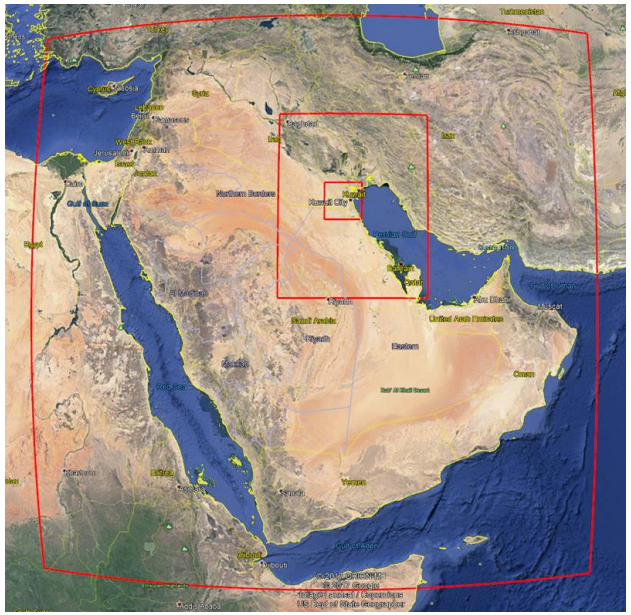
XI giornata sulla modellistica in ARIA(NET)
Milano, 11 aprile 2024

Air quality modelling in the Persian Gulf and Arabic Peninsula region

Sandro Finardi, Paola Radice, Nicola Pepe, Camillo Silibello e Giuseppe Calori

Air quality forecast system for Kuwait: annual assessment



Modelling system: WRF + FARM

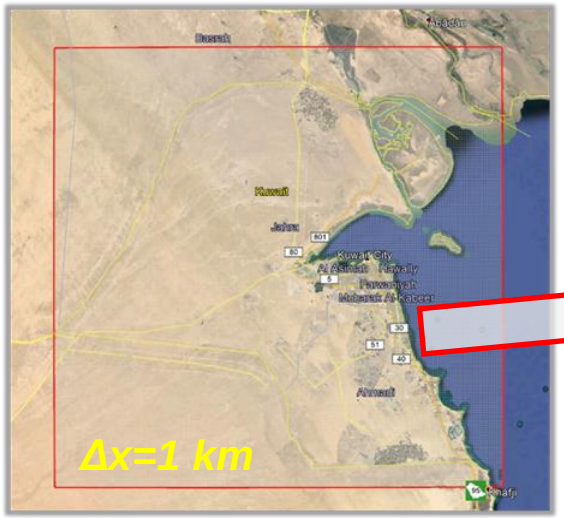
Synoptic scale drivers (BCs): ERA5 reanalyses and CAMS global forecast

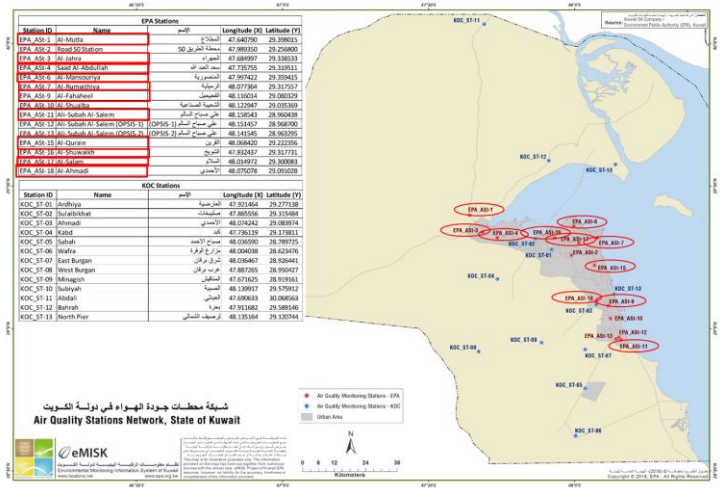
Target area resolution: 1 km

Simulation length: year 2022

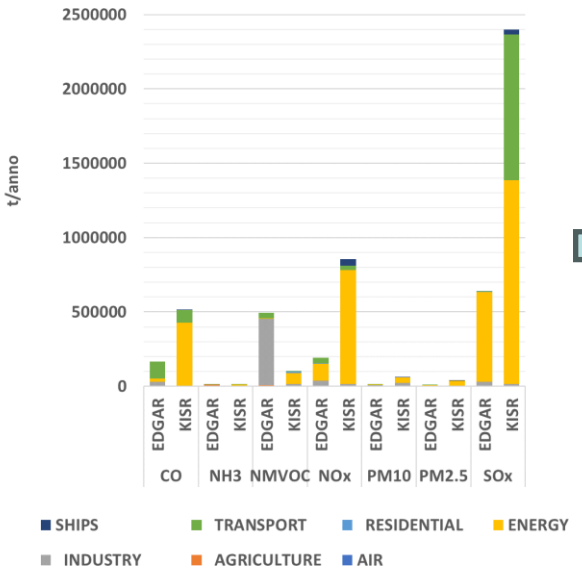
Emissions: - outside Kuwait: EDGAR 2018
- Kuwait: re-estimaterd by ARIANET starting from KISR inventory

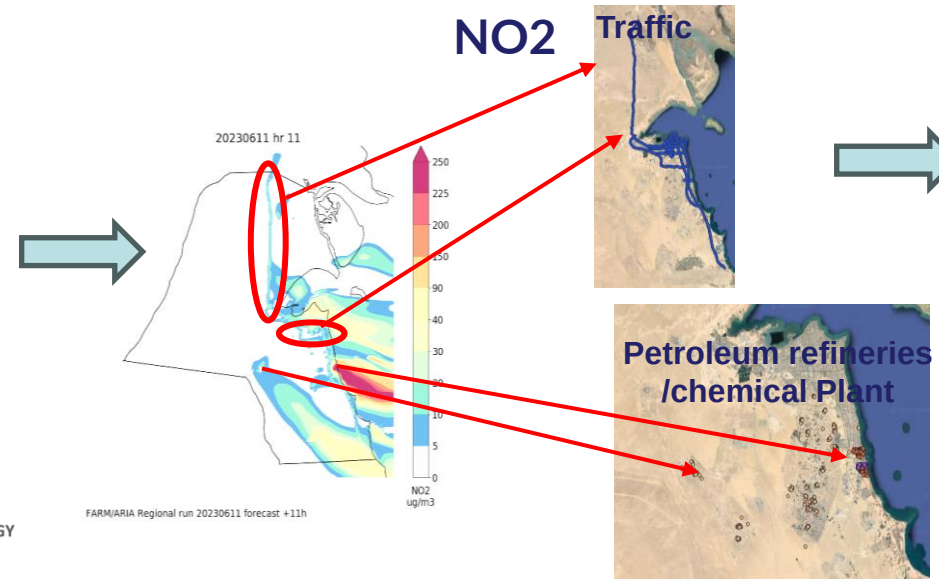
Model results verification: WMO/Metar & KEPA air quality network data



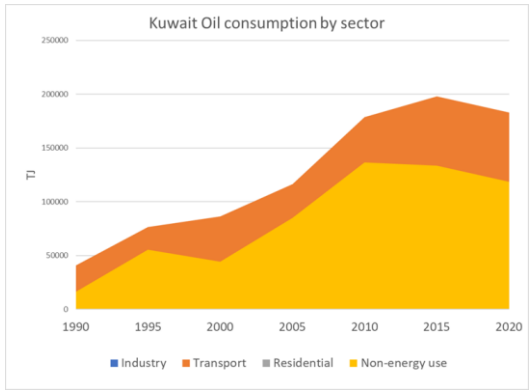


KISR - Air quality forecast system for Kuwait





TRAFFIC



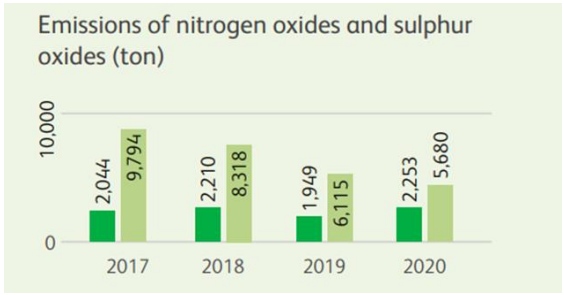
IEA Oil combustion: IEA World Energy Balances 2022

