CDOM on CLIVAR

Ocean Optics and Biogeochemistry on the U.S. CO_2/CLIVAR Repeat Hydrography Project

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Ocean Color Research Team 2007

Outline

- Objectives
- Background on global CDOM research -- prior results summary
- Background on CLIVAR/CO_2 Repeat Hydrography Project
- CDOM Project Activities on CLIVAR -- Measurements and Methods
- Some Results from Atlantic and Pacific
- Ongoing and future activities

The inevitable “Why CDOM” slide

- Light absorption by CDOM in the blue & UV is comparable to or greater than particle absorption in many open ocean regimes -- CDOM dynamics differ from particle (phytoplankton) dynamics.
- CDOM has a major impact upon ocean color -- influences retrieval of chlorophyll, penetration of PAR and UV to depth
- CDOM sensitizes photochemical reactions involving climate-relevant atmospheric trace gases (DMS, OCS, CO)

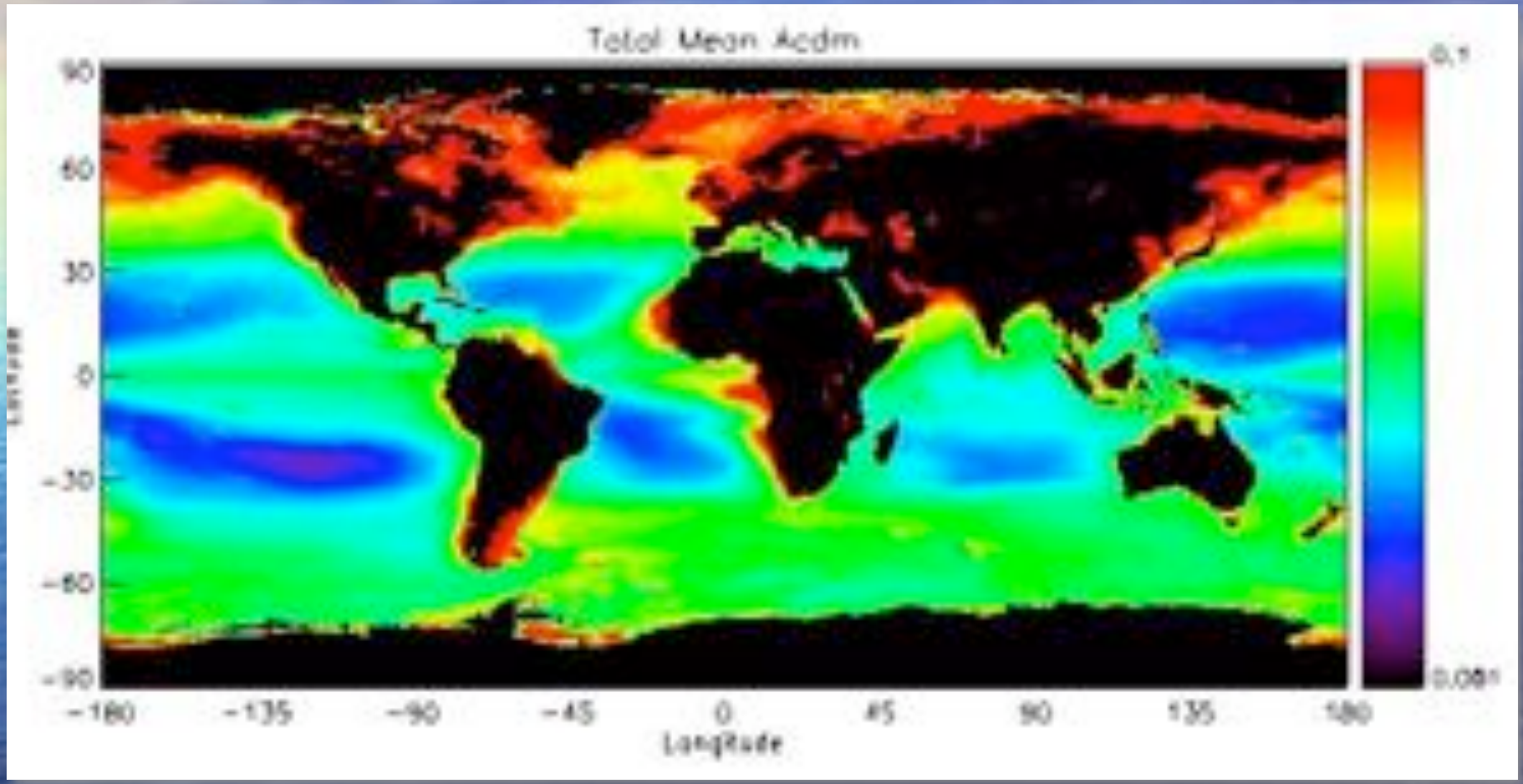
More “Why CDOM”

- CDOM reflects a (small) portion of the DOM pool with dynamics that differ from the DOM pool overall. This suggests the use of CDOM characteristics as an indicator of DOM diagenetic state.
- CDOM is found at all depths in the ocean and has very slow dynamics, further suggesting its application as a tracer of circulation and water mass renewal. Only deep ocean tracer so far with a remotely-sensible surface boundary condition …
- It’s the most important stuff in the ocean

UCSB Global CDOM Project Goals

- Quantify global distribution of CDOM
  Surface, intermediate, and deep water
- Determine physical and biological factors controlling CDOM distribution
- Apply knowledge gained to problems of ocean circulation and DOM characterization and cycling
- Collect calibration and validation data for ocean color models

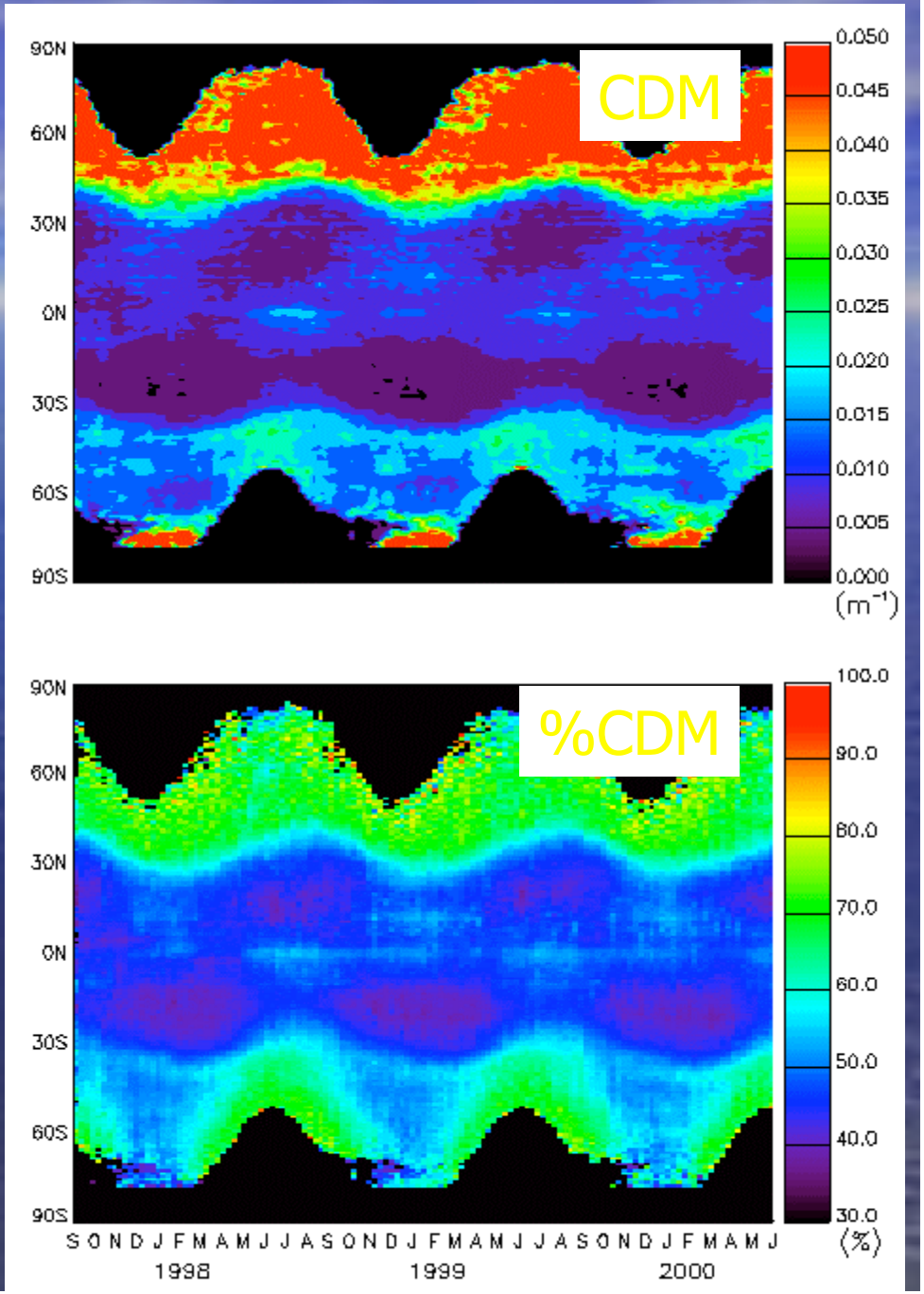
Global CDOM (CDM) Distribution



Siegel et al. [2005] JGR

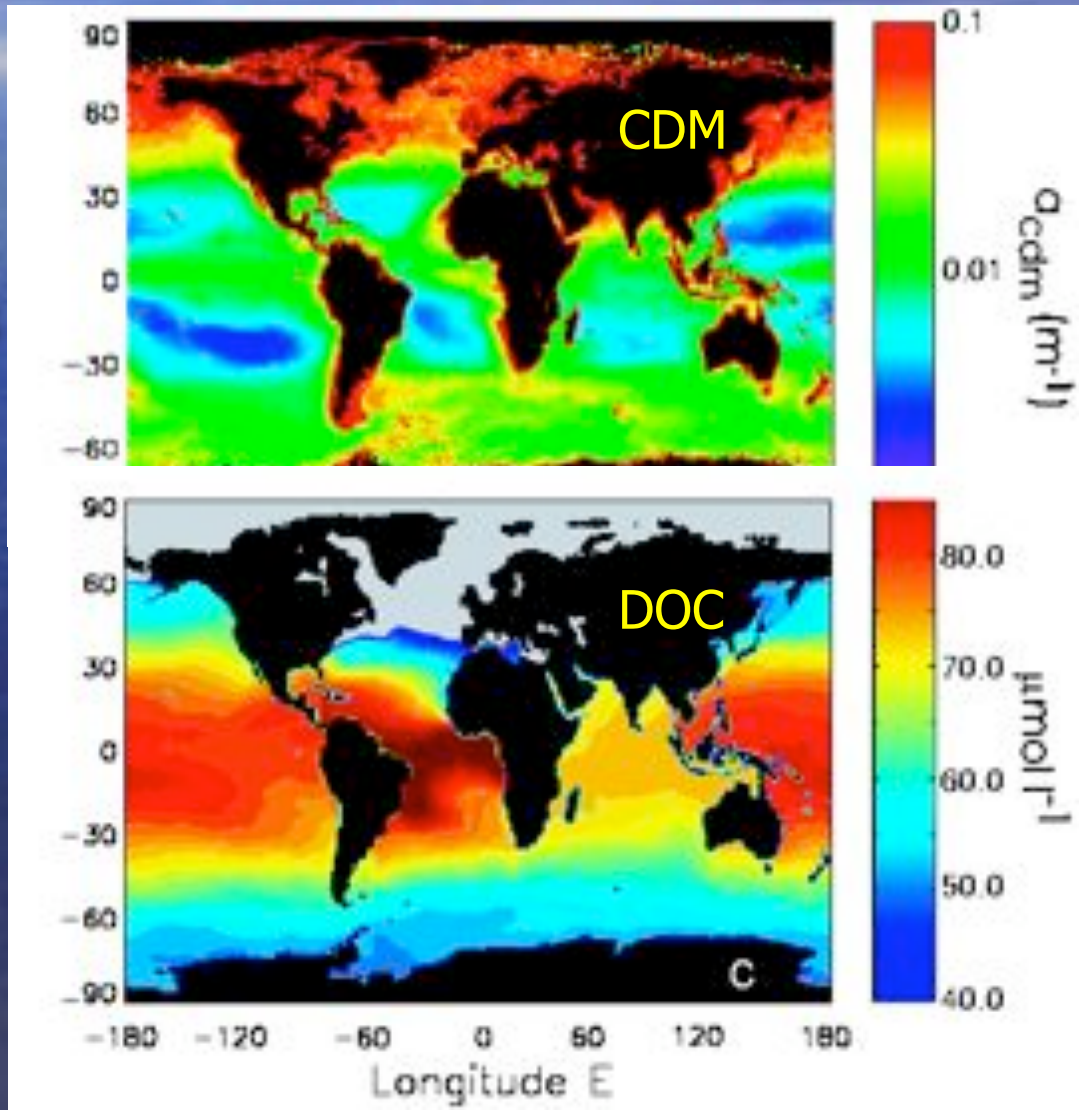
Seasonal CDOM Cycle

- Seasonal changes at most latitudes
- Lower in summer
- Reduced in tropics
- Higher towards poles
- Hemispheric asymmetry



Global CDOM & DOC

- CDOM ≠ DOC
- Completely different
  - Tropics vs. high latitudes
  - Subtropical gyres
- Different processes driving CDOM & DOC



