LACE Working Group for Physics: Research progress summary from 2003

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17 December 2003

Contents

1. Introduction / Summary

In the year 2003, research and development in the LACE Working Group for Physics focused on topics which are (a) associated with systematic errors in the current operational forecast and (b) relevant to the ongoing evolution towards the ALADIN-2 system.

A large part of the total person-power was invested in the low cloudiness prediction problem (P1), which consists in a strong and systematic underestimation of stratus in the ALADIN forecast, mostly during wintertime. The problem is closely connected to the prediction of inversions and not restricted to the ALADIN model, as has been shown by comparisons between ALADIN and ECMWF forecasts. Progress made in this area will most likely have positive effects beyond the ALADIN framwork. However, additional work on the topic is required in order to obtain a solution that can be implemented operationally in 2004.

The problem of the triggering of deep convection (P2) was investigated through case studies from the summer period of 2003, using both radar and surface data for verification. Similar to other NWP models, diurnally forced precipitating convection is on average triggered too early, and too widespread. Experiments with more selective trigger functions showed that more realistic onset times and mesoscale patterns can in principle be generated. The method used, however, is not yet ready for operational implementation. For example, as convective precipitation is suppressed in the model, large-scale precipitation tends to take over quite strongly, reducing the sought-for effect. Also, a clearer separation of error sources into (a) topographic, and (b) related to the convection scheme itself, must be achieved.

The ultimate goal of the orographic drag parametrization (P3) is to replace the envelope topography by a mean topography. Surprisingly, this has proven to be more difficult in a LAM than in a global model such as ECMWF. Dropping the envelope would have positive effects on the simulation of the boundary layer in mountain areas and would improve data assimilation in those areas. It is also expected to have a positive impact on the simulation of deep convection. After a first suite of validation and tuning experiments, it became apparent that a re-formulation of parts of the drag scheme is necessary. This has for the most part been completed and is ready now for further testing and tuning.

A necessary condition for the merging of ALADIN Dynamics and Meso-NH Physics in the march towards ALADIN-2 is a clean and transparent interface between the adiabatic part of the model and the various physics subroutines (P4). An important step in 2003 was the work on the so-called GMV/GFL array structure, allowing a more straightforward implementation of additional prognostic variables in the model. It will be available in CY28, for which a first export version will be created in March 2004.

2 Progress in research topics

2.1 Shallow convection and PBL cloudiness (P1)

At this stage, work is directed primarily at the ‘simplest’ form of low cloudiness, namely stratus. Since stratus is usually associated with a cloudiness value of 1 and covers large areas in a quasi-homogeneous manner, it can be treated as explicitly resolved cloudiness by the model. In 2003, emphasis was on further diagnosing and understanding the sources of stratus forecast errors. Three sources were identified, namely (a) problems in the analysis, (b) the vertical diffusion parametrization, and (c) the cloudiness parametrization.

More verification studies were carried out which showed that ALADIN tends to underestimate the strength and sharpness of inversions associated with stratus clouds. Most importantly, the cold air just beneath the inversion is systematically too warm in the model, leading to an underestimation of sub-inversion cloudiness. Also, if the vertical diffusion within an inversion layer is too high, i.e. if it is too similar in magnitude to the vertical diffusion above and below, then the inversion is too strongly smoothed. Only if the turbulent fluxes sharply decrease at the base of the inversion, then vertical diffusion alone can enhance the sharpness and magnitude of the inversion. The third source of errors lies with the cloudiness parameterization itself. The standard scheme, which was used in ALADIN up to cycle 15, did not produce single-layer cloudiness values close to 1 even if a layer was nearly saturated. An empirical inversion cloudiness scheme similar to the one proposed by Slingo (1987) has been shown to give good results (Seidl and Kann, 2002) but requires more tuning. Ultimately, a convergence between this scheme and the Xu and Randall (1996) cloudiness, as well as the statistical cloudiness scheme used in Meso-NH, should be achieved.

As a sub-topic of P1, the implementation of prognostic cloud water, including validation experiments, was planned. This was only partly achieved, due to unresolved problems associated with a specific version of the Lopez cloud microphysics scheme which produced unrealistically high cloud cover during the course of the integration. Nevertheless, some comparison experiments were carried out, showing the expected beneficial impact on mesoscale precipitation patterns in mountain areas. A systematic evaluation of the impact of prognostic cloud water on stratus prediction is planned in 2004 for CY28 which will provide a more straightforward way of implementing new prognostic variables.

In view of the evolution towards ALADIN-2, a subgrid-scale cloudiness scheme similar to the one used in Meso-NH was tested in one-dimensional mode, and compared with the ALADIN reference scheme, the Xu-Randall scheme, and the Seidl-Kann scheme. For a typical stratus case, the ALADIN reference scheme gives lowest cloud cover, Meso-NH and Xu-Randall give intermediate values, and Seidl-Kann the highest values.