EF GAINS

NOx	SO2
63271	3244317

EQUATE KISR database

VS



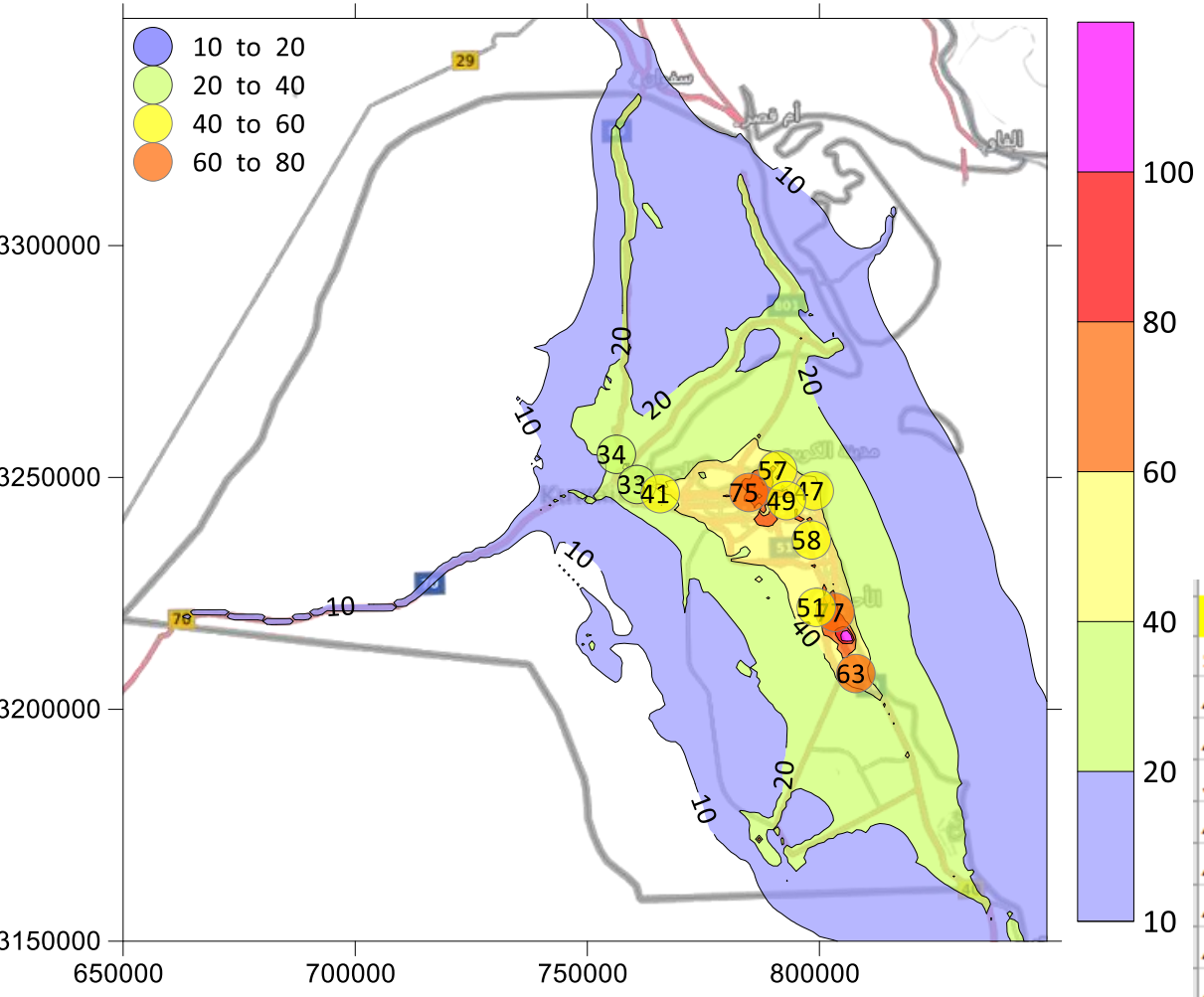
EQUATE-Sustainability-Report

Modification of flare stack parameters to get better dispersive parameters

CHEMICAL PLANT

PETROLEUM REFINERIES

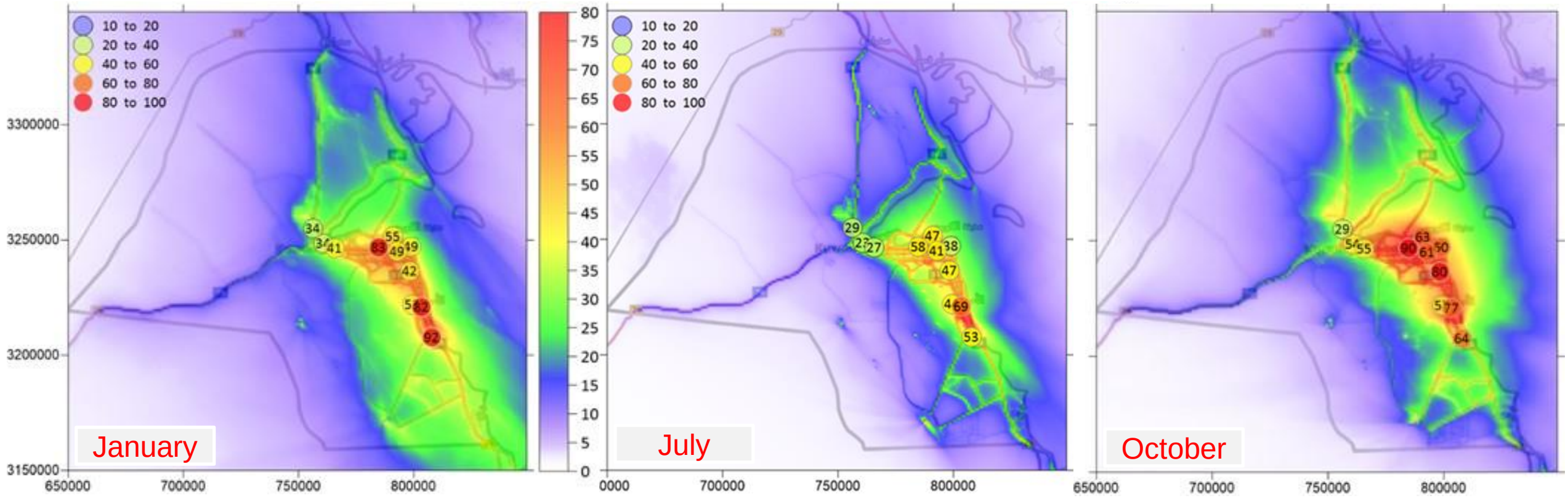
NO2 annual mean and statistics



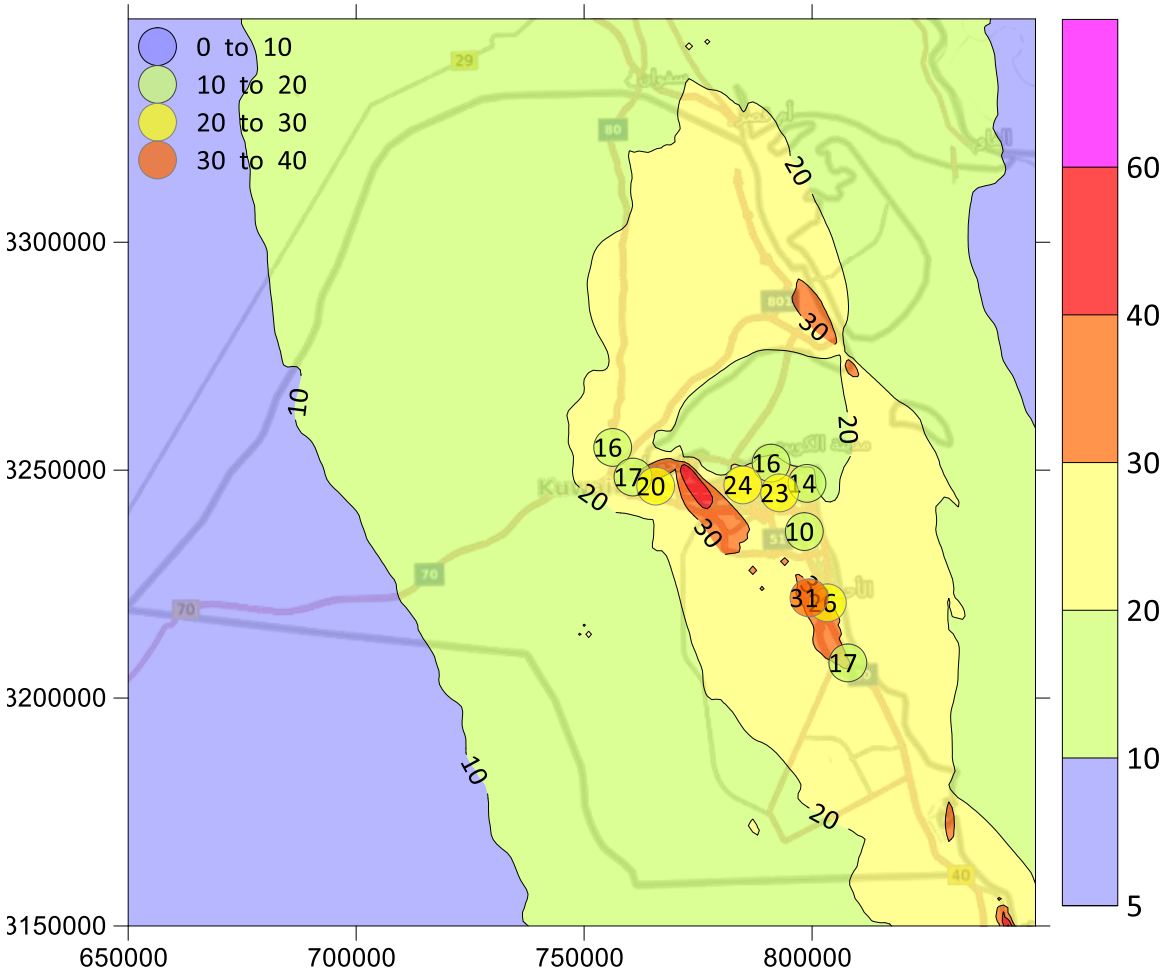
- Good reproduction of mean values and their space distribution
- Good reproduction of seasonal variability
- Acceptable values of BIAS and IOA
- Low correlation
- Emissions time modulations to be improved

NO2									
stat	Media oss	Media Calc	t.Dev. Oss	t.Dev. Calc	MB	NMB	RMSE	Corr.	IOA
Al-Mutla	35	31	14.0	13.1	-4.04	-0.12	15.86	0.36	0.62
Al-Jahra	34	38	14.0	14.8	4.69	0.14	12.82	0.66	0.79
