

Challenge II: Spatial continuity and weather prediction

*Olivier Niklaus, Geography UZH
Merlin Unterfinger, Geography UZH*

25 6 2017

Abstract

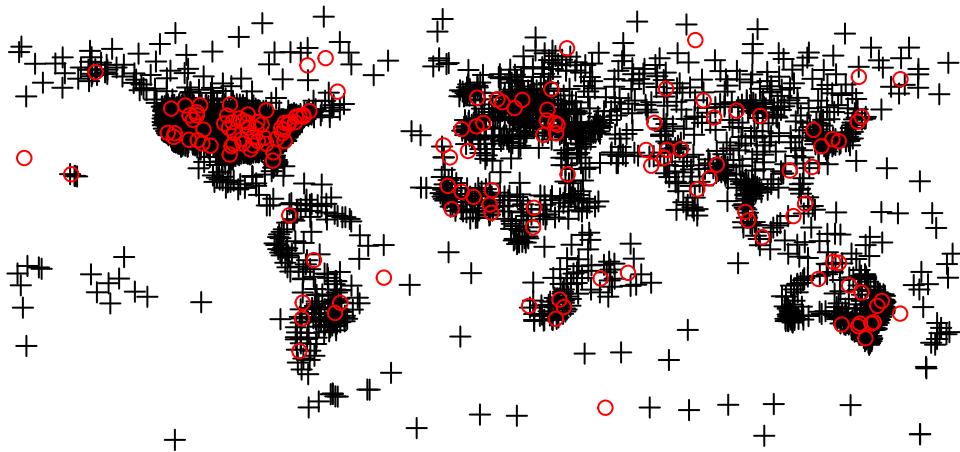
Spatial continuity of global temperature point measurements is analysed by creating H-Scatterplots, autocovariance plots and variograms. Universal Kriging is applied to interpolate global temperature maps from point measurements. Global layers of elevation, sun incidence angle, atmospheric distance and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

Contents

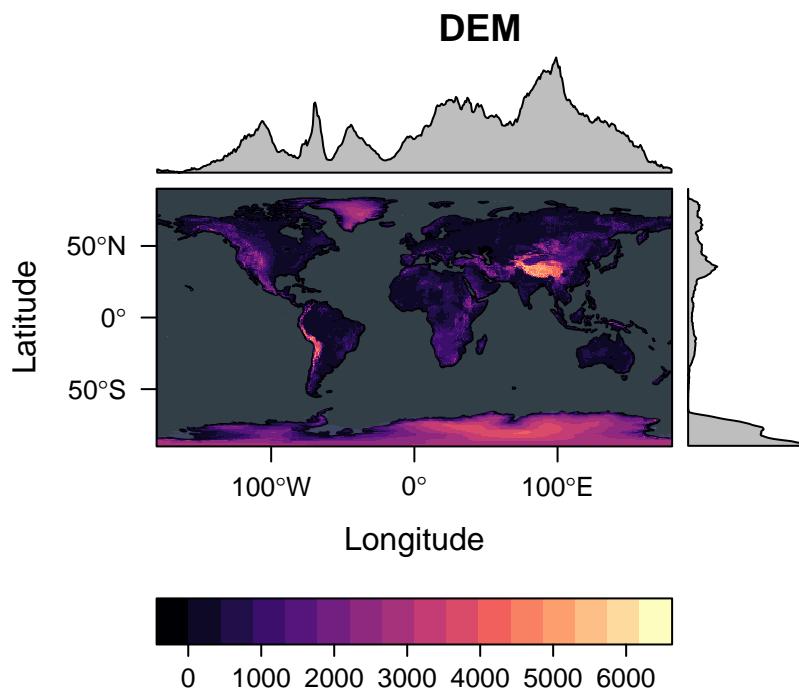
1 Data	2
2 TaskI: Spatial continuity	3
2.1 H - Scatterplots and autocovariance plots	3
2.1.1 Winter before 1970	3
2.1.2 Winter after 1990	4
2.1.3 Summer before 1970	5
2.1.4 Summer after 1990	6
2.2 Empirical Variogram	7
2.2.1 Winter before 1970	7
2.2.2 Winter after 1990	8
2.2.3 Summer before 1970	9
2.2.4 Summer after 1990	10
2.3 Fitted Semivariogram	11
2.3.1 Winter before 1970	11
2.3.2 Winter after 1990	12
2.3.3 Summer before 1970	13
2.3.4 Summer after 1990	14
3 Task II: Universal Kriging	15
3.1 Continentality: Create distance to ocean layer	15
3.2 Sun incidence angle	15
3.3 Atmospheric distance	17
3.4 Interpolation	18
3.4.1 Winter before 1970	18
3.4.2 Winter after 1990	21
3.4.3 Summer before 1970	23
3.4.4 Summer after 1990	26
4 Difference images	29
4.1 Winter	29
4.2 Summer	29

1 Data

All measurements and validation points



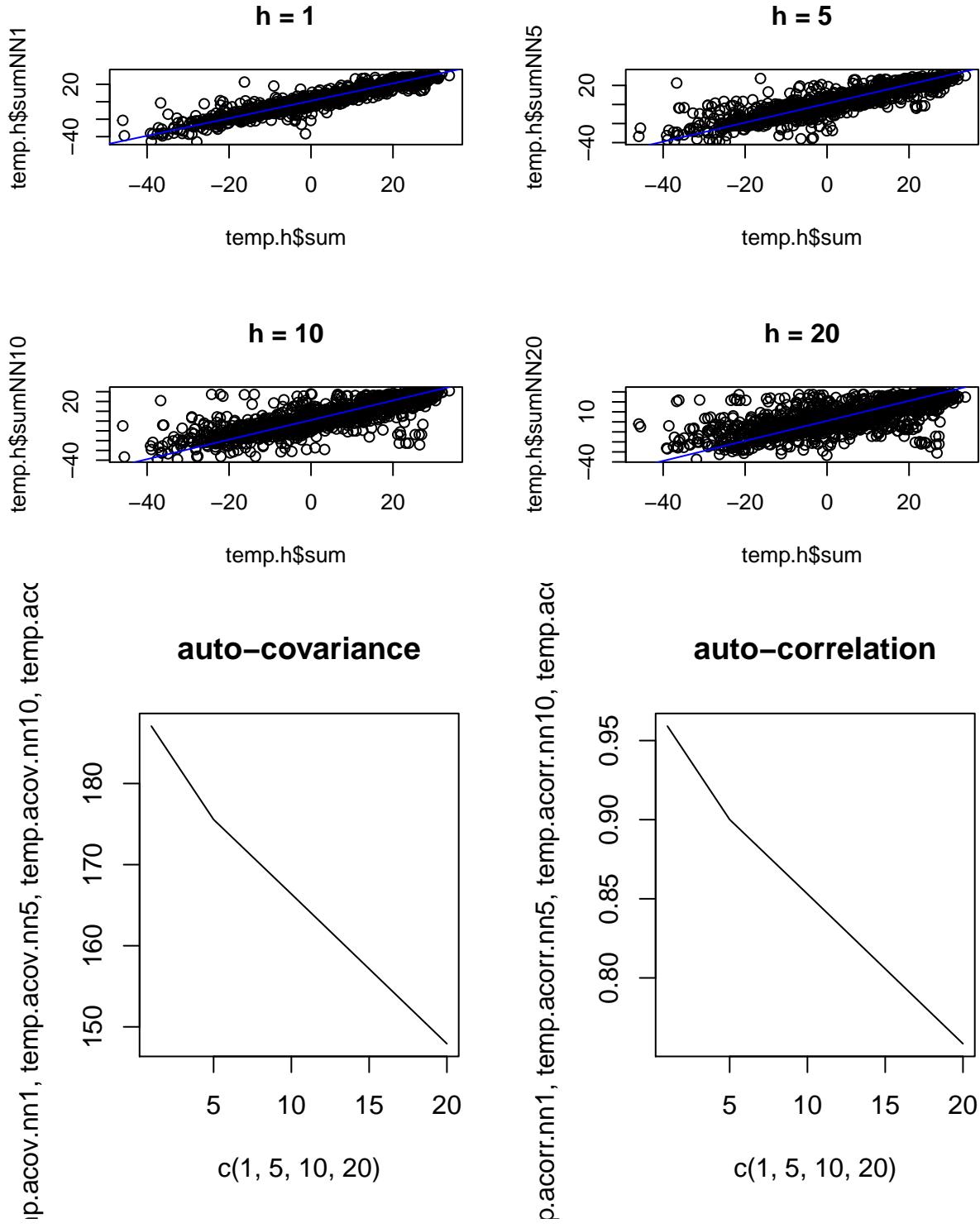
id	meanWi_before1970	meanSu_before1970	meanWi_after1990	meanSu_after1990	elev
1	11.83	23.27	13.09	24.75	7
2	10.21	22.43	11.35	23.94	4
3	10.83	22.78	11.32	24.76	25
4	10.30	22.00	11.44	24.02	2
5	6.13	22.37	7.00	24.56	694
6	8.14	24.90	9.35	26.15	715



