Near-inertial oscillations as a primary ecosystem driver (?)

Jay Austin
Large Lakes Observatory/ Physics
University of Minnesota, Duluth
Outline

• What are near-inertial oscillations?
• How do we observe them?
• What did we find?
• Why should we (or more to the point, you) care?
Previous work

• Lots of activity in large lakes the 70’s (Marmorino, Mortimer, Schwab, Fee, Rao, etc.)
• Very few observations to work with - severely technologically limited
• Still, nailed down several of the basic features
  – Vertical structure
  – Stratification dependence
• Work done in Kinneret in the last decade (Imberger, Antenucci, etc.) ... scales are very different
Gravity waves

- Gravity waves represent the response of an density interface to a displacement from equilibrium. Gravity as restoring force
- Energy propagates away from disturbance as waves
- Particles move back and forth in direction of wave, are not displaced over a cycle
The Coriolis force

Force acts perpendicular and in proportion to velocity

$f$ is the *Coriolis parameter* - about $1 \times 10^{-4} \text{s}^{-1}$
Poincare waves

• At low frequencies, particle paths become elliptical, approaching circular as their frequency ($\omega$) approaches the Coriolis frequency ($f$) (known as ‘near-inertial waves’)

• Surface (or interface) displacement associated with passage of wave, just as with gravity wave

• Energy concentrated around the inertial frequency ($T \sim 16.1h$)
Interfacial waves

- Waves can exist on any interface between fluids of different densities (e.g. oil and vinegar)
- A stratified lake typically has a strong density interface (the pycnocline) due to temperature stratification
- The speed of waves is proportional to the density difference between the fluids
Observations

• Moorings with current meters in Lake Superior from ~2007 to present
• Several sites; will focus on single sites in the western and eastern basins
• ADCPs (current profilers) and thermistors at a range of depths
Core Moorings, 2007-2012
Raw velocities, WM (E-W and N-S)
Acoustic Doppler Current Profiler (ADCP)
Near-sfc velocities (E-W and N-S)
Temperature, top 80m
Temperature @13m, WM

\[ \text{Spectral intensity vs. Cycles per day} \]

\( \text{Inertial frequency} \)
Raw velocities, WM (E-W and N-S)
E-W velocity with wavelet amplitude
$CW_{16}$ and $CCW_{16}$ wavelets, WM

(A) Clockwise

CCW

$\Delta \rho$, kg m$^{-3}$

Amplitude, m s$^{-1}$

Stratification and $CW^{16}$
Bottom Velocities, WM, Fall 2010

East-West

North-South
Too deep - bottom currents weak

Too close to shore

Backscatter

Depth, m

x 10^{-3}

6
4
2
m^{-1} sr^{-1}

Just right

Too deep - bottom currents weak

distance, km
• Temperature/Conductivity/Depth
• Currents (ADCP)
• Chl-a, CDOM, PC, and PE fluorescence
• Backscatter @ 700nm
• Dissolved Oxygen
• Nitrate
• PAR
Conclusions

• Near-inertial oscillations dominate
• Stratification matters
• Difficult to predict
• May play a role in determining sediment remobilization
• Pathways to Euphotic zone not clear
Now What?

• What happens at boundaries?
• What is the distribution of KE at the bottom of the lake?
• What wind conditions are efficient at creating these events?
  – Does the spatial or temporal scale of the wind field matter more?
• Bringing innovative instrumentation to the problem
Rotary Spectrum, Collier Crater Lake data

Spectral intensity

Cycles per day

CRATER LAKE

CRATER