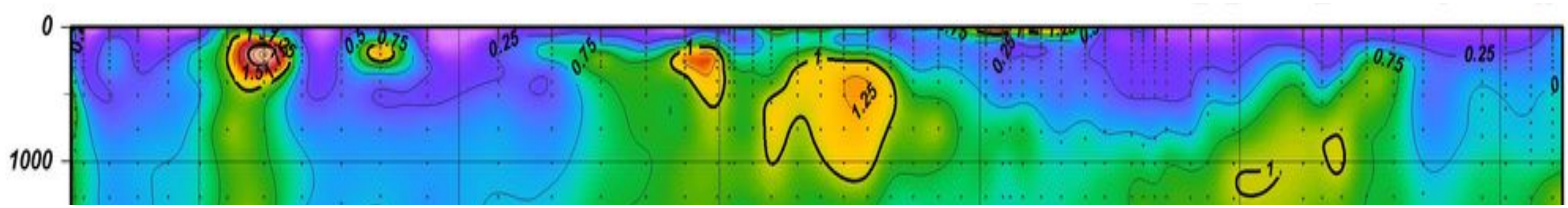
Observational strategies to quantify export and remineralization, including transfer of carbon cycle applications to trace elements and their isotopes.



Ken Buesseler and Erin Black

Preliminary particulate nutrients and metals from P. Lam
Preliminary dissolved metals from Bruland and Shiller Labs

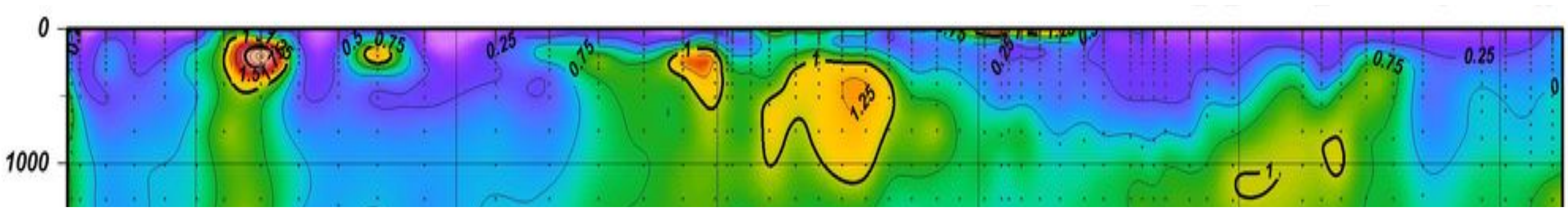
GEOTRACES

WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930

NSF

NASA

Upper Ocean Export



Ken Buesseler and Erin Black

Preliminary particulate nutrients and metals from P. Lam
Preliminary dissolved metals from Bruland and Shiller Labs

GEOTRACES

WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930

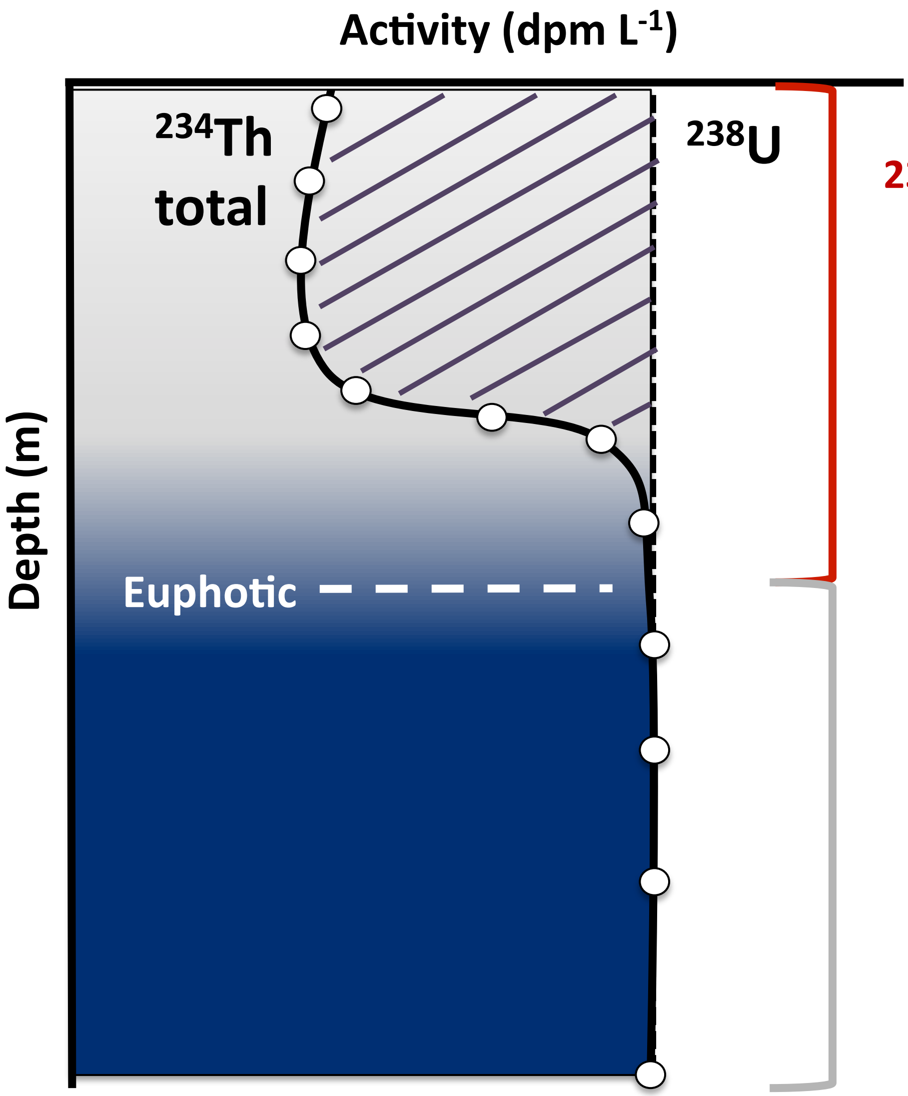
NSF

NASA

Many data in this talk are part of E. Black's ongoing PhD thesis work and not yet published but presented Aug. 2, 2016 at a GEOTRACES conference at LDEO

Please contact Black and Buesseler for more information or if you want to use any of these slides or data products.

^{234}Th Method



^{234}Th DEFICIT

Export

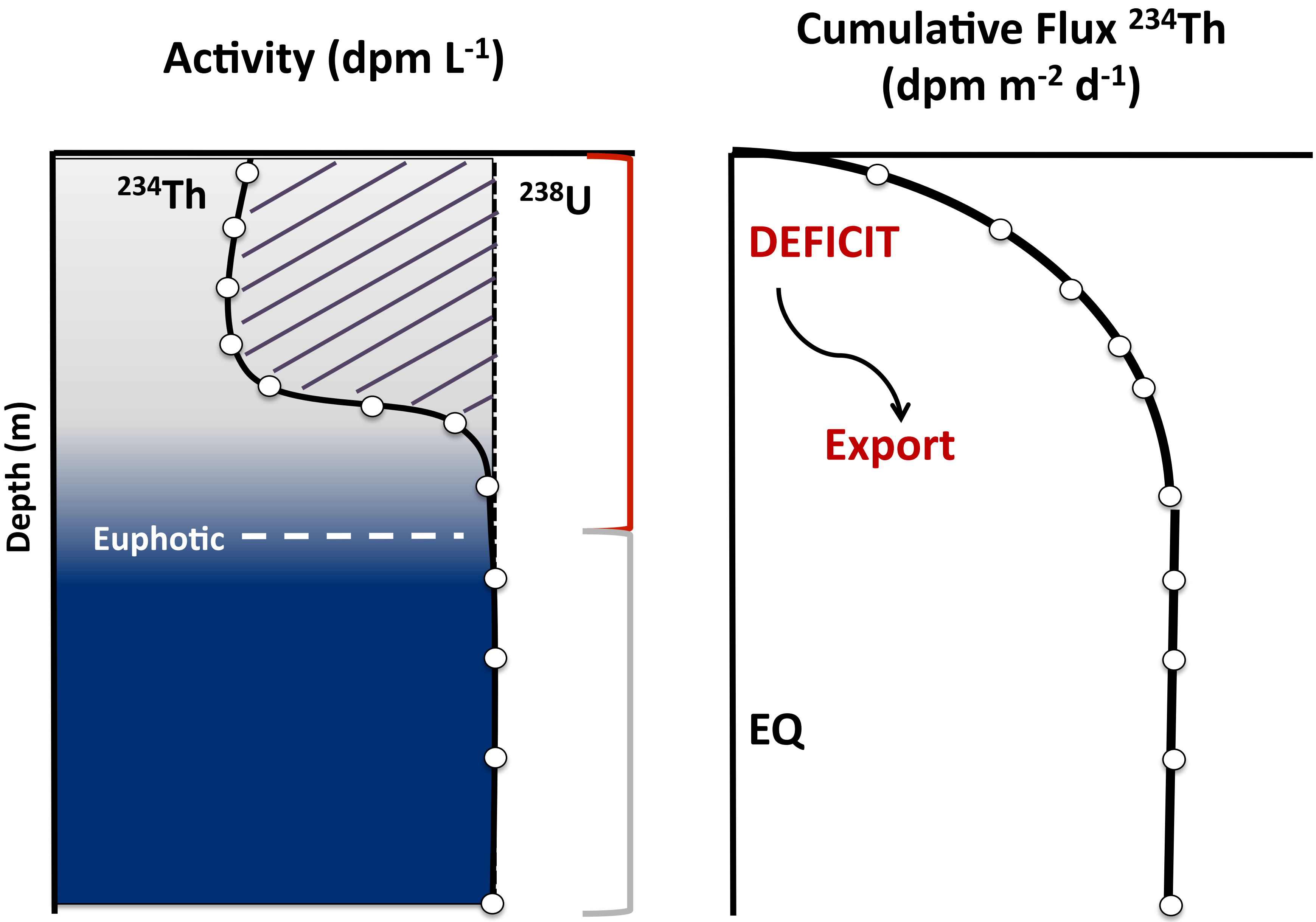
Sum of processes that lead to Th removal on sinking particles

