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National Institute for Public Health and the Environment
Ministry of Health, Welfare and Sport

Benchmark of Data Fusion
First results

October 20, 2024

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Contents

- A few words on the RIVM data fusion scheme.
- Analysis of the data / results of RIVM.
- Questions?
- Comparison of all models
- Discussion
- Questions?

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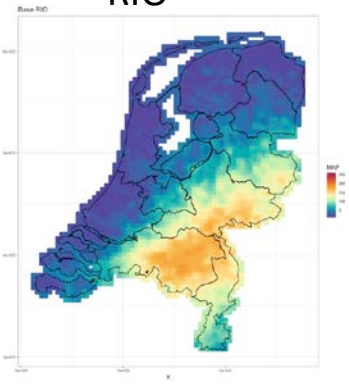
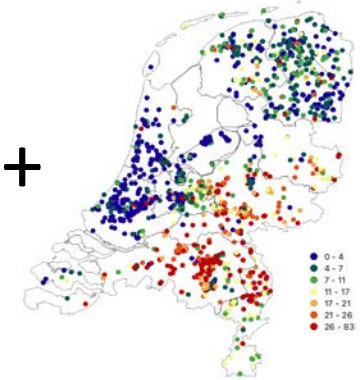
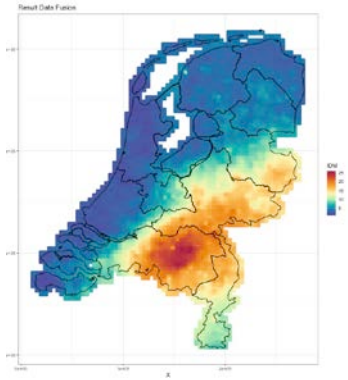
Data fusion RIVM

