Air pollution forecast system implemented in Romania at meso and smaller scales

Mihaela Caian, Rodica Sandu, Cristina Cojocaru, Simona Oancea

National Meteorological Administration Bucharest

- **Air pollution forecast numerical models implemented and run operationally in Romania.**
- **Towards finer scales**
- **Climatologycal trajectories for longer-range estimates.**

Air pollution forecast numerical models implemented and run operationally in Romania.

- 3D atmospheric diffusion and transport models
  - meso-scale ->oper
  - small scale (new topography, land cover, soil + new physical parameterisations) –> under validation
  - regional climate scale -> under validation
- Gaussian dispersion models ->oper
- Transport models -> oper

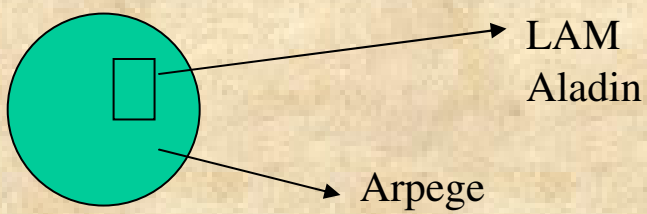
I) 3D atmospheric diffusion and transport models:

A) atmospheric model – **ALADIN**

- LAM spectral model , primitive equatioms

- coupled with ARPEGE (Météo-France) global model

- implemented in ANM on SUN (8procs)



- currently still in dynamical adaptation mode .

- dx=10km, LBC_dx=33km

- integrated 4times/day for 72 hours forecast.

- cpmplex, optional post-processing (horisontal and/or vertical)

- **DATA involved in the model integration:**
  - ***Prognostic variables*** **(Temperature, wind, specific humidity, surface pressure, surface temperature, water content, snow depth);**
  - ***"Constants" (some monthly)*** **(surface pysiography: topography and its parameters (std, anisotropy) , roughness length, albedo, emissivity, soil fraction, land cover,etc).**

Constants and monthly variables are generated in the grid once, at the beginning of the integration using US NAVY data basis) from which monthly surface and in depth temperature and humidity, snow depth are computed.

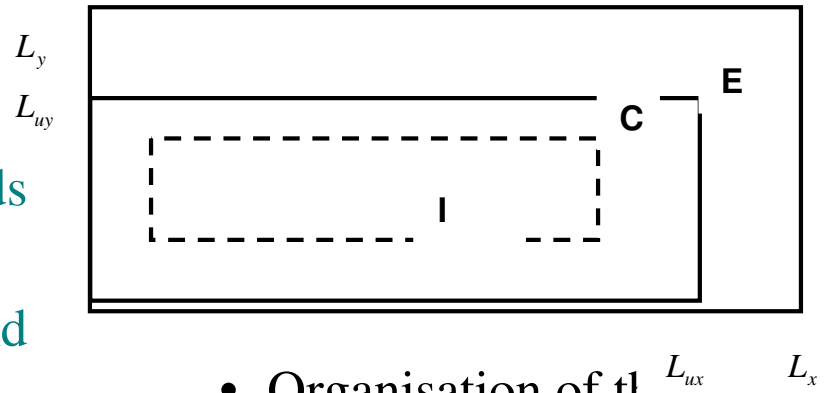
Initial and LBC data rezult through interpolation from the global model, taking into account cliamtological Aladin grid data. Here the contrast land/sea is taken into account. The operations chain is:

- **Horisontal interpolation;**
- **Bi-periodicisation of initial and LBC fields**
- **Vertical interpolation.**

The Domain :

- 27 levels η on vertical,
- $P(x,y,z,t) = A(\eta) + B(\eta)\, Ps(x, \eta, t)$,
  (Ps is surface pressure)
- Lambert conformal projection horisontal + spectral bi-Fourier fields decomposition.
- C coupling area: matches scales and absorbs gravity waves
- E extension zone.

Organisation of the horizontal domain of Arpege/Aladin



- Organisation of tl horizontal domain of Arpege/Aladin

- **Physical parameterisations**

  processes parameterised for wind: turbulent vertical diffusion, convection (vertical mass exchange due to temperature horisontal gradient), GWD (vertical mass exchange due to sub-grid topography), tendency of mass flux due to precipitation fall.

- processes parameterised for temperature: radiative balance (direct solar radiation absorbtion and scattering, vertical turbulent diffusion and surface exchange, vertical exchange due to convection; heat exchange due to condensantion/evaporation, tendency due to precipitation fall.
- The boundary layer and vertical turbulent transfer are computed following exchange coefficients K-theory and are function of Richardson number and altitude. Above the surface boundary layer vartical exchange is function of mixing length and shallow convection.
- The surface has a complex representation of land/sea contarst, albedo, emissivity, roughness length, vegetation proportion and sub-grid effects.

- **Input data for the pollution model:**

Parameter	Vertical level
u - wind	9 pressure levels and at 10m
v- wind	9 pressure levels and at 10m
Temperature	9 pressure levels and at 2 m
Specific humidity	9 pressure levels and at 2m
Precipitations: convective, stratiform, rain and snow	surface
Surface pressure	surface

gamma scales (urban case): the Aladin NH

- Z vertical coordinate
- Pressure departure (p'=hydrostatic-non-hydrostatic => errors reduced) as variable (Laprise) + semi-lag. with multiple iterations
- 2 more prognostic equations (for p' and for div_z(w))
- Used operationally down to 1-2 km.

3D atmospheric diffusion and transport models:
MEDIA - eulerian model for atmospheric disperssion

$$\frac{\partial C}{\partial t} + \mathbf{V} \cdot \nabla C = \nabla \left(\mathbf{K} \cdot \nabla C \right) + \dot{S}_0 + \dot{S}_i$$

- **C** - pollutant concentration at ;
- **V -** wind;
- **K** - Reynolds tensor;
- So - source terms;
- Si- sink terms.

• Numerical treatment

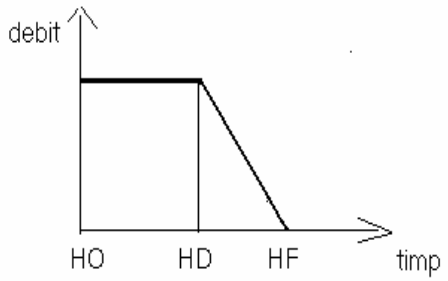
- advection : $(V \cdot \nabla C)$ discretised by “chapeau” functions to be conservative
- turbulent diffusion: $\nabla(\mathbf{K} \cdot \nabla C)$
  - horisontal: finite differences;
  - vertical: finite elements; is a function of thermal gradient and wind share; the exchange coeffiecient depends on:
    - Vh horisontal wind
    - L mixing length.
- sink terms:
  - wet deposition: $Dw = Cm \cdot E \cdot P / mw$
    - Cm – mean concentration in the precipitating layer;
    - E – washing coefficient;
    - P – precipitation intensity;
    - mw- water specific mass.
  - dry deposition; $Dd = vd \cdot Csol$
    - Vd – deposition velocity;
    - Csol - concentratition near surface
  - chemical transformations (not in this model version);
  - radioactive desintegration

So - source term

- Gaussian distribution describing sub-grid diffusion with hypothesis of:
  - horisontal isotropy;
  - vertical homogeneity

$$\frac{\partial C}{\partial t} = \frac{Q(t)}{2 \cdot \Pi \cdot \sigma_r^2 \cdot H} \cdot \exp \frac{-d^2}{2 \cdot \sigma_r^2}$$

C - pollutant concentration
Q(t) – source debit
σ - surface of the grid mesh
H - vertical extension of the pollutant cloud
d - distance to the source;



=> Need to know: geographycal position of the sources;
base and hight of pollutant cloud;
the debit (illustrated here for accidental release)

Media model:

sigma levels, spheric geometry

Operational domains for Media+Aladin:
D1 (country; dx=10km)
D2 (region; dx=5 km)
D3 (small (town) scale; dx=2km)

Input from atmospheric model:

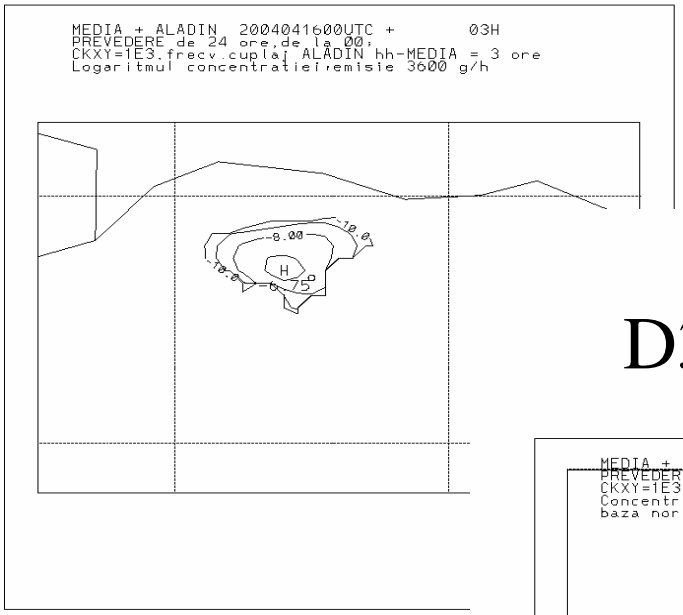
- wind_h (levels + 10m)
- vertical velocity (levels)
- temperature (levels + 2m)
- humidity (levels + 2 m)
- surface pressure
- precipitation

Input from sources:

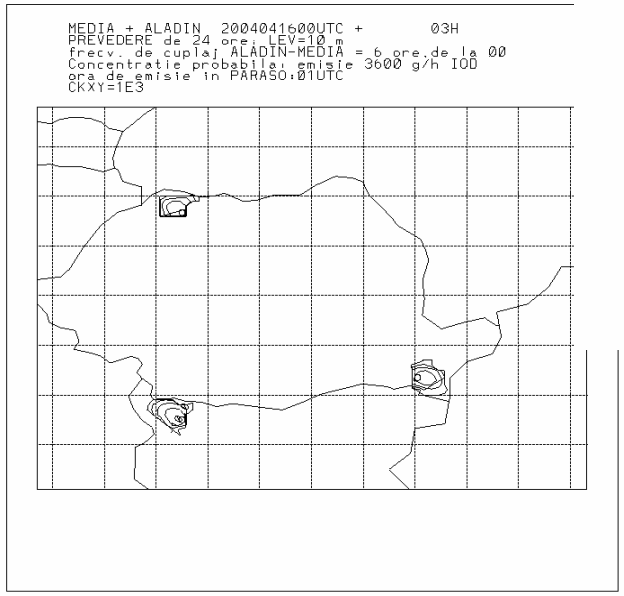
- no of sources
- nature of pollutant
- sources coordinates
- debit
- base and hight of pollutant (B,V)
- hour of emission start/end (H0,H1)

Results: Media+Aladin, for D1,D2, D3, same emission parameters:B=10m, V=500m,Q=1g/s, H1=11h; dt_D1=15min; dt_D2=7min

