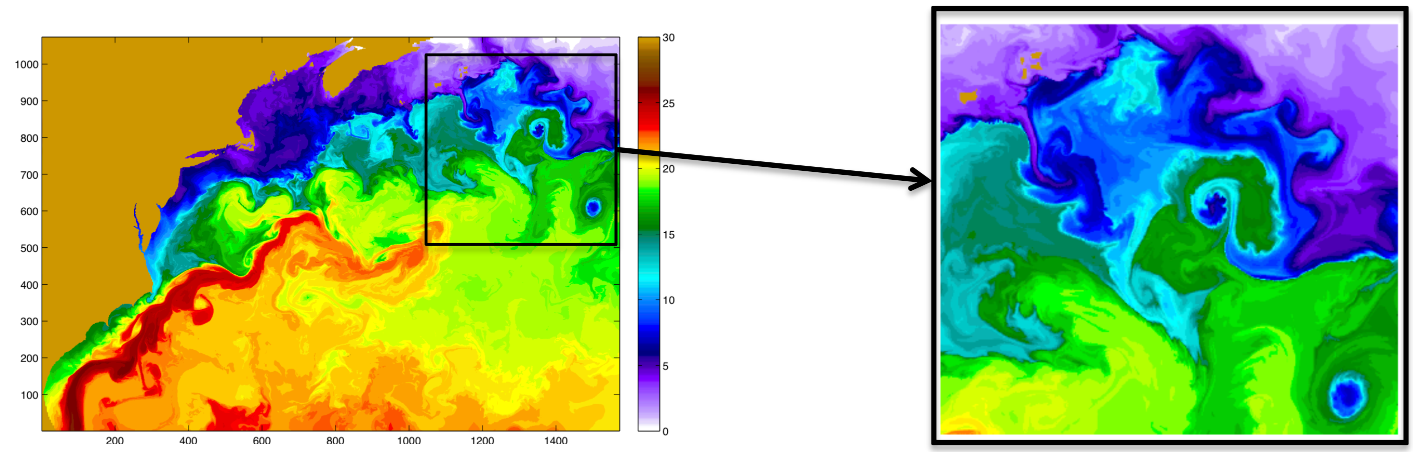
Submesoscale relative dispersion and Lagrangian parameterization

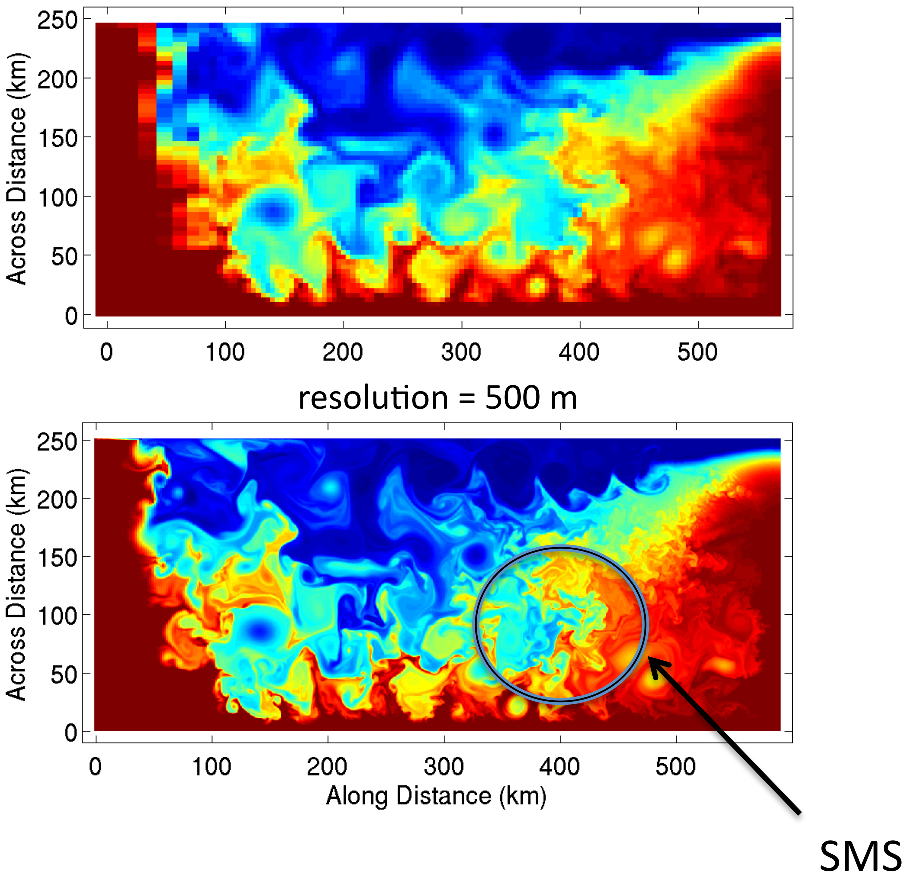
As the model resolution increases from mesoscale eddy-permitting to finer scale features , submesoscale filaments and eddies act to enhance particle pair separation at their scale range, affecting the rates of dispersion up to the radius of deformation.