One sub-topic of P1 was dropped entirely because it turned out not to be as crucial for the cloudiness prediction as was assumed initially: non-local vertical transport. Surprisingly, the standard ALADIN vertical diffusion scheme with first order *K*(Ri)-closure and shallow convection enhancement was found to be quite adequate, at least for stratus cloudiness. It is likely that non-local vertical transport, i.e. the modelling of vertical exchange by large coherent eddies, becomes an issue again as we proceed towards broken cloudiness (stratocumulus, cumulus).

Some 1-d diagnostic studies of radiation fluxes and cooling rates within PBL clouds were carried out, and compared to results from cloud-resolving models and observations. First results indicate that longwave radiative cooling rates near cloud top are reasonably captured by the model. With regard to short wave fluxes, more analysis is required before conclusions can be drawn.

It was found that in the presence of sub-inversion cloudiness in the model (using the Seidl-Kann scheme and the new vertical diffusion tuning of CY25), the combined effect of cloud-top cooling and inhomogeneous vertical diffusion can keep the model inversion in a realistic state and the cloudiness at, or close to, a value of 1 (Haiden, 2004). The most important question yet to be answered is whether a sharp inversion can form in the model *before* inversion cloudiness is present. According to observations, this is what actually happens in many cases. It will require further studies on the vertical structure of diffusion fluxes, possibly a modification of the *K*(Ri) dependence in the stable limit.

Actions:

- *Implementation of prognostic cloud water + Lopez microphysics scheme in 1-d and 3-d (LK, AK) (partially fulfilled)*
- *Tests of prognostic cloud water + Lopez microphysics scheme in 1-d and 3-d (LK, AK, HS) (fulfilled)*
- *Study of prognostic cloud water effects on stratus cloudiness persistence (AK) (not fulfilled)*
- *Tests with a MESO-NH type subgrid-scale cloudiness scheme (TH) (fulfilled)*
- *Development of a mass-flux scheme for the unstable PBL (TH) (not fulfilled)*
- *Investigation whether current deep convection scheme can be adapted for shallow convection (AK) (not fulfilled)*
- *1-d diagnostic studies of in-cloud radiation fluxes (HT) (partially fulfilled)*
- *Further development and tests of the Seidl-Kann scheme (AK, HS) (additional)*

Contributors: Laszlo Kullmann (3 months)
Alexander Kann (3 months)
Helga Toth (3 months)
Harald Seidl (1 month)
Thomas Haiden (2 months)

Total Effort: 12 person x months

Documentation:

Haiden, T., 2003: Forecasting stratus formation: experiments with a 1-dimensional model. *ALADIN Newsletter 24*.

Haiden, T., 2004: Improvement of low stratus forecasts. Proceedings, *13th ALADIN Workshop,* Prague.

Code availability: HMS, ZAMG

2.2 CAPE and deep convection triggering (P2)

The problem of parametrizing deep convection at resolutions in the 4-7 km range (sometimes called the 'grey zone'), as well as systematic precipitation forecast errors have prompted investigations on the triggering of convective precipitation. As a first step, predicted convective rainfall was validated against radar and surface observations for an extended period during the summer of 2003. It was found that ALADIN usually overestimates the speed at which diurnally forced convection develops, and that certain topographically favored areas receive rainfall on an almost daily basis, contrary to observations. Also, the spatial characteristics of the modelled precipitation are quite different from the observations. In the model, large areas receive small precipitation amounts, whereas in the real atmosphere precipitation is concentrated into smaller, higher-intensity clusters. Searching for the causes of these biases, it was found that in mountainous terrain there is too much moisture over certain regions of the Alps. Thermally-induced upslope flows carry moisture to higher levels and thereby favors cumulus formation and even convective precipitation over peaks on days when nothing was observed (Wimmer, 2003).

In view of the fact that triggering of deep convection happens too early in the model, experiments were started on modified trigger functions. The most successful of these experiments was the one where cumulated moisture convergence was introduced as a third condition, in addition to instantaneous moisture convergence and CAPE. The goal was to mimic the build-up stage of convective developments within the framework of the current diagnostic scheme. It was also hoped that a more realistic onset time of convection would, as a by-product, produce more realistic spatial rainfall patterns. This was actually confirmed by the experiments. Modelled precipitation patterns became more concentrated into higher-intensity clusters and thus more similar to radar observations (Bellus, 2003). There were also experiments with a time-delay equation for moisture convergence which consists in a modification of moisture convergence as an combination of the instantaneous and old values. However, it was found that manipulating the input in this way (without any explicit changes in triggering) does not give results like those achieved by the additional triggering condition. In their current form, none of these experimental approaches can be used operationally and there will be further research on creating the same effects through the entrainment parametrization. Nevertheless, the investigation has shown that better timing of convection will be beneficial to its spatial evolution, which is an important conclusion.

As a first step towards the ominous 'grey zone', convective rainfall predictions on 7 km and 10 km resolution were compared. Even though the area investigated contained alpine topography, there was very little change in rainfall patterns. The systematic errors diagnosed at 10 km are equally present at 7 km. A more significant effect is expected from changing, at a given resolution, the topography from envelope to non-envelope, which is planned for 2004.

