Inferring Advective Timescales and Overturning Pathways of the Deep Western Boundary Current in the North Atlantic through Labrador Sea Water Advection

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Introduction

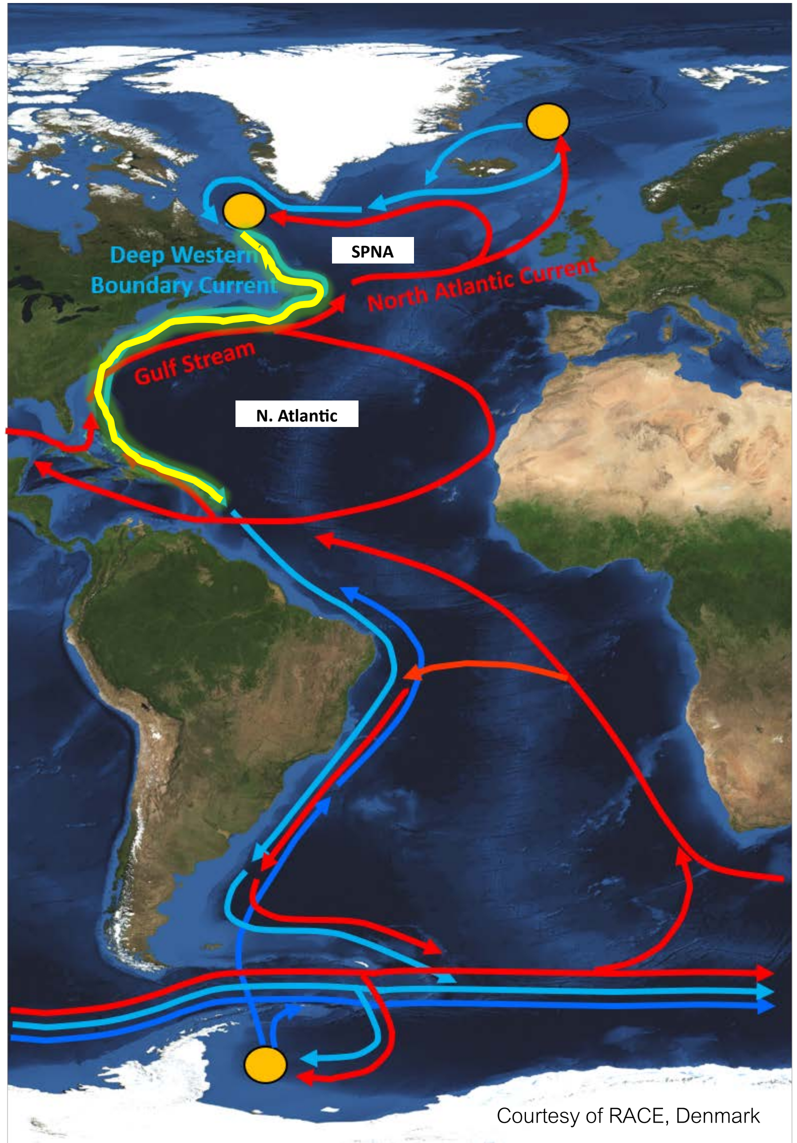
The Deep Western Boundary Current:

- Major transporter of newly formed North Atlantic deep water; driving force of AMOC
- Monitored through observing platforms and repeat hydrographic endeavors along the North Atlantic for current transport and variability

Deep waters formed in the SPNA are of special importance, can be used as advective tracers due to known watermass properties

- Advection timescales + spreading pathways in the North Atlantic are uncertain
  - General circulation models estimate **~4 years** from SPNA to Tropics[1]
  - Advective tracer studies estimate **~8-10 years**[1,3] to 26.5N, **~20 years** to equator[2]

In this study, we characterize DWBC advection by tracking Labrador Sea Water convective signals to the Tropical Atlantic via their unique T/S/density signatures



Courtesy of RACE, Denmark

[1] van Sebille et al. (2011); [2] Fine et al. (2002), [3] Molinari et al. (1998)

Methodology

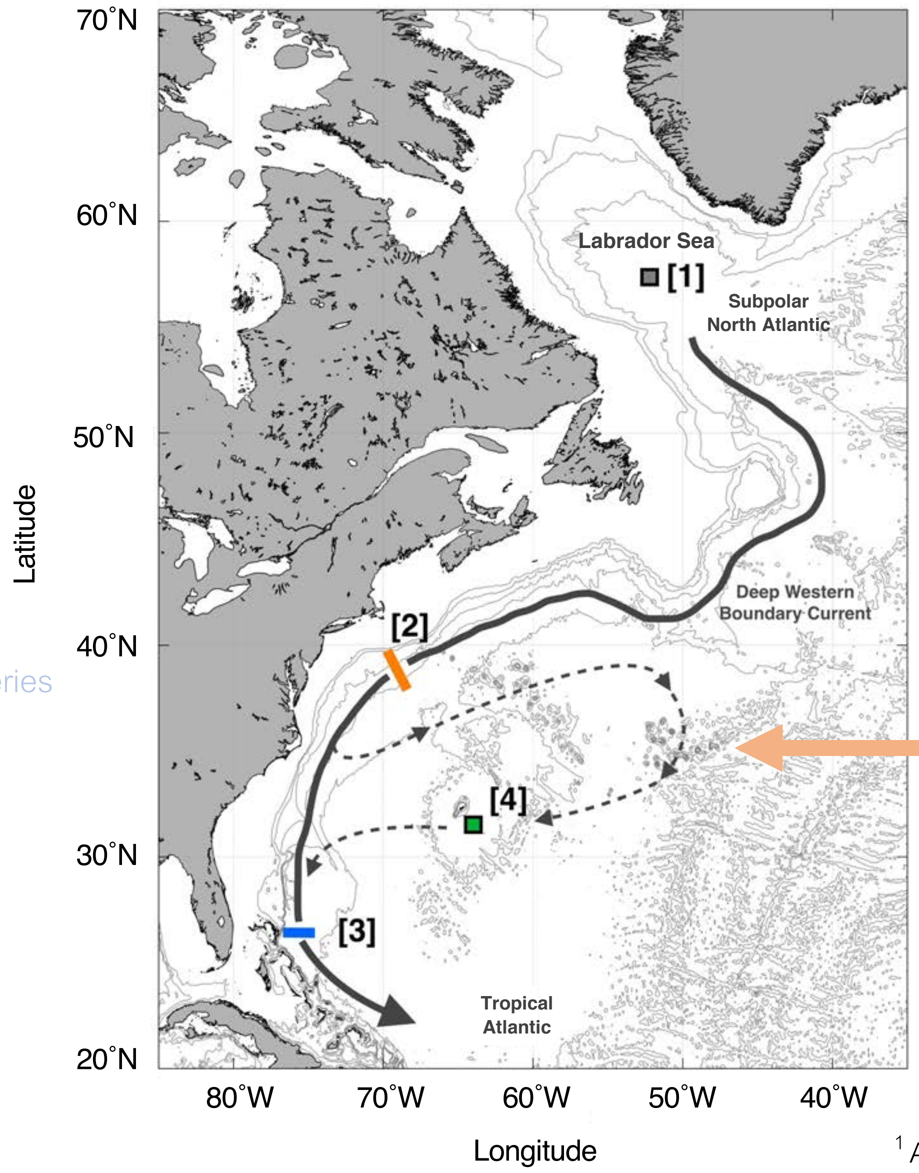
4 Hydrographic Locations:

[1] **Labrador Sea**
AR07W + Argo

[2] **Line W**
WHOI

[3] **Abaco**
NOAA 26.5N Western Boundary Time Series

[4] **Bermuda**
BIOS BATS + Hydrostation S



Goals:

1) To determine updated advective timescales of the DWBC throughout the N. Atlantic via passage of LSW convective signals

2) Gain insight to hypothesized alternative-advective pathways[1,2,3] via hydrography

