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COST EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

EuNetAir

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability

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Spatial Mapping and Data Assimilation of Observations from Low-Cost Air Quality Sensors within CITI-SENSE

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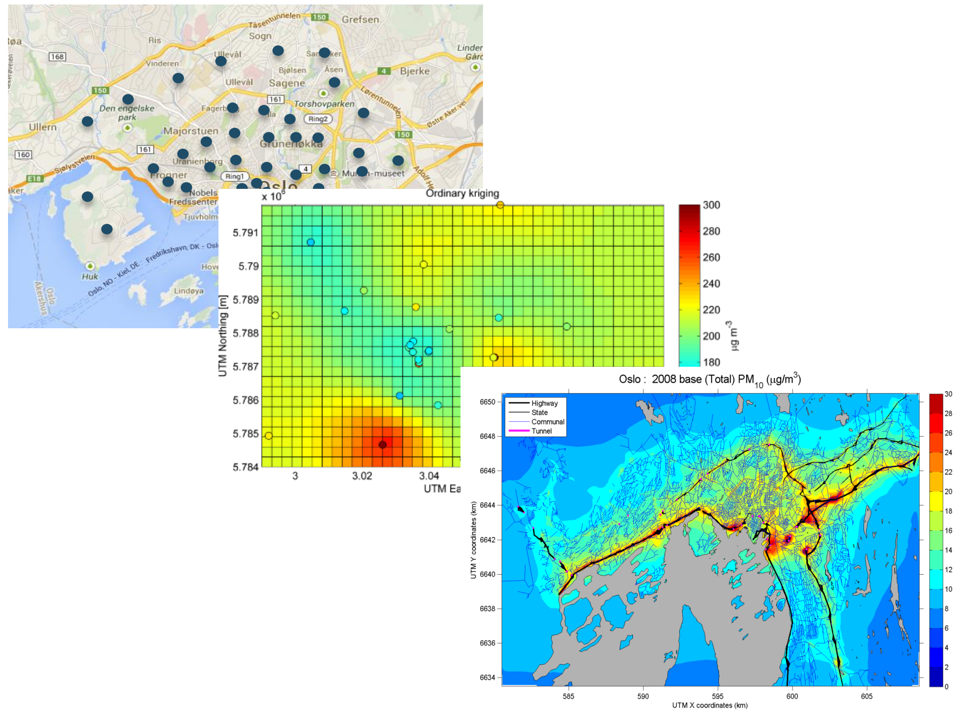


The CITI-SENSE project

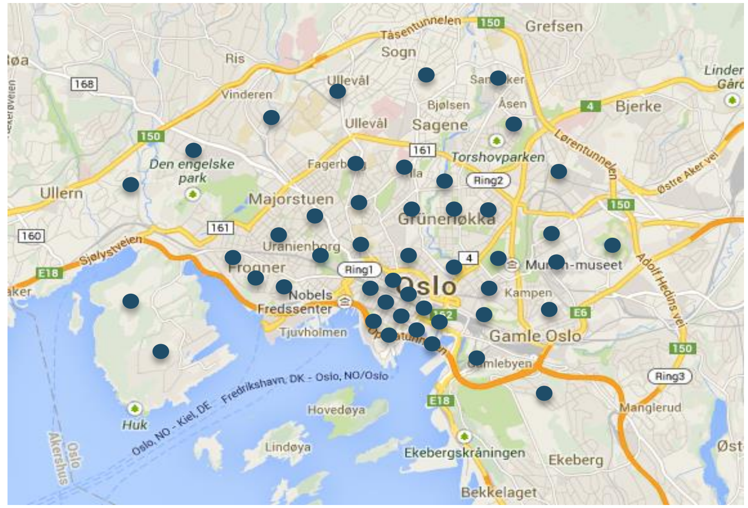
- Development of sensor-based Citizen's Observatories for improving the quality of life in cities
- Collaborative Project funded by FP7-ENV-2012
- 28 project partners from 12 countries (Europe, South Korea, and Australia)
- Total budget of EUR 12M
- Case studies at 9 locations throughout Europe

