Improved vertical gradients in an ocean temperature and salinity climatology

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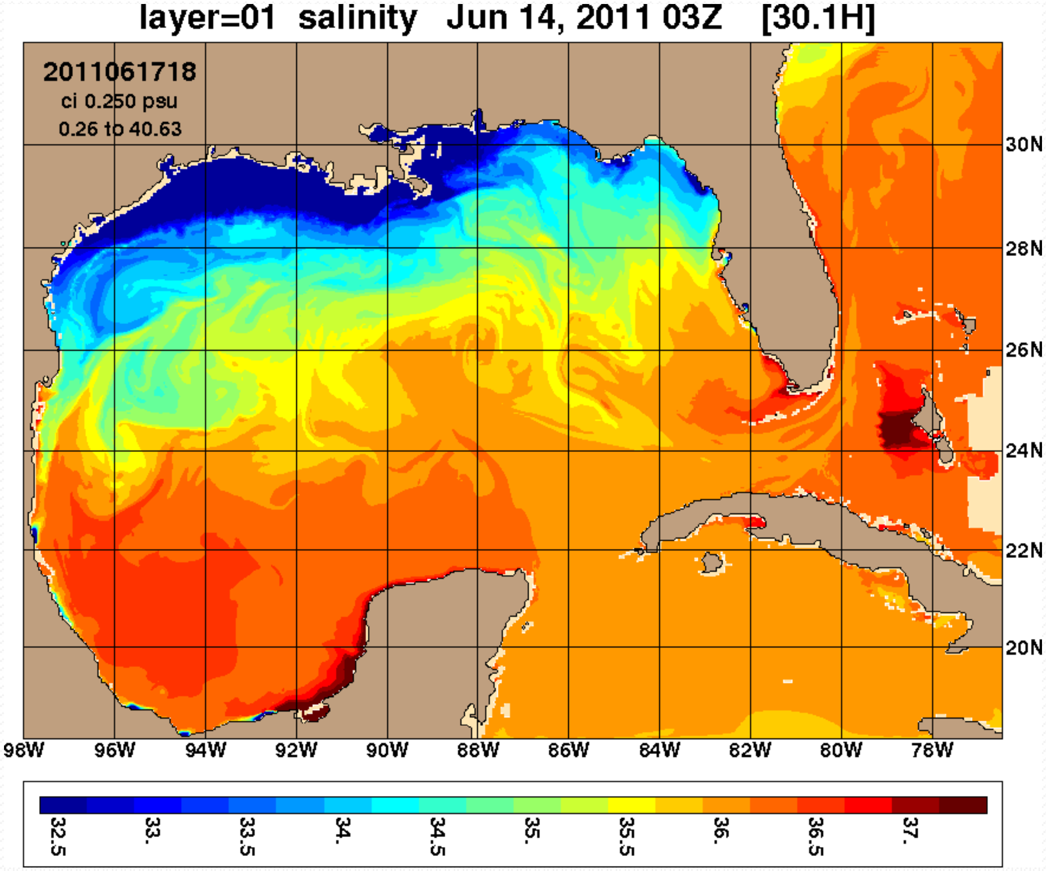
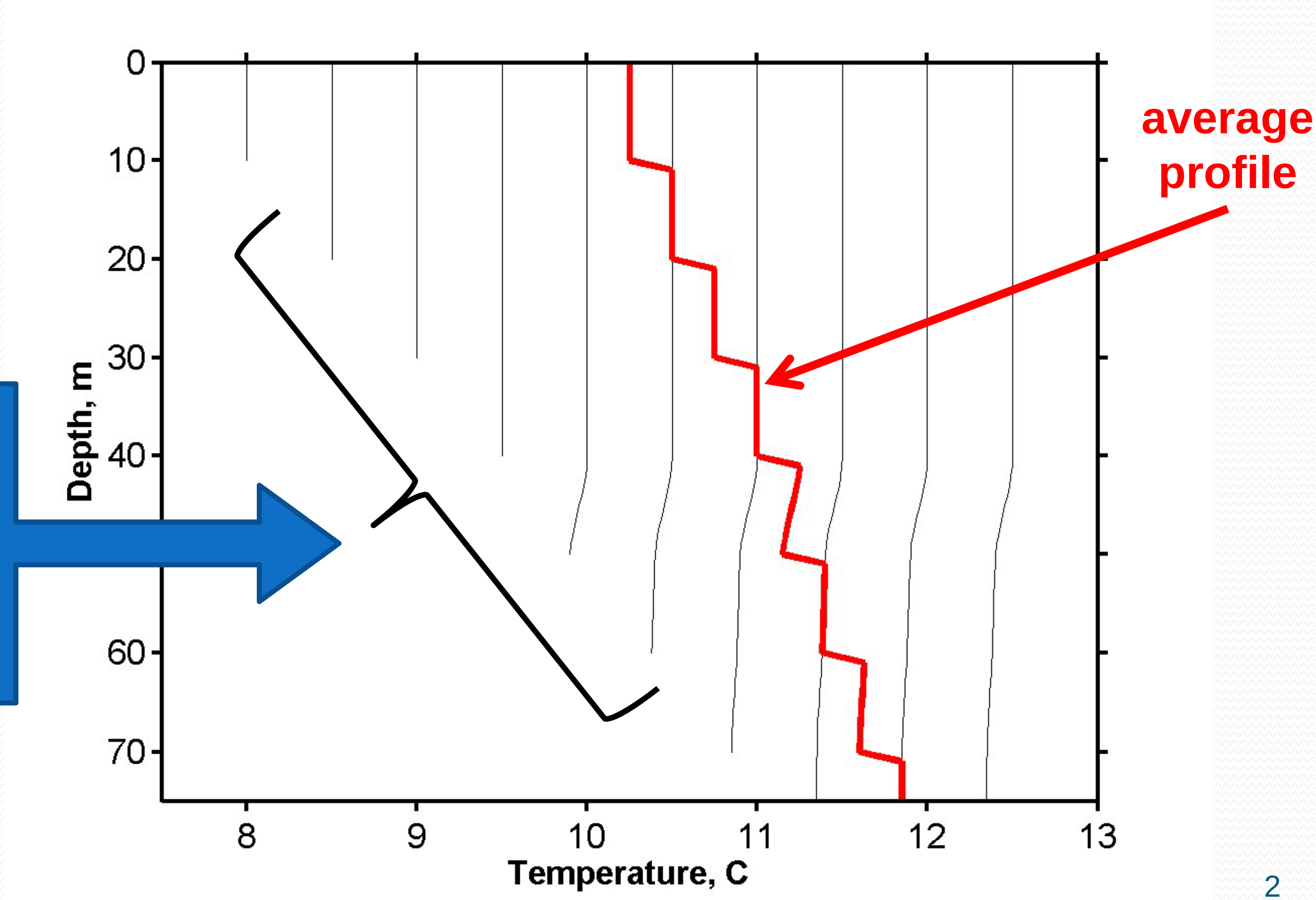
Generalized Digital Environmental Model (GDEM)