EQUILIBRIUM

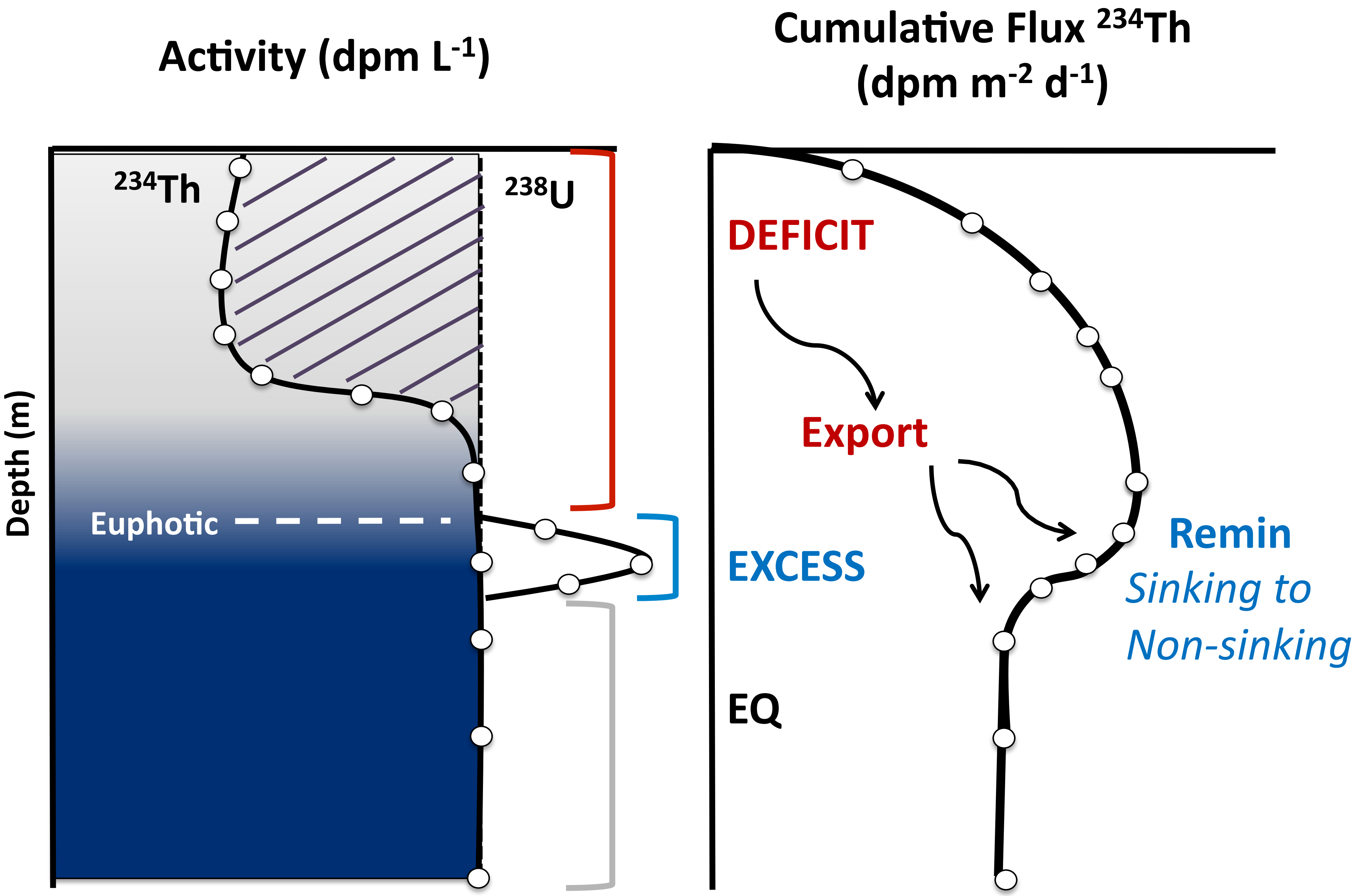
Processes are too slow relative to Th ingrowth

Half-life = 24.1 days

t-removal = 1/(λ+k)

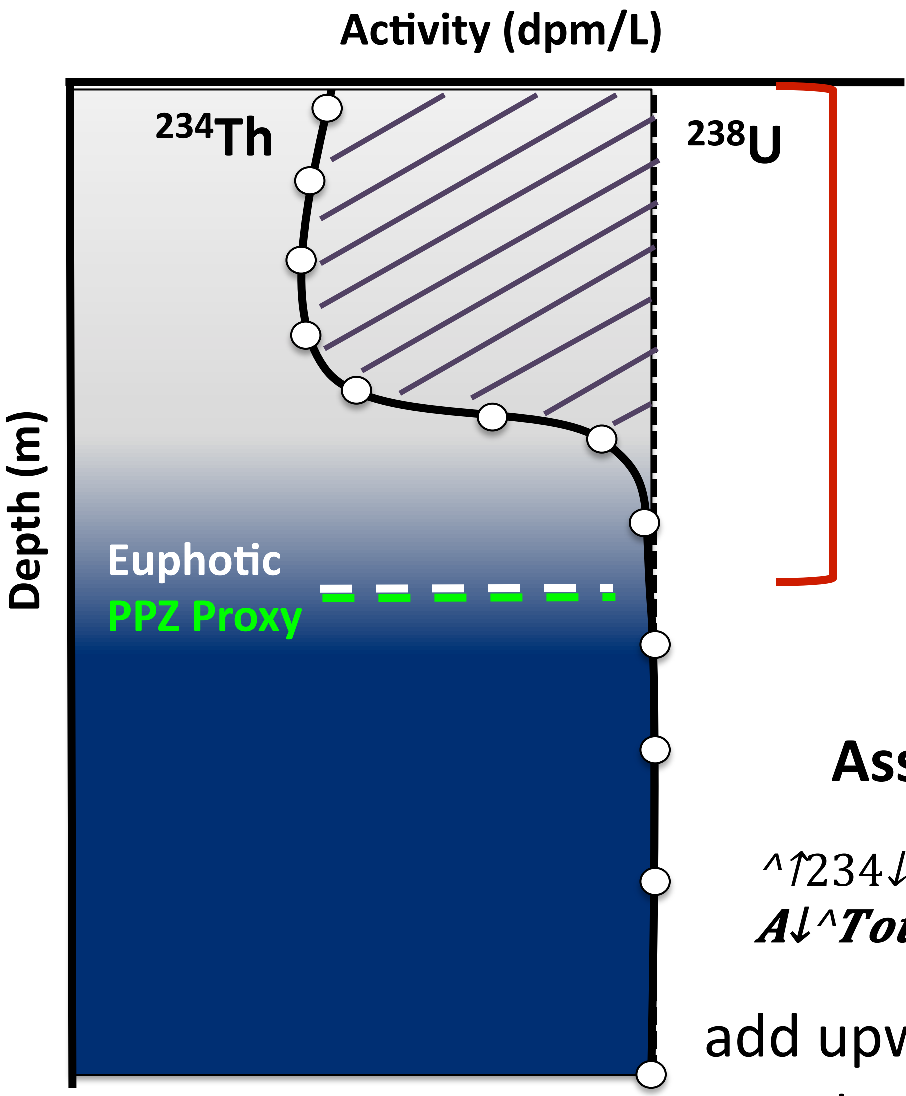


Activity (dpm L-1)
234Th
238U
Depth (m)
Euphotic
Cumulative Flux 234Th
(dpm m-2 d-1)
DEFICIT
Export
EQ



Activity (dpm L^{-1})
Cumulative Flux ^{234}Th (dpm m^{-2} d^{-1})
^{234}Th
^{238}U
Depth (m)
Euphotic
DEFICIT
Export
EXCESS
Remin
Sinking to Non-sinking
EQ

