Cold and Warm-Core Rings

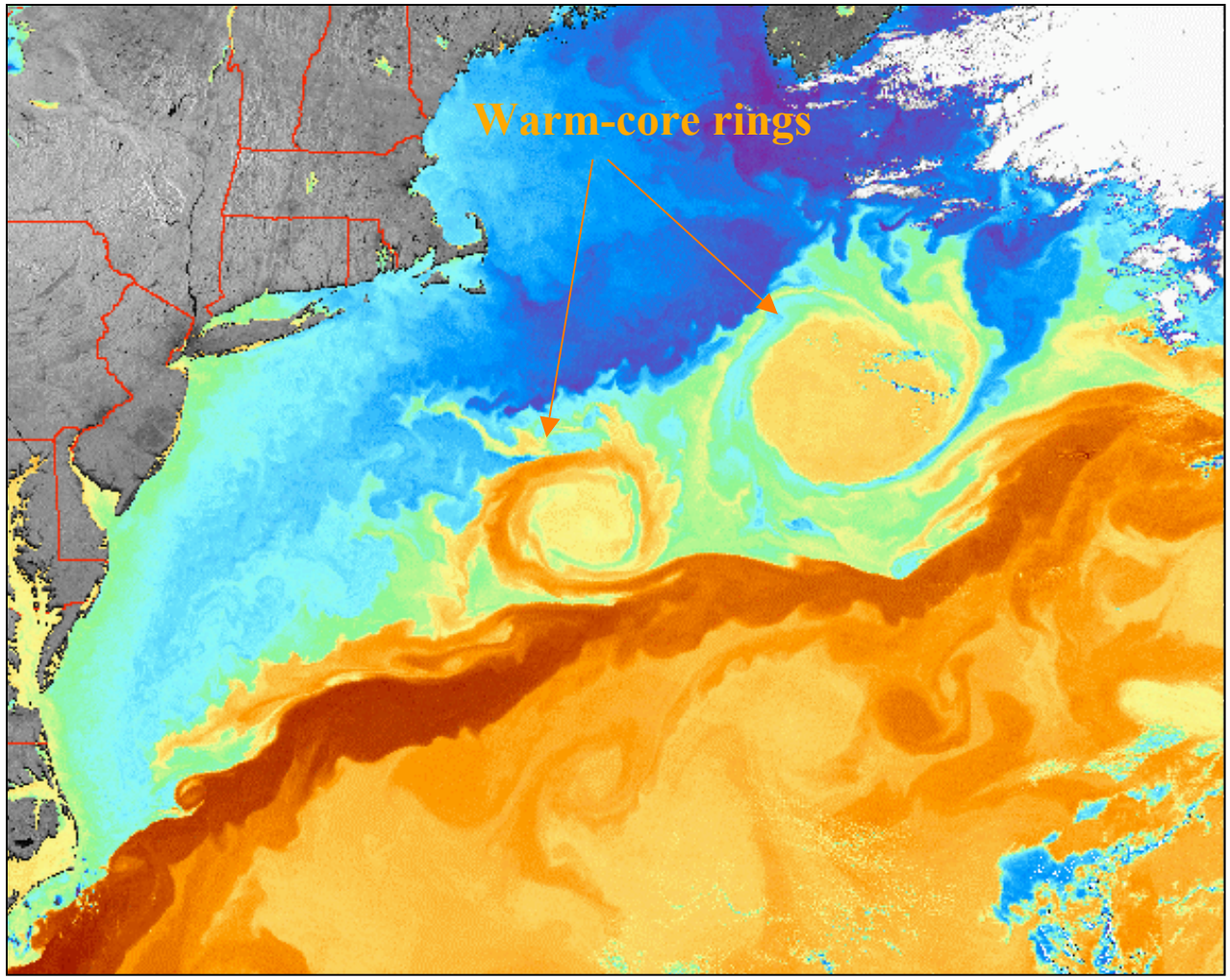
C. Chen

General Physical Oceanography

MAR 555

School for Marine Sciences and Technology

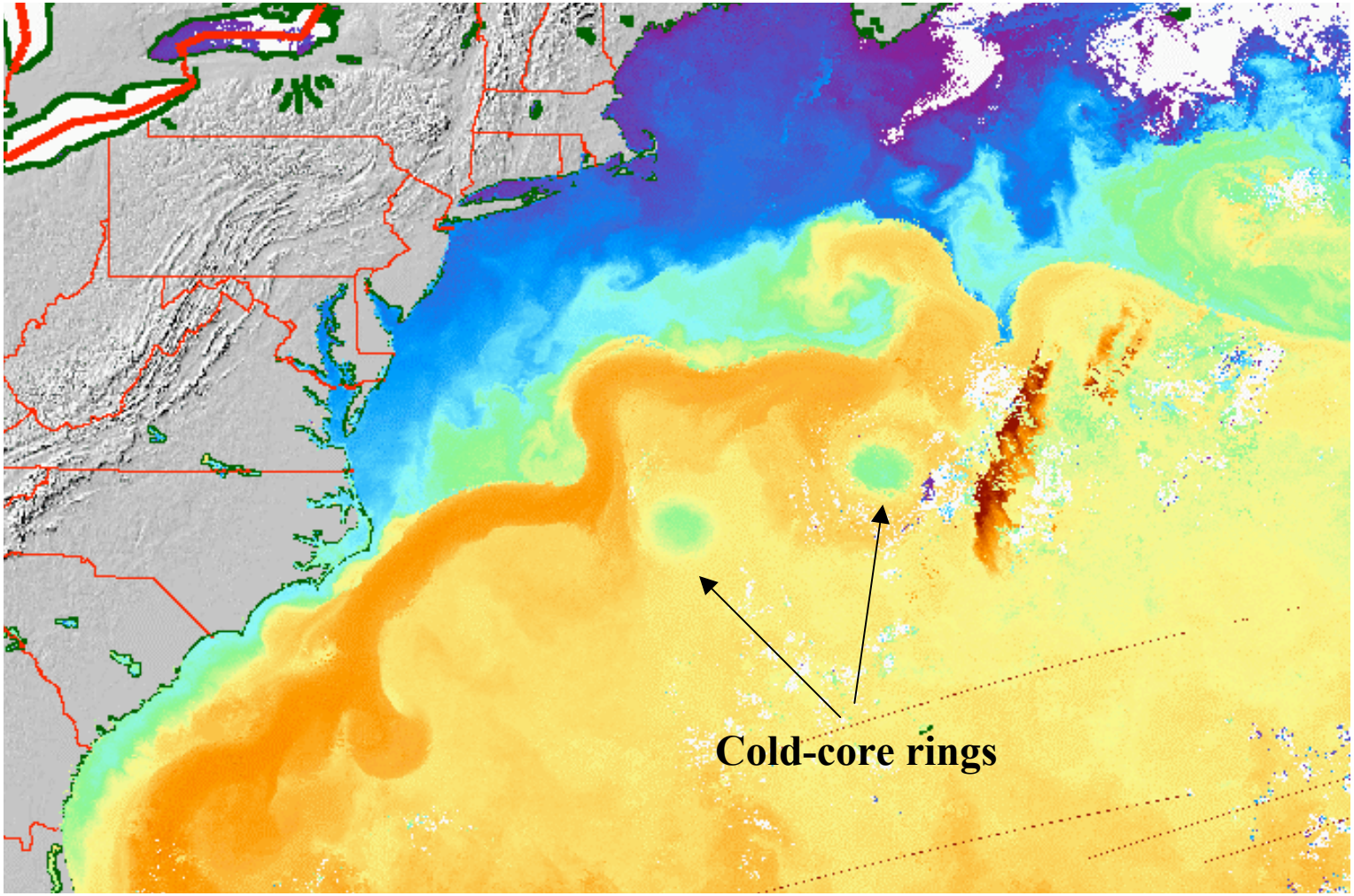
