Real-time sea-surface measurements of CDOM in the Strait of Georgia, Canada: Developing techniques to account for sensor fouling

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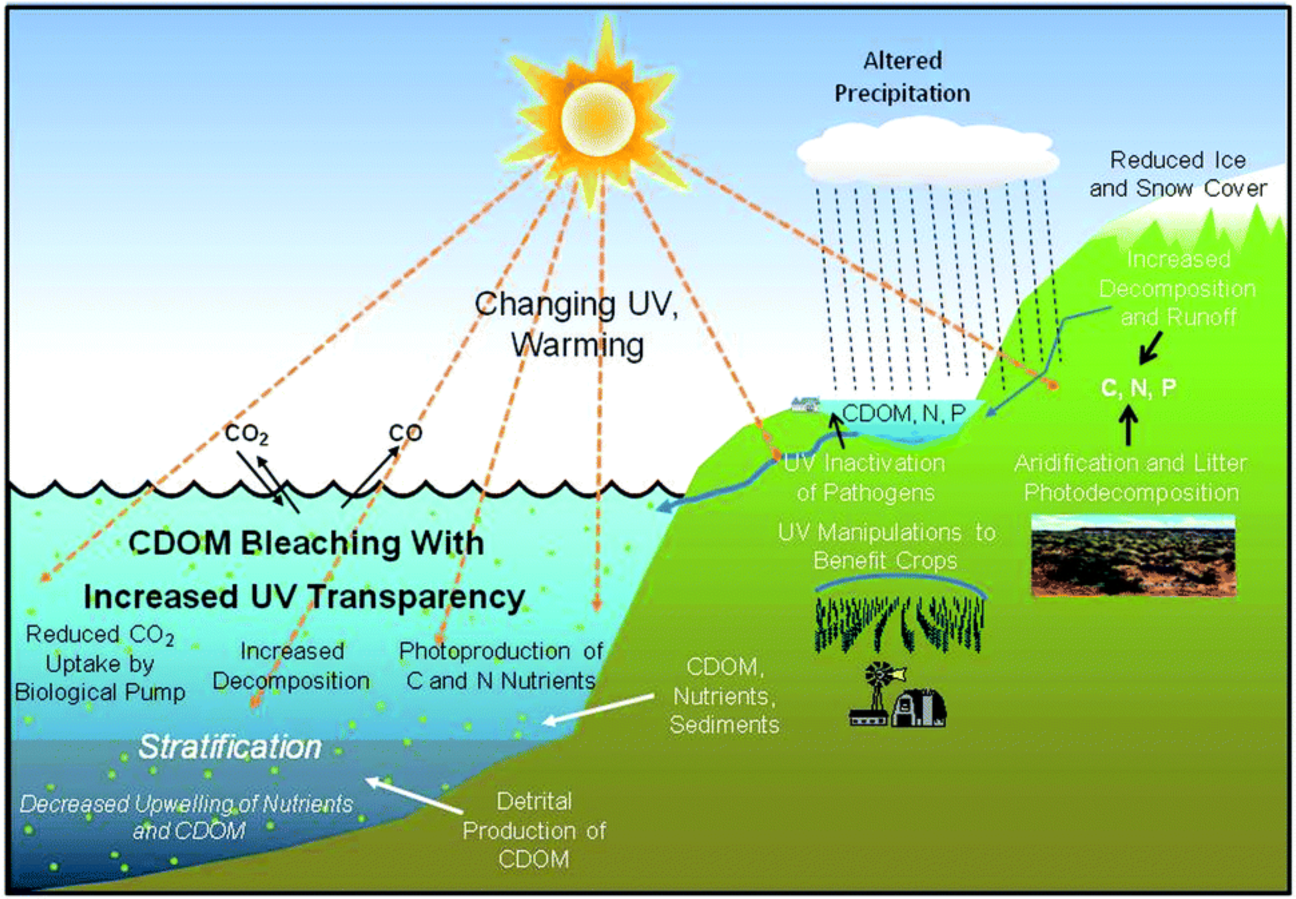
Coloured Dissolved Organic Material (CDOM)



(Figure: *Williamson et al. Nature Climate Change 2014*)