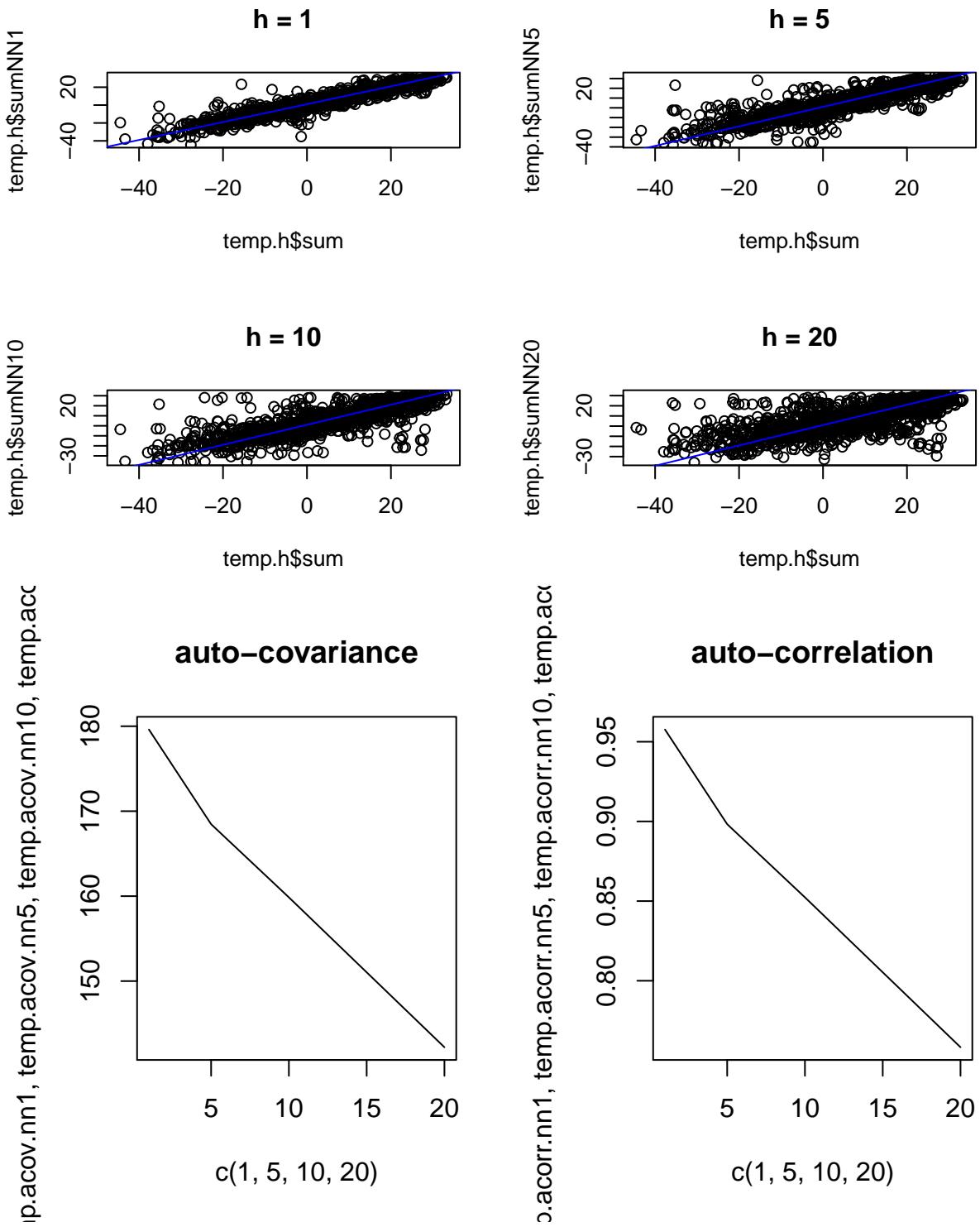
2 TaskI: Spatial continuity

2.1 H - Scatterplots and autocovariance plots

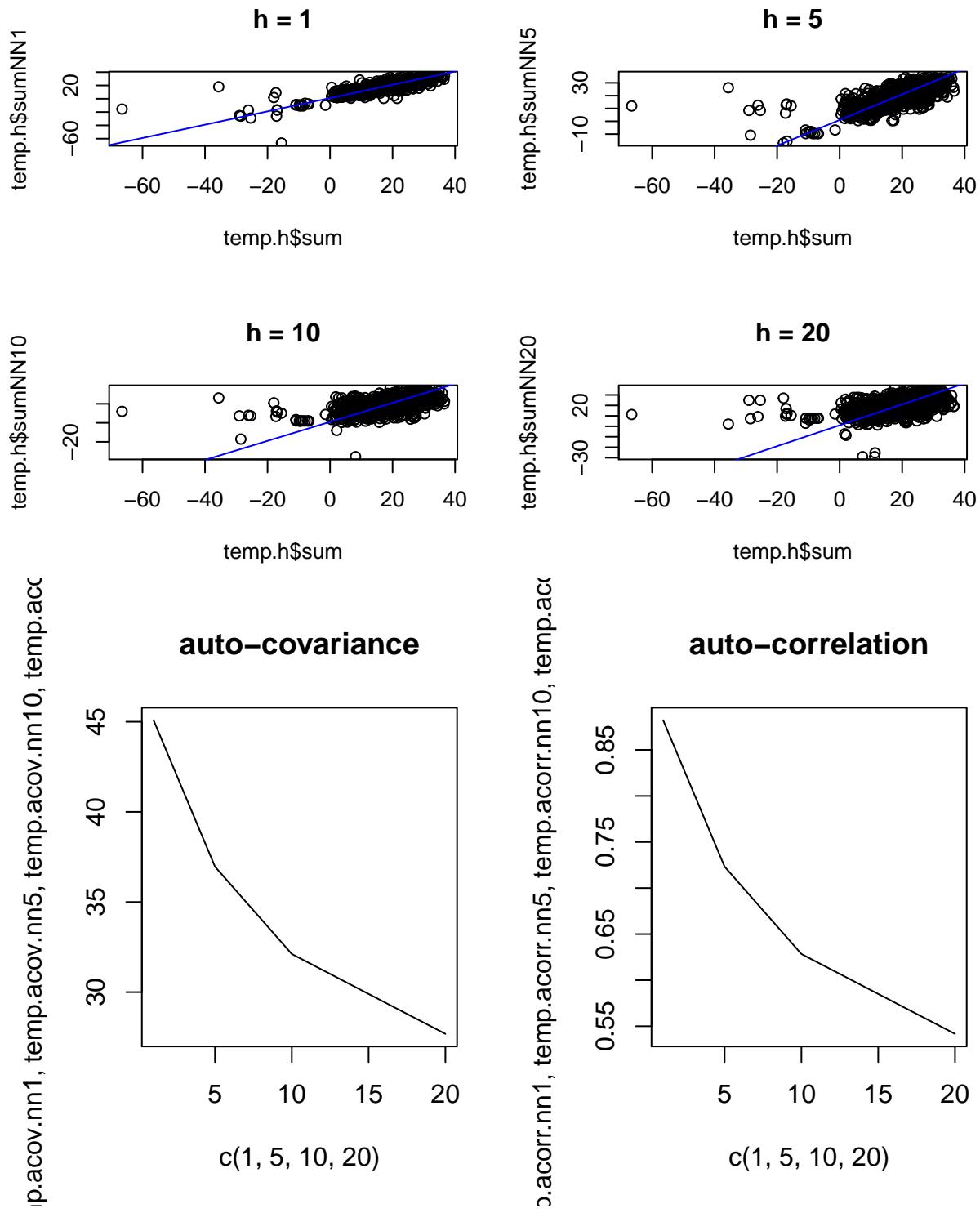
2.1.1 Winter before 1970



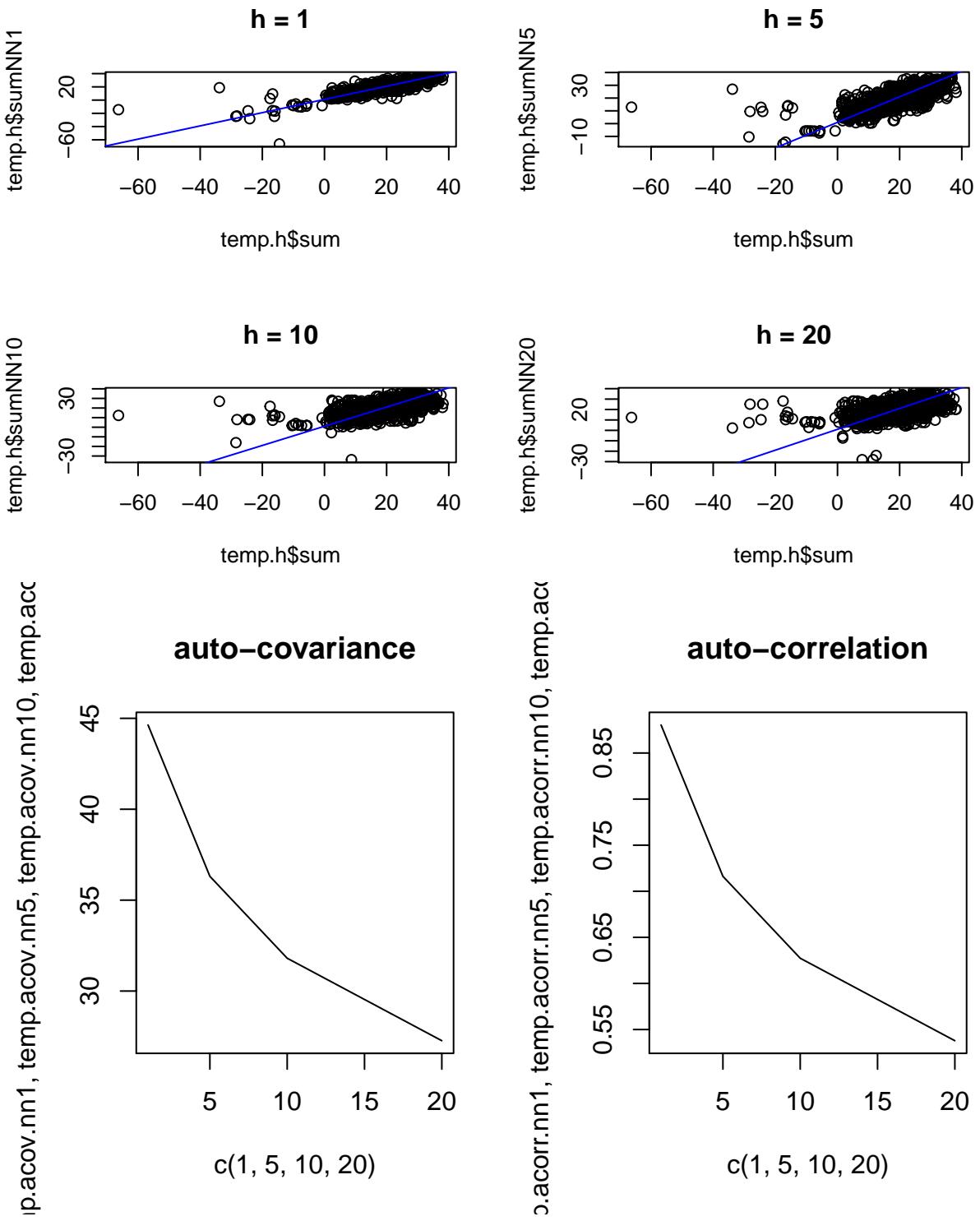
2.1.2 Winter after 1990



2.1.3 Summer before 1970

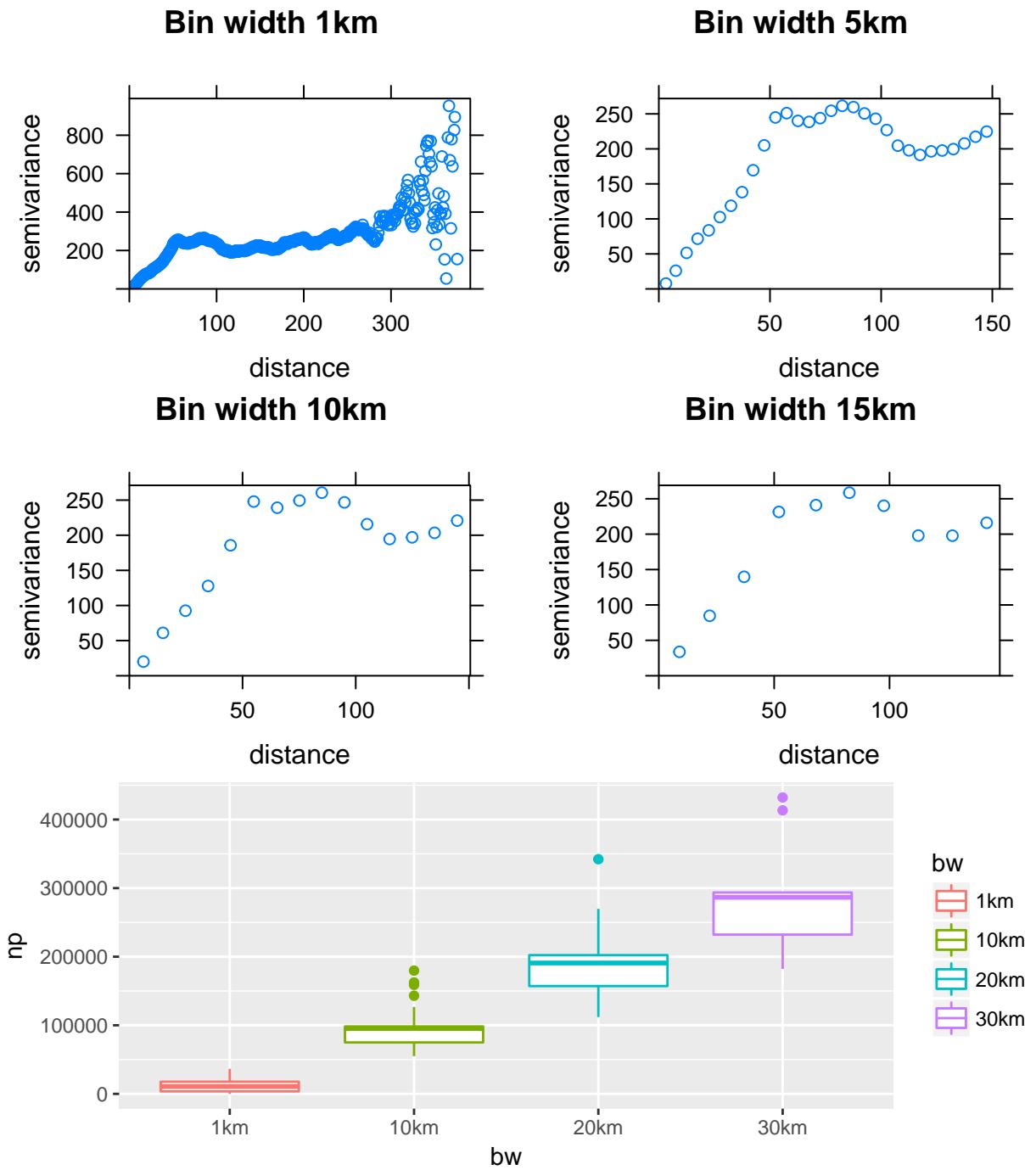


2.1.4 Summer after 1990

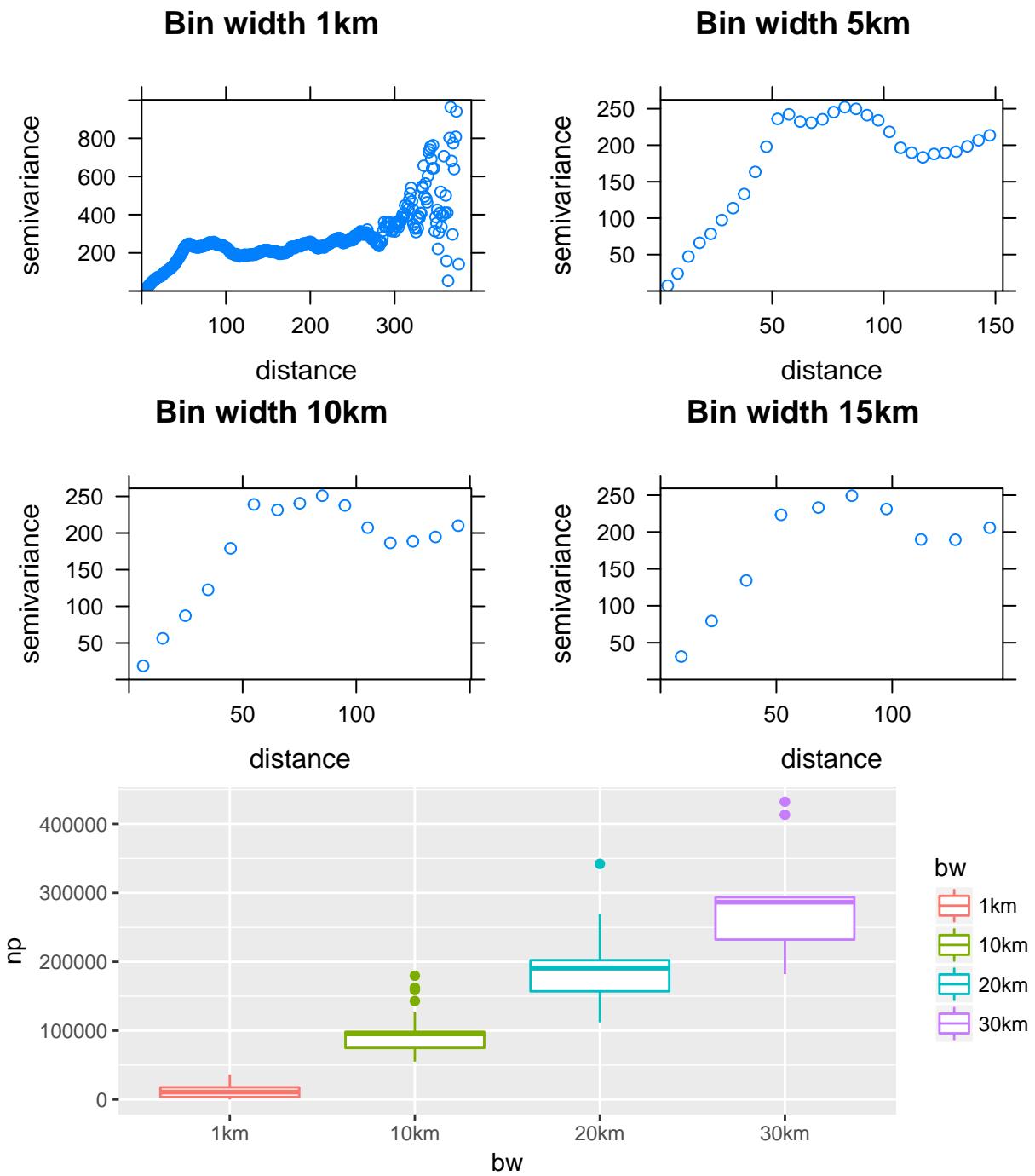


2.2 Empirical Variogram

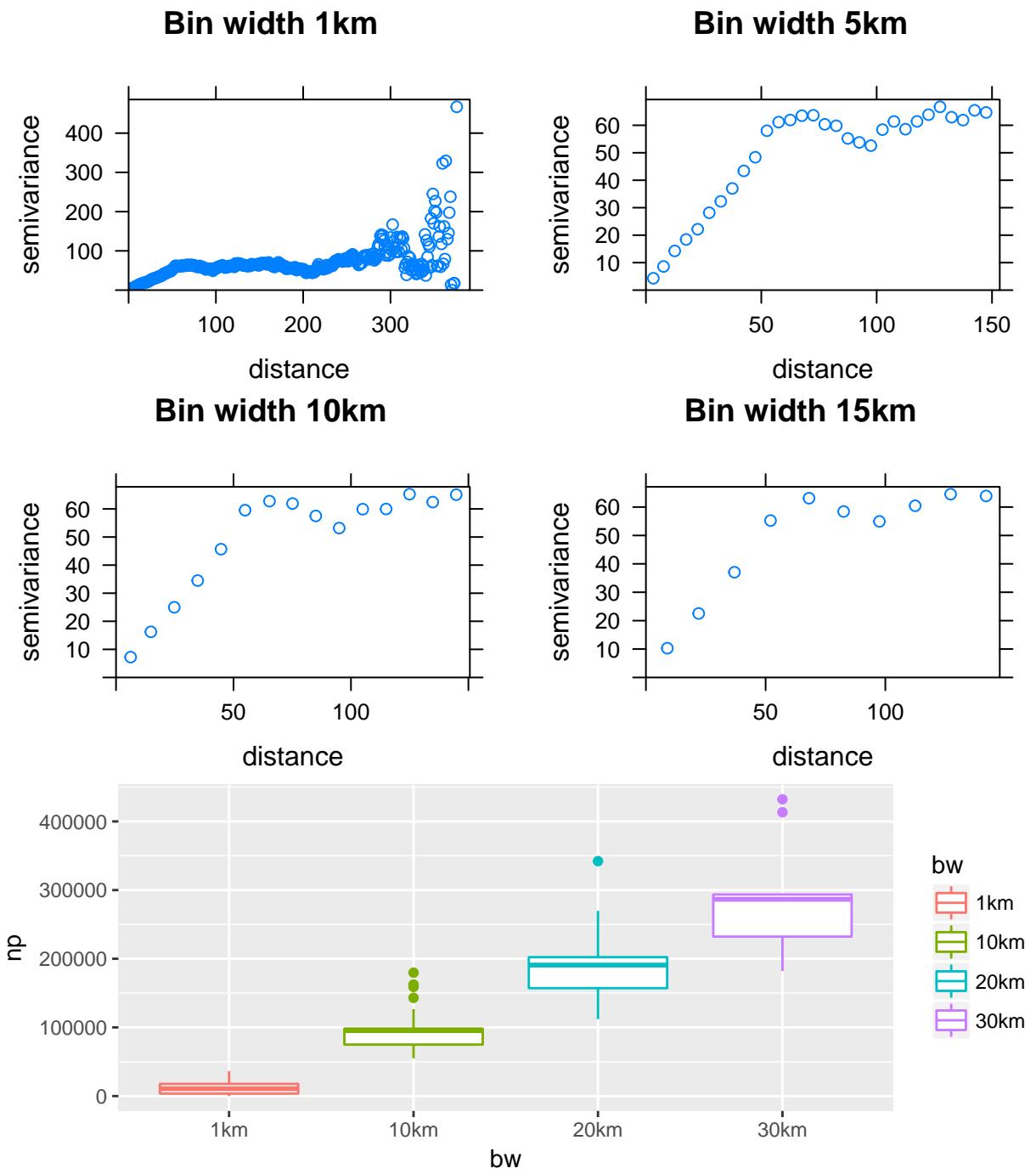
2.2.1 Winter before 1970



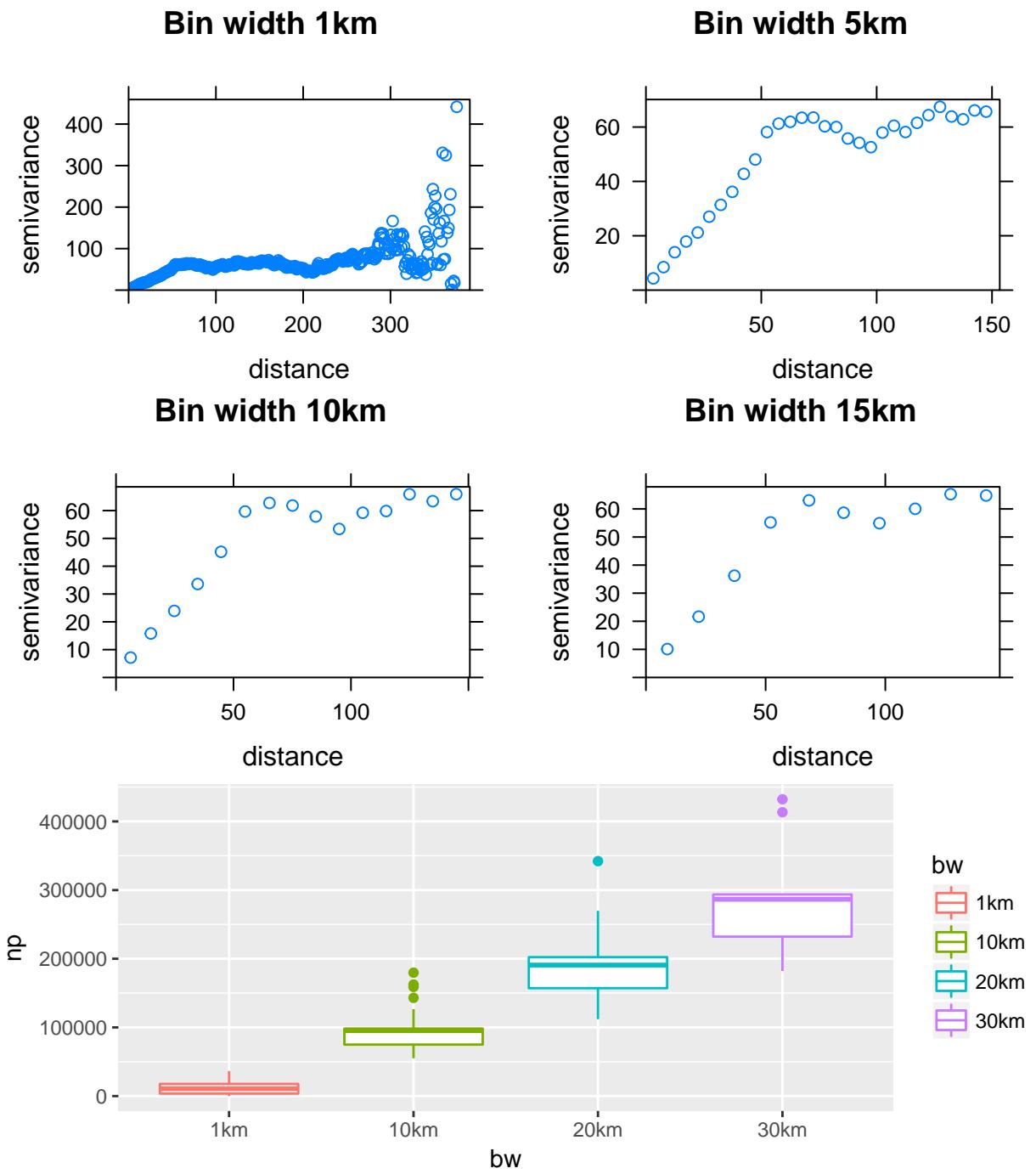
2.2.2 Winter after 1990



2.2.3 Summer before 1970



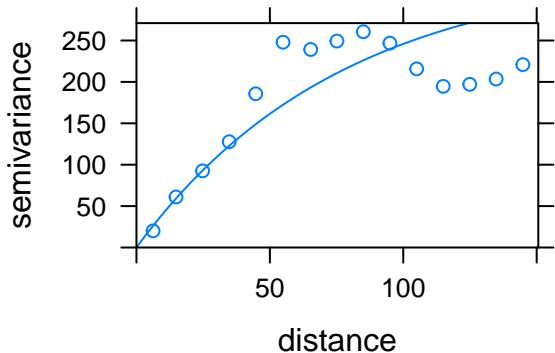
2.2.4 Summer after 1990



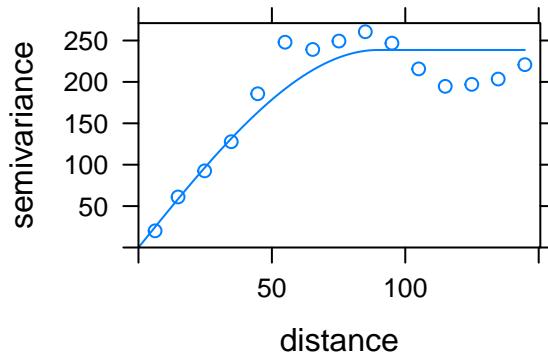
2.3 Fitted Semivariogram

2.3.1 Winter before 1970

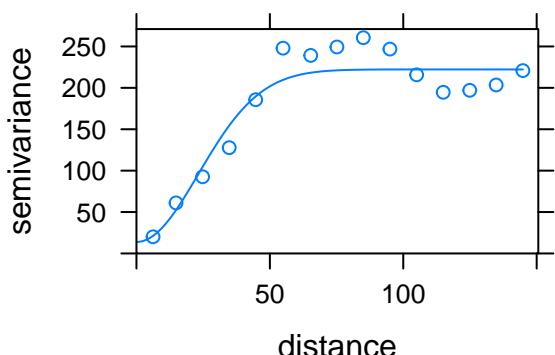
Exponential: 10km



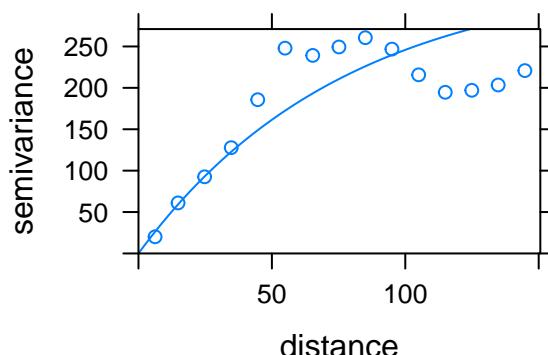
Spherical: 10km



Gaussian: 10km

