Revisiting viscosity coefficients and topography in NCAR CAM-SE

Peter Hjort Lauritzen

Atmospheric Modeling and Predictability Section
Climate and Global Dynamics Laboratory
National Center for Atmospheric Research

Collaborators: S. Goldhaber, B. Eaton, J. Bacmeister, C. Zarzycki, …

CESM Atmosphere Model Working Group Session
21 June 2017
NCAR, Boulder, Colorado

Revisiting viscosity coefficients and topography in NCAR CAM-SE

We are going through a similar exercise with MPAS for the development of CAM6-MPAS

Collaborators: S. Goldhaber, B. Eaton, C. Zarzycki, J. Bacmeister, …

CESM Atmosphere Model Working Group Session
21 June 2017
NCAR, Boulder, Colorado

NCAR UCAR | National Center for Atmospheric Research
Climate & Global Dynamics
climate • models • society

NCAR version of CAM-SE

- **Reformulation of the SE dycore using dry-mass vertical coordinates with a comprehensive treatment of condensates and energy**

  => 1st step towards a more accurate representation of energy in CAM (physics next …?)

  This research is closely related to the integration of non-hydrostatic dynamical cores into CAM that have comprehensive treatment of condensates (MPAS, FV3, …)

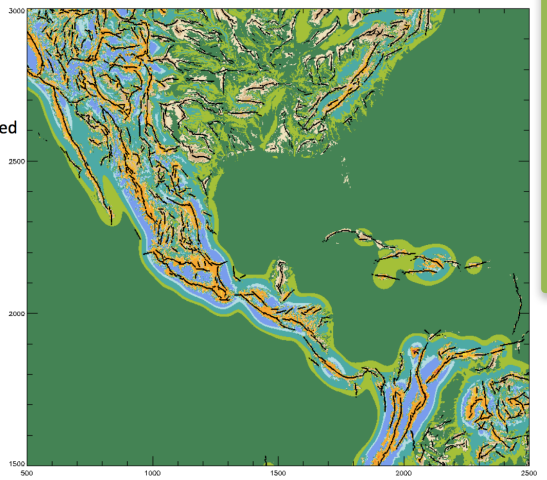
- **Other: SE code resides in CAM repo, control-volume grid can now be produced from CAM (no longer need to run HOMME), massive code clean-up, separate physics grid capability, CSLAM transport, performance enhancements and new threading capabilities (J. Dennis's group; CISL NCAR), ...**

New orographic drag parameterization (J. Bacmeister)

Feature-based ridge identification

Feature scale ~125km

Plotted over unresolved topography: Raw-Smooth(180km)



New variables: Orientation, ridge height, geographically-based estimate of "effgw_oro", ….

Algorithm requires PHIS to be internally smoothed in topo software

https://github.com/NCAR/Topo

Geoscientific Model Development
An interactive open-access journal of the European Geosciences Union

| EGU.eu | EGU Journals | Contact | Imprint |

Geosci. Model Dev., 8, 3975-3986, 2015
http://www.geosci-model-dev.net/8/3975/2015/
doi:10.5194/gmd-8-3975-2015
© Author(s) 2015. This work is distributed under the Creative Commons Attribution 3.0 License.

Volume 8, issue 12

Article | Peer review | Metrics | Related articles

Model description paper — 14 Dec 2015

NCAR_Topo (v1.0): NCAR global model topography generation software for unstructured grids

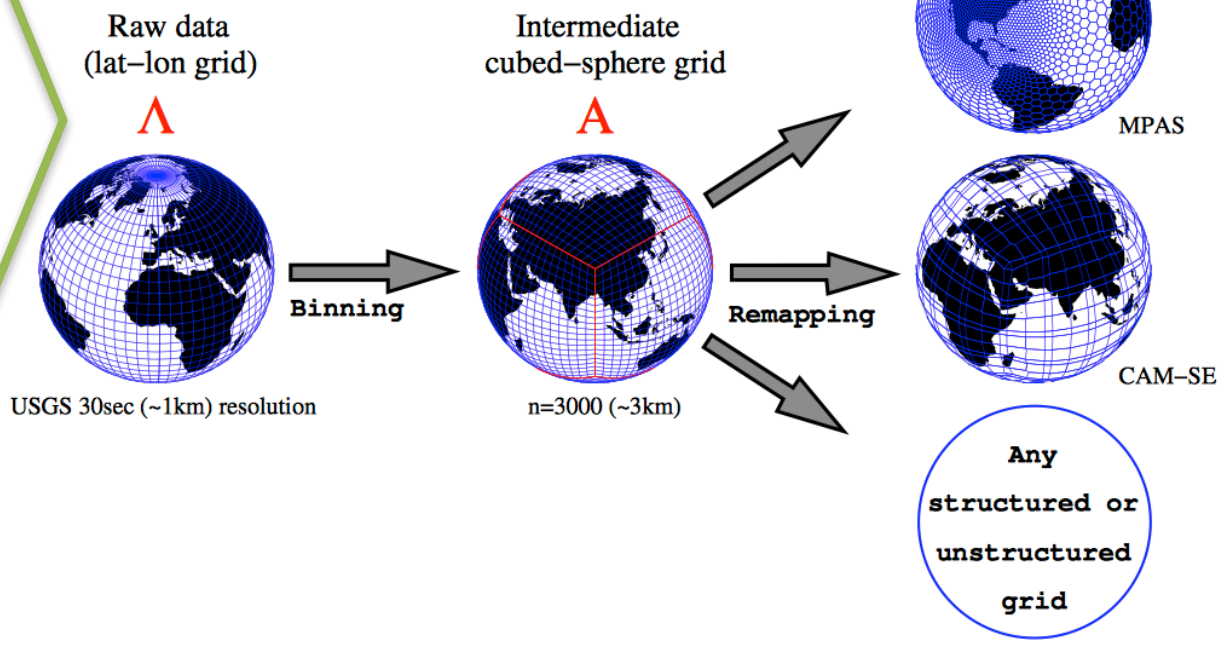
P. H. Lauritzen[1], J. T. Bacmeister[1], P. F. Callaghan[1], and M. A. Taylor[2]
[1]National Center for Atmospheric Research, 1850 Table Mesa Drive, Boulder, Colorado, USA
[2]Sandia National Laboratories, Albuquerque, New Mexico, USA

Received: 12 May 2015 – Published in Geosci. Model Dev. Discuss.: 22 Jun 2015
Revised: 30 Sep 2015 – Accepted: 01 Dec 2015 – Published: 14 Dec 2015

Abstract. It is the purpose of this paper to document the NCAR global model topography generation software for unstructured grids (NCAR_Topo (v1.0)). Given a model grid, the software computes the fraction of the grid box covered by land, the grid-box mean elevation (deviation from a geoid that defines nominal sea level surface), and associated sub-grid-scale variances commonly used for gravity wave and turbulent mountain stress parameterizations. The software supports regular latitude–longitude grids as well as unstructured grids, e.g., icosahedral, Voronoi, cubed-sphere and variable-resolution grids.

Citation: Lauritzen, P. H., Bacmeister, J. T., Callaghan, P. F., and Taylor, M. A.: NCAR_Topo (v1.0): NCAR global model topography generation software for unstructured grids, Geosci. Model Dev., 8, 3975-3986, doi:10.5194/gmd-8-3975-2015, 2015.

Search articles | Search | Title | Download | Short summary | Read more | Citation | BibTeX | EndNote | Share



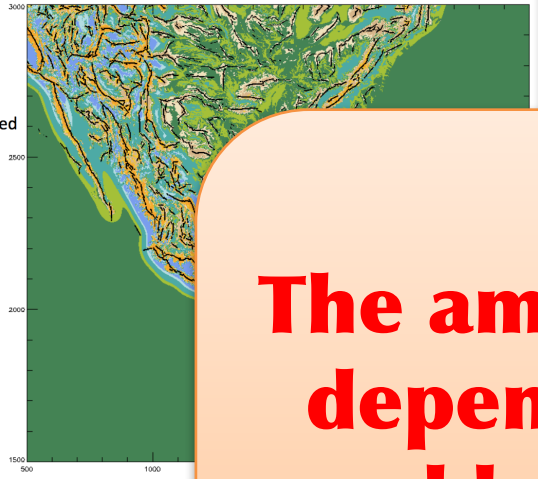
variables:
h
(height in m)
LANDFRAC
(land fraction [0,1])

variables:
PHIS
(surface geopotential)
LANDFRAC
SGH30
(standard deviation of 30sec h)

variables:
PHIS
LANDFRAC
SGH30
SGH
(standard deviation of ~3km cubed-sphere h)

New orographic drag parameterization (J. Bacmeister)

Feature-based ridge identification



Feature scale ~125km

Plotted over unresolved topography: Raw-Smooth(180km)

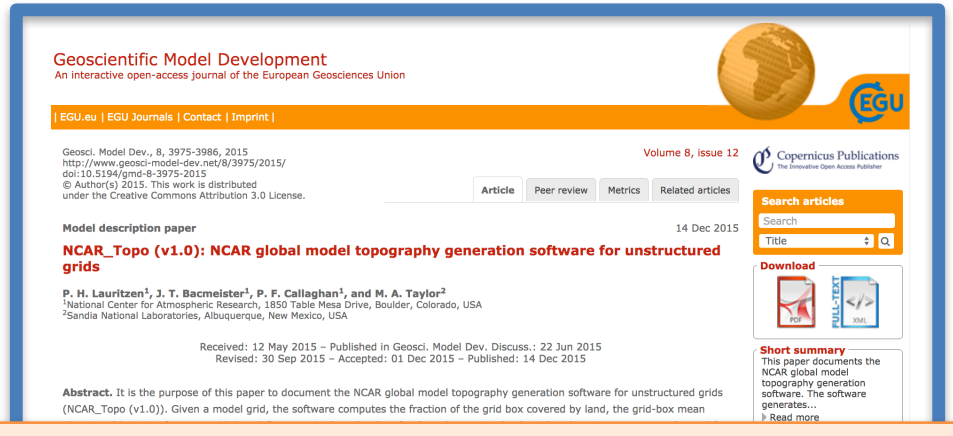
New variables

ridge height, geogr

estimate of "effgw_

Algorithm requires PHIS to be internally smoothed in topo software

https://github.com/NCAR/Topo



Geoscientific Model Development
An interactive open-access journal of the European Geosciences Union

| EGU.eu | EGU Journals | Contact | Imprint |

Geosci. Model Dev., 8, 3975-3986, 2015
http://www.geosci-model-dev.net/8/3975/2015/
doi:10.5194/gmd-8-3975-2015
© Author(s) 2015. This work is distributed under the Creative Commons Attribution 3.0 License.

Volume 8, issue 12

Article | Peer review | Metrics | Related articles

Model description paper — 14 Dec 2015

NCAR_Topo (v1.0): NCAR global model topography generation software for unstructured grids

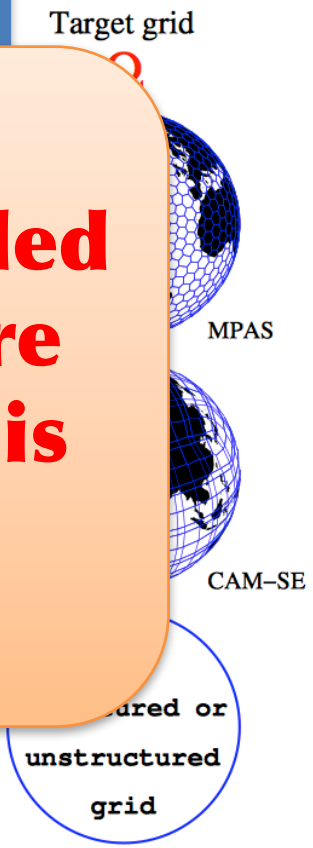
P. H. Lauritzen[1], J. T. Bacmeister[1], P. F. Callaghan[1], and M. A. Taylor[2]
[1]National Center for Atmospheric Research, 1850 Table Mesa Drive, Boulder, Colorado, USA
[2]Sandia National Laboratories, Albuquerque, New Mexico, USA

Received: 12 May 2015 – Published in Geosci. Model Dev. Discuss.: 22 Jun 2015
Revised: 30 Sep 2015 – Accepted: 01 Dec 2015 – Published: 14 Dec 2015

Abstract. It is the purpose of this paper to document the NCAR global model topography generation software for unstructured grids (NCAR_Topo (v1.0)). Given a model grid, the software computes the fraction of the grid box covered by land, the grid-box mean

Search articles
Search
Title
Download
Short summary
This paper documents the NCAR global model topography generation software. The software generates...
Read more

The amount of smoothing needed depends on the dynamical core and how much noise the user is willing to tolerate!



variables:
h
(height in m)
LANDFRAC
(land fraction [0,1])

variables:
PHIS
(surface geopotential)
LANDFRAC
SGH30
(standard deviation of 30sec h)

variables:
PHIS
LANDFRAC
SGH30
SGH
(standard deviation of ~3km cubed-sphere h)

PHIS smoothing and spurious noise

Geosci. Model Dev. Discuss., 8, 4623–4651, 2015
www.geosci-model-dev-discuss.net/8/4623/2015/
doi:10.5194/gmdd-8-4623-2015

