High-frequency Variability in Water Properties in Estuaries and the Implications for Monitoring Programs

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http://orca.ocean.washington.edu
http://nvs.nanoos.org

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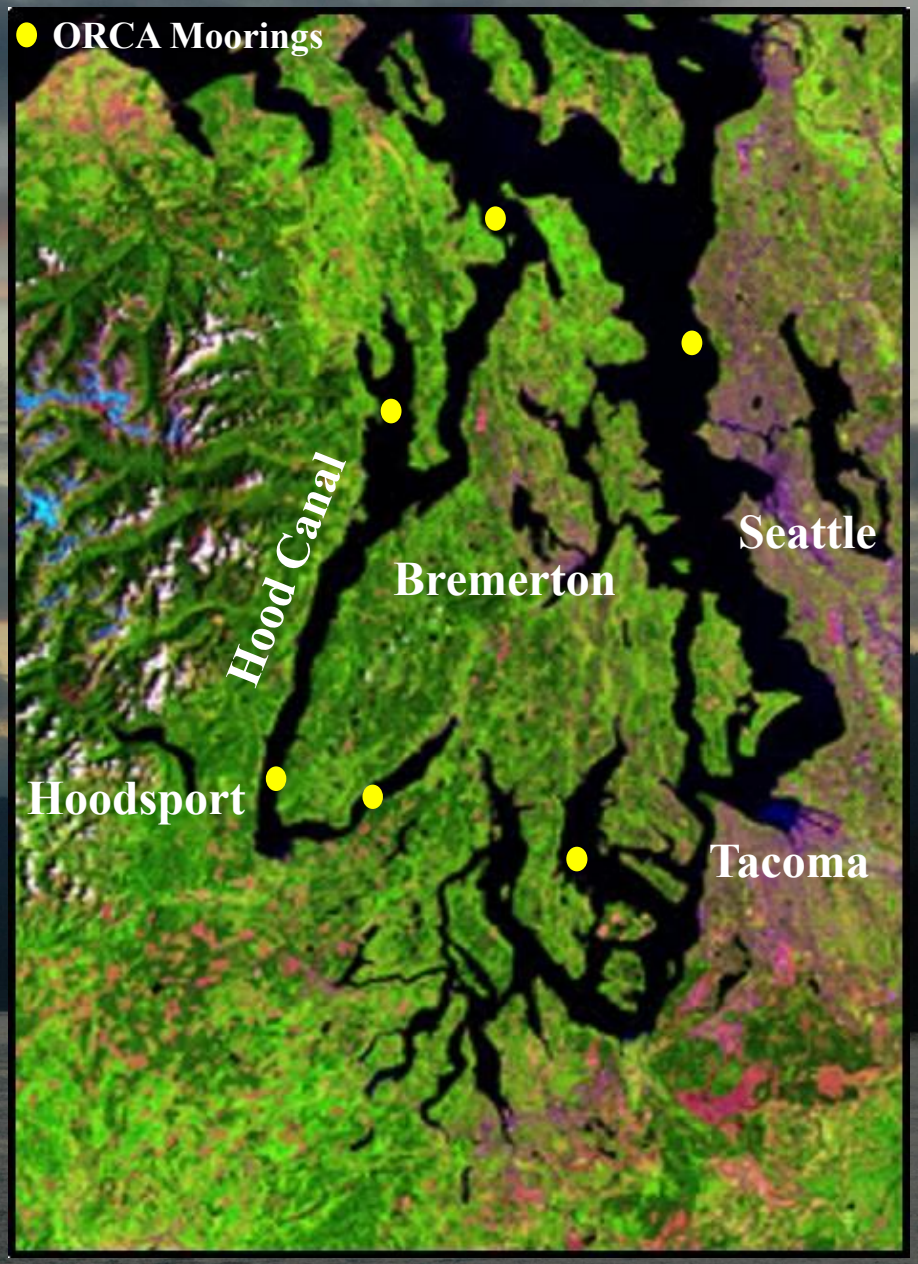
School of Oceanography
University of Washington

The ORCA mooring system

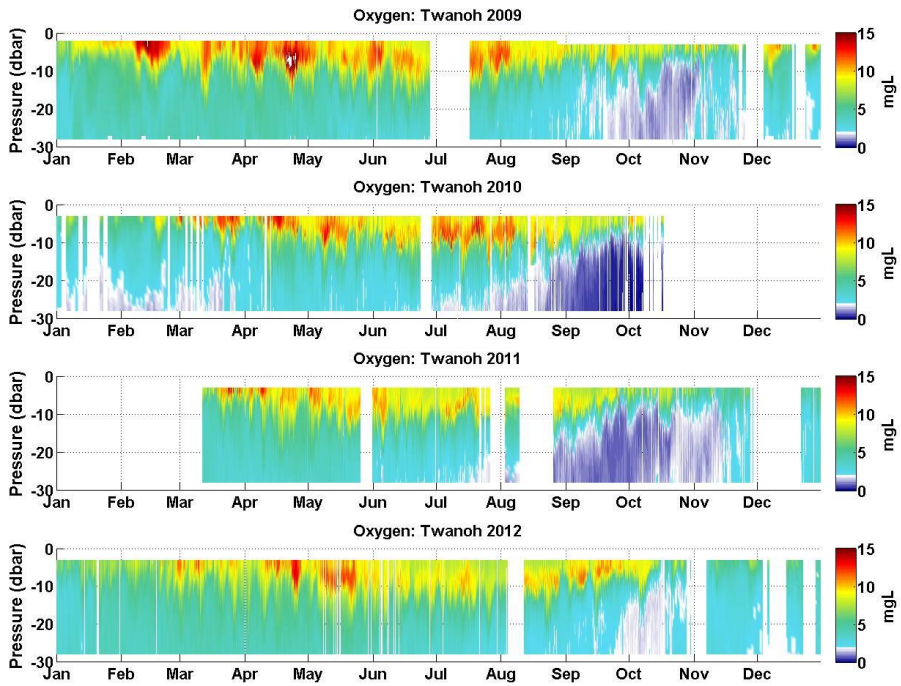
- CTD profiles up to 150 meters
- up to 12 profiles per day during the summer
- 6 moorings deployed through-out Puget Sound and Hood Canal
- Over 80,000 profiles since 2000

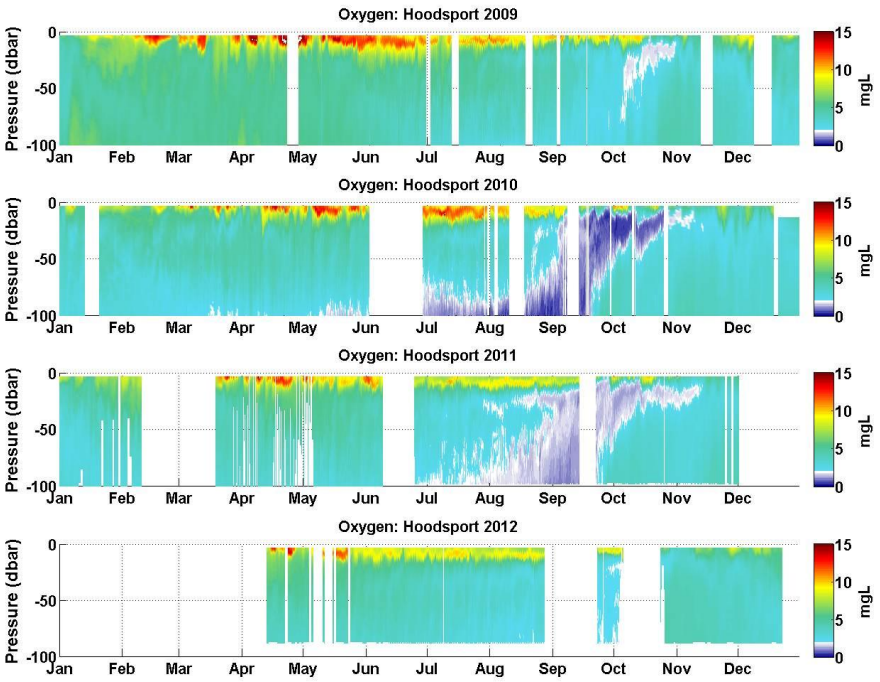
Hood Canal characteristics

- Long, narrow, deep fjord-like estuary with sill at the entrance
- Slow circulation (~100 days flushing time for southern end)
- History of seasonal hypoxia in southern end; fish kills documented as early as the 1920s
- Recently low oxygen has become more widespread and persistent
- Low oxygen conditions remain through-out winter, when concentrations normally get replenished
- Recorded fish kills in 2002, 2003, 2004, 2006, 2010
- Extensive monitoring network, including over 30 agencies, citizen volunteers, and 4 autonomous profiling moorings with over 60,000 profiles



