Improved modelled contributions of road transport to SOA and UFP concentrations

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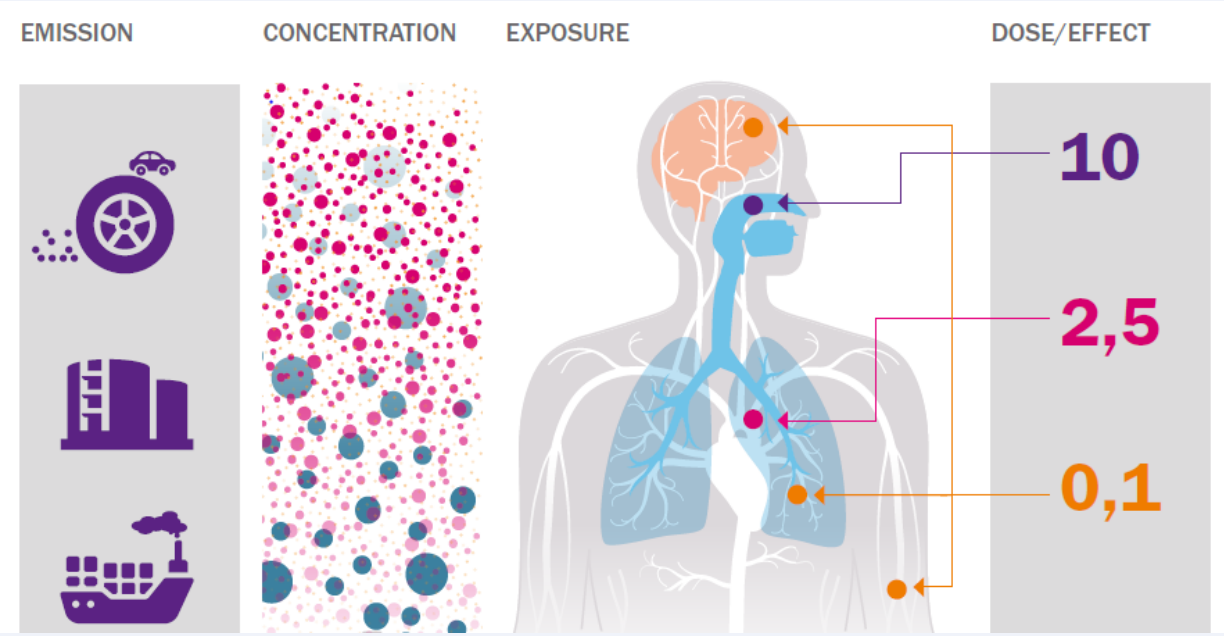
Rationale

How are health impacts of atmospheric particulates quantified best?

- Mass and composition-based, oxidative potential, source-specific effects
  - New EU target values for PM2.5, PM10 mass concentrations
- Particle number
  - UFP recognized as potential health relevant indicator (HRI), with particles protruding deeply into the body
  - New guidelines for UFP by WHO 2021. >10 000 particles/cm^3 as “enhanced concentration”
  - New EU directive to measure UFP in 2024

Road transport as relevant sector

- linked to population density and exposure
- significant emissions of particle number

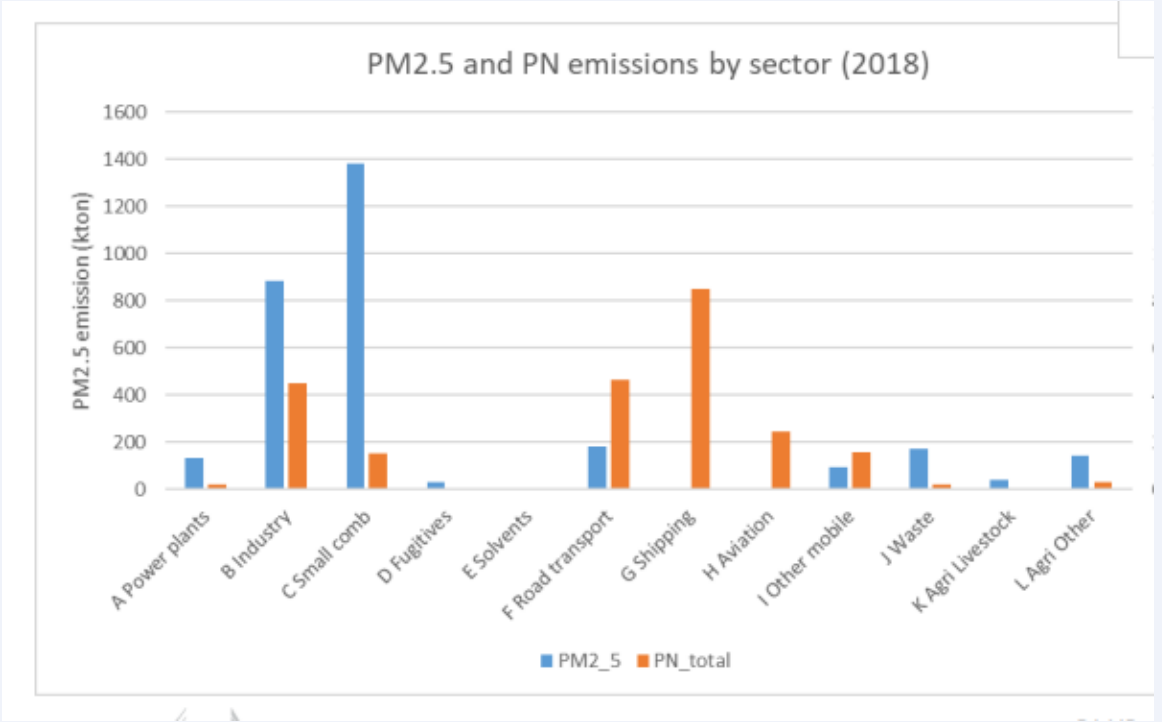


Emissions of PM an PN

- Only **primary, non-volatile emissions** of traffic regulated
  - Contribution of SVOC and IVOC to ambient PM poorly quantified
  - SPN23 -> total PN emissions poorly quantified

- RI-URBANS and EASVOLEE project to improve real-world emission factors and emission inventories for modelling focusing on road transport
  - New emission factors for SVOC/IVOC and PN, real driving conditions
  - Investigation of SOA formation potential (aging of direct emissions in reactors)