- Seeking the "optimal" balance between viscosity & PHIS smoothing

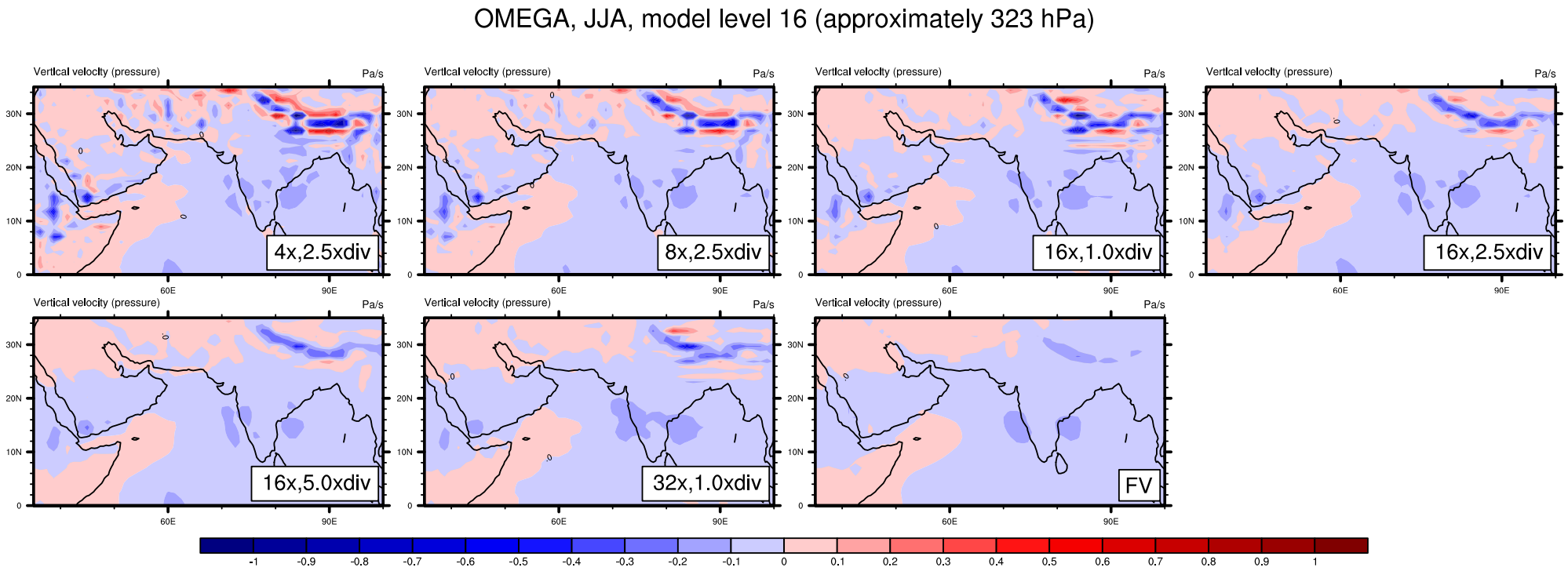
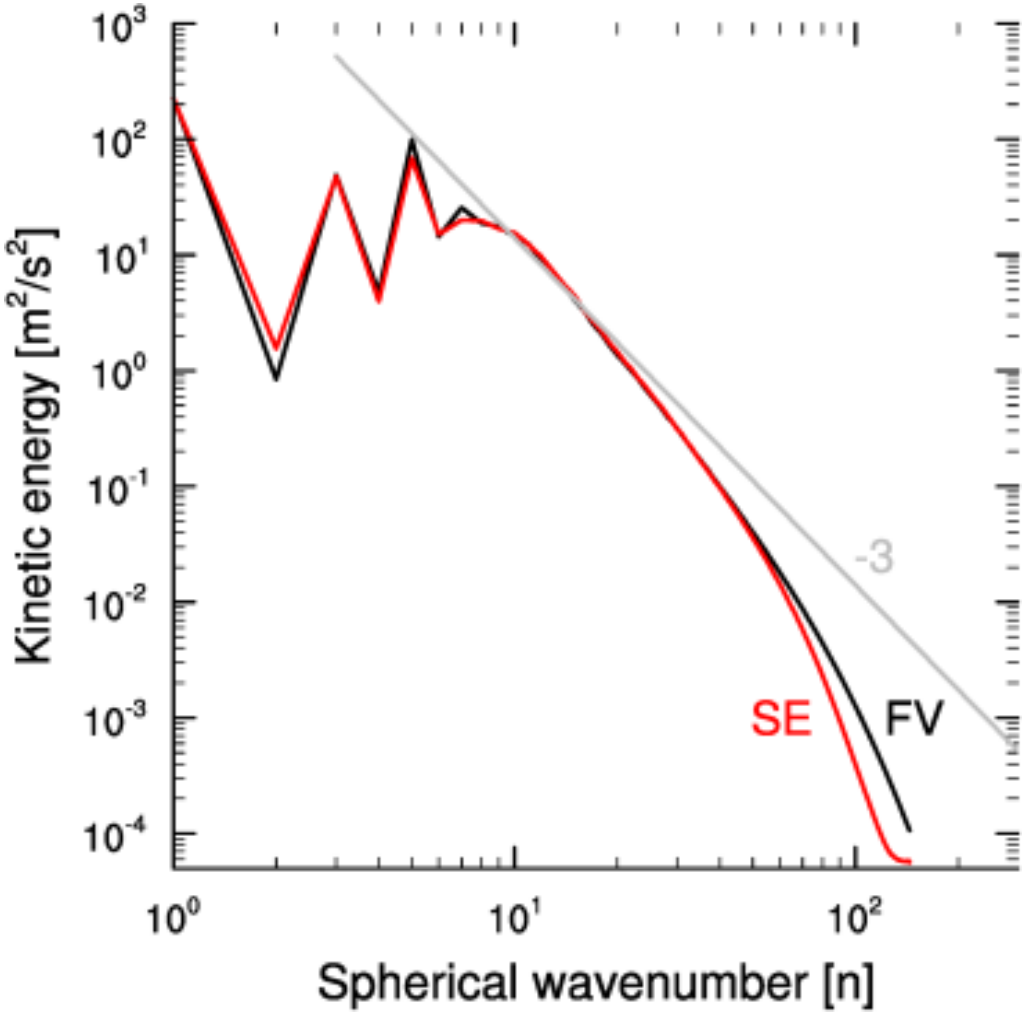


Figure 7. Diagnostics for 30 year AMIP simulations with CAM5.2. Upper and lower group of plots are model level 16 vertical velocity and total precipitation rate differences, respectively, Except for the lower right-most plot on the lower group of plots, the diagnostics are for CAM-SE with different amounts of smoothing of Φ_s and different levels of divergence damping. The amount of smoothing follows the same notation as Fig. 2 (right) and 1.0 x div, 2.5 x div, 5.0 x div refers to increasing divergence damping by a factor 1.0, 2.5^2, and 5.0^2, respectively. The second right-most plot on each group of plots (labeled FV) show results for CAM-FV. Lower right plot in the second group of plots show TRMM observations, respectively.

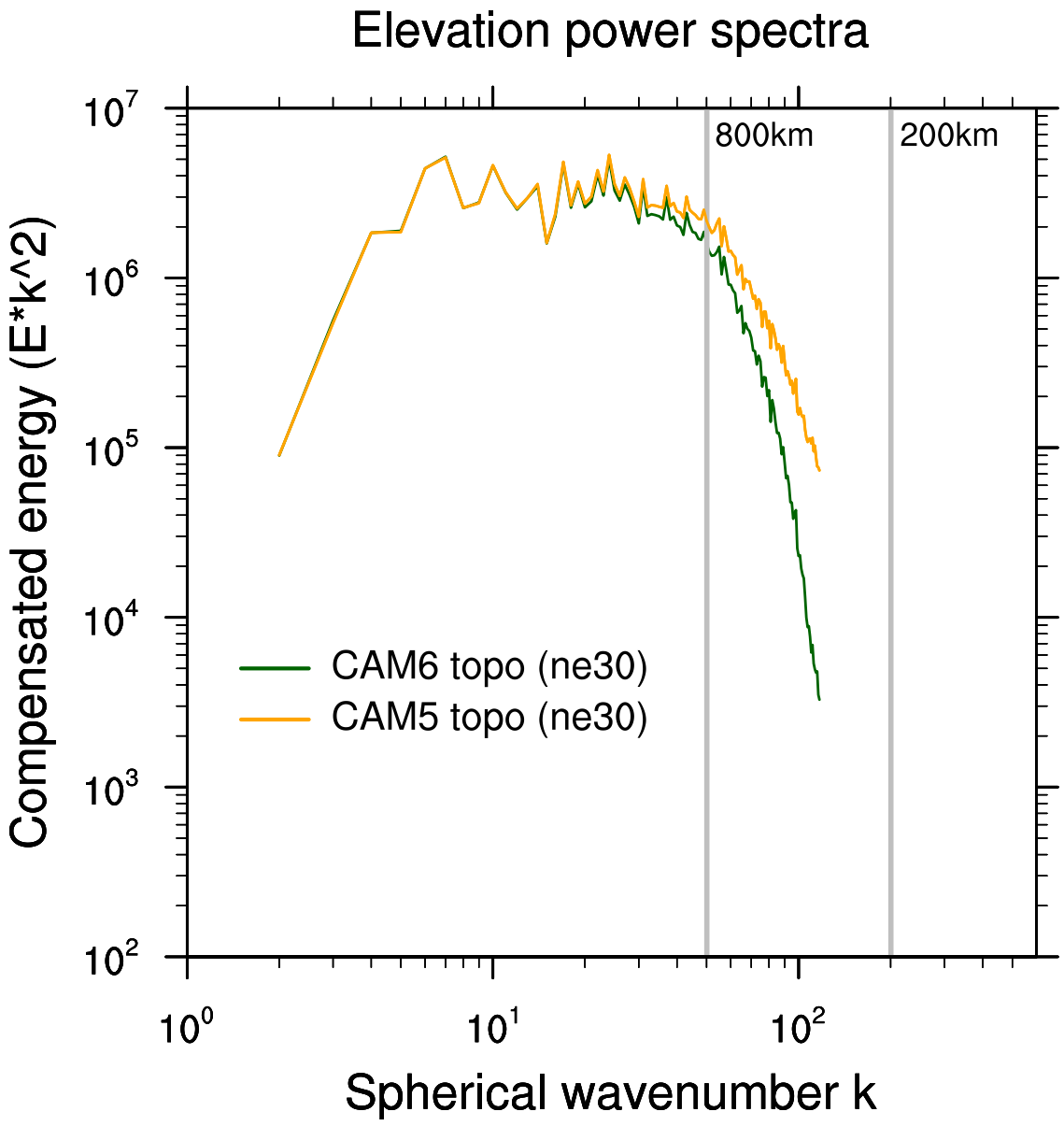
scales than in previous comparisons. This behavior is linked to a damping coefficient that is too large (future versions should be less strongly damped, P. Lauritzen, personal communication, 2015), but it is unlikely that aquaplanet scaling would return to the more Earth-like −3 behavior.

Medeiros et al. (2016)

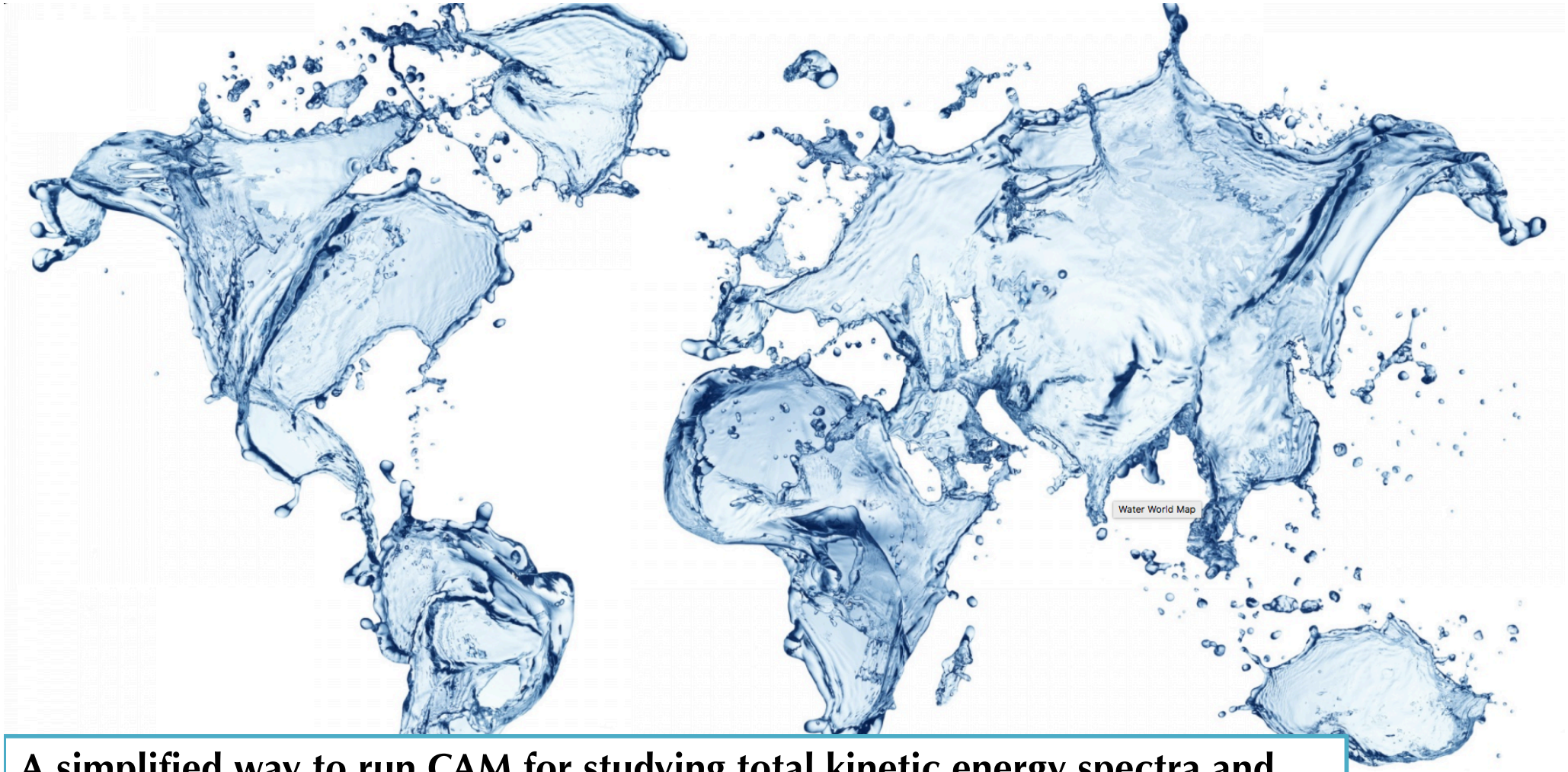


Journal of Advances in Modeling Earth Systems
Volume 8, Issue 1, pages 406-424, 18 MAR 2016 DOI: 10.1002/2015MS000593
http://onlinelibrary.wiley.com/doi/10.1002/2015MS000593/full#jame20263-fig-0015

Topography used in CAM-SE



The APE with topo ("tsunami world"?) experiment

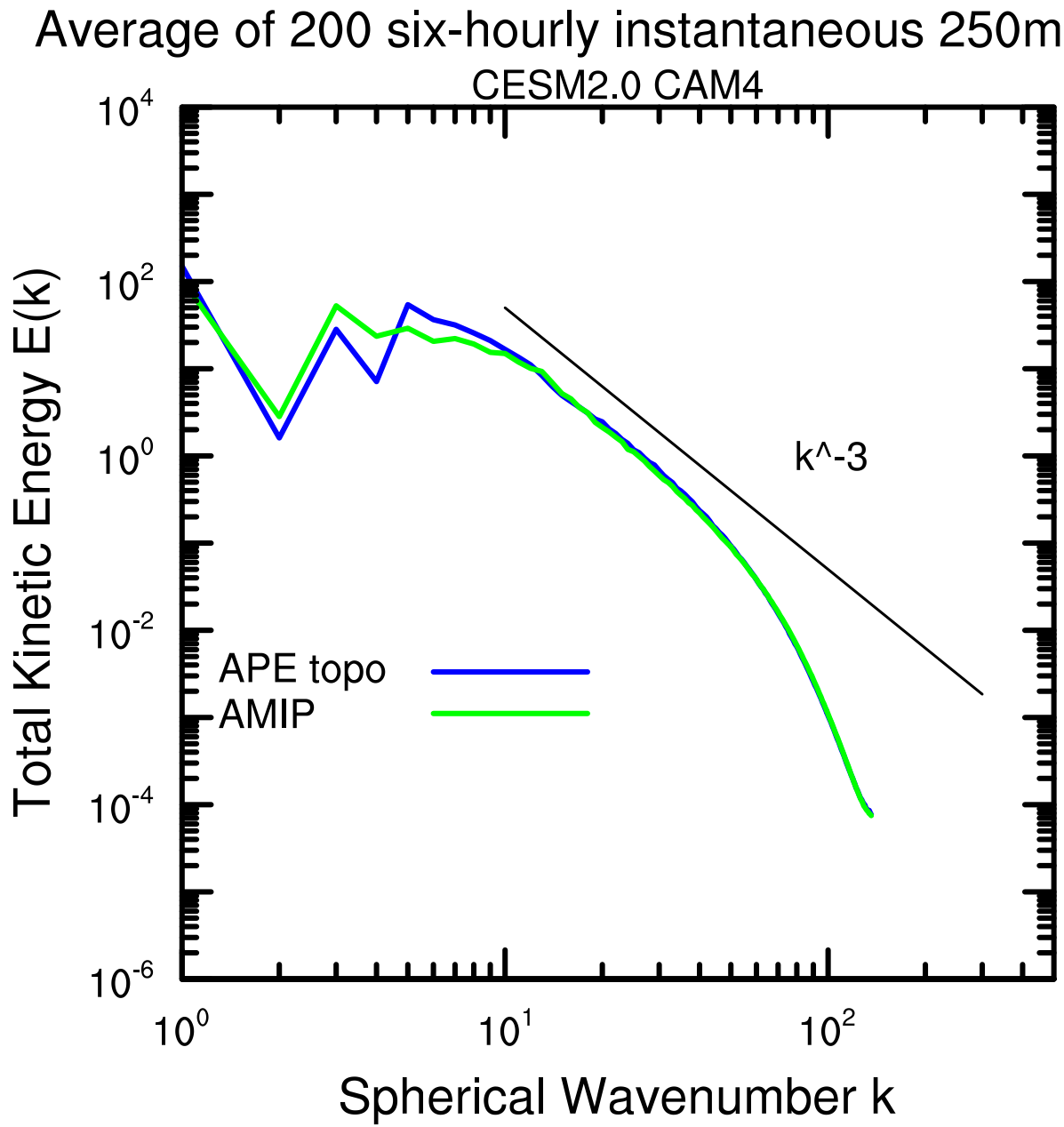


A simplified way to run CAM for studying total kinetic energy spectra and (orographic) noise

