# A Case Study of Inertial Oscillations and Diurnal Dynamics Offshore of Mobile Bay


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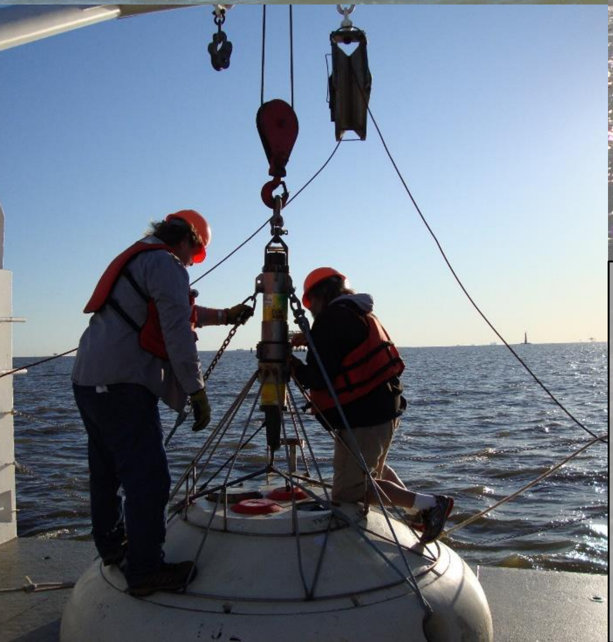
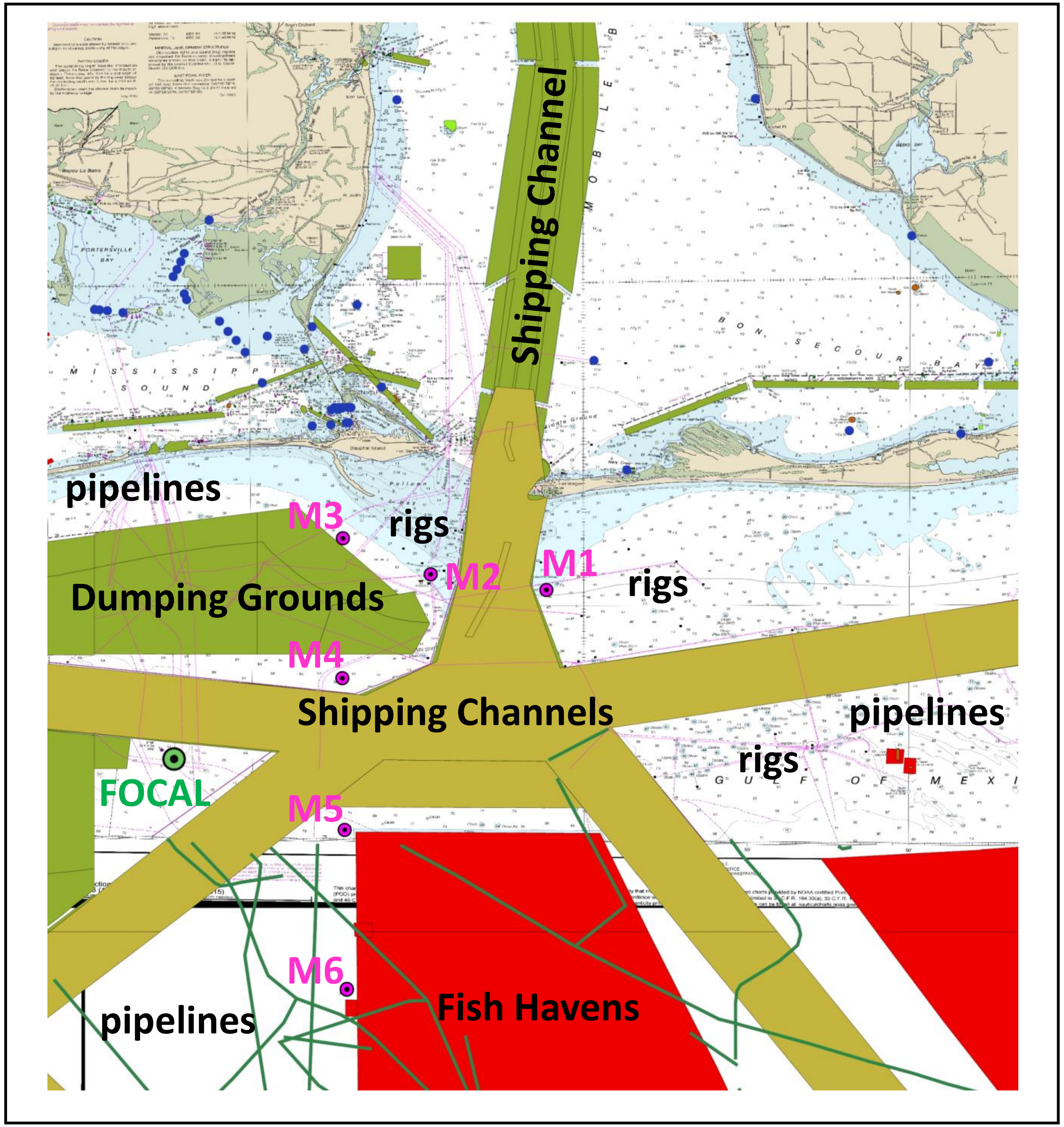


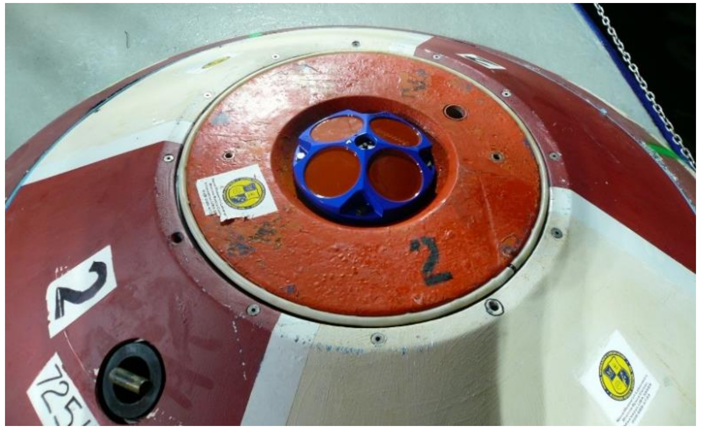
# Mobile Bay Outflow Mooring Array

Mississippi Bight is a very challenging area to study due to large numbers of oil and gas rigs, shipping channels, fishing activity, and restricted areas. The outflow area of Mobile Bay is particularly challenging for mooring work and possible mooring locations were restricted by regulation.

