

Lagrangian Statistics in the tropical South Atlantic

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Motivation

- Quantifying Lagrangian dispersion caused by submesoscale processes
- What is submesoscale?
 - ~1-10km horizontal length scale
 - ageostrophic, increased vertical velocities and dispersion
- Mesoscale ~30-100km
- Tropical South Atlantic:
 - not dominated by energetic dynamics and mesoscale features and seasonality of wind stress allows deepening of mixed layer and increase in available potential energy that can be dissipated through submesoscale instabilities

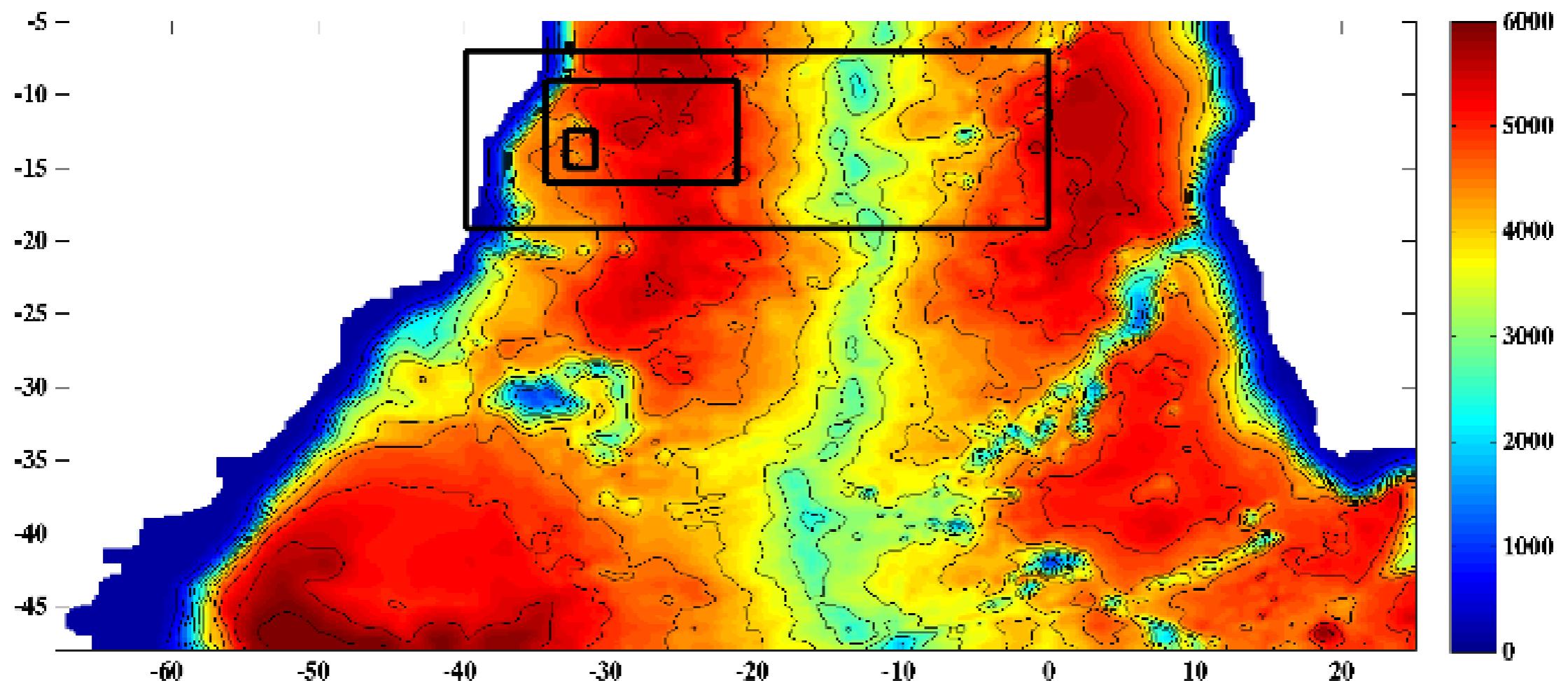
Model Setup and Results

- ROMS-AGRIF (Regional Oceanic Modelling System-Adaptive Grid Refinement in FORTRAN) - IRD version
- Free-surface, primitive equation, hydrostatic, with terrain-following vertical coordinates
- 60 levels

(Shchepetkin and McWilliams 2005; Penven et al. 2006; Marchesiello et al. 2003)

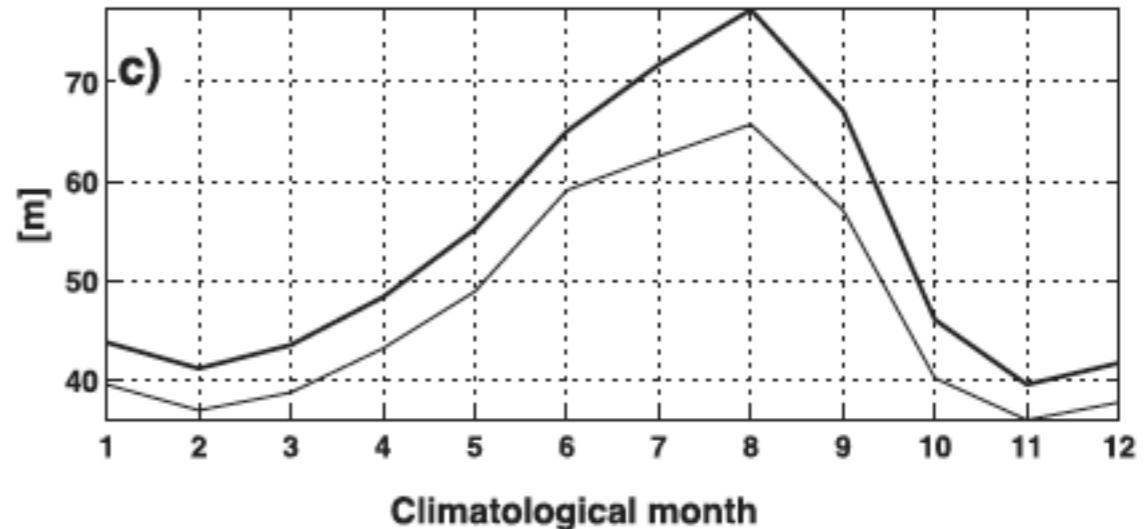
- $1/4^\circ$ resolution South Atlantic parent domain and $1/12^\circ$ (9km), $1/36^\circ$ (3km) and $1/108^\circ$ (1 km) resolution nested grids

Veneziani et al. , 2014. Barrier Layers in the Tropical South Atlantic: Mean Dynamics and Submesoscale Effects



Seasonality

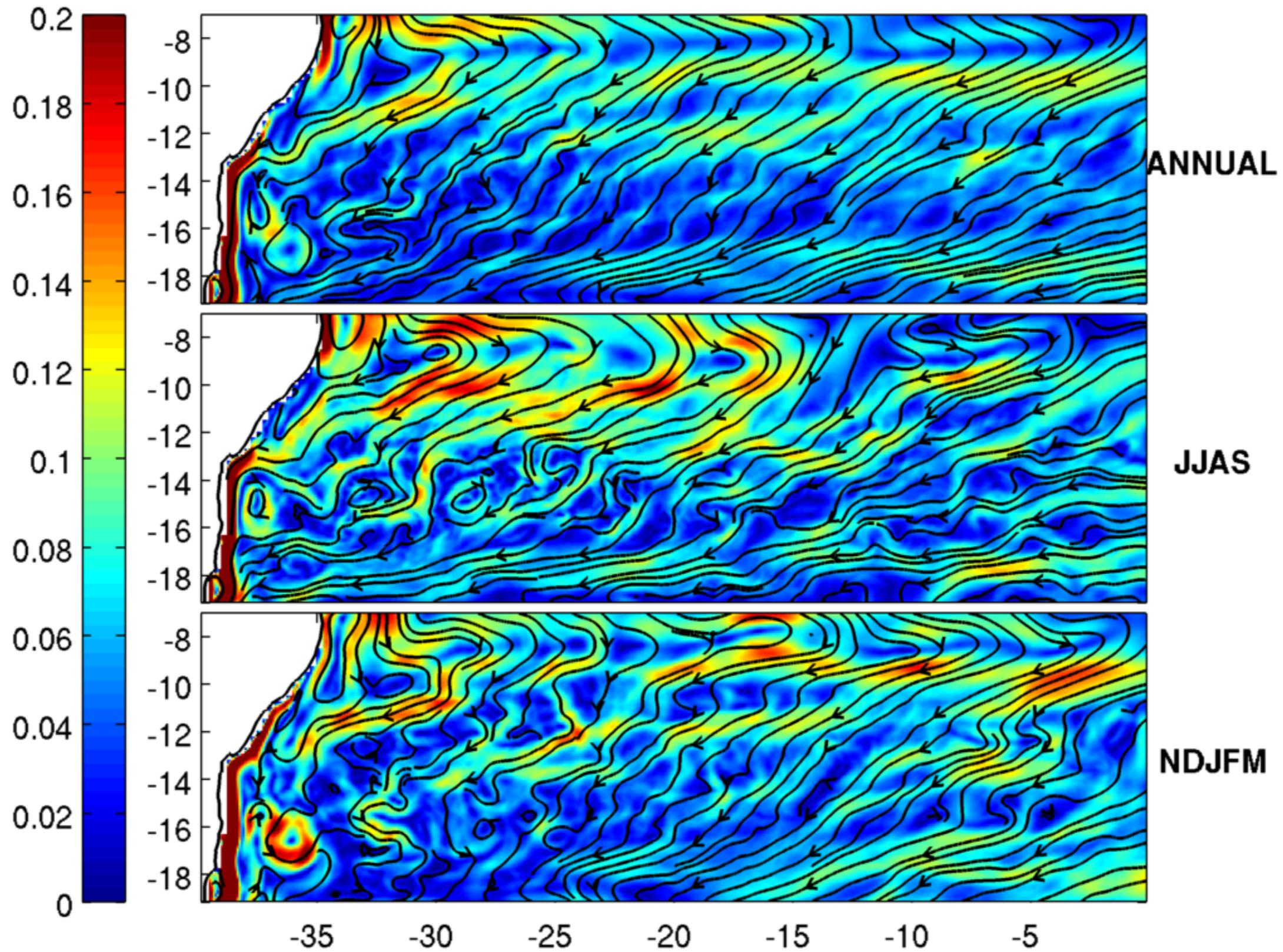
- 3-year (1999-2002) climatological MLD(thin line) & ILD(thick line)
- Seasons chosen for comparison:
JJAS(6:9) &
NDJFM(11:3)