RIO



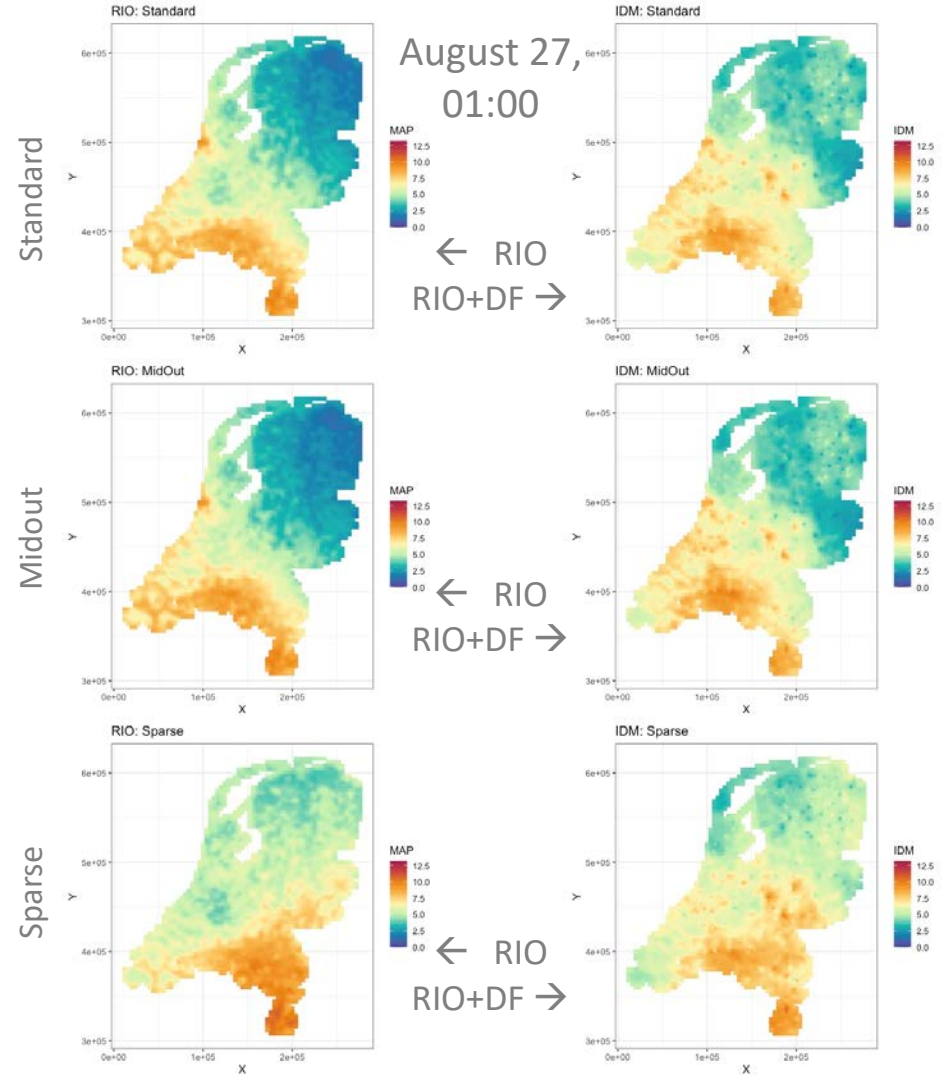
Sensors





- First, the calibrated sensor values are interpolated on a 1x1 km^2 scale over the whole country.
- The systematic uncertainty of the sensor calibration is estimated using a bootstrap, taking the number of sensors and the number of official measurements into account.
- The random uncertainty of the sensors is estimated from a relation derived from co-location of many sensors.
- The individual random uncertainties are included in the interpolated sensor field using a bootstrap.
- The uncertainty in the RIO field is combined with that of the sensor field to estimate a new, data fused, concentration map.

Data fusion RIVM



- The data fusion process is run parallel for all three variants: standard RIO, MidOut and Sparse RIO.
- Each data fusion run for one variant takes roughly 20 seconds on 1 core of a M1 Pro MacBook.
- As a test, sets of input and output concentration fields were checked.

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Analysis of time series

- Extract the values of the models, original RIO fields and results of data fusion at the locations of official measurements, i.e. NL10636 (Utrecht).
- Plot as a function of the number of the hour.
- Official (LML) measurements are grey circles.
- Solid curves are original RIO, standard, midOut and sparse.
- Dashed curves are the results of the data fusion.

Analysis of correlations

- Extract the values of the models, original RIO fields and results of data fusion at the locations of official measurements.
- Correlate the official (LML) measurements with the RIO results and the results of the data fusion.
- Standard deviations of differences LML-model are shown in the caption of the figures.

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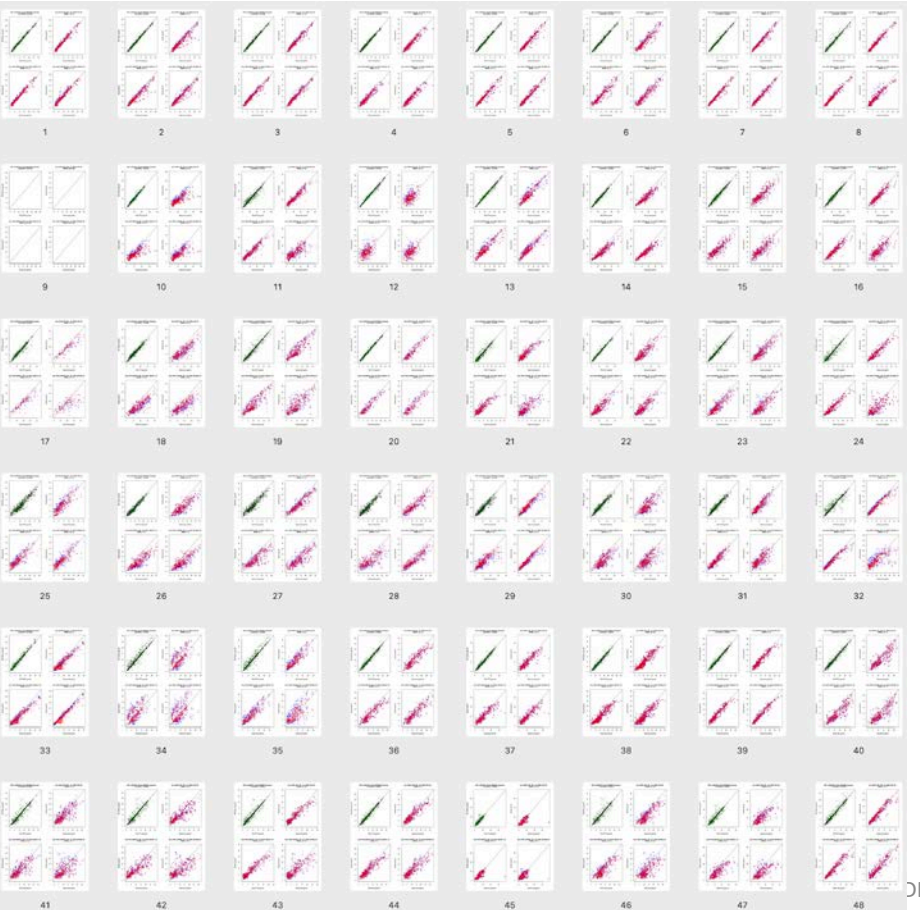
Correlations