Siegel et al. [2002] JGR

CDOM Dynamics at BATS

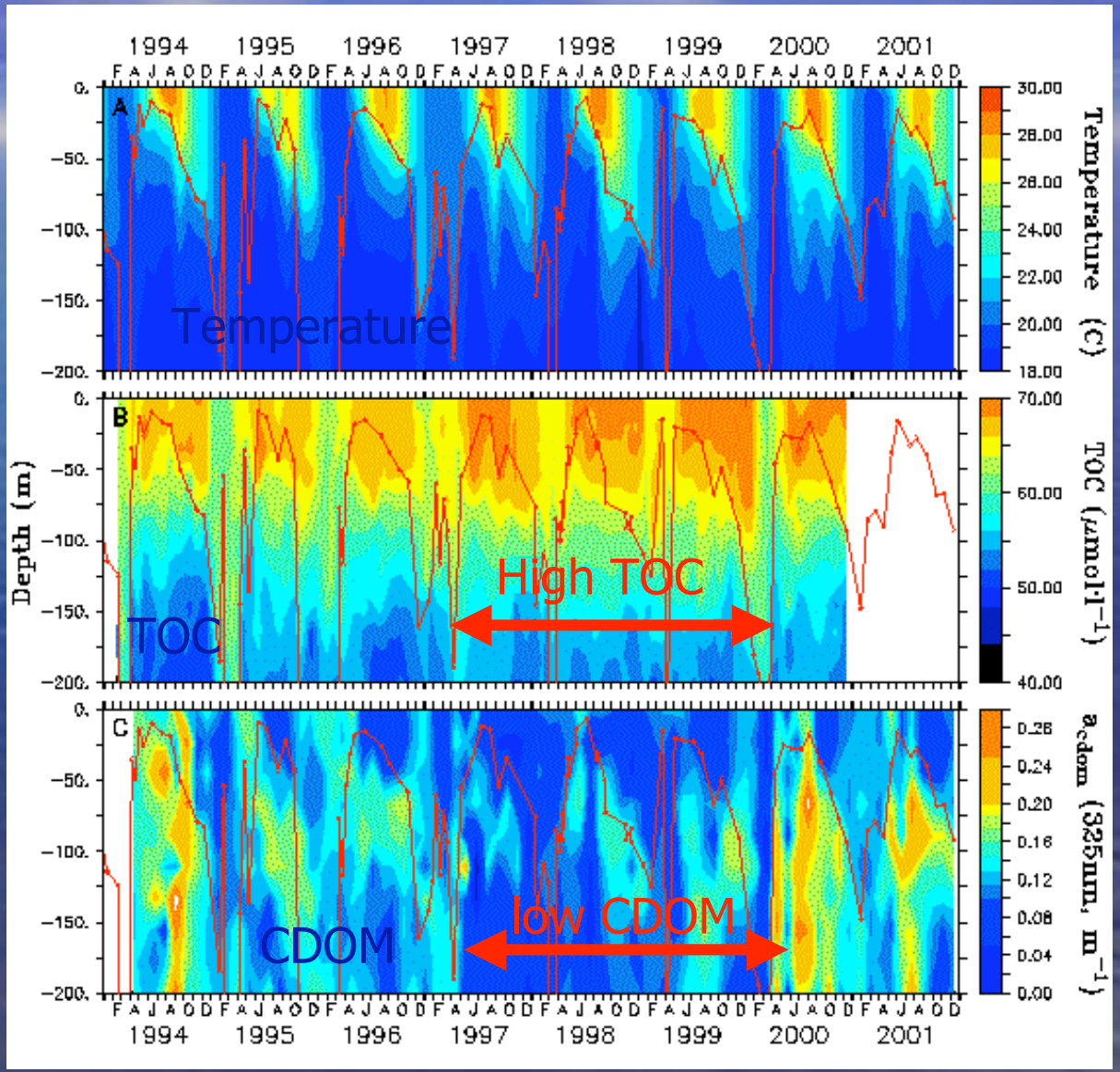
BATS data

Temp/TOC/CDOM

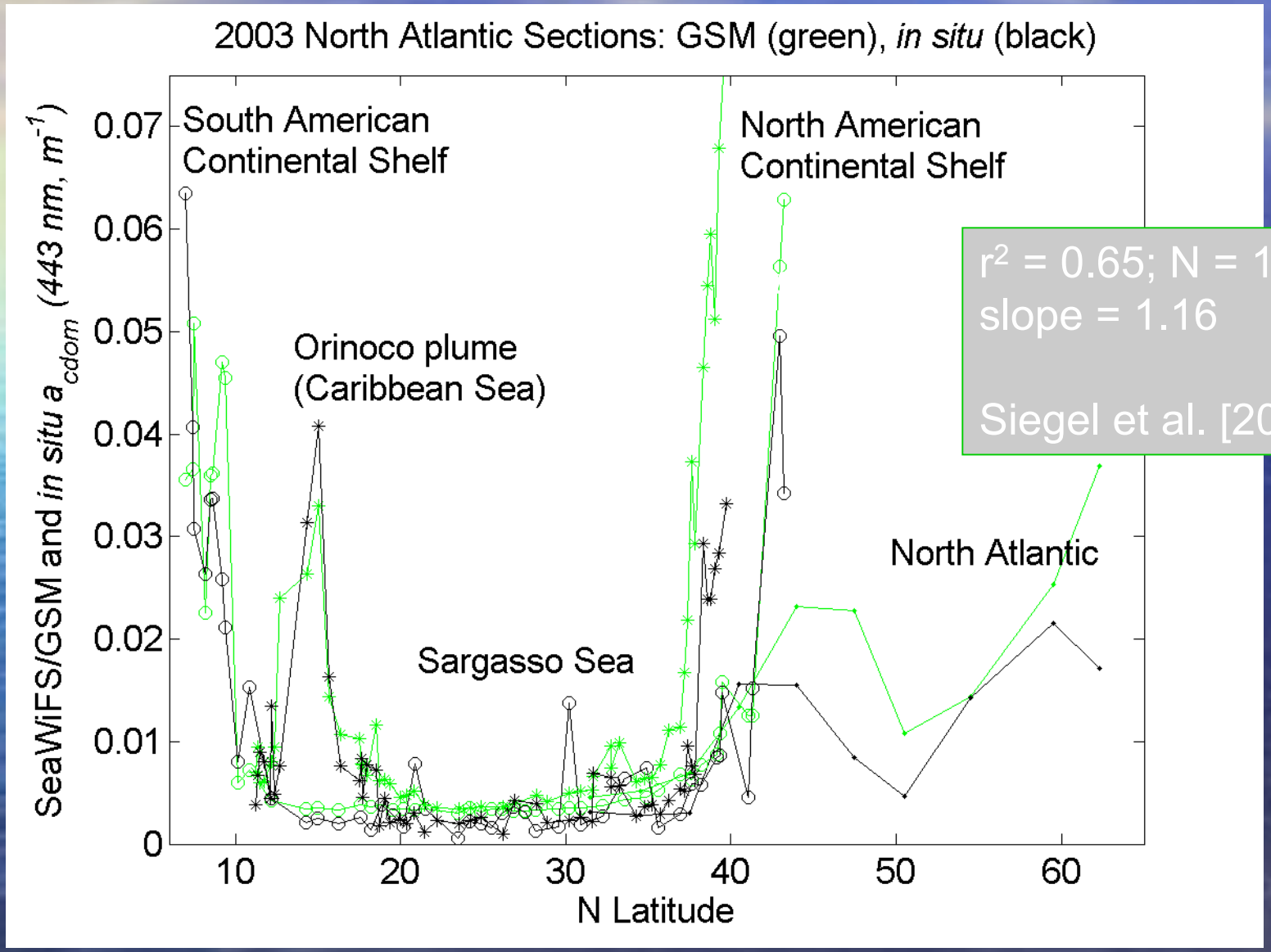
Control of CDOM profile related to bleaching and local production

CDOM low from 1997-1999

Related to water mass renewal?



Surface CDOM & SeaWiFS

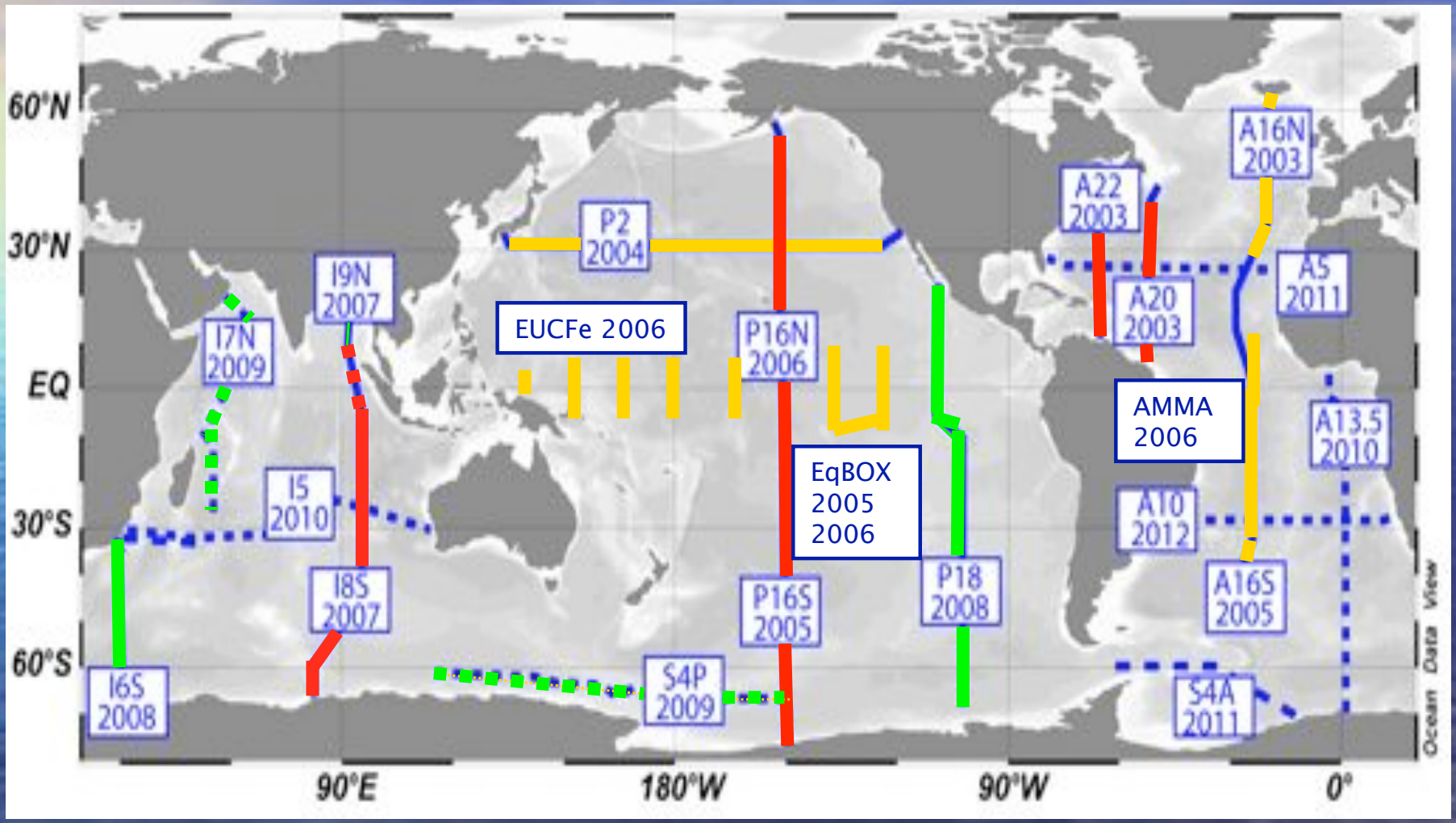


U.S. CLIVAR/CO_2 Repeat Hydrography Project

<http://ushydro.ucsd.edu/>

- Document in time and space, changes in ocean properties and circulation related to climate change
- Core measurements include T-S-O_2, nutrients, DIC, DOC/N, CFC, He/^{3}H, currents
- Repeat selected WOCE Hydrography Project sections with new technology and new measurements including **trace metals, pH, and CDOM and other ocean color related parameters** -- Stations every 30-60 nmi along sections.

Global CDOM Project Sections



OCRT 2007

UCSB Global CDOM Project
Measurements & Methods
Once Daily Bottle Samples

- CDOM Profile (surface - bottom)
- Chlorophyll Profile (top 250m)
- HPLC Samples (surface)
  (NASA Chls/carotenoids, UNH MAA)
- Particulate Absorption Sample (surface)
- DOM quality profile (top 1000m)
- Bacterial counts (full) & BP (top 250)

UCSB Global CDOM Project
Measurements & Methods
Occasional Bottle Samples

- Large-volume (~2L) samples for CDOM dynamics experiments
  - Photobleaching (Chantal Swan, NASA Grad Student Fellowship)
  - Microbial CDOM Production/Consumption
  - POC/PON for transmissometer calibration

UCSB Global CDOM Project
Measurements & Methods
Profiling instruments

- On Main Sampling Rosette (every cast)
  - WETLabs ECO CDOM Fluorometer
  - WETLabs C-Star Beam c meter (TAMU)

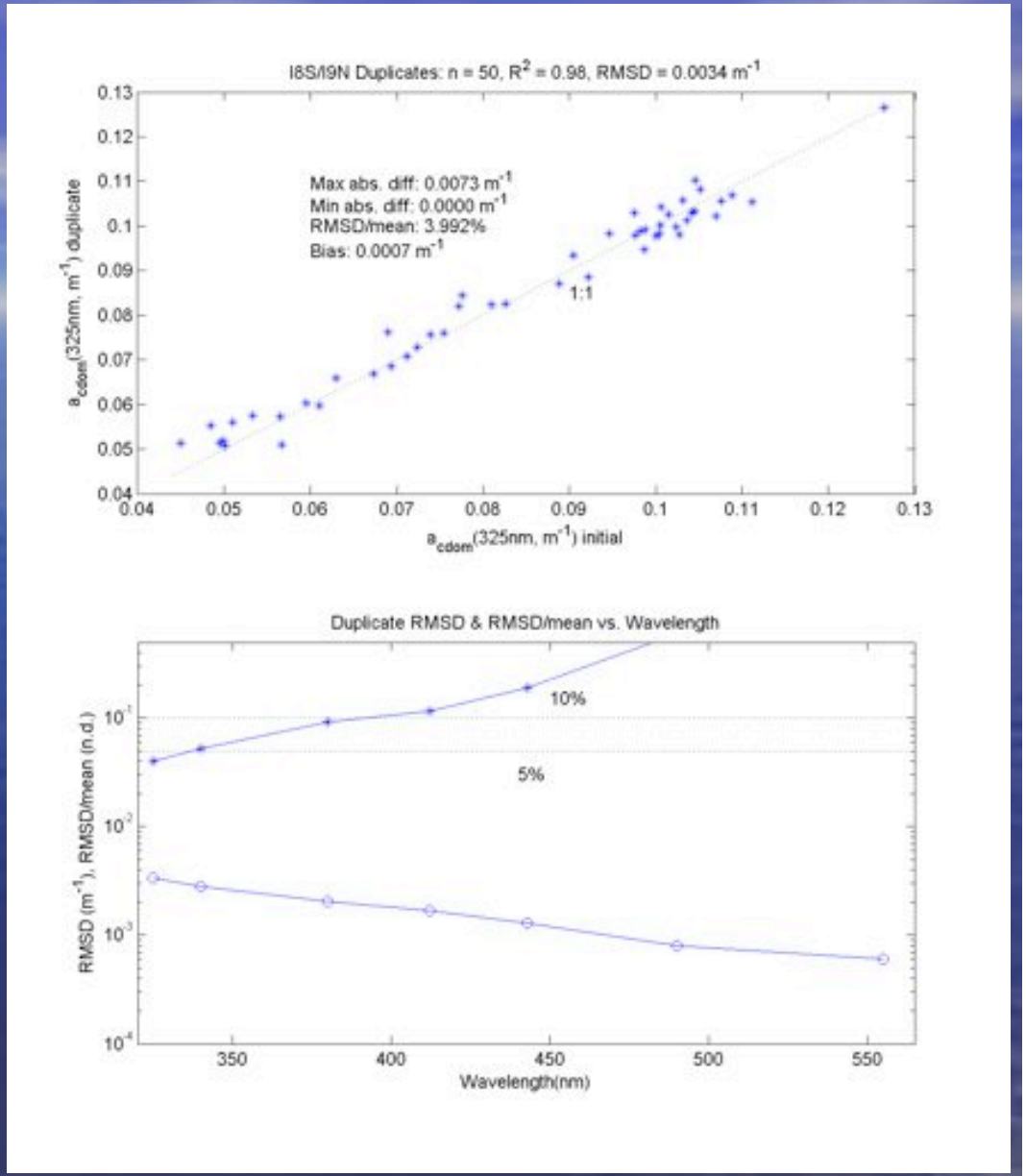
- Once daily radiometric profile
  - Satlantic MicroPro II with UV and visible E_d/L_u, SMSR deck reference

UCSB Global CDOM Project
Measurements & Methods
CDOM Analysis At Sea

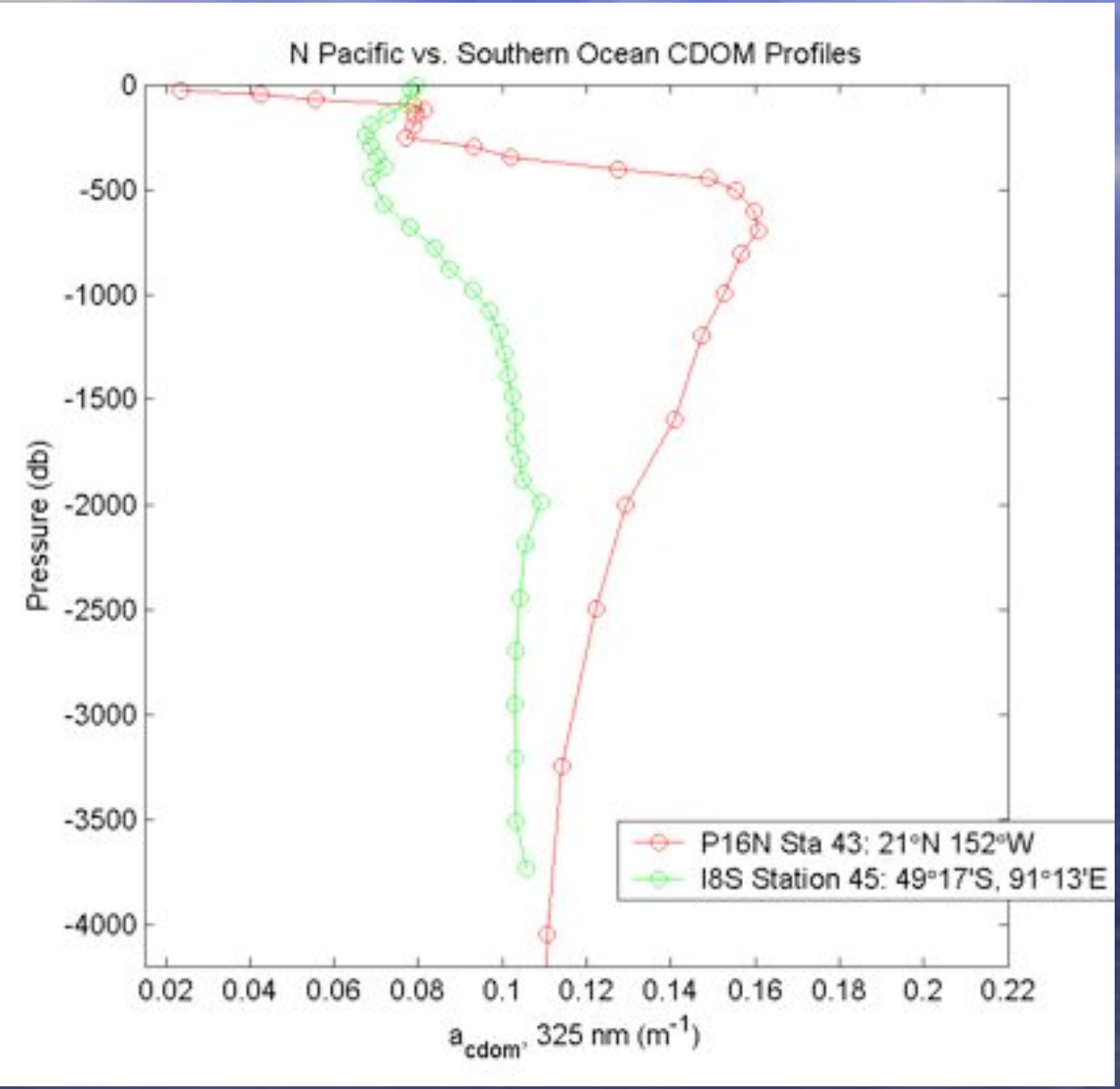
- 200 cm Liquid Waveguide Absorption Cell (UltraPath, WPI Inc)
- Single-beam spectrophotometer with D_2 & Tungsten-halogen light sources, diode-array spectrometer detector
- Fast, low sample volume (2 min/sample, 30-60 ml)
- Issues with blanks (refractive index correction, purity of open ocean water can exceed that of best pure water)

