



## Randomized fluid dynamics based on subgrid transport

Valentin Resseguier, Etienne Mémin, Bertrand Chapron

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# Randomized fluid dynamics based on subgrid transport

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# Motivations

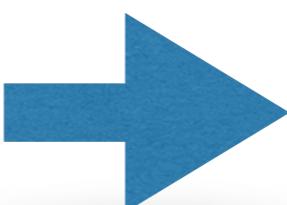
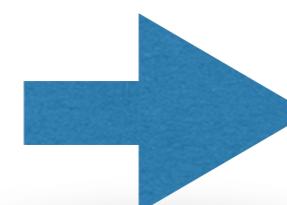
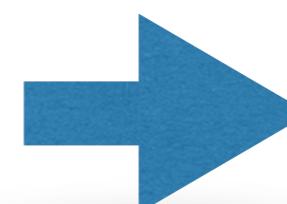
- Rigorously identified subgrid dynamics effects
- Injecting likely small-scale dynamics
- Predicting possible distinct scenarios
- Quantification of modeling errors:
  - Diagnose to design numerical simulations (mesh refinements, ...)
  - **Data assimilation: ensemble forecasts**

# Contents

- Randomized dynamics
- SQG under Moderate Uncertainty

# Randomized dynamics

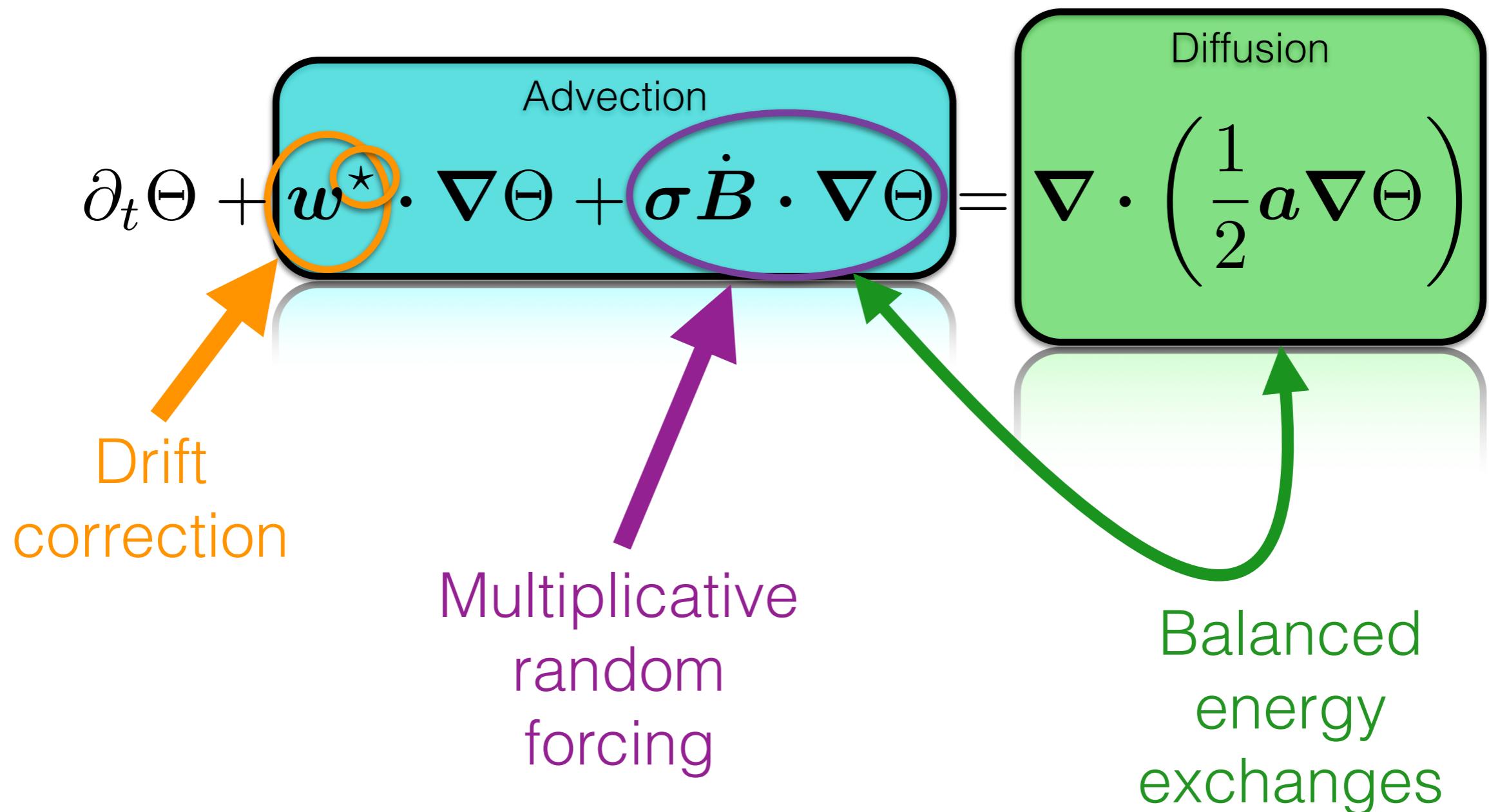
# Random equations

- Random initial conditions  Underdispersive
- Arbitrary Gaussian forcing  Adding energy  
+ wrong phase
- Averaging, homogenization  Previous talk
- Adding white  
random velocity 
$$v = w + \sigma \dot{B}$$