- Extract the values of the models, original RIO fields and results of data fusion at the locations of official measurements.
- Correlate the official (LML) measurements with the RIO results and the results of the data fusion.
- Standard deviations of differences LML-model are shown in the caption of the figures.

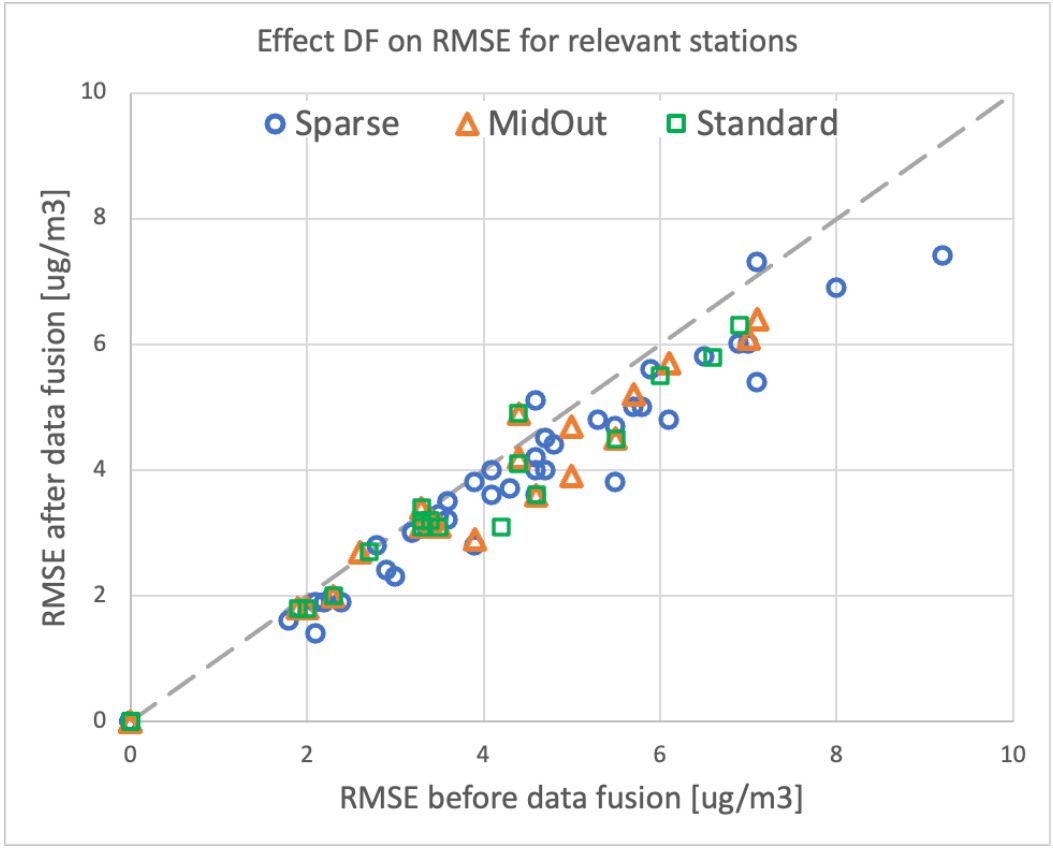
- Calculate RMSE for every location.