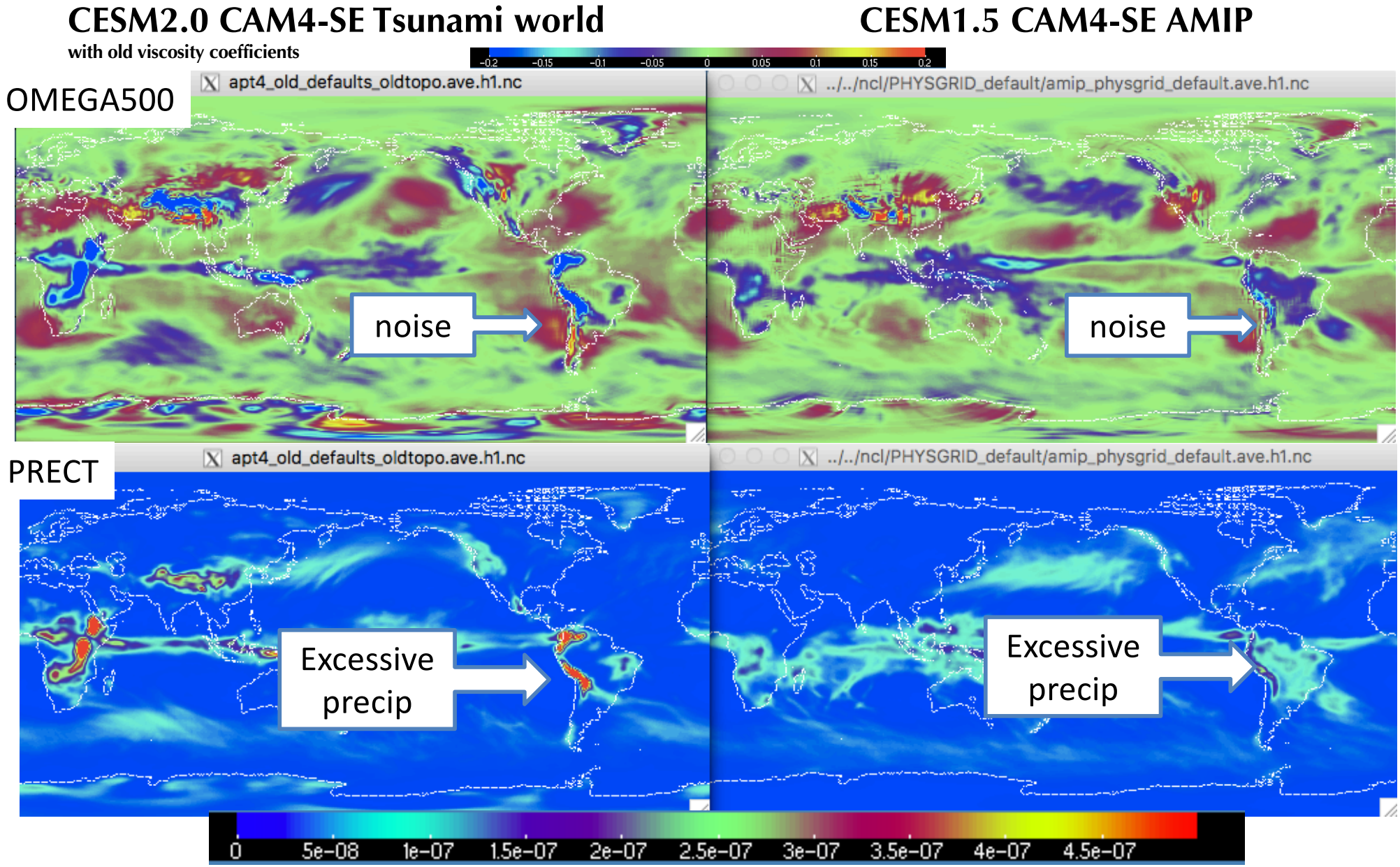
Very easy to setup: Aqua-planet COMPSET and change 3 namelist variables:

use_topo_file = .true., bnd_topo = …., ncdata = real-world initial condition

The APE with topo ("tsunami world"?) experiment



"Tsunami world" versus AMIP (2 month averages)



Results from CESM1.5 CAM4-SE configurations

New versus old viscosity coefficients

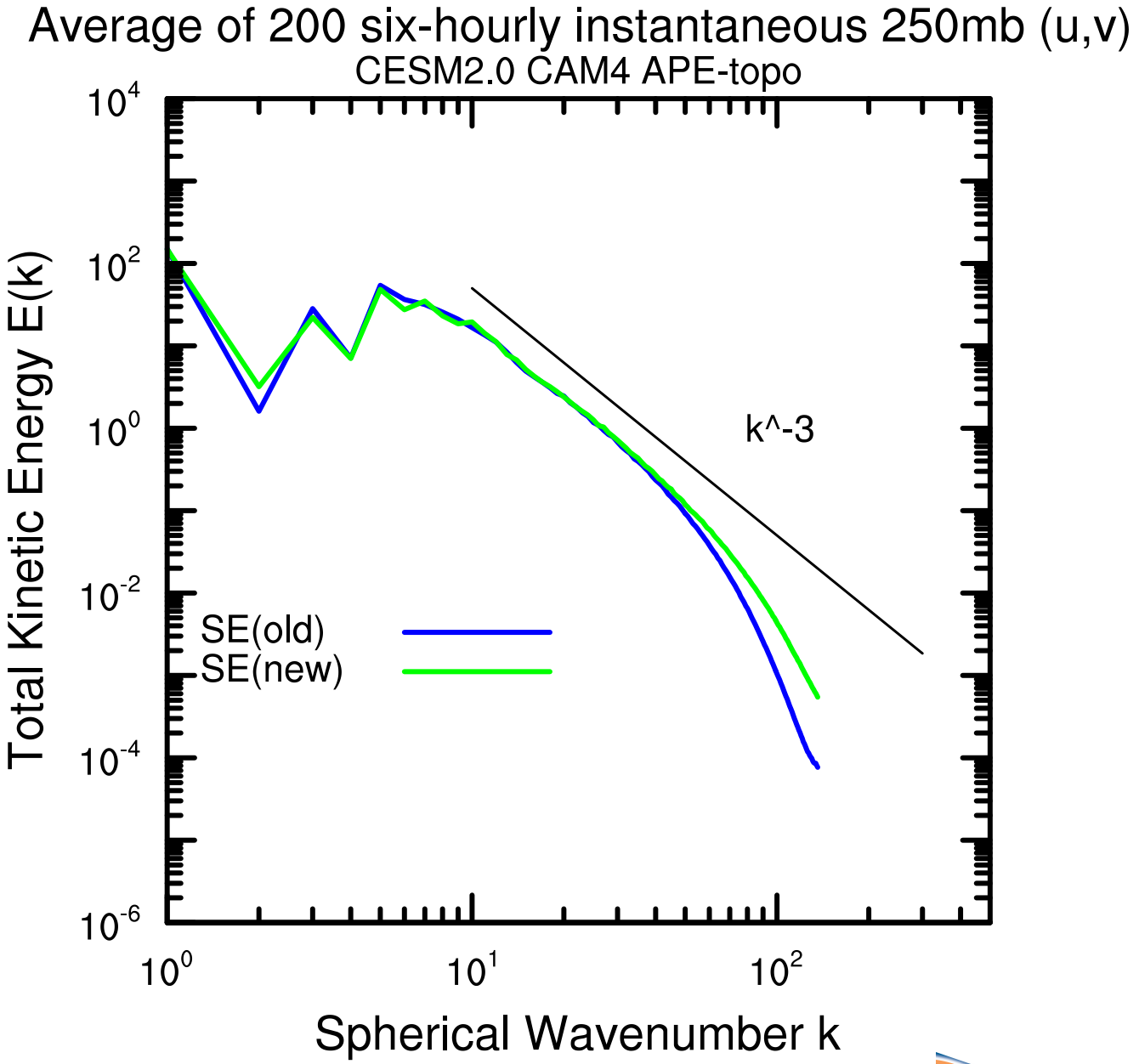
nu =viscosity on (u,v,T)
nu_p =viscosity on dp
nu_div =enhanced viscosity on divergence

”old” (CESM1.5):

nu = 1.00E15 m^4/s^4
nu_p = 1.00E15 m^4/s^4
nu_div = 6.25E15 m^4/s^4

“new” (CESM2.0):

nu = 2.00E14 m^4/s^4
nu_p = 1.00E15 m^4/s^4
nu_div = 1.00E15 m^4/s^4



Using CAM6 topography

New versus old viscosity coefficients

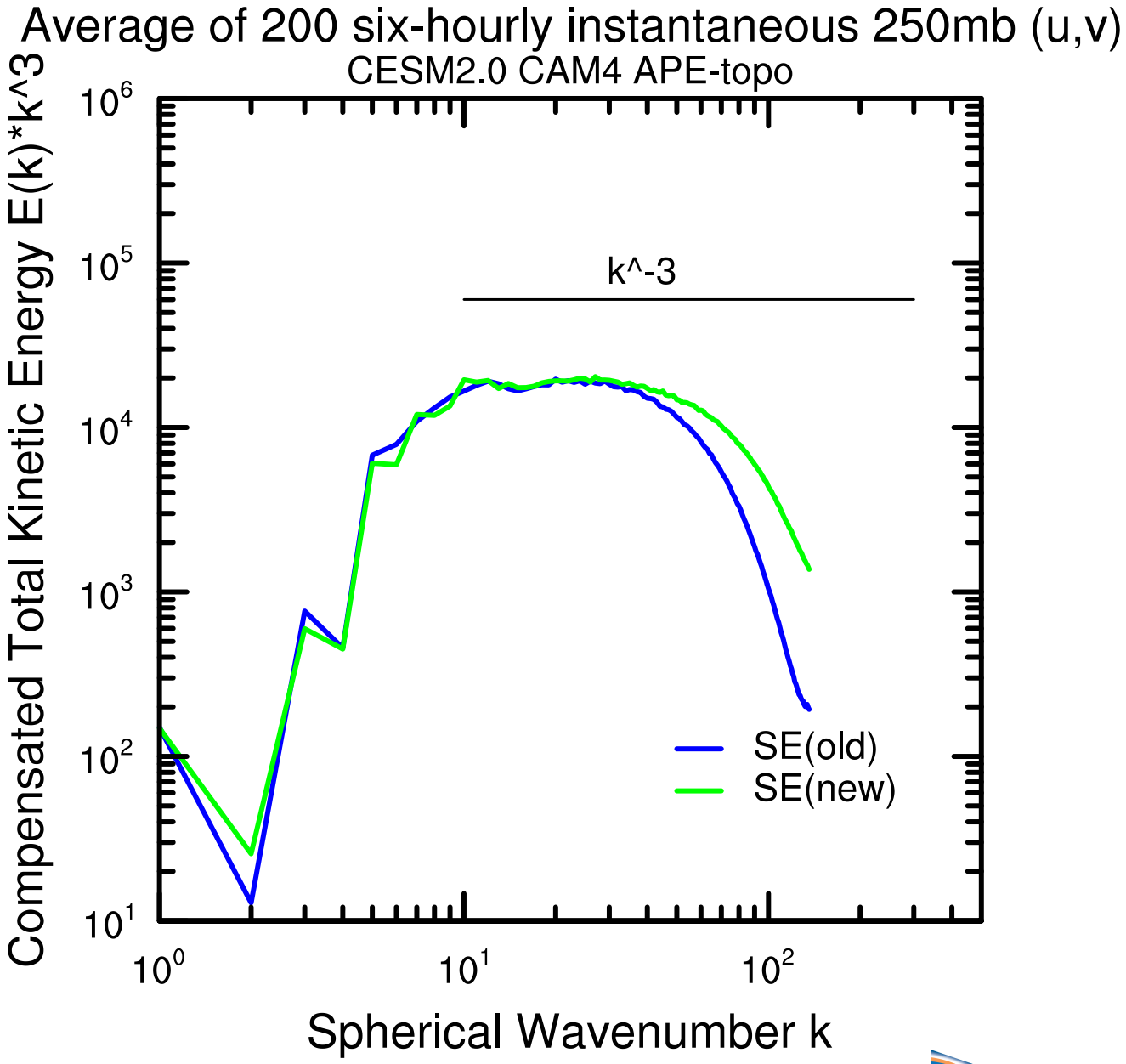
nu =viscosity on (u,v,T)
nu_p =viscosity on dp
nu_div =enhanced viscosity on divergence

”old” (CESM1.5):

Nu = 1.00E15 m^4/s^4
nu_p = 1.00E15 m^4/s^4
nu_div = 6.25E15 m^4/s^4

“new” (CESM2.0):