The final mooring array design combined scientific and survivability criteria to achieve a 3 week intense study of the outflow dynamics in spring using 9 short-term moorings to compliment long-term observations made at the Dauphin Island Sea Lab FOCAL mooring.



# Mobile Bay Outflow Mooring Array

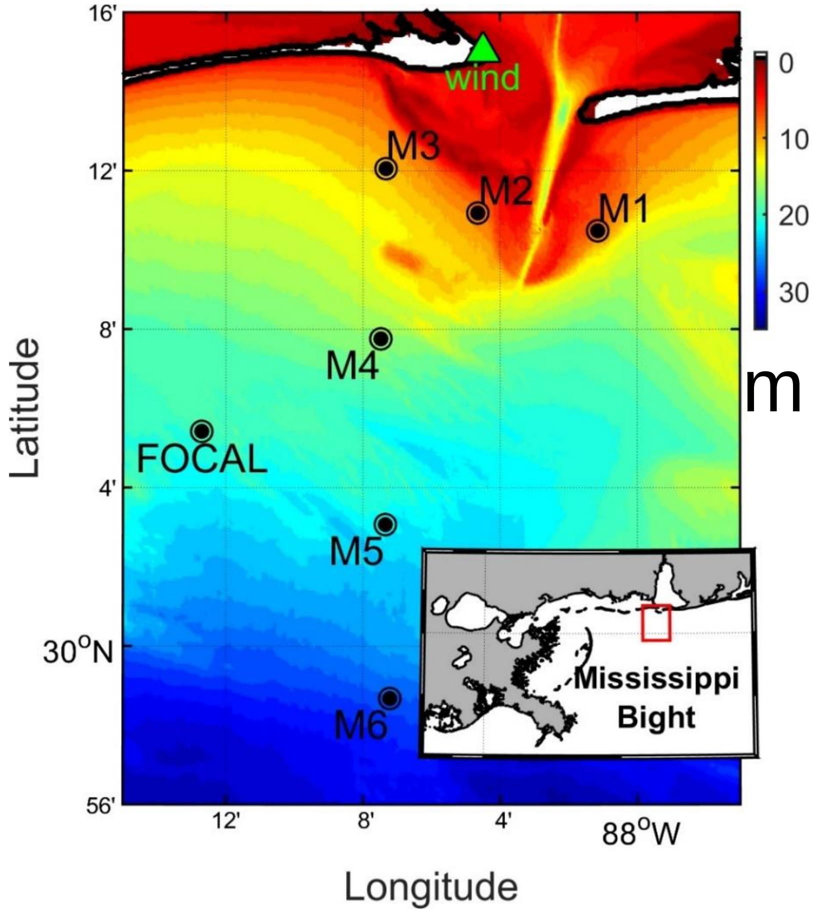


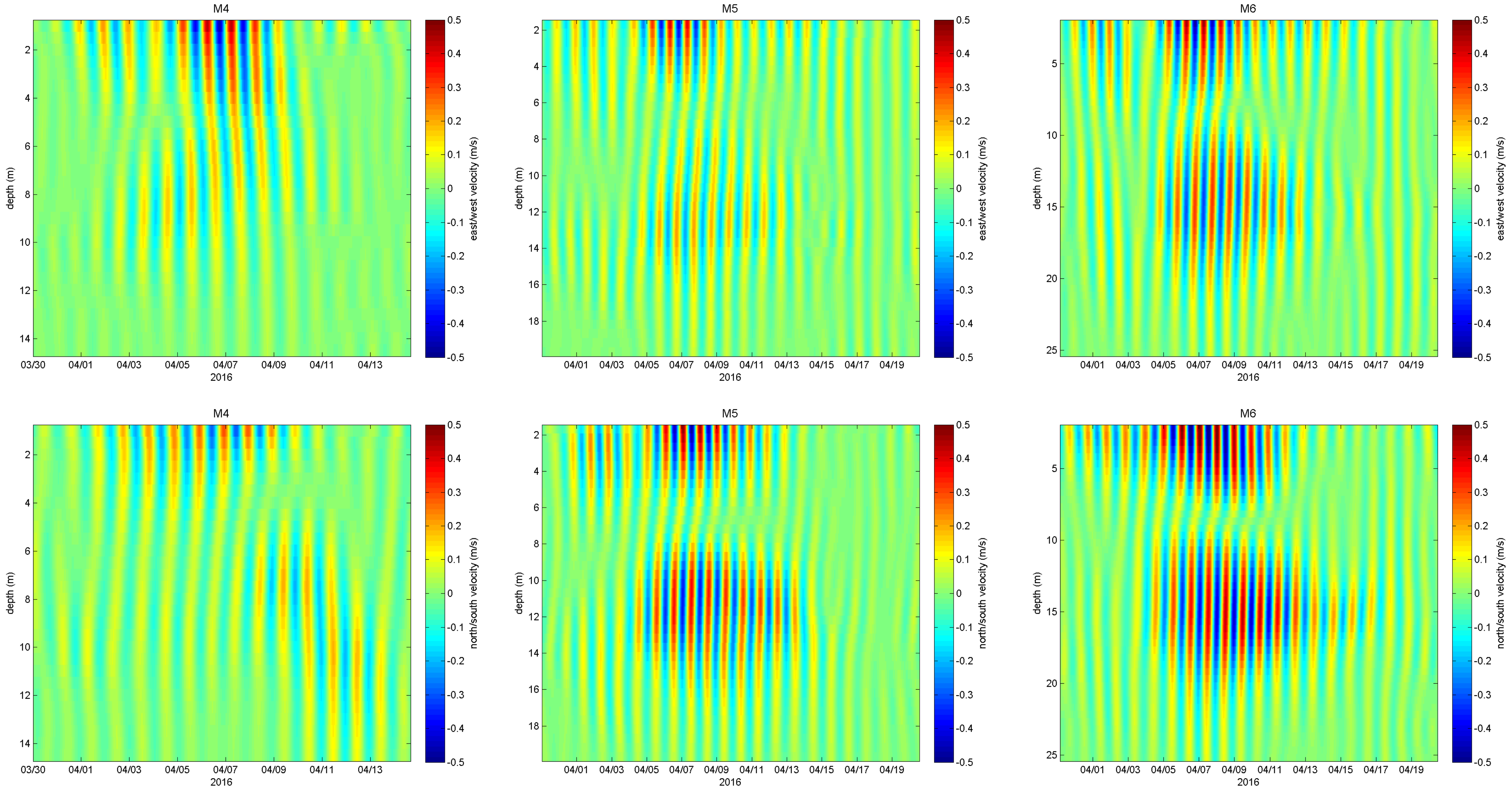
**Near-Inertial Oscillation Case Study**

