Norwegian
Meteorological Institute
met.no

Coupling of air quality and weather forecasting – plans and progress at met.no

Viel Ødegaard, Leonor Tarrason and Jerzy Bartnicki

Air quality modeling systems in operational use at met.no

Three different air quality models for different purposes

- SNAP - Severe Nuclear Accident Program, lagrangian transport model, to be run interactively in case of nuclear accident
- EMEP model for assesment
- EPISODE/AirQUIS (owner: NILU) model run for urban air quality forecasting in winter season

OUTLINE

- Coupling of operational NWP and CTM models at met.no
- What are the main issues we see with off-line coupling?
- Plans

SNAP model - general

- **SNAP** = Severe Nuclear Accident Program developed at met.no
- on-line emergency model at met.no + on-line model at Norwegian Radiation Protection Authority in case of nuclear accident
- Lagrangian particle model
- Gases, noble gases, particles of different size and density
- Advection and diffusion (Random Walk)
- Dry deposition (gravitational settling velocity for particles)
- Wet deposition (function of size and precipitation for particles)
- Meteorological input from HIRLAM 10 or 20km resolution and from ECMWF

HIRLAM → SNAP

- One way coupling: HIRLAM to SNAP
- HIRLAM provides updated forecast of meteorological data for SNAP on-line for operational applications
- Most important meteorological input: 3-D wind fields and precipitation
- Time resolution for meteorological input is 3 hrs in operational applications (1hour in same of the historical simulations)

The Unified EMEP model

- developed at met.no for simulating atmospheric transport and deposition of acidifying and eutrophying compounds, as well as photo-oxidans over Europe.
- The model domain covers Europe and the Atlantic Ocean with the grid size 50×50 km^2, 20 sigma layers reaching up to 100 hPa with approximately 10 off these layers are placed below 2 km
- Operationally, model simulates one year period of the transport on a domain that covers Europe and the Atlantic Ocean with the grid size 50×50 km^2. The current results of the model runs are available for the years 1980, 1985, 1990 and each year from 1995 to 2004.
- The Unified EMEP models uses 3-hourly resolution meteorological data from PARLAM-PS model, a dedicated version of the HIRLAM model.

EMEP Unified uses presently 3 main sets of meteorological data

- **ECMWF**
  - EMEP global – ECMWF IFS 1x1º
  - EMEP hemispheric – ECMWF ERA 40 with 2.5x2.5º
  - EMEP regional forecasting – ECMWF IFS 0.25x0.25 º
- **HIRLAM**
  - *EMEP regional – HIRLAM PS 50x50 km (*operational)*
  - EMEP regional new - HIRLAM 12x12km
- **Other**
  - EMEP4UK – WRF – UM 4x4 km
  - EMEP4HR – WRF - ALADIN 10x10km
  - EMEP4SE – MM5, WRF 4x4 km

HIRLAM PS parameters for EMEP

Table 3.1: Archived Meteorological Data Used in EMEP Model

Parameter	Unit	Description	Main Purpose
3D fields - for 20 σ levels			
u,v	m/s	Wind velocity components	Advection
q	kg/kg	Specific humidity	Chemical reactions, dry deposition
$\dot{\sigma}$	s^{-1}	Vertical wind in σ coordinates	vertical advection
θ	K	Potential temperature	Chemical reactions, eddy diffusion
CL	%	Cloud cover	Wet removal, photolysis
PR	mm	Precipitation	Wet and dry deposition
2D fields - for Surface			
Ps	hPa	Surface pressure	Surface air density
T^2	K	Temperature at 2m height	Dry deposition, stability
H	$W m^{-2}$	Surface flux of sensible heat	Dry deposition, stability
τ	$M m^{-2}$	Surface stress	Dry deposition, stability
LE	$W m^{-2}$	Surface flux of latent heat	Dry deposition