Vertical Gradient Issues

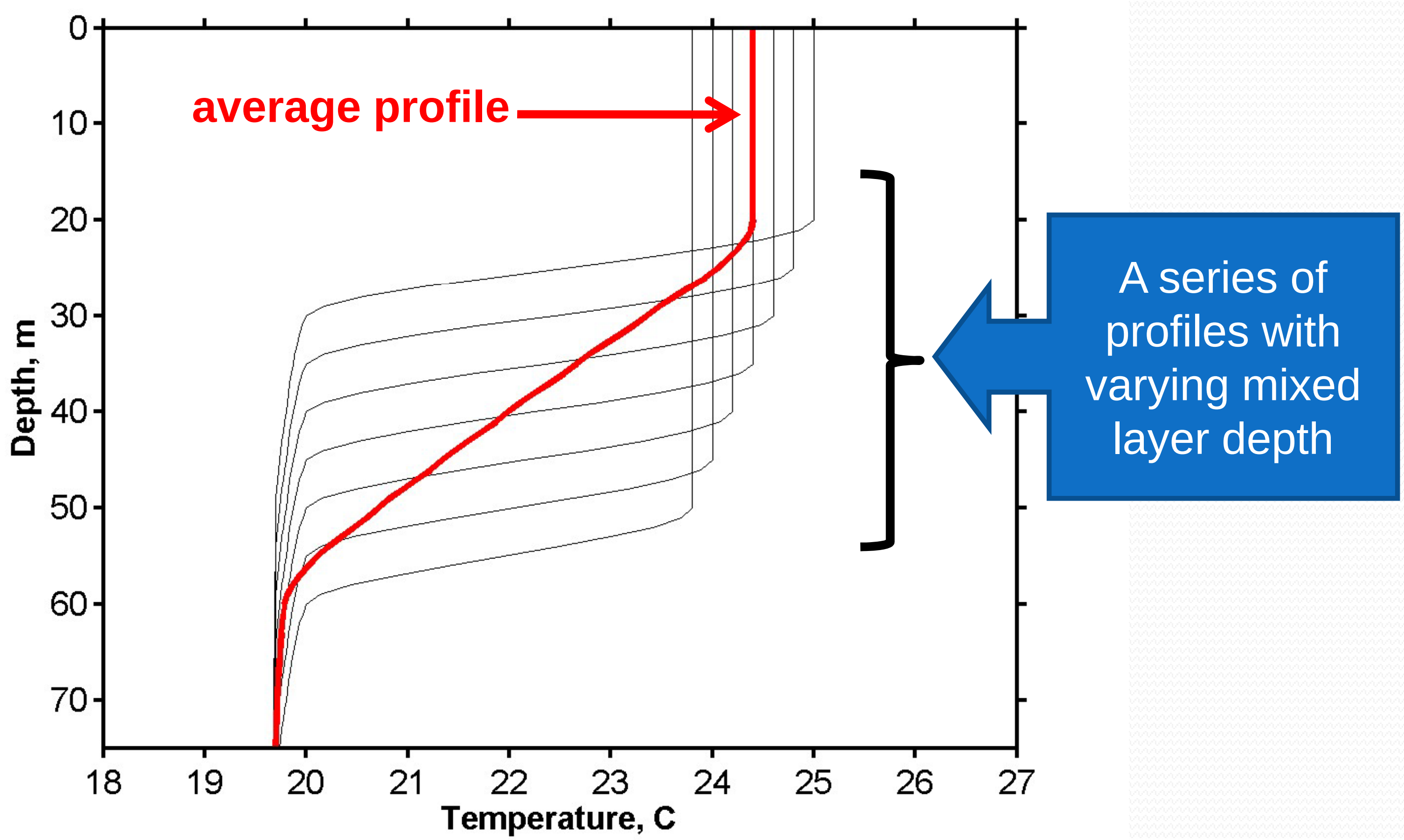
Case I: small observed gradients

a series of profiles with varying temperature and depth



Vertical Gradient Issues

Case II: large observed gradients

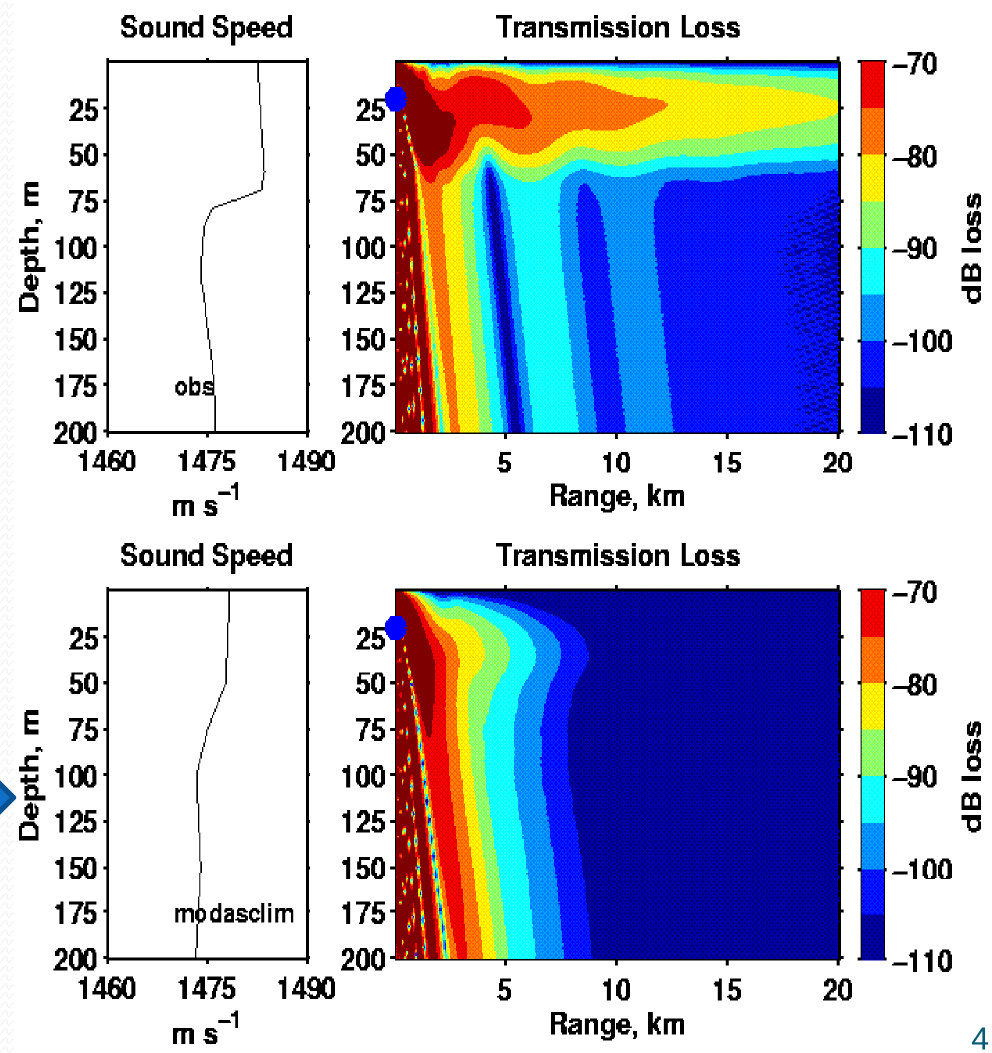


Vertical Gradient Issues

Vertical gradients are important for ocean acoustics.

Mixed layer is deep enough, acoustic energy is trapped in a surface duct.

Sonic layer missing, acoustic energy spreads spherically, giving short transmission ranges.



Presentation Outline

(1) Ocean observations (1.7 million XBTs)

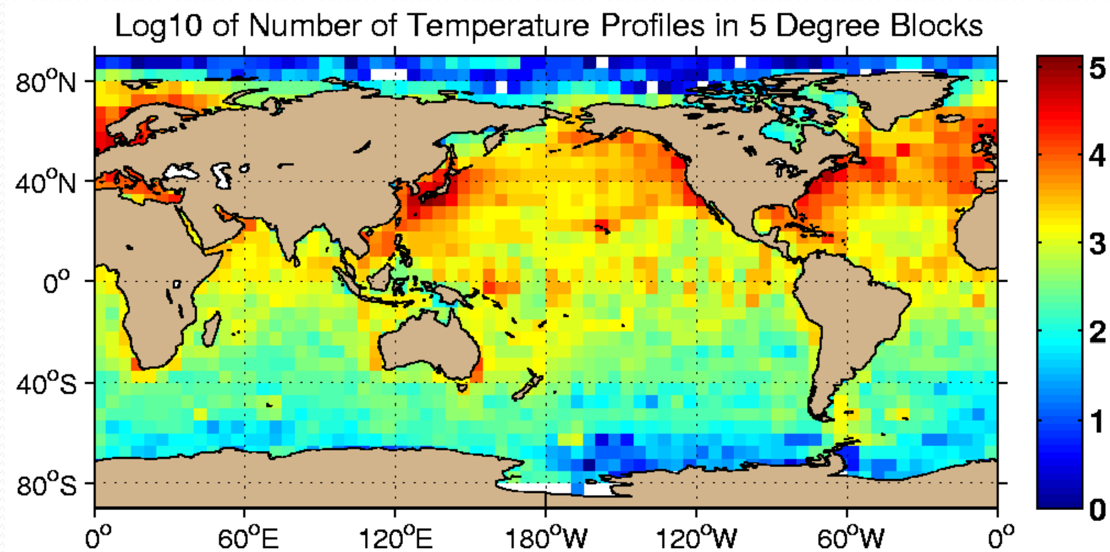
(2) XBTs are important

(3) Gridding techniques (vertical gradient constraints)

