

# Meso-Scale Eddy Tracking via Model- and Satellite-SSH Data

Update

NK

September 28, 2014

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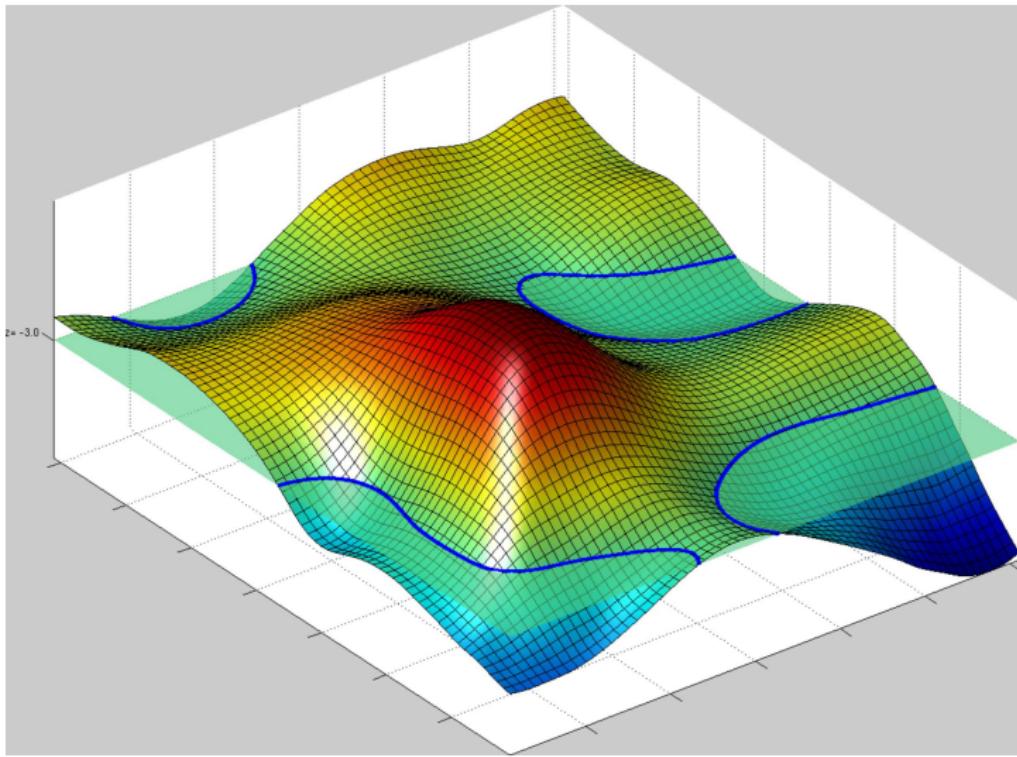
  Detection

  Tracking

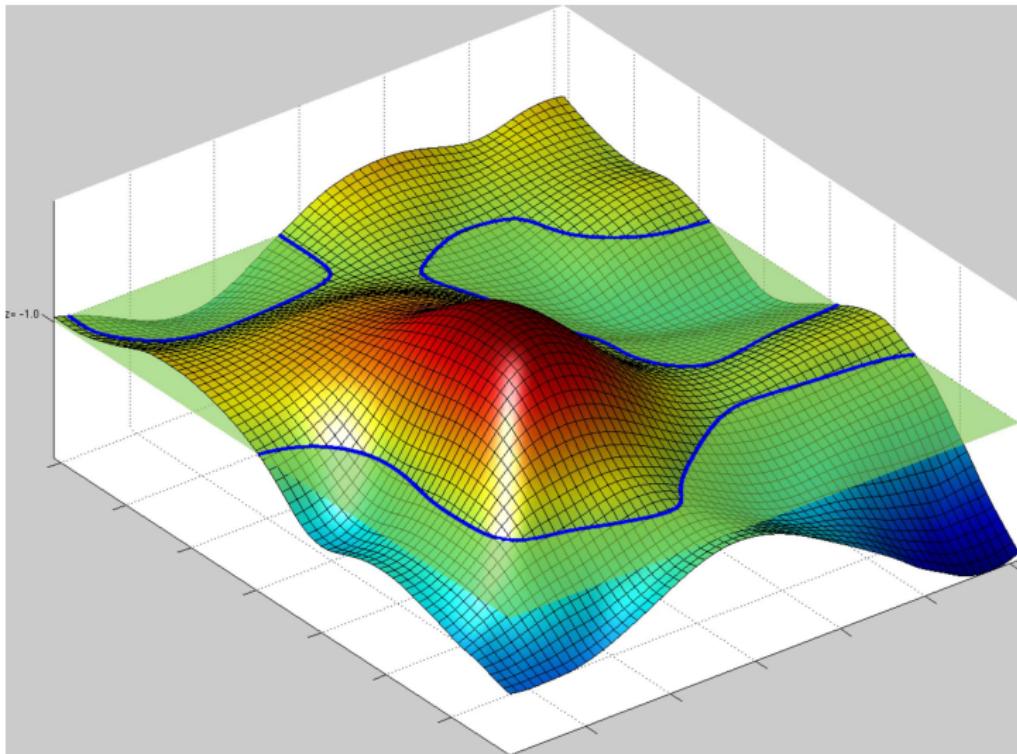
New Results

next..

