HARMO23
15 – 19 September 2025, Hamburg, Germany

Comparatively using the original CAMS and refined dataset of pollution sources for evaluation of a high-resolution application of SILAM model.

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SILAM

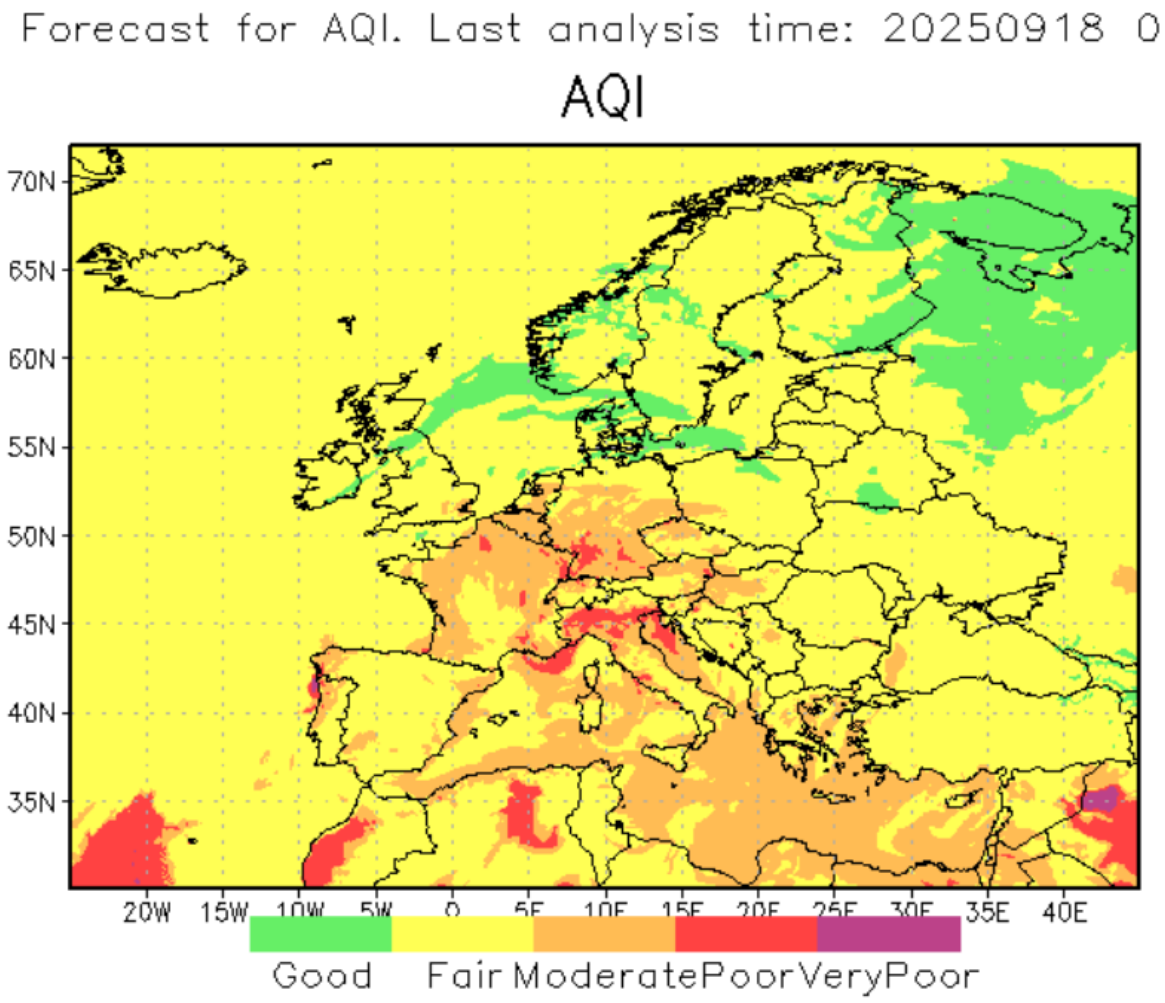
FINNISH METEOROLOGICAL INSTITUTE + Airviro

Atmospheric chemical-transport model, global-to-mesoscale, developed by FMI.

Varying input emissions: coarser CAMS v5.1 inventory *vs* finer national OSIS inventory.

Aim of study: does the finer resolution inventory perform better?

Model timeseries comparison with measurements at stations.



SILAM AQI forecast for current hour.

