Data assimilation and modeling

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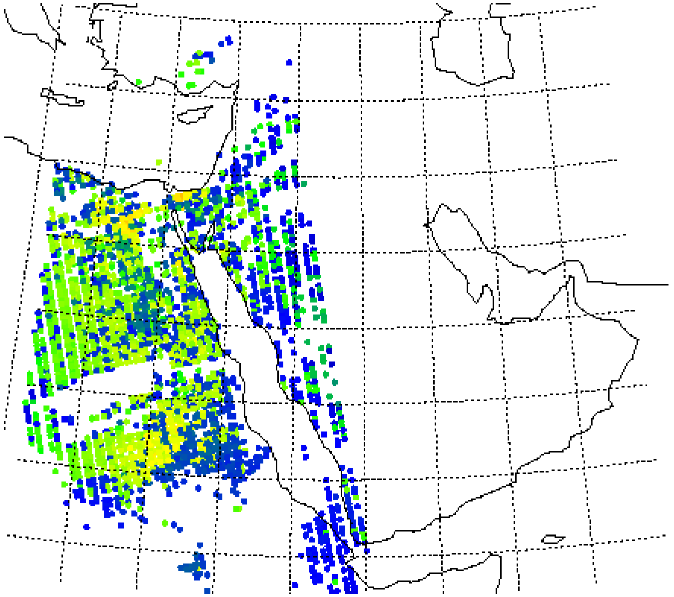
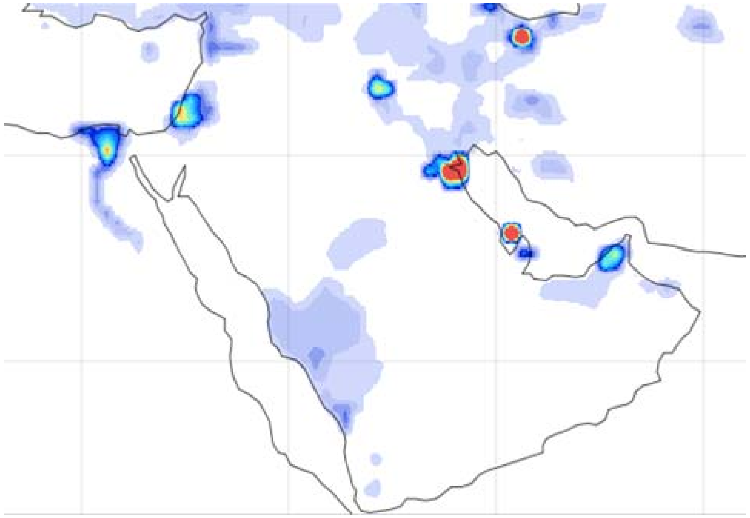
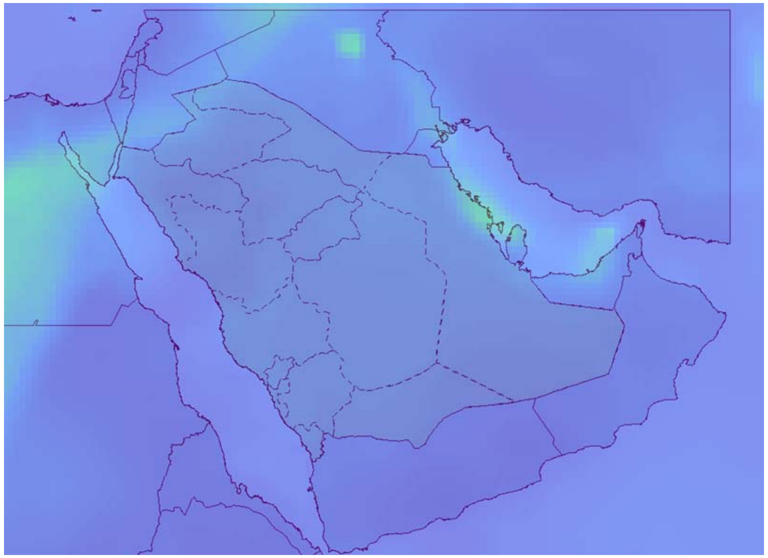
Objective of data assimilation in Saudi Arabia air quality system is to combine all kinds of data into one product to facilitate your work.

