Carbon export through submesoscale instabilities: Combining in situ and satellite products

Zachary K Erickson[1,2] and Andrew F Thompson[1]

[1]Division of Geological and Planetary Sciences, Caltech
[2]Ocean Ecology Laboratory, Goddard Space Flight Center, NASA

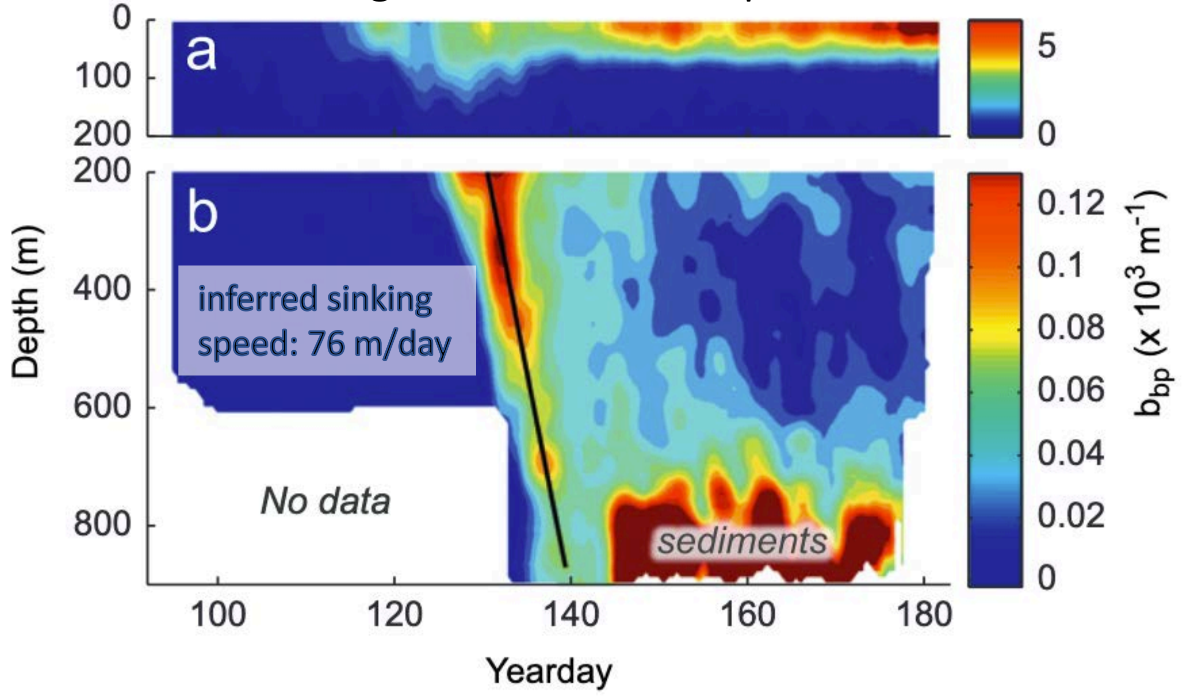
Export mechanisms

- Particulate sinking
- Mixed layer pump

