



Western Washington University  
**Western CEDAR**

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Salish Sea Ecosystem Conference

2014 Salish Sea Ecosystem Conference  
(Seattle, Wash.)

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May 2nd, 10:30 AM - 12:00 PM

## Eyes Over Puget Sound: Producing Validated Satellite Products to Support Rapid Water Quality Assessments in Puget Sound

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Suzan Pool

Julia Bos

Tarang Khangaonkar  
*Pacific Northwest Pollution Prevention Resource Center*

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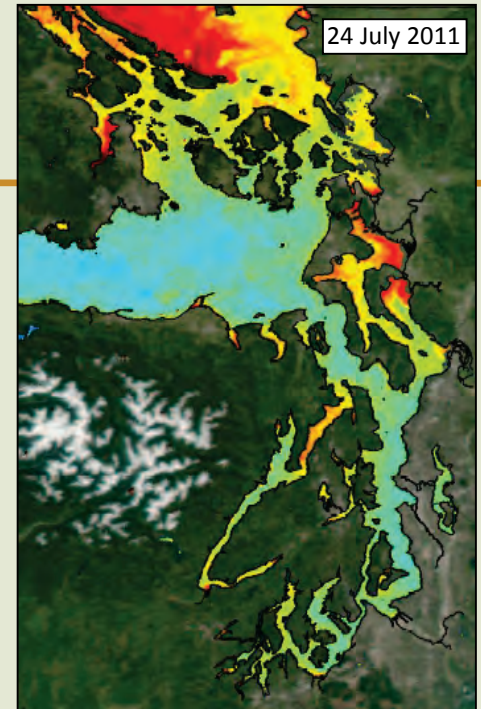


Part of the [Terrestrial and Aquatic Ecology Commons](#)

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Sackmann, Brandon S.; Krembs, Christopher; Pool, Suzan; Bos, Julia; and Khangaonkar, Tarang, "Eyes Over Puget Sound: Producing Validated Satellite Products to Support Rapid Water Quality Assessments in Puget Sound" (2014). *Salish Sea Ecosystem Conference*. 82.  
<https://cedar.wwu.edu/ssec/2014ssec/Day3/82>

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MODIS-Aqua 500-m Chlorophyll *a* product developed for Puget Sound, WA.

# Eyes Over Puget Sound

Producing Validated Satellite Products to Support Rapid Water Quality Assessments in Puget Sound

Brandon Sackmann ([bsackmann@integral-corp.com](mailto:bsackmann@integral-corp.com))  
Christopher Krembs, Suzan Pool, Julia Bos, and Tarang Khangaonkar

2 May 2014  
Salish Sea Conference 2014



# Eyes Over Puget Sound

Start here

- Flight log
- Water column
- Aerial photos

**Eyes Over Puget Sound**

Flight log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings

Guest Contribution: Brandon Sackmann

**Surface Conditions Report**  
January 15, 2013

We have a new website: [http://www.ecy.wa.gov/programs/esp/mar\\_wat/](http://www.ecy.wa.gov/programs/esp/mar_wat/) [Start here](#)

Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca

**Eyes Over Puget Sound**

Flight log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings

**Surface Conditions Report**  
February 26, 2013

Guest: Arvi Kveiven, State of Possession Sound Cruise

We have a new website: [http://www.ecy.wa.gov/programs/esp/mar\\_wat/](http://www.ecy.wa.gov/programs/esp/mar_wat/) [Start here](#)

Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca

**Eyes Over Puget Sound**

Flight log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings

+ Hood Canal and Coast

**Surface Conditions Report**  
March 25, 2013

We have a new website: [http://www.ecy.wa.gov/programs/esp/mar\\_wat/](http://www.ecy.wa.gov/programs/esp/mar_wat/) [Start here](#)

Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca

**Eyes Over Puget Sound**

Flight log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings

**Surface Conditions Report**  
April 8, 2013

We have a new website: [http://www.ecy.wa.gov/programs/esp/mar\\_wat/](http://www.ecy.wa.gov/programs/esp/mar_wat/) [Start here](#)

Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca

**Eyes Over Puget Sound**

Flight log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings

**Surface Conditions Report**  
May 20, 2013

Visit our website: [http://www.ecy.wa.gov/programs/esp/mar\\_wat/](http://www.ecy.wa.gov/programs/esp/mar_wat/) [Start here](#)

Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca

# 2013 Review

**Eyes Over Puget Sound**

Flight log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings

**Surface Conditions Report**  
June 17, 2013

Visit our website: [http://www.ecy.wa.gov/programs/esp/mar\\_wat/](http://www.ecy.wa.gov/programs/esp/mar_wat/) [Start here](#)

Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca

**Eyes Over Puget Sound**

Flight log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings

**Surface Conditions Report, July 15, 2013**

Guest contribution by the Encyclopedia of PUGET SOUND (page 3) [Start here](#)

Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca

**Eyes Over Puget Sound**

Flight log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings

**Surface Conditions Report, August 21, 2013**

Featured Report: The Marine Waters 2012 Overview Report, [log here](#) [Start here](#)

Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca

**Eyes Over Puget Sound**

Flight log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings

**Surface Conditions Report**  
September 11, 2013

Ozone sensors on board: Donovan Rafferty, Ecology Air Quality Program [here](#) [Start here](#)

Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca

**Eyes Over Puget Sound**

Flight log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings

**Surface Conditions Report**  
October 28, 2013

[Start here](#)

Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca

**Eyes Over Puget Sound**

Flight log | Weather | Water column | Aerial photos | Ferry and Satellite | Moorings

**Surface Conditions Report**  
November 21, 2013

[Start here](#)

Up-to-date observations of visible water quality conditions in Puget Sound and the Strait of Juan de Fuca

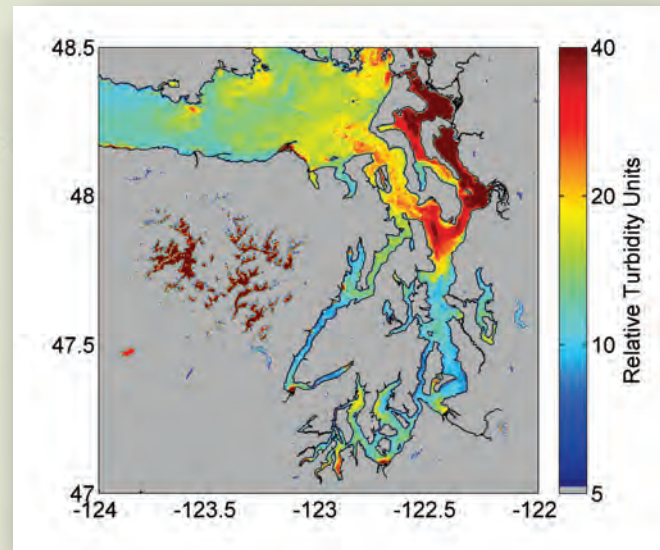
!!! 3+ yrs ... 640+ subscribers ... 1M+ downloads ... 2-day turn-around !!!

# Ferries provide a novel source of ground truth information

- Satellite observations are most useful when they can be reconciled with ground truth observations
- Ferries provide a unique dataset that lets us do this in a scientifically-rigorous and cost-effective way



Ferries



Satellites

PS-Wide Water Quality Products

# Ferries for Science



- Turner Designs C3 optical sensor (May 2010-present)
  - Phytoplankton (chl *a* fluor.)
  - Turbidity
  - River water (CDOM fluor.)
  - Sea Surface Temperature



- RDI Citadel Thermosalinograph (2012-present)
  - Sea Surface Temperature
  - Sea Surface Salinity



- RDI Workhorse Mariner ADCP 300 kHz (May 2014)
  - Depth-resolved currents
  - Acoustic backscatter

# Ferries for Science



Victoria Clipper IV



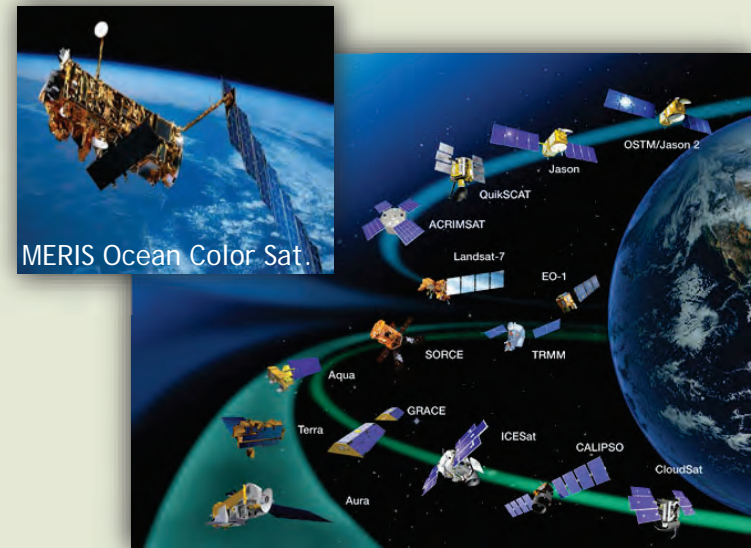
M/V Salish and Kennewick

- Cost-effective data collection
  - 100 m spatial resolution (5 sec.)
  - 4-hr temporal resolution
  - 300 m spatial resolution
  - ~1-hr temporal resolution
- Regular schedules/Reliable
  - 80 mile long transect (30 knots)
  - 5 mile long transect (8-10 knots)
  - 1-2 time **daily** (year-round)
  - 10-17 time **daily** (year-round)
- Daily data pickup (WSF data available via web)

# What can be measured from space?

Hi-res products for coastal and offshore applications

- Time period: 2000 - Present (1-8 day revisit)
- Resolution: 30 - 500 m, hi-res; >1 km, standard-res  
(*nearshore*) (*coastal/offshore*)
- Water Quality Indicators
  - Water Color (True Color/RGB)
  - Algal Biomass (Chlorophyll *a*, FLH, MCI)
  - Water Clarity (Turbidity)
  - Freshwater Influence (CDOM)
  - Sea Surface Temperature
- Combined approach using traditional ocean color sensors and terrestrial platforms