Nu = 2.00E14 m^4/s^4
nu_p = 1.00E15 m^4/s^4
nu_div = 1.00E15 m^4/s^4



New versus old viscosity coefficients versus FV

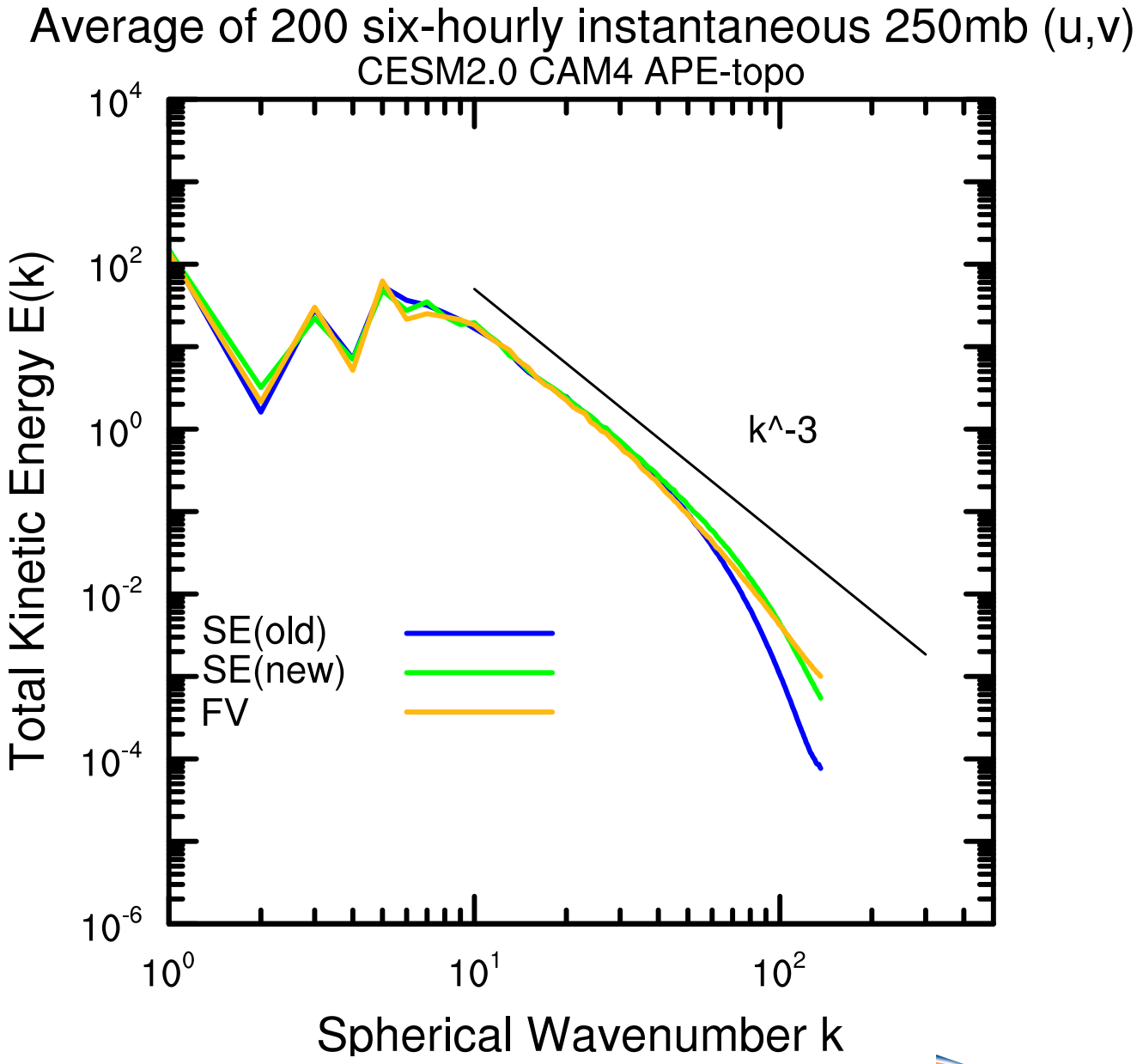
nu =viscosity on (u,v,T)
nu_p =viscosity on dp
nu_div =enhanced viscosity on divergence

<u>"old" (CESM1.5):</u>

nu = 1.00E15 m^4/s^4
nu_p = 1.00E15 m^4/s^4
nu_div = 6.25E15 m^4/s^4

<u>"new" (CESM2.0):</u>

nu = 2.00E14 m^4/s^4
nu_p = 1.00E15 m^4/s^4
nu_div = 1.00E15 m^4/s^4



Using CAM6 topography

New versus old viscosity coefficients versus FV

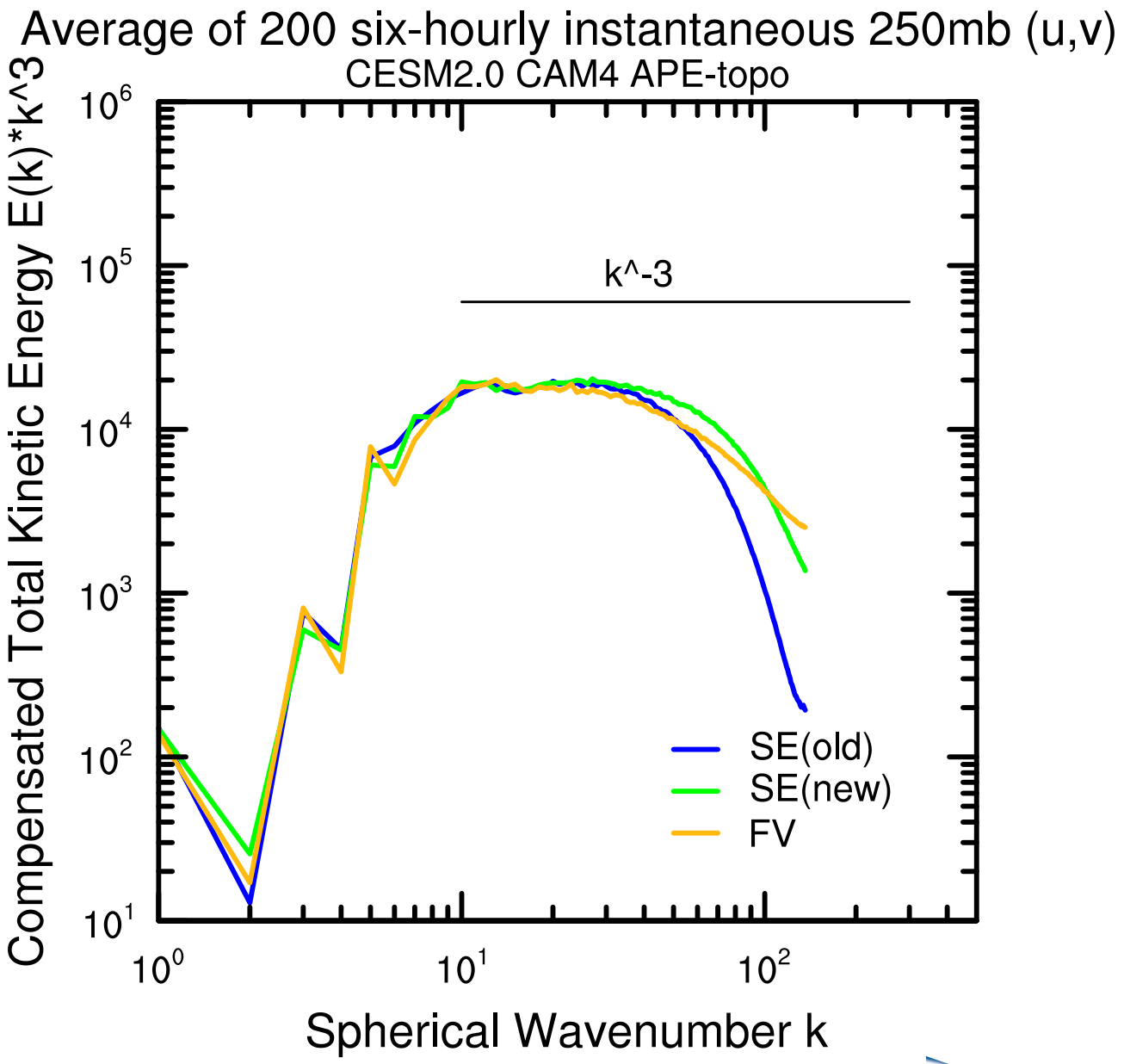
nu =viscosity on (u,v,T)
nu_p =viscosity on dp
nu_div =enhanced viscosity on divergence

”old” (CESM1.5):

nu = 1.00E15 m^4/s^4
nu_p = 1.00E15 m^4/s^4
nu_div = 6.25E15 m^4/s^4

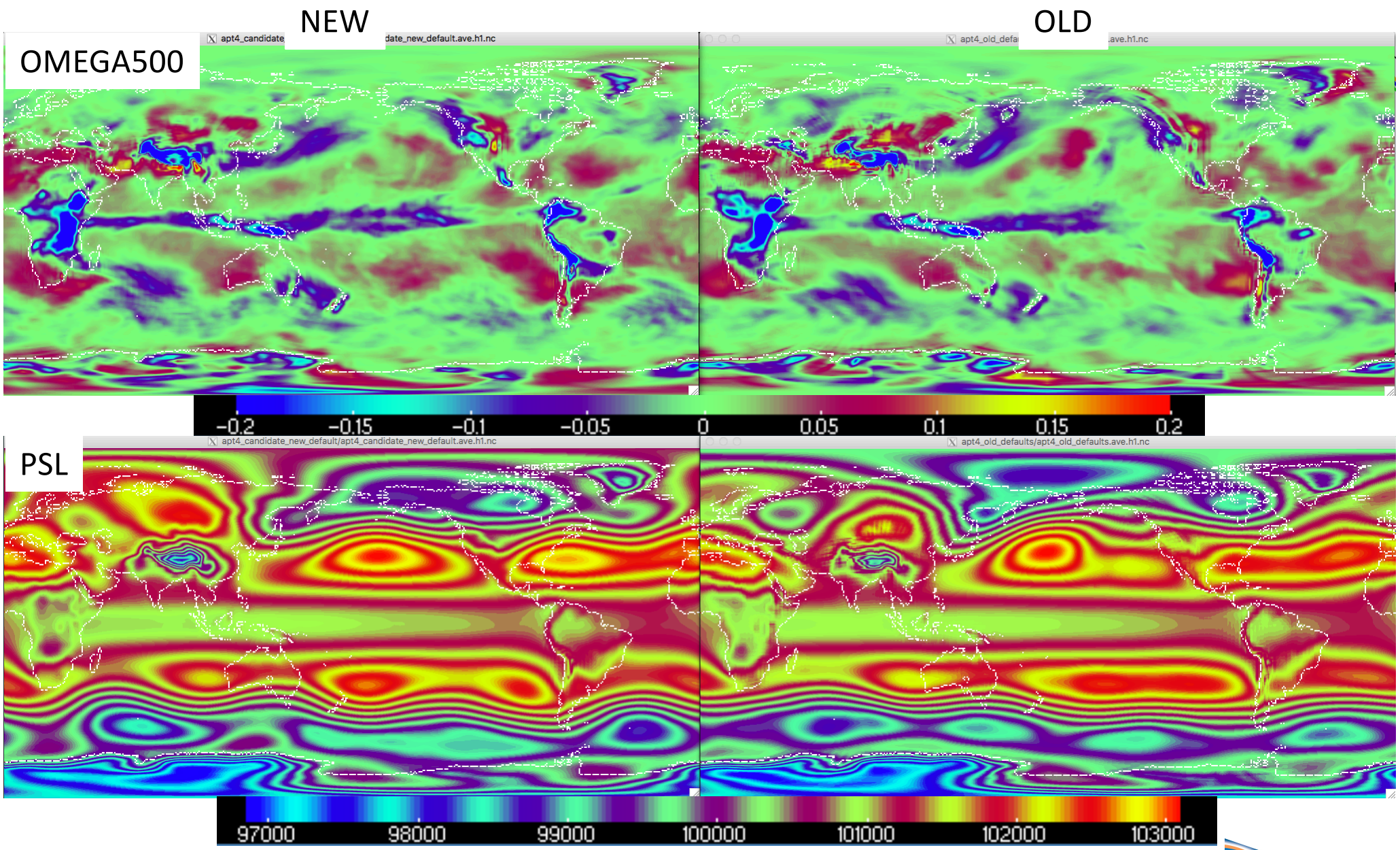
“new” (CESM2.0):