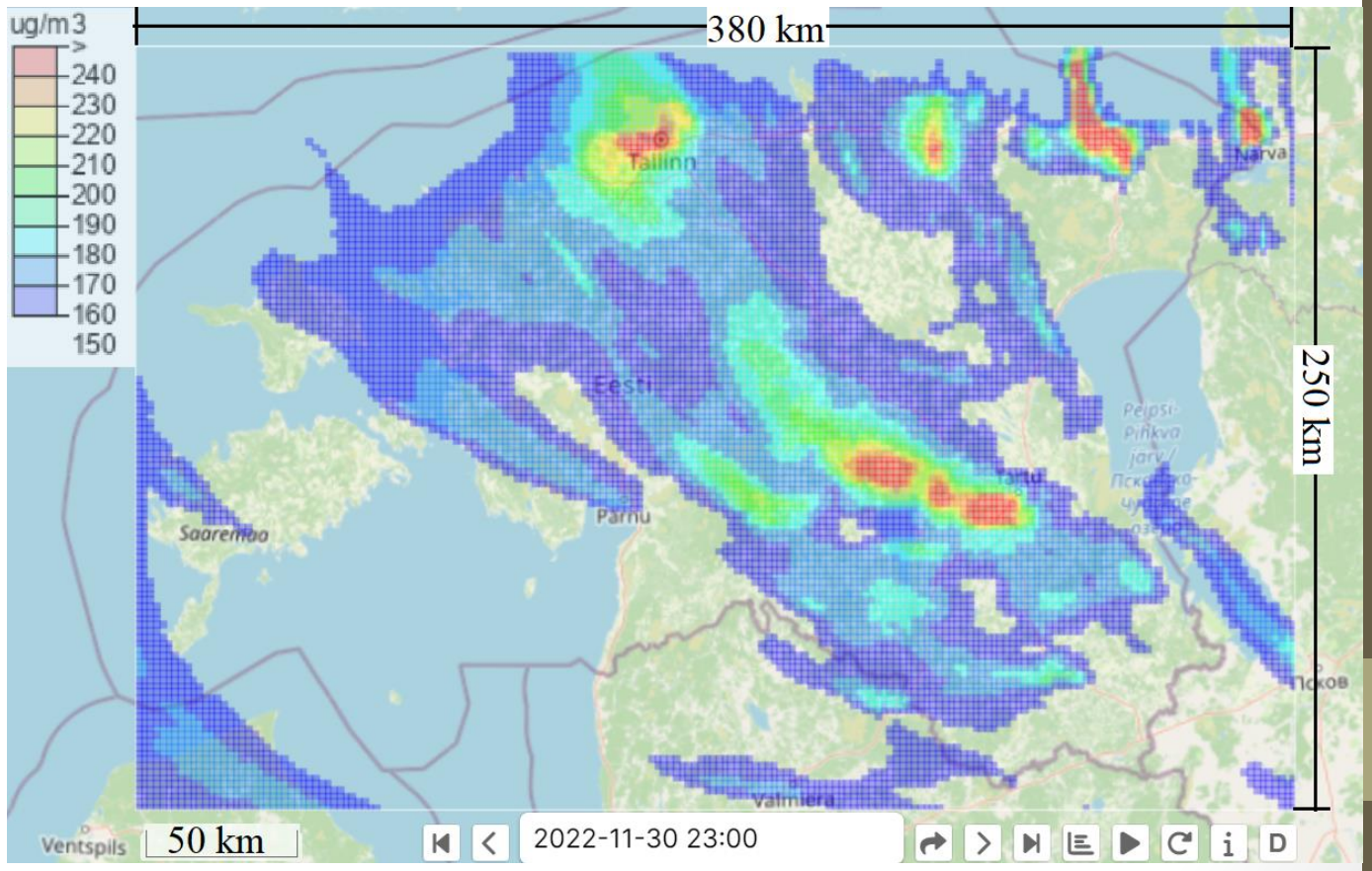
Modelling setup

- Period 01.02.2023 – 01.02.2024 (full year)
- 2 km resolution
- 11 vertical layers, bottom one: 20 m
- 2 minute time step

FMI SILAM boundary fields, ~11x6 km

CAMS-REG-AP v5.1, ~6x6 km
---------- OR ----------
CAMS-REG-AP v5.1, ~6x6 km
+ Estonian OSIS, 1x1 km

ECMWF meteorological fields, ~11x6 km



Domain example (CO hourly average concentration).

Modelling setup

- „Full chemistry“ setup
- Different emission data
- Validation runs for NO_x, O_3, SO_2, $PM_{2.5}$, PM_{10} and CO
- Time series comparison at stations

