P2.3-321

Improving Global ^{133}Xe Background Concentration Fields By Applying Nudging Techniques in FLEXPART-LCM

Johannes Fleisch[1)], Andreas Stohl[1)]

1) University of Vienna, Department of Meteorology and Geophysics

universität wien

INTRODUCTION AND MAIN RESULTS

A spatiotemporal nudging scheme was implemented in FLEXPART-LCM for 2014 to improve global ^{133}Xe background concentration fields. Substantial reductions in MSE and increases in R^2 were achieved at assimilation stations, confirming the successful implementation. However, improvements at independent validation stations were limited, largely attributable to the sparse station geometry and the short atmospheric lifetime of ^{133}Xe, both of which restrict the downwind propagation of observational corrections.

SnT 2025
8 SEPTEMBER ONLINE DAY
9 TO 12 SEPTEMBER AT HOFBURG PALACE, VIENNA & ONLINE
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE

Improving Global 133Xe Background Concentration Fields By Applying Nudging Techniques in FLEXPART-LCM

Johannes Fleisch, Andreas Stohl

P2.3-321

Introduction & Objectives

Within the CTBT verification regime, atmospheric radioxenon, especially ^{133}Xe, is an indispensable tracer of nuclear tests, and accurate background concentration fields are essential to discriminate between civilian and non-civilian signatures. Yet emission inventories are temporally incomplete, the monitoring network is sparse, and transport uncertainties persist, leading to model–observation mismatches.

To address these limitations, a spatiotemporal nudging scheme was implemented in FLEXPART-LCM to improve global ^{133}Xe background concentration fields. Objectives were to realise a stable nudging technique, identify physically plausible spatial kernels through sensitivity experiments, and quantify performance at assimilation stations as well as generalisability at independent validation stations.

Methods & Data

Global ^{133}Xe emissions for 2014, covering nuclear power plants, nuclear research reactors, and, predominantly, medical isotope production facilities, were prescribed to drive the simulations. Atmospheric observations from 20 IMS stations for February–December 2014 were used, with January reserved for spin-up.

Transport was simulated with FLEXPART-LCM in global domain-filling mode. Nudging was implemented as a four-dimensional relaxation that adjusts particle masses toward observations for particles located within a prescribed space–time kernel. Spatial kernel scales were station-adaptive, defined as

$$h_i = h_{base} \cdot \lambda \cdot \ln\left(1 + \frac{\sigma_{max}}{\sigma_i}\right),$$

where σ_i is the standard deviation of observed concentrations at station i and σ_{max} the maximum standard deviation of all stations. Spatial scale factors $\lambda \in \{4,6,8\}$ were analysed. $\lambda = 8$ was adopted for subsequent analyses.

Results & Conclusion

At assimilation stations (Fig. 1), MSE decreased by 88% and R^2 increased by 33 %. In contrast, performance at independent validation stations showed little to no improvement, indicating limited spatial generalisability.

The locality of benefit is attributable to physical constraints: the 5.24-day half-life of ^{133}Xe and the sparse station geometry limit the persistence and downwind propagation of observational corrections (Fig. 2). Impact is likely to increase with improved network density or when assimilating longer-lived isotopes.

Fig. 1: *Time series comparison of simulated and observed ^{133}Xe activity concentrations at station USX74, with and without nudging.*

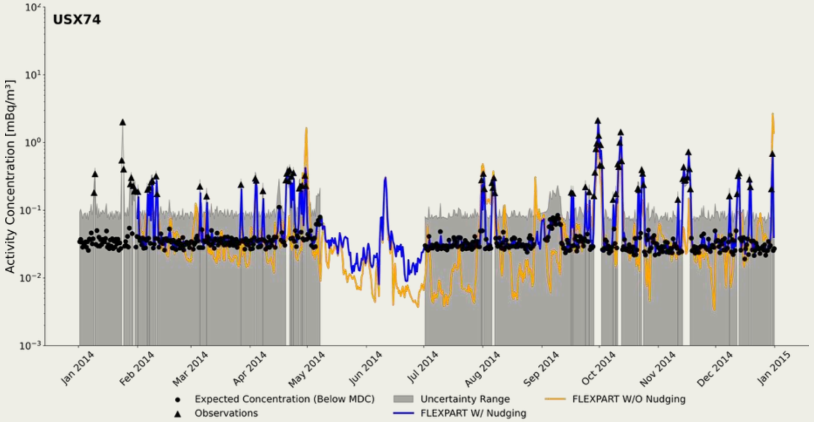
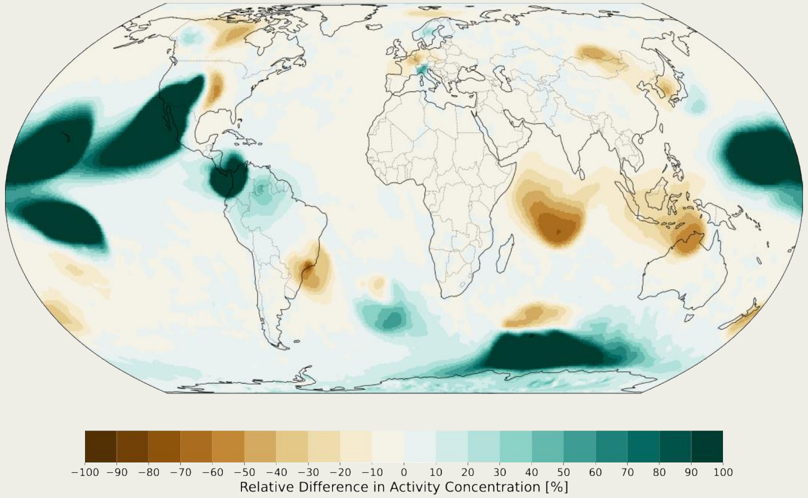


Fig. 2: *Mean relative difference in ^{133}Xe activity concentration between simulations with and without nudging for 2014.*



universität wien