

# Ultrafine particles from power plants: Evaluation of WRF-Chem simulations with airborne measurements

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# Ultrafine particles (UFP)

- Particles with a diameter  $< 100$  nm
- Highly variable in space and time
- Risk to human health
- May affect the number concentration of CCN
- No regulations for UFPs
- Not well described in common air quality models
- Ground based measurements : 13 UBA stations and GUAN network since 2008 (Birmili et al., 2009, 2015)
- Limited knowledge about vertical distribution

# Aerial survey of UFPs over Germany



Measurements  
from ultralight  
aircraft in 2012,  
2013, and 2014

4.5 nm – 350 nm: Scanning mobility particle spectrometer

300 nm – 20  $\mu\text{m}$ : Optical particle spectrometer

Total number > 4.5 nm: Condensation particle counter

**Junkermann et al., 2016, Ultrafine particles over Germany –  
an aerial survey (Tellus B 2016, 68, 29250)**

# UFP plumes from power plants

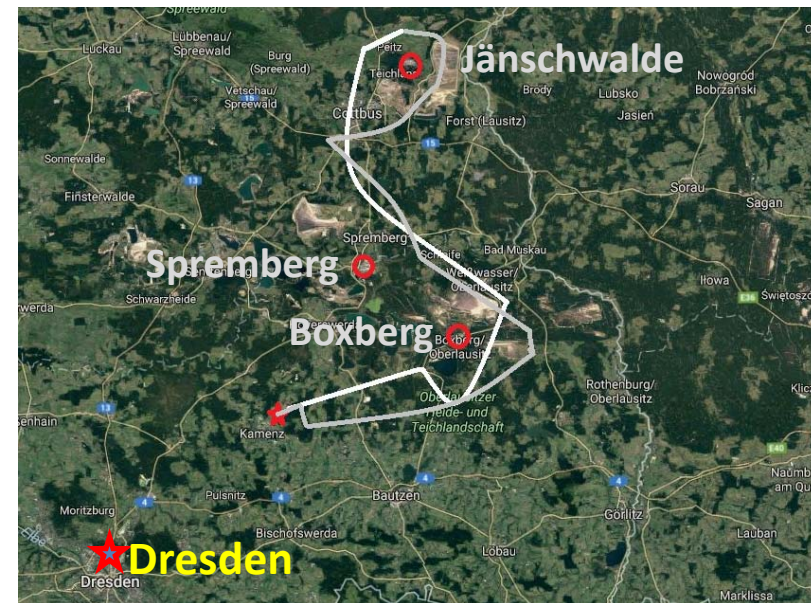
## Observations

Hot spot in the Lausitz area close to the Czech and Polish border

- ‘Clean’ coal fired power stations with flue cleaning technology and refineries have been identified as a major source of 1 – 10 nm UFP in the atmospheric boundary layer.
- Power plant plumes with particle numbers up to 90000 cm<sup>-3</sup>
- Geometric mean diameter (GMD) as low as 10 – 20 nm within the plumes
- No enhanced UFP concentrations downwind of ,dirty‘ power plants

