Source Location for the CTBTO-WMO Exercise 2008

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Outline

Guiding questions:

1. What can we learn from the new, rather different exercise 2008 compared to 2005?
2. Can we see effects from using higher resolution in meteorological input data for otherwise identical atmospheric transport simulations?
   (Answer: in this exercise we could not learn very much)

Outline

ATM at CTBTO, WMO cooperation, NDCs

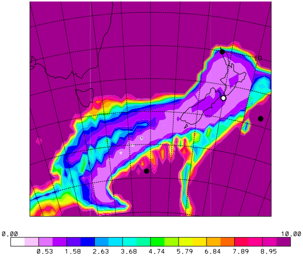
- CTBTO/IDC calculates source-receptor sensitivites (SRS) for their measurements of airborne radionuclide
- in the case of an important event, WMO-designated RSMCs and NMCs also calculate SRS and upload them to IDC
- IDC provides certain evaluations including a source location estimate based on correlation coefficients from IDC calculations and WMO ensemble means
- National CTBTO Data Centres (NDCs) may also do such evaluations
- NDC Preparedness Exercise 2008 used a seismic event to trigger a test of the ATM chain
  - Pseudo-observations were generated by a forward run
  - source time and location taken from the earthquake location
  - with FLEXPART v5, 1°-resolution ECMWF input wind fields, sampling kernel for stations

Our role and interest

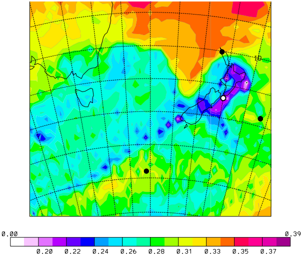
- ZAMG (Geophysics) is main NDC institution in Austria
- ZAMG (Environmental Meteorology) is RSMC for backtracking
- BOKU-Met is affiliated with NDC Austria and working on ATM and related source location methods
- BOKU-Met and ZAMG Environmental Meteorology cooperate on backtracking
  - For the NPE 2008, backtracking with 0.5° input was tested in addition to the routine 1.0°
  - Flexpart v6.2 was used with ECMWF input data (IDC at that time still Flexpart v5)

Our source location method

- developed for 2005 CTBTO-WMO exercise
- based on method developed by Seibert (2000) for ETEX
- minimises a cost function by checking all possible release locations and times
- cost function $J = \sum_{nobs} (\mathbf{M}x - y_{\mathrm{obs}})^2 / \sigma^2_{\mathrm{obs}}$ where σ^2_{obs} is set to a fixed value, e.g. $(1\ \mathrm{mBq\,m^{-3}})^2$
- can use a cost function with weighting by error variances (optionally also covariances) derived from ensemble ATM
- in 2005, lead to a tremendous improvement in the source location, both accuracy and stability
- Presently, release duration prescribed (NPE08: 24 h). Inversion demonstrated for ETEX.



ATNC (Austria NDC) SRS + simple J



including error variances and covariances

NPE 2008 key features compared with 2005

	2005	2008
Region	New Zealand	South American Andes
Flow type	mainly well-defined westerlies	partly weak winds, convergence over Andes
Source environment	ocean, near NZ	in the mountains
Source duration	δ-shape (3 h)	24 h
No. of detections	20 at 4 stations	5 at 1 station
No. of zeros used	29 at 13 stations	20 at 3 stations