  - Different sectors dominant for PM2.5 and for PN

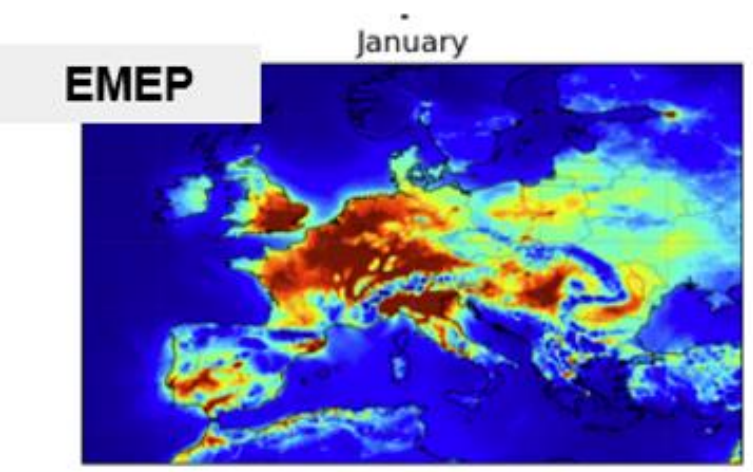


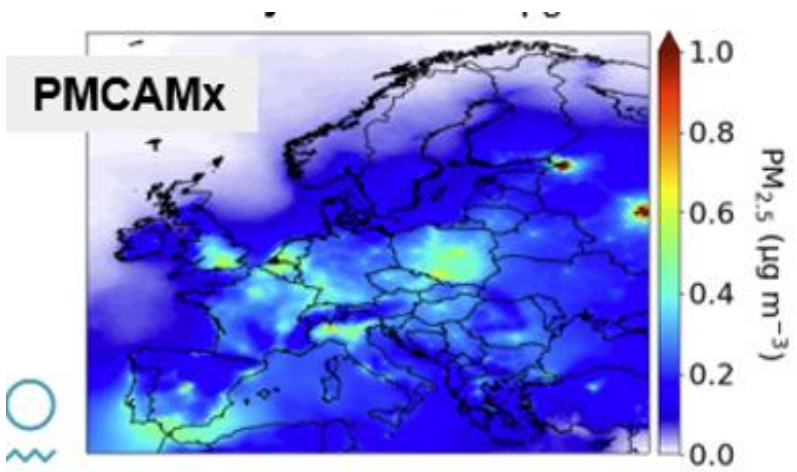
RI-URBANS emissions 2018

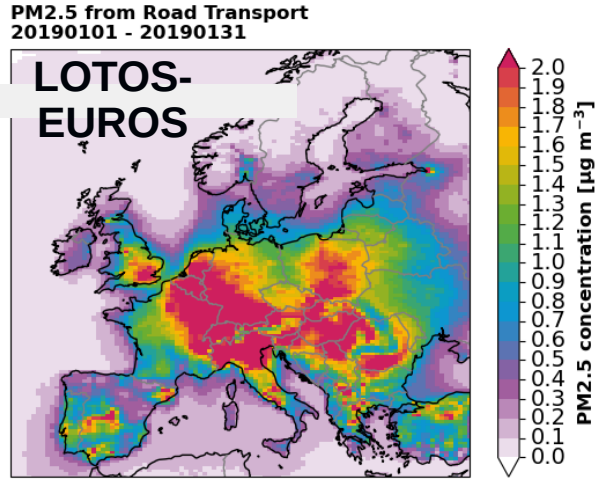
Model simulations for PM2.5

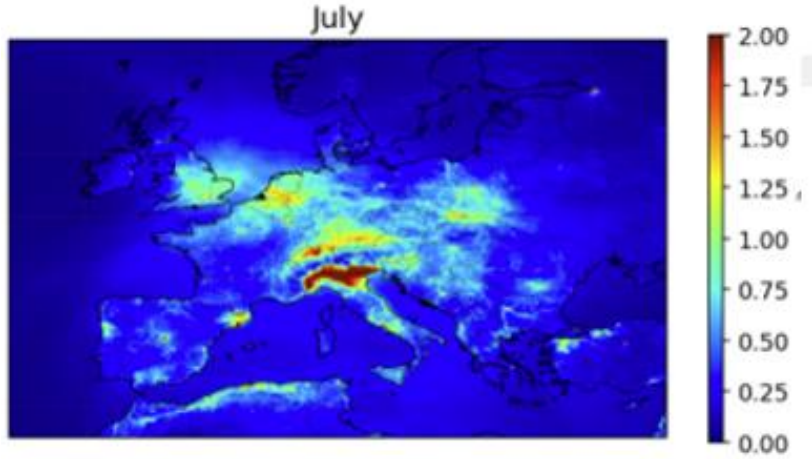
- EMEP, PM-CAMx, LOTOS-EUROS
  - New SVOC/IVOC lumping scheme for alkanes and PAH (Manavi and Pandis, 2024) for CTMs
  - Coupling to chemistry and VBS approach in PM-CAMx, EMEP, LOTOS-EUROS
  - Taking fraction of VOC, instead of fraction of PM2.5 to introduce SVOC/IVOC
    - SVOC/IVOC emissions are 8 times higher than Robinson et al. (2007)

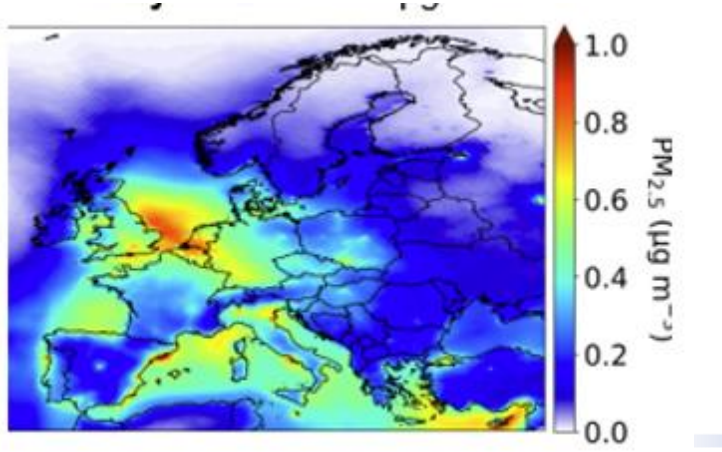
Spatial distribution of road transport PM2.5