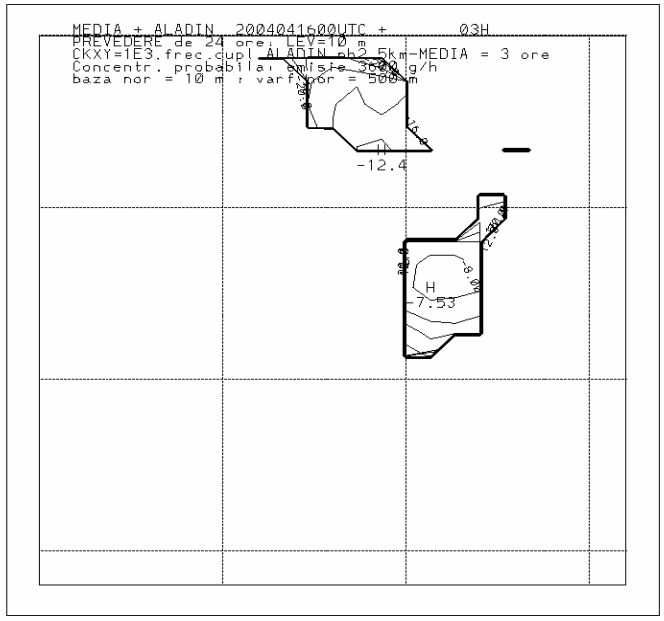
D2: 3 hours



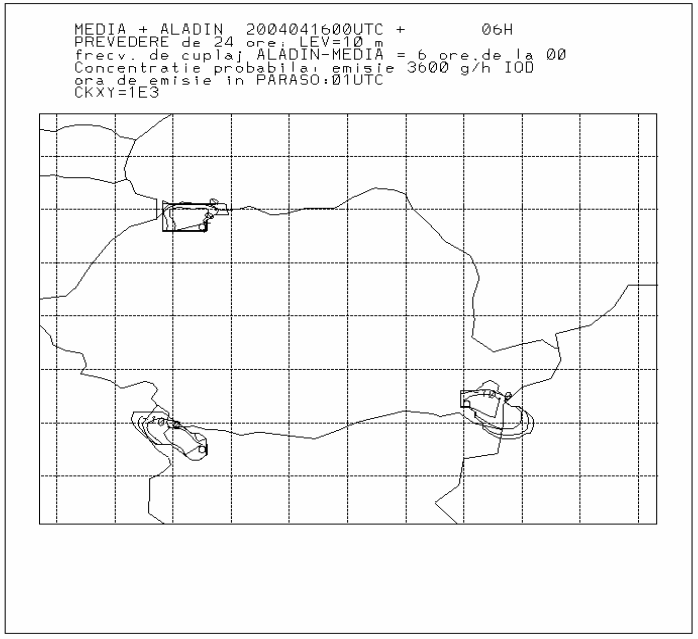
D1: 3 hours

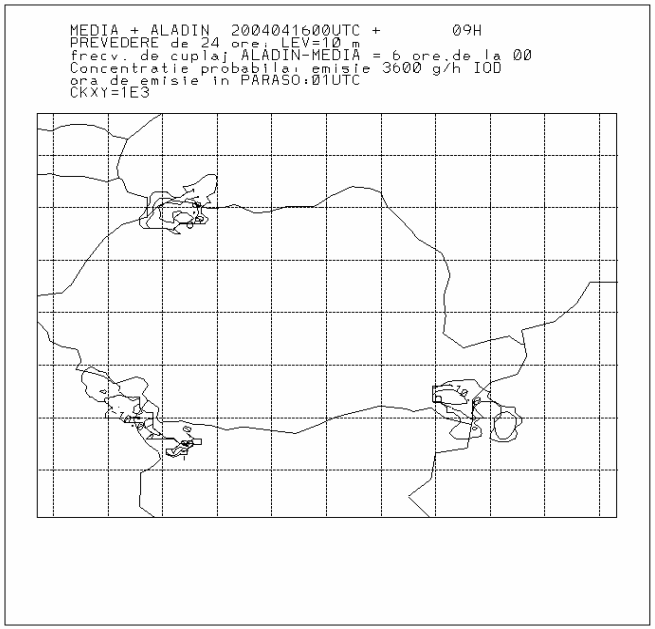


D3 (NH): 3 hours

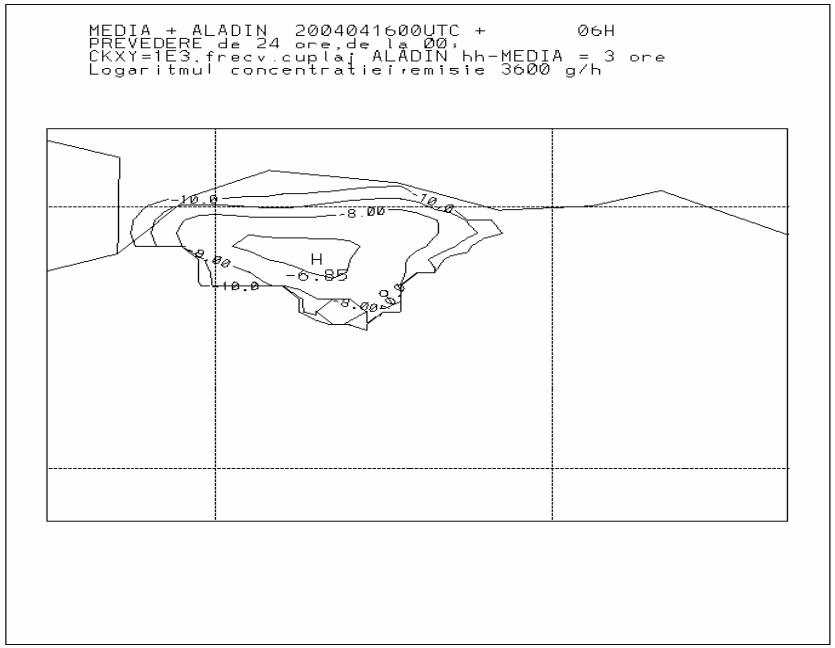


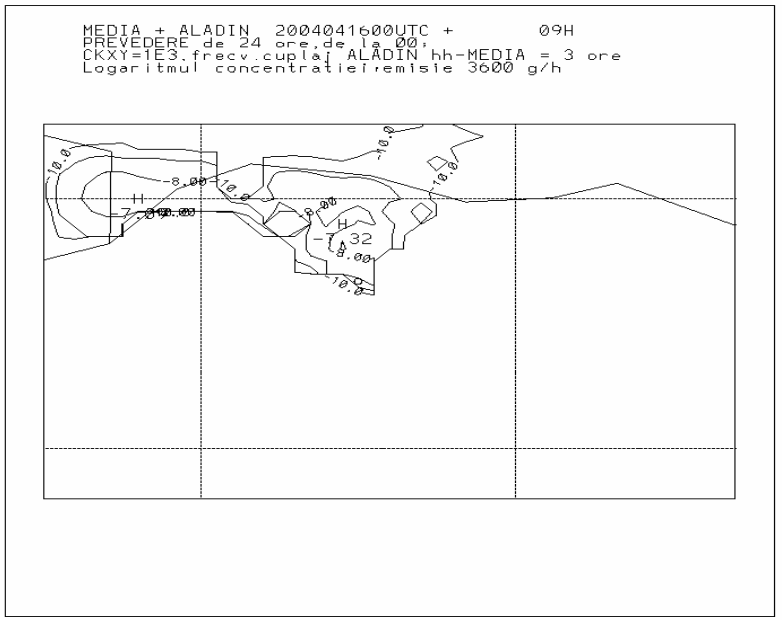
Cloud evolution after 6 and 9 hours (**D1**)



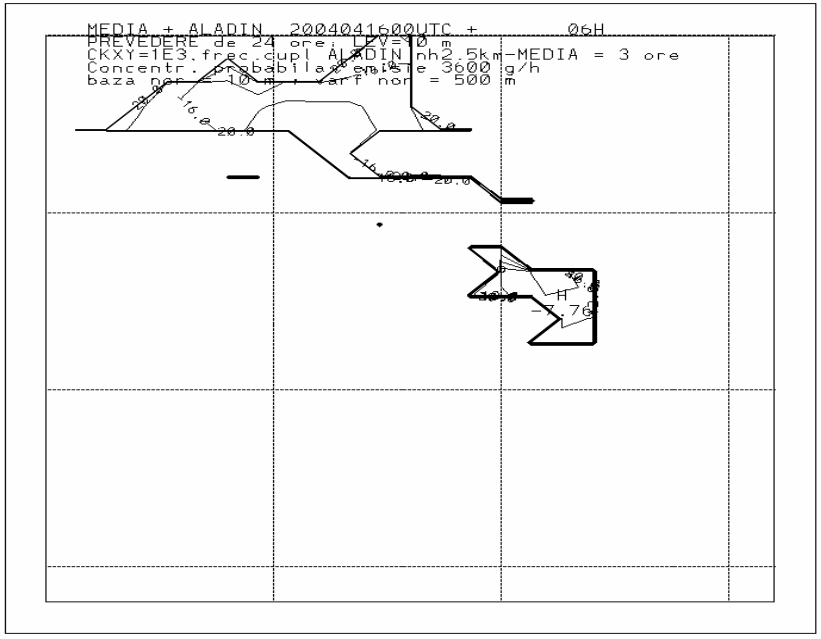


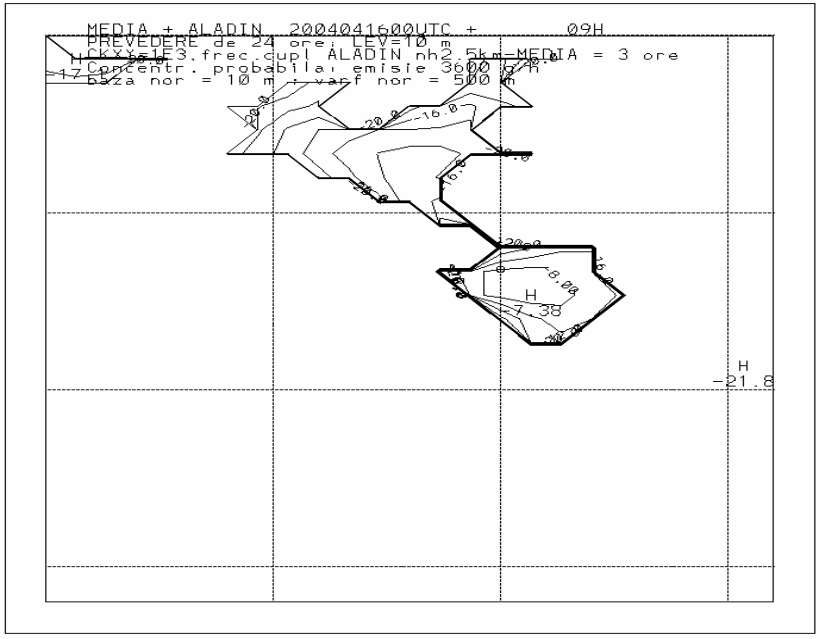
Cloud evolution after 6 and 9 hours (**D2**)



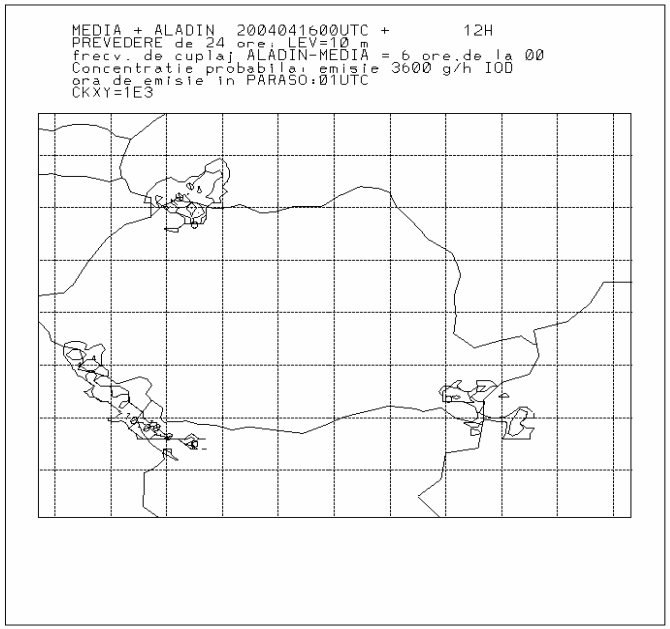


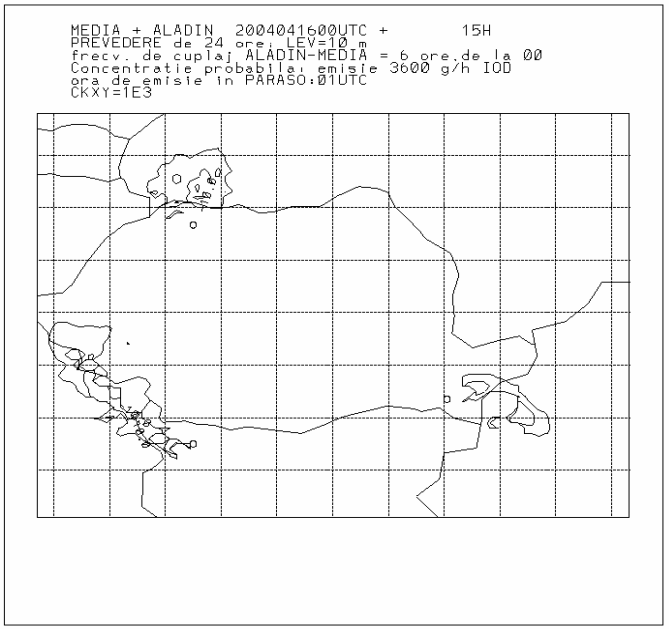
Cloud evolution at 6 and 9 hours (D3-NH)



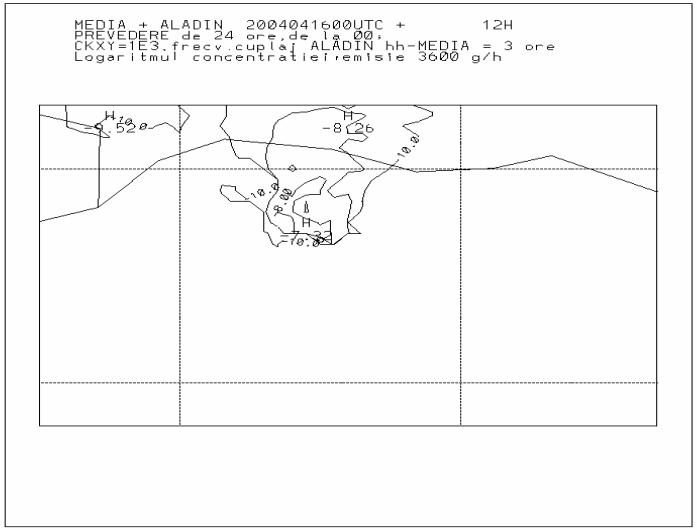


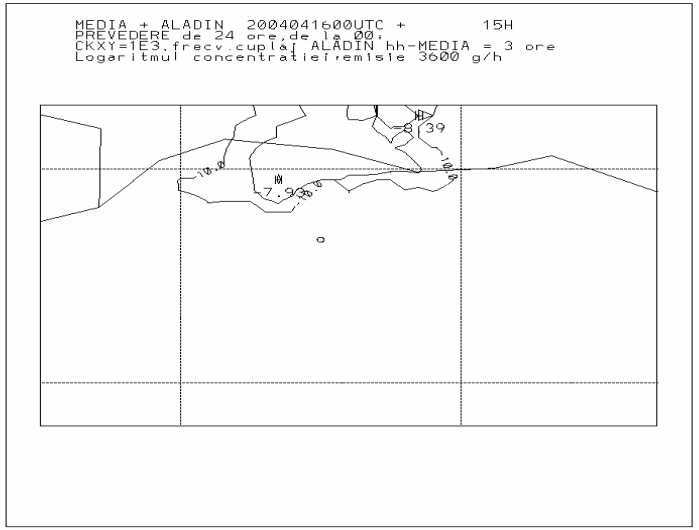
Cloud evolution after 12 and 15 hours (D1)