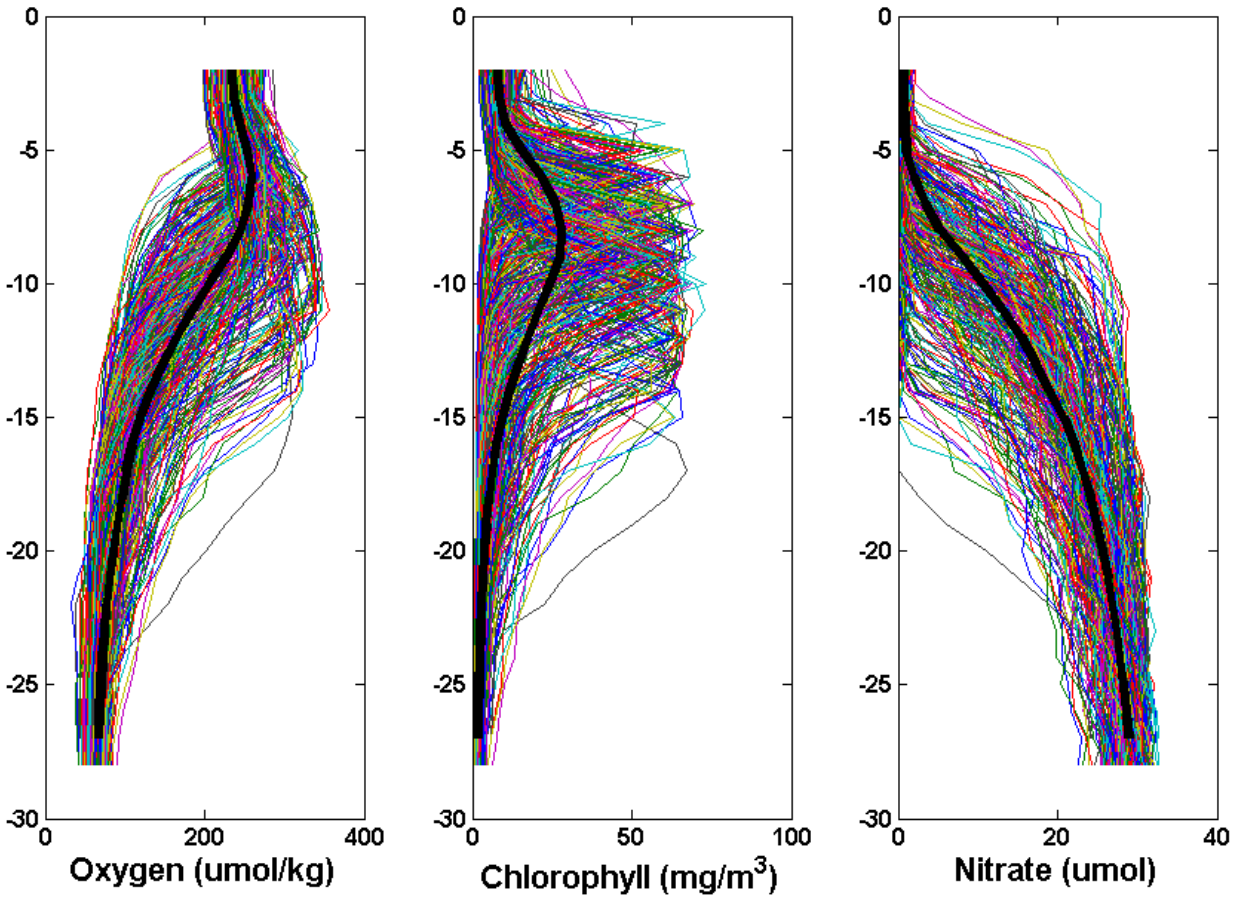
Inter-annual Variability: Southern Hood Canal





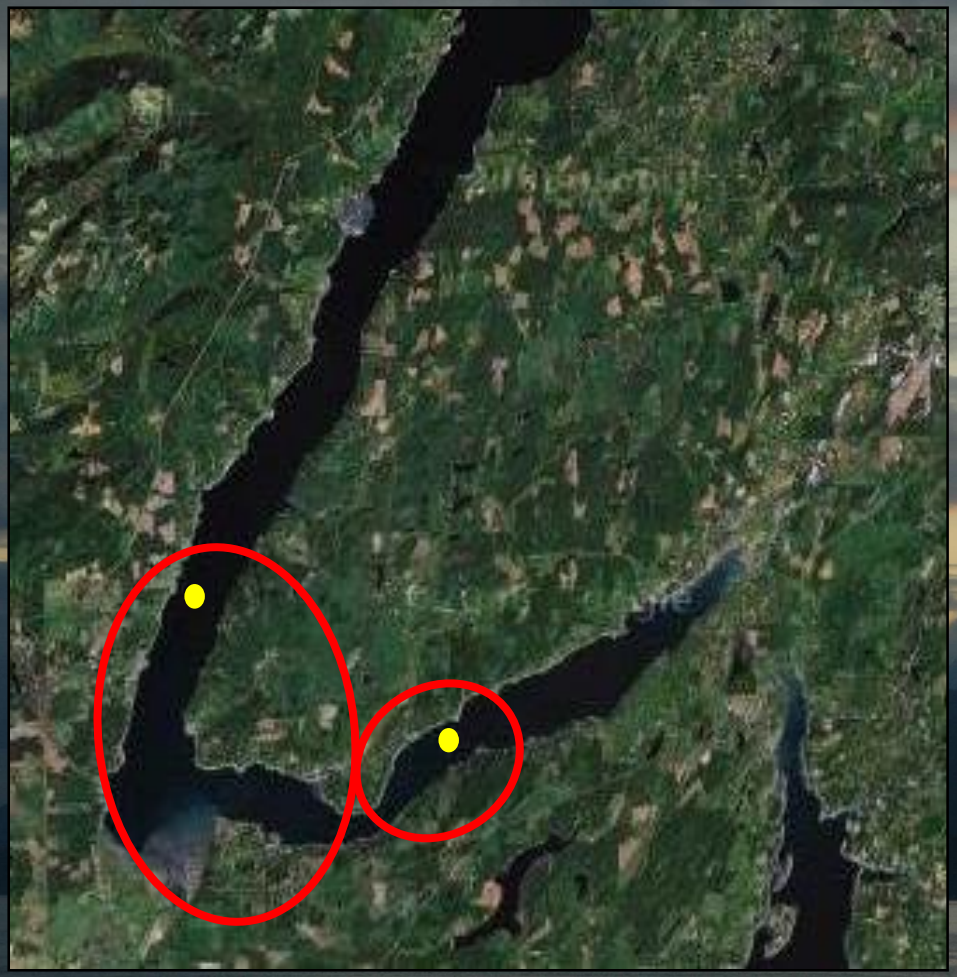
- **Oxygen time series in Southern Hood Canal**
- **White = 2 mg/L…dark purple = 0 mg/L**

