Atmospheric transport and dispersion modelling study of the I-131 detected in Jan/Feb 2017 in Europe

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Outline

1. Inverse atmospheric transport modelling: first attempts
2. Direct atmospheric transport modelling: using release assumptions, can we reconstruct the ^{131}I detections?
3. Effect of the meteorological conditions
4. Inverse atmospheric transport modelling revisited
5. Conclusions

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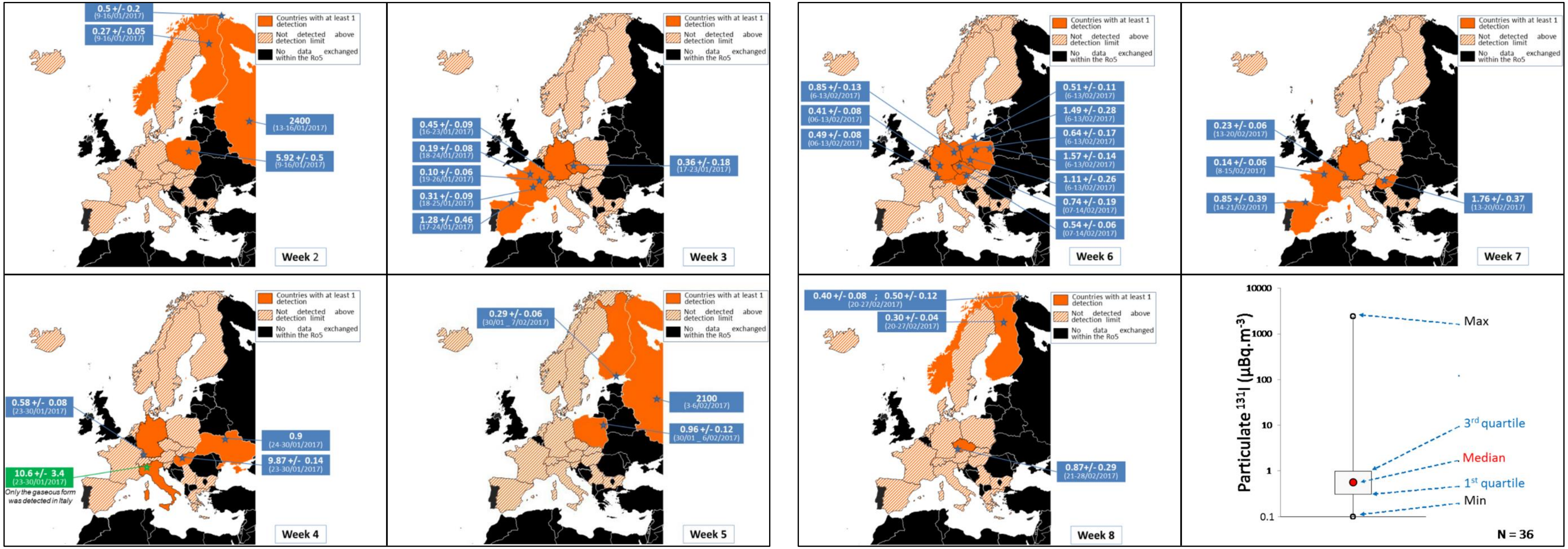
In January and February 2017, ^{131}I was detected throughout Europe; its origin is not fully understood



Masson et al., (2018). Potential Source Apportionment and Meteorological Conditions Involved in Airborne 131I Detections in January/February 2017 in Europe. *Environmental Science & Technology*, **52(15)**, 8488-8500.

Inverse atmospheric transport modelling: a three-step problem

1. Input data

Numerical weather prediction data:

ECMWF IFS: 3-hourly data coarse-grained to 1° horizontal grid spacings

Iodine-131 observations:

28 detections from the Ro5 + detections from the CTBTO IMS radionuclide network

2. Atmospheric transport and dispersion modelling

The Lagrangian particle model Flexpart in backward mode *(Seibert and Frank, 2004)*

Source-receptor relationship:

Flexpart calculates the source-receptor-sensitivities M_{ij} for each observation y_i:

$$y_i = M_{ij} x_j$$

3. Inverse modelling

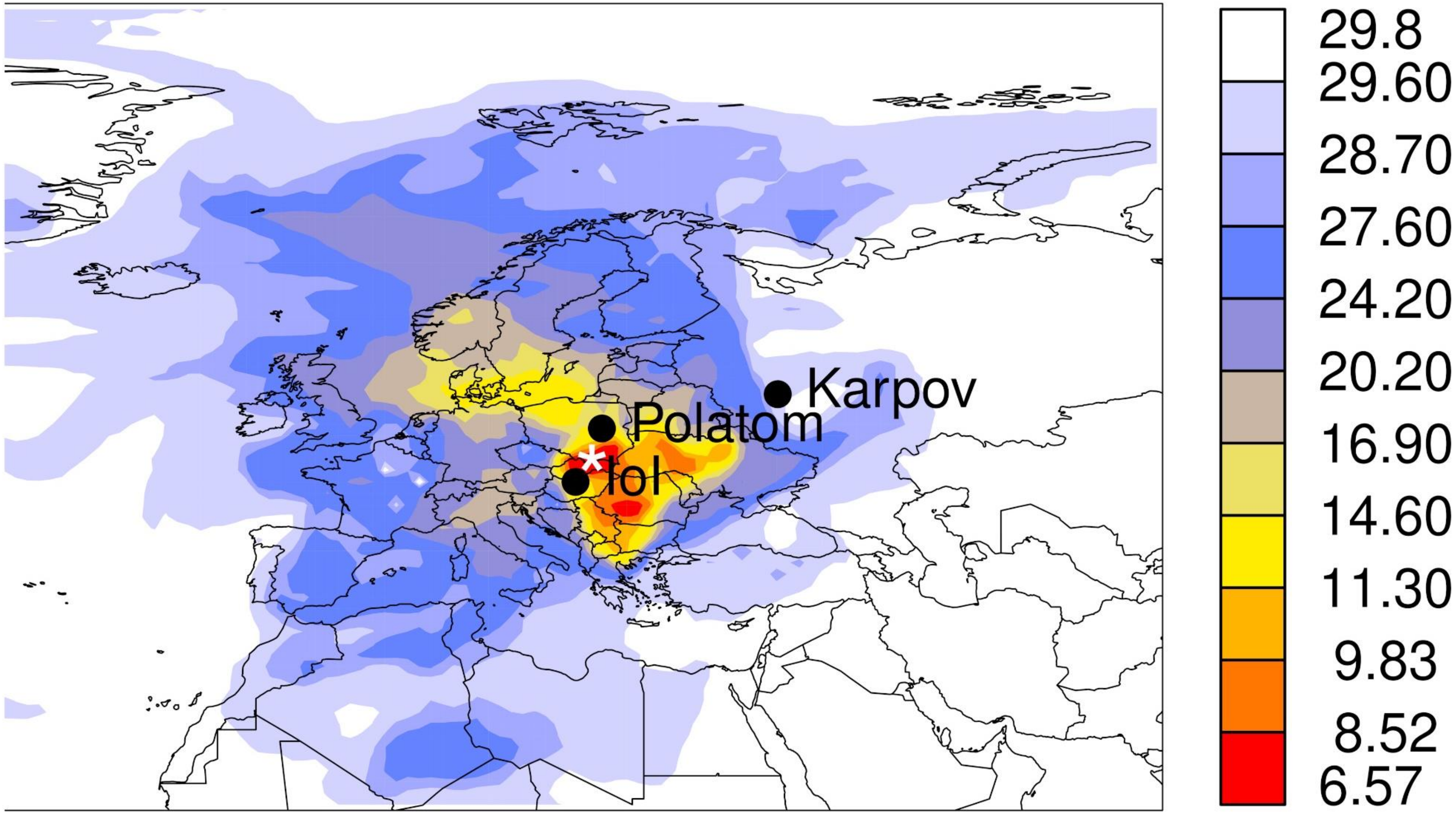
A source term x_j is found by minimizing a cost function:

$$exp\left(\frac{1}{n}\sum_i \left(\log(y_i + \alpha) - \log\left(M_{ij}x_j + \alpha\right)\right)^2\right)$$

The optimisation is solved using a quasi-Newton technique and does not require to rerun Flexpart.

The inverse modelling is applied to each grid box separately (single grid box source).

Source localization based on all available observations (single source assumption)



Large minimum cost suggests that multiple sources are involved

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Potential sources of the ^{131}I detections