Urban air quality forecasting

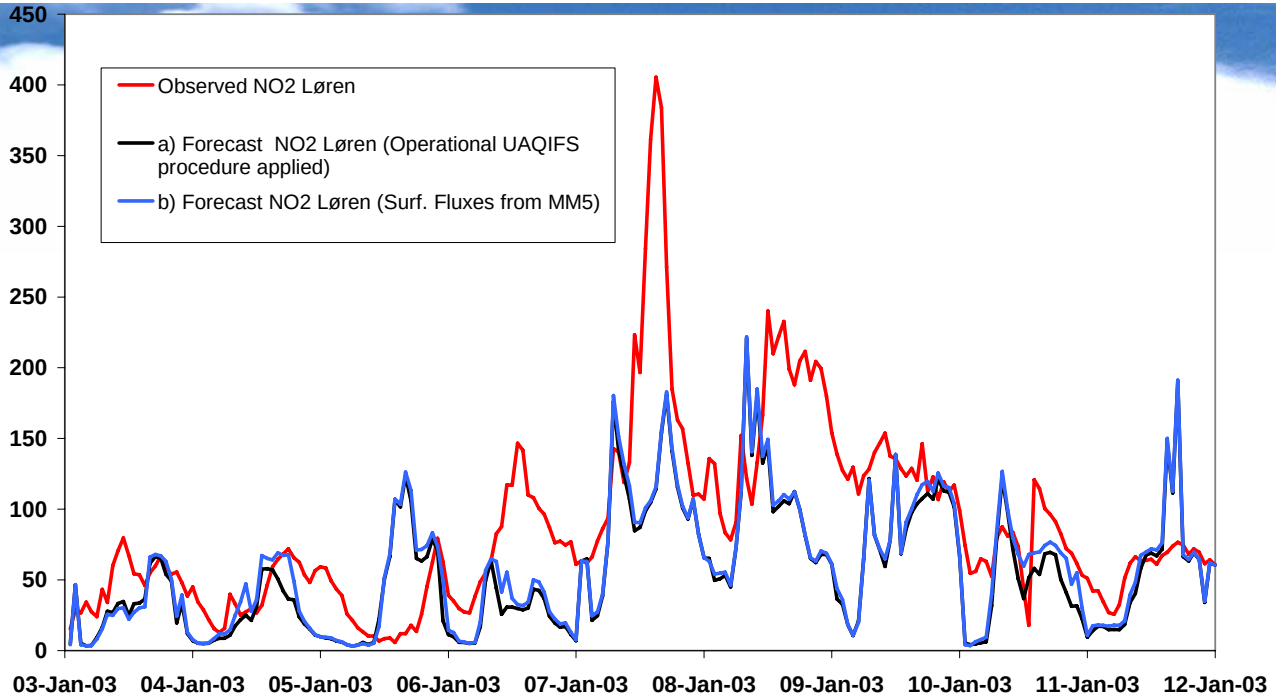
- operational system at met.no: MM5 – interface – AirQUIS
- running daily 48 hours forecasts for 6 Norwegian cities 1x1km horizontal resolution
- used for forecasting urban air quality during winter season. Norwegian cities are typically located in low elevated areas surrounded by hills and mountains. Winter time inversions inhibit ventilation of pollution.
- results distributed to end-users (forecasters) via internet

AirQUIS

- eulerian gridpoint model
- point source emissions, line source emissions and area source emissions
- components: pm_{10}, $pm_{2.5}$, no_2

