# An Eddy Atlas from Lagrangian Floats

J. M. Lilly[1], S. C. Olhede[2], J. J. Early[1], & A. M. Sykulski[2]

[1]NorthWest Research Associates, [2]University College London

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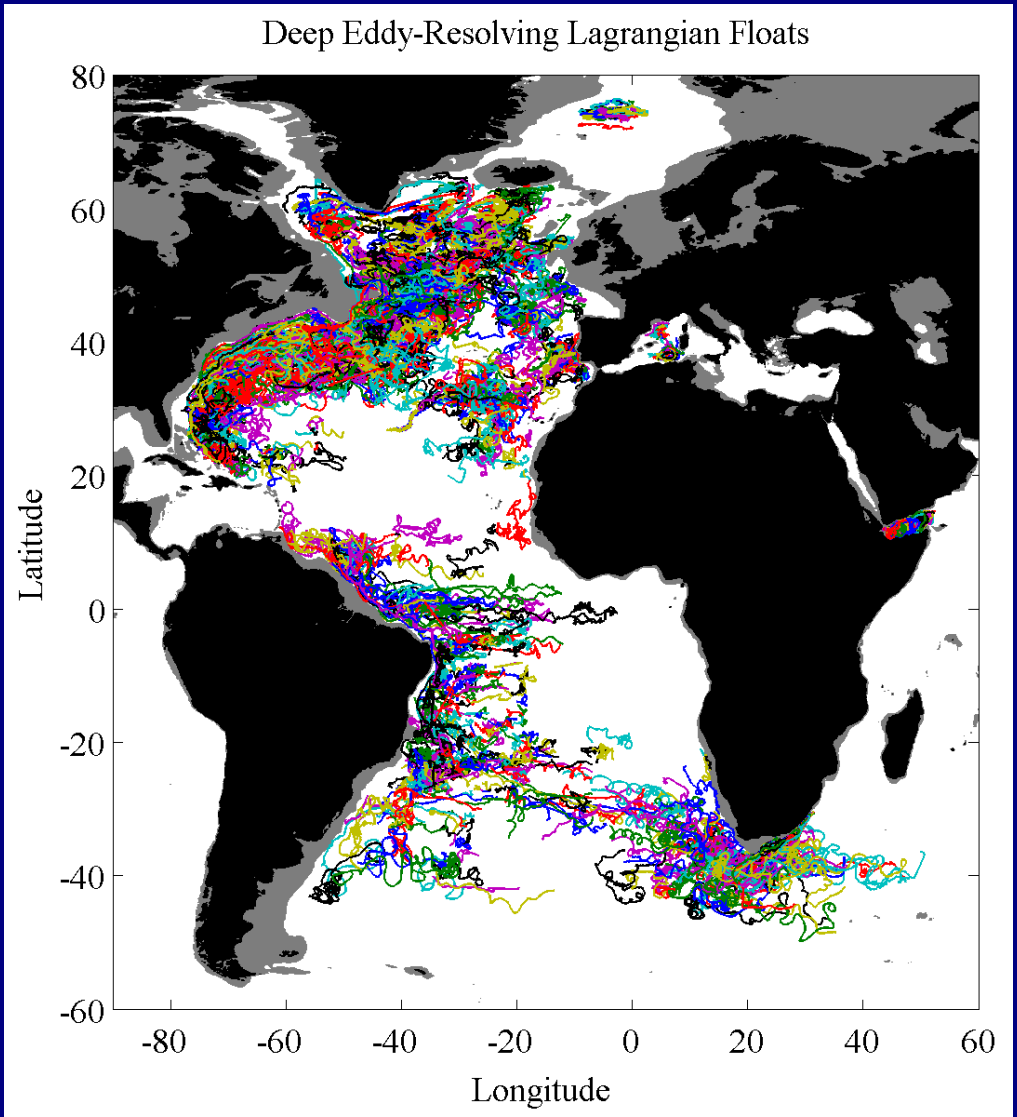
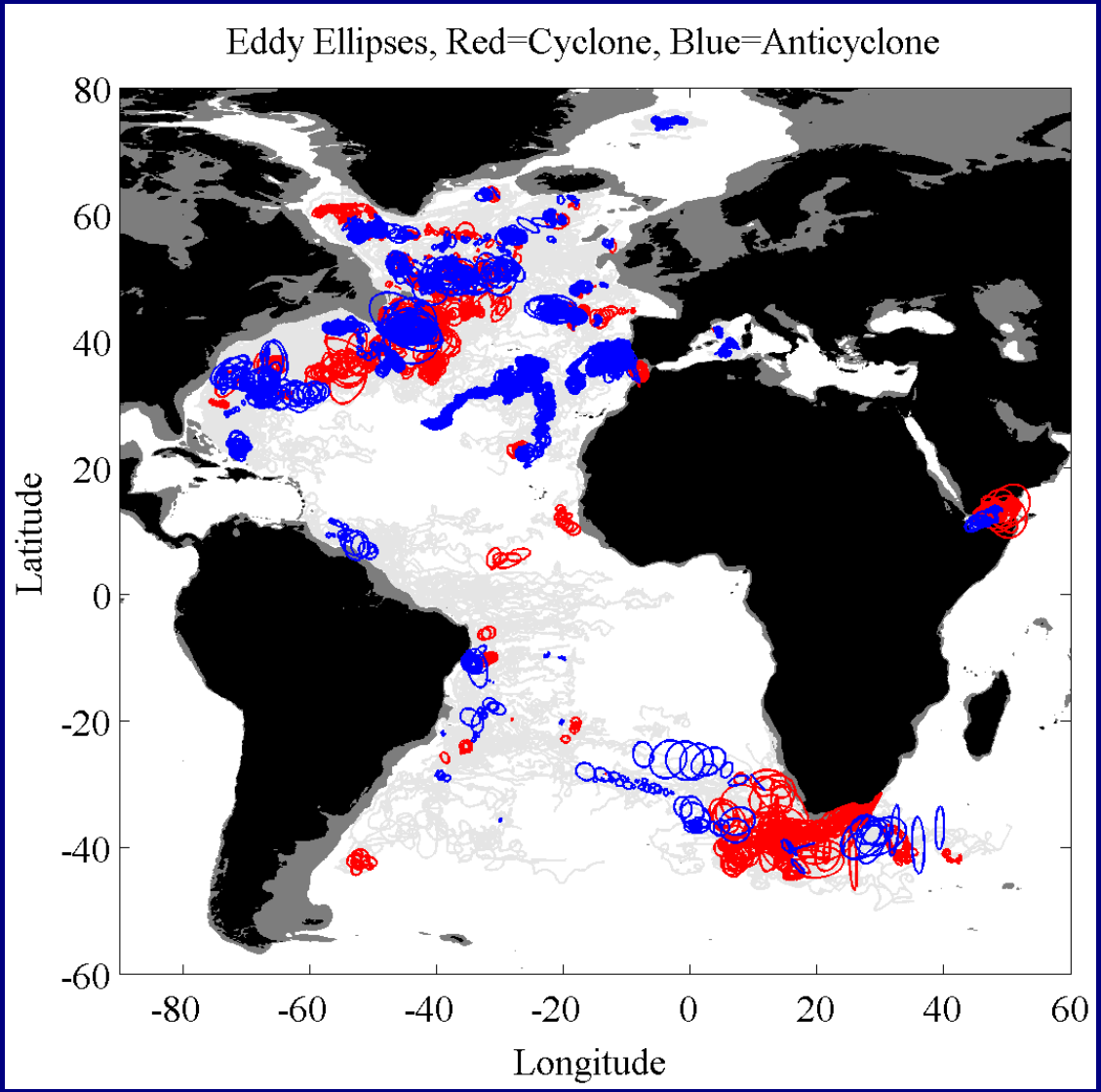
# Historical dataset of eddy-resolving subsurface floats




1471 different instruments, 700,000 data points.

# A preliminary eddy atlas




Apparent eddies in Rossby number band $Ro = 1/64$ to $Ro = 1$.

# Overview

Preliminary results from work carried out a as a part of

> A Vortex Census from Lagrangian Floats
> NSF-OCE #1235310

Goal: to understand coherent eddy properties and impacts from the Lagrangian float dataset.

- Eddy-resolving float dataset
- Eddy extraction method
- Development of a noise model

Highly statistically significant features are (i) persistent (ii) nearly circular and (iii) narrowband.

Low Rossby number, transient features (e.g. Gulf Stream rings) are more challenging to distinguish.

# Historical dataset of eddy-resolving subsurface floats

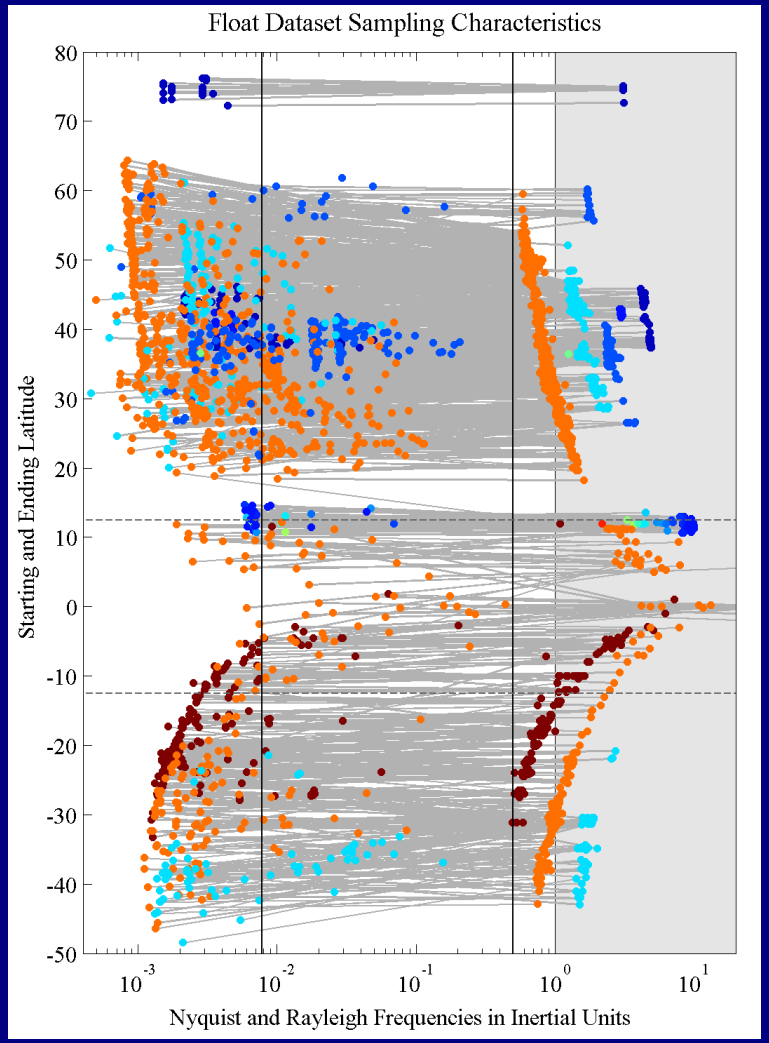
Composition of the eddy-resolving float dataset:

- WOCE Subsurface Float Data Assembly Center, `http://wfdac.whoi.edu/`
- J.-C. Gascard, LOCEAN
  Mediterranean+Greenland Sea+Subtropical Atlantic
- A. Bower, WHOI
  Red Sea (RedSOX) + Northern North Atlantic (ExPath)
- P. Brandt, IFM-GEOMAR
  Labrador Sea (see Funk et al., 2009 JGR)

WOCE dataset is 1265 instruments with 500,000 data points.
Total dataset is 1471 instruments with 700,000 data points.

