SIOC 210
Problem Set 3 (start)
Oct. 31, 2019, due Nov. 19

First 2 problems, useful for studying for mid-term exam.
I'm handing out answers. The actual problem set will have questions very similar to these.

There will be several additional problems in the actual problem set.

1. (a) On the attached potential temperature section, from the North Pacific at 24°N, indicate the direction of the near-surface flow (upper 100 m) at the western end of the section, that is, in the Kuroshio.
Assume it is geostrophic. Explain how you know the direction of the current given the temperature section. Note that this is a VERY narrow feature.
In a very narrow spot next to the western boundary, the isotherms have strong slope upward towards the boundary. That is the Kuroshio.
Explanation is as in class for geostrophic flow: isopycnals mirror isotherms on this section.
Sloping isotherms indicate that there is vertical shear.
Note that we cannot tell from this plot whether the sea surface has a tilt or not. The sea surface tilt completely determines the geostrophic flow at the sea surface.

The slope of the isotherms indicates that there is dense water to the west (inshore) and lighter water to the east (offshore).
If the sea surface were flat, then there would be zero geostrophic flow at the sea surface, and the flow would become more and more westward with depth.

However, we know from very long experience and measurements, that the surface flow is northward and very fast. Therefore the sea surface has a tilt, from low to the west and high to the east of the current.
The sloping isotherms then compensate this and reduce the northward flow. That is the sloping isotherms on their own would make southward flow, which is subtracted from the fast northward flow.

(b) Sketch the expected sea surface height above this current. (Ignore the large eddies that are east of about 150°E).
I expanded the west side of the plot, labeled the Kuroshio, and sketched the sea surface height above it. It should be drawn as a mirror image of the near-surface isotherms: rising quickly above the Kuroshio, and then rising more slowly to the 'bowl' just offshore of the Kuroshio.

(c) Look at the isotherm slopes beneath this surface flow, down to 2000 m depth. Describe what they look like.
In the narrow western boundary current region, they slope steeply down to the right (offshore).
One could describe more of the slopes farther offshore, but Ive only asked for the Kuroshio band itself.

Sketch the change in the geostrophic current (Kuroshio) with depth (vertical shear in the geostrophic current), on the vertical section, using our conventional icons for arrows either along the page or in and out of the page.
See circles with x's on the plot.

Source of figure: http://whp-atlas.ucsd.edu/pacific/p02/sections/printatlas/printatlas.htm

2. On the attached salinity section (from DPO 6th chapter 4):
(a) Label the "4 layers" (schematically)

(b) Label the major water masses based on our class examples.

Choose 2 of the water masses from (b). I'll list them all here.
(c) How do you identify each of the two water masses you've chosen?
STUW: subsurface salinity maximum
Central: more recognizable on temperature plot: thermocline
AAIW: salinity minimum in Southern Hemisphere
MOW: salinity maximum in N. Atlantic at Strait of Gibraltar latitude
LSW: salinity minimum in northern N. Atlantic
NADW: salinity maximum in the deep layer
AABW: fresher than NADW.

(d) What is the formation history of the two water masses you've chosen?
Note that for this mid-term exam, you will not be expected to know all of this detail.
I have written two points for each water mass: (i) process at its source, and (ii) spreading (advection) process that creates the extreme property that we use to identify it.
STUW:

1) high **evaporation** in subtropical gyres with
2) equatorward subduction into less saline waters, forming the salinity maximum

Central Water:
subduction of surface waters of densities that increase with increasing latitude
no extreme property except that it is the
AAIW:

1) cooling and **freshening** of surface water in the northern part and north of the ACC, with coldest, freshest water just west of Drake Passage
2) subduction to the north in all three oceans, forming a salinity minimum.

MOW:
high **evaporation** and cooling inside the Mediterranean cause convection to great depth (1000 m to bottom depending on location)
water flows out at bottom of Strait of Gibraltar, and sinks and spreads out through the mid-latitude N. Atlantic, forming a salinity maximum
LSW:

dense, relatively cold and **fresh** surface water in Labrador Sea convects to great depth (1000 to 1500 m)
spreads through the subpolar gyre of the N. Atlantic and southward along the western boundary of the N. Atlantic, forming a salinity minimum.
NADW:

1) dense, very cold water in the Nordic Seas (north of Iceland) convects to great depth
2) flows south into N. Atlantic across the sills, and sinks to the bottom of the N. Atlantic, spreads southward along the western boundary of the N. Atlantic, beneath the LSW.

