

Challenge II: Spatial continuity and weather prediction

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Abstract

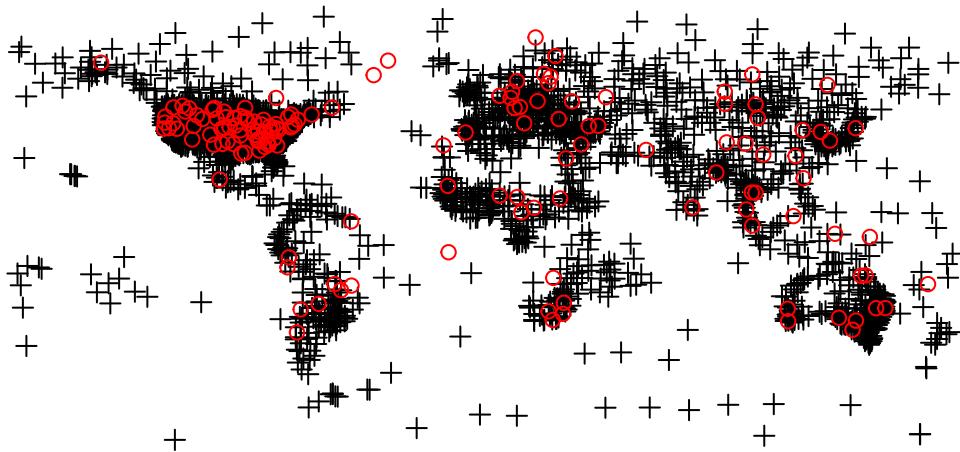
Spatial continuity of global temperature point measurements is analysed by creating H-Scatterplots, autocovariance plots and variograms. Universal Kriging is applied to interpolate global temperature maps from point measurements. Global layers of elevation, sun incidence angle, atmospheric distance and continentality are created and used in the Universal Kriging. Afterwards difference images are constructed and interpreted.

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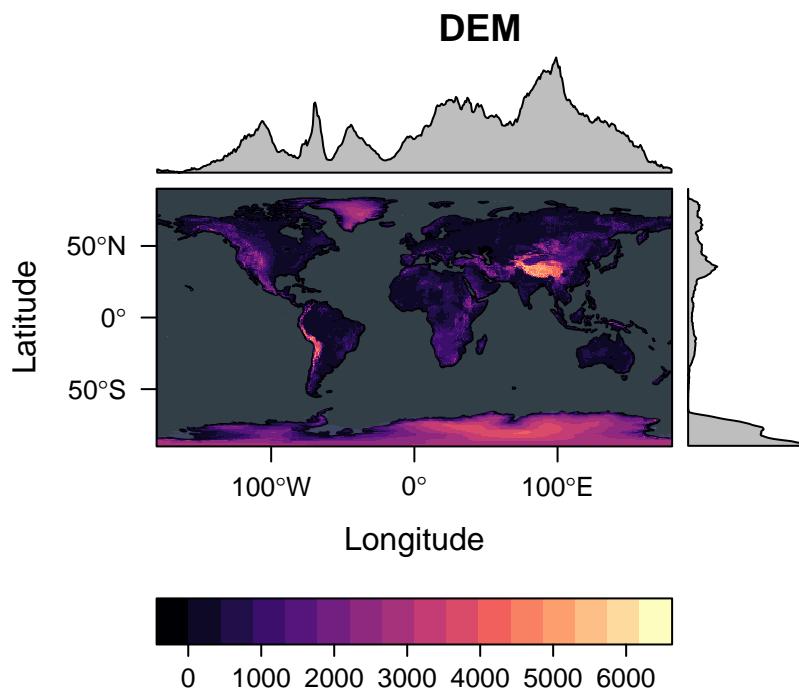
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1 Data

All measurements and validation points



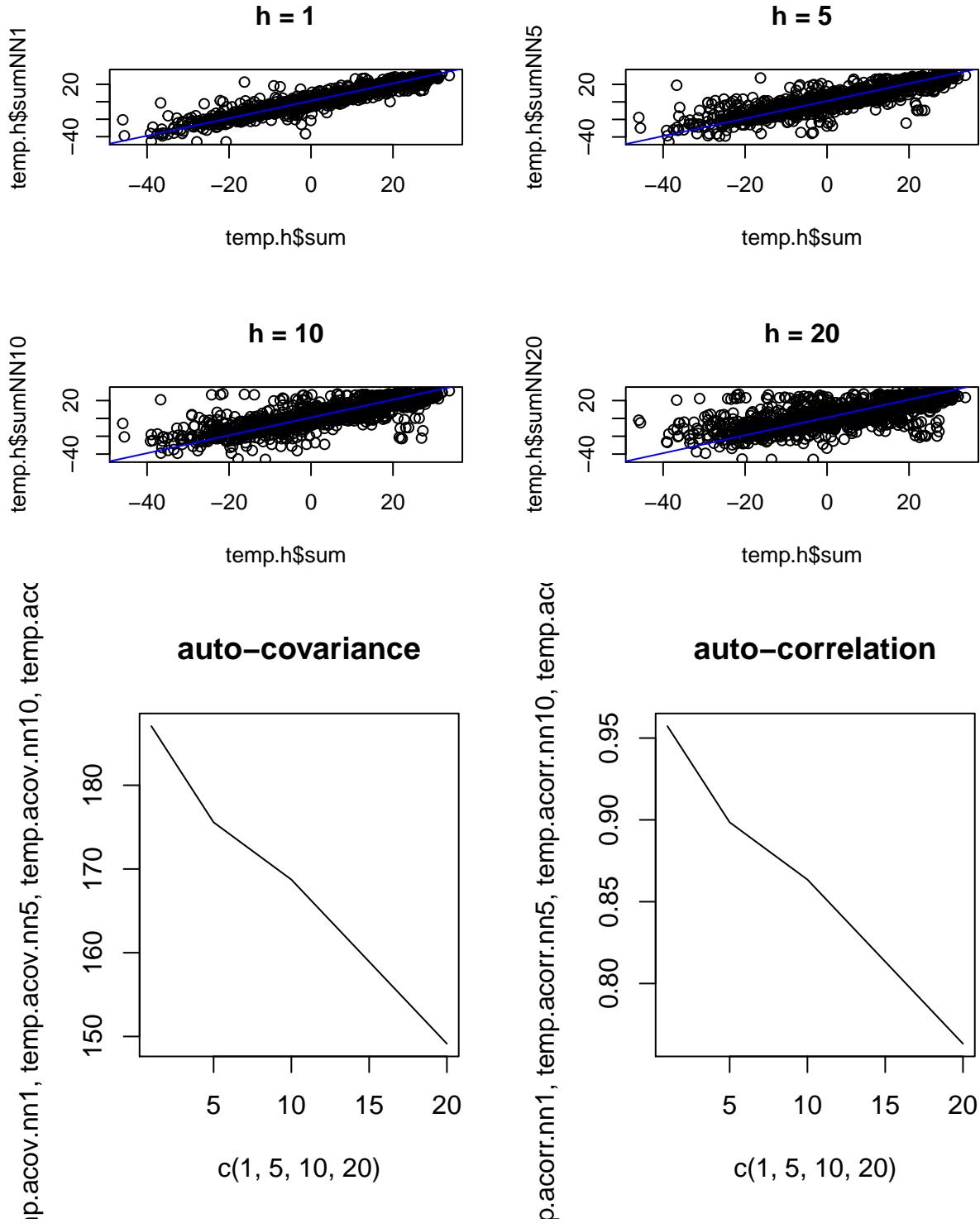
id	meanWi_before1970	meanSu_before1970	meanWi_after1990	meanSu_after1990	elev
1	11.83	23.27	13.09	24.75	7
2	10.21	22.43	11.35	23.94	4
3	10.83	22.78	11.32	24.76	25
4	10.30	22.00	11.44	24.02	2
5	6.13	22.37	7.00	24.56	694
6	8.14	24.90	9.35	26.15	715