SaadAl-Abdu	41	37	15.7	15.1	-3.67	-0.09	14.01	0.62	0.78
Al-Mansouri	56	58	20.7	22.7	1.99	0.04	22.26	0.48	0.70
Al-Rumaithi	48	42	18.3	16.4	-5.42	-0.11	19.97	0.39	0.62
Al-Fahaheel	77	65	22.1	21.8	-12.26	-0.16	28.23	0.33	0.56
Ali-Subah	62	48	26.5	18.0	-13.85	-0.22	30.49	0.30	0.52
Al-Qurain	59	52	22.1	16.8	-6.97	-0.12	22.26	0.44	0.63
Al-Shuwaikh	76	61	28.4	21.0	-14.36	-0.19	26.57	0.63	0.71
Al-Salam	50	54	18.7	17.9	4.71	0.10	18.10	0.54	0.73
Al-Ahmadi	51	55	19.8	23.1	3.52	0.07	24.35	0.38	0.64

NO2 monthly mean concentrations



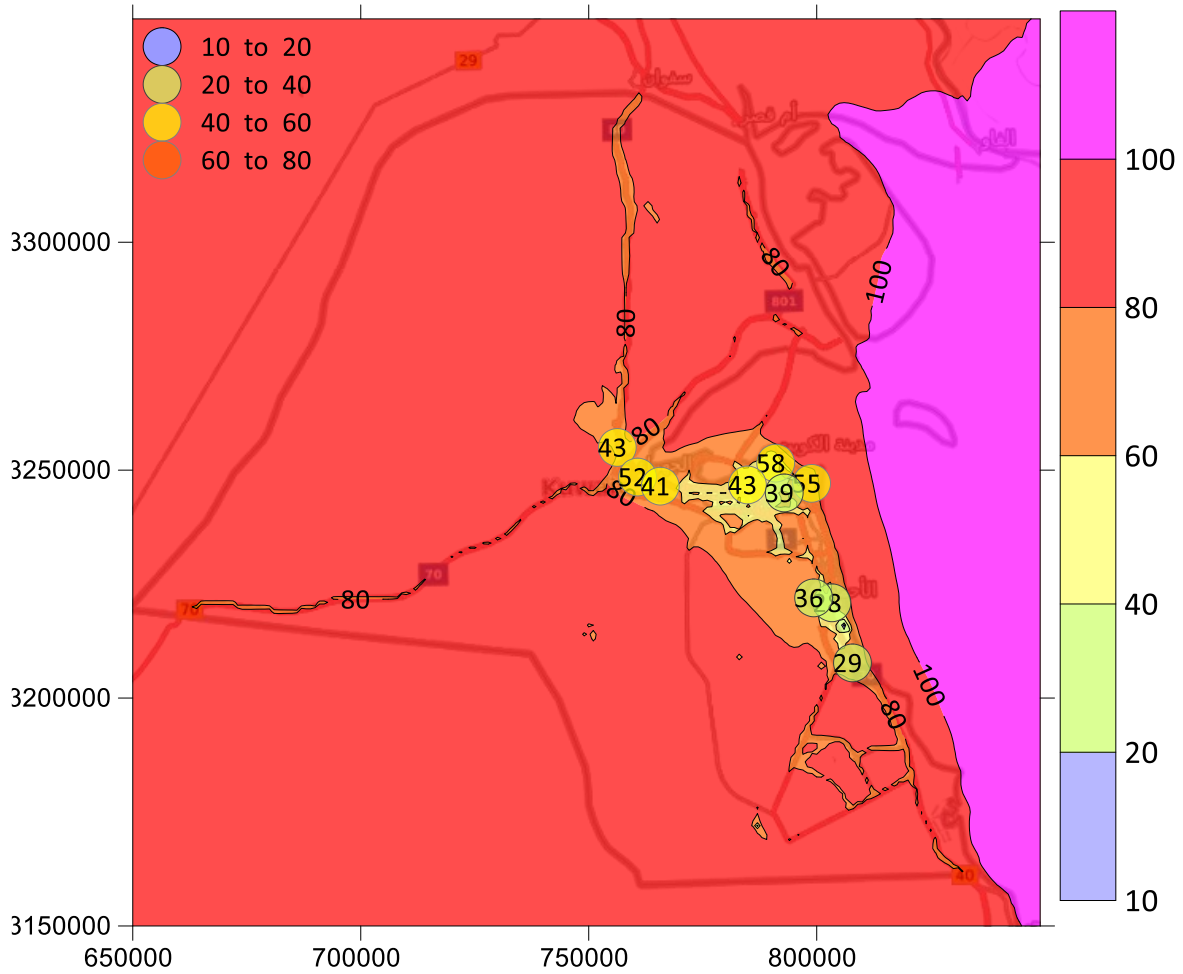
SO2 annual mean and statistics



- Main contribution due to elevated emissions
- Tendency to overestimate annual mean concentrations
- Large RMSE/mean
- No correlation
- Need to improve point sources treatment and time modulation

