3.2 A NEW LOOK AT ANTICYCLOGENESIS

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1. INTRODUCTION

Textbooks (e.g. Bluestein 1992) attribute the formation or intensification of a sea-level anticyclone to anticyclonic vorticity advection over the incipient anticyclone center. However, from interpretation of the quasigeostophic omega equation, anticyclonic vorticity advection will be associated with sinking motion and attendant adiabatic warming which, hydrostatically, would lower sea-level pressure and weaken the anticyclone. The purpose of the present contribution is to attempt to resolve this paradox through the development and application of a new conceptual model for sea-level anticyclogenesis.

2. CONCEPTUAL MODEL

A diagnostic equation for the geopotential height tendency, $\partial z_b/\partial t$, near the earth's surface may be obtained by differentiating the hypsometric equation and combining it with the thermodynamic energy equation to get:

$$(1)\quad \partial z_b/\partial t = \partial z_t/\partial t - (R_d/g)\int_{P_t}^{P_b} [\,(1/C_p)\, dH/dt - \mathbf{V_H}\cdot\nabla_p T + \omega\sigma/R_d\,]\, dP/P,$$

where z_t is the height of some pressure level P_t far above the near-surface pressure P_b. The other symbols have standard meteorological meanings (e.g. Bluestein 1992). Equation (1) is not strictly diagnostic since the time derivative of the upper boundary geopotential height appears on the right-hand side. Hirschberg and Fritsch (1991) have derived a similar equation and applied it to the problem of understanding near-surface cyclogenesis which they attribute, in one case, to vertically integrated (and mostly upper tropospheric) warm-air advection. By eq. (1), lower boundary geopotential height rises accompanying, for example, near-surface anticyclogenesis, would be forced by vertically integrated diabatic cooling ($dH/dt < 0$), cold-air advection ($\mathbf{V_H}\cdot\nabla_p T > 0$), and adiabatic cooling attending ascent ($\omega < 0$) in a stable environment ($\sigma > 0$). Since lower tropospheric anticyclones are usually characterized by subsiding air aloft, then the resulting adiabatic warming would oppose the near-surface geopotential height rises. Note that vorticity advection does not directly appear in eq. (1), although it enters it indirectly through the quasigeostrophic forcing of vertical motion. Ironically, anticyclonic vorticity advection, which is associated with descent and therefore adiabatic warming, would oppose anticyclone intensification by the interpretation of eq. (1). Thus, anticylonic vorticity advection aloft may accompany lower tropospheric anticyclogenesis but not cause it, according to eq. (1).

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3. APPLICATION OF MODEL

Case studies (Boyle and Bosart 1983, Tan and Curry 1993, King et al. 1995) suggest that upper tropospheric cold-air advection may force lower tropospheric vorticity and geopotential height tendencies during anticyclogenesis near the earth's surface. It is therefore hypothesized that vertically averaged cold-air advection would be the most important forcing mechanism for near-surface anticyclogenesis. Since temperature advection is typically small in the lower and middle troposphere over anticyclone centers, then the vertically averaged cold-air advection would be largely due to that in the upper troposphere.

In a preliminary test of this idea, the 1000-mb height tendencies following an intensifying near-surface anticyclone in the cold-air outbreak case studied by Colucci et al. (1999) were diagnosed with eq. (1), using their quasi-Lagrangian version of the thermodynamic energy equation to account for the motion of the system. Results of this diagnosis (Table 1) revealed that cold-air advection averaged over the 1000-100 mb layer contributed most importantly to the anticyclone intensification. Adiabatic warming accompanying descent, calculated quasigeostrophically, opposed this effect but did not overwhelm it. The contribution from diabatic warming, calculated as a residual among the other terms in eq. (1), was relatively small, consistent with earlier results (Tan and Curry 1993).

The model will ba applied to other cases, in different regions and seasons, to determine if the above results are typical of anticyclones or if they are just specific to the case studied.

4. REFERENCES

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Table 1: 1000-mb height change (meters) averaged over 10 X 10-degree latitude-longitude grids centered on an intensifying anticyclone and averaged over two periods: 0000 UTC 1/18/85 - 0000 UTC 1/19/85 (Per. 1) and 0000 UTC 1/19/85 - 0000 UTC 1/20/85 (Per. 2). Shown are the analyzed change (Anal. Change), the upper boundary contribution (Upper Bound.), advective change (Adv. Change), the Quasi-Lagrangian contribution (Quasi-Lagr.), adiabatic change (Adiab. Change) and the residual (Res.).

Per..	Anal. Change	Upper Bound.	Adv. Change	Quasi-Lagr.	Adiab. Change	Res.
1	+14.5	+60.5	+122.6	-113.8	-52.8	-1.9
2	+14.3	+26.7	+140.8	-31.9	-61.3	-60.0