Uncertainties in the simulation of XCO_2 plumes from power plant emissions: A comparison between 6 high-resolution atmospheric transport models

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Mesoscale models (1-2 km resol.)
- COSMO-GHG (Empa)
- WRF-GHG (MPI Jena)

LES models (200-600 m resol.)
- EULAG LES (SPASCIA)
- WRF-LES (DLR)
- ICON-Messy/ICON-LEM (DLR)

Lagrangian dispersion models
- ARTM (Bundesamt für Strahlenschutz)

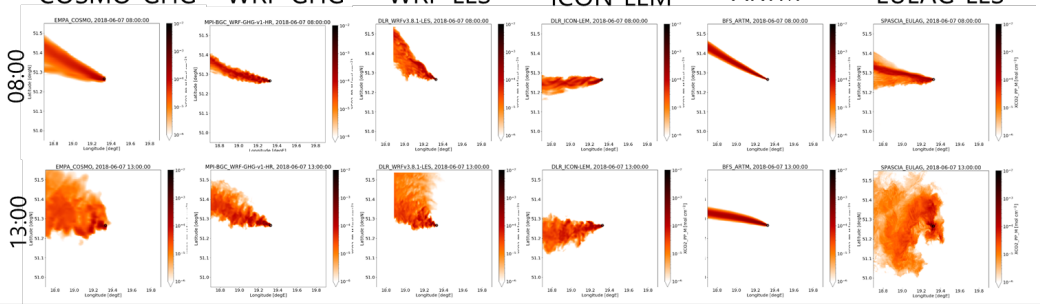
Observations

Belchatow, 07 Jun 2018
In situ (QCLAS) on DLR-Cessna
In situ (CRDS) on DLR-Halo
MAMAP on FUB-Cessna
CHARM-F LIDAR on DLR-Halo

Jänschwalde, 23 May 2018
In situ QCLAS on FUB-Cessna
MAMAP on FUB-Cessna
CHARM-F LIDAR on Halo

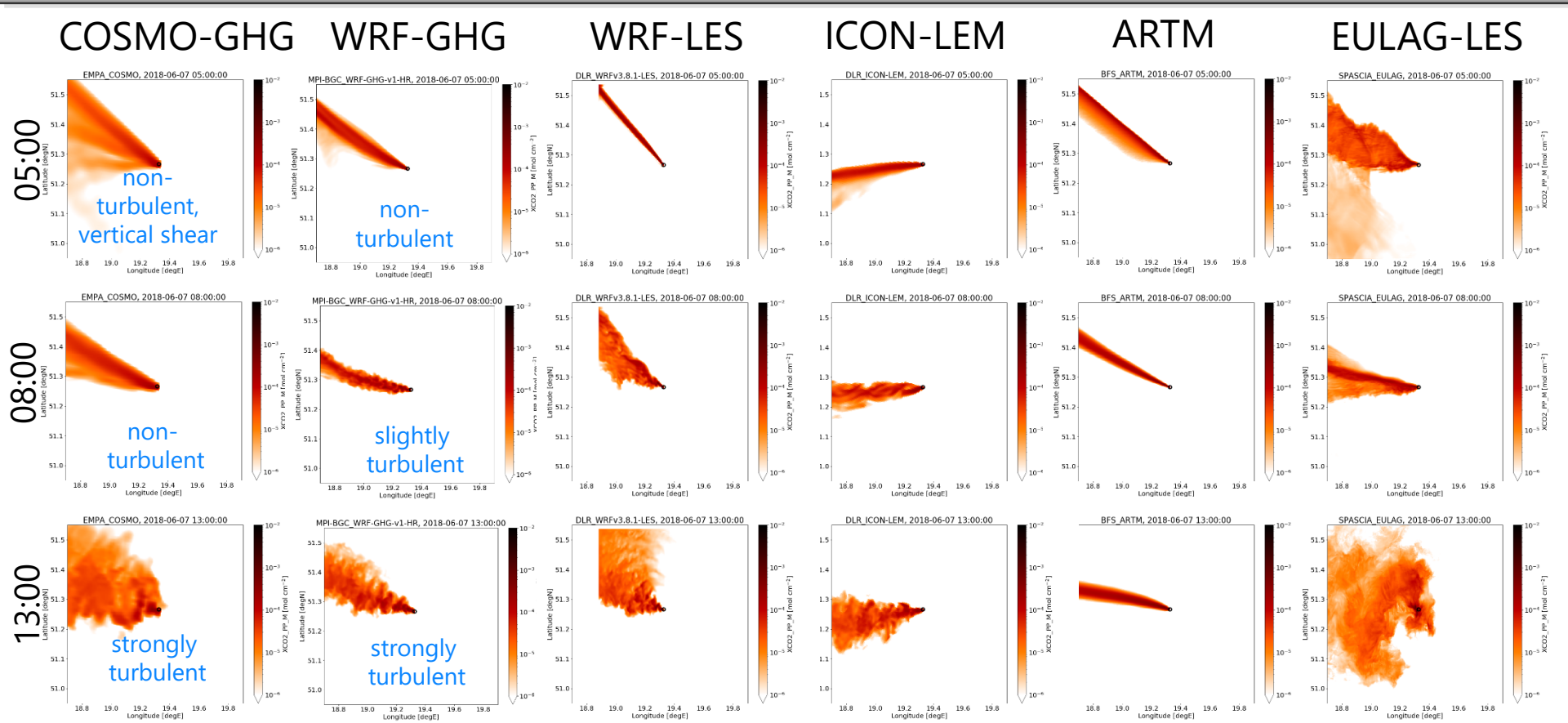
1 Empa
2 SPASCIA
3 DLR Deutsches Zentrum für Luft- und Raumfahrt
4 Universität Bremen
5 Max Planck Institute for Biogeochemistry
6 BfS

