HARMO 22

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SOURCE RECONSTRUCTION BASED ON INVERSE MODELLING WITH DEPOSITION MEASUREMENTS

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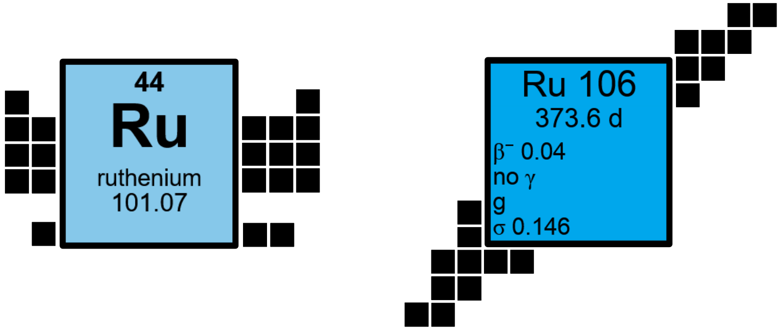
CASE STUDY // Undisclosed ^{106}Ru release in 2017



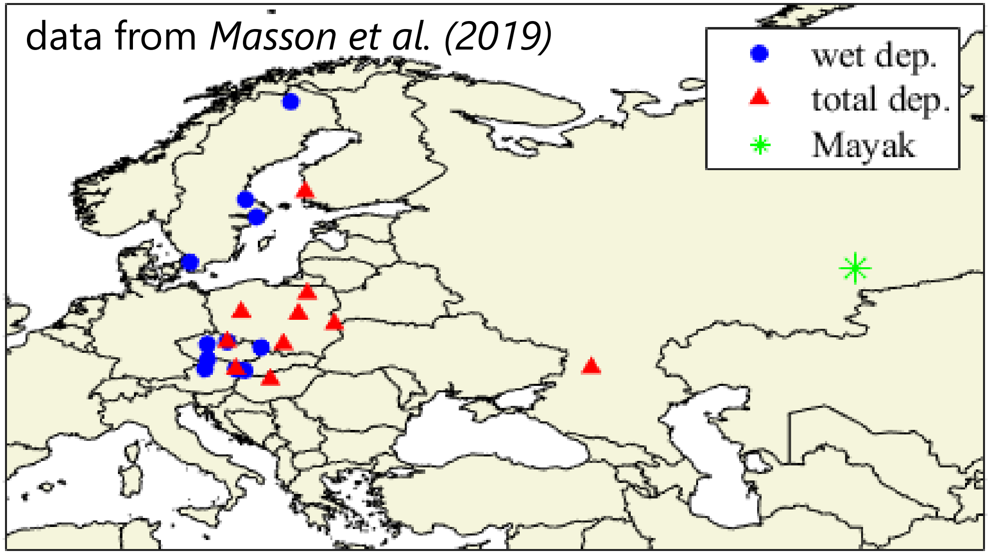
Observations

- September – October 2017
- air concentration (up to 180 mBq/m^3) and deposition (up to 90 Bq/m^2) in Europe

Source term from previous literature

- **location** → Mayak nuclear installation
- **release** → 200 – 500 TBq (1.6 – 4 g ^{106}Ru)
- based on air concentration measurements

Location of deposition detections



Research question

Theoretically, can (mobile, cheap) wet deposition measurements be used to complement (fixed, expensive) air concentration measurements for the purpose of inverse modelling?