CITI-SENSE: Oslo case study

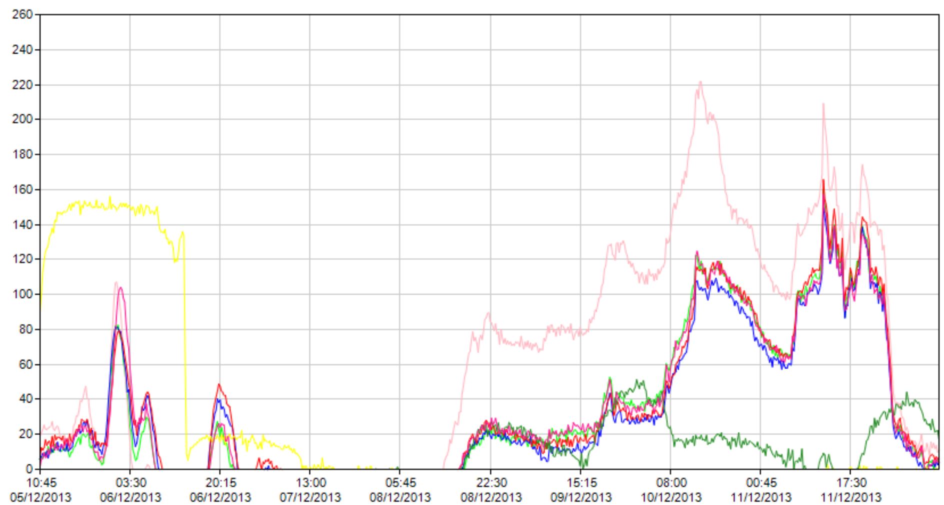
~40 Geotech sensors will be installed throughout Oslo

Parameters to be measured include NO, NO_2, SO_2, O_3, CO, as well as meteorological parameters such as air temperature, relative humidity, and atmospheric pressure

Temporal sampling: 15 minute intervals



High density network of static sensor nodes to be deployed throughout Oslo in 2014/2015



First few sensors units are currently in the evaluation phase at NILU (laboratory and real-world testing)

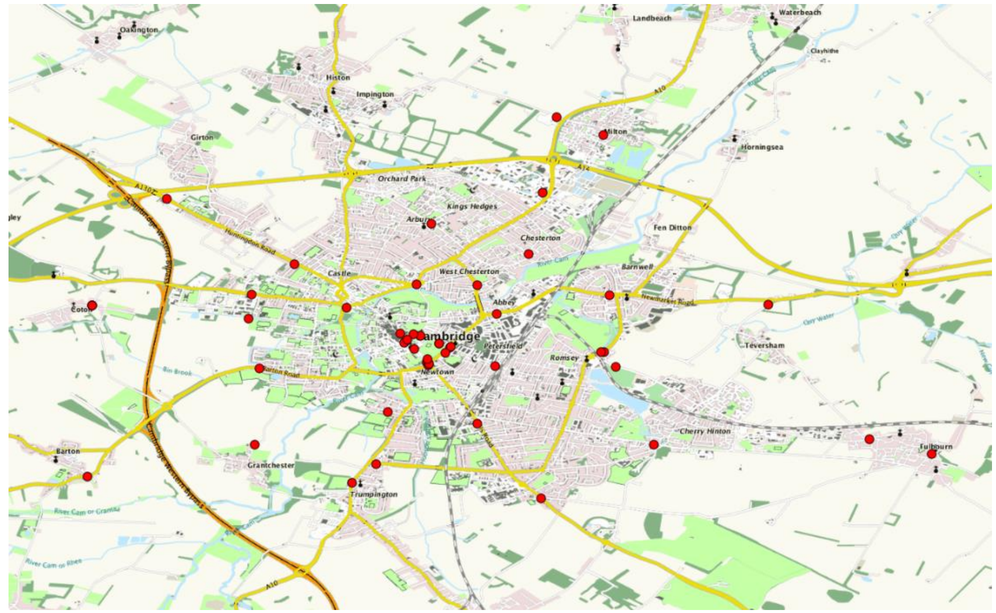
Spatial mapping of CITI-SENSE data

- One of the main goals of CITI-SENSE is to provide the users with a continuous map of crowdsourced air pollution data in their city
- Therefore spatial interpolation is required
- Many techniques of varying complexity exist
  - Basic interpolation techniques
    - Linear interpolation
    - Inverse distance weighting
    - Natural neighbor interpolation
  - Geostatistics
    - Ordinary kriging
    - Kriging with external drift (using spatially continuous auxiliary variables)
  - Data Assimilation
    - Variational: 3D-Var, 4D-Var
    - Sequential: Ensemble Kalman Filter (EnKF)

