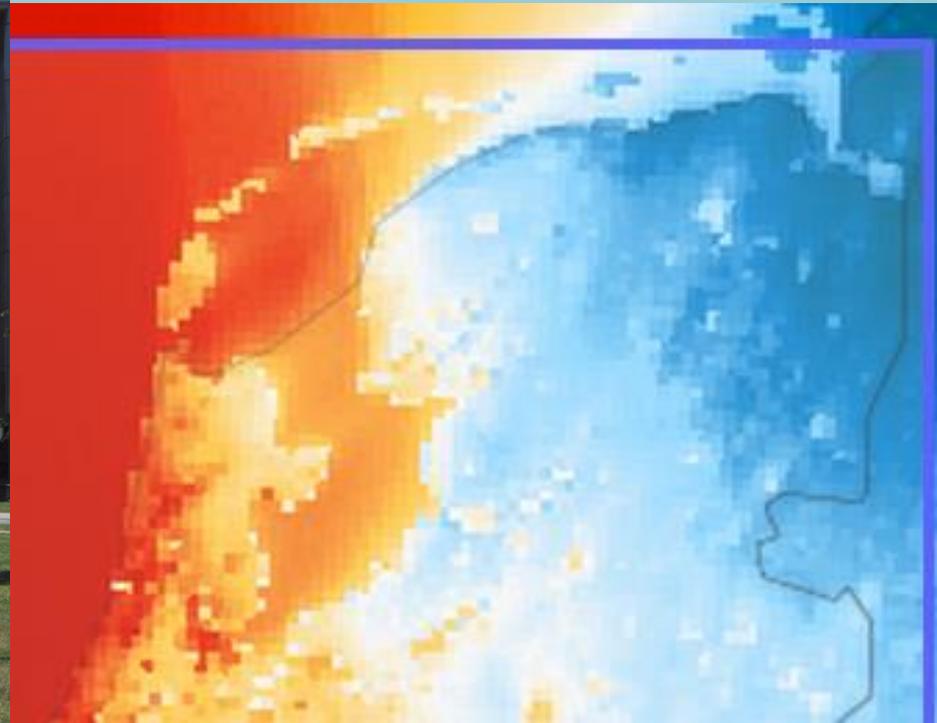Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

High Resolution Temperature Interpolation

Marieke Dirksen

Importance of high resolution Temperature

- Insurance, environment, agriculture

- Input for hydrological models and others

- Understanding Temperature patterns of the past helps to understand the current and future Temperature patterns
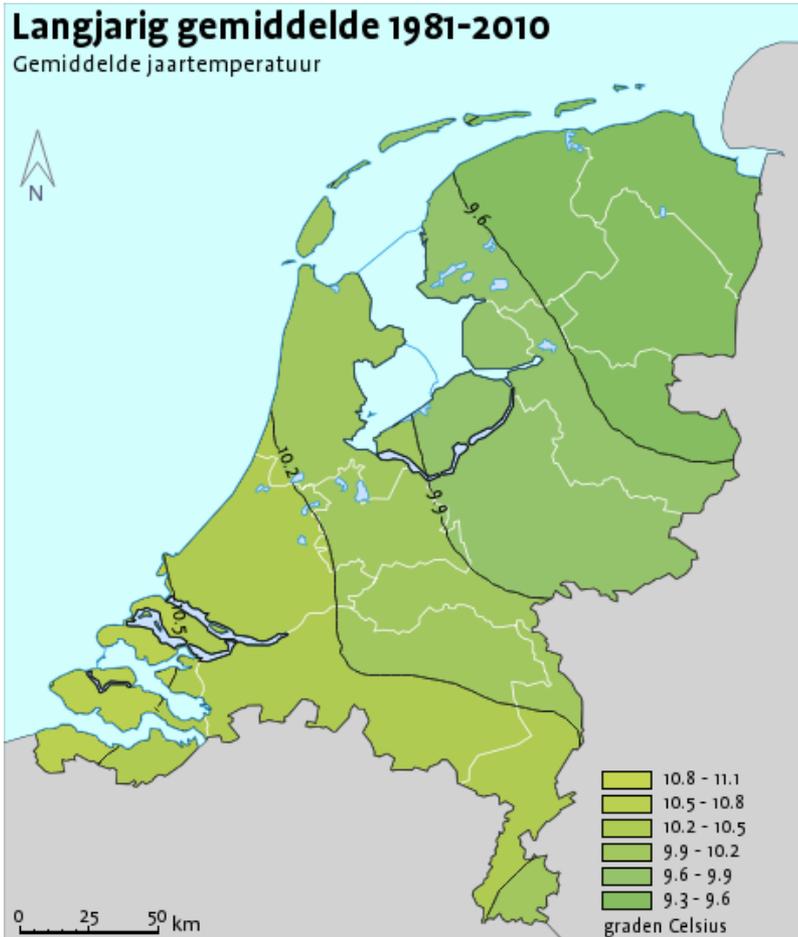
KNMI meteorologische stations

Hoorn (Terschelling) 251
Lauwersoog 277
Vlieland 242
Leeuwarden 270
Nieuw Beerta 286
Eelde 280
De Kooy 235
Stavoren 267
Hoogeveen 279
Marknesse 273
Berkhout 249
Wijk aan Zee 257
Lelystad 269
Heino 278
Schiphol 240
Twenthe 290
Valkenburg 210
De Bilt 260
Deelen 275
Hupsel 283
Voorschoten 215
Hoek van Holland 330
Rotterdam 344
Gabauw 348
Herwijnen 356
Volkel 375
Gilze-Rijen 350
Arcen 391
Vlissingen 310
Woensdrecht 340
Eindhoven 370
Westdorpe 319
Ell 377
Maastricht 380