We will discuss later in course why it is a salinity maximum (created from more saline surface waters than either AAIW or AABW), and why it is not as cold as AABW
AABW:

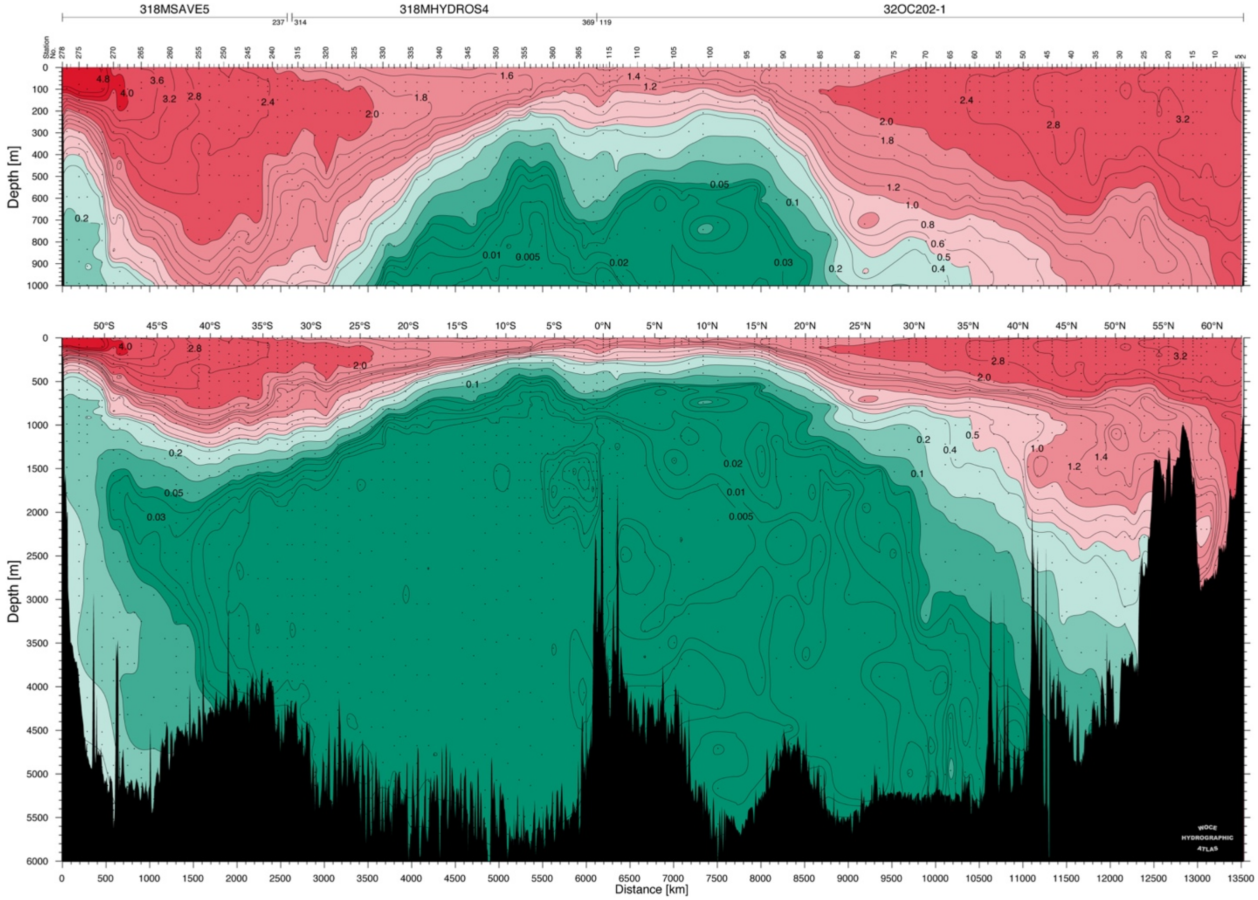
1) very cold, brine-rejected waters from sea ice formation sink to bottom around Antarctic
2) spreads northward at bottom, colder than all other waters

