

**Ivelina Georgieva and Nikolay Miloshev**

**National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences**

[iivanova@geophys.bas.bg](mailto:iivanova@geophys.bas.bg) [miloshev@geophys.bas.bg](mailto:miloshev@geophys.bas.bg)

## ABSTRACT

Some extensive numerical simulations of the atmospheric composition fields in Bulgaria have been recently performed and an ensemble, comprehensive enough as to provide statistically reliable assessment of the atmospheric composition climate – typical and extreme features of the special/temporal behavior, annual means and seasonal variations, etc. has been constructed.

The simulations were carried out using the US EPA Models-3 system for 7 year period from 2008 to 2014. As the NCEP Global Analysis Data with 1 degree resolution was used as meteorological background, the system nesting capabilities were applied for downscaling the simulations to a 9 km resolution over Bulgaria. The national emission inventory was used as an emission input for Bulgaria while outside the country the emissions were taken from the TNO high resolution inventory with  $0.25^\circ \times 0.125^\circ$  (about  $20 \times 15$  km) distributed over 10 emission categories (SNAP). Special pre-processing procedures are created for introducing temporal profiles and speciation of the emissions. The biogenic emissions of VOC are estimated by the model SMOKE.

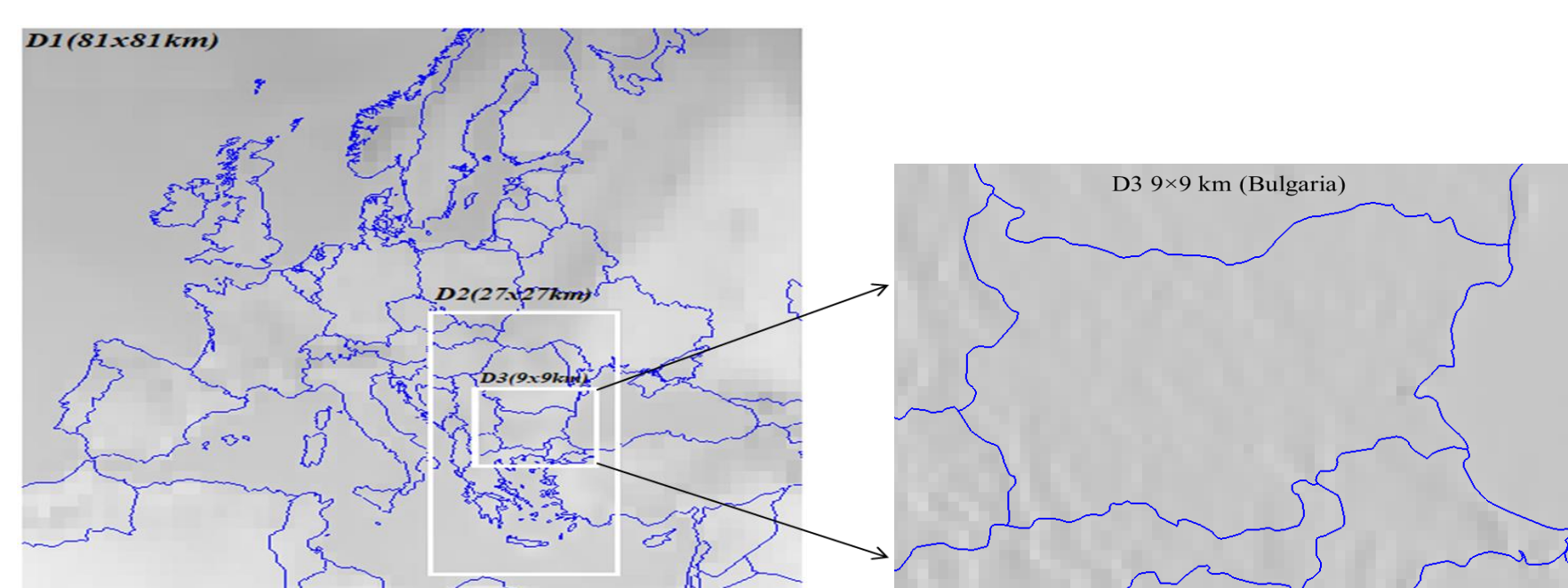
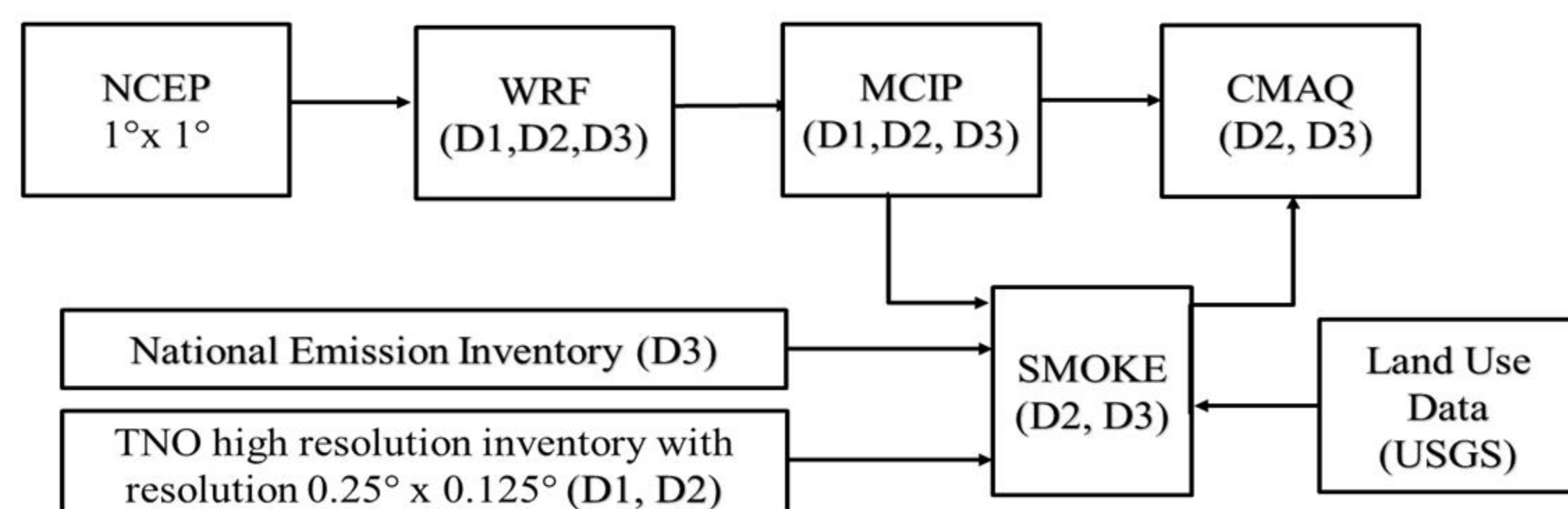
The air pollution pattern is formed as a result of interaction of different processes, so knowing the contribution of each for different meteorological conditions and given emission spatial configuration and temporal behavior could be interesting. The “Integrated Process Rate Analysis” model option was applied to discriminate the role of different dynamic and chemical processes for the air pollution formation in Bulgaria.