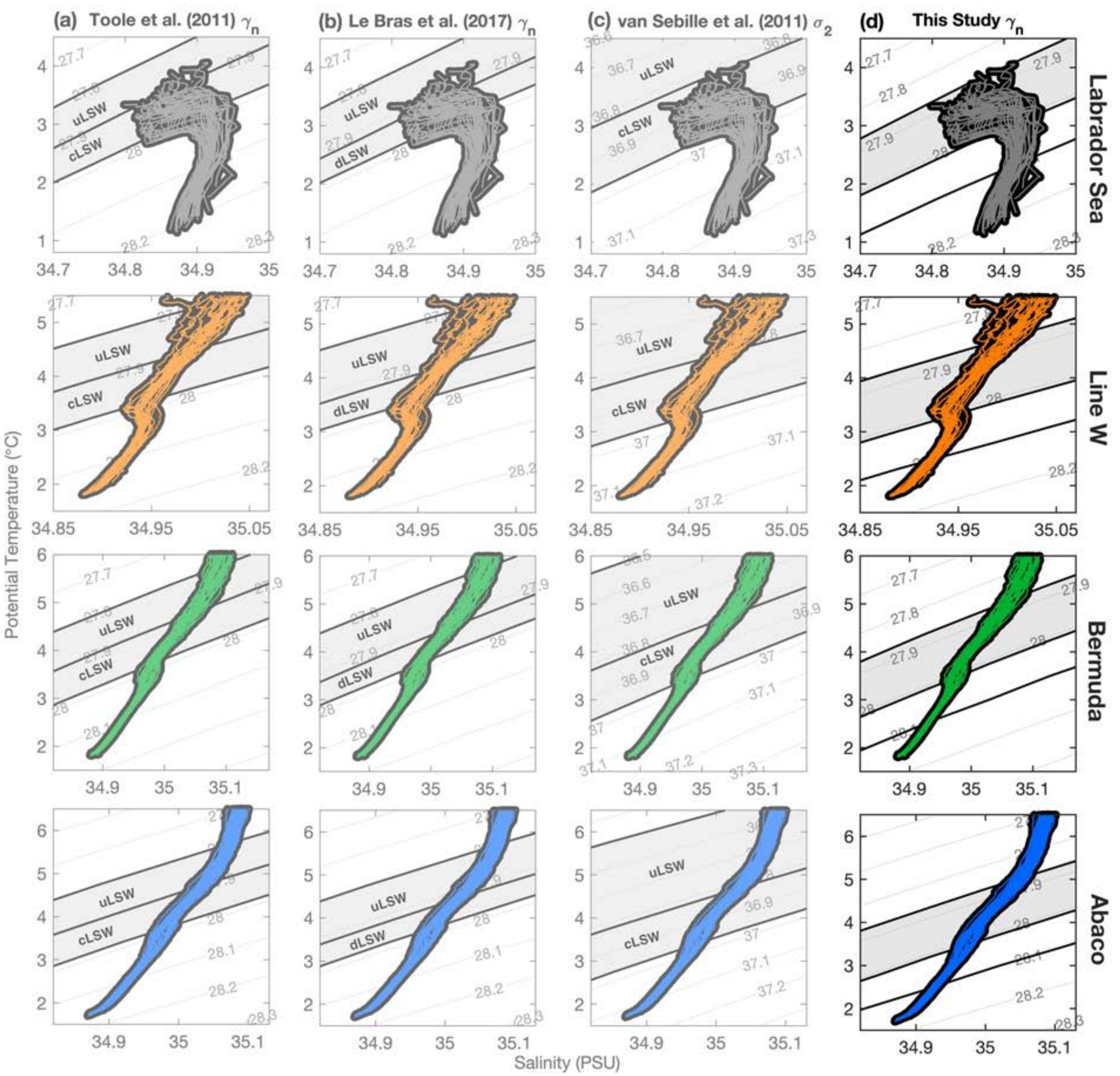
[1] Andres et al. (2018); [2] Bilo and Johns (2019); [3] Bower et al. (2019)

Methodology – LSW Classification

Methods of LSW classification:

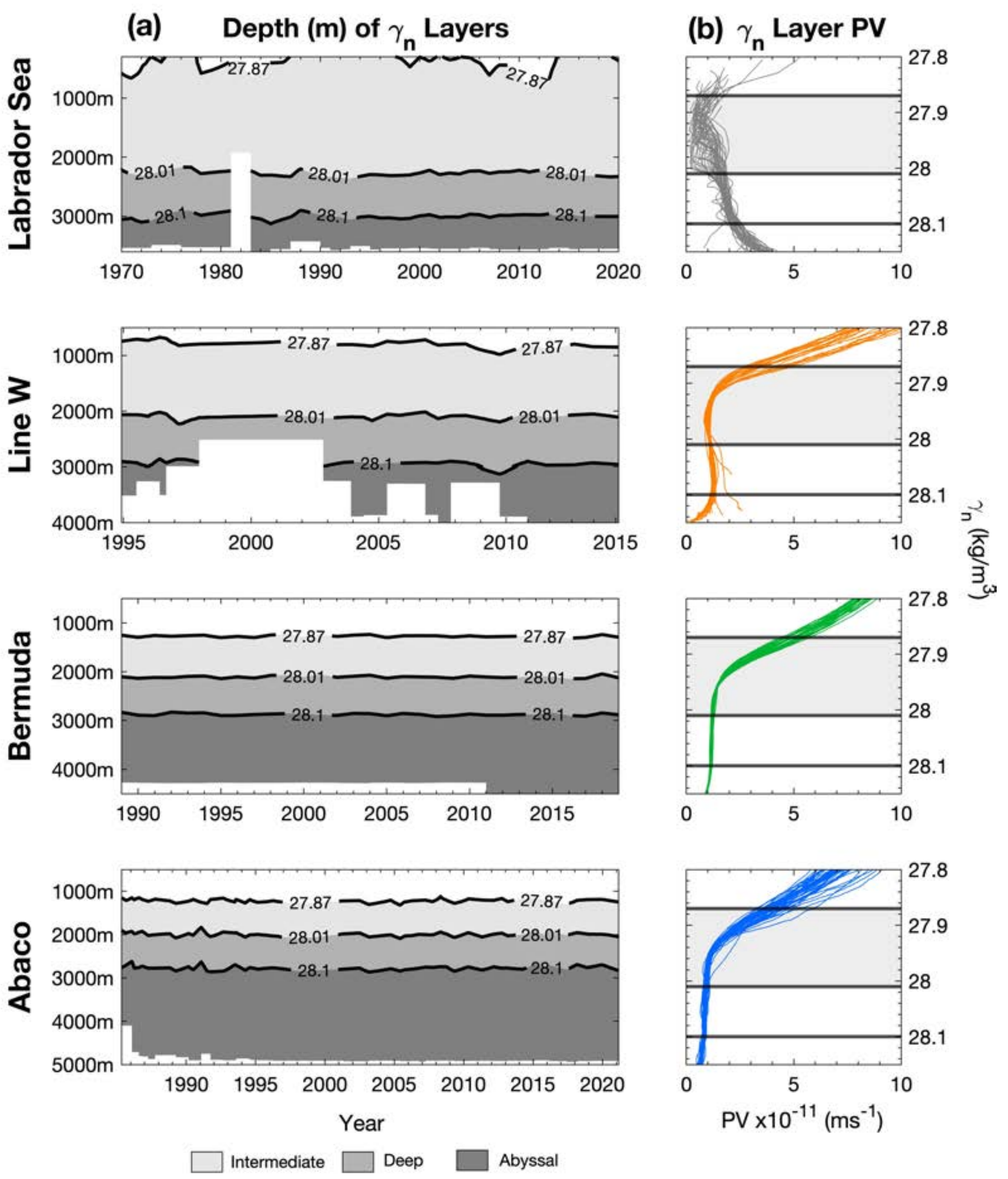
- Potential Density (σ_0, σ_1, $\sigma_{1.5}$, σ_2) space [1,2,3]
- Neutral Density (γ_n) space [4,5]
- Depth space [6]
- Static/layer definitions
  - "Classical" LSW (cLSW) [2,3]
  - "Upper" and "Deep" LSW (uLSW, dLSW) [3,4,5]
- Identification of convective classes [1]
  - i.e. $LSW_{1987\text{-}1994}$ [1]

Previous definitions are inconsistent across geographical locations, and do not work interchangeably for a large-scale basin analysis as such.



