

Challenge II: Spatial continuity and weather prediction

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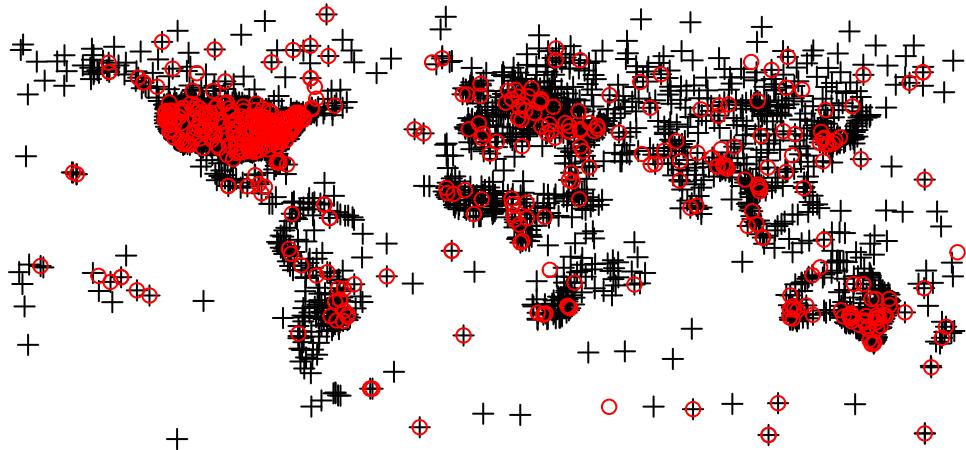
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1 Libraries

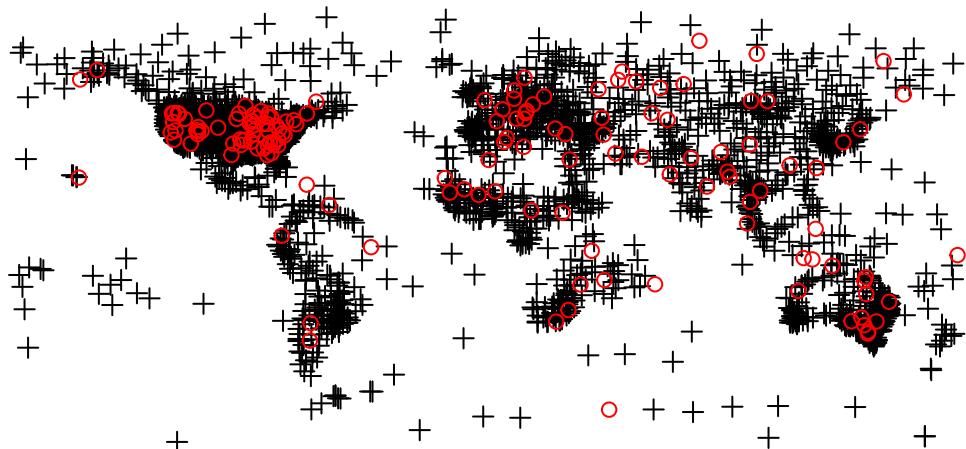
The following libraries are needed, to execute the code:

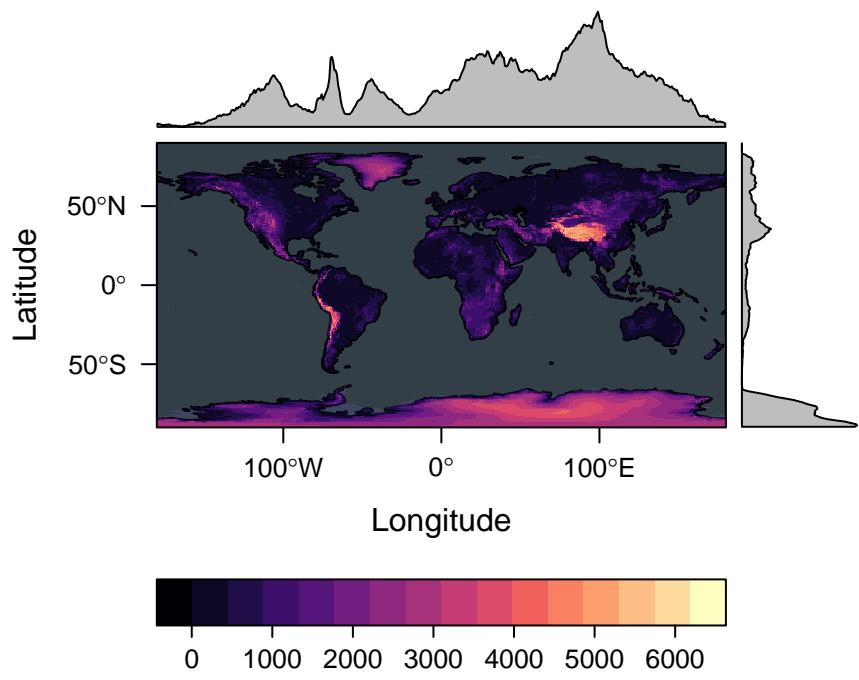
- **ggplot2** – Plots – [@ggplot2]
- **plyr** – Splitting, applying and combining data – [@plyr]
- **rgdal** – Open Shapefiles – [@rgdal]
- **sp** – Spatial datatypes – [@sp2; @sp1]
- **gstat** – Spatial statistics –[@gstat]
- **FNN** – Spatial statistics –[@FNN]

2 Data



id	meanW	i_before1970	meanS	u_before1970	meanW	i_after1990	meanS	u_after1990	elev
1	1	11.83		23.27		13.09		24.75	7
2	2	10.21		22.43		11.35		23.94	4
3	3	10.83		22.78		11.32		24.76	25
4	4	10.30		22.00		11.44		24.02	2
6	6	8.14		24.90		9.35		26.15	715
7	7	7.49		24.86		7.59		26.09	813