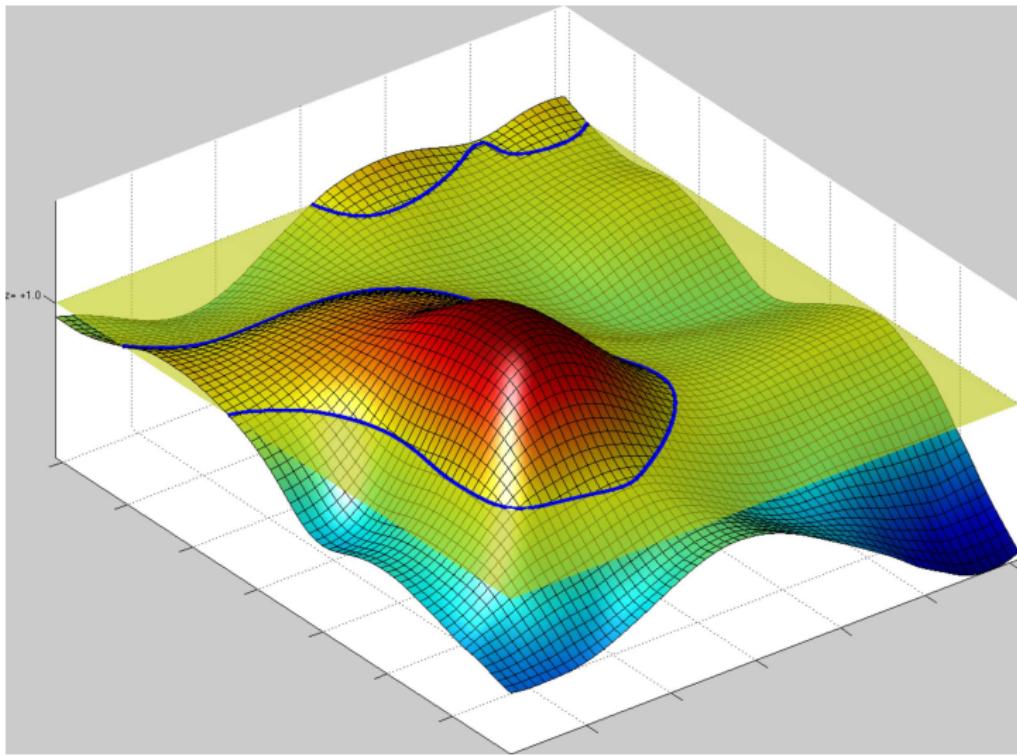
## SSH-based detection



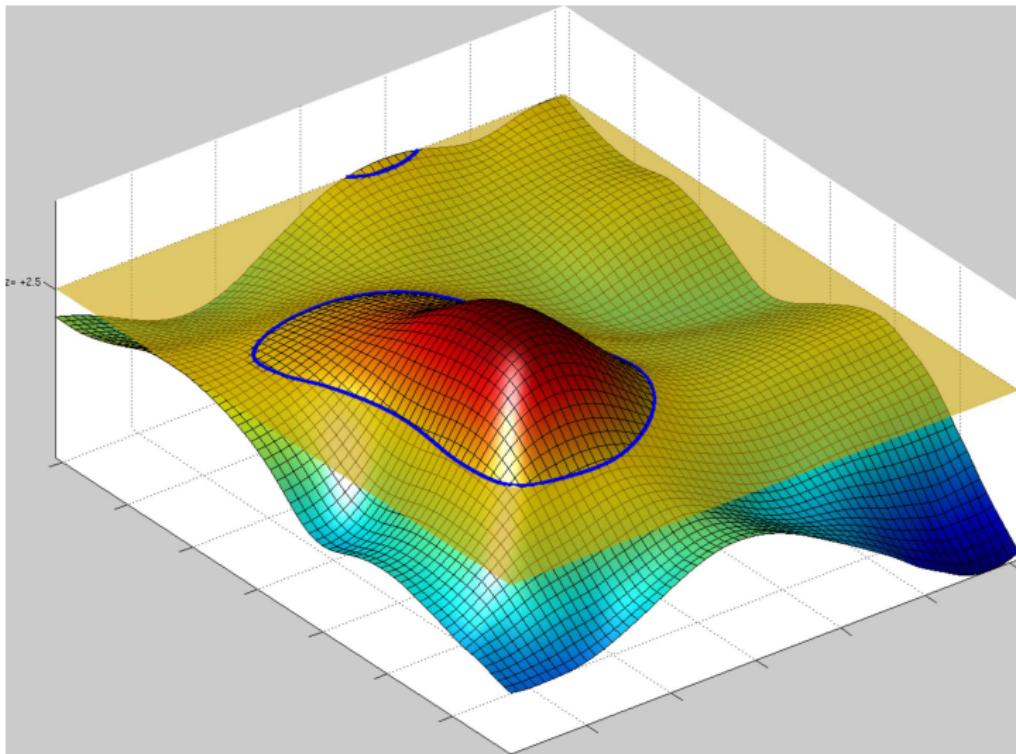
## SSH-based detection



## SSH-based detection

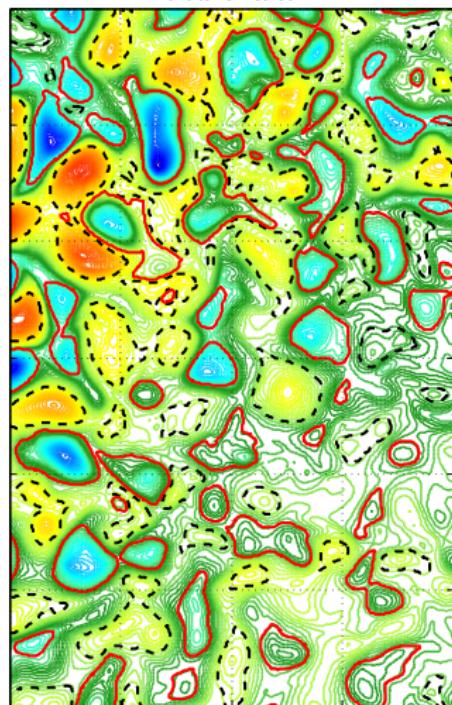


## SSH-based detection



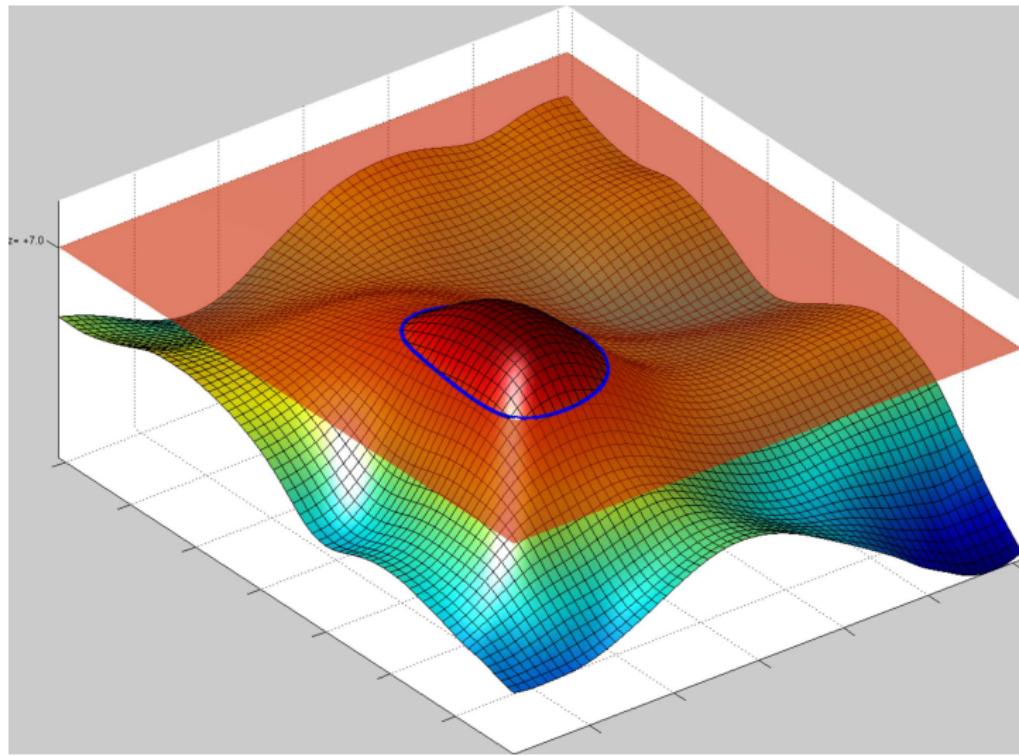
# does found contour qualify?

chelton's method



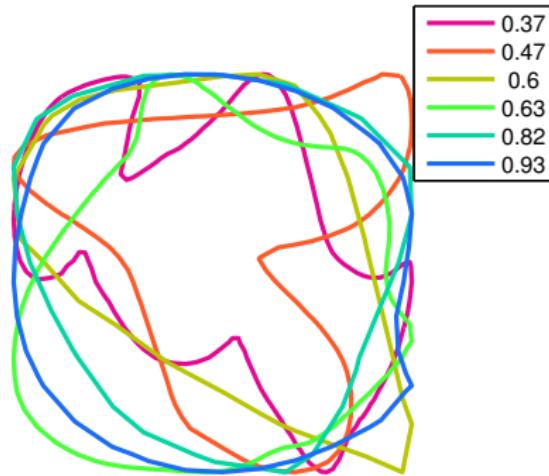
- (1) The SSH values of all of the pixels are above (below) a given SSH threshold for anticyclonic (cyclonic) eddies.
- (2) There are at least 8 pixels and fewer than 1000 pixels comprising the connected region.
- (3) There is at least one local maximum (minimum) of SSH for anticyclonic (cyclonic) eddies.
- (4) The amplitude of the eddy is at least 1 cm (see below).
- (5) The distance between any pair of points within the connected region must be less than a specified maximum.