FMI SILAM boundary fields, ~11x6 km

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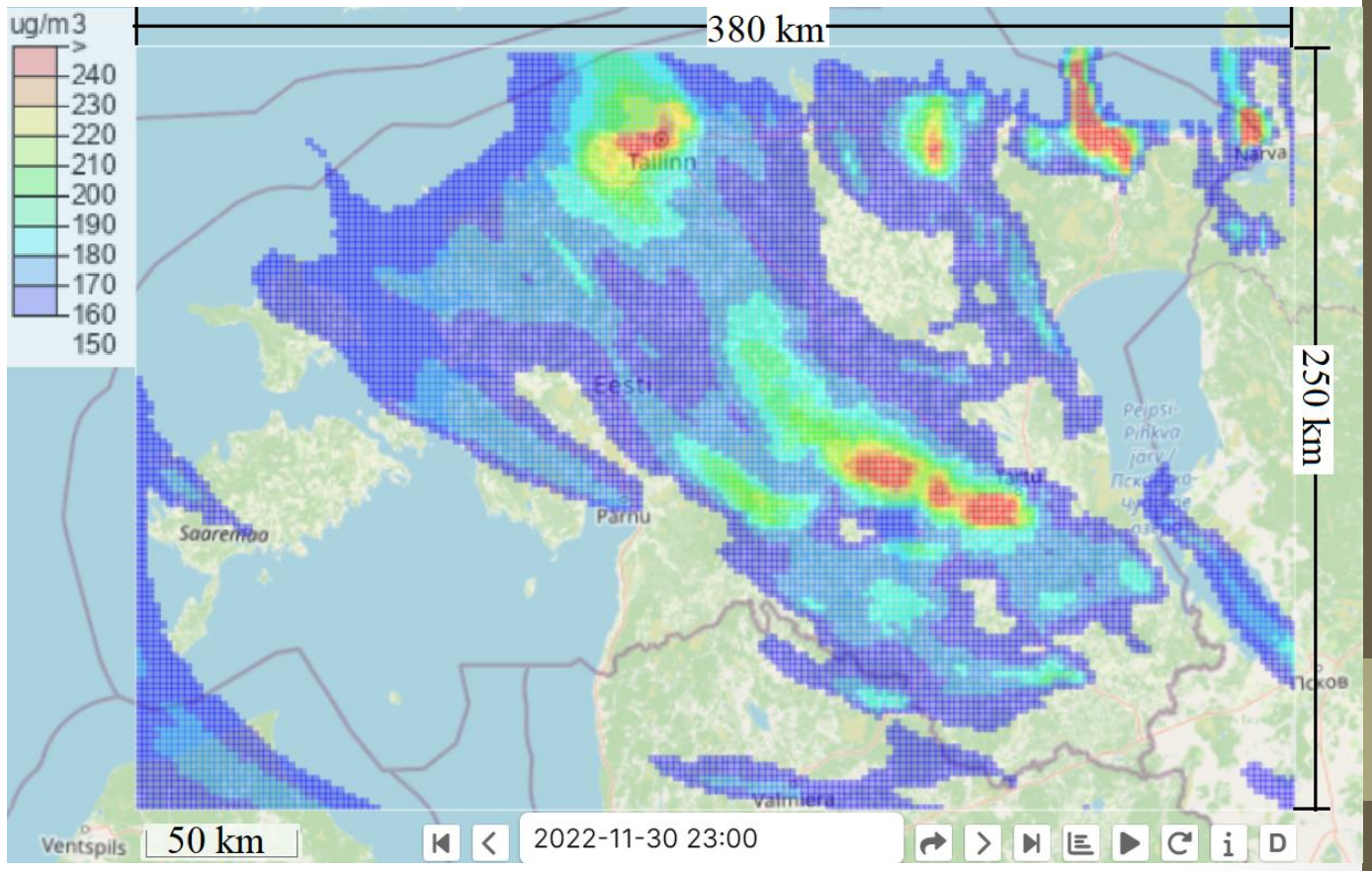
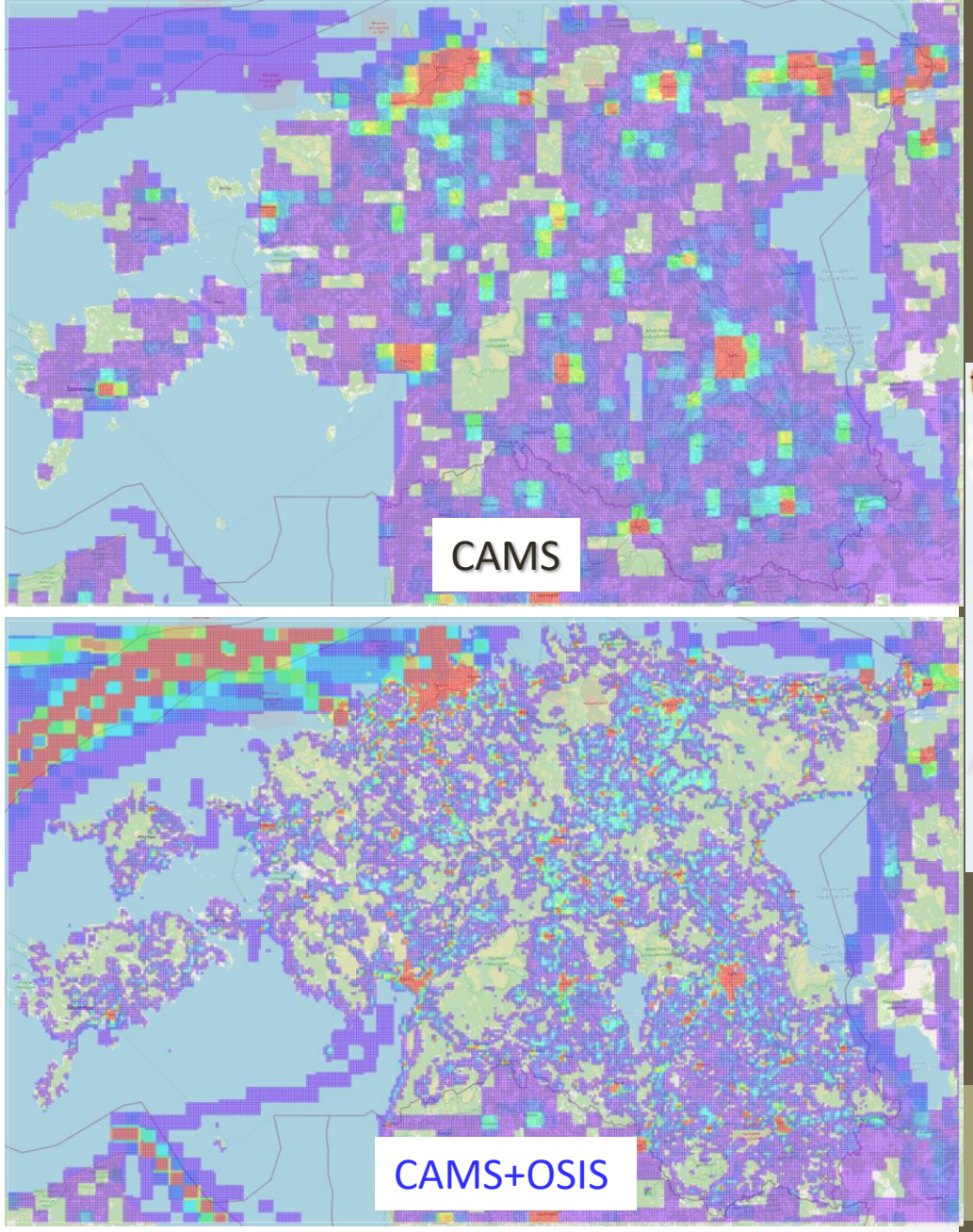


Domain example (CO hourly average concentration).