CITI-SENSE users will have access to crowdsenses air quality data on their mobile phones. Many applications, such as finding the least-polluted route in a city, require spatially continuous maps.

Basic Interpolation Techniques

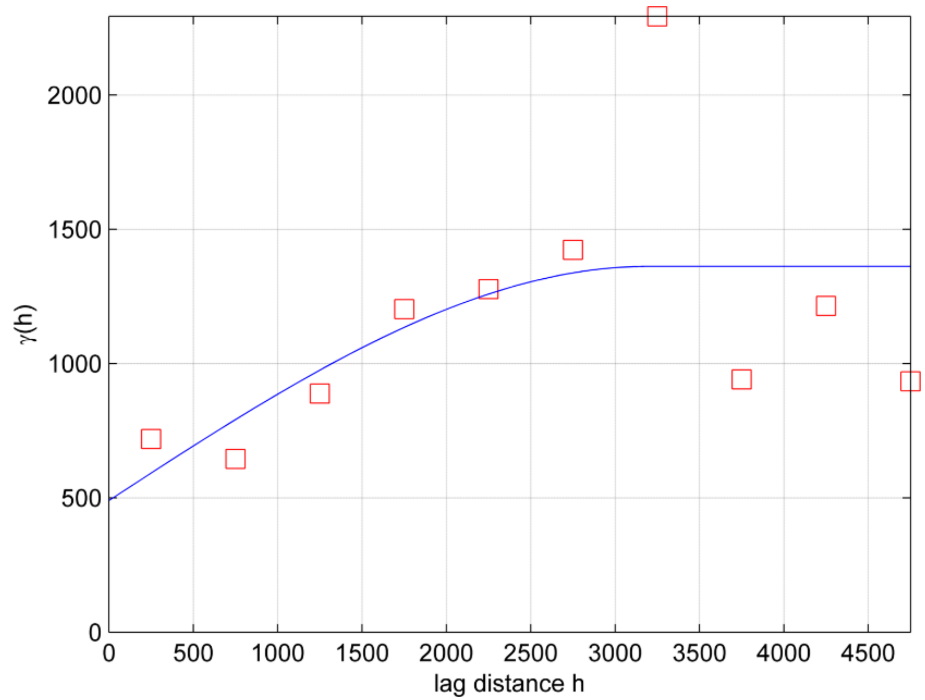
- Many varieties
  - Linear interpolation
  - Natural neighbor interpolation
  - Cubic spline interpolation
  - Inverse distance weighting
- Advantages
  - Fast
  - Easy to implement and automate
- Disadvantages
  - Do not take into account spatial autocorrelation
  - Often not optimal results (e.g. discontinuities)
  - Do not provide an uncertainty estimate



Locations of static sensor nodes described in Mead et al. (2013)