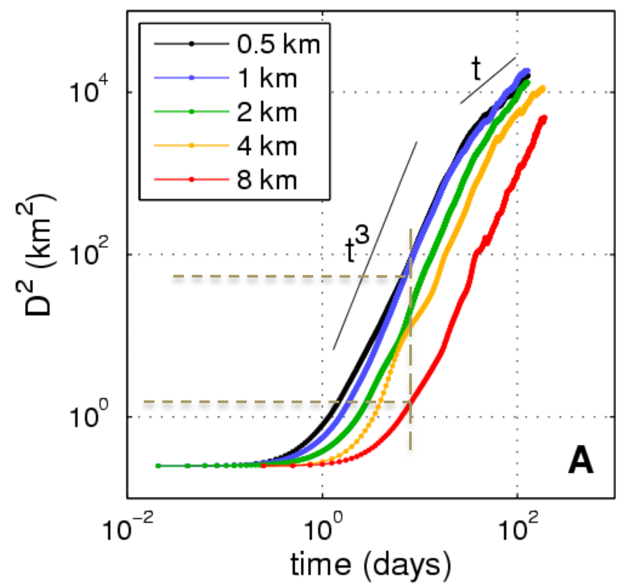
The use of dynamical system methods to compute submesoscale LCS, however, requires much more extensive data sets and high resolution accurate computations to provide further insight into complex rapidly-evolving submesoscale flows.

Statistical methods such as Lagrangian subgridscale (LSGS) models appear more suitable to represent the net effect of particle transport at the submesoscales.

Baroclinic jet (ROMS), resolution = 4 km



Relative dispersion for different resolutions:



Submesoscale dispersion is *most often underestimated in coastal and ocean models*, leading to delays in dispersion coverage and how fast particles separate from one another in the early stages of a dispersion event.

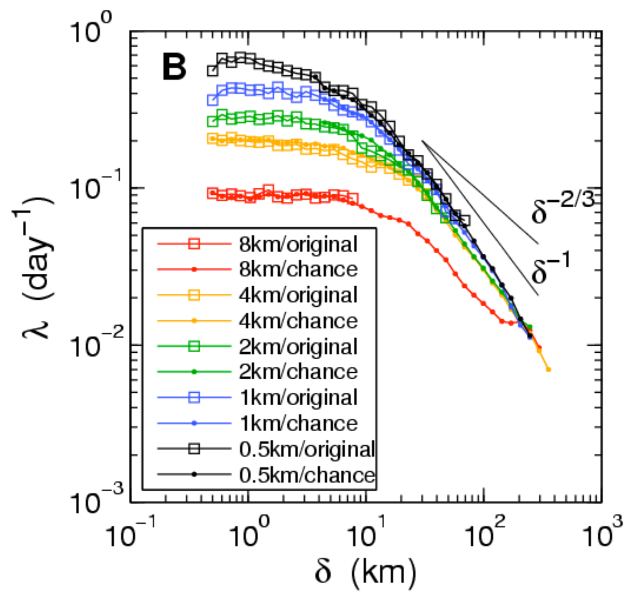
We aim to enhance the unrealistically low-strain level at the submesoscale range with statistical Lagrangian subgridscale (LSGS) parameterizations, while the mesoscale LCS are computed deterministically in OGCMs.