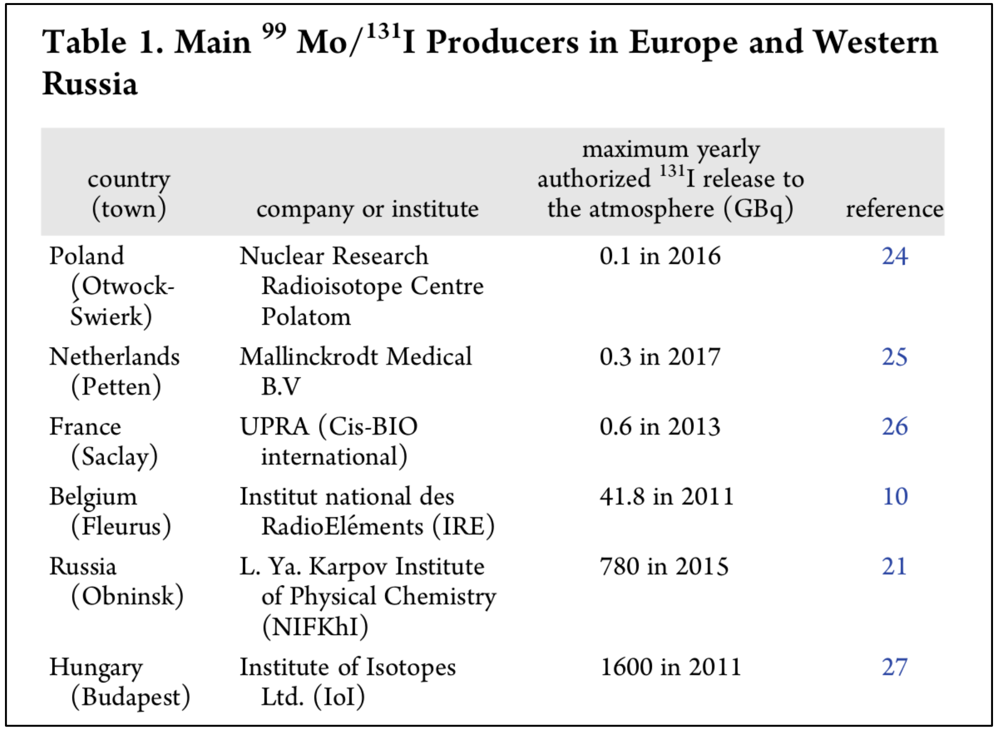
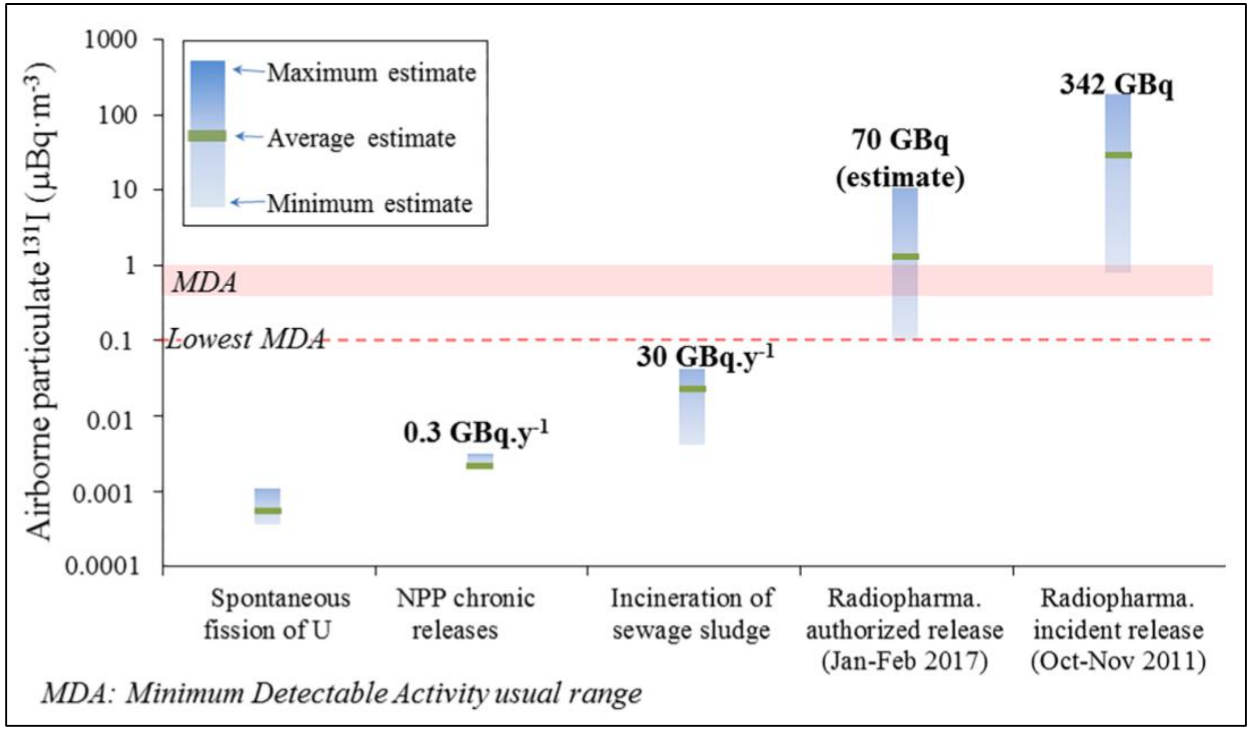


Table 1. Main ^{99} Mo/^{131}I Producers in Europe and Western Russia

country (town)	company or institute	maximum yearly authorized ^{131}I release to the atmosphere (GBq)	reference
Poland (Otwock-Swierk)	Nuclear Research Radioisotope Centre Polatom	0.1 in 2016	24
Netherlands (Petten)	Mallinckrodt Medical B.V	0.3 in 2017	25
France (Saclay)	UPRA (Cis-BIO international)	0.6 in 2013	26
Belgium (Fleurus)	Institut national des RadioEléments (IRE)	41.8 in 2011	10
Russia (Obninsk)	L. Ya. Karpov Institute of Physical Chemistry (NIFKhI)	780 in 2015	21
Hungary (Budapest)	Institute of Isotopes Ltd. (IoI)	1600 in 2011	27



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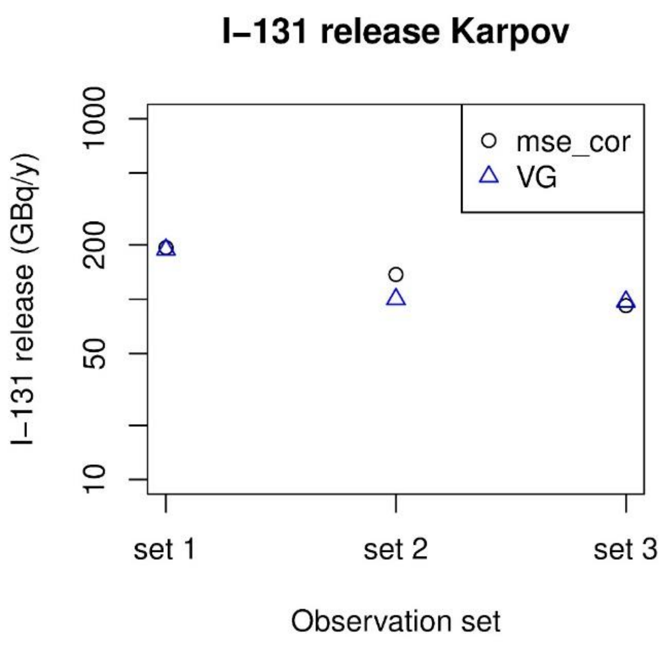
Release assumptions:

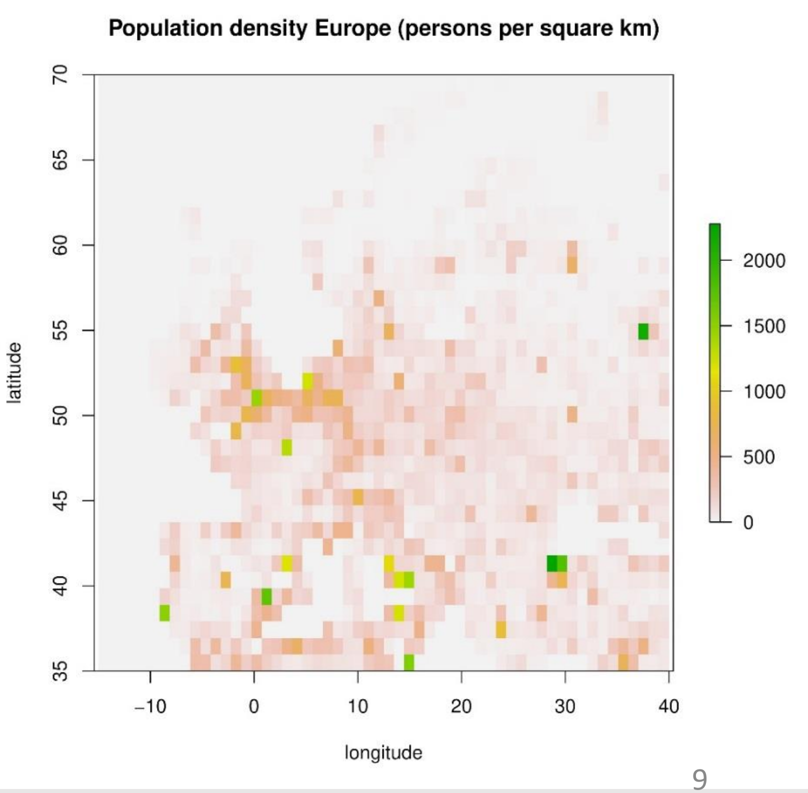
Polatom, Mallinckrodt, UPRA following Table 1 of Masson et al., 2018
IRE: 1 GBq/y (FANC report)
IoI: 100 GBq/y (initial assumption)

Karpov institute: 150 GBq/y (inverse modelling using CTBTO observations):

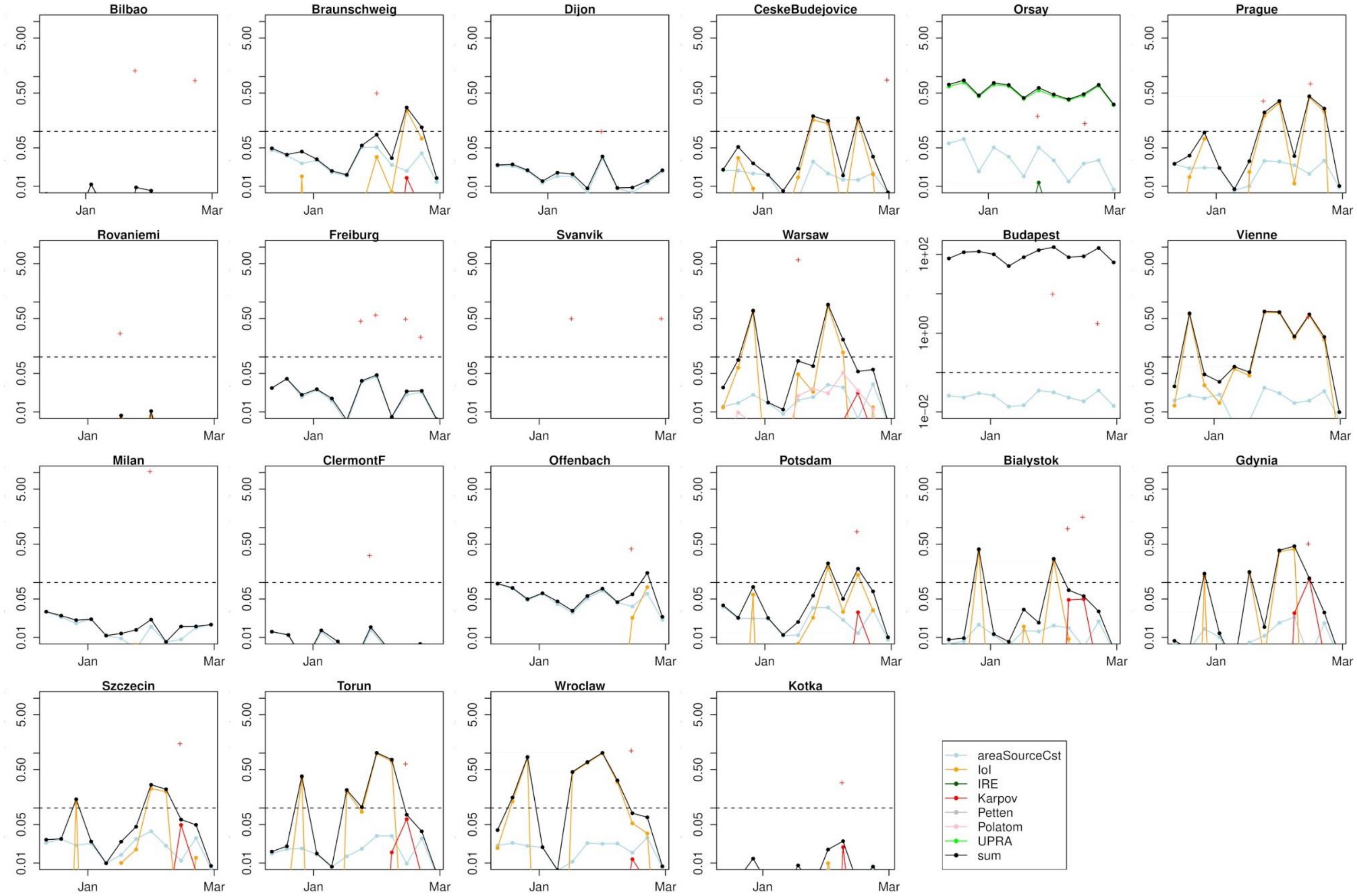
- Case 1: three detections at RN61 (12, 14, 18 January), one detection at RN54 (13 January)
- Case 2: six detections at RN61 (30, 31 January; 1, 4, 5, 6 February)
- Case 3: four detections at RN61 (17, 24, 25 February; 1 March)