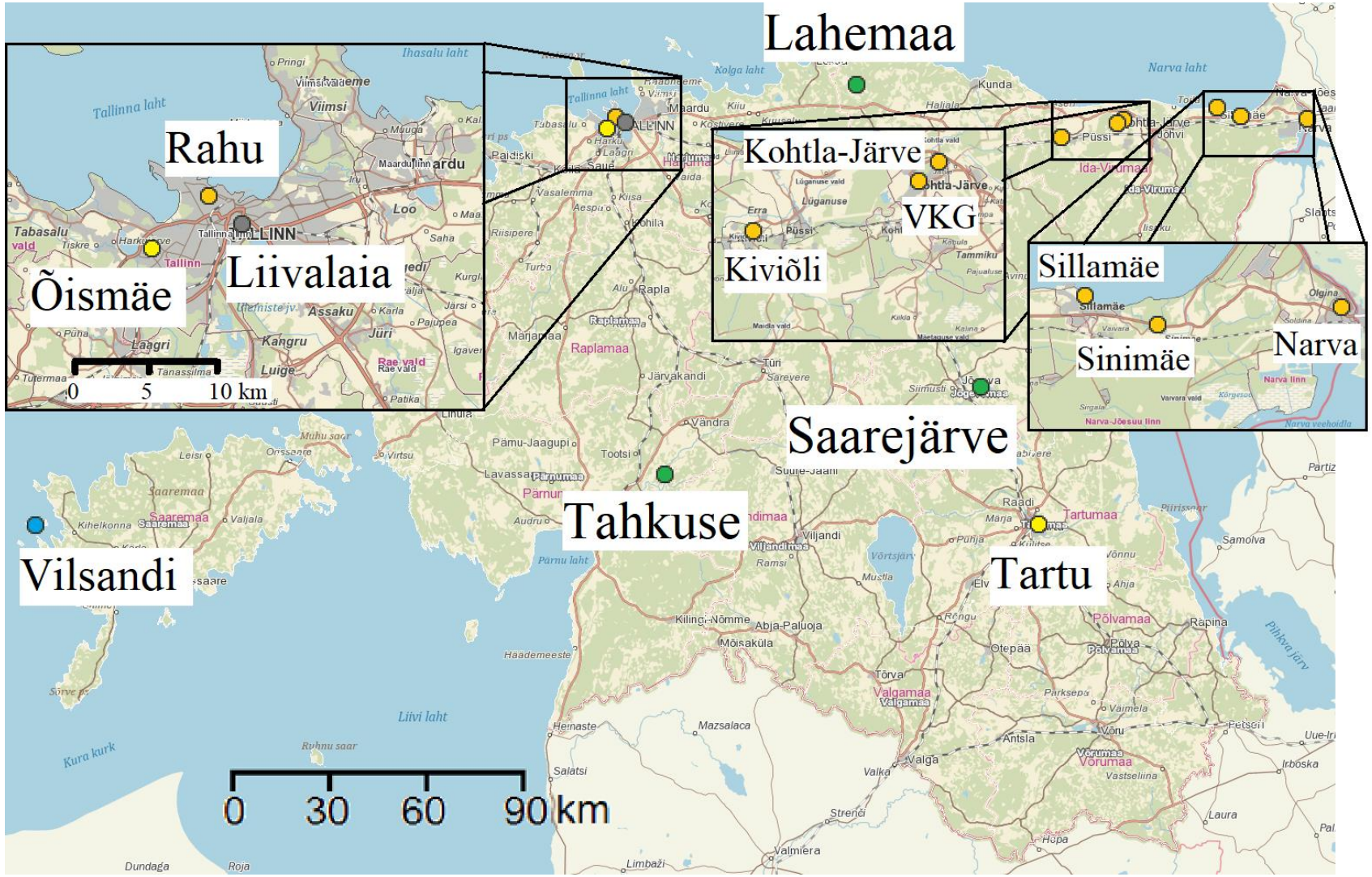
Emission inventories

- CAMS anthropogenic emissions v5.1, 2018 data
  - input from us, is harmonized, sent back, ~6x6 km resolution
- OSIS emissions, based on national reports, 2019 data
  - not harmonized similarly, but 1x1 km resolution
  - four pollutants: **NO_x, SO_2, CO, NH_3** (no PM-s!)
  - necessary additions: sector-based temporal variation and vertical distribution
- **Aim of study: which inventory / combination of them gives best modelling results?** (And is it worth the work?)



Different resolution emission examples: primary $PM_{2.5}$ (top), NO (bottom), yearly totals, tonne/year.

Monitoring stations



Urban-industrial, urban background, street, rural background and rural maritime monitoring stations used for timeseries validation, 14 in total.

Statistical procedure (recommended by HARMO initiative)

Linear correlation coefficient *R*

$$R = \frac{\overline{(C_p - \overline{C_p})(C_o - \overline{C_o})}}{\sigma_{C_o}\,\sigma_{C_p}}$$

Fractional bias *FB*

- Symmetrical measure of over- and underestimation

$$FB = \frac{(\overline{C_o} - \overline{C_p})}{0.5(\overline{C_o} + \overline{C_p})}$$

FB	$\pm$0.4	$\pm$0.67	$\pm$1.0	$\pm$1.2
missed by	$\mp$ 1.5x	$\mp$ 2x	$\mp$ 3x	$\mp$ 4x