Umass-Dartmouth



http://fermi.jhuapl.edu/avhrr/gs/averages/index.html

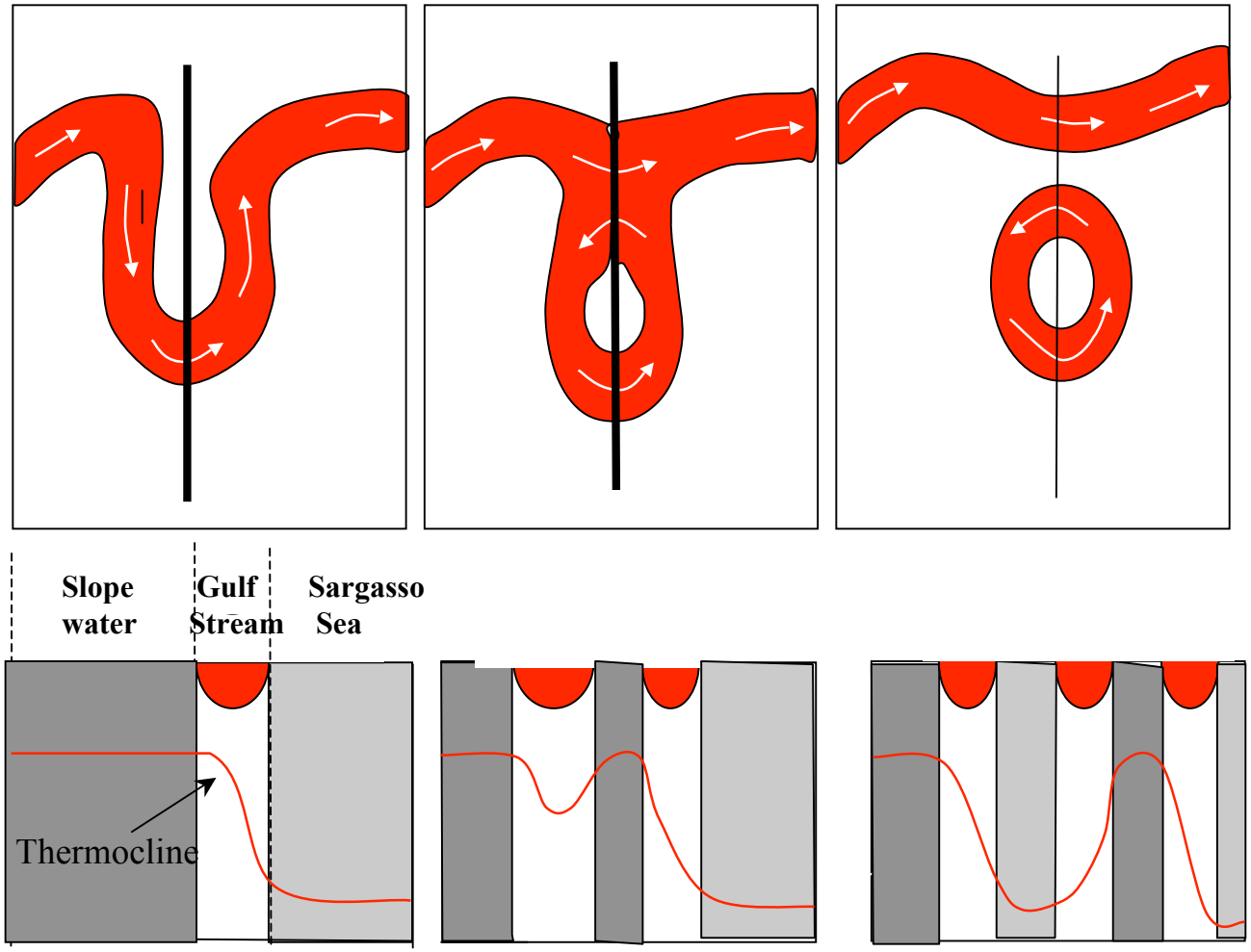
Mixed barotropic/baroclinic instabilities, bottom topography (seamounts)

