Remarks on HIRLAM physics

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Why mesoscale model?

A local meso-γ-scale model is expected to provide a three-dimensional picture of the atmosphere now, today and tomorrow. From this, the atmospheric state at any point at any moment of time can be derived. We wish to treat the local-scale processes in a physically correct way with less assumptions. More variables become directly predicted and less parametrized. In principle, this means development from tuning to calculation, from complicated to simple, from hidden assumptions to transparent equations. With the new local model we hope to utilize the available information - observations, properties of the underslying surface - more effectively.

Why physical parametrizations?

Physical parametrizations were developed to handle the sources and sinks of prognostic variables due to (large) sub-grid-scale processes: turbulent eddies, organized convection with updraughts and downdraughts, circulations forced by the local topography and vegetation etc. These processess are relatively close to the resolved scales, thus their definition depends on the scale. Also, there may be different processes connected with several sub-grid-scales, like the effects of small-scale and mesoscale orography. The traditional task of these parametrizations has been removal of the instabilities related to the sub-grid-scales.

A second group of parametrized processes consists of microscale phenomena, such as cloud microphysics from nucleation to precipitation and the absorption and emission of radiation by gas molecules and airborne particles. These are relatively far from the resolved scale and their definition depends less of the grid scale. However, not everything included in the radiation or cloud parametrizations is microscale, for example the influence of (subgrid-scale) surface slopes on radiation.

A practical task of physical parametrizations is to produce diagnostic variables for output and data assimilation. For example, the basic verified variables of HIRLAM - T_{2m}, RH_{2m}, V_{10m}, cloudiness and precipitation - are presently produced by the parametrization schemes. Data assimilation needs model-derived variables like radar reflectivity or satellite radiances. The relation of developing observation operators to the physical parametrizations of the forecast model may require more attention in the future.

Does a HIRLAM physics brand exist?

From the very beginning, the “HIRLAM physics package” has been designed for the use in a short-range limited-area NWP system. The schemes have been planned to be

+ quick and optimized

+ applicable in (operational) synoptic and meso-β-scale model systems with different horizontal and vertical resolutions

+ compatible with flexible surface and upper air data assimilation and climate generation systems over any area

+ used with Eulerian and semi-Lagrangian, hydrostatic and non-hydrostatic dynamics

+ applying simple structures and interfaces within the model

+ efficient in different computing environments

HIRLAM physics contains results of studies, work and experience of O(100) person-years of HIRLAM researchers. This means that

+ an active international team is continuously working with the parametrizations

+ the features, problems and error sources of the schemes and possible ways to attack them are known to the developers

- parametrization schemes have been developed during 20 years piecewise and spontaneously without systematic overhaul or streamlining

- processes are handled in various overlapping subroutines

- there are different, possibly contradicting assumptions within physics

- variables and constants are defined in a random way

- interfaces and connections with dynamics are not ideal in every detail

- obsolete programming solutions are used etc.

Questions along the road from synoptic to mesoscale

Renewal of the HIRLAM physics should be started with the analysis of the present system. It is relevant to ask what processes/features/assumptions of the present HIRLAM physics are ...

... not needed anymore in meso-γ scale? The meso-scale orography parametrizations, parametrized deep convection?

... too detailed for meso-γ scale? Surface subtypes (tiles), fractional cloud cover?

... too approximate for meso-γ scale? Radiation at horizontal surfaces only, flat virtual forests and cities?

... applicable both in synoptic and mesoscale? HIRLAM radiation scheme, moist CBR (three-dimensional) with TKE + diagnostic length scale?

... necessary in meso-γ scale but missing at present? Predicted cloud water and ice, precipitating water and ice/snow

... not so good even in synoptic scale? Parametrized heat, moisture and momentum fluxes in stable PBL, diffusion of heat and moisture in soil?

... inapplicable in meso-γ scale? Assumption of column physics?

With the assumption of column physics all horizontal interactions in the present model are realized through the resolved dynamics. In the future, parametrization schemes may need to take into account horizontal exchange. The surface and the atmosphere may not be balanced in local columns. Shadows from clouds and topographic features influence at large distances. With the increase of horizontal resolution, turbulence needs to be parametrized in three dimensions. The related problems are not only of practical (parallelization) character.

Physics and underlying surface

A detailed description of underlying surface is necessary in a meso-γ scale model. The required high-resolution description is provided by one-kilometer resolution data bases like GTOPO30, ECOCLIMAP, GLCC. However, the resolved dynamics can only see orography features of the horizontal size $\approx (4-6)\Delta x$ (Davies and Brown, 2001). Smaller features are to be smoothed and effects parametrized. Not so many surface-related parameters are directly used by the present HIRLAM physics subroutines. A quite comprehensive list consists of albedo, emissivity, roughness, analysed/climatic SST, snow depth, vegetation type, leaf area index, (deep) soil temperature and moisture, surface elevation, (meso- and small-scale orography height, slopes for radiation). Less is known how sensitive the physical parametrizations and the related surface analysis actually are to the surface details. The problem might deserve more systematical studies.

