Field Work (2004) Summary for Heat Budget of Thermal Plume in Mt. Hope Bay

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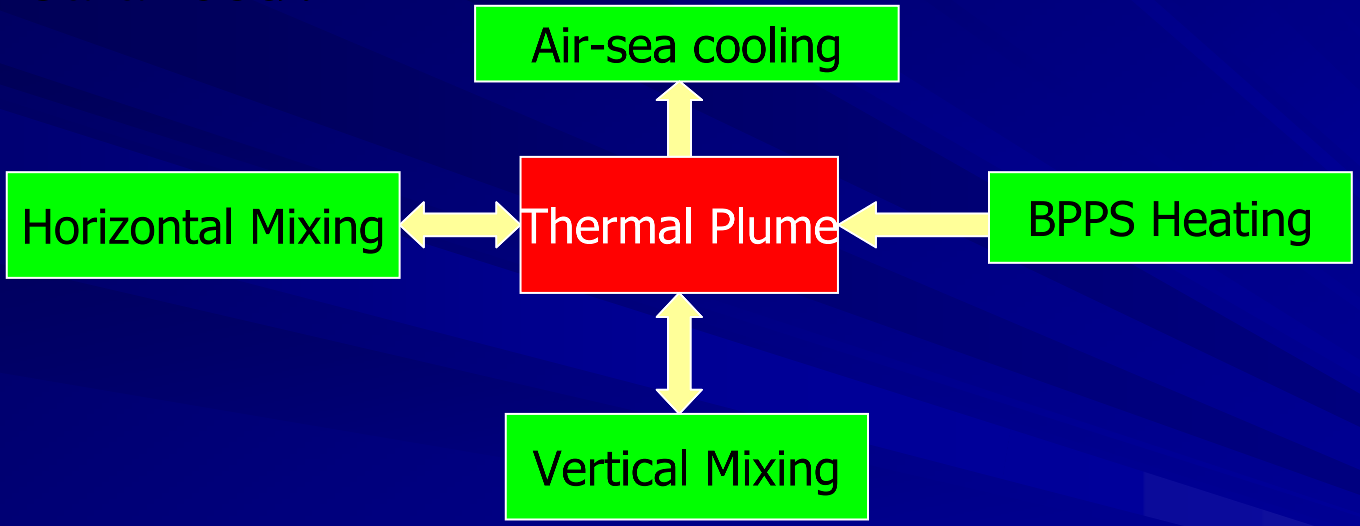
Questions:

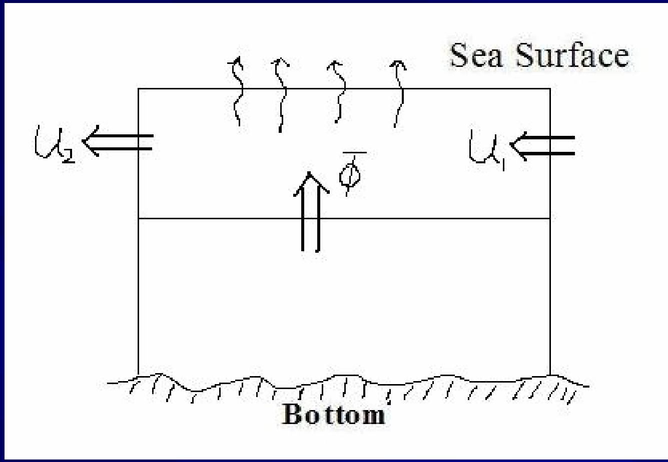
- Where does the heat coming out from the power plant discharge go?
- How are the different terms involved in heat flux balanced?



This is an sketch of the heat balance in the near field of the Brayton Point Power Station (BPPS) thermal plume. A continuous supply of heat is input into the plume by BPPS. Within MHB, a portion of the heat is lost to the air while some of it spreads into surrounding waters through horizontal and vertical mixing. An understanding of these processes is crucial for evaluating the impact of the thermal plume on the physical environment of MHB.

The control volume analysis (CVA) (MacDonald and Geyer, 2004) is chosen as the approach to study the heat budget of the BPPS thermal plume :