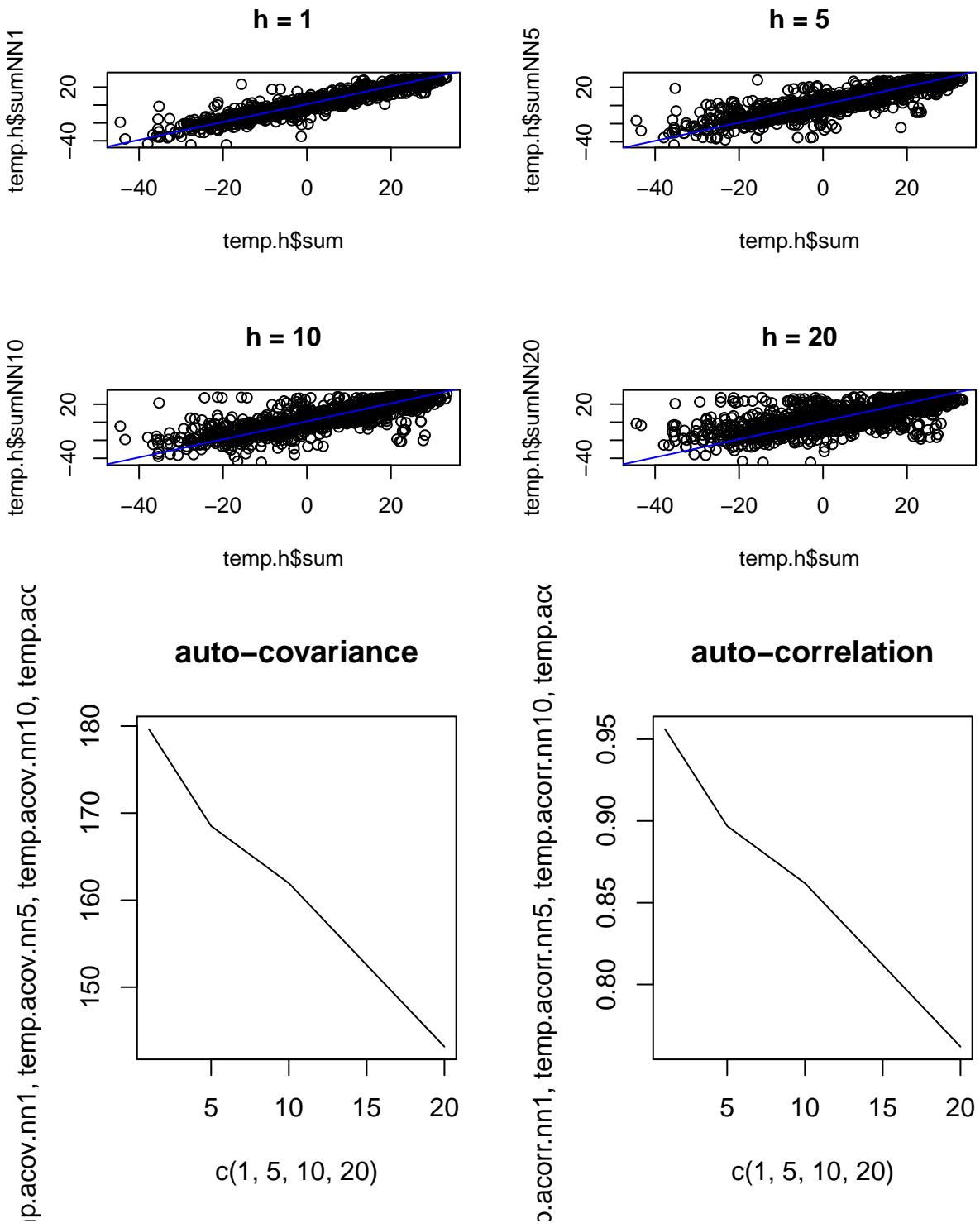
2 TaskI: Spatial continuity

2.1 H - Scatterplots and autocovariance plots

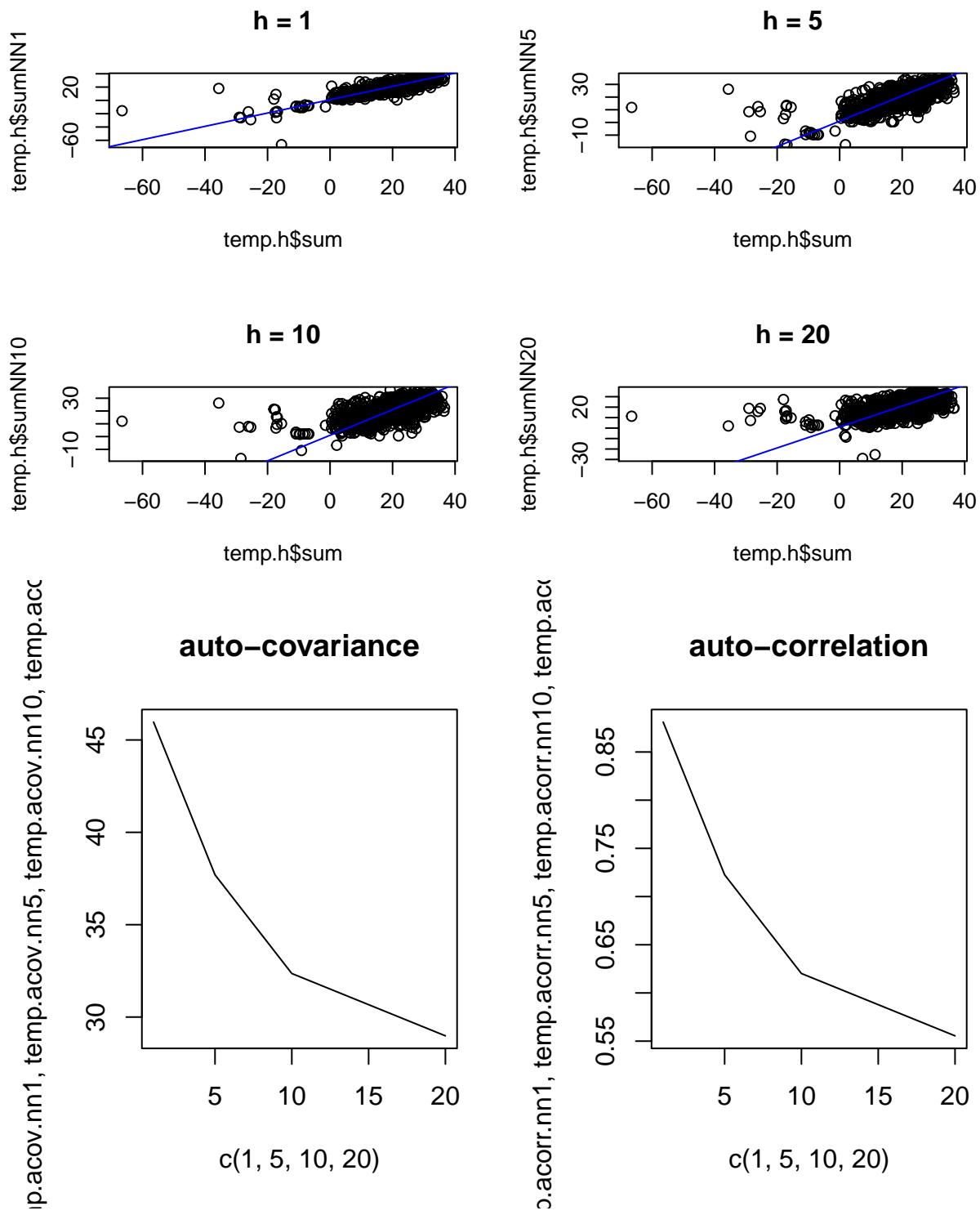
2.1.1 Winter before 1970



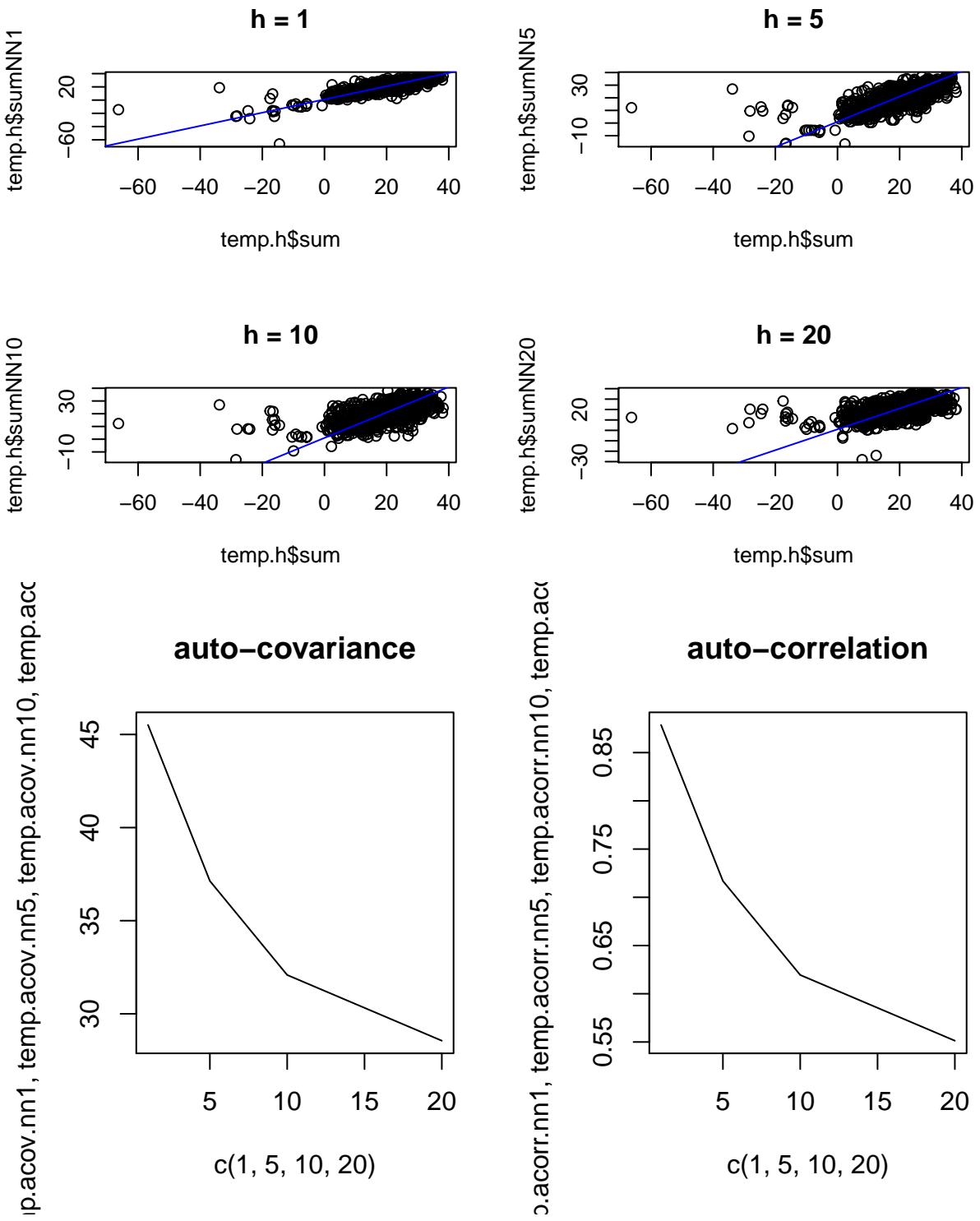
2.1.2 Winter after 1990



2.1.3 Summer before 1970

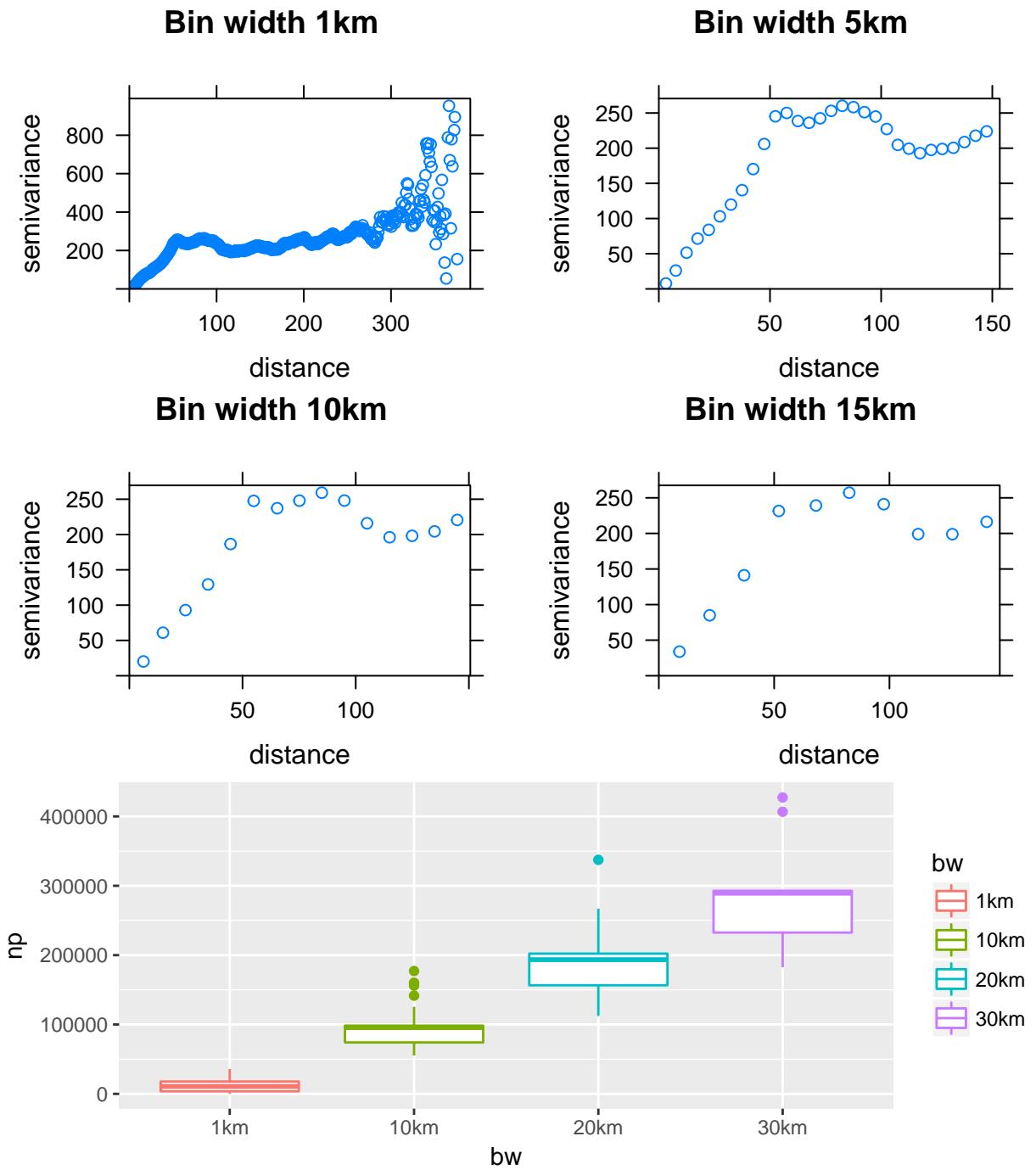


2.1.4 Summer after 1990

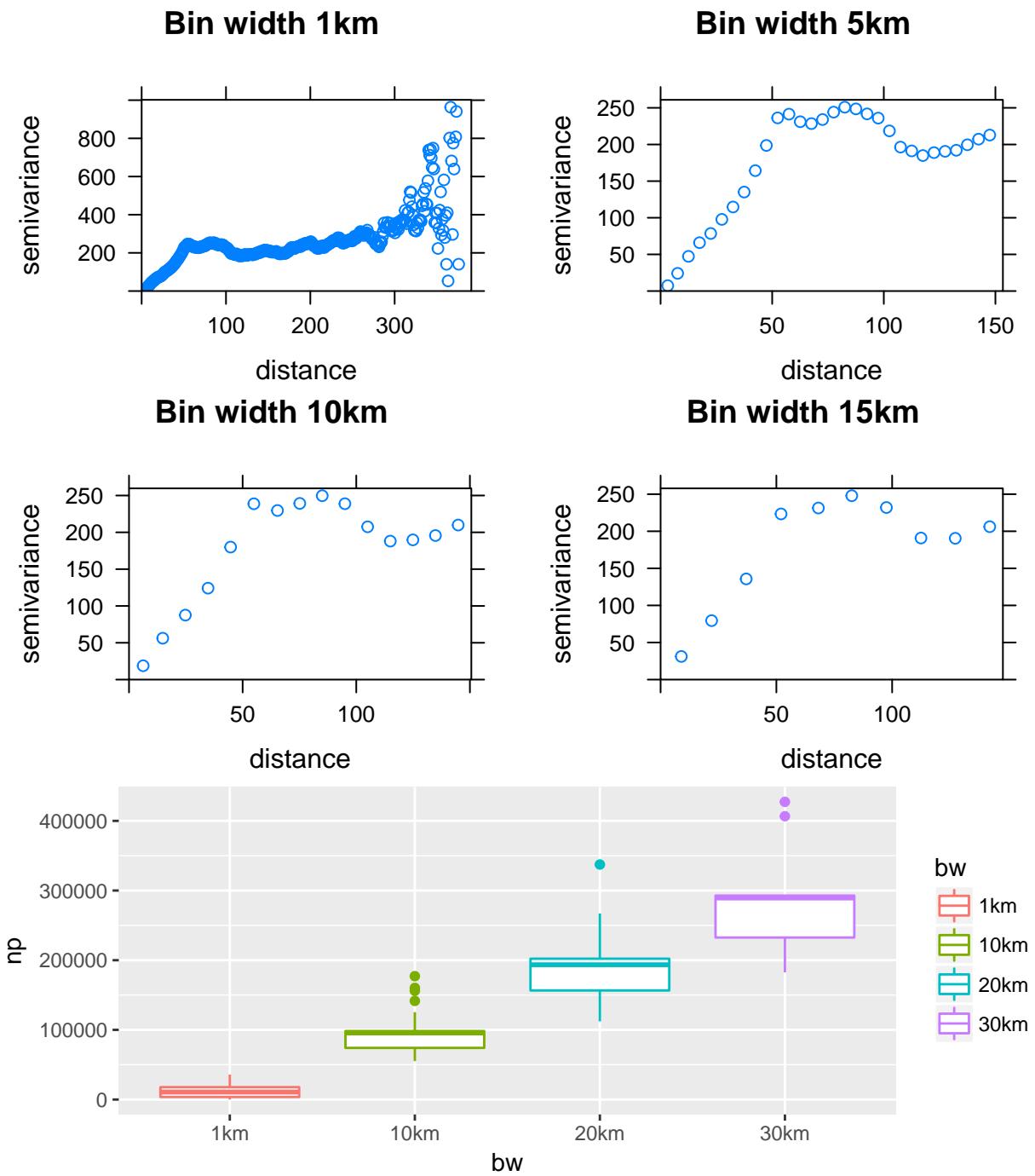


2.2 Empirical Variogram

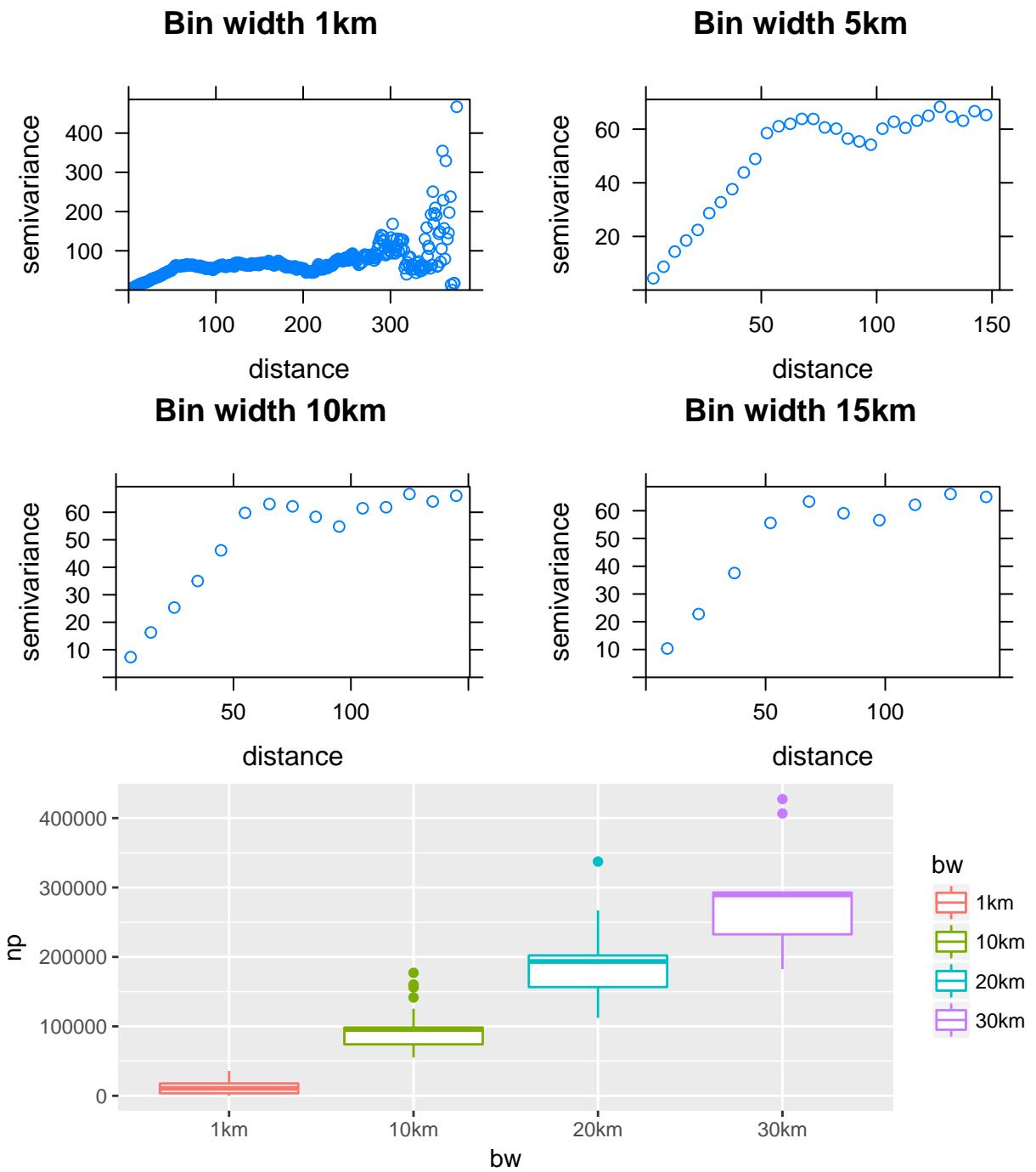
2.2.1 Winter before 1970



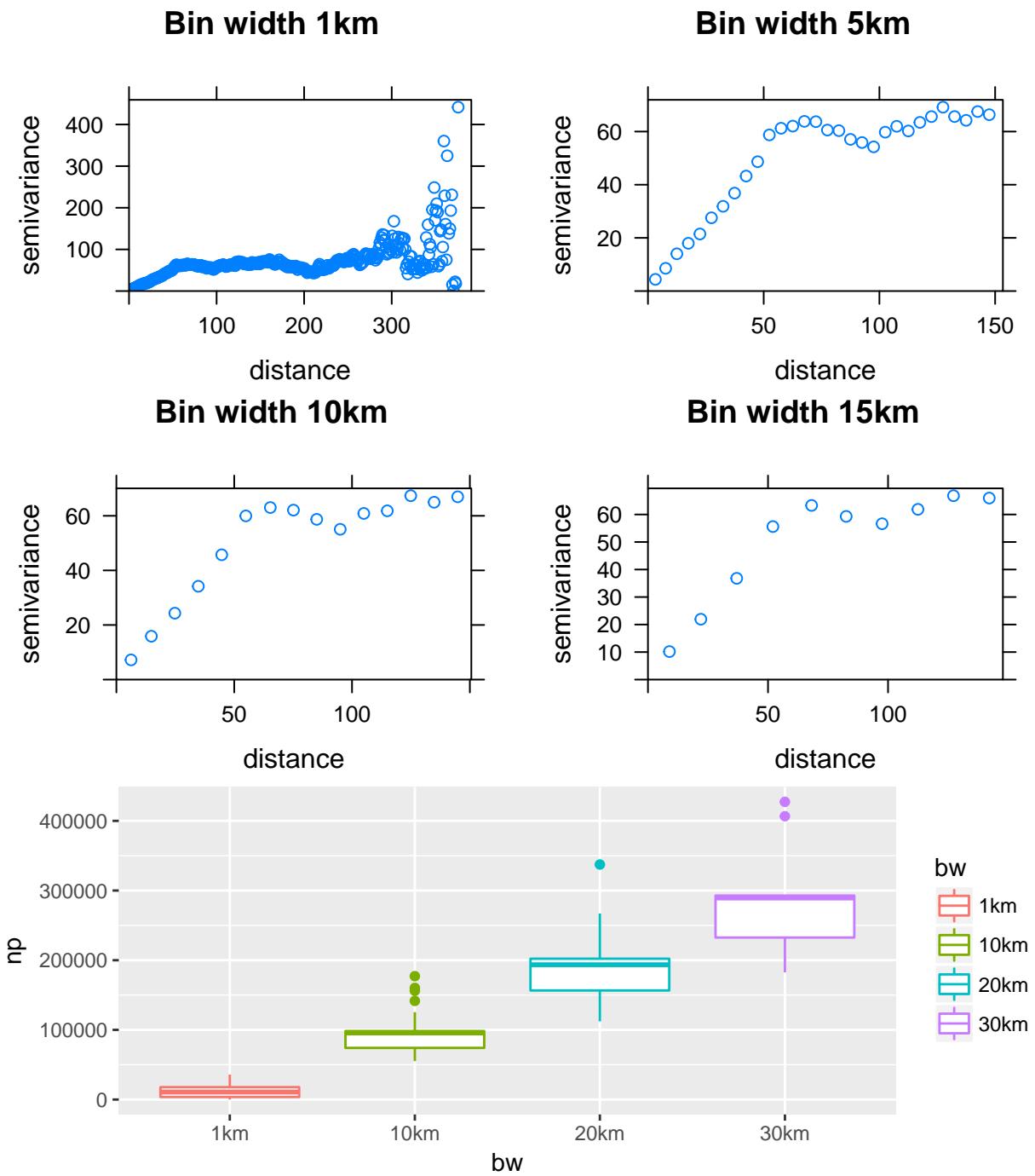
2.2.2 Winter after 1990



