# Gulf Stream separation in ACCESS-OM2-01

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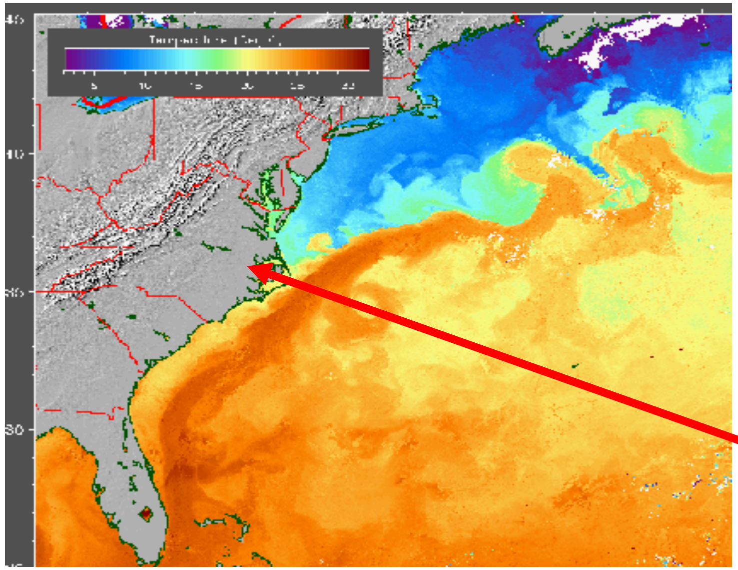
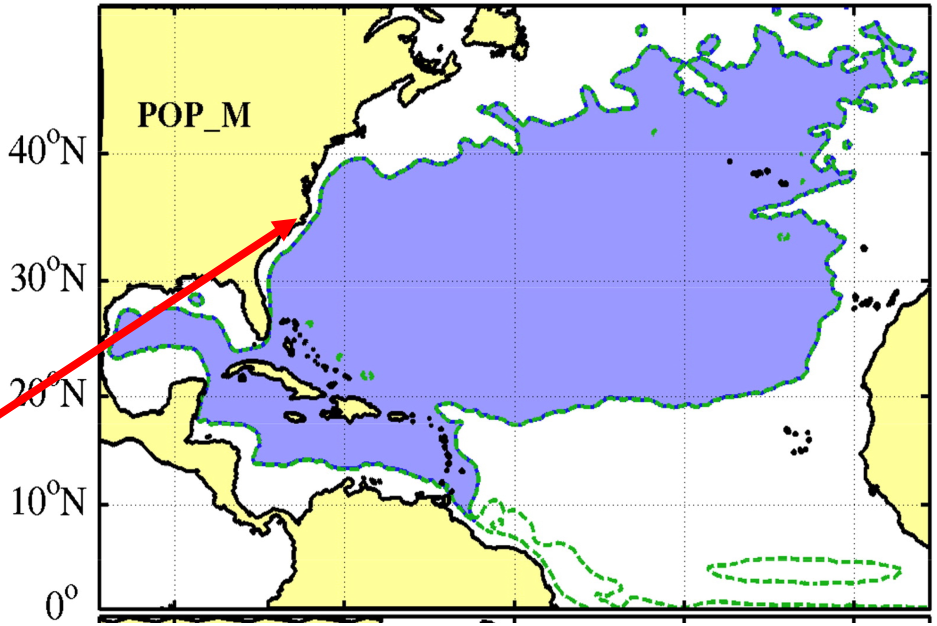
# Background: Gulf Stream Separation



Sea surface temperature estimated from satellite AVHRR

Cape Hatteras




Schoonover et al.2016

- The western boundary current along the east coast of the US and separates at Cape Hatteras

- It is predicted to decelerate in the future (Solomon et al. 2007)

- But the separation is not always captured by the numerical models (e.g. Schoonover et al.2016)

- The misrepresentation of the Gulf Stream can bring problems: overestimation of the temperature(Saba et al.2016), bias in predication of the sea level rise (Ezer 2016)

# Background: ACCESS-OM2-01

## Resolution

Horizontal resolution: 1/10$^o$, eddy resolving

Vertical resolution: 75 levels, ranging from 1m at the surface to 200m at the bottom

## Viscosity

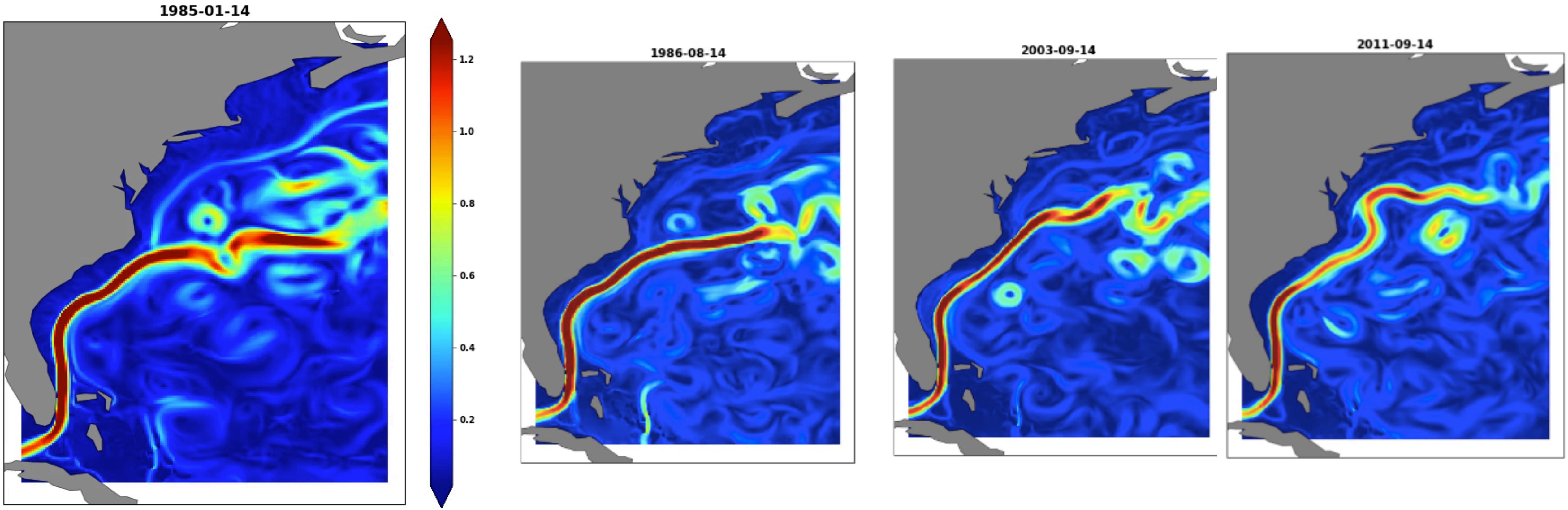
Biharmonic friction Smagorinsky scaling viscosity (Griffies and Hallberg. 2000)