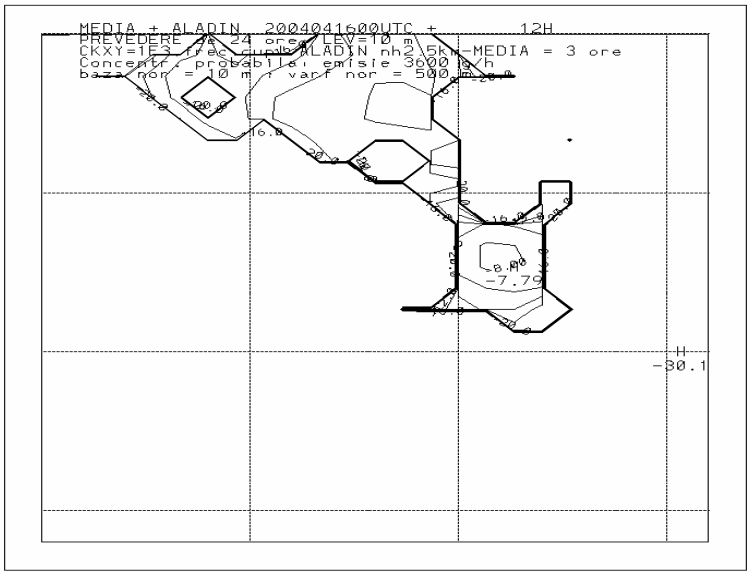


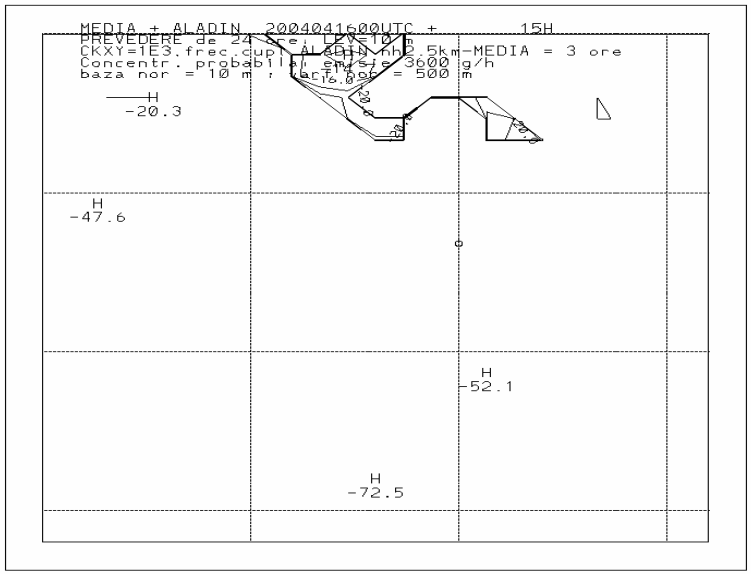
Cloud evolution after 12 and 15 hours (D2-HH)





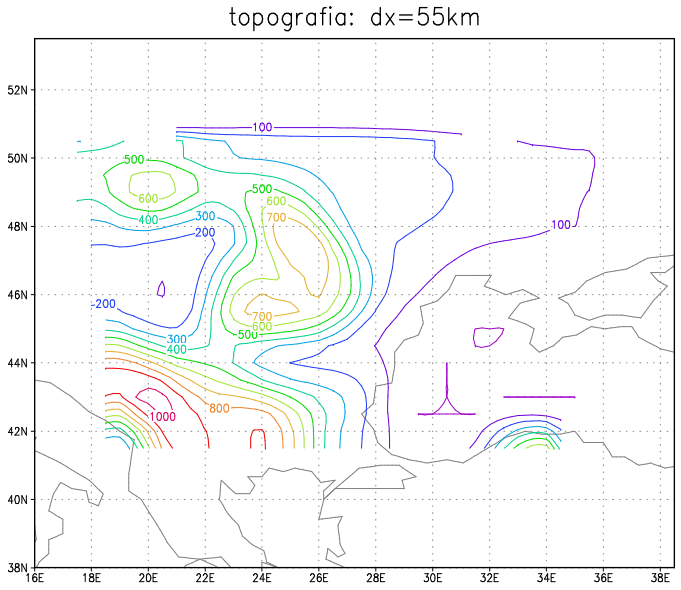
Evolutia norului de poluant dupa 12 si 15 ore de integrare (D3-NH)

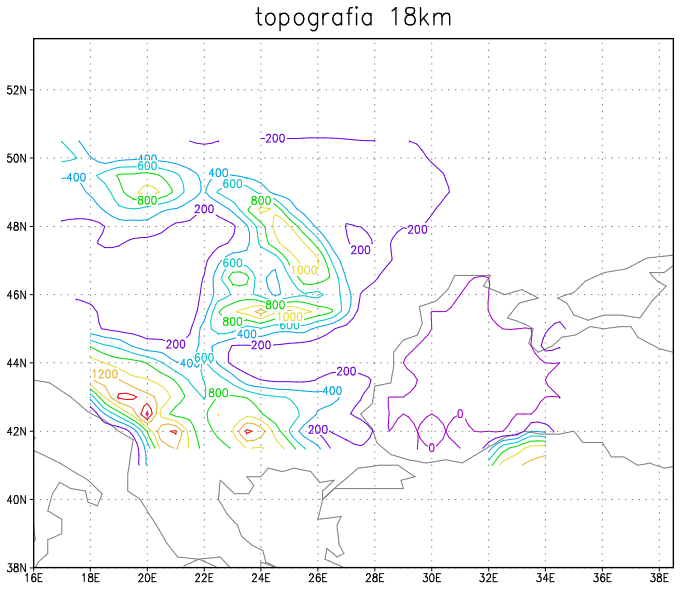




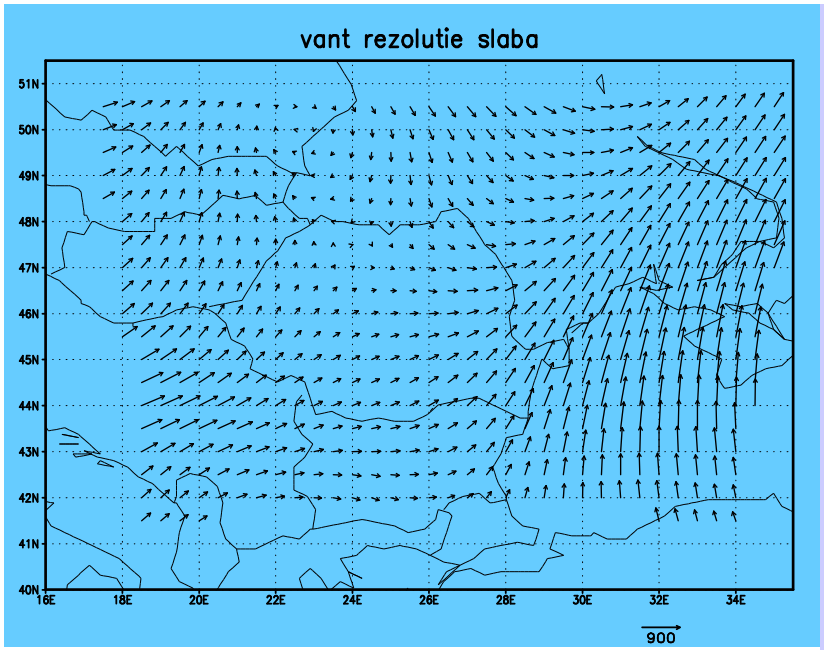
Towards smaller scales:

a) dynamical adaptation





GrADS: COLA/IGES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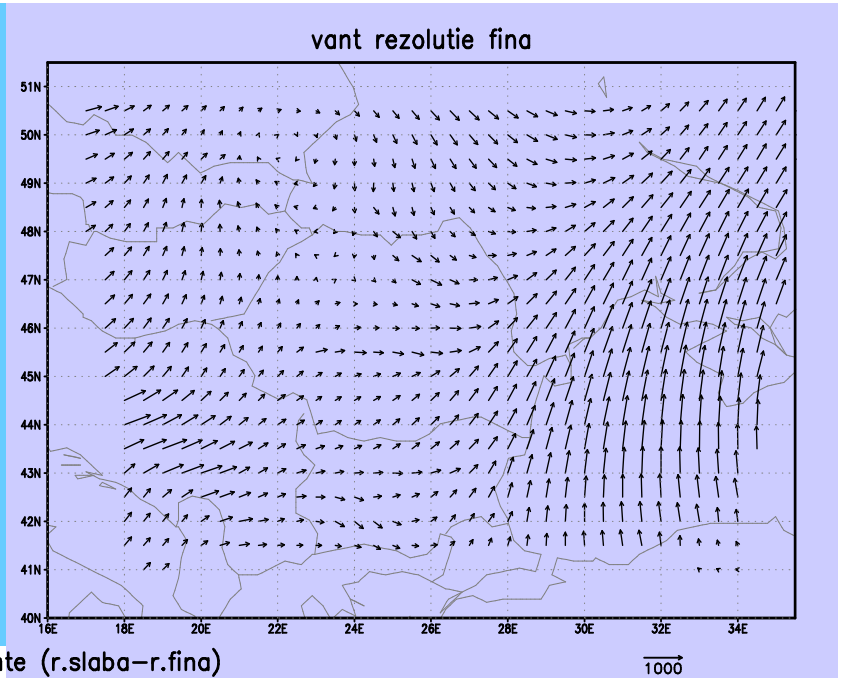
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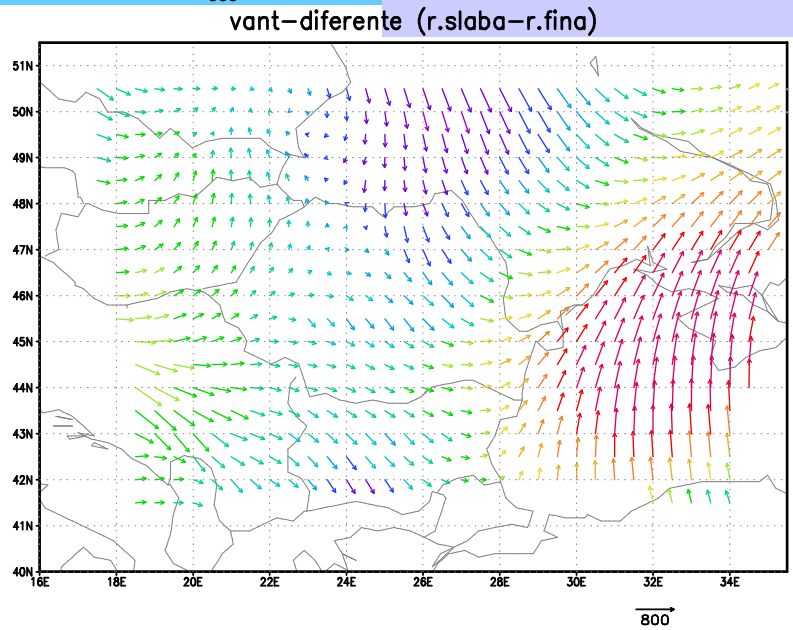
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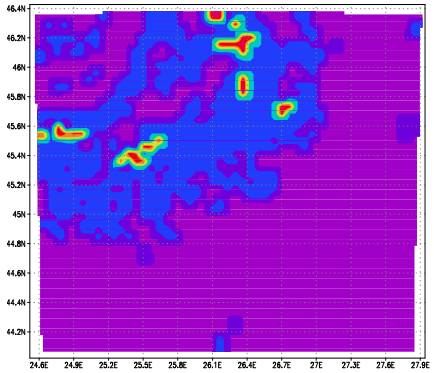
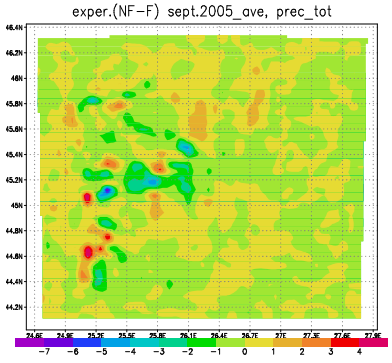
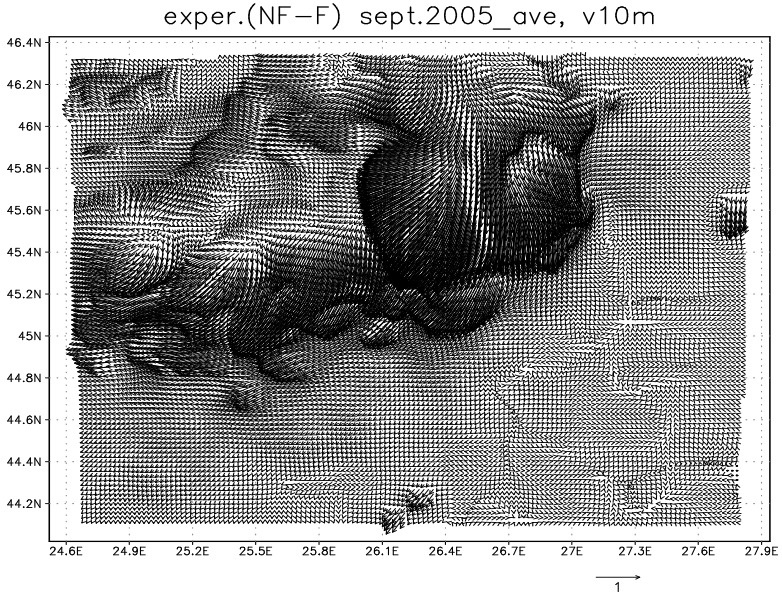