Data assimilation scheme





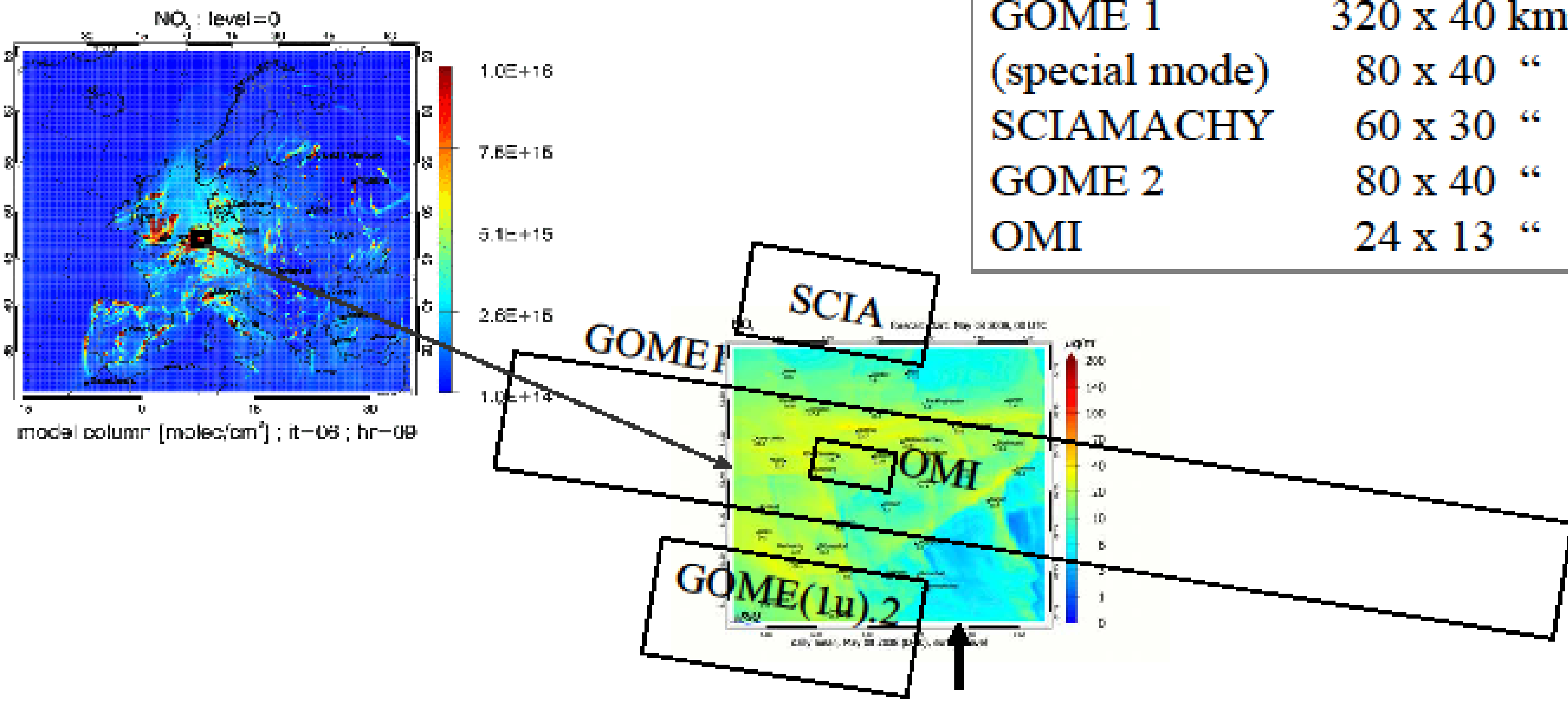
How to combine?



