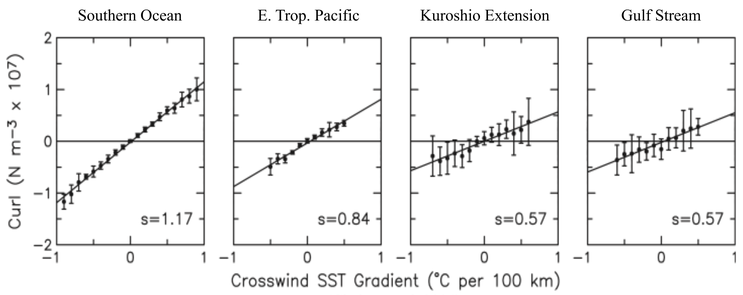
Surface Current Influence on Potential Vorticity Flux in Submesoscale Regime

Xu Chen[1,2], William Dewar[2], Eric Chassignet[1,2], Mark Bourassa[1,2], Steve Morey[1,3]

[1] Florida State University, Center for Ocean-Atmospheric Prediction Studies, Tallahassee, FL, United States. [2] Florida State University, Department of Earth, Ocean and Atmospheric Science, Tallahassee, FL, United States.
[3] Florida Agricultural and Mechanical University, School of Environment, Tallahassee, FL, United States.

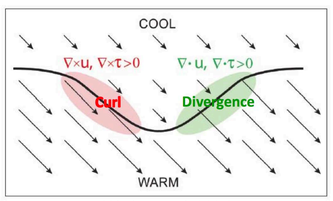
Introduction

- Positive linear relationship between wind stress curl and crosswind sea surface temperature (SST) gradient has been found by Chelton et al. (2004) on satellite observations (25-km resolution).



(Chelton et al. 2004)

- Stronger wind stress over warm water is argued to be the mechanism.



(Chelton et al. 2007)

- In the submesoscale regime, SST gradients are much stronger than those in the mesoscale and larger scale regimes. And surface current vorticity is significantly robust in submesoscale regime.

$$W_{total} = \frac{1}{\rho}\nabla\times\left(\frac{\vec{\tau}}{f+\zeta}\right)$$ (Stern, 1965)

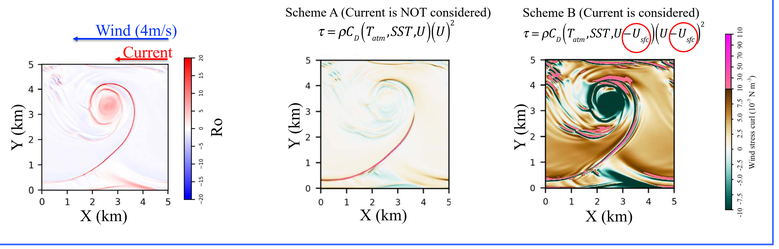
- Negative potential vorticity (PV) injection from the ocean surface is crucial for triggering instability in the upper ocean layer.

Goals

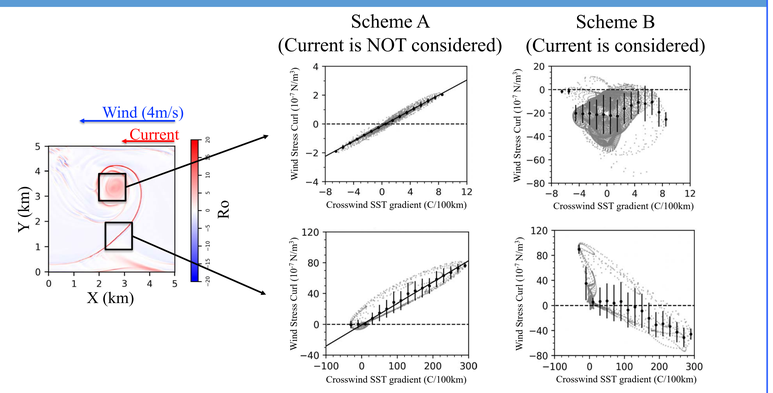
- Determine (quantitively) if wind stress field is significantly influenced by submesoscale surface features (SST gradient and current vorticity)?
- Assess (quantitively) the effect of including surface current in air-sea turbulent flux on the PV surface flux and vertical transports.

Model Setup

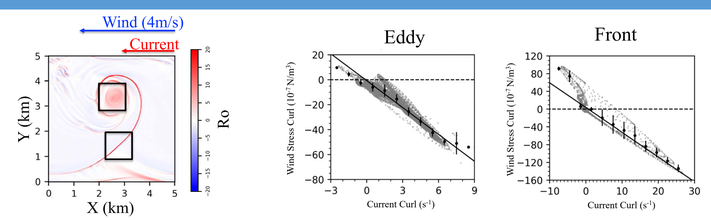
- Ocean: MITgcm; Atmospheric Boundary Layer: CheapAML
- Resolution: 10 m horizontal; 2 m vertical.