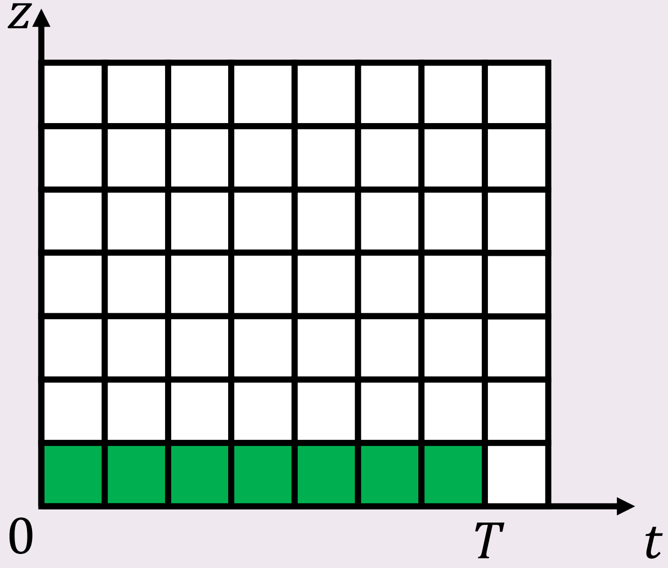
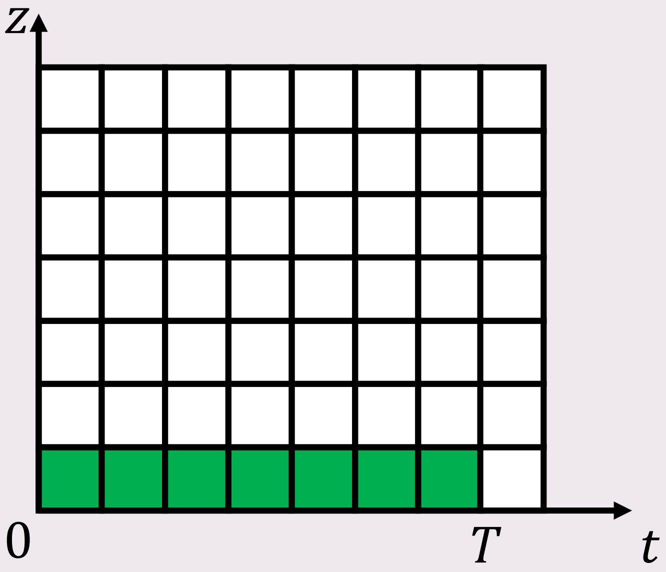
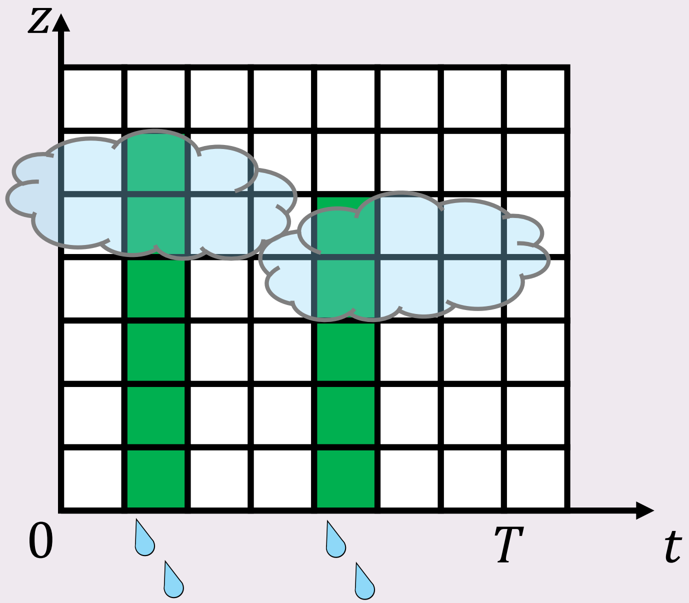
THEORY // Inverse modelling

- **source-receptor-sensitivity** M_{ij} is the sensitivity of **observation** y_i to **source term** x_j

$$y_i = \sum_j M_{ij} x_j$$

- only need to **calculate** M_{ij}**'s once** to generate y_i for any x_j
- we consider y as either **air concentration** (Bq/m^3) or **deposition** (Bq/m^2)
  → different SRS fields M_{ij} for each quantity

THEORY // Air concentration and deposition have different physical implications for inverse modelling

air concentration	dry deposition	wet deposition
$$y = \frac{1}{T}\int_0^T c \, \mathrm{d}t$$ T = measurement window	$$y = \int_0^T v_\mathrm{d} c \, \mathrm{d}t$$ v_d = deposition velocity	$$y = \int_0^T \mathrm{d}t \int_0^h \Lambda c \, \mathrm{d}z$$ Λ = scavenging coefficient h = height of cloud top
		

MODELS // Flexpart + FREAR

- **ATM →** Flexpart v10 (*Pisso et al. 2019*) in backward-in-time mode (*Seibert et al. 2004, Eckhardt et al. 2017*)
- **inverse modelling code →** FREAR (*De Meutter and Hoffman 2020*), open-source

FREAR v1

Input	• **SRS fields** from ATM (Flexpart) • environmental **observations** (air concentration)
Methods	• cost function optimisation • Bayesian inference • possible source region • field of regard
Output	**Source term** • release location (probability) • release amount • release timing

More info at
- *H22-066 (presentation)*
- *H22-079 (poster)*

OBJECTIVES // Adding deposition to FREAR

- **FREAR v1** uses activity air concentration

$$c = M_c \cdot x$$

- **new implementation** for this study

$$\begin{bmatrix} c \\ d_{\text{wet}} \\ d_{\text{dry}} \\ d_{\text{tot}} \end{bmatrix} = \begin{bmatrix} M_c \\ M_{d_{\text{wet}}} \\ M_{d_{\text{dry}}} \\ M_{d_{\text{tot}}} \end{bmatrix} \cdot x$$

→ inverse modelling with multiple types of measurements **simultaneously**!