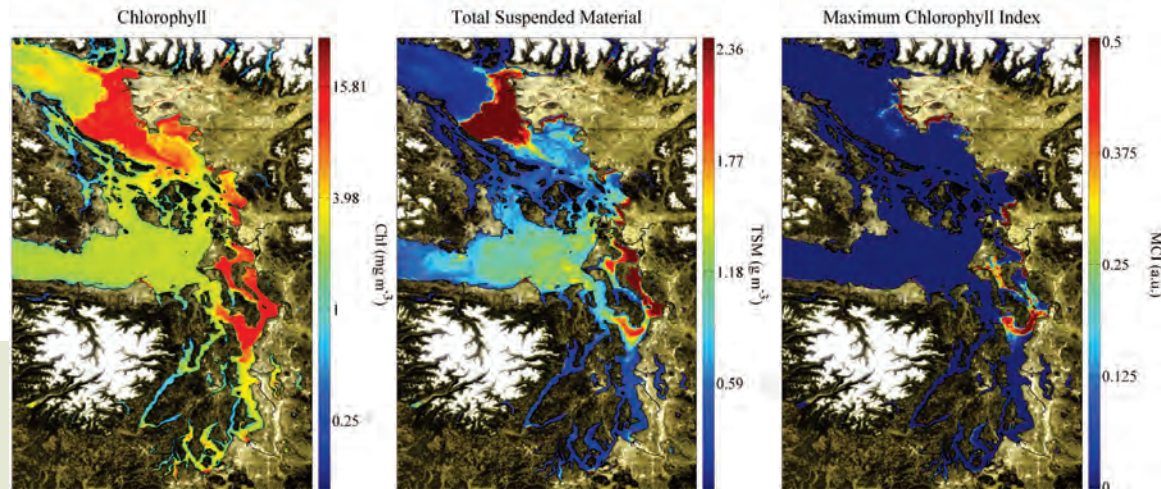
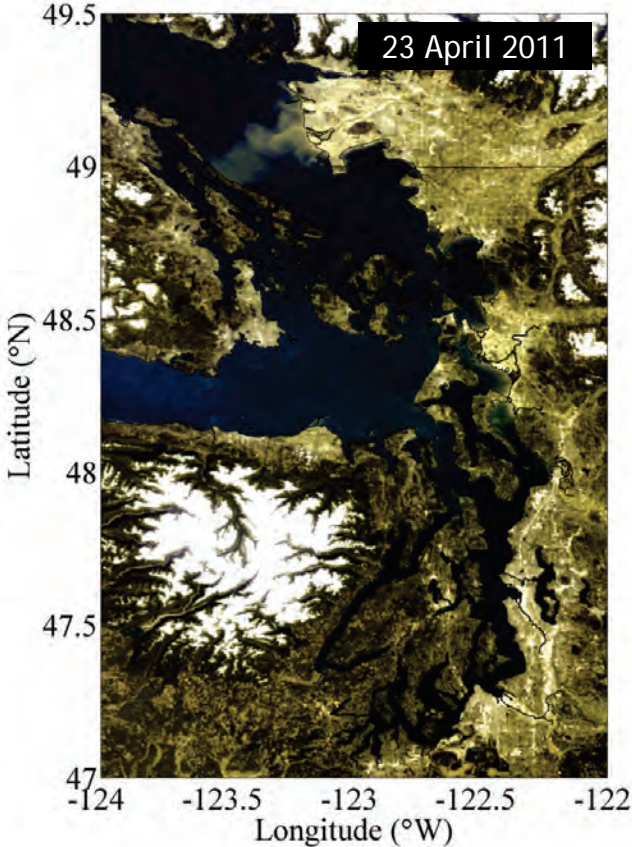
# What can be measured from space?

Hi-res products for coastal and offshore applications

- Multiple parameters from a single image
- MERIS (ESA) provided global, hi-res (300 m) ocean color products for coastal and offshore applications (2002-2012)
- Follow-on missions (OLCI) planned for 2015/2017; we need to be able to take advantage of these datasets...