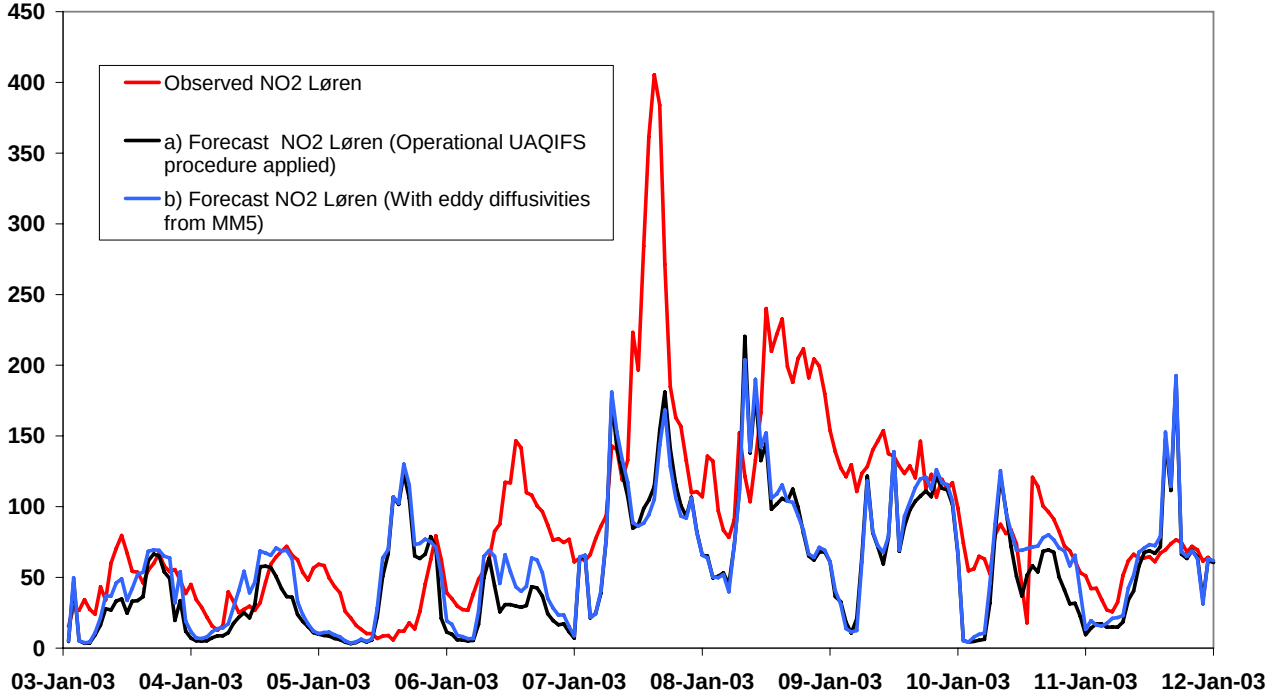
MM5 to AirQUIS

- constant parameters: topography, surface roughness
- surface parameters: precipitation, cloud cover, mixing height, soil temperature
- 2d parameters lowest level: temperature, dew point temperature, relative humidity, vertical temperature gradient
- 3d parameter: wind (10 levels)
- hourly data
- horizontal interpolation polar stereographic grid to utm
- no vertical interpolation (similarly defined vertical coordinate)
- meteorological pre-processor calculating dispersion parameters based on Monin-Obukhov similarity theory

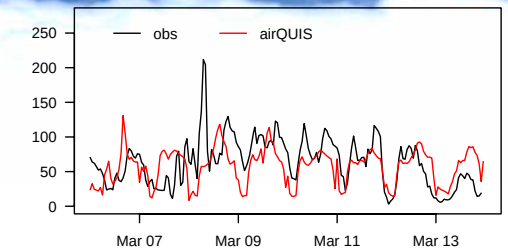


Which are the weakest parts of the off-line systems – the met models, the CTM models or the interface?

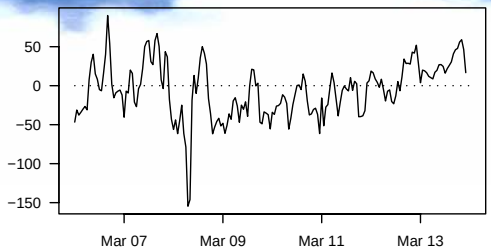
The air quality forecasts recalculated with direct application of the MM5 estimated 3-dimensional fields of surface fluxes, eddy diffusivities for heat (right)



