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Aerosol species in the AQ forecasting system of FMI: possibilities for coupling with NWP models

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Content

- Introduction
- Current features of regional AQ forecasts of FMI
  - Modelled parts of aerosol composition over Europe
- Feedbacks from off-line coupled CTM model??
- Suggestions

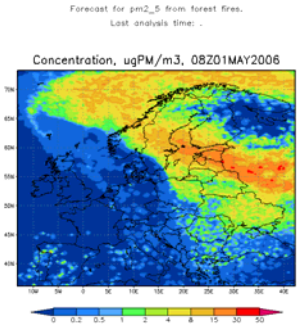
Operational air quality forecasts

- A ~1.5 years of experience
  - trials started in November 2005,
  - operational setup created in February 2006, Lagrangian SILAM v.3.8.1,
  - new Eulerian v.4.0.1 took the load in May 2007
- Forecasts are publicly available at http://silam.fmi.fi
- Forecast parameters (May 2007)
  - horizon: 54 hours
  - species:
    - Anthropogenic primary aerosol (2 size bins): PM 2.5; PM 2.5-10
    - Anthropogenic and natural SIA and precursors: SO_2, SO_4
    - wild-land fires: PM 2.5
    - sea salt: PM 0.01–0.1, PM 0.1-1, PM 1-2.5, PM 2.5-10, PM 10-30, original emission model (extended & corrected Monahan's formulations + water temperature & salinity)
    - natural: allergenic pollen
  - area: Europe
  - meteorology: HIRLAM reference RCR (ECMWF in backup)
  - resolution: 1 hour, 30km
  - updates: daily, ~4 AM
  - computation costs: ~40 CPU-hours

