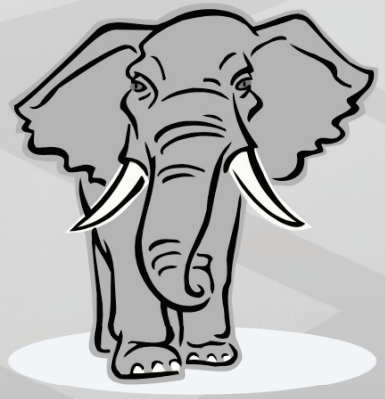
Physics for Multi-Resolution Grids: The Elephant in the Closet

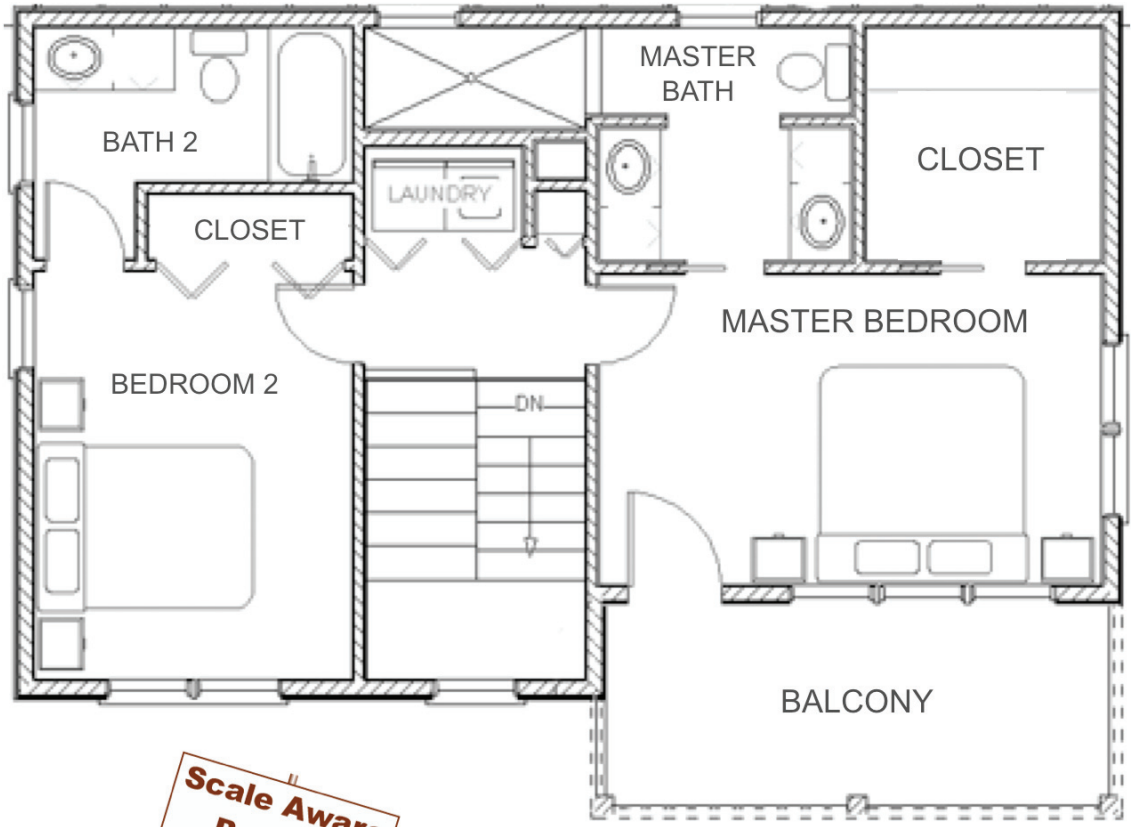


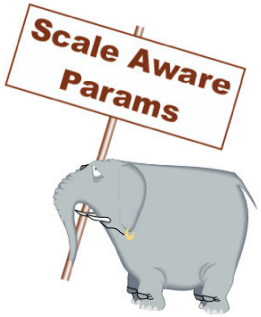
William I. Gustafson Jr.
Atmospheric Sciences & Global Change Division
Pacific Northwest National Laboratory

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by Battelle *Since 1965*

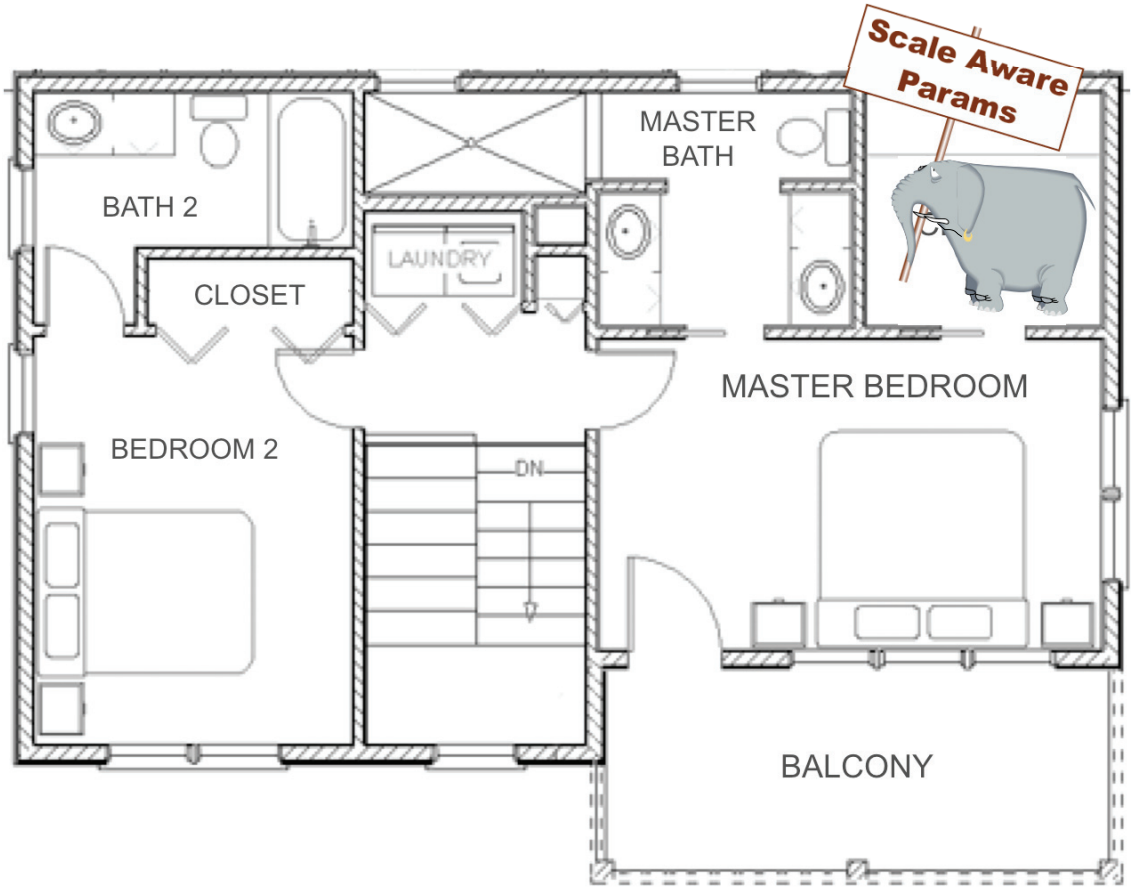
There is an elephant in our modeling house