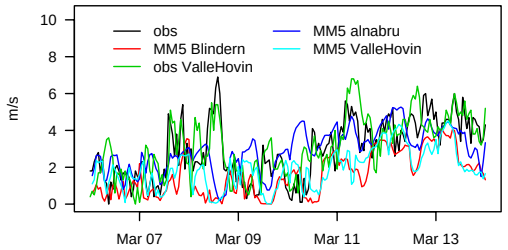
NO2 alnabru



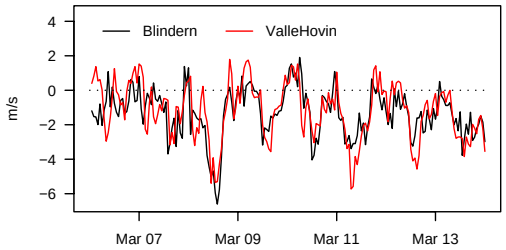
NO2 forecast error



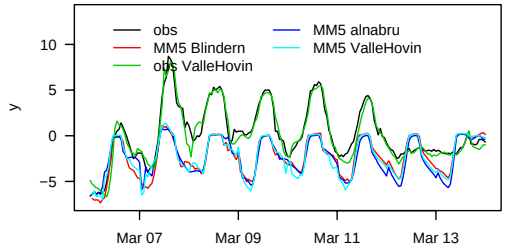
10m wind speed



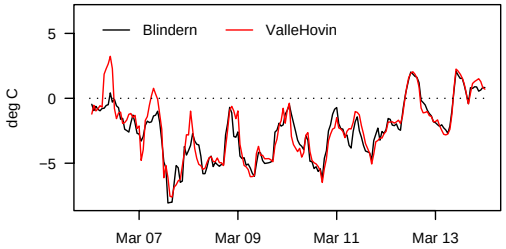
10m WS forecast error



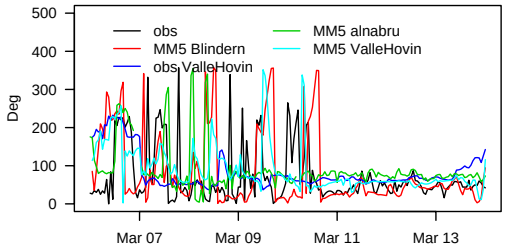
2m temperature



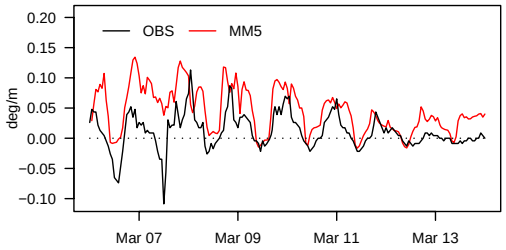
T2m forecast error



10m wind direction



stability − dTdz ValleHovin



EMEP model and interpolation issues

Up to now, EMEP air quality modelling adapted meteorology to the EMEP emission grid through the development of special polar stereographic NWP model versions

- Advantages:
  - Avoids introduction of interpolation errors in the air pollution model
- Drawbacks:
  - Resource demanding update of special "taylor-made version"
  - Little flexibility for further uses of the model by different community of users
- Future:
  - ✓ Allow the model to be run in all types of spheric coordinates,
  - ✓ with free choice of horizontal resolution and
  - ✓ different choices of vertical coordinates
  - ✓ Adapt the EMEP Unified model to the coordinate system of the available meteorology, and not the other way around, since interpolations of model meteorological input always introduce significant errors. It is better to interpolate emission data than the meteorological data

Still, there are remaining issues on off-line model integration

For instance, the parametrization of boundary layer processes is needed in air quality models for:

- Sophisticated dry deposition description in EMEP for effect and impact calculations
- Emissions from Biogenic sources

  - ✓ Needs consistent land use data in NWP and CTM
  - ✓ LAI information
  - ✓ Information on vegetation types is presently required for all state-of art air quality models while coarser information is presently used in NWP models.

Land use in EMEP model

Hirlam uses at present Kuo based convective scheme

Discussions have been initiated to take into account the requirements of the air quality applications, when deciding on parameterisation schemes in NWP. Important processes and parameters should be present.

