Example of the "Vorticity Advection" Pitfall

NOGAPS 60 h Forecast for 500 mb Heights and Absolute Vorticity

The 500 mb chart with absolute vorticity overlain is the first chart most operational meteorologists look at to assess the "dynamics" of a weather pattern. "Dynamics" here means the mid-tropospheric vertical motion linked to divergence patterns aloft which would encourage cloud development and surface pressure falls.

The 500 mb/Ab vort chart is used to pinpoint where vorticity advection is occurring in the mid-troposphere.

The case at left would indicate "negative" or "anticyclonic" vorticity advection and sinking motion over most of northern California and slightly offshore.

The trouble arises when "vorticity advection" is used as a synonym for "dynamics." In many situations, it may work out that way, but only because the other contribution to "dynamics," the thermal advection term, is very small.

The parent equations that can be used to understand this are all variations of the same theme. They are the Sutcliffe-Petterssen Development Equation, the Quasigeostrophic Omega Equation and the Quasigeostrophic Height Tendency Equation. Each of these equations has two terms to the right of the equal sign, the first having to do with vorticity advection and the second having to do with thermal advection. Why is it that the second term is generally neglected from the operational conception of "dynamics"?

In the case above, forecasters applying the rule of thumb "dynamics" = "vorticity advection" would find themselves misforecasting the implications of the pattern.
The same chart is shown at left above. Above right is the NOGAPs 60 h forecast of 1000-500 mb thickness (dashed), surface isobars and 700 mb vertical velocities (red or pink is upward motion). Notice that 700 mb upward vertical motion is forecast over northern and north central California, with a bullseye also just off the Oregon-northern California border.

Why does the model forecast such strong upward motion in a region of negative vorticity advection? Some of the pattern is undoubtedly related to model topography (orographic effects), but not the portion extending off the north-central California coastline and certainly not the strong maximum in upwards motion just west of the northern California coast out over open ocean.

Should the forecaster ignore the output vertical motion field and mentally remark "...model is out to lunch. Forecasts strong upward motion max with no favorable dynamics..."?

Not a trivial decision to make. Here is the model output precipitation forecast for the same verification time. Disbelieving the vertical motion field will mean disbelieving the forecast precipitation rate (64 mm/day or 32 mm/12h ending 12 UTC Monday 12 Jan).

In reality most of the expected precipitation is forecast to occur in the region where the surface pressure /1000-500 mb thickness pattern in the last graphic suggests (qualitatively) strong warm advection.¹

Each of the three equations mentioned above has a term proportional to the thermal

¹There is also a warm front aligned parallel to the coast that will contribute to a mesoscale region of
advection. In the case of the quasigeostrophic omega equation, "warm advection" is associated with synoptic-scale lift (not the same thing as warm frontal lifting) at the level where the advection is occurring. Since most of the temperature advection usually occurs in the lowest 10000 feet in West coast patterns such as the one shown here, that is where most of the thermal advection forcing for upwards motion is found. This is coincidentally where most of the moisture available for cloud formation is found too.

lift often called "overrunning" by forecasters; this could not account for the large, extensive region of heavy precipitation, just as orographies cannot be used to account for the heavy precipitation offshore. However, this is not a synoptic scale effect--such mesoscale effects are not included in the equations above that the forecasters are implicitly using when assessing "dynamics". Even so, both the frontal lifting and the orographic lifting are occurring in a region of negative vorticity advection. Forecasters who do not look beyond that rule of thumb would not have considered even important mesoscale effects.

---

More on the Quasigeostrophic Omega Equation's Look at the 12 UTC Pattern Monday 12 January

**Poor Man's Qualitative Quasigeostrophic Omega Equation:**

<table>
<thead>
<tr>
<th>Upwards Motion (Dynamics)</th>
<th>Proportional To</th>
<th>Positive Vorticity Advection Increasing With Height¹</th>
<th>and/or</th>
<th>Warm Temperature Advection</th>
</tr>
</thead>
</table>

(Note: there are constants multiplying each term so the equation above cannot be used quantitatively)

Applied at a given level, say, 850 mb, one would look at BOTH the way the vorticity advection is changing with height through the layer centered at 850 mb, (1000-700 mb), for example, AND whether warm or cold advection was occurring at the given level. The assumption is often made that the vorticity advection at the ground is zero, in which case vorticity advection at 700 or 500 mb can be used to assess the first term. Since 1000-500 mb thickness is proportional to the mean temperature of the layer, then an overlay of 850 mb winds and 1000-500 mb thickness can be used to qualitatively determine the second term.

¹Also true for negative vorticity advection decreasing with height. Thus, an area of negative vorticity advection at 500 mb can be actually "forcing" upward motion if there is stronger negative vorticity advection below.
This shows the vorticity advection at the 1000 mb level and the 700 mb level. We really should be using absolute geostrophic vorticity, but this gets the point across. Note that vorticity advection becomes more negative with height just off the California coastline.

This substantiates the forecaster's impression from the NOGAPS 60h forecast of the vorticity pattern off the coast. The "dynamics" look unfavorable so far.
The chart at upper right shows the temperature advection at 850 mb. The circled area is a qualitative approximation of the region of strongest warm advection at 850 mb.

At upper left is the vertical velocity forecast by the ETA model at 12UTC Monday. It does generally correspond to the area of warm advection, although frontal effects (warm front) and orographic effects are also contributing.

No matter, apparently the vertical motion field is being "forced" by a number of effects, not the least of which is warm advection, that are "overwhelming" the downward forcing from the vorticity advection.

The point here is that blind faith that negative vorticity advection completely accounts for the "dynamics "of this pattern is erroneous.

**Combining The Two Terms--Vorticity Advection By The Thermal Wind**