<u>CDOM in marine waters:</u>

1) Light attenuation

2) Influences reflected irradiance

<u>CDOM = CO_{2atm} source:</u>

1) **Photo-oxidation**

2) **Bacterial Respiration**

ONC-BC Ferries Sea-Surface Monitoring Program

Northern Route	2003-2006, June 2015-present
Central Route	2003-2006, 2012-present
Southern Route	2002-present

SoG Ferries Program: Surface Properties

<u>SoG Ferry time-series:</u>

1) Physically dynamic estuarine system (Fraser R.)
2) Nursery ground for juvenile salmon and YOY herring
3) 4-8 crossings/day
4) High spatial & temporal resolution of sea surface properties (0.1 Hz)
5) Each ferry often passes through the river plume

SoG Ferries Program: Instrumentation

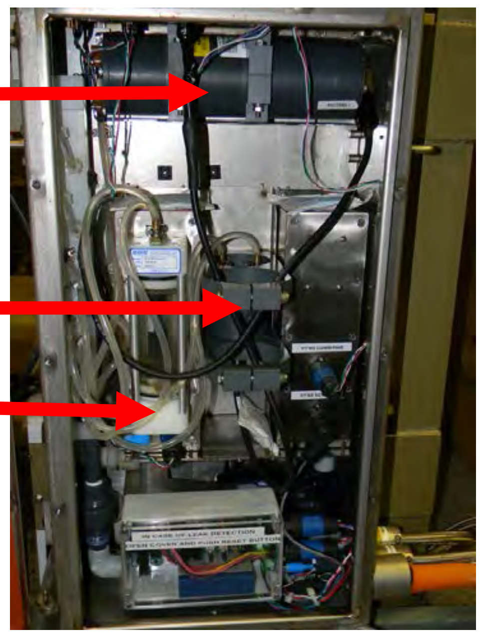
Meteorological Package:

- Air pressure/humidity
- Wind speed/direction
- Solar irradiance/surface reflectance
- Ships orientation

Chl.
CDOM/Turbidity

Oxygen Optode

Thermosalinograph



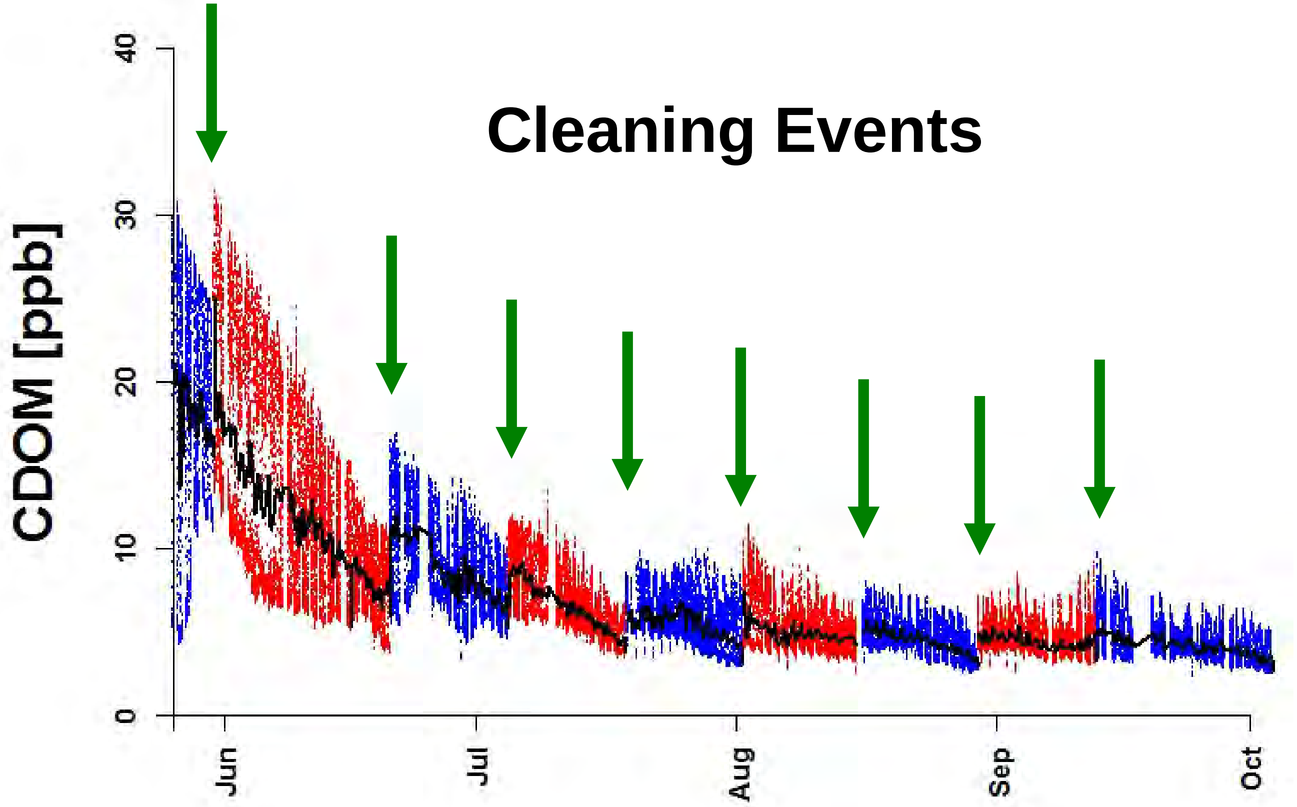
Oceanographic Package:

- WetLabs Eco-Triplet
- Aanderaa O_2 optode
- SeaBird CT sensor
- Pro-Oceanus $p$$CO_2$ sensor (2017)

Bio-fouling: CDOM & Chl fluorescence

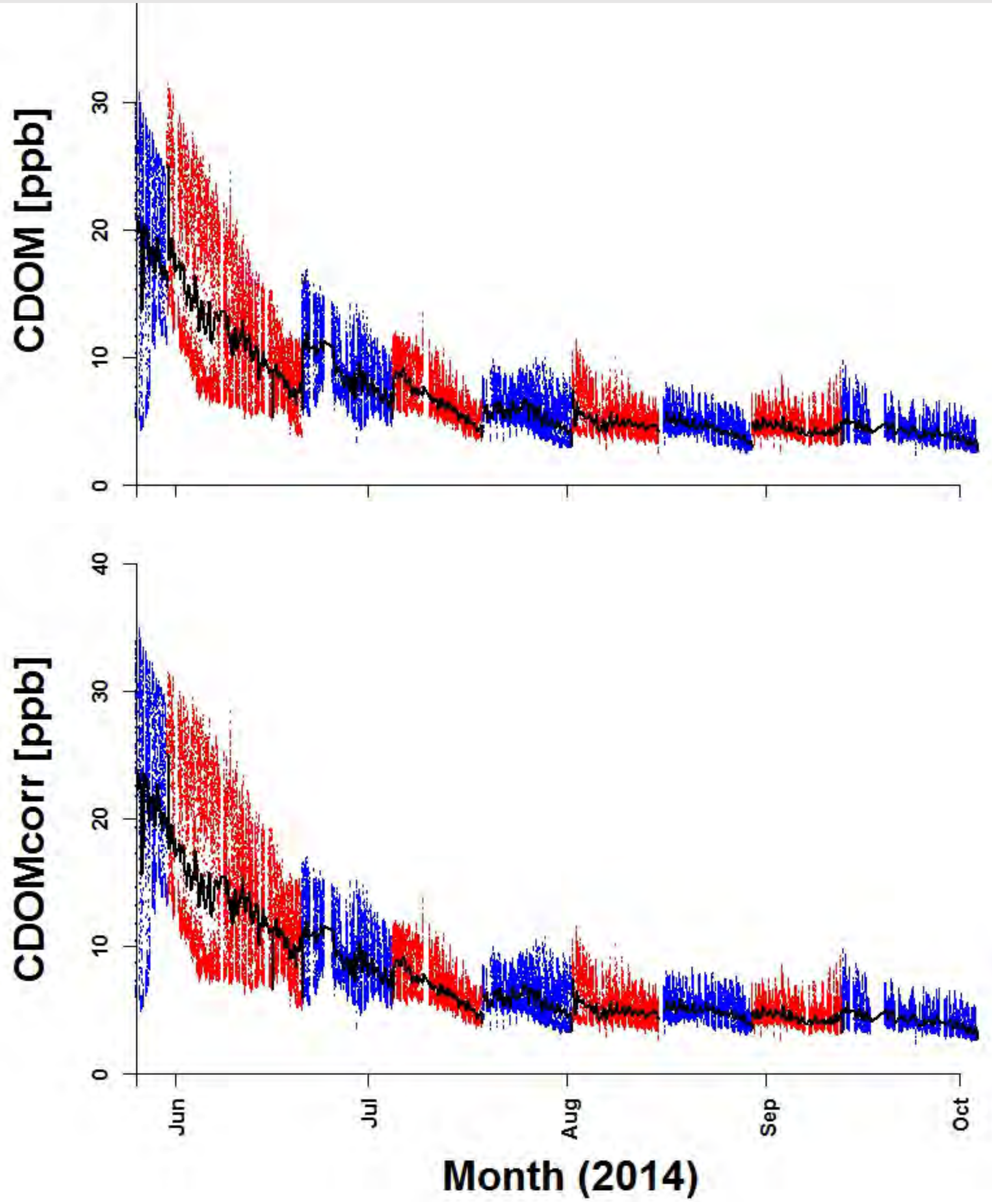
- Fluorometers housed within 500 mL capacity housing
- Cannot accommodate a wiper
- Significant build-up of surface growth and sediment within housing and on measuring face
- Fouling attenuates signal over short periods of time ~ 2 weeks
- CDOM is especially sensitive to fouling (Chl. Fluorescence more robust)