Case in MHB



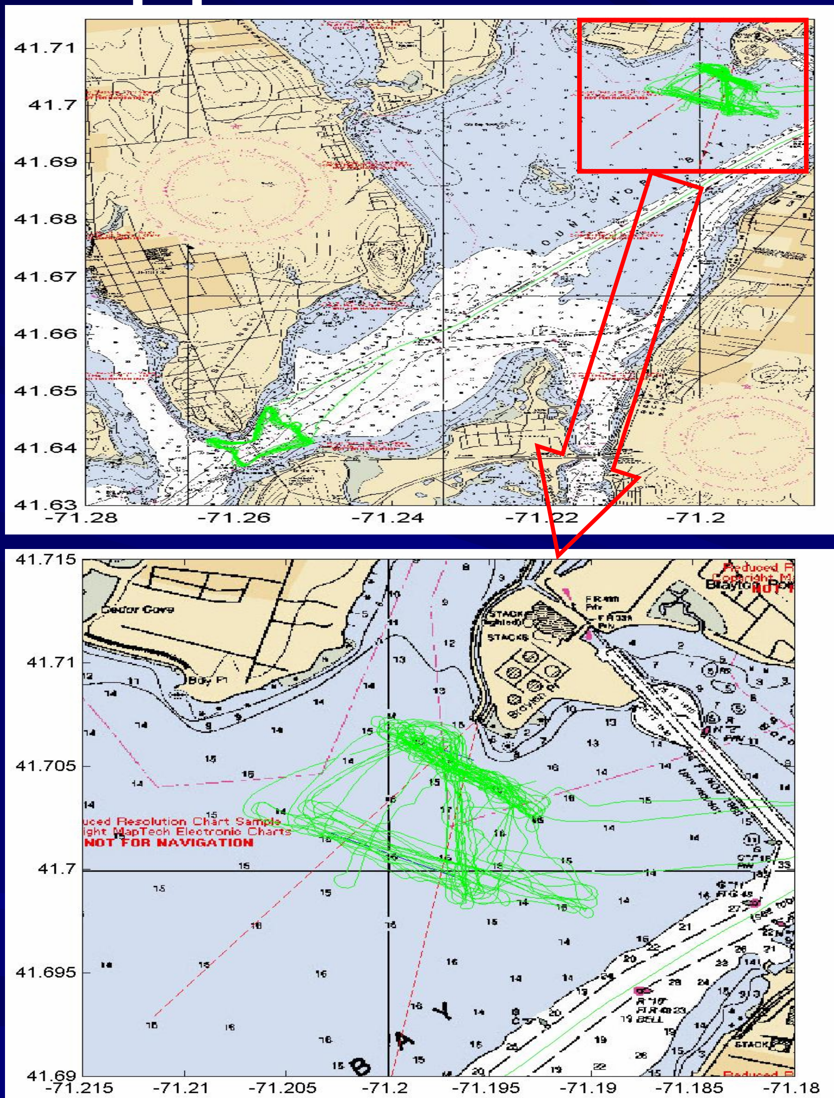
A cartoon of the CVA approach. The box above represents a 3-D control volume (picture the box also extending in and out of the screen). In this case, the BPPS discharge is located to the right, and the plume velocities are carrying heated water to the left. Assuming there is no heat exchange between water with the bottom, we can calculate the rate at which heat is lost to air as the difference in total heat flux across the two ends of the control volume. Mixing rates can also be evaluated in a similar way.

Therefore, in order to calculate the heat flux through air-sea interface and the plume mixing rate, we need :

- *Temperature*
- *Salinity;*
- *Velocity;*
- *Depth;*
- *Weather data;*

We sampled along two transects near the discharge: Transect 1 is 200m away from the BPPS discharge, and Transect 2 is 900m away from the BPPS discharge.

Application of CVA to BPPS plume



Maps of MHB. Green lines are the ship track for three-day field work (Sep07,2004~Sep09,2004).

Daily Sampling Plans:

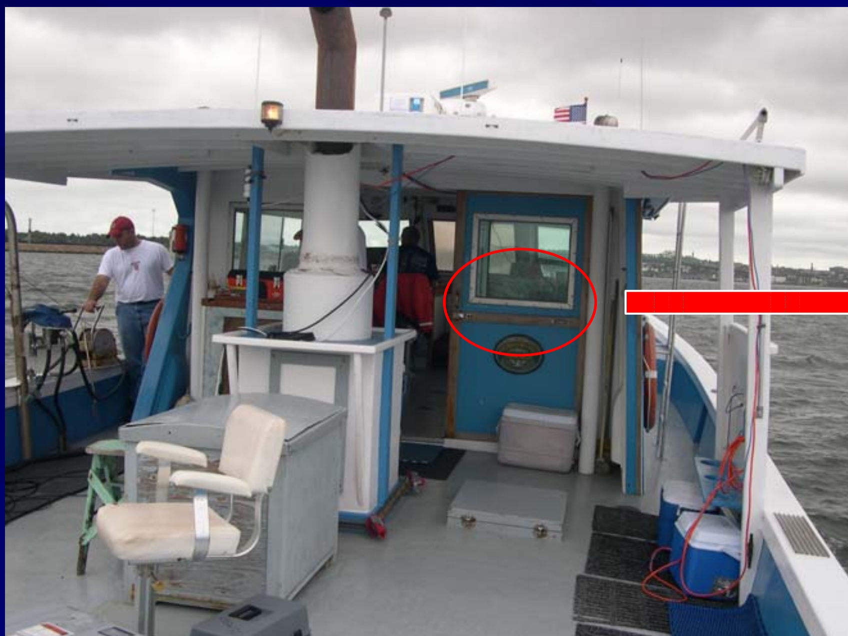
Day 1: 19 passes on trasect1; 18 passes on transect2, from 07:00~15:00 (low tide to high tide) ;

Day 2: 16 cycles on two transects beside the passage under Mt. Hope Bay Bridge, from 07:00~18:00 (08:59 low tide, and 16:33 high tide);

Day 3: 15 passes on transect1, 14 passes along the centerline of plumes, from 07:20~13:30 (10:17 low tide, and 17:27 high tide);

Data collected includes: *temperature, salinity, velocity, depth and GPS data for all the passes we worked on.*

