



HAL
open science

Oceanic models under uncertainty

Valentin Resseguier, Etienne Mémin, Bertrand Chapron

► **To cite this version:**

Valentin Resseguier, Etienne Mémin, Bertrand Chapron. Oceanic models under uncertainty. CMG 2016 : 31st IUGG Conference on Mathematical Geophysics, Jun 2016, Paris, France. . hal-01377710

HAL Id: hal-01377710

<https://inria.hal.science/hal-01377710>

Submitted on 9 Nov 2016

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

OCEANIC MODELS UNDER UNCERTAINTY

Valentin Resseguier, Etienne Mémin, Bertrand Chapron



Motivations

- Rigorous identification of subgrid dynamics effects
- Taking into account likely small-scale dynamics (stochastic backscatter)
- Forecast of likely distinct scenarios

- Quantification of the dynamics errors:
 - Diagnostic for numerical simulations (mesh refinements, ...)
 - **Ensemble data assimilation and forecasts**

Transport under location uncertainty

Assumption:

Velocity decomposition: $v = w + \sigma \dot{B}$ with

w large-scale velocity
 $\sigma \dot{B}$ uncorrelated in time, divergence-free, correlated in space, Gaussian, inhomogeneous and anisotropic

From stochastic calculus theory, we proved:

$$\frac{D\theta}{Dt} = \partial_t \theta + w^* \cdot \nabla \theta + \sigma \dot{B} \cdot \nabla \theta - \nabla \cdot \left(\frac{1}{2} a \nabla \theta \right) = 0$$

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

$$a = \sigma \sigma^T$$

Drift correction

Multiplicative random forcing

Balanced energy exchanges

Systematic derivation of random models with the new $\frac{D}{Dt}$

Conservations (mass, linear momentum, ...)

Navier-Stokes

Boussinesq

Uncertainty

QG MU

SQG under Strong Uncertainty

Description

- QG assumption under strong uncertainty:
- kills the interior dynamics
 - creates horizontal velocity divergence
 - provides a diagnostic relation