## new approach: demand circular shapes

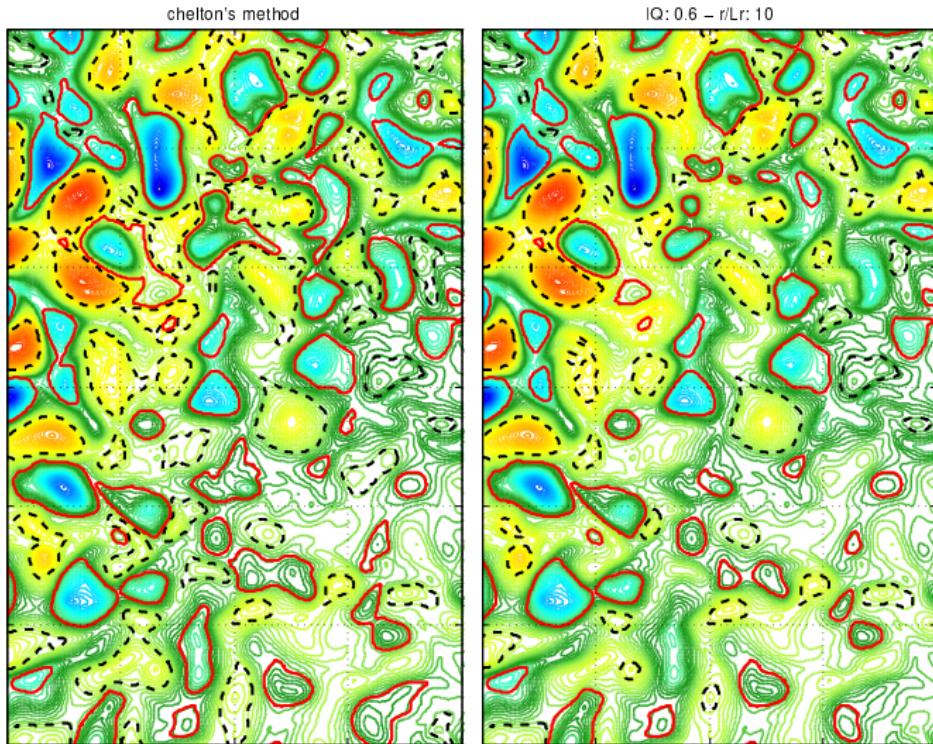


# Isoperimetric Quotient

$$IQ = A/A_c = \frac{4\pi A}{c}$$

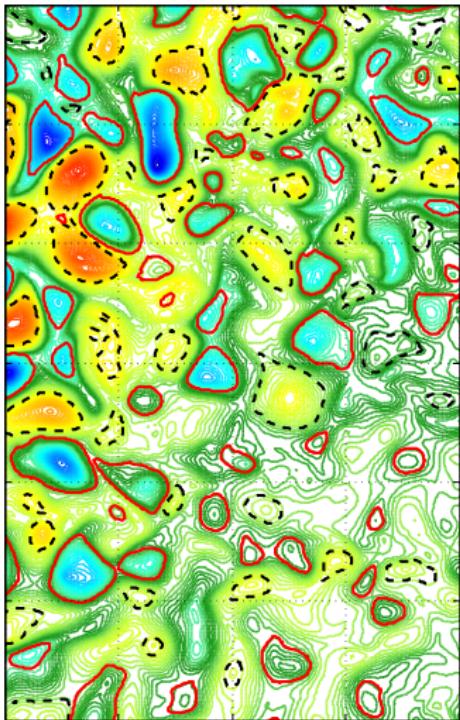


# new problem: deformed eddies get rejected

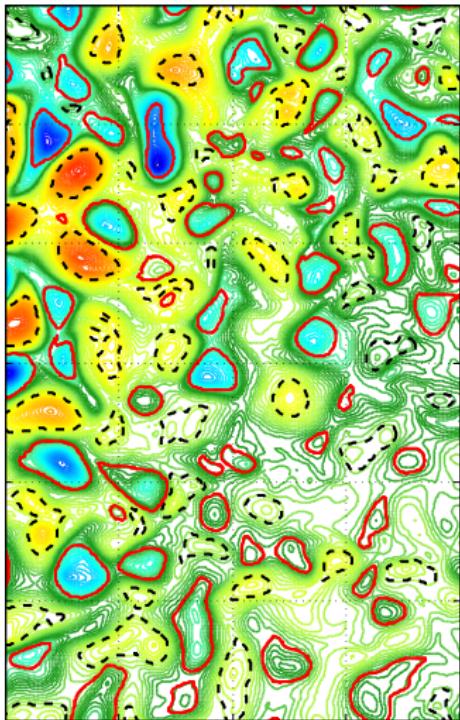


solution: allow more deformation but limit hor. scale

IQ: 0.6 –  $r/L_r$ : 10



IQ: 0.55 –  $r/L_r$ : 4



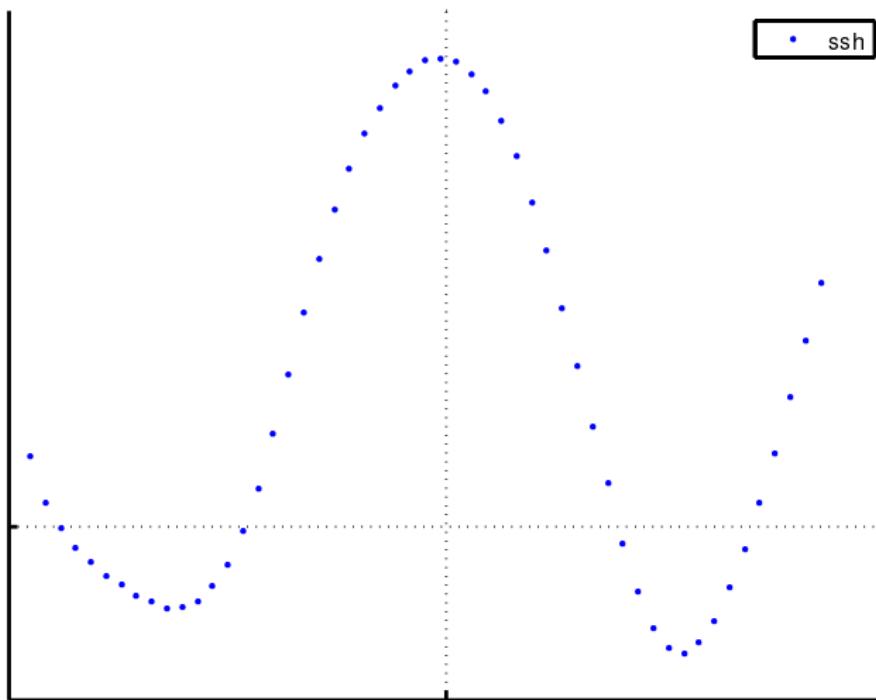
# Tracking

1. Build distance matrix  $\mathbf{D}(old, new)$  between all eddies( $t = now - dt$ ) to all eddies( $t = now$ ).
2. Flag all  $\mathbf{D}(old, new) > threshld$ .
3. Flag all not meeting a *similarity criterion* (function of scale and amplitude).
4.  $\min(\mathbf{D})$  in both directions.
  - ▶ agreement: eddy is tracked!  
→ append to respective track in running archive.
  - ▶ no new eddy agrees with old eddy: eddy just died..  
→ if age  $\geq$  threshold, write track to archive, else delete!
  - ▶ no old eddy agrees with new eddy: a new eddy was born  
→ initiate new track in running archive.

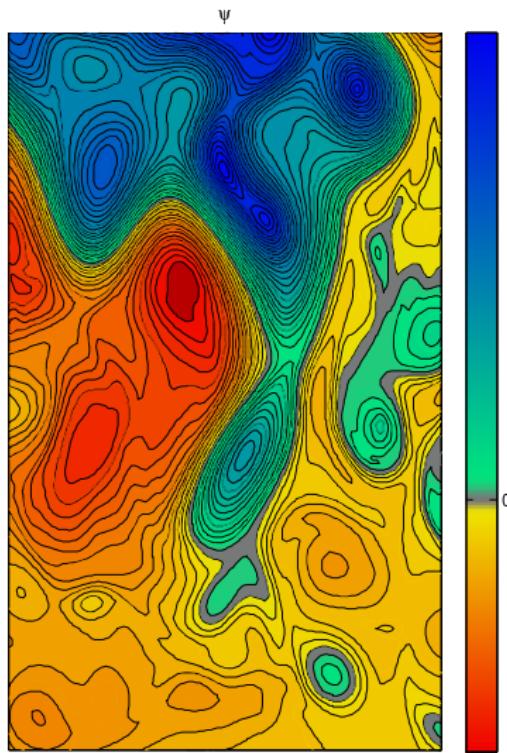
# Tracking

1. Build distance matrix  $\mathbf{D}(old, new)$  between all eddies( $t = now - dt$ ) to all eddies( $t = now$ ).
2. Flag all  $\mathbf{D}(old, new) > \text{threshld}$ .
3. Flag all not meeting a **similarity criterion (function of scale and amplitude)**.
4.  $\min(\mathbf{D})$  in both directions.
  - ▶ agreement: eddy is tracked!  
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  - ▶ no old eddy agrees with new eddy: a new eddy was born  
→ initiate new track in running archive.

