Surface Currents and Turbulent Dispersion in the Tropical North Atlantic

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Knauss Lecture Series

NOAA Central Library

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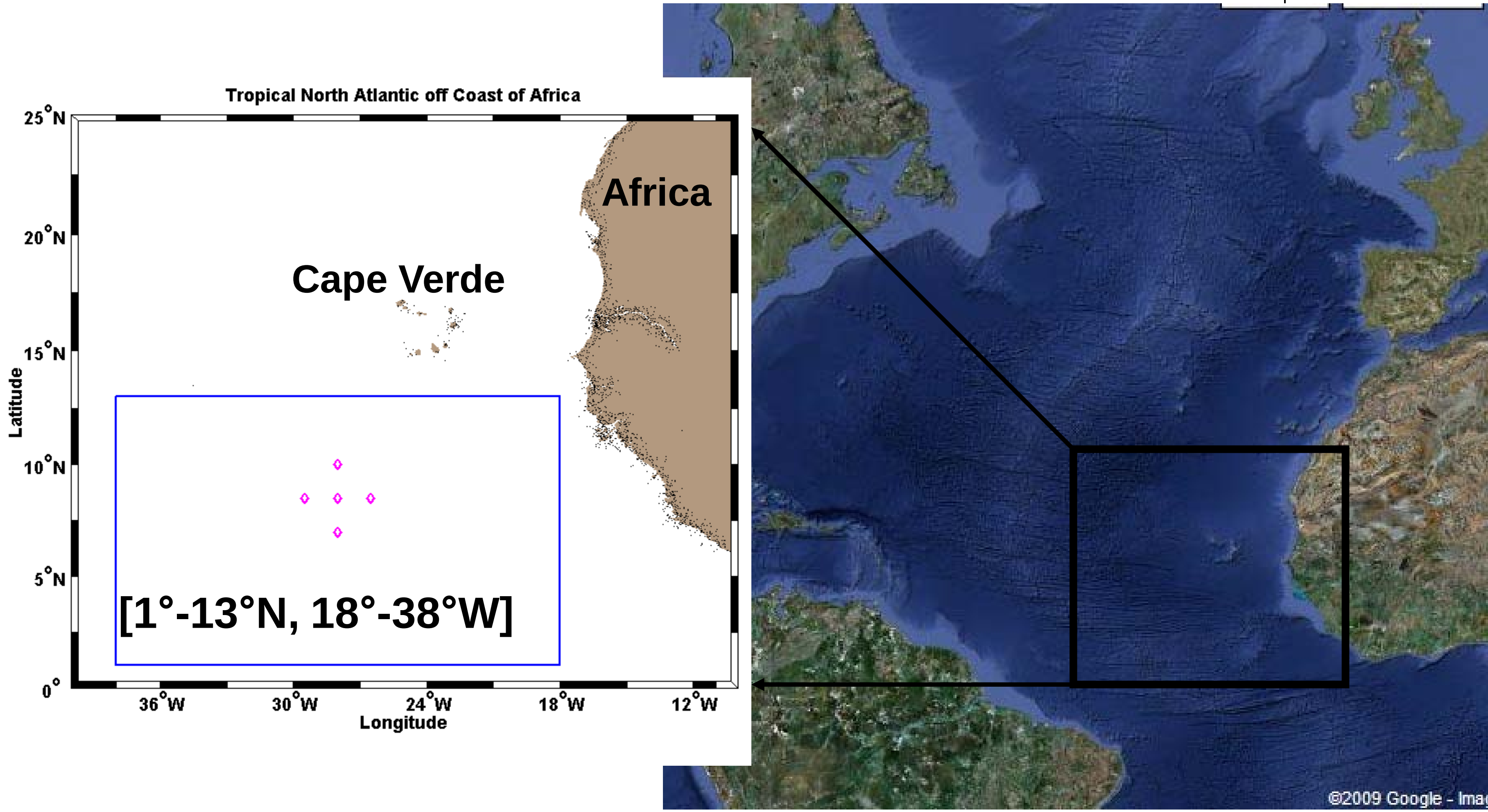
Outline

- Study area
- Motivation
- Mapping currents
- Mesoscale variability
- Turbulent dispersion
- Summary

Study area



Tropical North Atlantic off Coast of Africa
25°N
20°N
15°N
10°N
5°N
0°
Latitude
36°W
30°W
24°W
18°W
12°W
Longitude
Africa
Cape Verde
[1°-13°N, 18°-38°W]
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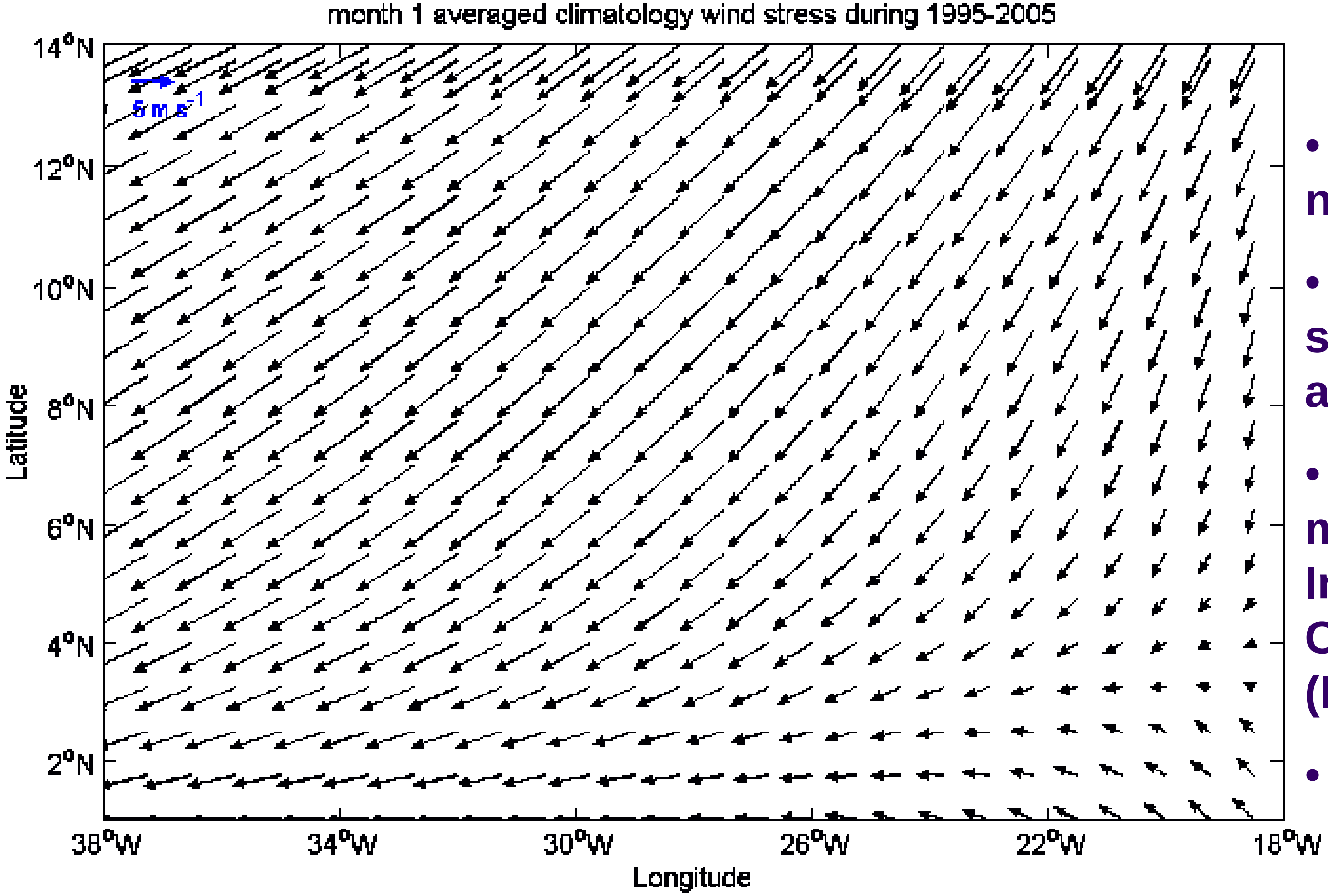
Study area - winds