MERIS True Color

23 April 2011

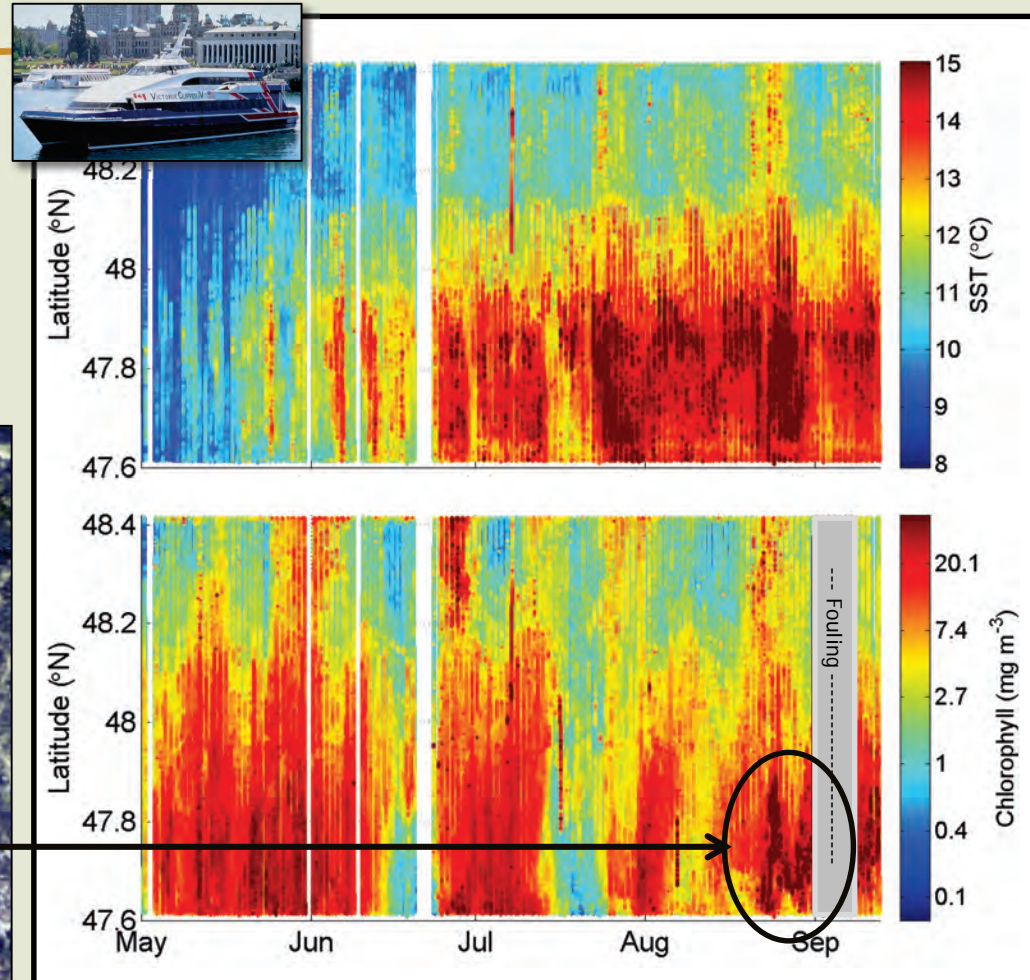
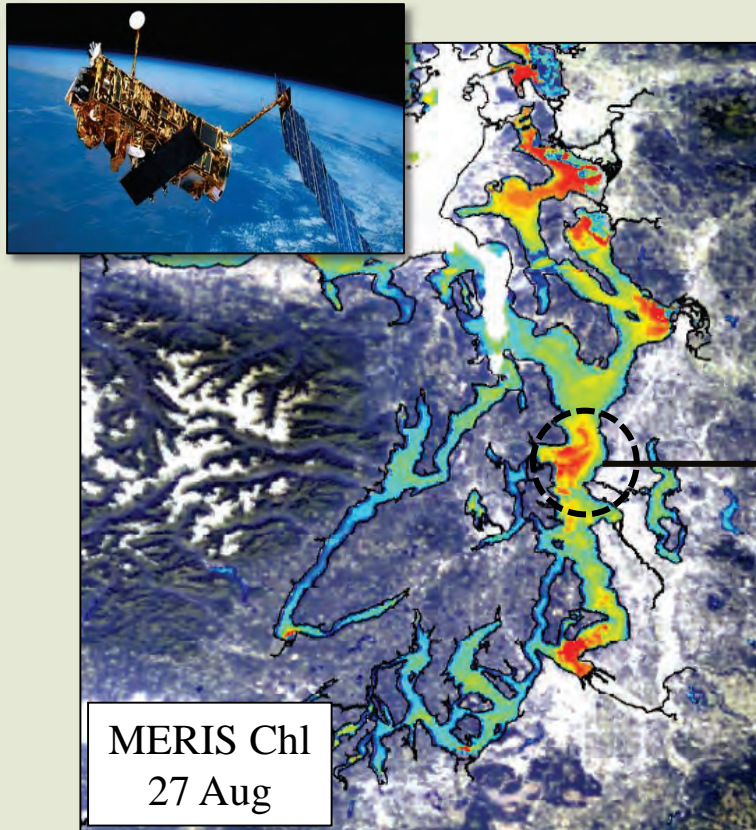




# Phytoplankton Bloom Off Bainbridge Island

## 22 August - 12 September 2011

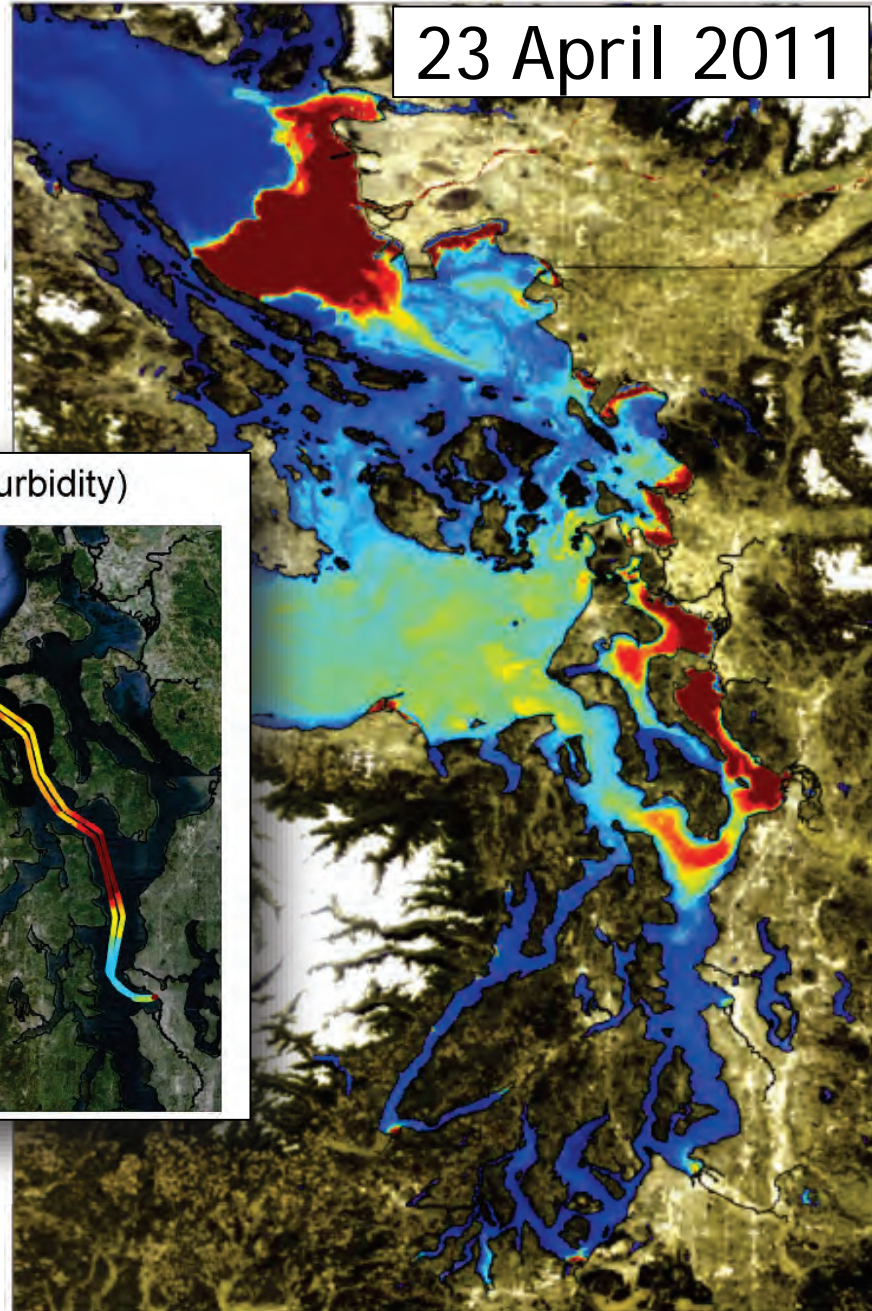
- Ferry data corroborated satellite images.
- Merged dataset remotely defined temporal and spatial extent of the bloom!



