SnT 2021

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PREPARATORY COMMISSION

Investigation of improvement possibilities for source localization using high-resolution atmospheric transport modelling within the framework of the CTBT – Application to Xe-133 observations at IMS station DEX33 in Germany

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Anne Tipka, Jolanta Kusmierczyk-Michulec and Martin Kalinowski

POSTER

Investigation of improvement possibilities for source localization using high-resolution atmospheric transport modelling within the framework of the CTBT – Application to Xe-133 observations at IMS station DEX33 in Germany

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ABSTRACT

The IDC investigates the utilization of High-Resolution Atmospheric Transport Modelling (HRATM) in the CTBTO's aim to locate possible source regions after detections of radioactive substances through the International Monitoring System (IMS). Supporting the decision process, the IDC accomplished a case study with two approaches; using the current operational atmospheric transport model FLEXPART on a regional domain with 0.1 degree horizontal and 1 hourly temporal resolution, and the Weather Research and Forecasting Model (WRF) which serves as an interface between the driving meteorological data and the HRATM FLEXPART-WRF to further increase the resolution. Optimizations of settings were done by a WRF sensitivity study. The performance was evaluated by using ATM backward simulations and their comparison with observational data which are comprised of seven episodes of elevated Xe-133 concentrations from the IMS noble gas system DEX33, located in Germany. Each episode consists of 6 to 11 subsequent samples with each sample being taken over 24 hours. Both FLEXPART models used the source terms from a medical isotope production facility in Belgium to simulate the resulting concentration time series at the DEX33 station. Statistical metrics are used for comparison.

Introduction

INTRODUCTION

Aim:

Increase accuracy in the CTBTO's localization process through even higher spatial resolution than currently used in operation (0.5 deg)

Situation:

- Numerical weather models at approx. 0.5° can reproduce observations well in case of flat terrain and the source location procedure for IMS stations located in such terrain will work well.
- But for complex terrain, such as in south Germany where IMS station DEX33 is located, higher resolutions are necessary to reproduce the atmospheric dynamics (such as turbulence in complex terrain).
- At CTBTO, we are investigating the possible improvements of source localization by using higher spatial resolutions taking all kinds of performance issues into account (different models, computational time, amount of data, complexity of usage, potential for automatization)

Methodology

METHODS

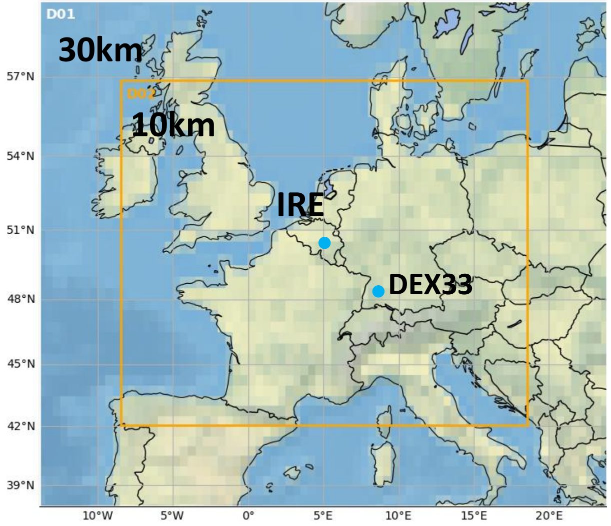
Methodology:

- Using different NWP models for meteorological input to the ATM Flexpart (ECMWF, NCEP, WRF)
- Conducting a sensitivity study on combinations of meteorological input and Flexpart output resolutions
- Compare model results against each other and against measurements from an IMS station in complex terrain which is influenced by a strong source nearby.

(HR)ATM input data and resolution:

- Input data from ECMWF and NCEP with 0.5° & 0.1° spatial resolution.
- Input data from WRF for Flexpart-WRF with different resolutions.
  - The first domain setup (approx. 30km/10km) is displayed on the right side.

WRF domain setup



(HR)ATM models:

- Flexpart-CTBTO with input from ECMWF/NCEP
- Flexpart-WRF with input from WRF and driven by ECMWF or NCEP

(HR)ATM output resolution:

- Investigation of differences between 0.5°, 0.25° & 0.1° output grids
- Variations of combinations from input and output resolutions

Evaluation

METHODS

Evaluation:

- Using selected observation periods of elevated Xe-133 concentrations at IMS station DEX33
- Run Flexpart and Flexpart-WRF backwards for each sample from DEX33
- Compare model results (different resolutions or models)
- Verify concentrations against stack emission data from medical isotope production facility in Belgium, IRE

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

First results for DEX33_1

RESULTS

- Peak of concentration in ATM simulations is delayed when using ECMWF input data and a finer input grid.
- Order of magnitude of peak increases with increasing output grid resolution for ECMWF input data.
- The coarser ATM simulation with NCEP data produces a peak twice as much as observed.
- Peak concentrations for ECMWF cases increase with finer output grid resolution.