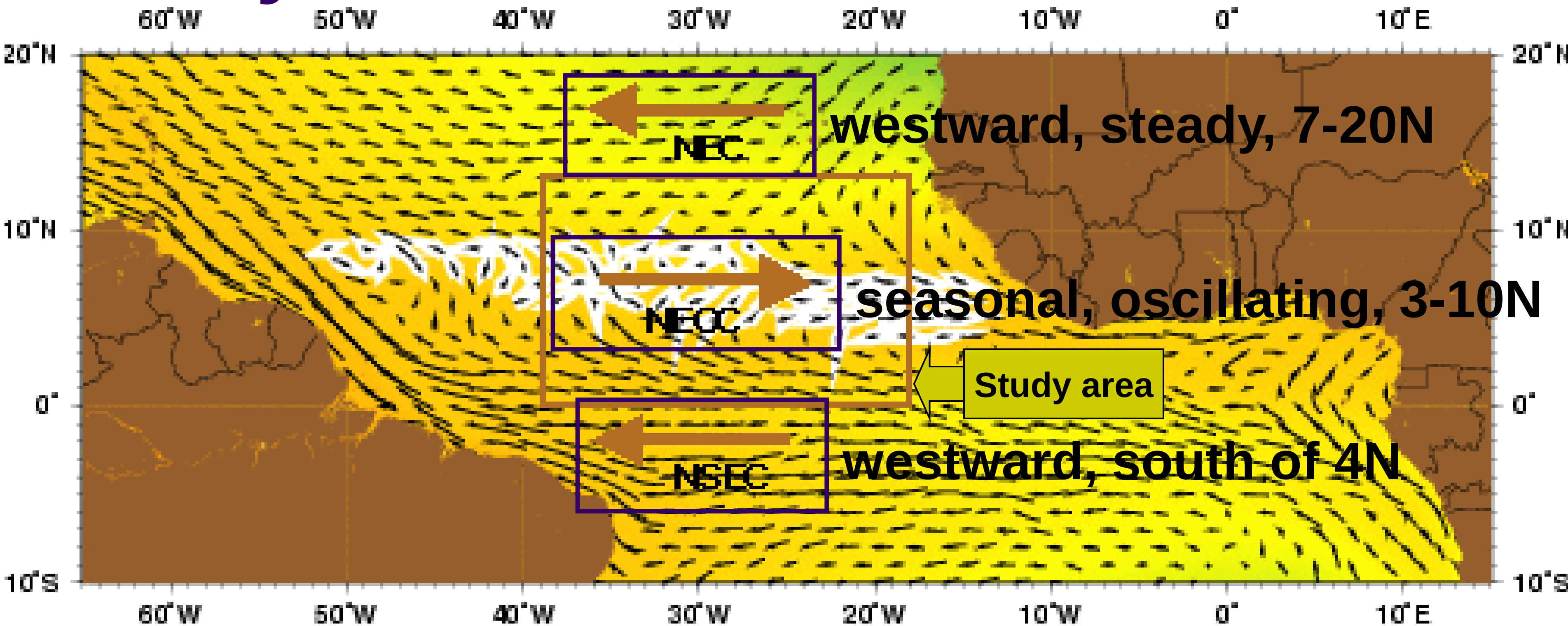


- Jan. to May, northeast wind
- By late summer, southeast wind across the equator
- leads to northward migration of the Intertropical Convergence Zone (ITCZ)
- East wind 7-10N

Seasonally varying wind field in the tropical North Atlantic

Data source: NOAA Multiple-Satellite Blended 0.25-degree Sea Winds

Study area – currents



Current Systems in the Tropical North Atlantic

NEC: North Equatorial Current

NECC: North Equatorial Counter Current

NSEC: North South Equatorial Current

Bischof et al., 2004; Strama et al., 2005

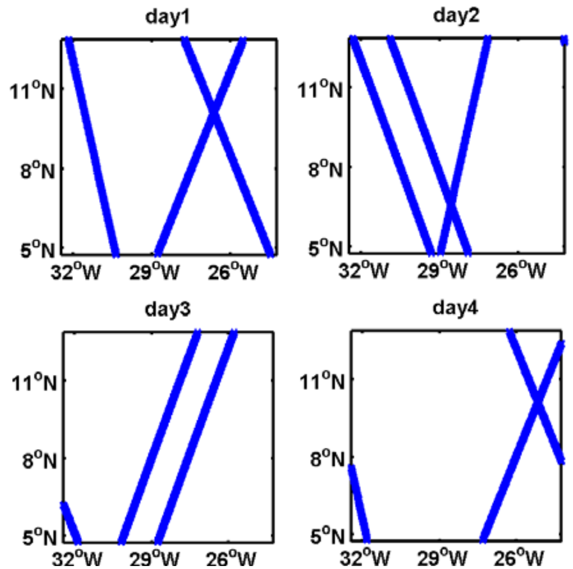
Motivation

- To better understand water dispersion at the sea surface as this applies to the fate of pollutants, larval transport
- To make climate numerical models more accurate
- To compare with results in the ocean interior from the Lagrangian Isopycnal Dispersion Experiment (LIDEX)

Mapping currents - data

- Along-track sea level anomaly (SLA) from multiple satellite altimeters
  - Generate daily SLA maps
  - Derive the mesoscale flow anomaly field that is superimposed on the mean flow (1993-1999)
- Hydrographic data
  - Validate mapping process and results

Mapping currents - method



→ Spatial correlation
Temporal correlation

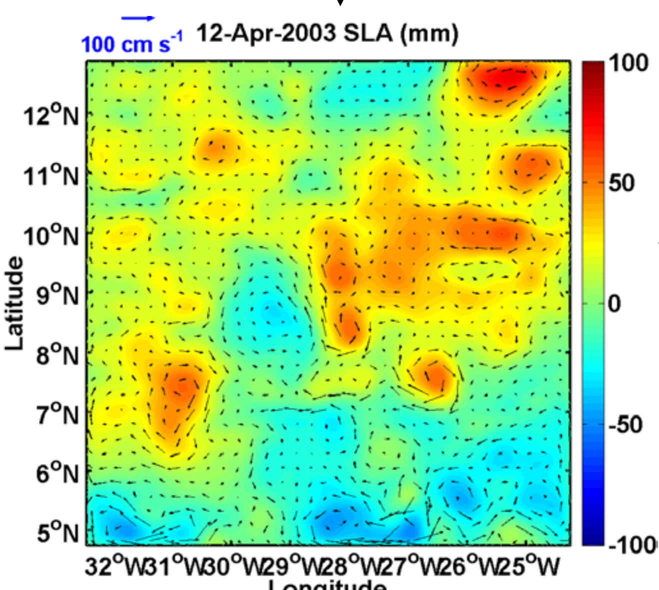
Space-time correlation model

$$C(R,\Delta t) = \exp(-\frac{R}{90})\cos(\frac{2\pi R}{920})\exp(-\frac{|\Delta t|}{32})$$

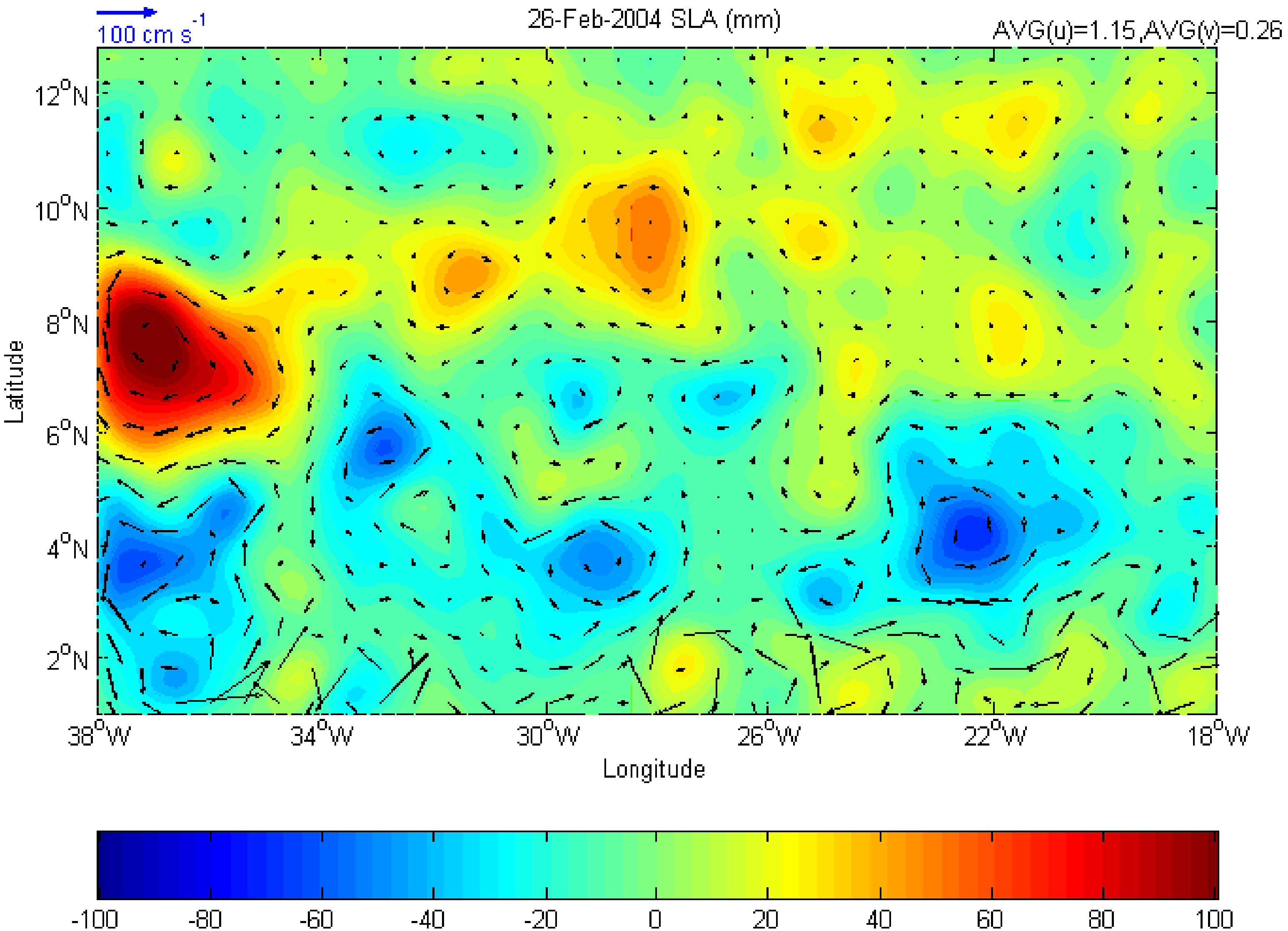
Objective analysis of data within the search radius in space and time