(any combination)

METHODS // Experiments

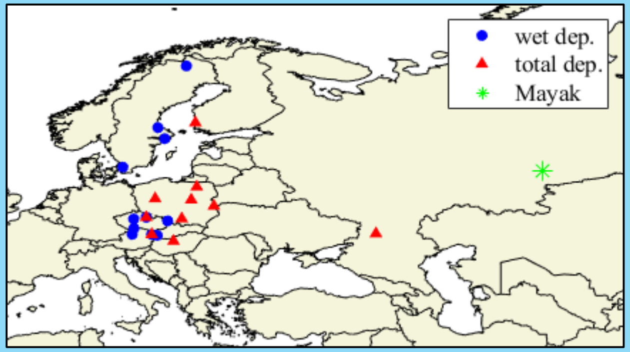
Twin experiment

1. forward ATM calculation with ^{106}Ru source term (*Saunier et al. 2019*)
2. generate synthetic observations
3. inverse modelling with synthetic observations

→ eliminates model- & observational errors

Real data

- inverse modelling with real observations
- observational data from *Masson et al. (2019)*



METHODS // Observations per experiment

Twin experiment

- wet deposition (18)
- total deposition (13)
- wet + total deposition (31)
- air concentration (31)

Real data

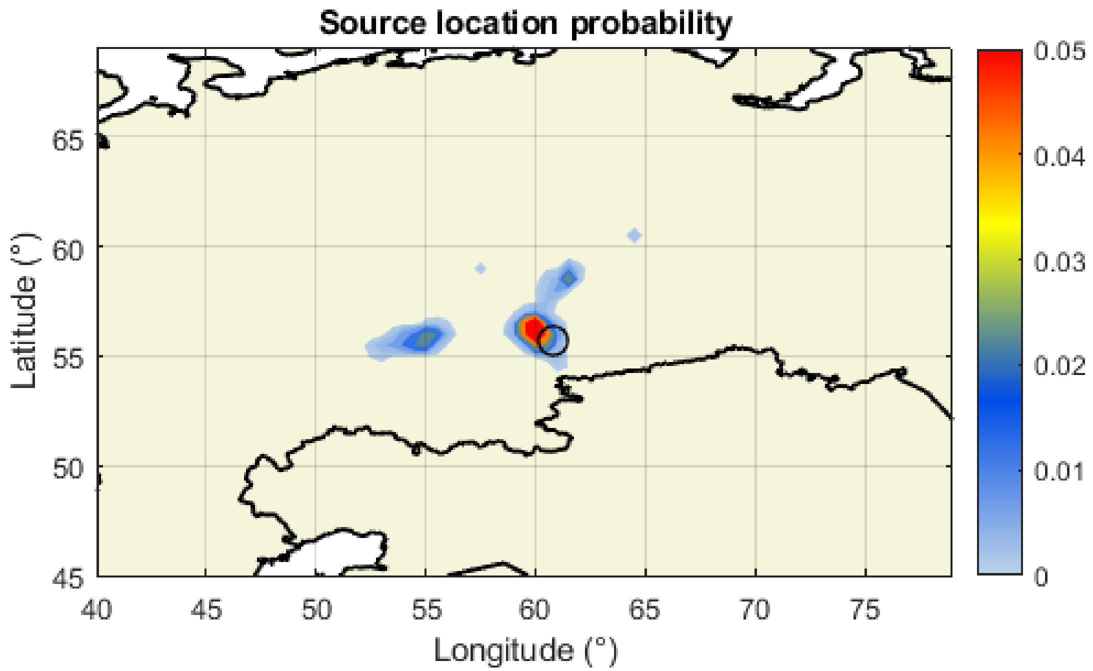
- wet deposition (18)
- total deposition (13)
- wet + total deposition (31)