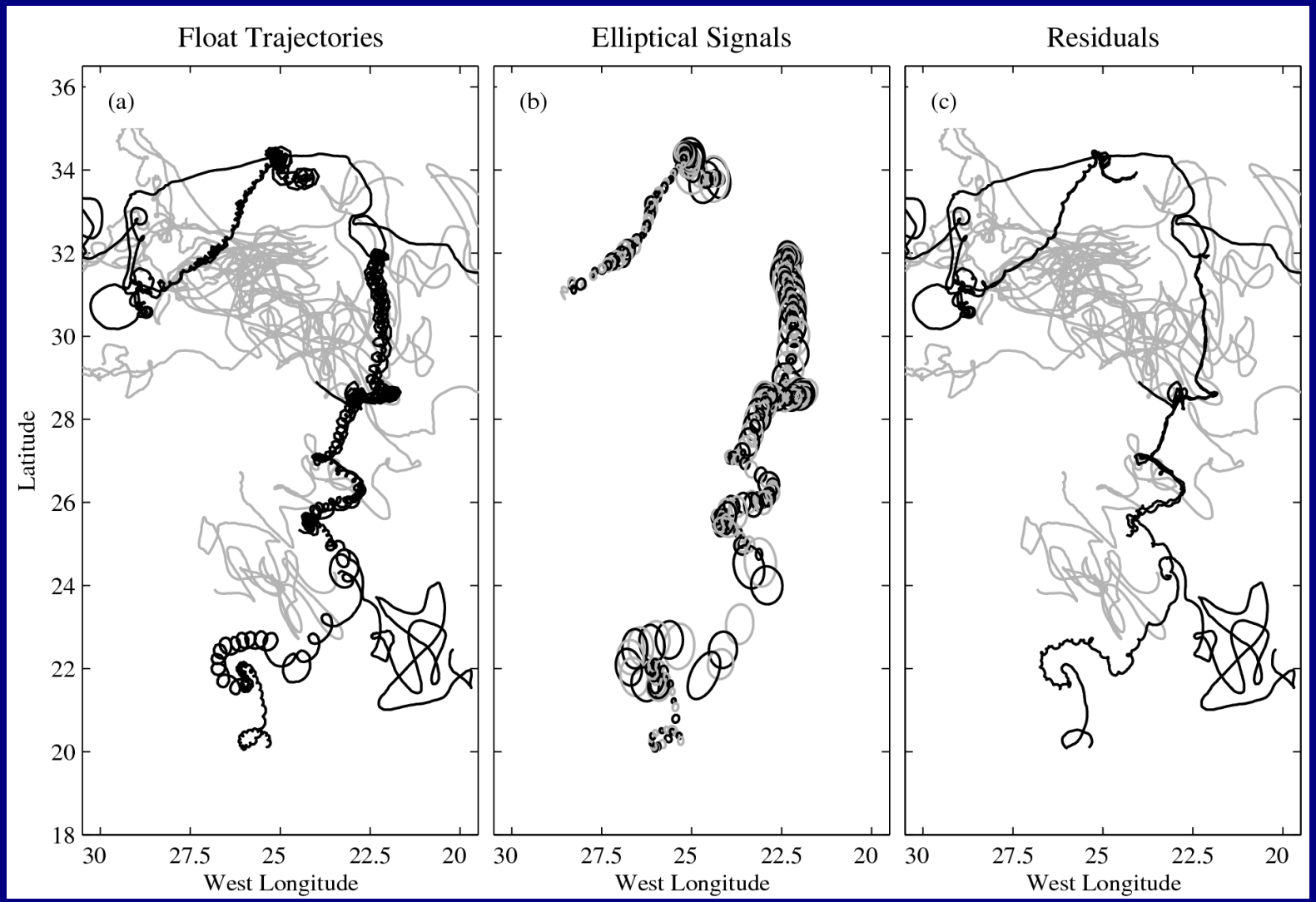
Sampling period $\Delta t$ by percentage of floats:
50% 24 hrs, 14% 12 hrs, 16% 8 hrs, 5% 6 hrs, 5% 4 hrs

# Float dataset sampling characteristics



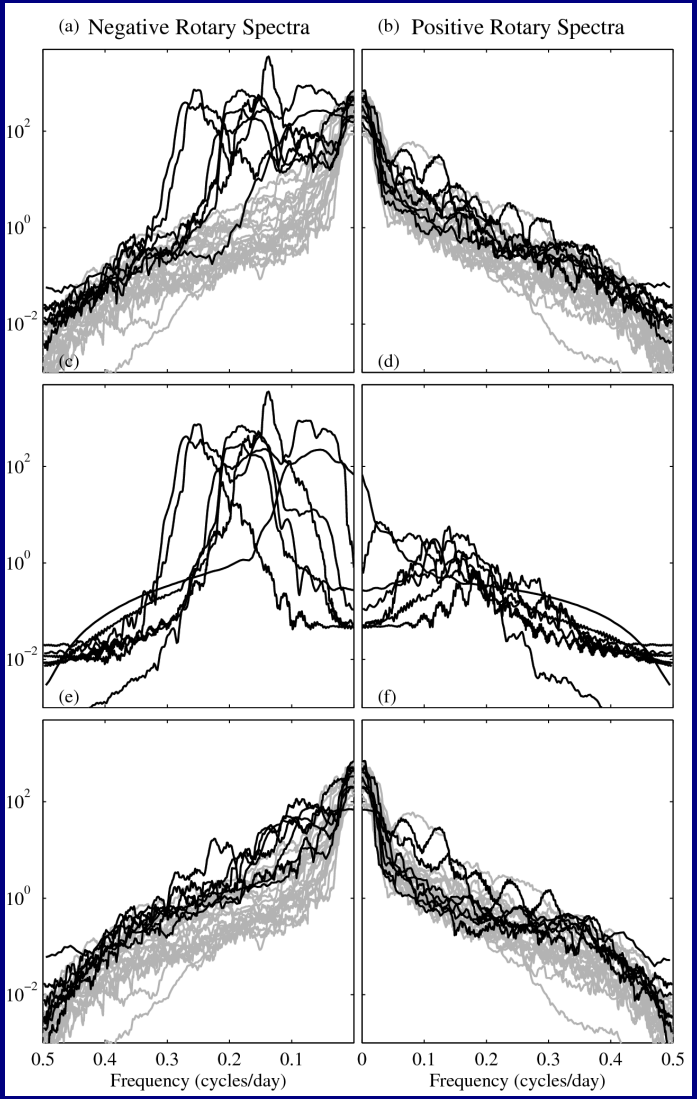

Nyquist (largest) and Rayleigh (smallest) frequency in inertial units, starting and ending latitude, sampling period $\Delta t$

# Method: Split trajectories into vortex portion + residual



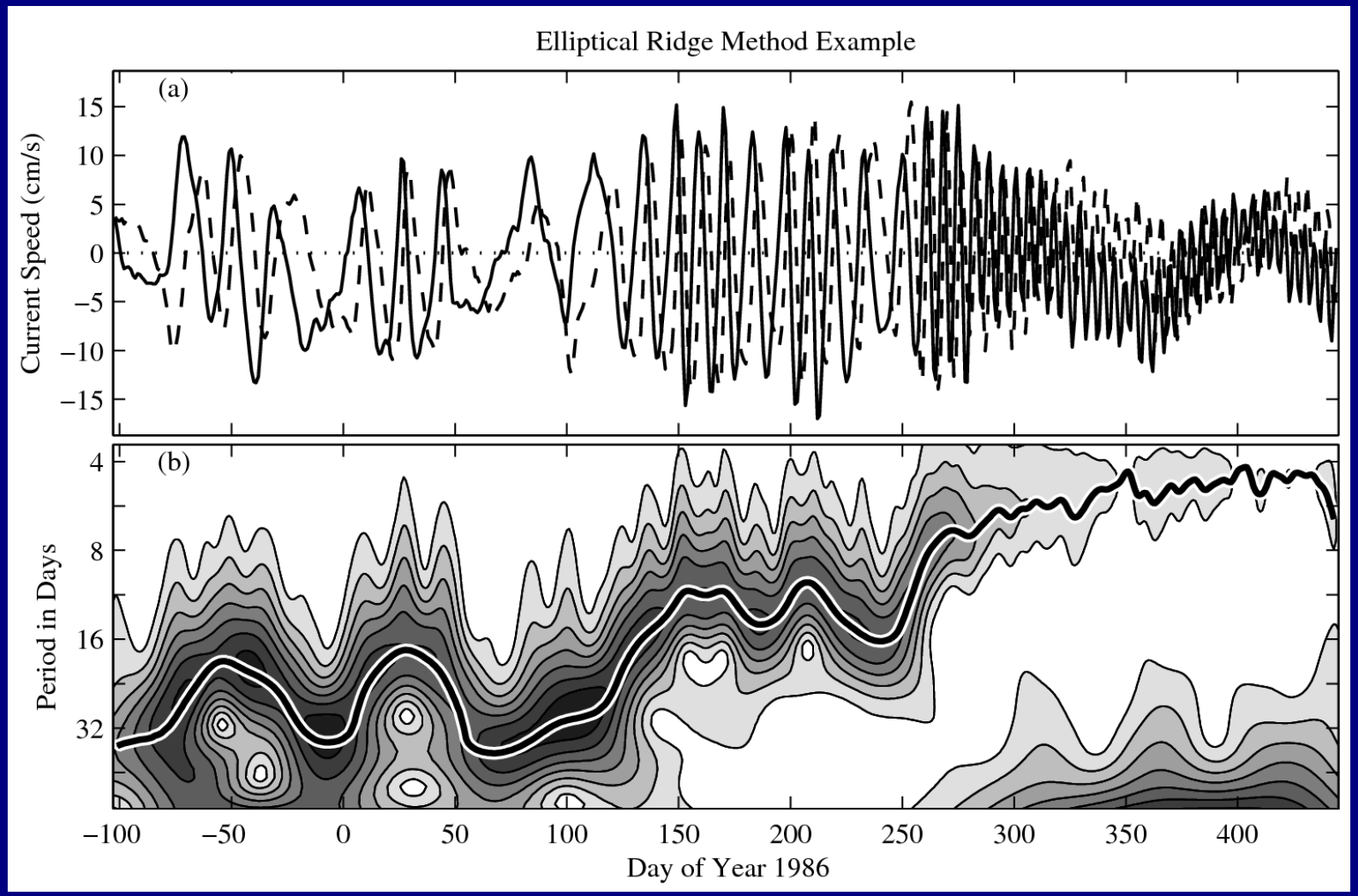

Meddies in Richardson et al. (1989) SOFAR dataset.

