Exam 2023

Dynamics Large Scale of Atmospheric Flow

Time: 2 h

Note: This is a reconstruction of the exam in February 2023. Maybe questions weren't asked exactly like this, but they capture the general sense. Overall, it was very similar to older exams.

1. State if the following are true or false
   (a) Potential temperature is bigger at poles than at mid-latitudes
   (b) Warm advection is associated with clockwise turning of the wind field
   (c) Two potential vorticity anomalies of equal strength but opposite sign propagate parallel to each other
   (d) The ageostrophic wind in the extra-tropics is typically smaller than the geostrophic wind
   (e) Diabatic heating produces PV constantly

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2. The Navier-Stokes equation is given as

$$\frac{D\mathbf{u}}{Dt} + (2\boldsymbol{\Omega} \wedge \mathbf{r}) = -\frac{1}{\rho}\nabla p + \mathbf{G}^* + \mathbf{F} \tag{1}$$

   (a) Explain each part of Equation (1). Which are relevent on a synoptic scale?
   (b) How does the coriolis force affect air parcels at the equator with a velocity of $10\,\mathrm{m\,s^{-1}}$ (a), at 45° with $60\,\mathrm{m\,s^{-1}}$ (b) and at the pole with a velocity of $0\,\mathrm{m\,s^{-1}}$ (c)?
   (c) How is the pressure gradient at these three points?

3. A weather chart is given
   (a) Cut drawn on map, draw vertical cross section with dynamic tropopause, isentropes and winds
   (b) How is the Q vector, where is ascent/descent?
   (c) How is the weather in norway?

4. Diabatic cooling and heating (Some formulas given)
   (a) Sketch a profile of $\dot{\theta}$ with a maximum of PV production at 3000m height
   (b) How does θ and PV evolve along a trajectory over of an air parcel ascending through a zone of evaporation cooling and then through a zone of condensation heating? Draw a diagram
   (c) How would it change, if the trajectory crosses the maximum of heating/cooling?

5. Rossby waves with given dispersion relation
   (a) Given formula for n^2, show that it follows from dispersion relation
   (b) Derive U_{crit} for $n > 0$ using the condition $0 < U_0 < U_{\text{crit}}$
   (c) Why can't synoptic Rossby waves propagate into the stratosphere? Use the condition from above to explain

6. Consider the wind field $\mathbf{v} = (u, v)$ in the domain $x \in [0, L]$, $y \in [-d, d]$ with

$$u = U_0 \sin\left(\pi \frac{x}{L}\right) \sin\left(\pi \frac{y}{d}\right)$$
$$v = 0$$

$$\zeta = -\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \tag{2}$$

$$\nabla \mathbf{v} = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} \tag{3}$$

   (a) Sketch the wind field
   (b) Calculate vorticity using Equation (2). Where are the extrema?
   (c) Calulate the wind change using Equation (3). Where are the extrema?
   (d) Calculate the vorticity change over 1 h with given formula using parts from b) and c)

7. Eady problem

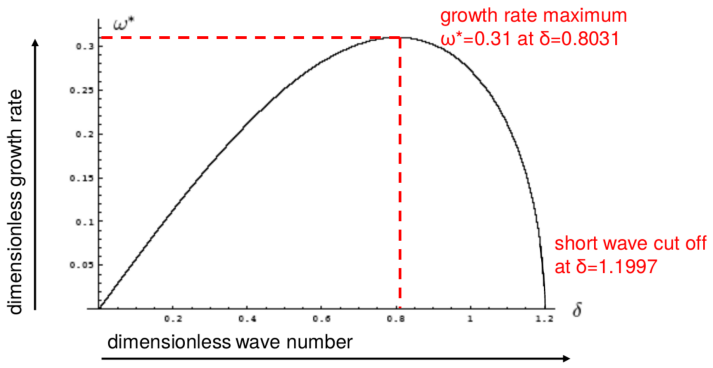

Figure 1: Growth rate vs wave number (given without red annotations)

   (a) Explain how an upper positive PV and a lower potential temperature anomaly develop over the next day(s) using less than 100 words and the terms *tilted isentropes*, *potential temperature anomaly*, *intensification* and *vertical coupling*
   (b) Explain Figure 1 using fastest growth mode and shortwave cut-off
   (c) Calculate e-folding time for most unstable wave using given formula