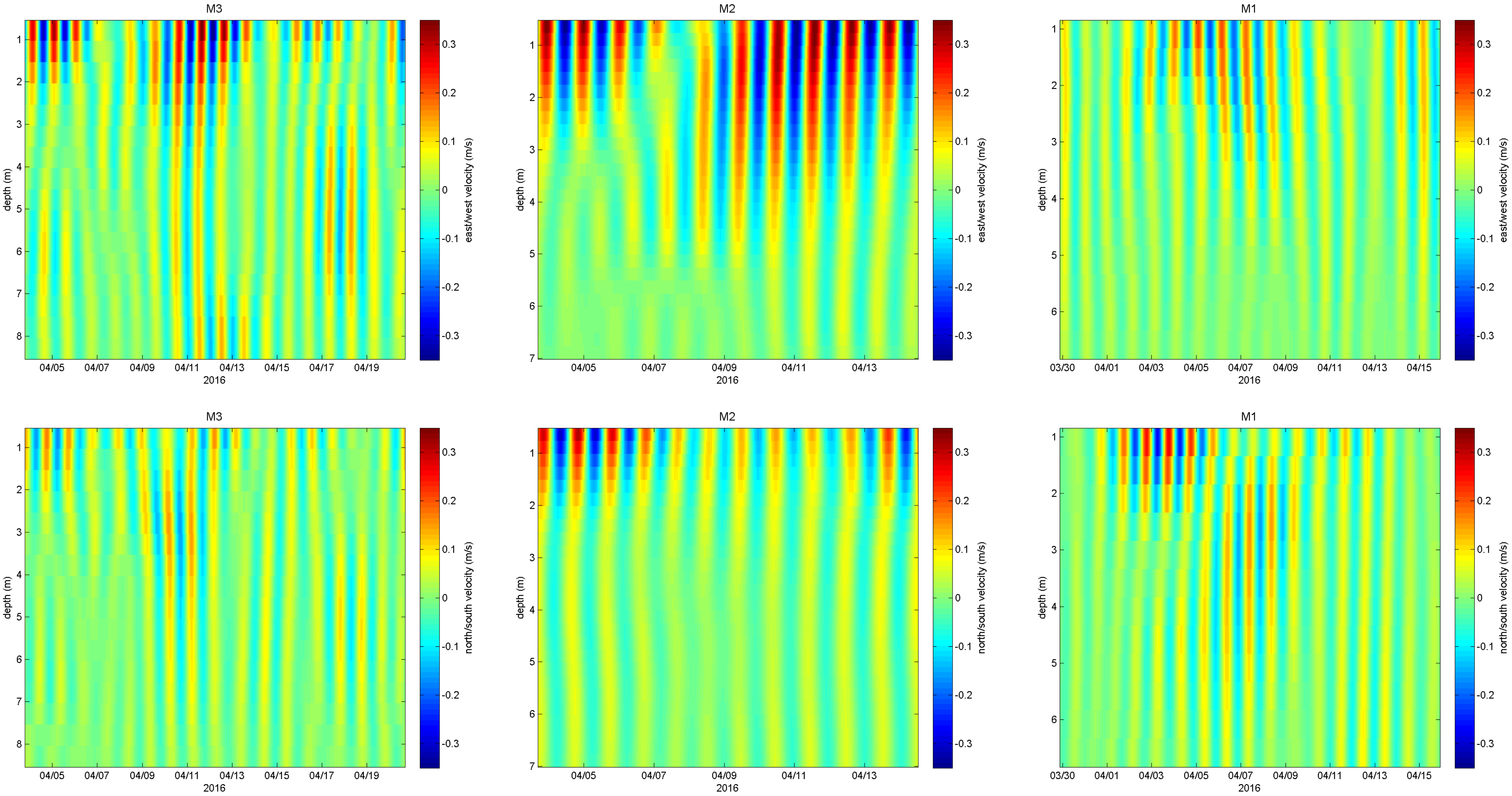
ADCP currents and bottom pressure measurements were band-passed filtered using ffts and inverse ffts, retaining only fft frequency components with periods between 20 and 28 hours.  40 hours of the resulting filtered time series were discarded from the beginning and end to mitigate against phase shift edge effects.

**Mobile Bay Outflow Moorings:**

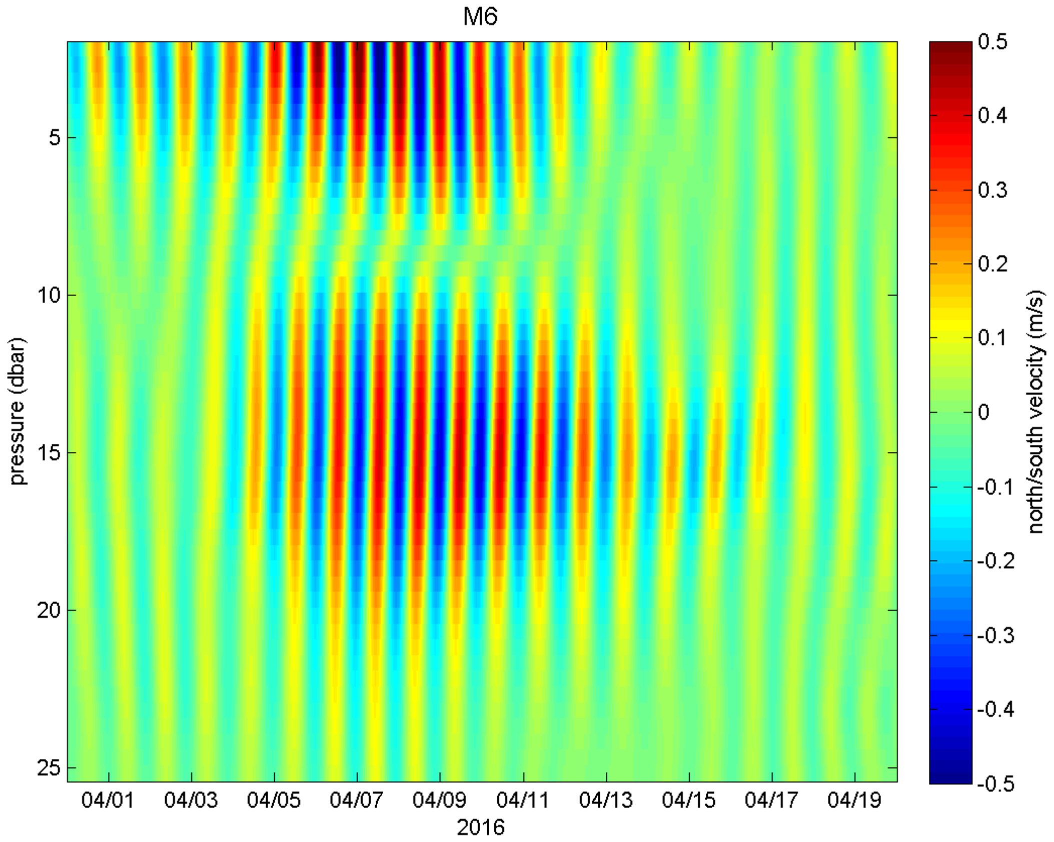
- 6 Trawl-resistant upward-looking Acoustic Doppler Current Profiler (ADCP) bottom moorings: M1-M6
- M2 also had a periodic water column profiler
- 3 Subsurface taut line moorings: M4-M6
- 1 Surface line mooring with an ADCP: FOCAL