2.2.3 Summer before 1970



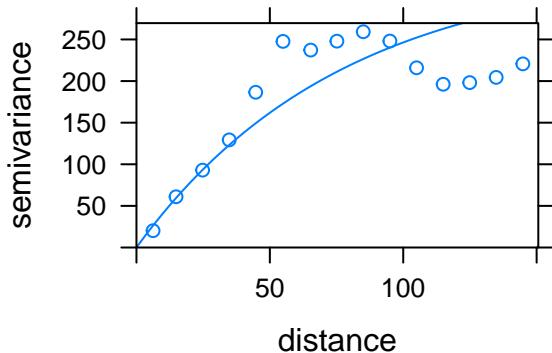
2.2.4 Summer after 1990



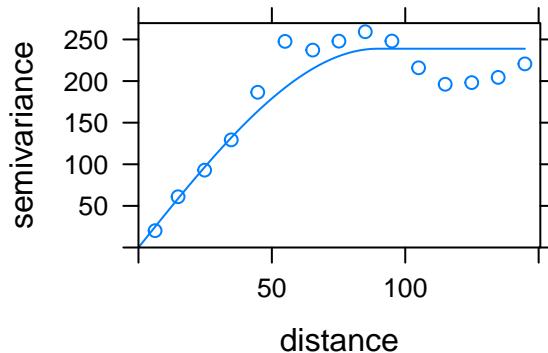
2.3 Fitted Semivariogram

2.3.1 Winter before 1970

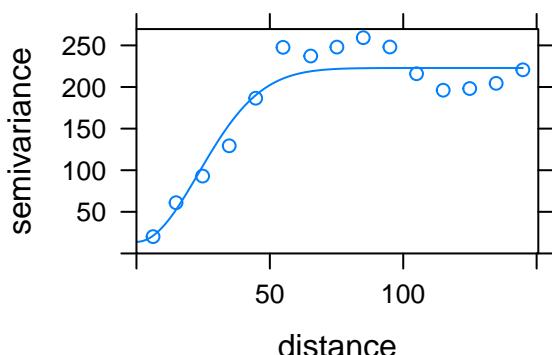
Exponential: 10km



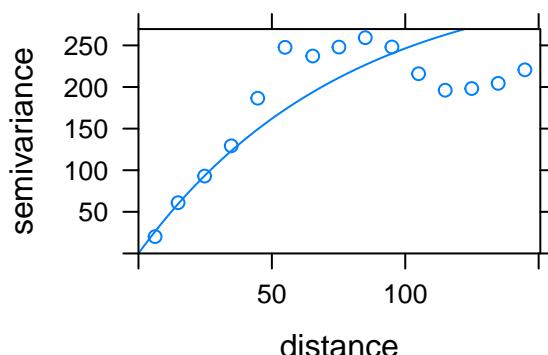
Spherical: 10km



Gaussian: 10km

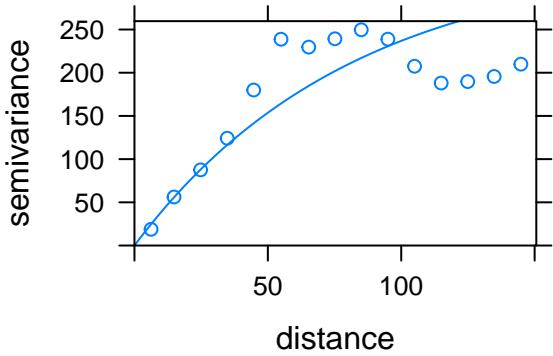


Mat: 10km

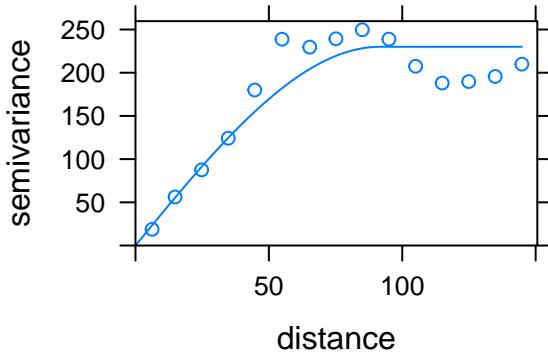


2.3.2 Winter after 1990

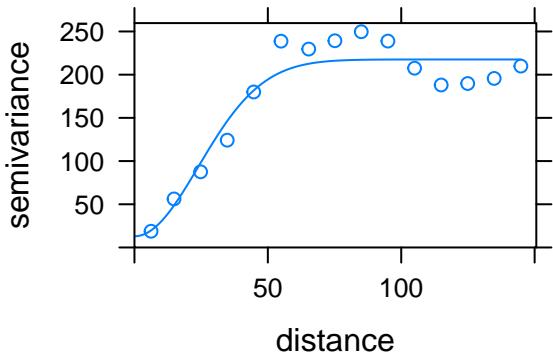
Exponential: 10km



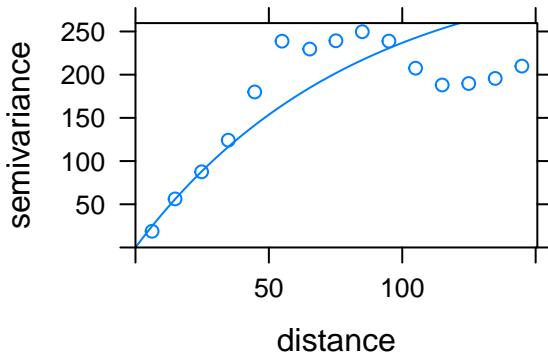
