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Long-range transport of Xe-133 emissions under convective and non-convective conditions

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Long-range transport of Xe-133 emissions under convective and non-convective conditions

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A B S T R A C T

To investigate the transport of xenon emissions, the Provisional Technical Secretariat (PTS) operates an Atmospheric Transport Modelling (ATM) system based on the Lagrangian Particle Dispersion Model FLEXPART. The air mass trajectory ideally provides a "link" between a radionuclide release and a detection confirmed by radionuclide measurements. This paper investigates the long-range transport of Xe-133 emissions under convective and non-convective conditions, with special emphasis on evaluating the changes in the simulated activity concentration values due to the inclusion of the convective transport in the ATM simulations. For that purpose a series of 14 day forward simulations, with and without convective transport, released daily in the period from 1 January 2011 to 30 June 2013, were analysed. The release point was at the ANSTO facility in Australia. The simulated activity concentrations for the period January 2011 to February 2012 were calculated using the daily emission values provided by the ANSTO facility; outside the aforementioned period, the median daily emission value was used. In the simulations the analysed meteorological input data provided by the European Centre for Medium-Range Weather Forecasts (ECMWF) were used with the spatial resolution of 0.5°. It was found that the long-range transport of Xe-133 emissions under convective conditions, where convection was included in the ATM simulation, led to a small decrease in the activity concentration, as compared to transport without convection. In special cases related to deep convection, the opposite effect was observed.

Introduction

To investigate the transport of xenon emissions, the Provisional Technical Secretariat (PTS) operates an Atmospheric Transport Modelling (ATM) system based on the Lagrangian Particle Dispersion Model FLEXPART.

The air mass trajectory ideally provides a “link” between a radionuclide release and a detection confirmed by radionuclide measurements.

In the operational simulations the convective transport is not included. The question arises whether including the convective transport in ATM simulations will change the results significantly.

