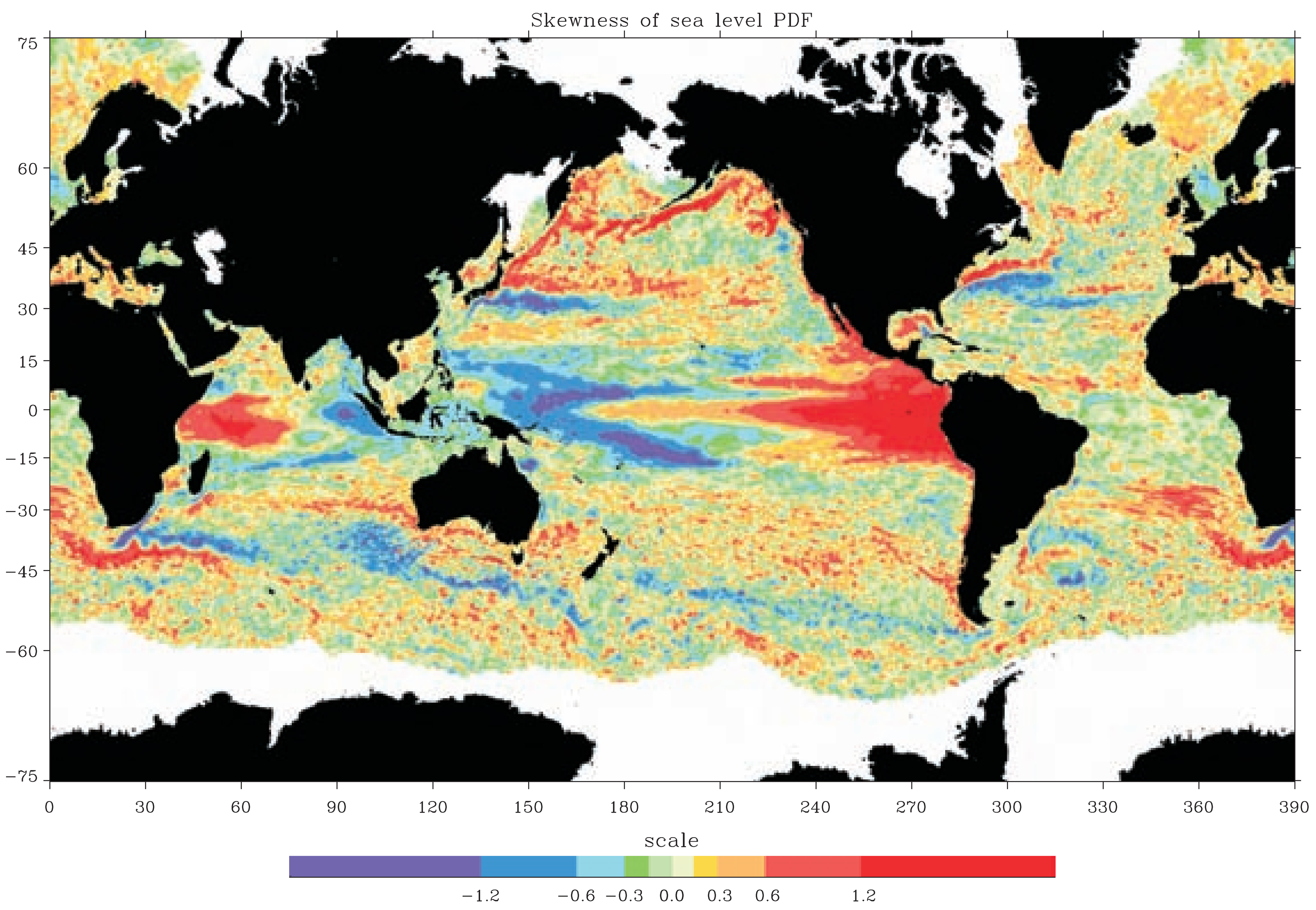
Varieties of variability:
Using simple statistics to characterize the mesoscale.