# Spectra show very good removal of eddy peaks




Residual is symmetric in positive and negative circular motion.

# Example of ridge analysis




Search for oscillatory signals in a frequency (Rossby number) band using a local best-fit method.

# Method overview

Search for oscillatory signals in a frequency (Rossby number) band. Chosen band is $Ro = 1/64$ to $Ro = 1$.

Inertial oscillations and internal waves are thus excluded.

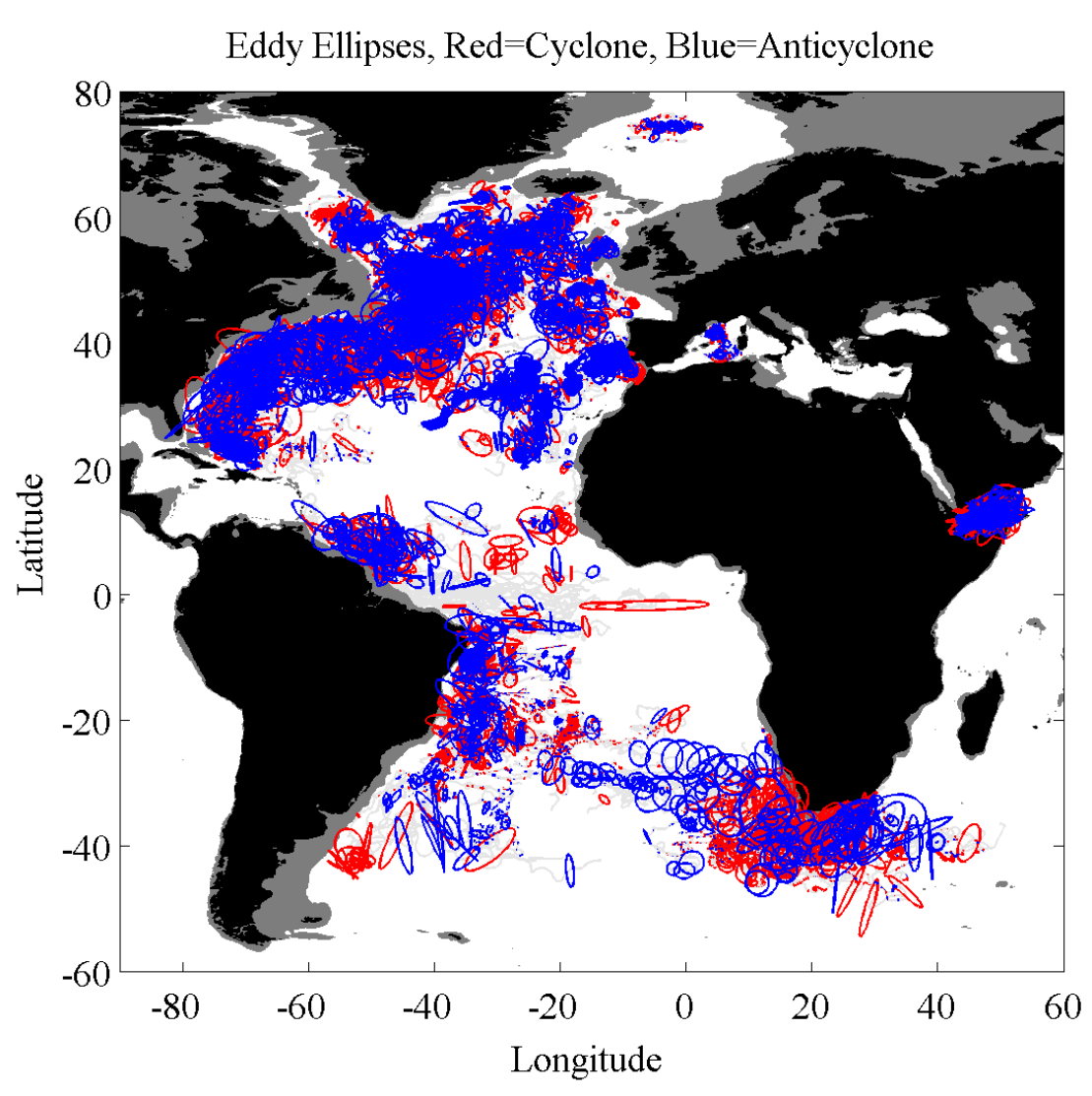
Wavelet (test oscillation) is characterized by $\sim 1$ oscillation. Keep signals greater than $L > 2$ full cycles.

For method details see Lilly, Scott, and Olhede (2011) GRL and Lilly and Olhede (2012) ITSP.

Using routines `wavetrans` and `ridgewalk` from JLAB, available at `www.jmlilly.net`.

See also Bower et al. (2013), Alpers et al. (2013), and Le Hénaff et al. (2014) for other applications using this code.

# Application of ridge method to float dataset




Rossby numbers $Ro = 1/64$ to $Ro = 1$, duration $L > 2$. Noisy!

# The need for a noise model

If we wish to (i) analyze a large dataset without needing to inspect each trajectory, and (ii) push the limits of the data, we need to understand the features that result randomly from "noise".

We represent the velocities of the unstructured turbulent background by a Matérn process, with isotropic spectrum

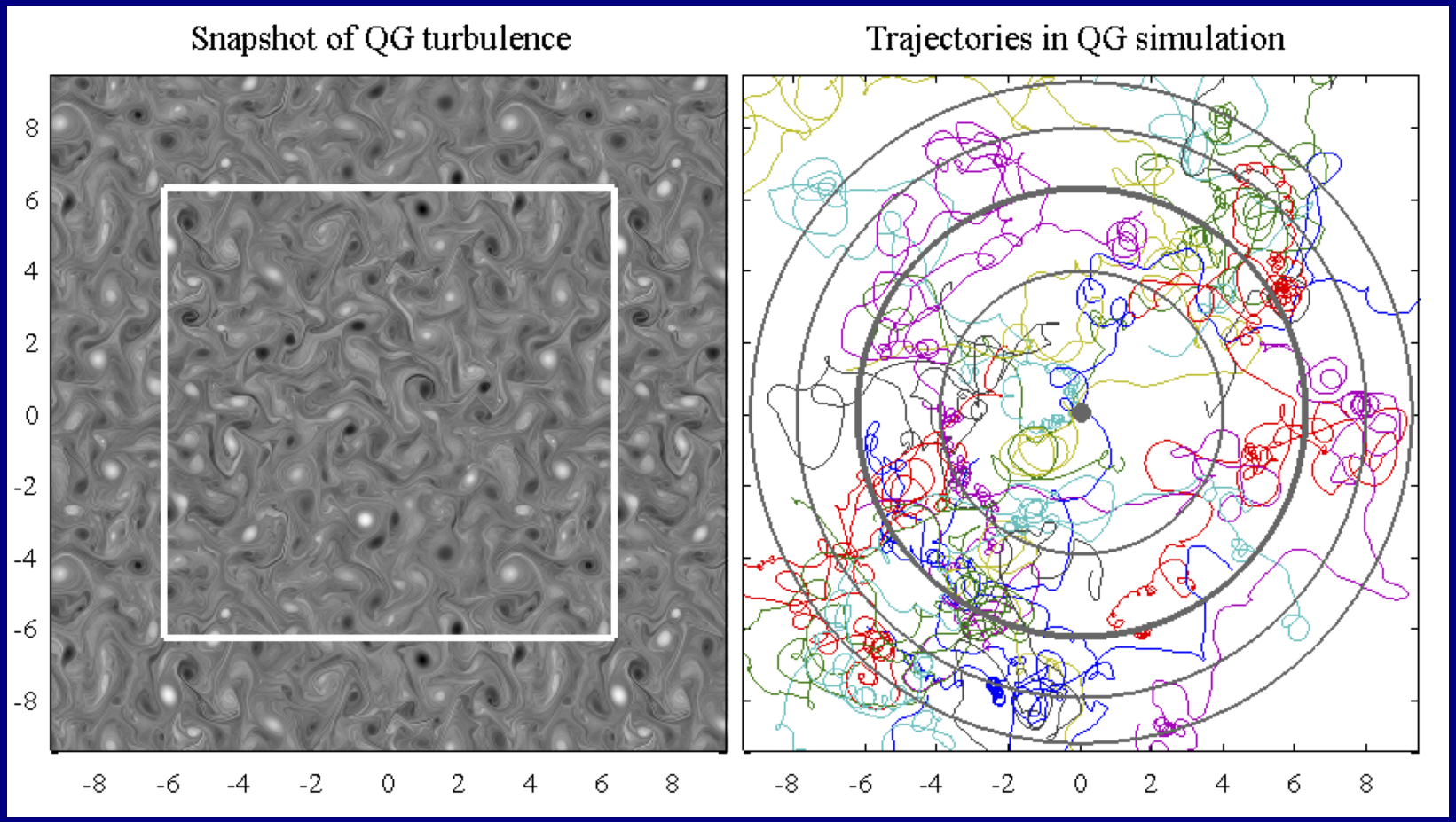
$$S(\omega) = \frac{A^2}{(\omega^2 + B^2)^\delta} \qquad \delta > 1/2.$$

This is *damped* fractional Brownian motion.