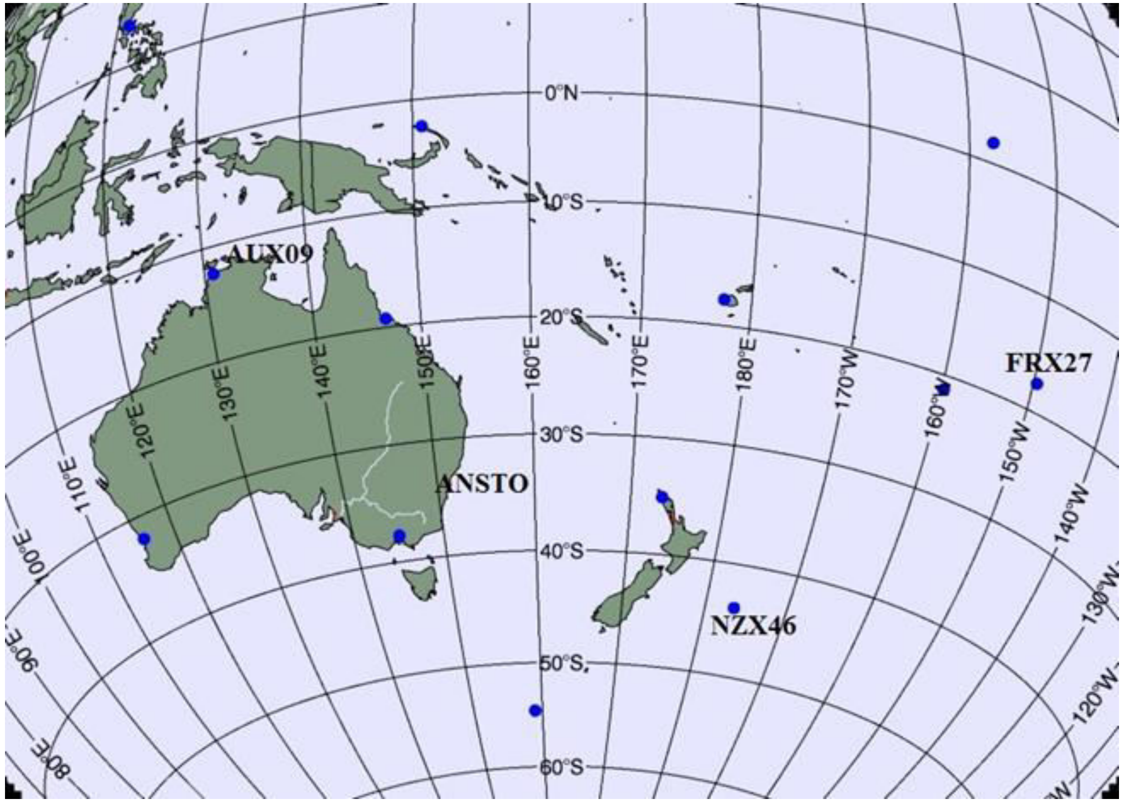
Modelling setup

To address this question a series of 14 day forward simulations, with and without convective transport, released daily in the period from 1 January 2011 to 30 June 2013, were analysed.

The hypothetical release point was at the ANSTO facility in Australia. For the period January 2011 to February 2012 the daily emission values provided by the ANSTO facility were used; outside the aforementioned period, the median daily emission value was used.

The analysed meteorological input data provided by the European Centre for Medium-Range Weather Forecasts (ECMWF) were used with the spatial resolution of 0.5.

The simulated activity concentrations were compared with the measurements at the neighbouring stations i.e. AUX09 (Darwin, Australia), FRX27 (Papeete, Tahiti) and NZX46 (Chatham Island).



Map showing the location of ANSTO facility as well as three IMS stations: AUX09 (Darwin, Australia), FRX27 (Papeete, Tahiti) and NZX46 (Chatham Island, New Zealand).

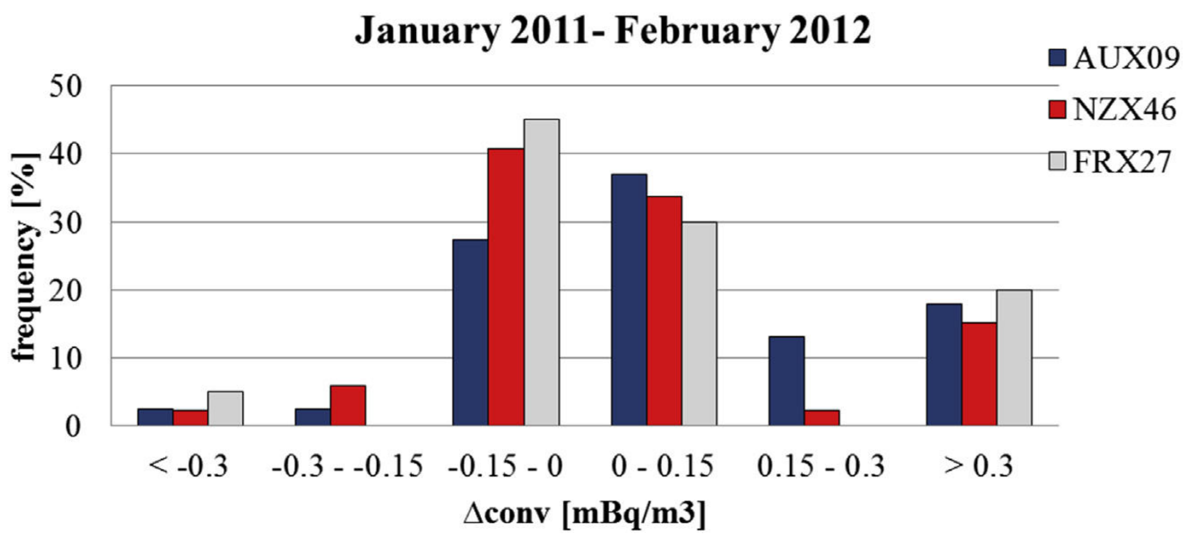
Convective transport in ATM simulations

To address the question of whether including the convective transport in ATM simulations will change the results significantly; the differences between the outputs with the convective transport turned off and turned on were computed:

$$\Delta conv = AC_N - AC_Y \ ,$$

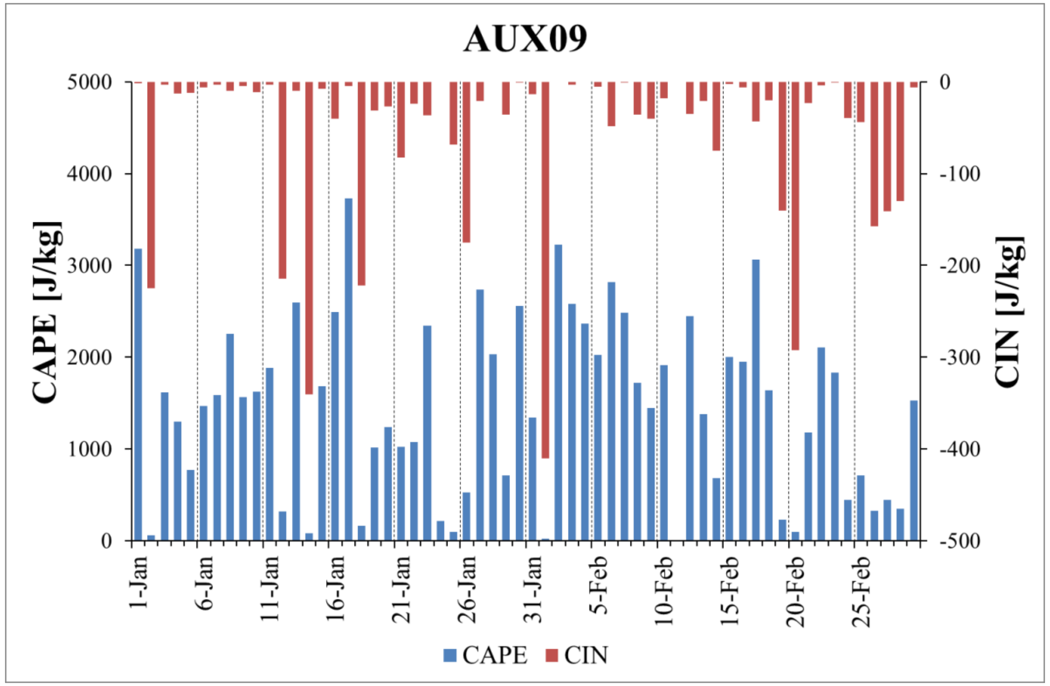
AC_N and AC_Y are the activity concentrations calculated with the convective transport turned off and turned on, respectively.

Frequency of occurrence of positive and negative values of Δconv for each station



Interpretation of the positive and negative values of Δconv

Period of study: 15 December 2011 to 29 February 2012
Reason: the high probability of atmospheric convection.



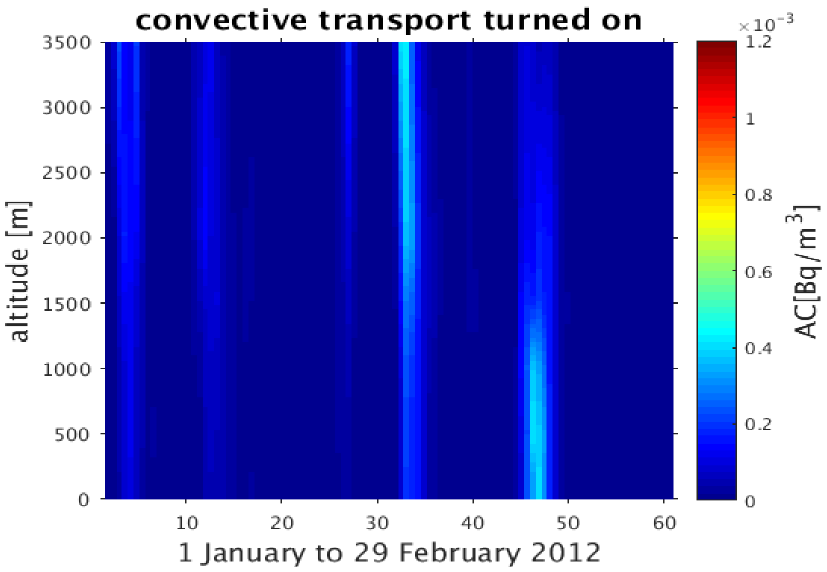
The operational 12-hourly soundings from the Darwin airport were available via http://weather.uwyo.edu/upperair/sounding.html