Validation with in-situ data

↓ ?



Mapping currents - example

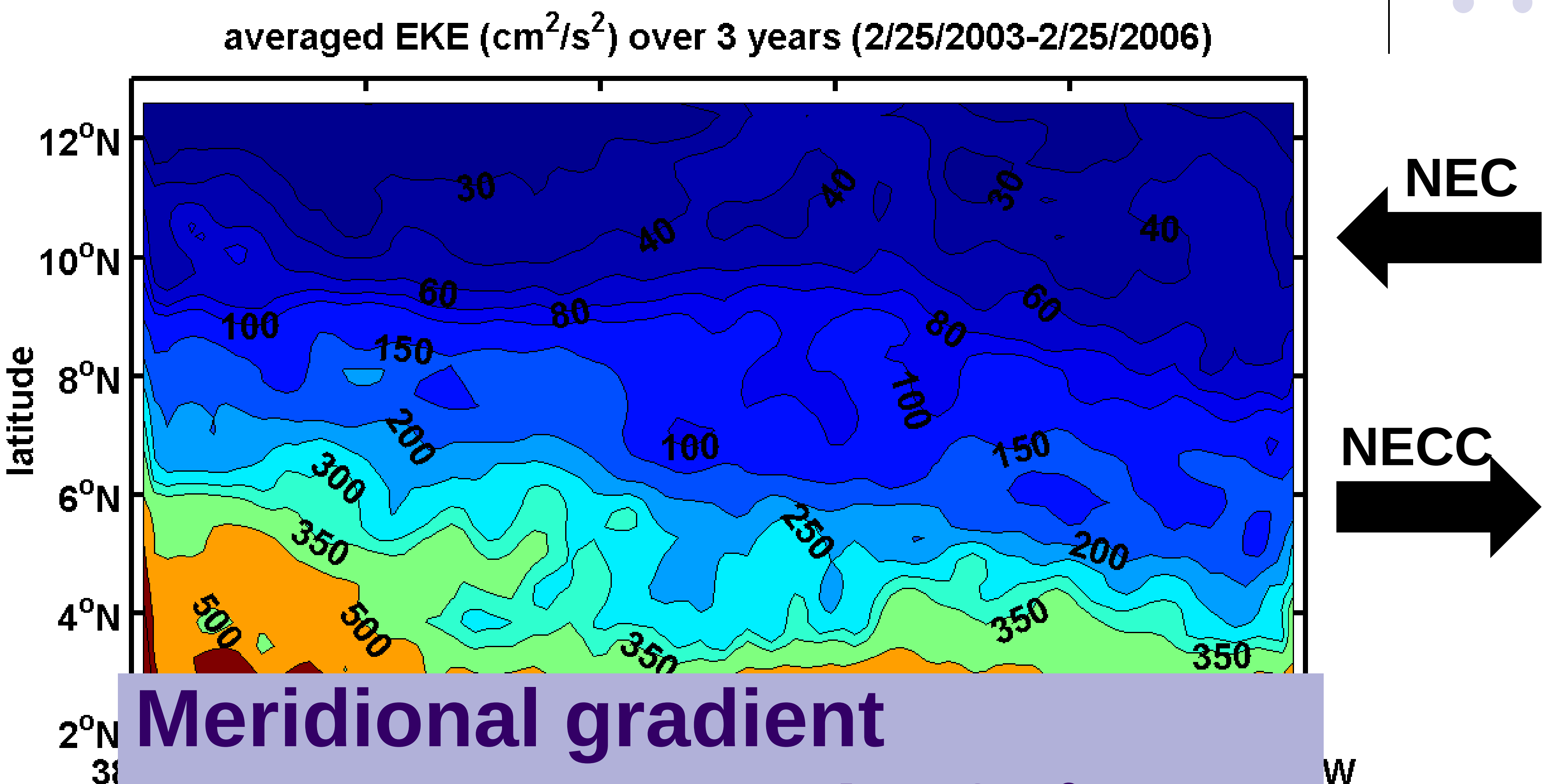


Mesoscale variability

- How does the mesoscale flow field vary across the study area?

- How does the mesoscale flow field change in time?

Mesoscale variability – spatial

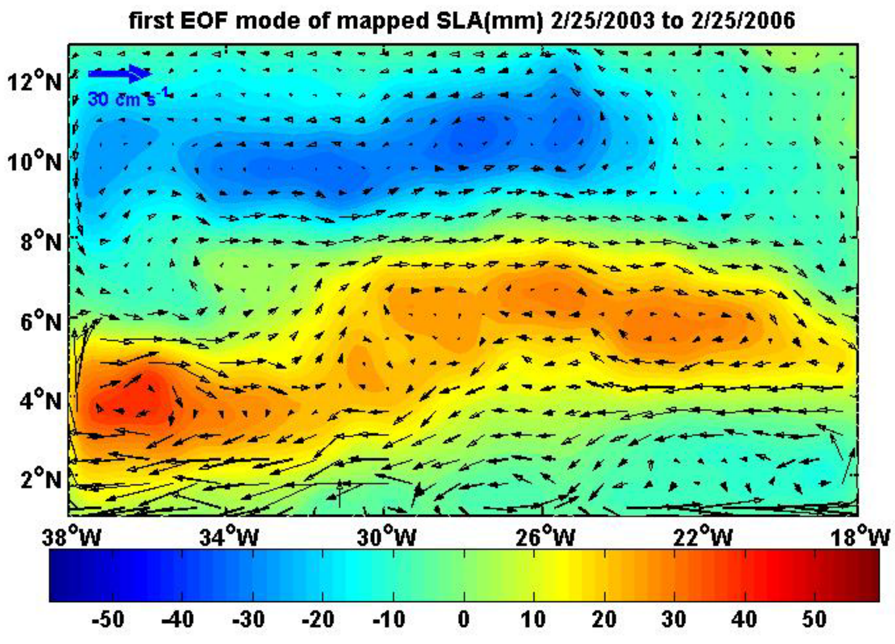


Meridional gradient

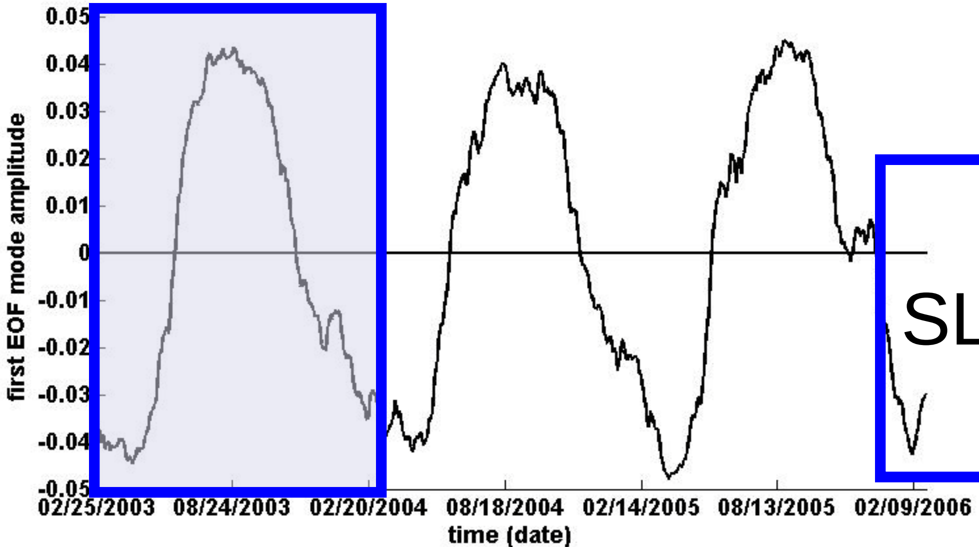
Homogenous north of 8°N

More active in 2°-7°N

Mesoscale variability - temporal (EOF mode 1)