Belchatow XCO_2 plumes on 7 Jun at 08:00 and 13:00 UTC



- Belchatow plume became highly turbulent during the morning, Jänschwalde plume much less
- Models are mostly able to reproduce these differences
- Plume shapes and spread differs significantly between models (independent of resolution)
- Details of how LES models are forced are very important
- Plume release hight not very important in this case because of strong mixing in PBL

Evolution of turbulent XCO_2 plume at Bełchatów 05 – 13 UTC

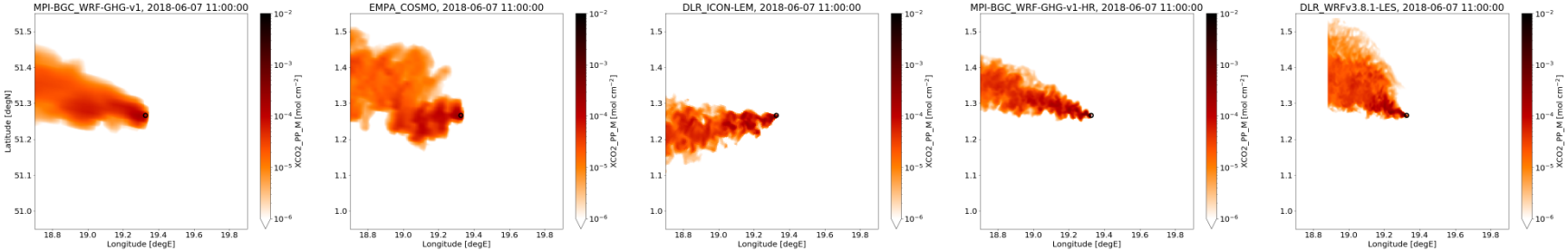


Effects of model resolution and plume release height

Turbulent puff-like structures start to be resolved at about 1 km resolution

Resolution

2 km	1 km	600 m	400 m	200 m
WRF-GHG lo-res	COSMO-GHG	ICON-LEM	WRF-GHG hi-res	WRF-LES

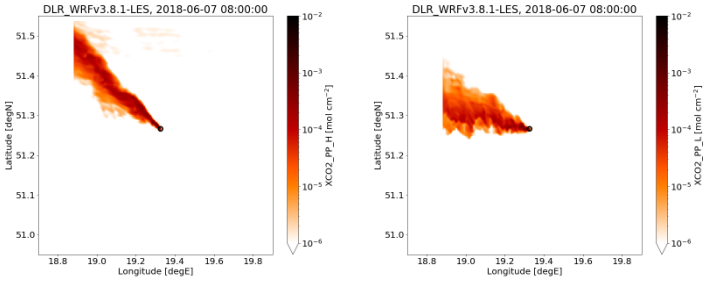


Release height

Morning (09 LT): strong vertical wind shear

High release (~600 m a.g.l)

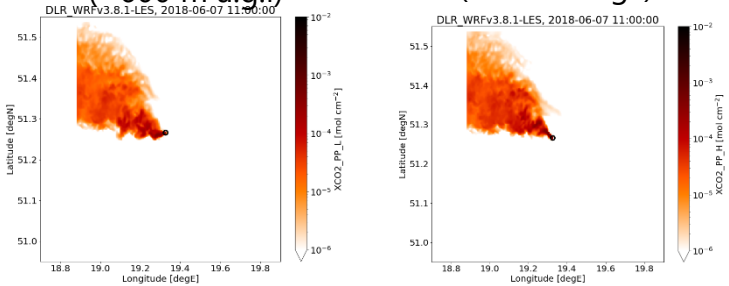
Low release (~150 m a.g.l)