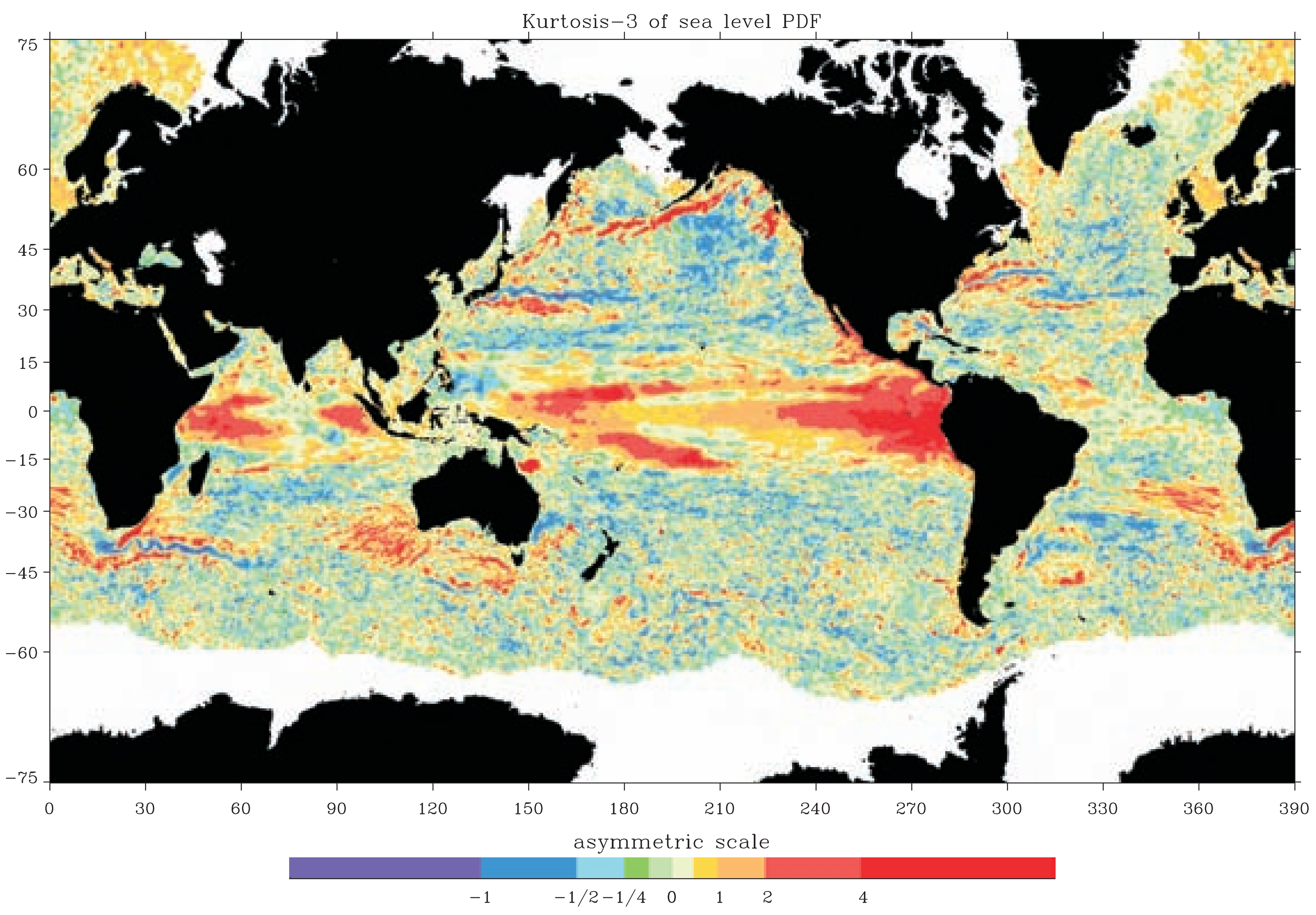
Chris W. Hughes[1], Simon D. P. Williams[1], Andrew F. Thompson[2], Joanne Williams[1], Rory J. Bingham[3], and Chris Wilson[1]

