# Reply

ALAN J. THORPE

*NERC Centres for Atmospheric Science, Department of Meteorology, University of Reading, Reading, United Kingdom*

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Stoelinga (2003, hereafter S03), commenting on the paper ''The evolution and dynamical role of reduced upper-tropospheric potential vorticity in Intensive Observing Period One of FASTEX'' by Pomroy and Thorpe (2000, hereafter PT00), remarks that PT00 did not ''reconcile'' their results with those of previous studies, by Stoelinga and coauthors, on the so-called indirect effect of potential vorticity (PV) modification by diabatic processes. S03 also calls into question the ''general applicability'' of the results of PT00 in applying to cyclones other than the one PT00 studied, namely, Intensive Observing Period One (IOP1) of the Fronts and Atlantic Storm-Track Experiment (FASTEX). In this reply we will argue that the indirect effect is of interest, particularly of academic interest, but that in any case PT00 considered the different problem of the response of cyclone evolution to the presence, or absence, of a PV anomaly in the initial conditions of cyclone forecasts. Furthermore, we will argue that while the FASTEX IOP1 cyclone may or may not be typical, neither S03 nor all previous studies are able to address this, as they do not carry out representative climatological surveys.

In summary, PT00 identified particular PV anomalies present in operational model analyses, calculated the winds and potential temperature directly attributable to particular PV anomalies, and made parallel forecast runs of the operational model in which the initial conditions either did or did not include the reduced upper-level PV anomaly. S03 states correctly that PT00 did not attempt to quantify the indirect effect of diabatic forcing on the PV distribution. Papers on the indirect effect, such as Davis et al. (1993, hereafter DSK) and Stoelinga (1996, hereafter S96) (both referred to in PT00), develop the idea that by running numerical simulations with and without diabatic processes one might be able to distinguish between what they call the direct and indirect effects of PV anomalies. While so defined the indirect effect is of academic interest; it does, however, rely on comparison with a hypothetical, and unrealizable, circumstance in which latent heating is eliminated (by, in effect, setting the latent heat of vaporization to zero). Such a physical realization cannot happen in nature. In contrast, PT00's rerun forecasts are consistent with the physics of the atmosphere, and they examine sensitivity to perfectly plausible perturbations to the initial conditions of cyclone forecasts.

PT00 consider issues concerned with the role of PV anomalies, so their study is related to these previous studies but differs in some essential ways also. PT00 utilized an operational analysis and rerun forecasts of IOP1 from FASTEX. They also performed rerun forecasts in which the subsequent time-integrated effect of the given anomaly was quantified by comparison of a model rerun with and without the given anomaly being present in the initial conditions. This quantification involves the total impact of the presence of that PV anomaly in the initial conditions, over the forecast period (say, 18 h). This is different than the withholding of a physical process such as carried out in S96 and in DSK. It is evident that the approach taken by PT00 is different than that of S96 and DSK, and it brings out complementary facets of the problem.

The issue of how representative the case used by PT00 might be is raised by S03. PT00 did not aspire to carry out a climatological study. This would be of interest of course. Previous studies, referred to by S03 and PT00, have also looked at particular cases, but those are, one could argue, at the extreme end of the spectrum. There is value in examining ''ordinary'' as well as extreme cases to develop an appreciation of the variety of behavior in nature. None of the published studies can claim to be representative. The choice of cases is always contentious in the sense that they may not be chosen at random but rather to prove a particular hypothesis (and thus are far from representative). The IOP1 case from FASTEX was chosen by PT00 because it has FASTEX verification observations fortuitously in the correct location to directly examine the reduced upper-tropo-

*Corresponding author address:* Dr. Alan J. Thorpe, NERC Centres for Atmospheric Science, Dept. of Meteorology, University of Reading, Earley Gate, P.O. Box 243, Reading RG6 6BB, United Kingdom. E-mail: a.j.thorpe@reading.ac.uk

spheric PV region. These observations provide corroborating evidence, perhaps for the first time, of the existence in nature of regions with substantial-amplitude reduced upper-level PV anomalies.

S03 discusses the so-called steady-state model of diabatic PV modifications. This is at one end of a range of behavior. One can argue that most cyclones are not in a steady state, as their growth phase is almost immediately followed by a decay phase. Also, the time taken for parcels of air to transit a typical extratropical cyclone is likely to be a significant proportion of the total lifetime of the cyclone. One also needs to remember that the mass-weighted volume integral of PV is constant while interior diabatic processes are occurring. This means that, in this sense, there must be (somewhere) as much negative as positive anomaly. PT00 show that the advection of reduced upper-level PV anomalies can significantly affect neighboring synoptic structures that over time can affect synoptic evolution, including that of the cyclone from which they emanated.

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