## Wind forcing

Inter-annual forcing JRA55-do (Tsujino et al. 2018), simulating from 1985-2018

Initialised from a repeat year forcing spin-up, repeating 1984-1985 wind forcing

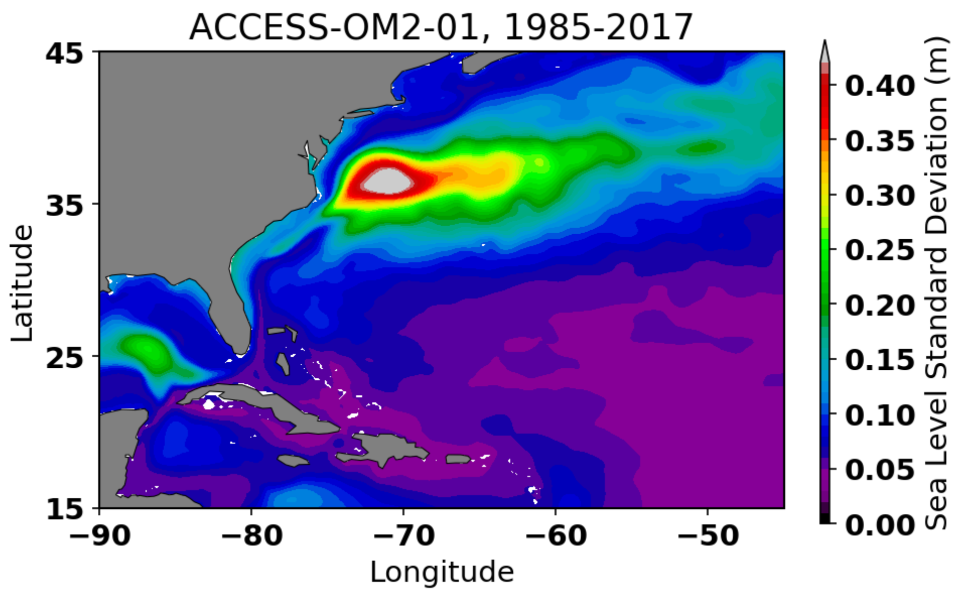
# Background: Gulf Stream separation in ACCESS-OM2-01

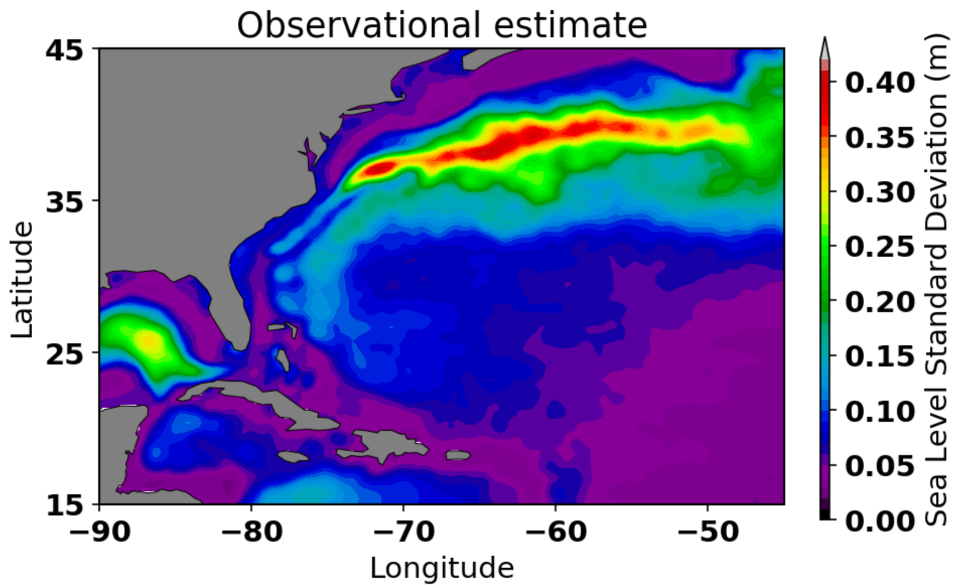



Surface speed in ACCESS-OM2-01

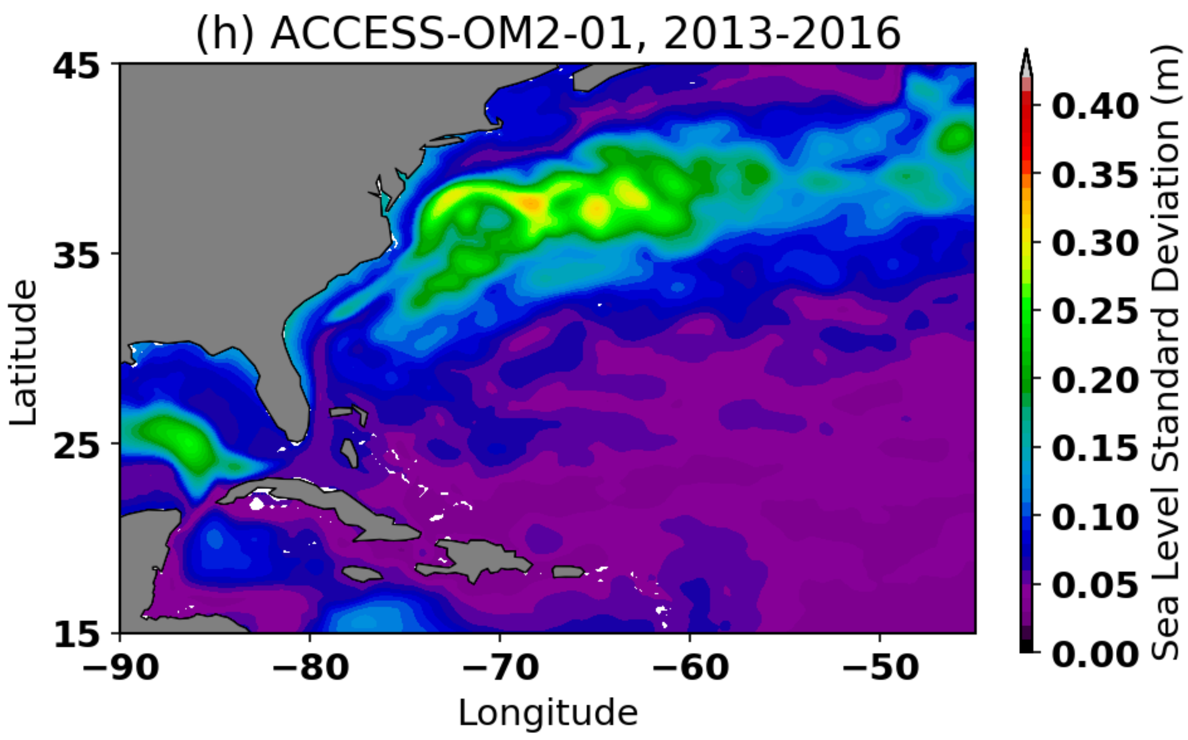
- The Gulf Stream separates properly at about the first 20 years
- But it keeps overshooting in the last ten years