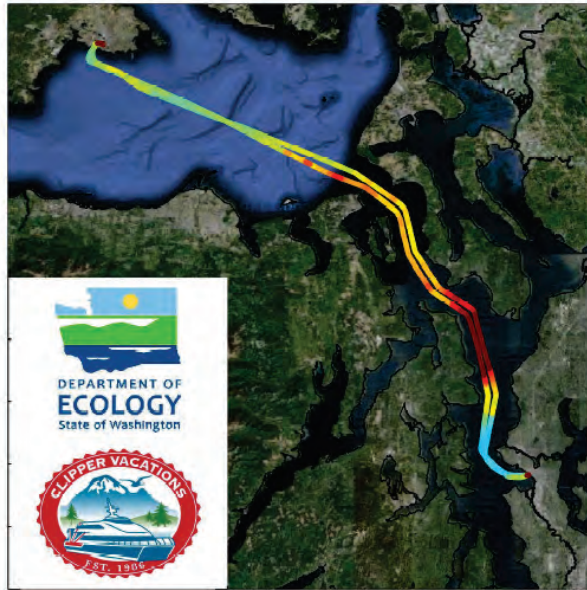
Hi-res satellite products can be challenging to produce due to optical complexity, lack of standard algorithms, and insufficient ground truth spanning large optical gradients.

## Total Suspended Material

23 April 2011

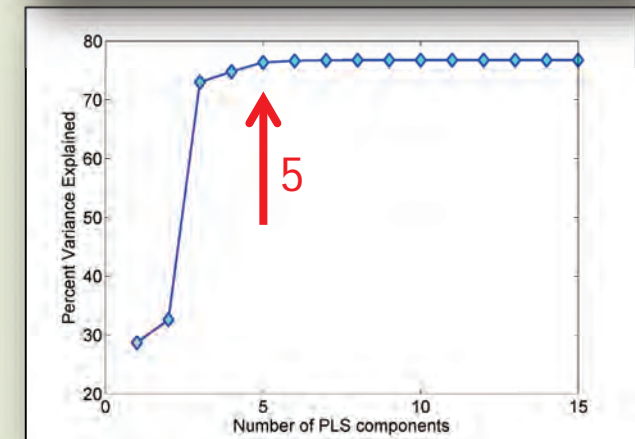
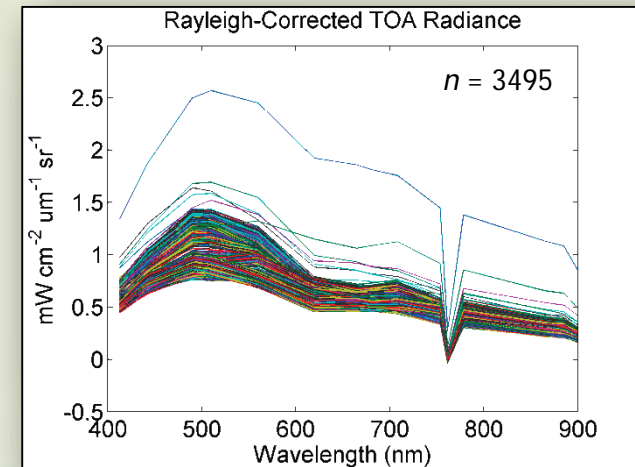


