Introduction
Oceanic uptake of atmospheric carbon dioxide (CO₂) is a key part of the global CO₂ budget. Human activities have increased the partial pressure of CO₂ (pCO₂) in the atmosphere from ~280 ppm before the Industrial Revolution to well above 400 ppm at present. The ocean has absorbed ~25-30% of the anthropogenic CO₂ from the atmosphere and has played an essential role in regulating atmospheric CO₂ concentration and our planet’s climate conditions.

The Mid-Atlantic Ridge separates the South Atlantic Ocean into the western and eastern oceans, with different geomorphology and circulation, and thus, anthropogenic CO₂ or carbon (CaCO₃) uptake and storage rates may have both a meridional and zonal gradient.

Study Region and Methods
The study region focuses on the South Atlantic Ocean from 60°W to 20°E (Figure 1a). The Mid-Atlantic Ridge separates the eastern and western Atlantic basins and rises to a depth of ~2000 m. Meridional transects A13.5 and A16 (Figure 1a) are located on the east and west sides of the Mid-Atlantic Ridge, respectively. In addition, there is a zonal section A10 along 20°S.

Applying the specific eMRI method: Step 1 divide water column into 5 layers based on water masses and neutral density
Step 2 compute Cw
Step 3 build regression equations
Step 4 apply anthropogenic CO₂ changes
ΔC(CO₂) = (ΔC₁ + ΔC₂) + ΔC₂

Figure 2. Vertical distribution of (a) pH, salinity, (c) & (d) ADI, (e) & (f) nitrate, (g) & (h) DIC, and (i) & (j) CFC-12 along transect A16S (5°S-65°S) in 2015 (left) and, along transect A13.5 (5°N-55°S) in 2010 (right).

Results and Discussion: 1. Water Properties
The spatial patterns of seawater properties are indicative of the large-scale water masses and their transport, and thus, provide important context in explaining the spatial distributions of CaCO₃ changes. Salinity, ADI, nitrate, DIC, and CFC-12 were chosen to represent physical, biological, and anthropogenic processes. Generally speaking, the main water property differences between transects A13.5 and A16 (Figure 2) were located in the mode and intermediate waters. Differences were also found in the deep and bottom waters (below 4000 m) in the tropical and subtropical region (north of 30°S).

A low salinity tongue originated from surface at about 45-55°S, and then transported northward centered at about 1000 m and extended to the equator. The low salinity region at the surface is indicative of the AAIW outcrop location, and the low salinity tongue represents AAIW, which is an important pathway for CaCO₃ input into the ocean interior (Brewer, 1978). The fresh-water tongue in the intermediate water was more northerly along A16S than A13.5.

DIC, ADI, and nitrate were higher and extended closer to the surface and further north than along A13.5 than A16S, likely as a result of more accumulation of metabolic signals over slower and longer water transport time in the former. Consistent with the observed biogeochemical traces, the CFC-12 signal was also stronger along A16S than A13.5 in the subsurface layer near the tropical region (south of 20°S).

2. Anthropogenic CO₂ Changes between 1988 and 2010s
Anthropogenic CO₂ uptake and storage increased along all three transects in the South Atlantic Ocean over the period with two common features (Figure 3). First, high ΔC(CO₂) was detectable in surface and near-surface waters. Second, ΔC(CO₂) penetrated to deeper depths in the subtropical and subpolar oceans and was limited to shallower depths in the tropical oceans.

3. Column Inventory Changes Along Transects
Water column inventory of anthropogenic CO₂ increases is an important quantity reflecting the total amount of ΔCO₂ in a region from both local atmospheric input and net lateral transport. Since changes in ΔC(CO₂) were mainly in the top 2000 m, here we focus on the column inventory changes in the upper 2000 m and 2000 m layers (Fig. 4). The following features emerged from this analysis: (1) ΔC(CO₂) column inventory was substantially higher along the A16S (red vs. black lines). (2) There were clear meridional variations in the ΔC(CO₂) inventory distribution with the highest water column inventory change in the subtropical and subpolar regions. (3) Decadal ΔC(CO₂) inventory increases accelerated from the 1990s to the 2000s.