A proxy for local sources: area source proportional to the population density, totaling 30 GBq/y (population density data: 1° resolution from the NASA EOSDIS database; release amount based on Fig. 2 of Masson et al., 2018)



^{131}I activity concentration time series



Very poor agreement; possible reasons:

- Errors in the meteorological data
- Errors in the atmospheric transport and dispersion processes
- Errors in the emission assumptions

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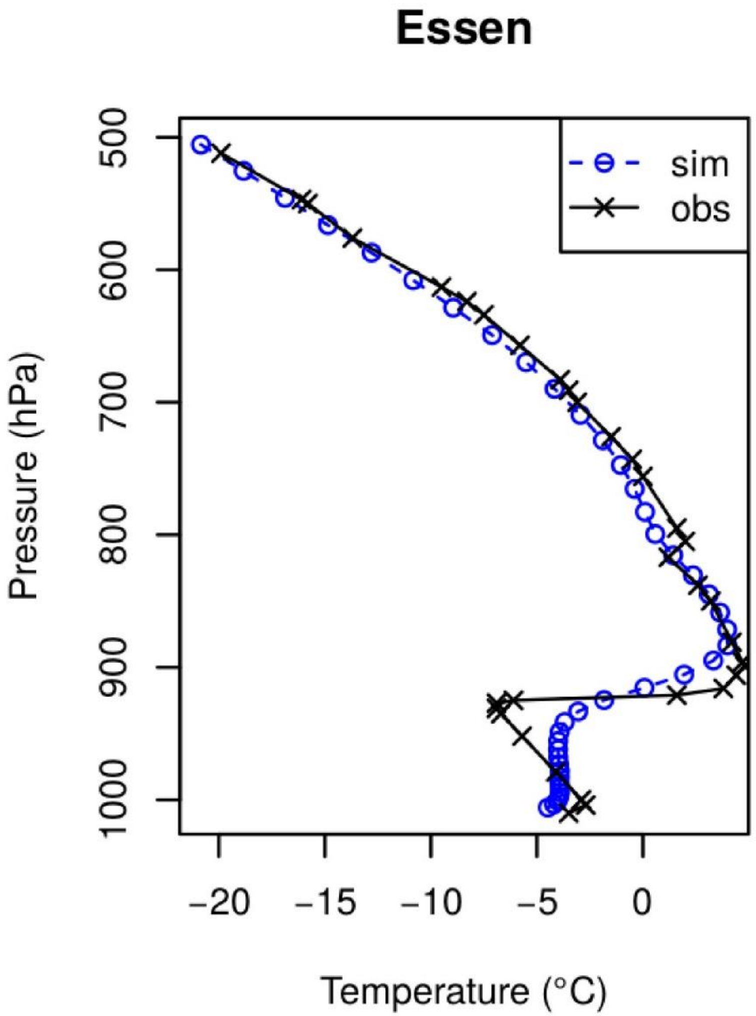
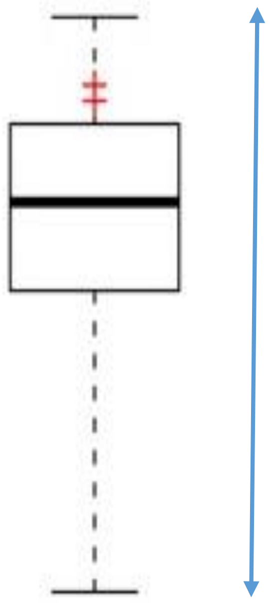
Assessing the effect of meteorology directly

- The episode of ^{131}I detections was associated with strong temperature inversions that deteriorate mixing in the lower troposphere
- In general, temperature inversions were present in the meteorological data; however, the strength of the inversion was generally underestimated (see Figure)
- Initial study suggest that in Flexpart, the parametrization of atmospheric transport and dispersion processes mainly depends on the height of the planetary boundary layer; an inversion does not seem to play a direct role



