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Validation study of the Flexpart-WRF model with episodes of Xe-133 releases and detections in Europe

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Overview

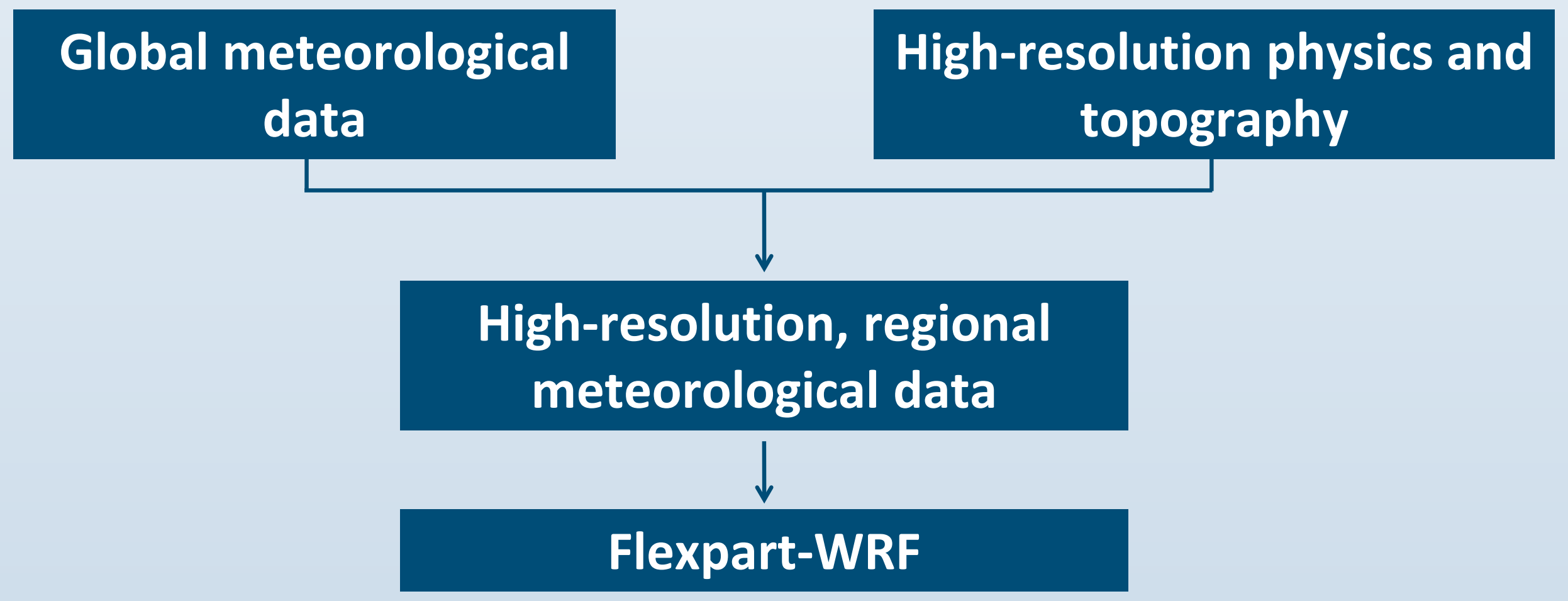
A new, high-resolution atmospheric transport model to simulate the dispersion of radioxenon is compared against a well-established model and measurements. The simulations are based on releases from a medical isotope production facility and validation is against detections at an IMS station.

Project description

The International Data Centre (IDC) of the CTBTO is developing the capability to conduct High-Resolution Atmospheric Transport Modelling (HRATM) simulations using the Numerical Weather Prediction model WRF (Skamarock et al., 2008) and the Atmospheric Transport Model (ATM) Flexpart-WRF (Brioude et al., 2013). The performance of Flexpart-WRF at the IDC is assessed by using source terms from a medical isotope production facility in Belgium to simulate the resulting concentration time series at IMS noble gas station RN33 in Germany. Seven episodes of elevated Xe-133 concentrations at RN33 were selected; each episode consists of 6 to 11 subsequent samples with each sample being taken over a 24-hour period. For each sample a high-resolution backward simulation was performed with nests of increased resolution around the source and the receptor. The simulated concentrations were produced by HRATM for different output resolutions (10, 30 and 50 km) and are compared to simulated results by the conventional Flexpart model as well as verified by the available measurements for RN33. The comparison includes similar statistical metrics as established during the two ATM challenges (Eslinger et al., 2016, Maurer et al., 2018) are applied for the comparison of the model outputs against the measurements.