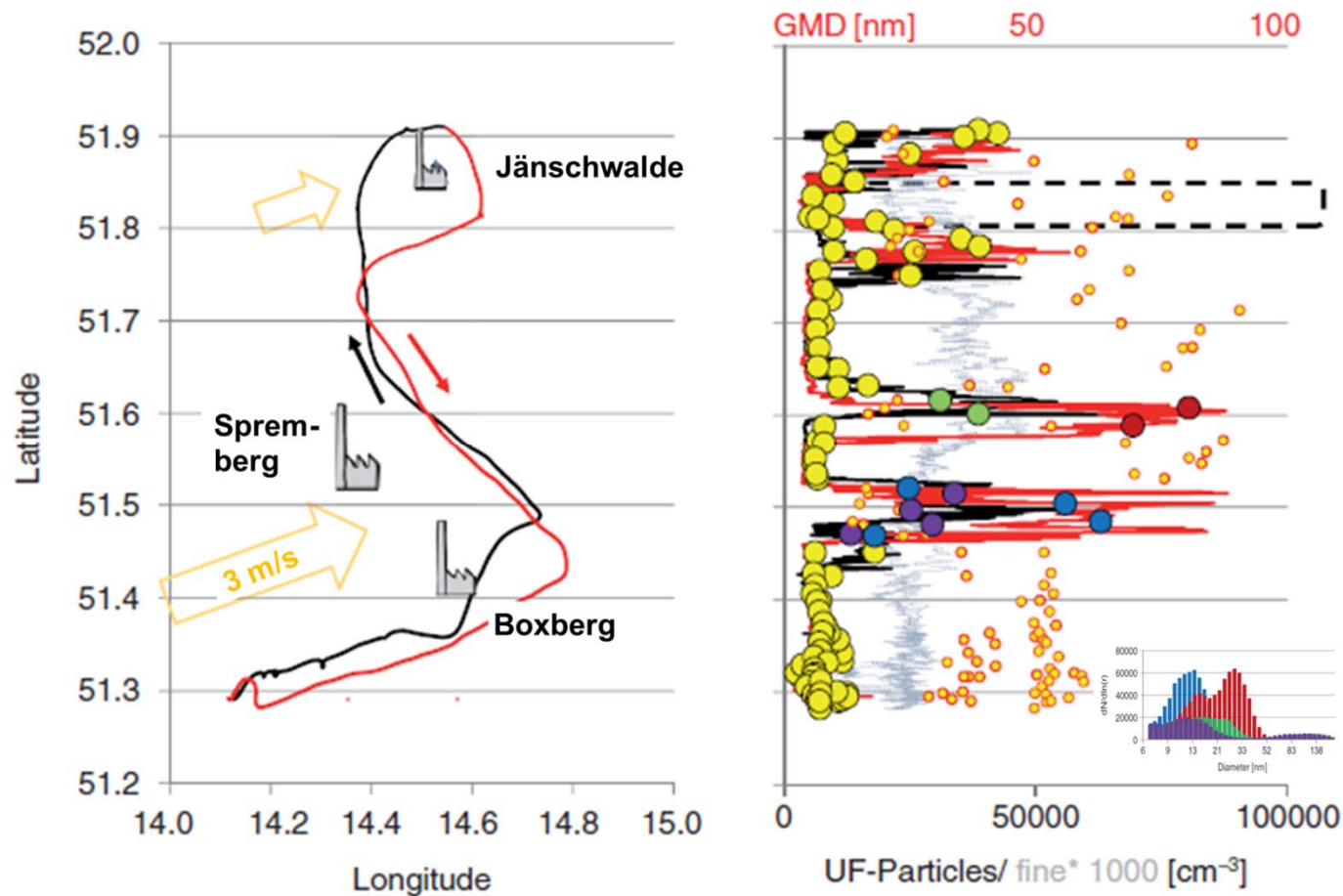
# WRF-Chem simulations

- 3 nested domains with 18 km, 6 km, and 2 km
- Starting with public version of WRF-CHEM with RADM2 and MADE/SORGAM modal aerosol module
- TNO/MACC II emission inventory for 2009: ca. 7 km grid width for area sources and explicit point sources
- Simulation of measurements from flight on 8th June 2014 (ca. 8 – 10 UTC)



# Observed UFP plumes from power plants

KIT  
Karlsruhe Institute of Technology



Flight path along the German-Polish border at June 8 2014

UFP concentrations (black and red lines) and GMD (geometric mean diameter; small red/yellow points).