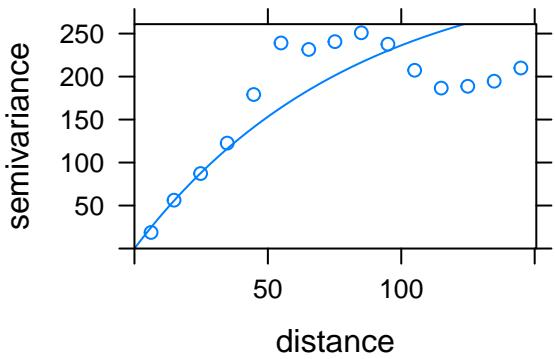


Mat: 10km

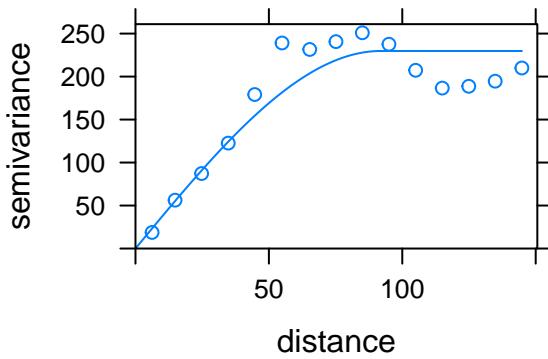


2.3.2 Winter after 1990

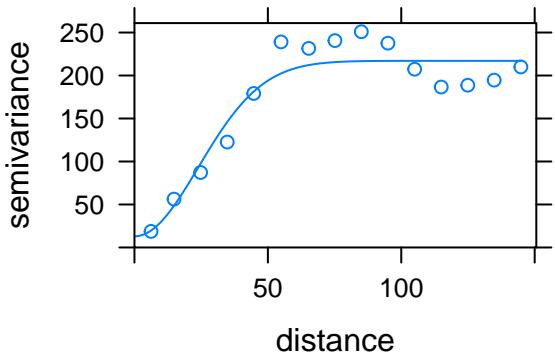
Exponential: 10km



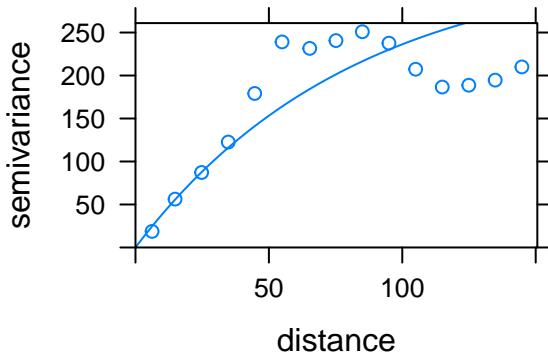
Spherical: 10km



Gaussian: 10km

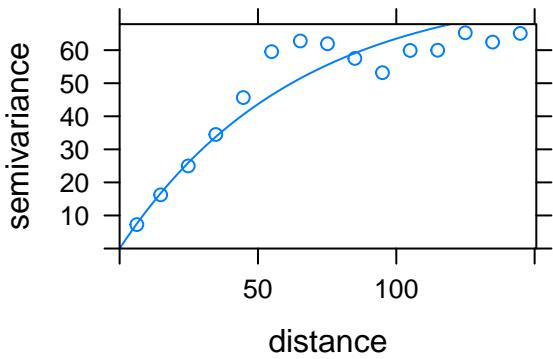


Mat: 10km

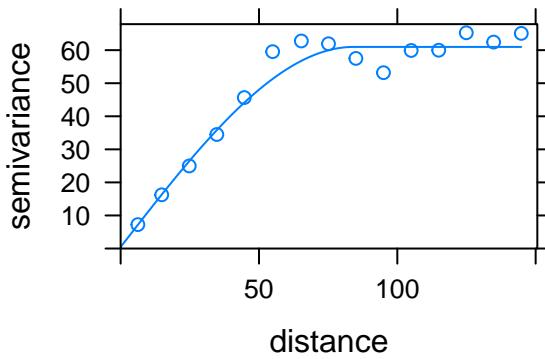


2.3.3 Summer before 1970

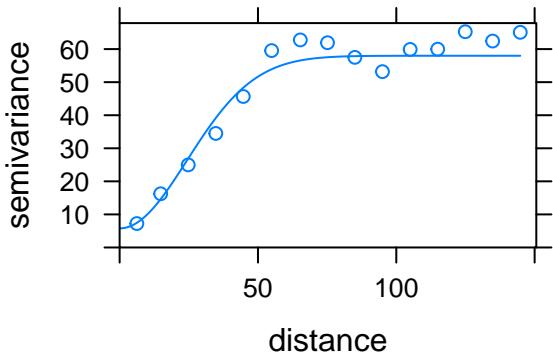
Exponential: 10km



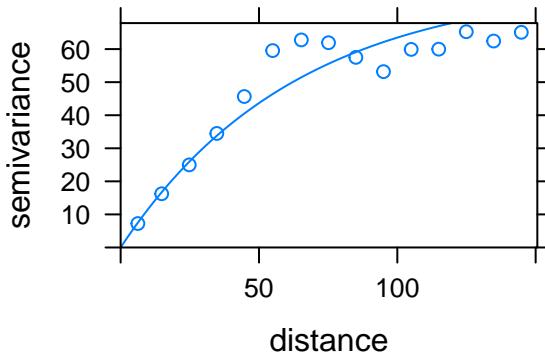
Spherical: 10km



Gaussian: 10km

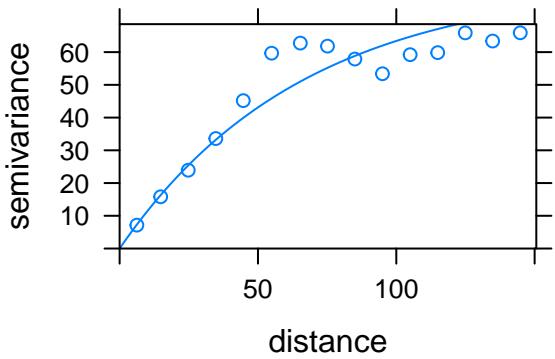


Mat: 10km

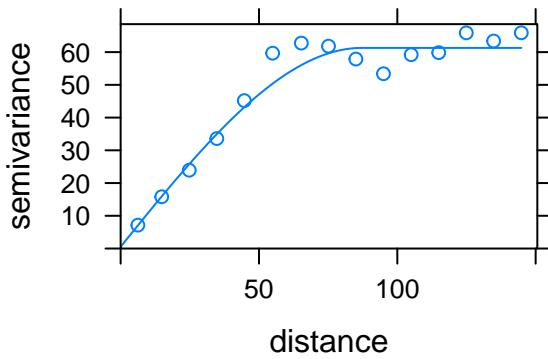


2.3.4 Summer after 1990

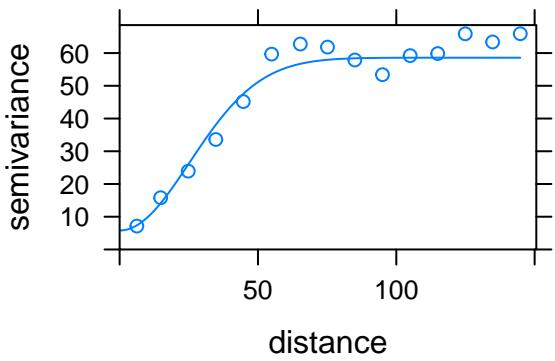
Exponential: 10km



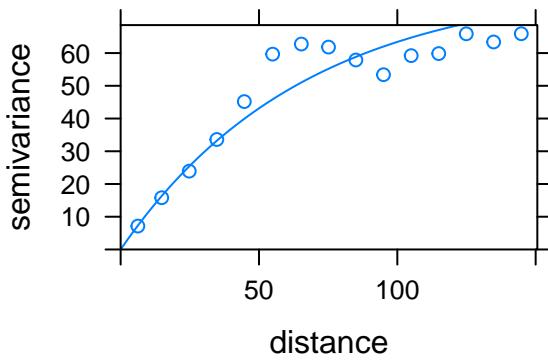
Spherical: 10km



Gaussian: 10km

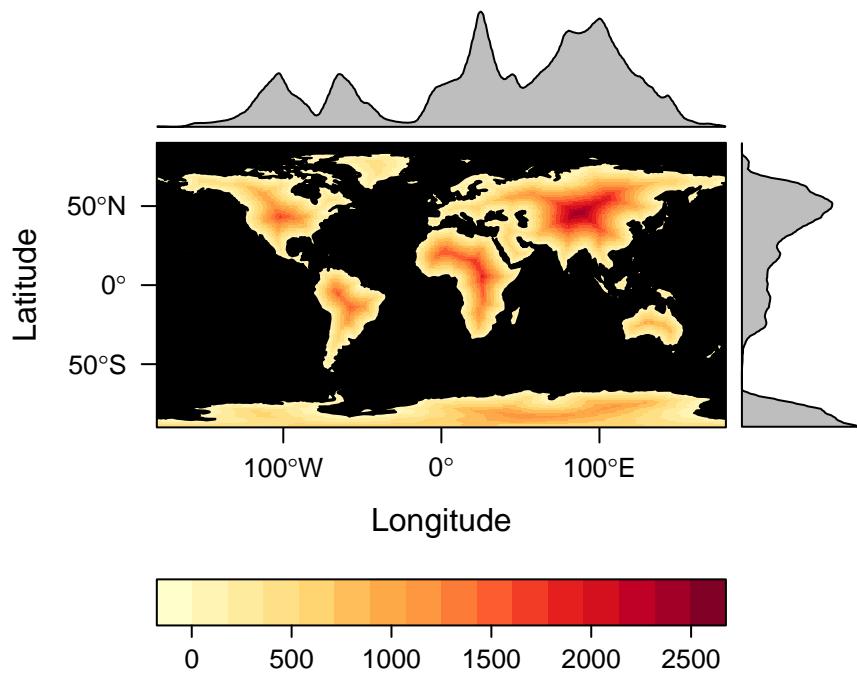


Mat: 10km

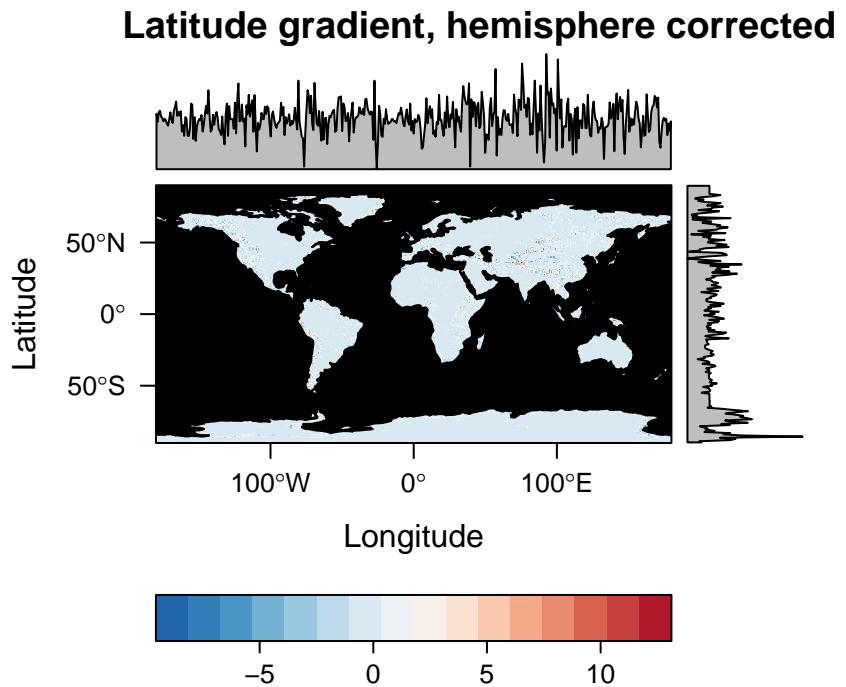


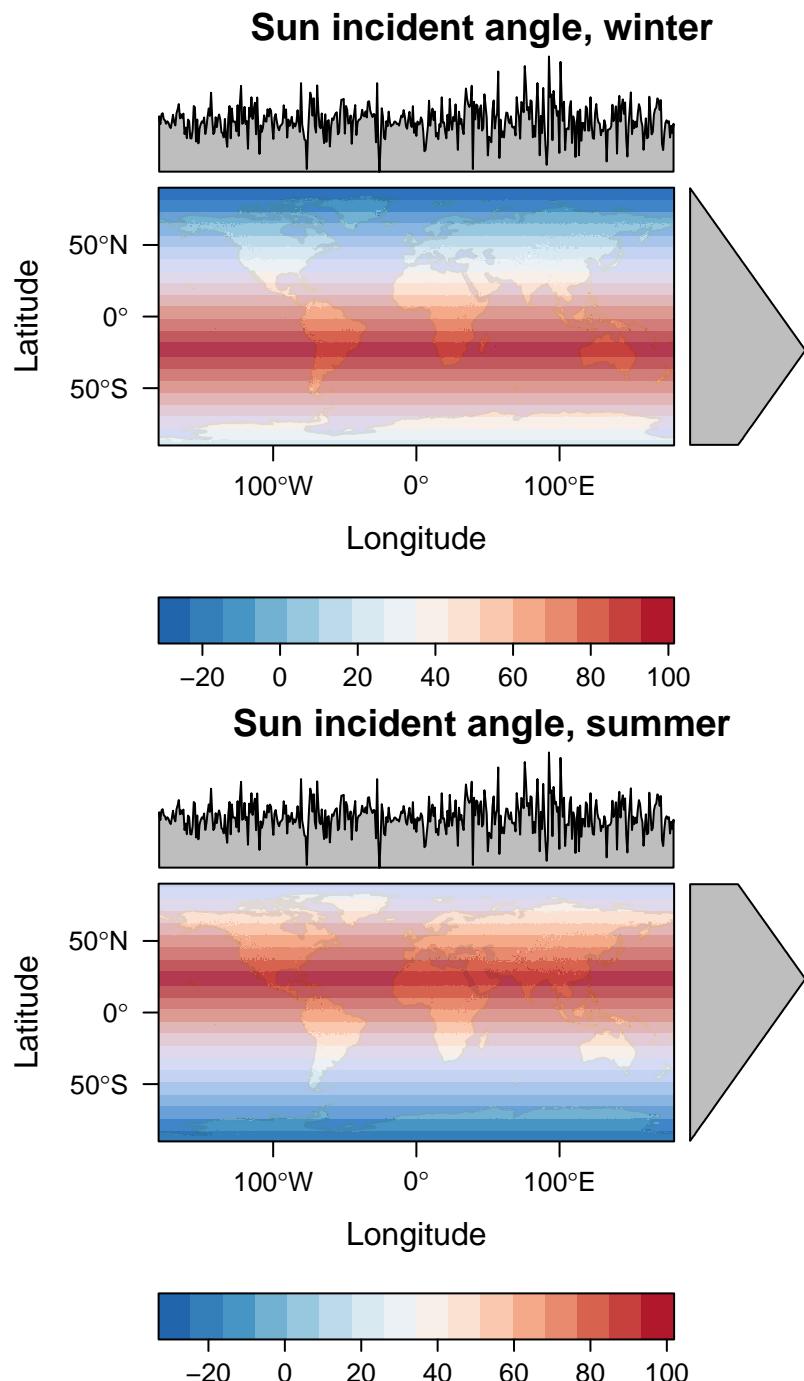
