Measuring the Effect of the Pacific Decadal Oscillation on Alaska Temperature Data

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Abstract

We analyse the effect of the Pacific Decadal Oscillation (PDO) on temperatures recorded in Fairbanks (Alaska). We perform a graphical analysis based on seasonal paths and conditional densities obtained through quantile regressions. The results show evidence in agreement with the models and patterns discussed in the literature of climatology.

1 Introduction

Hartmann and Wendler (2005) found a significant correlation between the PDO and the temperatures in Alaska. They also studied the trend (fit and compare a linear trend) in different phases of the PDO. The previous analysis do not account for non-linearities and, since it is based on subsamples, such analysis gives an overall description of the data in different subsamples. In this document, we will use a statistical model to measure the effect of the PDO on temperature data that will reveal some further facts that improve the view to this issue.

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[Figure 1 about here.]

Similarly to the traditional approach of regression, where the expected value (mean) of the dependent variable is estimated conditional to some regressor variables (as we did before for in the regression of temperature on the PDO index), the conditional quantile τ may be estimated from a regression model. We use the `R` package `quantreg` (Koenker, 2009), which implements an algorithm to fit quantile regressions. We employ quantile regressions to estimate conditional quantiles in a regression of the seasonal temperatures on an intercept and the PDO index. Following Koenker (2005, pp. 52), we specify the quantile regression function as a linear B-spline:

$$Q_{T_i}(\tau|\text{PDO}_i) = \sum_{j=1}^{p} \phi_j(\text{PDO}_i)\beta_j(\tau)\,, \tag{1}$$

where $\phi_j(\text{PDO}_i)$, $j = 1, \ldots, p$ are the basis functions of the spline. The splines allow the model to capture non-linear relationships between the temperature data, T_t, and the PDO index. Then, upon the estimated quantile functions the conditional density can be built (Portnoy and Koenker, 1989).

[Figure 2 about here.]

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[Figure 7 about here.]

References

Hartmann, B. and Wendler, G. (2005), 'The Significance of the 1976 Pacific Climate Shift in the Climatology of Alaska', *Journal of Climate* **18**, 4824–4839.

Koenker, R. (2005), *Quantile Regression*, Cambridge U. Press.

Koenker, R. (2009), *quantreg: Quantile Regression*. R package version 4.44. **URL:** *http://CRAN.R-project.org/package=quantreg*.

Portnoy, S. and Koenker, R. (1989), 'Adaptive L-estimation for Linear Models (Corr: V18 P986)', *The Annals of Statistics* **17**, 362–381.

Table 1: Correlation coefficient between seasonal temperatures and the PDO index.

	MAM	JJA	SON	DJF
Correlation	0.18	0.23	0.18	0.43
p-value	0.01	0.00	0.01	0.00
95% CI lower	0.05	0.11	0.05	0.32
95% CI upper	0.30	0.35	0.30	0.53

Table 2: Mean values of temperature for several ranges of the PDO index.

PDO	MAM	JJA	SON	DJF
$[-4, -1)$	26.65	58.33	19.91	-12.70
$[-1, 0)$	27.94	57.97	23.17	-9.09
$[0, 1)$	29.76	59.41	27.74	-3.86
$[1, 4]$	33.16	60.23	27.42	-1.14

Table 3: Parameter estimates from a linear regression model with ARMA errors.

	ARMA	Intercept	PDO	Error mean
MAM	$(3, 1)$	29.33 (0.54)	2.36 (0.38)	20.67
JJA	$(3, 0)$	58.89 (0.36)	0.56 (0.17)	1.07
SON	$(3, 1)$	24.85 (0.49)	2.70 (0.35)	23.59
DJF	$(3, 0)$	-6.32 (0.66)	3.86 (0.52)	-0.07

Table 4: Mean values of the estimated conditional densities. Based on quantil regression. See Figures 2-4.