Different characteristics of the numerically obtained PM concentration fields of as well as of determining the contribution of different processes to the formation of surface PM concentrations will be demonstrated.

## MODELLING WORKFLOW

### US EPA Model-3 system used as modelling tool for 3D simulations

- Initial and Boundary Conditions - NCEP Global Analysis Data  $1^\circ \times 1^\circ$
- Meteorological model – WRF-ARW version 3.4.1
- Meteorology - Chemistry Interface - MCIP version 3.6
- Emission pre-processor - SMOKE
- Chemical-transport model - CMAQ version 4.6
- Spatial resolution - D1  $81 \times 81$  km (Europe), D2  $27 \times 27$  km (Balkan Peninsula), D3  $9 \times 9$  km (Bulgaria)
- Simulation period – 7 years (2008 – 2014)



## CONTRIBUTION OF DIFFERENT PROCESSES

The air pollution pattern is formed as a result of interaction of different processes!

The Models-3 “Integrated Process Rate Analysis” option was applied to discriminate the role of different dynamic and chemical processes for the air pollution pattern formation.

The procedure allows the concentration change for each compound for an hour  $\Delta C$  to be presented as a sum of the contribution of the processes, which determine the concentration:

**HADV** - Horizontal diffusion  
**ZADV** - Vertical diffusion  
**HDIF** - Horizontal advection  
**VDIF** - Vertical advection  
**EMIS** - Emissions  
**DDEP** - Dry deposition  
**CLDS** - Cloud processes  
**CHEM** - Chemistry processes  
**AERO** - Aerosol processes

$\Delta C$  – Sum of the contribution of the processes (the concentration change):  $\Delta C = \sum_{i=1}^n \Delta C_i$

Where  $\Delta C_i = \frac{1}{h} \int_0^h (c_i(t + \Delta t) - c_i(t)) dz$  is the mean concentration change for the time of  $t \rightarrow t + \Delta t$ .

$$\Delta C_i^1 = (\Delta C_i^1)_{hdif} + (\Delta C_i^1)_{vdif} + (\Delta C_i^1)_{hadv} + (\Delta C_i^1)_{vadav} + (\Delta C_i^1)_{drydep} + (\Delta C_i^1)_{emiss} + (\Delta C_i^1)_{chem} + (\Delta C_i^1)_{cloud} + (\Delta C_i^1)_{aero}$$

Two groups of dust pollutants CPRM and FPRM (Coarse and Fine Particulate Matter) are considered:

**FPRM** =  $SO_4 + NH_4 + NO_3 + EC + (ORGA + ORGB) + PM_{2.5}$

Particulate Matter (PM) which are fine particles with a diameter between 0 and 2.5 micrometers.

**CPRM** (ACOARSE) = ACORS + ASEAS + ASOIL

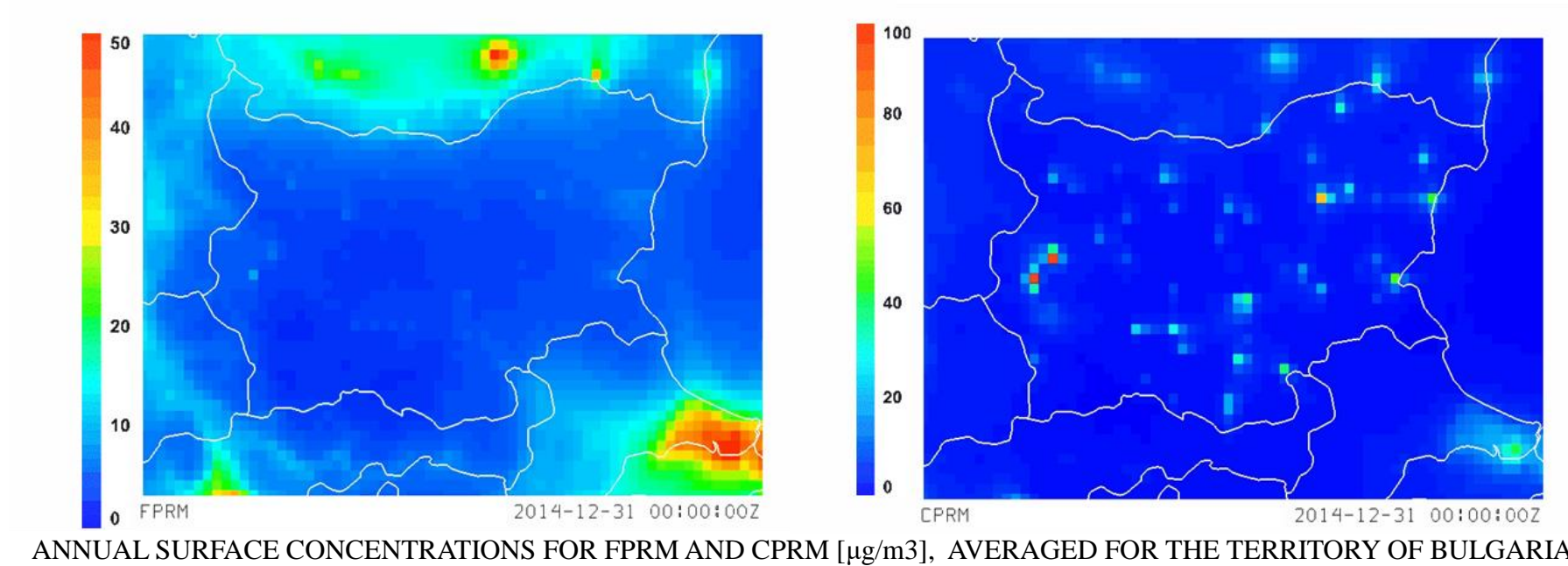
Particulate Matter (PM) which are coarse particles with a diameter between 2.5 and 10 micrometers.