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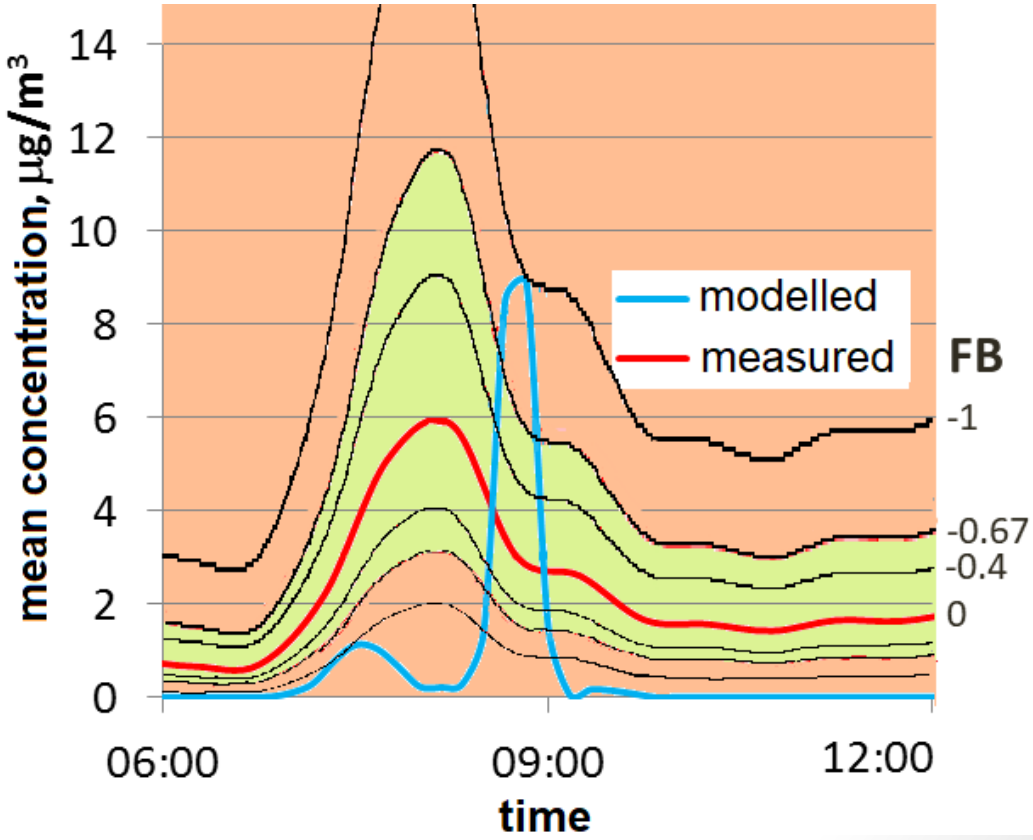
FB	±0.4	±0.67	±1.0	±1.2
missed by	∓ 1.5x	∓ 2x	∓ 3x	∓ 4x

Fraction in factor two *FA2*

- the fraction of cases, when measured and modelled value differs less than two times (in green).



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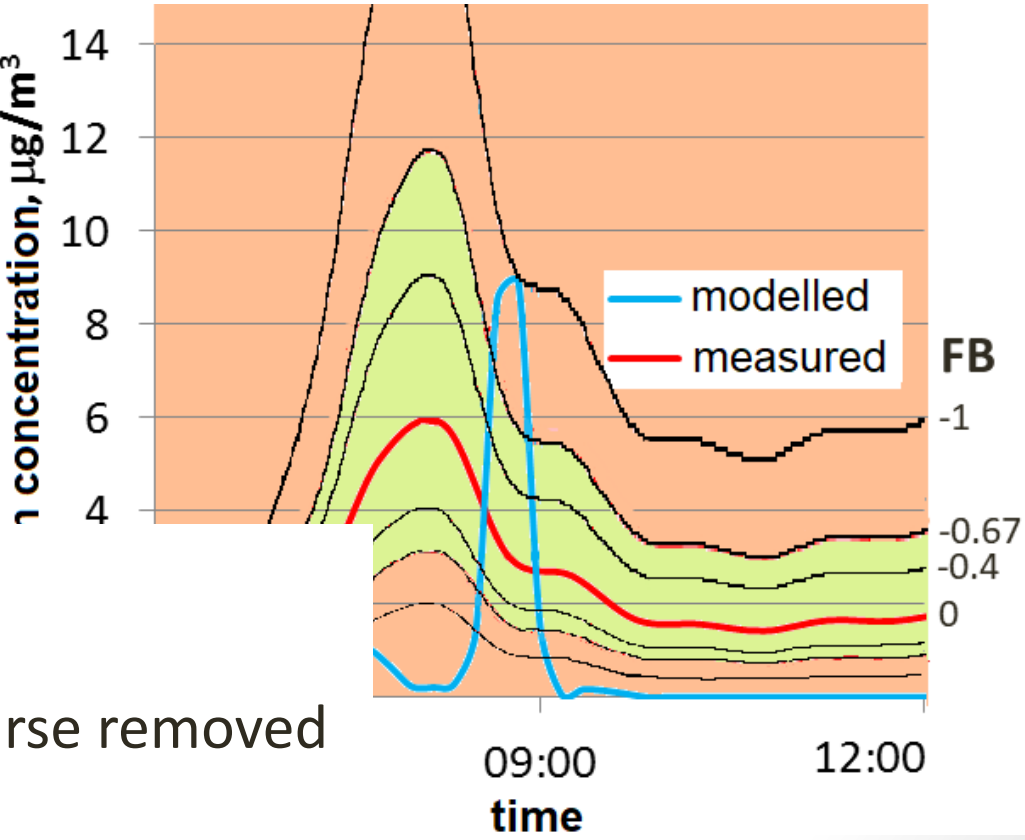
FB	±0.4	±0.67	±1.0	±1.2
missed by	∓ 1.5x	∓ 2x	∓ 3x	∓ 4x

Fraction in factor two *FA2*

- How much modelled data differs less than two times, in green.