	PDO						
	-3	-2	-1	0	1	2	3
Jan	-18.25	-15.51	-12.85	-10.05	-7.20	-4.25	-1.29
Feb	-14.08	-9.76	-5.45	-1.17	3.07	7.32	11.65
Mar	2.56	5.08	7.51	9.91	12.36	14.85	17.21
Apr	24.95	26.77	28.85	30.93	32.97	35.03	37.06
May	46.09	46.90	47.69	48.47	49.21	49.93	50.69
Jun	57.56	58.25	58.95	59.66	60.38	61.14	61.98
Jul	59.45	59.94	60.67	61.44	62.19	62.95	63.68
Aug	53.86	54.81	55.27	55.76	56.39	57.08	57.79
Sep	43.11	43.36	44.02	44.54	45.03	45.51	46.00
Oct	19.92	22.10	24.31	26.50	28.66	30.78	32.89
Nov	-9.22	-4.94	-0.61	3.85	8.50	13.28	17.90
Dec	-15.28	-12.26	-9.08	-5.90	-2.87	0.22	3.77

Table 5: Mean values of the estimated conditional densities. Based on kernel smoother. See Figures 5-7.

	PDO						
	-3	-2	-1	0	1	2	3
Jan	-13.28	-13.47	-12.79	-9.99	-7.21	-4.75	-4.43
Feb	-14.27	-10.52	-6.46	-1.60	1.79	2.83	3.97
Mar	3.05	5.08	8.17	9.56	12.08	13.76	13.51
Apr	27.34	27.80	29.54	30.55	31.99	33.60	37.04
May	45.77	46.64	47.55	48.23	48.78	49.20	49.56
Jun	58.88	59.17	59.06	59.21	59.67	60.40	61.31
Jul	61.00	60.88	61.08	61.41	61.75	62.14	62.58
Aug	54.42	54.97	55.27	55.77	56.47	56.82	57.33
Sep	44.07	44.37	44.63	44.79	44.90	45.05	45.28
Oct	21.34	22.69	24.28	25.51	26.81	27.96	29.17
Nov	-7.13	-4.00	1.54	4.09	7.78	7.74	9.87
Dec	-13.59	-13.04	-10.66	-6.46	-3.89	-2.33	-1.08

Table 6: Local maximum values of the estimated conditional densities (modes). Based on quantile regression. See Figures 2-4.

	PDO						
	-3	-2	-1	0	1	2	3
Jan	-21.24	-18.38		-6.16	-14.79	-12.45	-9.75
					-3.36	-0.60	1.97
Feb	-9.35	-6.03	-2.92	-0.31	2.99	7.06	11.29
							22.51
Mar	-4.49	-1.46	1.81	11.72	11.19	13.28	15.69
	4.32	6.94	9.47				21.85
Apr	19.70	21.70	24.00	32.33	32.92	28.25	29.62
	28.68	30.55	31.59			34.44	36.45
						42.67	45.33
May	43.91	47.40	48.16	48.42	48.11	48.84	49.63
	46.56						
Jun	57.42	58.11	58.80	59.55	59.35	59.74	60.48
					61.52	62.26	62.82
Jul	58.93	59.38	59.89	60.64	62.65	63.37	64.24
	62.45	61.03	61.65	62.14			
Aug	52.69	53.53	54.60	55.84	56.71	55.55	56.41
	55.85	56.90	57.64			57.44	58.11
						63.29	64.46
Sep	41.07	41.40	42.09	42.86	43.48	43.97	44.43
	44.16	45.12	46.00	47.05	48.03	49.01	49.95
Oct	18.42	20.39	24.05	26.47	28.72	30.94	33.14
		24.47					
Nov	-9.01	-4.33	0.42	5.83	13.12	18.89	23.90
	-5.18						
Dec	-10.67	-8.05	-5.52	-9.03	-5.10	-0.98	2.97
				-3.01	-0.59	1.93	4.85
							8.59

Table 7: Local maximum values of the estimated conditional densities (modes). Based on kernel smoother. See Figures 5-7.