WRF enhancement of meteorological data

A high-resolution atmospheric transport model consisting of the Weather Research and Forecasting Model (WRF) and a special Flexpart version (Flexpart-WRF) was introduced at the IDC.

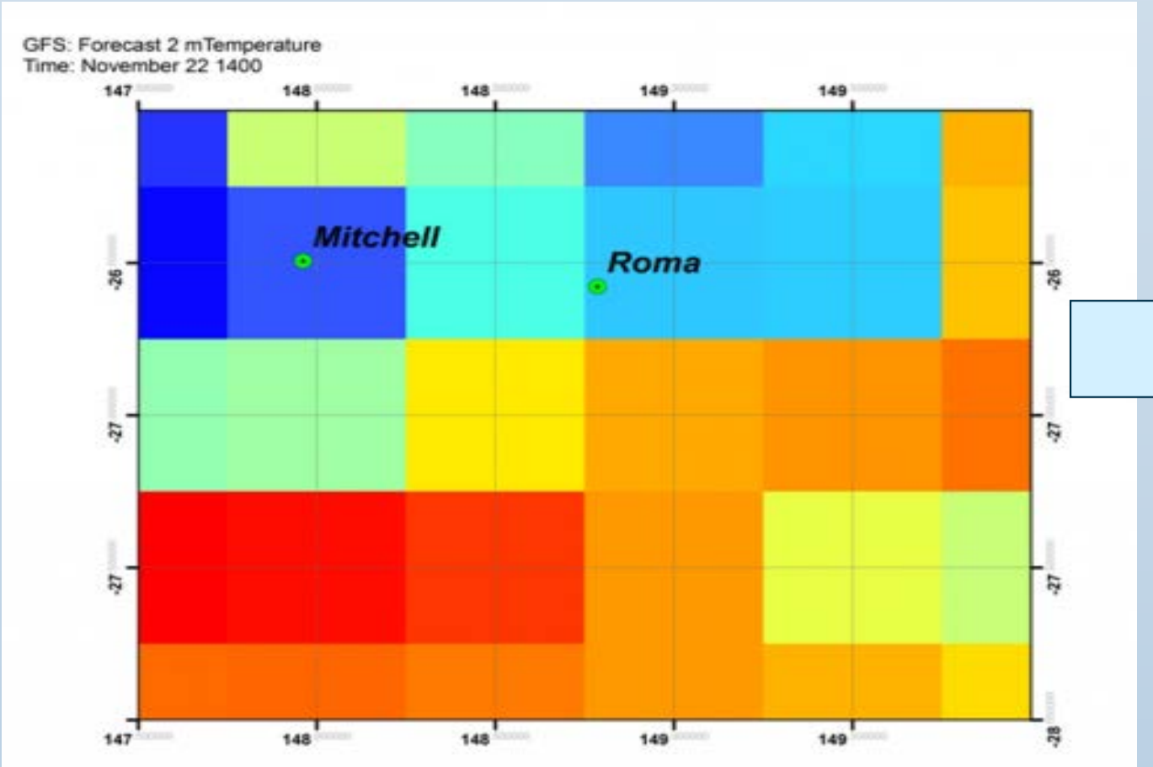


Global meteorological data

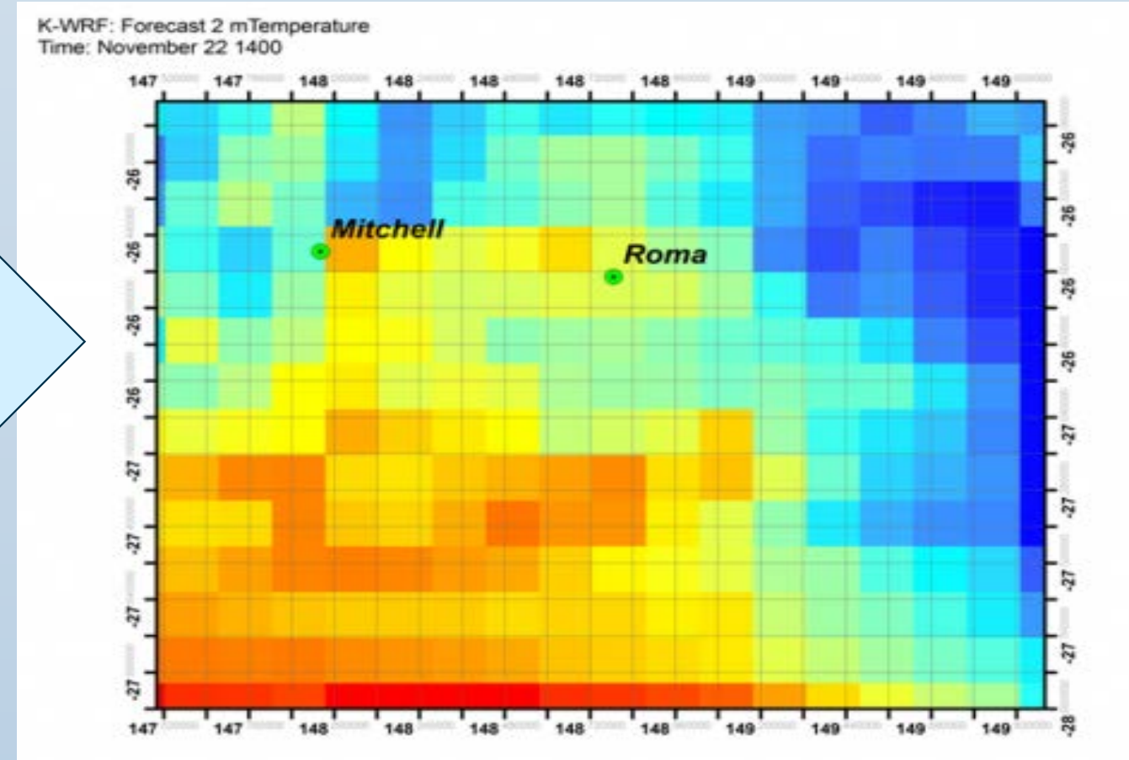
High-resolution physics and topography

High-resolution, regional meteorological data

