ICHEC
Irish Centre for High-End Computing

# Stabilizing High-Resolution HARMONIE

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An Roinn Oideachais agus Eolaíochta | Department of Education and Science

HEA
Higher Education Authority
An tÚdarás um Ard-Oideachas

# Mission

"A Usable*
High-Resolution**
HARMONIE"

* (Able to run a ~24 hr forecast in ~1 hr wall-time)

** (~ 0.5 km grid-size)

# Simple, just edit "config_exp.h"

**Current Operational**:

```
IRELAND25)
     TSTEP=60       # Time step
     NLON=540       # No. x points
     NLAT=500       # No. y points
     LONC=-7.5      # Central lon.(deg)
     LATC=53.50     # Central lat.(deg)
     GSIZE=2500.    # Gridsize in m (x,y)
     LON0=5.0       # Ref. lon.(deg.)
     LAT0=53.5      # Ref. lat.(deg.)
     BDNLON=600     # No. X intermed.pts.
     BDNLAT=540     # No. Y intermed. Pts
```

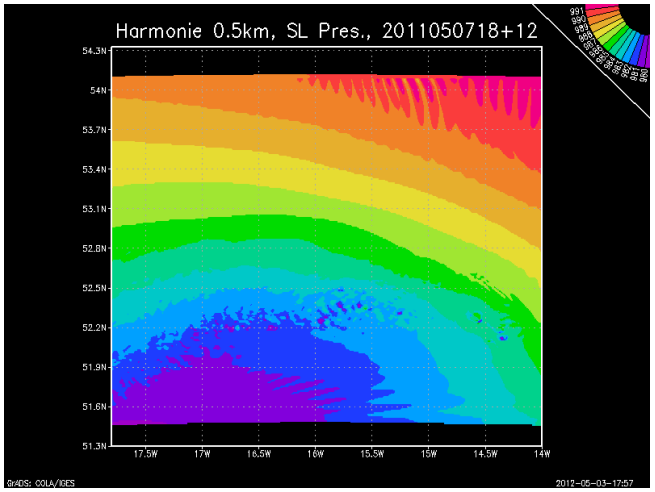
**New High-Resolution**:

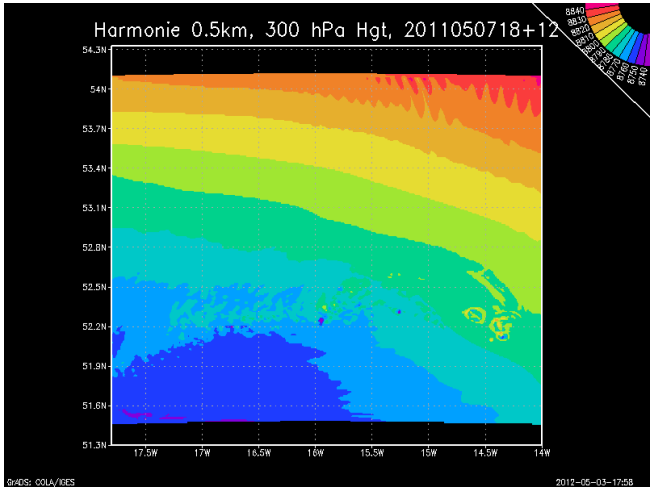
```
IRELAND05)
     TSTEP=12       # Time step
     NLON=600       # No. x points
     NLAT=600       # No. y points
     LONC=-9.0      # Central lon.(deg)
     LATC=52.80     # Central lat.(deg)
     GSIZE=500.     # Gridsize in m (x,y)
     LON0=-9.0      # Ref. lon.(deg.)
     LAT0=53.0      # Ref. lat.(deg.)
     BDNLON=600     # No. X intermed.pts.
     BDNLAT=600     # No. Y intermed. Pts
```

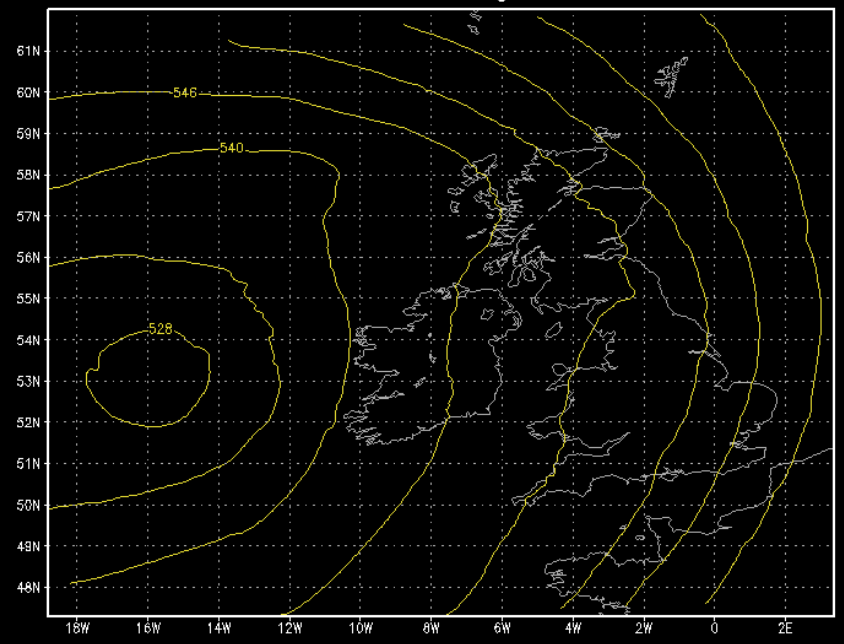
*Allocate lots of nodes, lots of system time, and run…*

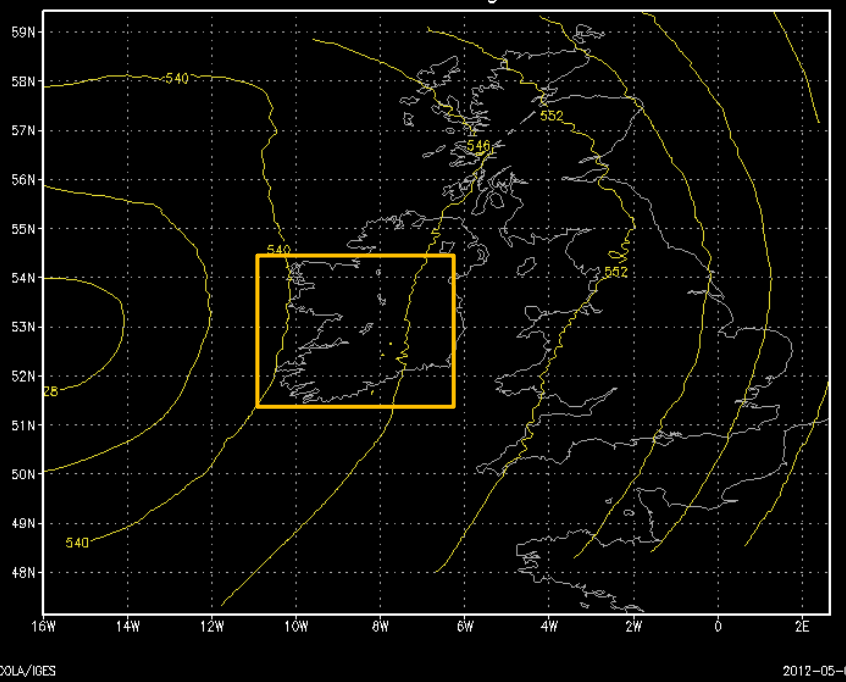
# Frequently get, in Forecast.1...

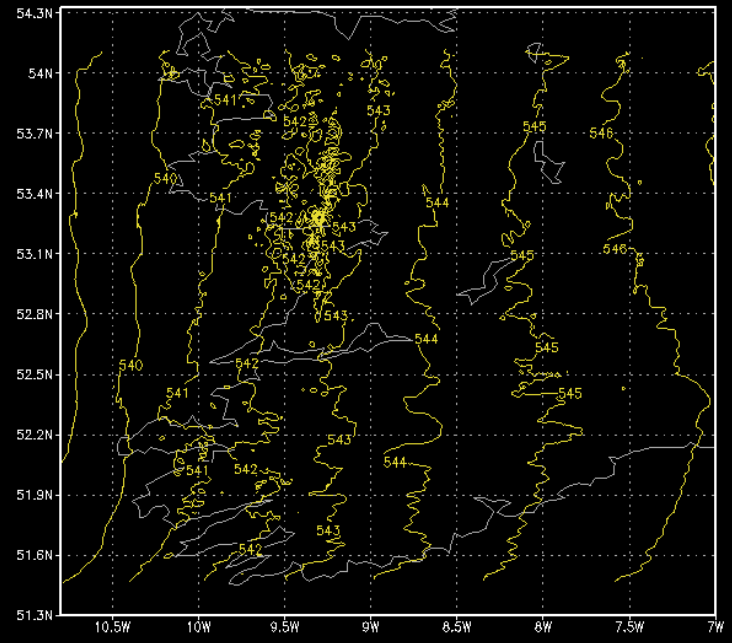
```
...
...
  03:29:46 STEP 3668 H=  12:13 +CPU=  2.460
  03:29:49 STEP 3669 H=  12:13 +CPU=  2.564
  03:29:51 STEP 3670 H=  12:14 +CPU=  2.364
  MAX V WIND=   222.829526211251
  LEVEL=            7  POINT=           23
  PCOLON=   0.967007914304197
  PGEMU=   0.793557144704579
SMILAG TRAJECTORY OUT OF ATM      1 TIMES.
  03:29:53 STEP 3671 H=  12:14 +CPU=  2.152
  MAX V WIND=   355.429345651749
  LEVEL=           11  POINT=           11
  PCOLON=   0.966946123280087
  PGEMU=   0.793892880470571
  V WIND =   355.429345651749       IS TOO STRONG, EXPLOSION.
  LEVEL=           11  POINT=           11
  PCOLON=   0.966946123280087
  PGEMU =   0.793892880470571
 ABORT!  106  !V WIND TOO STRONG, EXPLOSION!!!
MPL_ABORT: CALLED FROM PROCESSOR    106 THRD     1
 MPL_ABORT: THRD           1    !V WIND TOO STRONG, EXPLOSION!!!
```