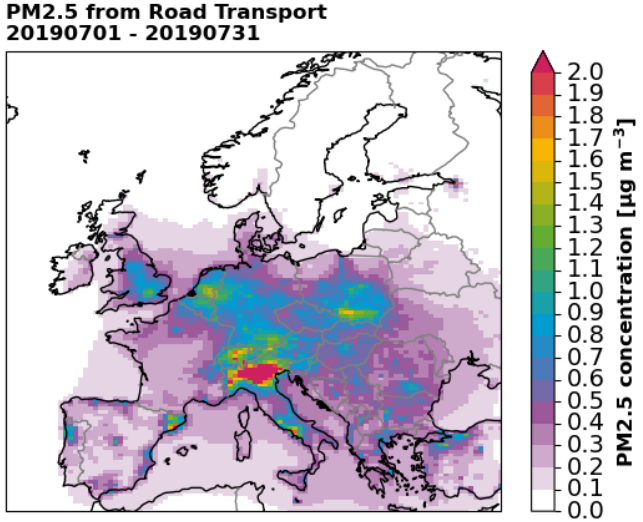




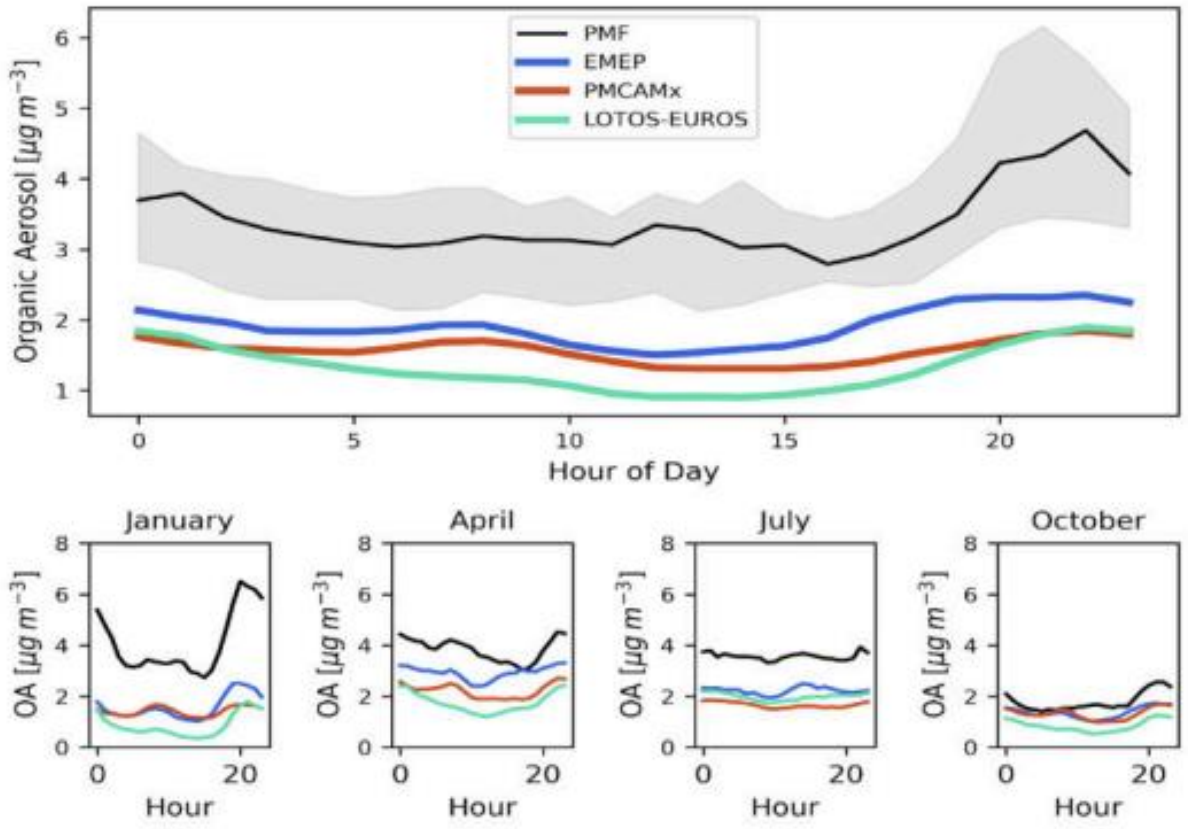


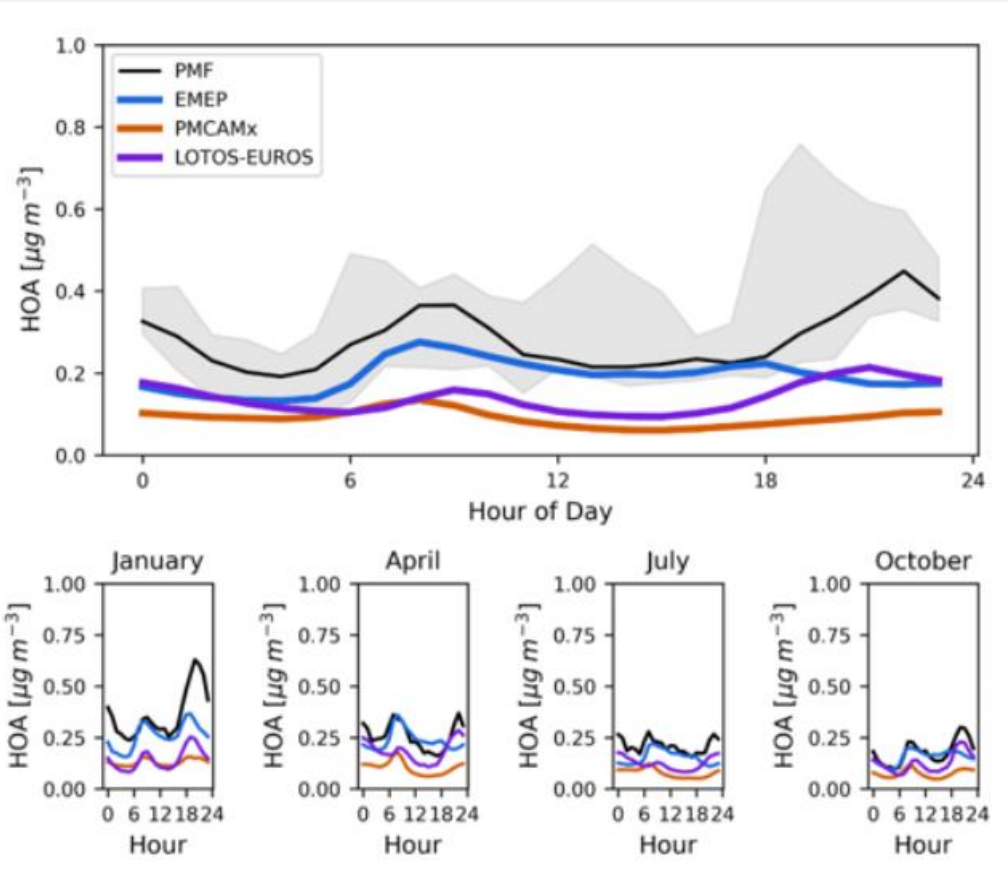






Intercomparison of EASVOLEE CTMS

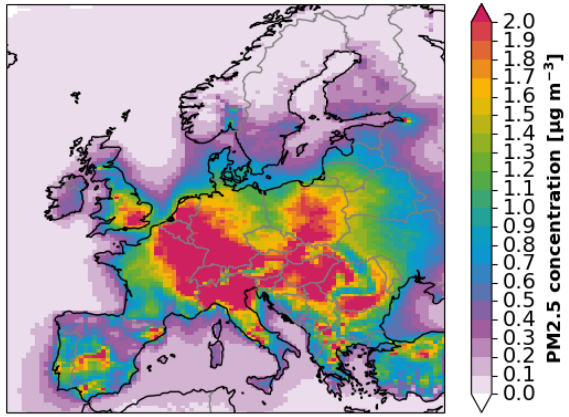


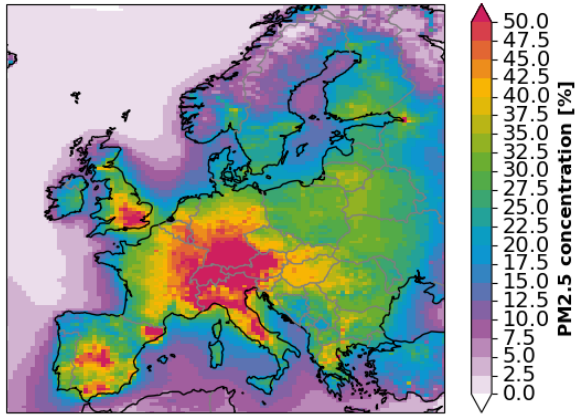


Similar behaviour of the three models. OA underestimated, mainly from OOA in winter

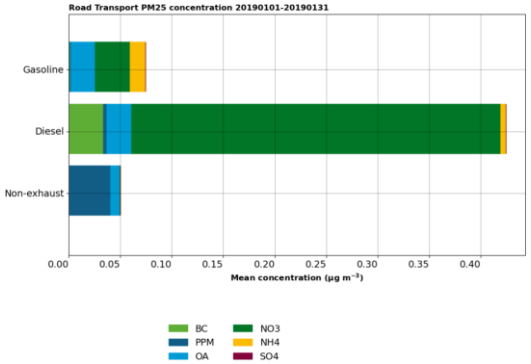
Spatial distribution Road Transport PM2.5 LOTOS-EUROS