More specifically: Correct the relative dispersion at each spatial scale, based on the *scale-dependent Finite Scale Lyapunov Exponent ($\lambda(\delta)$)*.

$$\lambda(\delta) = \frac{ln(\alpha)}{< \tau(\delta) >}$$

(< τ > = averaged time for all particle pairs to separate from distances **δ** to **αδ**)

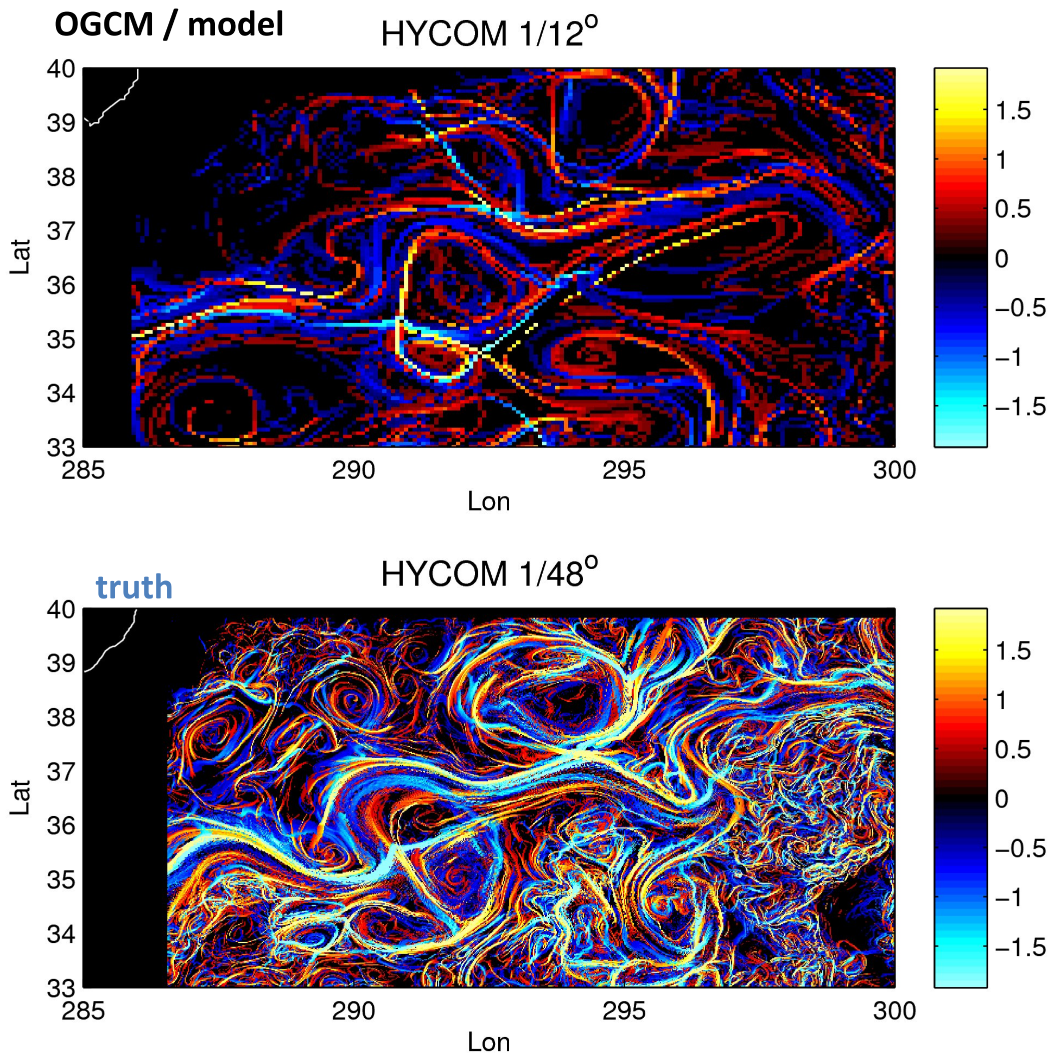
Model scale-dependent FSLE:



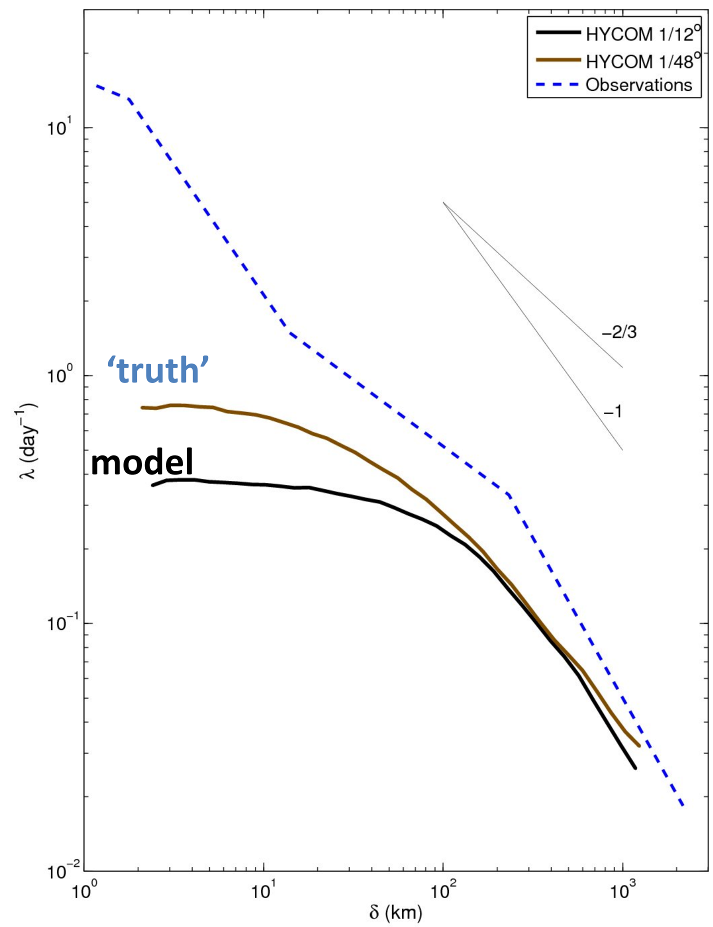
- change/improve the spurious exponential regime at the small scales.
- Preserve the mesoscale transport pathways by controlling the addition of diffusion.

Parameterization setting (Gulf Stream)

local FSLE:



Scale-dependent FSLE



(Ocean Modelling, 42 (2012) 31-49)

Lagrangian stochastic model 1: Random walk (Markov-0)

Flow decomposition:

Mean flow: $U_M(x,t) = U_{OGCM}(x,t)$.

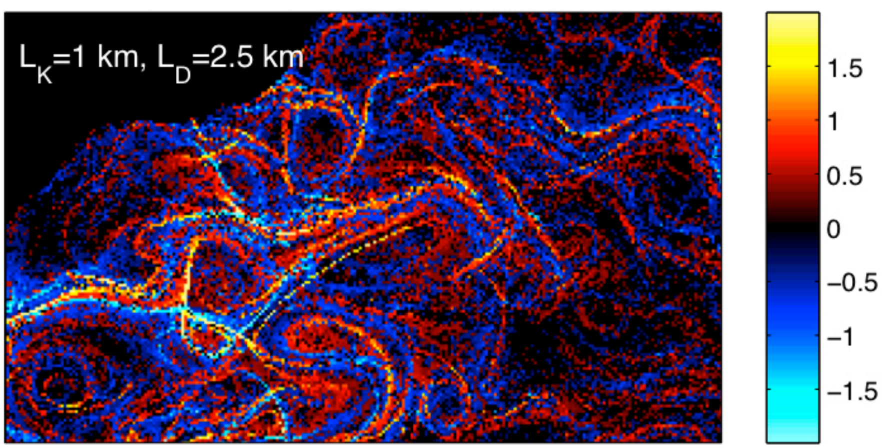
Turbulent flow: Random walk for two-particle motion:

$$dx_1 = L_K\, dw_{0A} \quad \text{and} \quad dx_2 = \mathcal{D}\, dx_1 + (1-\mathcal{D}) L_K\, dw_{0B}$$