UltraPath Precision

- Duplicate sample analysis (same Niskin)
- RMS difference at 325 nm: 0.0034 m^{-1}
- This is ~4% of mean
- RMS/Mean is between 5 and 10% between 300 and 400 nm
- Longer wavelengths are not as good



UltraPath Example CDOM Profiles

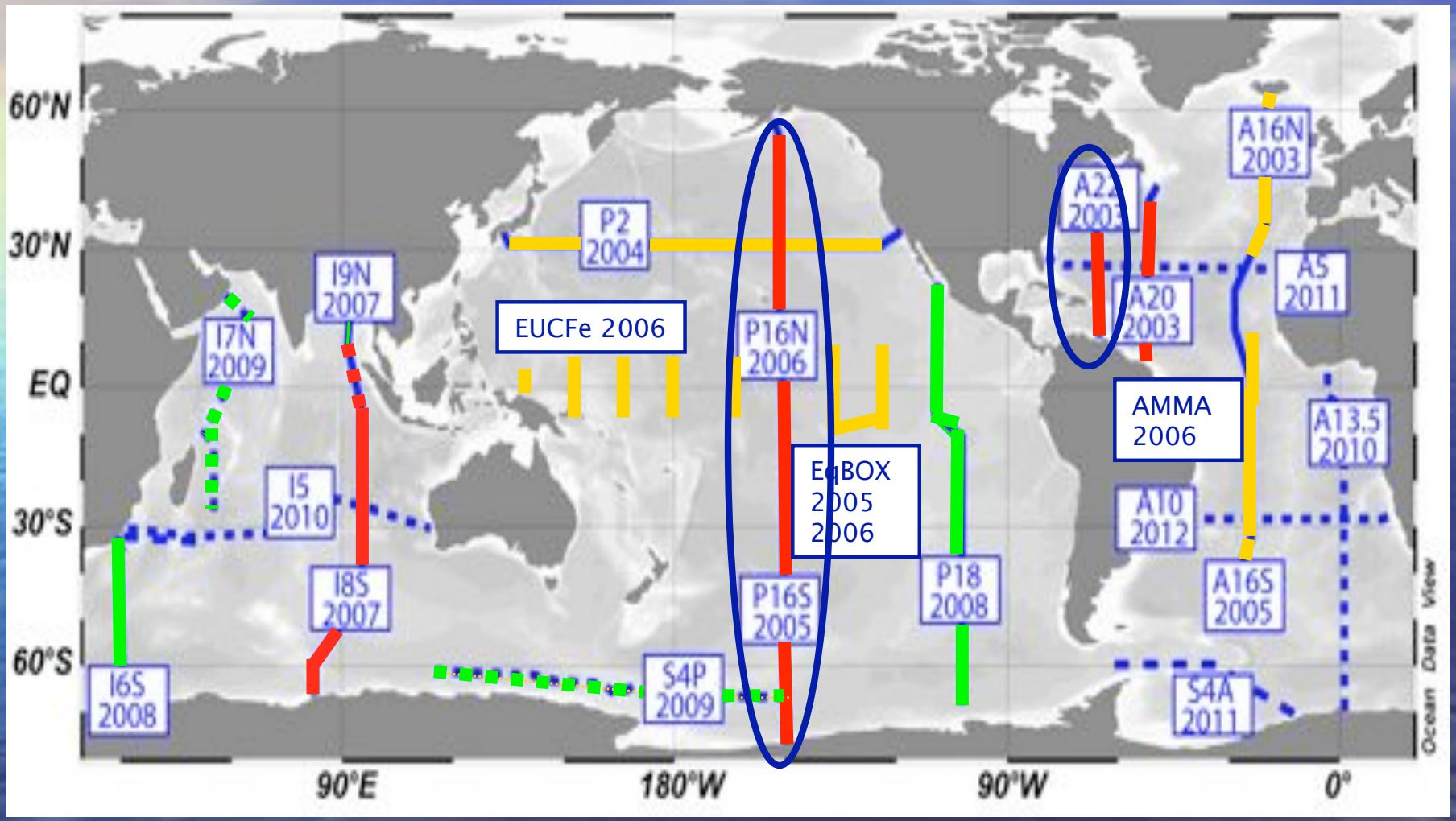


Selected Project Results
Distribution of CDOM

- N. Atlantic (S.A. -> N.A. shelves, subtropical)
- Pacific (Antarctic->Alaska)

- CDOM in the upper 1000m
- CFC (ventilation age tracer)
- Apparent Oxygen Utilization (quantifies remineralization, a known CDOM source in surface waters)

Results from A22 and P16



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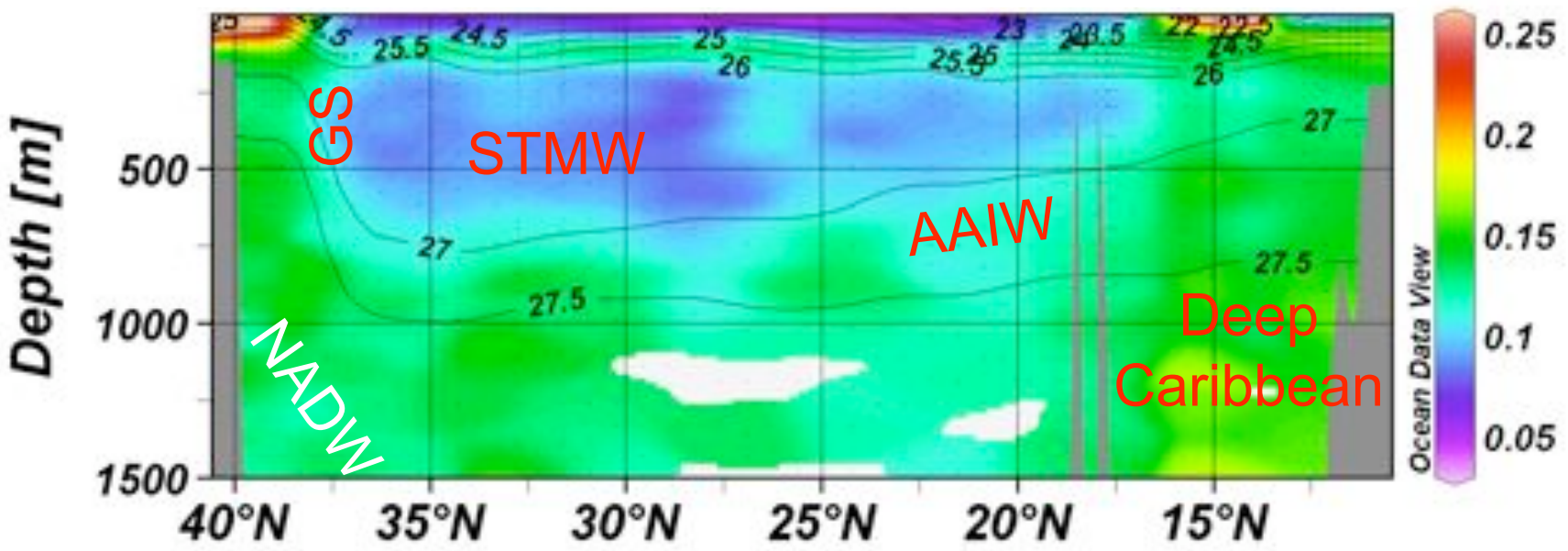
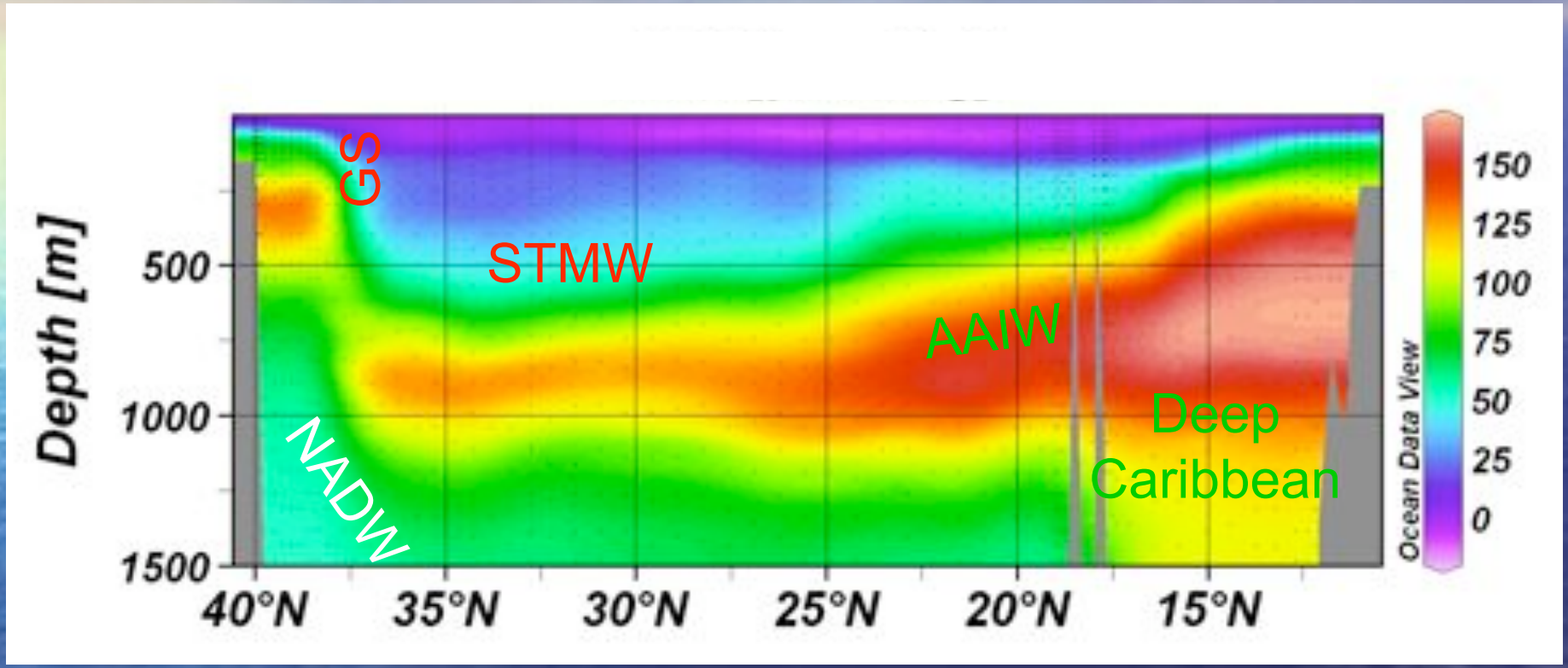
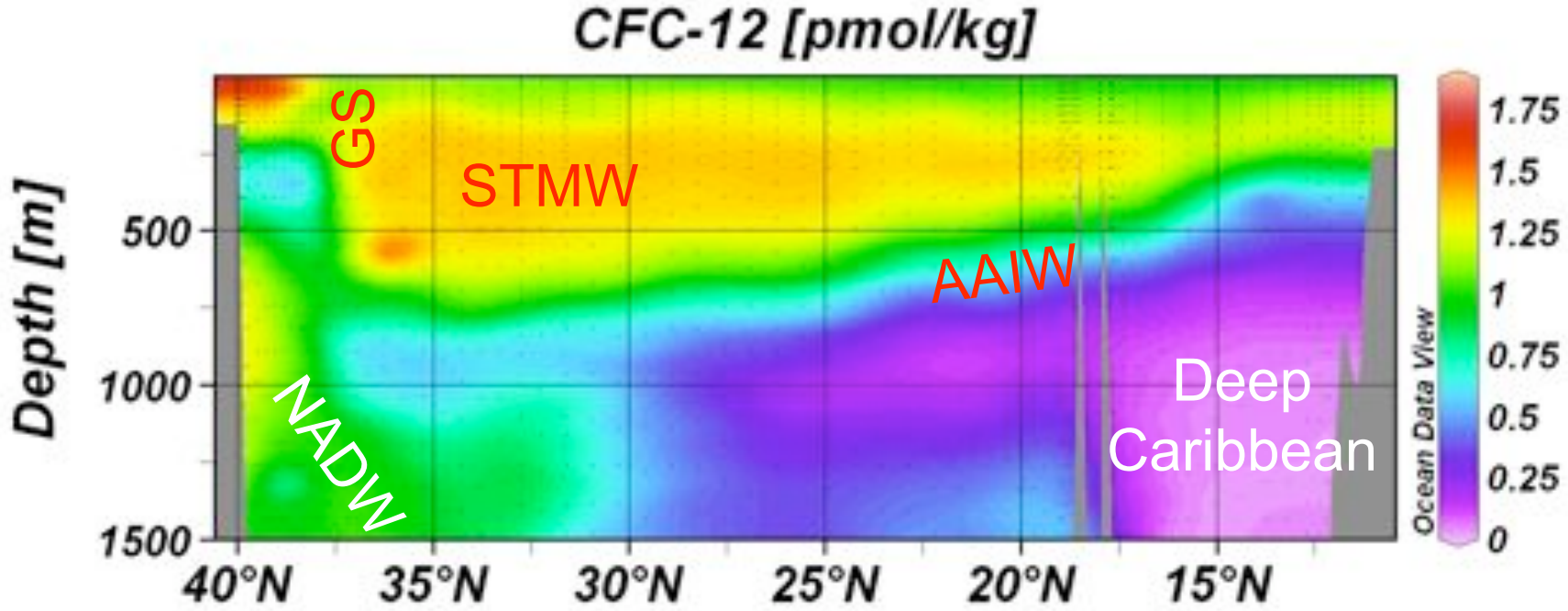
Atlantic A22 CDOM