N

50 km

(c) 2014, KNMI Klimaatdata en advies

Netherlands

De Bilt

Current Interpolation: with distance to the sea

Langjarig gemiddelde 1981-2010
Gemiddelde jaartemperatuur

10.8 – 11.1
10.5 – 10.8
10.2 – 10.5
9.9 – 10.2
9.6 – 9.9
9.3 – 9.6

graden Celsius

- 33 Observations

- Trend: Distance to sea

- Kriging interpolation

KNMI meteorologische stations
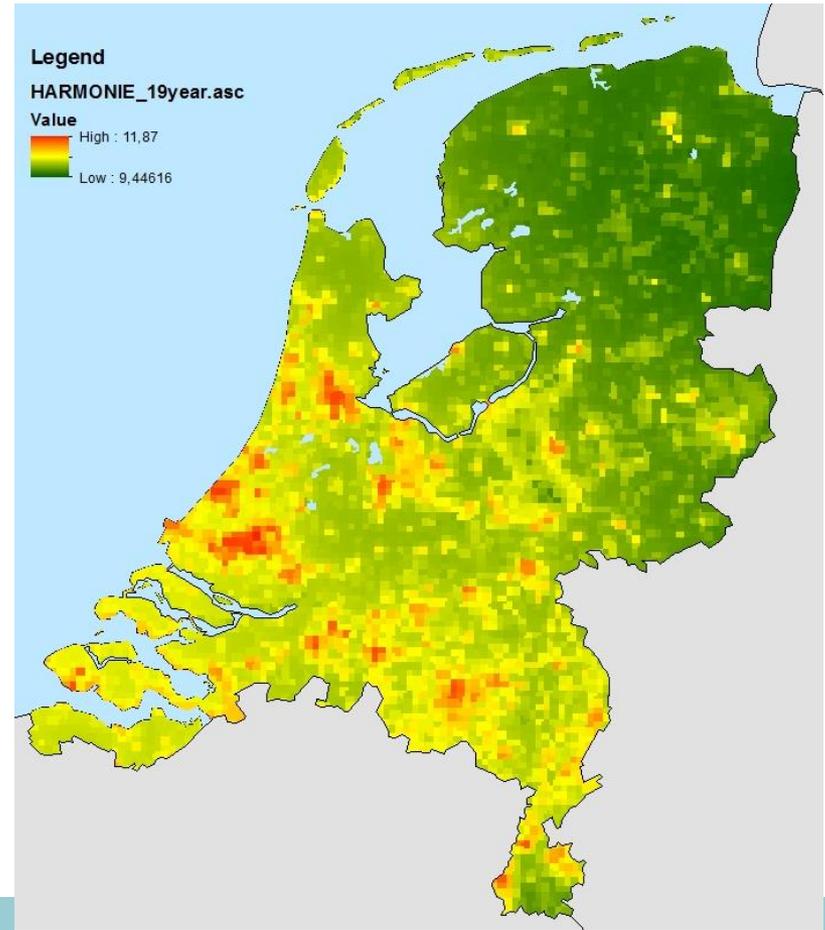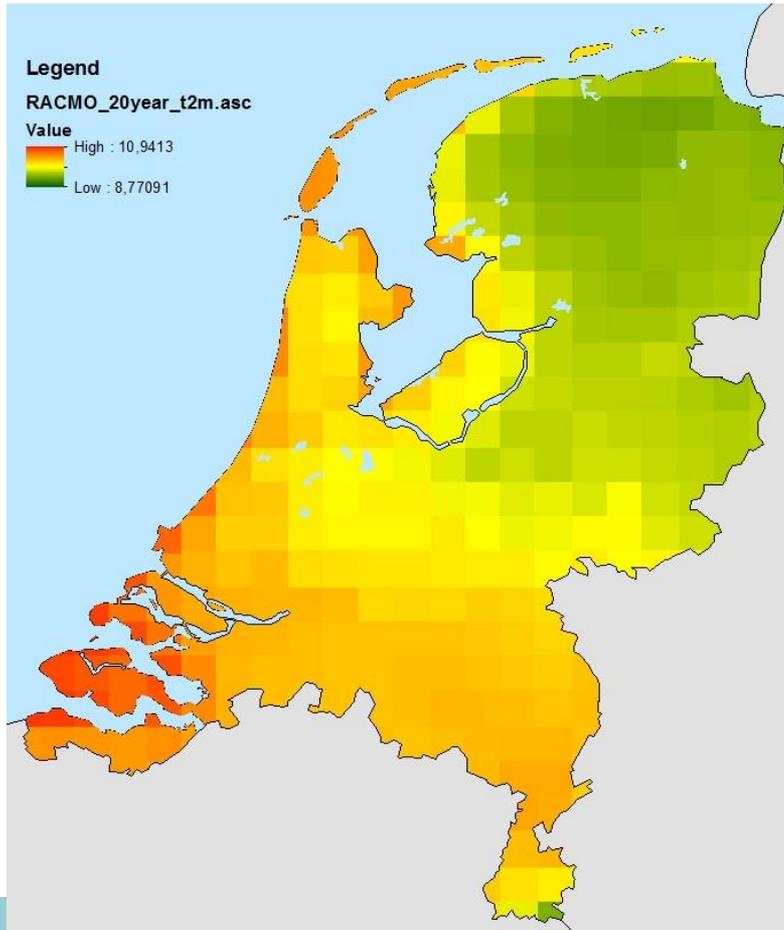

Distance to the Sea
Ancillary data

Marieke Dirksen
July 2015
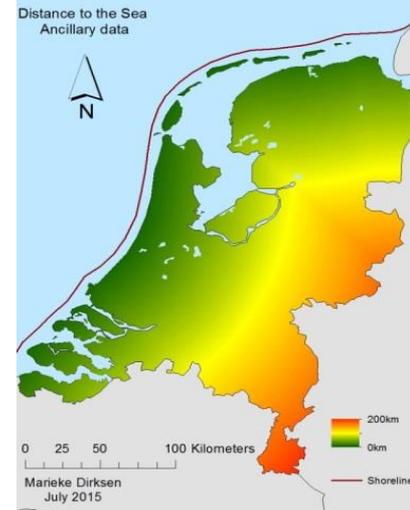
Numeric Weather Prediction model data

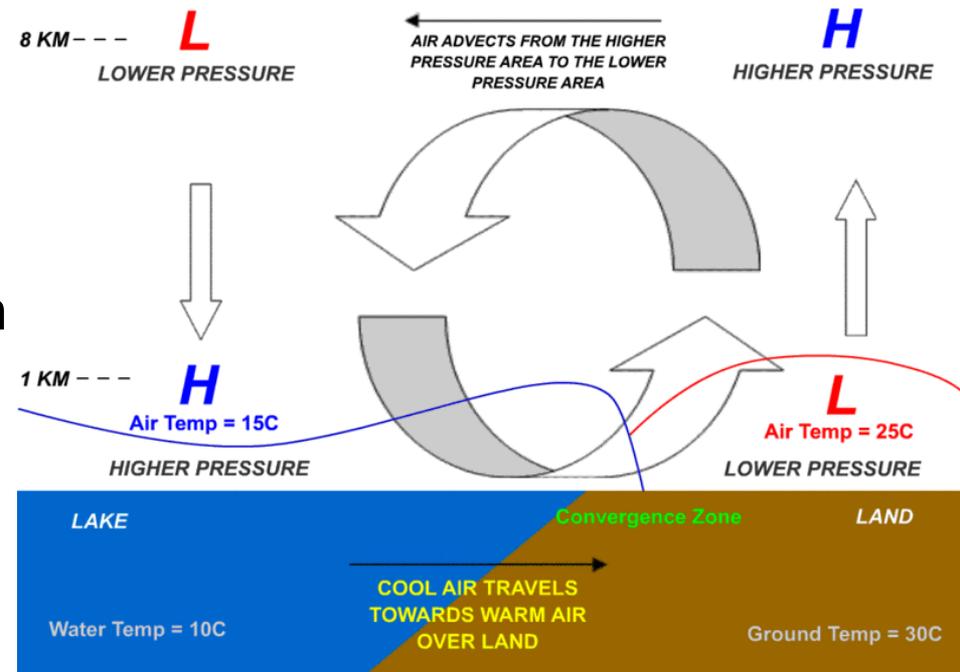RACMO (12km grids)   &   HARMONIE (2.5km grids)