Forward modelling

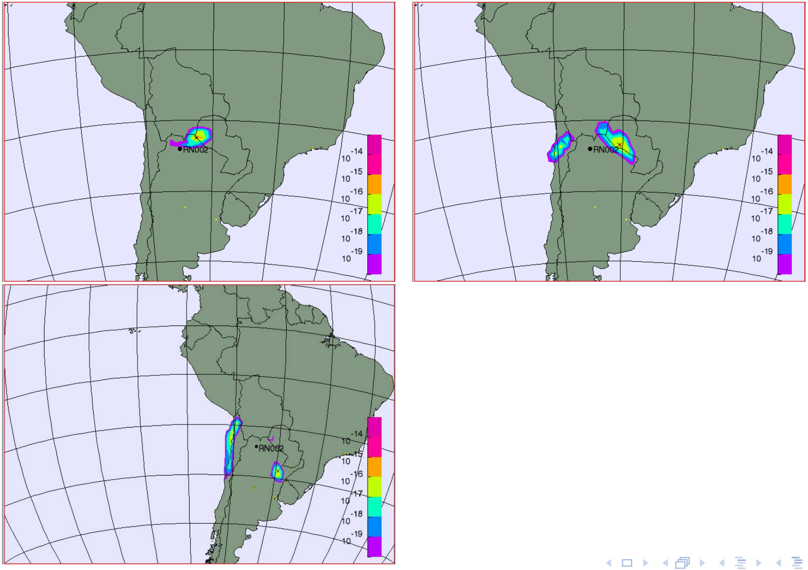
Movie produced by IDC

Release time: Oct 2008, 27/09–28/09

>>> Start movie

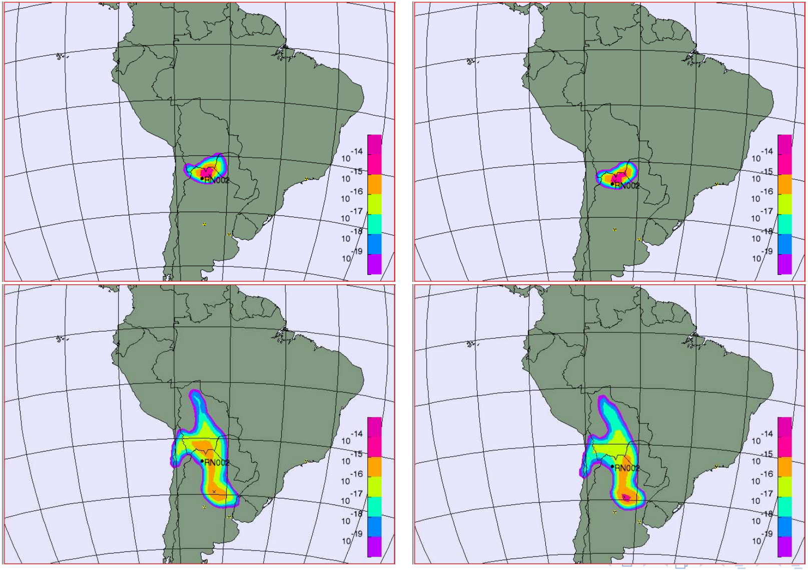
Source-receptor relationship. Measurement RN002 20091029 00

Model: **AMMC** Timesteps : **0..-24 h / -24..-48 h /-48..-72 h**



Source-receptor relationship. Measurement RN002 20091029 00

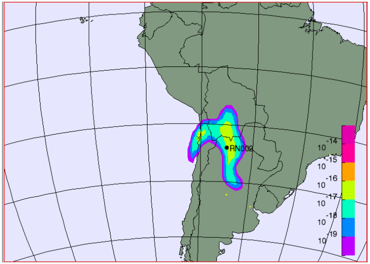
Models: **ATNC | ATND** Timesteps: **-0..-24 h / -24..-48 h /-48..-72 h**



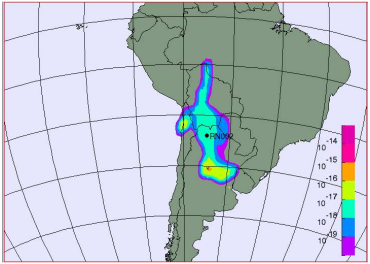
Source-receptor relationship. Measurement RN002 20091029 00

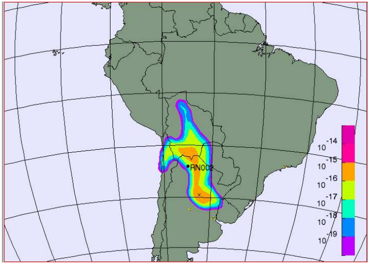
Models: **CTBTE / CTBTN** Timestep: **-48..-72 h**