3 Task II: Universal Kriging

3.1 Continentiality: Create distance to ocean layer



3.2 Sun incidence angle

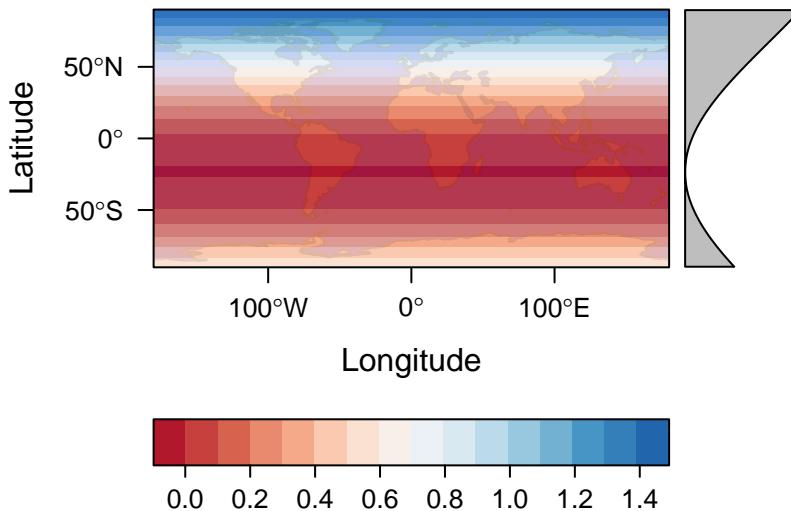




3.3 Atmospheric distance

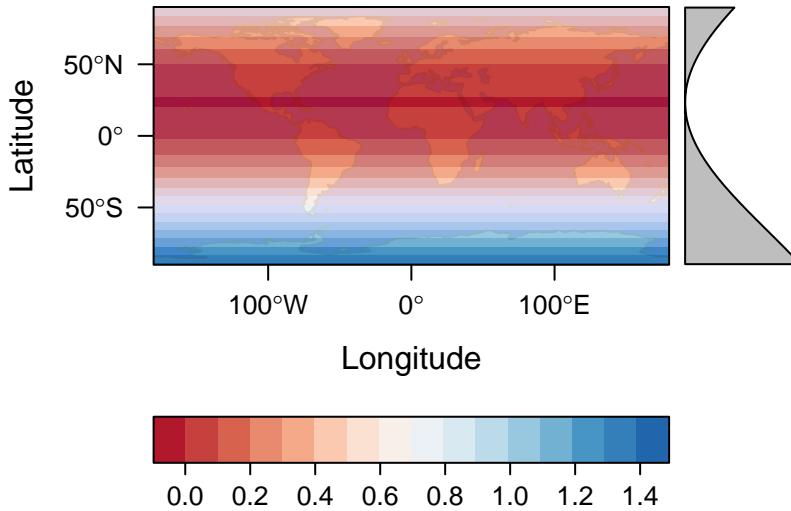
```
## Warning in min(x): kein nicht-fehlendes Argument für min; gebe Inf zurück  
## Warning in max(x): kein nicht-fehlendes Argument für max; gebe -Inf zurück
```

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

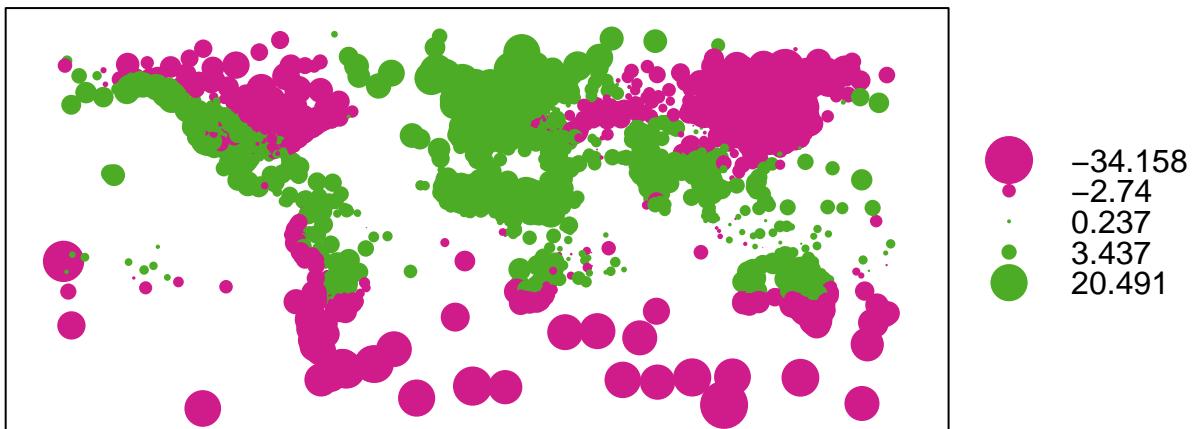


3.4 Interpolation

3.4.1 Winter before 1970

```
##  
## Call:  
## lm(formula = meansum ~ elev + cont + hsun + dist, data = temp1970w@data)  
##  
## Residuals:  
##      Min       1Q   Median       3Q      Max  
## -34.158  -2.740   0.237   3.437  20.491  
##  
## Coefficients:  
##             Estimate Std. Error t value Pr(>|t|)  
## (Intercept) 51.909261963 1.572865696 33.00 <2e-16 ***  