M4
M5
M6
depth (m)
east/west velocity (m/s)
north/south velocity (m/s)
2016
03/30
04/01
04/03
04/05
04/07
04/09
04/11
04/13
04/15
04/17
04/19

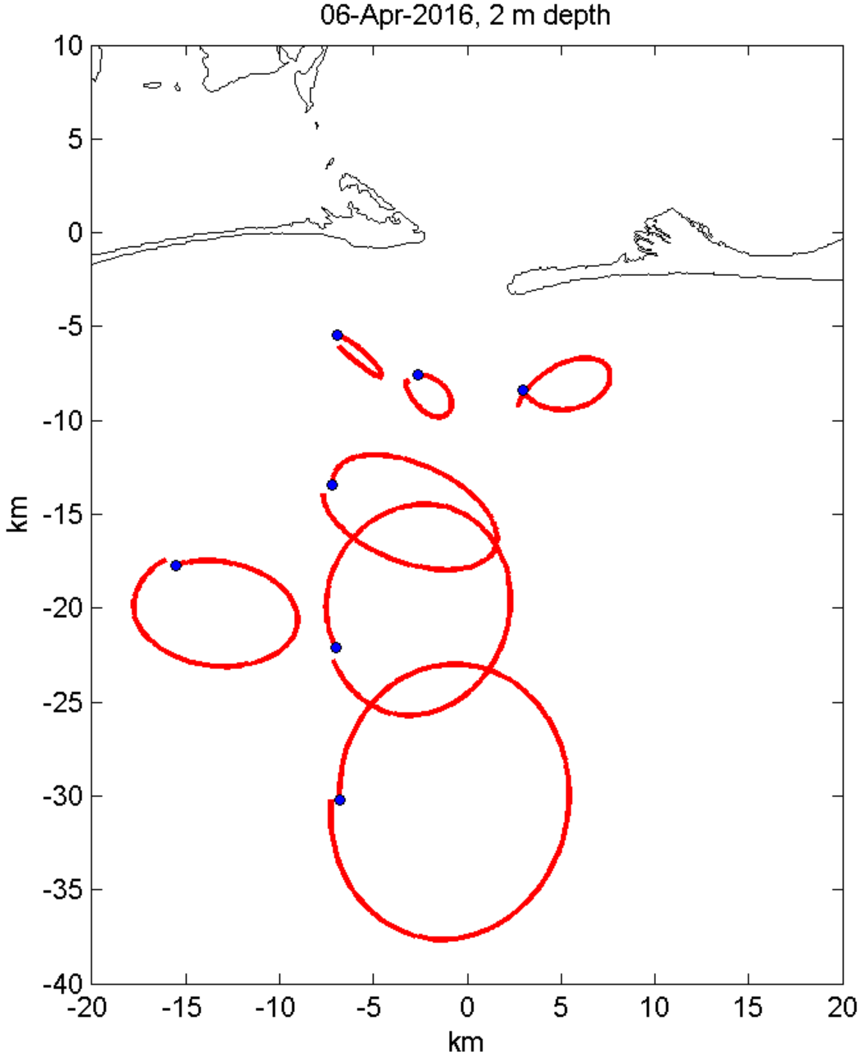

M3
M2
M1
depth (m)
east/west velocity (m/s)
M3
M2
M1
depth (m)
north/south velocity (m/s)
04/05
04/07
04/09
04/11
04/13
04/15
04/17
04/19
03/30
04/01
04/03
2016
0.3
0.2
0.1
0
-0.1
-0.2
-0.3