 House plan: Gillespie Park Houses by Antony Stefan

There is an elephant in our modeling house



 House plan: Gillespie Park Houses by Antony Stefan

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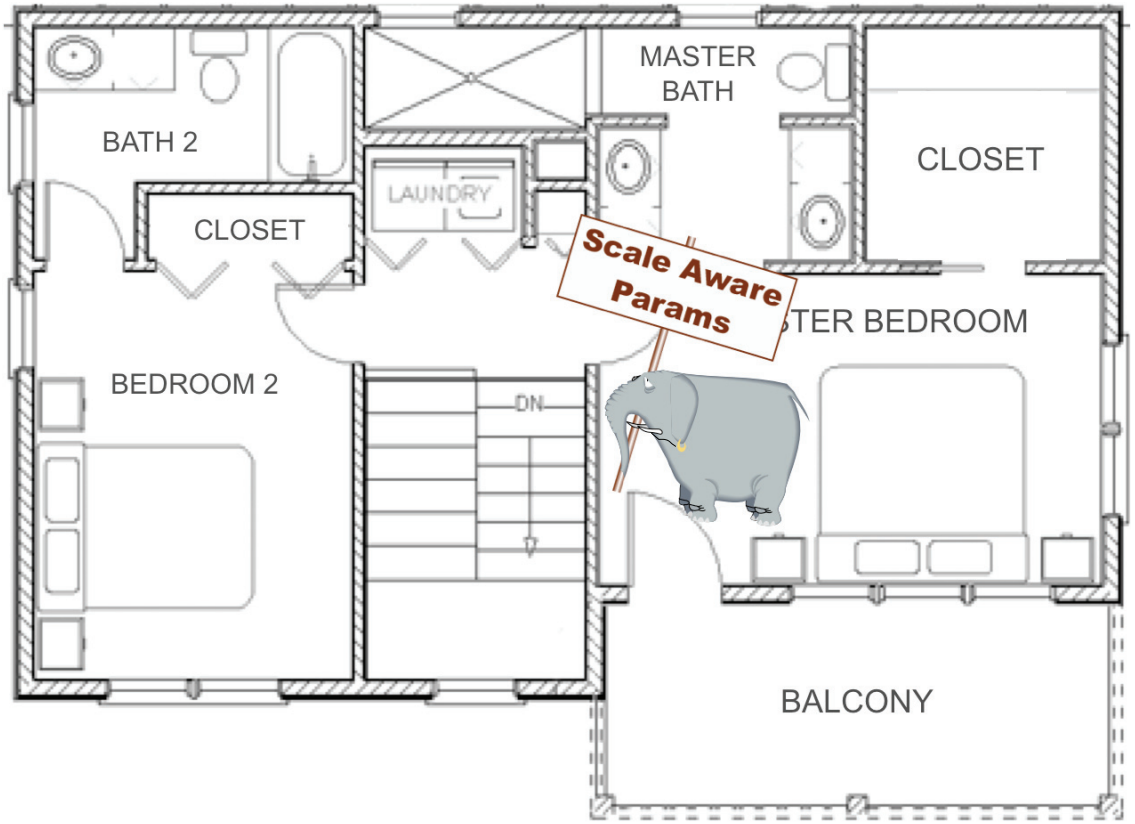


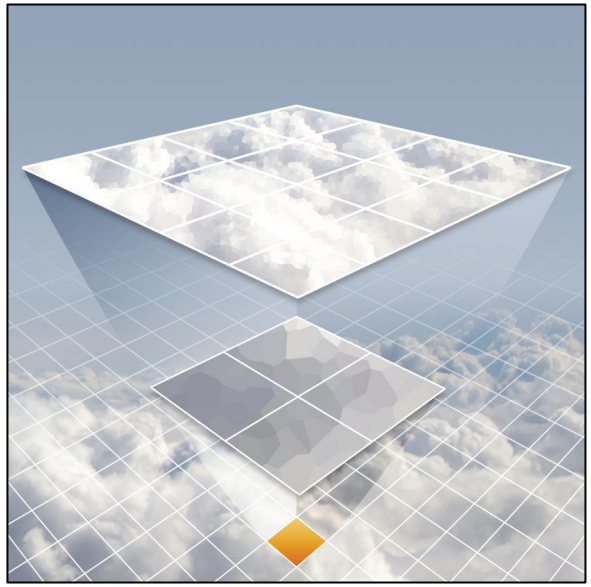
4 House plan: Gillespie Park Houses by Antony Stefan