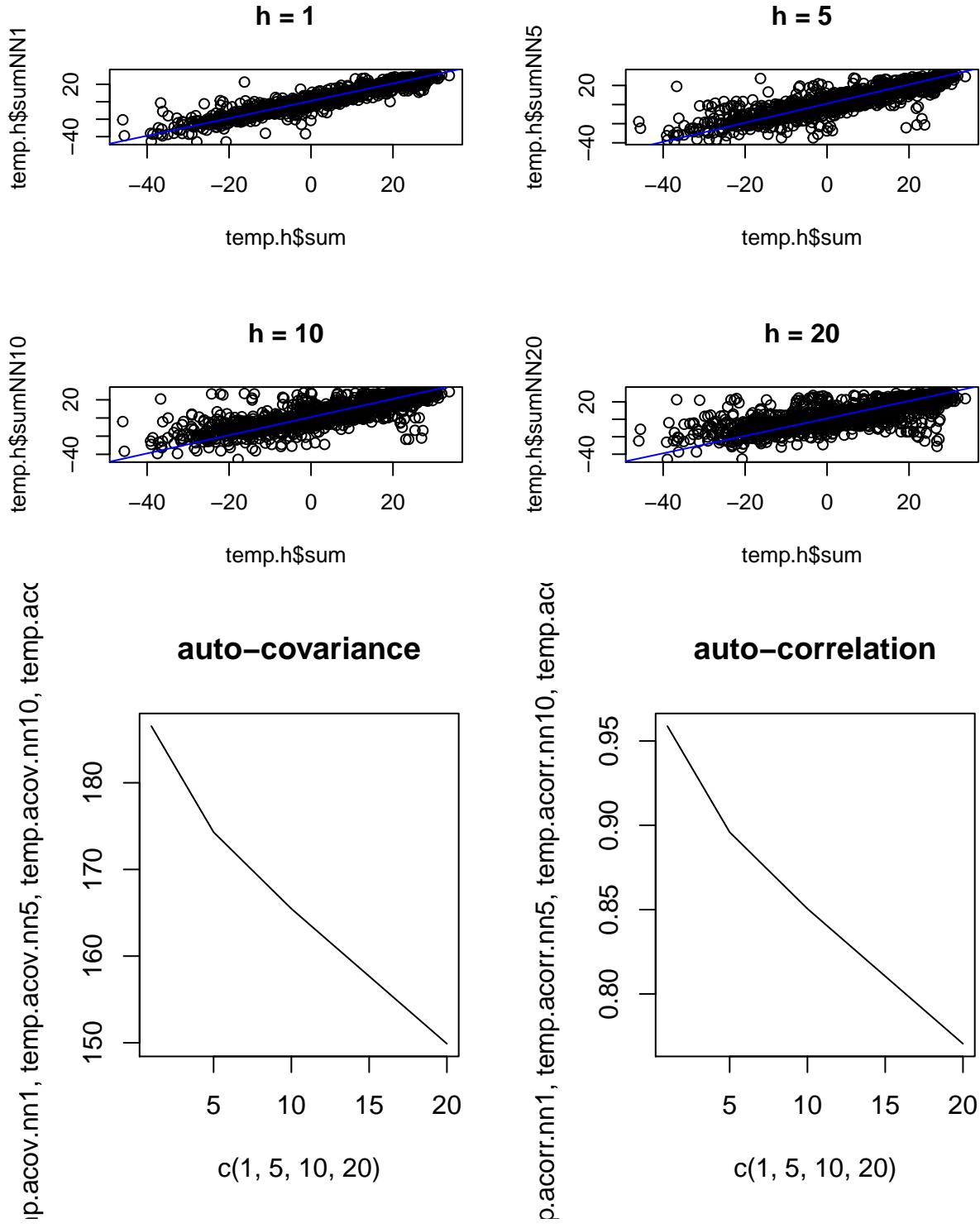




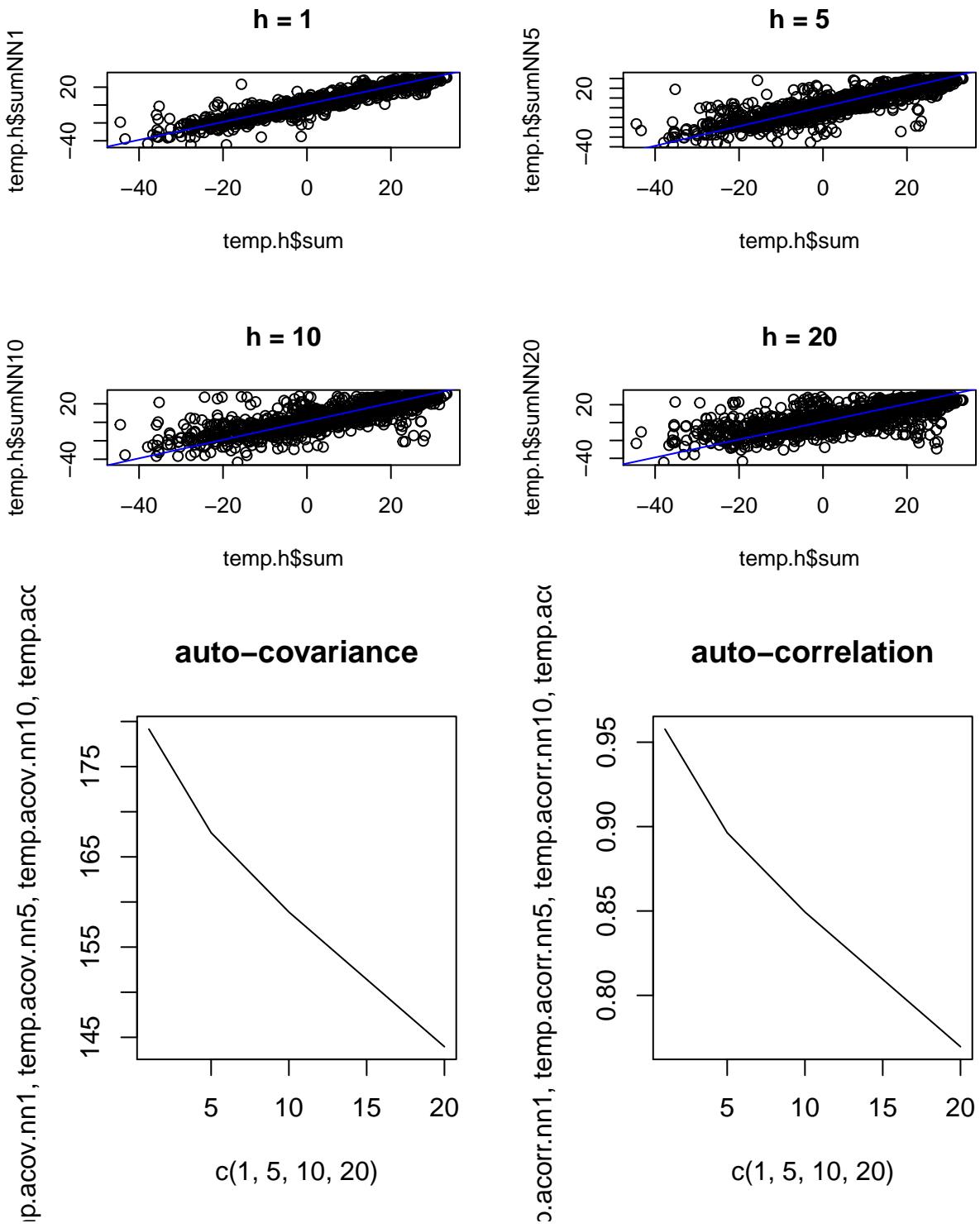
3 TaskI: Spatial continuity

3.1 H - Scatterplots and autocovariance plots

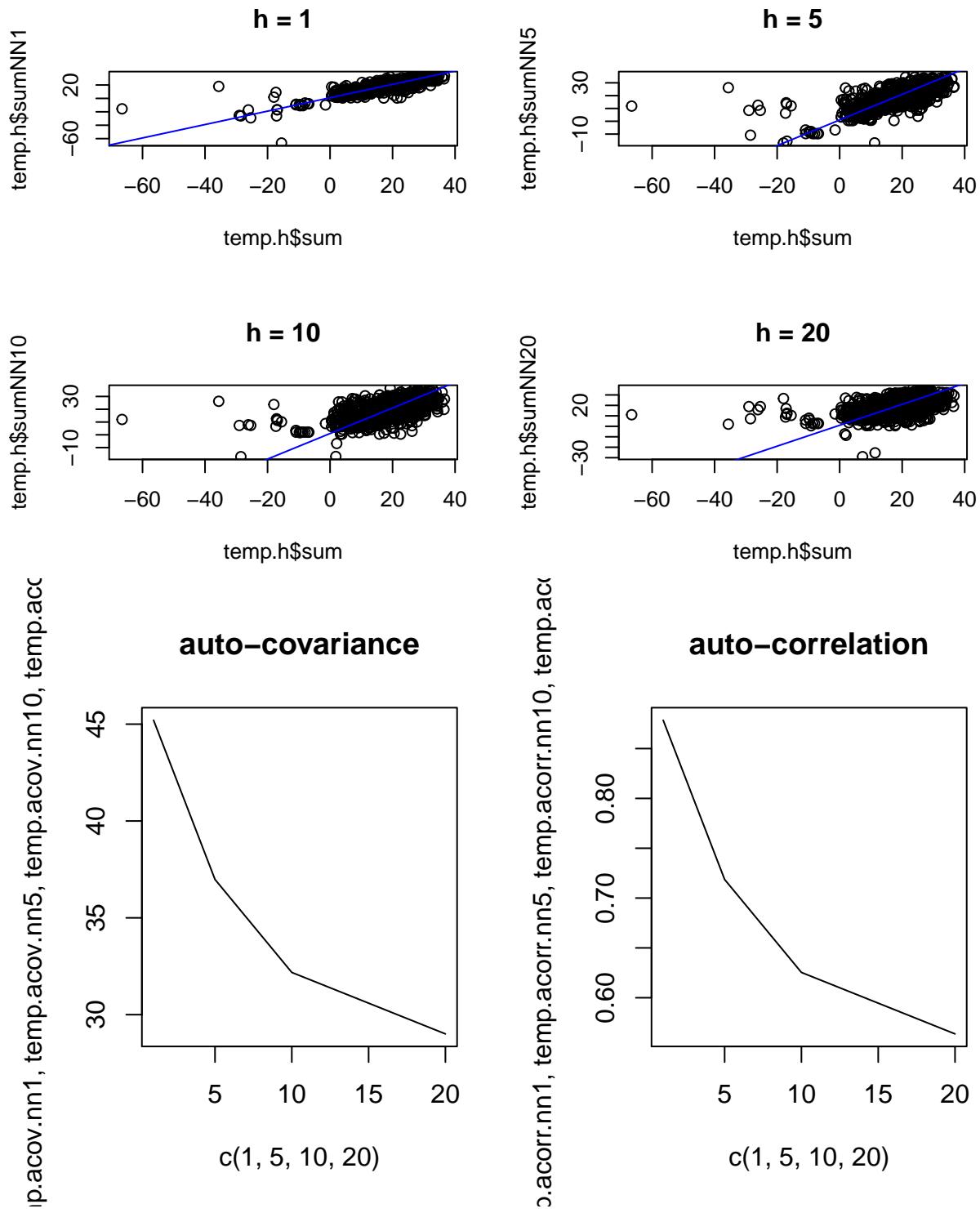
3.1.1 Winter before 1970



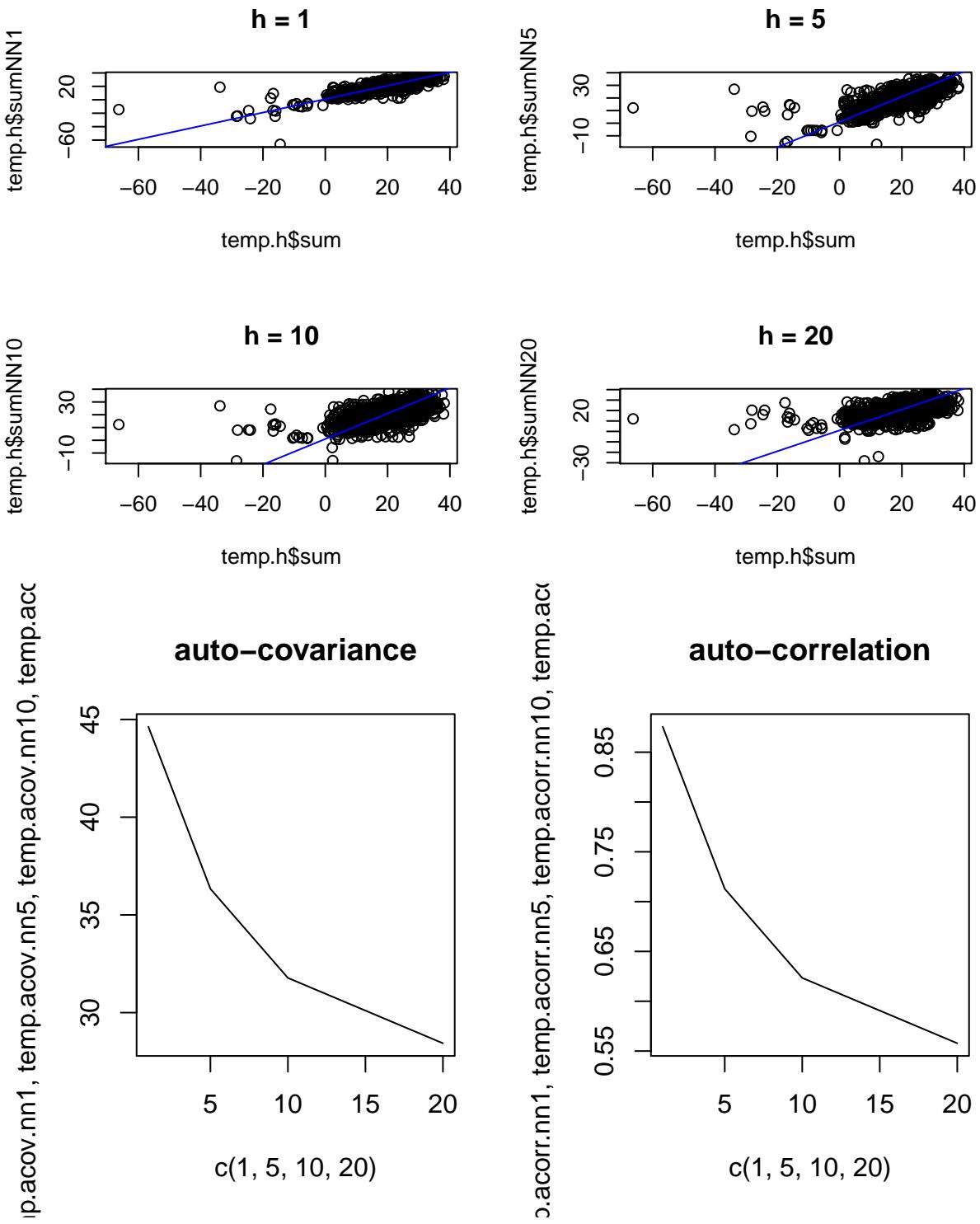
3.1.2 Winter after 1990



3.1.3 Summer before 1970

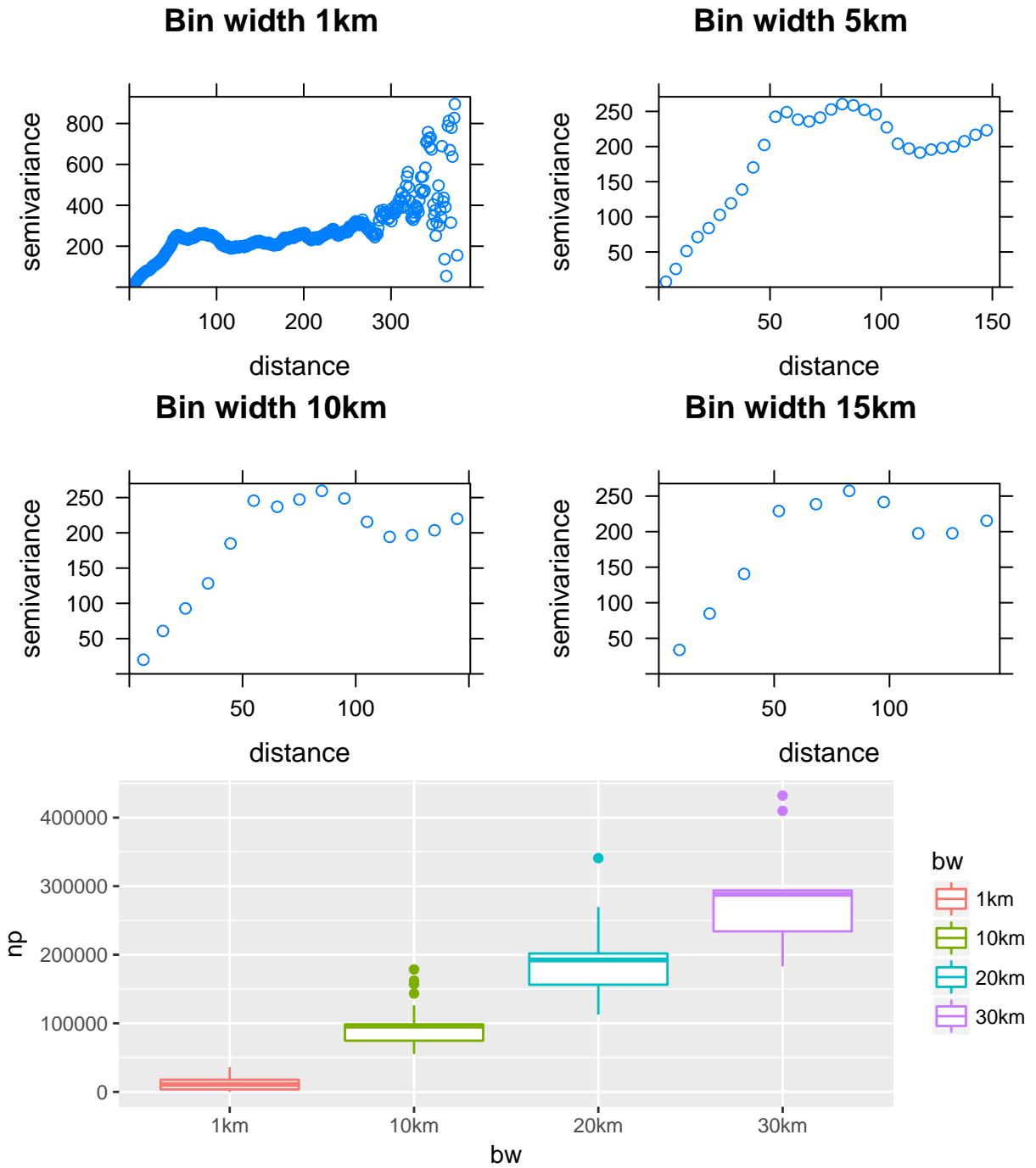


3.1.4 Summer after 1990

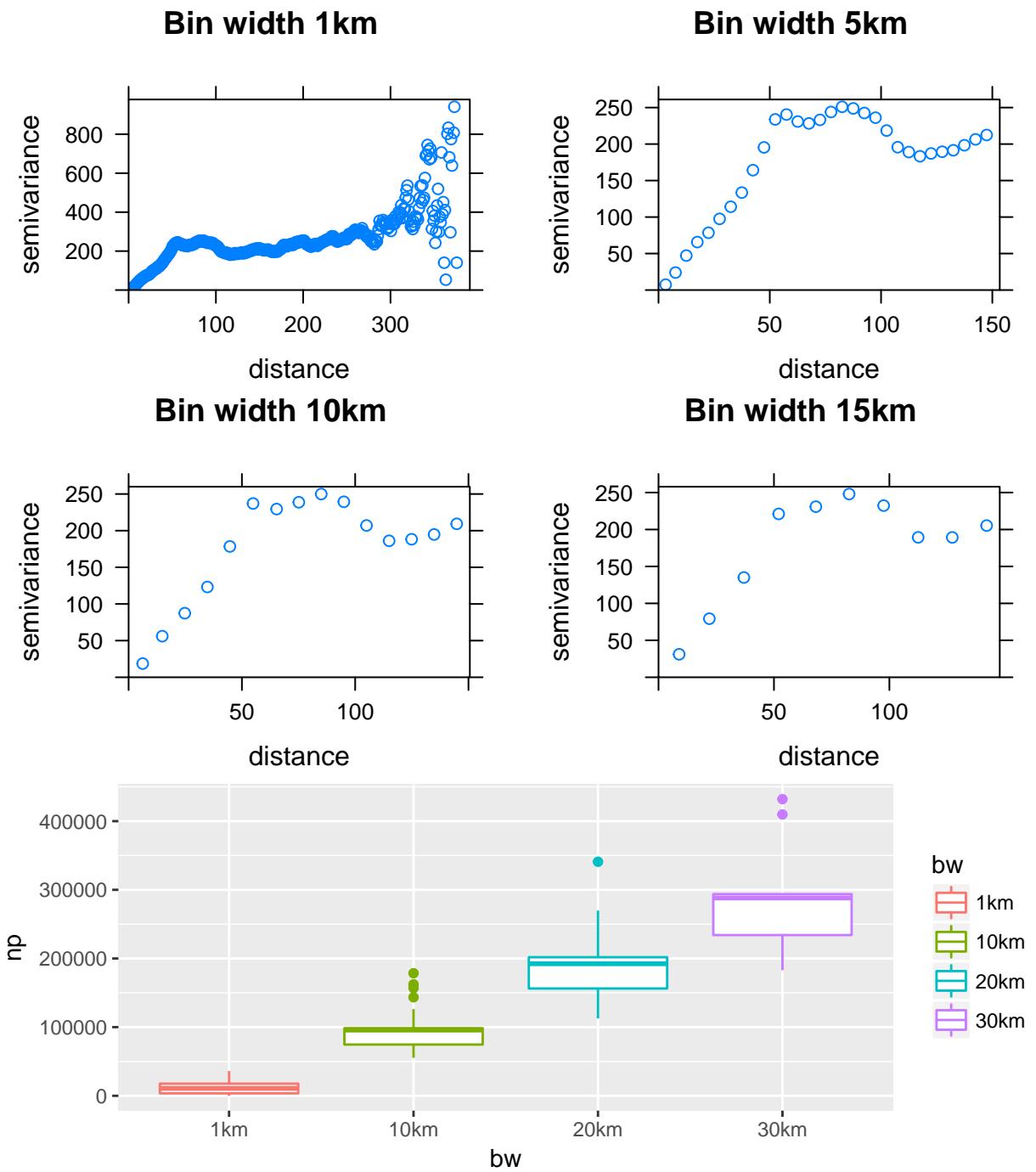


3.2 Empirical Variogram

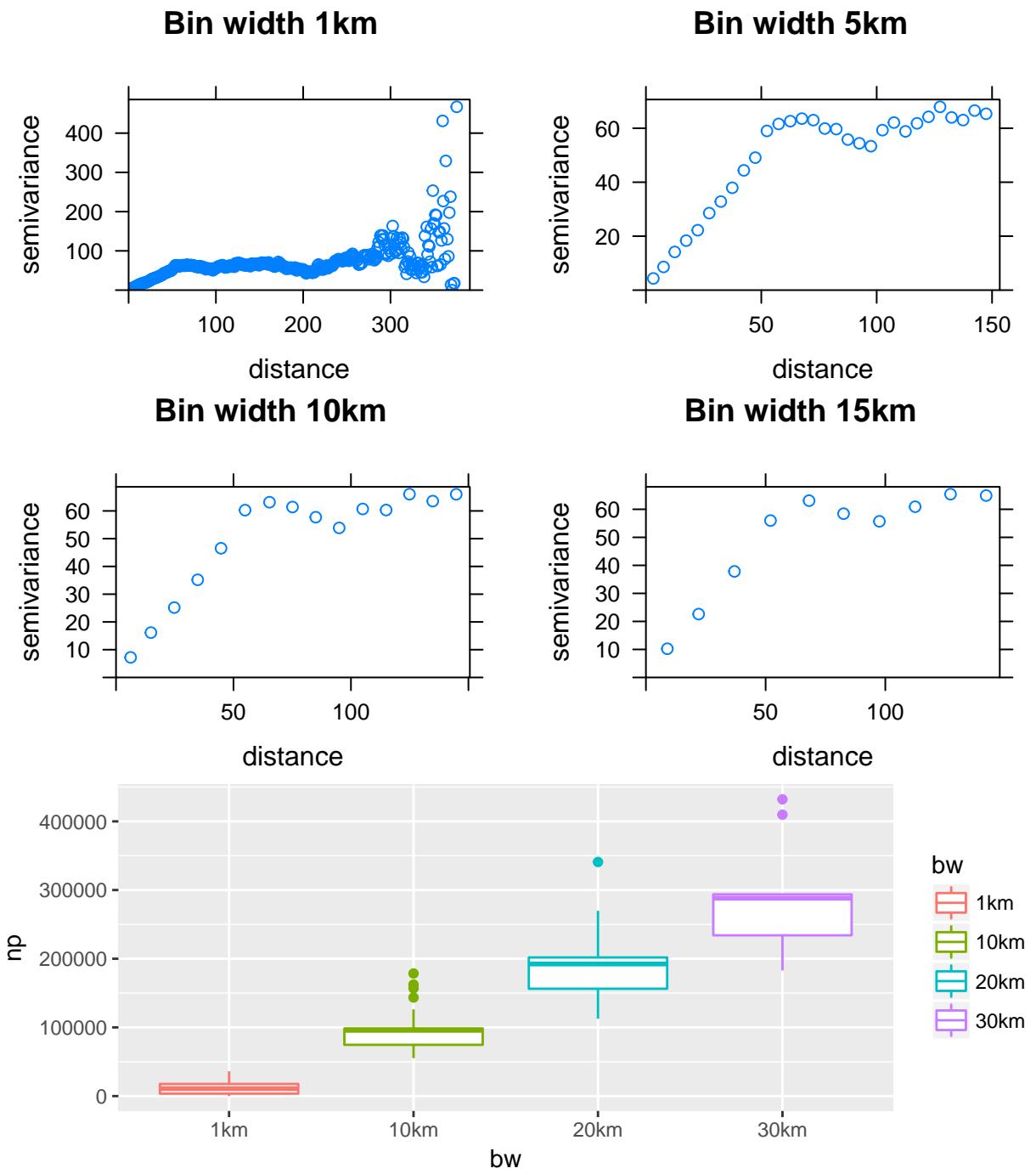
3.2.1 Winter before 1970



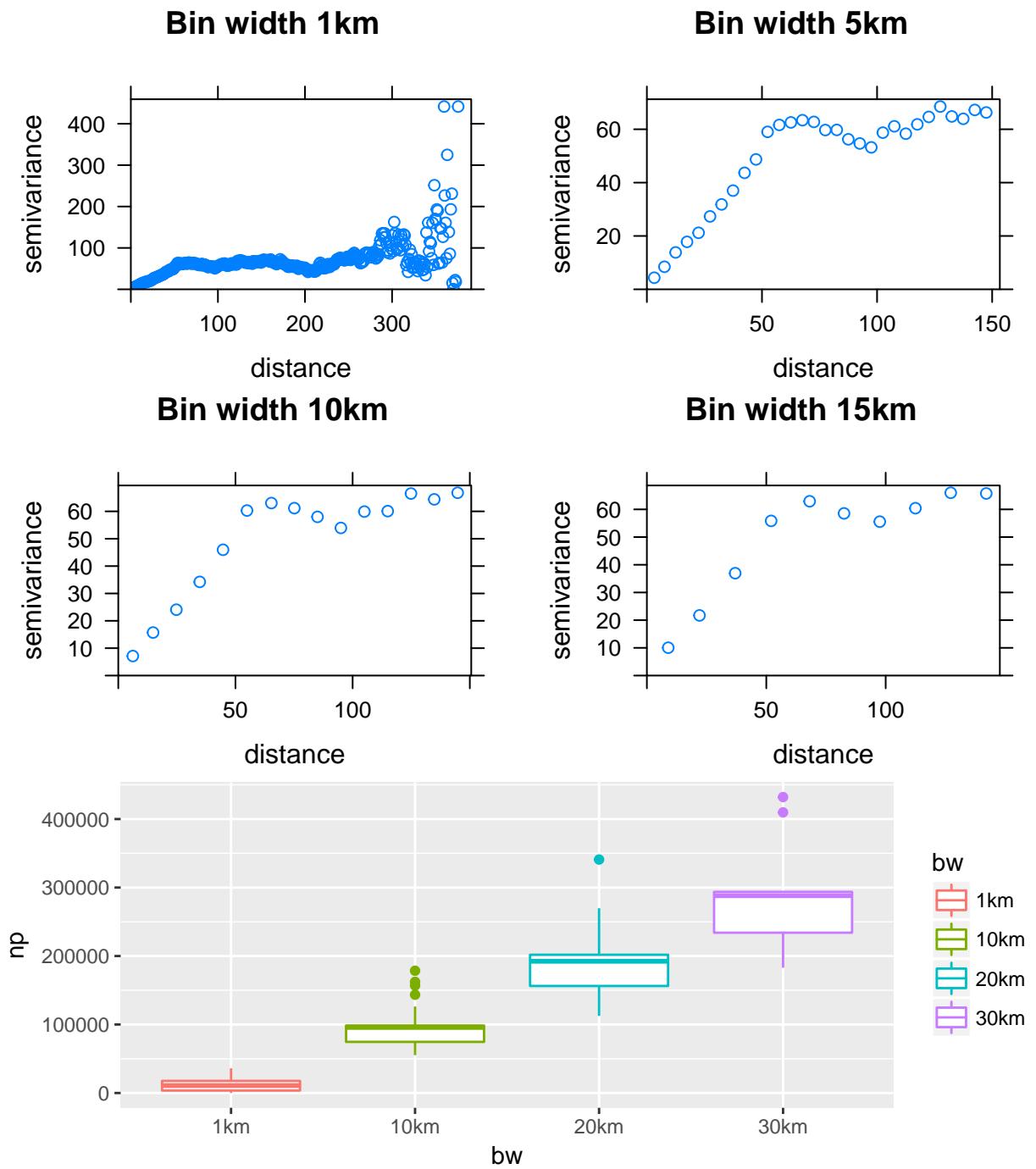