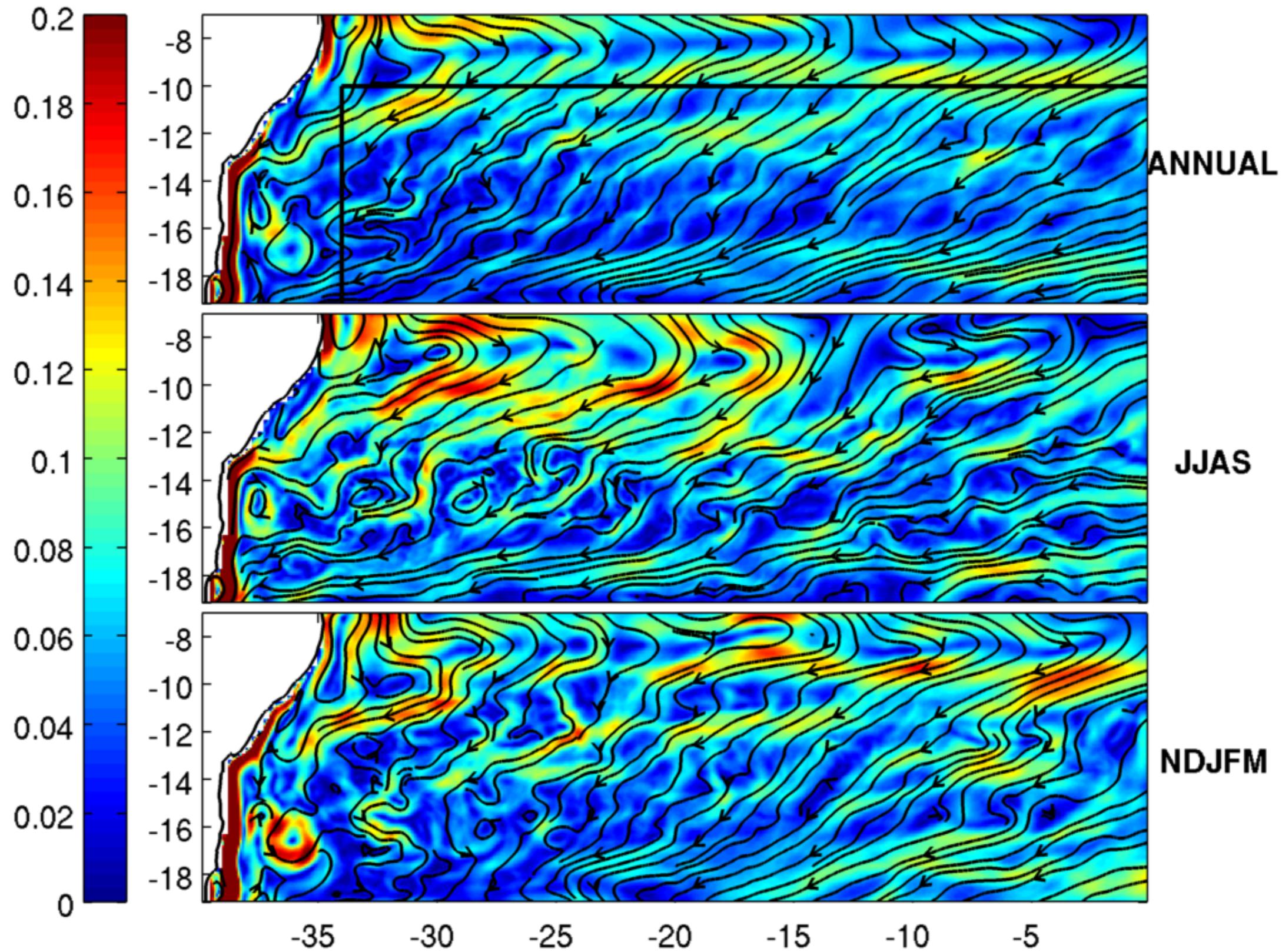
Mean Flow

Seasonal average of Aug1999-Aug2002

| 5m



| 5m

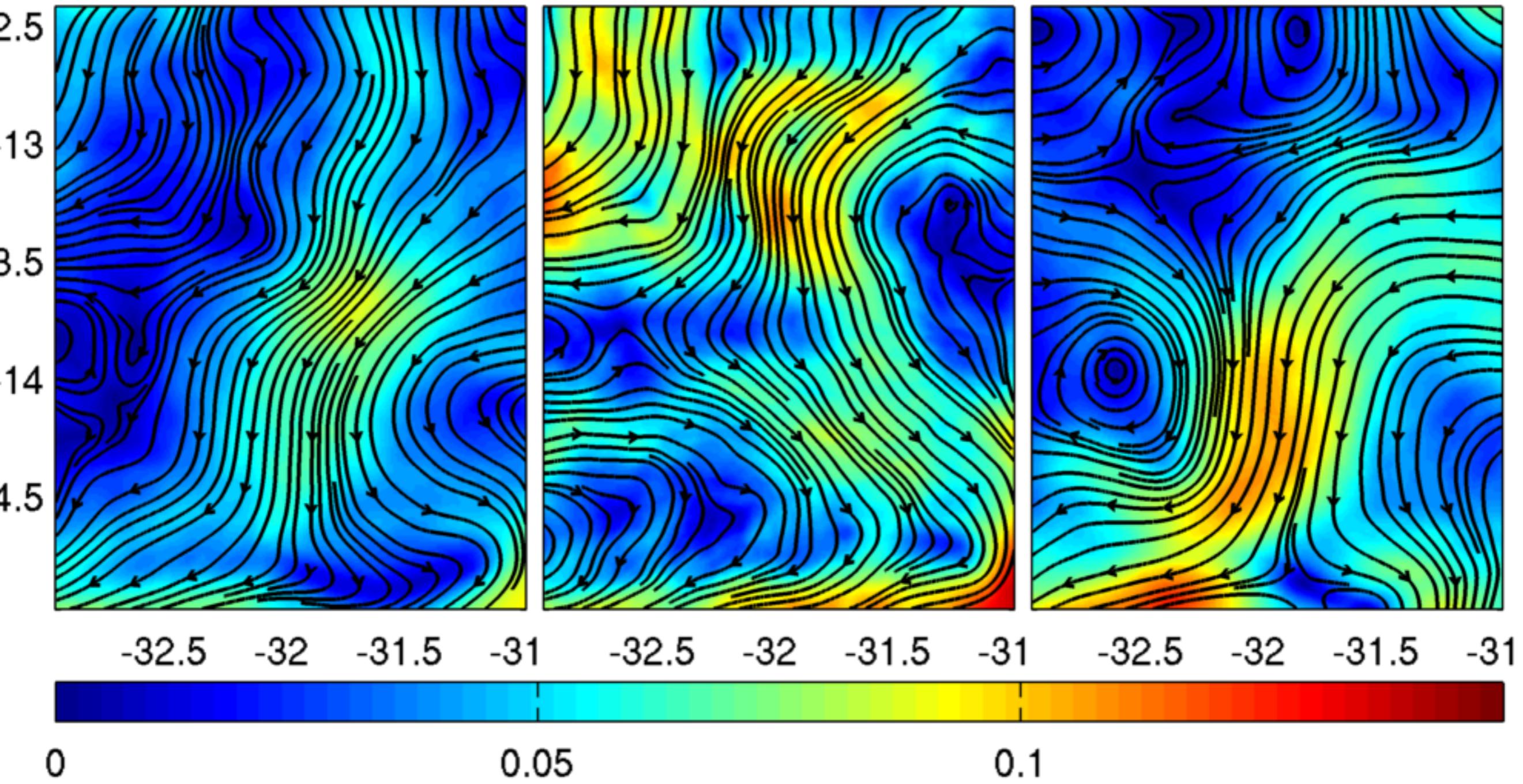


HR 15m

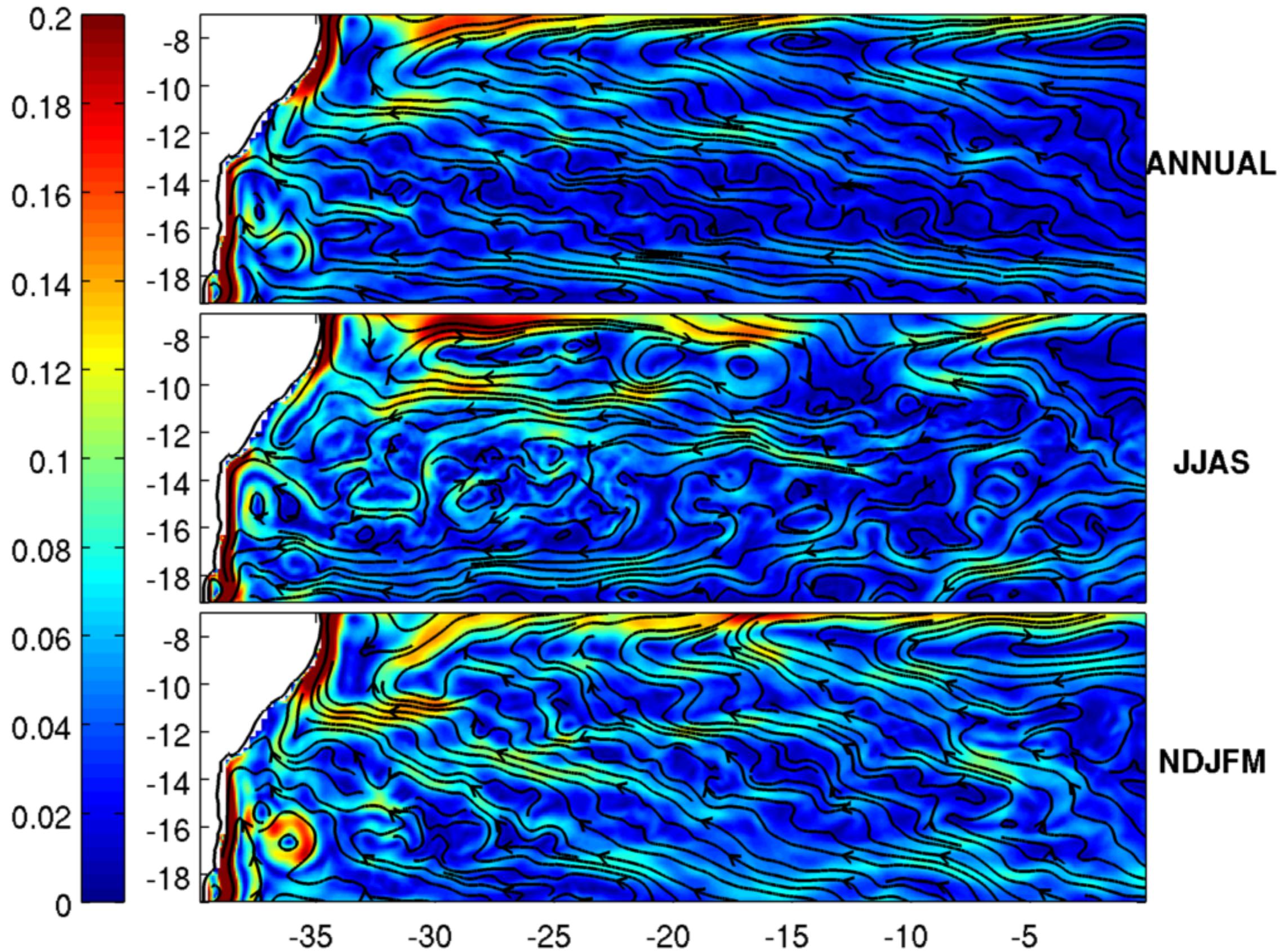
ANNUAL

JJAS

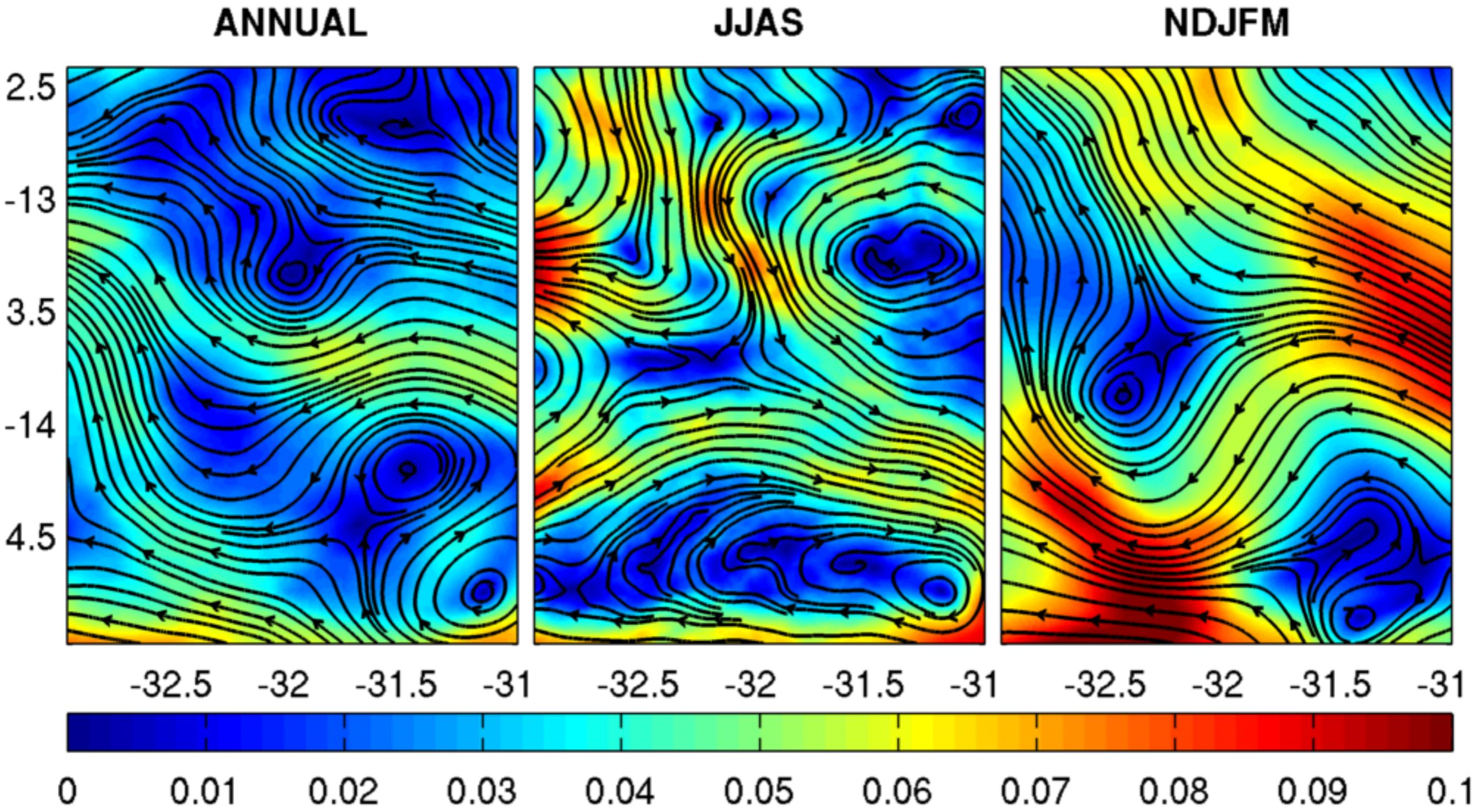
NDJFM



60m



HR 60m



Relative vorticity animation (zoom on subtropical nested domains)



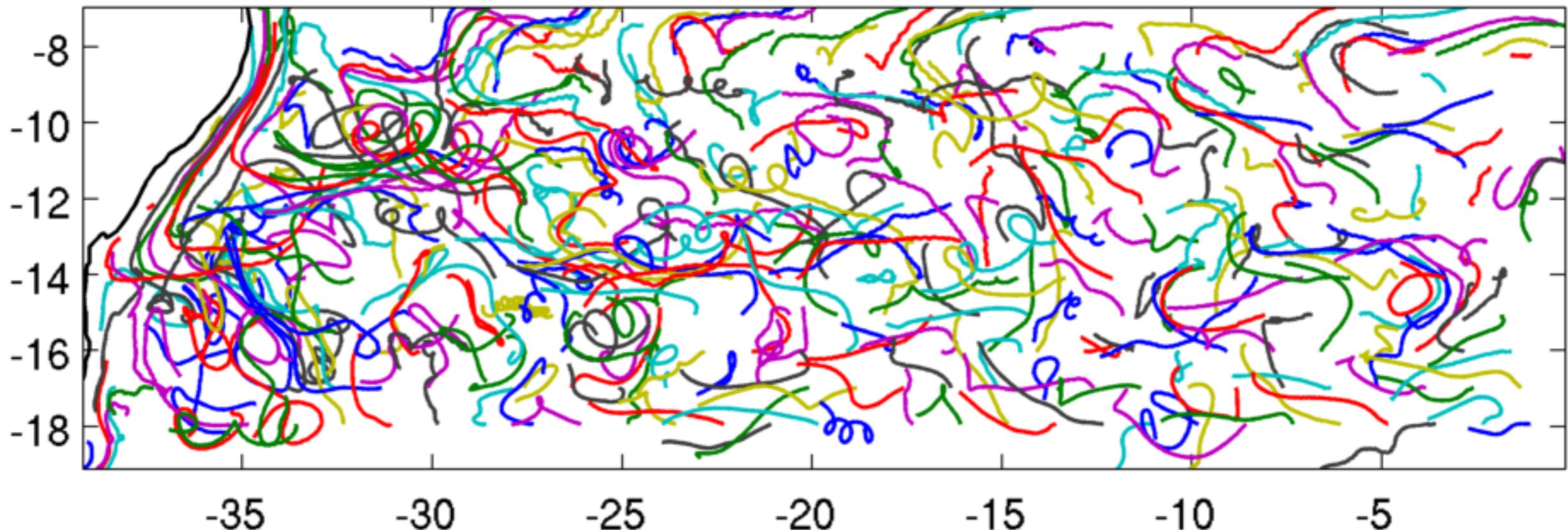
Lagrangian Setup

- Using output from two-way online nested ocean model ROMS-AGRIF 4 deployments of trajectories were initialized and advected on both 9km and 1km resolutions
- 6-hourly velocity fields are used to advect the particles using a RK-4 integration
- Particles were released every three grid points with a spacing of 27km (LR) and 3km (HR)
- Releases were initialized in August 1999 and every three months thereafter (totalling 4 releases) in LR and every month (12) in HR
- In both resolutions a set of isopycnal-following particles were released at 15m inside the ML throughout the year and 3D particles at 15,30,60 and 150m effectively sampling the mixed layer and below