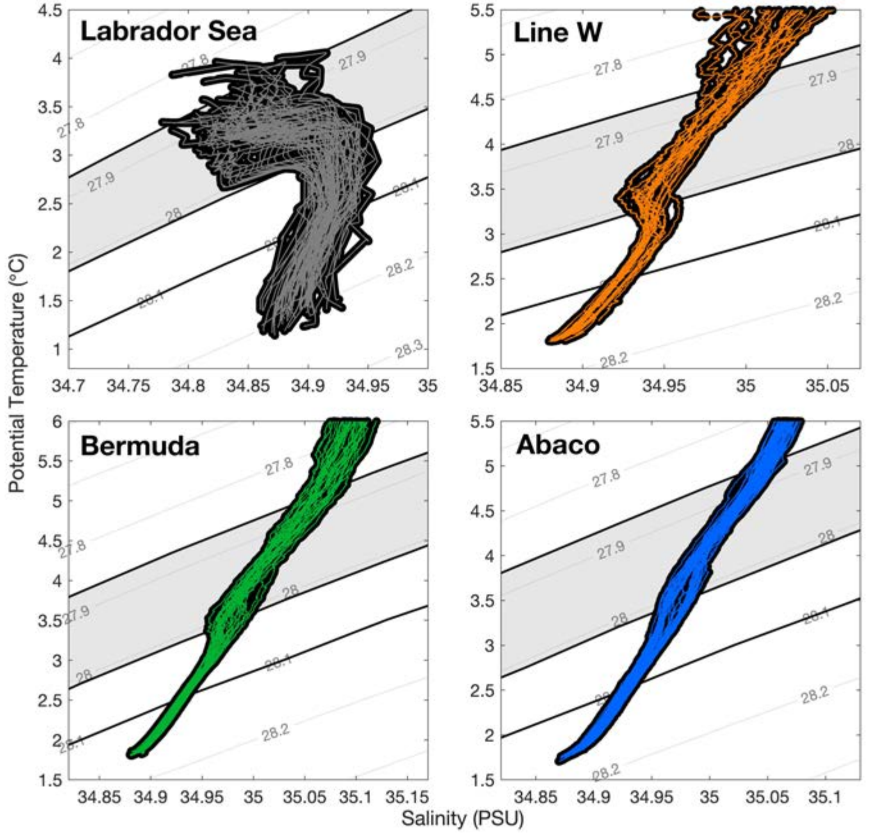
[1] Yashayaev (2007); [2] Molinari et al. (1998); [3] van Sebille et al. (2011); [4] Toole et al. (2011); [5] Le Bras et al. (2017); [6] Fine and Molinari (1988)

Methodology – LSW Classification



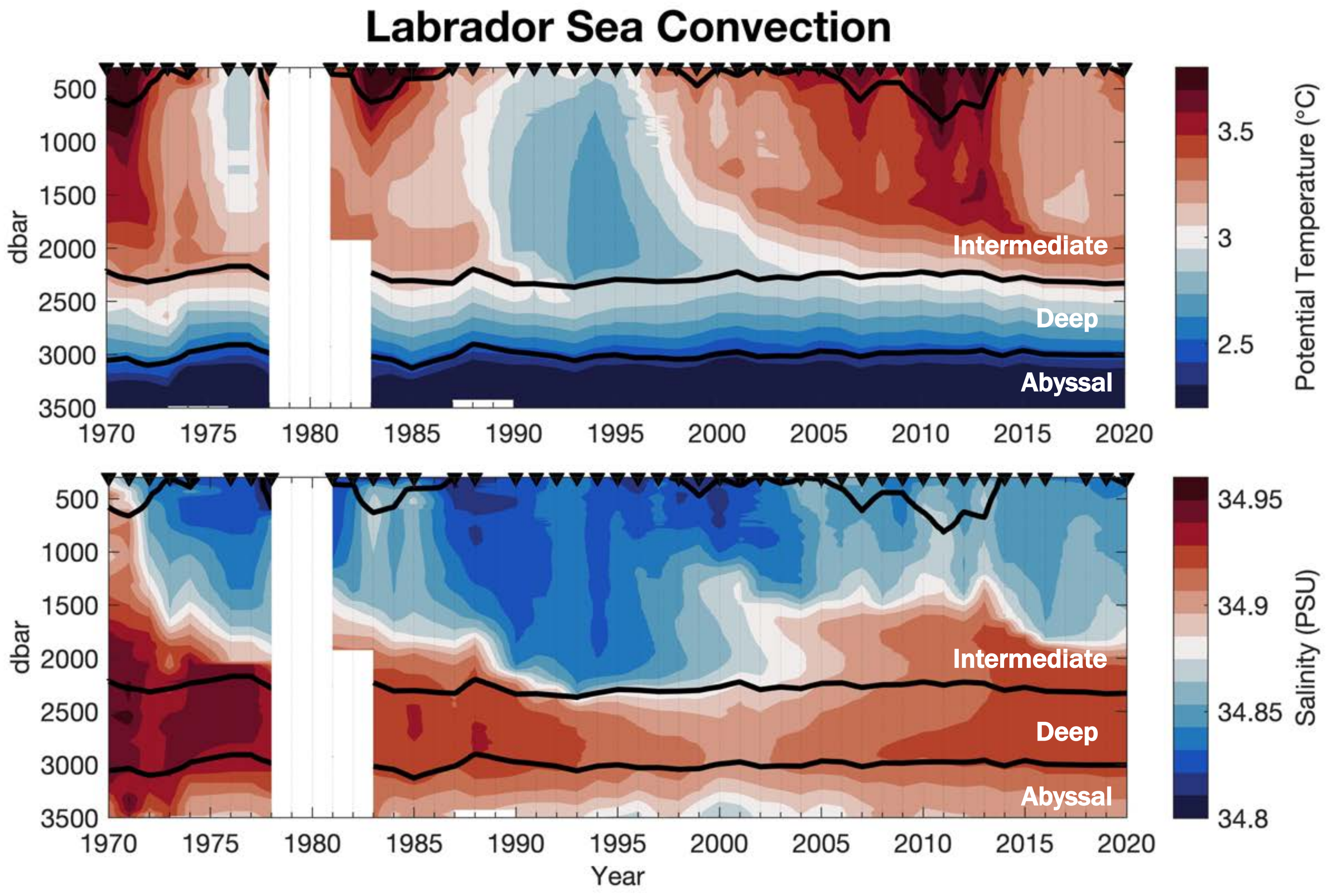
Neutral Density (kg/m³) Layer Definitions:

<u>**Intermediate**</u>	γ_n = 27.87 – 28.01
Deep	γ_n = 28.01 – 28.10
Abyssal	γ_n = > 28.10



