Waves I

EPS131, Introduction to Physical Oceanography and Climate

Dept of Earth and Planetary Sciences, Harvard University

Eli Tziperman

https://en.wikipedia.org/wiki/File:Tsunami_by_hokusai_19th_century.jpg

Surface ocean waves

look at 2:57–4 minutes

https://www.youtube.com/watch?v=RMUxSwUB0p0

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Internal waves and ocean mixing

show 1:40-3:30

first 20 sec, and then jump to 1:11

https://www.youtube.com/watch?v=x7GXLJQ2Zn0

https://swot.jpl.nasa.gov/resources/147/internal-wave-tank-demonstration/

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Notes
1 Inertial oscillations

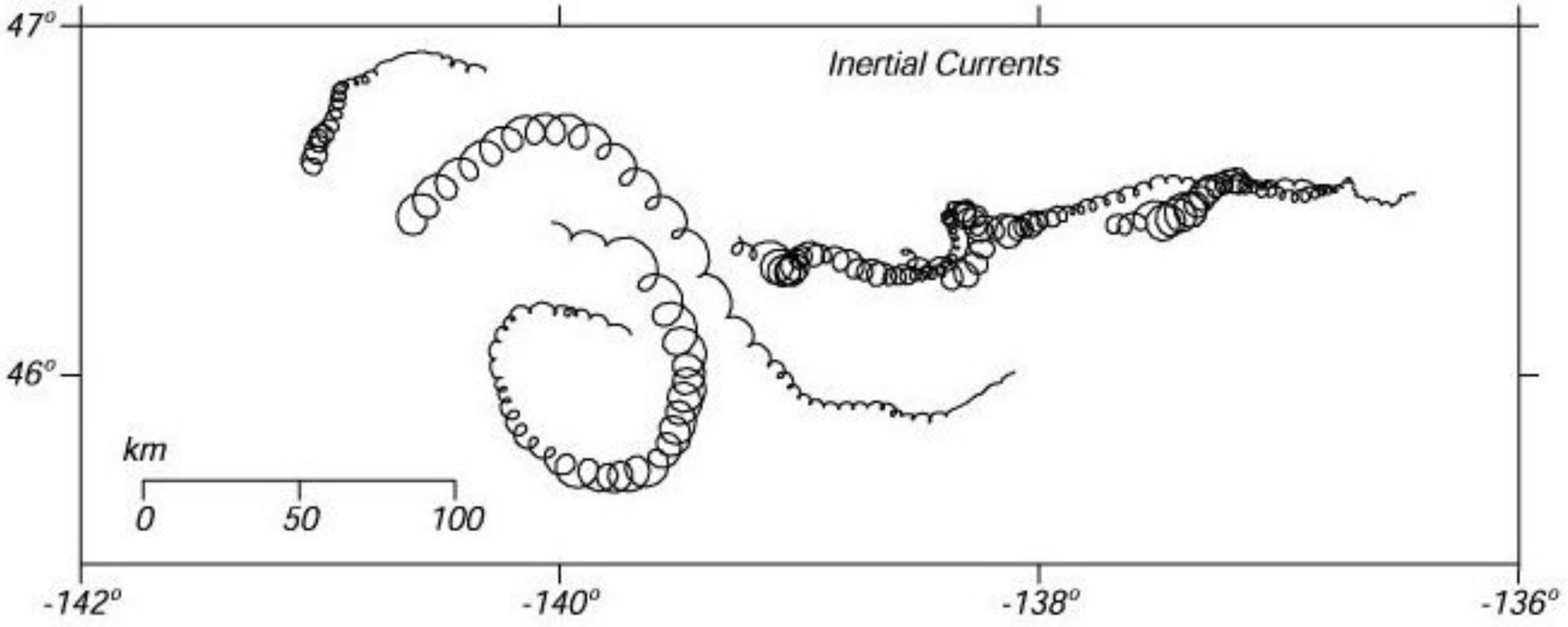
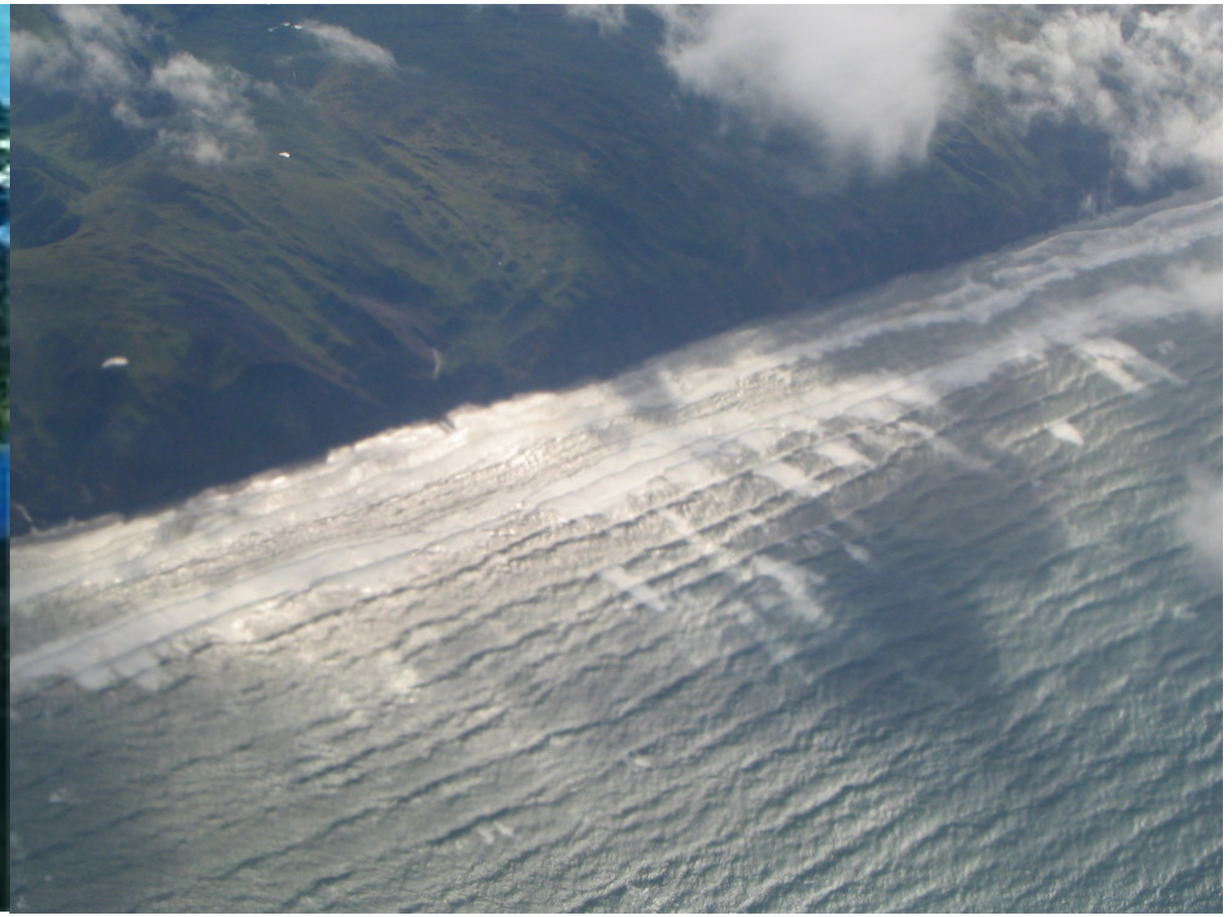


Figure 9.1 Inertial currents in the North Pacific in October 1987 (days 275-300) measured by holey-sock drifting buoys drogued at a depth of 15 meters. Positions were observed 10-12 times per day by the Argos system on NOAA polar-orbiting weather satellites and interpolated to positions every three hours. The largest currents were generated by a storm on day 277. Note: these are not individual eddies. The entire surface is rotating. A drogue placed anywhere in the region would have the same circular motion. From van Meurs (1998).

Miniquiz
F=ma for inertial oscillations

Notes
2 **Wave basics:** Definitions/ Phase velocity/ Group velocity



Why do waves arrive parallel to the coastline?

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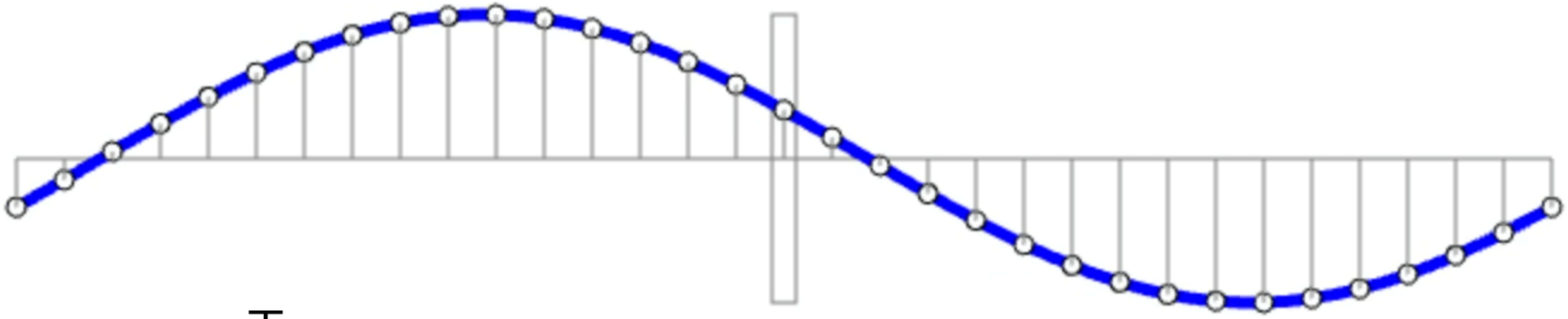
2 **Wave basics:** Definitions/ Phase velocity/ Group velocity

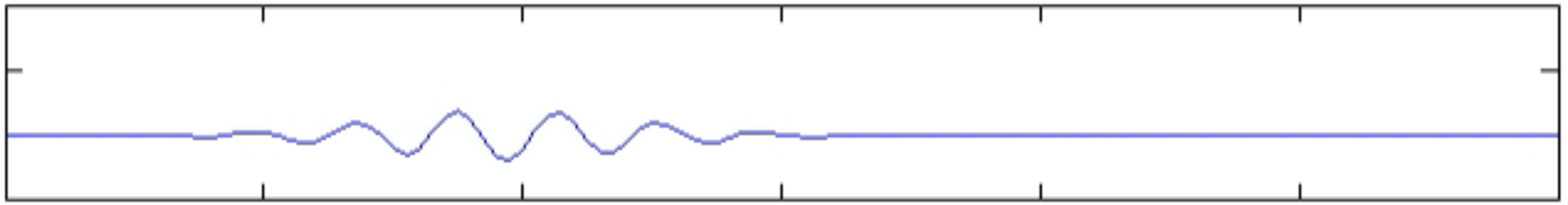


Transverse waves surendranath.org/GPA/Waves/TW01/TW01.html

longitudinal waves https://www.surendranath.org/GPA/Waves/LW01/LW01.html

surface gravity wave in deep water

Phase speed vs group speed



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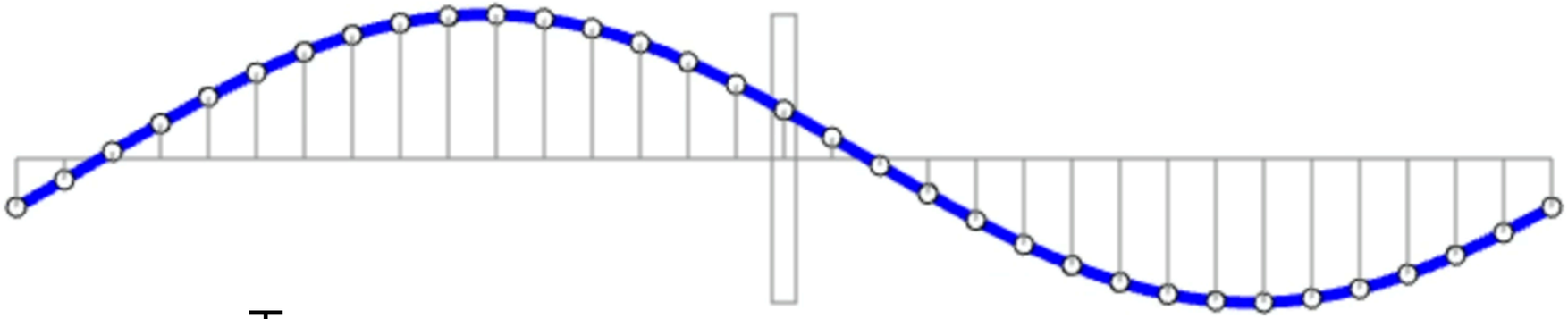

