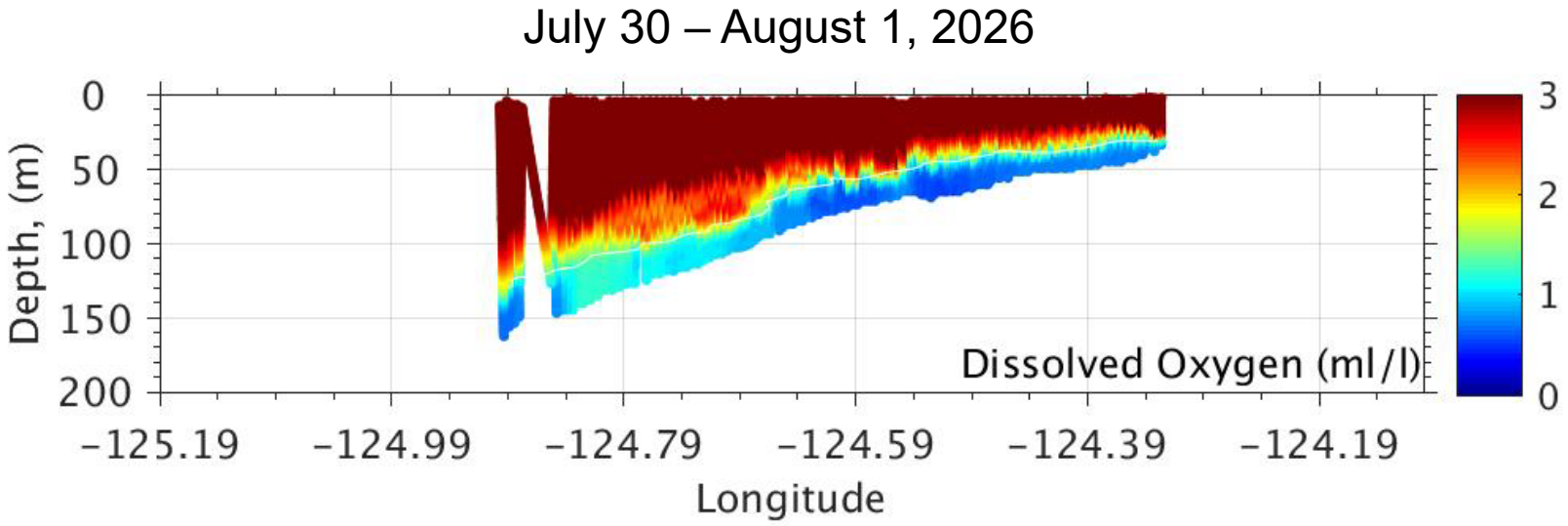
Repeated Autonomous Underwater Glider Surveys Reveal Extreme, Near-Bottom, Shelf Hypoxia during the Upwelling Season off Central Washington, U.S.A.

Jack Barth (jack.barth@oregonstate.edu)
Brian VerWey and Jace Marquardt

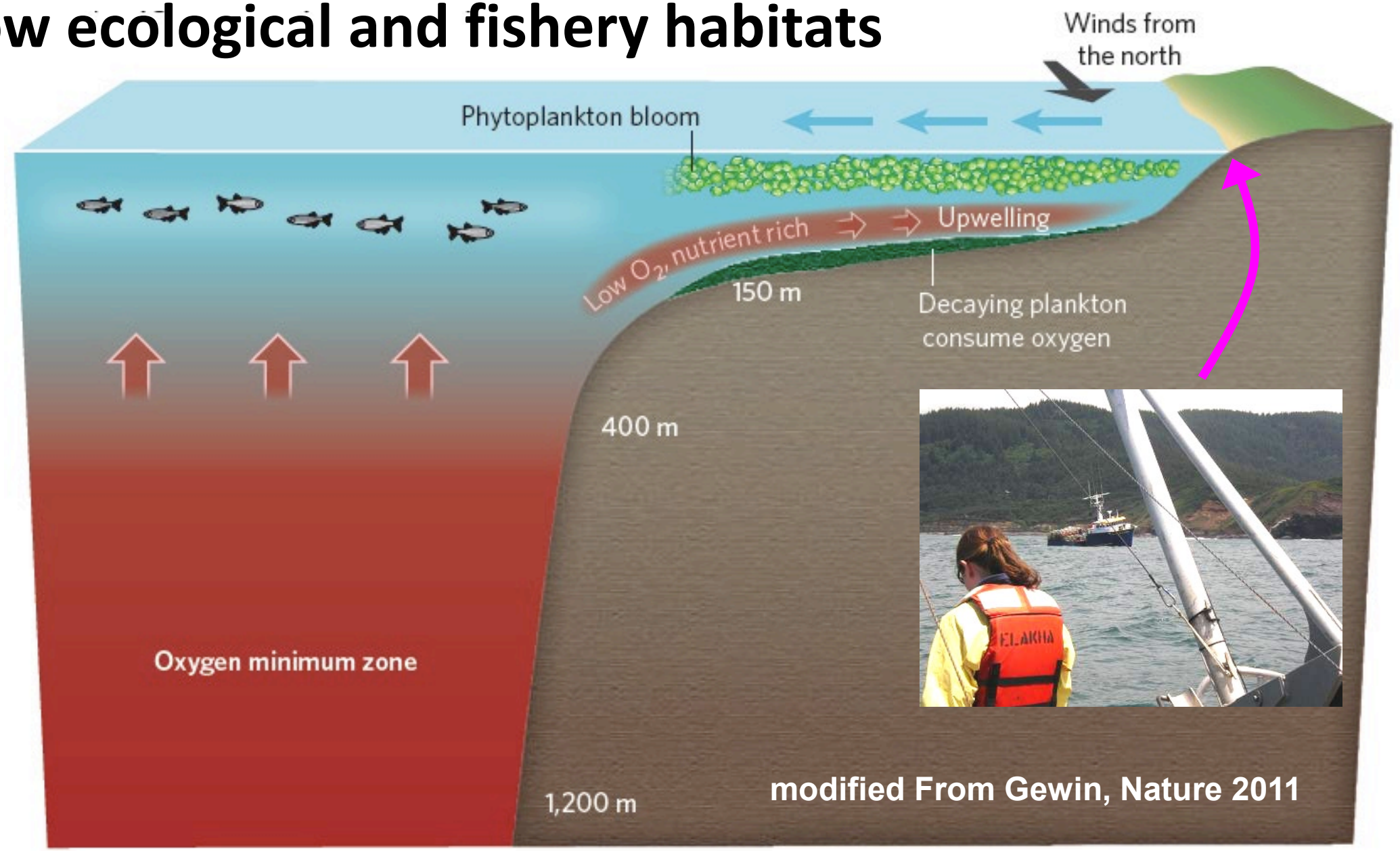
- Upwelling-driven hypoxia

→ Why aren't bottom waters hypoxic all the time?

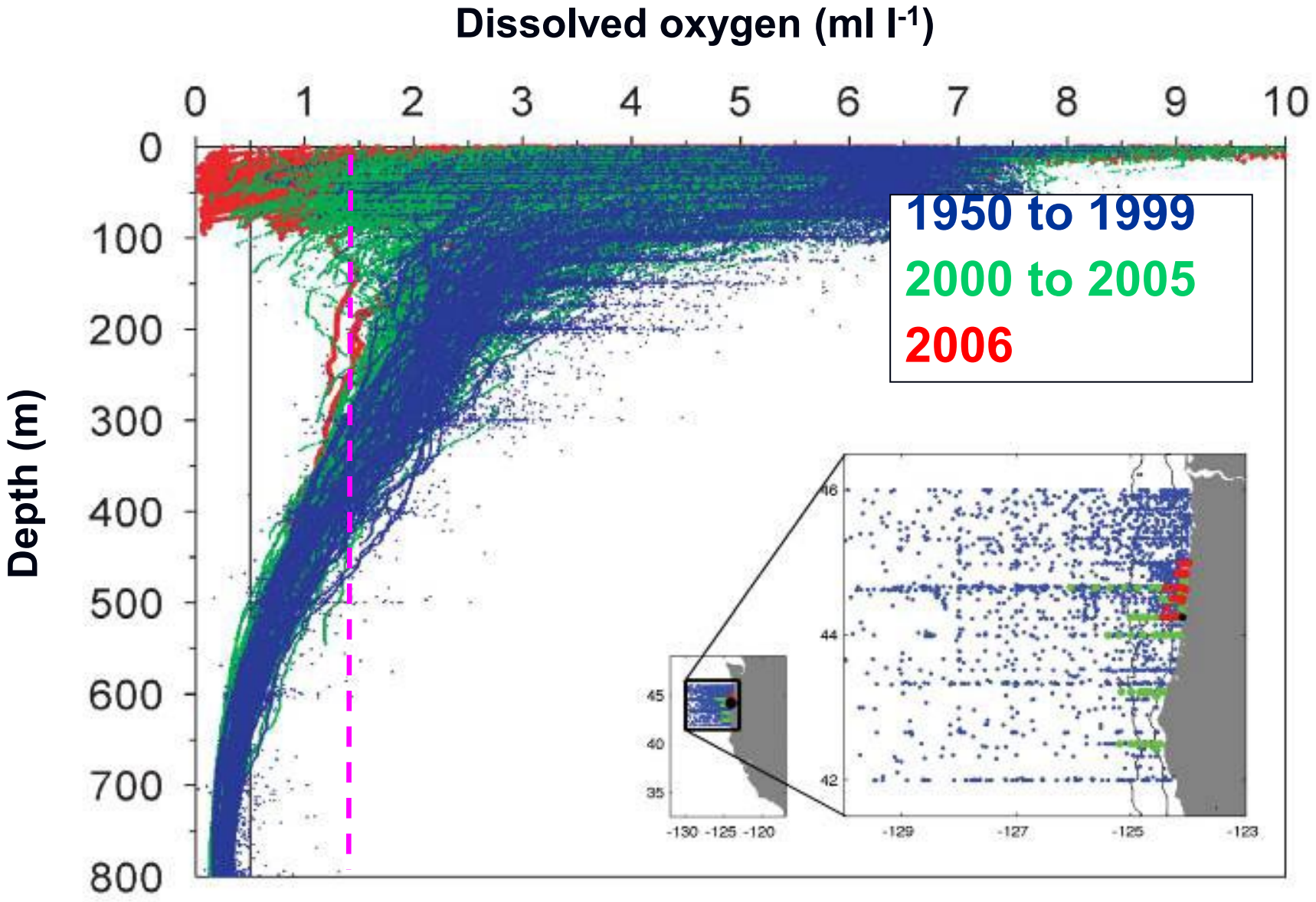




Low-oxygen (hypoxia) threatens important shallow ecological and fishery habitats



Anoxia (zero oxygen) observed on Oregon shelf





OREGON
Fish & Wildlife

Chan, Barth et al. (2008, *Science*)

