



DFG – CRC 1114

QG-DL: Dynamics of a Diabatic Layer in the Quasi-Geostrophic framework

JAS, submitted; arxiv:2104.10598

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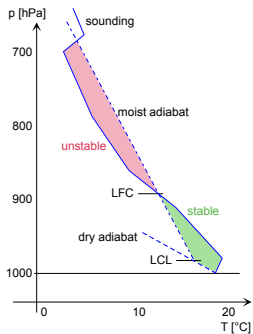


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QG-DL: Dynamics of a Diabatic Layer in the QG framework



adapted and translated from
<https://www.wetterdienst.de>

Authors:

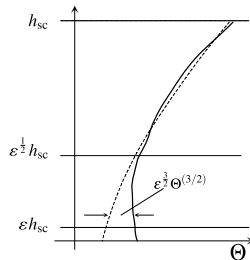
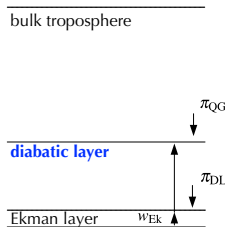
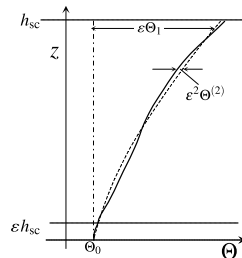
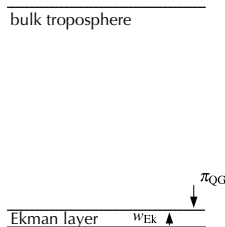
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QG theory ...

- requires small deviations from stable stratification
- misses strong diabatic effects at lower altitudes

QG-DL theory ...

- provides a remedy
- via a **diabatic layer** in
- triple-deck asymptotics



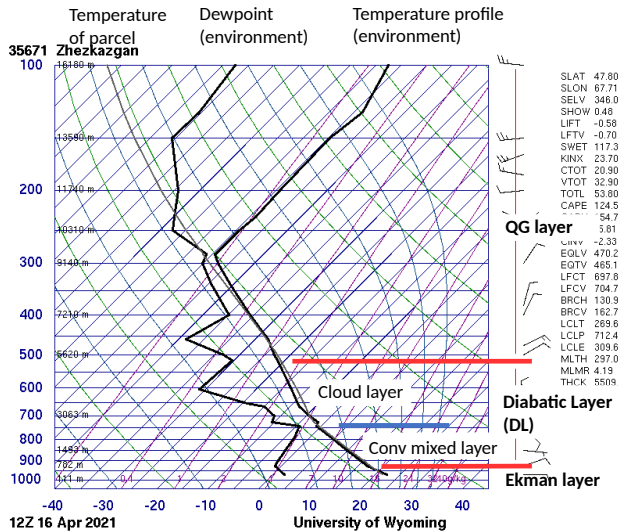


QG-DL: Dynamics of a Diabatic Layer in the QG framework

Moist and diabatic processes in the lower 2-4 km can strongly affect the mean stratification

- ▷ in the course of a day and
- ▷ on synoptic scales.

This is the scaling regime of QG theory.
Yet ...



Source: University of Wyoming <http://weather.uwyo.edu/upperair/sounding.html> (last access: 19-Apr-2021)



QG-DL: Dynamics of a Diabatic Layer in the QG framework

QG-Ekman – dominant balances

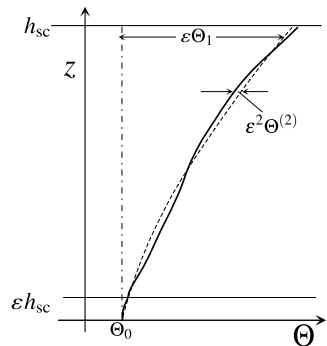
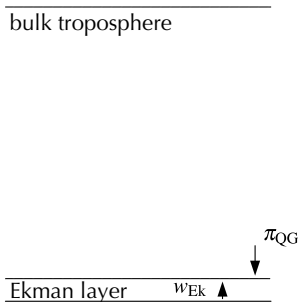
- sound-proof
- hydrostatic
- geostrophic
(in the bulk troposphere)
- Coriolis, pressure gradient, friction
(in the Ekman layer)

QG-Ekman – couplings

- $\pi_{\text{QG}}(t, \mathbf{x}, 0)$ drives Ekman flow
- $w_{\text{Ek}}(t, \mathbf{x}, \infty)$ “pumps” QG flow

QG – pressure Poisson equation

$$\nabla_{\parallel}^2 \pi_{\text{QG}} + \frac{f_0^2}{\rho_0} \frac{\partial}{\partial z} \left(\frac{\rho_0}{\Theta'_1} \frac{\partial \pi_{\text{QG}}}{\partial z} \right) = f_0 (q - \beta y)$$



QG-Ekman theory ...

- ... requires small deviations from a stable stratification with
- ... diabatic sources $\sim 3 \text{ K/day}$ or $\sim 0.5 \text{ mm/h}$ precipitation



QG-DL: Dynamics of a Diabatic Layer in the QG framework

QG-DL-Ekman theory ...

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- provides a remedy
- via embedded **diabatic layer** in
- triple-deck matched asymptotics

DL equations

$$f_0 \mathbf{k} \times \mathbf{u} + c_p \Theta_0 \nabla_{\parallel} \pi' = 0$$

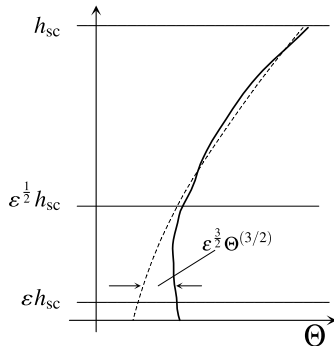
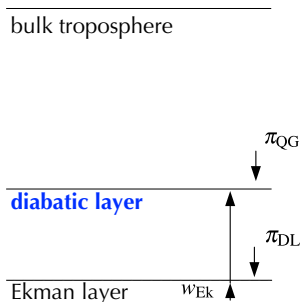
$$c_p \Theta_0 \frac{\partial \pi'_{\text{DL}}}{\partial \eta} = g \frac{\Theta'}{\Theta_0}$$

$$\cancel{\nabla_{\parallel} \cdot \mathbf{u}} + \frac{\partial w}{\partial \eta} = 0$$

$$\left(\frac{\partial}{\partial t} + \mathbf{u} \cdot \nabla_{\parallel} \right) \Theta' = Q_{\Theta}$$

Diabatic source strength:

$Q_{\Theta} \sim 15 \text{ K/day}$ or 2.5 mm/h



QG-DL-Ekman – couplings

- $\pi_{\text{QG}}(t, \mathbf{x}, 0)$ drives **DL** flow
 - $\pi_{\text{DL}}(t, \mathbf{x}, 0)$ drives Ekman flow
 - $w_{\text{Ek}}(t, \mathbf{x}, \infty)$ “pumps” QG flow
- $$\left. \begin{array}{l} \text{– } \pi_{\text{QG}}(t, \mathbf{x}, 0) \text{ drives DL flow} \\ \text{– } \pi_{\text{DL}}(t, \mathbf{x}, 0) \text{ drives Ekman flow} \end{array} \right\} \Delta\pi = \pi_{\text{QG},0} - \pi_{\text{DL},0} = \mathcal{O}(1)$$