SO2 - daily avg									
stat	Media oss.	Media Calc	St.Dev. Oss	St.Dev. Calc	MB	NMB	RMSE	Corr.	IOA
Al-Mutla	17	24	6.8	23.3	7.43	0.45	25.41	-0.01	0.19
Al-Jahra	18	28	13.9	31.2	10.65	0.60	33.53	0.18	0.35
SaadAl-Abdu	20	26	13.0	27.8	6.17	0.30	30.25	0.09	0.33
Al-Mansouri	16	21	10.1	15.7	4.46	0.28	19.66	-0.06	0.25
Al-Rumaithi	14	21	10.6	14.1	6.26	0.43	19.23	-0.07	0.29
Al-Fahaheel	26	30	16.9	19.9	3.82	0.14	26.88	-0.04	0.30
Ali-Subah	17	30	10.5	19.7	13.29	0.78	25.93	0.00	0.24
Al-Qurain	11	25	10.1	17.6	14.12	1.28	25.31	-0.09	0.22
Al-Shuwaikh	24	23	12.5	17.4	-1.51	-0.06	21.64	-0.02	0.31
Al-Salam	24	22	16.2	15.7	-2.06	-0.09	22.80	-0.01	0.38
Al-Ahmadi	31	31	15.8	20.6	0.15	0.00	24.98	0.08	0.38

O3 annual mean and statistics

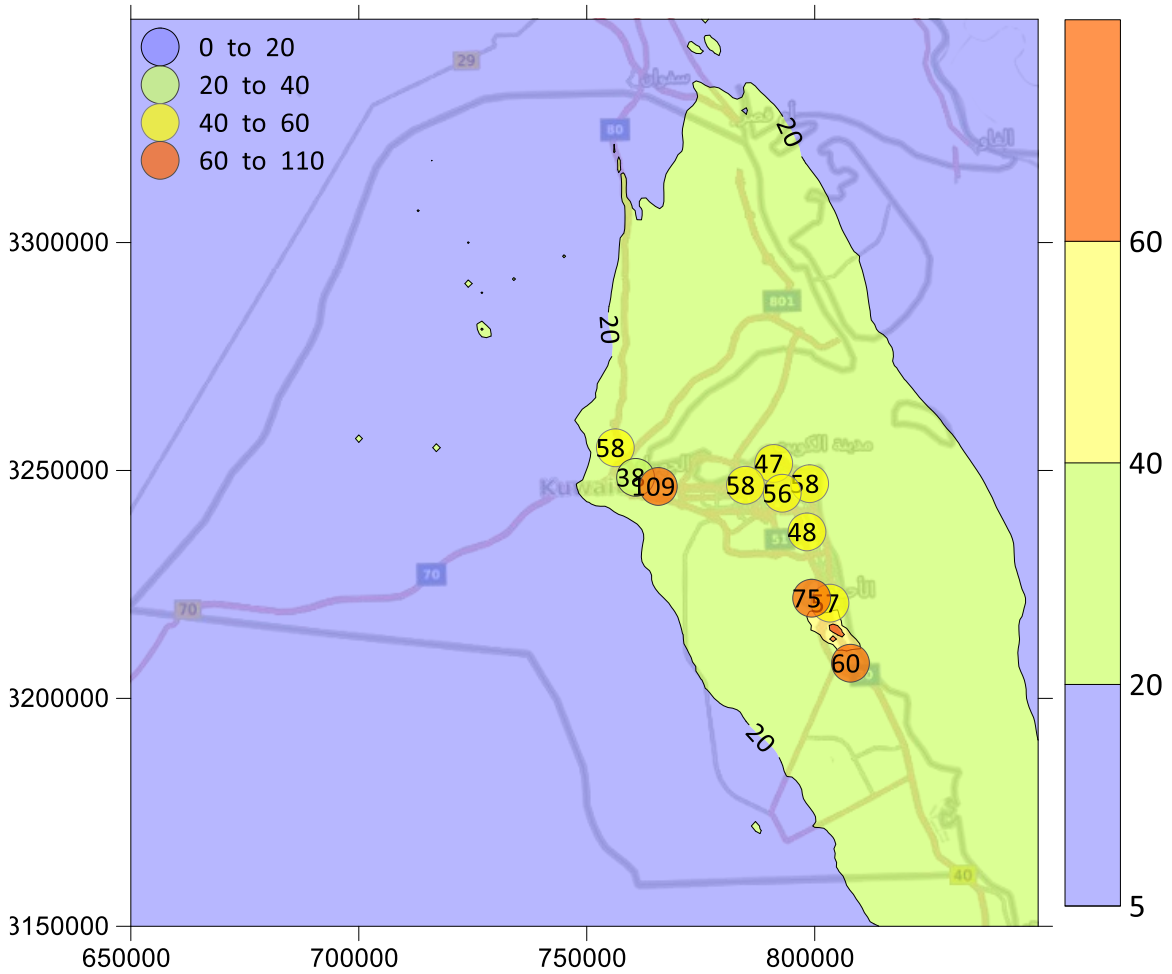


O3 - daily max MD8H									
stat	Media oss.	Media Calc	St.Dev. Oss	St.Dev. Calc	MB	NMB	RMSE	Corr.	IOA
Al-Mutla	68	99	21.7	34.5	30.38	0.44	44.39	0.41	0.80
Al-Jahra	79	92	24.0	34.2	13.34	0.17	36.50	0.36	0.87
SaadAl-Abdu	64	96	23.9	33.1	31.71	0.50	46.87	0.30	0.76
Al-Mansouri	81	91	33.1	36.7	9.70	0.12	45.01	0.21	0.83
Al-Rumaithi	78	121	34.5	50.7	43.05	0.55	70.82	0.17	0.75
Al-Fahaheel	48	90	20.2	38.0	42.14	0.88	59.25	0.08	0.43
Ali-Subah	48	90	20.2	38.0	42.14	0.88	59.25	0.08	0.43
Al-Qurain									
Al-Shuwaikh	70	83	26.3	33.8	12.47	0.18	36.12	0.39	0.84
Al-Salam	63	97	26.5	41.3	33.37	0.53	54.28	0.26	0.71
Al-Ahmadi	57	89	19.9	31.5	31.93	0.56	44.71	0.33	0.70

- Mean values overestimated
- Seasonal concentration change overestimated

To be investigated:
- BC impact (CAMS reanalyses overestimate local ozone)
- Dust impact on solar radiation (WRF overestimates radiation)
- Ozonolisys induced by elevated NMVOC concentration

PM2.5 annual mean and statistics



PM2.5 - daily avg									
stat	Media oss.	Media Calc	St.Dev. Oss	St.Dev. Calc	MB	NMB	RMSE	Corr.	IOA
Al-Mutla	58	22	80.2	11.6	-36.58	-0.63	89.94	-0.09	0.26
Al-Jahra	38	23	27.9	13.4	-14.85	-0.39	34.40	-0.01	0.34
SaadAl-Abdu	106	23	101.9	12.3	-82.88	-0.78	133.32	-0.15	0.39
Al-Mansouri	47	25	46.1	13.9	-21.71	-0.46	53.69	-0.07	0.29
Al-Rumaithi	58	26	71.0	15.8	-31.88	-0.55	80.35	-0.07	0.28
Al-Fahaheel	57	37	54.3	21.3	-19.80	-0.35	62.54	-0.05	0.29
Ali-Subah	60	36	58.1	16.2	-24.67	-0.41	65.82	-0.04	0.29
Al-Qurain	48	29	43.6	16.7	-18.83	-0.39	51.61	-0.09	0.29
Al-Shuwaikh	61	25	71.4	12.4	-35.35	-0.58	81.64	-0.09	0.26
Al-Salam	56	26	61.1	14.4	-30.45	-0.54	71.28	-0.12	0.28
Al-Ahmadi	75	36	108.2	20.4	-39.17	-0.52	120.01	-0.17	0.24

