Studying Tracer Diffusivity using Lagrangian Particles

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http://oceans11.lanl.gov/drupal/

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Motivation

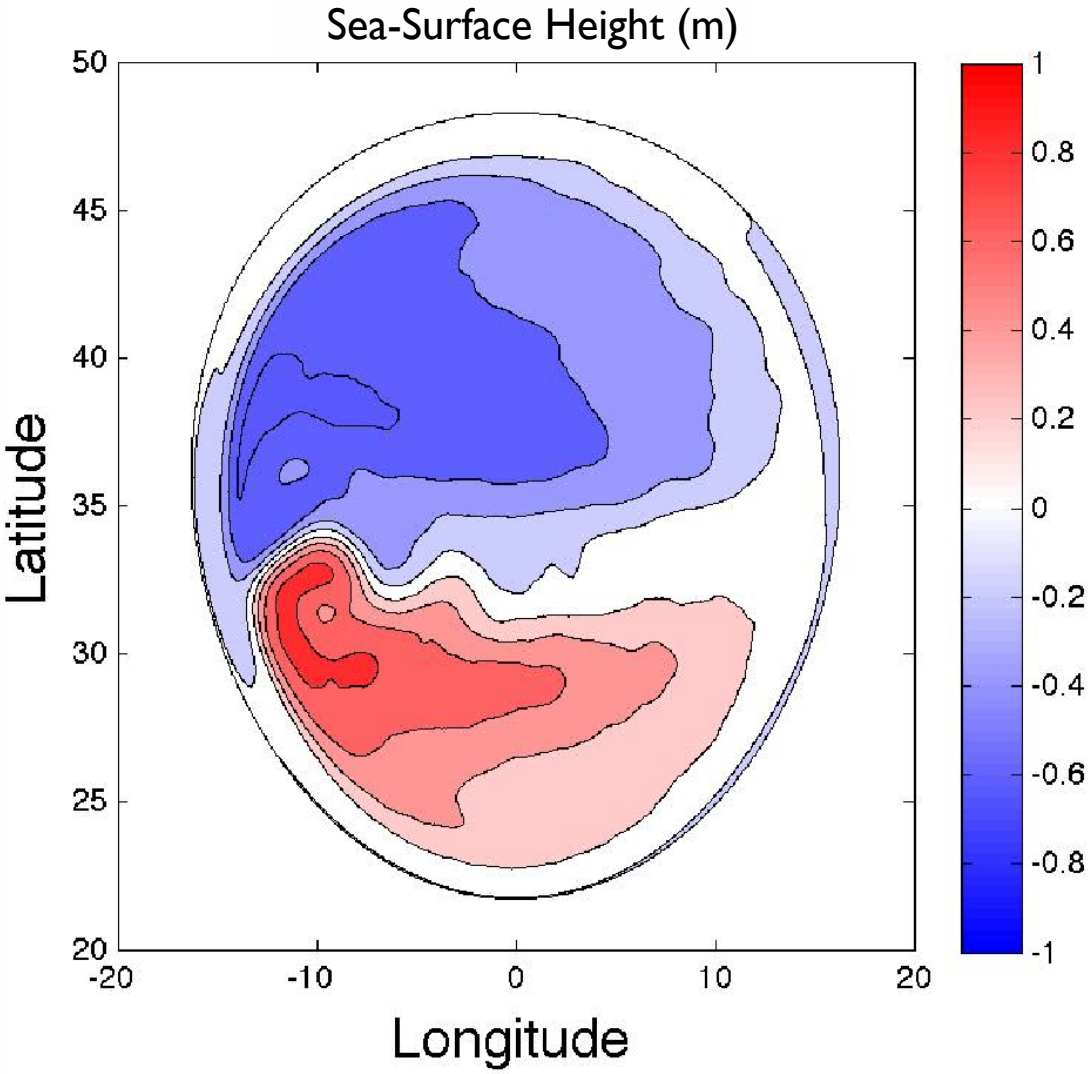
Why tracer diffusivity [κ]?

- Fundamental property of ocean circulation (observational estimates in progress)
- Isopycnal mixing key to ventilation of important climate system tracers:
  - Dynamically active tracers (temp, salinity)
  - Carbon and **B**io**G**eo**C**hemistry
- Strongly impacted by baroclinic eddies

Outline

1. SOMA: **S**imulating **O**cean **M**esoscale **A**ctivity
2. Diffusivity via **L**agrangian **P**article **T**racking
3. SOMA Diffusivity
   A. Numerics
      i) Resolution dependence
      ii) Filtering dependence
   B. Physics
      i) Eddy velocity scale dependence
      ii) Eddy length scale dependence
4. Summary

Dynamics of the SOMA wind-driven double gyre system



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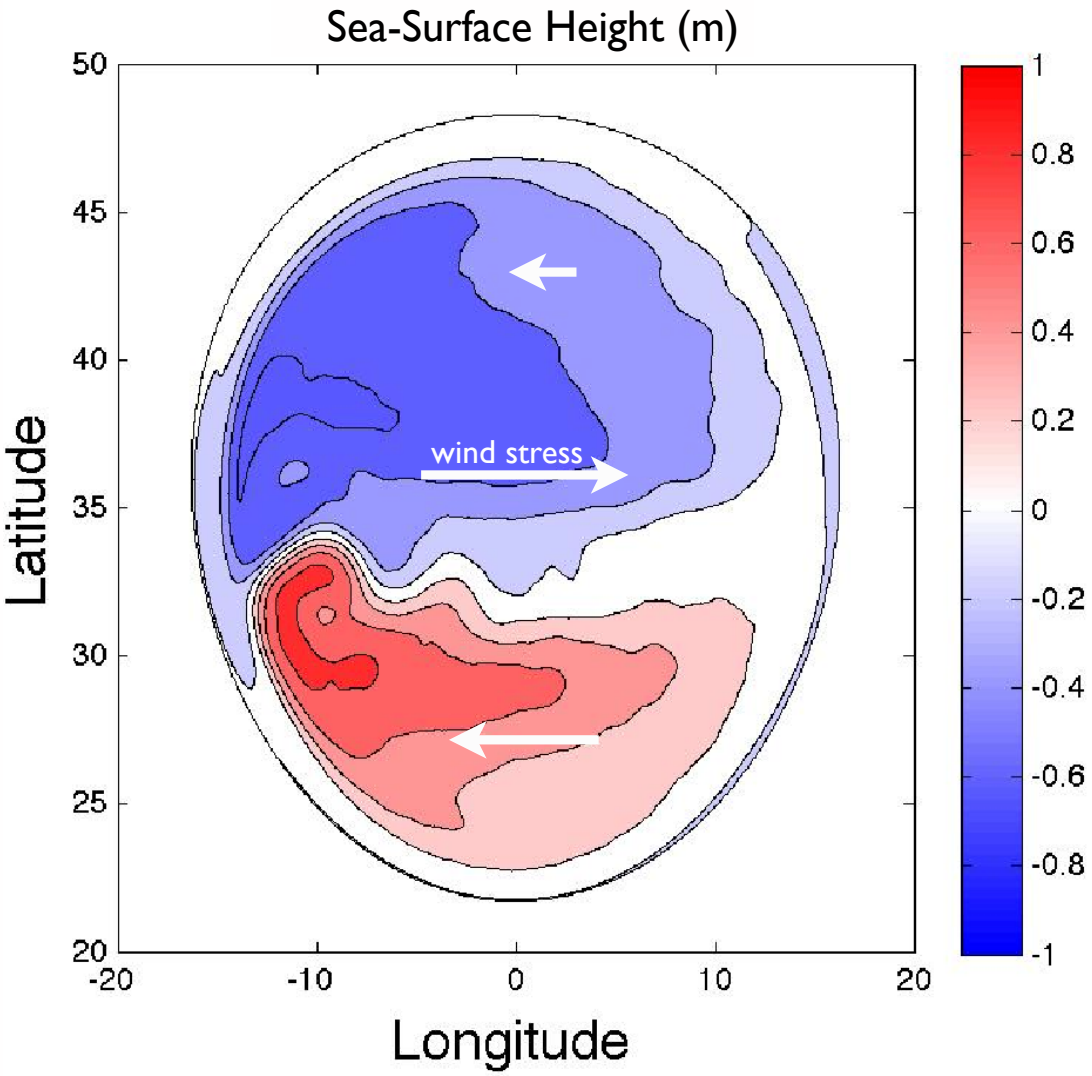

