How do we estimate the climate impact on the Arctic due to long range transported aerosol particles from shipping emissions?

Adam Kristensson

Goals

I want to show one way to improve the modeling of atmospheric aerosol particles in the Arctic, especially for future scenarios with more intense ship traffic in the Arctic:

1. Develop a solid emission database for various ship emitted particle types.
2. Improve our understanding of how these ship emitted particles evolve (transform) during long range transport using aerosol dynamics modeling in case studies with measurement data at field sites.
3. Emission data and aerosol dynamics modeling can be used to improve the performance of large-scale models predicting the concentration in the entire Arctic due to ship-emitted particles.

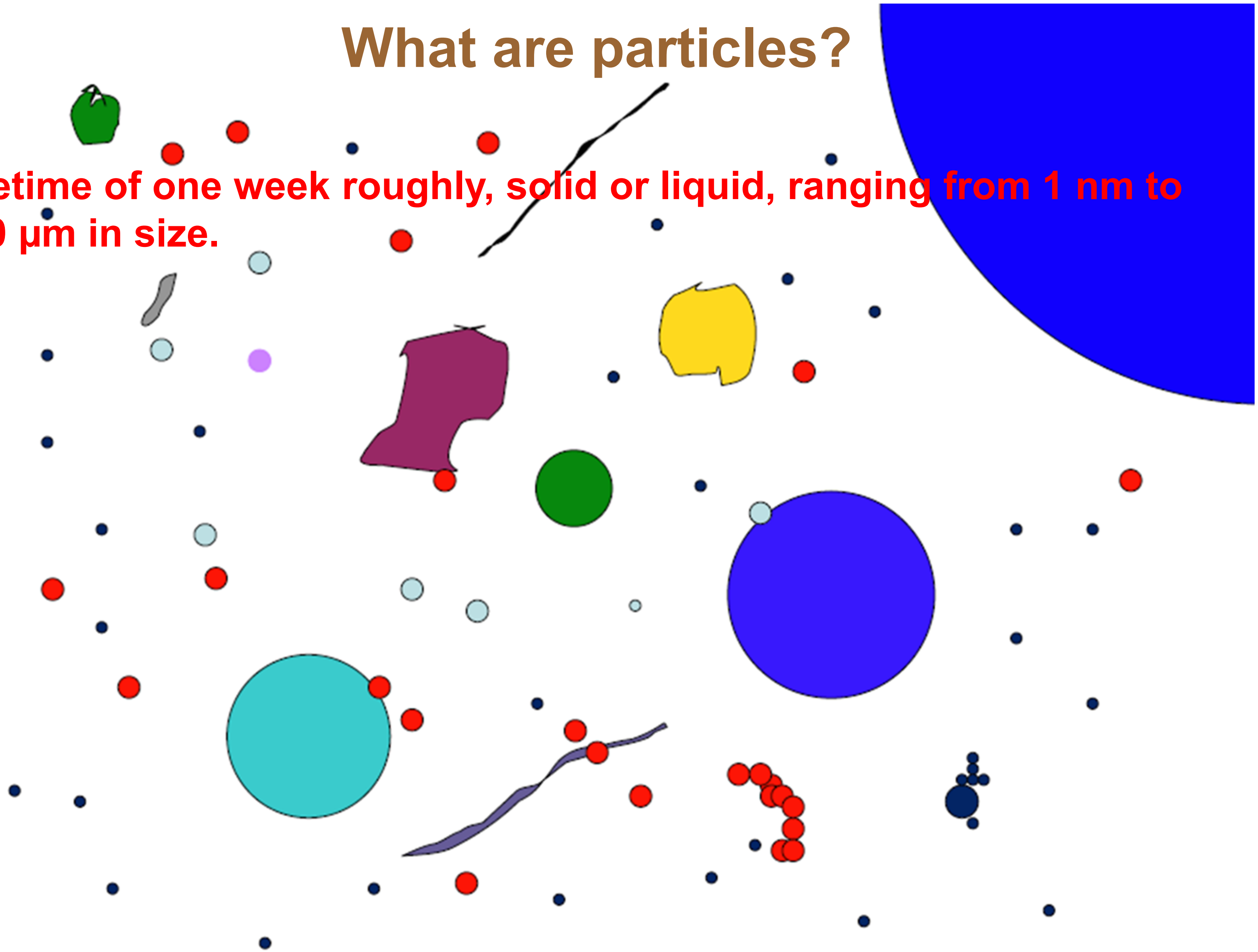
A discussion is appreciated on other ways of accomplishing this.

Contents

- What are atmospheric aerosol particles?
- How particles affect climate
- Large-scale modeling and we’re done?
- How to calculate particle concentrations from shipping
- Ship emissions
- Aerosol dynamics box modelling along trajectories
- Measurement stations
- Flexpart modelling
- Source/receptor modelling
- Large-scale modelling and validation

What are particles?

Lifetime of one week roughly, solid or liquid, ranging from 1 nm to 100 µm in size.



How particles affect climate

- **Direct Aerosol Effect:** aerosol particles scatter (e.g. sulfate particles) and absorb (e.g. black carbon particles) the incoming solar radiation and can thus contribute to global warming or cooling
- **Indirect Aerosol Effect:** aerosol particles serve as cloud condensation nuclei and ice nuclei for the formation of clouds and fog which reflect solar radiation and thus contribute to global cooling. In the Arctic, also absorption of outgoing long wave radiation by clouds and re-emission to the ground contributes to warming.
- **Semi-direct aerosol effect:** Black Carbon (BC) can be deposited on snow and ice-covered surfaces and thus change the surface albedo leading to warming of the surface area followed by enhanced melting

