Experience in creating orography ancillary files

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European Centre for Medium-Range Weather Forecasts (ECMWF)

Thanks to many colleagues at ECMWF and in particular Anton Beljaars, Geir Austad, Sinisa Curic, Christian Kühnlein, Sylvie Malardel, Gianpaolo Balsamo, Irina Sandu, …

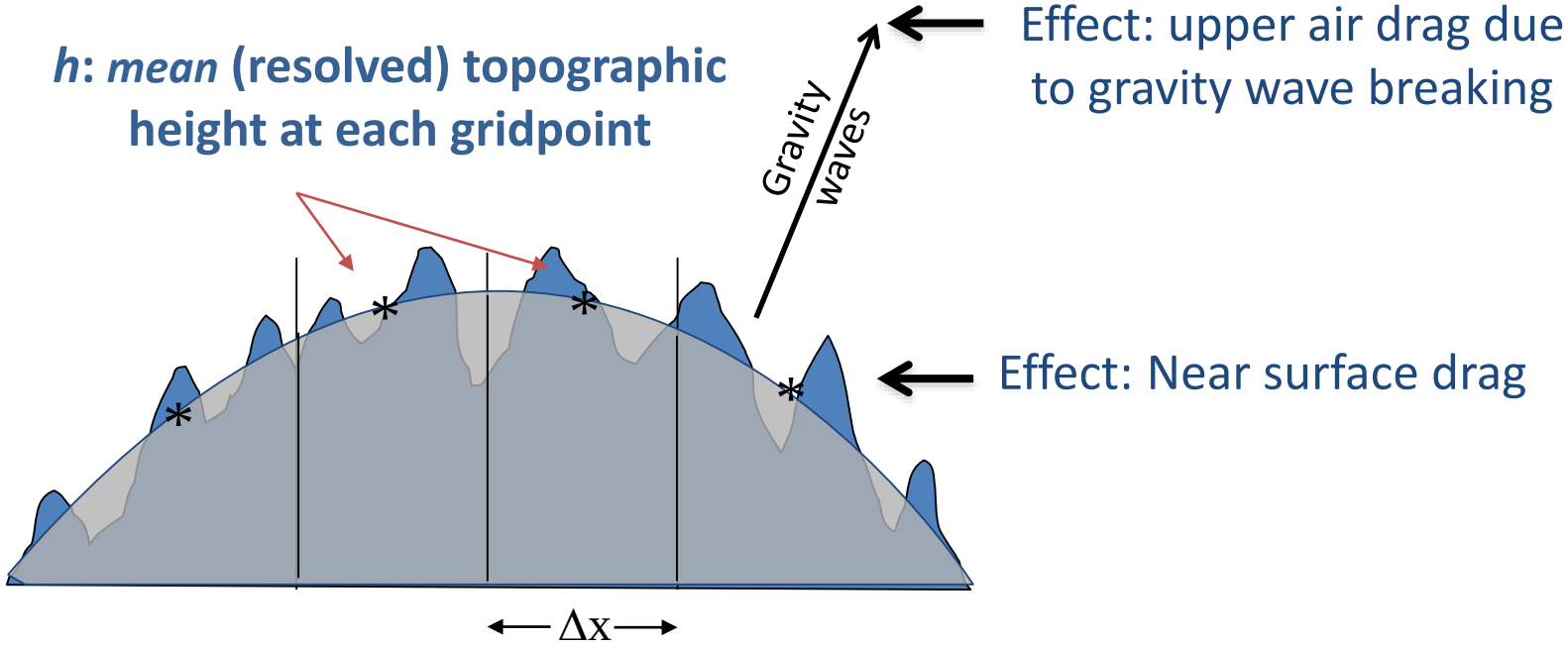
ECMWF

Outline

- How to fit satellite derived information to the model ?
- Mean orography and subgrid-scale orography (SSO) parameters
- Statistics and sensitivities of mean orography representation and SSO parameters
- Conclusions

Sub-grid scale and mean orography

***h*: *mean* (resolved) topographic height at each gridpoint**

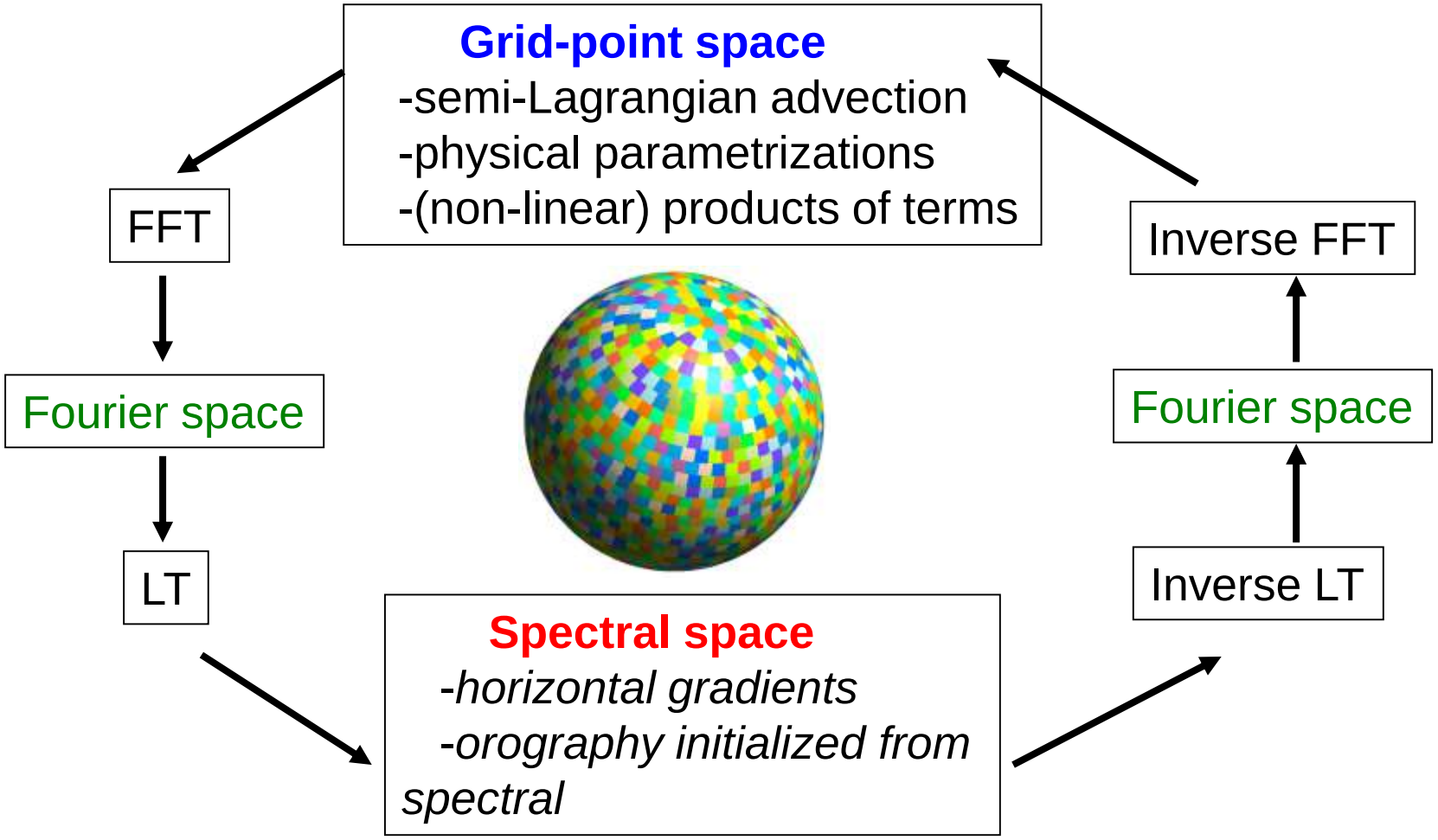


h: topographic height above sea level (from global 1km data set)

Data sources … NOT AS EASY AS IT LOOKED INITIALLY …

- SRTM30 is the 30'' version of the Shuttle Radar Topography Mission used 60N to 60S
  - U.S. Geological Survey (2000)
- GLOBCOVER V2.2 10'' used to derive fractional land-sea mask 85N to 60S
  - Bicheron P. (Medias-France), Defourny P. (UCL), Brockmann C. (BC), Schouten L. (Infram), Vancutsem C. (UCL), Huc M. (Medias-France), Bontemps S. (UCL),Leroy M. (Medias-France), Achard F. (JRC), Herold M. (GOFC-GOLD), Ranera F. (ESA), Arino O. (ESA), ESA product description and validation report (2008)
- GLOBE is a 30'' global elevation dataset used north of 60N
  - GLOBE Task Team and others (Hastings, David A., Paula K. Dunbar, Gerald M. Elphingstone, Mark Bootz, Hiroshi Murakami, Hiroshi Maruyama, Hiroshi Masaharu, Peter Holland, John Payne, Nevin A. Bryant, Thomas L. Logan, J.-P. Muller, Gunter Schreier, and John S. MacDonald), eds., 1999. The Global Land One-kilometer Base Elevation (GLOBE) Digital Elevation Model, Version 1.0. National Oceanic and Atmospheric Administration, National Geophysical Data Center, 325 Broadway, Boulder, Colorado 80303, U.S.A. Digital data base on the World Wide Web (URL: http://www.ngdc.noaa.gov/mgg/topo/globe.html) and CD-ROMs.
- Antarctic RAMP2 (Radarsat Antarctic Mapping Project DEM Version 2) is used south of 60S
  - Liu, H., K. C. Jezek, B. Li, and Z. Zhao (2015). Radarsat Antarctic Mapping Project Digital Elevation Model, Version 2. [60S-90S]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. [2013].
- BPRC for Greenland (Byrd Polar Research Center, Ohio State University) is used for Greenland
  - J.L. Bamber, S. Ekholm, W. B. Krabill (2001). A new, high-resolution digital elevation model of Greenland fully validated with airborne laser altimeter data, J. Geophys Res, Solid Earth, 106, 6733–6745.
- Iceland Digital Elevation Model (DEM) by IMO (Icelandic Meteorological Service) and NLSI (National Land Survey of Iceland) is used for Iceland

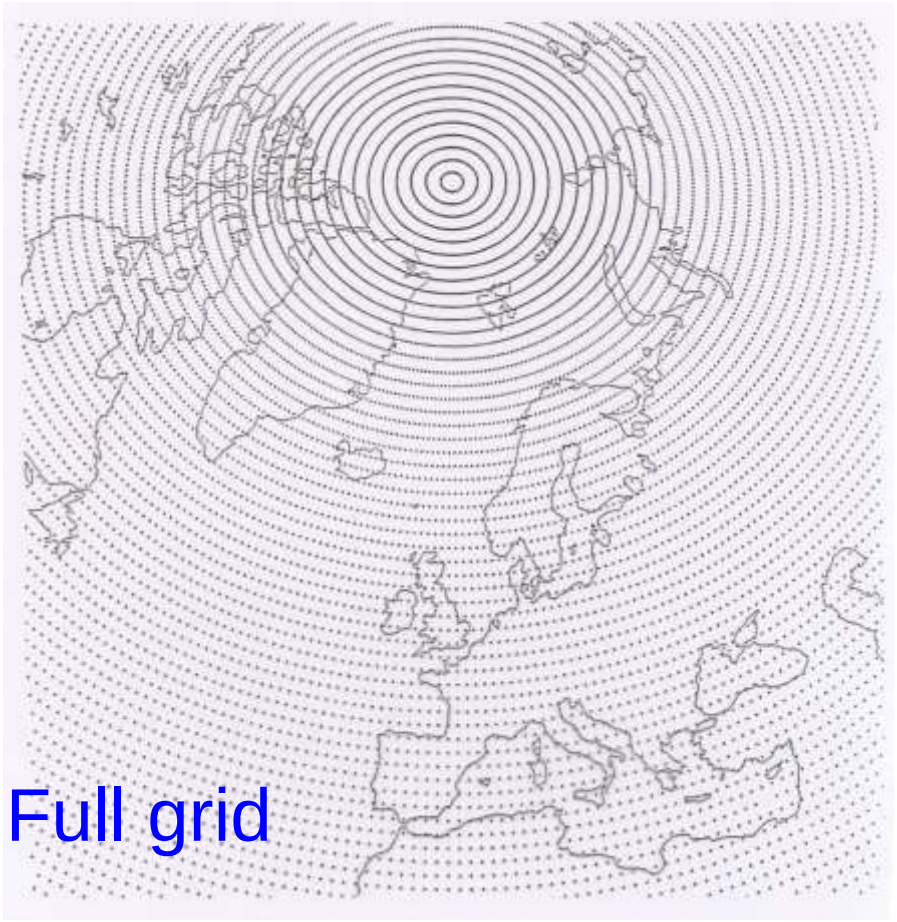
the *spectral transform method* in the ECMWF IFS