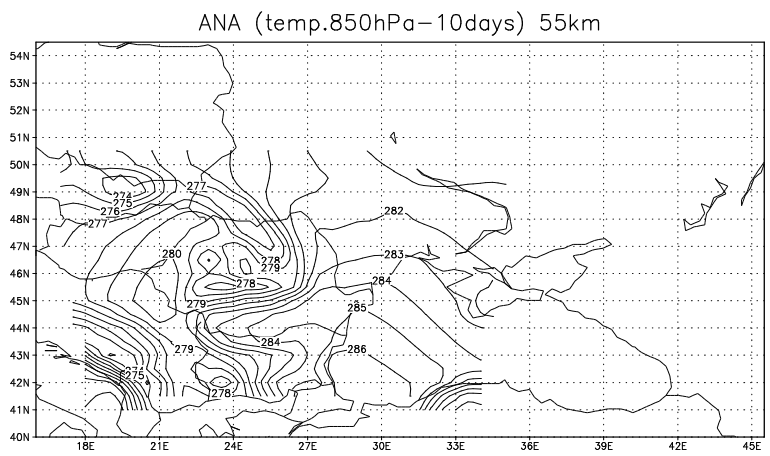


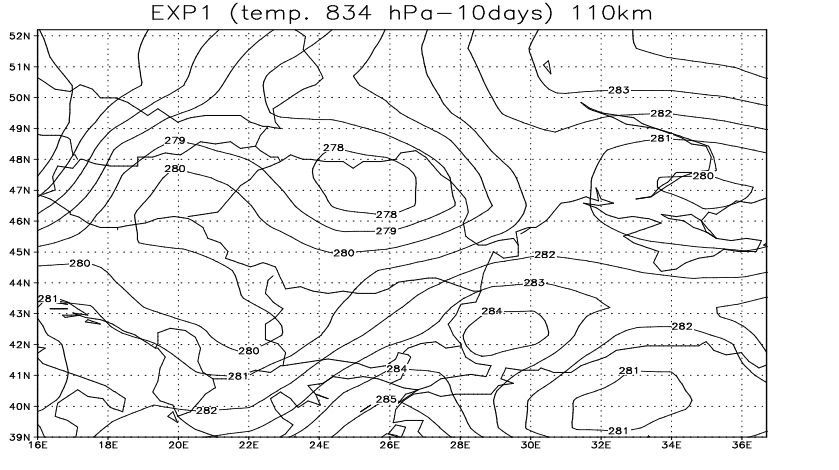
Deforestation: => prec. decrease intra-forest area and slight increase in the deforested areas where total water soil content increases and so the evaporation.

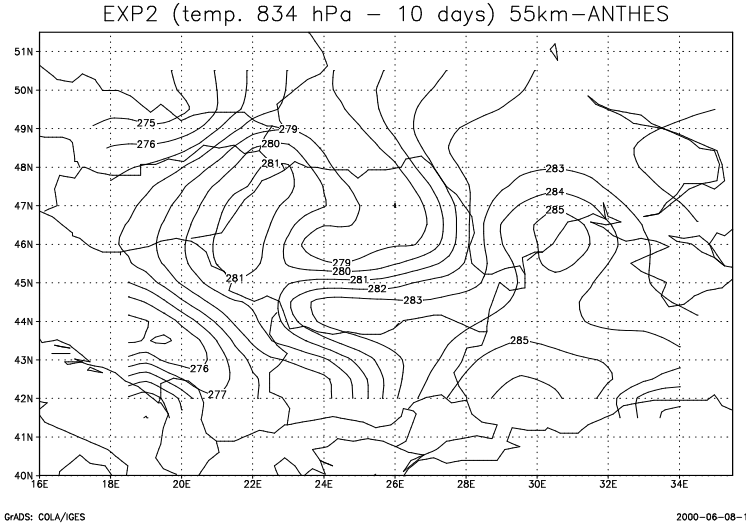


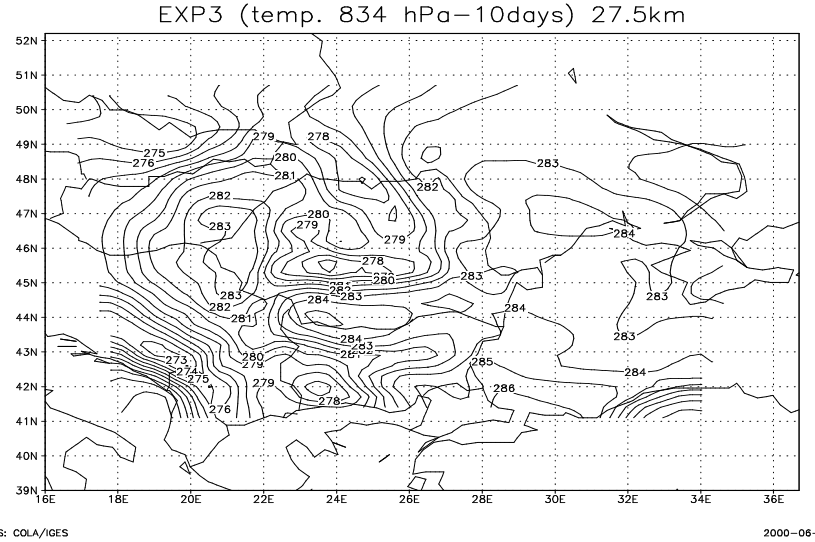
Wind difference: no-forest-forest (one month average, Sept, dx=5km)