Table 5.1: Land-use classes used in EMEP model, with default heights (h), albedo (α), growing-season and LAI-parameters

Code	Landcover	h	α	Growing	LAI parameters			
		(m)	(%)	season	LAI min	LAI max	L S	L E
				(SGS-EGS)				
CF	Temperate/boreal coniferous forests	20 †	12	All year	3.4	4.5	192	96
DF	Temperate/boreal deciduous forests	20 †	16	90-270	3.5	5.0	56	92
NF	Mediterranean needleleaf forests	15	12	All year	3.5	3.5	192	96
BF	Mediterranean broadleaf forests	15	16	All year	3.5	3.5	192	96
TC	Temperate Crops	1	20	105-197 *	0.0	3.5	70	22
MC	Mediterranean Crops	2	20	105-197 *	0.0	3.0	70	44
RC	Root Crops	1	20	130-250	0.0	4.2	35	65
SNL	Seminatural/Moorland	0.5	14	All year	2.0	3.0	192	96
GR	Grassland	0.5	20	All year	2.0	3.5	140	135
MS	Mediterranean scrub	3	20	All year	2.5	2.5	1	1
WE	Wetlands	0.5	14	All year	na	na	na	na
TU	Tundra	0.5	15	All year	na	na	na	na
DE	Desert	0	25	All year	na	na	na	na
W	Water	0	8	All year	na	na	na	na
I	Ice	0	70	All year	na	na	na	na
U	Urban	10	18	All year	na	na	na	na

Notes: For explanation of LAI parameters, see section 5.1 and figure 5.1.

† For boreal forests north of 60deg.N, height is reduced by 5% per degree extra latitude, down to a minimum of 6 m for 74deg.N and above.

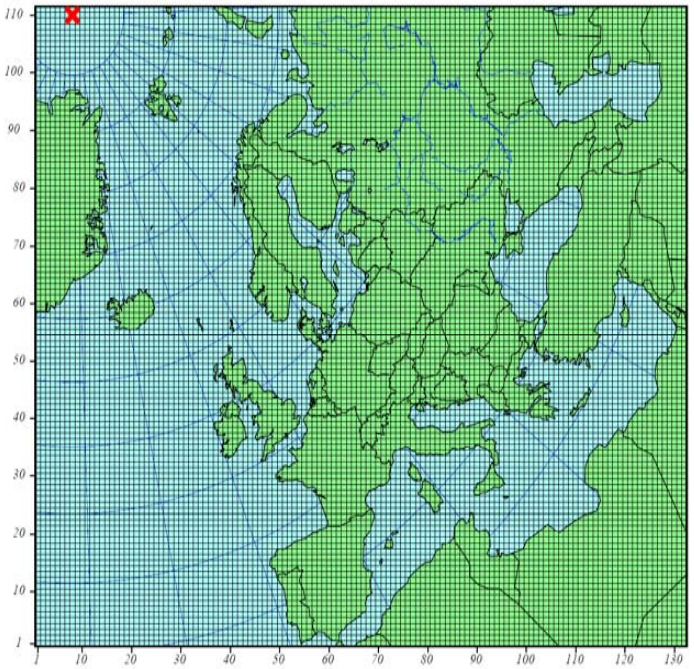
* For these crops growing seasons vary with location. Currently we use a simple latitude-based function, although this will likely be replaced in future. Default values here apply to 50deg.N. SGS and EGS occur earlier at the rate of 3 days per degree latitude on moving south, or increase on moving north.

- HIRLAM land use
  - Water, lakes
  - Ice
  - Forests
  - Grass
  - Bareland
- Not satisfactory, basic information on vegetation type is missing !

SNAP - Future plans

- Small scale SNAP version for simulating local effects in the range of 30 -50 km (already in 2007)
- Coupling to UM model or small scale HIRLAM model
- Full coupling of SNAP to regional HIRLAM model (SNAP as subroutine in HIRLAM code)

EMEP at national and local scale



Main goals:

1. Allow national experts to do their own assessments of the origin of local air pollution with consistent regional boundary conditions from EMEP Unified
2. Allow improved air pollution impact estimations at national level

Additional advantages:

