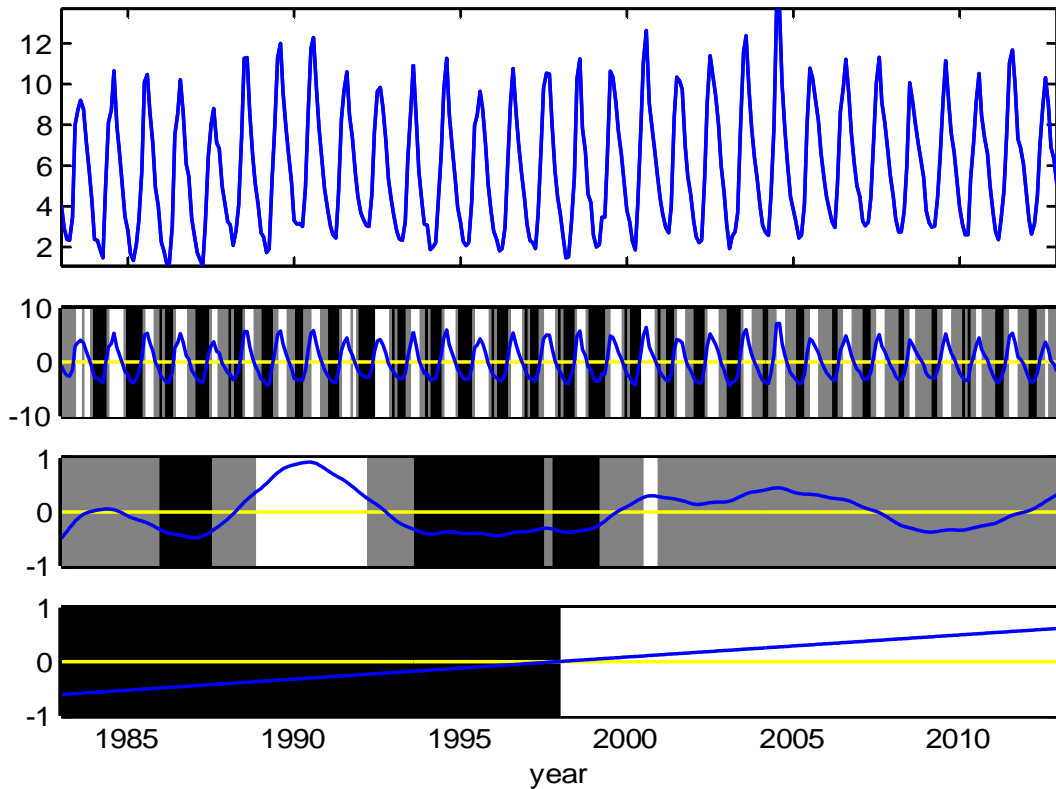


Figure 12. The credibility of the extraction of sea temperatures in Varangerfjord (depth of 4 m).

The sea temperatures in Kola section (depth of 0-50 m) have been observed since 1951 (Figure 13). The seasonal component is obvious but also a long term component could be seen. The extraction of sea temperatures includes a linear trend, two long term curves, a seasonal component and a noise component, which is included to clarify the credibility (Figure 14). In Figure 14, the warmer and the cooler periods are seen every decade. For almost 30 years there was a cooler period in the longest component. A slightly

upward trend is seen over the whole 60-year period.

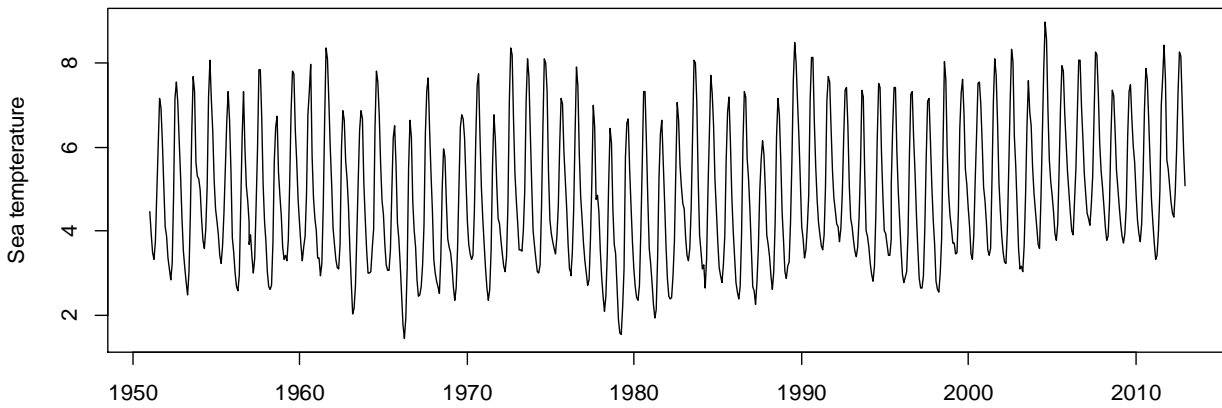


Figure 13. The observed sea temperatures in Kola section (depth of 0-50 m).