## elev        -0.002411139 0.000190255 -12.67 <2e-16 ***  
## cont        -0.0000004842 0.0000000249 -19.44 <2e-16 ***  
## hsun        -0.306077551 0.020426903 -14.98 <2e-16 ***  
## dist        -70.824389211 1.795926019 -39.44 <2e-16 ***  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Residual standard error: 5.397 on 2873 degrees of freedom  
## Multiple R-squared:  0.8509, Adjusted R-squared:  0.8507  
## F-statistic: 4098 on 4 and 2873 DF, p-value: < 2.2e-16
```

Residual Values

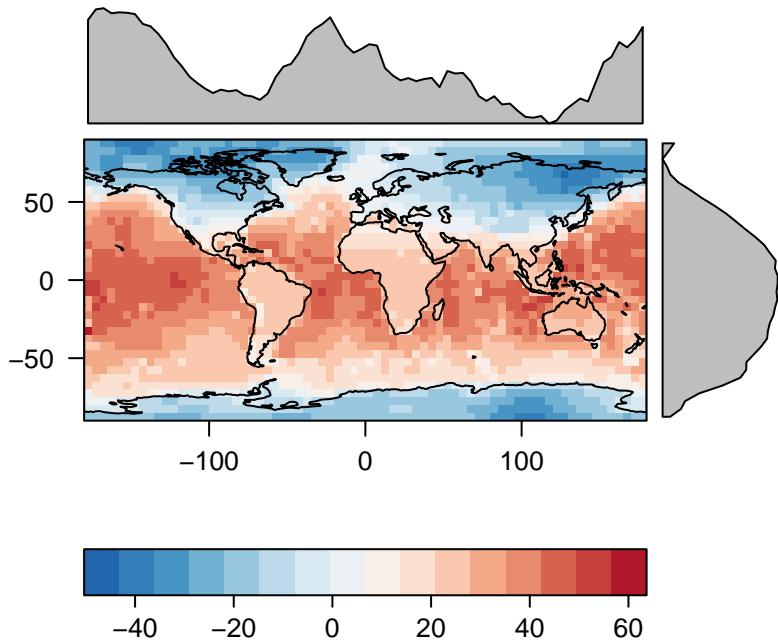


Relative Residual Values

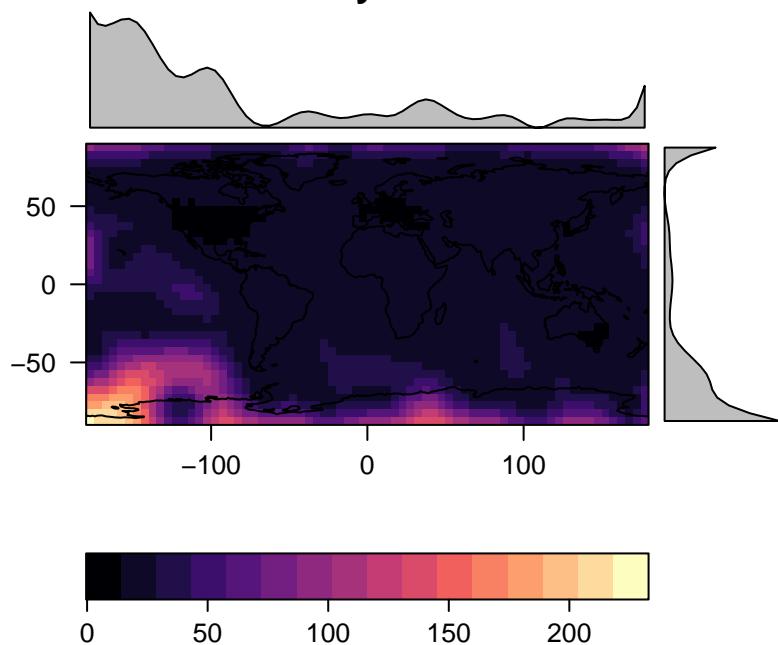


```
## [1] "Observed autocorrelation: 0.199721929289645"  
## [1] "P-value of H0 (residuals are randomly distributed): 0"  
## [using universal kriging]  
## [1] "Observed RMSE (5% validation data): 5.78°C"
```

Prediction: Winter before 1970



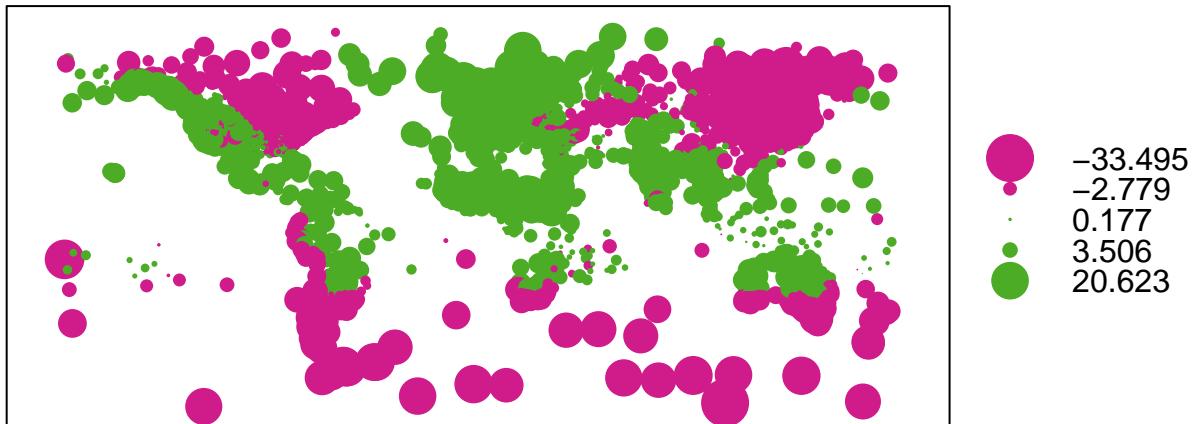