High Frequency Variability: Southern Hood Canal



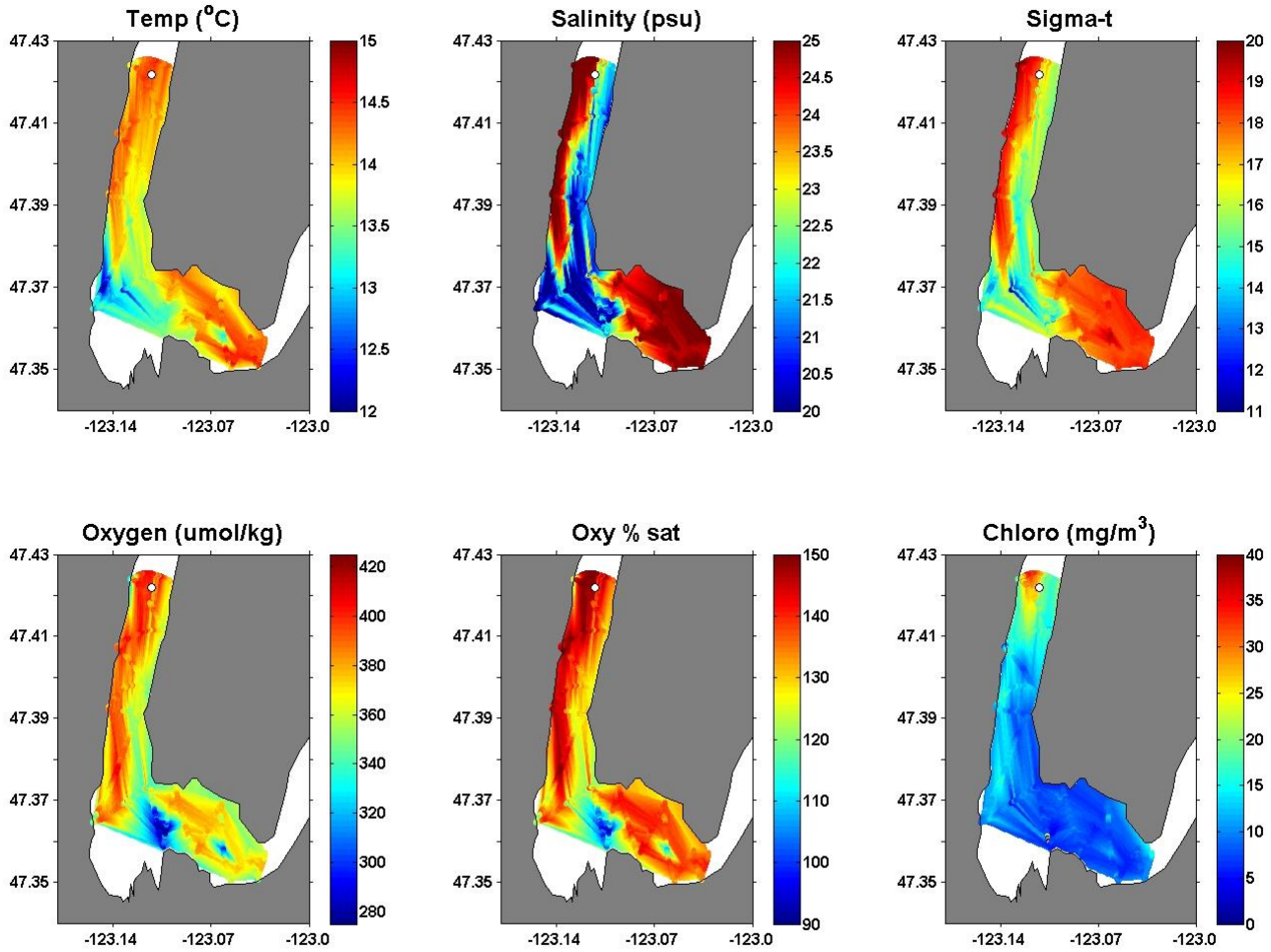
- Compilation of all ORCA profiles at Twanoh during July 2008
- Thick black line is the numerical average of all 370 profiles

Variability around ORCA Moorings: Surface mapping

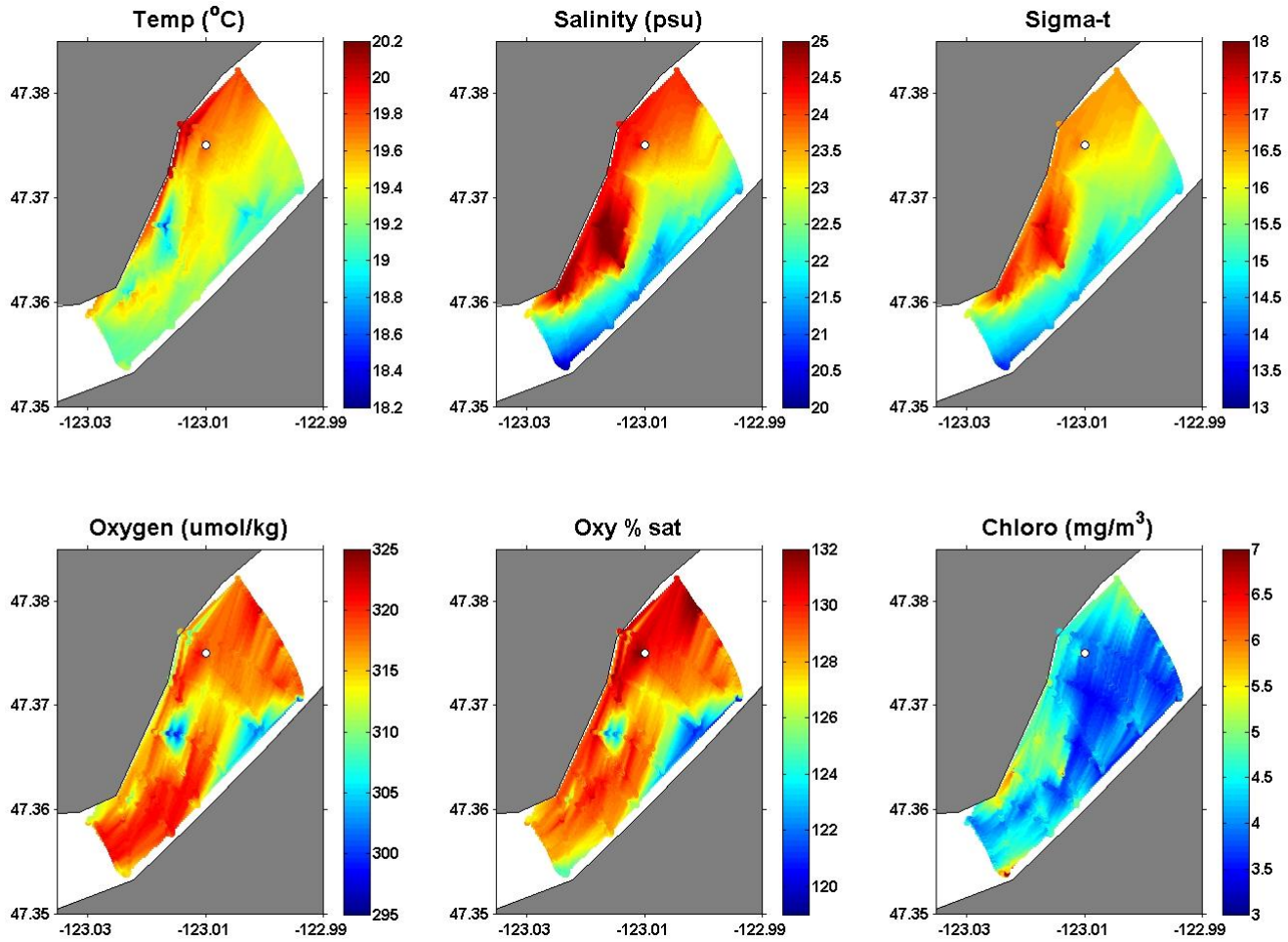


- Two spatial surveys of lower Hood Canal
- CTD sensor package measuring temperature, salinity, oxygen, chlorophyll
- Sensors mounted to bow of boat with intake ~0.5 meters below the surface
- Boat speed, GPS refresh, pump speed = 3 - 4 m resolution