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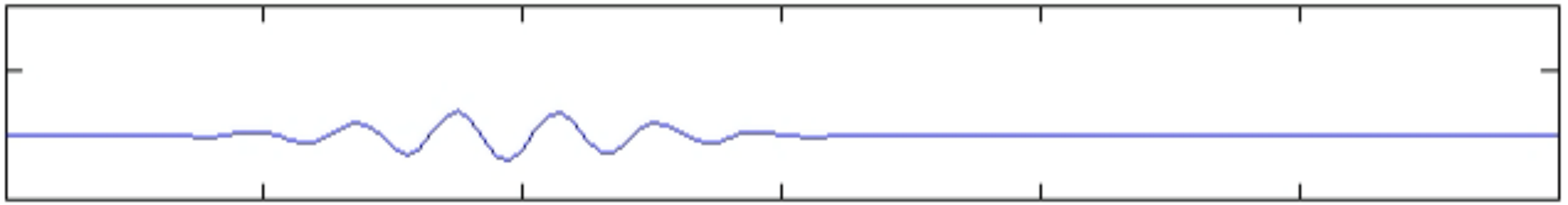

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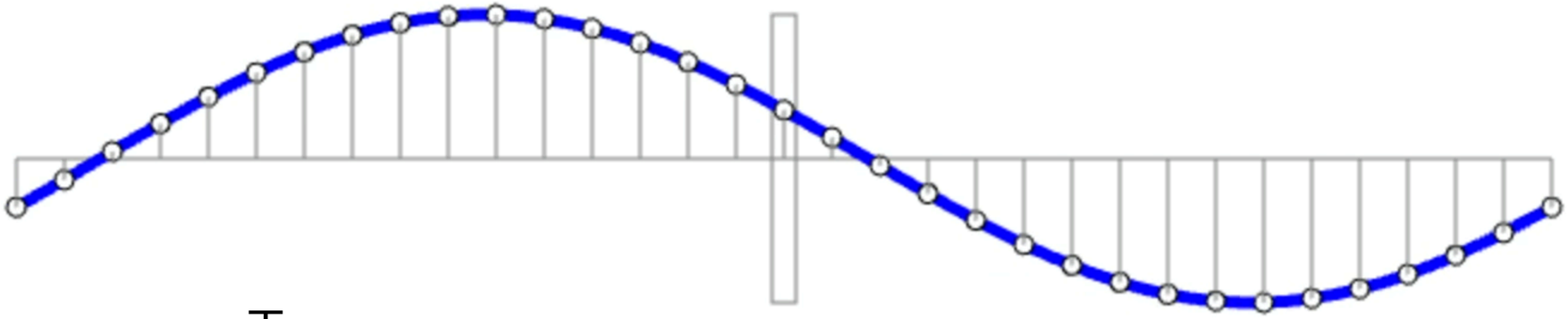

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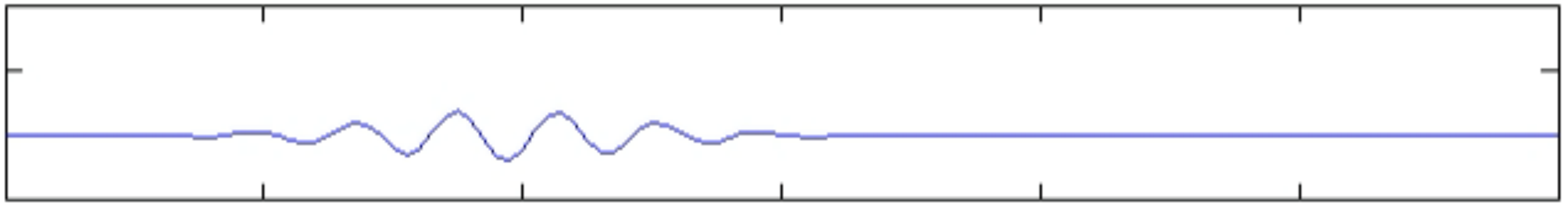

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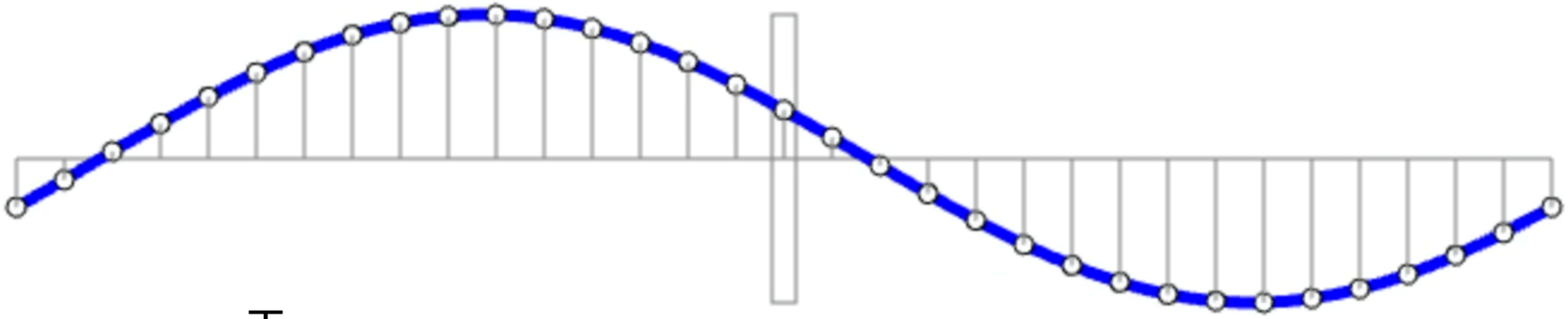

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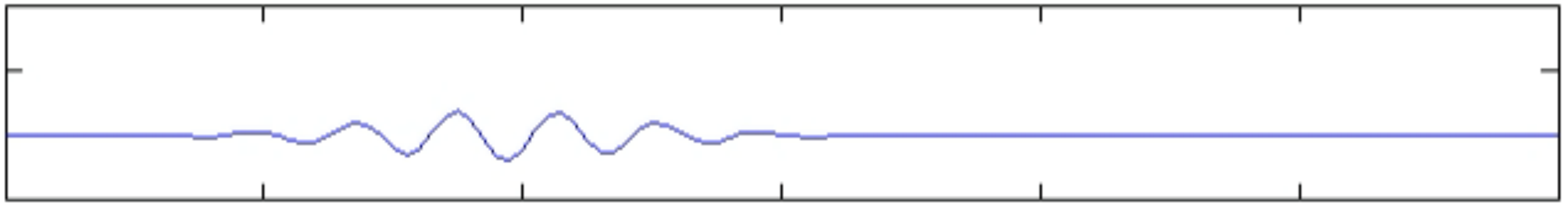


Notes

3 Surface gravity waves – without rotation

3.1 dimensional analysis

miniquiz

dispersion relation from dimensional arguments

Notes

3 Surface gravity waves – without rotation

3.2 Shallow water 1d mass conservation

3.3 Shallow water 1d momentum equation

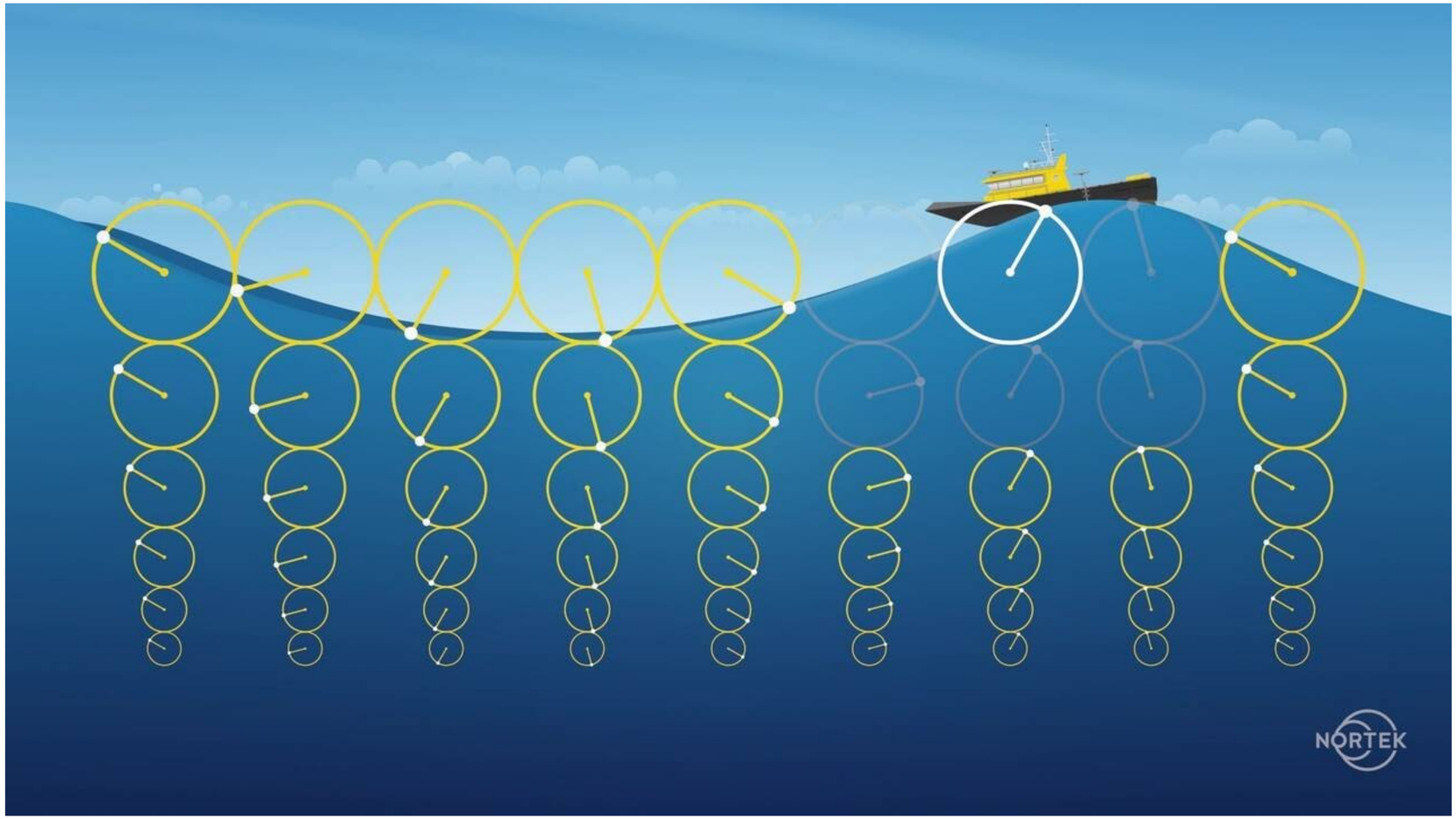
Miniquiz

derive the shallow water 1d wave equation, use it to find the dispersion relation