## Water Clarity (Turbidity)



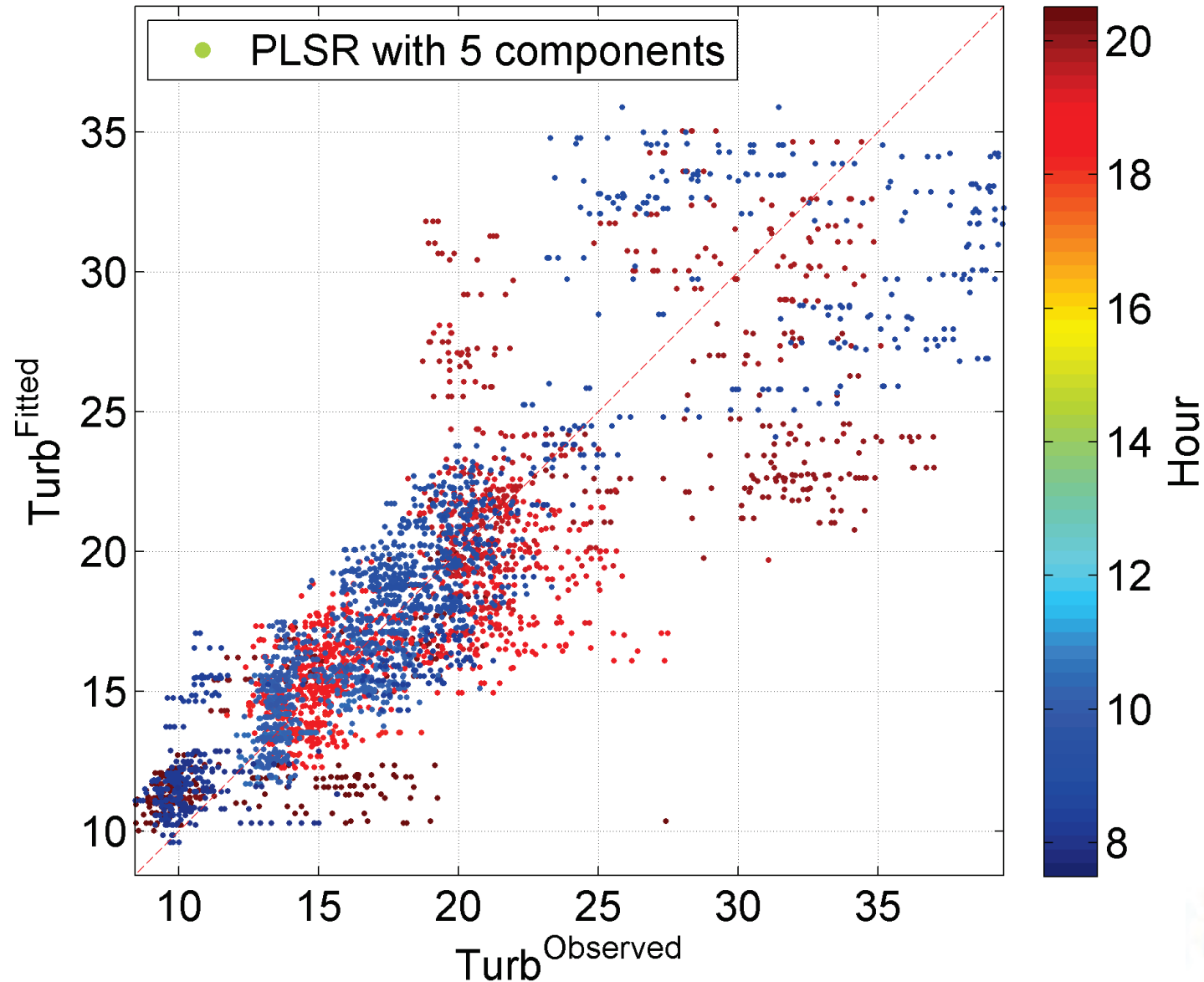
# Partial Least Squares Regression

- Widely used in chemometrics, bioinformatics, sensometrics, neuroscience and anthropology
- Well suited when predictors are many and highly collinear
- Emphasis is on predicting the responses; not necessarily on understanding the relationship between variables
- Leverages information from all spectral channels (visible -> near IR)
- Can be used with a variety of ocean color sensors
- Requires no atmospheric correction (TOA radiances adjusted for Rayleigh scattering only)