nu = 2.00E14 m^4/s^4
nu_p = 1.00E15 m^4/s^4
nu_div = 1.00E15 m^4/s^4



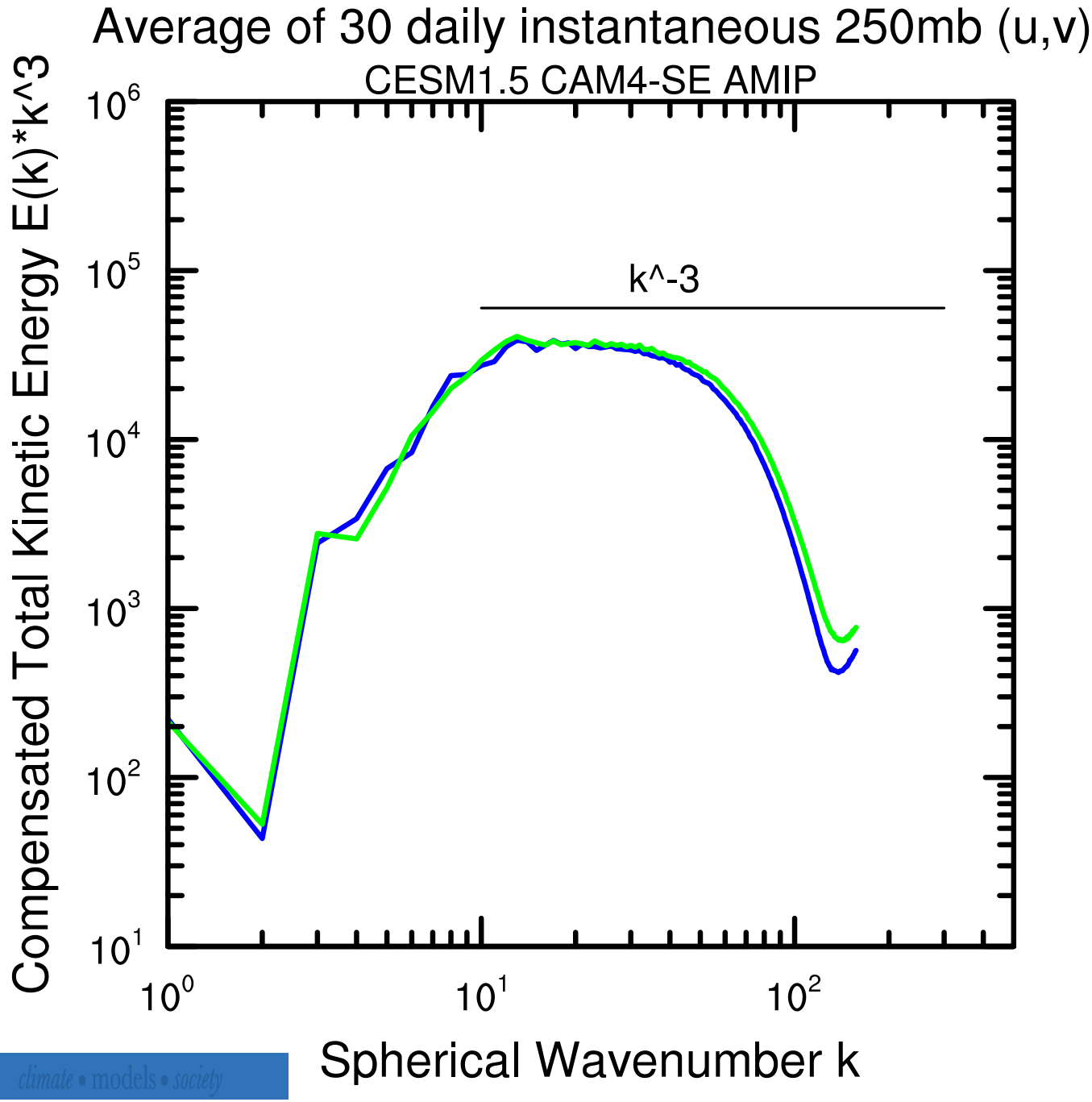
Using CAM6 topography

New versus old viscosity coefficients

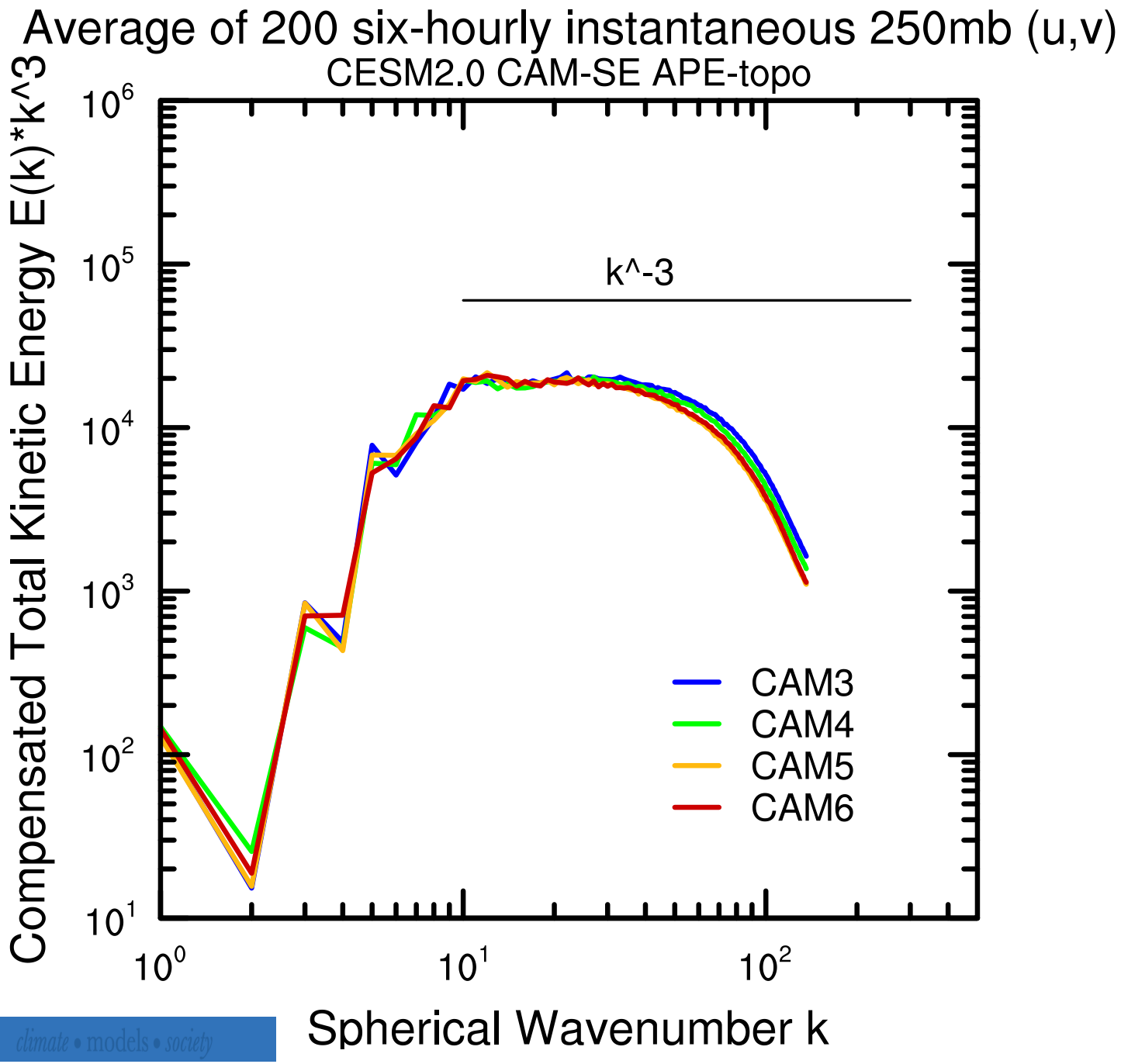


What else influences the TKE energy spectra?

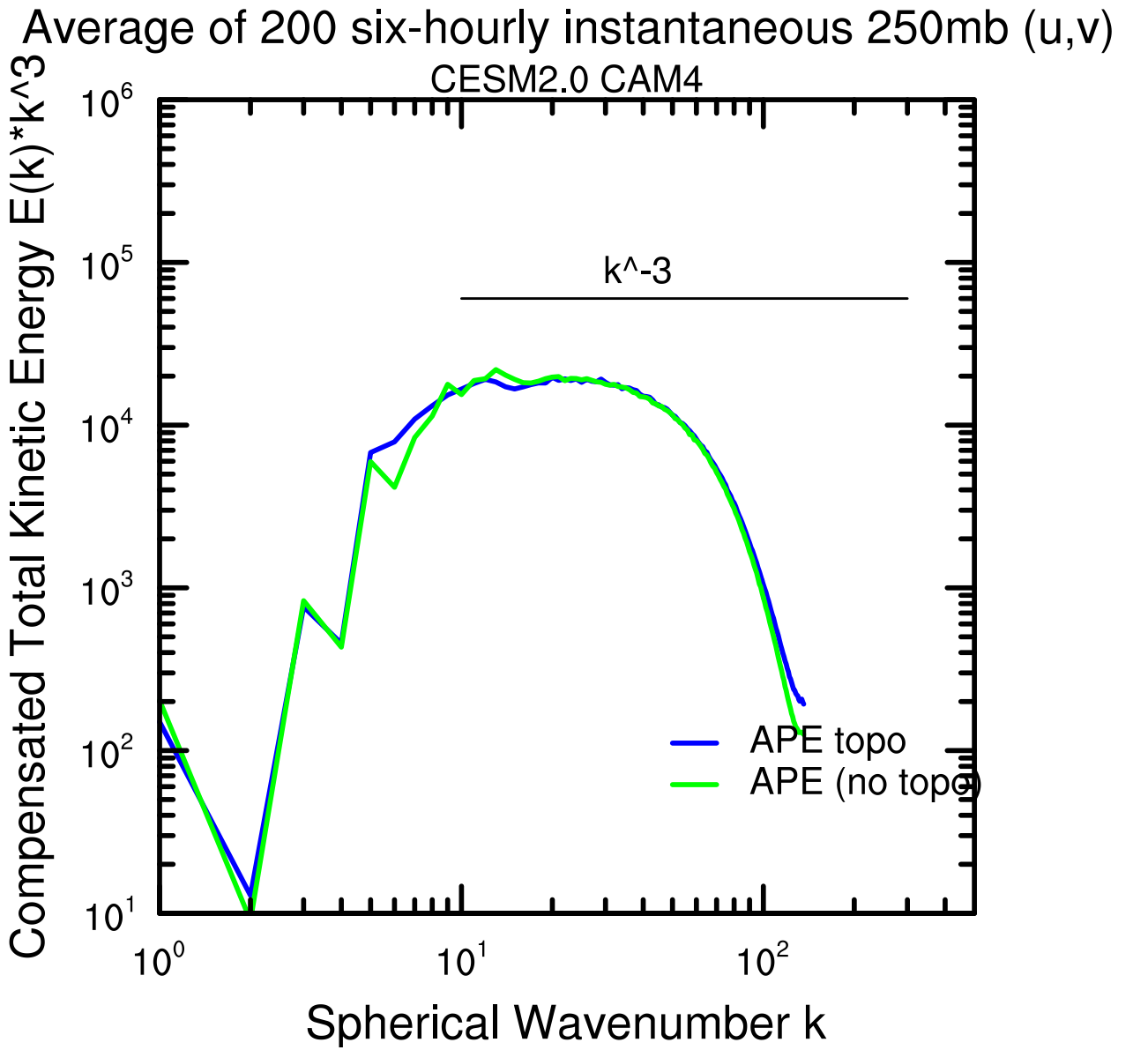
Floating Lagrangian vertical coordinates versus Eulerian



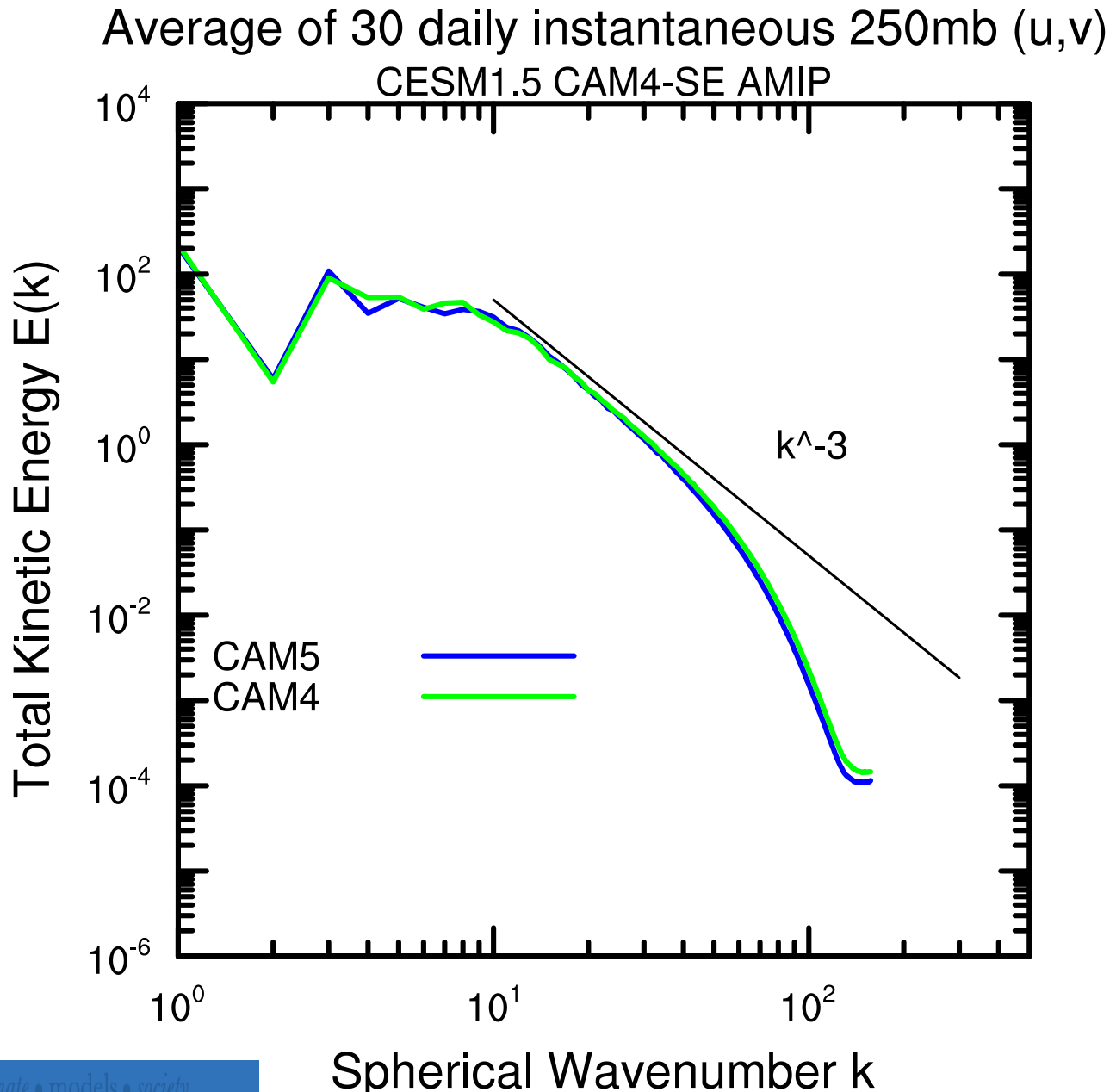
Different CAM physics packages



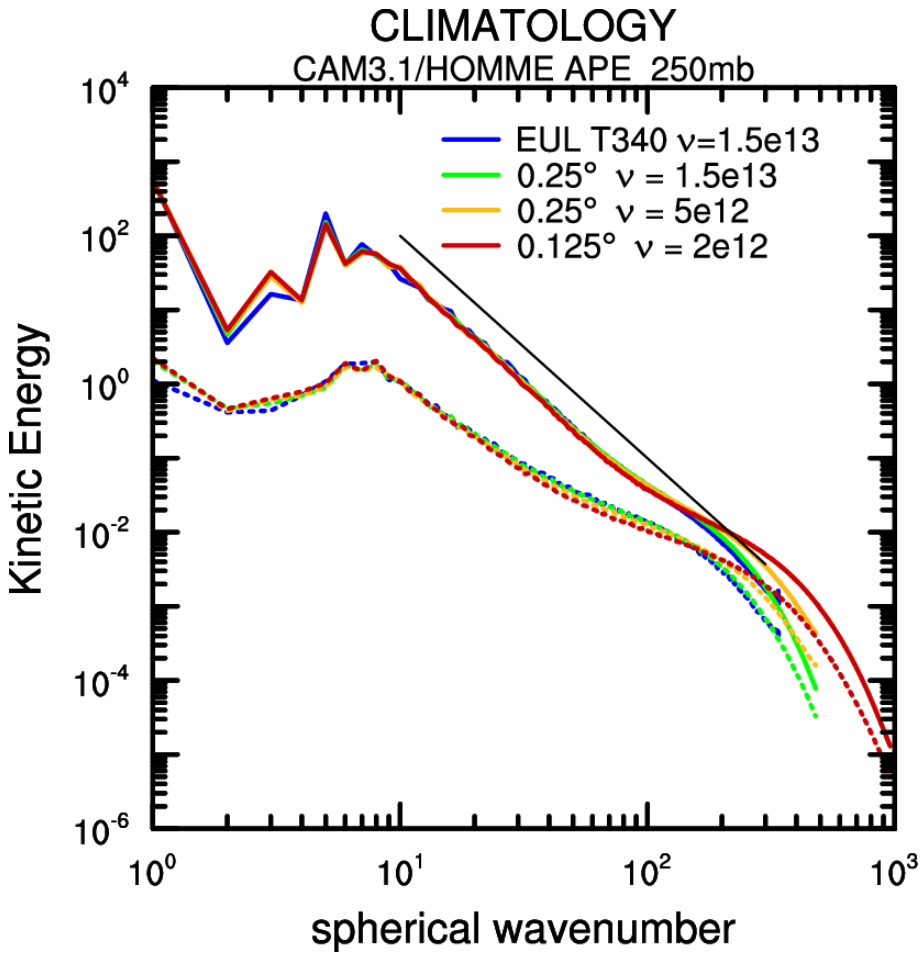
The "tsunami world" versus APE (no topo)

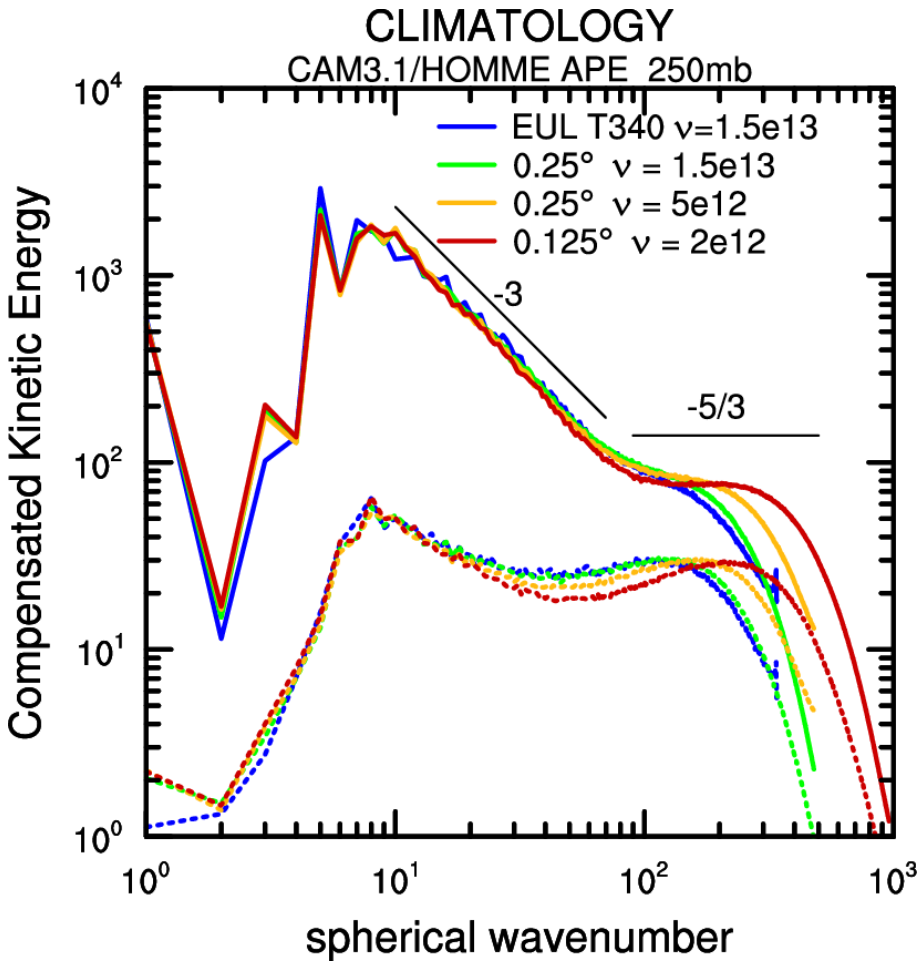


Is it physics package?