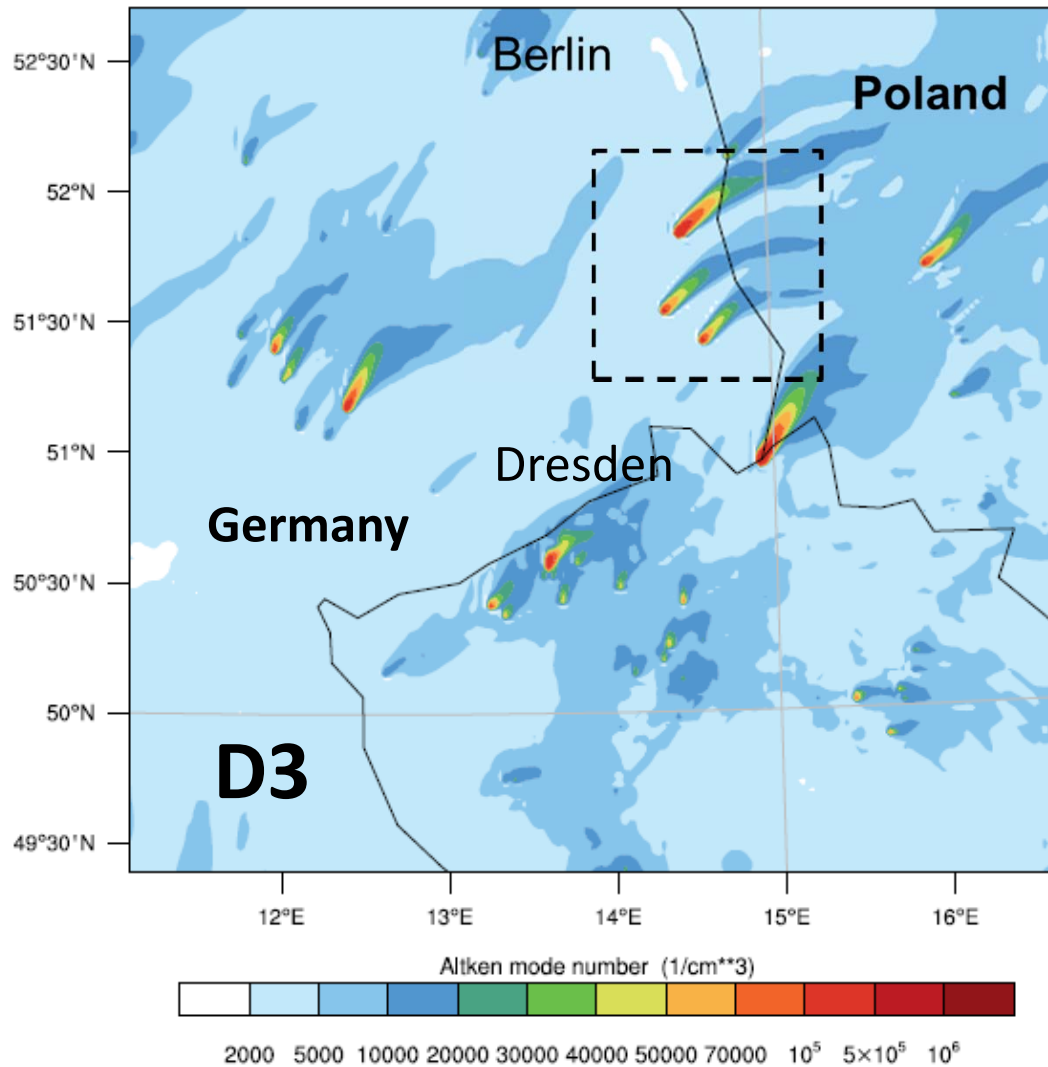
# WRF-Chem simulations

## Can WRF-Chem reproduce these observations?

Public release is not optimized for description of UFPs

- **MADE/SORGAM:** For emissions of Aitken mode particles a GMD of 30 nm is assumed for mass to number conversion
  - **However:** UFP with GMD < 30 nm is possible as nucleation may lead to small particles with radii below 10nm
- **MOSAIC:** Minimum radius for 8 bin version is 40 nm
  - **However:** A special version with 20 bins and a minimum radius of 1 nm exists