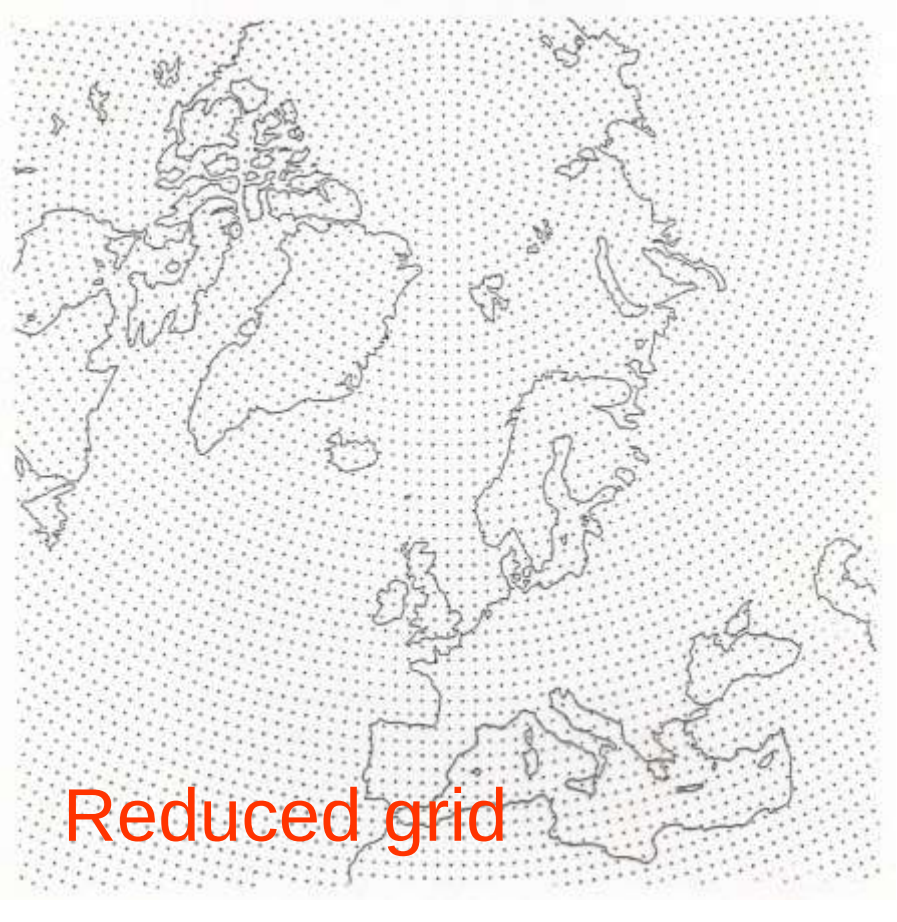
FFT: Fast Fourier Transform, LT: Legendre Transform

The Gaussian grid

About 30% reduction in number of points



Full grid

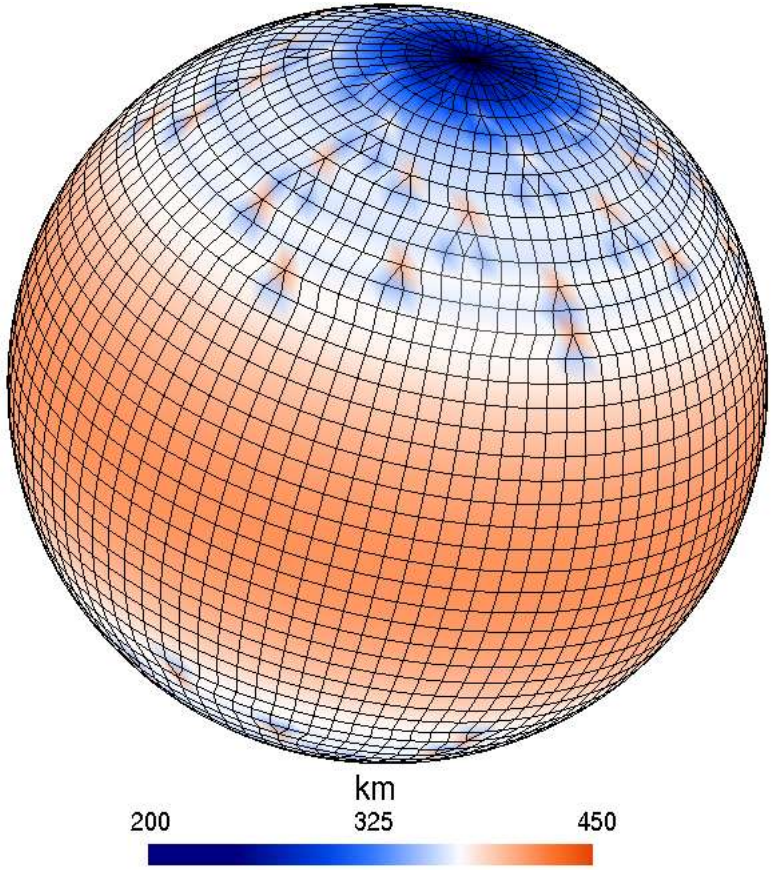


Reduced grid

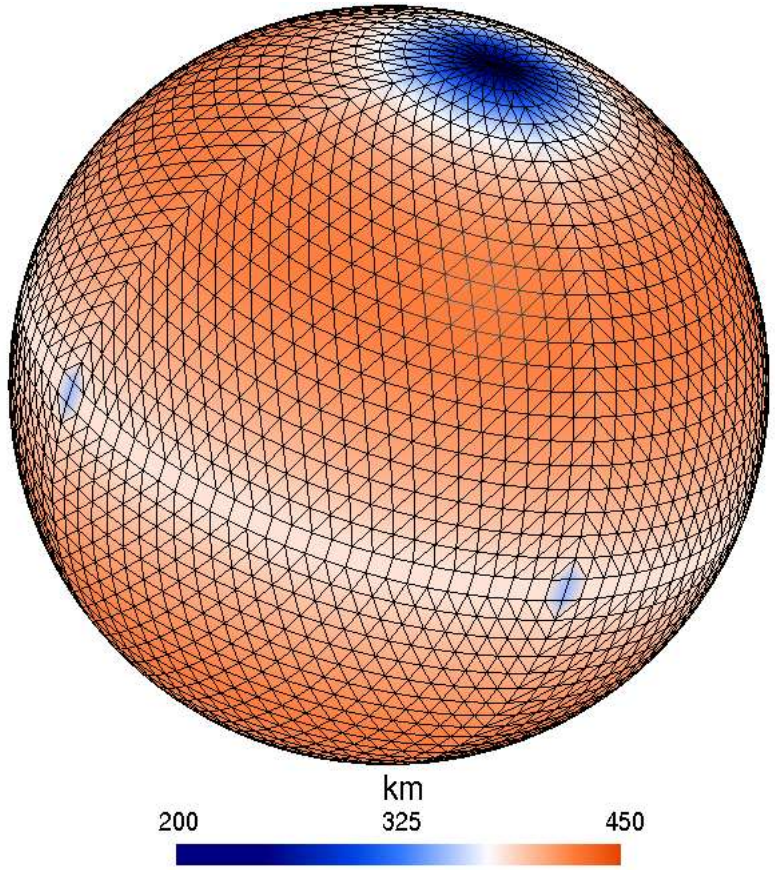
Hortal, M. and Simmons, A. J. (1991)

A new grid for ECMWF

A further ~20% reduction in gridpoints
=> ~50% less points compared to full grid



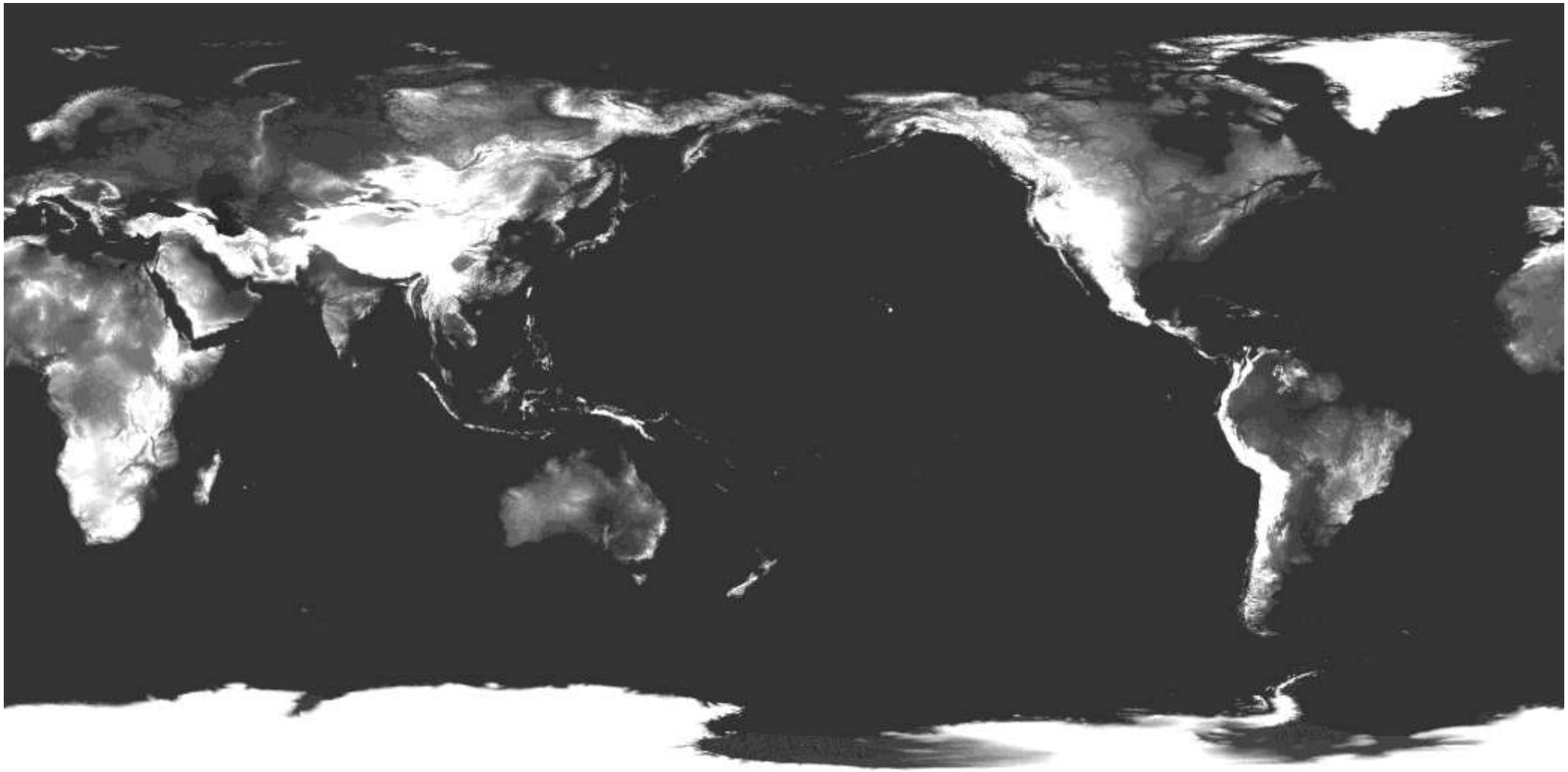
N24 reduced Gaussian grid



N24 octahedral Gaussian grid

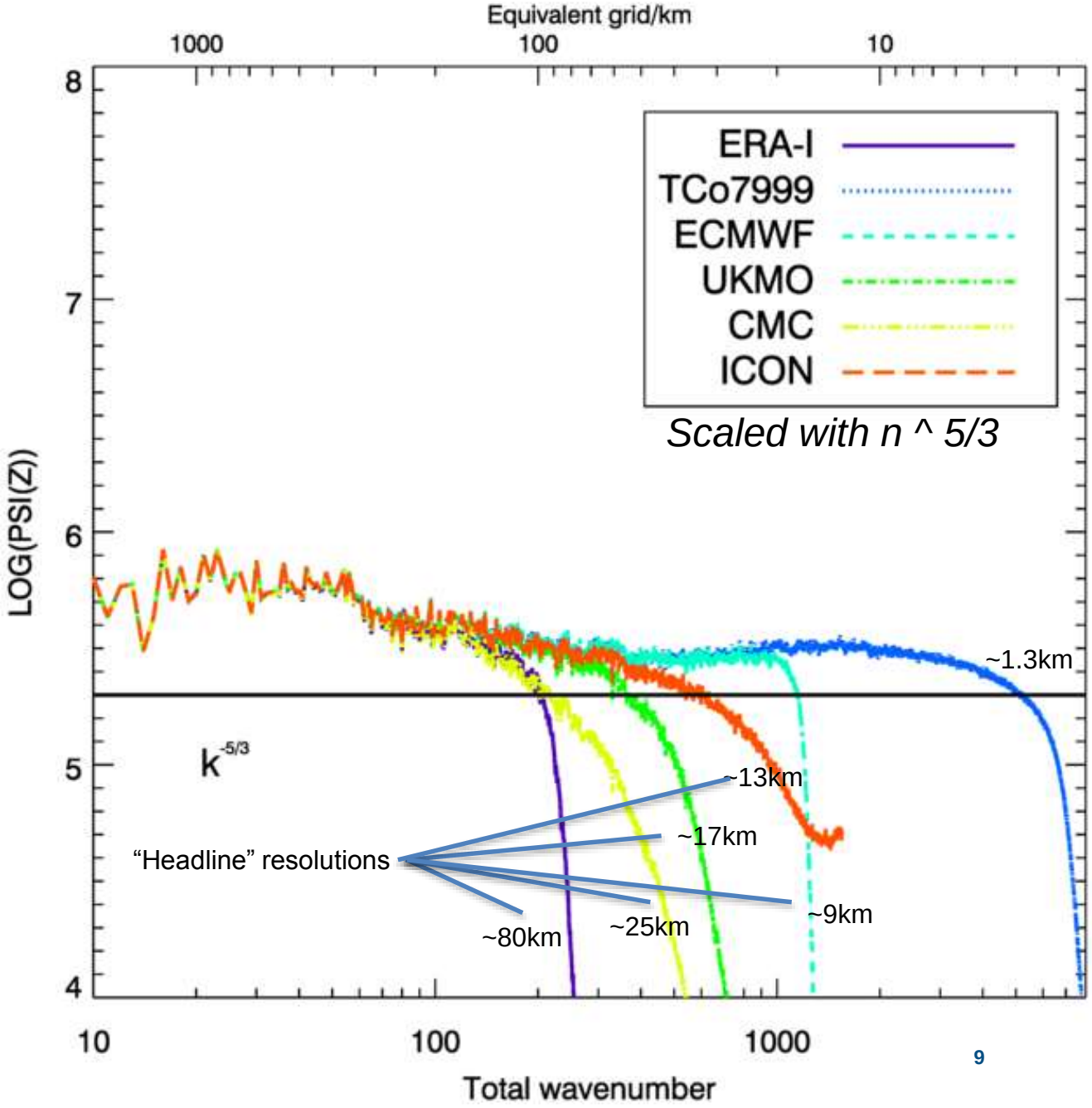
(Wedi et al, 2015)

