Freie Universität Berlin

Theoretical Meteorology I
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Numerics practical

Discussion Feb 16th, 4pm (neuer Hörsaal)

This practical gives a practical perspective on some aspects of the quasi-geostrophic approximation. We will use the Quasi-geostrophic barotropic vorticity with and without a forcing and the two-layer model to reflect on some of the theoretical findings derived during the semester.

We devote the final exercise on Feb 16^{th} to a discussion of your results. Please hand in your code and a small exposé consisting of some figures showing results from the model prior to this discussion. We expect a brief discussion / presentation of the exposé during this exercise.

1 Preliminaries - model infrastructure

3 P

You can use the model infrastructure provided for python that is provided on the whiteboard. (Alternatively, you may develop an infrastructure with similar capabilities in a programming/scripting language of your choice.)

Make sure you understand the following aspects before you get started to implement any other aspect of this assignment:

- How is the model controlled (how does it learn about its input / parameters / configurations?) ?
- Which classes exist and what is there purpose?
  1. _____ – _____
  2. _____ – _____
  3. _____ – _____
  4. _____ – _____
- What time integration scheme is used? In wich class and routine is it implemented?

Scheme _____

Class _____

Routine _____

- What kind of output is generated to the following streams/files

stdout _____

*.log _____

*.iter _____

*.nc _____

2 Time integration 3 P

Check the time integration scheme implemented in the class `INTEGRATOR`. Setting `rhs` [1] to `exponential` (a member of the class `integrator`) evaluates to the input, i.e. we solve the equation

$$\frac{dx}{dt} = x \Rightarrow \tilde{x}(t) = \frac{x_0}{e^{t_0}} e^t.$$

a) What is the expected result for $t_0 = 0$ and $x_0 = 1$ when integrating up to $t = 2$? Check for $\Delta t = 1$!

b) Varying the time step τ of the integration, check the order of the time integration scheme and produce a log-log plot of the error $x_{num} - \tilde{x}$ as a function of τ.

c) What is the order of the numerical error for the time integration scheme used?

d) Why does the numerical error reach a limit as $\tau \to 0$?

3 Rossby waves 15 P

For this task, you need to use the `rhs` dummy routine `rossby` and the section `Rossby` in `qg.ini`

a) Implement the barotropic vorticity equation

$$\left[\frac{\partial}{\partial t} + (U_j + u'_j)\frac{\partial}{\partial x_j}\right]\nabla^2\zeta - \beta v = 0$$

b) Investigate the behavior of waves for a `harmonic` initial perturbation! Can you prodcue standing waves? Give the parmaeter setting!

c) Investigate the behavior of a `singular` perturbation!

- What do you observe?
- How does the behavior differ from a harmonic initial condition?
- Can you explain this?

4 Two-layer model 20 P

a) Implement the two-layer model using a prognostic equation for ζ at the 250 and 750 millibar level (assuming $p_{\text{sfc}} = const. = 1000\,\text{hPa}$)!

b) Investigate the growth rate of a baroclinic instability!

c) Analyze the terms of the Lorenz energy cycle!

[1] Note that with `rhs`, we are passing a function as argument, i.e. we are using the concept of function pointers