A brief review of some key issues related to the modelling of cloud and precipitation

By Bent H Sass , DMI

January 2005

Important questions:

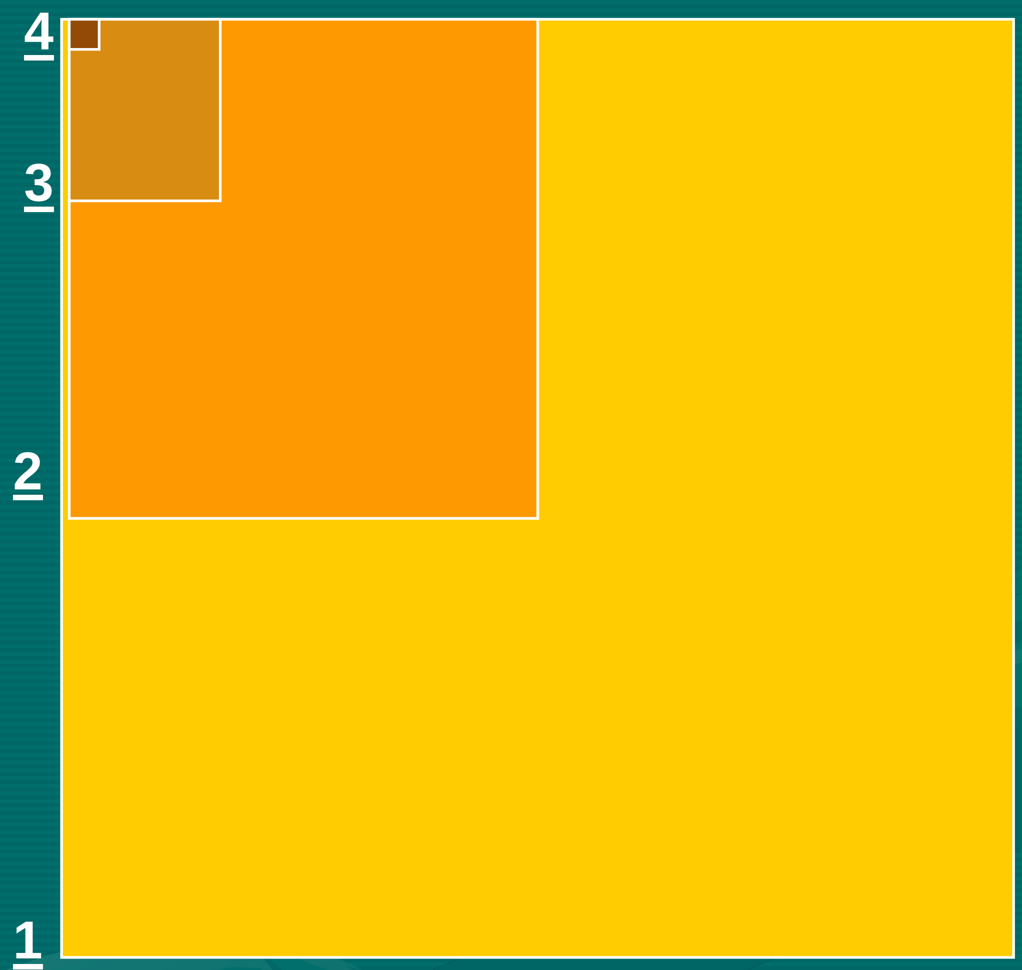
-

(1) Can it be quantified from observations that the mesoscale structure of precipitation is significant ?
The answer is : Yes

(2) Can we summarise typical weaknesses and/or limitations of the methods for cloud and precipitation prediction used in the operational weather prediction models ?

(3) Which modelling strategies for high resolution are expected to lead to increasingly realistic operational schemes in the coming years ?

The answer to (3) will appear as a concluding remark based on (1) and (2).