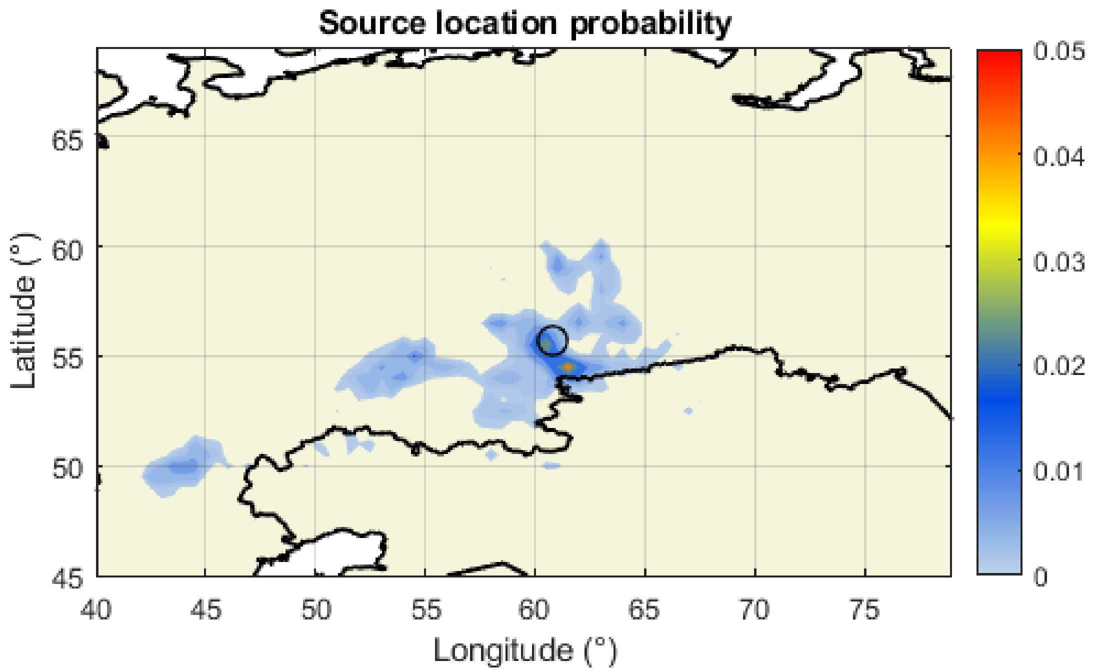
legend

identical
- location
- start & end time

Bayesian inference

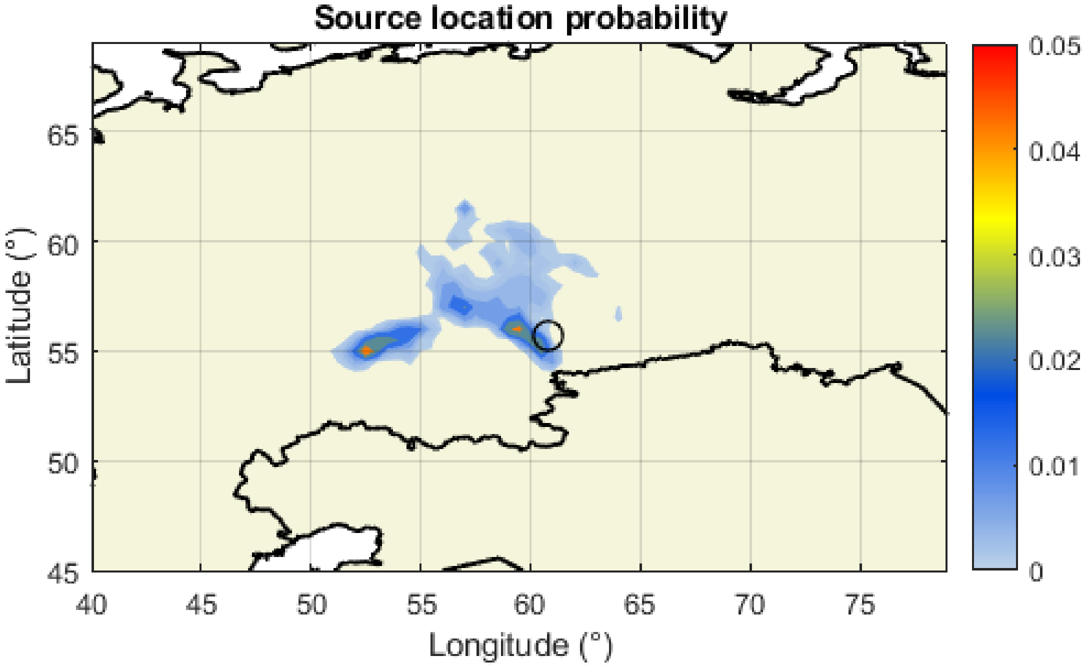
Wet deposition

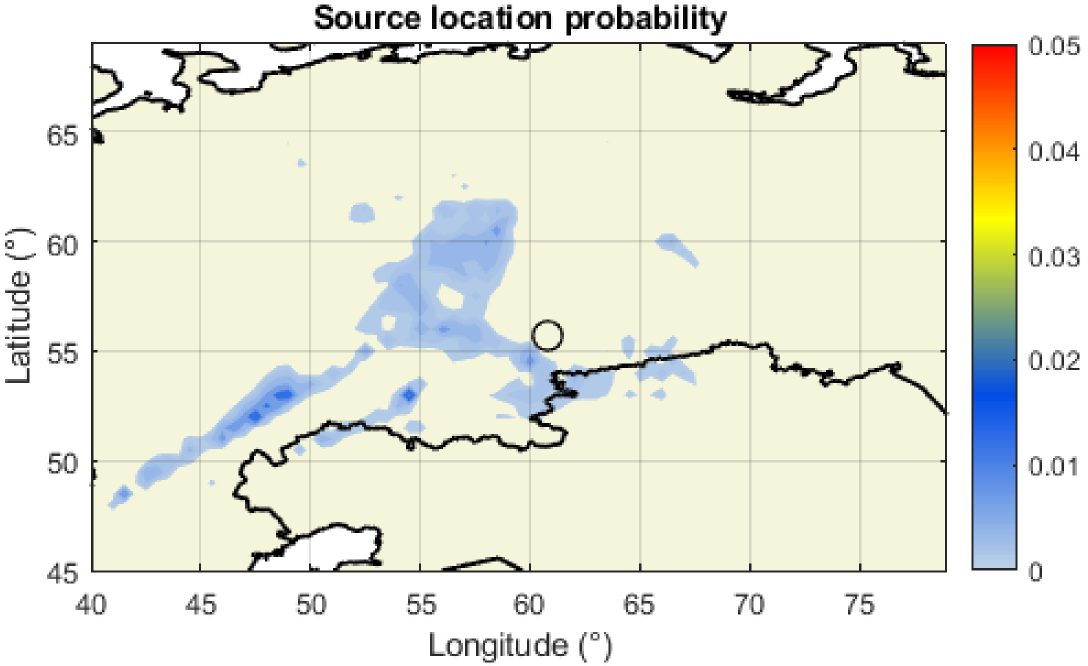




Bayesian inference