Atlantic A22 AOU



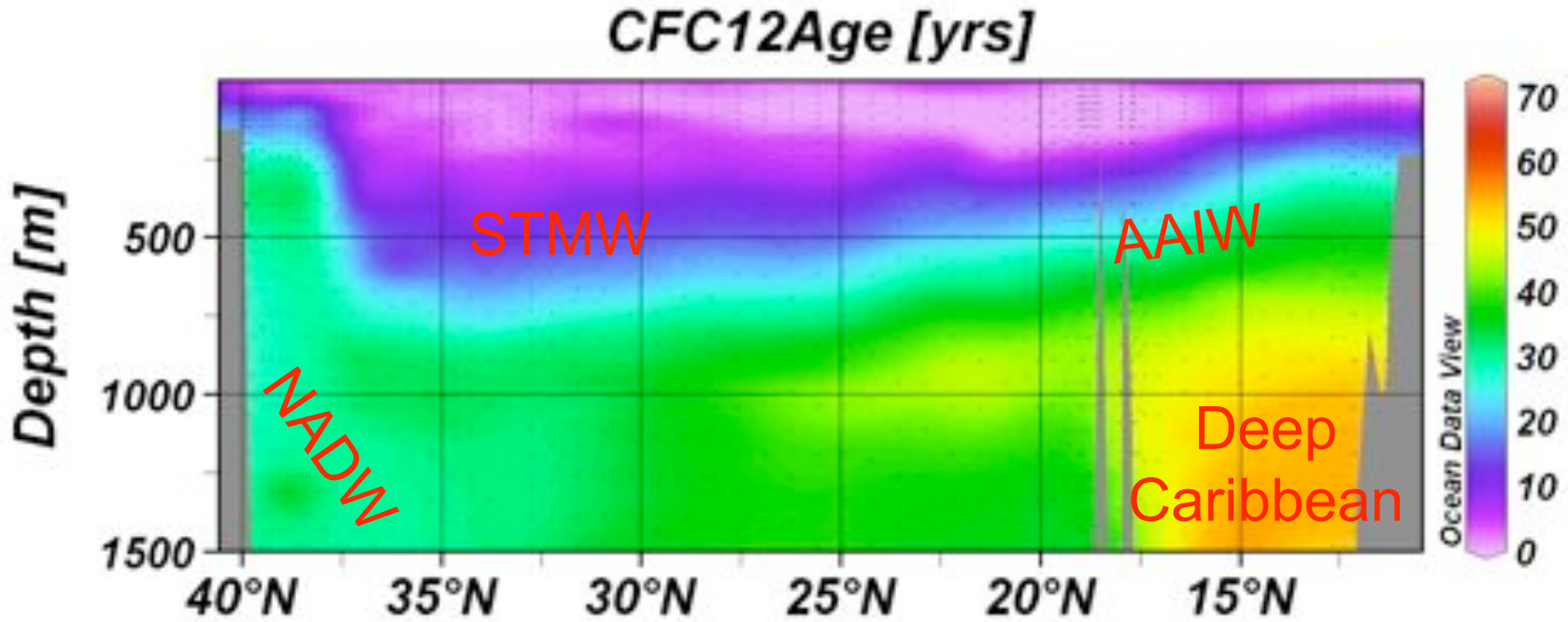
A22 CFC-12 Concentrations



High CFC's – recently ventilated waters

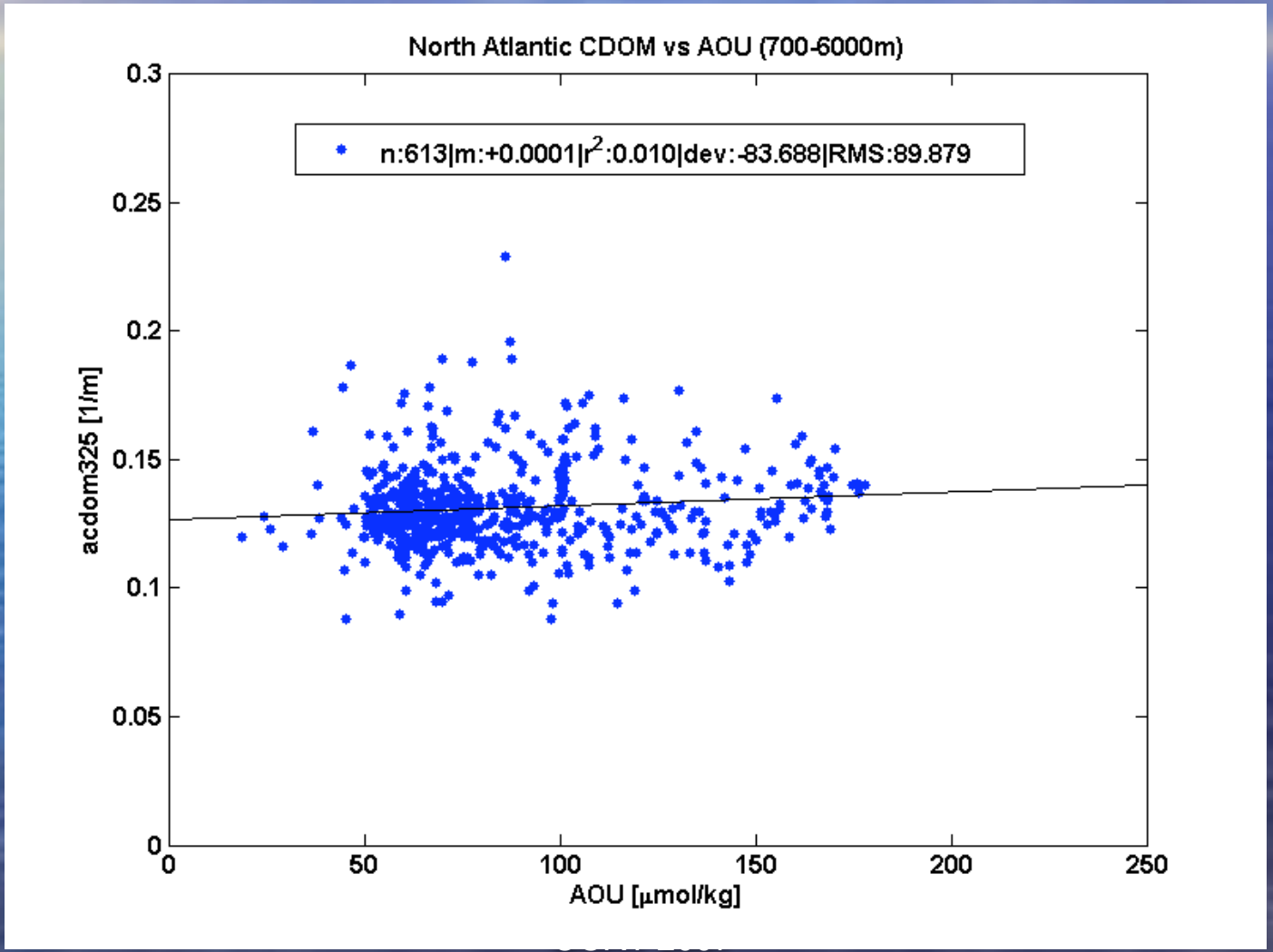
Low CFC's – old water

Atlantic A22 CFC-12 Age

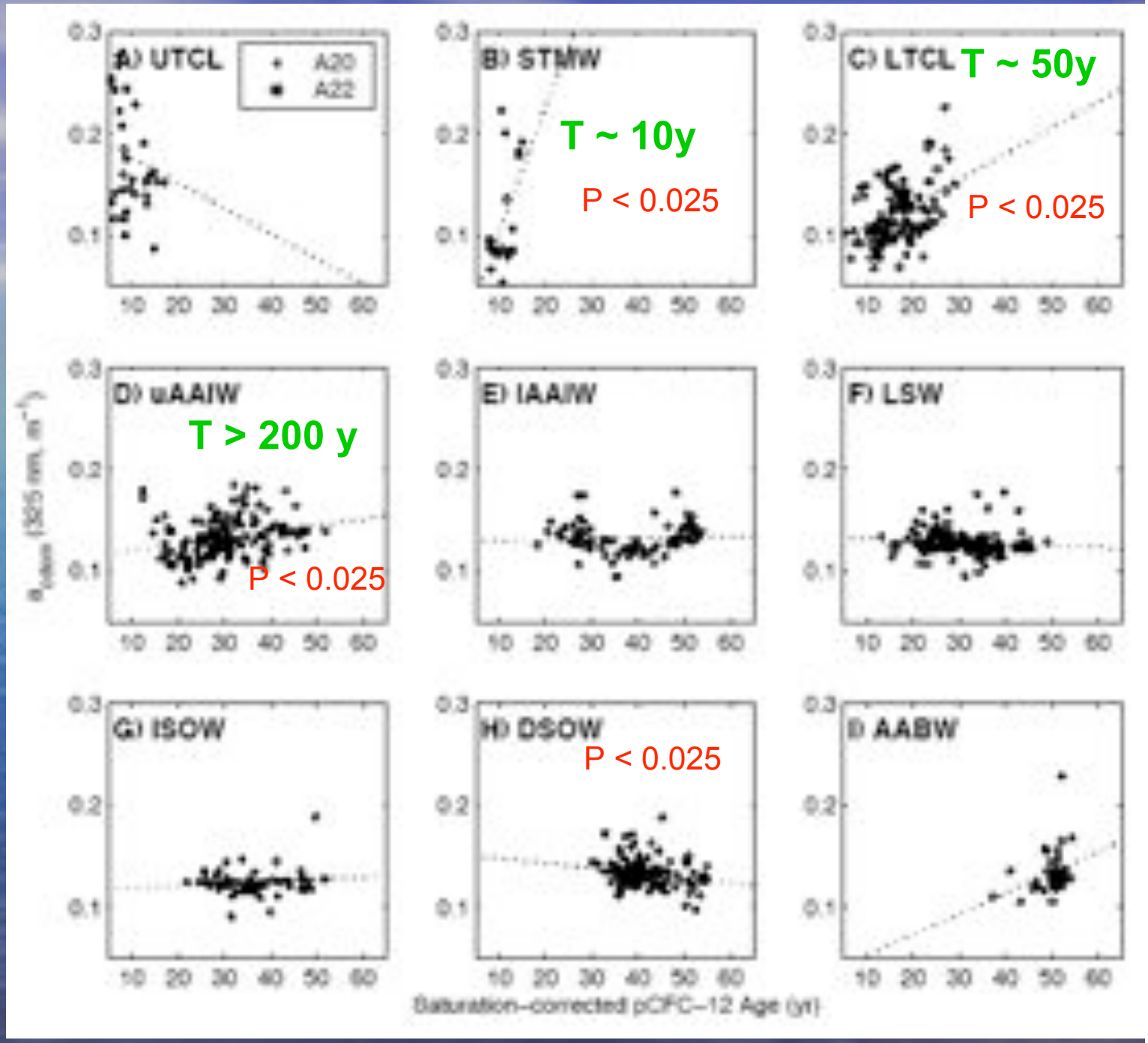


Age calculations by Bill Smethie & Samar Khatiwala [LDEO]

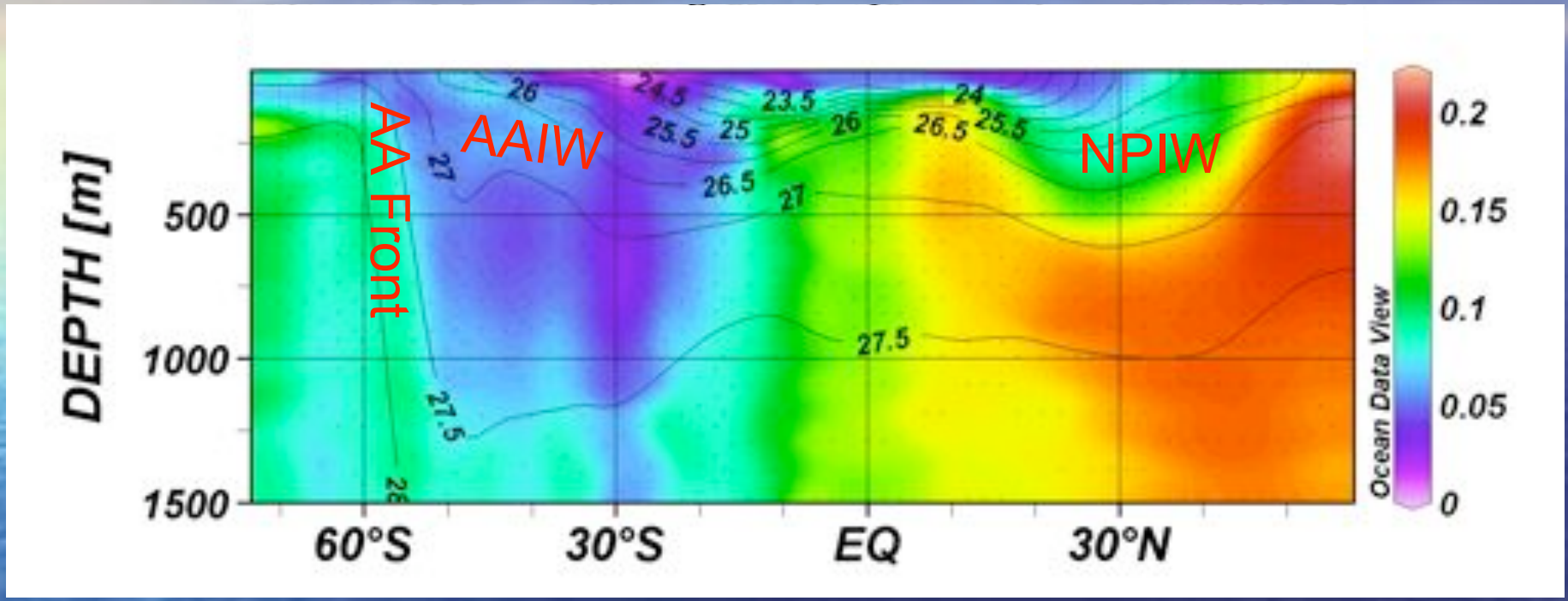
North Atlantic AOU vs. CDOM



Age vs. CDOM

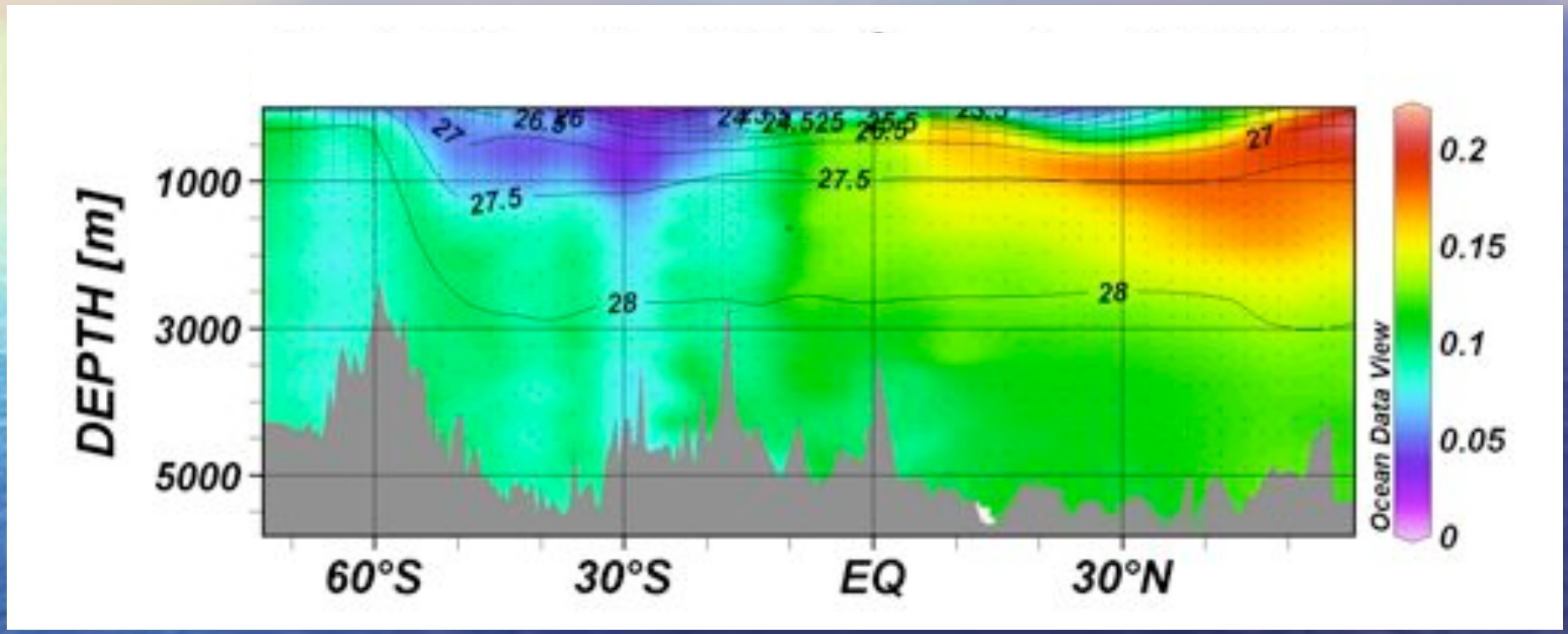

A) UTCL
A20
A22
B) STMW
T ~ 10y
P < 0.025
C) LTCL
T ~ 50y
P < 0.025
D) uAAIW
T > 200 y
P < 0.025
E) IAAIW
F) LSW
G) ISOW
H) DSOW
P < 0.025
I) AABW
Saturation–corrected pCFC–12 Age (yr)