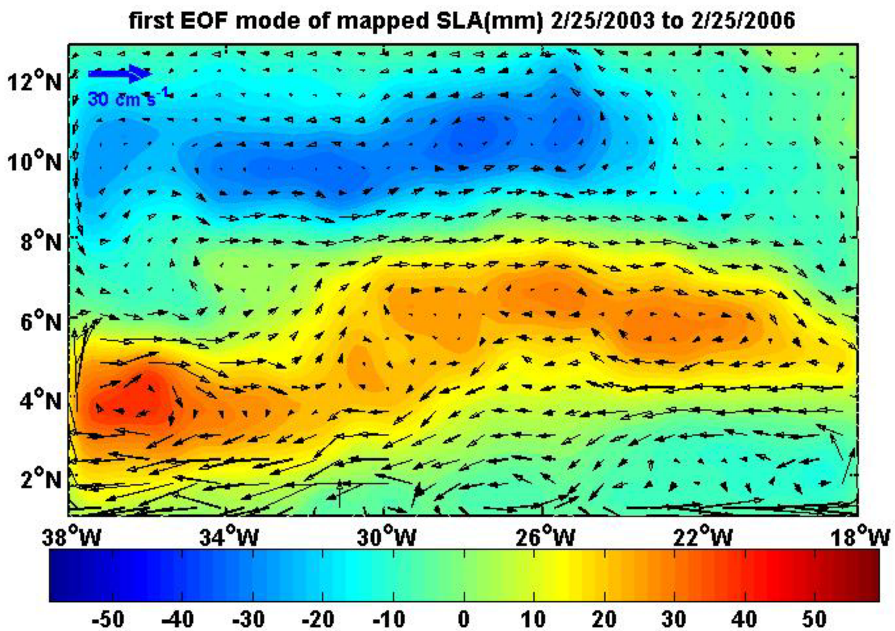
- Strongest negative in February; strongest positive in August.
- Currents strengthen and weaken seasonally.

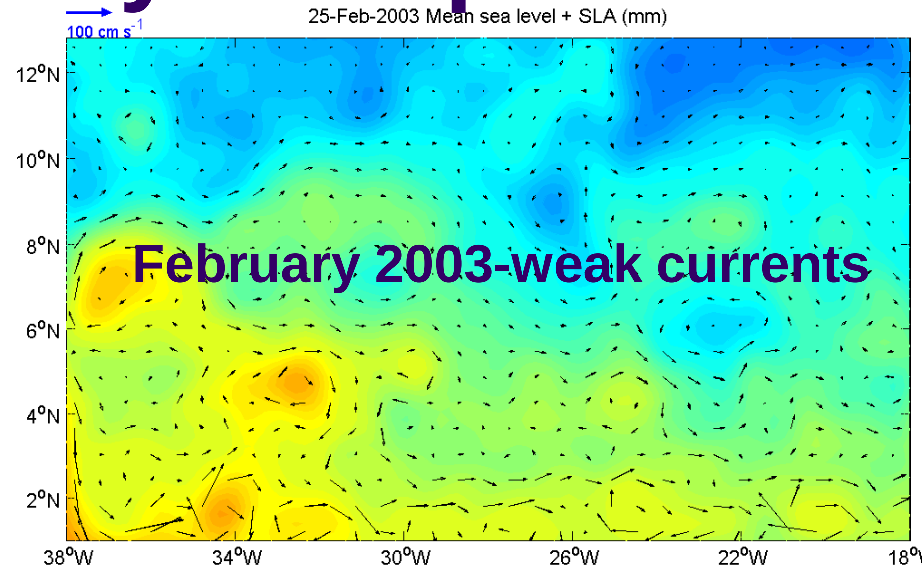


Next slide:

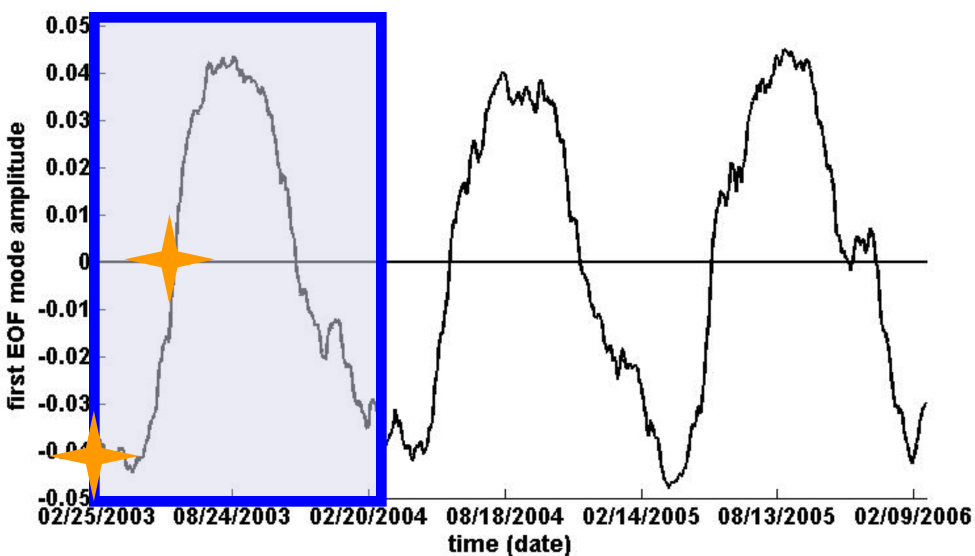
Total mesoscale flow = SLA + Mean sea level (93-99) in 2003