RMSE

	91%	STANDARD		91%	MIDOUT		88%	SPARSE		Average RATIO RMSE=	92%	91%	88%
	RMSE	RMSE	SE in CHEC	RMSE	RMSE	SE in CHEC	RMSE	RMSE	SE in CHECK?				
NL01485	1.5	1.2	0	1.5	1.2	0	2.1	1.4	1	NL01485 Hoogvliet-Leemkuil			67%
NL01487	2.7	2.7	1	2.6	2.7	1	2.8	2.8	1	NL01487 Rotterdam_Zuid-Pleinweg	100%	104%	100%
NL01488	1.7	1.5	0	1.6	1.5	0	1.7	1.5	0	NL01488 Rotterdam_Zuid-Zwartewaalstraat			
NL01489	2.0	1.8	1	2.0	1.8	1	2.1	1.9	1	NL01489 Ridderkerk-Hogeweg	90%	90%	90%
NL01491	1.9	1.8	1	1.9	1.8	1	1.8	1.6	1	NL01491 Rotterdam-Oost_Sidelinge_A13	95%	95%	89%
NL01493	2.3	2.0	1	2.3	2.0	1	2.2	1.9	1	NL01493 Rotterdam_Noord_-Statenweg	87%	87%	86%
NL01494	1.6	1.4	0	1.6	1.4	0	1.5	1.3	0	NL01494 Schiedam-Alphons_Arienstraat			
NL01495	1.2	1.3	0	1.2	1.3	0	2.3	2.0	1	NL01495 Maassluis-Kwartellaan			87%
NL01496									1	NL01496 Hoek_v._Holland-Berghaven			
NL01913	4.4	4.9	1	4.4	4.9	1	4.6	5.1	1	NL01913 Sluiskil-Stroodorpestraat	111%	111%	111%
NL10131	2.7	2.7	0	2.7	2.7	0	5.5	4.7	1	NL10131 Vredepeel-Vredeweg			85%
NL10136	4.6	3.6	1	4.6	3.6	1	4.6	3.6	1	NL10136 Heerlen-Looierstraat	78%	78%	78%
NL10138	3.0	2.6	0	3.0	2.6	0	2.6	2.4	0	NL10138 Heerlen-Jamboreepad			
NL10230	4.4	4.6	0	4.5	4.6	0	4.7	4.7	0	NL10230 Biest_Houtakker-Biestsestraat			
NL10240	3.3	3.4	1	3.3	3.4	1	3.9	3.8	1	NL10240 Breda-Tilburgseweg	103%	103%	97%
NL10241	2.5	2.7	0	2.4	2.7	0	4.1	4.0	1	NL10241 Breda-Bastenakenstraat			98%
NL10247	4.7	4.8	0	4.6	4.8	0	9.2	7.4	1	NL10247 Veldhoven-Europalaan			80%
NL10248	6.9	6.3	1	7.1	6.4	1	8.0	6.9	1	NL10248 Nistelrode-Gagelstraat	91%	90%	86%
NL10404	3.3	3.4	0	3.3	3.4	0	4.7	4.0	1	NL10404 Den_Haag-Rebecquestraat			85%
NL10418	2.4	2.5	0	2.4	2.5	0	3.2	3.0	1	NL10418 Rotterdam-Schiedamsevest			94%
NL10444	2.7	2.9	0	2.7	2.9	0	4.6	4.2	1	NL10444 De_Zilk-Vogelaarsdreef			91%
NL10449	3.5	3.1	1	3.5	3.1	1	3.6	3.2	1	NL10449 Vlaardingen-Riouwlaan	89%	89%	89%
NL10450	3.4	3.2	1	3.4	3.2	1	4.1	3.6	1	NL10450 Den_Haag-Neherkade	94%	94%	88%
NL10538	2.4	2.4	0	2.4	2.3	0	5.3	4.8	1	NL10538 Wieringerwerf-Medemblikkerweg			91%
NL10636	4.2	3.1	1	3.9	2.9	1	3.9	2.8	1	NL10636 Utrecht-Kardinaal_de_Jongweg	74%	74%	72%
NL10641	6.6	5.8	1	7.0	6.1	1	7.0	6.0	1	NL10641 Breukelen-Snelweg	88%	87%	86%