# What is the scale and amplitude of an eddy ???

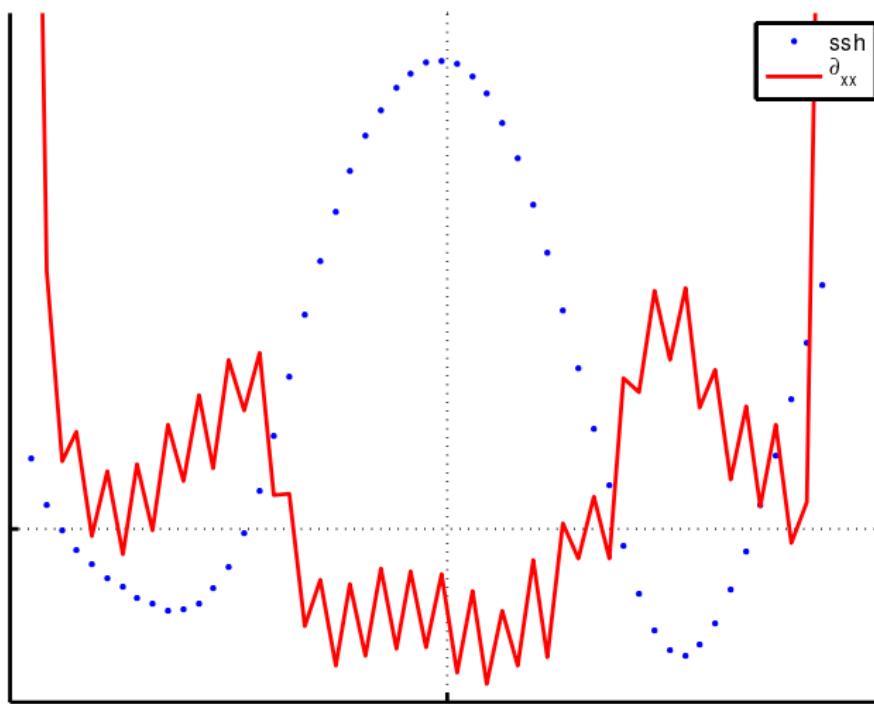


## example: meander

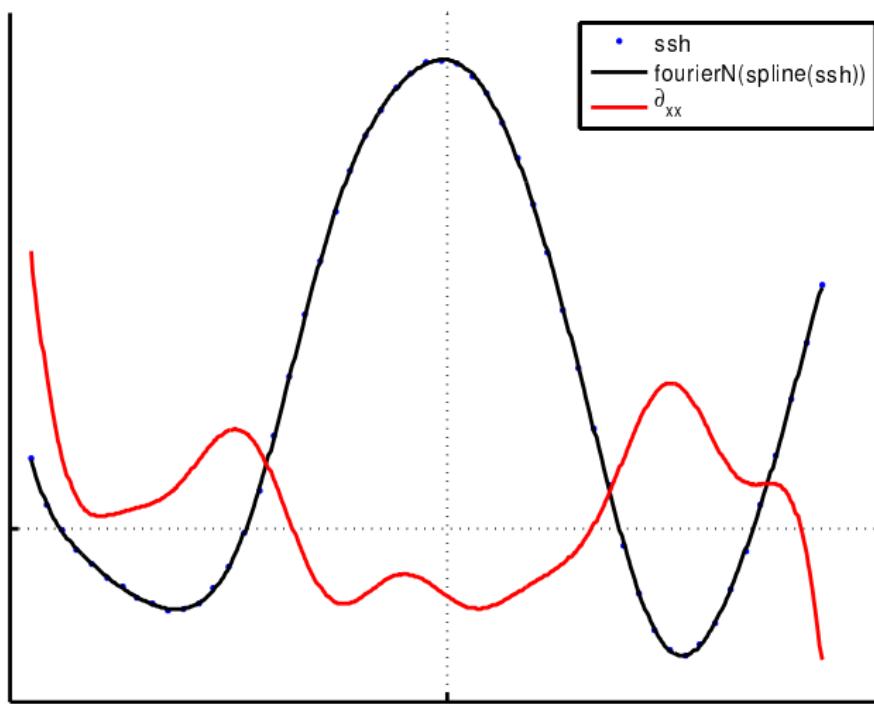


## Problem: coarse resolution

$$\partial_x \sim \mathbf{U}, \partial_{xx} \sim \omega$$

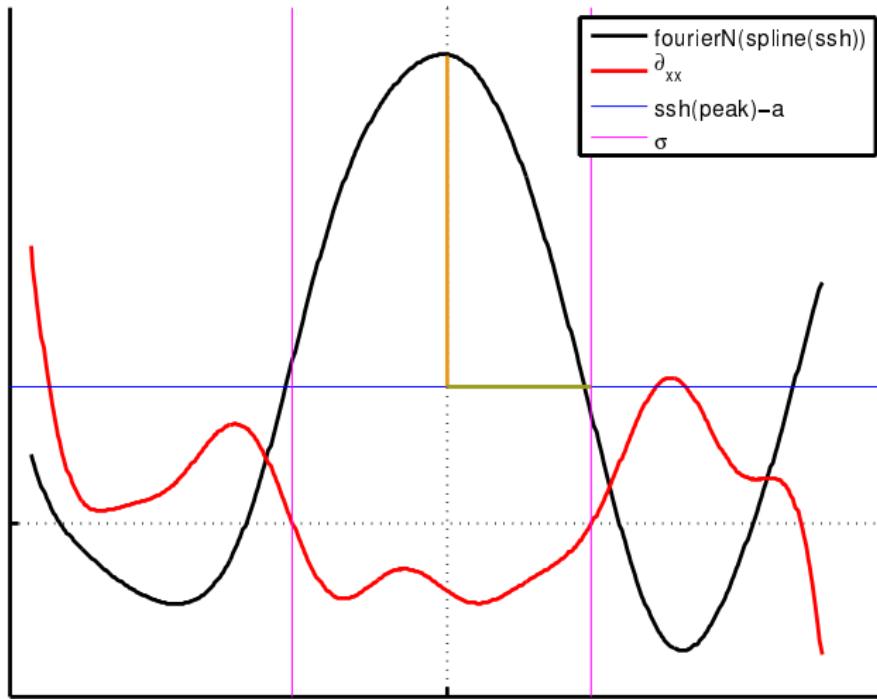


## Solution: Interpolate and use Fourier Series for differentials

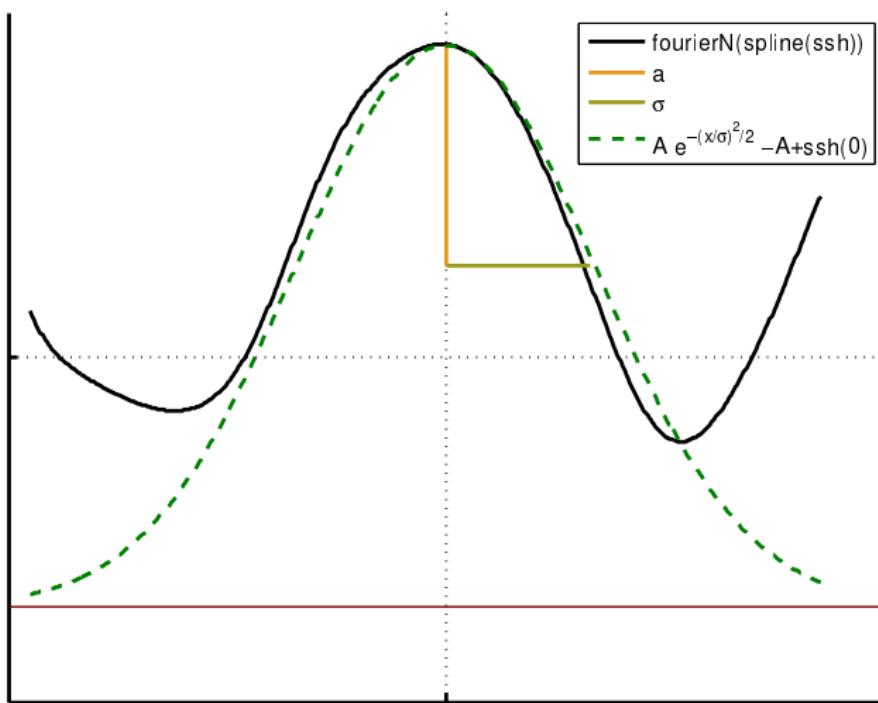


Assuming gauss shape:  $Ae^{(-x^2/2\sigma^2)}$ ;  $a = A(1 - e^{-1/2})$

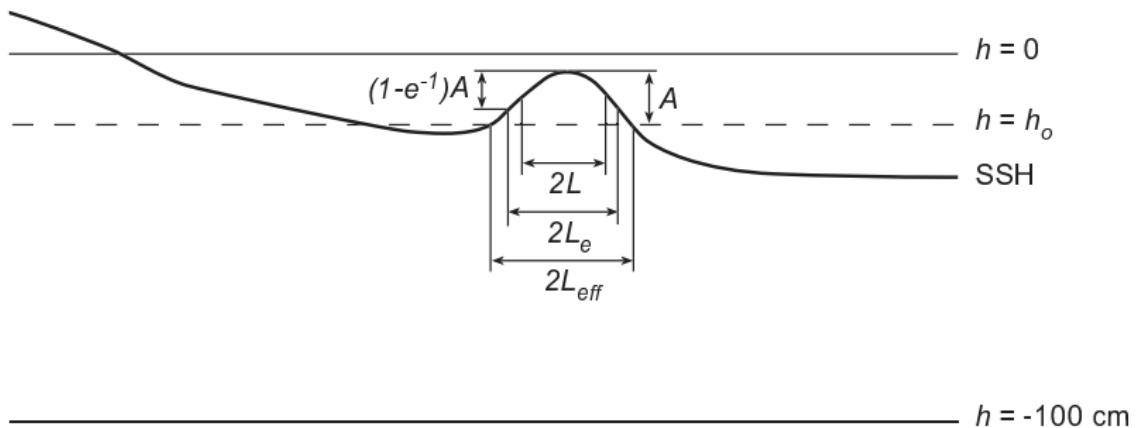
All shape-defining parameters for the *similarity criterion* are determined!