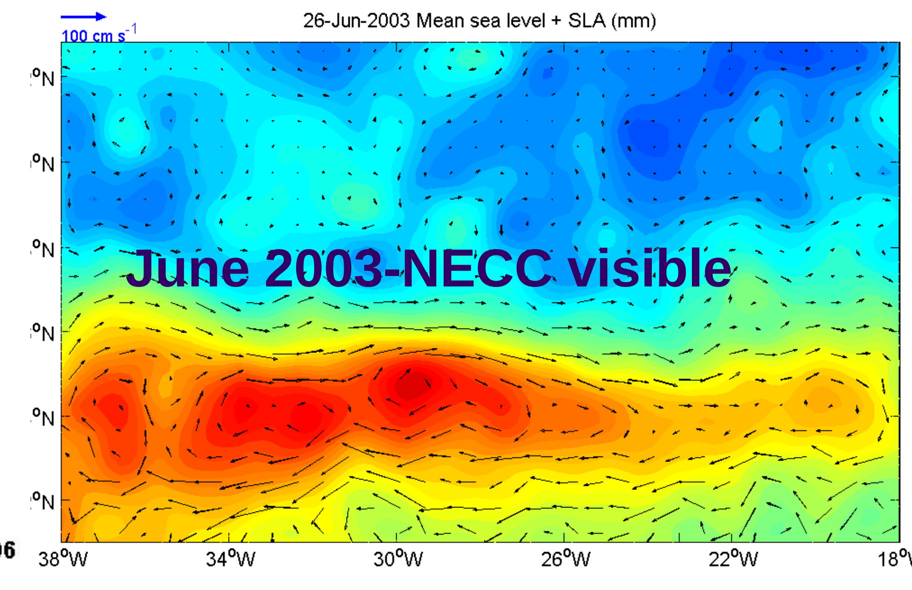
Mesoscale variability - temporal



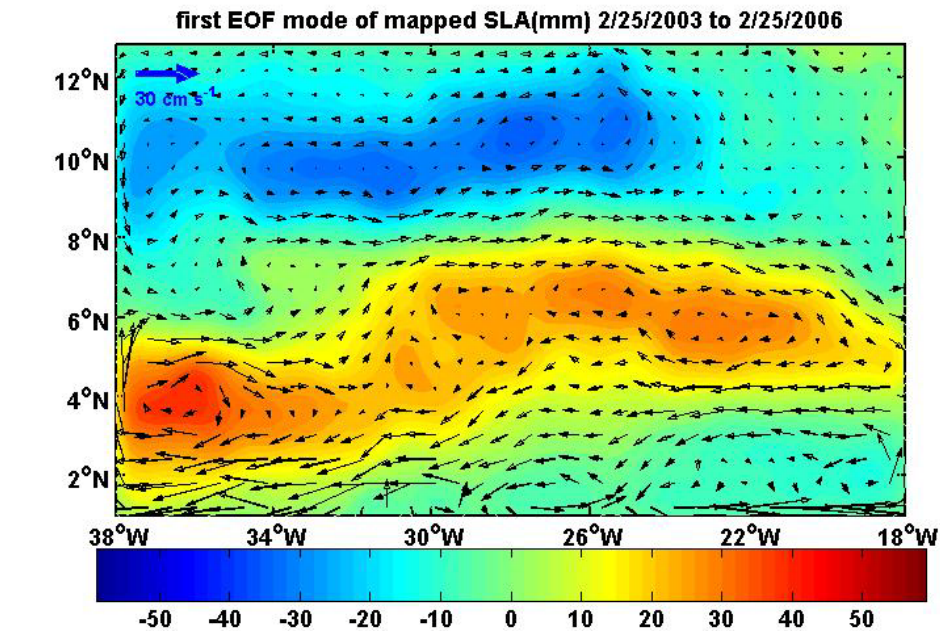


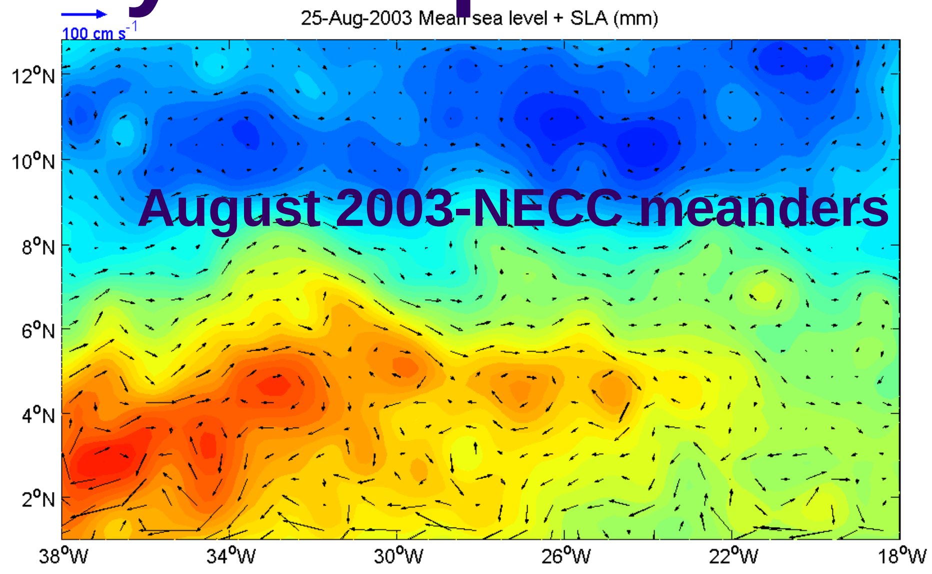
Snapshot of total mesoscale flow



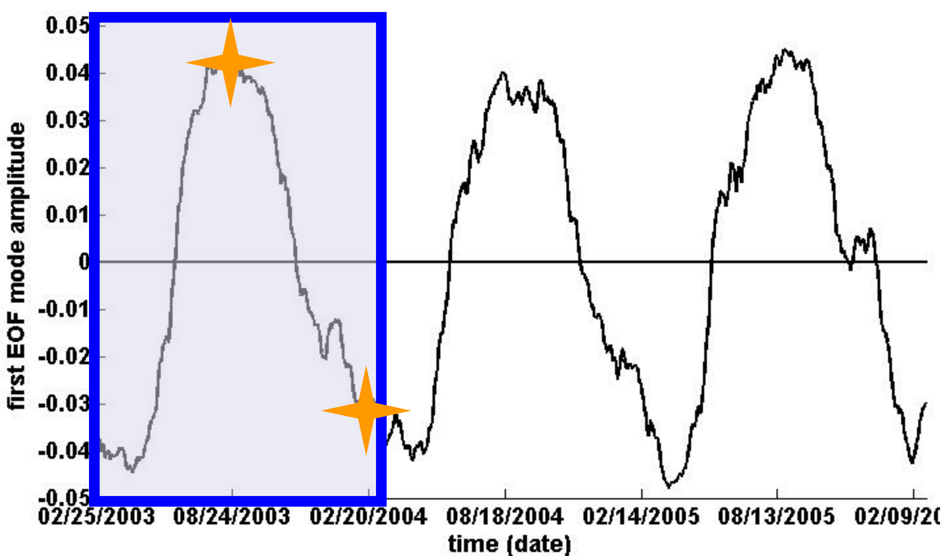


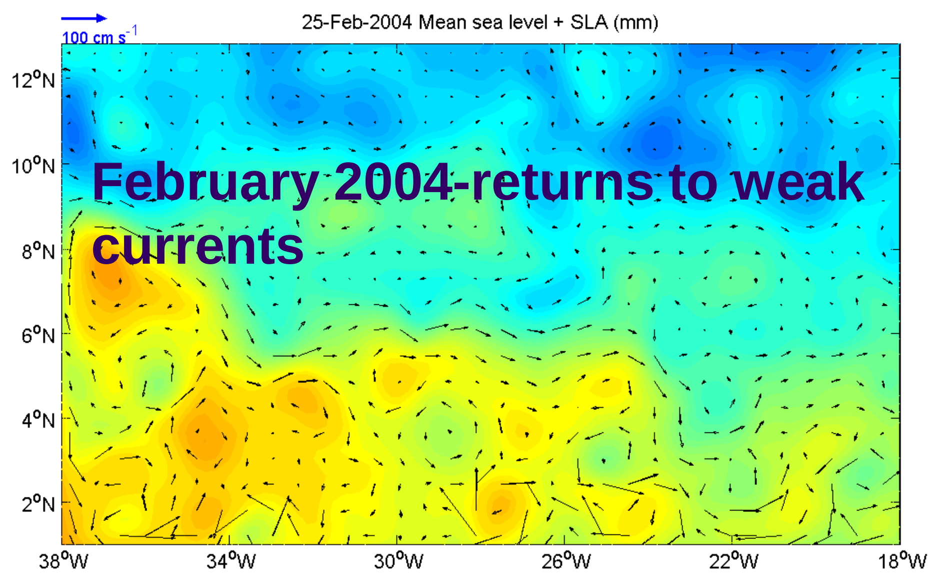
Mesoscale variability - temporal





Snapshot of total mesoscale flow



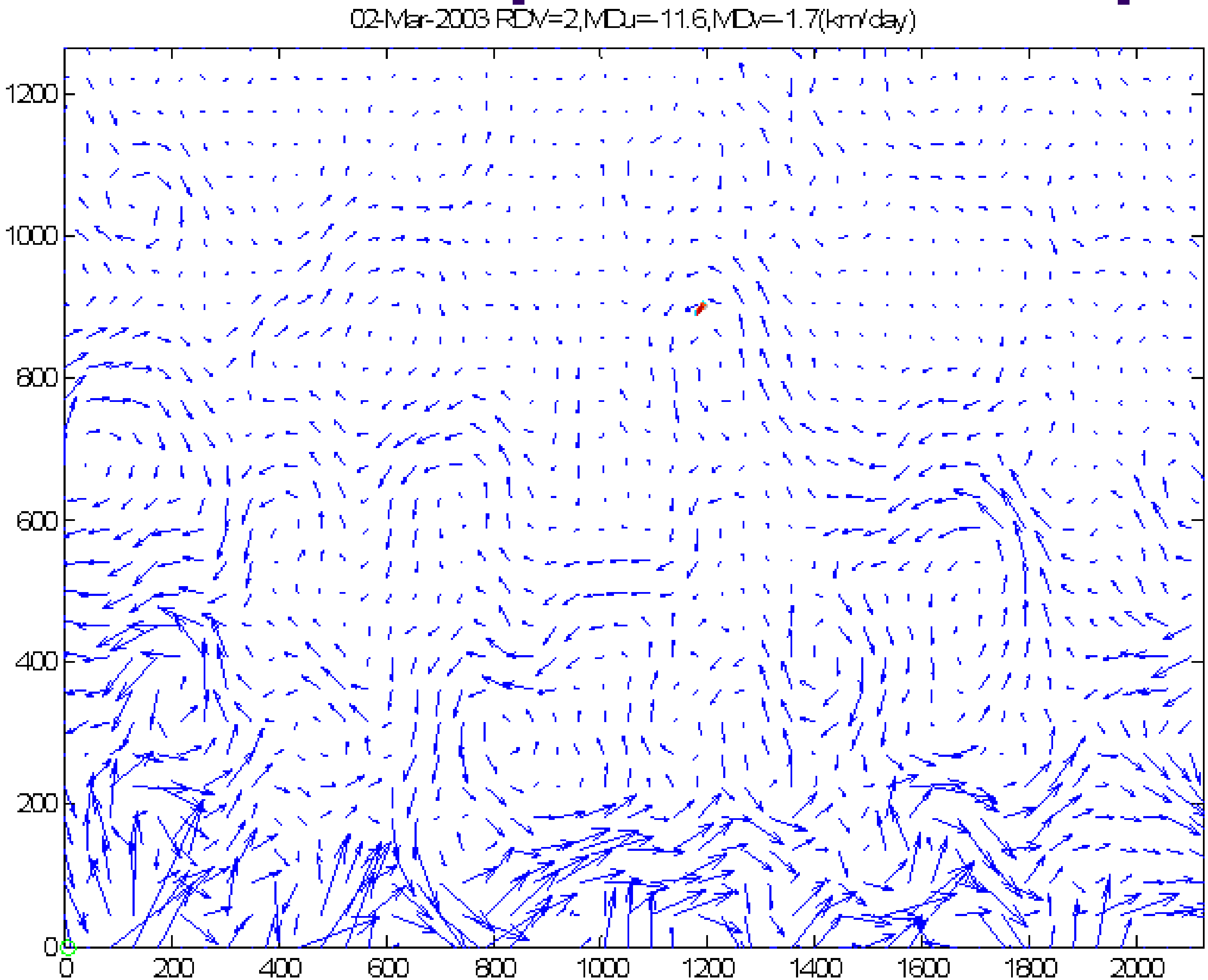


Turbulent dispersion - data

- In-situ drifters – 23 years
  - Part of NOAA's Global Drifter Program
  - Measure overall flow in the mixed layer (4 parts)
- Numerical drifters
  - Numerical simulation of altimeter-derived mesoscale flow field
  - Measure only the mesoscale flow
  - 900 experiments each with 67 years of trajectories on average

Next slide: Dispersion movie of numerical drifters

Turbulent dispersion - example



Turbulent dispersion - method

- Decompose turbulent velocities
- Taylor particle dispersion theory
  - Lagrangian statistics from turbulent velocities
    - Integral time scale T_u T_v
    - Integral length scale L_u L_v
    - **Absolute diffusivity** K_{1x} K_{1y}