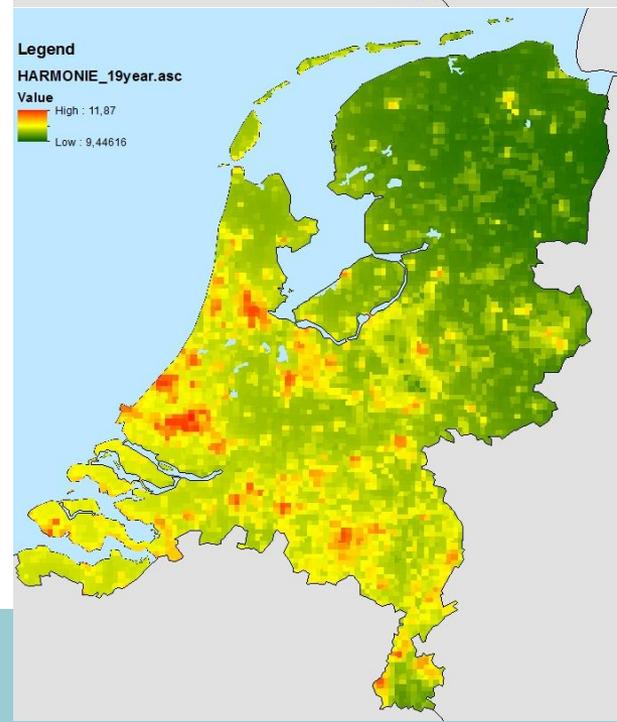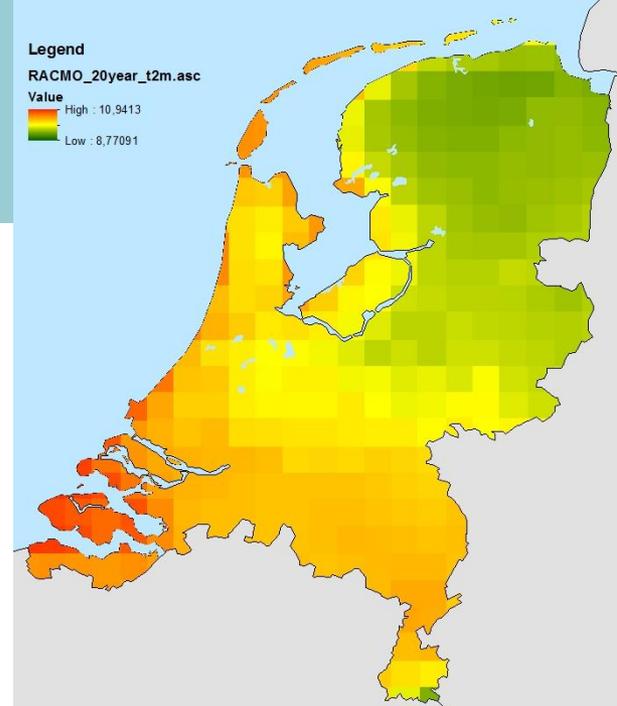# Combining observation and NWP model trend

- 33 observations=limited

- Large scale patterns: Land

  surface atmosphere interaction

- Included in models

- Use model trend for

  interpolation

Data Analysis: an example

- Period: 20 years, from 1995-2014

- Observations: 33 stations

- NWP models: RACMO & HARMONIE

- Interpolation method: Universal Kriging

  with an exponential variogram model
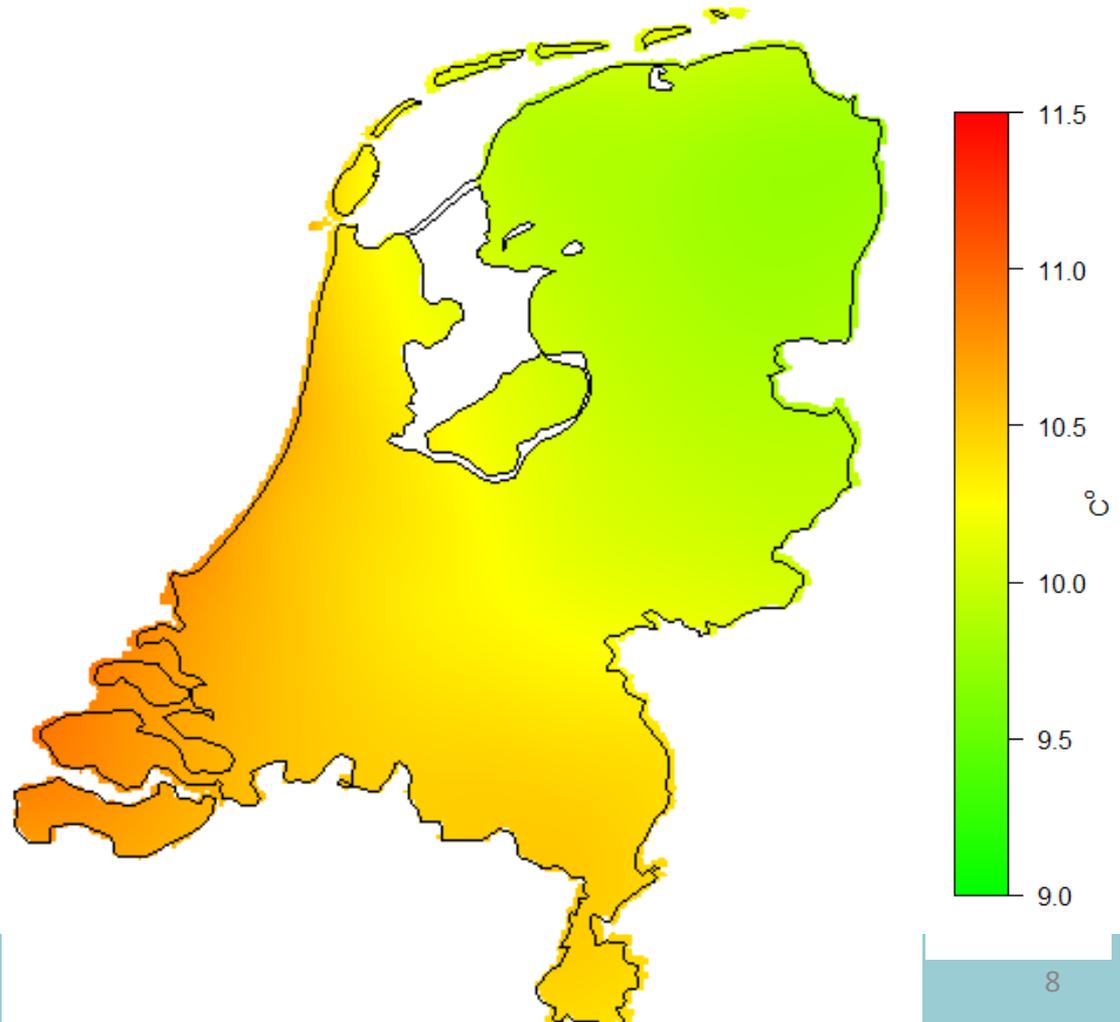
- Output: 1x1km Temperature grid