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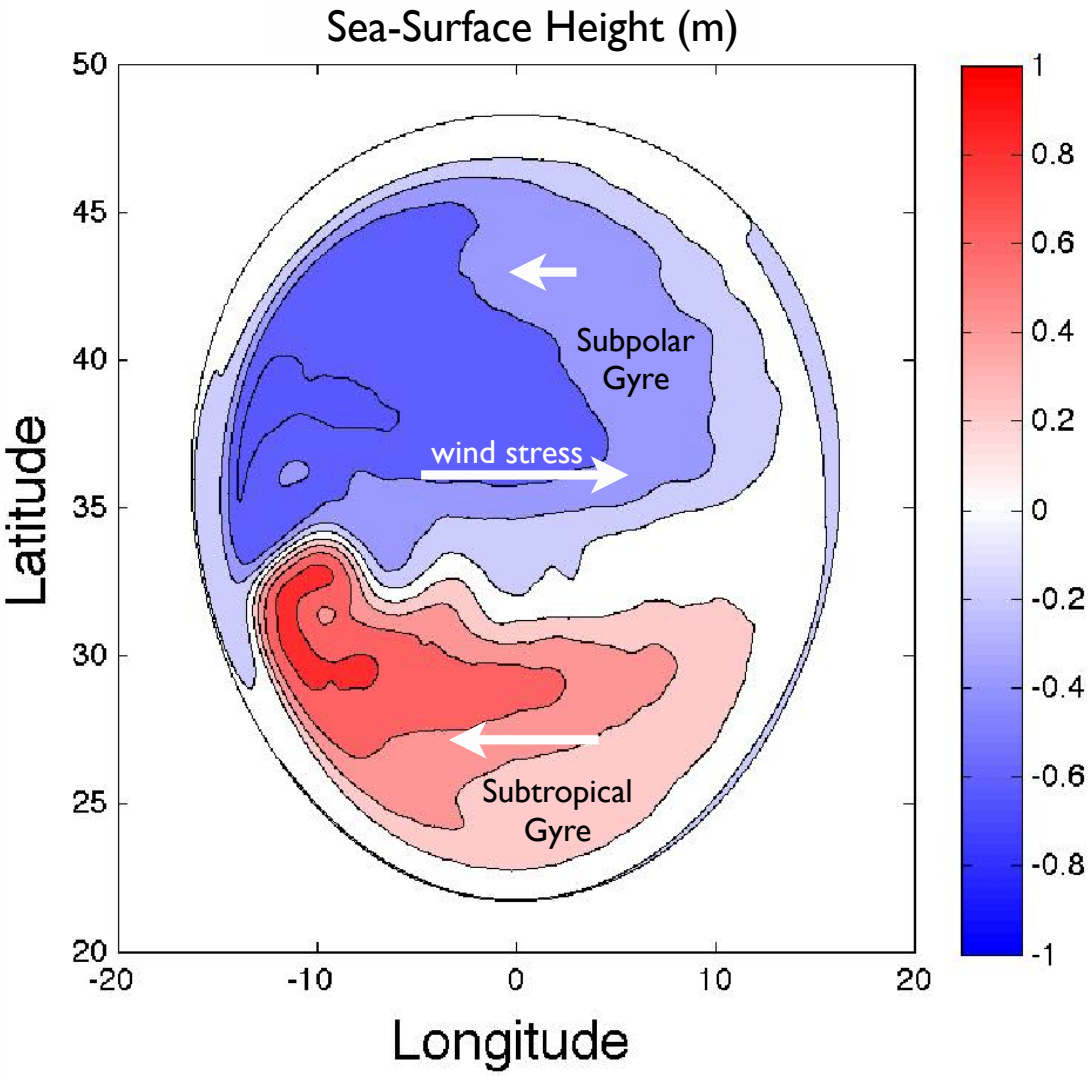

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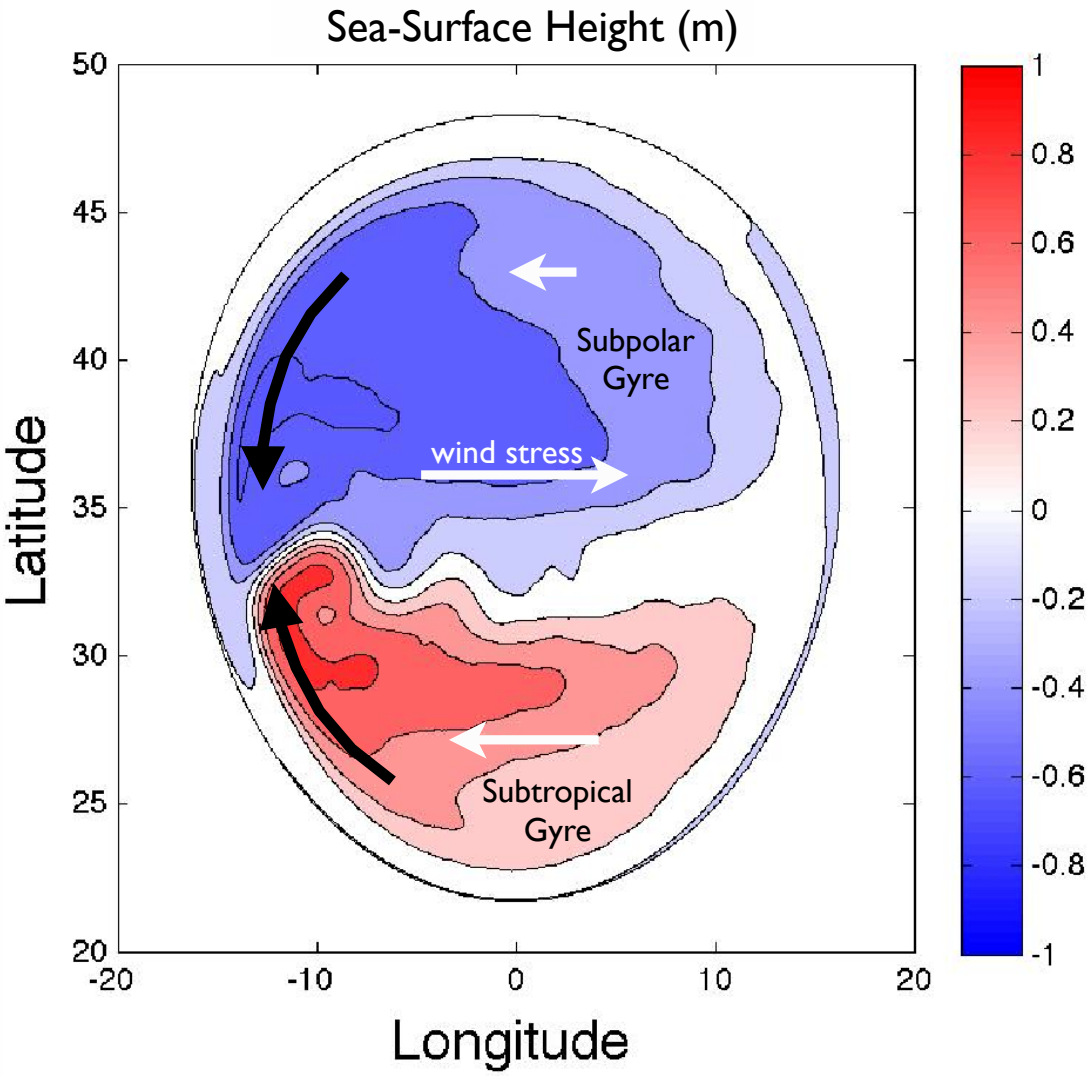