Noon (12 LT): well-mixed PBL

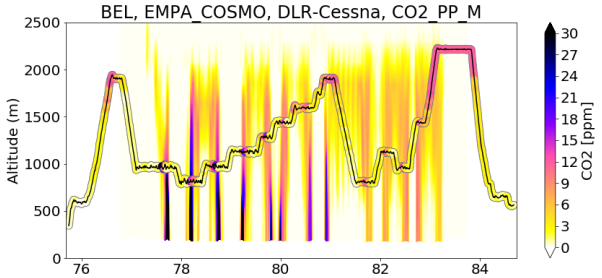
High release (~600 m a.g.l)

Low release (~150 m a.g.l)

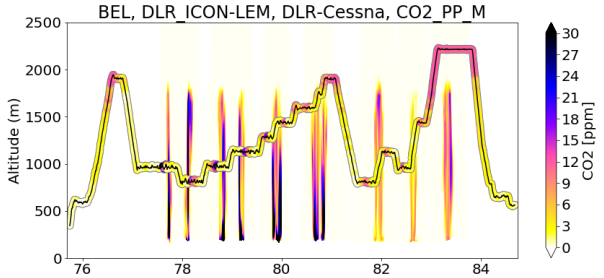


Comparison of CO_2 curtains with in-situ CO2 measurements on DLR-Cessna flight, Belchatow, 7 Jun 2018