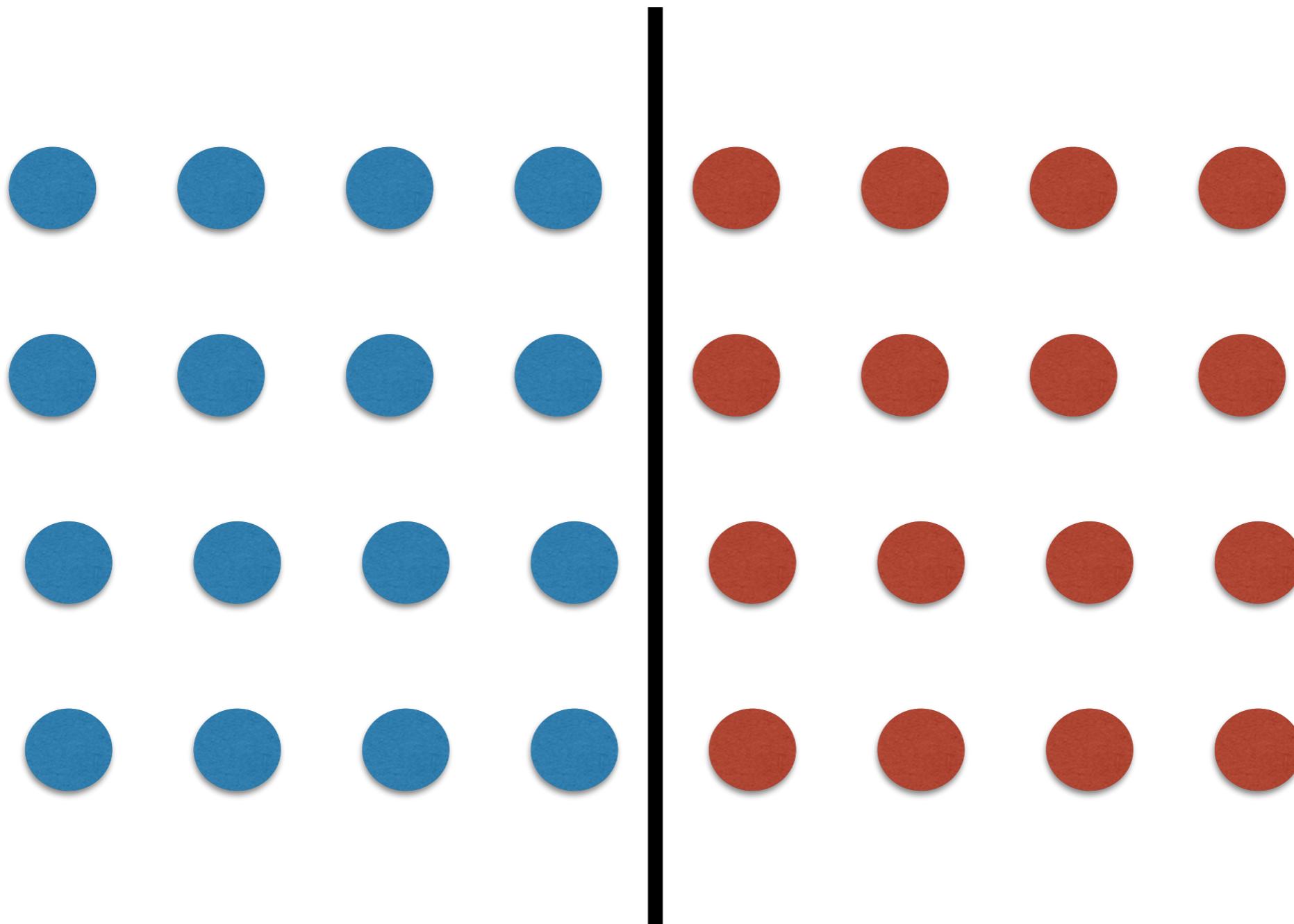
# Advection of tracer $\Theta$

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

# Advection of tracer $\Theta$

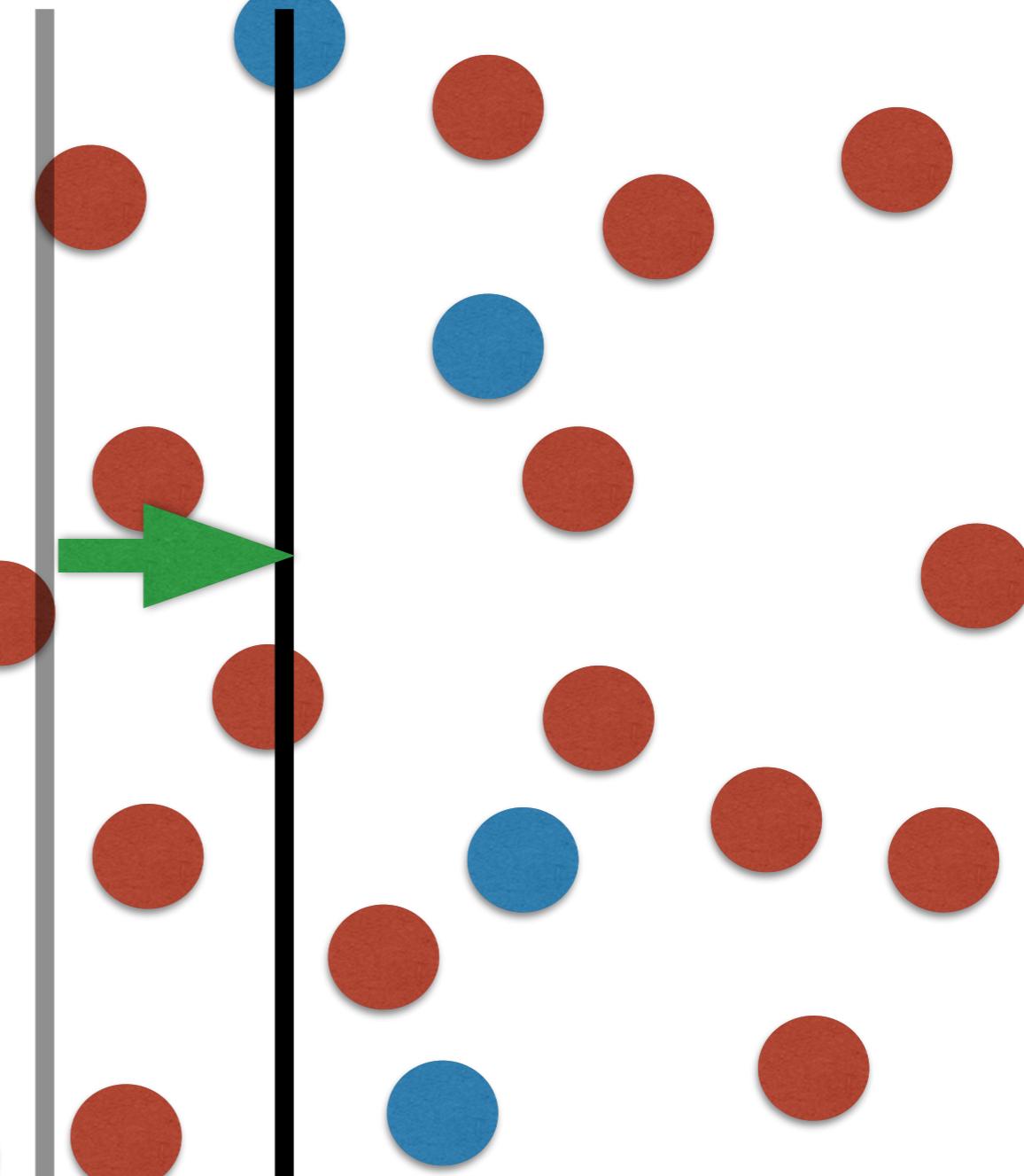


# Drift correction

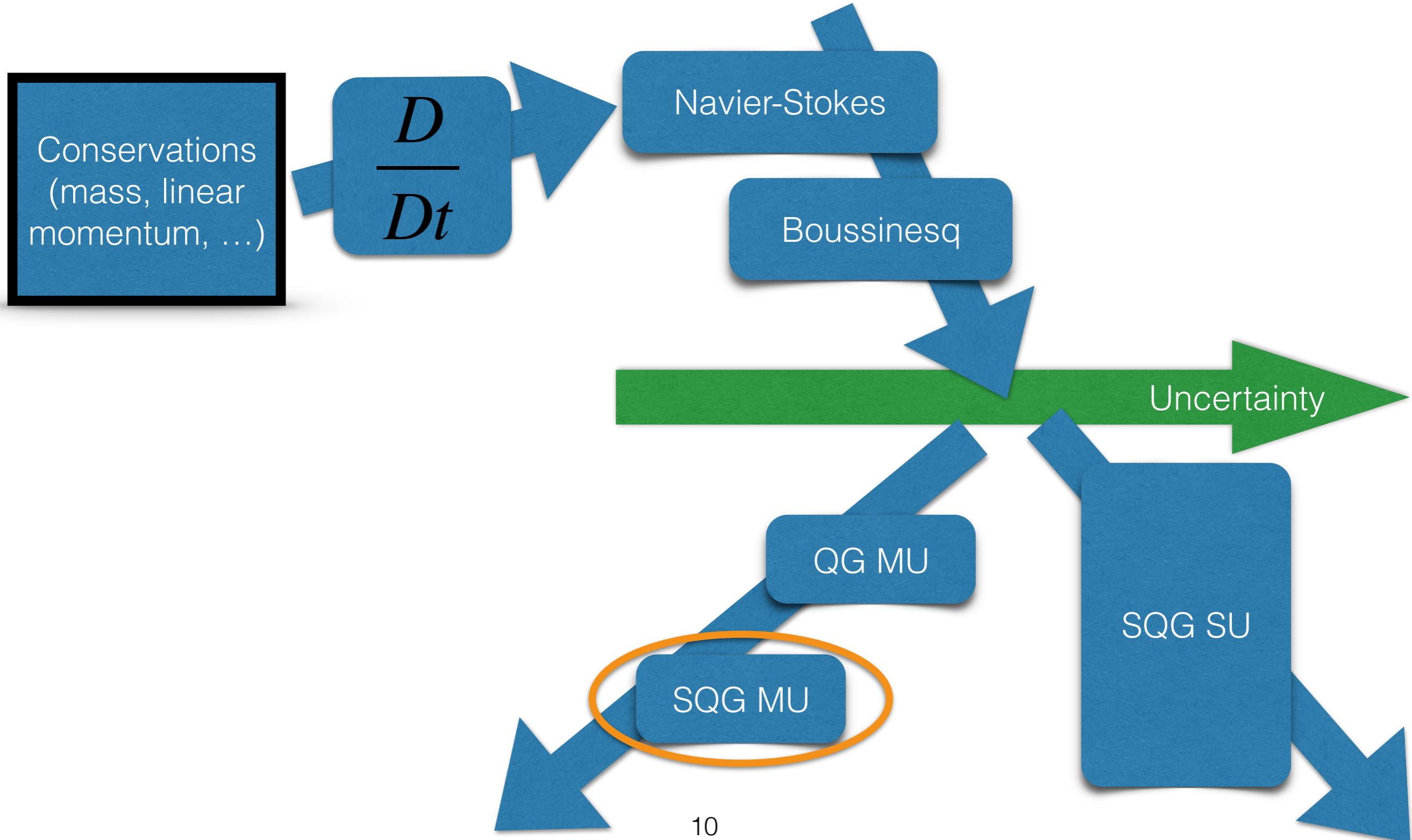


# Drift correction

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