Statistics applied to concentration…

- …annual average daily course
- …hourly values, hourly values with daily course removed
- …daily averages, maxima and minima

Results: NO_2

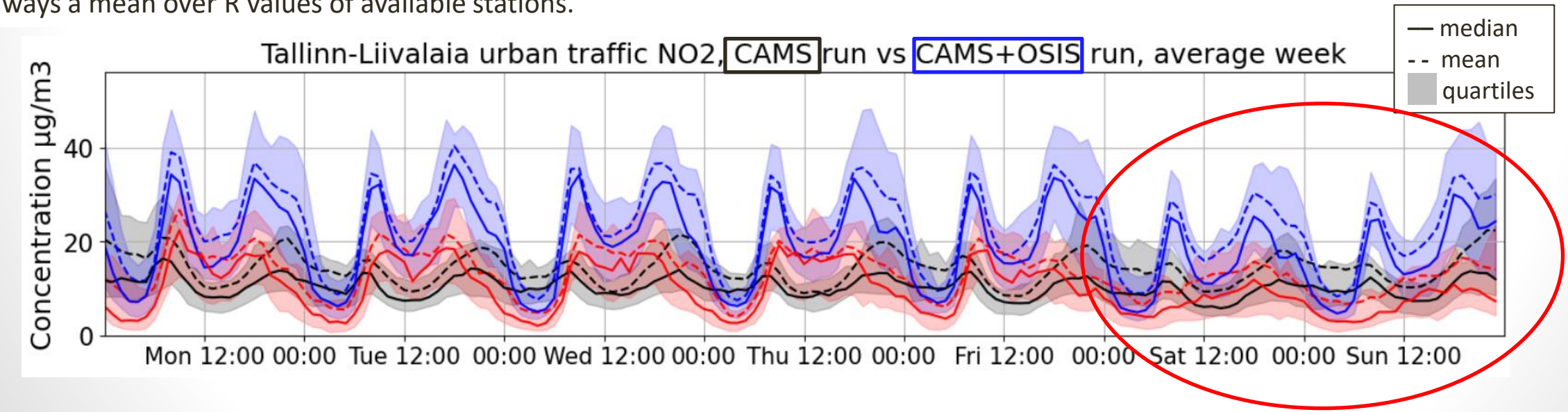
- Initial CAMS run: hourly values mean* R=0.62.
- Daily minimum overestimated on average by 2x.

Main problem: CAMS+OSIS overestimates urban measured values, more than CAMS.

Potential to outperform CAMS: NO_x urban overestimation, weekend temporal variation.

hourly values	rural	urban	industrial
FB, CAMS	-0.42 1.53x	-0.18 1.20x	0.11 1.12x
FB, CAMS+OSIS	-0.38 1.47x	-0.53 1.72x	0.45 1.58x

*always a mean over R values of available stations.



Results: NO

- Initial CAMS run: urban hourly values mean R=0.39, other stations mean R=0.23.
- CAMS+OSIS run: urban R=0.43, others R=0.17.

hourly values	rural	urban	industrial
FB, CAMS	0.66 -1.98x	0.30 -1.35x	1.17 -3.82x
FB, CAMS+ OSIS	0.73 -2.14x	-0.83 +2.42x	1.55 -7.8x

Mean daily course (urban stations mean)	NO	NO_2
Urban mean R, CAMS	0.53	0.46
Urban mean R, CAMS+OSIS	0.73	0.93
Urban mean FA2, CAMS	0.96	0.97
Urban mean FA2, CAMS+OSIS	0.46	0.71

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Results: O_3

- Initial CAMS run: hourly values mean R=0.79, mean FB=0.02.
- Traffic station daily course R=0.38, other stations R > 0.94.
- CAMS+OSIS run: mean urban R=0.74, FB=0.16 due to overestimated NO

Mean daily course (urban stations mean)	NO	NO_2
Urban mean R, CAMS	0.53	0.46
Urban mean R, CAMS+OSIS	0.73	0.93
Urban mean FA2, CAMS	0.96	0.97
Urban mean FA2, CAMS+OSIS	0.46	0.71

Results: SO_2

- Initial CAMS run: SO_2 is the worst-performing pollutant: poor R, overestimated.

- CAMS+OSIS run: most statistics in all stations improved or stayed the same. Urban and industrial improved more than rural.

mean | best FA2 **change**	rural	urban	industrial
Daily course	0.09 | 0.33	0.99 | 1.00	0.18 | 0.67
Daily min	0.00 | 0.09	0.15 | 0.19	0.07 | 0.25
Daily mean	0.04 | 0.18	0.42 | 0.56	0.11 | 0.23
Daily max	0.04 | 0.13	0.22 | 0.42	0.07 | 0.17

hourly values	rural	urban	industrial
R, CAMS	0.19	0.36	0.04
R, CAMS+ OSIS	0.22	0.34	0.21
FB, CAMS	-0.50 1.66x	-1.12 3.55x	-0.32 1.38x
FB, CAMS+ OSIS	-0.37 1.45x	-0.38 1.47x	-0.24 1.27x

- CAMS v6.1 has 13% (2019) and 24% (2020) less SO_2. Might yield even better results.

Results: $PM_{2.5}$ and PM_{10}

- No OSIS emissions, no CAMS+OSIS run.
- CAMS run: hourly $PM_{2.5}$ mean R=0.51, FB=-0.27 (1.31x)
  Urban mean FB=-0.46 (1.60x)