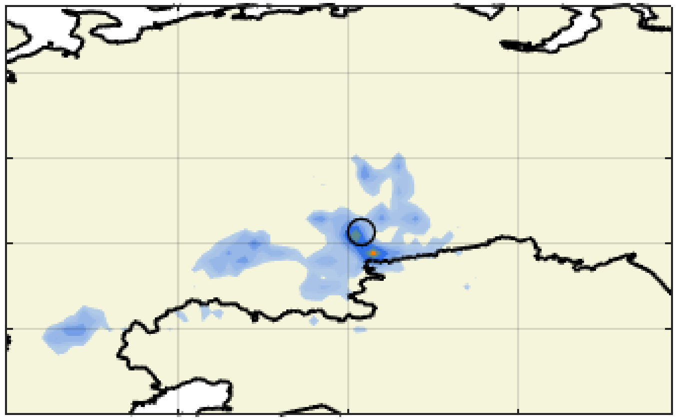
Total (wet+dry) deposition

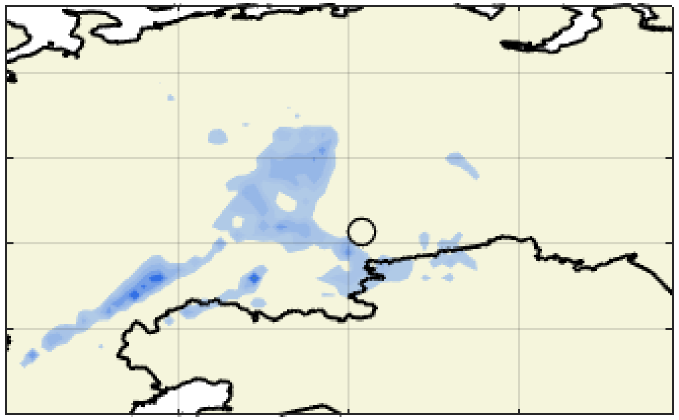


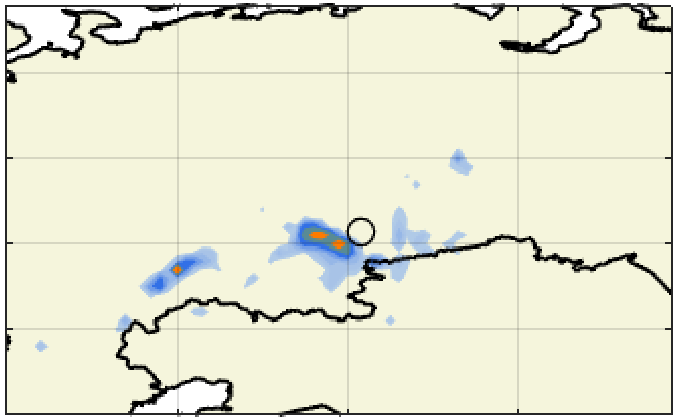


Bayesian inference

wet deposition	total deposition	wet + total deposition



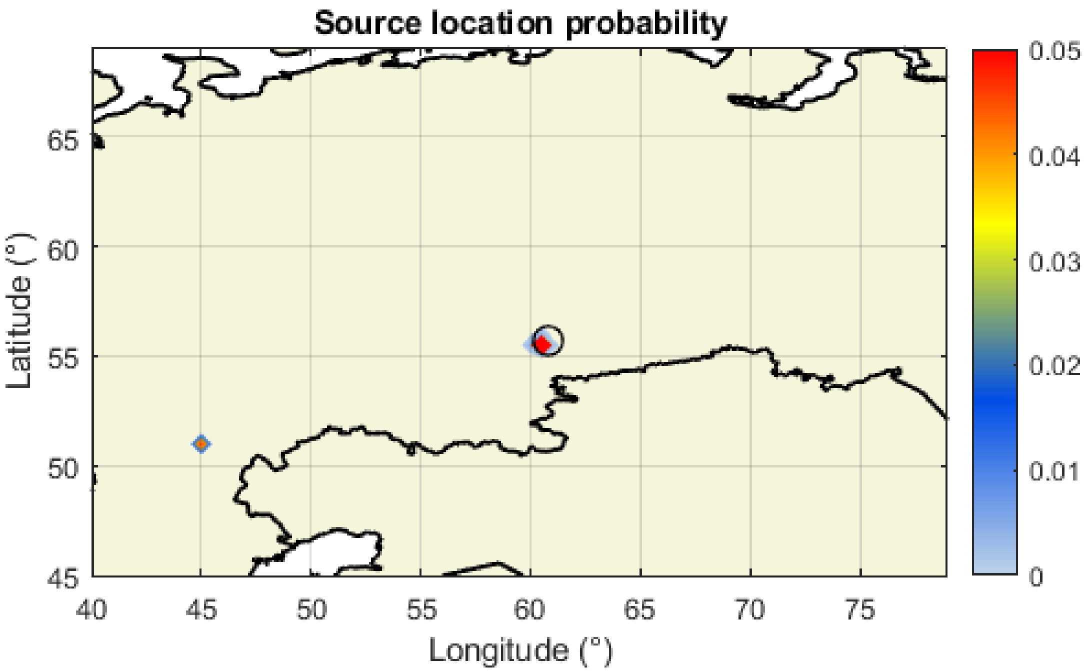