January

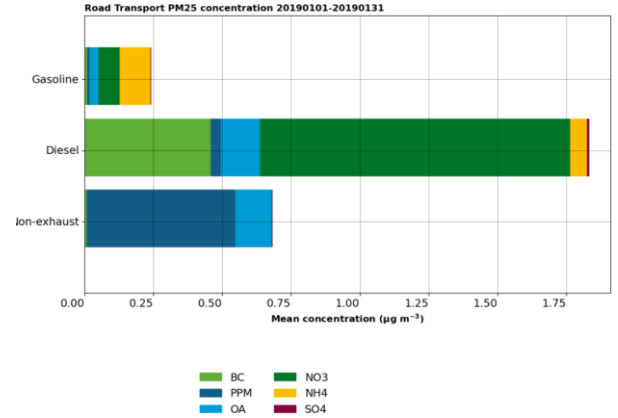




mean

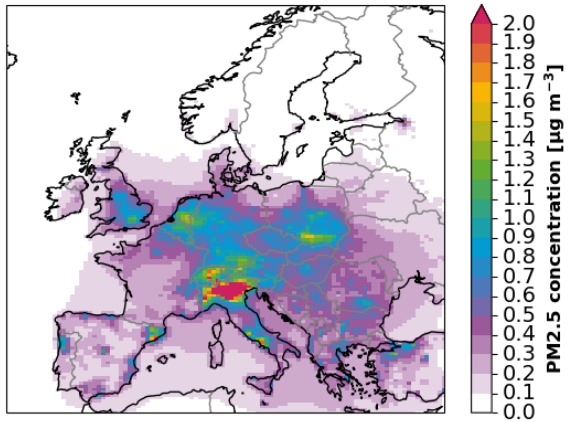


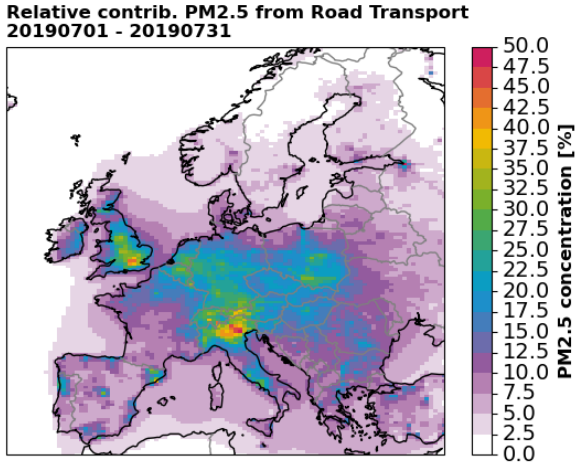
Paris



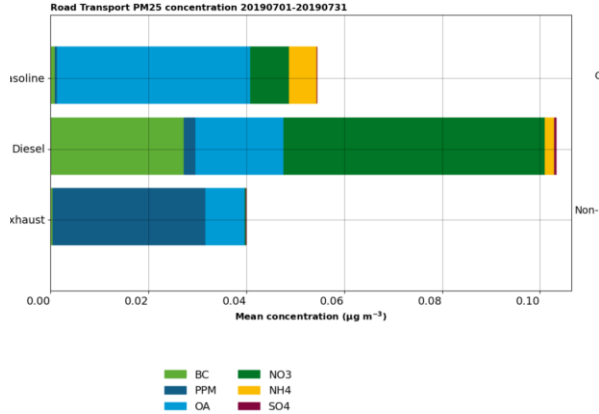
January mean: 0.56 µg m^{-3}

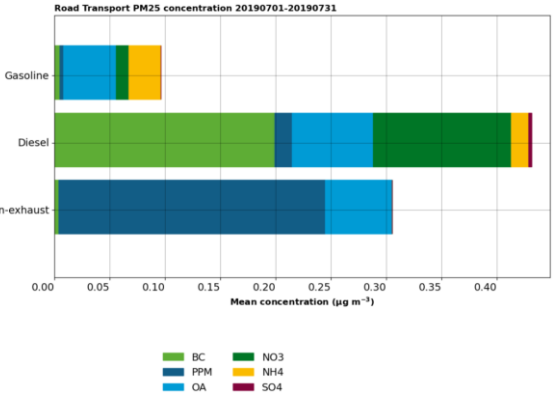
June



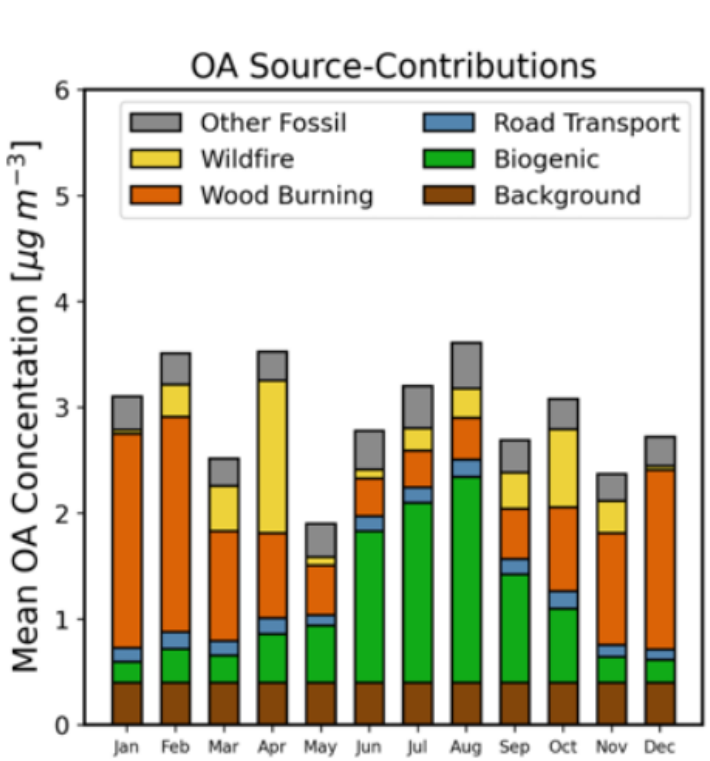


July mean: 0.21 µg m^{-3}

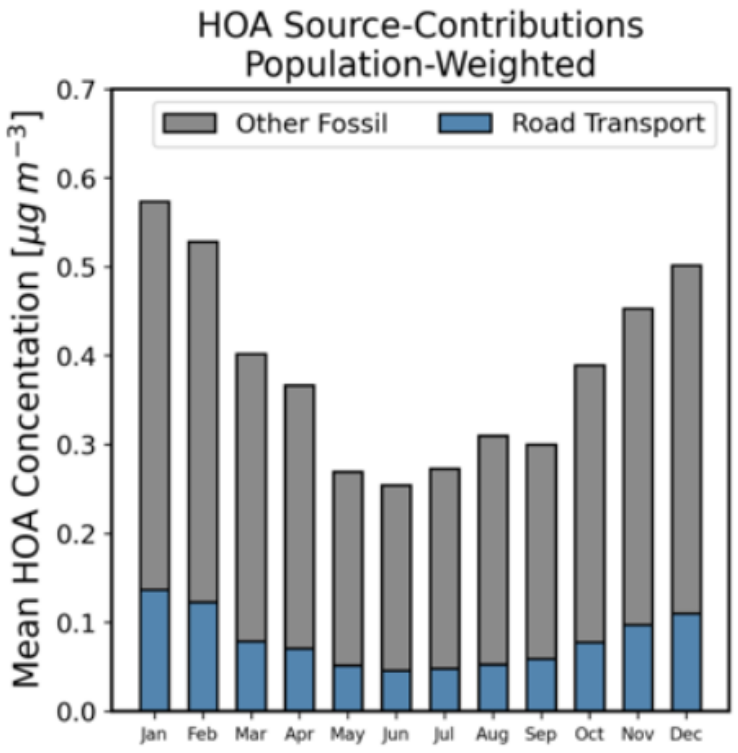




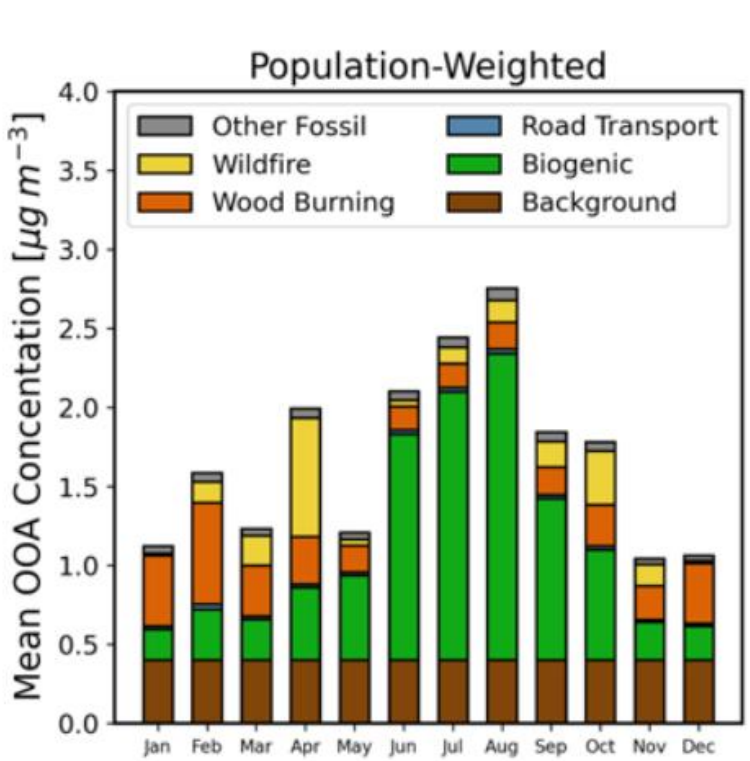
Predicted Contribution of Transportation to OA