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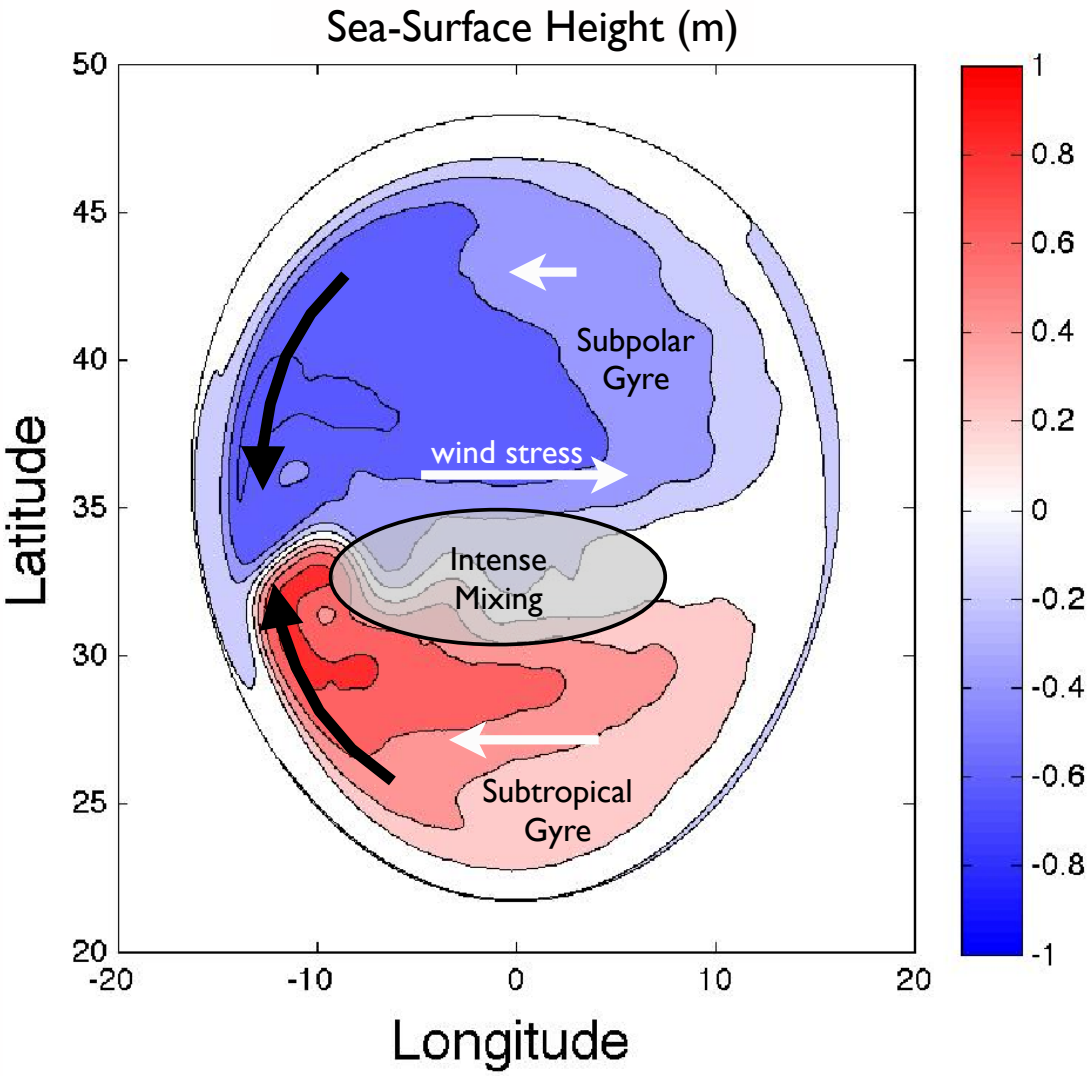
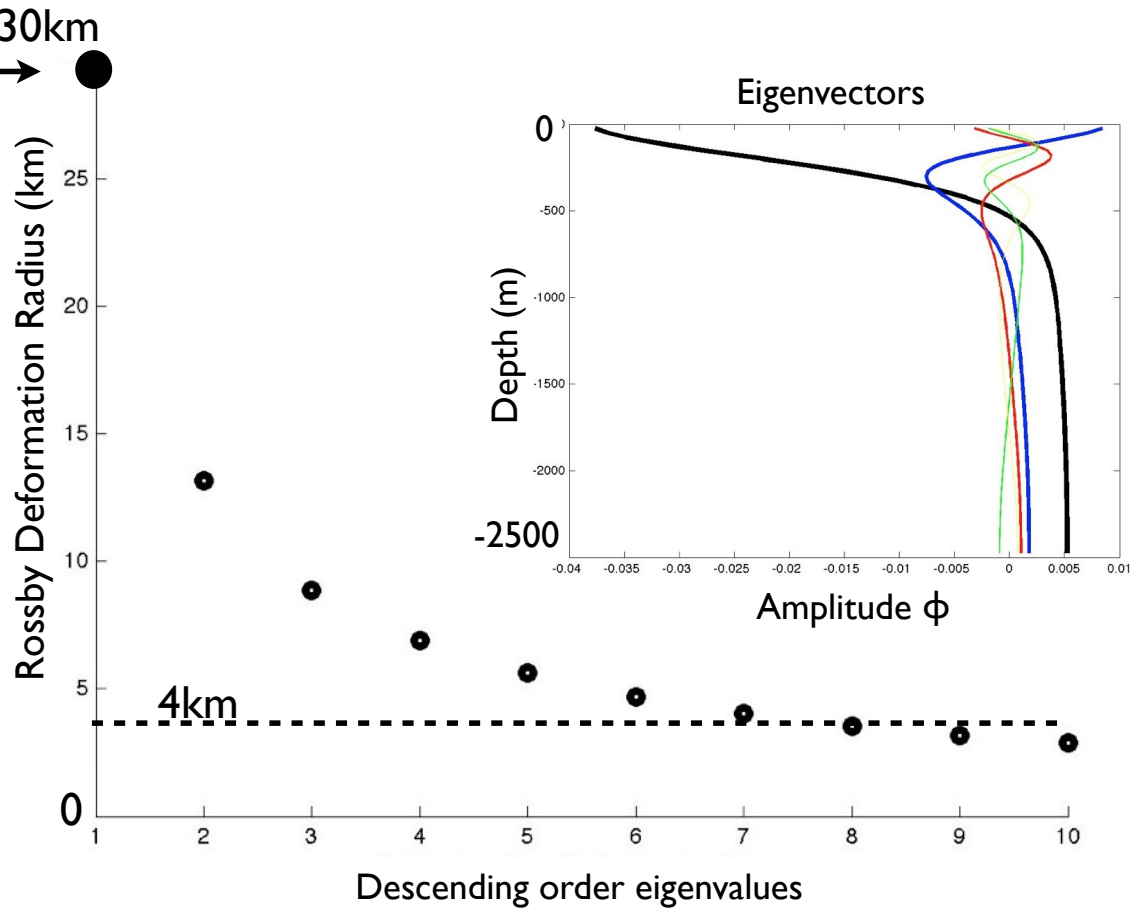


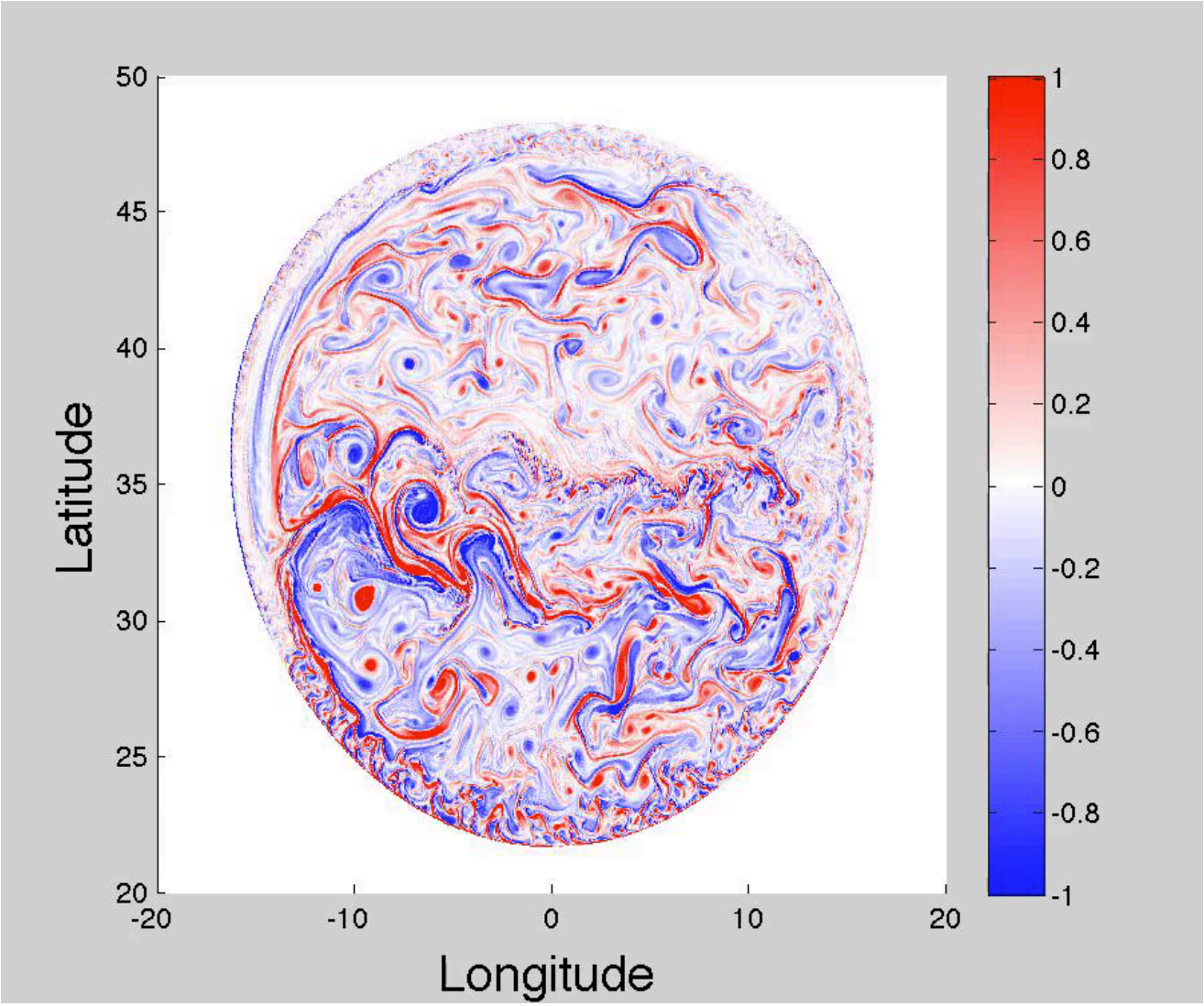
SOMA: Rossby radius of deformation spectrum

Characteristic scale for baroclinic instability



MPAS-O: 4 km grid resolution

Relative vorticity at 100 m depth with one frame every 15 days.