Variability around ORCA Moorings: Surface mapping



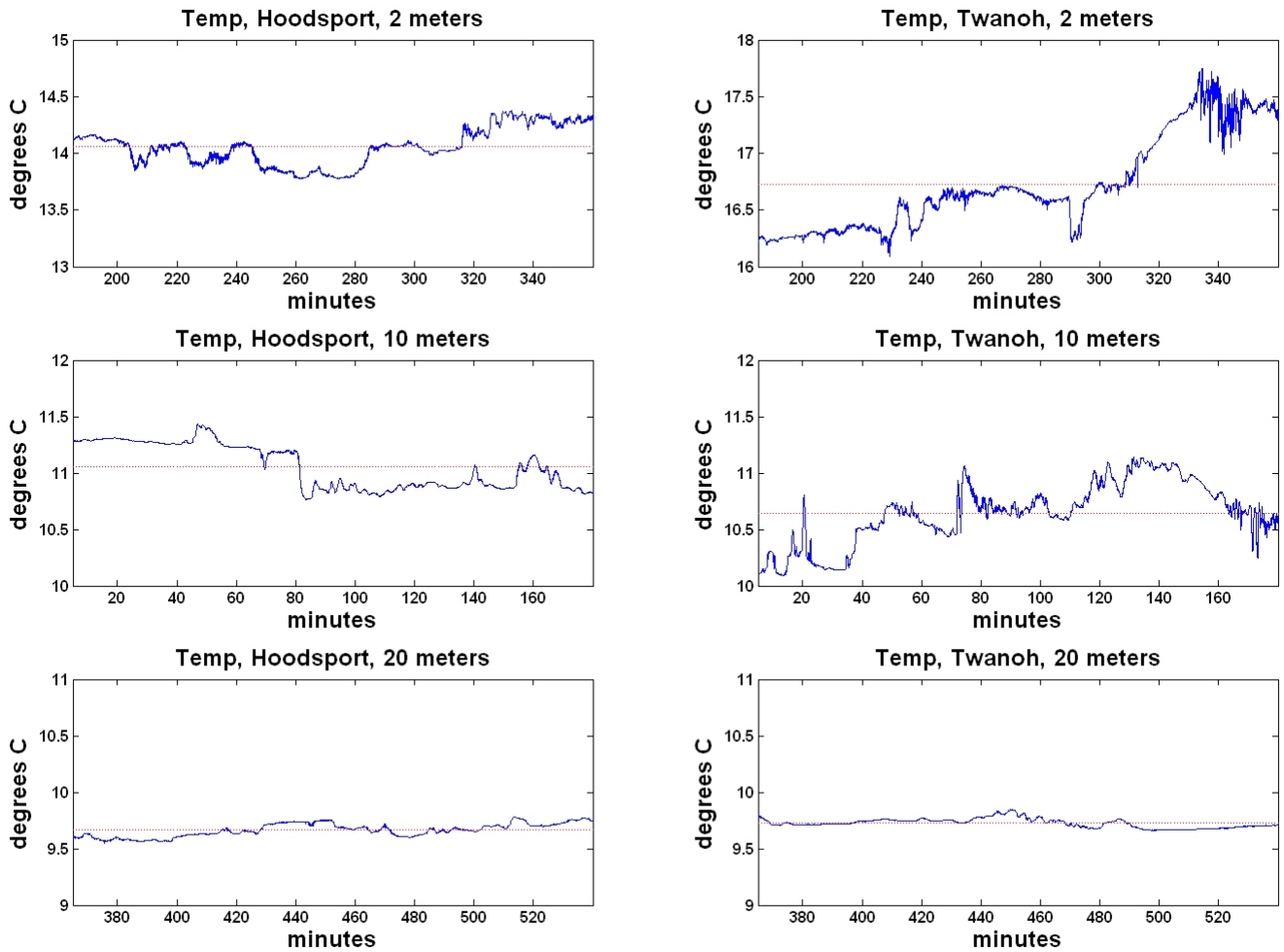
Variability around ORCA Moorings: Surface mapping



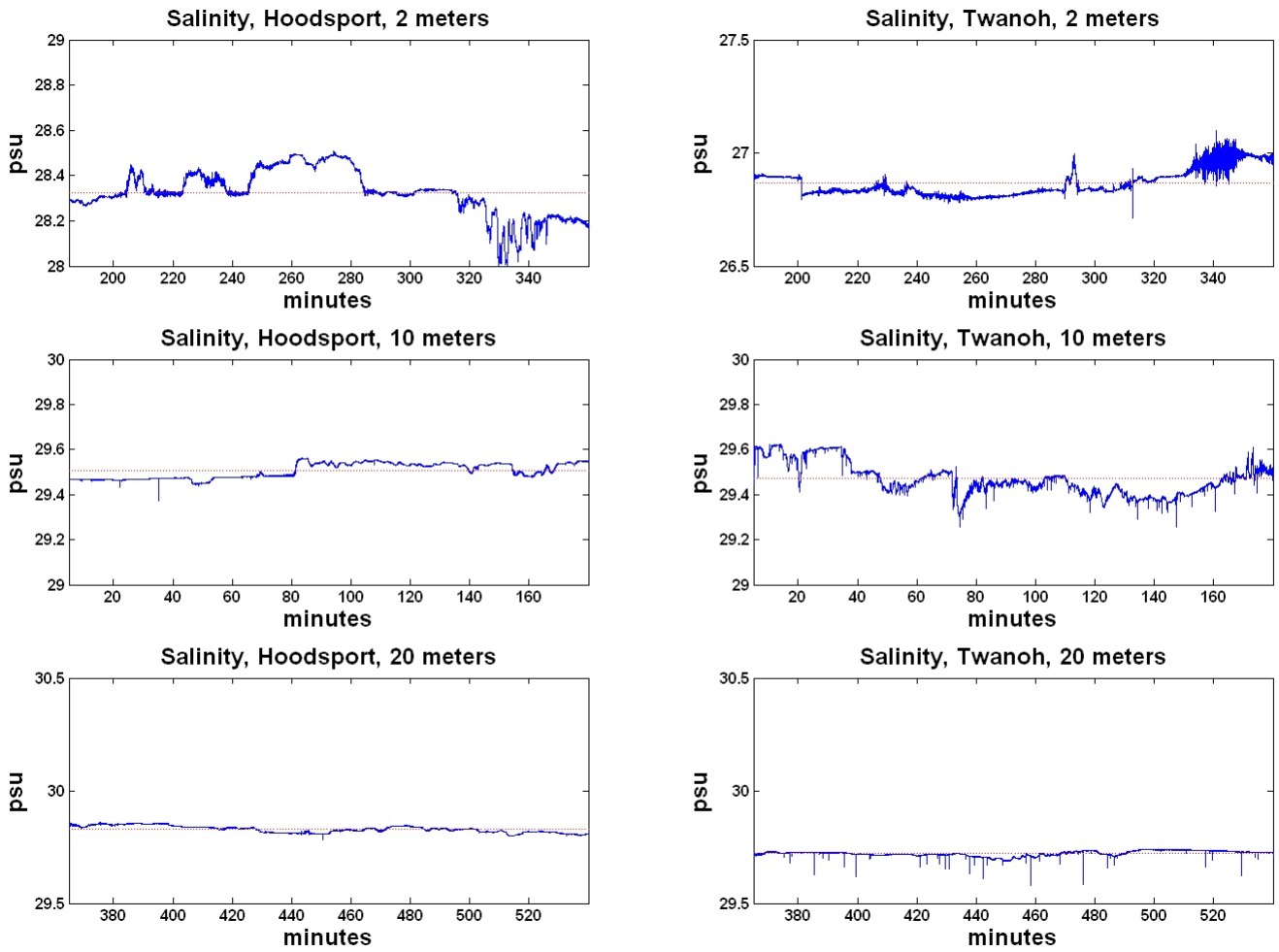
Experiment at ORCA Moorings:
3 hour time series

- CTD sensor package measuring temperature, salinity, oxygen, chlorophyll
- Sensors kept stationary at specified depth for 3 hours
- Simultaneous measurements at Hoodsport and Twanoh