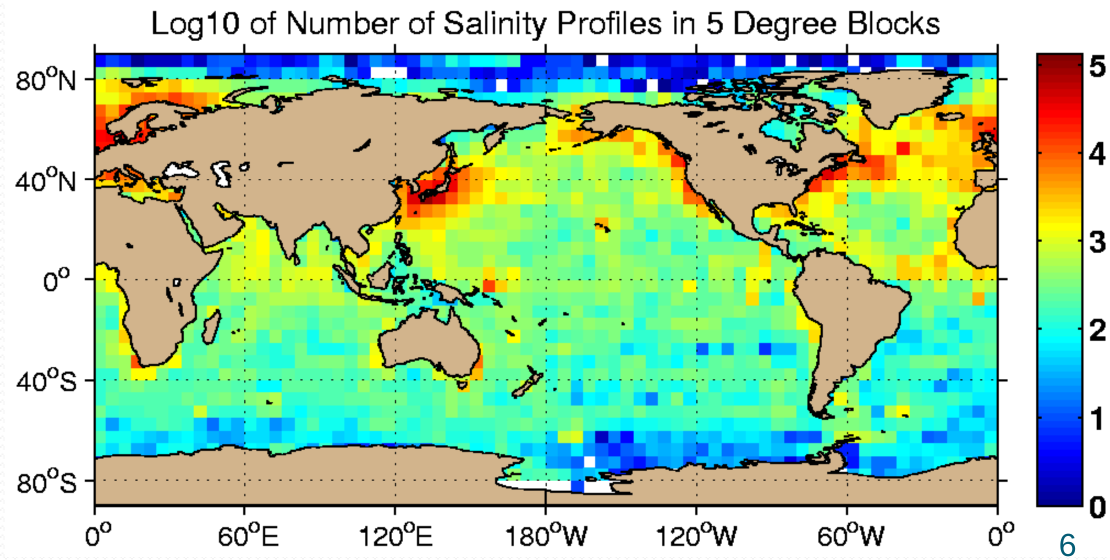
(4) Results: preservation of the observed vertical gradients of temperature and salinity

Observations

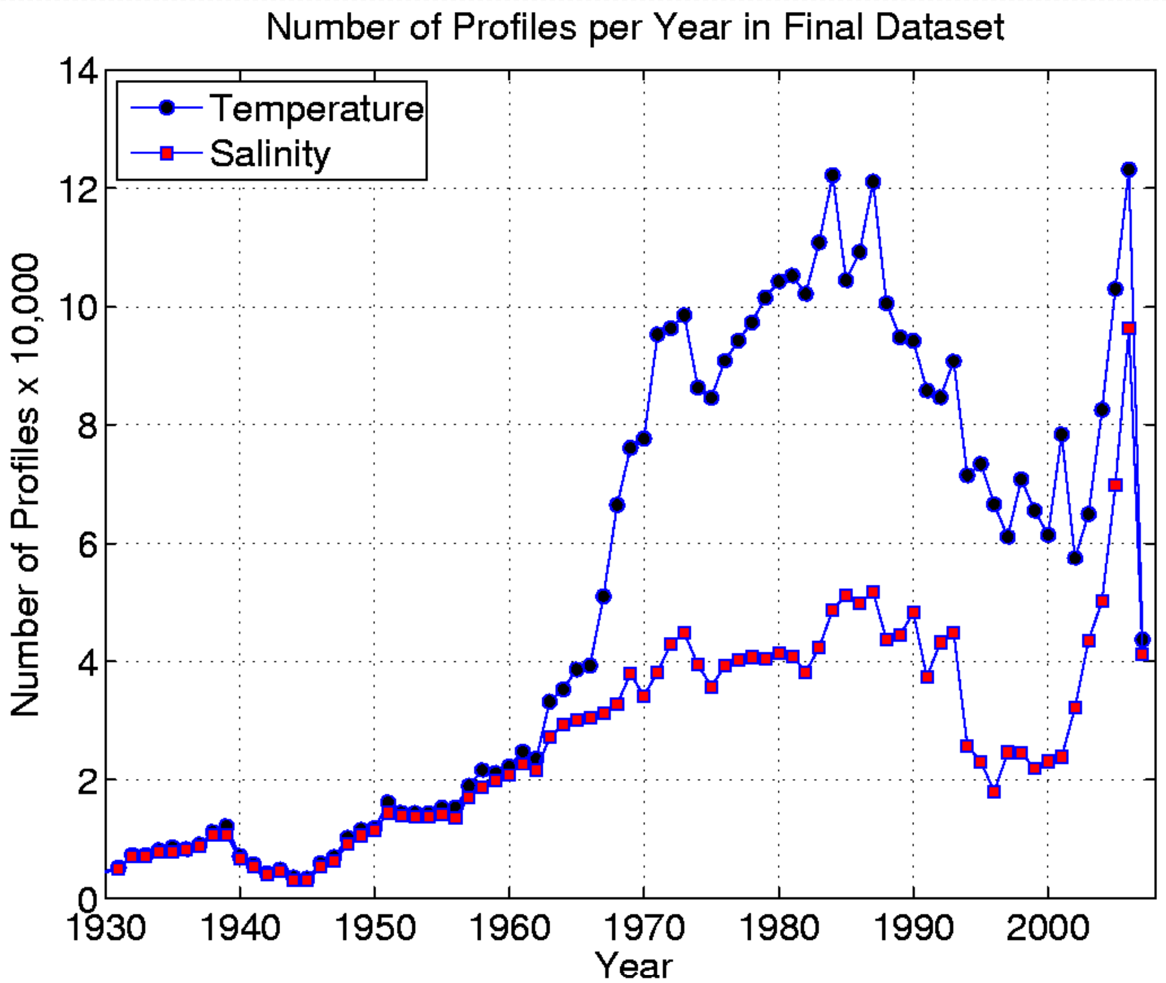
log(number) temperature profiles



log(number) salinity profiles



Observations



The number of observed temperature (blue circles) and salinity (red squares) profiles for each year starting in 1930. The last partial year is 2007 and extends only through October.