# Background: Gulf Stream separation in ACCESS-OM2-01



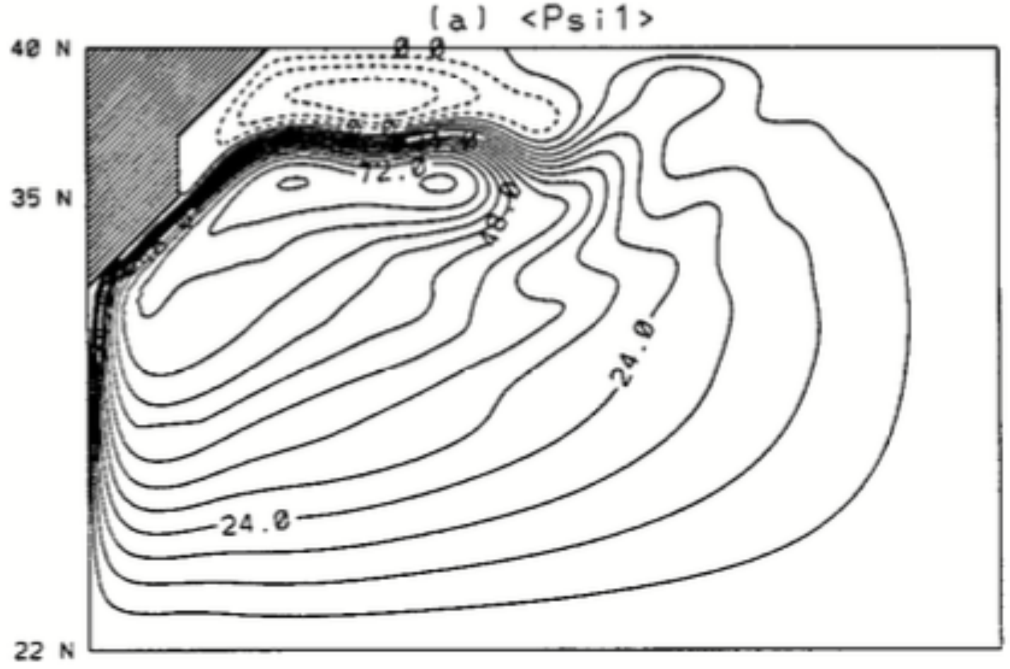

Standard deviation of Sea Level for 4-year segment



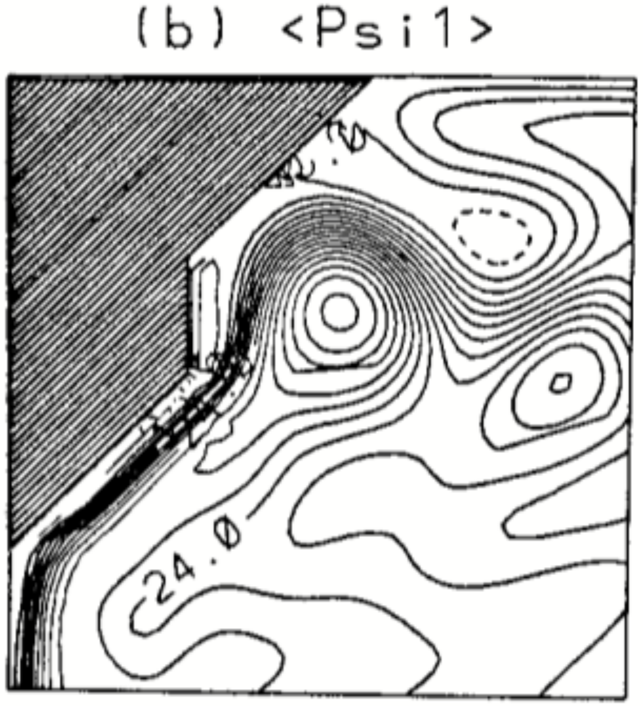

- The erroneous in separation is steady
- High variability is because of the long-time current shifting

# Potential cause: Insufficient inertia

- One of the potential causes is insufficient inertia (Ozgokmen et al. 1997)
- High inertia can decouple the flow so the upper layer can cross f/h contour

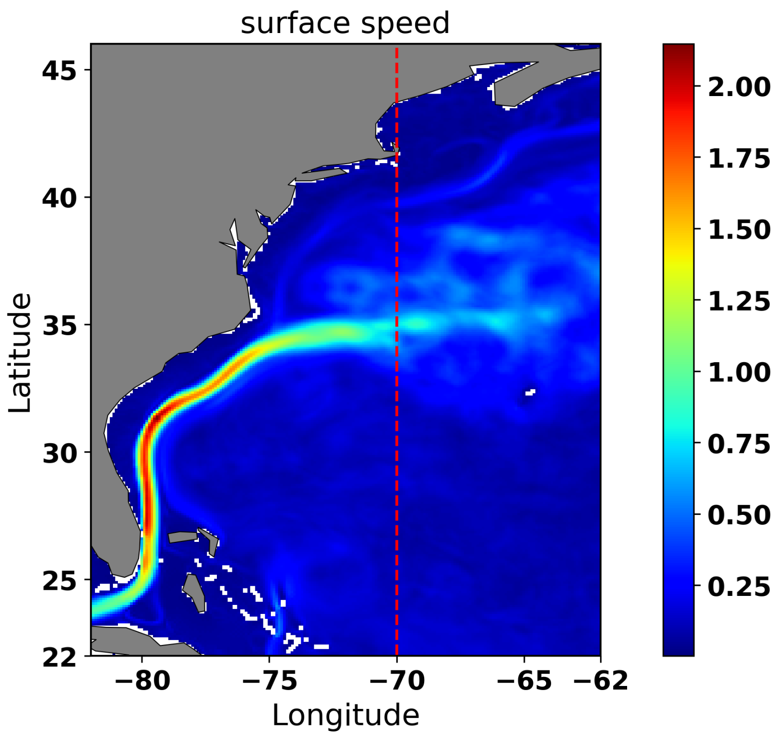


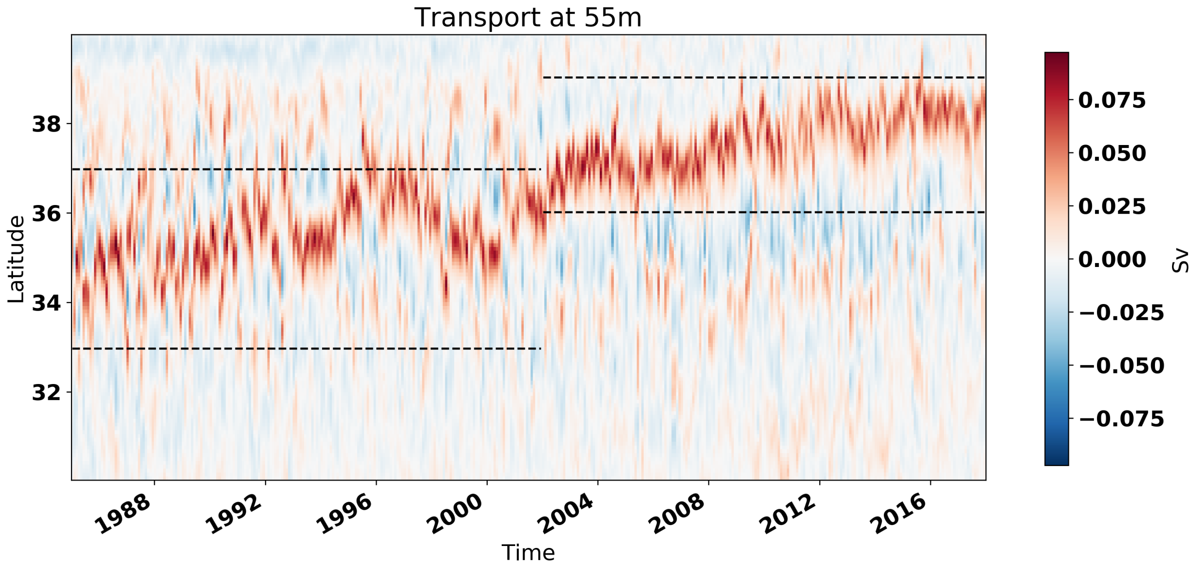

Streamfunction in **high inertia** case (double wind stress)

