Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

Community climatology

Combining official observations, crowd-sourced observations and covariates to obtain high-resolution gridded climate data sets

Jouke de Baar, Gerard van der Schrier, Theo Brandsma (KNMI)

Budapest, 11 May 2023 (online)

Koninklijk Nederlands
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Introduction

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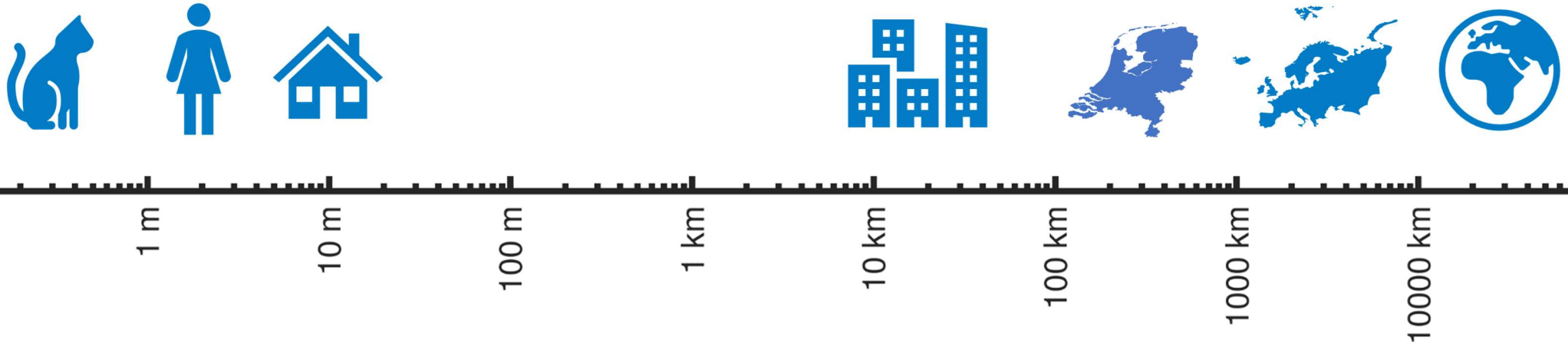
Introduction

The scale we live on

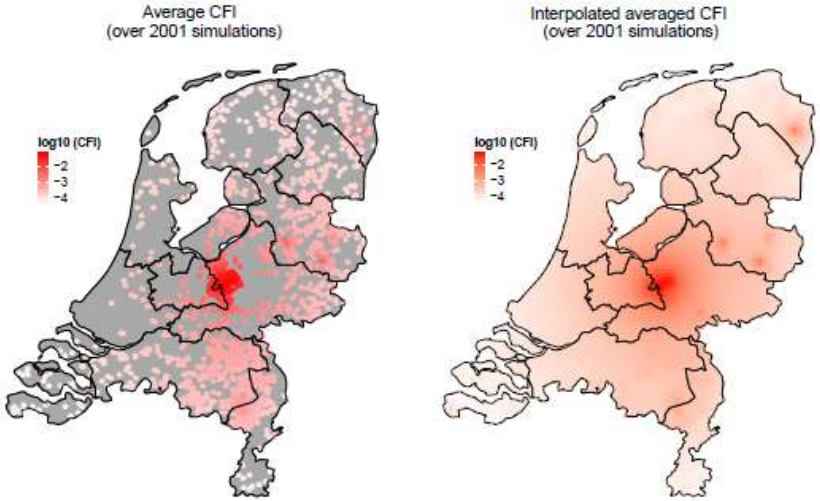
weather & impact warnings



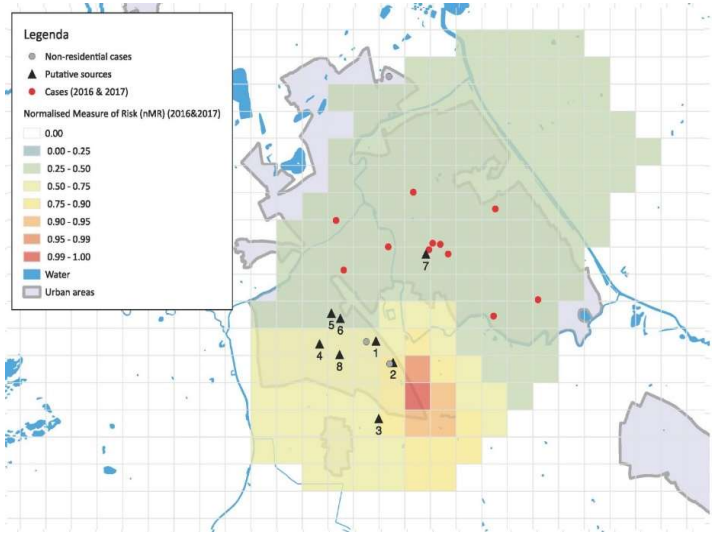
Introduction

Question from: National Institute for Public Health and the Environment

Can KNMI provide historical weather maps at 1 km X 1 km X 1 hour resolution?



Risk mapping for airborne infectious diseases



Source detection of airborne infectious diseases

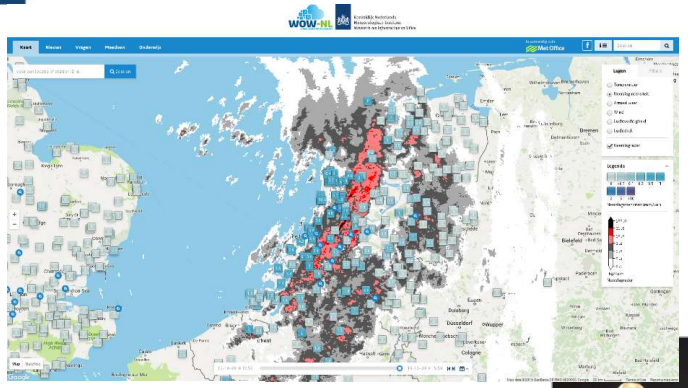
Source: RIVM, https://doi.org/10.3201%2Feid2410.180906

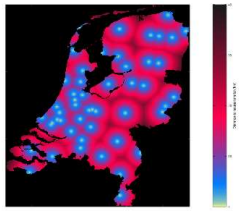
Introduction

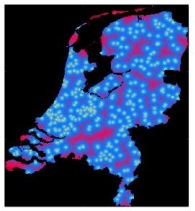
- Initiated by UK Met Office
- WOW-NL portal launched 2015
- Teaching Material and Outreach
- Smart Cities – Senshagen Zwolle
- User support by back office
- Exchange of best practices with other WOW partners

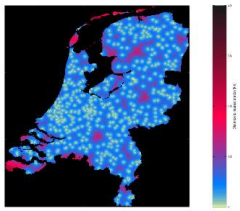
We are very grateful
for all the efforts from
the WOW community
in providing data!