# WRF-Chem simulations



## Original WRF-Chem

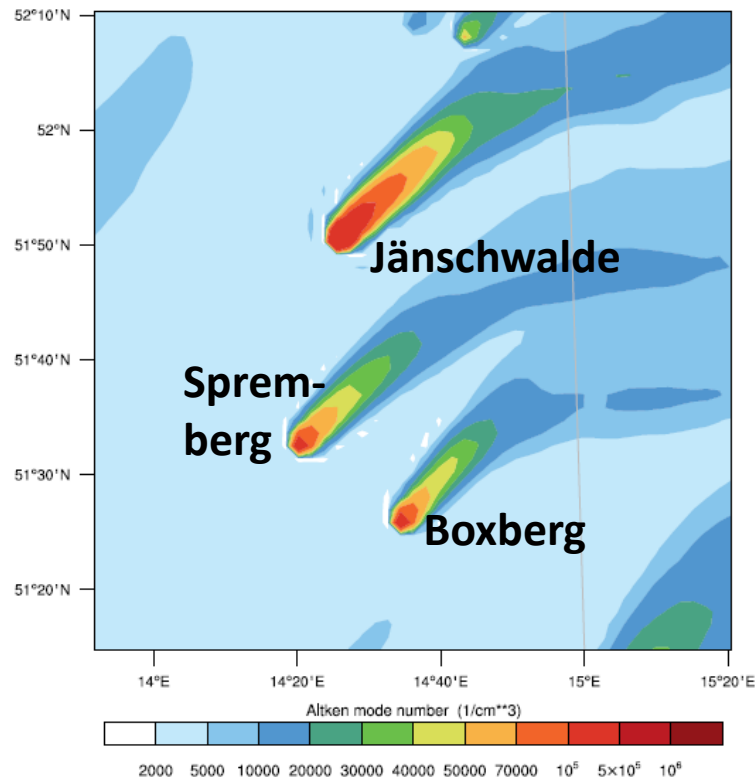
Aitken mode particle number concentration  
500 m above ground  
at 9:00 UTC

The dashed square  
(100km x 100km / 50 x  
50 grid points) shows  
the area of interest.