Road Transport Mean = 4.7%



Road Transport Mean = 20.1%



Road Transport Mean = 1.8%

Role of off-road vehicles/mobile machinery relevant for HOA

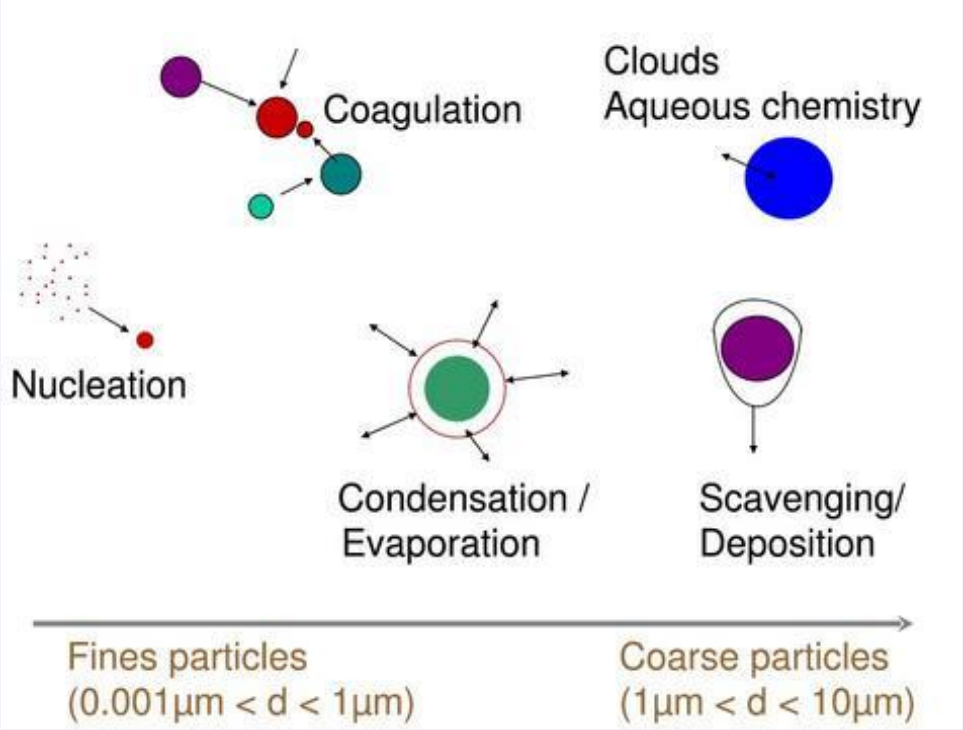
Summary of PM2.5 Evaluation

- Models give in general consistent results
- EASVOLEE SVOC/IVOC emissions are 8 times higher than Robinson et al. (2007)
  - Estimates in EASVOLEE inventory based on reported VOC, not on PM emissions
- SVOC SOA yields are 86%
  - SVOC emissions are relevant
- Primary HOA
  - EASVOLEE models tend to underestimate it by 40-70%
  - Underestimation of off-road emissions or errors in volatility?
  - Population weighed modelled road transport contribution 20%.
- Secondary OOA
  - Underestimated especially in winter
  - Population weighed predicted road transport contribution only 2 %
  - Errors in biomass burning emissions and processing and also biogenic SOA?

- RT is important contributor to PM2.5 (up to 50%)
  - Significant part of RT PM comes from SIA contributions rather than SOA

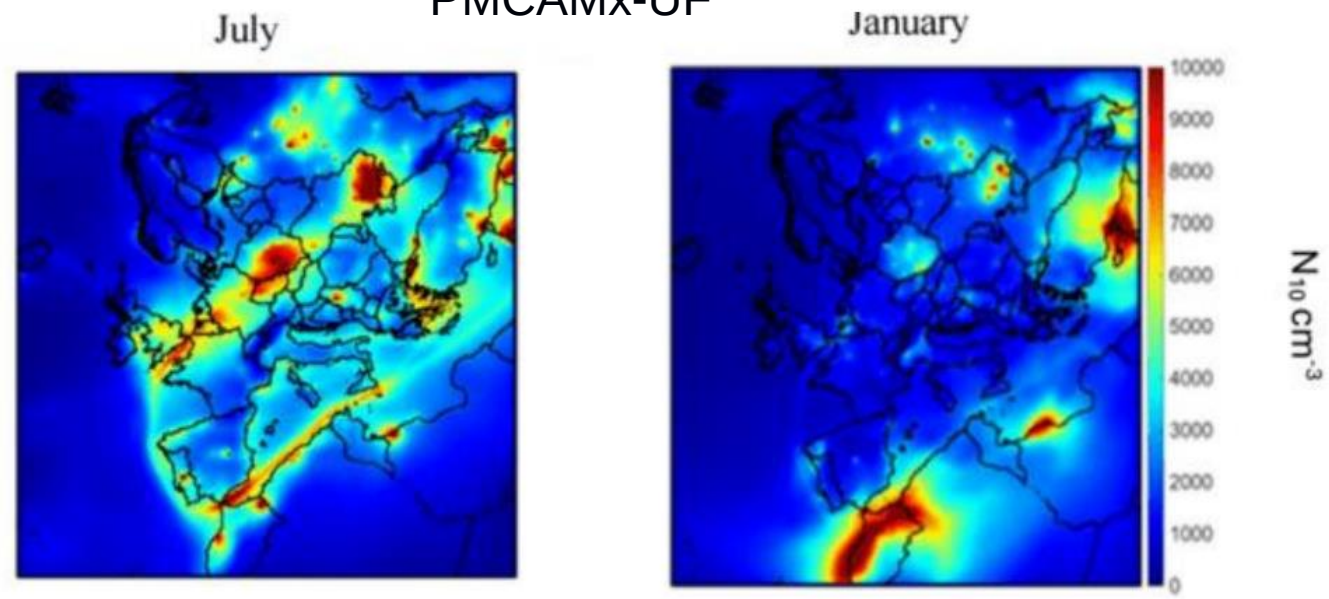
Model simulations for UFP

- LOTOS-EUROS, PMCAMx-UF
  - UFP not a conserved quantity
    - Model city domain with background conditions from SMPS measurements include coagulation process but not nucleation/condensation for good correlations with local measurements
    - Model European domain, including nucleation process in model, but accepting loss of good hourly/daily correlations with local measurements
  - High spatial resolution required due to strong gradients
    - 500m -1000m -> computational efforts & data volumes, only on city scale
  - Emission inventories more uncertain than for other species
    - Higher emission factors for HDV in EASVOLEE
  - Model evaluation with inhomogeneous data sets