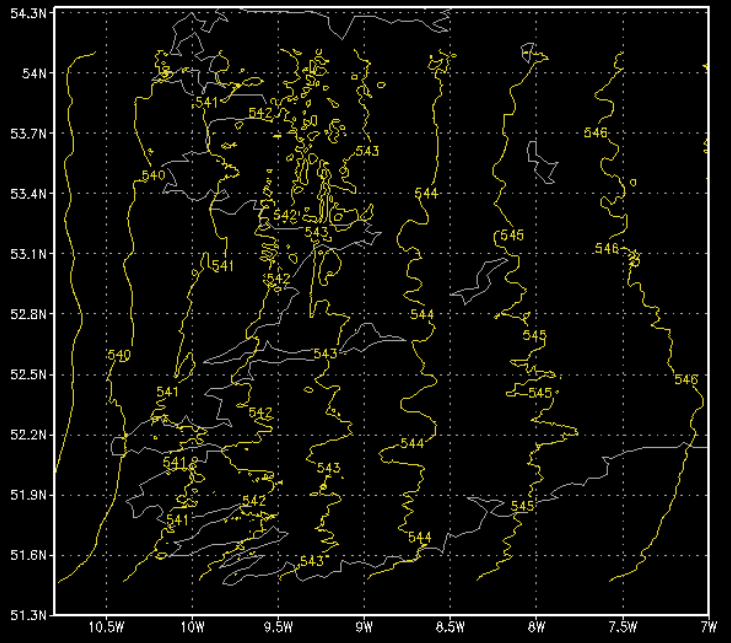


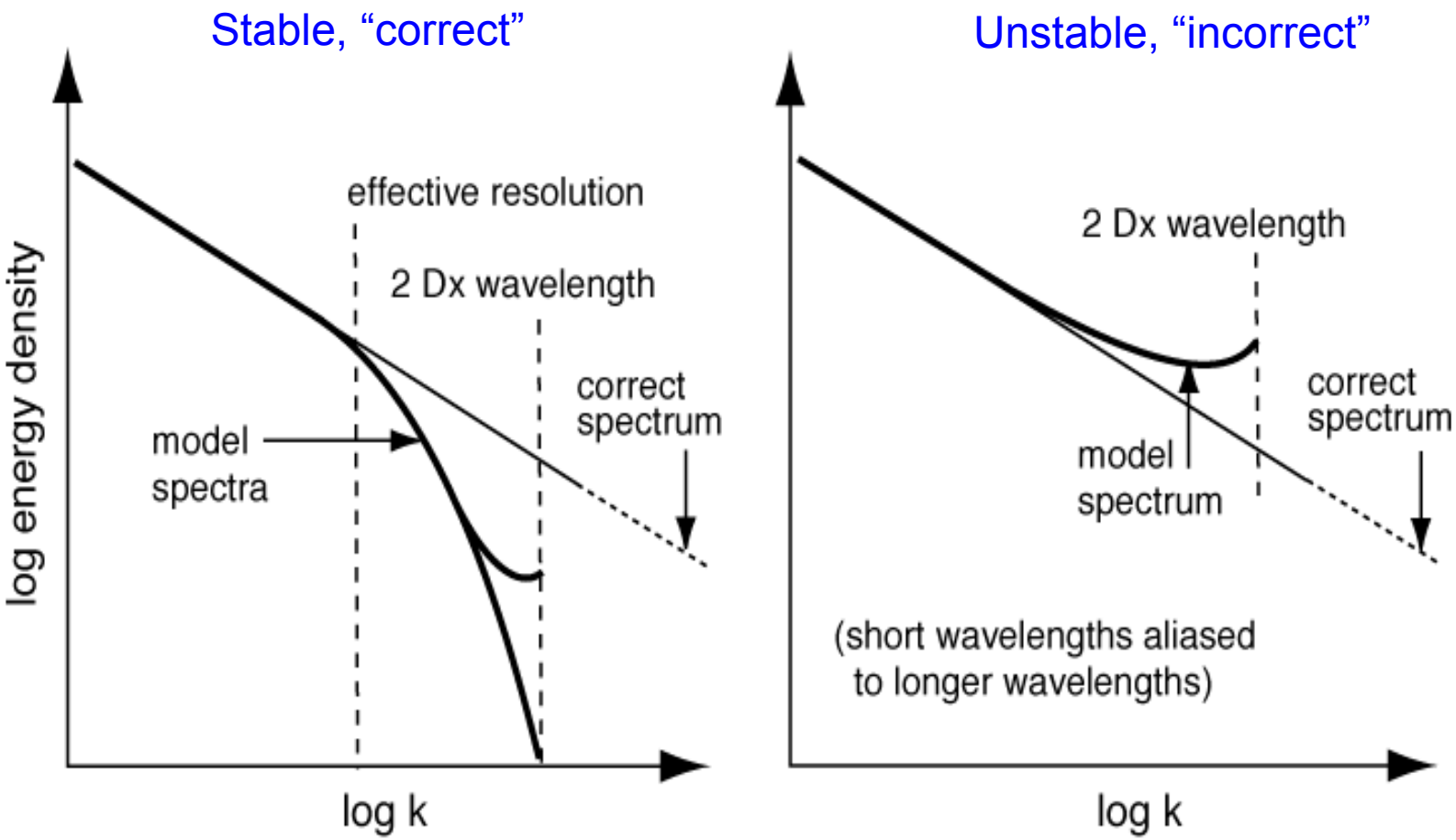

Harmonie 5.5km 500mb Hgt 2011050718+23
546
540
528
61N
60N
59N
58N
57N
56N
55N
54N
53N
52N
51N
50N
49N
48N
18W
16W
14W
12W
10W
8W
6W
4W
2W
0
2E


Harmonie 2.5km 500mb Hgt. 2011050718+23
540
552
546
540
552
528
540
59N
58N
57N
56N
55N
54N
53N
52N
51N
50N
49N
48N
16W
14W
12W
10W
8W
6W
4W
2W
0
2E
GrADS: COLA/IGES
2012-05-04-17:19


Harmonie 0.5km 500mb Hgt 2011050718+23
54.3N
54N
53.7N
53.4N
53.1N
52.8N
52.5N
52.2N
51.9N
51.6N
51.3N
10.5W
10W
9.5W
9W
8.5W
8W
7.5W
7W


Harmonie 0.5km (damped) 500mb Hgt 2011050718+23
54.3N
54N
53.7N
53.4N
53.1N
52.8N
52.5N
52.2N
51.9N
51.6N
51.3N
10.5W
10W
9.5W
9W
8.5W
8W
7.5W
7W

# Schematic of some typical atmospheric spectra




(from Skamarock, 2008)

# Enhanced Scale-Selective Damping

For variable X, default scale-selective damping has the form:

$$\partial X/\partial t = -\boldsymbol{KX}\,|\nabla^{\boldsymbol{r}} X|$$

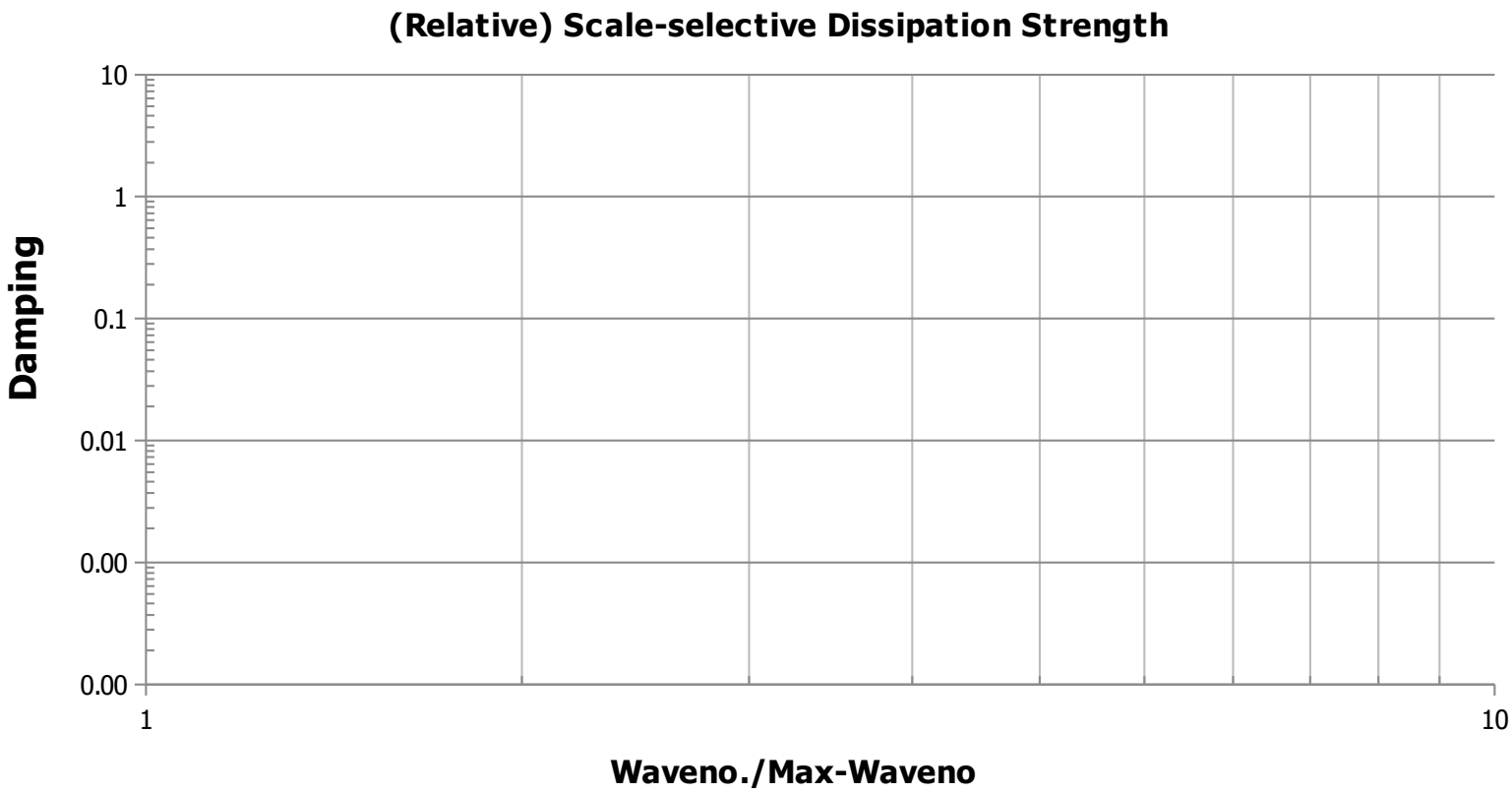
Exponent ***r = 4*** by default, labelled REXPDH.

Coefficient ***KX = 123*** by default, labelled RRDXTAU.