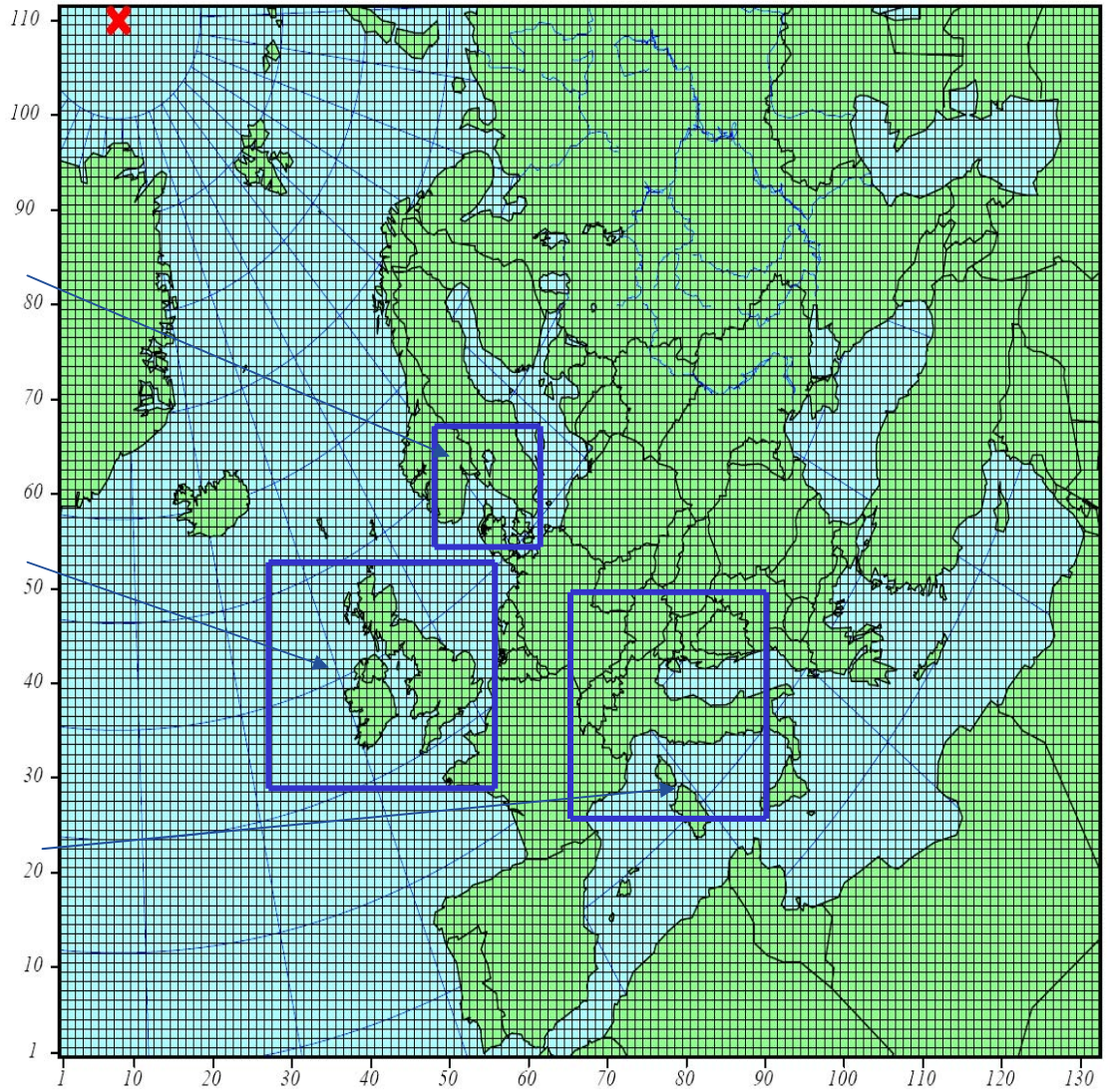
- Improved flexibility and robustness of the EMEP model by allowing use with different meteorology
- Improved evaluation and testing of the EMEP model results by a large community of users

EMEP at national and local scale

EMEP4SE

EMEP4UK

EMEP4HR



National projects in UK, Croatia and Sweden

Recommendations

Adapt the EMEP Unified model to the coordinate system of the available meteorology and not the other way around

For EMEP long term applications, apply mass conservation filters to the forecast data