The damping ($B^2$ in the denominator) is essential—it keeps the velocities from randomly walking off to e.g. 2000 cm/s.

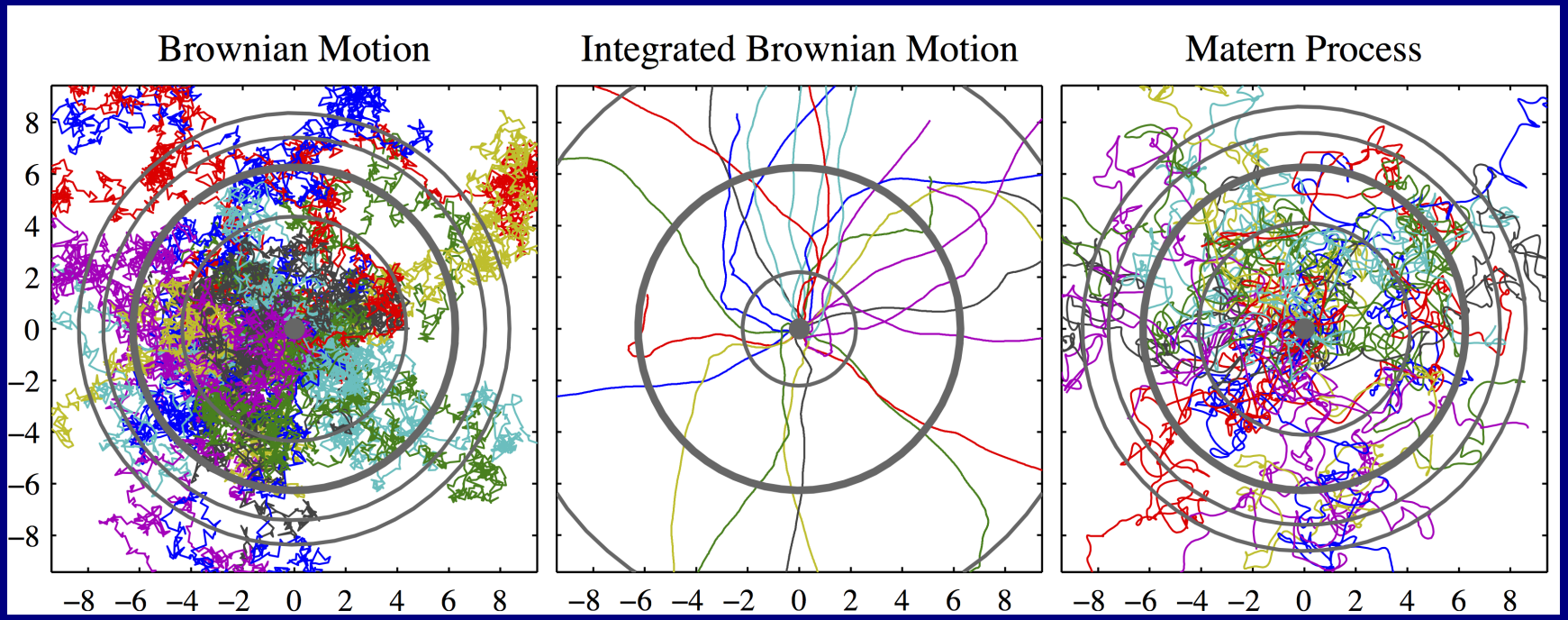
For details: 09:30 Friday, Session 071. Sykulski, Lilly, Olhede, Danioux, and Early: Stochastic models for Lagrangian data.

# Stochastic Modeling



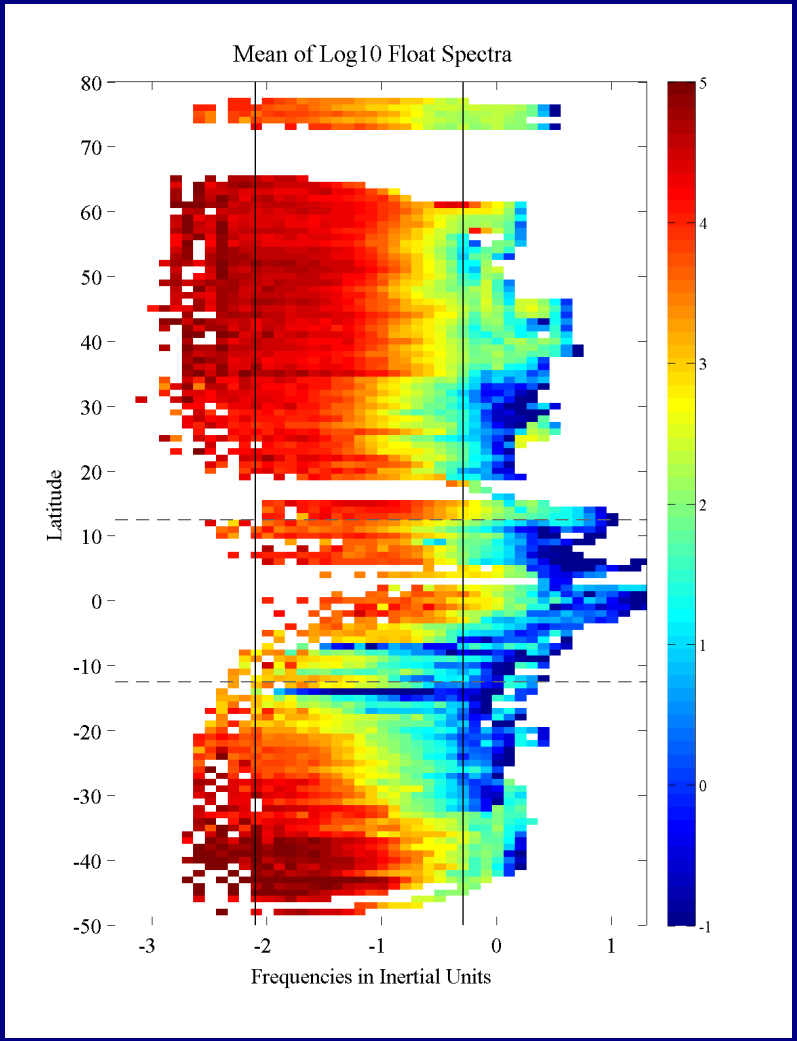

Trajectories from a QG model. How can these be described as a stochastic process, with no explicit oscillations due to eddies?

# Stochastic Modeling



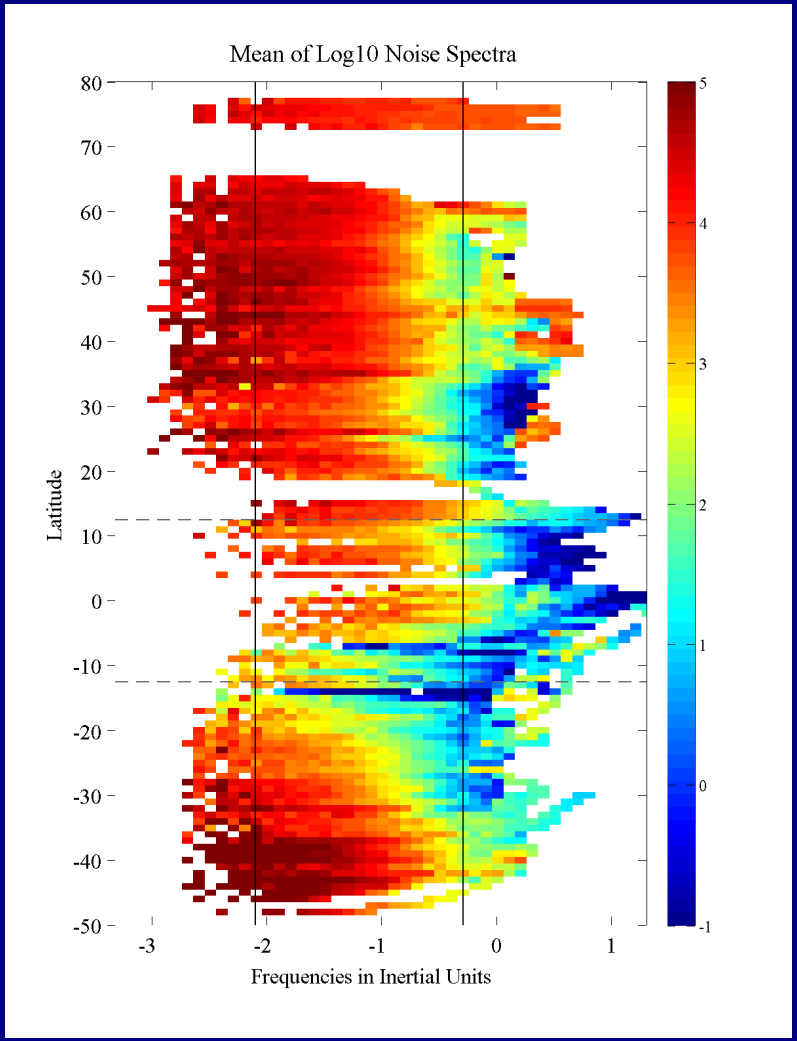

Brownian motion is not a good fit to Lagrangian trajectories. The Matérn process, *damped* fractional Brownian motion, can reproduce both smoothness *and* dispersion. Useful for testing significance of eddies, inertial oscillations, etc...