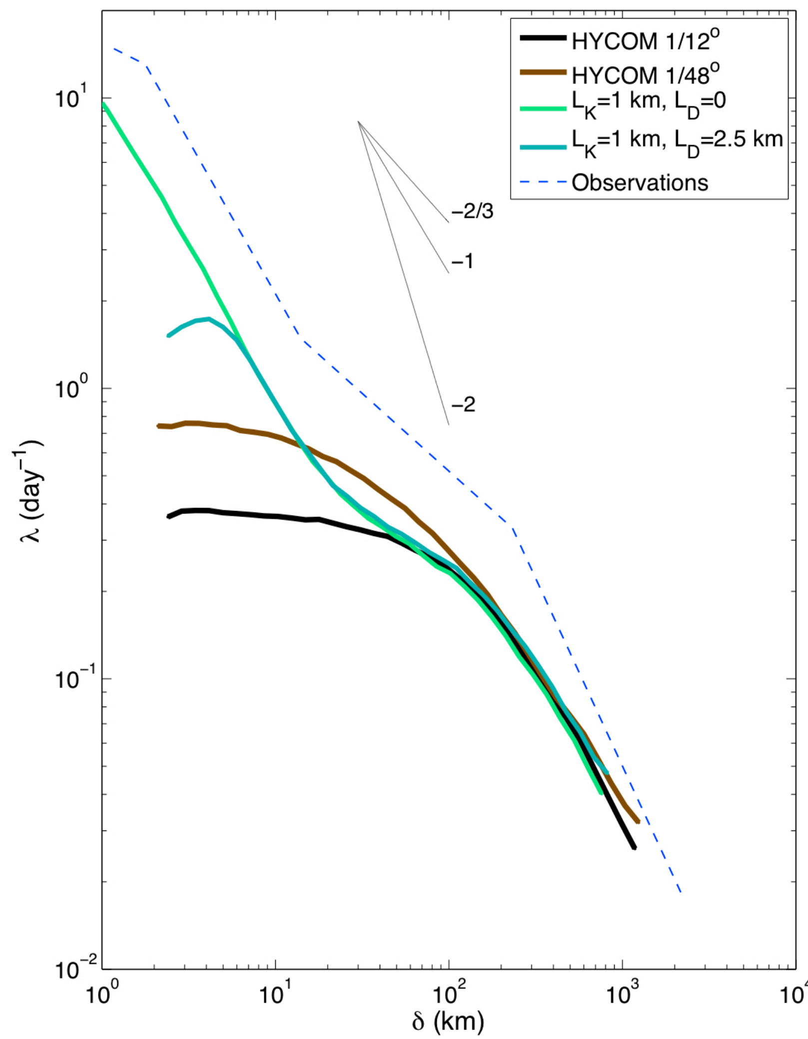
$\mathbf{L_K}$ = σ.dt, = std random displacement during 1 time-step ~ 10% Gulf Stream velocity scale

$$\mathcal{D} = \exp\left(-\frac{\delta^2}{2L_{\mathcal{D}}^2}\right)$$

L_D = space correlation scale.



Scale-dependent FSLE



Lagrangian stochastic model 2: IMC (Markov-1)

Flow decomposition:

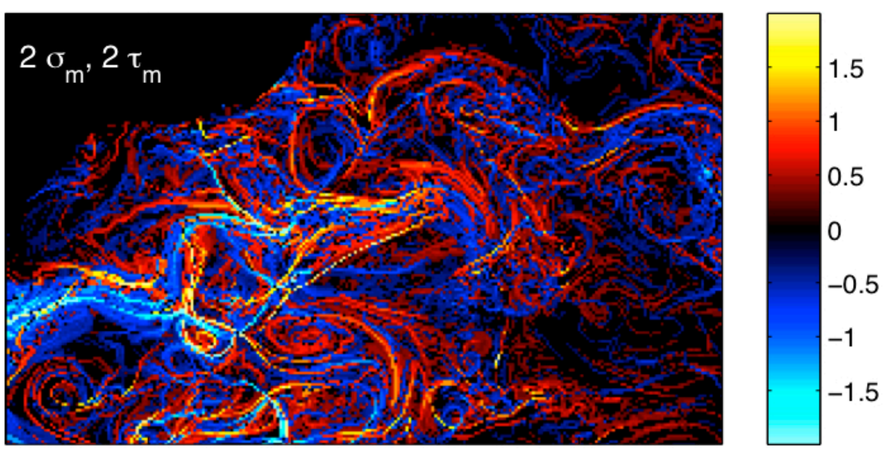
Mean flow: $U_M(x,t)$ = <$U_{OGCM}(x,t)$> low-passed (T=20 days).

