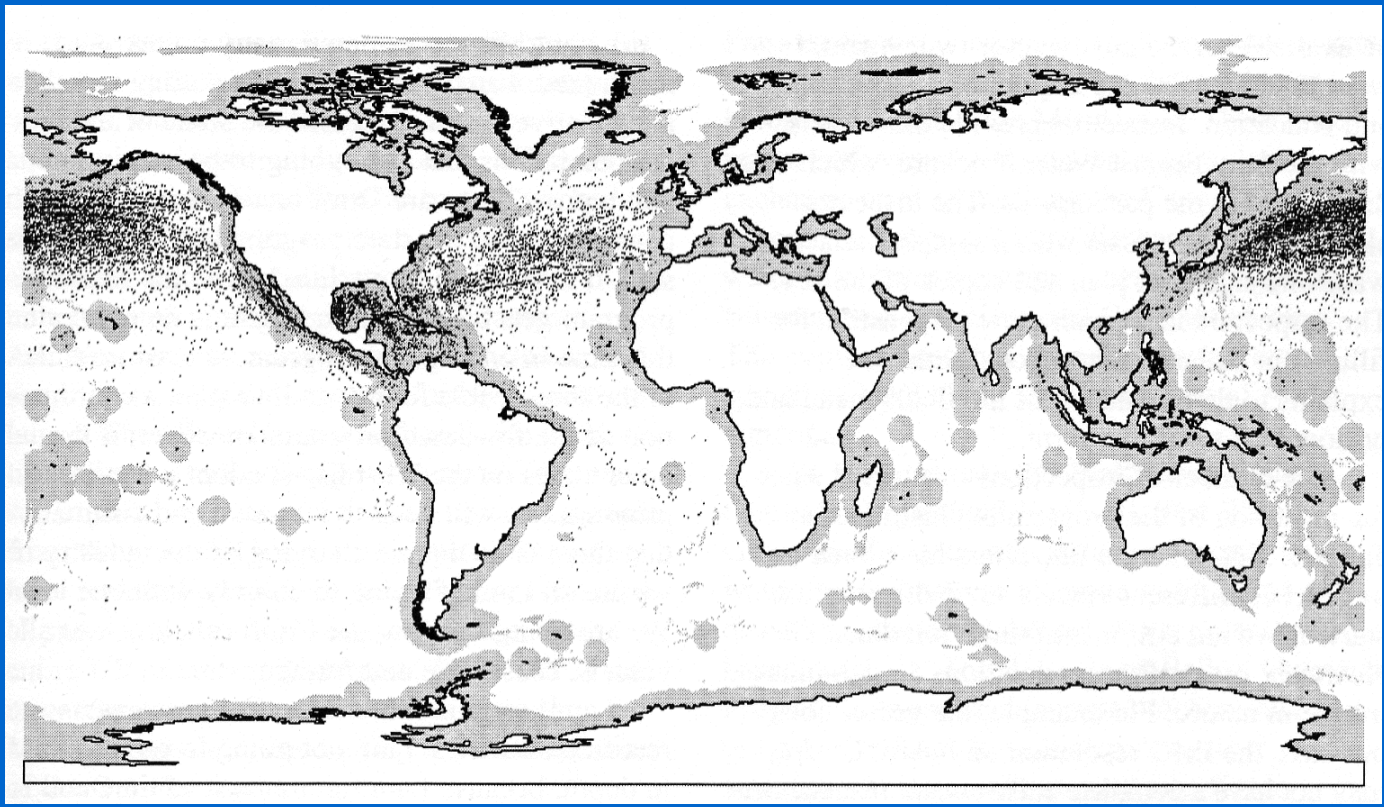
Ballast Water Exchange Verification Using the Optical Characteristics of Dissolved Organic Matter

Jennifer R. Boehme and Mark Wells
University of Maine
Darling Marine Center

Species Transport via Ballast Water



Ballast water exchange locations (SERC)

- 10,000s of organisms daily transported in ballast tanks
- 21 billion gallons of ballast discharged in North America annually
- Treatment measures up to 10 years away

Goal - Reduce invasive species transport

BWE currently the only accepted means of controlling spread of exotic species Murphy et al., 2004

U.S. moving quickly towards mandatory exchange for all vessels

Ballast Water Exchange - Verification

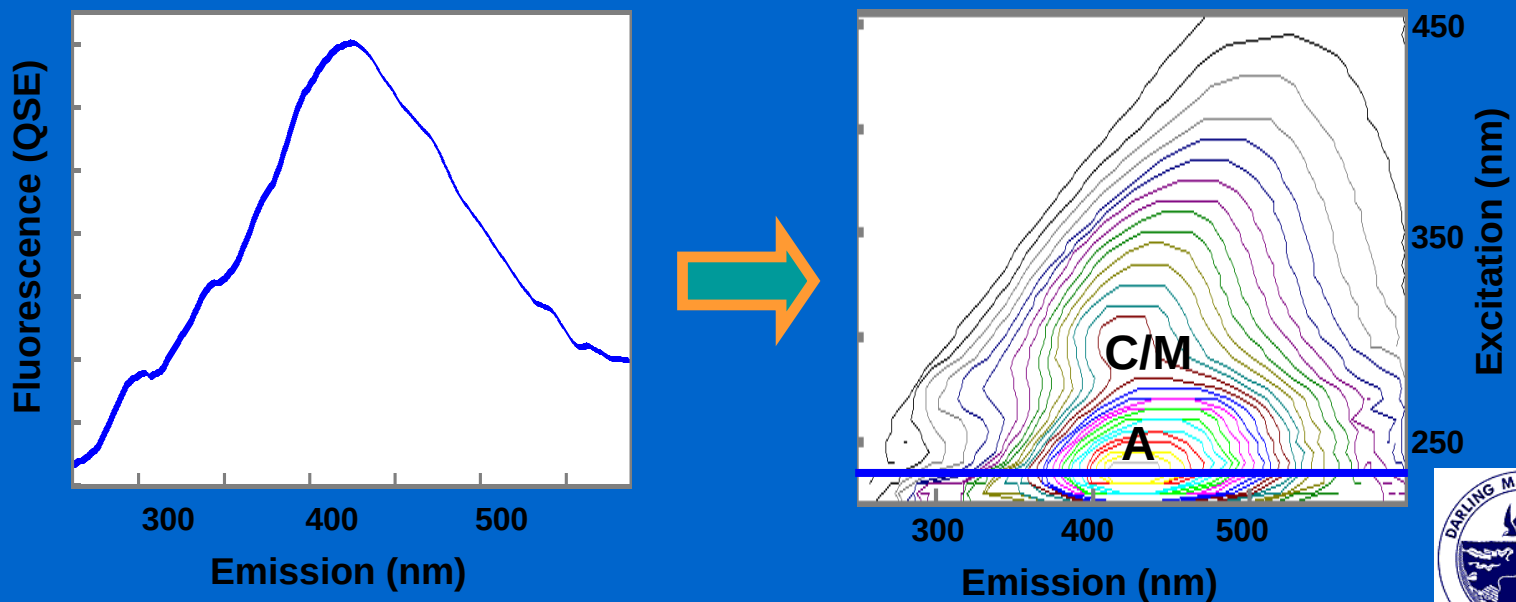
- Monitoring challenge

  Salinity methods not always definitive

- Optical characteristics of seawater - chromophoric dissolved organic matter (CDOM)