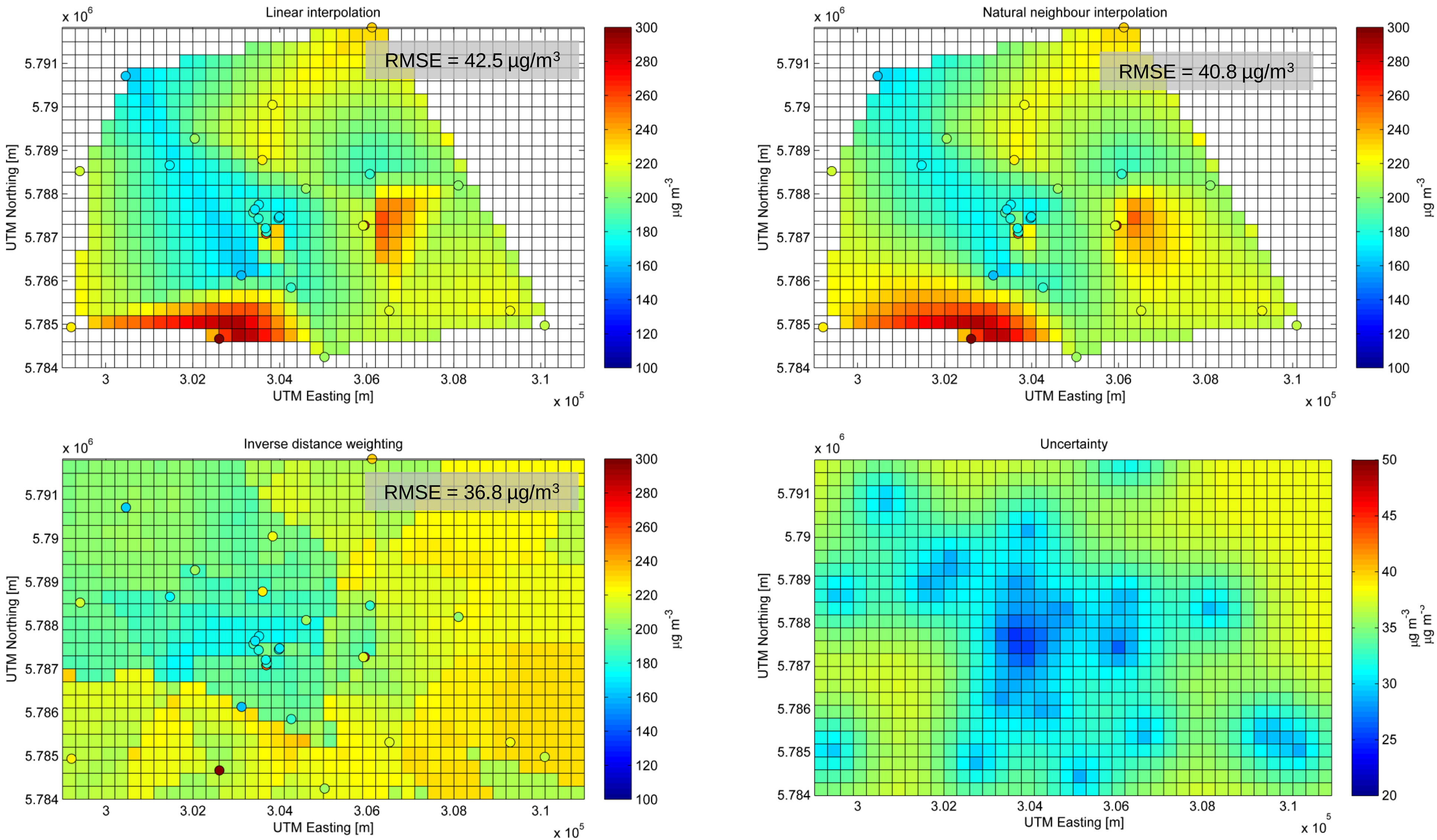
Geostatistics and Data Fusion

- Uses a model of the spatial autocorrelation of the observations
- Can easily integrate spatially exhaustive auxiliary data to “guide” the interpolation (-> data fusion)
- Advantages
  - Explicitly takes spatial autocorrelation into account
  - Provides Best Linear Unbiased Estimate (BLUE)
  - Provides uncertainty estimates
  - Allows for the use of auxiliary data
- Disadvantages
  - Computationally more expensive
  - Full automatization of semivariogram model challenging