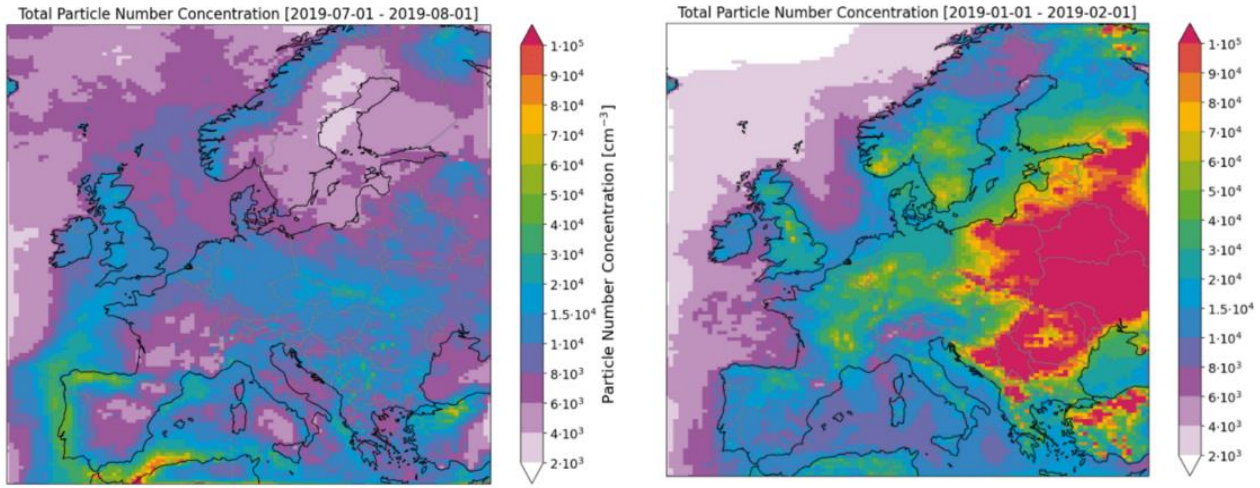


Predictions of Particle Number

PMCAMx-UF



LOTOS-EUROS



Including (semivolatile) OA improves performance of PMCAMx-UF and LOTOS-EUROS

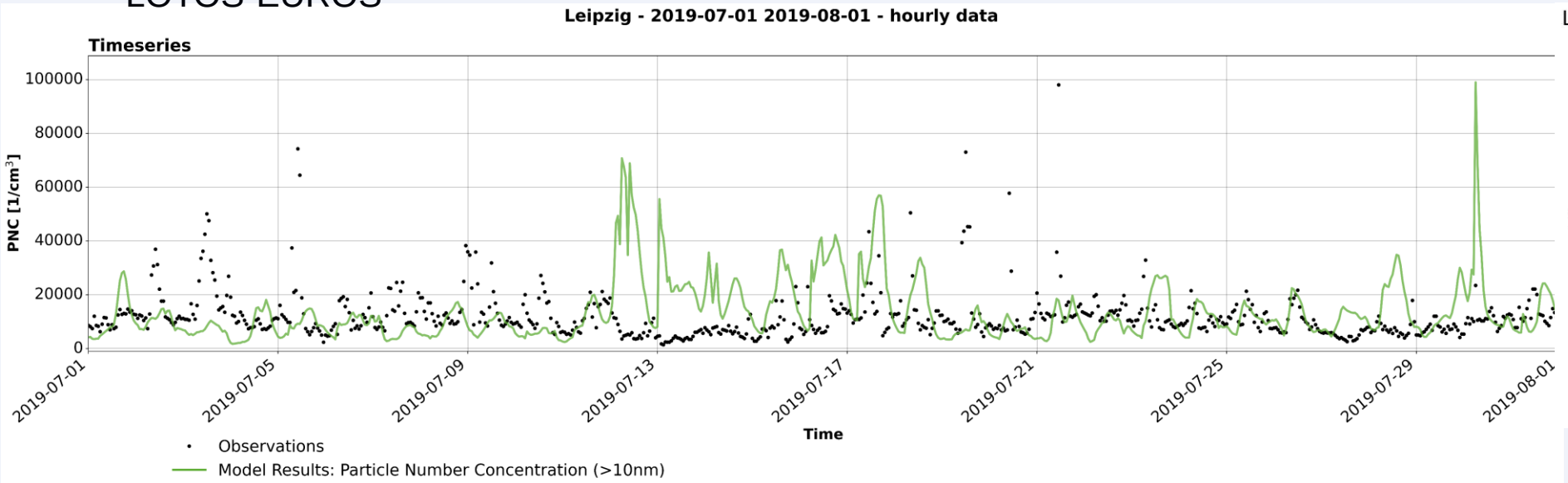
Summer conditions rather well represented by both models

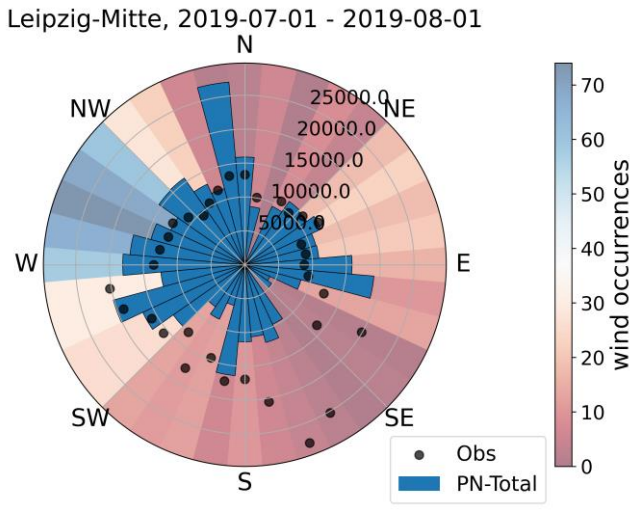
Winter N overestimated by LOTOS-EUROS, underestimated by PMCAMx-UF.

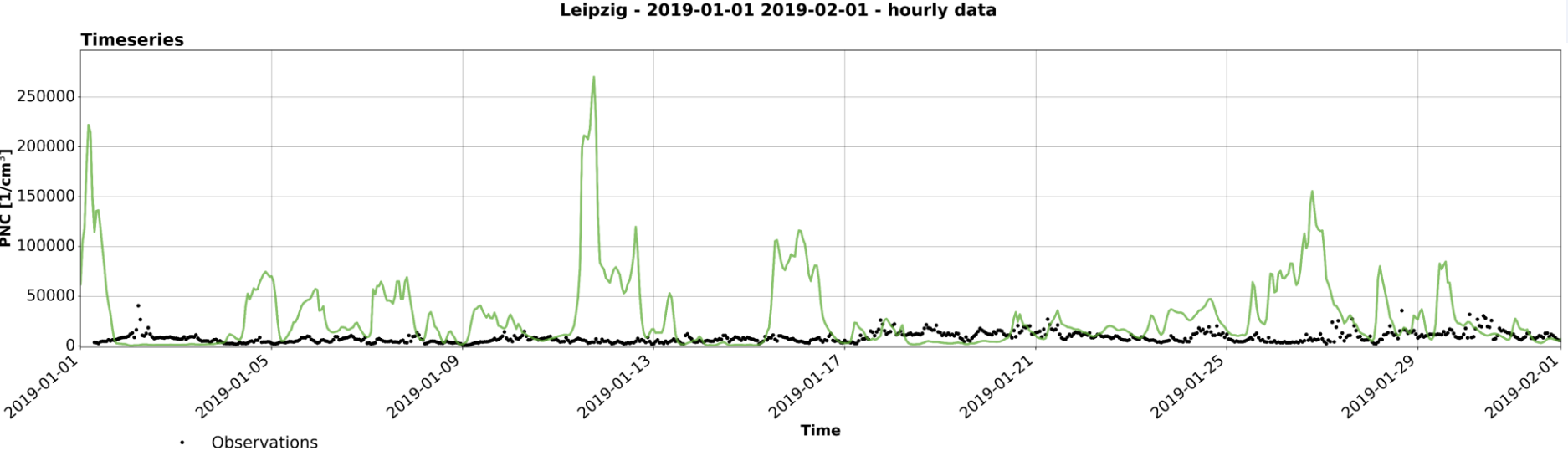
Interplay emissions and nucleation/condensation
Road transport emissions might be underestimated especially in the winter.