Weather Observation Website: WOW





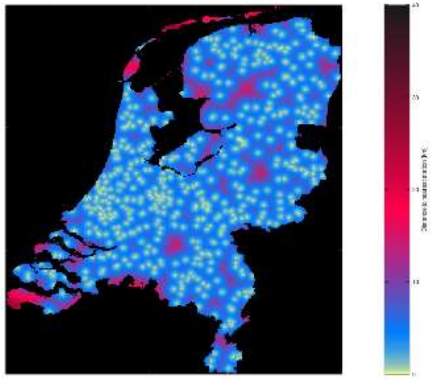


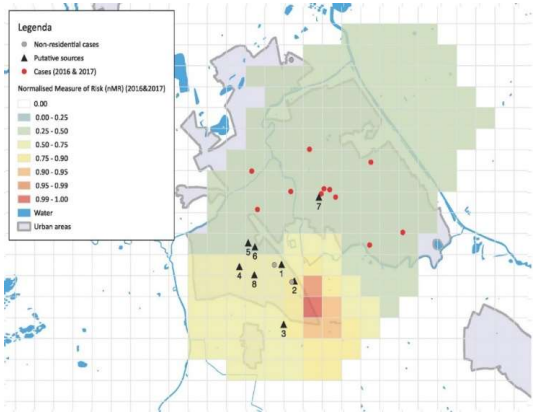


Introduction

data by community,

results for community





KNMI

Source: RIVM, https://doi.org/10.3201%2Feid2410.180906

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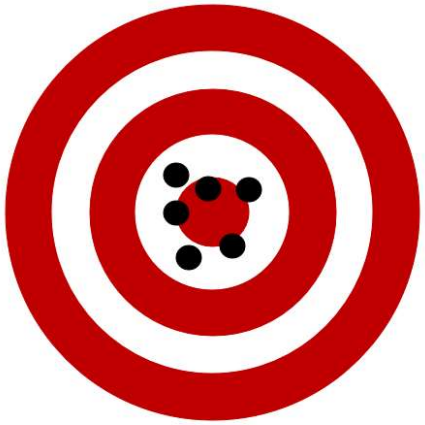
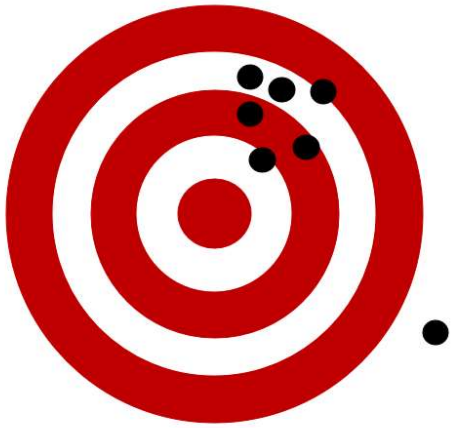
"accurate"
(≠ reality)



noise

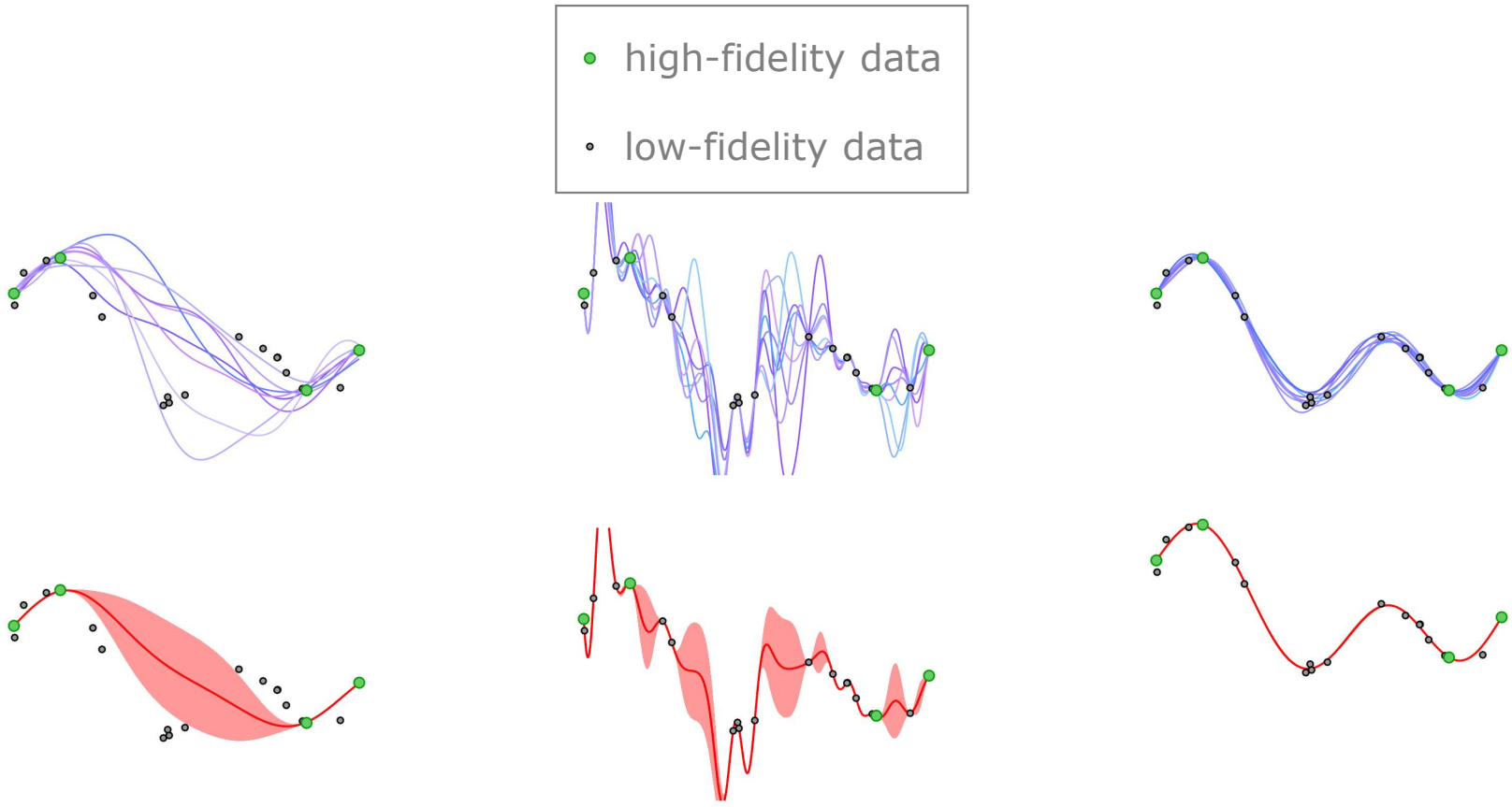
bias + noise



bias + noise
+ outlier

Methodology

Multi-fidelity Gaussian process regression



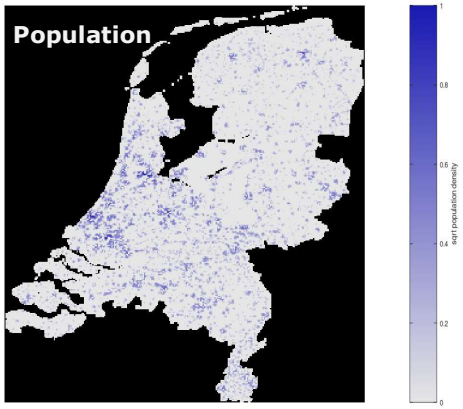
ignoring low-fi data

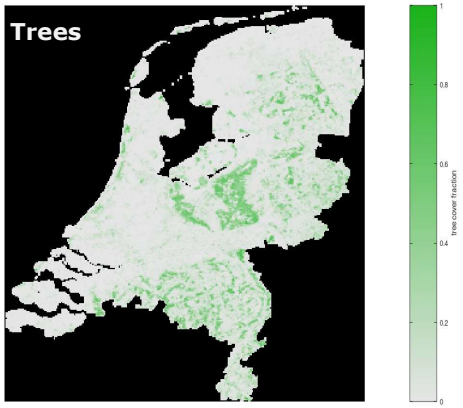
exact interpolation

regression with noise treatment

Methodology

High-resolution covariates





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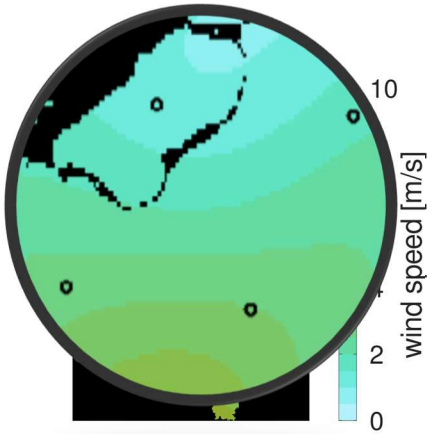
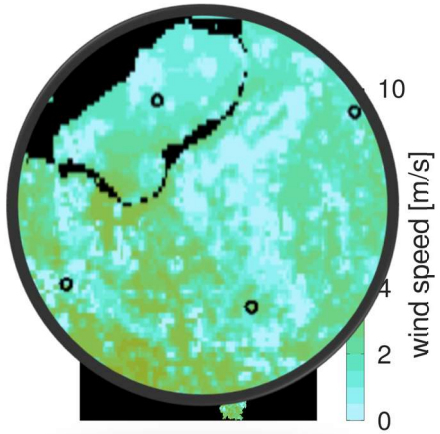
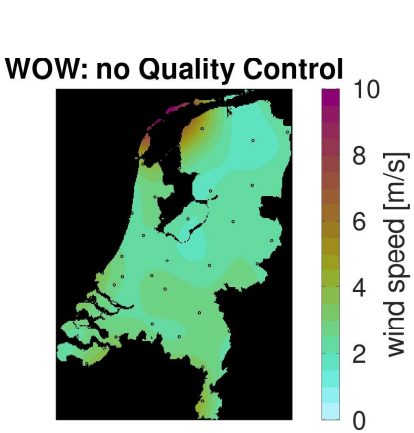
Wind speed (29 June 2021, 8am-9am)