Answer: with data assimilation

Different satellite pixel sizes

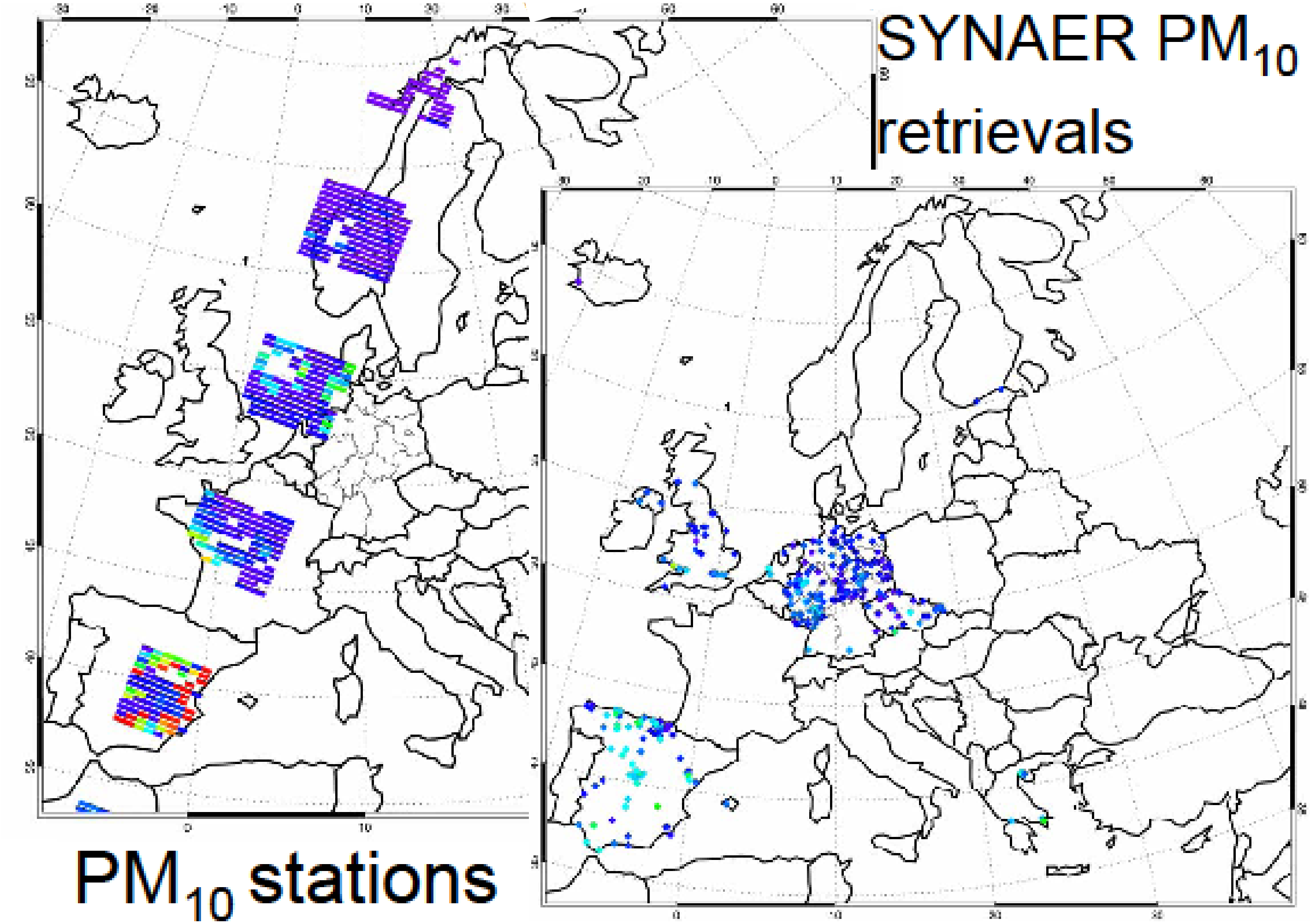
minimal areas:	
GOME 1	320 x 40 km^2
(special mode)	80 x 40 “
SCIAMACHY	60 x 30 “
GOME 2	80 x 40 “
OMI	24 x 13 “