3.2.2 Winter after 1990



3.2.3 Summer before 1970



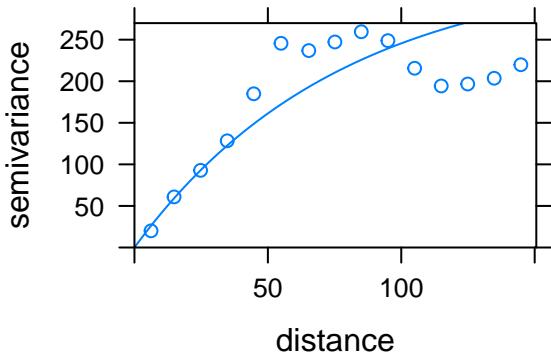
3.2.4 Summer after 1990



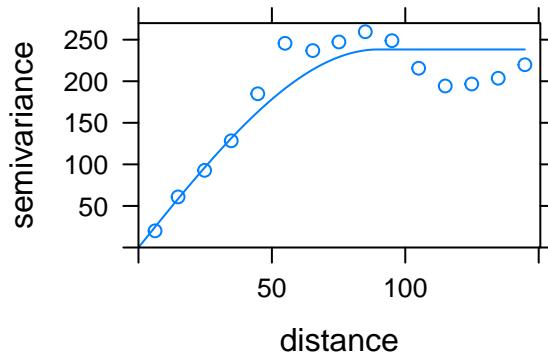
3.3 Fitted Semivariogram

3.3.1 Winter before 1970

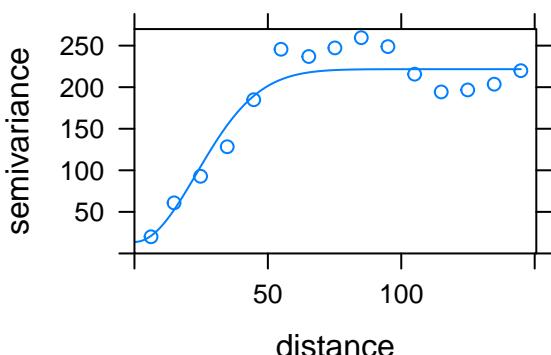
Exponential: 10km



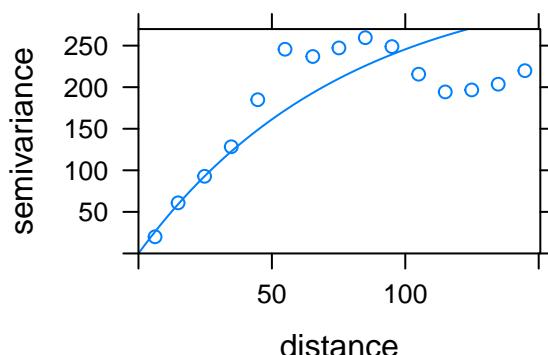
Spherical: 10km



Gaussian: 10km

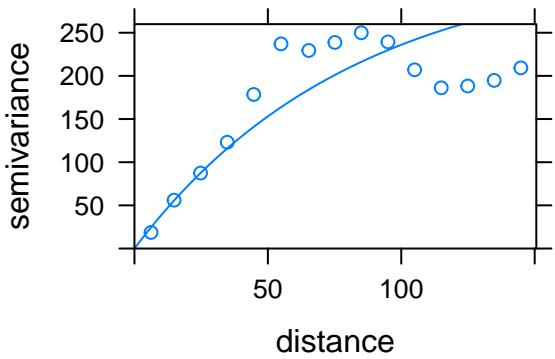


Mat: 10km

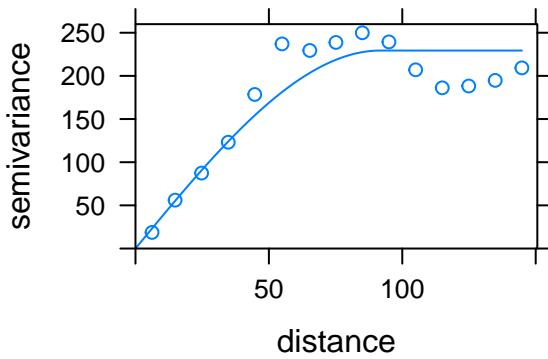


3.3.2 Winter after 1990

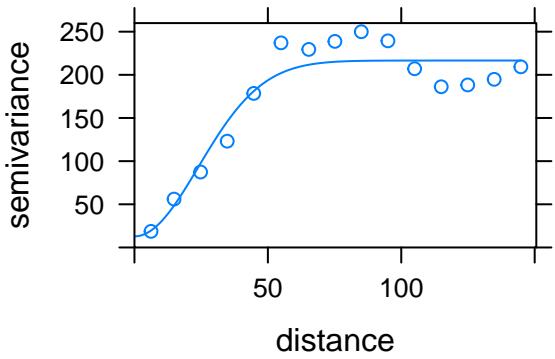
Exponential: 10km