TCo7999 (~1.3km) orography

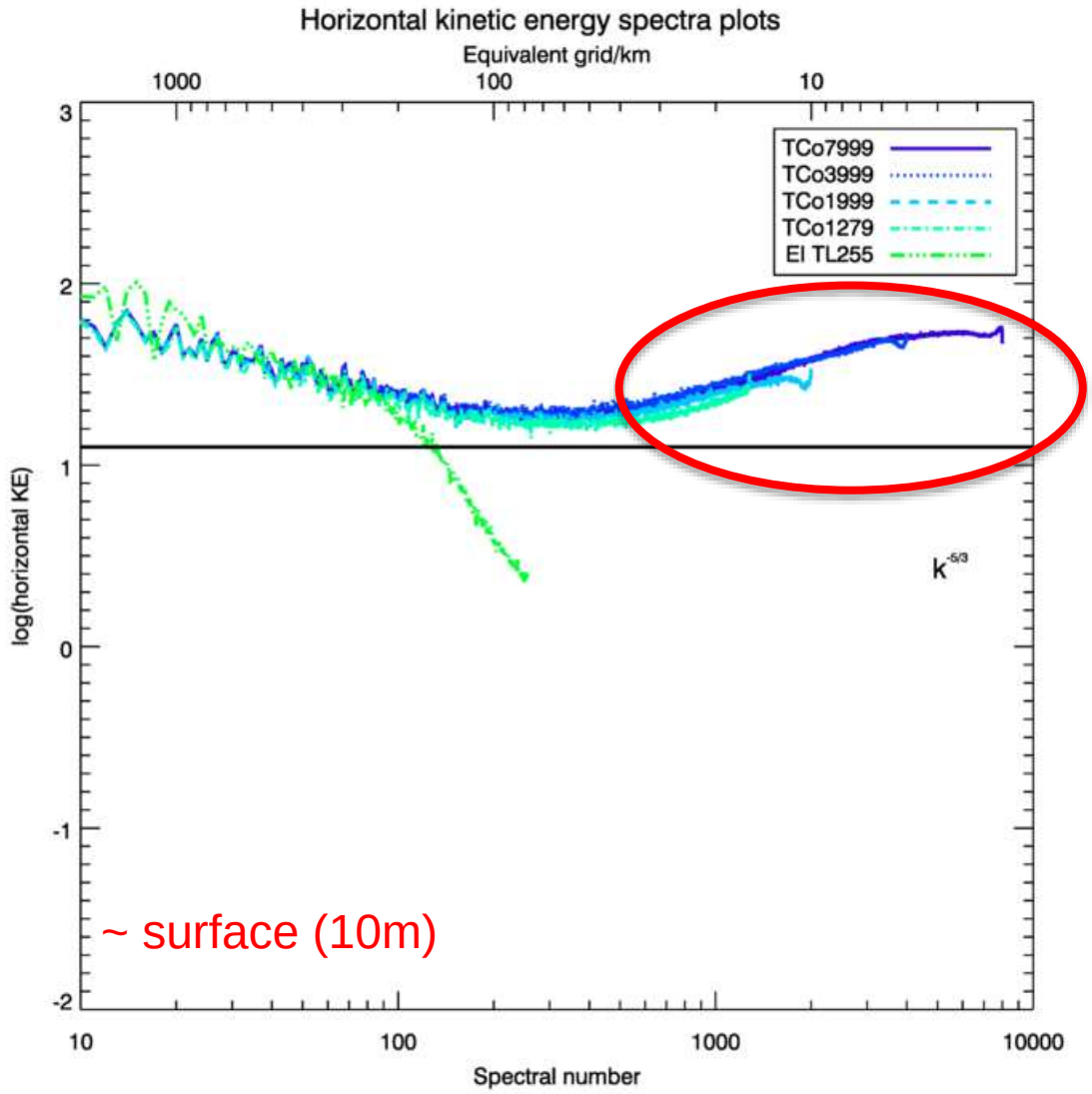


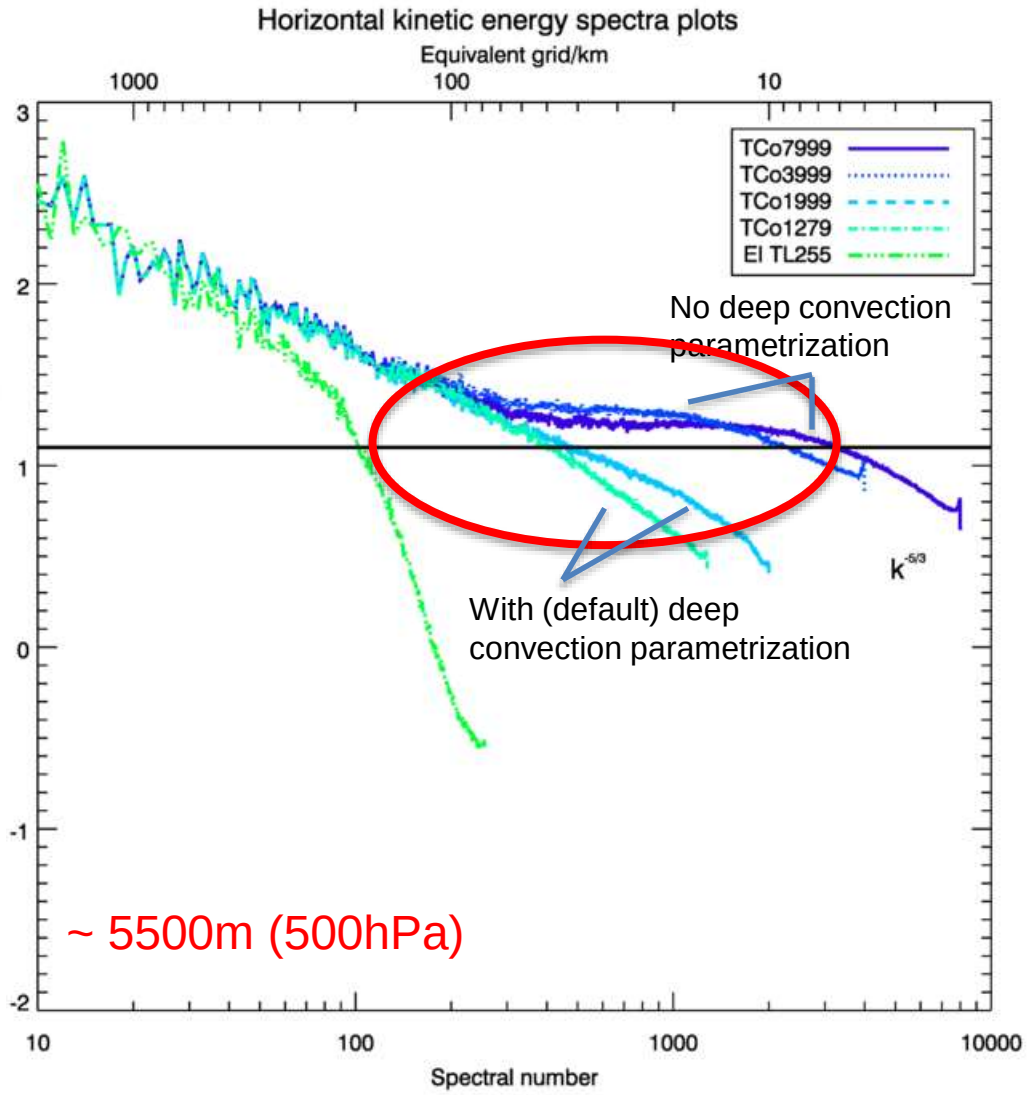
Mean Orography spectra at different NWP centres

Sylvie Malardel, Irina Sandu,
Ayrton Zadra, Simon Vosper,
Annelize van Niekerk, Daniel Klocke



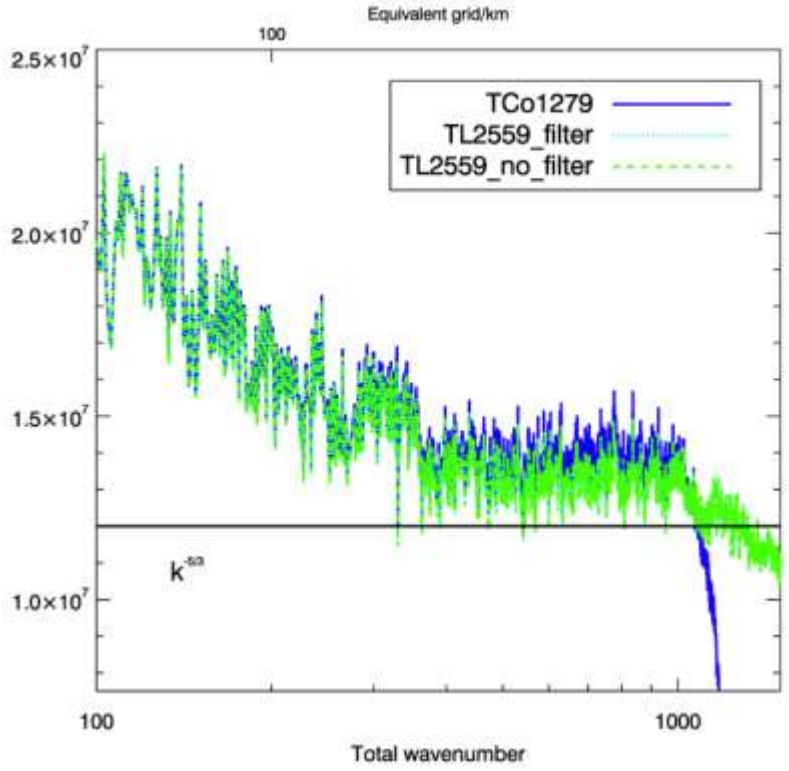
Global Kinetic Energy (scaled by n^5/3) in 1.3km global simulations TCo7999 L62

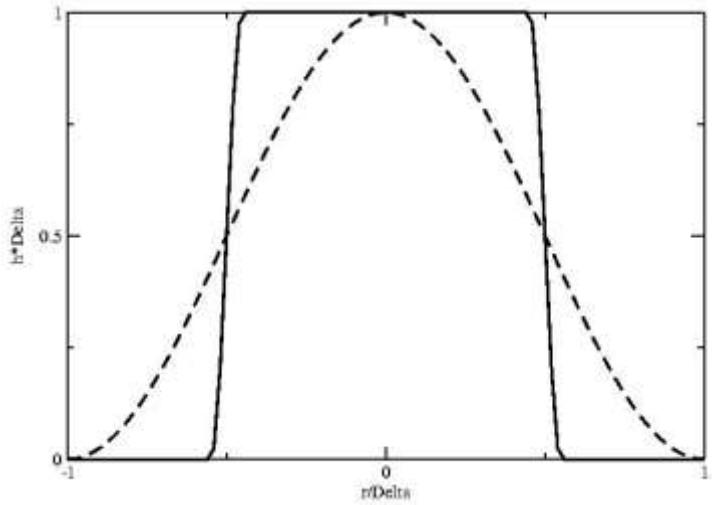




Mean orography filtering

- Top hat filter applied to 30’’ data, with 1km side lobe and filter scale according to (nominal) target resolution
- Spectral filtering