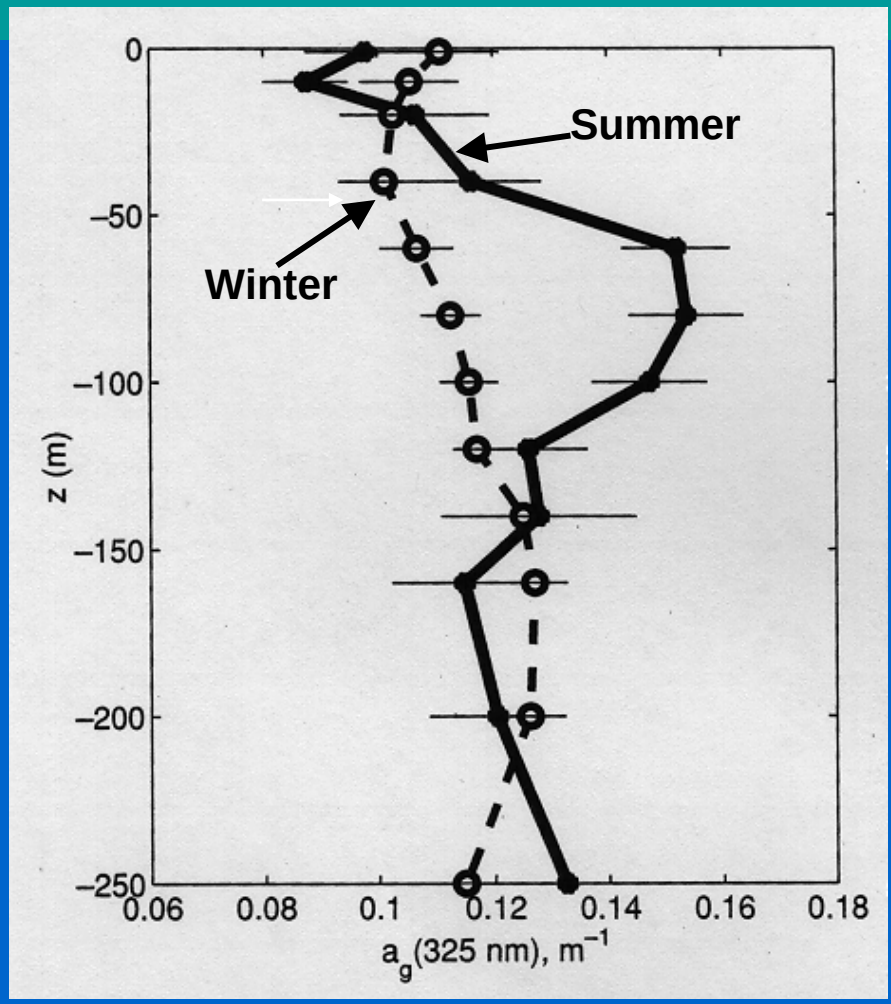
  Absorbance

  Fluorescence via Excitation Emission Matrix Spectroscopy



World Oceans - CDOM Variability

Seasonality and Photochemistry

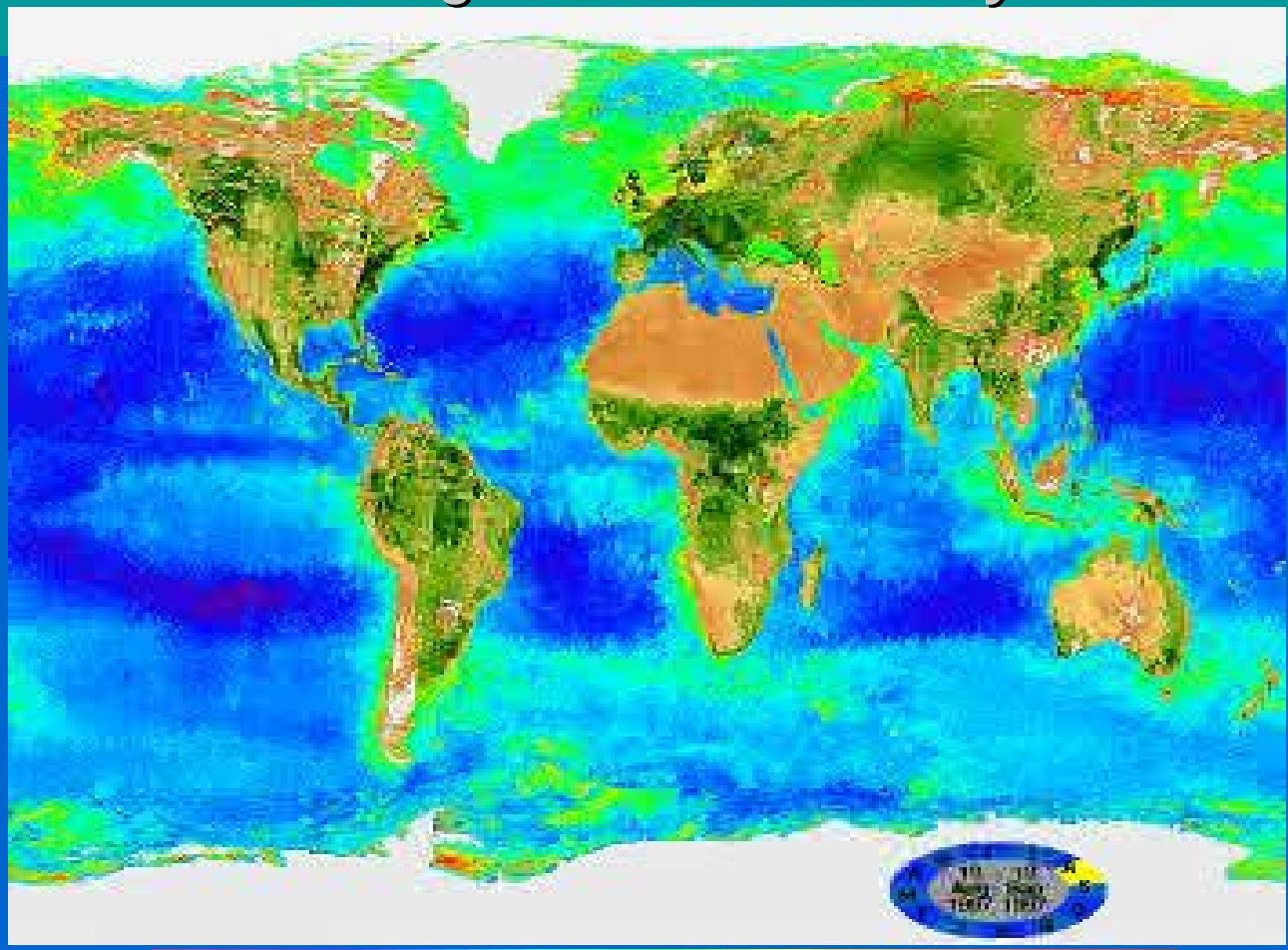


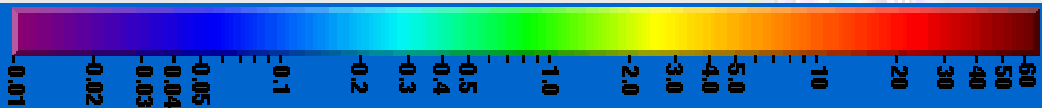
BATS seasonal CDOM absorption

(Nelson and Siegel, 2002)