Notes

3 Surface gravity waves – without rotation

3.5 Particle trajectories (for shallow water waves w/o rotation)



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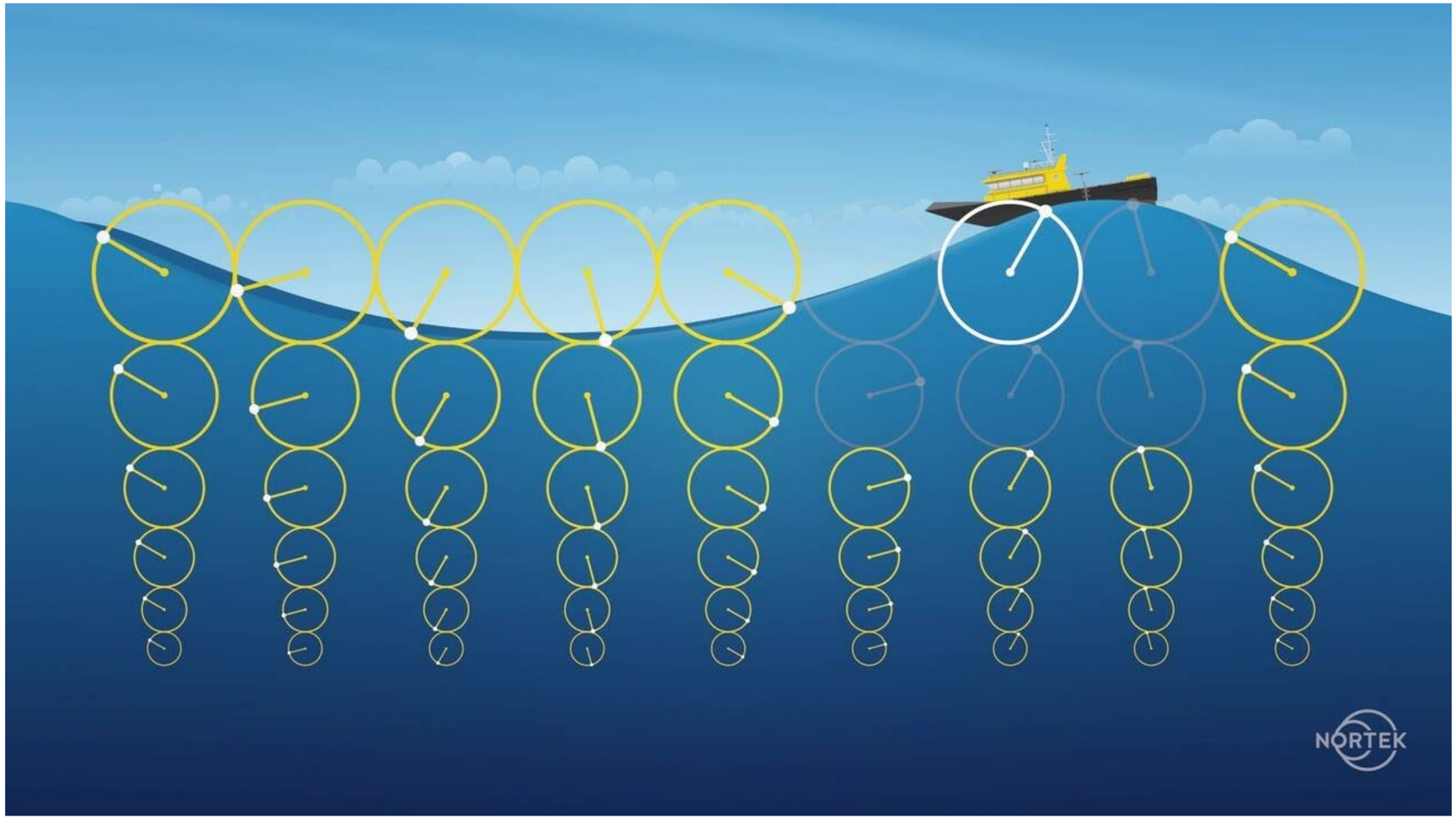

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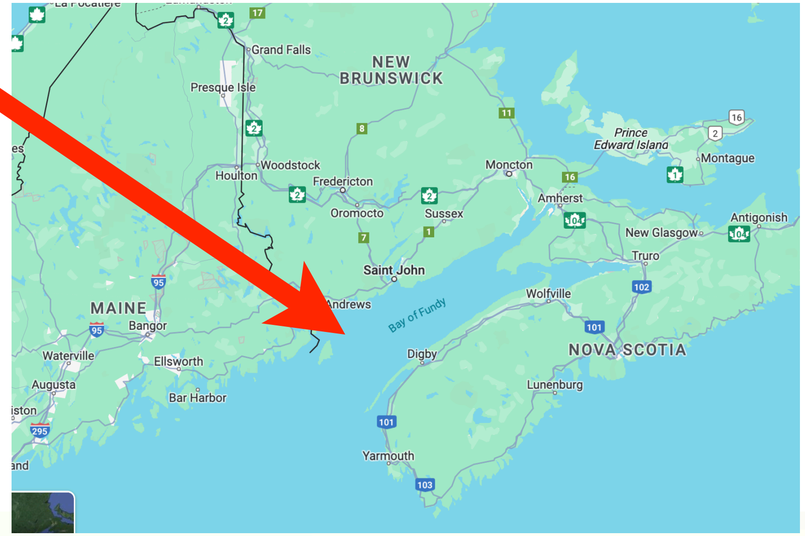
Tides in the Bay of Fundy



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https://www.youtube.com/watch?v=u3LtEF9WPt4

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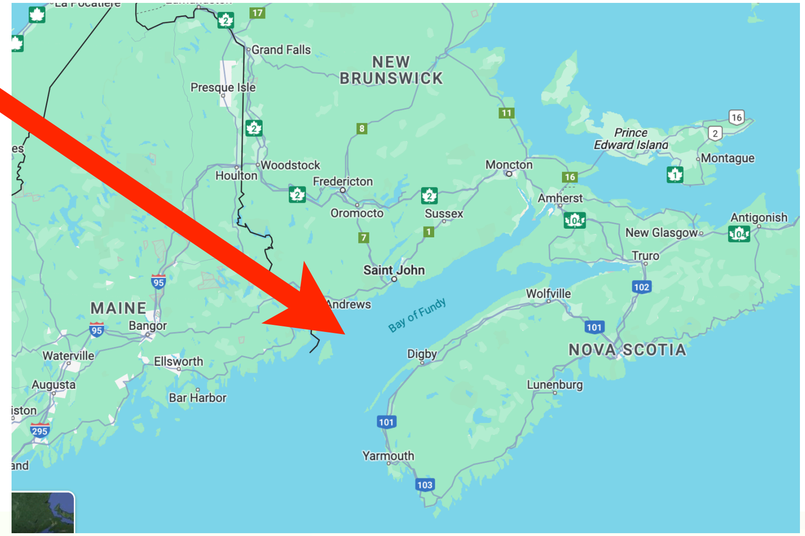

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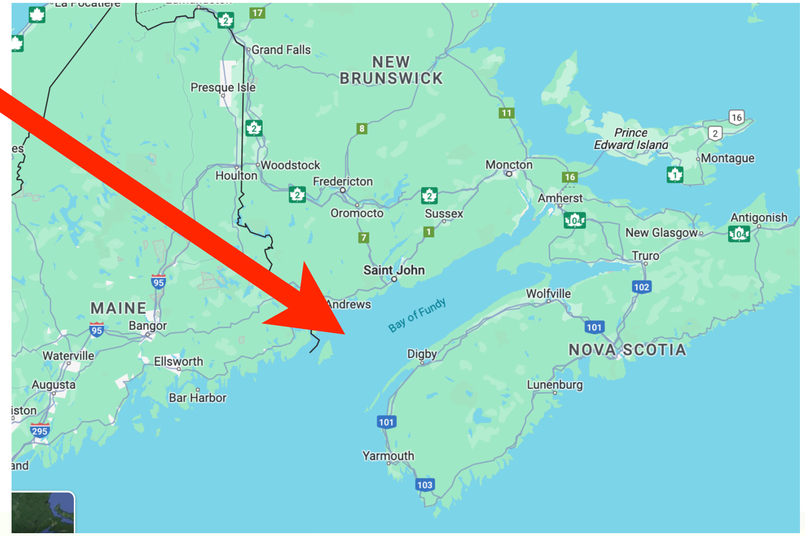