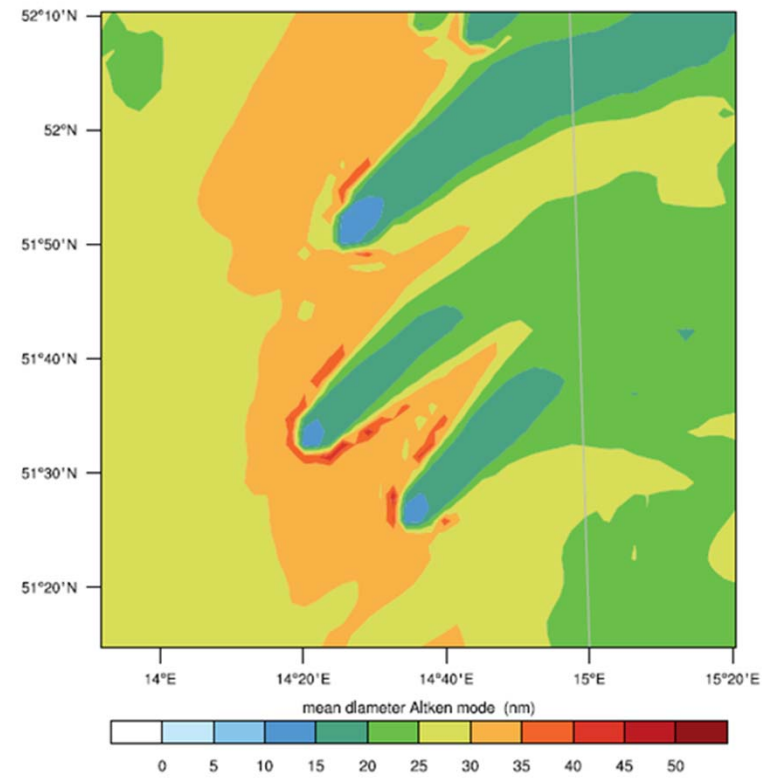


# WRF-Chem simulations

## Original WRF-Chem



► UFP numbers too low



► GMD in plumes too high

# Modification of Aitken mode emissions



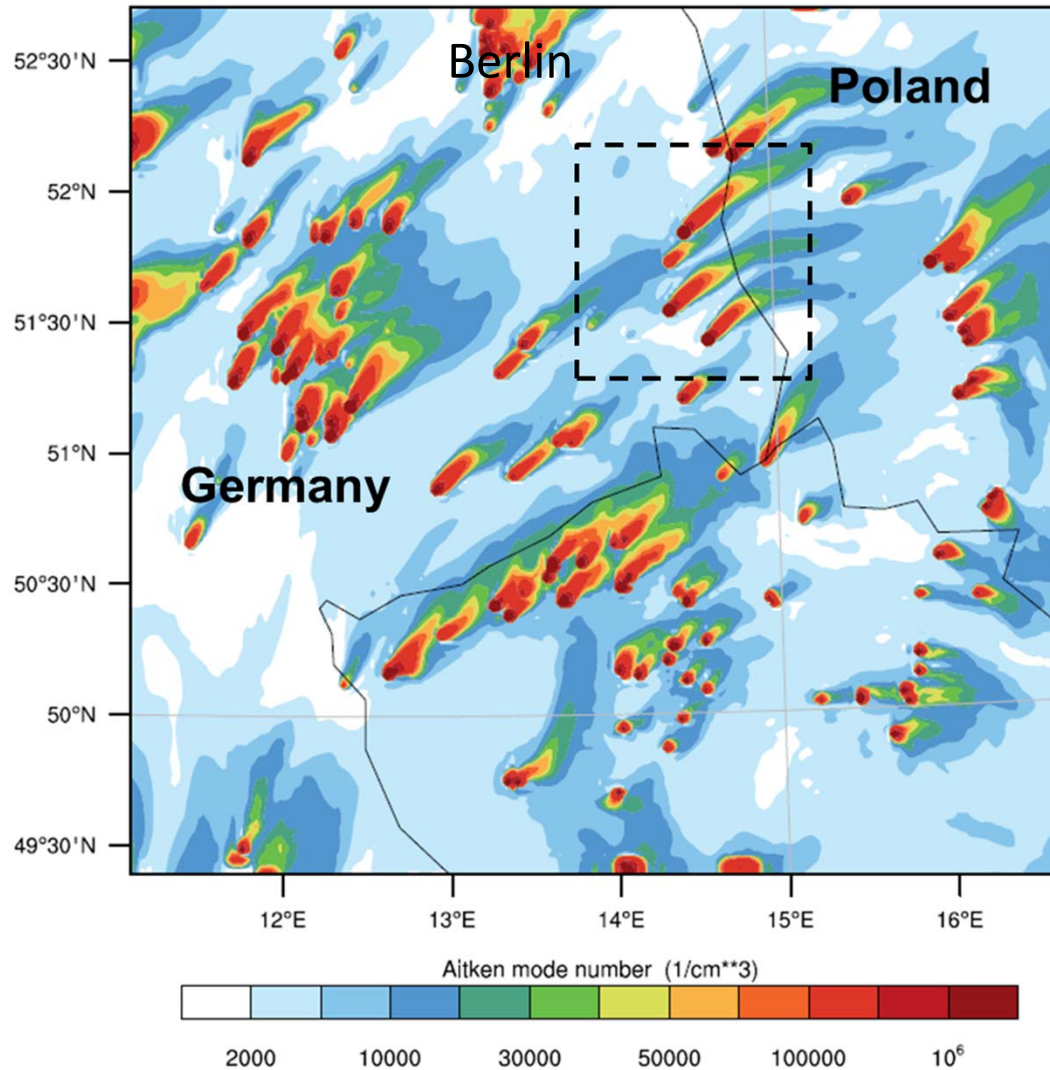
## Original code:

- Conversion of emitted mass to particle number for Aitken mode is based on **GMD = 30 nm**

## Modification:

- Changed mass to particle number conversion for Aitken mode to **GMD = 3 nm**
- Modification only applied to energy sector point sources (except Turow power plant [no flue cleaning])