Legend
RACMO_20year_t2m.asc
Value
High : 10,9413
Low : 8,77091

Legend
HARMONIE_19year.asc
Value
High : 11,87
Low : 9,44616

Observations & trend Distance to the Sea

LOOCV

R2=0.76
RMSE=0.012

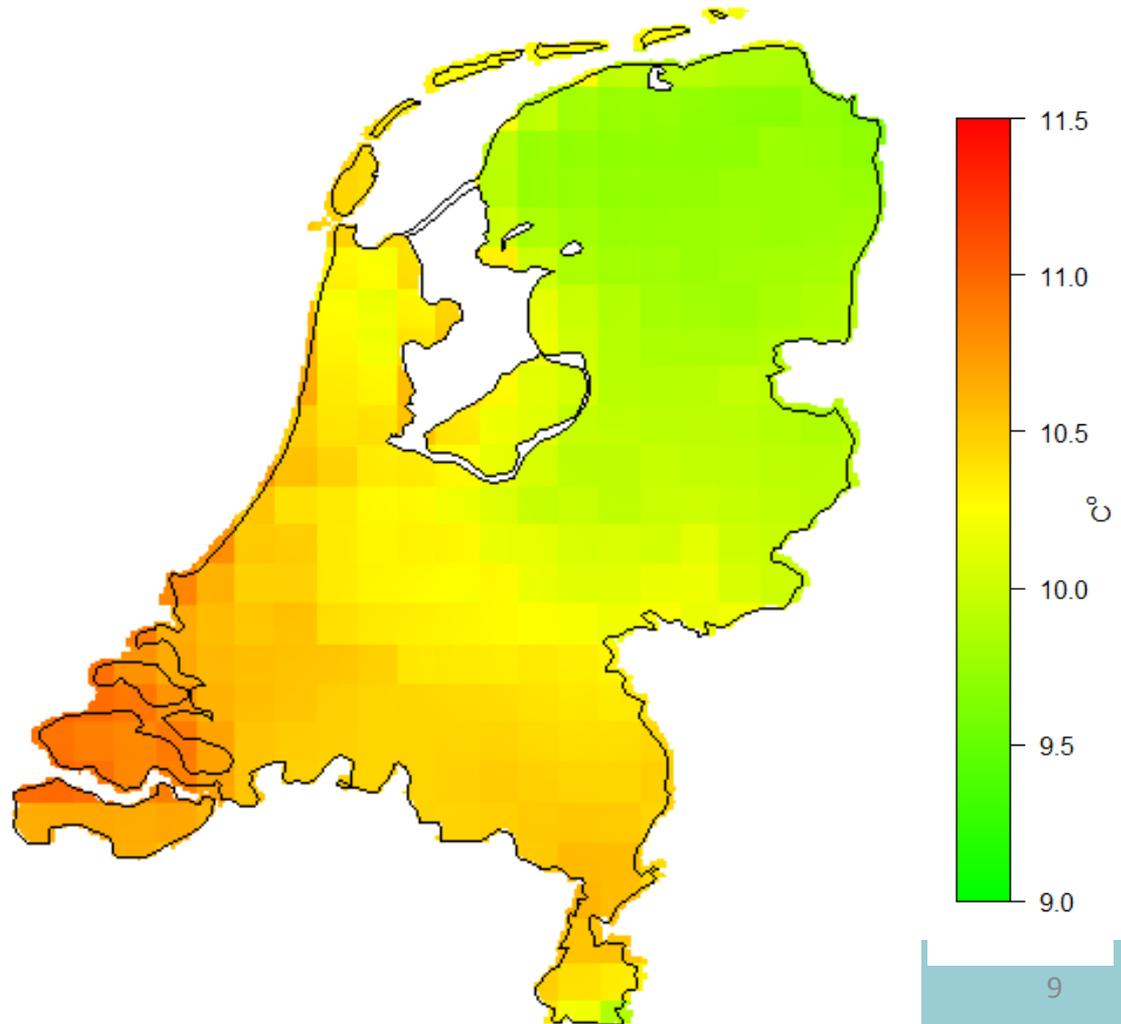# Observations & trend RACMO Temperature Grid
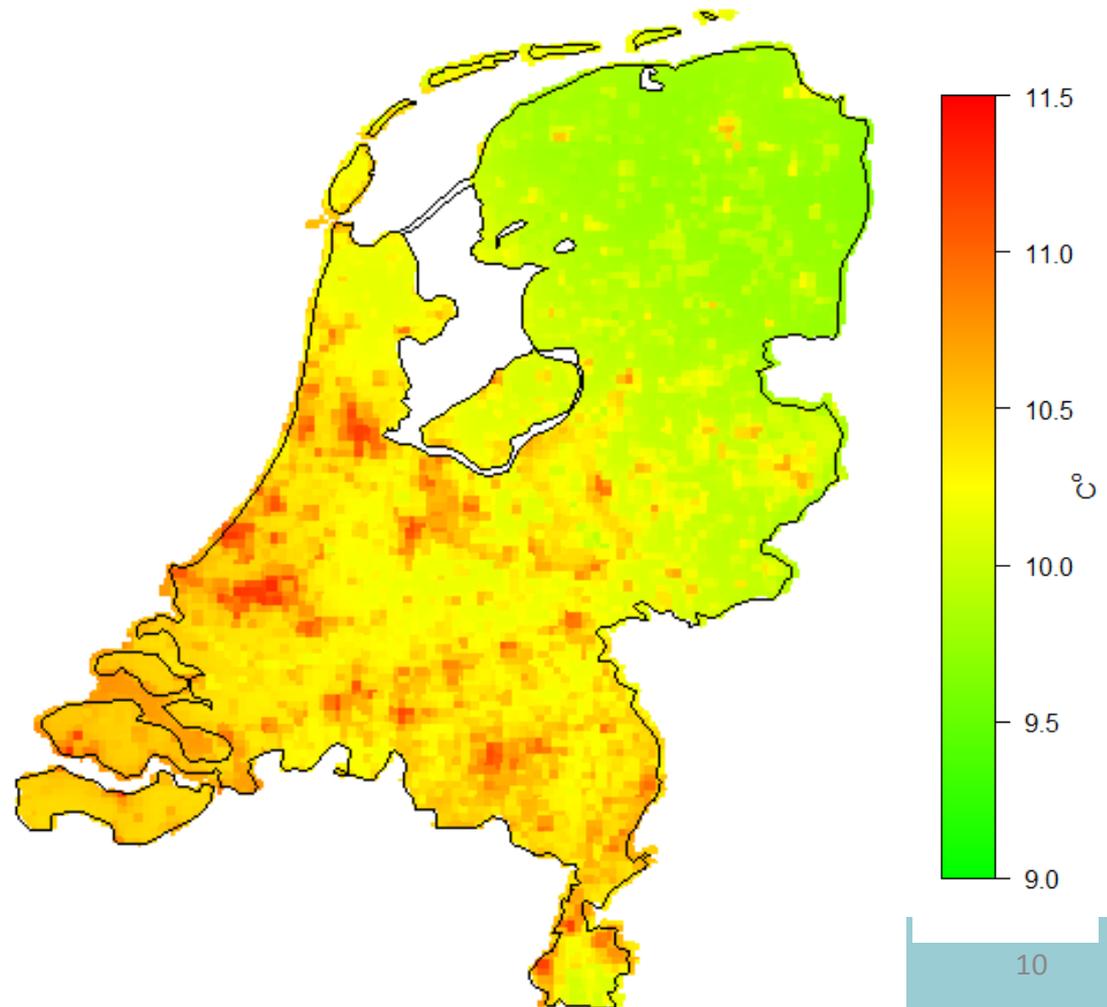
LOOCV