Ruhr area domain 90 x 80 km^2

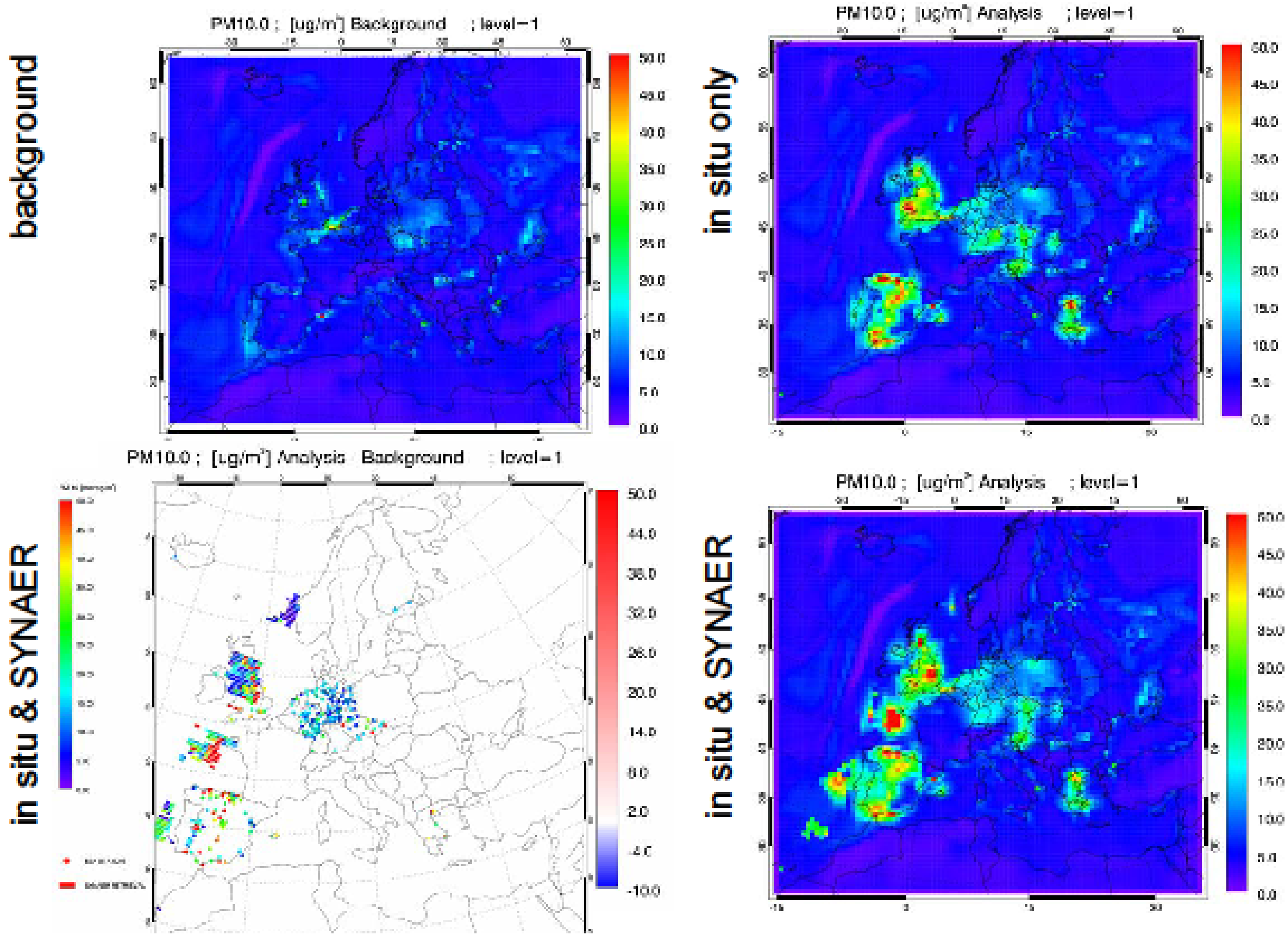
Input data for assimilation

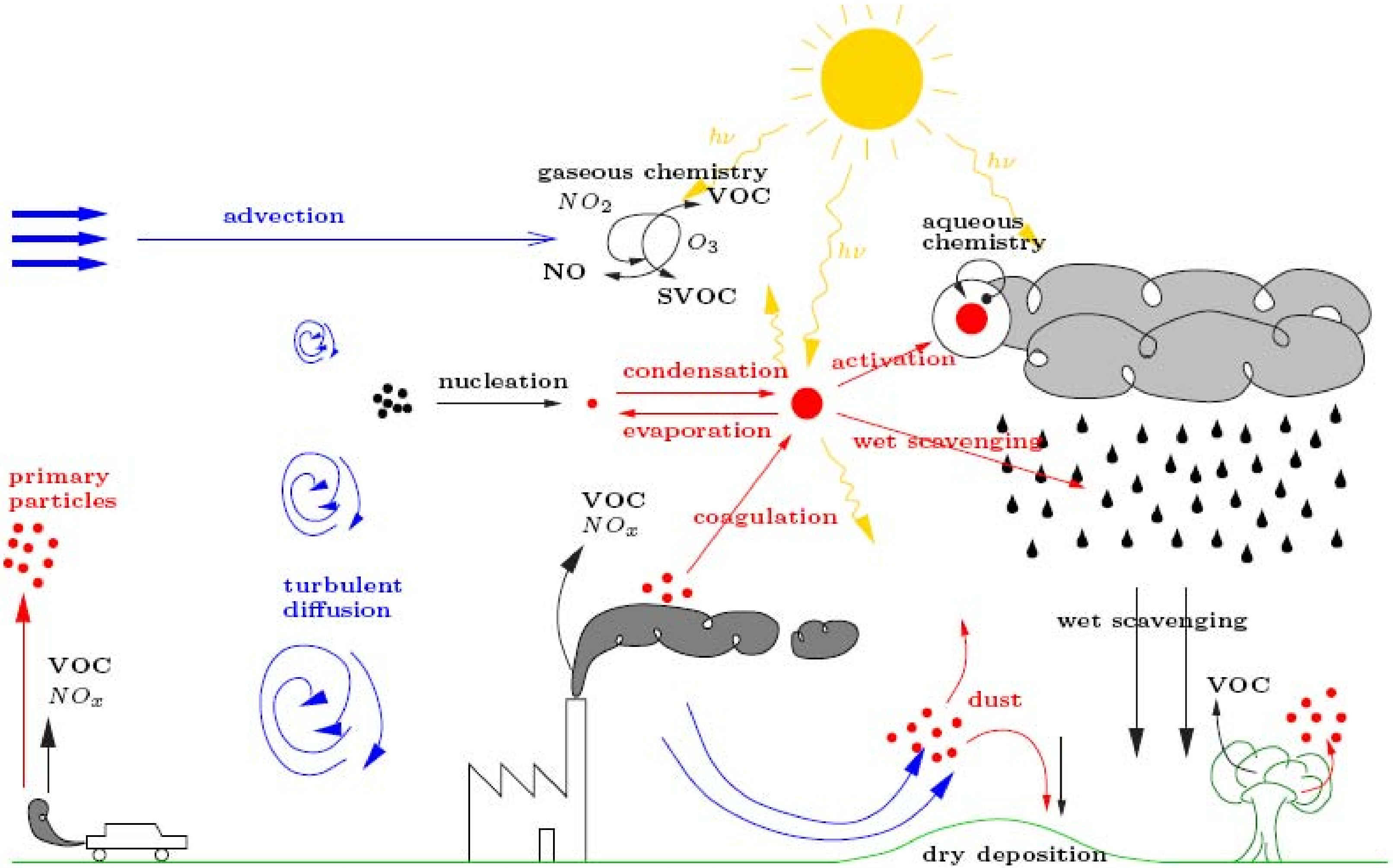
SYNAER PM_{10} retrievals



PM_{10} stations

3Dvar aerosol assimilation (13.7.2003)



