Thermobaricity in the Transition Zones between Alpha and Beta Oceans

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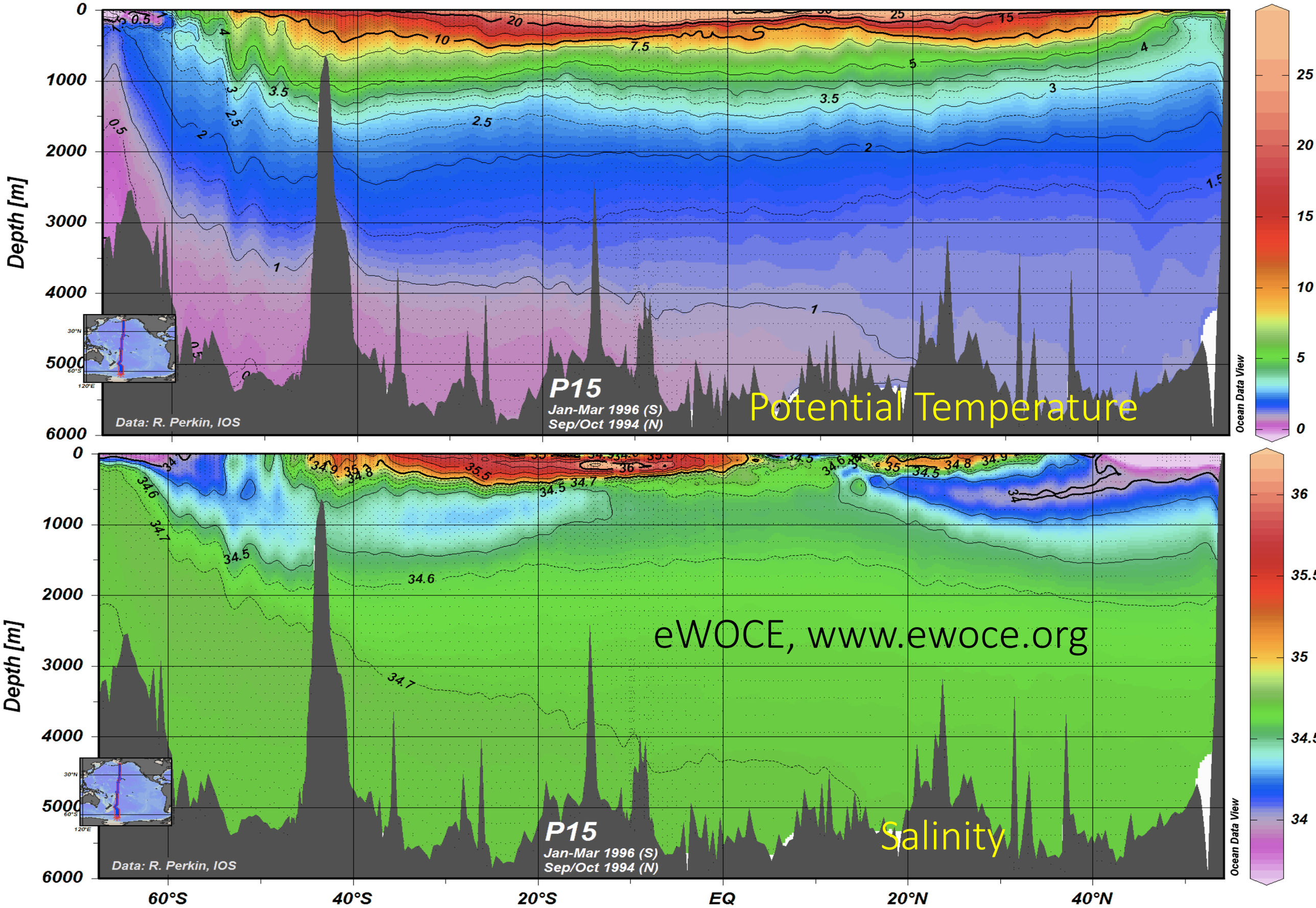
Australian National University

JOHNS HOPKINS KRIEGER SCHOOL of ARTS & SCIENCES

ARC CENTRE OF EXCELLENCE FOR CLIMATE SYSTEM SCIENCE

ASOF Arctic-Subarctic Ocean Fluxes

Does heat or salt provide the dominant contribution to the ocean stratification?



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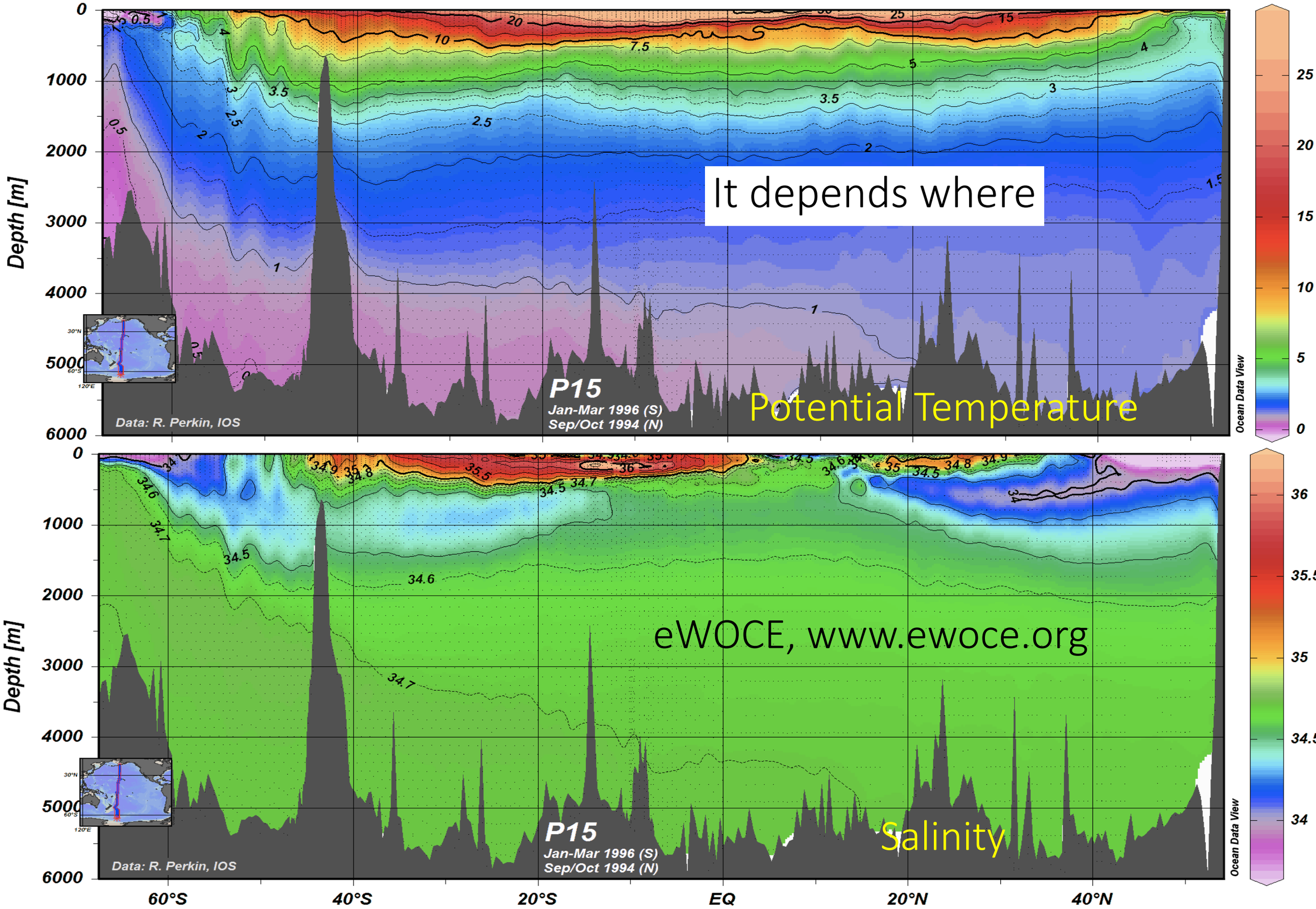