Issue # I

Convergence

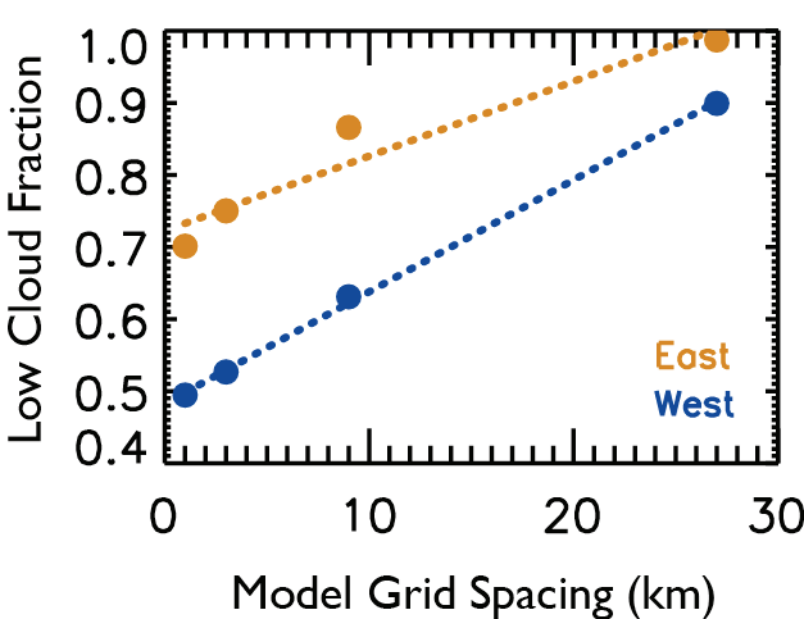
Convergence

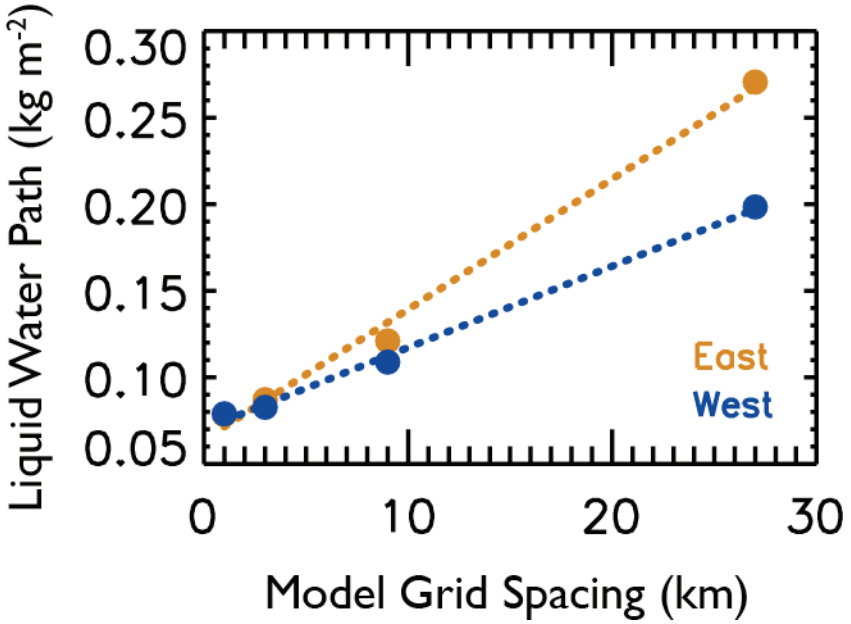
- A numerical model has "converged" if it gives the same answer using a finer grid spacing as it does at a given coarser spacing.
- Range of scales and non-linearities of physics, particularly clouds, precludes convergence in atmospheric models (e.g. Pope & Stratton, 2002).



Lack of convergence

- Example of grid spacing dependence for marine stratocumulus during VOCALS using WRF

