

Localization of an Atmospheric Source by Inverse Modeling

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HYSPLIT MODEL

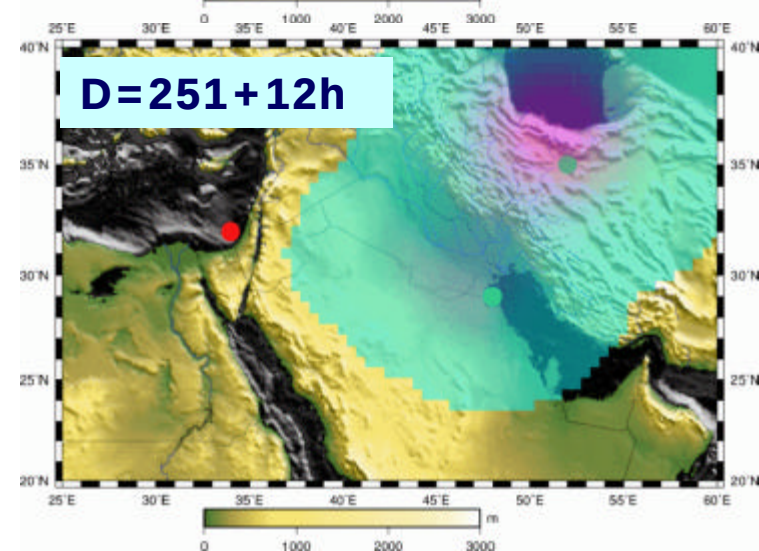
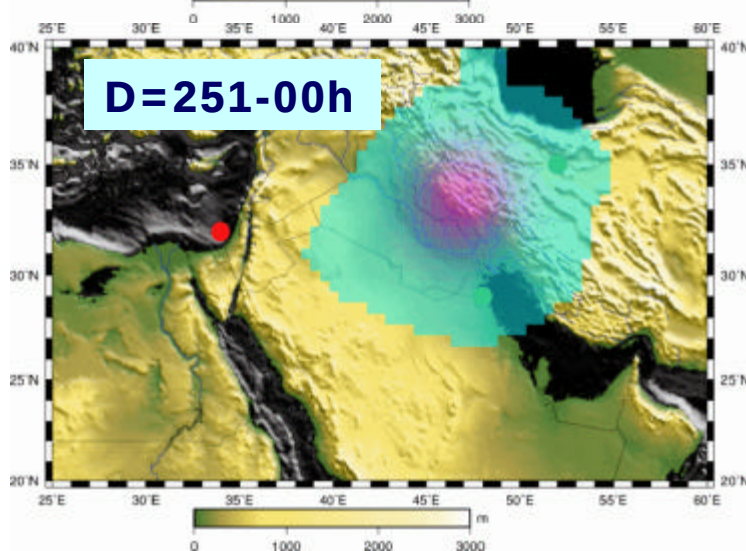
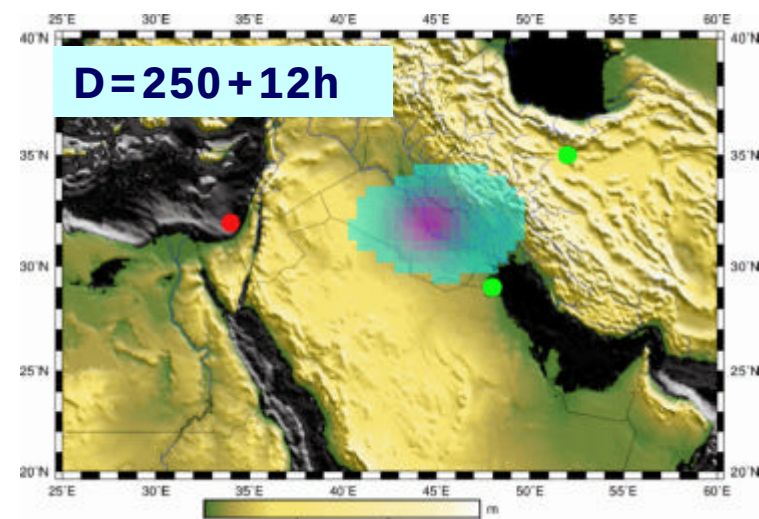
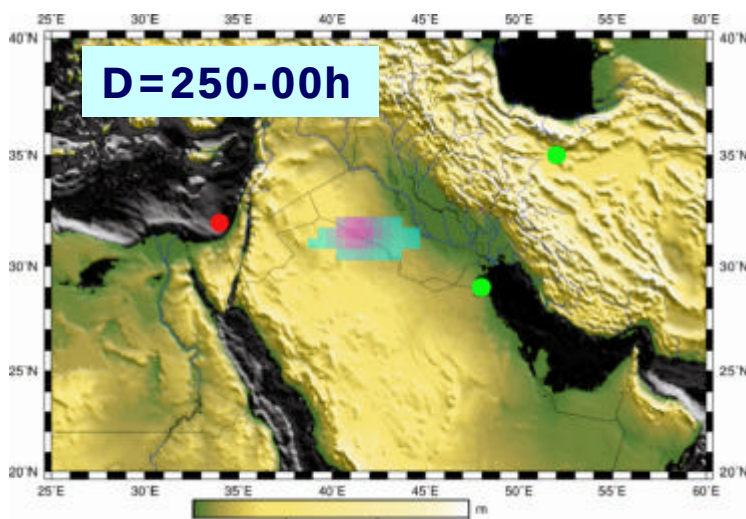
Hybrid Single-Particle Lagrangian Integrated Trajectory