ECMWF wind



NCEP winds

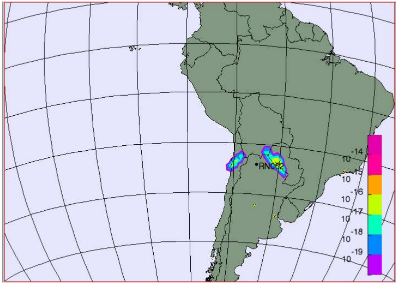


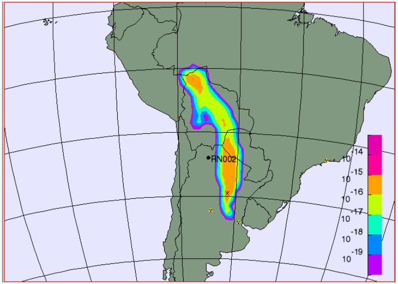


<< ATNC

Source-receptor relationship. Measurement RN002 20091029 00

Model: **BABJ** Timestep: **-0..-24 h/ -24..-48 h /-48..-72 h**

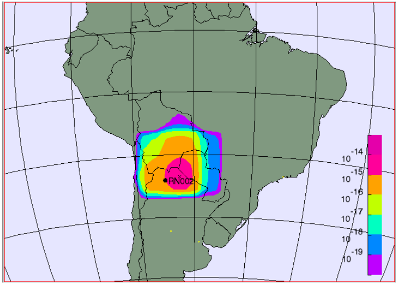


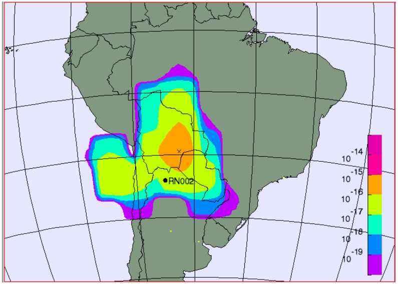


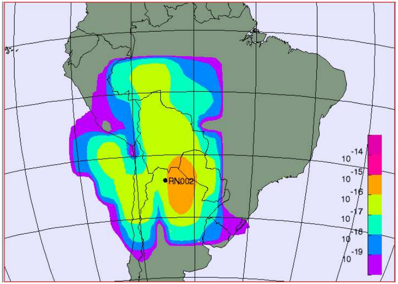
values (too?) low

Source-receptor relationship. Measurement RN002 20091029 00

Model: **RTHO** Timestep: **-0..-24 h / -24..-48 h /-48..-72 h**







resolution only nominally 1°!

Overview results

MOD	COST	DATE	HR	SOURCE	DIST
TRUE		20081027	09	??	0

unweighted RMSE minimisation

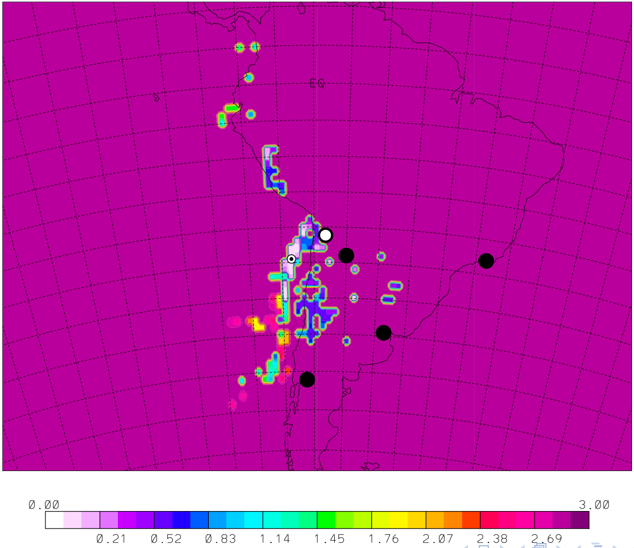
MOD	COST	DATE	HR	SOURCE	DIST
AMMC	0.002	20081023	21	0.248	582
ATNC	0.033	20081025	21	0.357	1246
MEFR	0.042	20081026	18	0.074	1257
BABJ	0.069	20081023	18	920.	129
CTBE	0.077	20081024	21	2.1	511
CTBN	0.079	20081020	06	435.	747
CWAO	0.126	20081026	06	0.058	871
ATND	0.135	20081022	21	0.796	707
RUOB	0.231	20081023	03	1.7E8	2099
EGRR	0.232	20081026	00	0.937	899
RTHO	0.384	20081027	03	0.197	551