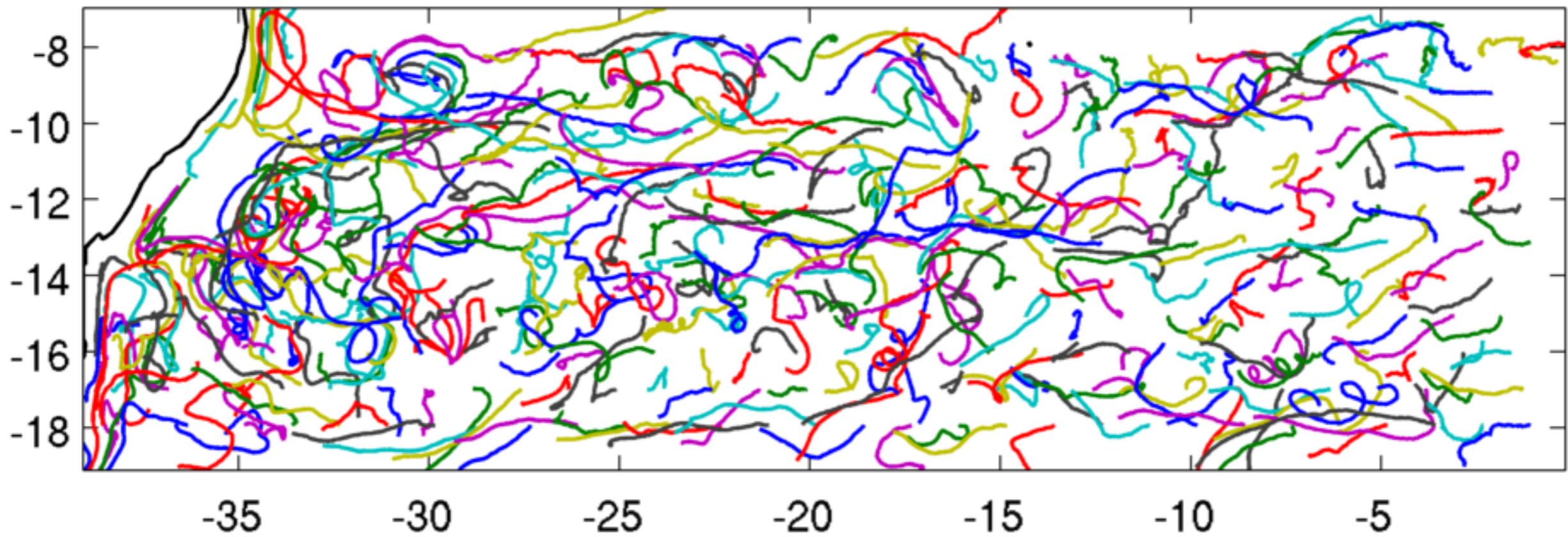


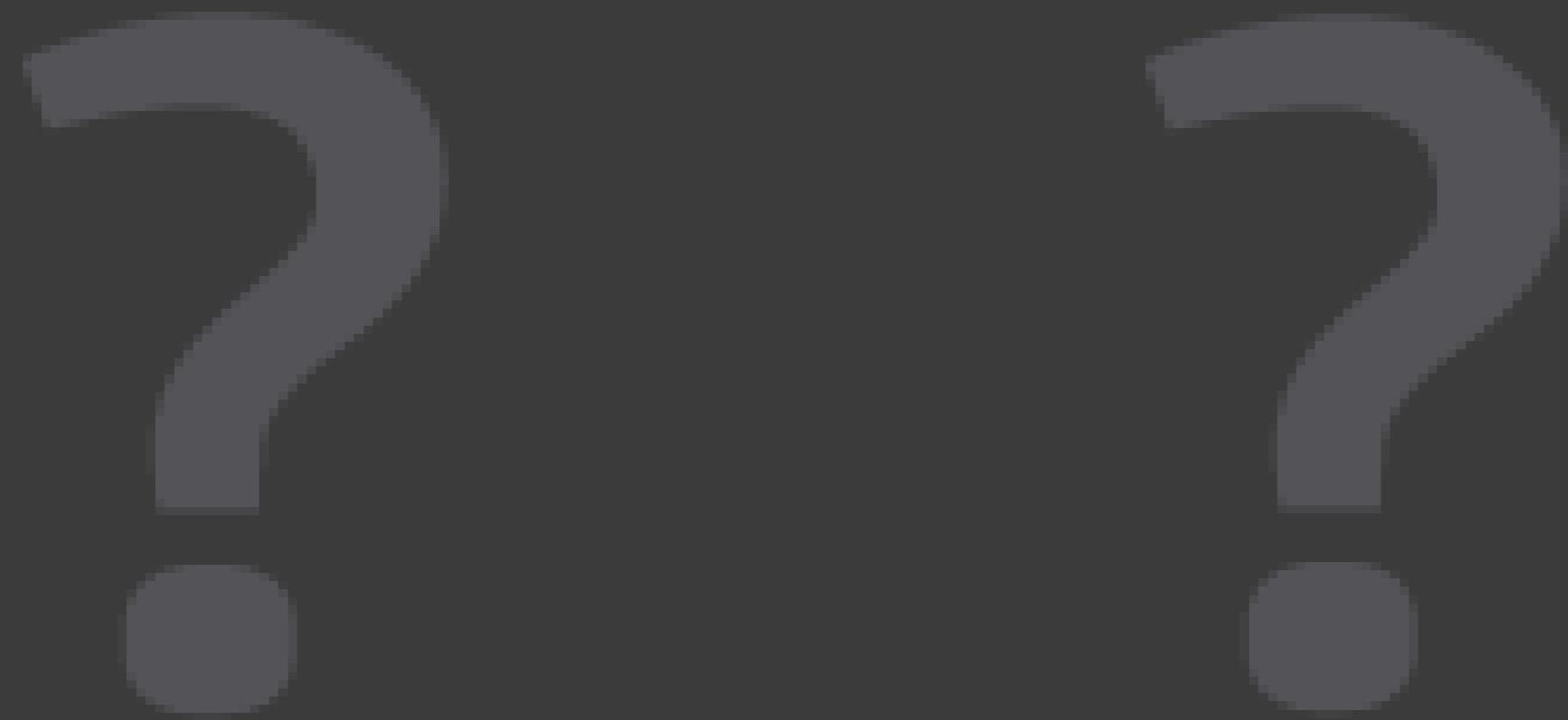
Comparing seasons in LR

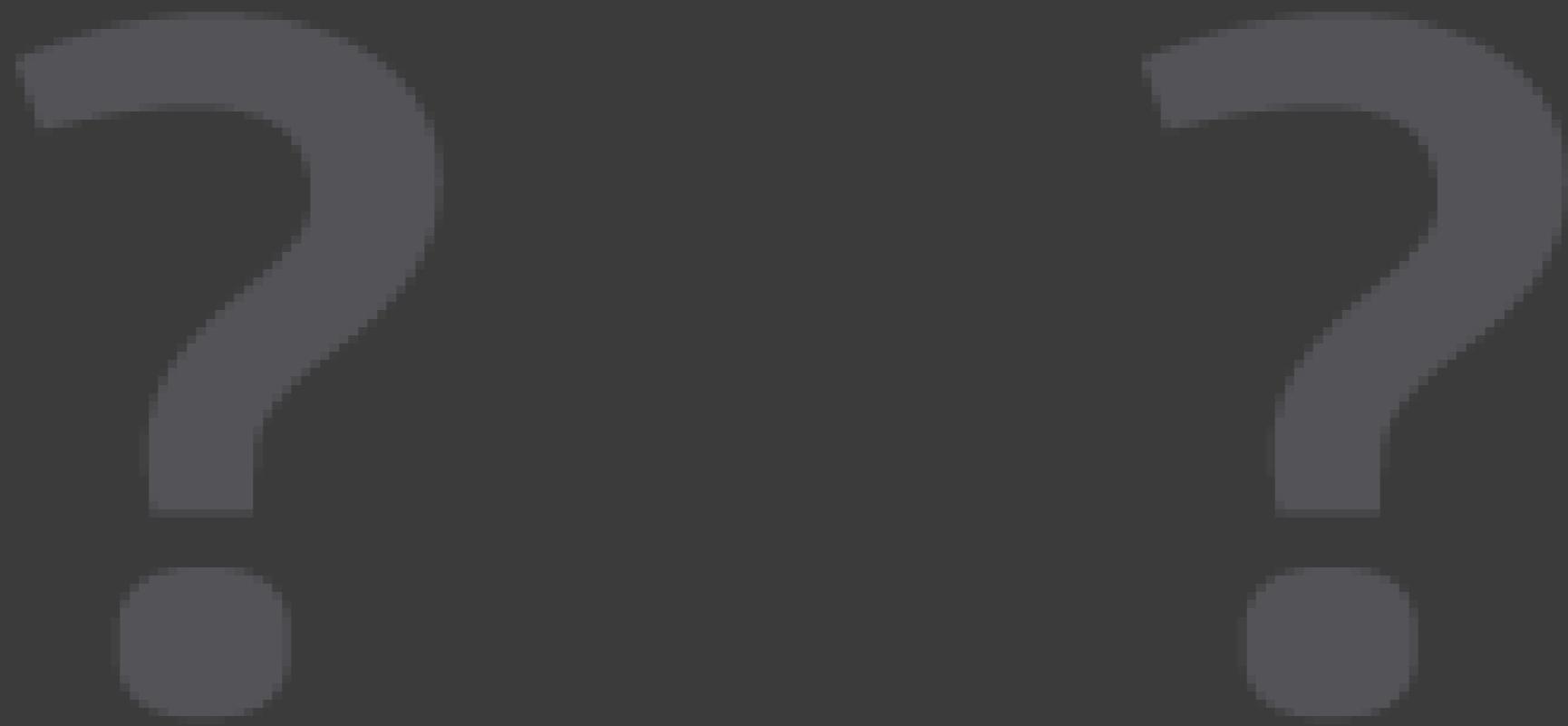
Trajectories 3d LR 1999M11 60m



Trajectories 3d LR 1999M08 60m

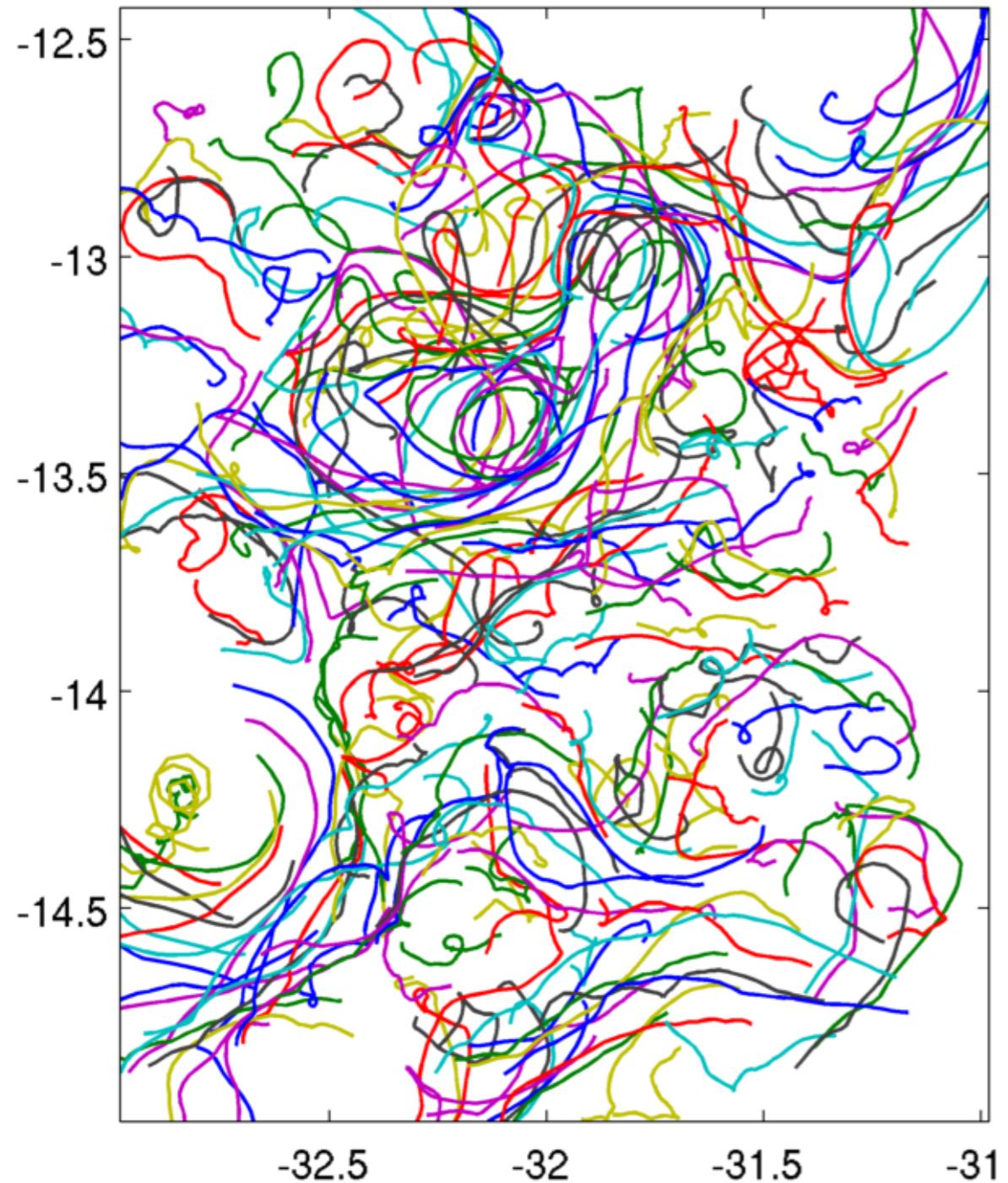




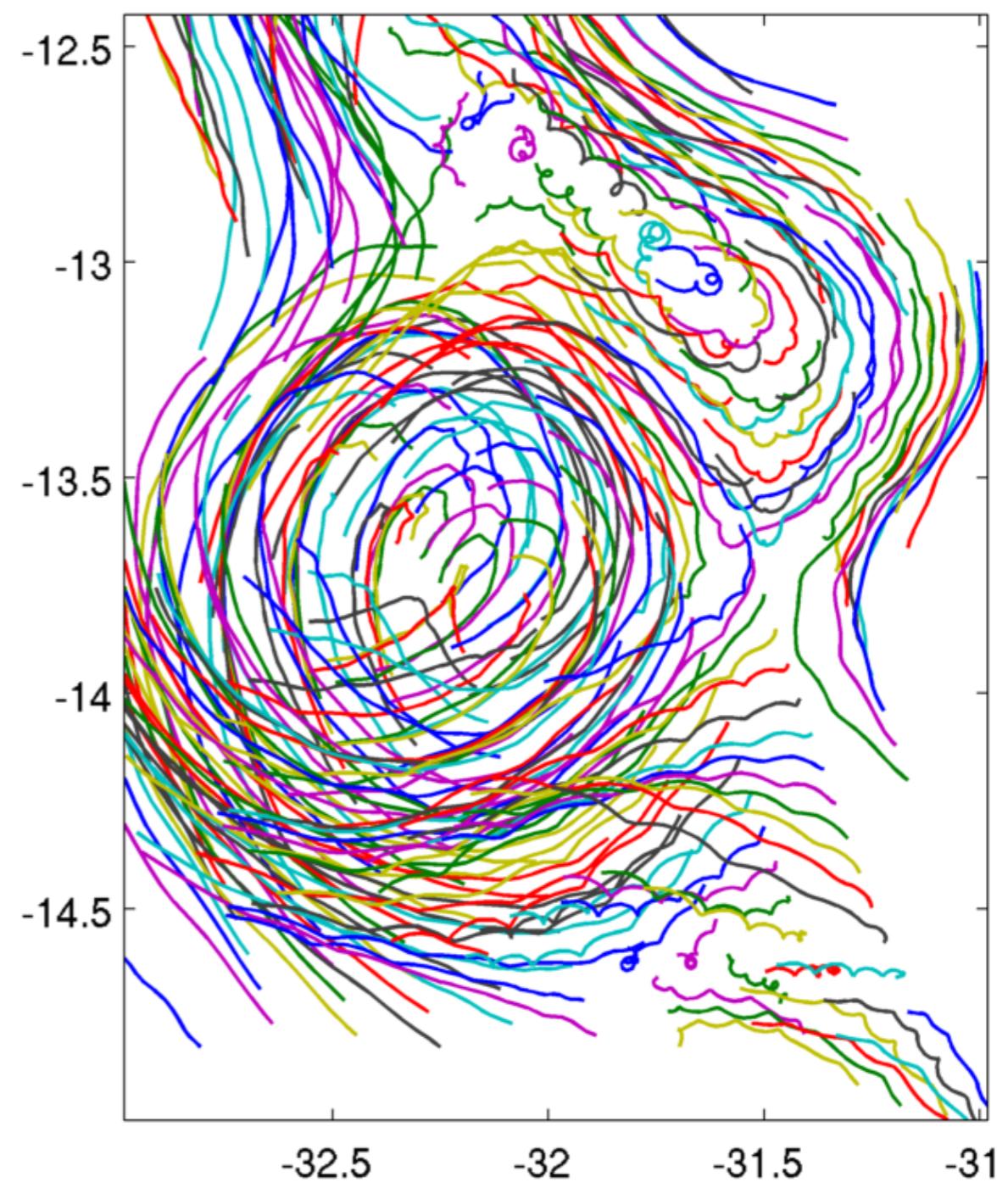


2D vs 3D (colored by depth)

Trajectories 3d HR 1999M08 60m

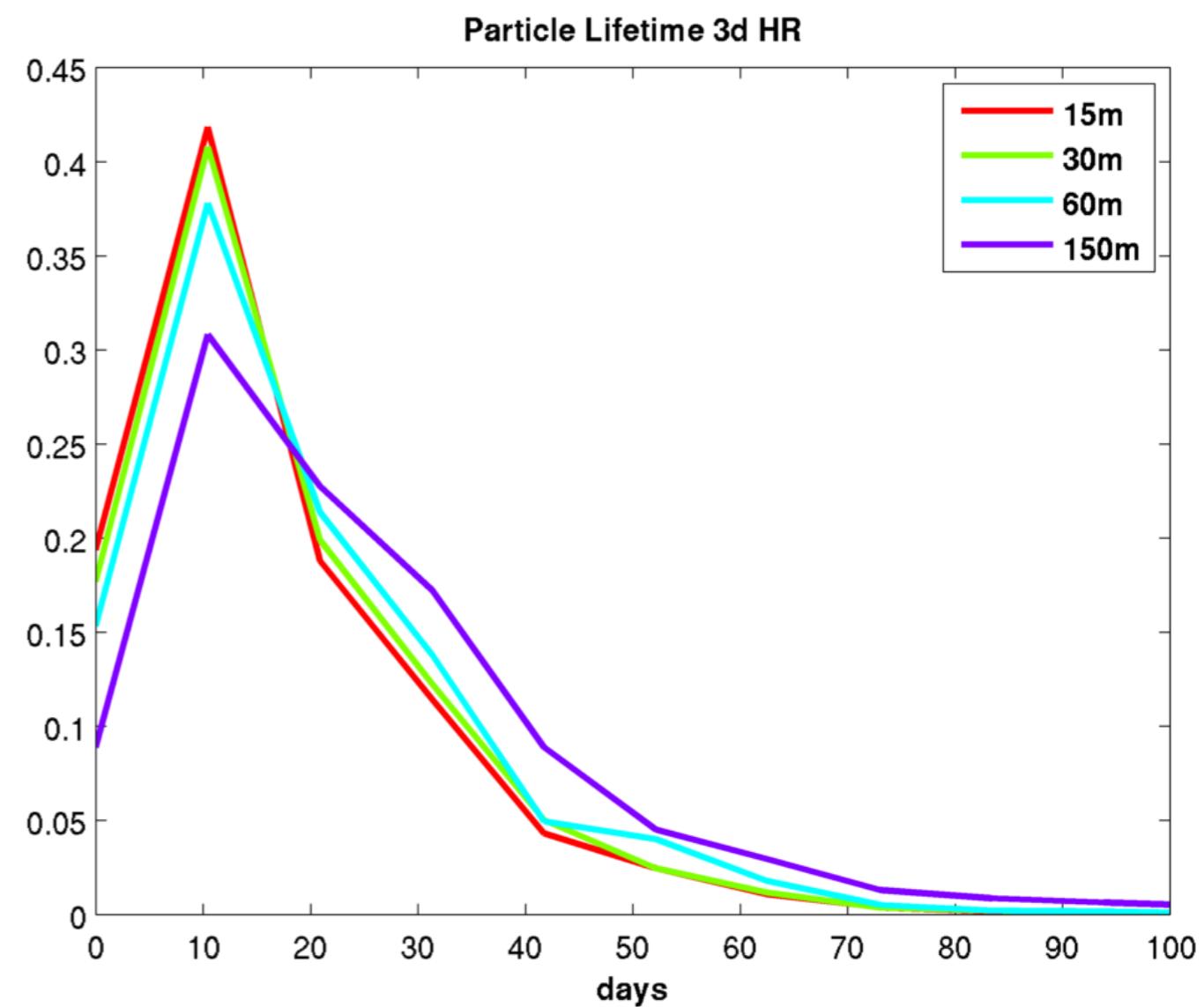
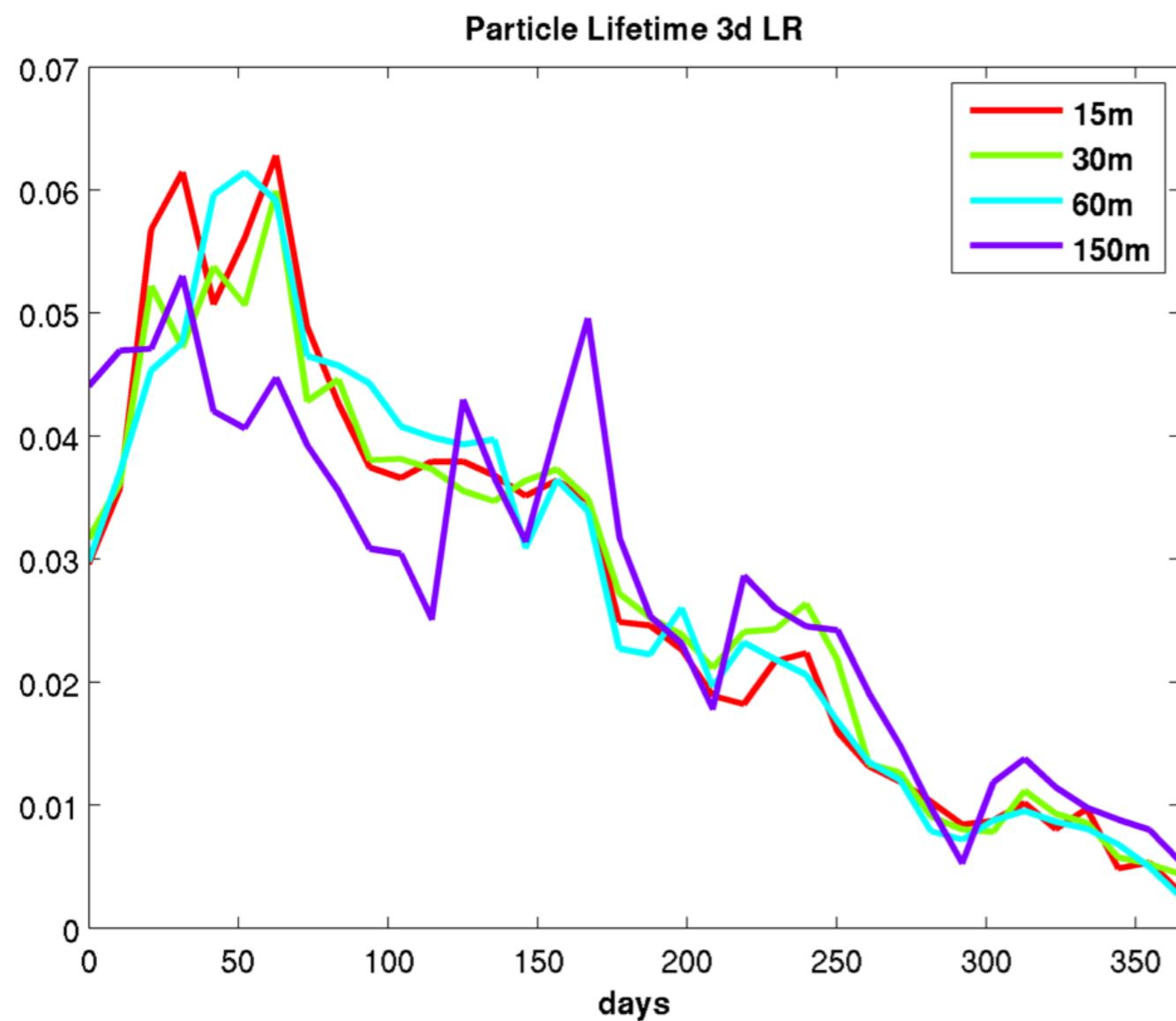