- NCEP wind fields: 1,5°, 13+1 levels + 6 hours resolution. Input data : u,v,w,T,ps,p
- Test case : noble gaz. Output in a domain of 50°x50° with a grid resolution of 0.5°x0.5°
- Forward simulations:
 - Hybrid mode: particle dispersion (vertical direction) and puff dispersion (horizontal direction)
- Backward simulations:
 - particle dispersion mode $\frac{dX}{dt} = \mathbf{v}[X(t)]$ with $\mathbf{v} = \bar{\mathbf{v}} + \mathbf{v}'$
 - 10,000 particles
 - 4-hours sampling (output and source emissions)

Direct Calculation (HYSPLIT)

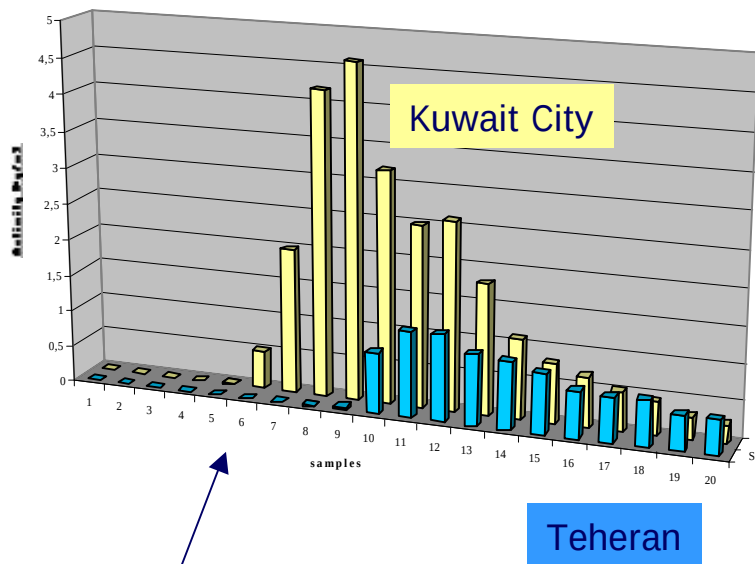
Release of 1.10^{16} Bq at 5000m(aerial nuclear test 1KT)