Uncertainty: Winter before 1970



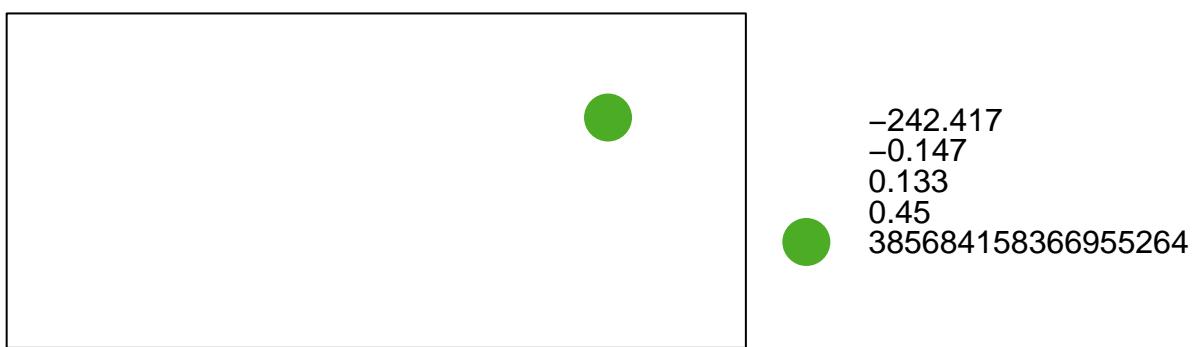
3.4.2 Winter after 1990

```
##
## Call:
## lm(formula = meansum ~ elev + cont + hsun + dist, data = temp2010w@data)
##
## Residuals:
##    Min     1Q Median     3Q    Max 
## -33.495 -2.779  0.177  3.506 20.623 
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 50.1840833455  1.5628644671   32.11 <2e-16 ***
## elev        -0.0024304377  0.0001890454  -12.86 <2e-16 ***
## cont        -0.0000045688  0.0000002474  -18.46 <2e-16 ***
## hsun        -0.2787757727  0.0202970165  -13.73 <2e-16 ***
## dist       -67.6381879309  1.7845064371  -37.90 <2e-16 ***
## ---        
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 
##
## Residual standard error: 5.363 on 2873 degrees of freedom
## Multiple R-squared:  0.8469, Adjusted R-squared:  0.8467 
## F-statistic: 3972 on 4 and 2873 DF, p-value: < 2.2e-16
```