# M6 band-pass filtered north/south velocities

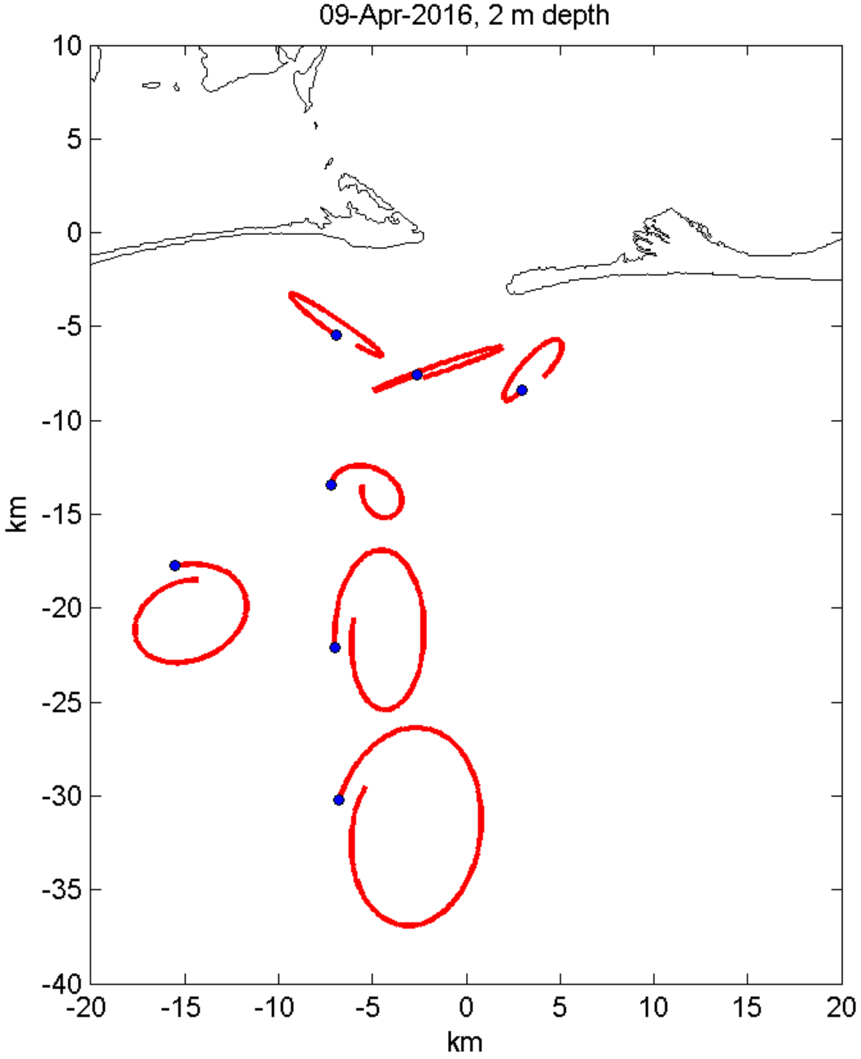



Near-inertial velocities are strong and show the classic two-layer form with opposing phases above and below the pycnocline. As shown by Simpson et al. (2002) and others, for a coastal environment, energy does not have to transfer through the pycnocline to drive the lower layer oscillations, but can be driven instead by sea-surface setup/set-downs against the coast.

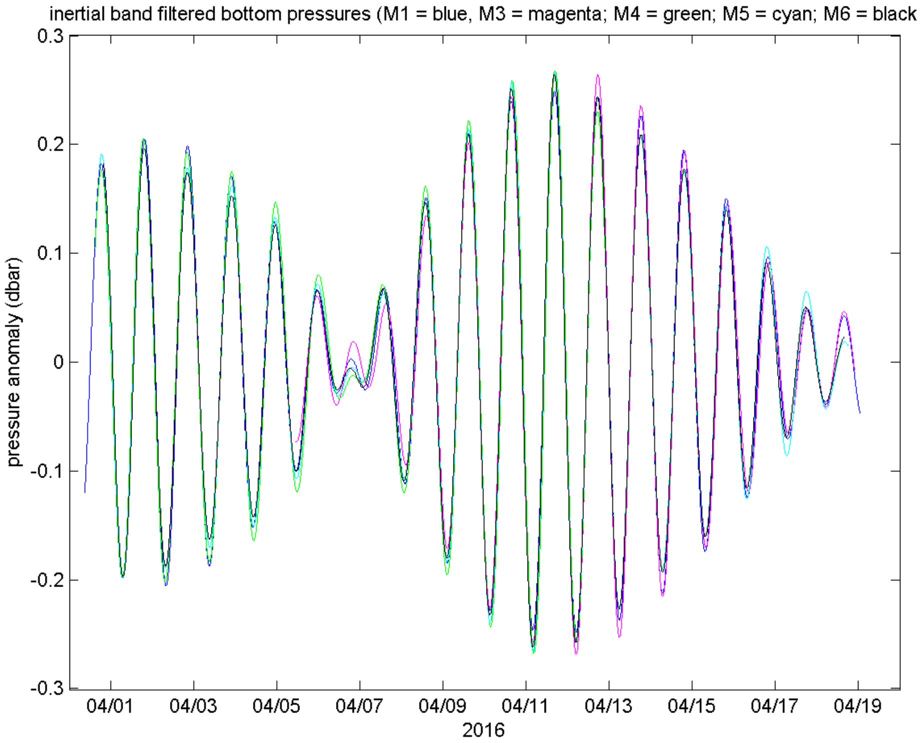
# Progressive vector diagrams for select days




Our results additionally show marked departures from circular oscillations at various times and locations.