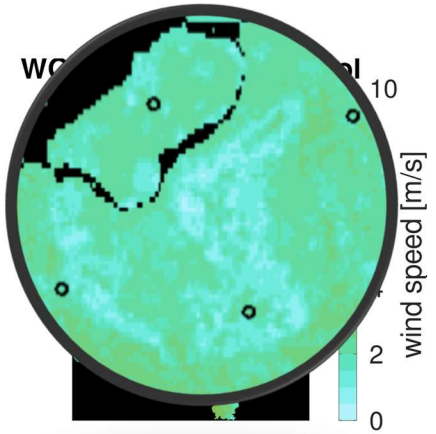
KNMI



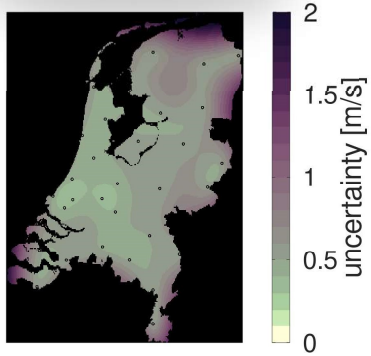
KNMI + cov



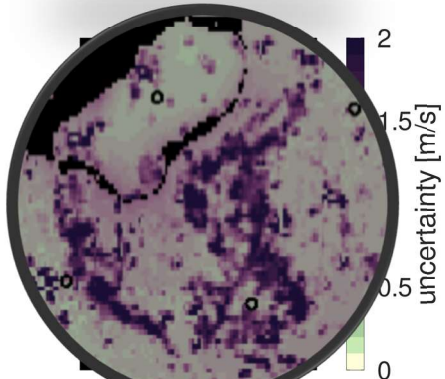
KNMI + WOW



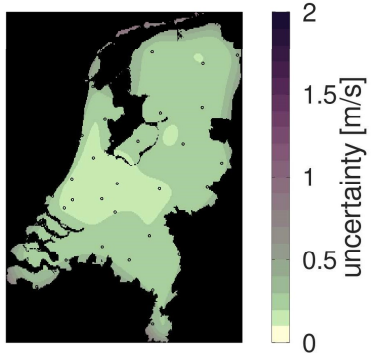
KNMI + WOW + cov



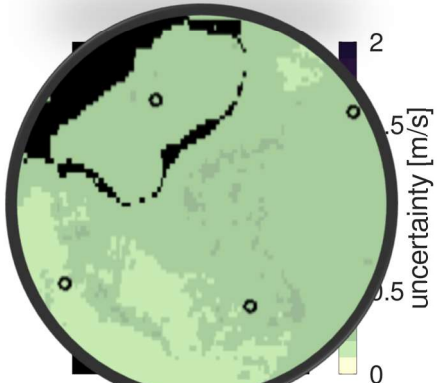
KNMI



KNMI + cov



KNMI + WOW

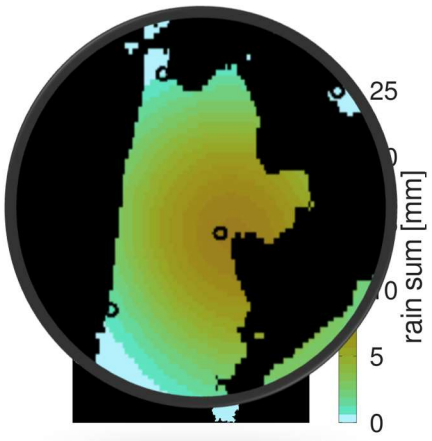


KNMI + WOW + cov

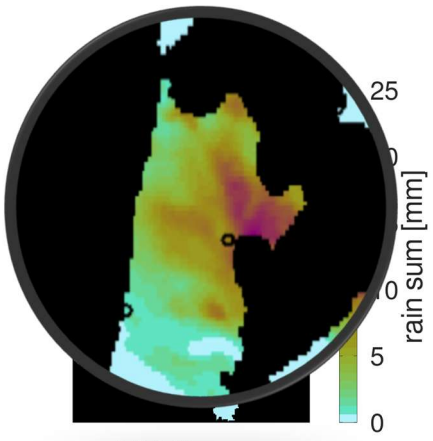
Source: De Baar, Garcia-Marti, Van der Schrier, EMS2022-53

Results

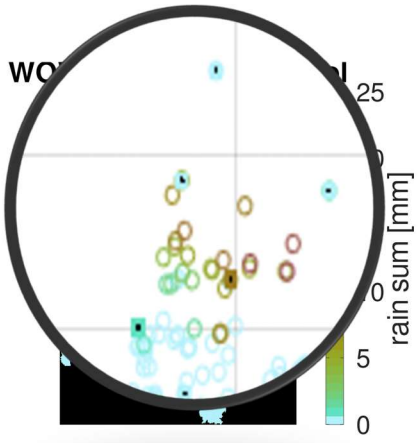
Rain (29 June 2021, 8am-9am)



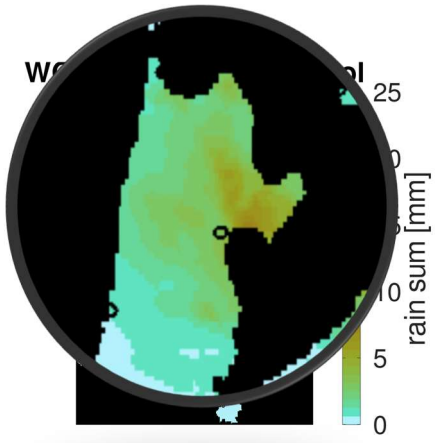
KNMI



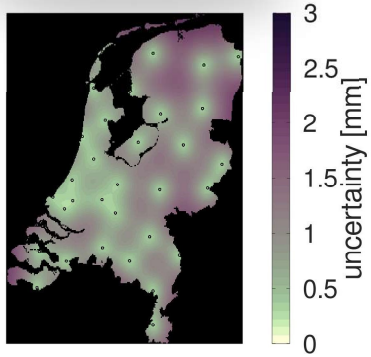
KNMI + cov



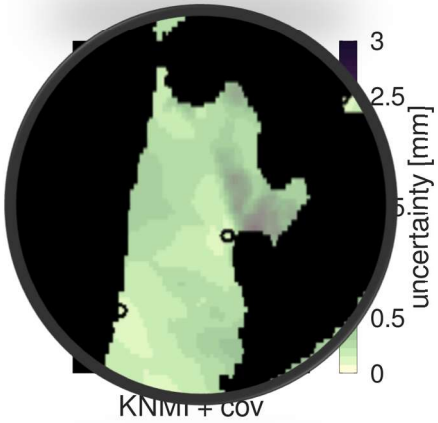
KNMI + WOW



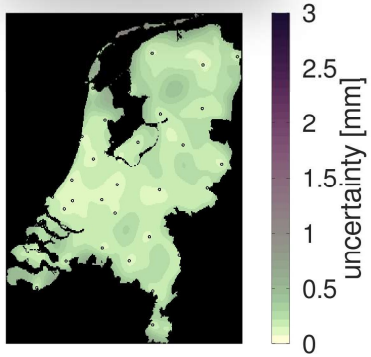
KNMI + WOW + cov



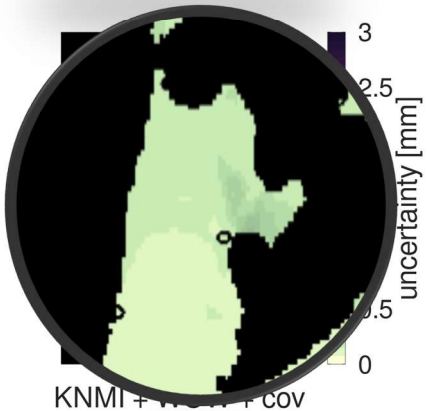
KNMI



KNMI + cov



KNMI + WOW

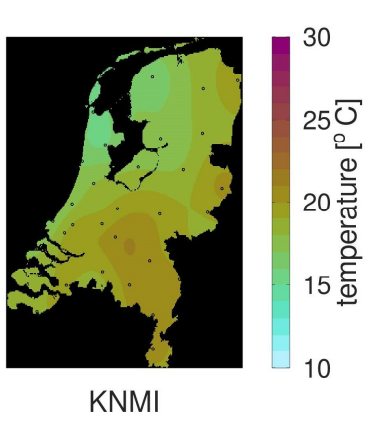


KNMI + cov

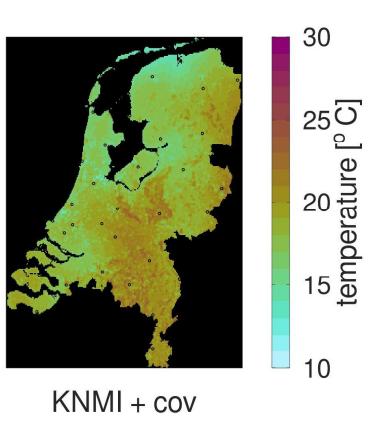
Source: De Baar, Garcia-Marti, Van der Schrier, EMS2022-53

