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

COST Action TD1105

INTERNATIONAL WG1-WG4 MEETING on

New Sensing Technologies and Modelling for Air-Pollution Monitoring

Institute for Environment and Development - IDAD

Aveiro, Portugal, 14 - 15 October 2014

Action Start date: 01/07/2012 - Action End date: 30/06/2016 - Year 3: 2014-15 (*Ongoing Action*)

Emergency Response and Chemical Weather Forecast Systems in NIMH

Speaker **Kiril Slavov**

Invited Expert

NIMH / Bulgaria

COST is supported by the EU Framework Programme

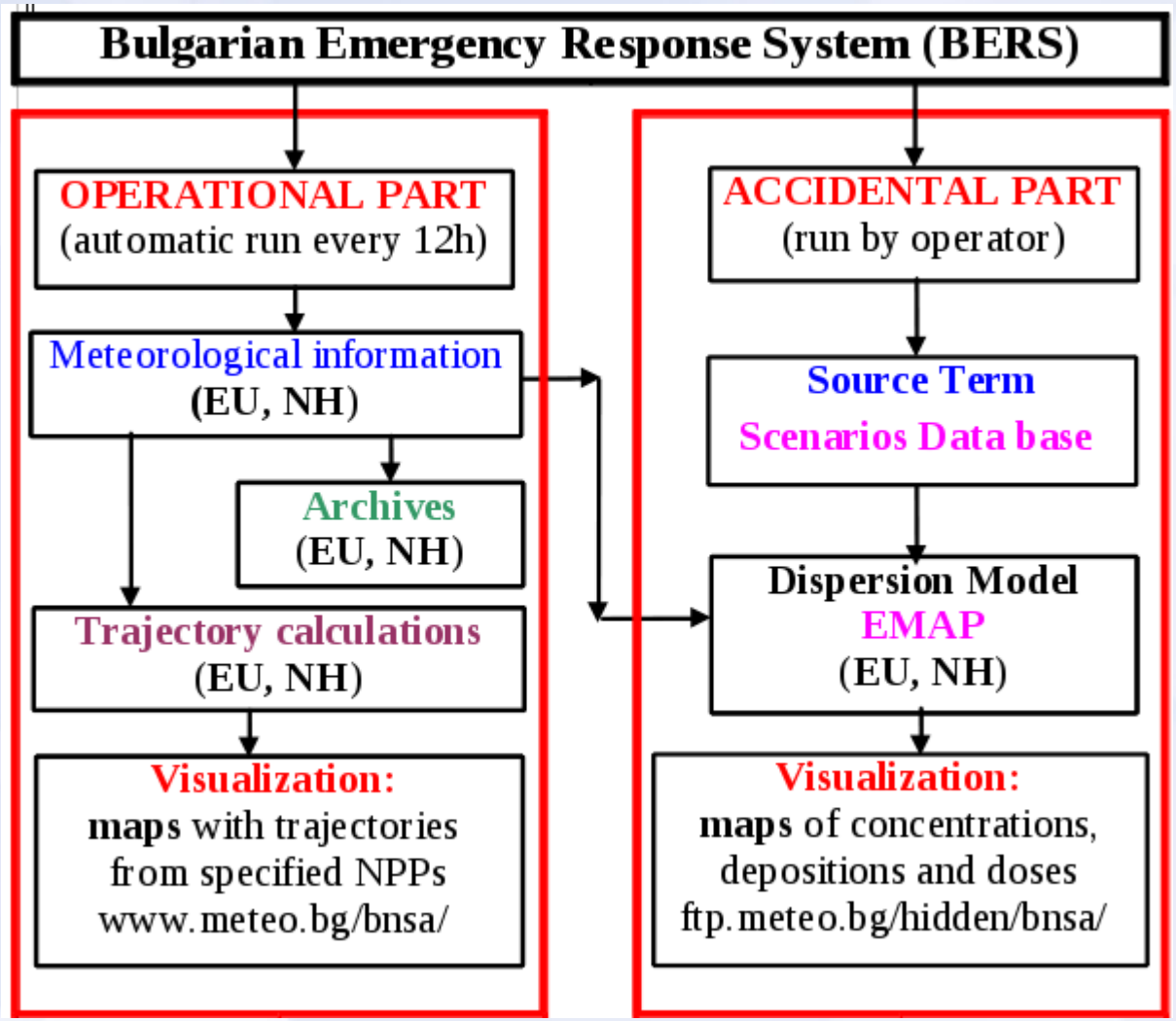
ESF provides the COST Office through a European Commission contract

BERS - context and objectives ...

Why did we build BERS?

- **Nuclear Accidents – long range transport**
  Chernobyl, Fukushima ...
- **Volcano**
  Island Eyjafjallajokull - Millions of passengers stranded; 1.5 – 2 billions euros losses ...
- **Other "conventional" events**
  Jugoslavian wars, Iraq, Chelopech ...