# WRF-Chem simulations



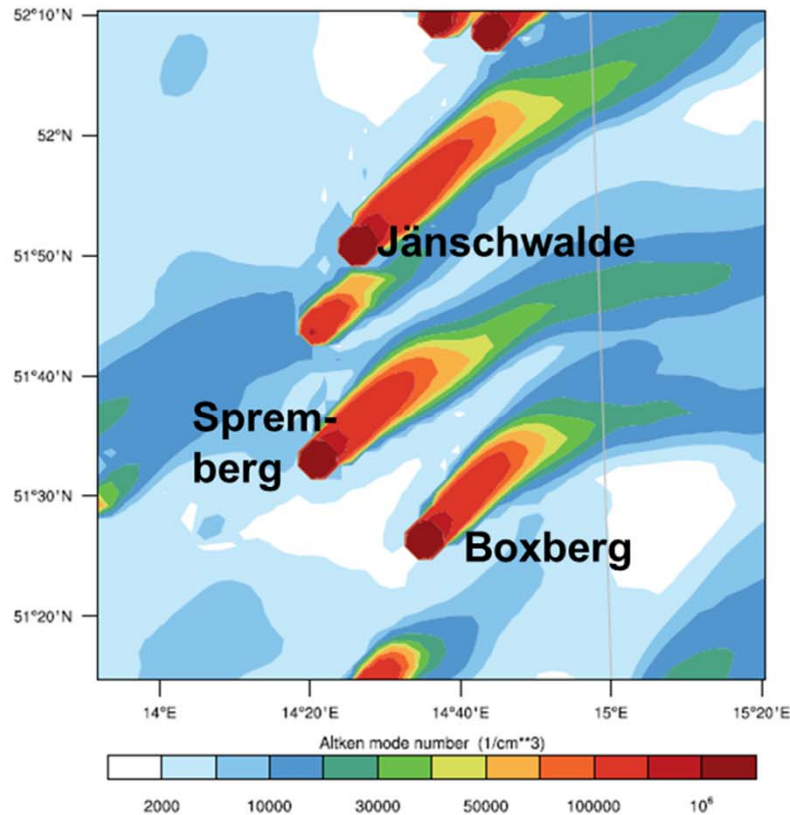
## WRF-Chem with modified conversion factor

Aitken mode particle number concentration 500 m above ground at 9:00 UTC

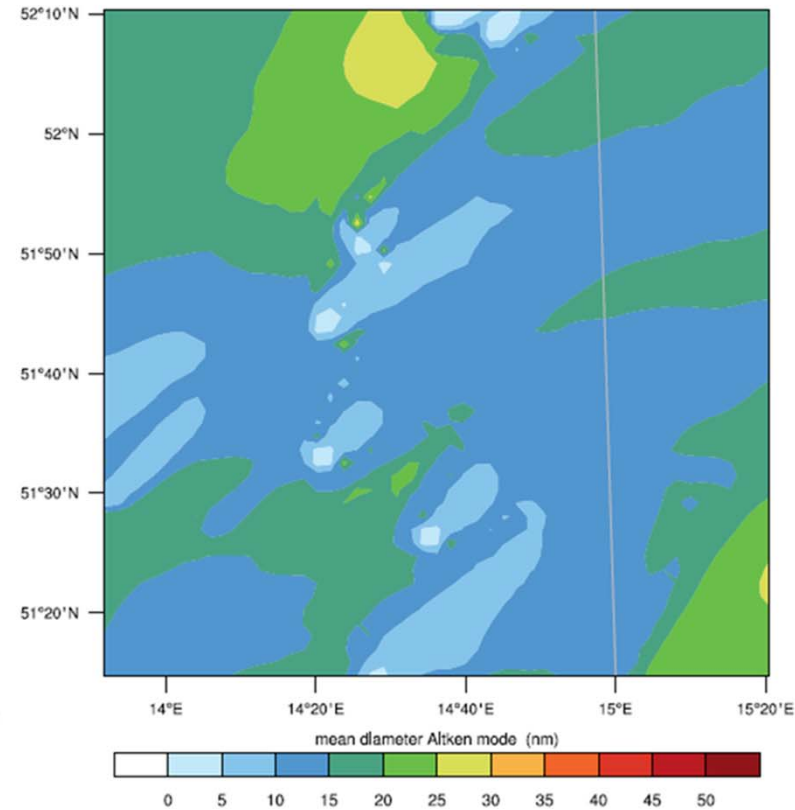
The dashed square (100km x 100km / 50 x 50 grid points) shows the area of interest.