Spherical: 10km



Gaussian: 10km

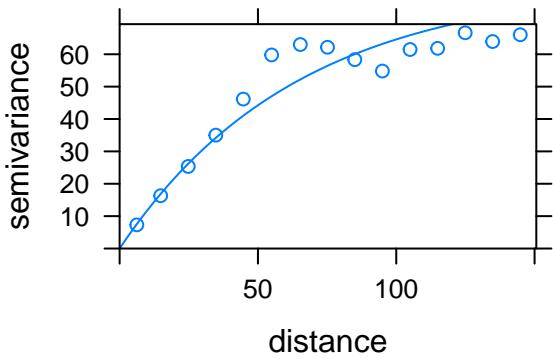


Mat: 10km

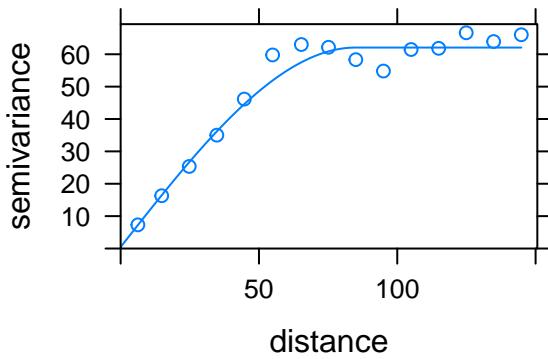


2.3.3 Summer before 1970

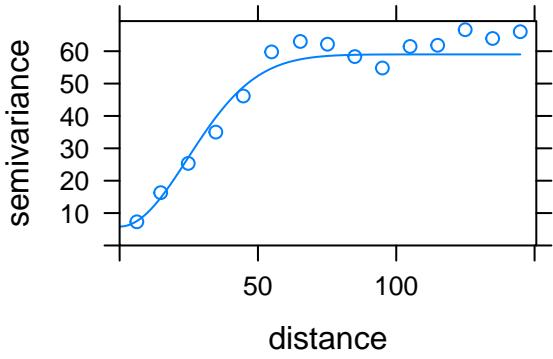
Exponential: 10km



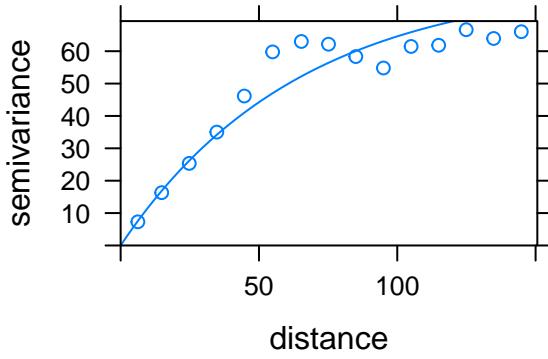
Spherical: 10km



Gaussian: 10km

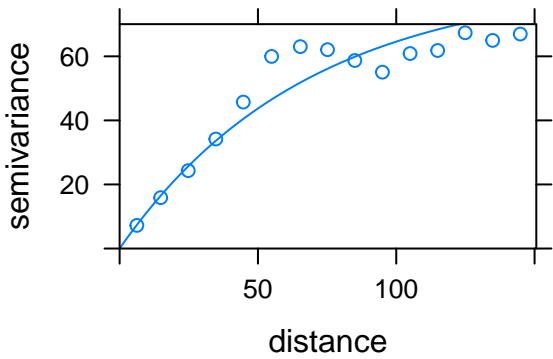


Mat: 10km

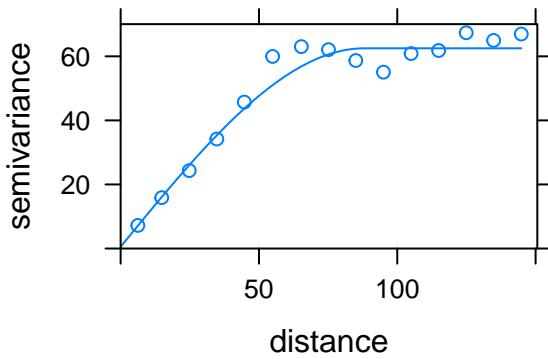


2.3.4 Summer after 1990

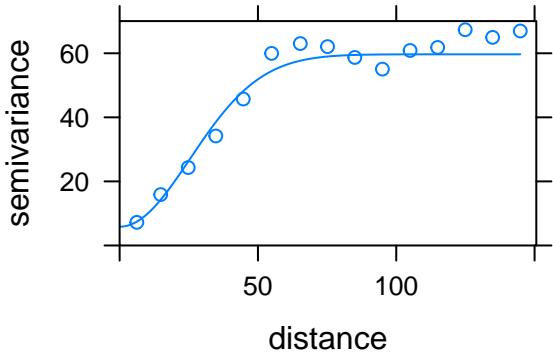
Exponential: 10km



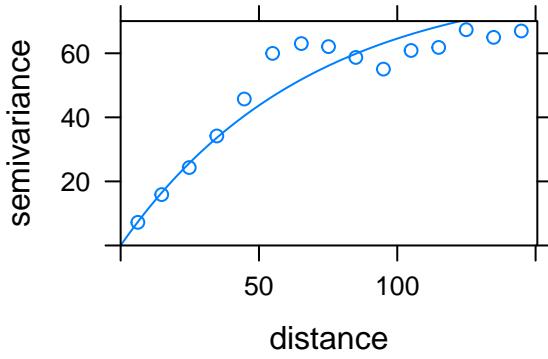
Spherical: 10km