R2=0.79
RMSE=0.037

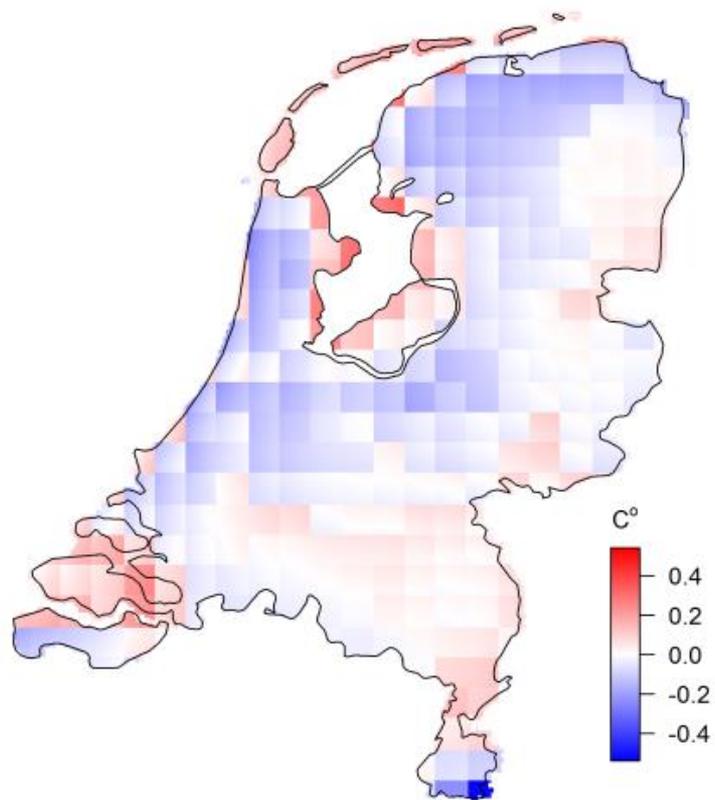# Observation & trend HARMONIE Temperature Grid
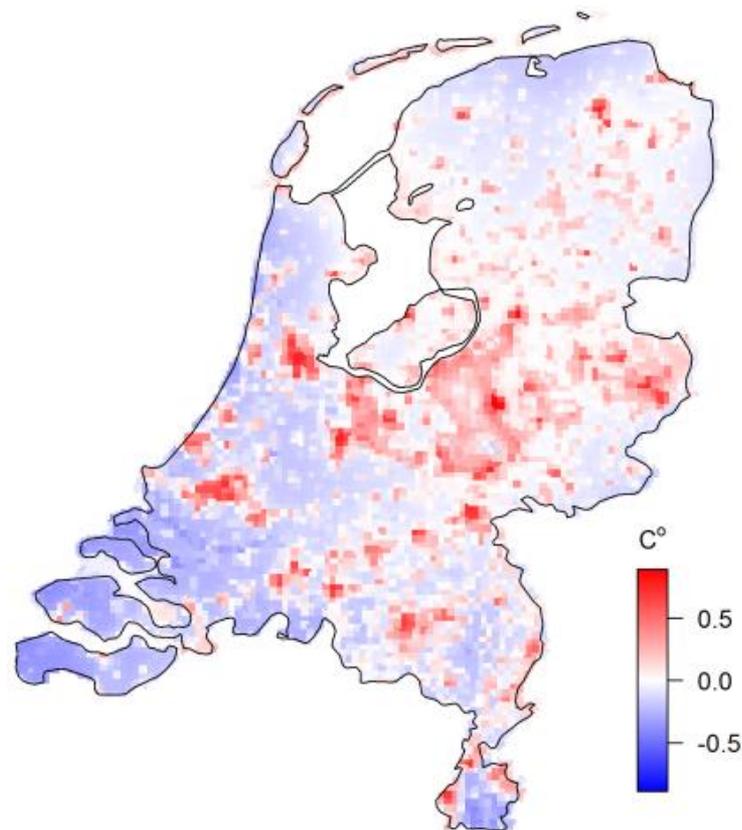
LOOCV

R2=0.79
RMSE=0.150

Differences

RACMO-distance sea

HARMONIE-distance sea

Case Example: Daily interpolation

- Period: day 2010/01/01

- Observations: 33 stations

- NWP models: RACMO & HARMONIE

- Interpolation method: Universal Kriging with an

  exponential variogram model
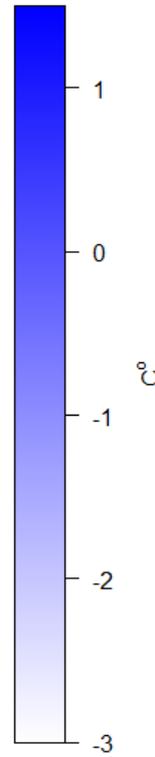
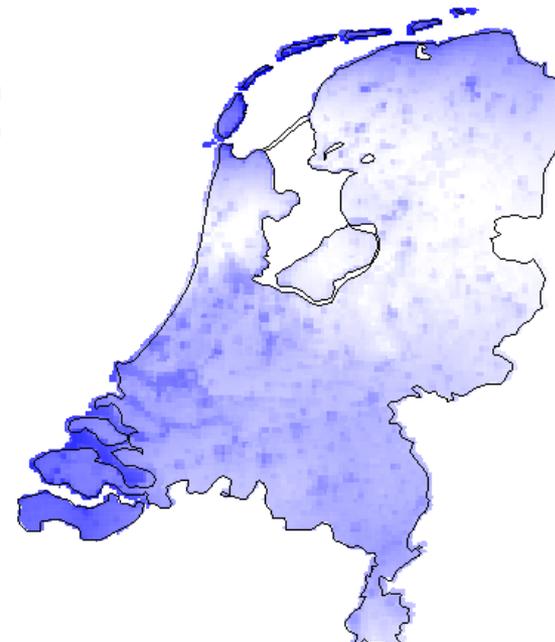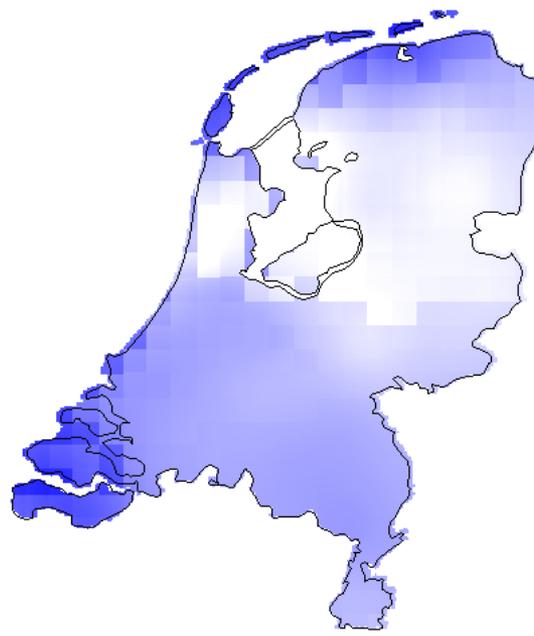- Output: 1x1km Temperature grid