^{234}Th Flux



^{234}Th DEFICIT

Export

Assume Steady State, Deficit = Flux

$$^{234}Th\ Flux = (A^{238}U - A_{Total}^{234}Th)\lambda$$

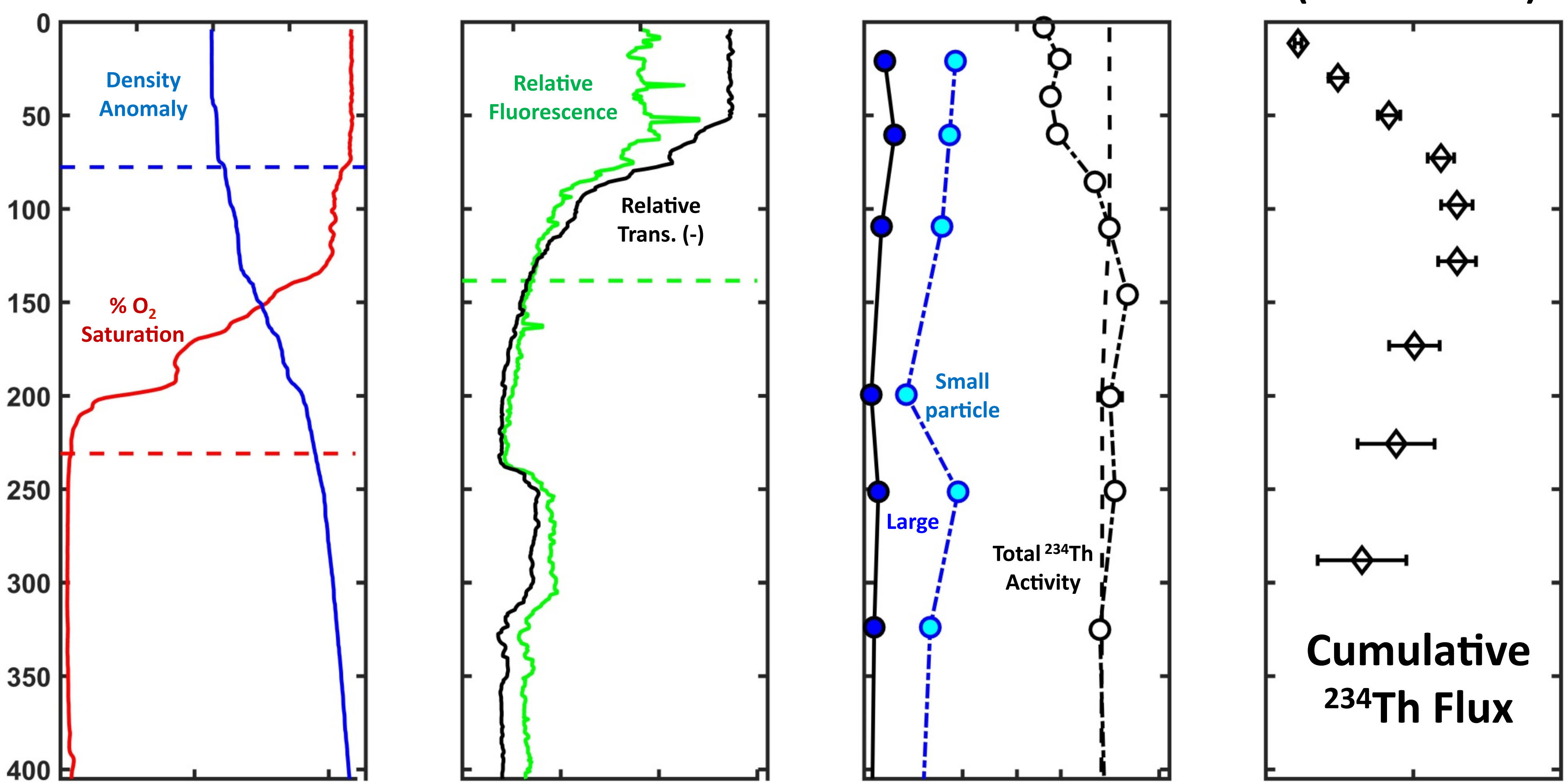
add upwelling as appropriate

use steady state model or t-series sampling

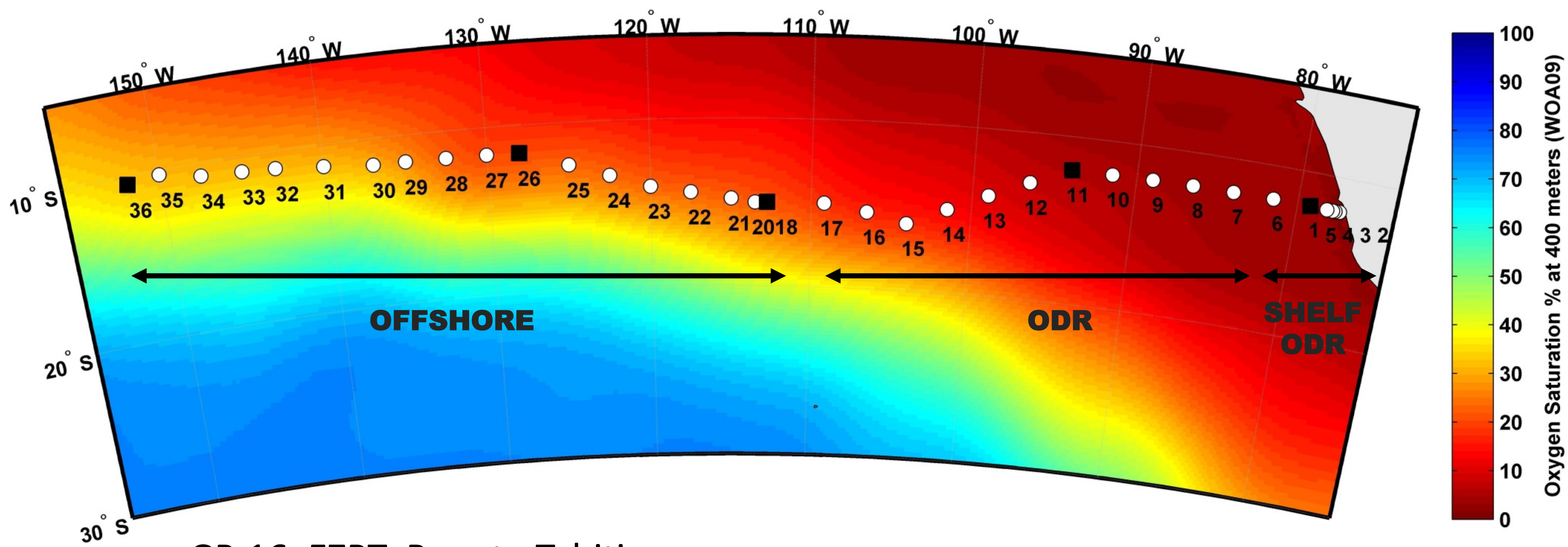
GEOTRACES Advancements

- high ^{234}Th resolution allows for flux extrapolations at any depth in the surface ocean (at features of interest)
- Paired dissolved sampling = residence times

(GP-16: St 13)



Use in-situ pumps for large and small particles

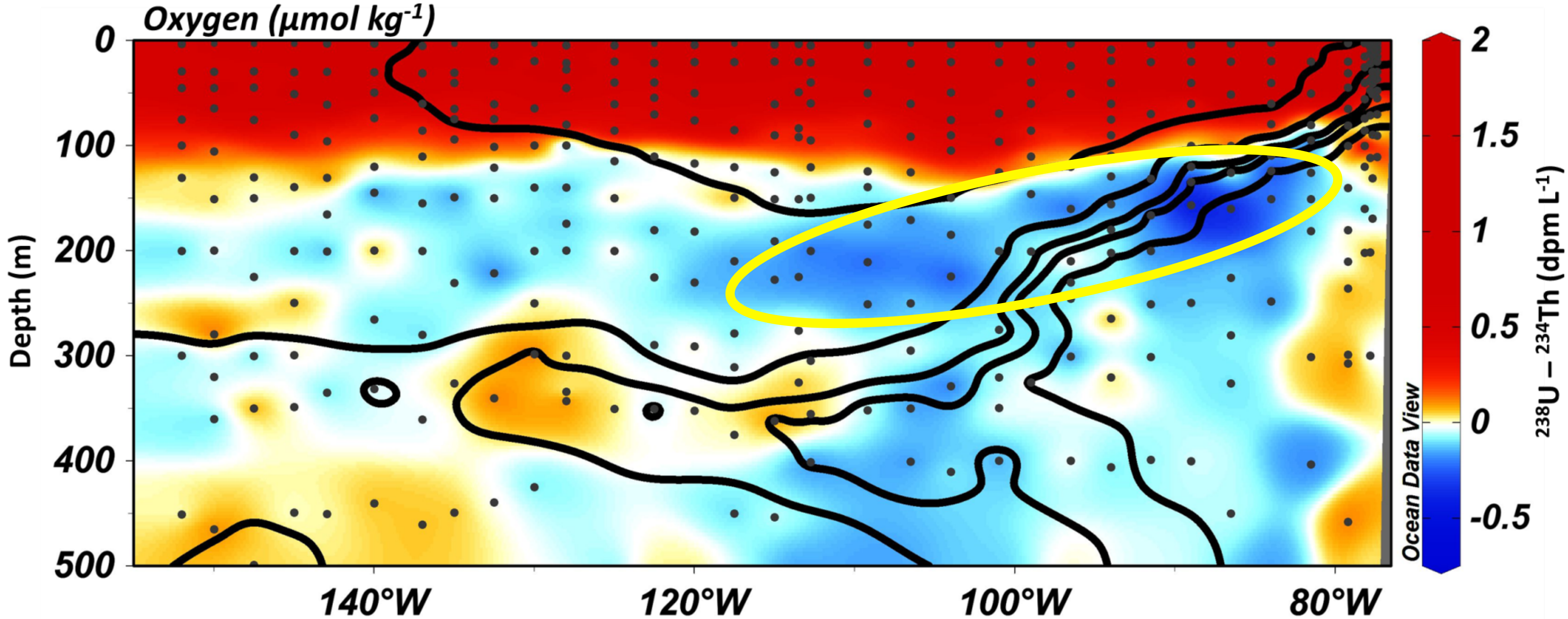


GP-16, EZPT Peru to Tahiti

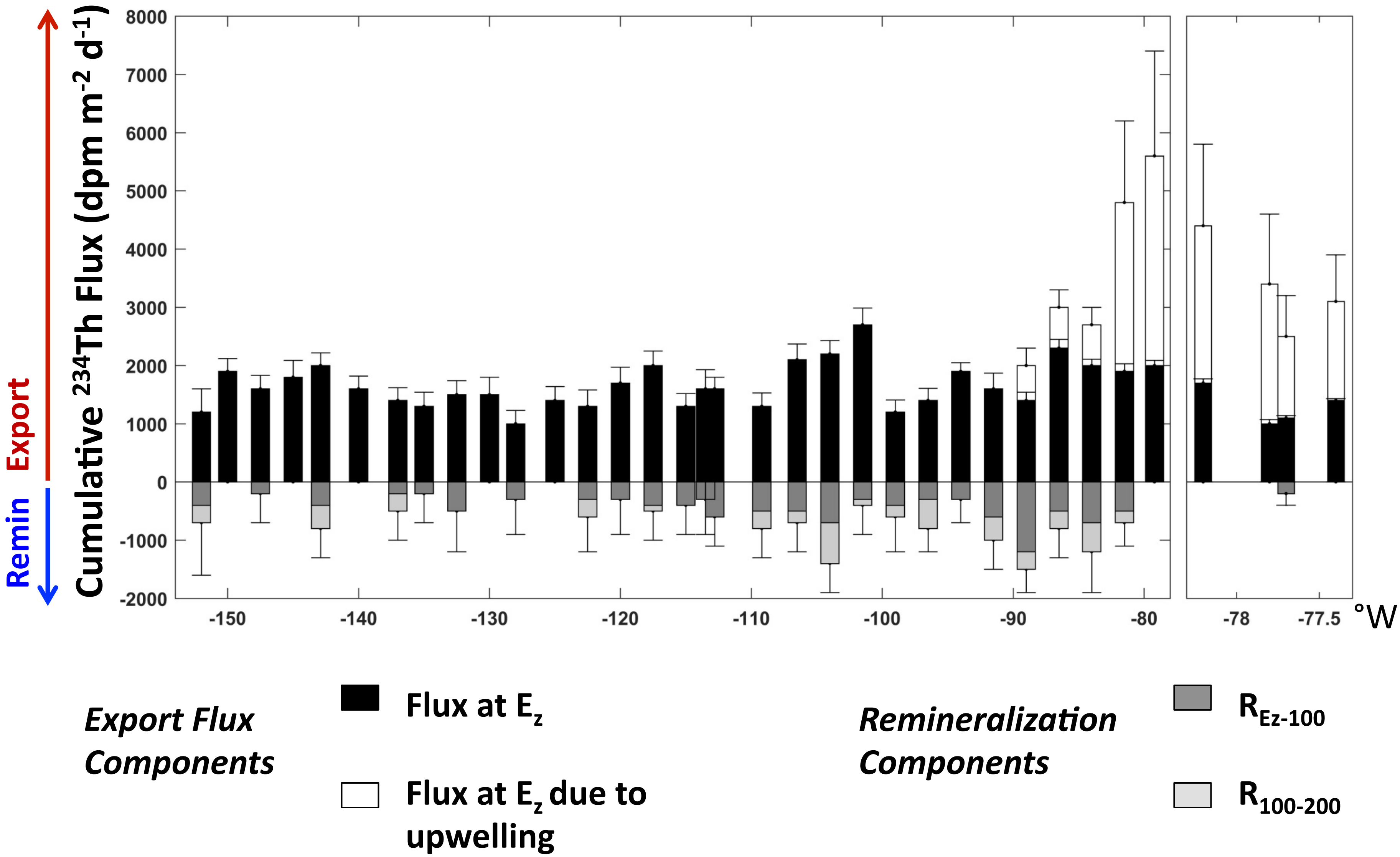
	Offshore Region	Oxygen Deficient Region (ODR)	Shelf Oxygen Deficient Region
Community Dominance*	Pico	Nano (Pico in ODZ)	Micro
Mean Euphotic Depth (m)	171	133	49
ODZ Upper Boundary (m)	NA	159	64

*Ohnemus et al., 2016

^{234}Th deficit in upper 75-150m & some excess above ODZ



- Greatest ^{234}Th excesses coincide with the upper boundary of the oxygen minimum zone
- These regions may be an important site for remineralization of carbon and TEIs