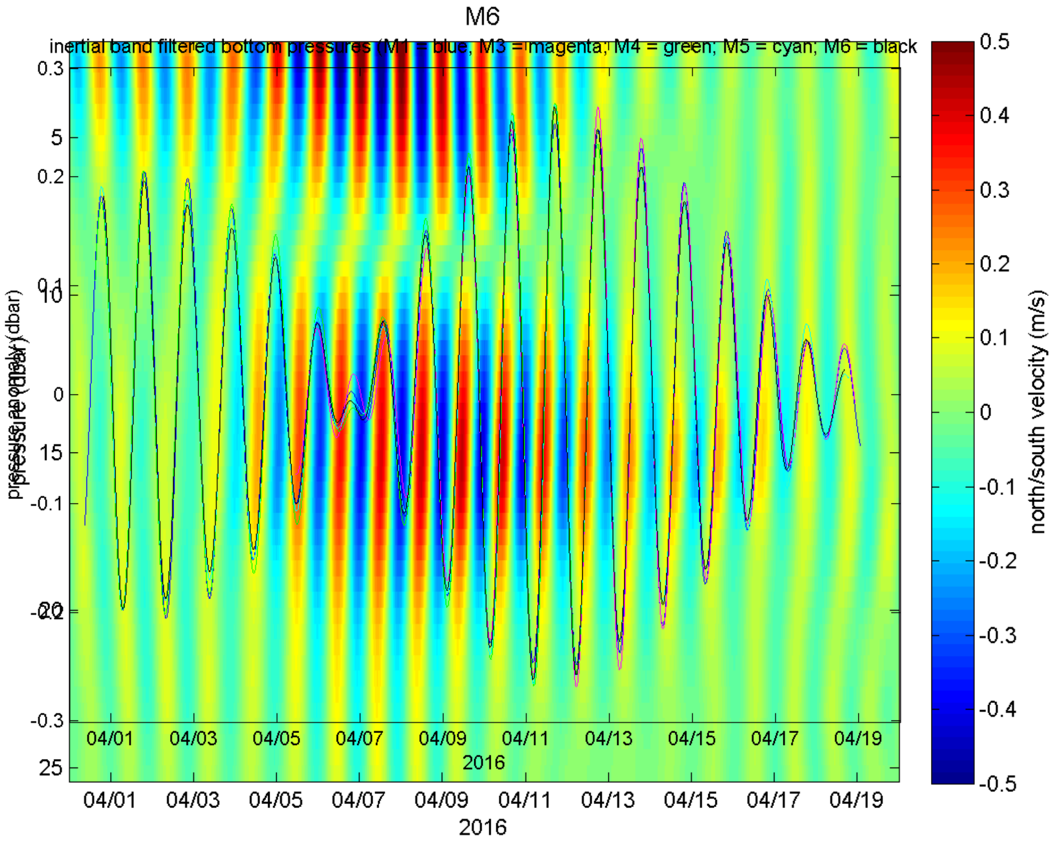


# Bottom pressure observations



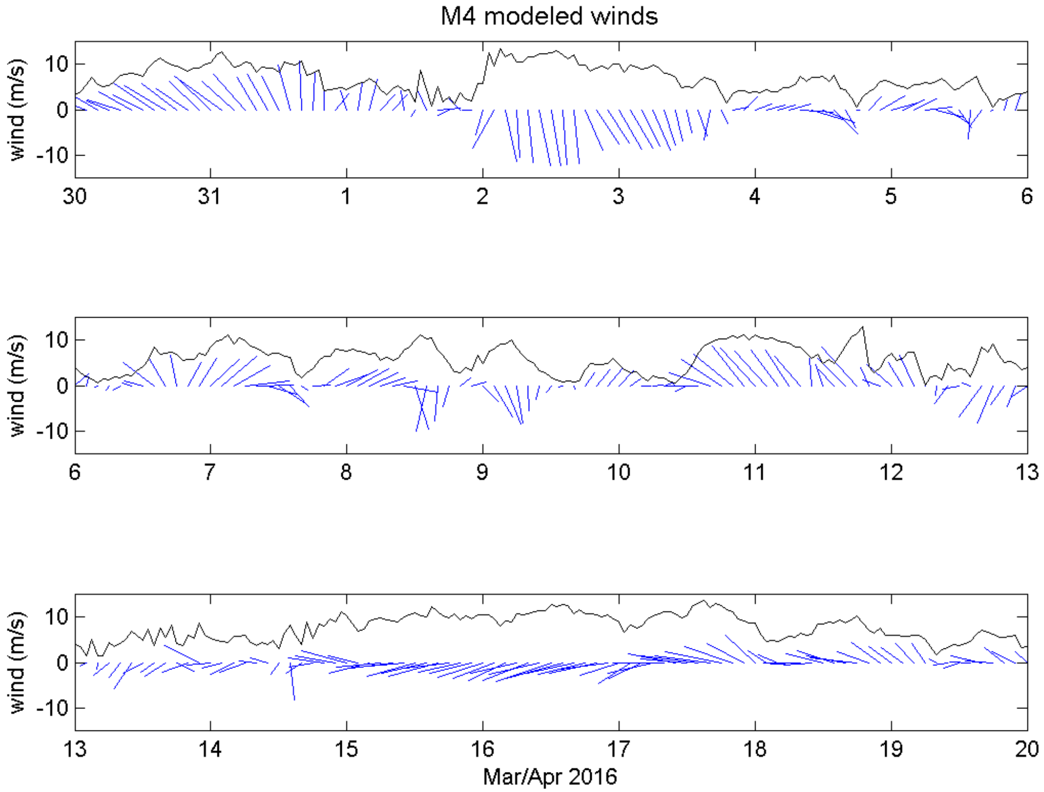

Bottom pressure oscillations closely agree at all sites and show a classic spring/neap tidal structure. However, pressure variations between sites are large enough to drive order 0.1 m/s currents.

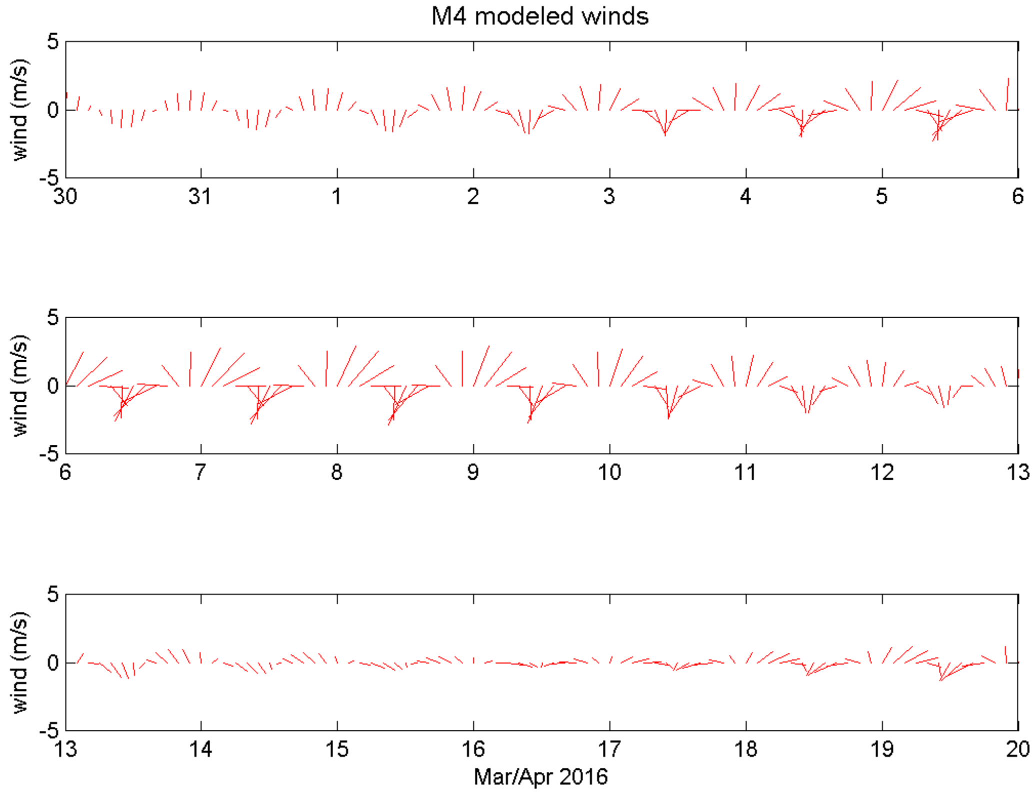
# Comparing pressure and currents



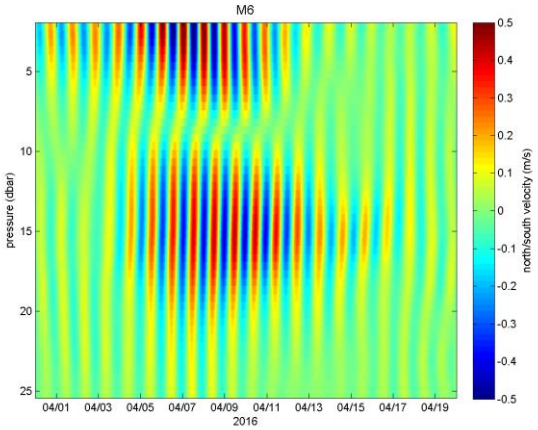

Timing of the bottom pressure oscillations and the velocity oscillations do not align with each other.