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Mont Saint Michel

https://www.youtube.com/watch?v=ks90u6nY26M

Bay of Fundy

https://www.ferries.ca/experience-the-bay-of-fundy/

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Notes

3 Surface gravity waves – without rotation

3.6 Standing waves (springs demo!)

3.7 Tidal resonance

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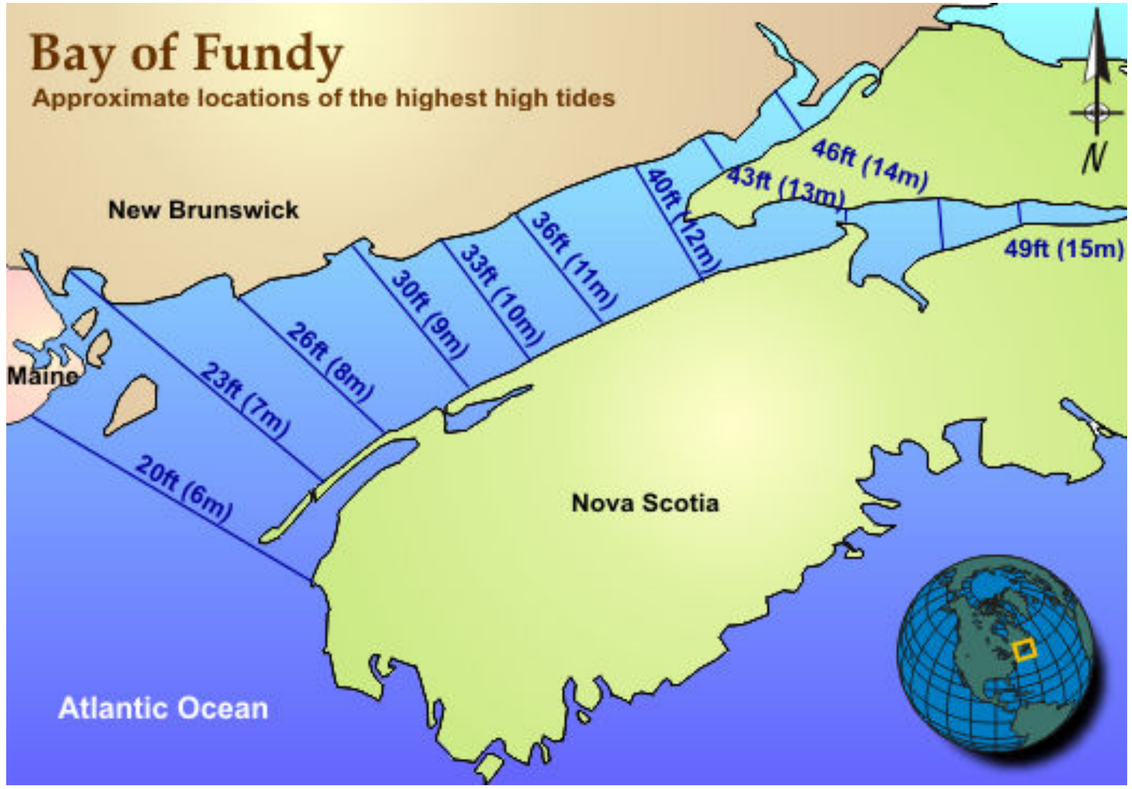
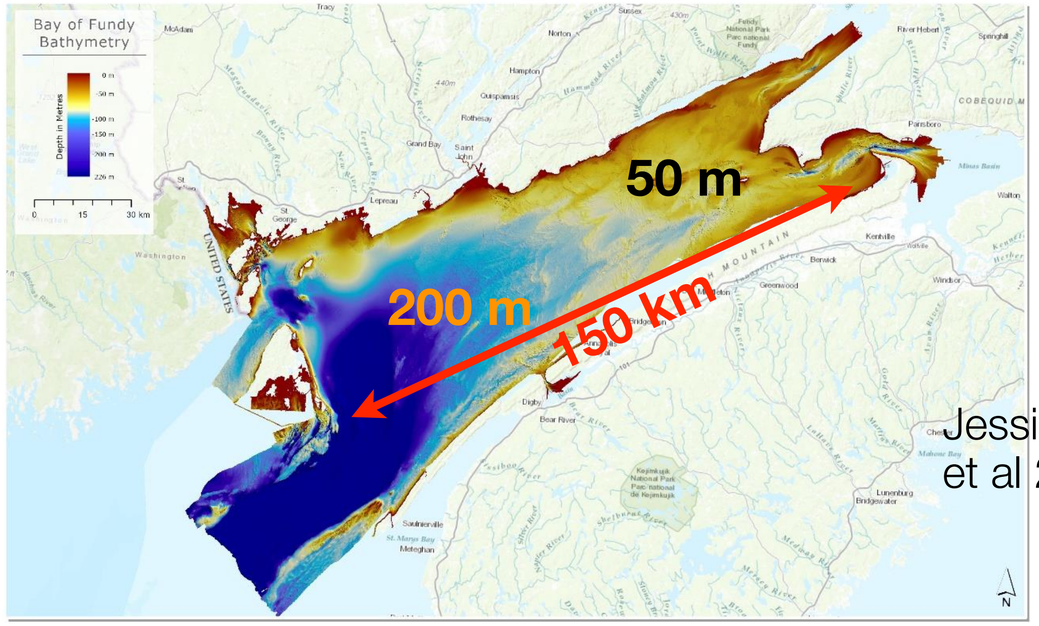
Bay of Fundy: The Highest Tides in the World





Jessica A. Sameoto et al 2020

https://www.noaa.gov/ocean/fundy-max

“While the Earth's average tide-driven variation in sea level is 3 feet, the water level near Wolfville, in Nova Scotia's Minas Basin, can be as much as 53 feet (16 m) higher than at low tide.”

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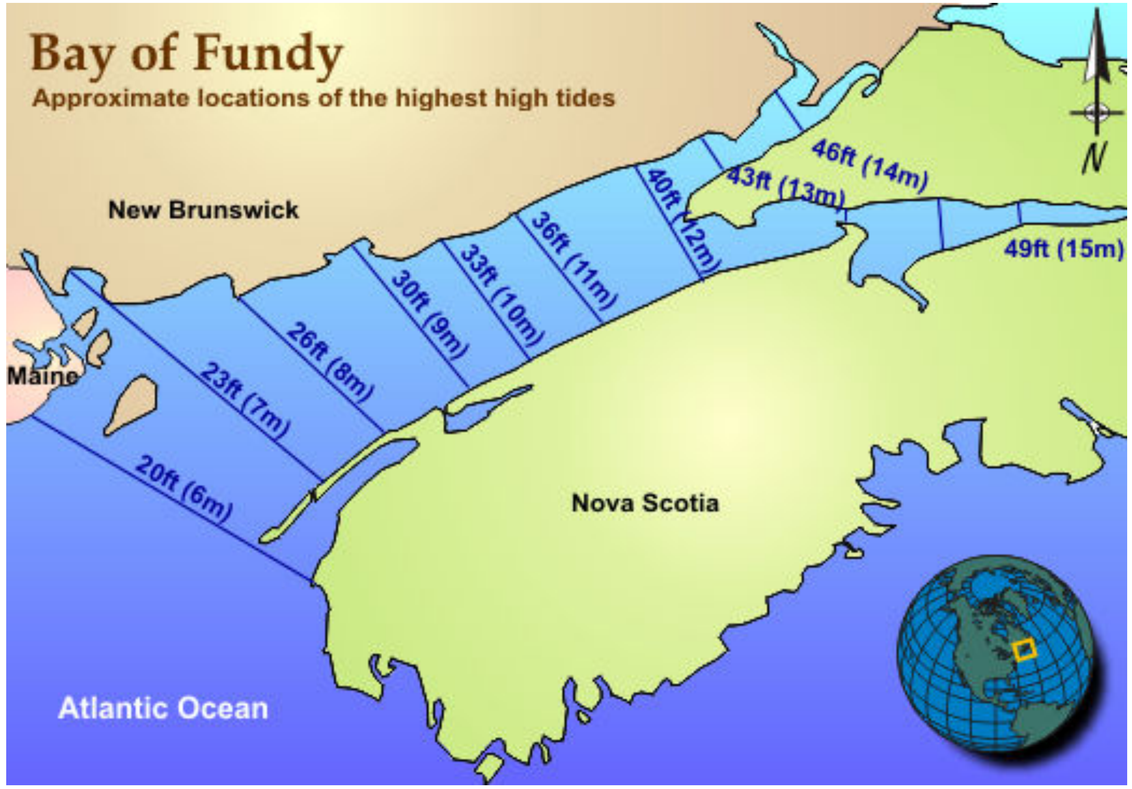

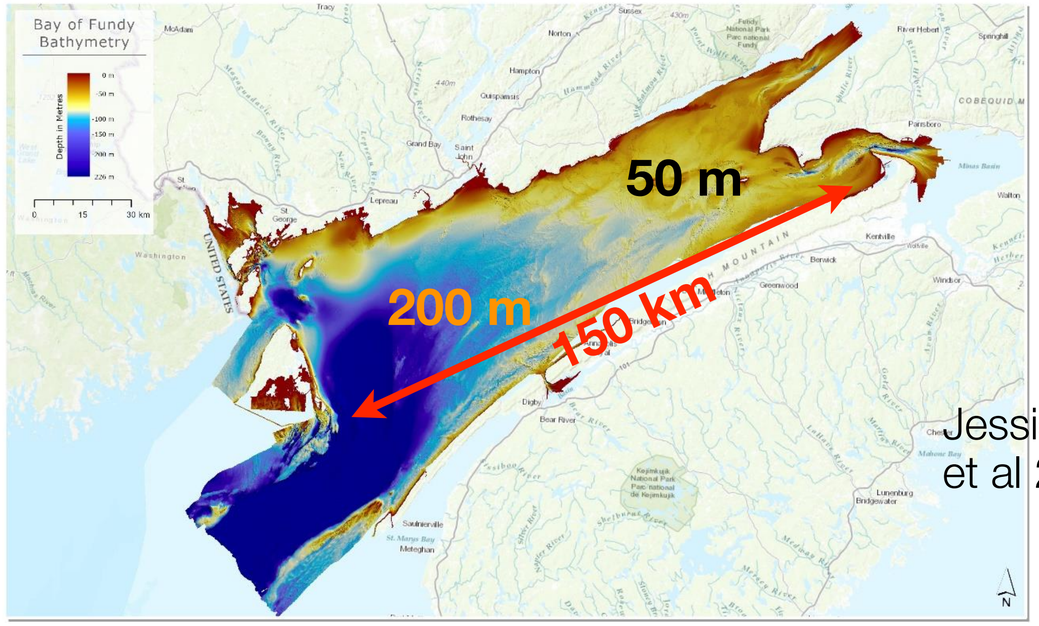

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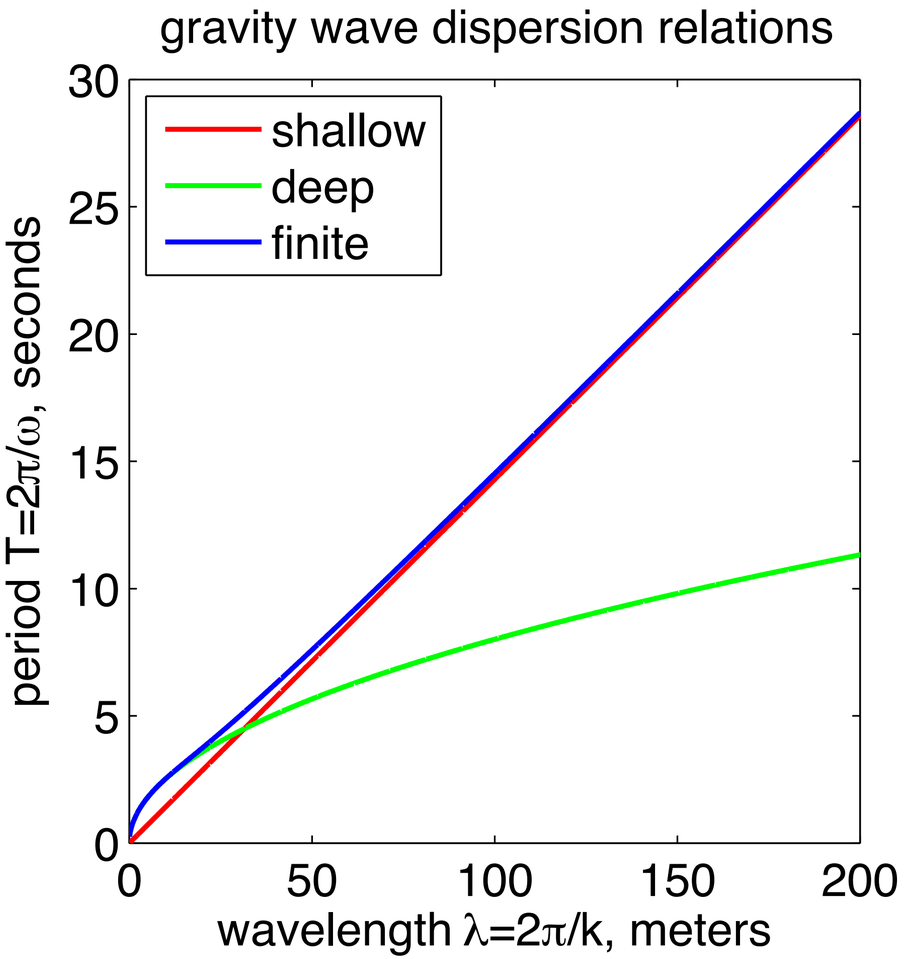
Notes