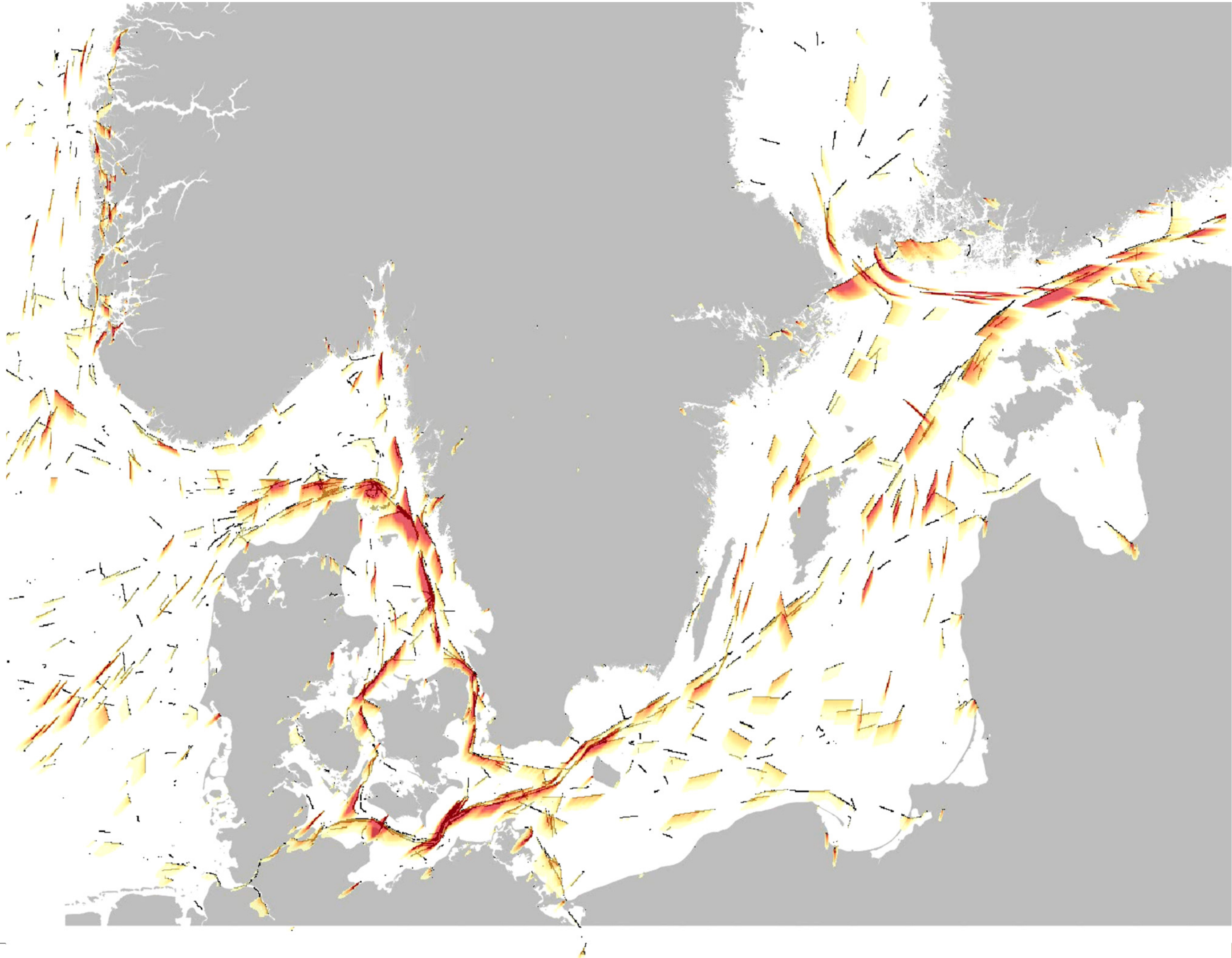
Increased human emissions lead to either increased warming or cooling.

How particles affect climate

- **All these 3 effects Depend on the size-dependent chemistry and particle number concentration of aerosol particles**

We have large-scale models that can predict the chemistry of ship emitted particles in the entire Arctic.

We even have models that can estimate the size dependent chemistry and number concentrations, which as far as I know haven't yet been simulated for the Arctic. But, these are available to Europe for example.



Large scale modelling and we're done?

So, we just run the models, we collect the results, and we're finished?

Large scale modelling and we're done?

No!

- Sometimes the yearly average concentration calculated by models is not correct compared to measurements.

- Even, if it is, the models don't predict the right concentration elsewhere.

- It doesn't agree during different seasons.

- Emissions are wrong, for example from ship emissions.

- Particles change (transformed) during long range transport due to aerosol dynamic processes in a complicated way.

- Particles complicated – detailed chemistry can be wrong

We need something to improve our modeling certainty

How to calculate particle concentrations from shipping?

aerosol dynamics transformation

Ship emission factor → follow the air (trajectory) → concentration at field station (validation)

improved process understanding
validation of large-scale model

Emission database → large scale modelling (incl. aerosol dynamics and meteorology) → concentrations (validation)

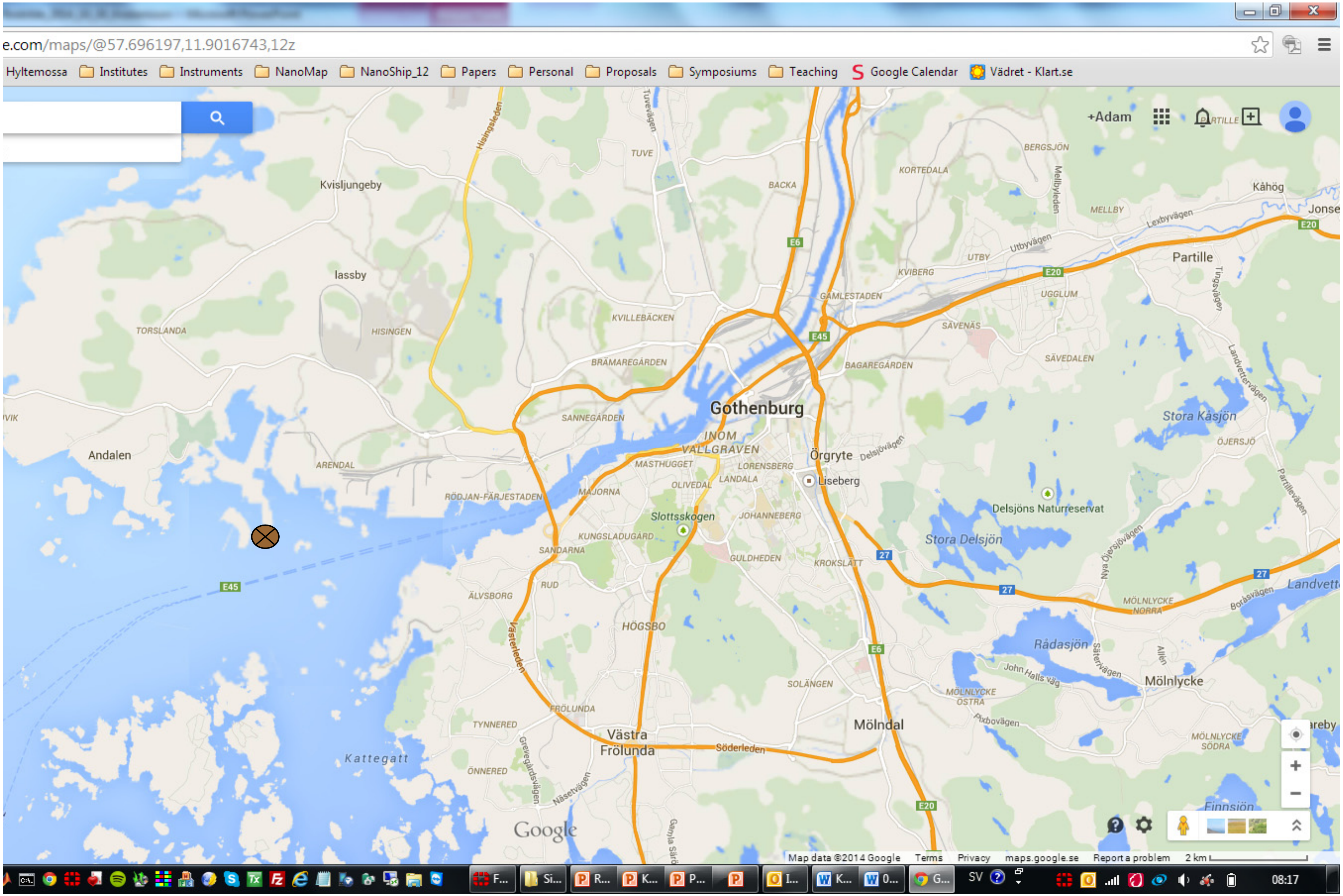
Ship emissions

Local ship emission factors – particles emitted per kg fuel used

At sea-shore, on-board ships, aircraft measurements.