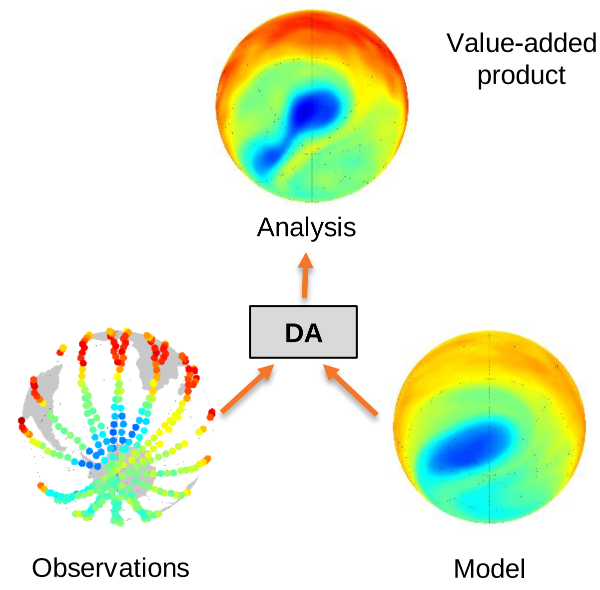
Empirical and theoretical semivariogram to describe spatial autocorrelation

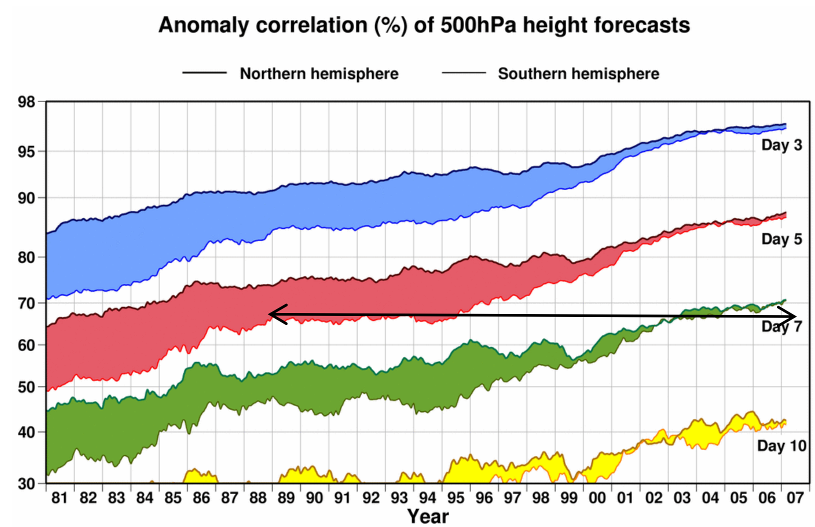
Example: Mapping Cambridge CO data (Mead et al. 2013)



Data Assimilation

- Combining observational and model information
- Based on mathematical principles (optimality; Bayes's rule)
- Added value:
  - Analysis better than either observations or model alone
  - Observations: filling in gaps
  - Model: constrain using observations (and learn about model deficiencies)
- Enormous success in NWP (ECMWF) and used for various elements of the Earth System
- Provides a way to account for the uncertainty of the observations (critical for "crowdsourced" microsensor data of AQ!)
- Data assimilation at the urban scale will be used experimentally within CITI-SENSE