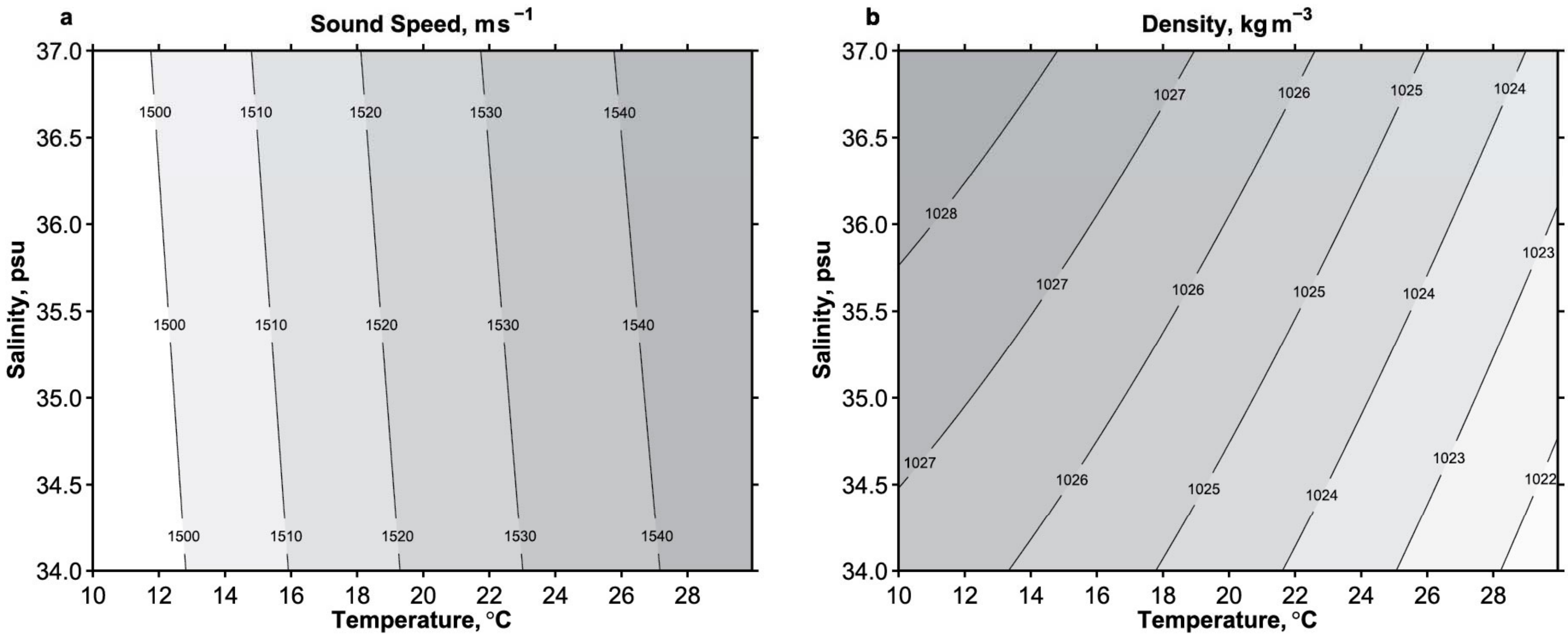
Observations

Sources: MOODS, WOD05, and Argo

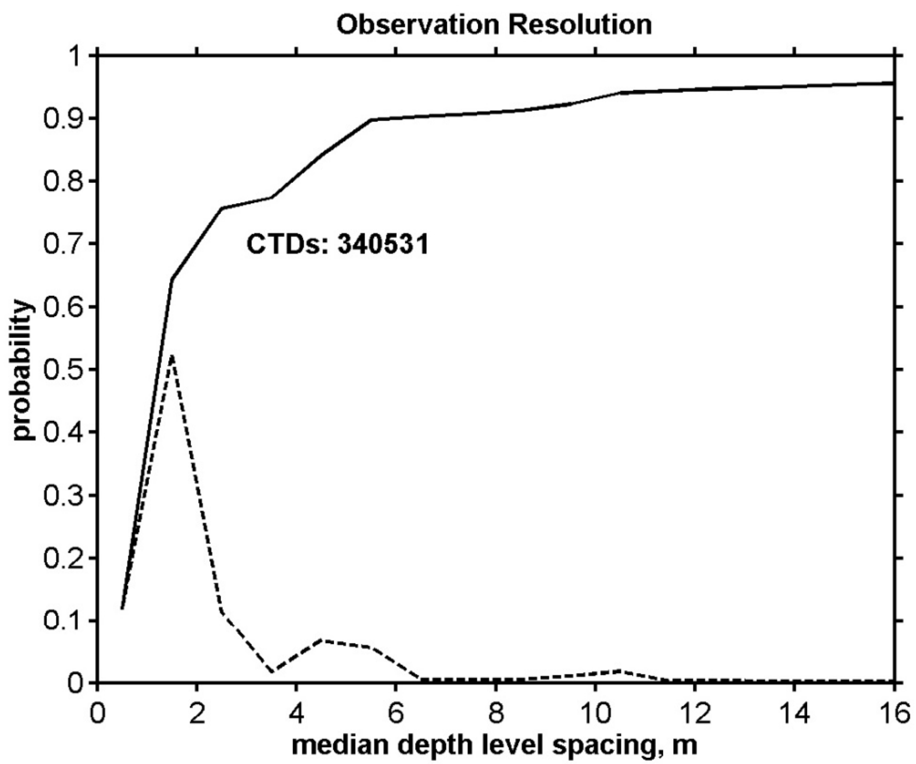
Data Type	Number of profiles
Raw Total	8,302,197
Editing	-3,621,099 (-2,237,379 MBTs removed)
Short profile in deep water	-268,644
Total remaining T	4,412,454 (approx. 1,742,000 XBTs)
Total remaining S	1,969,081

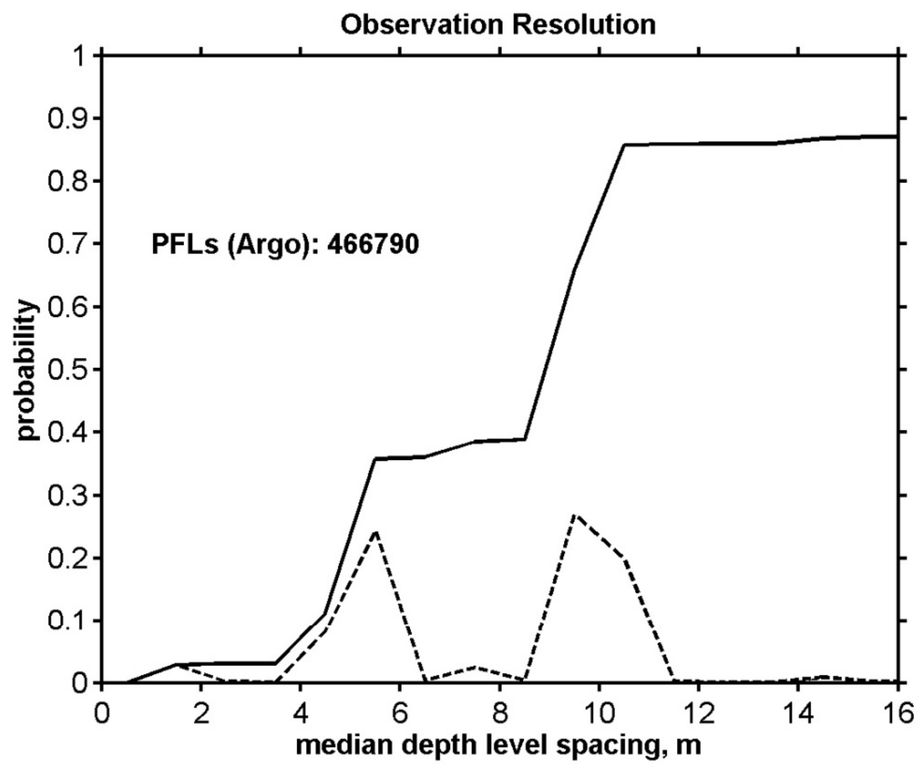
For the XBT drop rate corrections were applied to WOD05 data based on the secondary header # 54 as directed in the WOD05 database documentation (Johnson et al. 2006).