Results

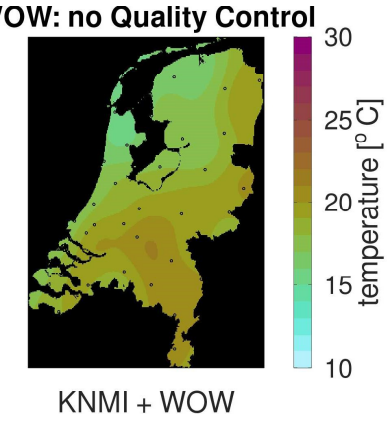
Temperature (29 June 2021, 8am-9am)



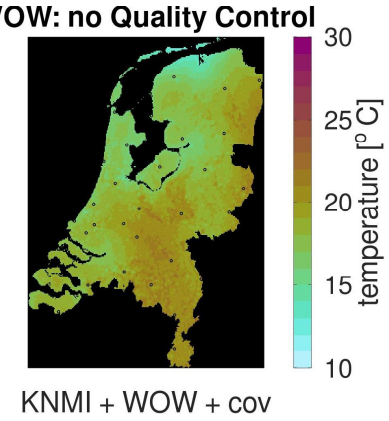
KNMI



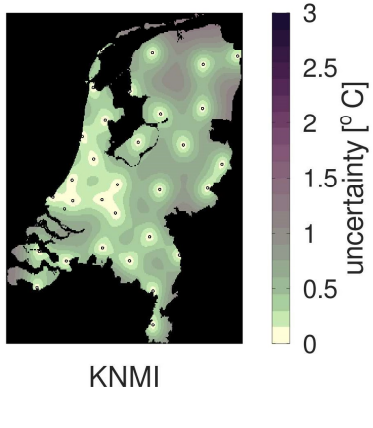
KNMI + cov



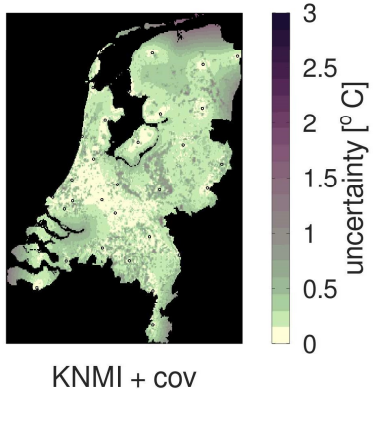
KNMI + WOW



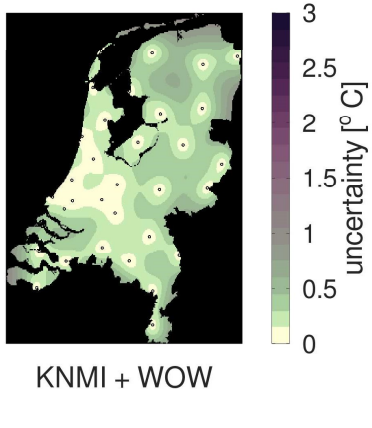
KNMI + WOW + cov



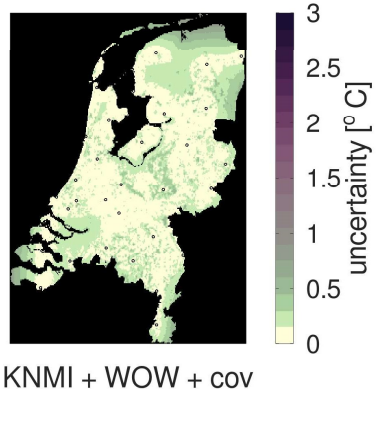
KNMI



KNMI + cov



KNMI + WOW

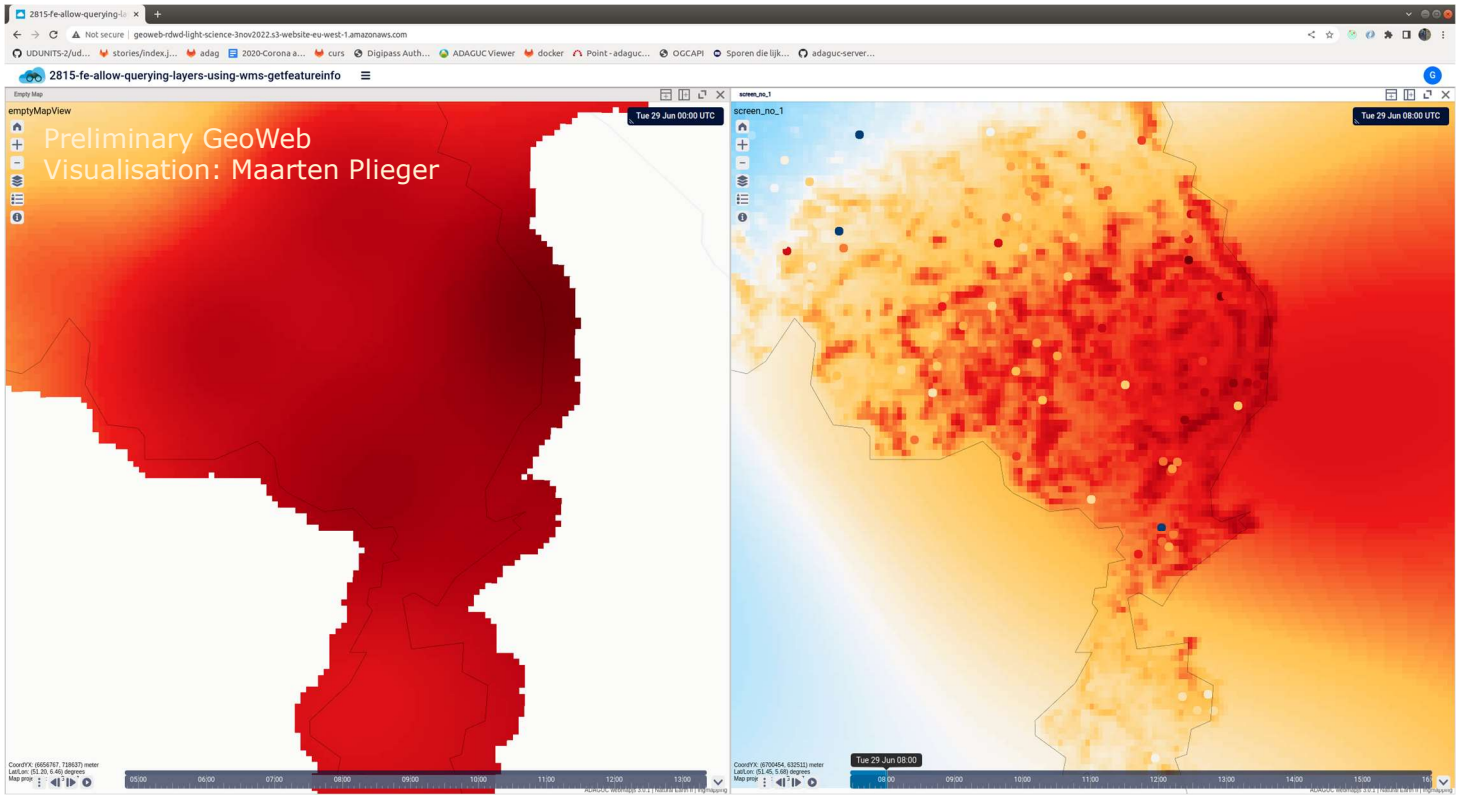


KNMI + WOW + cov

Source: De Baar, Garcia-Marti, Van der Schrier, EMS2022-53

Results

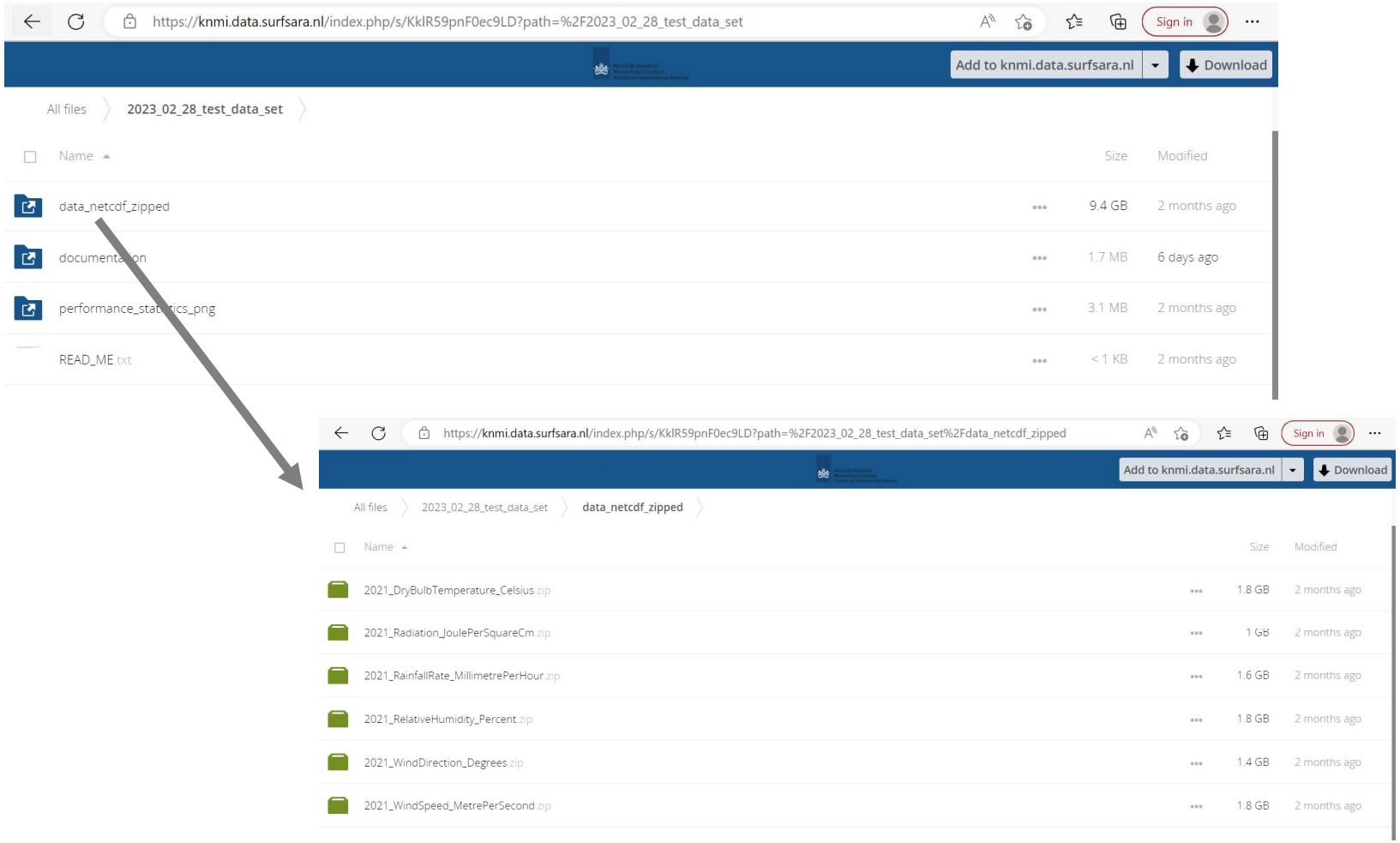
Temperature (29 June 20212, 24h)