# Derived random models



# SQG under Moderate Uncertainty

SQG MU

*Code available online*

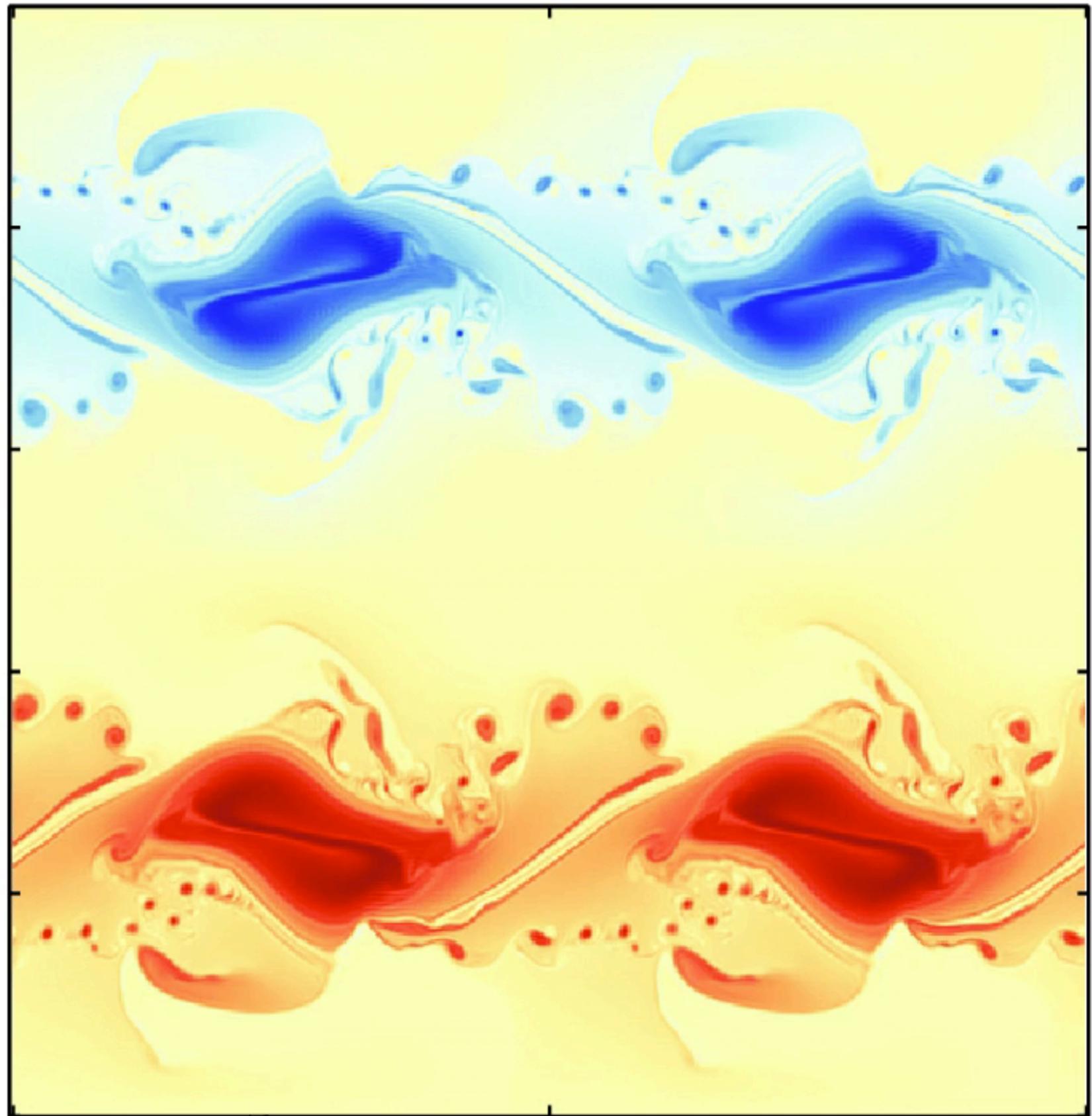
$t = 17$  days

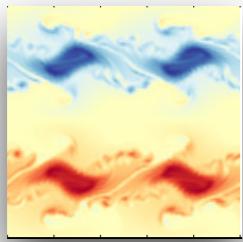
Reference flow:

deterministic

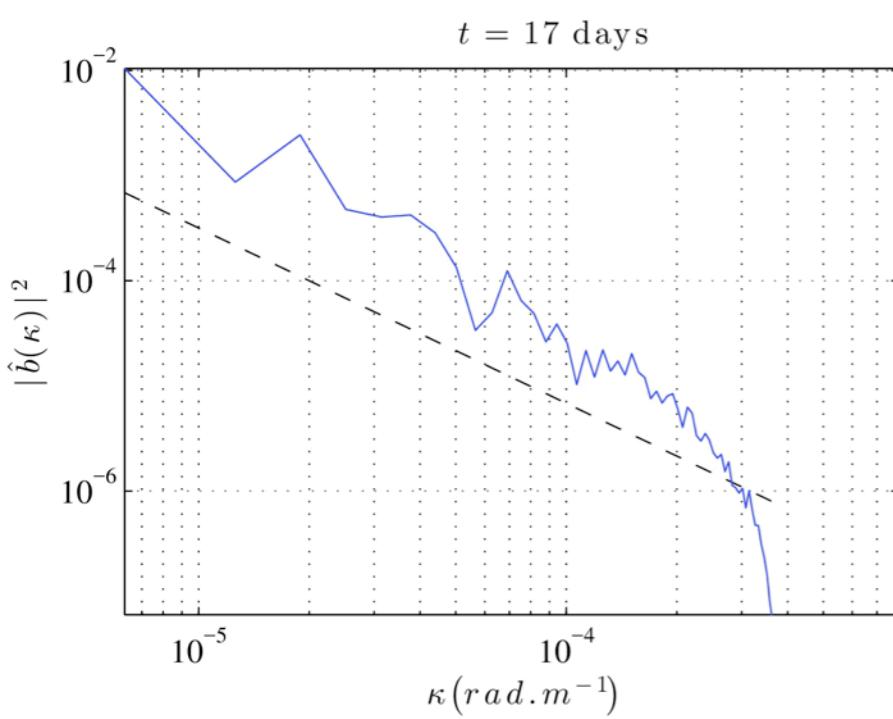
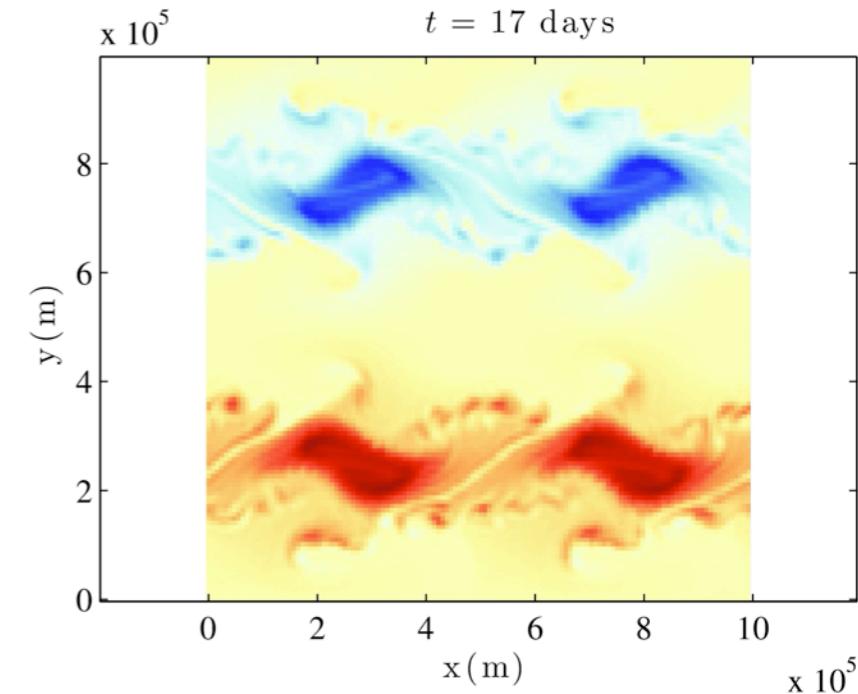
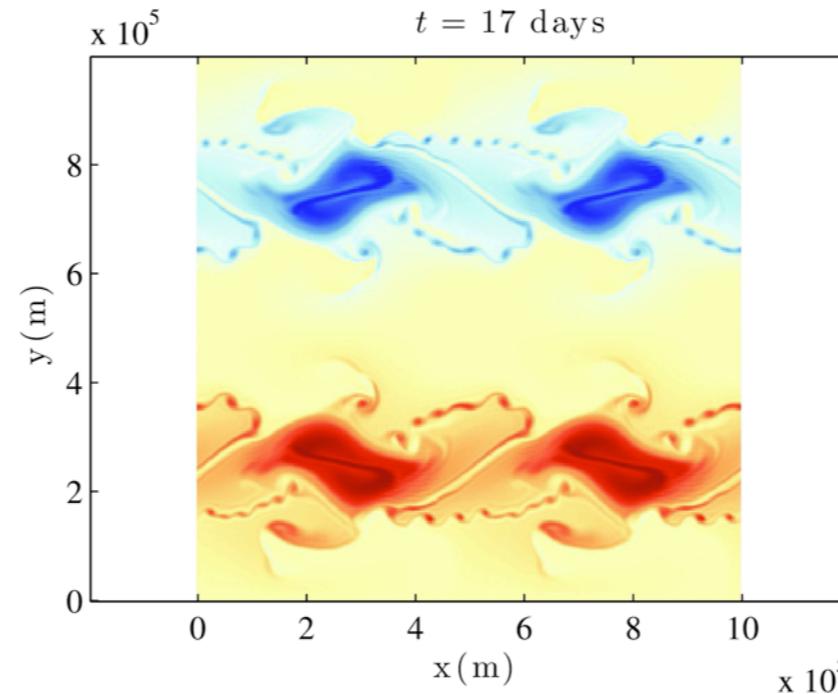
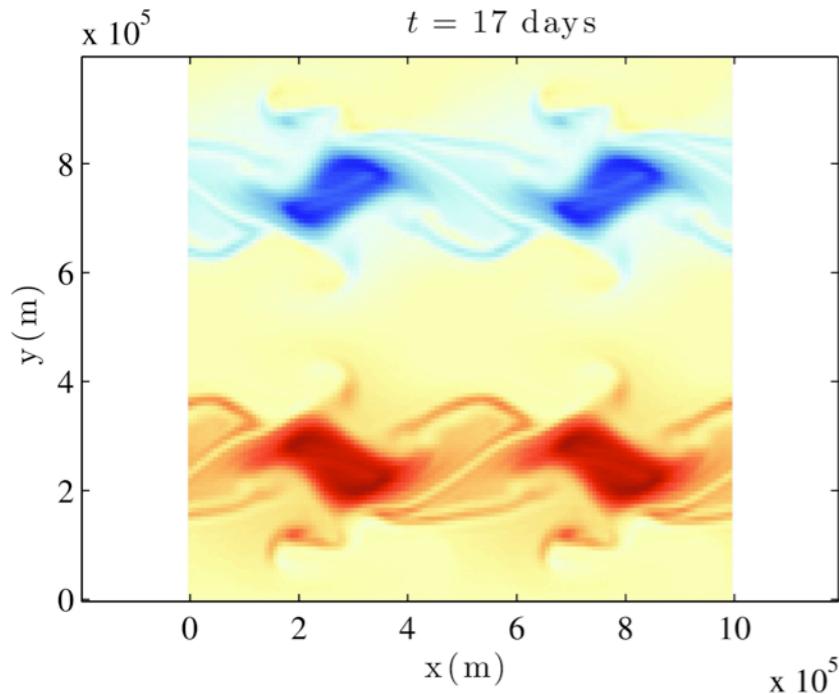
SQG