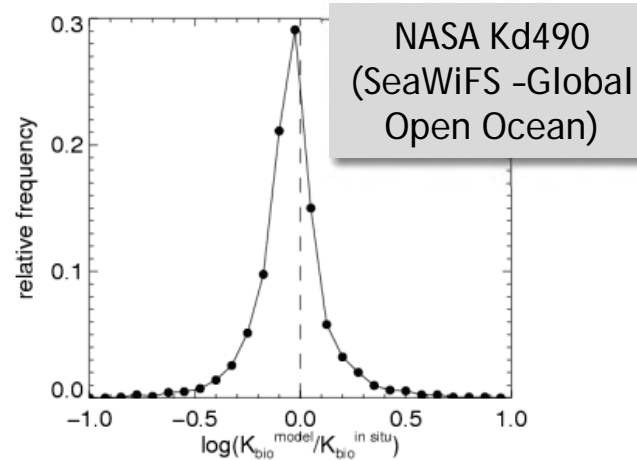
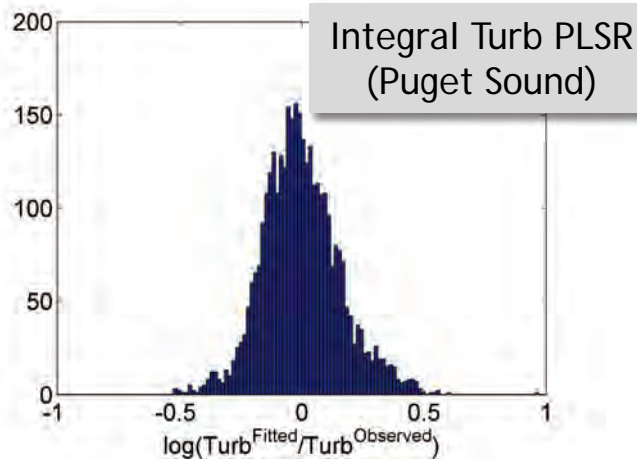
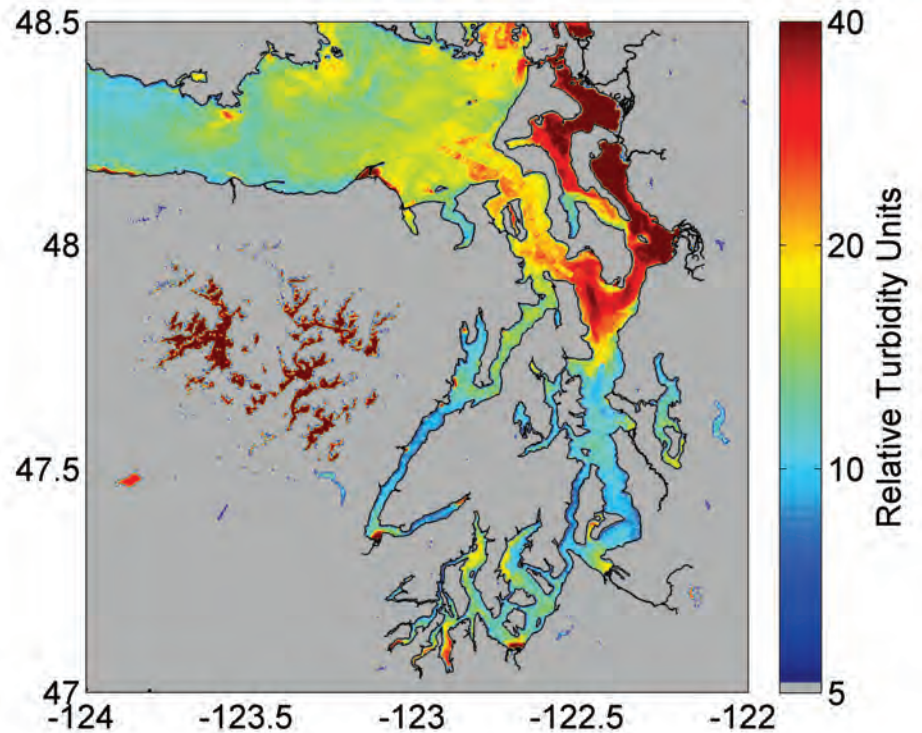
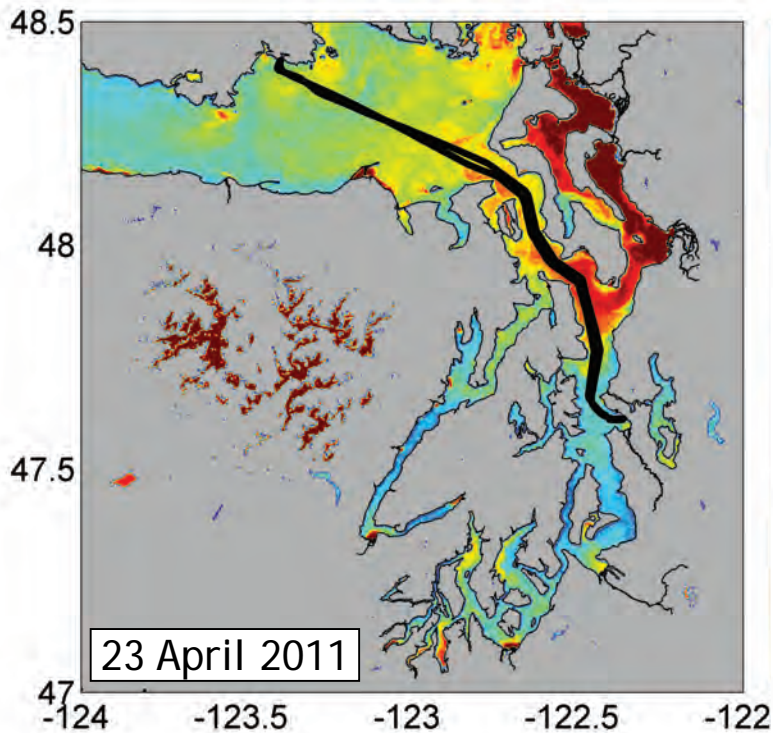