Daily interpolation: 2010/01/01

Observation

RACMO

HARMONIE

R2=0.65
RMSE=0.036

R2=0.50
RMSE=0.088

R2=0.73
RMSE=0.0057

Discussion

$$T_{diff} = T_{observed} - T_{HARMONIE}$$

-0.087

- Growth cities: not in model

- Not all stations are representative for the area
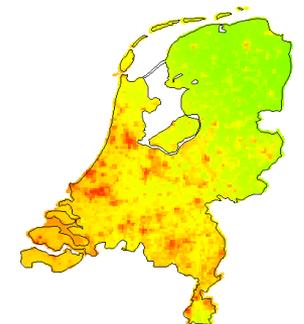
- Statistical values: performance indicator for interpolation methods
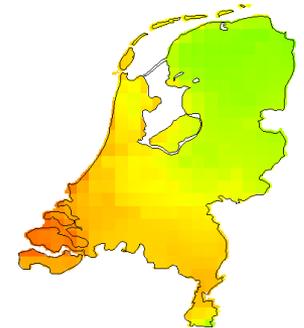
Conclusion

- Statistically good correlations (R2, RMSE), shorter time periods interpolation with model data preferred

- Including NWP model data: better spatial patterns

- Cities & elevated area's can be recognized when using HARMONIE

Questions?

Additional slides

- Comparison: RACMO & HARMONIE 20 year difference
- Comparison: models RACMO & HARMONIE vs. observations
- Daily interpolation (cold day)
- 20 year monthly (September)
- Background Kriging

In general, it can be observed that when the time period decreases R2 decreases and RMSE increases

Temperature difference RACMO and Observations

$$T_{diff} = T_{observed} - T_{RACMO}$$

+ 0.26

- Wadden & IJsselmeer: higher than observed
- Rest of NED: lower than observed values

Temperature difference HARMONIE and Observations

$T_{diff} = T_{observed} - T_{HARMONIE}$

-0.087
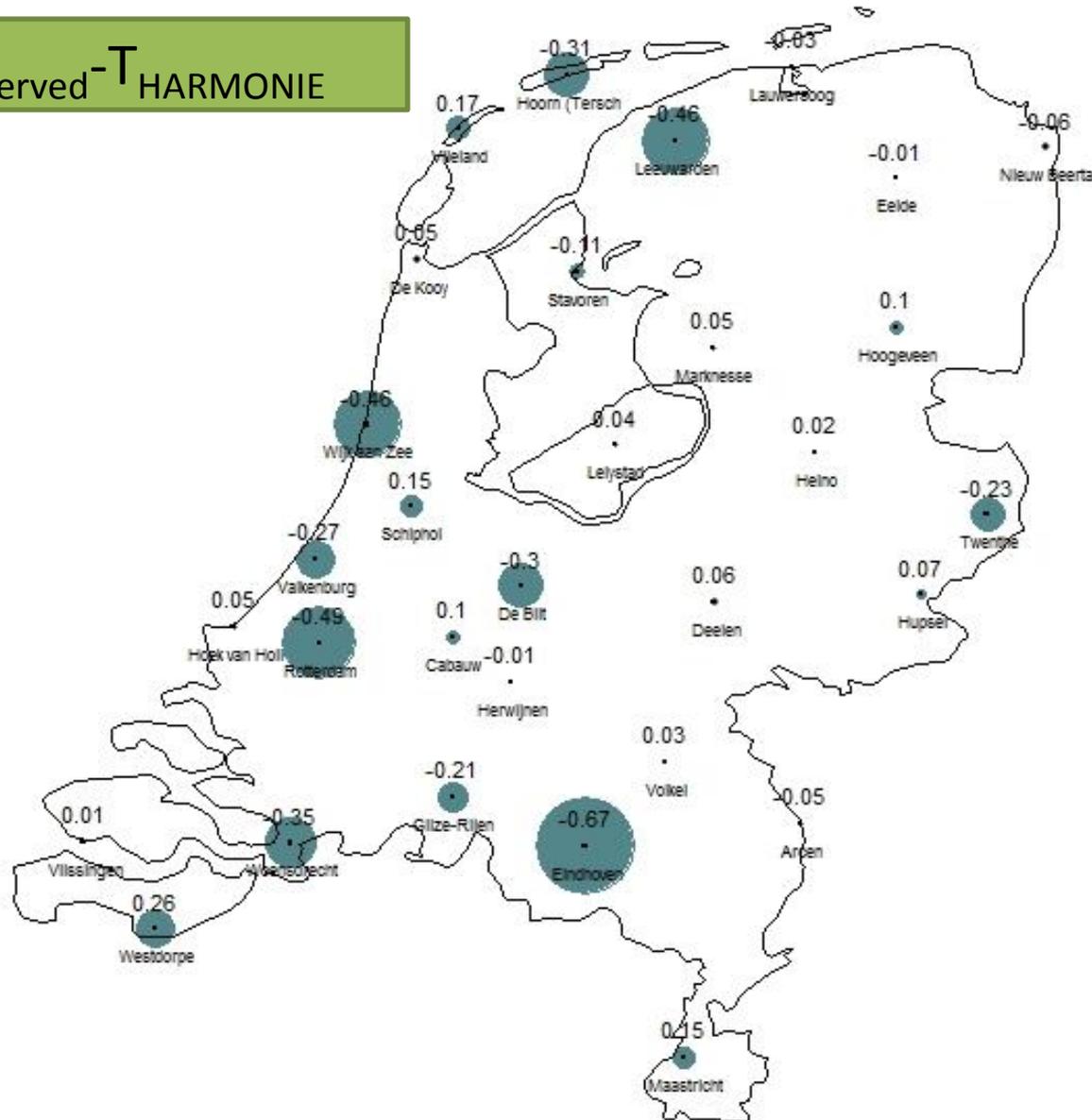
| Overview of the data analysis	
Variables	Mean Temperature Maximum Temperature Minimum Temperature
Time	Day Month Year 20 year (including 20 year monthly average)
Interpolation	Ordinary Kriging Universal Kriging TPS IDW
Ancillary data	RACMO HARMONIE Distance to the sea
Validation	Cross validation Point difference (observation vs. prediction) Variance maps