Regulation No. 9 (State Gazette No. 46/1999, amended and supplemented, SG No. 86/2005) the defined limit values for PM concentrations are:

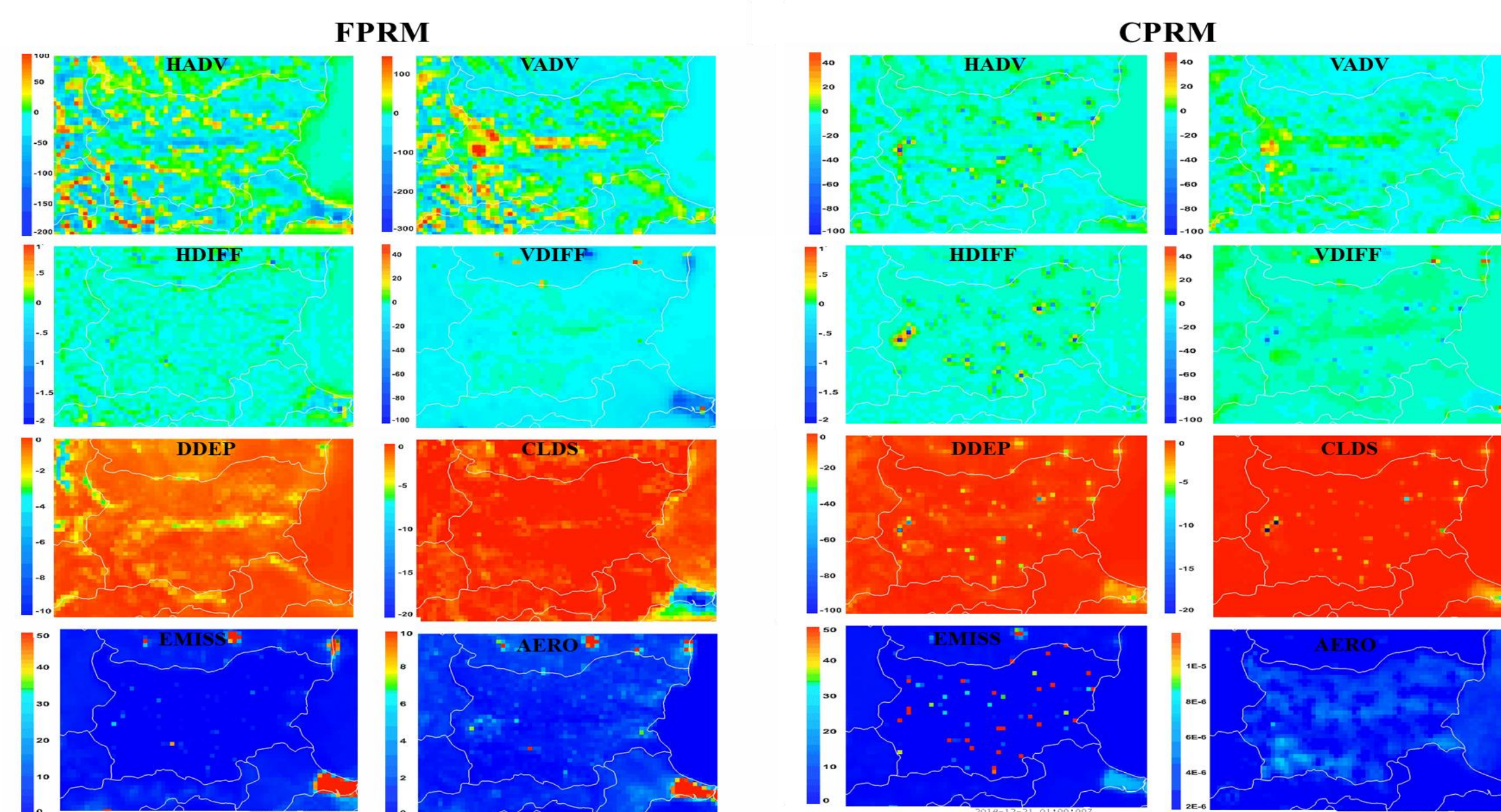
<http://eca.government.bg/en/output/daily/pollutants/pm.html>