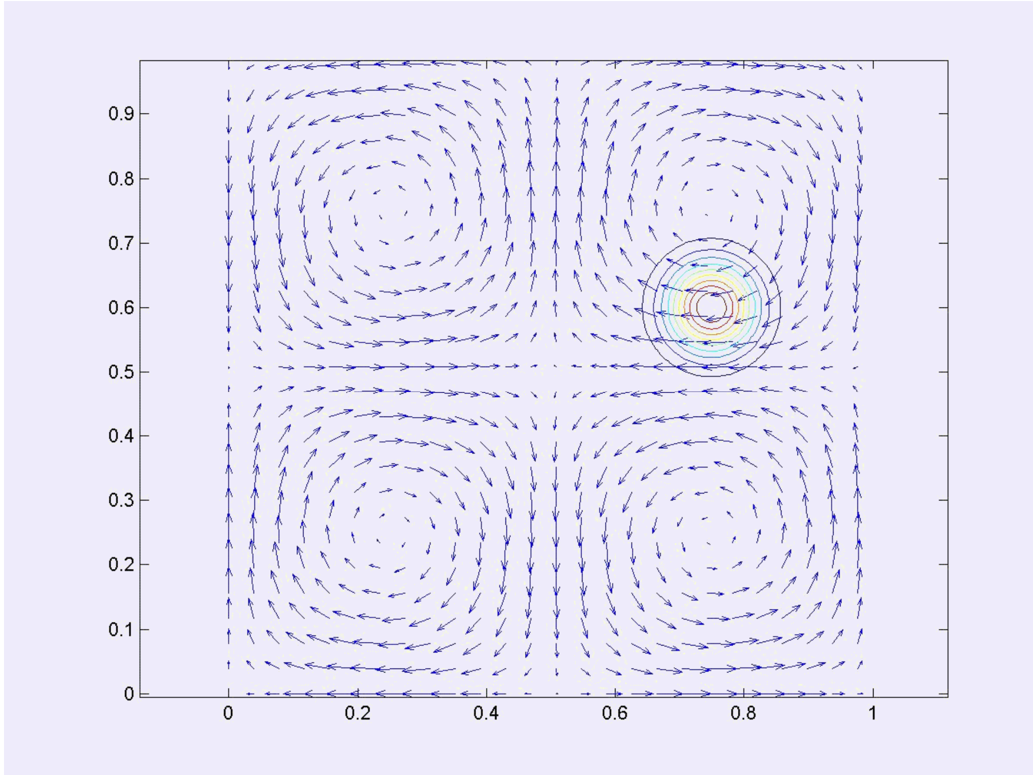


hν
gaseous chemistry
NO_2
VOC
O_3
NO
SVOC
advection
aqueous chemistry
nucleation
condensation
evaporation
activation
wet scavenging
coagulation
primary particles
turbulent diffusion
VOC
NO_x
wet scavenging
dust
dry deposition

Advection Equation

- The 2D advection equation:

$$\frac{\partial C}{\partial t} + a^x \frac{\partial C}{\partial x} + a^y \frac{\partial C}{\partial y} = 0$$