Can separate different ship types, engine types, fuels, engine load.

Time to start to collect this information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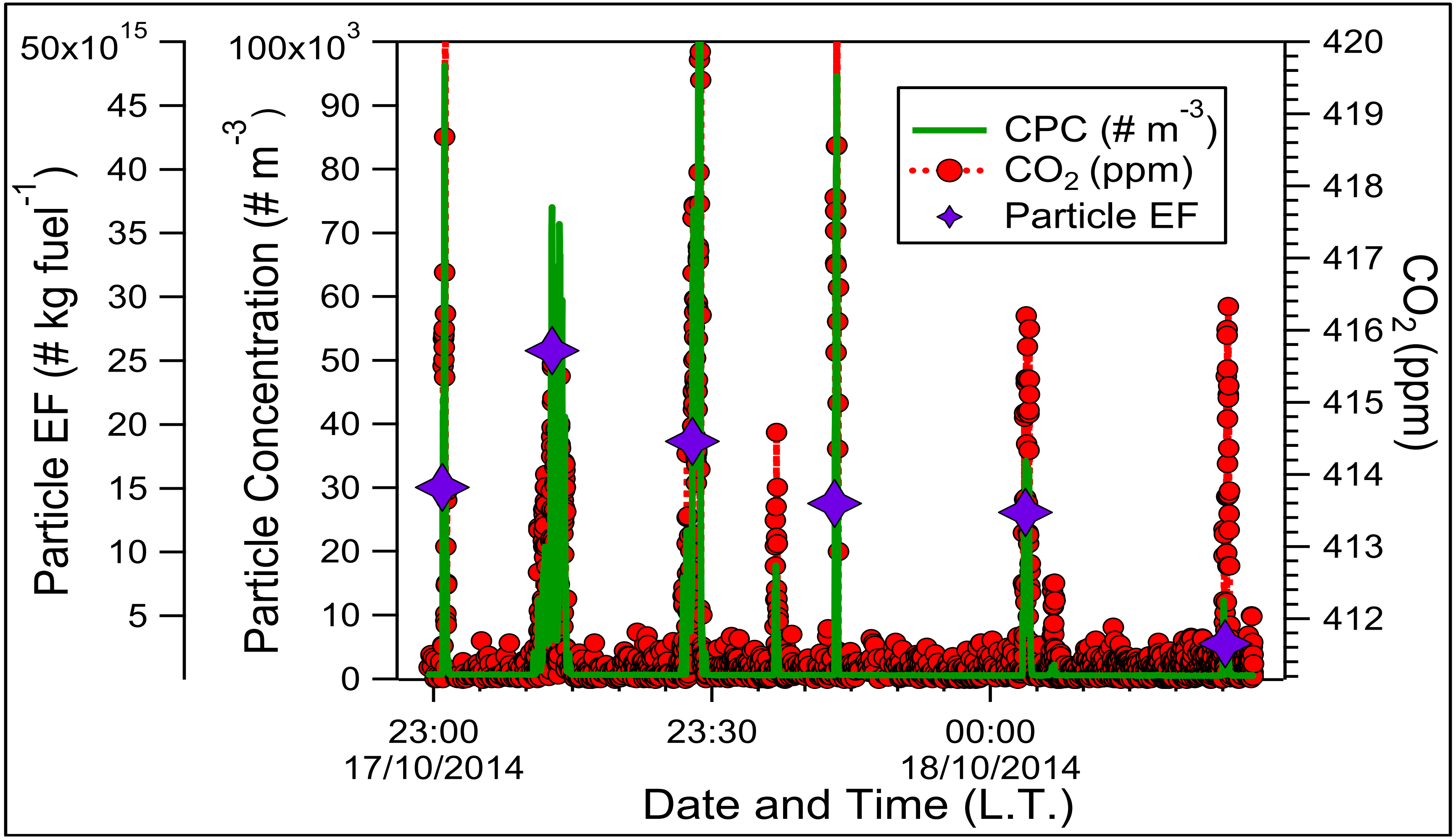
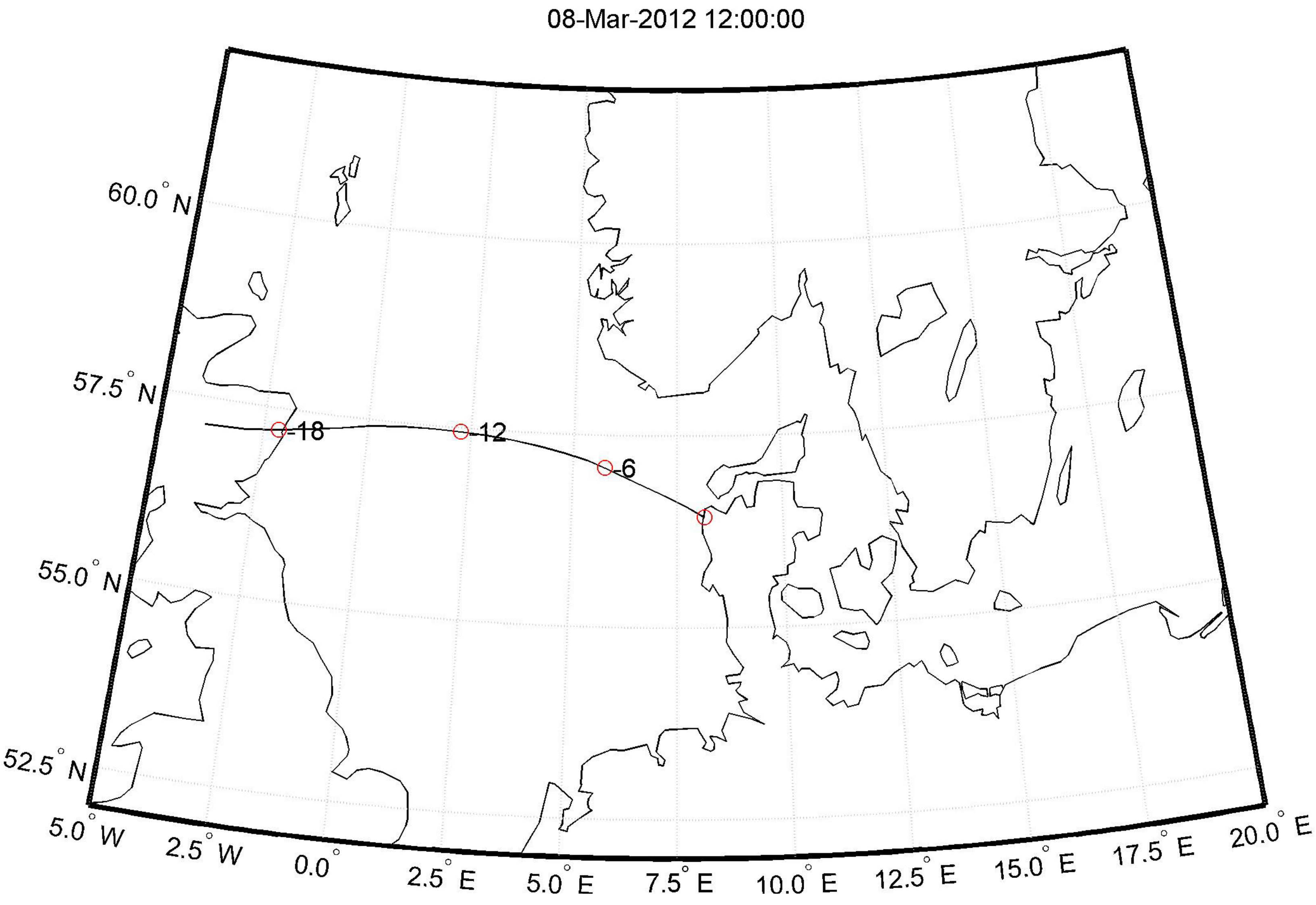
Ship emissions