Trajectories 3d HR 2000M01 60m

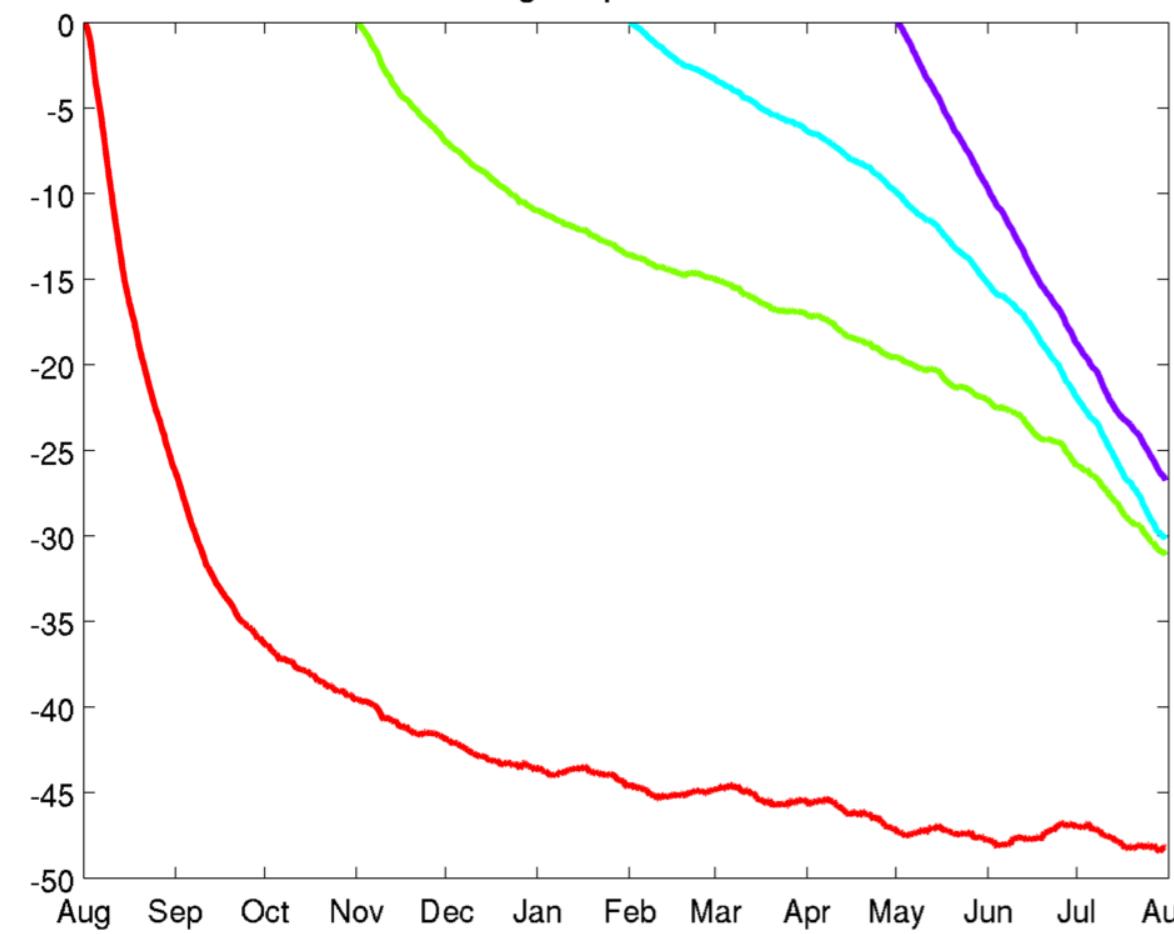


Trajectories for 10 days

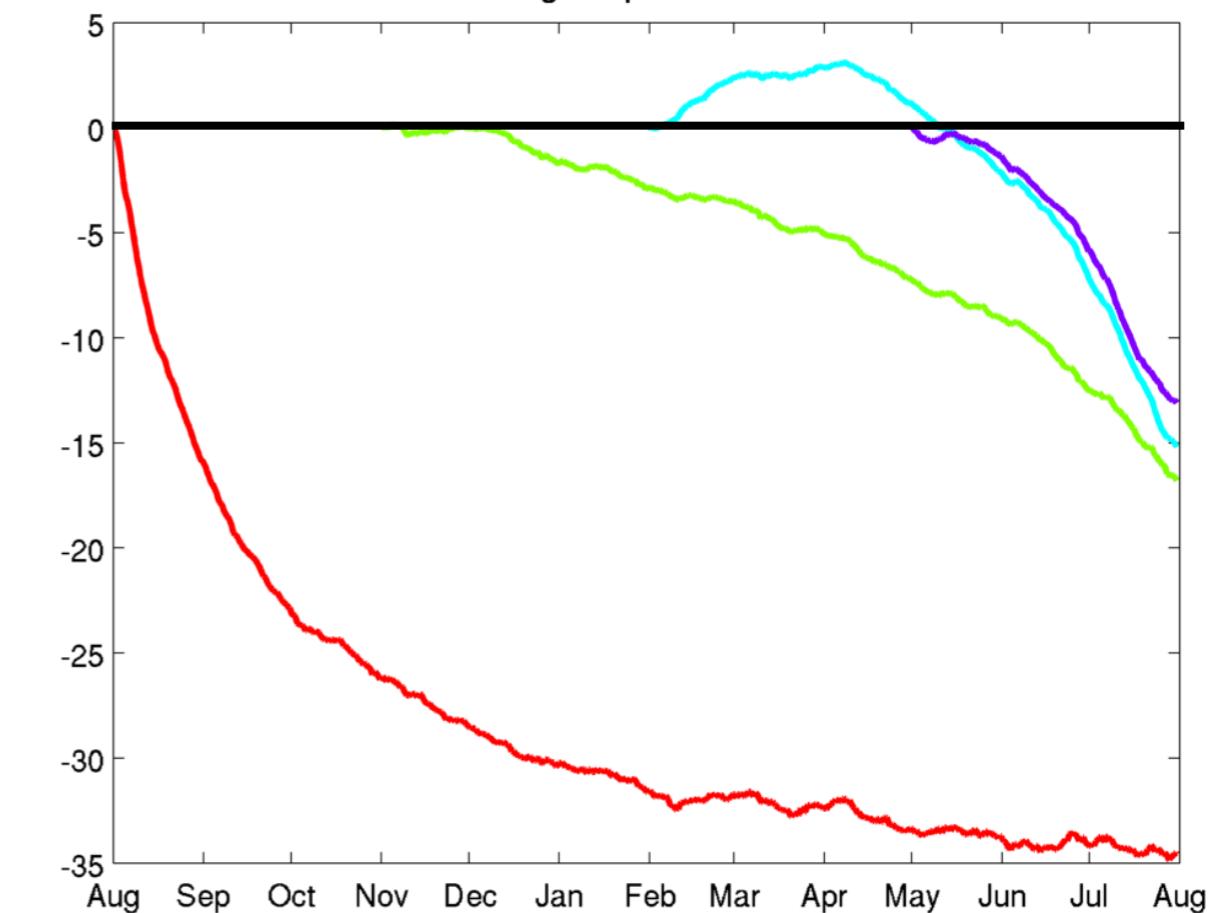
Particle Statistics



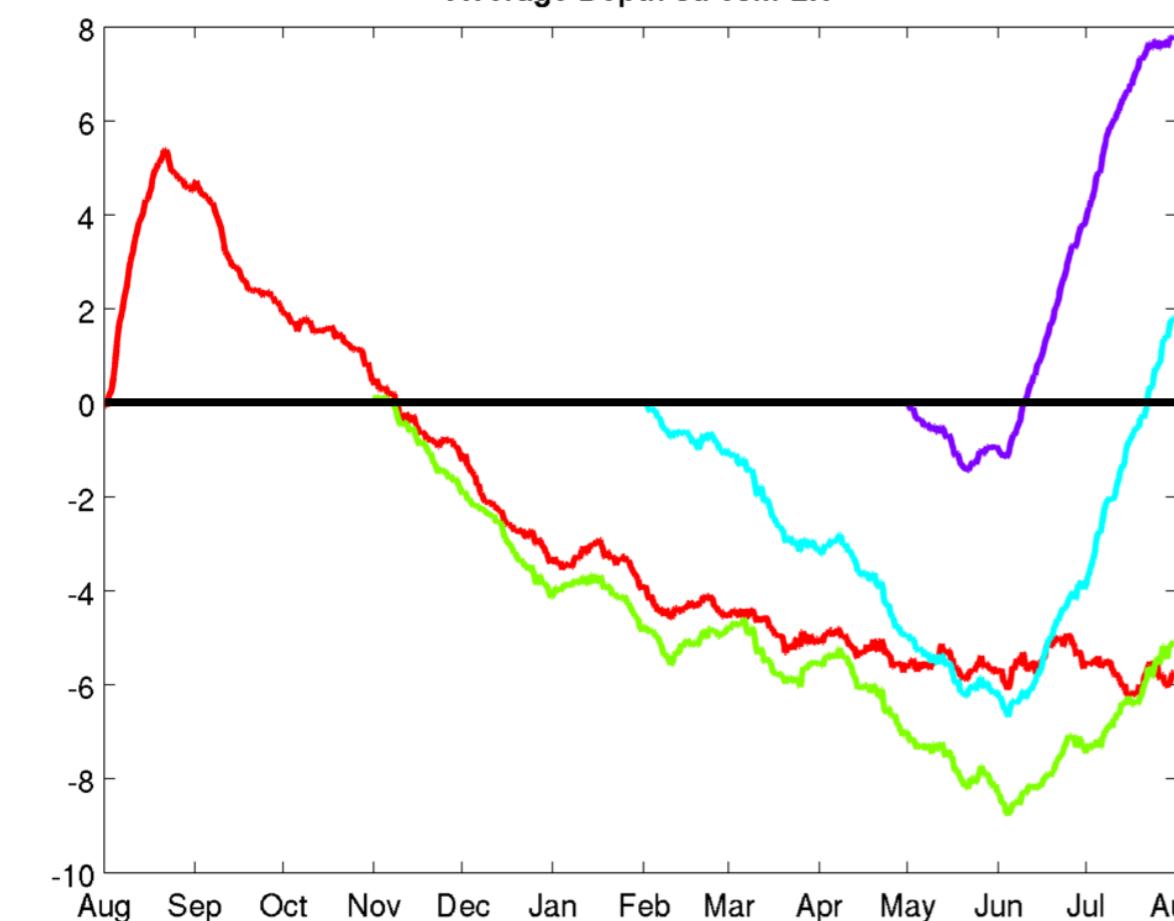
Average Depth 3d 15m LR



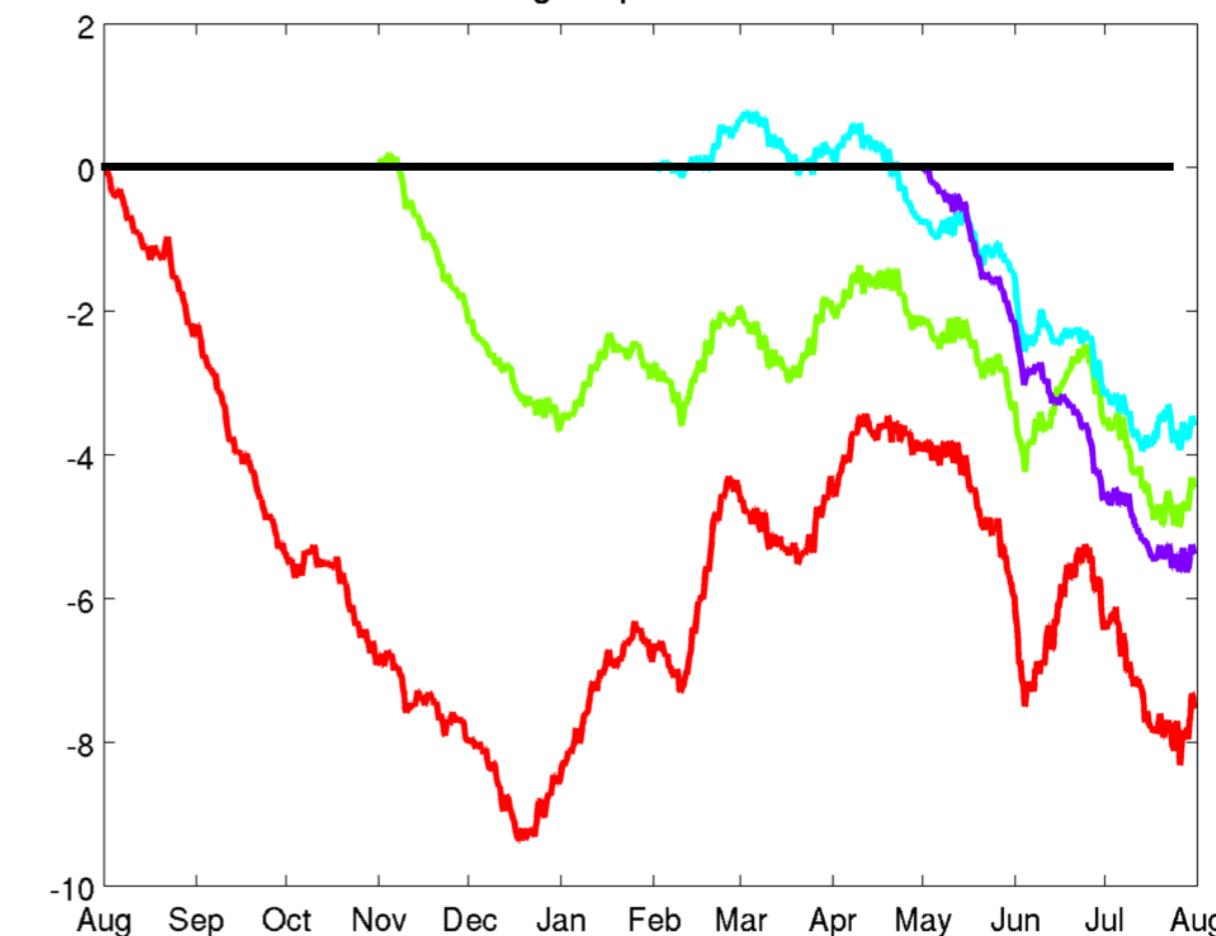
Average Depth 3d 30m LR



Average Depth 3d 60m LR

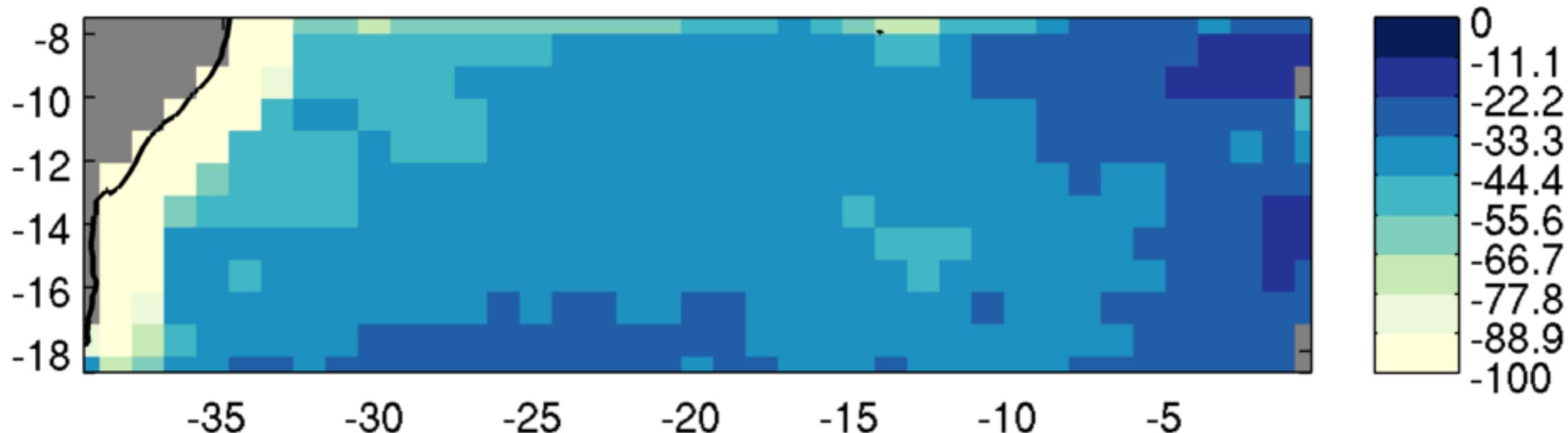


Average Depth 3d 150m LR

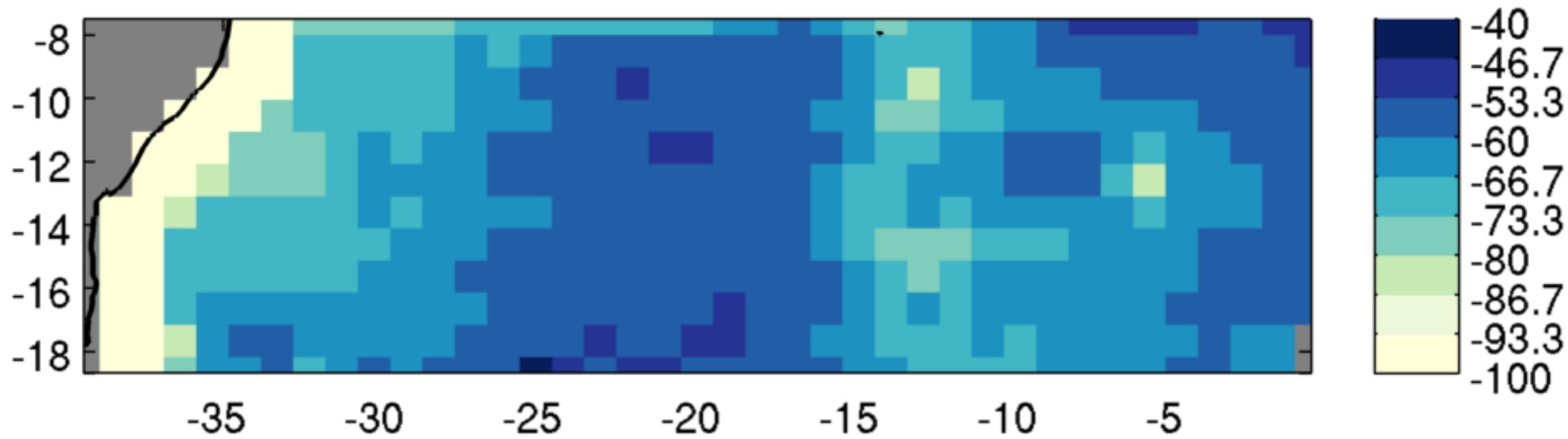


Lagrangian mean depth

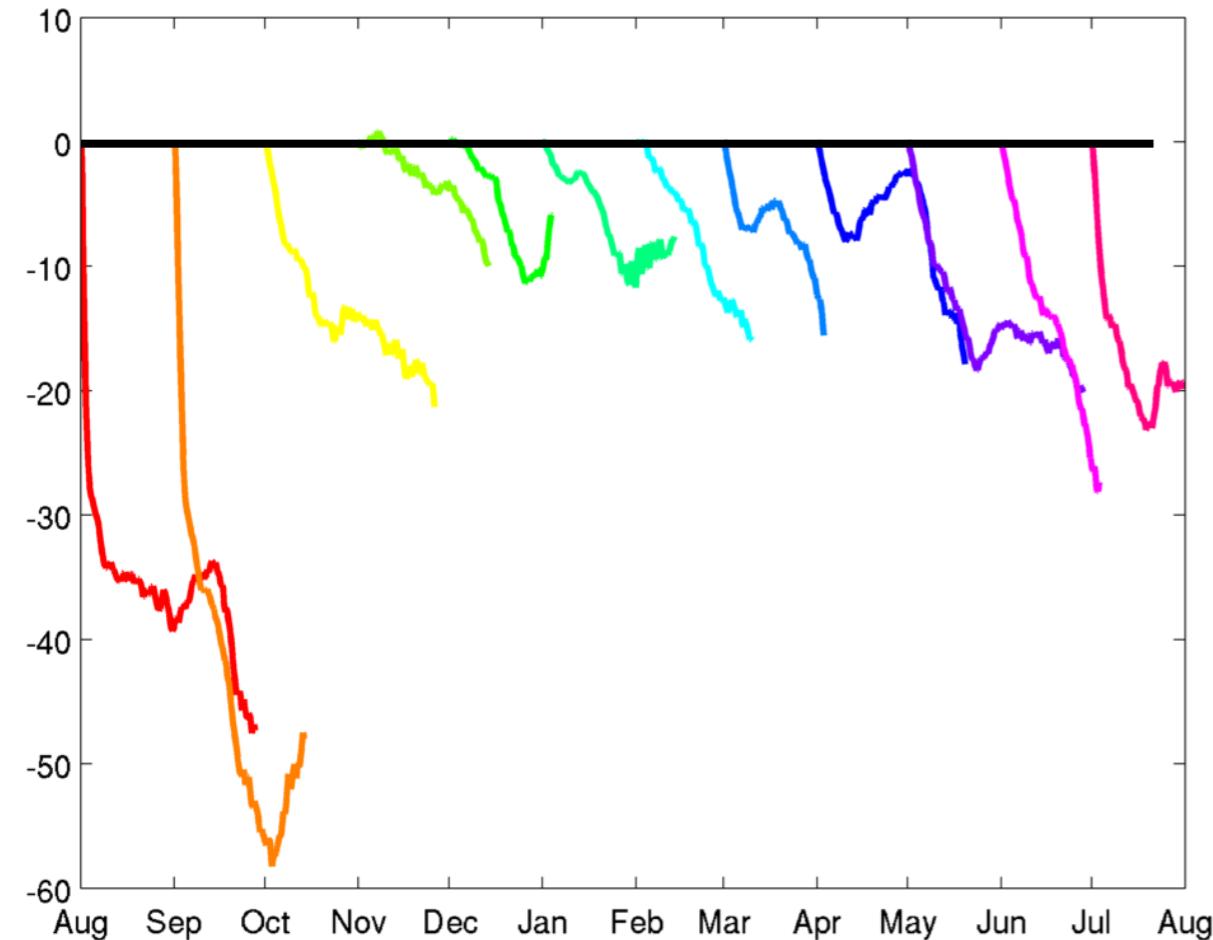
z 3d 15m LR



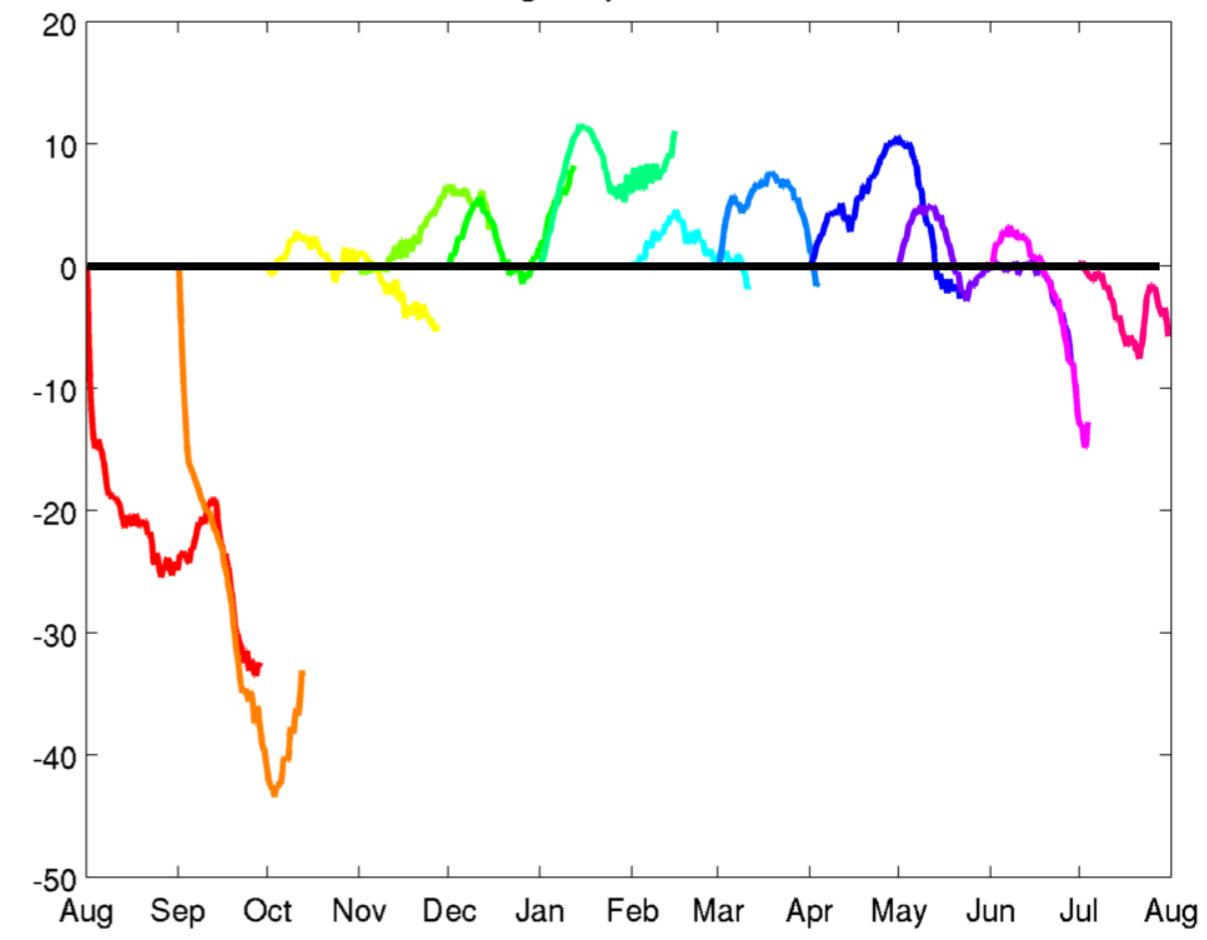
z 3d 60m LR



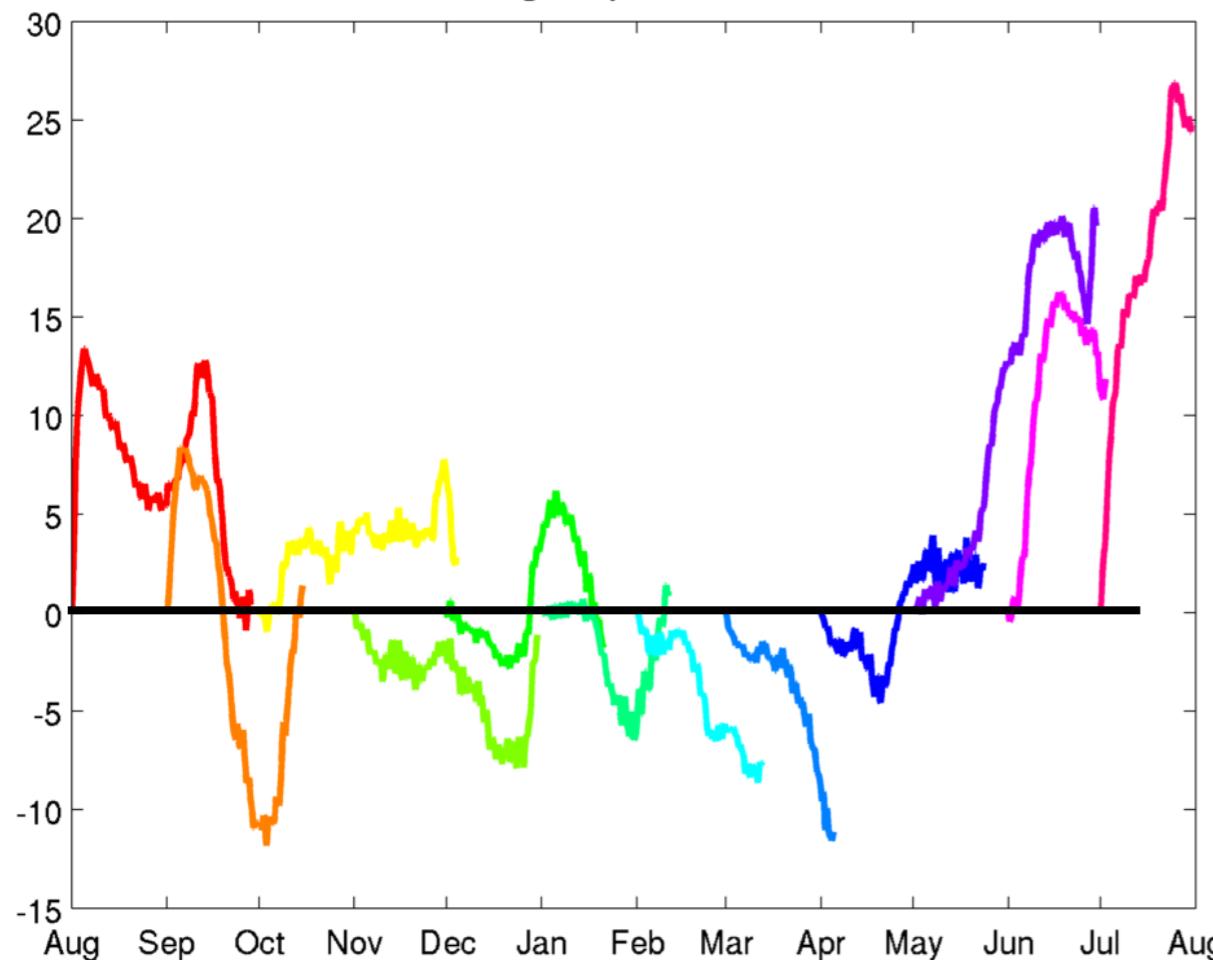