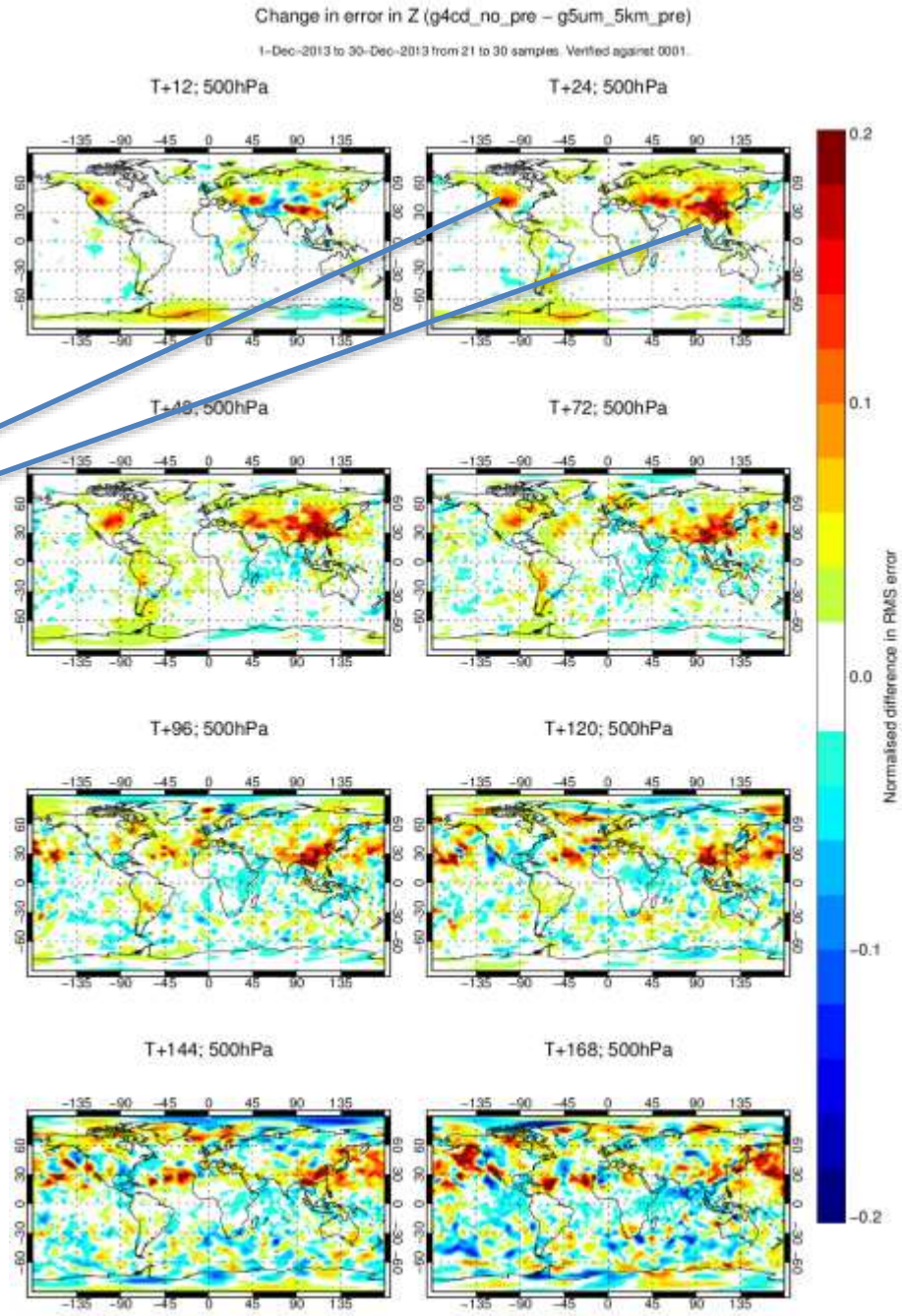




Mean orography filtering

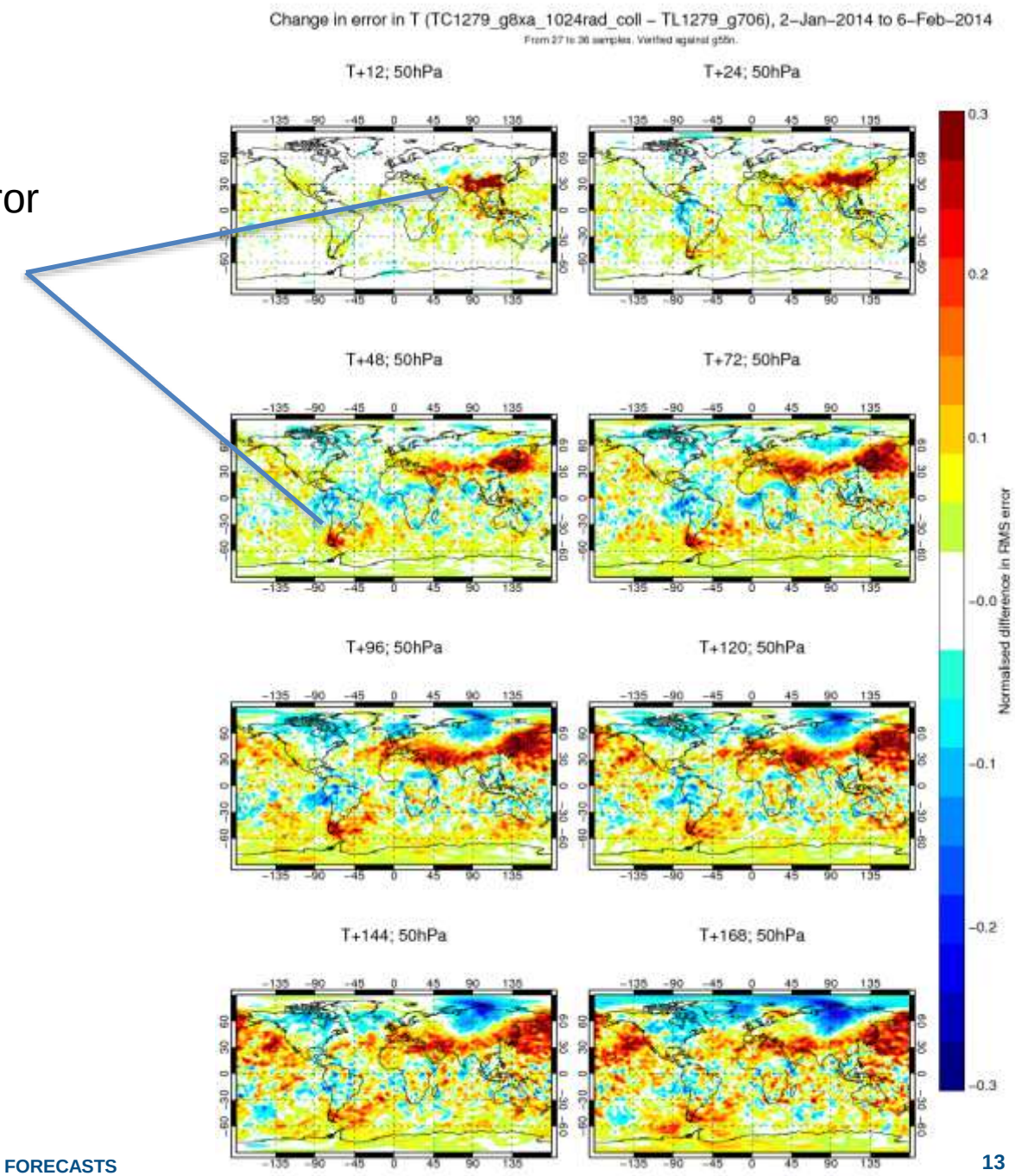
No pre-averaging to 5km before interpolating to target resolution (here 10km using TL2047)

Results in significant errors in Z 500 related to mean orography filtering



Resolution increase – side effects

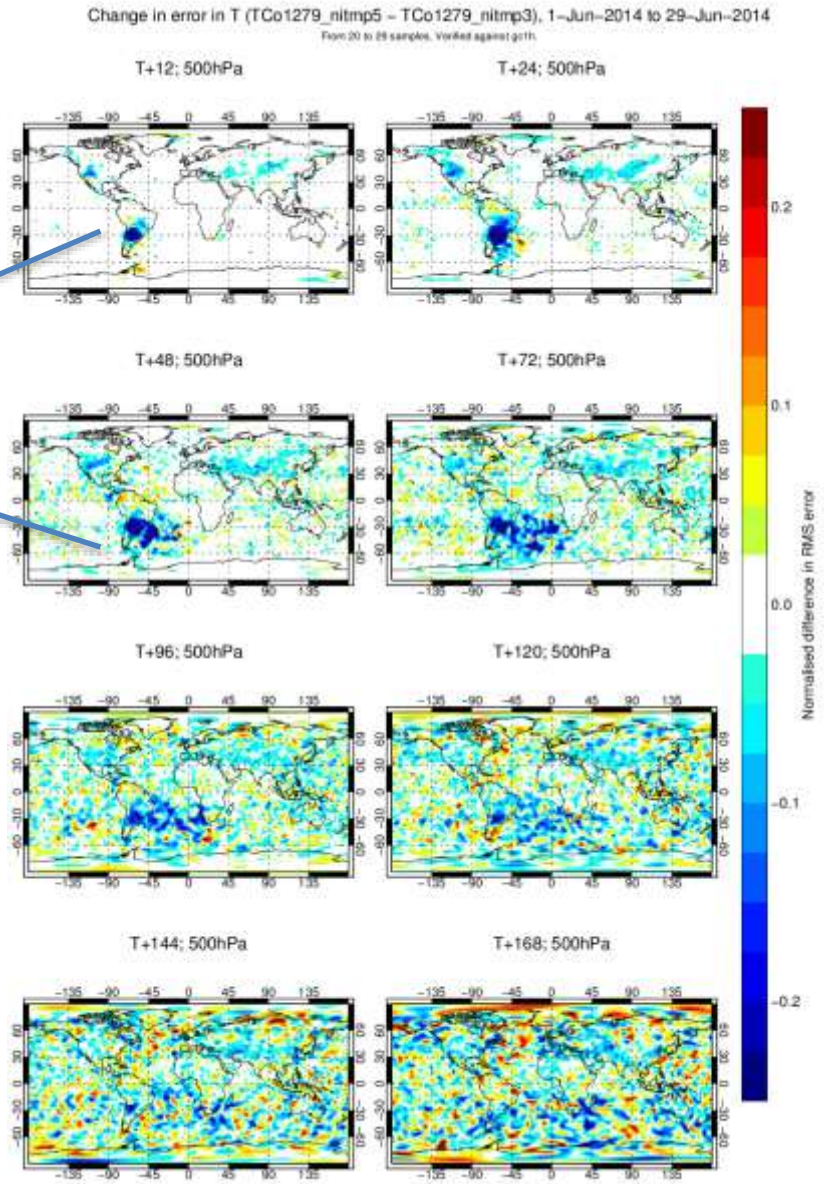
50hPa (lower stratosphere) temperature error
TCo1279 vs TL1279
Mixing effect on temperature due to gravity wave breaking ?



Numerics – Orography interaction

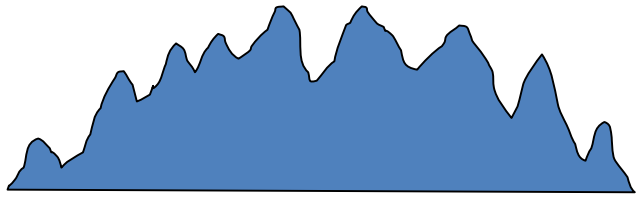
5 vs 3 departure point search iterations influence the winter hemisphere temperature error in regions with pronounced gravity wave activity.

(Diamantakis, M. and L. Magnusson, 2016)
Sensitivity of the ECMWF model to Semi-Lagrangian departure point iterations



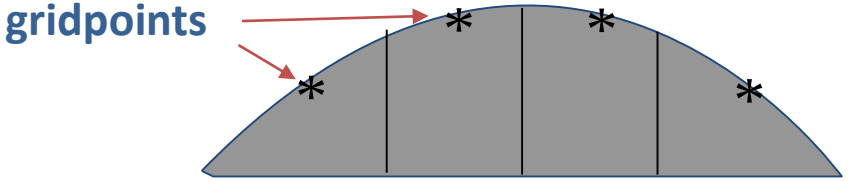
Preparation of the data sets to characterize the sub-grid orography

1. Global 1km resolution surface elevation data



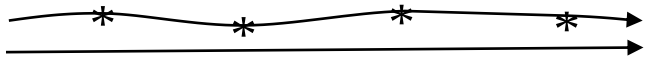
2. Reduce to 5 km resolution by smoothing

3. Compute mean orography at model resolution gridpoints



4. Subtract model orography (3) from 5km orography (2)

5. Compute standard deviation, slope, orientation and anisotropy for every grid box

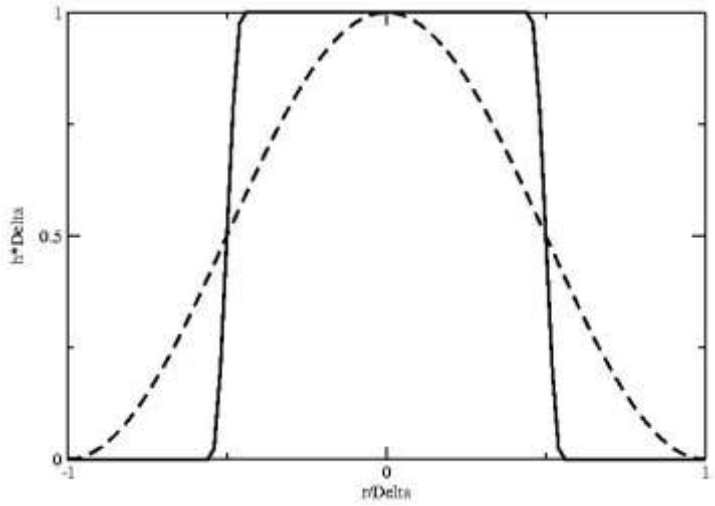


SSO parameters: TOFD

- Standard deviation of filtered orography

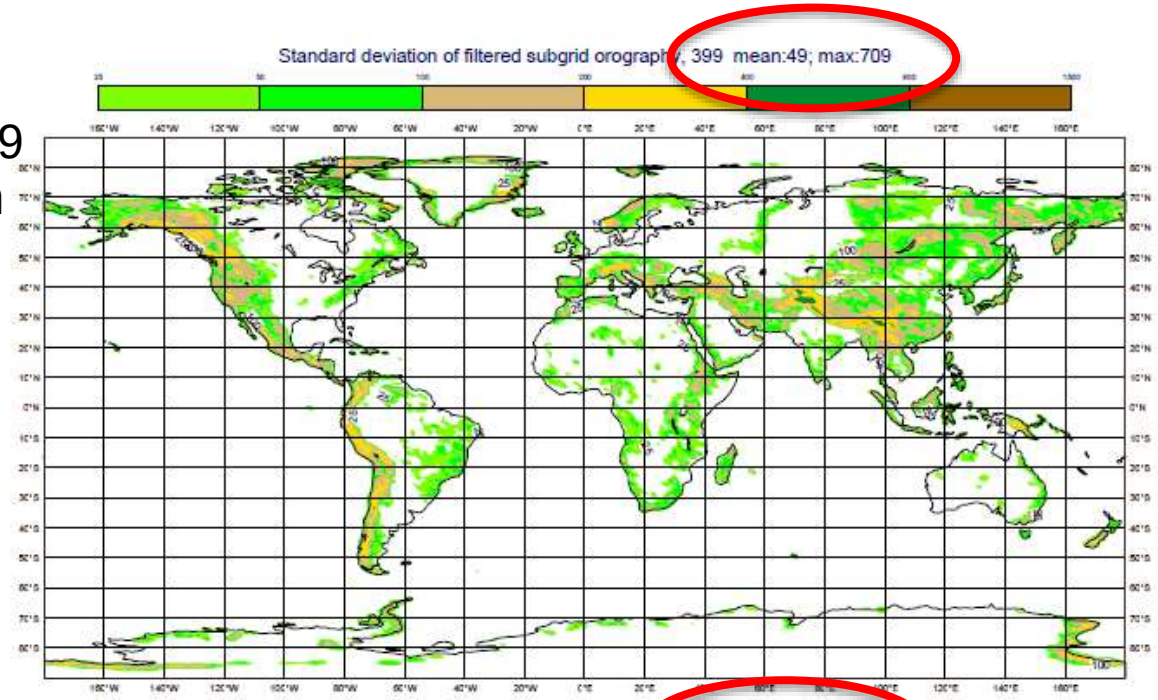
Beljaars, A. C. M., Brown, A. R. and Wood, N. (2004b).

