Challenges in Observing the Ocean Submesoscale

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Why observe the Submesoscales?

- Buoyancy Budget
- Energetics
- Carbon Cycle
Buoyancy ($N^2$) Budget – Johnson et al 2016

Energy Budget – Dong et al 2016

Carbon Export – Omand et al, 2015

Springtime POC export by eddy-driven subduction (mgC m$^{-2}$d$^{-1}$)
How important are submesoscales?

1 – Understand **dynamics** at submesoscale fronts
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2 – What is the **impact** of those processes
How important are submesoscales?

1 – Understand **dynamics** at submesoscale fronts

2 – What is the **impact** of those processes

3 – What is the **global significance** of that impact
For SMCs, their awkward size presents an observational barrier that delayed an appreciation of their abundance: they are large for shipboard instrument detection, small and rapidly evolving for typical ship surveys, small for many satellite remote sensing footprints, and often difficult to distinguish from inertia-gravity waves (IGWs) in single-point time series or individual vertical profiles.

--McWilliams, 2016

1 – Understand **dynamics** at submesoscale fronts

--McWilliams, 2019
Example from ONR AESOP campaign

California Current System

Johnson et al. 2020 - Pt 1 & 2

Pallas Sanz et al. 2010 - Pt 1 & 2
DENSITY STRUCTURE AT DIFFERENT SCALES
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VORTICITY AT DIFFERENT SCALES

AVISIO (not shown)
Resolution >100km
\( \zeta/f \sim O(0.01) \)

SeaSoar*
Lx = 12km, Ly = 45km
\( \zeta/f \sim O(0.1) \)

Triaxus
Lx = 5km, Ly = 5km
\( \zeta/f \sim O(1) \)
$N_{INT}^2 = \int (u z b_x + v z b_y) \, dt$

- Resolve horizontal and vertical gradients ‘simultaneously’
- Lagrangian reference frame
- Choose and maintain relevant scales to capture target dynamics
\[ N_{INT}^2 = \int u_z b_x + v_z b_y \, dt \]

- Resolve horizontal and vertical gradients ‘simultaneously’
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What if there were even **MORE** assets?
- calculated gradients on a range of scales
- understand evolution in space and time
S-MODE

- Buoyancy Budget
- Energetics
ARCTRX
• Energy Transfer
• Eddy Tracking
ARCTRX
• Energy Transfer
• Eddy Tracking
EXPORTS

- Carbon Export
- Eddy Tracking
EXPORTS

- Carbon Export
- Eddy Tracking
Biovolume in Eddy Center ONLY

Lagrangian sampling isolates Carbon Export

Johnson et al, submitted

Siegle, Kiko, Fields
2 – What is the **impact** of those processes

- Parameterize impact of submesoscale processes for models that can’t resolve them
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- Parameterize impact of submesoscale processes for models that can’t resolve them
- MLI is only parameterization in climate models. SI is parameterized in regional and process models
- Our understanding of the physics exceeds our ability to account for it in climate models
Cross-scale interactions: Parameterizations change in different regimes

Example – Ocean surface boundary layer parameterizations (i.e. surface forced mixing) break down in presence of submesoscale flows.

Re-evaluate current parameterizations in submesoscale frontal regions

Johnson and Fox-Kemper, in prep
3 – What is the global significance of that impact

Su et al. 2018
- Clouds obscure surface signal and complicate statistics and evolution tracking
- SST fronts don’t account for density compensation in salinity dominated regions

Johnson et al, submitted
Global distribution of fronts by ships of opportunity

Whalen, in prep

- Seasonal cycle of sharp fronts near the Amazon river
- Sharper fronts near the coastlines
- Winter elevation of frontal gradients in the Gulfstream and Kuroshio extension
Ship based programs tend to bias most **energetic** (i.e. interesting) regions

MISOBOB - 2019

Drifting assets tend to accumulate in **convergence** zones

D’Asaro, 2017

Submesoscale impacts are **highly localized**

Dong at al, submitted

Statistics of in-situ observational data **likely biased**
Summary

1 – Understand **dynamics** at submesoscale fronts

Process studies – coordinated multi-asset campaigns are offering broader picture of multiple scales

2 – What is the **impact** of those processes

Understanding impact of submesoscale dynamics and how to implement them as parameterizations in GCMs - the importance of linking observations with numerical simulations

3 – What is the **global significance** of that impact

Global observations of fronts still a challenge, but are needed to scale up process studies and compare with global models