2021 Near-bottom Dissolved Oxygen upwelling season average

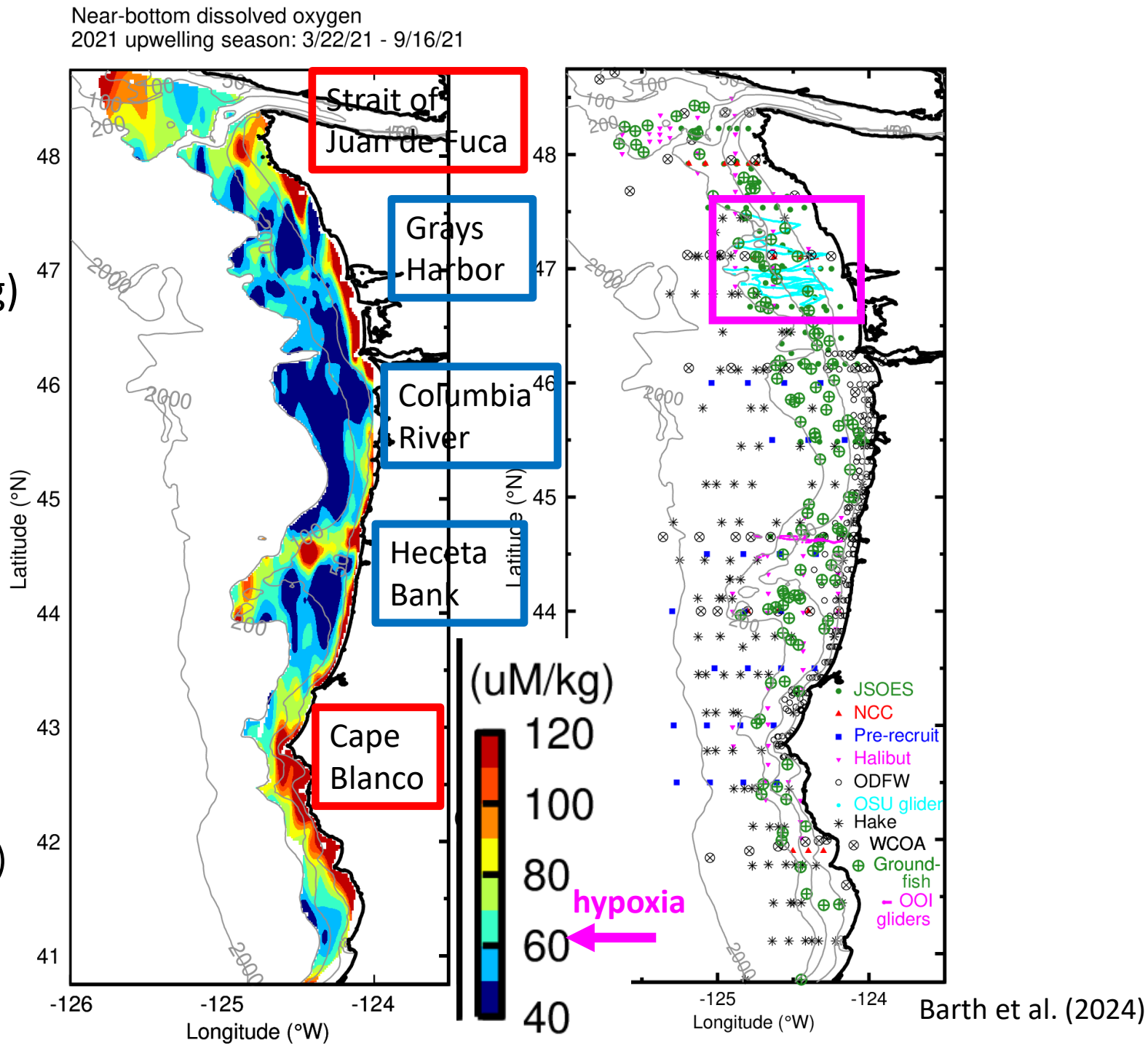
48% of shelf hypoxic (DO < 61 µM/kg)
15,500 km² (~6000 square miles)

Low-Dissolved Oxygen

- over wide shelf
- associated with river plume
- over submarine bank

High-Dissolved Oxygen

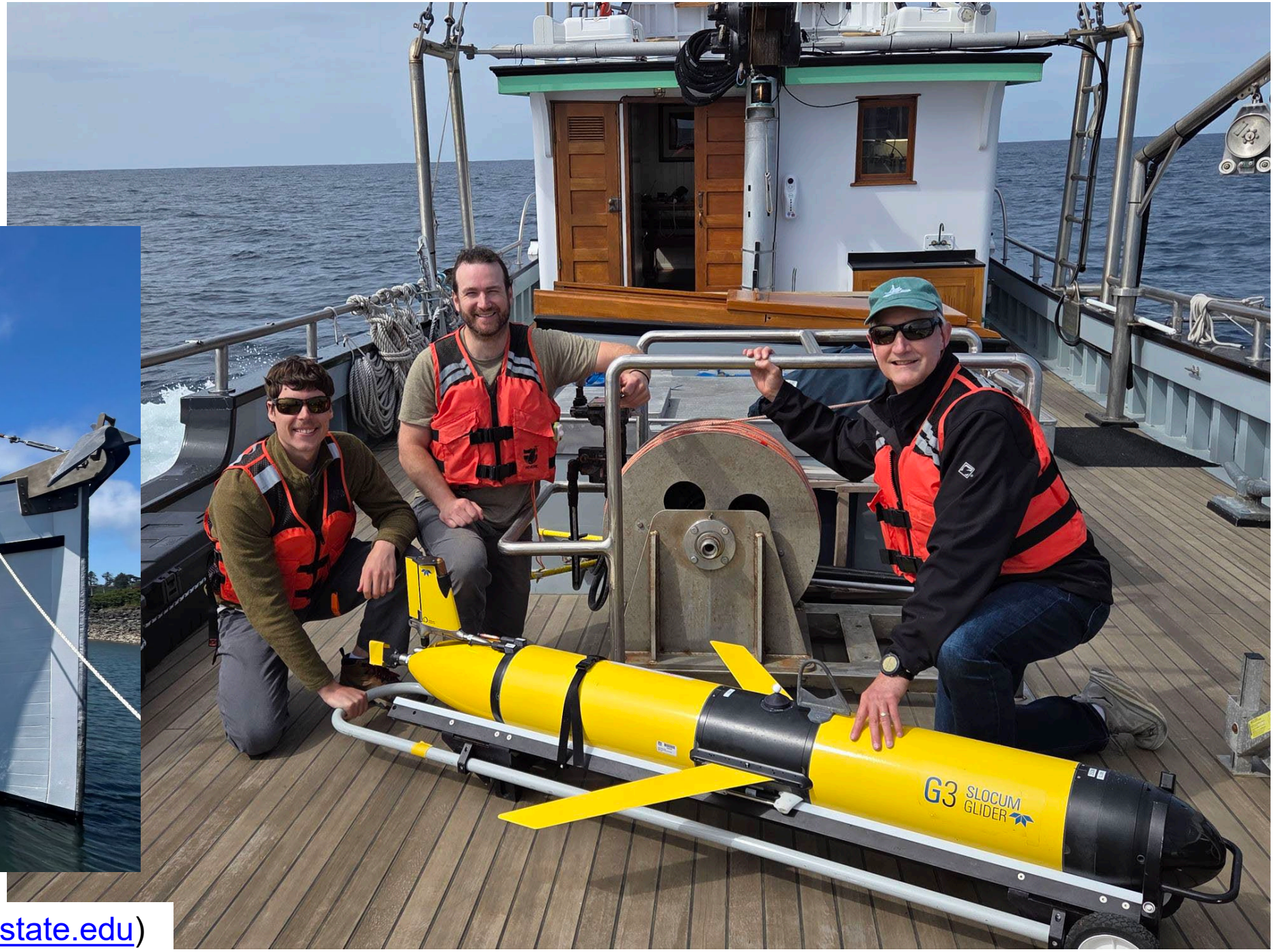
- narrow shelf
- near the coast (< 25-50 m water depth)
- mixing over shallow banks



Barth et al. (2024)

May 24, 2026
Deployment from historic vessel ***Western Flyer*** … a story for another time





Jack Barth (jack.barth@oregonstate.edu)