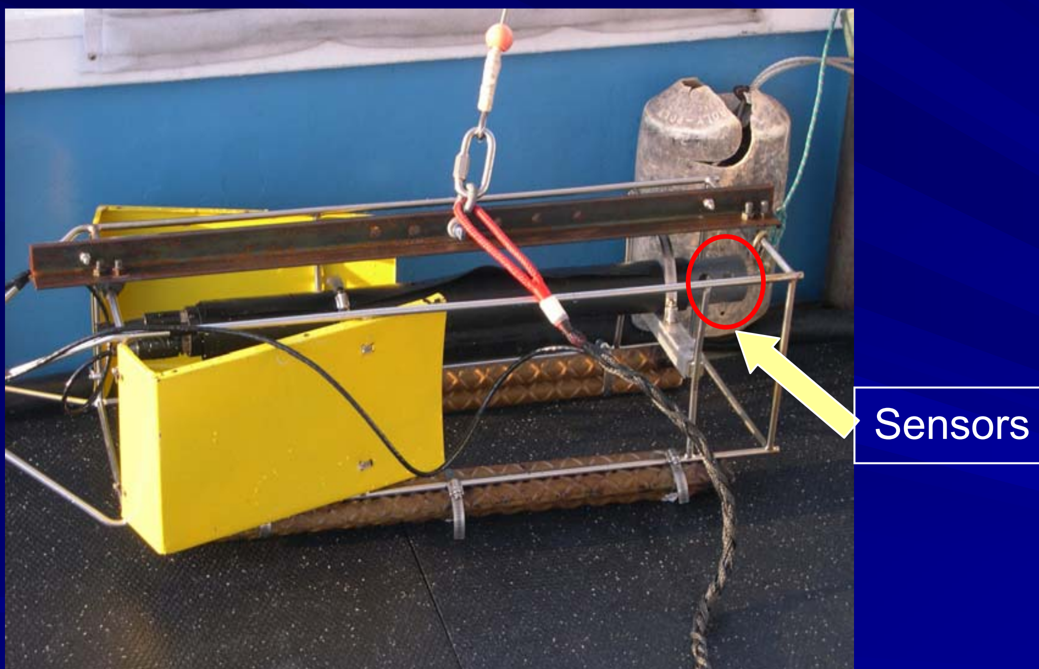
Ship (R/V Lucky Lady) and Work space



We had three laptops set up inside the cabin, with which we can get the real time data from our three instruments, CTD, ADCP and GPS.

Instruments:

1. Conductivity Temperature Depth instrument (CTD), which measures temperature, salinity and depth data.



The sample frequency of CTD is 6Hz.

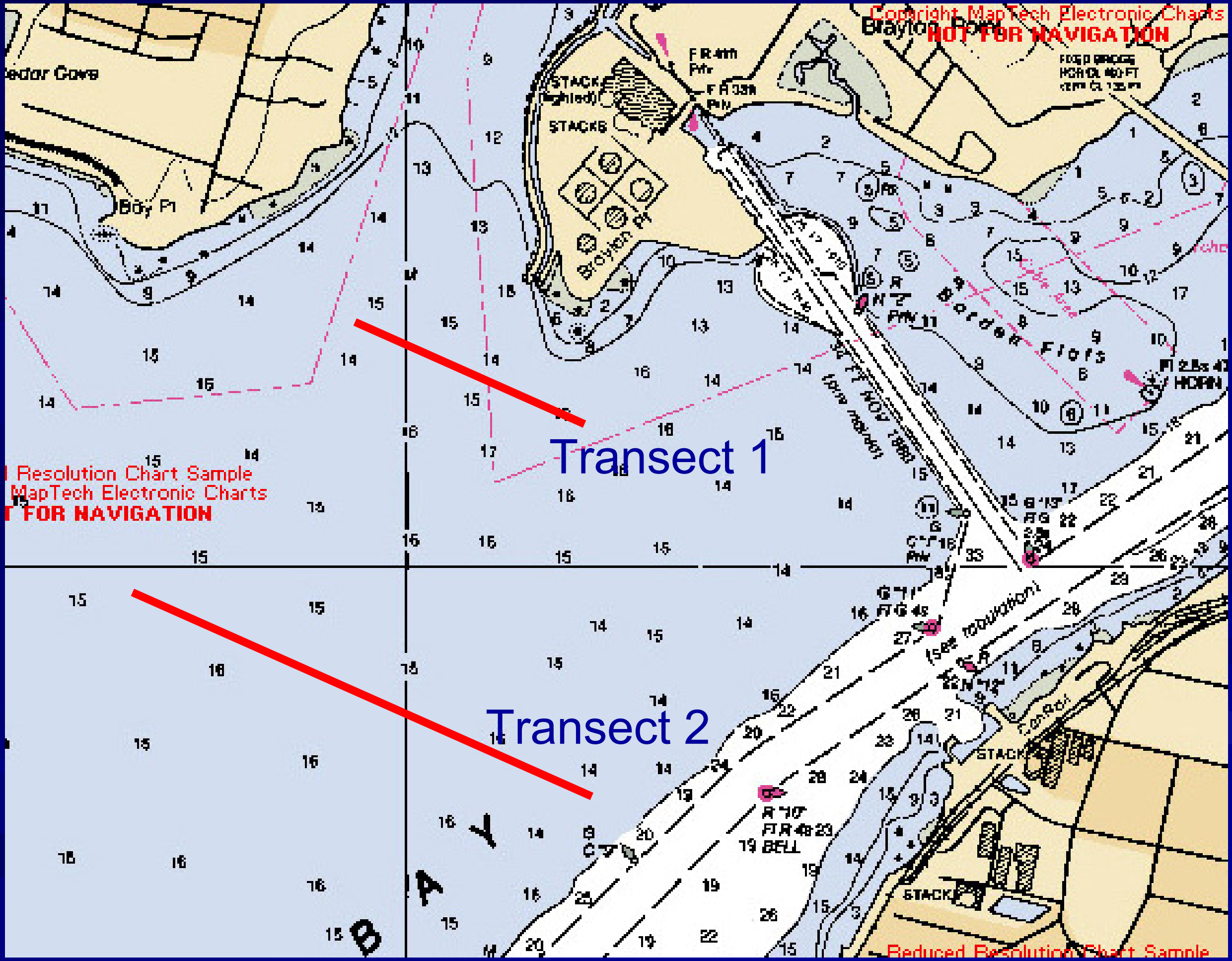
2. Acoustic Doppler Current Profiler(ADCP), which measures current velocity.