512 x 512

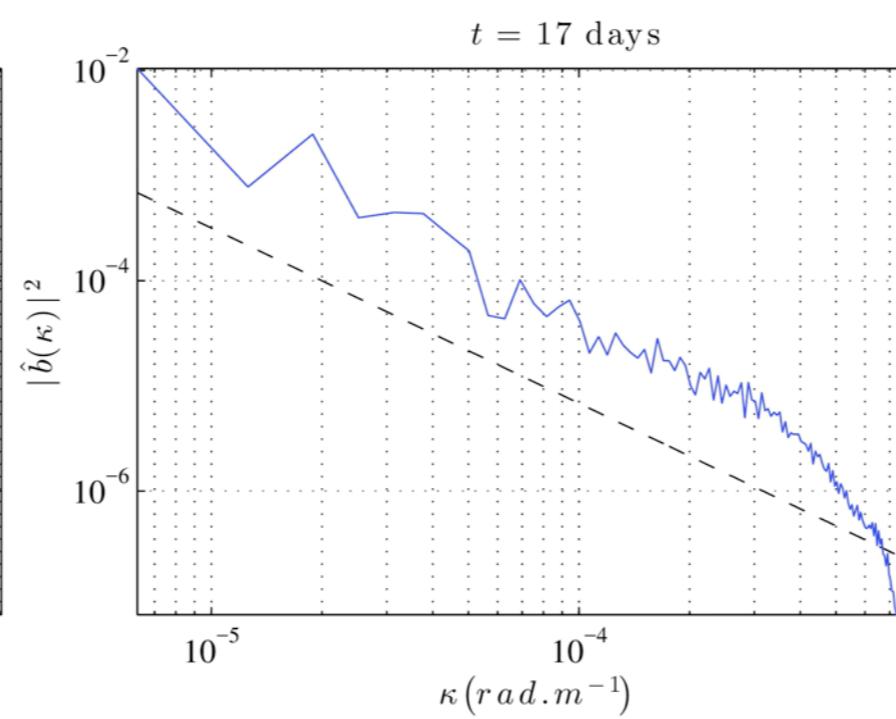




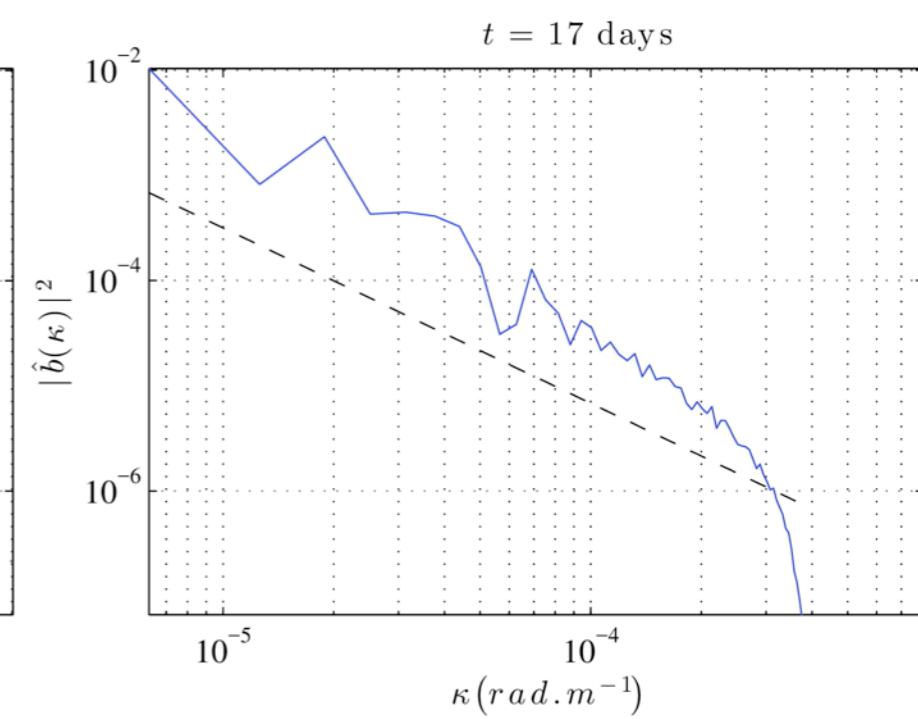
# One realization



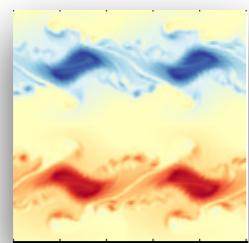
Deterministic 128x128



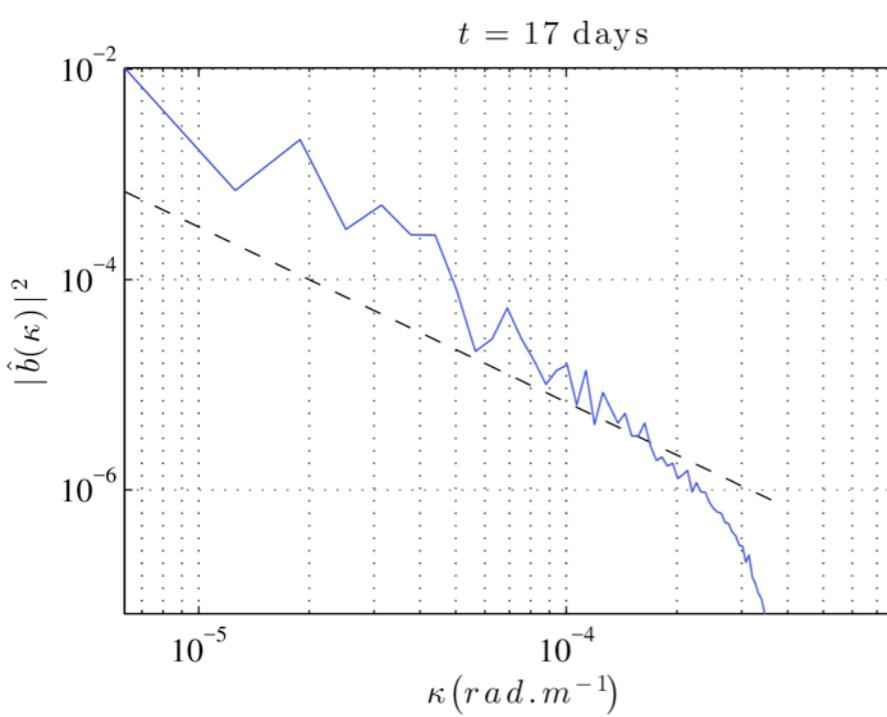
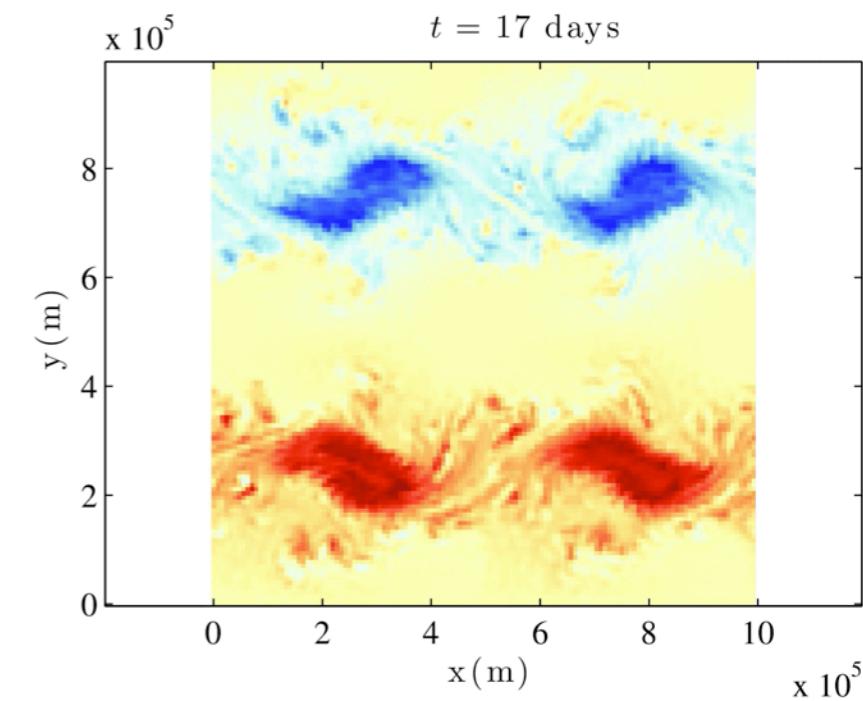
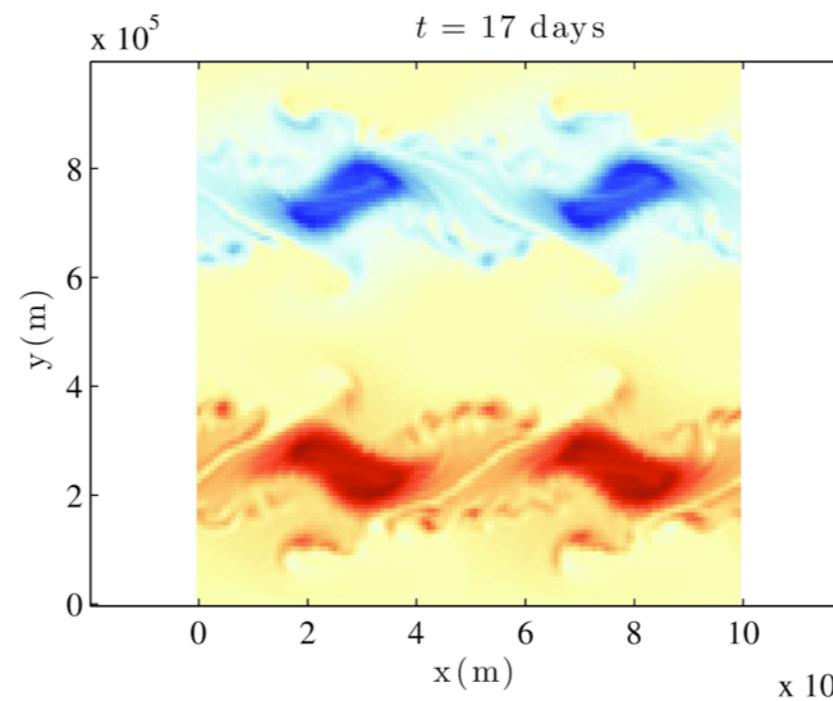
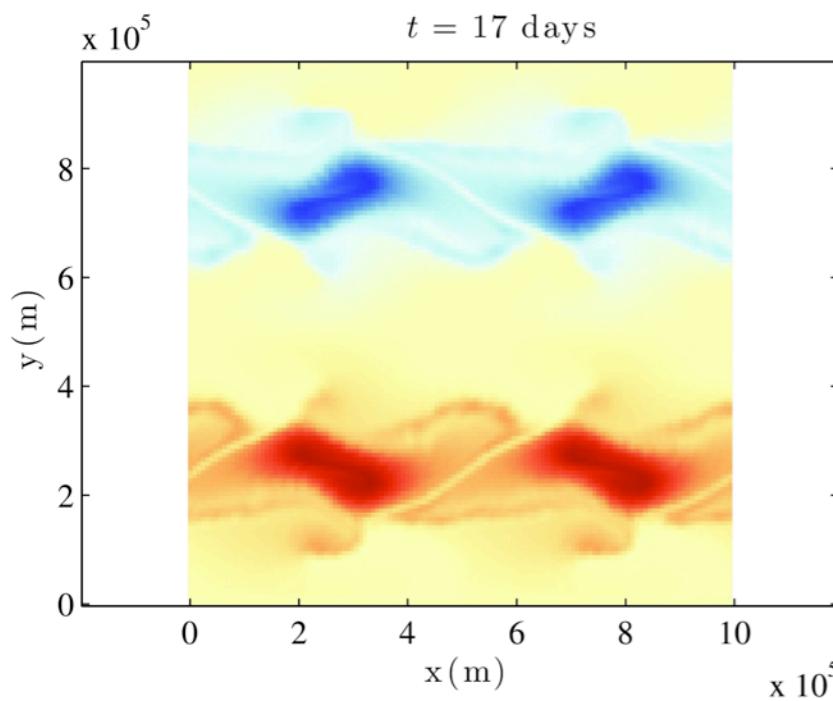
Deterministic 512x512  
13