with a priori source and error variances

MOD	COST	DATE	HR	SOURCE	DIST
AMMC	0.003	20081023	21	0.220	582
ATNC	0.021	20081026	03	0.144	1275
MEFR	0.042	20081026	18	0.071	1257
CTBE	0.065	20081024	21	2.063	511
ATND	0.082	20081024	21	0.249	1437
CWAO	0.084	20081025	21	0.138	929
EGRR	0.159	20081025	00	2.259	1020
CTBN	0.167	20081026	06	0.606	1007
BABJ	0.200	20081024	12	0.725	1052
RTHO	0.232	20081027	00	0.162	457
RUOB	0.442	20081028	03	80.41	1246

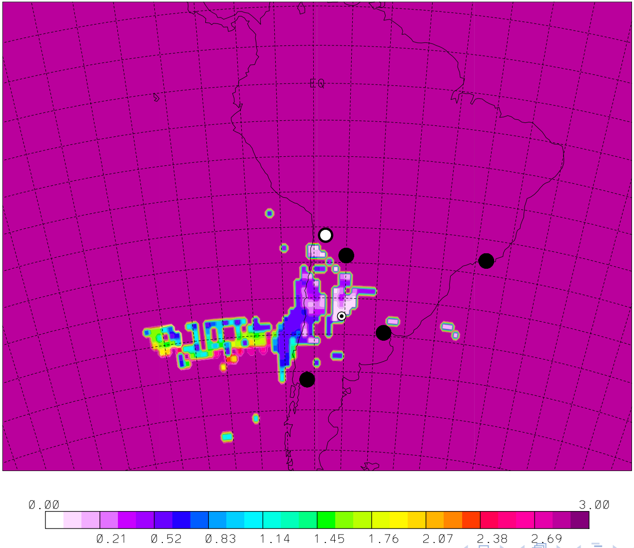
Cost function $J_n(i,j) = \mathrm{Min}_{(\forall n)}\{J(i,j,n)\}$ (n ... source times)

Model: **AMMC** Cost $\mathrm{Min}_{(\forall i,j)}\{J_n(i,j)\}=\mathbf{0.002}$ Source $x=\mathbf{0.248}$ PBq



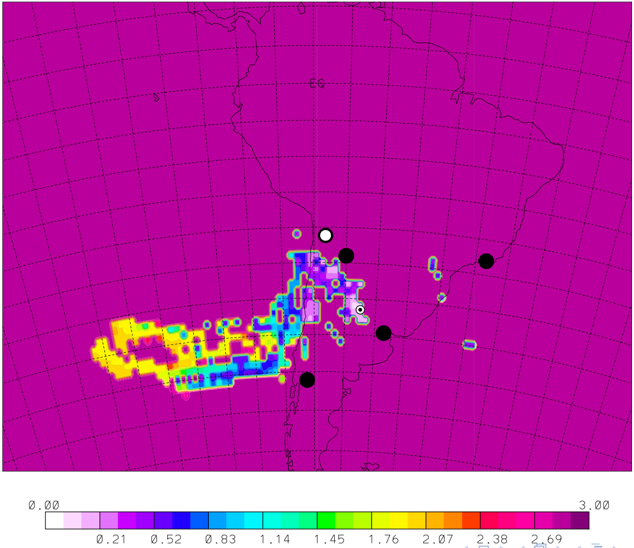
Cost function $J_n(i,j) = \text{Min}_{(\forall n)}\{J(i,j,n)\}$ (n ... source times)