>75% of variance explained using 5 PLS components

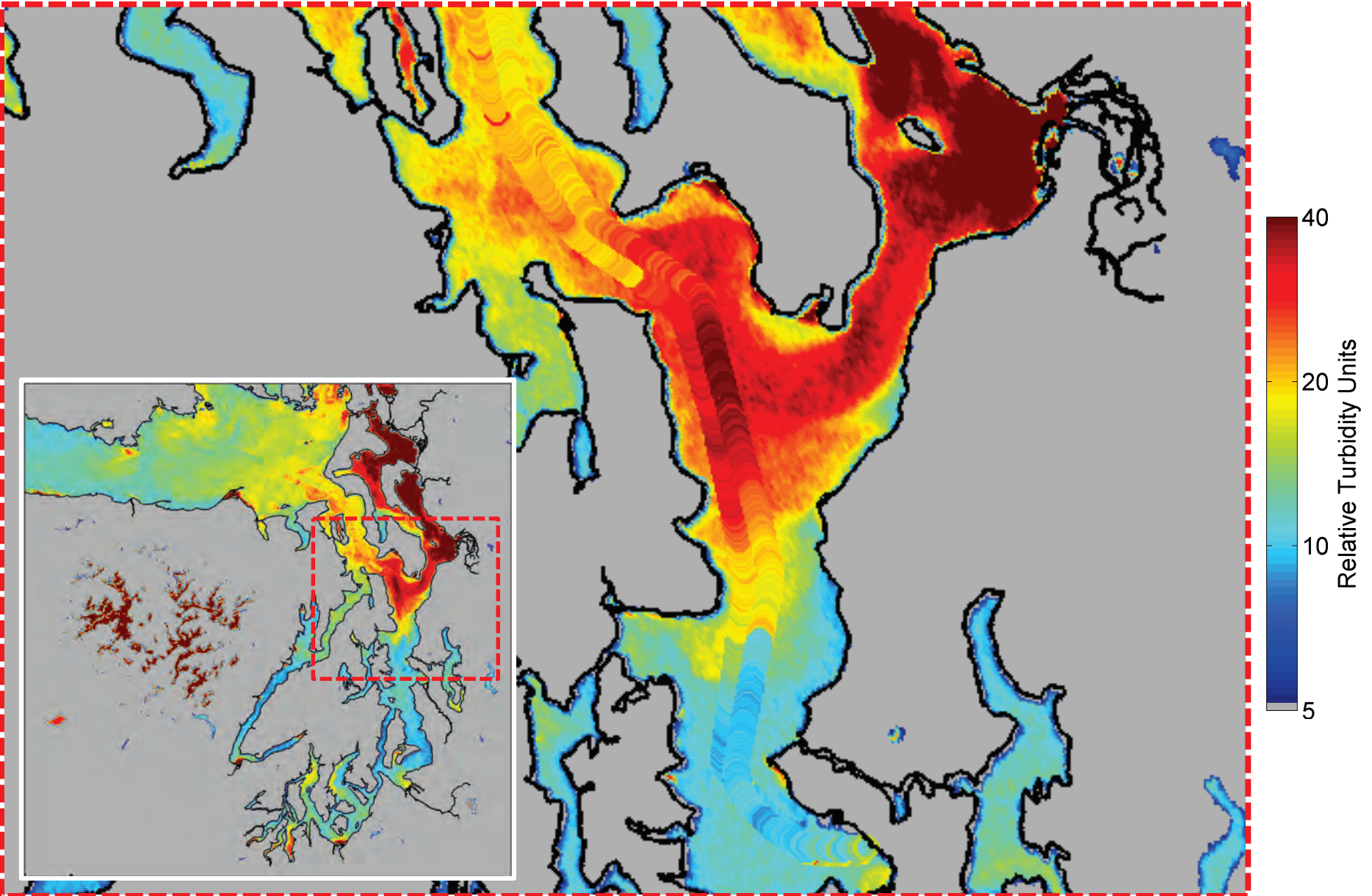
# Partial Least Squares Regression



# Partial Least Squares Regression



# Partial Least Squares Regression



# Uses for validated satellite information products

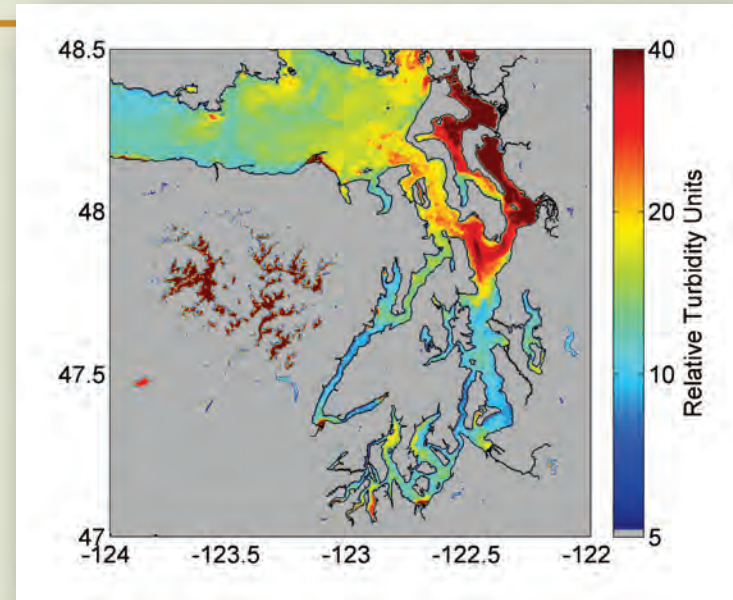
Retrospective Analyses <-> Real-time Monitoring <-> Forecasting/Risk Assessment

- Habitat characterization, ecological impact assessments, and permitting (e.g., aquaculture facilities)
- Seasonal anomalies <-> climate change (e.g., develop a comprehensive ocean color baseline for Puget Sound)
- Red tides and harmful algal blooms
- Eutrophication/shifting food webs
- Optimize field operations/sampling in dynamic areas
- Spill assessment and management
- Initial conditions and cal/val data for WQ modeling



# Recommendations/Future Efforts

- Blend data from multiple sources to create value-added information products
- PLSR method refinements
- QA procedures for *in situ* data (including mid-day F quenching)
- Operational workflow for creating validated products
- Move beyond static maps of individual WQ indicators
  - Characterize spatial variability/gradients
  - Feature/anomaly detection



DATA RESOURCE