… BERS - context and objectives …



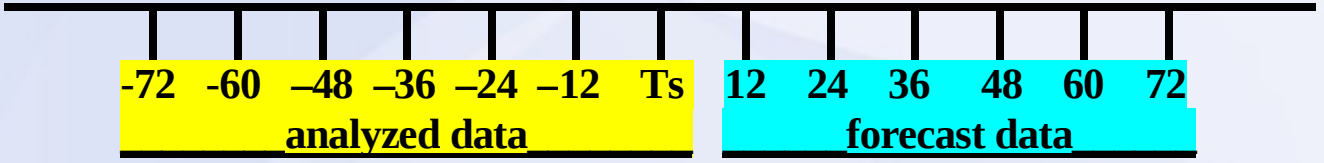
… BERS - context and objectives …

Meteorological pre-processing (input to the built in PBL model)

Two sources of met-data: from UK Met.Office, Bracknell (2.5°, GRID)
from DWD, Offenbach (1.5°, GRIB)

Type of meteo-data: U_{850}, V_{850}, T_{850}, T_{gl}, Prec (Δt=12 h)

Operational data base (Ts - current synoptic term)

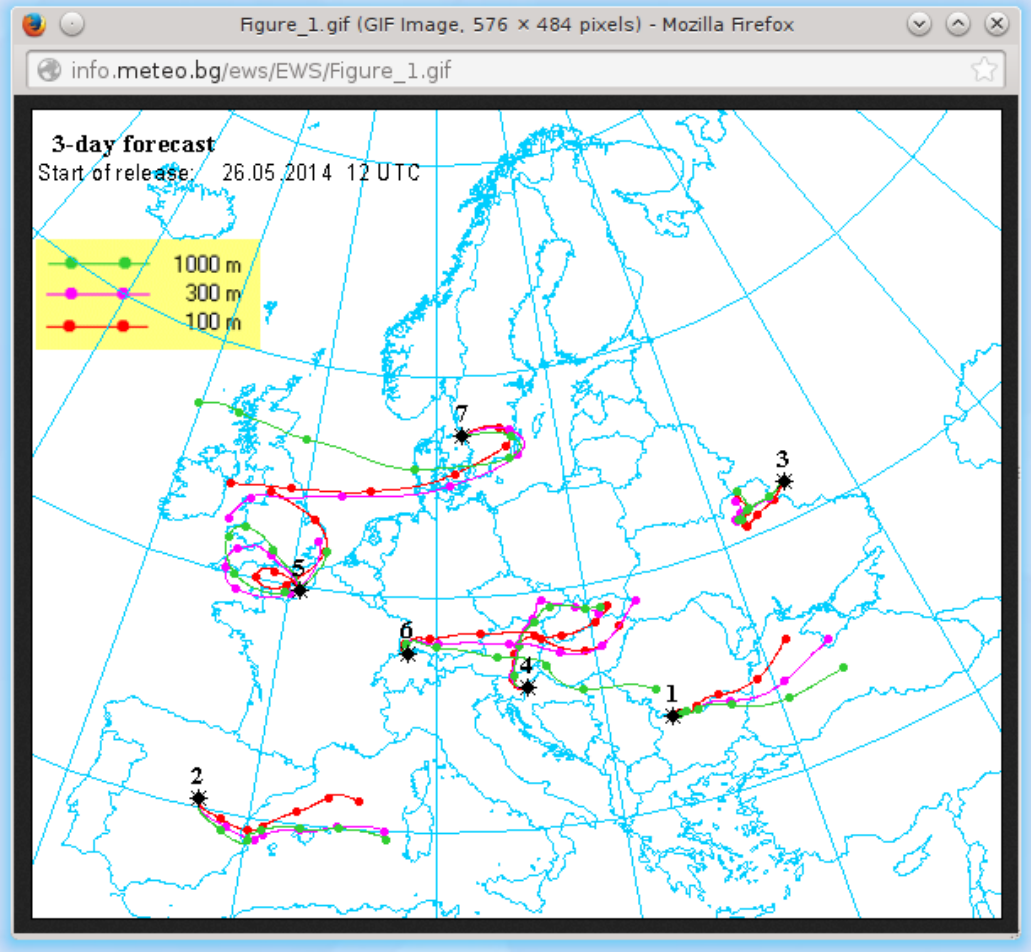


Archive data base

Trajectory calculations

$$X(t+\Delta t) = X(t) + V(t).\Delta t$$

Current activities ...



Фигура 1

1. Козлодуй, BG
2. Хосе Кабрерас, ES
3. Курск, RU
4. Кришко, SL
5. Палуел, FR
6. Лейбщадт, CH
7. Рингхалс, SE

http://info.meteo.bg/ews/index-en.html

… BERS - context and objectives …

Dispersion model EMAP (Eulerian Model for Air Pollution)

Time splitting approach.
Cartesian coordinate system in horizontal (Arakawa's C type).
Log-linear terrain-following staggered Z-coordinate system.
Processes involved:

Advection

TRAP scheme

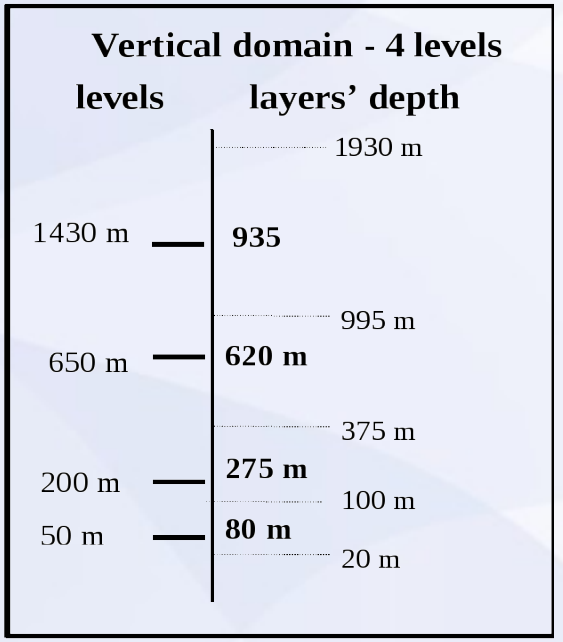
Bott's type
explicit
positively definite
conservative
limited numerical viscosity
very fast

