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## Randomized fluid dynamics based on subgrid transport

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# Randomized fluid dynamics based on subgrid transport

Valentin Resseguier,  
Etienne Mémin,  
Bertrand Chapron

# Motivations

- Rigorously identified subgrid dynamics effects
- Injecting likely small-scale dynamics
- Predicting possible distinct scenarios
- Quantification of modeling errors:
  - Diagnose to design numerical simulations (mesh refinements, ...)
  - **Data assimilation: ensemble forecasts**

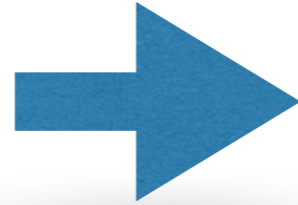
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- Randomized dynamics
- SQG under Moderate Uncertainty

# Randomized dynamics

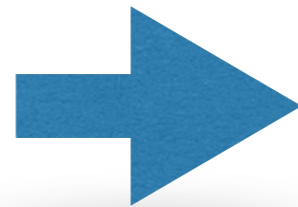
# Random equations

- Random initial conditions



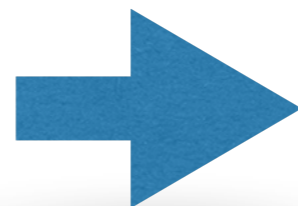
Underdispersive

- Arbitrary Gaussian forcing



Adding energy  
+ wrong phase