World Oceans - CDOM Variability

Biological Productivity





http://seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/IMAGES.html

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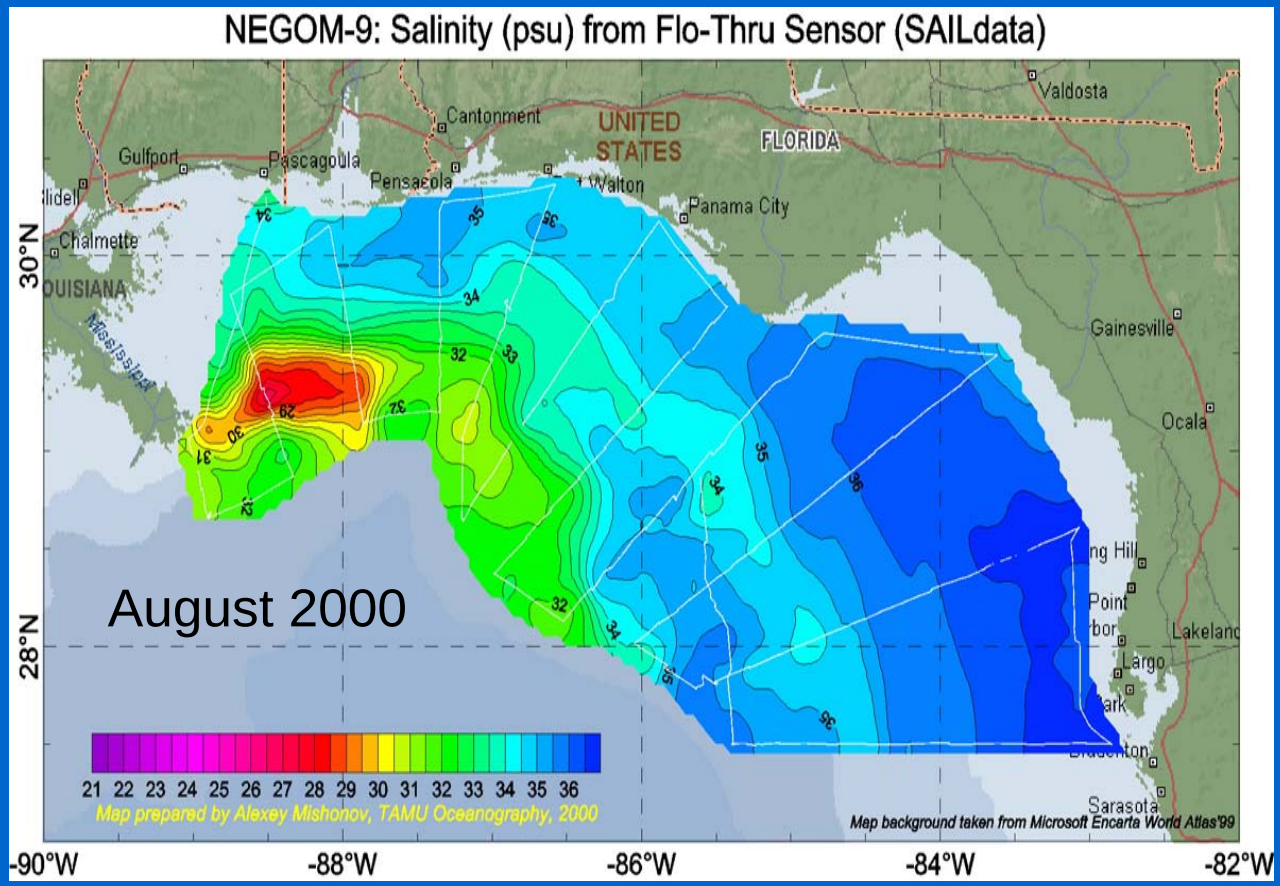
World Oceans - CDOM Variability

Terrestrial Runoff



Boehme et al., 2004

World Oceans - CDOM Variability

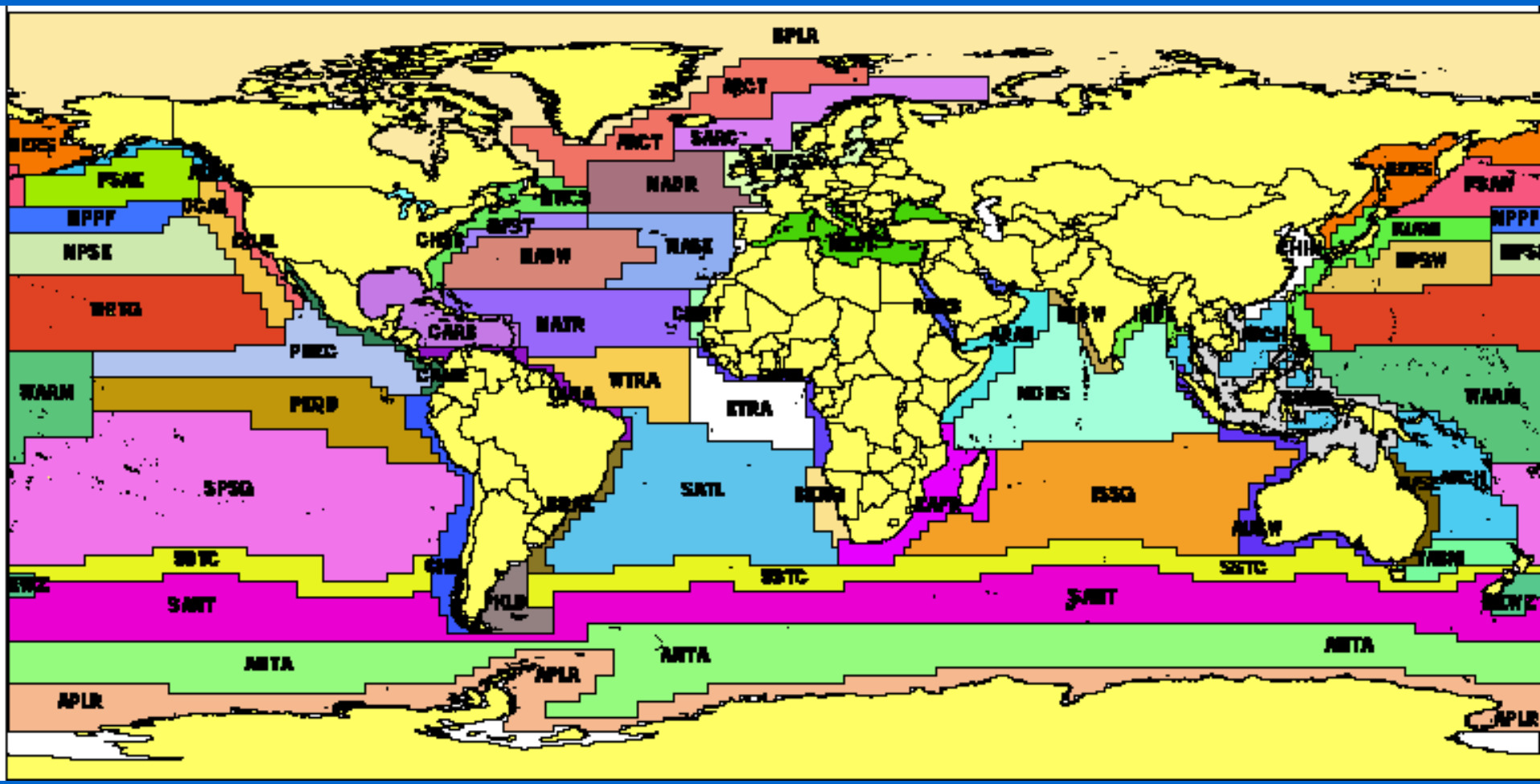
What We Know

Observed Seasonal Changes

- Biological production
- Photochemistry
- Terrestrial runoff
- Species Composition?