Horizontal diffusion:

the simplest **explicit** scheme

Vertical difusion

the simplest **implicit** scheme
variable steps
variable diffusion coefficient



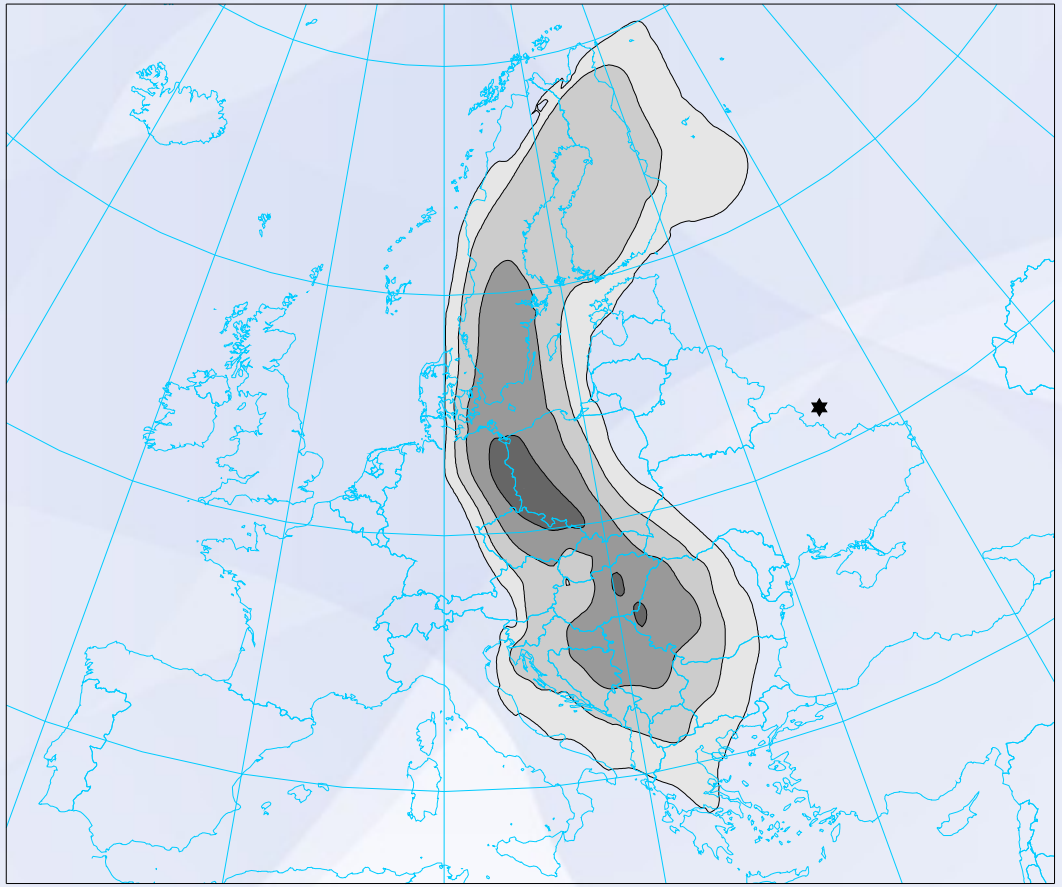
Dry deposition: bottom boundary condition to vertical diffusion equation

Wet removal: simple decay rate

… Current activities

NATIONAL INSTITUTE OF METEOROLOGY AND HYDROLOGY

Numerical Simulation of Radioactive Pollution Distribution



Ground-Level Concentration in Air (Bq/cub.m)

SIMULATION DESCRIPTION:

Source Location (*):
51.75N 35.62E

Release Rate:
0.10E+11 Bq/s

Release Height:
650

Release Duration:
12.00 hrs

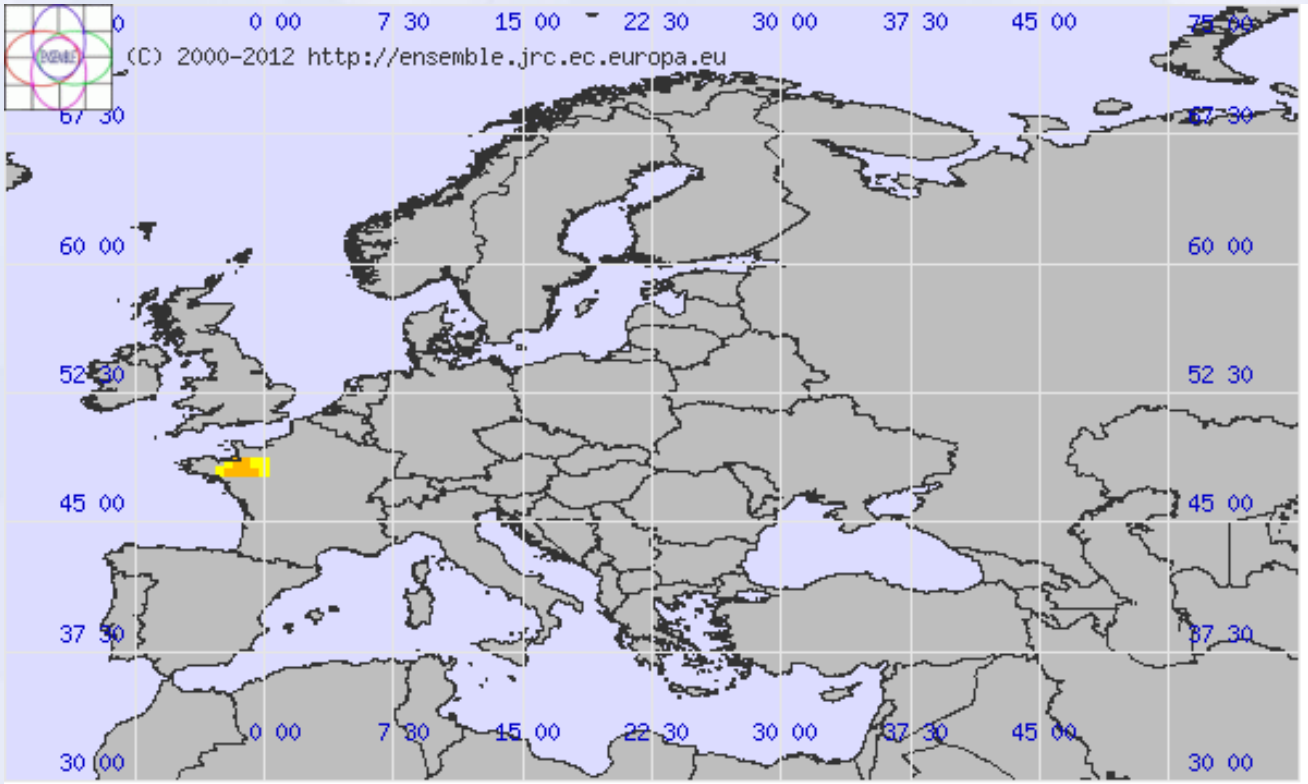
Start of Release:
30/11/01 09:00 UTC

Forecast for:
03/12/01 09:00 UTC

Maximum Value:
0.266E-01

0.1
0.01
0.001
0.0001
1E-005

RESULTS ...



Case 0901-001 - Space overlap - PMCH Concentration (0 m agl)

Date and time: 1994-10-23 18:00 UTC (+2h0m after release start)

Threshold: 1.00E-12

Overlap: 55.0%

Created by user dsyrakov on 2012-01-05 12:00:33 UTC

Release from: Rennes (FR)

Coordinates: -2 48.05

Start: 1994-10-23 16:00 UTC

Figure of Merit in Space

… RESULTS

Verification of EMAP: comparison with ETEX-I data

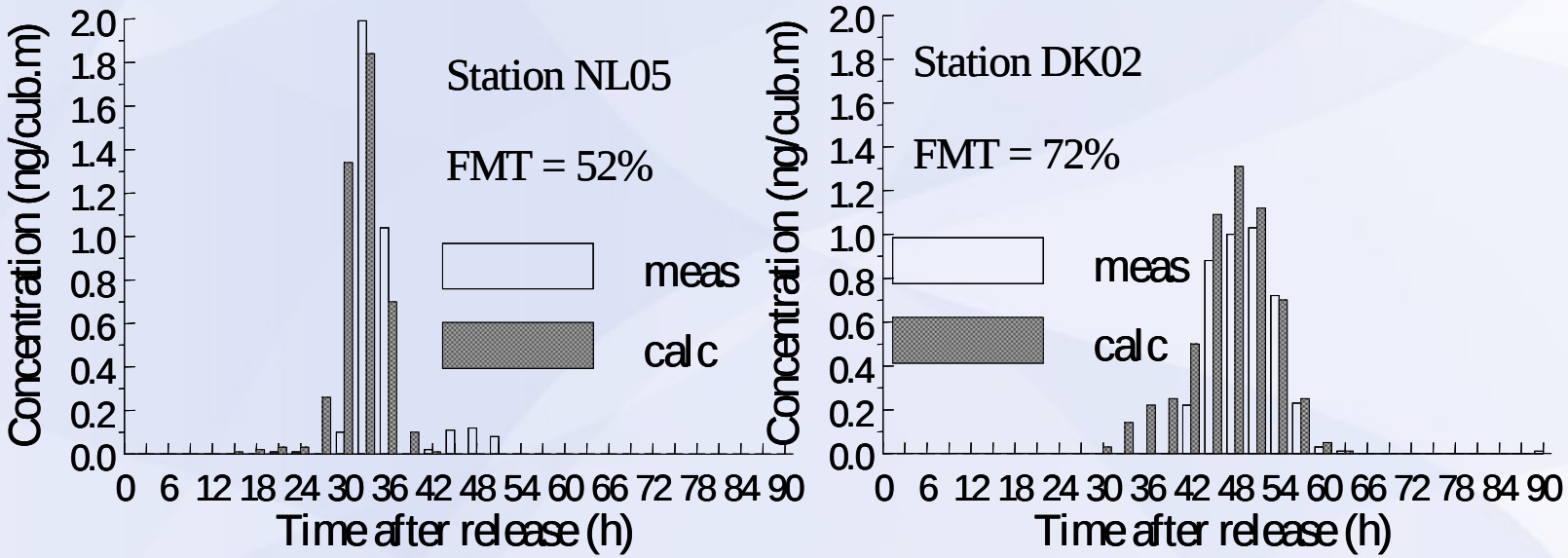


Figure of Merit in Time

BERS - Activities

UPGRADES of BERS

2001 – putting of BERS into operation

2007 – multi-nuclide treatment, exposure doses calculations

2010 – for ENSEMBLE Volcano exercise:

- **new vertical structure – up to 12 km, exercise specific levels**
- **vertical diffusion coefficients aloft – 10% of PBL ones**
- **NCEP meteorology added over 2 km (to the DWD data)**
- **continuous source long term calculations**

2011 – for ENSEMBLE Fukushima exercise:

- **increase the space resolution of NH from 300 to 25 km**
- **respective upgrade of meteorological pre-processing**
- **respective upgrade of EMAP and visualizing software**
- **new Figures 7, 8 added to BERS web-site containing the results from every day hypothetical release simulations (animated).**

2014 – new data format and source for meteorological information

CW - context and objectives ...

WHAT IS THIS: "CHEMICAL WEATHER"?

Analogy: Meteorological Weather ⇔ Chemical Weather

In fact: Forecast of Pollution Levels in a particular area for particular time

COST Action ES0602 **"Towards a European Network on Chemical Weather Forecasting and Information Systems"** (http://www.chemicalweather.eu/Domains)

Aim: To setup a forum for benchmarking, harmonizing and developing approaches and practices for chemical weather forecasting network and near-real-time information systems in Europe (exchange of information, BCs).

Grant from National Science Fund (Contract №Д002-161/16.12.2008).

Prototype of the System (BgCWFIS,ver.1) was created

EC FP7 Project PASSODOBLE (NIGGG) – version 2 created

… CW - context and objectives ...

MODELS USED, EXPERIENCE, DOMAINS

The US EPA Models-3 modeling system is planned to be used, consisting of:

- **CMAQ - (Community Multi-scale Air Quality model), the chemical-transport model (CTM) – the most important part of the System;**
- **WRF - Weather Research and Forecasting Model, the meteorological pre-processor to CMAQ;**
- **SMOKE (Sparse Matrix Operator Kernel Emissions Modelling System) – emission pre-processor to CMAQ.**

In addition FORTRAN programs and Linux Scripts created and used

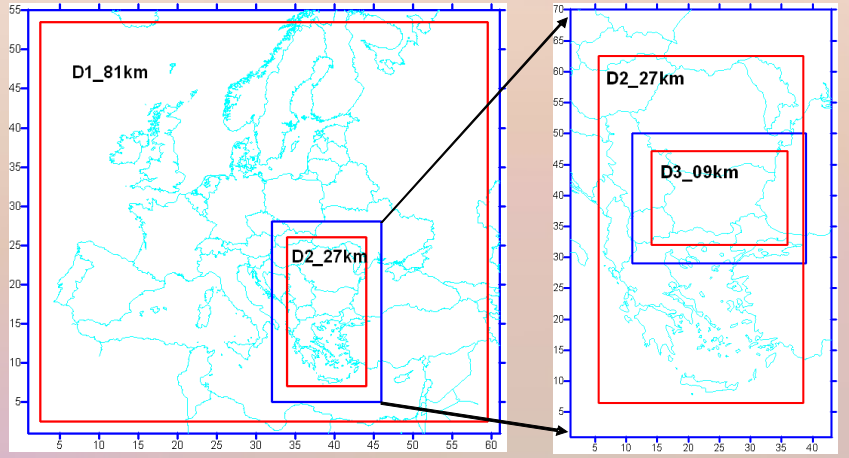
Experience: (EC FP5 and FP6 Projects BULAIR, ACCENT, QUANTIFY)

- **Early warning and forecast system for air quality around TPPs "M-I"**
- **Climate change impact on air quality – CECILIA project**

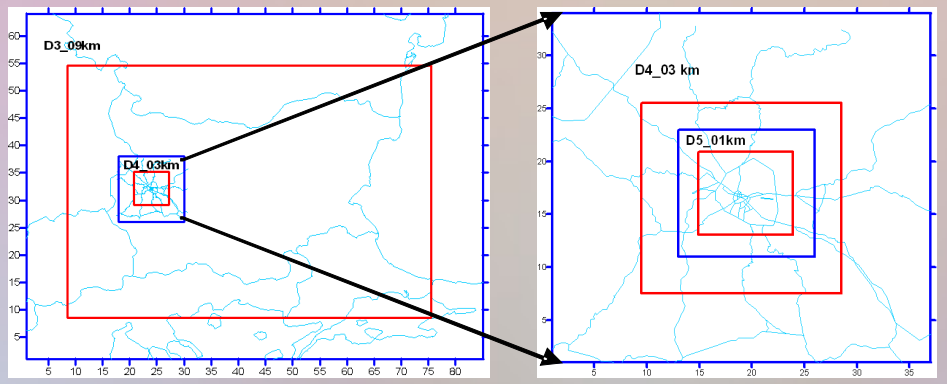
… CW - context and objectives ...