- **Aerosol dynamics box modelling along trajectories**



• Aerosol dynamics box modelling along trajectories

Aerosol dynamic processes that affect the concentration during transformation are:

- **Condensation**
- **Coagulation**
- **Cloud activation**
- **Dry and wet deposition**

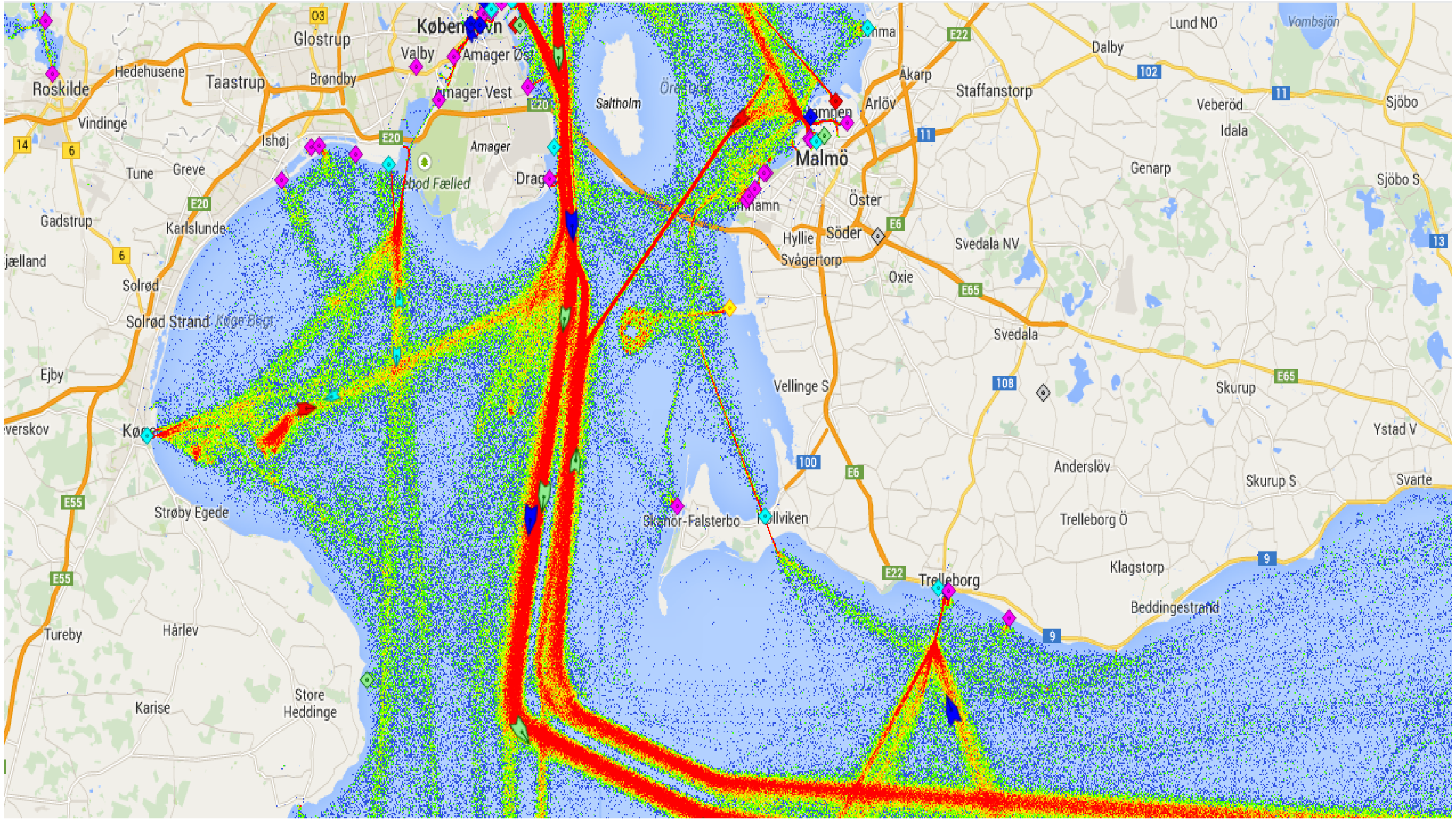
So, emission factors, then aerosol dynamics modeling along trajectories.

Continue modeling with one day to one week trajectories to see how this eventually affects the concentrations in Europe. Lund University has the ADCHEM model.

Repeat with Arctic area, and validate with the few stations available.

Gives emission factors, process understanding of the particle transformation and case-to-case validation to large-scale models

Transformation during long range transport



• Maesurement stations

There is a dense network of stations, for example in Europe to validate particle concentrations.

Measurements at Svalbard might also be used to study influence of ship emissions, since quite a few ships pass this area.