March 6, 2008



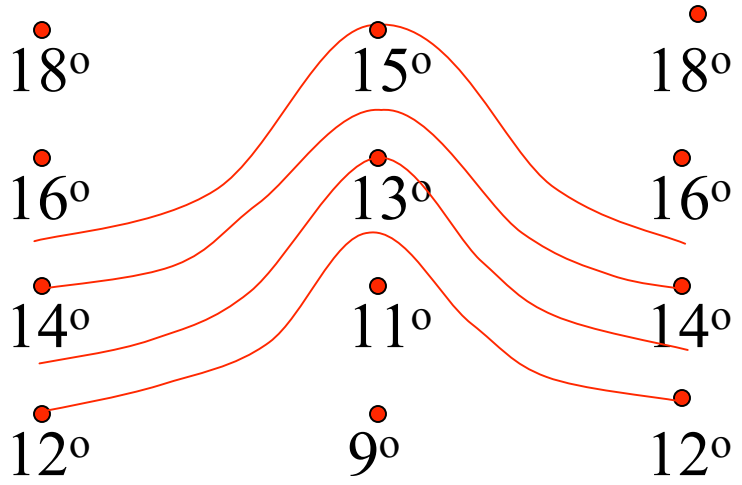
http://fermi.jhuapl.edu/avhrr/gs/averages/index.html