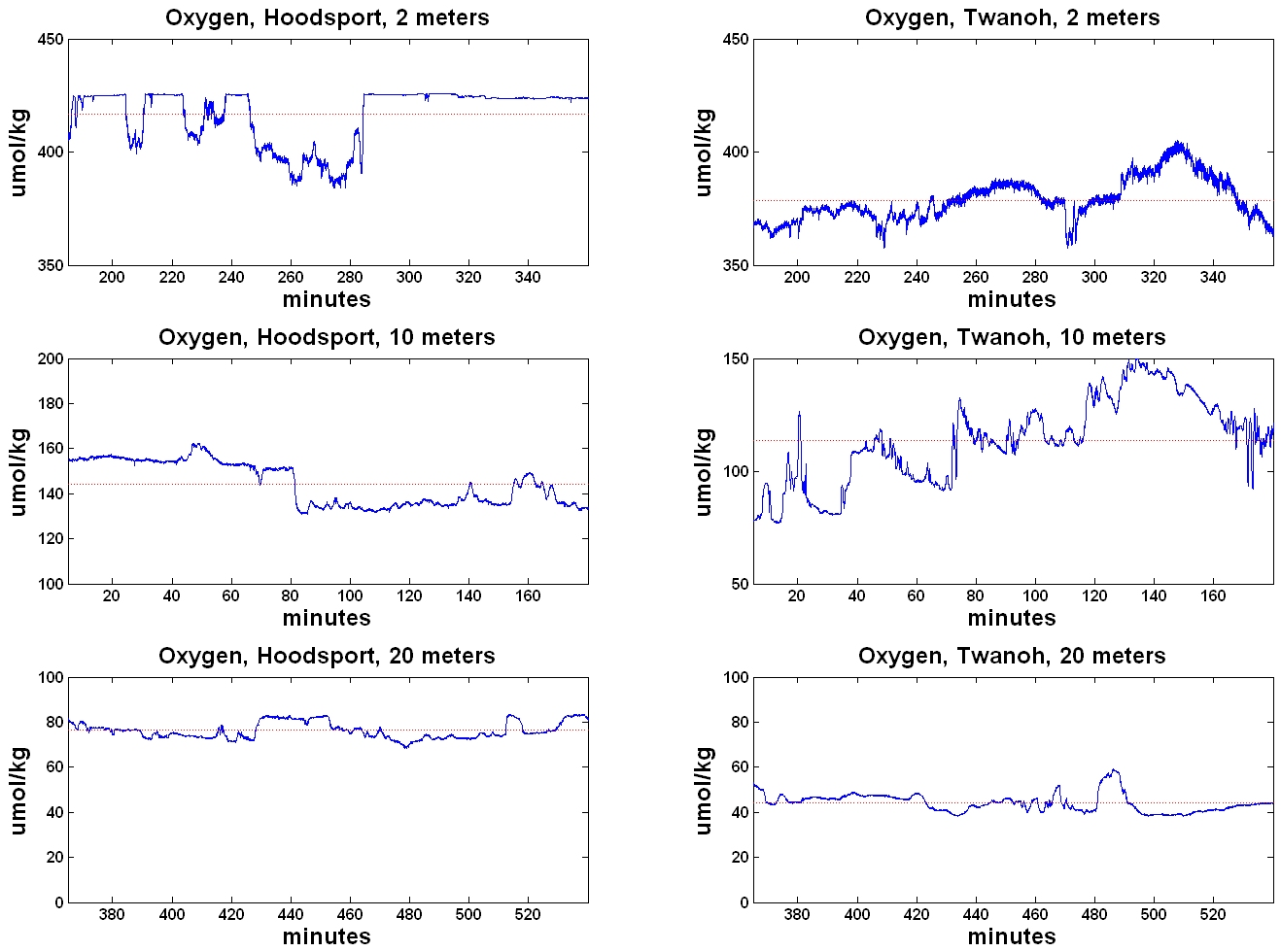
Experiment at ORCA Moorings:
3 hour plots, Temperature



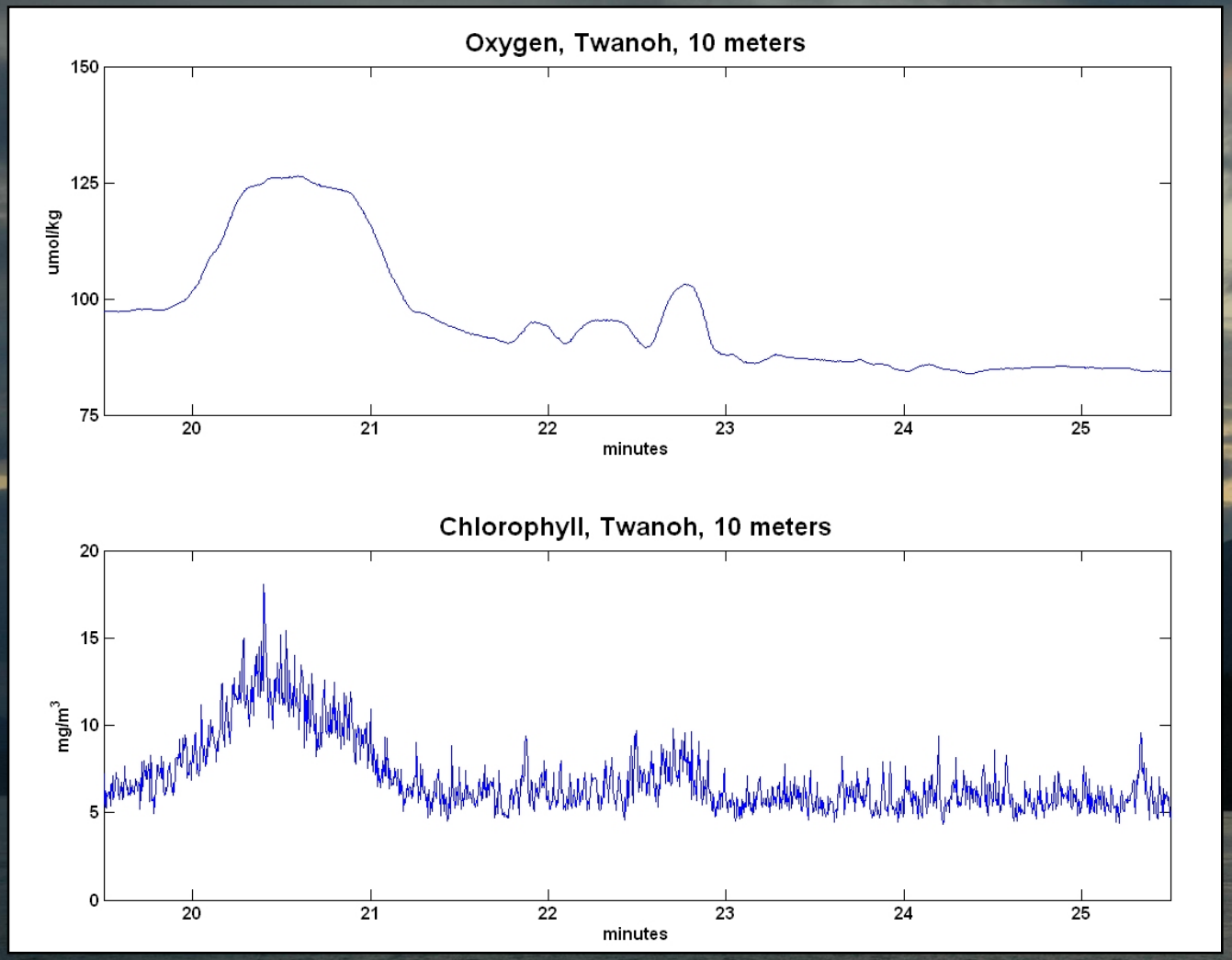
Experiment at ORCA Moorings:
3 hour plots, Salinity



