The problem of parameterization.

1 Introduction

There are many different time/space scales in the atmosphere. They are normally linked together, i.e. phenomenons which have small spatial extension, often also have short time scales. There are a few exceptions, e.g. sea breeze, which have a horizontal scale of the order of some kilometers, but a time scale of many hours. The smallest processes that are of interest in meteorology is turbulence, which have time/space scales of about 10 s/ 10 m. At the other end we have the planetary waves, with horizontal scales of 10^4 km and lifetimes of more than a week.

The equations describing a fluid on the rotating earth, the Navier-Stokes equations are very general. They describe motions on *scales* from "the sound of a flute" to planetary waves. Therefore these equations are applied to a meteorological problem by *scaling* and physical *assumptions*:

- Hydrostatic assumption.
- Limited resolution $\Delta x \approx 20$ - 50 km

This implies that non-hydrostatic and "small" scale processes are not described in the model. This is the present state of HIRLAM, but work is going on to allow non-hydrostatic formulations. The gridlength of a non-hydrostatic model could be about a few kilometers.
Define a gridsquare mean value af a variable A according to:

$$\overline{A} = \frac{1}{\Delta x \Delta y} \int A(x,y)\, dx\, dy$$

$$A = \overline{A} + A' \qquad ; \qquad \int A'\, dx\, dy = 0$$

As an example, put the mean values and deviations into the u-equation, utilize the equation of continuity, and perform the integration over the gridsquares, which yields:

$$\frac{d\,\overline{u}}{dt} = -\frac{1}{\rho}\frac{\partial\,\overline{p}}{\partial x} + f\,\overline{v} \,+\, \frac{1}{\rho}\frac{\partial}{\partial x}\left(-\rho\,\overline{u'u'}\right)$$

$$+ \frac{1}{\rho}\frac{\partial}{\partial y}(-\rho\,\overline{u'v'}) \;+\; \frac{1}{\rho}\frac{\partial}{\partial z}(-\rho\,\overline{u'w'})$$

The terms $\rho\,\overline{u'u'}$ etc. are called Reynold stress terms and represent not resolved process.

To express not resolved process in terms of resolved variables (and some parameters) is known as ***parameterization***

i.e. The effect on the resolved variables $\overline{u}$, $\overline{v}$, $\overline{T}$, $\overline{q}$ etc. from perturbations u', v', T', etc. due to non-resolved processes like radiation, turbulence, condensation and convection.

A remark: It is implictly assumed that there is some scale separation between the resolved and not resolved processes, in other words, a process could either be resolved by the model or "not at all" resolved and thus parameterized. This means that a process like convection is difficult to parameterize if the gridlengths are below, say 5-10 km. I think that this is one of the key problems in modelling, how to handle partly resolved processes when the gridlengths are decreasing?

2 How is it done in HIRLAM ?

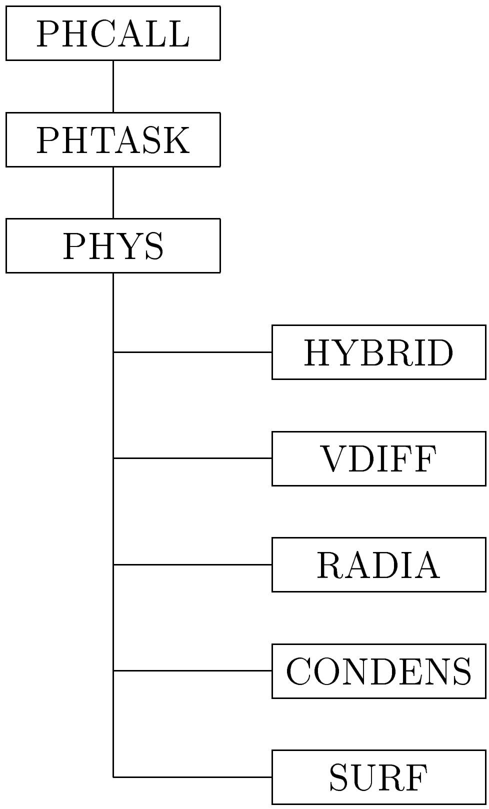
In HIRLAM the tendency of a variable Ψ can formally be written:

$$\frac{\partial\Psi}{\partial t} = \left(\frac{\partial\Psi}{\partial t}\right)_{Dynamics} + \left(\frac{\partial\Psi}{\partial t}\right)_{Physics}$$

The physical tendency is assumed to be composed by
different processes:

$$\left(\frac{\partial\Psi}{\partial t}\right)_{Physics} = \left(\frac{\partial\Psi}{\partial t}\right)_{Rad} + \left(\frac{\partial\Psi}{\partial t}\right)_{Vdif} + \left(\frac{\partial\Psi}{\partial t}\right)_{Cond}$$

2.1 The code structure of the physical parameterization



Here PHCALL is calling PHTASK for parallell computing of the physical processes (in turn called by PHYS). Note that there is no horizontal coupling within the physics, which makes it easy and suitable for parallell computing. Each routine are using values at $\tau - 1$. HYBRID is used to compute the pressure on the model levels. The other main routines treats radiation, vertical turbulent mixing and surface processes.