Flexpart-WRF



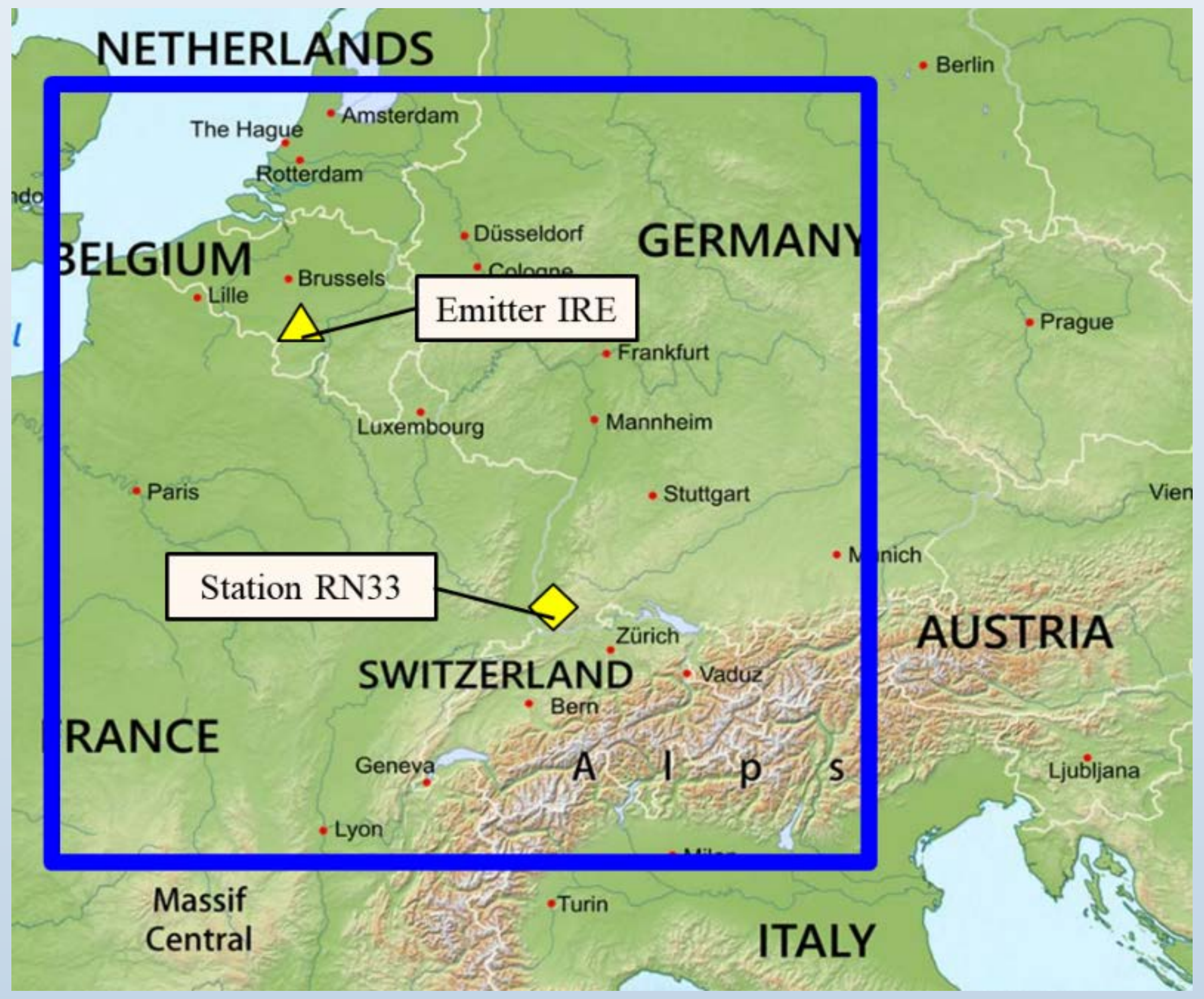
Typical met data in 0.5 deg



Refined WRF output in 12 km

Higher resolution, but computationally expensive
→ Not suitable for operational application
→ Suitable for case studies or special event analysis
→ May require parametrization adjustments

Setup and scenario for backward high-res ATM



Domain parameters