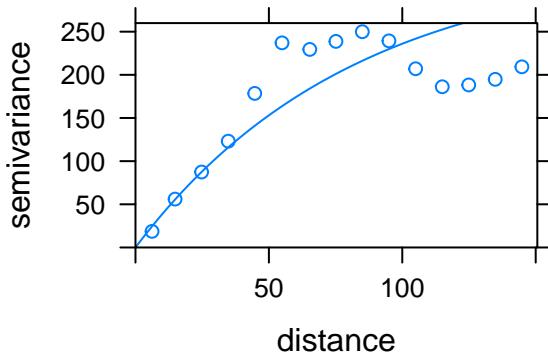
Spherical: 10km



Gaussian: 10km

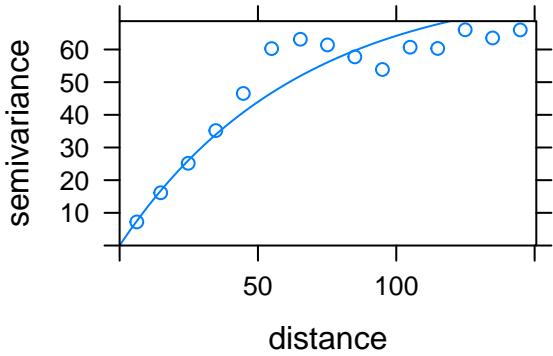


Mat: 10km

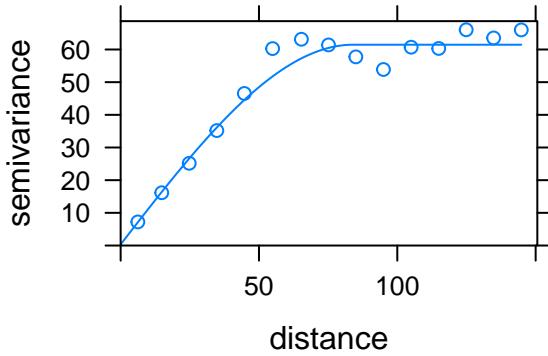


3.3.3 Summer before 1970

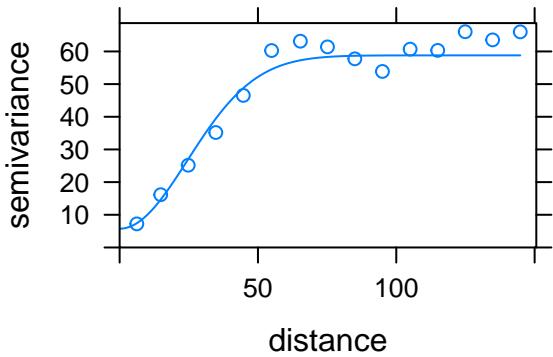
Exponential: 10km



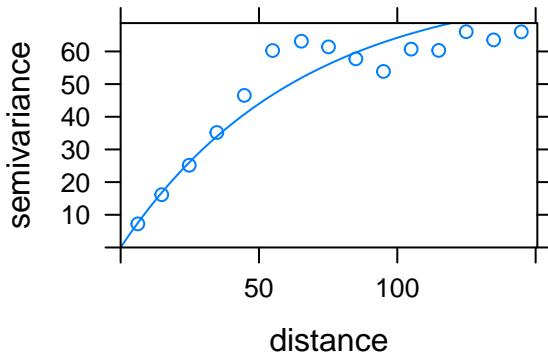
Spherical: 10km



Gaussian: 10km

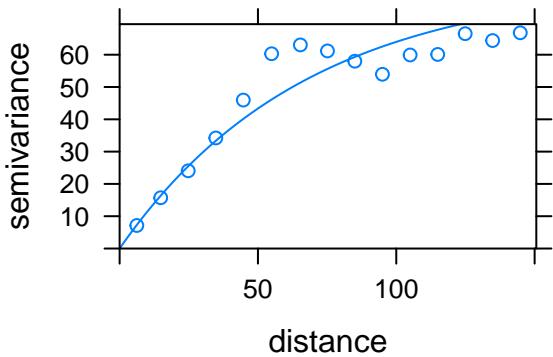


Mat: 10km

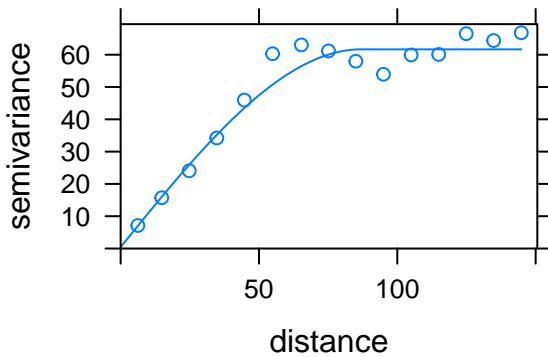


3.3.4 Summer after 1990

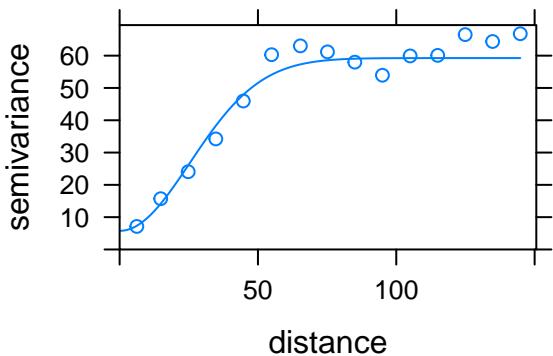
Exponential: 10km



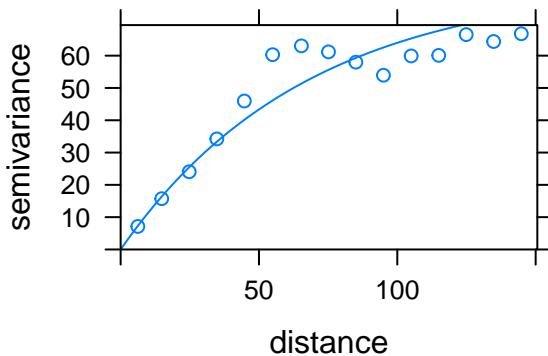
Spherical: 10km



