



Introduction

At the turn of September and October 2017, low concentration of ¹⁰⁶Ru of unknown origin was detected in the atmosphere in the Czech Republic. Immediate communication with other European laboratories involved in the RO5 (Ring of 5) network confirmed that it was a Europe-wide occurrence. Although the concentration was low (tens of mBq/m³) and of no health risk, the unknown origin of ¹⁰⁶Ru raised concerns. Therefore, very shortly after the first detections, efforts were made to estimate the source location based on measured data. Initial analyses pointed to a possible source located to the east of the Czech Republic. Here, we use Czech monitoring data to estimate possible location and the source term.

We aim to estimate the location and the source term from two types of data:

- Raw measured data.
- Data included real-time sampling.

Bayesian inverse modeling and source location

A common formulation of the source term determination problem is based on linear inverse formulation

$$y = Mx$$

where y is the vector of observations, M is the source-receptor-sensitivity (SRS) matrix, x is the unknown source term, and e is the model residue. The observation model is selected as

$$\ln p(y | x, \omega) = N(Mx, \omega^{-1}I_p) \propto \exp((y - Mx)^T \omega (y - Mx))$$

where precision of noise is also estimated from the data. The model of the source term x is formulated as locally sparse and smooth using specific form of covariance matrix:

$$p(x | V, L) = tN(0, (LVL^T)^{-1}, [0, +\infty])$$

where L and V are variable estimated together with the source term and modeling smoothness (L) and sparsity (V) of the source term. When multiple matrices M are available as hypotheses on source locations, we can also estimate the probability of each location using variational lower bound:

$$p(M = M_k | y) \propto p(M = M_k) \exp(L_{M_k})$$

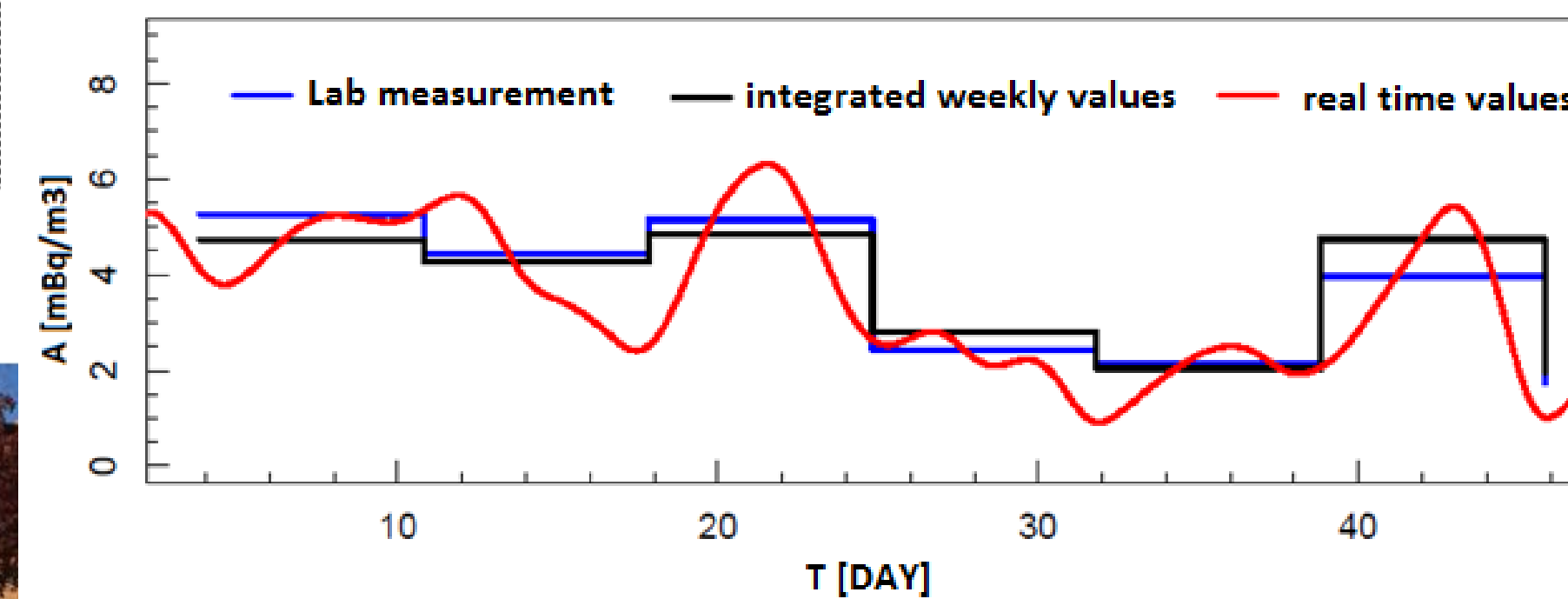
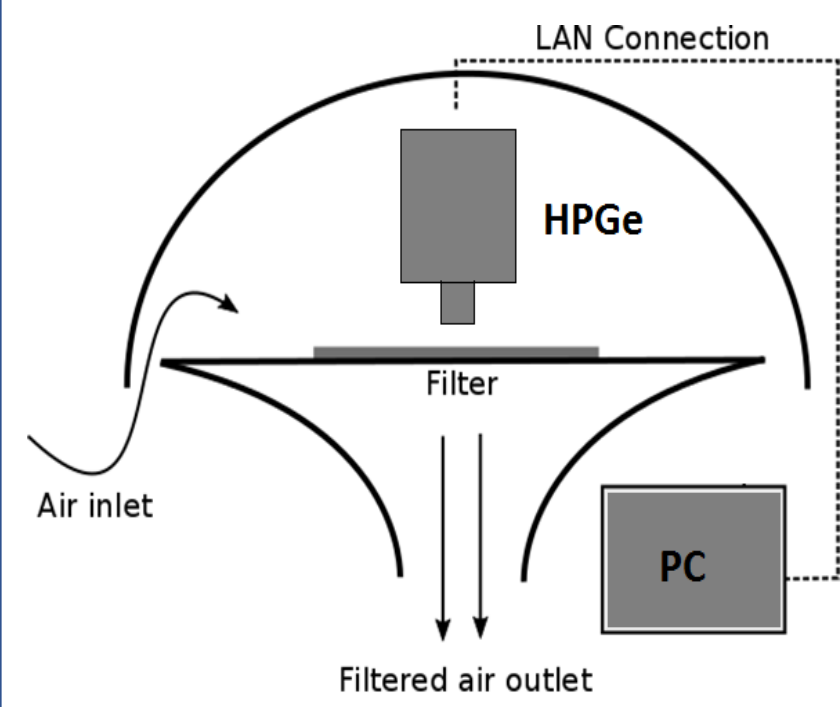
where $p(M=M_k)$ is prior probability of given location and can be omitted for cases where each location has the same probability, and L_{M_k} is variational lower bound given as

