Atmospheric Model Unification at NCAR
Singletrack

Dynamical Cores working group

Facilitators: Bill Skamarock, Peter Lauritzen;
input from a lot more people

1. Dynamical core requirements for the range of applications for which a unified atmospheric modeling system will be used.
2. Where we are today.
3. Roadmap for what needs to be done for dynamical core(s).

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Singletrack – Dynamical Cores

Climate:

coarse resolution: 1 degree (100 km)
High resolution: ¼ degree (25 km)
Years – thousands of years simulated time.

Weather:

Standard/coarse resolution: 1/4 - 1/8 degree (25-12 km)
High resolution O(1) km.
Hours – months simulated time.

Geospace:

Spanning climate and weather resolutions.
Very high model top (600 km).

Dynamical core wish list

Essential: Judged necessary for some application(s)

Desirable: Would be nice to have for some application(s)

Highly Desirable: Would be really nice to have for some application(s)

Blank: Don't care, or none of the above

	capability/characteristic	Climate	Weather	Geospace
(1)	Throughput: cost and scalability	Essential	Essential	Essential
(2)	Strong scaling	Essential	Desirable	Desirable
(3)	Efficient tracer transport	Essential	Essential	Essential
(4)	Conservation of mass (dry air, scalars)	Essential	Essential	Essential
(5)	Good tracer transport characteristics (shape-preservation, correlation, etc.)	Essential	Essential	Essential
(6)	Good conservation of total energy	Essential	Desirable	Essential
(7)	Conservation of angular momentum	Highly desirable		Essential
(8)	Dycore characteristics with topography			
(9)	Non-hydrostatics	Desirable	Essential	Highly desirable
(10)	Global mesh-refinement capability	Desirable	Essential	Essential
(11)	Regional capability		Essential	
(12)	Cartesian geometry	Desirable	Essential	
(13)	Data assimilation capability. Has to play well with DA	Desirable	Essential	Essential
(14)	Support simplified setups on the sphere	Essential	Essential	Essential
(15)	Support by developers	Essential	Essential	Essential

Dynamical core wish list

Specific for geospace modeling

		Climate	Weather	Geospace
(16)	Stable over 30 scale heights (~700km)/O(13) in pressure			Essential
(17)	Efficient 2 way 3D inline grid coupling			Essential
(18)	Species dependent mean molecular mass and specific heats			Essential
(19)	Deep atmosphere: variation of gravity, Coriolis force and geometry			Highly desirable
(20)	High top thermodynamics (prefer solving thermodynamic eqn. with T rather than theta, which is not well defined above homopause)			Essential

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Weather: WRF and MPAS

- Nonhydrostatic.
- Global (primarily MPAS) and regional (primarily WRF, MPAS soon) capabilities.
- Local refinement capabilities.
- Tested for weather applications with WRF physics.
- Neither WRF nor MPAS are available to the community in CESM/CAM, although MPAS V4 is being run in CAM.
- Plans and schedule for supportable/sustainable MPAS port to CESM, including regional capability.
- MPAS extensions for geospace applications are being examined.

Atmospheric Model Unification at NCAR
Singletrack – dynamical core status

Climate: SE core, Spectral core, FV core

- All are hydrostatic
- All are global.
- SE core allows local refinement within the global configuration.
- Tested for climate applications with CAM physics.
- All are available to the community in CESM.
- FV core used in geospace applications, however, it is hydrostatic and solves the shallow-atmosphere equations.
- FV core is effectively frozen.
- FV3 port, supported by NOAA, is ongoing.

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Working group is addressing the following:

- Ensure the mass budget in the system as a whole is closed.
- Ensure some level of energetic consistency between the dynamical core and physical parameterizations, or at the very least quantify energy leaks in the system as a whole.
  - Do the continuous equations of motion conserve the same total energy as used by parameterizations (assuming the parameterizations have a closed energy budget)?
  - What total energy formula should we use (e.g., include condensates or not)?
  - Are the discrete total energies the same in the dynamics and physics? Not trivial if, for example, different vertical coordinates are used in dynamical core and physics.
- Ensure that the way in which the physics tendencies are added to the dynamical core leads to a closed mass and total energy budgets.

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Singletrack – dynamical core roadmap

Climate:

- Port of FV3 to CESM/CAM (ongoing, NOAA supported).
- Testing of SE, MPAS and FV3 to assess how well they satisfy dynamical core requirements, beginning at 1 degree resolution (CESM3).
  - Idealized configuration testing.
  - Full physics testing.
- Plans for nonhydrostatic SE core development (no schedule). This would precede extension to deep-atmosphere and full geospace capability (no schedule).

What to expect in the near future

- Testing of dynamical cores for CESM3 as they become available.

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Singletrack – dynamical core roadmap

Geospace:

- No core satisfies important geospace requirements (deep atmosphere, nonhydrostatic, etc). Comprehensive plans/resources/timelines have not yet been formulated for evolving any of the cores.

What to expect in the near future

- A plan

Atmospheric Model Unification at NCAR
Singletrack – dynamical core roadmap

Weather: WRF and MPAS

- Plans and schedule for supportable/sustainable MPAS port to CESM, including regional capability (as an external model).
  - Goal is to attain same efficiency and scalability as stand-alone MPAS.
- MPAS extensions for geospace applications are being examined.
  - Full (deep atmosphere) equations.
  - General state equation, 3D gravity, etc.
  - Coupling to ionosphere/thermosphere models.
- Common Physics Framework (CPF) in standalone MPAS, CAM and WRF (see Dave Gill's talk after this one).
- Plans for evolving CAM workflow for weather applications.
- No plans to implement WRF as an external model in CAM.

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Singletrack – dynamical core roadmap

What to expect in the near future

Weather:

- MPAS could/should be available in CESM for coupled simulations soon (next year)? What is needed:
  - Successful port of MPAS as CESM external.
  - Reasonable efficiency and scalability compared with stand-alone MPAS.
  - Successful Common Physics Framework implementation and availability of WRF/MPAS physics in CAM.
  - Workflow suitable for weather applications.
  - Ability to run coupled to other components (ocean, land, ice, etc).
- WRF/MPAS will have access to CAM physics, and vice versa, through the CPF.