Explaining the variation in radioactivity levels by the variation in rainfall intensity

Context

In the Netherlands the National Radioactivity Monitoring network (NRM) was established to detect radiological accidents and monitor how the contamination spreads. Interpolated maps provide a good way of visualizing the spatial distribution of radioactivity levels, and they provide estimated radioactivity levels at unmeasured locations. The interpolation method we use can take into account trends that are present in the data.

A trend present in the radioactivity data is caused by rainfall, daugther products of radon are washed out of the atmosphere increasing the radioactivity level. Rainfall intensity is estimated using rainfall radar. In this study we focused on the following research questions:

- Radon daughter products deposited for example half an hour ago still influence the current radioactivity level. So, is a weighted averaged rainfall intensity a better predictor than rainfall intensity?
- Does taking the trend into account improve our interpolated map?

Fig 1: The Dutch National Radioactivity monitoring network

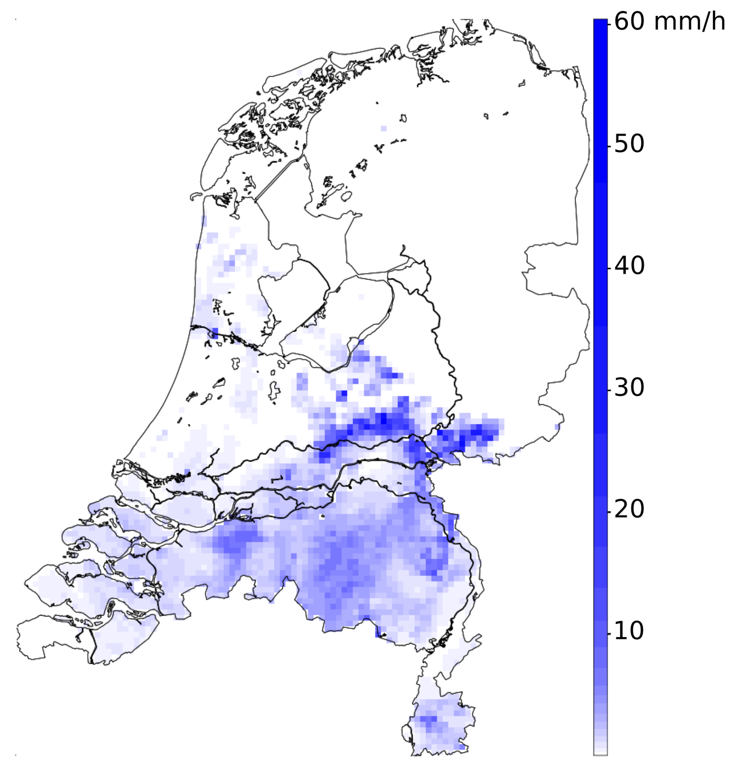

Fig 2: Example of a rainfall intensity map constructed using rainfall radar

1. Is weighted averaged rainfall intensity a better predictor than rainfall intensity?

Figure 3 shows a time series of a) the rainfall intensity, (b) the weighted averaged rainfall intensity, and c) the increase in radioactivity. The scatterplots (d and e) show that the amount of explained variance in time increases from 18% to 86% if we use the weighted averaged rainfall intensity. On average the amount of explained variance in time increases from 16% to 73%. This indicates that the weighted averaged rainfall intensity is a better predictor of radioactivity than rainfall intensity.

The amount of explained variance in time is not high for all monitoring stations, sometimes as low as 15% for weighted averaged rainfall intensity. This can be attributed to the fact that rainfall radar is not a perfect estimator of rainfall intensity. For example: the atmospheric volume sampled by radar increases with distance, thus underestimating rainfall intensity. Additionally, the radar beam is attenuated by rain storms making it harder to detect rain beyond that storm. A possible solution would be to improve the estimate of rainfall intensity using rain gauges.