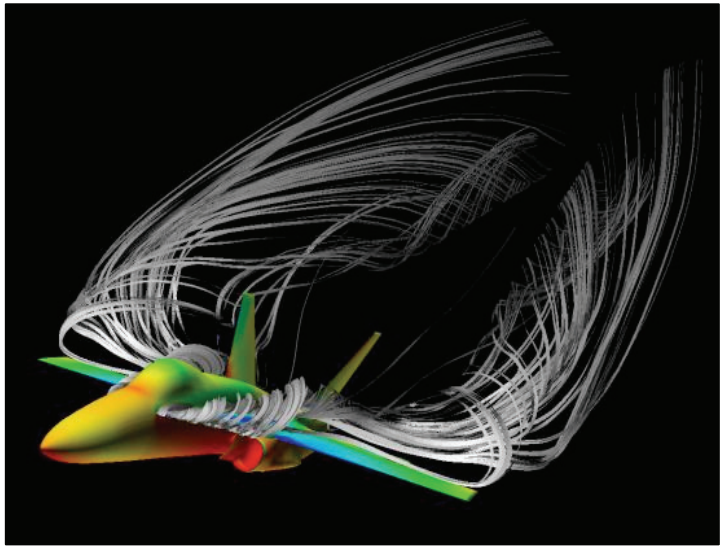




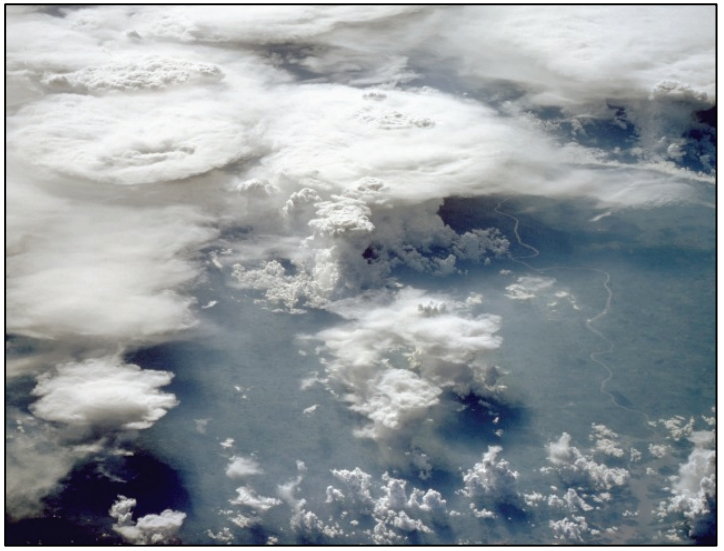
Scale of forcing

- The scale of the forcing is key to reaching numerical convergence

Airplane wing: fixed



Clouds: variable

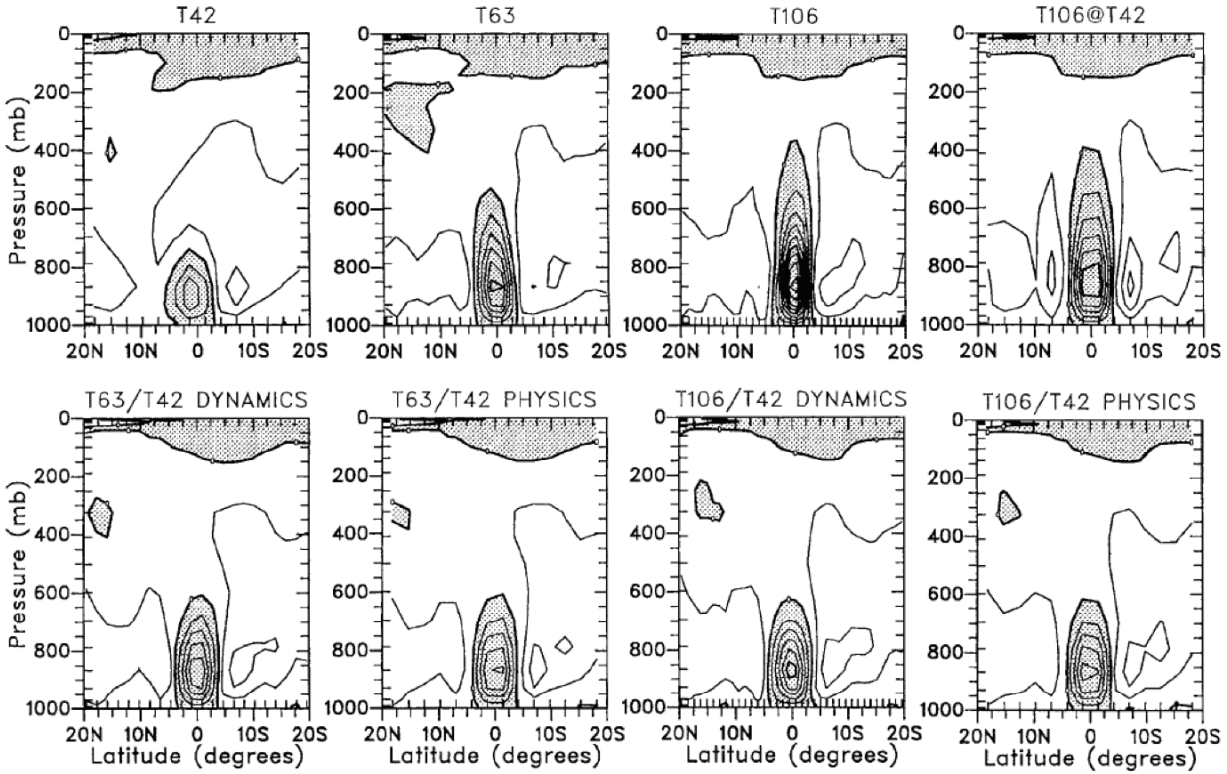


 http://www.aerospaceweb.org/question/planes/q0176.shtml; http://eol.jsc.nasa.gov/sseop/EFS/lores.pl?PHOTO=STS41B-41-2347

Evidence for param. limiting convergence

- Williamson (1999) separated dynamics and parameterizations onto independent grids in CAM2
  - Results reminiscent of a fixed forcing scale leading to convergence

Atlantic Basin Vertical Velocity



 Williamson (1999, Tellus)

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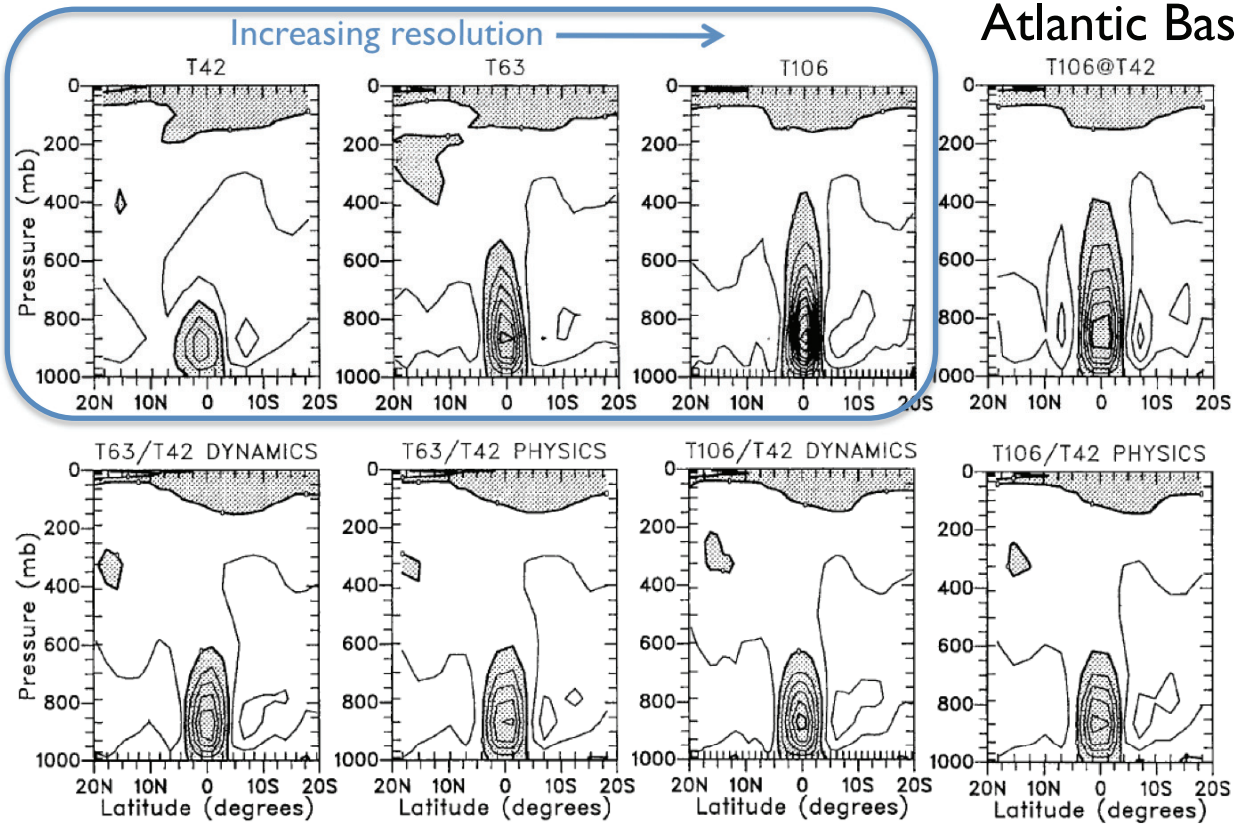