A new parametrization of turbulent orographic form drag. Q. J. R.

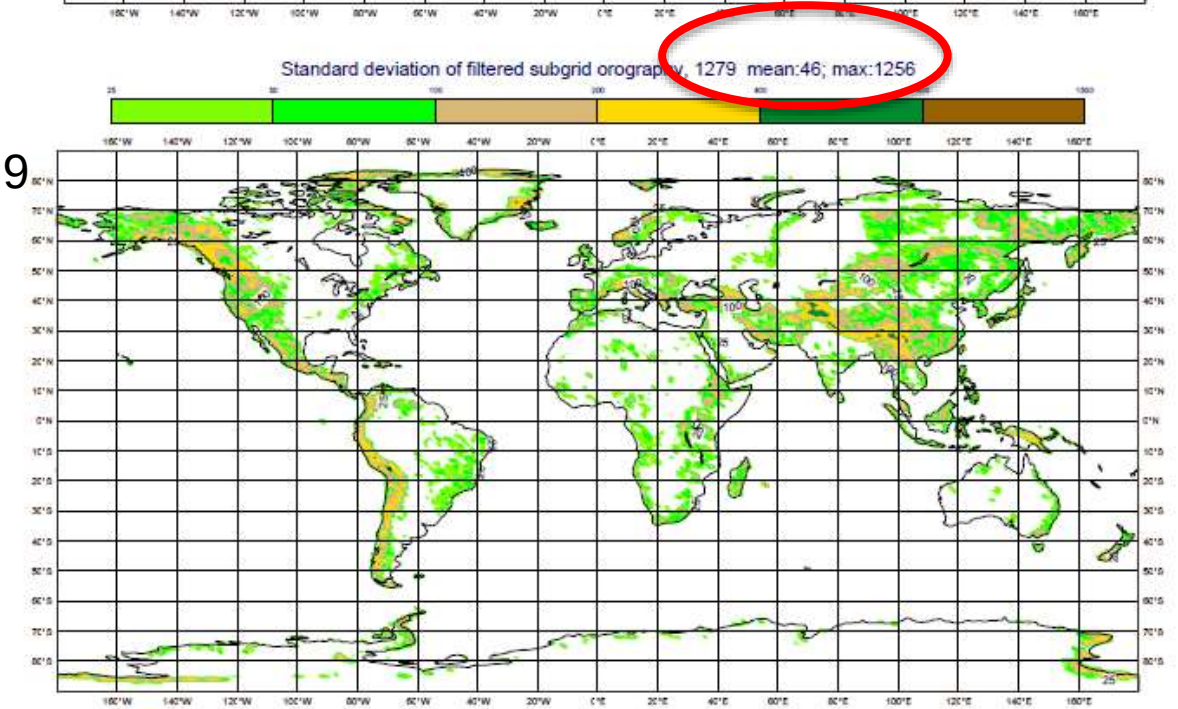


Based on the difference with two filter scales: 20km minus 2km

TCo399
~25km



TCo1279
~9km



SSO parameters: Standard deviation, anisotropy, orientation, slope

- SSO drag parametrization separating low-level blocking effect and gravity waves

Lott, F. and Miller, M. J. (1997). A new subgrid-scale orographic drag parametrization: Its formulation and testing. Q. J. R. Meteorol. Soc., 123, 101-127.

h == Difference *target* (non-spectrally filtered) orography minus 5km orography

$$\gamma^2_{\mathrm{GW}} = \frac{K - (L^2 + M^2)^{1/2}}{K + (L^2 + M^2)^{1/2}}$$

$$\theta_{\mathrm{GW}} = \frac{1}{2}\mathrm{atan}\frac{M}{L}$$

$$\sigma^2_{\mathrm{GW}} = K + \sqrt{L^2 + M^2}$$

$$\mu^2_{\mathrm{GW}} = O - P^2$$

K,L,M,O,P conservatively aggregated to target resolution

$$K = \frac{1}{2}\left\{\left(\frac{\partial h}{\partial x}\right)^2 + \left(\frac{\partial h}{\partial y}\right)^2\right\}$$

$$L = \frac{1}{2}\left\{\left(\frac{\partial h}{\partial x}\right)^2 - \left(\frac{\partial h}{\partial y}\right)^2\right\}$$

$$M = \left\{\left(\frac{\partial h}{\partial x}\right)\left(\frac{\partial h}{\partial y}\right)\right\}$$

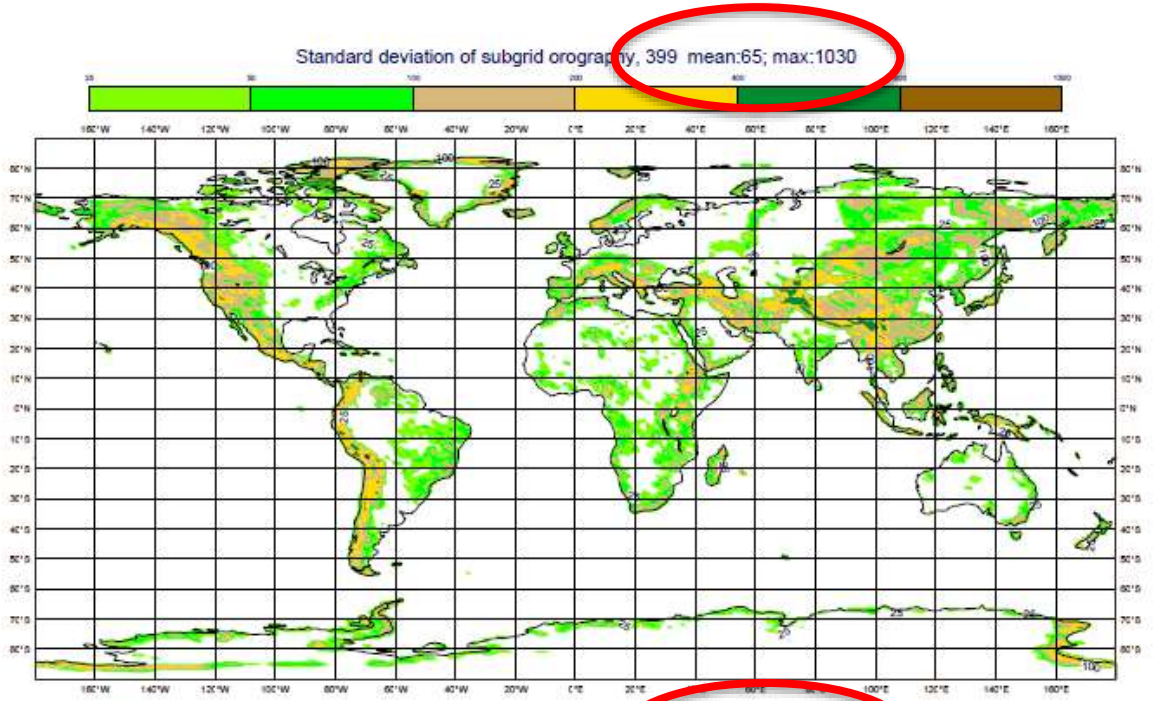
$$O = h^2$$

$$P = h$$

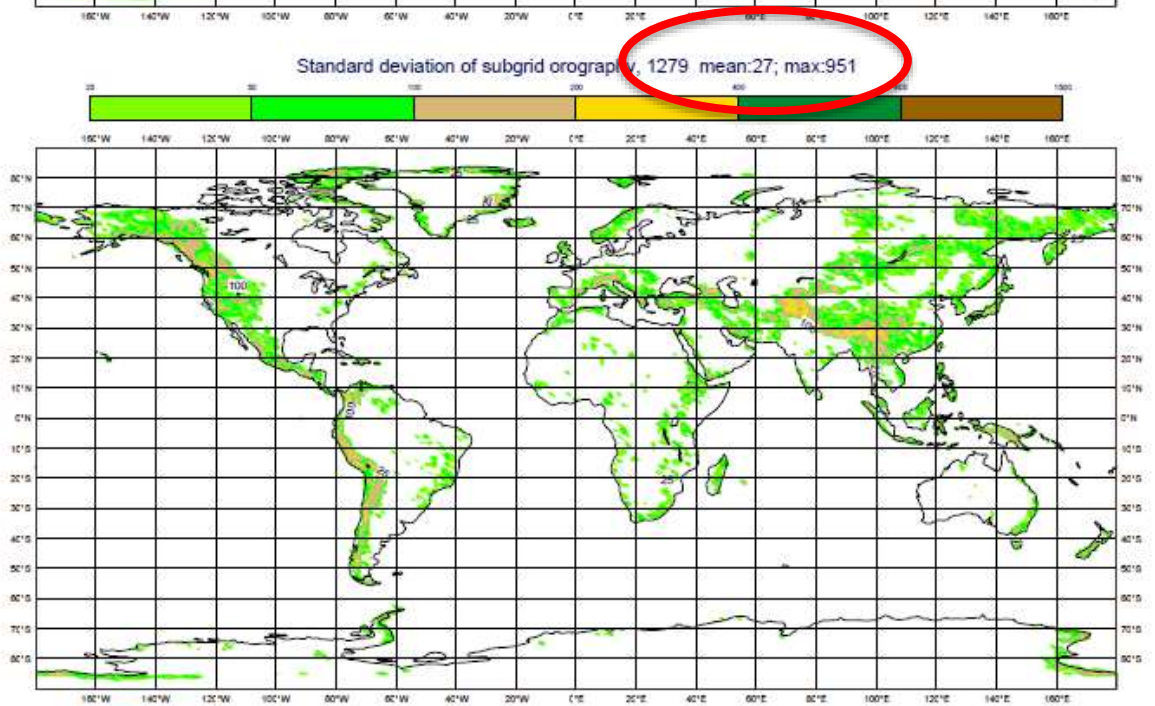
Based on pre-averaged data at ~5km calculated on a 5km grid

