<u>Quasi-Geostrophic Height Tendency Equation Quick Reference</u>

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Four forcing terms comprise the quasi-geostrophic height tendency equation. Note that in this framework, these represent the <u>**only**</u> processes that can locally change the geopotential height on an isobaric surface. If an attribute of the atmosphere is not present within one or more of these forcing terms, it <u>**cannot**</u> result in a non-zero height tendency.

The four forcing terms to the quasi-geostrophic height tendency equation are:

- **Geostrophic Advection of Geostrophic Absolute Vorticity**
  - <u>Height Falls</u>: Cyclonic geostrophic absolute vorticity advection on the isobaric surface on which the height tendency equation is applied.
  - <u>Height Rises</u>: Anticyclonic geostrophic absolute vorticity advection on the isobaric surface on which the height tendency equation is applied.
  - *This term primarily <u>only</u> impacts the <u>movement</u> of a trough or ridge!* While there are some situations that can result in this term impacting the amplitude of a trough or ridge, such effects are generally minor at best.
- **Differential Geostrophic Advection of (Potential) Temperature**
  - <u>Height Falls</u>: Cold air advection that decreases with height –or– warm air advection that increases with height.
  - <u>Height Rises</u>: Warm air advection that decreases with height –or– cold air advection that increases with height.
  - *This term impacts both the amplitude <u>and</u> movement of a trough or ridge!* When differential advection is found in the *base* of a trough or *apex* of a ridge, it can influence amplitude. When differential advection is found upstream and downstream of a trough and ridge, it can influence motion. It can do both at once.
  - This term can be evaluated utilizing analyses of winds and temperature on two isobaric surfaces – one above and one below the surface on which the height tendency equation is applied – or using thermal wind principles over layers above and below the surface on which the height tendency equation is applied.
- **Friction**
  - <u>Height Falls</u>: Anticyclonic geostrophic relative vorticity on the isobaric surface on which the height tendency equation is applied.
  - <u>Height Rises</u>: Cyclonic geostrophic relative vorticity on the isobaric surface on which the height tendency equation is applied.
  - *This term is non-zero only at and near the ground, which is generally below the isobaric surfaces on which we consider height tendency!*
- **Differential Diabatic Heating**
  - <u>Height Falls</u>: Diabatic cooling that decreases with height –or– diabatic warming that increases with height.
  - <u>Height Rises</u>: Diabatic warming that decreases with height –or– diabatic cooling that increases with height.
  - Since we do not directly analyze diabatic heating, we must make use of our knowledge of atmospheric physics to determine how we can assess this term. Both sensible and latent heating can contribute, including influences from such phenomena as snow cover, land/sea contrasts, cloudy/clear sky contrasts, water substance phase changes (both warming and cooling).
  - *This term can exert a small impact both the amplitude and movement of a trough or ridge!*

<u>**Quasi-Geostrophic Omega Equation Quick Reference**</u>

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Four forcing terms comprise the quasi-geostrophic omega equation. Note that in this framework, these represent the <u>**only**</u> processes that can result in vertical motion on an isobaric surface. If an attribute of the atmosphere is not present within one or more of these forcing terms, it <u>**cannot**</u> result in non-zero vertical motion. Further, note that the omega equation is typically applied *only* in the **middle troposphere**, where vertical motions are typically largest.

The four forcing terms to the quasi-geostrophic omega equation are:

- **Differential Geostrophic Advection of Geostrophic Absolute Vorticity**
  - <u>Rising Motion</u>: Cyclonic vorticity advection that increases with height –or– anticyclonic vorticity advection that decreases with height.
  - <u>Sinking Motion</u>: Anticyclonic vorticity advection that increases with height –or– cyclonic vorticity advection that decreases with height.
- **Geostrophic Advection of (Potential) Temperature**
  - <u>Rising Motion</u>: Warm air advection on the isobaric surface on which the omega equation is applied.
  - <u>Sinking Motion</u>: Cold air advection on the isobaric surface on which the omega equation is applied.
  - This term can be evaluated using an analysis of winds and temperature on the isobaric surface on which the omega equation is applied. It can also be evaluated in light of thermal wind principles, in consideration of how the wind changes with height between two isobaric surfaces on either side of the one on which the omega equation is applied.
- **Differential Friction**
  - <u>Rising Motion</u>: Lower tropospheric cyclonic geostrophic relative vorticity (Ekman pumping).
  - <u>Sinking Motion</u>: Lower tropospheric anticyclonic geostrophic relative vorticity (Ekman suction).
  - *Generally speaking*, this term is negligible since we primarily apply the omega equation in the middle troposphere, above the isobaric levels at which friction is non-zero.
- **Diabatic Heating**
  - <u>Rising Motion</u>: Diabatic warming on the isobaric surface on which the omega equation is applied.
  - <u>Sinking Motion</u>: Diabatic cooling on the isobaric surface on which the omega equation is applied.
  - As with the quasi-geostrophic height tendency equation, since we do not directly analyze diabatic heating, we must make use of our knowledge of atmospheric physics to determine how we can assess this term.
  - As we typically apply the omega equation in the middle troposphere, *only latent heat release associated with phase changes of water contributes meaningfully to this term*.