Experiment at ORCA Moorings:
3 hour plots, Oxygen

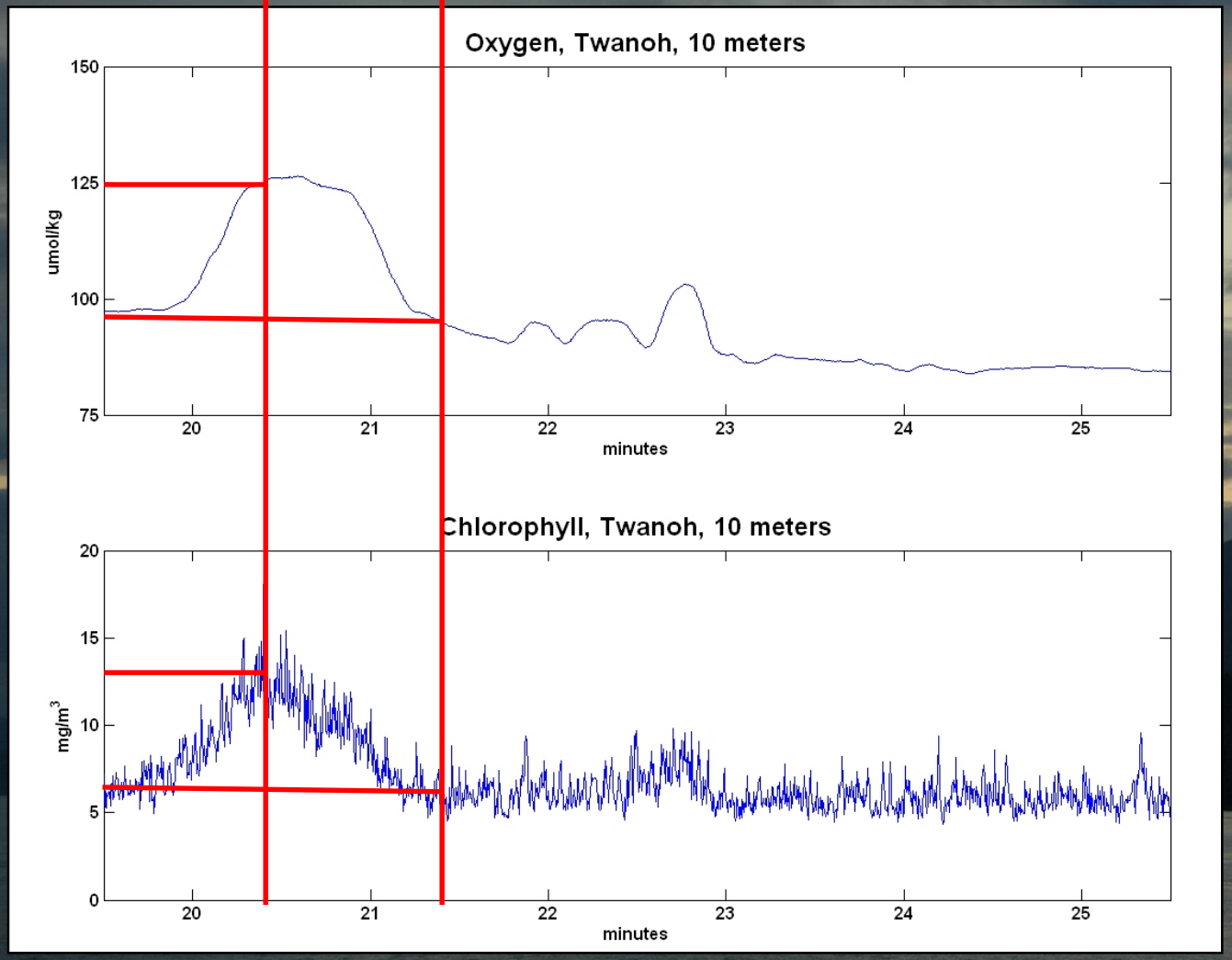


Experiment at ORCA Moorings: 10 meter close up



Experiment at ORCA Moorings: 10 meter close up

ΔT = 1 min



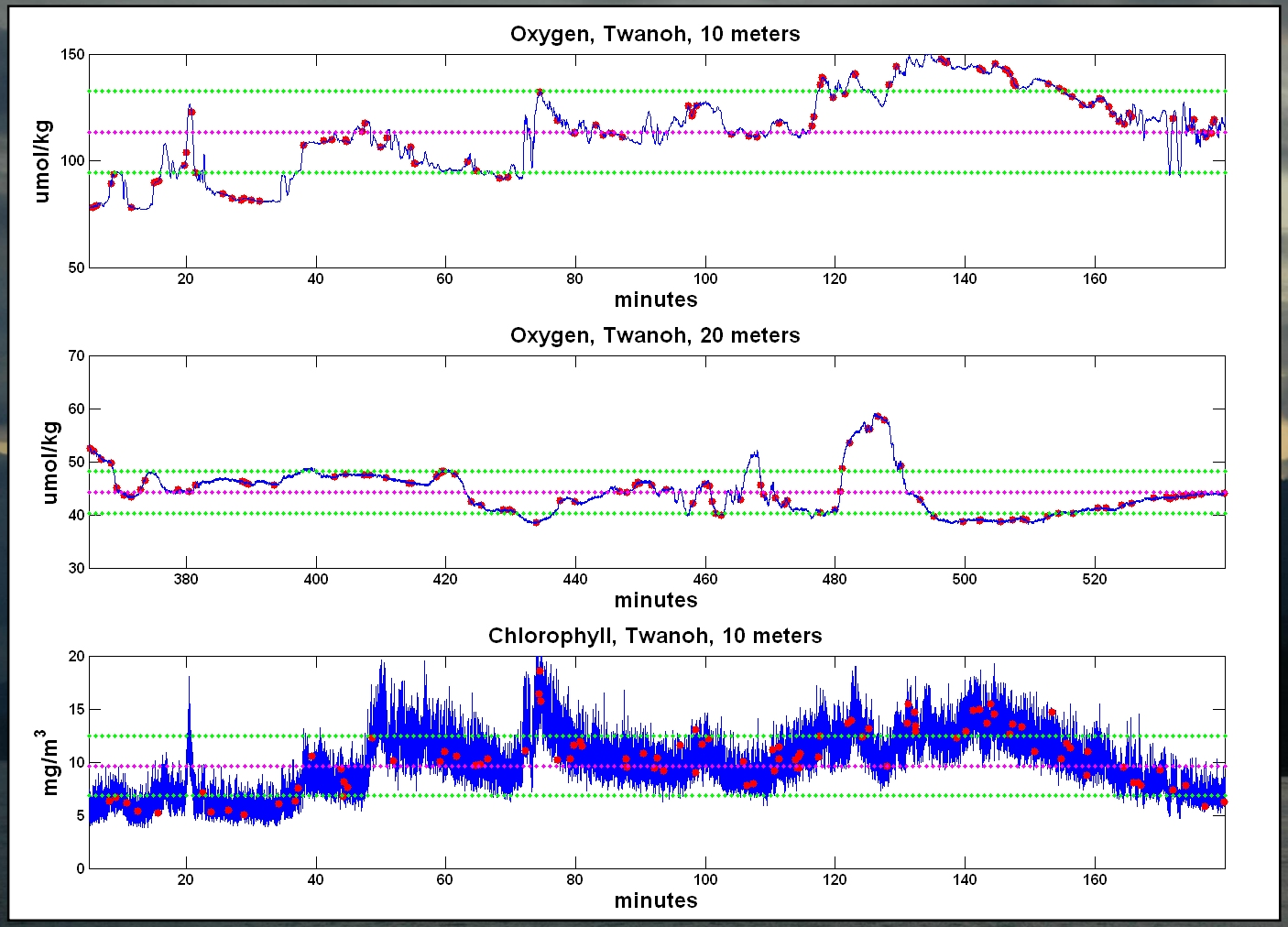
Δ O2 = ~30 µmol (~1 mg/L)

Δ Chloro = ~8 mg/m^3

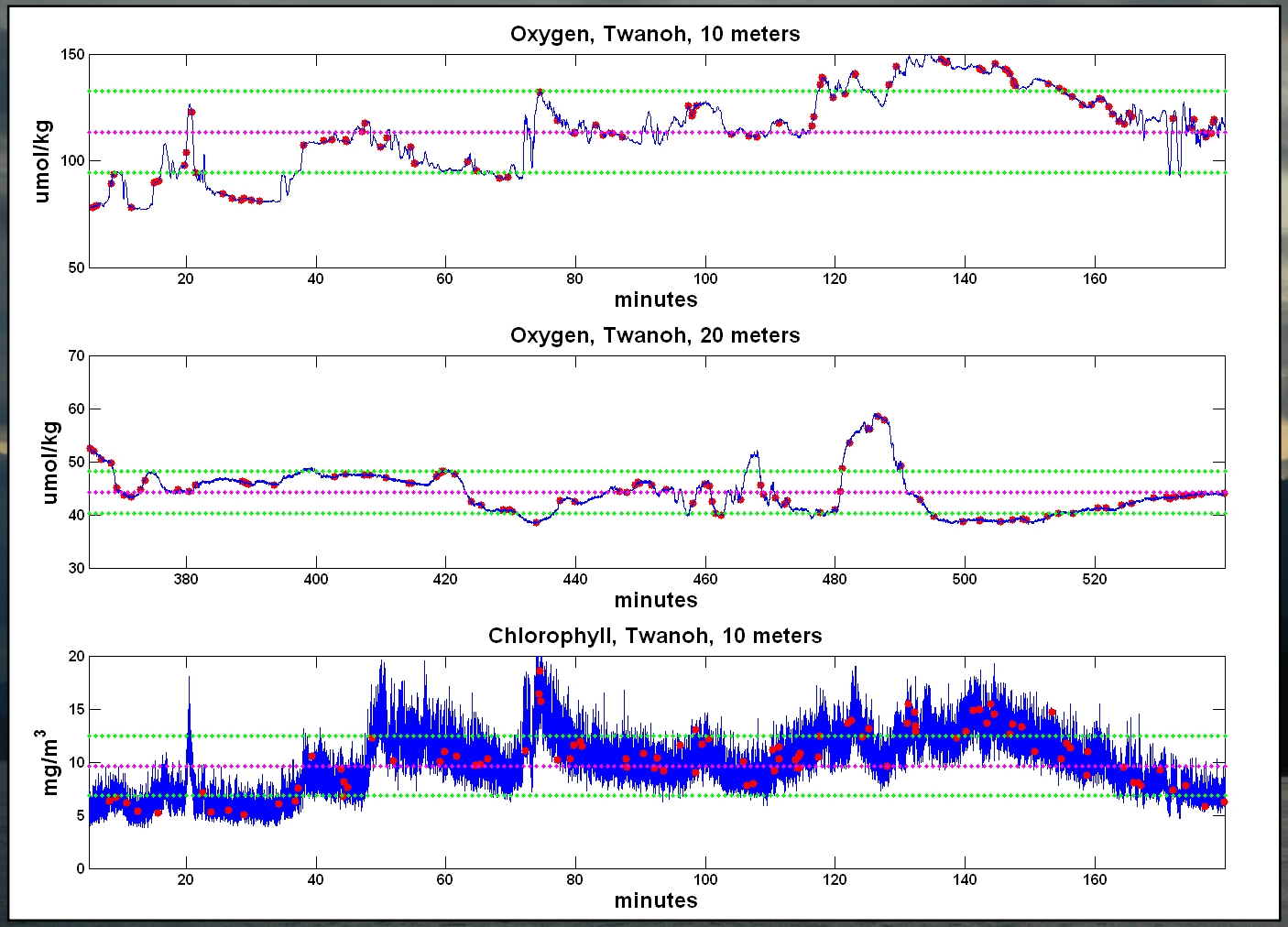
Experiment at ORCA Moorings: Sub-sampling