	PDO						
	-3	-2	-1	0	1	2	3
Jan	-17.25	-13.62	-13.62	-7.25	-4.53	-3.62	-3.62
Feb	-21.67	-12.62	-3.57	-1.31	3.98	-13.38	-14.13
	-10.36	-	-	-	-	3.98	7.75
Mar	5.72	-0.92	9.34	8.74	12.97	14.78	14.17
		7.53					
Apr	21.79	29.48	27.77	26.92	32.89	34.17	35.45
	30.76			33.32			43.56
May	38.68	39.30	47.87	48.48	48.78	41.74	41.44
	47.25	47.25				49.40	49.09
Jun	58.57	58.84	59.11	59.11	59.93	61.58	62.12
Jul	61.15	60.47	60.47	60.92	61.61	63.43	64.11
Aug	53.89	55.11	54.86	54.38	56.56	57.05	57.78
Sep	42.76	42.76	43.10	43.10	43.44	44.12	44.12
Oct	21.67	22.12	24.82	26.63	29.33	30.69	17.61
							30.69
Nov	-7.64	-5.33	-1.85	2.20	9.14	2.77	10.88
				7.98		7.40	
Dec	-23.65	-8.53	-7.16	-4.41	-3.03	-1.66	-16.78
	-7.84						1.09

Figure 1: Boxplot of seasonal temperatures conditional on ranges of the PDO index.

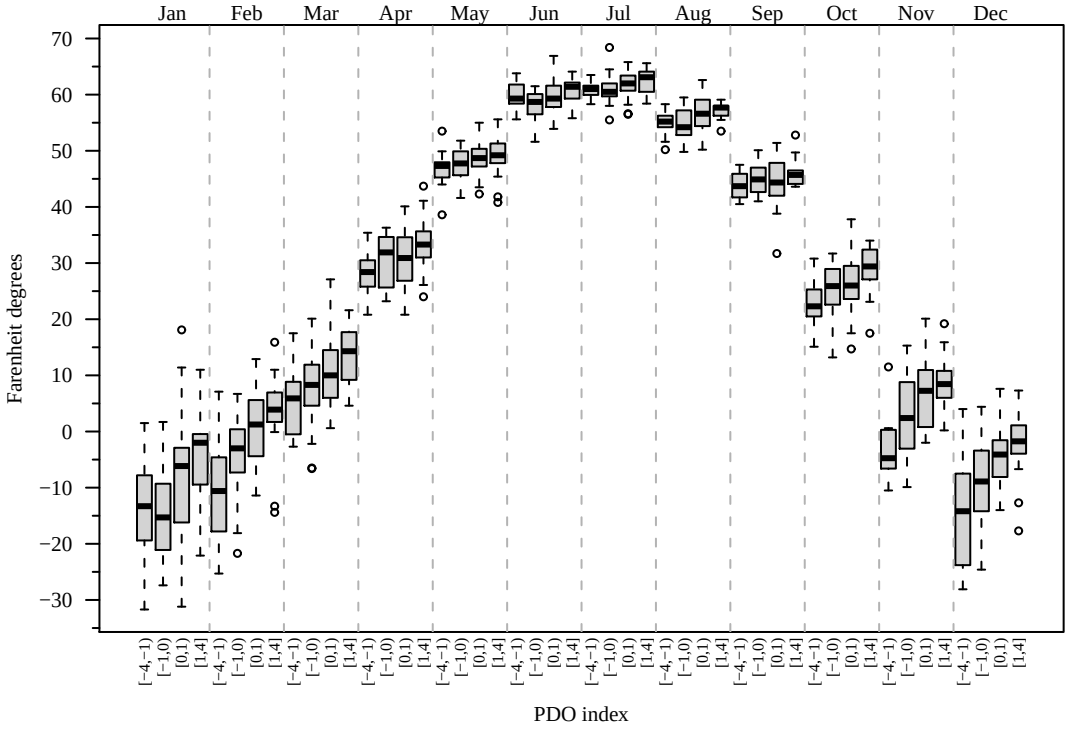

Figure 2: Estimated density of temperature conditional on the PDO index. Parametric approach. Plot 1/3.