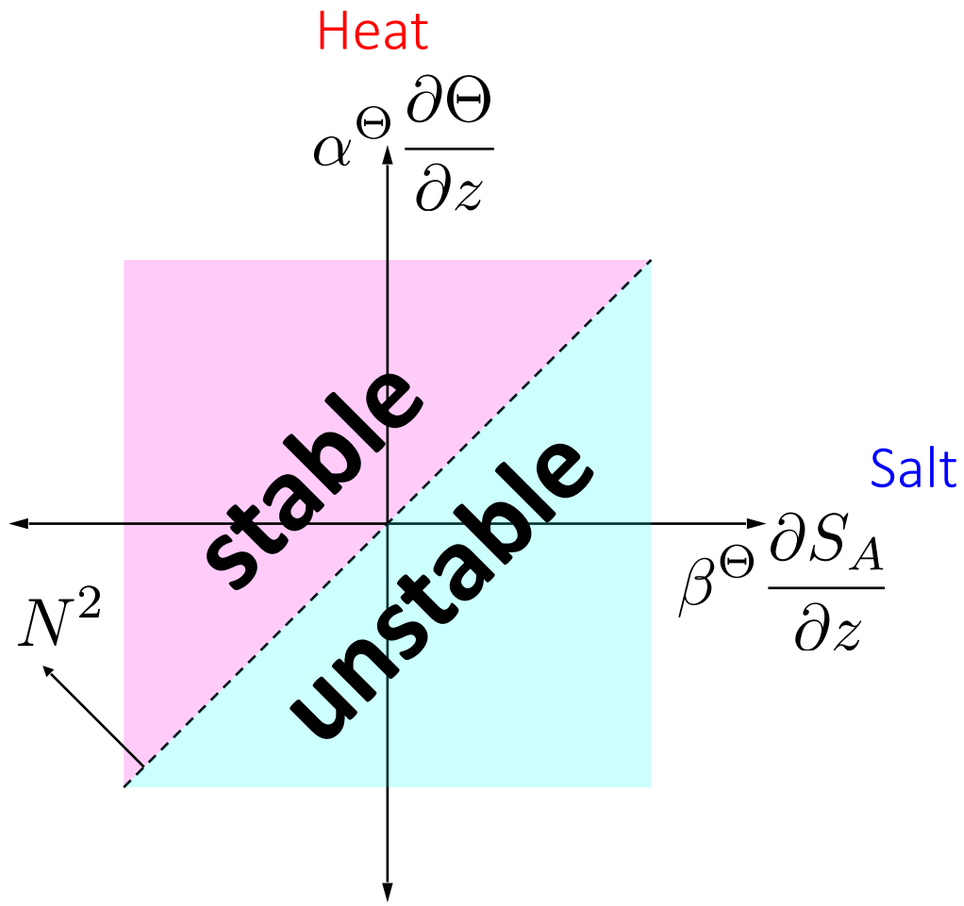
Quantifying the dominant contributor to the ocean stratification

Density Stratification

$$N^2 = g\left(\alpha^{\Theta}\frac{\partial \Theta}{\partial z} - \beta^{\Theta}\frac{\partial S_A}{\partial z}\right)$$

Heat contribution

Salt contribution



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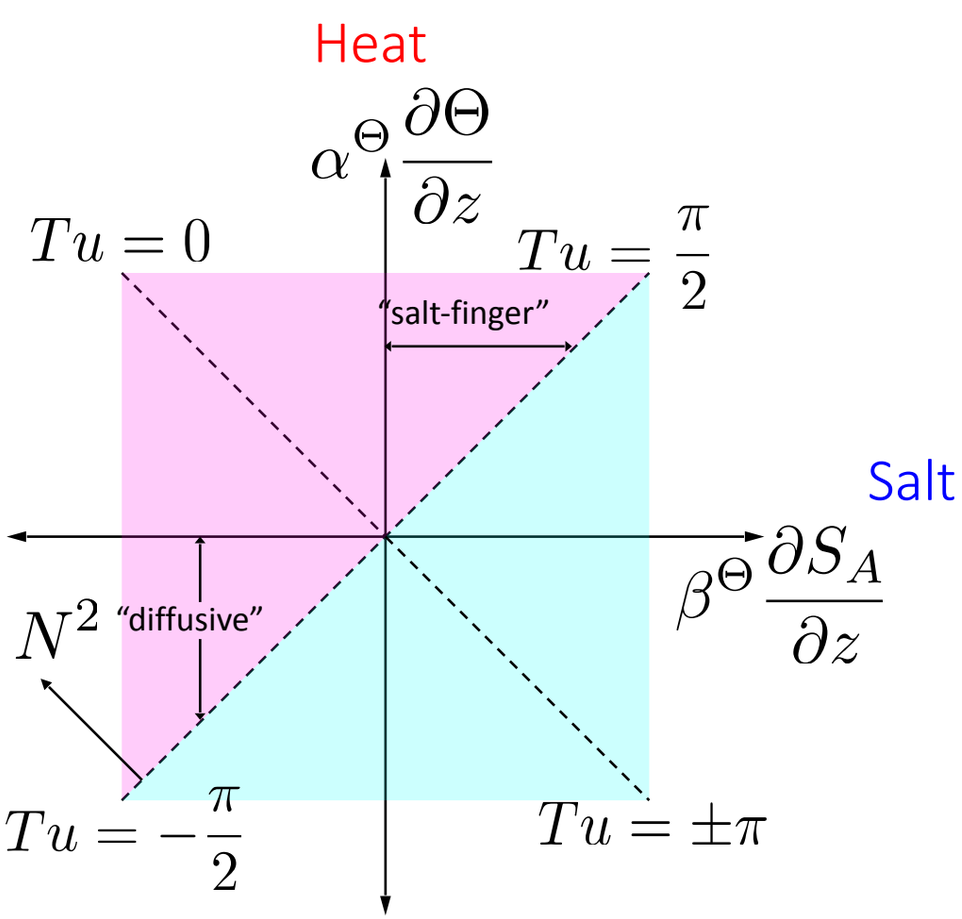


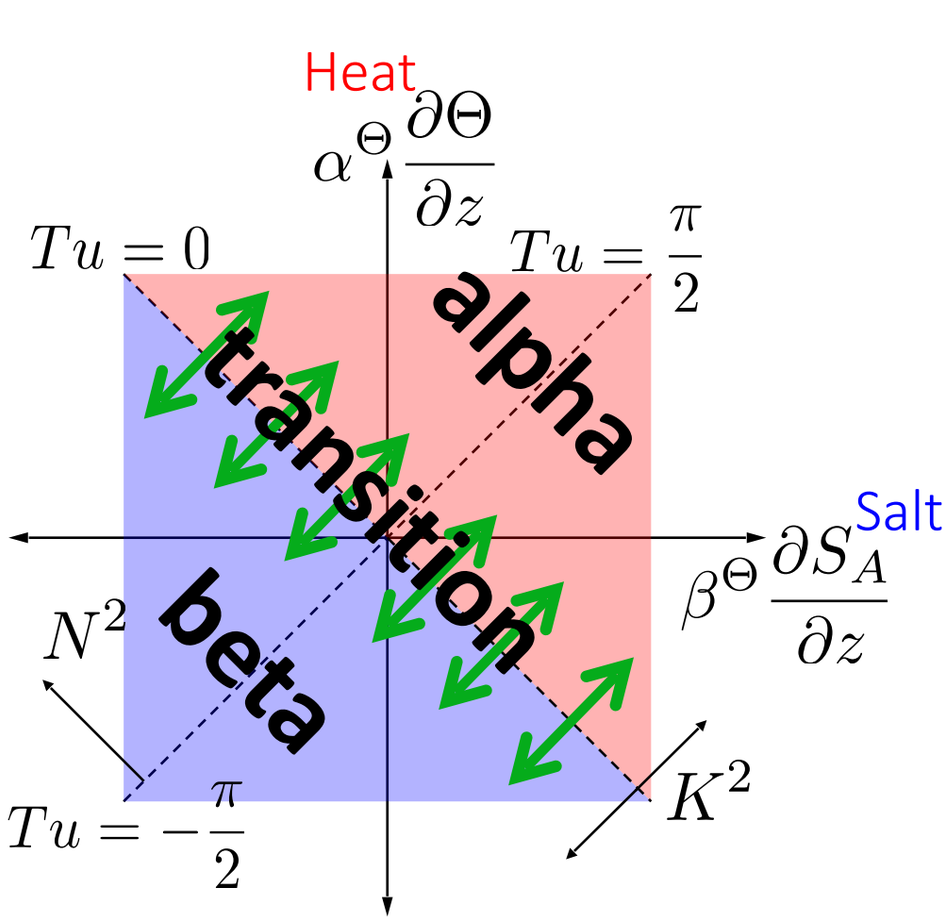
Spice Stratification

$$K^2 = g\left(\alpha^{\Theta}\frac{\partial \Theta}{\partial z} + \beta^{\Theta}\frac{\partial S_A}{\partial z}\right)$$