- **Flexpart**

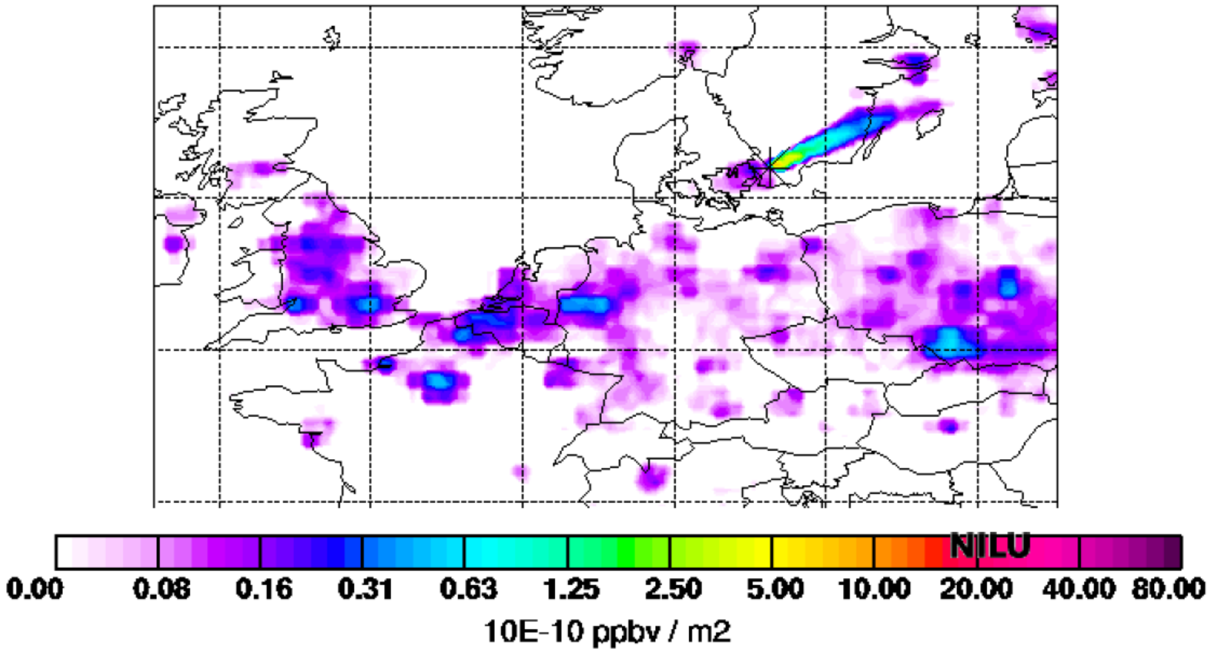


Figure 5. Flexpart example from January 2, 2010, 09:00. Source contributions to CO concentrations in Vavihill (marked with a star) using meteorological data from Flexpart and CO emission data from EMEP.

Flexpart modeling can be used to predict where the particles came from.

You get only inert type of particles accounted for. Difficult with aerosol transformation.

• Source/receptor modelling

Source/receptor modeling can be used to predict what are the source contribution to the particles by using only measurement station data and statistics.

You get only inert type of particles accounted for. Difficult with aerosol transformation.

• Summary

- **We are in need of better data to support large-scale models to predict future aerosol particle concentrations in the Arctic:**

What we need is:

1. **Better emission factors, which we get from existing and new measurements.**
2. **Better understanding of aerosol dynamic processes transforming the aerosol particles during long range transport. This we get with aerosol dynamic box models following the air movement.**
3. **Validating aerosol dynamics modeling with measurements.**