Turbulent flow: $u'_c(x,t) = u_{OGCM}(x,t) - U_M(x,t) + \eta(t)$

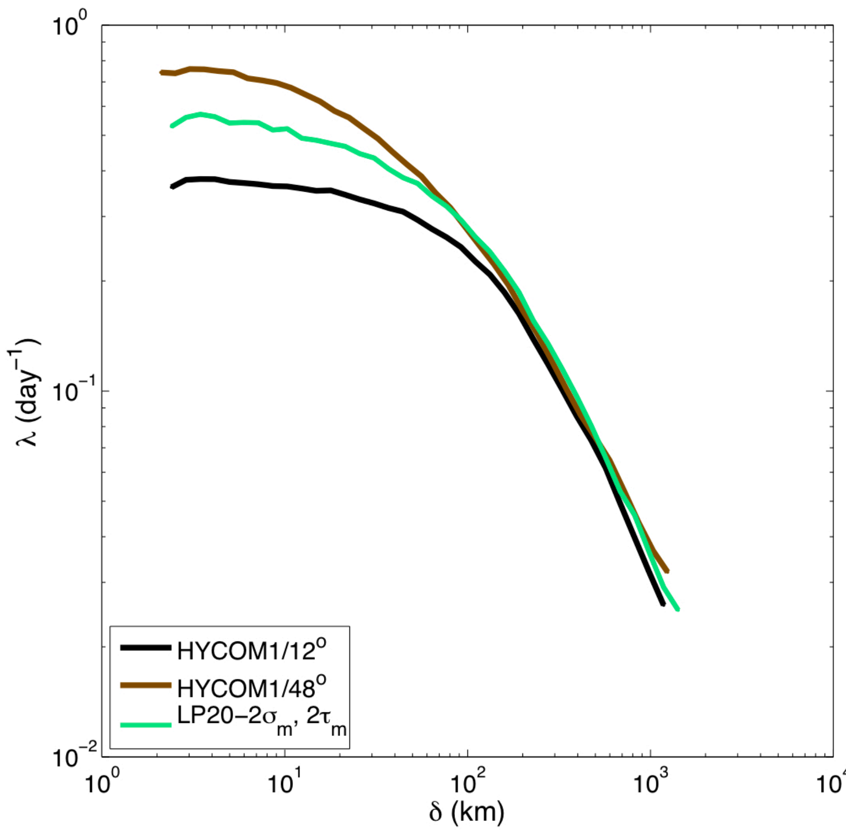
$\mathbf{u}'_c = \mathbf{u}'_m + \boldsymbol{\eta}$ = corrected turbulent velocity

$$\frac{d\eta(t)}{dt} = a\frac{du'_m(t,\mathbf{r}_c(t))}{dt} + bu'_m(t,\mathbf{r}_c(t)) + c\eta(t)$$

$$a = \frac{\sigma_r\sqrt{\tau_m}}{\sigma_m\sqrt{\tau_r}} - 1, \quad b = \frac{\sigma_r}{\sigma_m\sqrt{\tau_r\tau_m}} - \frac{1}{\tau_r}, \quad c = -\frac{1}{\tau_r}$$



Scale-dependent FSLE



➔ *turbulent fluctuations are added selectively to regions of high stretching rate.*

- ➢ Classic LSGS models appear to *overestimate the small scale* (<10km) relative dispersion and *underestimate the intermediate scale* (around the baroclinic radius of deformation) relative dispersion.
- ➢ The new LSGS model (IMC) *injects submesoscale turbulence selectively* and less randomly, which allows for a *more realistic scale-dependent relative dispersion*.