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

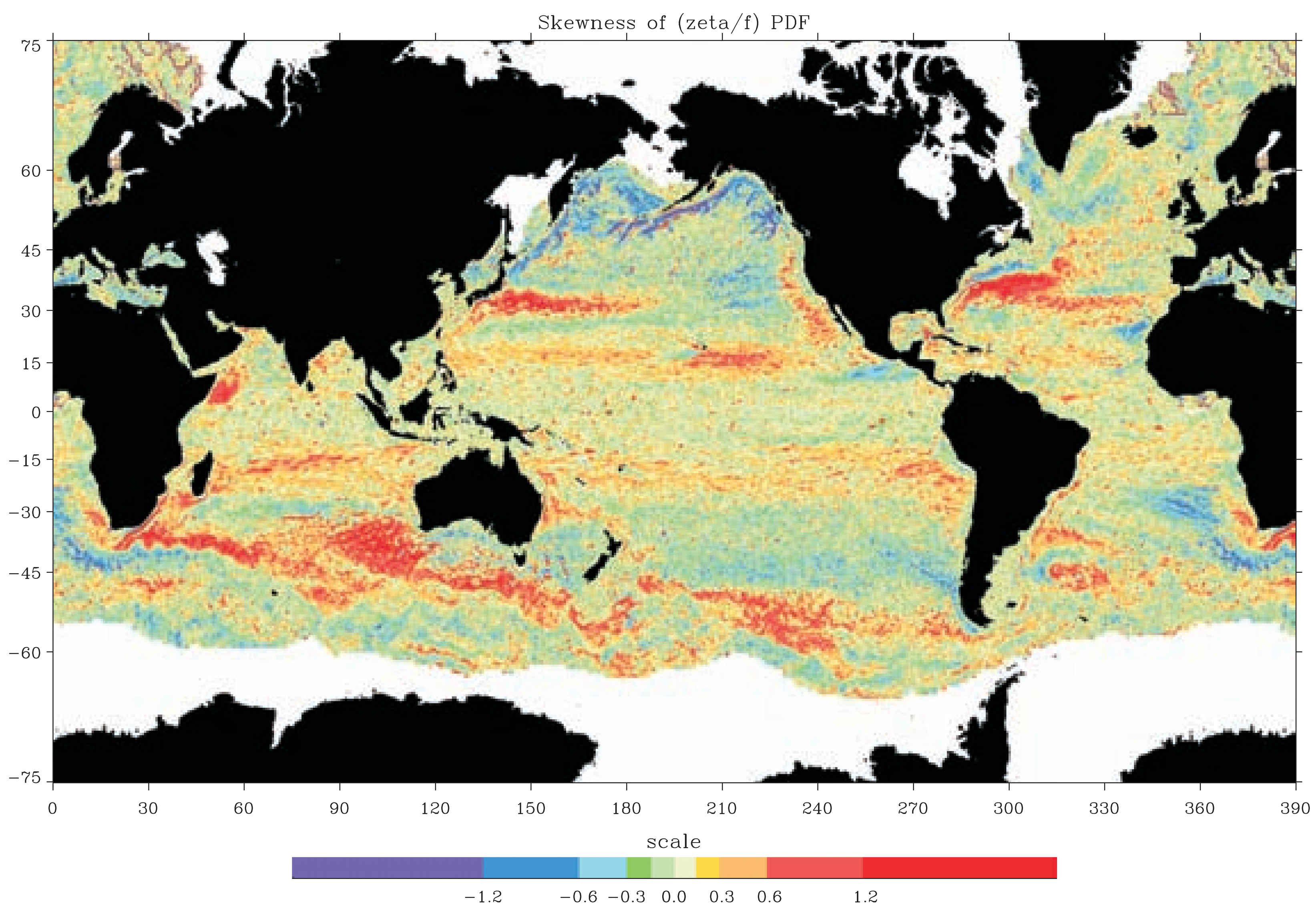
[1]National Oceanography Centre, Liverpool; [2]DAMTP, Cambridge University; [3]University of Newcastle