Blue box:
Parent domain in 9 km resolution

Nesting:
2-level nests with 3 km and 1 km resolution around emitter and receptor

(Yellow markers are not related to the sub-domain size)

Selected episodes

Selected time periods with elevated concentrations at RN33.

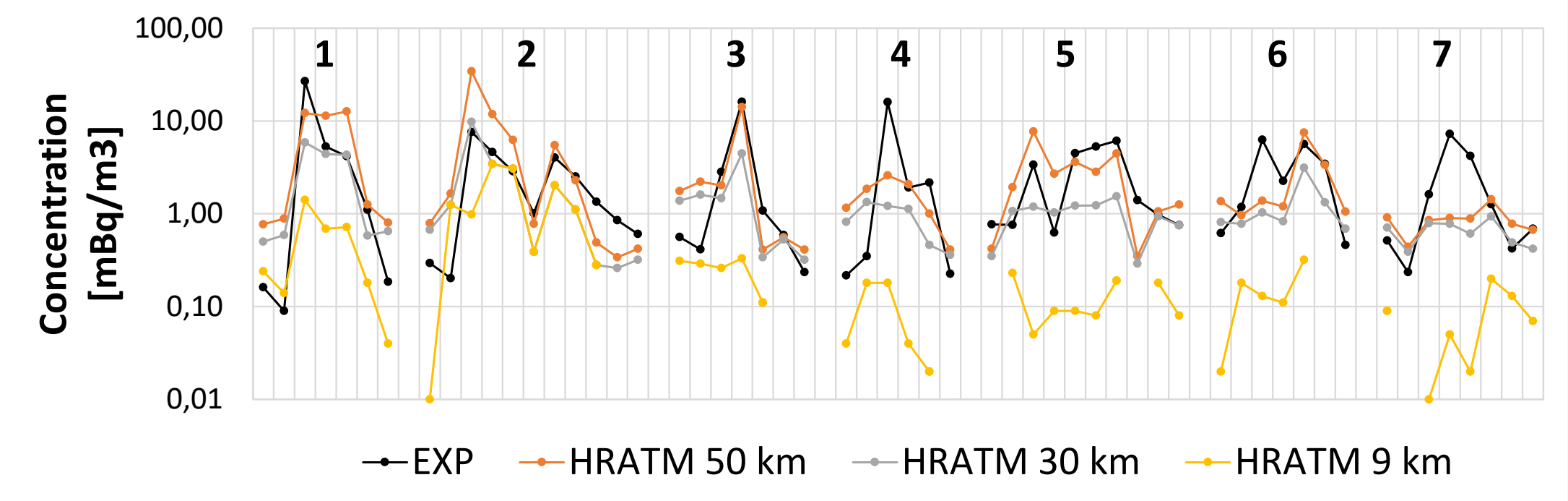
Sampling periods start at 06 UTC and were 24 hours long. (Dates indicate the collection stop time.)