- Averaging, homogenization



Previous talk

- Adding white  
random velocity

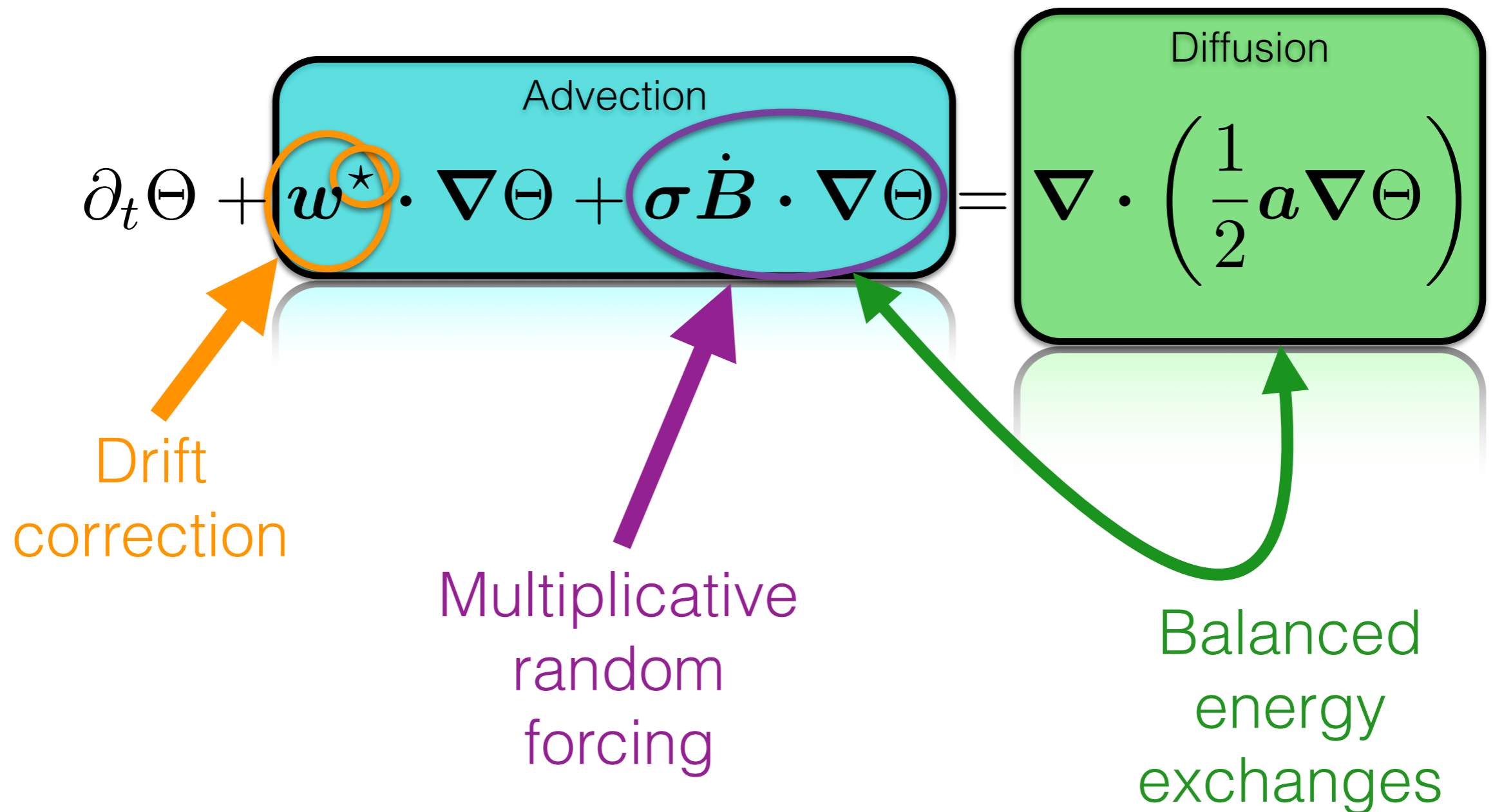


$$\boldsymbol{v} = \boldsymbol{w} + \sigma \dot{\boldsymbol{B}}$$

Advection of tracer  $\Theta$

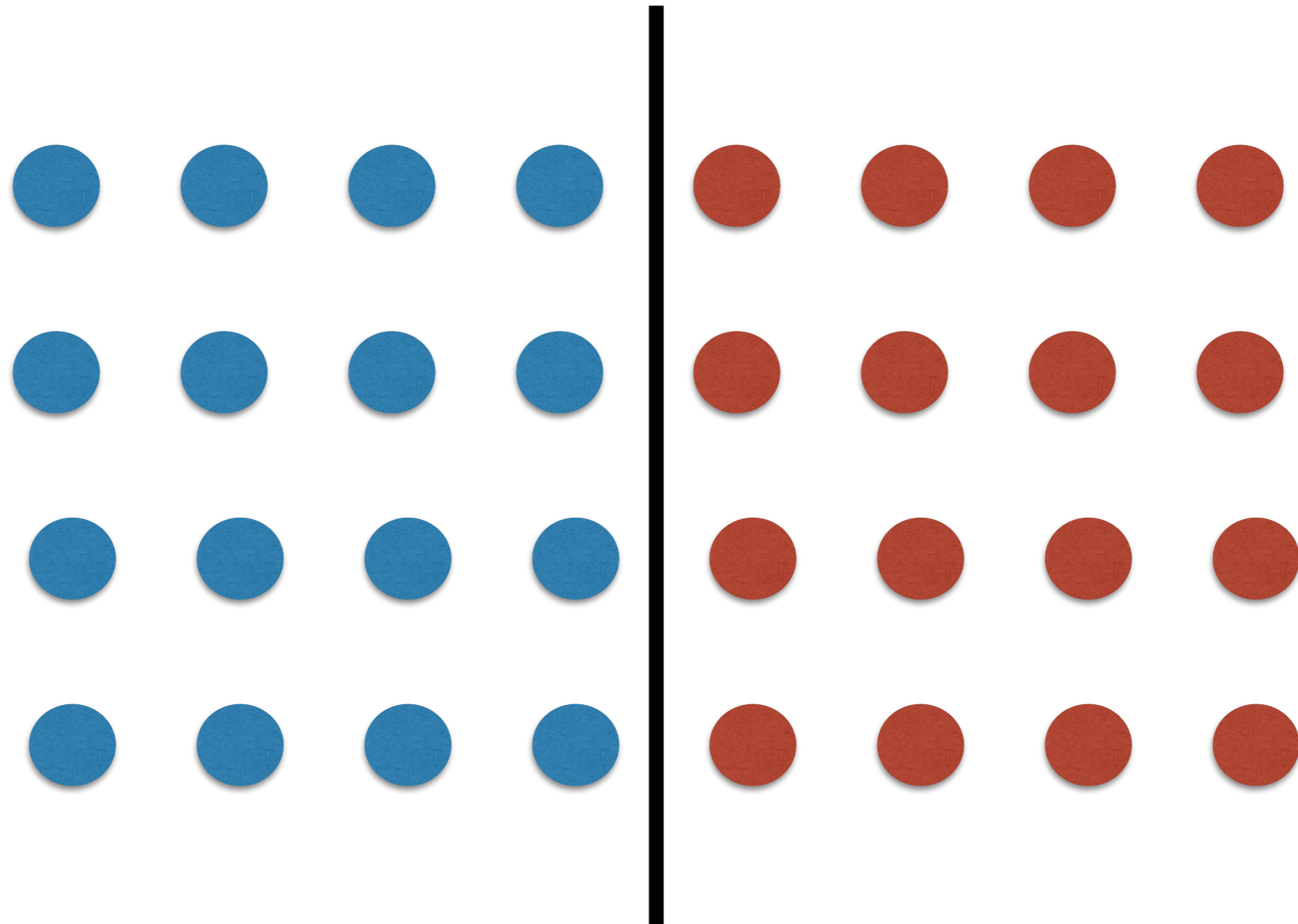
$$\frac{D\Theta}{Dt} = 0$$

# Advection of tracer $\Theta$



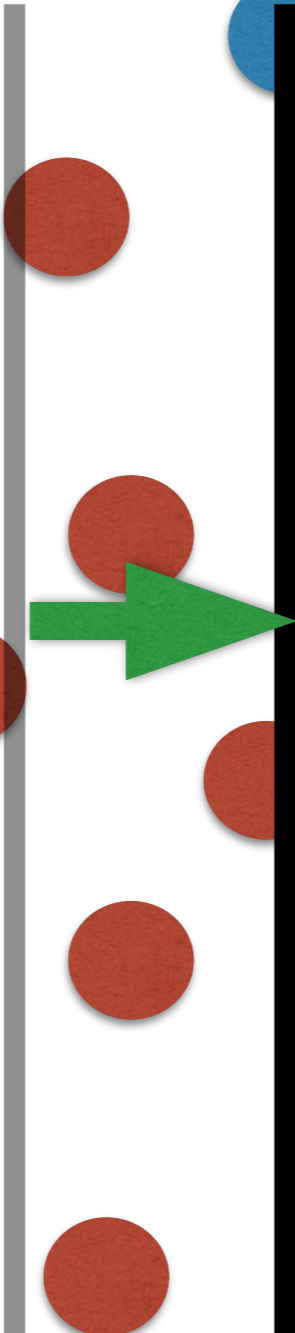


# Drift correction

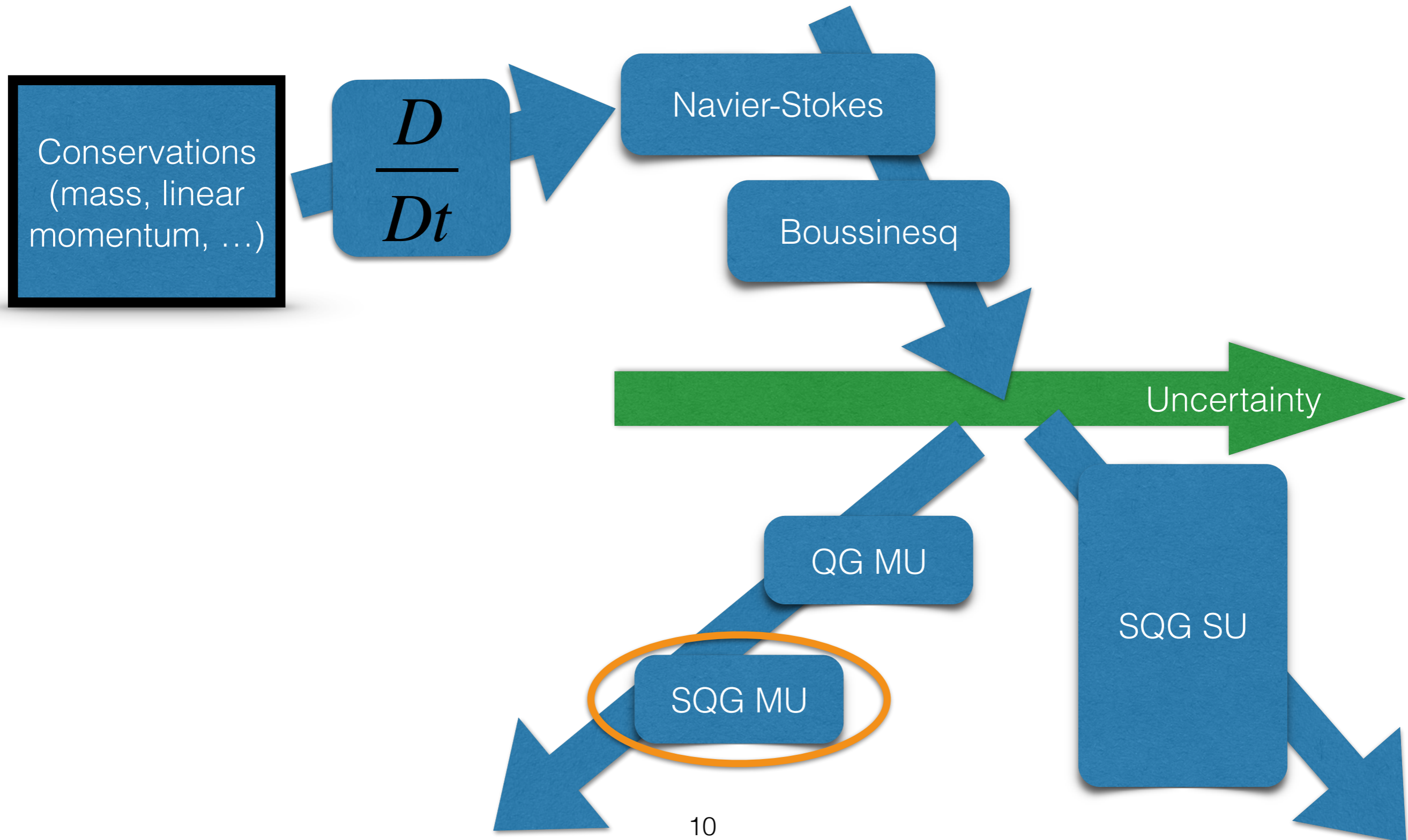


# Drift correction

$$w^* = w - \frac{1}{2} (\nabla \cdot \mathbf{a})^T$$