Pacific P16 CDOM



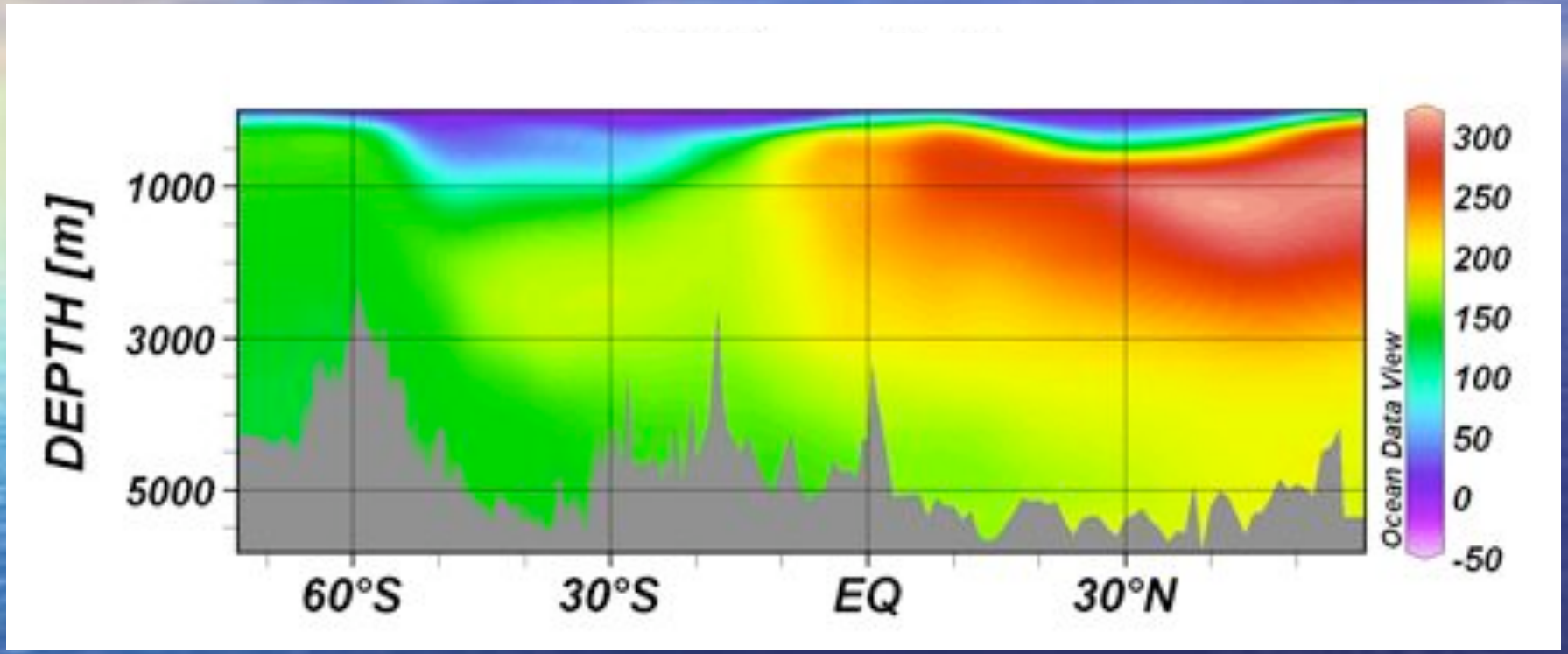
- Low CDOM in SH subtropical gyre
- Very high in NH thermocline
- Some subducting water mass signatures are seen in CDOM

Pacific P16 CDOM



- SH Subtropical CDOM low extends thru upper 1000 m
- High CDOM in NH thermocline

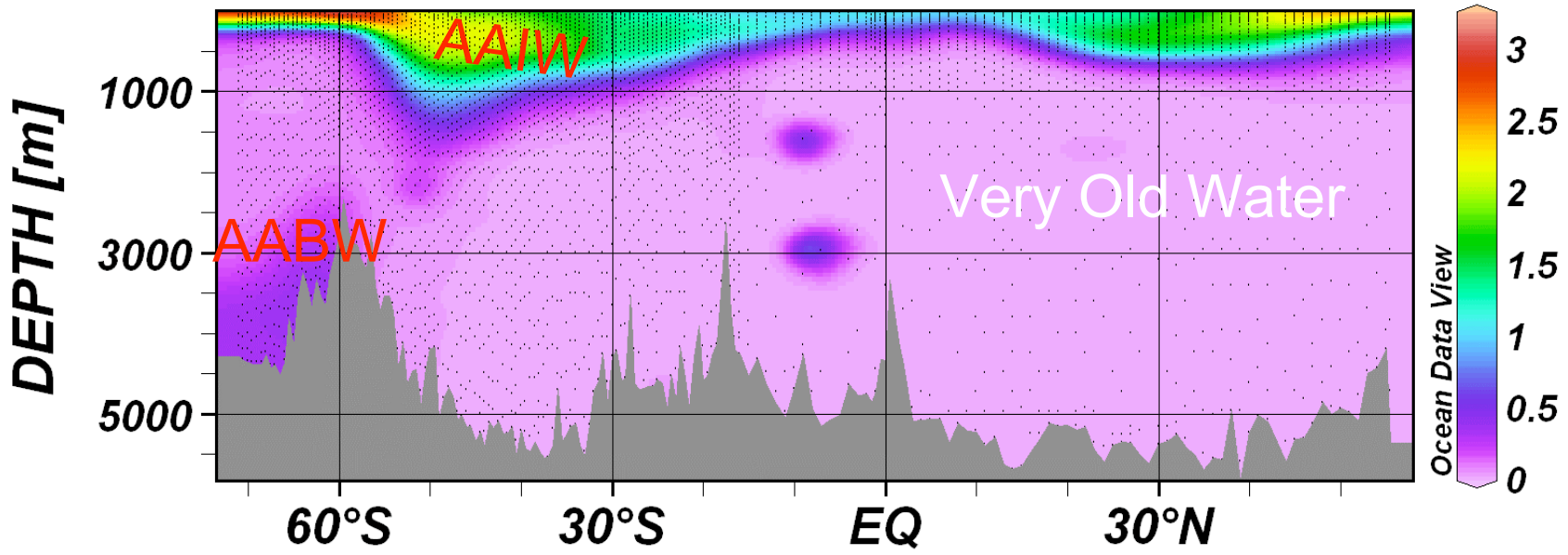
Pacific P16 AOU



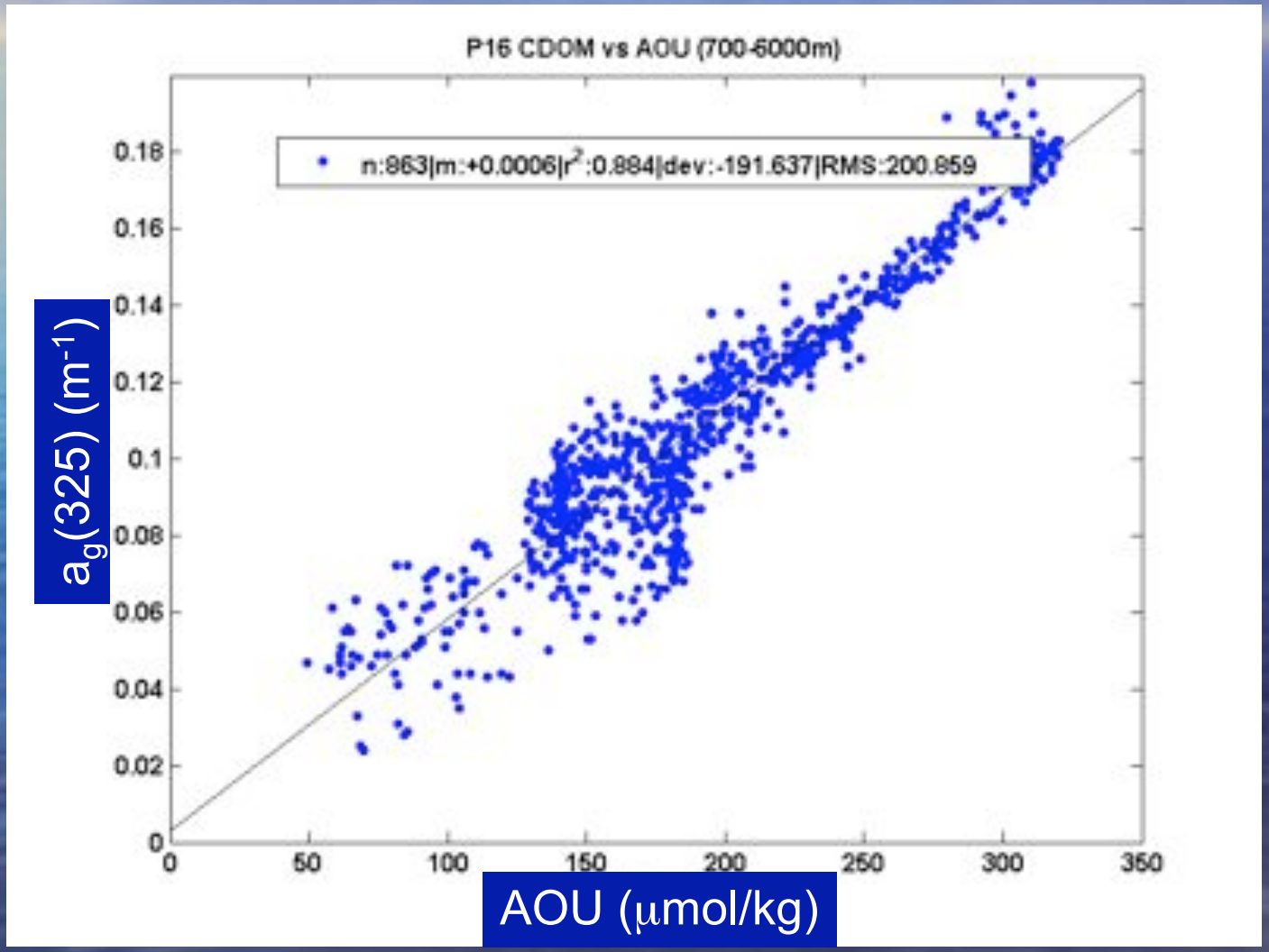
Apparent Oxygen Utilization = $O_{2sat} - O_2$

Measure of *past* remineralization of organic carbon

Pacific P16 CFC-12



Pacific AOU vs. CDOM



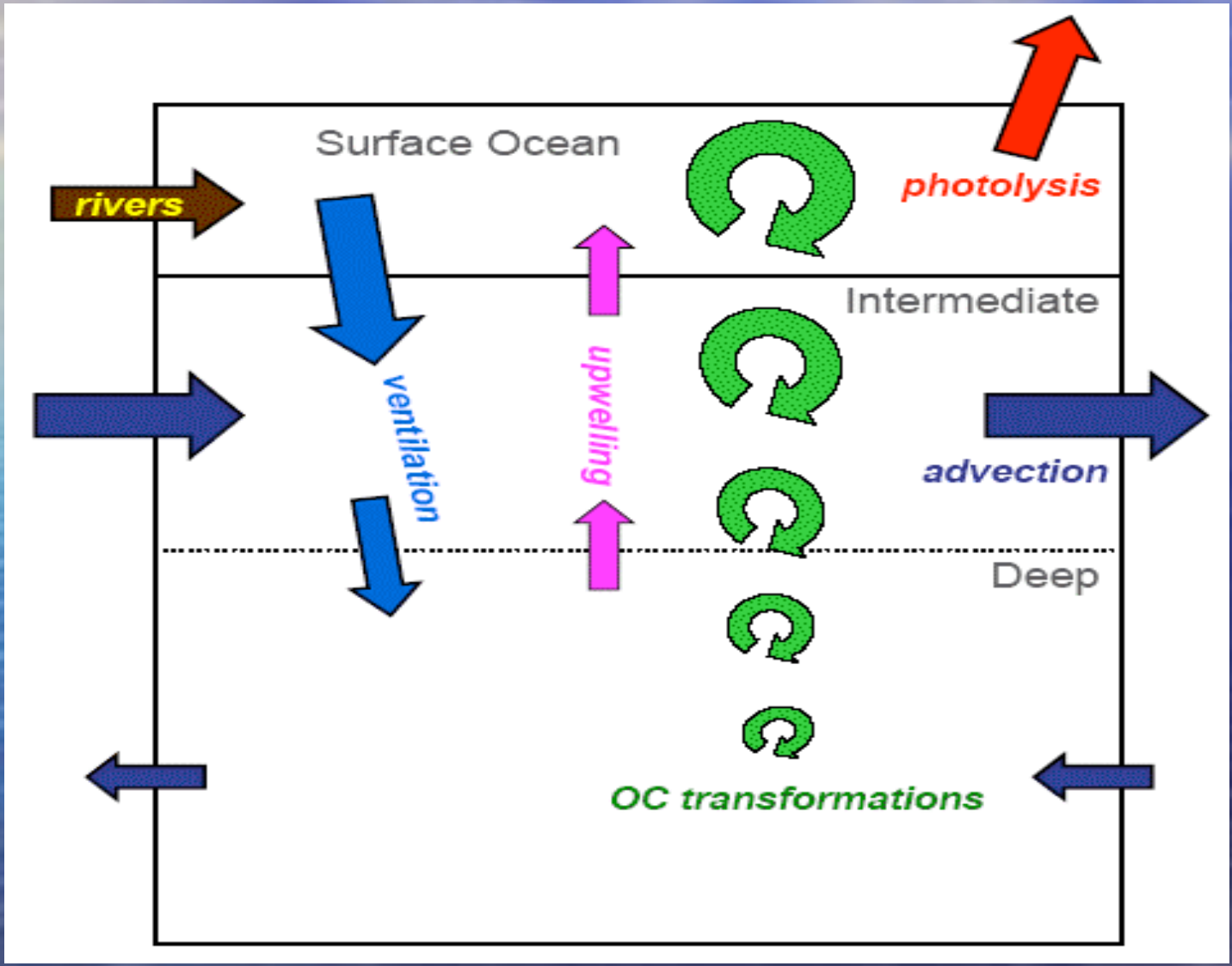
Atlantic vs. Pacific CDOM

- Significant spatial and depth gradients
- CDOM distribution is relatable to water mass distribution

But …

- Atlantic profiles do not show remineralization-correlated accumulation of CDOM like in the N. Pacific

CDOM Conceptual Model - Ocean Scale



CDOM Conceptual Model - Whole Ocean Scale

It's a simple ratio of time scales - T_{phys}/T_{bio}

Small T_{phys}/T_{bio}

Slow ventilation & Fast biology

* Pacific Ocean

Large T_{phys}/T_{bio}

Fast ventilation & Slow biology

* North Atlantic Ocean

Selected Project Results
North Atlantic CDOM/DOM Diagenesis

Nelson et al. Deep-Sea Res. I in press
<doi:10.1016/j.dsr.2007.02.006>

- CFC age estimation based on atmospheric CFC history and % saturation at origin (Smethie and Khatiwala, LDEO)
- CDOM and CFC Age compared by water mass component
- DOC-Specific absorption of CDOM