Aqua Planet - CAM 3.4 Physics

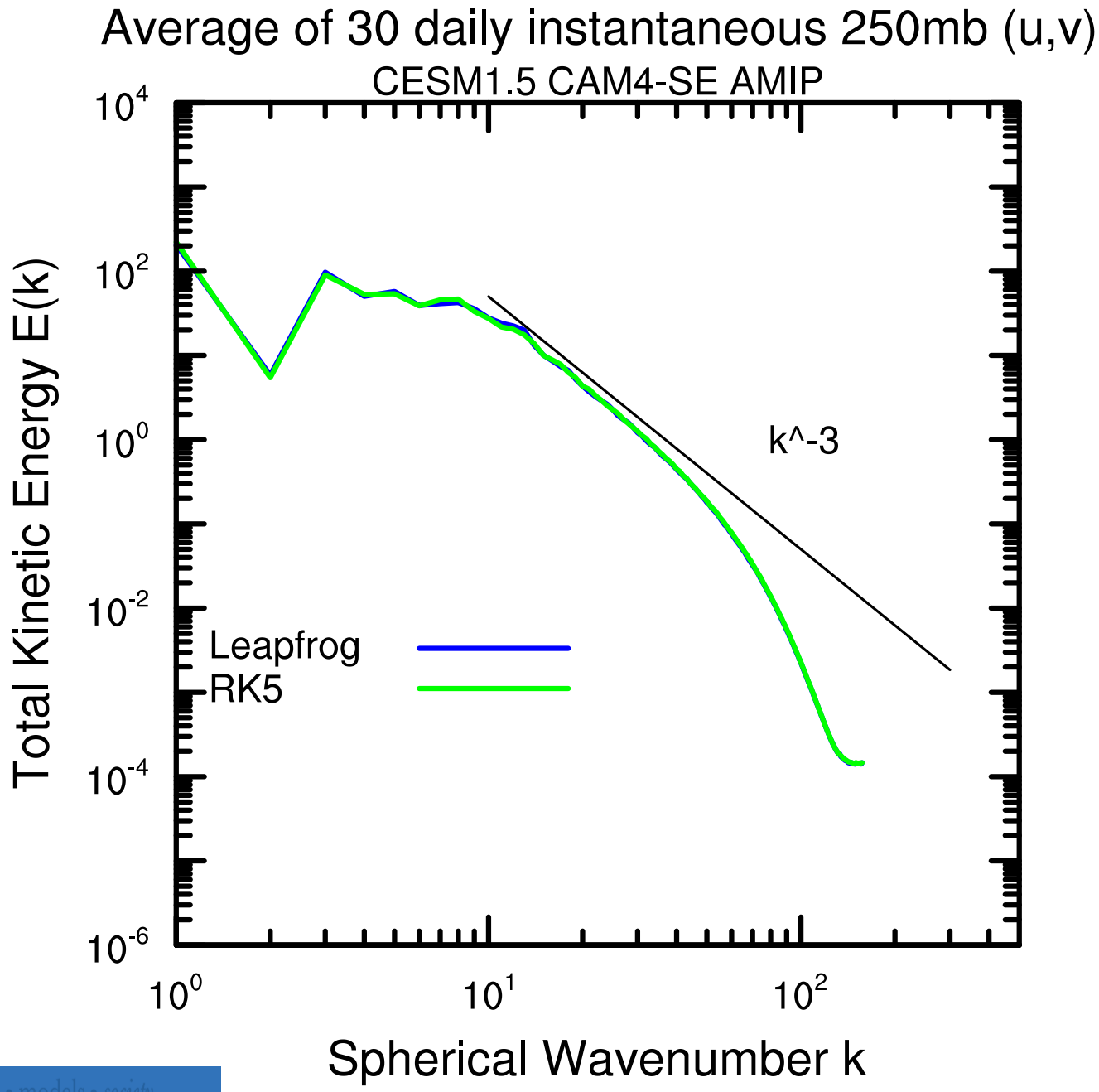




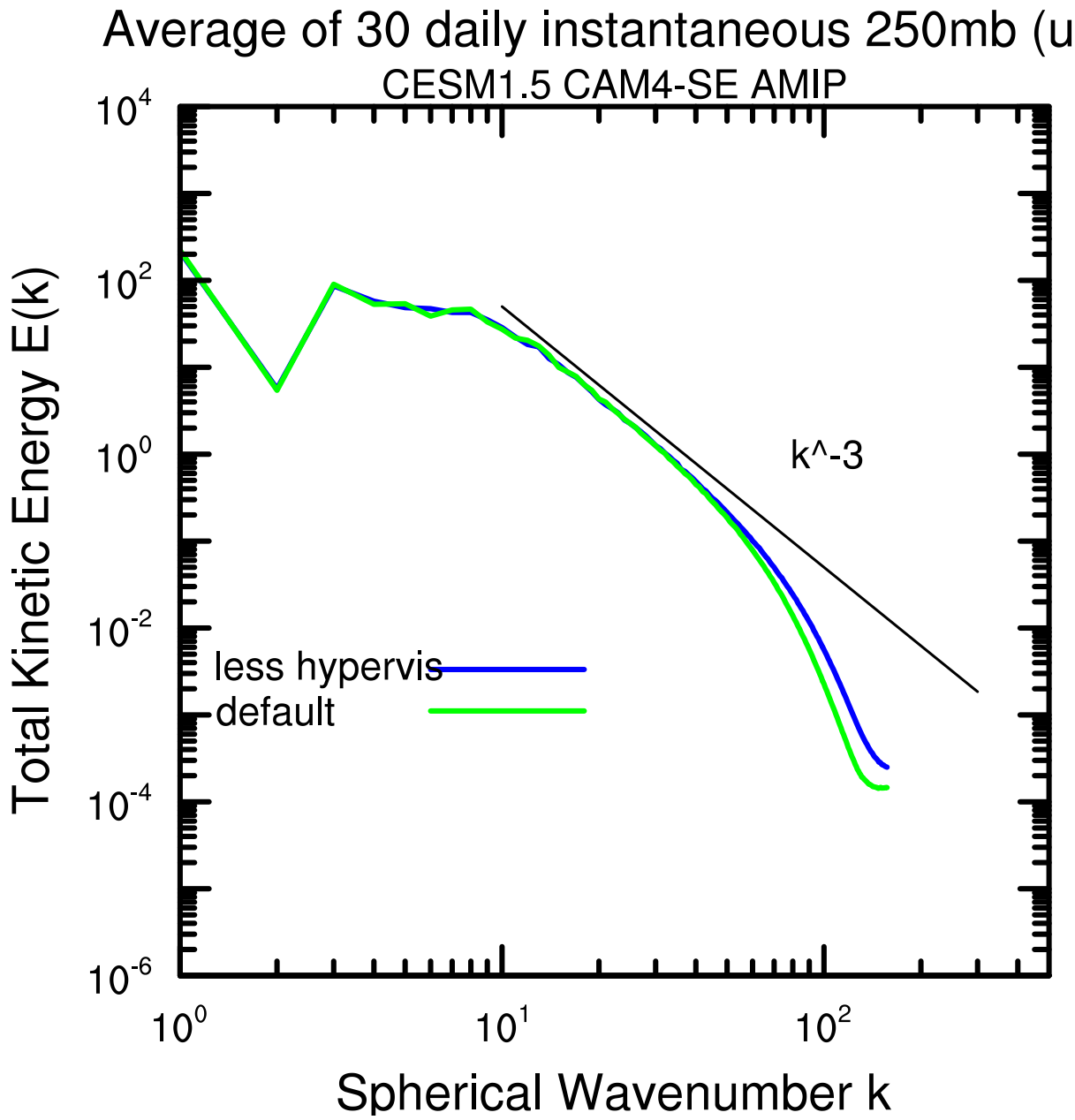
Total (solid lines) and compressible (dotted lines) components

From Mark Taylor's talk at *IPAM – Numerical Hierarchies for Climate Modeling*, April 15 2010

Time-stepping method



Is it hyperviscosity coefficients?



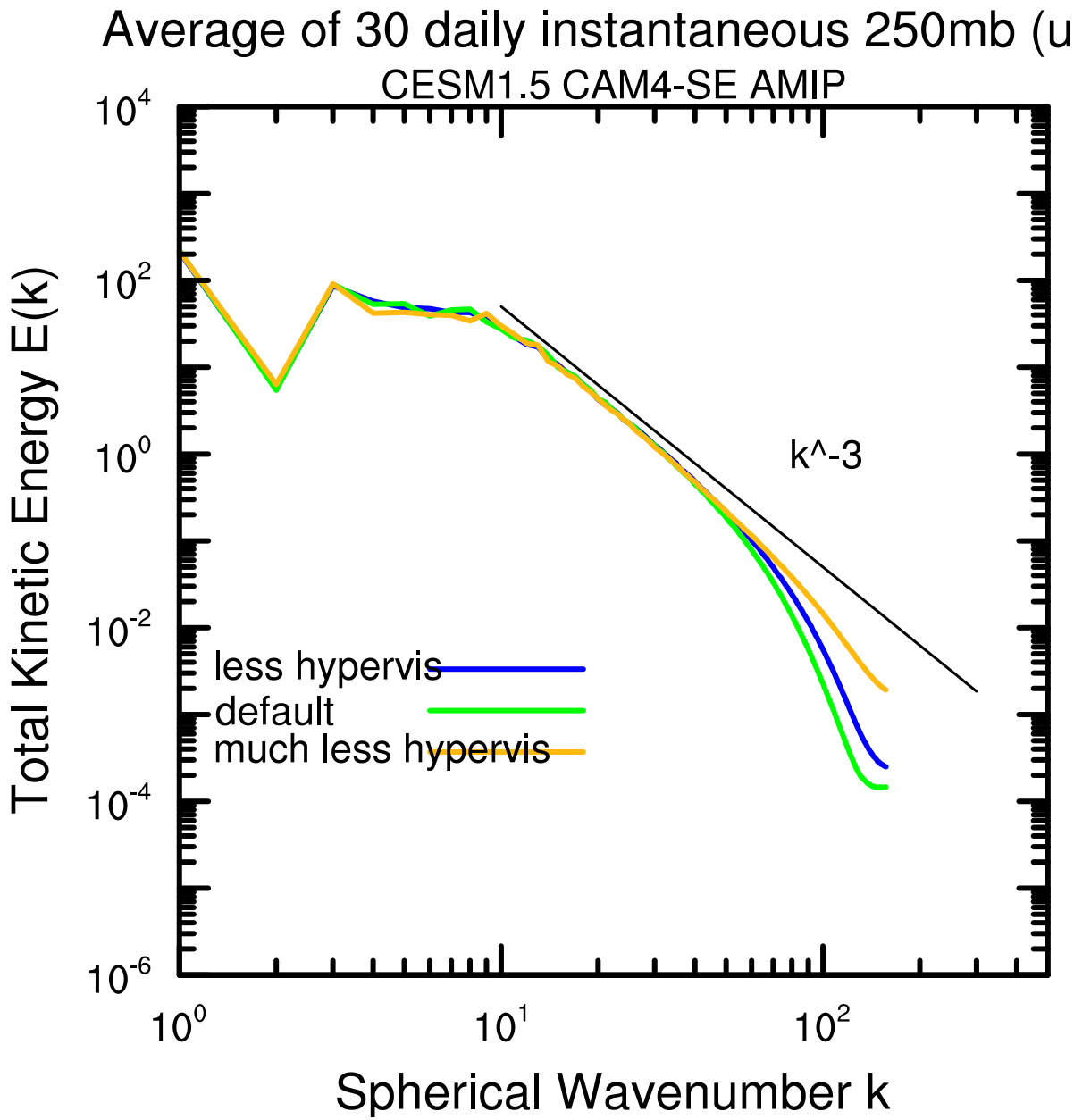
"Less hypervis":

- nu = 0.50E15 m^4/s^4
- nu_div = 1.00E15 m^4/s^4

Default hypervis values:

- nu = 1.00E15 m^4/s^4
- nu_div = 6.25E15 m^4/s^4

Is it hyperviscosity coefficients?