The ADCP is mounted on the starboard side, looking downward.

The bin size used was 25 cm in the plume, 50 cm in the passage under the MHB Bridge. The ensemble time is 15 seconds.

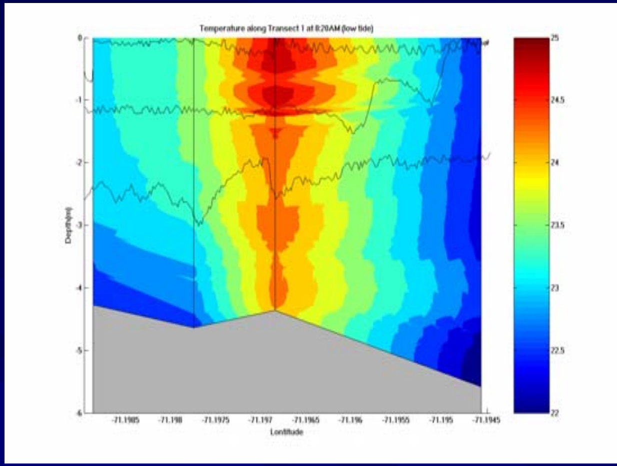
Lateral Plume Transects

See Next Two Slides for Preliminary Data

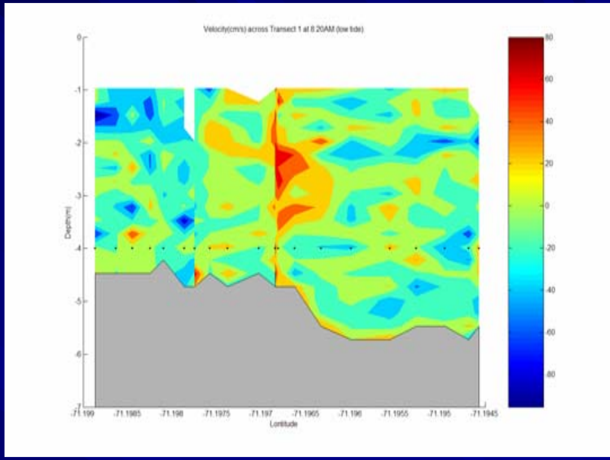


NOTE: Transect locations approximate

Preliminary Data Analysis
Temperature (left) and Velocity (right) at transect1 (upper) and transect2 (lower), at low tide

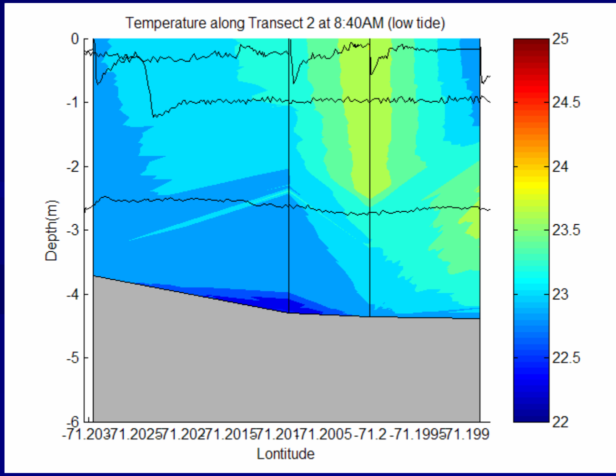


Black lines are CTD tracks, in which we have four vertical casts and three horizontal tows. The plume is attached at the narrow center from surface to bottom. Maximum temperature difference is 2~3 degrees.

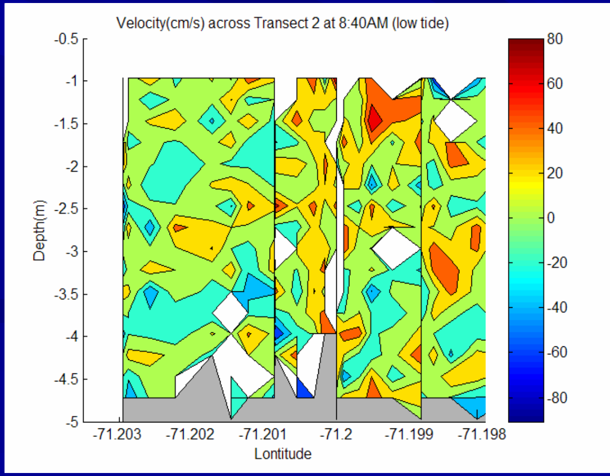


200 m

Red colors represent velocity away from BPPS, and blue colors represent velocity toward BPPS. In this figure, the maximum velocity of plume is at mid-depth. This data is visibly “noisy” and will need to be averaged further prior to detailed analyses.