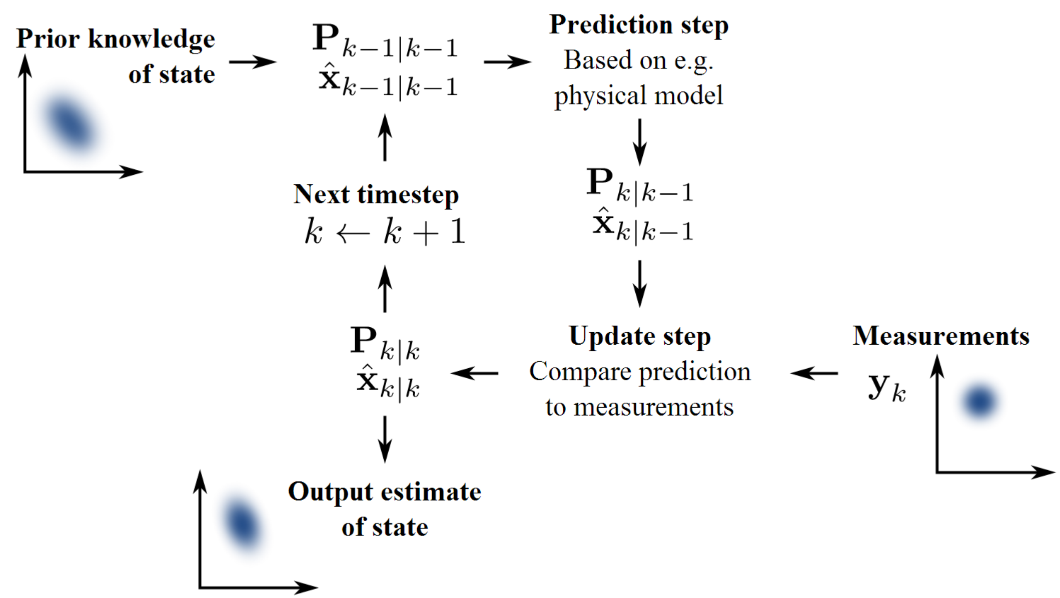




Forecast improvement at EMCWF, based to a large extent on DA of satellite data

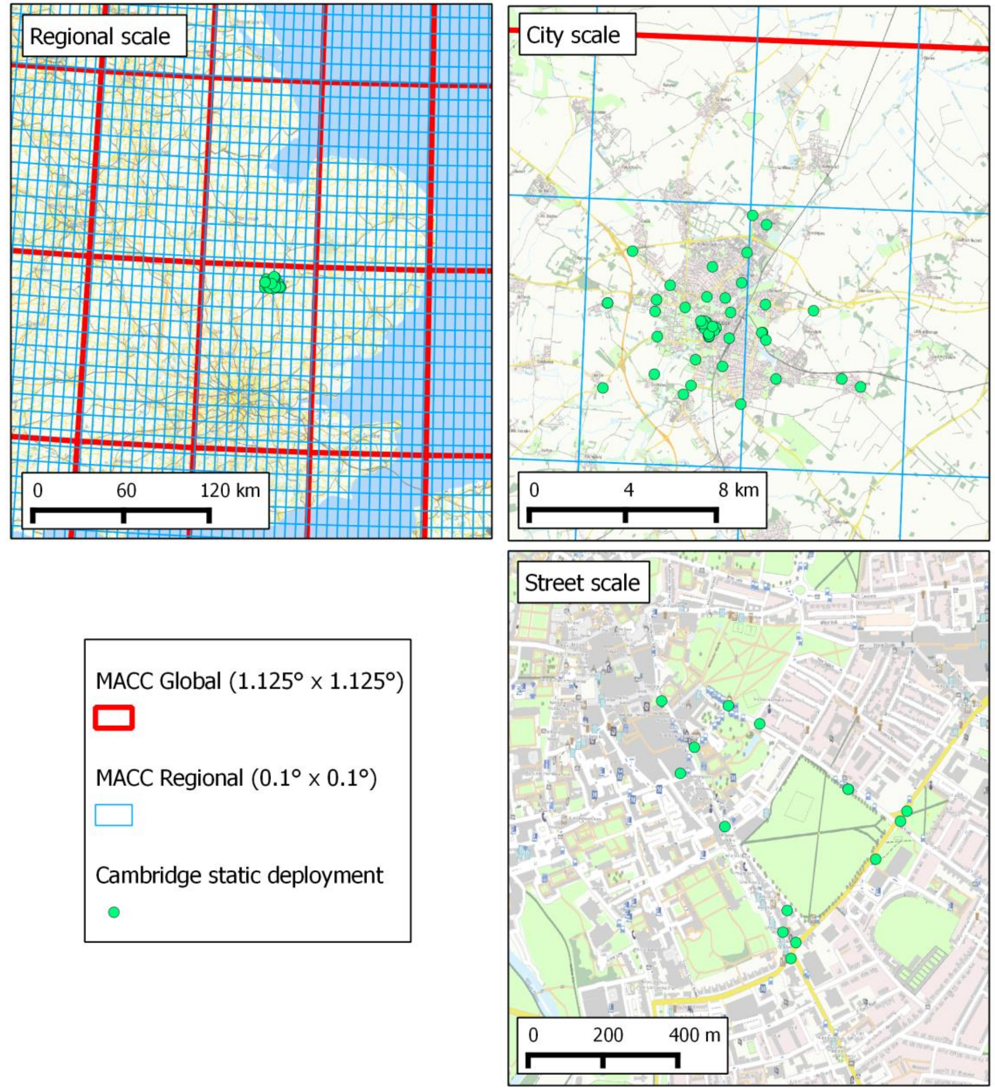
The Ensemble Kalman Filter (EnKF)