Remineralization features evident at 26 of 35 stations

Flux of POC and TEI's

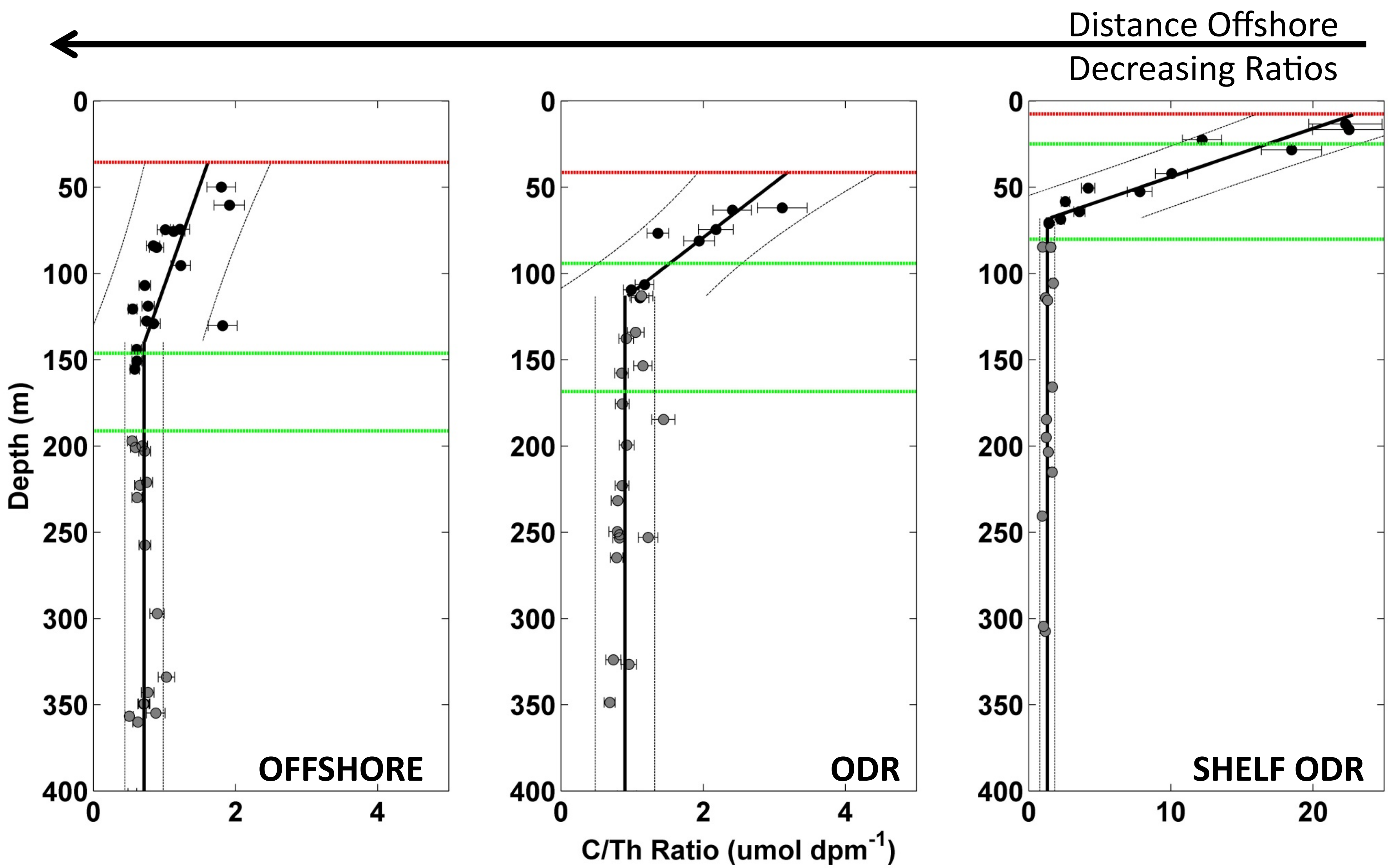
POC flux = $[POC/^{234}Th]_{sink\ part}$ x ^{234}Th flux

TEI flux = $[TEI/^{234}Th]_{sink\ part}$ x ^{234}Th flux

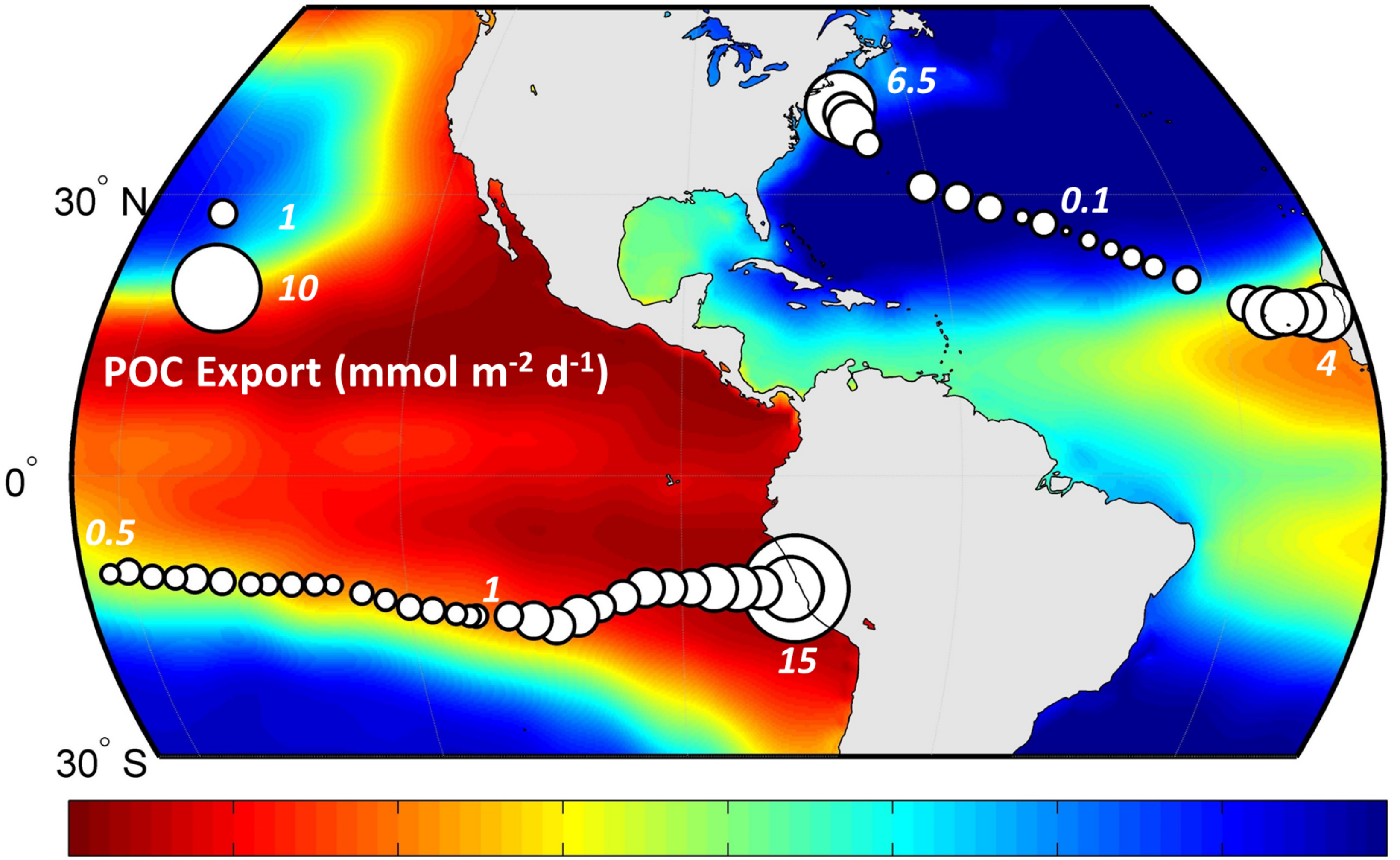
Use large size particles from base of layer of interest to approximate

- Empirical approach works if particles collected represent bulk sinking matter
- Approach fails if a class of sinking particles are not collected AND they differ greatly in composition

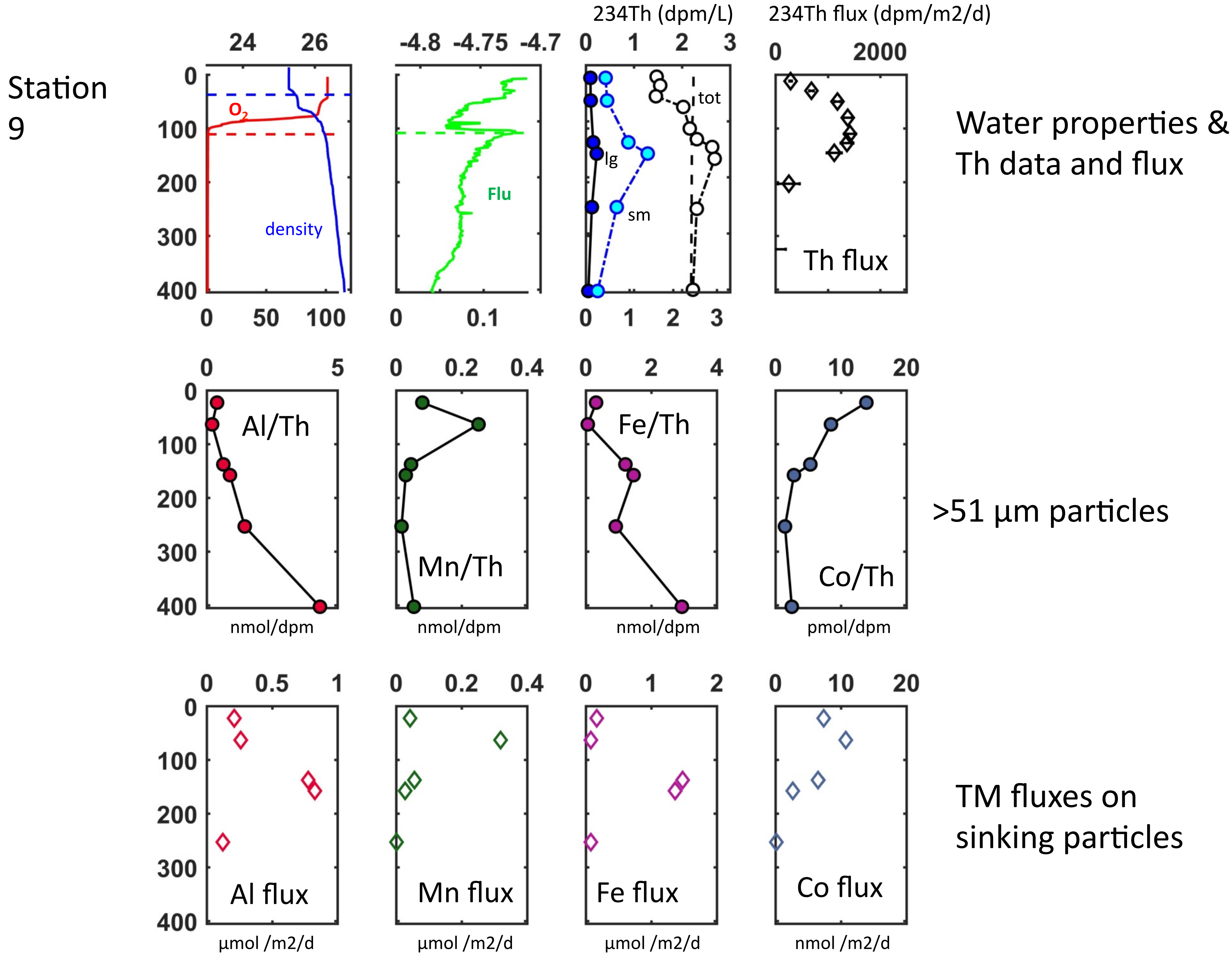
Regional POC:^{234}Th Ratios (>51 µm) in µmol dpm^{-1} for the upper 400 meters.