Turbulent dispersion - results

- Anisotropic Lagrangian statistics

- The altimeter based mesoscale flow explains between 73% to 90% of the overall diffusivities from *in-situ* drifter observation in the Tropical North Atlantic.

Summary – contributions

- Use optimized space-time correlation for the mapping of mesoscale flow field.
- Proposed a standard method to separate the turbulent velocities and the pseudo-Eulerian mean flow.
- Investigated the mesoscale flow field and surface turbulent dispersion in the tropical North Atlantic.

Summary – conclusions

- The mesoscale flow field demonstrates meridional gradient and seasonal cycle.
- The turbulent dispersion of water particles is dominated by the mesoscale currents as opposed to other components of the overall flow

Thanks for your attention.

Backup Slides

Acknowledgments

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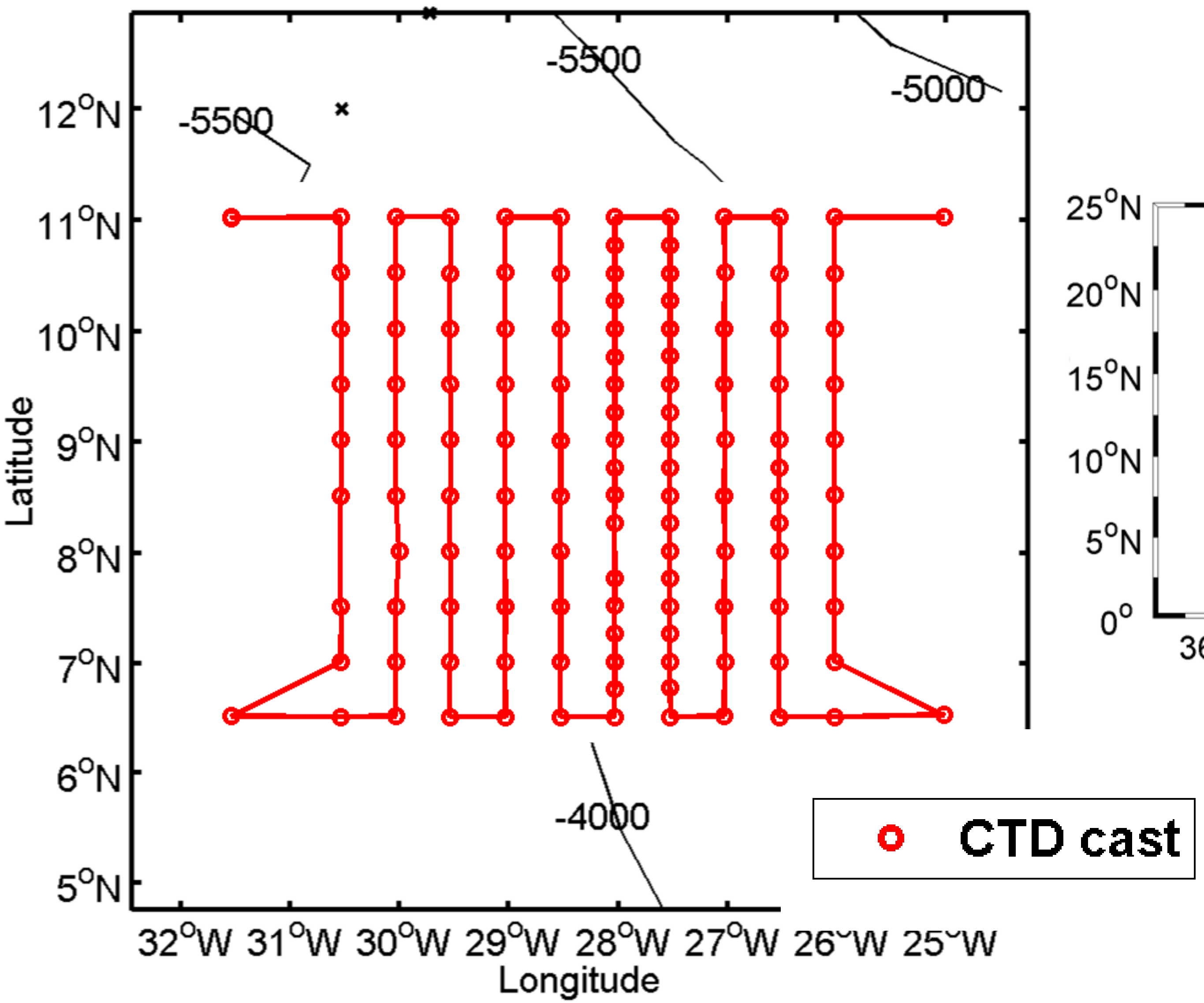
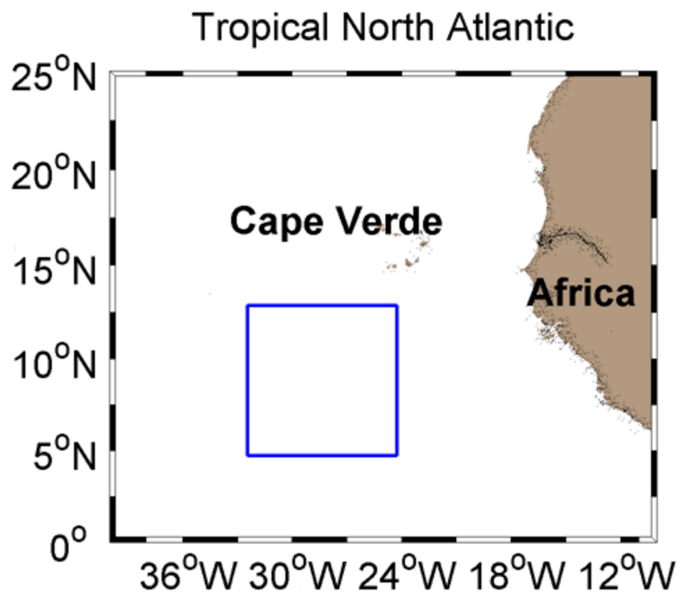
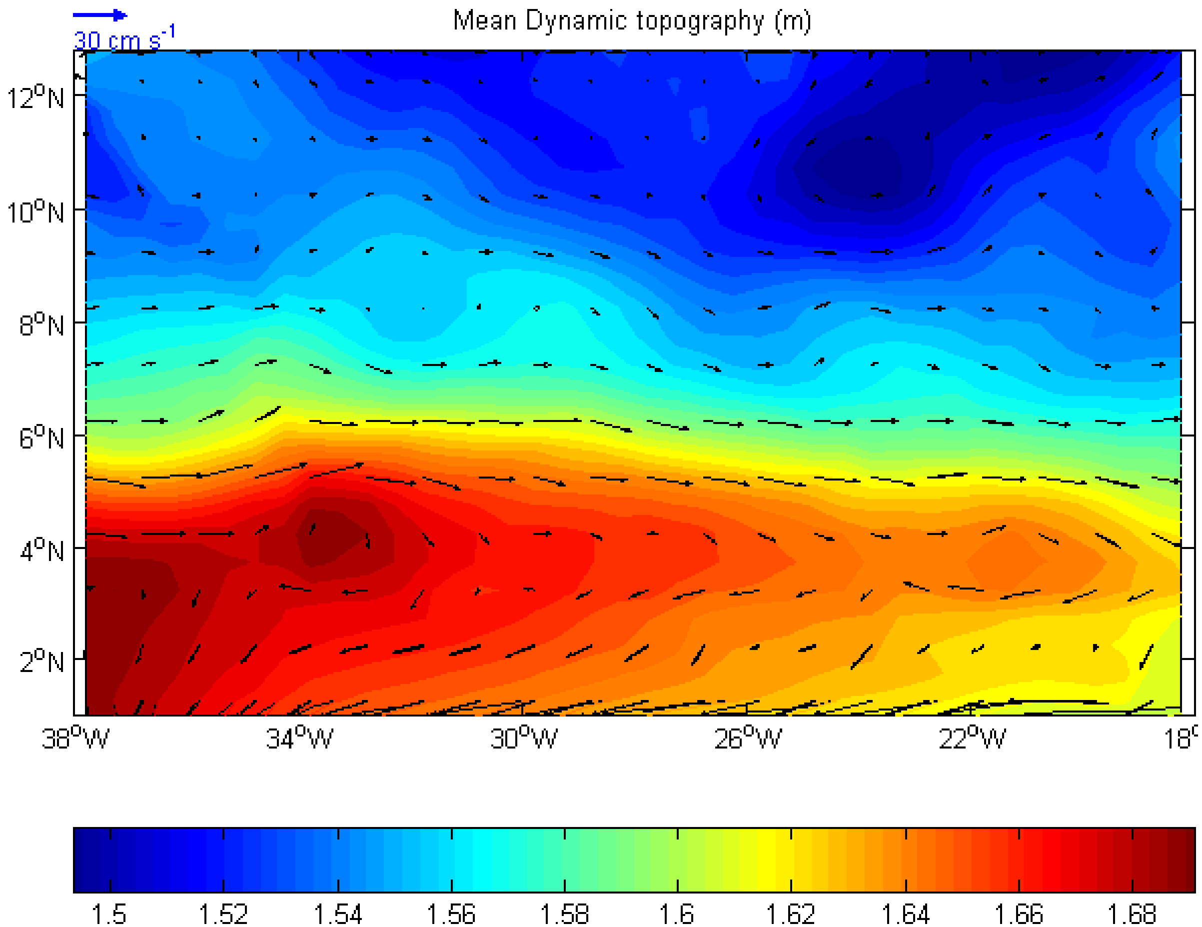
- NOAA's National Climatic Data Center