- 100 random draws of 100 data points
- counted the number of extracted samples that fell outside of 1 standard deviation of the mean
- Calculated the average of these counts for the 100 draws

Experiment at ORCA Moorings: Sub-sampling



Experiment at ORCA Moorings: Sub-sampling



42% / 37.75%

24% / 26.02%

41% / 36.41%

Implications: calibrations

- Field calibrations rely on spatial and temporal variation occurring at a much lower frequency then the time involved in sampling logistics
    - assumption that the only difference between sample and sensor reading is calibration factor
    - point field calibrations are used to correct larger sets of data, perpetuating any calibration errors until the next calibration point
    - many sensors, such as fluorometers, rely on in situ calibrations to correct for different environmental conditions and correct for local species

Implications: monitoring programs

- Spatial and temporal variation introduce large uncertainties in the interpretation of discrete samples as representative of the mean

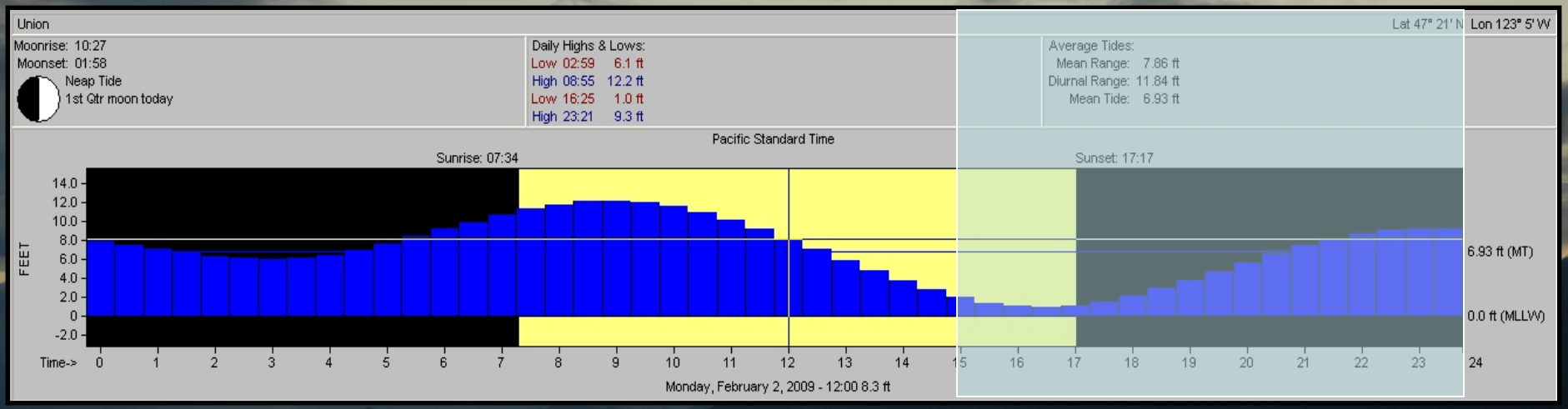
  - 20 meter oxygen time-series at Twanoh included changes as high as 20 umol/kg (0.6 mg/L) over 10 minutes….an uncertainly larger than the changes being monitored

  - Chlorophyll changes of up to 10 mg/m^3 over 1 minute, patches on the order of 5–10 mg/m^3 less than 200 meters wide

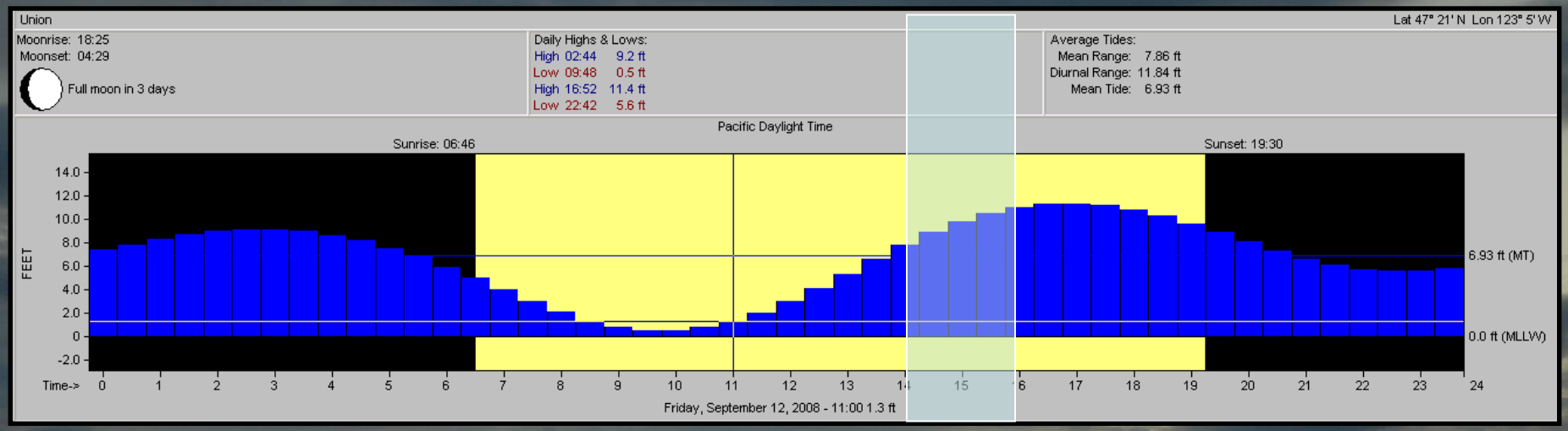
Conclusions

- Hood Canal experiences high frequency variability
  - spatial variability on the order of hundreds of meters
  - temporal variability on the order of minutes
- High frequency variability impacts the interpretation of discrete samples
  - Field calibrations
  - weekly and monthly monitoring programs
- Next steps to characterize how the variability changes...