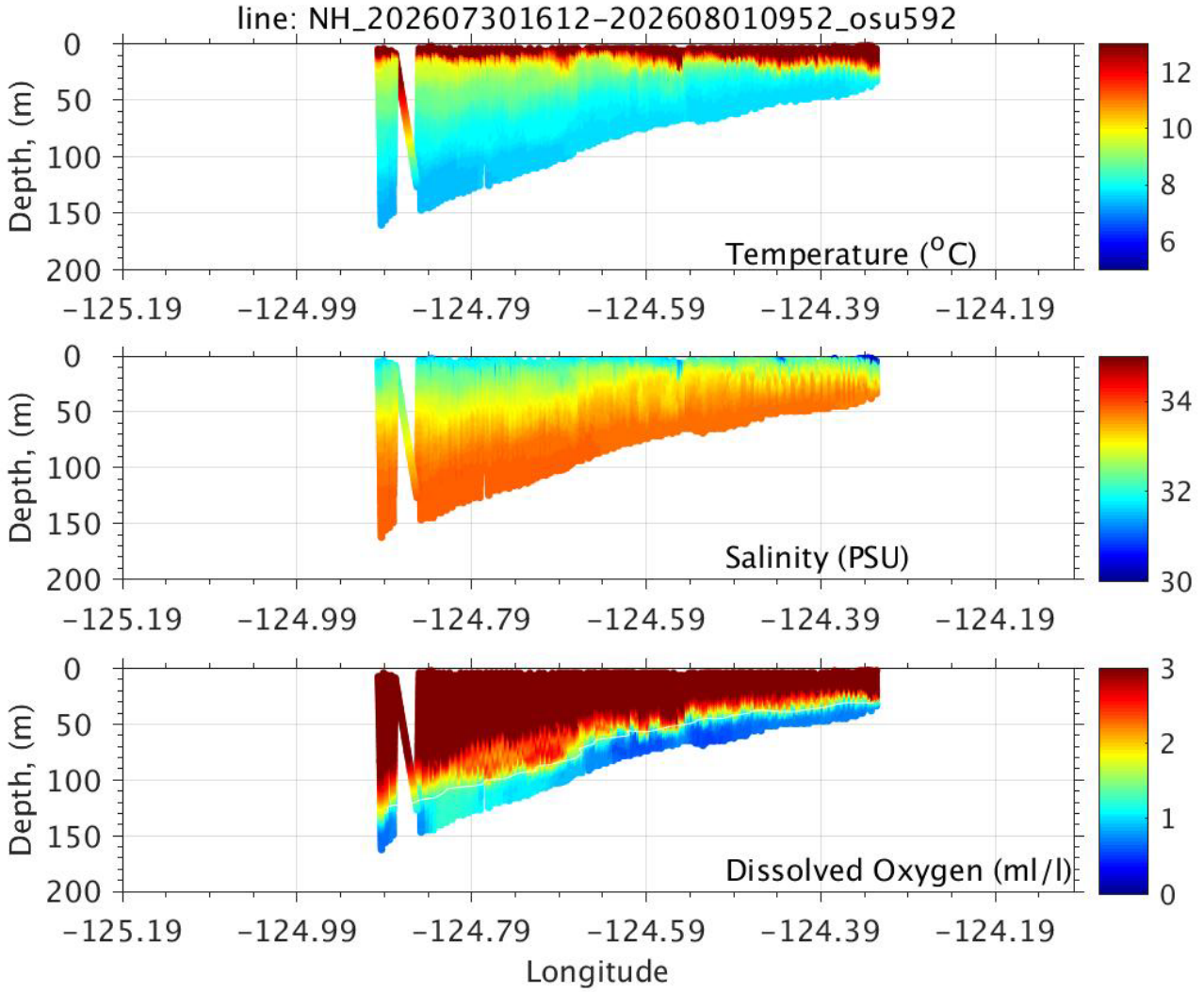
WA shelf observations in collaboration with Quinault Indian Nation and CRITFC



Aanderaa oxygen optode

July 30 to August 1, 2026





Jack Barth (jack.barth@oregonstate.edu)

Courtesy of Joe Schumacker, QIN

Quinault Indian Nation

PO Box 189 * Taholah, WA 98587

Date: July 25, 2024

To: Quinault Indian Nation Leadership and Ocean Fishers

From: Quinault Department of Fisheries

Subject: **NOTICE: LOW OXYGEN EVENT IN QUINAULT TREATY AREA**

Quinault Leadership and Ocean Fishers,

Recent observations on our beaches combined with data collected from two sources offshore have confirmed a low oxygen event (hypoxia) currently occurring in the marine areas adjacent to and south of the Quinault Canyon (west of Taholah).

This is a Quinault Dept. of Fisheries advisory notice to keep the Quinault Nation informed of ocean conditions.

Any data point colored white or purple in the graph image is hypoxic.

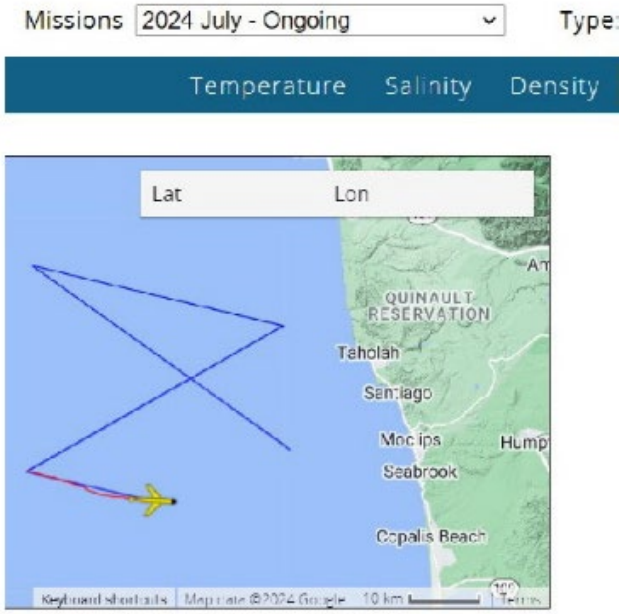
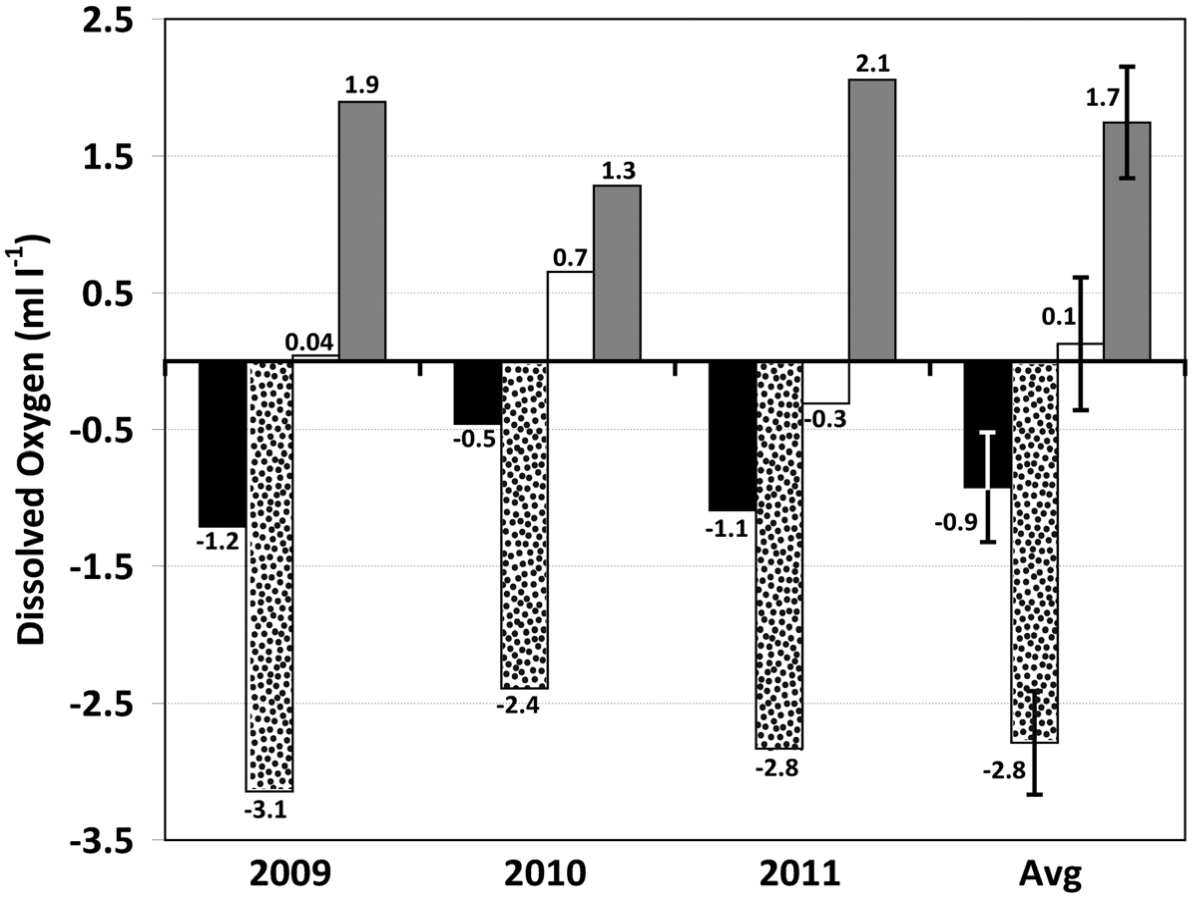


Fig. 3-Imagery courtesy NANOOS



But what keeps the near-bottom water from being hypoxic all the time during upwelling season?

