Scalability concerns for the current dynamical kernel of ARPEGE/AROME NWP models.

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Outlook

Main features of ARPEGE/AROME Dynamics

Worries about scalability property of Spectral SISL technology

Summary of our views on the dynamical core aspect

Météo-France NWP models

ARPEGE :

- Hydrostatic global operational model at Météo-France.
- Essentially same software as IFS developed through 27 years of close cooperation with ECMWF.

AROME :

- NH compressible Limited-area model (LAM).
- Shares as much as possible the same code as ARPEGE & IFS.
- NH option codeveloped with scientists from countries members of ALADIN consortia.
- AROME is used by some HIRLAM countries under the name HARMONIE.

Main dynamical features of ARPEGE/AROME

- Euler compressible system of equations based on Laprise's 92 formalism/coordinate : (NH$\rightarrow$ H easily switchable).
- Semi-implicit (SI): Stabilizes fast moving waves at the cost of solving a 3D Helmholtz elliptic problem.
- Spectral (SP): Legendre/Fourier (Global), Bi-Fourier (LAM) $\Rightarrow$ enables high-order of accuracy and powerful for solving a separable form of the implicit problem.
- Semi-Lagrangian (SL) transport : combined with SI, allows large timesteps (Courant number > 10).

Scalability concerns about Spectral SISL

Spectral SISL technology has been applied successfully at Météo-France and other locations for the last 25 years ..., but, there are some worries about its strong scalability property for computing on massively parallel computers for science today.

1. Spectral $\Rightarrow$ Global communications for transposition (2D memory transfert).
2. SL transport $\Rightarrow$ increase number of increase number of inter-mpi-tasks for large advective courant numbers can ruin the efficiency of the method.

Alternatives to Spectral, trying to keep the grid

Exploring local methods on the current collocation grid and with long timesteps (SI) that preserves grid structure of existing code.

1. Revisiting High-order Finite differences SISL methods on lat-lon reduced A-grid $\Rightarrow$ "a minimal change" strategy in the existing code, (recent investigation by P. Bénard).
2. Revising SISL finite-element method on Z-grid $\Rightarrow$ Extra 2D Poisson solvers, (S. Caluwaerts PhD's Belgium, IRM and Univ. of Ghent within ALADIN consortia).
3. Keeping an eye on Edged-based Finite-volume method on unstructured A-grid-like with SI treatment, (but SL does not seem very easy on this mesh).

Implications for SI schemes

Local space discretization methods ⇒ Use of elliptic gridpoint (GP) 3D solvers for solving implicit problem.

- **Advantage** : possible implicit treatment of orographic forcing terms ⇒ gain in stability for steep slopes, (Caluwaerts PhD).
- **Drawback** : need for efficient 3D solvers ⇒ practical scalability for NWP still to be assessed.
- **Fallback if 3D solvers not efficient enough** : Horizontally Explicit Vertically Implicit schemes. Feasibility study of HEVI temporal schemes in Laprise's 92 formalism of fully compressible system. (Ch. Colavolpe, MF's PhD starts).

1. Preserving SISL : Dimensioning of Halo size for limiting communications $\Rightarrow$ moderate Δt $\Rightarrow$ Loss of interest of SL.
2. Back to SI Eulerian : not really enthusiastic $\Rightarrow$ too much stability control of Δt.
3. Non-oscillatory forward-in-time transport methods : equations cast in flux-form $\Rightarrow$ Δt imposed by accuracy only.
4. Explore high-order transport methods combined with HEVI schemes (Colavolpe PhD).

Summary of our views on the dynamical core aspect

1. Replace Spectral by high-order local discretizations, trying to keep the current grid-structure

   → main caveat : need for efficient Helmholtz 3D solver

2. Explore alternative approaches : HEVI schemes, other vertical coordinate and horizontal grids.

   → drawback : nearly impossible to explore in existing code.

3. Define interfaces with physics and data assimilation allowing to plug and test alternate dynamical cores.

   → useful for possible convergence with PantaRhei idea.

4. Strong interest in designing consistent set of equations. considerable effort in that direction at MF and in ALADIN consortia.

Collaborations

- Maintain our collaboration with ALADIN consortia and HIRLAM countries.
- Preserve longtime collaboration with ECMWF.
- Try recently to gather existing expertise from French numerical modelling community (e.g, INRIA, IPSL,CERFACS) through Highly-Efficient ATmospheric modelling (HEAT) project, which is being submitted.