# Mean of log10 float spectra



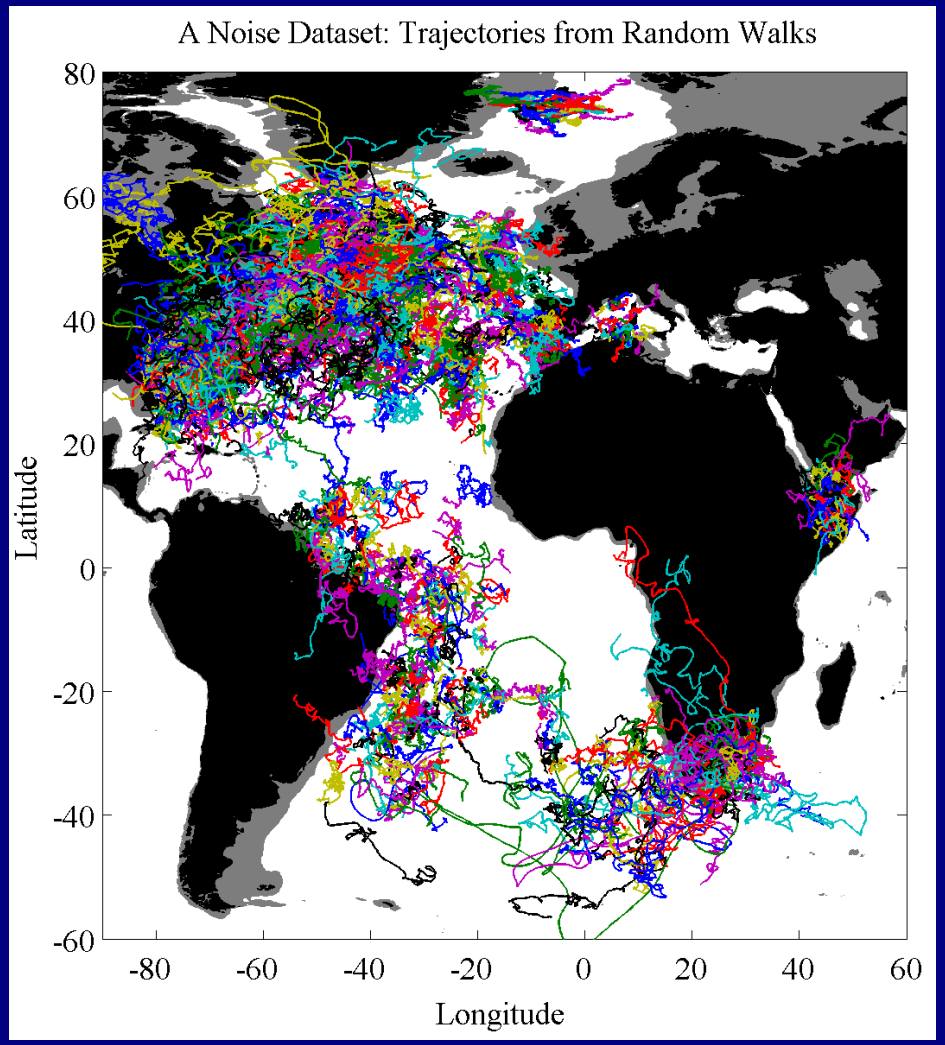

The average velocity spectrum as a function of latitude, with frequency in inertial units.

# Mean of log10 noise spectra



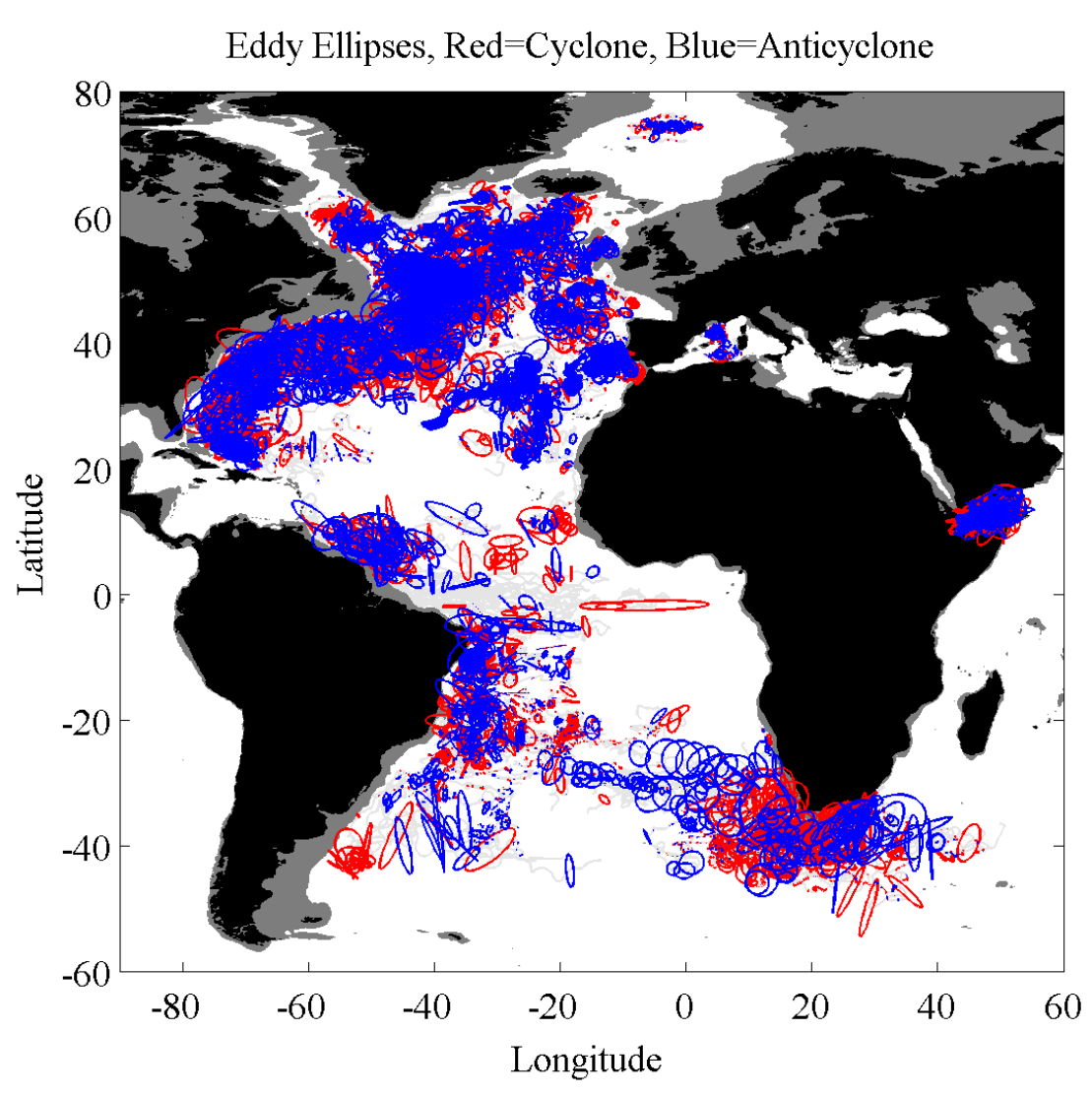

The average velocity spectrum of a float-by-float fit to the noise model. Sampling characteristics are identical to the data.

# A synthetic dataset of trajectory "noise"




Damped random walks, fit to data on a float-by-float basis.

# Application of ridge method to float dataset

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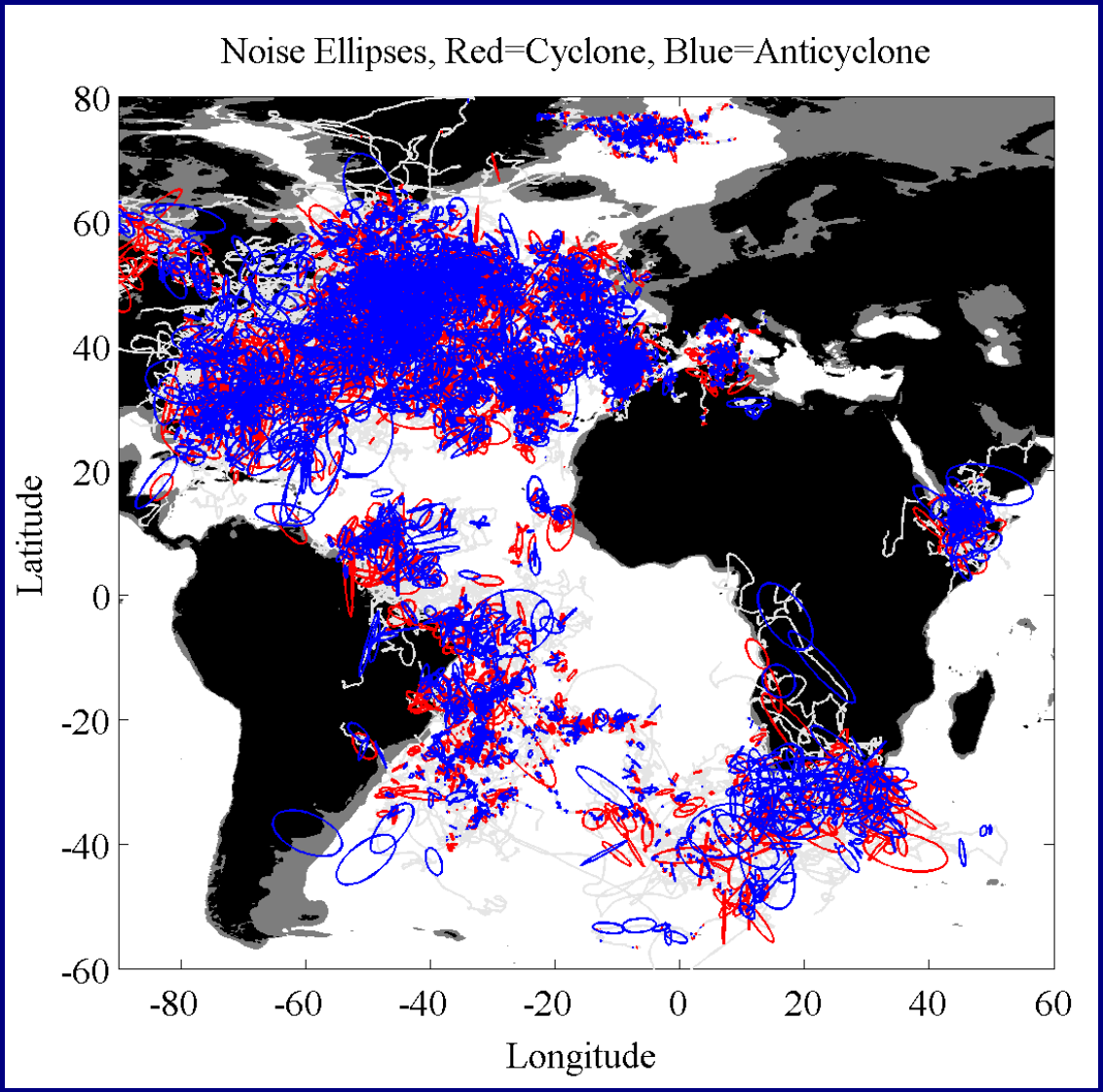
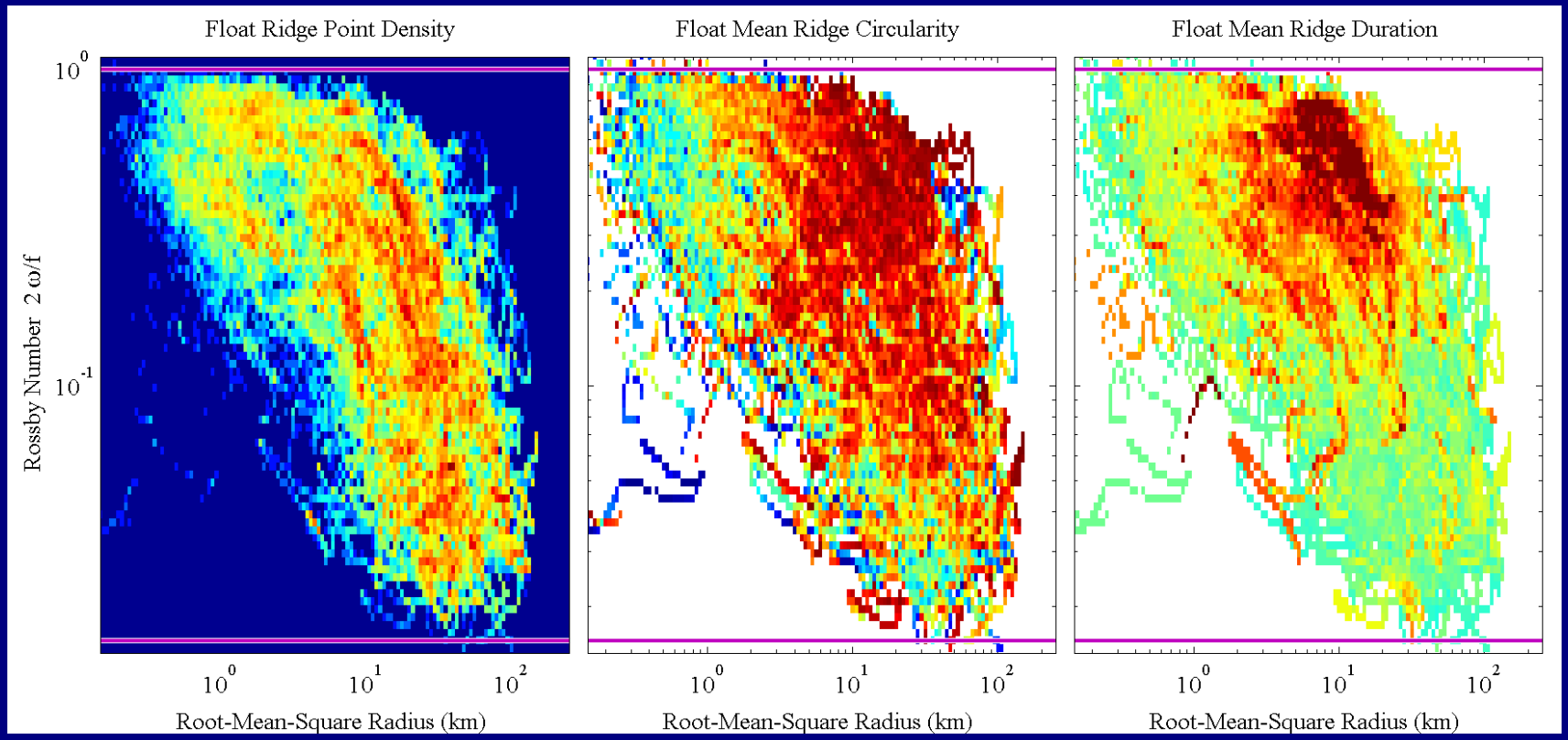