Model: **ATNC** Cost $\text{Min}_{(\forall i,j)}\{J_n(i,j)\}$=**0.033** Source x=**0.357** PBq



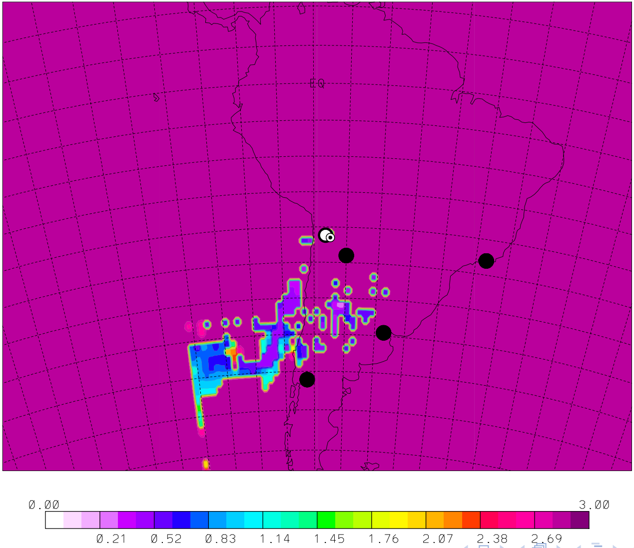
Cost function $J_n(i,j) = \mathrm{Min}_{(\forall n)}\{J(i,j,n)\}$ (n . . . source times)

Model: **MEFR** Cost $\mathrm{Min}_{(\forall i,j)}\{J_n(i,j)\}$=**0.042** Source x=**0.074** PBq



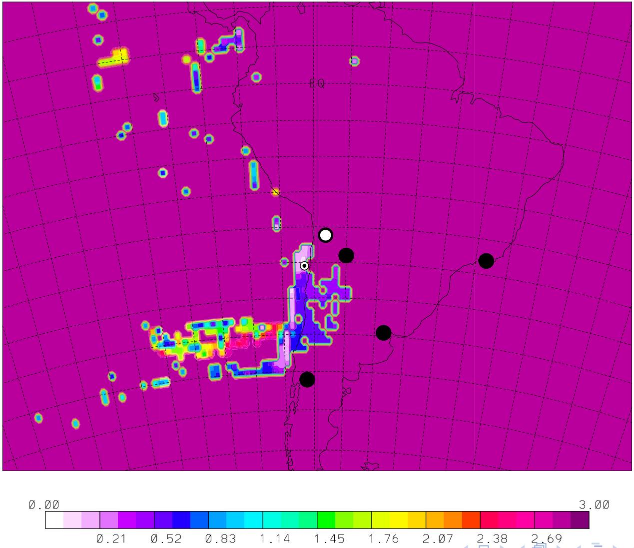
Cost function $J_n(i,j) = \mathrm{Min}_{(\forall n)}\{J(i,j,n)\}$ (n . . . source times)

Model: **BABJ** Cost $\mathrm{Min}_{(\forall i,j)}\{J_n(i,j)\}$=**0.069** Source x=**920** PBq



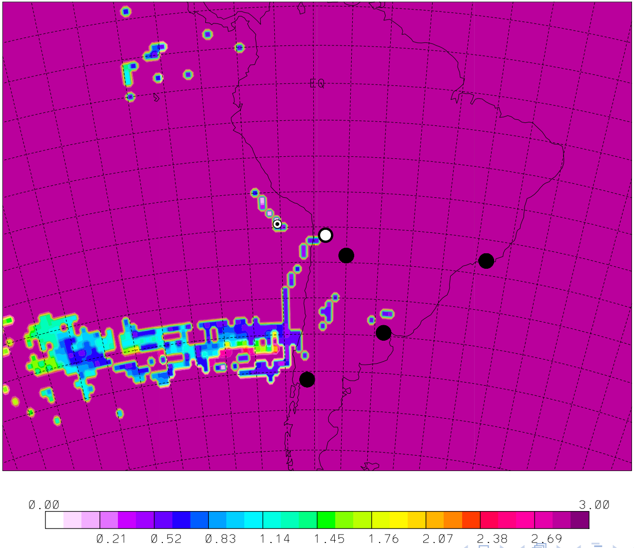
Cost function $J_n(i,j) = \mathrm{Min}_{(\forall n)}\{\, J(i,j,n)\,\}$ (n ... source times)