T: good proxy for sound speed

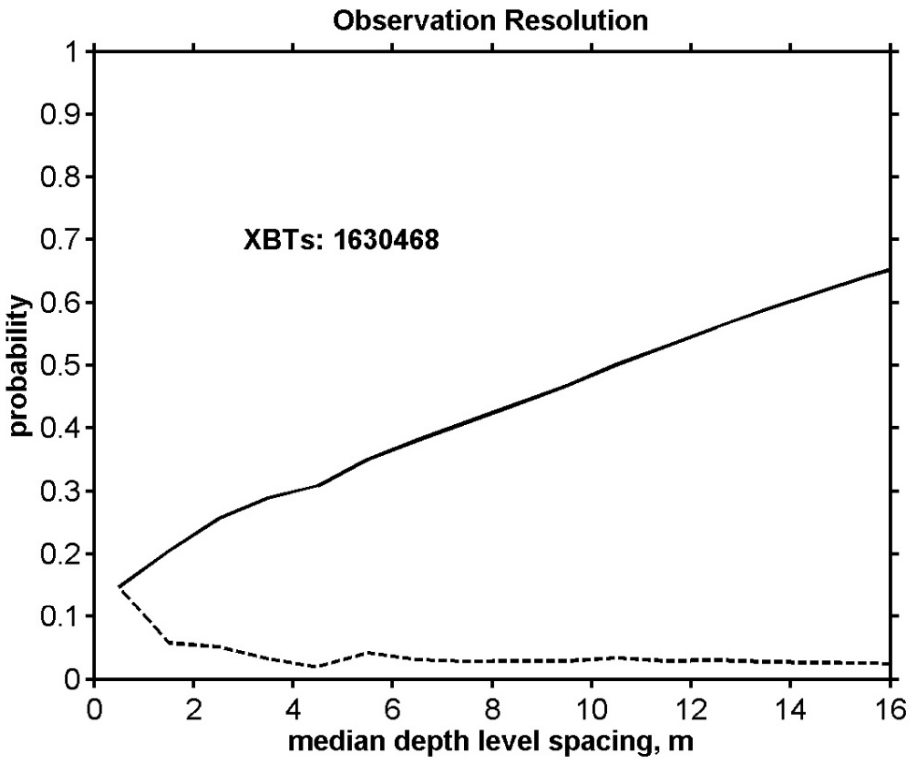


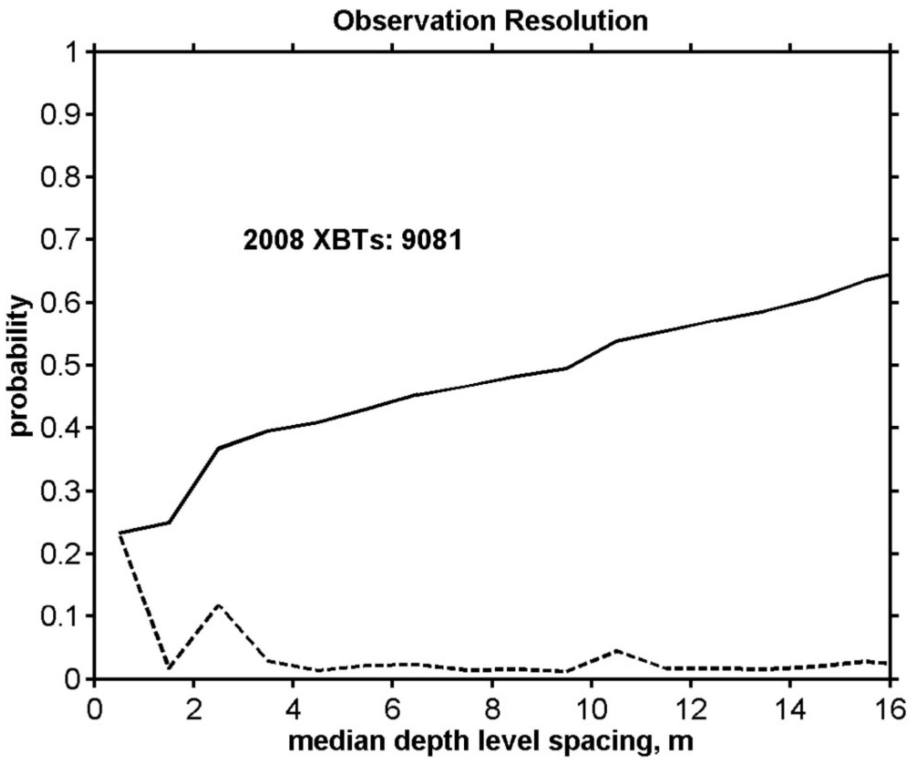
Vertical Resolution



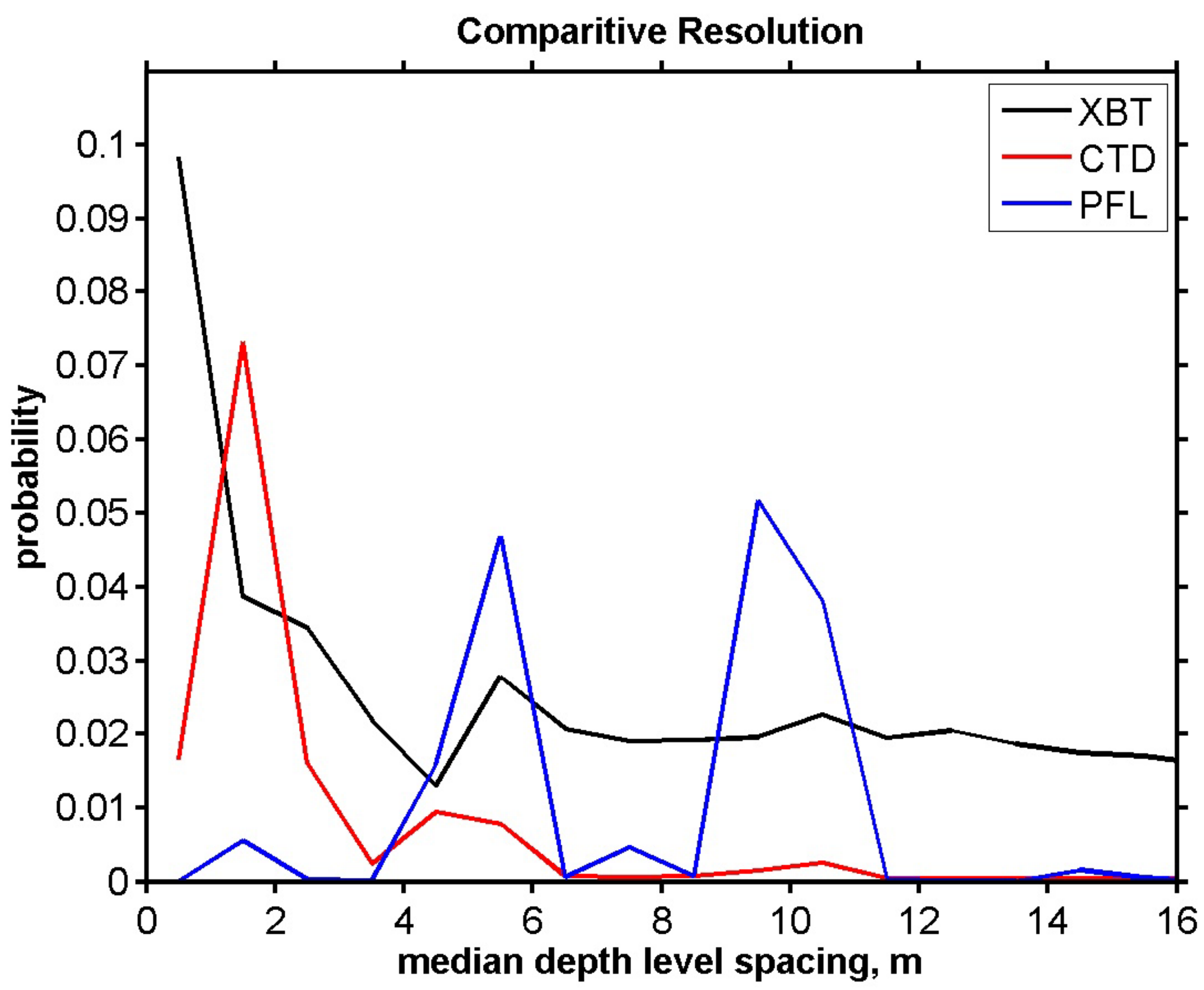


Vertical Resolution





Vertical Resolution



Horizontal Gridding, 1/4º

Cost function: minimize the squared slope and data misfit

$$J = \sum_m \sum_n \left\{ \left(\frac{T_{n+1,m} - T_{n,m}}{\Delta x} \right)^2 + \left(\frac{T_{n,m+1} - T_{n,m}}{\Delta y} \right)^2 + \sum_k \left(T_{m,n} - \theta_{m,n,k} \right)^2 \right\}$$

$T_{m,n}$	Field solution *T* or *S* being sought at grid points *m*, *n* that are not over land.
$\theta_{m,n,k}$	Data for each month are selected to be within 45 days of the center of the month.

- Zero-gradient boundary conditions were applied at land boundaries.

- Solution is system of Poisson diffusion equations solved using the Gauss-Seidel method.

Vertical Gradient Constraints

Minimize:

(1) different between analysis and observed vertical gradients

(2) difference between the original and corrected gridded profile:

$$J = \sum_{k=2}^{N} \left(\frac{\hat{T}_k - \hat{T}_{k-1} - D_k}{\delta_k} \right)^2 + \sum_{k=1}^{N} \left(\frac{\hat{T}_k - T_k}{\sigma_k} \right)^2$$

$\hat{T}_k, k = 1, N$ The *T* or *S* solution being sought

$T_k, k = 1, N$ The *T* or *S* from the 2D gridding

$D_k, k = 1, N$ The gridded *observed* vertical differences

The adjusted $\hat{T}$ or $\hat{S}$ is determined by the minimization of the cost function in a tri-diagonal system of N equations.

Vertical Stability Constraints

Potential temperature and density is referenced to pressure midway between layers.

$$\theta_{i-1} = \theta\left(S_{i-1}, T_{i-1}, p_{i-1}, pr\right)$$

$$\theta_i = \theta\left(S_i, T_i, p_i, pr\right)$$

$$\rho_{i-1} = \rho\left(S_{i-1}, \theta_{i-1}, pr\right)$$

$$\rho_i = \rho\left(S_i, \theta_i, pr\right)$$

$$N^2 = -\frac{g}{\left(\rho_{i-1} + \rho_i\right)/2} \frac{\left(\rho_i - \rho_{i-1}\right)}{\left(z_i - z_{i-1}\right)}$$