Average Depth 3d 15m HR



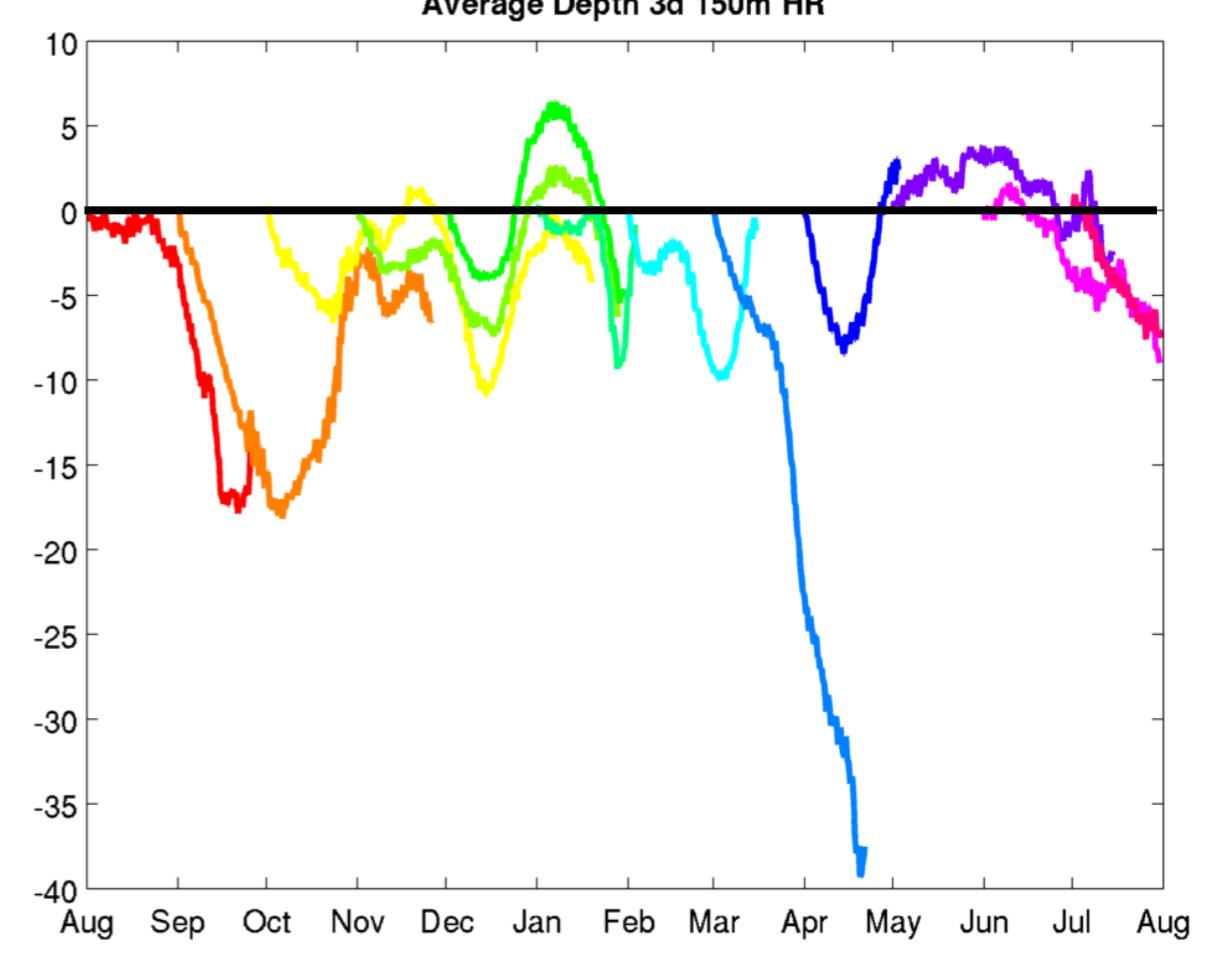
Average Depth 3d 30m HR



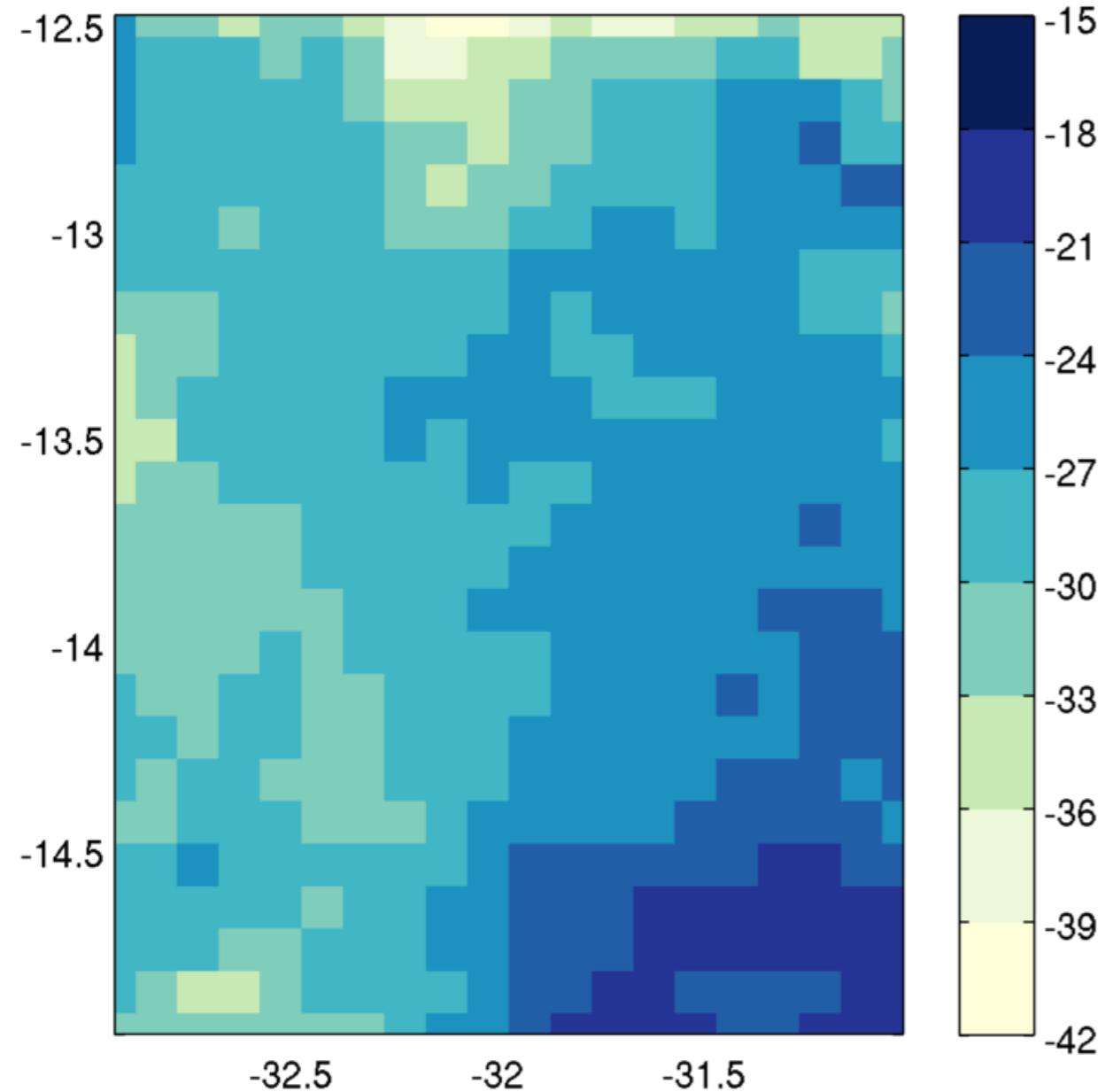
Average Depth 3d 60m HR



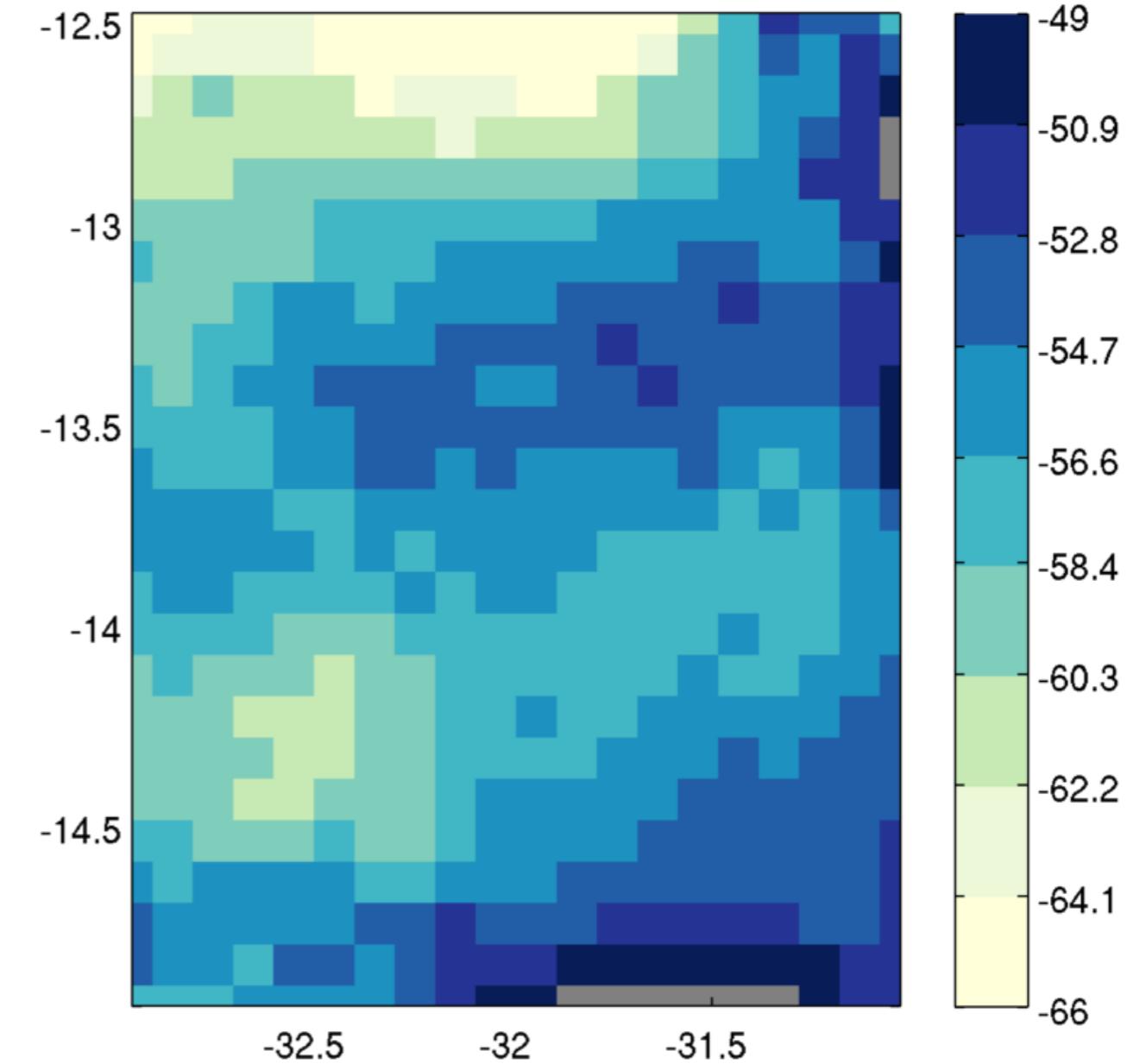
Average Depth 3d 150m HR



z 3d 15m HR



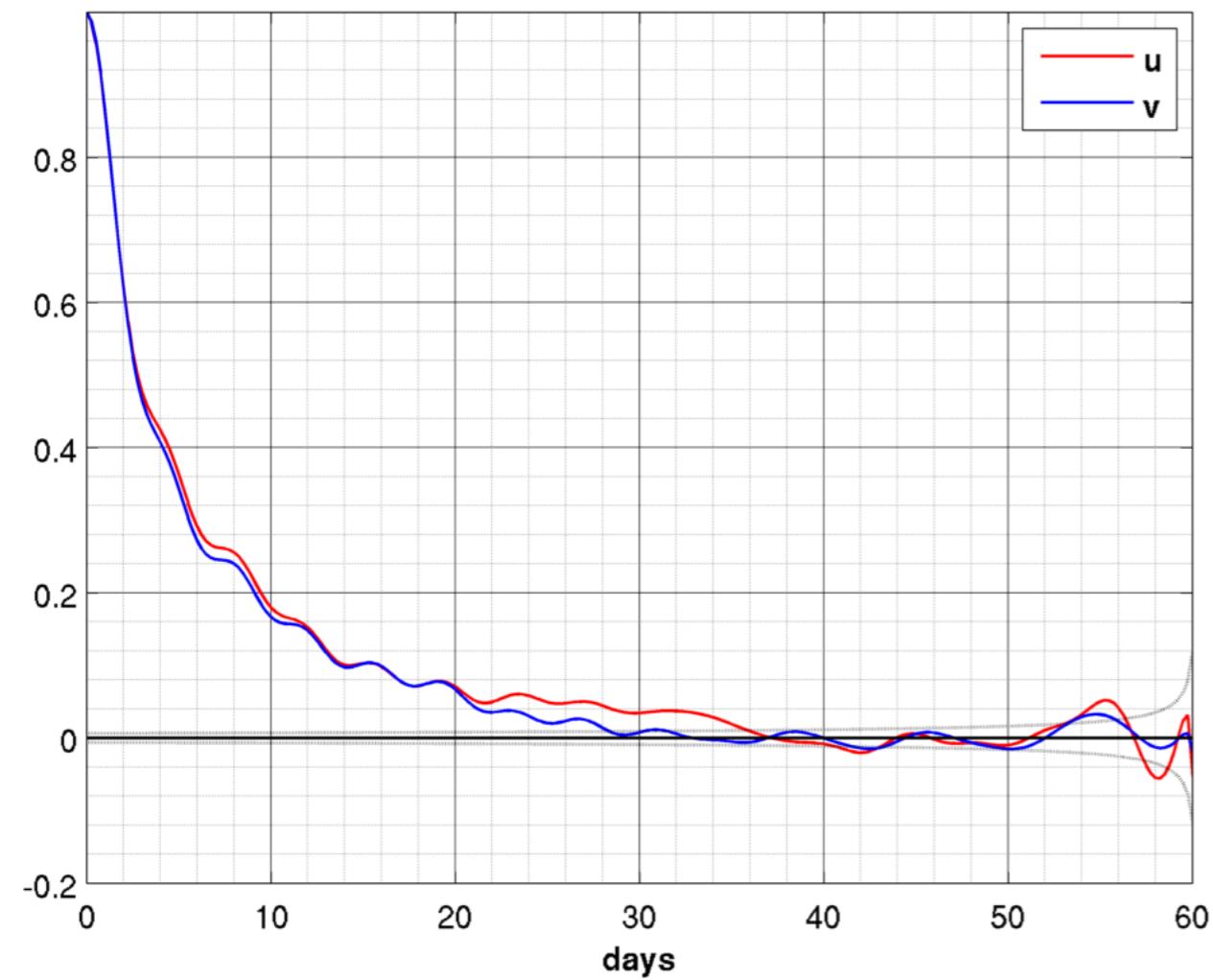
z 3d 60m HR



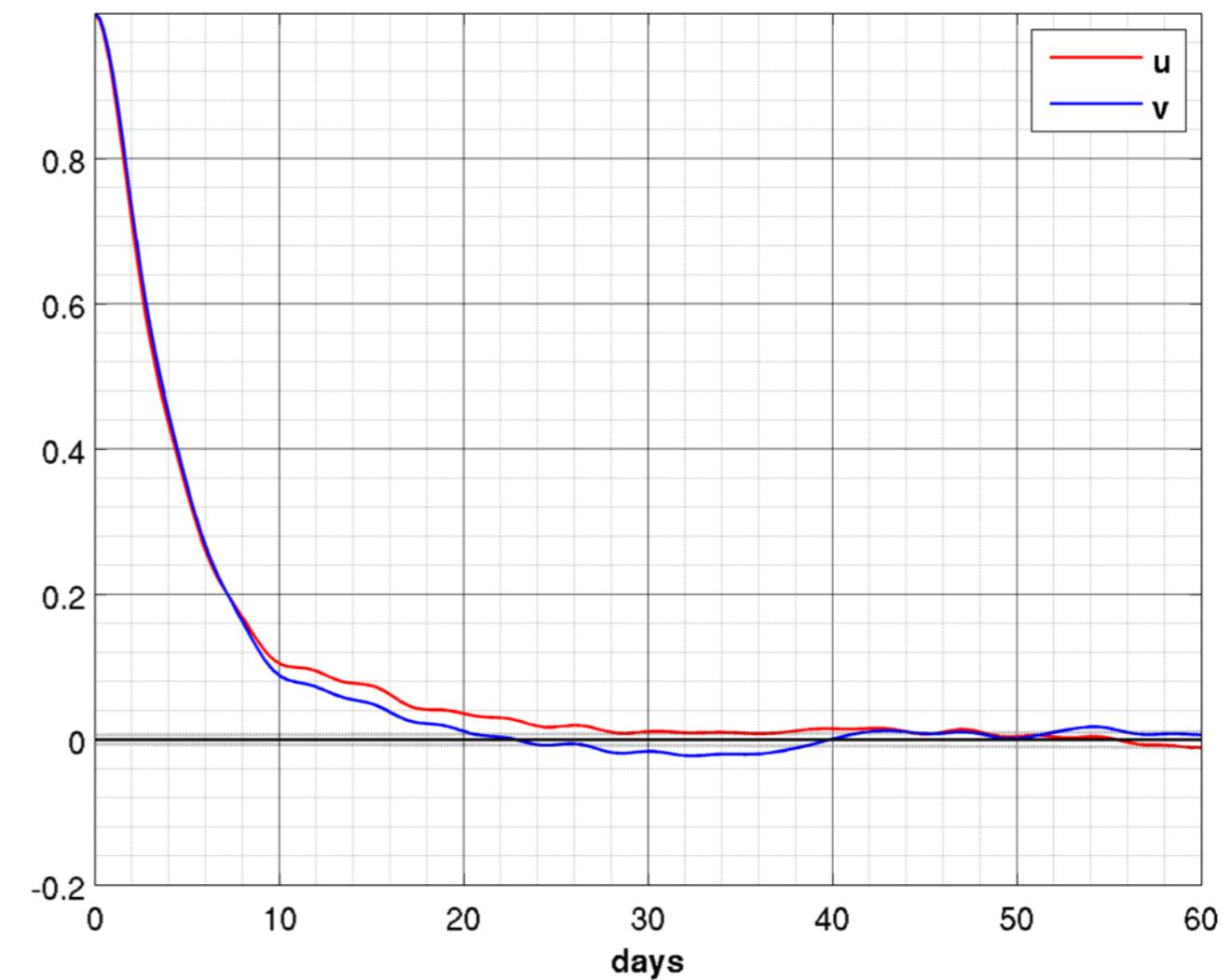
Time-series analysis

- Residual velocities are used for most analysis: $u = u_{\text{actual}} - u_{\text{seas}}$
- Inertial periods ranging from 1.9~2.3 days in HR and 1.5~3.6 days in LR
- Dispersion statistics calculated using bandpassed trajectories about those periods