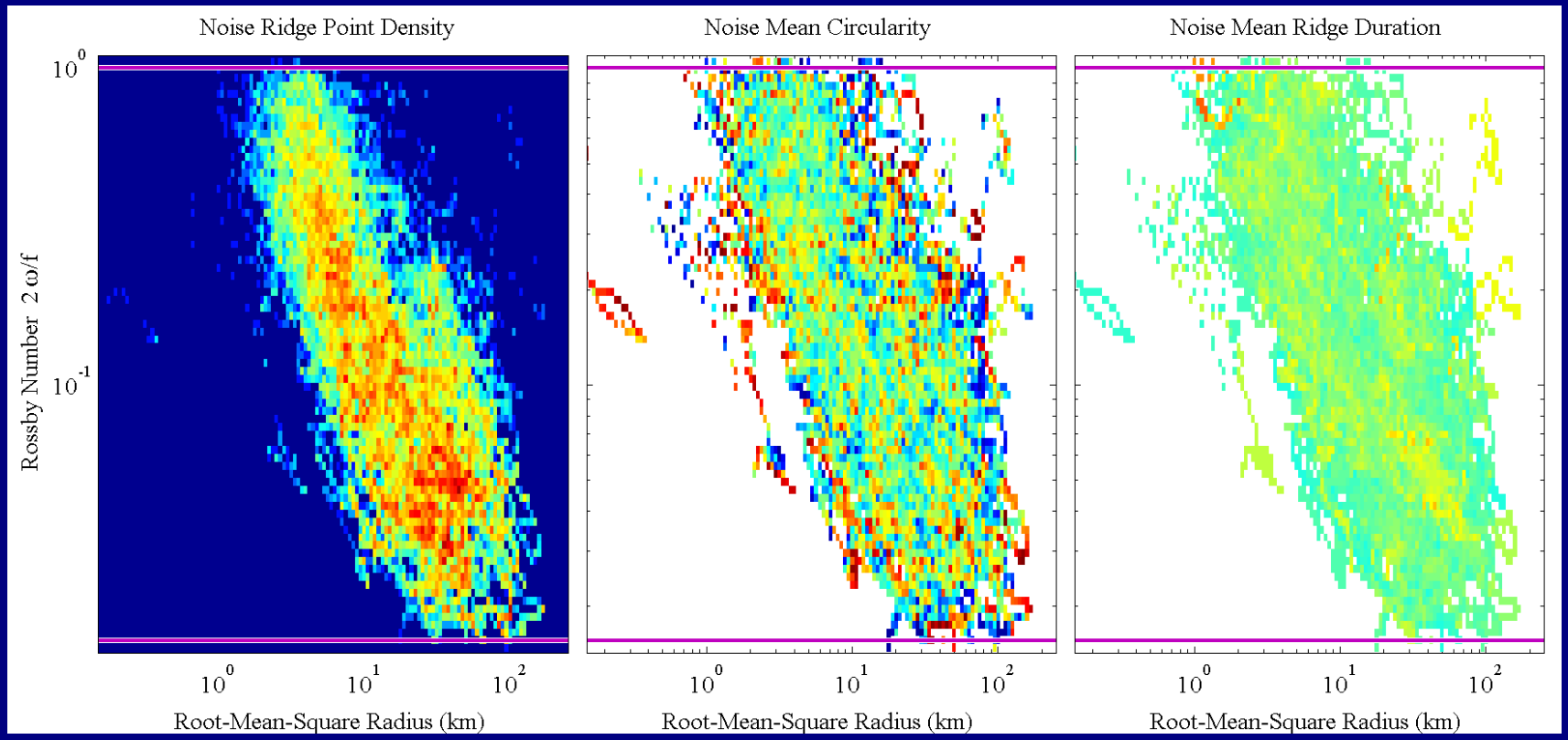

Important: turbulent background makes apparent oscillations.

# Distribution of ridge points from floats



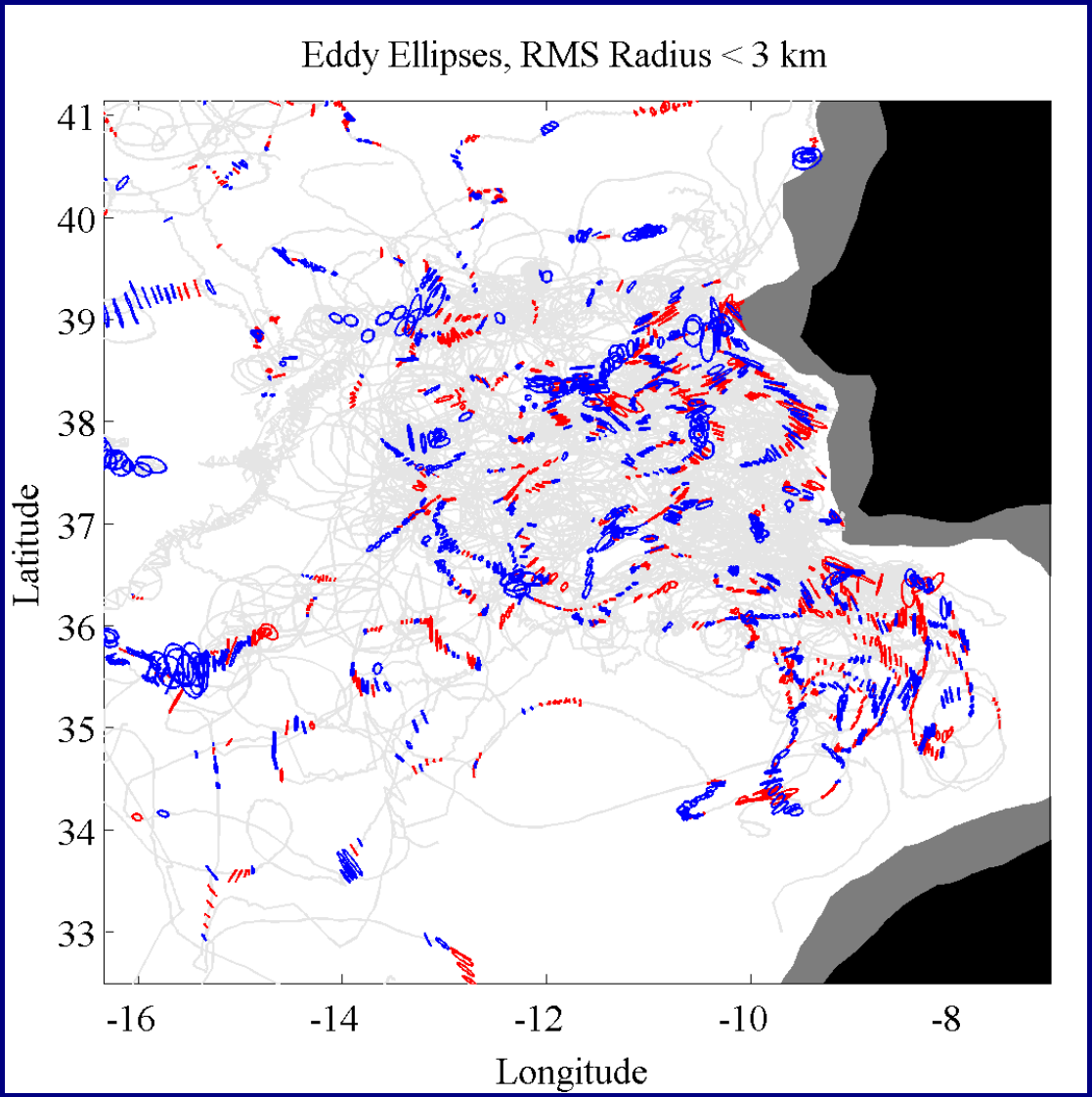

Floats dataset shows a concentration of highly persistent (long duration), nearly circular features.