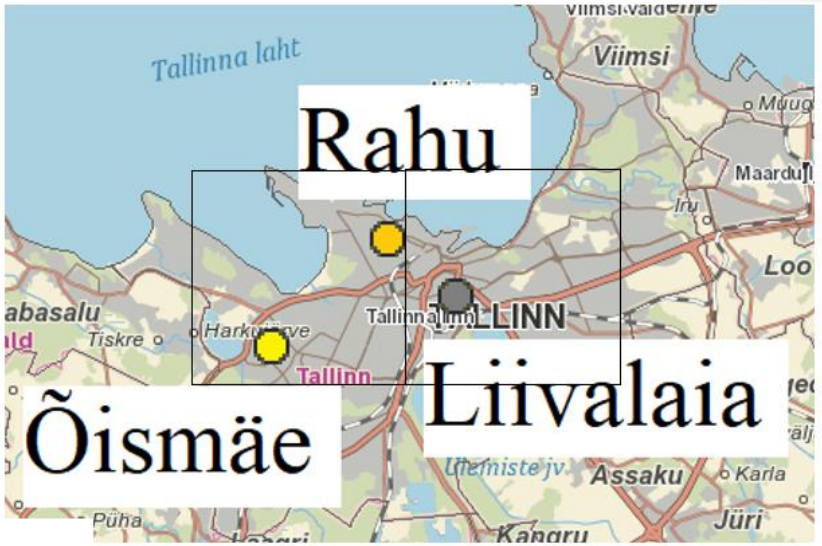
  Hourly PM_{10} mean R=0.28, FB=0.20 (1.20x)
- Both $PM_{2.5}$ and PM_{10} daily course FA2 > 0.95, but PM_{10} 7/9 stations R<0, $PM_{2.5}$ 6/10. Outliers from R=-0.87 to 0.87.
- May improve with better temporal variations.

Results: CO

- Initial CAMS run: hourly values mean FB=0.23 (1.26x), R=0.62
- Daily course mean R=0.65 with FA2=1, mean urban R=0.55 outlier traffic station, R=0.32.
- CAMS+OSIS run: goes both ways in small magnitudes.
- Urban daily course improved most, mean urban R=0.75, now outlier R=0.69.
- Urban hourly values mean R slightly up, FB slightly down.

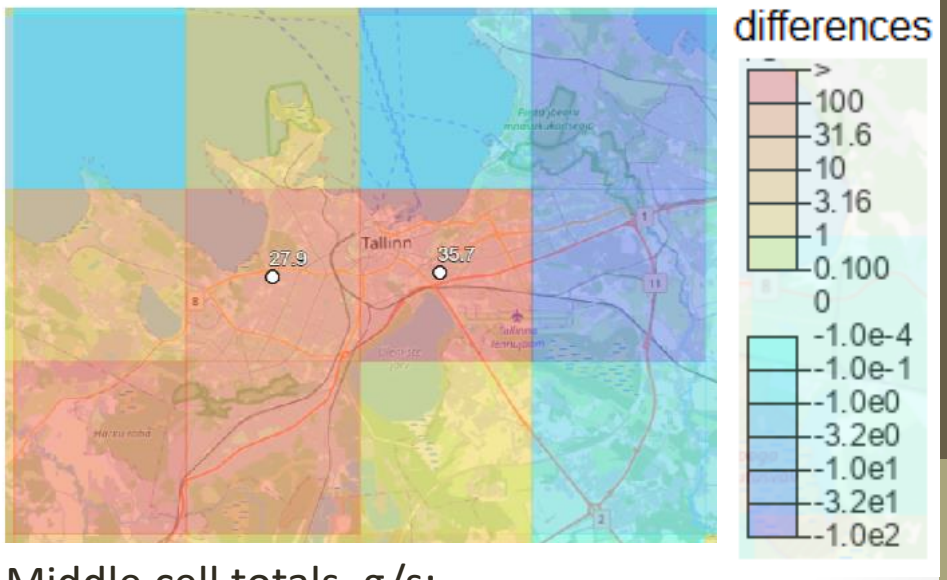
Conclusions, future plans

- Higher resolution emissions improved SO_2 results
- Potential to improve NO_x results, influencing O_3



- Find out why urban/industrial NO_x emissions are over/underestimated (sectors F and A?); make better temporal variation.
- Move on to CAMS v6.1, to potentially improve SO_2 emissions.
- Try a different PM temporal variation
- Fairmode evaluation

Total NO_x difference



Middle cell totals, g/s:

OSIS	46.8 (2.4x)	53.9 (3.0x)
CAMS	19.2	18.1

Acknowledgements

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Thank you!

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	NOX_diff									
	Kohtla-Jar	Narva	Tallinn_Lii	Tallinn_Oi	Tallinn_Rahu	Tartu	Lahemaa	Saarejarve	Tahkuse	Vilsandi
Initial										
CORREL	-0.07	-0.10	-0.02	-0.04	-0.02	-0.01	-0.03	-0.05	-0.05	-0.03
FA2	-0.09	-0.08	-0.06	-0.26	-0.05	0.02	-0.01	-0.01	-0.01	0.01
FB	0.19	0.52	0.56	0.91	0.53	0.14	0.02	-0.08	-0.02	-0.08
Daily course removed										
CORREL	-0.07	-0.11	-0.11	-0.06	-0.04	-0.02	-0.02	-0.06	-0.06	-0.03
FA2	-0.12	-0.14	-0.29	-0.41	-0.18	-0.07	0.00	0.05	-0.02	0.00
Daily course only										
CORREL	0.09	0.38	0.82	0.39	0.54	0.10	0.18	-0.50	0.09	0.15
FA2	0.00	0.00	-0.33	-0.83	-0.54	0.00	0.00	0.00	0.00	0.00
Daily min.										
CORREL	-0.16	0.02	-0.03	-0.04	-0.10	-0.07	-0.01	-0.02	-0.03	-0.04
FA2	0.00	-0.01	0.06	-0.16	0.23	0.03	0.02	0.07	-0.02	0.02
FB	-0.22	0.09	-0.06	0.23	-0.32	-0.07	-0.01	-0.10	-0.08	-0.09
Daily average										
CORREL	-0.09	-0.11	-0.15	-0.03	-0.04	0.00	0.00	-0.06	-0.04	-0.04
FA2	-0.21	-0.21	-0.40	-0.64	-0.32	-0.10	0.01	0.08	-0.01	0.01
FB	0.19	0.52	0.55	0.91	0.53	0.14	0.02	-0.08	-0.02	-0.08
Daily max.										
CORREL	-0.04	-0.09	-0.08	-0.03	-0.01	0.00	-0.06	-0.09	-0.05	-0.04
FA2	-0.07	-0.13	-0.25	-0.38	-0.34	0.04	-0.04	-0.01	-0.03	-0.01
FB	0.09	0.42	0.53	0.90	0.75	0.21	0.12	-0.04	0.05	-0.07