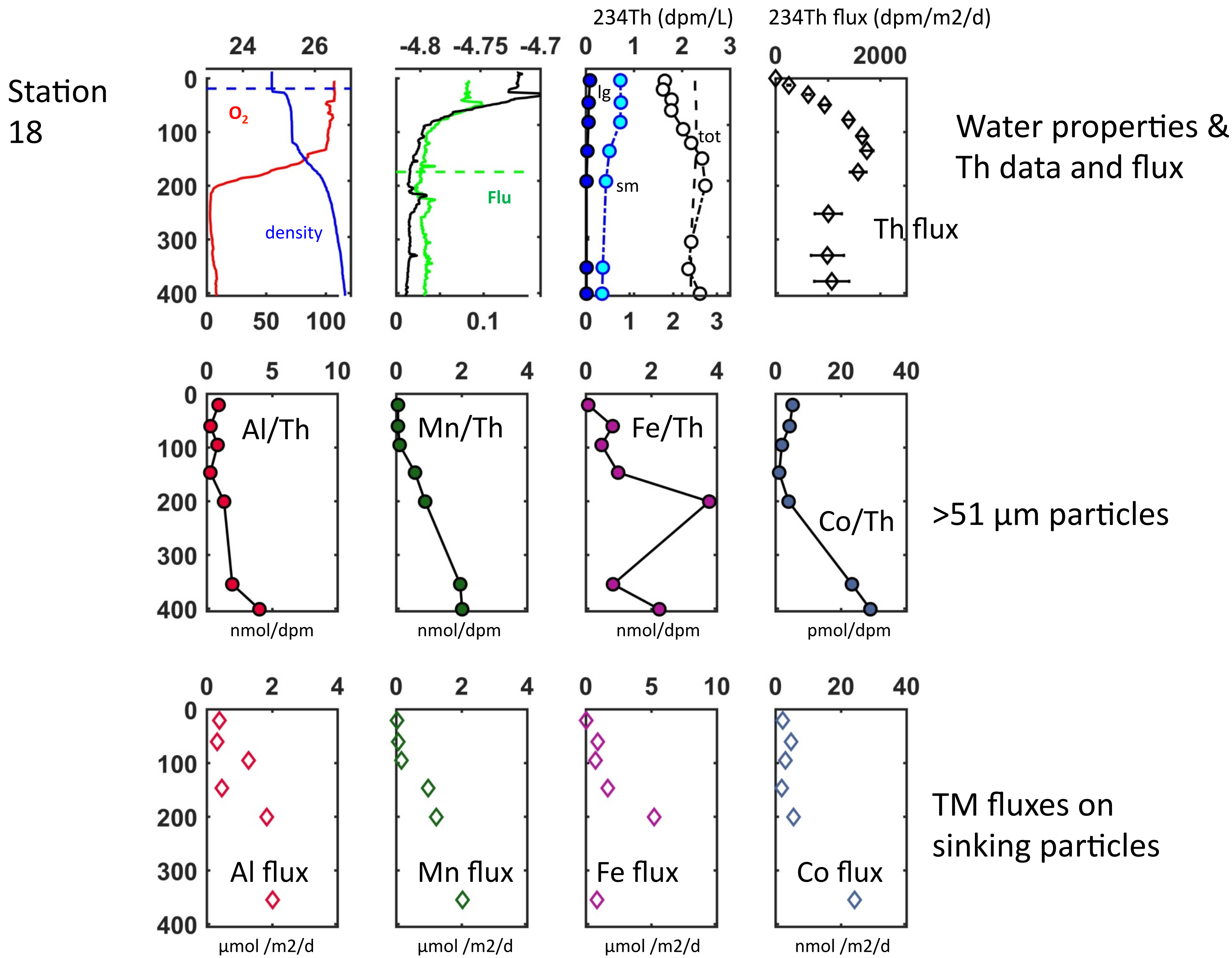
POC flux at EZ using ^{234}Th in Atlantic vs Pacific



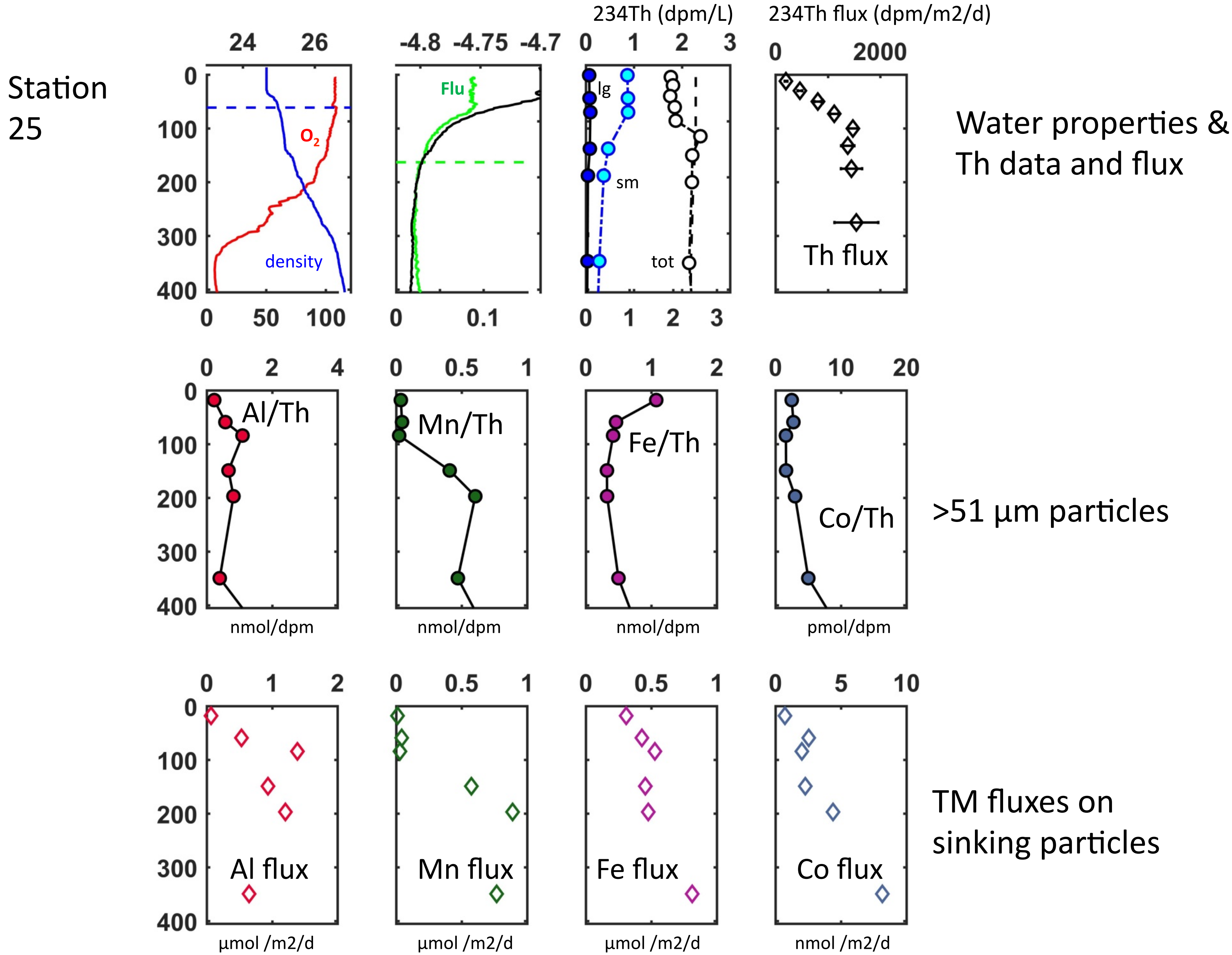
Oxygen Saturation % at 400 meters Depth (Source: WOA09)



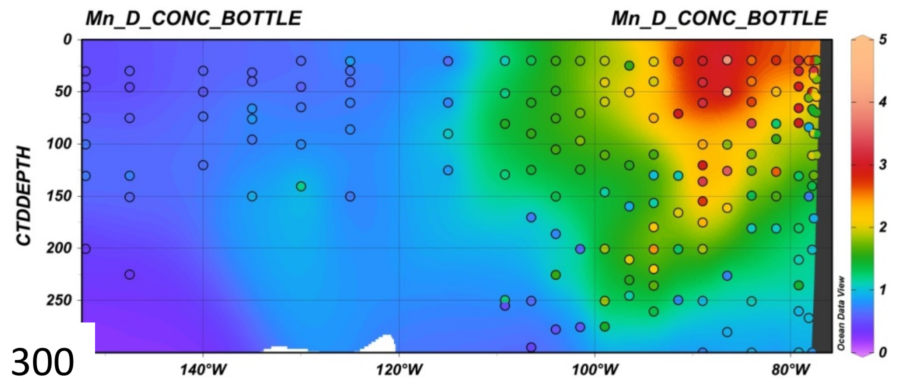
Station 9
24
26
-4.8
-4.75
-4.7
234Th (dpm/L)
234Th flux (dpm/m2/d)
0
2000
O2
density
Flu
tot
lg
sm
Th flux
Water properties & Th data and flux
Al/Th
Mn/Th
Fe/Th
Co/Th
nmol/dpm
pmol/dpm
>51 µm particles
Al flux
Mn flux
Fe flux
Co flux
µmol /m2/d
nmol /m2/d
TM fluxes on sinking particles



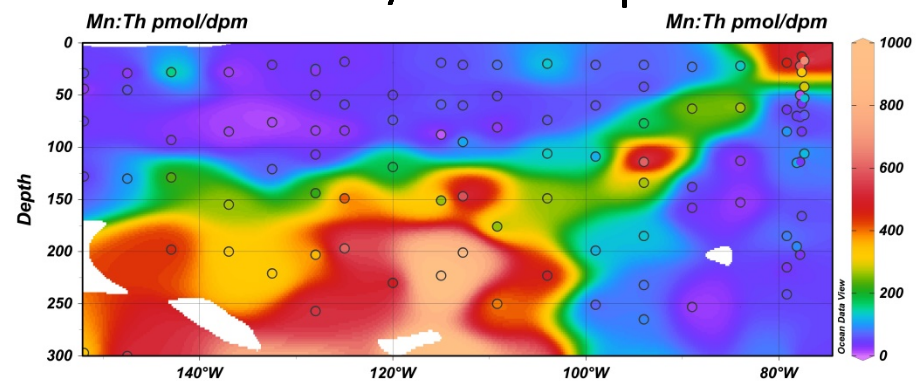
Station 18
Water properties & Th data and flux
O2
density
Flu
234Th (dpm/L)
lg
sm
tot
234Th flux (dpm/m2/d)
Th flux
>51 µm particles
Al/Th
Mn/Th
Fe/Th
Co/Th
nmol/dpm
pmol/dpm
TM fluxes on sinking particles
Al flux
Mn flux
Fe flux
Co flux
µmol /m2/d
nmol /m2/d


Station 25
234Th (dpm/L)
234Th flux (dpm/m2/d)
O2
density
Flu
lg
sm
tot
Th flux
Water properties & Th data and flux
Al/Th
Mn/Th
Fe/Th
Co/Th
nmol/dpm
nmol/dpm
nmol/dpm
pmol/dpm
>51 µm particles
Al flux
Mn flux
Fe flux
Co flux
µmol /m2/d
µmol /m2/d
µmol /m2/d
nmol /m2/d
TM fluxes on sinking particles