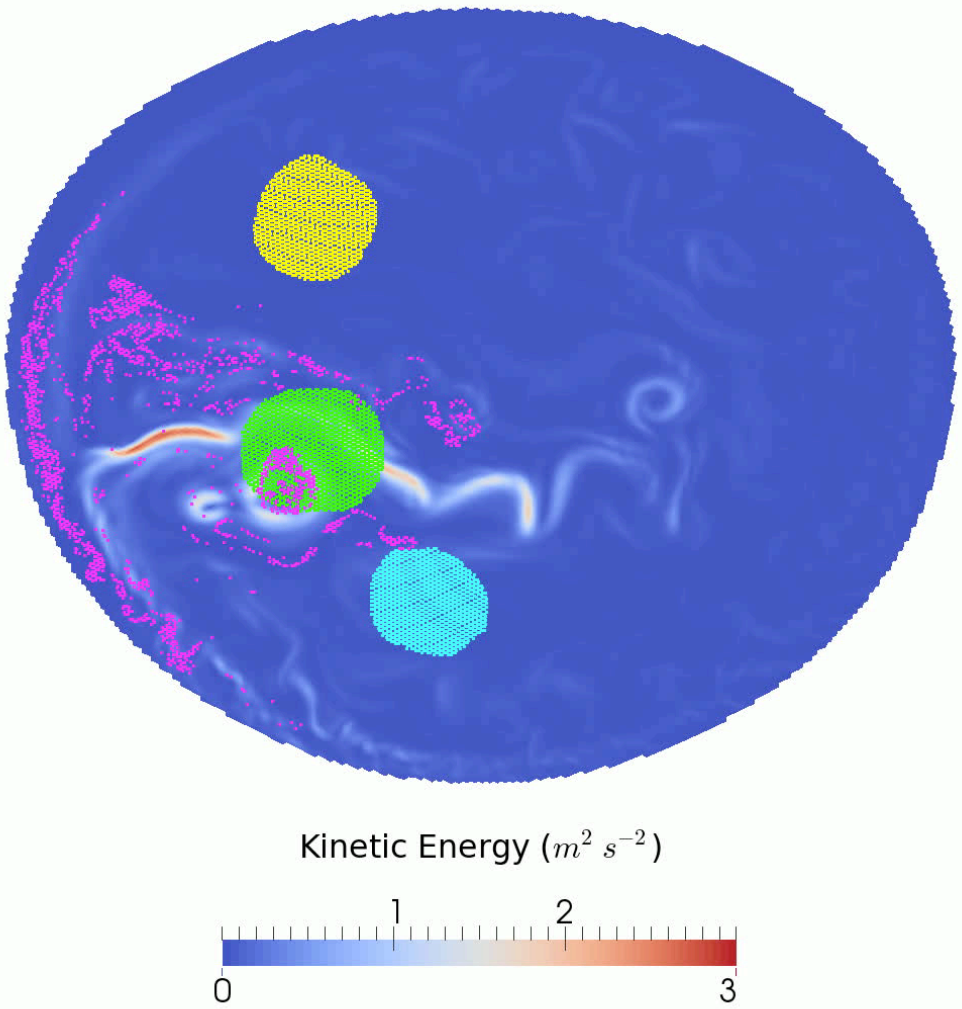


movie here: https://www.dropbox.com/s/q2unhxi51rpz243/SOMA_4km.mov

LPT cluster mixing

Each frame represents a day of simulation

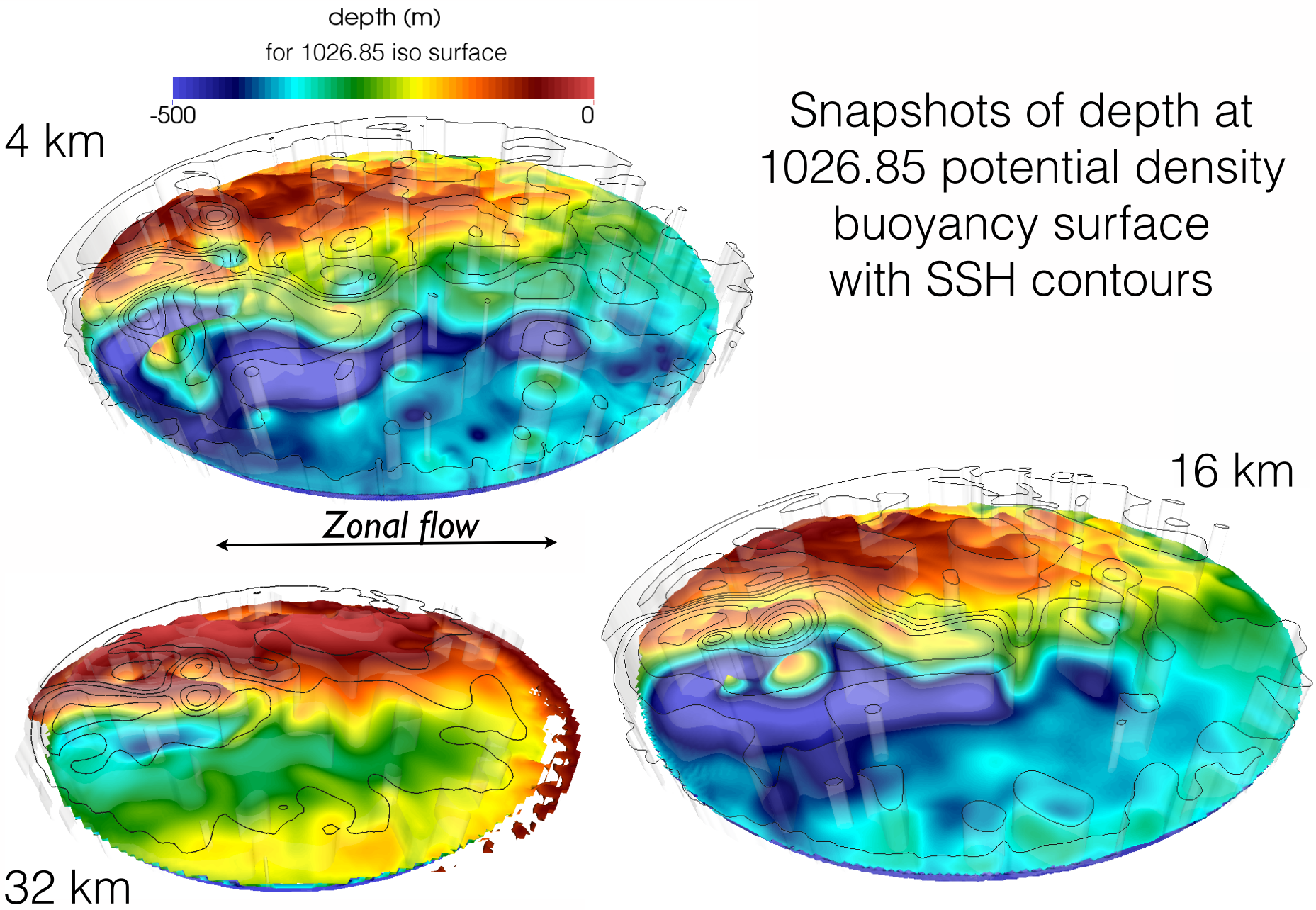
LPT cluster mixing



Each frame represents a day of simulation

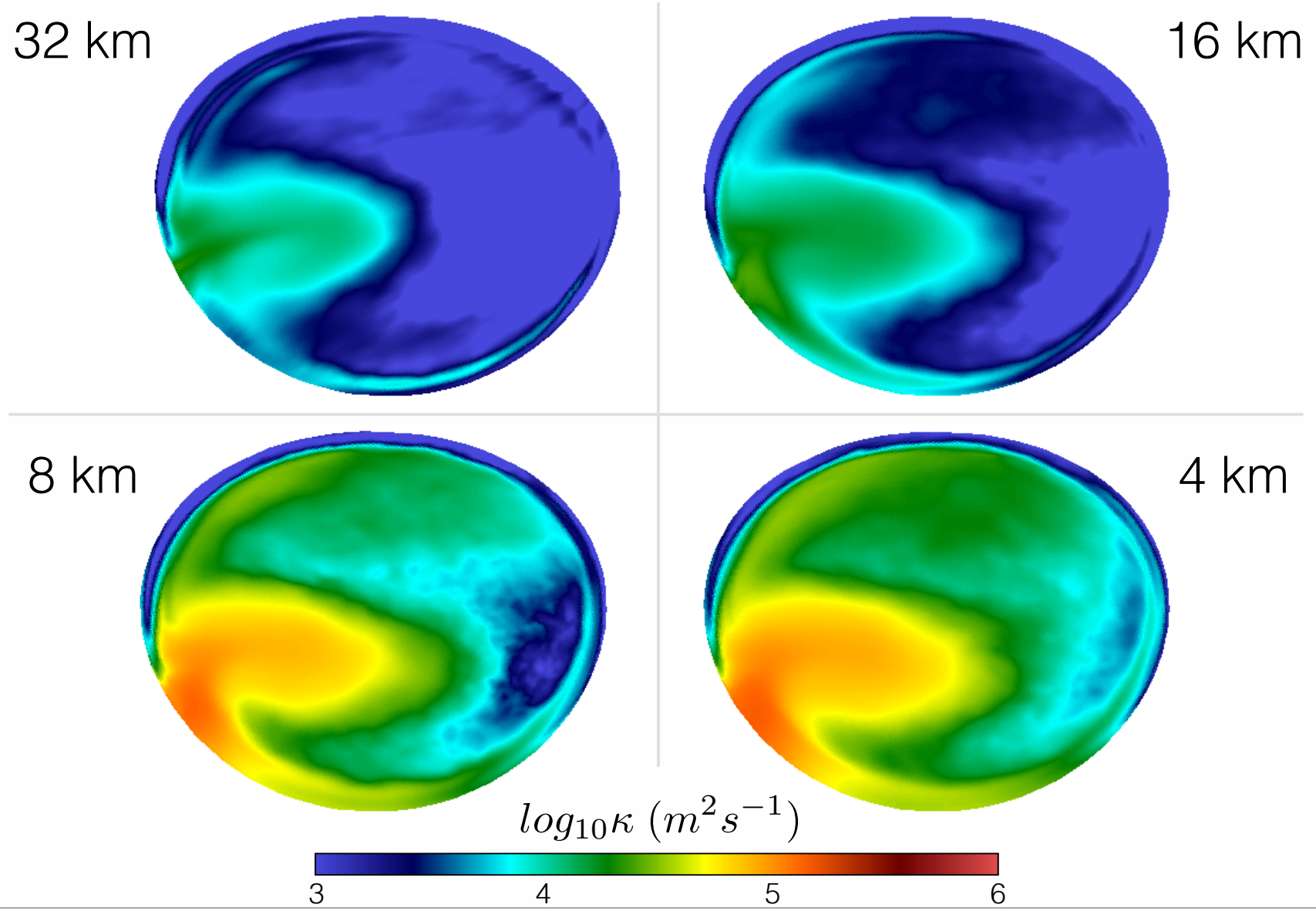
Experimental design

- *in situ* HPC Lagrangian particle tracking
- Particles seeded in clusters, and along 1026.85 potential density surface