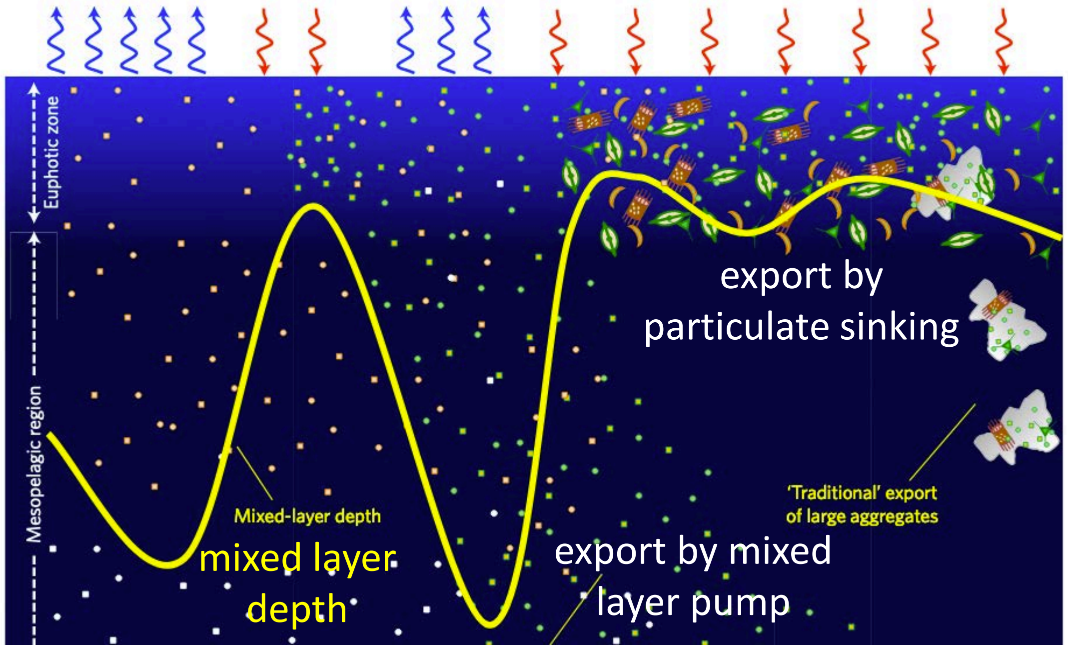
} passive

- Mixed layer baroclinic instability – active

Seaglider backscatter spikes



Briggs et al., DSRII, 2011



wintertime
transient stratification events

summer
re-stratification

Dall'Olmo et al., Nat. Geosci., 2016

Export mechanisms

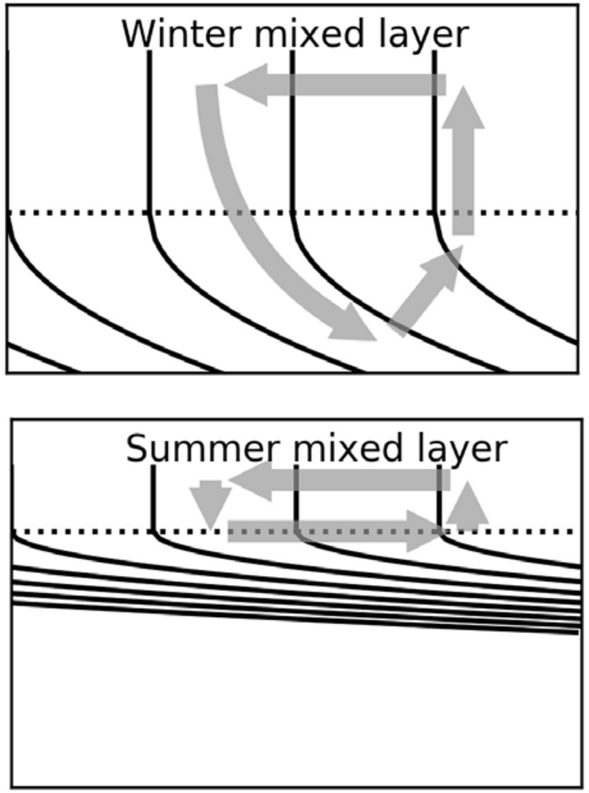
- Particulate sinking
- Mixed layer pump