Model: **CTBE** Cost $\mathrm{Min}_{(\forall i,j)}\{\, J_n(i,j)\,\}$=**0.077** Source x=**2.116** PBq !



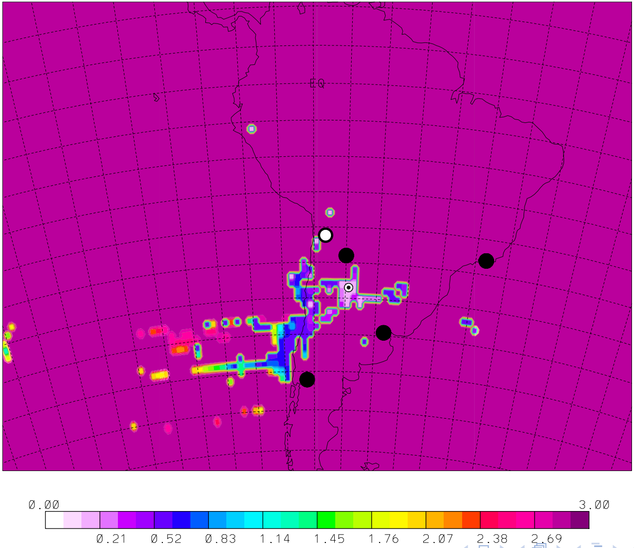
Cost function $J_n(i,j) = \mathrm{Min}_{(\forall n)}\{J(i,j,n)\}$ (n ... source times)

Model: **CTBN** Cost $\mathrm{Min}_{(\forall i,j)}\{J_n(i,j)\}$=**0.079** Source x=**435** PBq



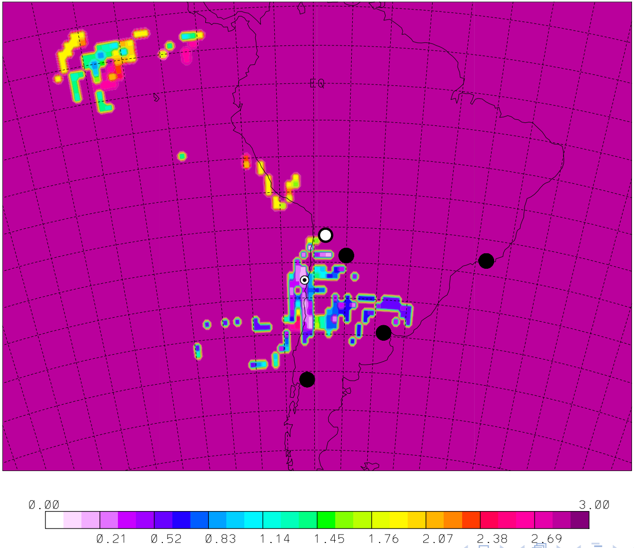
Cost function $J_n(i,j) = \text{Min}_{(\forall n)}\{J(i,j,n)\}$ $(n \ldots \text{source times})$

Model: **CWAO** Cost $\text{Min}_{(\forall i,j)}\{J_n(i,j)\}$=**0.126** Source x=**0.058** PBq