Formation of a cold-core ring

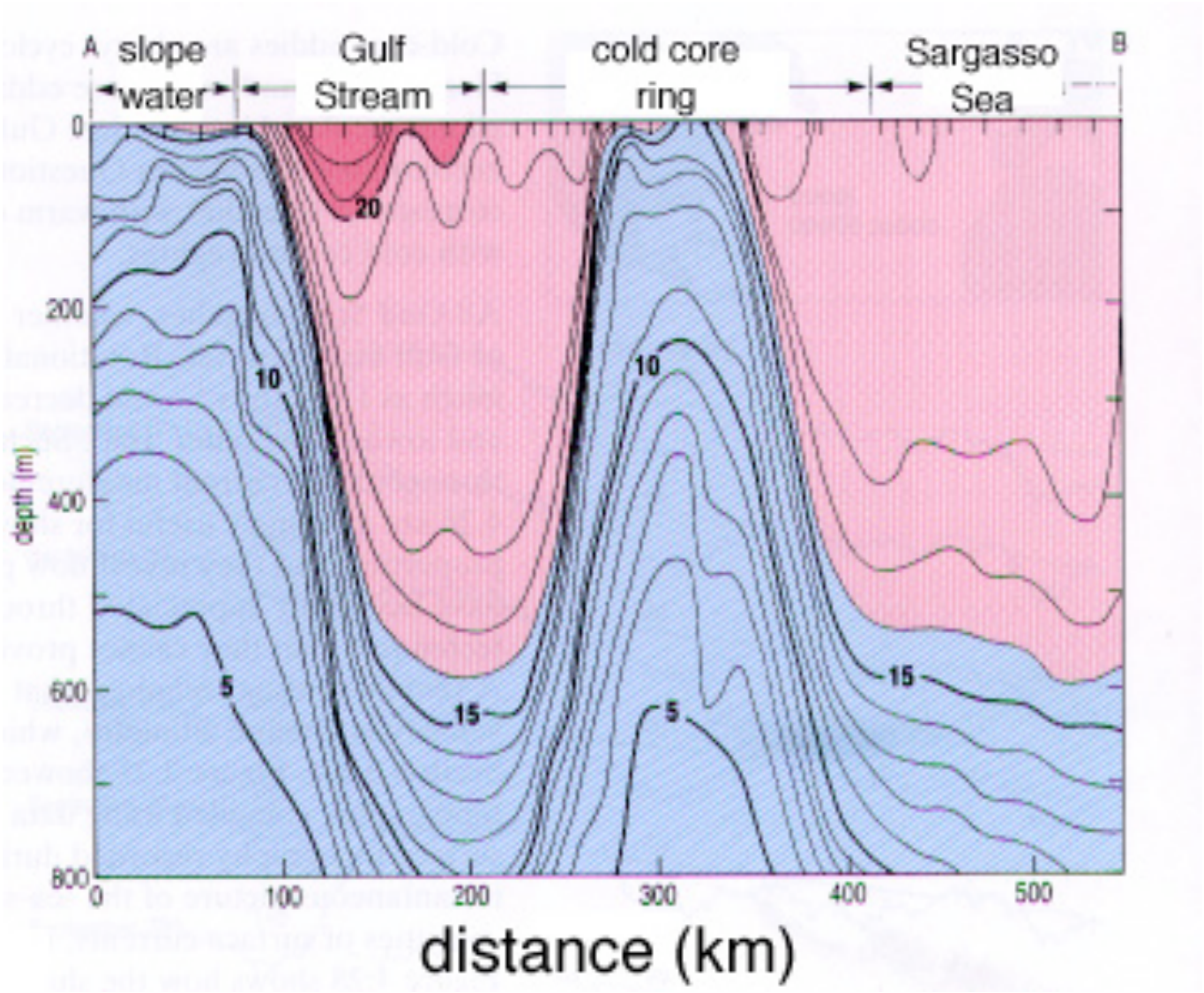


Southern meanders

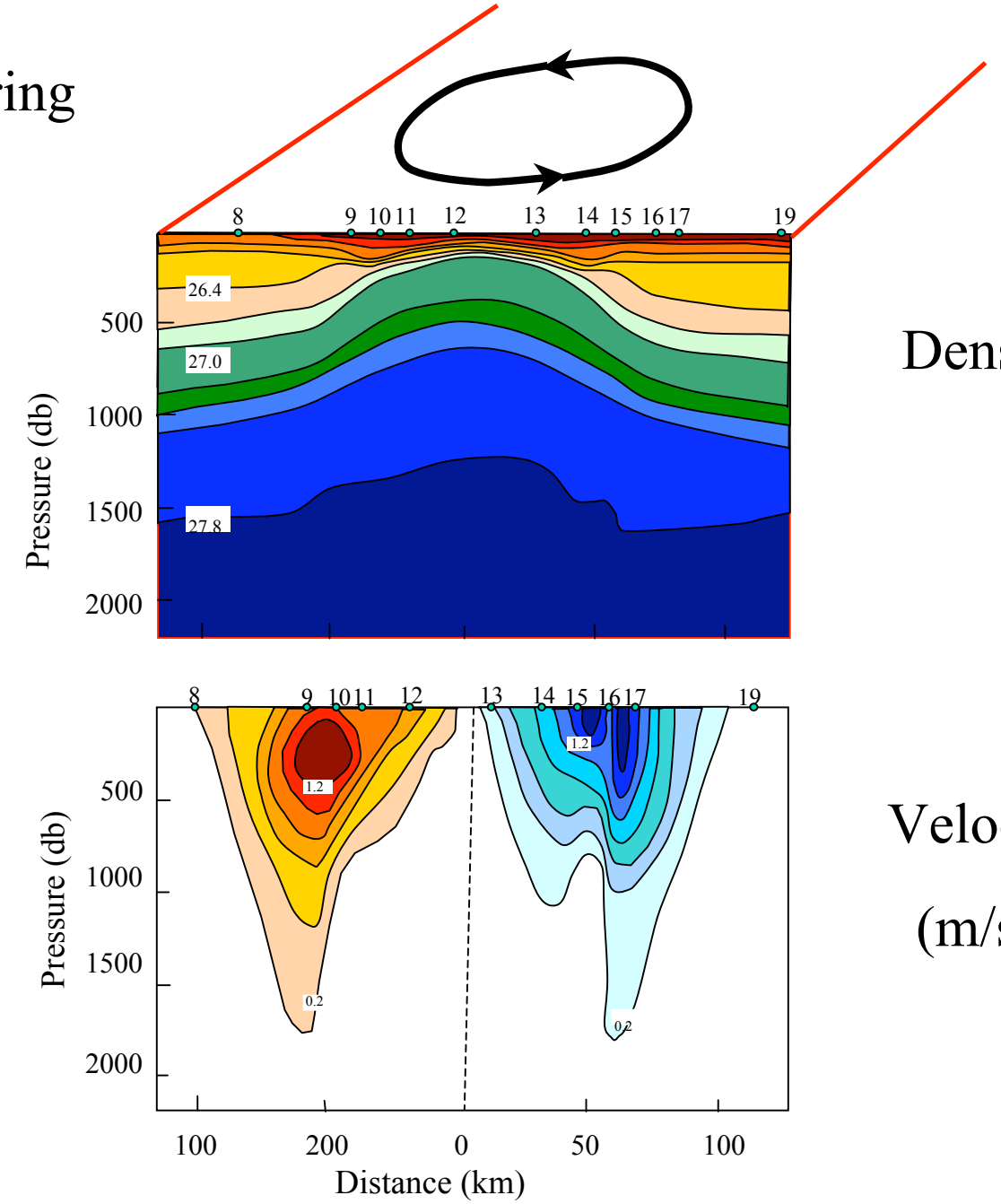
Explanation of the temperature profile across the cold-core ring



Like a “raised dome”!


A
slope water
Gulf Stream
cold core ring
Sargasso Sea
B
depth (m)
0
200
400
600
800
20
10
10
5
15
5
15
0
100
200
300
400
500
distance (km)

Cold-core ring



Density

Velocity

(m/s)

Property of Cold-Core Rings

Frequent Formation Region: 70^{o} W eastward, mostly in 60-70^{o} W, with a maximum number north of Bermuda near 65^{o}W

Only occurs on the southern side of the Gulf Stream

Shape: Elliptical, become nearly circular as it moves away from the Gulf Stream;

Size: 200~300 km (diameter),

Vertical Range: ~ 2000 m

Velocity: Cyclonic, 150 cm/s (near the surface)

Longevity: 1 year (up to 4 years)

