WRF Physics: Issues and Future Directions

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Key Physics Applications From WRF Priorities Document

Convection-Resolving NWP

- All physics

Hurricane Research and Prediction

- Surface fluxes, Subgrid turbulence, Microphysics
- Physics ensembles
- Ocean coupling

Regional Climate

- Radiation
- Turbulence and shallow convection
- Microphysics
- Parameterization of convection?

Key Physics Applications From WRF Priorities Document - 2

Ensembles

- All Physics (but application at coarser resolution)

Data Assimilation

- Potentially All physics (Adjoints)
- Should adjoints be of simpler schemes?

Specific Physics Issues

Radiation

Effects of clouds

- scattering and absorption as a function of hydrometeor type and ice crystal habit (especially s/w)

Effects near the surface especially at night (important for surface temperature forecasting)

- sharp vertical gradients of water vapor
- shallow cloud layers and ground fog (feedbacks)

Land-surface schemes

Partial snow cover – Keep separate track of snow-covered and snow-free areas?

Canopy treatment – How complex does one need to be?

Specific Physics Issues - 2

Surface layer and PBL (basic to much that happens in the atmosphere)

How far down in scale is it safe to ignore 3-d turbulence effects (i.e., $\partial/\partial x << \partial/\partial z$)?

Surface fluxes – roughness lengths for momentum and heat

Stable nocturnal BL – $\varphi(z/L)$ stability functions applicable?

Cloud (Cu, Sc) topped mixed layers – don't yet have WRF scheme combining treatment of mixed layer itself and shallow clouds rooted in mixed layer (link with microphysics also)

Specific Physics Issues - 3

Convection

Get to cloud-resolving resolutions as quickly as possible, at least for forecast applications for which deep moist convection is the main concern

Conundrum – Ensembles require coarser resolution

Prediction – regional operational NWP in the USA will require parameterization for at least some applications for the next decade

At cloud-resolving scales

- microphysics and dynamics interactions (e.g., P5.7)
- formulation of 3-d turbulence.

Specific Physics Issues - 4

More Convection

Mass-flux parameterizations – fundamental limitations to the single-column approach for $\Delta x < 10\text{-}15$km

Can the Grell-Devenyi approach of ensemble closures and feedbacks, together with statistical optimal weighting of the ensembles, make substantial improvement in convective schemes?

Are there any promising fresh approaches?

Or, do we just throw up our hands and trust in Moore's Law … oops … petaflop computing?

Specific Physics Issues - 5

Cloud and Precipitation Microphysics

Are there fundamental limitations of single-moment schemes

- too large precipitation efficiency (too much precipitation, not enough hydrometeors aloft) in orographic flow and MCS simulations?
- newer schemes suffer less from this problem than, say, Lin

Can 2-moment schemes be made sufficiently efficient for operational NWP in next few years?

Need link with aerosols (cloud condensation nuclei, ice nuclei), aqueous chemistry

Is it necessary to call microphysics every (large) time step?

Specific Physics Issues - 6

Linkages, feedbacks and synergistic behavior between the physics schemes

Example of the importance of this: Morris Weisman's talk on PBL schemes yesterday

"Tuning" versus concentration on making sure individual schemes are accurate

Uniformity of moist thermodynamics – how important?

Each physics module tends to have its own
  * values of latent heats
  * form of Clausius-Clapeyron Eqn
  * etc.

Some Code-Design Issues

Load balancing

- Dynamical load balancing – may need to consider for complex microphysics and radiation (air chemistry also?)

- Smaller tiles in cloudy areas?

Limitations of single-column physics

- Obvious for very high resolution forecasts when cloud shading is important (s/w radiation)

- Convection parameterization (especially mass-flux schemes)

Some Broader Considerations

Greater accuracy and completeness (usually meaning greater complexity) for physics schemes is a goal

But, for ensembles, diversity and efficiency are necessary

It is important to distinguish between physics limitations that are due to insufficient compute cycles
from
those that are due to lack of fundamental understanding.

The latter need to be more clearly identified and strategies devised to obtain the necessary understanding.

Physics Research Needs

Field campaigns with carefully focused and limited objectives

Detailed numerical studies to examine simplifying approximations and for other purposes

Theoretical and lab work on fundamental physics problems

Possible catalyst: Working groups targeted at specific physics areas (e.g., PBL, microphysics)

- Guiding and coordination of ongoing research
- Design, proposal and organization of field campaigns
- Interface with funding agencies

Beware of creating structures that become self-serving