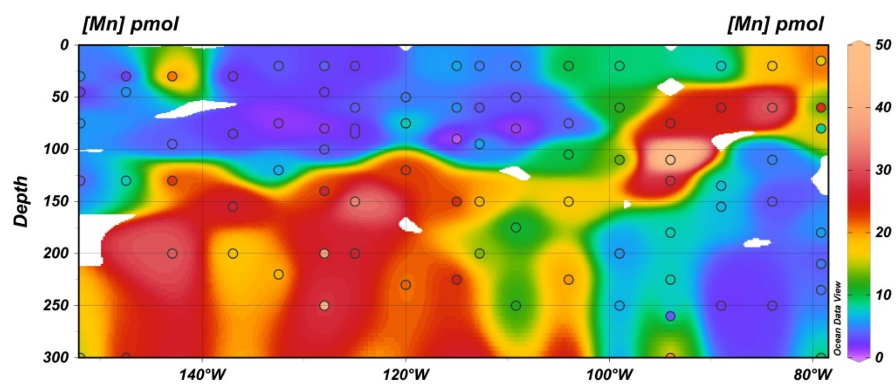
Mn diss (nmol/kg)



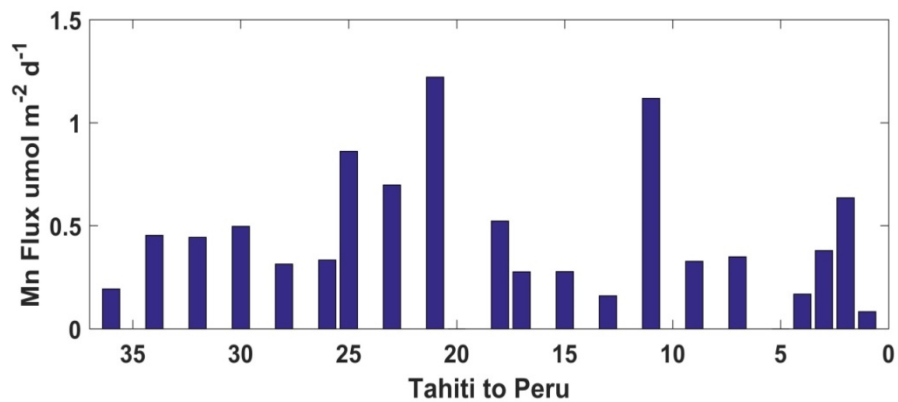
Mn/Th > 51 µm



Mn part > 51 µm

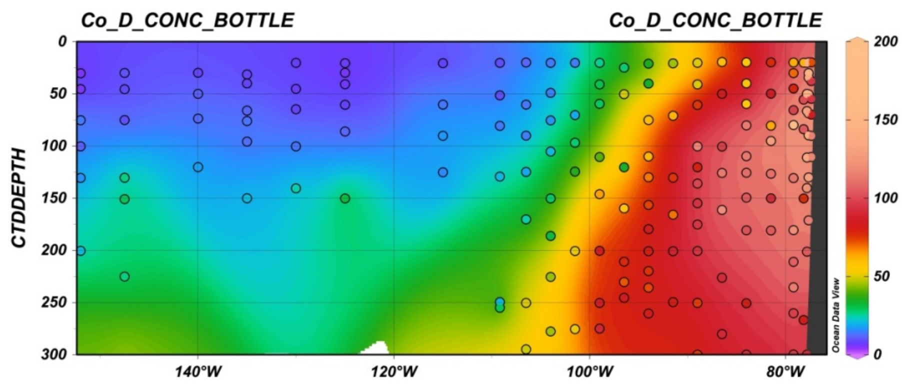


Mn flux at EZ (µmol/m²/d)

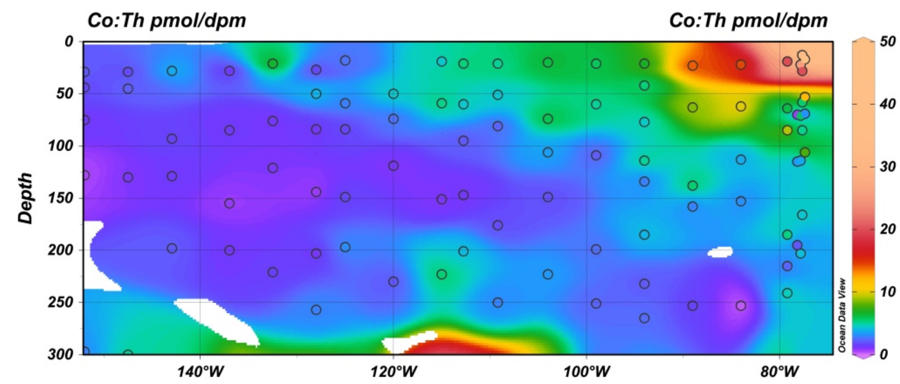


EZ 150 → → → → → → 30m

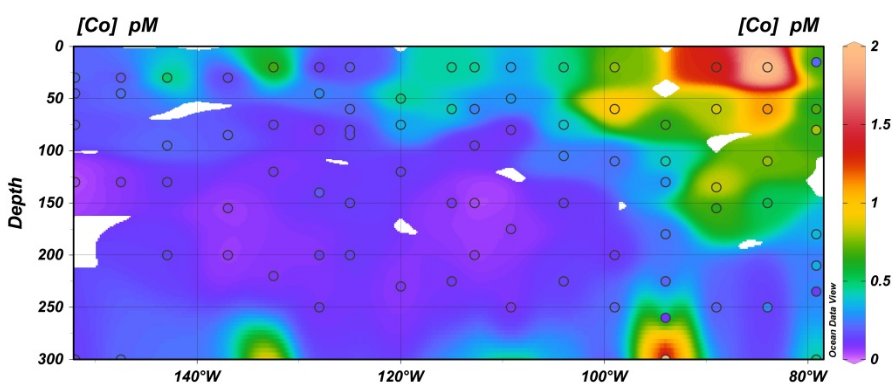
Co diss (pmol/kg)



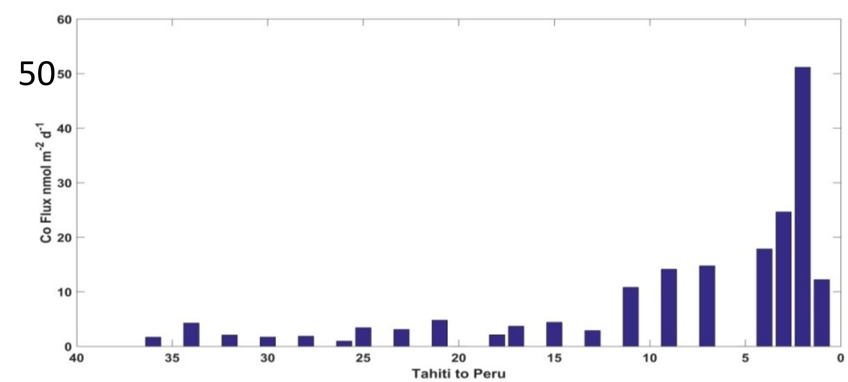
Co/Th > 51 µm



Co part > 51 µm



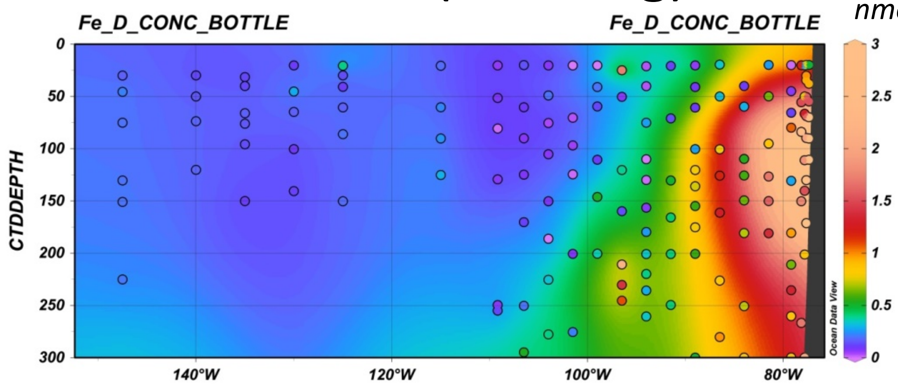
Co flux at EZ (nmol/m^2/d)



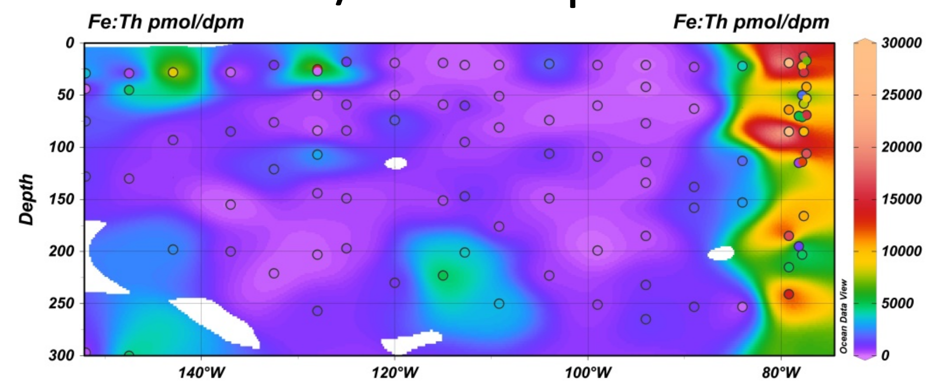
EZ 150 → → → → → → 30m

Fe diss (nmol/kg)