NL10643	3.1	3.7	0	5.0	4.7	1	4.7	4.5	1	NL10643 Utrecht-Griftpark		94%	96%
NL10644	3.9	4.0	0	5.7	5.2	1	4.0	4.0	0	NL10644 Cabauw-Wielsekade		91%	
NL10738	2.8	2.7	0	5.0	3.9	1	2.6	2.5	0	NL10738 Wekerom-Riemterdijk		78%	
NL10741	6.0	5.5	1	6.1	5.7	1	6.5	5.8	1	NL10741 Nijmegen-Graafseweg	92%	93%	89%
NL10742	3.0	2.9	0	2.6	2.7	0	4.6	4.0	1	NL10742 Nijmegen-Ruyterstraat			87%
NL10821	2.4	2.2	0	2.5	2.3	0	6.1	4.8	1	NL10821 Enschede-Winkelhorst.			79%
NL10934	2.2	3.1	0	2.2	3.1	0	1.1	2.6	0	NL10934 Kollumerwaard-Hooge_Zuidwal			
NL10937	5.5	4.5	1	5.5	4.5	1	7.1	5.4	1	NL10937 Groningen-Europaweg	82%	82%	76%
NL10938	3.0	2.4	0	3.0	2.4	0	5.5	3.8	1	NL10938 Groningen-Nijensteinheerd			69%
NL49007	3.3	3.2	1	3.4	3.2	1	3.5	3.3	1	NL49007 Amsterdam-Einsteinweg	97%	94%	94%
NL49012	3.3	3.1	1	3.3	3.1	1	3.2	3.0	1	NL49012 Amsterdam-Van_Diemenstraat	94%	94%	94%
NL49014	2.8	2.8	0	2.9	2.9	0	3.4	3.2	1	NL49014 Amsterdam-Vondelpark			94%
NL49016	2.0	1.8	0	1.9	1.8	0	1.7	1.5	0	NL49016 Amsterdam-Westerpark			
NL49017	4.4	4.1	1	4.4	4.2	1	4.8	4.4	1	NL49017 Amsterdam-Stadhouderskade	93%	95%	92%
NL49551	4.0	4.2	0	4.0	4.2	0	5.7	5.0	1	NL49551 IJmuiden-Kanaaldijk			88%
NL49553	4.0	4.2	0	4.0	4.2	0	5.8	5.0	1	NL49553 Wijk_aan_Zee-Burgemeester_Roth			86%
NL49556	2.5	2.5	0	2.5	2.5	0	4.3	3.7	1	NL49556 De_Rijp-Oostdijkje			86%
NL49561	3.0	3.0	0	3.0	3.0	0	3.6	3.5	1	NL49561 Badhoevedorp-Sloterweg			97%
NL49570	5.5	5.3	0	5.5	5.3	0	6.9	6.0	1	NL49570 Beverwijk_West-Creutzberglaan			87%
NL49572	4.5	4.8	0	4.5	4.8	0	5.9	5.6	1	NL49572 Velsen-Staalstraat			95%
NL49573	6.0	6.5	0	6.0	6.5	0	7.1	7.3	1	NL49573 Velsen-Reijndersweg			103%
NL49701	1.9	1.7	0	1.9	1.7	0	2.4	1.9	1	NL49701 Zaandam-Wagenschotpad			79%
NL49703	2.0	2.0	0	2.0	2.0	0	2.9	2.4	1	NL49703 Amsterdam-Spaarnwoude			83%
NL49704	2.3	2.2	0	2.3	2.2	0	3.0	2.3	1	NL49704 Amsterdam-Hoogtij			77%

- Take differences between time series of measurements and model results at specific locations.
- Calculate RMSE of differences observation – model, with and without data fusion.
- Calculate ratio data fused model versus original model.
- Only locations not used in the data fusion.