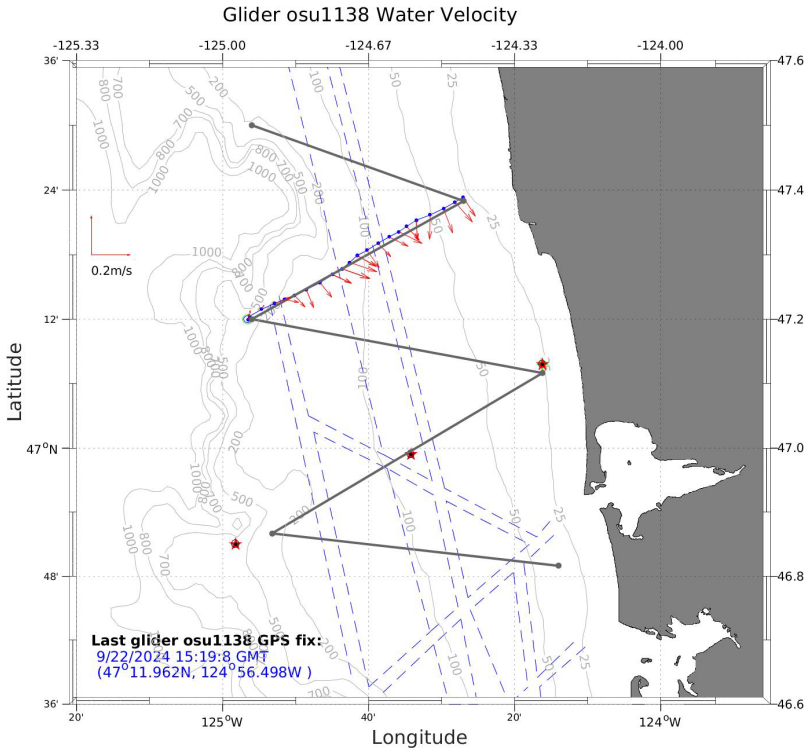


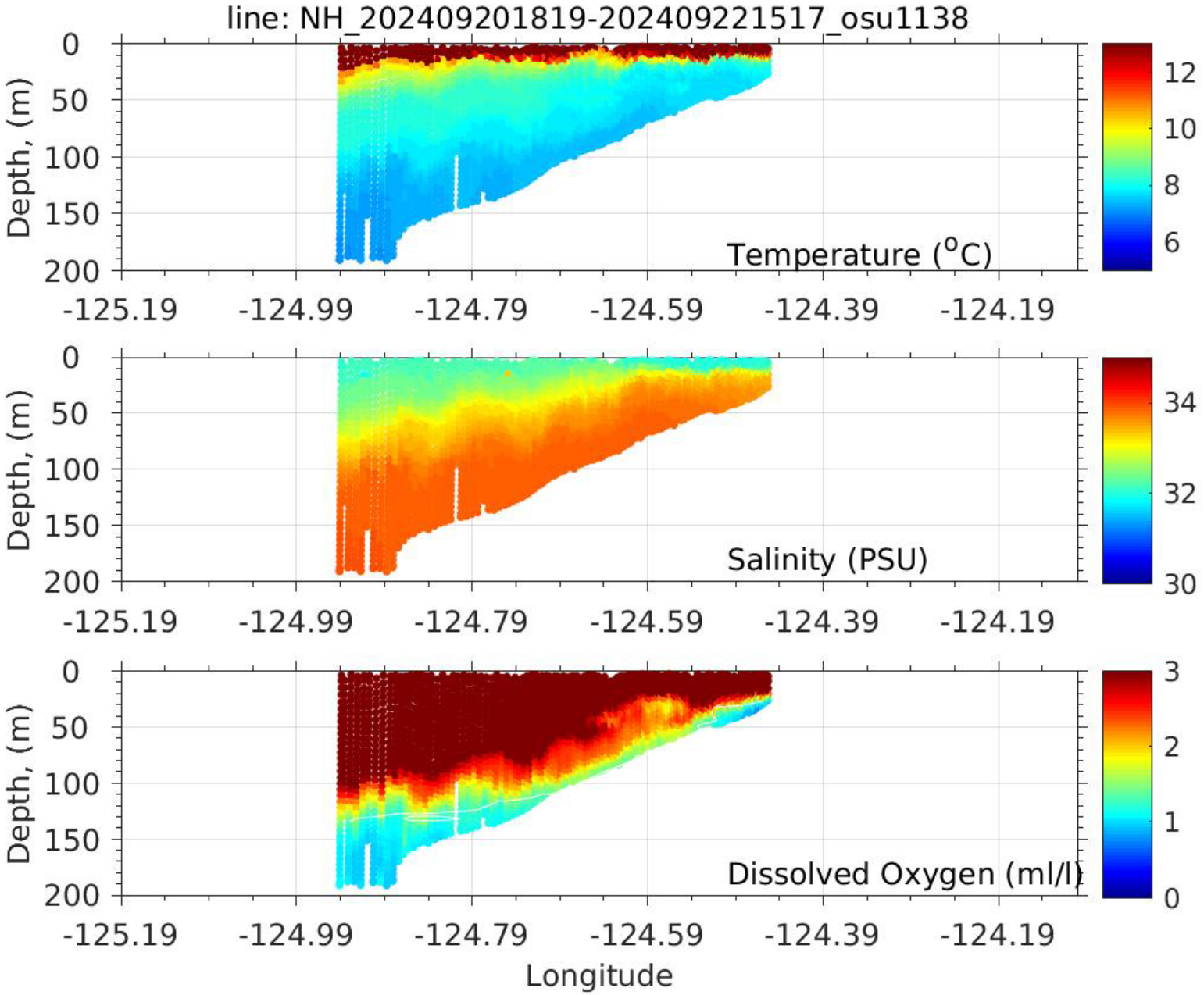
The net observed decrease is about **30% of the expected draw down** due to water-column respiration.

- **Observed**
- **Bottle Respiration**
- **Density (Adv/Mixing)**
- **Residual (Adv/Mixing @ 26.5 kg m^{-3})**

Adams, Barth, and Chan (*J. Geophys. Res.*, 2013)

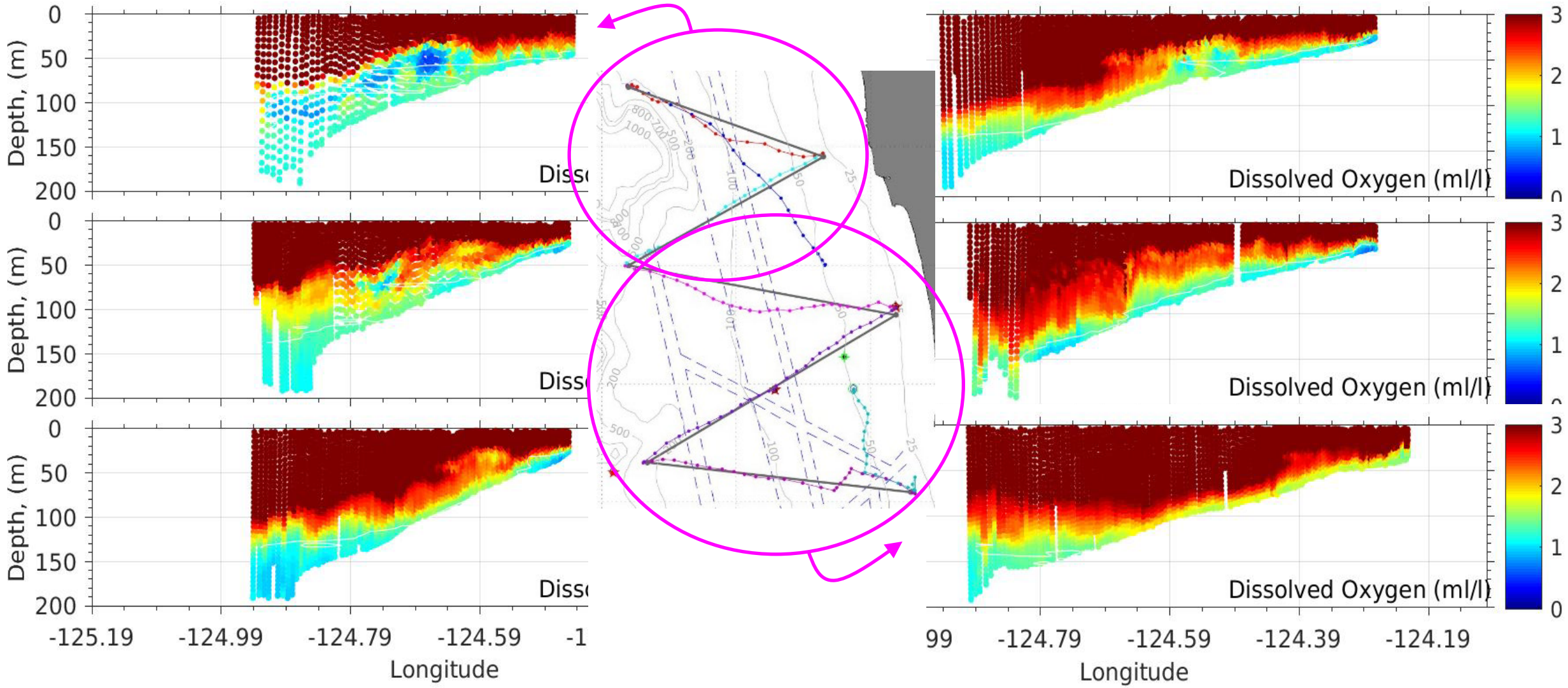
September 20-22, 2024





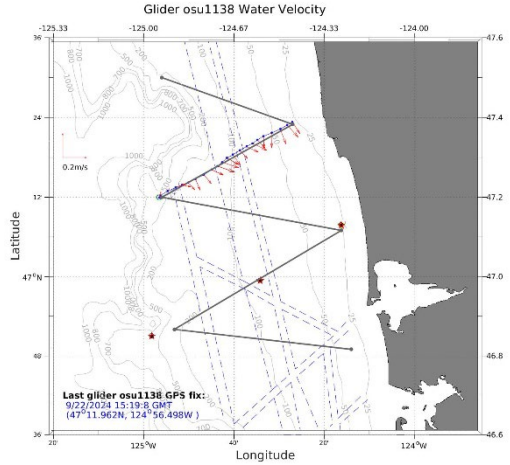
Jack Barth (jack.barth@oregonstate.edu)

September 17 to October 1, 2024

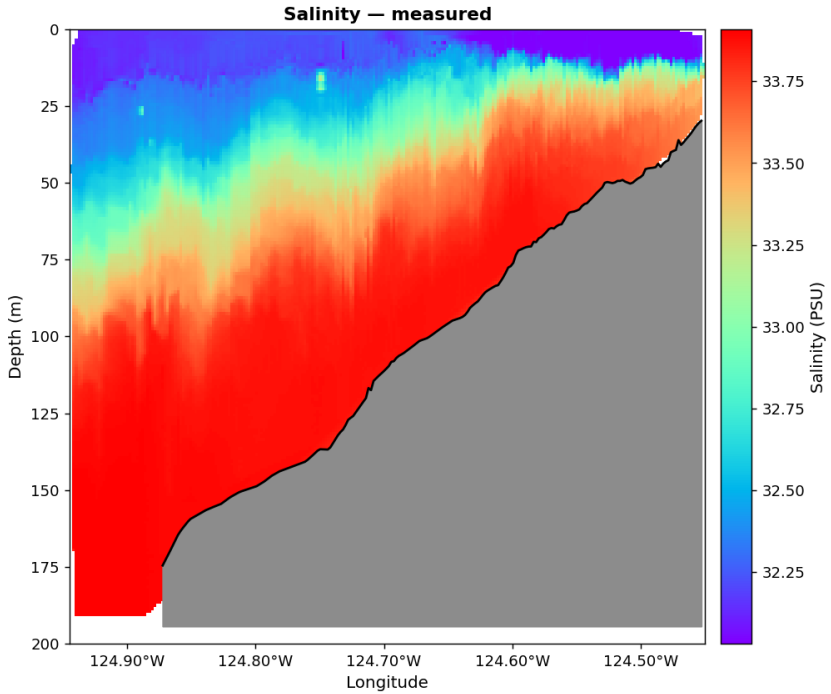


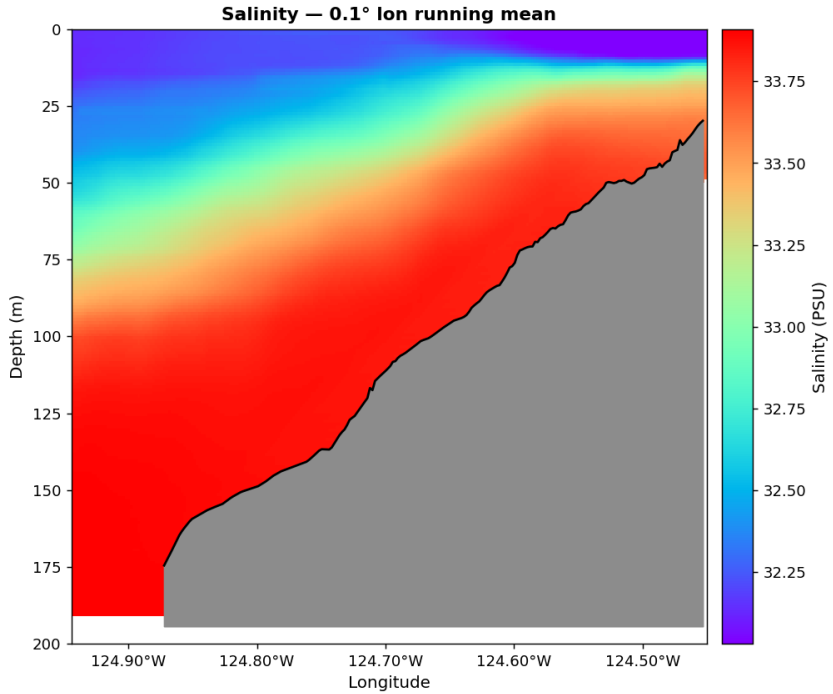
Jack Barth (jack.barth@oregonstate.edu)