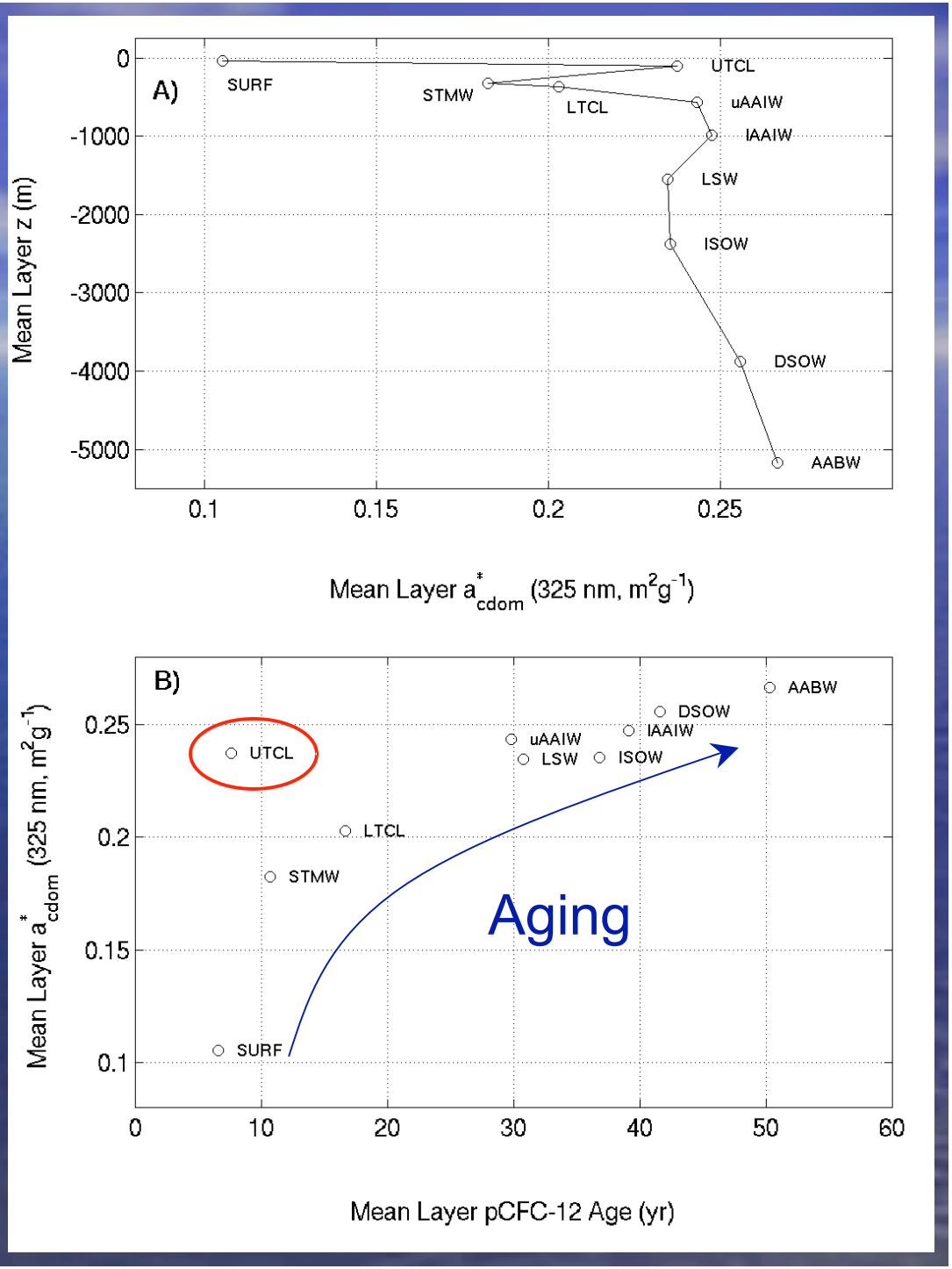
$a^*_{cdom}(325)$

a^*_{cdom} = CDOM / DOC (units m^2g^{-1})

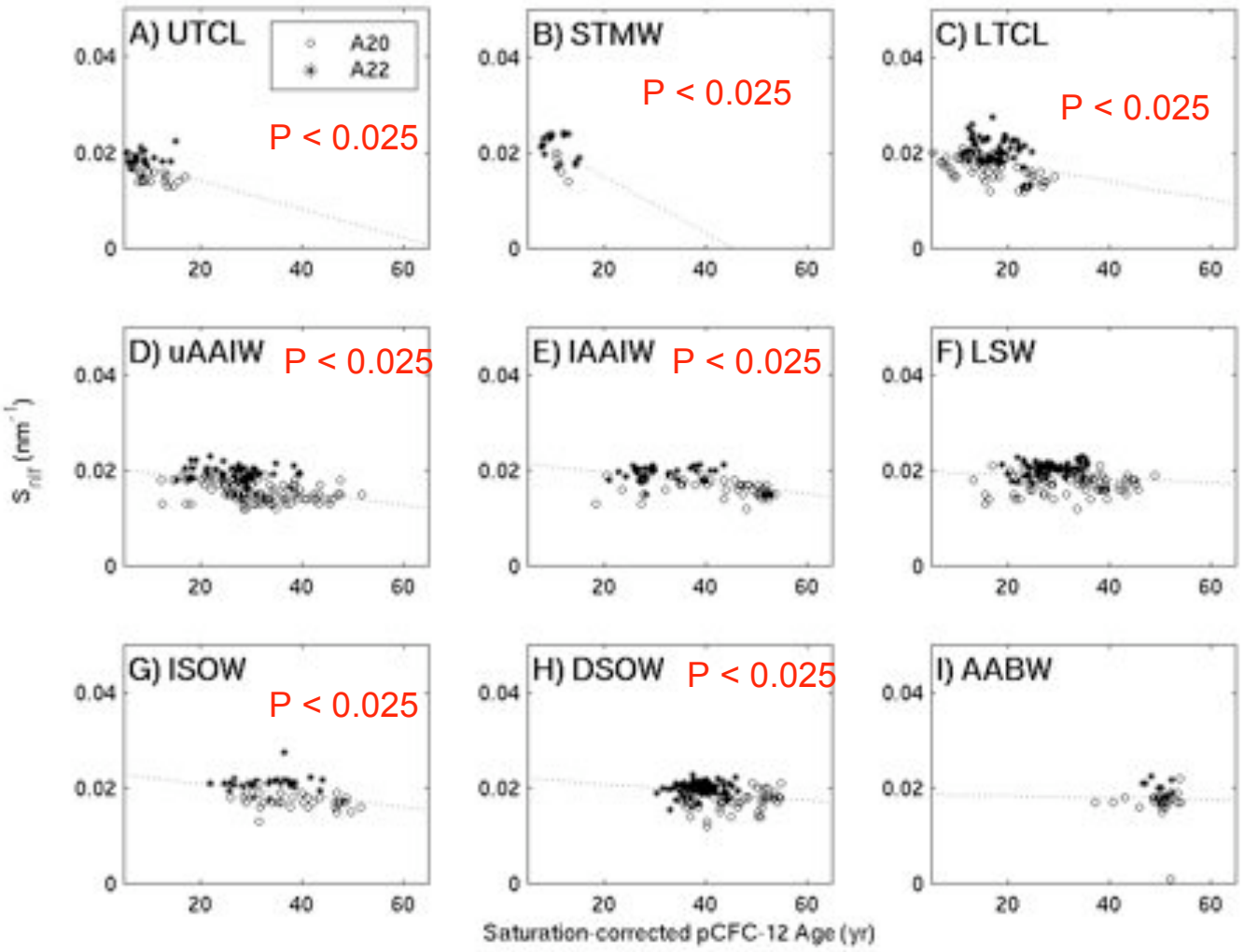
Upper layers bleaching & production signals

a^*_{cdom} increases w/ depth & age

CDOM is more recalcitrant than bulk DOC



Diagenesis of CDOM spectral characteristics



Summary

- Global CDOM distribution reflects not only local input, production and removal processes but also larger-scale features of ventilation and remineralization.

- CDOM represents a (small) portion of the DOM pool that resists remineralization on decadal time scales and is therefore useful as a semiconservative circulation tracer and indicator of DOM diagenesis.

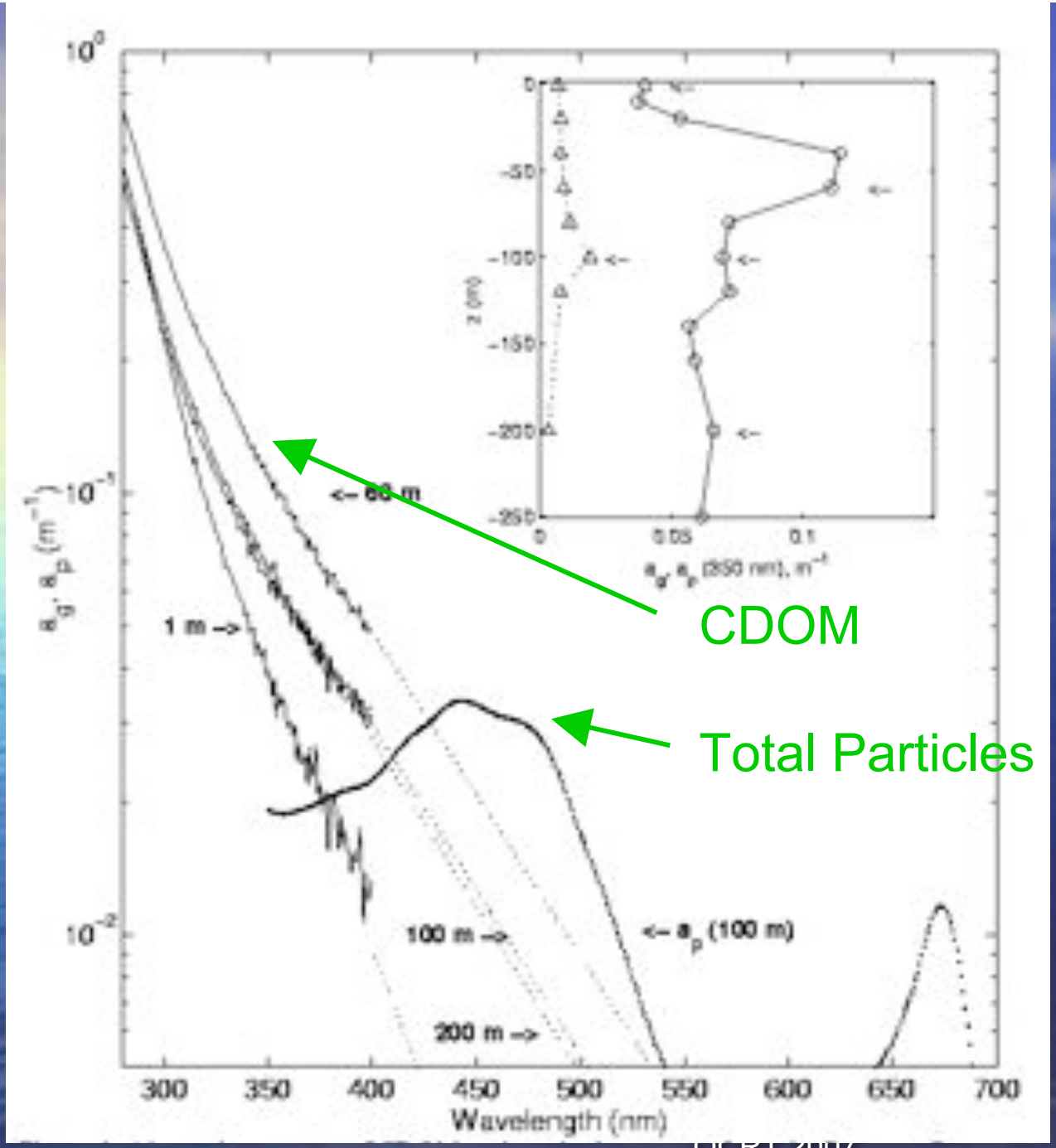
Ongoing and future work

- Completion of global survey (see map) (in collaboration with GSFC cal/val group)
- Photobleaching of CDOM at open ocean concentrations (Chantal Swan)
- Relationships between DOM quality/composition (e.g. carbohydrate composition) and CDOM (Stu Goldberg)
- CDOM characterization using fluorometric techniques -- archived and new samples, profiling (ECO) and (lab) spectrofluorometers

Acknowledgments

- NASA OBB & NSF Chem Oce
- CLIVAR/CO2 Repeat Hydro Program
  (Jim Swift, Lynne Talley, Dick Feely, Rik Wanninkhof, Rana Fine)
- UCSB Field Teams: Dave Menzies, Jon Klamberg, Meredith Meyers, Ellie Wallner, Meg Murphy
- Bill Landing (FSU) and Chris Measures (UHI) (Water samples @ sea)
- Ru Morrison & Mike Lesser, UNH (MAA analysis)
- Bill Smethie, Samar Khatiwala, LDEO (CFC Age analysis)
- Dennis Hansell & Team, U Miami (Sampling and collaboration)
- Wilf Gardner and Team, TAMU (C-Star transmissometer)
- Mike Behrenfeld and Team, OSU (Equatorial BOX project)
- Erica Key and Team, U Miami (AMMA-RB 2006)
- Jim Murray and Team, UW (EUCFe 2006)
- R/Vs *Brown, Knorr, Revelle, Melville, Thompson, Ka'I, Kilo Moana*

Extra Slides



CDOM

Total Particles

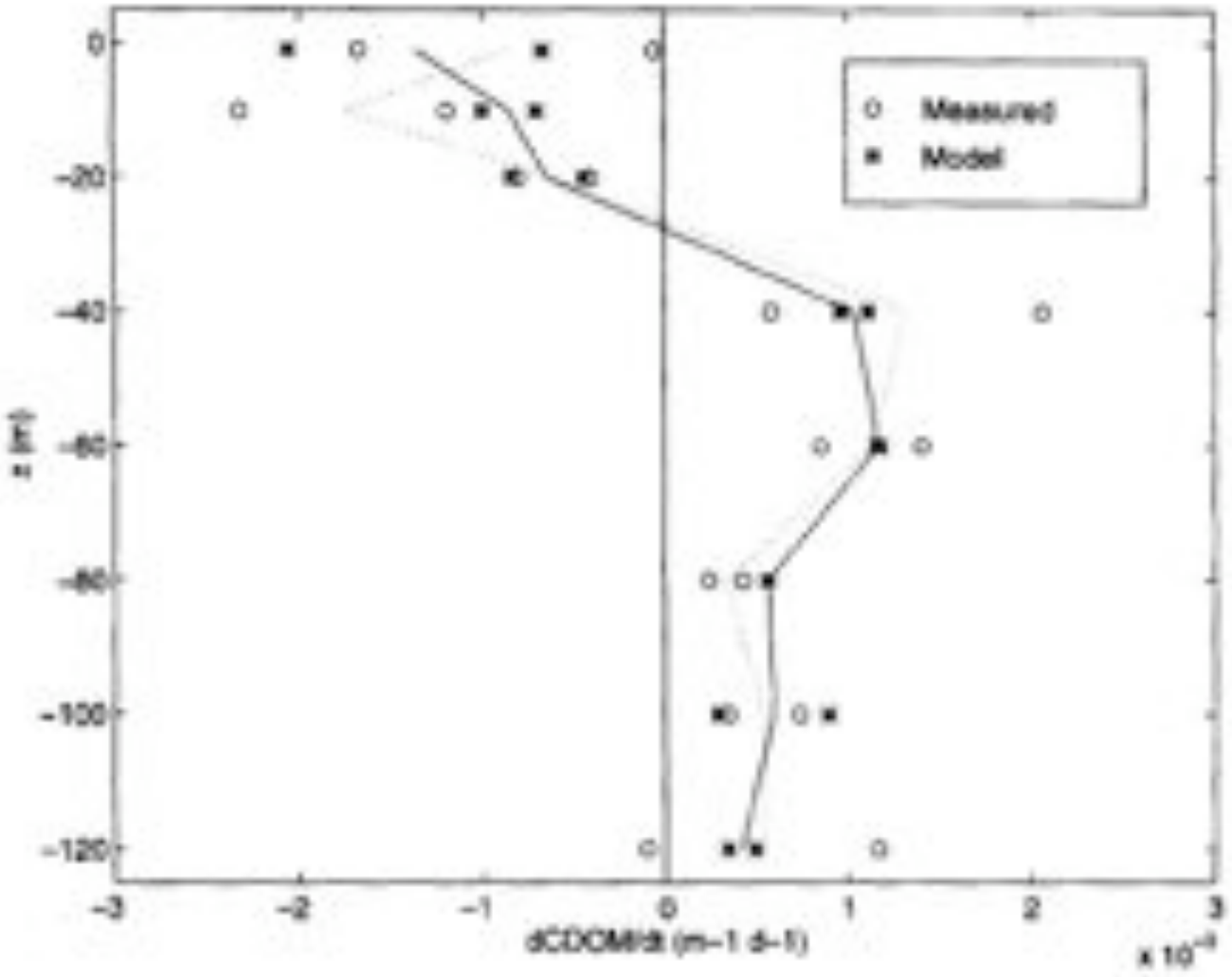
Sargasso Sea

(open ocean; summer-time)

Nelson et al [1998]