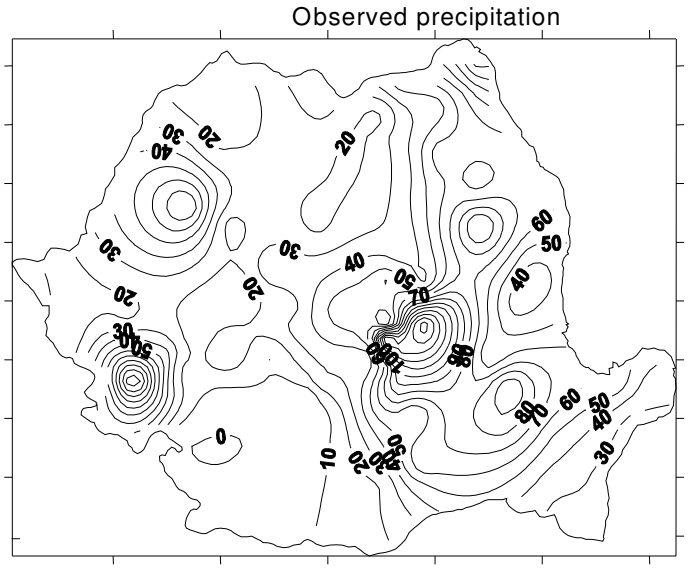
b) new physical parametrisations

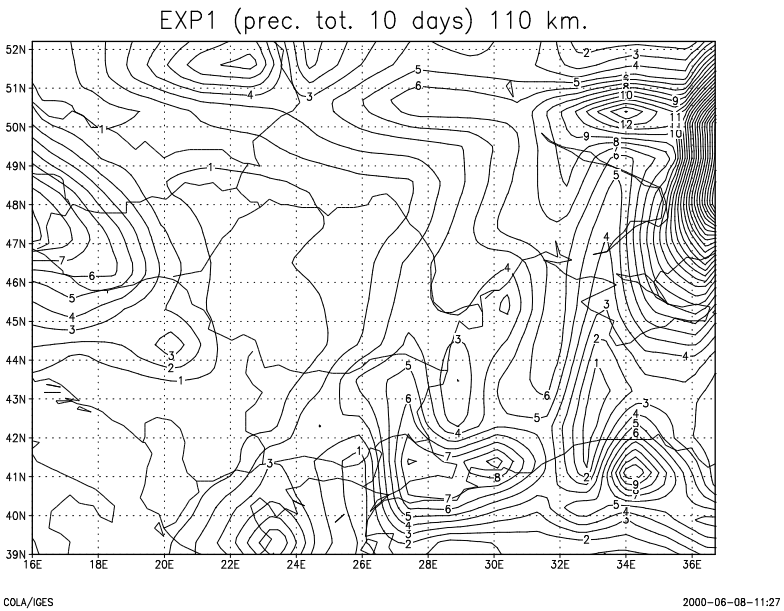


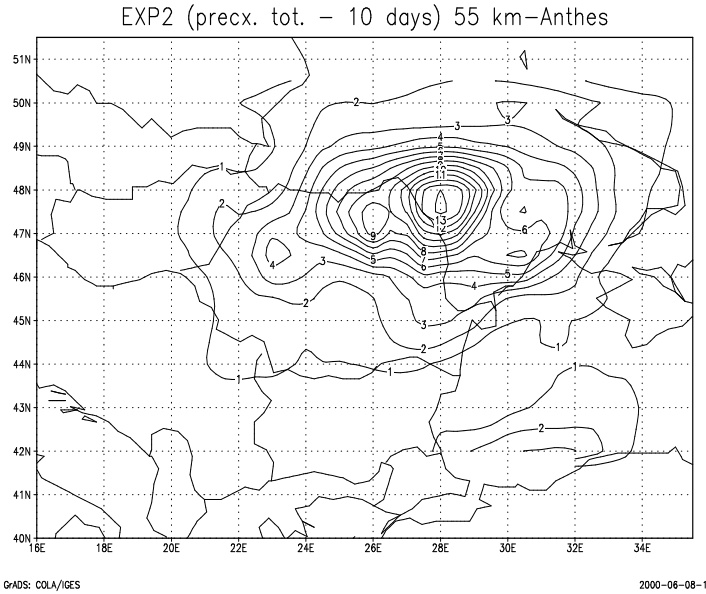


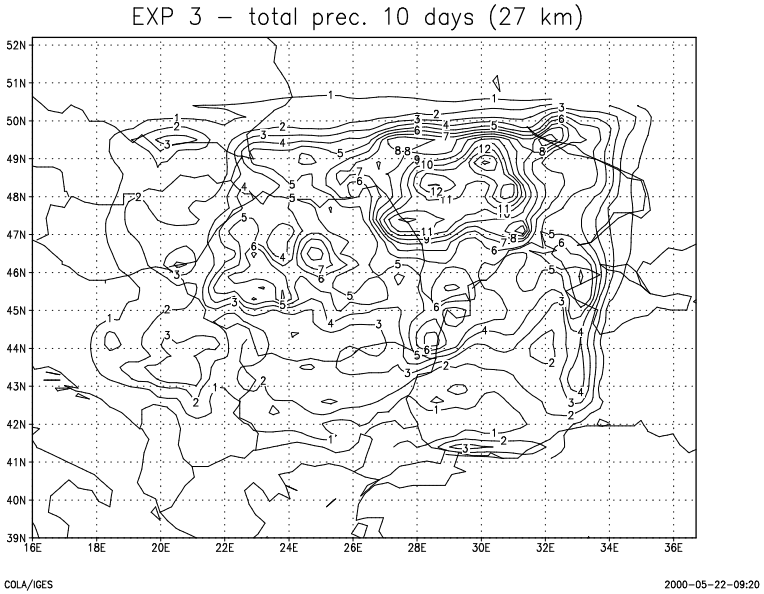




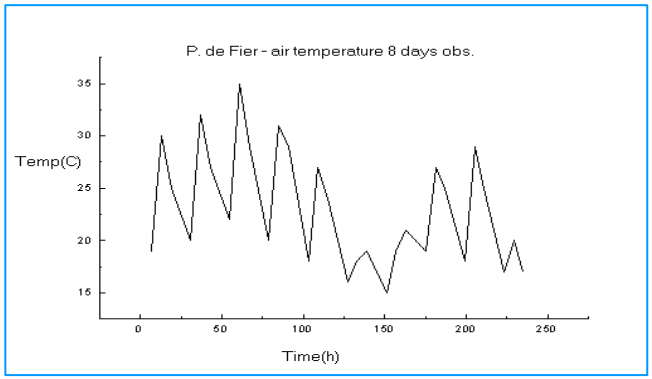

Observed precipitation


EXP1 (prec. tot. 10 days) 110 km.
GrADS: COLA/IGES
2000-06-08-11:27

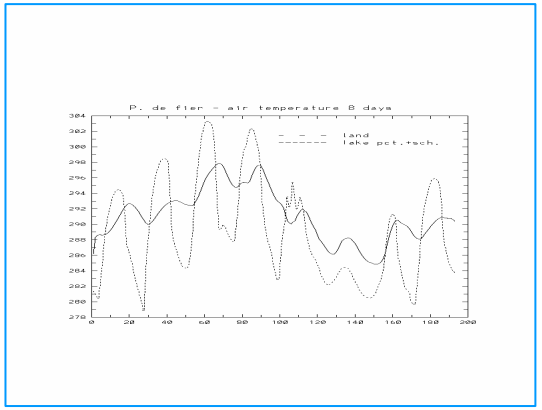

EXP2 (precx. tot. – 10 days) 55 km–Anthes
GrADS: COLA/IGES
2000-06-08-11:33


EXP 3 – total prec. 10 days (27 km)
GrADS: COLA/IGES
2000-05-22-09:20

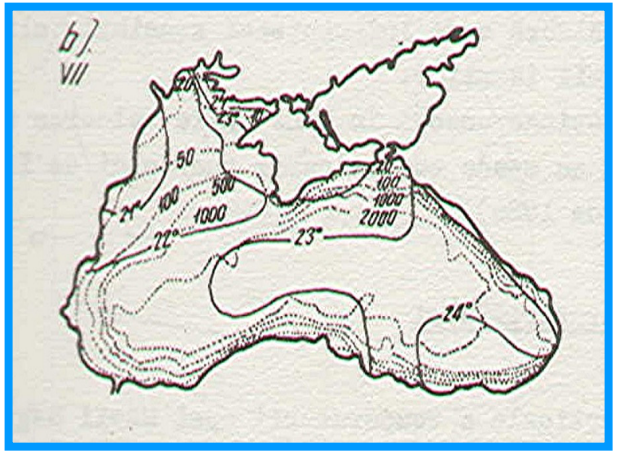
Coastal point- Obs



Coastal point- one way and 2-way interaction- + 1D energy budget model



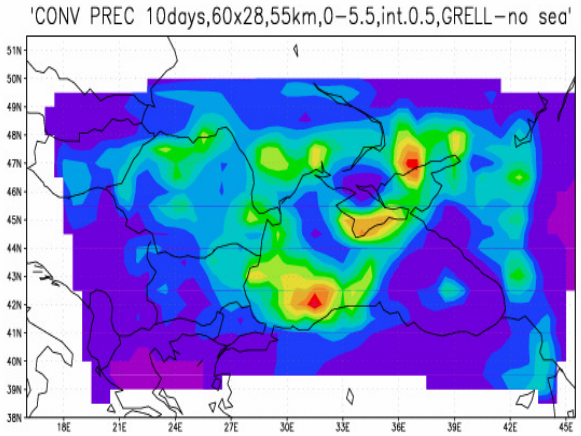
Black Sea – clim.



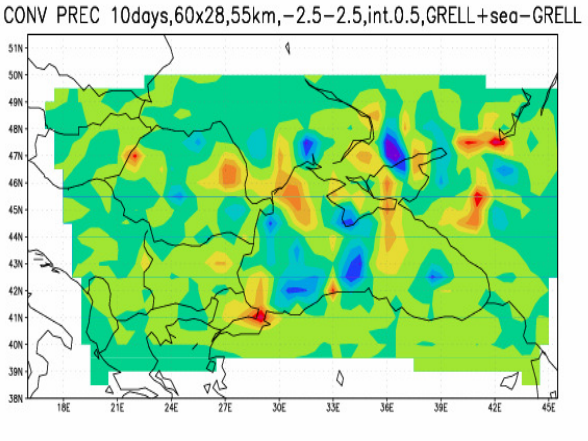
Black Sea – 2-way interaction

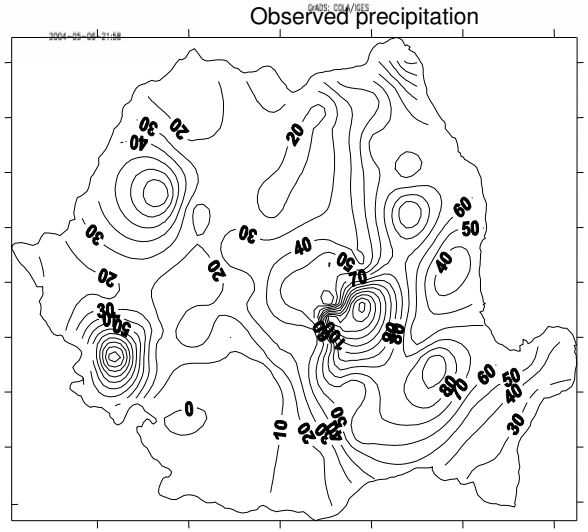
Cumulated precipitation (10days)