UV JJAS autocorrelation 2d 15m LR



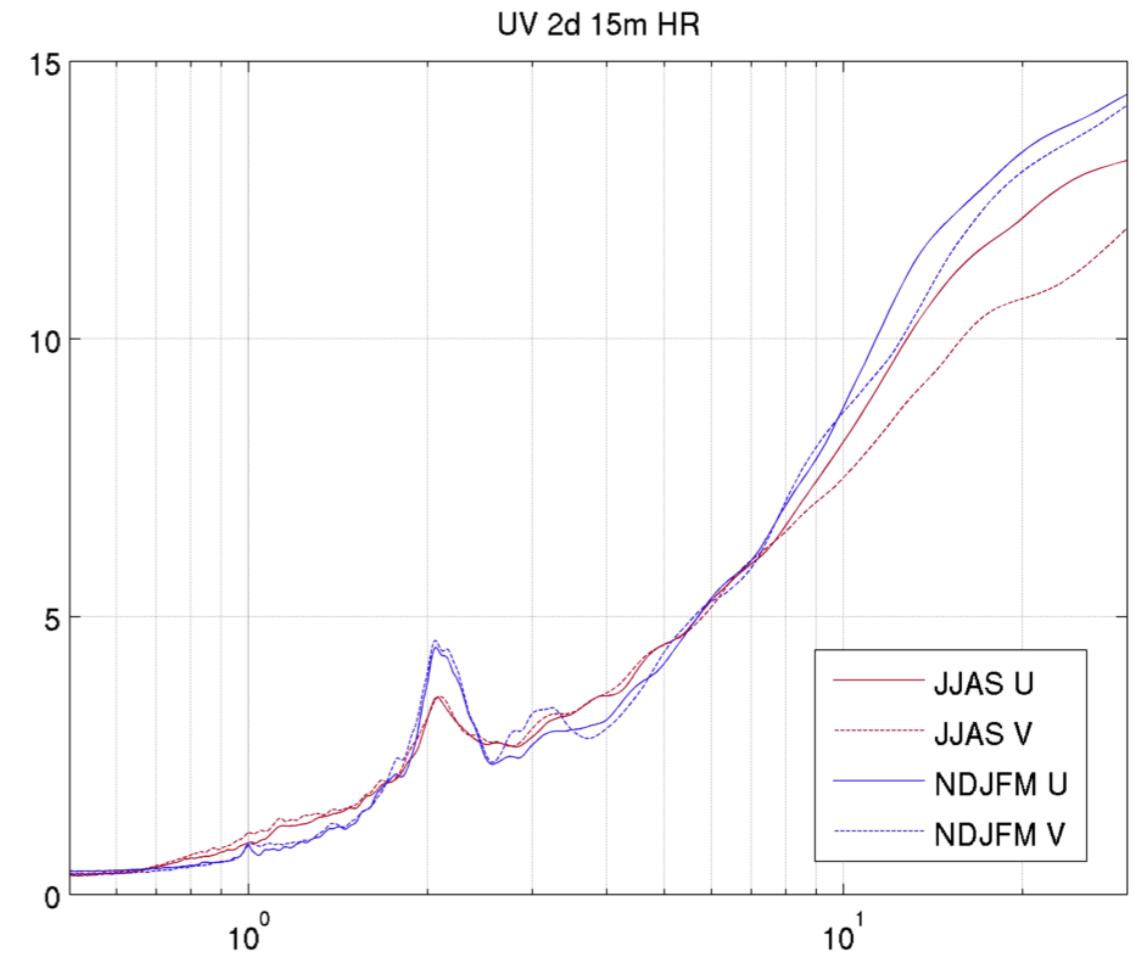
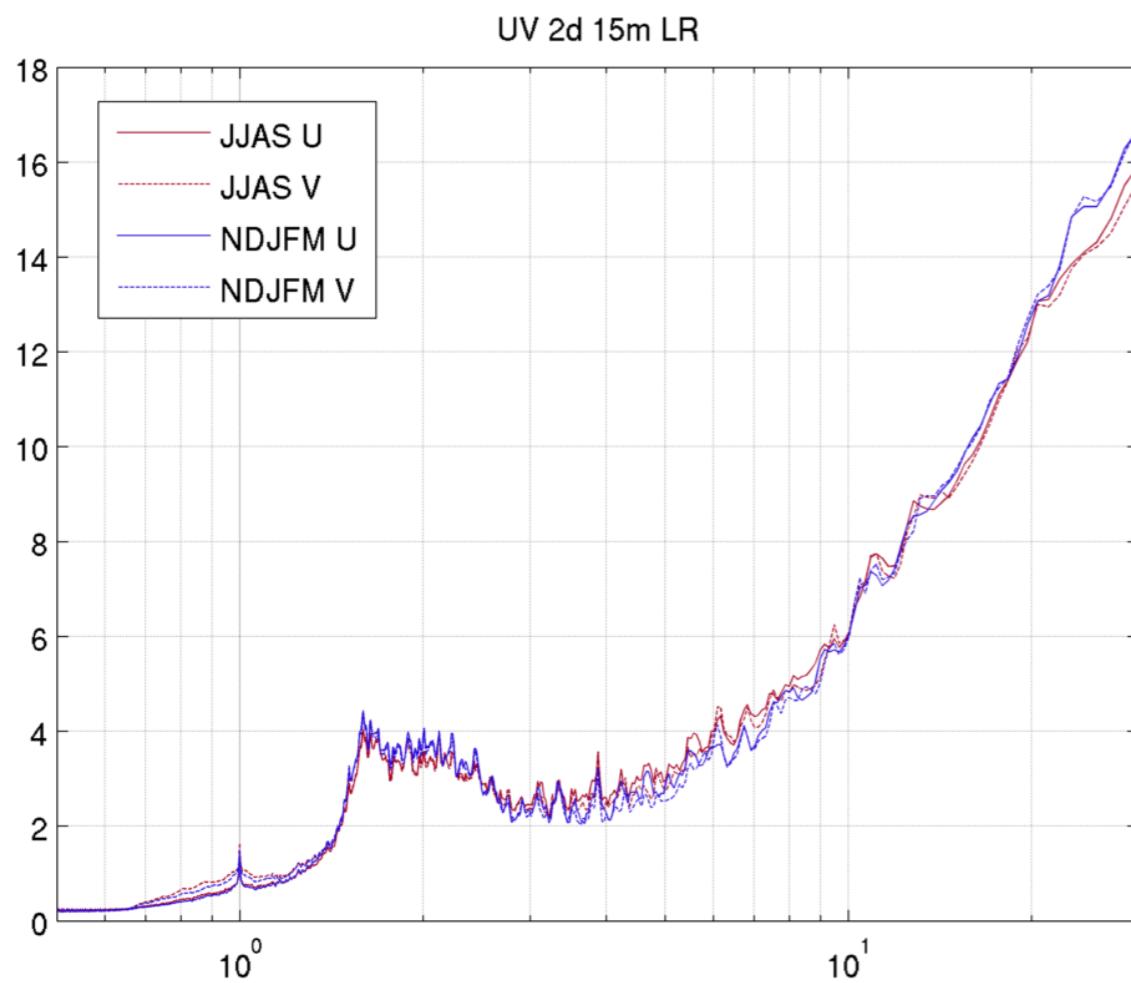
UV NDJFM autocorrelation 2d 15m LR



Residual Velocities from fixed seasonal interpolation (bandpass plus no coast)

Lagrangian Timescale (e-folding - days)			U (JJAS)	V (JJAS)	Mean	U (NDJFM)	V (NDJFM)	Mean
LR	2D	15m	5.25	5	5.125	5	5.25	5.125
	3D	15m	6.75	6	6.375	5.75	5.75	5.75
		30m	6.75	6.25	6.5	6.25	5.75	6
		60m	7.5	6.5	7	7.75	6.5	7.125
		150m	17	12	14.5	12.75	11	11.875
HR	2D	15m	2.25	2.25	2.25	2.75	3	2.875
	3D	15m	3	3	3	3.25	3.25	3.25
		30m	3.25	3	3.125	3.25	3.5	3.375
		60m	3	2.75	2.875	4.5	4.75	4.625
		150m	8.75	6.75	7.75	10	9.75	9.875

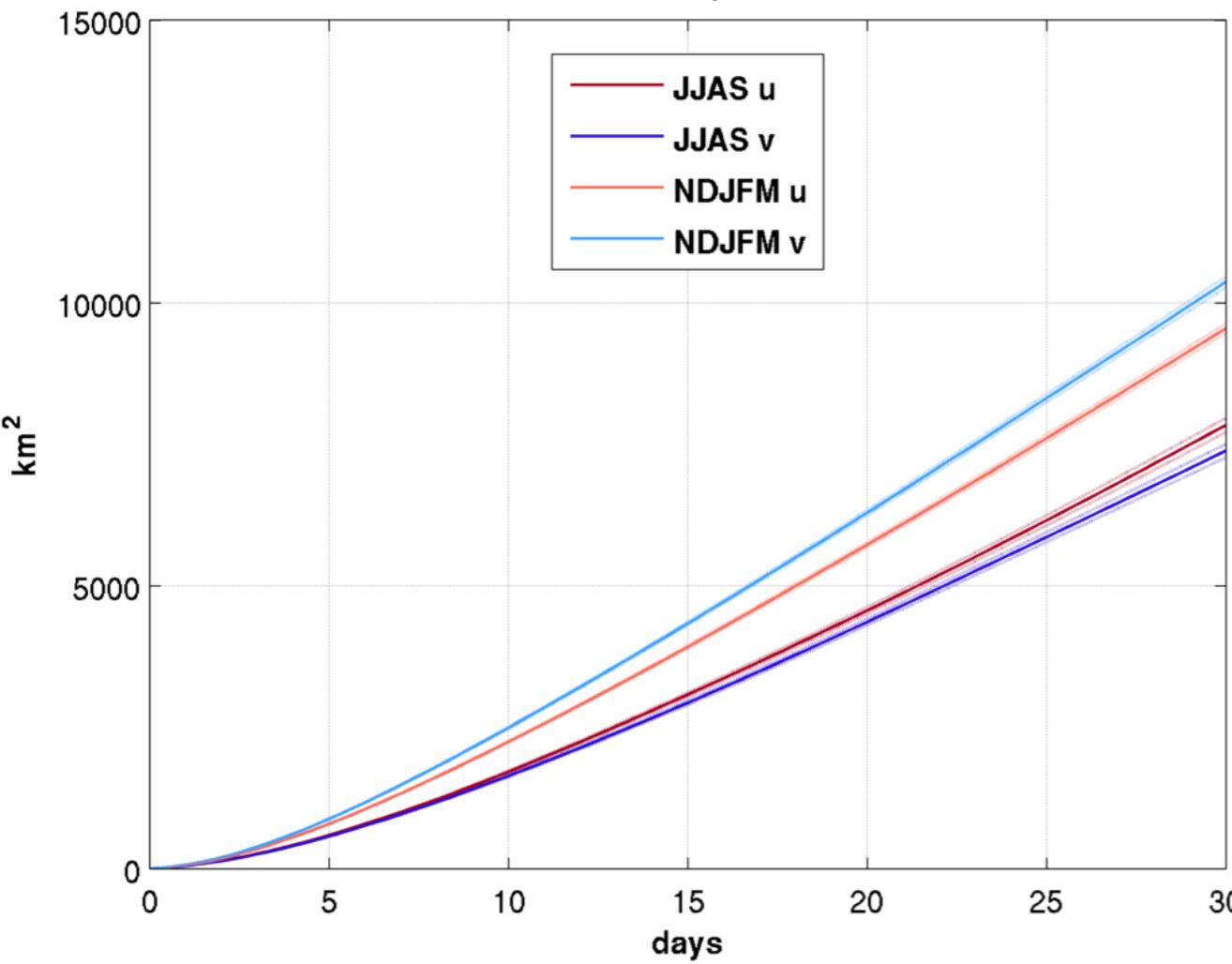
Spectra



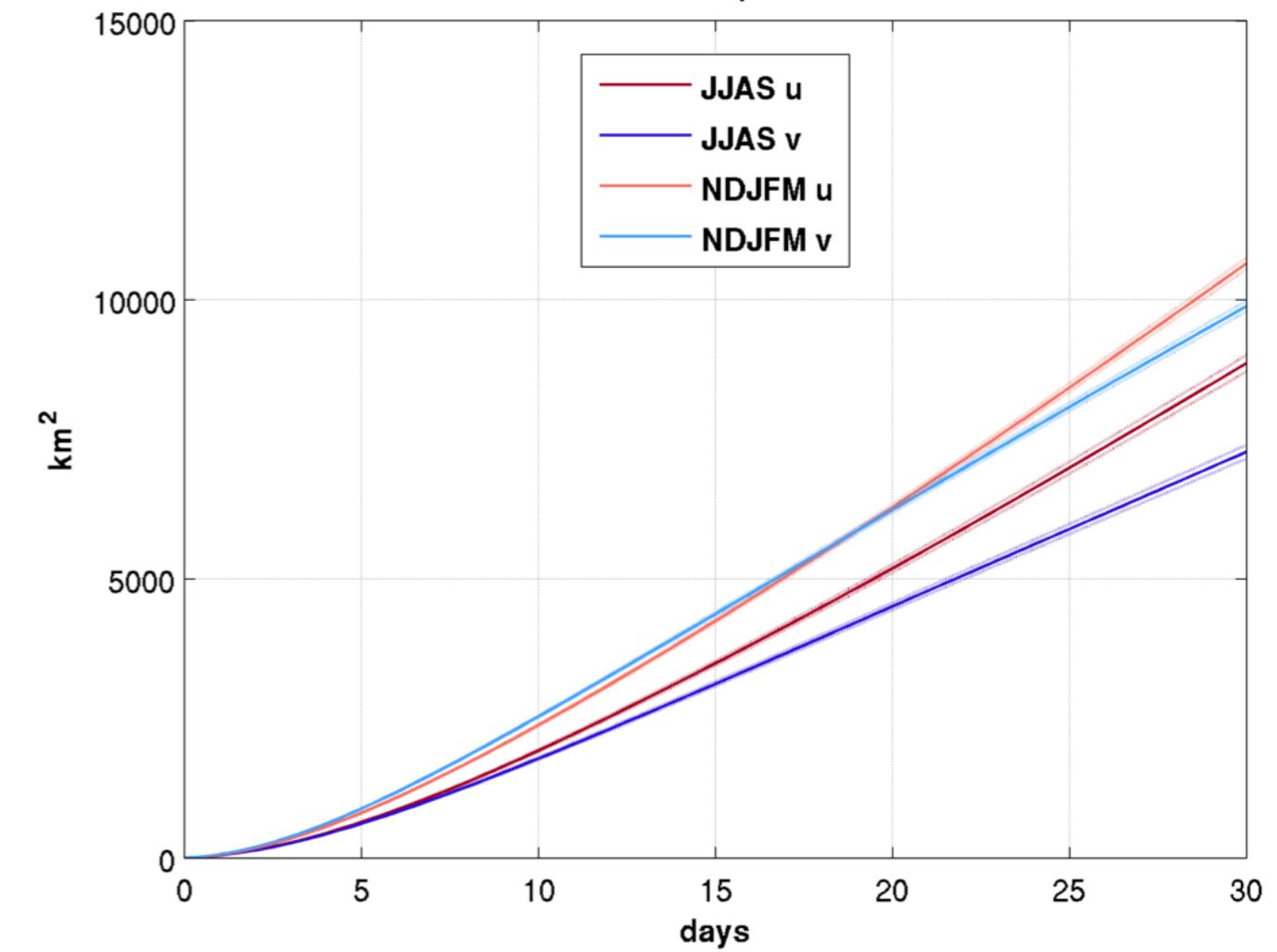
Dispersion

- Single particle absolute dispersion calculated from bandpassed residual velocities averaged over all trajectories in the season