Precipitation scales:

1: Synoptic scale (100 km*100 km)	Time scale 24 h	Scaled intensity:	1
2: Large mesoscale (50 km * 50 km)	Time scale 6 h	Scaled intensity	2
3: Small meso-scale (15 km*15 km)	Time scale 1 h	Scaled intensity	8
4: Very small mesoscale (3 km *3 km)	Time scale 0.5 h	Scaled intensity	80

Based on Austin and Houze (1972) from studies of 9 storms .
”Analysis of the structure of precipitation patterns in New England (J.Appl. Meteor. 11, 925-936)
Heavy rain occured in stratiform as well as showery conditions.

Examples of mesoscale precipitation features:

1) Influence of orographic features is well establised, not only for high mountains, but also for small hills of less than 50 m height. For example, Tor Bergeron writes in Uppsala Rep. No. 6 (1968):

   ” Unexpectedly, small orographic features are reflected in the fine structure of rain fall distribution” (averaged over months). Only 20m-30m plateau is needed in the Uppsala field to produce approximately a 20 % precipitation increase.

2) Recently very fine scale structures of precipitation (typically 20-30 % variation) was measured in Denmark with 9 rain gauges of same design evenly spaced over a 500 m*500 m flat field. The measurement campaign took place over a period og 65 days during Autumn 2003 (for details see http://www.exigo.dk/project/summary)

Model uncertainties/weaknesses (1)

1) Microphysics

a) Cirrus clouds: Formation of ice clouds has little relation to ice saturation and the onset of cloud formation is complicated (concentration and types of ice nuclei vary across the globe). A lot of research activity exists ,e.g. a COST 723 action (www.cost723.org)

In HIRLAM a modified cirrus cloud formation has been implemented recently. Is there a need for further updates ?

b) Some presently used parameterizations might be too inaccurate and more detailed microphysics will then be needed. Is it relevant to explicitly forecast droplet/particle size distributions in the near future ?

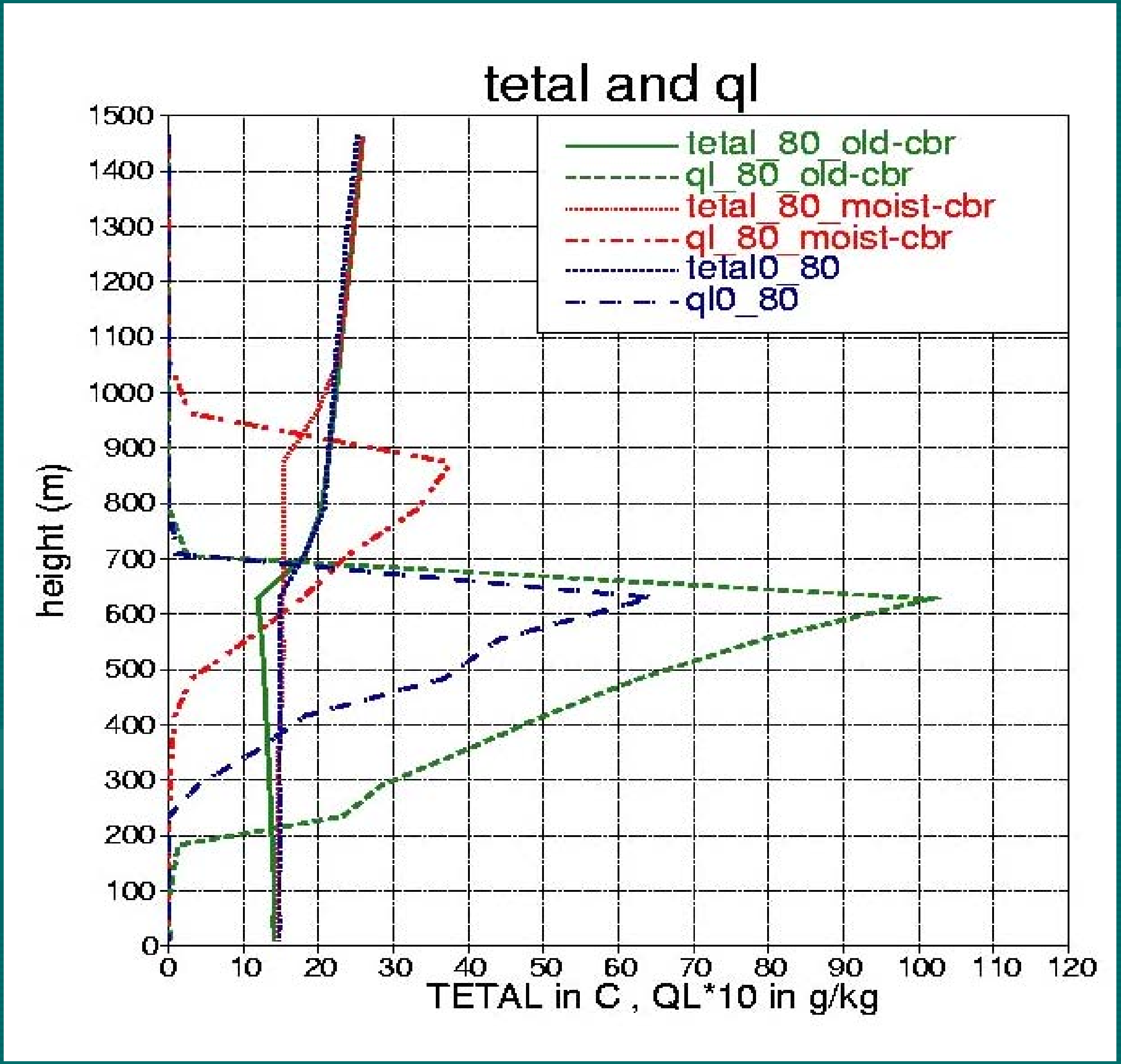
Model uncertainties/weaknesses (2)