Motivation

Lagrangian Isopycnal Dispersion Experiment (LIDEX) 2003-2006







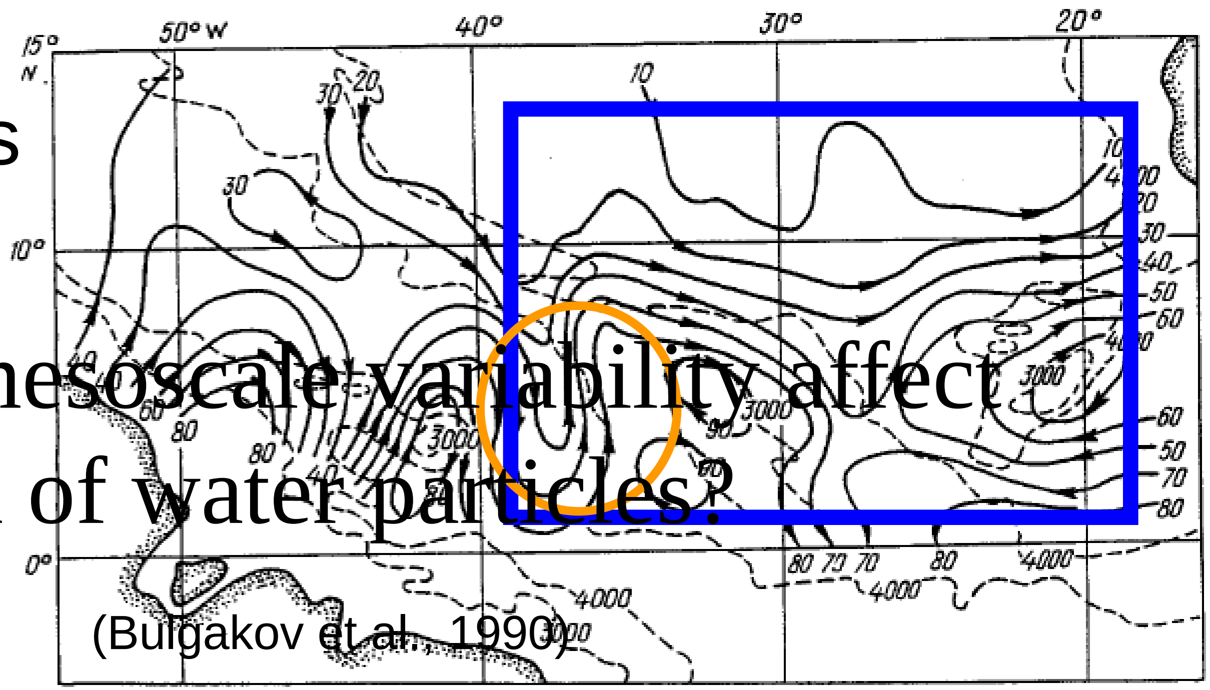
The mean sea surface dynamic topography (1993-1999) in the Tropical North Atlantic (Rio et al., 2004). The major currents can be located along 7°N and 5°N latitude lines.

What causes the variability of mesoscale flow field?