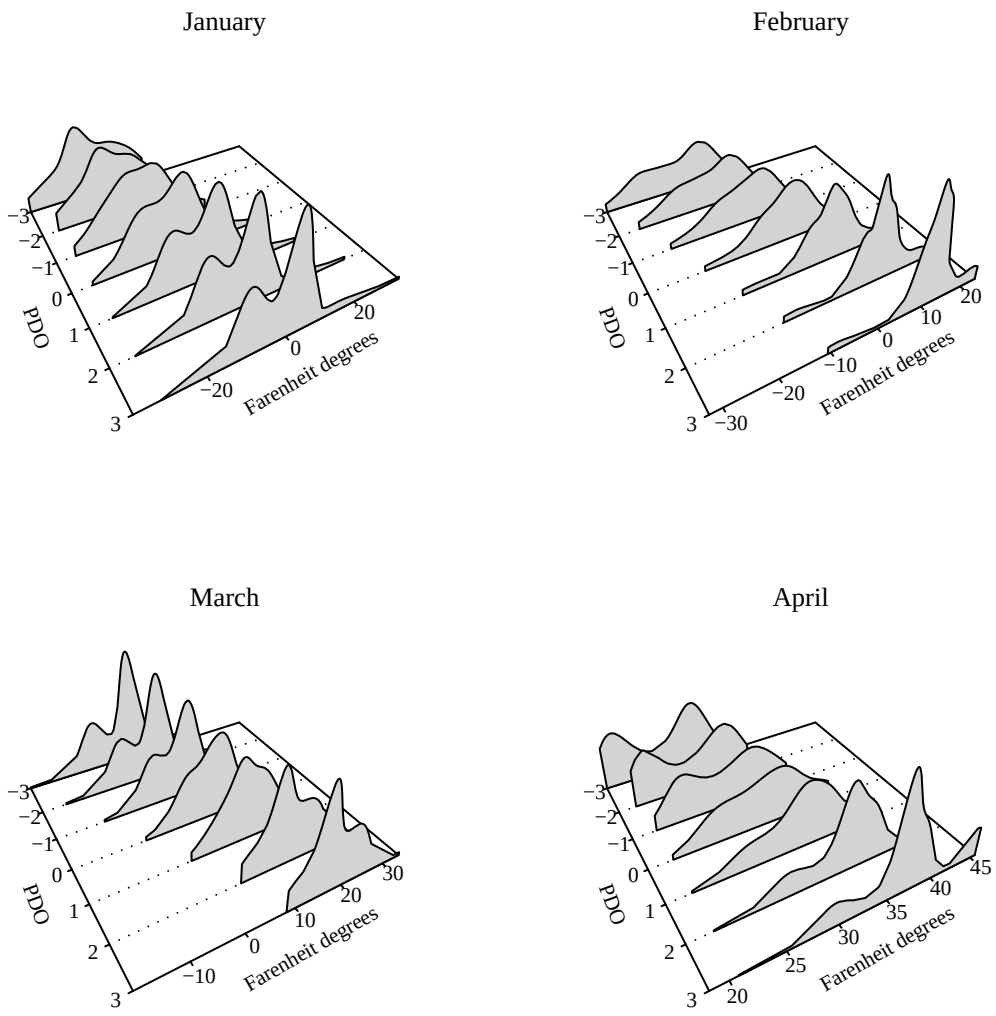

Figure 3: Estimated density of temperature conditional on the PDO index. Parametric approach. Plot 2/3.