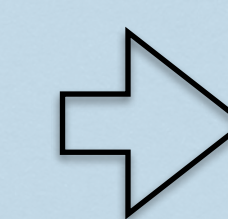
Modified geostrophic balance

Geostrophic balance

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

Horizontal Diffusion

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



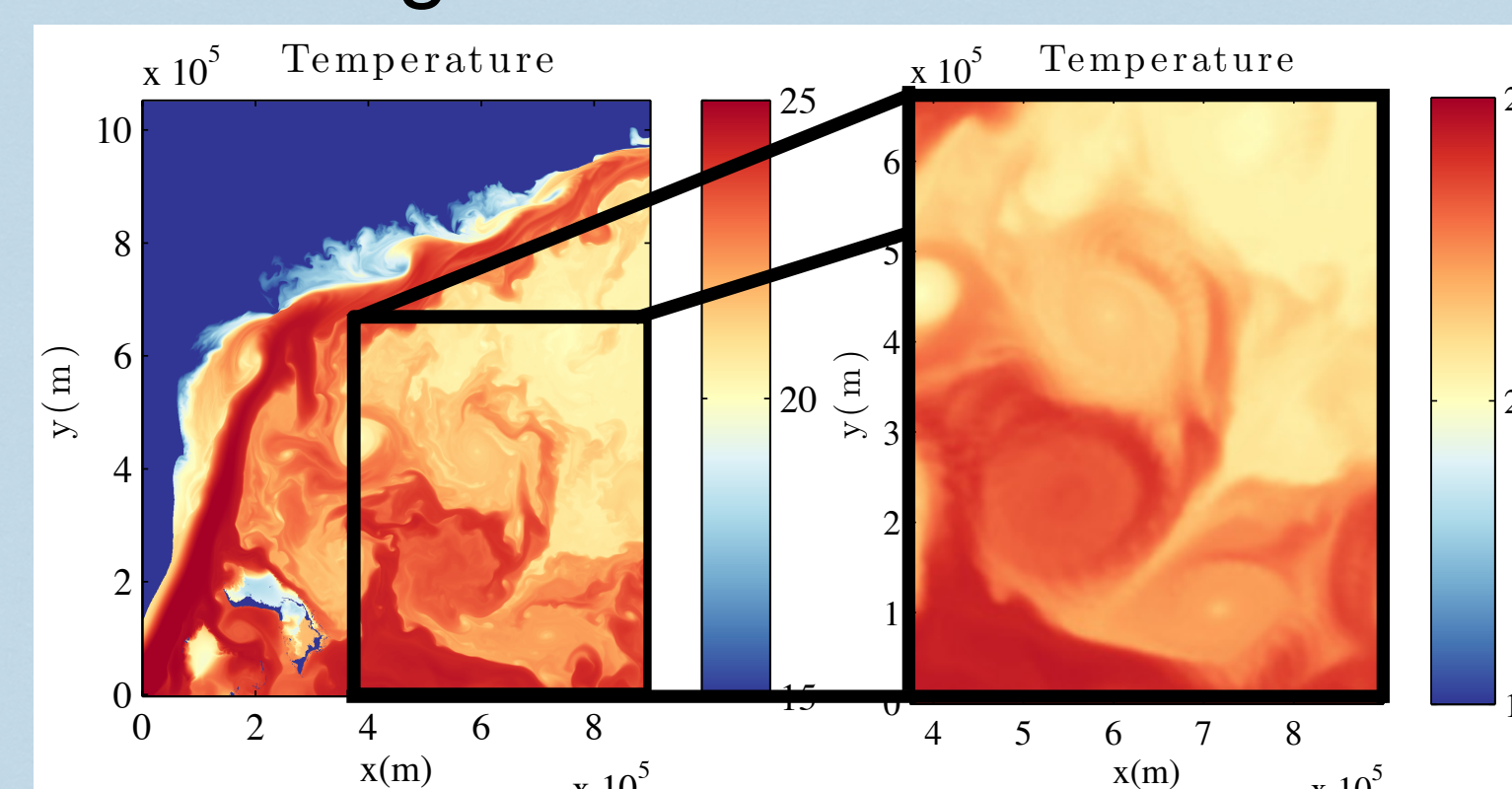
$$\nabla \cdot u \propto \Delta \nabla^\perp \cdot u$$

Testbed data:

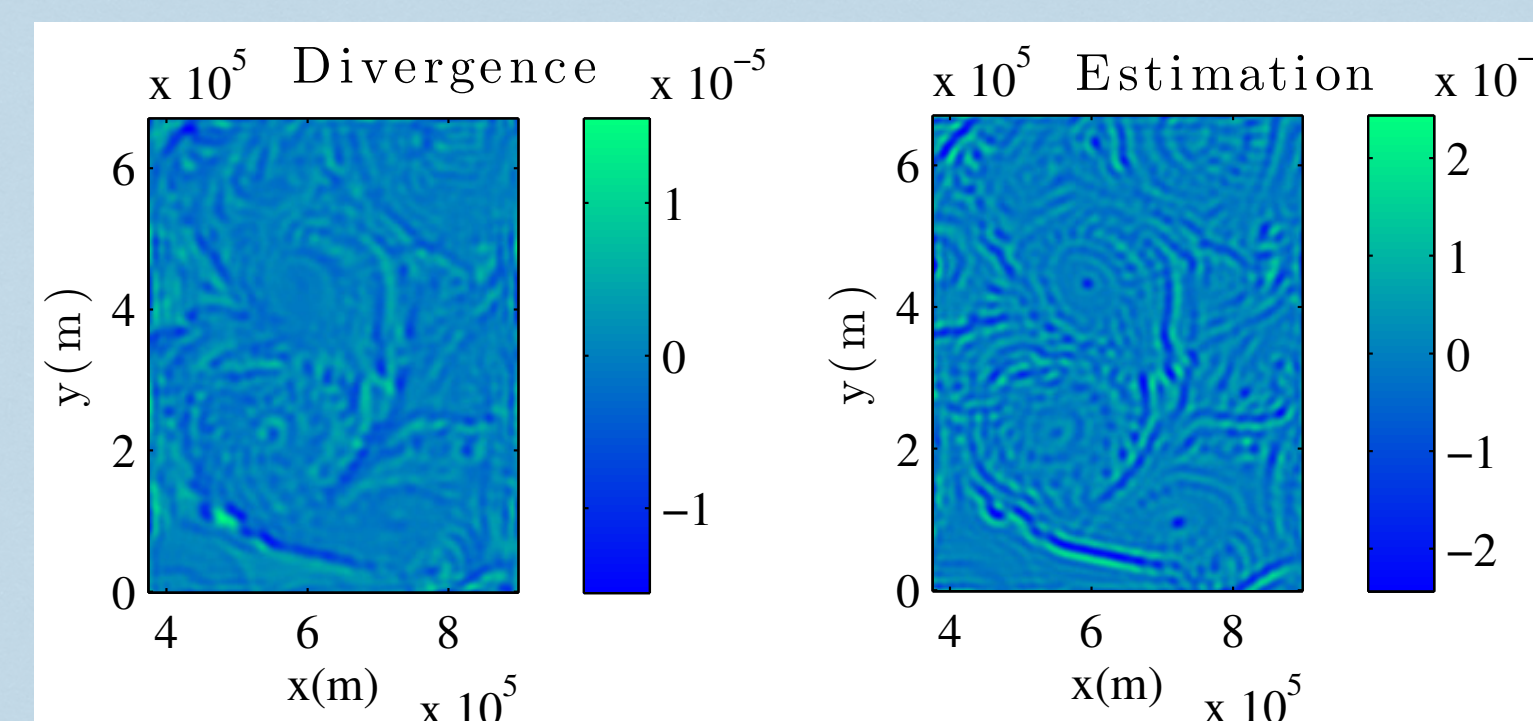
very high-resolution model outputs
 Gula, J., Molemaker, J., and McWilliams J.
 "Gulf Stream dynamics along the southeastern US seaboard."
Journal of Physical Oceanography 45.3 (2015): 690-715.

Original

Filtered



Results



Conclusion

- Frontolysis / frontogenesis on warm / cold side of fronts
- Estimation of horizontal divergence or diffusive coefficient and subgrid variance
- Strong uncertainty assumption verified *a posteriori* for the Gulf Stream during wintertime at mesoscales

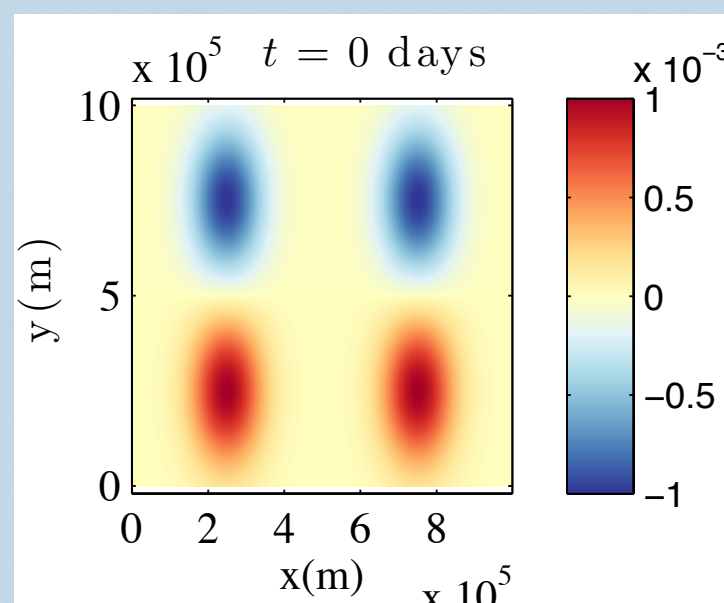
SQG under Moderate Uncertainty

Description

- Usual SQG relationship and transport under uncertainty of buoyancy
- Good illustration of our stochastic transport
- Simulations done with homogeneous small-scale velocity