Five nested domains with resolution 81 km, 27 km, 9 km, 3 km, 1 km

For convenience divided to two parts



BgCWFIS ver.2.1 domains: **Europe – Balkan Peninsula - Bulgaria**

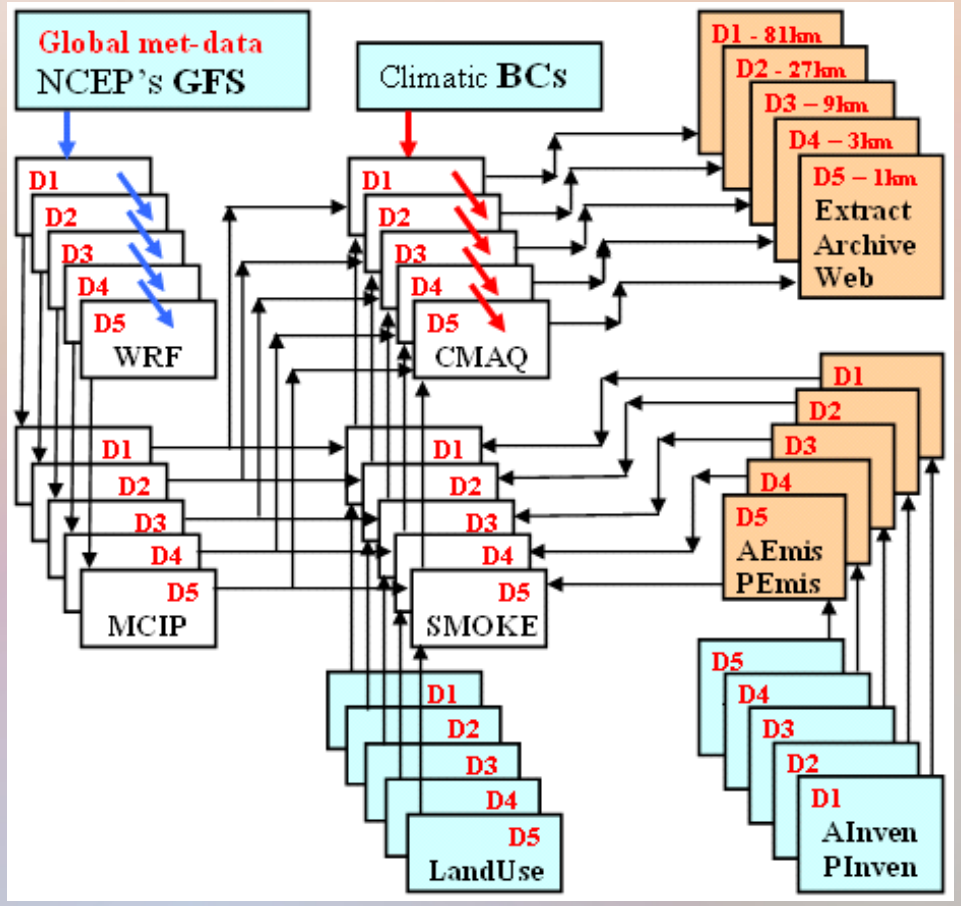


BgCWFIS ver.2.2 domains: **Bulgaria – Sofia district – Sofia city**

… CW - context and objectives ...

3. OPERATIONAL DESIGN OF BgCWFIS, version 2

BgCWFIS ver.2 runs automatically every day at 00 UTC
Produces 72-hour forecast on hourly bases



- **White boxes:**
  Models-3 elements
- **Blue boxes:**
  Input data
- **Brown boxes:**
  Own Fortran routines.

=== ==========

TRANSFER OF DATA BETWEEN DOMAINS:

- **Blue arrows:**
  Meteorological BCs
- **Red arrows:**
  Chemical BCs
- **Black arrows:**
  Exchange of data inside each domain

… CW - context and objectives ...

4. METEOROLOGICAL CALCULATIONS (WRF and MCIP)

Weather Research and Forecasting (WRF) Model - successor to the MM5
WRF is a fully compressible and non-hydrostatic.
Terrain-following hydrostatic pressure coordinates.

Here, ARW (Advanced Research WRF), version 3.2.1, is exploited.
The vertical structure is of 27 levels.
The Analysis Nudging option (FDDA) switched on (first domain, only)

Big variety of physics options that can be combined in any way. Here:

Physics Options	Parameterization
Microphysics	WSM6 scheme (Hong and Lim, 2006)
Cumulus Parameterization	Kain-Fritsch scheme (Kain, 2004)
Planetary Boundary Layer	YSU scheme (Hong et al., 2006)
Longwave Radiation	RRTM scheme (Mlawer et al., 1997)
Shortwave Radiation	Dudhia scheme (Dudhia, 1989)
Land Surface Model	NOAH LSM scheme (Chen and Dudhia, 2001)

Free Meteorological data: US NCEP's GFS (Global Forecast System)
Each day, at 00 UTM, 84-hour forecast downloaded, first 12 hours - spin-up.

MCIP (Meteorology-Chemistry Interface Processor) makes met. input to CMAQ and SMOKE, vertical interpolation to CMAQ's 14 sigma-levels.

… CW - context and objectives ...

