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REPRESENTING UFP URBAN BACKGROUND CONCENTRATIONS WITH THE CHEMISTRY-TRANSPORT MODEL LOTOS-EUROS

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BACKGROUND AND AIM

- Ultrafine particles may be important for health but good maps to relate concentrations to exposure and health effects are currently lacking
- Health impacts: UFP and confounders (BC, NOx, PM2.5….)
- Case study: Berlin, impact of airport, UBA ULTRAFLEB project, related to BEAR health study

- Show approach and preliminary results
- Challenges
  - emissions of PN from airport, not just nvPN
  - No PN emission inventory available for target area

MODELING MASS CONCENTRATION AND PNC
2 TRACKS

MASS (BC, NO2, PM2.5…)

- Mass as conserved quantitty
- Source contributions (Labeling)
- Emissions CAMS, GRETA, EKATASTER Berlin, Airport
- Nesting LOTOS-EUROS Europe-Berlin

- Emissions relatively well-known, standard procedure
- Models well validated, per species

PARTICLE NUMBER

- PNC not conserved quantity
- Size distribution indicative of source
- PN-Emissions Berlin for road transport and airport using direct PN emission factors
- PN-Emissionen for ohter sectors: scaling of PM10, (CO2)
- LOTOS-EUROS with SALSA2: Berlin with observed background concentrations Neuglobsow

- Emissions poorly known, only solid particles
- Modelling of background concentratons uncertain, nucleation events
- Validations on PNC and size distributions

EMISSIONS
MAKING GOOD INVENTORY IS A HUGE TASK

Starting point: E-Inventory of senate of Berlin, reporting of Brandenburg (both at high resolution), Airport reporting, UBA-Greta

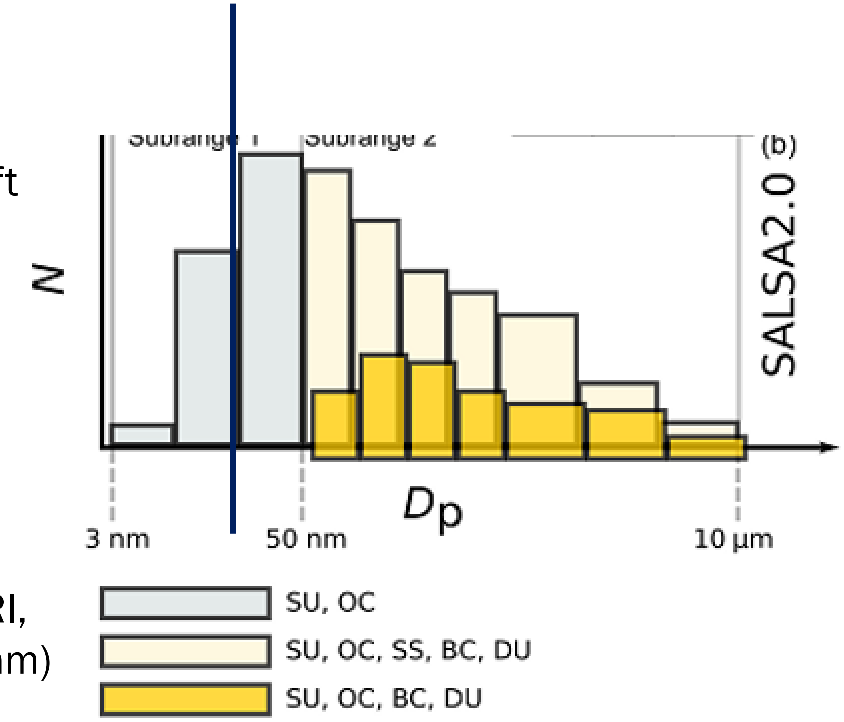
Construct emission inventory for target area based on

- direct PN EF with associated size distribution for traffic
- estimates on fuel consumption from CO2 or PM10 and associated EF for shipping, wood combustion, mobile machinery
- PM mass for other sectors fractions of mass PM0.3/PM1 and PM1/PM10 can be used (Paasonen et al., 2013, TRANSPHORM, EUCAARI)

