Though mostly a lecture course we will visit the GFD lab, and use numerical modelling products, and many kinds of observations. If we had to give some key-words for the course they would be: Rossby waves, general circulation, potential vorticity dynamics, heat- and fresh-water dynamics, climate of atmosphere and ocean. After a couple of introductory problems, the course will treat many, but certainly not all, of the following topics:

1. **further description of the climate system:**
   - density-layered, rapidly rotating fluids with interesting boundary conditions and complex boundary shapes
   - radiation and the greenhouse blanket
   - the planetary heat- and fresh-water engine
   - defining general circulation:
     - transport and transformation of water masses, and exchange with the atmosphere; coupled heat- and fresh-water cycles on the θ-S plane: joint atmosphere-ocean circulation modes.
     - the ‘field theory’ of oceans and atmospheres: the discovery of electromagnetic fields and their expression in Maxwell’s equations unified the many strange properties and forces involved in charges and magnets, and the underlying wave field.
   - Potential vorticity conservation does much the same for vortices, mesoscale eddies, Rossby waves, baroclinic instability, jet streams and much of the general circulation. But, it must be augmented by a serious level of thermodynamics and ‘halodynamics’ (fresh-water cycles and salinity).

2. **brief review of geostrophic flow**
   - the connection with internal/inertial wave dynamics
   - geostrophic adjustment
   - thermal wind veering and backing of the currents

3. **potential vorticity**
   - the β-effect
   - the quasi-geostrophic equation for ψ, the geostrophic stream-function, with stratification
   - mapping the geography of potential vorticity

4. **Rossby waves**

5. **general circulation: general remarks about the climate heat engine**
   - **overturning circulations**
     - Ekman driven overturning
     - meridional overturning circulation: Hadley cells in atmosphere and ocean
     - heat- and fresh-water transports in ocean and atmosphere. *Does buoyancy drive the global overturning circulation? Are the deep, cold branches of the circulation important to meridional heat- and fresh-water flux? Is the ocean circulation significant in the combined atmosphere-ocean heat flux and the warming of western Europe? Does the Gulf Stream drive the mid-ocean circulation or vice versa?* We thought we knew the answers to these questions but they are now under active debate.
   - **the planetary scale ‘environment’**:
     - Ekman pumping and upwelling, air-sea heat flux
revisiting the geography of potential vorticity
- **lateral circulation**: wind-driven ocean gyres and boundary currents
- **circumpolar ocean currents and the atmospheric westerly winds**: stationary Rossby waves with mountains; wave drag
- **spin-up of the circulation from rest**: ray-tracing
  introduction to wave/mean-flow interaction

6. **development of concentrated jets and synoptic scale eddies: instability dynamics**
  barotropic and baroclinic instability as generalized Rossby waves

7. **brief discussion of climate dynamics: dynamics vs. thermodynamics; global warming**
  and decadal natural variability modes; storm tracks and the ocean beneath them

Note on textbooks: We now are overflowing with good books on GFD. Gill is my choice for the classic reference but he does not do much vorticity dynamics. Pedlosky’s GFD text is excellent for 1- and 2-layer models of waves and instability of quasi-geostrophic flows. Now we have Vallis’ new book which is long but modern and vorticity oriented. Salmon’s text is elegant, theoretical, good for basics but narrow in scope. Cushman-Roisin is excellent at the basic level. Holton’s Dynamic Meteorology, in its 4th edition, is really an excellent complement to the GFD texts. It starts at a basic level but takes you far. Ian James’ Introduction to Circulating Atmospheres (Cambridge, 1994) is like Holton not taking you to a very advanced level but introduces the key methods for understanding the GFD of the atmospheric general circulation.

The sad thing though is that **none** of these texts, excepting Gill’s, make a serious attempt at using observations. Observationalists, as a rule, rarely write text-books. Wallace & Hobbs undergraduate text Atmospheric Circulation: an introductory survey, in a new edition, is worth looking at in this respect.

Another remark about omission: hard-core theoretical work is not carried out by many oceanographers today. Running computer models is more popular. But, beware of giving a research seminar of the form “Here is what I changed in my ocean model (or climate model) and here is what happened.”. Experiments are good, but dynamics goes deeper than changing parameters, playing with parameterizations and seeing what happens. A little theory can take you a long way.