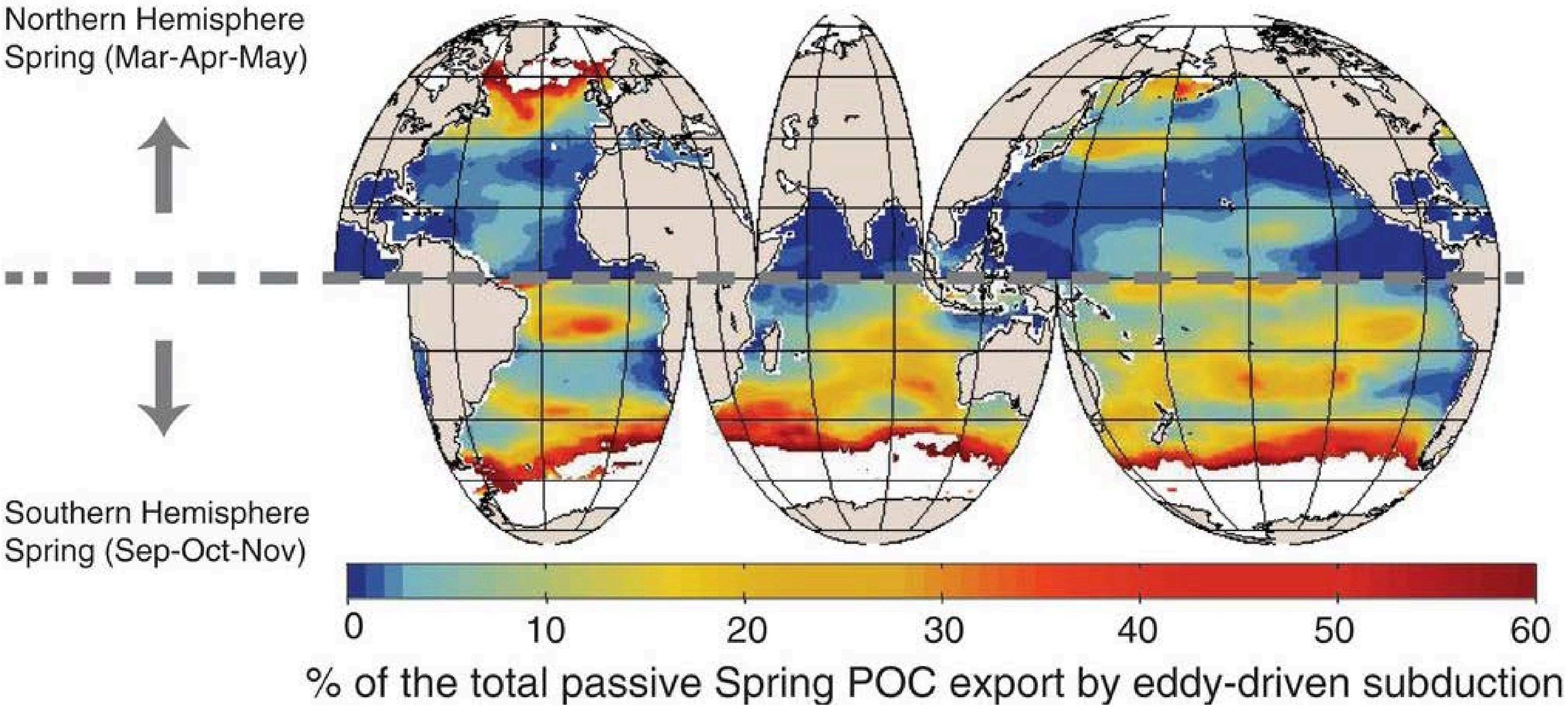
} passive

- Mixed layer baroclinic instability – active

Omand et al. (2015) algorithm
(after Fox-Kemper et al., JPO, 2008)