Alpha: K^2 always positive:

Beta: K^2 always negative:

Transition zone: K^2 changes sign:



Stewart & Haine, JPO, 2016

Vertical Profiles of thermal, salinity, density and spice stratifications

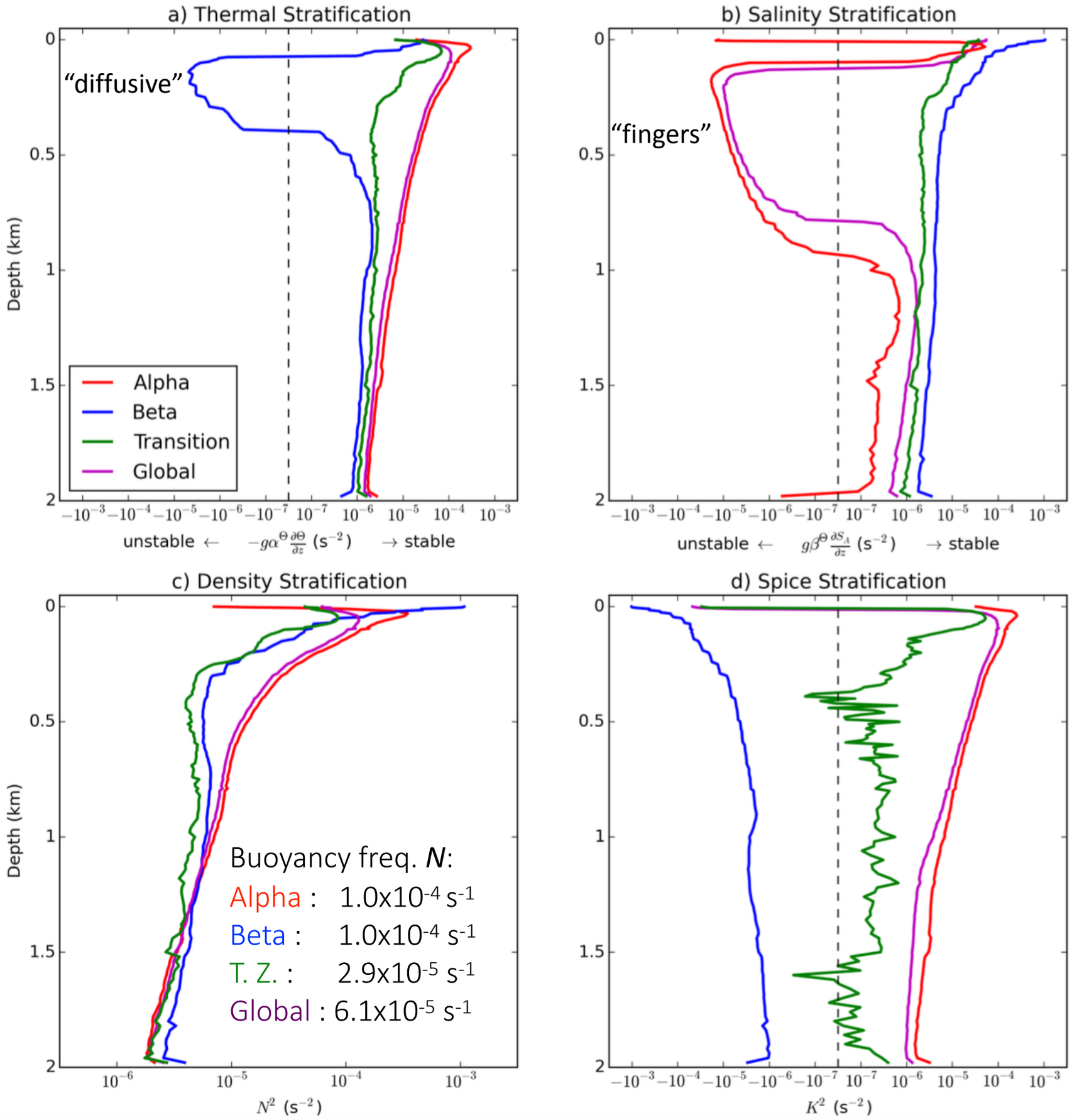
- Ifremer, predominantly **Argo,** product 2010–2013
- Global 0.3° x 0.5° (lat. x lon.)
- 152 vertical levels to 2000m

Global distribution:

Alpha: 67.2%

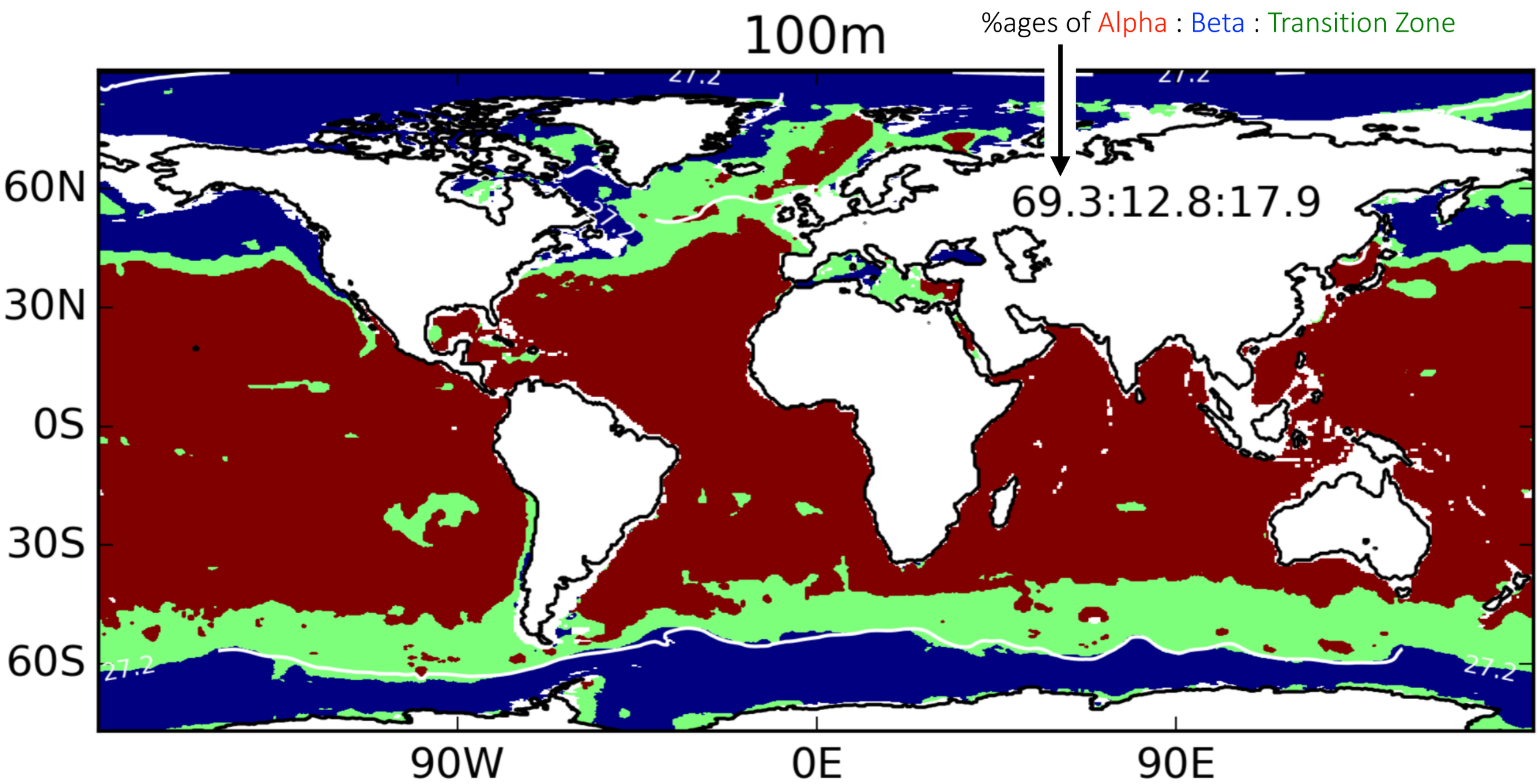
Beta: 15.1%

T. Z. : 17.5%



Alpha : Beta : Transition Zone

Spatial Distribution: Depth Slices



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