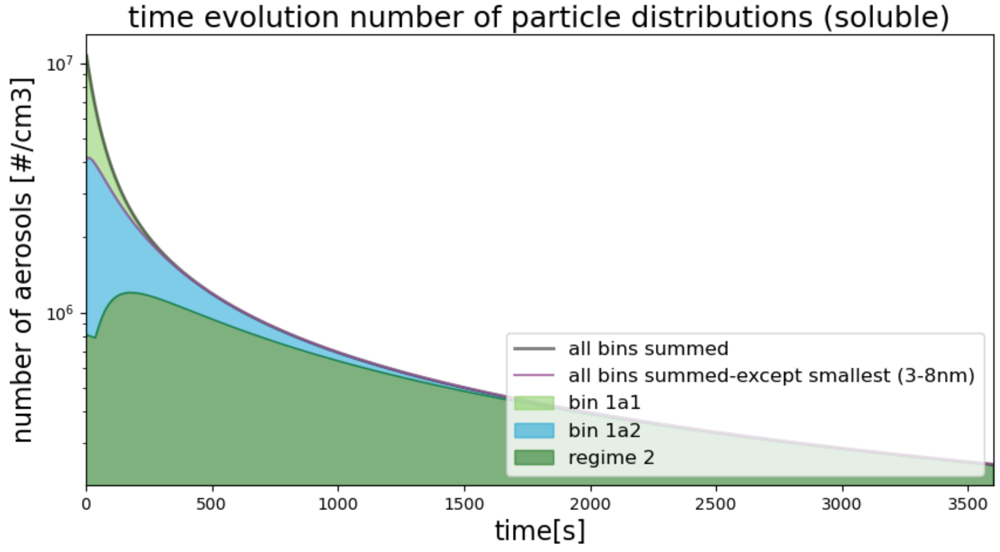
- For aircraft emissoins, only nvPN is reported
  - This is only ~1.4 % of total PN emissions (Zhang et al 2020, Zürich)
  - SO4 and OC traditionally seen as nucleating species, but smallest particles dominated by OC whereas SO4 condenses more easily on soot mode. (Wong et al., 2014, Peck et al., 2014, Kilic et al., 2018 , Yu et al., 2019)
  - Rapid nucleation, condensation, coagulation processes at high concentrations close to the source, how to deal with these emissions in air quality models of resolution s 50m-500m-5 km?

BOX EXPERIMENTS
INVESTIGATE TIME SCALES AND PARTICLE SIZE EVOLUTION

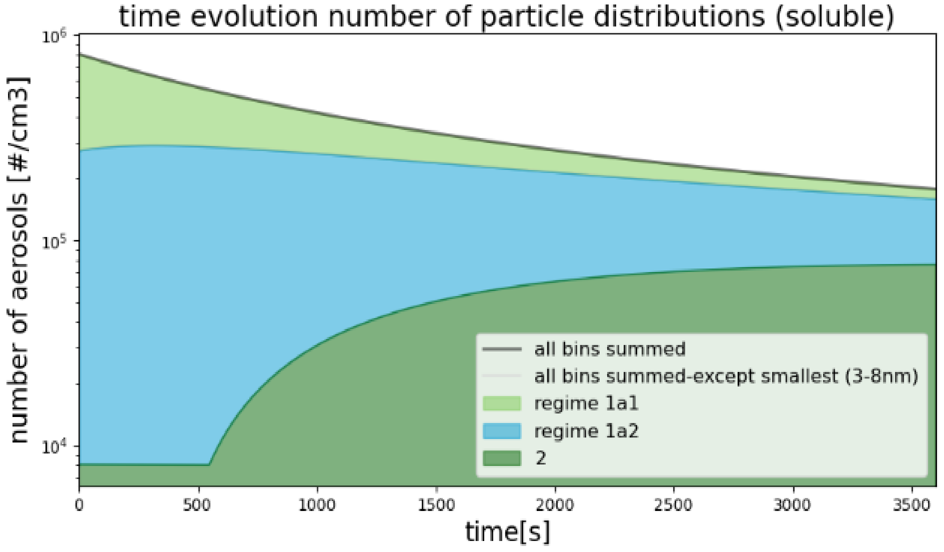
- SALSA2 box model (Kokkola et al., 2018)
- 10 size bins
- Moved subrange one size bin down to account for soot mode traffic and aircraft
- Representative concentrations:
  - Aircraft (1.08e7 #/cm^3 , 8e5 as soot particles in bin3, rest in bin 1,2)
  - Airport (8.08e5 #/cm^3 , 8e3 as soot particles in bin3, rest in bin 1,2)
  - Ambient: 5000 #/cm^3 , annual mean observed concentrations from city Cottbus, size as in LOTOS-EUROS Dg=370nm, sigma=1.5)
  - Ambient: mean number and size distribution as observed in Melpitz (EUCAARI, mode 1 3500 #/cm^3, Dg=58nm, sigma=2.5, mode 2 340 #/cm^3 , Dg=200 nm)
  - Close to road (15000 #/cm^3 , taken from measurements in Germany, sizes following emission size distributions, single mode, 20nm, sigma=2)
  - Close to road (15000 #/cm^3, equally divided over double mode, Dg=20nm, sigma=1.2, Dg= 65 nm, sigma=1.75
  - Several temperature and relative humidities. (5, 25 °C, 40%, 80% RH)