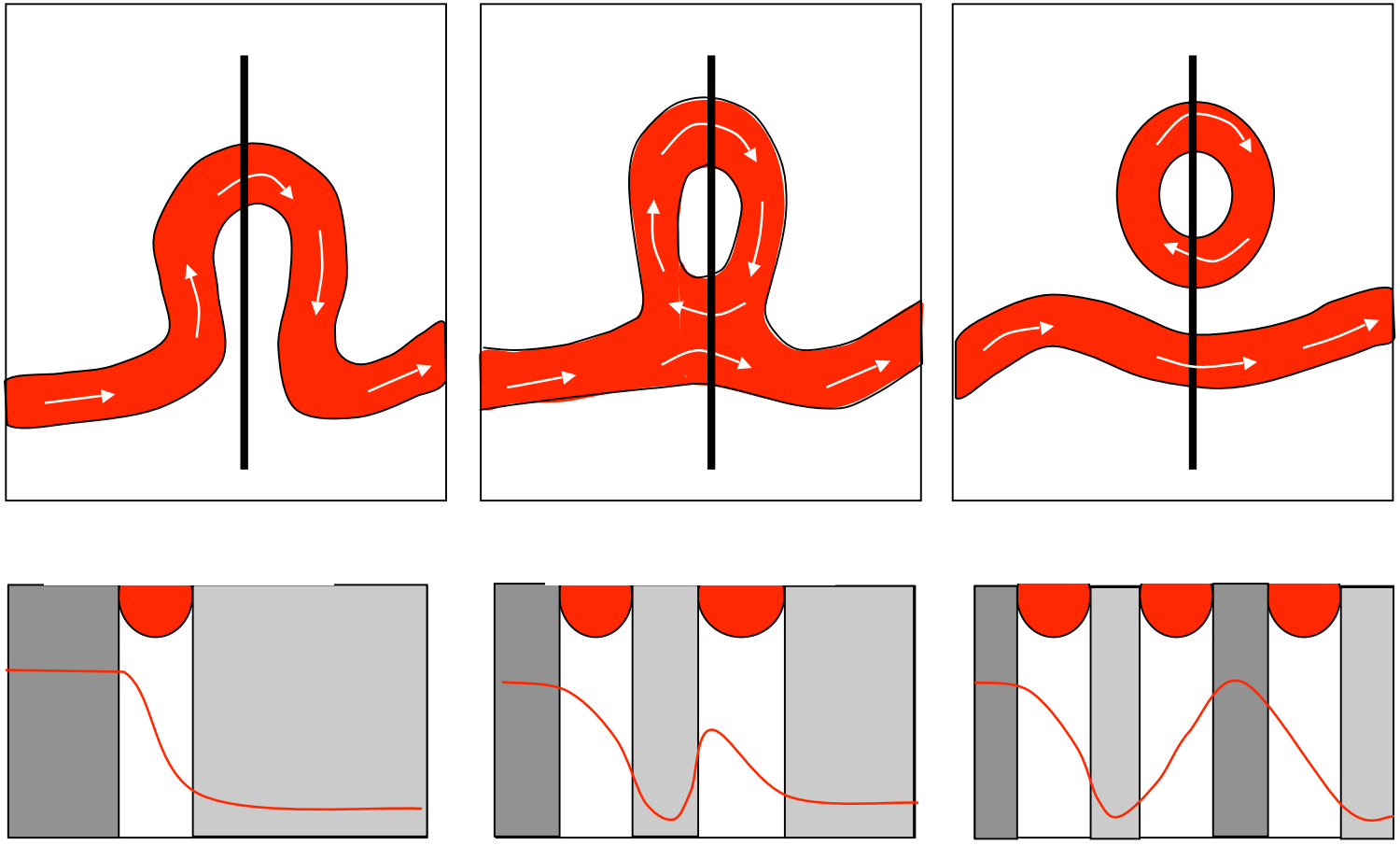
Transport: ~20 Sv

Distribution and Numbers: 5-8 per year, 10 co-existing at once time

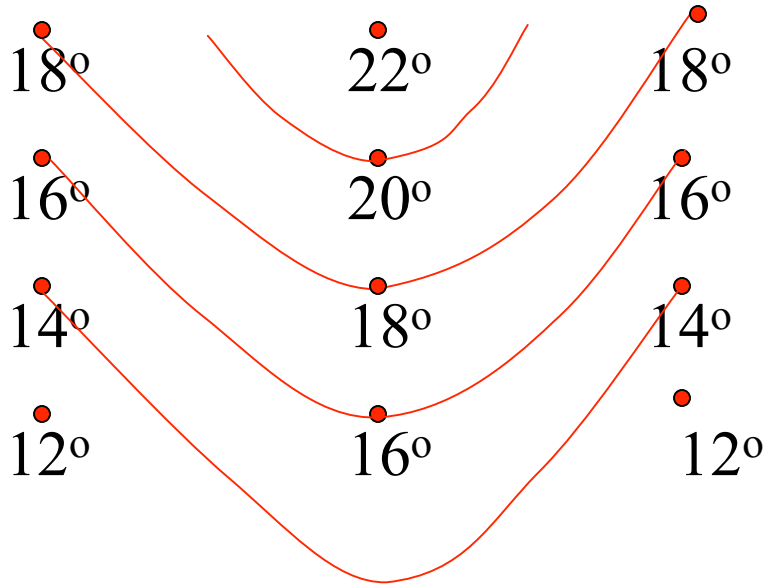
Surface height: Depressed (0.5 to 1 m)