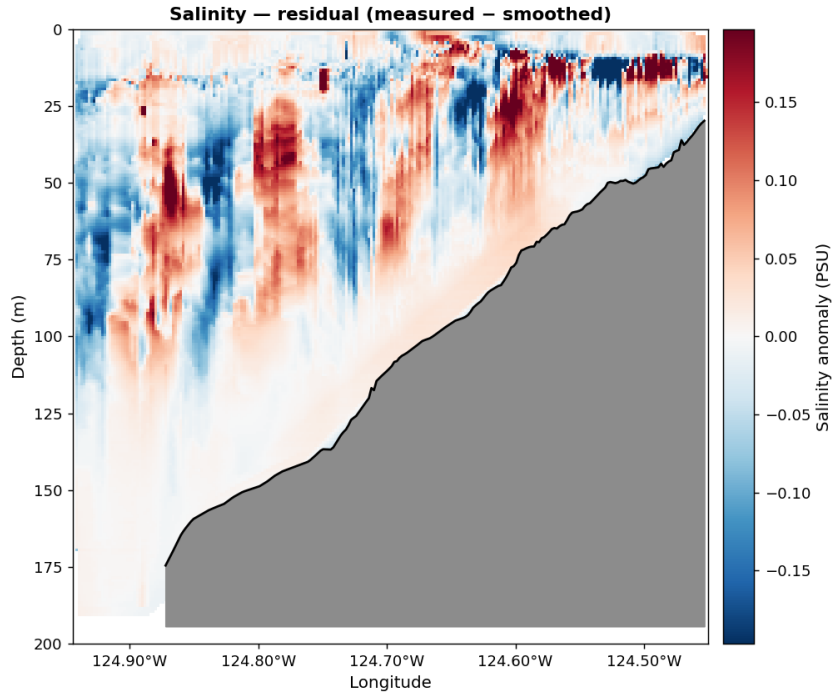
September 20-22, 2024



OSU1138 salinity – — 2024-09-20 18:19 to 2024-09-22 15:17







Jack Barth (jack.barth@oregonstate.edu)

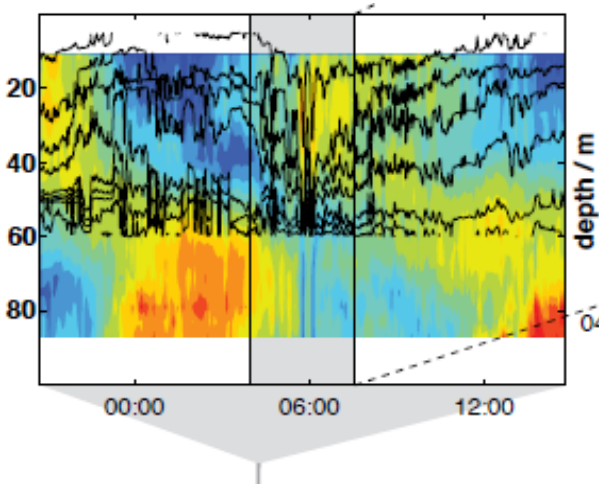
Internal Waves on the Washington Continental Shelf



BY MATTHEW H. ALFORD, JOHN B. MICKETT, SHUANG ZHANG, PARKER MACCREADY, ZHONGXIANG ZHAO, AND JAN NEWTON

Oceanography, 2012

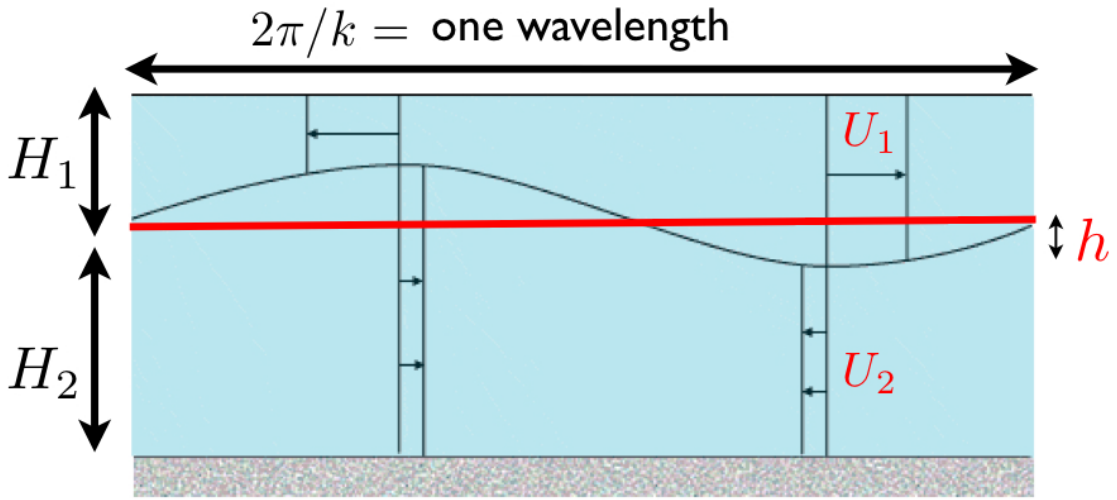
Internal tide: 3 2 1



Phase speed
~ 0.4-0.5 m/s

20-25 hours to cross
~ 40-km wide shelf

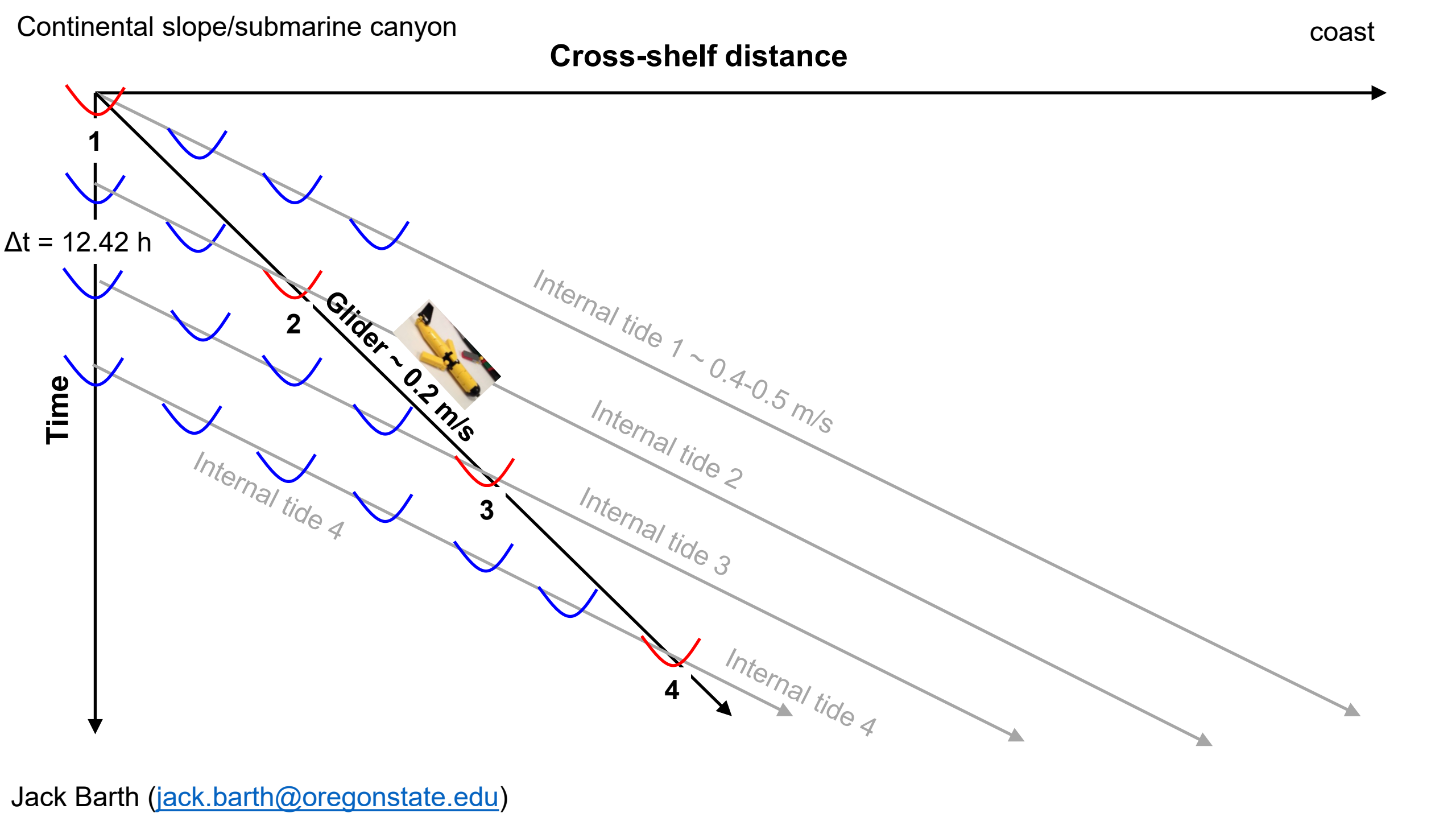
so should be about **two internal tides** on the shelf at one time



Baroclinic Wave

after Gill,
Atmosphere-Ocean Dynamics

Jack Barth (jack.barth@oregonstate.edu)