SSO: Standard deviation orography

TCo399
~25km

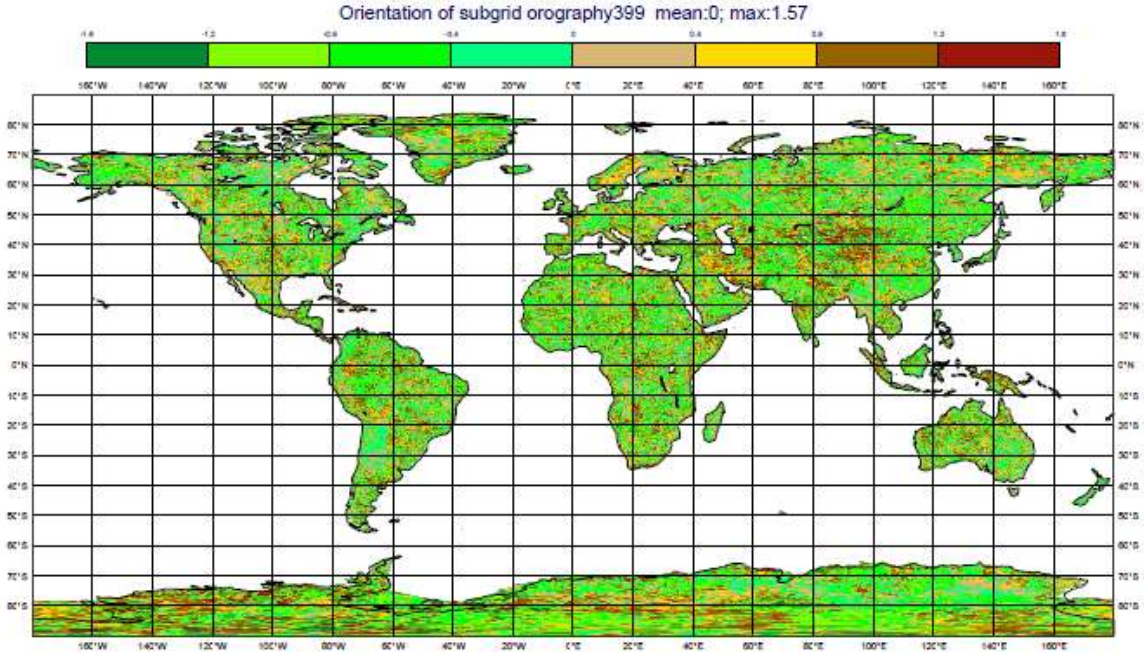


TCo1279
~9km

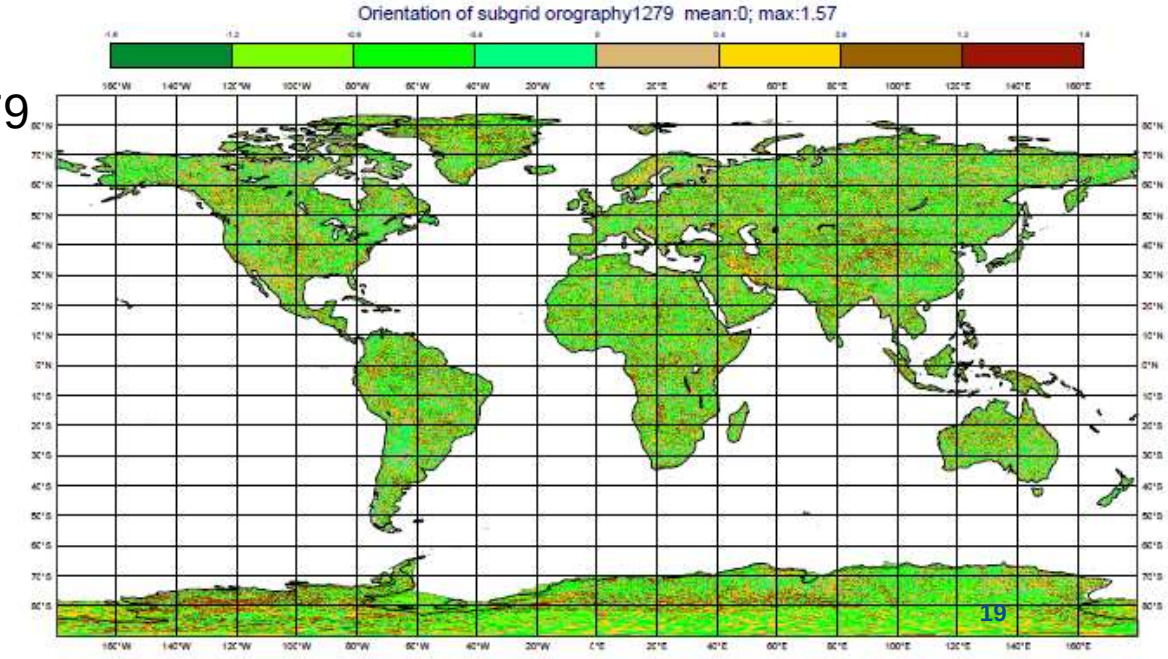


SSO: Orientation

TCo399
~25km

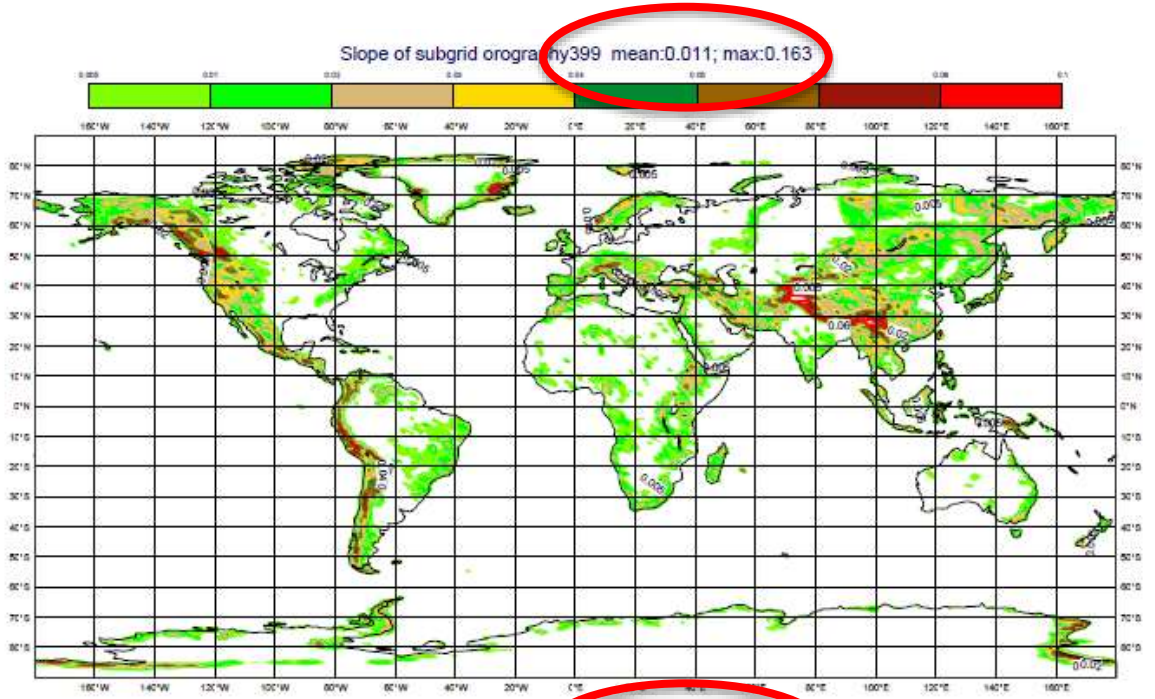


TCo1279
~9km

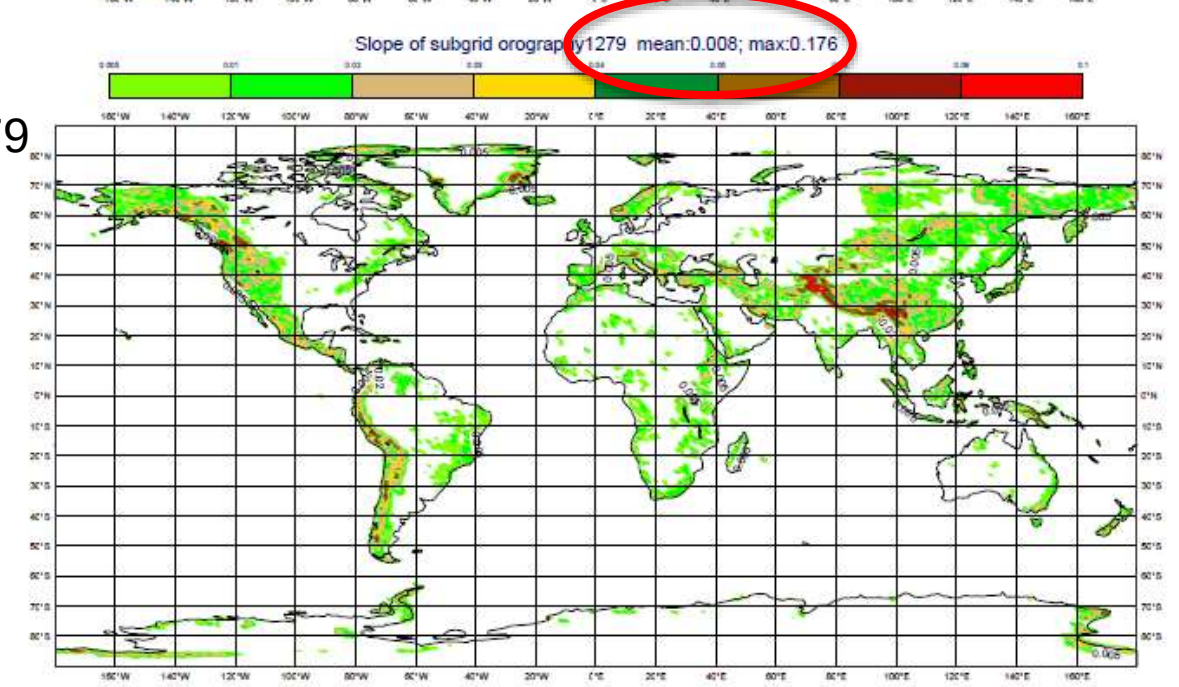


SSO: Slope

TCo399
~25km

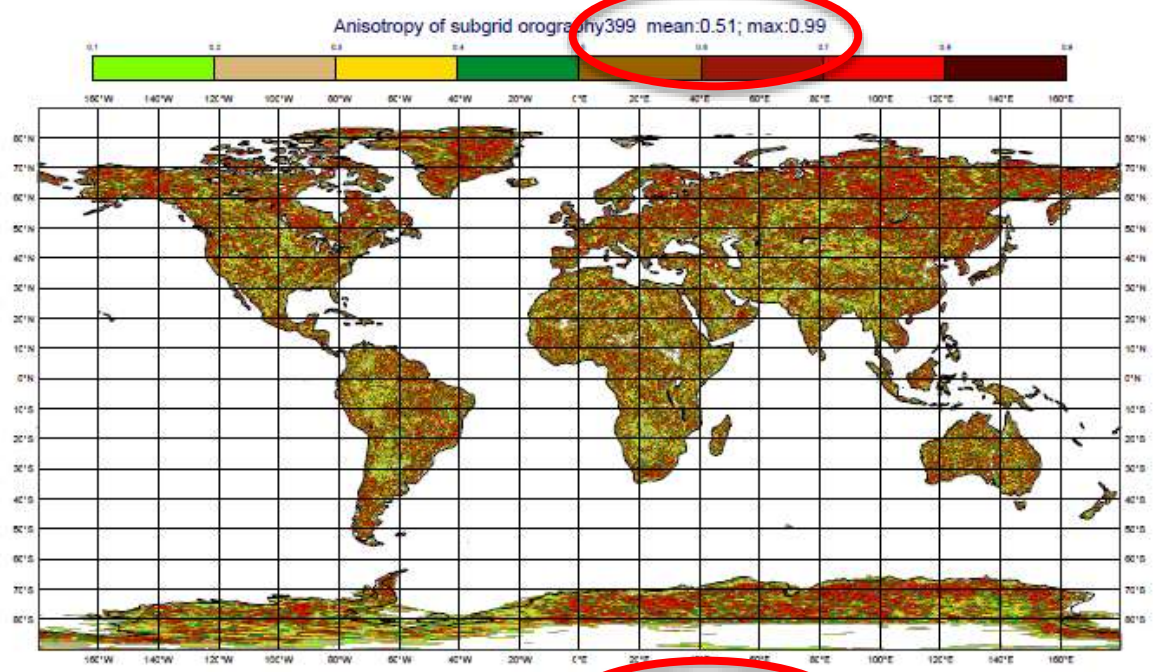


TCo1279
~9km

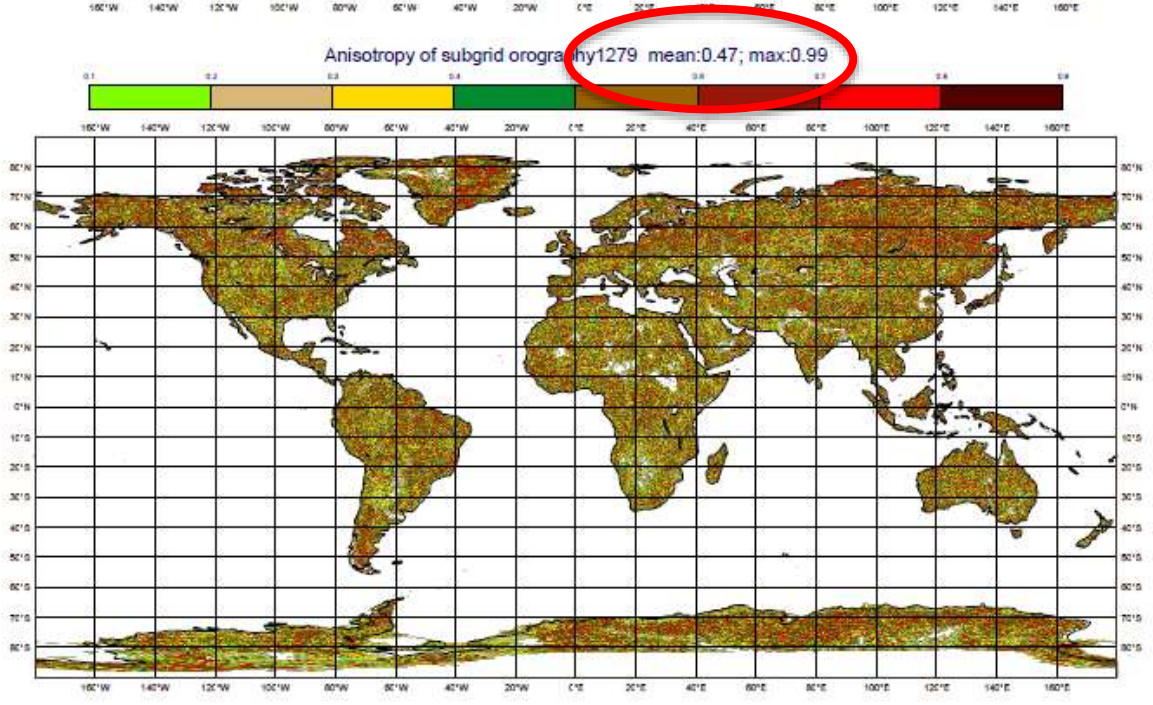


SSO: Anisotropy

TCo399
~25km



TCo1279
~9km



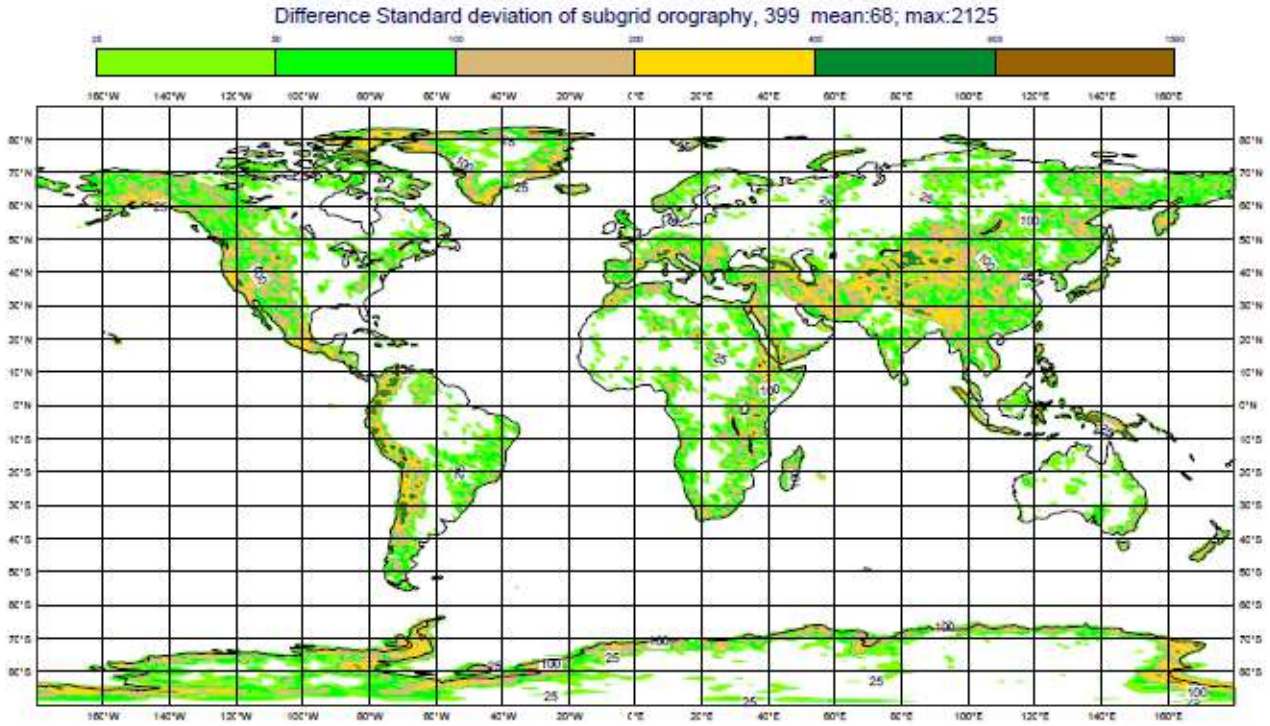
Conclusions

- Good and consistent global datasets still hard to get !
- Mean orography different between different NWP centres