- For DA in CITI-SENSE the Ensemble Kalman Filter will be used
- The original Kalman Filter relies on a manual update of the covariance matrix
- This is not feasible for complex systems such as NWP
- The EnKF solves this
  - Monte Carlo implementation of the Bayesian update problem
  - Covariance matrix is estimated from an ensemble of model states
  - Allows to account for uncertainty in observations and model



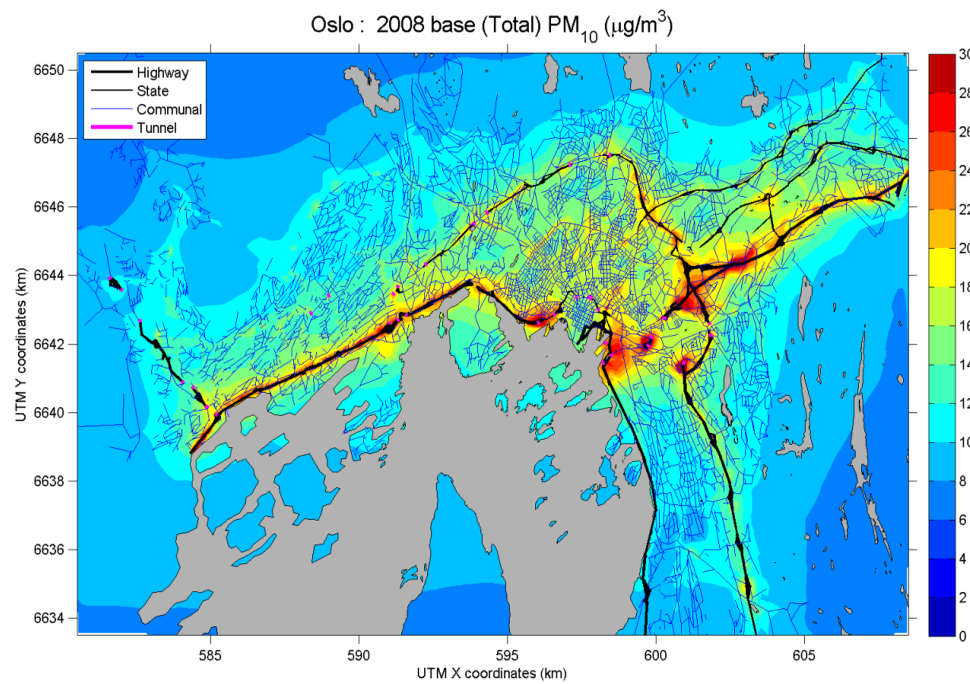
The issue of scale…

- Data Assimilation for atmospheric applications (and chemical weather) currently happens at very coarse spatial resolutions
- Data Assimilation of AQ observations at the urban scale has not been done before
- Underlying physics, chemistry, and statistics are very different at high spatial resolution
- Requires a much higher-resolving AQ model than operational CTMs



The EPISODE model

- Three-dimensional, combined Eulerian/Lagrangian air pollution dispersion model, developed at NILU
- Main focus on urban and local-to-regional scale applications
- Provides gridded fields of ground-level hourly average concentrations
- Spatial resolution down to 100m
- Time step between 10 s and 300 s
- Schemes for advection, turbulence, deposition, and chemistry



Summary

- CITI-SENSE is an ongoing FP7 project dedicated to demonstrating the use of low-cost AQ sensors as a tool for the “Citizen’s Observatory”.
- As one of 9 case studies, ~40 static sensor nodes will be deployed throughout Oslo (NO, NO_2, SO_2, O_3, CO, Met) in late 2014.
- Operational mapping for CITI-SENSE users will be carried out using a combination of basic spatial interpolation routines and Geostatistics.
- Experimental component of the project involves mapping using Data Assimilation of the observations into an urban scale AQ model using the Ensemble Kalman Filter.