Actions:
- *Quasi-operational verification of ALADIN convective precipitation forecasts, both qualitative and quantitative (FW, TK) (partially fulfilled)*
- *Perform the direct overlay of the trigger conditions (CAPE, moisture convergence) with radar images. (SG) (not fulfilled)*
- *Compare CAPE computed from modelled and observed T2m,Td2m (FW) (fulfilled)*
- *Cases study of ALADIN on finer scale (7 km, 4 km) to evaluate the resolution dependency (FW) (partially fulfilled)*
- *First experiments with modified trigger/closure assumptions (MB) (fulfilled)*

Contributors: Martin Bellus 2 months (1 month at ZAMG),
Stefan Greilberger, Franz Wimmer (3 months)
Tomislav Kovacic (6 months)
Thomas Haiden (1 month)

Total Effort: 12 person x months

Documentation:
Bellus, M., 2003: Deep convection triggering experiments. ALADIN-LACE report, 14p.
Wimmer, F., 2003: Convective activity in ALADIN-VIENNA. ALADIN-LACE report, 6p.

Code availability: ZAMG

2.3 Orographic drag (P3)

The ultimate goal of the orographic drag parametrization is to replace the envelope topography by a mean topography. This would have positive effects on the simulation of the boundary layer in mountain areas and would improve data assimilation in those areas. It is also expected to have a positive impact on the simulation of deep convection. After a first suite of validation and tuning experiments, it became apparent that a re-formulation of parts of the drag scheme is necessary. The new scheme, following ideas and methods presented in Geleyn et al. (2003) is based on three main proposals: (a) a new theoretical justification for the proportionality between wave drag and mountain height at inverse Frounde numbers above the critical value, (b) a new vertical partitioning of gravity wave drag deposition, and

(c) application of the lift force to the geostrophic rather than the actual wind. The implementation of thses concepts has for the most part been completed and is now ready for further testing and tuning.

Actions:

- *Case studies with and without envelope, on different resolutions, down to 4 km. (DD) (partially fulfilled)*
- *Comparison of modelled orographic precipitation, with and without envelope, with observations (YW)) (fulfilled)*
- *Tests of the combined effect of the Lopez microphysics scheme and non-envelope setting (not fulfilled)*

Contributors: Dunja Drvar 2 months (6 weeks at Meteo France)
Yong Wang 1 month

Total Effort: 3 person x months

Documentation:
Drvar, D., 2003: Reduction of envelope and optimisation of subgrid orographic drag parametrization in ARPEGE. ALADIN report, 13p.

Code availability: METEO France

2.4 Physics/dynamics interface (P4)

An important step in the evolution towards ALADIN-2 is a clean and transparent interface between the adiabatic part of the model and the various physics subroutines (P4). In 2003, work was done on the so-called GMV/GFL array structure (Hamrud, 2003), allowing a more straightforward implementation of additional prognostic variables in the model. It was phased into CY27 (Tudor, 2003) and will be available through the CY28 export version in March 2004. Central to the work was the phasing of the physics-dynamics interface for the predictor-corrector (PC) scheme, which required some new development, in order to obtain a consistent treatment of physics tendencies.

Actions:

- *Design a flexible physics/dynamics interface that can accomodate new microphysics (new types of variables) (MB, LK) (fulfilled)*
- *Perform the essential preparation steps for later AROME developments (MB, LK) (fulfilled)*

Contributors: Martin Bellus 1.5 months in TLS
Laszlo Kullmann 3 months in TLS
J.-F. Geleyn (supervisor)

Total Effort: 4.5 person x months

Documentation:
Tudor, M., 2003: A short description of physics/dynamics interface in the new data flow. ALADIN report, 16p.
Tudor, M., 2004: Robustness of the physical parameterization schemes. Proceedings, *13th ALADIN Workshop,* Prague.

Code availability: METEO France

2.5 Miscellaneous

The diagnosis and investigation of physics instabilities was continued in 2003 (Tudor, 2004), and will be extended to Meso-NH routines in 2004. There were also studies on the tendency of the model to produce too often very intense 'meso-cyclones' of 200-300 km diameter in the mid-troposphere, producing heavy rainfall. The problem appears to be connected to latent heat release but a more detailed investigation is needed.

The extensive test of the mountain drag/lift effects in the ACDRAG parametrisation scheme, co-ordinated by Jean-Francois Geleyn, were performed in Toulouse and Prague. The achievements were presented on 13th ALADIN Workshop (Geleyn, J-F.2004).

References

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Tudor, M., 2004: Robustness of the physical parameterization schemes. Proceedings, *13th ALADIN Workshop,* Prague.

Wimmer, F., 2003: Convective activity in ALADIN-VIENNA. ALADIN-LACE report, 6p.

Xu, K.-M., and D. A. Randall, 1996: A semiempirical cloudiness parameterization for use in climate models. *J. Atmos. Sci.,* **53,** 3084-3102.