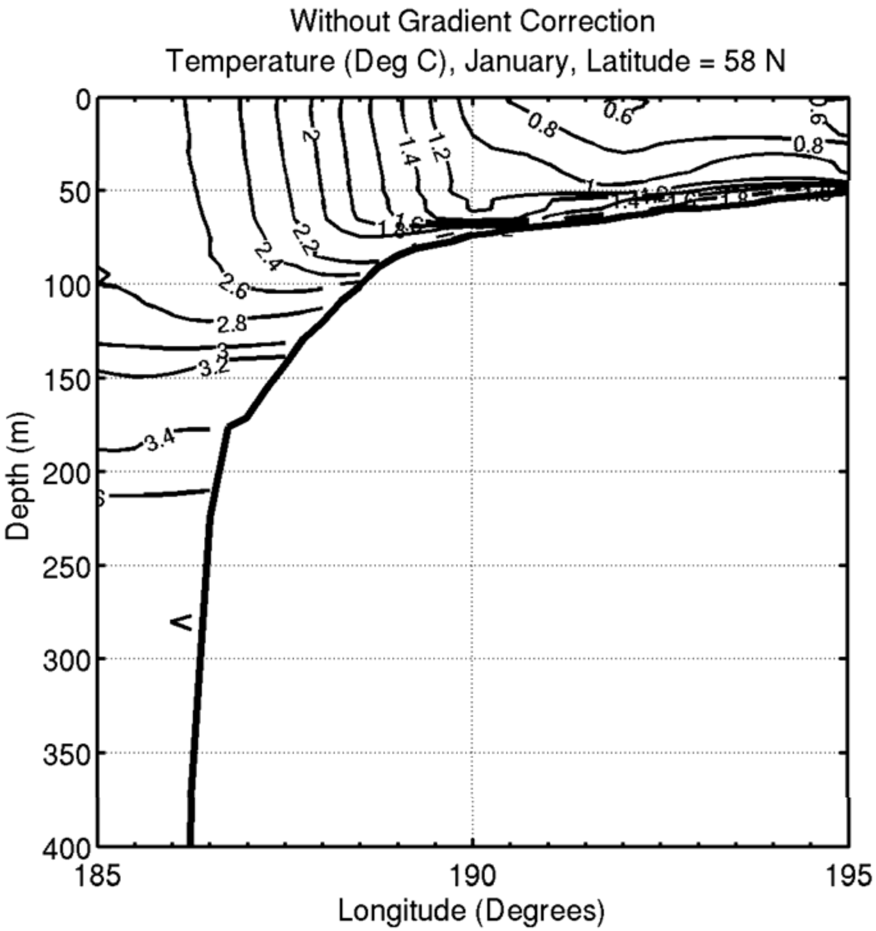
A stabilizing salinity difference is incrementally increase until:

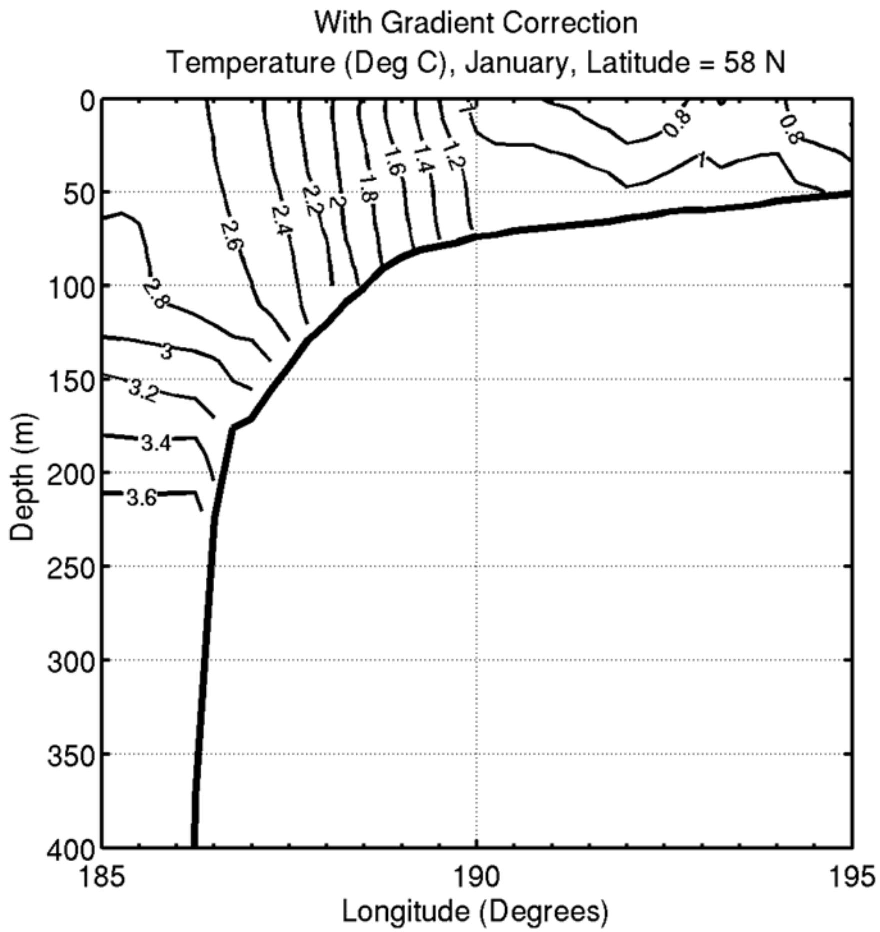
$$N^2 = 1.5x10^{-7} s^{-2}$$

Case I

Impact of vertical gradient constraint

Bering Sea shelf east of Bristol Bay along 58 N





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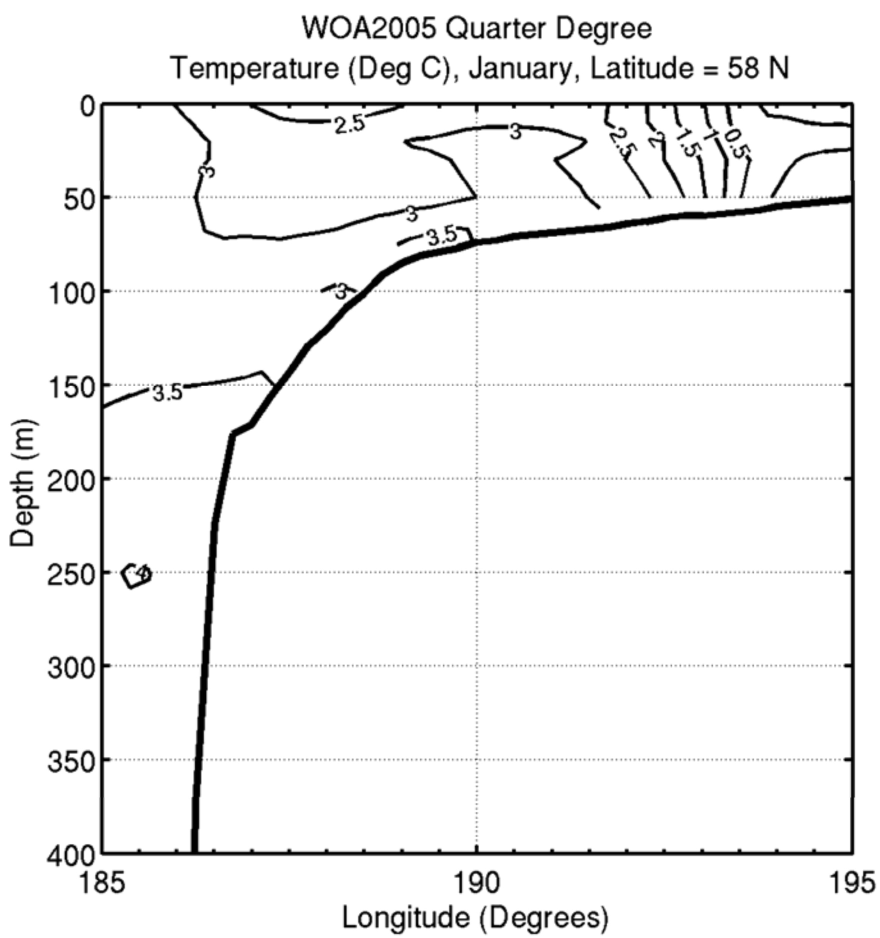
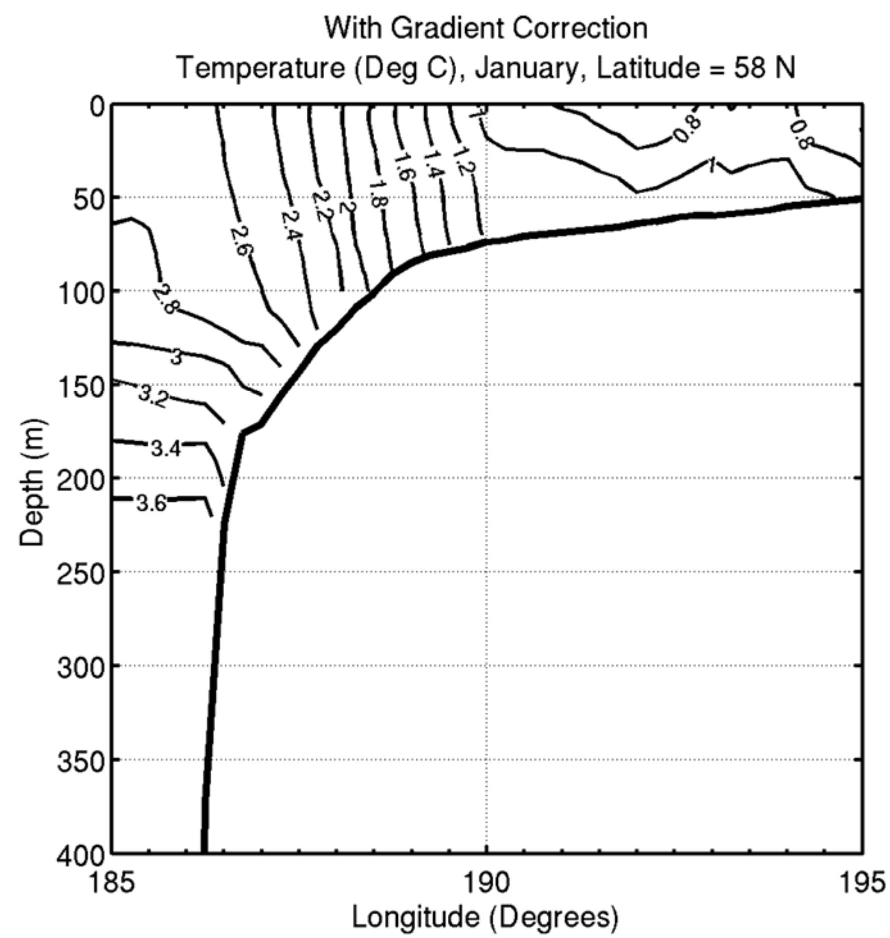
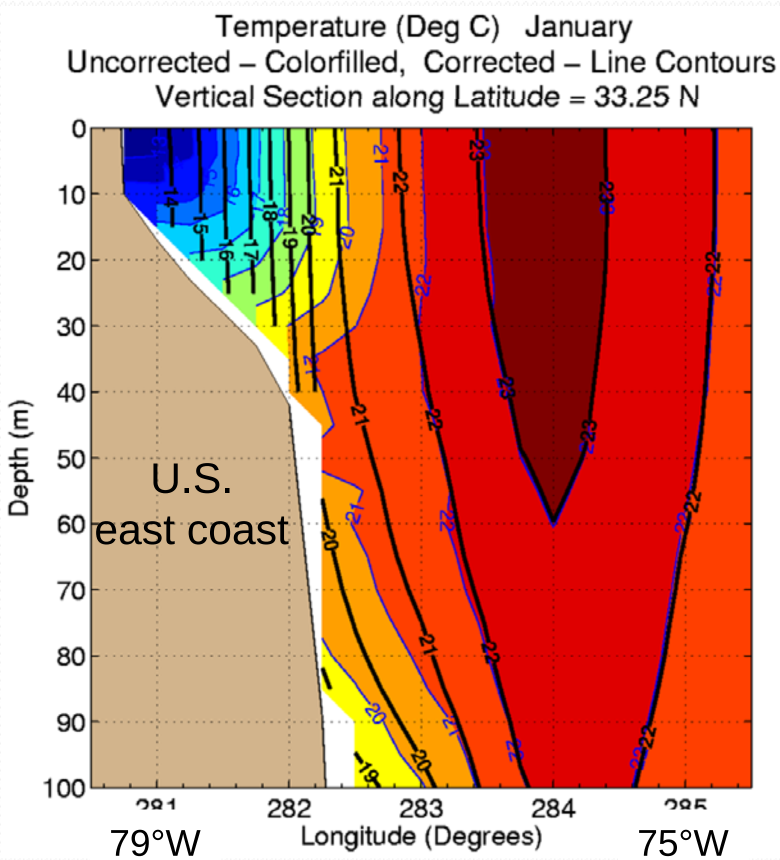




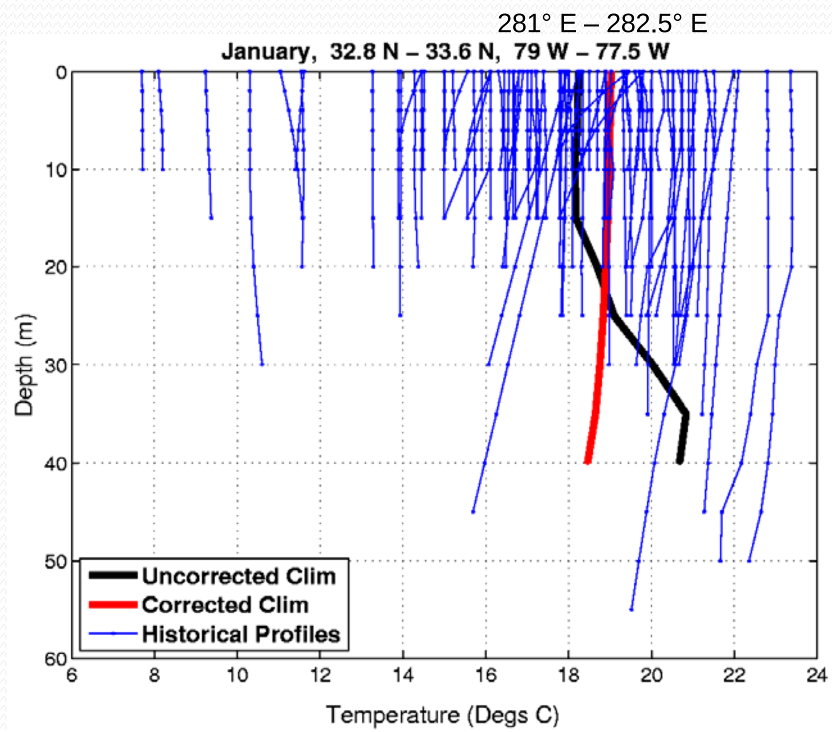
Case I

Impact of vertical gradient constraint

Before (Colorfilled) and
After (Black Line Contours)
Vertical Gradient Correction



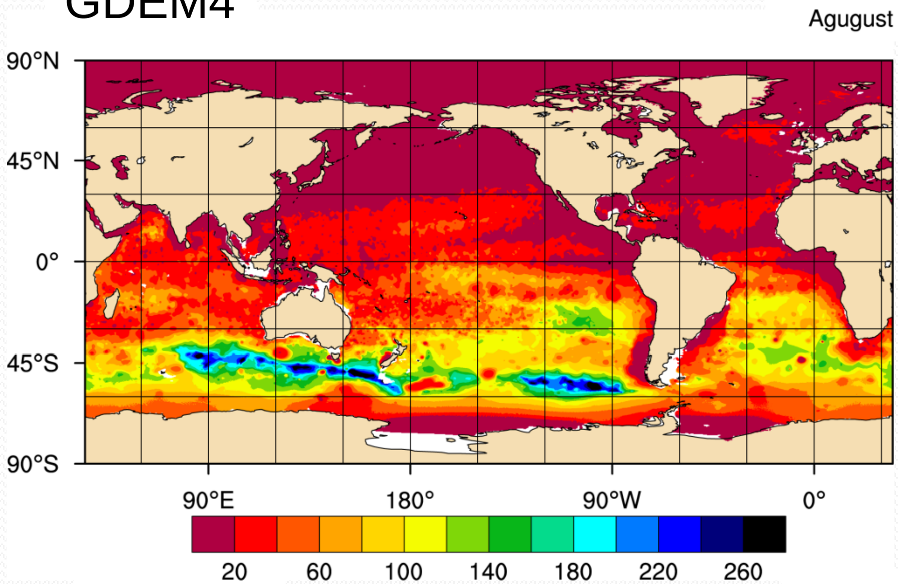
Uncorrected and **corrected**
mean temperature profiles
computed from local **observations**.