den # Upptäck

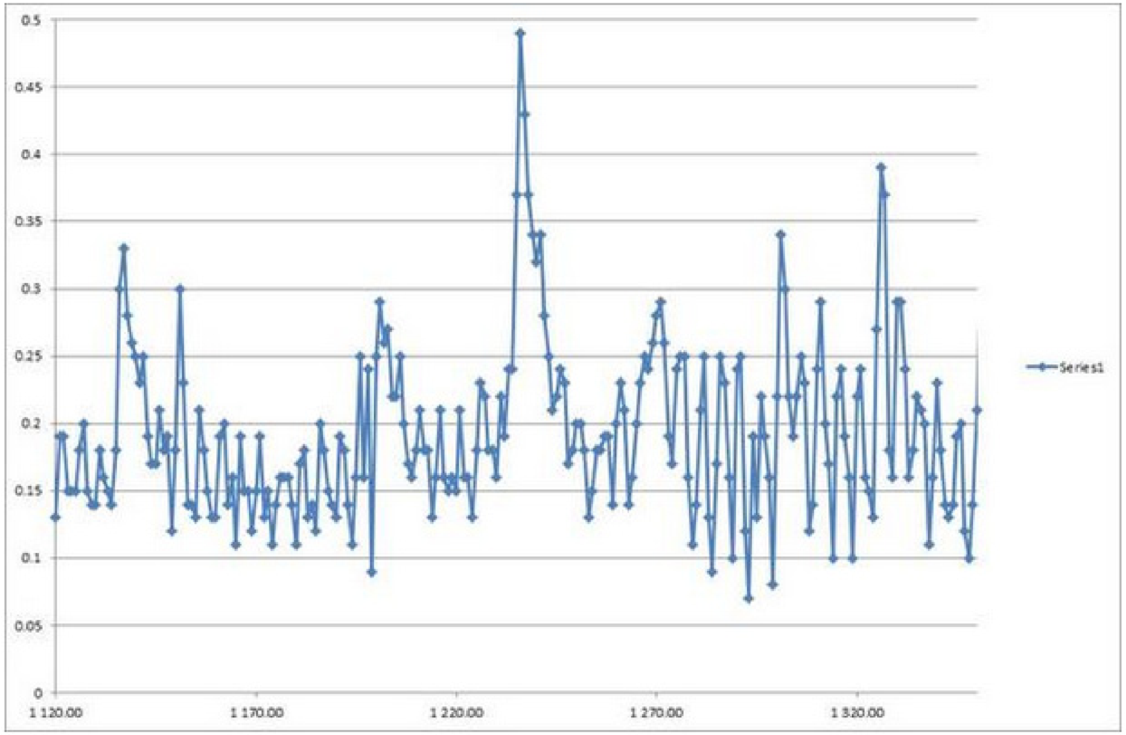
Sök på Twitter

Tweeta

Adam Kristensson
@AdamKristensson

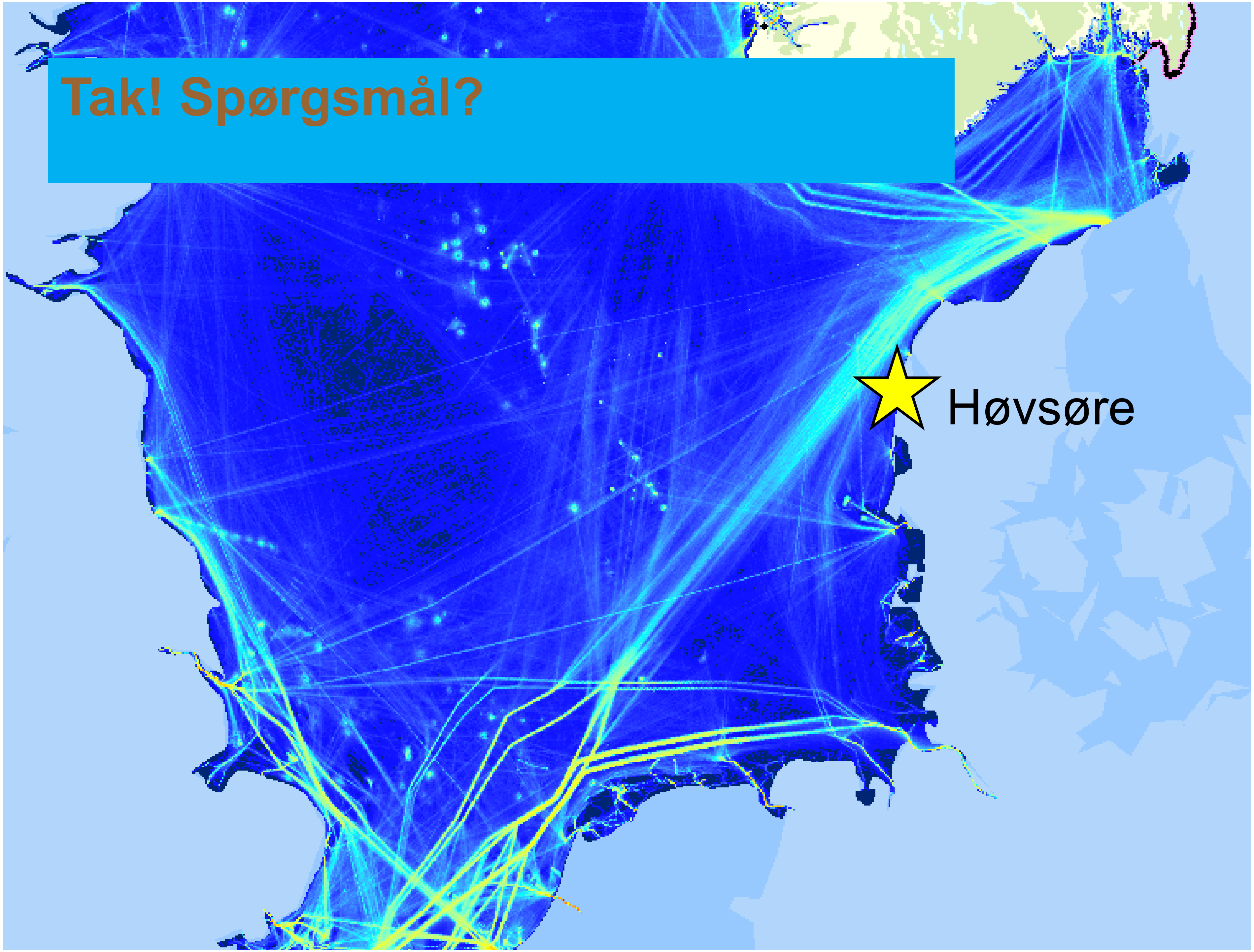
Todays Gothenburg soot concentrations reach over 0.3 microg/m3 in #shipemissions plumes, twice as high as background

Stockholm



13:51 - 21 okt 2014

Tak! Spørgsmål?