Movement: Westward, with a mean speed of ~5 cm/s

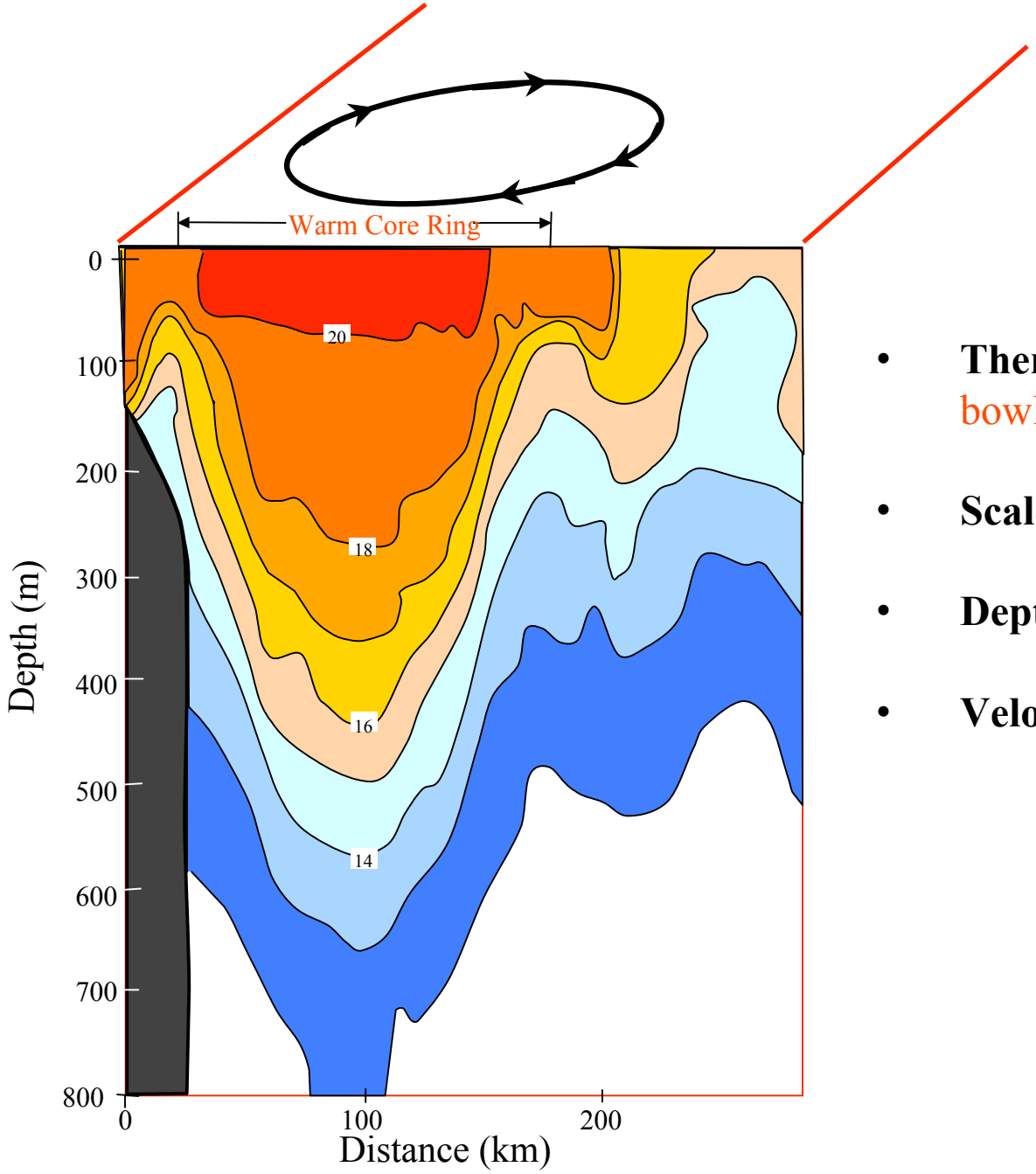
Formation of A Warm-Core Ring



Explanation of the temperature profile across the cold-core ring



Like a “bowl”!



- **Thermal shape**: Like a bowl
- **Scale**: ~130-150 km
- **Depth**: ~ 800 m
- **Velocity**: Clockwise

Properties of Warm-Core Rings

Frequent Formation Region: Northern side of the Gulf Stream: a triangular region bounded by the Gulf Stream to the south and by the continental slope to the north. Many occur east of Georges Bank

Shape: Not well-defined, spiral, elliptical or circular

Size: ~100 km (diameter): west of Georges Bank
~200-300 km: east of Georges Bank

Vertical Range: ~ local depth

Surface Height: Elevated

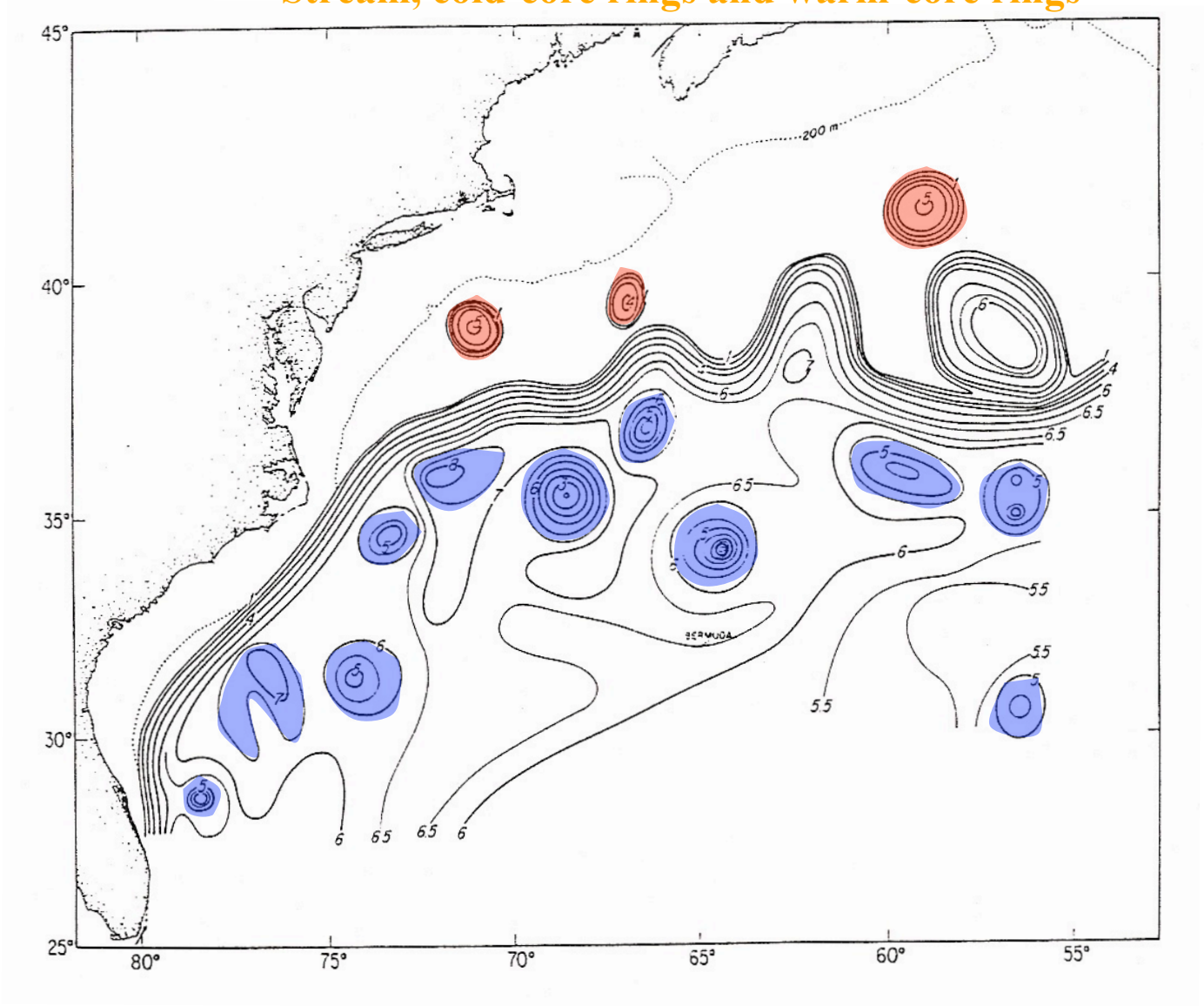
Velocity: Anticyclonic, 150 cm/s (near the surface) at 30 to 60 km from the center