# WRF-Chem simulations

## WRF-Chem with modified mass to number conversion

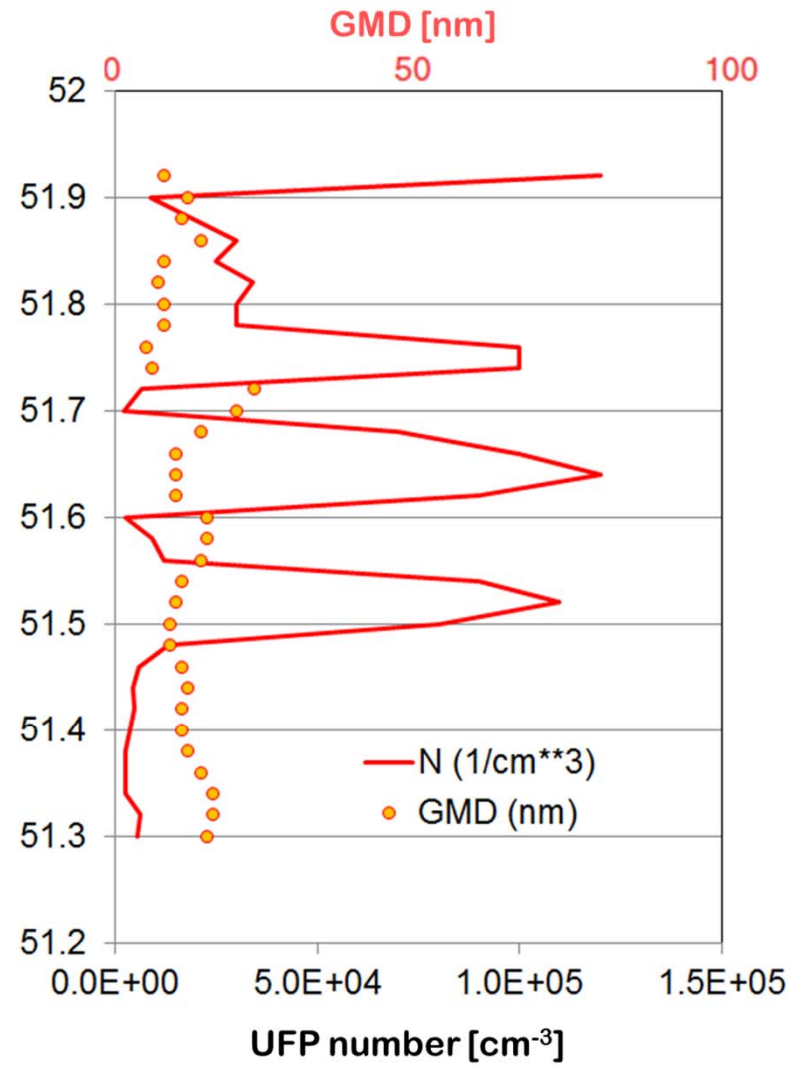
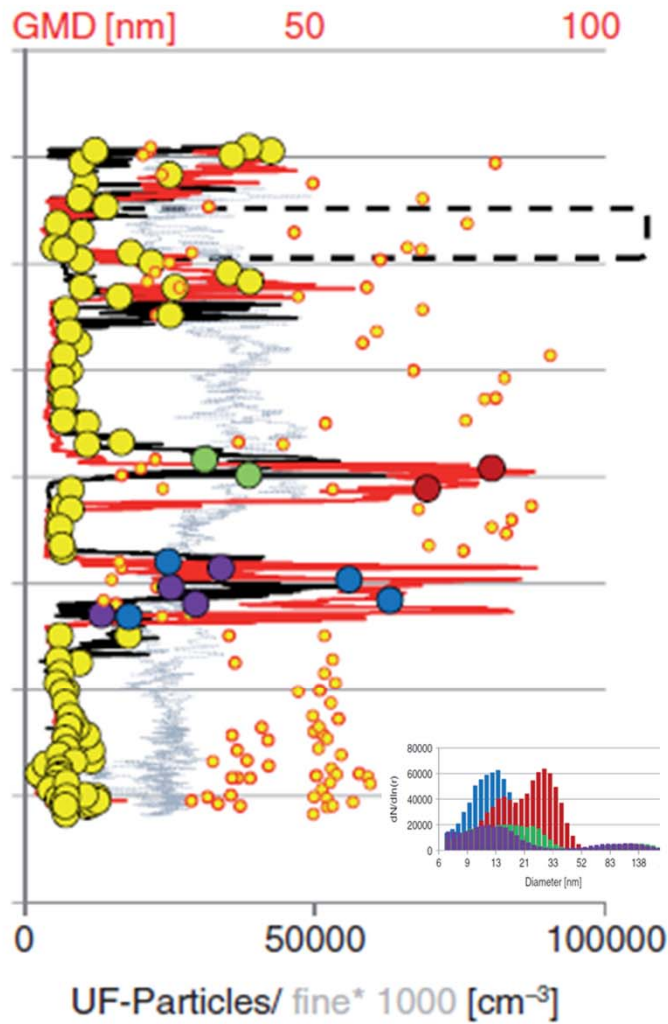