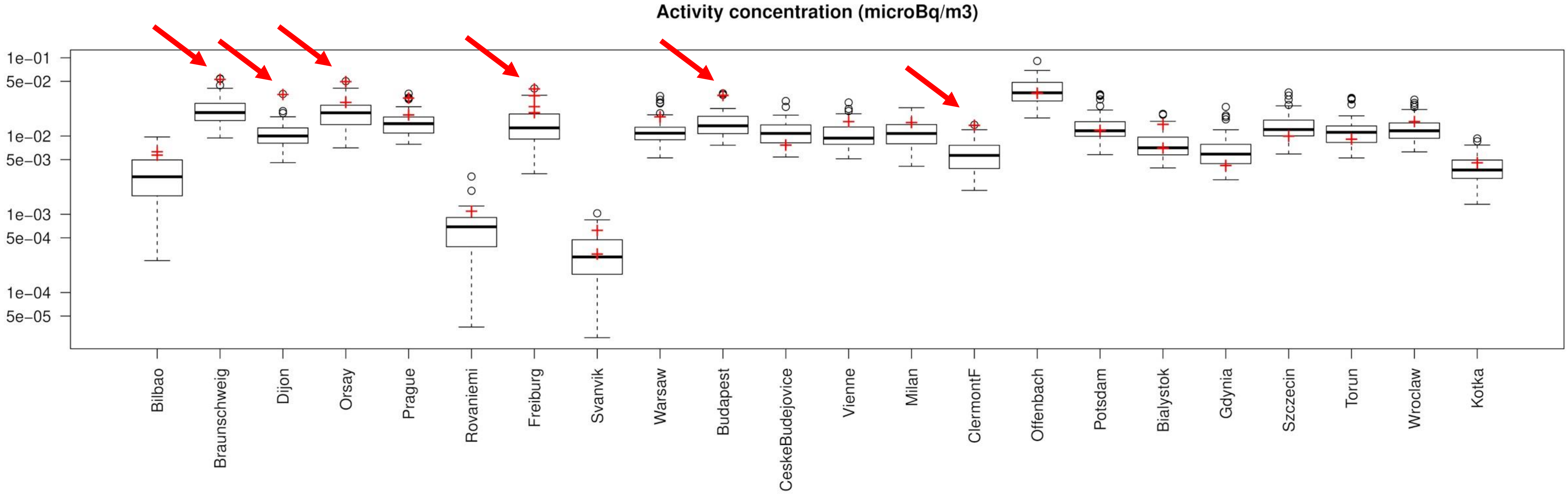
Assessing the effect of meteorology indirectly

- Flexpart forward simulation during one full year 2017
- Release: area source with constant emission proportional to the density population (as proxy for local sources)
- Output:
  - 3-hourly simulated concentrations are converted into weekly simulated concentration (by averaging and applying a decay correction)
  - 51 simulated concentrations per station in 2017
- A quantile plot is made for each station; the simulated concentration is marked by ‘+’ when a detection took place



Variation in concentration only depends on the meteorological conditions

Certain detections took place when Flexpart predicts a maximum influence from local sources



Results suggest that certain detections can be explained by exceptional meteorological conditions rather than unusual emissions