RESULTS



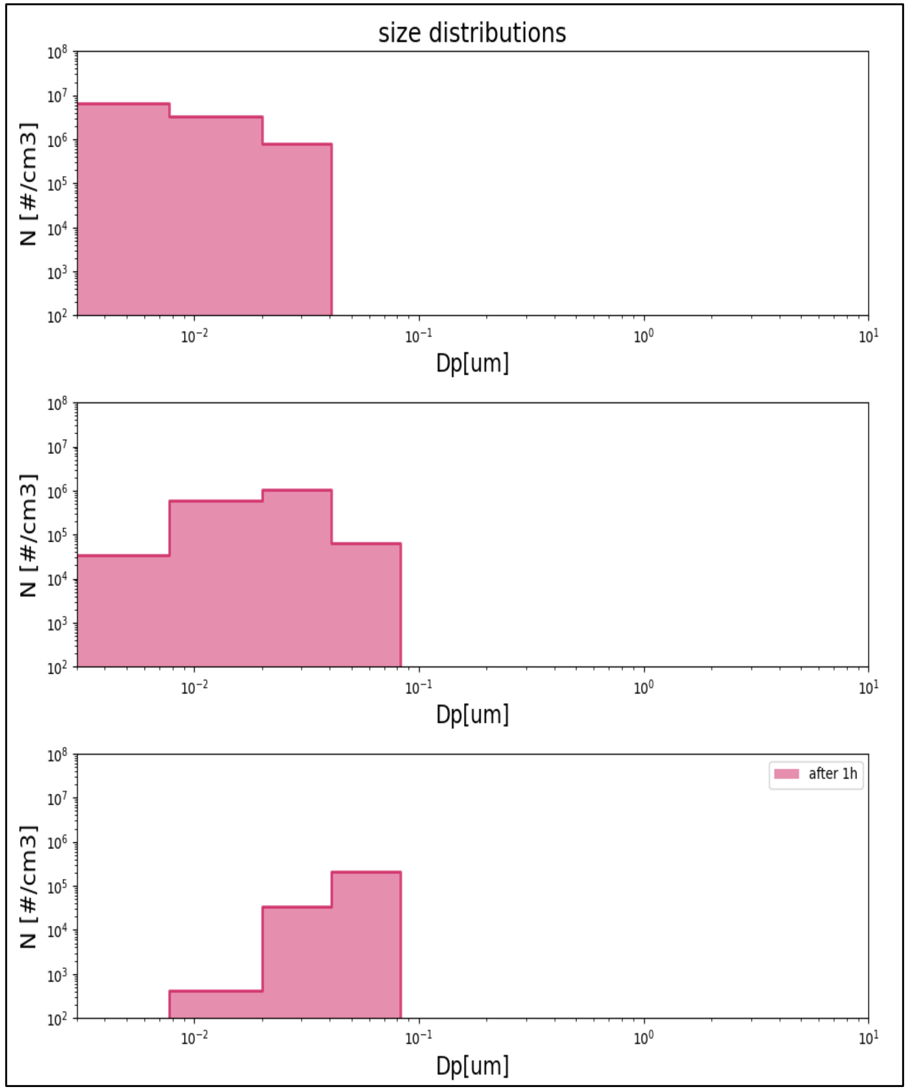
Aircraft



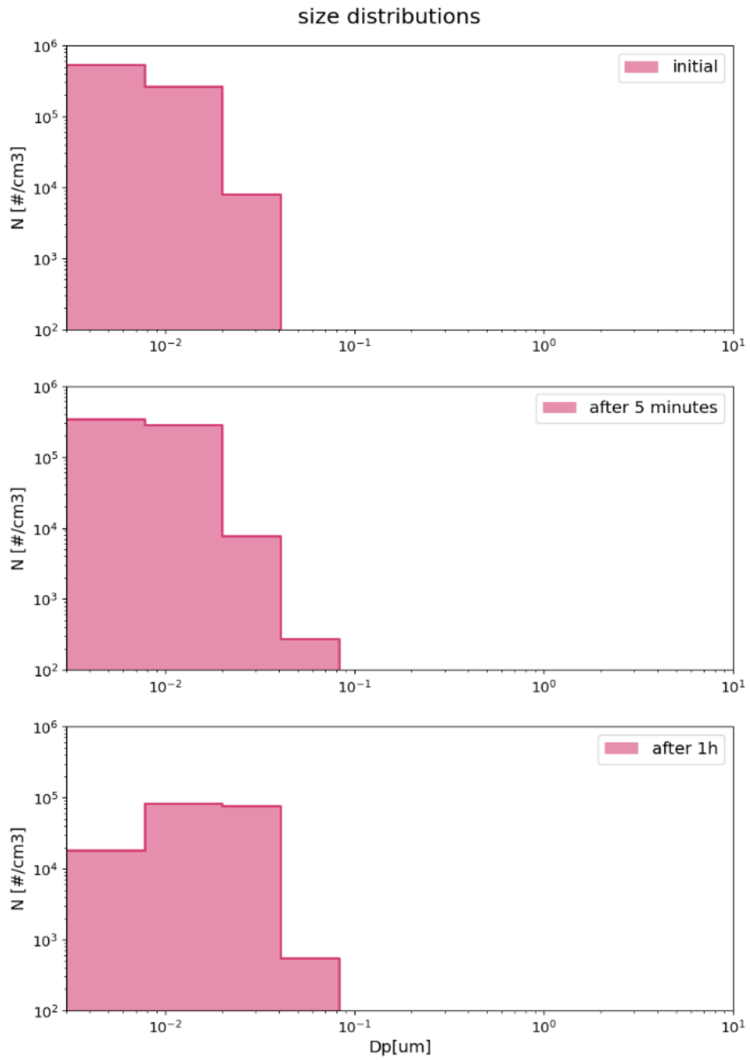
Airport

Coagulation leads to decrease of number of smallest size particles, increase in larger size particles
Much faster for high concentrations, where even decrease in regime 2 is found (>20nm)
After 1 hour, level of PN concentrations not so different from airport concentrations