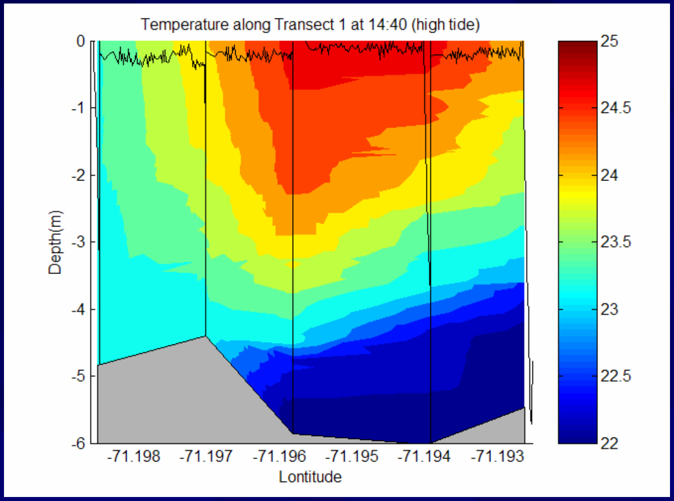
At Transect 2, the maximum difference decreases to 1.5 degrees. And the plume has separated from the bottom.



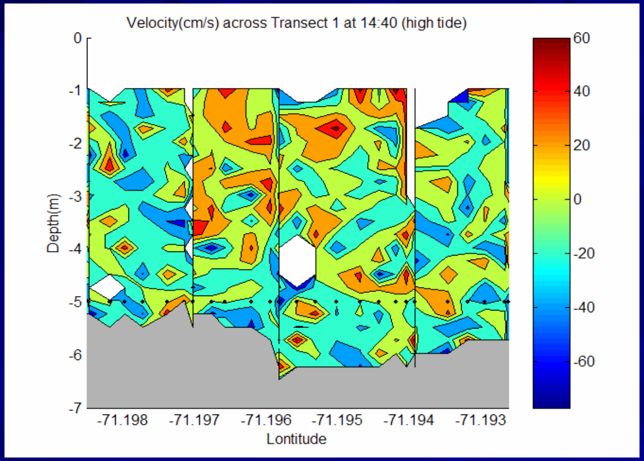
900 m

Maximum velocity is at top 2 meters at transect 2.

Temperature (right) and velocity (left) at transects perpendicular to thermal plume at high tide

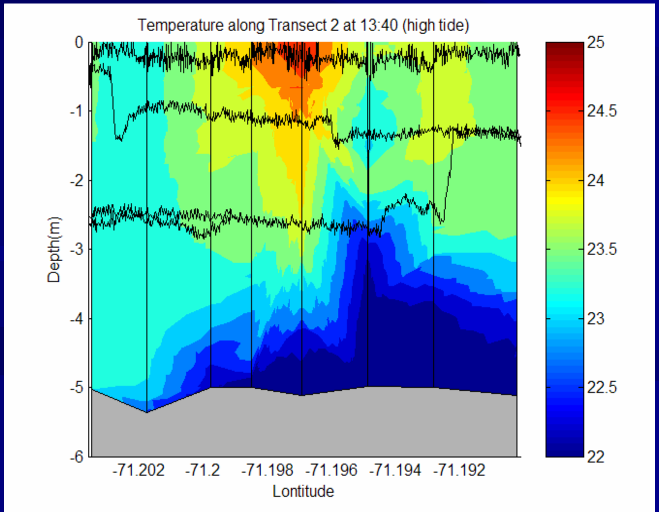


At high tide, the plume is pushed northward, widening and detaching from the bottom closer to BPPS Note the ‘cold’ water (relative to plume) at bottom.

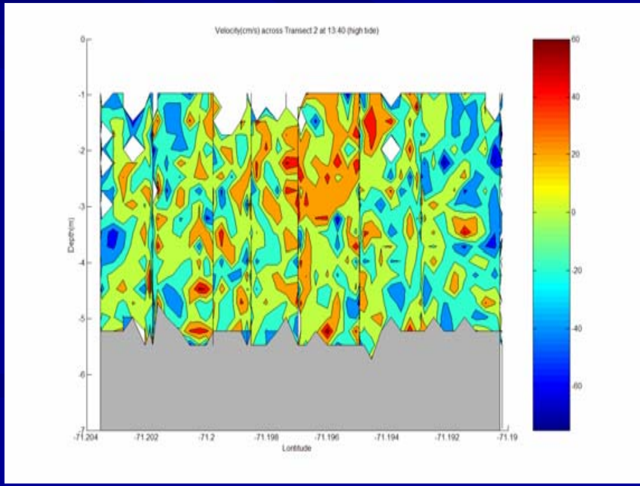


200 m

Velocity figures show the similar signals as to the temperature plots at left.