$$E_{O15} = w_{ML} C_{ML} = \frac{c_e \nabla b^2 H}{|f| b_z} C_{ML}$$



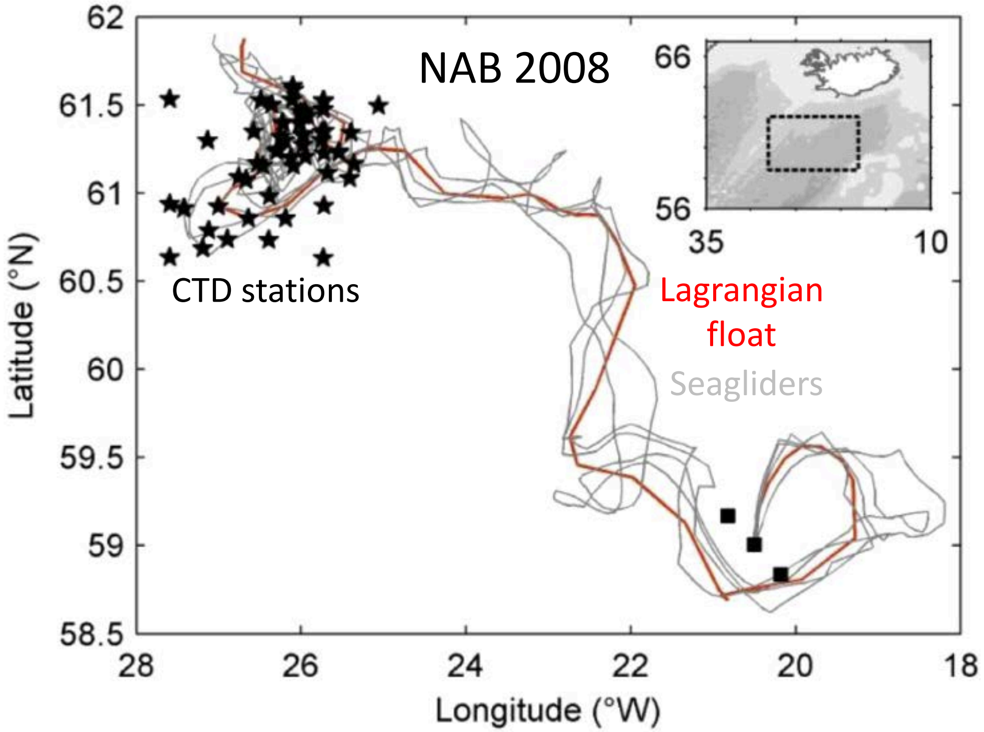


Erickson and Thompson, GBC, 2018

Omand et al., Sci., 2015

Lagrangian export studies

- Most export studies are done in a Lagrangian reference frame (horizontal advection smears out export signal)
- Most satellite-based export metrics are done in a Eulerian reference frame (e.g. individually for each pixel)