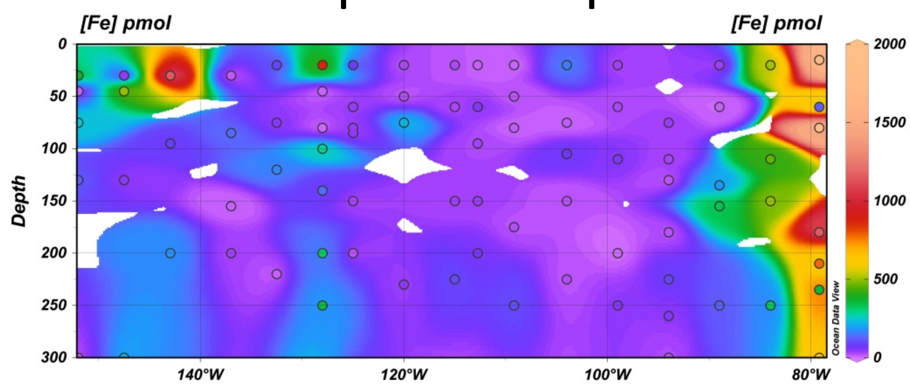
Max Value = 35 nmol/kg



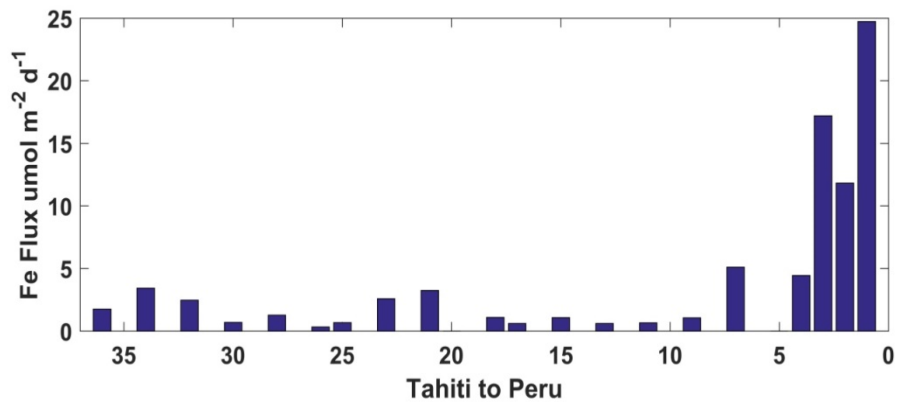
Fe/Th > 51 µm



Fe part > 51 µm



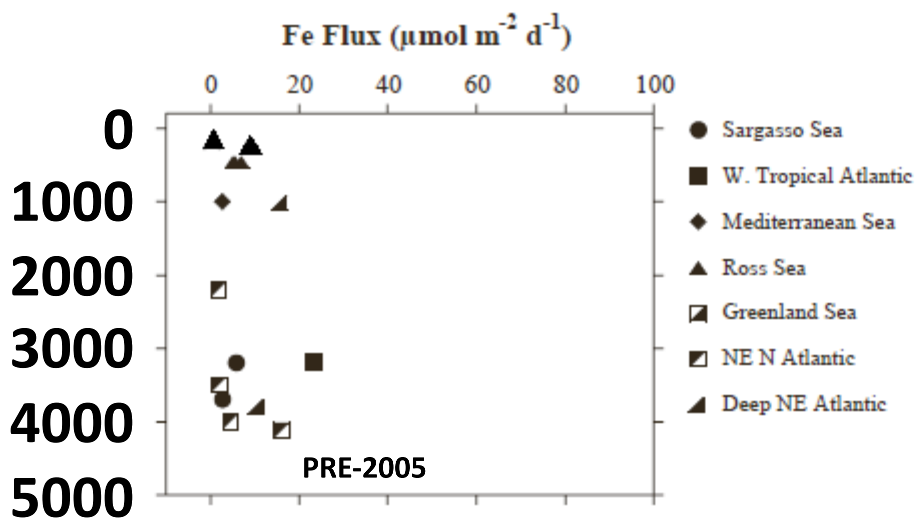
Fe flux at EZ (µmol/m²/d)



EZ 150 → → → → → → 30m

Historical Fe fluxes in deep traps

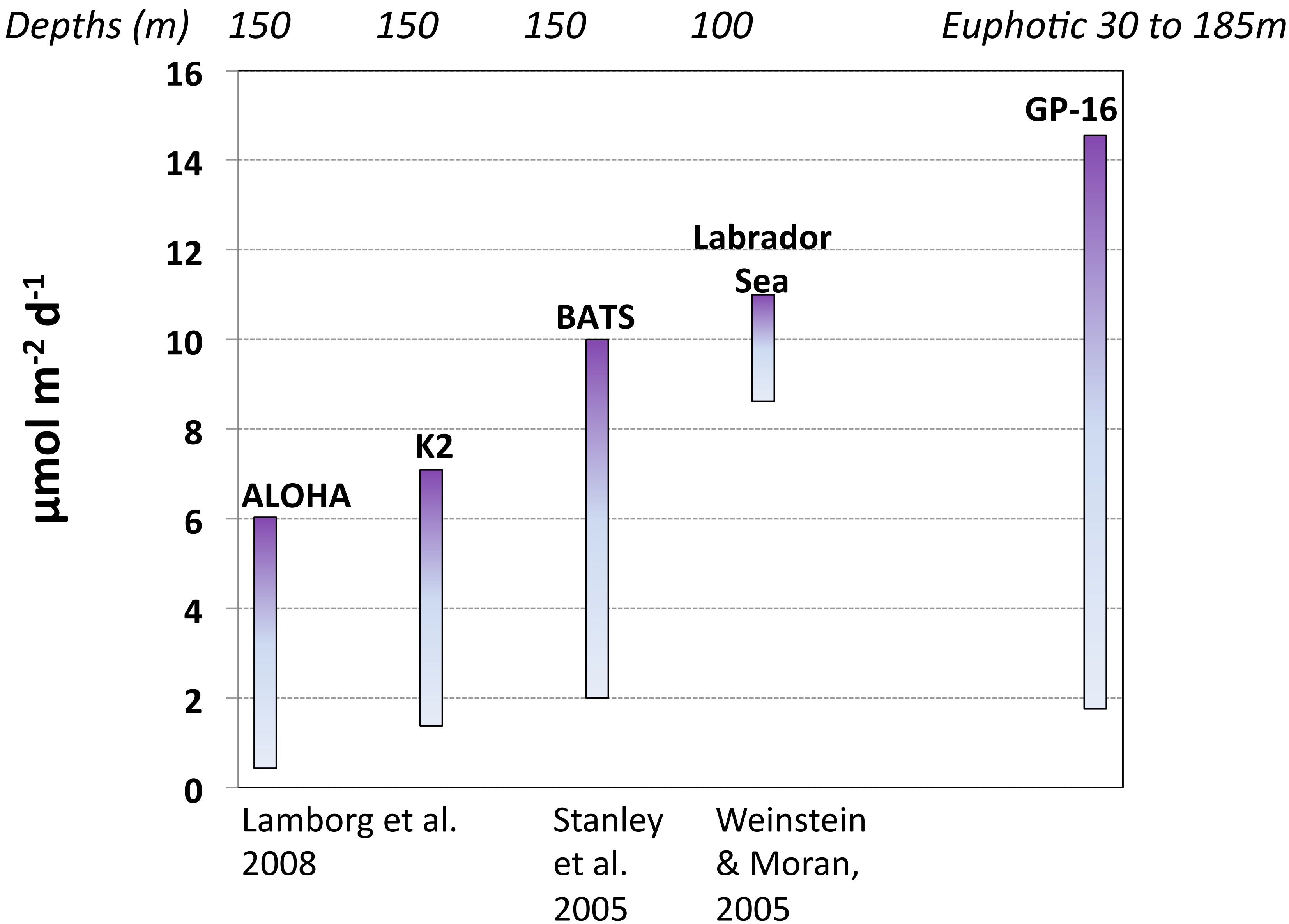
- Use of single or paired traps only provided broad indicators for trends (e.g. increase with depth)

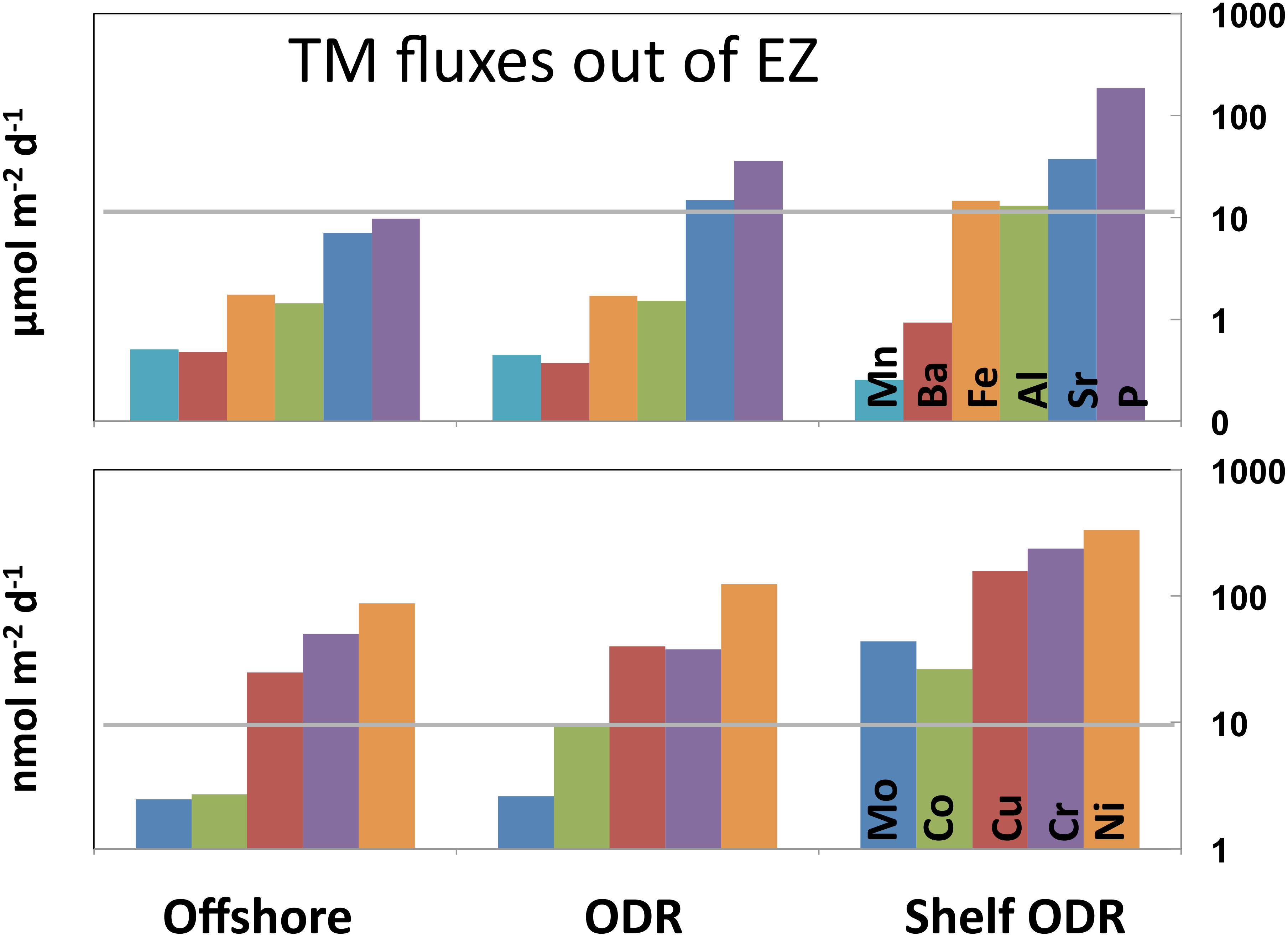


Adapted from Weinstein and Moran (2005)

- Until 2005, scarcity of SHALLOW metal flux data and profiles (<500 m fluxes above only existed for the Ross Sea)