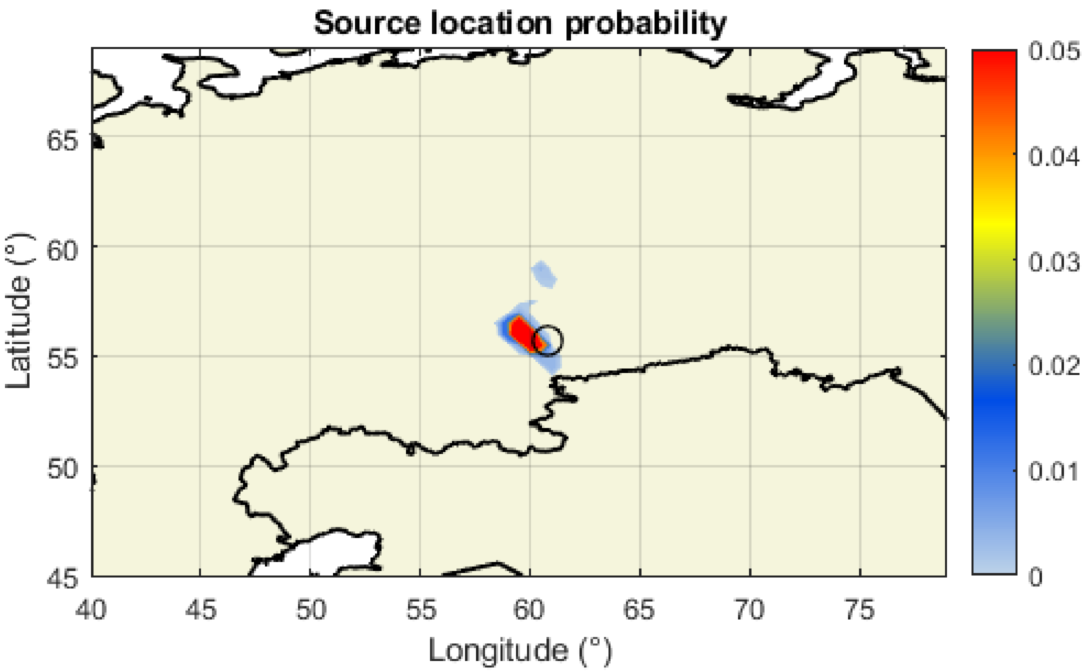
Twin experiment

Bayesian inference

Air concentration



Wet + total deposition



CONCLUSIONS

- ✓ Source reconstruction & localisation with deposition measurements is possible.

