Introduction to limited area modelling

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FINNISH METEOROLOGICAL INSTITUTE

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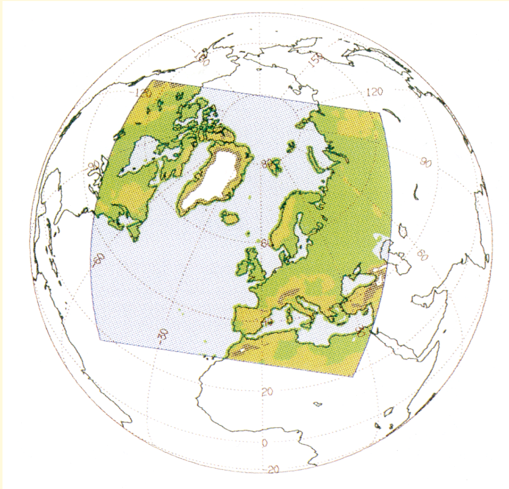
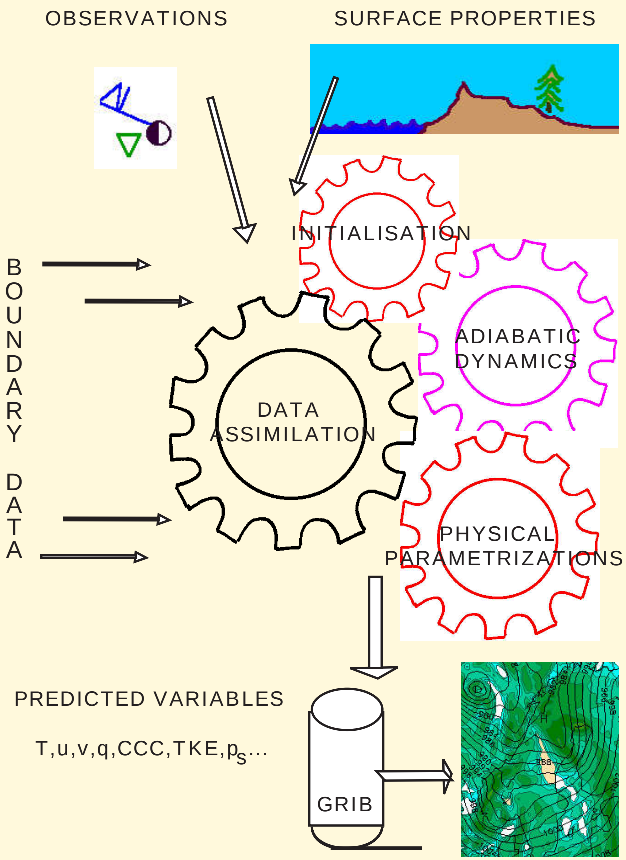
Definitions



- NWP model = Numerical Weather Prediction model
- LAM = Limited Area Model
- HIRLAM = HIgh Resolution Limited Area Model

Model	Domain	Grid size	Forecast length	Time step
Global	globe/hemisphere	O(100 km)	days - years	O(30 min)
Regional	O(1000 km)	O(10 km)	days - years	O(10 min)
Local	O(100 km)	O(1 km)	day	O(1 min)

Model


OBSERVATIONS
SURFACE PROPERTIES
INITIALISATION
ADIABATIC DYNAMICS
BOUNDARY DATA
DATA ASSIMILATION
PHYSICAL PARAMETRIZATIONS
PREDICTED VARIABLES
T,u,v,q,CCC,TKE,ps...
GRIB

Basic equations

$$\frac{\mathrm{du}}{\mathrm{dt}} + \frac{1}{\rho}\frac{\partial p}{\partial x} + fv = F_x \tag{1}$$

$$\frac{\mathrm{dv}}{\mathrm{dt}} + \frac{1}{\rho}\frac{\partial p}{\partial y} - fu = F_y \tag{2}$$

$$0 = -\frac{1}{\rho}\frac{\partial p}{\partial z} - g \tag{3}$$

$$c_v\frac{\mathrm{dT}}{\mathrm{dt}} + p\frac{d\rho^{-1}}{dt} = Q \tag{4}$$

$$\frac{\mathrm{dq}}{\mathrm{dt}} = S \tag{5}$$

$$\frac{\mathrm{dC}}{\mathrm{dt}} = P \tag{6}$$

$$\frac{1}{\rho}\frac{d\rho}{dt} = -\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}\right) \tag{7}$$

$$p = \rho RT \tag{8}$$

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Solving the equations in LAM