#	Period start date	Length	Highest concentration
1	2013 11 27	7 days	26.8 mBq/m^3
2	2014 01 19	11 days	7.6 mBq/m^3
3	2014 03 13	7 days	16.1 mBq/m^3
4	2014 04 04	6 days	16.0 mBq/m^3
5	2014 07 07	10 days	6.1 mBq/m^3
6	2014 07 26	7 days	6.3 mBq/m^3
7	2014 08 28	8 days	7.3 mBq/m^3

Results of WRF and Flexpart-WRF simulations

VARYING OUTPUT RESOLUTIONS

- **Backwards simulations with WRF and Flexpart-WRF for the seven episodes of elevated Xe-133 concentrations.**
- **Use stack emission data from IRE to calculate concentration.**
- **Every dot is one daily sample at RN33; sample periods are separated by gaps.**
- **Varying the HRATM output resolution and comparing to measurements (black).**

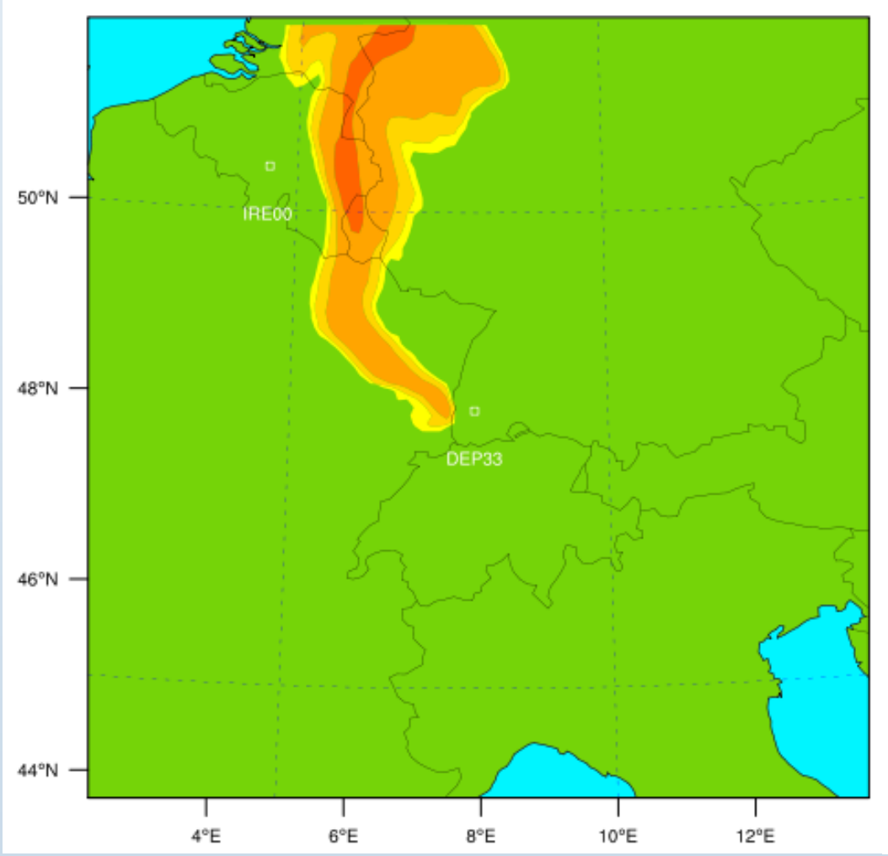


Statistics for high-resolution ATM results in comparison to measurements

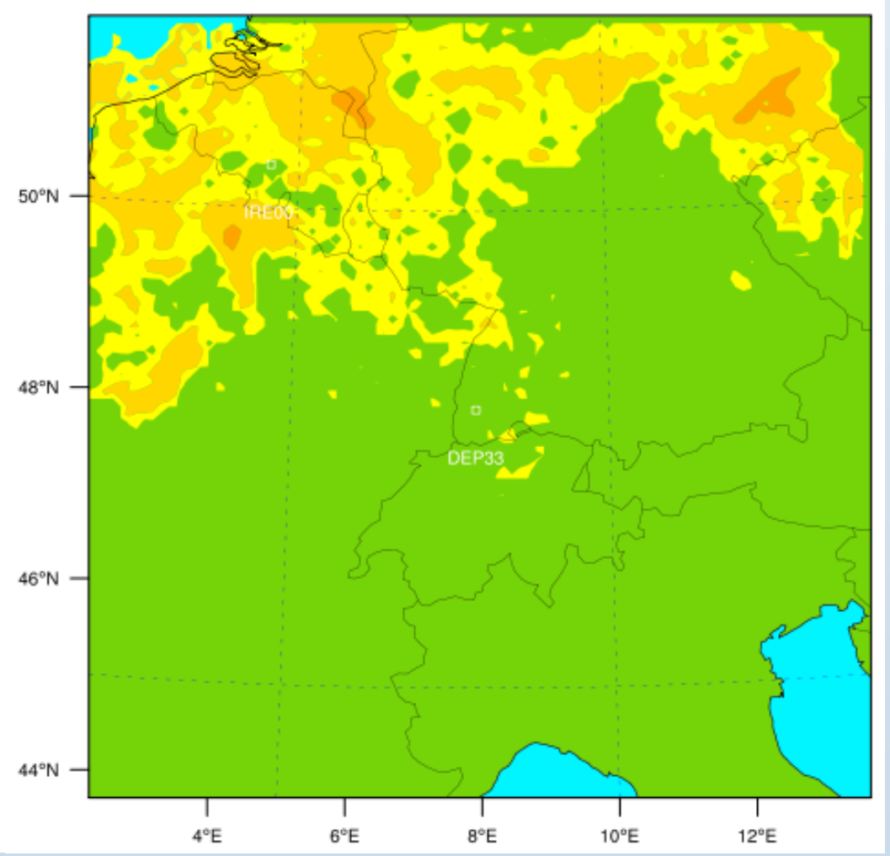
	50 km	30 km	9 km
Correlation (1)	0.51	0.60	0.25
Fractional bias (0)	0.10	-0.72	-1.56
F5 (1)	0.88	0.89	0.25
KS (0)	0.19	0.27	0.65
Rank	**3.14**	**2.86**	**1.08**

→ Lowest resolution yields the best rank
→ Possible explanation, see next column

DIFFERENT PLUME BEHAVIOURS



Example for a plume that is contained with positive gradients from the rim to the centre in almost all directions.

