Connections between AMOC, meridional heat transport and heat content in the North Atlantic from satellite altimetry

LuAnne Thompson, Kathryn A. Kelly
University of Washington
Eleanor Frajka-Williams, Southampton University, U. K.
Maude Gibbons
Cambridge University, U.K.

NASA Ocean Surface Topography Science Team
Question: How are the different components of North Atlantic Upper Ocean Circulation connected to the winds, to each other and to heat content changes?

Approach: use altimetry to enhance direct observations of those components

1. Interannual variability using lagged regressions
2. 10 year trend
AMOC trend in observed AMOC: mostly owing to Upper Mid-Ocean transport Smeed et al 2014

\[
\text{AMOC} = \text{Florida Current} + \text{Ekman} + \text{Upper Mid Ocean}
\]

Mean \(17.5 = 31.5 + 3.5 - 17.5\) Sverdrups
Circulation and heat content variability enhanced by SSH:

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSH</td>
<td>Monthly AVISO fields spatially smoothed with 400 km Gaussian smoother to removed eddies. Use SSH as a proxy for upper ocean heat content (Lyman and Johnson, 2014)</td>
</tr>
<tr>
<td>Florida Current</td>
<td>Fill 1.5 year gap of cable measurements using SSH difference across Florida Strait</td>
</tr>
<tr>
<td>Gulf Stream path and strength</td>
<td>Fit the across path structure of the SSH to an error function (Kelly and Gille, 1990)</td>
</tr>
<tr>
<td>Quantity</td>
<td>Method</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Gulf Stream path and strength</td>
<td>Fit the across path structure of the SSH to an error function (Kelly and Gille, 1990)</td>
</tr>
</tbody>
</table>
Using sea level as a proxy for heat content.
Lyman and Johnson 2014

Local sea level determined by thermosteric (thermal expansion), and halosteric (haline contraction). Thermosteric dominates in tropics and subtropics

Correlation coefficient seasonal heat content with SSH 300-700 m
**Example:**
Influence of North Atlantic Oscillation (the dominant mode of atmospheric variability) on Gulf Stream Path on interannual times scales

NAO leads location of Gulf Stream by 1-18 months at almost all longitudes (Frankignoul et al, 2001)

Smoothed with 1.5 year Tukey filter
Results: Gulf Stream moves north and gets stronger about a year after changes in transport or winds

<table>
<thead>
<tr>
<th>Index</th>
<th>Gulf Stream Path</th>
<th>Gulf Stream Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAO-North Atlantic Oscillation</td>
<td>35 km/unit NAO Over Entire Path (See Frankignoul et al, 2001)</td>
<td>9 cm/unit NAO Near New England Seamounts</td>
</tr>
<tr>
<td>AMOC at 26N</td>
<td>7.7 km per Sverdrup Upstream of New England Seamounts <em>Opposite to what is found in climate models (Joyce and Zhang, 2010)</em></td>
<td>4 cm per Sverdrup Downstream of New England Seamounts</td>
</tr>
<tr>
<td>Florida Current</td>
<td>-</td>
<td>1.6 cm per Sverdrup Over entire path</td>
</tr>
<tr>
<td>UMO/Thermocline Transport at 26N</td>
<td>5 km per Sverdrup Over entire path</td>
<td>-</td>
</tr>
</tbody>
</table>
SSH pattern Forced by the NAO (interannual, spatially smoothed)

- SSH increases in the central tropical gyre and decreases in the subpolar and SE Subtropical gyre.
- GS path shifts North and increases in strength downstream.

SST pattern associated with NAO (Vizbeck et al., 2001)
SSH pattern forced by changes in the Florida Current (interannual, spatially smoothed)

SSH increases in the western subtropical gyre (heat content increase)
Decreases in NAC (heat content decrease)

GS increases in strength downstream of seamounts
SSH pattern forced by increases in UMO

SSH/heat content increases in North Atlantic Current

Decreases northeast of North America

Decreases across the basin at 26N

Northward shift of GS path upstream of seamounts
SSH pattern forced by changes in AMOC:
Dominated by Upper Mid Ocean response

SSH/heat content increases in “intergyre” and decrease off northeast North America

UMO shows similar pattern

AMOC

Upper Mid Ocean

Gulf Stream Strength downstream of NE Seamounts
Trend in SSH 2004-2014

SSH pattern associated with AMOC

SSH difference decrease
• **Interannual Variability**
  - Response of Gulf Stream different upstream and downstream of New England Seamounts; the location where the mean speed of Gulf Stream decreases.
  - Confirmation of the important role of the NAO in controlling Gulf Stream position, and we also find a relationship with strength
  - Increase UMO linked to northward shift
  - Increase in Florida Current linked to increase in Gulf Stream Strength
  - Increase in AMOC linked to northward shift and increase in strength

• **Trends**
  - Downward trend in AMOC occurs at the same time as the decrease in Gulf Stream Strength downstream of the New England Seamounts
  - Structure of SSH trend mirrors the response of SSH to AMOC on interannual time scales.