To Stabilize High-resolution Harmonie, set:

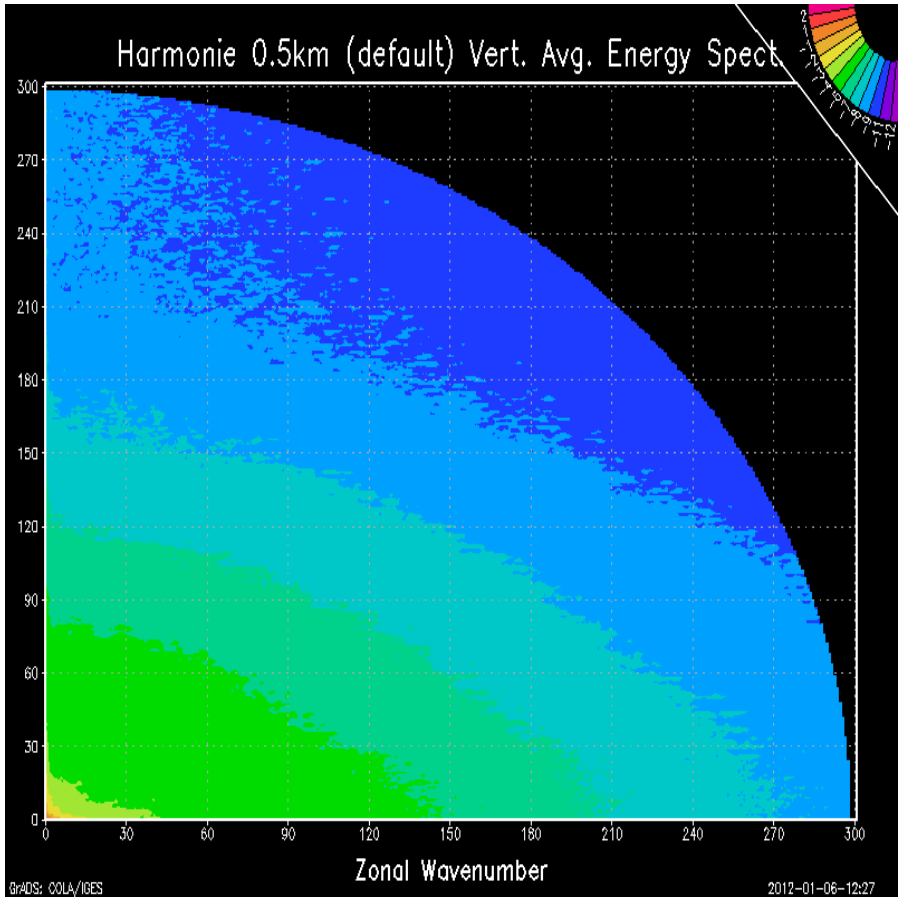
***r = 6 ,  KX = 12,300***

# Shape & Strength of Scale-Selective Damping

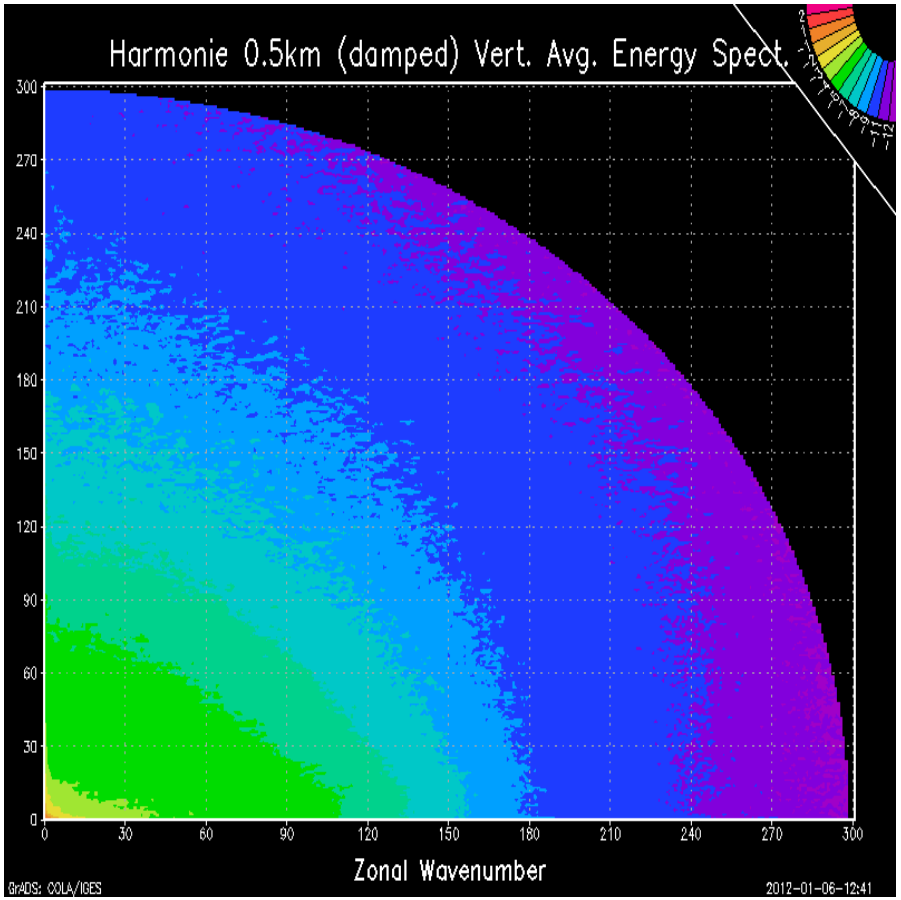



(Damping operates on normalized wavenumbers, between 0 and 1.
Larger exponent ***r*** reduces most values, so larger coefficient ***Kx*** is needed to compensate.)