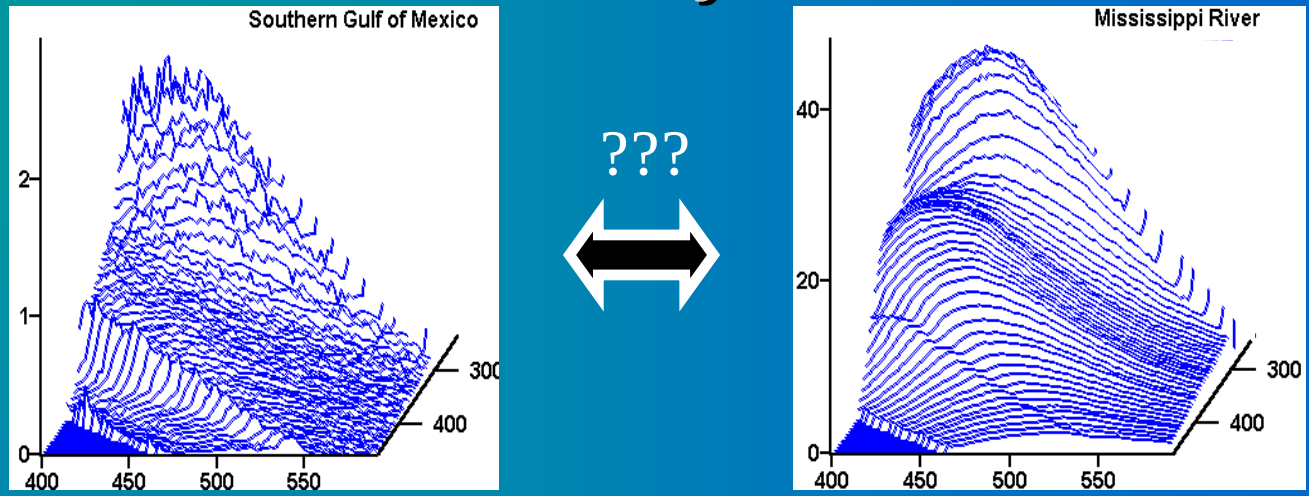
In addition, potential for CDOM variability based on differences in regional ecology

World Oceans - Biogeochemical Provinces



Pauly et al., ICES 2000 Annual Science Conference

DOM Variability - Statistics

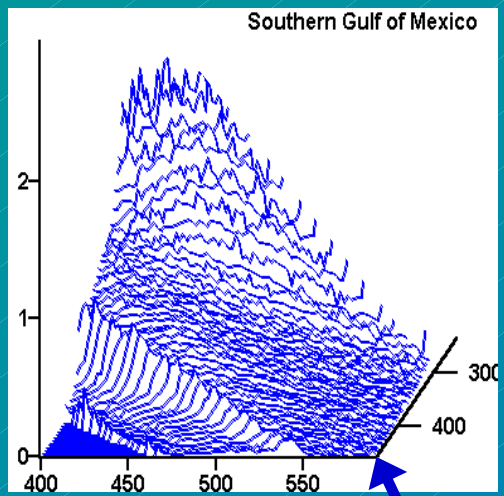


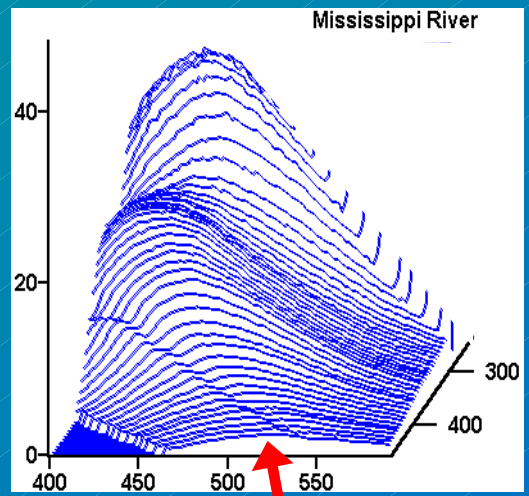
Statistics are useful in discriminating changes in DOM fluorescence via EEMS

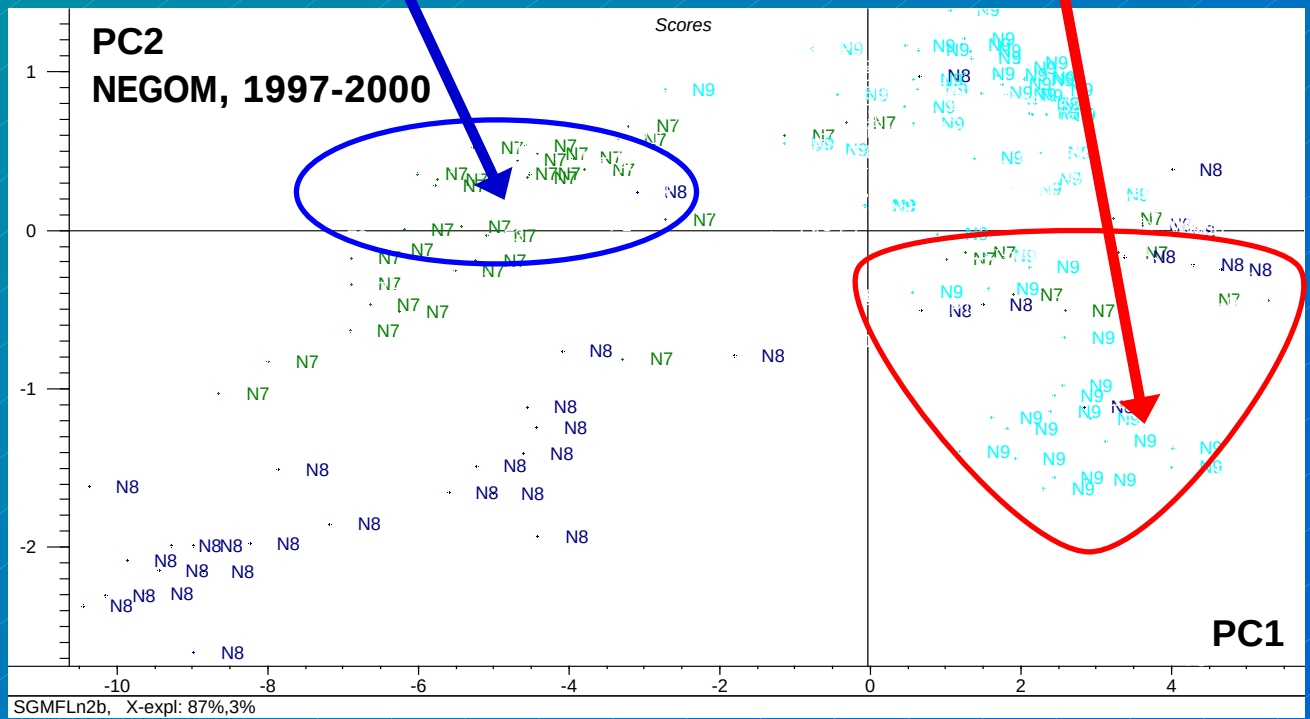
- Mahlinobis distance (Murphy et al, 2004); 12 wavelength pairs
- PARAFAC (Stedmon et al., 2003); 3d