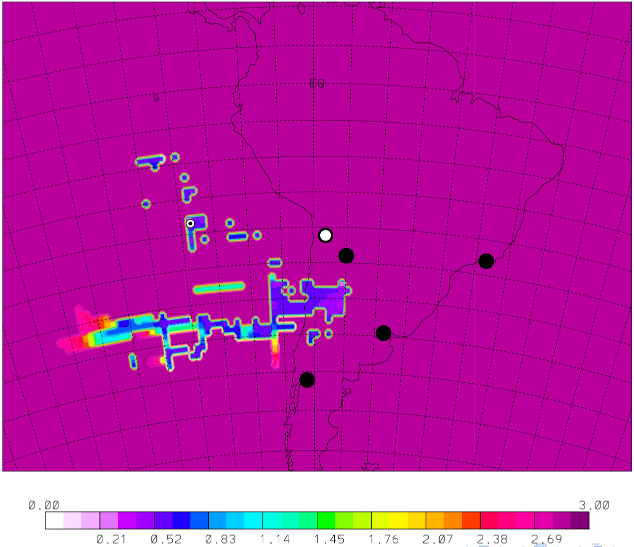
Cost function $J_n(i,j) = \mathrm{Min}_{(\forall n)}\{J(i,j,n)\}$ (n . . . source times)

Model: **ATND** Cost $\mathrm{Min}_{(\forall i,j)}\{J_n(i,j)\}$=**0.135** Source x=**0.796** PBq



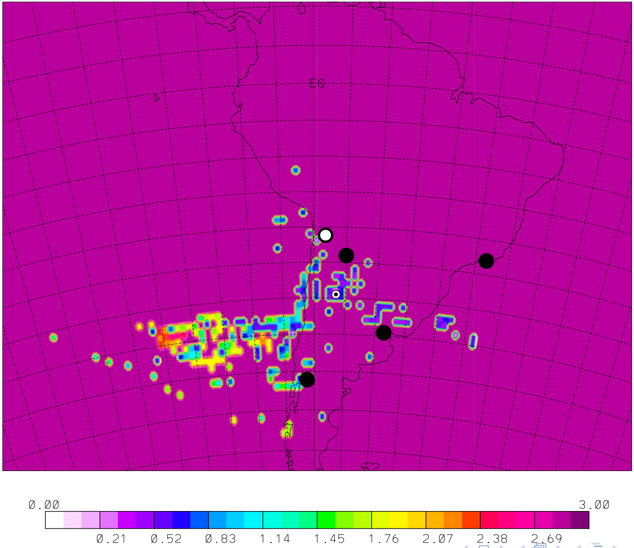
Cost function $J_n(i,j) = \mathrm{Min}_{(\forall n)}\{J(i,j,n)\}$ (n ... source times)

Model: **RUOB** Cost $\mathrm{Min}_{(\forall i,j)}\{J_n(i,j)\}$=**0.231** Source x=**1.7E8** PBq !!



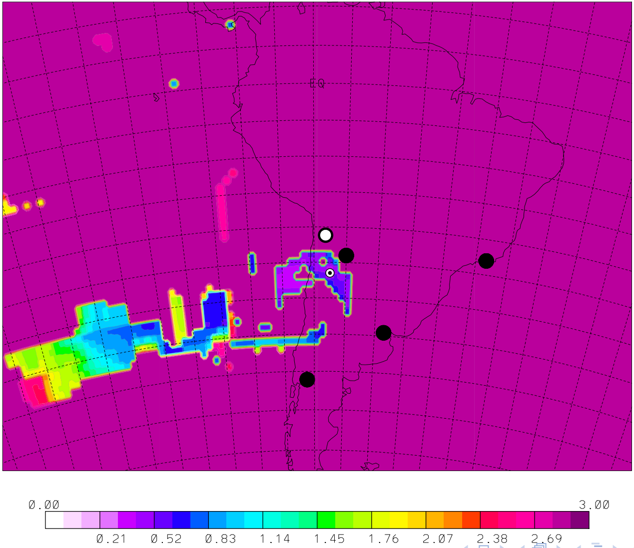
Cost function $J_n(i,j) = \text{Min}_{(\forall n)}\{J(i,j,n)\}$ (n ... source times)

Model: **EGRR** Cost $\text{Min}_{(\forall i,j)}\{J_n(i,j)\}$=**0.232** Source x=**0.937** PBq



