GASS Project Proposal: Numerical Treatment of Physics-Dynamics Coupling in Atmospheric Models

Hui Wan (Hui.Wan@pnnl.gov) and Ben Shipway (ben.shipway@metoffice.gov.uk)

Along with availability and use of observations, improvements in the skill of Weather and Climate models over the past few decades can largely be attributed to developments of the subgrid physics schemes and increases in model resolution. The latter aspect is the result of development of model dynamical cores that are carefully designed to provide appropriate accuracy, stability and computational performance. Physics scheme developments are also carefully and thoughtfully constructed – and GASS has traditionally focussed on attempting to bring in observations and process modelling to guide such development. However, when these carefully designed components are combined, the errors introduced in their coupling could arguably undermine all that effort.

The intricacies of coupling physics schemes are numerous and varied: different numerical treatments of the dynamical solver lead to different approaches in the physics timestepping; different spatial treatments of physics and dynamics (e.g. finite elements/finite differences/superparametrization) require choices in mapping between them; different choices for the 'partitioning' of continuous equations lead to different approaches to calculating resolved and subgrid terms(e.g. convective transports). We also see different partitioning between physics schemes, e.g. convective vs large-scale cloud/rain or boundary layer vs shallow vs deep convection. In order to make progress in this area, the current proposal seeks to initiate a model intercomparision acitivity to quantify the numerical accuracy of process coupling in current models, to identify error sources, and to understand the relative importance of the coupling errors.

Why now?:

Issues related to physics-dynamics are becoming more pressing as:

- global model resolutions start to push towards the convective 'gray-zone'; removing any notion of a spectral gap in physics scheme design.
- 'weather' features appear on the gridscale and meaning is inappropriately interpreted below the filter scale (both as diagnostic quantities and as input to subgrid physics).
- supercomputer (exascale) hardware development pushes us away from the paradigm of serial computation towards task parallelism.
- New generations of dynamical cores are developed to tackle exascale issues.
- As models become more and more complex, 'tuning' exercises (and thus compensating errors) become more involved. Isolating and tackling a known source of error should be the first step in this process.

Questions:

- How do different models behave when run with different timesteps?
- How does any change in behaviour relate to climate sensitivities or sensitivities in model tuning?
- What metrics are important to evaluate if the process coupling is appropriate?

- Do numerical aspects of process coupling change with the use of a different physics parametrization?
- How do different timestepping strategies influence model evolution?
- What are sensible timesteps for parametrizations? e.g. is current convection parametrization designed to work with <1 min timestep?

Case participants (and all are welcome)

Institute	Model(s)	PIs
PNNL	E3SM	Hui Wan, Phil Rasch
Met Office	Met Office Unified Model (UM), LFRic	Ben Shipway, Terry Davies, Ian Boutle
DWD/MPI	ICON	Daniel Klocke/Marco Giorgetta

Methodology

The issues regarding physics-dynamics coupling are numerous and in some cases specific to the numerical choices made within a given modelling system. The proposal is to explore the aspects set out below with the expectation that additional experiments will be developed along the way and where relevant. Baseline simulations will be relatively cheap to run, while individual groups may explore behaviour at higher resolution or with coupled models.

Model sensitivities: Modellers run present day and climate change simulations.

- Horizontal and vertical resolutions similar across range of models.
- Models run with different timestep sizes to explore the timestep behaviour.
- Short 'NWP-type' runs of several days
- Longer, but still relatively cheap, runs of several years

Reduced models:

- Aquaplanets: As above, but also exploring convergence with Courant number (velocity x time step over grid size)
- Single column models (exploring timestepping of physics schemes in isolation)

Suggested additional sensitivity tests:

- Changes to choices of temporal coupling, e.g.
    - physics updates within an iterative solver or in parallel,
    - drip-feeding/lagging of physics tendencies,
    - sub-stepping of physics schemes.
- Incremental removal/addition of different physics components

One big challenge of this intercomparison is to define model evaluation metrics that are revealing of the numerical properties of different coupling strategies and meanwhile relevant to weather and climate applications. Bringing together expertise on model development and process studies will be crucial for the success of this activity.

Proposed timeline:

2018: First set of participants conduct baseline simulations with “operational” model configuration; Select an initial set of evaluation metrics. Intercomparison results compiled and present at conferences or as publications to attract wider participantion.

2019: Explore additional evaluation metrics, possibly also conduct simulations with reduced models (e.g., aquaplanet and single-column)

2019-2022: Design and conduct numerical experiments involving changes in process coupling and with incrementally removed physics components, aiming at understanding sources of coupling errors.

Links to other activities

The PDC workshop series explicitly targets the issues outlined here. The next workshop is at ECMWF, UK in July 2018. Hui Wan is a member of the PDC organizing committee. DCMIP aims to develop intercomparisons of dynamical cores. In recent years these have started to extend to use simple physics parametrizations. We aim to engage with both of these communities.