Interannual Variations of the Gulf Stream Location and Transport from 20 years of XBT measurements

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- Gulf Stream plays an important role in the poleward transfer of heat and salt.
- Gulf Stream may impact mid-latitude storm tracks and intensity.

High-Density AX10 Transect



- AX10 started in September 1996, runs between New York City and Puerto Rico, crosses the Gulf Stream at ~72° W.
- Approximately 4 transects per year, a total of 77 realizations have been carried out since 1996.
- About 100 XBTs deployed along each transect with resolution of 0.25 degree latitude. Within the Gulf Stream region, the resolution is increased to 0.1 degree latitude.

Temperature along AX10 Transect



- Strong temperature gradient in the Gulf Stream region.
- Large meridional shift of the Gulf Stream.

Temperature Variability (Standard Deviation)



0 6 -100 5 -200 4 -300 -400 3 -500 2 -600 1 -700 . -800 0 32N 36N 38N 30N 34N 40N

Stream coordinate

Much of the variability is due to meridional shifts of the Gulf Stream.

Strong temperature variability in the Gulf Stream region below surface mixed layer.

Time-mean Temperature from AX10



• Deeper reaching warm temperature

Methodology

- Salinity: Argo gridded salinity from SIO is used, monthly climatology is interpolated to the year day of each transect.
- Seostrophic velocity is then computed from temperature and salinity, with reference level at 800 m ($v_{800m}=0$).

Criteria:

- **GS position:** latitude of the surface velocity maximum.
- **GS transport:** sum of the upper 800 m geostrophic transport.

The northern and southern boundaries of the Gulf Stream are chosen where the flow changed from eastward to westward.



Gulf Stream Location and Transport from AX10 and Altimeter



Gulf Stream position and transport from AX10 compare well with those determined from satellite altimeter measurements.

Correlation for location: 0.86 Correlation for transport: 0.51

Time-mean Velocity Section



• The mean Gulf Stream velocity is much larger, and the jet is much narrower when averaged in stream coordinate.



2

1.5

1

0.5

0

Time-mean Surface Geostrophic Velocity



• The Gulf Stream is about one degree latitude wide, with maximum velocity exceeds 2 m/s.

Relationship between GS Location and Transport



- The Gulf Stream location and transport are negatively correlated (-0.52).
- No trends in both the Gulf Stream location and transport.



Relationship between GS Location and Transport



- Correlation between the Gulf Stream location and transport are dominated by short time scale fluctuations (shorter than one year).
- The interannual variations of the Gulf Stream location and transport are marginally correlated on 90% significance level.

Vertical Distribution of the Gulf Stream Transport



- Gulf Stream transport (almost) linearly decreases with depth.
- The integrated baroclinic transport is highly correlated with transport at each depth.

Temperature Section during Strong and Weak Transports



Gulf Stream Properties from Satellite Altimeter SSH

Altimeter SSH: (daily, 1993–2015)

Gulf Stream (GS) center positionGS speed (at the GS center)GS transport (cross-front SSH difference)

Methodology:

GS position: local velocity maximum close to a SSH contour $[h_{GS}(t)]$.

GS speed: velocity at the GS position.

GS transport: cross-front SSH difference. Northern and southern boundaries are chosen where the flow changed from eastward to westward.



Zonally-averaged Gulf Stream Properties



The zonally averaged GS properties (position, speed, and Δ SSH) experience decreasing trends.

Position:	-0.10° latitude per decade
Speed:	−3.9 cm/s per decade
ΔSSH :	-3.2 cm per decade

Changes in the Gulf Stream Properties



Relationship between NAO and Gulf Stream Changes

GS position

∆SSH



Conclusions

- XBT measurements suggest that the Gulf Stream is about 1 degree latitude wide, with maximum velocity exceeds 2 m/s.
- No tends in the Gulf Stream location and transport were fund during last 20 years along AX10.
- Gulf Stream experiences decreasing trends in its position, speed, and transport. However, those trends are dominated by the region east of ~65° W.
- NAO leads Gulf Stream position by one year, and leads Gulf Stream transport by three years.

THANK YOU!

Correlation between GS speed and transport



Changes in GS Transports



75° W-70° W: (1) Increase in SSH both north and south of the GS. (2) Δ SSH slightly increased due to relatively larger increase in SSH south of GS.

 65° W- 50° W: Δ SSH decreased due to decrease in SSH north of the GS.



Trends in SSH, SST, and Air-Sea Heat Fluxes



The trends suggest that there may be heat convergence to the west of 65° W, which increases heat content. This positive heat content forces a large heat release to the atmosphere.