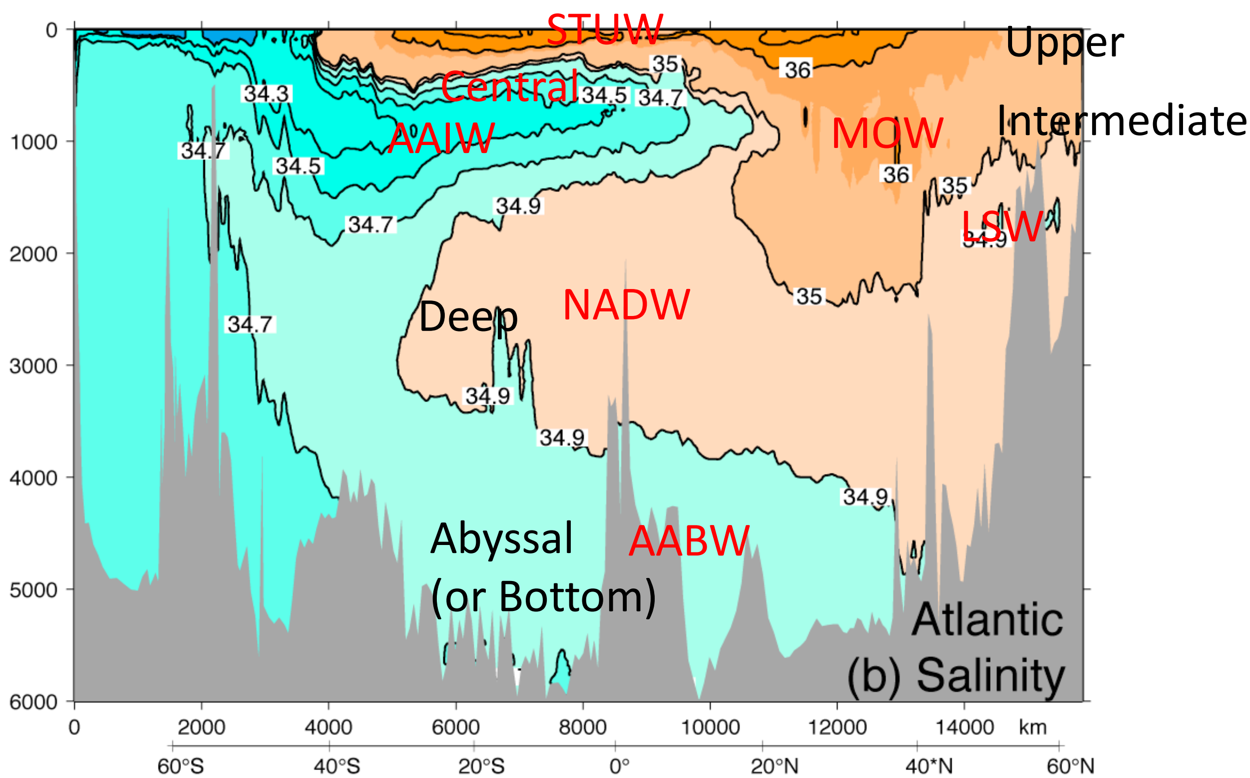
(e) Look up a chlorofluorocarbon section that corresponds to the salinity section. Describe its main features in terms of the water masses. The Atlantic hydrographic atlas is located at http://whp-atlas.ucsd.edu/atlantic_index.html. The salinity section in this problem is from section "A16".