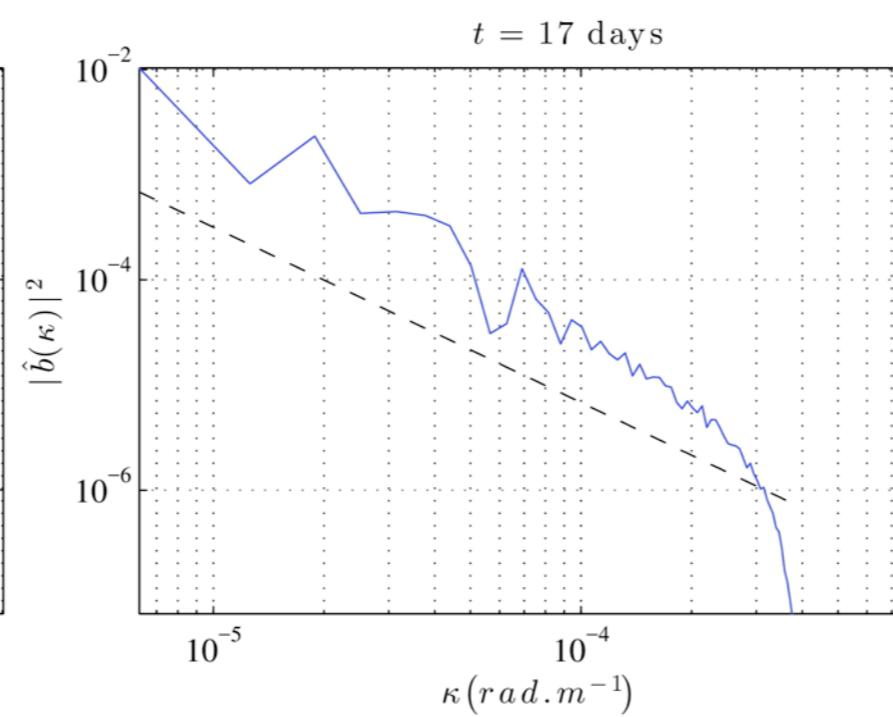
Stochastic 128x128



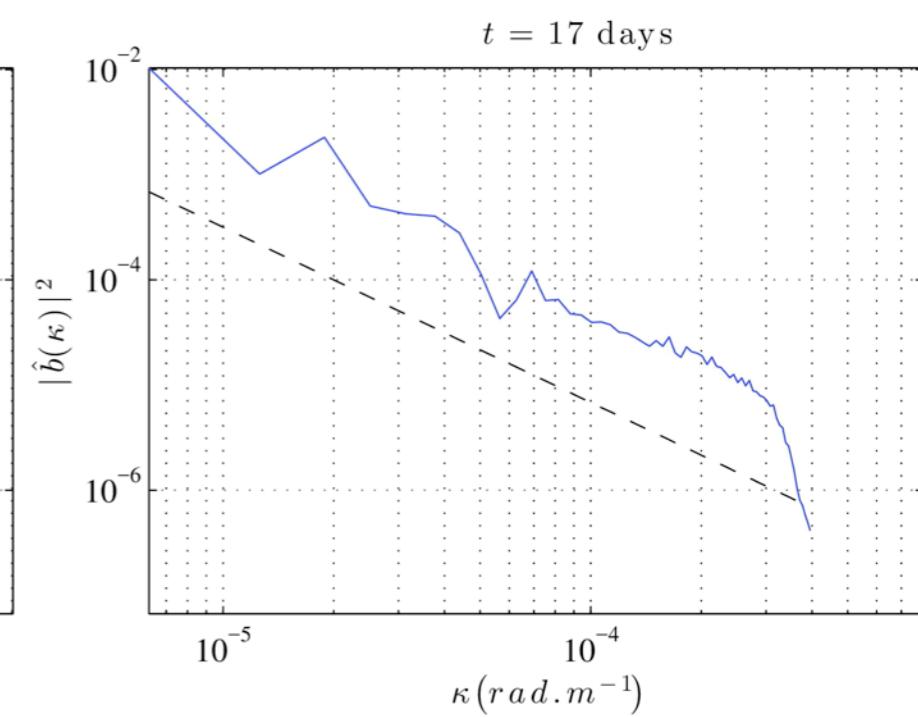
# One realization



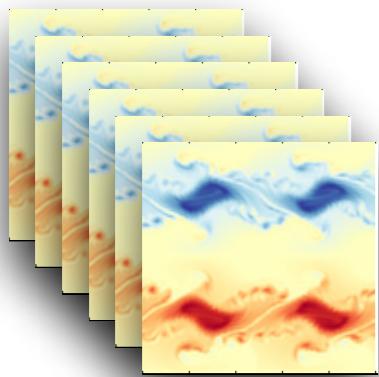
**Lower noise**



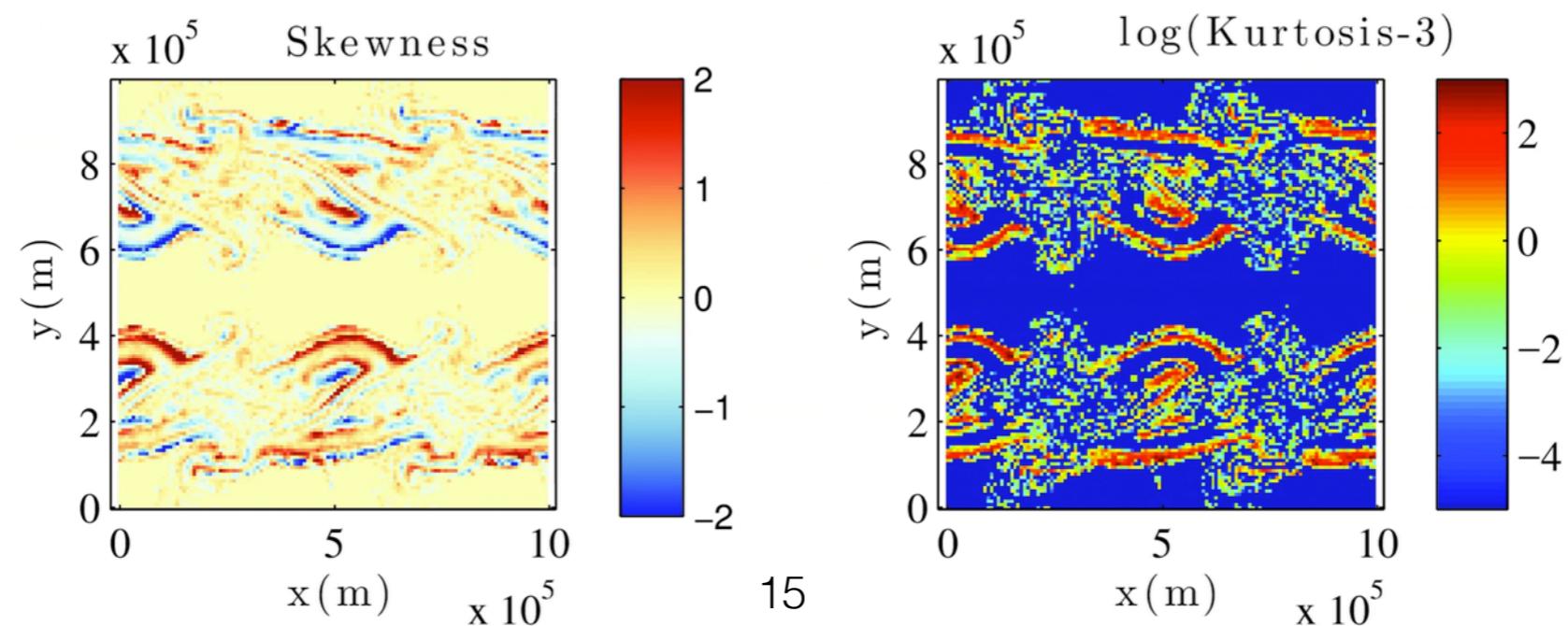