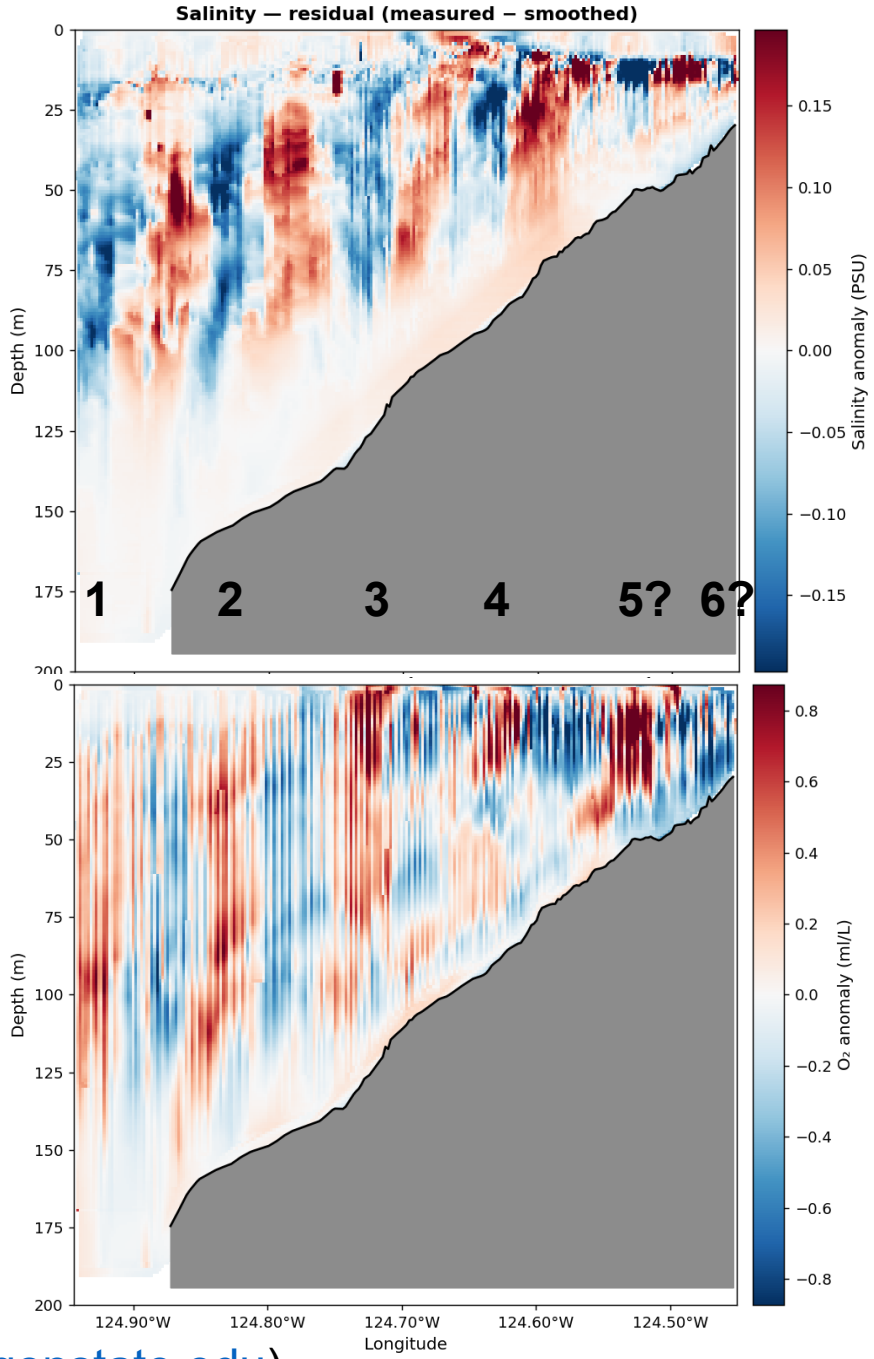


Jack Barth (jack.barth@oregonstate.edu)

September 20-22, 2024

Salinity anomaly

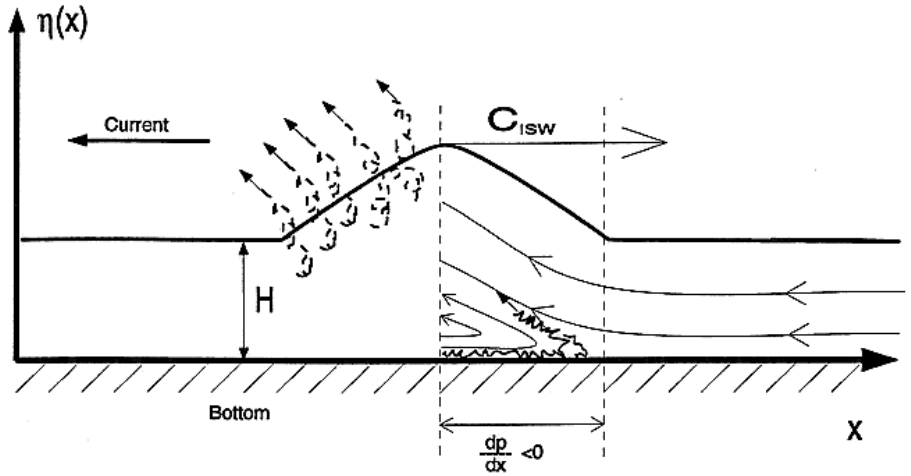
Dissolved oxygen anomaly



Mixing of relatively high dissolved oxygen from above down into near-bottom low-oxygen layer

Possible mechanism?

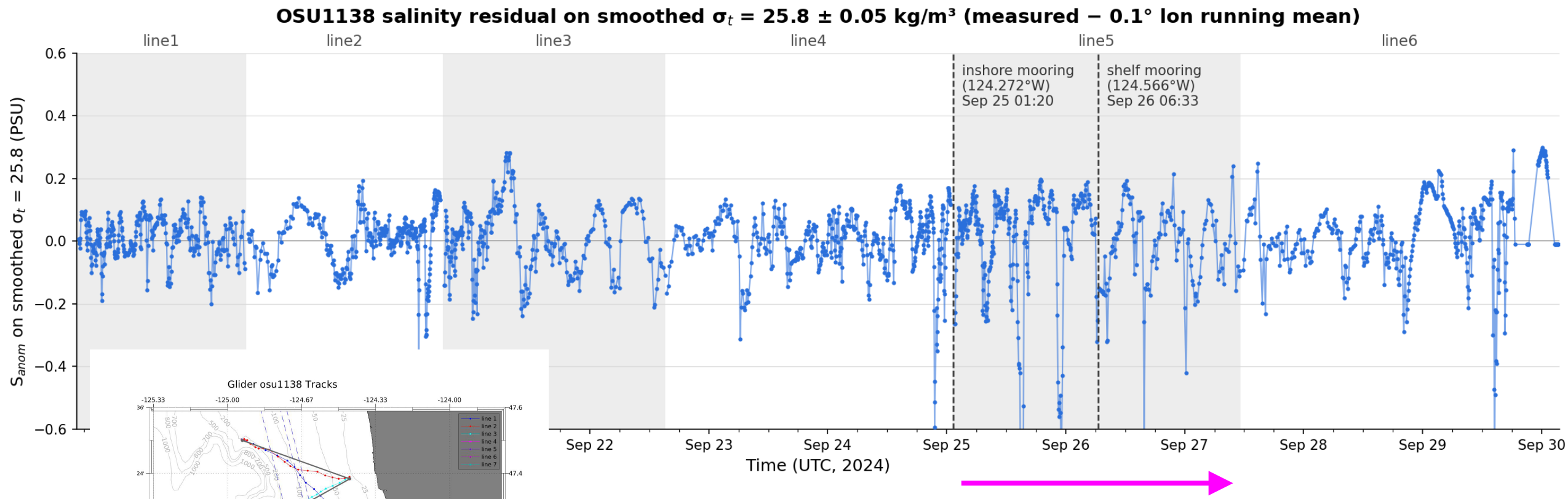
Bottom boundary layer alteration by **Nonlinear Internal Waves** (NLIWs) … and interaction with sheared shelf currents

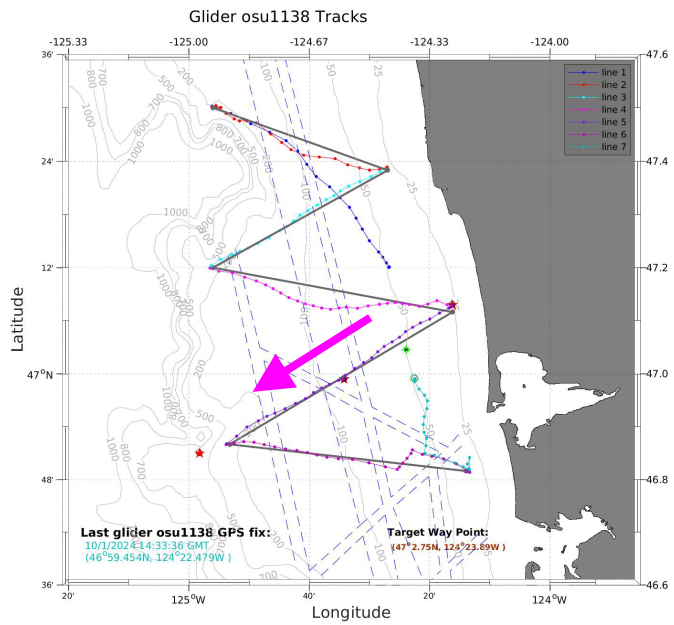


Bogucki et al. (JPO, 1997)

Jack Barth (jack.barth@oregonstate.edu)