Structure of Regional AQ forecasting system

Satellite observations

Fire Assimilation System



Final AQ products

Phenological observations

Aerobiological observations

Physiography, forest mapping

Phenological models

SILAM AQ model

EVALUATION: NRT model-measurement comparison

HIRLAM NWP model

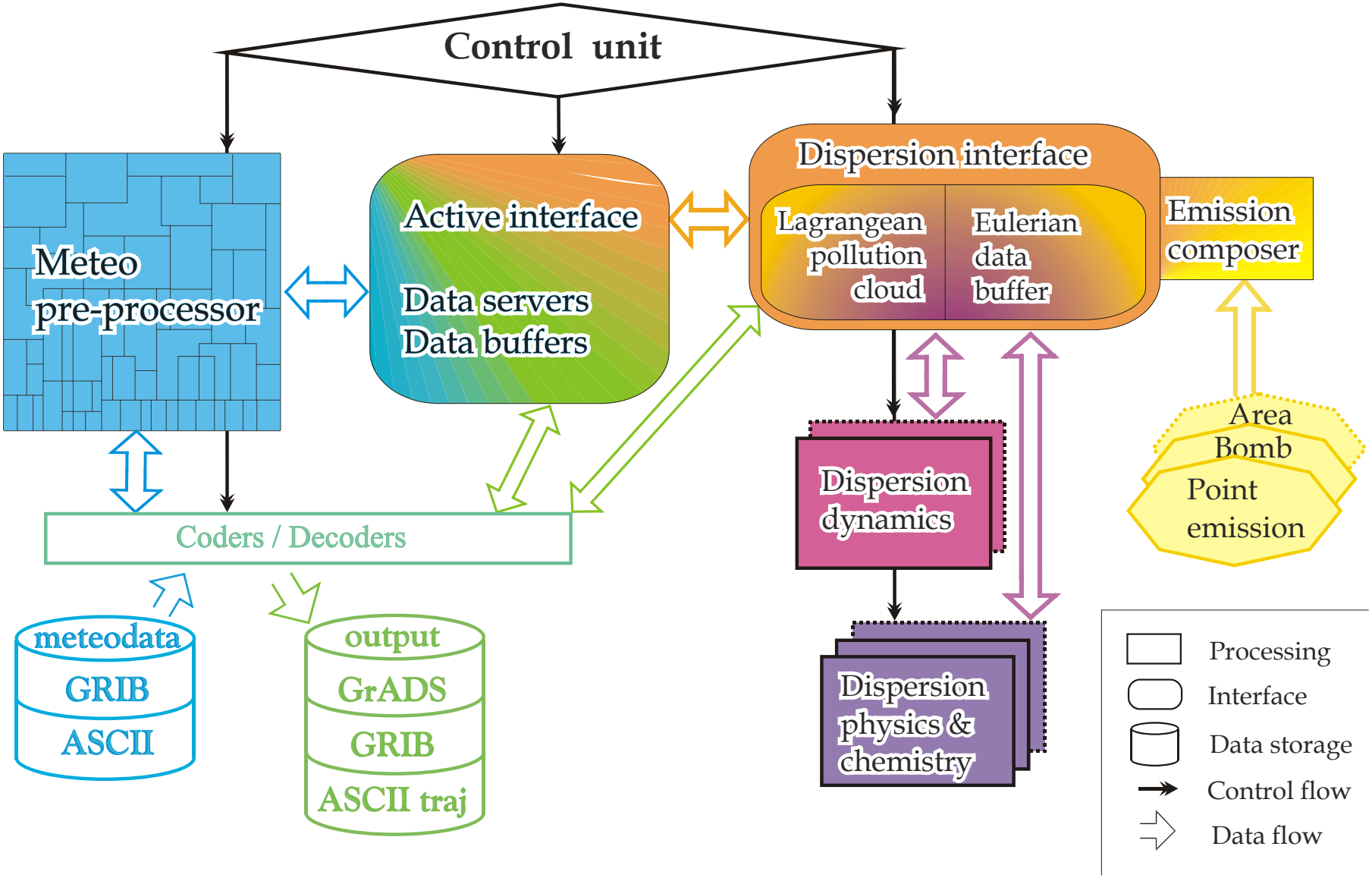
UN-ECE CLRTAP/EMEP emission database

Meteorological data: ECMWF

Aerobiological observations

Online AQ monitoring

SILAM modelling system

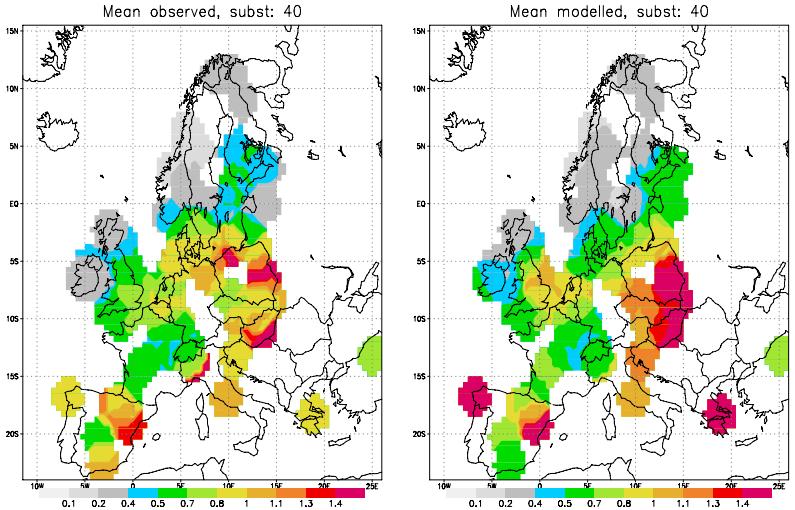


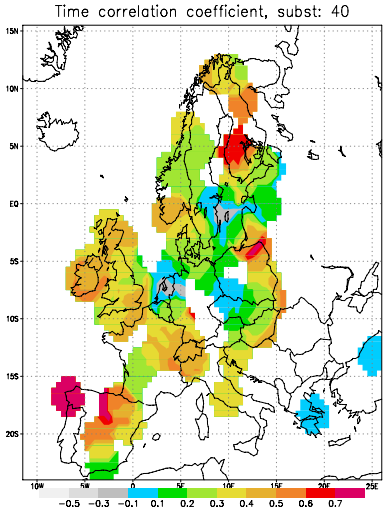
Evaluation of the re-analysis results

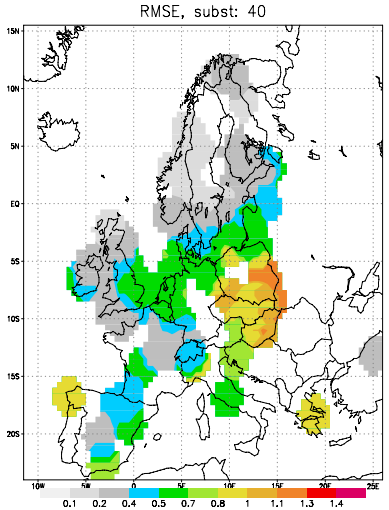
- Comparison with EMEP data
  - SO_x as the main dataset: SO_2 in air, SO_4 in aerosol, SO_4 wet deposition
  - aerosol observations are scarce and do not include speciation; however, work is on-going to compare the bulk concentrations (PPM 2.5 / PPM 10 + SO_4 + SeaSalt $\Rightarrow$ ~20-80% of PM)
  - Mean values are good and quality is homogeneous in space
  - Temporal correlation is somewhat low for monthly level (seasonality of emission is 15 years old)
  - Specific parameters – FMT, RMSE, RelDiff – are within fair-to-good limits
- Comparison with some campaign results: (Biofor-1999, Varrio-2003, etc…)