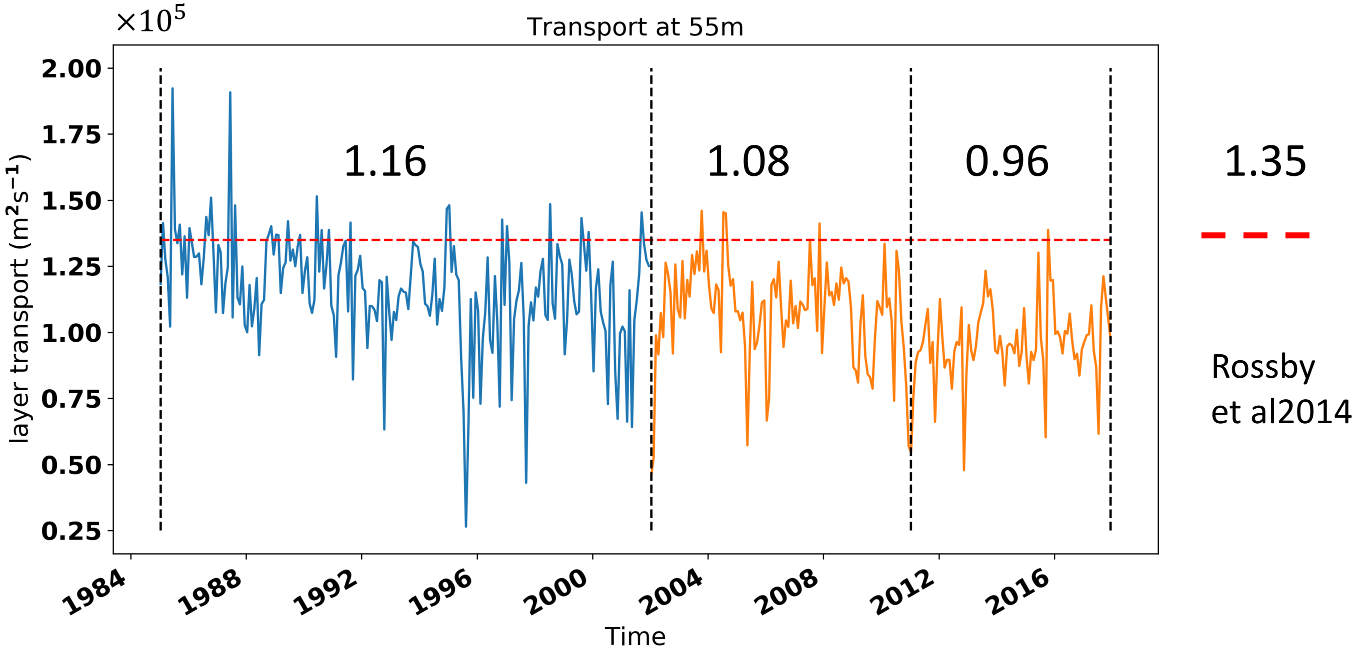



Streamfunction in **low inertia** case

# Potential cause: Insufficient inertia

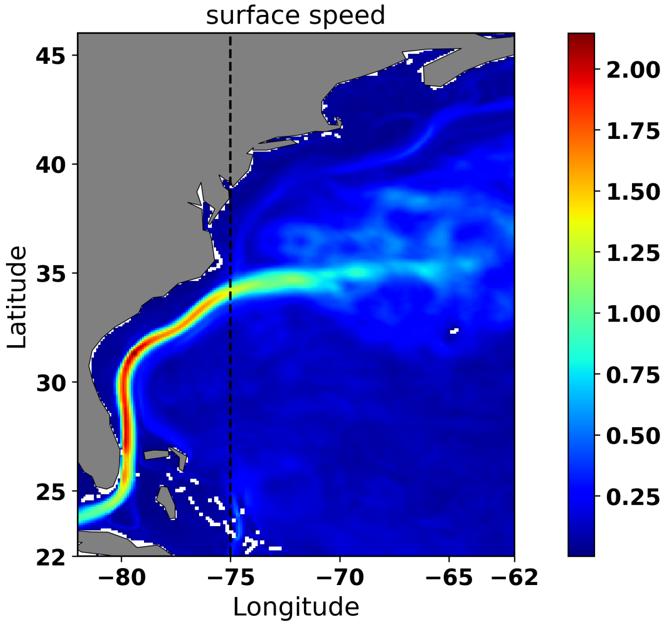


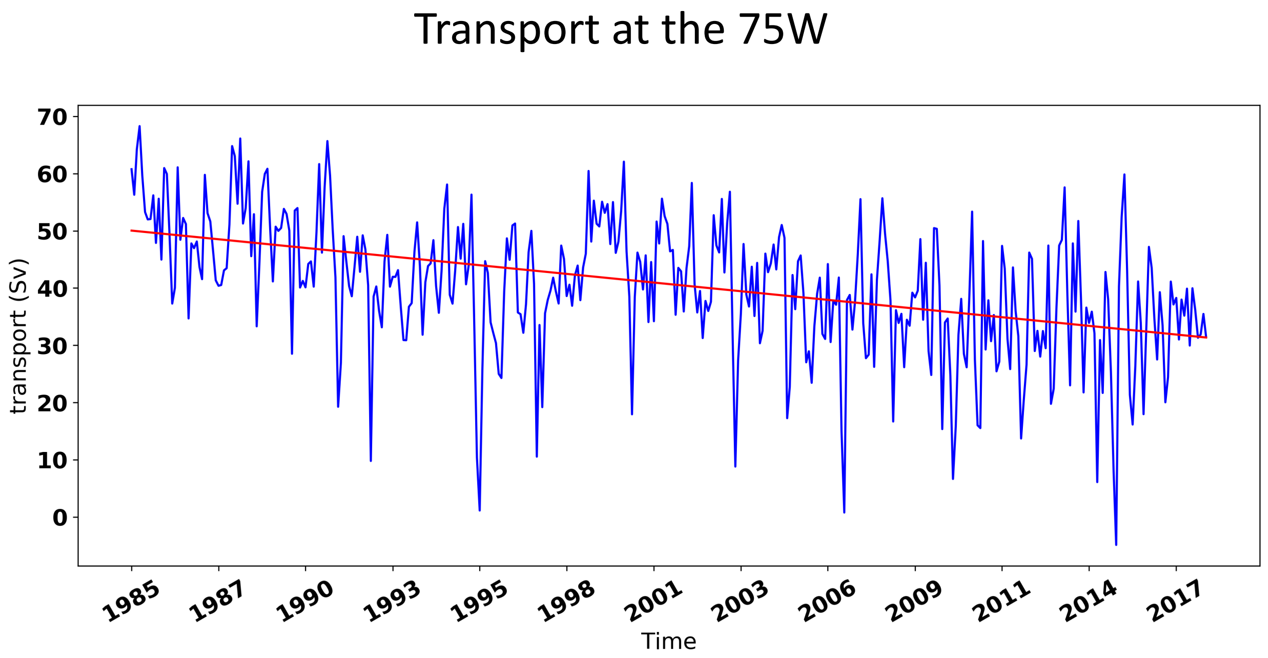



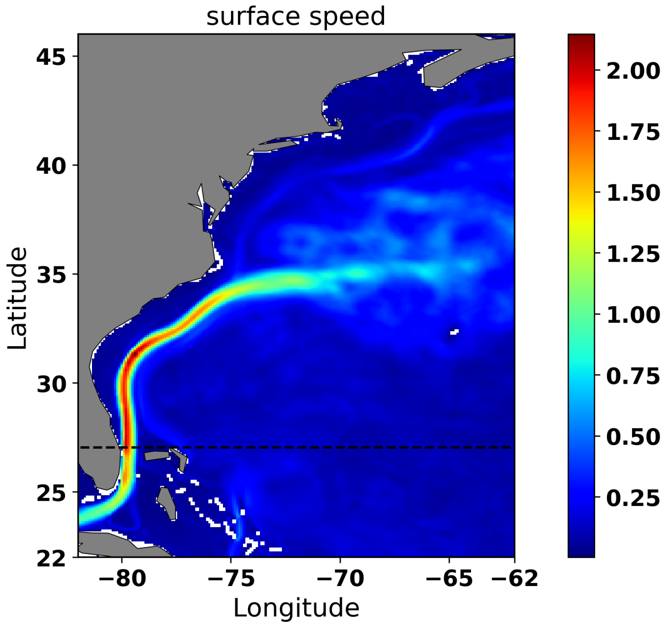

- An overview of the model performance in the GS: comparison with the observation (Rossby et al 2014)
- Transport per meter at 70°W
- The model underestimated the transport slightly

