

# Limited Area 4D-Var over a North Atlantic and European Domain



M.A. Wlasak, S.P. Ballard, M.J. Cullen

## Introduction

The first operational implementation of four-dimensional data assimilation (4D-Var) has now been achieved at the Met Office over a global domain. In this poster we show that a limited-area version has now been developed for use in a Northern Atlantic European (NAE) domain.

## Met Office implementation

The 4D-Var limited-area code was built upon the already used 3D-Var limited area system. The majority of the work involved the development of the linearised model and adjoint used within 4D-Var, namely the Perturbation Forecast model (PF model).

We assume that the atmosphere outside and on the outer boundary is unchanged by the data assimilation and uses Davies nudging scheme at the beginning of every time-step between the outer and inner boundaries in the border of the domain. The border, outer and inner boundaries are defined in Figure 1.

The Davies scheme takes a weighted average of the PF increments with the assumed zero increments of the border. The weighting is such that zero increments exist on the outer boundary while on the inner boundary the PF increments are unchanged.

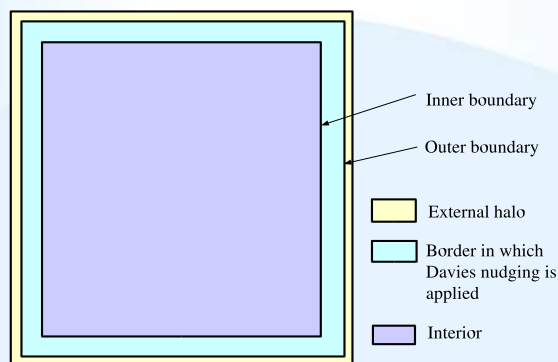


Figure 1: description of the limited area region showing the border in which the Davies nudging scheme is applied.

## Description of Linearisation Tests

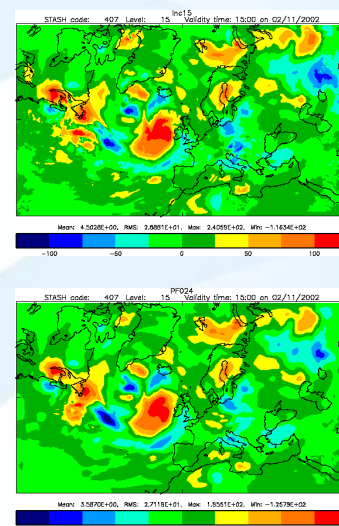
A way of testing the validity of the PF model is to compare its evolution to that of nonlinear increments that are given by the difference between two fully nonlinear Unified Model (UM) forecasts. We do not expect there to be an exact match between the two as the full forecast model is run at 20 km resolution while the data assimilation is run on a 40 km resolution grid. The full forecast has also a full armory of nonlinear physics while in this case the PF model is running with a simplified linearised microphysics scheme and boundary-layer scheme. There is also a limit to how a linearisation can approximate a nonlinear set of equations. Nevertheless, despite these caveats, this test gives a clear indication of the PF model's validity.

The generation of nonlinear increments is as follows: A full forecast is run for 15 hours. A 3D-Var analysis is found, valid 3 hours from the start, using the first 6 hours as the assimilation window. A second forecast is run for 12 hours starting at the analysis time. The analysis increment is added piecemeal over the first 6 hours of this second forecast. The difference of the forecasts, the nonlinear increments, are taken for the last 6 hours. The PF model then uses the first nonlinear increment as a starting point for the PF run.

## Visual comparison of nonlinear increments and PF increments

We present the nonlinear UM increment (above) and PF increment (below) for the pressure at level 15 (approximately 4500m above ground) after 6hrs (24 time-steps).

We see that the PF Model increment closely resembles the UM increment. The PF increment is smoother due to being generated from a model run at lower resolution with a limited physics package.



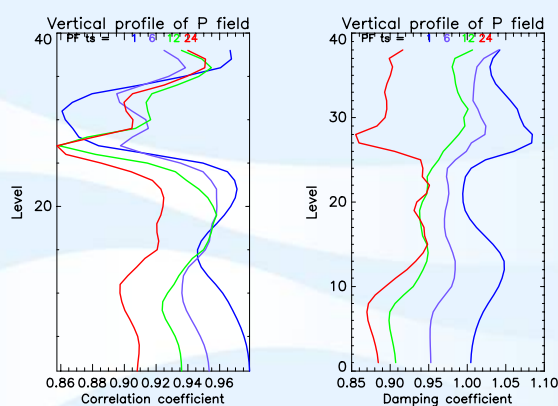
## Vertical profiles of statistics

We present vertical profiles for the pressure increment after: 15 minutes, 1.5 hours, 3 hours and 6 hours into the run. As statistical measures we use a correlation coefficient (left) and damping coefficient (right).

The correlation coefficient is defined in the standard way where the average values used are those for each model level.

The damping coefficient is defined as

$$\text{RMS}(\text{PF\_increment})/\text{RMS}(\text{UM increment}) \text{ at each model level.}$$



## State of Play and Future Work

- The limited area 4D-Var model has been run for 3 consecutive 6 hour cycles and a preliminary comparison has been made with 3D-Var over the NAE domain and has demonstrated its functionality. A longer trial is needed to show the benefits of 4D-Var over 3D-Var.
- The NAE model's domain has changed since these experiments were performed. It will cover a slightly reduced domain at a higher 12 km resolution with the edge of eastern America and some of Greenland not included. The data assimilation will be at 24 km resolution. It will replace the current 12 km limited-area model over the UK.
- There are plans to have an operational version of limited area 4D-Var with linearised physics by the end of 2005.