Gaussian: 10km

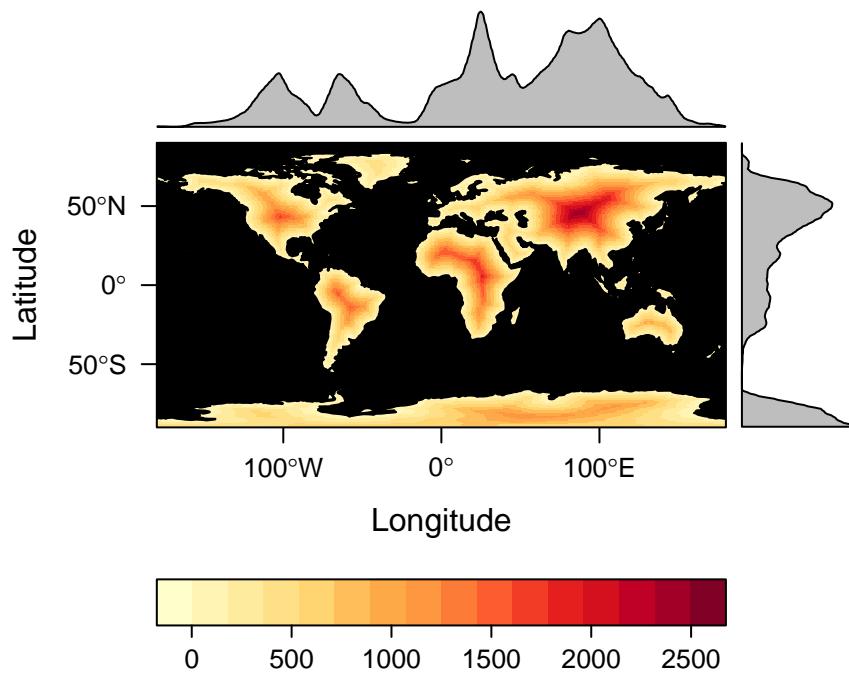


Mat: 10km

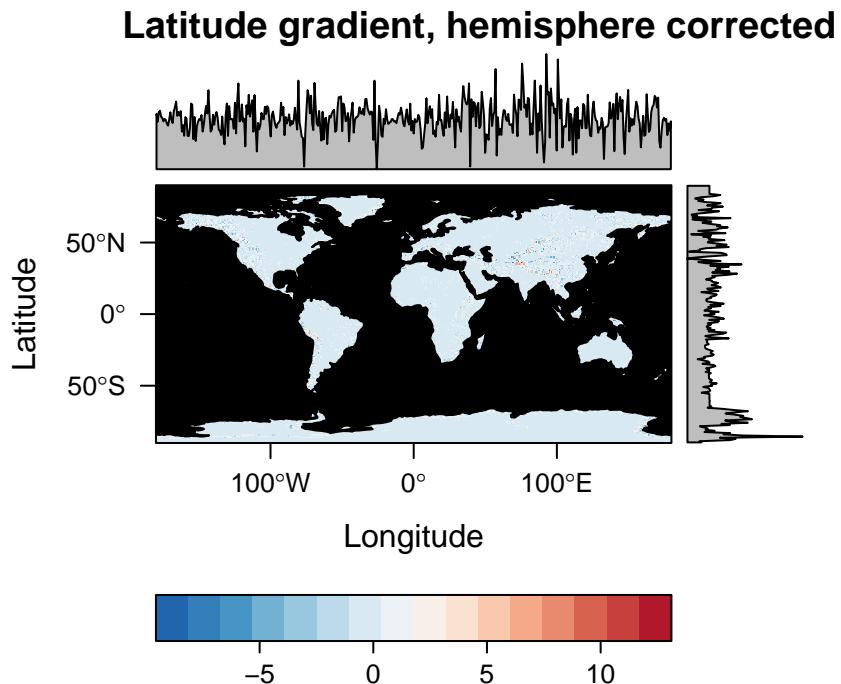


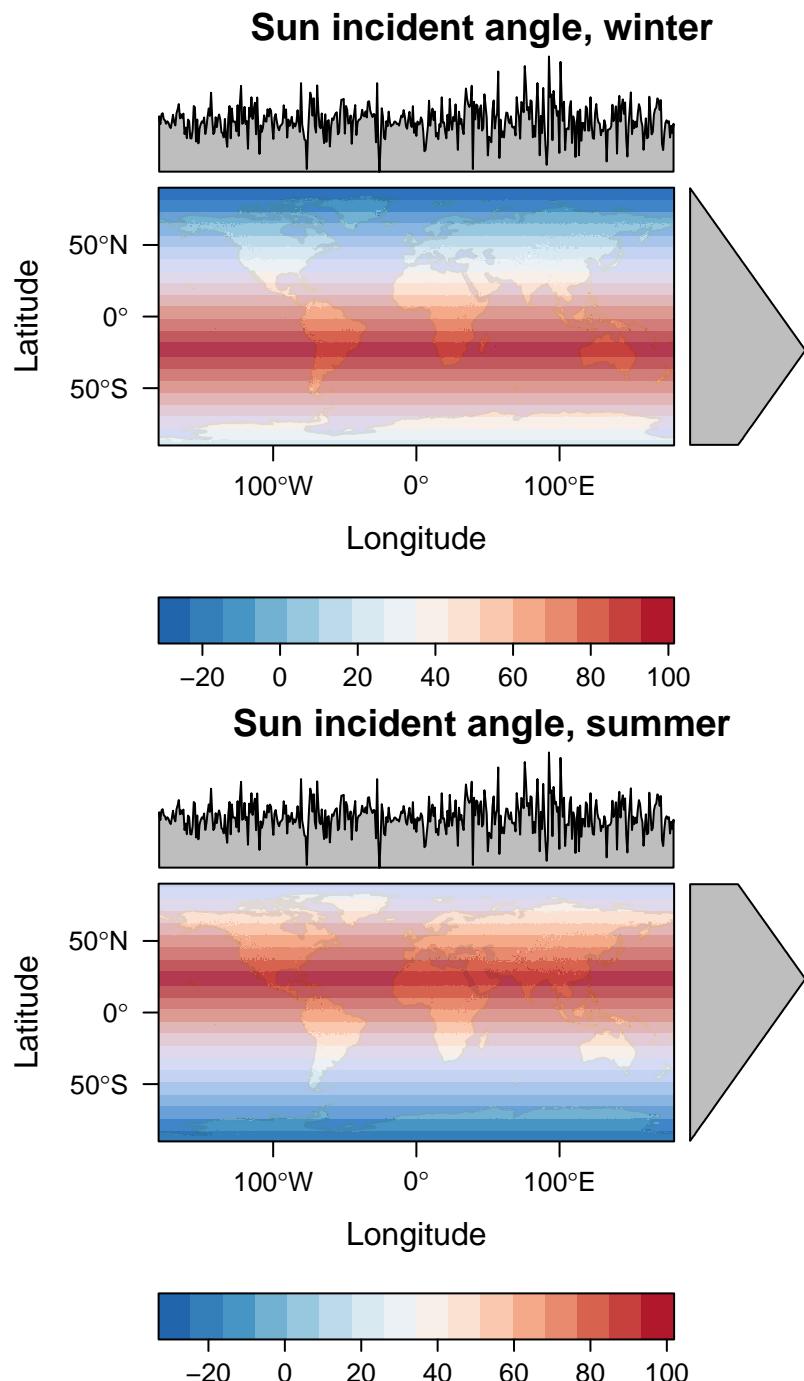
3 Task II: Universal Kriging

3.1 Continentiality: Create distance to ocean layer



3.2 Sun incidence angle

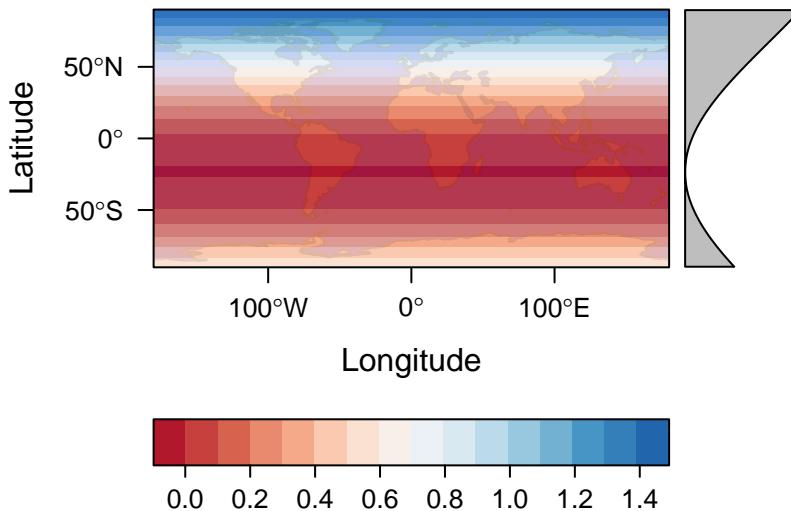




3.3 Atmospheric distance

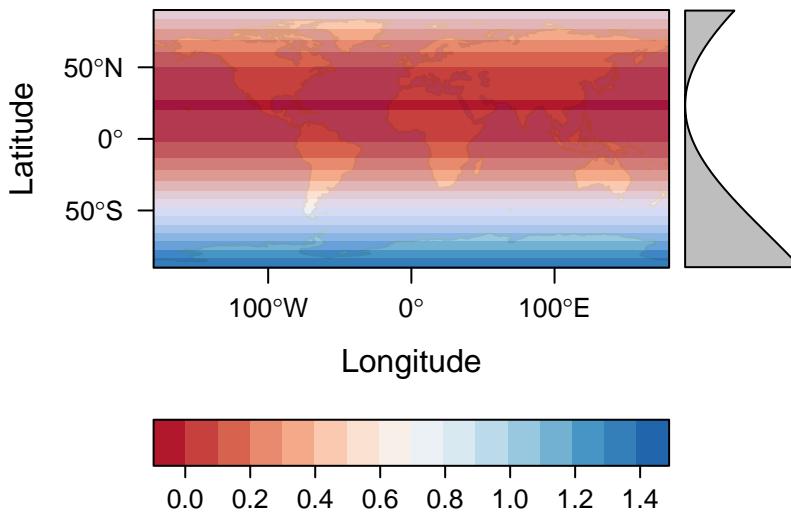
```
## Warning in min(x): kein nicht-fehlendes Argument für min; gebe Inf zurück  
## Warning in max(x): kein nicht-fehlendes Argument für max; gebe -Inf zurück
```