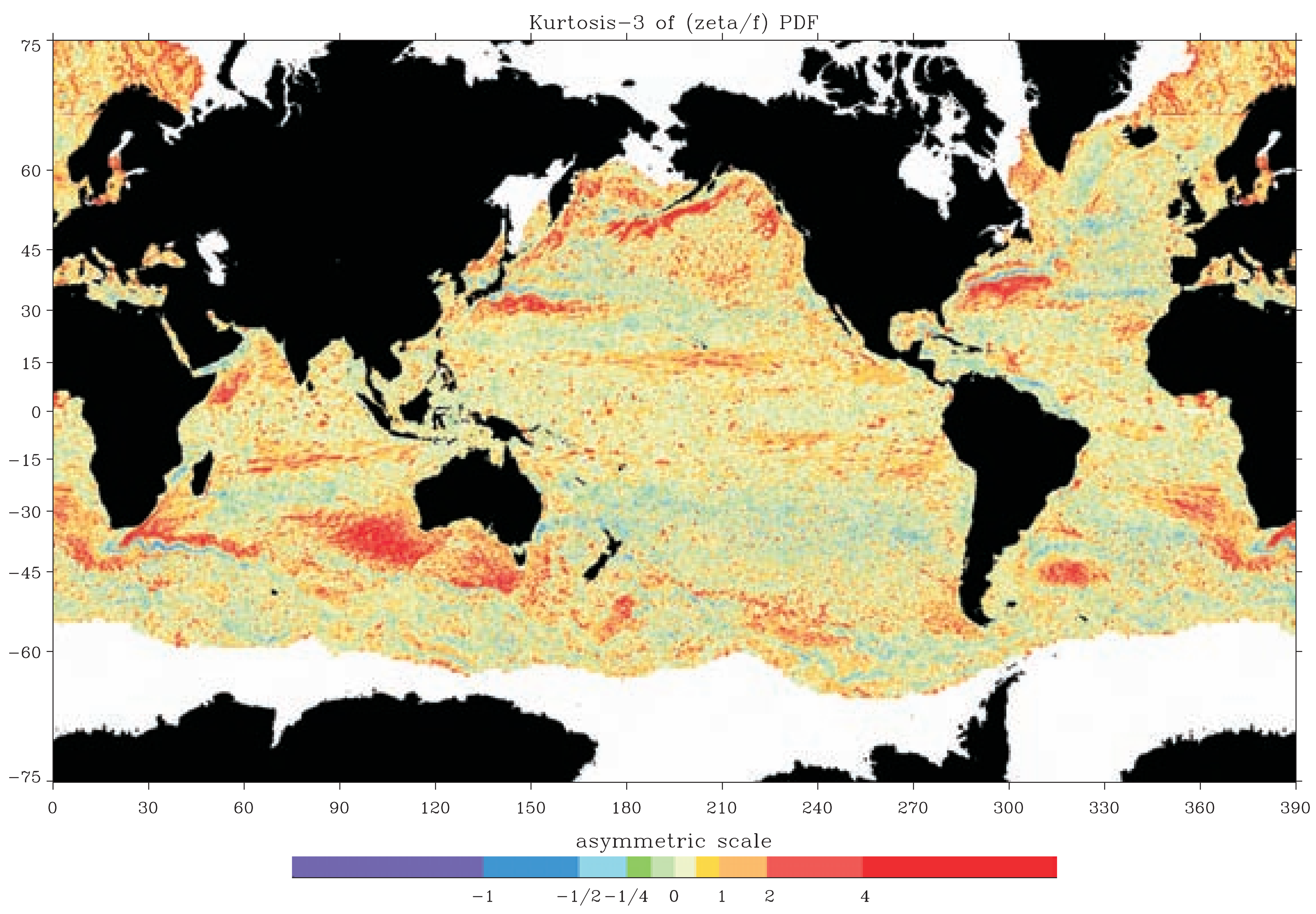
Skewness and Kurtosis of sea level





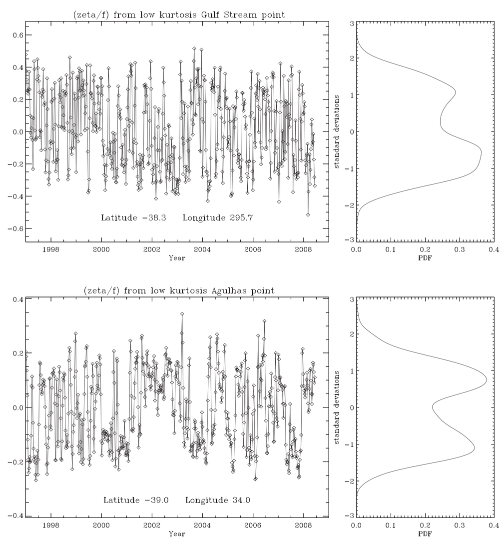
Skewness and Kurtosis of vorticity





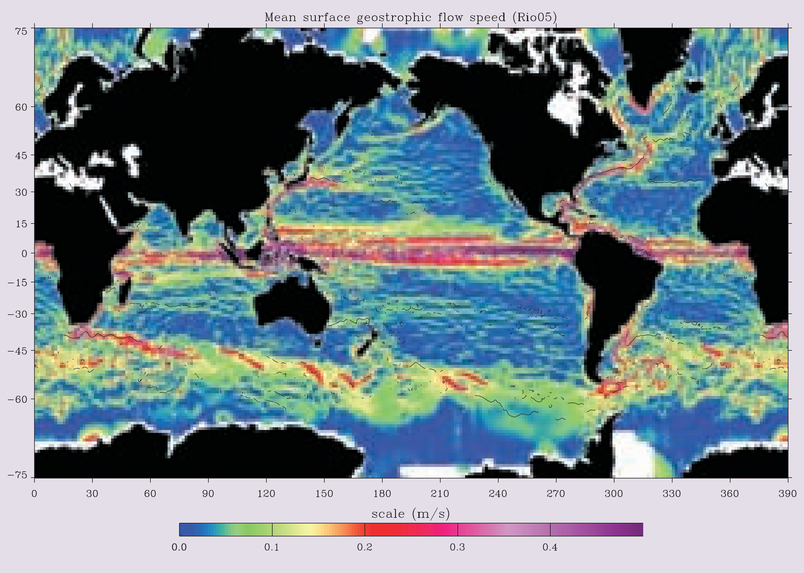
As noted by Thompson and Demirov (2006),skewness of sea level variability shows clear patterns associated with the strongest oceanic jets, such as the Gulf Stream, Kuroshio and Agulhas Return Current. This prompted us to look at the next moment of variability, the kurtosis, and indeed we found that the same jets are identified as regions of low kurtosis too. This is understandable as, near a jet centre, as the jet meanders, sea level tends to alternate between two values: the value south of the jet, and that to the north. This results in a bimodal PDF of sea level, which has low kurtosis.

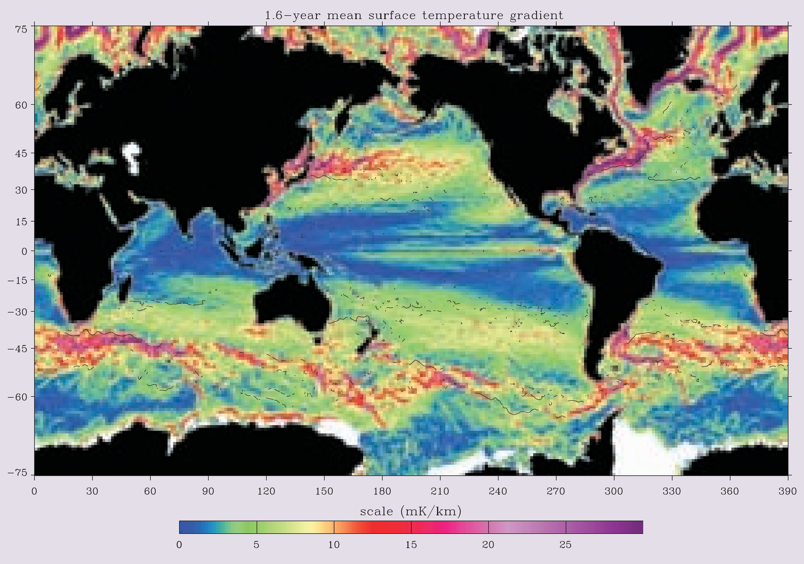
This works even better using vorticity (which is a local property where sea level is not). If we choose to highlight those places where skewness is zero and kurtosis is small, we have a means of identifying meandering jets (see below).



Low kurtosis requires a step in sea level or vorticity, which is larger than the background variability. Thinking in terms of potential vorticity, this is reminiscent of the model of a jet as a PV front which forms a barrier to PV mixing. So, could low kurtosis be indicative of the presence of a mixing barrier?

We tested this using data from 4 idealized quasigeostrophic channel model simulations (with topography), which displayed a wide range of behaviours (described in Thompson, 2010). In all cases (see below), low kurtosis occurred along jet centres, and a scatterplot indicated that there is a strong relationship between kurtosis and effective diffusivity, especially at low kurtosis values. The only thing which was done to produce a similar relationship in all four cases was to normalize the diffusivity by the domain-averaged eddy kinetic energy.