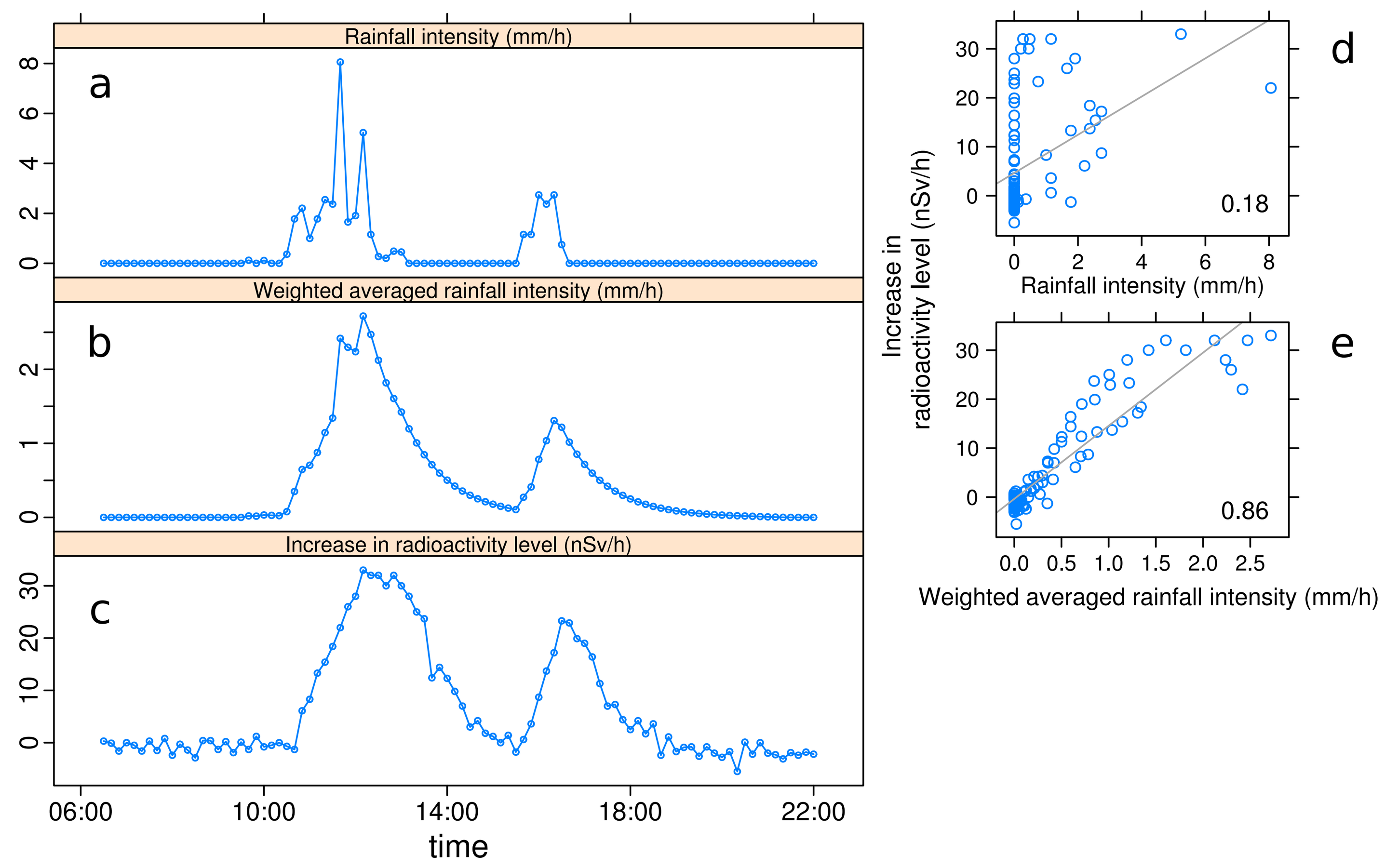

Fig 3: Timeseries of increase in radioactivity, rainfall intensity and weighted averaged rainfall intensity for a monitoring station.