One realization: better small-scale representation

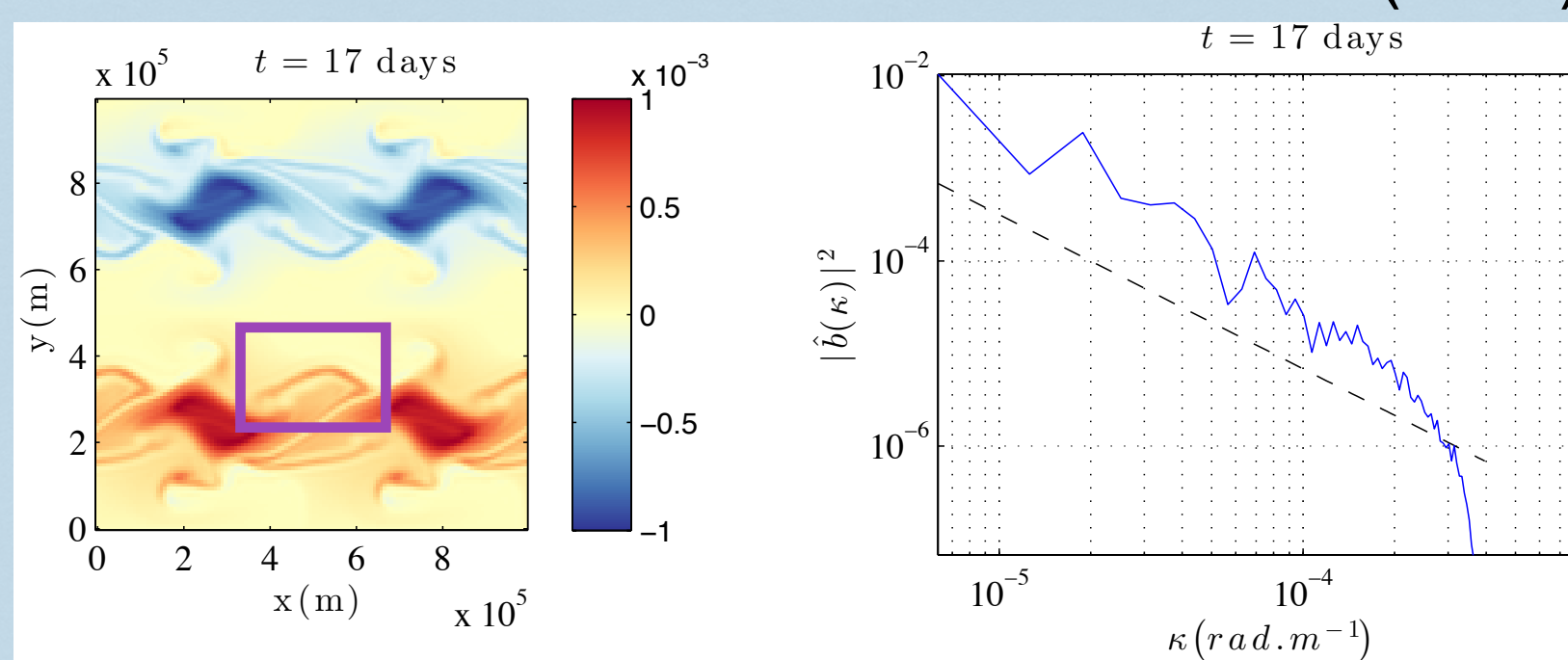
Initial condition



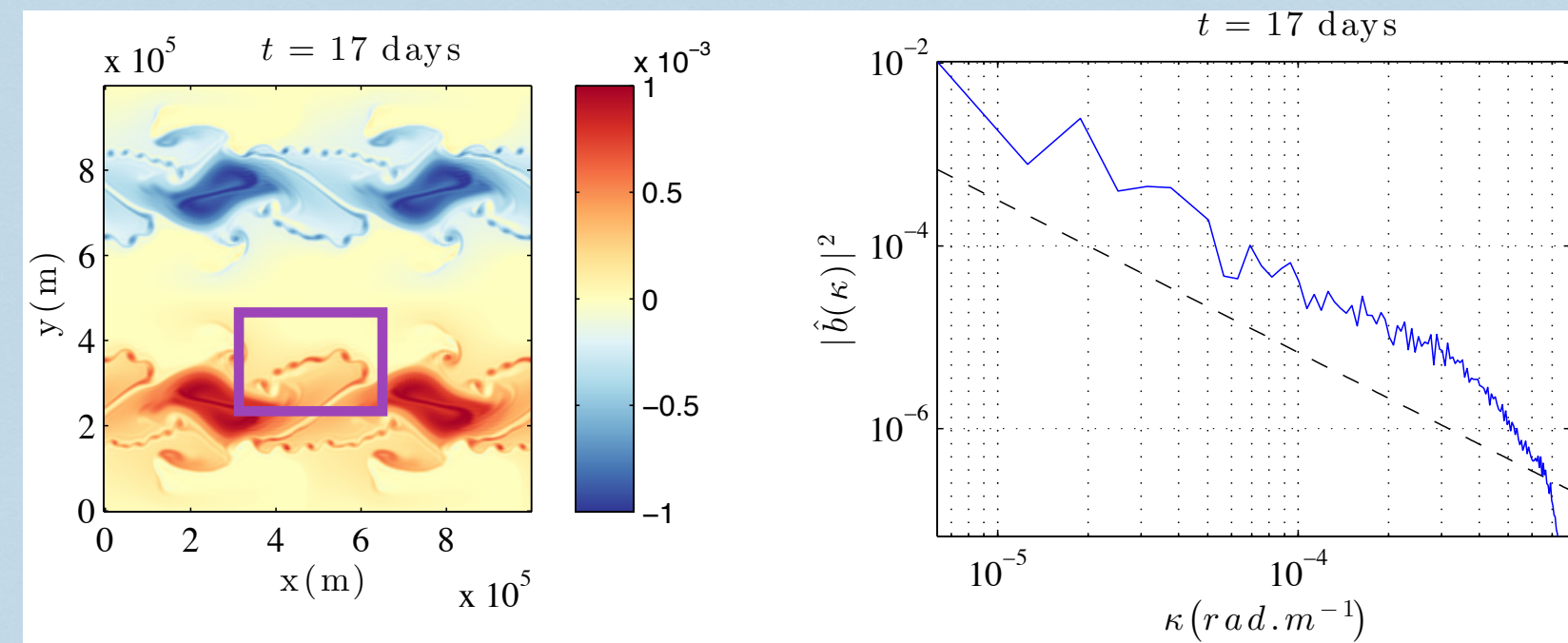
Spectrum of $w|_{t=0}$ and $\sigma \dot{B}$