# Potential cause: Insufficient inertia

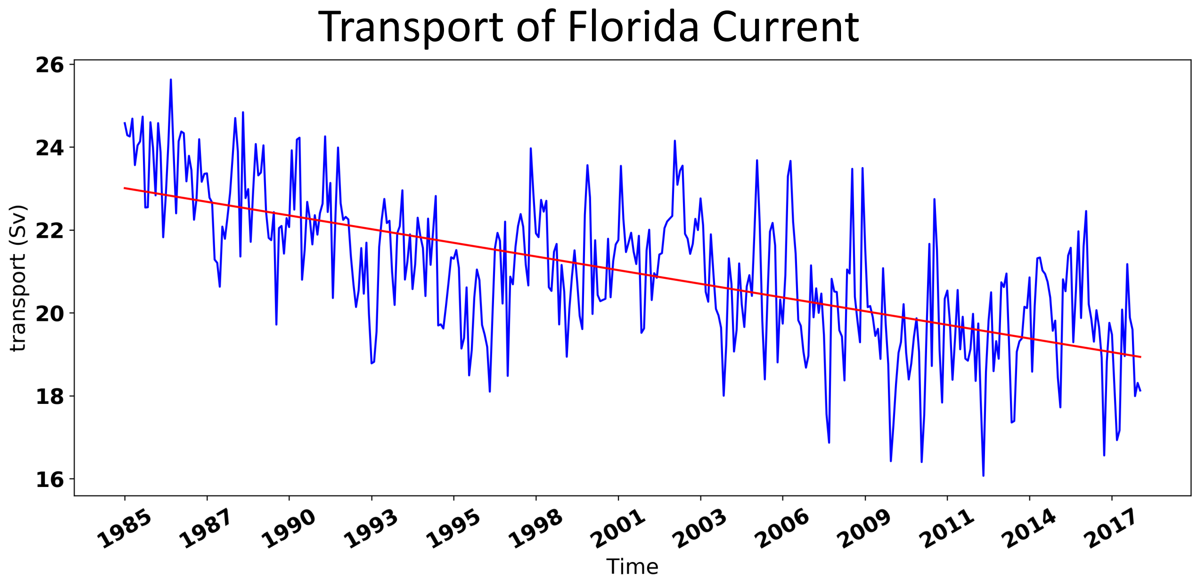



Slope fitted by Theil-Sen estimator




32.1Sv (Meinen et al 2010)



# Potential cause: Insufficient inertia

Is the wind forcing that leads to the insufficient inertia of the Gulf Stream?

Wind stress: $\tau = \rho C_D |\mathbf{U}|\mathbf{U}$

Relative wind: $\mathbf{U} = \mathbf{U_a} - \mathbf{U_o}$

Absolute wind: $\mathbf{U} = \mathbf{U_a}$

Resolution: 1/4°

$\mathbf{U}$: wind velocity relative to surface current

$\mathbf{U_a}$: scatterometer measured wind velocity, JRA55-do is adjusted to match scatterometer wind

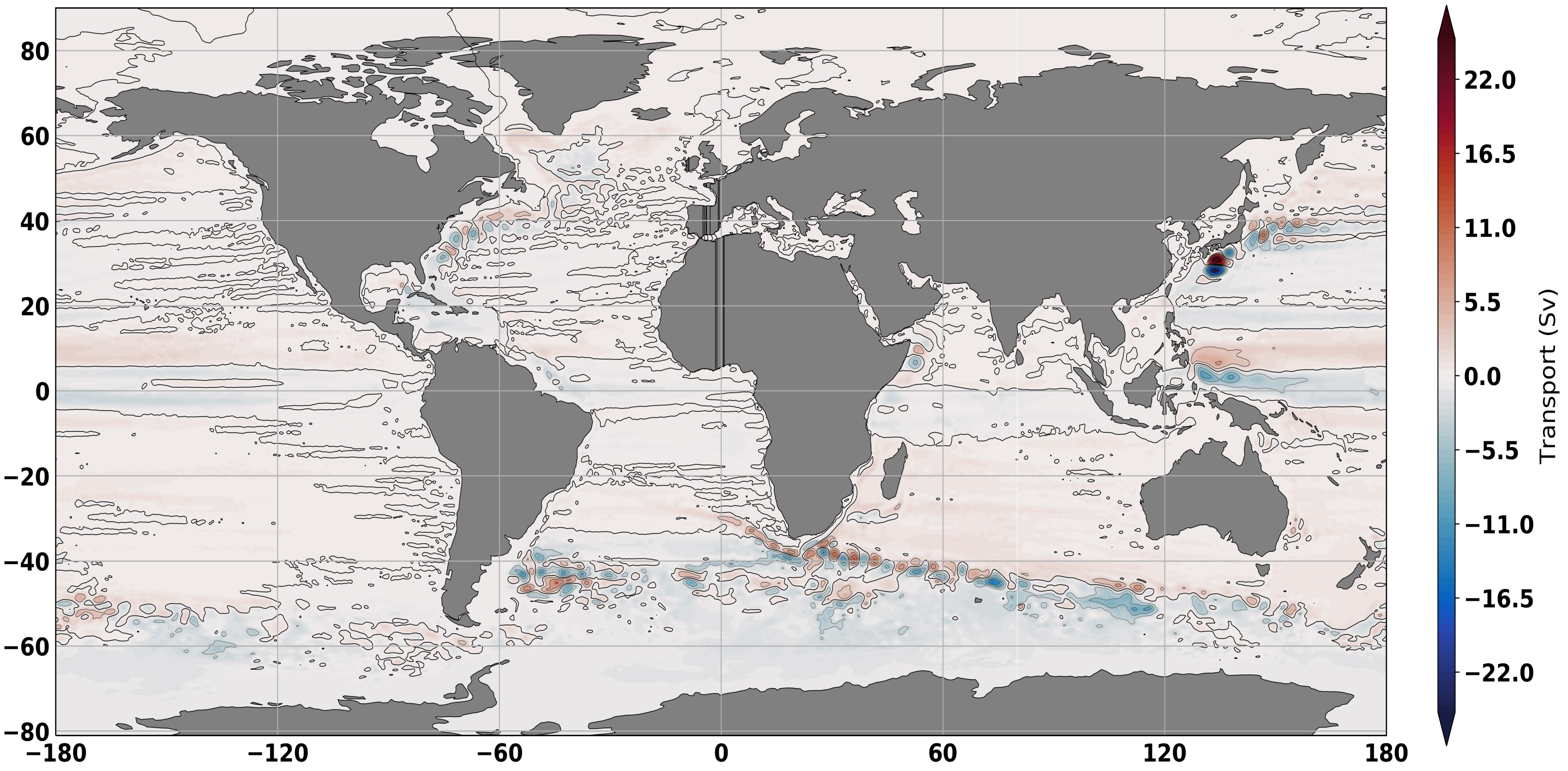
$\mathbf{U}_{\boldsymbol{o}}$: surface current velocity