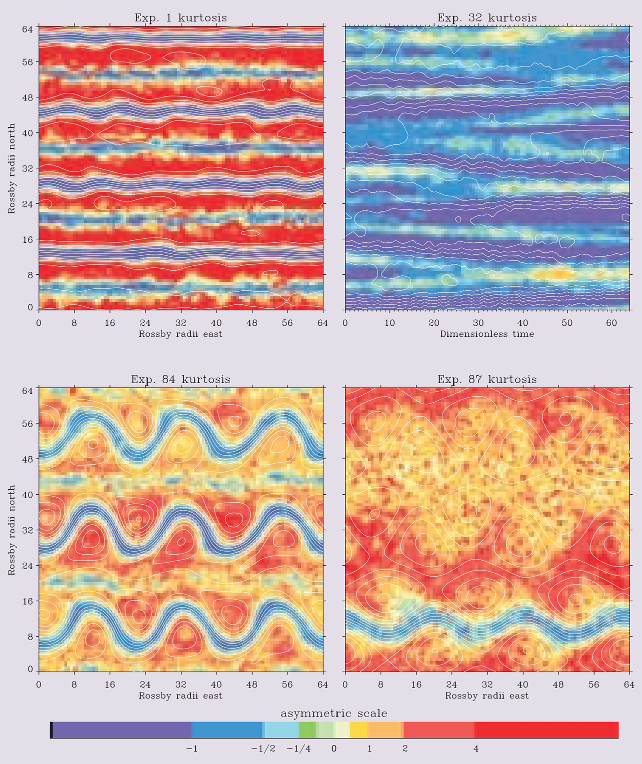
Conclusions

1) Structure in skewness and kurtosis makes it possible to identify regions where the variability is dominated by the influence of meandering jets.

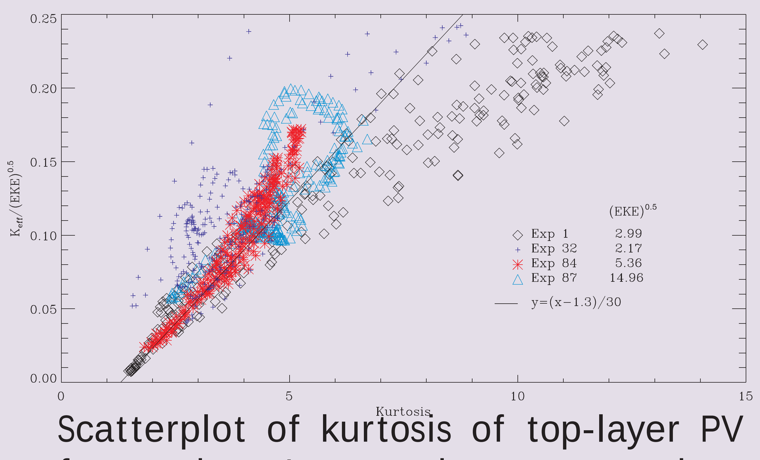
2) Kurtosis provides a simple way of determining where mixing barriers occur in the ocean

This work is published as
Hughes, C. W., A. F. Thompson and C. Wilson, 2010: Identification of jets and mixing barriers from sea level and vorticity measurements using simple statistics. Ocean Modelling 32, 44-57.

Download a copy from
http://www.pol.ac.uk/home/staff/?user=HughChri
or email *cwh@noc.ac.uk*



Kurtosis of PV (colour scale), and streamfunction (contours) for the surface layer of 4 different quasigeostrophic model runs.