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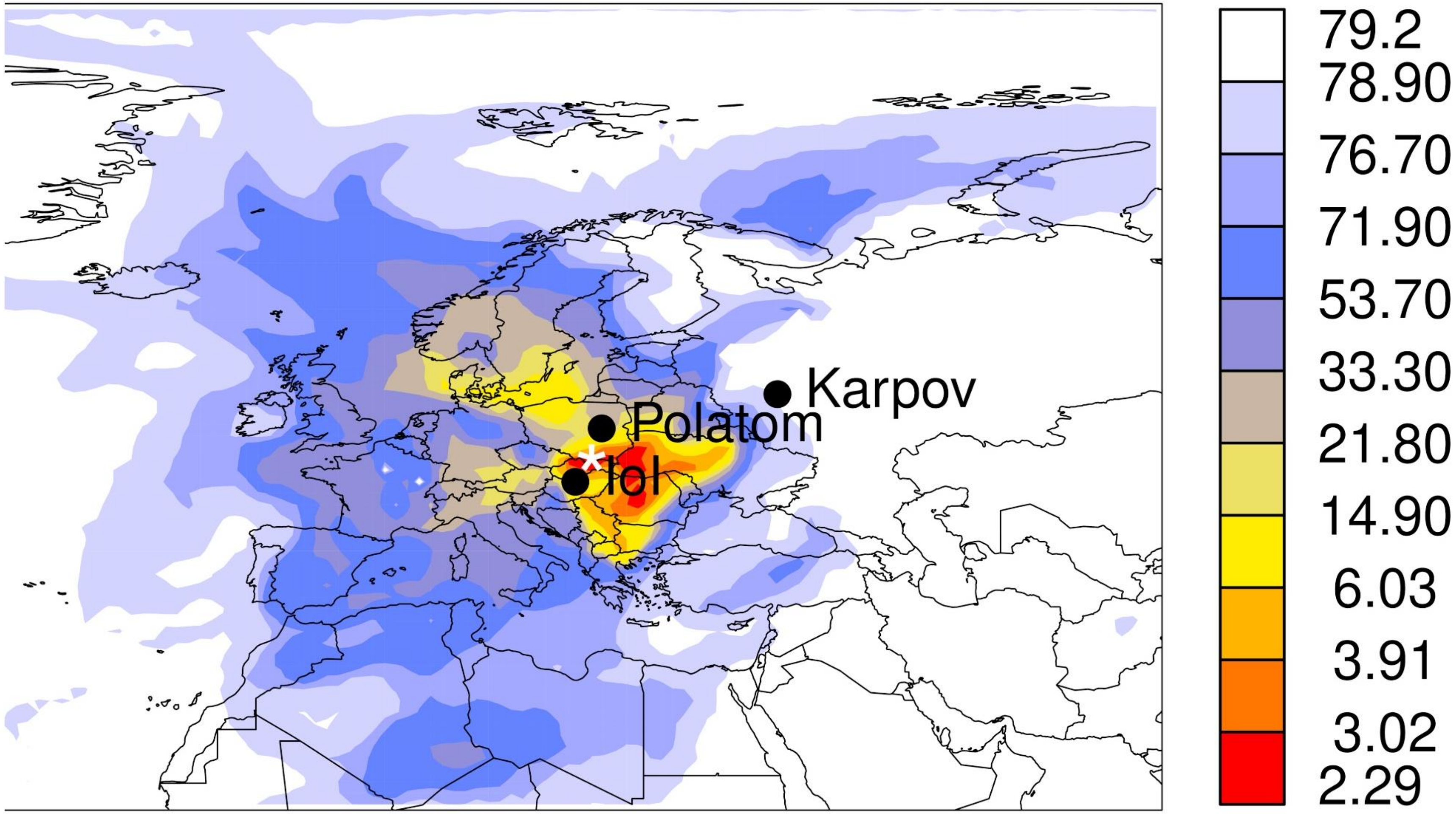
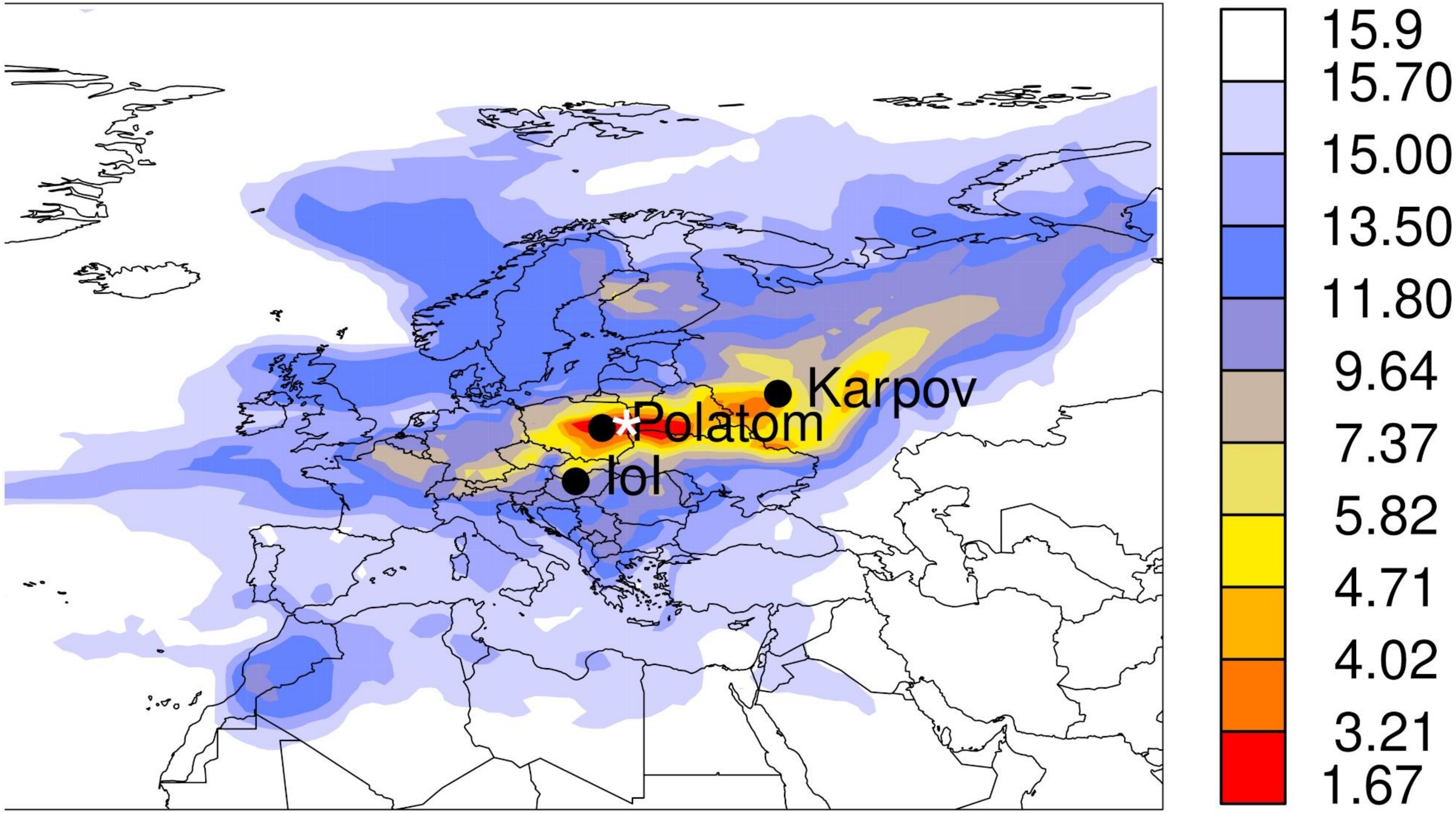
Source localization: subset of 9 observations that can be explained by exceptional meteorological conditions