# Modeled wind fields at M4




Wind during the 3 week study period had a number of moderate to strong wind events, oriented in a variety of directions.




Inertial forcing by the wind built from Mar 30 to Apr 4, was relatively steady from Apr 5 to 12, and then diminished to weak values from Apr 13 to 20 during the period of strong and steady westward winds.

# Near-Inertial Dynamics

$$\frac{\partial \vec{u}}{\partial t} = \; -\vec{f} \times \vec{u} \;\; - \frac{1}{\rho_0}\vec{\nabla} p \;\; + \frac{\vec{\tau}}{H\rho_0} \quad - \vec{F} \;\; - (\vec{u} \cdot \vec{\nabla})\vec{u}$$

| acceleration | Coriolis | pressure gradient | slab model wind input | friction loss | non-linear advection |
|---|---|---|---|---|---|

We observe at a given location that $\vec{u}$ describes a clockwise rotating ellipse with angular frequency nearly equal to $\left|\vec{f}\right|$. We can describe this in rotated coordinates that align the negative y axis with the ellipse semi-major axis as:

$$v_r = -A_{maj} \; \sin(ft \; - \theta) \qquad\qquad u_r = +A_{min} \; \cos(ft \; - \theta)$$

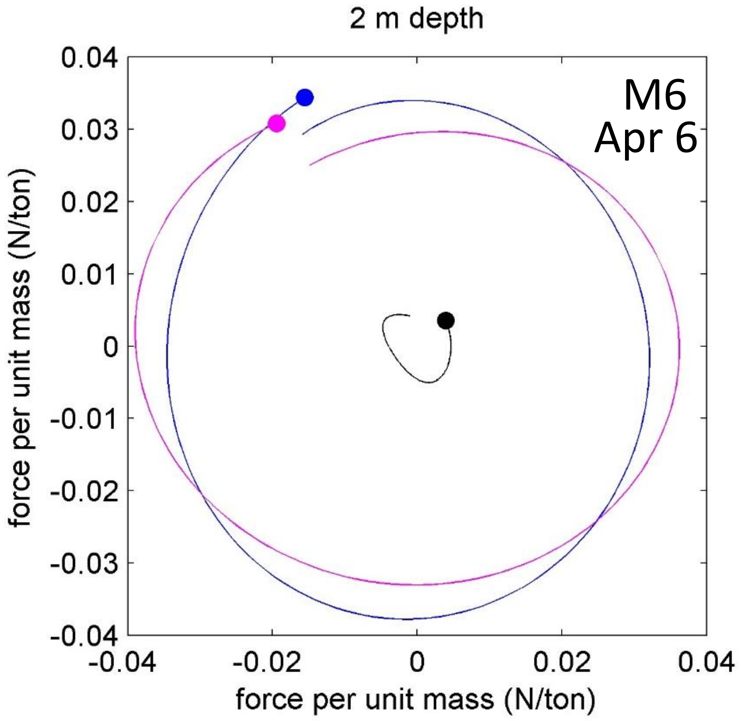
Now calculate the two components of $\frac{\partial \vec{u}}{\partial t} + \vec{f} \times \vec{u}$

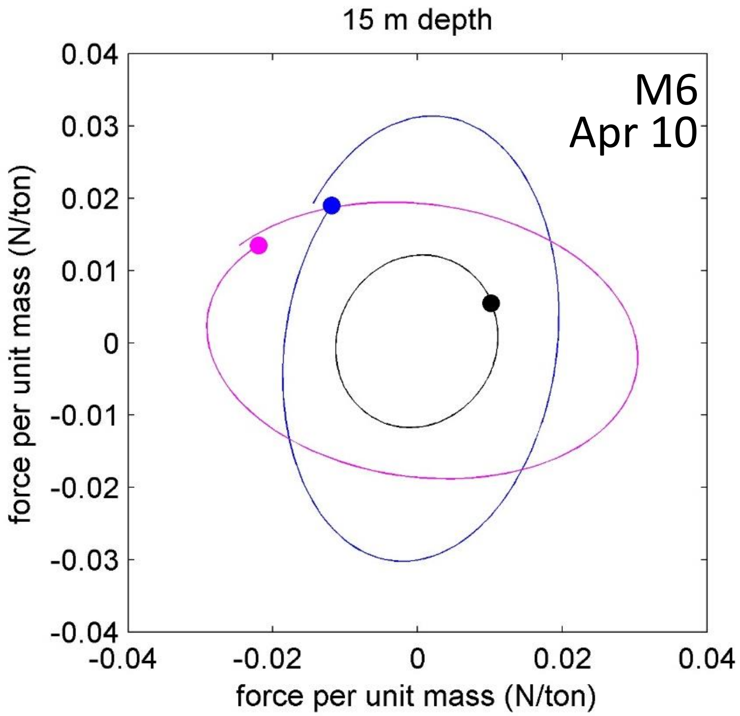
$$\frac{\partial u_r}{\partial t} - f v_r = \left(A_{maj} - A_{min}\right) f \sin(ft \; - \theta)$$