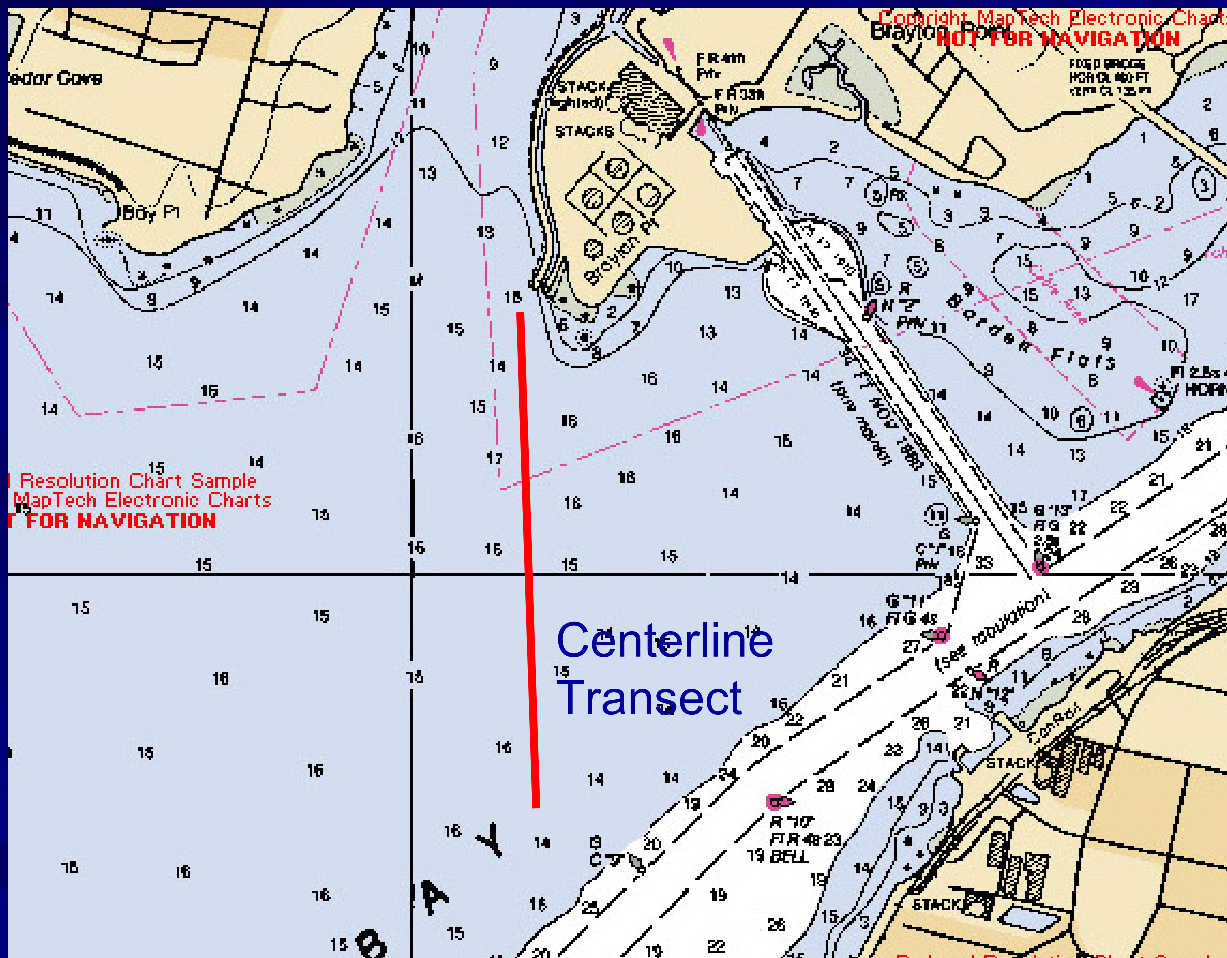
Similar widening and ‘cold’ water at depth is seen at Transect 2.



900 m

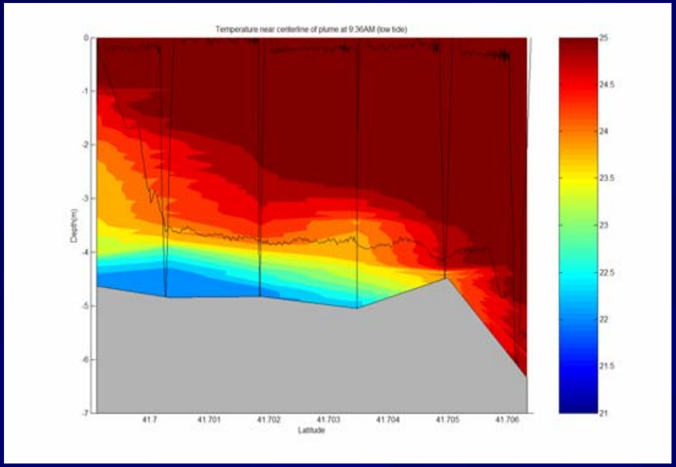
Centerline Plume Transects

See Next Slide for Preliminary Data

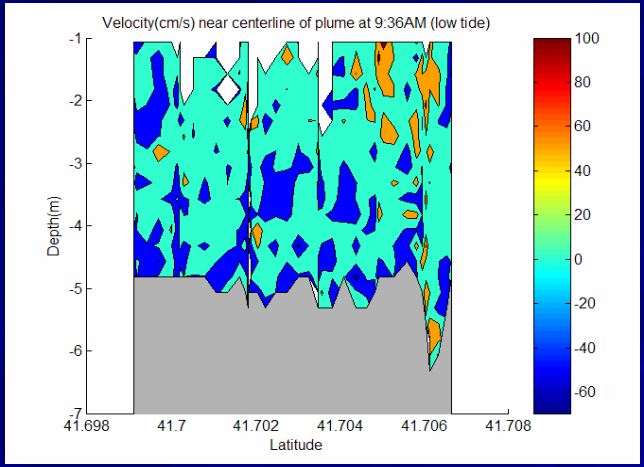


NOTE: Transect location approximate

Temperature (right) and velocity (left) along transects near the centerline of plume, ebbing (upper) and flooding (lower)

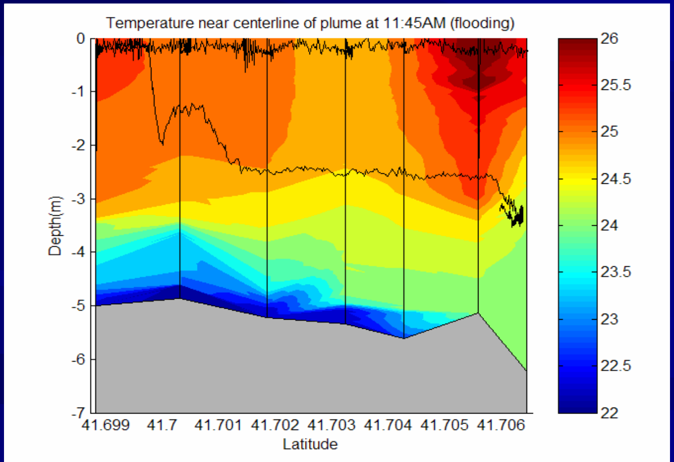


This figure shows that the thermal plume gradually rises to the surface during the ebb tide.