PURE AIRCRAFT EMISSIONS



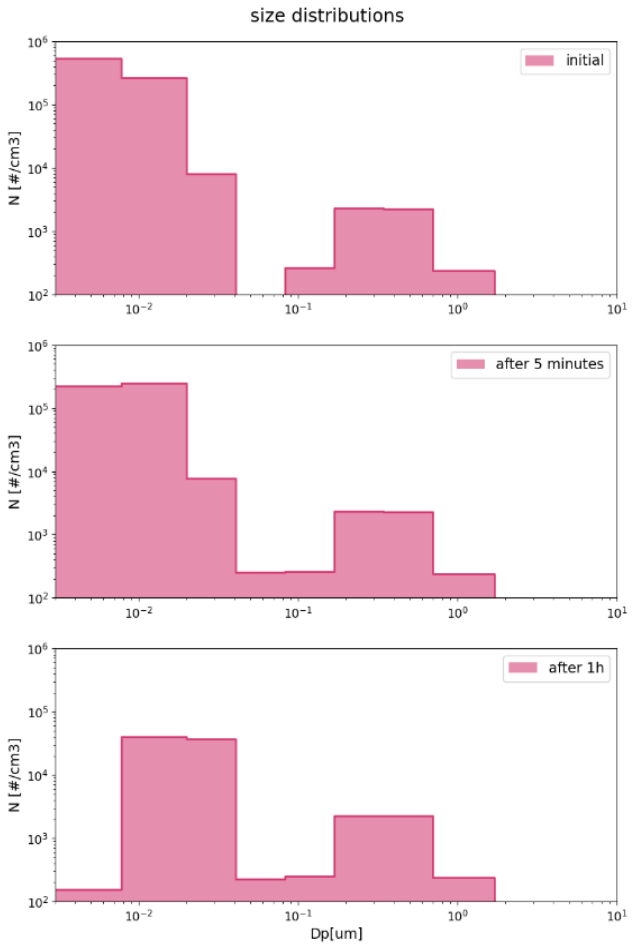
Aircraft



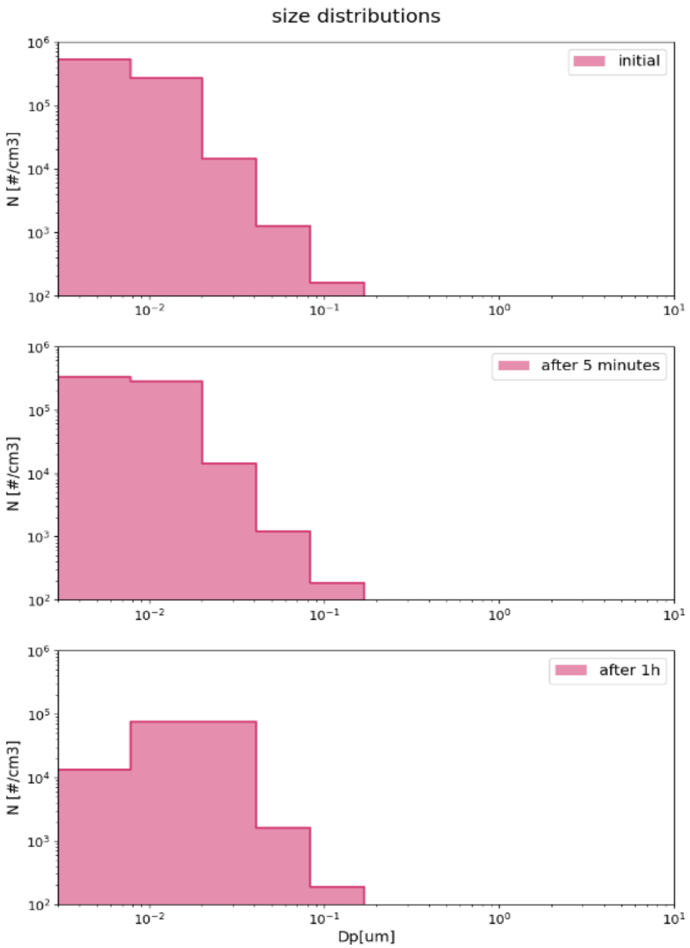
Airport

Size distribution is different however, with first bin empty and growth towards particles > 100nm

Note difference in vertical axis



Airport+ambient



Airport+road

Ambient particles strong coagulation sink

Interaction with road emissions less efficient.

RESULTS

- Rapid processes close to source lead within 1 hour to similar total PN concentrations as background. However, differences in size distribution exist
- Coagulation with large ambient particles very effective sink for the smallest particles, but upper estimate
- Looking at coagulation rates, concentrations in bin 1 must be ~500 x higher than ambient mode particles in order to be more efficient
- No condensation and nucleation taken into account, assume that this is taken into account directly by defining volatile particles in size bins

LOTOS-EUROS

- Eulerian chemistry transport model, part of CAMS ensemble, used for policy support
- Full implementation of SALSA (in testing phase). Numerically expensive due to large number of tracers
- Simple coagulation model: all particles coagulate with coagulation rate based on size bin containing most ambient mode particles. Cheap, sensitivity experiments
- Use of UFP emission inventory constructed for Berlin
- Airport as point source with constant time profile: close to source higher concentrations than in reality.
- Resolution ~500x500 m^2, use of ICON meteorology and vertical layering