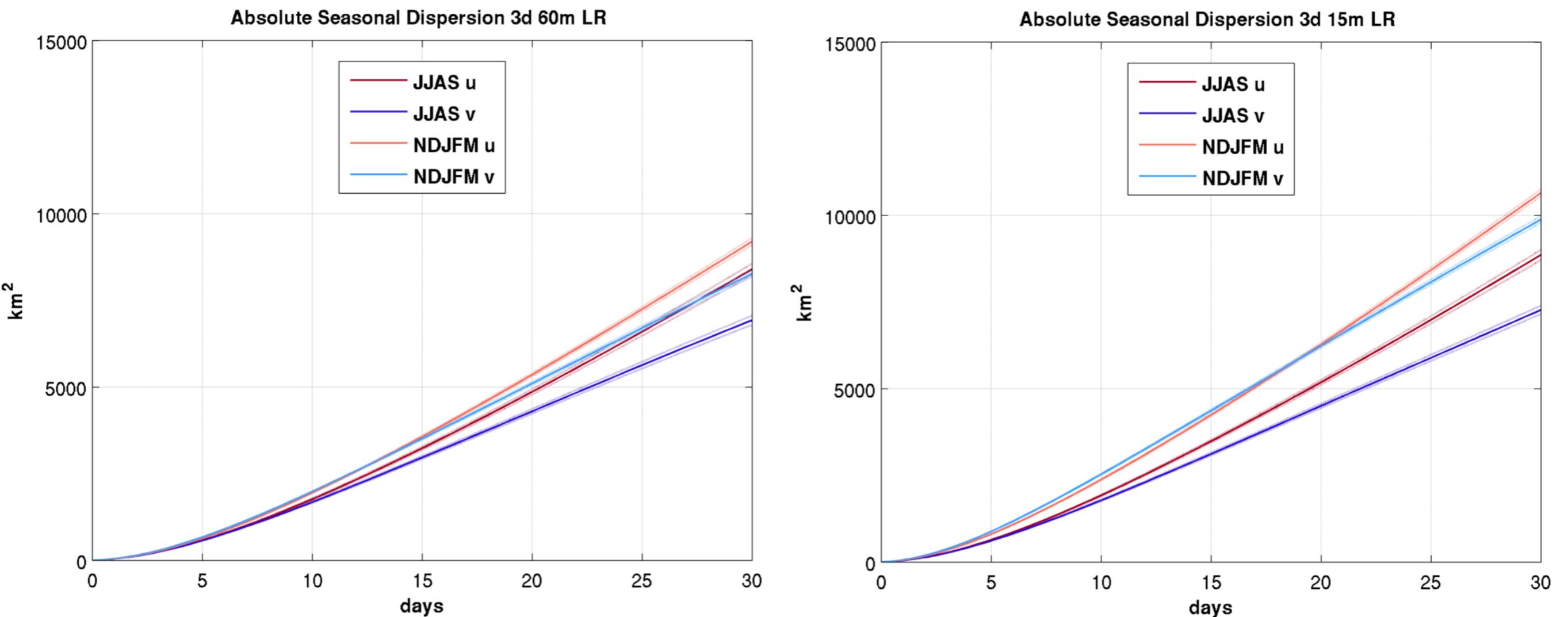
Absolute Seasonal Dispersion 2d 15m LR

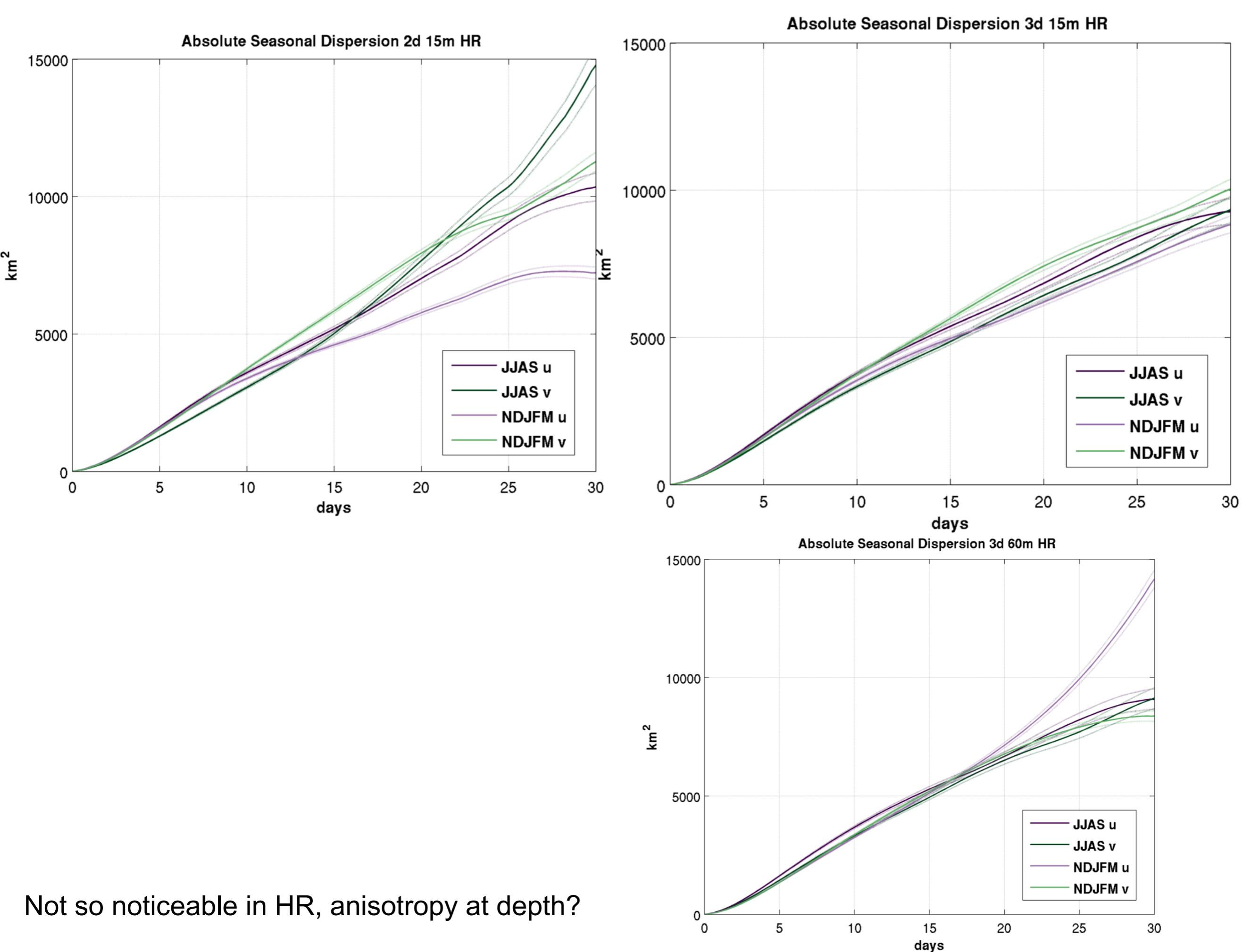


Absolute Seasonal Dispersion 3d 15m LR

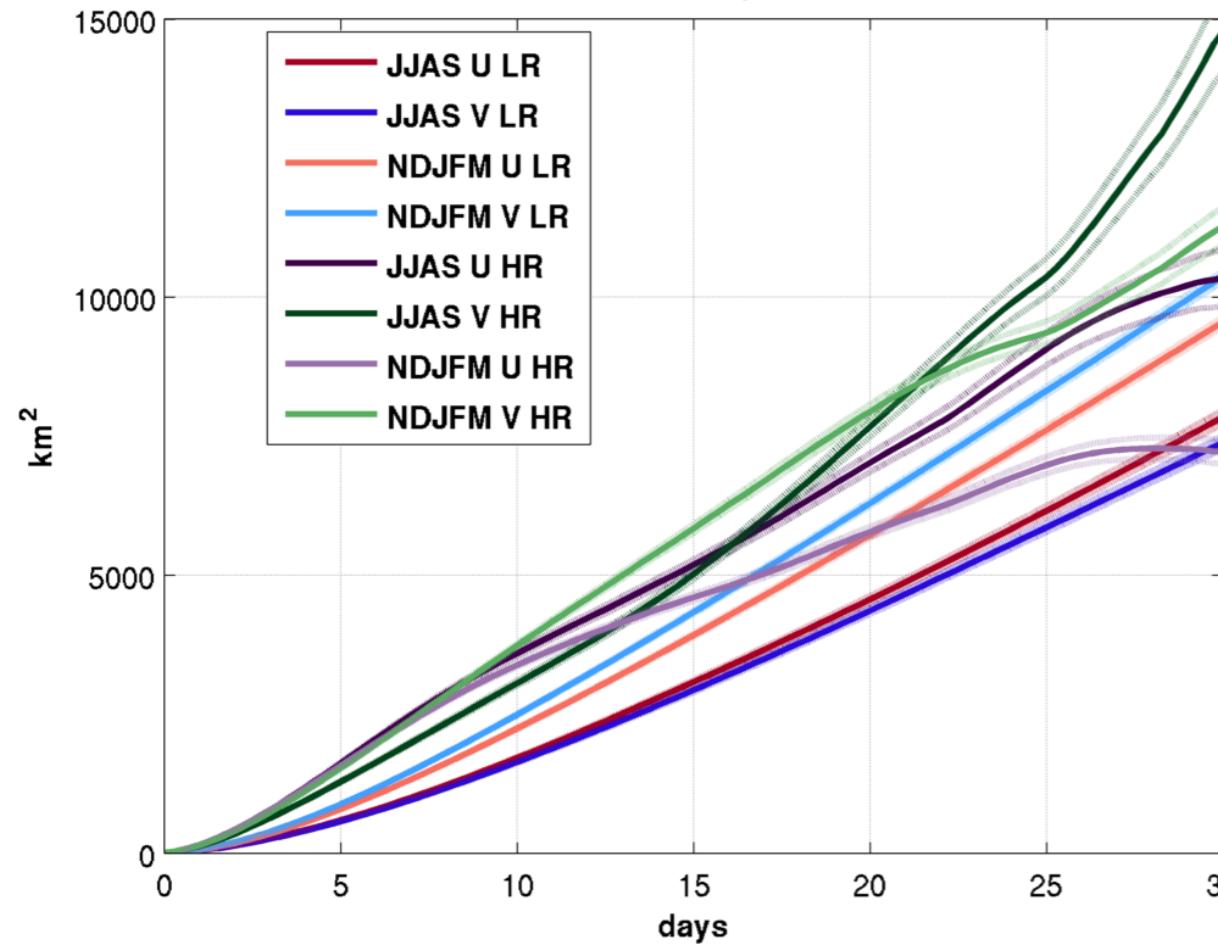


More dispersion in summer

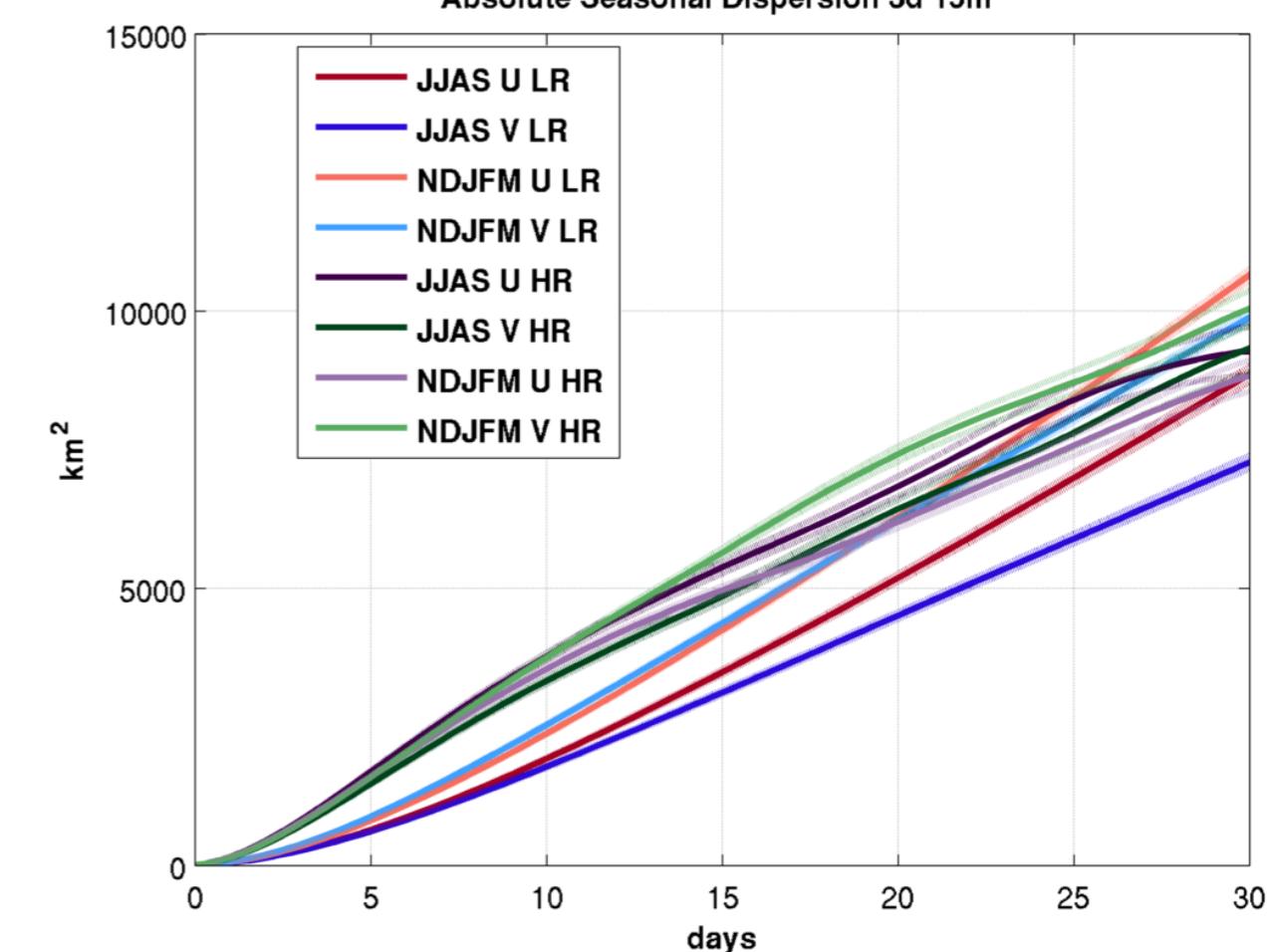




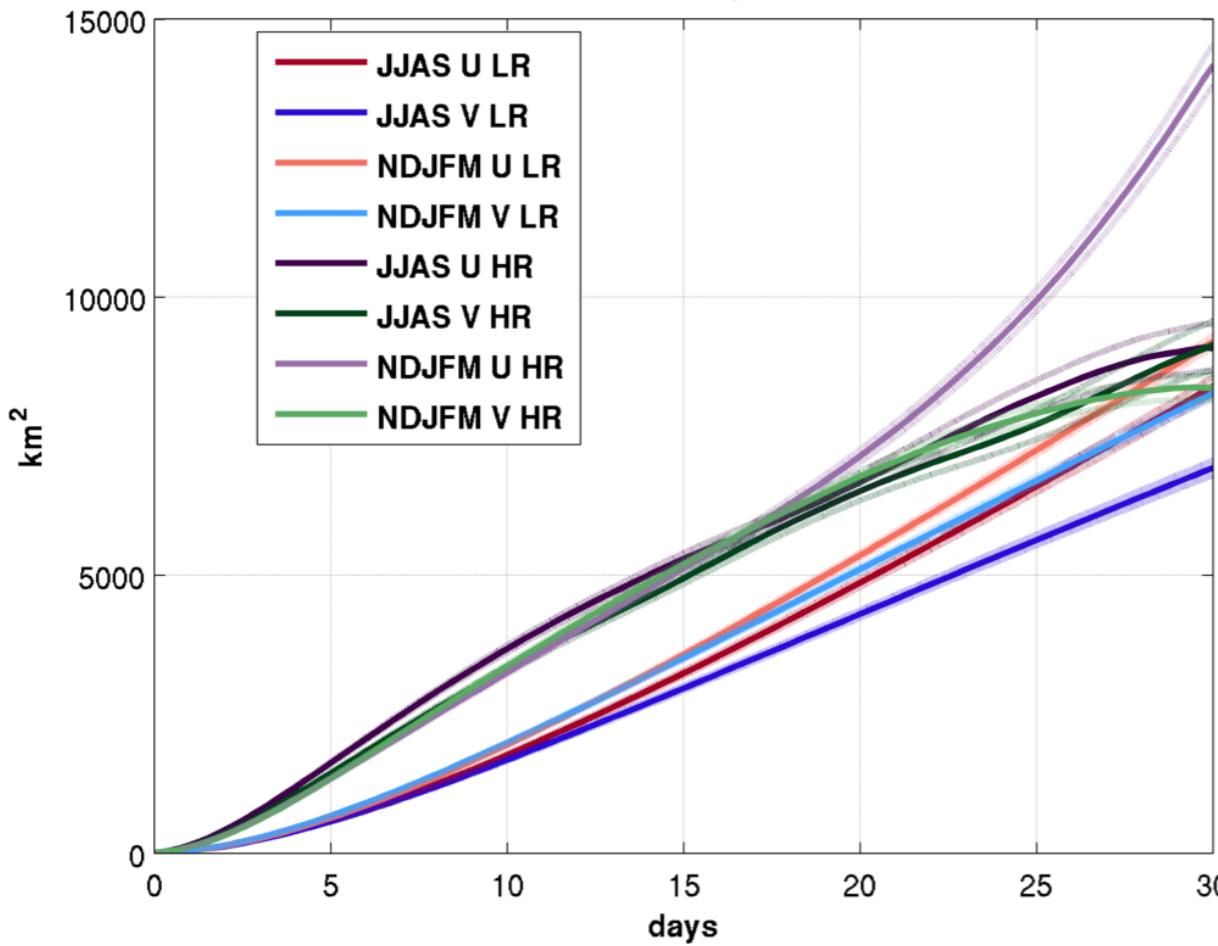
Absolute Seasonal Dispersion 2d 15m



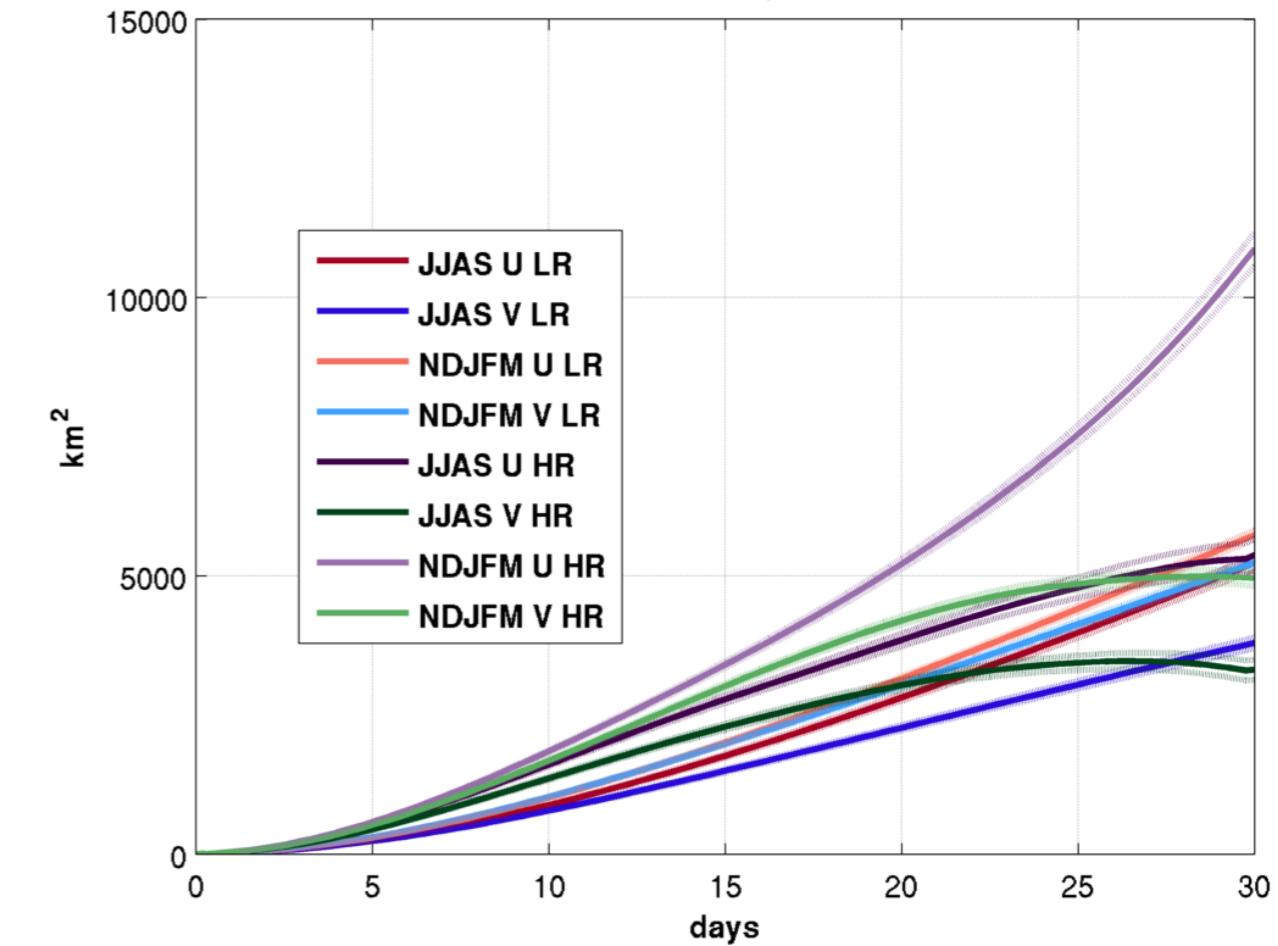
Absolute Seasonal Dispersion 3d 15m



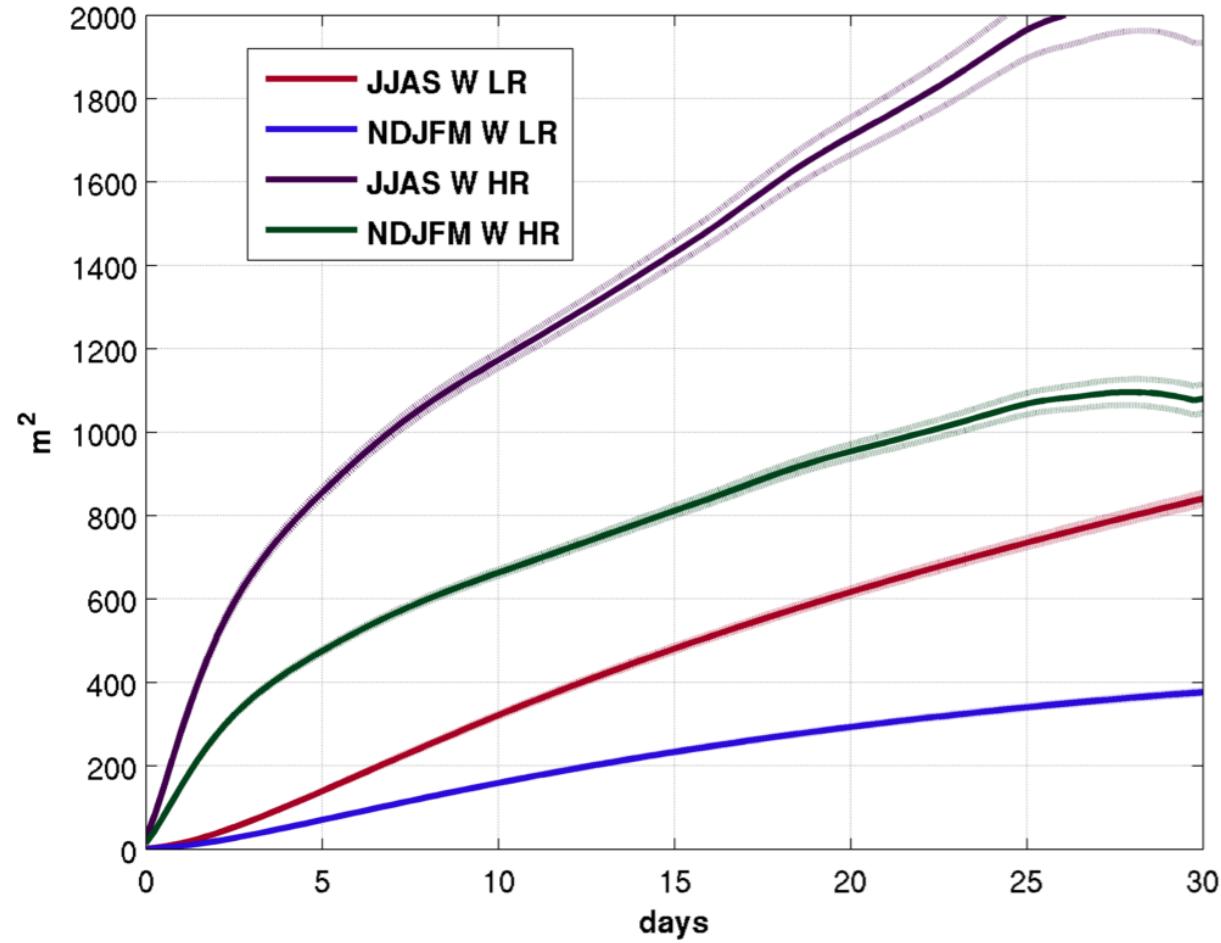
Absolute Seasonal Dispersion 3d 60m



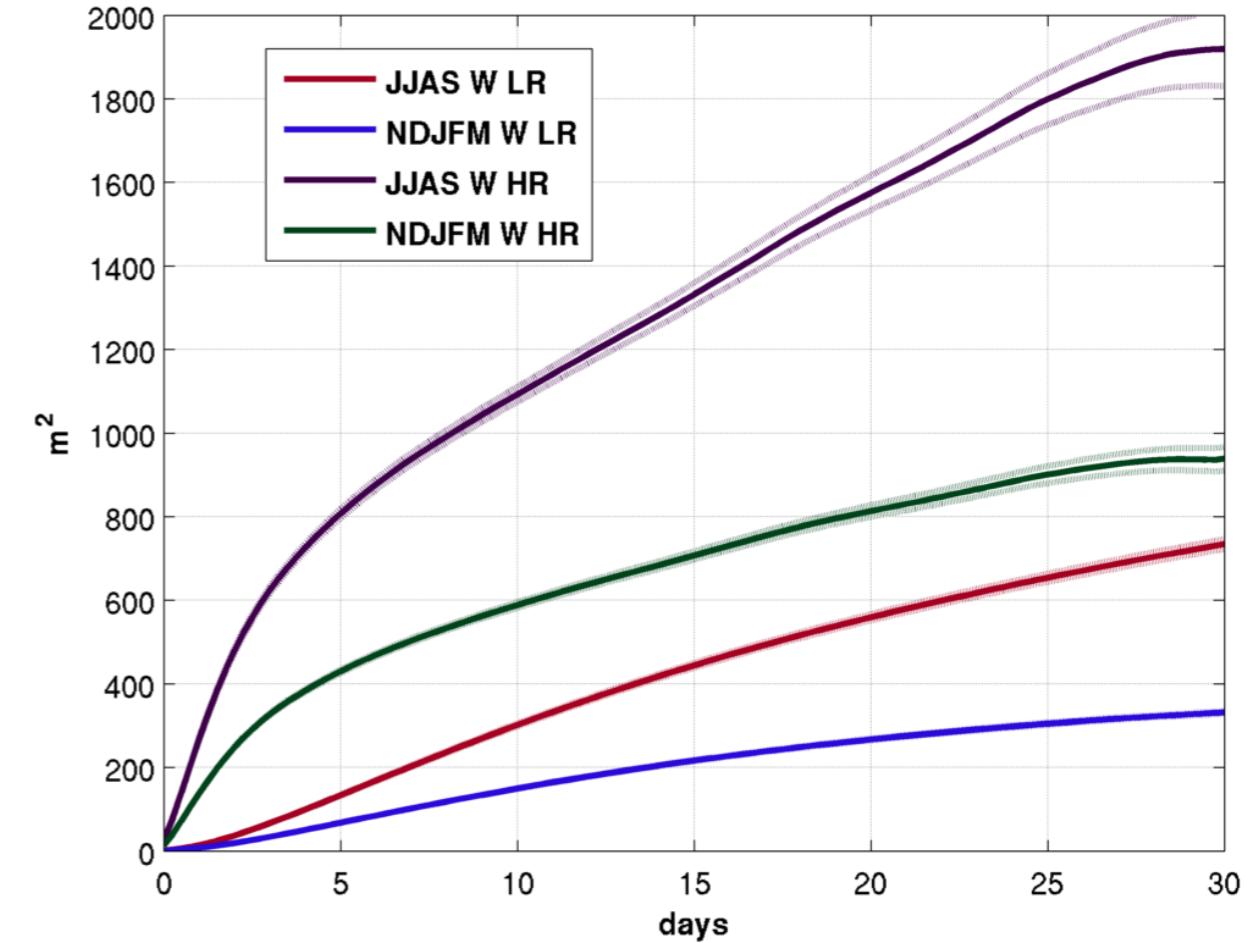
Absolute Seasonal Dispersion 3d 150m



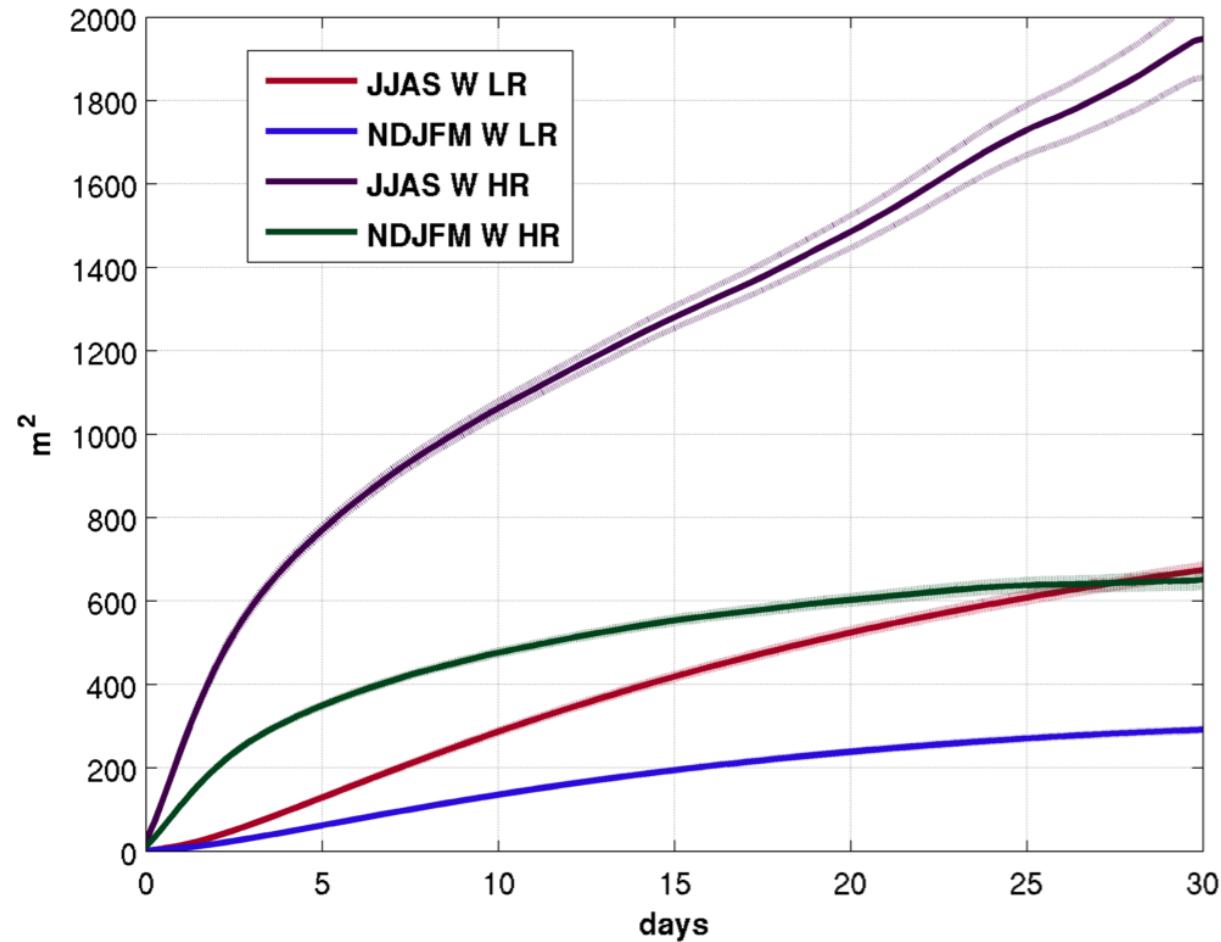
Absolute W Seasonal Dispersion 3d 15m



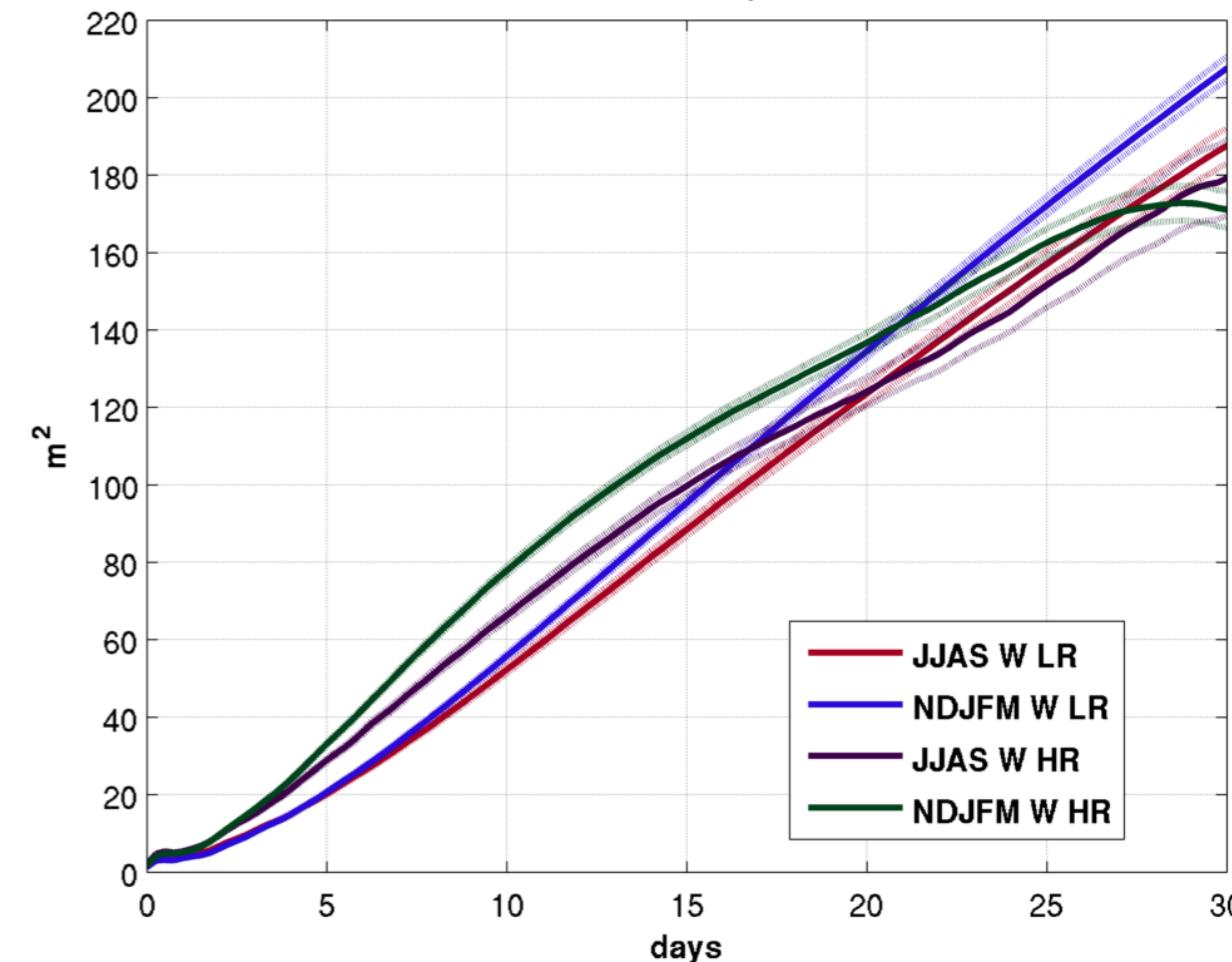
Absolute W Seasonal Dispersion 3d 30m