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

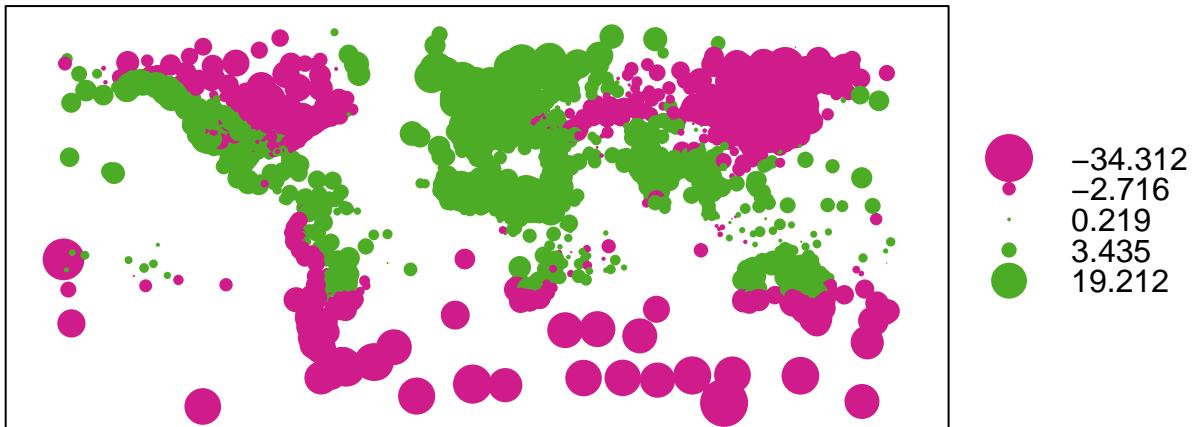


3.4 Interpolation

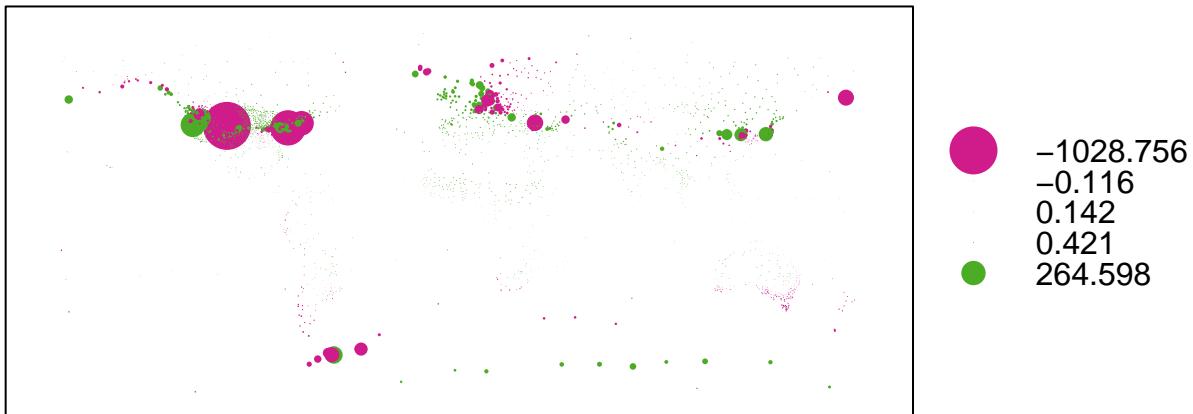
3.4.1 Winter before 1970

```
##  
## Call:  
## lm(formula = meansum ~ elev + cont + hsun + dist, data = temp1970w@data)  
##  
## Residuals:  
##      Min       1Q   Median       3Q      Max  
## -34.312  -2.716   0.219   3.435  19.212  
##  
## Coefficients:  
##              Estimate    Std. Error t value Pr(>|t|)  
## (Intercept) 52.6173520157 1.5666267823 33.59 <2e-16 ***  
## elev        -0.0023841205 0.0001941377 -12.28 <2e-16 ***  
## cont        -0.0000047890 0.0000002497 -19.18 <2e-16 ***  
## hsun        -0.3151416644 0.0203485538 -15.49 <2e-16 ***  
## dist        -71.7342020134 1.7897476161 -40.08 <2e-16 ***  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Residual standard error: 5.386 on 2873 degrees of freedom  
## Multiple R-squared:  0.8518, Adjusted R-squared:  0.8516  
## F-statistic: 4127 on 4 and 2873 DF, p-value: < 2.2e-16
```

Residual Values

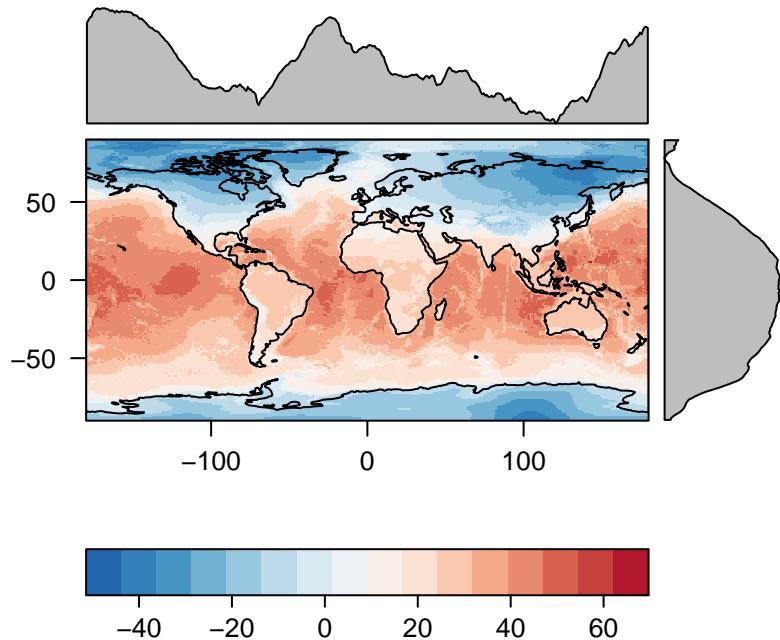


Relative Residual Values

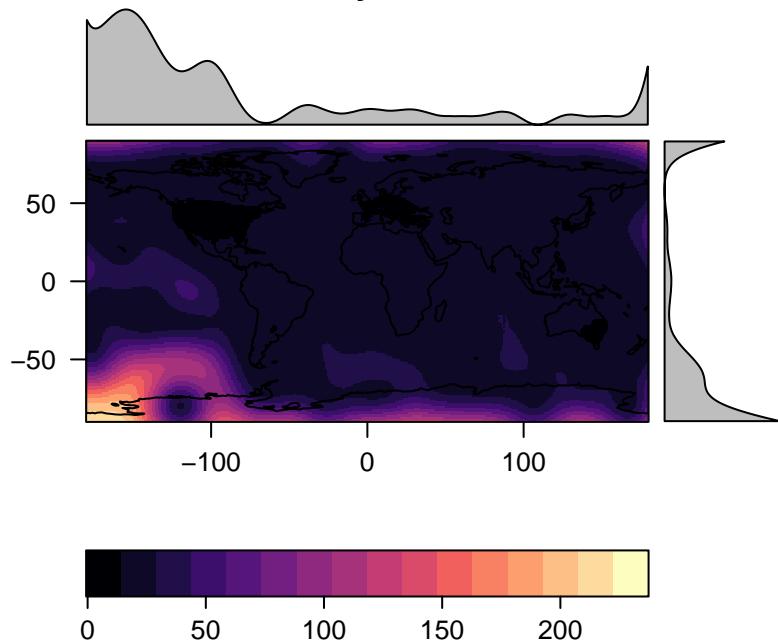


```
## [1] "Observed autocorrelation: 0.201319217138784"  
## [1] "P-value of H0 (residuals are randomly distributed): 0"  
## [using universal kriging]  
## [1] "Observed RMSE (5% validation data): 2.83°C"
```

Prediction: Winter before 1970



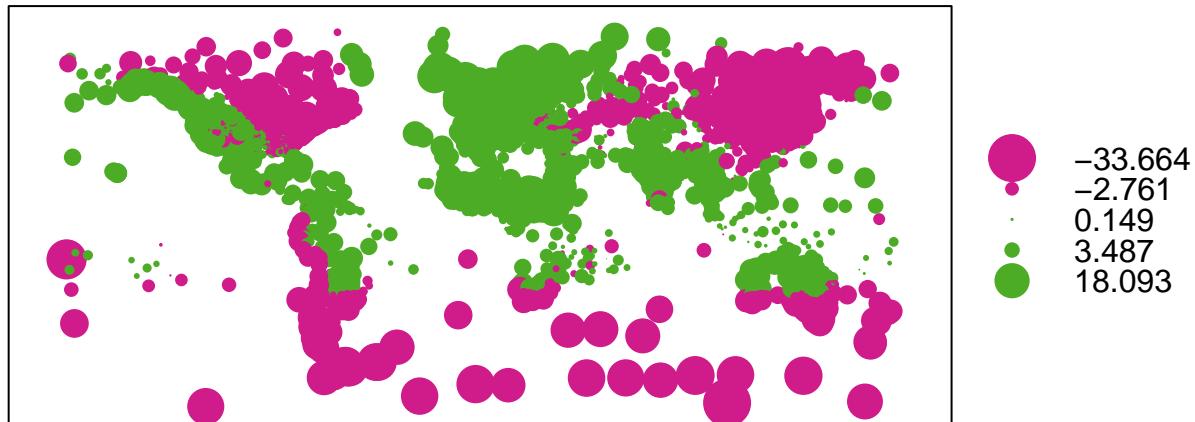
Uncertainty: Winter before 1970



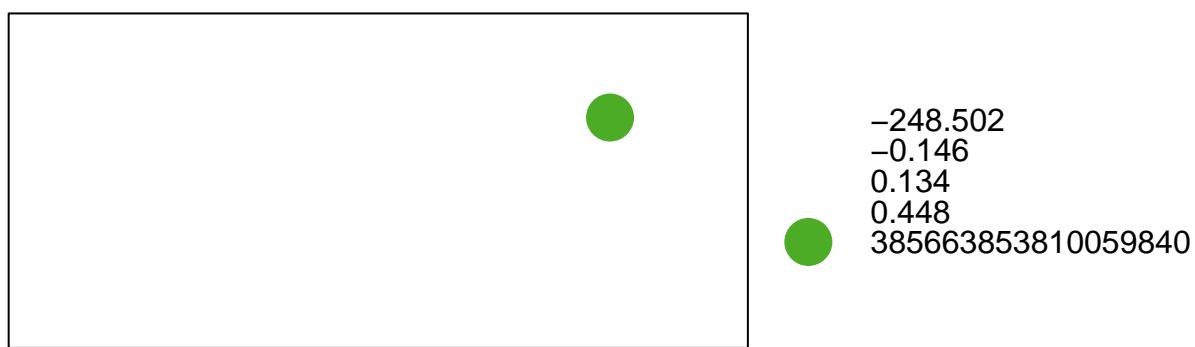
3.4.2 Winter after 1990

```
##
## Call:
## lm(formula = meansum ~ elev + cont + hsun + dist, data = temp2010w@data)
##
## Residuals:
##    Min     1Q Median     3Q    Max 
## -33.664 -2.761  0.149  3.487 18.093 
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 50.9587627810  1.5564482620   32.74 <2e-16 ***
## elev        -0.0024013788  0.0001928764  -12.45 <2e-16 ***
## cont        -0.0000045058  0.0000002481  -18.16 <2e-16 *** 
## hsun        -0.2887840380  0.0202163473  -14.29 <2e-16 *** 
## dist       -68.6351162264  1.7781194589  -38.60 <2e-16 *** 
## ---        
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 
##
## Residual standard error: 5.351 on 2873 degrees of freedom
## Multiple R-squared:  0.8478, Adjusted R-squared:  0.8476 
## F-statistic: 4002 on 4 and 2873 DF, p-value: < 2.2e-16
```