- Sensitive to details of truncation and/or filtering and/or interpolation (the latter two often combine)
- Numerics relevant in the interaction with increasingly resolved topography
- Substantial uncertainty in SSO parameter generation and in their respective impact on the flow

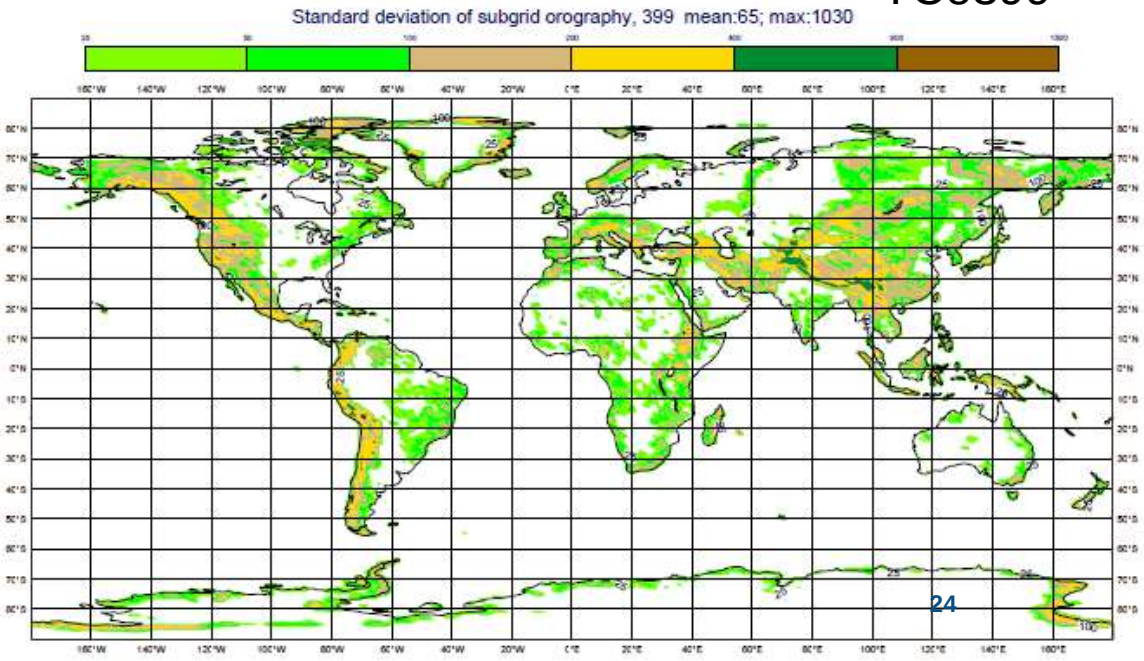
  >> Opportunities with emerging global simulations at O(1km)

Additional

Varying the filter scale: Stdev difference **8 Δ** - ctrl

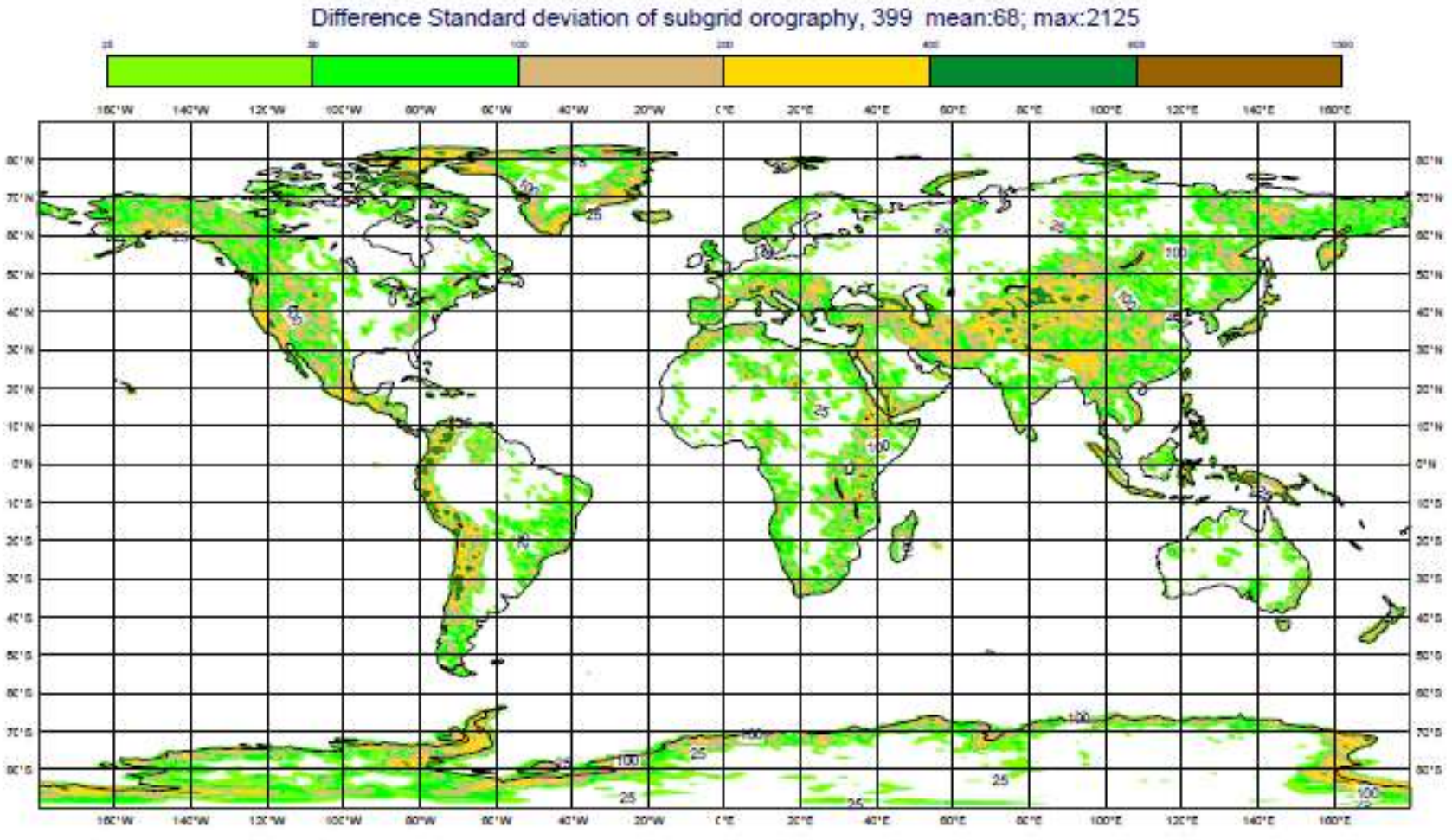


TCo399



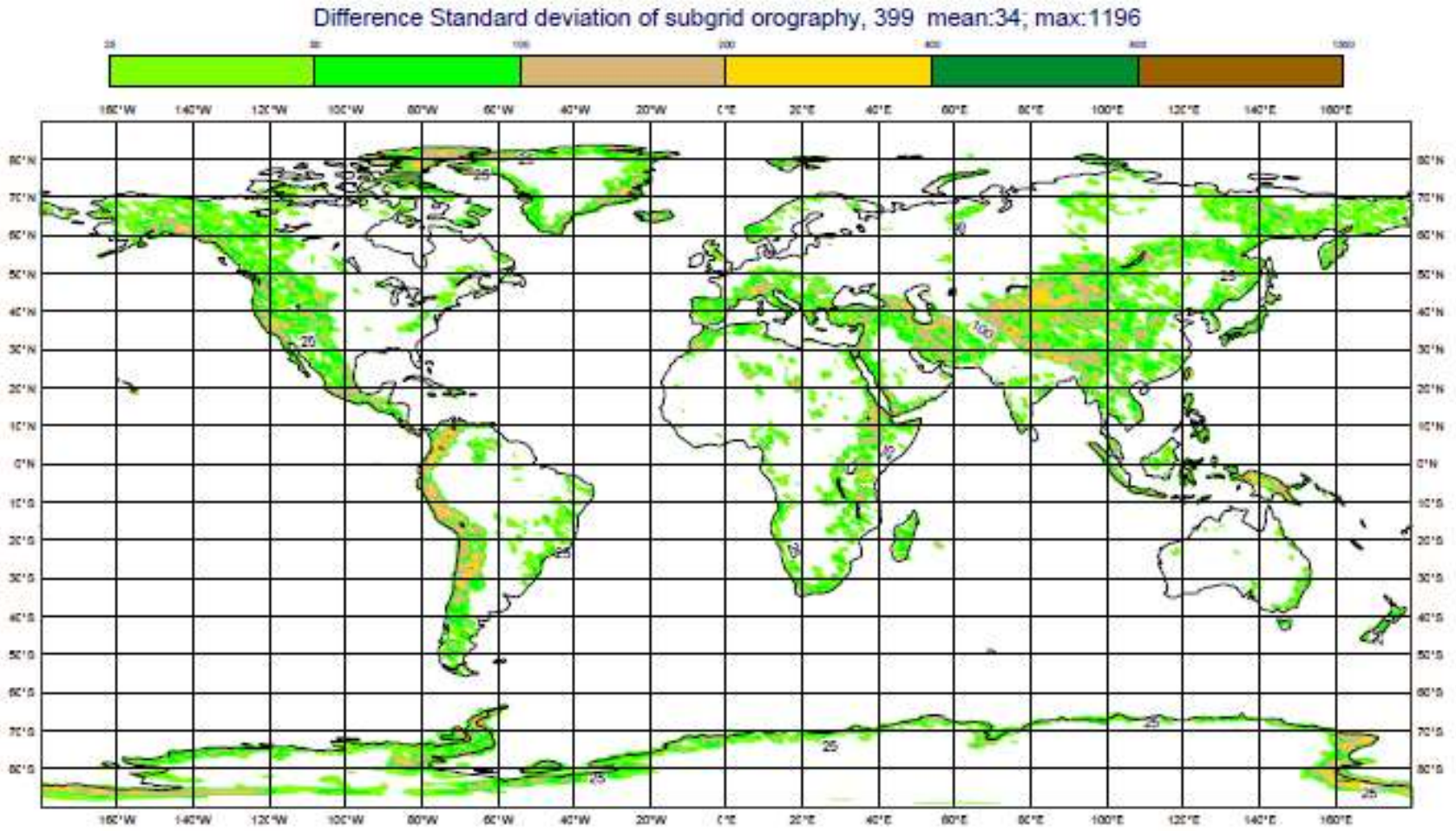
Varying the filter scale: Stdev difference **8 Δ** - ctrl