# 2-d KE Spectra from Harmonie

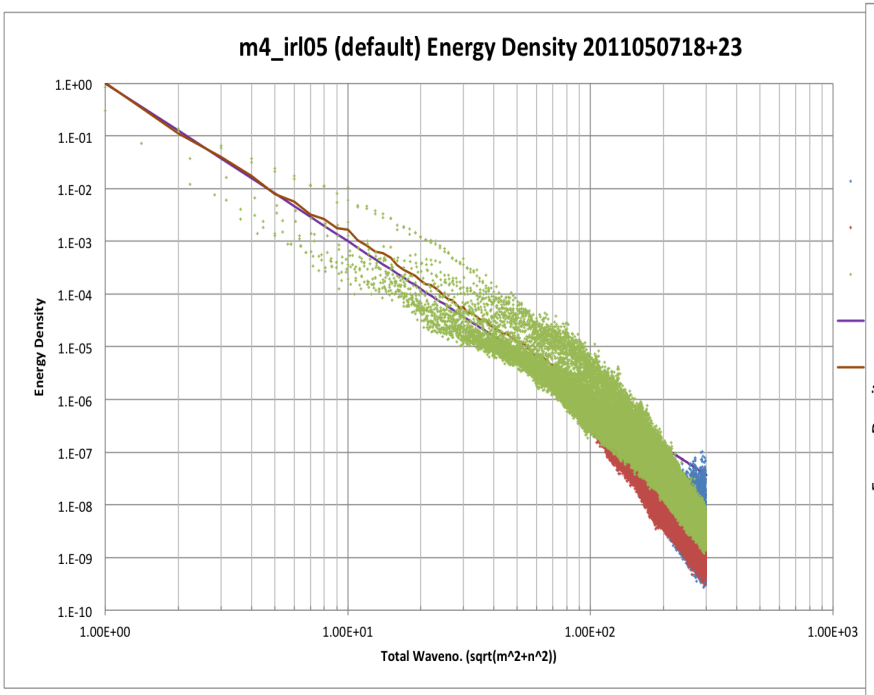



Standard (default) damping

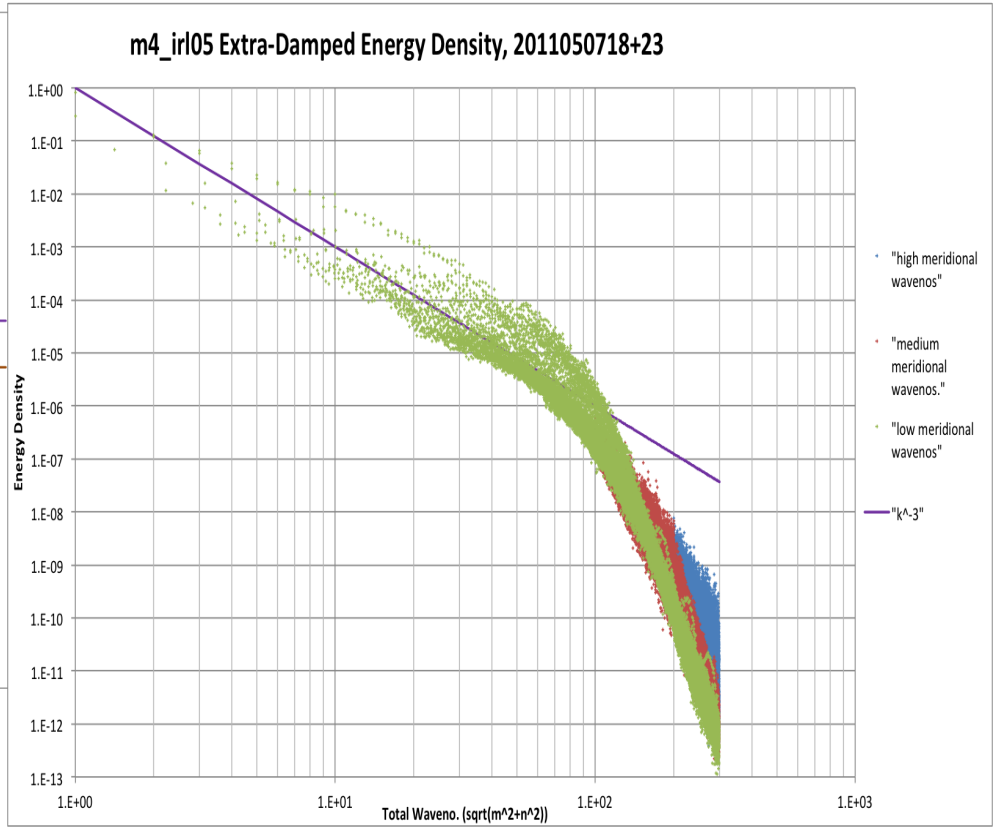



Enhanced scale-selective damping

# Spectra Projected onto 1-D



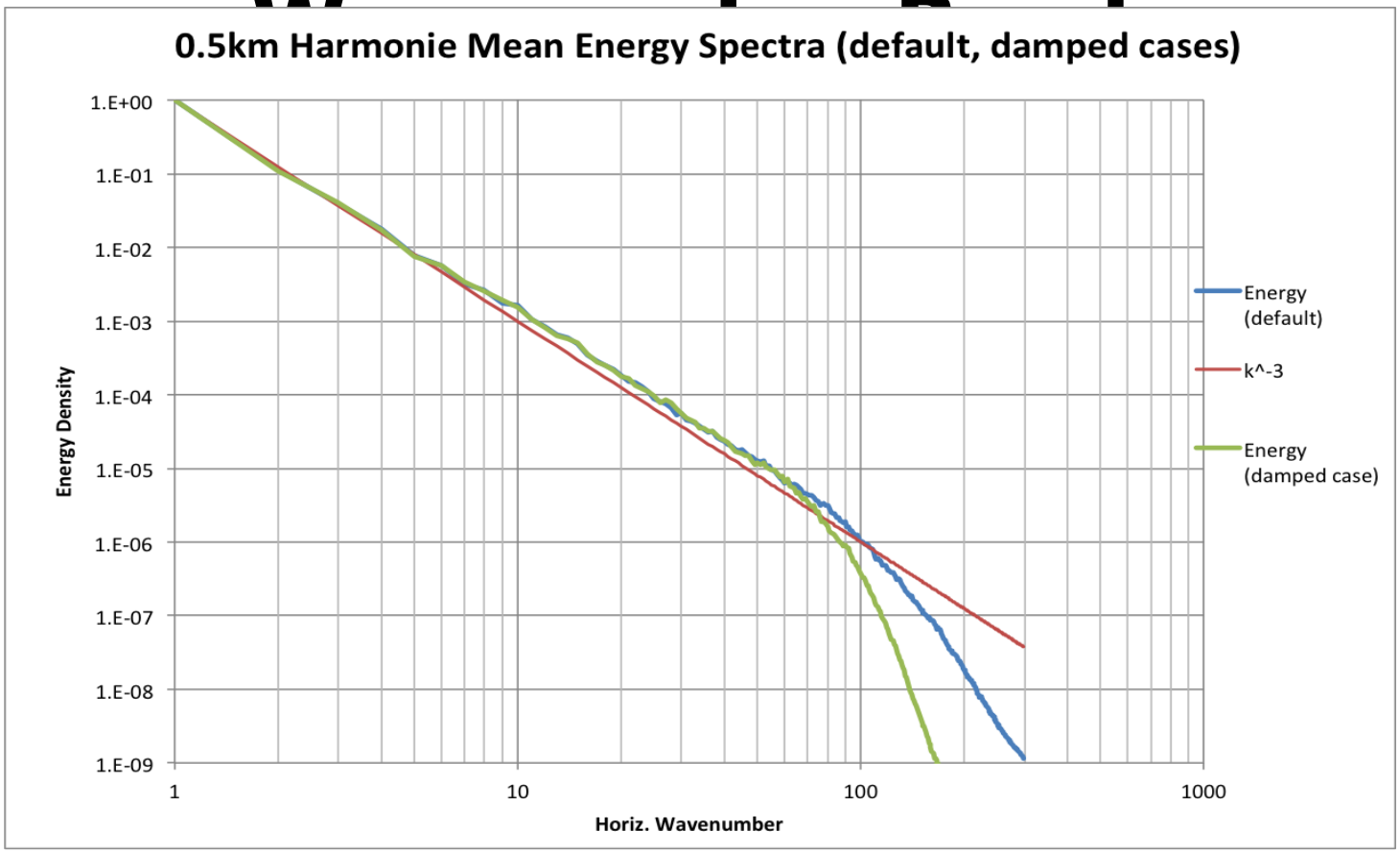

Standard (default) damping




Enhanced scale-selective damping