Chomiak et al., in prep

Methodology

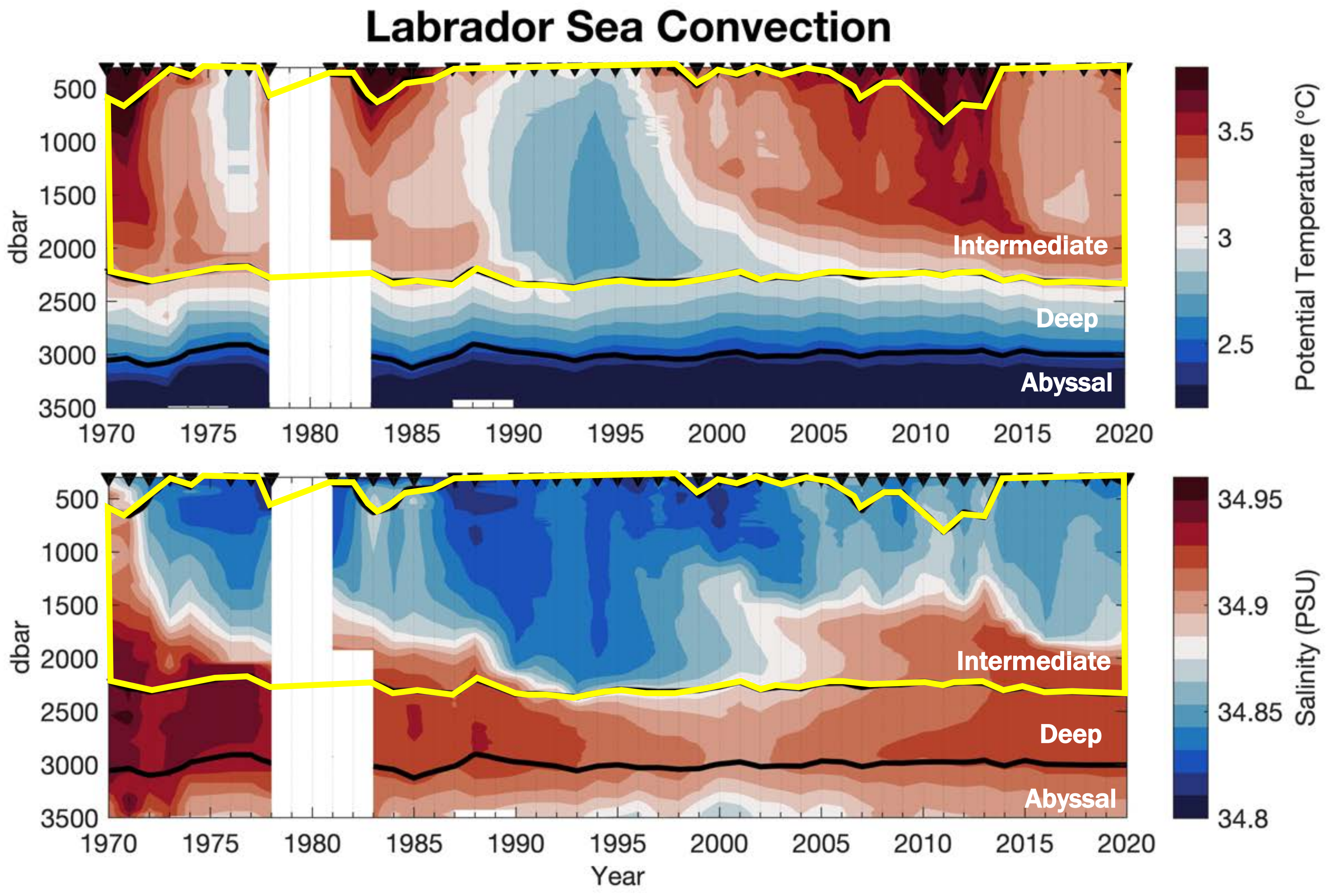


Source Region LSW Attributes:

- Convective events 1970s, late 1980s into 1990s, early 2000s, 2012-2018
  → Minima in T/S/potential vorticity
- Major convective event (1987-1994) produced ***coldest, freshest, densest, deepest, and most voluminous*** LSW layer in historical record

Chomiak et al., in prep

Methodology

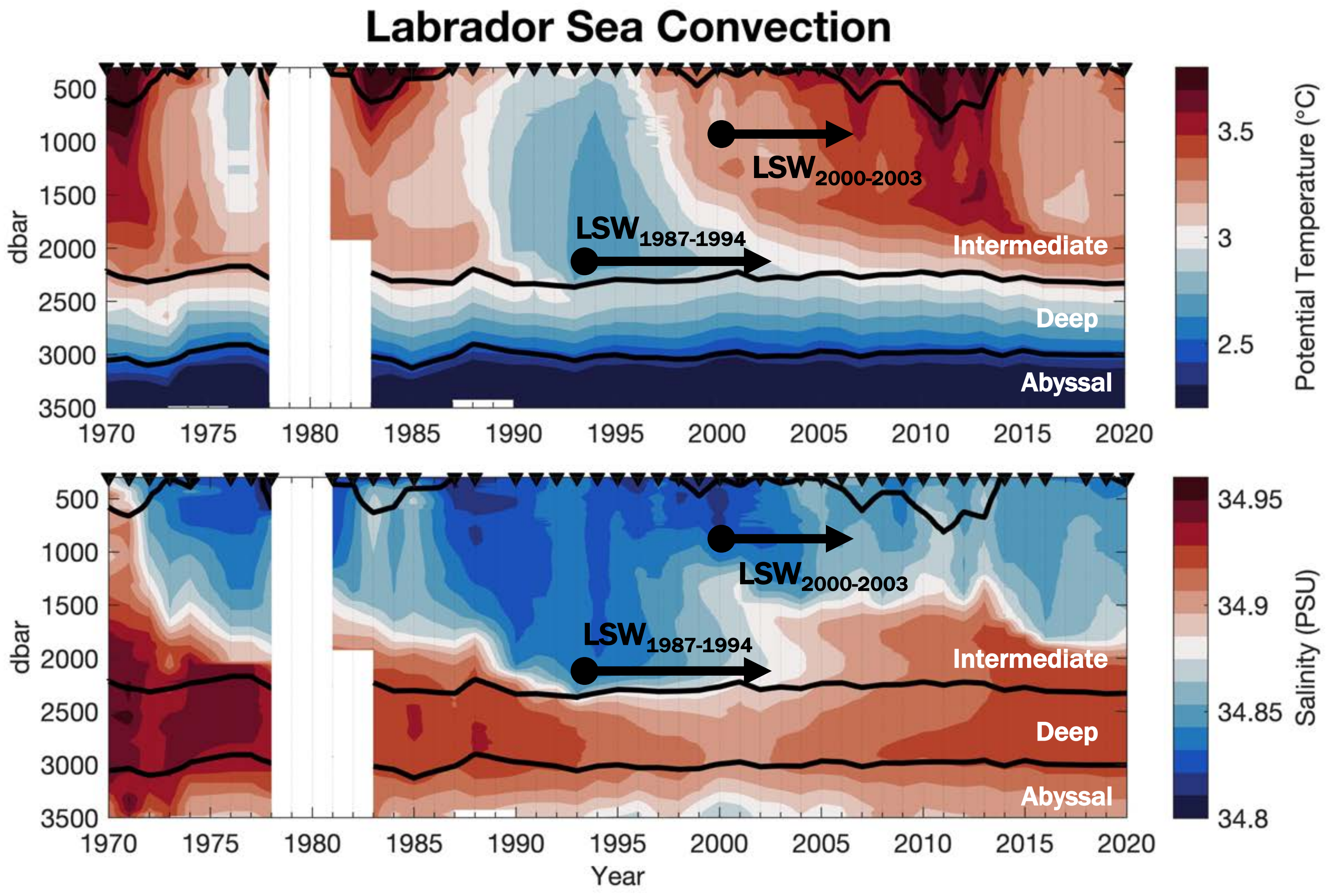


Advective Estimates from 3 methods:

1. Intermediate Layer analysis

Chomiak et al., in prep

Methodology

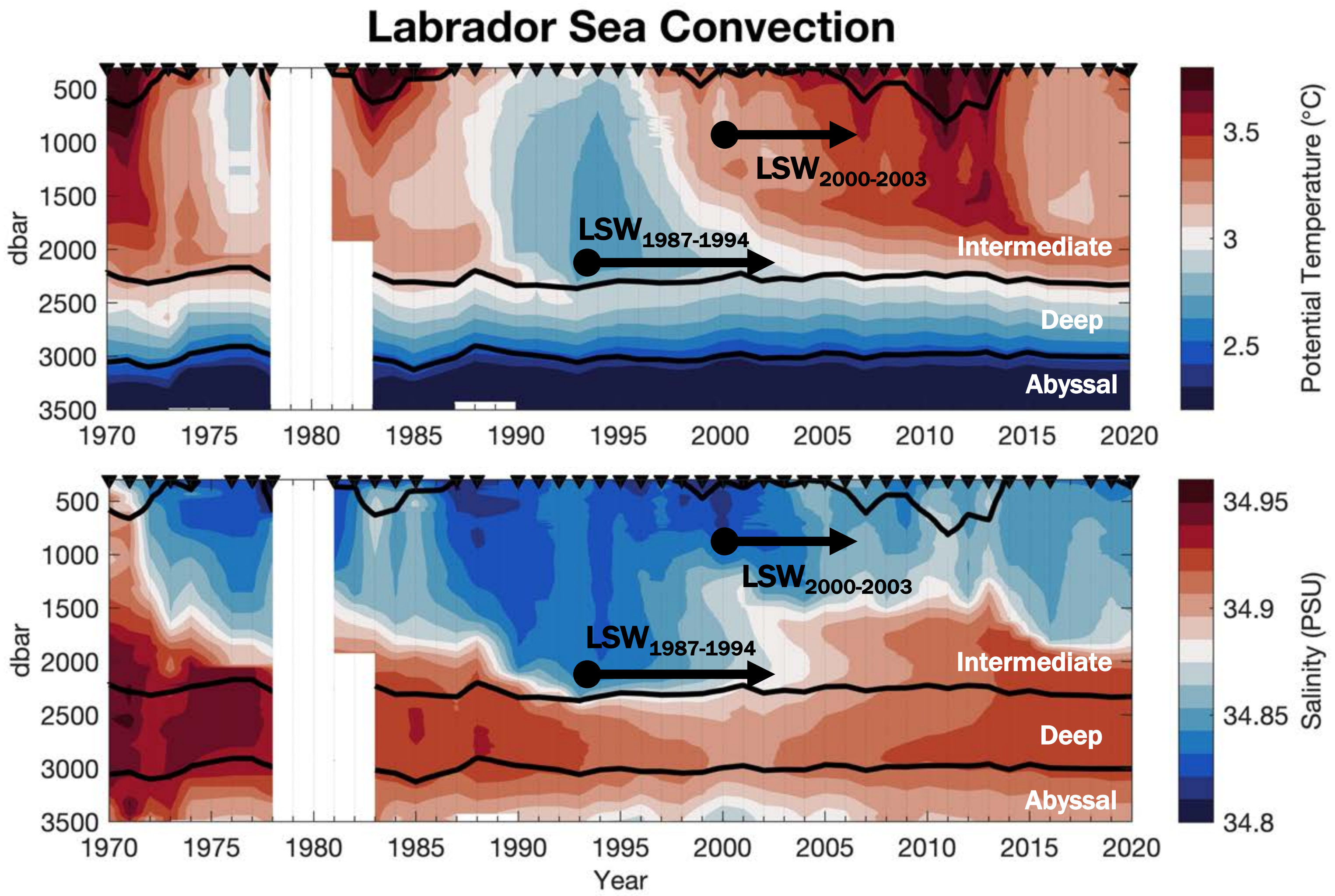


Advective Estimates from 3 methods:

1. Intermediate Layer analysis
2. LSW core analysis
   i. $LSW_{1987-1994}$
   ii. $LSW_{2000-2003}$

Chomiak et al., in prep

Methodology



Advective Estimates from 3 methods:

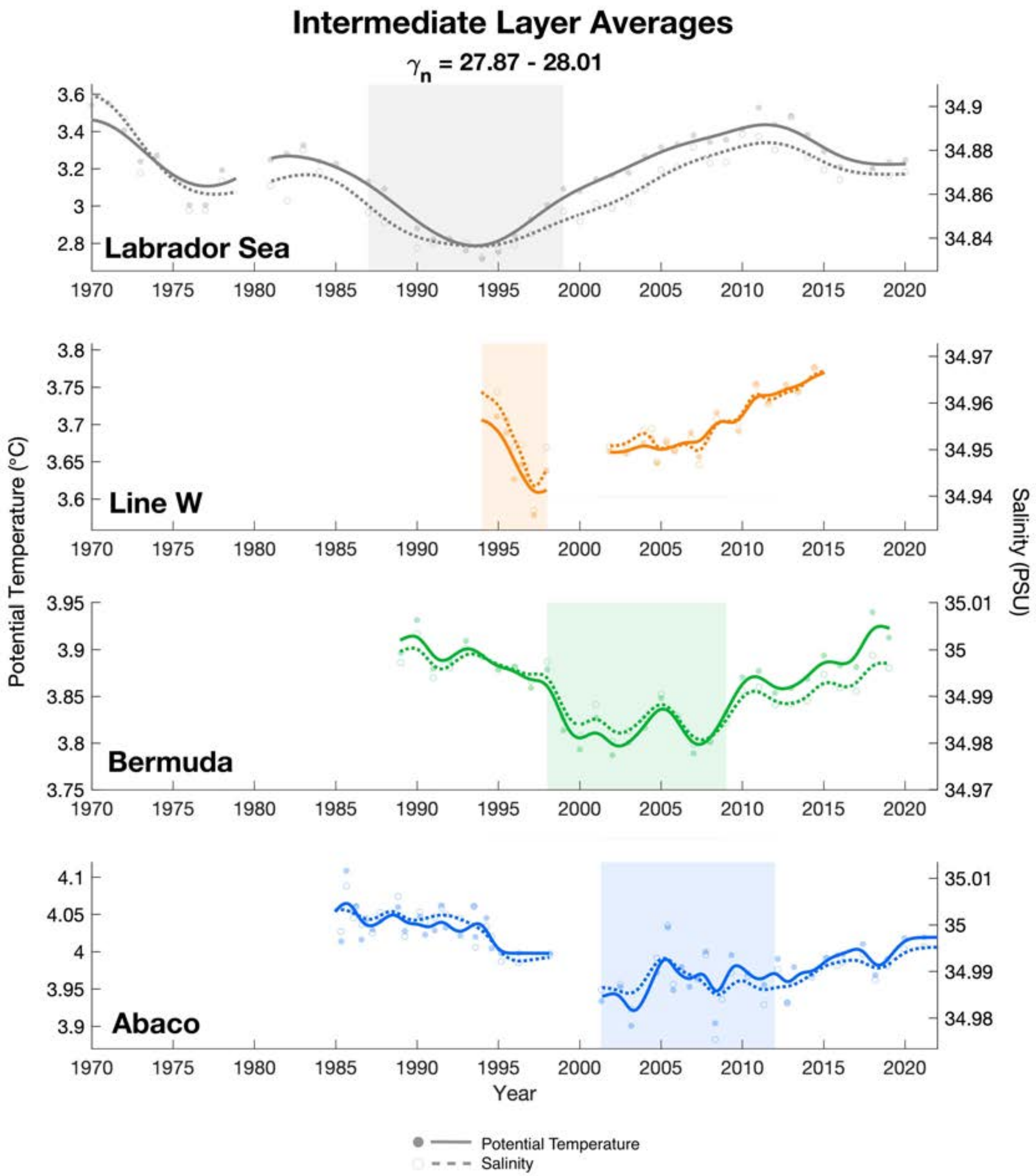
1. Intermediate Layer analysis
2. LSW core analysis
   i. $LSW_{1987-1994}$
   ii. $LSW_{2000-2003}$
3. Cross-correlation analysis

Chomiak et al., in prep

Results – (1) Intermediate Layer Assessment

Advective Timescales from Labrador Sea (yrs)

	Line W	*Bermuda*	*Abaco*
Int Layer	3	9-14	9-14
Core 1: LSW90s			
Core 2: LSW00s			
XCorr 1: LSW90s			
XCorr 2: LSW00s			