3 Surface gravity waves – without rotation

3.8 Deep 1d water waves scaling argument, particle trajectories

3.9 Finite ocean depth & limits of shallow & deepwater

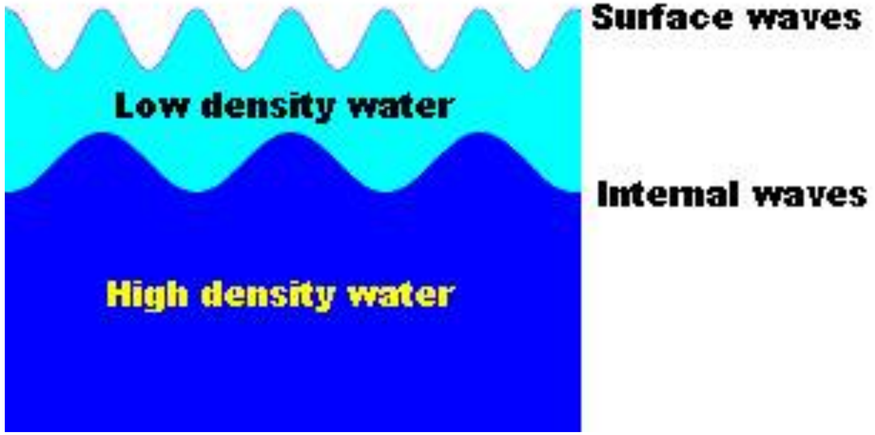


Miniquiz

deep gravity waves dispersion relation from dimensional arguments

5 Internal waves

https://www.youtube.com/watch?v=oljinlD2yho



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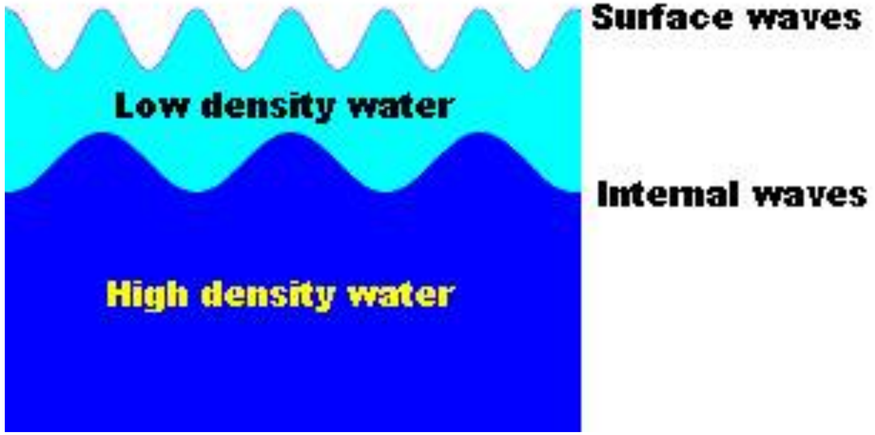

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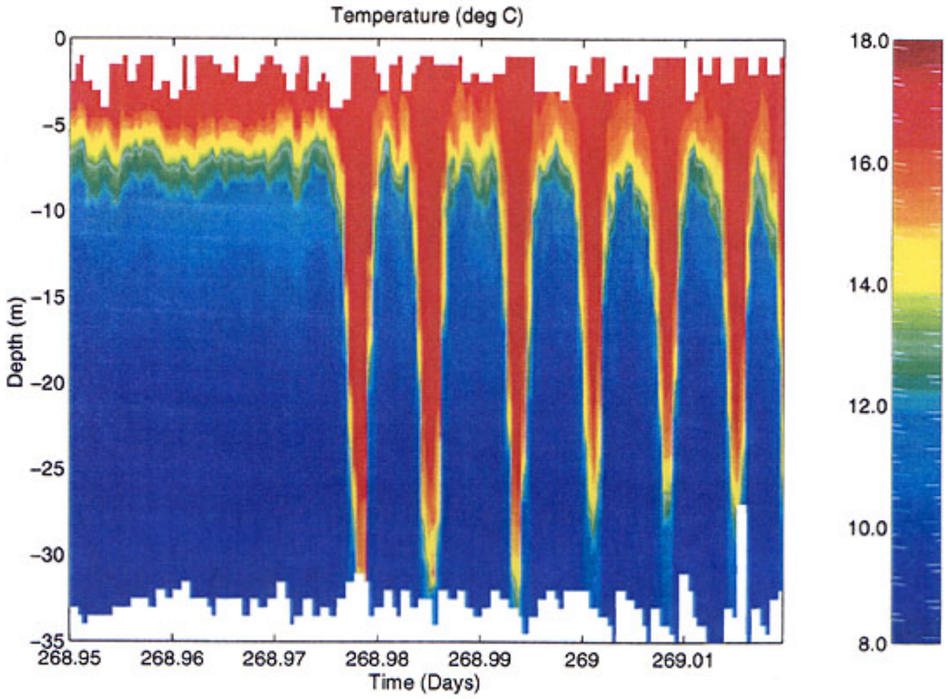
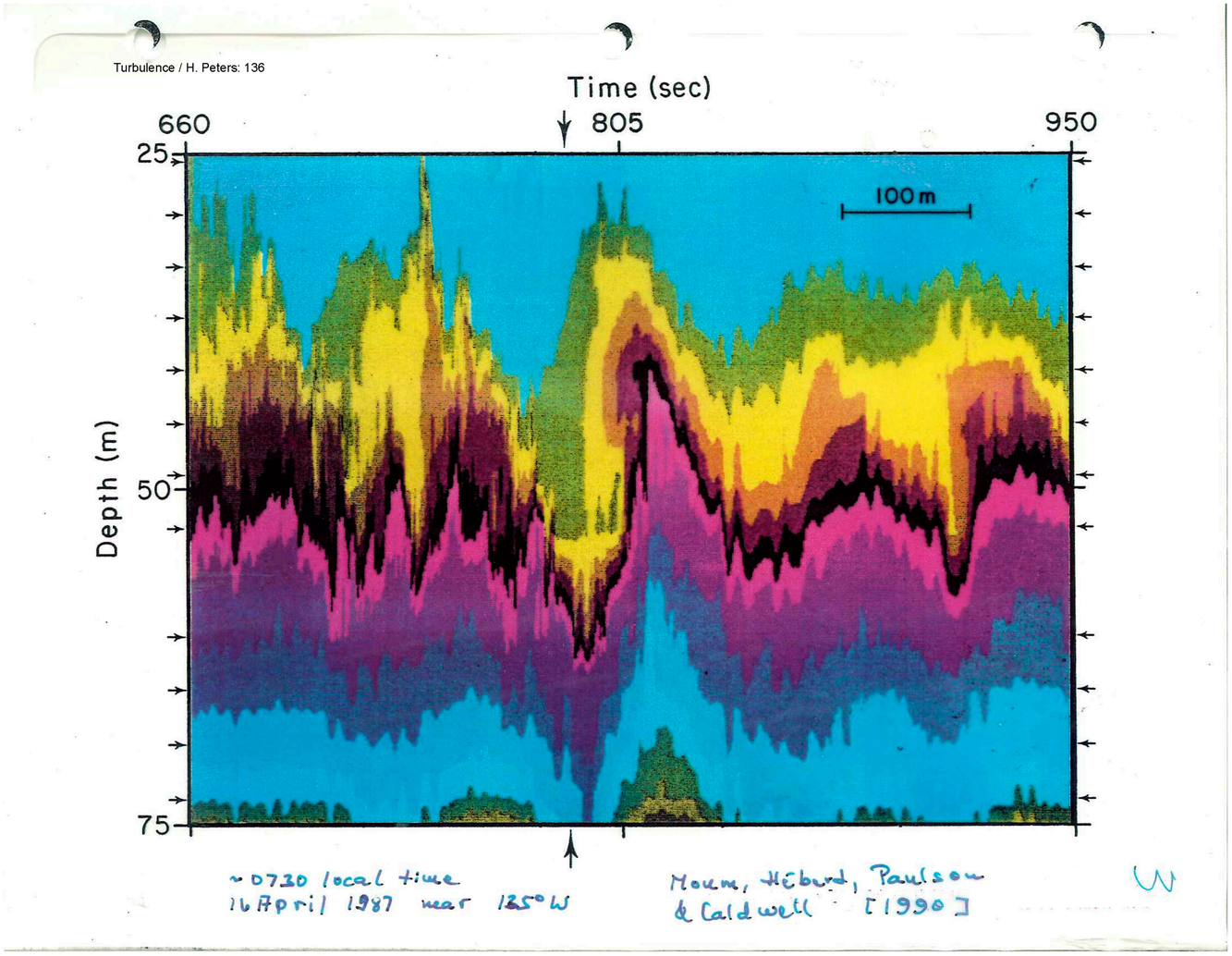
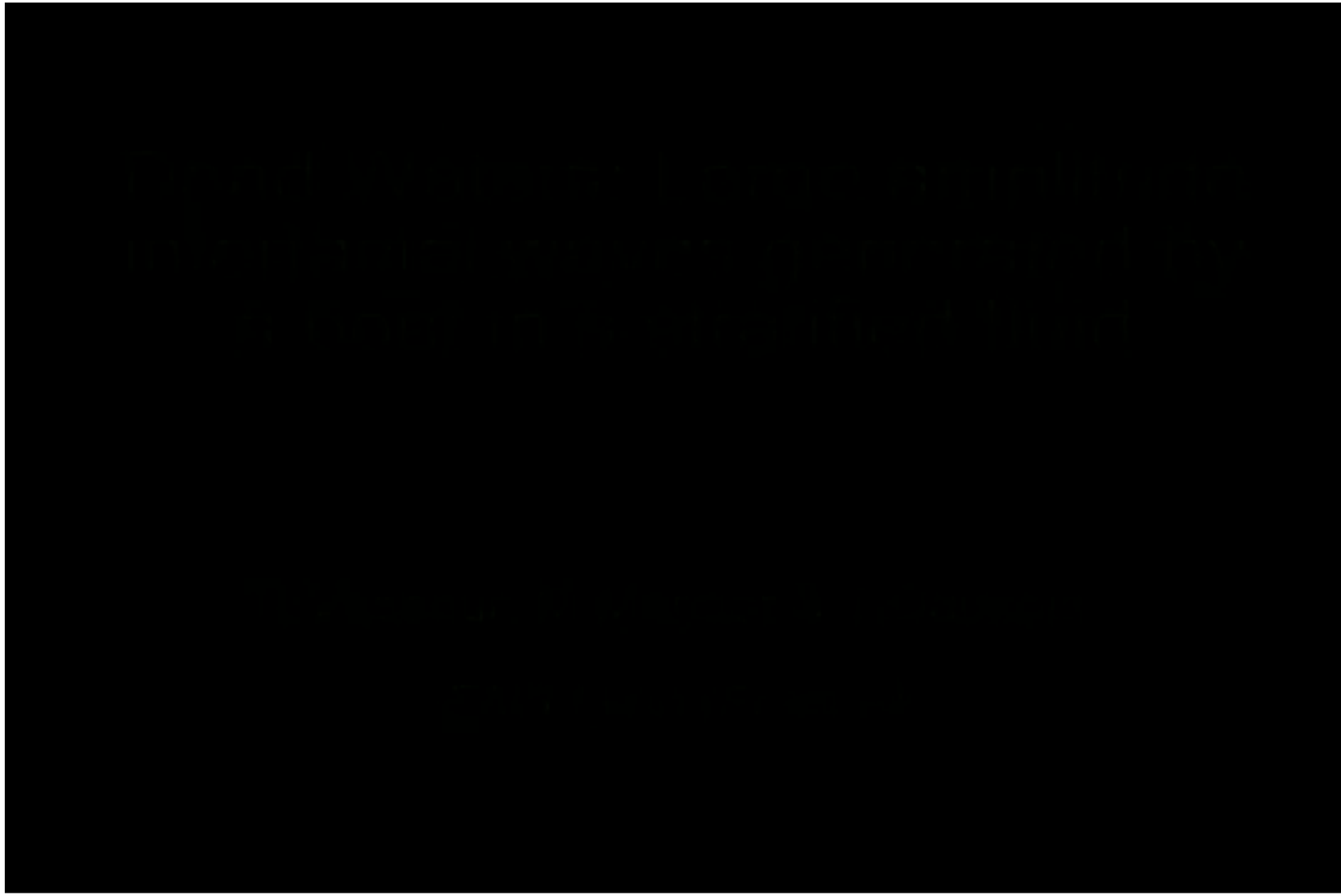