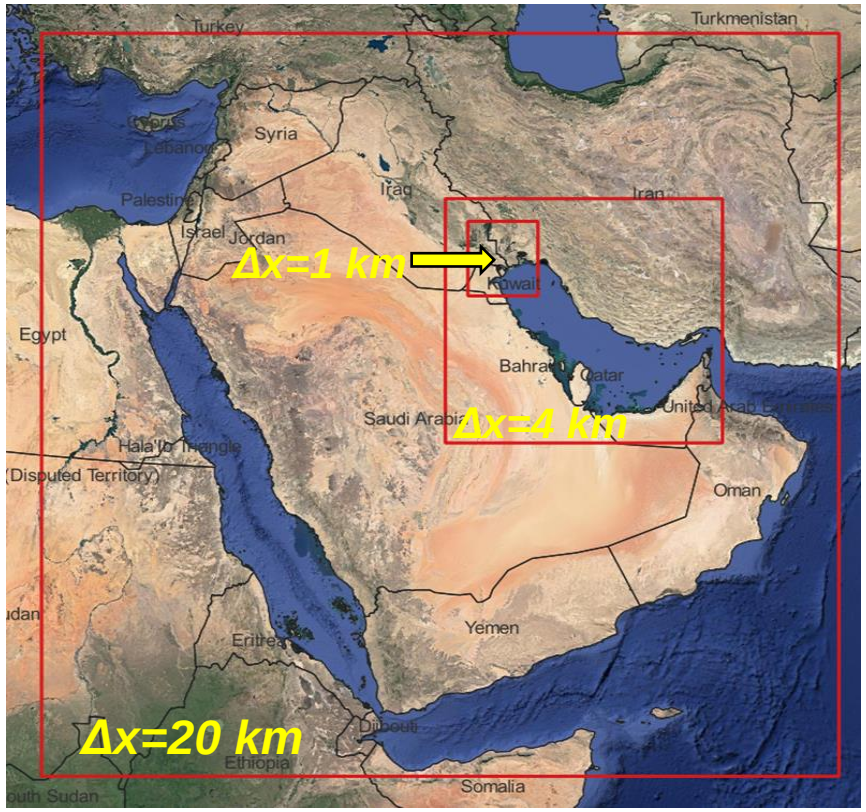
- Anthropogenic emissions “explain” 37÷60% of annual mean concentrations
- High concentration events are due to desert dust transport

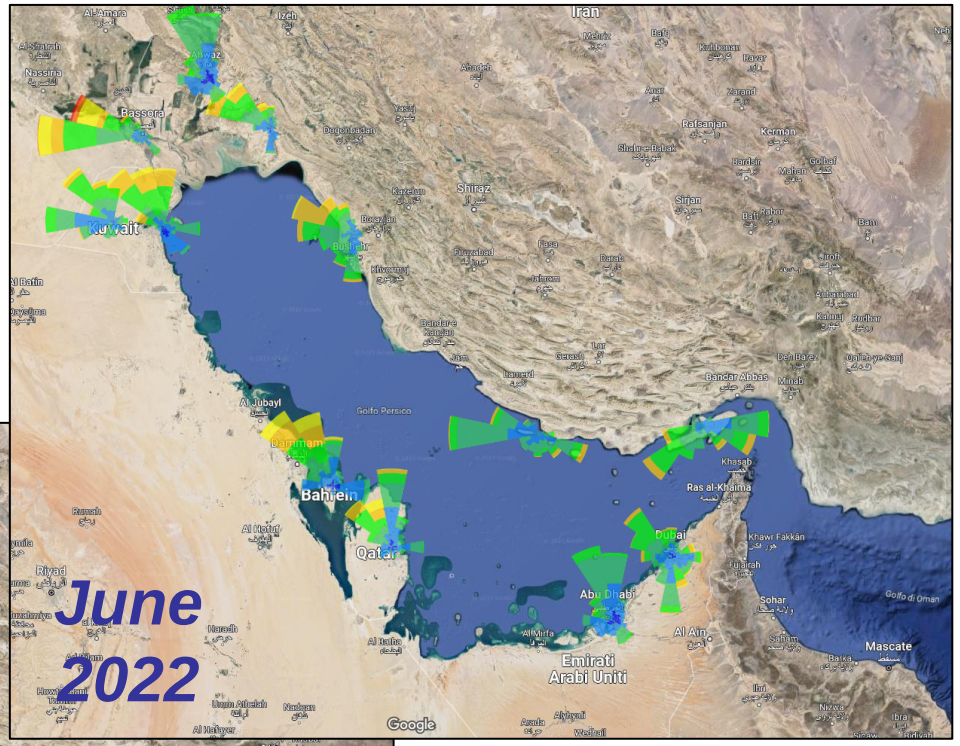
Observed concentrations cannot be predicted without the integration of dust transport model, e.g.:

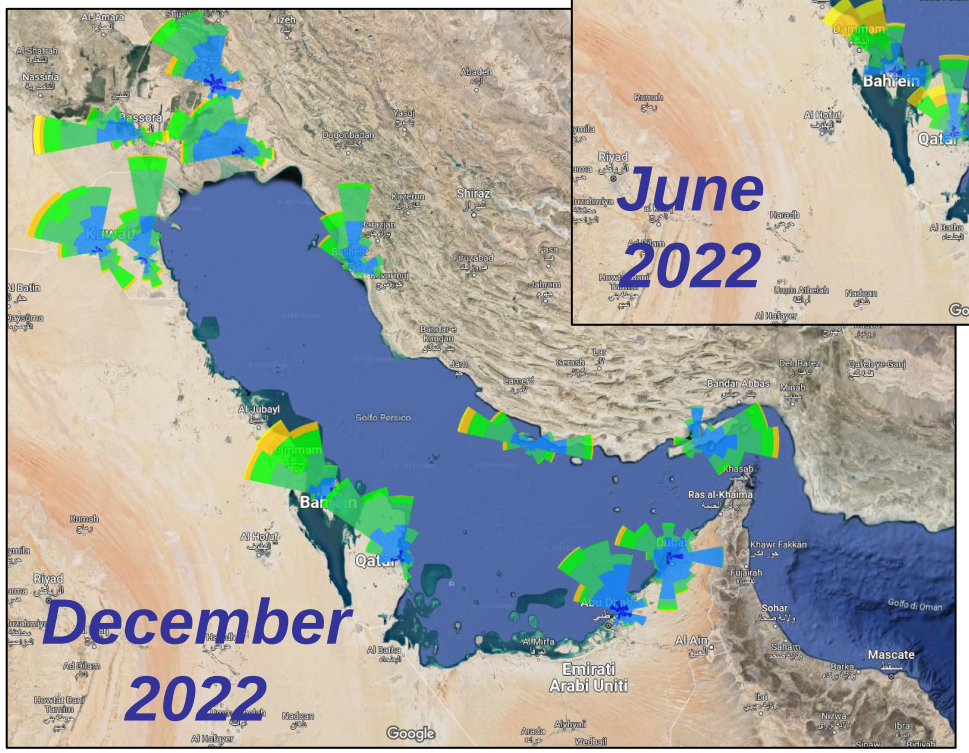
- Obtained from external service (https://dust.ncm.gov.sa/)
- Integrated into FARM simulation

BBC - Air quality impact of gas flaring from oil fields in the Gulf area

- Modelling system: WRF + FARM
- Synoptic scale drivers (BCs): ERA5 reanalyses and CAMS global forecast
- Simulation length: 2 months, June and December 2022
- Emission scenarios:
  - 1) full emissions (EDGAR+flares)
  - 2) no flares (EDGAR inventory)