- The observational process (ie bias and noise) is an intrinsic part of the regression
- Even without any QC on the crowd-sourced data, we can get reasonable results
- However, in the project we now do a first step of basic QC

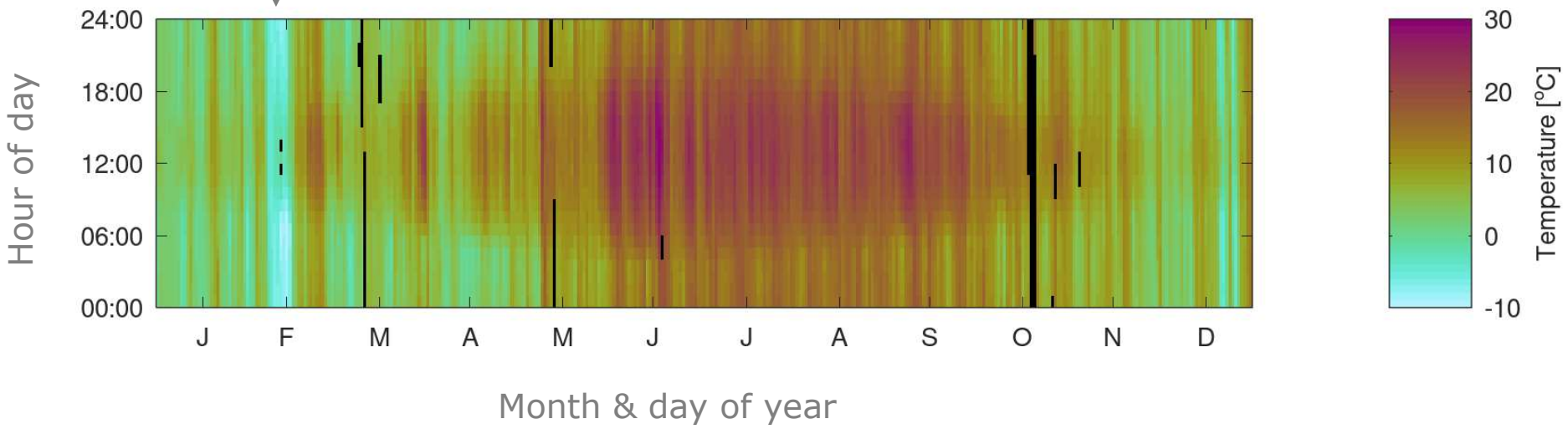
Results

Prototype data set: Year 2021



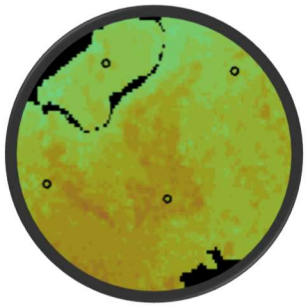
Results

Prototype data set: Year 2021

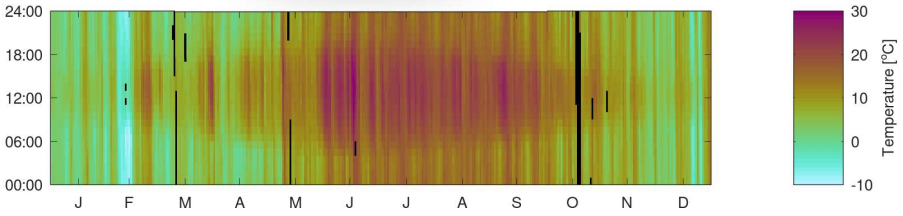


Results for prototype data set

The x-validation only represents official KNMI locations; however, we expect the largest improvements in non-official locations!