- Ensemble of 30 LPT realizations with diffusivity computed as mean time-rate of change of cluster dispersion tensor (covariance) from 30 - 60 days
- 4km, 8km, 16km, and 32km grids
  (30km Rossby radius is dominant scale)
- Filter widths of $2\Delta x$ and $4\Delta x$ utilized
  (8km - $4\Delta x$ approx. grid scale of 32km)

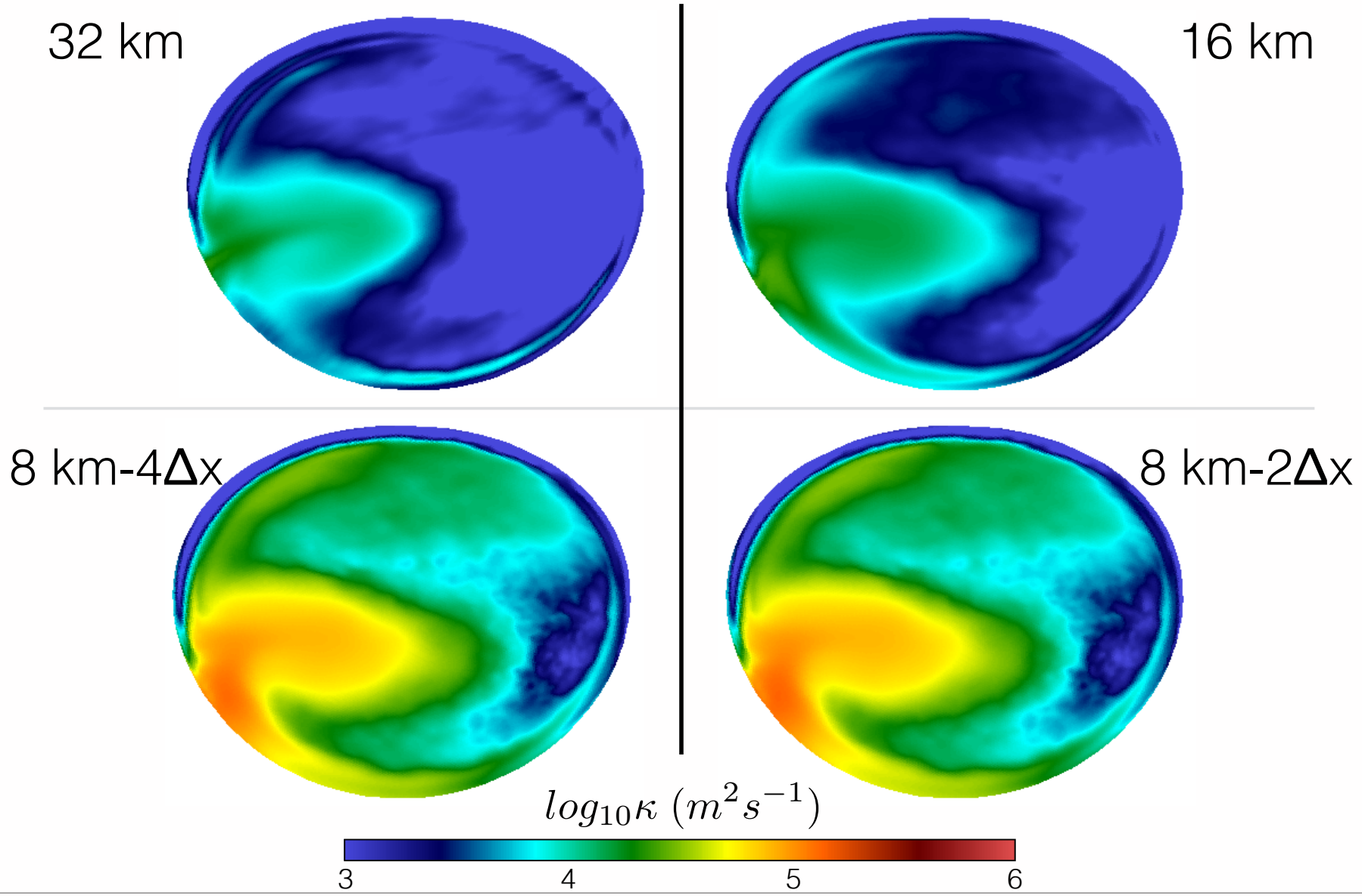


Snapshots of depth at 1026.85 potential density buoyancy surface with SSH contours

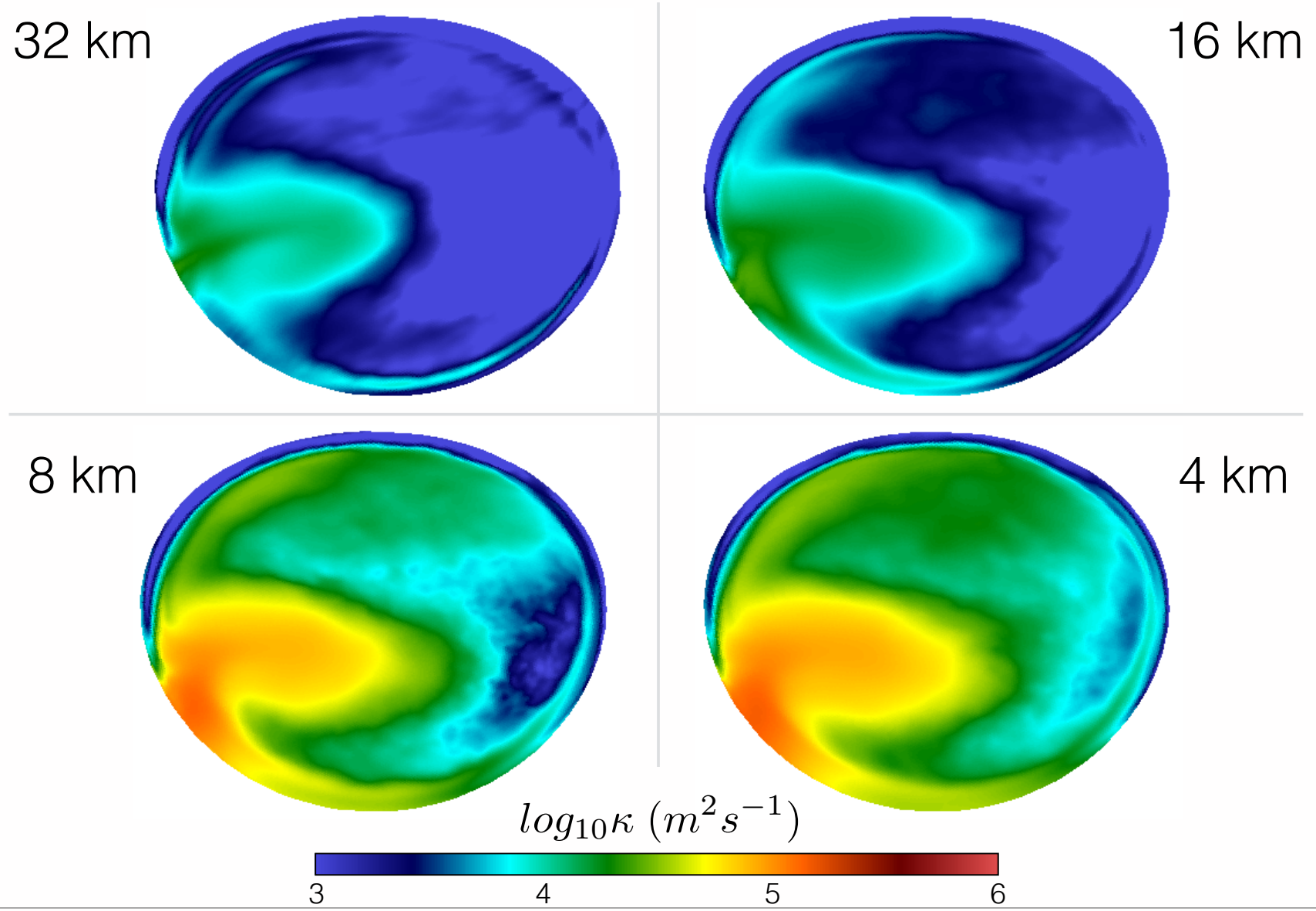
Diffusivity dependence on model resolution