Longevity: 6 months

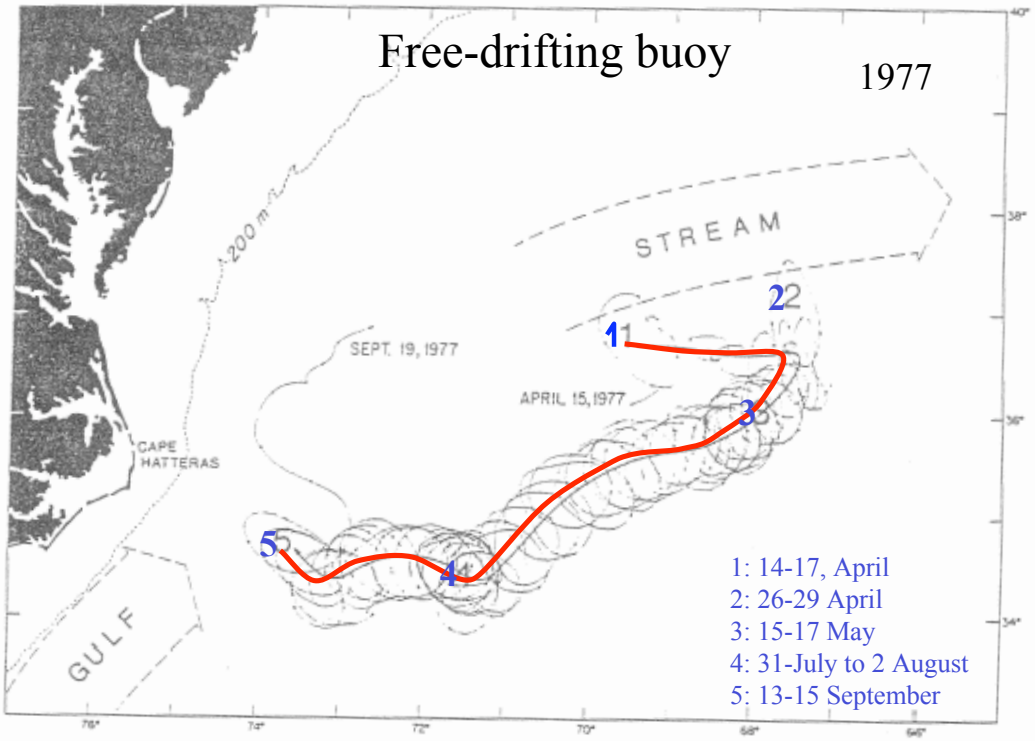
Distribution and Numbers: ~5 per year, ~3 co-existing simultaneously

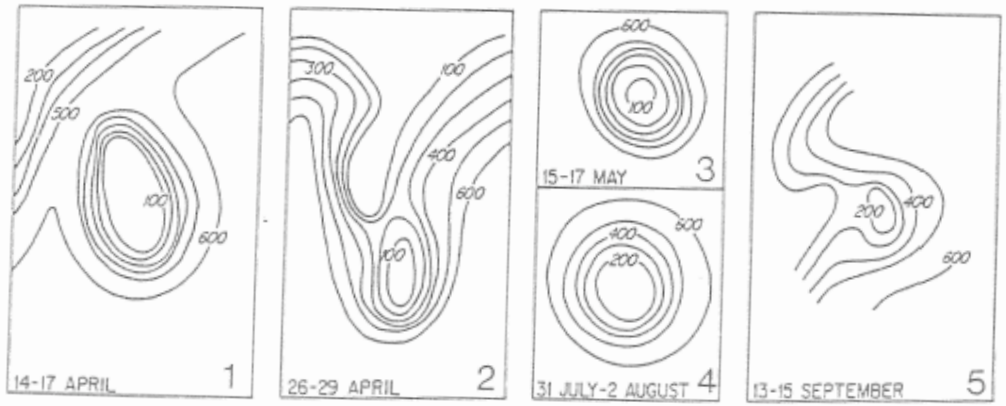
Movement: Westward

A chart of the topography of the 150 isothermal surface showing the Gulf Stream, cold-core rings and warm-core rings