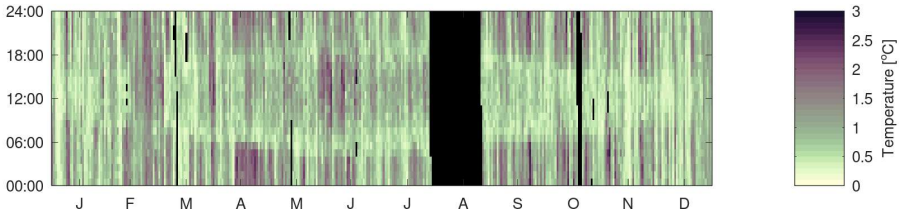


Air temperature

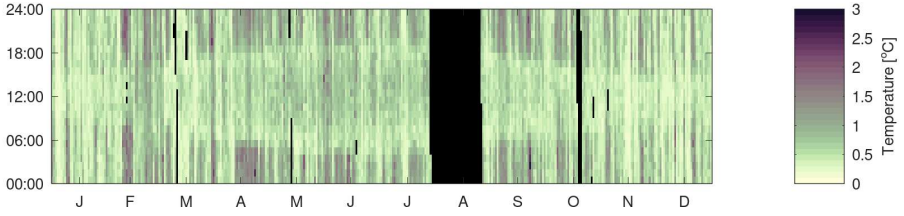


Cross-validation: air temperature

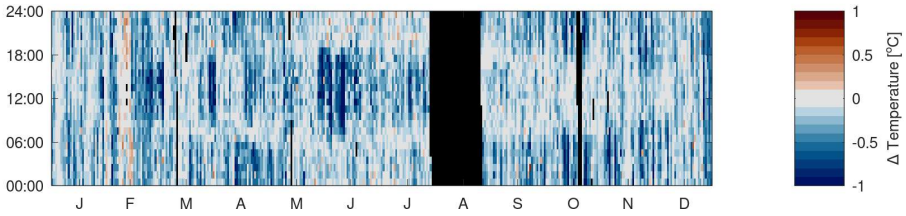
x-Val RMSE: KNMI



x-Val RMSE: KNMI + WOW + cov

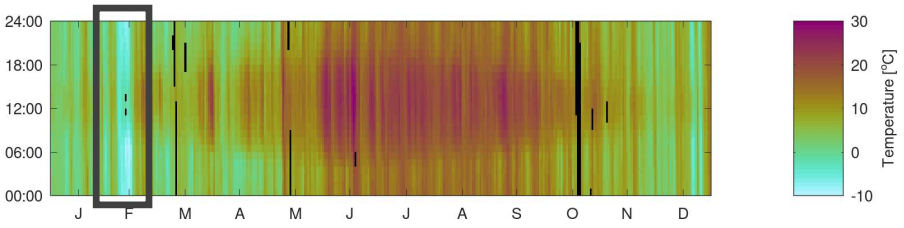


x-Val difference (blue = better)

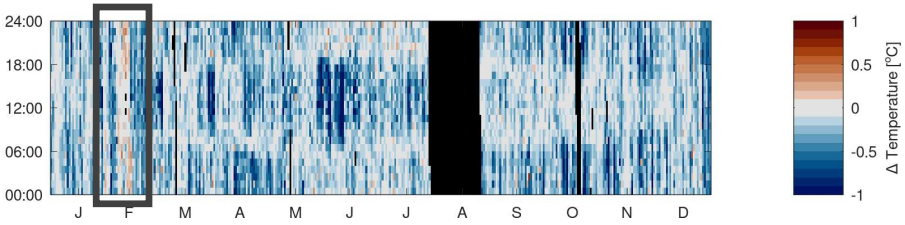


Results for prototype data set

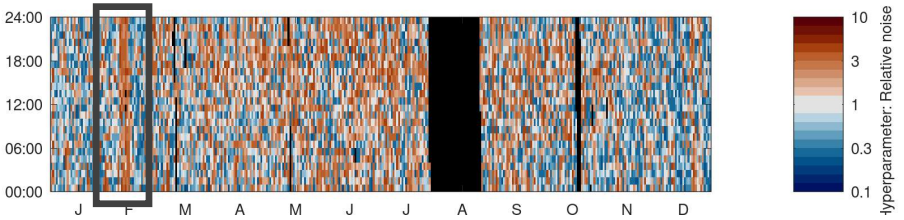
Air temperature



x-Val difference (blue = better)

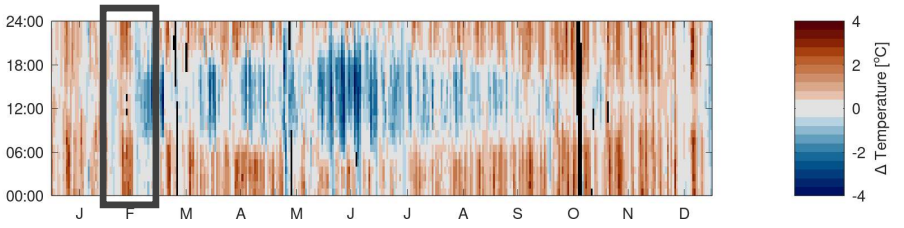


Hyperparameter: estimated noise level

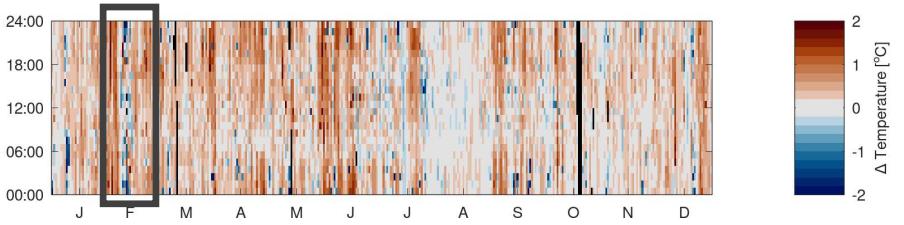


Issue with noise estimation & over-fitting

Coastal effect? (10% closest to water)

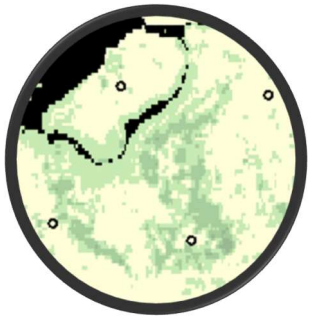


Population effect? (10% highest population)

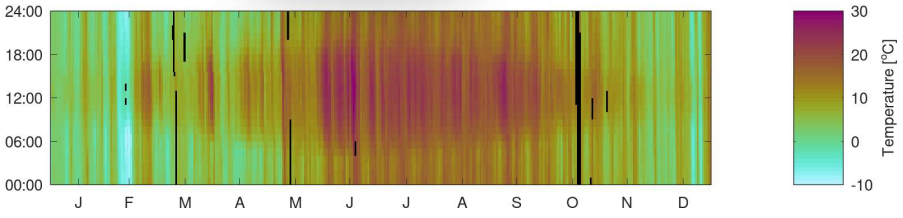


Results for prototype data set

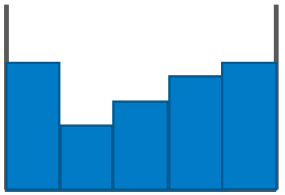
Looking for ways to improve the uncertainty maps!