5 Internal waves

Dead waters demo



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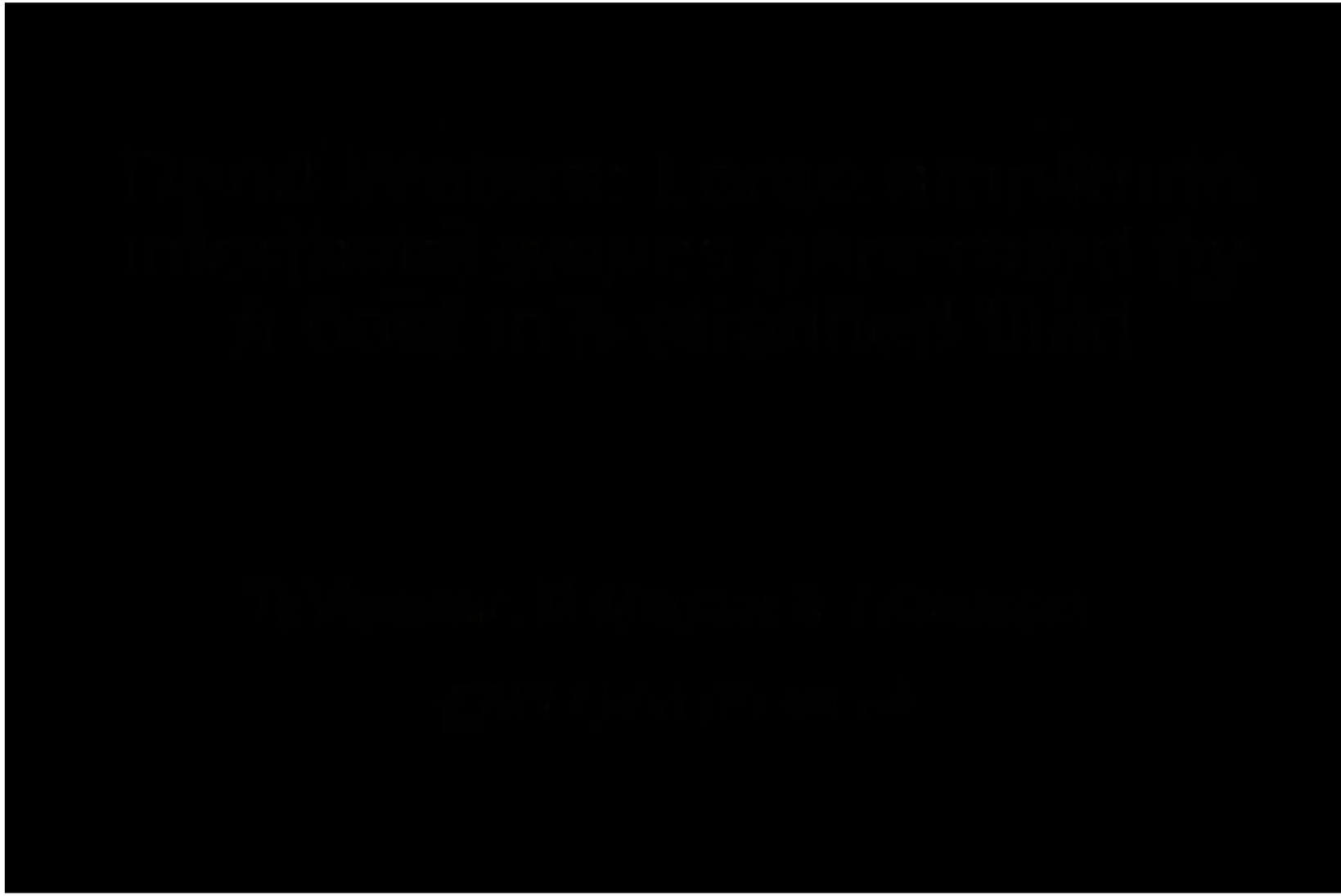

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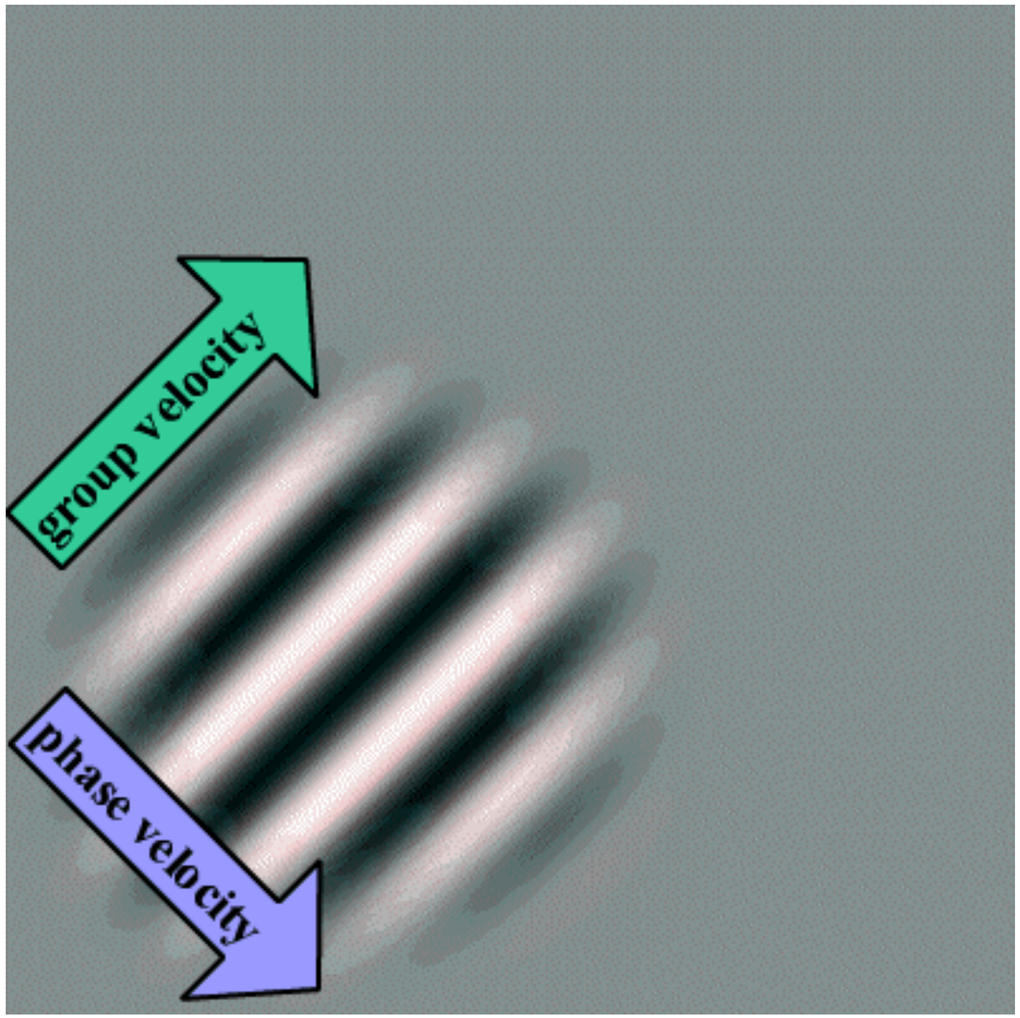
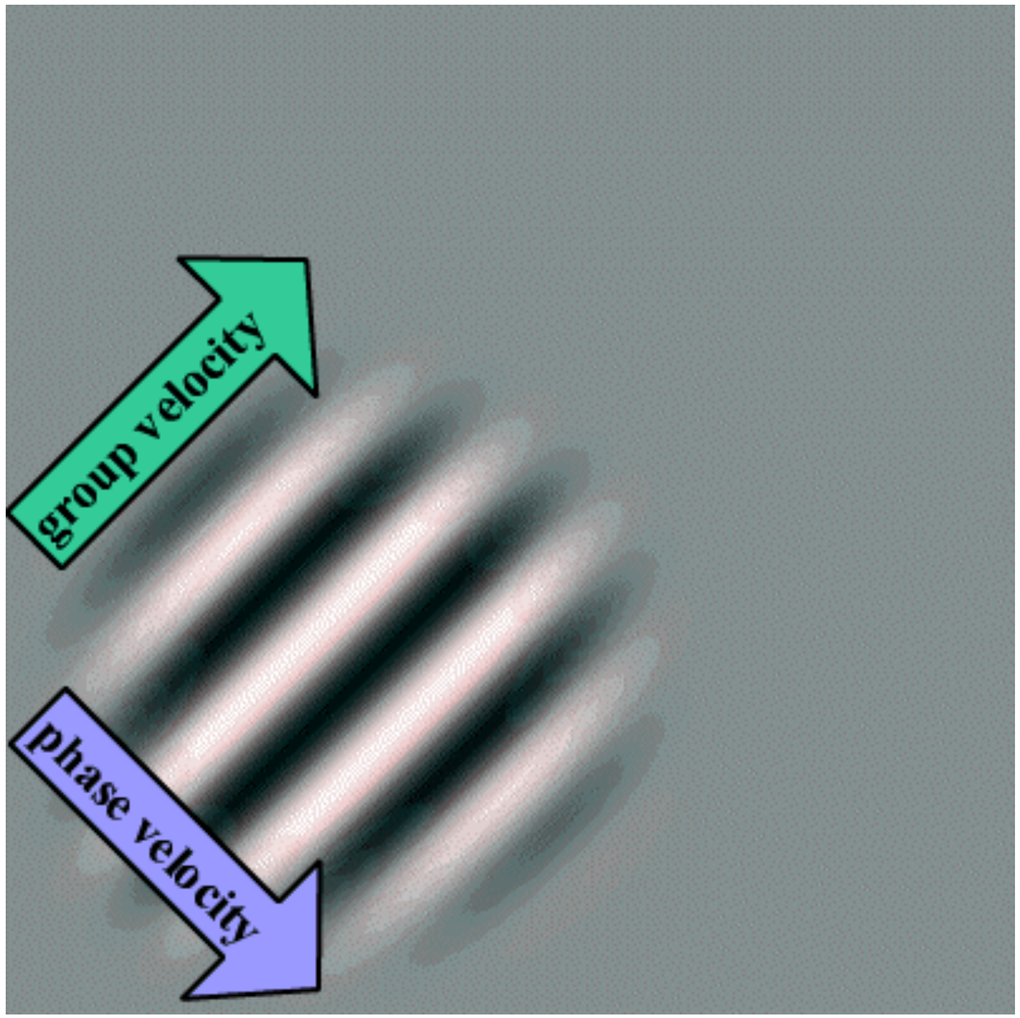


The directions of the group velocity and phase velocity of internal waves are orthogonal!