Absolute W Seasonal Dispersion 3d 60m



Absolute W Seasonal Dispersion 3d 150m



2 particles statistics

$$FTLE(x, y)_{\tau} = \log \left(\frac{r_2(x, y, \tau) - r_1(x, y, \tau)}{r_2(x, y, 0) - r_1(x, y, 0)} \right) / |\tau|$$

2d 15m

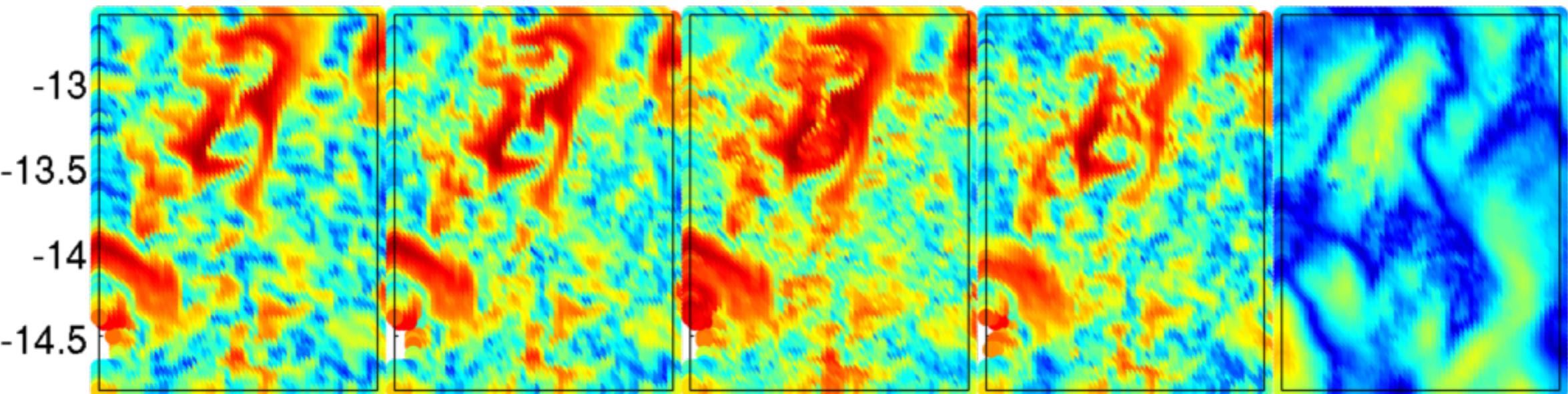
3d 15m

3d 30m

3d 60m

3d 150m

1999M08



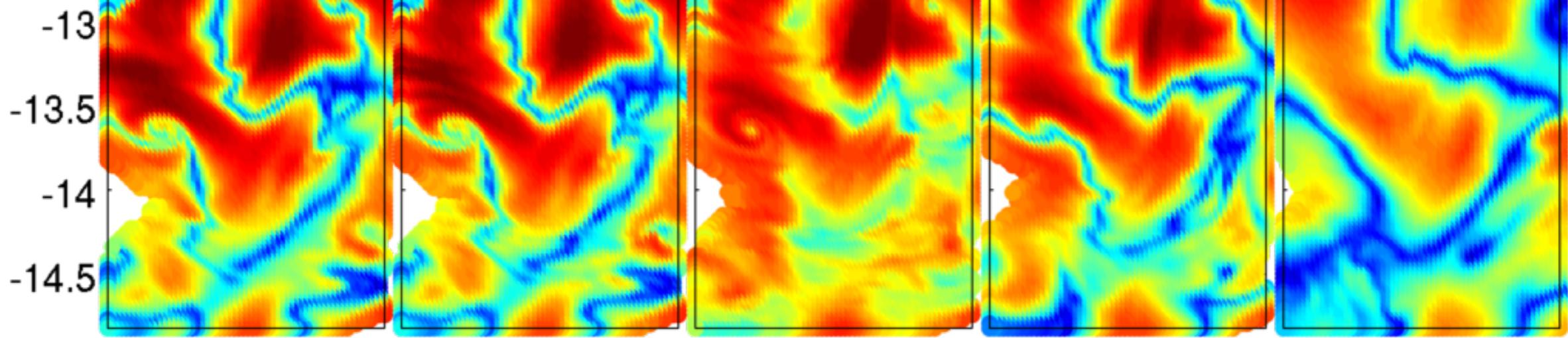
0

0.5

1

1.5

1999M11



-32.5 -32 -31.5 -32.5 -32 -31.5 -32.5 -32 -31.5 -32.5 -32 -31.5 -32.5 -32 -31.5

0

0.5

1

1.5

FTLE 3 DAYS, ignore 30m (doesn't sample all neighboring particles)

Future work

- Continuing 2-particle statistics
- Filtering timeseries into mesoscale/submesoscale components; quantifying seasonal contribution of each to dispersion
- Similar analysis on new HR runs