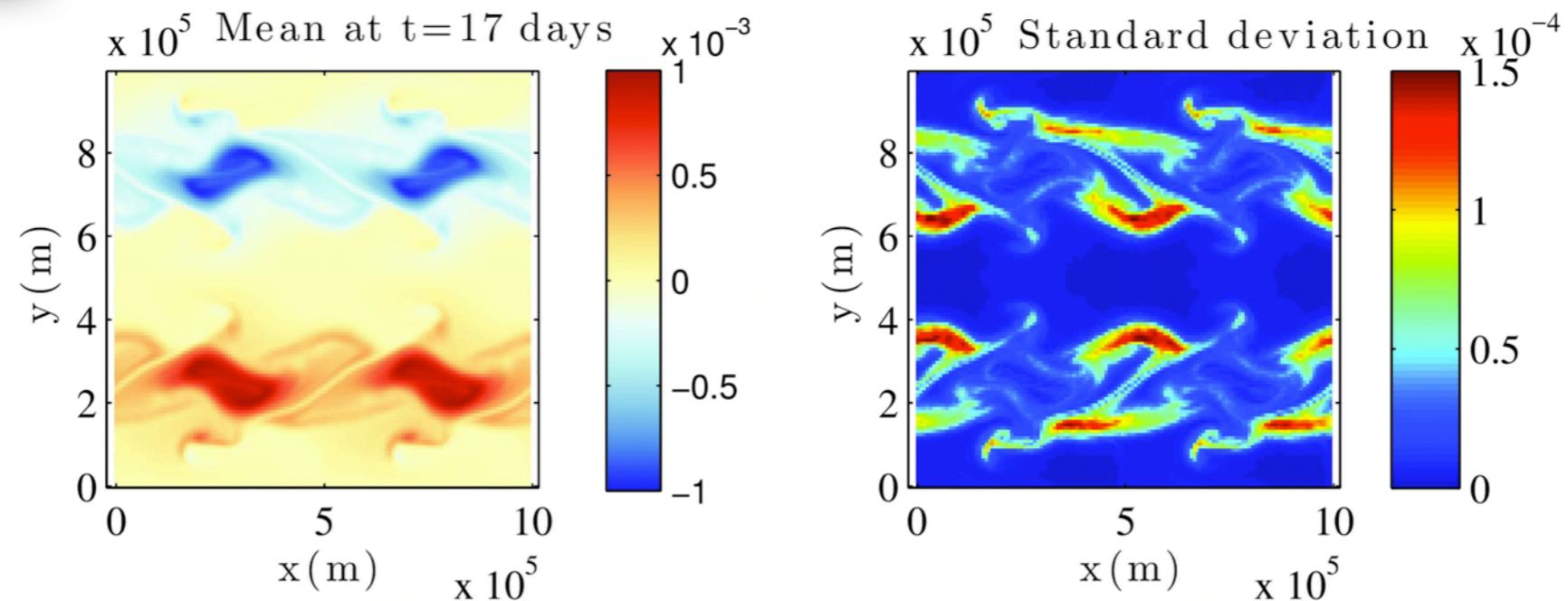
**Our model**  
14

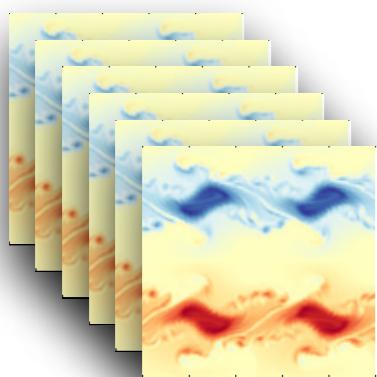


**Larger noise**

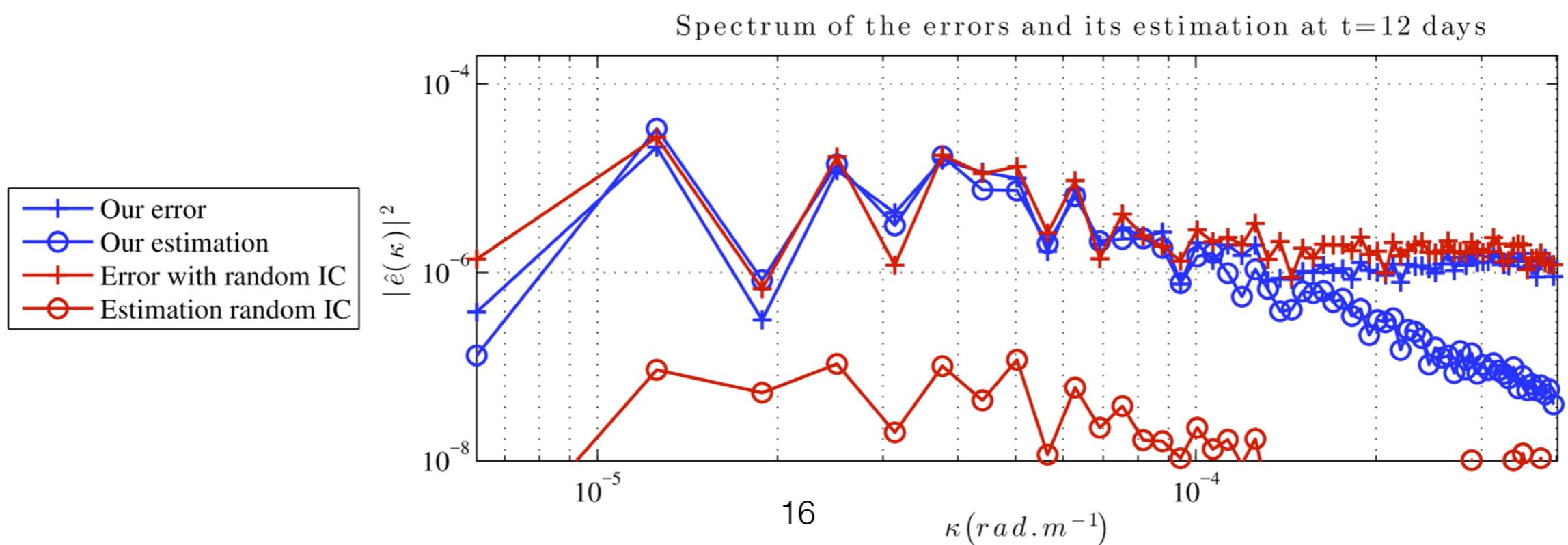
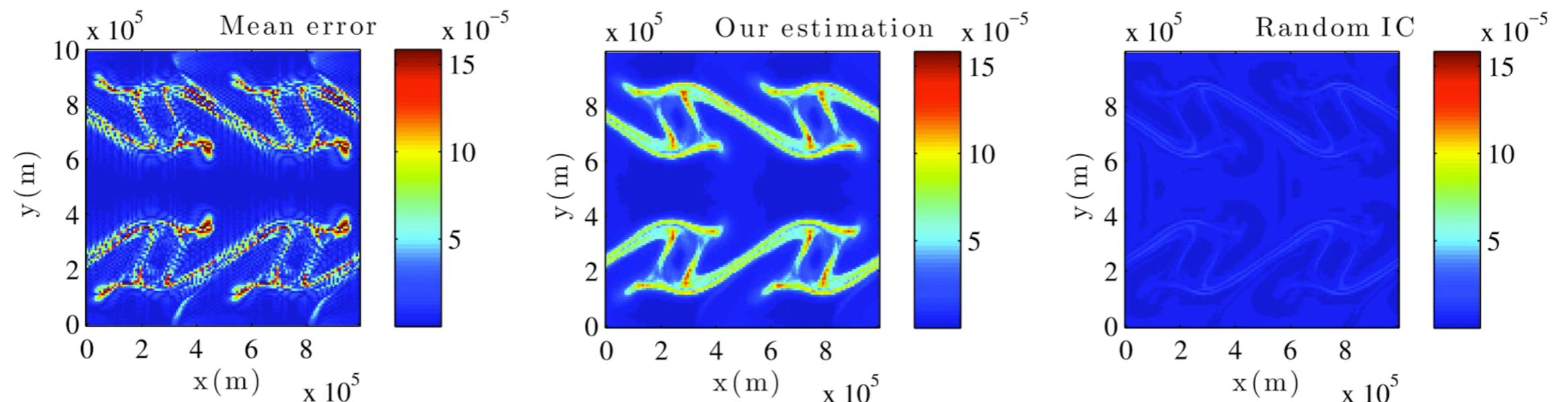