Residual Values



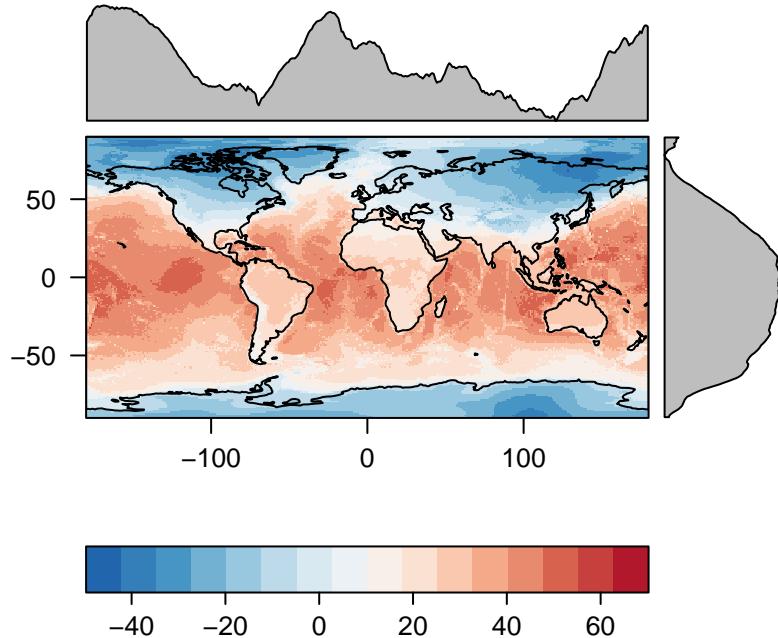
Relative Residual Values



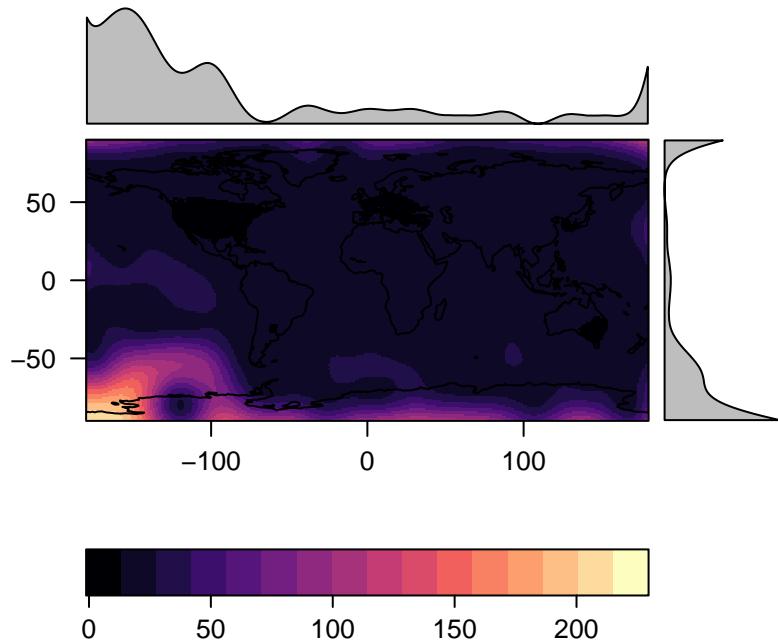
```
## [1] "Observed autocorrelation: 0.20278683798791"
```

```
## [1] "P-value of H0 (residuals are randomly distributed): 0"  
## [using universal kriging]  
## [1] "Observed RMSE (5% validation data): 2.88°C"
```

Prediction: Winter after 1990



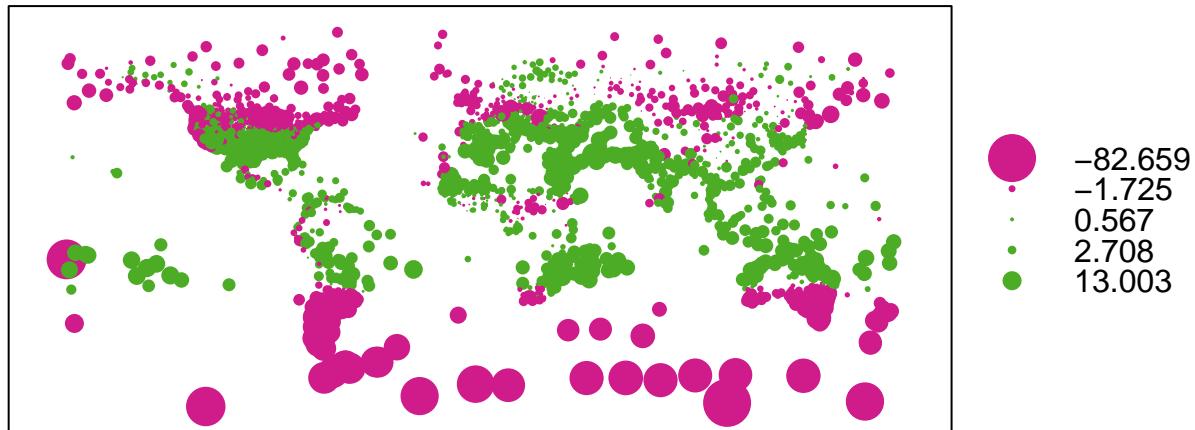
Uncertainty: Winter after 1990



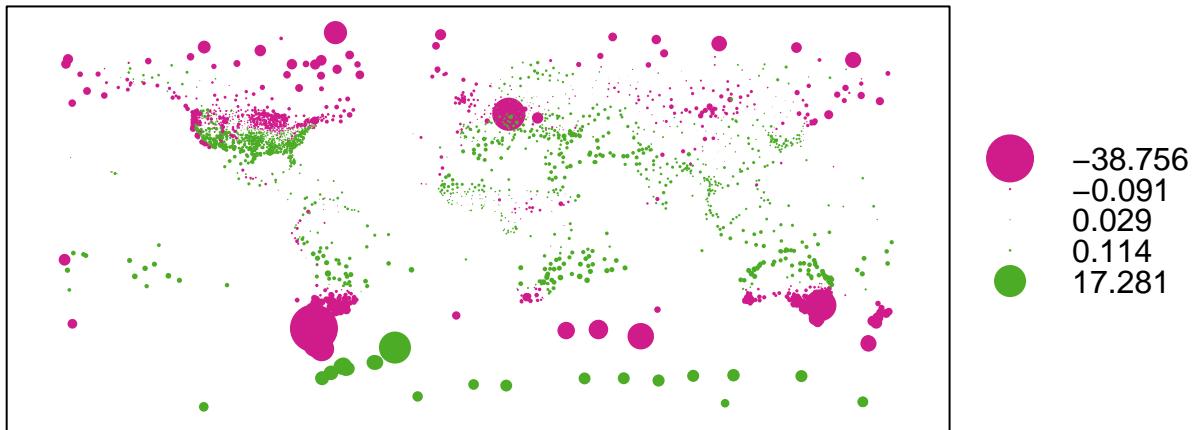
3.4.3 Summer before 1970

```
##
## Call:
## lm(formula = meansum ~ elev + cont + hsun + dist, data = temp1970s@data)
##
## Residuals:
##    Min     1Q Median     3Q    Max 
## -82.659 -1.725  0.567  2.708 13.003 
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 81.5654332813  1.6906062730   48.25 <2e-16 ***
## elev        -0.0030363189  0.0002095013  -14.49 <2e-16 ***
## cont         0.0000030760  0.0000002695   11.41 <2e-16 *** 
## hsun        -0.8022060239  0.0219588948  -36.53 <2e-16 *** 
## dist       -70.6938622722  1.9313844121  -36.60 <2e-16 *** 
## ---        
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 5.812 on 2873 degrees of freedom
## Multiple R-squared:  0.3535, Adjusted R-squared:  0.3526 
## F-statistic: 392.7 on 4 and 2873 DF,  p-value: < 2.2e-16
```

Residual Values

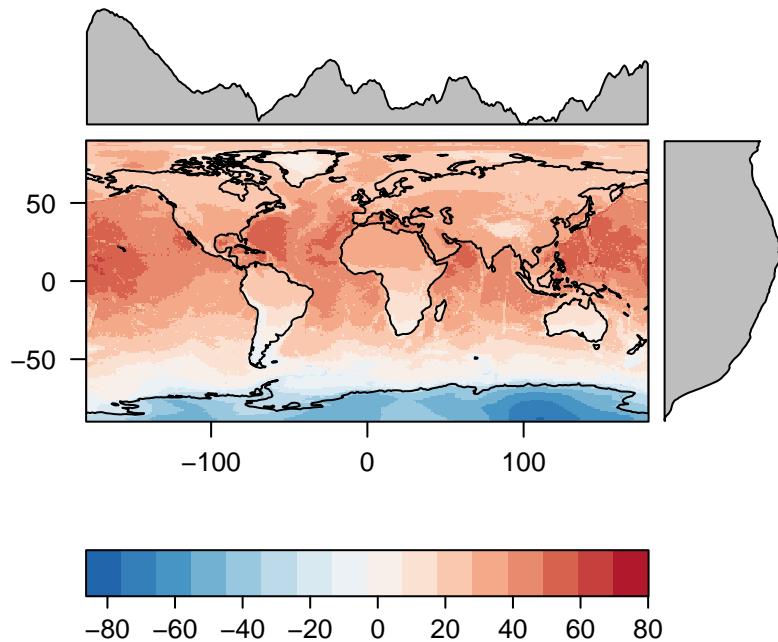


Relative Residual Values

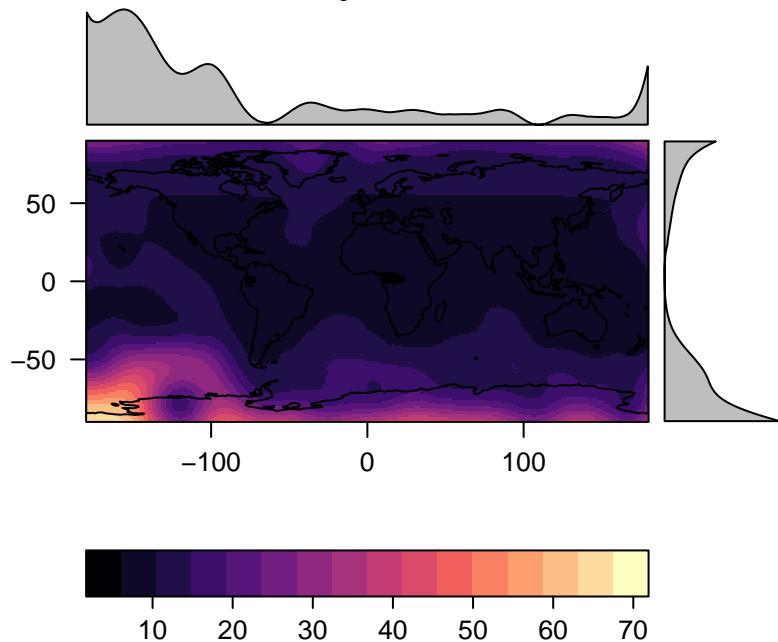


```
## [1] "Observed autocorrelation: 0.138510678007933"  
## [1] "P-value of H0 (residuals are randomly distributed): 0"  
## [using universal kriging]  
## [1] "Observed RMSE (5% validation data): 9.07°C"
```