► UFP numbers too high



► GMD outside plumes too low

# WRF-Chem simulations

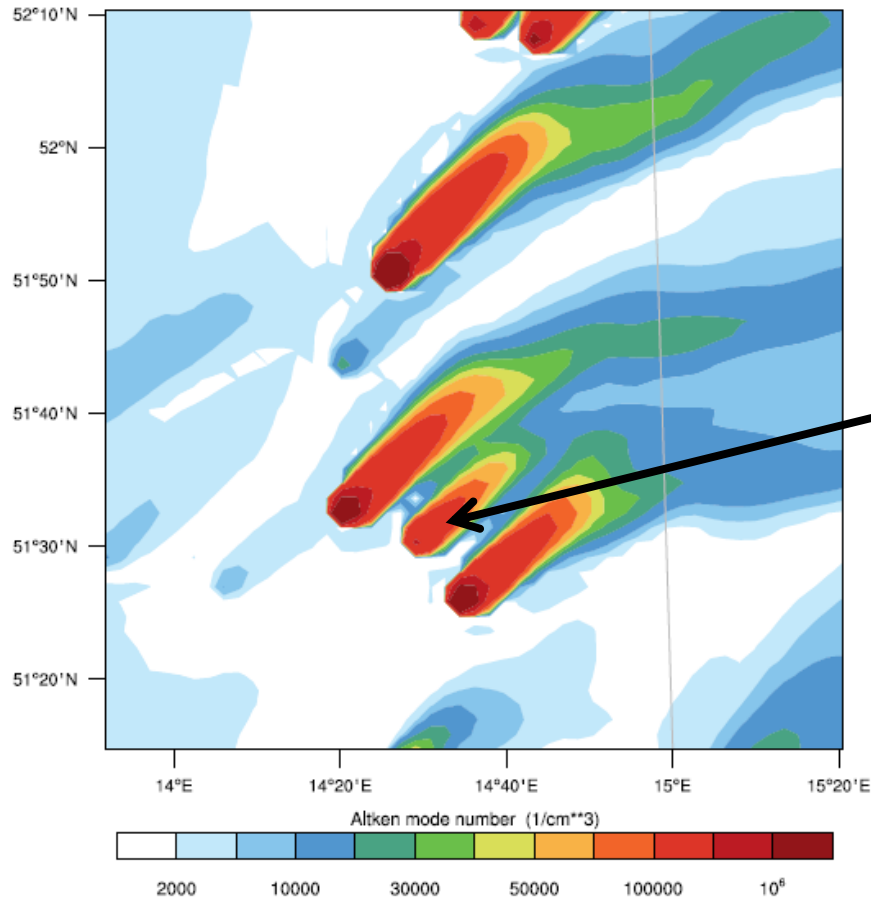


# Conclusions & Outlook

- Quick & dirty adaptation of MADE/SORGAM to UFP emissions partly successful
- Effect too strong, probably over-done modification
  - Applied to too many sources?
  - Too small initial GMD?
  
- ⇒ Try more recent emission inventory (TNO/MACC III)
- ⇒ Try a somewhat larger GMD for power plant emissions

# Conclusions & Outlook

## New emission inventory = new luck ?



MACC III emissions  
for 2011

?

Not observed!

# Conclusions & Outlook

- Check emissions
- Further tests with MADE/SORGAM
- If feasible, try to obtain WRF-Chem MOSAIC with representation of radii smaller than 40 nm  
(After all, it's just a hobby)