# Derived random models



# SQG under Moderate Uncertainty

SQG MU

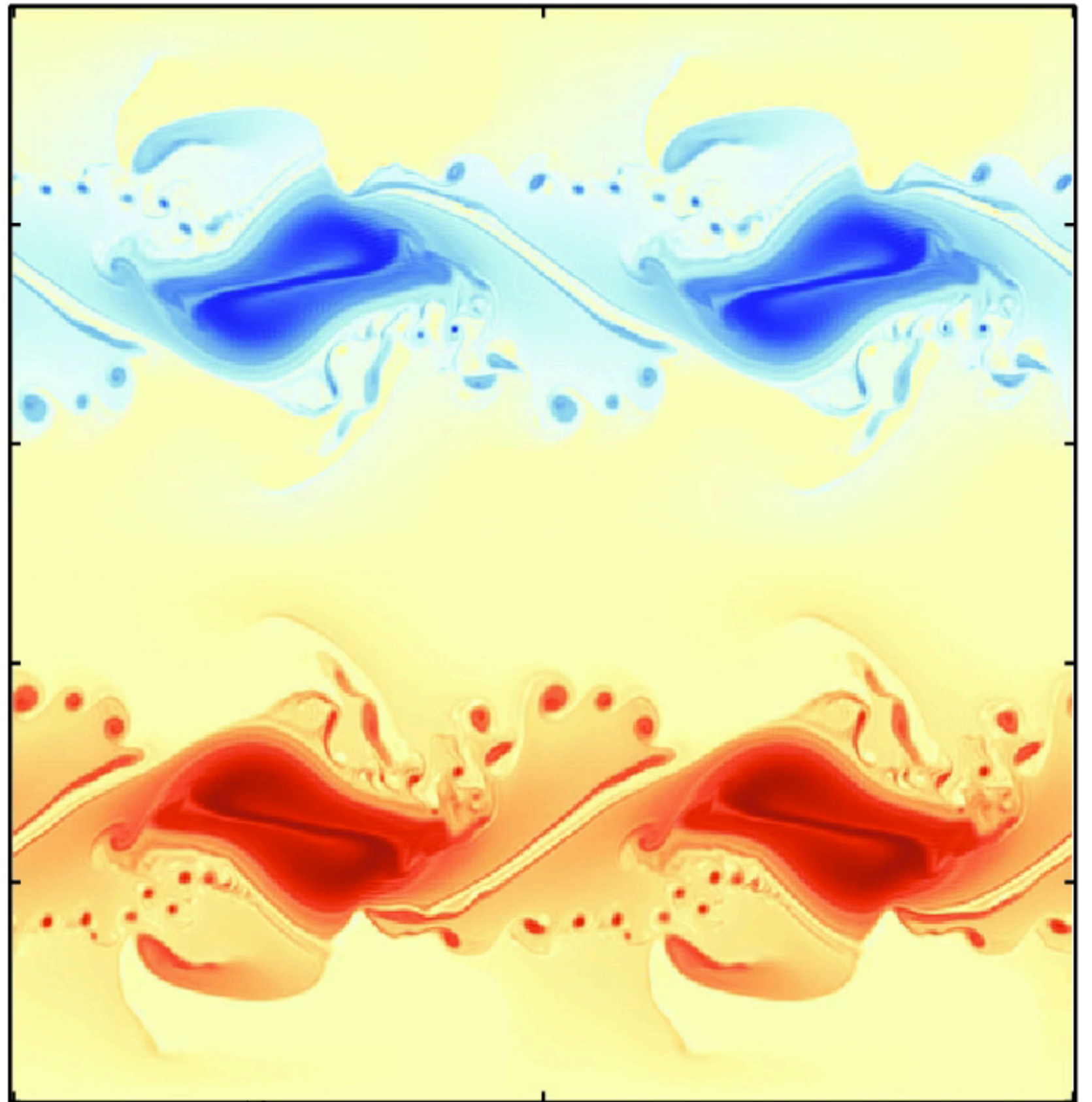
*Code available online*

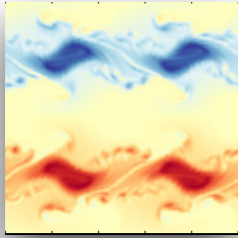
$t = 17$  days

Reference flow:  
deterministic

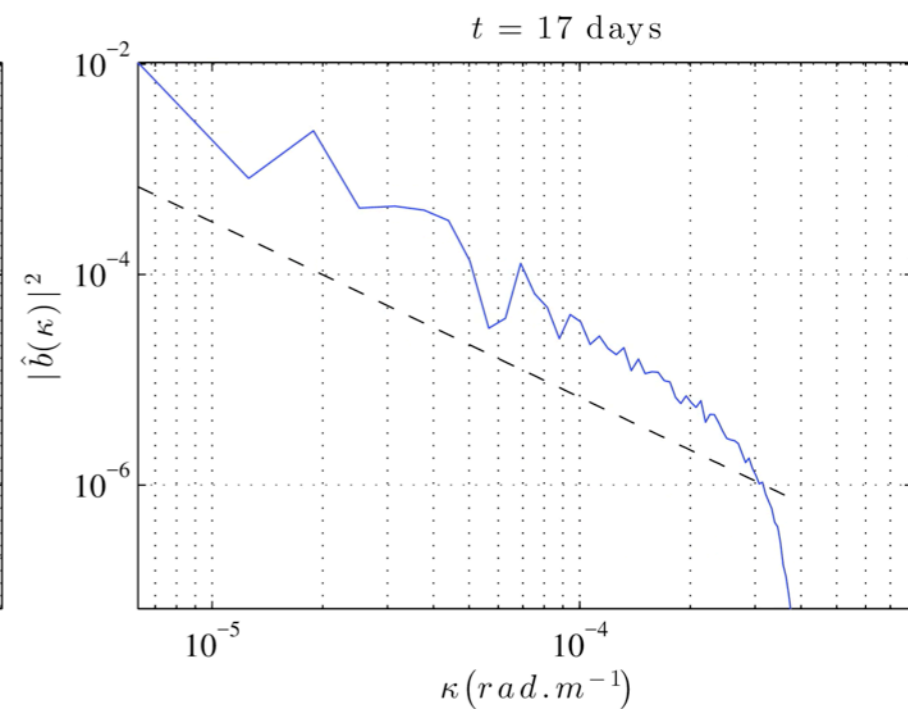
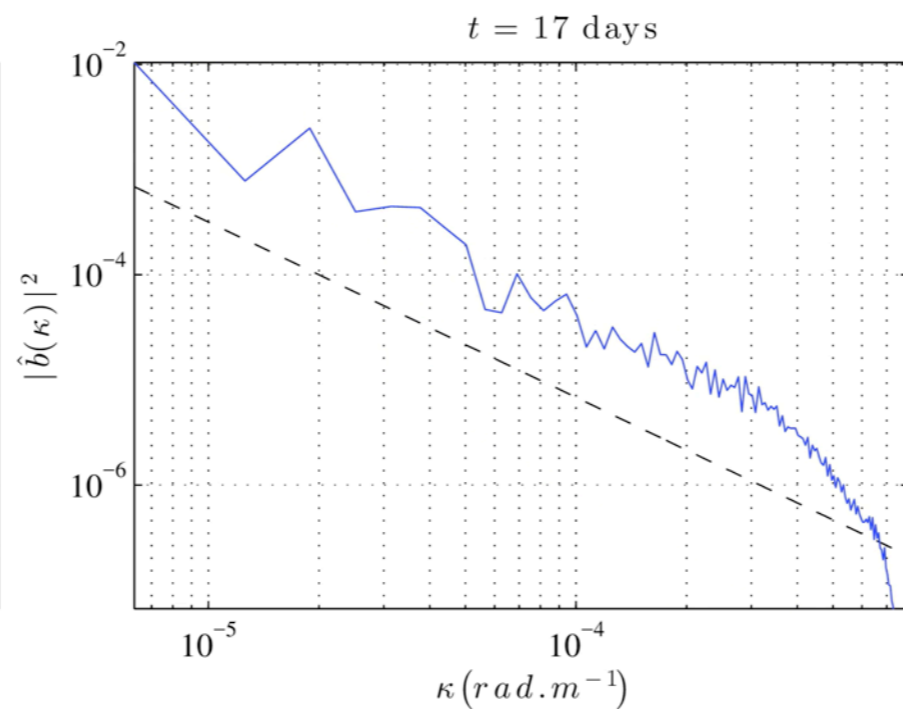
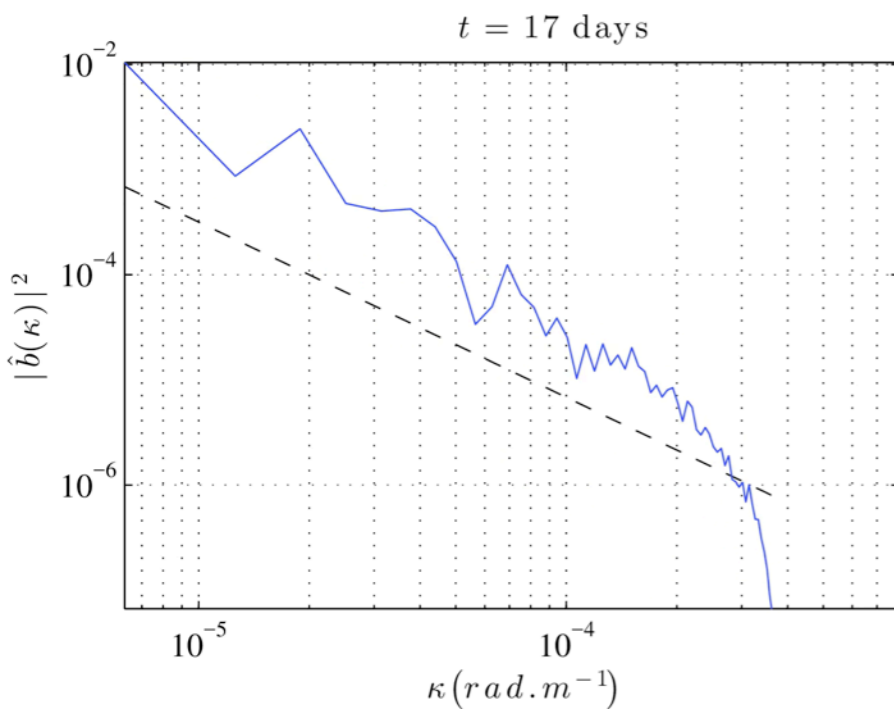
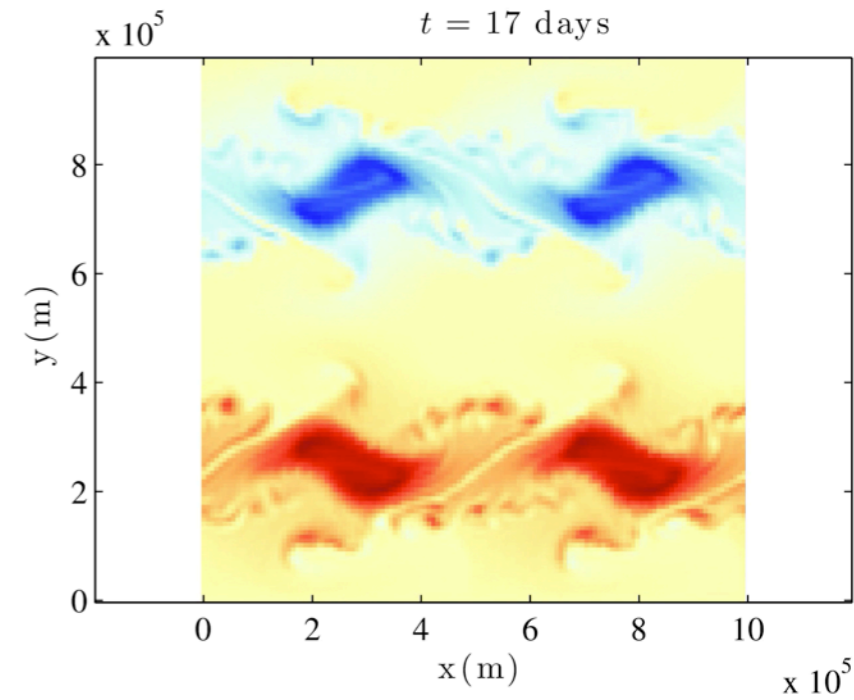
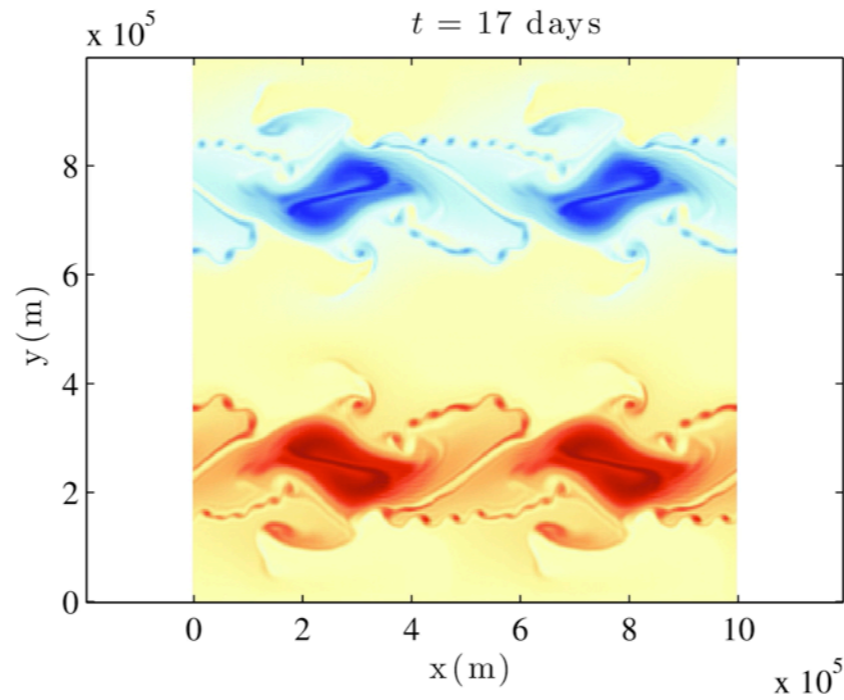
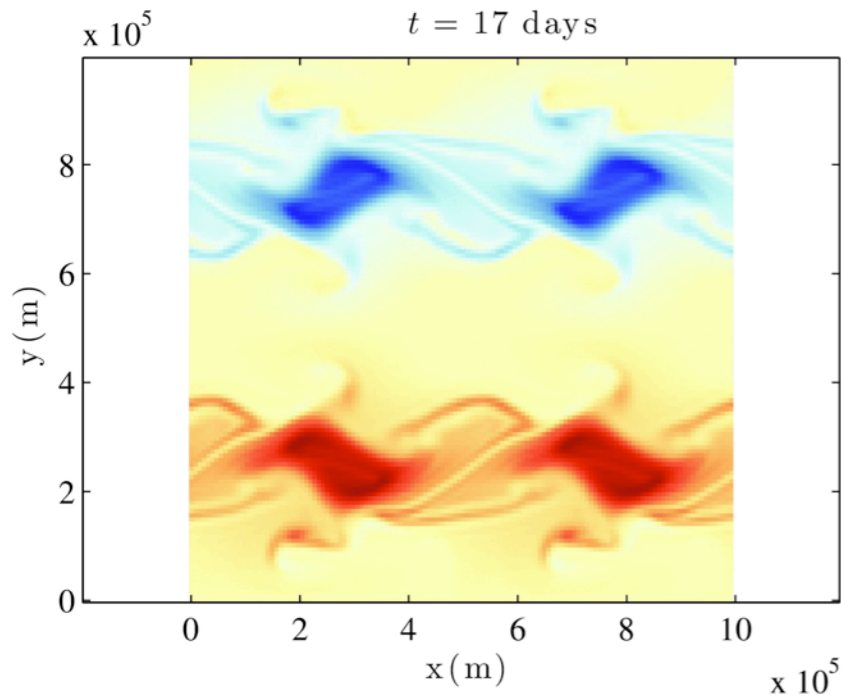
SQG