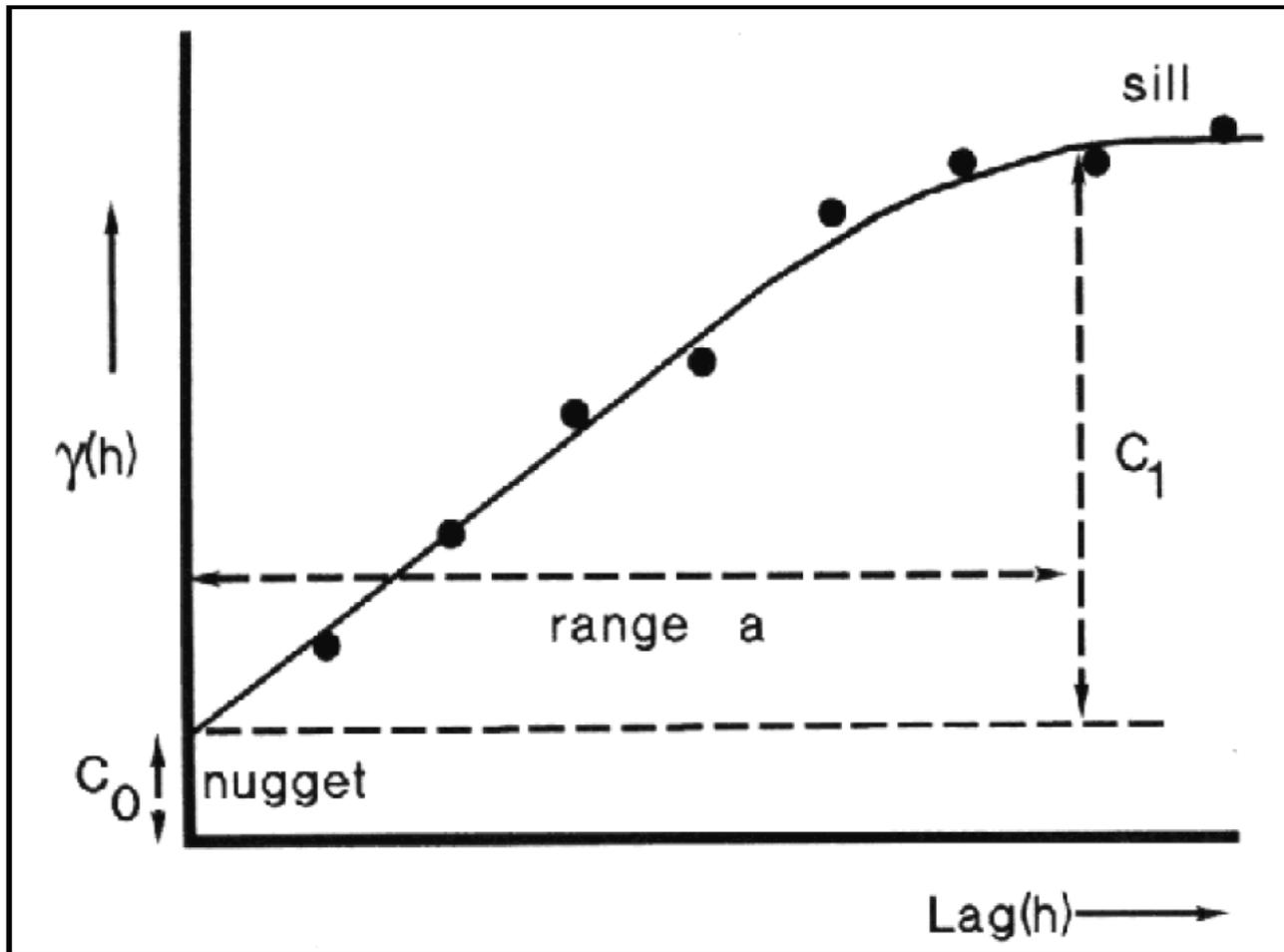# 20year month: September

Klimaatatlas

RACMO

HARMONIE

R2=0.71
RMSE=0.032
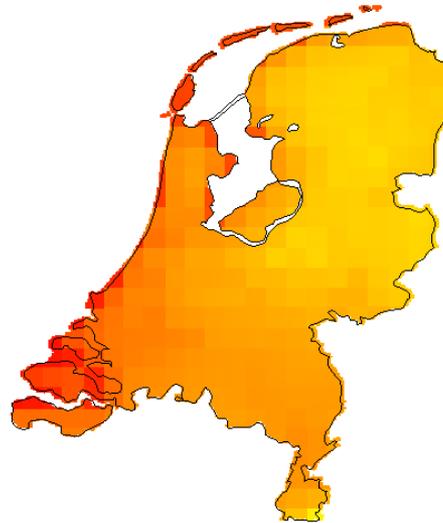
R2=0.82
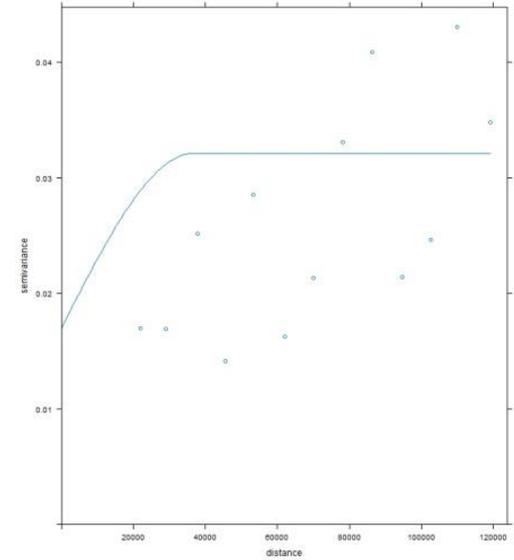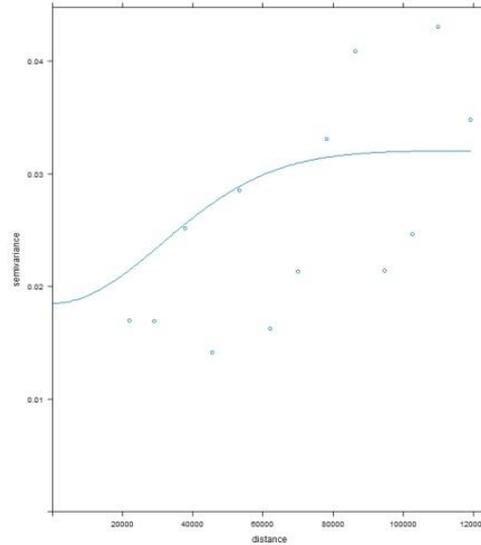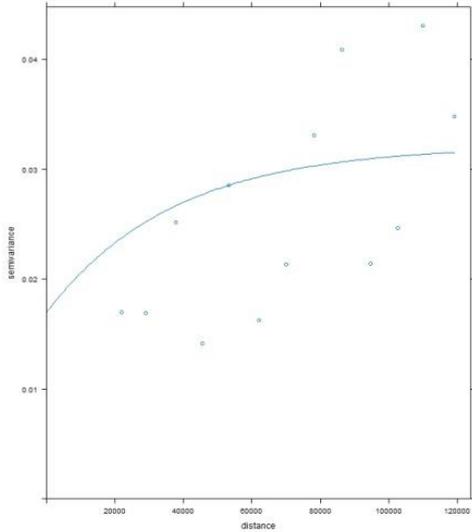RMSE=0.033
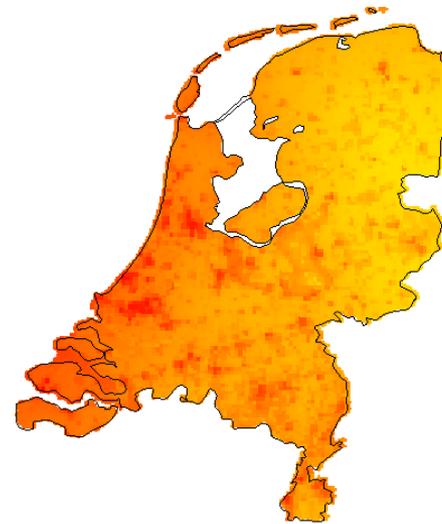
R2=0.56
RMSE=0.015
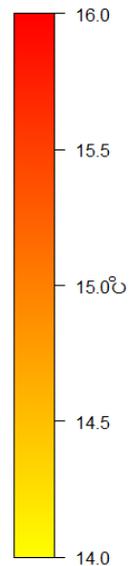
Kriging: the basics