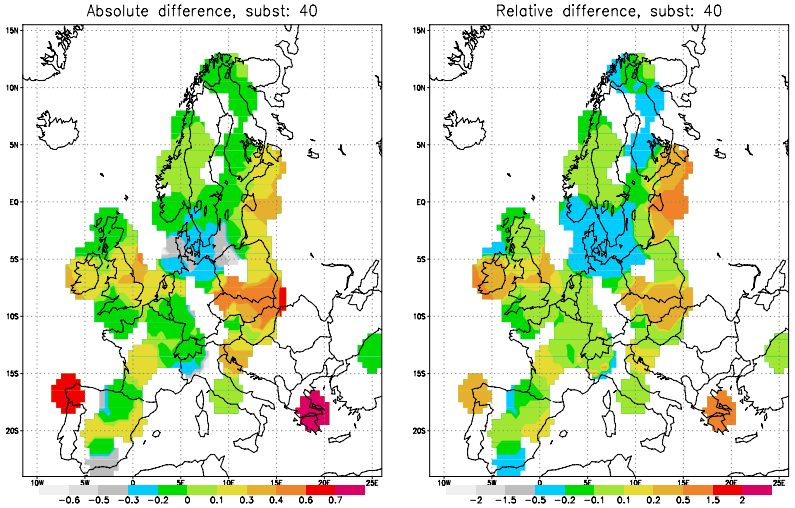
Examples of the comparison

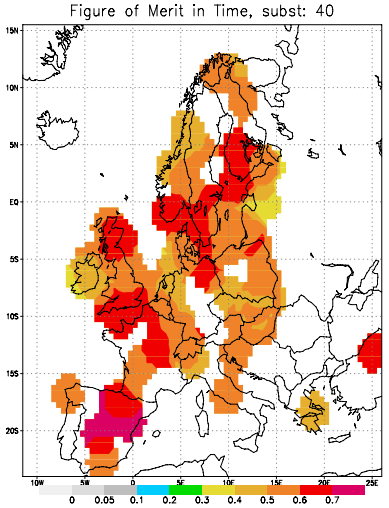
- SO_4 concentrations, μg S m^{-3}

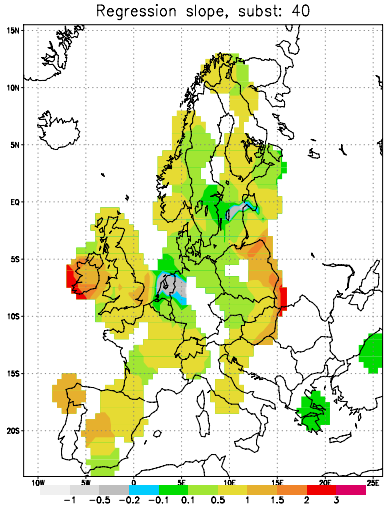




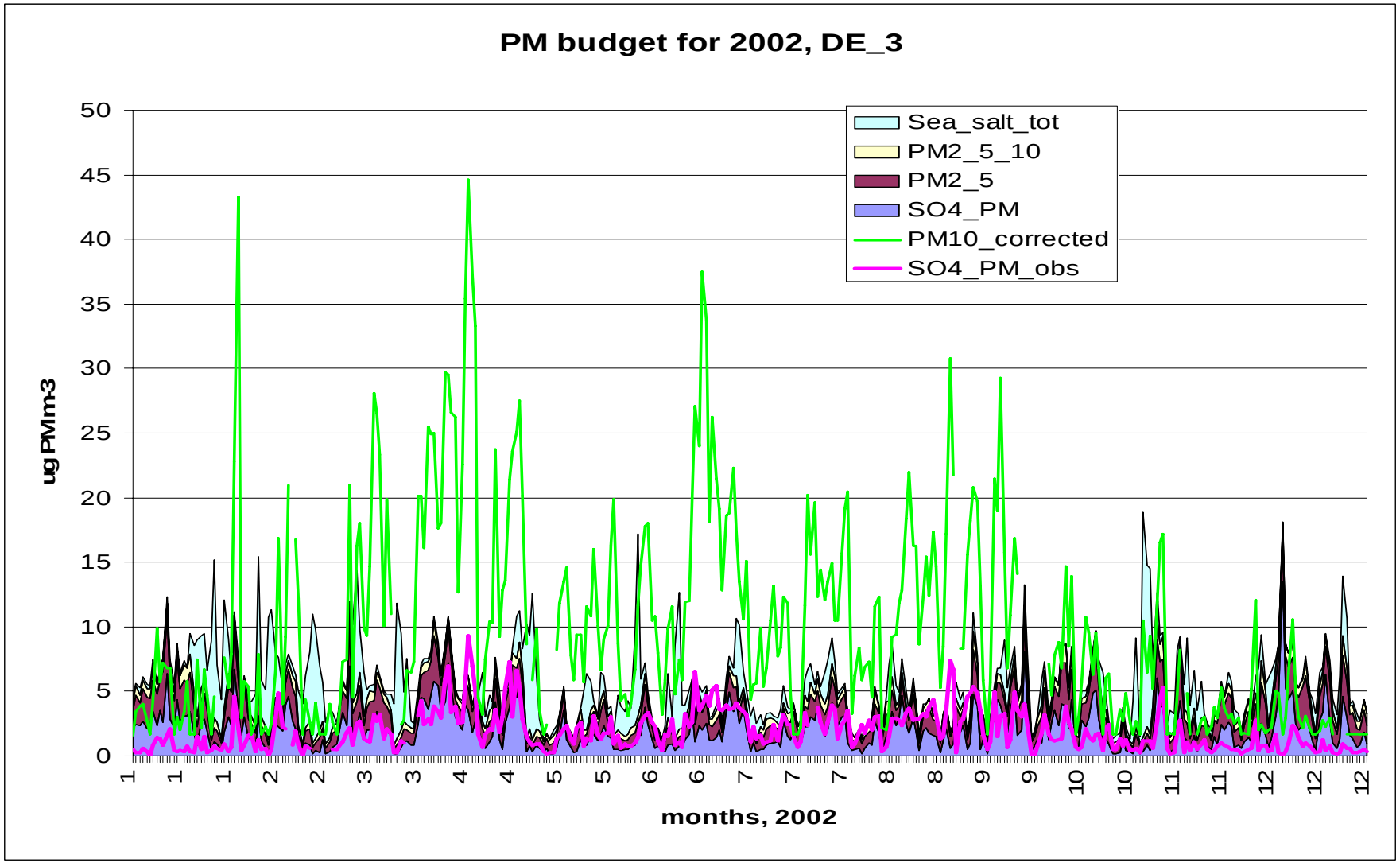








Example of central-Germany EMEP station GE-3



Re-analysis: summary

- SILAM quality scores for anthropogenic pollutants: typical for this type of models
- PM species dependent on meteorology (those covered so far)
  - sea salt, wind-blown dust: dependent on NWP driver
    - CTM reparameterization might be needed for each new NWP (new version of NWP)
- SILAM meteo pre-processor seems to handle the main problems of Met-CTM model off-line coupling
  - very strict requirements to the data consistency: explicitly re-stated
  - a wide range of scales to be covered: meteo- and dispersion- scales are entirely independent
  - sensitivity to parameters non-existent or of low-priority for NWP community: ABL parameters are explicitly re-stated