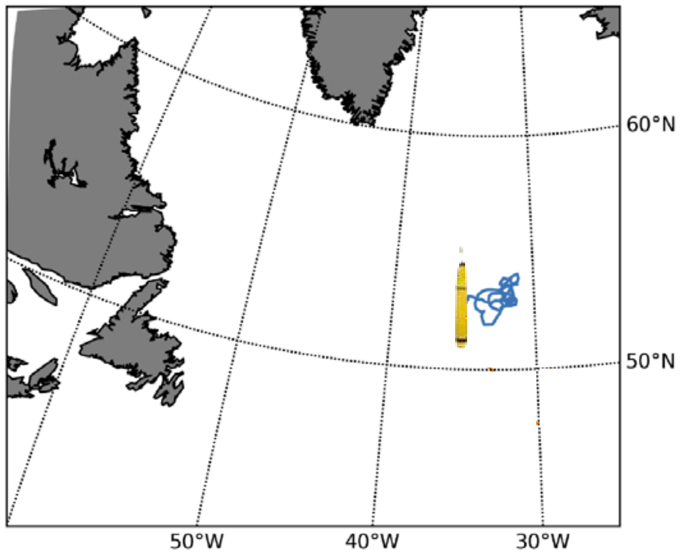


Cetinić et al., Biogeosci., 2015

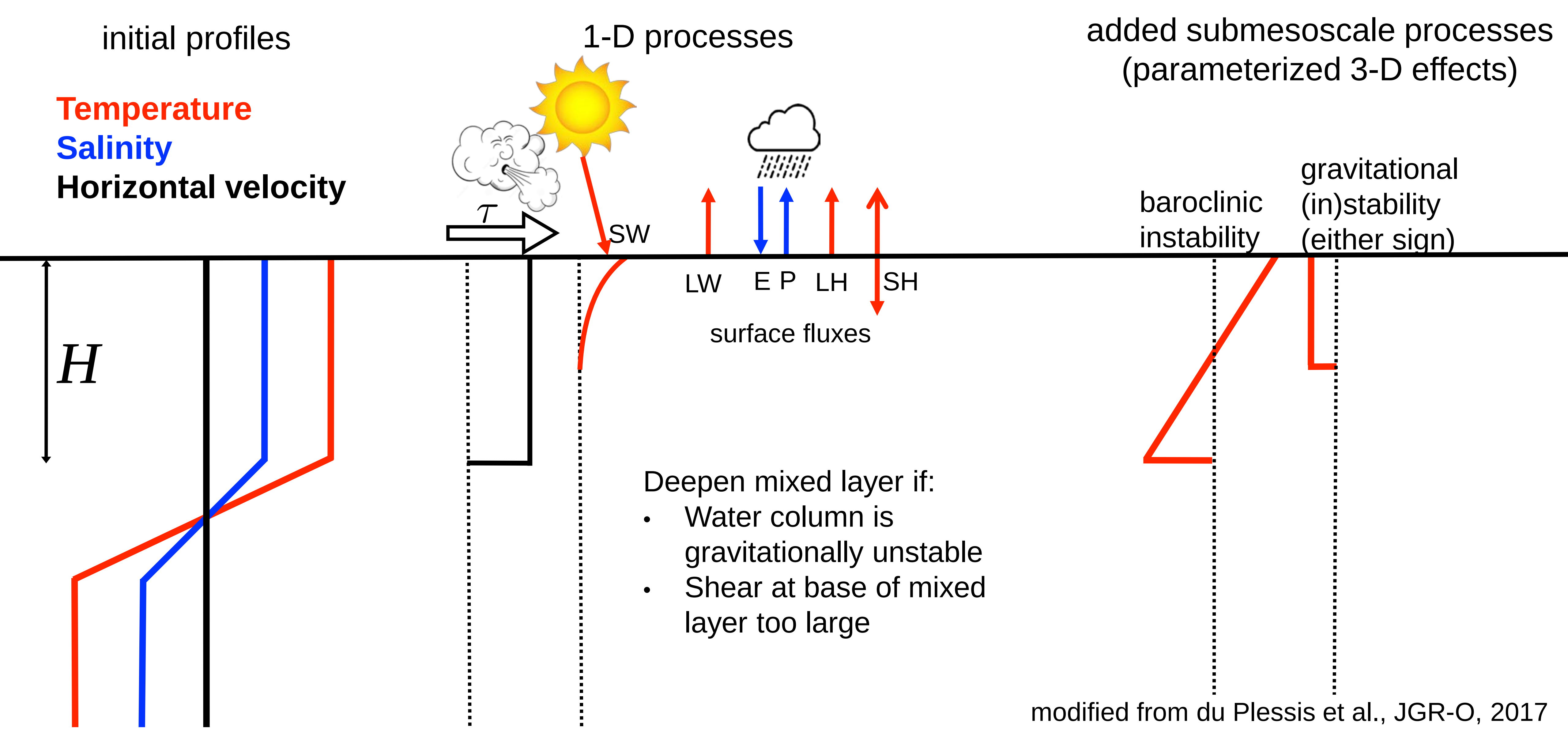
Can we use Argo floats and surface properties to augment dedicated research campaigns?