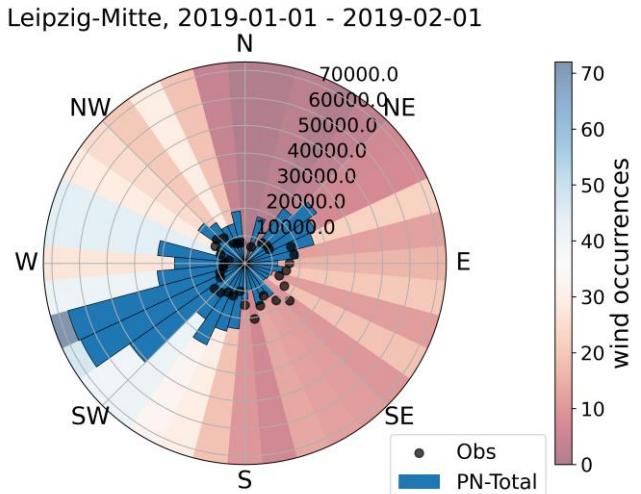
Example: Leipzig

LOTOS-EUROS



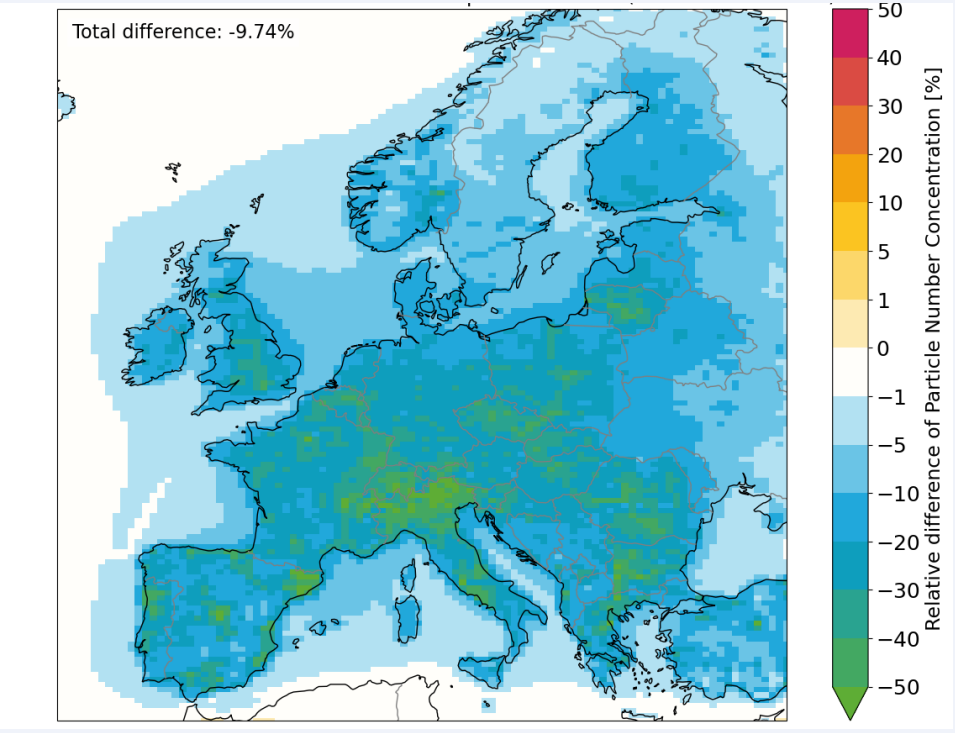


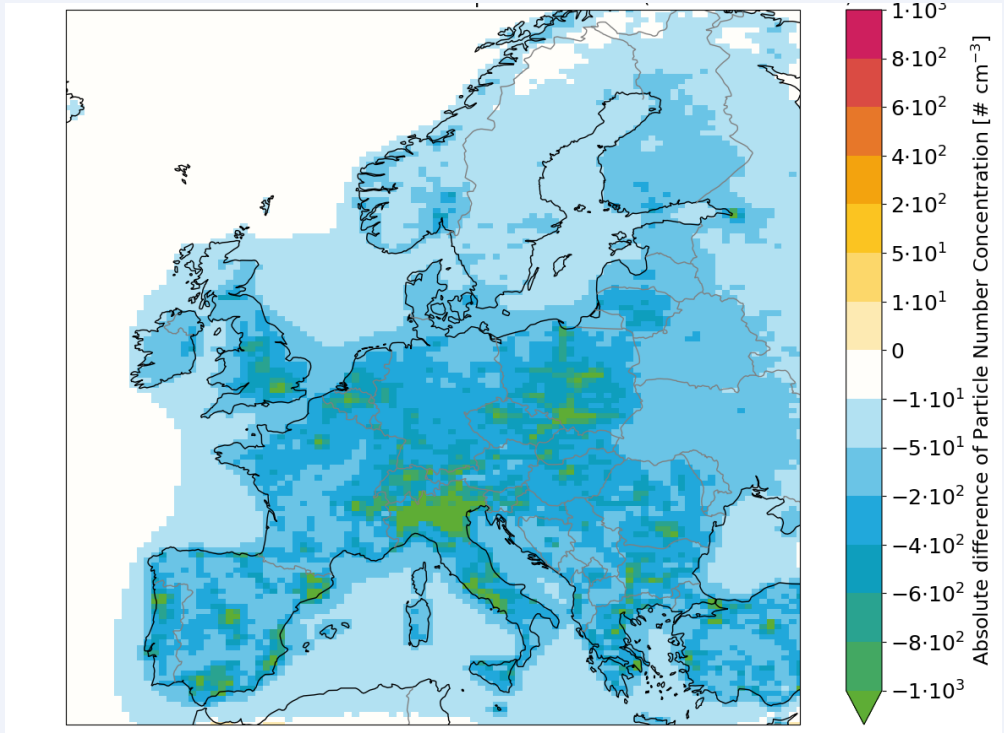




Road contributions

LOTOS-EUROS annual mean differences: impact of anthropogenic UFP emissions only



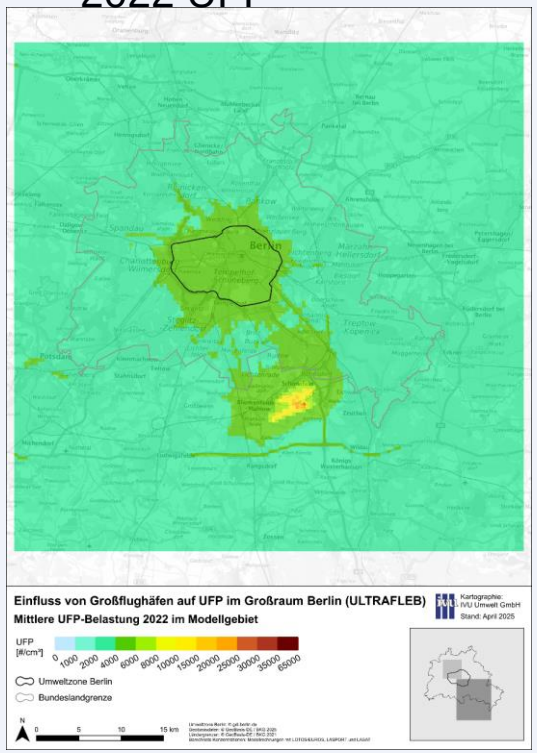


- LOTOS-EUROS Difference simulation excluding nuclelation ->relative effect on total number will be smaller
- Coarse resolution

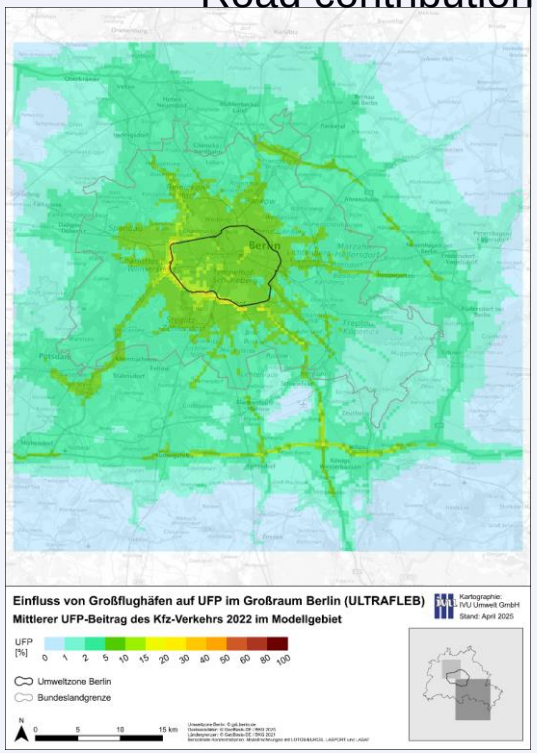
Road contributions PN in Berlin

- Simulations from ULTRAFLEB and KOPILOT projects, modelling city and taking measurements as background
- LOTOS-EUROS at high resolution (500 m-1km), no nucleation
- Combination with local scale models for high resolution (50 m) LASAT & LASPORT
- Emission scenarios to avoid double counting on high resolution domain & source apportionment