				NCEP			ECMWF								
		DATE	OBS/Exp	ATM i:0.5 o:0.5			ATM i:0.1 o:0.5			ATM i:0.1 o:0.25			ATM i:0.1 o:0.1		
				CONST	STACK	TOTAL	CONST	STACK	TOTAL	CONST	STACK	TOTAL	CONST	STACK	TOTAL
DEX33_1 (2013)	1	27-Nov	0.16	0.30	0.00	0.30	0.31	0.00	0.31	0.60	0.00	0.60	1.71	0.00	1.71
	2	28-Nov	0.09	1.95	0.00	1.95	1.08	0.00	1.08	0.13	0.00	0.13	0.24	0.00	0.24
	3	29-Nov	**26.80**	1.52	**52.62**	54.14	1.40	0.64	2.04	2.69	0.96	3.65	0.09	1.03	1.12
	4	30-Nov	5.28	0.28	18.76	19.04	0.59	1.25	1.84	0.17	1.21	1.38	0.18	1.29	1.47
	5	01-Dec	4.18	0.54	3.69	4.23	0.46	**3.10**	3.56	0.18	**5.39**	5.57	0.06	**7.30**	7.36
	6	02-Dec	1.11	0.35	1.42	1.77	0.27	0.39	0.66	0.57	0.53	1.10	0.03	0.73	0.76
	7	03-Dec	0.19	0.59	0.01	0.60	0.48	0.05	0.53	0.02	0.05	0.07	0.01	0.02	0.03

all data is in mBq/m³

i: input data; o: output data
const: constant source emission (NPP,MIPF)
stack: stack emission (IRE)

First results for DEX33_1

RESULTS

- Using HRATM with ECMWF input data and an improved setup with 0.5 degree output grid shows also a delay.
- Using new setup and ECMWF input data seems to improve the order of magnitude of concentration values but moves the peak one day ahead of the measured peak.
- HRATM with NCEP data and approx. 0.5 output grid has a delayed peak and with approx. 0.1 degree a correct peak arrival time but the concentration is very low.

				NCEP						ECMWF					
		DATE	OBS/Exp	HRATM i:9km o:54km			HRATM i:9km o:9km			HRATM i:10km o:0.5			HRATM i:10km o:0.1		
				CONST	STACK	TOTAL	CONST	STACK	TOTAL	CONST	STACK	TOTAL	CONST	STACK	TOTAL
DEX33_1 (2013)	1	27-Nov	0.16	0.03	0.00	0.03	0.02	0.00	0.02	0.13	0.00	0.13	0.02	0.00	0.02
	2	28-Nov	0.09	0.03	0.00	0.03	0.00	0.00	0.00	0.25	3.56	3.81	0.06	**8.27**	8.33
	3	29-Nov	**26.80**	0.23	9.28	9.51	0.01	**0.55**	0.56	0.14	3.15	3.29	0.15	1.22	1.37
	4	30-Nov	5.28	0.56	9.97	10.53	0.01	0.50	0.51	0.07	**4.18**	4.25	0.1	1.21	1.31
	5	01-Dec	4.18	0.15	**11.12**	11.27	0.00	0.37	0.37	0.08	0.71	0.79	0.07	0.23	0.30
	6	02-Dec	1.11	0.03	0.62	0.65	0.04	0.02	0.06	0.32	3.88	4.20	0.08	1.35	1.43
	7	03-Dec	0.19	0.15	0.02	0.17	0.00	0.00	0.00			0.00			0.00