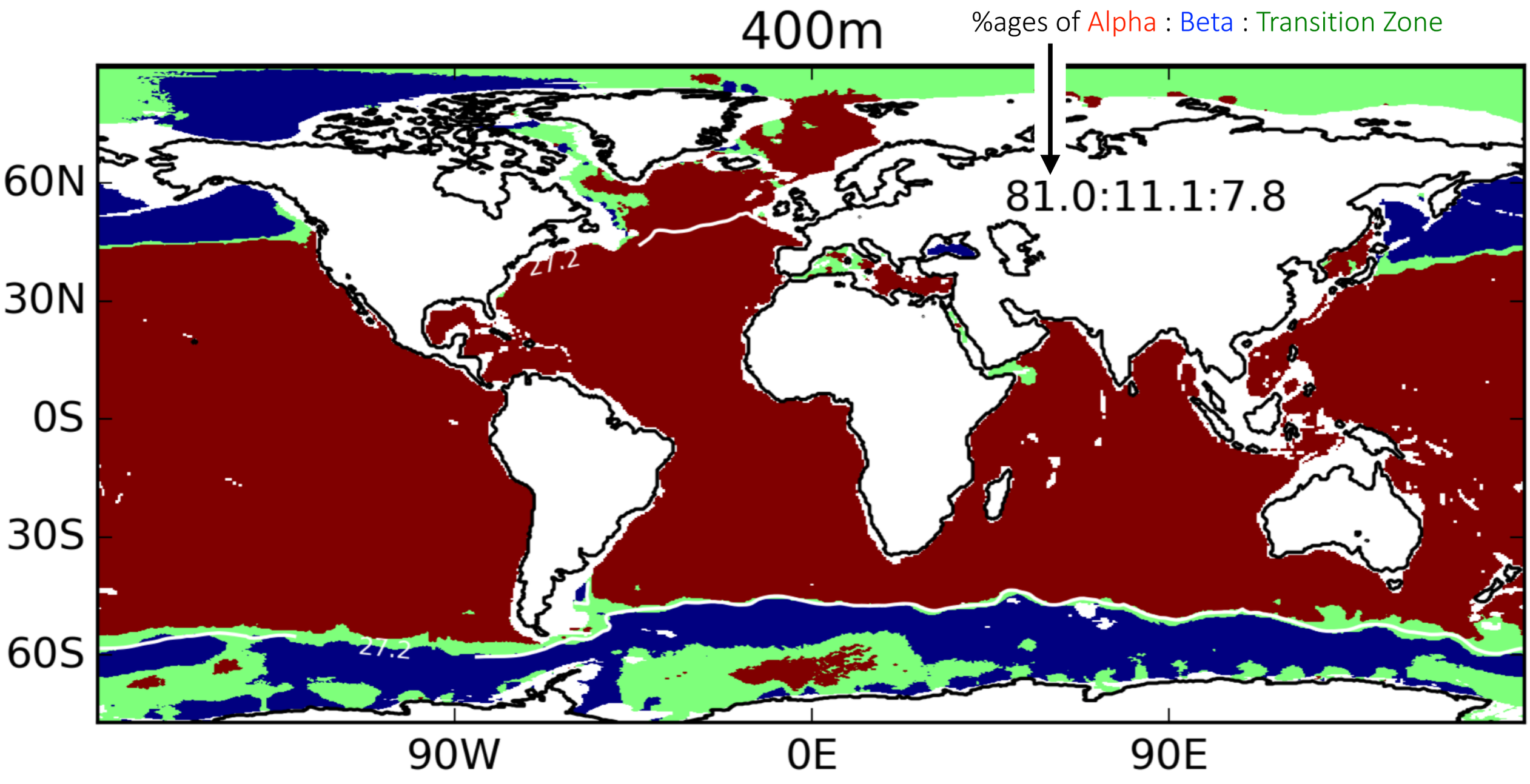
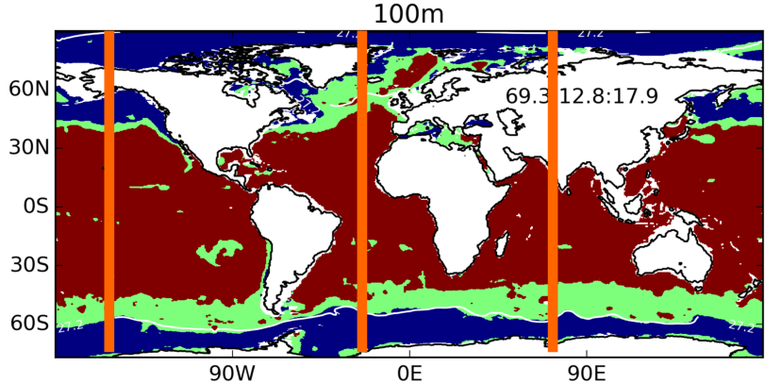
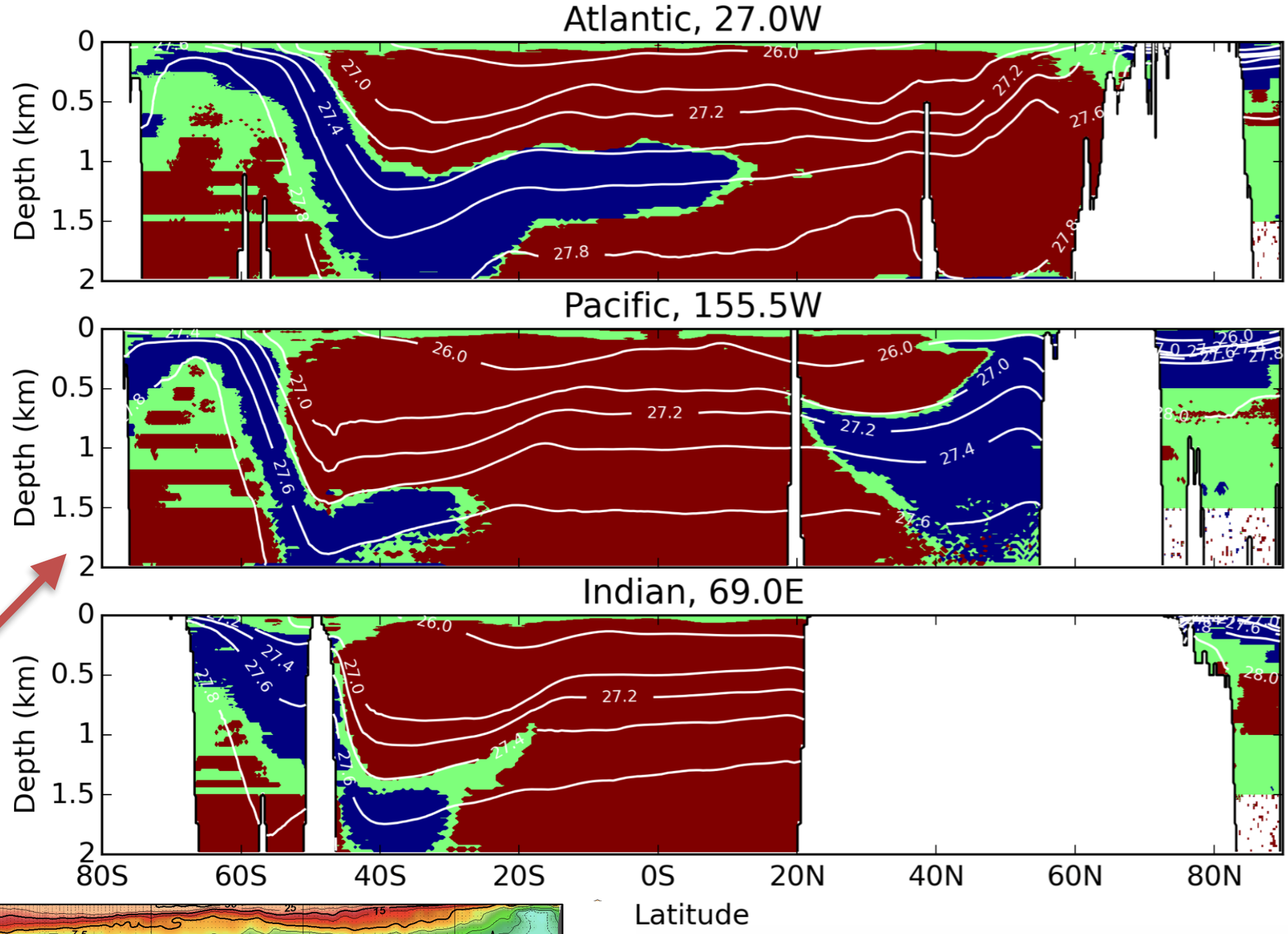
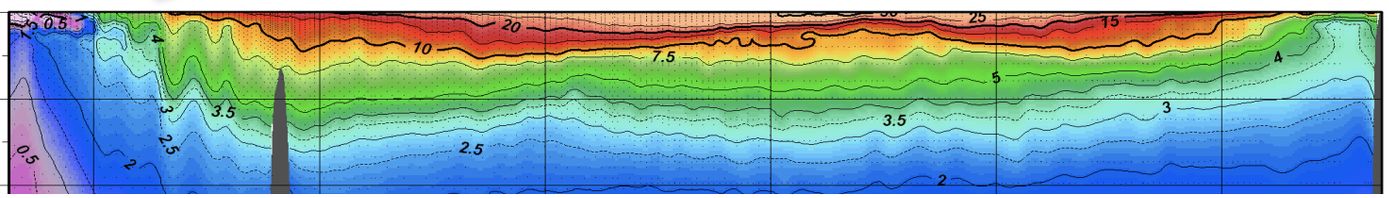