Bio-fouling: CDOM & Cleaning



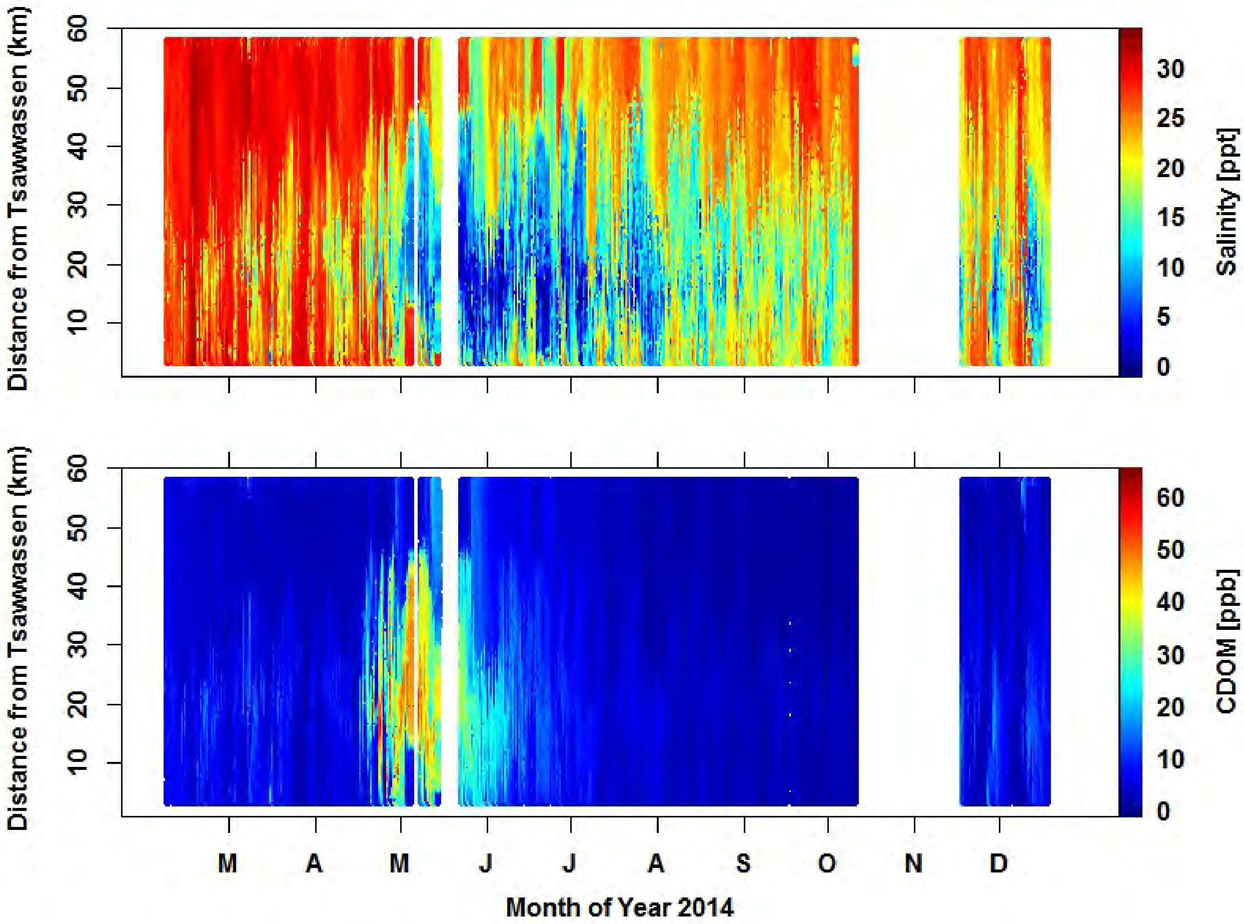
- Instruments were cleaned every two weeks
- ‘Saw-toothed’ pattern indicative of the degree of short-term fouling and the positive impact of regular cleaning
- CDOM fluorescence is particularly sensitive to bio-fouling over two-week intervals