$$L_{M_k} = E[\ln p(y, x, V, L, \omega, M_k)] - E[\ln \tilde{p}(x)] - E[\ln \tilde{p}(V)] - E[\ln \tilde{p}(L)] - E[\ln \tilde{p}(\omega)]$$

where p are posterior probability distributions derived using variational Bayes procedure, see details in Tichý, O., et al. "Bayesian inverse modeling and source location of an unintended ¹³¹I release in Europe in the fall of 2011." Atmospheric Chemistry and Physics 17.20 (2017): 12677-12696.

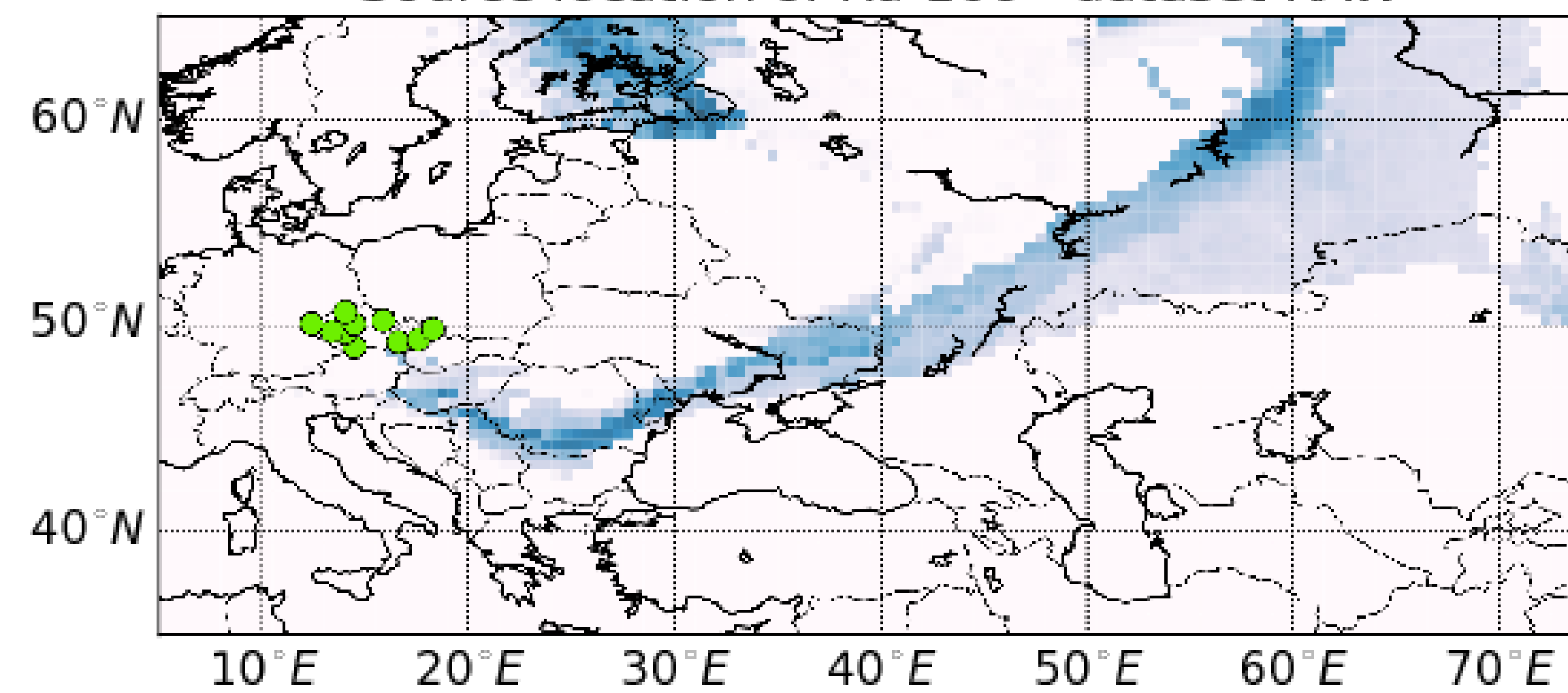
Measurements procedures

- Standard sampling and measurement procedure is based on high volume air sampler (150 – 900 m³/h)
 - dataset RAW
- Real-time sampling and measurement procedure, where the aerosol filter is counted via the HPGe detector placed directly above the aerosol filter already during sampling
 - dataset FAST