# Distribution of ridge points from noise



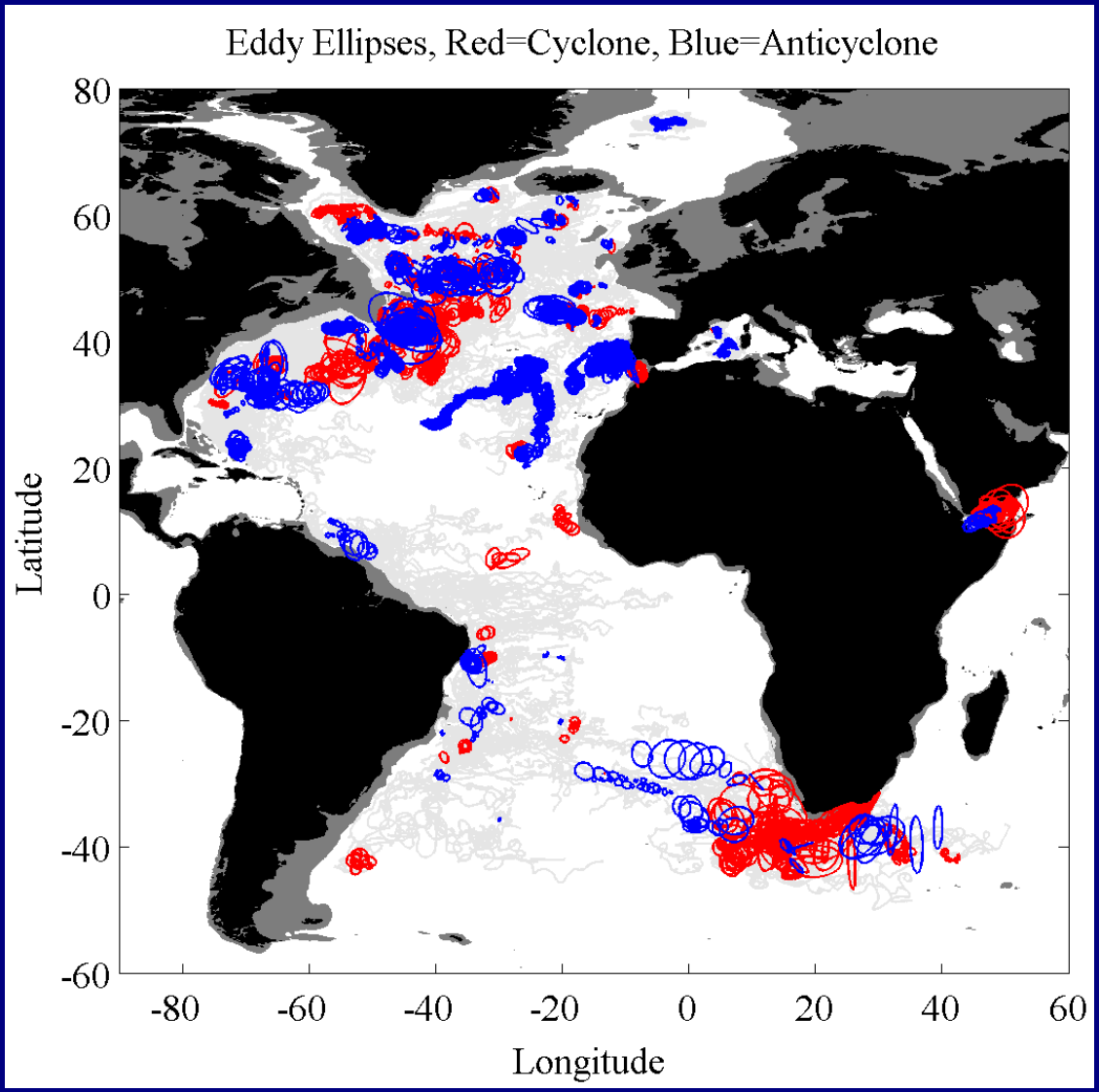

Noise does not tend to make features that are persistent or strongly polarized (e.g. circular). High *Ro* features are largely artifacts.

# False events due to measurement errors



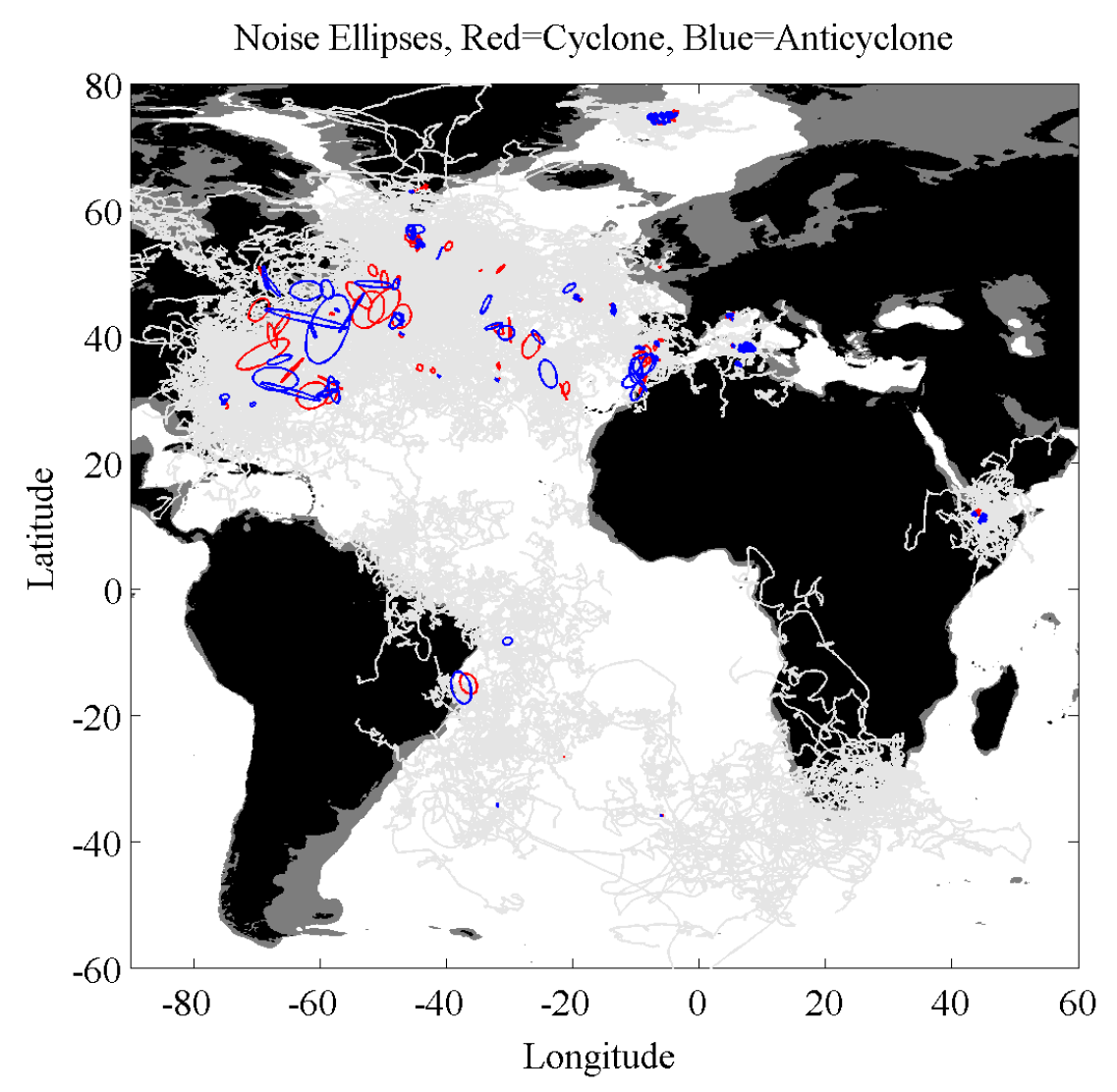

Small radius, high *Ro* features appear due to measurement errors.