Diffusivity dependence on filter scales



Diffusivity dependence on model resolution



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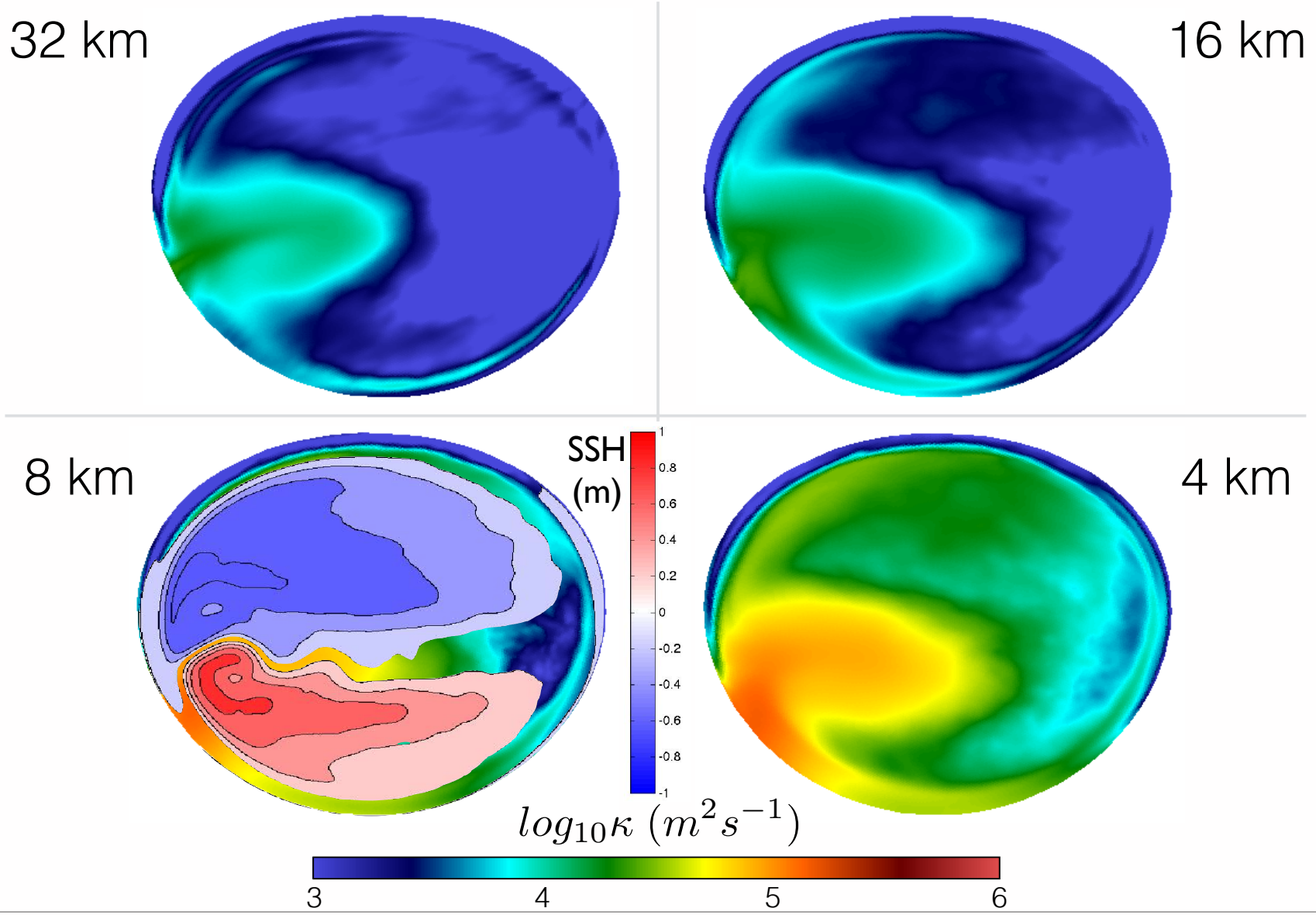

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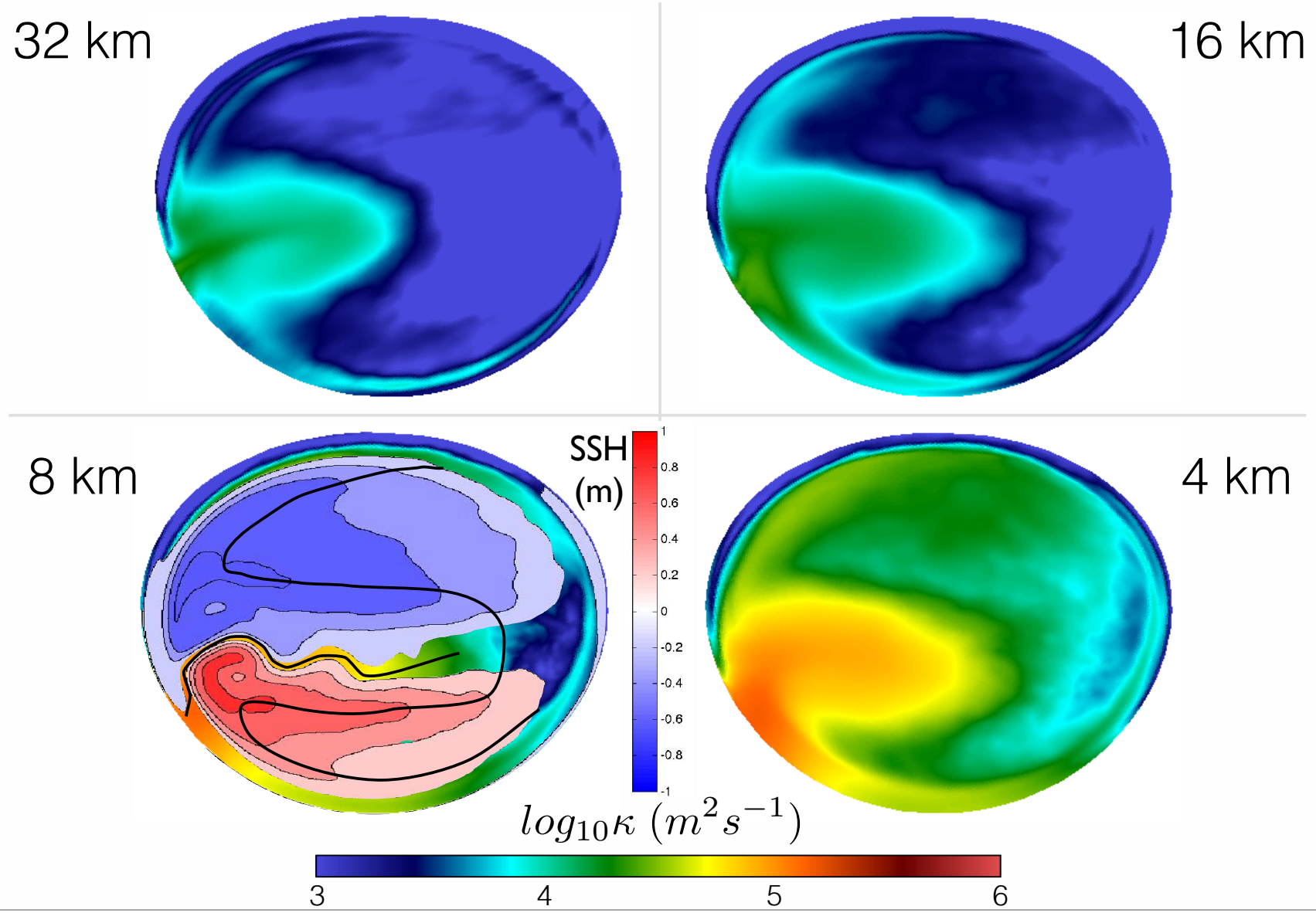

