1. Introduction

Piecewise potential vorticity inversion (PPVI), applied to Ertel’s potential vorticity (PV), was first introduced about 20 years ago (Davis and Emanuel 1991; Davis 1992) and has become an important tool in diagnosing midlatitude synoptic-scale weather developments (e.g., Stoelinga 1996; Plant et al. 2003; McInnes et al. 2009). It has also been used in studies of tropical cyclones (Wu and Emanuel 1995a,b; Kieu and Zhang 2010) and polar lows (Bracegirdle and Gray 2009; Føre et al. 2011). A few years ago, PPVI came under criticism by Egger (2008, hereafter E2008), who, based on a few examples from quasigeostrophic theory, questioned its usefulness as a diagnostic tool. In Røsting and Kristjánsson (2012, hereafter RK12) we argued that the methodology used by E2008 is incomplete, giving a wrong impression of the usefulness of PPVI. We further presented two additional cases—one idealized, the other from a real weather situation—to clarify how PPVI works, not only in the context of quasi-geostrophy but also in the more general Ertel's nonlinear PV. In all three examples given by E2008, the conclusion was given that PPVI is useless as far as the causal relation between PV anomalies and the inverted circulation anomalies. On the other hand, we agree with E2012 that in RK12 the following sentence was ambiguously worded: “In E2008, in connection with Fig. 1, it was stated that PPVI claims that the resulting winds in region D2 are induced by the positive PV anomaly Z1 in region D1” (p. 936).

2. Citations of E2008 in RK12

E2012 claims that in RK12 we assign him an incorrect and too negative view of PPVI (e.g., “PPVI is useless for understanding the dynamics of the flow” in the abstract of RK12). We sincerely regret that Egger feels that we ascribe to him conclusions that he does not advocate. However, as the following exact quotes from E2008 indicate, our comment was not entirely unjustified. First, in the section of Rossby waves in zonal mean flow, one finds the quote “It is obvious that the result of PPVI is useless as far as the dynamics of the Rossby wave (2.1) are concerned” (section 2a, p. 2019). Second, in the section of confined PV anomalies, it is stated that “the result of PPVI is fairly useless in this case” (section 2b, p. 2020). Third, in the section on baroclinic waves in zonal shear flow one finds “The results of PPVI are obviously not helpful” (section 2c, p. 2022). Hence, in all three examples given by E2008, the conclusion was given that PPVI is more or less useless in terms of the causal relation between PV anomalies and the inverted circulation anomalies. On the other hand, we agree with E2012 that in RK12 the following sentence was ambiguously worded: “In E2008, in connection with Fig. 1, it was stated that PPVI claims that the resulting winds in region D2 are induced by the positive PV anomaly Z1 in region D1” (p. 936).

3. PPVI in E2008

We have claimed that the contributions obtained through PPVI from all PV (and boundary θ) anomalies have to add up to the observed fields. Although this may sound trivial, this requirement is necessary if PPVI is to have any meaning.
Individual wind fields obtained through PPVI may, for instance, in some regions add up to a strengthened wind field and explain observed dynamical features of the flow, while cancellation may take place in other regions, also in agreement with observations. This certainly means that more than one PV anomaly is required for describing the flow in the region of cancellation. For instance, the winds associated with two neighboring positive PV anomalies tend to cancel in the region between them. However, the cancellation between the wind fields associated with, for example, two PV anomalies does not imply that the individual PV anomalies are useless in describing the flow.

To illustrate this we may by analogy refer to the quasigeostrophic omega equation. During strong cyclogenesis the forcing terms (i.e., differential vorticity advection with height and the spatial distribution of temperature advection) tend to be spatially separated, yielding strong vertical velocity fields. In other cases (e.g., upper-level vorticity advection overrunning lower-level cold advection) there tends to be a cancellation between the forcing terms. Clearly, the tendency for cancellation does not imply that the individual forcing terms fail to provide physical insight into the dynamics of the flow.

4. Concluding remarks

We maintain that based on the examples in E2008 and the reasoning presented in RK12 and above, one cannot conclude that PPVI is useless or of little value for understanding dynamical developments in the atmosphere. As stated in E2008 (section 3), the fields obtained through PPVI are never observed, and we certainly agree on this. On the other hand, several case studies (e.g., Thorsteinsson et al. 1999; Bracegirdle and Gray 2009; Nordeng and Røsting 2011) have demonstrated that PPVI is conceptually meaningful as they show individual flow structures that provide valuable insight into the observed dynamical developments. There are limitations with PPVI; for example, the interaction between PV anomalies is uncertain when the distance between the PV anomalies is large, and when the PV anomaly is very large compared to the entire PV perturbation field (Davis 1992; Birkett and Thorpe 1997). Such limitations call for some care when PV anomalies are selected, in agreement with some of the conclusions in E2008.

REFERENCES