Net Production of CDOM

Summer – Spring CDOM



BATS data

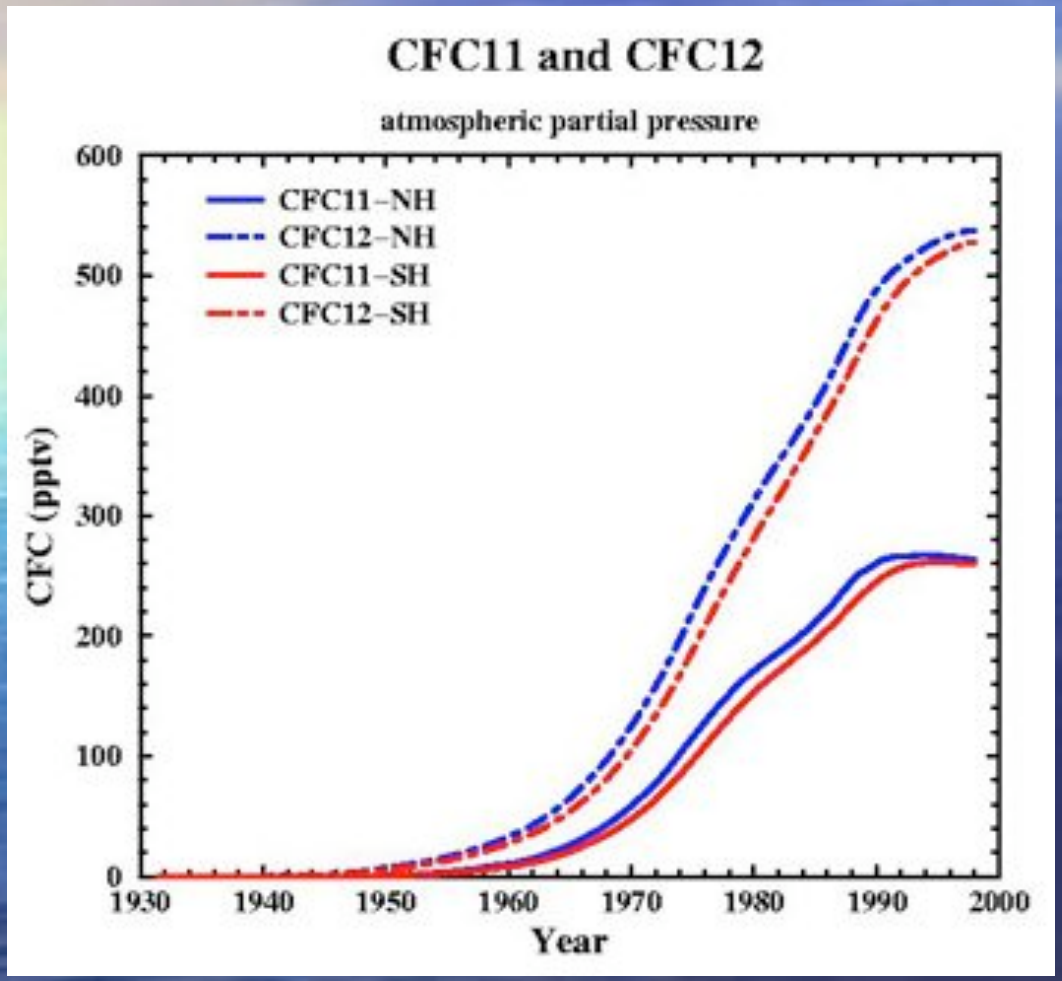
Sargasso Sea

(Nelson et al. 1998)

Production max at 40-60 m

Similar to the bacterial production

CFC's as Transient Tracers



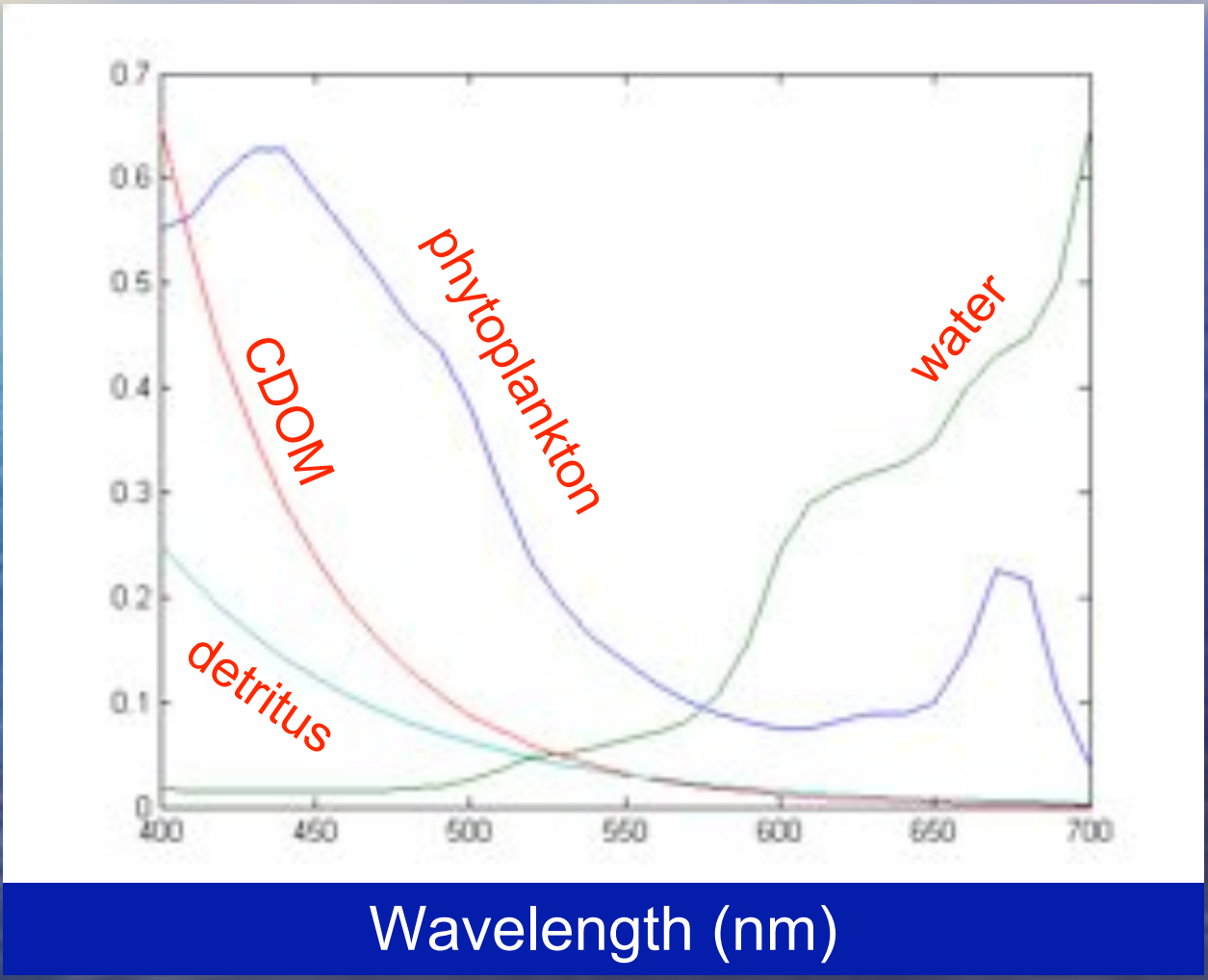
Mixing with ocean imprints ventilated waters w/ CFC levels

Provides a ventilation "age" for water mass

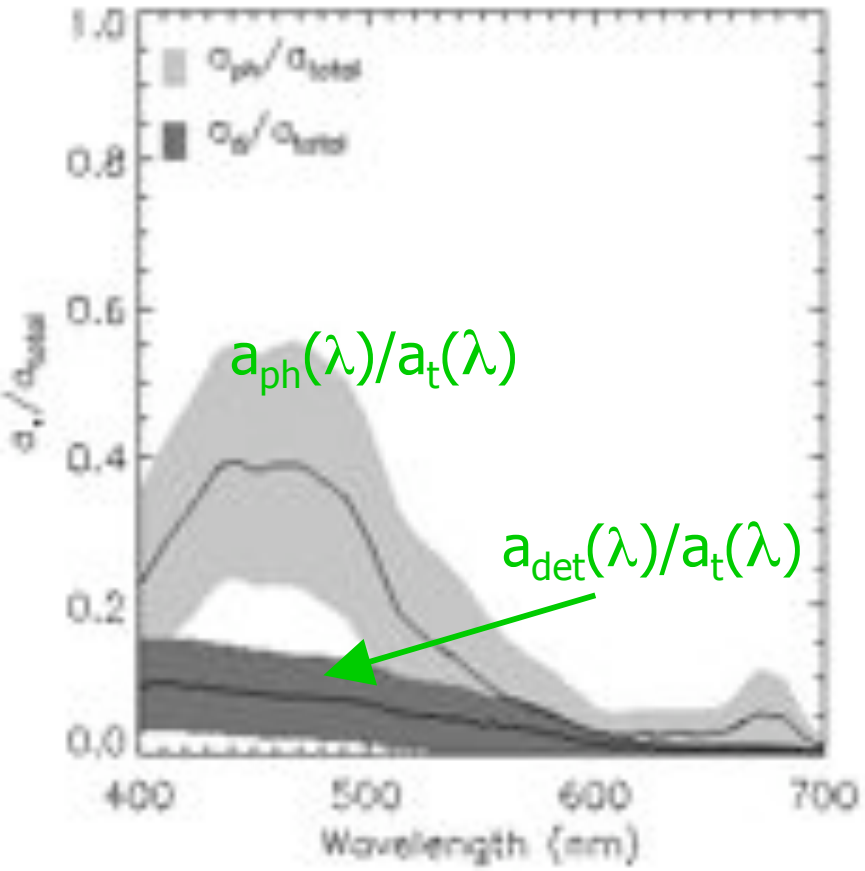
Atmospheric CFC's are now dropping

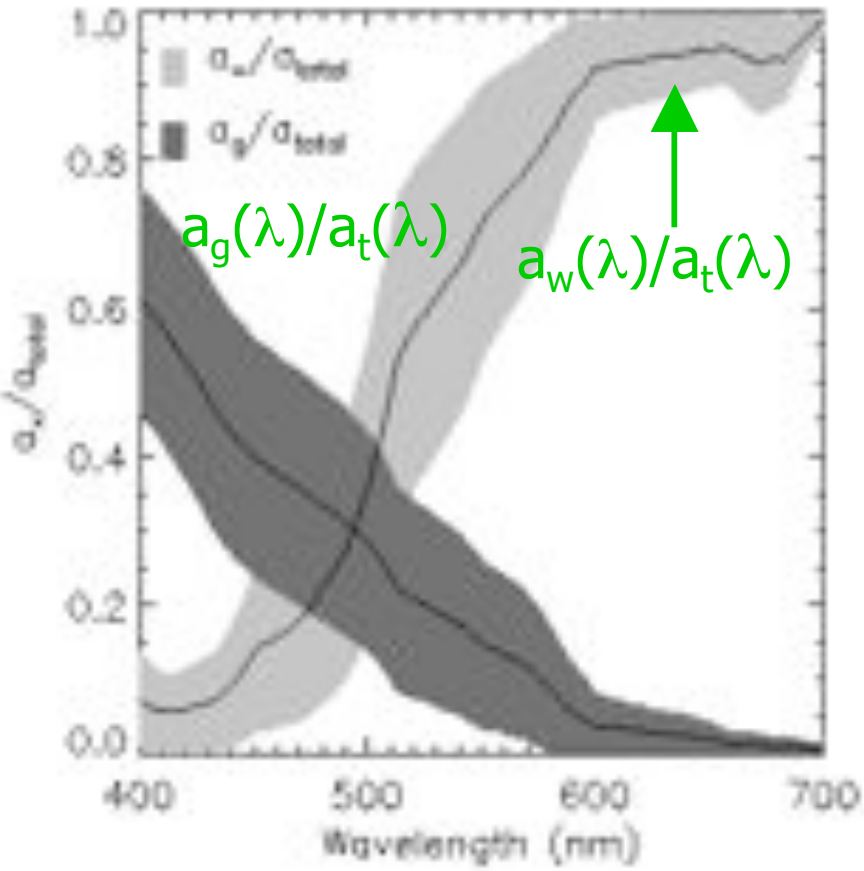
- Good for O_3 hole
- Bad for tracer work…