Both Vertically-averaged spectra, from single snapshot in time

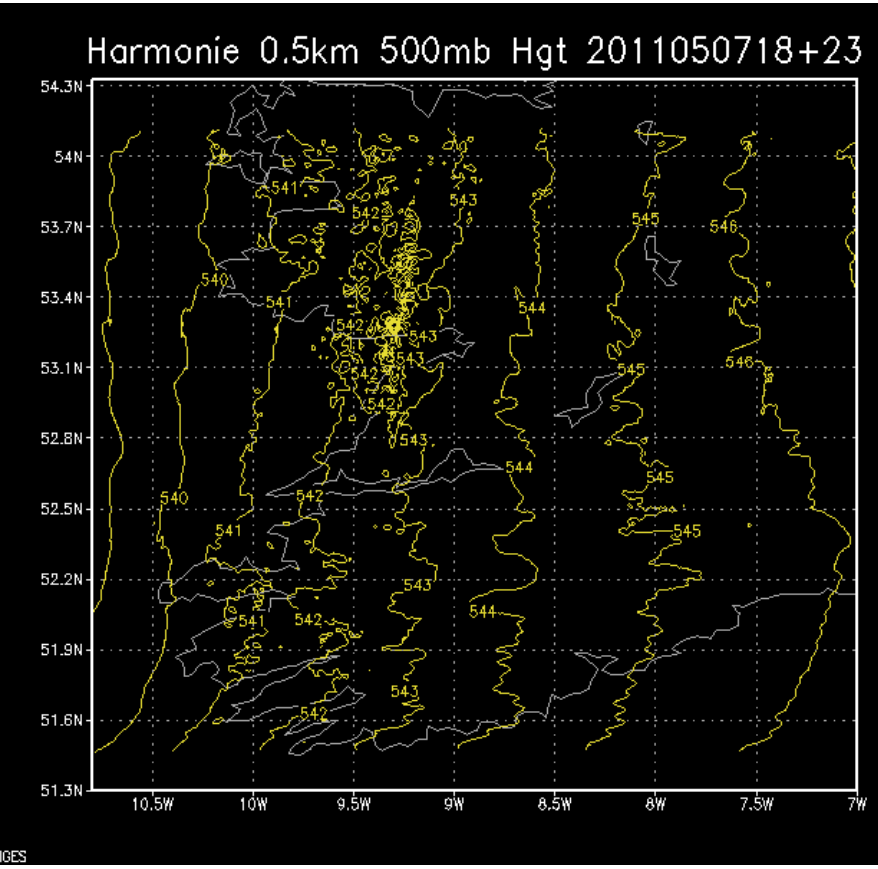
# Spectra Averaged within

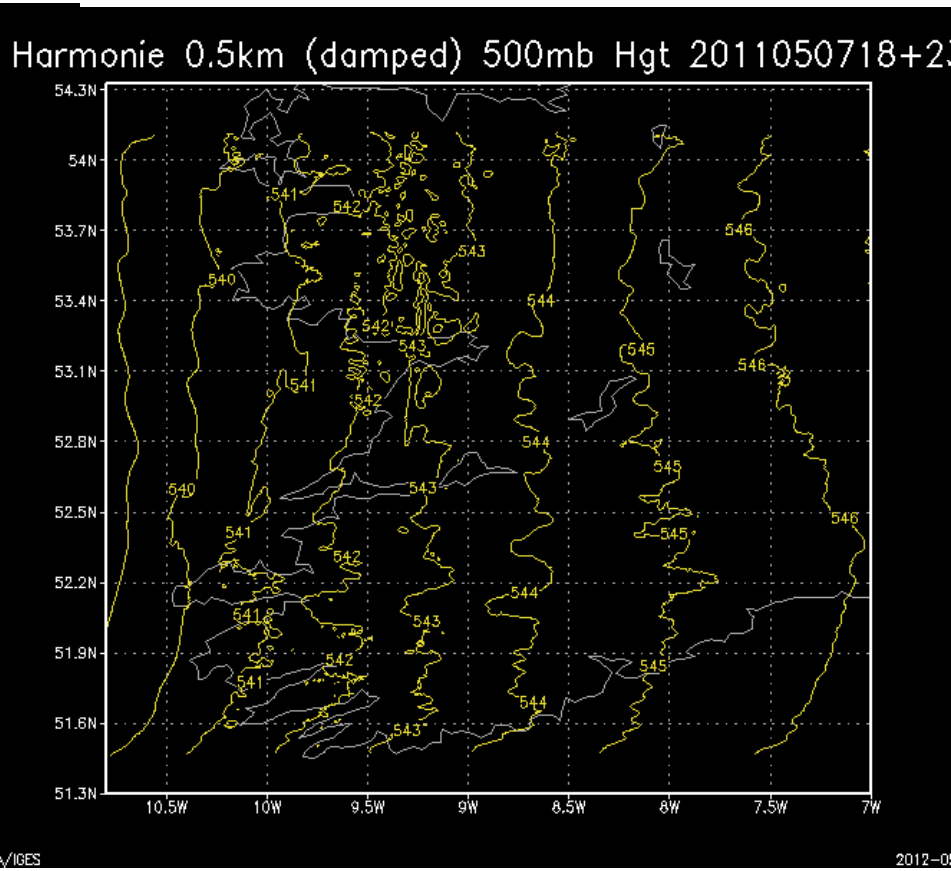



(No hint of any K-5/3 slope….)

# Enhanced Damping in Physical Space

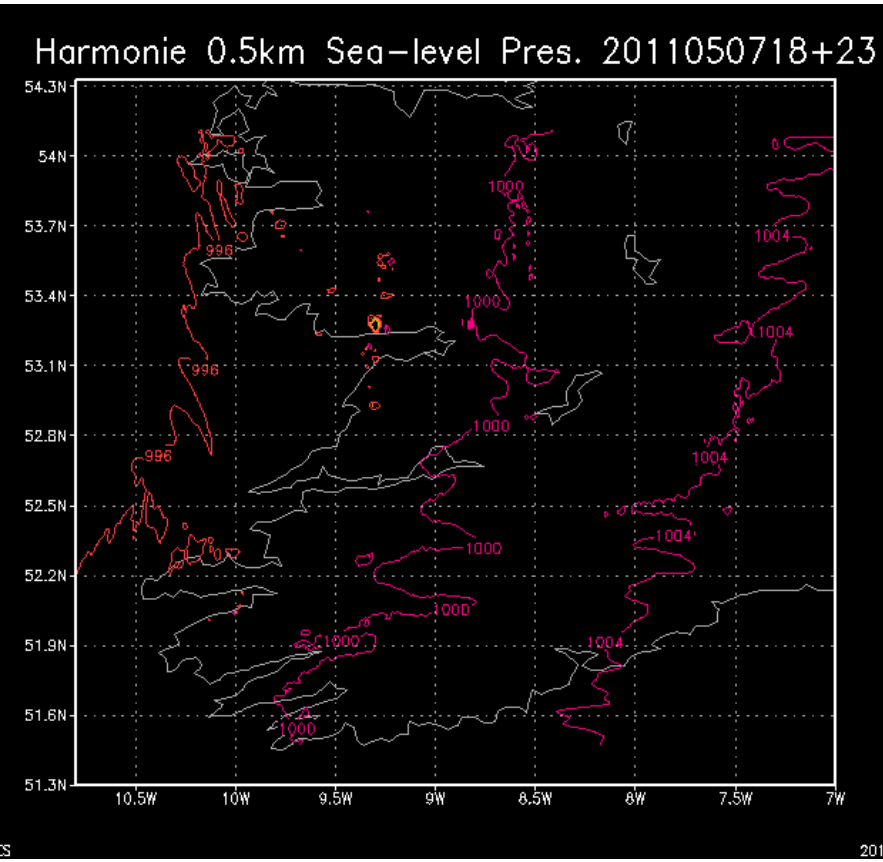
## (500 hPa Heights)