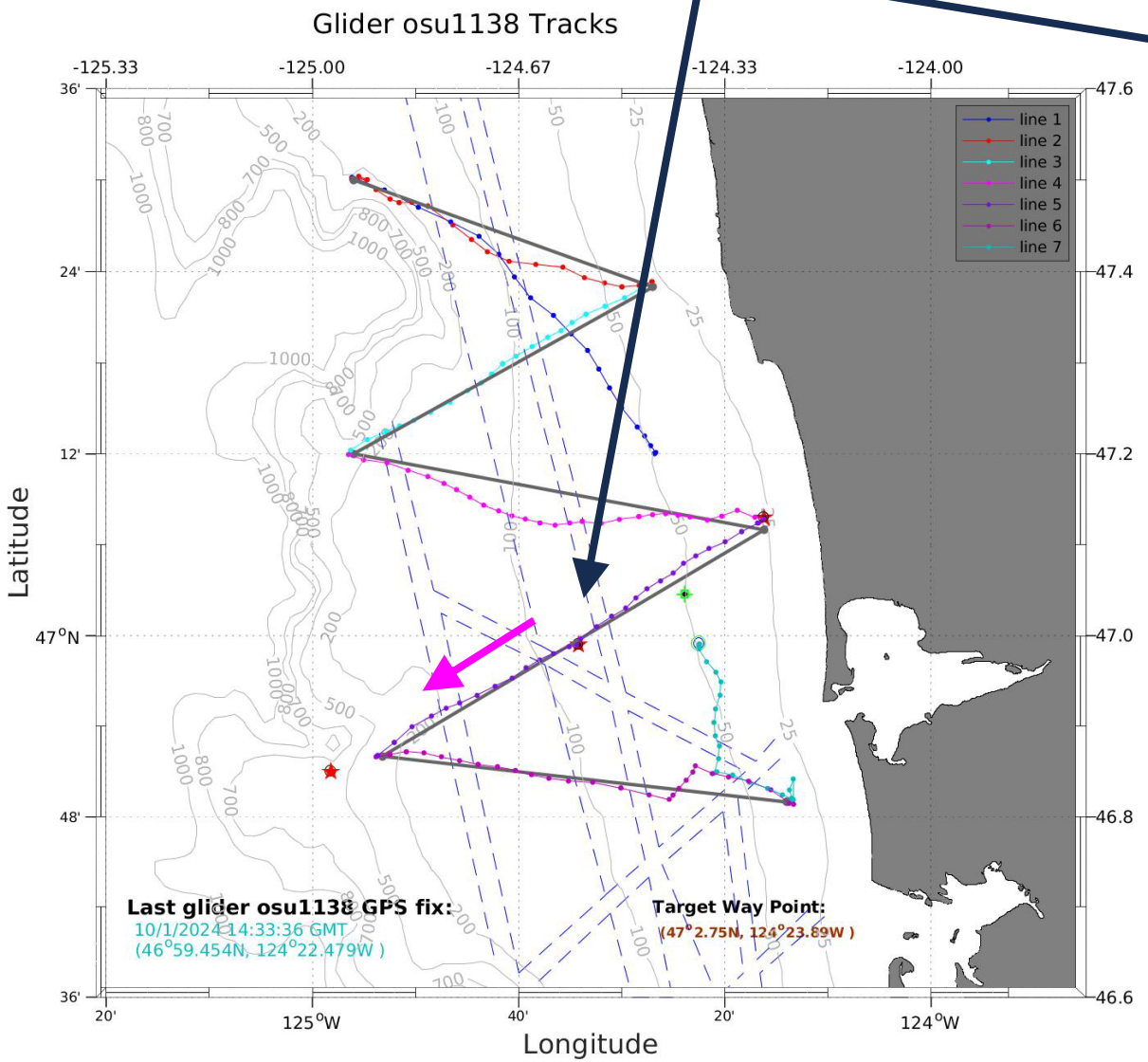
Turn anomalies along glider track into time series:

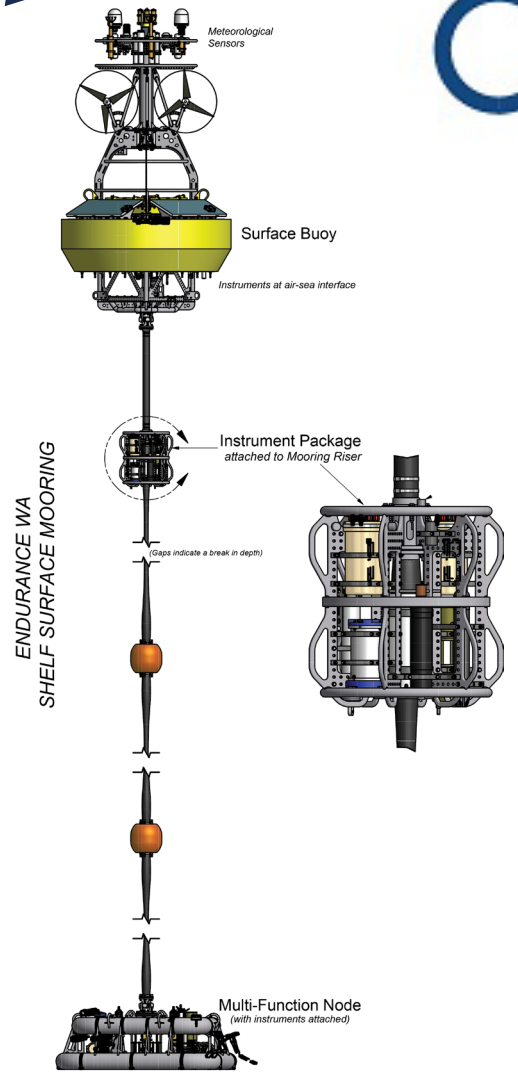


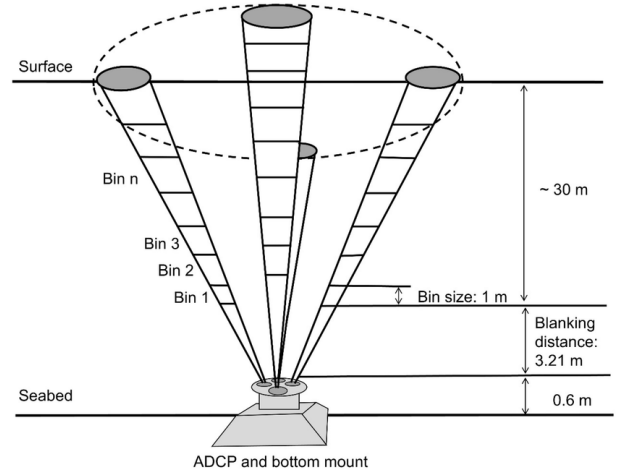


Jack Barth (jack.barth@oregonstate.edu)

Use nearby ocean mooring to measure internal tide



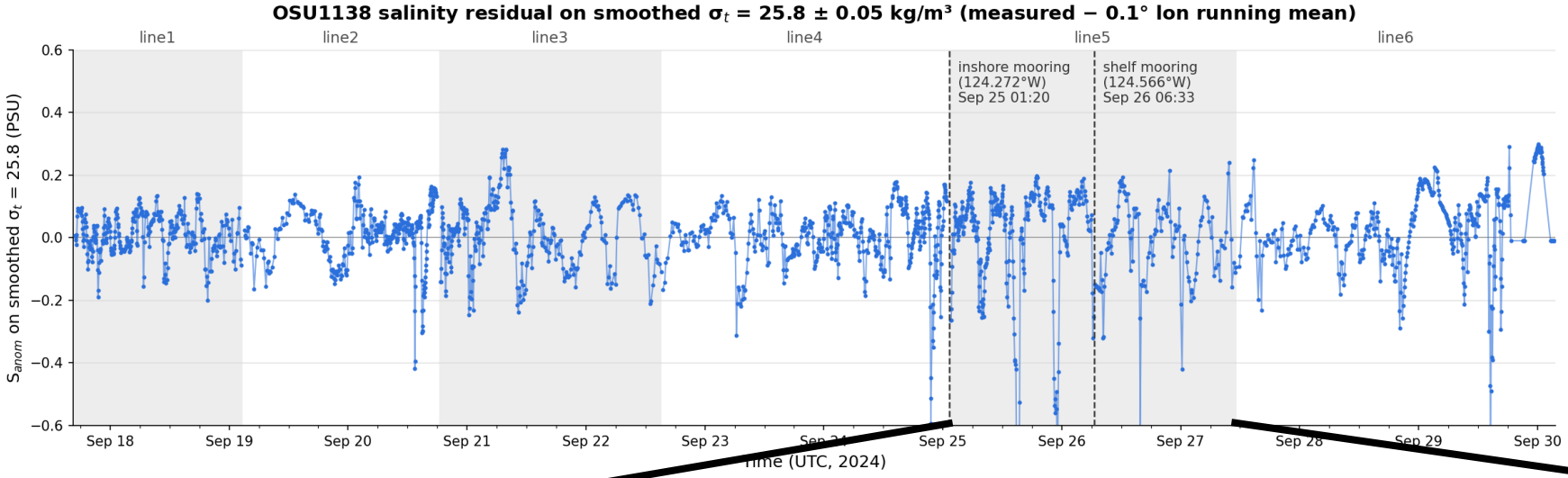


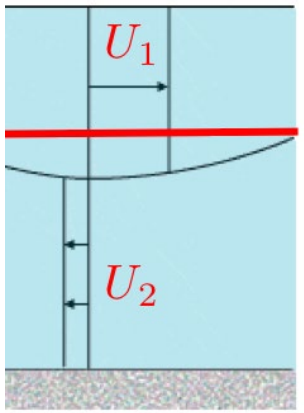


https://dataexplorer.oceanobservatories.org/

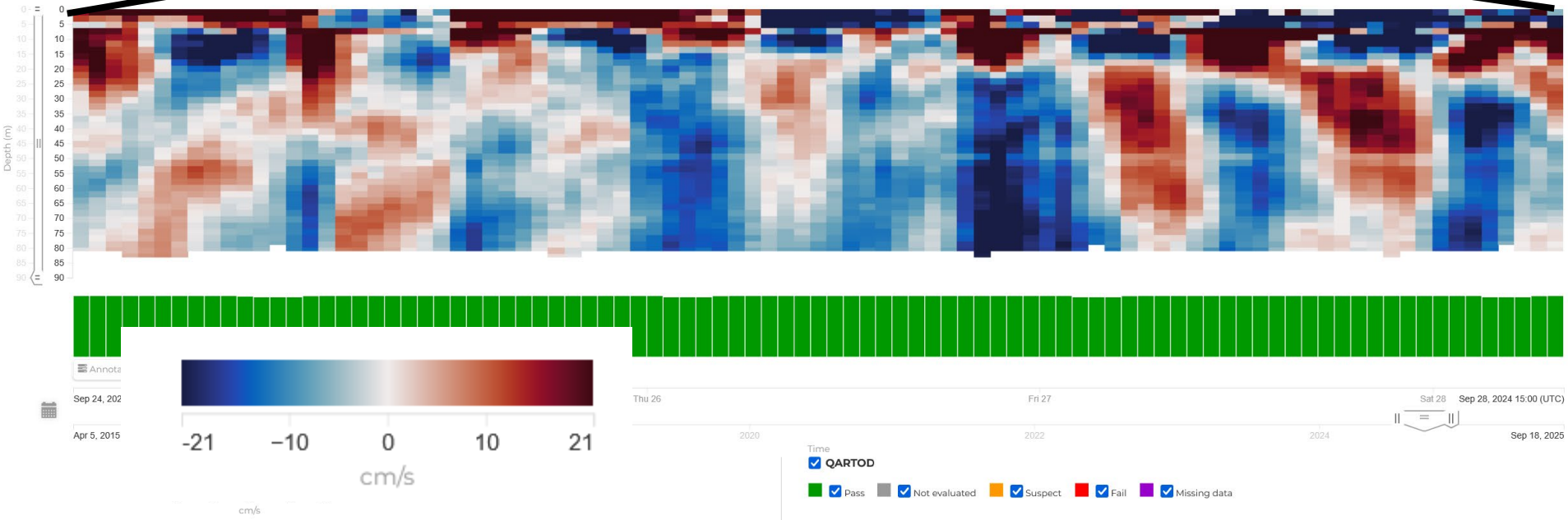
From Creane et al. (*Water*, 2025)