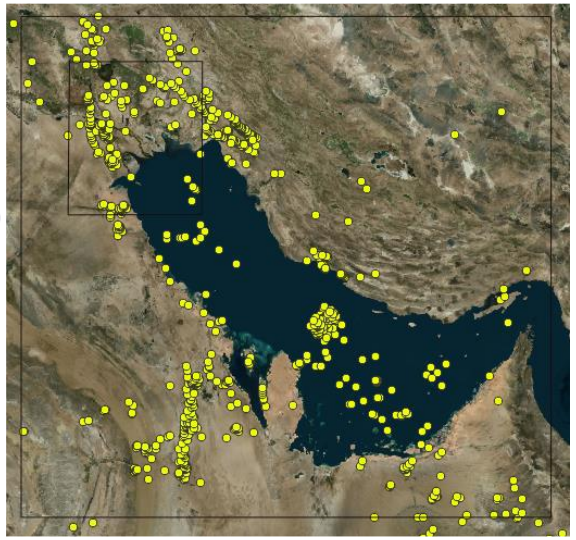
Goal: technical support to BBC documentary

Assignment: 08/2022

Deadline: 10/2023 - data
11/2023 - report

BBC - Air quality impact of gas flaring from oil fields in the Gulf area

Flares (bottom-up)

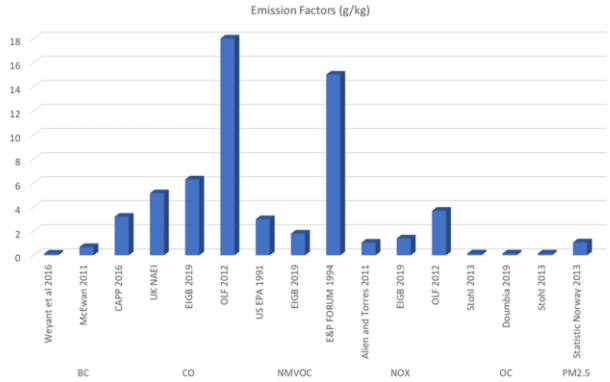


Posizione delle singole torce (fonte: database Banca Mondiale)

Activities

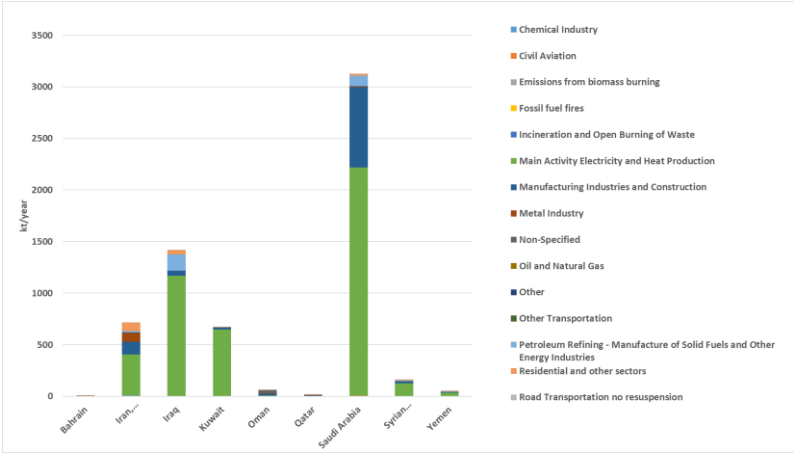
country	Flaring Vol (million m3)
Bahrain	93.9
Iran, Islamic Rep.	17224.1
Iraq	17901.7
Kuwait	582.2
Oman	2071.7
Qatar	987.5
Saudi Arabia	1838.2
Syrian Arab Republic	1069.2
Yemen, Rep.	727.5

EF



Emissions

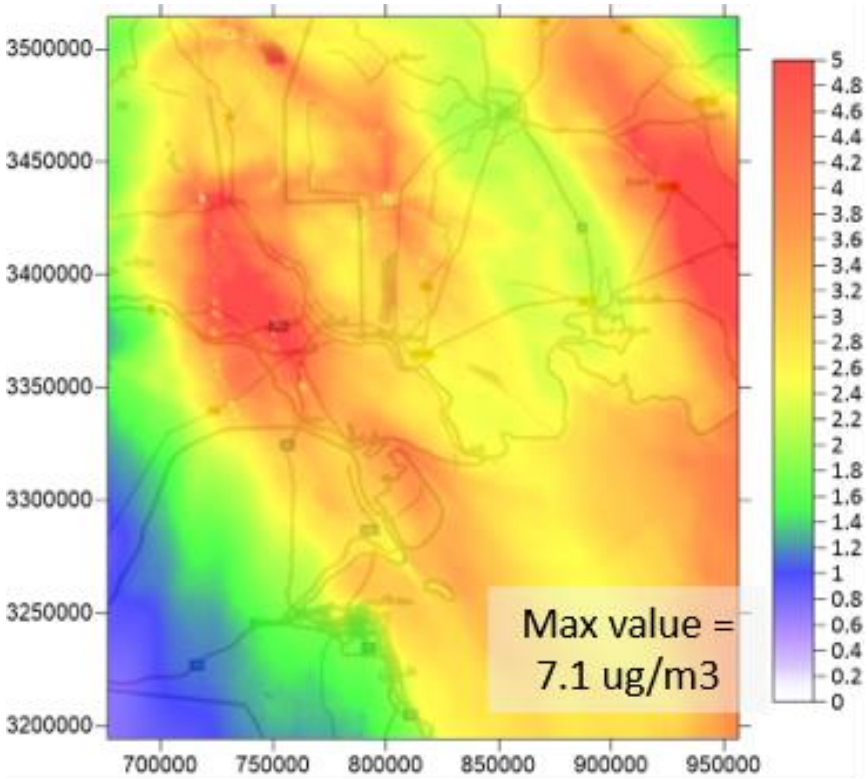
Other emissions (EDGAR)



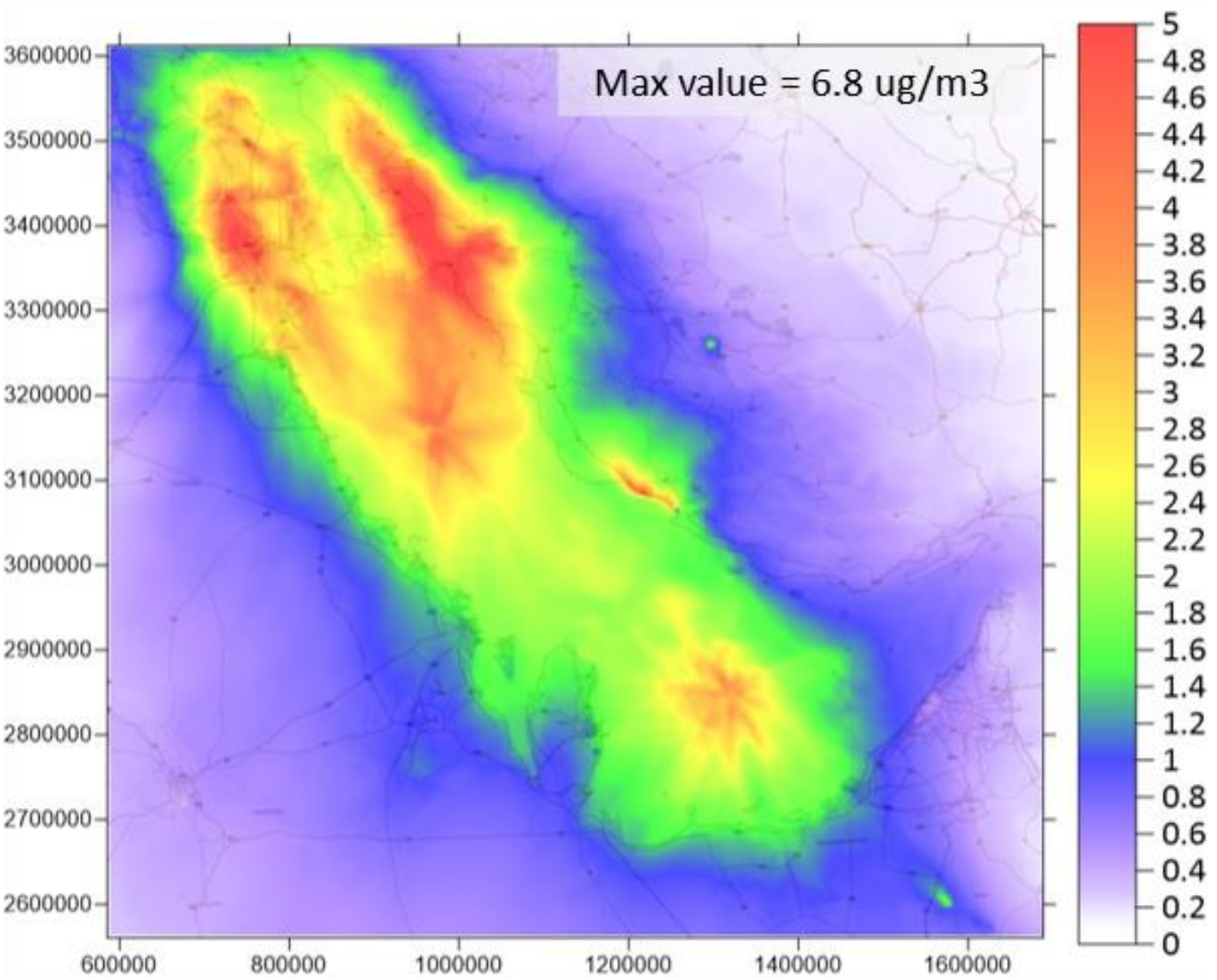
SO2 emissions (EDGAR)