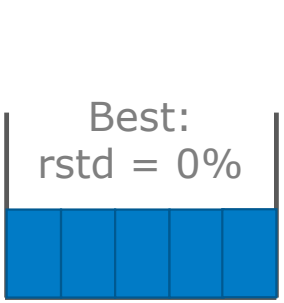


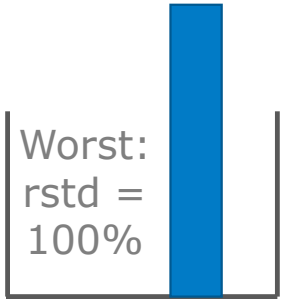
Air temperature



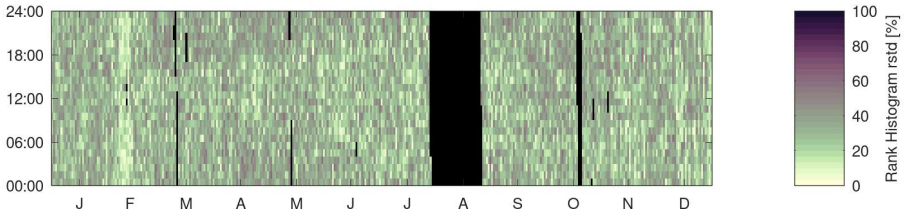
Cross-validation: rank histogram







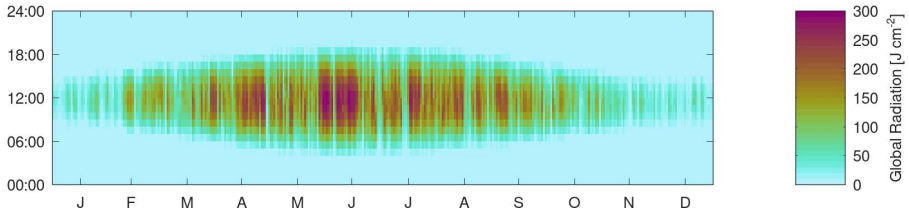
x-Val rank histogram rstd



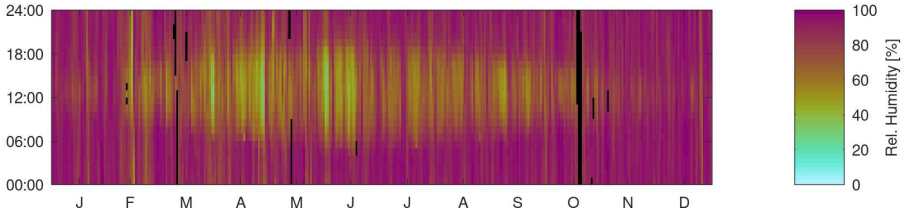
Results

Prototype data set: Year 2021

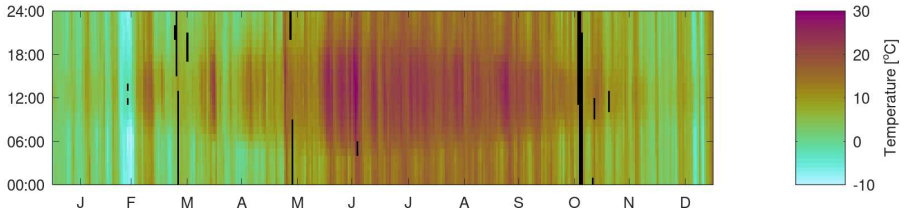
Global radiation



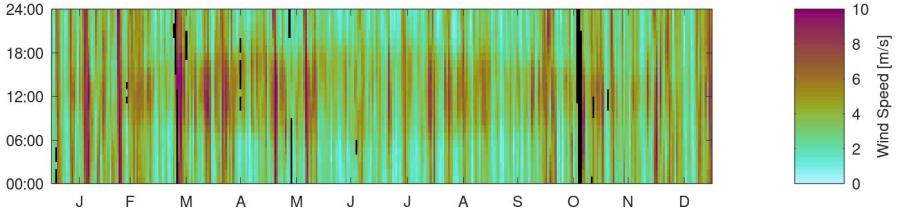
Relative humidity



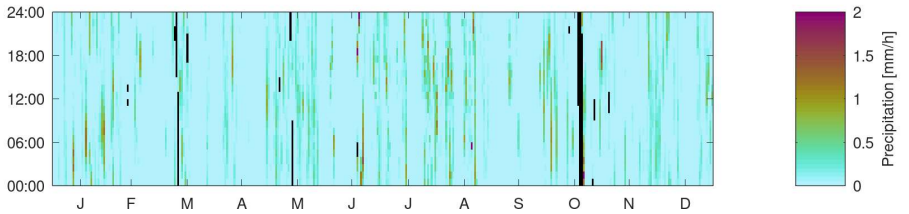
Air temperature



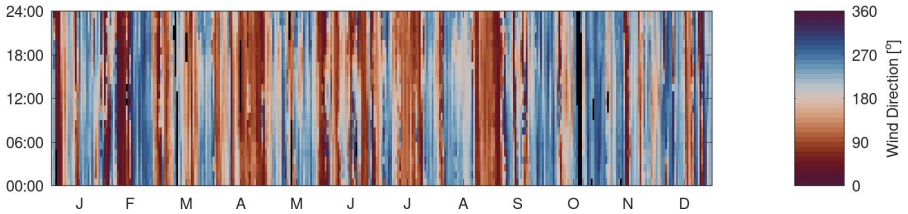
Wind speed



Precipitation



Wind direction



Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat

Introduction

Methods

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Next steps

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Next steps

- Collect & implement feedback from user group

- Correct issues

- Think about verification & validation

- Provide data set for full period (2015-2022)

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Ministerie van Infrastructuur en Waterstaat

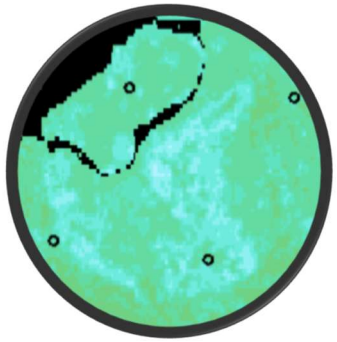
Thank you very much for your kind attention

Jouke de Baar, Gerard van der Schrier,Theo Brandsma (KNMI)

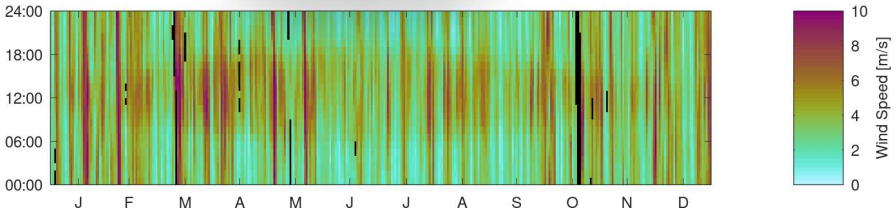
Budapest, 11 May 2023 (online)

Question & answer slide

The x-validation only represents official KNMI locations; however, we expect the largest improvements in non-official locations!

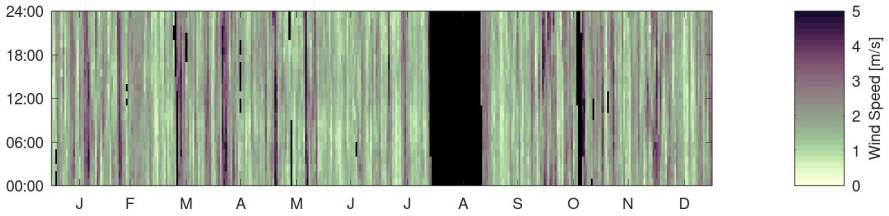


Wind speed

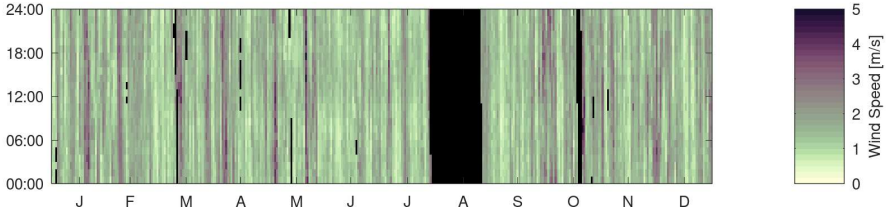


Cross-validation: wind speed

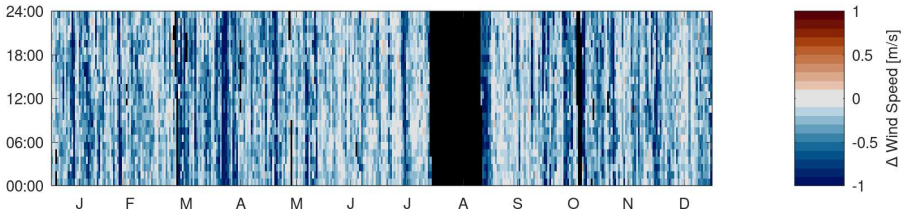
x-Val RMSE: KNMI



x-Val RMSE: KNMI + WOW + cov



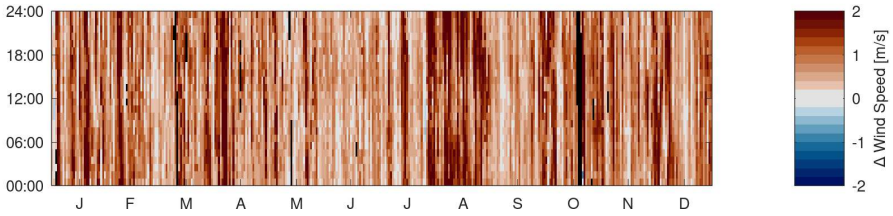
x-Val difference (blue = better)



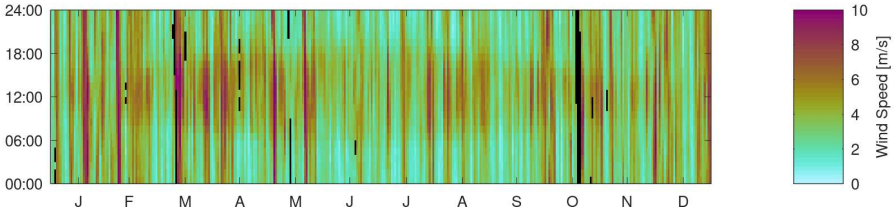
Question & answer slide

Local wind speed effects?