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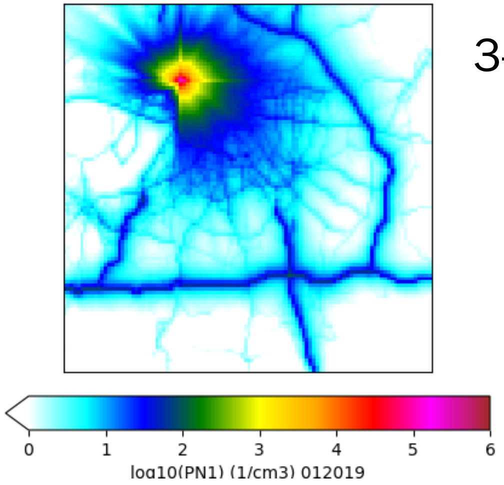
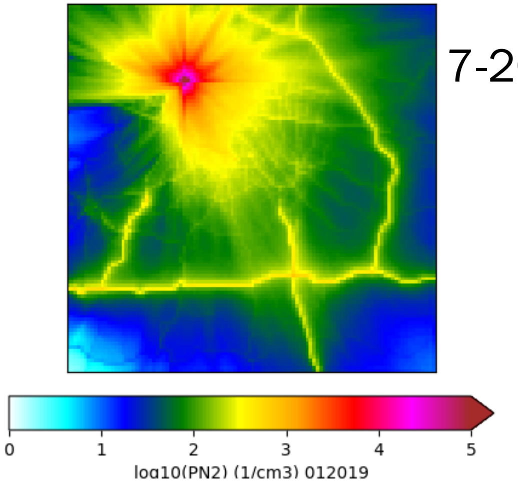
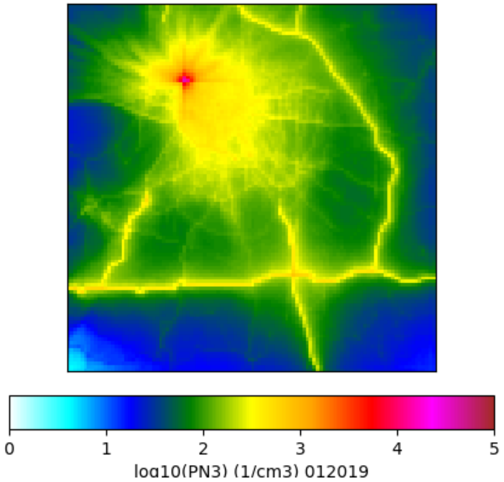
LOTOS-EUROS
MEAN CONCENTRATIONS JAN 2019