Residual Values



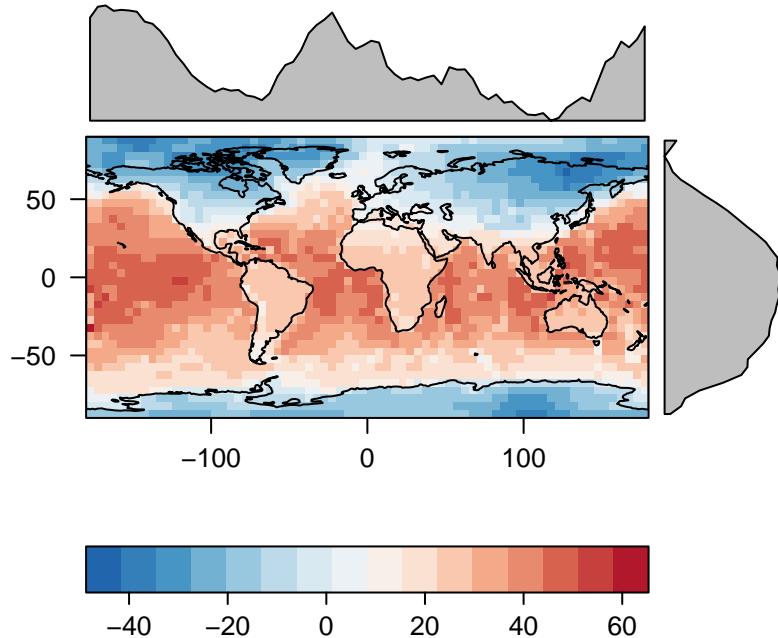
Relative Residual Values



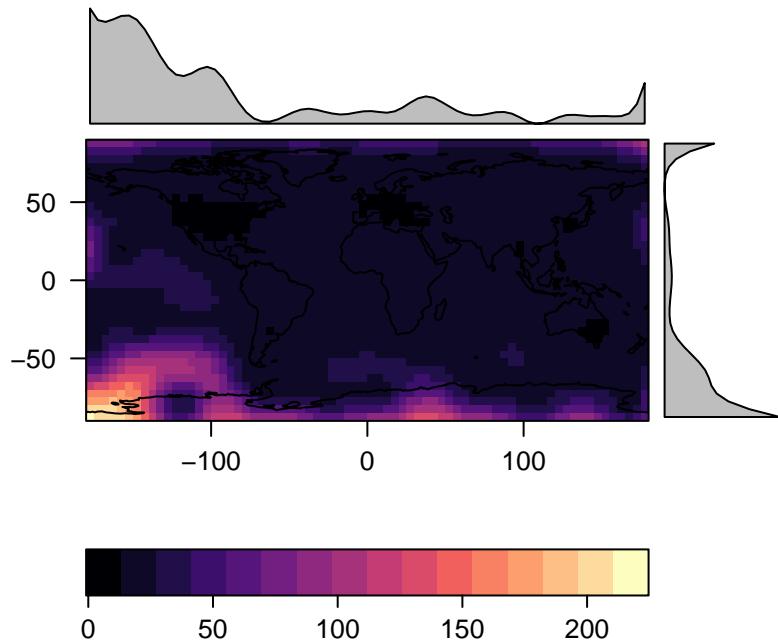
```
## [1] "Observed autocorrelation: 0.201178678868625"
```

```
## [1] "P-value of H0 (residuals are randomly distributed): 0"  
## [using universal kriging]  
## [1] "Observed RMSE (5% validation data): 5.82°C"
```

Prediction: Winter after 1990



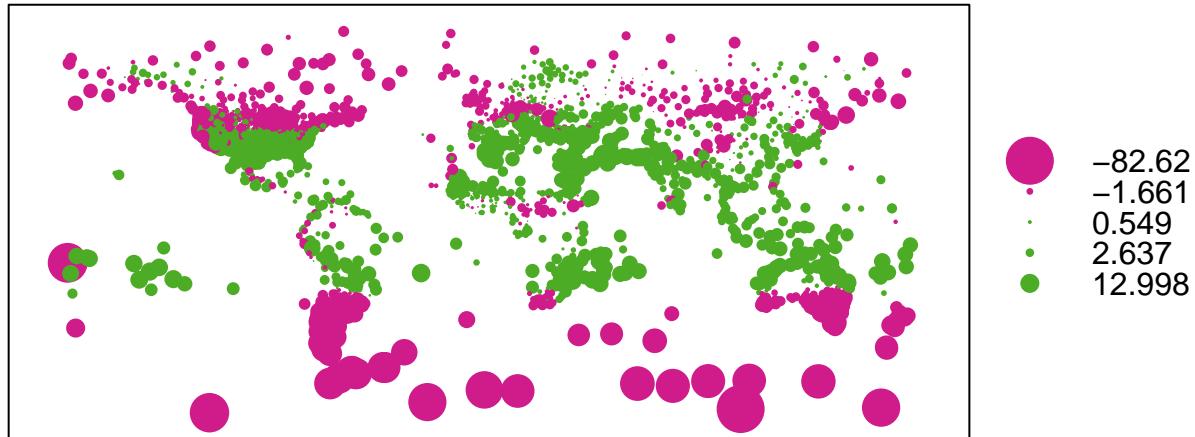
Uncertainty: Winter after 1990



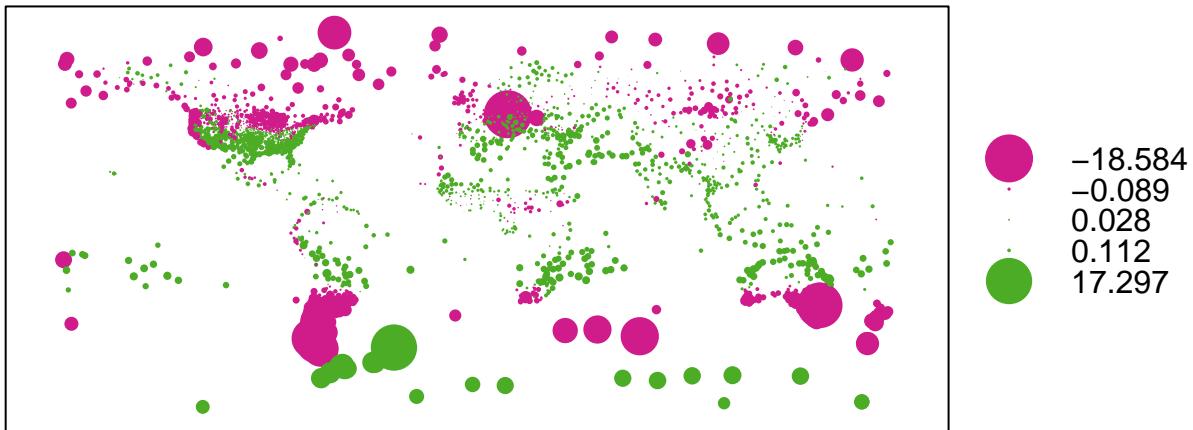
3.4.3 Summer before 1970

```
##
## Call:
## lm(formula = meansum ~ elev + cont + hsun + dist, data = temp1970s@data)
##
## Residuals:
##    Min     1Q Median     3Q    Max 
## -82.620 -1.661  0.549  2.637 12.998 
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 81.3649777132  1.6706161168   48.70 <2e-16 ***
## elev        -0.0030381676  0.0002020792  -15.04 <2e-16 ***
## cont         0.0000030286  0.0000002645   11.45 <2e-16 *** 
## hsun        -0.7990591804  0.0216963937  -36.83 <2e-16 *** 
## dist       -70.4405610996  1.9075391867  -36.93 <2e-16 *** 
## ---        
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1 
##
## Residual standard error: 5.733 on 2873 degrees of freedom
## Multiple R-squared:  0.3578, Adjusted R-squared:  0.357 
## F-statistic: 400.2 on 4 and 2873 DF,  p-value: < 2.2e-16
```

Residual Values

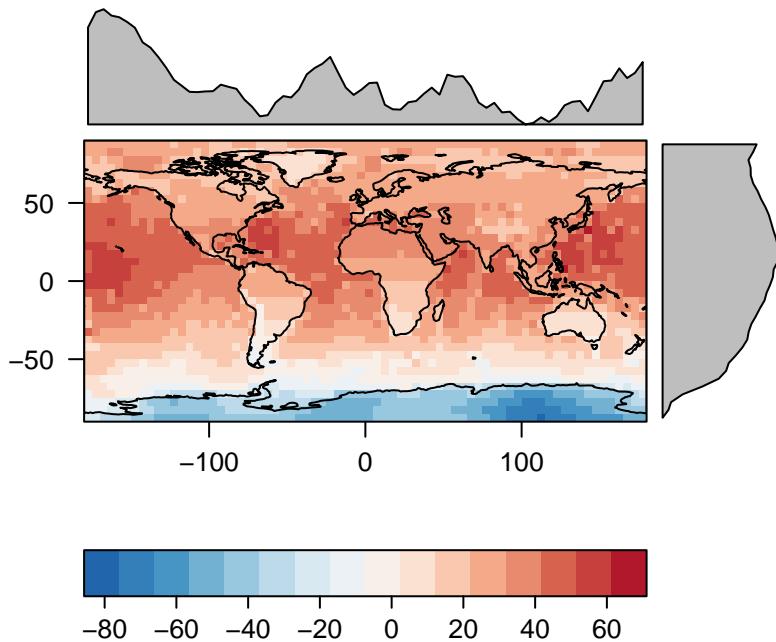


Relative Residual Values

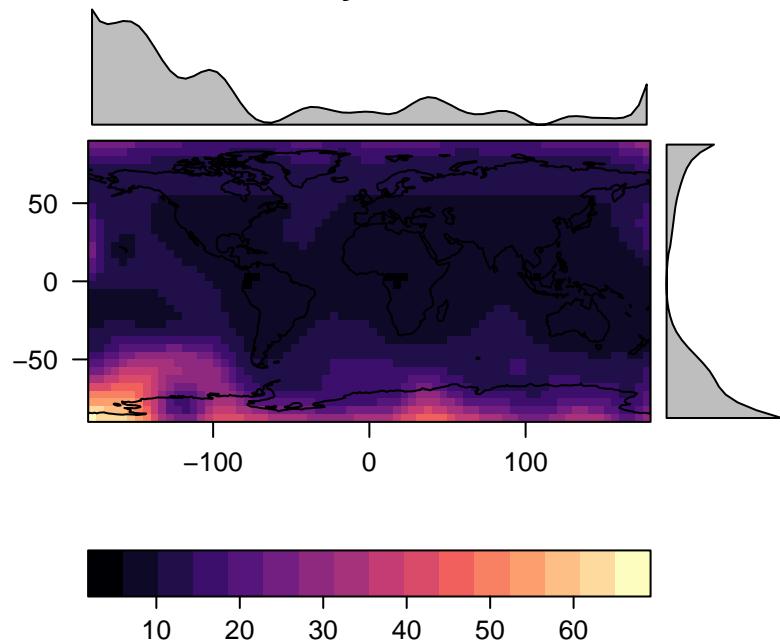


```
## [1] "Observed autocorrelation: 0.137802789056033"  
## [1] "P-value of H0 (residuals are randomly distributed): 0"  
## [using universal kriging]  
## [1] "Observed RMSE (5% validation data): 10.15°C"
```