2) Turbulence and convection

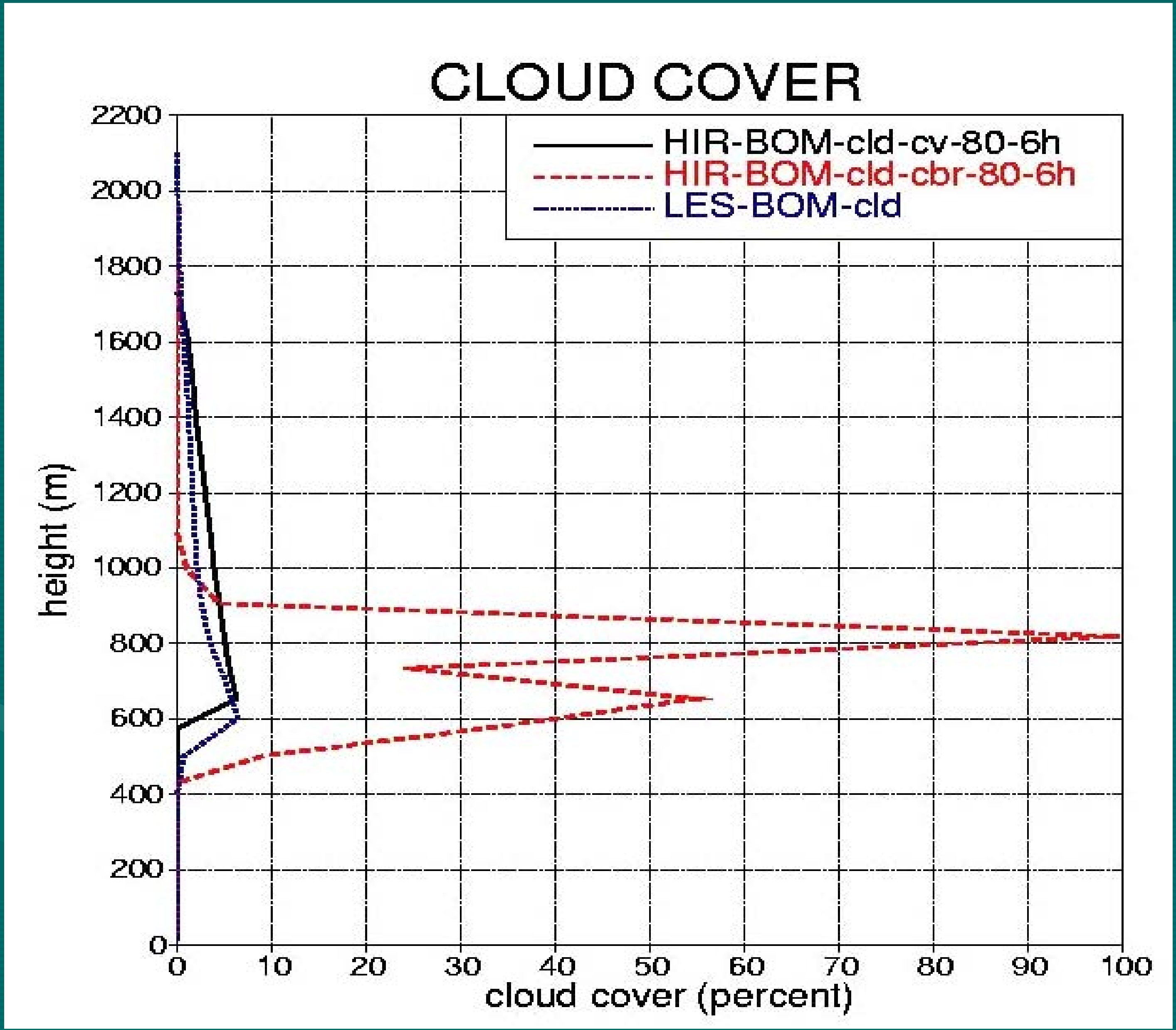
a) Moist CBR scheme has recently been tested. It provides a better description of the vertical moisture transports in stratus/stratocumulus conditions (e.g. ASTEX) , but has difficulties to describe cloud field for shallow cumulus situations such as BOMEX where the convection scheme takes well care of the vertical tranports (has been verified in 1D HIRLAM simulations with ”moist” CBR and STRACO cloud scheme).