- grid, or the coordinate system
- initial state
- lower and upper boundary conditions
- lateral boundary conditions
- resolved and parametrized processes

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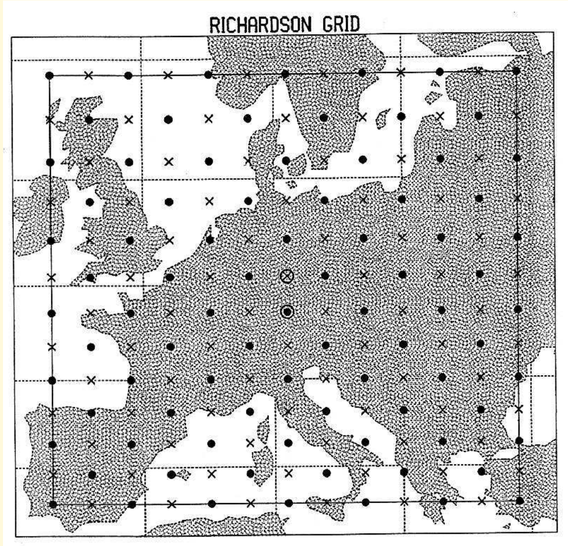
Grid

The first numerical forecast



Lewis Fry Richardson, 1881-1953 and his grid, 1922

The first numerical forecast calculated with a computer

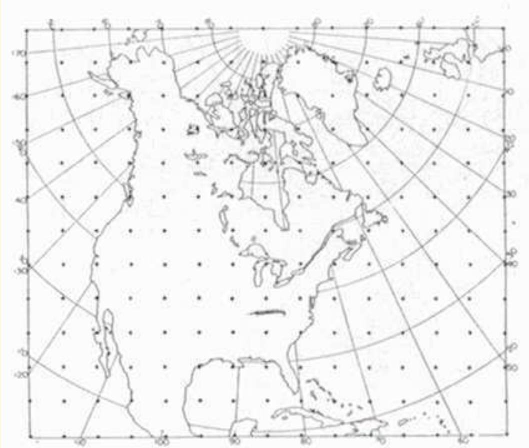


Fig. 1. A typical finite-difference grid used in the computations. A strip two grid intervals in width at the top and side borders and one grid interval in width at the lower border is not shown.

Jule Charney, 1917-1981 and the grid

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The problem of lateral boundaries

Transparent/well posed boundaries - difficult

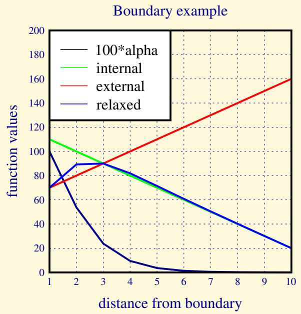
In practice:

Davies relaxation for all prognostic variables within a boundary zone of e.g. 8 grid points wide

$$\phi_i = (1 - \alpha_i)\phi_i^{in} + \alpha_i \phi^{out} \tag{9}$$

where

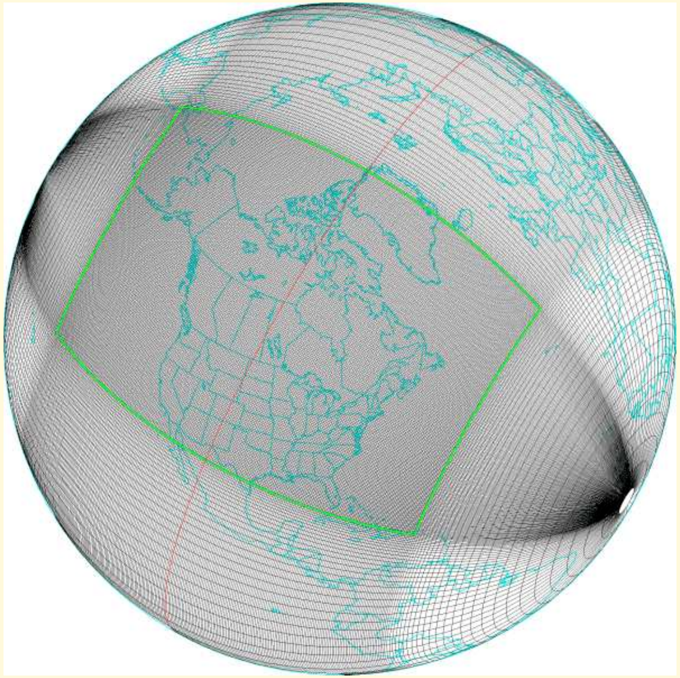
$$\alpha_i = 1 - tanh[(i-1)/2)] \tag{10}$$



Practical boundaries

- fresh and good boundary data
- keep the boundaries as far as possible
- horizontal and vertical interpolation
- filtering of boundaries

Stretched coordinates - an alternative?