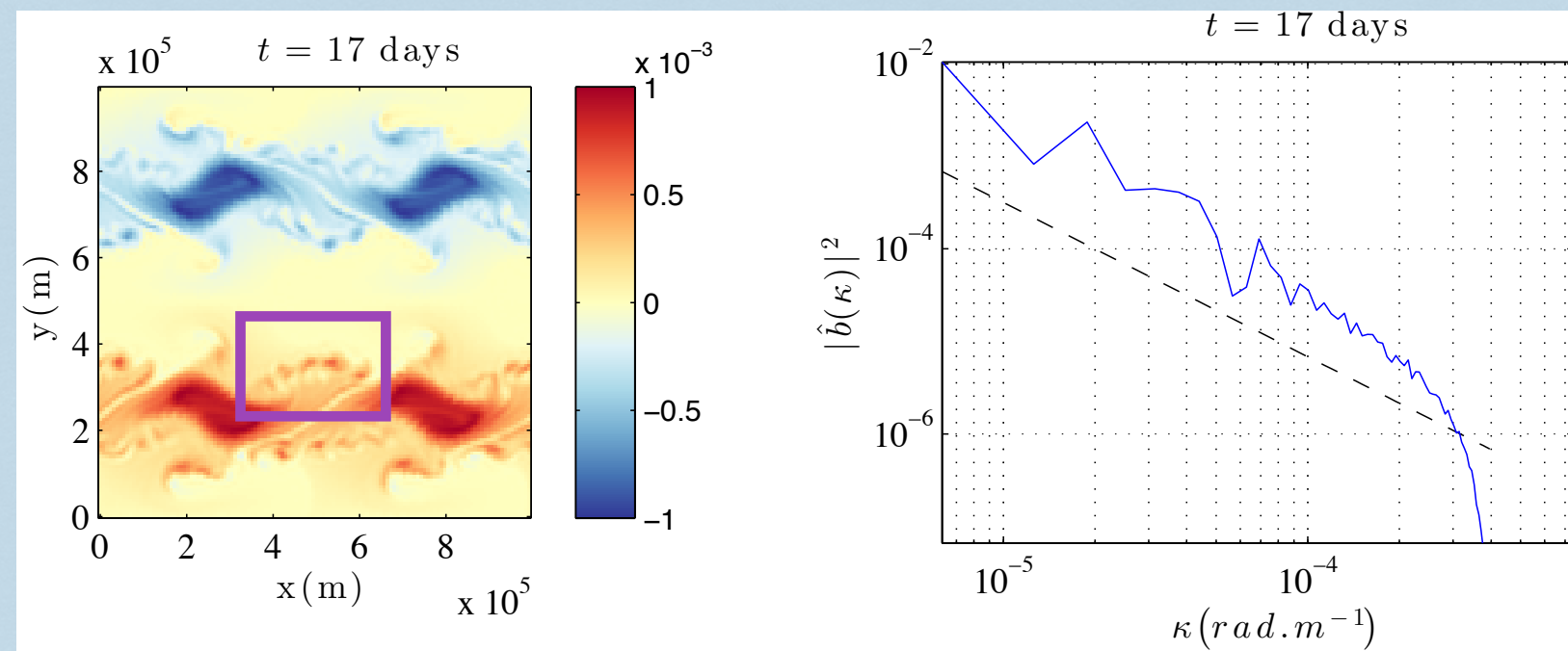
LR deterministic simulation (128²)



Reference: HR deterministic simulation (512²)