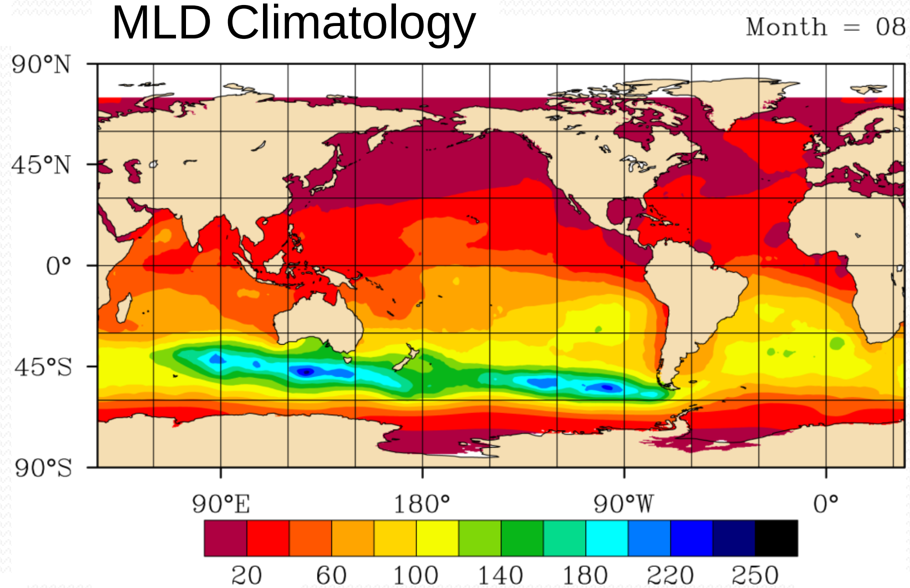
Case II

August MLD

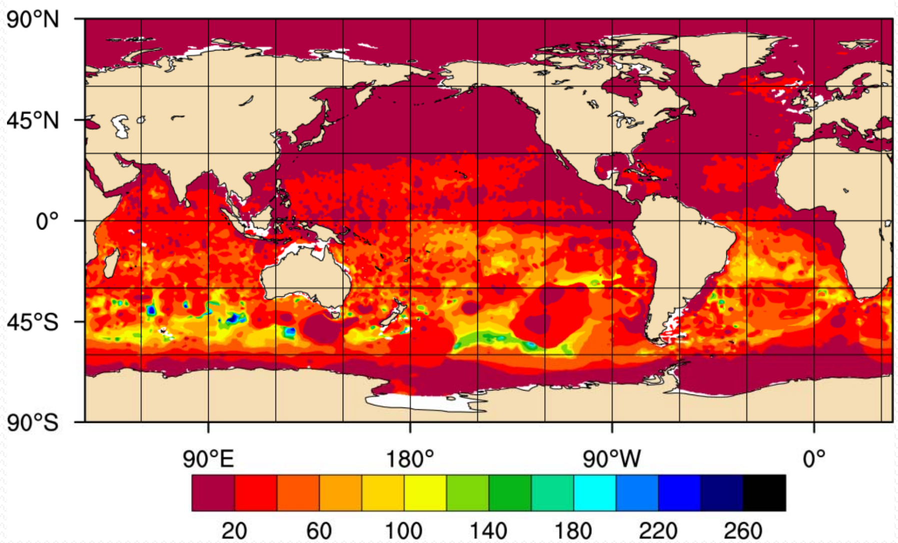
GDEM4



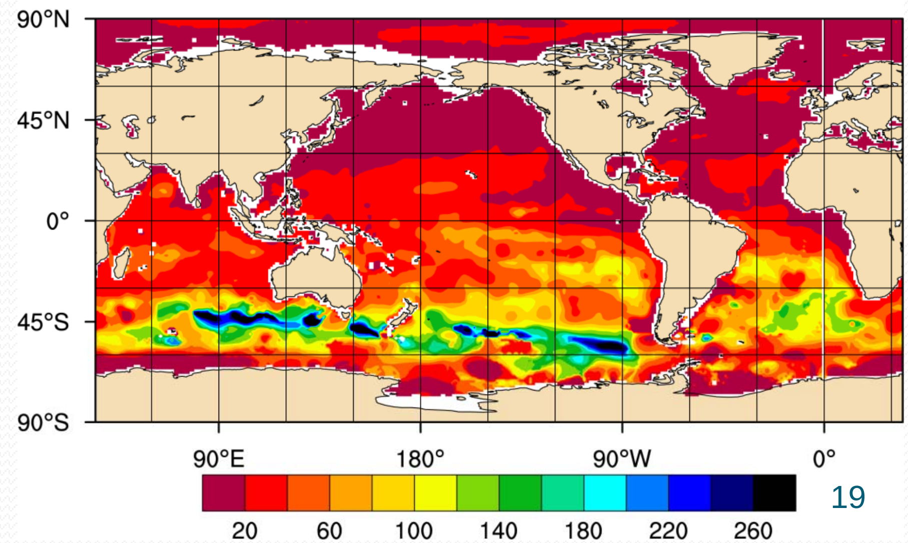
MLD Climatology



GDEM3

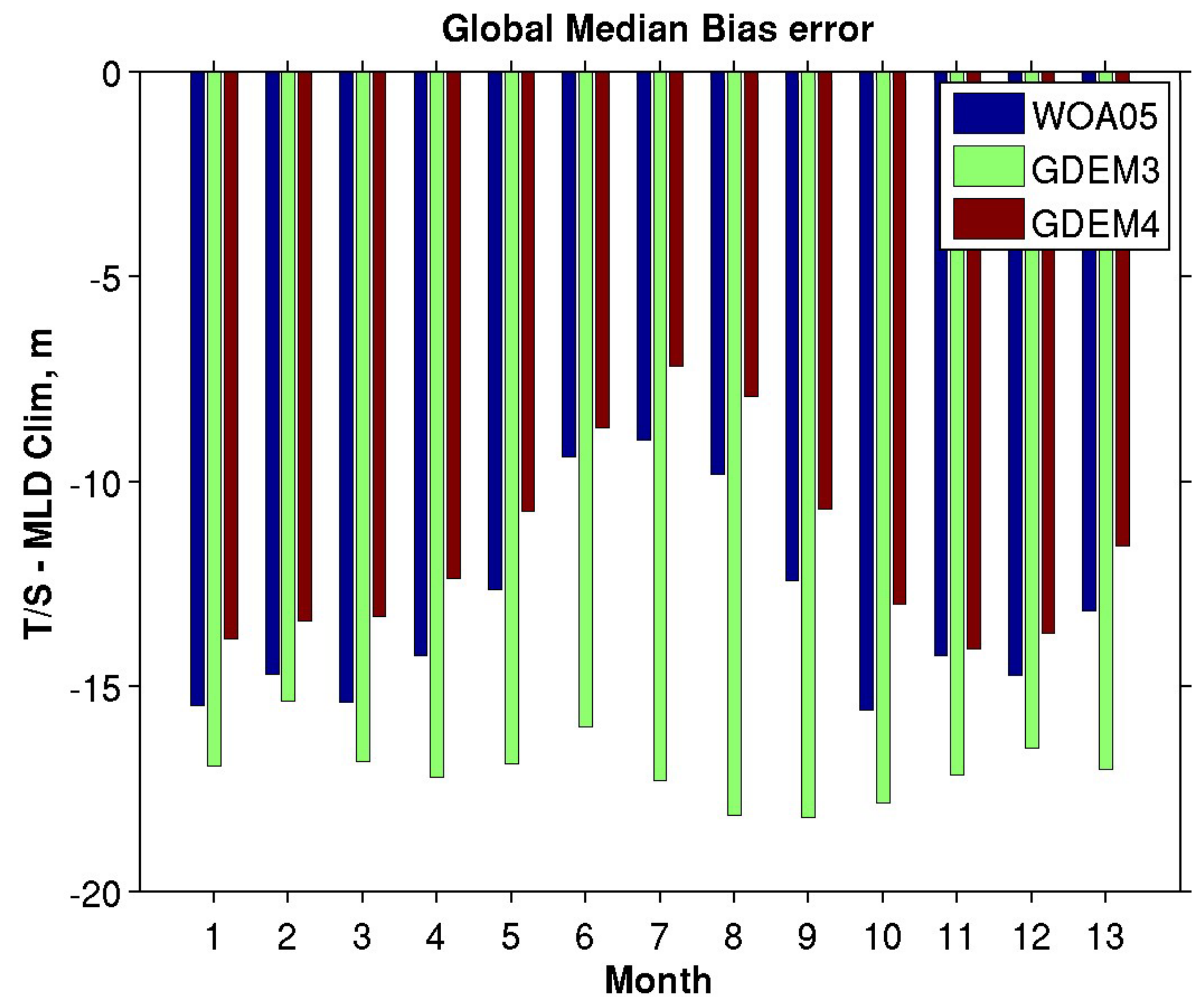


WOA05



Case II

MLD Bias Error



Conclusions

- XBTs provide vertical gradients for acoustic applications.
- Vertical gradient constraints correct for:

  Case I: small observed gradients
  Sampling irregularities near shelf breaks

  Case II: large observed gradients
  small improvement on mixed layer depth representation

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