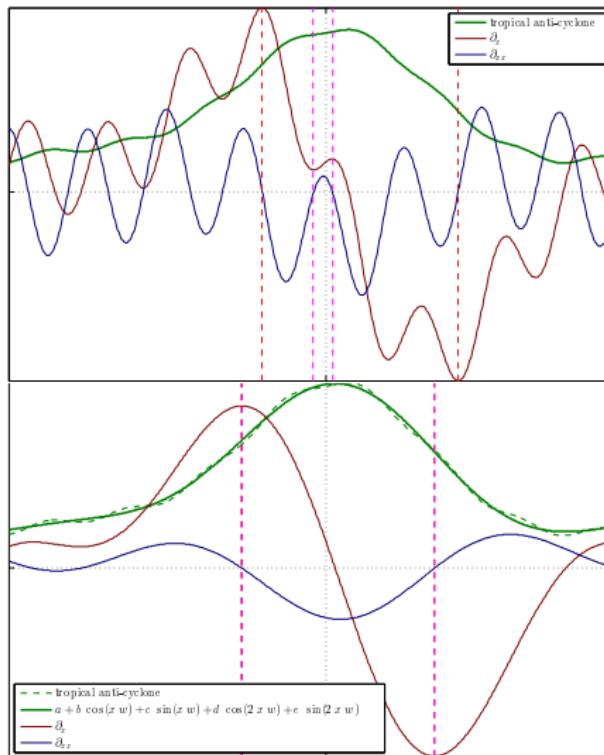
Note: Gauss shape assumption not necessary for this method.



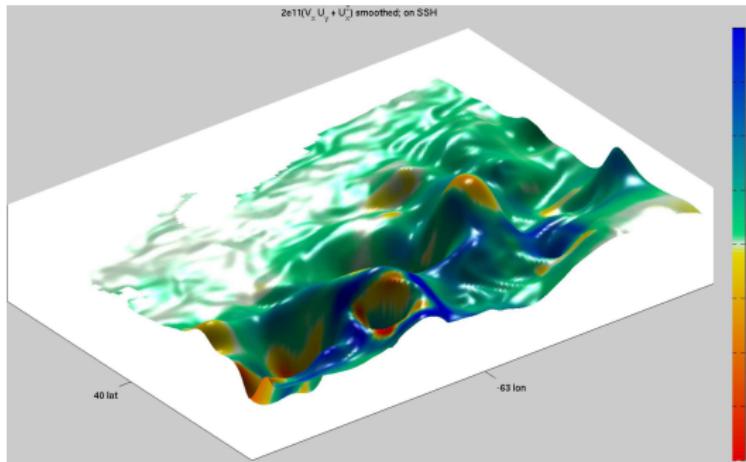
Chelton et al. define 4 different eddy scales.



## problematic: broad flat *wobbly* eddies



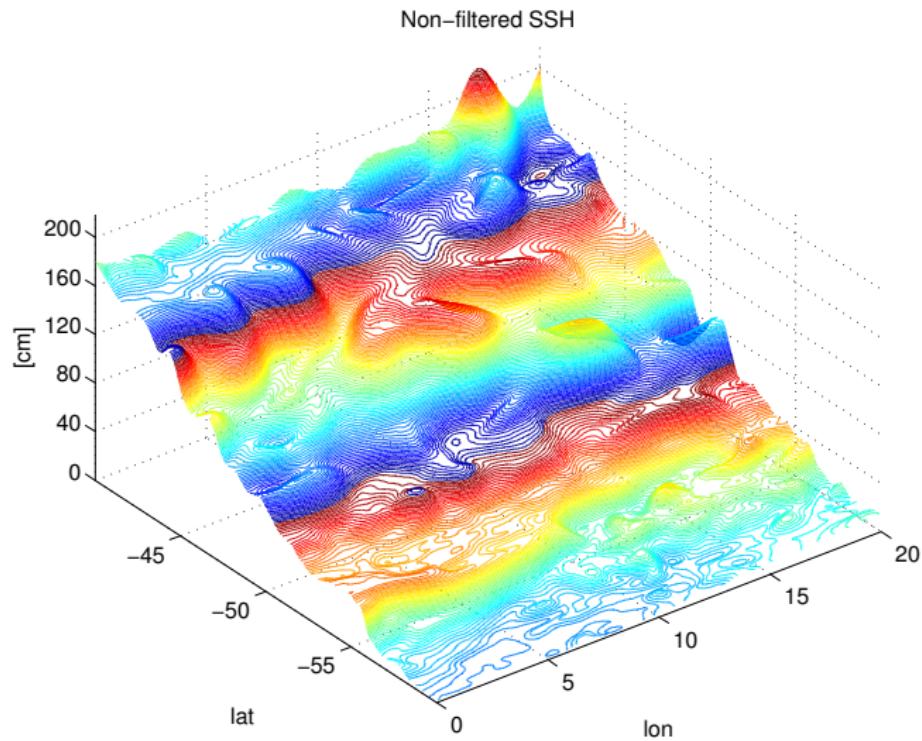
# Okubo-Weiss



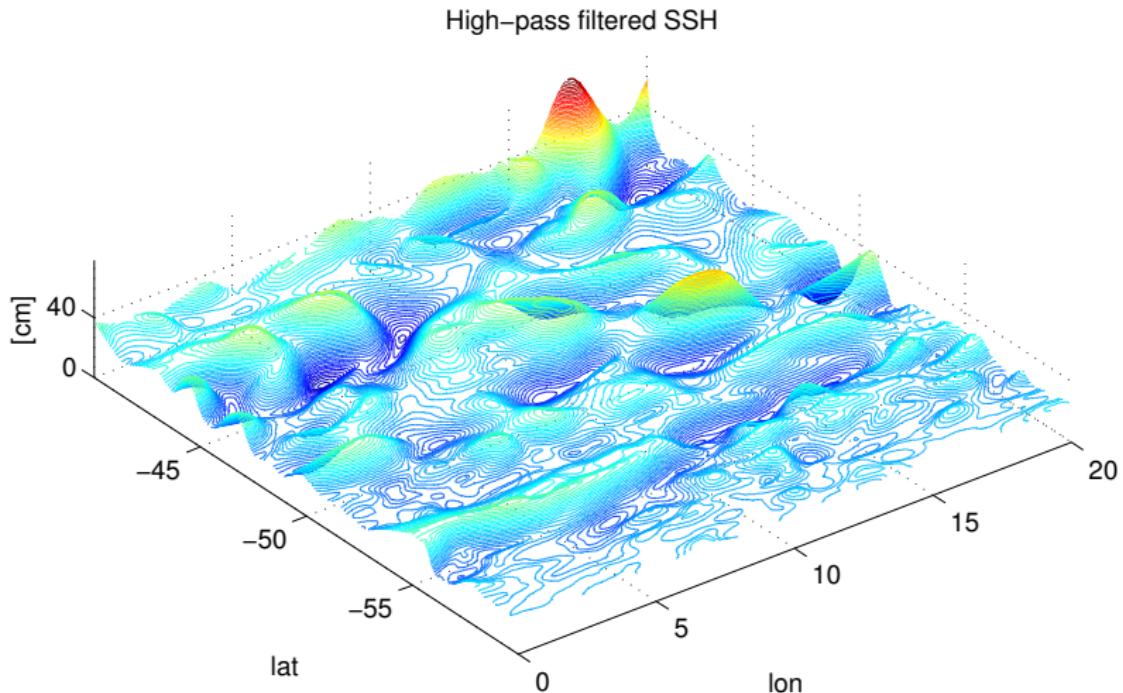
use eigenvalues of 2d deformation tensor to detect vortex:

$$\det(\lambda \mathbf{I} - \nabla \mathbf{u}) = 0$$
$$\lambda^2 = OW/2 = 2u_x^2 + v_x u_y$$