Gaussian: 10km

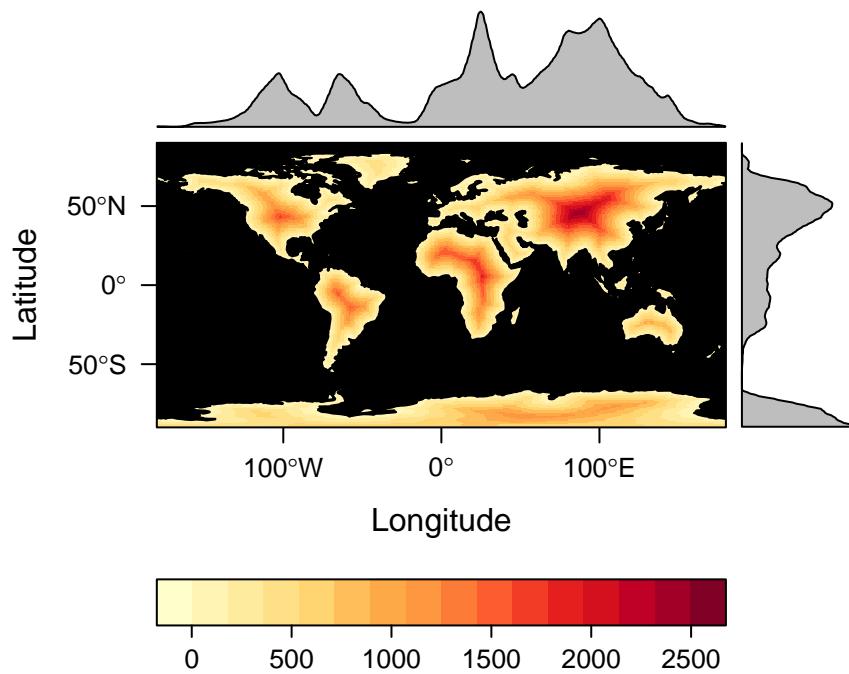


Mat: 10km

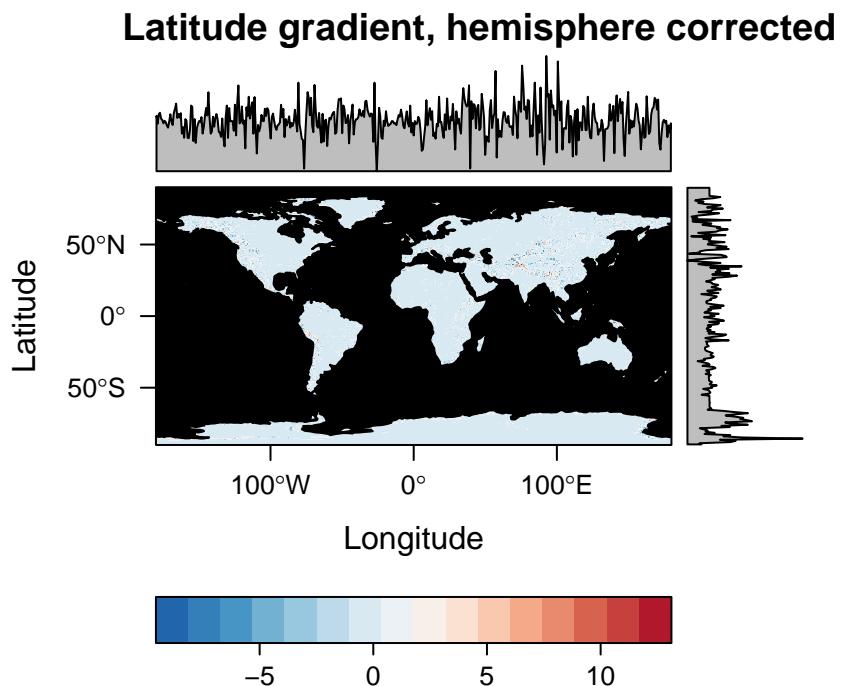


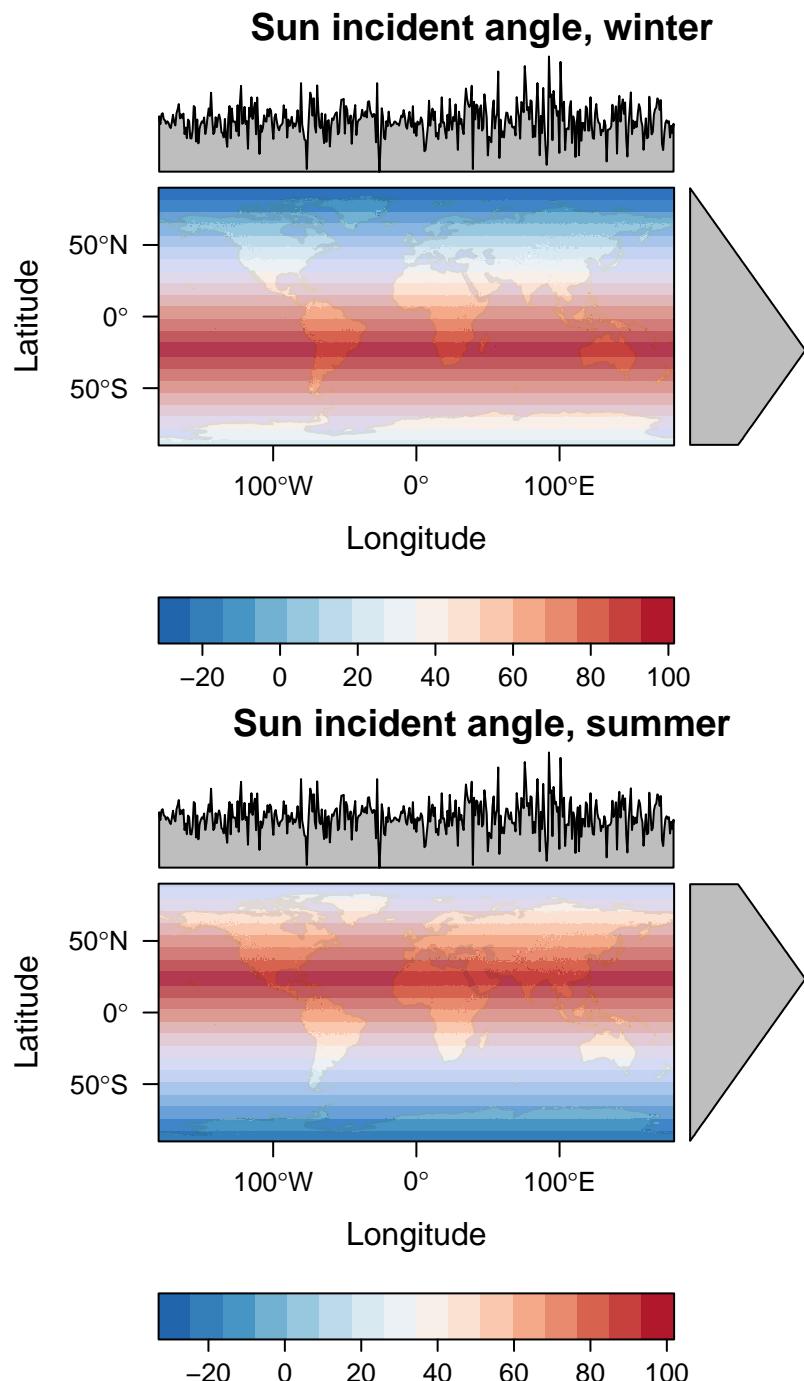
4 Task II: Universal ordinary Kriging

4.1 Continentiality: Create distance to ocean layer



4.2 Sun incidence angle

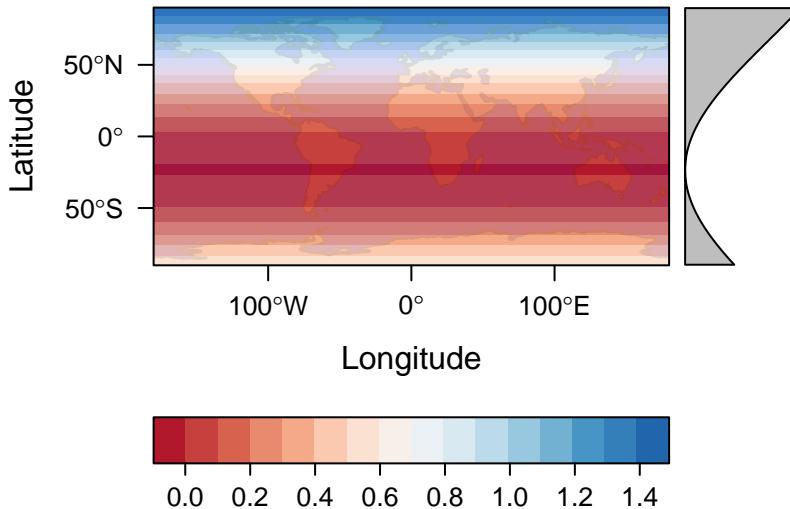




4.3 Atmospheric distance

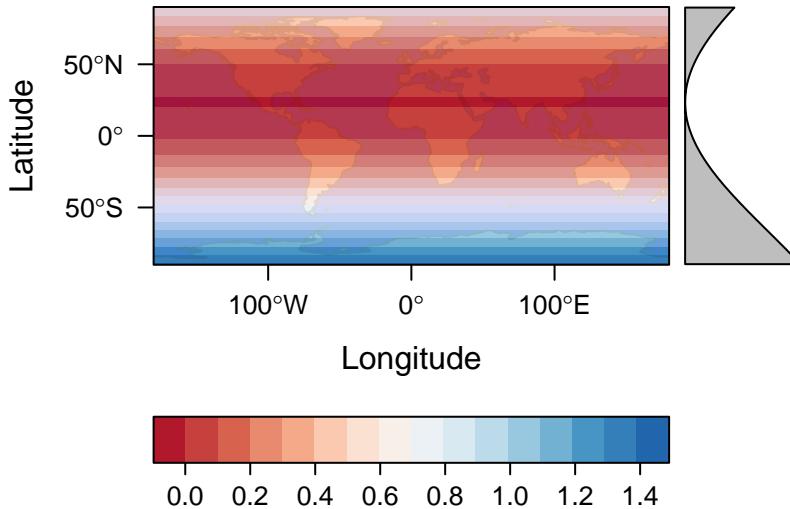
```
## Warning in min(x): kein nicht-fehlendes Argument für min; gebe Inf zurück  
## Warning in max(x): kein nicht-fehlendes Argument für max; gebe -Inf zurück
```