Scale-dependent independent physics?

Recently, a parametrization to take account the effects of sloping surfaces on radiation fluxes has been developed. Basically, the problem here is a straight-forward geometric and astronomic exercise. However, the radiation fluxes in a grid cell will now depend on (sub-grid scale) orography details in a grid-box, profiles of mountains far away (creating shadows) and time of year and day through solar azimuth and zenith angles. Several principles of HIRLAM physics need to be considered:

Make averages of radiation fluxes, not orography

Use the most detailed digital elevation data to prepare orographic parameters for the grid-scale

The parametrization should work correctly with any model resolution

The approach should be accurate enough but computationally inexpensive

In general, the parametrization modules of HIRLAM should be independent and interchangeable, so that they

can be freely combined with other parametrization schemes according to accepted rules

can be used with any dynamical core of the model using accepted interfaces

utilize optimally the analysed and climatic data prepared by using finest-scale available sources

produce reasonable output and diagnostics as required by the model system

This kind of approach would mean building a kind of physics warehouse. For operational use, optimal configurations should be choosen. Is the approach realistic and correct?

Understanding interactions within the model

With the present physical parametrizations a cauldron method is used: throw all ingredients into the pot (HFS), boil it and hope that the interactions will take care of themselves, producing a physically reasonable forecast. Surprisingly often this indeed happens, that has created a lot of optimism in solving the model problems. We feel convinced that there must always be a key parameter/process to correct and get rid of the problem.

The problem is that HIRLAM is not less complicated than the atmosphere it tries to simulate. The only difference is that we can make experiments with the model. To really understand, we need

scientifically and practically reasonable experiments

tools for experimenting, like the single column HIRLAM

advanced methods for the analysis of the results

observations and detailed refence simulations (LES, RTM's ...) to compare the results with

When analysing the simulation results, we meet the problem of isolating the different processes and effects: surface description/analysis/boundaries/dynamics/physics. There is the problem of representativeness of the case studies and observations. The standard (SYNOP) observations provide huge amount of valuable data. More advanced methods than creating the standard pictures of bias and RMS over EWGLAM stations are urgently needed to handle them. Collected over individual stations observed and predicted values (Eerola., 2005) offers possibilities for this. Correlations between the model parameters might be useful, i.e. answering questions like “does the lowest level wind really depend on roughness, how?” “What are the relations between the components of surface energy balance and two-metre temperature, why?”

Contribution of HIRLAM to evolving mesomodel physics

HIRLAM physics team might offer for the development of AROME physics:

- Existing simple and optimized schemes, like radiation
- Scale-dependent solutions like in STRACO, SSO/MSO, sloping surface radiation
- Work with new simple schemes, like Schultz microphysics
- Model intercomparisons using HIRLAM physics in the existing nonhydrostatic HIRLAM system applying advanced diagnostic tools

A necessary condition for this and further development of the HIRLAM physical paramatrizations is an overhaul and rewriting of the existing physics code. We need

- Cleaning and streamlining of constants, variables, processes
- A code to obey the common interface rules
- Possible rewriting in Fortran90

In the cleaning work, tools and definitions are needed:

- Cleaning questions to analyse the code
- Interface rules prepared in cooperation with ALADIN people
- Knowledge of IFS structures and conventions
- A detailed plan of the tasks for the low-level physics overhaul
- A plan related to the externalization of the surface code (also related to the data assimilation, climate generation and forecast model)

Conclusions

1. The present HIRLAM physics is in good shape for the use in a synoptic scale HIRLAM-ALADIN system. Solution of the Nordic Temperature Problem is of high priority.
2. The present HIRLAM physics contains valuable elements that can be used as such as a basis for development of meso-γ scale physics. The simple and optimized parametrizations schemes can be our contribution to the evolving mesomodel (AROME) system.
3. The possibilities and restrictions of the present HIRLAM physics should be analysed systematically, to see the key processes that should be improved, modified, developed towards the mesoscale.

4. Development of advanced tools for planning and running 1D-2D-3D model experiments and analysing the results as well as providing observation data for comparison is an extremely important task and a possible contribution of HIRLAM (physics) team to the mesomodel development and model intercomparisons.

5. A systematic physics overhaul is needed now. It should include cleaning and streamlining + recoding in Fortran 90. The new code should obey the interface rules agreed with ALADIN-AROME community and fit into the common (IFS) framework. It should be possible to use the components of recoded HIRLAM physics in wide variety of combinations of physical parametrizations and model systems. A plan should be prepared together with the HIRLAM mesogroup.

References

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