Julian Day=248, 0h00



OBJECTIVE OF THE WORK : DETERMINATION OF THE SOURCE

**19x2 Synthetic
Measurements**

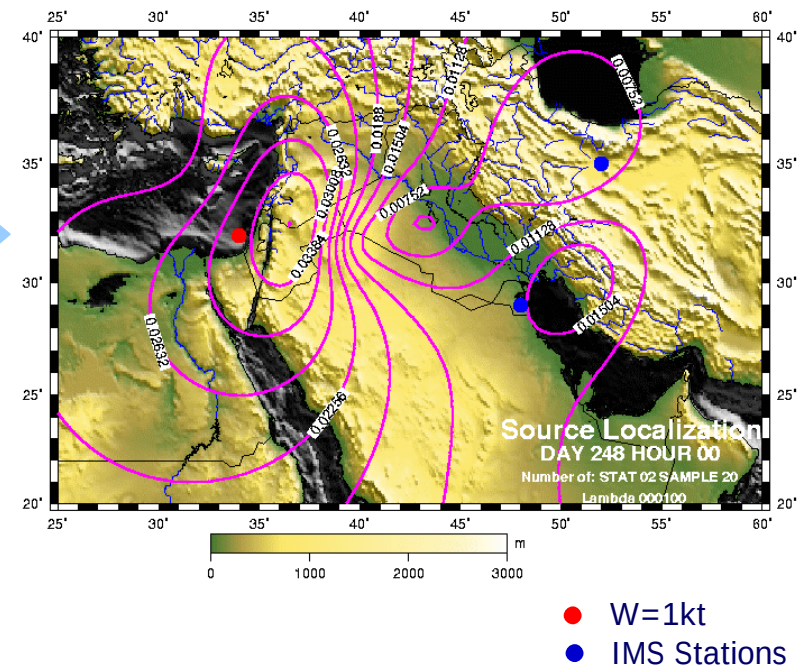


1st detection: 7 september 2000 (julian day=250)