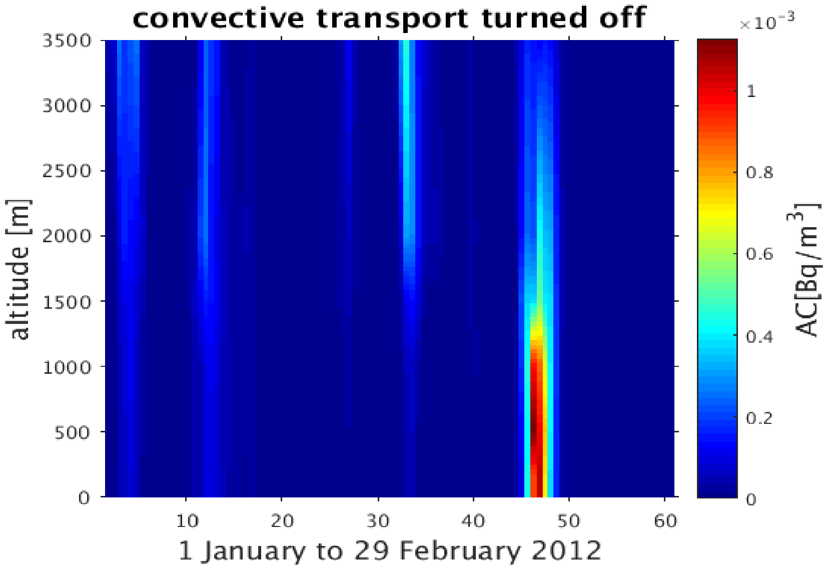
CAPE = Convective Available Potential Energy
CIN = Convective Inhibition

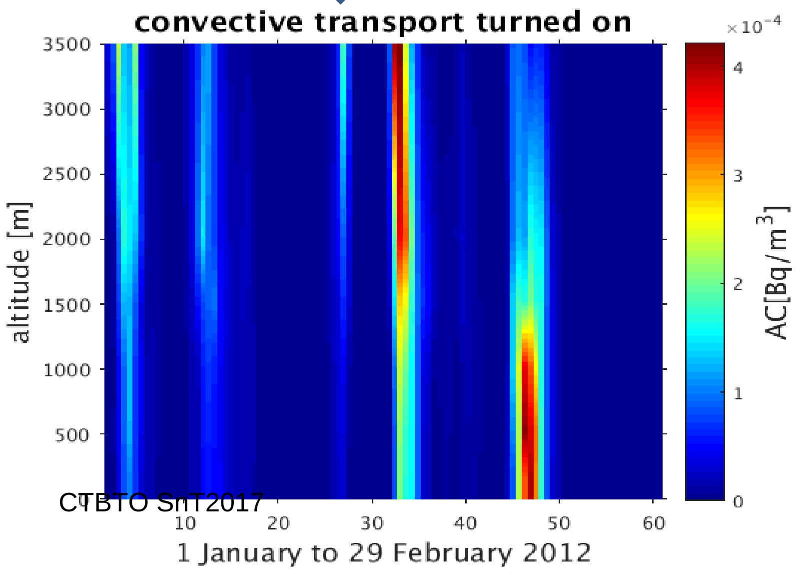
CAPE is the maximum energy available to an ascending parcel, and thus a good indicator of atmospheric instability.