- Use 1-D column model (PWP) to model upper ocean following a Bio-Argo float
- Add submesoscale processes (mixed layer baroclinic instability and Ekman-driving de/re-stratification) to model
- Run model with reanalysis and satellite observations
- Use simple biological model to estimate export

Argo float



PWP model — mPWP



(adapted from Price, Weller, and Pinkel, JGR, 1986)

modified from du Plessis et al., JGR-O, 2017
and Viglione et al., JPO, 2018

PWP biological model

$$\frac{\mathrm{d}\mathbf{C_{bio}}}{\mathrm{d}t} = (\gamma - m)\mathbf{C_{bio}} \quad -w\mathbf{C}_{\mathbf{bio},z} \quad +\kappa\mathbf{C}_{\mathbf{bio},zz}$$

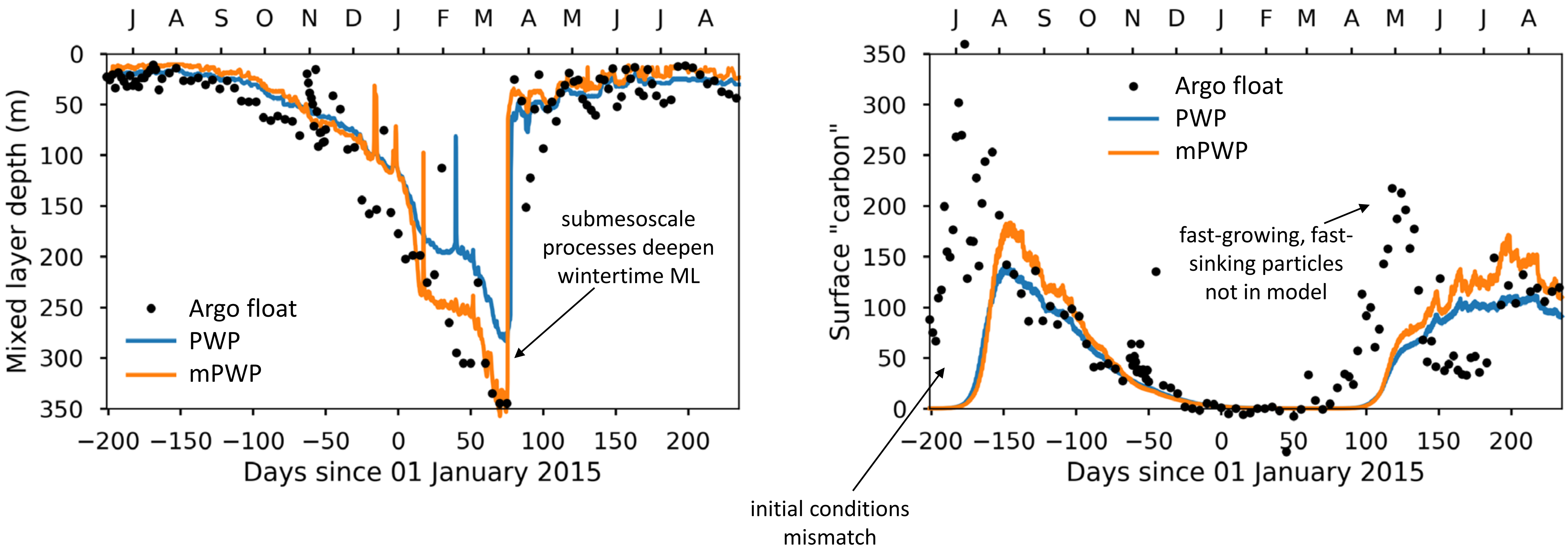
$$\frac{\mathrm{d}\mathbf{DOC}}{\mathrm{d}t} = am\mathbf{C_{bio}} \quad - k\mathbf{DOC} \quad +\kappa\mathbf{DOC}_{zz}$$

$$\frac{\mathrm{d}\mathbf{DIC}}{\mathrm{d}t} = ((1-a)m - \gamma)\mathbf{C_{bio}} \quad k\mathbf{DOC} \quad +\kappa\mathbf{DIC}_{zz} - \mathrm{ASF}$$