Inversion
process

Inversion Map

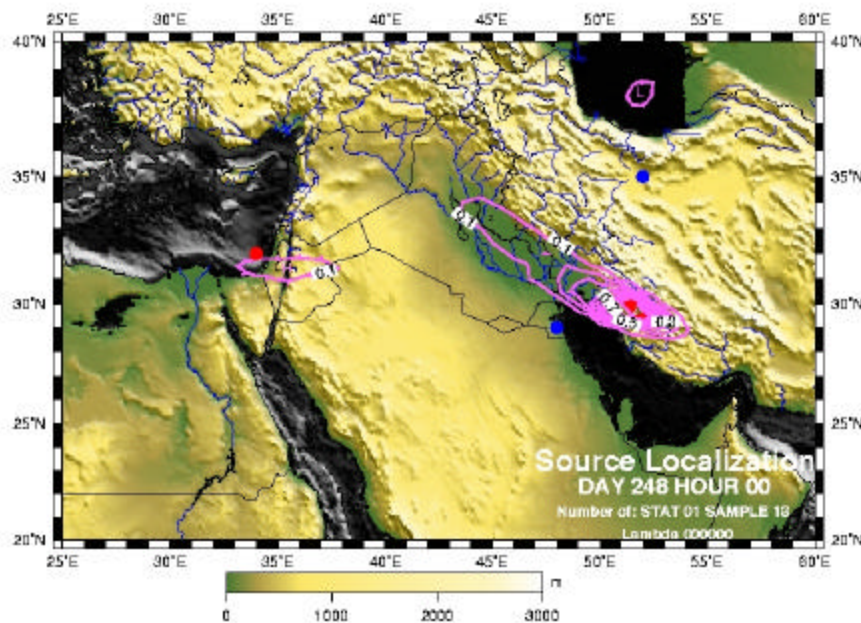
Activity: Bq



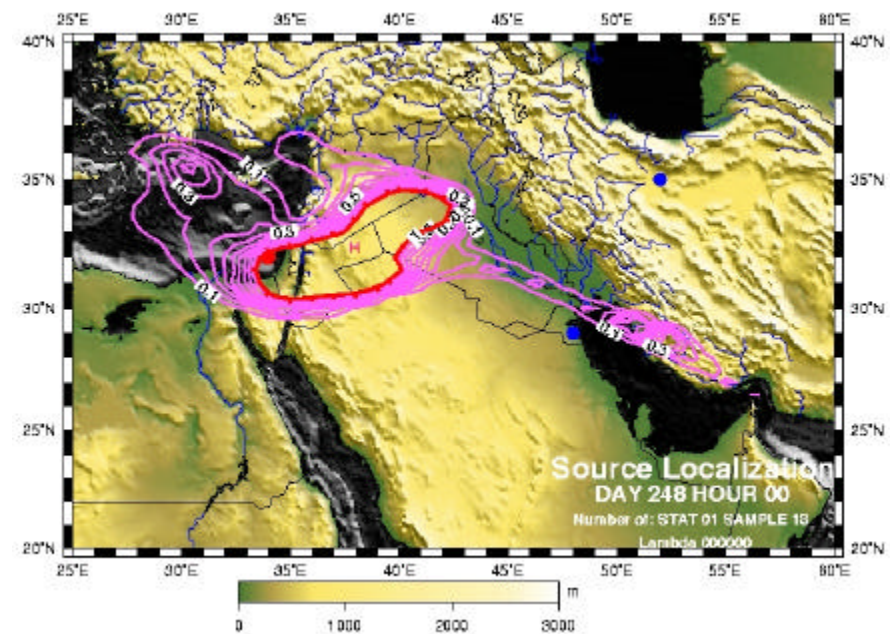
Linear Combination of Backward FORs

weights proportional to measurements

from Teheran station (500m)



from Kuwait City station (500m)



Normalized residence times (between 4 and 6 km)

SOURCE LOCALIZATION BY INVERSION MODELING: $M.S=Y$

■ ASSUMPTIONS:

- The release time is assumed to be known (Julian day=248,0h)
- We look for an aerial nuclear test : known altitude= 5000m
- measurements at 2 IMS stations during 3 days= 2x19 samples averaged over 4 hours

■ 1st step: CONSTRUCTION from backward calculations of the source-receptor matrix M , consisting of residence times (formalism of P. Seibert)

- Dimensions of the Matrix M : 10,000 spatial elements by 2x19

■ 2nd step: INVERSION

- $M.S = Y$ (S = vector of 10,000 elements, $Y=38$ measurements)

1. INVERSION MODELING : $M.S=Y$

■ BACKUS-GILBERT without any *a priori* on the source

- Minimize a functional $\mathbf{A}(\mathbf{S}) + l \mathbf{B}(\mathbf{S})$
- $\mathbf{S}(x) =$ true solution vector (sources)

$$\hat{\mathbf{S}}(x) = \int \hat{d}(x, x') \mathbf{S}(x') dx' \quad \hat{d} = \text{resolution function}; \quad \int \hat{d}(x, x') dx' = 1$$

$\hat{\mathbf{S}} = \mathbf{K} \cdot \mathbf{Y}$ where $\mathbf{K}$ = "inverse response kernels" matrix, $\mathbf{Y}$ = observations vector

$\mathbf{K}$: $\mathbf{K} \cdot \mathbf{R} = \mathbf{I}$, where $\mathbf{R}_j = \text{vector} = \sum_i m_{ij}$

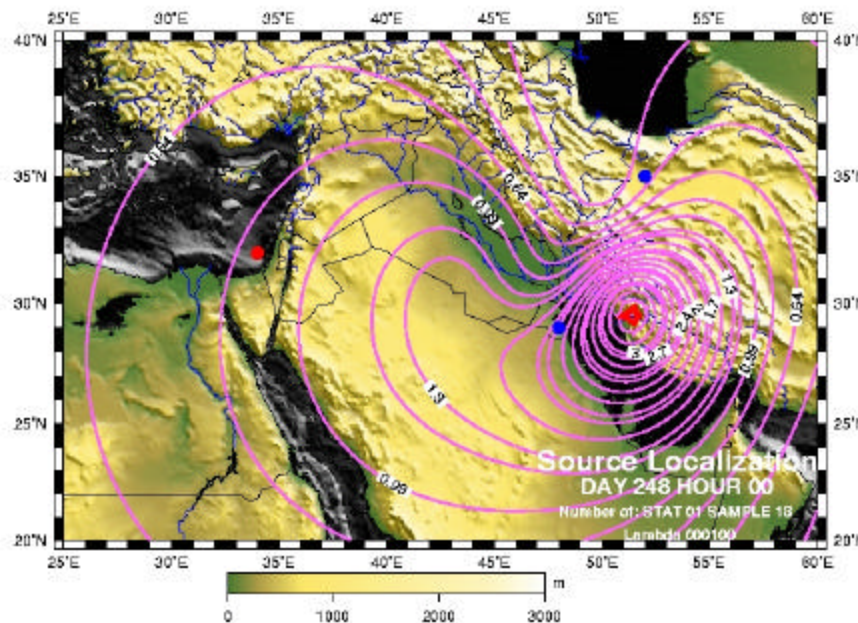
- Minimize the spread of $\hat{d}$: $\mathbf{A} = \int (x' - x)^2 \hat{d}(x, x')^2 dx'$
- Maximize the stability of the inversion: $\mathbf{B} \equiv \text{Var}[\hat{\mathbf{S}}(x)]$