EMISSION PROCESSING (the most uncertain part of the task)

Two kinds of emissions used in BgCWFIS, ver.2:
Anthropogenic emissions (emission inventories as primary data)
Biogenic emission sources (BgS) – calculated by SMOKE

Emission Inventories: determined by direct measurements (some stacks) and by expert calculations – CORINAIR, SNAPs, big areas

BgCWFIS ver.2.1 inventories: 2005 TNO data (~7× 8 km), 10 SNAPs, 8 pollututants. (CH4, CO, NH3, NMVOC, NOx, SOx, PM10, PM2.5)

BgCWFIS ver.2.2 inventories: 2010 Bulgarian Inventory (MOSW) - SNAP 1-6: by sources, SNAP 7-10: by country totals; same 8 pollutants

Emission Processing: gridding, temporal (vertical) allocation, speciation

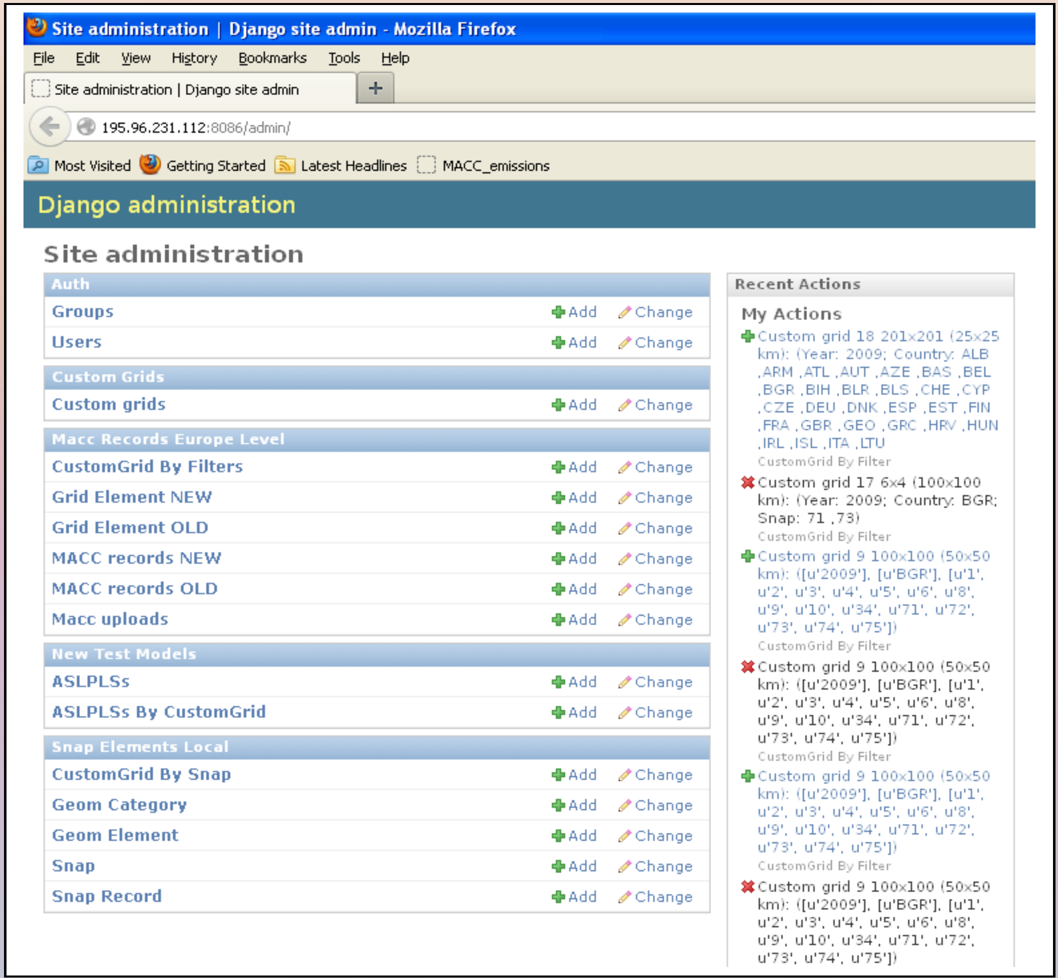
Temporal allocation profiles (TNO – Daily, Weekly, Yearly)
Speciation profiles (US EPA,)

- **VOC's and PM2.5 speciation profiles**
- **Coincidence between SNAPs and US SCC (several sources per SNAP)**
- **Weighted average for every SNAP; weight - % of pollution created**

… CW - context and objectives ...

Gridding: Web-based GIS System created (GridEmis)

Main Board



… CW - context and objectives ...

Emissions producing (time allocation and speciation):

Area Soureces (AS): FORTRAN Code **AEmis** created.

- **Input:** gridded inventory, temporal and speciation profiles
- **Output:** 2-D NetCDF files for 1-hour emissions for the 3 forecast days
- **Pollutants:** CO, NH3, NO, NO2, SO2, SULF, 10 VOCs, PMC, 5 PM2.5

Large Point Sources (LPS): FORTRAN Code **PEmis** created.

- **Input:** gridded inventory, temporal, vertical and speciation profiles
- **Output:** 3-D NetCDF files for 1-hour emissions for the 3 forecast days
- **Pollutants:** the same 22 lump pollutants

Biogenic Source (BgS): SMOKE's *Biogenic Processing* used

- **Input:** gridded LandUse (USGS data base, extracted by WRF)
- **Output:** 2-D NetCDF files for 1-hour emissions for the 3 forecast days
- **Pollutants:** CO, NO and 10 VOCs

Final CMAQ emission input: SMOKE's *MrgGrid Processing* used to merge AS-, LPS- and BgS-emission files in a common NetCDF file

… CW - context and objectives ...