Sea- 1 way



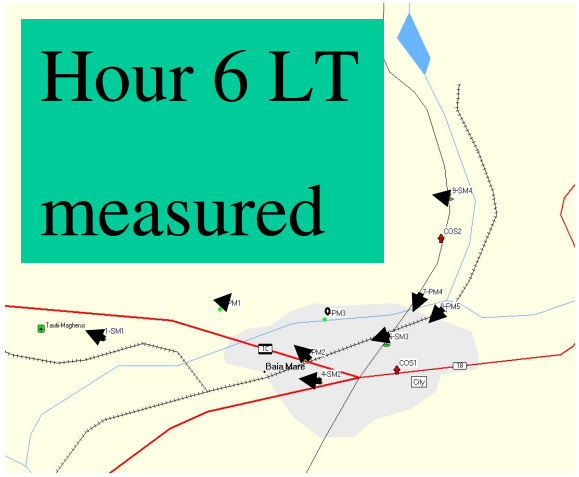
Sea- 2 way

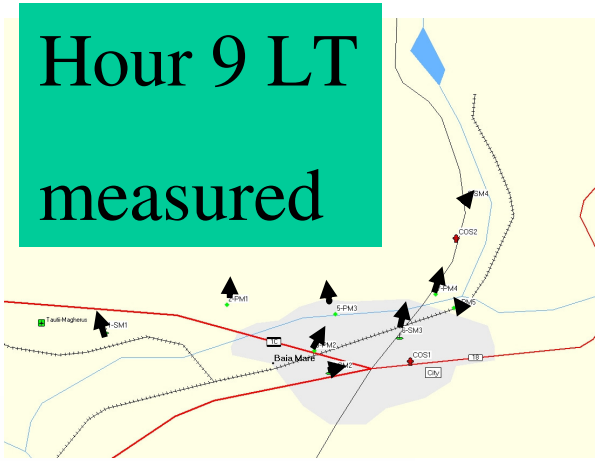


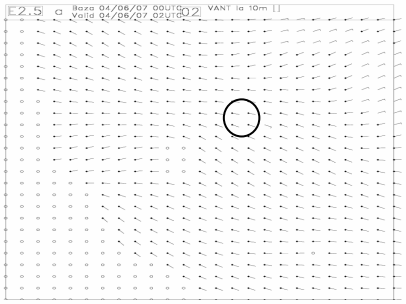


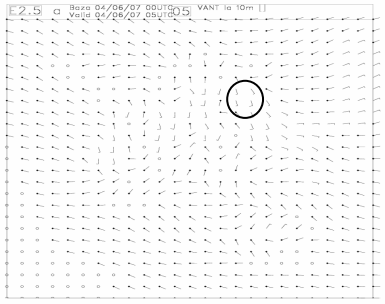
Observed

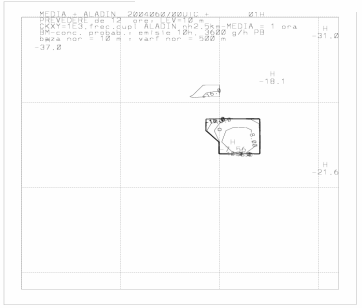
Simplified urban pshysiography

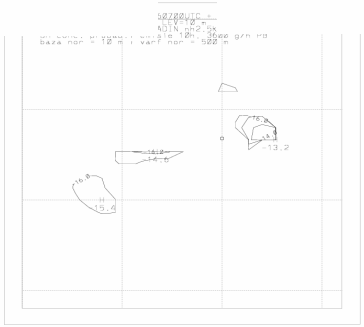


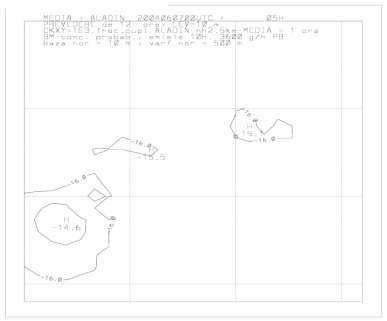




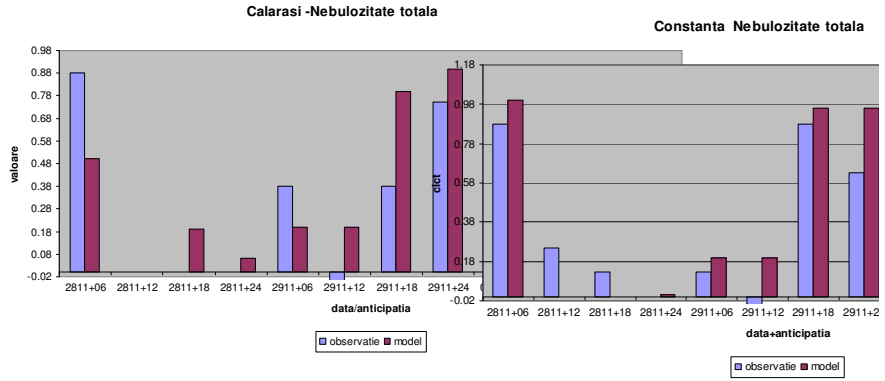


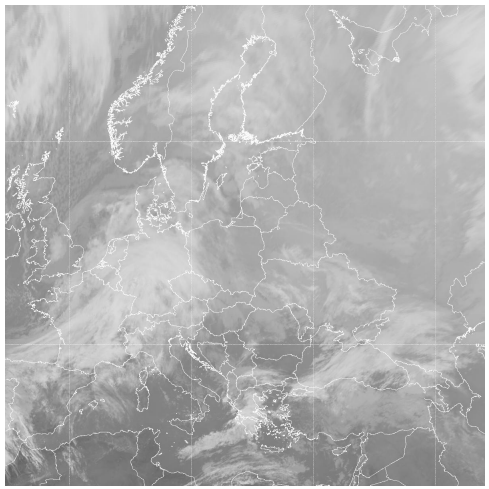


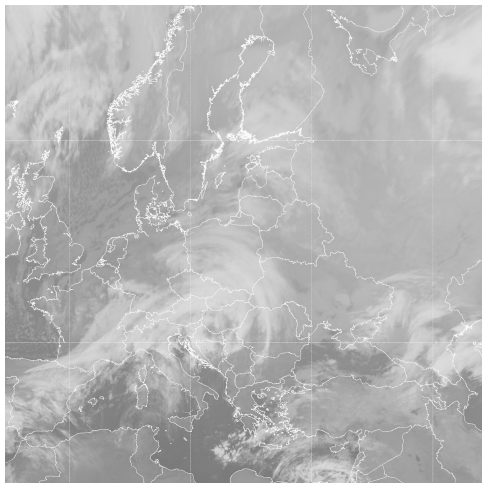


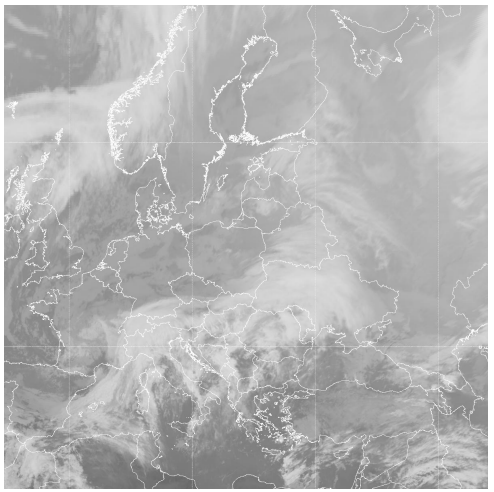


Cloudiness improved by small scale configuration

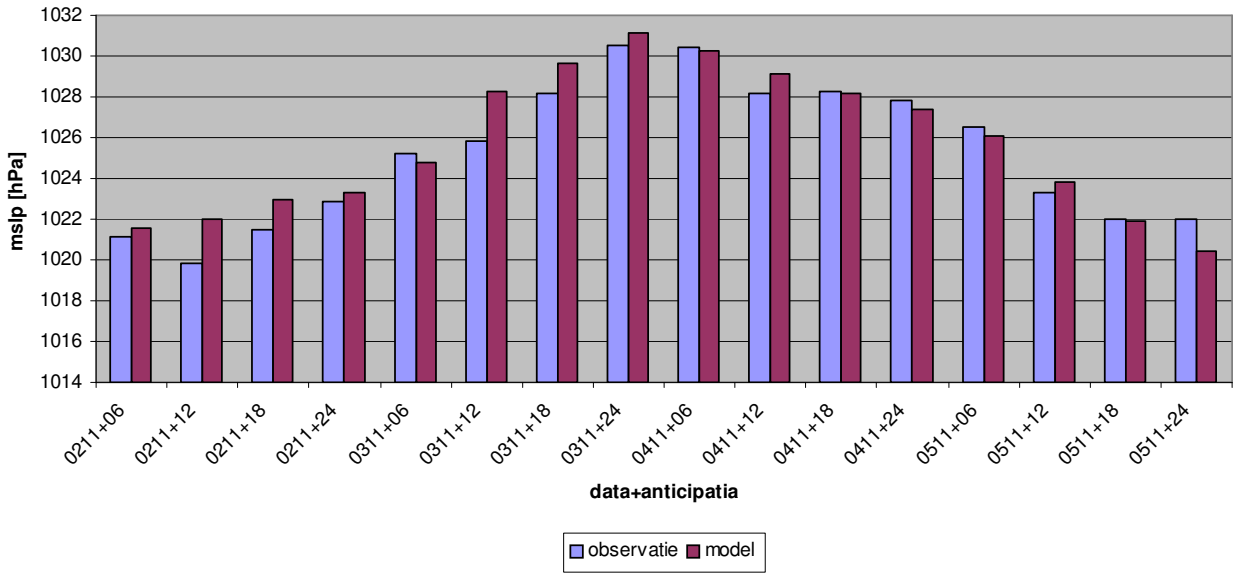




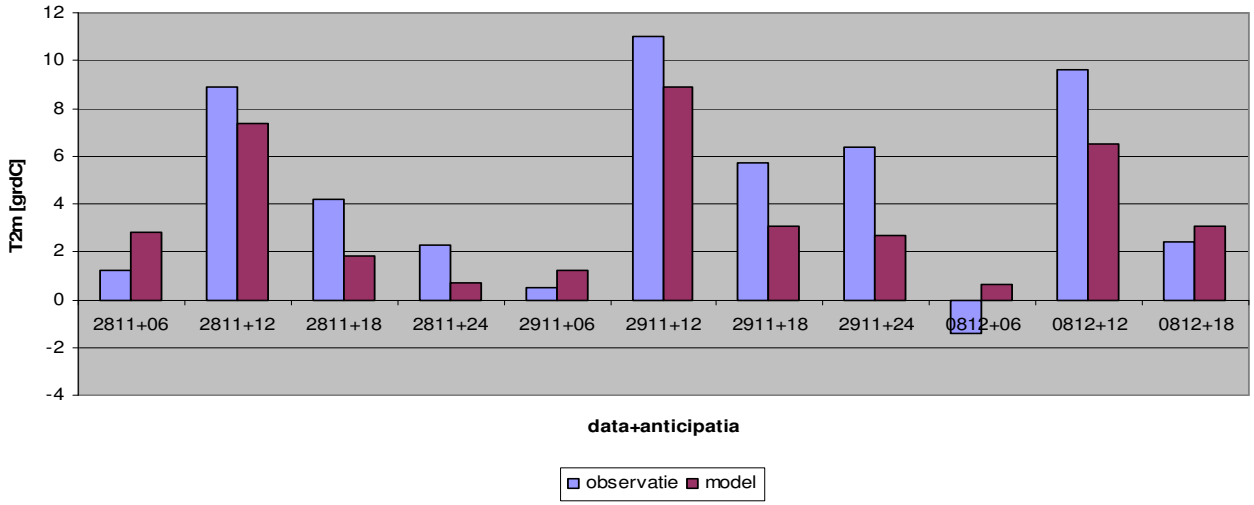




Baia Mare -MSLP



Medgidia - T2m

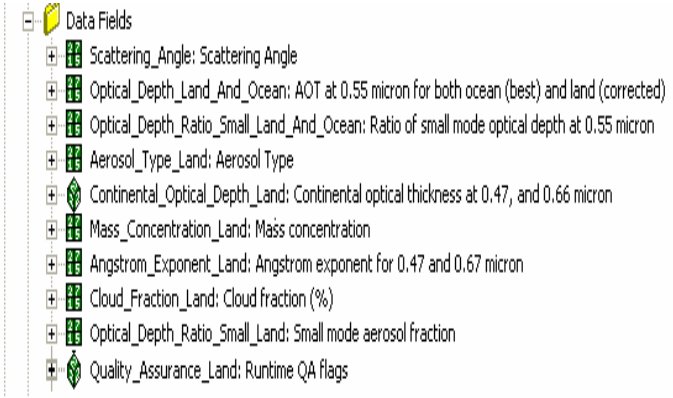


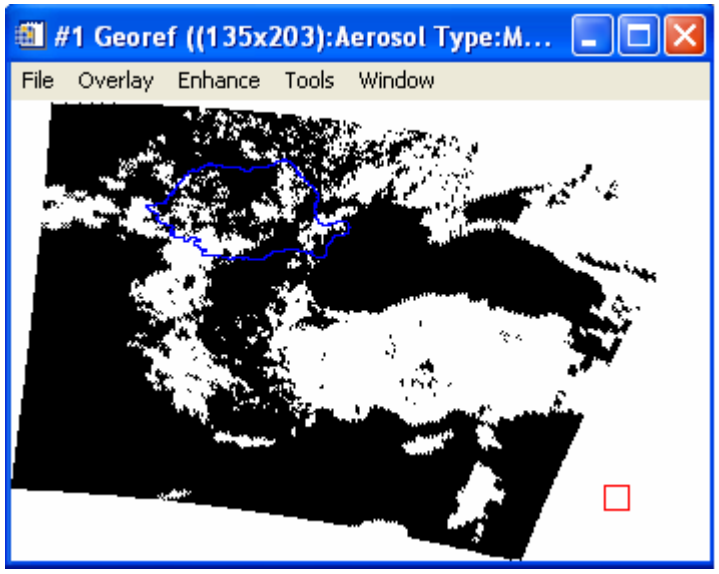
Future: further validation

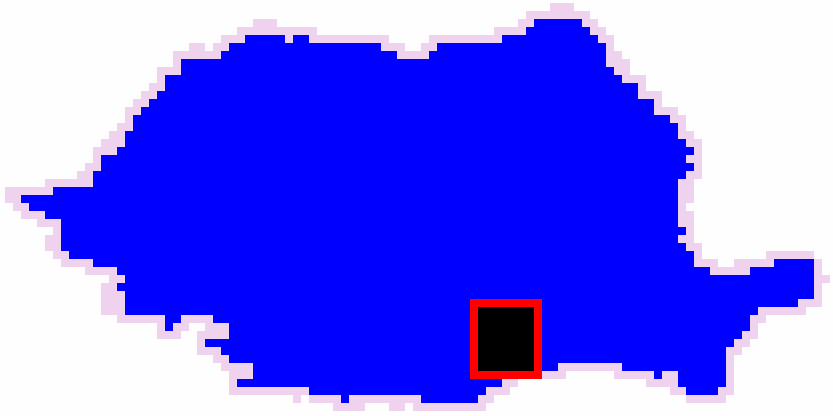
Extracting and geo-referencing images MOD04_L2 si MYD04_L2 TERRA-MODIS and AQUA

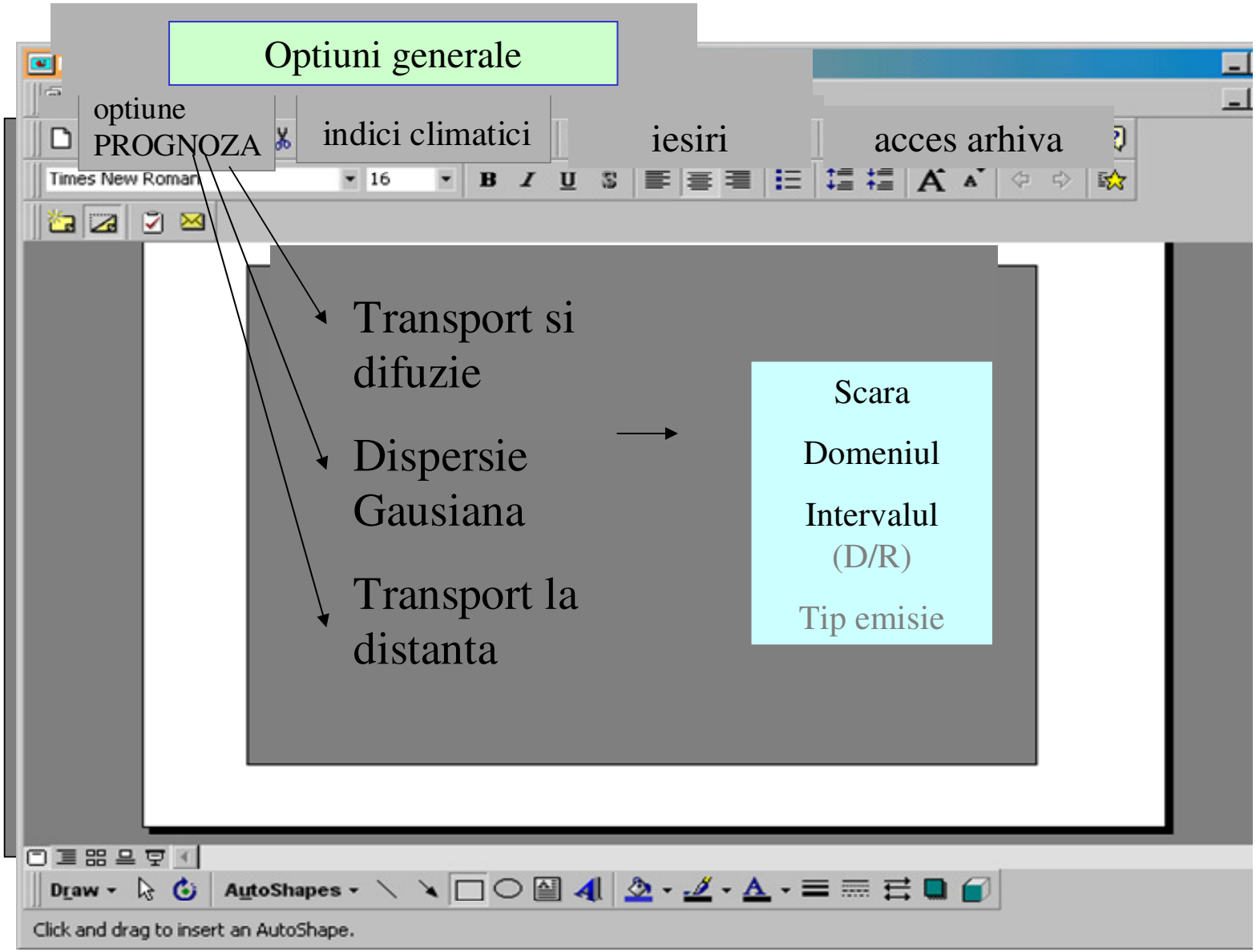
TABLE 1: CHARACTERISTICS OF MODIS CHANNELS USED IN THE AEROSOL RETRIEVAL

Band #	Bandwidth (μm)	Weighted Central Wavelength (μm)	Resolution (m)
1	0.620 - 0.670	0.646	250
2	0.841 - 0.876	0.855	250
3	0.459 - 0.479	0.466	500
4	0.545 - 0.565	0.553	500
5	1.230 – 1.250	1.243	500
6	1.628 – 1.652	1.632	500
7	2.105 – 2.155	2.119	500



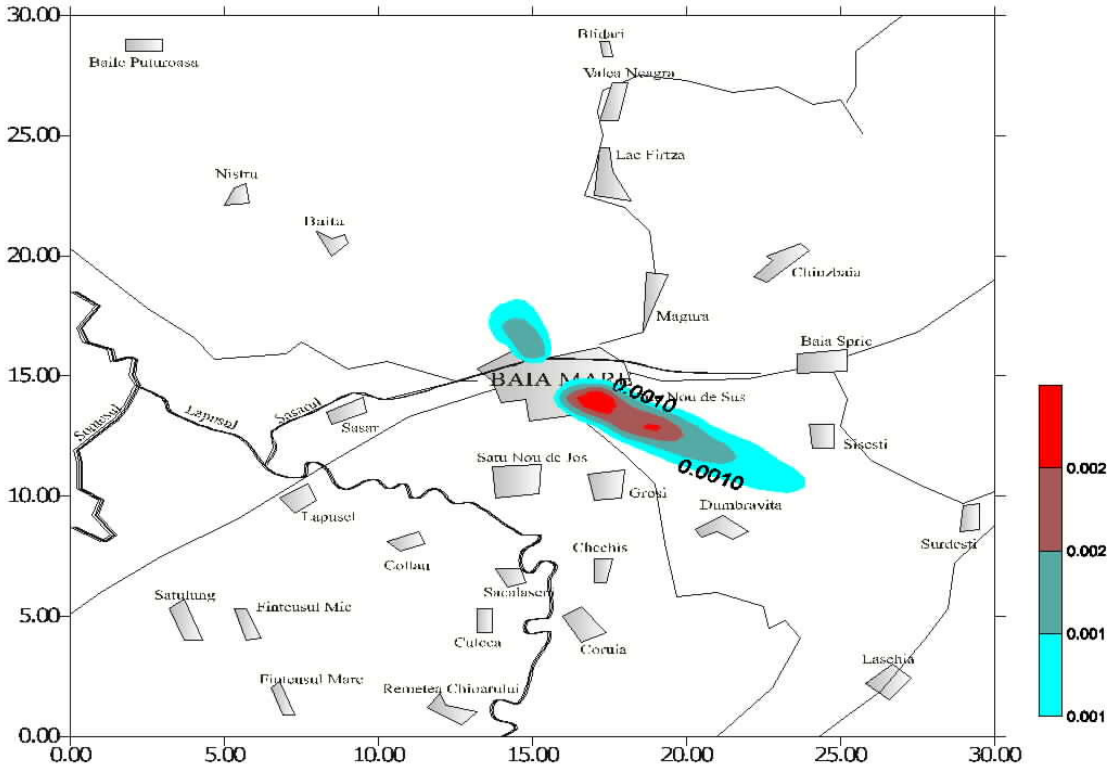




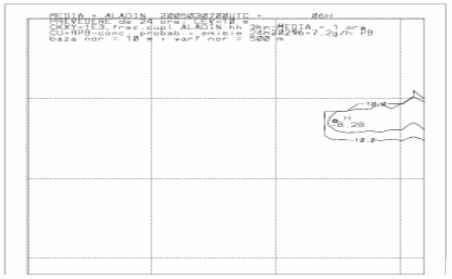

Optiuni generale
optiune PROGNOZA
indici climatici
iesiri
acces arhiva
Times New Roman
16
Transport si difuzie
Dispersie Gausiana
Transport la distanta
Scara
Domeniul
Intervalul (D/R)
Tip emisie
Draw
AutoShapes
Click and drag to insert an AutoShape.