😳

https://www.gfd-dennou.org/library/gfd_exp/exp_e/doc/iw/guide05.htm

5 Internal waves



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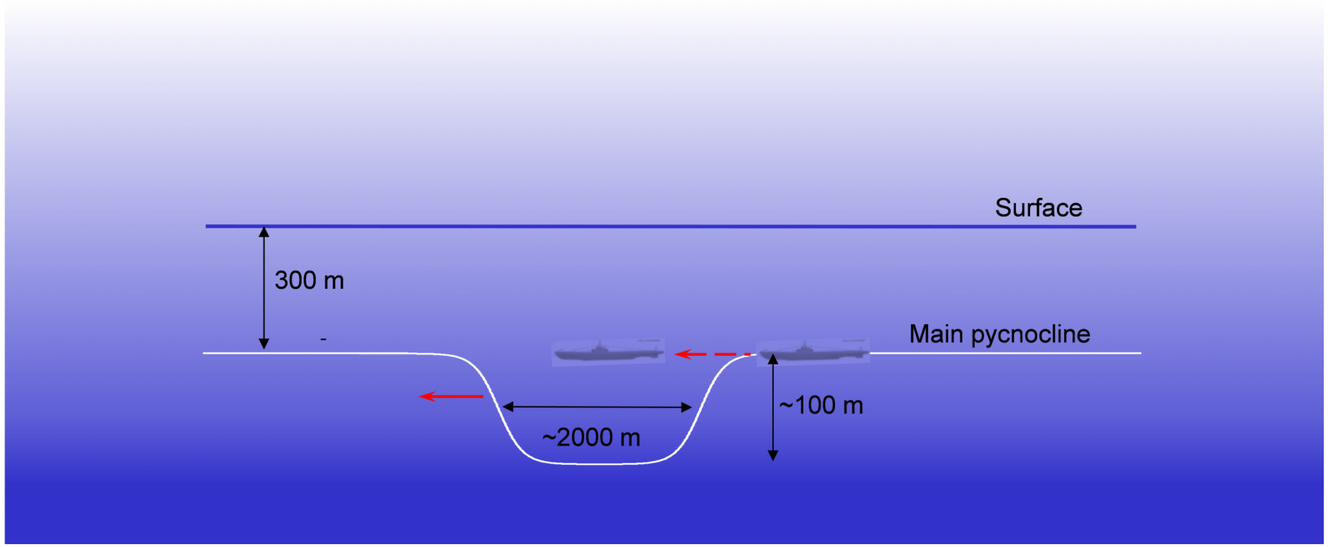
Internal waves speculations



Stepanyants, Y. (2021) arXiv: American nuclear submarines, Thresher and Scorpion, perished in the 1960s due to large-amplitude solitary internal waves? Also the diesel Indonesian submarine Nanggala-402…? https://researchfeatures.com/can-internal-waves-sink-a-submarine/

An interesting historical possibility is that the effect caused Cleopatra's ships difficulties and loss at the Battle of Actium in 31 BC in which legend attributes the loss to "suckerfish" attaching to the hulls. https://en.wikipedia.org/wiki/Dead_water

Thanks to Zoe & Inko, spring 2024

Notes
4 Buoyancy oscillations

Miniquiz
derive equation for buoyancy oscillations

Notes:
5 Internal waves

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Notes

6 Shallow water waves in the presence of rotation

6.1 Coastal Kelvin waves

https://www.youtube.com/watch?v=bYI1zljJr4g

https://www.youtube.com/watch?v=B6AQxktoYhU

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Notes

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Coastal Kelvin waves: Lake seiches and along-coast propagation

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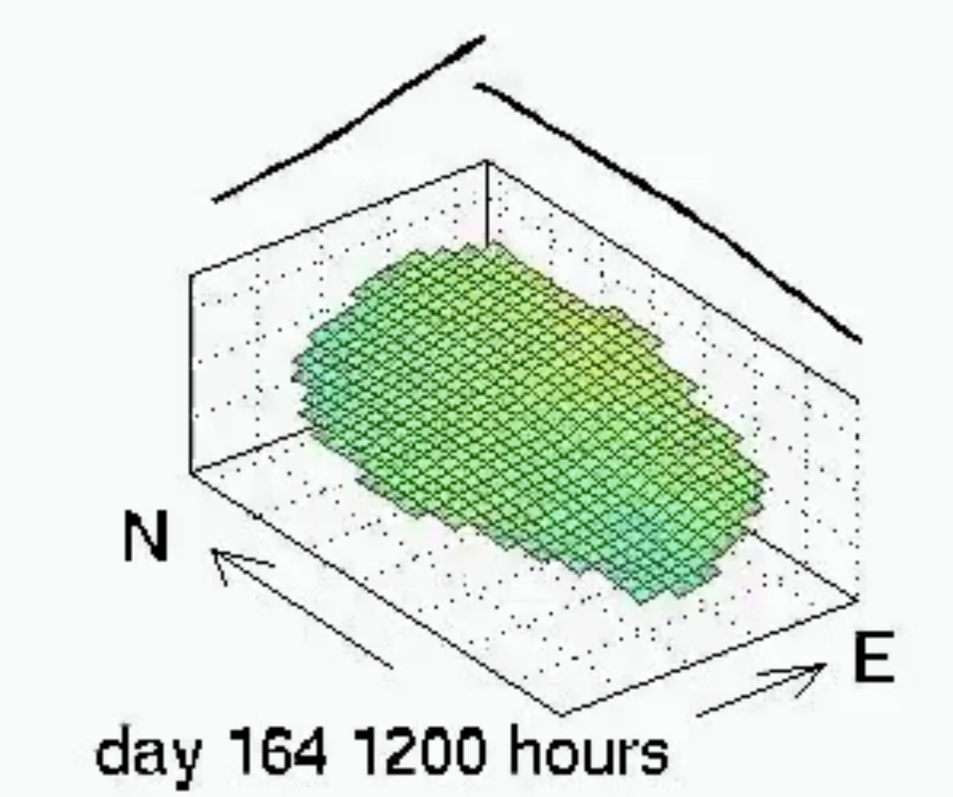
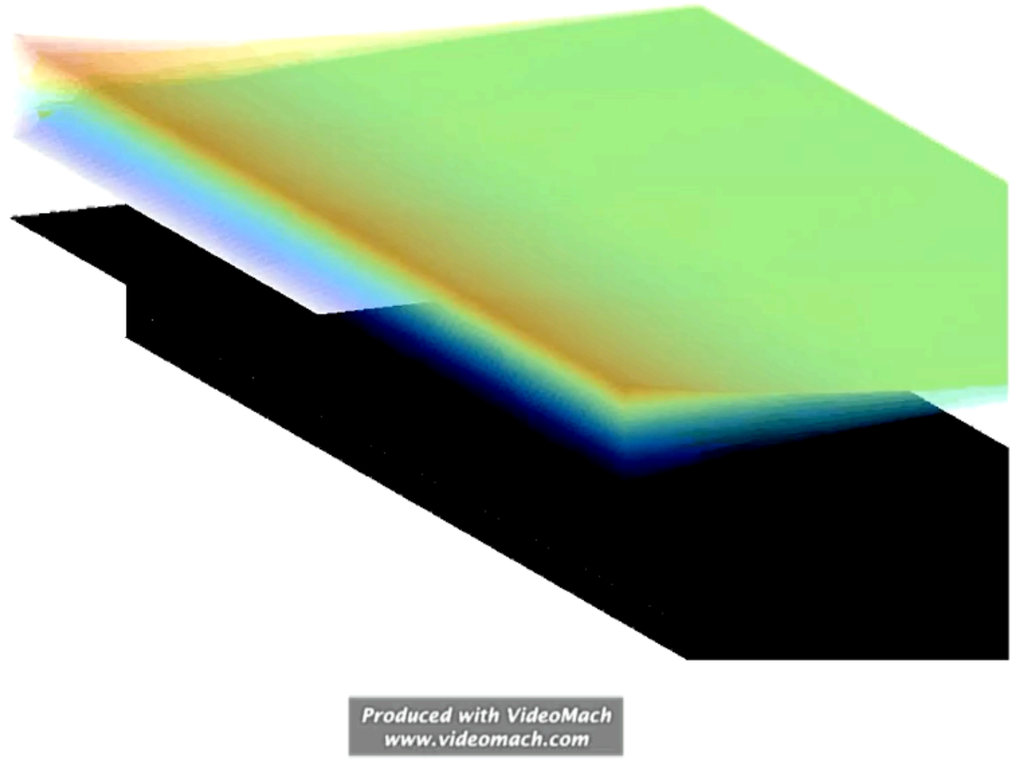


Onda de Kelvin costeira
roberto fioravanti 2010



Coastal Kelvin waves: Lake seiches and along-coast propagation

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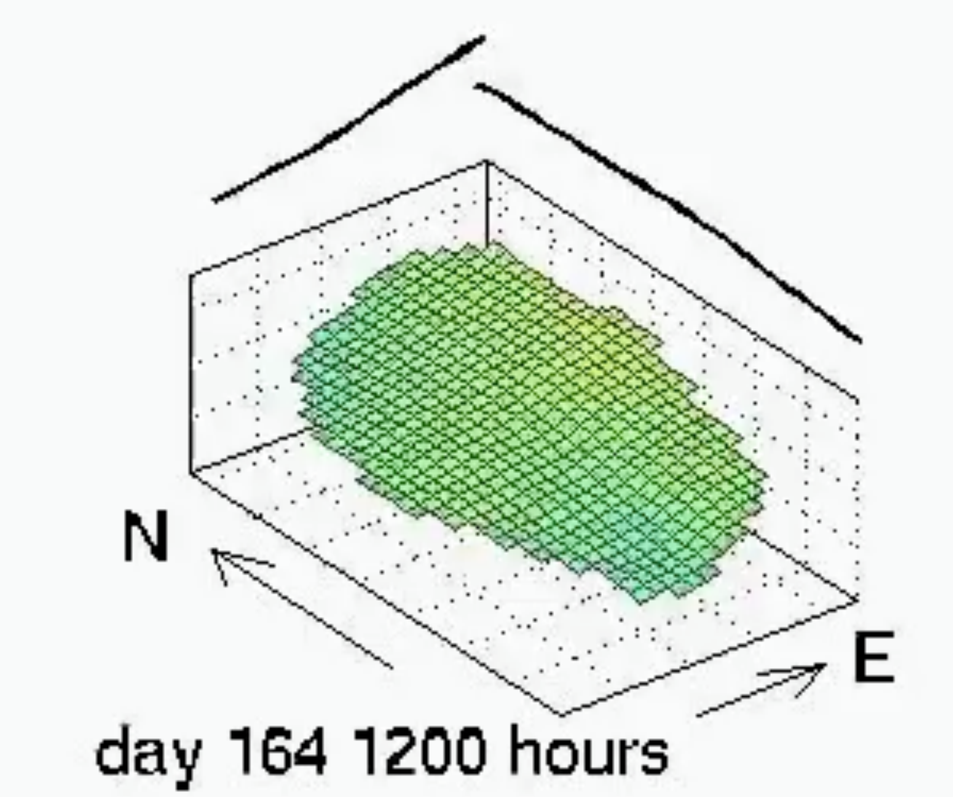