Minima in 1994

Minima in 1997
+ 3 years

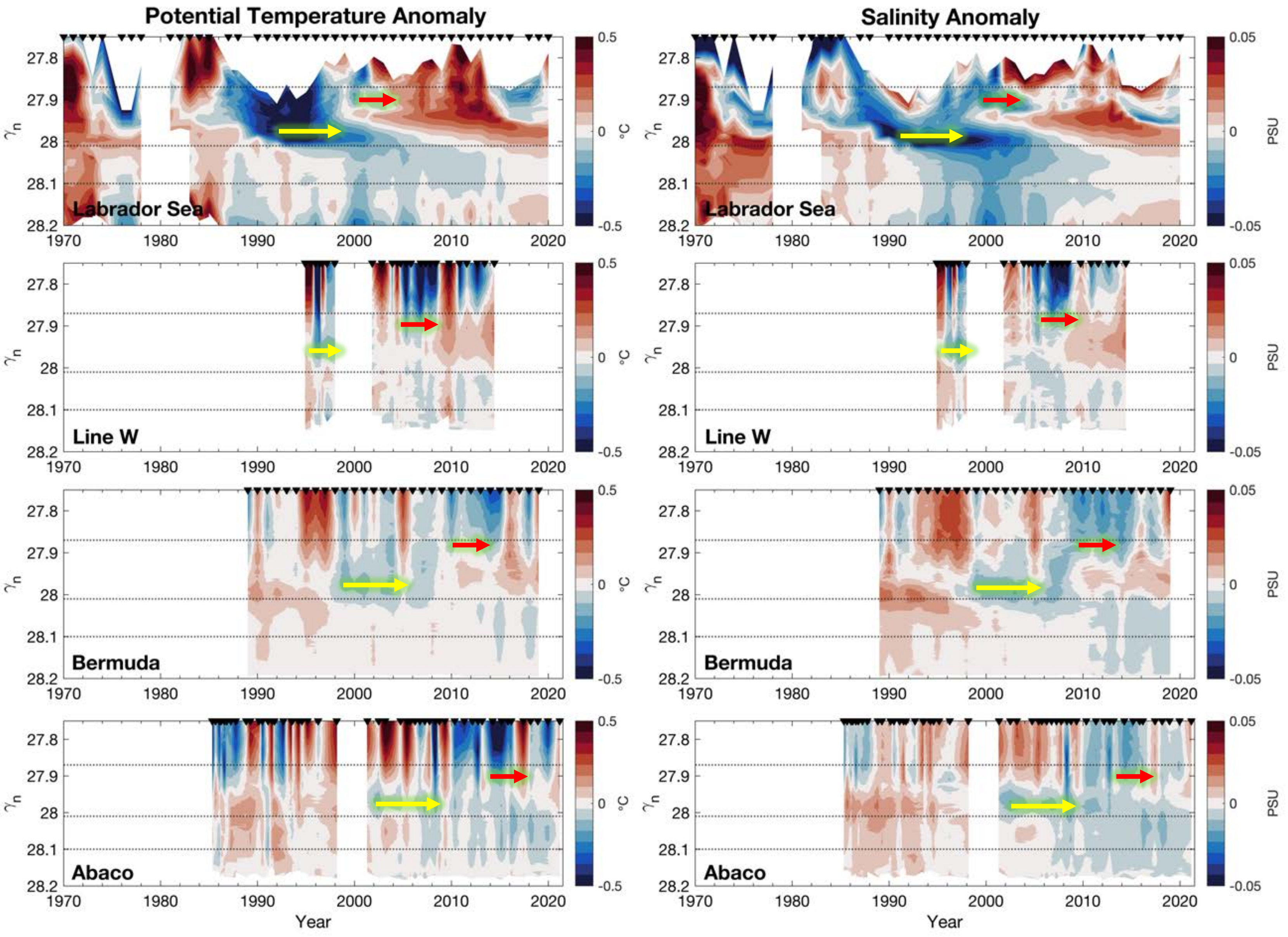
Dual Minima 2003 & 2008
+ 9 - 14 years

Dual Minima 2003 & 2008
+ 9 - 14 years

Results – (2) Isopycnal Core Assessment

Advective Timescales from Labrador Sea (yrs)

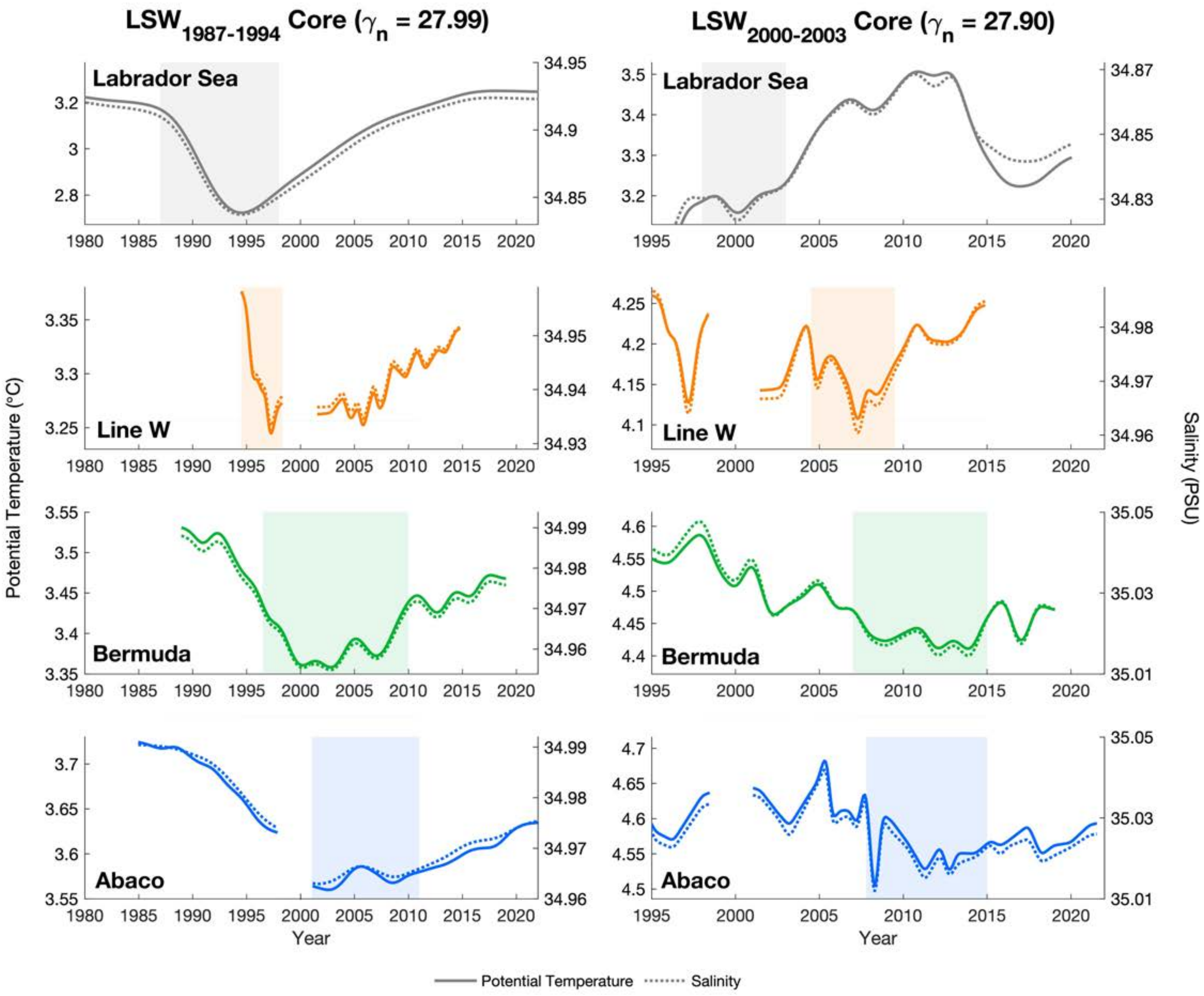
	Line W	*Bermuda*	*Abaco*
Int Layer	3	9-14	9-14
Core 1: LSW90s			
Core 2: LSW00s			
XCorr 1: LSW90s			
XCorr 2: LSW00s			



Results – (2) Isopycnal Core Assessment

Advective Timescales from Labrador Sea (yrs)

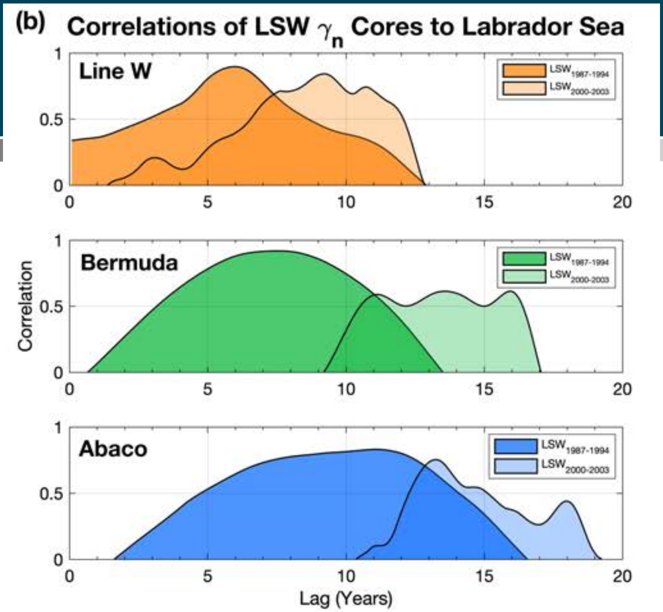
	Line W	*Bermuda*	*Abaco*
Int Layer	3	9-14	9-14
Core 1: LSW90s	3	9	9
Core 2: LSW00s	7	12-14	8, 11-13
XCorr 1: LSW90s			
XCorr 2: LSW00s			