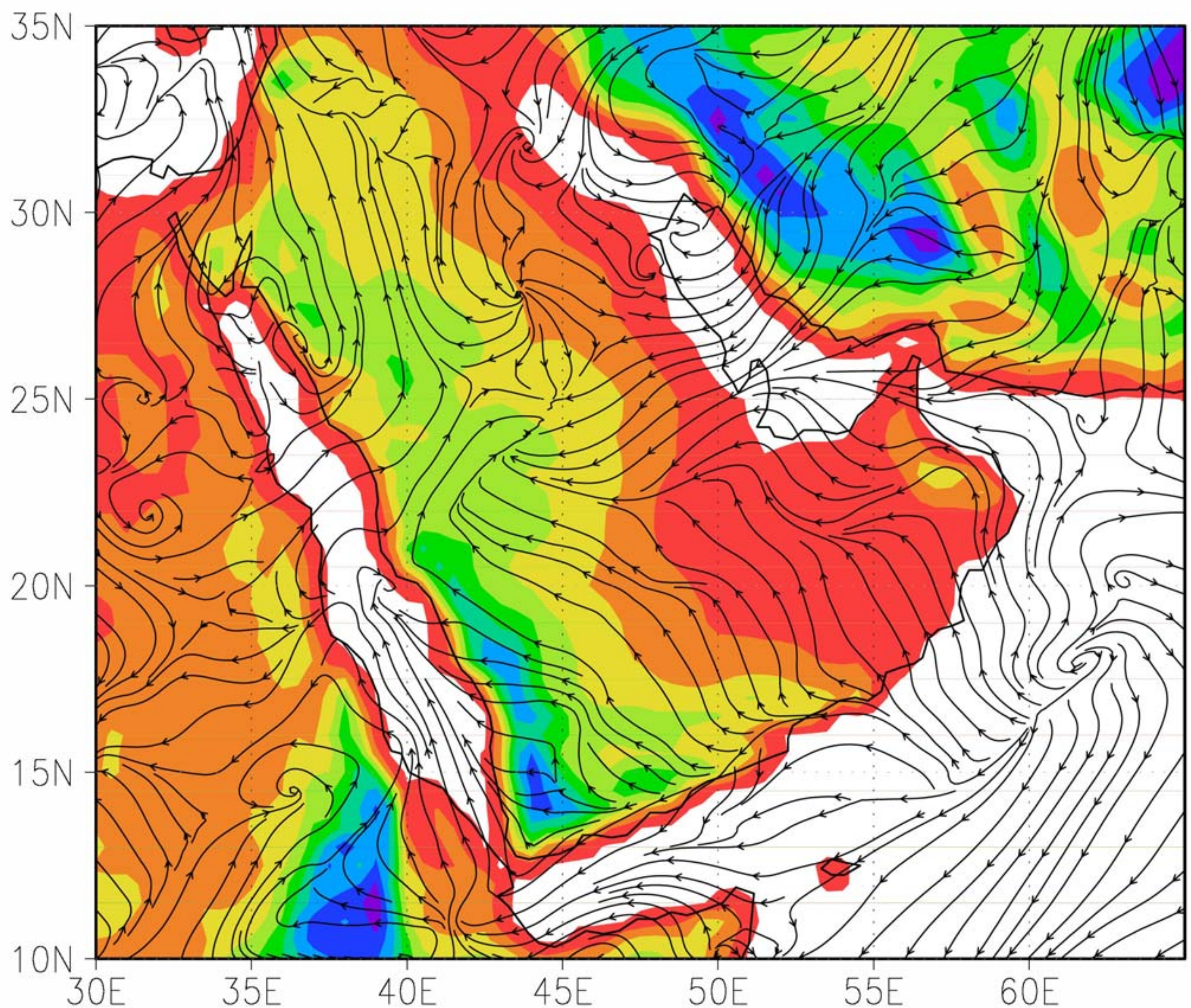


$$\frac{\partial C}{\partial t} + a^x \frac{\partial C}{\partial x} + a^y \frac{\partial C}{\partial y} = 0$$

$$C\left(t=0,x,y\right) = e^{-200\left(\left(x-.75\right)^2+\left(y-.6\right)^2\right)}$$

$$a^x = -\sin\left(2\pi x\right)\cos\left(2\pi x\right)$$

$$a^y = \cos\left(2\pi x\right)\sin\left(2\pi x\right)$$


35N
30N
25N
20N
15N
10N
30E
35E
40E
45E
50E
55E
60E

Basic general equation

advection, diffusion, chemistry removal, emission

$$L\overline{\varphi} \equiv \frac{\partial \overline{\varphi}}{\partial t} + \frac{\partial}{\partial x_i}(\overline{u}_i \overline{\varphi}) + \frac{\partial}{\partial x_i}(\overline{u_i' \varphi'}) + \sigma(\overline{\varphi}) = \bar{f}$$

Basic general equation

1D case: $\frac{\partial \varphi}{\partial t} + u \frac{\partial \varphi}{\partial x} = 0; \quad let \ \ \varphi_k^j = \varphi(x_k, t_j)$

- Explicit scheme

$$\frac{\varphi_k^{j+1} - \varphi_k^j}{\tau} + u \frac{\varphi_k^j - \varphi_{k-1}^j}{\Delta x} = 0$$

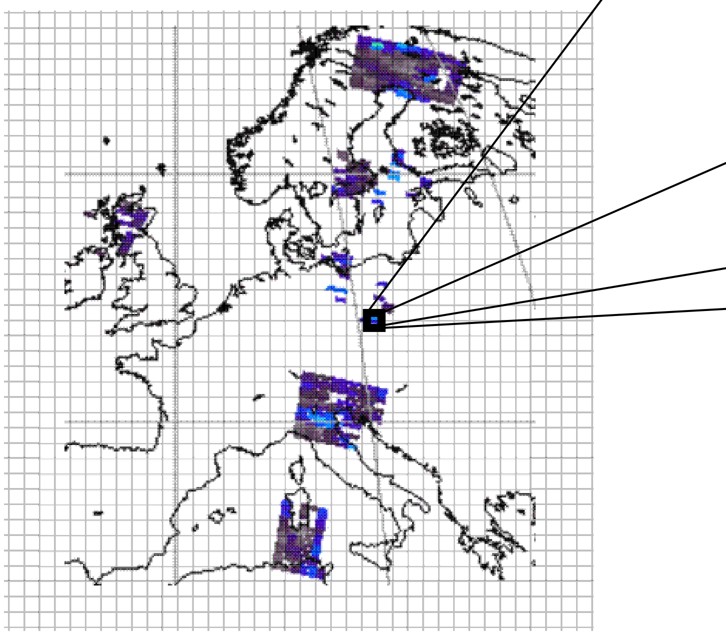
- Implicit scheme

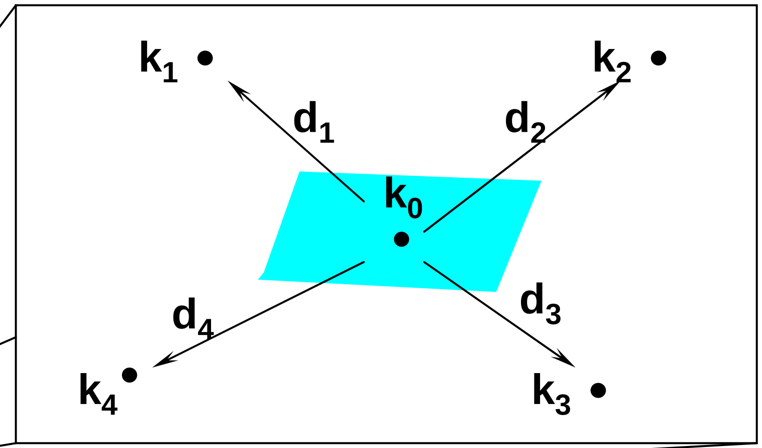
$$\frac{\varphi_k^{j+1} - \varphi_k^j}{\tau} + u \frac{\varphi_k^{j+1} - \varphi_{k-1}^{j+1}}{\Delta x} = 0$$

