TEMPORAL VARIABILITY IN SURFACE EDDY MIXING

WHOI SSS WORKSHOP MAY 2017
Eddies mixing is important for the global climate:

The global ocean circulation

Tracer transports (heat, freshwater, carbon and SALINITY)
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The global ocean circulation

Tracer transports (heat, freshwater, carbon and **SALINITY**)
GOAL

Investigate **temporal variability** in eddy mixing and the connection to climate variability

SPURS specific message:

Watch the **K** in your salinity budget! Particularly when residuals are interpreted as a physical process.

\[-\nabla \cdot (K \nabla S)\]

**SALINITY TENDENCY DUE TO EDDY MIXING**
**MODEL SETUP**

1/10° surface setup (MITgcm$^1$).

AVISO velocities advect passive tracer field.

No surface forcing or vertical processes to isolate effect of eddies.

Initial conditions are reset in regular intervals to preserve large scale characteristics.

Diffusivity and transport dominated by velocity characteristics not sub-grid scale diffusivity$^2$.

$^1$ABERNATHEY AND MARSHALL 2013

$^2$MARSHALL ET AL. 2006
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\(^2\)MARSHALL ET AL. 2006
Eddies $v' \sim 100 \text{ km / weeks-months}$

Eddies diffuse tracer fields by enhancing the ‘contact area’ of an isohaline

Water mass coordinate system - Advection does not affect the budget

Eddy diffusivity (velocity field)

$$K_{eff} = \kappa \frac{L_e^2}{L_{min}^2}$$

Eddy mixing (velocity + tracer field)

$$TFR(S_0, t) = \frac{\partial}{\partial t} \int\int_{(S > S_0)} dA \frac{MLD(S_0)}{MLD(S_0)}$$

BUSECKE ET AL. 2017, JPO
Reference isohalines from Gordon et al. 2015

Eddy mixing does matter in all ocean basins

Regional differences in the importance of eddy mixing for the mixed layer salinity budget

But what about temporal variability?
TEMPORAL VARIABILITY

Multiple experiments with seasonal/interannual SSS fields as initial conditions reveal sensitivity to position of SSS-max

North Atlantic and Pacific show a seasonal cycle in eddy mixing.

**North Atlantic** dominated by **diffusivity** (velocity field)

**North Pacific** dominated by **initial conditions** (large scale SSS)
Regional differences in mechanism might influence how each region ‘reacts’ to a changing climate.

In the South Pacific strong peaks around 97/98 suggest a coupling of eddy mixing/diffusivities to large scale climate variability.
Both diffusivity and total diffusive flux are regionally and temporally variable - ‘Character’ of SSS-maxima also manifest in the eddy mixing characteristics.

Water mass framework is well suited to investigate the salty water masses but not able to localize the results.
Stretching of isolines corresponds to increased lateral tracer gradients

a) Smooth surface
   low $K_{\text{eff}}$
   low integrated flux

b) Contorted surface due to stirring
   high $K_{\text{eff}}$
   high integrated flux

Advection
Diffusion

BUSECKE ET AL. 2017, JPO
OSBORN COX DIFFUSIVITY

\[ K_{OC} = \kappa \frac{\left| \nabla q' \right|^2}{\left| \nabla \bar{q} \right|^2} \]

Eulerian Diagnostic - Results in monthly map of diffusivities (\(K_{OC}(x,y,t)\))

Represents the **local destruction of tracer variance** by small scale diffusion

Mesoscale eddies form filaments and fronts, thus increasing the tracer gradient variance over the background gradient variance
$K_{OC}$ is a scalar diffusivity, relevant to the background tracer field.

The actual diffusivity tensor is anisotropic - Use multiple initial conditions to cover different projections of the diffusivity tensor onto the background gradient.

$K_{min}$: The minimum diffusivity at each grid point, representing the minor axis of the diffusivity tensor - Important for transport barriers.
**RESULTS**

Large spatial variability of $K_{\text{min}}$. In agreement with previous studies (Abernathey et al. 2013, Cole et al. 2015)

Interannual range of $K_{\text{min}}$ is very large compared to the mean (80% of the global ocean have a ratio above 0.5)

In the subtropical Pacific surface diffusivities show high correlation to ENSO index, suggesting a potential feedback mechanism.
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In the subtropical Pacific surface diffusivities show high correlation to ENSO index, suggesting a potential feedback mechanism.
$K_{\text{min}}$ is elevated over most of the Pacific during high ENSO periods

Particularly relevant since the diffusivity in the subtropics is generally low.
$K_{\text{min}}$ is not well correlated to the EKE.

Interaction with the large scale flow field could have a primary role in modulating the surface diffusivities in the Pacific Ocean.

Mixing length shows similar response.
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CONCLUSIONS

These studies suggest that **surface eddy diffusivity/eddy mixing vary in time** in most areas of the global ocean.

This has **implications for surface tracer budgets**. Careful consideration of eddy diffusivities (including NOT applying it to ‘partially mesoscale resolving’ fields) might help reconcile different approaches for salinity budgets within SPURS.

The dominant **mechanisms for temporal variability in eddy mixing differ regionally**.

This should be taken into account when relating the SSS fields to a change in the hydrological cycle - particularly on ‘shorter’ (interannual - decadal) time scales.

**Eddy diffusivities seem connected to large scale climate variability**, possibly representing an important climate feedback.

The strong variability in the Pacific is not related to EKE implying the **importance of eddy mean flow interaction** (Ferrari and Nikurashin 2010, Klocker and Abernathey 2014, Bates 2014).
The data set will be made available including all code...soon
OUTLOOK

Investigating of the physical mechanisms coupling the large scale climate to the surface diffusivities

Comparison of "hybrid" results to high resolution models and observations
AVeraging Method

1. **Histogram of KOC**
   - Count vs. Histogram of gradient criterion
   - Different mean calculations: arithmetic, geometric, harmonic.

2. **Histogram of log10(KOC)**
   - Count vs. Histogram of log10(gradient criterion)

3. **Histogram of eke**
   - Count vs. Histogram of eke

4. **Histogram of log10(eke)**
   - Count vs. Histogram of log10(eke)
ERROR ESTIMATES (RESET)
ERROR (INITIAL CONDITIONS)
GRADIENT CRITERION

\[ l_{mix} = \frac{\sqrt{(c')^2}}{2 \left| \nabla c \right|} \]

\[ l_{curv} = \frac{\left| \nabla c \right|}{\left| \nabla^2 c \right|} \]

\[ 1 \gg cr = \frac{l_{mix}}{l_{curv}} = \frac{\sqrt{(c')^2} \left| \nabla^2 c \right|}{\left| \nabla c \right|^2} \]
MIXING EFFICIENCY?