Hirlam

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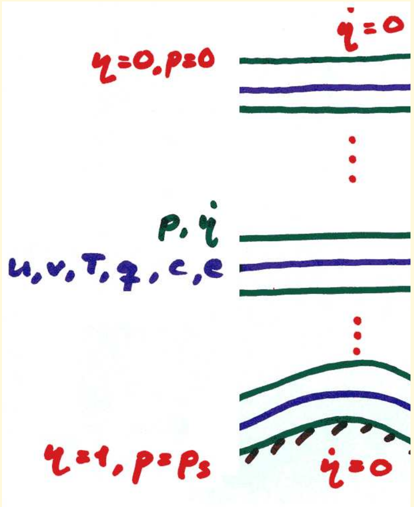
Lower boundary problems

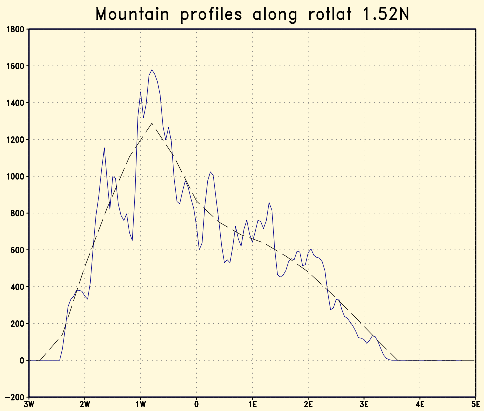
Vertical coordinate of HIRLAM

Terrain-following hybrid levels: pressure at model level k

$$p_k(x, y) = a_k(z) + b_k(z)p_s(x, y) \tag{11}$$



Fine scale modelling problems related to the lower boundary condition

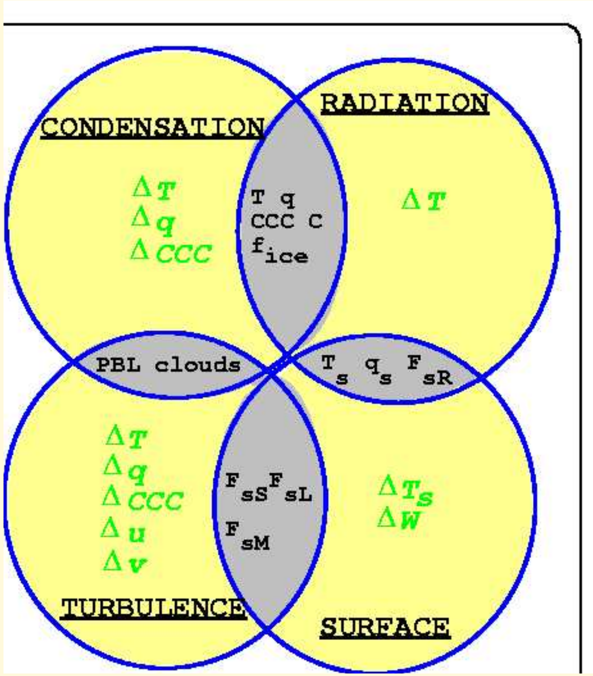


An example of mountains profile accross Southern Scandinavian mountains. Grid-size of HIRLAM 5.5 km (dashed) and 44 km (solid).

- free-slip and no-slip conditions (surface friction)
- practical problems for numerical schemes (semi-Lagrangian) ⇒ filtering of orography
- streamlines over orography, flow blocking and turbulence
- smoothing of numerical noise with the 4th order horizontal diffusion

Introduction to physical parametrizations

- Right hand side of the equations = sources and sinks
- Two types of parametrizations: (1) describing very small phenomena and (2) mixing and removing instabilities; Resolved and parametrized processes
- Parametrization provides additional model output variables



Parametrization schemes of HIRLAM