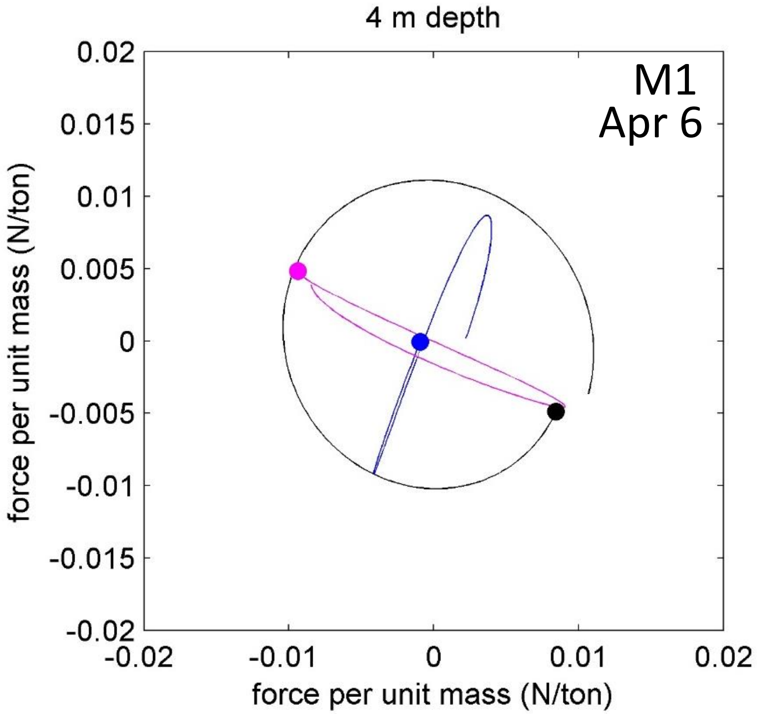
$$\frac{\partial v_r}{\partial t} + f u_r = \left(A_{min} - A_{maj}\right) f \cos(ft \; - \theta)$$

This requires the remaining force term vectors to describe a counterclockwise rotating circle as the frequency of the currents approaches inertial.

# Near-Inertial Dynamics




Inertial Oscillation: $A_{maj} = A_{min}$

Intermediate Wave: $A_{maj} > A_{min} > 0$

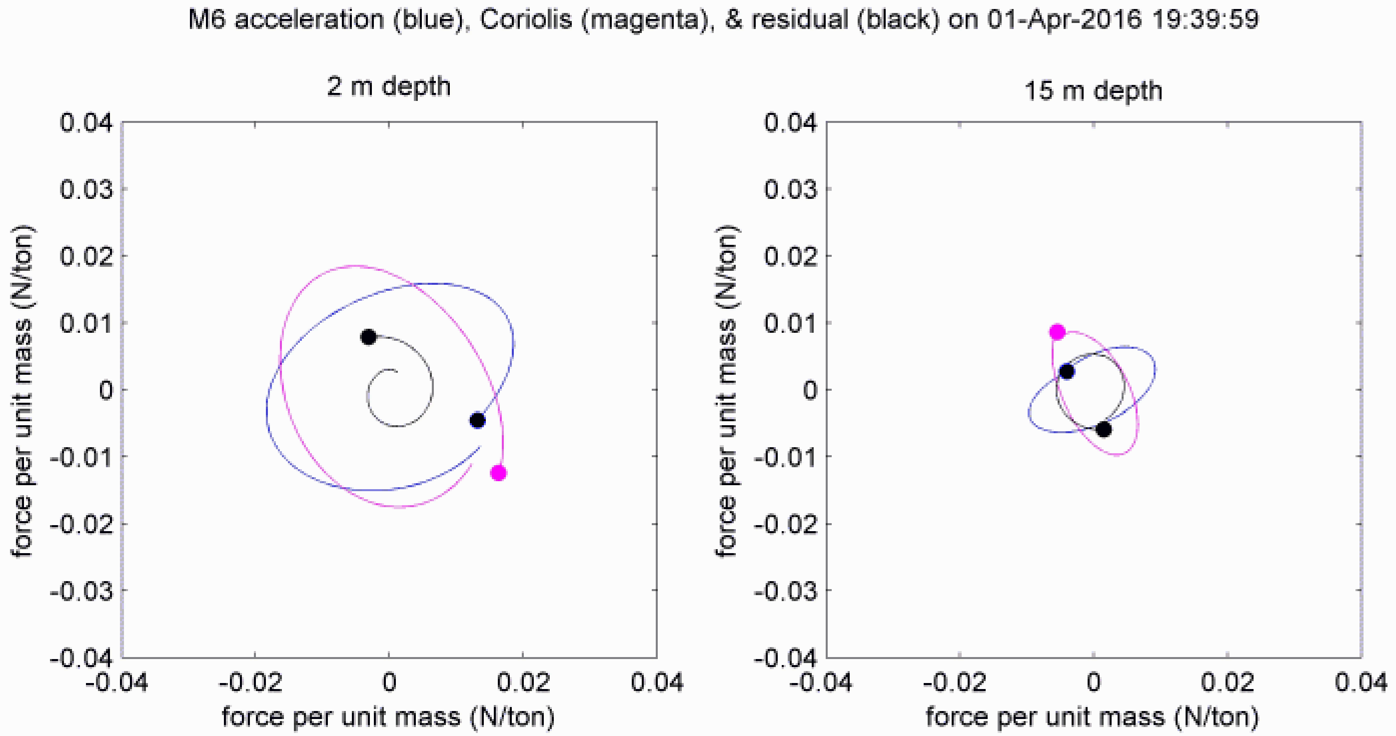
Kelvin Wave: $A_{min} = 0$

$$\frac{\partial \vec{u}}{\partial t} = -\vec{f} \times \vec{u} + \ \ldots$$

$$(A_{maj} - A_{min}) f \sin(ft \ - \theta) = -\frac{1}{\rho_0} \nabla_{x_r} p + \frac{\tau_{x_r}}{H\rho_0} - F_{x_r}$$

$$(A_{min} - A_{maj}) f \sin(ft \ - \theta) = -\frac{1}{\rho_0} \nabla_{y_r} p + \frac{\tau_{y_r}}{H\rho_0} - F_{y_r}$$

# Observed near-inertial force ellipses at M6




$$\frac{\partial \vec{u}}{\partial t} = -\vec{f} \times \vec{u} + \ \ldots$$

# Preliminary Conclusions

- Strong near-inertial oscillations occurred at all sites with strong magnitudes offshore (0.5 m/s), but also significant magnitudes (0.35 m/s) within a few km of the coast.
- Dynamics exhibit characteristics of both “pure” inertial oscillations and coastal Kelvin waves, often showing a mix of the two forms and different forms above and below the pycnocline.
- Winds input energy into the inertial band, triggering this event, but pressure gradients are required to balance the anti-cyclonic momentum discrepancies associated with non-circular oscillations near the inertial frequency.
- The potential for strong resonant forcing of velocity oscillations has important implications for the dispersion of biological and anthropogenic substances in this region.

# Acknowledgements

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