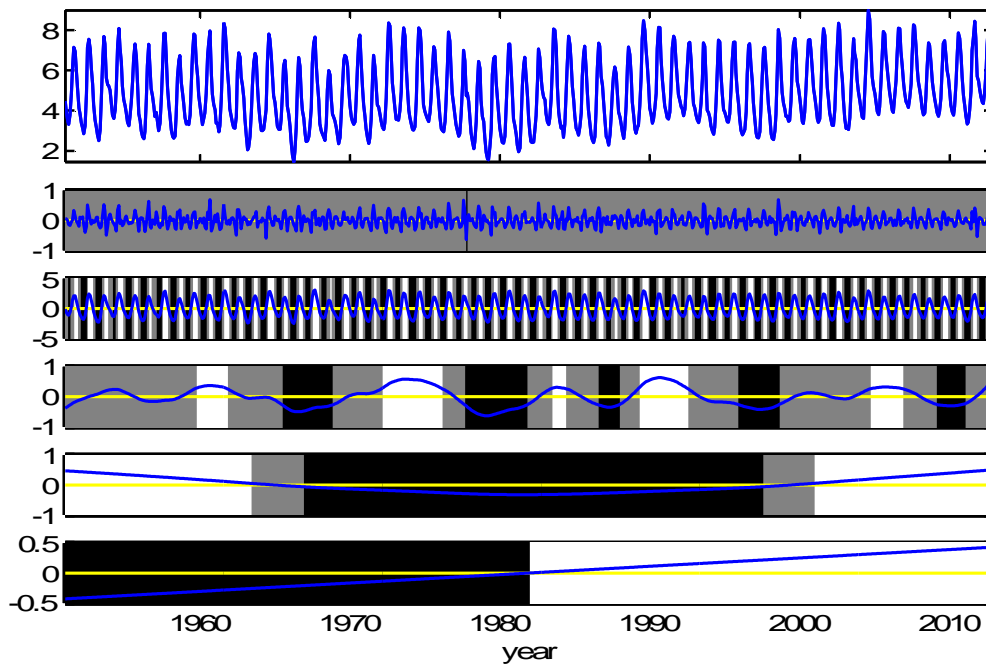


Figure 14. The credibility of the extraction of sea temperatures in Kola section (depth of 0-50 m).

The sea temperatures in Kola section (depth of 0-200 m) have been observed since 1921 (Figure 15). Beside the seasonal component, interesting long-term components could be seen. The extraction of sea temperatures includes a linear trend, two long term curves, a seasonal component and a noise component, which is included to clarify the credibility (Figure 16). In Figure 16, one whole 25-30-years warmer period is seen and half of the ongoing warmer period. For almost 30 years was a cooler period in the longest

component. A slightly upward trend is seen over the whole 90-year period.

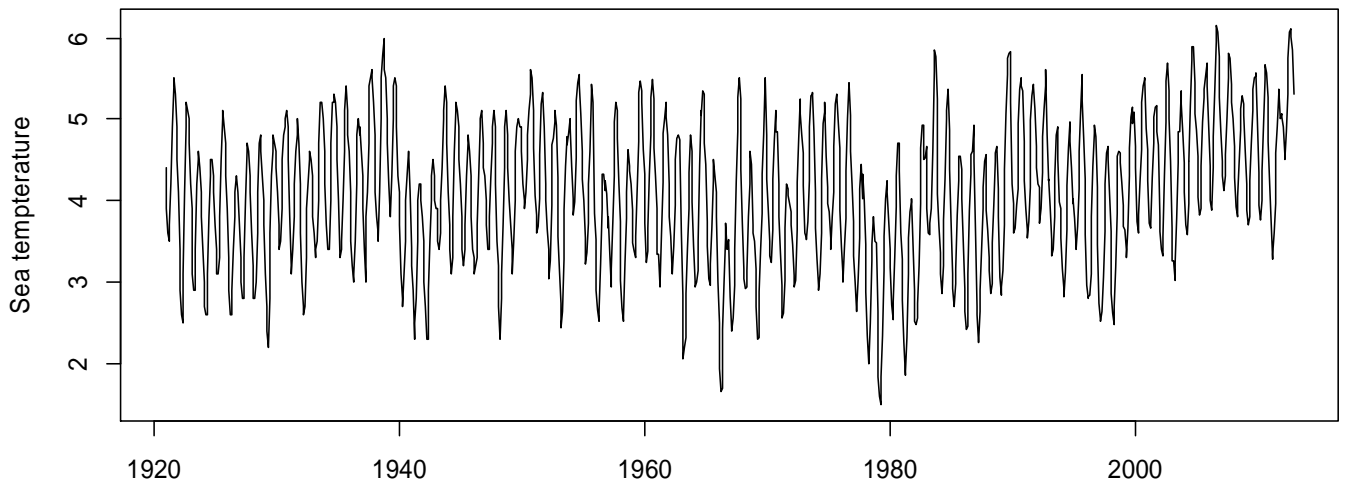


Figure 15. The observed sea temperatures in Kola section (depth of 0-200 m).