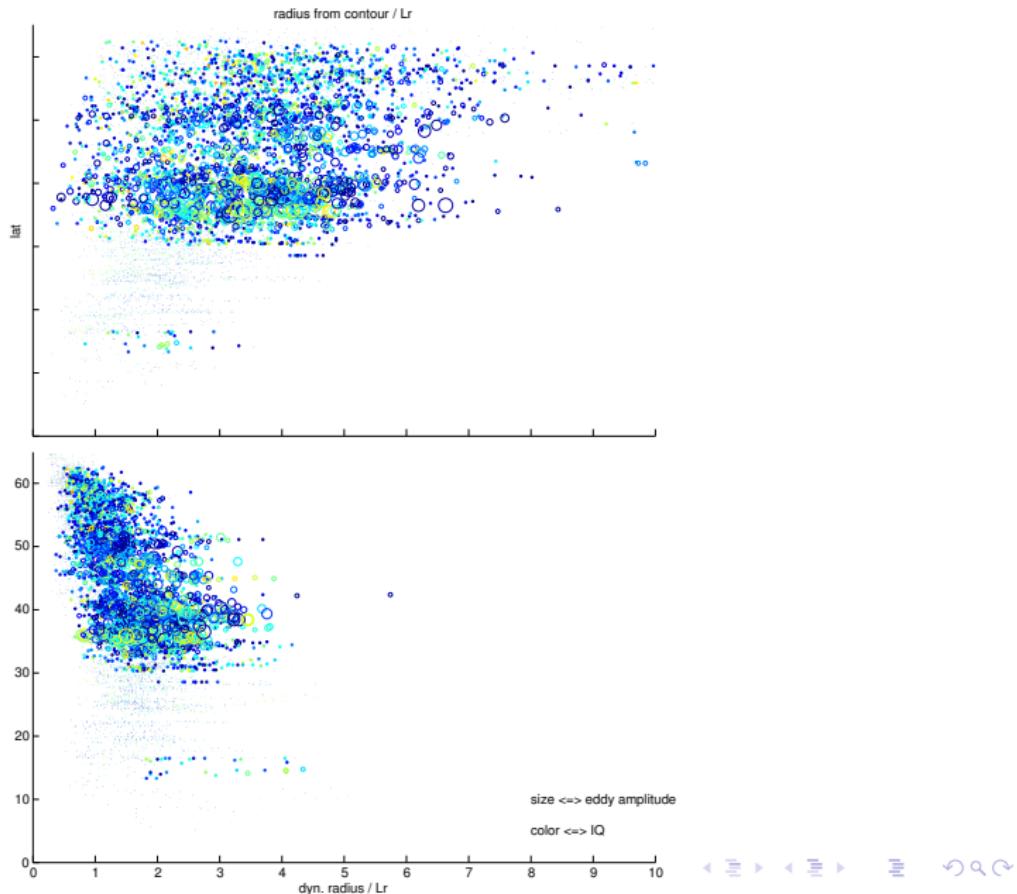
# Removing larger scale signals important for Chelton's method.