	SO2_diff														
	Kivioli	Kohtla-Jar	Narva	Sinimae	VKG		Tallinn_Lii	Tallinn_Oi	Tallinn_Rahu	Tartu		Lahemaa	Saarejarve	Tahkuse	Vilsandi	
Initial																
CORREL	0.06	0.35	0.06	0.08	0.31		-0.03	-0.01	0.01	-0.05		0.05	0.10	-0.01	-0.01	
FA2	0.00	0.22	0.19	0.03	0.13		0.24	0.18	0.22	0.11		0.09	0.10	-0.02	0.01	
FB	0.34	-0.35	-0.59	0.17	0.27		-0.88	-0.69	-0.80	-0.56		-0.06	-0.20	-0.20	-0.05	
Daily course removed																
CORREL	0.09	0.37	0.07	0.08	0.32		-0.01	-0.01	0.01	-0.04		0.05	0.10	-0.01	-0.01	
FA2	-0.01	0.22	0.08	-0.03	0.01		0.37	0.12	0.26	0.23		0.02	0.11	-0.05	0.00	
Daily course only																
CORREL	-0.03	0.12	-0.04	0.28	0.36		-0.14	-0.22	-0.02	0.09		0.03	-0.16	-0.15	0.25	
FA2	-0.46	0.67	0.67	0.00	0.00	0.18	1.00	1.00	1.00	0.96	0.99	0.04	0.33	0.00	0.00	0.09
Daily min.																
CORREL	-0.01	0.21	0.01	0.06	0.46		-0.02	-0.04	0.01	0.02		0.05	0.05	0.02	-0.01	
FA2	0.04	0.25	0.10	0.01	-0.03	0.07	0.14	0.12	0.19	0.16	0.15	0.02	0.09	-0.10	0.01	0.00
FB	-0.17	-0.54	-0.54	-0.33	-0.04		-0.29	-0.35	-0.46	-0.26		-0.07	-0.20	0.26	-0.04	
Daily average																
CORREL	0.12	0.62	0.08	0.08	0.47		-0.06	-0.04	0.00	-0.13		0.02	0.12	-0.01	-0.01	
FA2	0.06	0.23	0.16	-0.01	0.11	0.11	0.56	0.32	0.34	0.47	0.42	0.01	0.18	-0.03	-0.01	0.04
FB	0.34	-0.35	-0.59	0.17	0.28		-0.88	-0.69	-0.80	-0.56		-0.06	-0.20	-0.20	-0.05	
Daily max.																
CORREL	0.19	0.40	0.04	-0.02	0.37		-0.06	-0.04	-0.03	-0.04		0.00	0.18	-0.07	0.00	
FA2	0.05	0.17	0.05	-0.02	0.10	0.07	0.42	0.02	0.28	0.18	0.22	-0.01	0.13	0.01	0.01	0.04
FB	-0.50	0.02	-0.50	0.10	-0.39		-0.88	-0.44	-0.82	-0.52		-0.08	-0.22	-0.23	-0.06	

	PM2.5									
	Kohtla-Jar	Narva	Sillamae	Sinimae	Tallinn_Lii	Tallinn_Oismae	Tartu	Lahemaa	Saarejarve	Vilsandi
Initial										
CORREL	0.50	0.38	0.59	0.58	0.58	0.51	0.50	0.56	0.61	0.32
FA2	0.56	0.44	0.64	0.59	0.57	0.54	0.66	0.58	0.64	0.52
FB	-0.38	-0.40	0.08	-0.10	-0.49	-0.50	-0.38	-0.01	-0.32	-0.14
Daily course removed										
CORREL	0.51	0.41	0.59	0.57	0.59	0.52	0.55	0.56	0.61	0.33
FA2	0.57	0.58	0.71	0.71	0.62	0.61	0.63	0.65	0.66	0.50
Daily course only										
CORREL	-0.40	-0.06	0.54	0.87	-0.01	-0.04	0.11	-0.87	-0.15	0.54
FA2	1.00	1.00	1.00	1.00	0.88	0.88	0.83	1.00	1.00	1.00
Daily min.										
CORREL	0.57	0.56	0.62	0.60	0.67	0.67	0.62	0.57	0.65	0.60
FA2	0.51	0.59	0.74	0.72	0.64	0.68	0.67	0.65	0.69	0.56
FB	-0.42	-0.26	0.02	0.04	-0.30	-0.24	-0.27	0.12	-0.21	-0.08
Daily average										
CORREL	0.65	0.54	0.70	0.66	0.77	0.68	0.69	0.66	0.68	0.40
FA2	0.68	0.64	0.82	0.83	0.71	0.67	0.76	0.78	0.75	0.59
FB	-0.38	-0.40	0.08	-0.10	-0.49	-0.50	-0.38	-0.01	-0.32	-0.15
Daily max.										
CORREL	0.53	0.33	0.51	0.52	0.61	0.43	0.56	0.51	0.62	0.22
FA2	0.68	0.59	0.72	0.76	0.59	0.59	0.60	0.75	0.72	0.64
FB	-0.37	-0.40	0.27	-0.17	-0.65	-0.63	-0.42	-0.13	-0.36	-0.04