Cost function $J_n(i,j) = \mathrm{Min}_{(\forall n)}\{J(i,j,n)\}$ (n ... source times)

Model: **RTHO** Cost $\mathrm{Min}_{(\forall i,j)}\{J_n(i,j)\}$=**0.384** Source x=**0.197** PBq

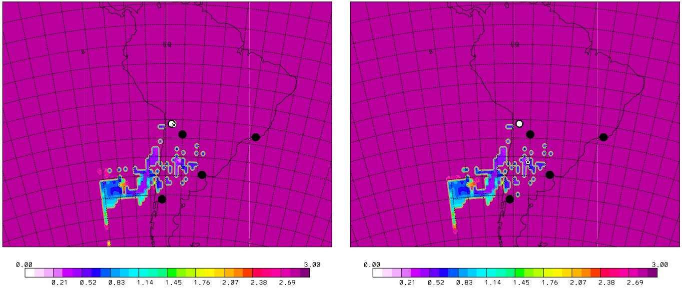


First resume

- Source not well constrained
- Ill-conditioned problem (spotty and some extremly high source values)
- Including ATM-ensemble-derived error variances helps not much because of the underdetermined nature of the problem (errors are small anyway)
- Idea: at least constrain source magnitude to a reasonable value
- Method: add a term $(x - x^a)^2/\sigma_x^2$
  x^a a priori source estimate set to 1 PBq, σ_x to 0.2 PBq
  (also tried much larger σ_x, still quite useful)
- Result:
  - Reasonable solutions not affected
  - unreasonable solutions become (more) reasonable

Cost function $J_n(i,j) = \text{Min}_{(\forall n)}\{\, J(i,j,n)\,\}$ $\quad (n \ldots \text{source times})$

Model: **BABJ** Cost $\text{Min}_{(\forall i,j)}\{\, J_n(i,j)\,\}$=**0.069** | 0.200 Source x=**920** | 0.72 PBq




```
BABJ 0.069 20081023 18 920.       129
BABJ 0.200 20081024 12   0.725   1052

CTBN 0.079 20081020 06 435.       747
CTBN 0.167 20081026 06   0.606   1007

RUOB 0.231 20081023 03 1.7E8     2099
RUOB 0.442 20081028 03  80.41    1246 something wrong with data?
```

Conclusions I

What do we see in NPE 08?

- Source location results are not good
- Results scatter widely between ATM systems
- The value of increased resolution in meteorological input cannot be assessed with this kind of test.

Why?

- Meteorological situation was complicated
- Receptor kernel of forward modelling system may have introduced non-reversible features
- The detections, but also the set of measurements used in the “event definition” is not constraining the solution well enough.

Conclusions II

What can we learn for future exercises?

- Until now we have assumed that we know the duration of the release and its temporal variation (here: constant). In reality, this would also needed to be determined by the inversion. Some a priori idea of possible shapes and durations are needed, though.
- To avoid unjustified bias towards ATM systems similar to the forward modelling system, this should be designed to be as realistic as possible
  - highest resolution input and output fields
  - don't use recepter kernel
  - very high particle number
  - short time steps ("slow mode") of FLEXPART
  - maybe two runs (EC and NCEP) and use a mixed result?
- Work with real releases and measurements.

  Ideas:
  - artifical tracer releases by new DLR system.
  - Volcanos (see our new SAVAA project - requires however different setup of backtracking models.).

Conclusions III

What can we learn for real events (and of course exercises)?

- In not-well-defined cases, it could be valuable to provide and use a first-guess of the source term magnitude along with an appropriate uncertainty range to exclude unrealistic solutions
- Include sufficently large and useful selection of measurements (including non-detections) in the event. At least one should include the zero measurement immediately prior to the first detection in the event definition.
- Prescribing possible release times (data fusion in CTBT jargon) will be useful.
- Some screening of the ATM ensemble members may be necessary, criteria to be developed.
- The present IDC operational method of defining a *potential source region* using correlation coefficients may be appealing as easy to grasp, but using a more general cost function is the key to many of the possible improvements.