For the homework answer I've included the CFC section, from http://whp-atlas.ucsd.edu/atlantic/a16/sections/printatlas/A16_CFC-11.jpg
To interpret a CFC distribution, the important fact is that all CFCs have entered the ocean within the last 60 or so years (call it 60 years for this problem), and so any water with CFCs includes a component that is younger than that. Water with no CFCs is older than this.
Some principal features (this answer can be wide-ranging):

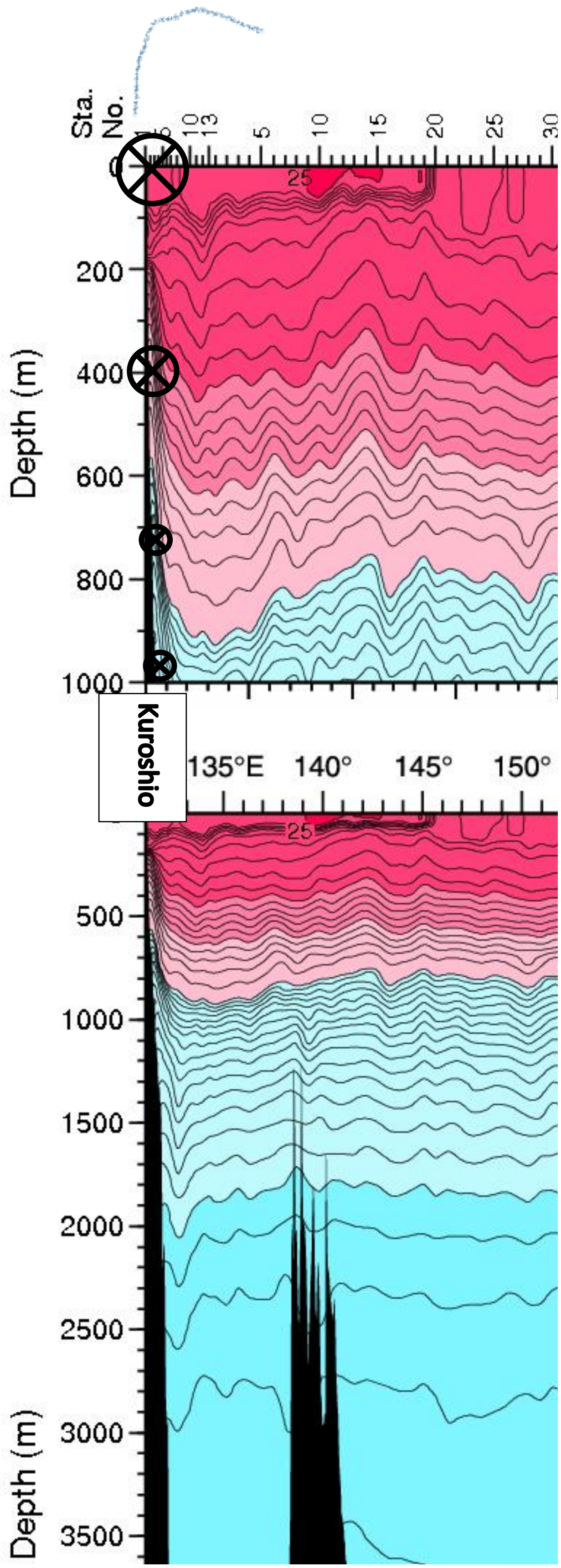
- CFCs are high (magentas) in the upper ocean and thermocline, corresponding to all of the subducted water masses mentioned above (within the STUW, Central Water).
- CFCs are absent in the deep and bottom water layer of the S. Atlantic, indicating that the timescale for NADW and AABW to reach this region is longer than 60 years.
- CFCs are relatively high in the LSW layer of the northern N. Atlantic, indicating young age
- CFCs are present in the deeper waters beneath the LSW, indicating that some portion of the overflow from the Nordic Seas is younger than 60 years; this is part of the source of NADW.
- CFCs are present in the AABW in the Southern Ocean.

CFC-11 [pM/kg] for A16 25° W





STUW
Upper
Central
Intermediate
AAIW
MOW
LSW
Deep
NADW
Abyssal
(or Bottom)
AABW
Atlantic
(b) Salinity
34.3
34.5
34.7
34.9
35
36
0
1000
2000
3000
4000
5000
6000
0
2000
4000
6000
8000
10000
12000
14000
km
60°S
40°S
20°S
0°
20°N
40*N
60°N


Sta. No.
10
13
5
10
15
20
25
30
0
25
200
400
600
800
1000
Depth (m)
Kuroshio
135°E
140°
145°
150°
500
1000
1500
2000
2500
3000
3500
Depth (m)

v