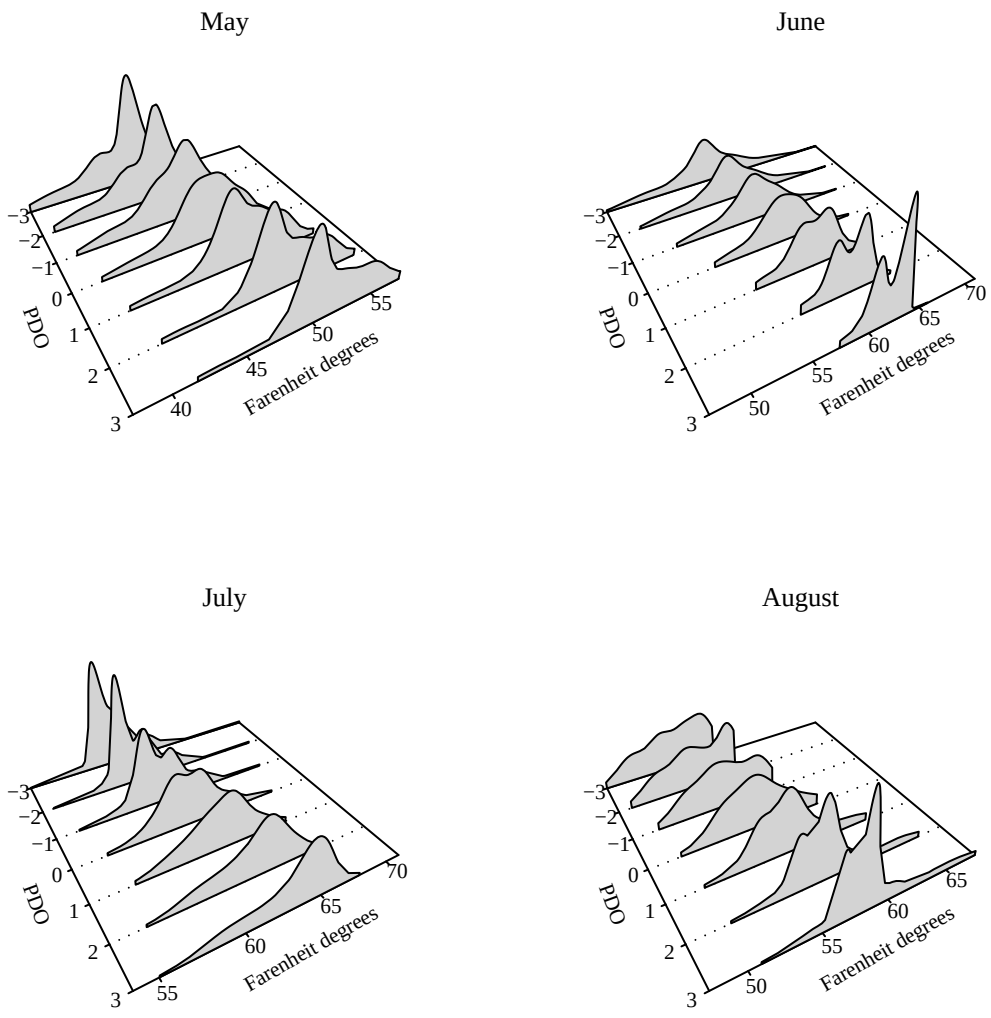

Figure 4: Estimated density of temperature conditional on the PDO index. Parametric approach. Plot 3/3.