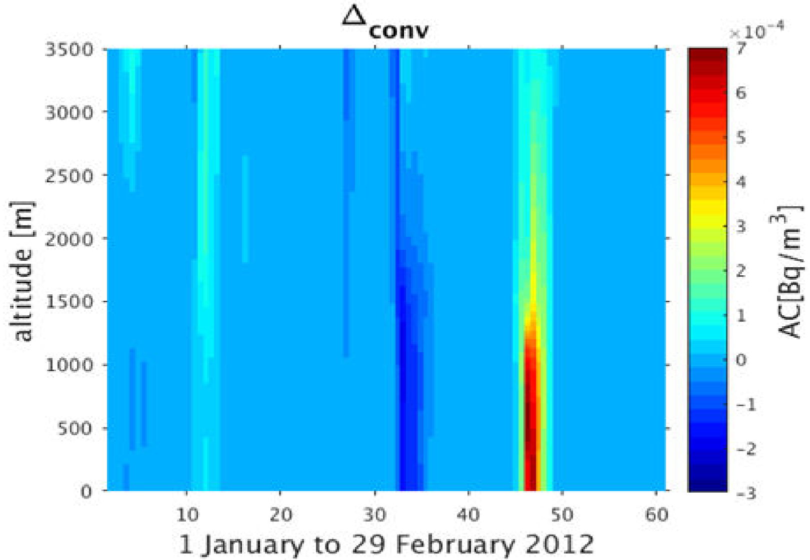
CIN is the amount of energy that will prevent an air parcel from rising from the surface to the level of free convection.