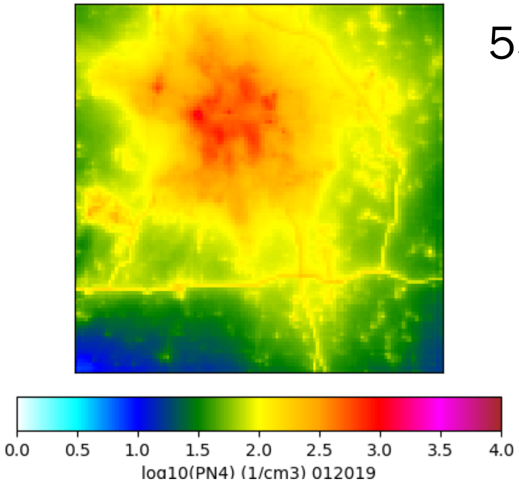
3-7nm



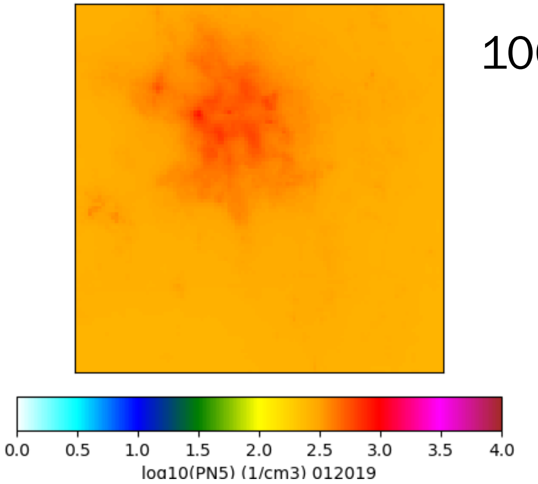
7-20nm



20-50 nm



55-100 nm



100-190 nm

Smallest size range: highways and airport

Order of magnitude realistic

UFP emission airport may be overestimated

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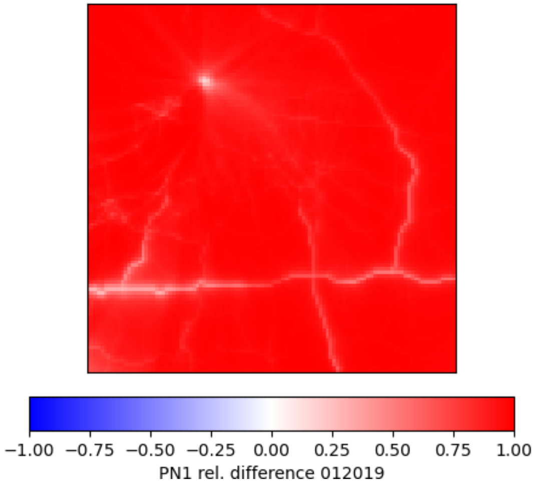
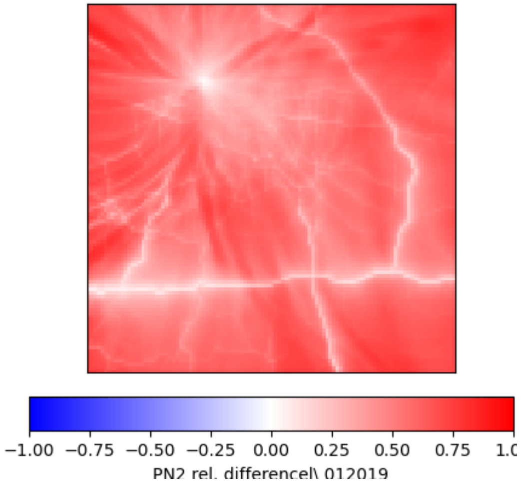
LOTOS-EUROS

MEAN CONCENTRATIONS JAN 2019, IMPACT COAGULATION

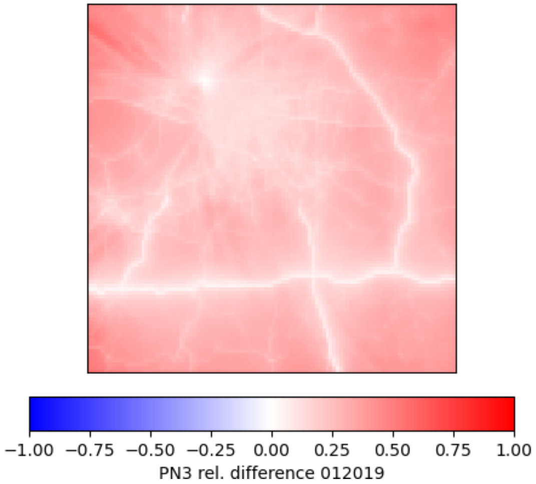
3-7nm



7-20nm



20-50 nm



- Relative differences with simulation without coagulation
- Impact of coagulation outside the source area is considerable

CONCLUSIONS AND OUTLOOK

- Current results are just ballpark estimates and sanity checks, but are useful to investigate relevance of processes, open possibilities to parameterize e.g. losses for passive tracer models like plume models
- Useful approach for city level assessments, not yet for larger domains. But cities are emission and exposure hotspots
- Improved emission distribution for Berlin airport & boundary conditions from observations
- Evaluation with measurement campaign data, adapt emission parameterizations?
- Generalize to larger domains, include particle formation processes and Europe-wide emission inventory from RI-Urbans -> longer stretch

THANK YOU FOR YOUR TIME

ALSO THANKS TO ULTRAFLEB PROJECT

IVU Umwelt GmbH
Umweltplanung - Informationssysteme

Janicke Consulting
Environmental Physics

TROPOS

Umwelt Bundesamt

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TNO NOVEL POINT OF VIEW
OXIDATIVE POTENTIAL AND PARTICLE NUMBER CONCENTRATIONS

- https://www.tno.nl/particulate-matter