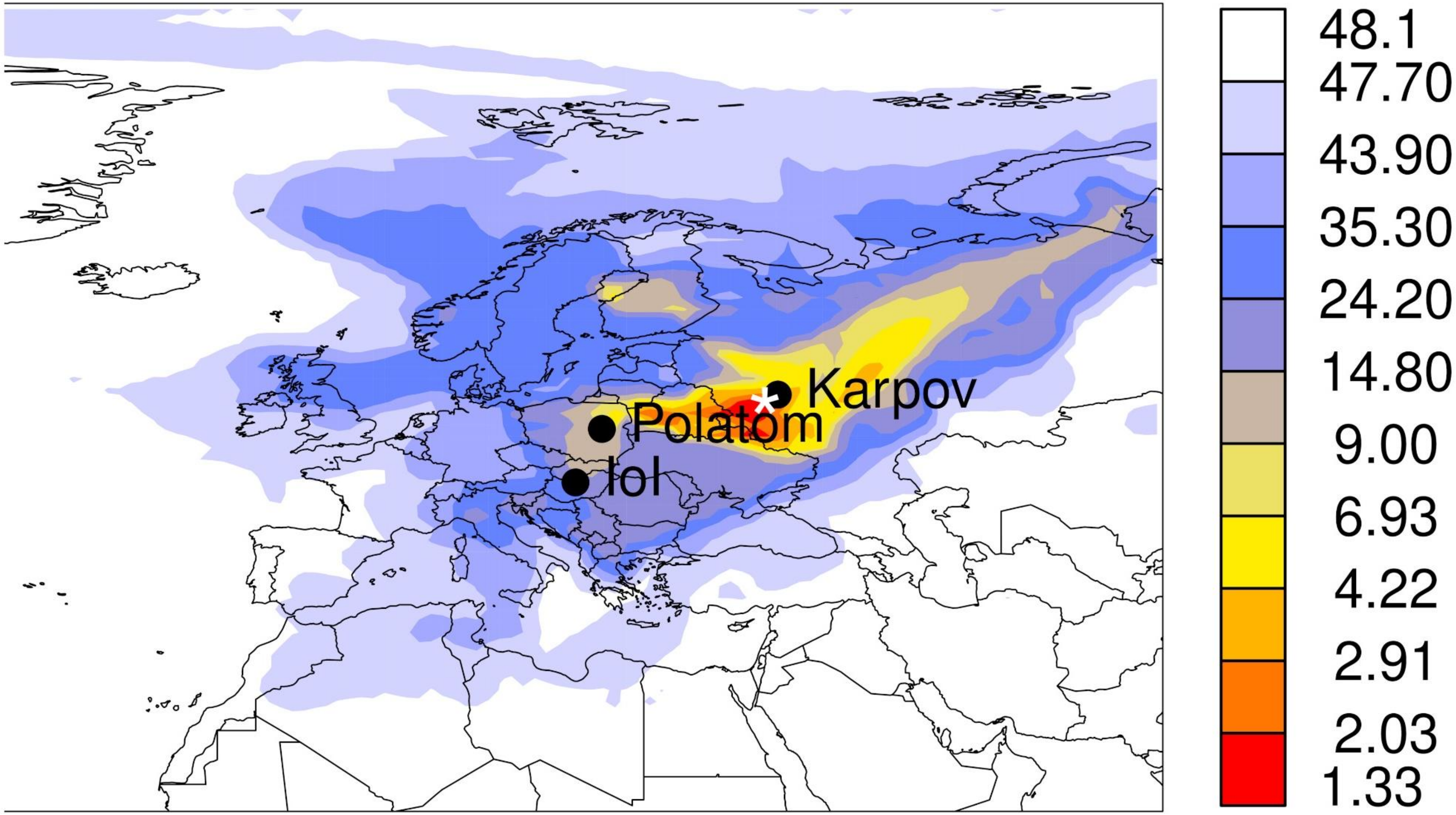
Given the large costs, the detections are possibly originating from multiple local sources

Source localization: subset of 11 observations



Low minimum cost; Polatom seems possible source for these detections

Source localization: subset of 7 observations



Low minimum cost; Karpov seems possible source for these detections

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- In January and February 2017, ^{131}I was detected throughout Europe; its origin is not fully understood
- Determination of the origin is hard because there are many possible sources with time-varying emissions → many more degrees of freedom than observations
- Comparing simulated activity concentrations obtained from direct modelling with observed activity concentration leads to a poor agreement: likely we have insufficient knowledge of the emissions, in particular related to peak releases from local sources
- Results suggest that part of the detections can be linked to the exceptional meteorological conditions
- Inverse modelling results suggest that part of the detections can be linked to releases from Polatom and Karpov