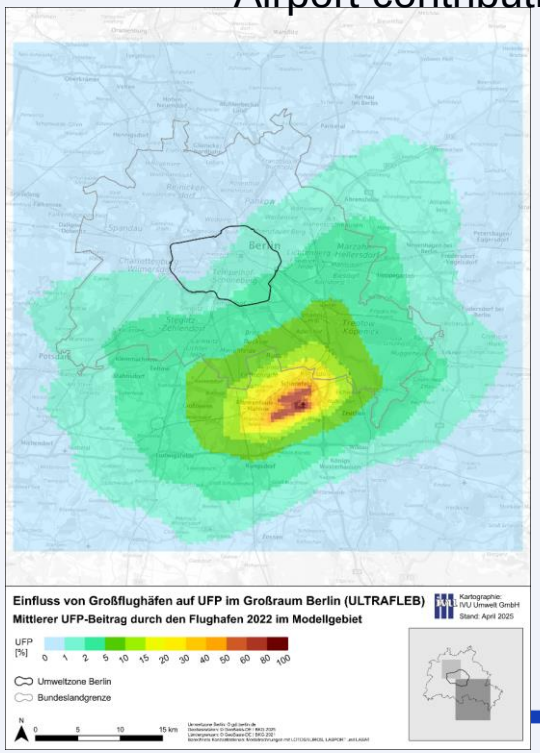
2022 UFP



Road contribution



Airport contribution

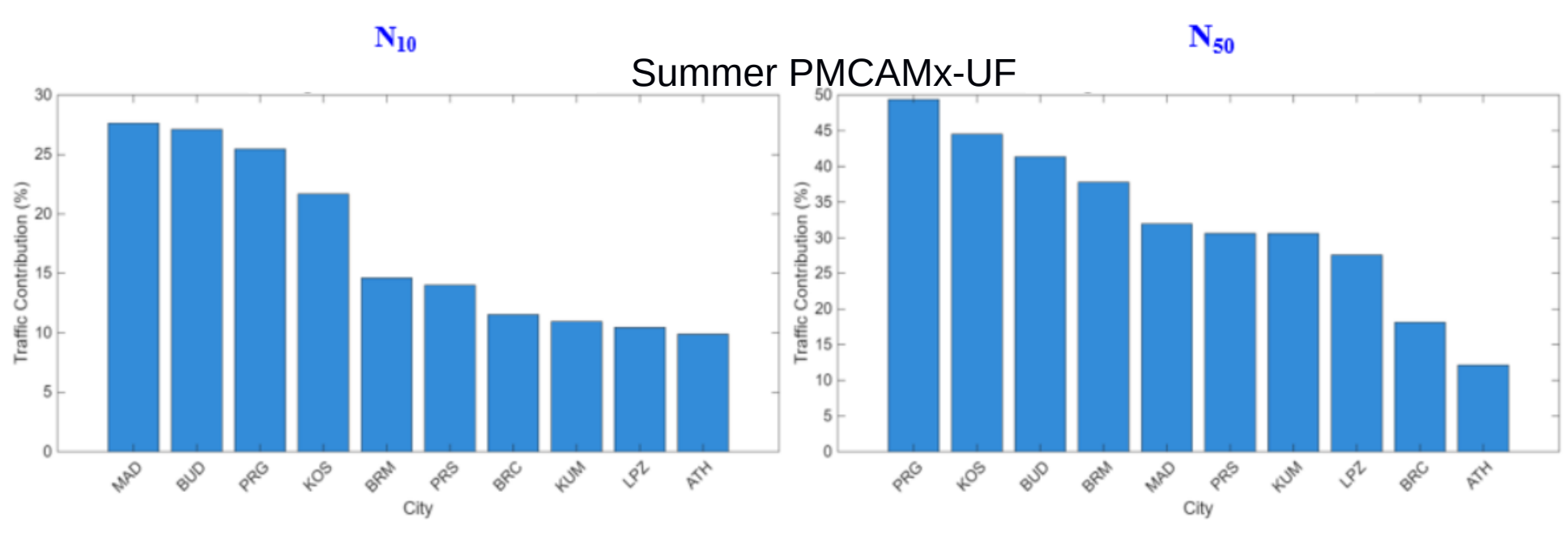


ULTRAFLEB results, 500m

- LOTOS-EUROS
- LASAT (IVU)
- LASPORT (IBJ)

Road contributions ~1000 #/cm^3

Predicted contribution of transportation to N in selected urban areas



PMCAMx-UF simulations for selected cities, 1 km resolution

Impact of road transport emission on N_{50} higher, N_{10} more affected by nucleation

Summary of PN evaluation

- Current estimations: at city scale road contributions up to 50%.
- Model scale is highly relevant, for coarse resolution contrast with background rapidly decreases (500m-1000m)
- PN emissions from road transport have increased w.r.t previous estimations
  - Not simply as a factor to SPN23
  - Emissions under cold conditions may still be underestimated

- Modelling of nucleation remains challenging, strongly affecting N_{10}
  - City scale modelling with measurements as background for local studies
  - Statistical evaluation for large-scale simulations
  - N_{50} more robust than N_{10} (but e.g. aircraft emissions largely around 10 nm)

Conclusions

- Road transport important
  - contributes up to 50% of PM2.5
  - EASVOLEE SVOC and IVOC emissios 8x higher than previously assumed
  - OA small, but contribution to SIA significant
  - contributes up to 50% to urban N10

- PN modelling remains challenging due to uncertainties in nucleation process representation

- Model scale matters (uEMEP, LOTOS-EUROS combined with LASAT/LASPORT) for primary road transport contributions

Thank you for your attention

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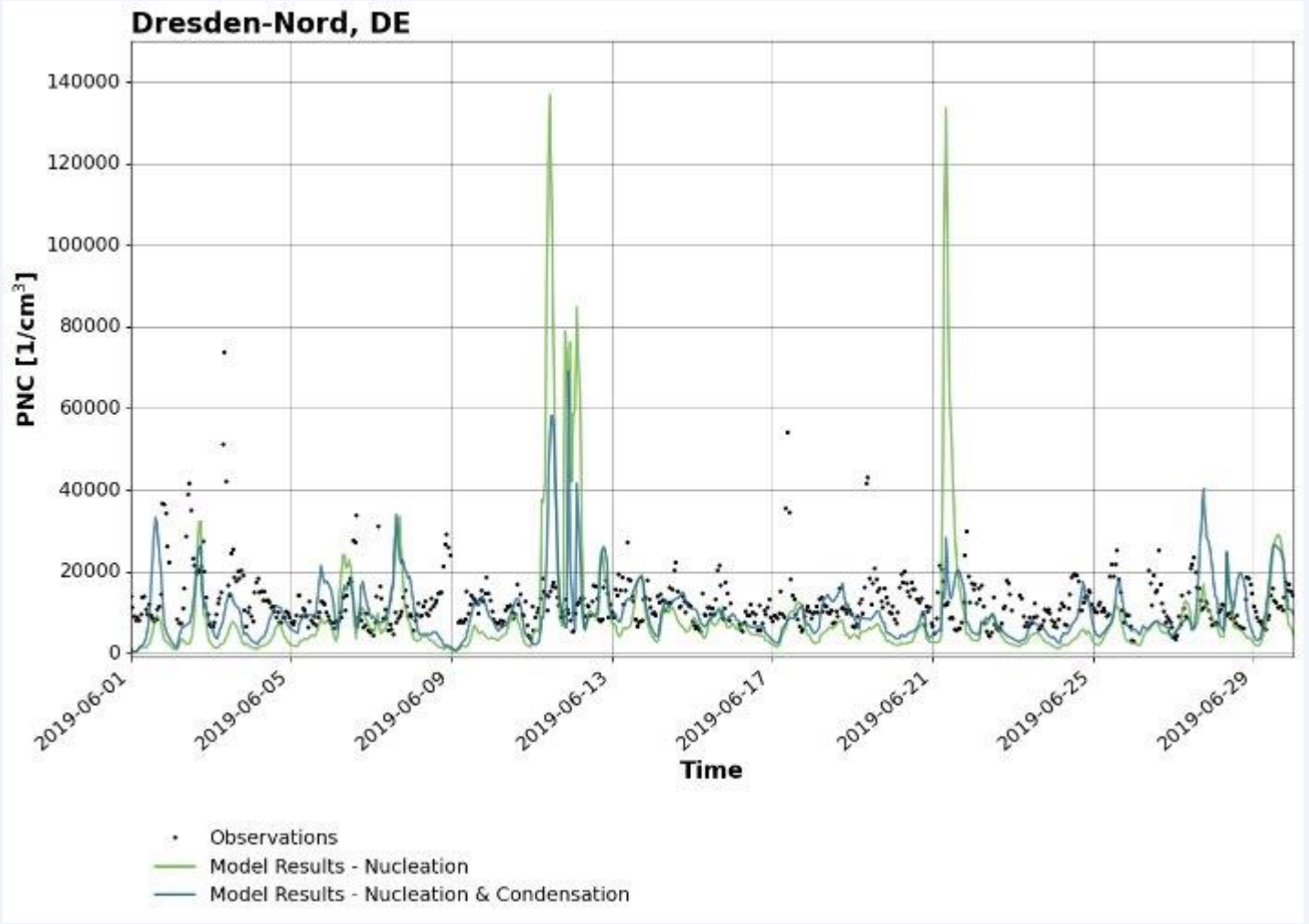
Thanks to EASVOLEE and ULTRAFLEB partners


Dresden-Nord, DE
PNC [1/cm³]
140000
120000
100000
80000
60000
40000
20000
0
2019-06-01
2019-06-05
2019-06-09
2019-06-13
2019-06-17
2019-06-21
2019-06-25
2019-06-29
Time
Observations
Model Results - Nucleation
Model Results - Nucleation & Condensation