Wind Stress Curl & Crosswind SST Gradient (Scheme A & B)

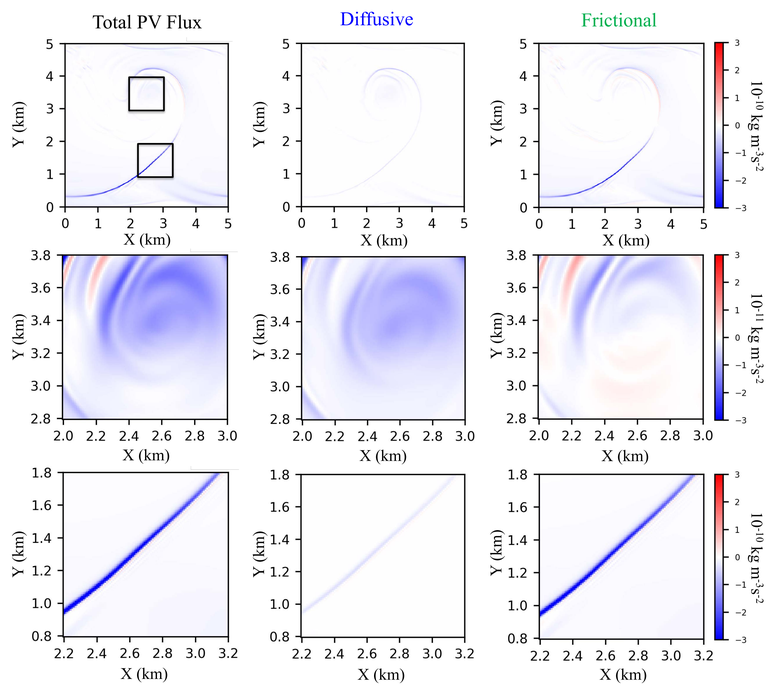


Wind Stress Curl & Surface Current Vorticity (Scheme B)



PV Flux at Surface (Scheme B – Scheme A)

$$\vec{J} = \vec{\omega}\frac{D\sigma}{Dt} + \vec{F}\times\nabla\sigma$$ (Marshall et al. 2001)



References

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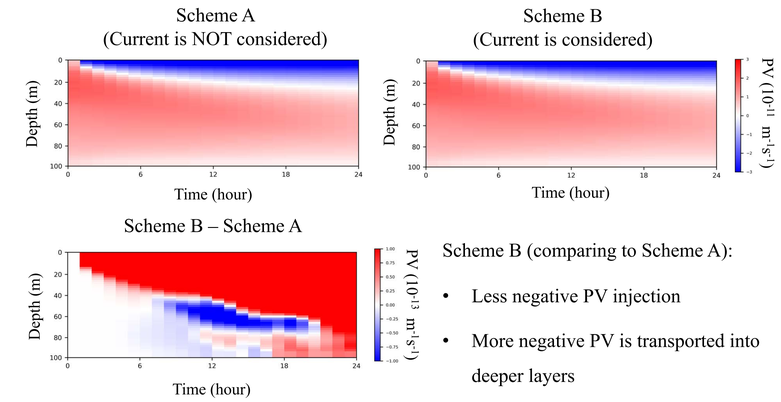
Hovmöller Diagrams of Horizontally Averaged PV

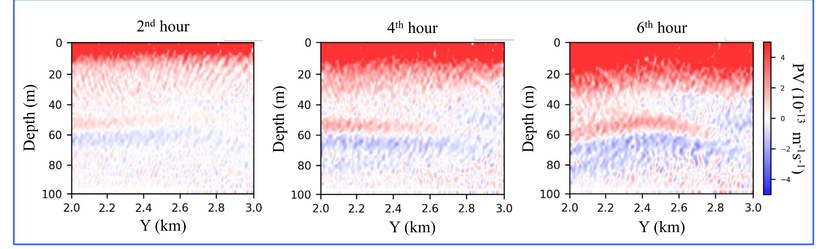
- Comparison between 24-hour experiments using Scheme A and Scheme B



Scheme B (comparing to Scheme A):

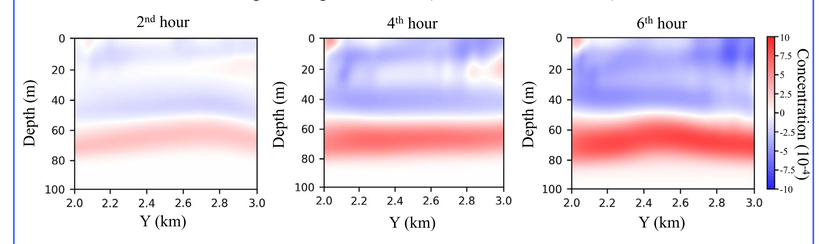
- Less negative PV injection
- More negative PV is transported into deeper layers

Difference of PV Averaged along X direction (Scheme B – A)

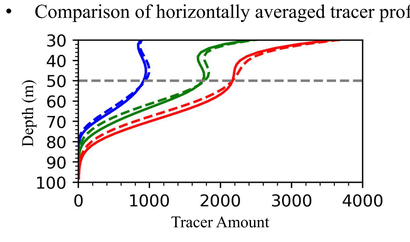


Vertical Transport of Passive Tracer from Surface

- Difference of Tracer Averaged along X direction (Scheme B – Scheme A)



- Comparison of horizontally averaged tracer profiles at 2nd, 4th, 6th hour (dashed: A; solid: B).



In Scheme B (compare to Scheme A):

- More passive tracer is transported into layers beneath 50 m depth.

- Table: Quantitative assessment of passive tracer transported into layers beneath 50 m depth.

Time (hour)	Current (B)	No Current (A)	Current – No Current (B-A)	Percentage Increase (%)
1	4064	3966	98	2.5
2	8294	7790	504	6.5
3	11856	10808	1048	9.7
4	16287	14788	1499	10.1
5	20477	18529	1948	10.5
6	24339	21963	2376	10.8