Atmospheric distance, winter



```
## Warning in min(x): kein nicht-fehlendes Argument für min; gebe Inf zurück  
## Warning in min(x): kein nicht-fehlendes Argument für max; gebe -Inf zurück
```

Atmospheric distance, winter

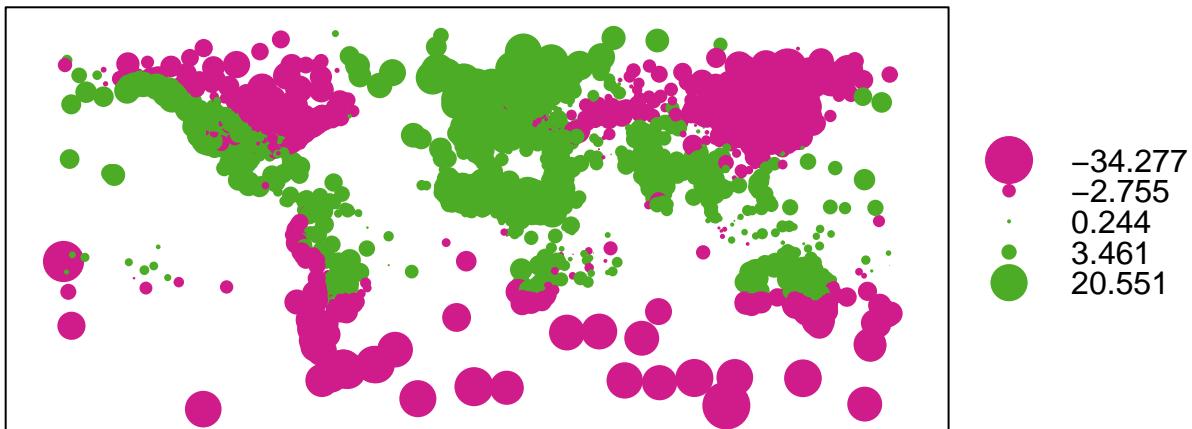


4.4 Interpolation

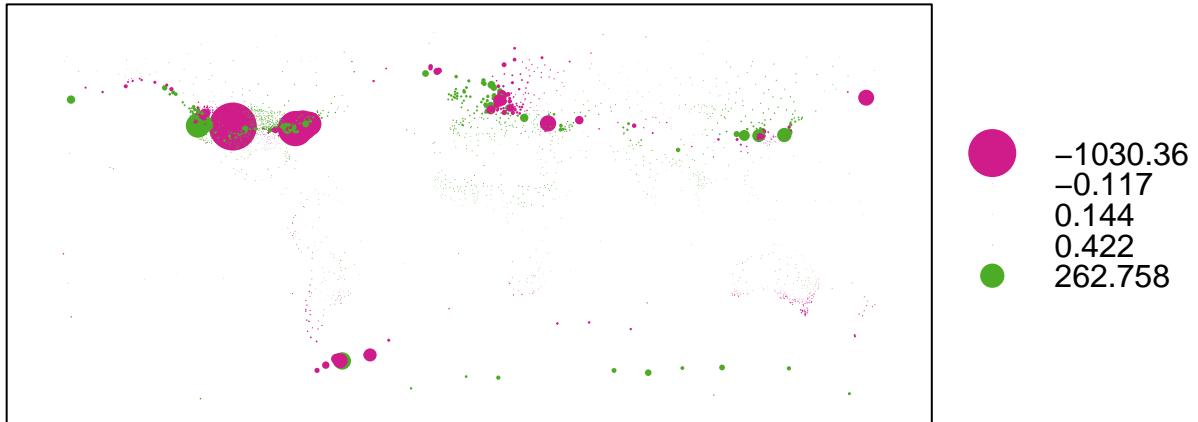
4.4.1 Winter before 1970

```
##  
## Call:  
## lm(formula = meansum ~ elev + cont + hsun + dist, data = temp1970w@data)  
##  
## Residuals:  
##      Min       1Q   Median       3Q      Max  
## -34.277  -2.755   0.244   3.461  20.551  
##  
## Coefficients:  
##              Estimate Std. Error t value Pr(>|t|)  
## (Intercept) 51.8801322534 1.5759498629 32.92 <2e-16 ***  
## elev        -0.0023793492 0.0001937784 -12.28 <2e-16 ***  
## cont        -0.0000047771 0.0000002491 -19.18 <2e-16 ***  
## hsun        -0.3065991419 0.0204543218 -14.99 <2e-16 ***  
## dist        -70.8548805698 1.8005333613 -39.35 <2e-16 ***  
## ---  
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Residual standard error: 5.416 on 2873 degrees of freedom  
## Multiple R-squared: 0.8495, Adjusted R-squared: 0.8492  
## F-statistic: 4053 on 4 and 2873 DF, p-value: < 2.2e-16
```

Residual Values

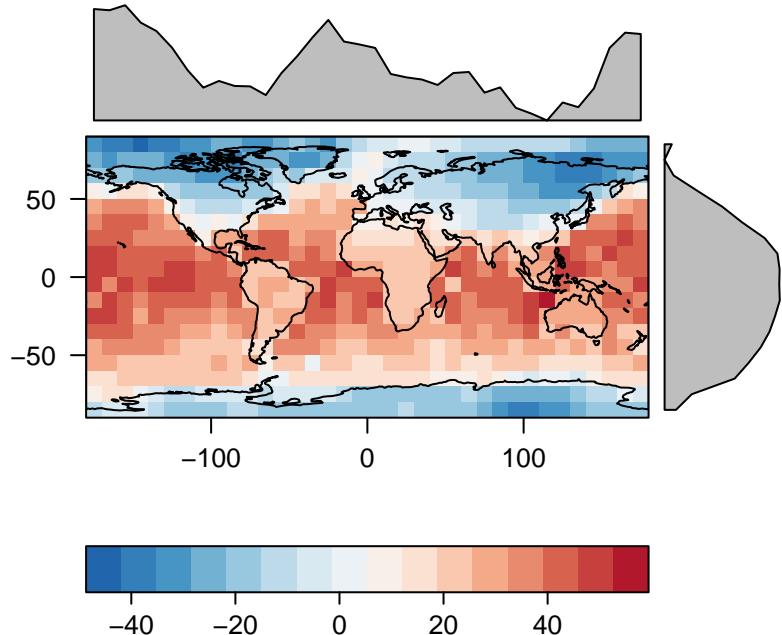


Relative Residual Values

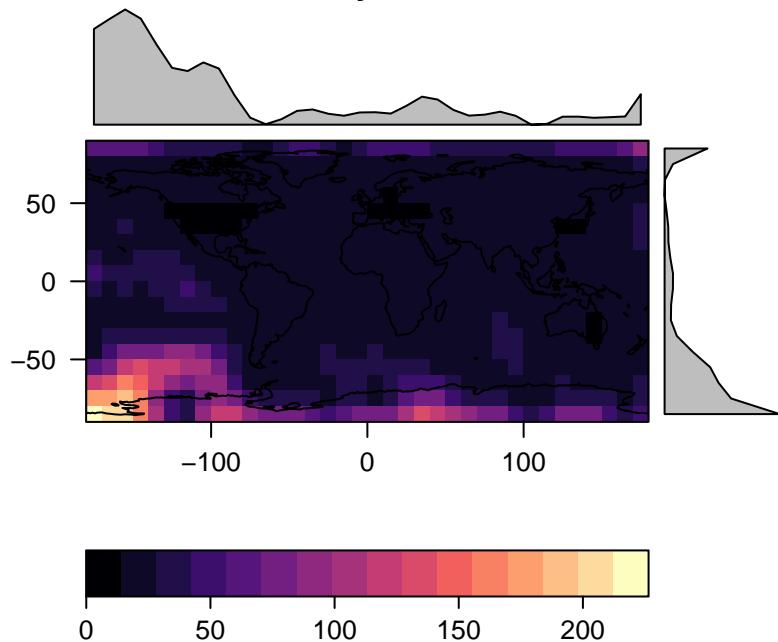


```
## [1] "Observed autocorrelation: 0.200529903071495"  
## [1] "P-value of H0 (residuals are randomly distributed): 0"  
## [using universal kriging]  
## [1] "Observed RMSE (5% validation data): 8.24°C"
```

Prediction: Winter before 1970



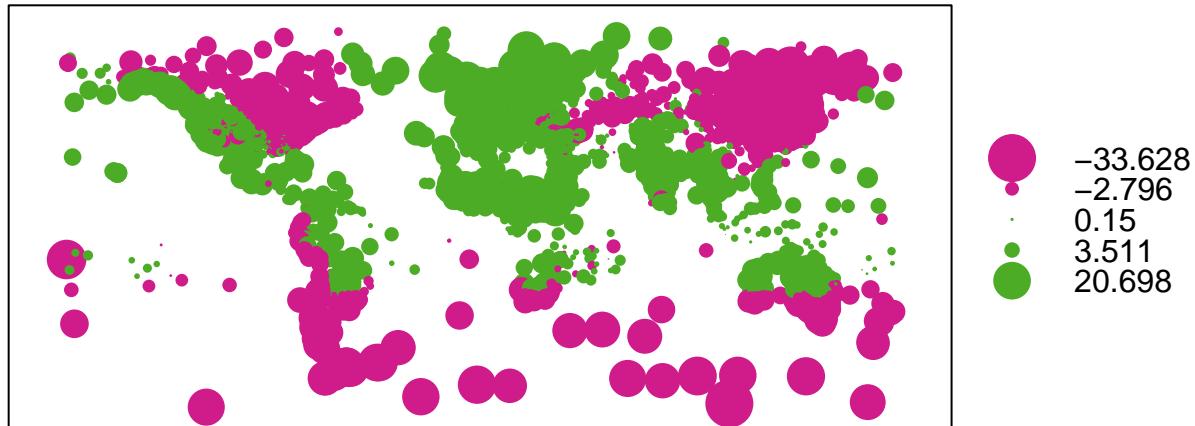
Uncertainty: Winter before 1970



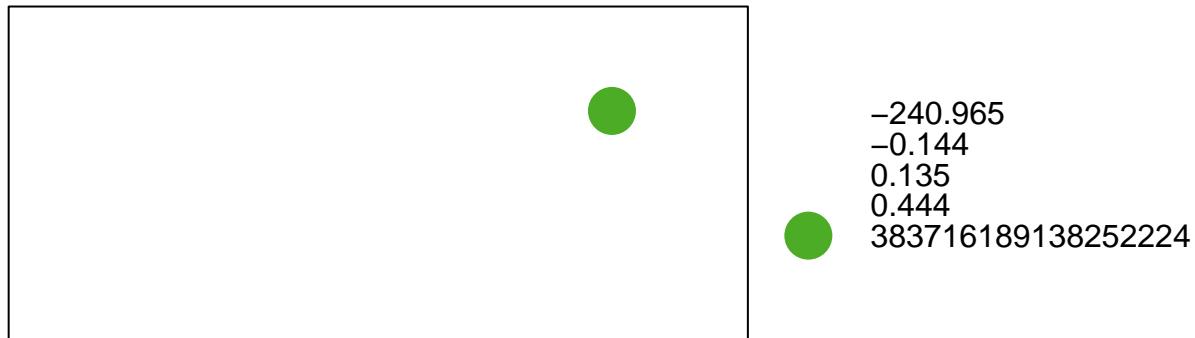
4.4.2 Winter after 1990

```
##
## Call:
## lm(formula = meansum ~ elev + cont + hsun + dist, data = temp2010w@data)
##
## Residuals:
##    Min     1Q Median     3Q    Max 
## -33.628 -2.796  0.150  3.511 20.698 
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 50.2421594101  1.5641116038   32.12 <2e-16 ***
## elev        -0.0023935591  0.0001923227  -12.45 <2e-16 ***
## cont        -0.0000045138  0.0000002472  -18.26 <2e-16 *** 
## hsun        -0.2804324508  0.0203006725  -13.81 <2e-16 *** 
## dist       -67.7660939452  1.7870080702  -37.92 <2e-16 *** 
## ---        
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 
##
## Residual standard error: 5.375 on 2873 degrees of freedom
## Multiple R-squared:  0.8458, Adjusted R-squared:  0.8456 
## F-statistic: 3939 on 4 and 2873 DF, p-value: < 2.2e-16
```