Correcting for Fouling: “Standard” Solutions

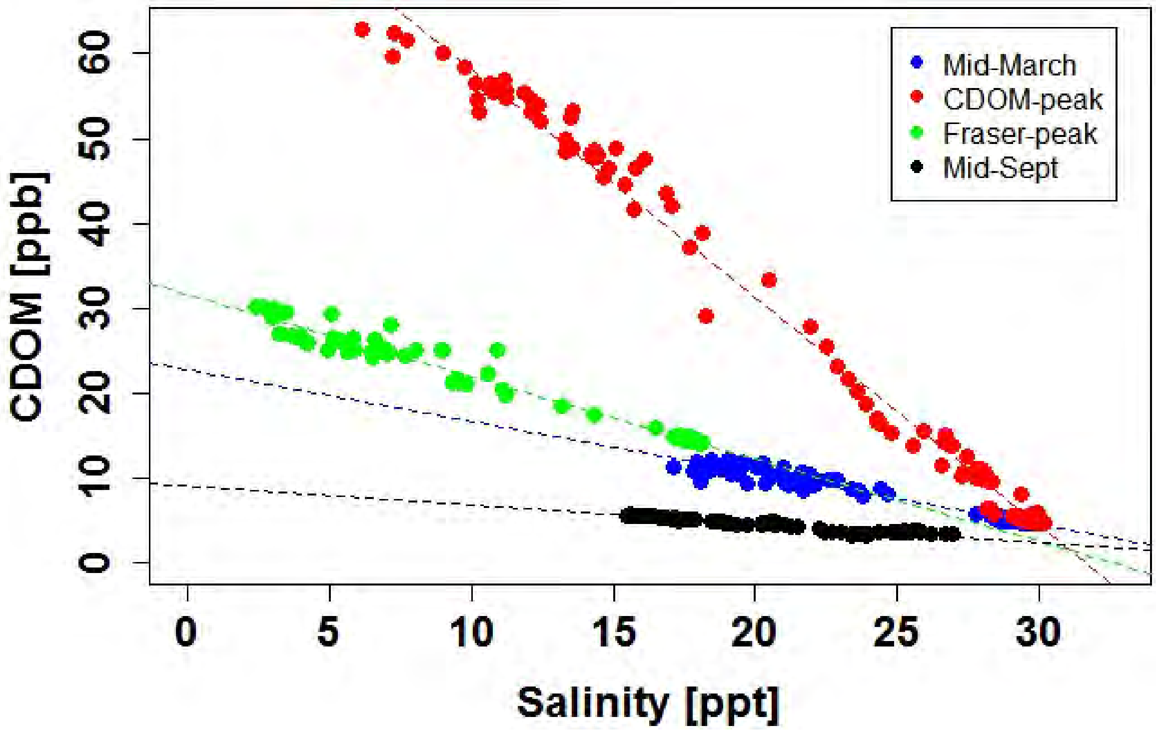


- The CDOM sensor is sensitive to the fluorescence of ‘Tonic Water’ and ‘Sprite Zero
- Useful standards :
  1. manufacturers standardization
  2. long-term stability of fluorescence signal
- Correction factors = relative difference (%) between pre- and post-cleaning measurements of fluorescence
- Retrospective correction factor
- CDOM time-series is visibly improved when corrections applied