Principal Component Analysis – PCA (Boehme et al., 2004); 3d

DOM Variability - PCA

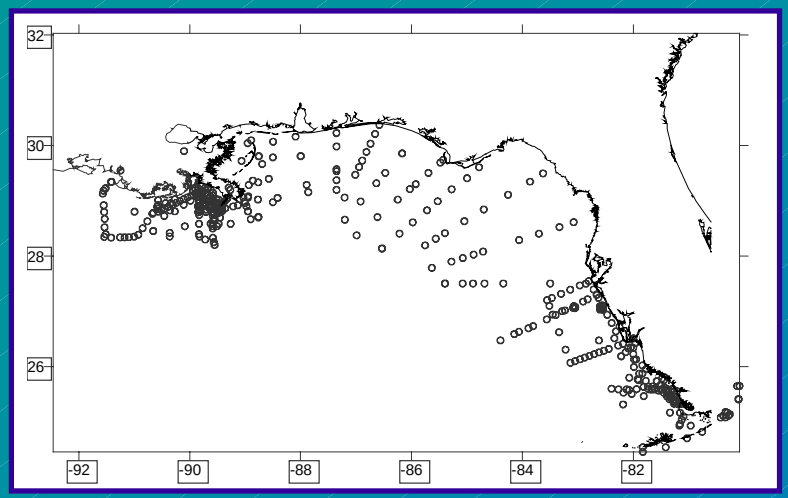




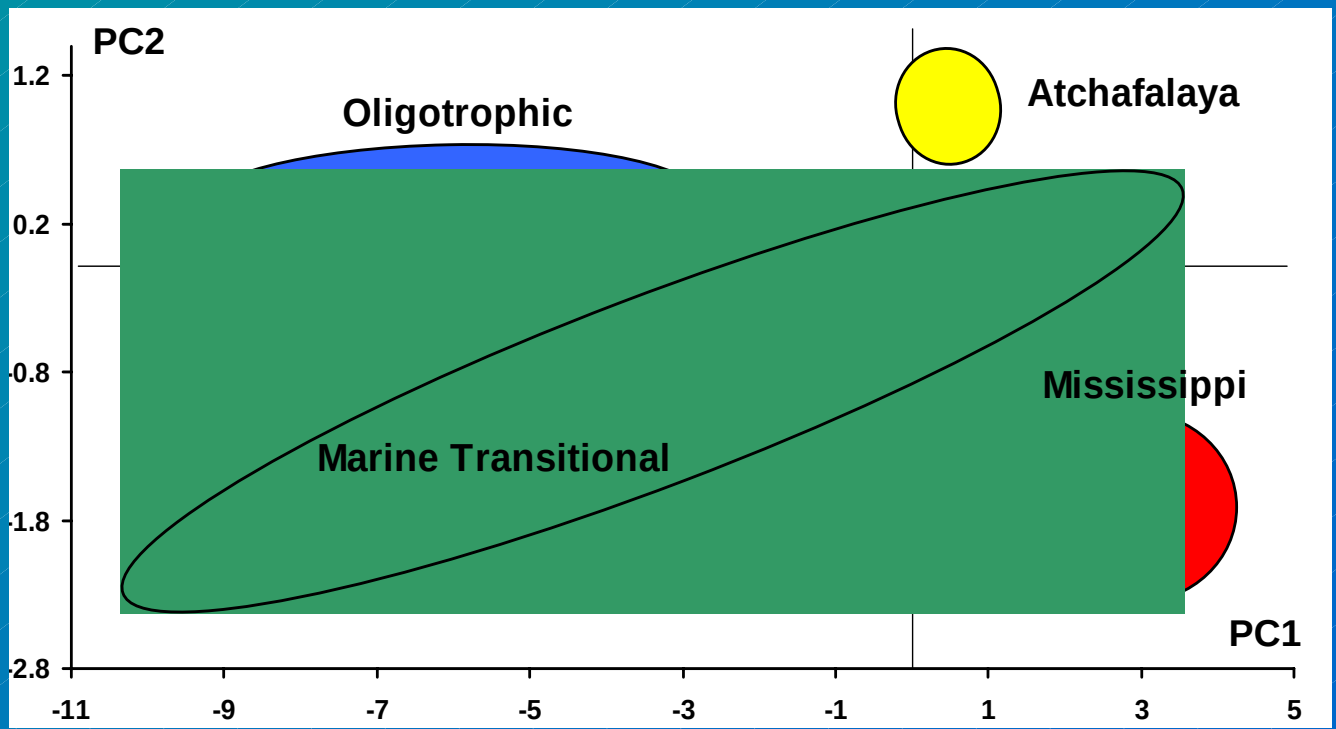


- Clusters: similar EEM, water masses

DOM Variability - PCA

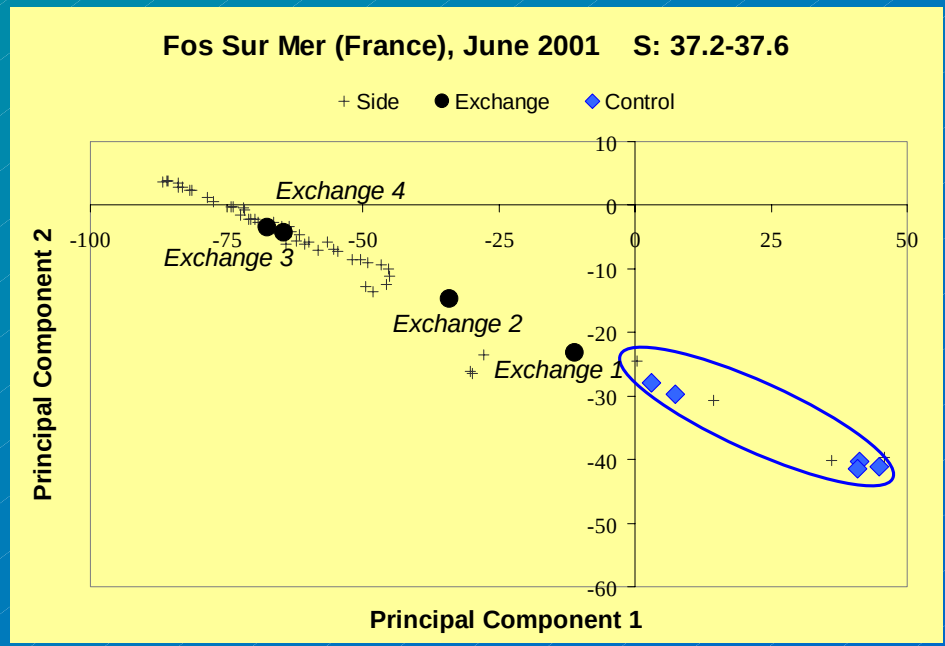


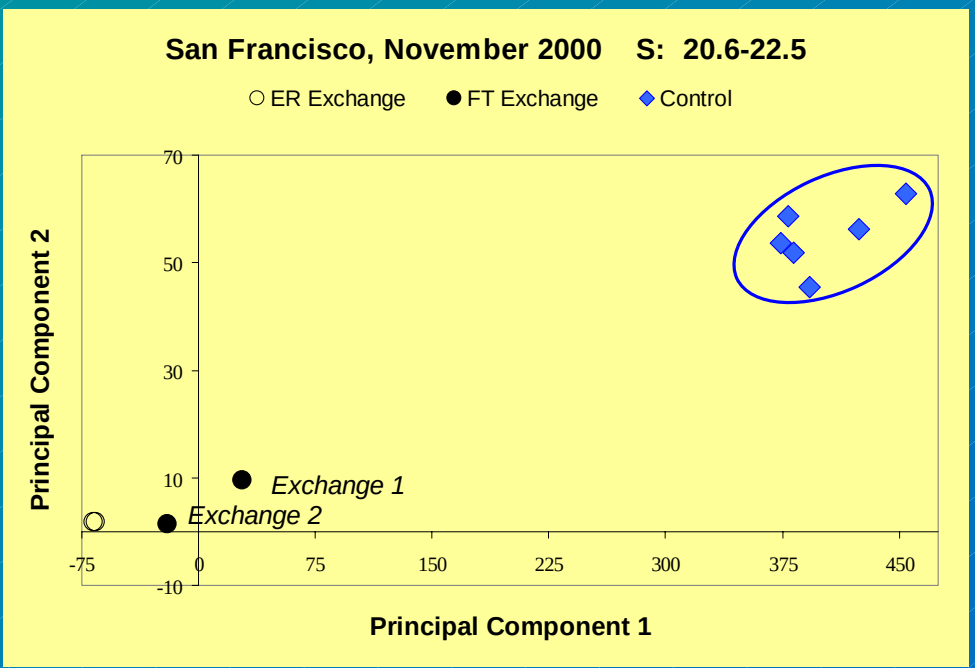
- Over 600 samples
- Water masses identified
- Basis for global database