RMSE



- Take differences between time series of measurements and model results at specific locations.
- Calculate RMSE of differences observation – model, with and without data fusion.
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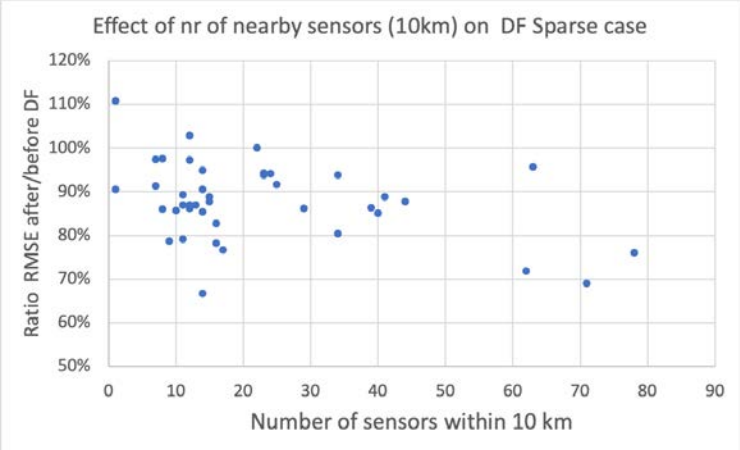
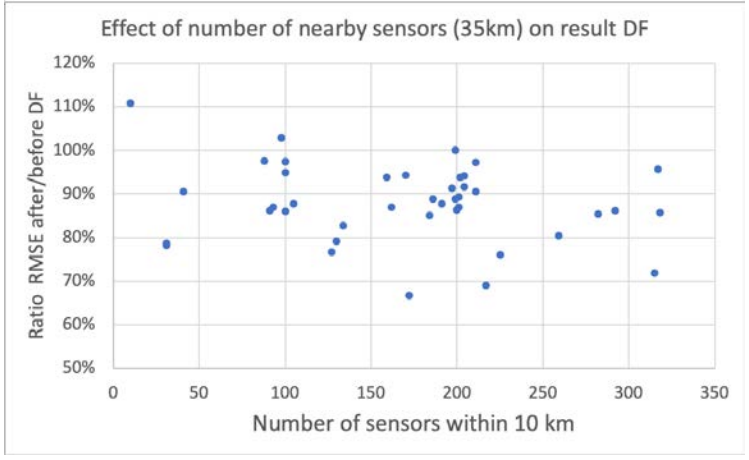
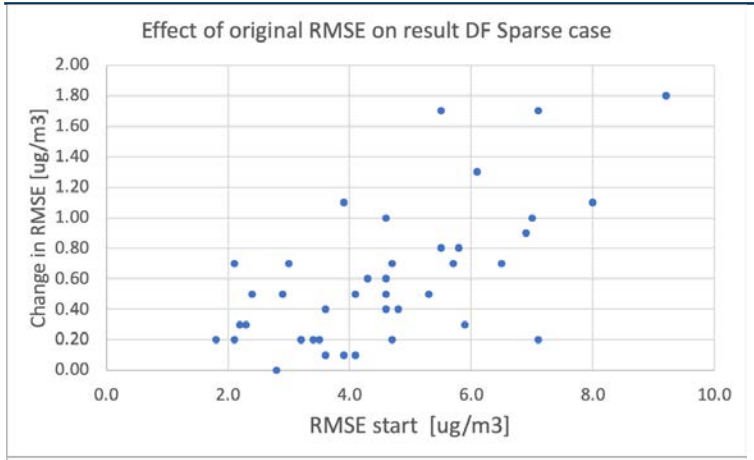
Effect number of sensors