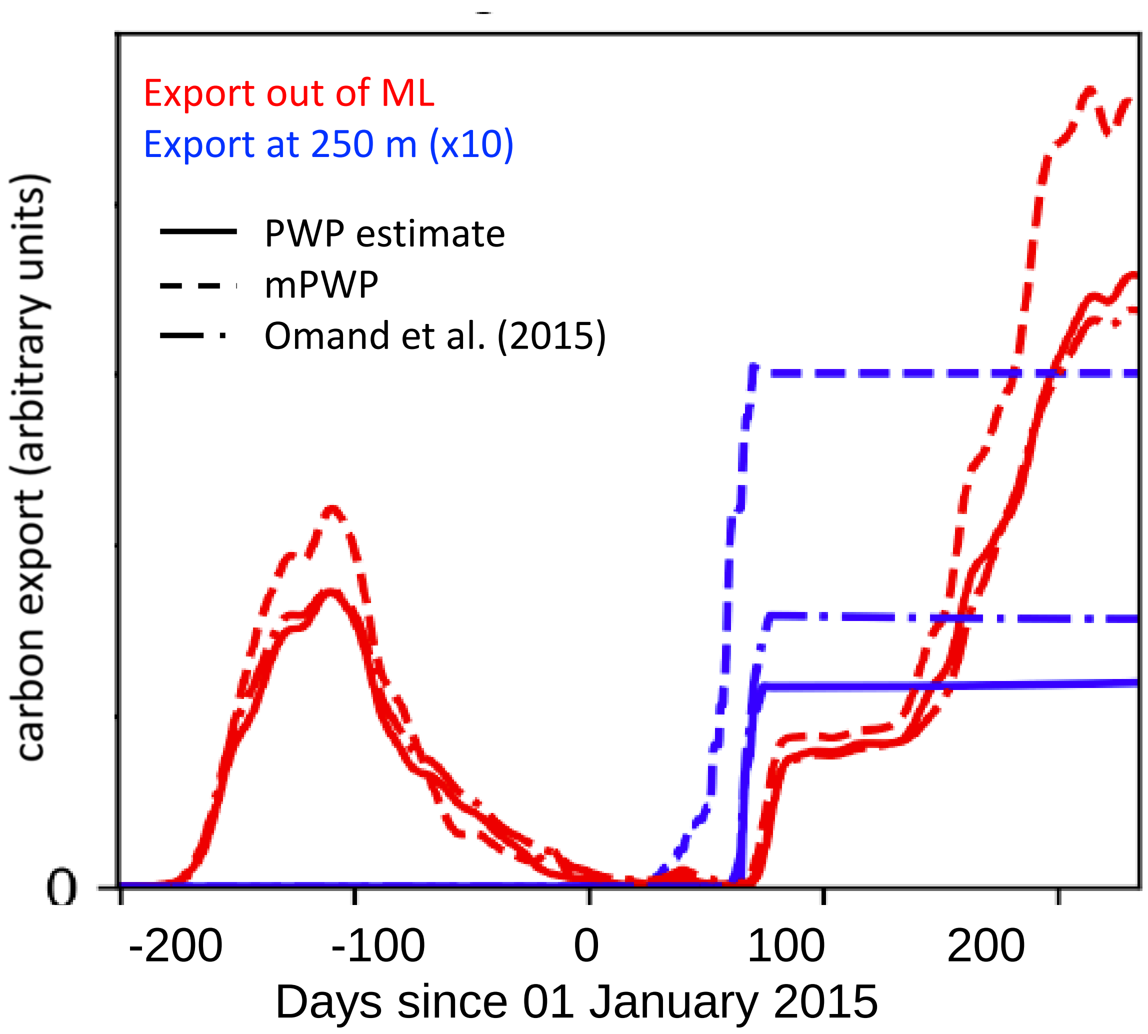
- γ: growth rate (hyperbolic)
- m: death rate (constant)
- w: sinking speed
- κ: vertical diffusivity
- a: sloppy feeding
- k: DOC decay rate
- ASF: air-sea flux (instantaneous)