$$\rightarrow \hat{\mathbf{S}}(x) = f(\mathbf{M}, \mathbf{Y}, l)$$

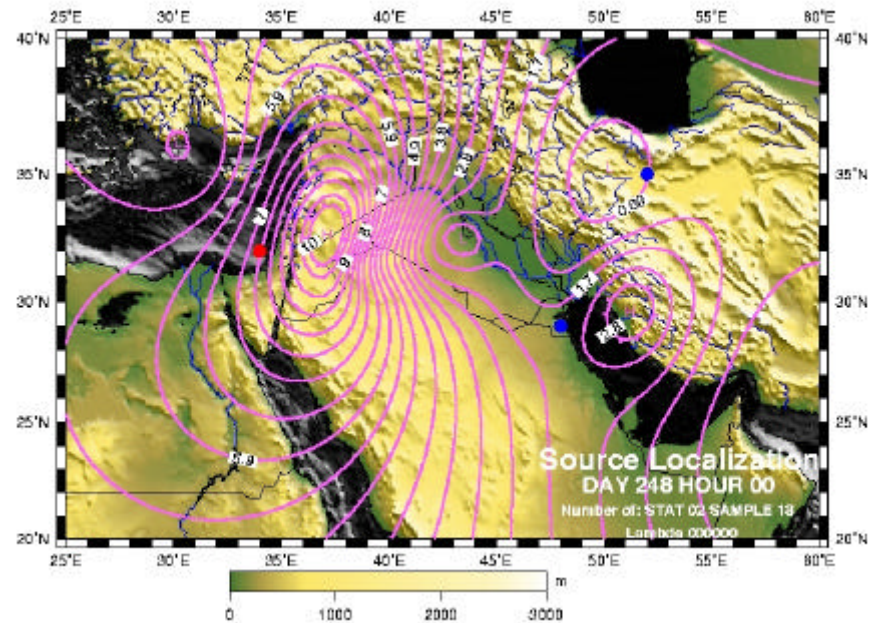
Inverse Modeling

Backus-Gilbert Inversion for a known release time

from Teheran station (500m)



from K-City & Teheran stations (500m)



Source intensity $S(x)$ in 10^{12} Bq

2. INVERSION MODELING WITH A PRIORI

$$\mathbf{M} \cdot \mathbf{S} = \mathbf{Y} \quad ; \quad \begin{bmatrix} m_{i1} \\ \dots\dots\dots m_{ij} \dots\dots\dots \\ \vdots \\ m_{i,38} \end{bmatrix} \mathbf{S} = \begin{bmatrix} y_1 \\ y_j \\ \vdots \\ y_{38} \end{bmatrix}$$

$\mathbf{m}_i$ vector
↓
 m_{i1}

■ Point source in space and time i_0 : $\exists i_0, \mathbf{S}_i = Q d_{i,i_0}$

$$\Leftrightarrow \exists i_0, \mathbf{m}_{i_0} Q = \mathbf{Y} \Leftrightarrow \frac{\mathbf{m}_{i_0}}{\|\mathbf{m}_{i_0}\|} = \frac{\mathbf{Y}}{\|\mathbf{Y}\|}$$

1st step : calculation of

$$f_i = \left\| \frac{\mathbf{m}_i}{\|\mathbf{m}_i\|} - \frac{\mathbf{Y}}{\|\mathbf{Y}\|} \right\|$$