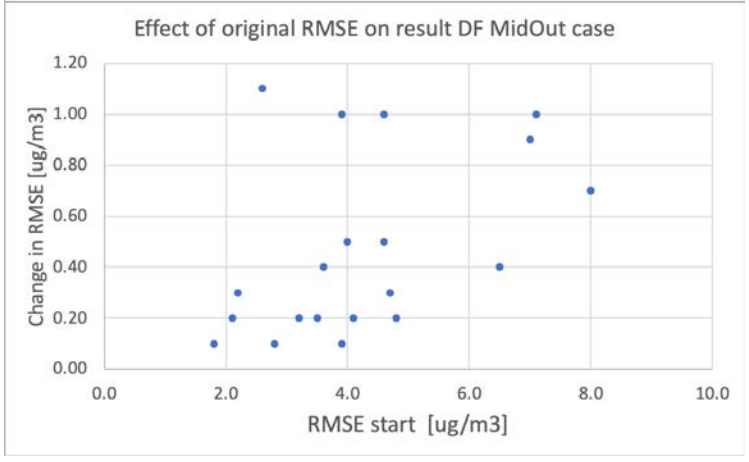




- For the case of the RIVM results, the relative effect of the data fusion on the RMSE at all test locations was compared to the number of nearby sensors.
- Two tests were performed, number of sensors within 10km range and 35 km range.
- There is an effect of the numbers of sensors, especially of the number of nearby sensors.
- Also some effect of sensors further away.

Effect RMSE at start





- For the case of the RIVM results, the relative effect of the data fusion on the RMSE at all test locations was compared to the RMSE before the data fusion.
- There is a clear (but modest) effect: the effect increases with larger initial RMSE.
- The effect is largest for the sparse case.

1st results RIVM Jan/Aug 2024

Overall conclusions results RIVM:

- For more than 90% of the test-locations the RMSE (observations versus model) is reduced after the data fusion.
- On average, the RMSE is reduced by 16% in January and by 11% in August.
- Note: the test-locations were not used in the data fusion,

Questions so far?

Comparison of All results

- A similar analysis was performed for all contributing models: INERIS, VITO, ISSeP, CERC, MetNo and RIVM.
- Some models used reference measurements at selected locations, on top of the sensor measurements.

NL10636 (Utrecht) Effect of data fusion on standard RIO map.

Data January and August (where possible)

Comparison of All results

- A similar analysis was performed for all contributing models: INERIS, VITO, ISSeP, CERC, MetNo and RIVM.
- Some models used reference measurements at selected locations, on top of the sensor measurements.
- There are differences between the results of the different types of data fusion, especially for the sparse case.

NL10248 (Nistelrode) Effect of data fusion on SPARSE RIO map.
Data January and August (where possible)