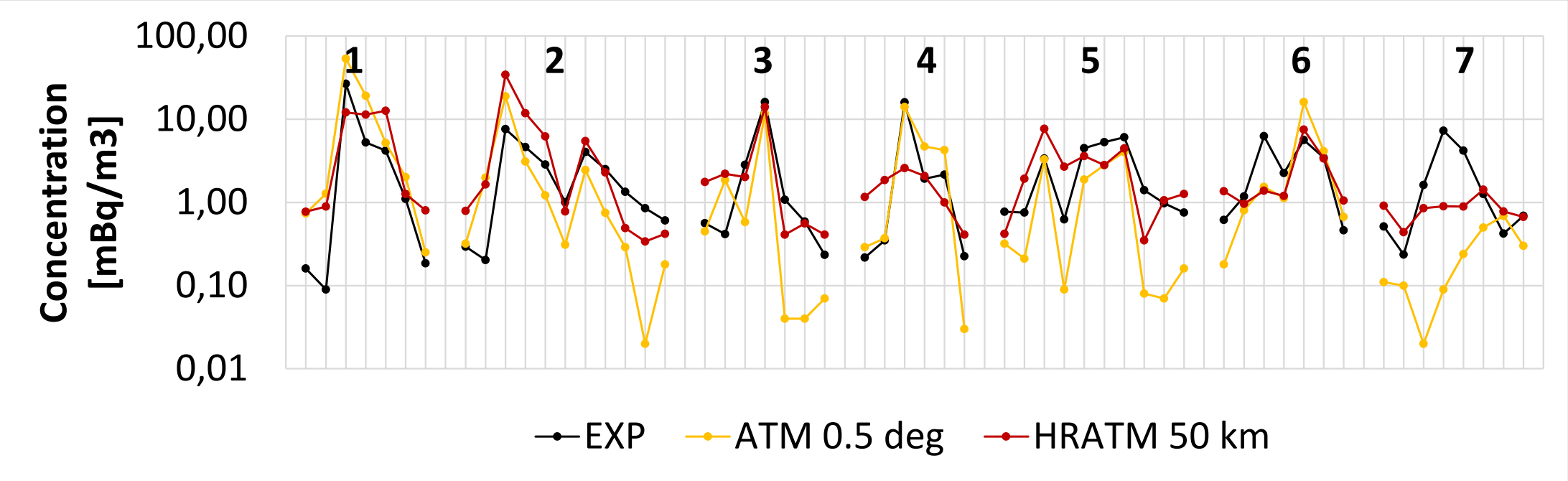


Dispersed plumes are often characterized by heterogeneous spotty patterns that are not representative of real conditions.

→ Dispersed plumes and high output resolutions can lead to biased results.
→ Contained plumes are more independent of output resolution.

VALIDATION AGAINST STANDARD FLEXPART

- **Comparison of best HRATM output resolution (50 km) to operational and established Flexpart ATM model with 0.5 degree resolution.**
- **Both simulations are evaluated against the measurements (black).**



Statistics for high-resolution ATM results and the operational ATM model in comparison to measurements

	ATM 0.5 deg	HRATM 50 km
Correlation (1)	0.85	0.51
Fractional bias (0)	0.13	0.10
F5 (1)	0.79	0.88
KS (0)	0.27	0.19
Rank	**3.31**	**3.14**

→ HRATM yields a rank comparable to standard Flexpart ATM

Summary

- The high-resolution atmospheric transport model consisting of **WRF** and **Flexpart-WRF** has been validated in a regional scenario with known stack emission data and atmospheric detections.
- Various output resolutions were compared against each other.
- Performance of high-resolution model depends on scenario.
- The best result was validated against the operational Flexpart model.
- WRF and Flexpart-WRF can currently deliver results comparable to the conventional Flexpart model.

Outlook

- Further optimization of physical and computational parameters needed.
- Going high-resolution requires adjustments to different parametrizations (e.g. boundary layer).
- High-resolution modelling will be used for regional case studies.
- Other fields of application, e.g. CTBT On-Site Inspection, will be explored.

References

- A Description of the Advanced Research WRF Version 3 – William C. Skamarock et al. (NCAR/TN–475+STR NCAR Technical Note, June 2008).
- The Lagrangian particle dispersion model FLEXPART-WRF version 3.1 – J. Brioude et al. (Geosci. Model Dev., 6, pp. 1889–1904, 2013).
- International challenge to predict the impact of radioxenon releases from medical isotope production on a comprehensive nuclear test ban treaty sampling station – Paul W. Eslinger et al. (Journal of Environmental Radioactivity 157, 41–51, 2016).
- International challenge to model the long-range transport of radioxenon released from medical isotope production to six Comprehensive Nuclear-Test-Ban Treaty monitoring stations – Maurer et al. (Journal of Environmental Radioactivity 192, 667-686, 2018)

PUTTING AN END TO NUCLEAR EXPLOSIONS