Atlantic Basin Vertical Velocity

Standard model at various resolutions from T42 to T106

10 Williamson (1999, Tellus)

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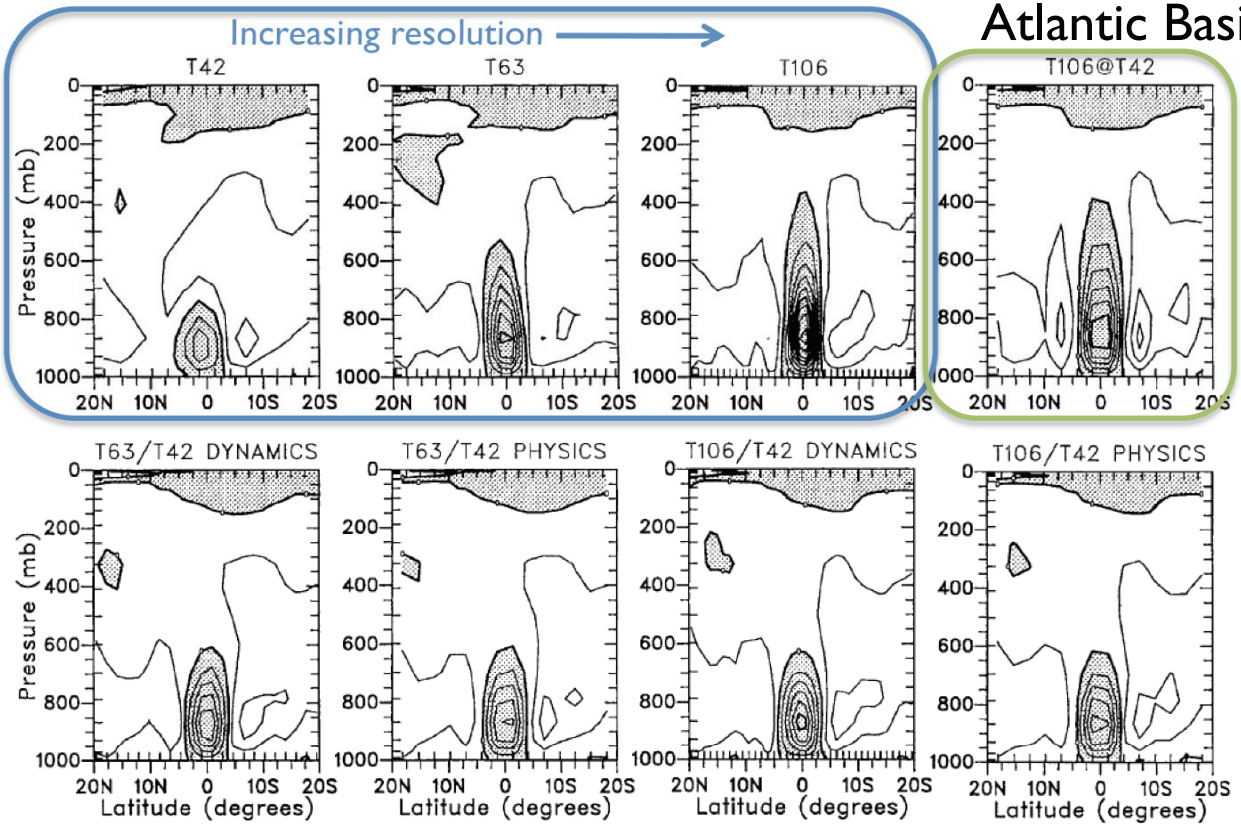

Atlantic Basin Vertical Velocity

Standard model at various resolutions from T42 to T106

Standard model at T106 shown on T42 grid

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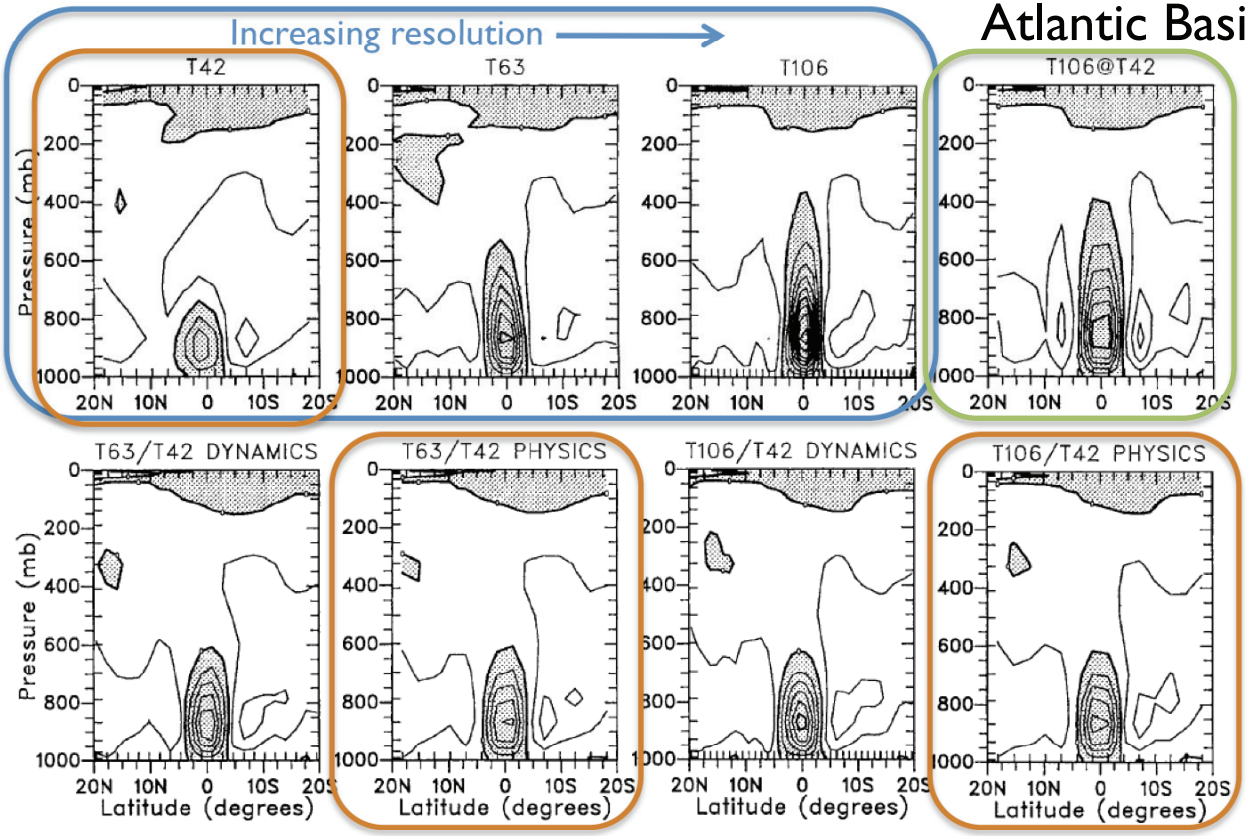