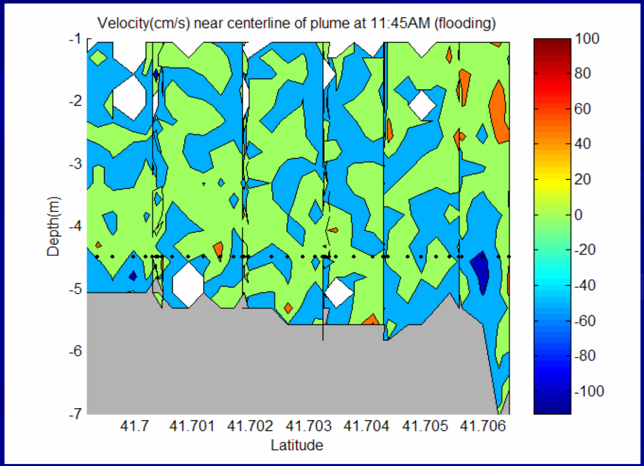


Velocity contours show that the plume travels in the surface with significant velocities.

EBB



However, during flood tide, plume water detaches from the bottom much more quickly than during ebb.

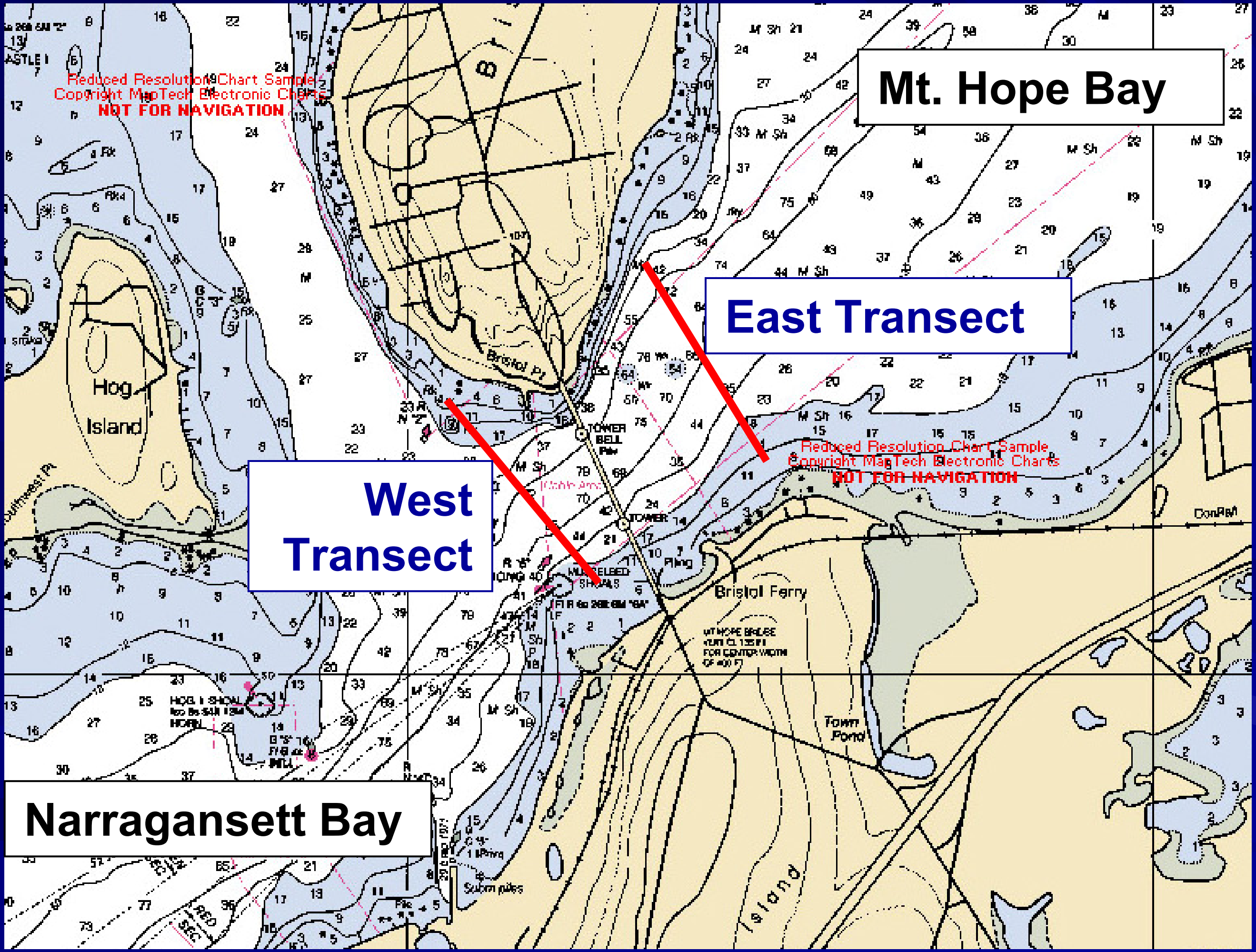


High velocities are restricted to the very near field during flood tide.