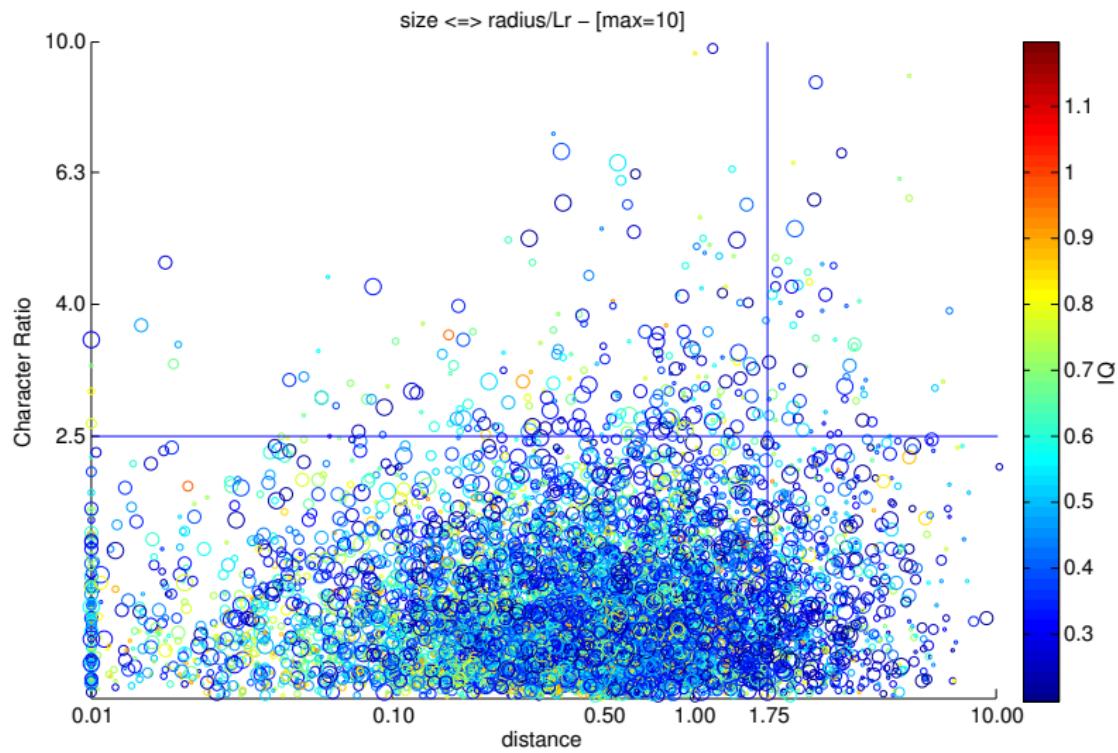


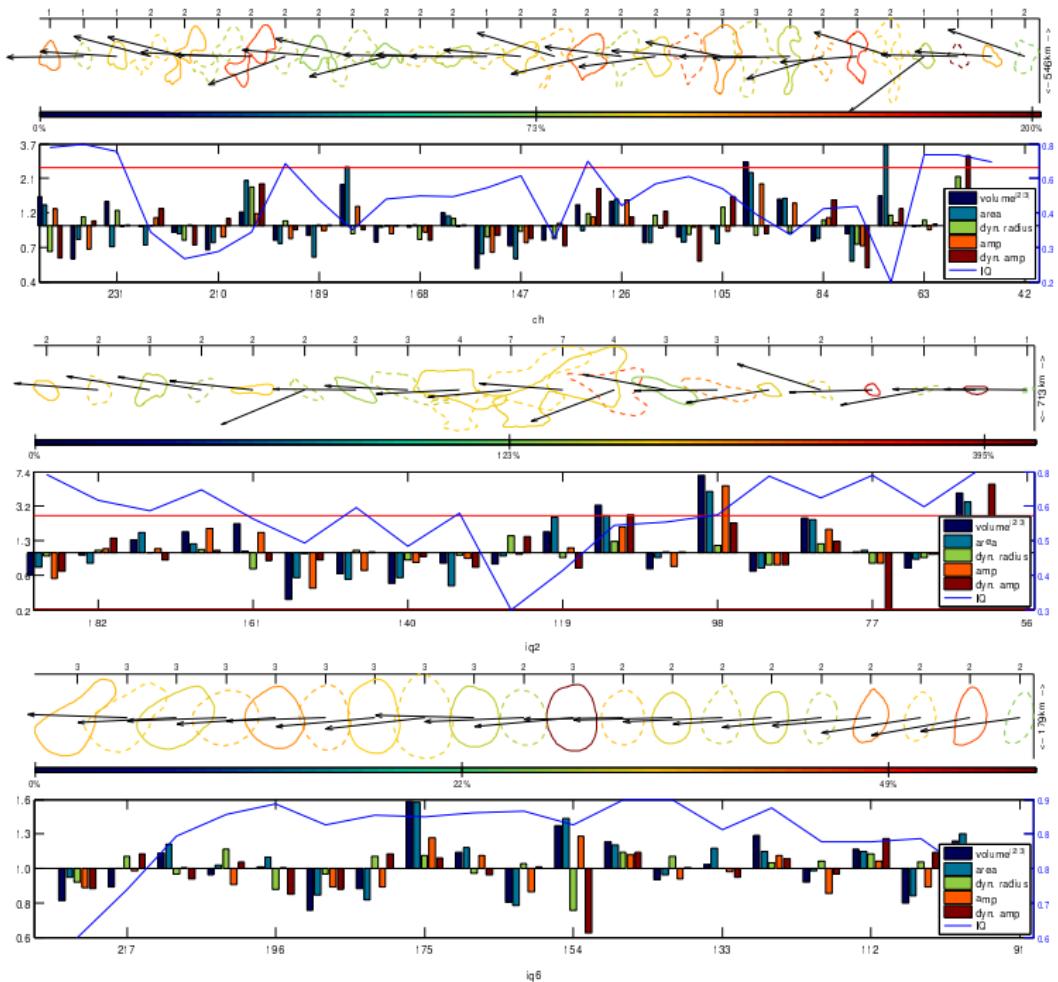
## easiest: subtract annual mean

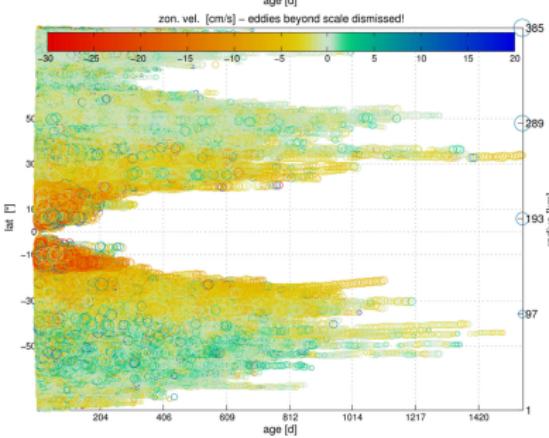
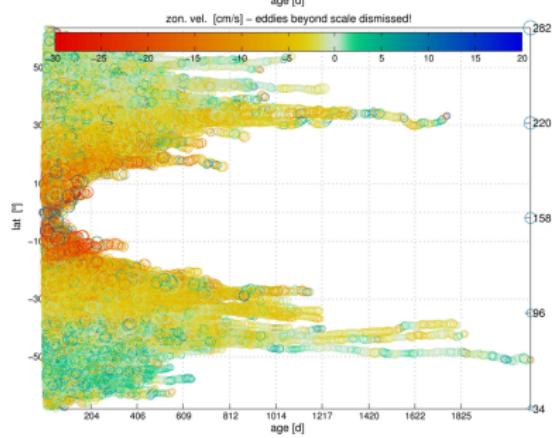
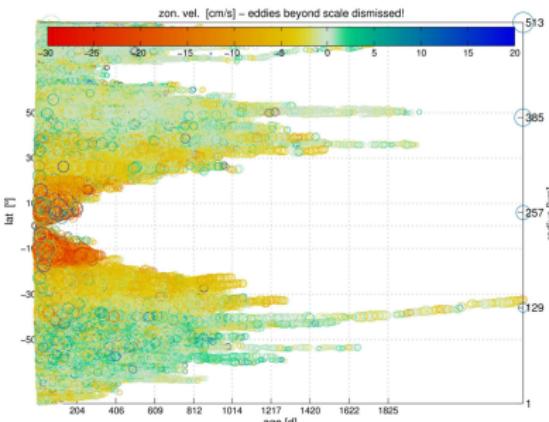
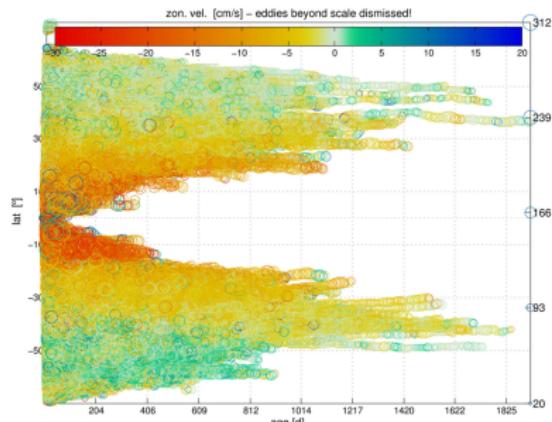


## finding a suitable scale threshold

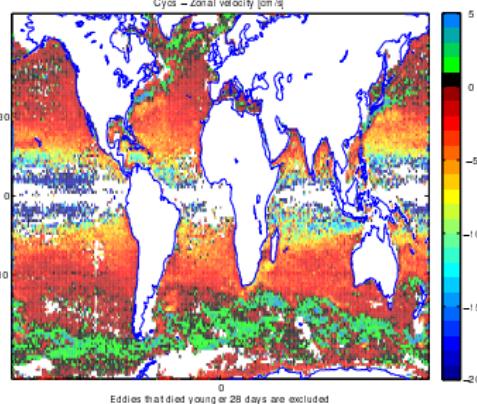
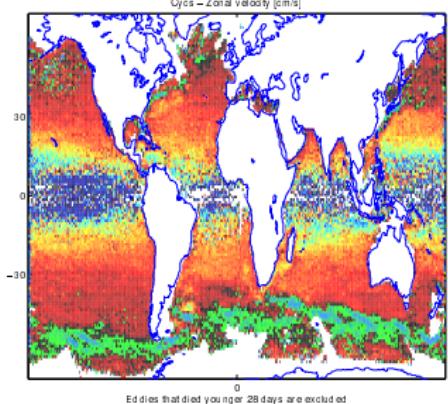
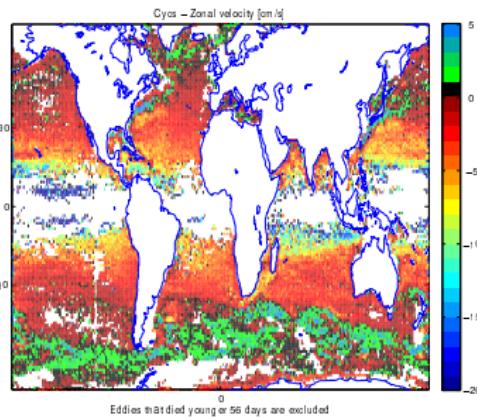
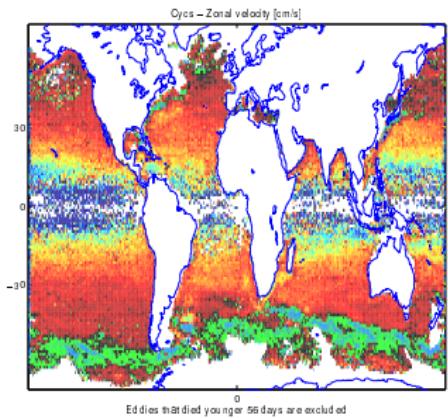