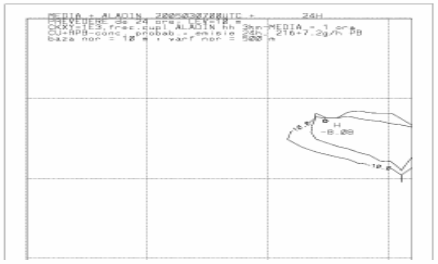
April average concentration – OML dispersion 1D model (2 sources)

Fig.1.4 Concentratia medie lunara NOx (µg/m³) S.C CUPROM BAIA MARE- Aprilie

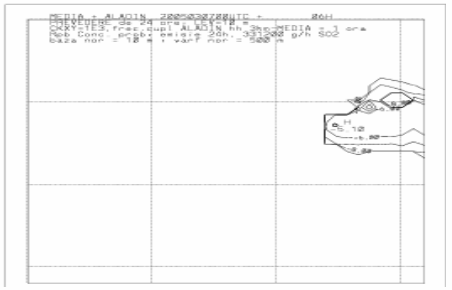


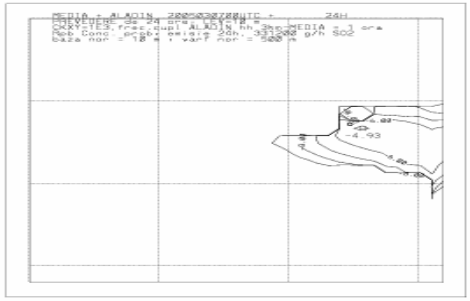
Evolutia norului de poluant (PB) dupa 6 si 24 ore de integrare
(dx=2.5km) (CU+RPB)



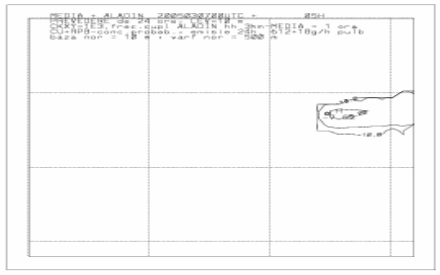


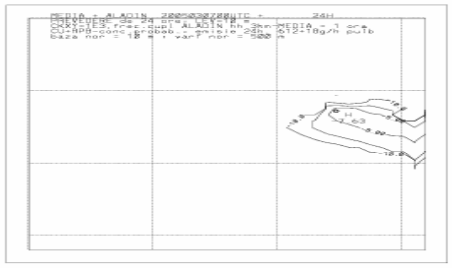
Pb



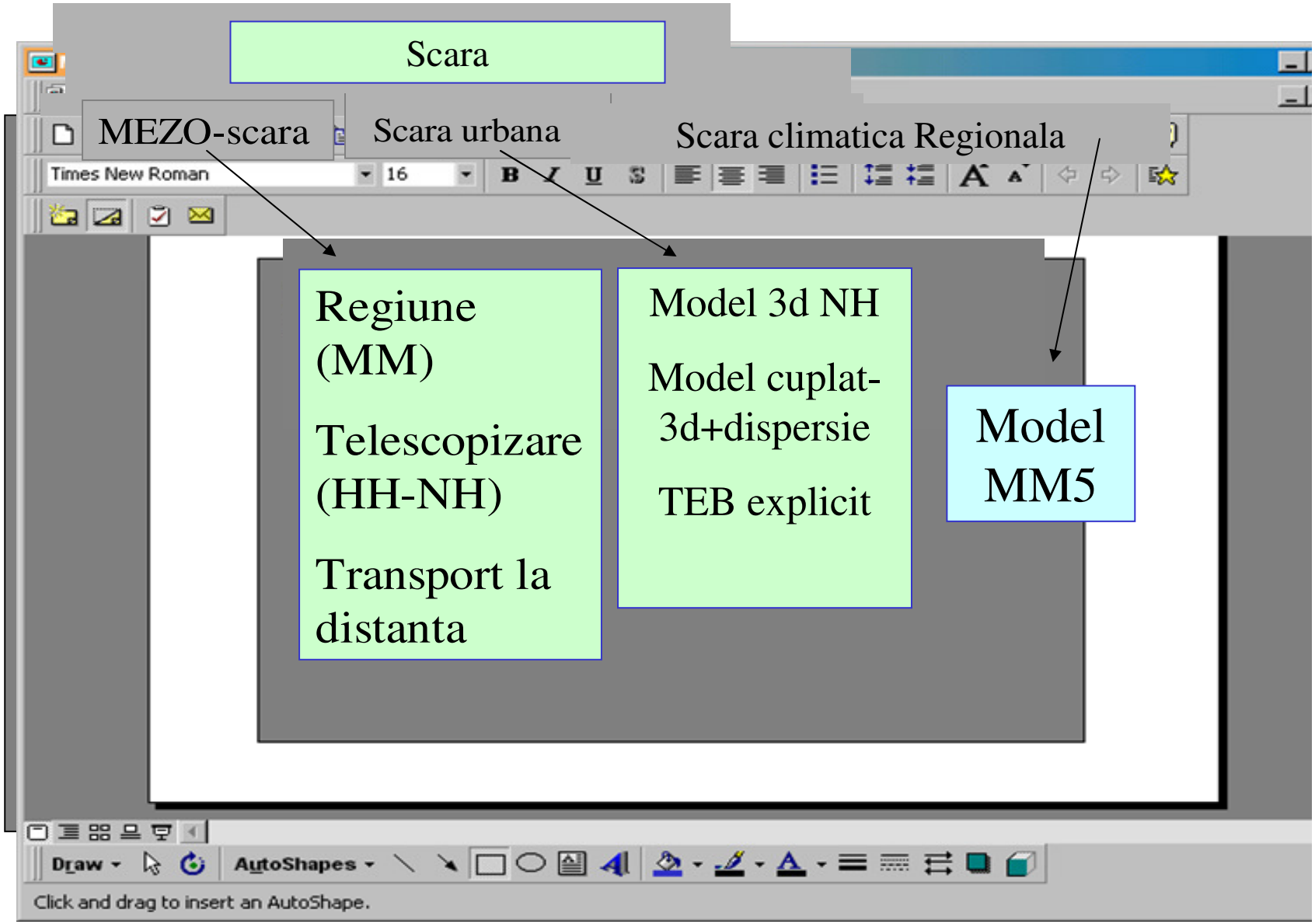


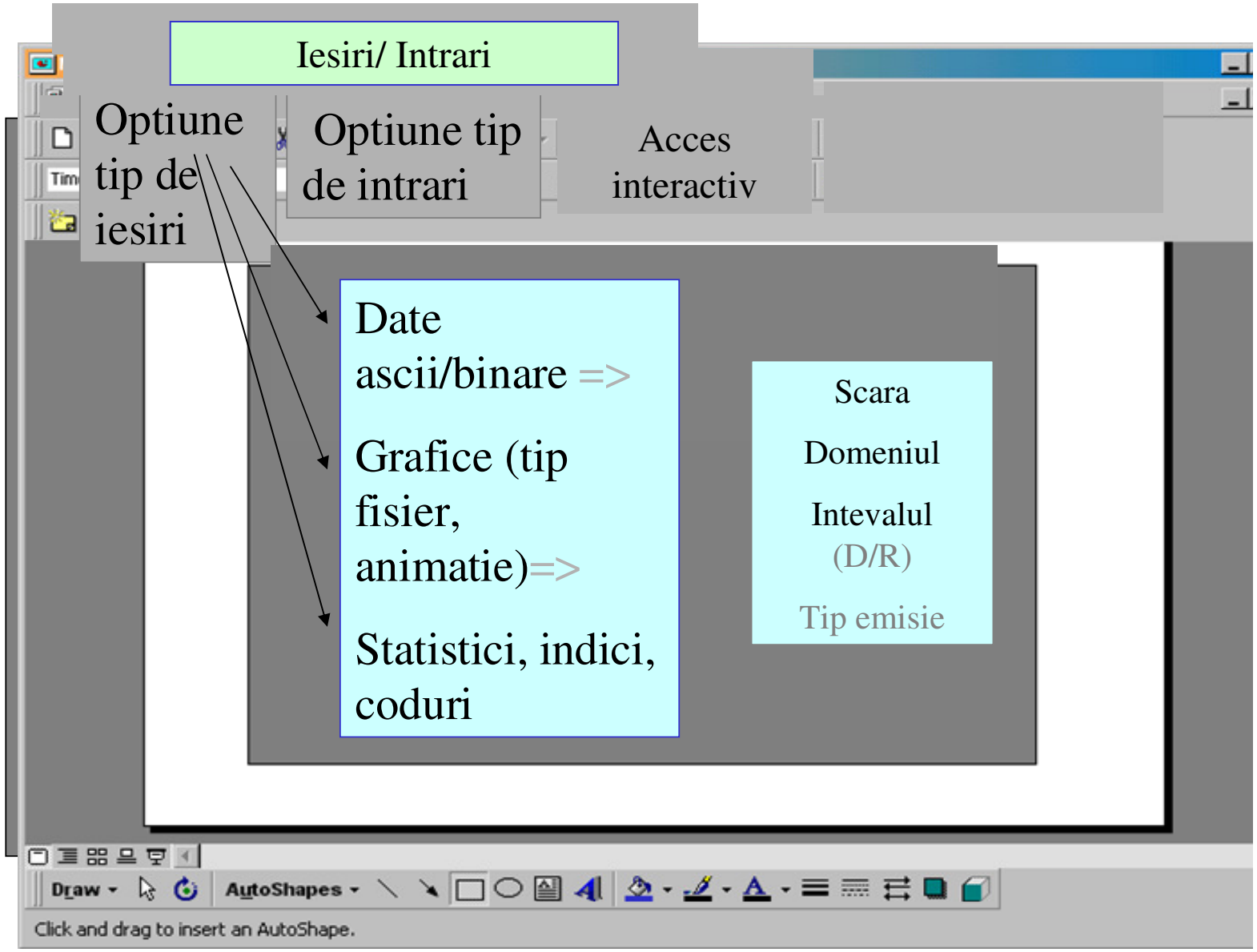
SO2





PM


Scara
MEZO-scara
Scara urbana
Scara climatica Regionala
Regiune (MM)
Telescopizare (HH-NH)
Transport la distanta
Model 3d NH
Model cuplat-3d+dispersie
TEB explicit
Model MM5
Times New Roman
16
Draw
AutoShapes
Click and drag to insert an AutoShape.


Iesiri/ Intrari
Optiune tip de iesiri
Optiune tip de intrari
Acces interactiv
Date ascii/binare =>
Grafice (tip fisier, animatie)=>
Statistici, indici, coduri
Scara
Domeniul
Intevalul (D/R)
Tip emisie
Draw
AutoShapes
Click and drag to insert an AutoShape.