all data is in mBq/m³

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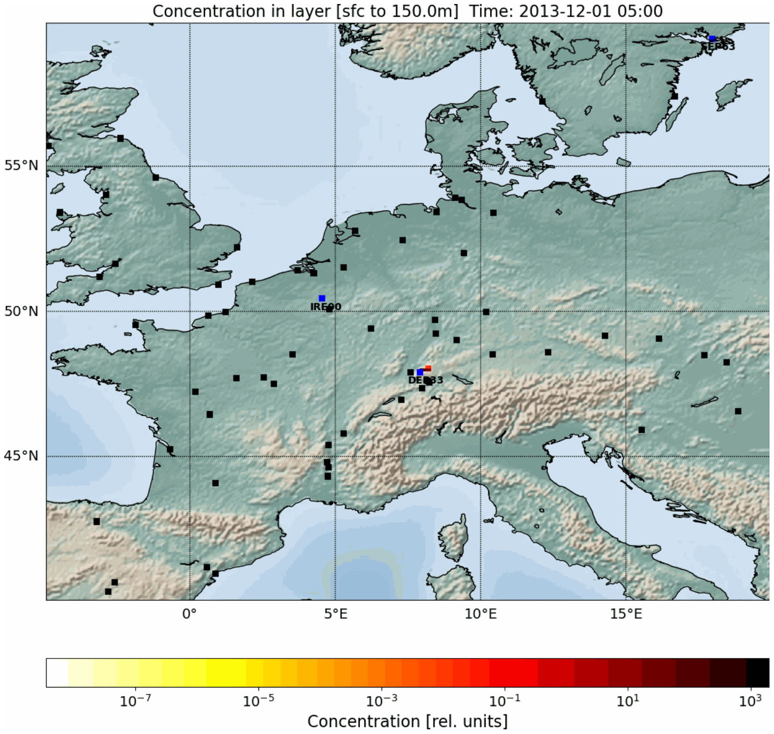
stack: stack emission (IRE)

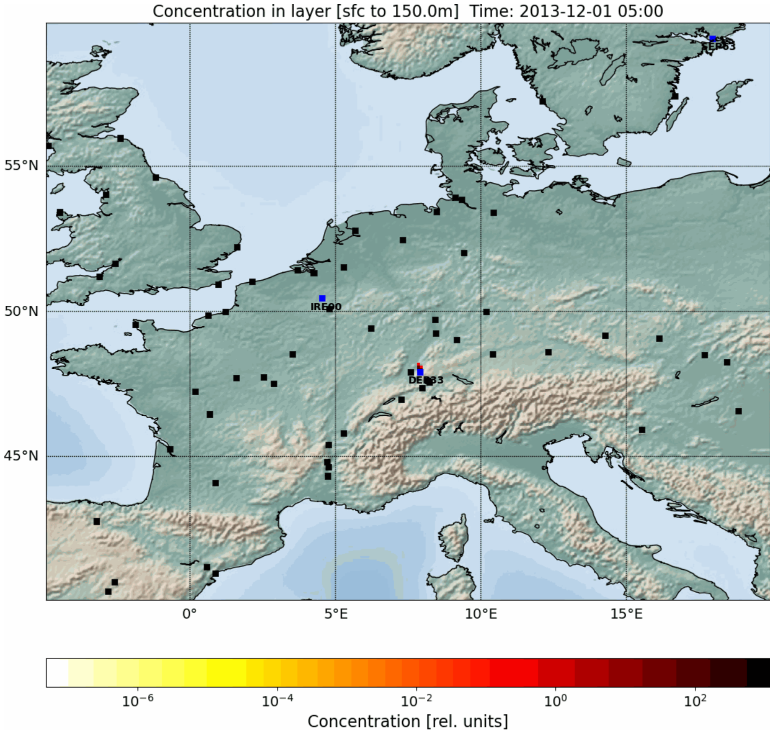
First results for DEX33_1 sample 5

RESULTS

ATM ECMWF i:0.1 o:0.1



HRATM ECMWF i:10km o:0.1



First results for DEX33_4

RESULTS

- This case shows a good agreement in peak arrival time for multiple setups.
- Simulations using high-resolution ECMWF input data have a lower order of magnitude of concentration values.
- HRATM with NCEP data on approx. 0.1 degree output grid has almost no contribution.

				NCEP						ECMWF					
		DATE	OBS/Exp	ATM 0.5			HRATM i:9km o:9km			ATM i:0.1 o:0.1			HRATM i:10km o:0.1		
				CONST	STACK	TOTAL	CONST	STACK	TOTAL	CONST	STACK	TOTAL	CONST	STACK	TOTAL
DEX33_4 (2014)	1	04-Apr	0.22	2.52	0.00	2.52	0.01	0.00	0.01	0.03	0.00	0.03	0.11	0.00	0.11
	2	05-Apr	0.35	1.18	0.00	1.18	0.01	0.00	0.01	0.25	0.11	0.36	0.07	0.00	0.07
	3	06-Apr	**16.00**	0.34	**13.50**	13.84	0.01	0.01	0.02	0.38	**3.22**	3.60	0.19	**2.53**	2.72
	4	07-Apr	1.92	0.51	4.38	4.89	0.01	**0.02**	0.03	0.06	0.16	0.22	0.13	1.91	2.04
	5	08-Apr	2.16	0.50	3.61	4.11	0.01	0.01	0.02	0.35	0.81	1.16	0.22	0.87	1.09
	6	09-Apr	0.22	0.06	0.00	0.06	0.00	0.00	0.00	0.04	0.00	0.04	0.06	0.00	0.06

all data is in mBq/m³

i: input data; o: output data
const: constant source emission (NPP,MIPF)
stack: stack emission (IRE)