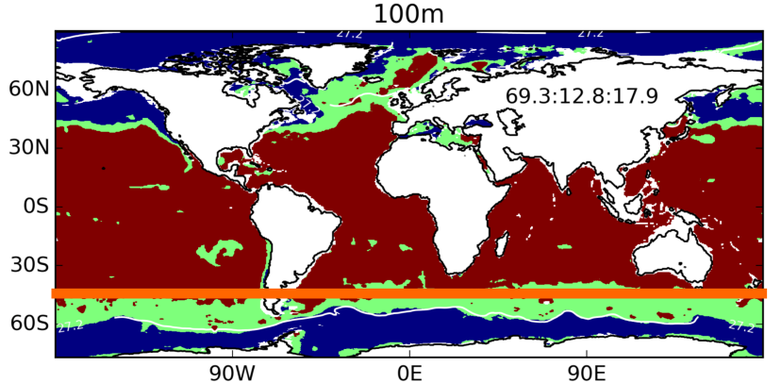
Spatial Distribution: Meridional Transects



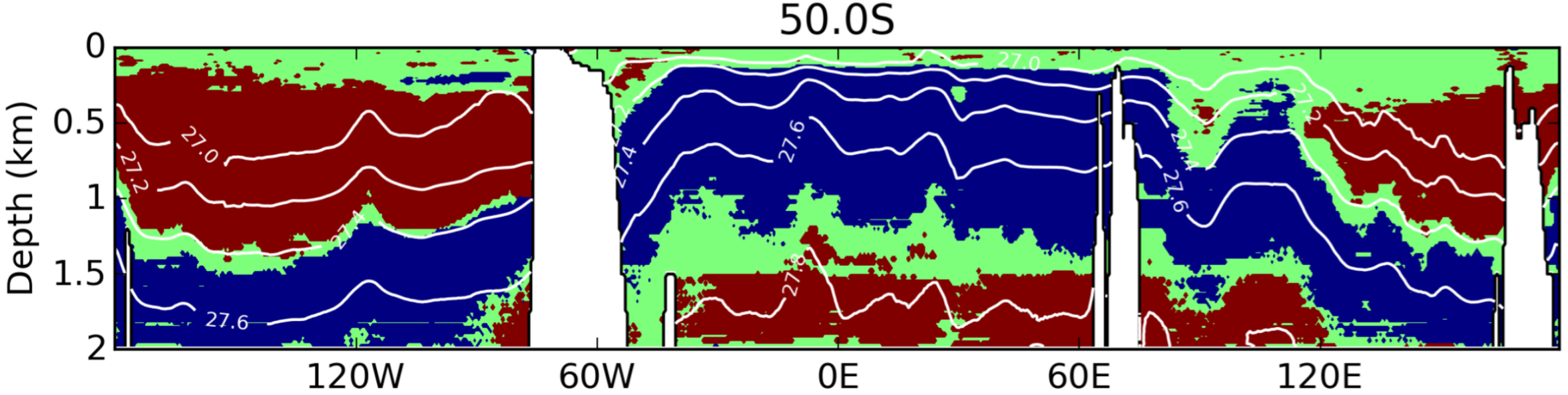




Alpha : Beta : Transition Zone

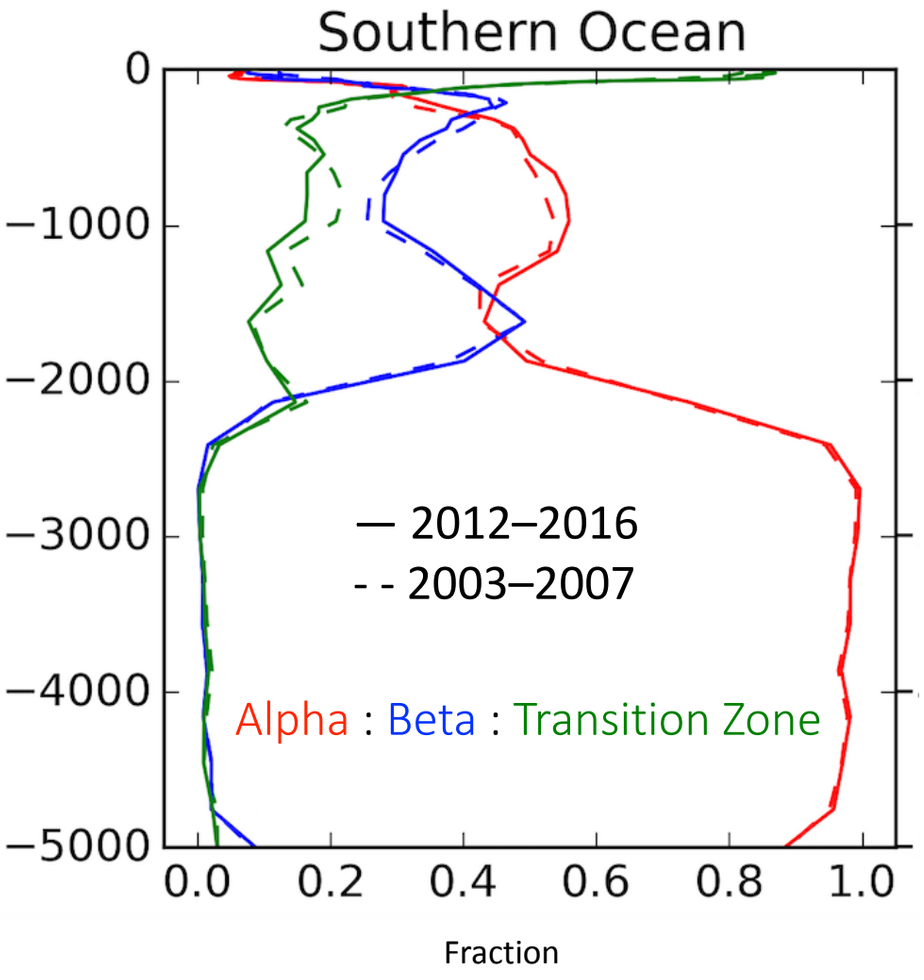


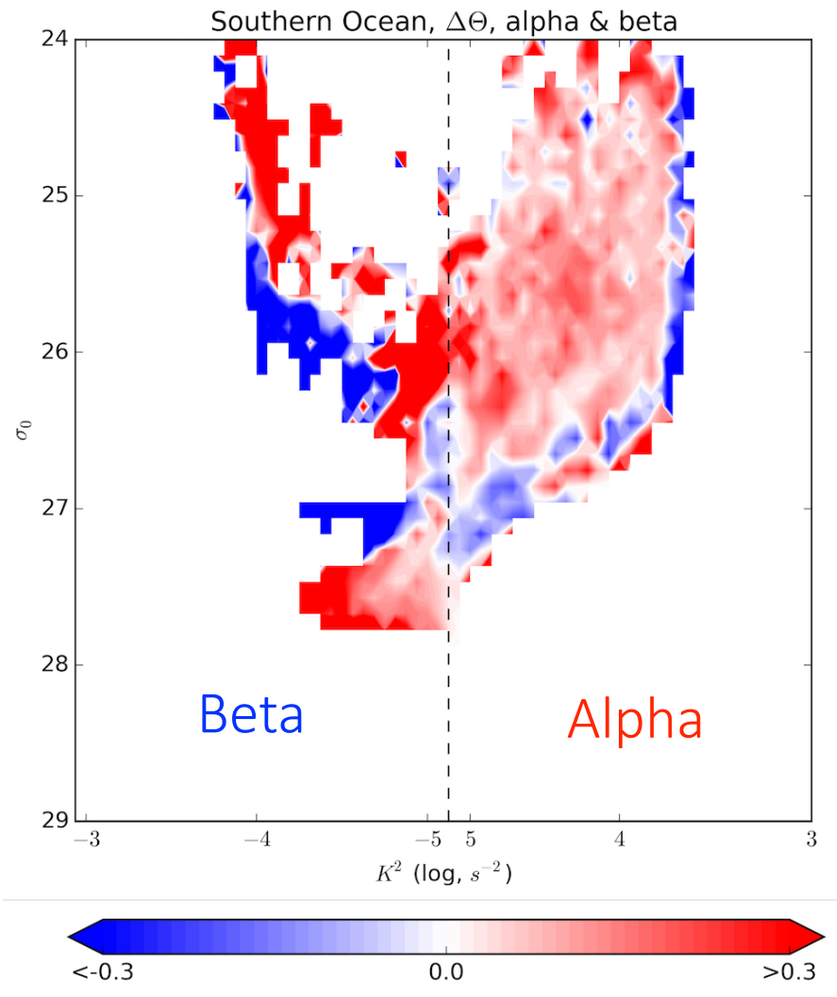
Spatial Distribution: Zonal Transect



Alpha : Beta : Transition Zone

Changes in Southern Ocean Alpha/Beta Character



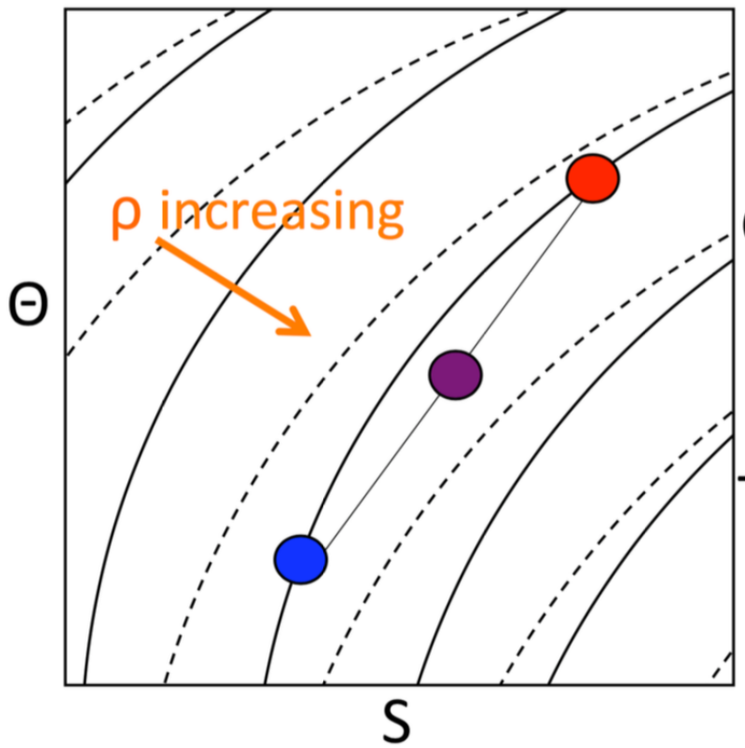


- EN4, predominantly **Argo,** product 2003–2016

Stewart et al., in prep.

EOS Nonlinearity: Thermobaricity

a) Density in Θ-S space



— $\rho(\Theta,S,P_s)$

--- $\rho(\Theta,S,P_\delta)$

$P_s < P_\delta$

Cabbeling:

$\Theta_m=(\Theta_1+\Theta_2)/2$, $S_m=(S_1+S_2)/2$

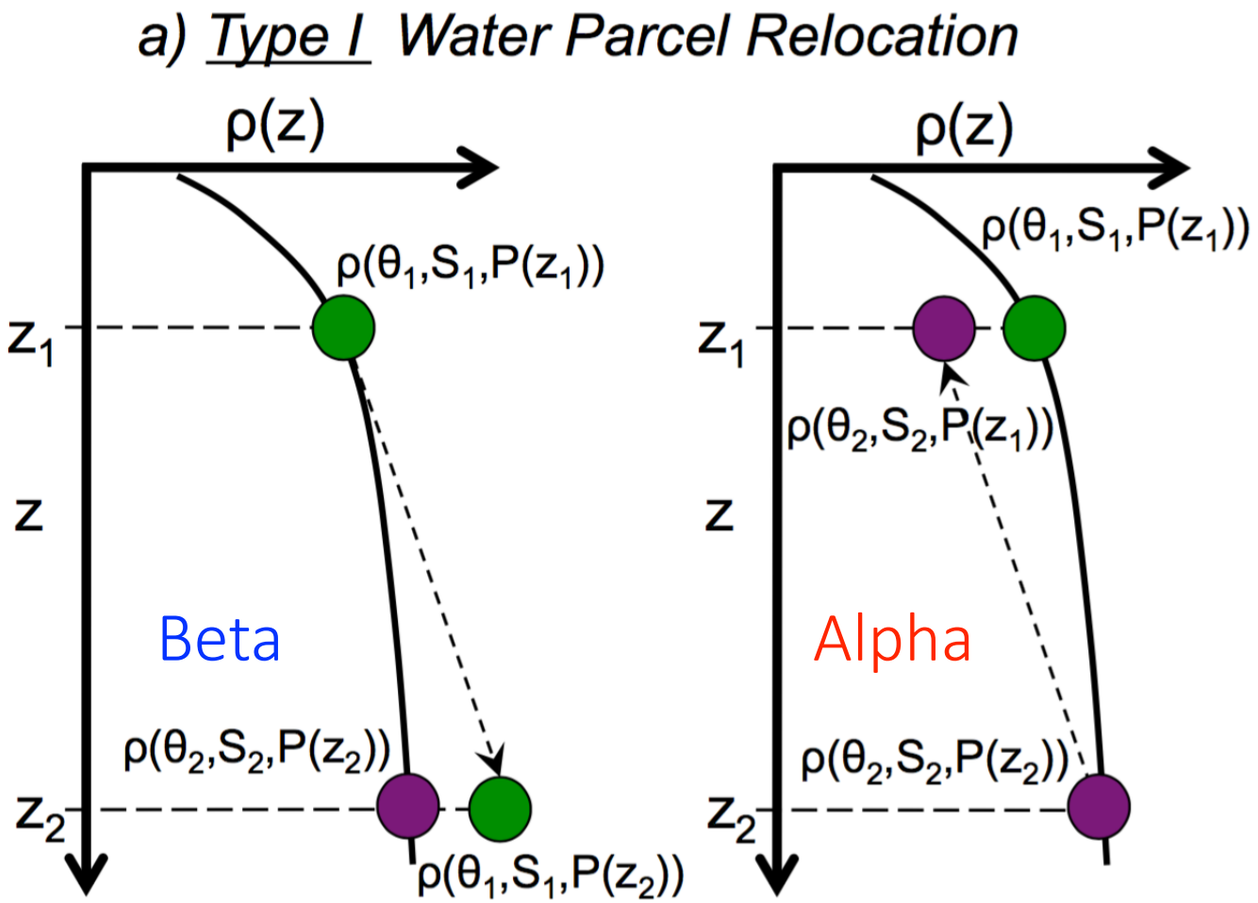
$\rho_m(\Theta_m,S_m,P_S) > \rho(\Theta_1,S_1,P_S), \rho(\Theta_2,S_2,P_S)$

Thermobaricity:

$\rho(\Theta_1,S_1,P_S) = \rho(\Theta_2,S_2,P_S)$

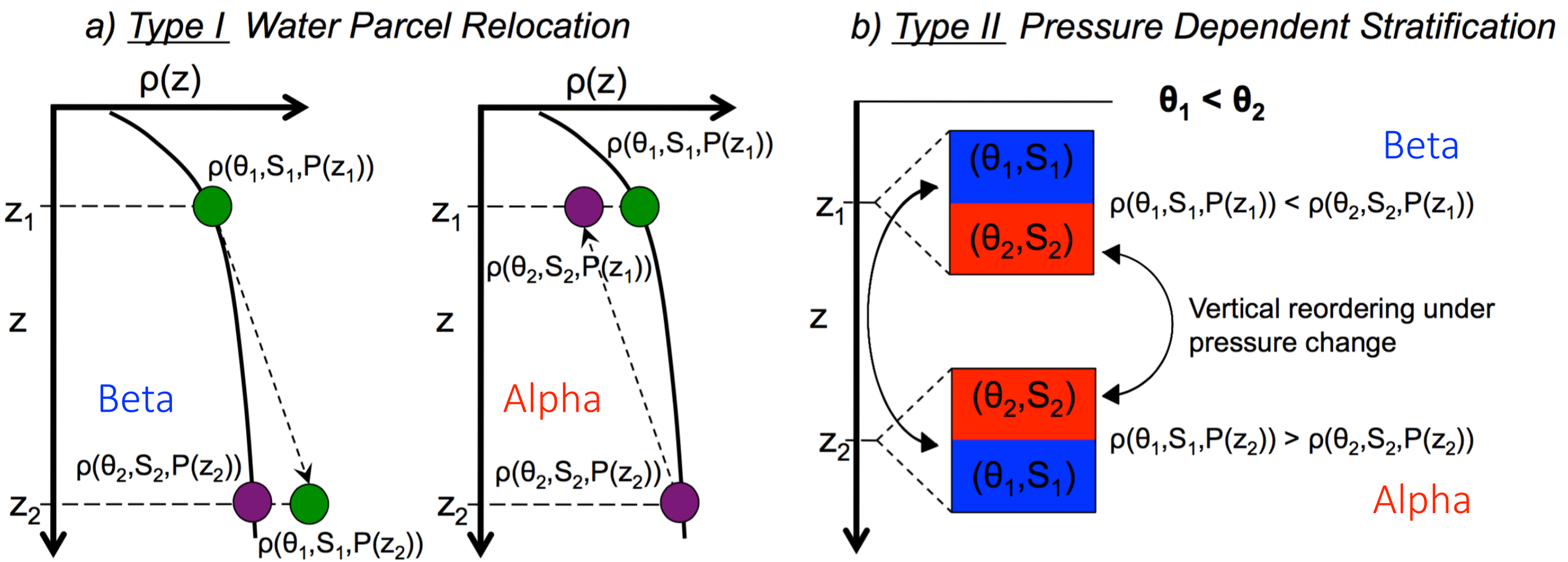
$\rho(\Theta_1,S_1,P_\delta) < \rho(\Theta_2,S_2,P_\delta)$