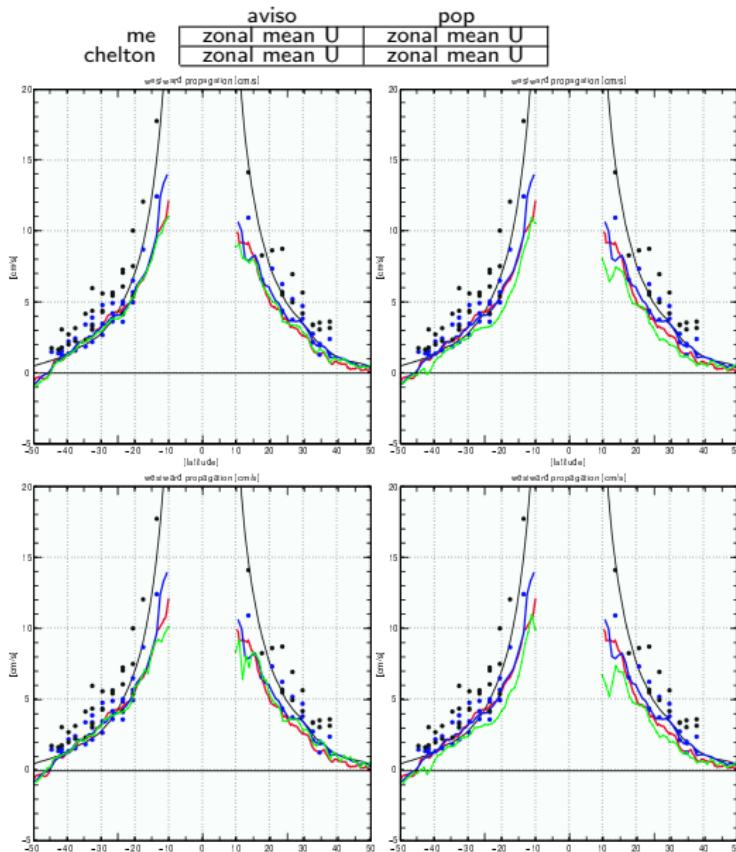






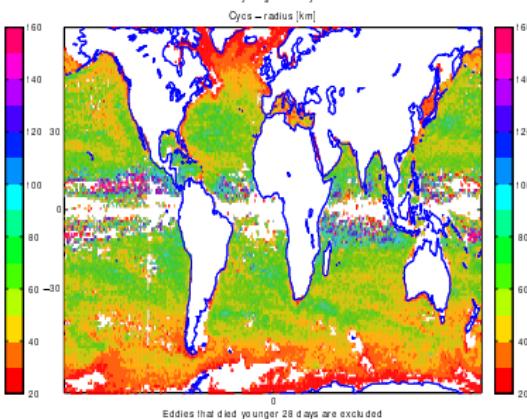
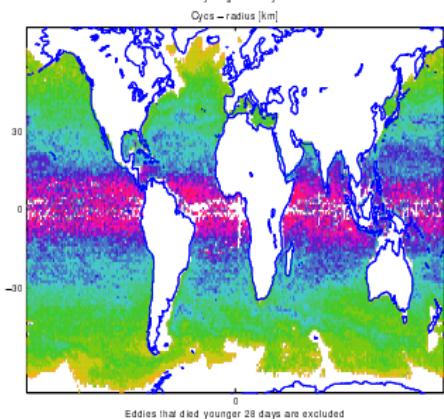
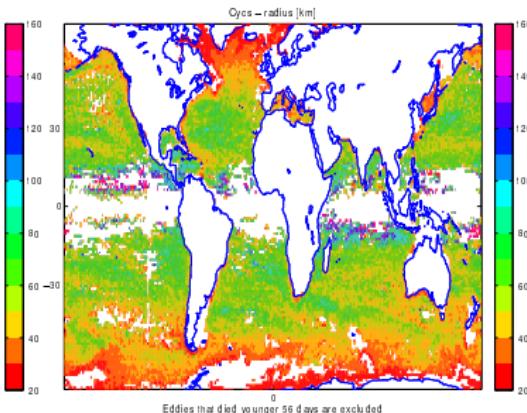
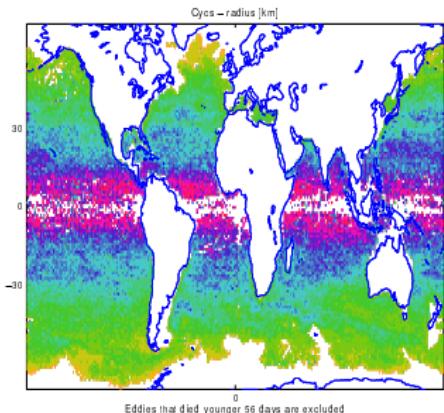
me	aviso	pop
chelton	U	U



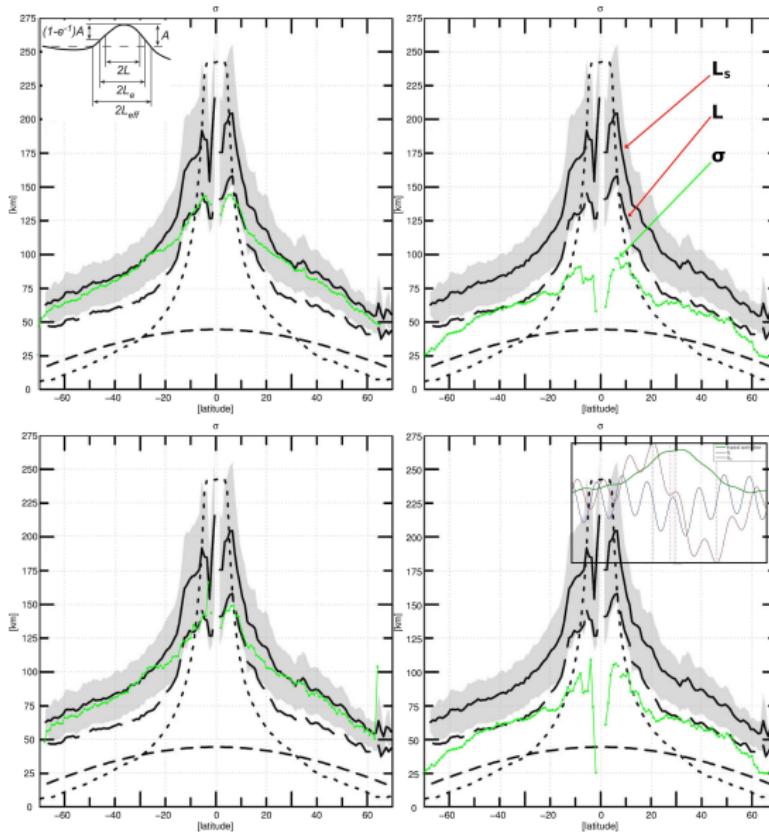


**Figure:** black dots: Radon transforms of  $20 \times 10$  high-pass filtered SSHelds along the 45 zonal sections. Red dots: means of  $U$  along those sections (age  $\geq 16$  weeks). red line: zonalmean( $U$ ). blue line: space-time-lagged cross-correlation (Fu 2009).

	me	aviso	pop
chelton	$\sigma$	$\sigma$	$\sigma$
	$\sigma$	$\sigma$	$\sigma$



		aviso	pop
me	zonal mean $\sigma$	zonal mean $\sigma$	
chelton	zonal mean $\sigma$	zonal mean $\sigma$	

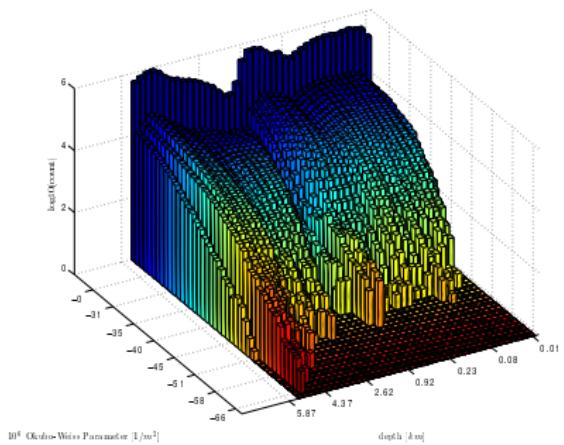
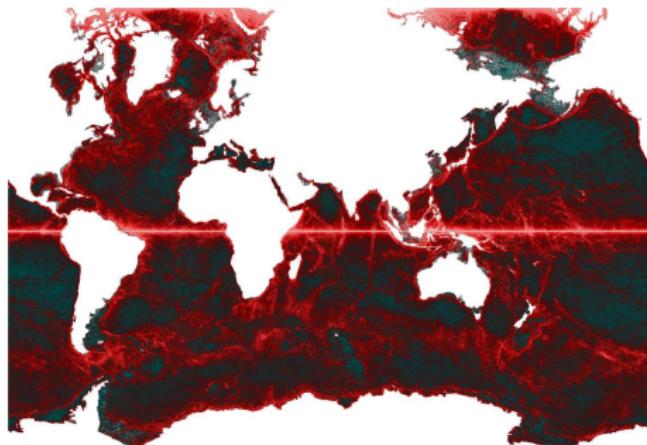


# to-do-matrix

	pop	aviso	comparison
U	[3]	[1, 2]	[3]
scale	[3]	[1, 2]	[3]
method Chelton	N	[1], N	N
method $R^2$	[3]	n/a	n/a
method OW	[3]	[2]	[3]
method IQ	N	N	N
net U	N	N	N
steering level	N	n/a	n/a
$p(z)$	N	n/a	n/a
$f/H$	N		
remap pop2avi			
drop buoys into eddies			
go 3d			

- [1] CHELTON, D. B., SCHLAX, M. G., AND SAMELSON, R. M. Global observations of nonlinear mesoscale eddies. *Prog. Oceanogr.* 91, 2 (Oct. 2011), 167–216.
- [2] CHELTON, D. B., SCHLAX, M. G., SAMELSON, R. M., AND DE SZOKE, R. A. Global observations of large oceanic eddies. *Geophys. Res. Lett.* 34, 15 (Aug. 2007), L15606.
- [3] PETERSEN, M. R., WILLIAMS, S. J., MALTRUD, M. E., HECHT, M. W., AND HAMANN, B. A three-dimensional eddy census of a high-resolution global ocean simulation. *J. Geophys. Res. Ocean.* 118, 4 (Apr. 2013), 1759–1774.

# Which depth to take mean current from?



14-Oct-1913