**FPRM** - 40  $\mu g/m^3$  24 hour average and 20  $\mu g/m^3$  annual average;

**CPRM** - 50  $\mu g/m^3$  24 hour average and 40  $\mu g/m^3$  annual average.

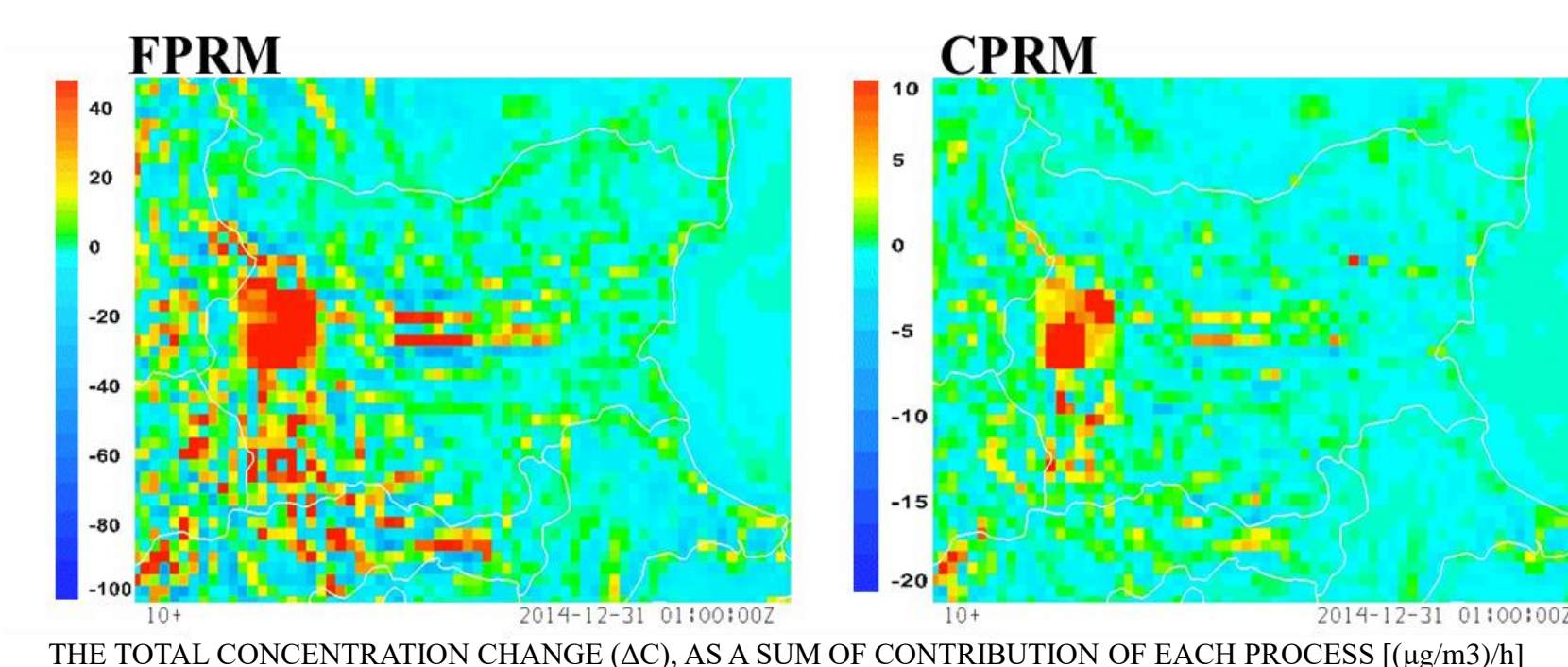


- All the processes have different contribution, with different sign, in different scale and have different meaning
- The “+” contribution means that this process increase the concentrations
- The “-” contributions means decreasing of the concentrations



ANNUALLY AVERAGED SURFACE CONTRIBUTIONS OF THE PROCESSES TO THE FPRM AND CPRM [(MG/M3)/H] OVER TERRITORY OF BULGARIA.