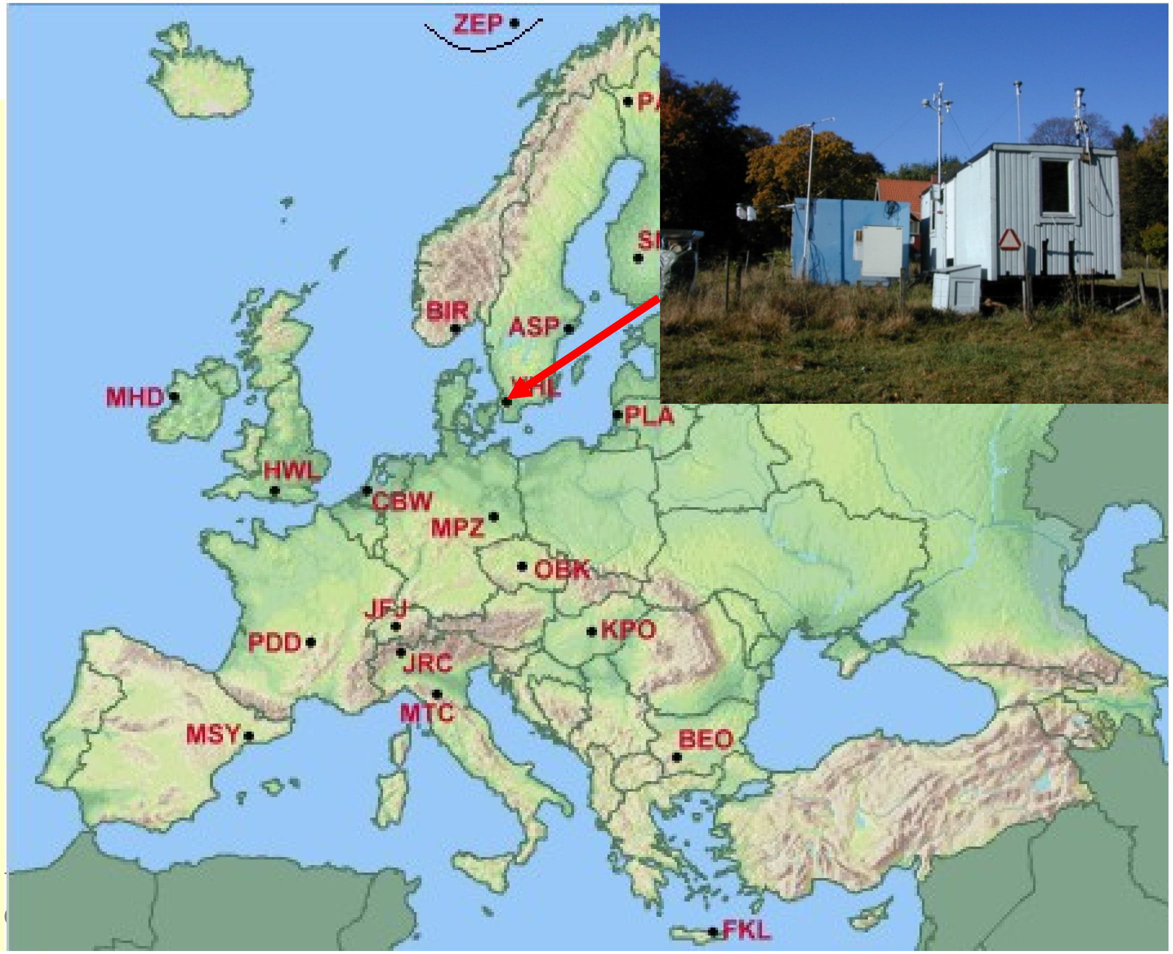


ACTRIS
An EU-Infrastructure Project

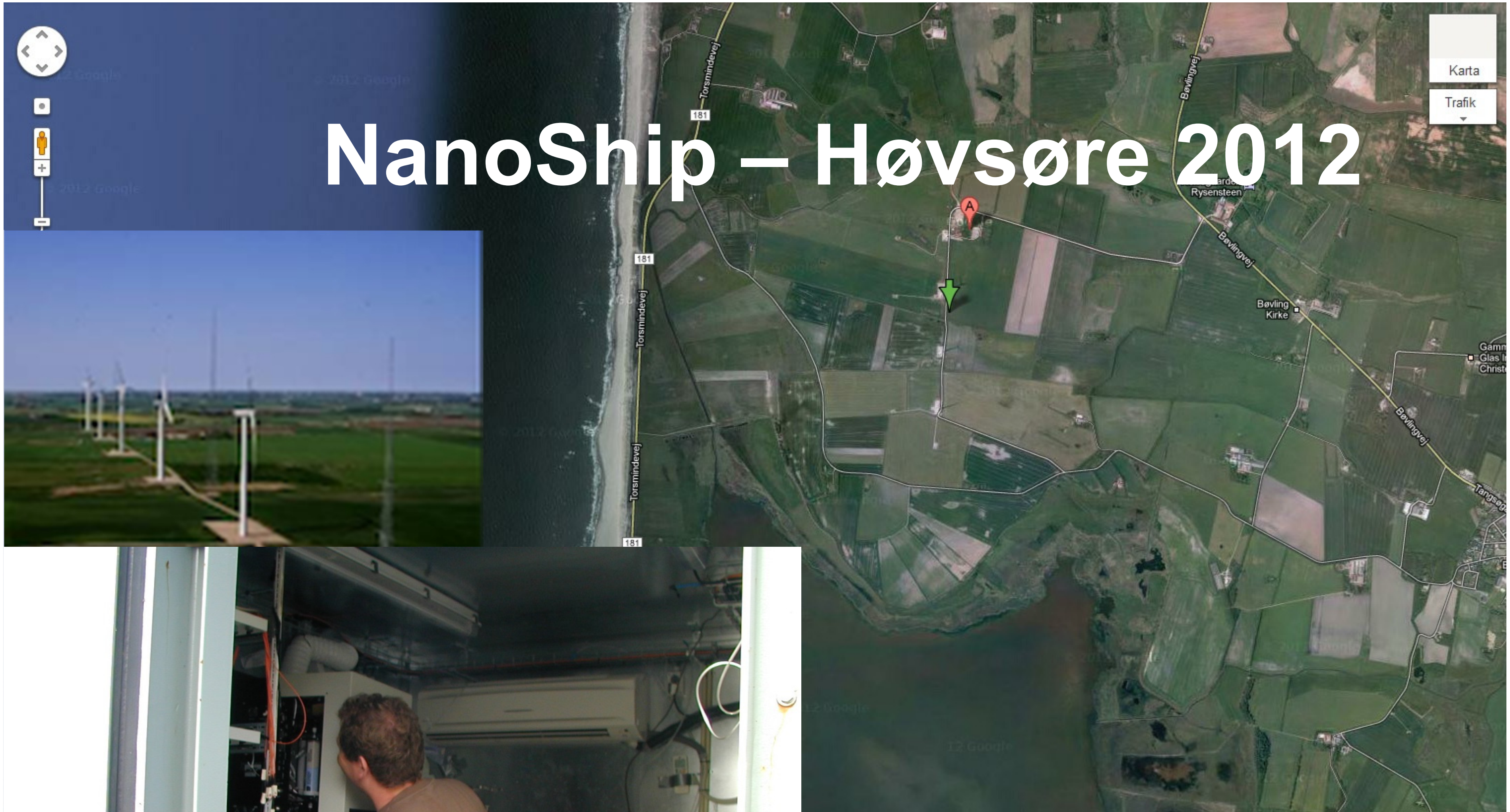
21 European Partners

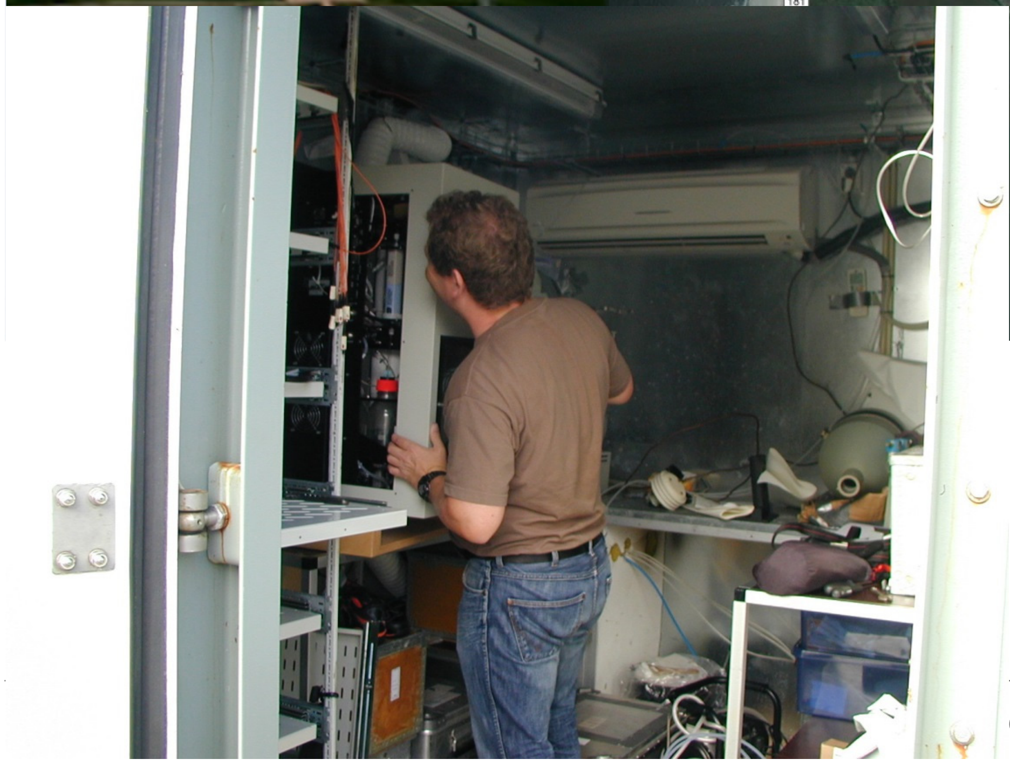
Objectives

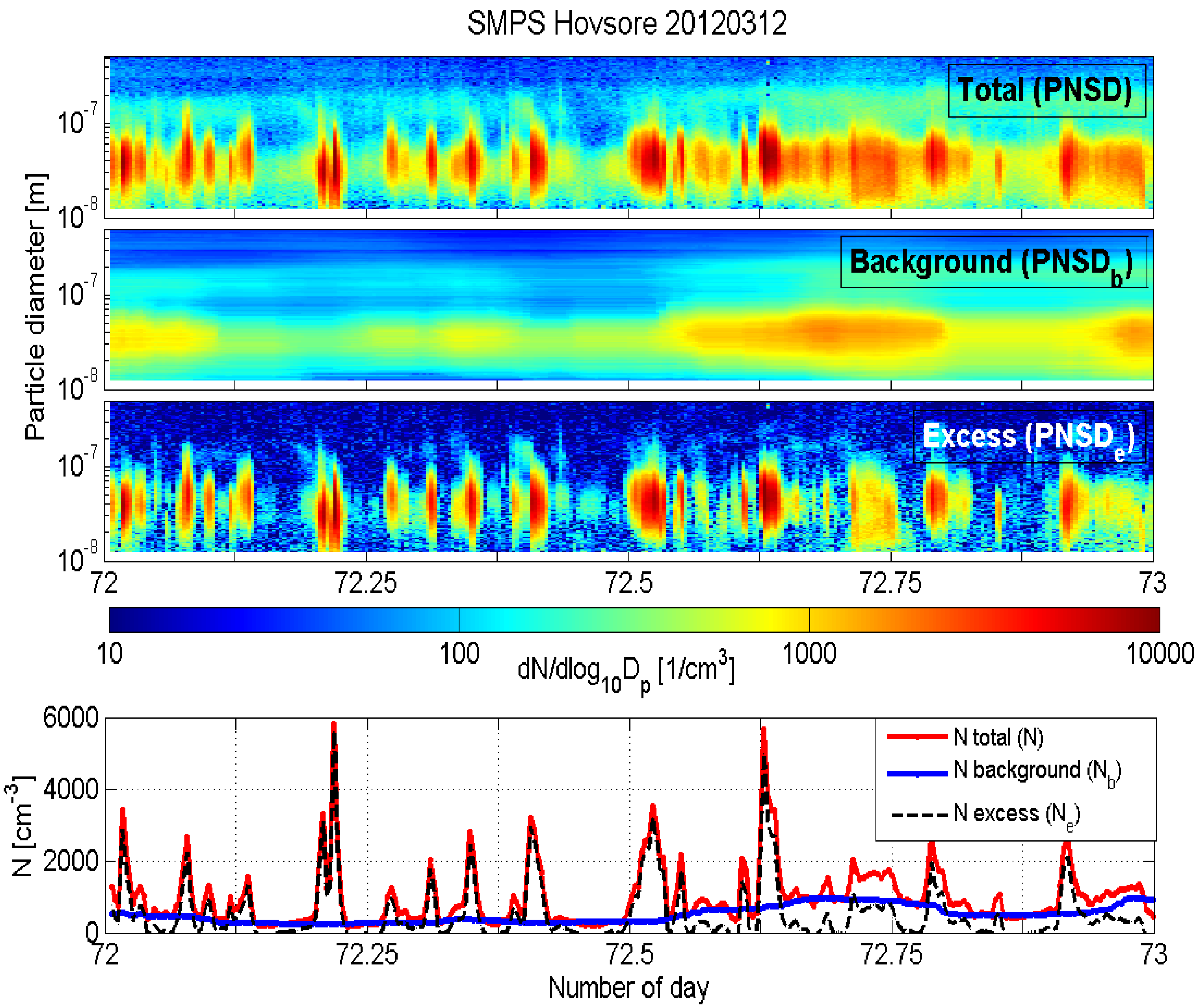
1: Ensure measurements and QA/QC of aerosol chemical, optical and physical properties
2: Ensure dissemination of data and capacity building
3: Develop future tools for aerosol monitoring and dissemination of information
4: Ensure trans-national access of research infrastructures