TCo399

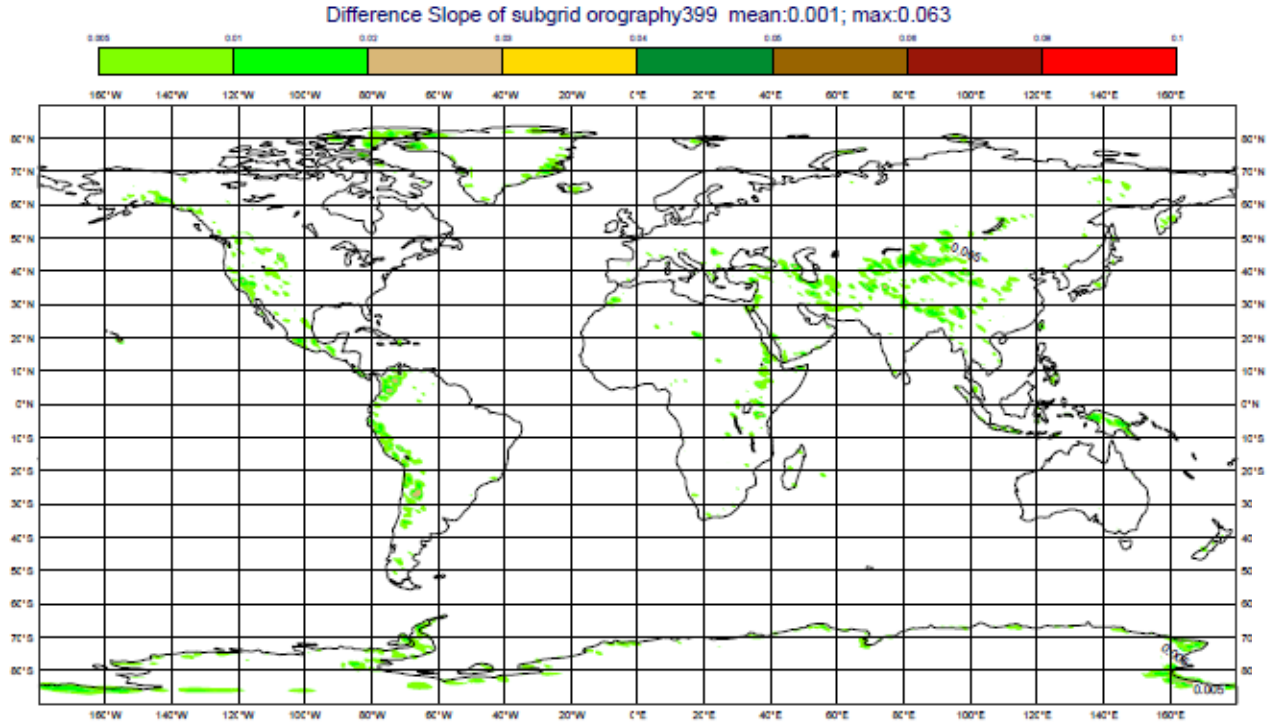


Varying the filter scale: Stdev difference **4 Δ** - ctrl

TCo399



Varying the filter scale: Slope difference **8 Δ** - ctrl



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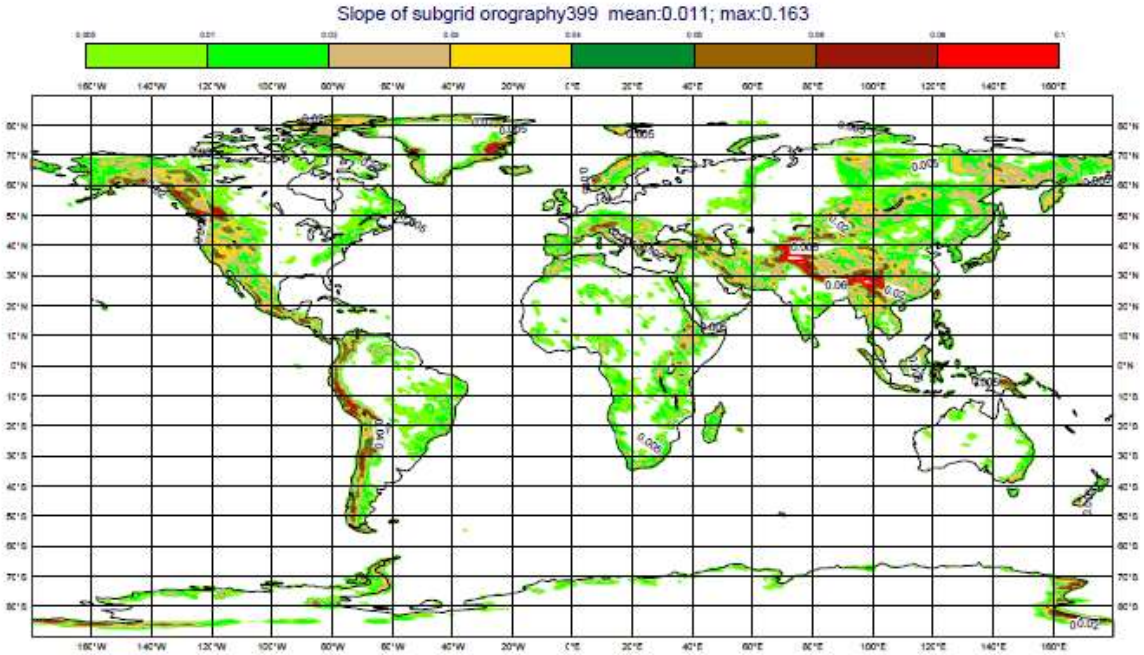
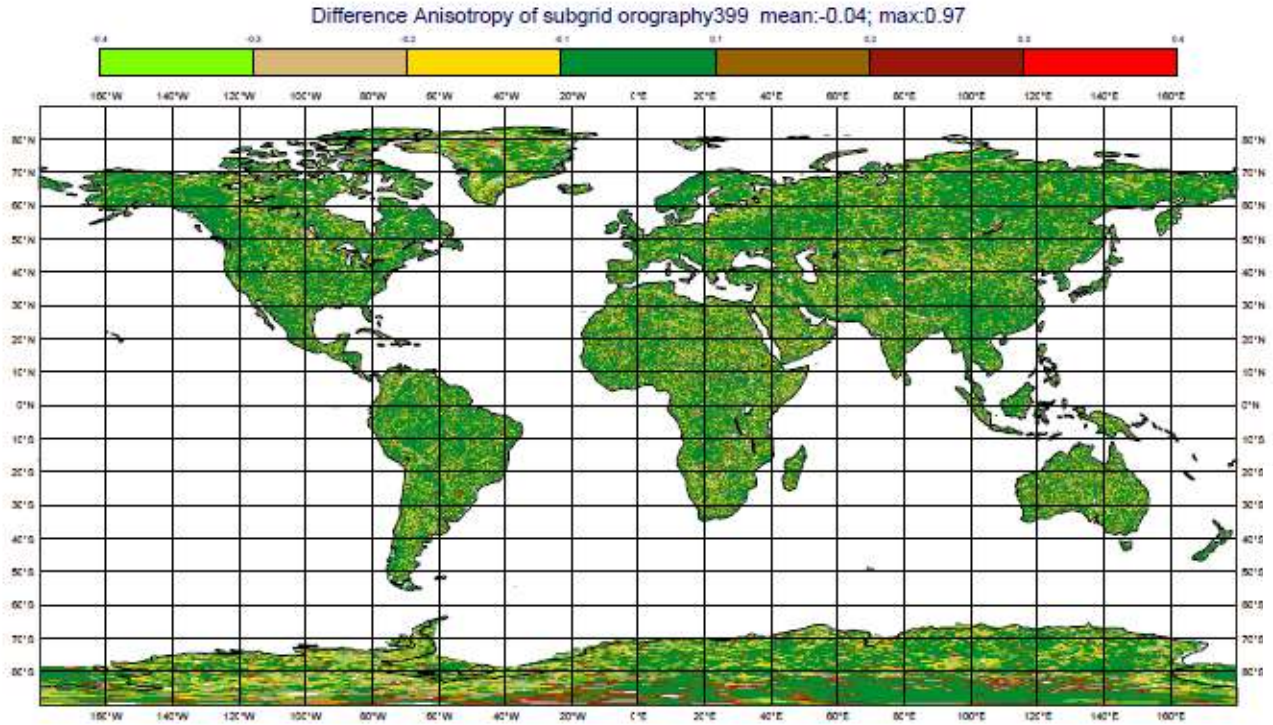
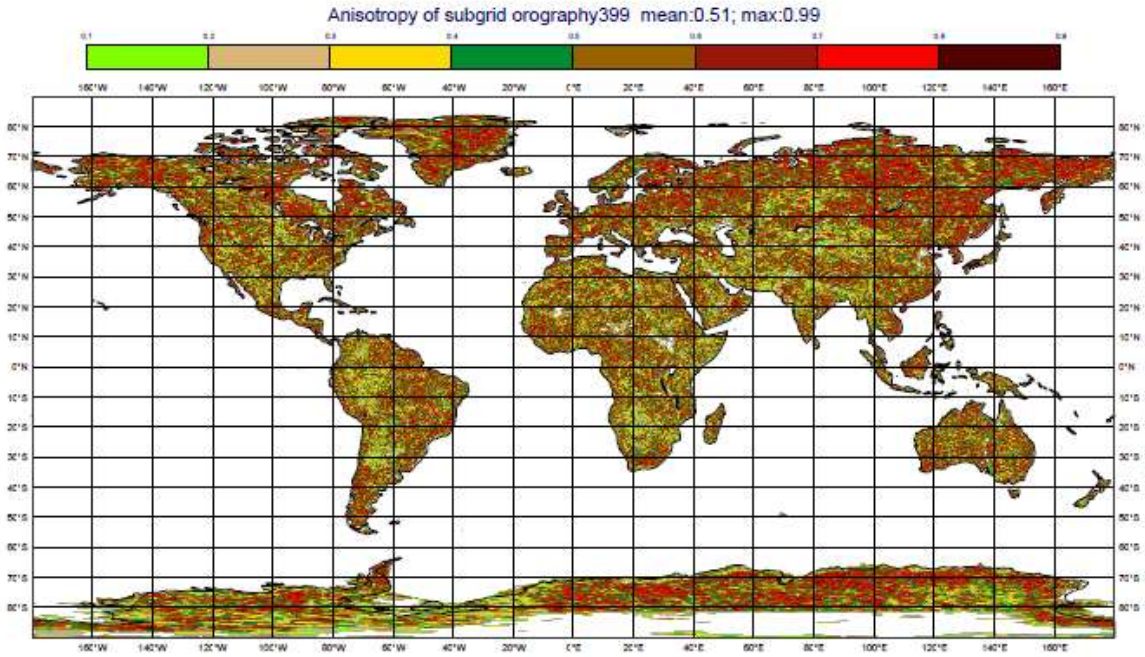


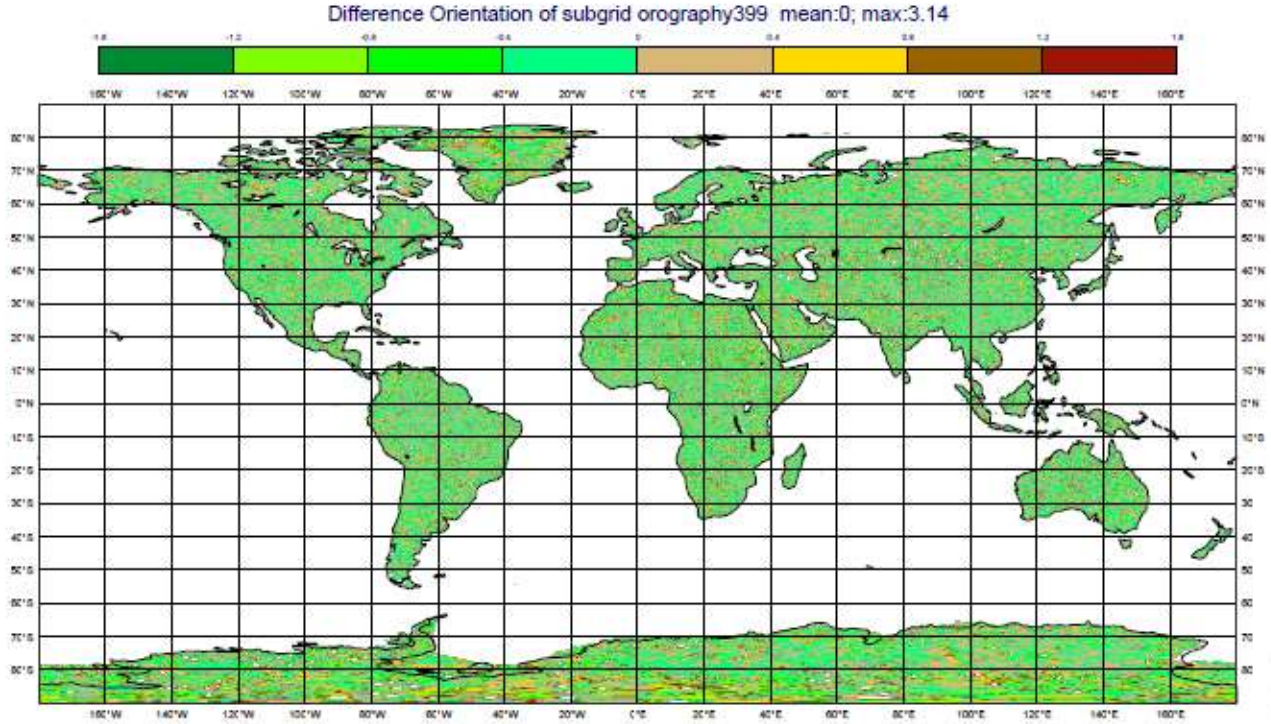
Varying the filter scale: Anisotropy difference **8 Δ** - ctrl



TCo399



Varying the filter scale: Orientation difference **8 Δ** - ctrl



TCo399