Two types of Thermobaricity



Cold water is more compressible

Two types of Thermobaricity



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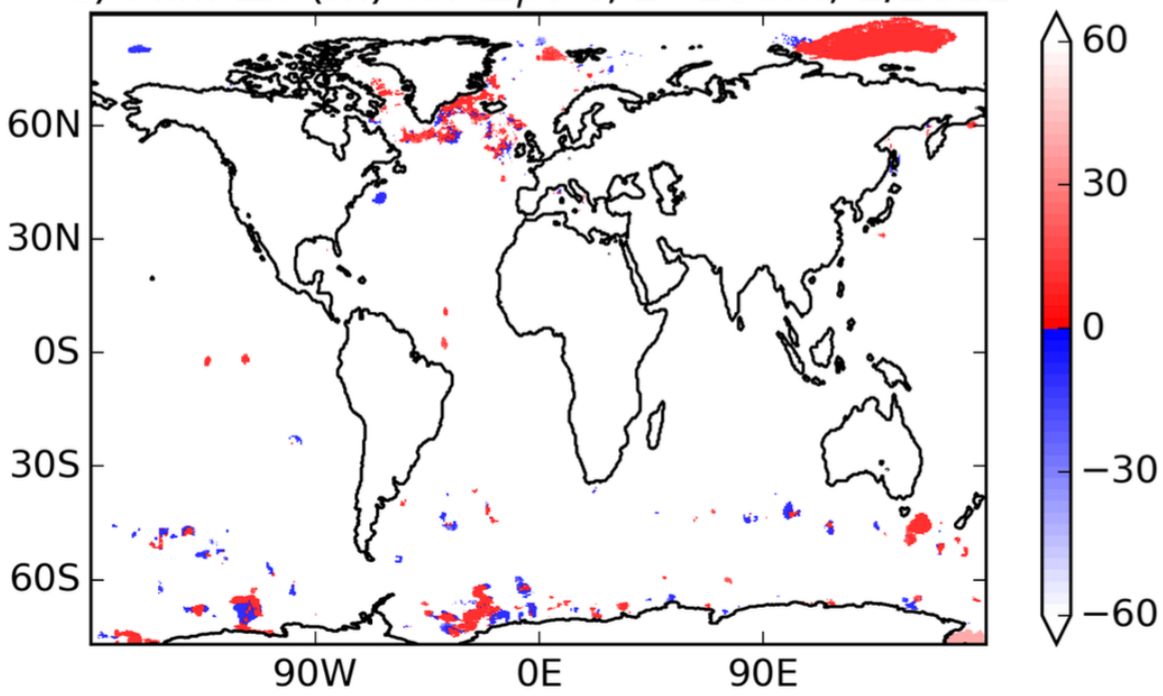
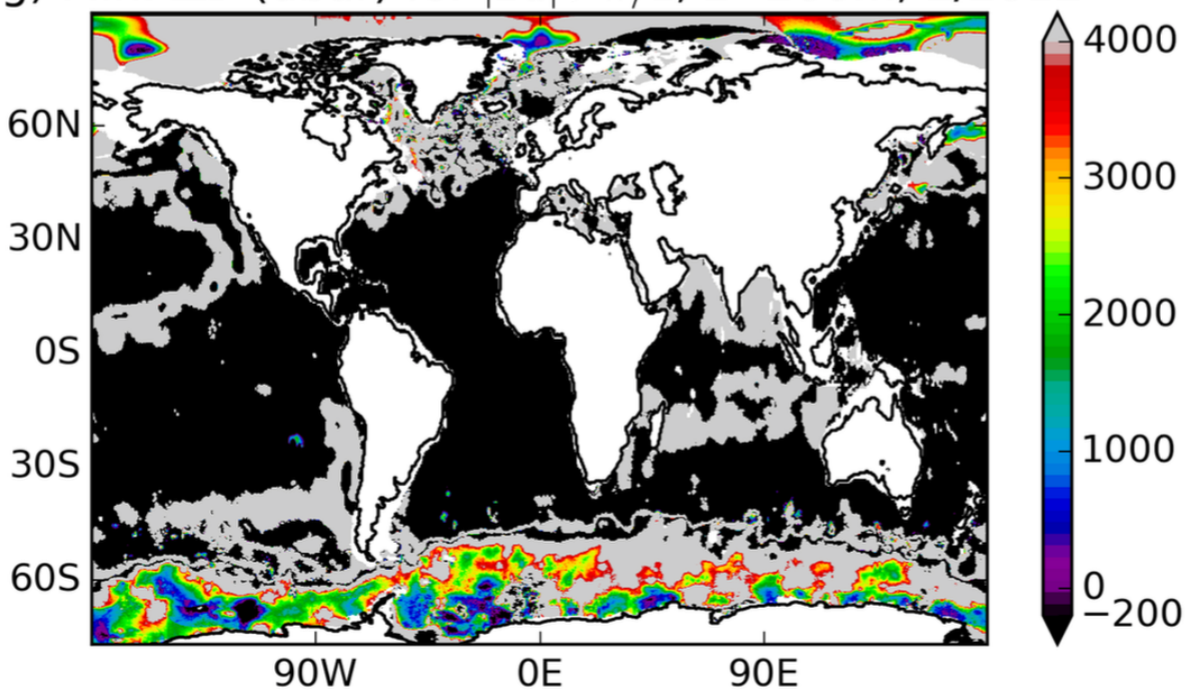
Two types of Thermobaricity

a) Type I Water Parcel Relocation



3% unstable

b) Type II Pressure Dependent Stratification



7% unstable

Summary

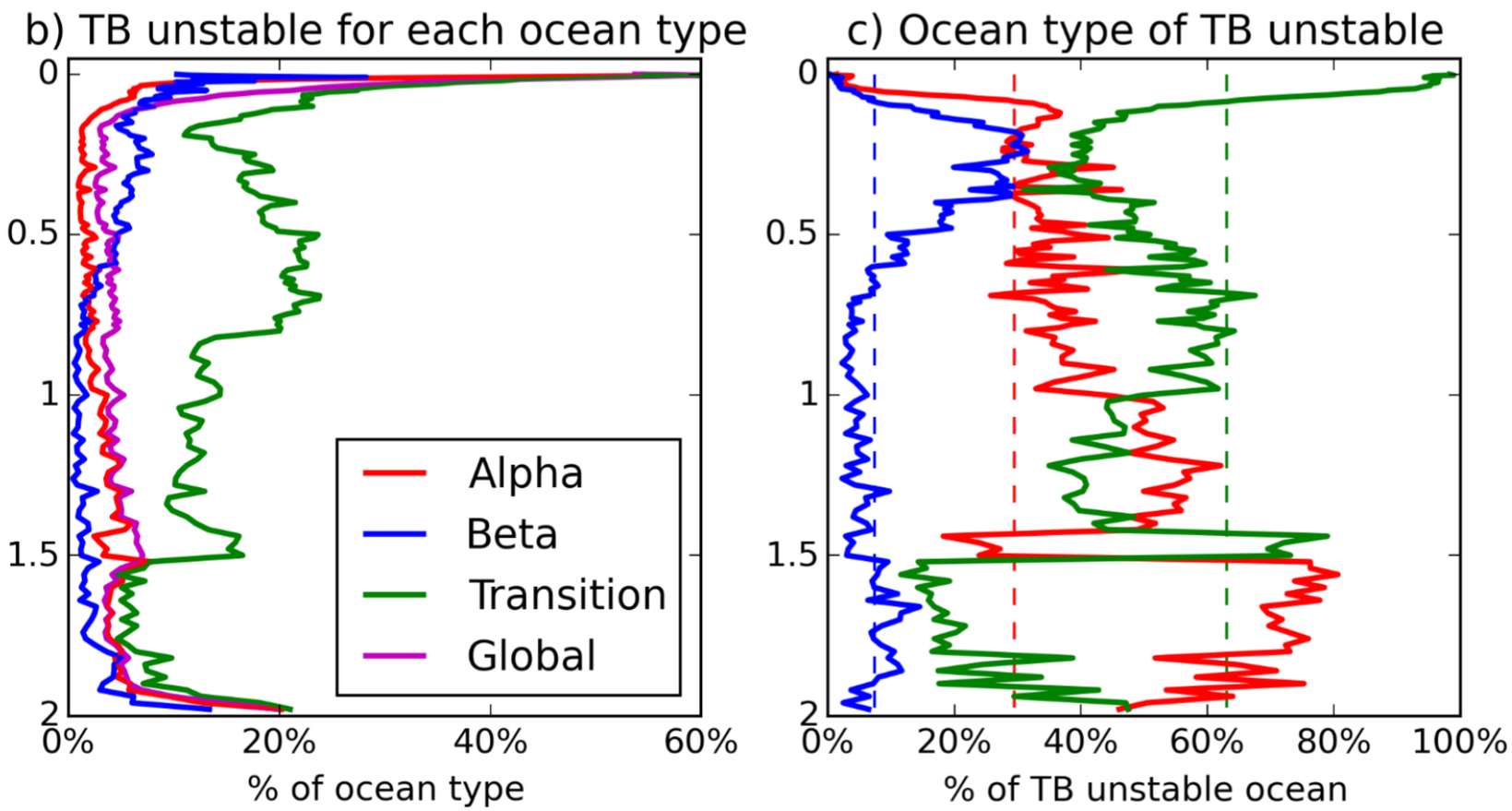
- Classification by dominant stratifying property into Alpha, Beta and Transition zone oceans
- Complicated spatial distribution with major intrusions
- TB instability occurs in 2 types with different spatial distributions
- Weakly stratified Transition zone oceans are ideal locations for sinking and vertical exchange, including TB instability (and cabbeling)

Outlook

- Surface Beta oceans are necessary for sea ice and ice albedo feedback
- Alpha, Beta and Transition zone oceans respond differently to change: Anthrop. heat/C stored at light (dense) levels in Alpha (Beta) ocean?
- How important is TB in SO?

K. D. Stewart and T. W. N. Haine, Thermobaricity in the transition zones between alpha and beta oceans, JPO, 2016, http://dx.doi.org/10.1175/JPO-D-16-0017.1

Vertical Profiles of Ocean Type



Static unstable: 2.3%

TB unstable: 5.7%

Alpha: 29.5%

Beta: 7.4%

Transition Zone: 63.0%

Global Data Analysis

- Ifremer product 2010–2013
- Global 0.3^{o} x 0.5^{o} (lat. x lon.)
- 152 vertical levels to 2000m (3–20m spacing)
- Predominantly Argo (below); uses ISAS for under-sampled regions