Surface Salinity and CDOM

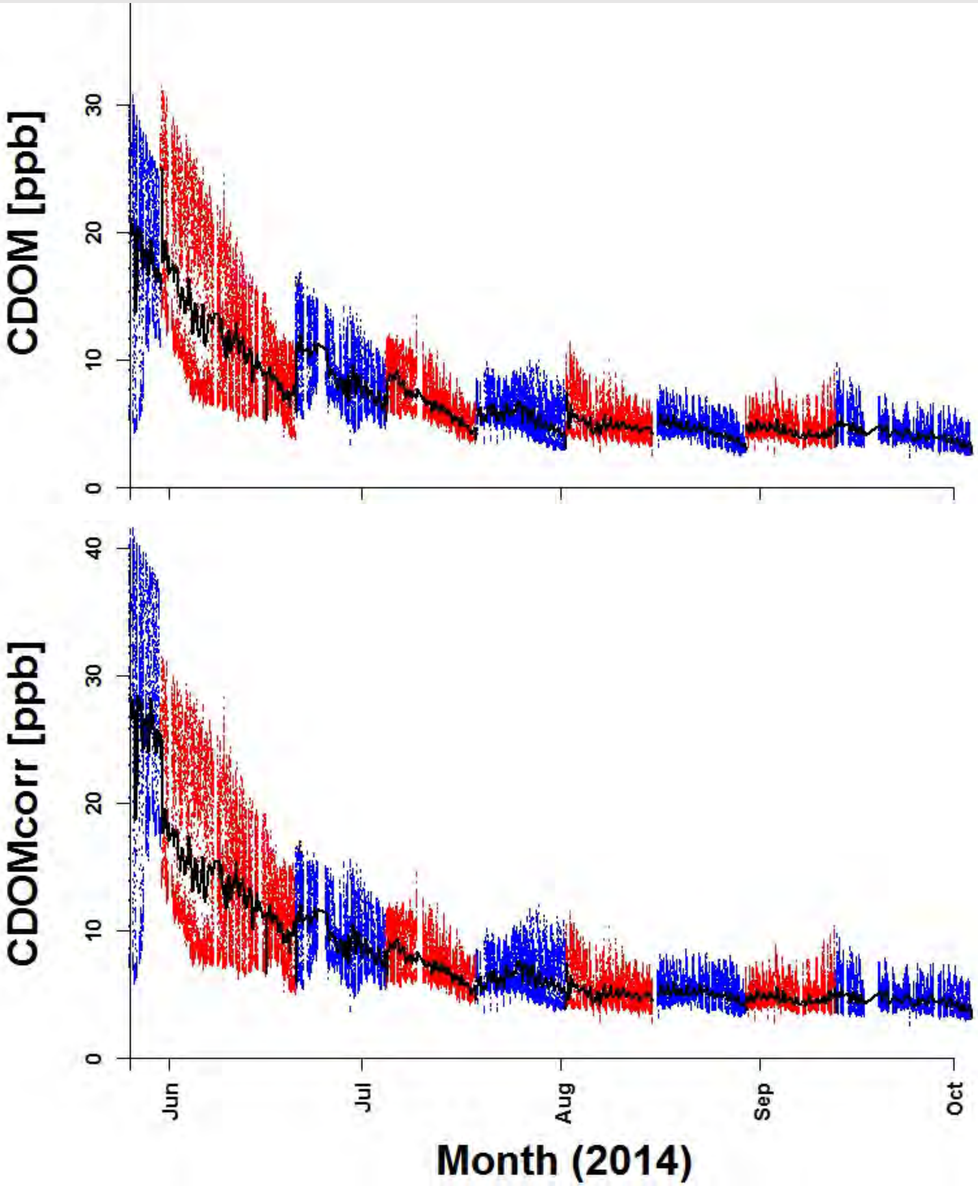


Correcting for fouling: Inter-Sensor Corrections



- Fraser River is primary source of CDOM in the Strait of Georgia
- Relationship between CDOM and salinity is strong and conserved due to mixing of fresh (CDOM-laden) and seawater
- Slope and intercept vary with season but not appreciably within days