- Similar idea as IDW ($w(x_i) = \|x_i - x_0\|^{-p}$)
- Residuals are spatially correlated and represented by the covariance
- Below an example of a variogram model:

Variogram fits

Exponential, Gaussian and spherical models, RACMO 20 year t2m

Interpolation method	SSERR
OKexp	3.9e-11
OKsph	1.2e-10
KEDexpS	3.4e-11
KEDsphS	9.5e-11
KEDgauS	2.1e-11
KEDexpLS	1.9e-11
KEDsphLS	3.0e-11
KEDgauLS	8.0e-11
KEDexpR	3.1e-12
KEDsphR	8.2e-12
KEDgauR	2.5e-12

KED RACMO	Nugget	Sill	Range
Exponential	0.0169	0.0321	36894
Gaussian	0.0185	0.0321	44273
Spherical	0.0169	0.0321	36894

Kriging Interpolation in R

Example of universal kriging with an exponential variogram model:

ked_exp <- autoKrige(Tg_new~distshore, var, distshore.grd, maxdist=mxdkrige, block=c(blocksize,blocksize), model = c("Exp"), na.action=na.pass, fix.values=c(NA,NA,NA), miscFitOptions = list(merge.small.bins = TRUE))

Notice:
- *The model depends on ancillary data (~distshore)*
- *The temperature observations (Tg_new from var) are interpolated over a grid (distshore.grd)*
- *For the variogram a maximum distance, blocksize and model is chosen*
- *For a complete analysis not only the model is (Exp, Sph, Gauss) is adapted but also maxdist and block!*

Cross-validation in R

By means of e.g. cross-validation the performance of different interpolation methods can be assessed (Hiemstra & Sluiter, 2011). Below an example for the cross validation for Kriging:
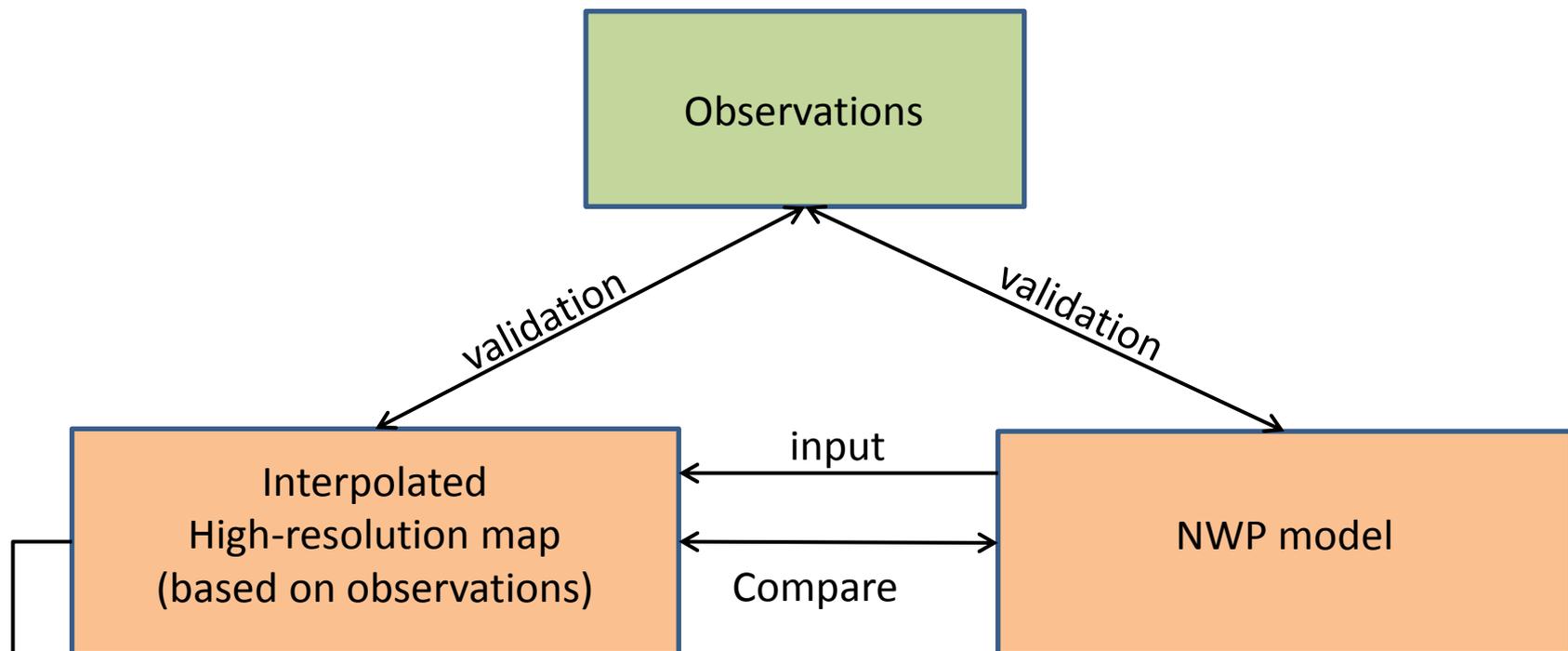
ked_exp.cv<-autoKrige.cv(Tg_new~distshore,var,model=c("Exp"), maxdist=mxdkrige, fix.values=c(NA,NA,NA), miscFitOptions = list(merge.small.bins = TRUE))

Input: same variables as in autokrige!
Output: spatial data frame with LOOCV

Overview of the data analysis in R

- Available interpolation methods
- New interpolation methods
- Comparison and improvement