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First results for DEX33_4 sample 3

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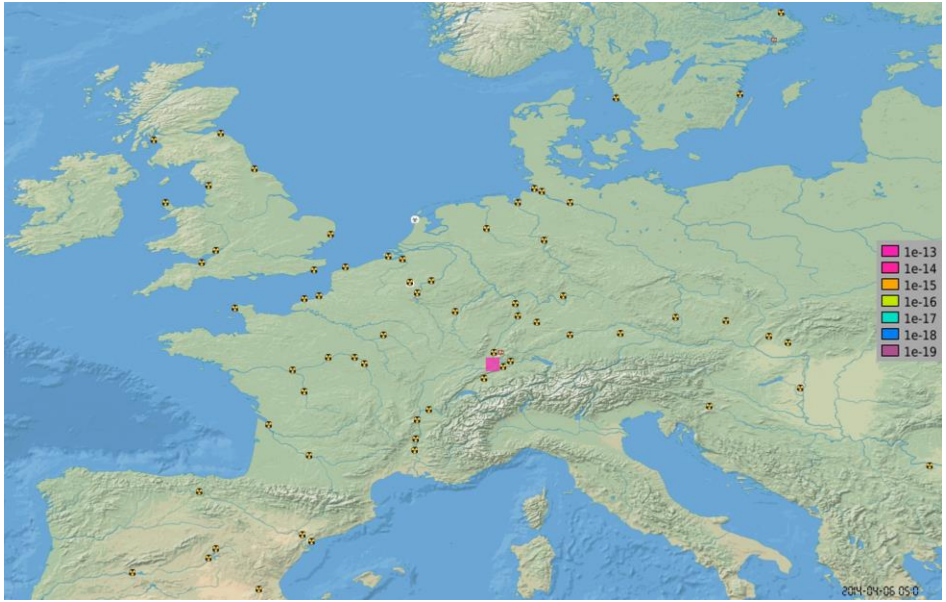
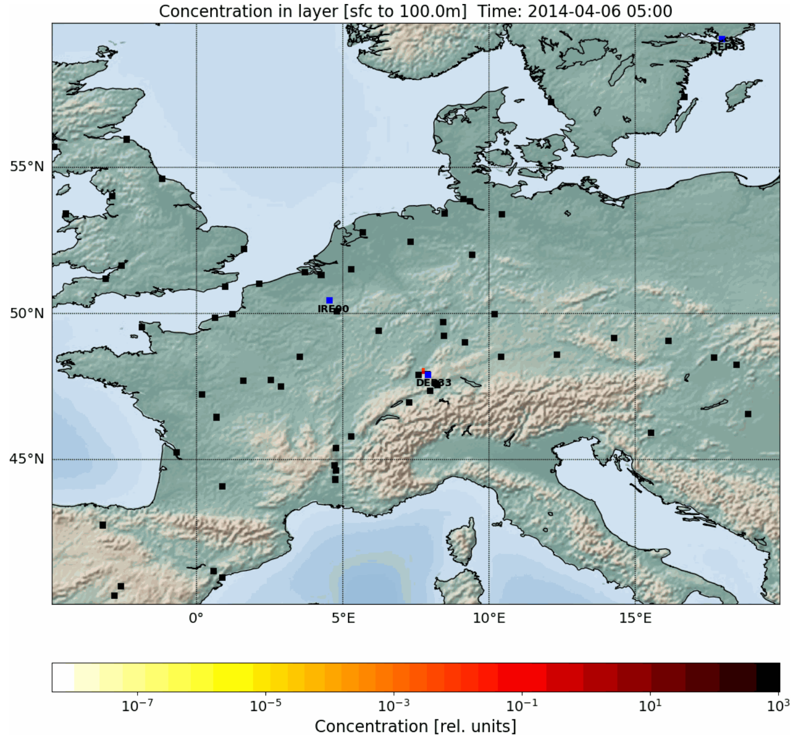
RESULTS

ATM NCEP i:0.5 o:0.5



HRATM ECMWF i:10km o:0.1



Summary

CONCLUSIONS

- From first results, it seems that the smoothing of 0.5 degree input data over the complex terrain around DEX33 station has no negative influence on ATM when observations show a clear and dominant peak in observations.
- In the case of a non dominant peak (observation over multiple samples), the arrival time is usually delayed, also for ATM with NCEP and 0.5 degree. (Not shown in this presentation)
- HRATM setup still has room for improvement.
- Still no clear tendency for best model setup.

Work in progress/Outlook

- Investigate the weather situation from input data and compare them with observations.
- Run (HR)ATM simulations with other spatial resolutions.
- Further optimization in WRF parameterizations needed.

Thank you