DOM Variability – PCA and Ballast Water Exchange

- PCA of fluorescence data set from Murphy, et al. 2004

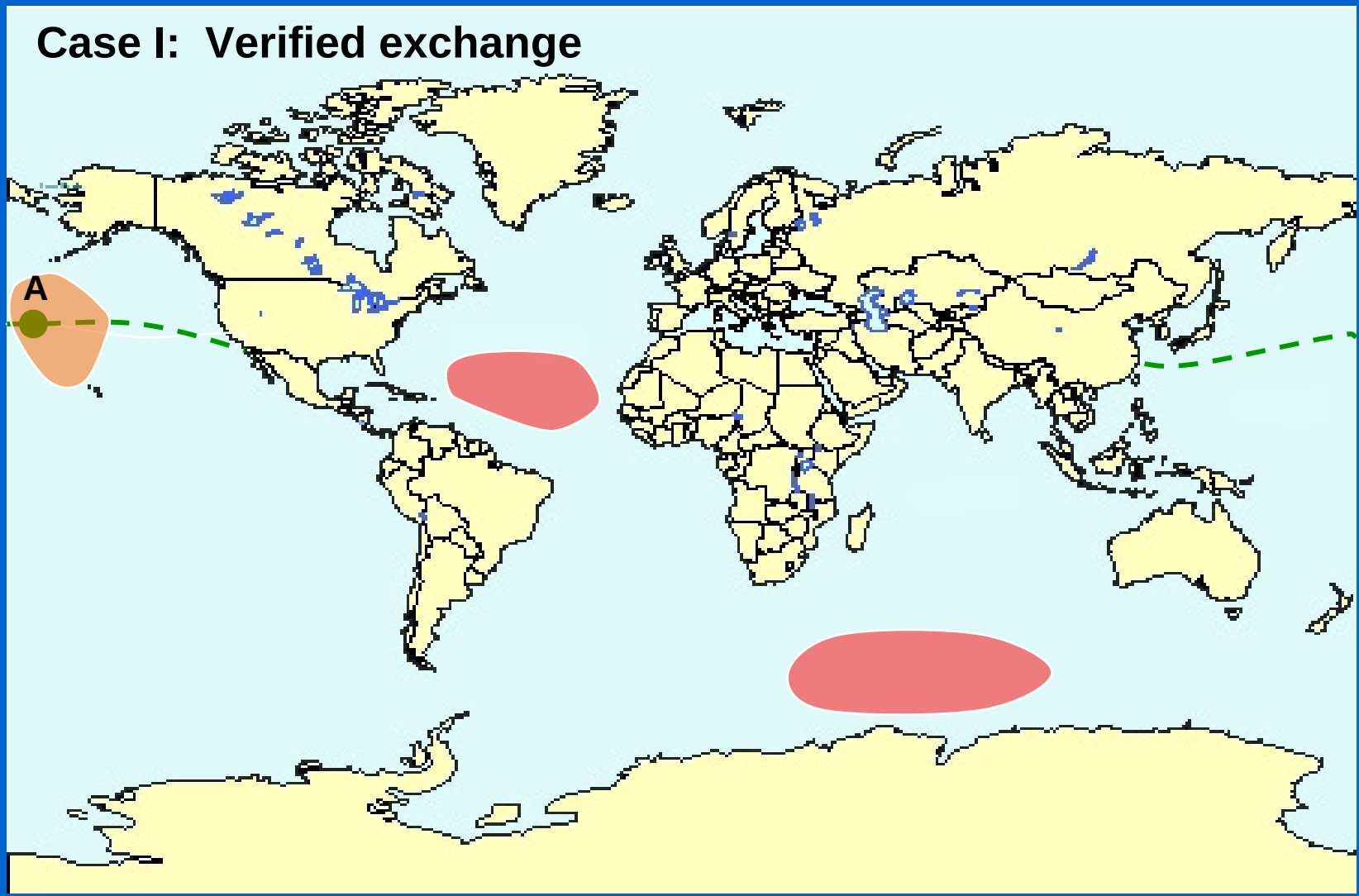




Future work – instrument development

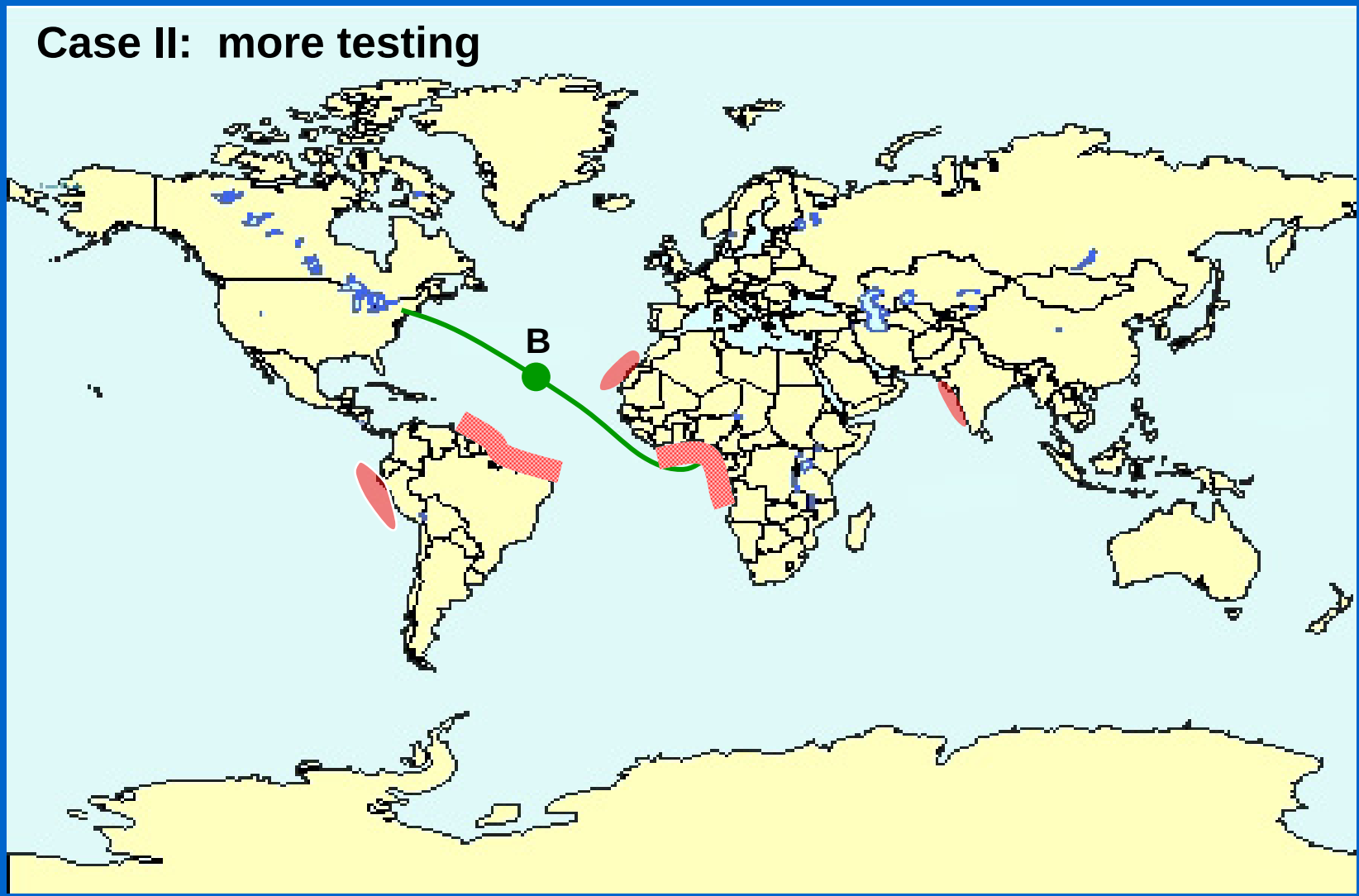
UN Atlas of the Oceans

Future work – instrument development



UN Atlas of the Oceans

Future work – instrument development



UN Atlas of the Oceans

Summary

- Ballast water exchange requirements
- USCG currently looking for verification test