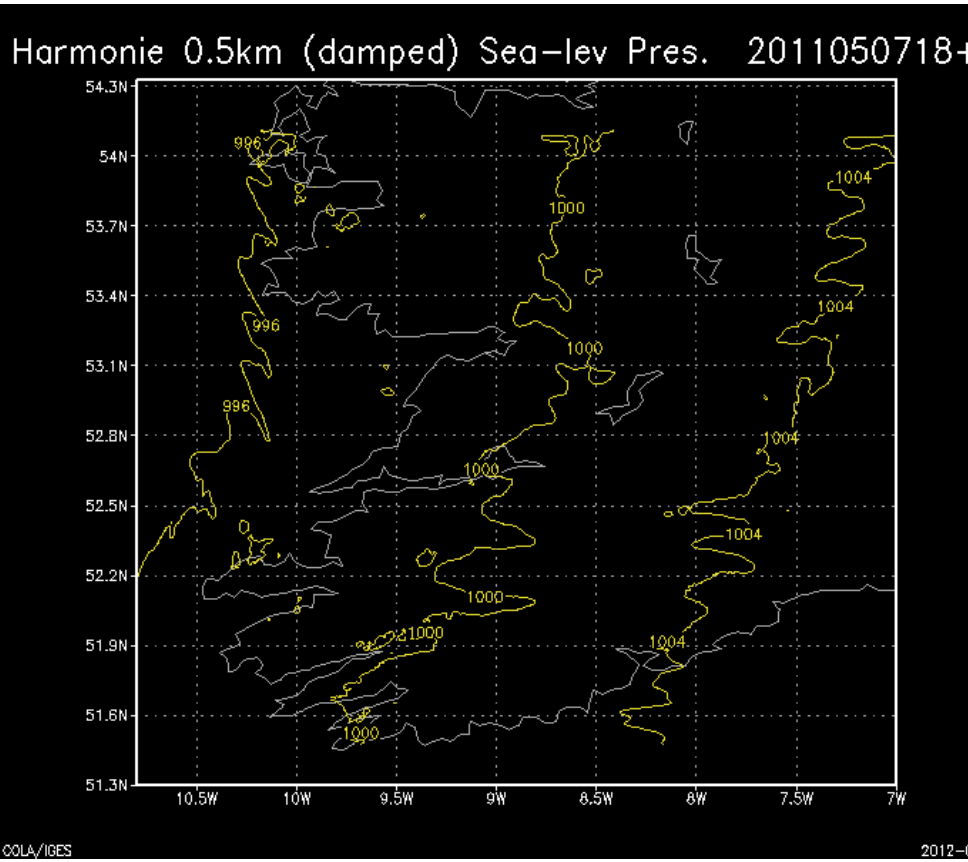


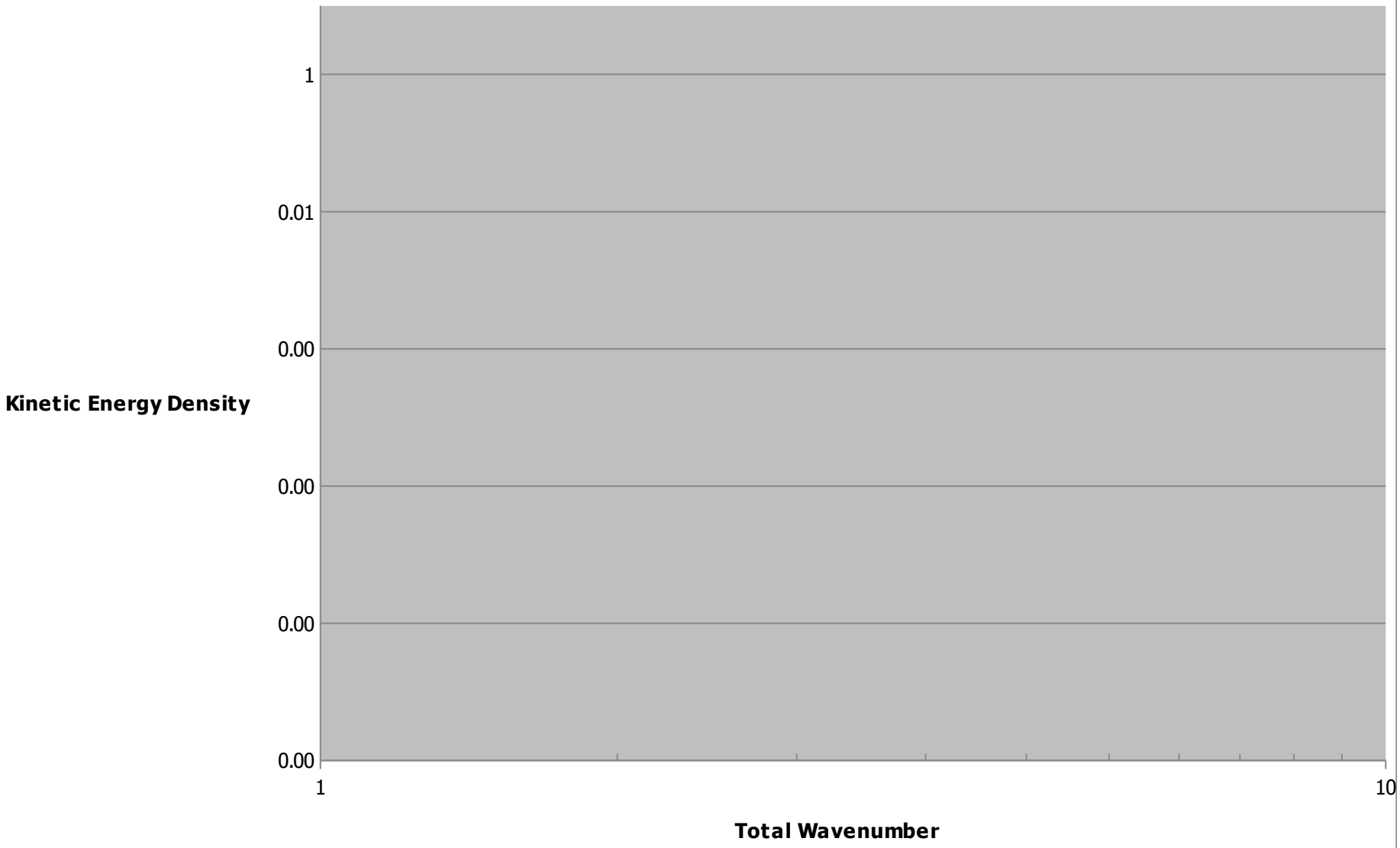
# Enhanced Damping in Physical Space

## (Sea-level Pressure)

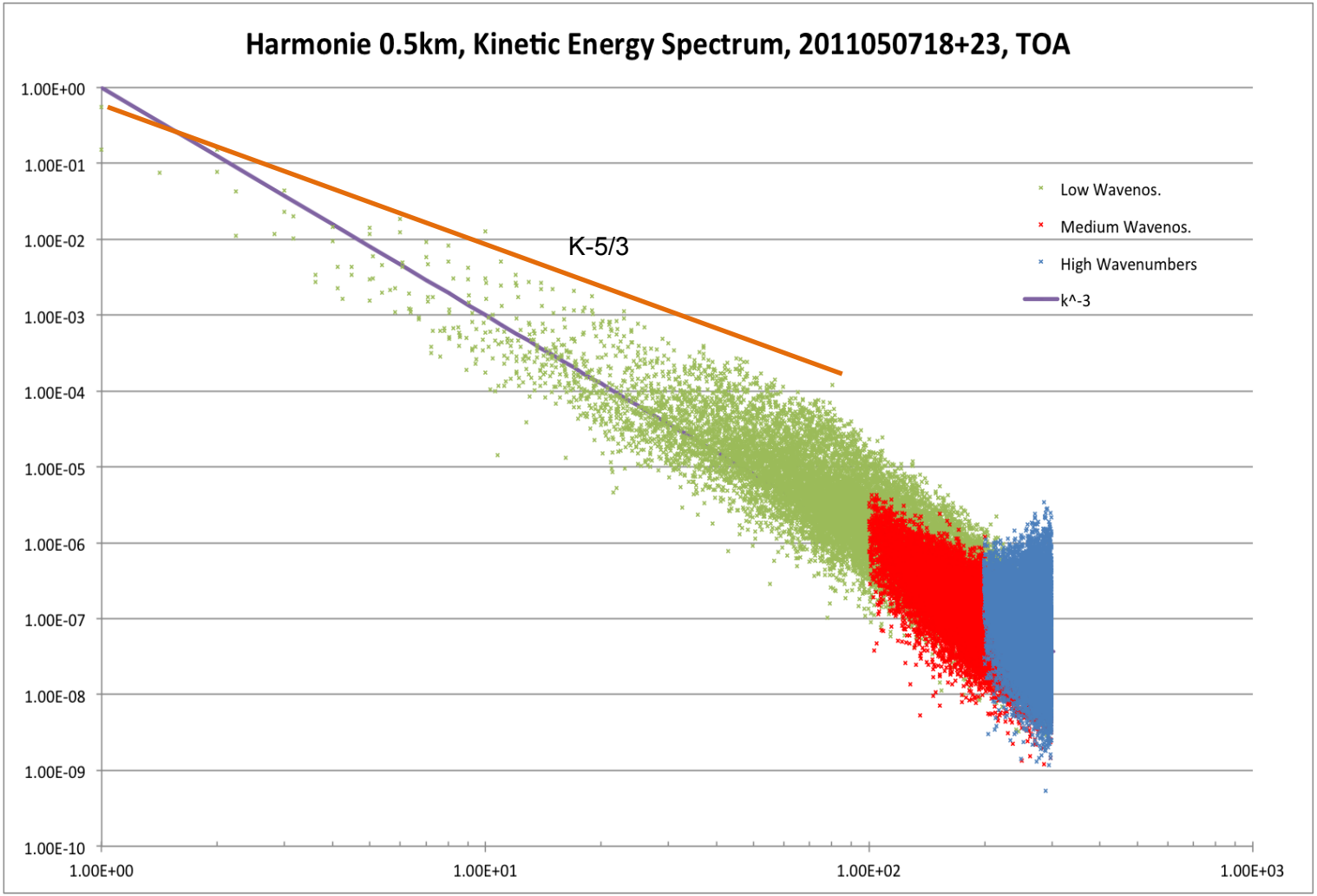


# Harmonie 2.5km KE Spectrum Spin-Up (from cold start)

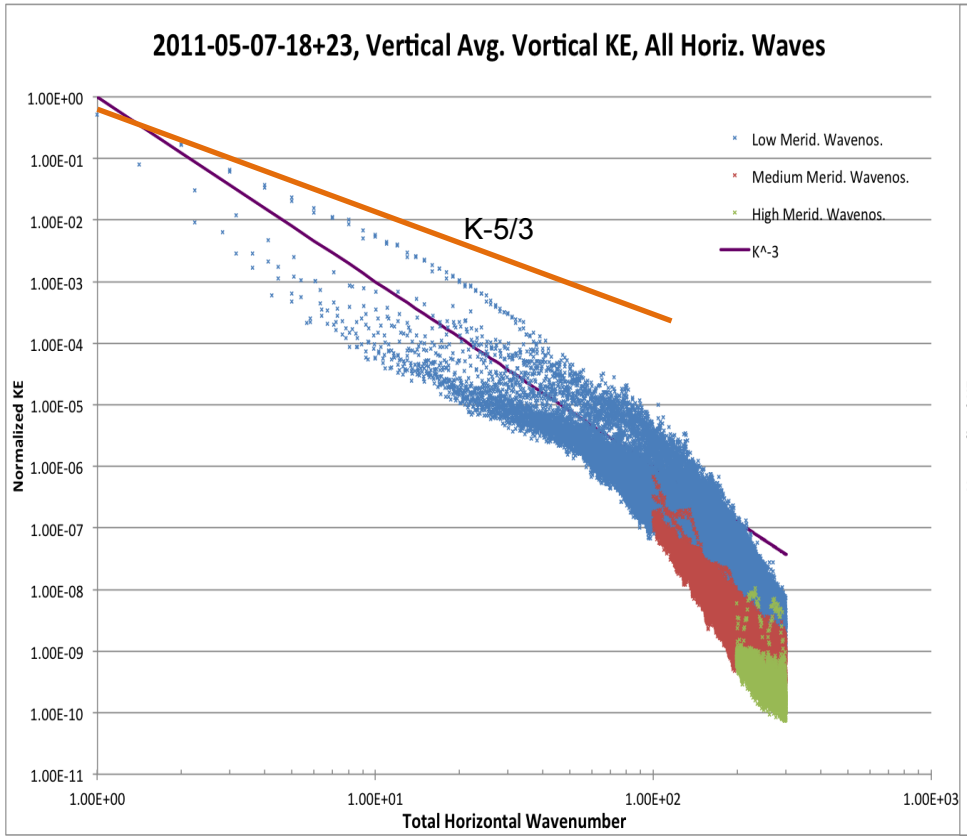


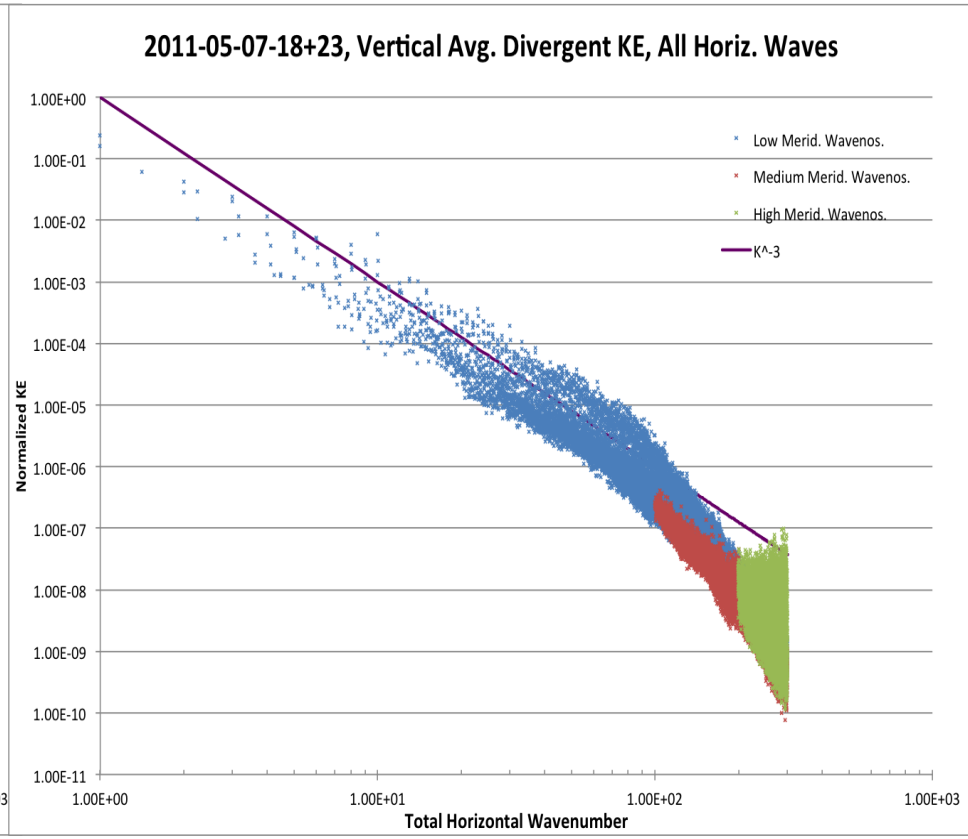
# Upper-Level KE Spectra
## (Default Damping)