ONC-BC Ferries Sea-Surface Monitoring Program

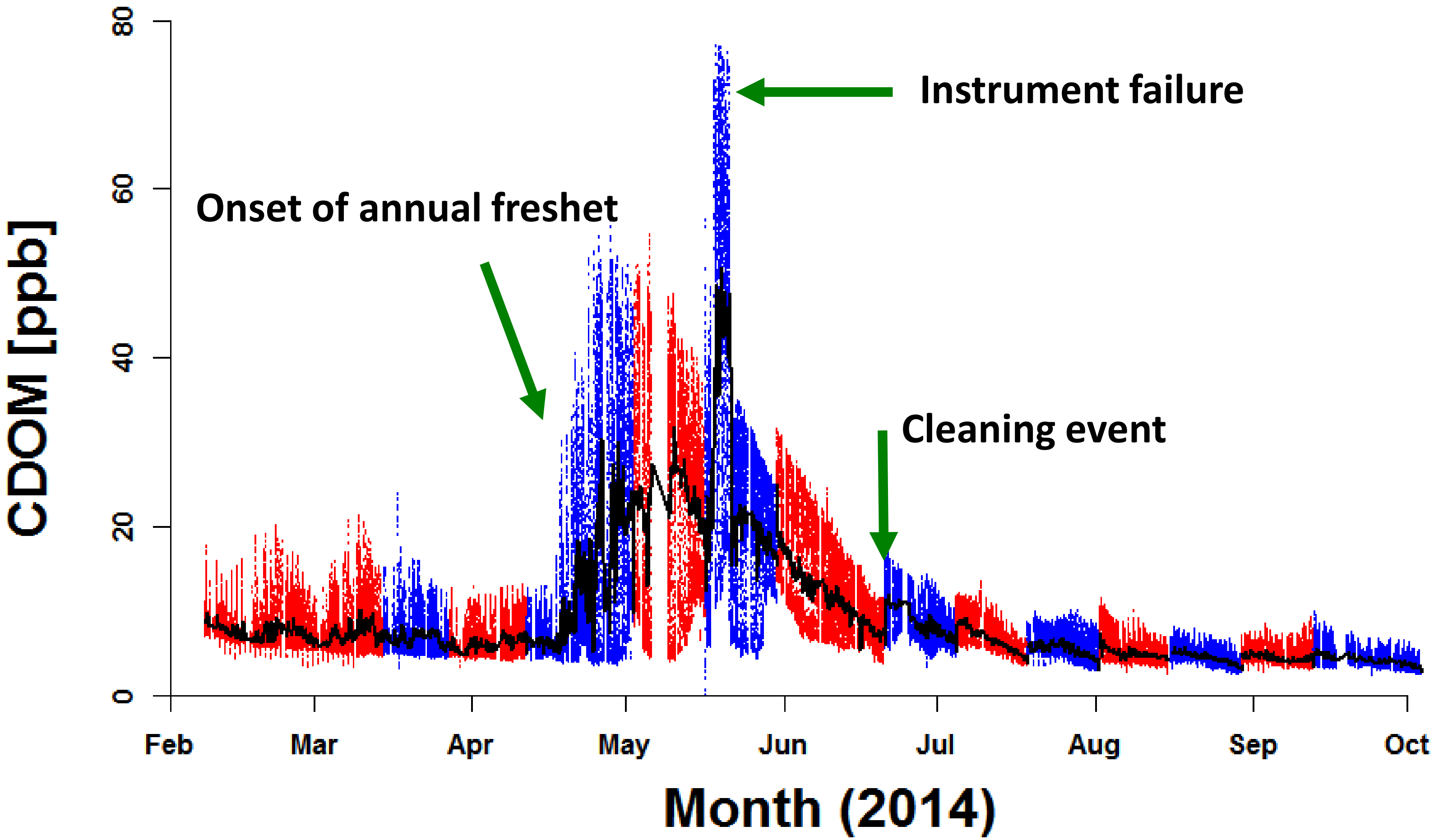


- Ratio of pre- and post-cleaning CDOM-salinity intercept =useful correction factors
- Assumes little degradation of the salinity signal over two week intervals
- Accounts for sedimentation on lens surface washed out when using standard solutions
- <u>Superior method to standardized solutions</u>