FLOOD

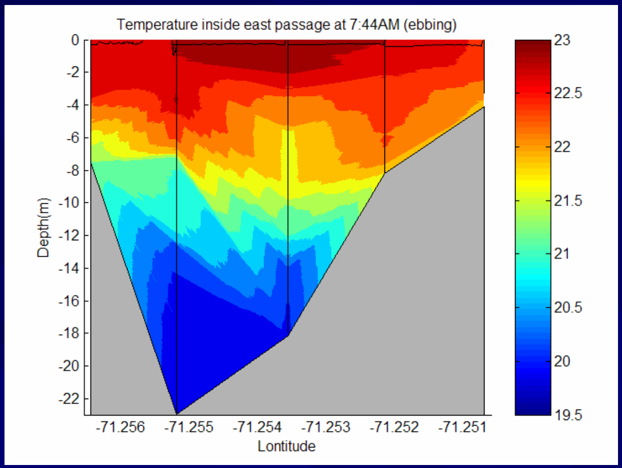
Mt. Hope Passage Transects

See Next Slide for Preliminary Data

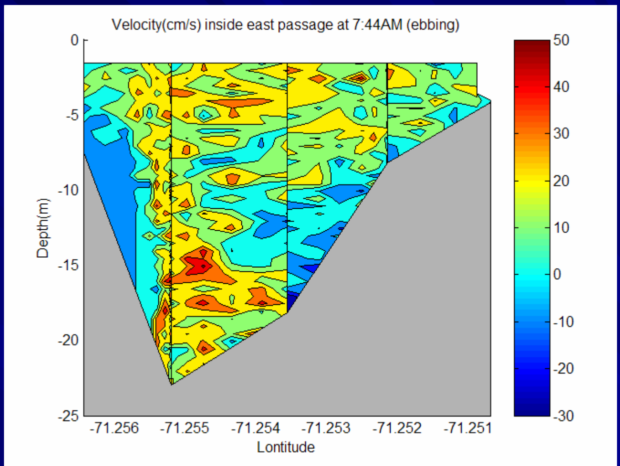


NOTE: Transect locations approximate

Temperature (right) and velocity (left) at transects inside (upper) and outside (lower) the passage under MHB bridge, ebbing

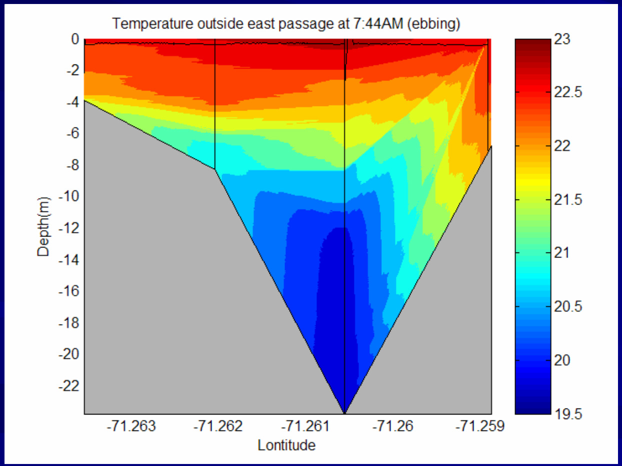


Note significant thermal stratification within the water column with cold water at depth.

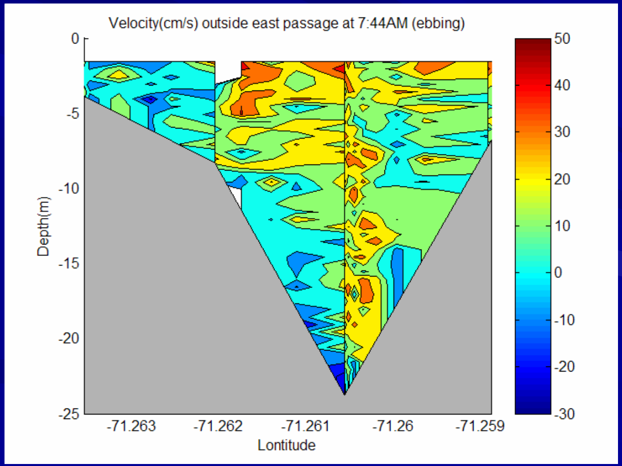


Water is flowing out of MHB in the center at all depths, this includes a significant flow of colder deep water.

INSIDE MHB



Visually, the temperature signal in the surface appears to have weakened, indicating possibly intense mixing under the bridge, which will be a focus of further analyses.



OUTSIDE MHB

Using these data, we can calculate:

- Heat flux through air-sea interface;
- The mixing rate of the plume with surrounding water;
- Spreading rate of the plume;
- Turbulence intensity/characteristics.

Final Goal

After our calculation and data analysis, we expect to

- Gain an understanding of the heat budget in the near field (within 1km) of the BPPS thermal plume;
- Understand
  - dynamics of the plume mixing processes;
  - turbulence caused by the thermal plumes;
- Compare our results with the MHBNL numerical model results.

This picture is taken from Transect Line 1 in the plume looking northward into the discharge channel. The boundary of the plume can be seen as the transition from turbulent to smoother water at the upper right (less visible at upper left), as shown by the arrow. As this picture clearly shows, the plume is a highly visible feature in MHB, and as such, draws a significant amount of attention (perhaps greater than other less visible impacts to MHB, such as nutrient loading). It is in the best interest of all concerned about the health of the ecosystem in MHB to understand the physical dynamics of the plume.