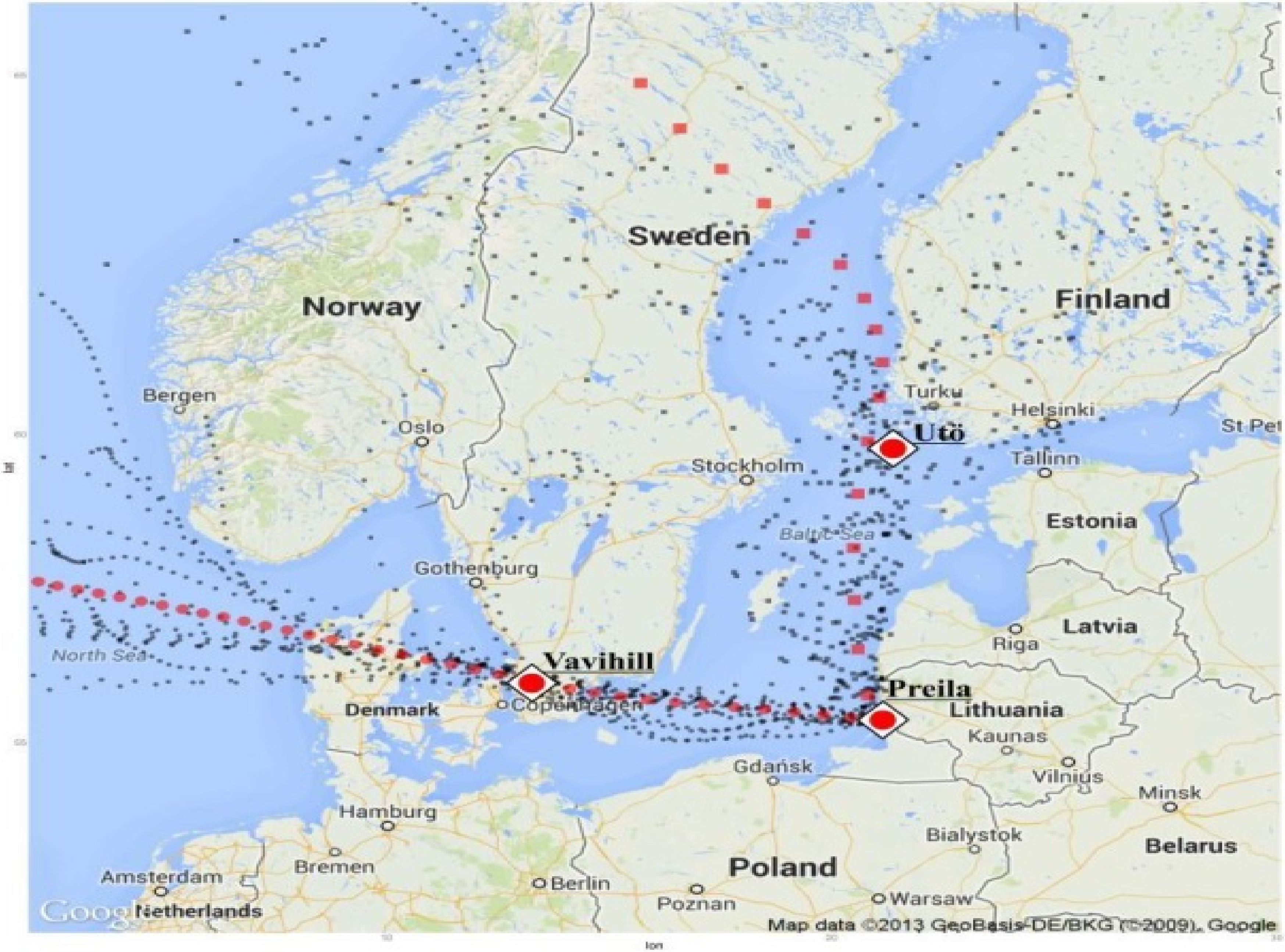


NanoShip – Høvsøre 2012






SMPS Hovsore 20120312
Total (PNSD)
Background (PNSD_b)
Excess (PNSD_e)
Particle diameter [m]
10^-7
10^-8
72
72.25
72.5
72.75
73
10
100
1000
10000
dN/dlog10Dp [1/cm3]
6000
4000
2000
0
N [cm-3]
N total (N)
N background (N_b)
N excess (N_e)
Number of day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lon

Measurement site

Flygers Hut at Station Nord, equipped with inlets and instruments for particle and gas measurements..