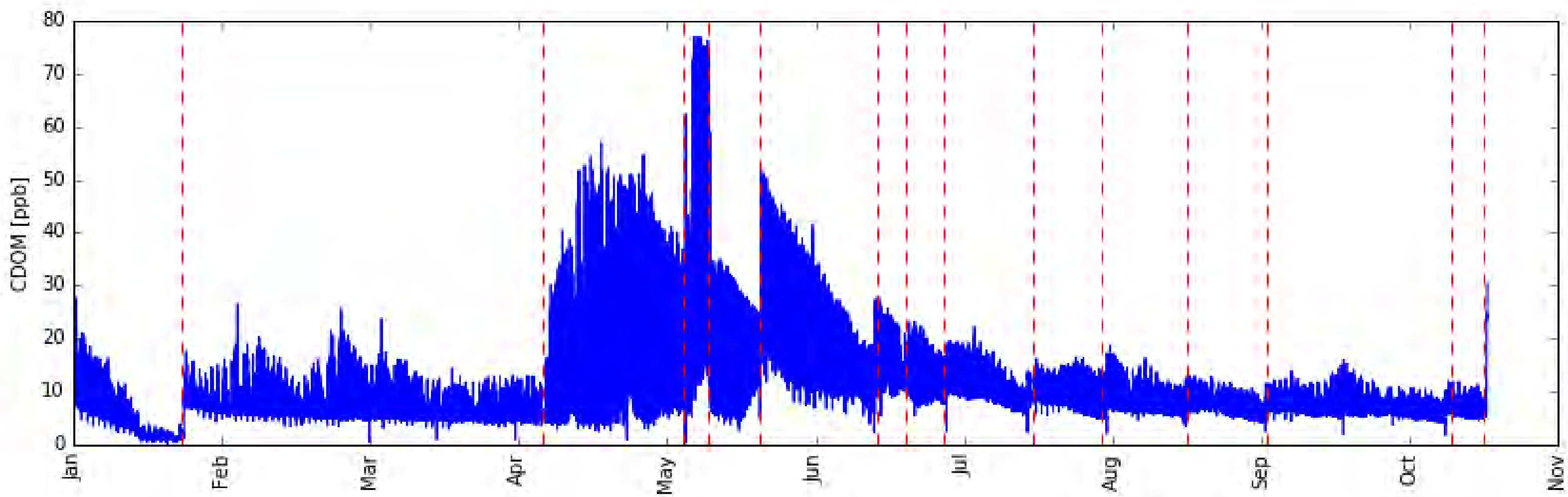
Summary: Retrospective Methods

- Strait of Georgia surface waters very productive and represent a good model for assessing bio-fouling effects on sensors
- CDOM fluorescence is quite sensitive to bio-fouling and lens occlusion by sediment
- Cleaning instruments on a regular basis improves long-term data-quality
- Standard solution benchmarks are suitable for retrospective corrections for fouling – but cannot account for sediment interference
- Inter-instrument comparisons are also useful and account for both lens fouling and sediment interference
- Both approaches assume linear fouling with time: longer-term fouling patterns may not be rectifiable
- We are now exploring baseline trend-analyses and auto-correlative techniques to assess fouling – useful for long-term remote deployments

Toward real-time or near real time event detection



Event detection: Change-point analyses



- Change point detection = identification of abrupt variation time series due to distributional or structural changes (Sharma et al. 2016)
- 'Wild-Binary Segmentation' approach for this CDOM time-series (Baranowski and Fryzlewicz 2014)
- Identifies several events including most (not all) cleaning events, seasonal events and instrument failures
- Attempting to discriminate between event-types with inter-instrument change-point comparisons

Toward Best Practices for mitigating/assessing sensor fouling

- Which sensors should we be most concerned about? i.e. sensitivity to fouling?
- Identify current protocols for corrections for fouling?
- Identify optimal deployment duration for a given sensor/environment/season?
- Development and implementation of standardized real-time techniques for assessing fouling