# Ensemble





# Ensemble



# Conclusion

# Conclusion

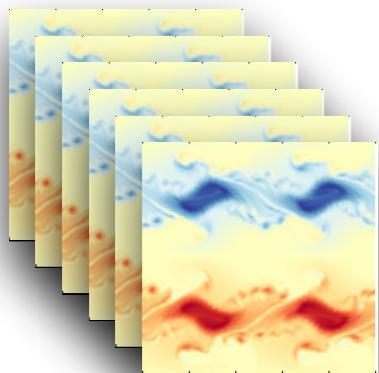
- Random transport applicable to any dynamics
- Better small scales
- Estimate position and amplitude of errors
- Extreme events
- Likely scenarios
- under Strong Uncertainty:
  - Simple 2D description of frontolysis/frontogenesis

Thank you for your attention

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

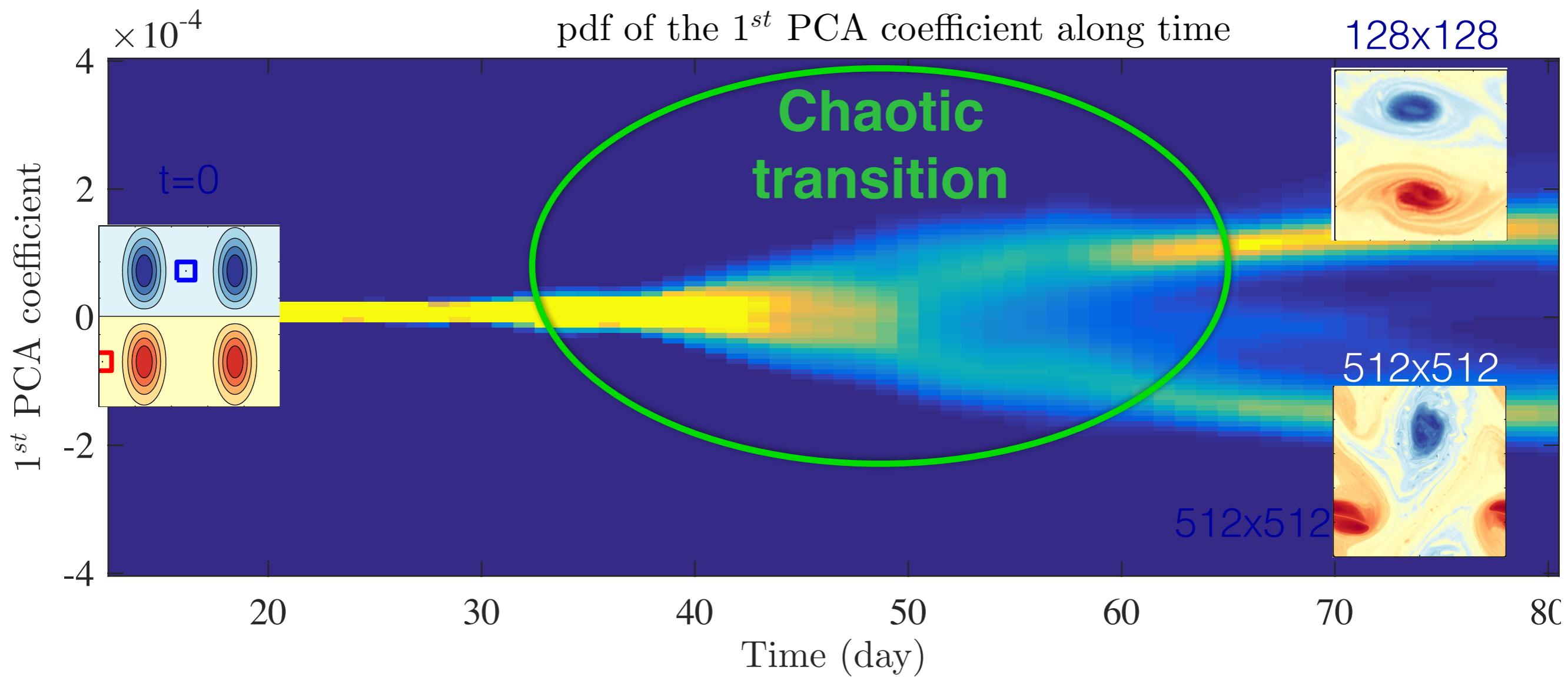
# Likely SQG scenarios

tracked by SQG MU