Interpretation of the positive and negative values of Δconv





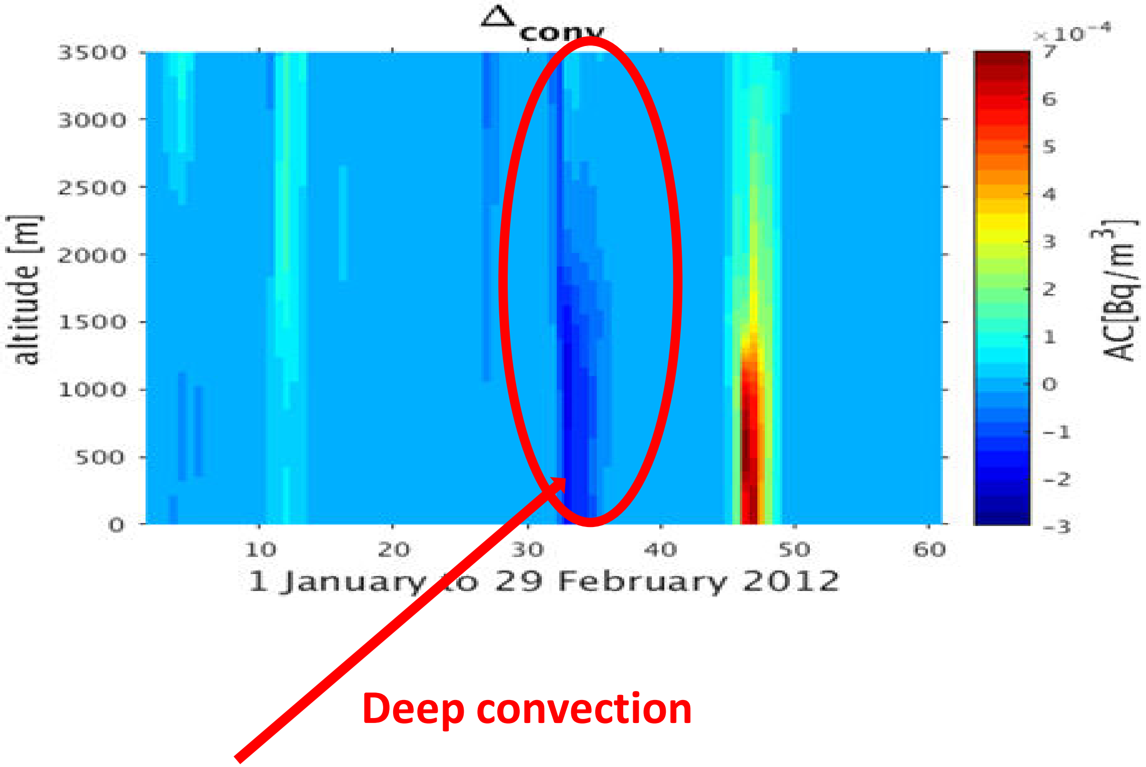


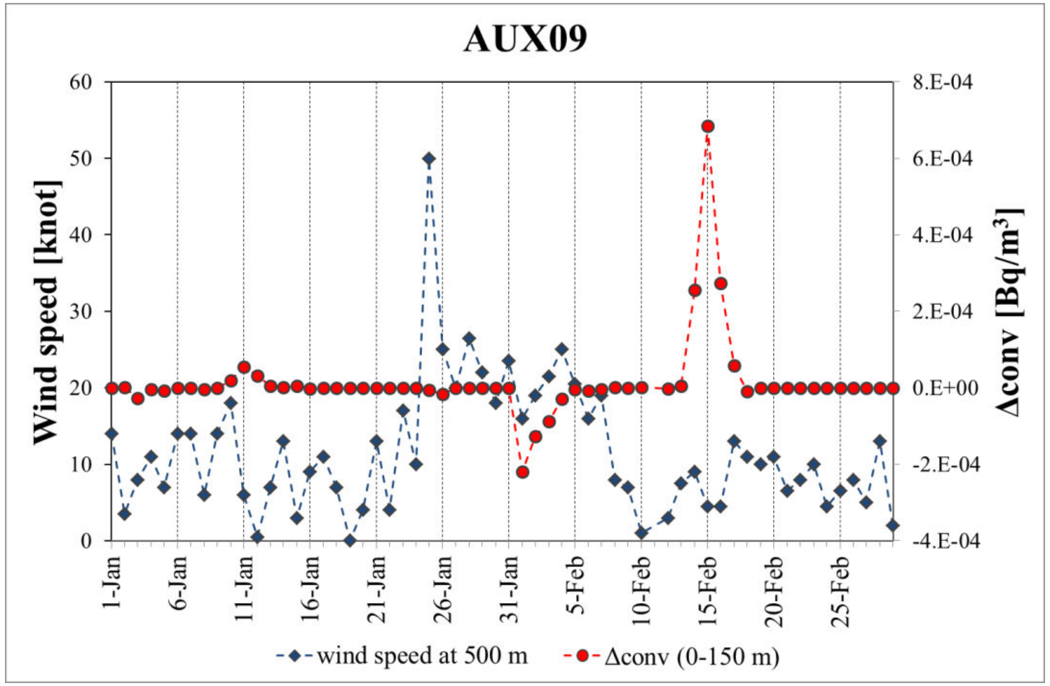


The following vertical layers were considered: 0-150, 150-500, 500-1000, 1000-1500, 1500-2000 and 2000-3500 m.

Each data point for a given layer represents 12 h collection time and is generated by summing over the individual contributions of the individual FLEXPART runs launched each day.

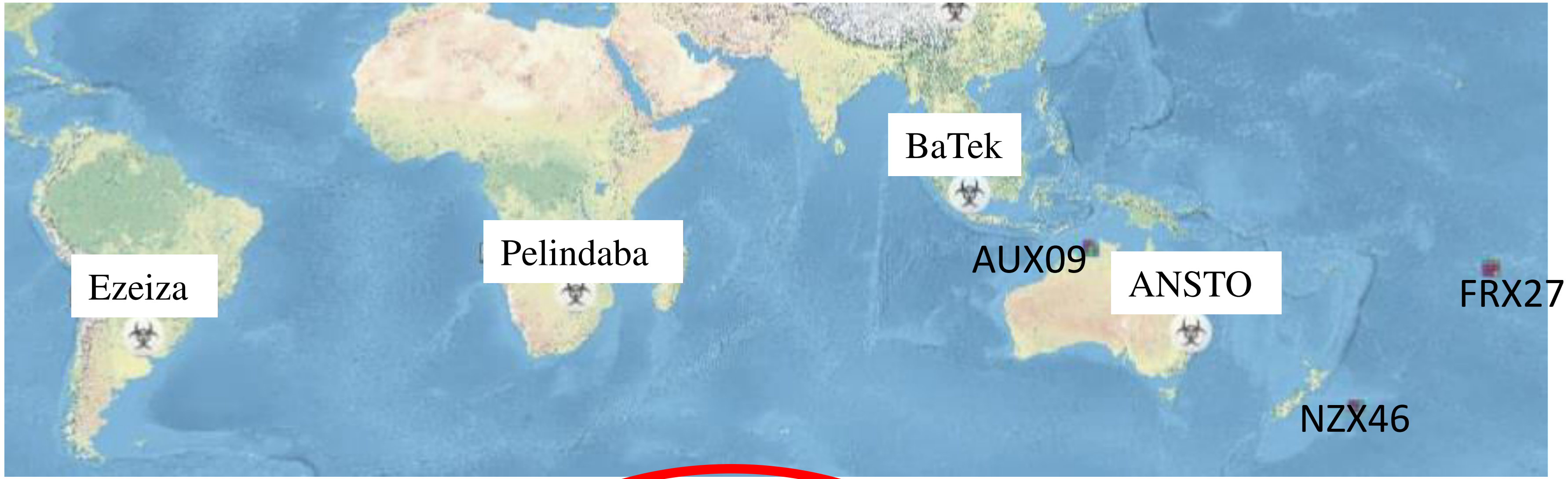
Interpretation of the positive and negative values of Δconv