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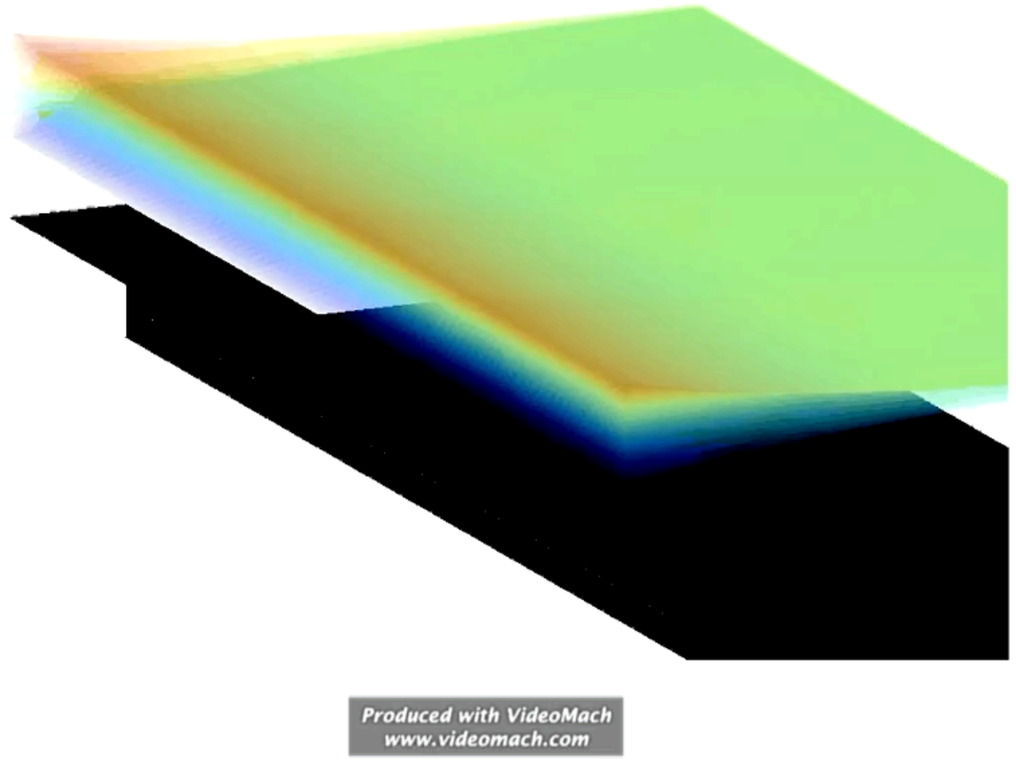

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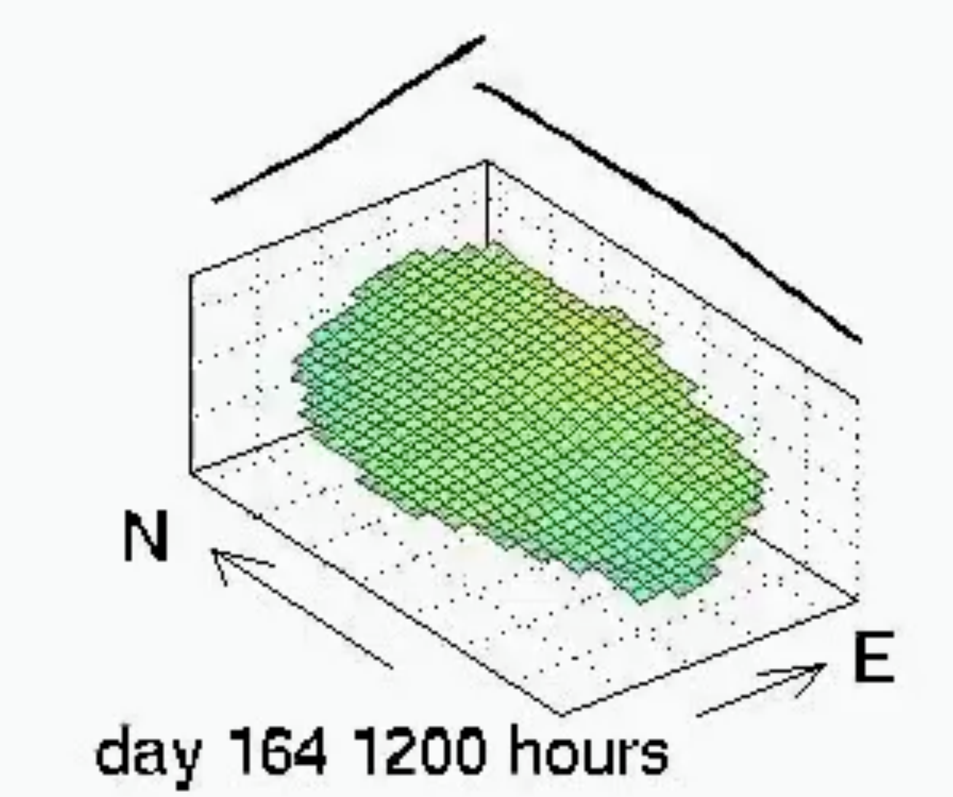

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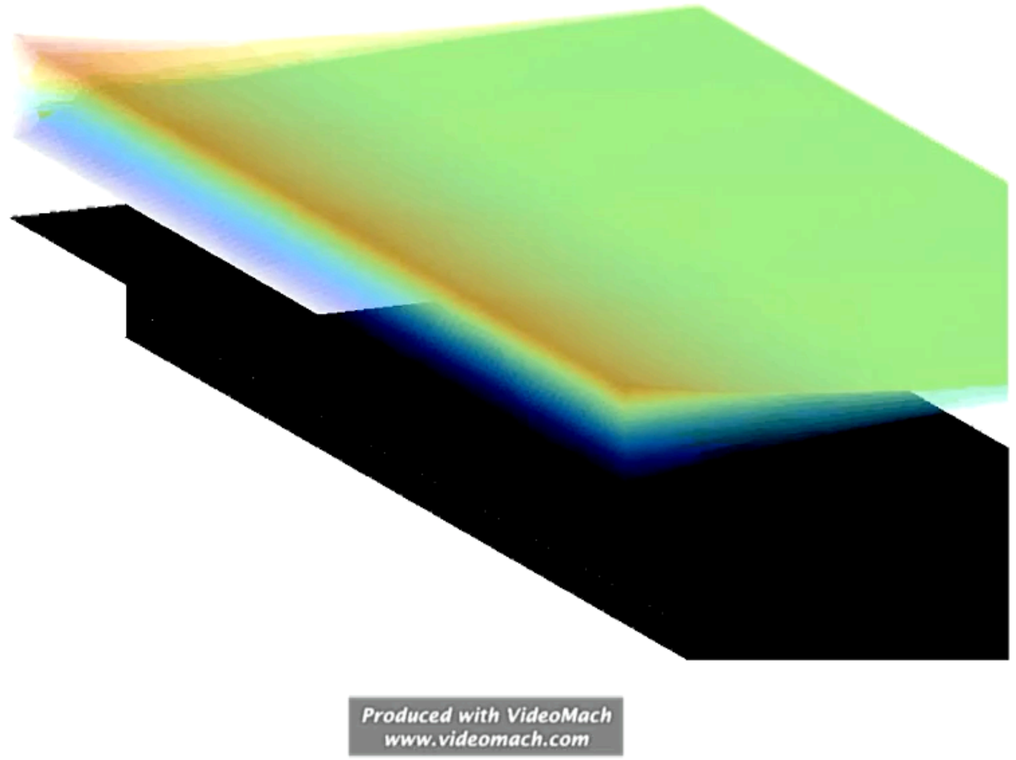
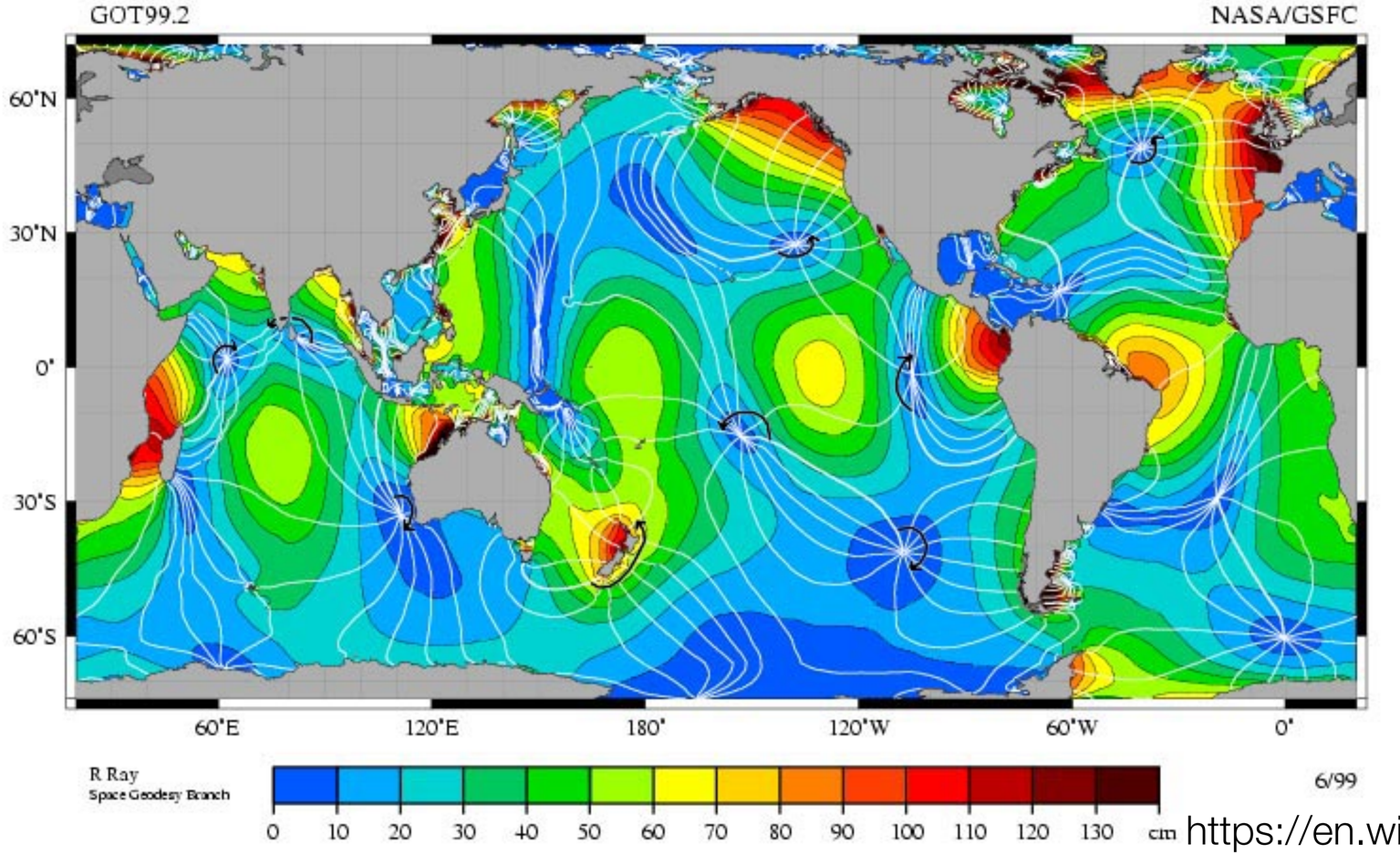


Coastal Kelvin waves and tidal Amphidromic points



https://en.wikipedia.org/wiki/Amphidromic_point

"An amphidromic point (tidal node): a geographical location in the ocean, sea, or bay where the tidal range is zero, meaning there is no vertical rise or fall in sea level. Tidal waves rotate around these points due to the Coriolis effect & the confinement of water by landmasses. They act as centers for cotidal lines."

Notes

6 Shallow water waves in the presence of rotation

6.1 Coastal Kelvin waves

Notes

6 Shallow water waves in the presence of rotation

6.2 Poincare waves

The End