Residual Values



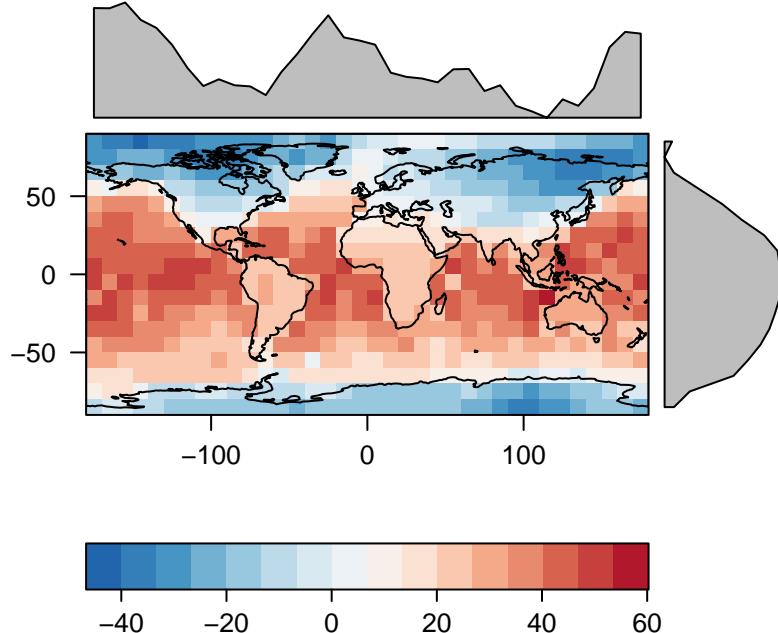
Relative Residual Values



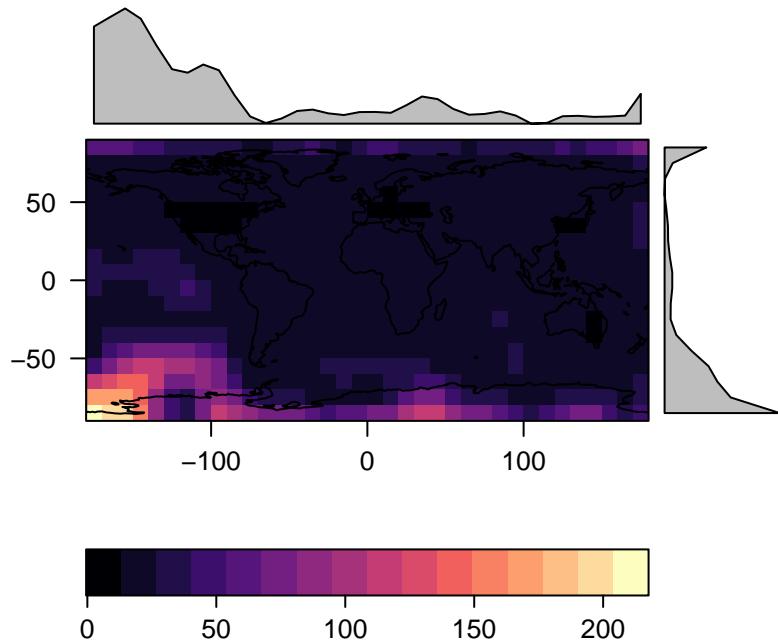
```
## [1] "Observed autocorrelation: 0.201950255671165"
```

```
## [1] "P-value of H0 (residuals are randomly distributed): 0"  
## [using universal kriging]  
## [1] "Observed RMSE (5% validation data): 8.25°C"
```

Prediction: Winter after 1990



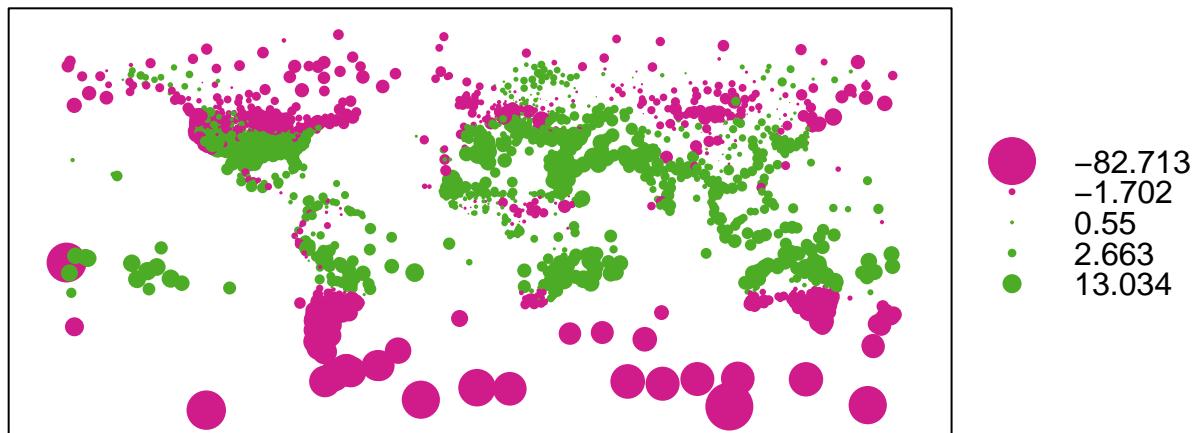
Uncertainty: Winter after 1990



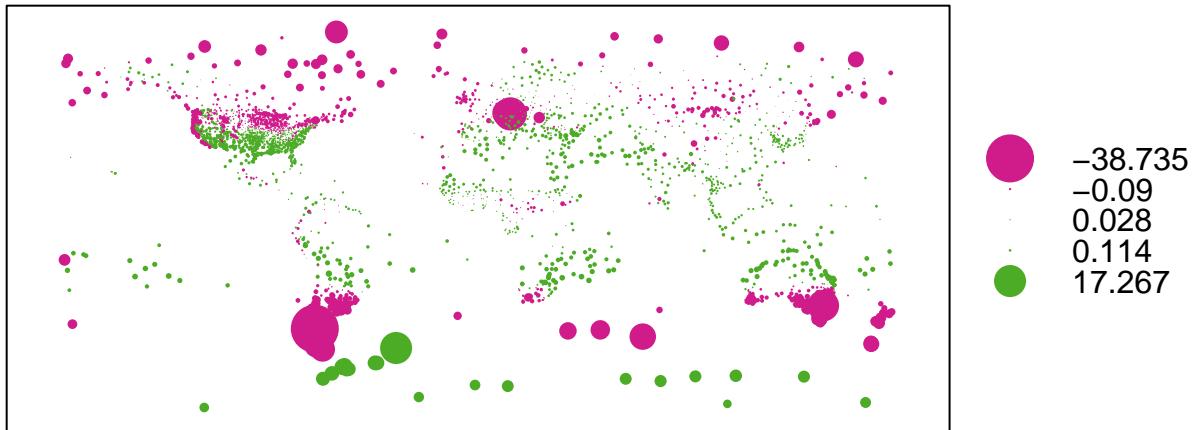
4.4.3 Summer before 1970

```
##  
## Call:  
## lm(formula = meansum ~ elev + cont + hsun + dist, data = temp1970s@data)  
##  
## Residuals:  
##      Min       1Q   Median       3Q      Max  
## -82.713  -1.702    0.550    2.663   13.034  
##  
## Coefficients:  
##              Estimate Std. Error t value Pr(>|t|)  
## (Intercept) 81.6931578675 1.6694458595 48.93 <2e-16 ***  
## elev        -0.0030212719 0.0002052746 -14.72 <2e-16 ***  
## cont         0.0000031098 0.0000002639 11.78 <2e-16 ***  
## hsun        -0.8041929708 0.0216678104 -37.12 <2e-16 ***  
## dist        -70.9107857793 1.9073531688 -37.18 <2e-16 ***  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Residual standard error: 5.737 on 2873 degrees of freedom  
## Multiple R-squared:  0.3613, Adjusted R-squared:  0.3604  
## F-statistic: 406.3 on 4 and 2873 DF,  p-value: < 2.2e-16
```

Residual Values

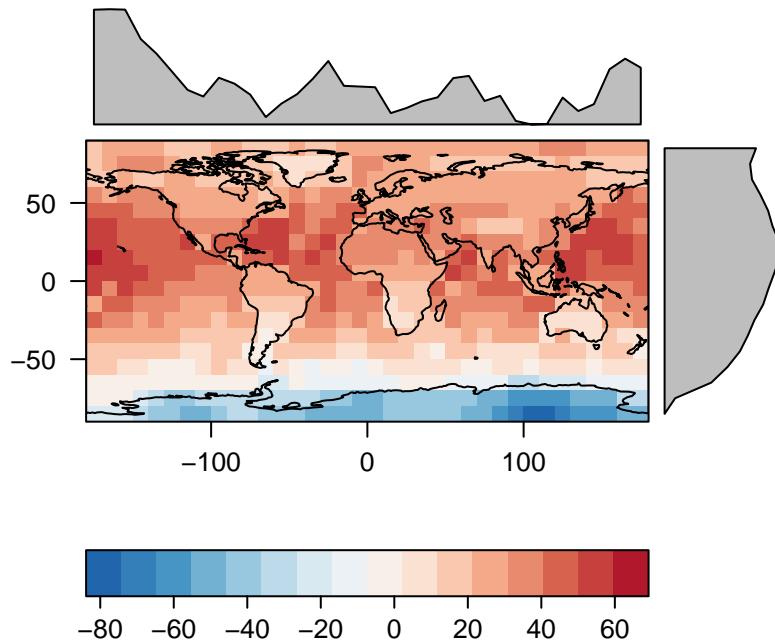


Relative Residual Values

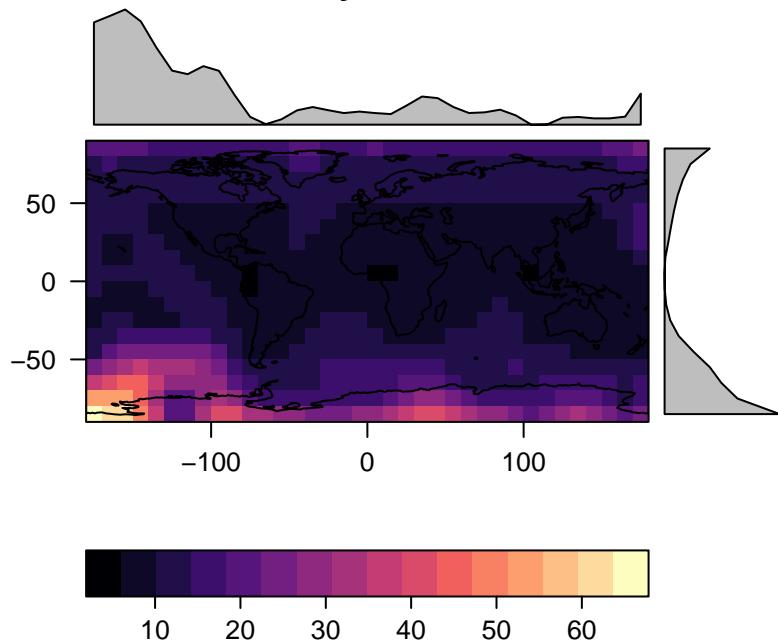


```
## [1] "Observed autocorrelation: 0.137673841995618"  
## [1] "P-value of H0 (residuals are randomly distributed): 0"  
## [using universal kriging]  
## [1] "Observed RMSE (5% validation data): 11.47°C"
```