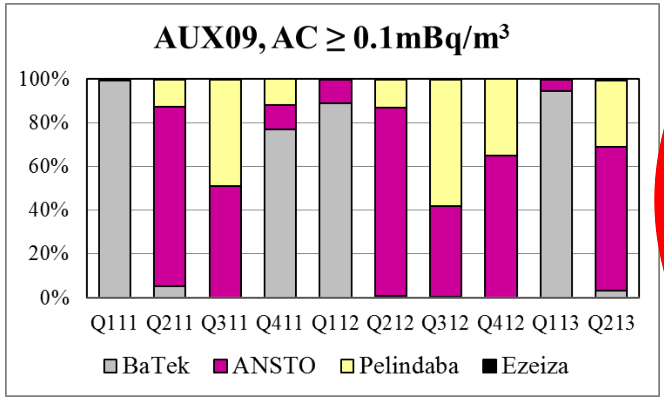


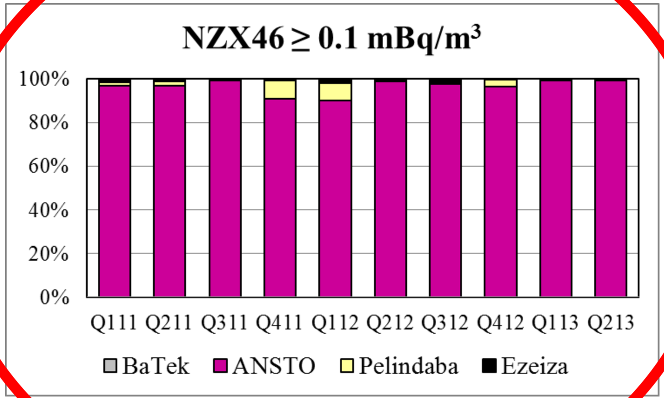


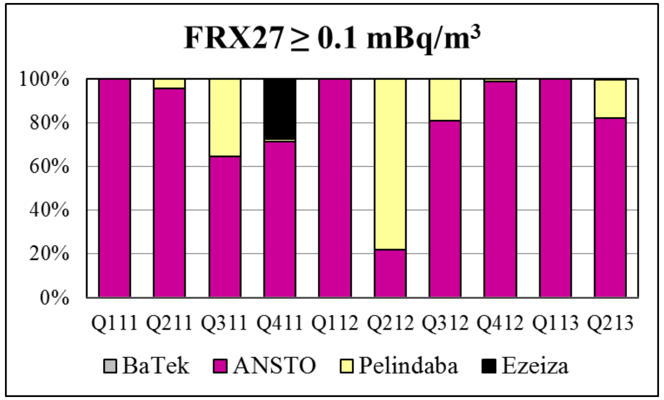
The archive meteorological reports published by the Australian Bureau of Meteorology revealed that between January 25 and February 2, the Tropical Cyclone Iggy moved over the country. The deep convection associated with Iggy could cause air masses to be well mixed at higher altitudes.

Seasonal contribution of Xe-133 emissions from individual sources as observed at IMS stations.