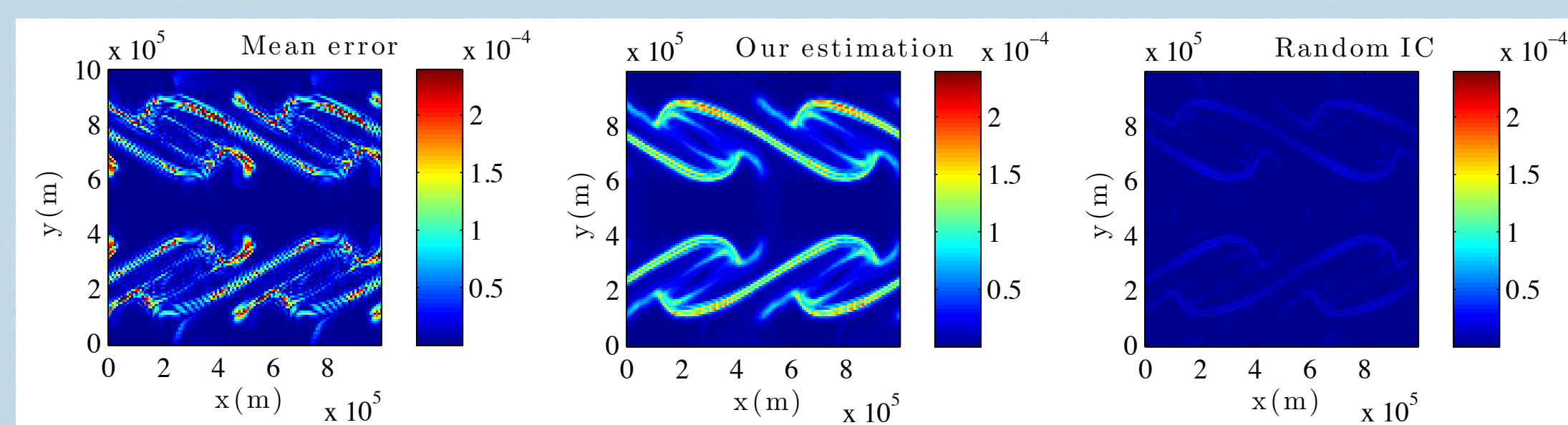


LR stochastic simulation (128²)