# KE from Rotational & Divergent Winds

## (default damping)

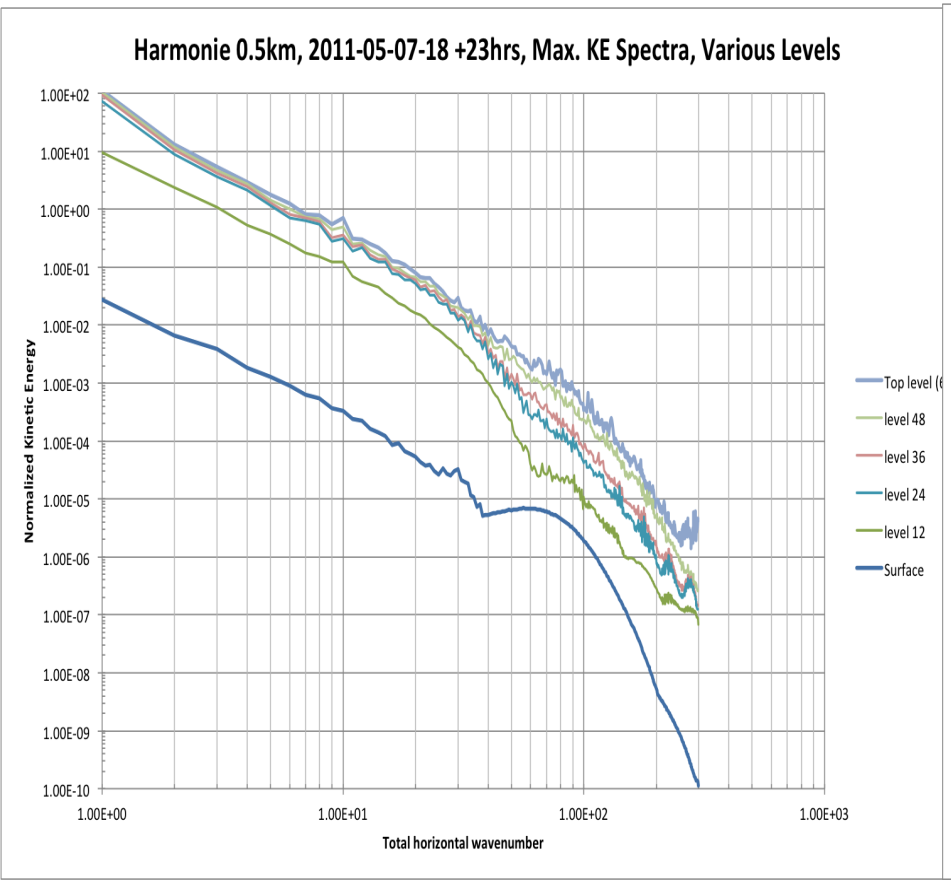


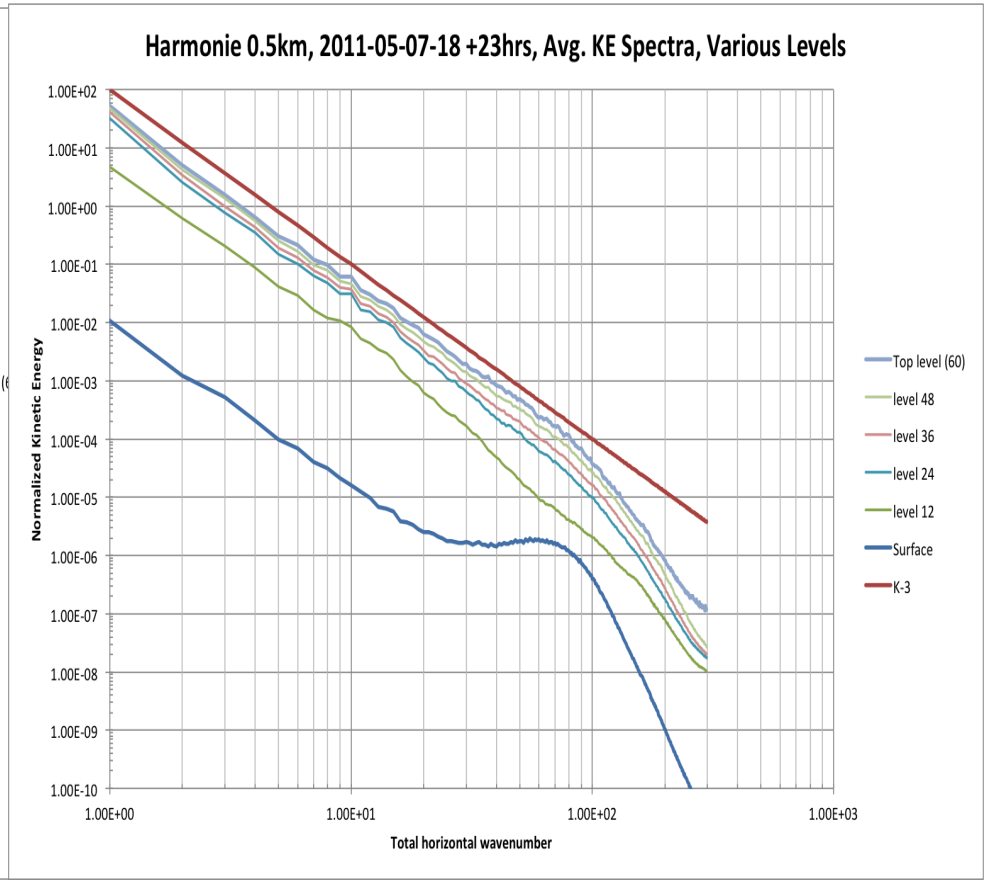

KE from “Vortical” winds only

KE from “Divergent” winds only

# Max. vs. Avg. KE Spectra
## (as functions of height)

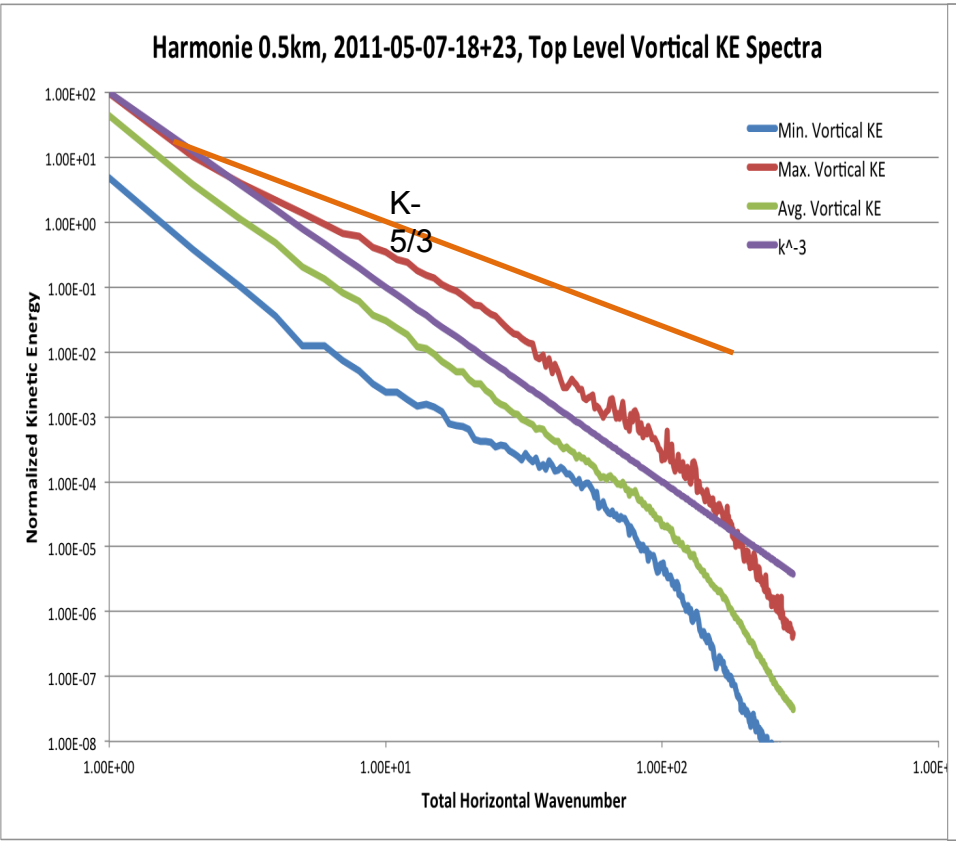


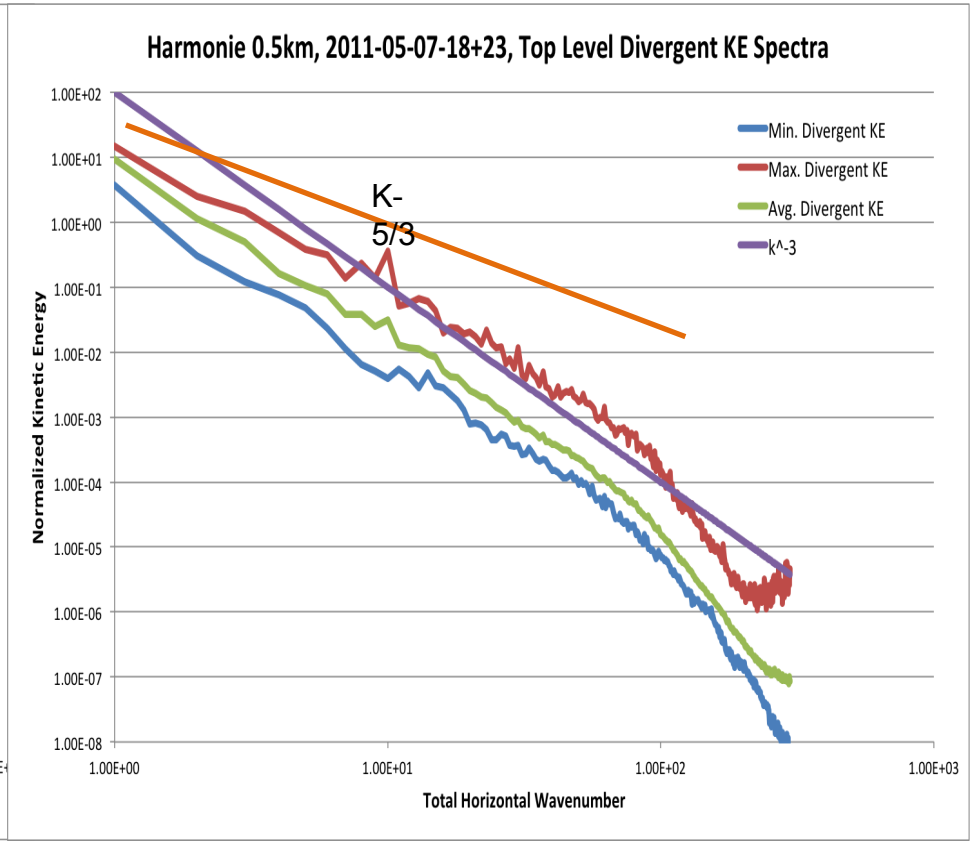

Maximum Energy per unit wavenumber



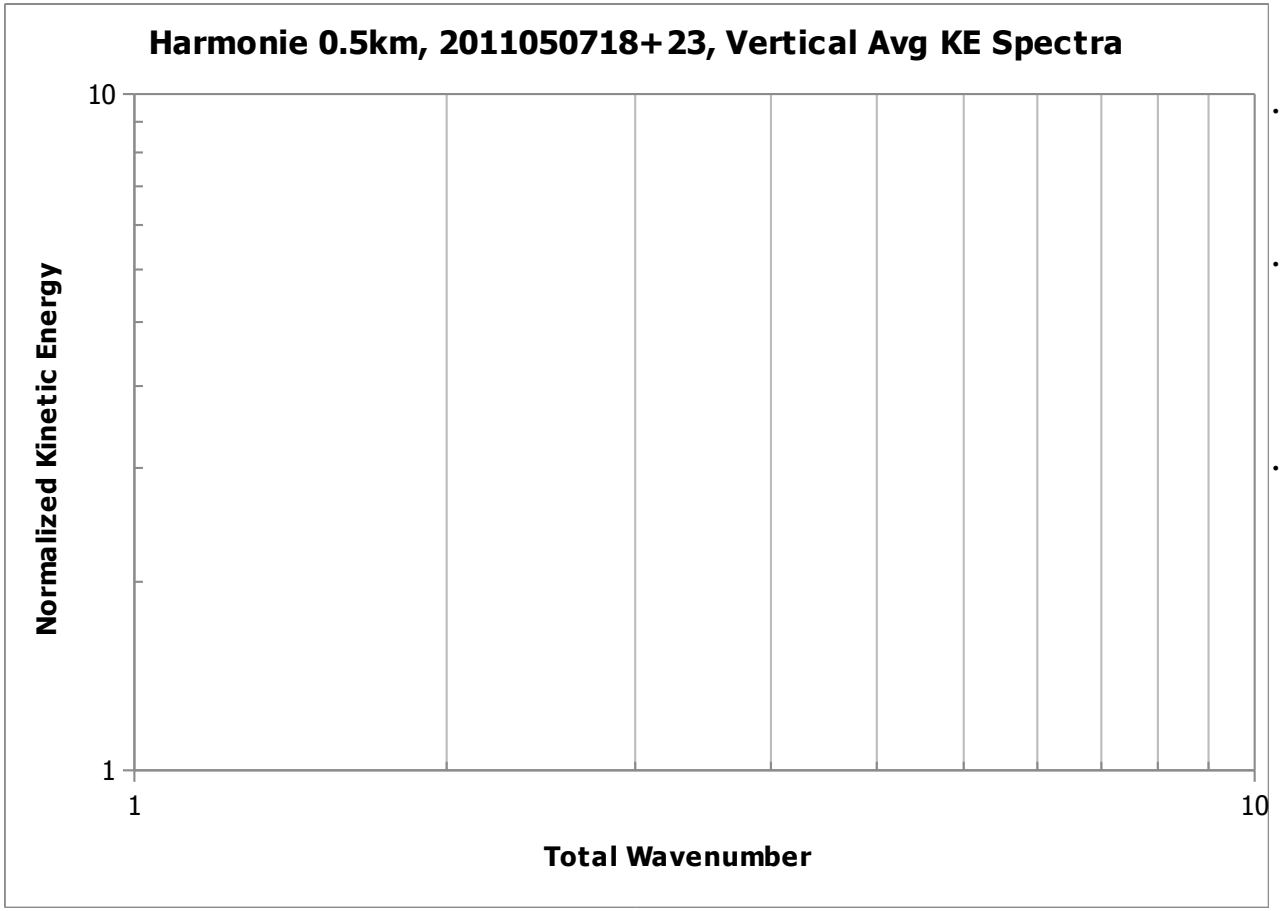

Average Energy per unit wavenumber

# Upper-Level KE Spectra



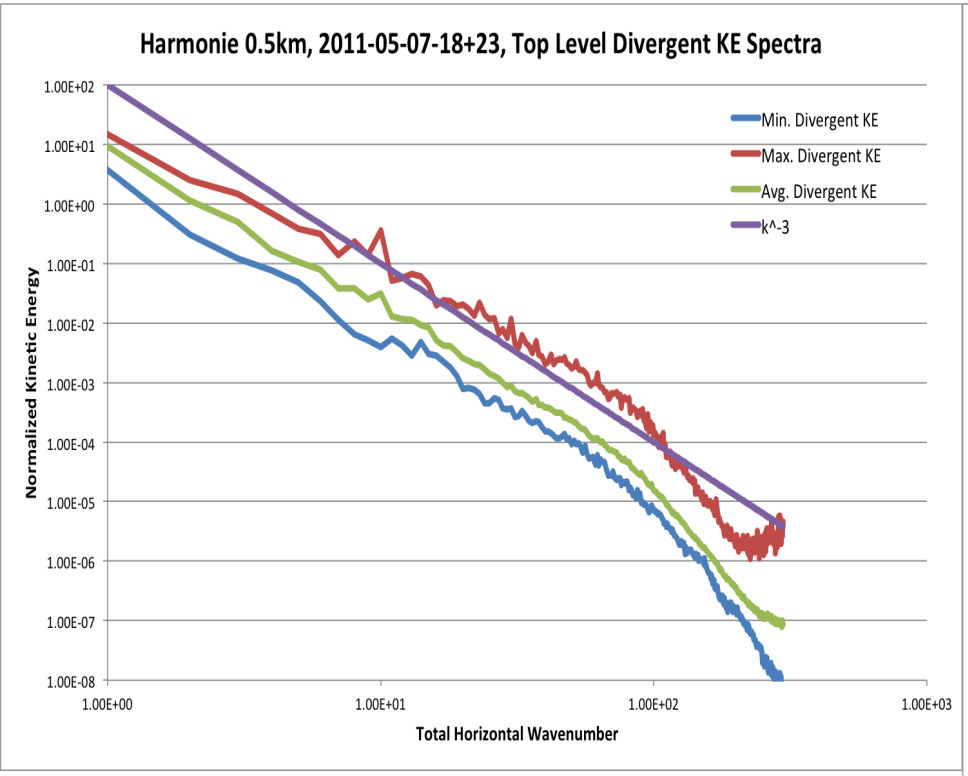
# Vertical Average KE Spectra
## (default damping)



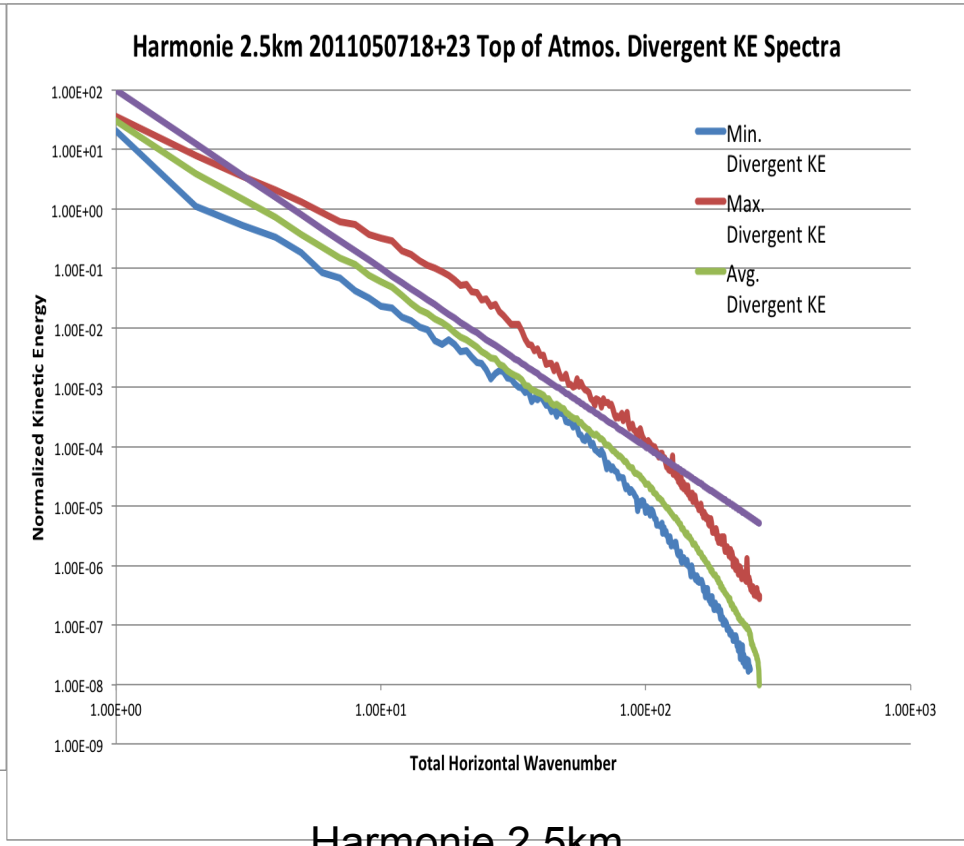

- No turn-up in spectral tails in vertical average
- Mainly vortical energy at small k; more divergent KE at large k
- More k-3 than k-5/3 slopes

# Harmonie 0.5km vs. 2.5km Spectra

## (all default damping)



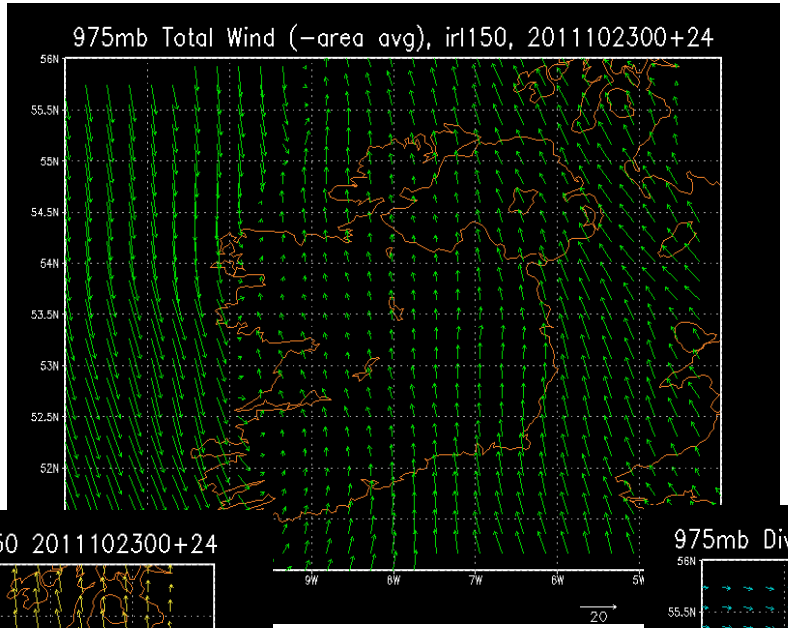

Harmonie 0.5km

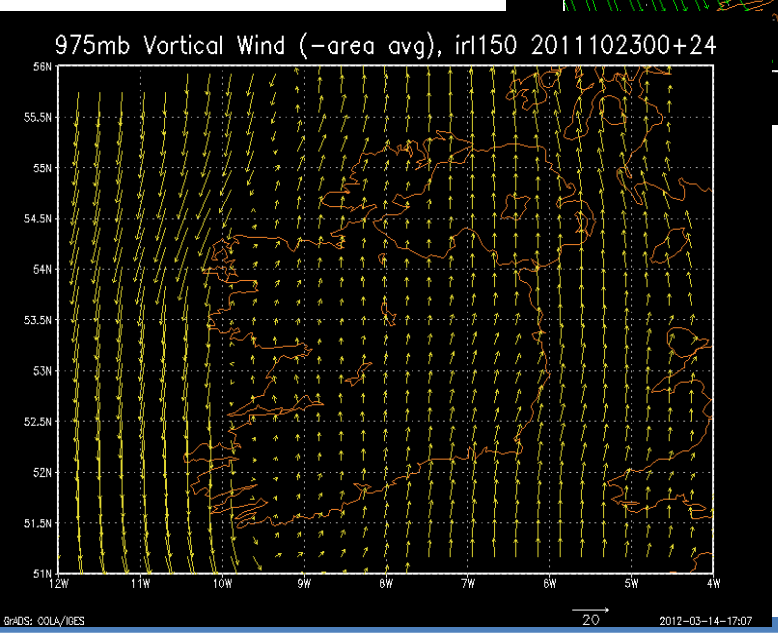


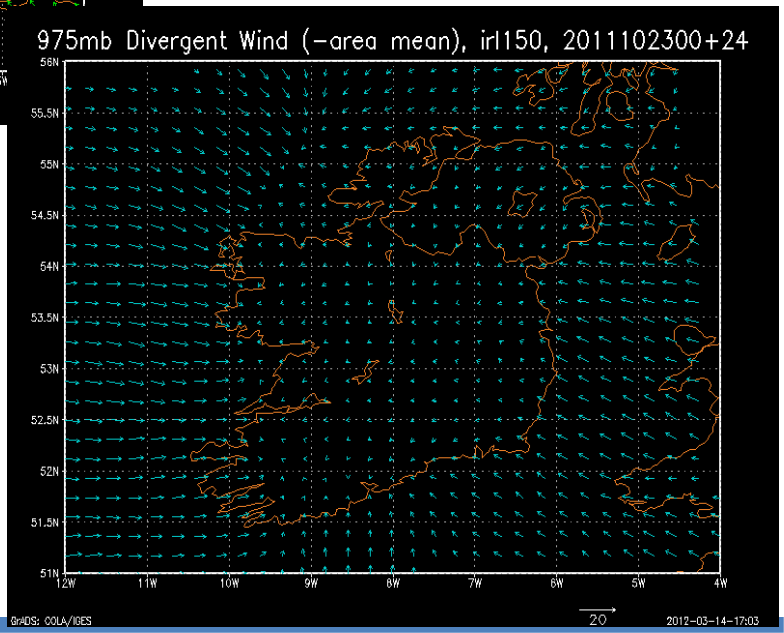

Harmonie 2.5km

*Turn-up in tail of Divergent KE at large k only really apparent at 0.5km resolution.*

# Physical Vortical, Divergent Fields:



# Conclusions (1)

- Standard damping not strong enough to prevent spurious KE build-up at small scales in 0.5km Harmonie
- Spurious KE build-up ("up-turned spectral tails") associated with:
  - Early adjustment phase of model spin-up
  - Divergent flow (as distinct from rotational flow)
  - Upper levels
- 0.5km Harmonie can be stabilized by enhanced scale-selective damping. (Could be even more selective…)
  - A poor-man's gravity-wave drag?
  - A "scale-adaptive" physical parameterization that is not adaptive enough?

# Conclusions (2)

- Most KE spectra (especially averages) closely follow a ***k-3*** power law.

- Evidence for shallower spectral slopes in the *most energetic waves* at each wavenumber – but a ***k-5/3*** inertial range only appears here as a limiting slope for the spectral "envelope".

- Total or "accumulated" energy (instead of averages) at each wavenumber will show shallower slopes – exactly what slope remains to be seen.