2. Does taking into account the trend improve our interpolated map?

To see if adding the trend improves our prediction we compare maps made by Ordinary Kriging (no trend) to Universal Kriging (trend). Our comparison is based on the RMSE of the leave-one-out cross-validation residuals. The RMSE should be as small as possible. Note that the trend is no longer in time as with question 1 but in space.

The results of our research showed that taking the trend into account leads to mixed results in terms of RMSE. This seems counter intuitive: we expected that taking the trend into account would improve our map.

Figure 4 illustrates how adding a trend can increase the leave-one-out cross-validation RMSE. Maps show how a point is predicted within cross-validation for Ordinary (a) and Universal Kriging (b). The real measured value for the most left point (shown in red) is 19.2 nSv/h. From (b) it is obvious that the trend part of the prediction grossly overestimates the radioactivity level at that location, which is confirmed by (c). We conclude, Universal Kriging only performs as well as we can describe the trend.

Figure 5 shows examples of a map of increase in radioactivity level for both Universal Kriging and Ordinary Kriging. Despite the fact that the cross-validation results do not show a clear improvement with Universal Kriging, we believe that Universal kriging matches more what is known about radioactivity data and its interaction with rainfall. This is particularly true given the strength of the relationship shown in figure 3.

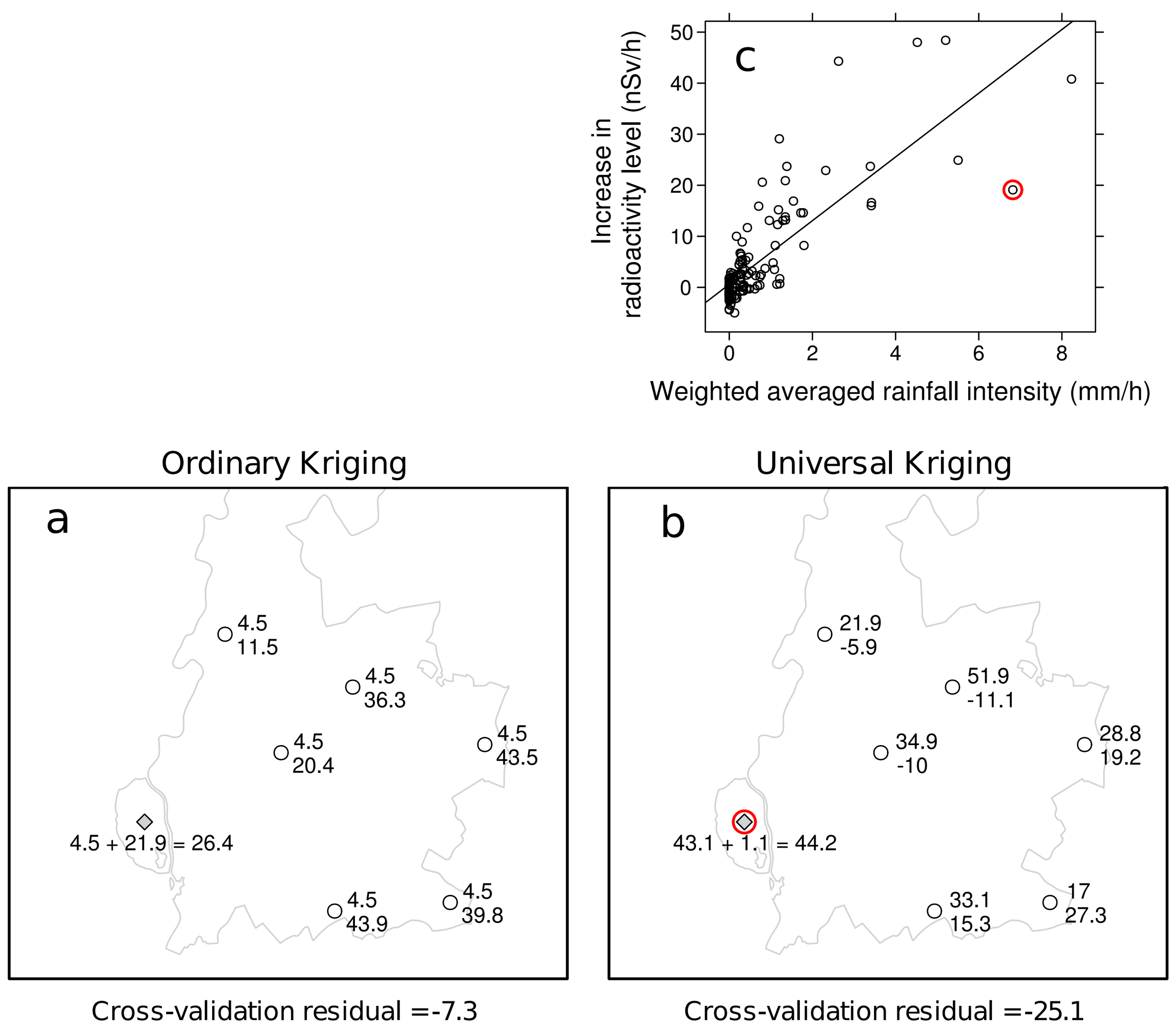

Fig 4: If the trend does not describe the process accurately, OK maps can have a lower leave-one-out cross-validation RMSE than UK maps.

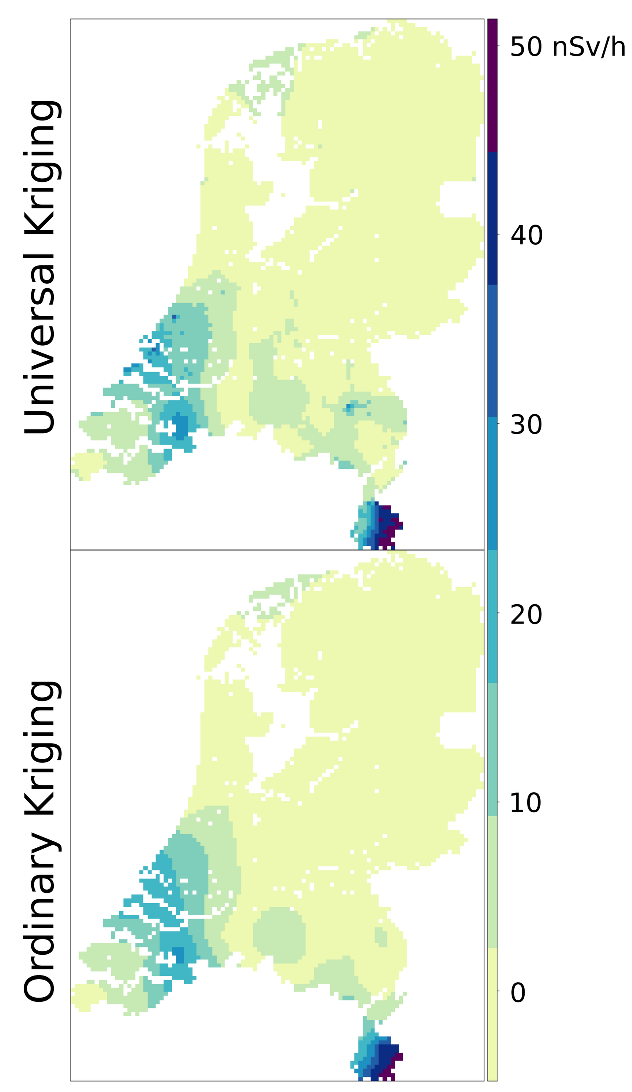

Fig 5: Interpolated maps using Universal and Ordinary Kriging

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