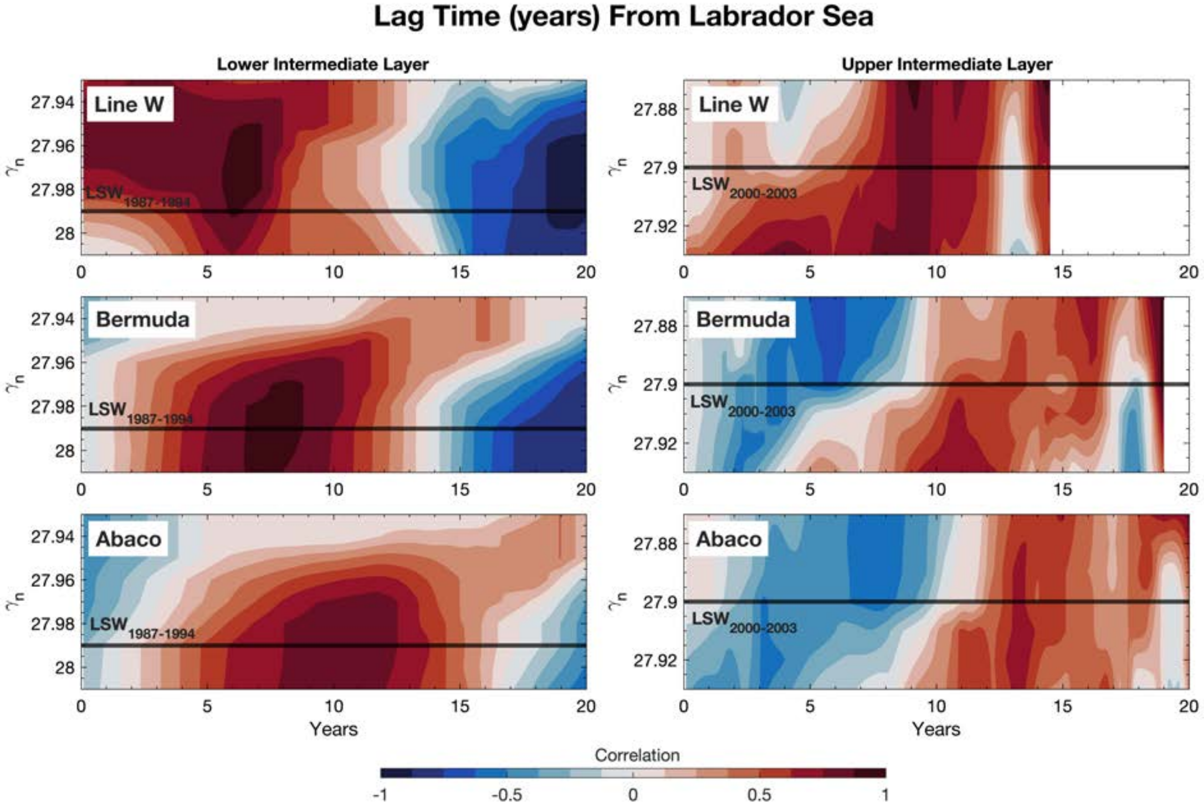


Results – (3) Cross-Correlation

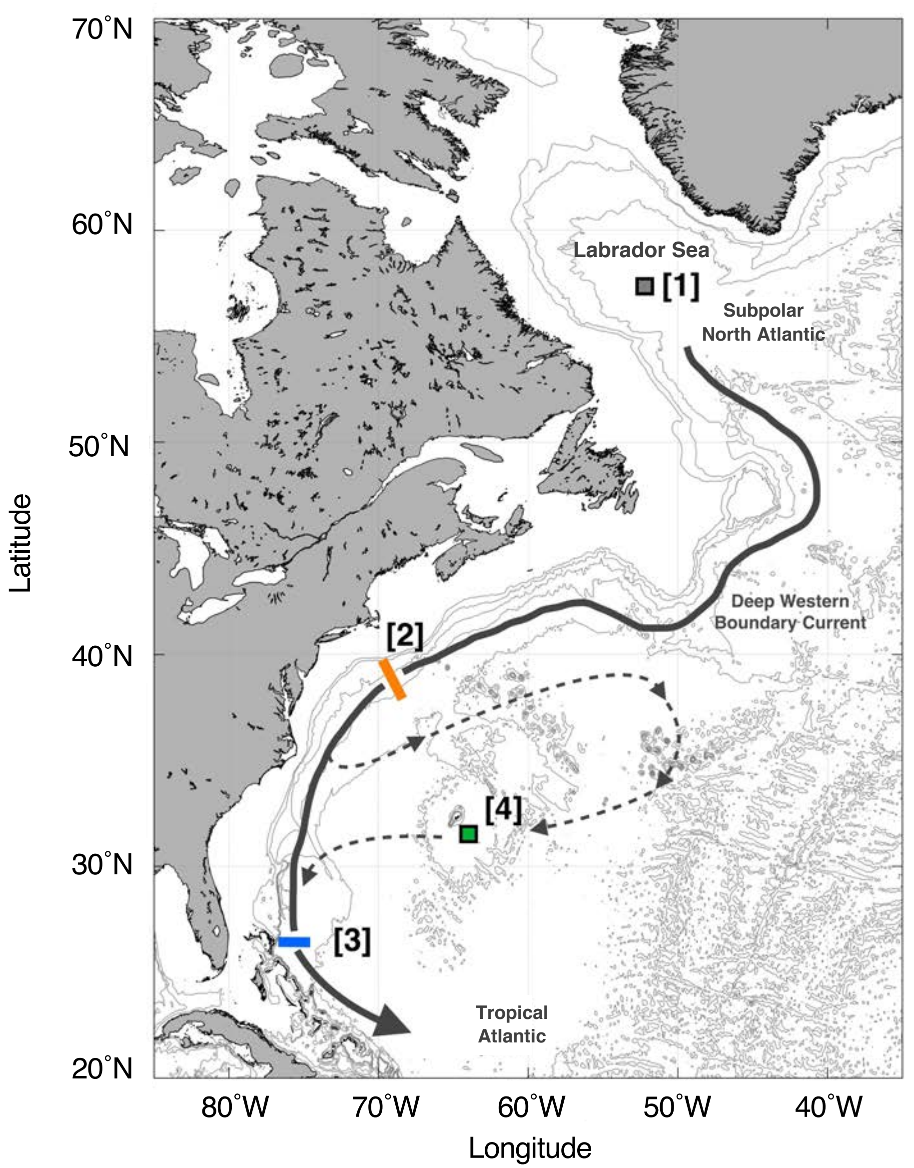
Advective Timescales from Labrador Sea (yrs)

	Line W	*Bermuda*	*Abaco*
Int Layer	3	9-14	9-14
Core 1: LSW90s	3	9	9
Core 2: LSW00s	7	12-14	8, 11-13
XCorr 1: LSW90s	6 (core) 6 (layer)	8 (core) 8 (layer)	11 (core) 10 (layer)
XCorr 2: LSW00s	9 (core) 5-11 (layer)	11-16 (core) 10-15 (layer)	13-18 (core) 11-18 (layer)