$\rho$: density
$C_D$:drag coefficient

# Potential cause: Insufficient inertia

Results of relative and absolute wind experiment

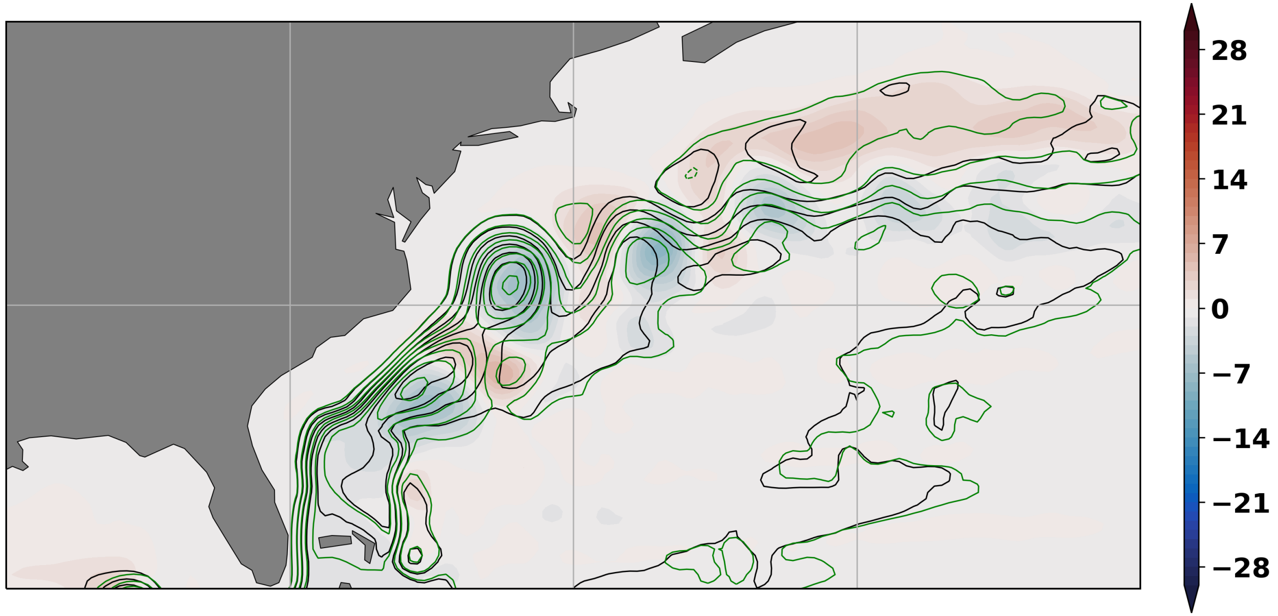
relative-absolute wind




Time-mean (1958-2018) barotropic streamfunction

# Potential cause: Insufficient inertia

relative-absolute wind

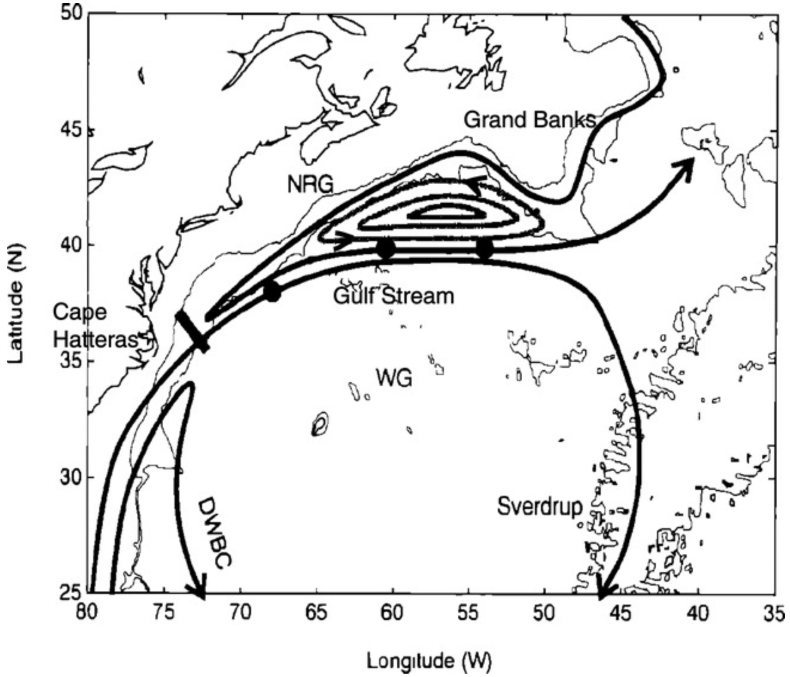



- The diploe difference shown around the Gulf Stream is because of the current shift
- There is little change in dynamics
- Wind forcing is not likely to be the cause of weak inertia of the Gulf Stream, at least for the 1/4$^{o}$ model

Streamlines of absolute wind simulation

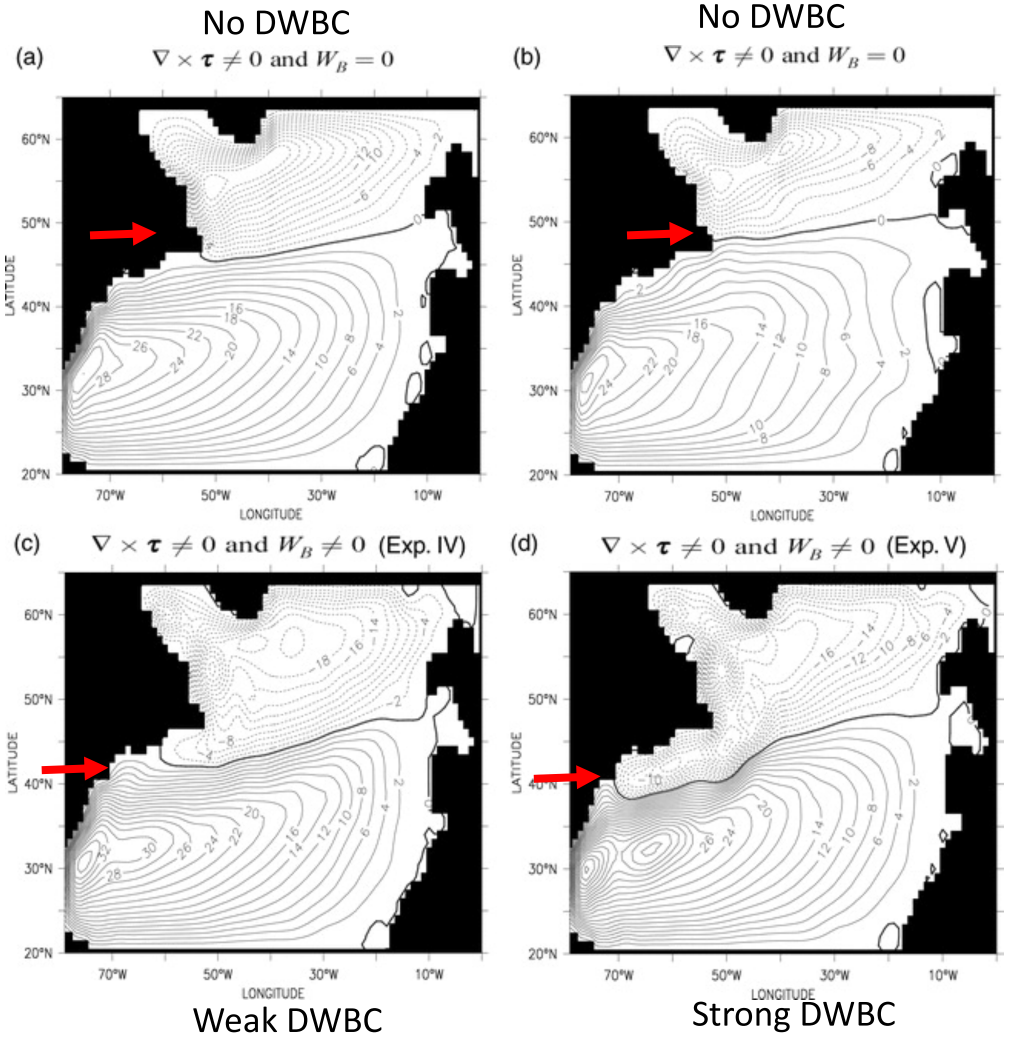
Streamlines of relative wind simulation

# Potential cause: Deep Western Boundary Current




Zhang & Vallis 2007

- Another mechanism proposed by Ozgokmen et al. 1997 but overlooked by them is the northern recirculation gyre (NRG)
- Zhang & Vallis, 2007 suggest the NRG is important and produced by a downslope Deep Western Boundary Current **(DWBC)** through vortex stretching