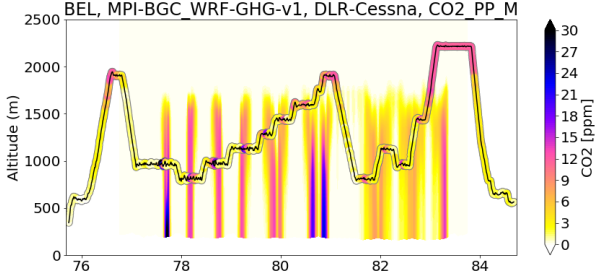
COSMO-GHG



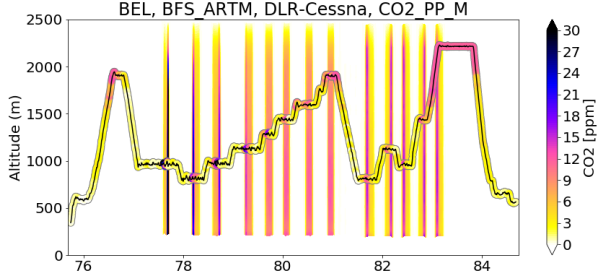
ICON-LEM



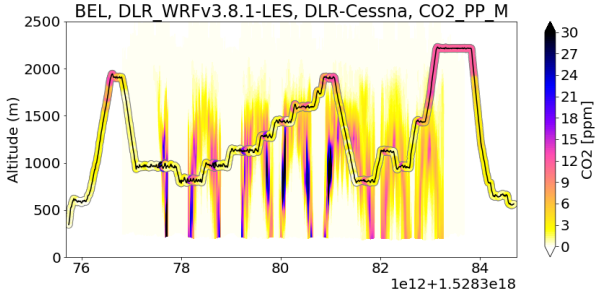
WRF-GHG



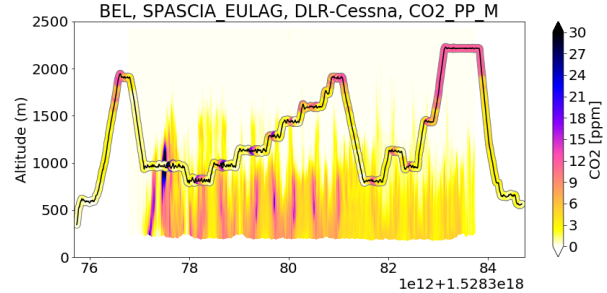
ARTM



WRF-LES

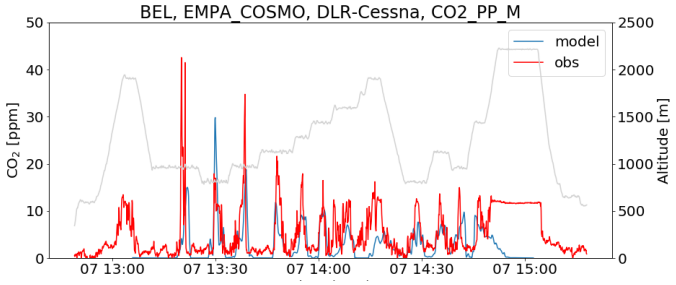


EULAG-LES

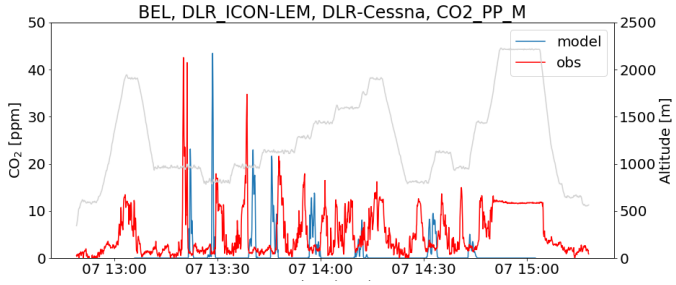


Comparision simulated vs. in-situ CO_2 on DLR-Cessna flight, Belchatow, 7 Jun 2018

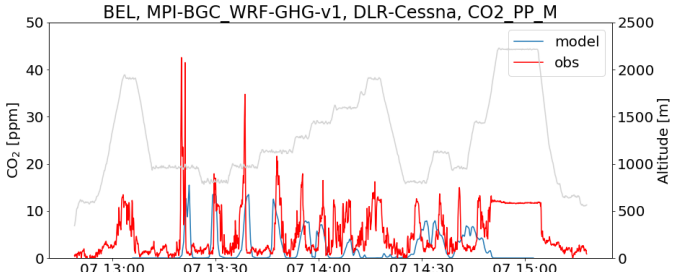
COSMO-GHG



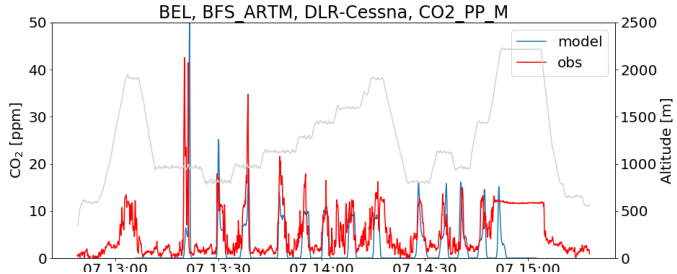
ICON-LEM



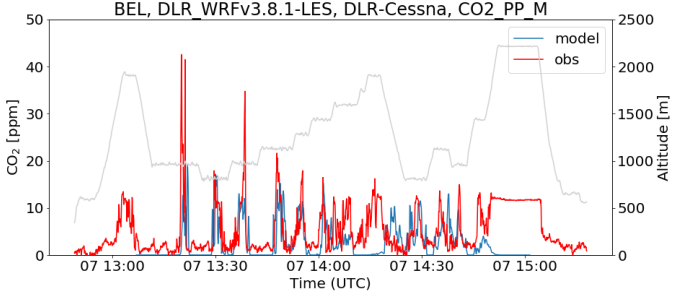
WRF-GHG



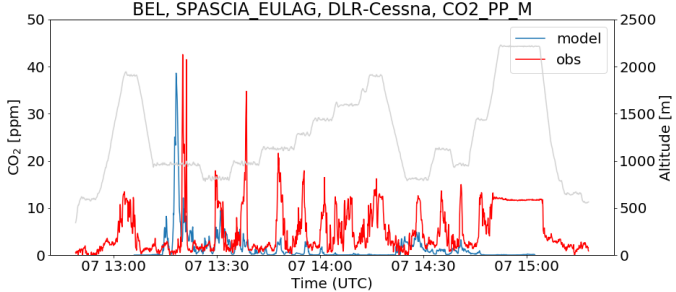
ARTM



WRF-LES



EULAG-LES



Conclusions and outlook

- 6 models with resolutions from 2 km to 200 m simulated same power plant plume cases using similar meteorological driving and the same emission strengths and profiles
- Plume at Belchatow became highly turbulent with growing PBL during the morning
- Turbulent structures start being resolved at a resolution of 1 km or better; at coarser resolution (and in Lagrangian model ARTM) plumes are more Gaussian-shaped
- Dispersion/plume widening differed quite substantially between models, with no clear dependence on model resolution or type (NWP vs. LES)
- Results of LES and Lagrangian dispersion models critically depend on meteorological forcing: E.g. constant vs. time-varying fields, resolution of forcing data.
- Plume direction strongly depended on emission height in the morning, but not during well-developed PBL. CO2M (at 11:30 LT) likely to sample plumes when PBL is fully developed 😀, but plumes will often be turbulent 😕.
- Plume amplitude and position well captured by some models (e.g. WRF-LES, COSMO-GHG), sometimes too narrow (ICON-LEM, ARTM), or at too low altitude (EULAG)
- Statistical analysis of model performance ongoing, focus is on representation of plume dispersion parameters. Accurately capturing structure of a real turbulent plume is impossible.