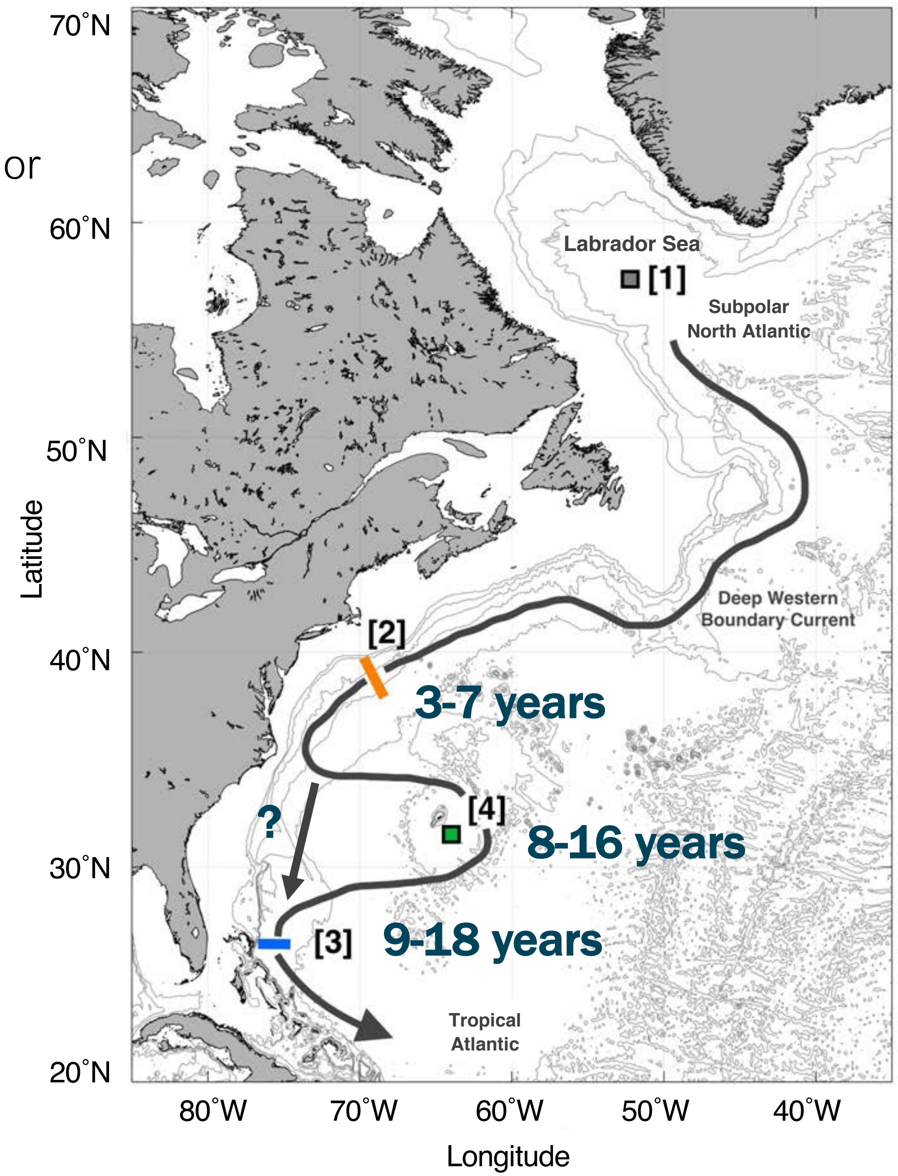




Conclusions – Alternate Advective Pathway



A new observable interior advective pathway, supported solely by hydrographic data



Conclusions – Alternate Advective Pathway

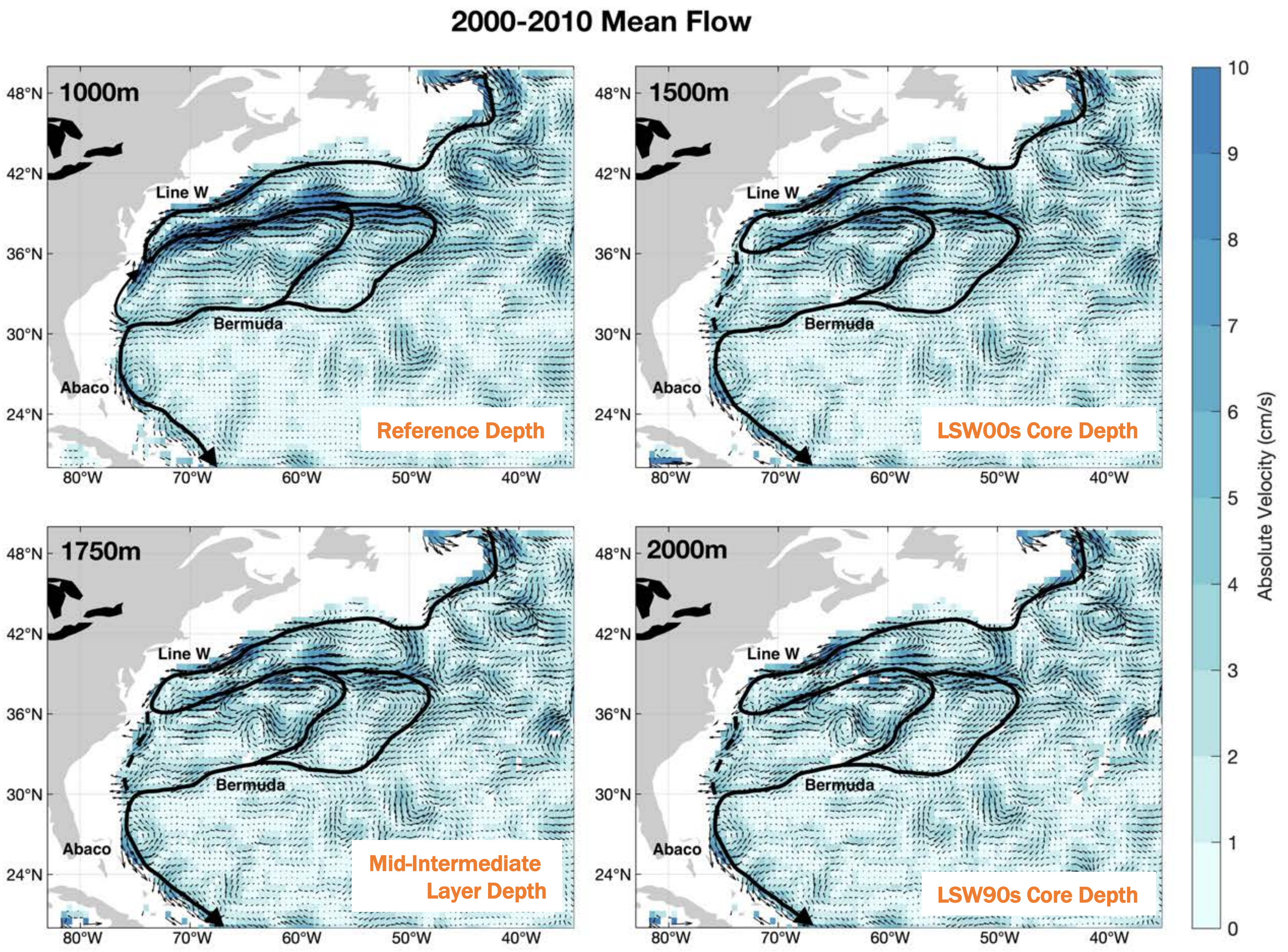
Interior Pathway Validated ✓

Adjusted geostrophic velocities derived from Argo + Altimetry[1] showcase a *bifurcation* off Cape Hatteras (36N), extending to ~56W and ~50W, rejoining continental slope at 30N

Difficult to determine if DWBC southward throughflow is present at 36N given Argo limitation, but leakage is likely

Different advective pathway options likely explain varying advective timescale estimates

[1]Schmid (2014)



Conclusions

1. **Updated Neutral Density definitions**
   - Intermediate layer [$LSW_{1987\text{-}1994}$ and $LSW_{2000\text{-}2003}$]
   - Deep layer
   - Abyssal layer
2. **Identification of LSW classes within all timeseries**
   - Observed as temperature/salinity/potential vorticity minima
3. **Estimation of DWBC advective timescales based on observable LSW advection across all locations**
   1. Intermediate Layer Assessment
   2. Isopycnal Core Assessment
   3. Cross-Correlation
4. **Arrival of LSW at Bermuda *prior to* or *on similar timescales* as Abaco**
   - Offers contrary route to DWBC advective pathway, supported through hydrographic data & adjusted geostrophic velocities

Thank You!

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