Three factors

- Seasonally strengthening and weakening of the NECC (Richardson and McKee, 1984)
- meanders of NECC
- coherent eddies

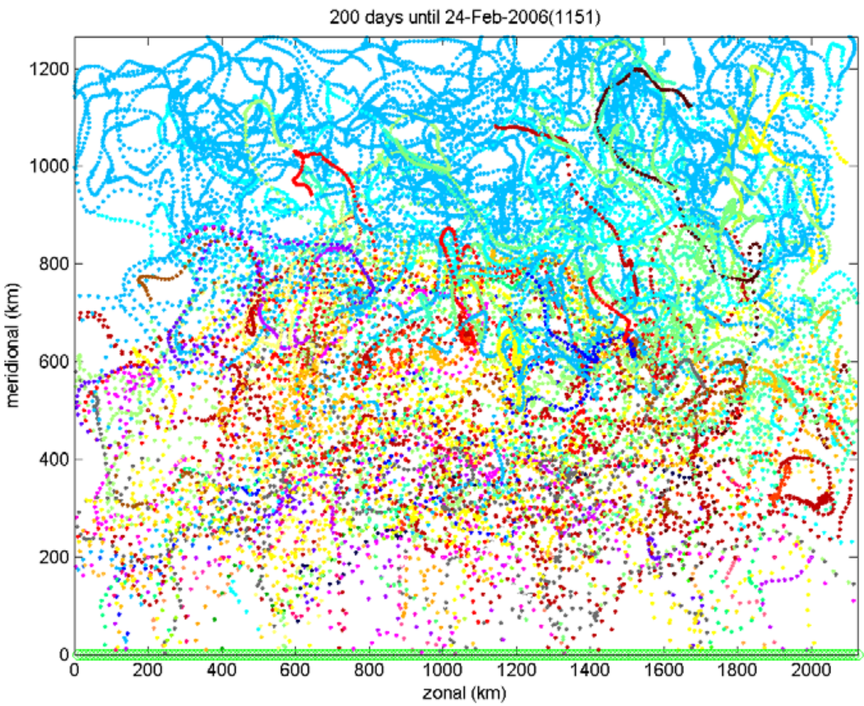
Surface geostrophic circulation summer 1987



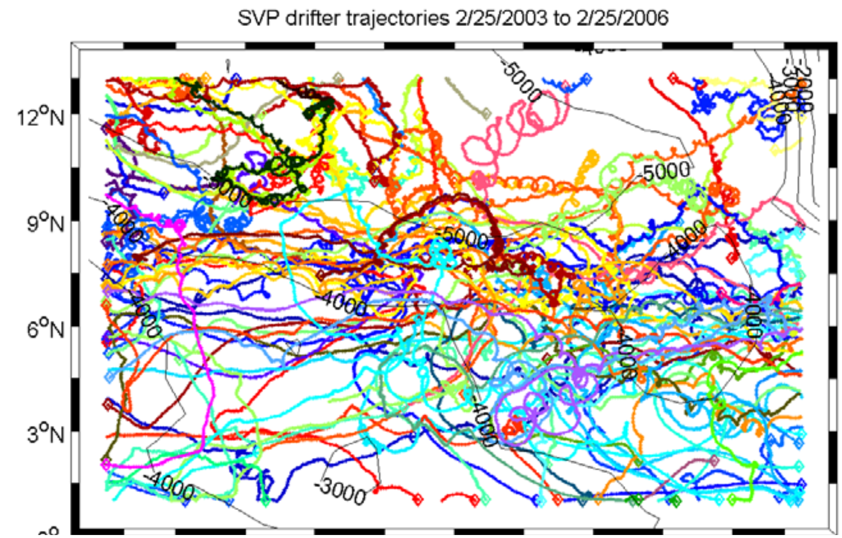
How does the mesoscale variability affect the dispersion of water particles?

(Bulgakov et al., 1990)

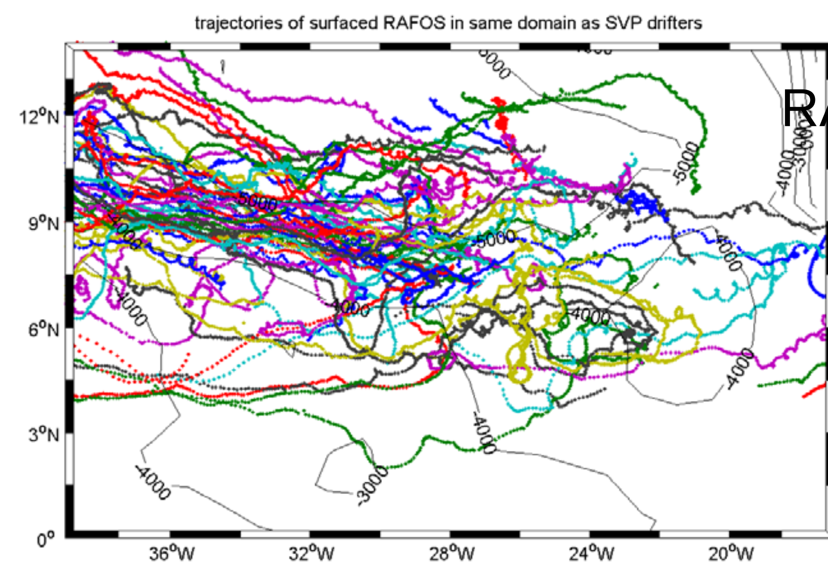
Numerical particles vs. in-situ drifters



120 numerical particles deployed across the domain for 200 days starting from every day in three years



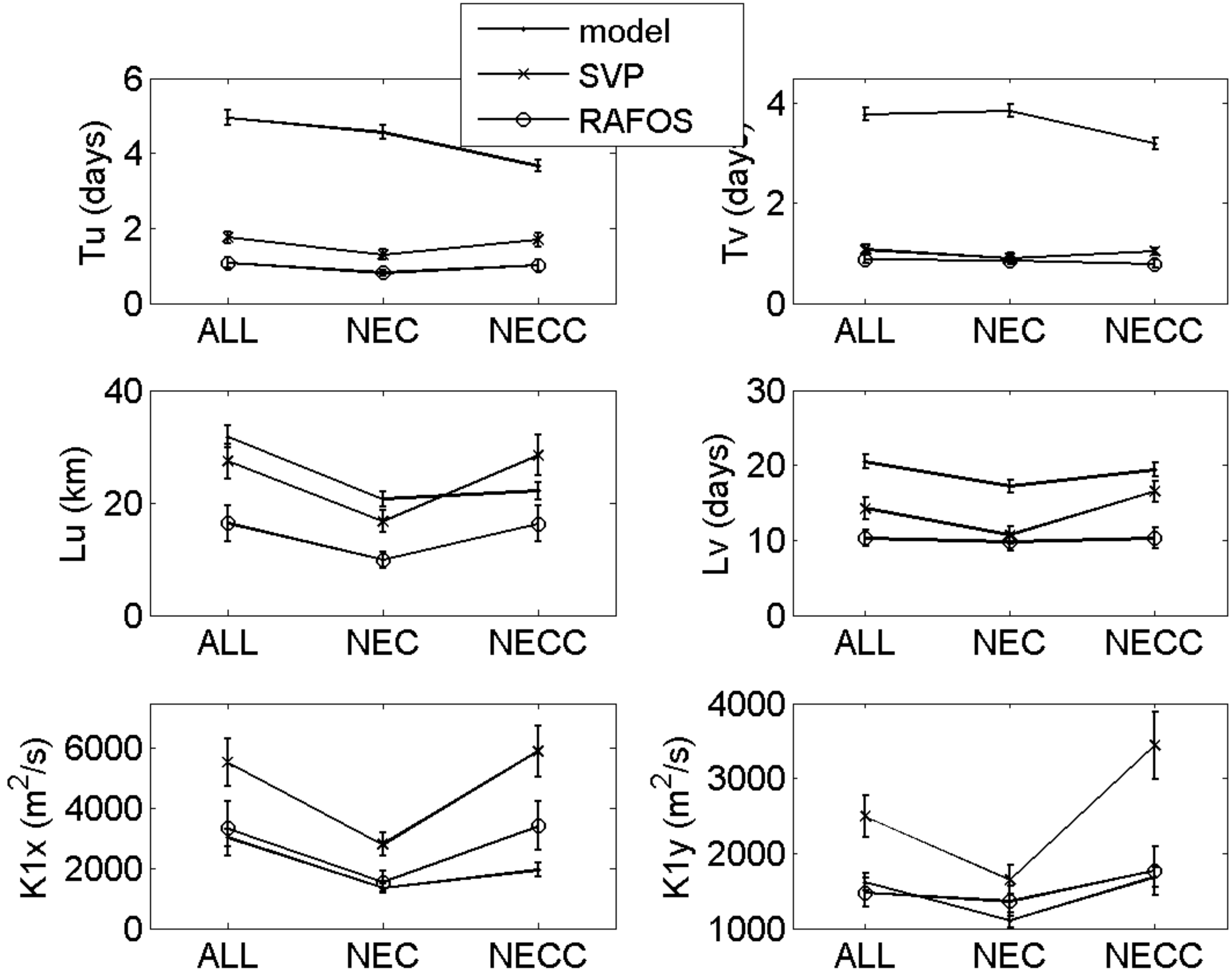
SVP



RAFOS

Method

- Decompose turbulent velocities
  1. Initial data quality control
  2. Identify the bin size of mean flow based on independent observations
  3. Exclude bins with few degrees of freedom
  4. Construct pseudo-mean flow
  5. Examine resulted turbulent velocities


model
SVP
RAFOS
Tu (days)
Tv (days)
Lu (km)
Lv (days)
K1x (m^2/s)
K1y (m^2/s)
ALL
NEC
NECC