Prediction: Summer before 1970



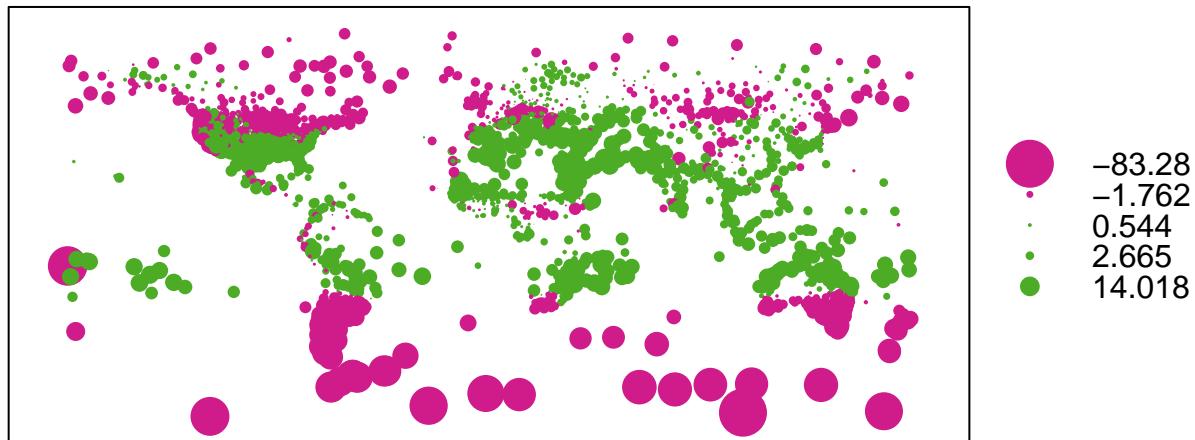
Uncertainty: Summer before 1970



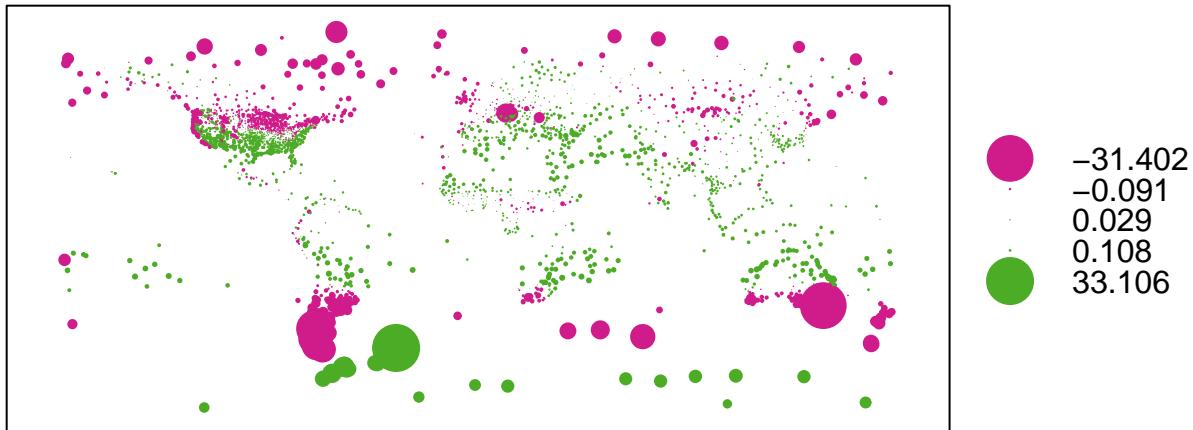
4.4.4 Summer after 1990

```
##
## Call:
## lm(formula = meansum ~ elev + cont + hsun + dist, data = temp2010s@data)
##
## Residuals:
##    Min     1Q Median     3Q    Max 
## -83.280 -1.762  0.544  2.665 14.018 
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 81.7067764182  1.6758452583   48.76 <2e-16 ***
## elev        -0.0028661872  0.0002060615  -13.91 <2e-16 ***
## cont         0.0000027710  0.0000002649   10.46 <2e-16 ***
## hsun        -0.7958529248  0.0217508685  -36.59 <2e-16 ***
## dist       -70.1112736973  1.9146645251  -36.62 <2e-16 ***
## ---        
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 
##
## Residual standard error: 5.759 on 2873 degrees of freedom
## Multiple R-squared:  0.3503, Adjusted R-squared:  0.3494 
## F-statistic: 387.2 on 4 and 2873 DF,  p-value: < 2.2e-16
```

Residual Values

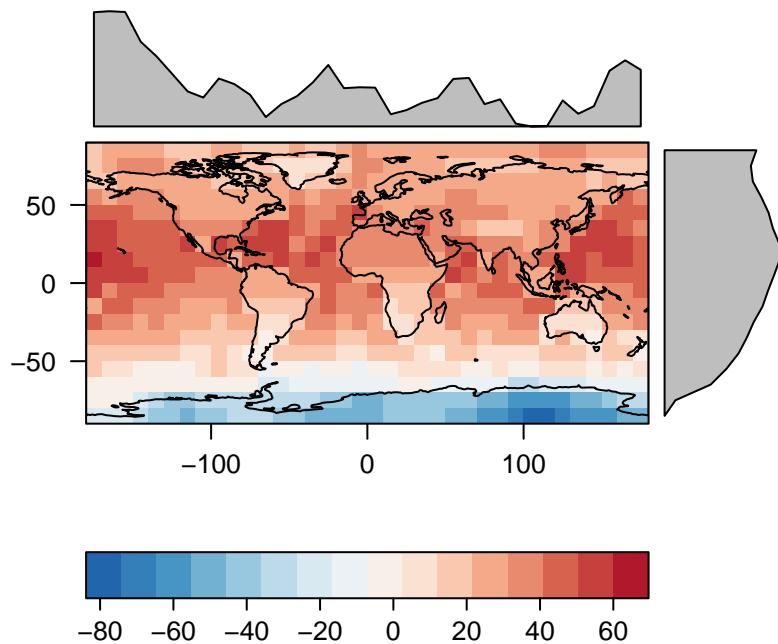


Relative Residual Values

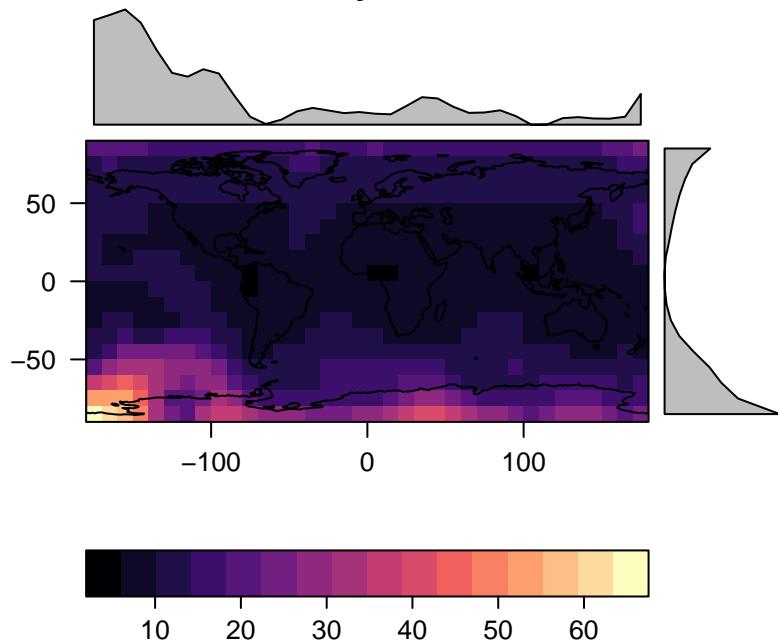


```
## [1] "Observed autocorrelation: 0.138073060873073"  
## [1] "P-value of H0 (residuals are randomly distributed): 0"  
## [using universal kriging]  
## [1] "Observed RMSE (5% validation data): 11.74°C"
```

Prediction: Summer after 1990

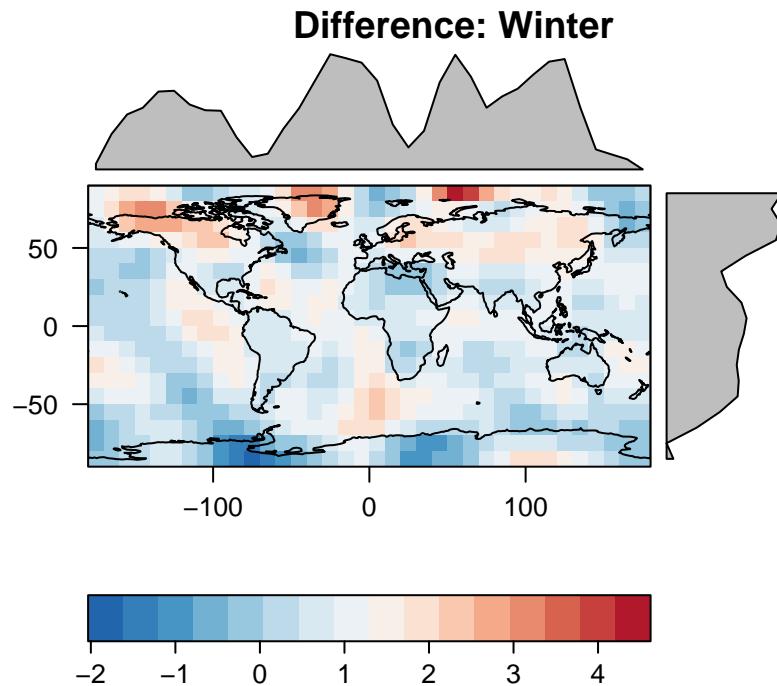


Uncertainty: Summer after 1990



5 Difference images

5.1 Winter



5.2 Summer