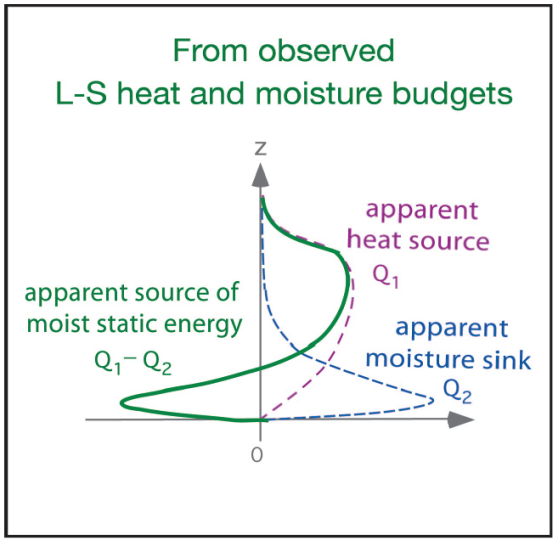
Standard model at various resolutions from T42 to T106

Standard model at T106 shown on T42 grid

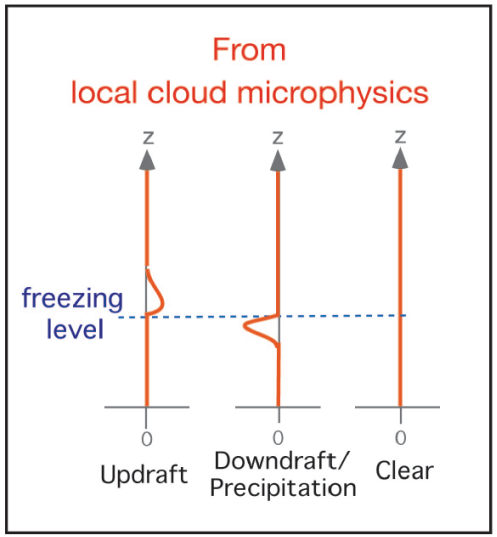
Dual-resolution model with:
Physics @ T42
Dynamics @ T42, T63, or T106
Shown on T42 grid

Scale-dependent tendencies from clouds

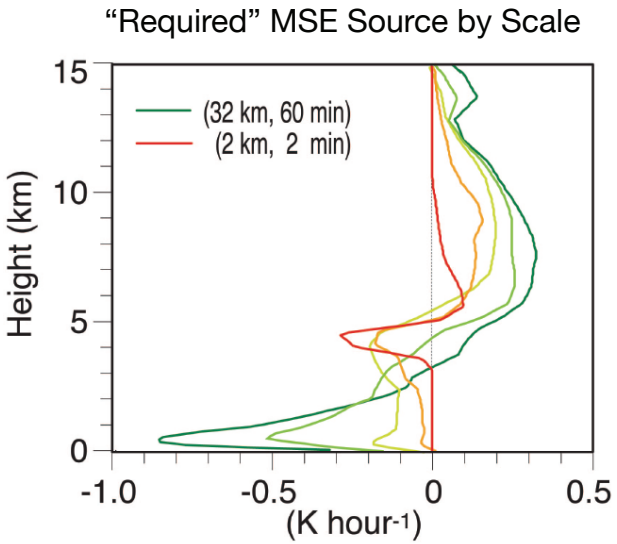
- Average of instantaneous cloud-scale tendencies does not result in the net large-scale tendency over a longer period.
- Interactions between subgrid processes broaden cloud-scale tendencies



GCM-type profile



CRM-type profile

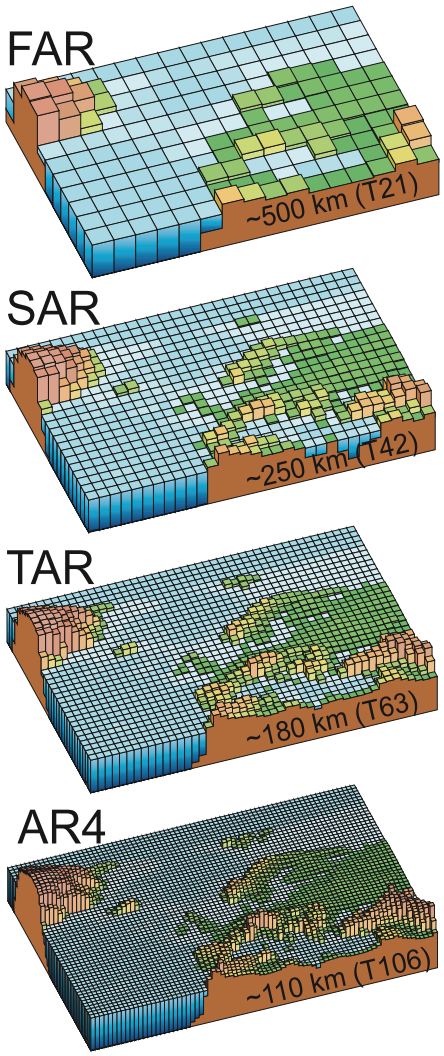


 Arakawa (2011, ACP), see also Jung and Arakawa (2004, JAS)

Issue #2

Radical shift in climate model grids

History lesson: climate model grids

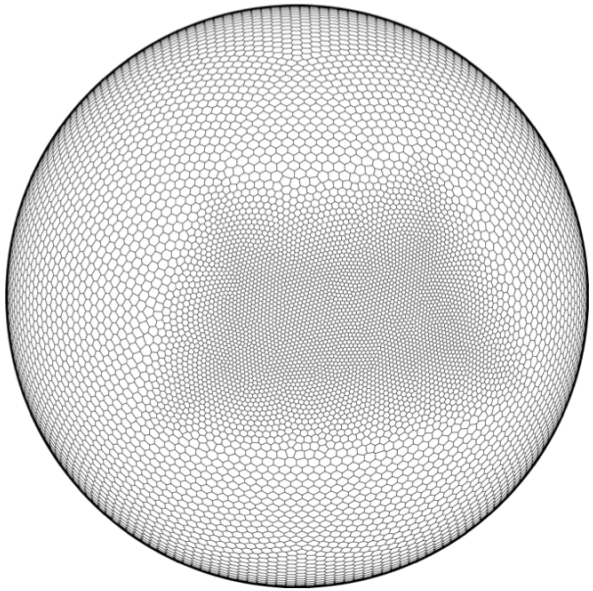


- 1965: First "GCM"
  - dx~500 km, Hemisphere so G=general
- 1990: IPCC 1st Assessment Report (FAR)
  - dx~500 km (T21)
- 2007: IPCC 4th Assessment Report (AR4)
  - dx~110 km (T106)
- 2013: IPCC 5th Assessment Report (AR5)
  - dx~110 km, some ~25 km, MMF

Almost exclusive use of uniform, regular grids.