512 x 512





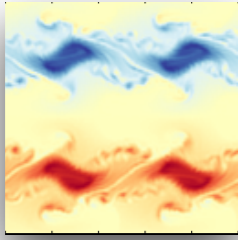
# One realization



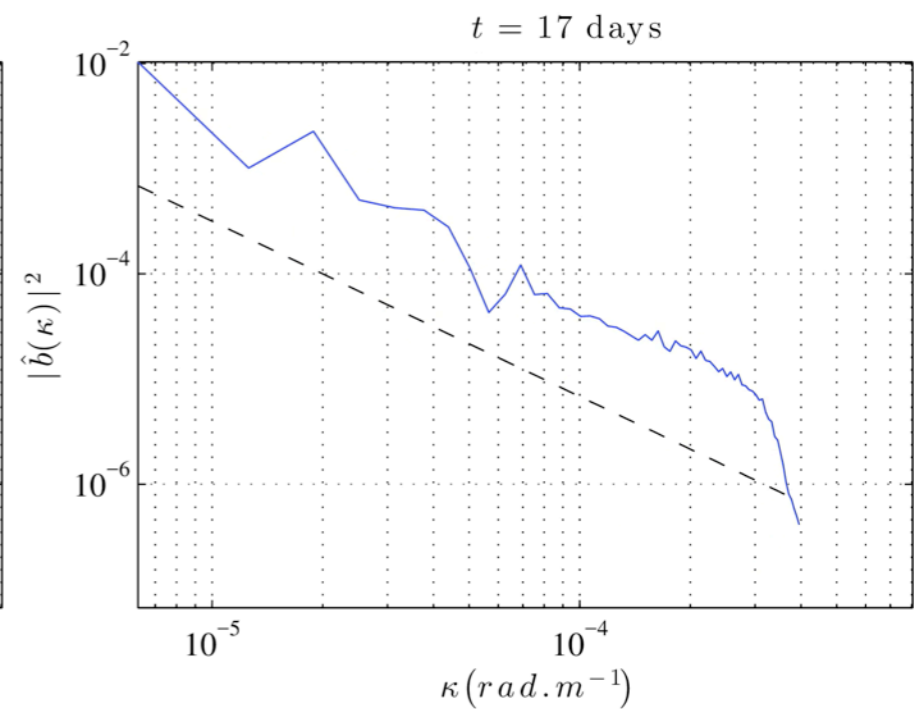
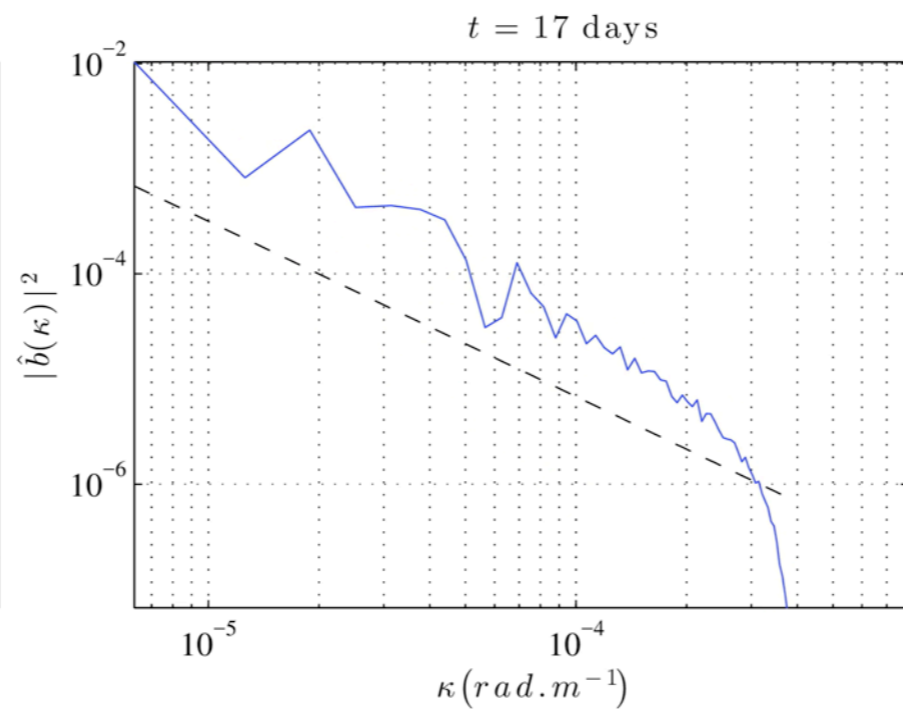
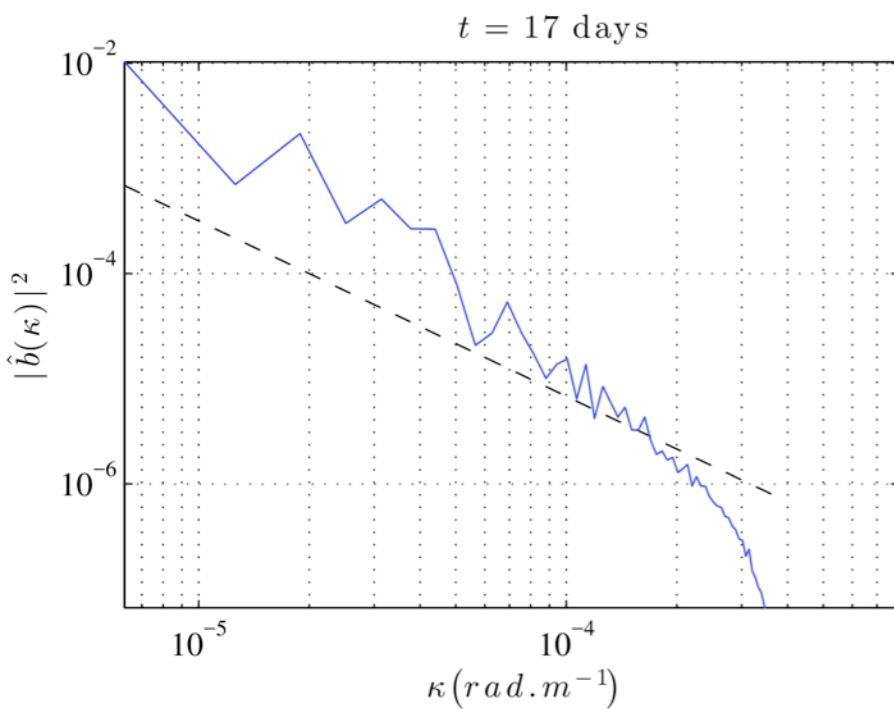
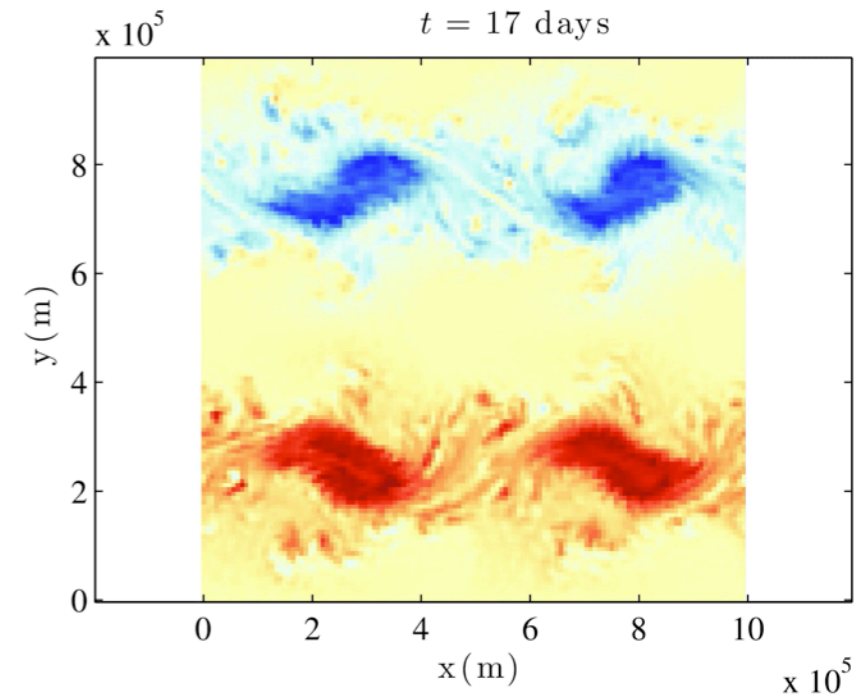
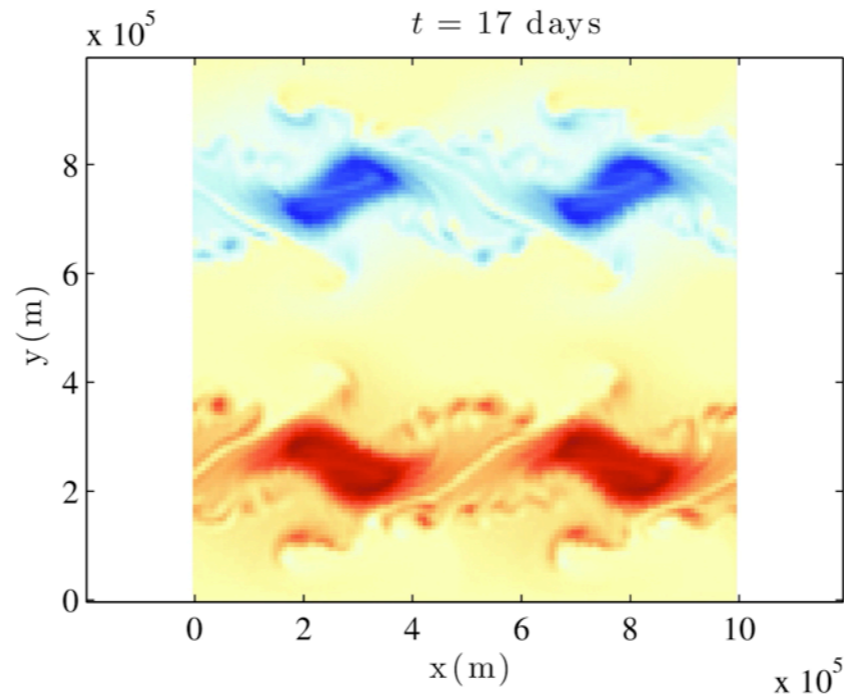
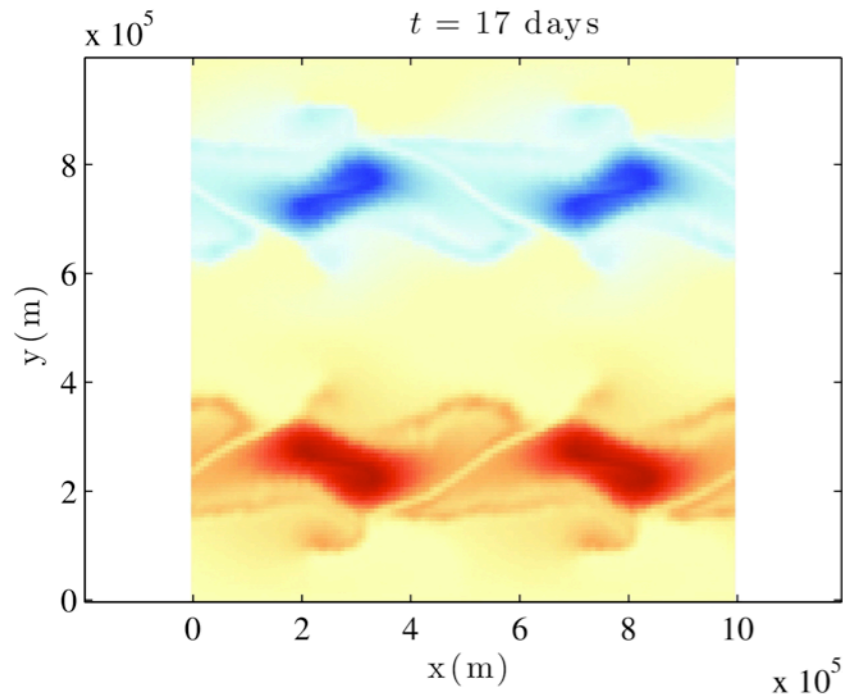
**Deterministic 128x128**