"Less hypervis":

- nu = 0.50E15 m^4/s^4
- nu_div = 1.00E15 m^4/s^4

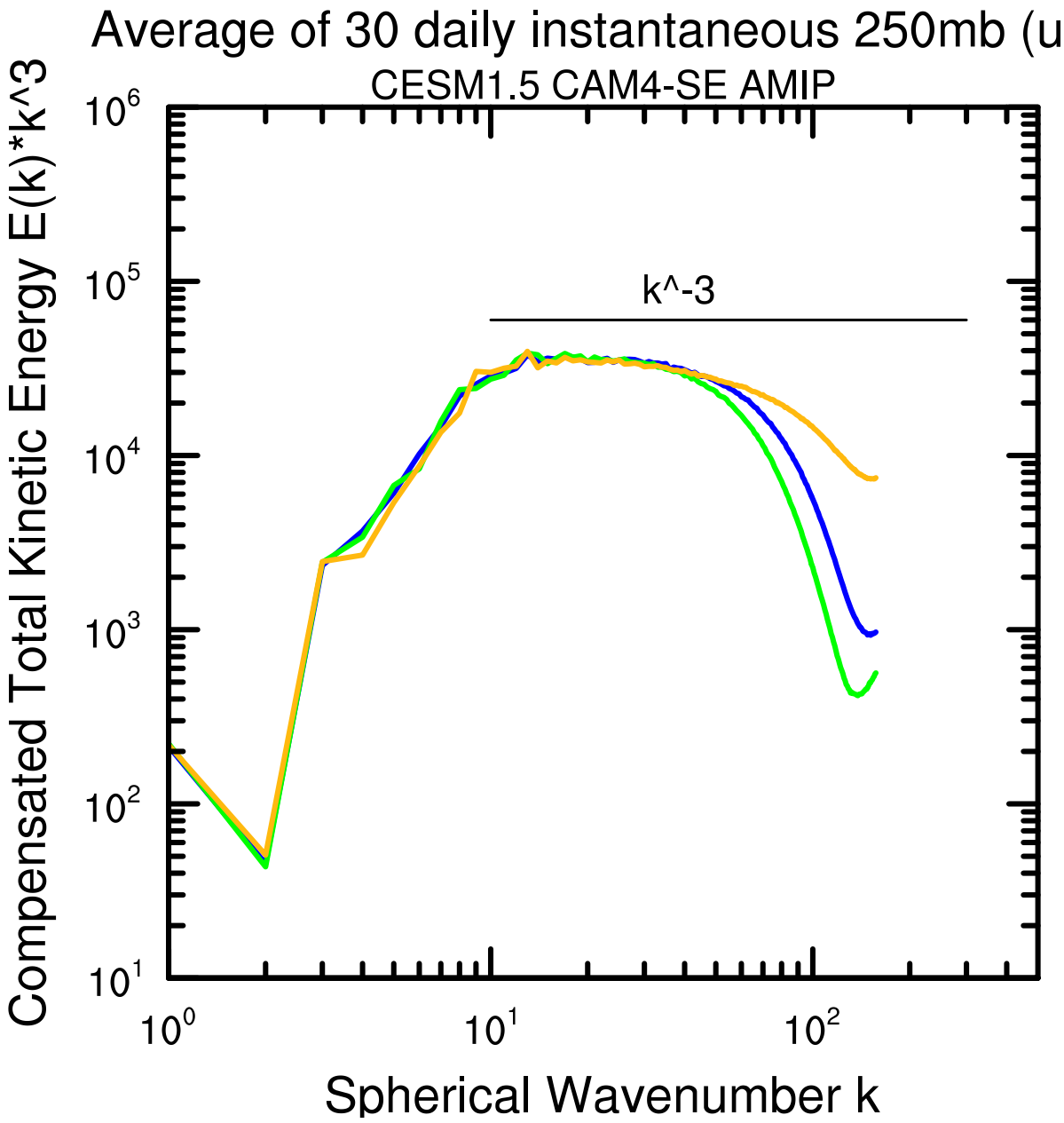
Default hypervis values:

- nu = 1.00E15 m^4/s^4
- nu_div = 6.25E15 m^4/s^4

"Much less hypervis":

- nu = 0.10E15 m^4/s^4
- nu_div = 0.10E15 m^4/s^4

Is it hyperviscosity coefficients?



"Less hypervis":

- nu = 0.50E15 m^4/s^4
- nu_div = 1.00E15 m^4/s^4

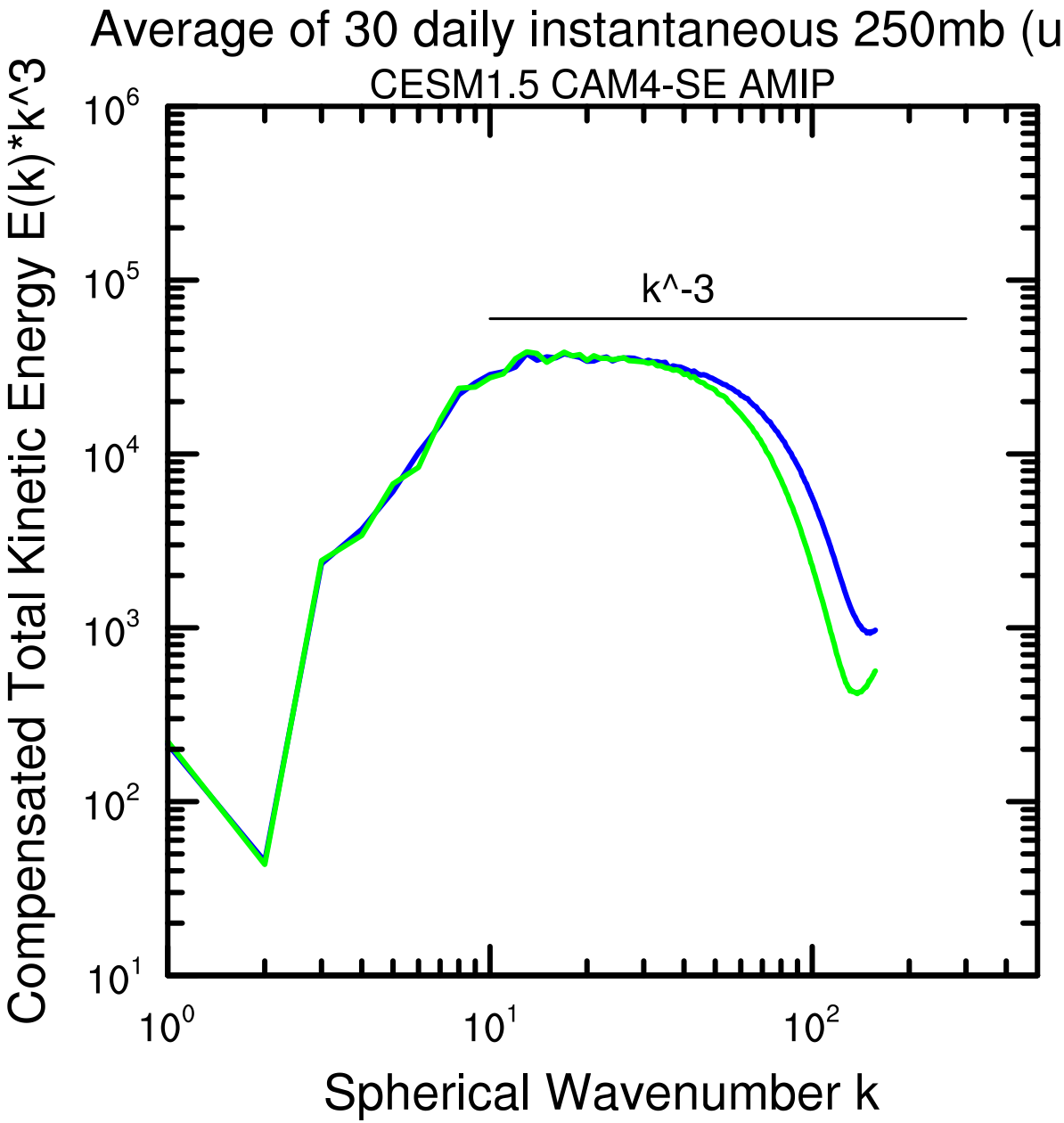
Default hypervis values:

- nu = 1.00E15 m^4/s^4
- nu_div = 6.25E15 m^4/s^4

"Much less hypervis":

- nu = 0.10E15 m^4/s^4
- nu_div = 0.10E15 m^4/s^4

Is it hyperviscosity coefficients?



"Less hypervis":

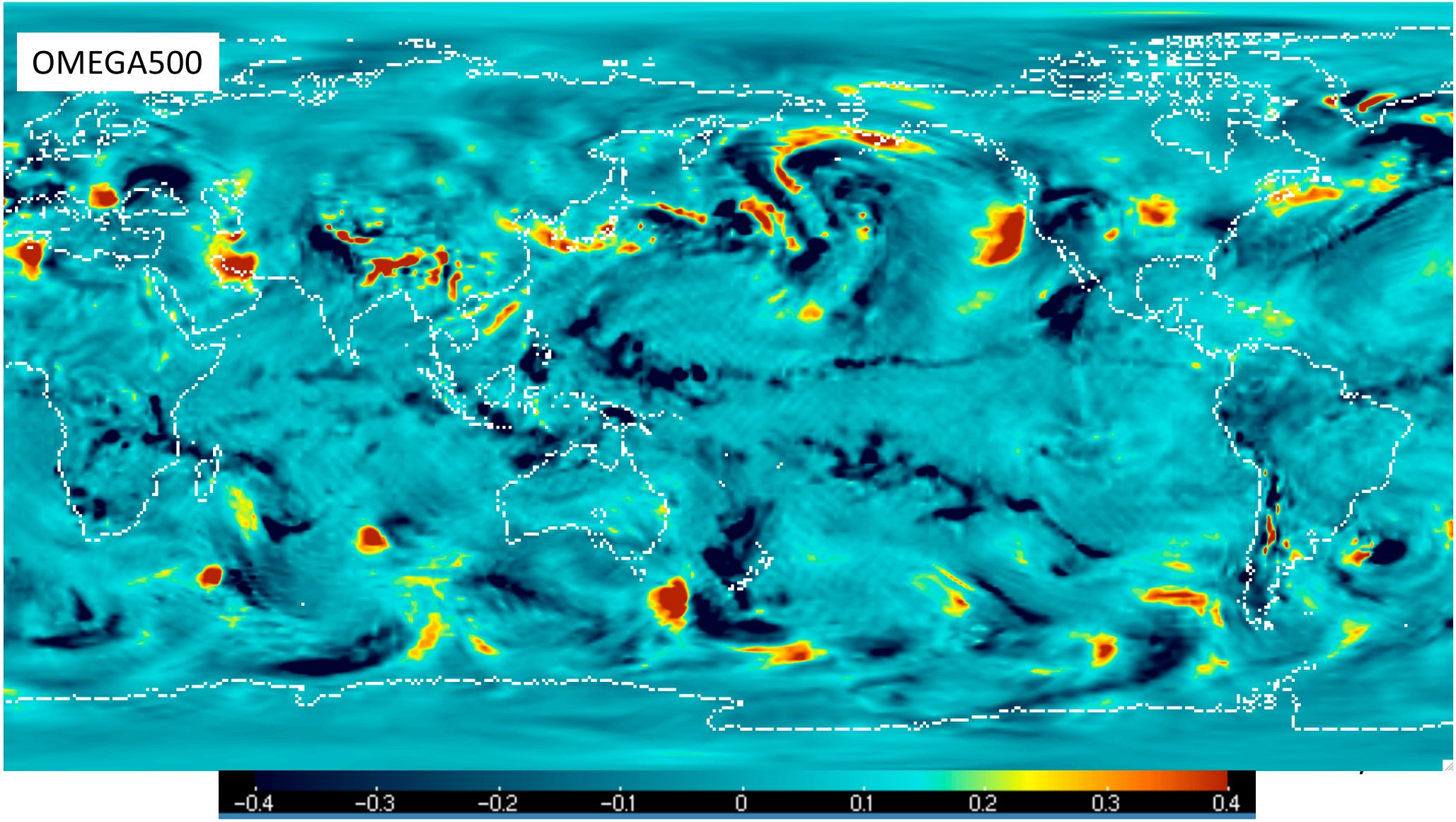
- nu = 0.50E15 m^4/s^4
- nu_div = 1.00E15 m^4/s^4

Default hypervis values:

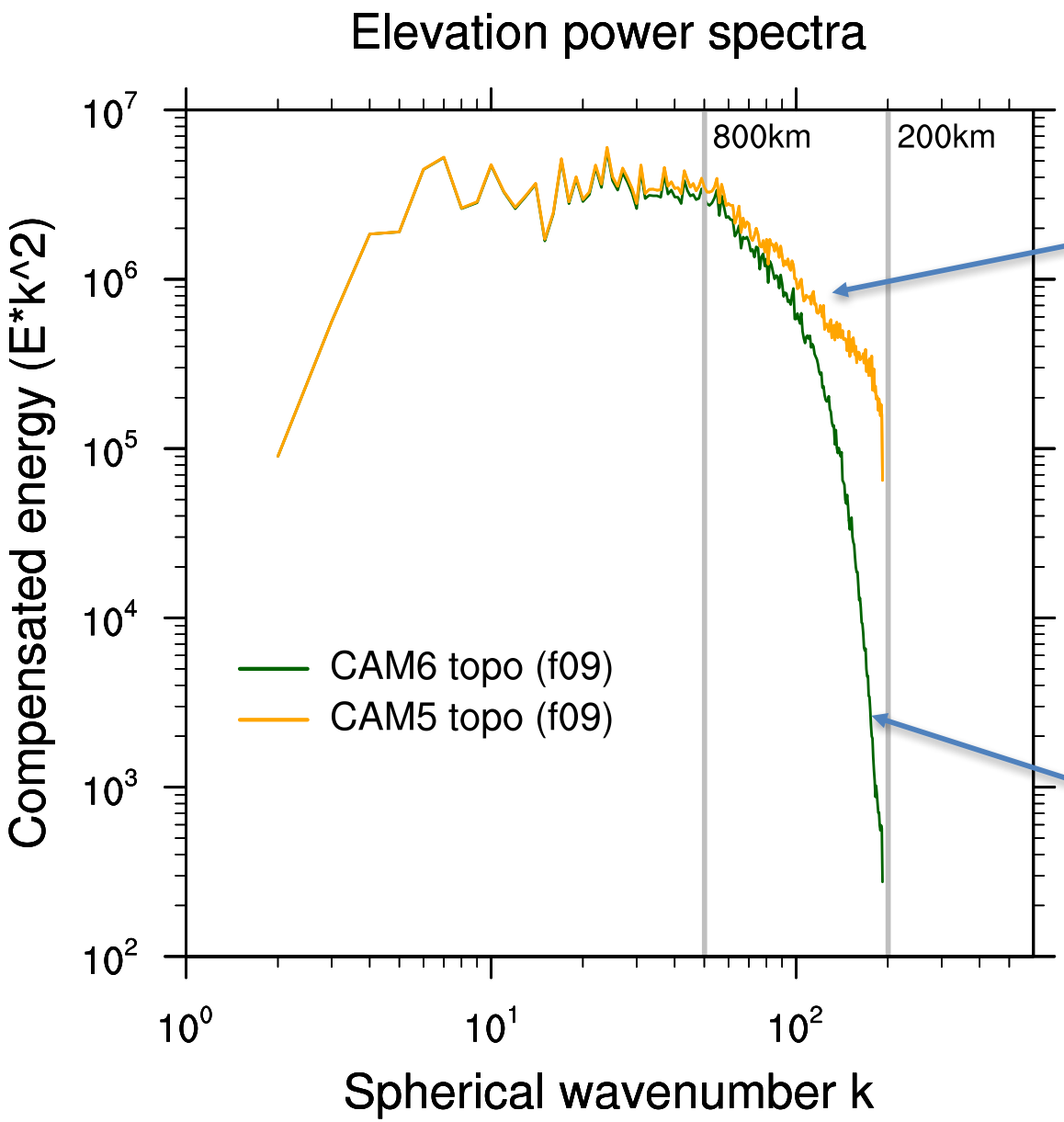
- nu = 1.00E15 m^4/s^4
- nu_div = 6.25E15 m^4/s^4

Is it hyperviscosity coefficients?