(model adapted from Mahadevan et al., Sci., 2012)

PWP model results and comparison to Bio-Argo



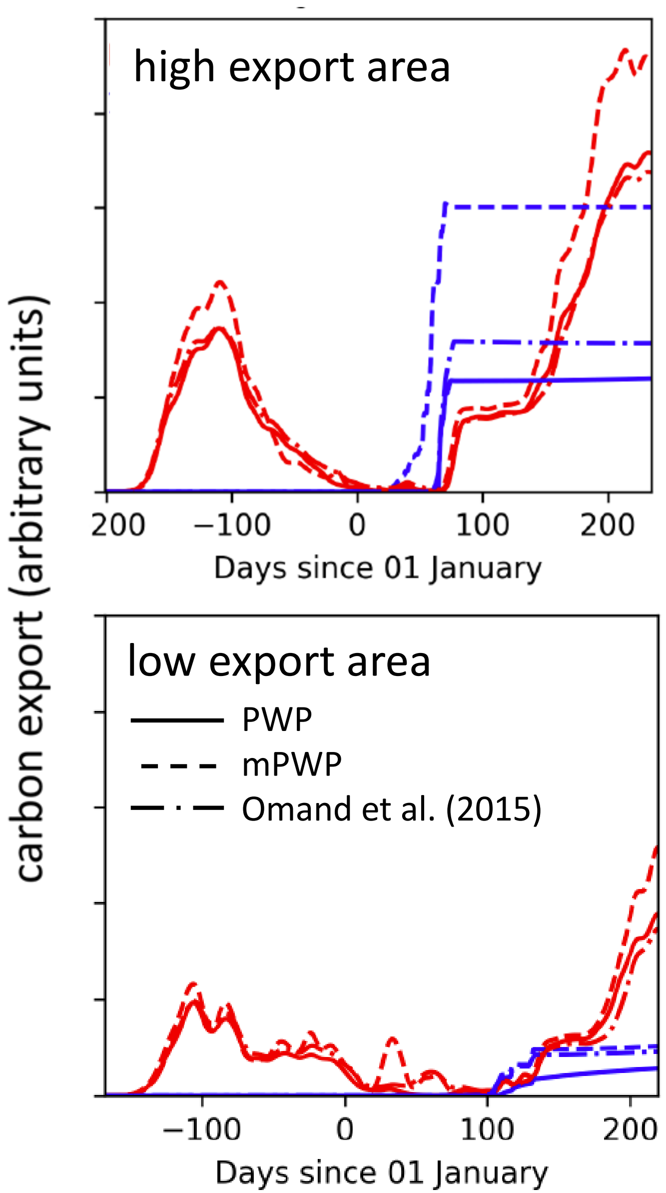
PWP model results (carbon export)



- Submesoscale processes increase export in both Omand et al. (2015) parameterization and when they are explicitly modeled (mPWP)
- Increase is greater when submesoscales are explicitly modeled
  - Increases production (and death and sinking) in upper mixed layer
  - Pumps carbon to greater depths than just below the mixed layer

Conclusions and future directions

- PWP model (and submesoscale variant) reasonably match Argo float results
  - Supports use of Argo float as a Lagrangian platform
- Biological model provides vertical carbon flux at all depths
  - Support export calculations at various depth horizons
- Export increases when submesoscale fluxes are included
  - Increase is above that from the Omand et al. (2015) algorithm
- Multiple Argo platforms provide opportunity for global estimates of carbon export by submesoscale processes
  - Evidence for substantial spatiotemporal variability



For more information,
contact me at zachary.k.erickson@nasa.gov
or see Z.K. Erickson, Ph.D. Thesis, Chapter 5 (https://thesis.library.caltech.edu/11729/)