**Deterministic 512x512**

**Stochastic 128x128**



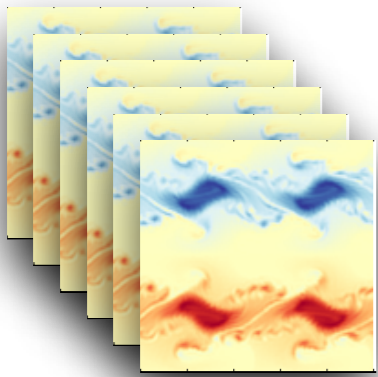
# One realization



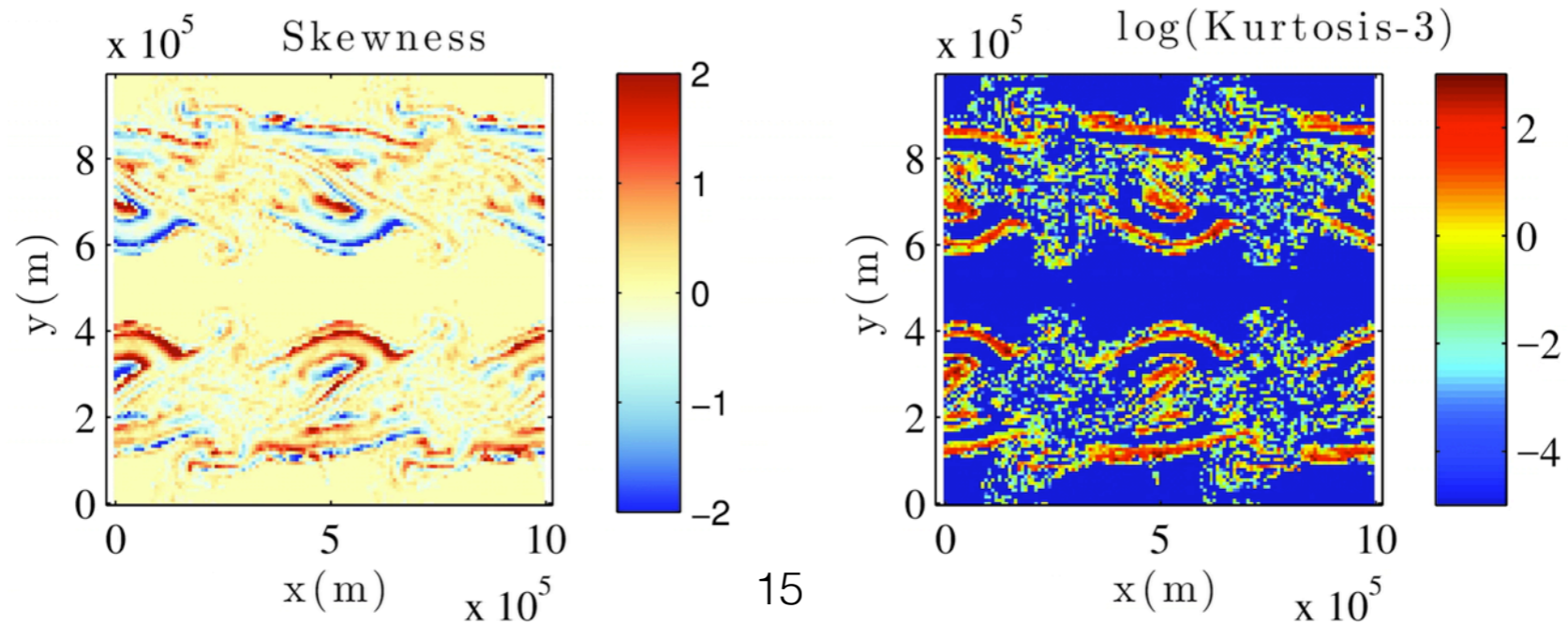
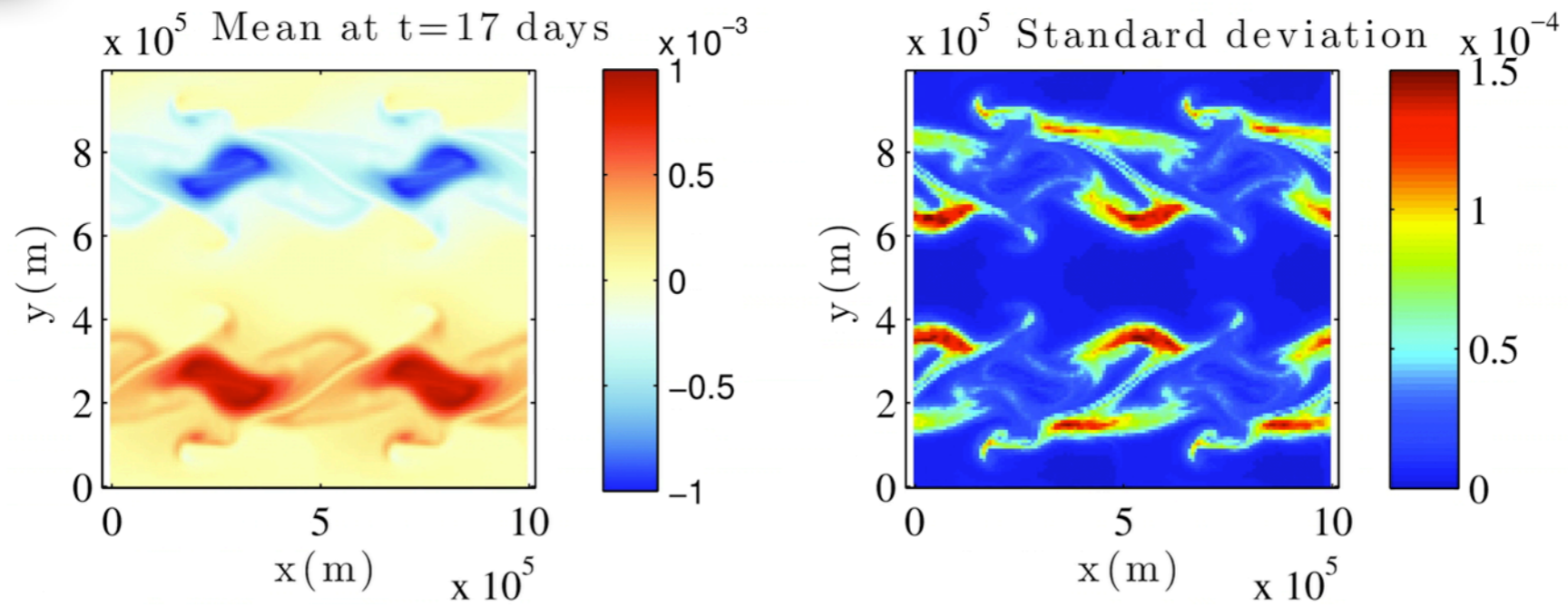
**Lower noise**

**Our model**  
14

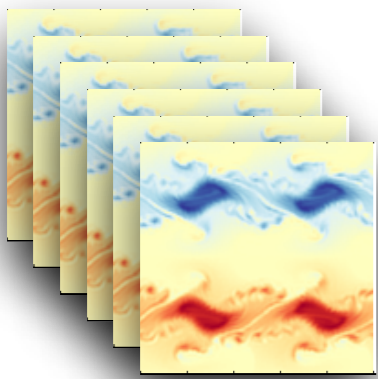
**Larger noise**



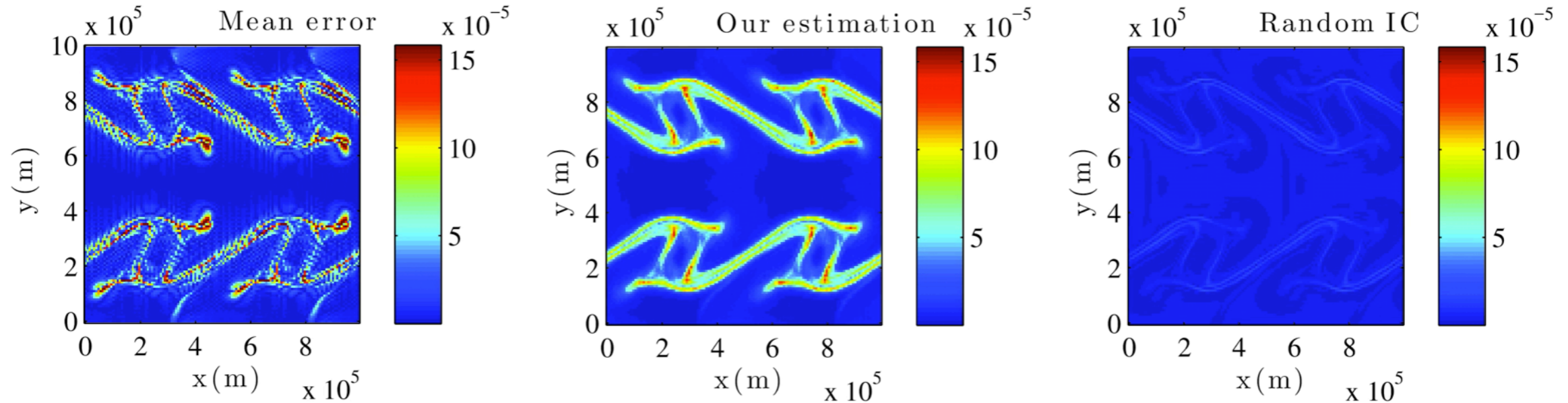
# Ensemble



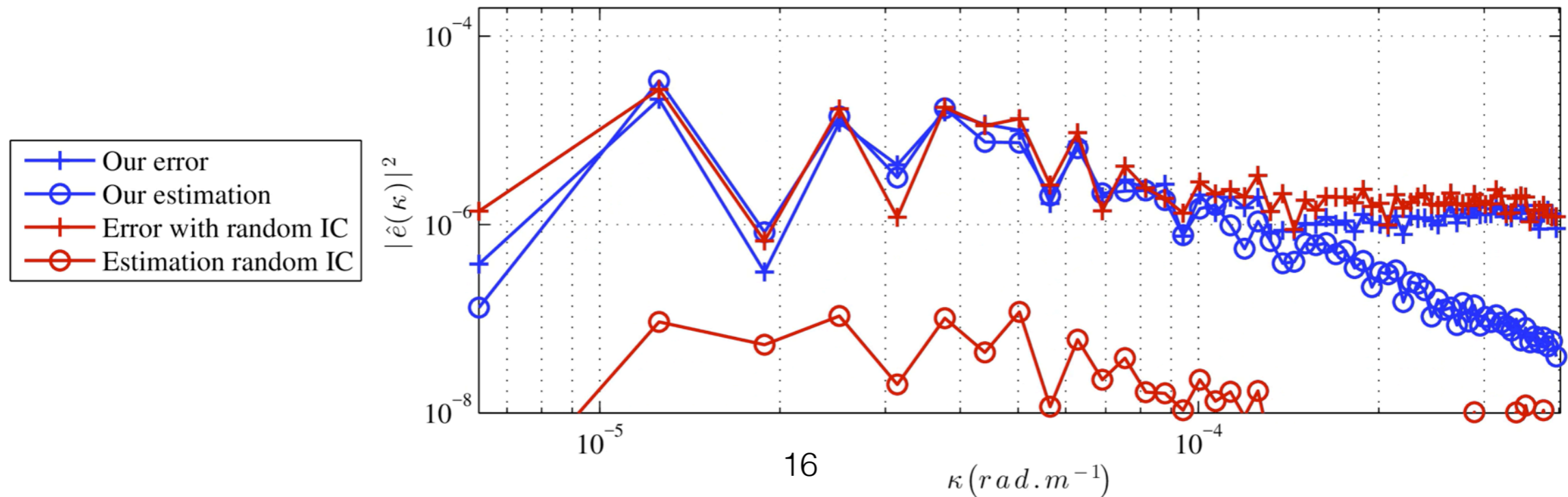




# Ensemble



Spectrum of the errors and its estimation at  $t=12$  days



# Conclusion

# Conclusion

- Random transport applicable to any dynamics
- Better small scales
- Estimate position and amplitude of errors
- Extreme events
- Likely scenarios
- under Strong Uncertainty:  
Simple 2D description of frontolysis/frontogenesis