CMAQ CALCULATIONS

Initial conditions: Previous run's concentration file

Boundary conditions: From the senior domain; for Europe - climate

CMAQ Output

NetCDF file on 1-hour basis for the 3 days of forecast (14 layers)

Pollutants: 78 pollutants, from which:

- 52 gaseous (NOx, SOx, Ozone etc.)
- 21 aerosols (Coarse, Aitken and Accumulation modes)
- 5 aerosol distributions (3 by number, 2 by area)

Post-processing

- Extracting surface values of 19 most important pollutants
- Creating and archiving of a NetCDF file, containing this data
- Visualization of NO2, SO2, Ozone and PM10 fields (automatic) PAVE software used

Current activities

BgCWFISv2 PERFORMANCE (http://info.meteo.bg/cw2.1/)

BULGARIAN ACADEMY OF SCIENCE
National Institute of Meteorology and Hydrology

POLLUTANTS

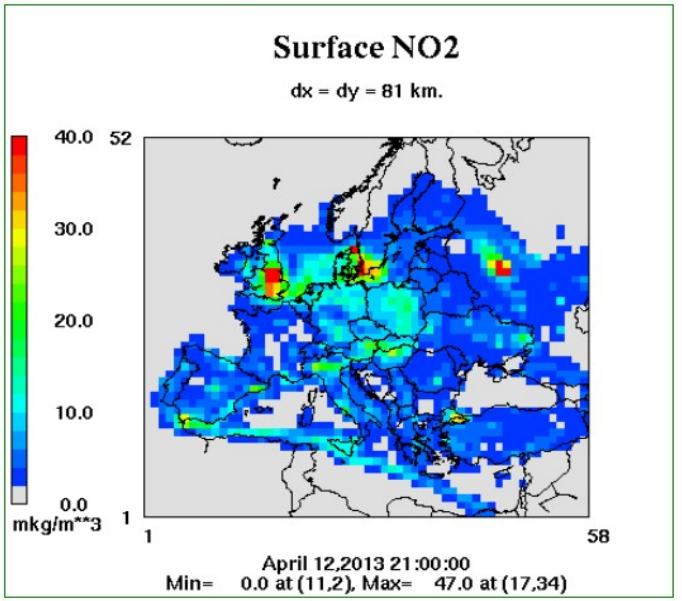
Nitrogen dioxide (NO2)
72-hours forecast
Sulfur dioxide (SO2)
72-hours forecast

OZONE
72-hours forecast

First day
Daily maxima
8-hour daily maxima
Second day
Daily maxima
8-hour daily maxima
Third day
Daily maxima
8-hour daily maxima

PM10
72-hours forecast

Description of Bulgarian Chemical Weather Forecast and Information System (ver. 2)(PDF)



Bulgarian legislation for Nitrogen Dioxide (NO2):
Hourly threshold value (HT): 200 µg/m3
Permitted number of exceedings of HT in a year: 18
Yearly threshold value (YT): 40 µg/m3
Permitted number of exceedings of YT: impermissible
Alert threshold (hourly value): 400 µg/m3

+1h +6h +12h +18h +24h +30h +36h +42h +48h +54h +60h +66h +72h
Play

DOMAINS

ФОНД НАУЧНИ ИЗСЛЕДВАНИЯ
Министерство на образованието, младежта и науката

Funded by the National Science Fund of Bulgaria

CONCLUSIONS - BERS

1. In this ENSEMBLE exercises, the BERS produced concentration and deposition fields are presented in evolution vs. the ensemble ones

2. Despite many unfavourable circumstances:

- **very poor met-data – only earth surface and 850 hPa level**
- **very low space resolution of the met-data – 1.5 deg**
- **very low time resolution of the met-data – 12 h**
- **the possibly most simple numerical schemes**

EMAP produces quite satisfactory results

3. All main features of the volcano ash and radioactivity distribution are captured by BERS and its dispersion model EMAP

All this means that BERS can be used with confidence in case of nuclear accidents and that NIMH with its BERS is a useful member of the ENSEMBLE Consortium.

CONCLUSIONS - CW

The Bulgarian Chemical Weather Forecast and Information System is designed on the base of US EPA Models-3 System: CMAQ (Chemical Transport Model), WRF (meteorological pre-processor) and SMOKE (emission pre-processor).

It comprises 5 nested domains: Europe (81 km resolution), Balkan Penin-sula (27 km), Bulgaria (9 km), Sofia district (3 km) and Sofia city (1 km).

The meteorological input to the system is the NCEP's GFS data (84-hour simulation, first 12 hours used for spinning-up followed by 3-day forecast).

The emission input exploits the high resolution inventory for year 2005 produced by TNO, the Netherlands and the National emission inventory for 2010, provided by MOSW. The inventory data is gridded by means of a specialized Web-based GIS system. Temporal allocation and speciation are applied. Biogenic emissions are prepared by SMOKE.

The system is run automatically every day at 00 UTM. The results of each System's run are post-processed in a way to archive the most important pollutants. Part of these pollutants is visualized as sequences of maps giving the evolution of the air quality over the various domains.

ACKNOWLEDGEMENTS

Grant from National Science Fund (Contract №Д002-161/16.12.2008).

Grant from National Science Fund (Contract № ДЦВП-02/1/29.12.2009).

COST Actions ES0602 and ES1004.

5thFP project BULAIR (Contract Nr. EVK2-CT-2002-80024).

6thFP Network of Excellence ACCENT (Contr. Nr. GOCE-CT-2002-500337).

6thFP Integrated Project QUANTIFY (Contract Nr. GOGE-003893).

7thFP project SEE-GRID-SCI (Contract Nr. FP7 –RI-211338).

7th FP project EGI-InSPIRE (Contract Nr. 261323).

7th FP project PASODOBLE (Contract Nr. 241557).

US EPA, NSEP, EMEP, TNO for providing free-of-charge models and data