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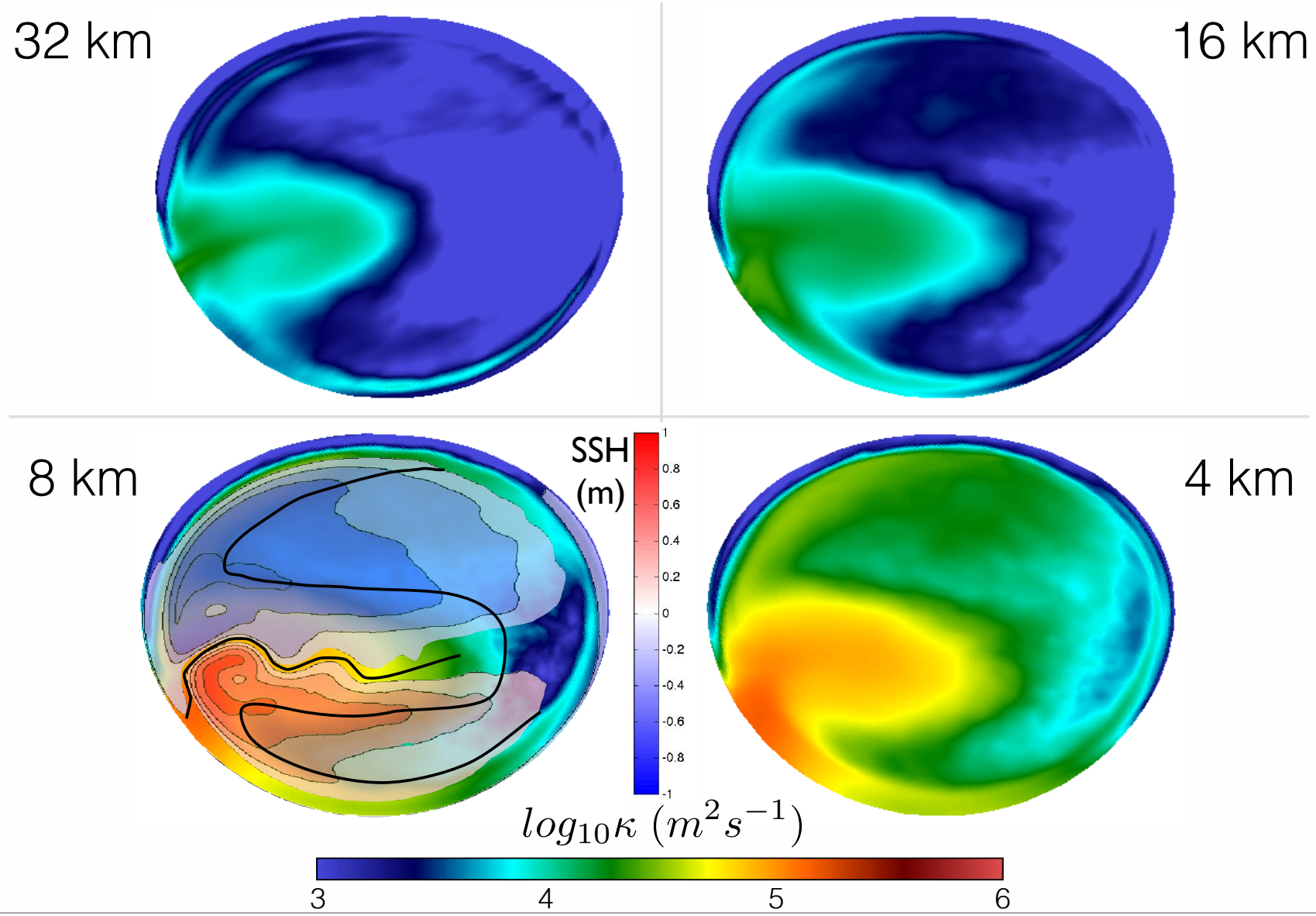

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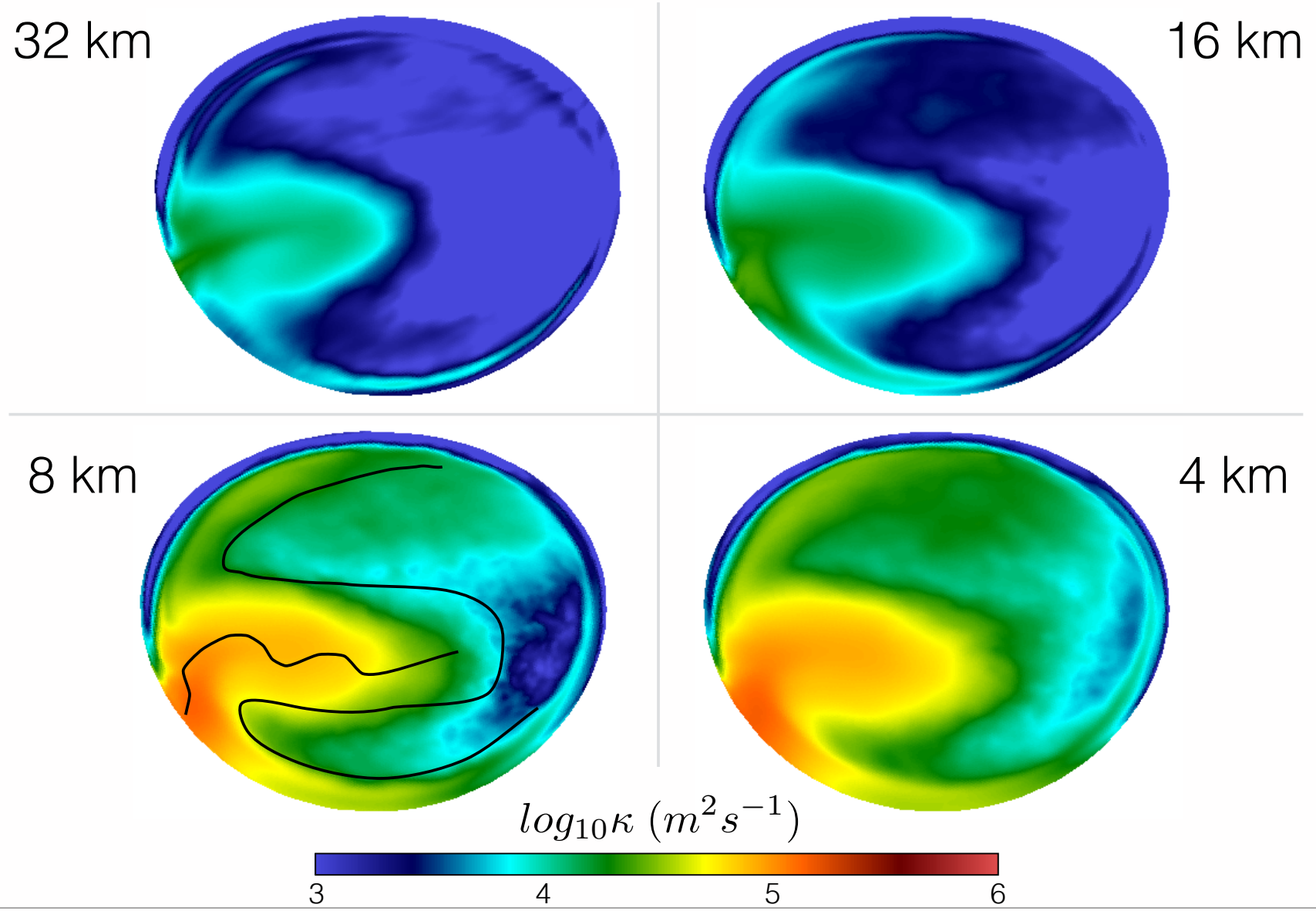
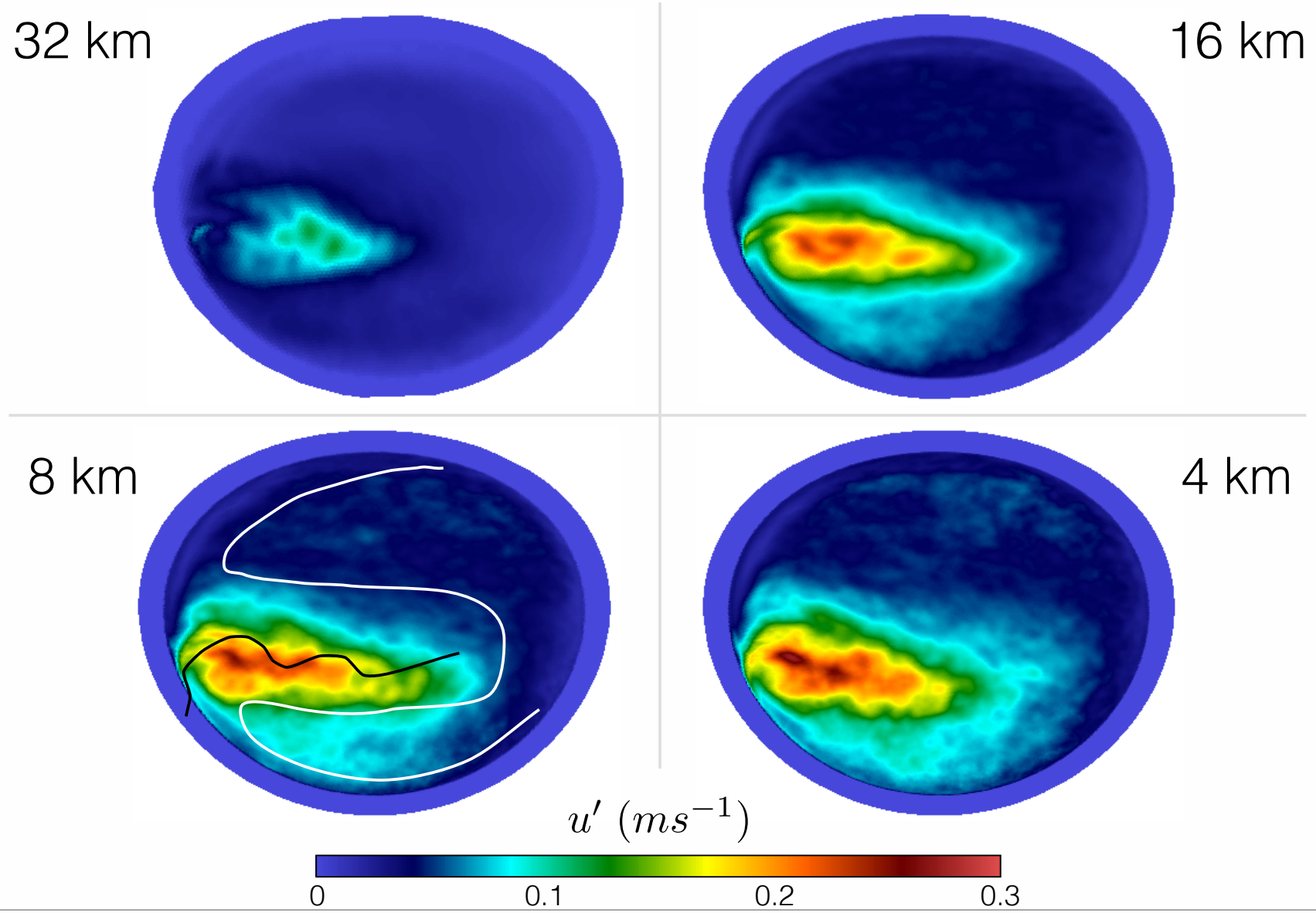
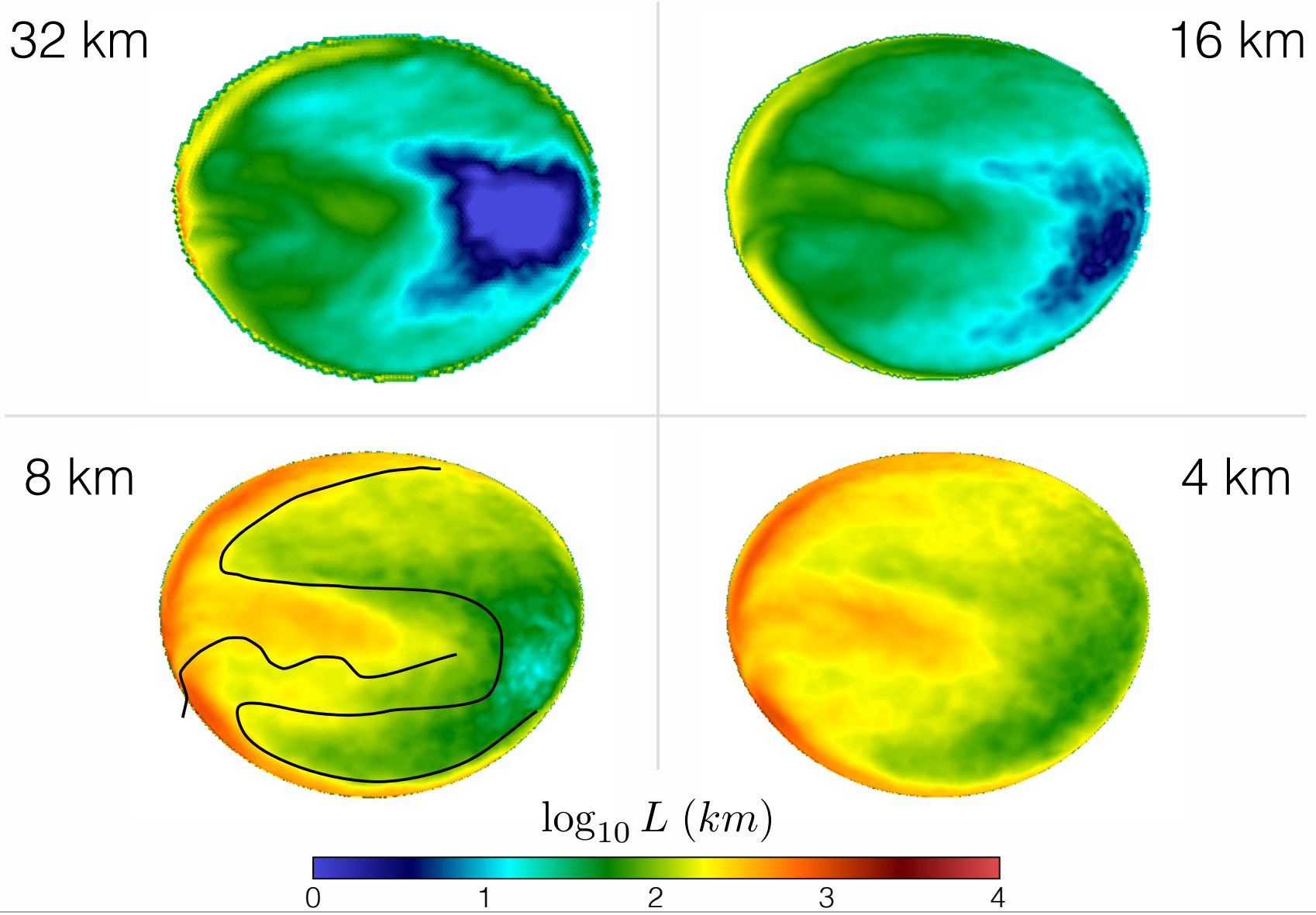