# Near-circular, persistence, and amplitude cutoffs



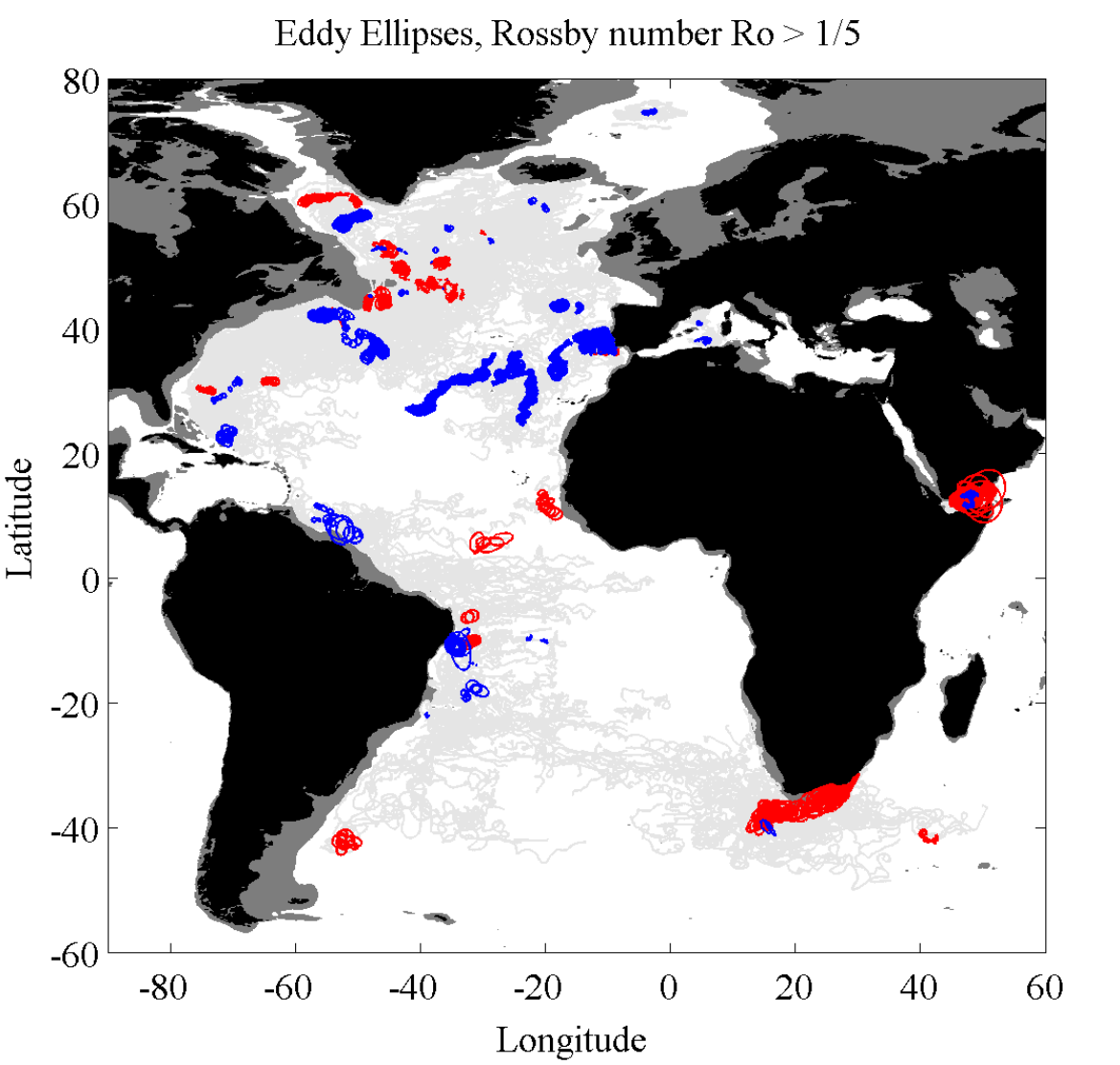

Duration $L > 6$, circularity $\xi = 0.6$, rms radius $R > 3$.

# Noise with same cutoffs



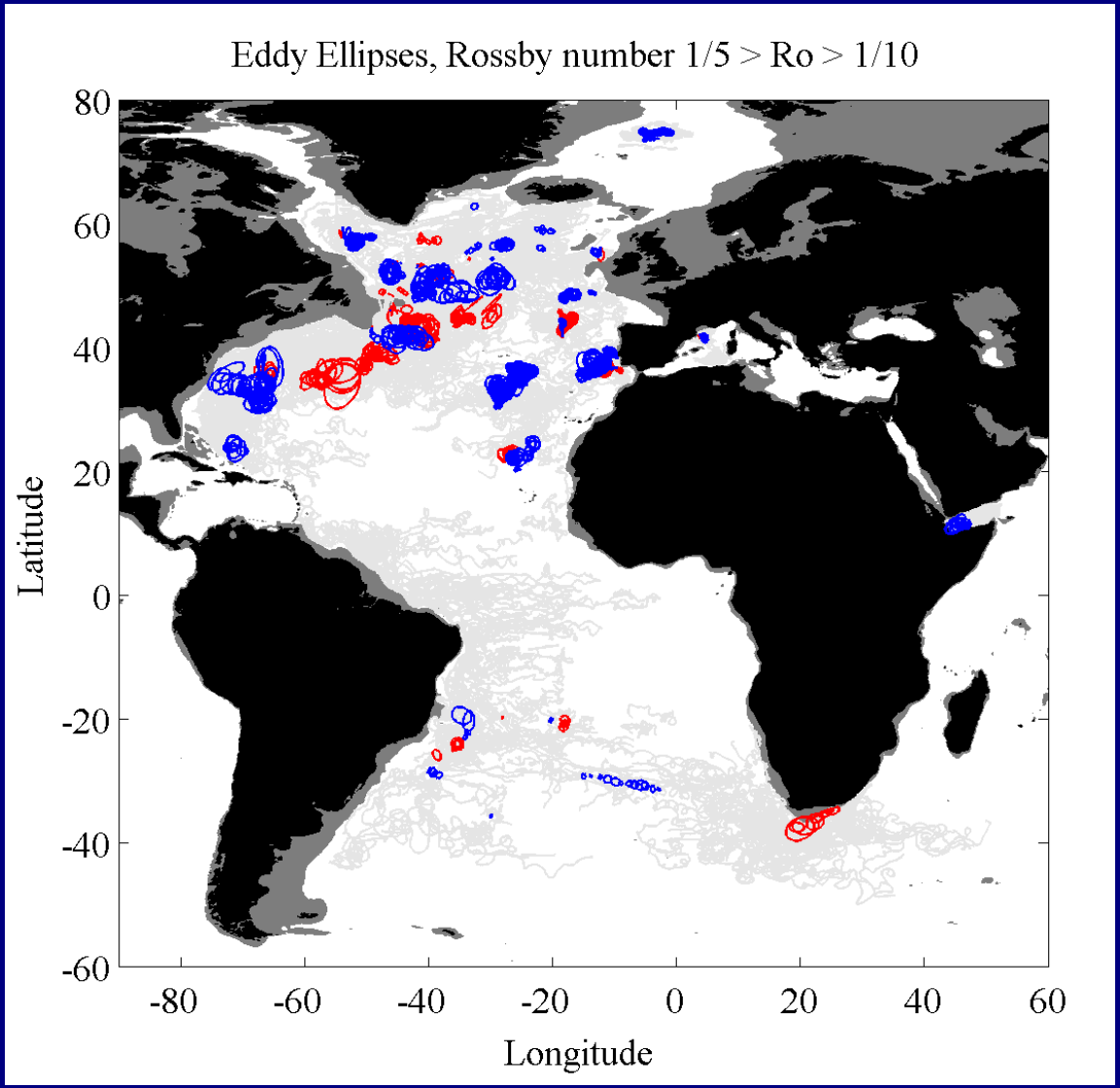

This band of features appears highly statistically significant.

# High Rossby number features in eddy band

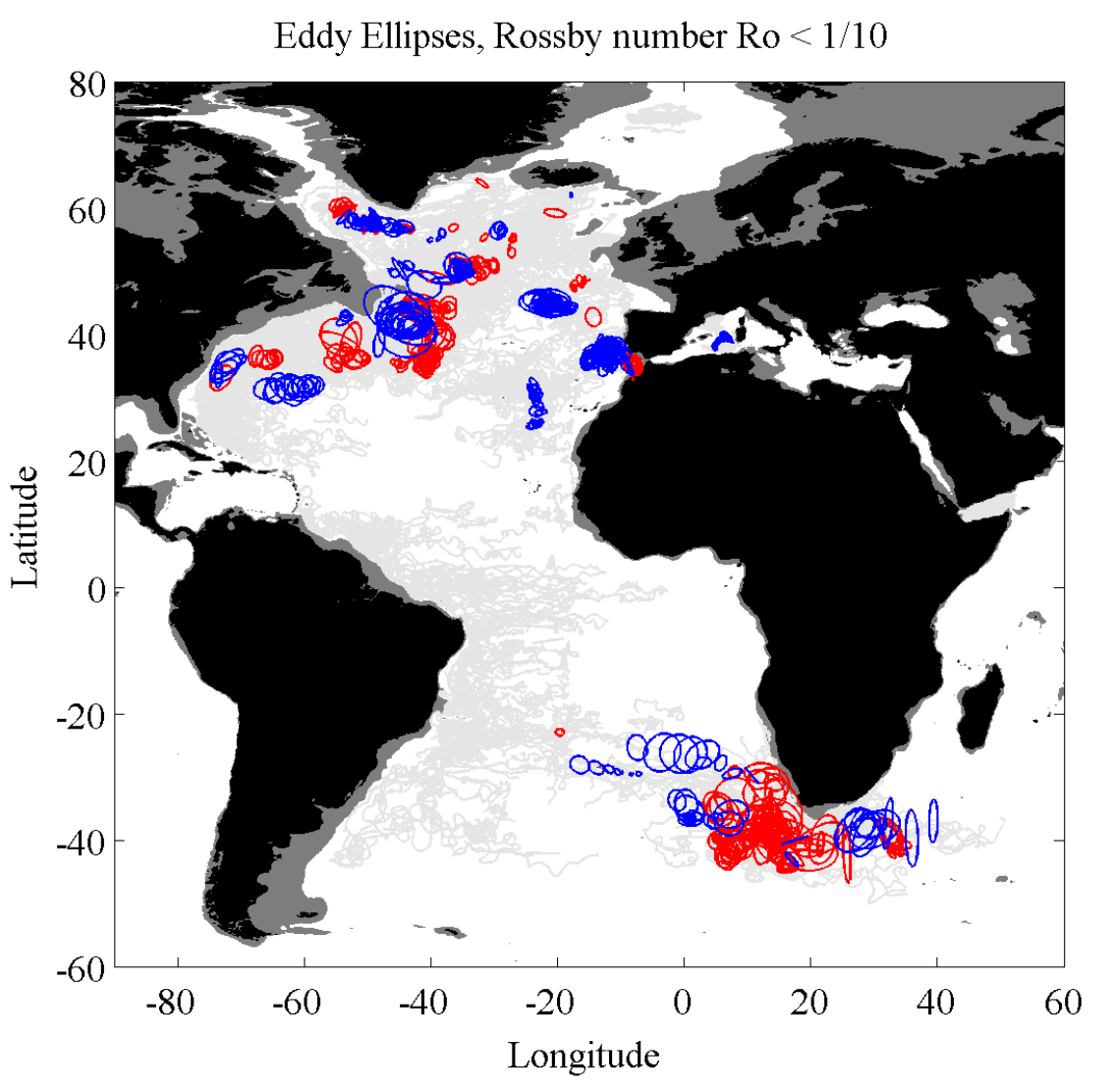



High *Ro* features are often associated with bathymetry.

# Intermediate Rossby number features in eddy band



# Low Rossby number features in eddy band




Low *Ro* includes boundary current rings and recirculations.

# Results

A systematic investigation of eddy currents from all available Lagrangian floats is underway.

- Noise model can help identify statistically significant events
- Beware of artifacts from measurement errors!
- The most highly significant events are persistent and circular (and also narrowband)
- High *Ro* features are often associated with bathymetry

Next: finalization of "eddy band" identification, determination of inside / outside core radius, propagation patterns, etc...