Operational forecasts

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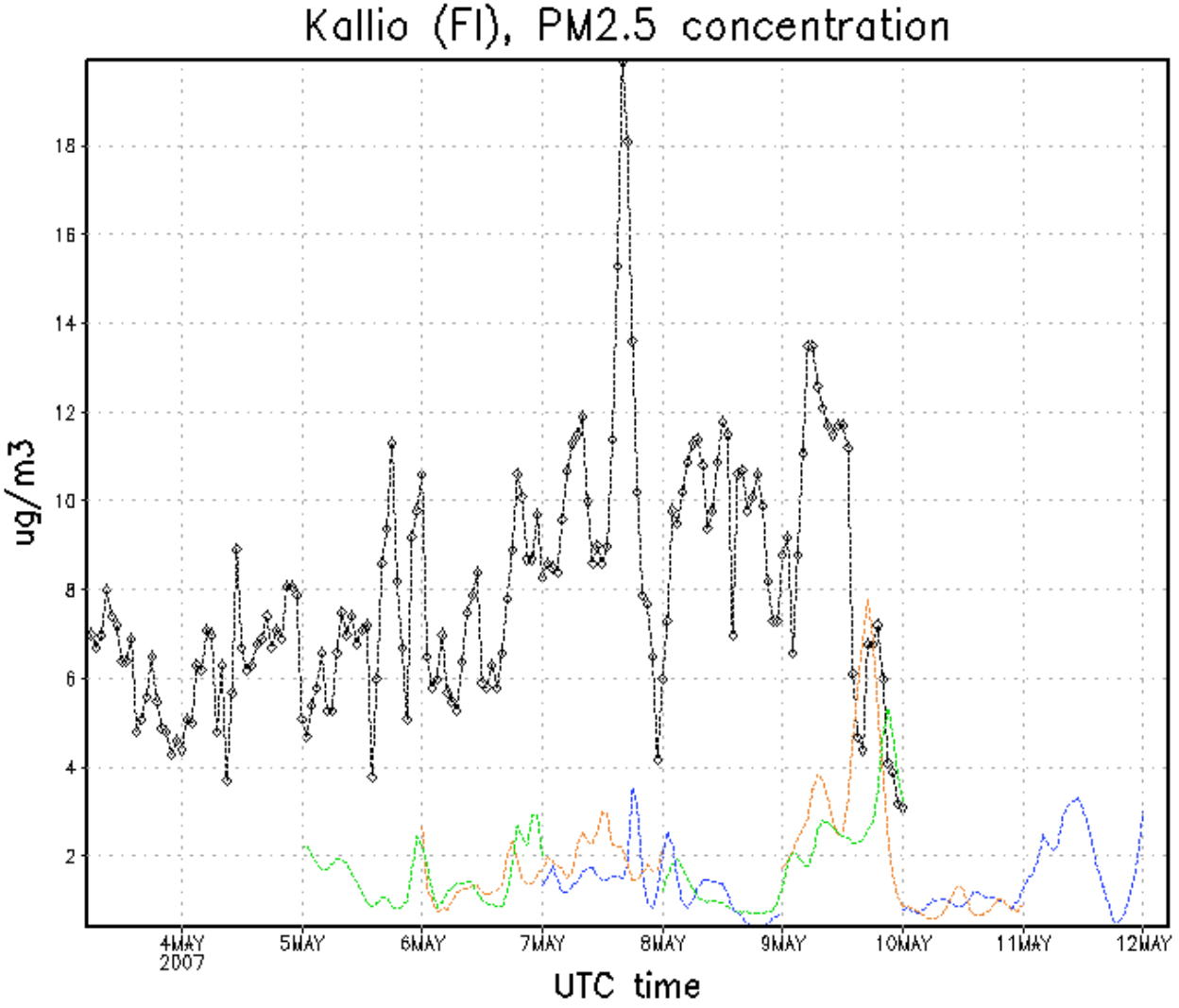

AQ forecast: coupling challenges

- NWP$\rightarrow$CTM: Methodological
  - AQ meteo pre-processors tend to run ahead (or in another direction) than NWP model development $\Rightarrow$ consistency problems
    - downscaling of NWP fields without rerunning the whole model
    - hydrostatic/non-hydrostatic equations
    - vertical wind with zero-values at the top and bottom
  - wind-driven emissions usually involve threshold-based fast-growing emission functions: $e=1(U-U_{threshold})*U^{power}$
    - high sensitivity to upper tail of wind velocity distribution
      - … sensitive to NWP model version and resolution, seen already for sea-salt
  - missing/unreliable variables
- NWP$\rightarrow$CTM: Technical
  - growing resolution pushes file sizes to infinity. AQ model may need 5-10% of stored stuff but has to read the whole GRIB
    - meso-HIRLAM: reading meteo data takes 80-90% of the run time

Feedback from off-line CTM to NWP ??

- Technically: no problem
  - Regular forecasts $\Rightarrow$ shift to one cycle does the trick
  - Nested forecasts $\Rightarrow$ shift to one nesting step does the trick
- Methodologically: devil in details
  - Two most-evident ways of influence of atmospheric composition to weather forecast (mind the time scale!)
    - aerosol radiative forcing
    - aerosol influence on cloud and precipitation formation
  - Nearly all “classical” NWP models have the effects parameterised, in most cases hard-coded into the corresponding schemes
    - schemes themselves are developed and tested for “average” aerosol content $\Rightarrow$ a dynamic composition is a limp to the dark
    - parameterizations of these schemes is made deliberately crude (and robust to variations of actual composition), thus diminishing the effect of dynamic composition

Steps forward

- Impact on radiation transfer and 3D atmospheric heating is the most-straightforward
  - though probably not the most powerful
  - HIRLAM radiative transfer scheme is much too crude to accommodate the CTM input
  - Depending on the episode and location, SILAM includes ~20-80% of the total aerosol amount $\Rightarrow$ a combination of modelled and "standard" aerosols may be needed
- Cloud microphysics: potentially more significant but requires complete re-shaping of the HIRLAM cloud formation scheme
- Simplified feasibility studies needed to evaluate the significance of each mechanism