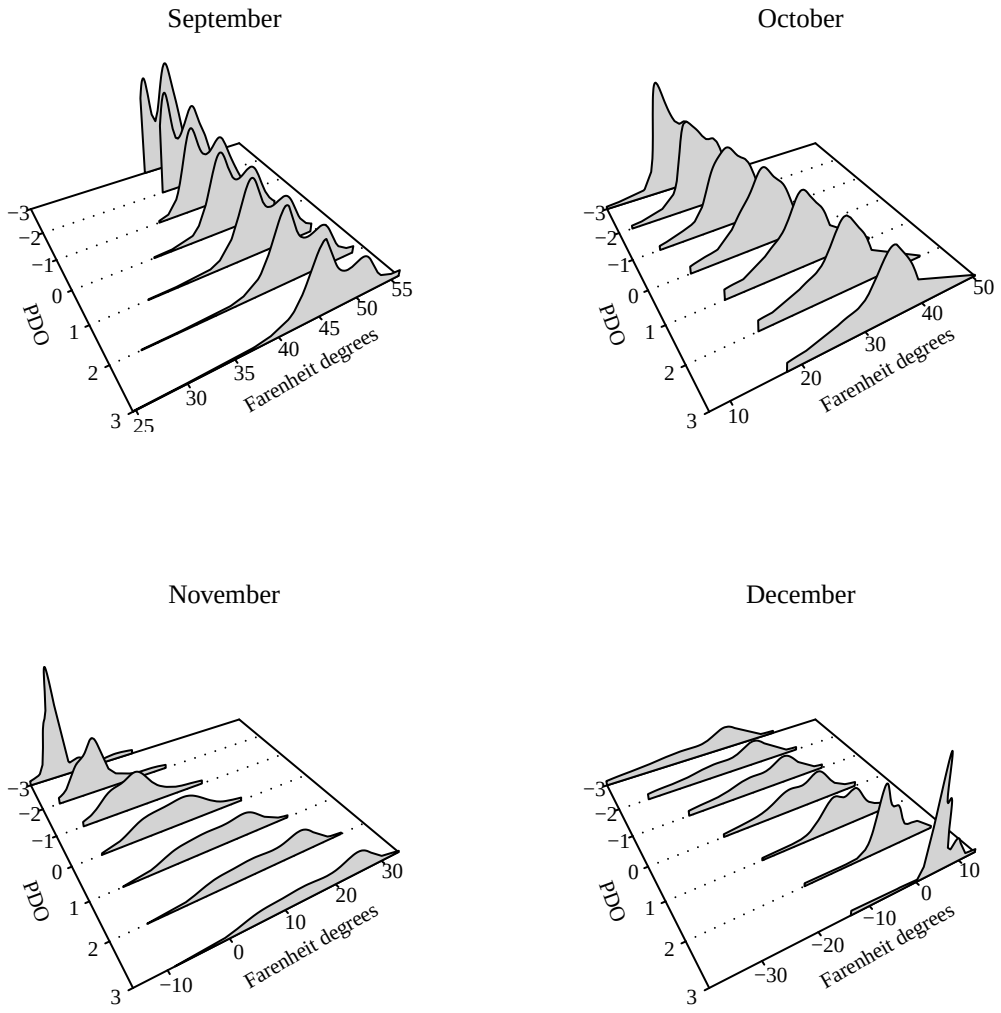

Figure 5: Estimated density of temperature conditional on the PDO index. Non-parametric approach. Plot 1/3.