Radical change in next generation models

- Designed with sub-10 km grid spacing in mind
- Proliferation of unstructured grids
- Include options for variables resolution grids



16 Figures from Michael Duda (NCAR)

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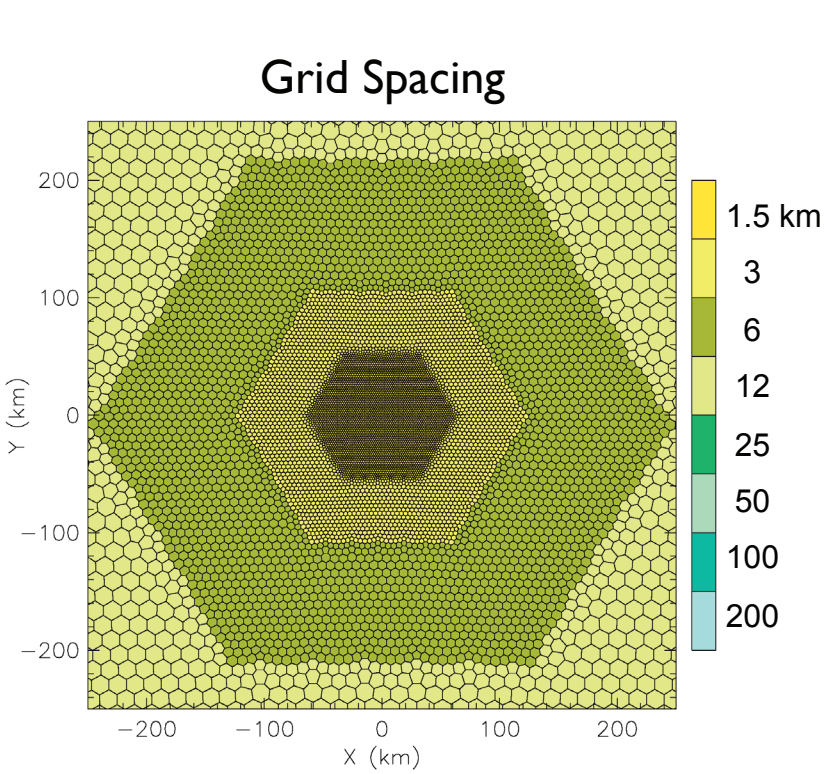
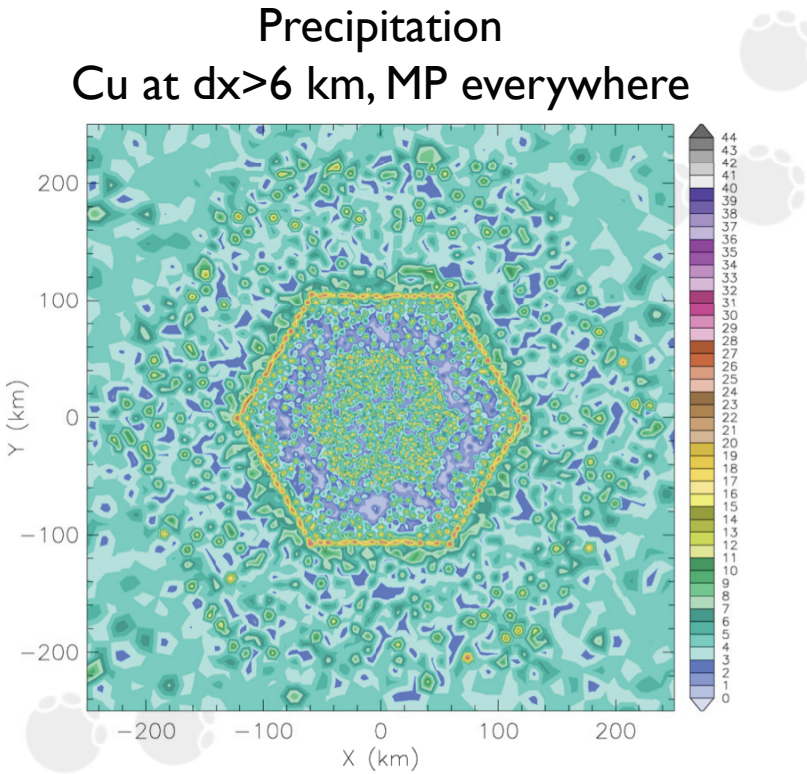
Looking ahead…

Convergence + New Grids = Road Block

Transition issues

- R. Walko demonstrates the parameterization issue at grid transitions using an unstructured, refined grid in OLAM