Trajectories of Ring Bob in 1977

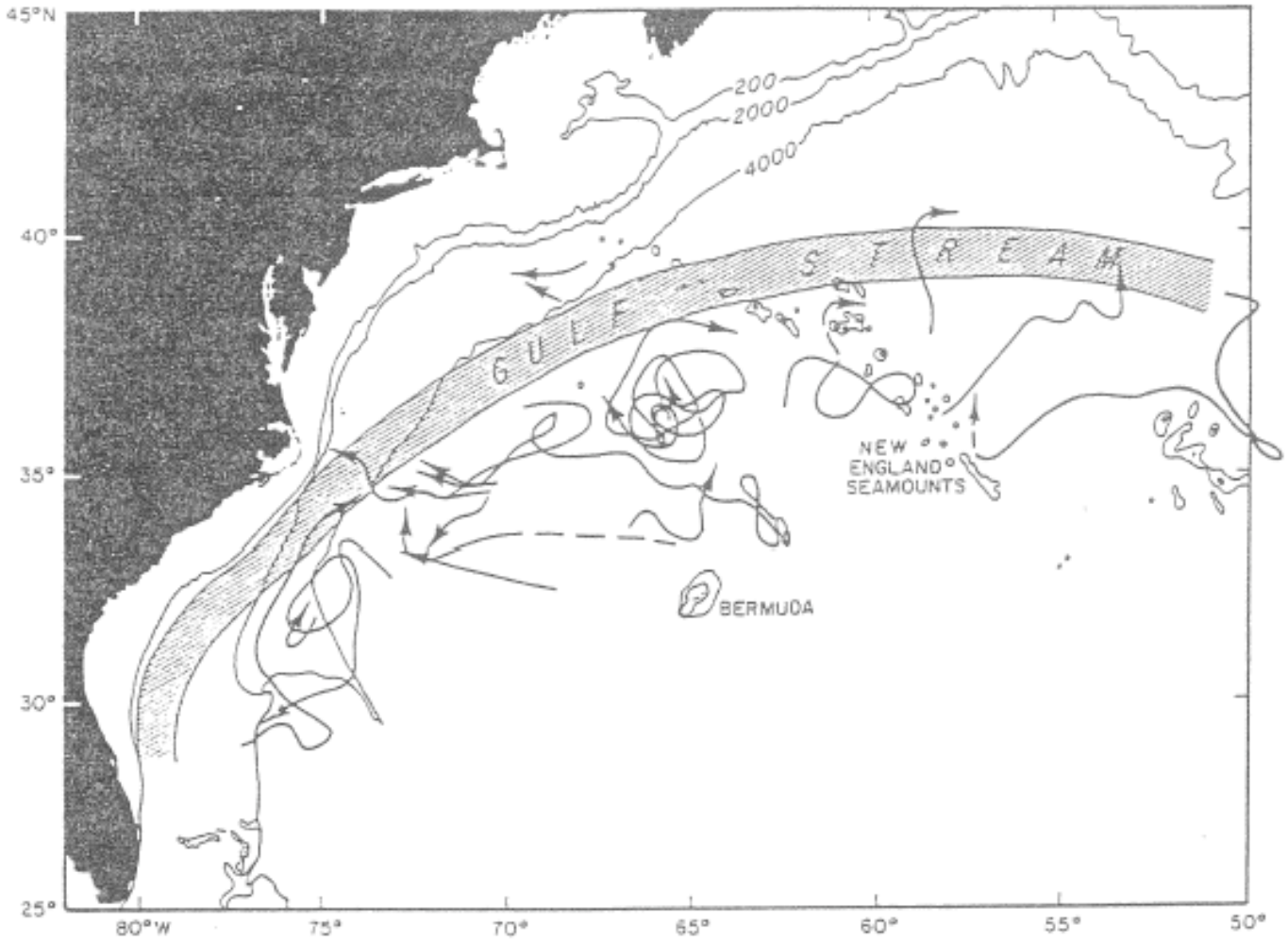




Trajectories of free-drifting buoy looping around Bob's core.

The depth of the 15° isotherm in Bob at select times during its life.

5 km/day, westward; 20 Sv



Discussion

QS 1: Why do all cold-core and warm-core rings move toward the west after they detach from the Gulf Stream?

QS 2: How could we estimate the transport of a ring when it enters the Gulf Stream?

QS 3: Why does a warm-core ring has a much shorter life than a core-cold ring?

QS 4: Is the ecosystem affected by rings?

Cold-core rings: colder water from the continental shelf with rich nutrients and abundant plankton species

↓ Move into the Sargasso Sea

Nutrient concentration, phytoplankton biomass and zooplankton abundance is relatively higher than the surrounding water

Because of the quasi-geostrophic flow field with weak water exchange with surrounding water, surfaces of nutrients and density are overlapped, rising up! Be aware that the density field is conservative, but nutrients and phytoplankton fields are not! Phytoplankton will tend to sink and food web cycling makes the biological field more complicated.

Spring: chl-a concentration has a maximum at a depth of 20 m below surface: 4 μg/L, which is 40 times larger than that found in the Sarggaso Sea (0.4 μg/L);

Spring-summer: the near-surface temperature increases in cold-core rings, larger phytoplankton species decrease in abundance, while small phytoplankton species increase.

Summer: maximum chl-a concentration sinks to 80 m, its value decreases to 0.6 μg/L, caused by mixing with surrounding water, thermoclines limit the upward nutrient supplies, leading to larger phytoplankton's rapid death.

Zooplankton in a cold-core ring originally come from the outer shelf, where species favor relatively cold water. When the temperature begins to increase due to solar radiation exchange with the Sargasso Sea, these animals migrate to deeper waters. Zooplankton in the Sargasso generally are in the upper 100 m, but in a cold-core ring can be found at 800 m. However, moving to depth can reduce the ability to respire, which reduces the ability to produce eggs, etc. If they are not able to find enough nutrients at depth they can die after ~17 months.

Warm-core rings: come from the biological desert , characterized by lower nutrients and plankton biomass

Moves onto the slope

Interaction with the slope can cause upwelling, which can advect the high nutrient water from the deep region to the euphotic layer near the surface. As a result, the chl-a concentration near the surface of a warm-core ring is higher than surrounding water.

Zooplankton in warm-core rings are directly related to water exchanges with the shelf water due to interaction with the slope and friction as well as mixing due to surface cooling. When a warm-core ring forms, it is characterized by low phytoplankton and zooplankton biomass. As it moves onto the slope, shelf phytoplankton and zooplankton species are wrapped into the ring, leading to a significant increase of phytoplankton and zooplankton biomass.

Importance:

A warm-core ring's horizontal scale is 100-300 km, which can include 20-30 Sv of water. Although it only lasts for 6 months, it represents a significant source of nutrients to the euphotic layer at the shelf break.