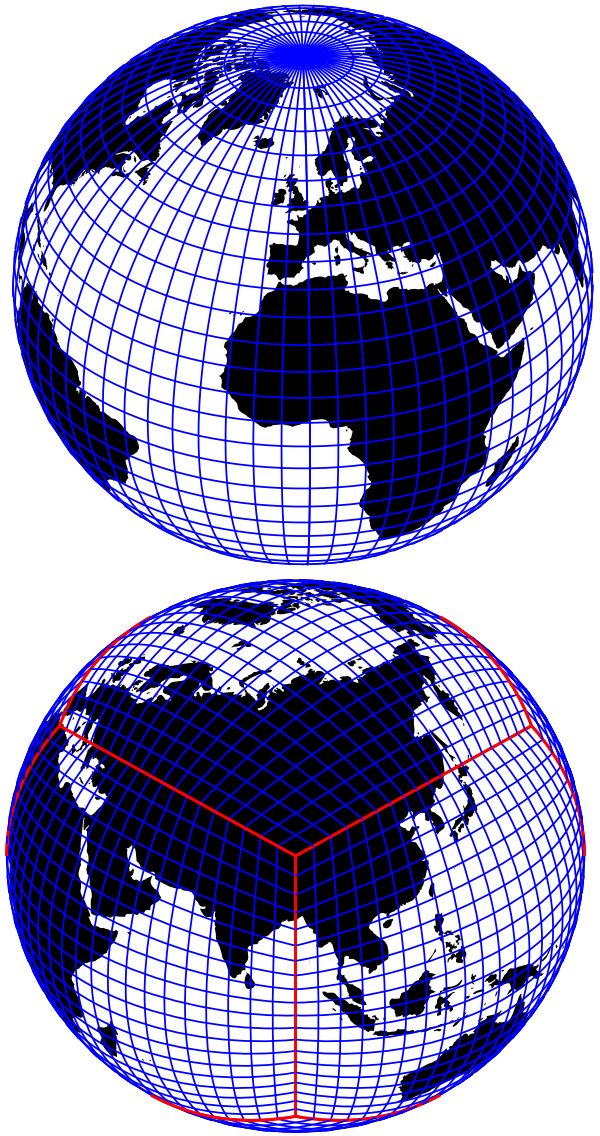
"Much less hypervis" (configuration blows up after a month or so)



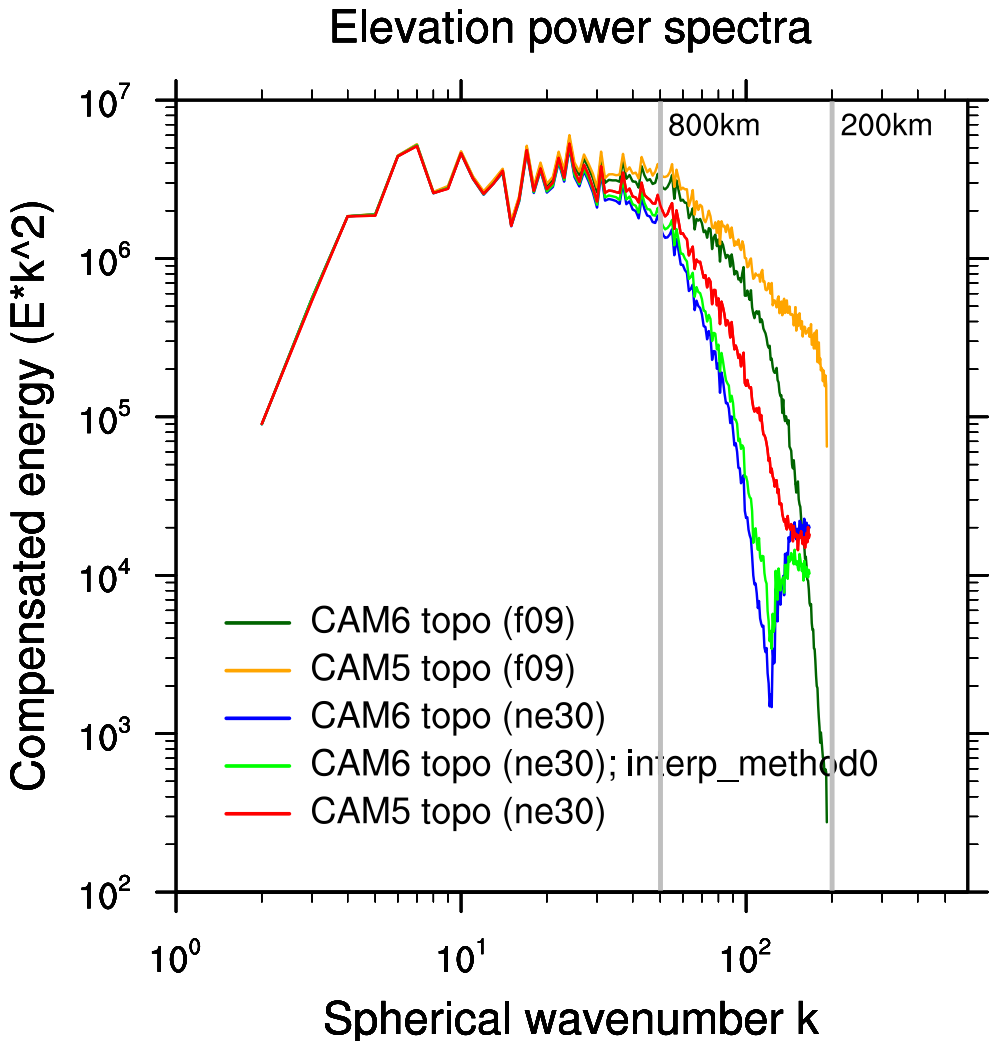
Topography used in finite-volume dynamical core

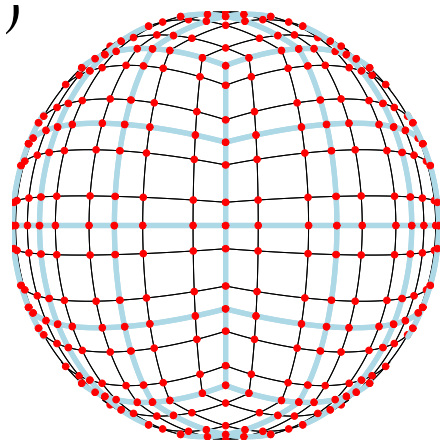


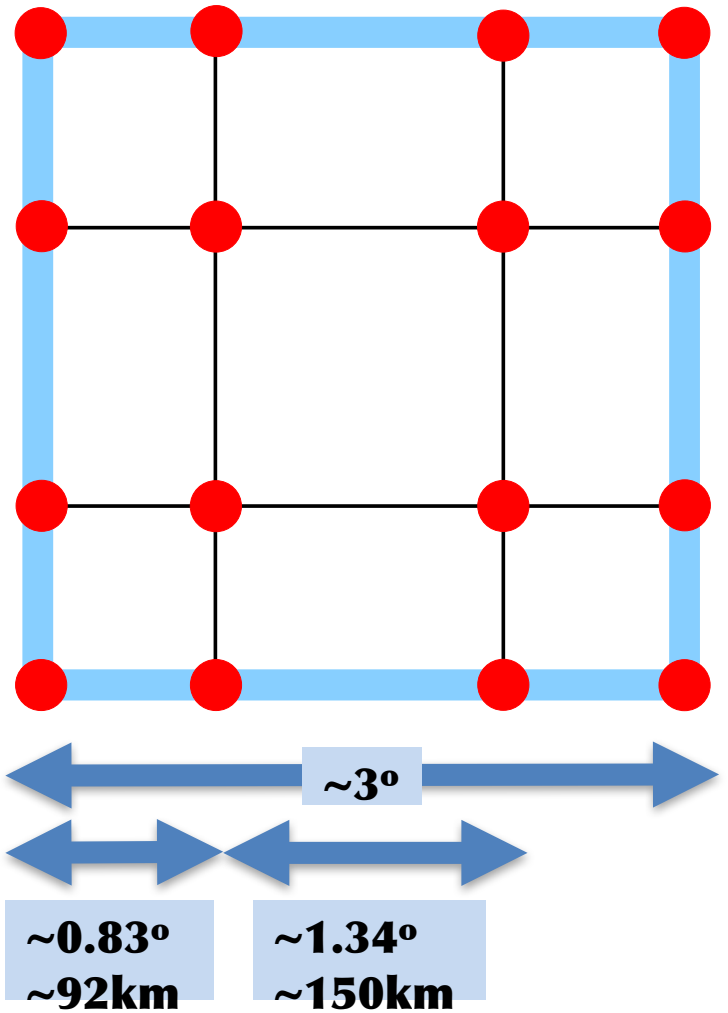
Grid on which smoothing is performed:



Topography used in CAM dynamical cores

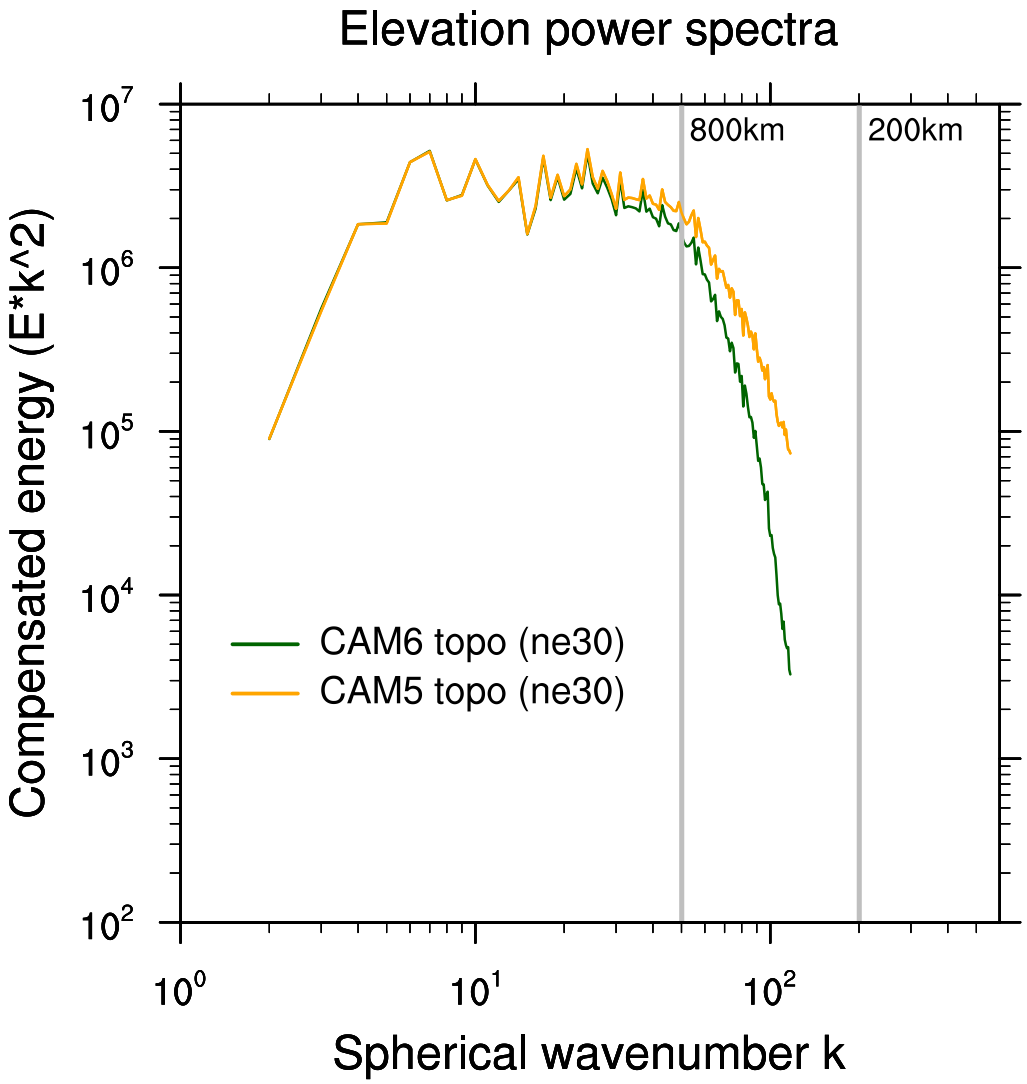


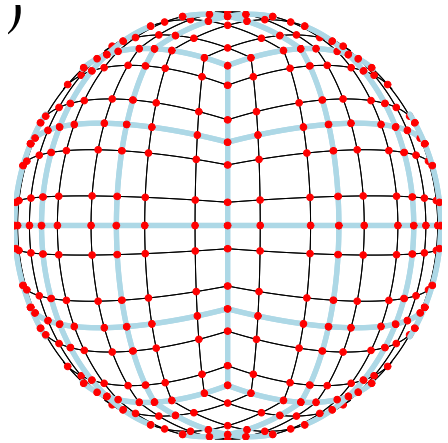


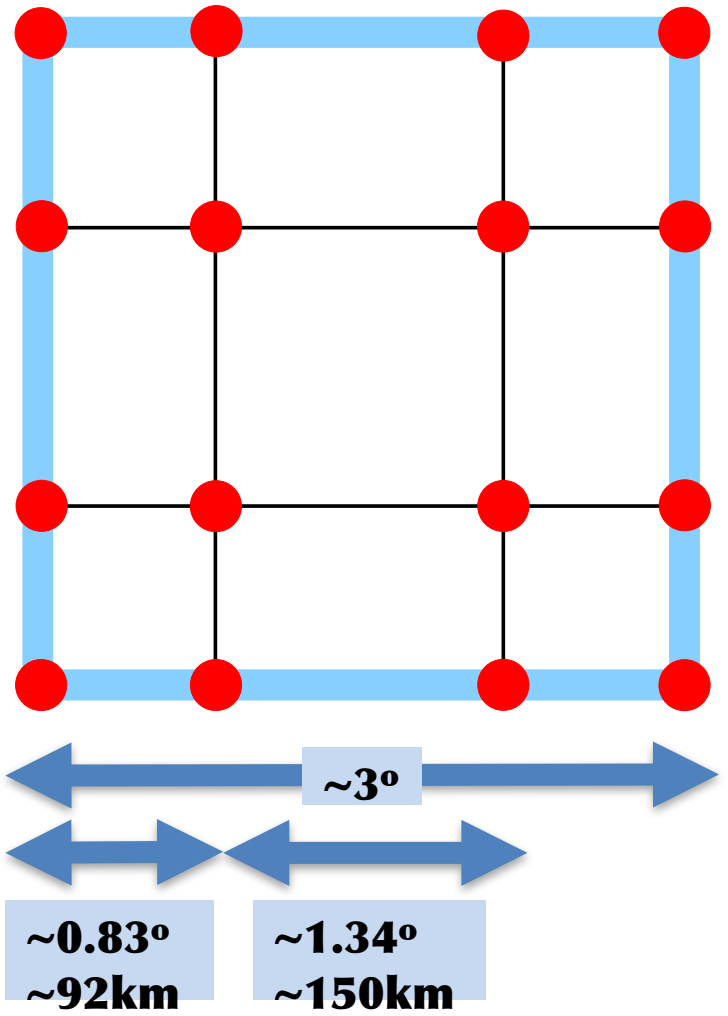


At the Equator the shortest resolvable wave in terms of max grid distance has wavenumber ~133 (=40E3km/300km)

Topography used in CAM dynamical cores







At the Equator the shortest resolvable wave in terms of max grid distance has wavenumber ~133 (=40E3km/300km)