Historical Fe fluxes in upper ocean

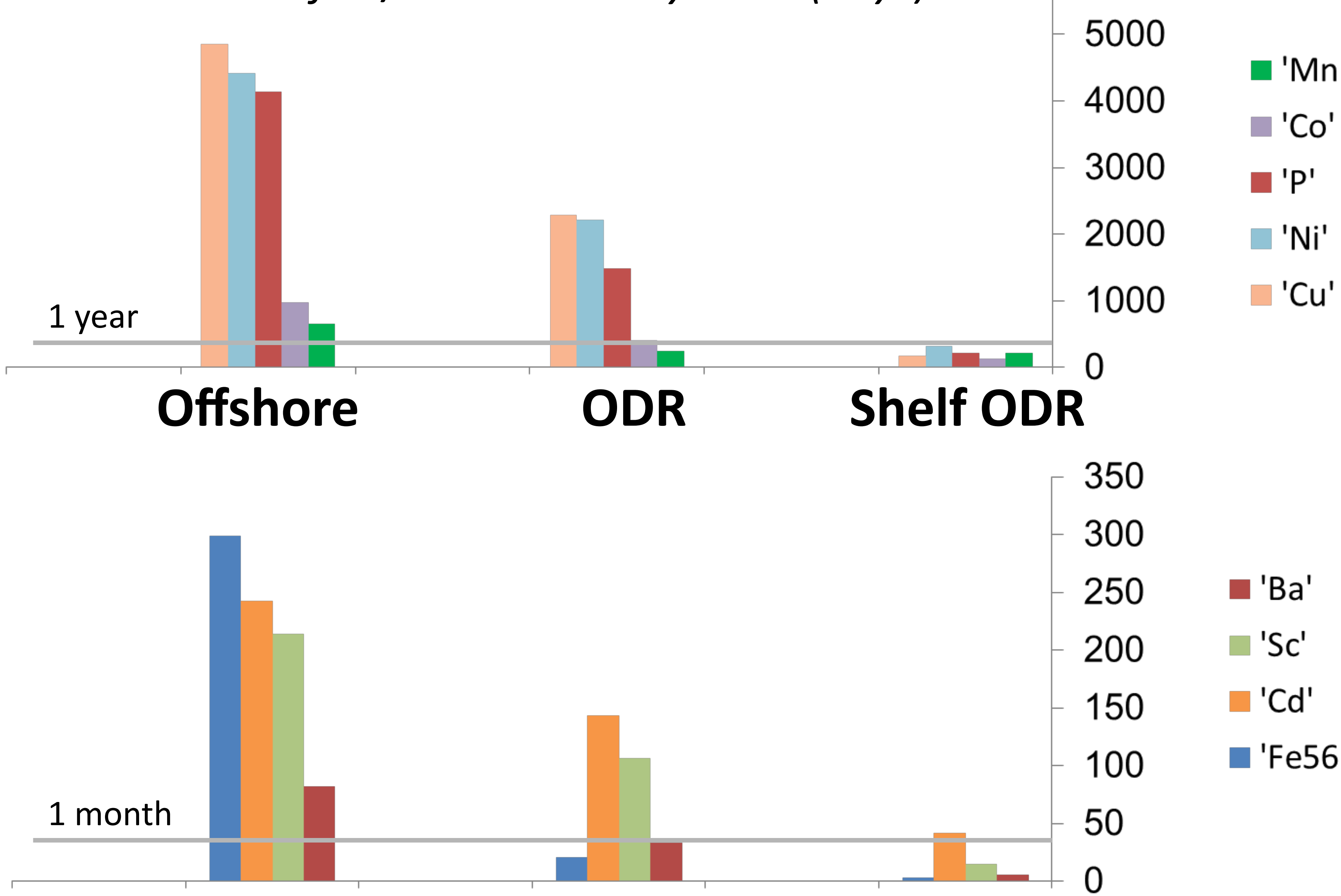




TM fluxes out of EZ
µmol m-2 d-1
nmol m-2 d-1
1000
100
10
1
0
1000
100
10
1
Mn
Ba
Fe
Al
Sr
P
Mo
Co
Cu
Cr
Ni
Offshore
ODR
Shelf ODR

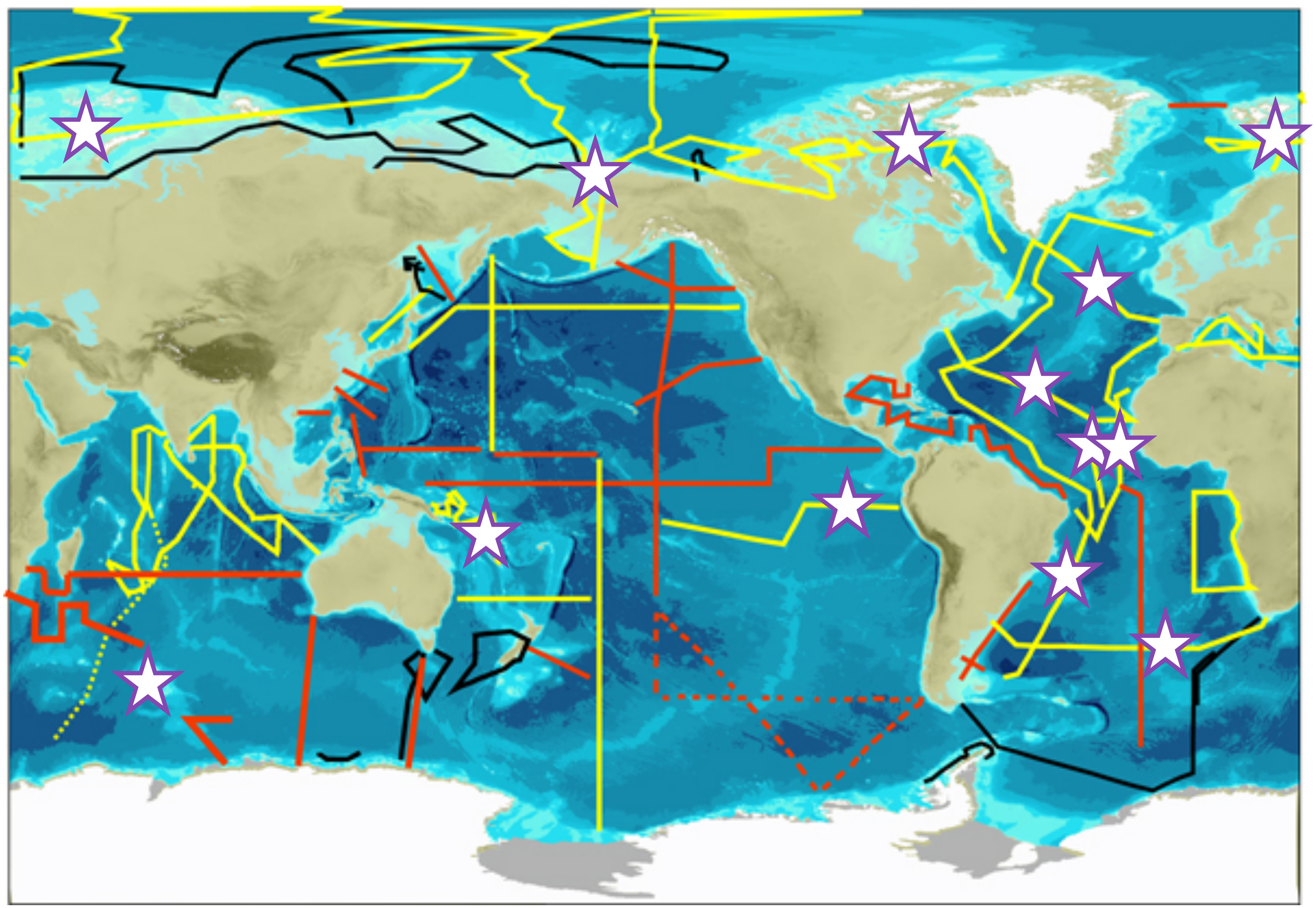
Average Residence Time in the Euphotic Zone

t^res = flux/total inventory at EZ (days)



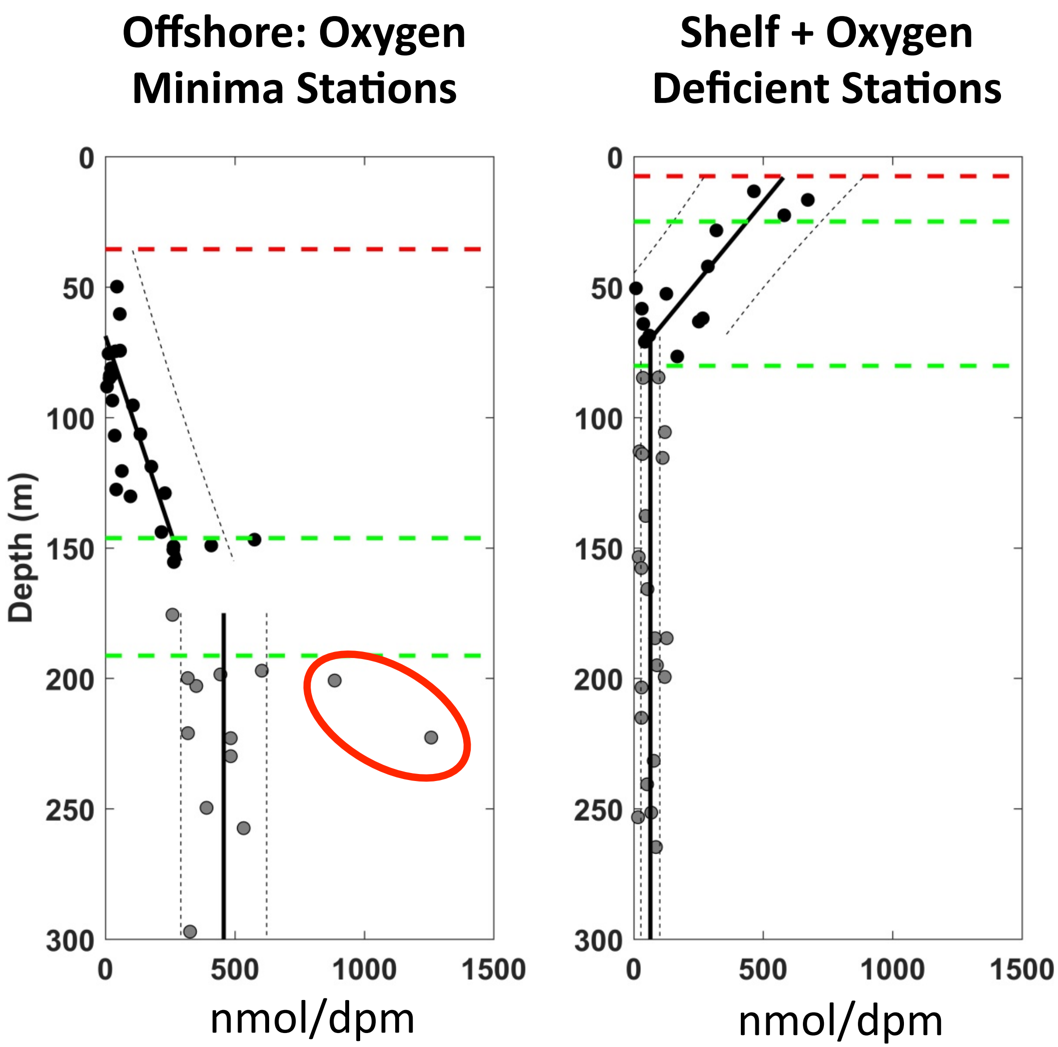
GEOTRACES transects with ^{234}Th sampling

- but not all with in situ large particles



Mn:Th on large particles

2 Zone Linear Best Fits



Particulate Mn goes away in ODZ

Does it make sense to average ratios of large particles?

Challenges & Opportunities

- What are most appropriate boundaries to compare TEI fluxes and processes (light, redox, water mass...)?
- Use ^{228}Th for longer timescales
- Need to resolve upwelling vs. depth to fully interpret data near coast line
- Can we determine a TEI/Th relationship between small and large particles as small particle data is much more abundant?
- GEOTRACES ^{234}Th data will allow for global constraints on upper ocean TEI fluxes- important for understanding processes, models, etc.

A wise man once said *"Engage in group activities that further transformation"*