➡ Q elimination

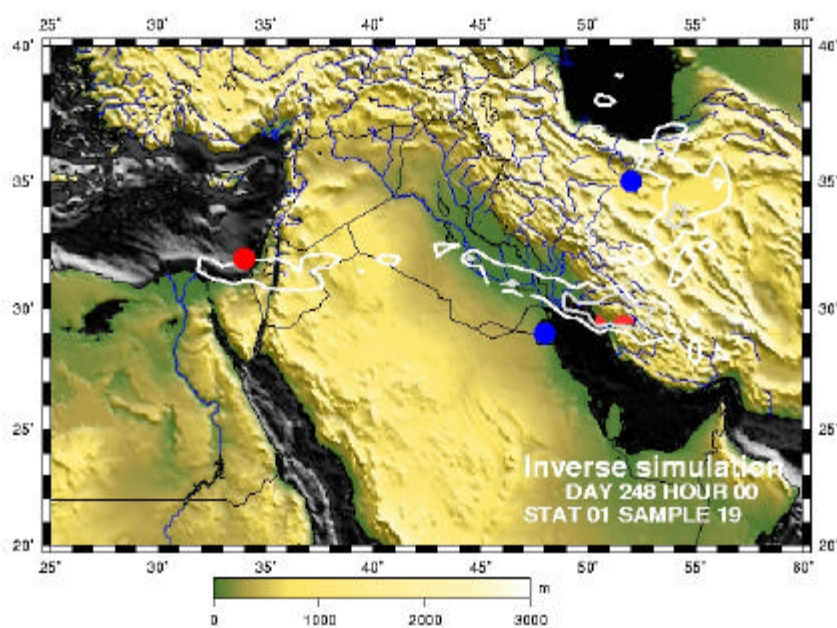
2nd step : calculation of Q

$$\bar{Q} = \frac{1}{38} \sum_j \frac{y_j}{m_{i_0 j}}$$

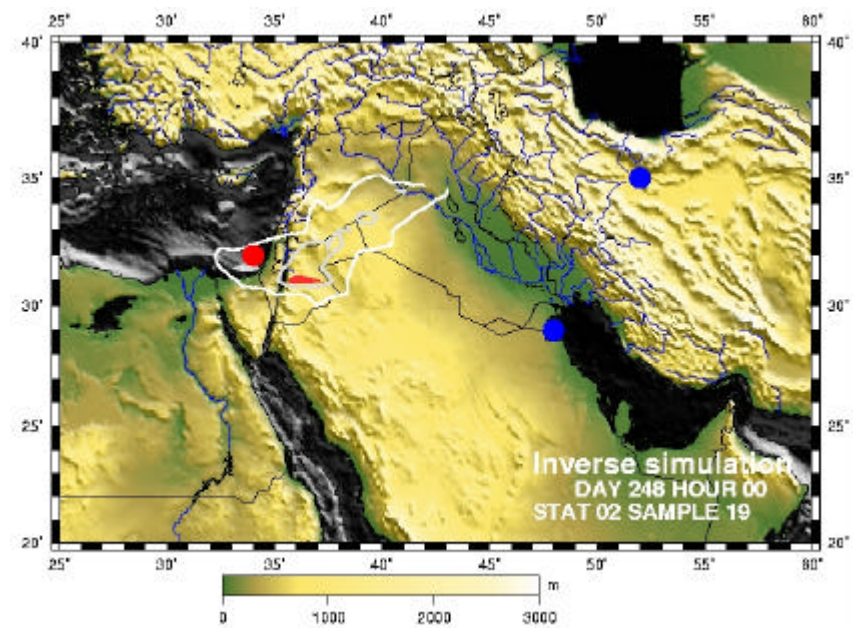
Inverse Modeling

assuming a point spatial source (known release time)

from Teheran station (500m)