CONCLUSIONS I)

- **The atmospheric model at high resolution catches some of the small scale features but needs further validation & new parameterisation of urban processes**

- **The air pollution model presents two main limitations:**

- Treats passive pollutants for the atmosphere, not changing the meteorological fields;

- Does not represent chemical transformations

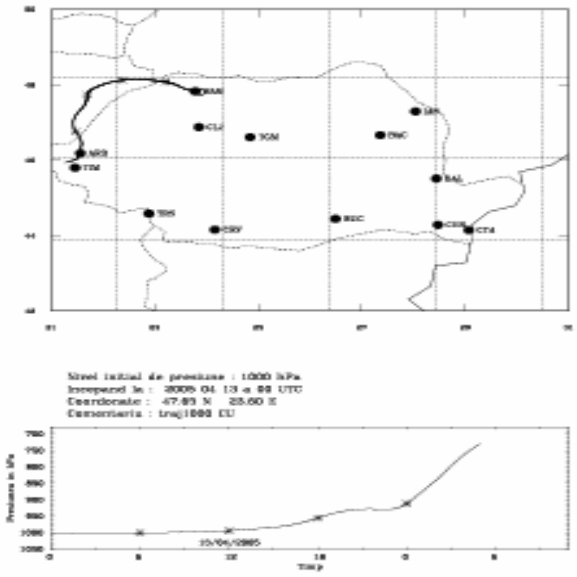
- **The coupled system provides a tool for short range forecast at regional to small scales of air pollution from pointwise sources and/or for accidental release**

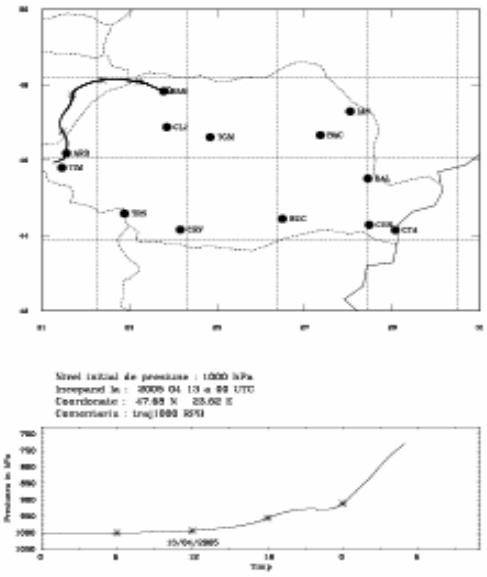
- **The coupled system may be adapted to other regions**

- **Treating long distance transport it is suitable for being used in national inter-regional network of air pollution forecast.**

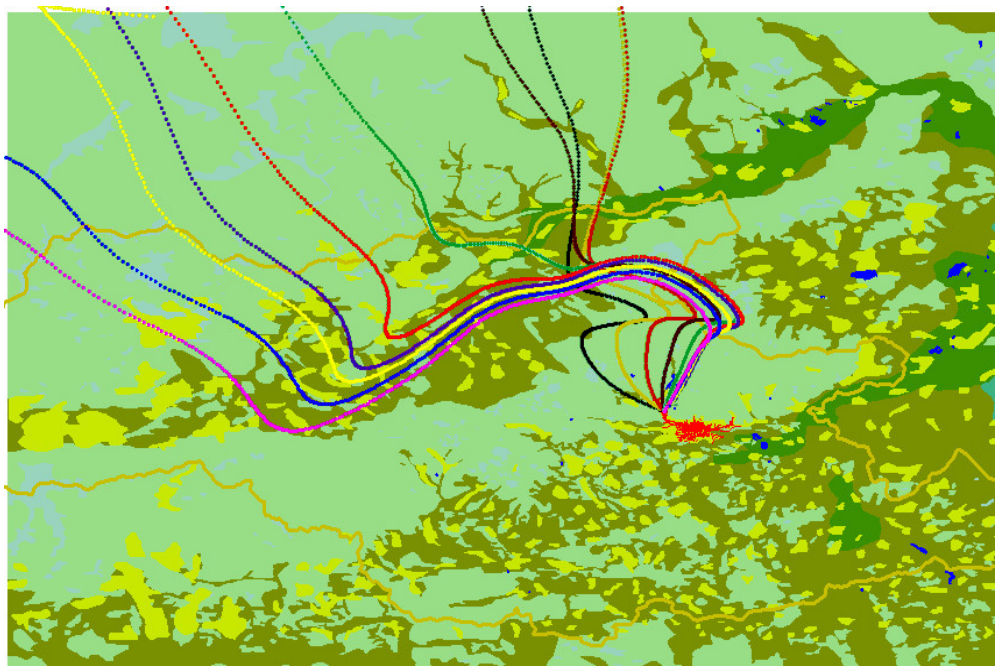
Trajectories computation:
3 succesive interpolations of the 3d-forecasted wind:
-Horisontal
-vertical
-temporal

Trajectory forecasted for 48 hours for 2 sources: at CUPROM and at Romplumb, 13 April 2005



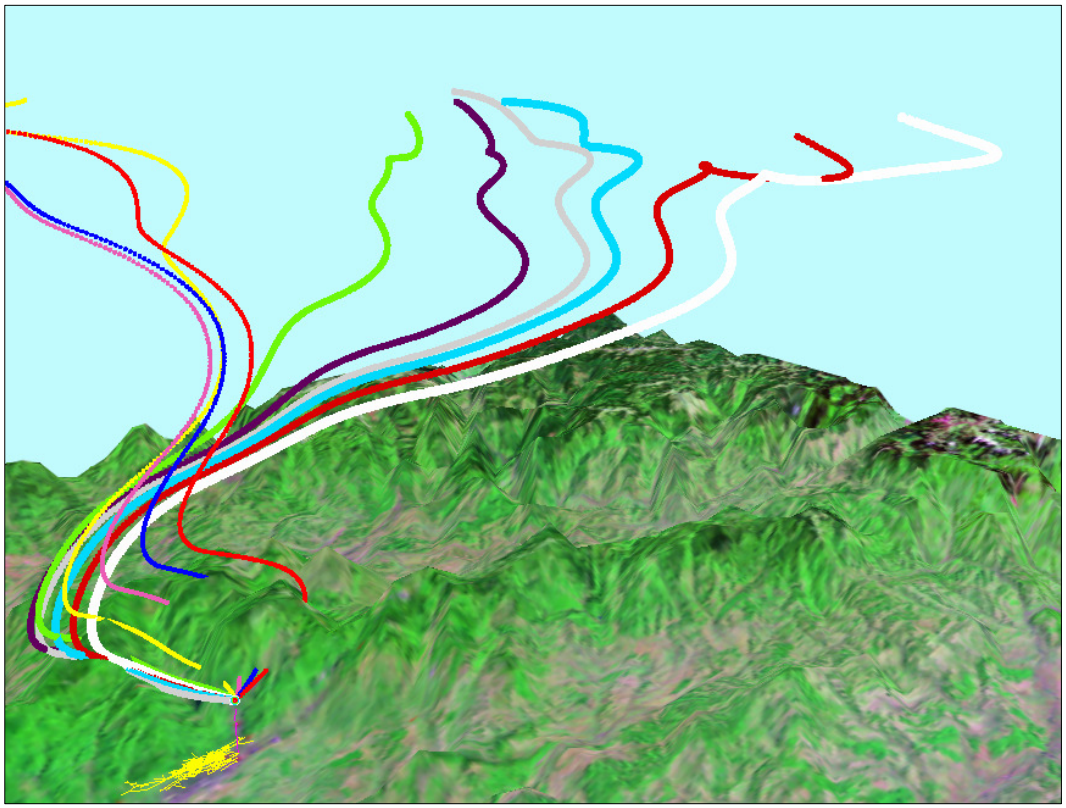


2D GIS temporal series of pollutant forecasted trajectories at Cuprom Baia-Mare.

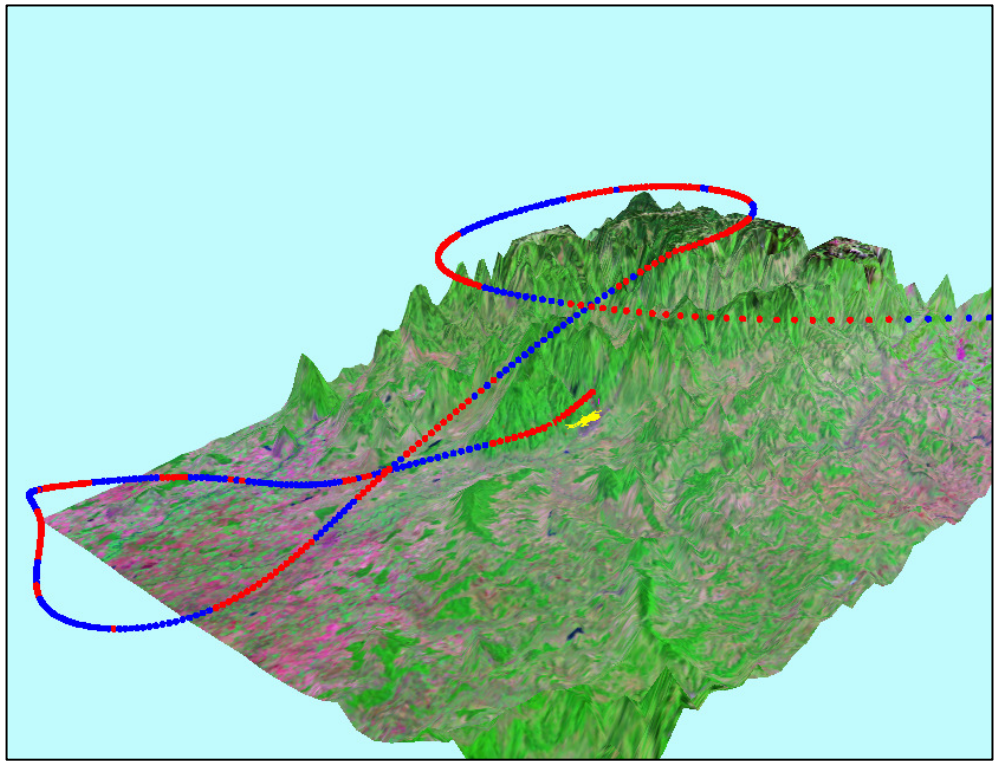


3D presentation of the multiple pollutant trajectories started from a source in Baia Mare (Romania), using NTM (Numerical Terrain Model)

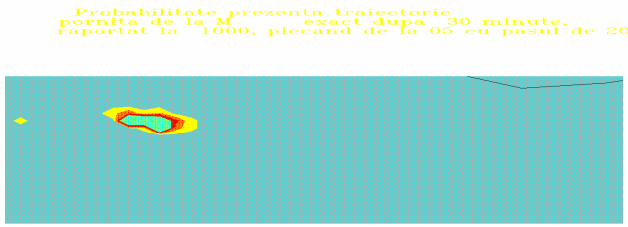
The map, results of running the air pollutant trajectories is visualized in GIS. Here the input from the databases is linked with the air pollution modeling on layers covering three nested high-to-low resolution databases: the database of the territory of Romania, the extended Baia Mare and environments area, and the limited area high resolution town map.

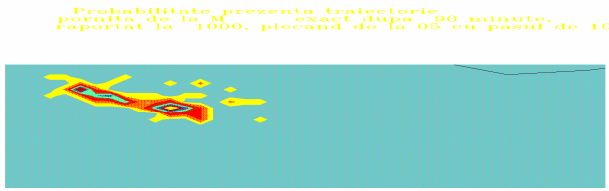


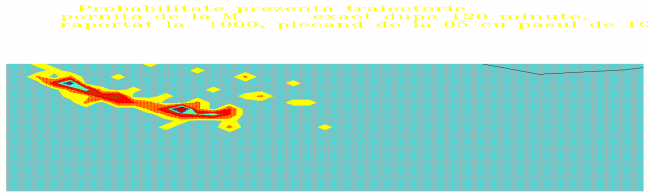
3D representation of the trajectory (each 5 minutes) of the pollutant release from Romplumb (Baia Mare - Romania) source
(the alternation of the red and bleu colors signifies the alternation of the hourly forecast during the interval of 48 hours forecast)



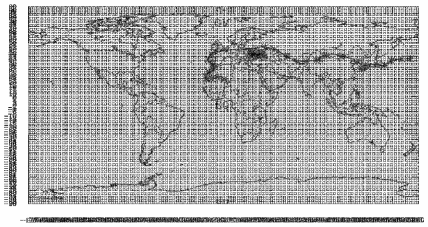
Trajectories frequency after 30,60,90,120 min., DJF 2003, Baia Mare

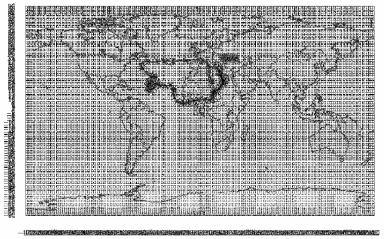


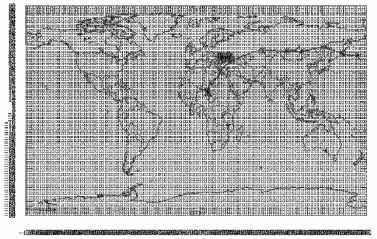


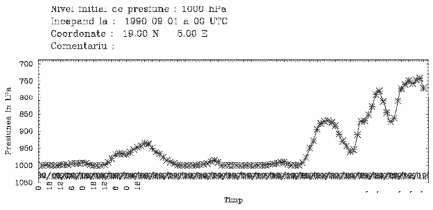


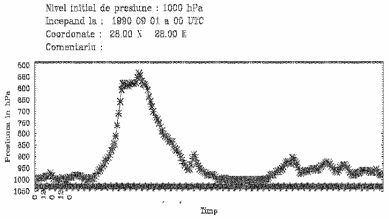
Sahara dust transport in 01/09 (10 y climatology) for 1000, 1000,500 mb.

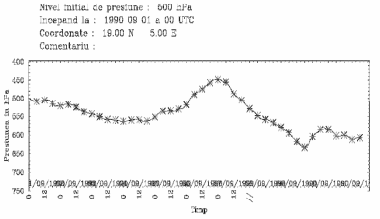












CONCLUSION II)

- **The method may be used to answer some of the questions faced by the authorities when revisiting particular intervention plans;**

- **Computation may be done at any resolution, for particular areas afected by pollutant sources;**

- **An advantage of the trajectories statistics method is the geographycal referencing that allows visualisation and data treatment through GIS.**