The column inventory changes of CaCO₃ from the 1980s to 2010s showed a similar meridional pattern for A16S and A13.5, which increased from high latitude, peaked at 30°-40°S, then decreased to the equator. The mean upper 2000 m column inventory change was 0.91±0.25 mol m⁻² yr⁻¹ and 0.57±0.22 mol m⁻² yr⁻¹, respectively, for A16S (2000-2015) and A13.5 (1988-2010). The largest west-east difference occurred at low latitudes, and then gradually decreased toward higher latitudes.

4. Basin-wide Total Inventory Change in the South Atlantic Ocean
Earlier, it was suggested that A16 (both the north and south transects) could be used to provide a good estimate for the entire Atlantic Ocean from the Arctic to the Antarctic (Wanninkhof et al., 2010; Talley, 2011). However, there are significant west-east ΔC(CO₂) variability in the South Atlantic Ocean as is demonstrated here. Thus, A16S may not be representative for the entire South Atlantic Ocean. To evaluate this issue, we used both A16S (western basin) and A13.5 (eastern basin) and compared this to that using only A16S (Table 1).

4.1. Basin-wide Total Inventory Change in the South Atlantic Ocean
The total ΔC(CO₂) uptake in the South Atlantic Ocean (0-6000 m) from the 1980s to 2010s estimated from the sum of the western basin and eastern basin was 27% lower than that based on overall A16S (1988-2016, 8.57°C C decade⁻¹). This is the main reason for the (0.034 ± 0.01%) typical past publications may have underestimated the total ΔC(CO₂) uptake rate based on A16S only in the South Atlantic Ocean.

Table 1. Total inventory changes of ΔC(CO₂) (py C decade⁻¹) (0-6000 m) for each 1° latitude band in the South Atlantic Ocean between 1980s and 2010s.

<table>
<thead>
<tr>
<th>Latitude band</th>
<th>Total Inventory Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°- 5° S</td>
<td>0.49±0.05</td>
</tr>
<tr>
<td>5°- 10° S</td>
<td>0.34±0.03</td>
</tr>
<tr>
<td>10°- 15° S</td>
<td>0.14±0.03</td>
</tr>
<tr>
<td>15°- 20° S</td>
<td>0.08±0.03</td>
</tr>
<tr>
<td>20°- 25° S</td>
<td>0.05±0.03</td>
</tr>
<tr>
<td>25°- 30° S</td>
<td>0.02±0.03</td>
</tr>
<tr>
<td>30°- 35° S</td>
<td>0.00±0.03</td>
</tr>
<tr>
<td>35°- 40° S</td>
<td>0.01±0.03</td>
</tr>
<tr>
<td>40°- 45° S</td>
<td>0.01±0.03</td>
</tr>
<tr>
<td>45°- 50° S</td>
<td>0.00±0.03</td>
</tr>
<tr>
<td>50°- 55° S</td>
<td>0.00±0.03</td>
</tr>
</tbody>
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Note: In the first column, A16S-based western basins results are extrapolated to the entire South Atlantic Ocean.

Summary
1. Largest ΔC(CO₂) in SW SAMW and AAIW
2. A16S uptake rate along A16S was 2.1±2.4 of that along A13.5
3. X A16S alone would overestimate the ΔC(CO₂)
4. Distributions in and recent outcrop events were the main reasons for the ΔC(CO₂) differences between the two sides of the Mid-Atlantic Ridge in the South Atlantic.
5. Water export from the Weddell Sea is the main reason for the deep penetration into the LCDW and AABW.

The latest observation in March 2020

Acknowledgement
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References

Figure 5. Phytoplankton and zooplankton biomass and chlorophyll a concentration along A16S in 2009 and A13.5 in 2010.

Figure 6. Annual mean profile of in situ ADC and DIC and from 2000 to 2020 in the region of the South Atlantic Ocean.

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