# Ensemble

$t=70$  days



# SQG under Strong Uncertainty

SQG SU

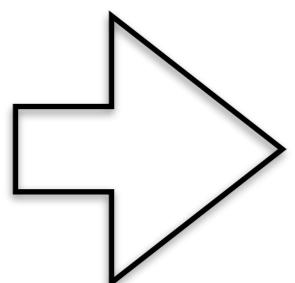
# Mesoscale divergence

Geostrophic balance

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

Horizontal  
Diffusion

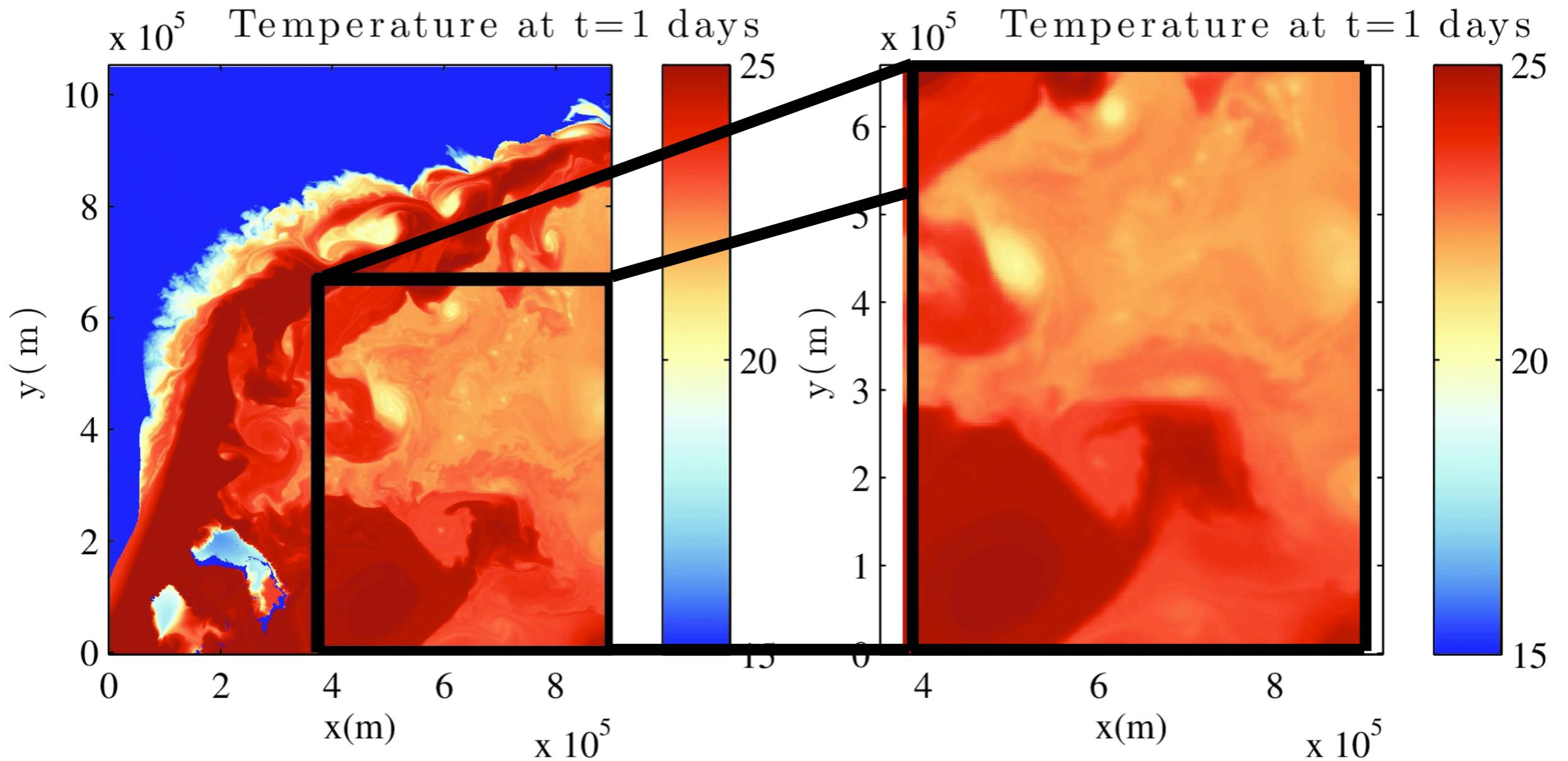
$$+ \frac{a}{2} \Delta \mathbf{u}$$



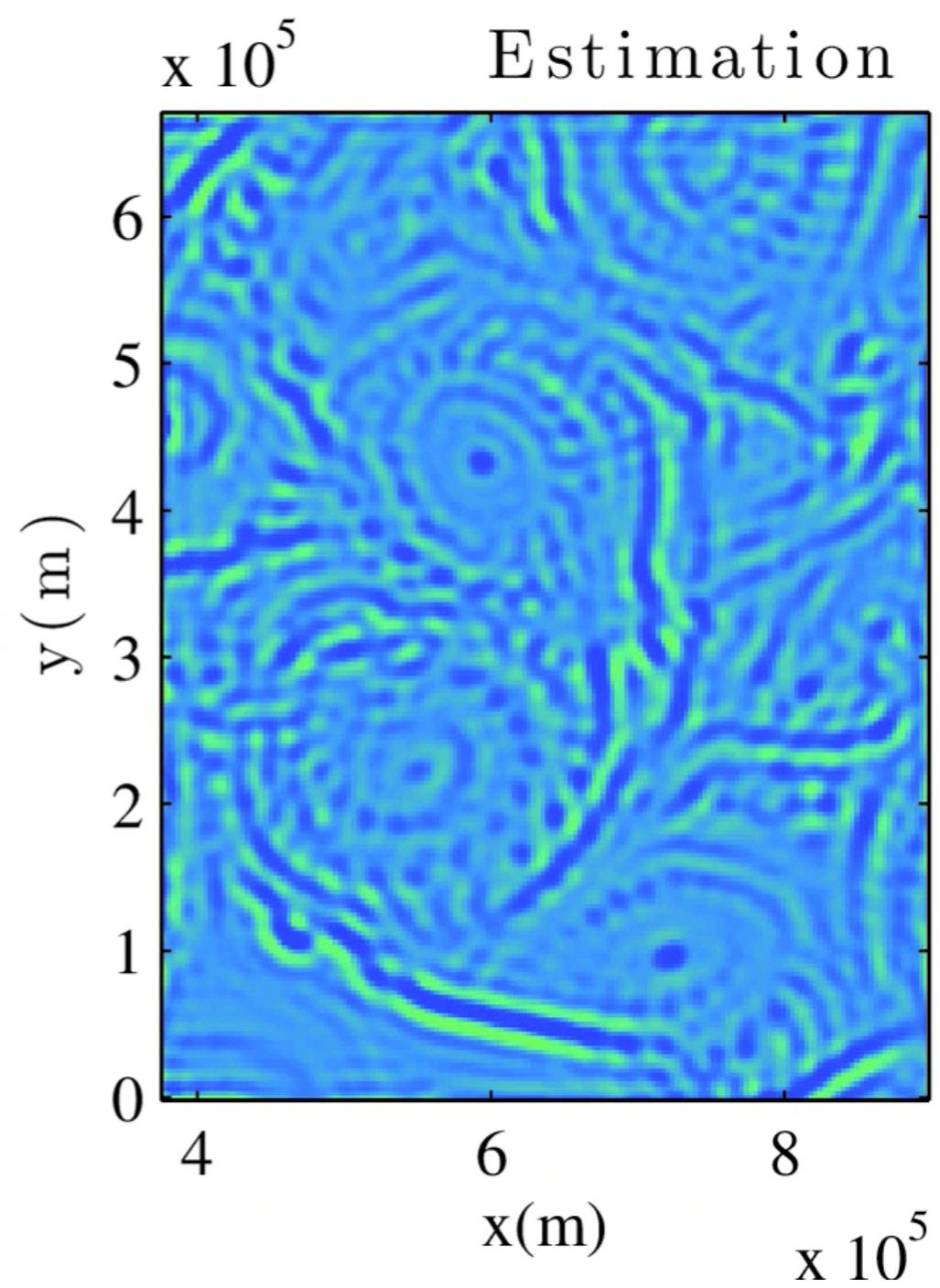
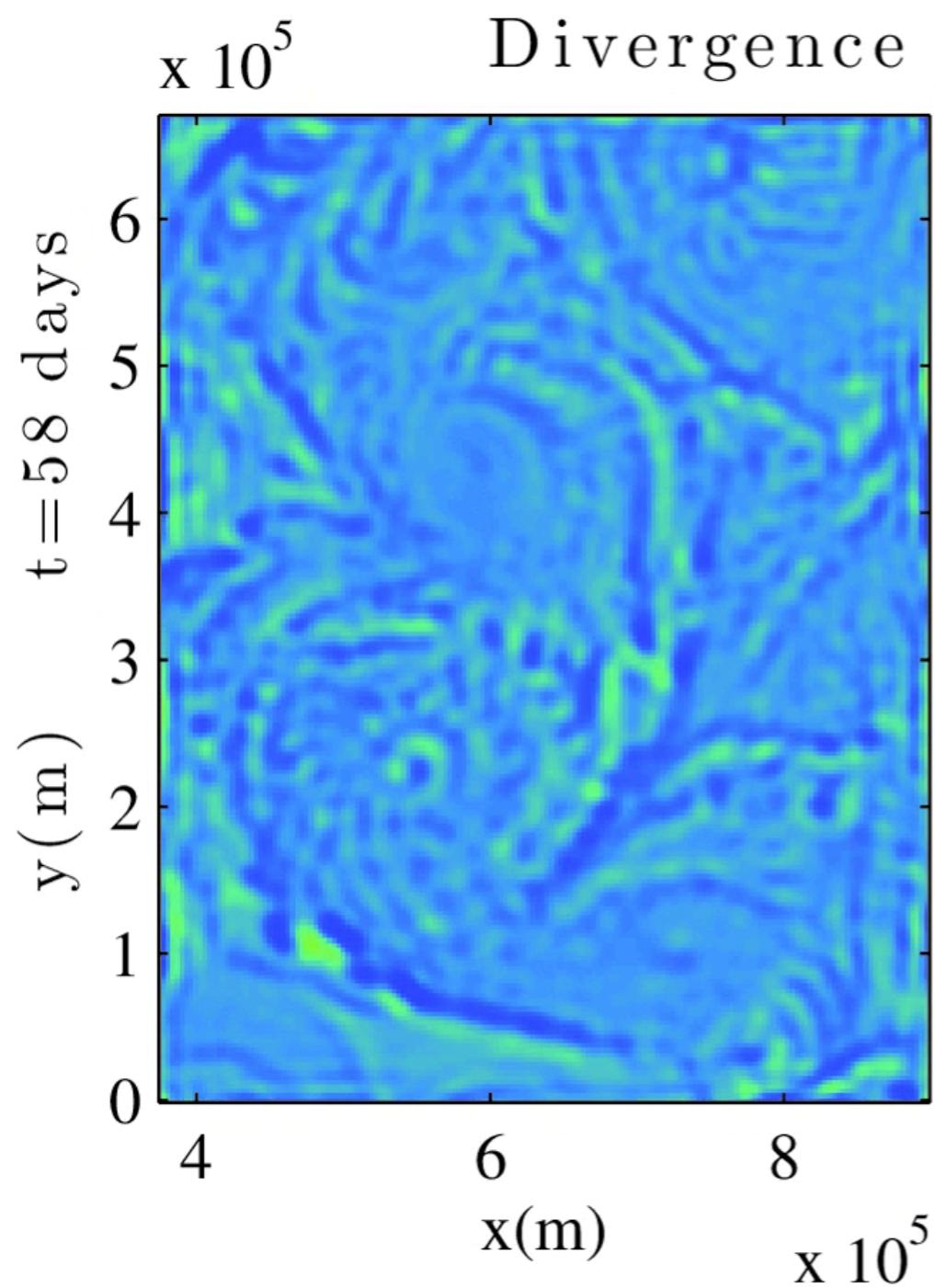
$$\nabla \cdot \mathbf{u} \propto \Delta \nabla^\perp \cdot \mathbf{u}$$

# 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