- ✓ This demonstrates that (mobile, cheap) wet dep measurements can theoretically be used to complement (fixed, expensive) air concentration measurements for the purpose of inverse modelling.

- ✓ Wet deposition measurements seem to contain less ‘information’ compared to air concentration (see twin experiment), but still provide very good results (see real data).

- ✓ Localisation with real data of total deposition seems to work less well (in this case + dataset).

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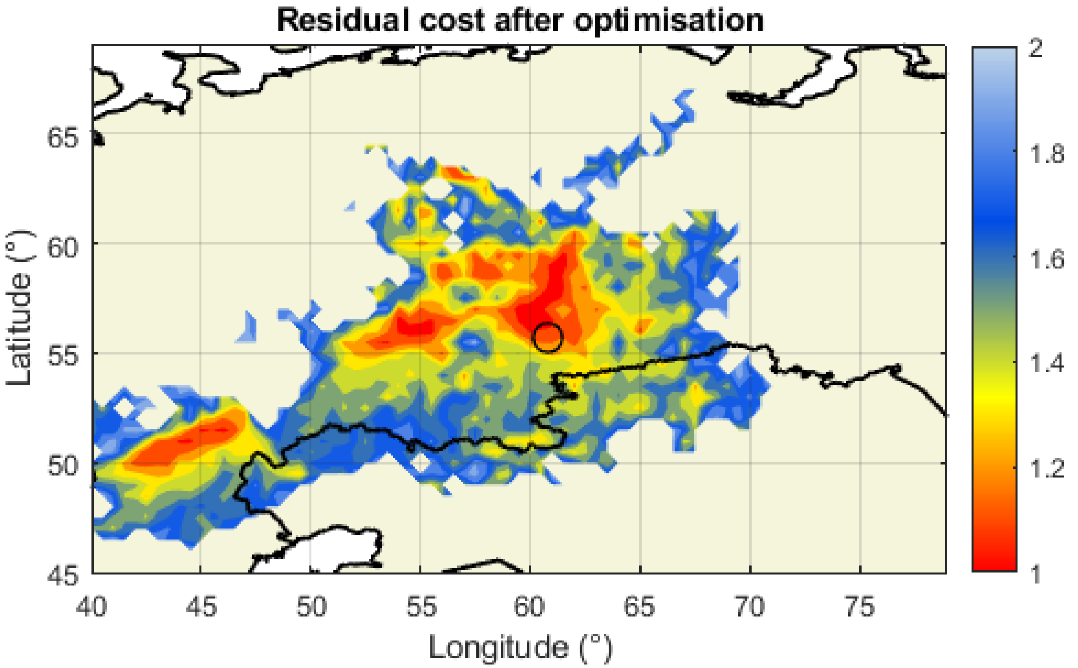
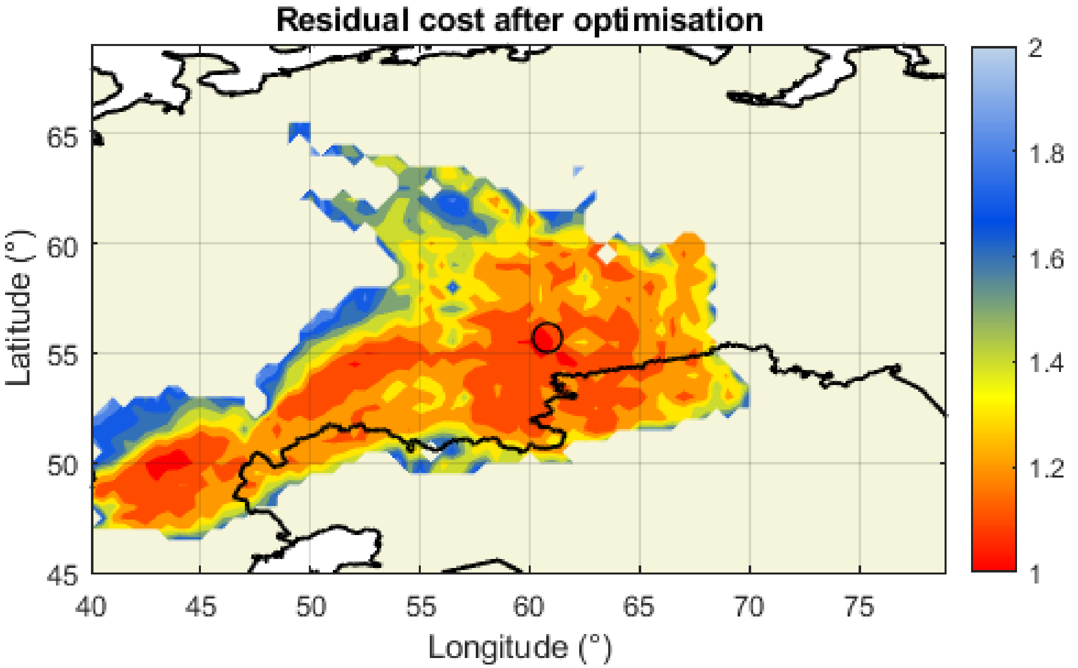
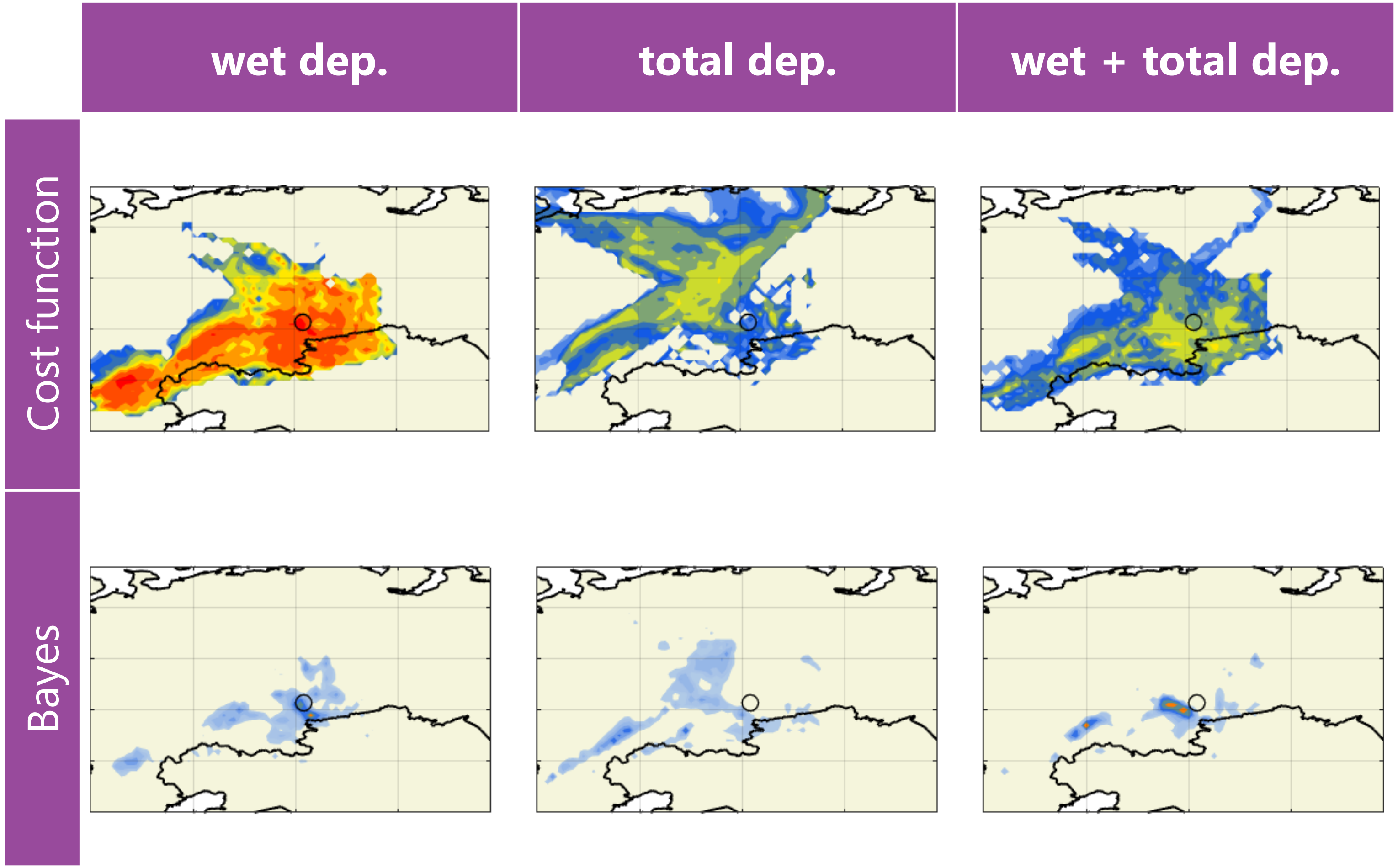
Wet deposition

Cost function optimisation





Real data



Twin experiment

	wet dep.	total dep.	wet + total dep.	air conc.	all
Cost function					
Bayes