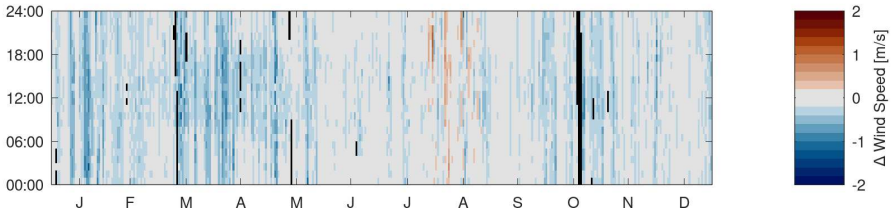
Coastal effect? (10% closest to water)



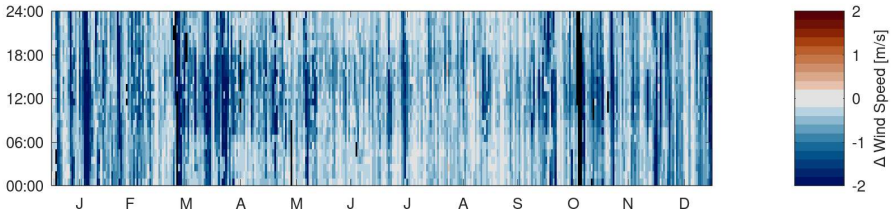
Wind speed



Population effect? (10% highest population)

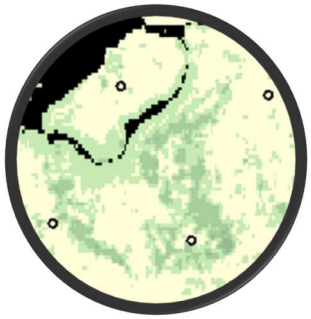


Tree effect? (10% highest tree cover)

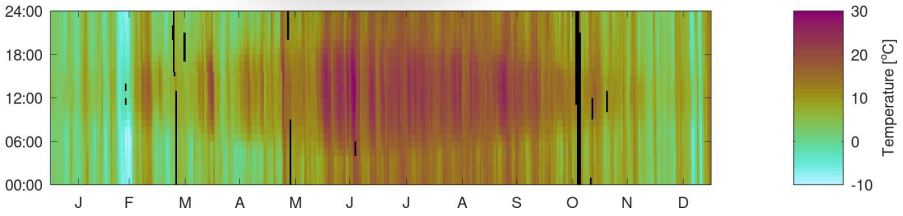


Question & answer slide

Looking for ways to improve the uncertainty maps!



Air temperature



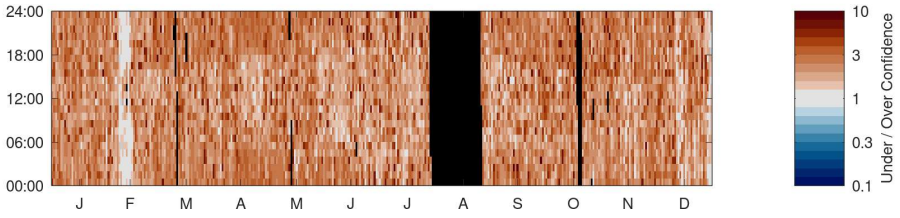
Cross-validation: confidence

- Compare x-validation errors with the local x-validation uncertainty map:
- Error < Uncertainty estimate:

  "Under-confident"
- Error > Uncertainty estimate:

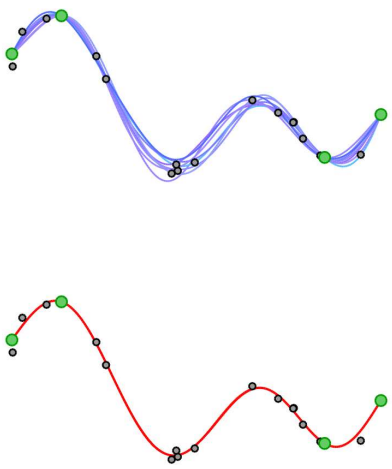
  "Over-confident"

x-Val under/over confidence



Question & answer slide

Equations



regression with noise treatment

Prior $$p(\boldsymbol{X}) = \mathcal{N}(Q\hat{\boldsymbol{\beta}}_Q, P)$$

Likelihood $$p(\boldsymbol{Y}|\boldsymbol{x}) = \mathcal{N}(H\boldsymbol{x} + B\boldsymbol{\beta}_B, R)$$

$$\sqrt{R} = N\hat{\boldsymbol{\beta}}_N I_{n\times n}$$

Posterior $$p(\boldsymbol{X}|\boldsymbol{y}) = \mathcal{N}(\hat{\boldsymbol{x}}, \hat{C})$$

Source: De Baar, Garcia-Marti, Van der Schrier, EMS2022-53 / Proceedings asr-2023-5

Question & answer slide

Equations

Standard GPR

$$E[f(x)] = m(x) + k(x,\mathbf{x'},\theta)\, K(\mathbf{x'},\mathbf{x'},\theta)^{-1} \{ \mathbf{y} - \mathbf{m}(\mathbf{x'}) \},$$

$$var[f(x)] = k(x,x,\theta) - k(x,\mathbf{x'},\theta)^{T}\, K(\mathbf{x'},\mathbf{x'},\theta)^{-1}\, k(x,\mathbf{x'},\theta),$$

With external drift

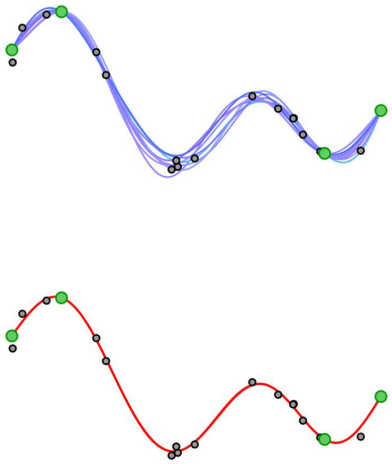
$$E[f(x)] = M(x)\,\boldsymbol{\beta} + k(x,\mathbf{x'},\theta)\, K(\mathbf{x'},\mathbf{x'},\theta)^{-1} \{ \mathbf{y} - \mathbf{M}(\mathbf{x'})\,\boldsymbol{\beta} \},$$

$$var[f(x)] = k(x,x,\theta) - k(x,\mathbf{x'},\theta)^{T}\, K(\mathbf{x'},\mathbf{x'},\theta)^{-1}\, k(x,\mathbf{x'},\theta) + C_M(x,x,\theta,\boldsymbol{\beta}),$$

With bias and noise

$$E[f(x)] = M(x)\,\boldsymbol{\beta} + k(x,\mathbf{x'},\theta) \{ K(\mathbf{x'},\mathbf{x'},\theta) + R(\mathbf{x'},\mathbf{x'},\boldsymbol{\varepsilon}) \}^{-1} \{ \mathbf{y} - \mathbf{M}(\mathbf{x'})\,\boldsymbol{\beta} \},$$

$$var[f(x)] = k(x,x,\theta) - k(x,\mathbf{x'},\theta)^{T} \{ K(\mathbf{x'},\mathbf{x'},\theta) + R(\mathbf{x'},\mathbf{x'},\boldsymbol{\varepsilon}) \}^{-1}\, k(x,\mathbf{x'},\theta) + C_M(x,x,\theta,\boldsymbol{\beta}).$$



regression with noise treatment

Source: De Baar, Garcia-Marti, NATO STO-MP-AVT, 2022, Varna