Compare anomalies to east-west internal tide velocities at mooring



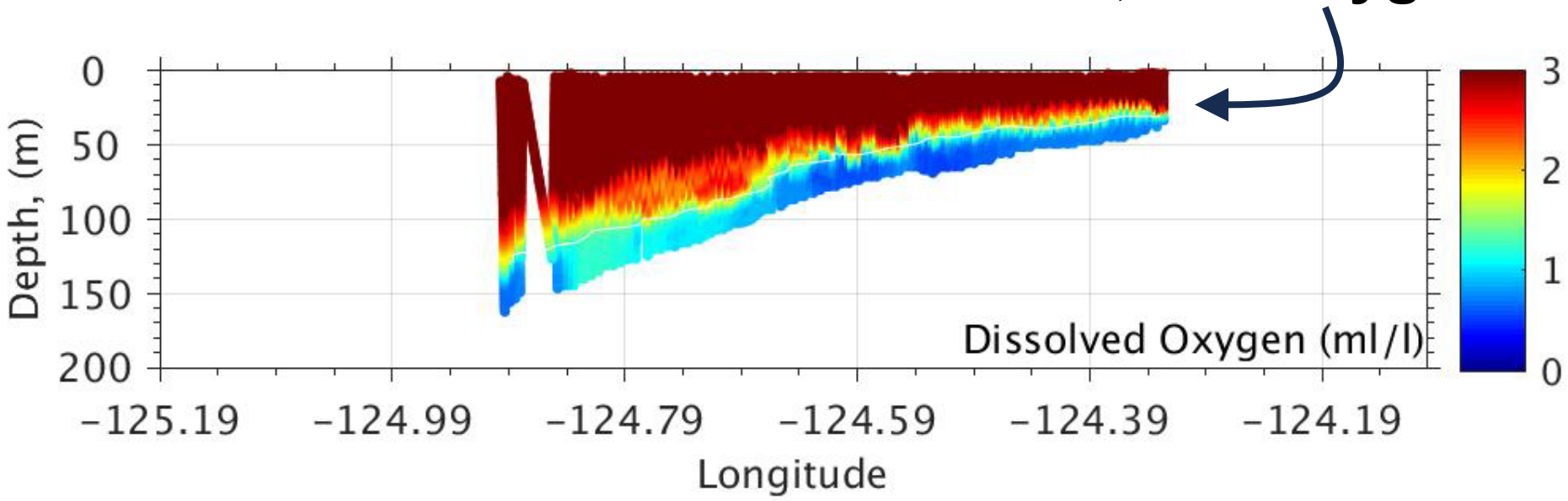


East-West velocity



https://dataexplorer.oceanobservatories.org/

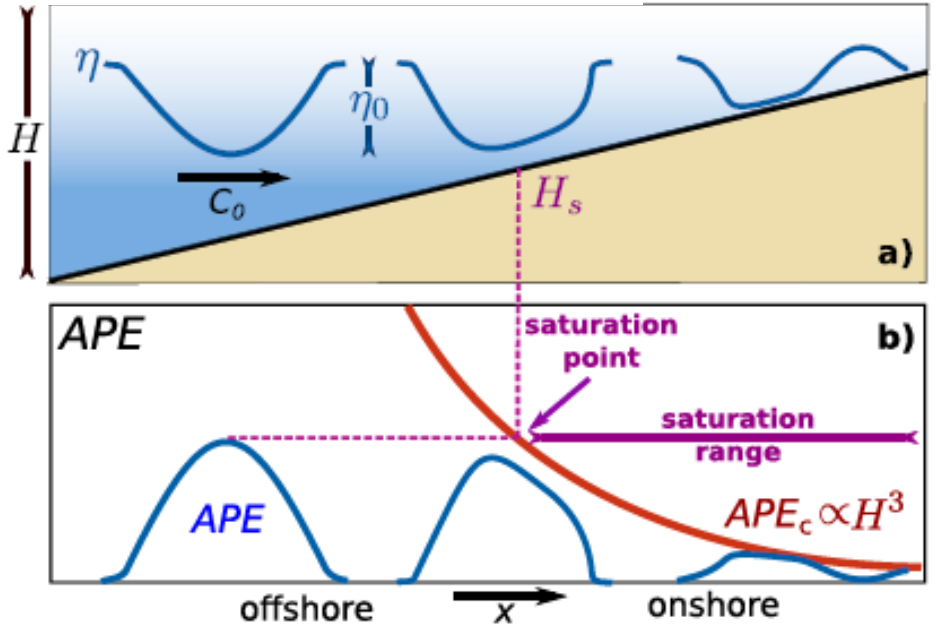
What limits onshore extent of near-bottom, low-oxygen layer?



From Becherer et al. (2021):

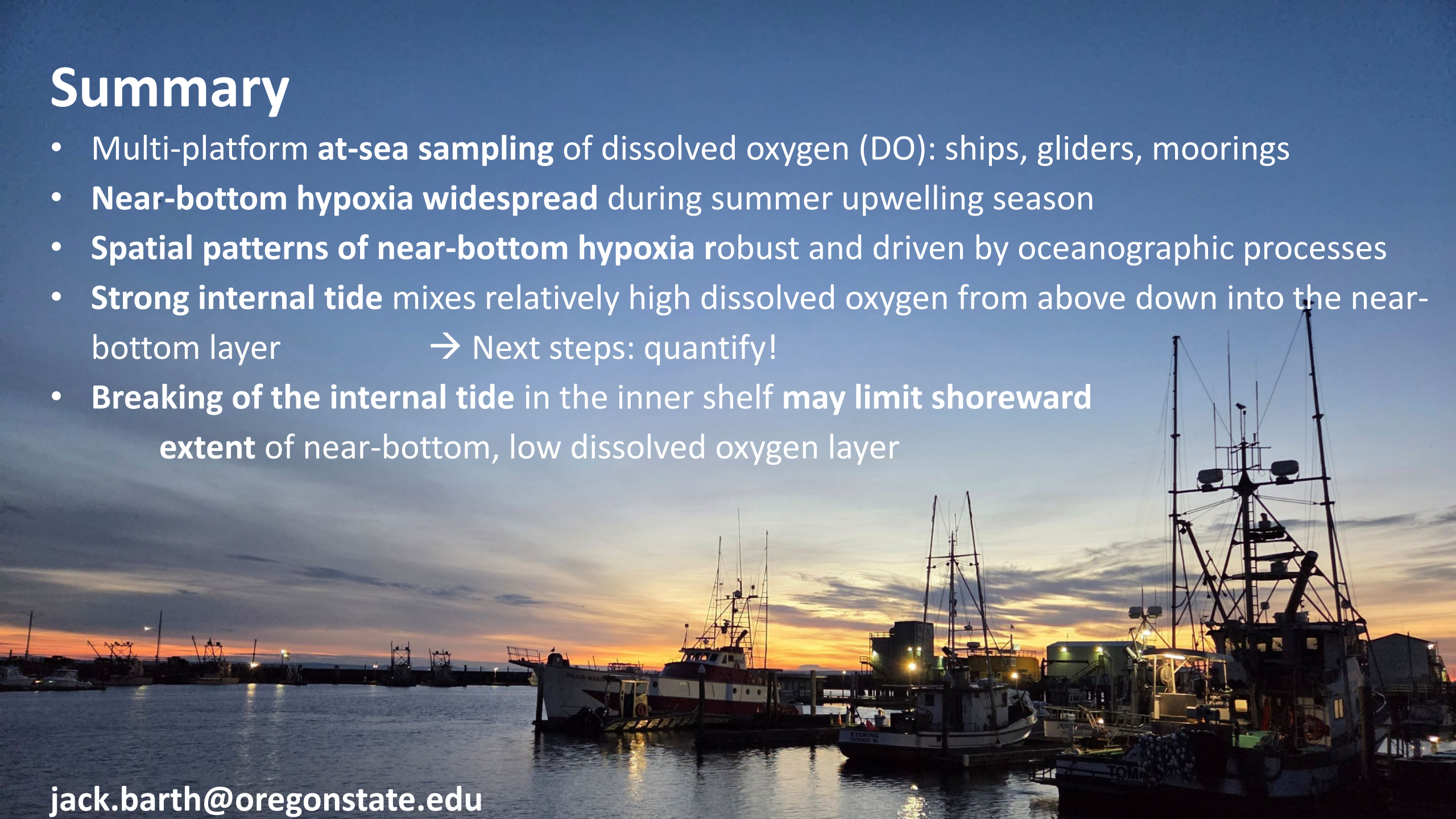
“the internal tide dissipates most of its energy between the 100- and 20-m isobaths”

“The analogy of our framework to surface waves approaching the beach suggests **that the inner shelf is the surf zone for the internal tide**.”



Summary

- Multi-platform **at-sea sampling** of dissolved oxygen (DO): ships, gliders, moorings
- **Near-bottom hypoxia widespread** during summer upwelling season
- **Spatial patterns of near-bottom hypoxia r**obust and driven by oceanographic processes
- **Strong internal tide** mixes relatively high dissolved oxygen from above down into the near-bottom layer → Next steps: quantify!
- **Breaking of the internal tide** in the inner shelf **may limit shoreward extent** of near-bottom, low dissolved oxygen layer



jack.barth@oregonstate.edu