Tides: 09/02/08



Tides: 9/12/08



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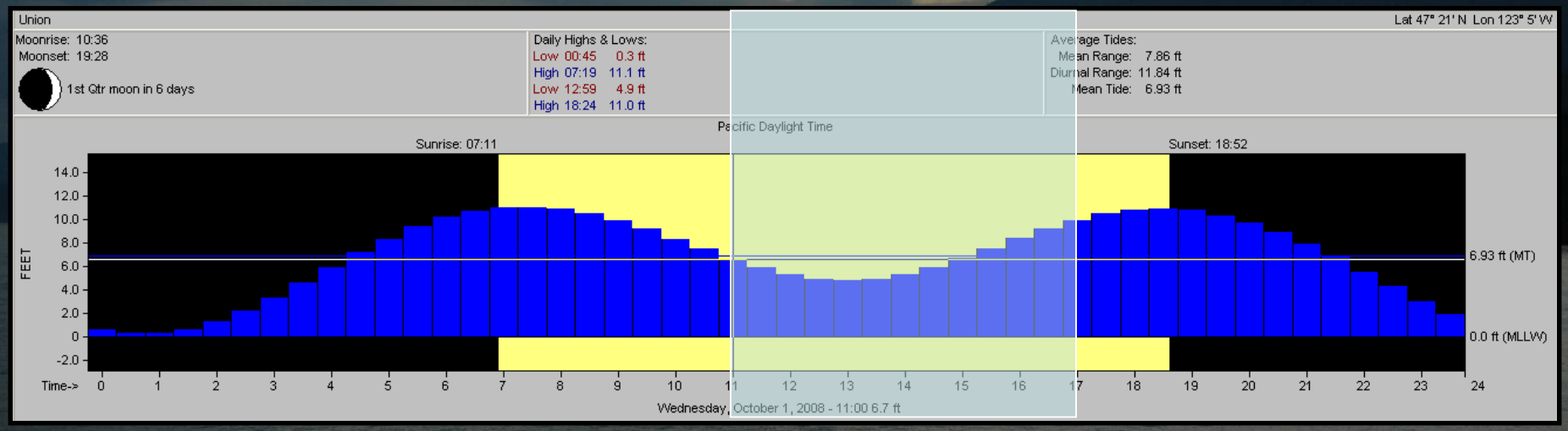
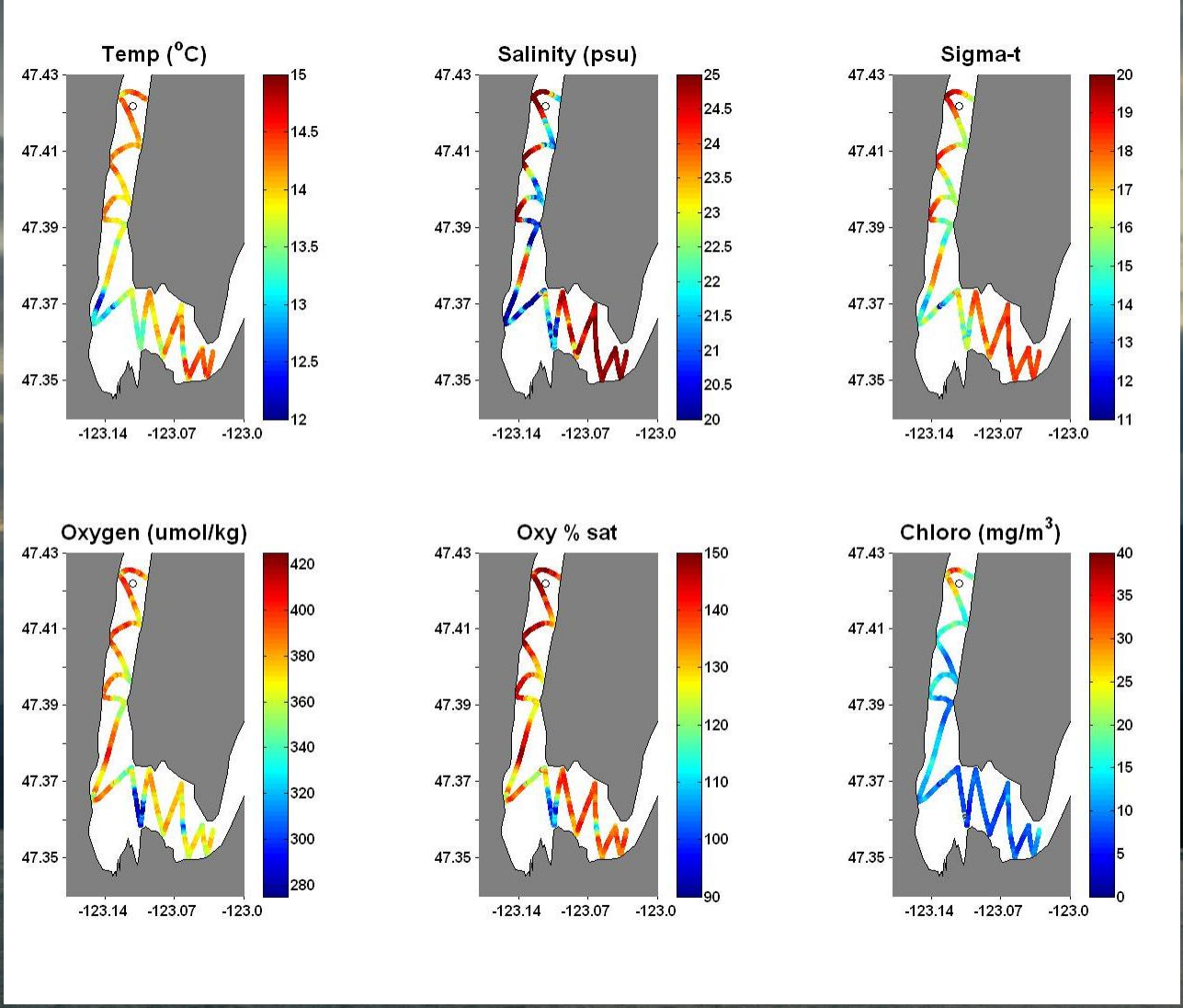
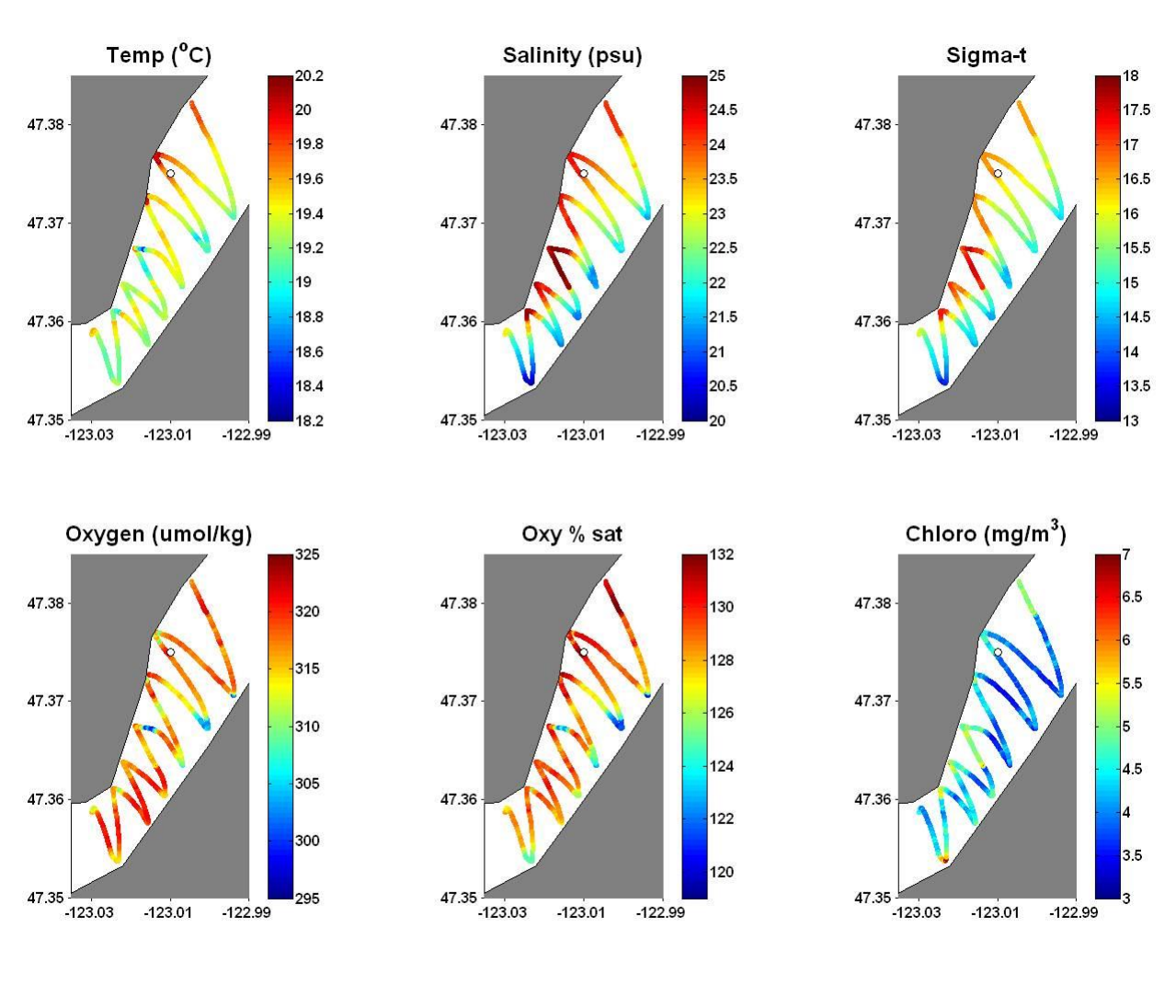


Tracks of survey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