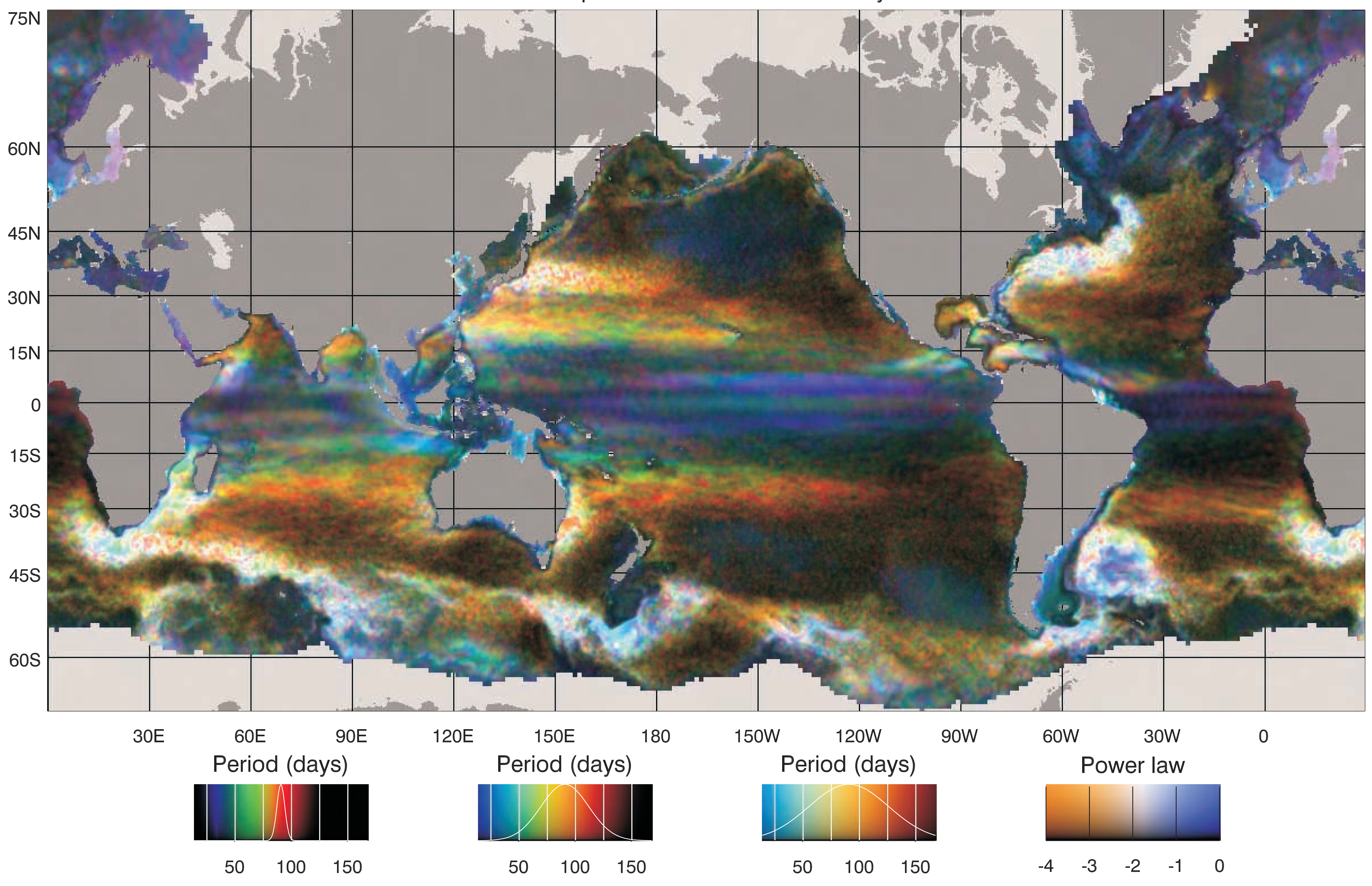
Scatterplot of kurtosis of top-layer PV from the 4 experiments, against effective diffusivity (normalized by domain-averaged EKE).

Other works referenced:

Thompson, K. R. and E. Demirov, 2006: Skewness of sea level variability of the world's oceans. J. Geophys. Res. (Oceans)111, C05005.

Thompson, A. F., 2010: Jet Formation and Evolution in Baroclinic Turbulence with Simple Topography. J. Phys. Oceanogr. 40(2), 247-278

The spectrum of sea level variability



This shows the spectrum of sea level variability as it would appear if the period range 2-24 weeks was mapped onto the period range of visible light. The scale bars show the colours which would result from various Gaussian (as a function of period) spectra, and of different power law spectra. Note that "red" noise, power proportional to frequency to the power -1/2, appears here as white or grey.

Paper in press as Hughes, C. W. and S. D. P. Williams: The color of sea level: Importance of spatial variations in spectral shape for assessing the significance of trends. J. Geophys. Res. 2010.

Download from http://www.pol.ac.uk/home/staff/?user=HughChri or email cwh@noc.ac.uk