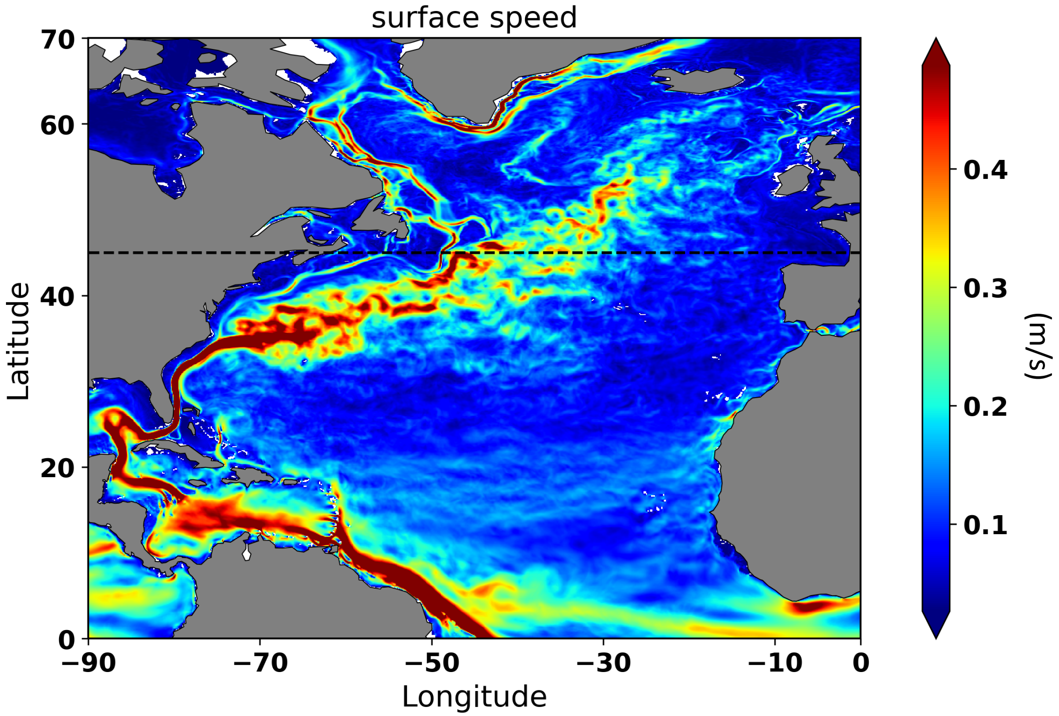



Zhang & Vallis, 2007

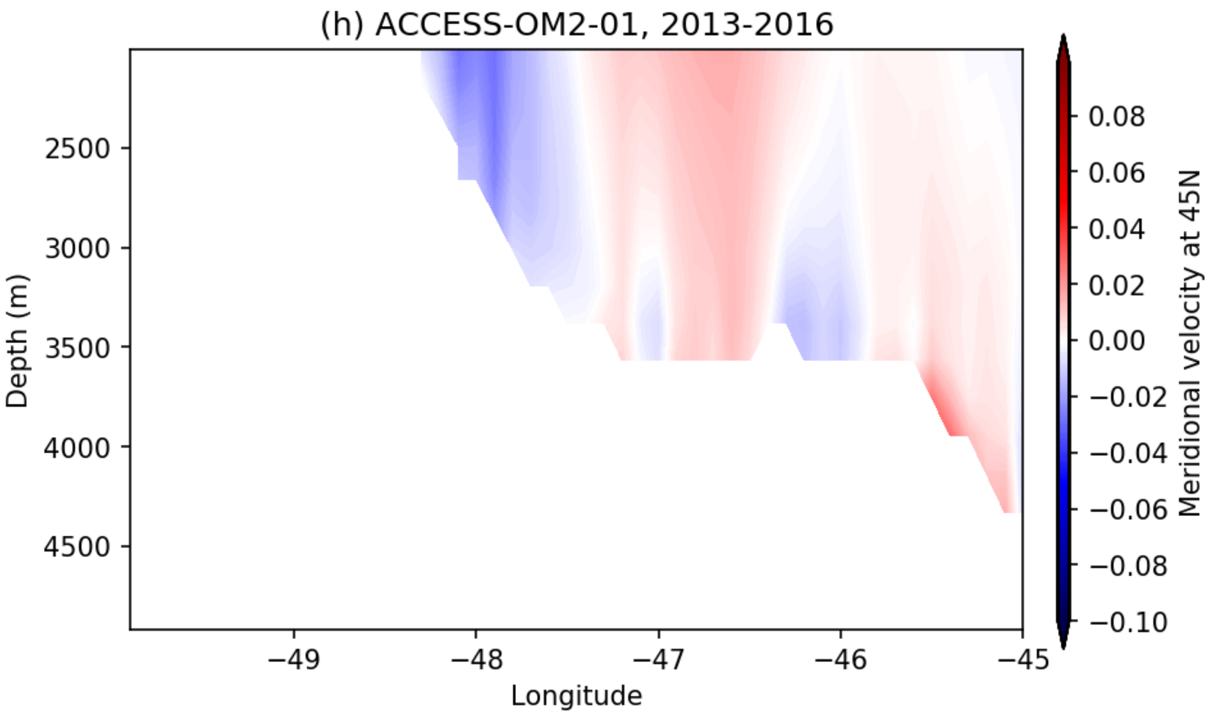
- This process is related to the **Nordic Sea overflow** and **the AMOC**