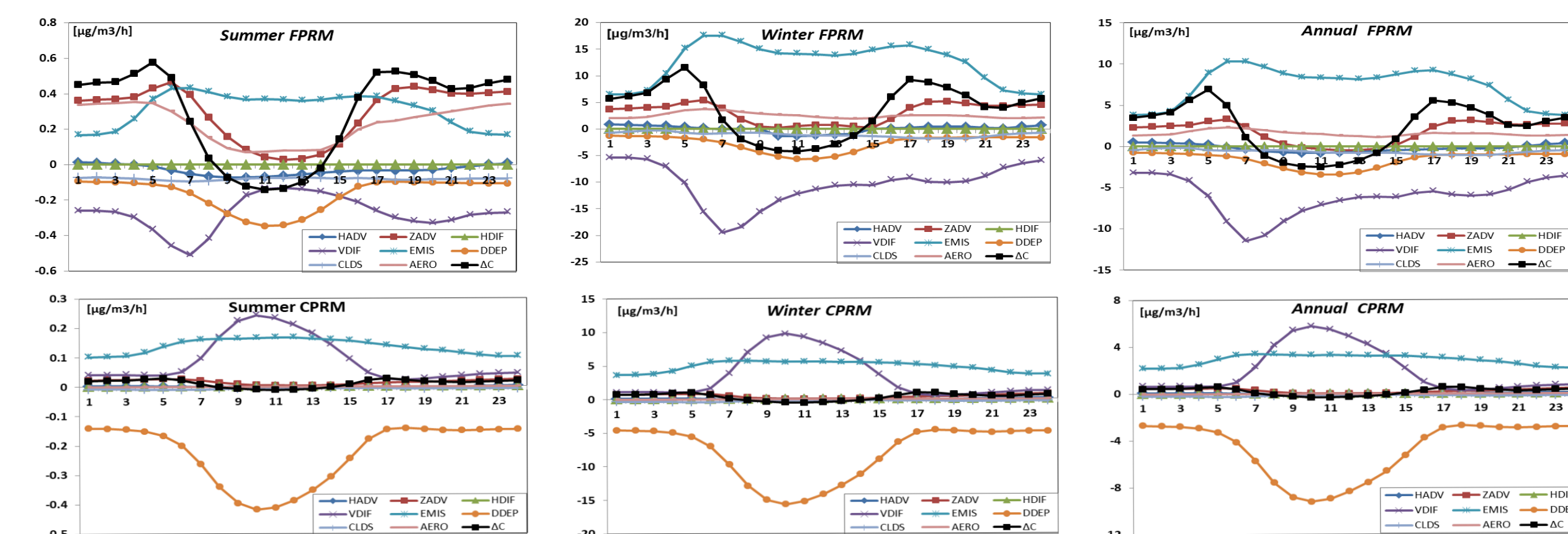
- HADV and VADV are effected by local circulation systems and their contributions reflect topography of the region.
- The impact of VDIF is mostly negative over the country and much bigger than those of HDIF. More visible for the CPRM.
- The contributions of DDEP and CLDS are negative and have maximal values over the big cities.
- The EMIS has positive contribution to formation of PM in the cities.
- The contribution of AERO is mostly positive in the cities and TPPs.



THE TOTAL CONCENTRATION CHANGE ( $\Delta C$ ), AS A SUM OF CONTRIBUTION OF EACH PROCESS [( $\mu g/m^3$ )/h]

✓ The  $\Delta C$  is a result of all processes which have large values with opposite sign and phases, could be positive, as well as negative and is different for each pollutant.

✓ The  $\Delta C$  sign depending on the type of emissions, emission sources, weather conditions and topography.



SUMMER/WINTER/ANNUALLY AVERAGED CONTRIBUTION OF THE DIFFERENT PROCESSES TO THE FORMATION OF FPRM AND CPRM [( $\mu g/m^3$ )/h].

## CONCLUSION

The behavior of the surface concentrations, averaged over the whole ensemble annually, or for the four seasons is reasonable and demonstrates effects which for most of the compounds can be explained from a point of view of the generally accepted schemes of dynamic influences (turbulent transport, atmospheric stability), local atmospheric circulations or chemical transformations; The air pollution pattern is formed as a result of interaction of different processes, so knowing the contribution of each for different meteorological conditions and given emission spatial configuration and temporal behavior, are very helpful for understanding the air pollution climate in particular PM pollution climate. The results produced by “Integrated Process Rate Analysis” demonstrate the very complex behavior and interaction of the FPRM and CPRM. Further analysis of these processes, their spatial, diurnal and seasonal variability and interaction could be helpful for explanation of the overall picture and origin of the pollution in the considered region. The total concentration change ( $\Delta C$ ), leading to a change in a concentration is determined mainly by a small number of dominating processes which have large values, and could be with opposite sign and phases. The temporal behavior of the processes is very complex. The sign of the contributions of some of the processes is obvious, but some of them may have different sign depending on the type of emissions, as well as weather conditions and topography.

## ACKNOWLEDGMENT

The present work is supported by:

The Bulgarian National Science Fund (grant DCVP- 04/2/13.12.2016), EU-H2020 project 675121 (project VI-SEEM), Program for career development of young scientists, BAS (grant DFNP 17-105/28.07.2017).

Deep gratitude to the US EPA and US NCEP, EMEP and TNO for providing us free-of-charge data and software.