Urban air quality forecasting – progress and plans

- AirQUIS coupled to UK-UM, run in parallel since mid February 2007
- interface built similar to MM5-AirQUIS: same parameters transferred, horizontal interpolation from 1x1km spherical rotated grid to 1x1km utm grid, vertical interpolation (10 AirQUIS layers are located within the range of 11 lowest UM layers)
- evaluation of parallel run and probably move to UM from winter season 2007/2008

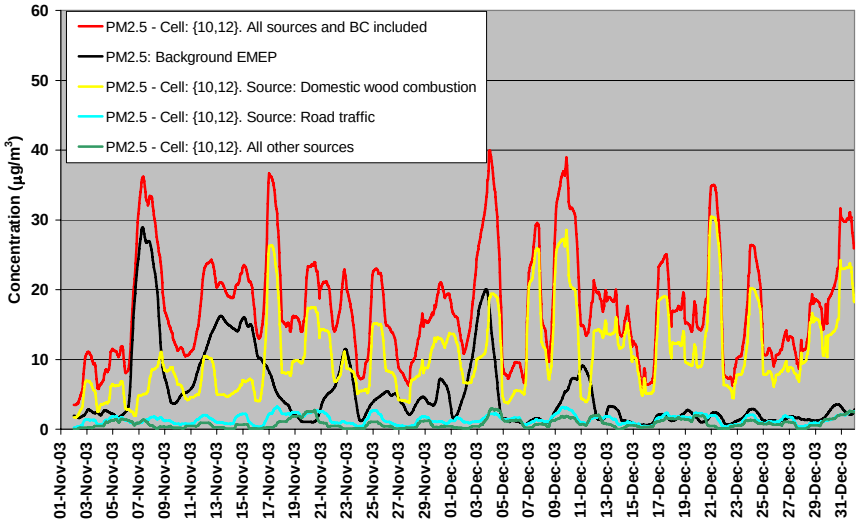
Towards a fully integrated system?

- EMEP model run inside HIRLAM?
- EnviroHIRLAM?
- EMEP model run inside a nested system of HIRLAM and some high resolution non-hydrostatic NWP (HARMONIE, ALADIN, UM ..)?
- Continuation of the urban air quality forecasting system - co-operation with NILU?

Influence of transboundary PM in Oslo

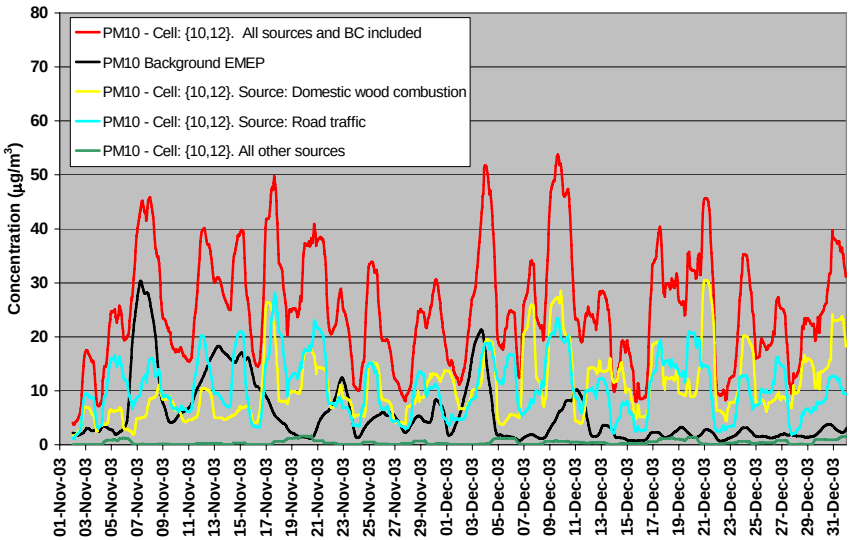
Nested EMEP – EPISODE Local scale model

$PM_{2.5}$ Source Contribution Grid Cell (10,12)



Domestic heating and LRT dominates PM2.5

PM_{10} Source Contribution Grid Cell (10,12)



Road traffic and resuspension dominates PM10