- DOM fluorescence a promising method, independent of port salinity
- Utility of statistical tests with EEMS provides a method of ballast water exchange verification

- End

Ballast Water Exchange - Verification

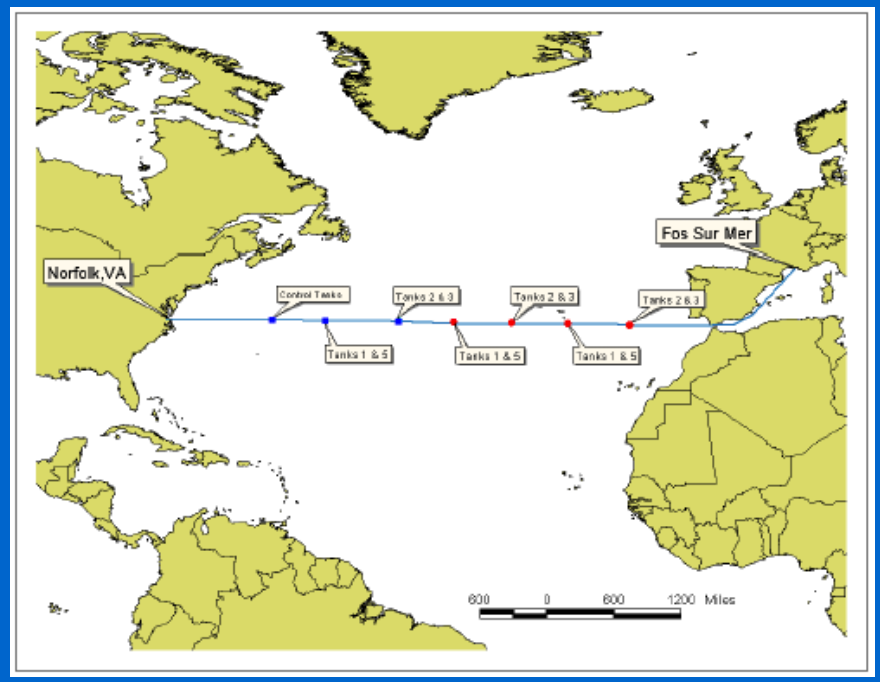
- Fluorescence diagnostic properties

  Changes of Wavelength, Spectral bandwidth,

  Fluorescence Intensity

- Effectiveness based on our understanding of DOM variability in the global oceans