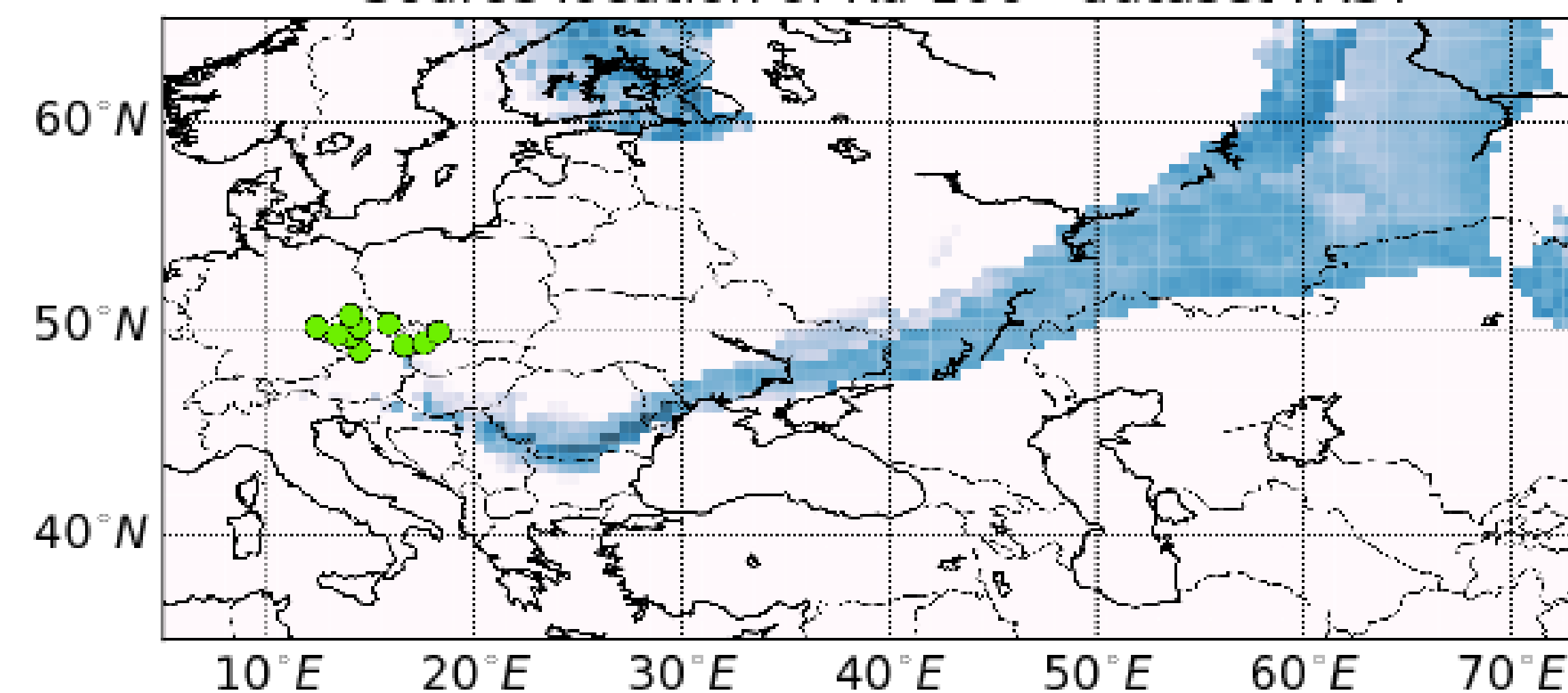


Results on ¹⁰⁶Ru release in 2017

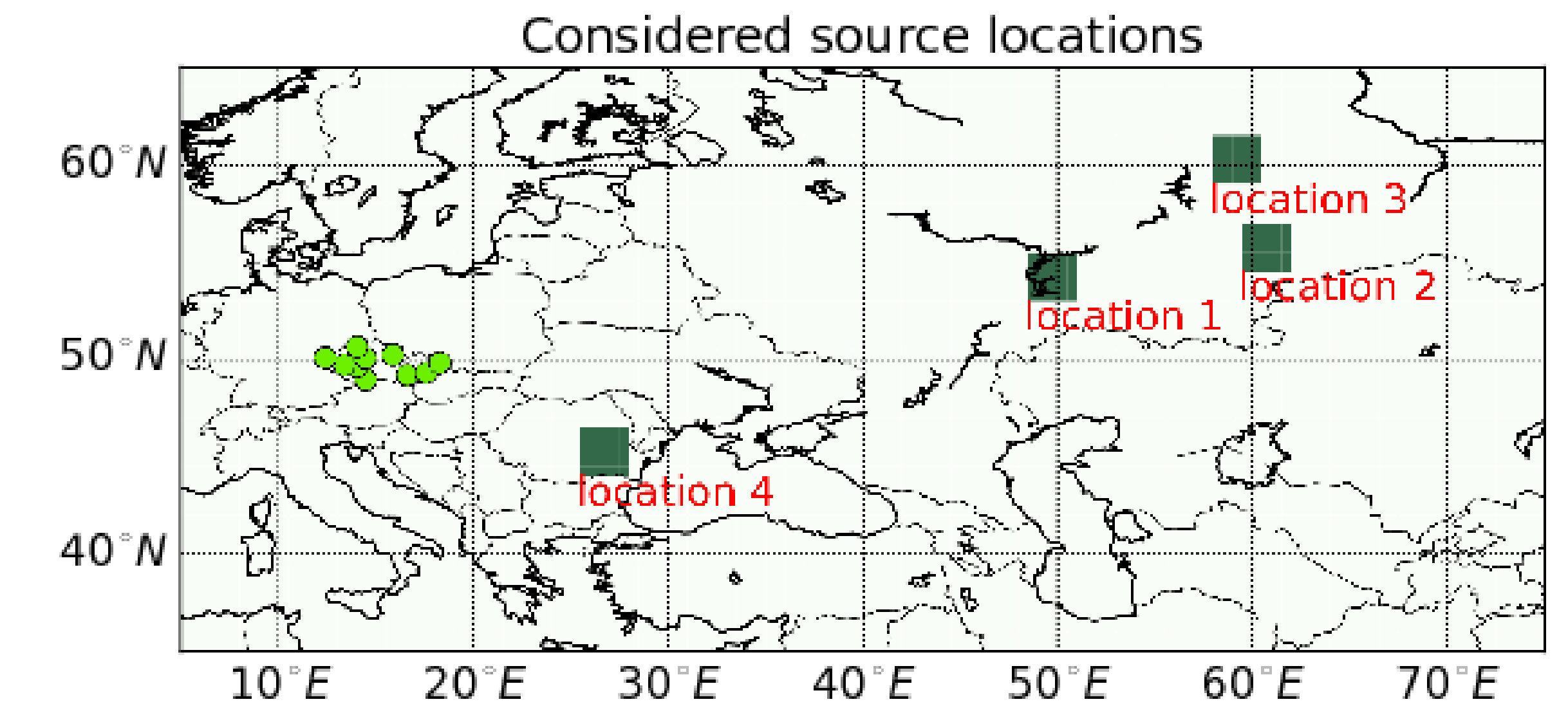
Source location of Ru-106 - dataset RAW



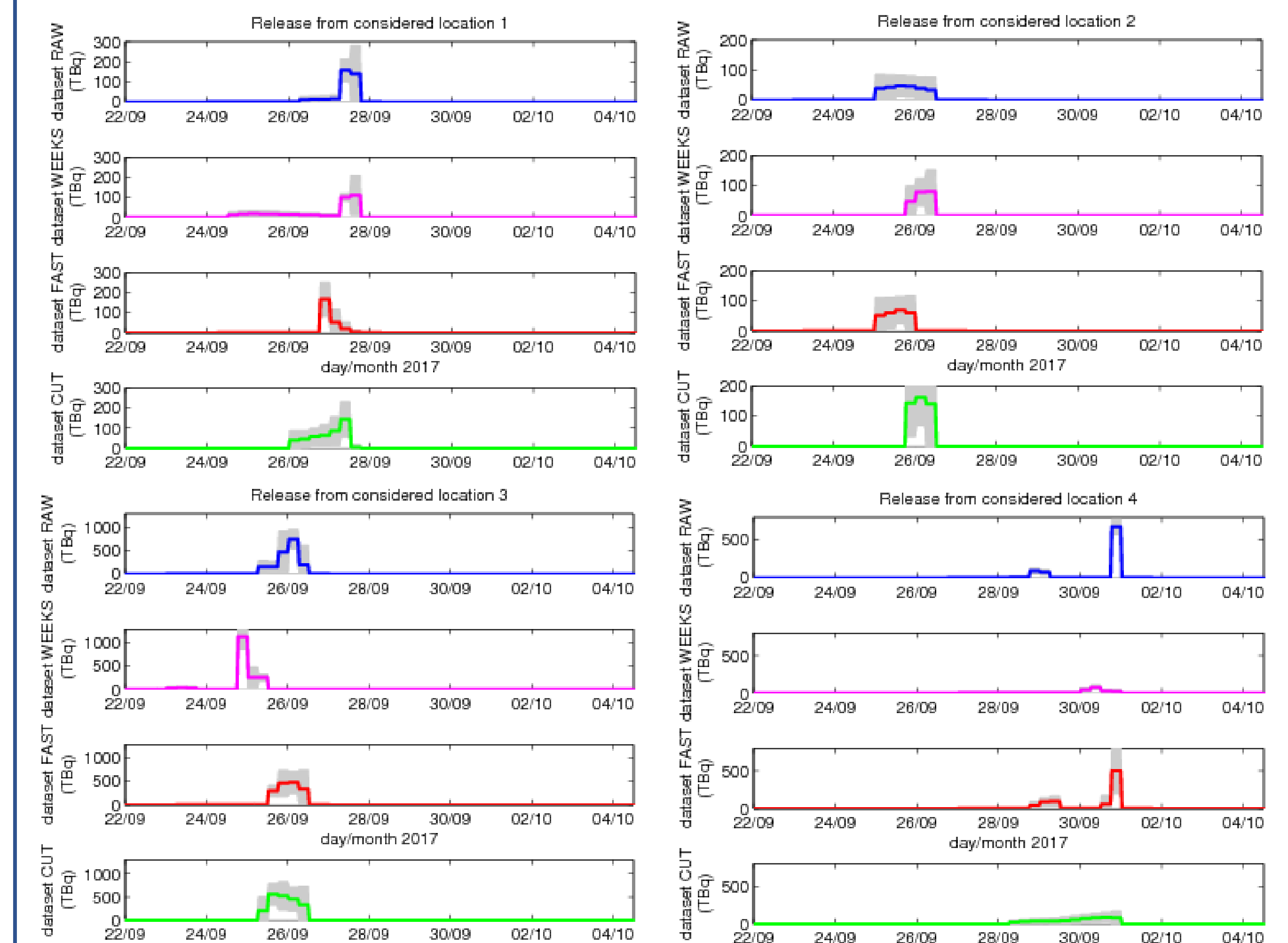
Source location of Ru-106 - dataset FAST



Based on Bayesian source location, we considered 4 locations:



For these locations, estimated source terms are displayed together with their lengths (in Table below). This demonstrates the benefit of real-time sampling procedure where temporal profile is more time-specific. We also conclude that even with Czech data only, the estimates are quite similar to those with whole Europe data.



Estimated lengths (hours)	Dataset RAW	Dataset WEEKS
Location 1	36	24
Location 2	36	24
Location 3	30	24
Location 4	30	30