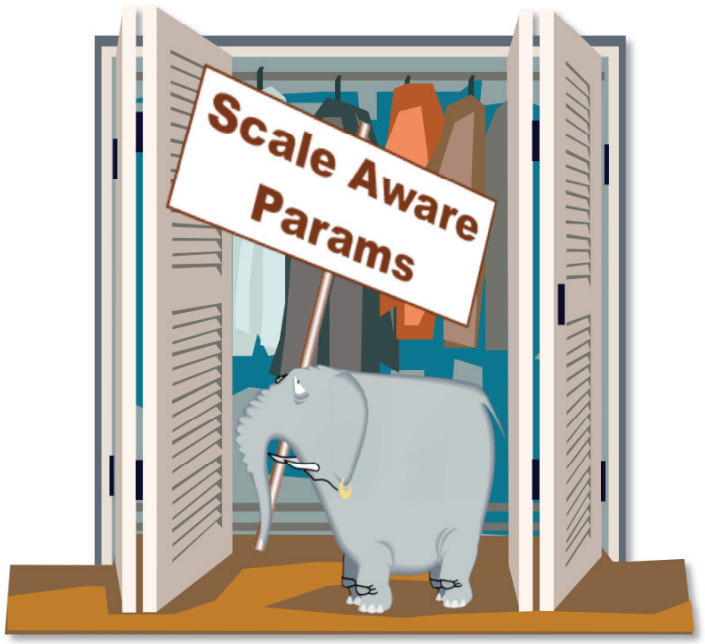




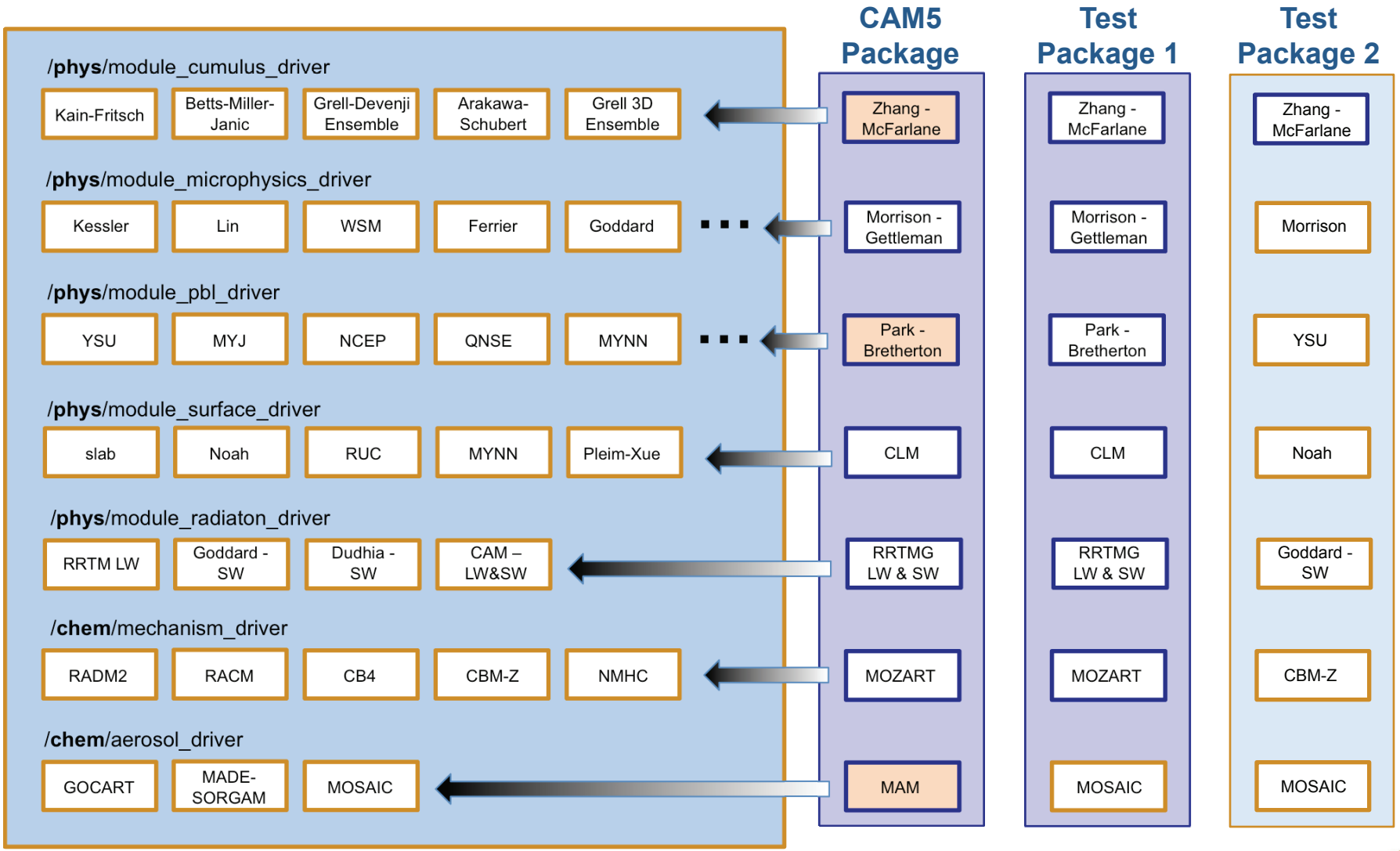
Figures from Walko et al., 2010 Fall AGU Meeting (A24D-07)

Physics requirements for next-gen. models

- Multi-resolution grids require scale-aware parameterizations.
- Until now, we could pick params. that worked well for the grid we were using, e.g. nesting. This will not work anymore.
- The elephant hiding in the closet is about to walk into the room. Are we, as a community, going to invest the resources to see him?

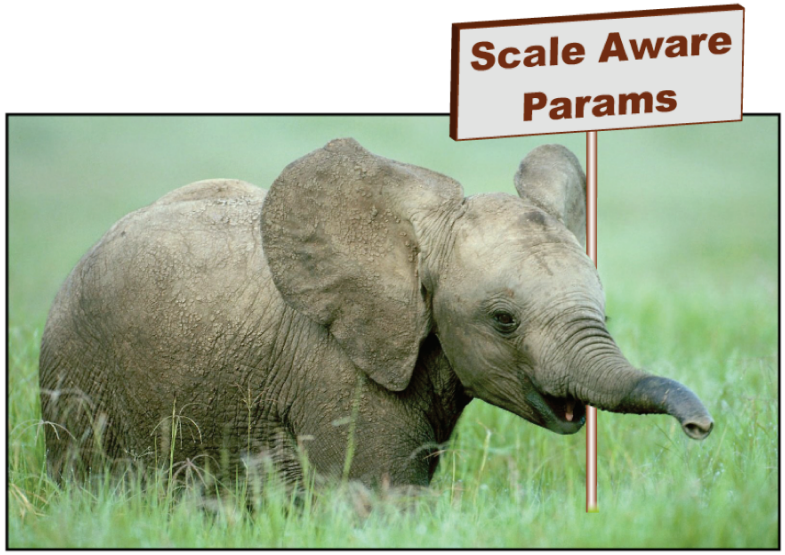


CAM5 Physics Package in WRF



Acknowledgements

- I'm looking for a post-doc interested in this project. Contact William.Gustafson@pnnl.gov for details.



http://www.splendidwallpaper.com

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