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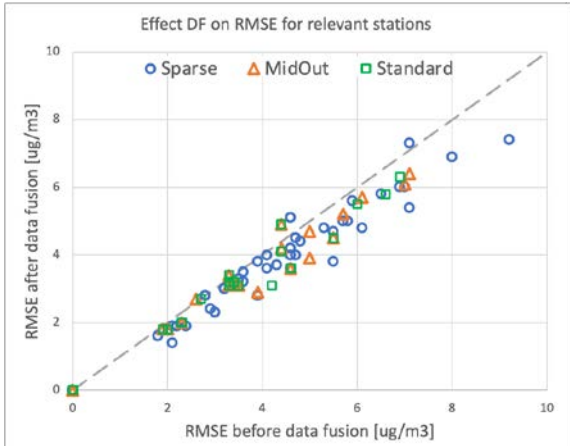
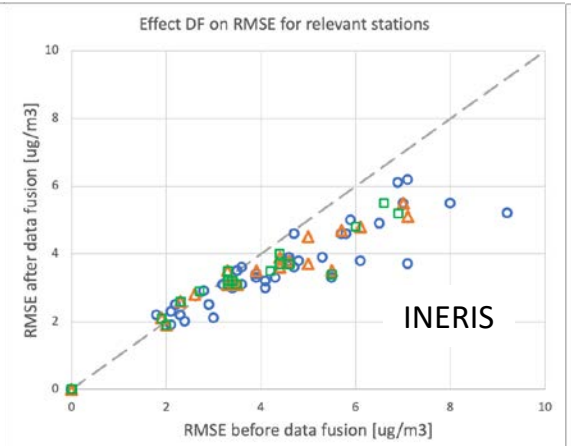
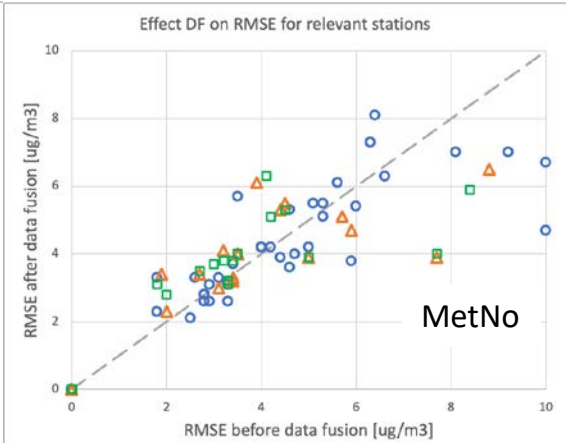
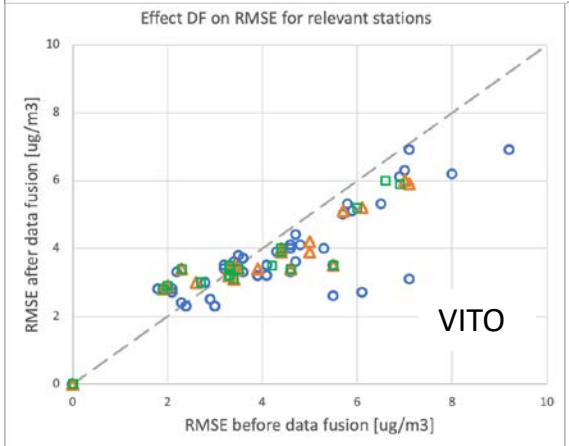
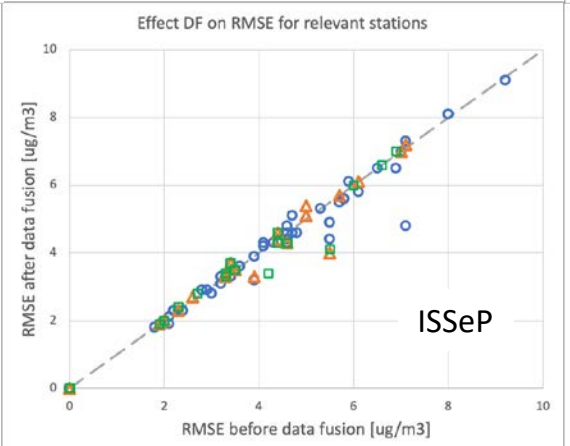
Comparison

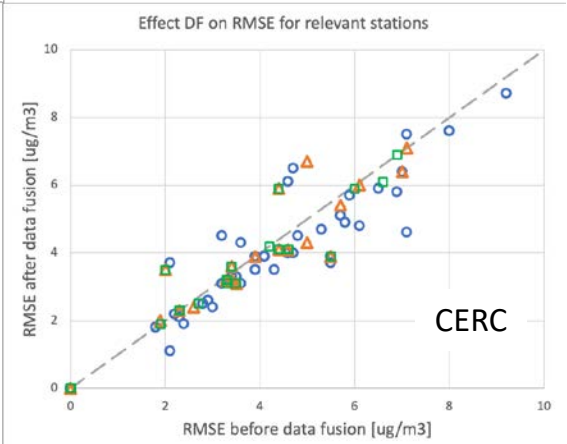












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Overall conclusions, so far

- There are non-trivial differences between the results of the data fusion approaches.
- The largest effects of data fusion are observed for the sparse case.

- The RIO model that is used as a start of the DF already performs quite good.
- We should test with another model/map as a start. CAMS?
- Using official measurement data in the data fusion has a substantial effect.

- More models welcome!

- NOTE: all 1st results!

Next steps ...

- Hopefully more models.
- Several participants have indicated they want to tweak their models ☺
- Process more hourly data, the week of September, 16-23, seems interesting, with concentrations/variations up to 40 ug/m3.
- More/better metrics to compare the performance of the models?
- Use other concentration fields as input for the data fusion?

- More discussion in 2nd session of WG6!

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Questions?