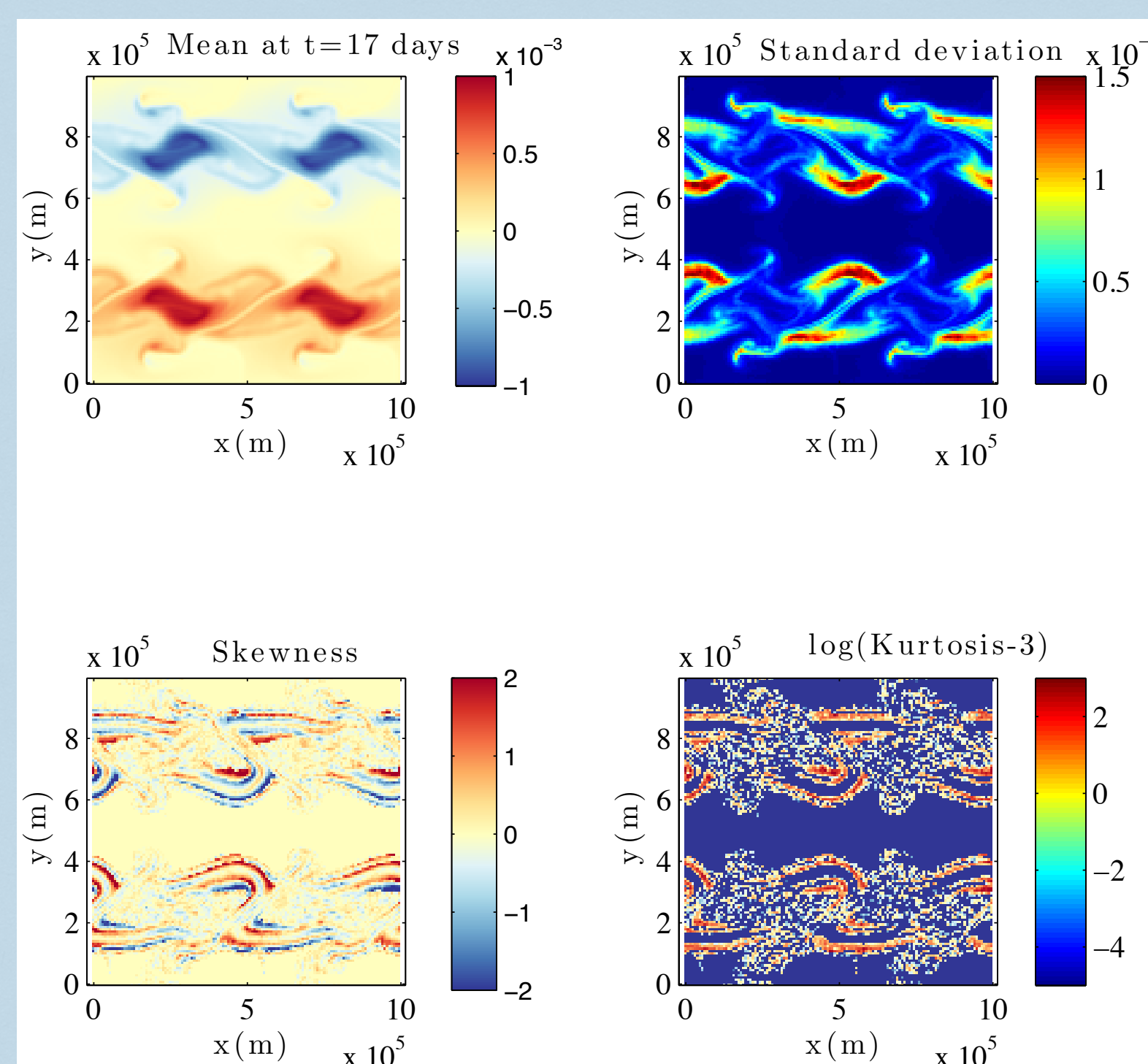


Ensemble of simulations

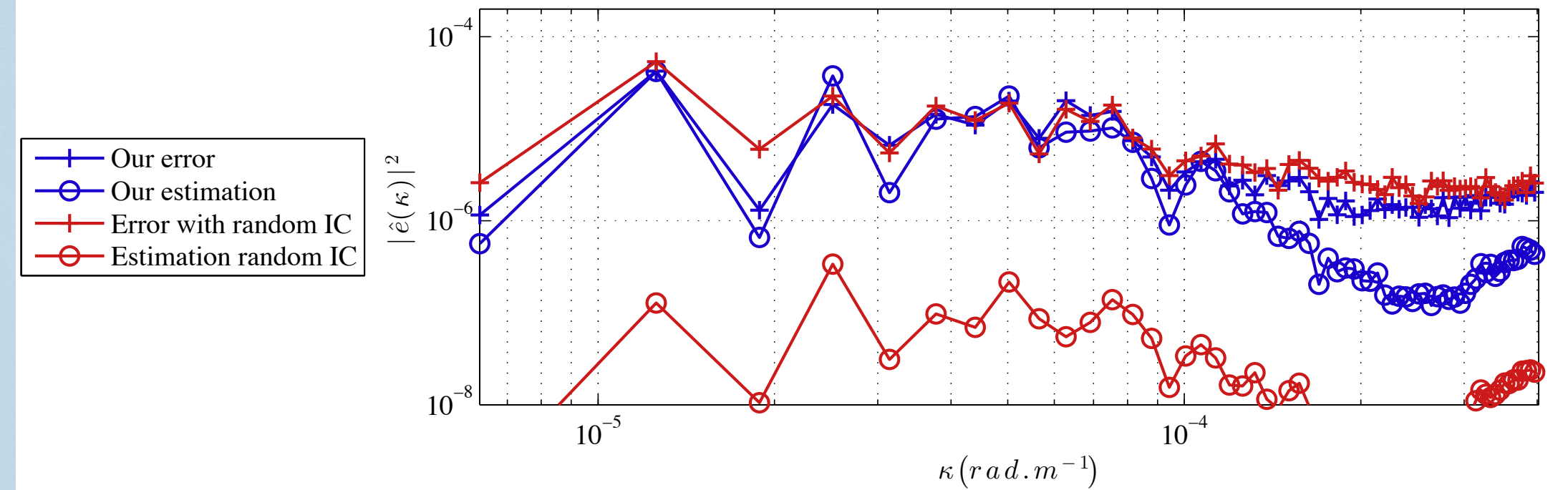
Errors estimation



Point-wise moments: variability, extreme events, ...



Spectrum of the errors and its estimation at t=13 days



Conclusion

- Random transport applicable to any dynamics
- Better representation of small scales
- Extreme events
- **Good errors estimation in location and amplitude**
- Likely scenarios

code available online: [link from Flumiance website](#) - V. Resseguier