TT dynamics ALADIN/HIRLAM

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OUTLINE

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Concern 1 : Scalability

- Gridpoint to spectral transform and back at every step enable the efficient solving of an implicit system that, in combination with the semi-lagrangian advection scheme, allows to use large timesteps.
- Those transforms require global communications that might become more and more expensive on future generations of HPC.
- In the past 15 years some scientists kept on announcing the collapse of spectral methods in the next few years.
- A recent simulation with ARPEGE using 82 millions points (that would correspond to a 9000x9000 gridpoints LAM) shows that the model is still cost-efficient despite the spectral transforms. More impressive recent experiment on IBM summit up to 4800 nodes, still a good scalability of spectral NH core.

Concern 2 : Steep slopes

- The increase of horizontal resolution leads to steeper slopes in the orography as it is represented in the model. Since the model layers follow the ground this induces instability. With the latest model improvements, the current horizontal grid spacing limitation for a domain over the Alps is around 300m.

Concern 3 : Evolution from ECMWF (1/2)

- Our models did benefit a lot from ECMWF cooperation (data assimilation, some parts of the dynamics, radiation scheme...).
- ECMWF developed a new core: FVM, a non-spectral NH system that uses a different set of equations on the same horizontal grid and with different vertical levels. It is currently under evaluation but should not become their reference system at least in the 10 years to come.
- On shorter terms, up to 2030, ECMWF intends to keep operational the historical spectral IFS, possibly using our NH options. For later terms spectral kernel should be maintained and still used for some configurations for a while.

Concern 3 : Evolution from ECMWF (2/2)

- Evolution concerning code structure : a large part of the source code should be ready for running efficiently on GPU by 2024, and the ATLAS-based structures should replace the current structures meaning that IFS might operationally work as well with the ATLAS library
- Lots of new features concerning software infrastructure : the use of SCA abstraction in combination to DSL (CLAW) that should help us being more efficient on various architectures.

Solution to scalability

- The gridpoint response when simulated in the spectral core do not alter the quality of the model on A-grid (Phd).
- We successfully managed to solve the implicit problem in grid space in an AROME configuration and some extended testing with different solvers and multi-grid approach have been performed.
- Actions :
  - Continue the work on full grid-point, work on solvers. Two options are possible : either to wait for an operational ATLAS to implement our grid-point solutions or to immediately go further with the testing. Currently we are not far from a full gridpoint LAM kernel.

Improving steep slove limitation

- We are quite confident with the stability down to 500m grid-spacing, which is enough for covering our operational needs for the next 5 years. For the 5-10 years terms we might want to set up local configurations with refined gridspacing
- Plan of actions :
  - Explore the actual limits of the dynamics in terms of horizontal resolution, with the latest equations development (at least going down to 300m gridspacing should be feasible).
  - The ICI scheme do not converge when the number of iterations is increased This misbehavior must be investigated.
  - A new formulation of fully compressible mass coordinate equations has been successfully developed. It is based on the use of a new prognostic variable for the vertical wind, reducing the effects of slopes on the surface boundary condition. The testing should be taken further.
  - Another option to improve stability is to include orography in the basic state used for the implicit system. The work has started on the topic and should be continued.

Keep on improving the quality of the core

Planned actions :

- The influence of the way orography is implemented in the model on the stability must be further investigated. Today we are forced to cut orography at the domain boundary, some smoothing close to domain boundary might help. The spurious oscillations that were observed at 1.3km horizontal resolution forcing an off-centering of the time-scheme is something we would like to get rid of.
- The vertical diffusion may become partly resolved in high resolutions and its interaction with horizontal diffusion (SLHD) has to be more understood.
- It might be possible to make the current available and stable ICI scheme less expensive for example applying corrector only "when needed".
- The vertical finite element (VFE) options should continue to be developed and tested
- There is an initiative to reduce the file size of the LBC files, it would be interesting to compress data regarding the vertical level (for example we could apply averaging when going to sparse levels near the LAM model top).
- The coupling frequency could be increased, moving from 3-hours to hourly coupling, the size of the coupling zone is also something that must be carefully tuned.
- Advection is an important topic, with the use new physics-related prognostic variables, the cost and the accuracy of the lagrangian computations must be carefully looked at. Here we can rely on the innovation developed at ECMWF.

Developing a new core

- When ?
  - If the research and development actions taken fail to overcome the stability issues the only remaining option would be to develop a new dynamical core. Another external constraint that would prompt us to develop something new is if the models ARPEGE and IFS start using another core. In one or two years, results with full physics FVM including performance should be available and a plan for moving to FVM might be eventually available.
- This new model would be using the ATLAS/OOPS framework. The set of equations, vertical leveling and advection could be entirely or partially based on FVM. In this regard we want to assess the pros and cons of using different FVM components for our system.
- To this purpose building a set of LAM reference cases could be done, this can also be very useful to test different options of our current core.
- Care must be taken to match the left hand side of the equations (choice of the thermodynamic variable) and it would be advantageous to use prognostic variables quantities with smooth and regular variations (potential temperature associated with the moist-air entropy).

Conclusion from last week meeting with ECMWF

- Oral conclusions from last week meeting :
  - *Keep together the code IFS/ARPEGE as close as possible and also in association with Aladin/Hirlam*
  - *Joint commitment ot ATLAS*
  - *Agree to use join resource as effectively as possible to meet requirements driven by both organization HPC procurement timelines where do we need to be with respect to atlas to allow sufficient GPU capabilities for benchmark*
  - *FVM : we go further together (including lam + stretched)*
  - *Develop a plan for FVM lam experimentation within 1 year*

How

- The current workforce in the dynamics enable us to maintain our model and allows us some exploration for future improvement, but in the same framework.
- Developing a new kernel would require a bigger effort and require collaboration.
- High-level programming and GPU-related knowledge will be the necessary skills that we will need in the next few years. We will probably rely on collaboration with ECMWF concerning code reorganization.
- Necessity to participate in funded projects.

Summary/Conclusion

- Tasks to be done :
  - Obvious tasks : continue current improvements (VFE, more stable formulations, grid-point operators…) all what has been already started with success.
  - More or less constrained work : adaptation to ATLAS, DSLs.... but this should enable us to improve readability and performance on future architecture.
  - Less clear actions : Develop something new, clearly in the context of ATLAS and based upon FVM. But should we start with the development of a LAM version or with the evaluation of some parts like the advection or vertical coordinate ? Should we start now or wait a bit for FVM to deliver scores and performance comparison.

Timeline

- Timeline proposition