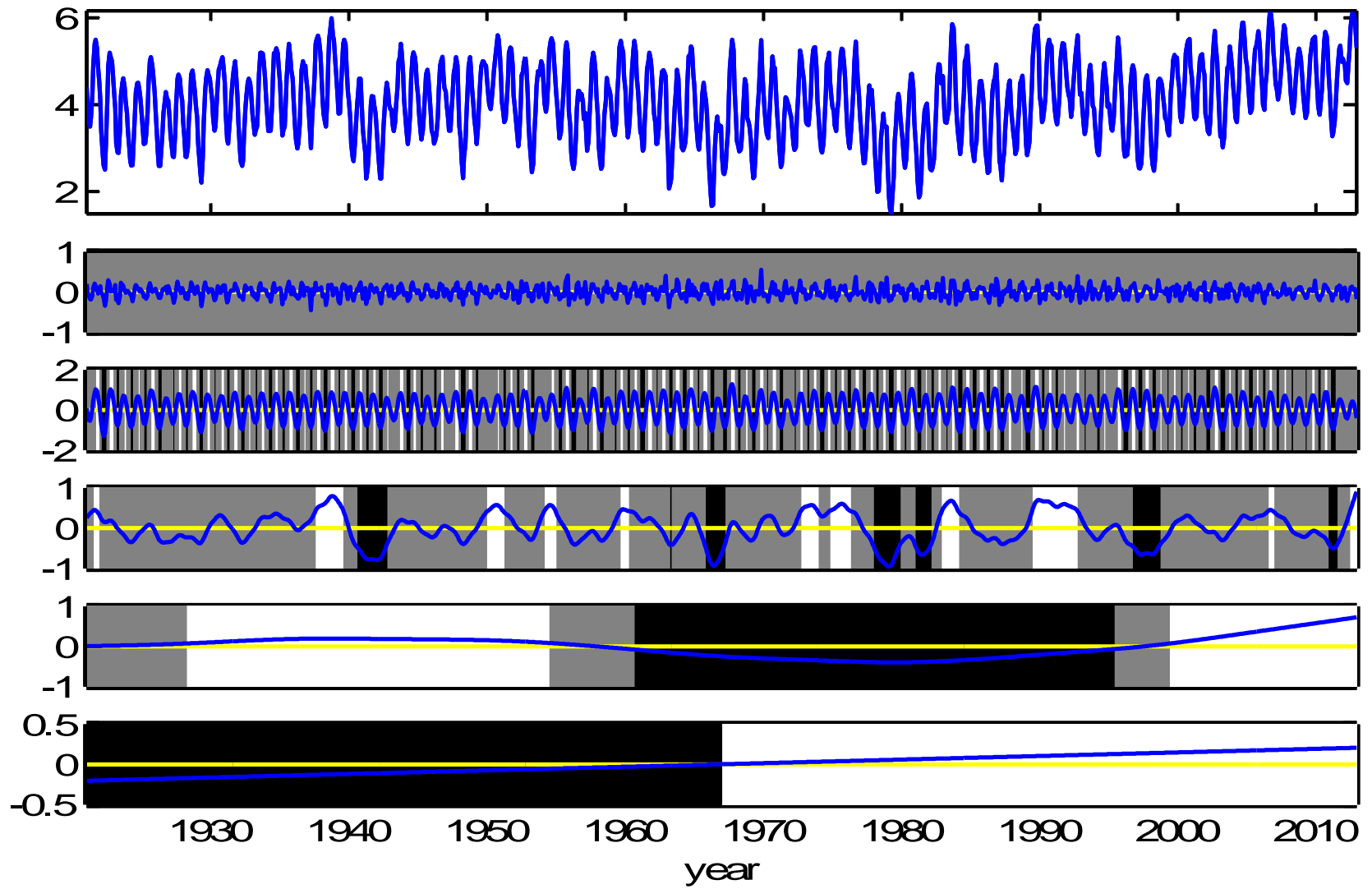


Figure 16. The credibility of the extraction of sea temperatures in Kola section (depth of 0-200 m).

2. Prospects

The extraction of sea temperatures in different locations could be applied to the models of median date of capture. The credibility analysis reveals cool and warm periods, which with additional calendar year as a continuous variable in a model could be useful. The observed cool and warm periods could give more information about the factors affecting the median date of capture.

The true potential of extracted long scale components in modeling the median date of capture is not yet clear. Should we use two classified variables and the linear year-variable in the models? Or should we combine the information about two long scale components? These questions are still open.

References

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