Use of a predictor-corrector scheme to couple the dynamics and physics in the IFS model.

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This work evaluates the performance of an interfacing of the dynamics and physics in the ECMWF model using a predictor-corrector scheme, Cullen (2001). All dynamics and physics terms (except the radiation) are evaluated twice each timestep. Since previous work reported in this publication it has been established that to get stable results it is necessary to use the same spatial interpolation of the physics in both the predictor and corrector steps. In order to get satisfactory performance within the semi-Lagrangian scheme it is necessary to do the interfacing as follows. Consider the simple equation

$$\frac{Du}{Dt} = F + P \qquad (1)$$

where F represents the dynamical source terms and P the physics. The corrector step can be represented as the average of two first-order estimates, one of which calculates $F + P$ at each point, and then advects the result, and the other advects values first and applies $F + P$ to the result. The predictor step use the same spatial scheme, but with all values at time t.

$$\begin{aligned} u^* &= u^t_d + \frac{1}{2}\delta t(F^t_d + P^t_d + F^t_a + P^t_a) \\ u^A &= (u^t + \delta t(F^t + P^t))_d \\ u^B &= u^t_d + \delta t(F^* + P^*)_a \\ u^{t+\delta t} &= \frac{1}{2}(u^A + u^B) \end{aligned} \qquad (2)$$

Suffices a, d refer to arrival and departure points for the semi-Lagrangian scheme. The equations for u^A, u^B are solved implicitly for the 'fast' parts of the calculation.

Use of this formulation avoids the use of partly updated values in the physical parametrisations, and is consistent with the single column formulation of the physics package. However, it requires the individual parts of the physics to be formulated consistently, with each scheme receiving a profile and a tendency as separate inputs. In the current ECMWF scheme the deep convection does not receive these inputs separately.

The two schemes were tested using 14 forecasts at T_L511L60 resolution run from experimental T511 analyses spread over 18 months between August 1998 and December 1999. The results are shown in Figure 1 . The effect of the predictor-corrector scheme is compared with that of halving the timestep in the operational scheme. The results show that the spread of differences is substantially greater than that given by halving the timestep, suggesting that the formulation changes to the physics allowed by the predictor-corrector scheme have a significant impact.

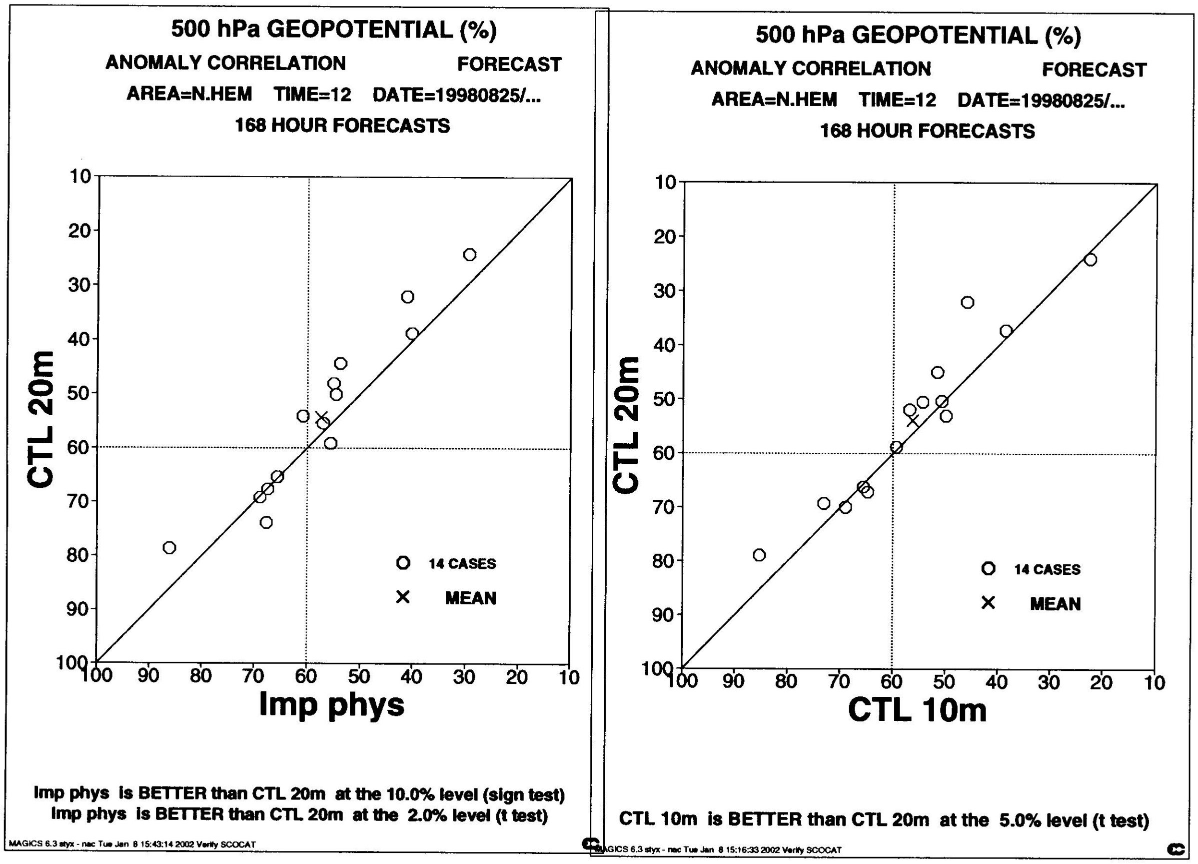

Figure 1 . Scatter plots of 7-day 500hpa geopotential forecasts for 14 cases. Left panel: Control against predictor-corrector (15m timestep) right panel: Control 10 minute timestep against 20 minute timestep

The predictor-corrector scheme reduces the tropical convective precipitation by 10%, which is almost exactly made up by an increase in large-scale precipitation. If the predictor-corrector scheme is iterated a second time, the convective precipitation falls by a further 10% and the total precipitation is decreased by 5%. This illustrates the need to use a formulation of the convection scheme which is consistent with the predictor-corrector scheme.

These results suggest that the predictor-corrector scheme may be a cost-effective way of improving model performance, especially allowing a more satisfactory implementation of the parametrisations. However, all the parametrisations need to be integrated in a consistent way in time. Predictor-corrector schemes may also be a good method for non-hydrostatic models, where the current ECMWF single-step scheme would be unstable.

Cullen,M.J.P. (2001) Alternative implementations of the semi-Lagrangian semi-implicit scheme in the ECMWF model. *Quart. J. Roy. Meteorol. Soc*, **12**, 2787-2802.