  Quantify seasonal and spatial differences



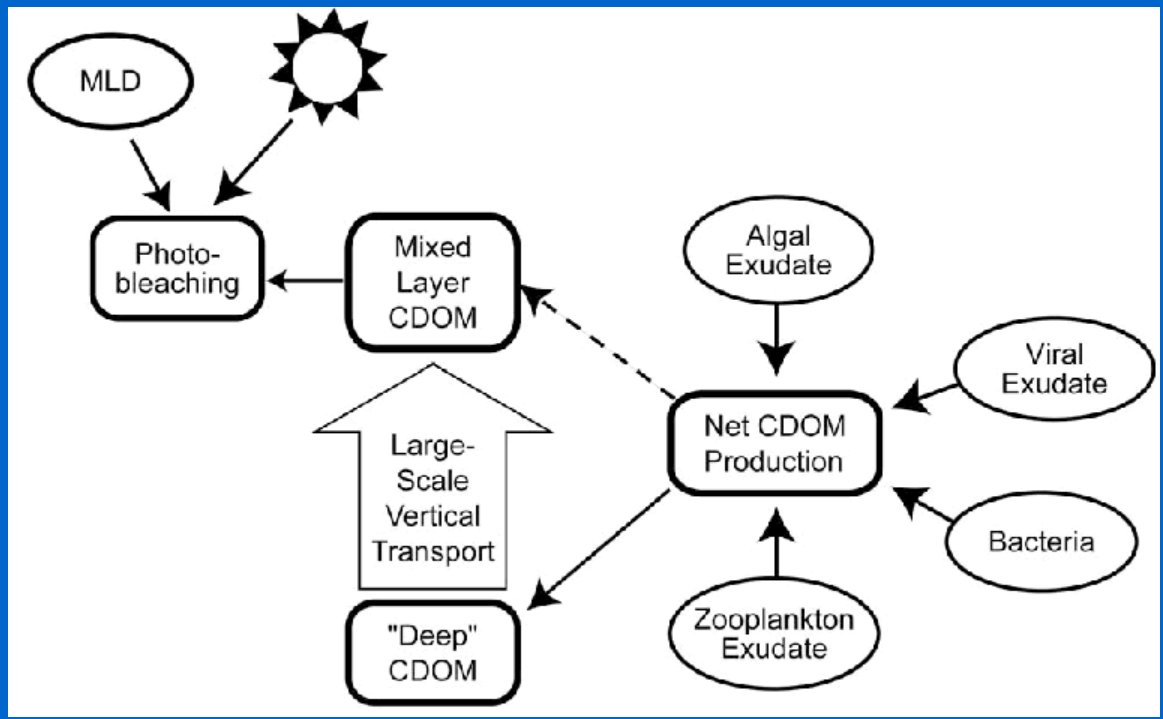
Murphy et al., Final Report to USCG R&D Center, 2001

Results : fluorescence of CDOM has the greater potential for determining ballast water exchange

World Oceans - CDOM Variability

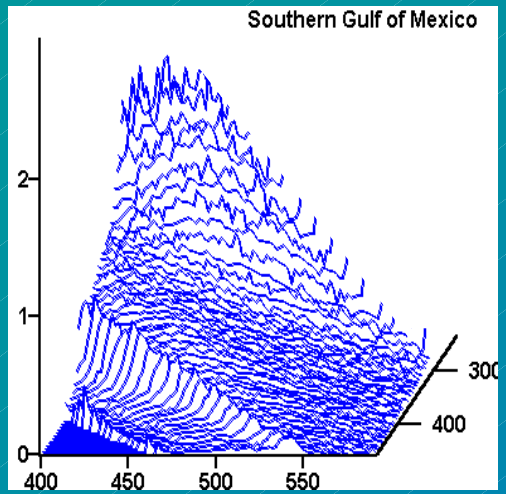
Photochemistry

- Significant for removal of terrestrial CDOM in coastal waters
- Alters bioavailability of CDOM
- Alters measured fluorescence and absorption characteristics



Siegel et al., 2002

DOM Variability - PCA



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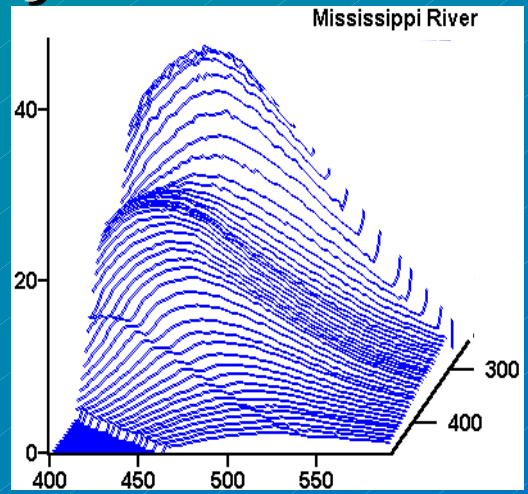
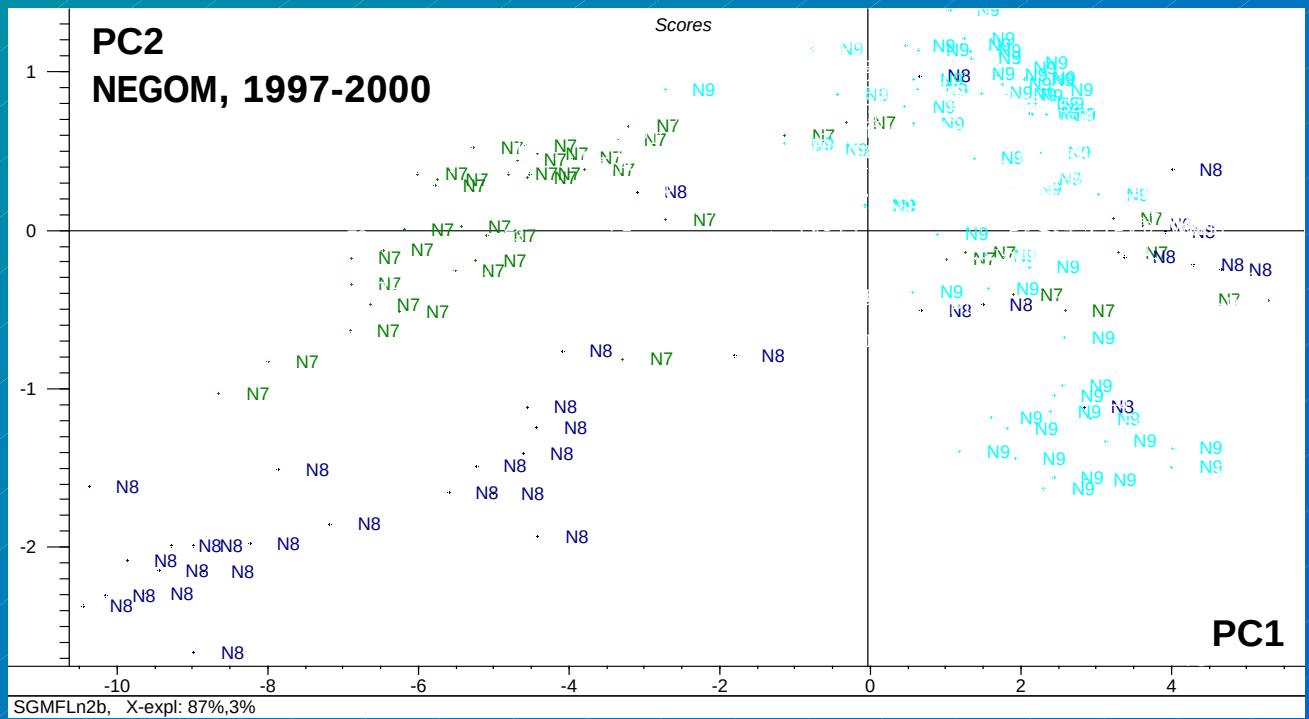


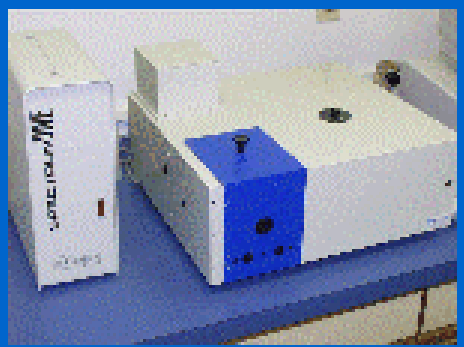
Scores: differences between samples



Future work – instrument development

Where can we go from here?

- 3d EEMS based on CCD technology
- Fiber optic probes
- Software development
  - [illegible]



Spex 3D, JY Horiba