Light Absorption Spectral Shapes



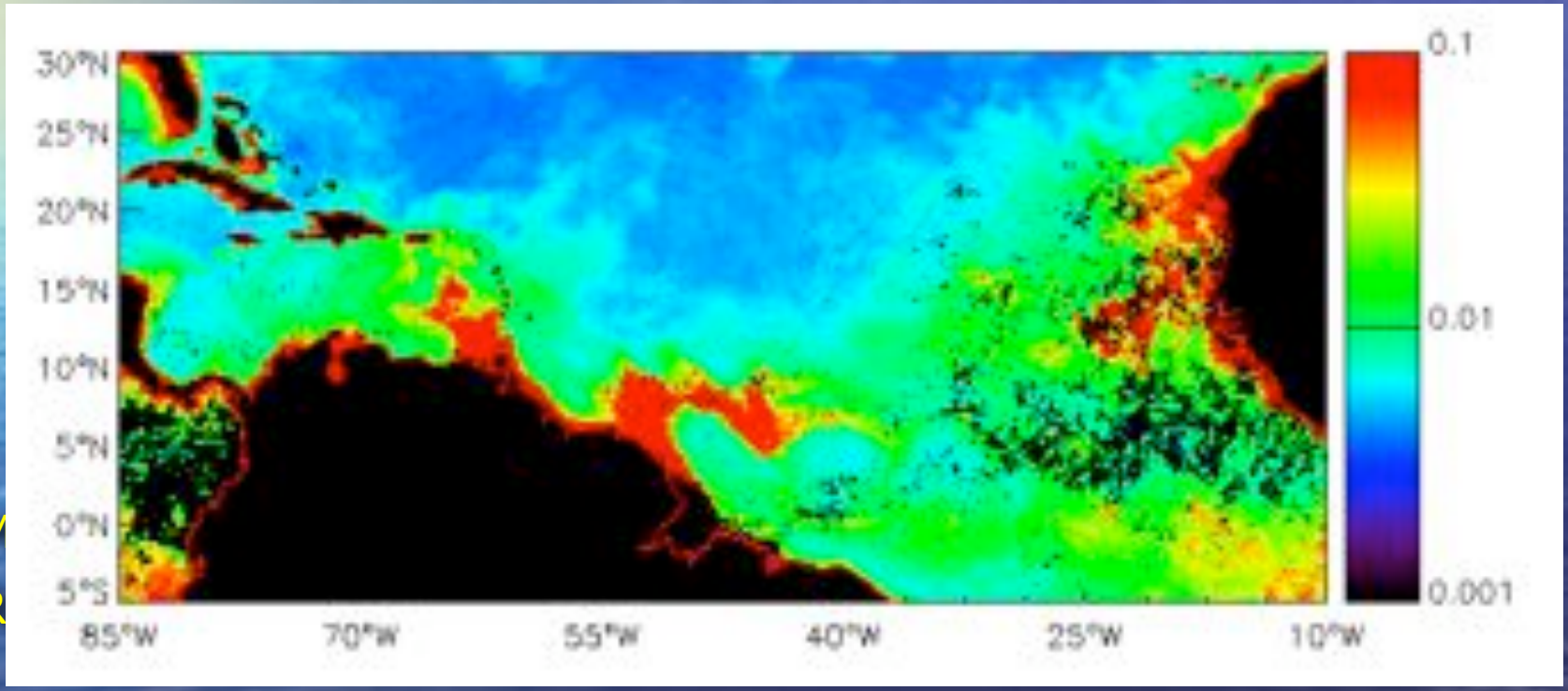
Relative Spectral Contributions





Role of Rivers

Large River Outflows…

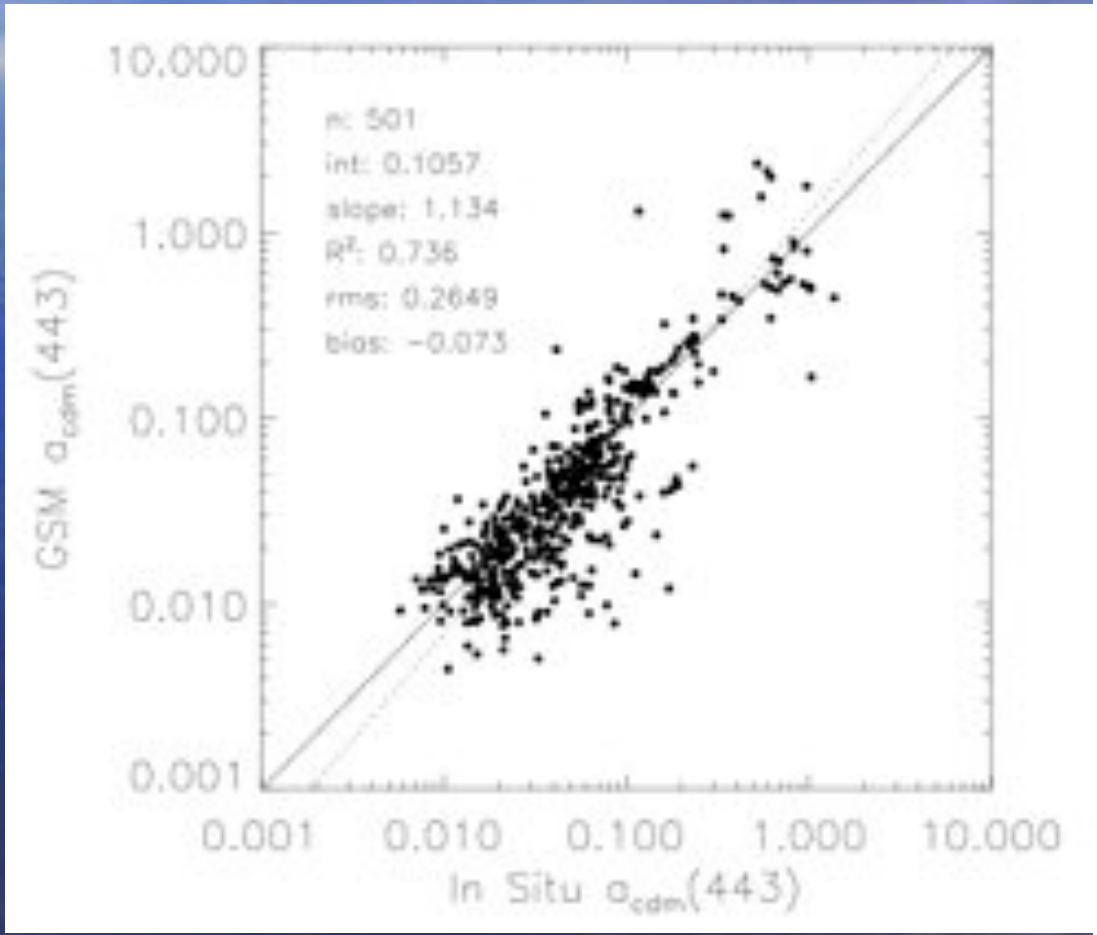


M

R

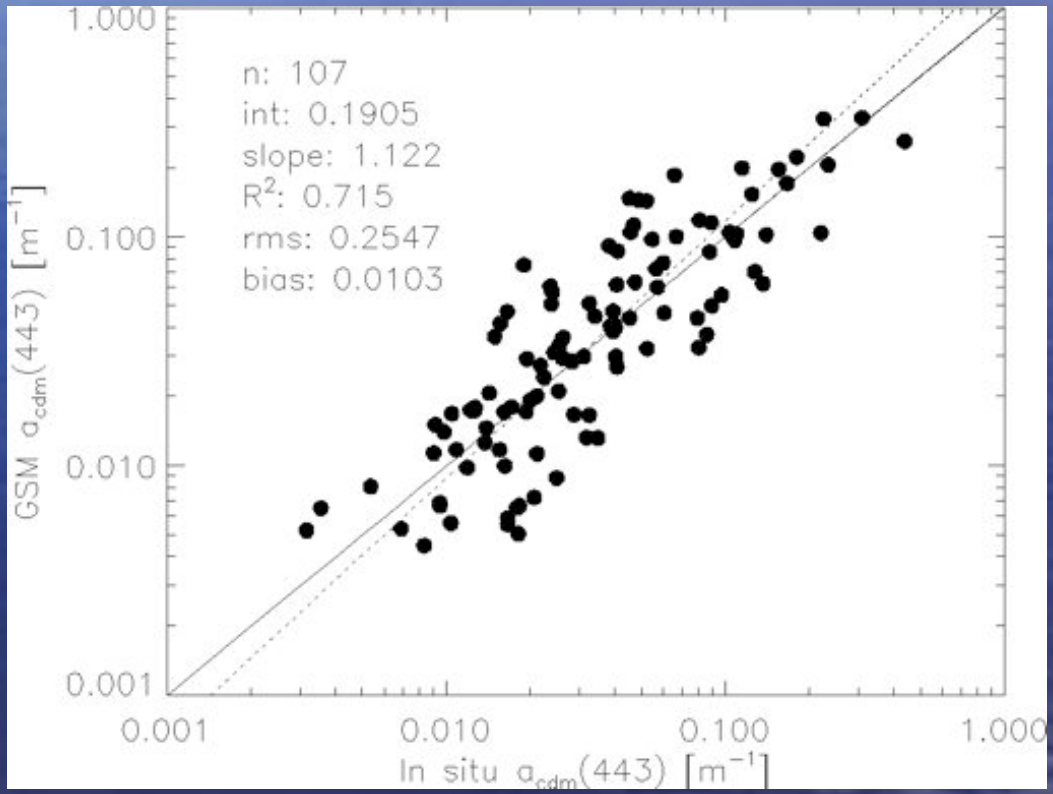
Does this all work??

- Matchup with NOMAD data (IOCCG IOP report; Lee et al. 2006)
- Model-data fits are pretty good – though not excellent
- GSM01 is optimized for all 3 retrievals



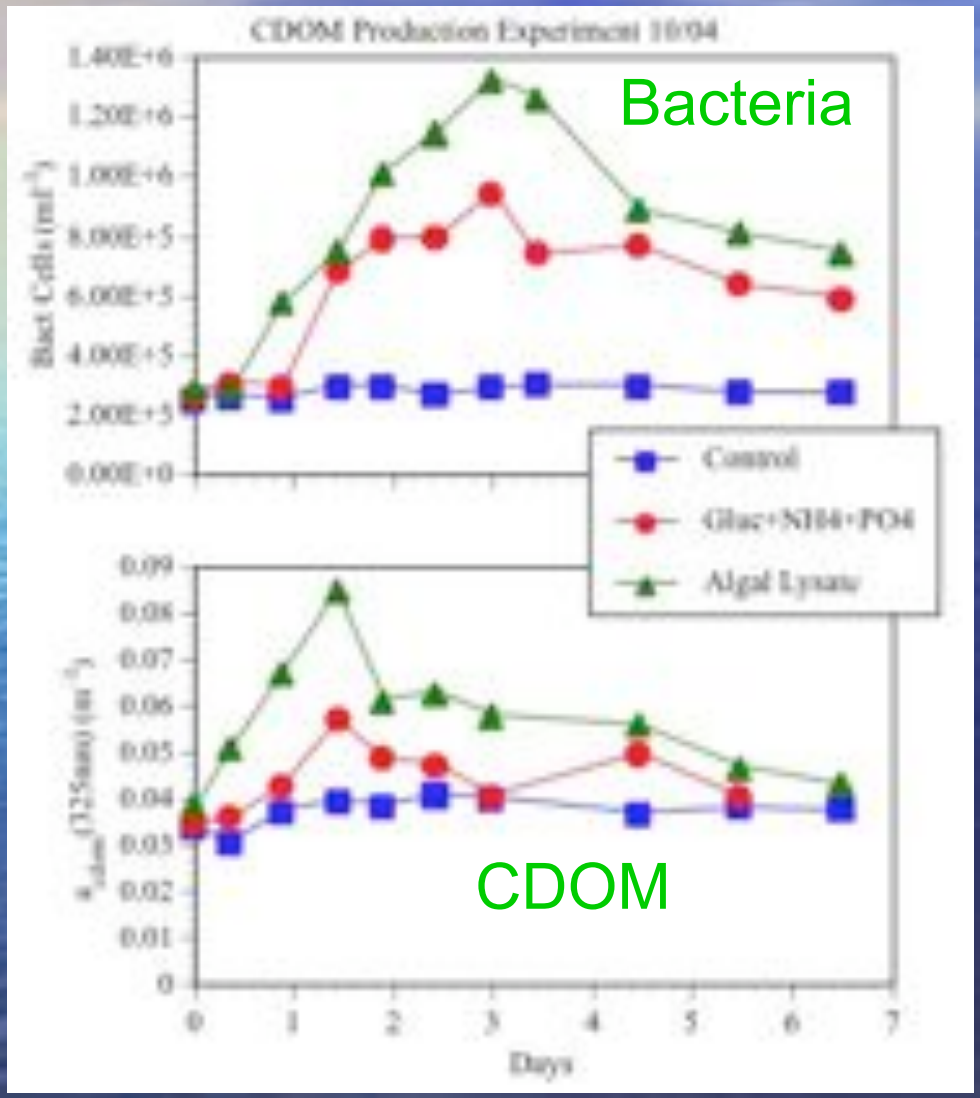
Does this all work??

- Independent global match-up data set of SeaWiFS & CDM observations
- Regression is good, not great



Siegel et al. [2005] JGR

Microbial Production of CDOM

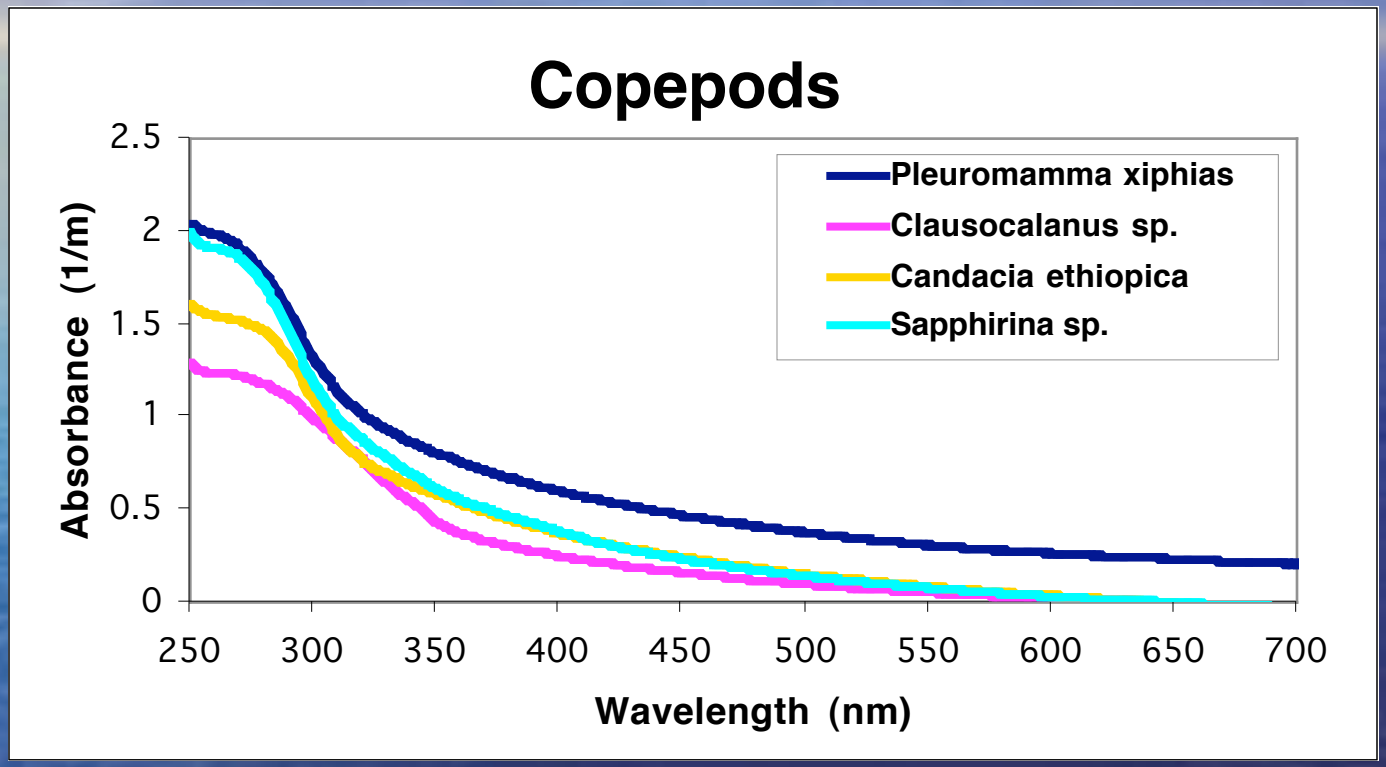


Microbes produce long-lived CDOM

Experiments from BATS 60m water by Nelson & Carlson

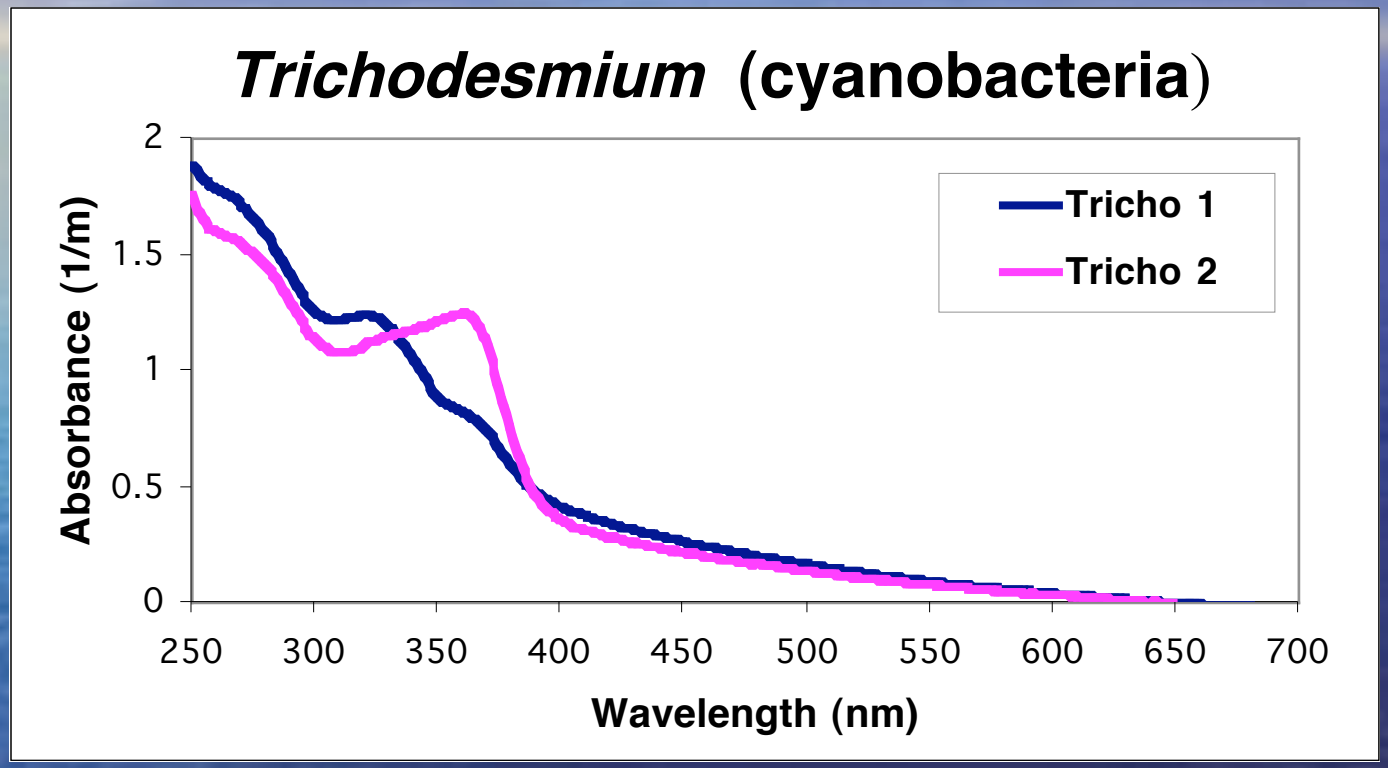
After Nelson et al. [2004]

Zooplankton & CDOM



Debbie Steinberg, Norm Nelson & Craig Carlson (MEPS 2004)

Trichodesmium & CDOM



Debbie Steinberg, Norm Nelson & Craig Carlson (2004)