Satellite correction for PM 2.5, PM10

Interpolation scheme:

Model Grid





Normalization and Inversion:

$$d_i = 1 - \frac{d_i}{\max(d_1, d_2, d_3, d_4, d_5)}, i = 1..4$$

Linear Interpolation:

$$k_0 = \frac{k_1 \cdot d_1 + k_2 \cdot d_2 + k_3 \cdot d_3 + k_4 \cdot d_4}{d_1 + d_2 + d_3 + d_4}$$

Data assimilation scheme

$$J = J_b + J_o$$

$$J = (x - x_b)^T B^{-1} (x - x_b) + (y - H(x))^T R^{-1} (y - H(x))$$

R – Observation error covariance matrix

y - Observations

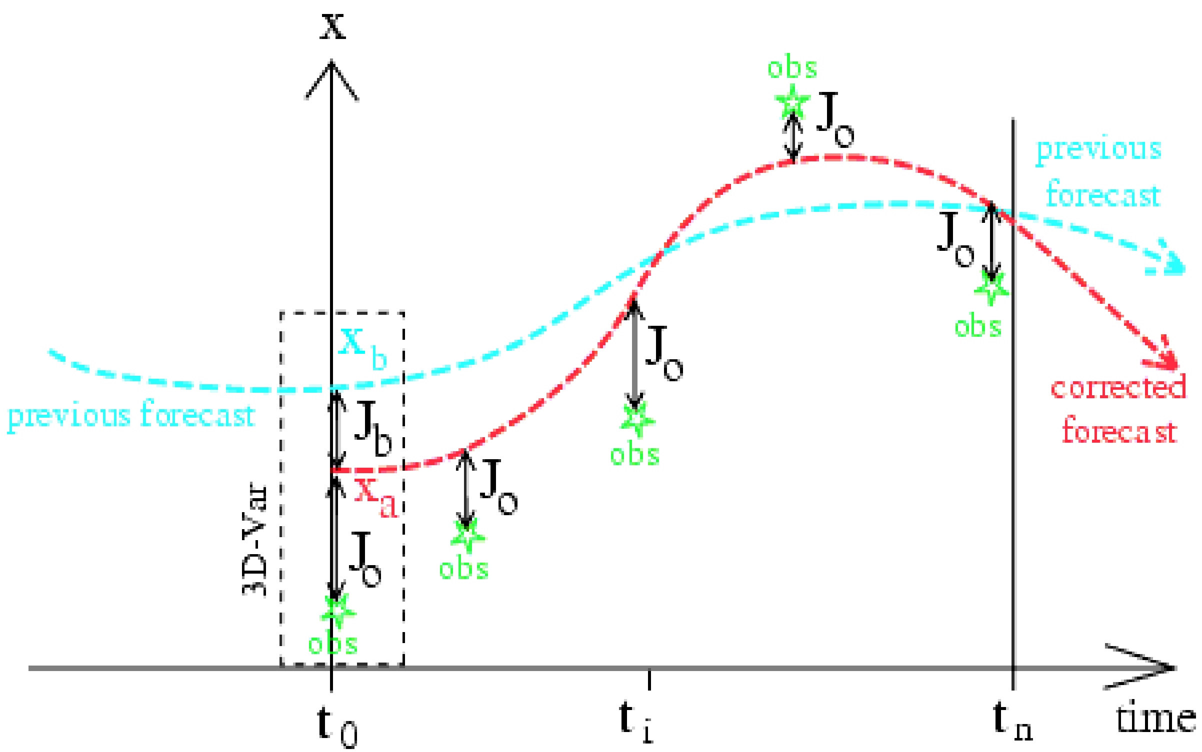
H – Observational operator

B – Background error covariance matrix

x – Model variables

Data assimilation scheme

$$J = J_b + J_o$$



Summary

- Forecasting of air quality for Saudi Arabia

  is based on solving the turbulent diffusion equation

- chemical assimilation forecasts can be performed on all scales (from national to street level)

- chemical data assimilation best method to combine sparse and heterogeneous observations from ground and satellite, with variable error characteristics

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