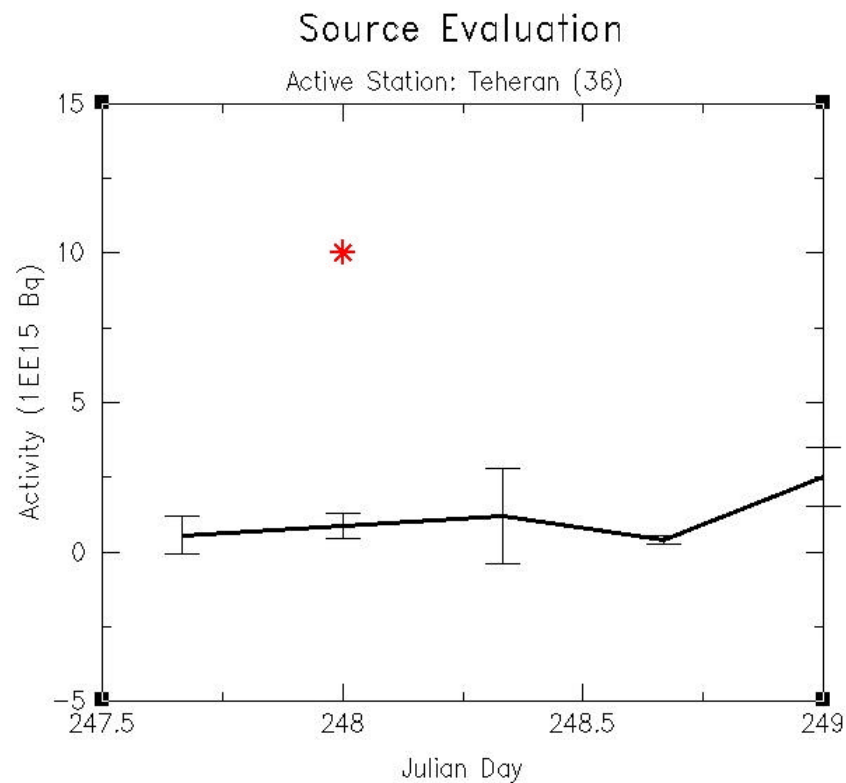
from K-City & Teheran stations (500m)



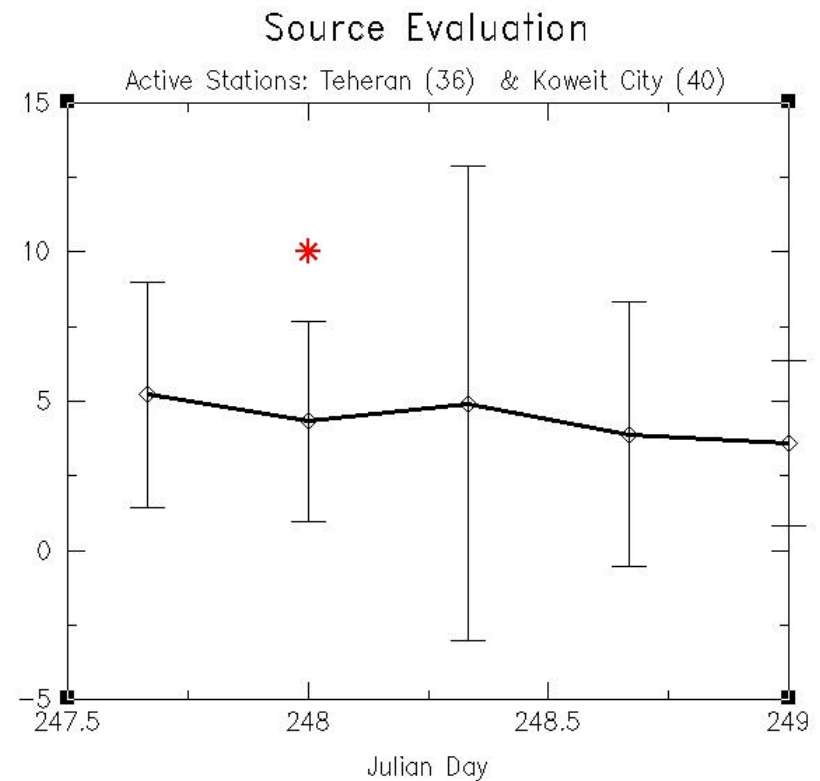
Optimization levels : 50% - 75% - 95% of the best fit level

Inverse Modeling assuming a spatio-temporal dirac source

from Teheran station



from K-City & Teheran stations



Representation of Q in 10^{15} Bq

CONCLUSION

- Time required: ~4h on workstation
- Comparison HYSPLIT-LMDZ
- Sensitivity tests on wind fields (NOAA/ECMWF)
- Direct calculation of source receptor matrix
- Tests on solid particles, influence of dry/wet deposition