Almost exclusively influenced by ANSTO

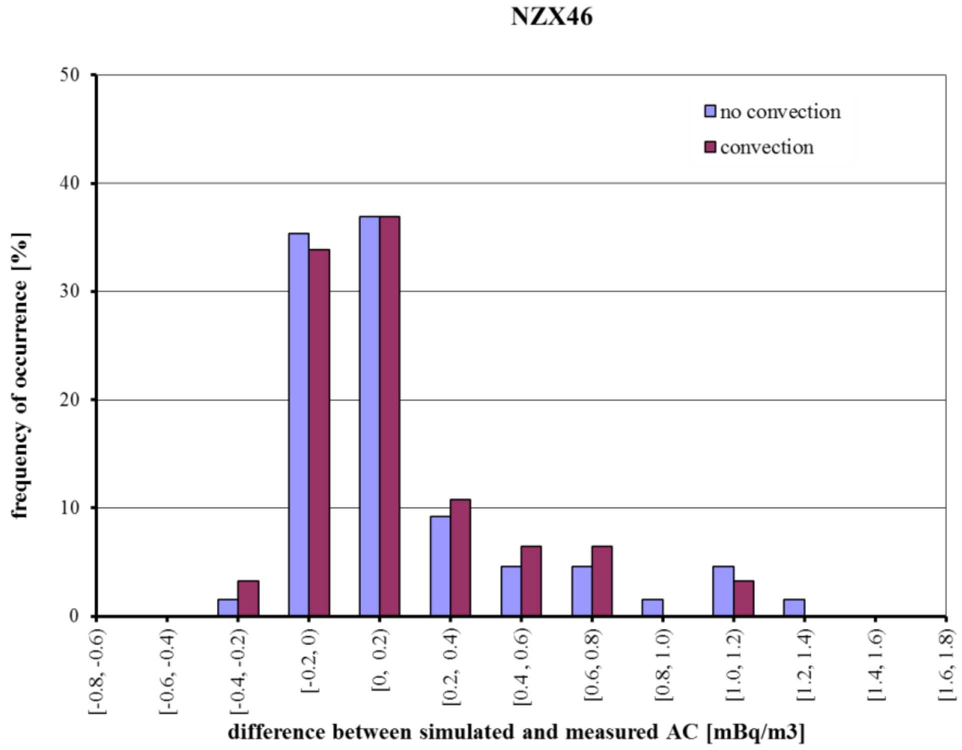
Validation

The unique opportunity of having access to both daily emission values for ANSTO as well as measured Xe-133 activity concentration (AC) values at the IMS stations, gave us a chance to validate our simulations.

Station NZX46 was selected.

A 95% confidence interval for the true mean difference , ε , between simulated and measured values was constructed.

The histogram on the right panel is generated by our data set consisting of 65 pairs of data points.



ε_1 =(0.08, 0.25) mBq/m^3 – for simulations without convective transport included

ε_2 =(0.06, 0.20) mBq/m^3 - for simulations with the convective transport included

The study presented in this section leads to the conclusion that the added value of inclusion the convective transport in the operational runs would be insignificant.

Conclusions (1)

Comparison of outputs with the convective transport turned off and turned on revealed that their difference Δconv can be positive or negative.

In case of atmospheric convection, the output generated with the convection transport turned on produced lower values near the surface, because it allows for dispersion of particles. Hence, Δconv can be positive.

In some situations when the plume is mainly aloft, convection may redistribute particles vertically, thus increasing the surface concentration. This may happen when the atmospheric conditions are associated with deep convection. Hence, Δconv can be negative.

Conclusions (2)

Based on the paired t-test, a 95% confidence interval for the true mean difference between simulations and measurements, being the indication of the uncertainty, was constructed.

In case of simulations with the convective transport turned off, the uncertainty was in the range between 0.08 and 0.25 mBq/m^3.

In case of simulations with the convective transport turned on, the uncertainty was in the range between 0.06 and 0.20 mBq/m^3.

The uncertainty can be attributed to uncertainties in the daily emission values, uncertainties related to the meteorological input and also to the imperfect modelling of atmospheric processes.

Conclusions (3)

The practical aspect of including the convective transport in the simulations is related to a significant increase in the processing time.

It is not evident that the accuracy of simulated activity concentration will be significantly improved by including the convective transport.

Therefore, it is recommended to run simulations with the convective transport rather for case studies, not for operational purpose.

THANK YOU