Prediction: Summer before 1970



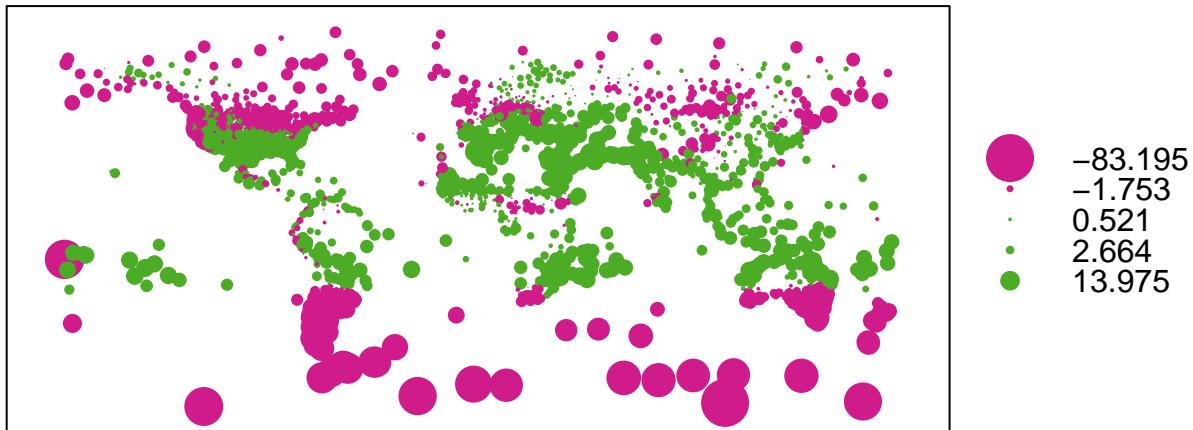
Uncertainty: Summer before 1970



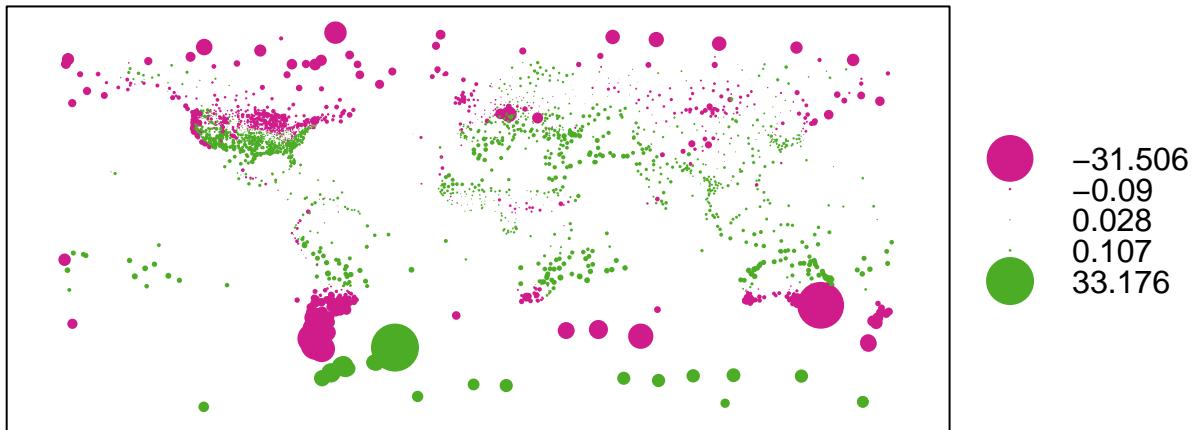
3.4.4 Summer after 1990

```
##  
## Call:  
## lm(formula = meansum ~ elev + cont + hsun + dist, data = temp2010s@data)  
##  
## Residuals:  
##      Min       1Q   Median       3Q      Max  
## -83.195  -1.753   0.521   2.664  13.975  
##  
## Coefficients:  
##              Estimate Std. Error t value Pr(>|t|)  
## (Intercept) 81.4762802910 1.6774667725 48.57 <2e-16 ***  
## elev        -0.0028830597 0.0002029078 -14.21 <2e-16 ***  
## cont         0.0000026902 0.0000002656 10.13 <2e-16 ***  
## hsun        -0.7919405619 0.0217853636 -36.35 <2e-16 ***  
## dist        -69.7504583961 1.9153613871 -36.42 <2e-16 ***  
## ---  
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1  
##  
## Residual standard error: 5.756 on 2873 degrees of freedom  
## Multiple R-squared:  0.3473, Adjusted R-squared:  0.3464  
## F-statistic: 382.3 on 4 and 2873 DF,  p-value: < 2.2e-16
```

Residual Values

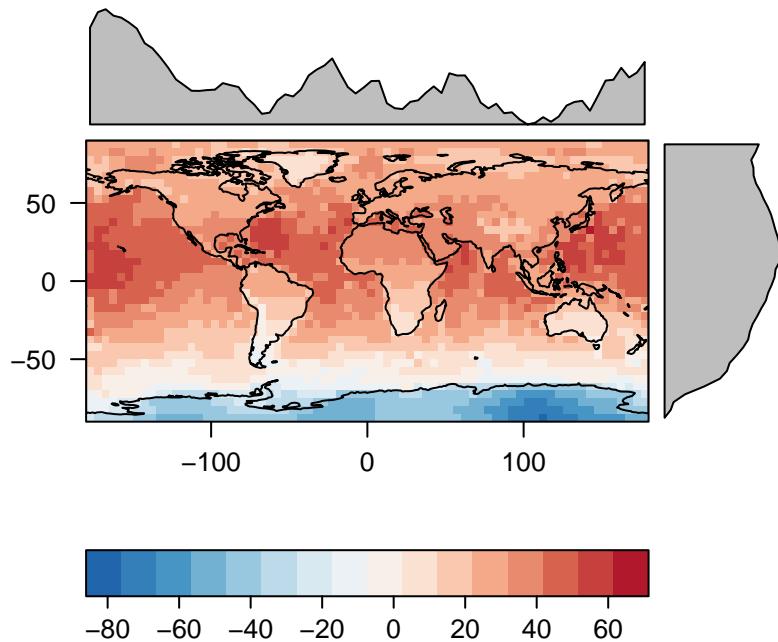


Relative Residual Values

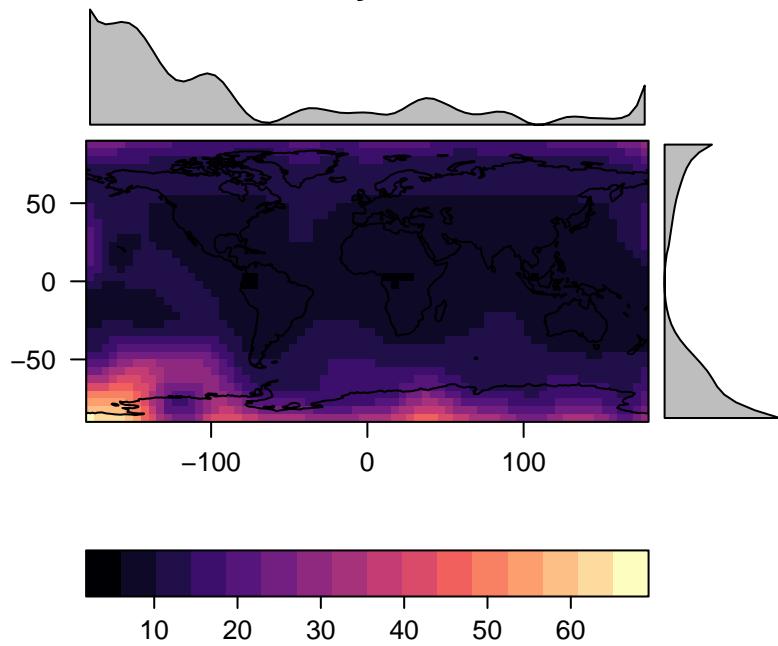


```
## [1] "Observed autocorrelation: 0.138141092734498"  
## [1] "P-value of H0 (residuals are randomly distributed): 0"  
## [using universal kriging]  
## [1] "Observed RMSE (5% validation data): 10.45°C"
```

Prediction: Summer after 1990

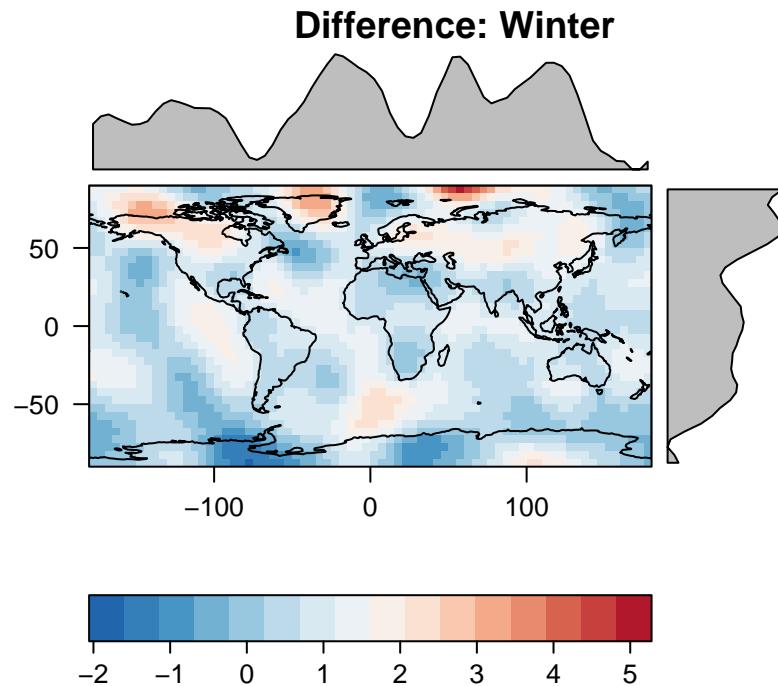


Uncertainty: Summer after 1990



4 Difference images

4.1 Winter



4.2 Summer