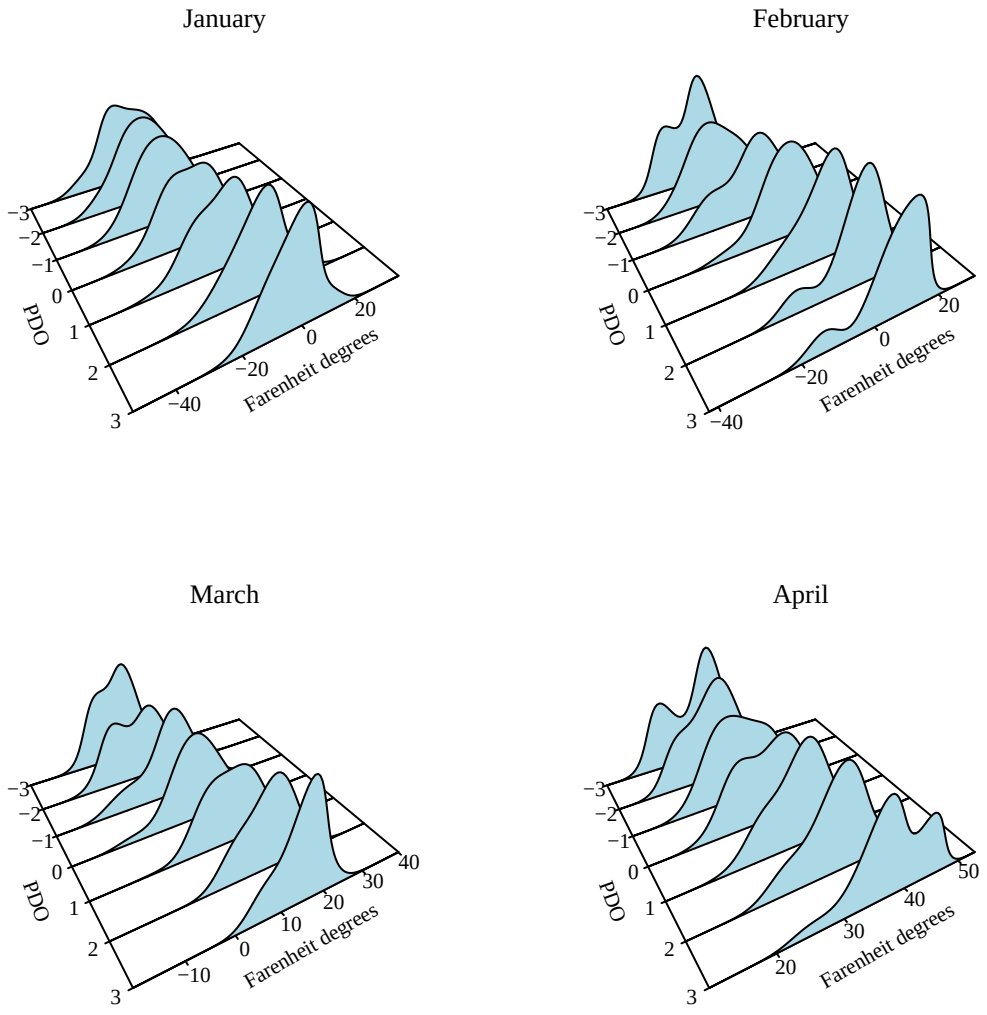

Figure 6: Estimated density of temperature conditional on the PDO index. Non-parametric approach. Plot 2/3.

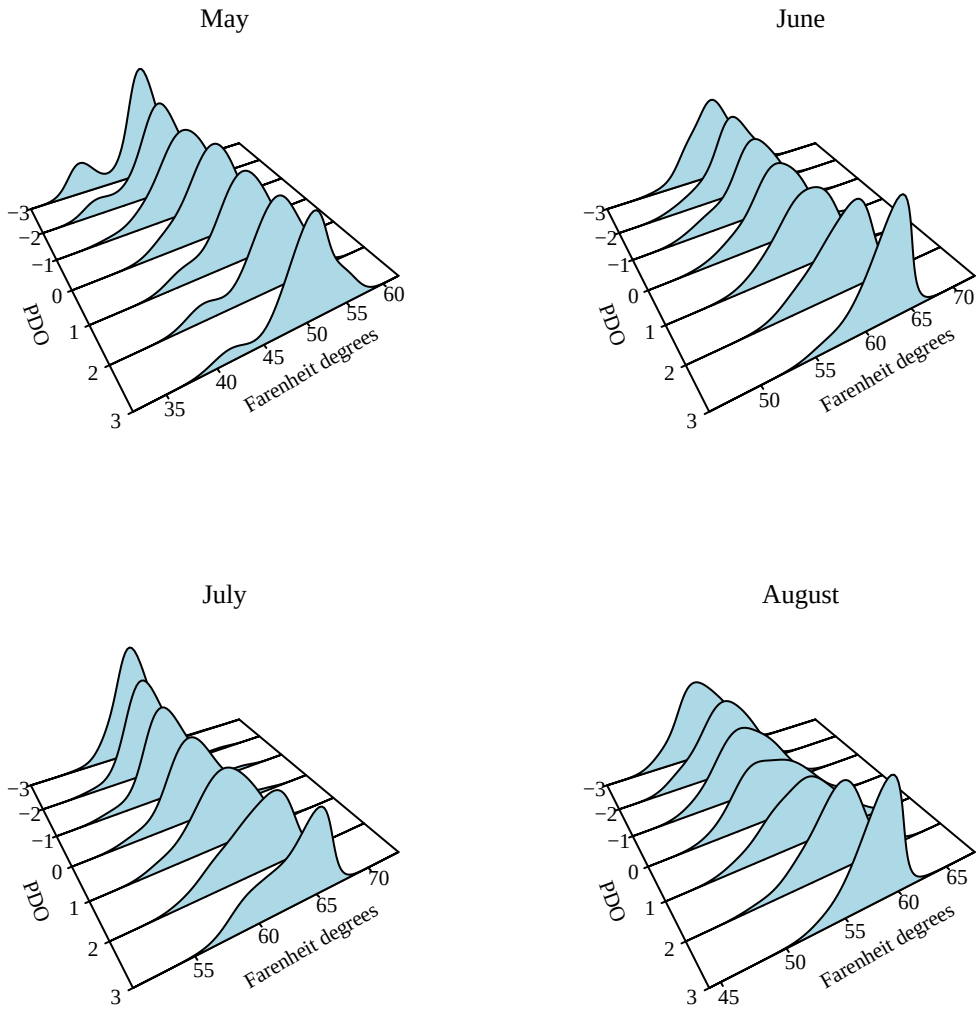

Figure 7: Estimated density of temperature conditional on the PDO index. Non-parametric approach. Plot 3/3.