Some power generation and combustion sources in refineries were treated as point sources

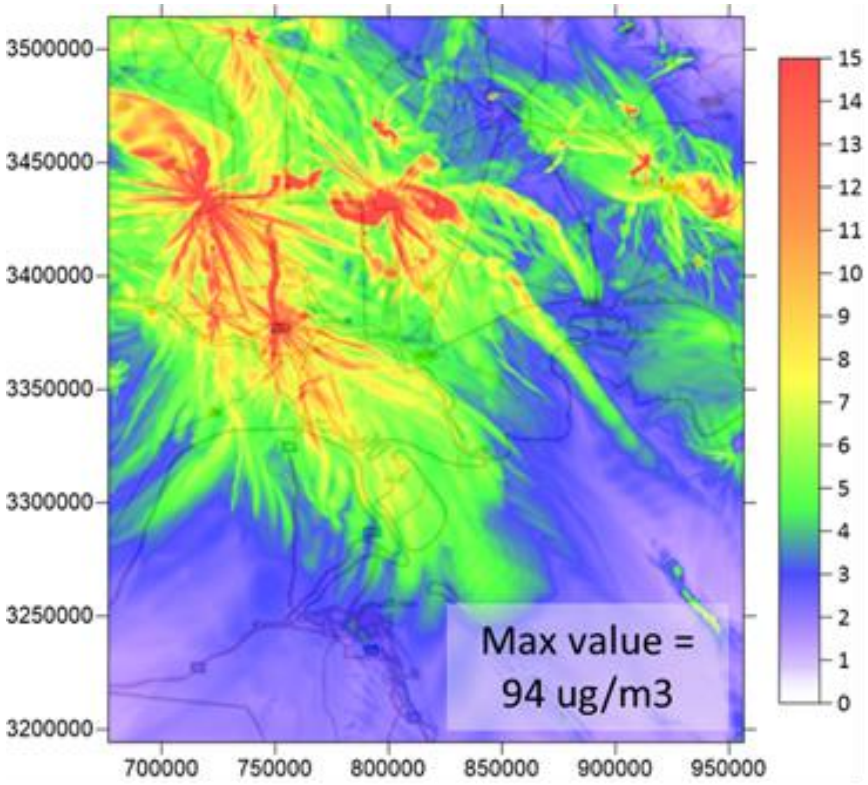
Monthly mean of O3 MDA8h (flares contribution)