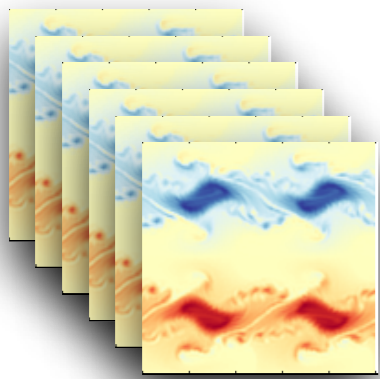
Thank you for your attention

Code SQG MU:  
link from Fluminance website - V. Resseguier

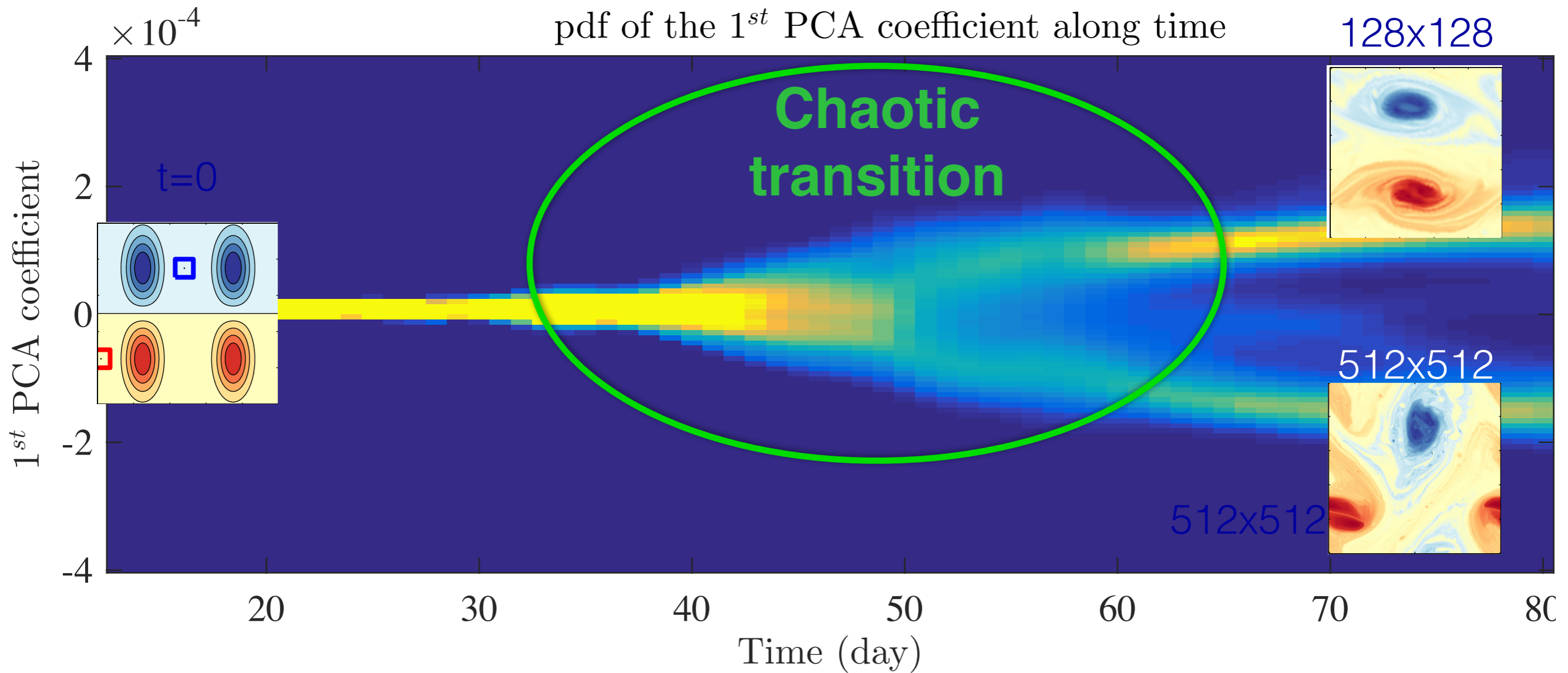
# Likely SQG scenarios

tracked by SQG MU

# Ensemble



t=70 days



# SQG under Strong Uncertainty

SQG SU

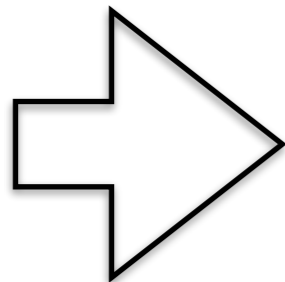
# Mesoscale divergence

Geostrophic balance

$$\mathbf{f} \times \mathbf{u} = -\frac{1}{\rho_b} \nabla p'$$

Horizontal  
Diffusion