b) The ideal assumptions connected to convecton schemes break down at (very) high horizontal resolution of meso-scale models, but the use of convection schemes may still be desirable (as indicated by a), provided that they are used with care (conditionally). Research is probably still needed to optimise the use of convection schemes at very high resolution.

ASTEX simulation comparing 'moist' CBR with 'dry' CBR and no vertical transports by the convection scheme.



BOMEX : 'moist' CBR versus full convection scheme



Model uncertainties/limitations (3)

a) Triggering of convection: Uncertainties remain on how to parameterize the fluctuations of momentum, heat and moisture resposible for initiation of convection.

d) Assumptions of ”instantaneous” precipitation fallout in the vertical air column becomes increasingly unrealistic at high horizontal resolution due to the actual drift of precipitation with the wind. This effect can easily account for horizontal precipitation displacements of more than 10 km, especially for drifting snow.

Model uncertainties/weaknesses (4)

3) Dynamics

a) Hydrostatic model dynamics is expected to be less realistic than non-hydrostatic dynamics at grid sizes below about 5 km.

b) If the problem to describe convective cloud cover (and vertical humidity transports) for shallow cumulus conditions from turbulence alone is a general one (not having a convection scheme activated), does this mean that a reasonable description of shallow cumulus requires explicit dynamics of a LES model (e.g. 100 m grid size or less ?). The answer will to some extent depend on the details of the turbulence scheme and of the cloud cover parameterization (experimentation needed).

Tentative conclusions concerning modelling strategies:

1) Continue to make high quality ”physiography databases” partly because stationary forcing (e.g. from orography) shows up in observed precipitation statistics (also very small scale orography).

2) Introduce ”prognostic” 3D precipitation fields with several hydrometors (rain, snow, etc.) to avoid unrealistic fallout of precipitation.

3) For a given model resolution investigate whether the vertical and horizontal humidity transports can be adequately described by the turbulence parameterization and the model dynamics. – If not, continue to develop and use a convection scheme for very high resolution, perhaps even at finer scales than 2-3 km.

4) The observations showing precipitation variability at scales down to about 100m seem to indicate that very fine scale dynamics on the ”turbulent scale” is playing a role to explain this. This probably indicates that inhomogeneous 3-dimensional turbulence modelling is required as a framework for the very detailed description of precipitation processes at very high resolution. In a real forecasting environment a probabilistic component will probably be needed to deal with the high variability in space and time of the precipitation intensity.