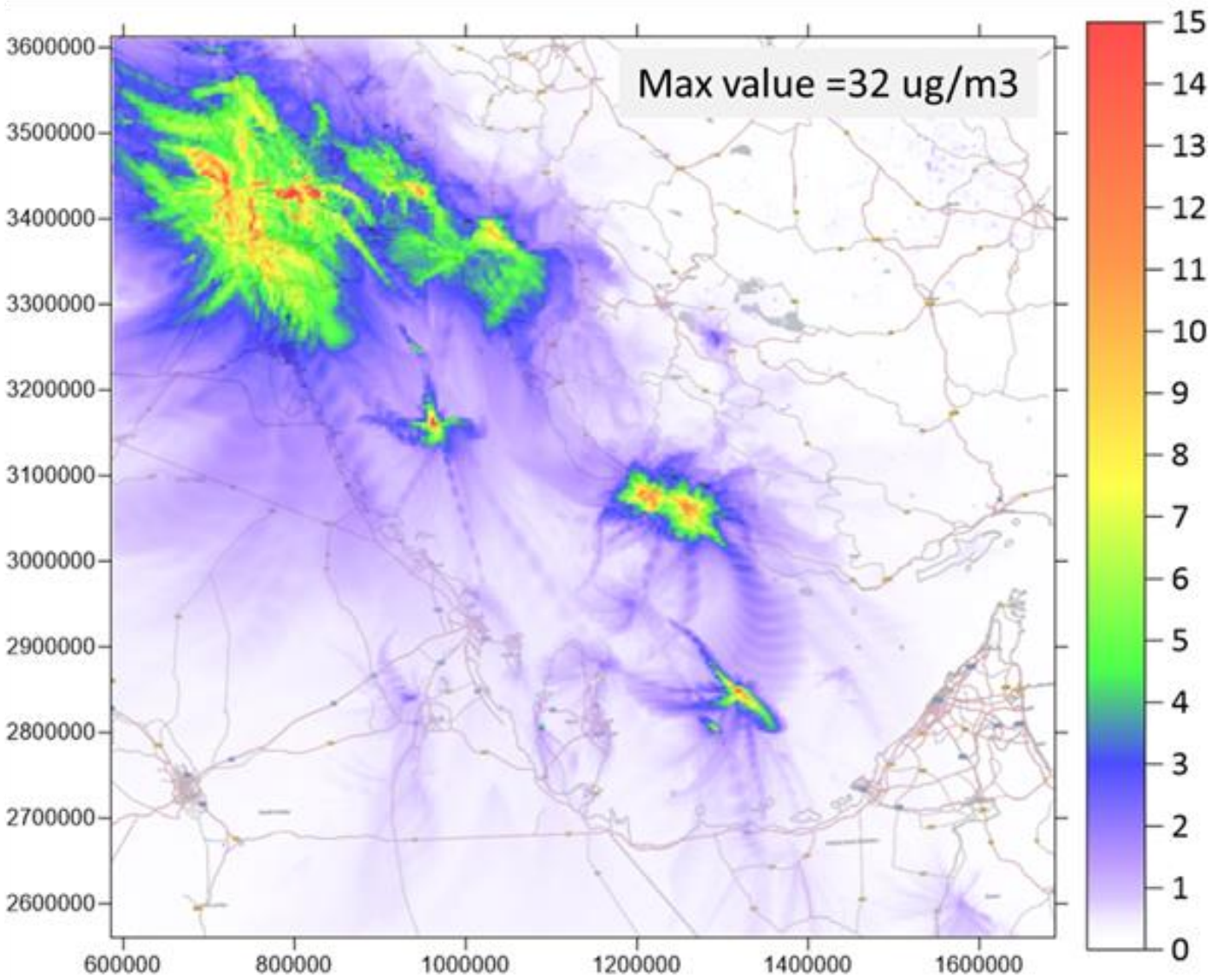
June 2022



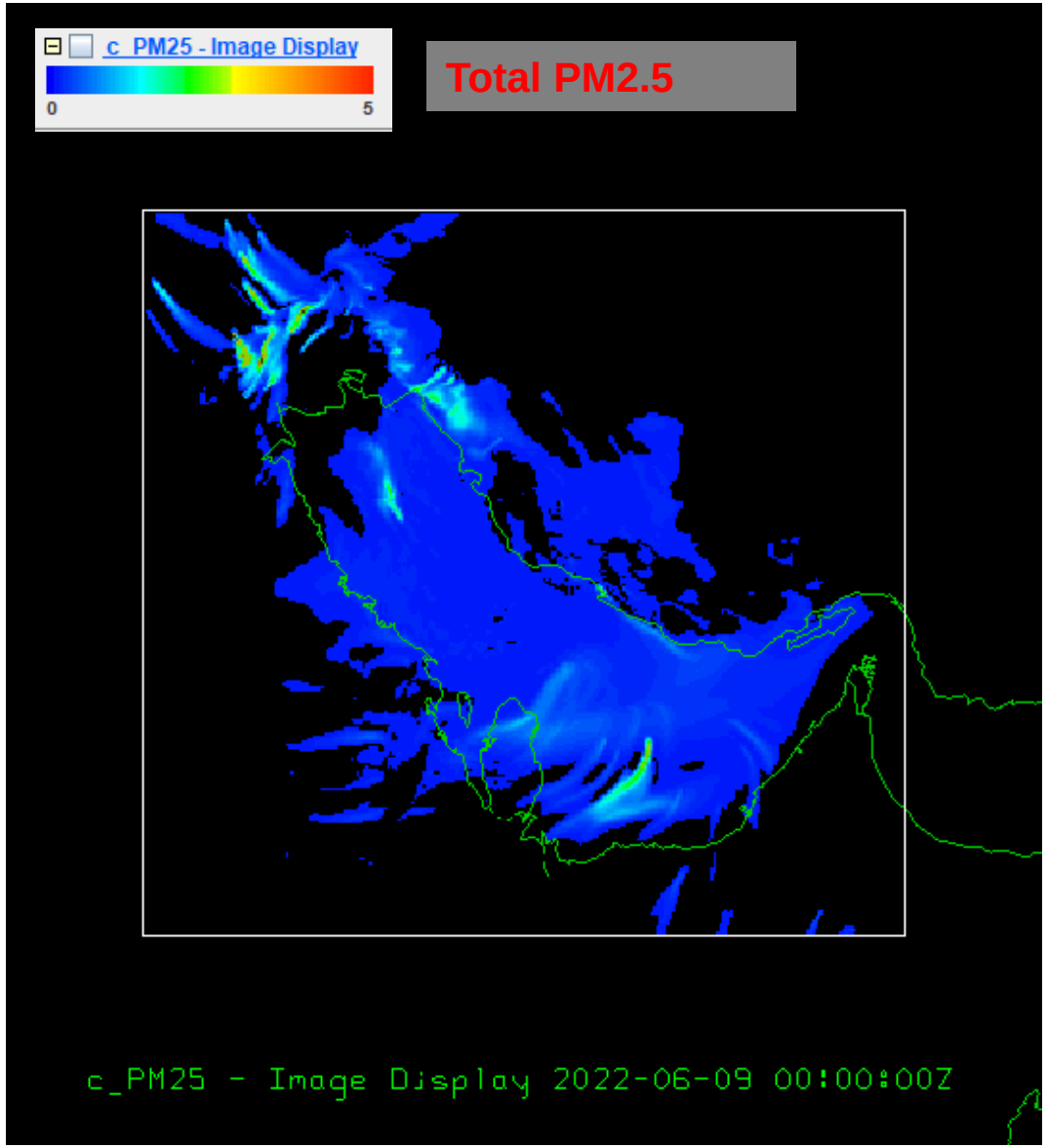
PM2.5 maximum hourly mean concentrations (flares contribution)

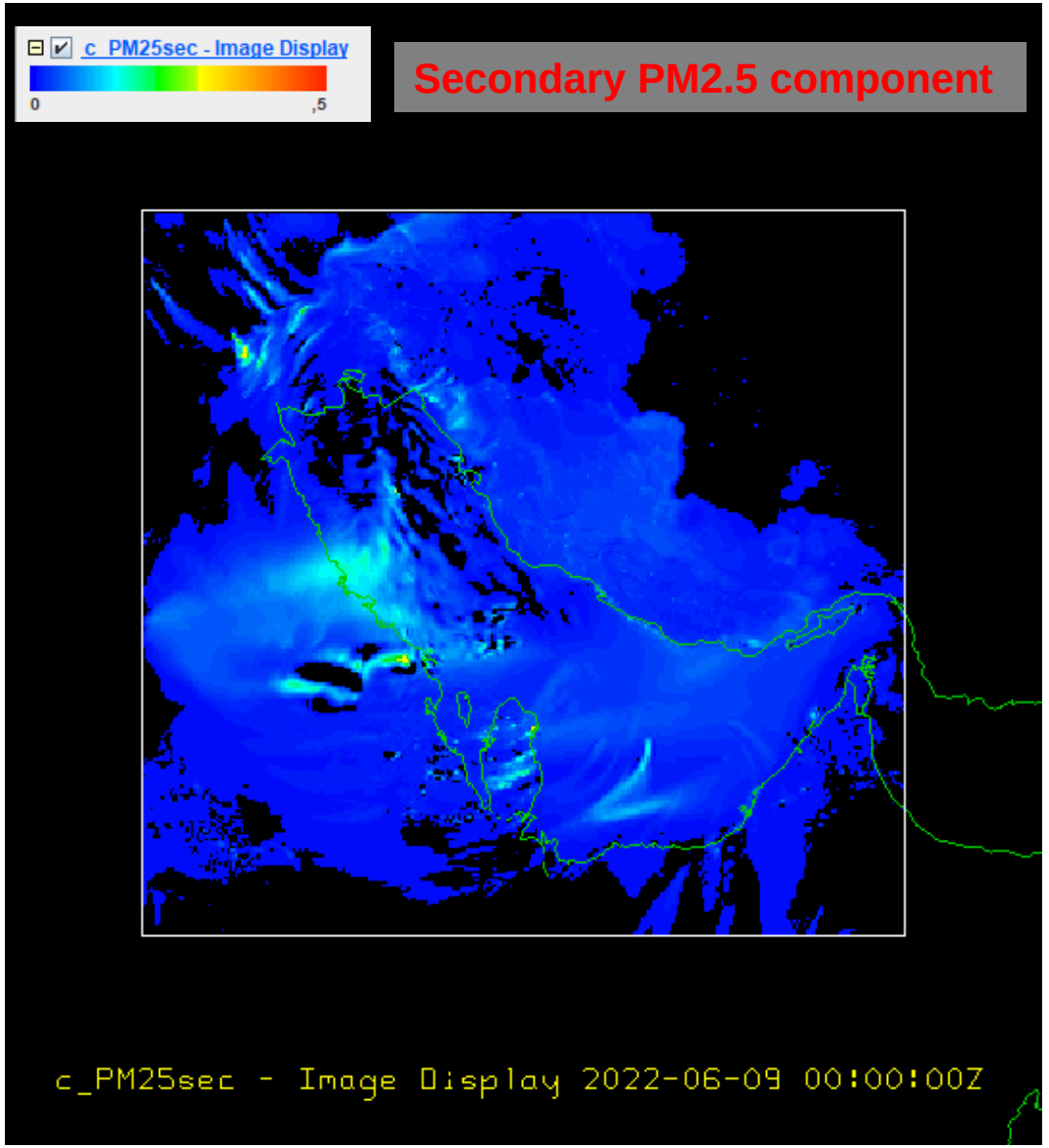


December 2022



PM2.5 & secondary component - June 09-10 hourly average concentration animation – g2





BBC Documentary clip

Thank you for your attention!

شكرًا لكم على اهتمامكم!

The BBC documentary film is available here:
https://www.youtube.com/watch?v=nDmtnFV4njA

the film is also presented here:
https://www.bbc.com/news/science-environment-67522413