$$+ \frac{a}{2} \Delta \mathbf{u}$$

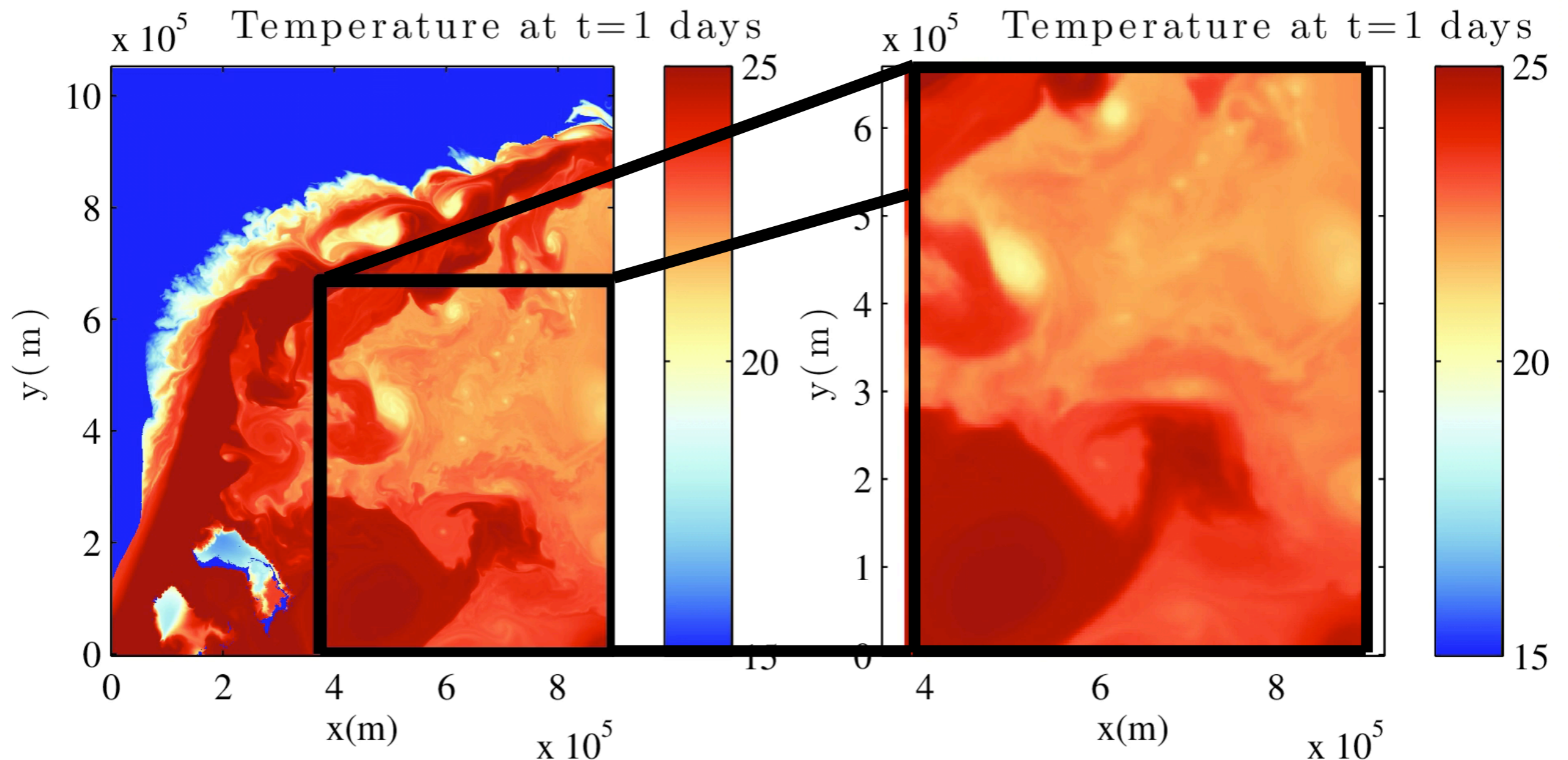


$$\nabla \cdot \mathbf{u} \propto \Delta \nabla^\perp \cdot \mathbf{u}$$

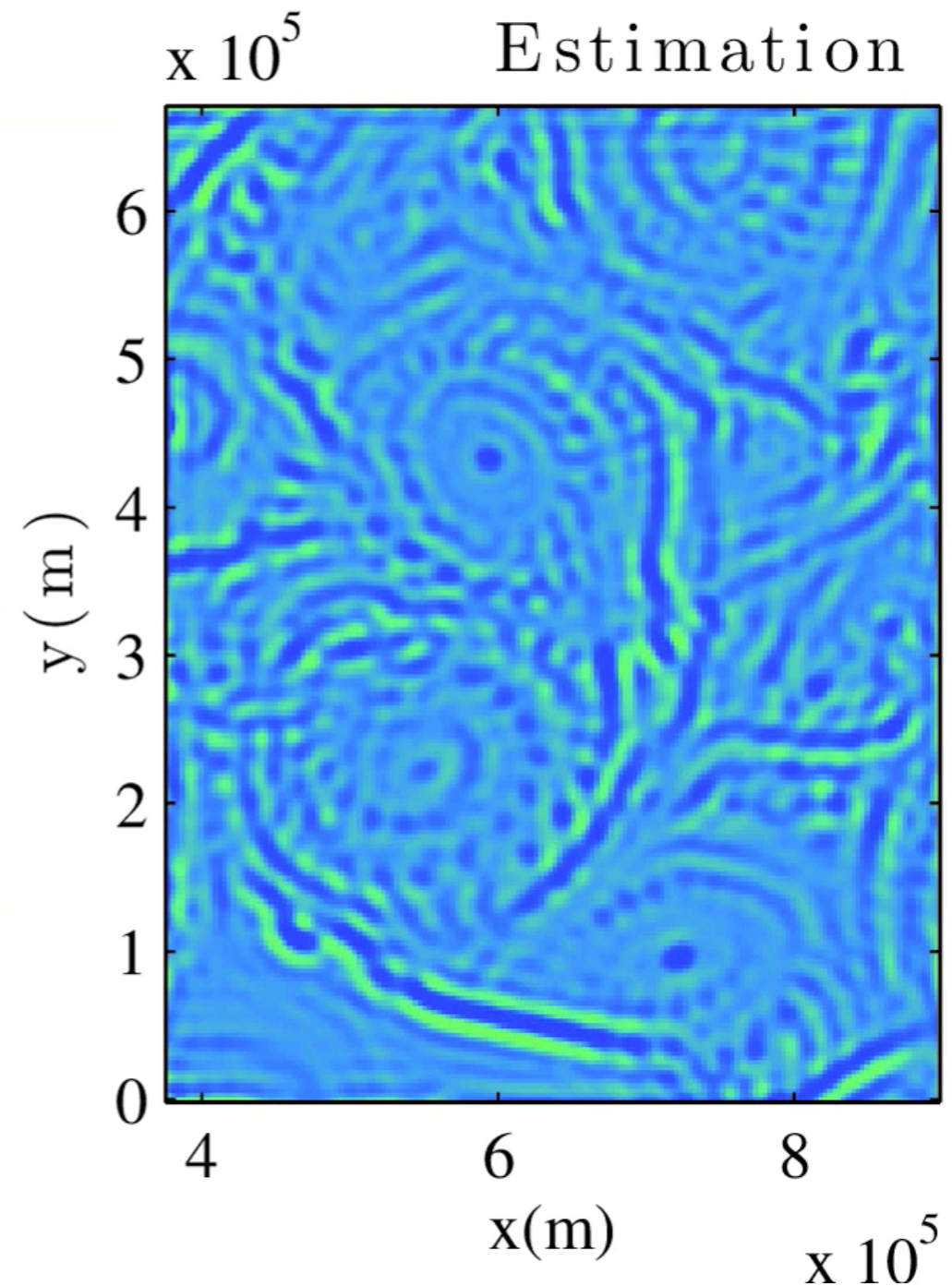
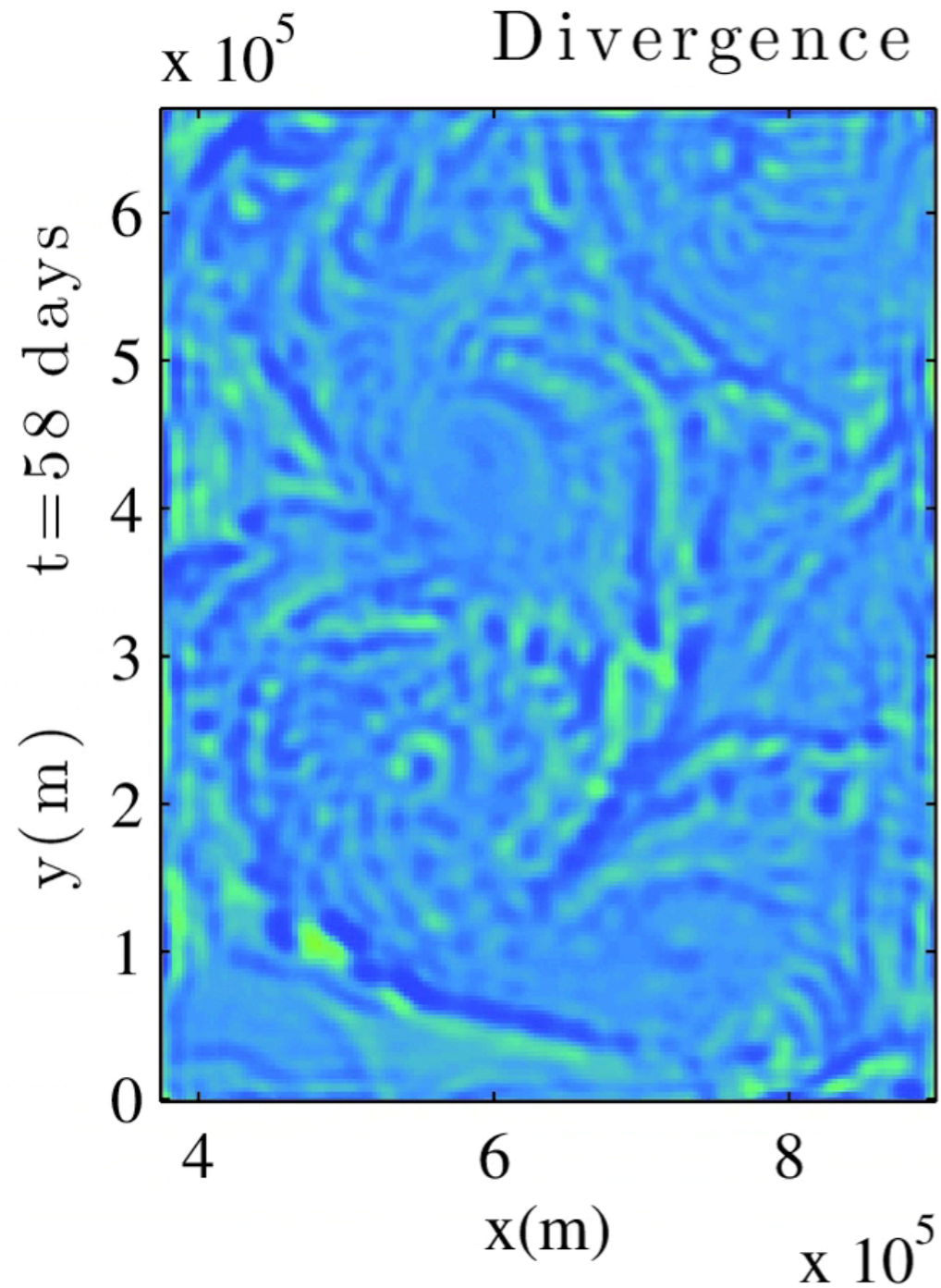


# Filtering of model outputs:

Gula, Jonathan, M. Jeroen Molemaker, and James C. McWilliams  
"Gulf Stream dynamics along the southeastern US seaboard."  
*Journal of Physical Oceanography* 45.3 (2015): 690-715.



# Spatial test



# Spectral test