# Potential cause: Deep Western Boundary Current

Meridional velocity at 45$^o$N



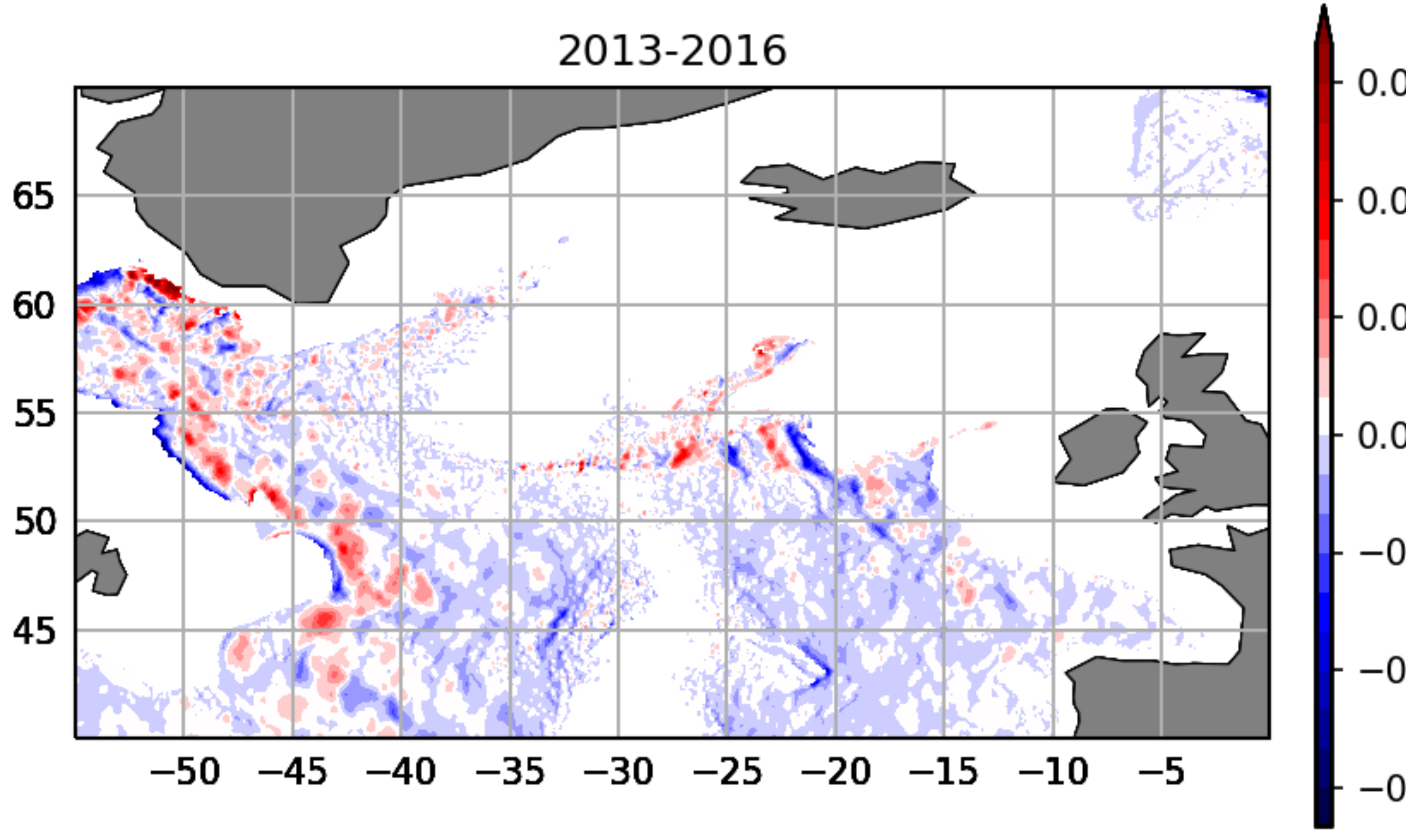

The velocity at the entrance of the DWBC is weakening over time



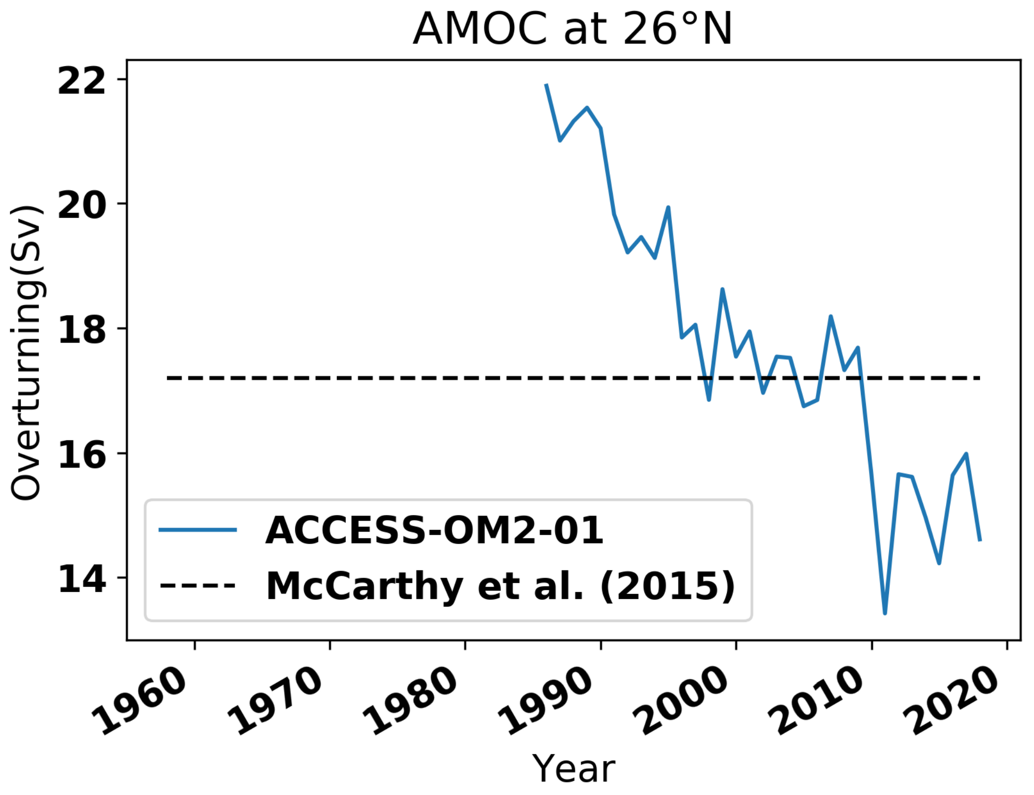
# Potential cause: Deep Western Boundary Current

The deep circulation in the Nordic Sea is also weakening

AMOC drops quickly over time




Meridional velocity at 3000m



# Summary

- Gulf Stream separates properly in the first 20 years but keeps overshooting in the last 10 years
- The problematic separation can be caused by the insufficient inertia of the Gulf Stream
- But the weak inertia is not likely to be induced by the wind forcing
- Another possible mechanism of the problematic separation is the weakening Deep Western Boundary Current
- The quick drop in the AMOC may be induced by the initial bias from the repeat year forcing spin-up

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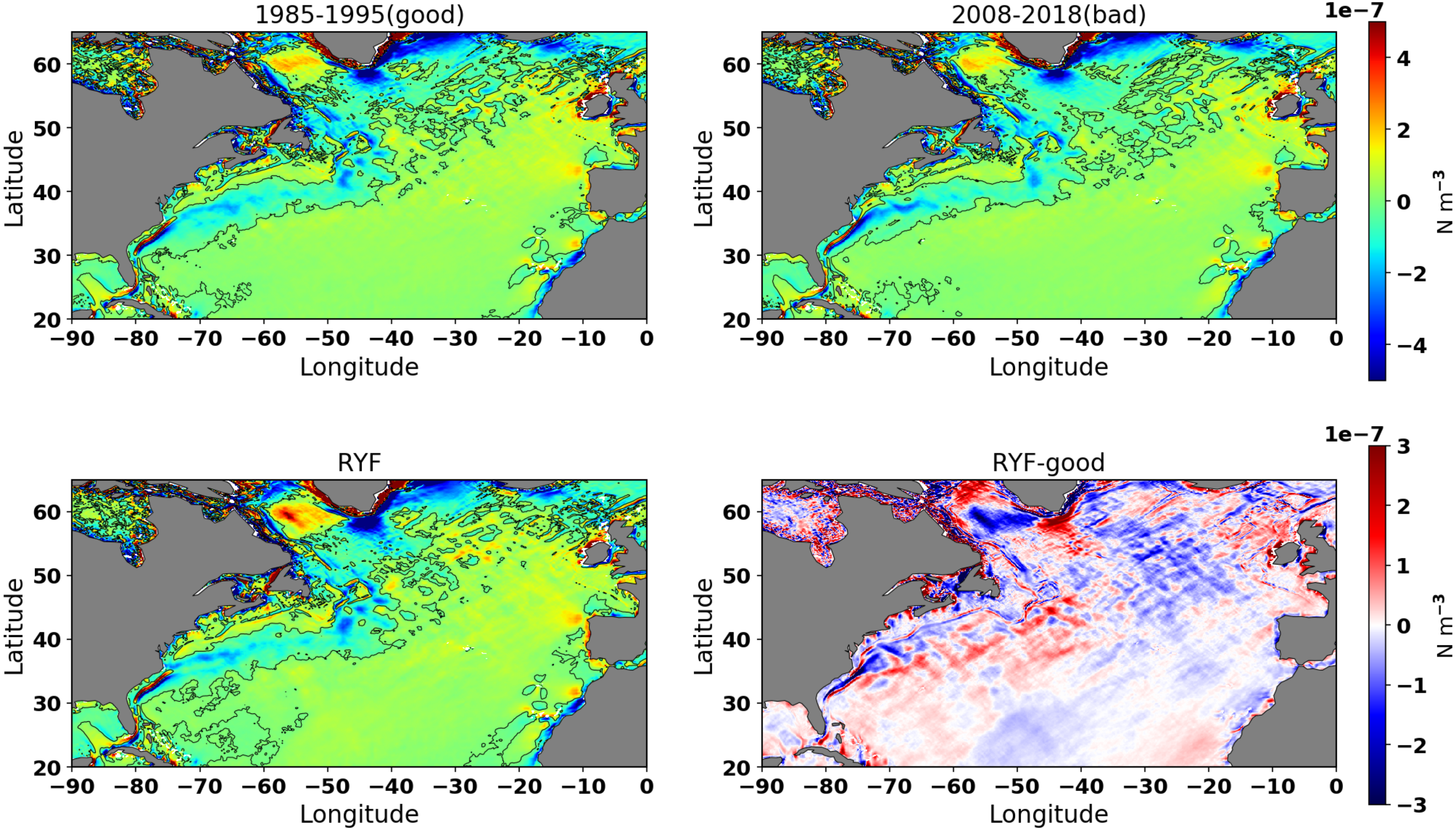
# Wind stress curl



# Sverdrup transport