Characteristic eddy velocity scale at depth of 291 m



Characteristic eddy length scale at depth of 291 m

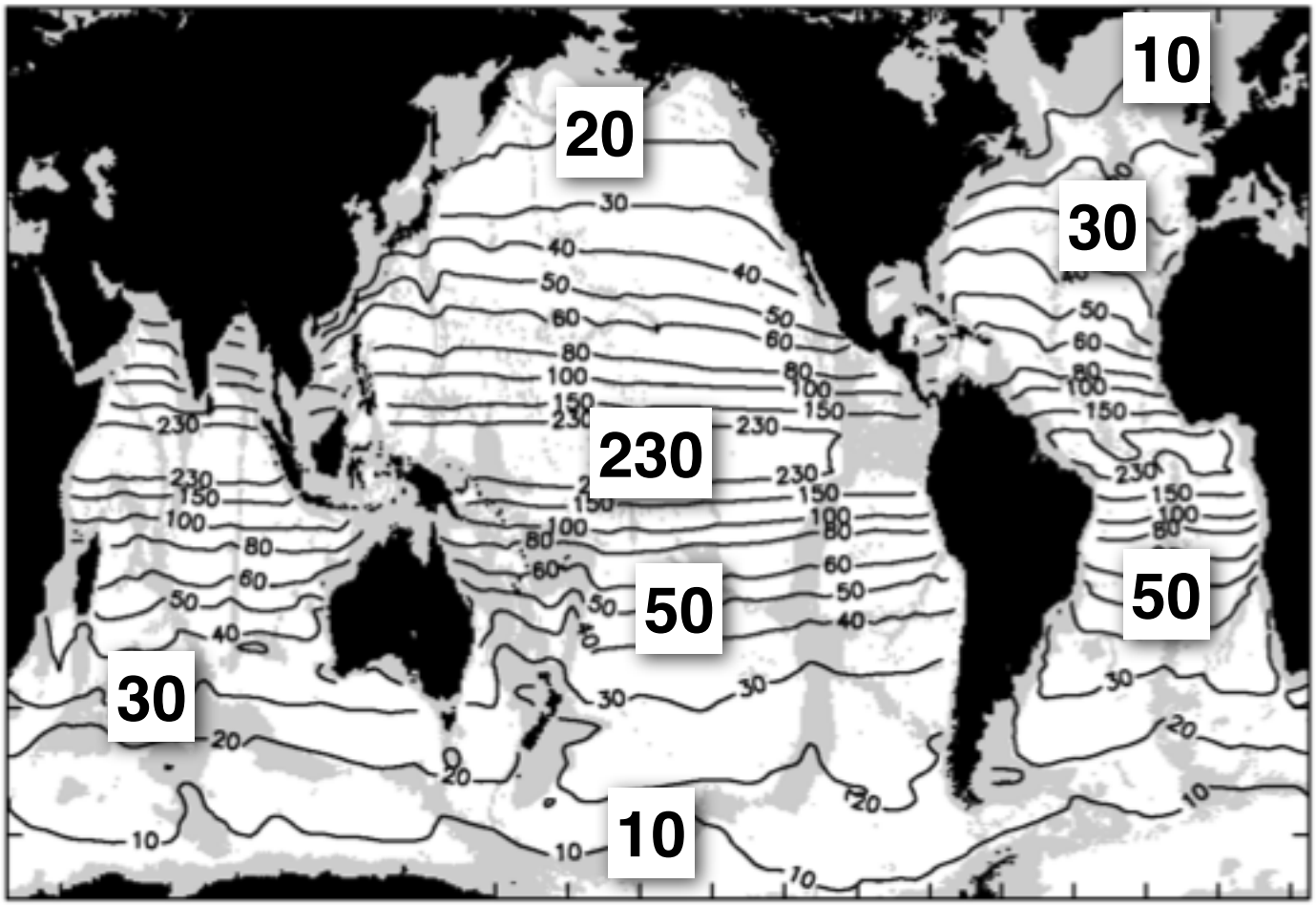


Summary

- LPT capable of measuring diffusivity of fluid
- Diffusivity strongly dependent on grid resolution
- Eddy velocity scale and EKE increase with resolution
- Diffusivity weakly dependent on filters
  - Resolution response overwhelms filter response
  - Primary mixing occurring at scales larger than Rossby radius ($L_m \gtrsim 10\ L_d$)
  - Diffusivity region located in valley of mean SSH
- Rossby radius of deformation must be adequately resolved to simulate tracer diffusivity for baroclinic eddies

$$\Delta x \leq \frac{L_d}{4}$$

First Rossby deformation radius (km) in global ocean



Chelton et al. (1998)

$$\Delta x \leq \frac{L_d}{4}$$

Questions & comments?