Prediction: Summer before 1970



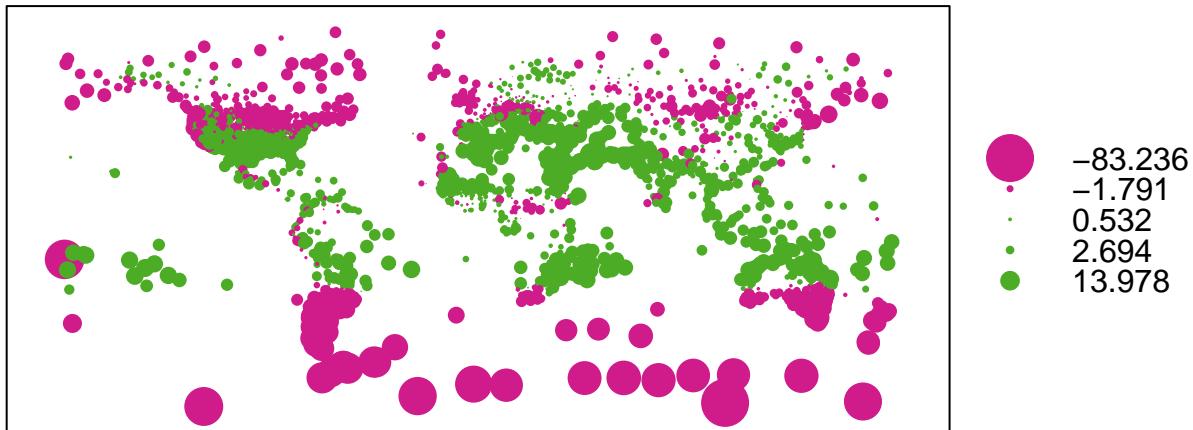
Uncertainty: Summer before 1970



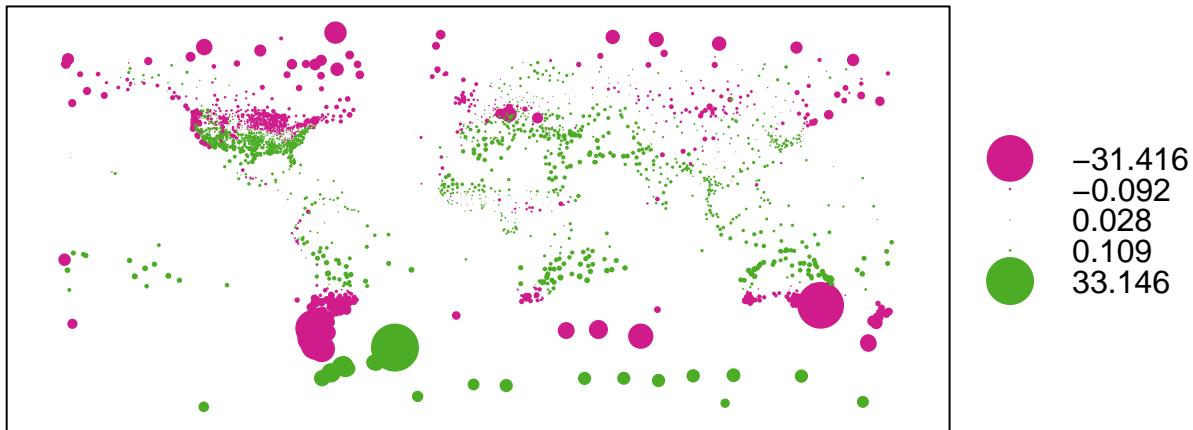
3.4.4 Summer after 1990

```
##
## Call:
## lm(formula = meansum ~ elev + cont + hsun + dist, data = temp2010s@data)
##
## Residuals:
##    Min     1Q Median     3Q    Max 
## -83.236 -1.791  0.532  2.694 13.978 
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 81.6720146632  1.6981369109   48.09 <2e-16 ***
## elev        -0.0028814804  0.0002104345  -13.69 <2e-16 ***
## cont         0.00000027386 0.0000002707   10.12 <2e-16 *** 
## hsun        -0.7950361539  0.0220567085  -36.05 <2e-16 *** 
## dist        -69.9937179967  1.9399875723  -36.08 <2e-16 *** 
## ---        
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 
##
## Residual standard error: 5.838 on 2873 degrees of freedom
## Multiple R-squared:  0.3429, Adjusted R-squared:  0.342 
## F-statistic: 374.8 on 4 and 2873 DF,  p-value: < 2.2e-16
```

Residual Values

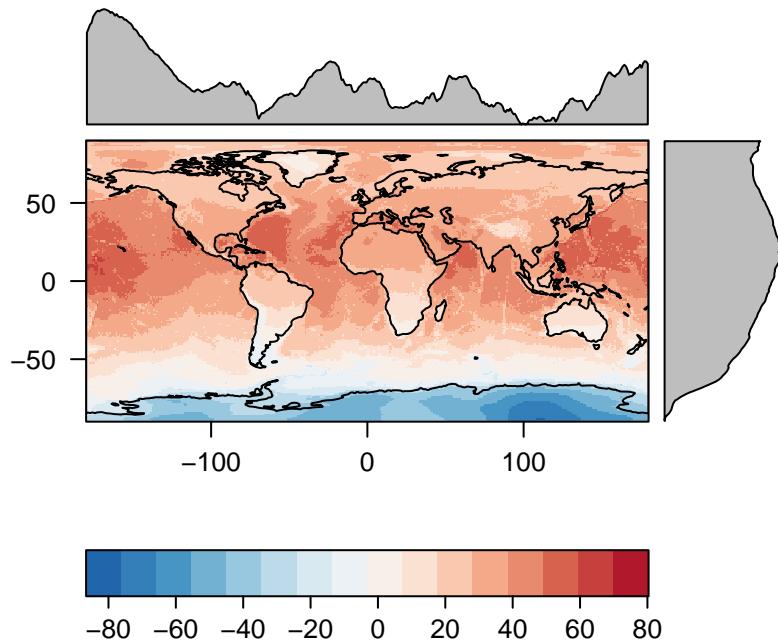


Relative Residual Values

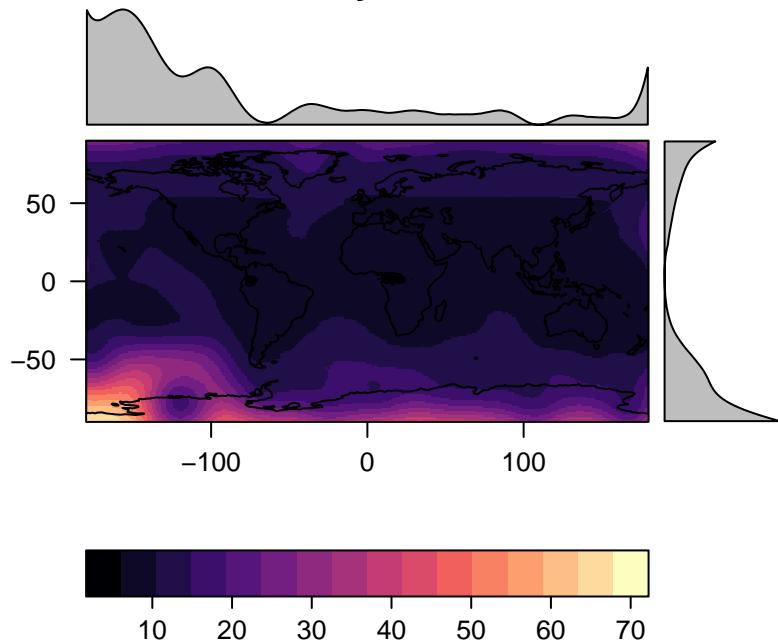


```
## [1] "Observed autocorrelation: 0.139044993897779"  
## [1] "P-value of H0 (residuals are randomly distributed): 0"  
## [using universal kriging]  
## [1] "Observed RMSE (5% validation data): 9.47°C"
```

Prediction: Summer after 1990

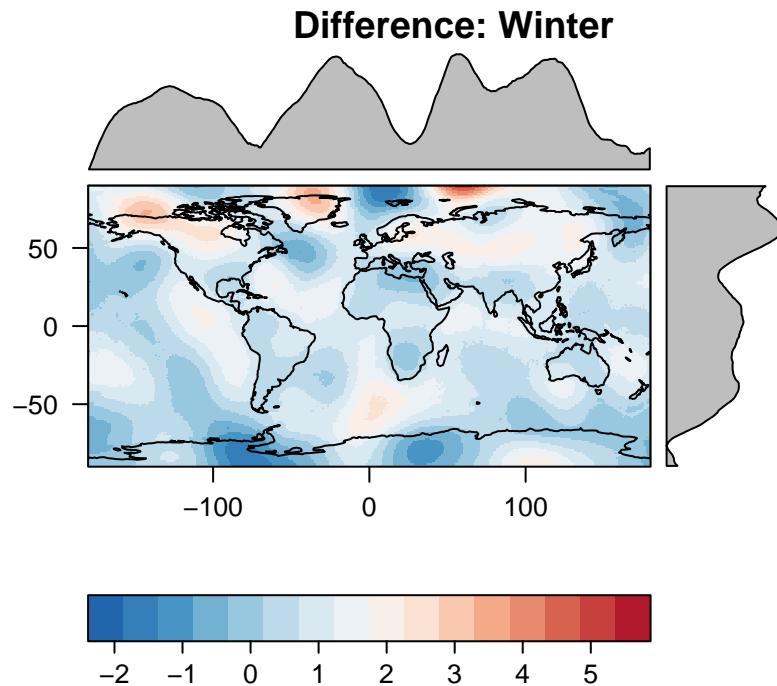


Uncertainty: Summer after 1990



4 Difference images

4.1 Winter



4.2 Summer

