Trace elements II
US N Atlantic GEOTRACES results

OCN 623 – Chemical Oceanography

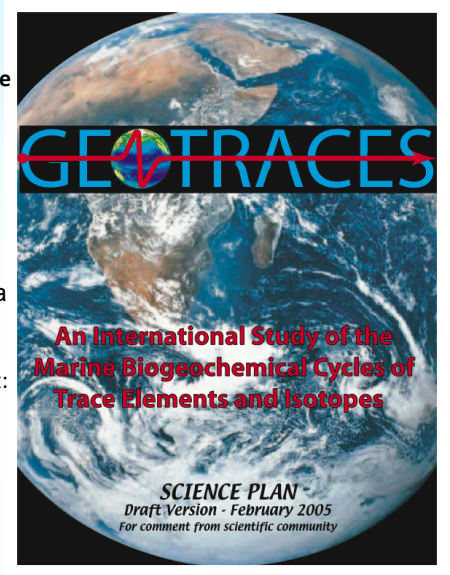
GEOTRACES guiding mission

To identify processes and quantify fluxes that control the distributions of key trace elements and isotopes in the ocean, and to establish the sensitivity of these distributions to changing environmental conditions.

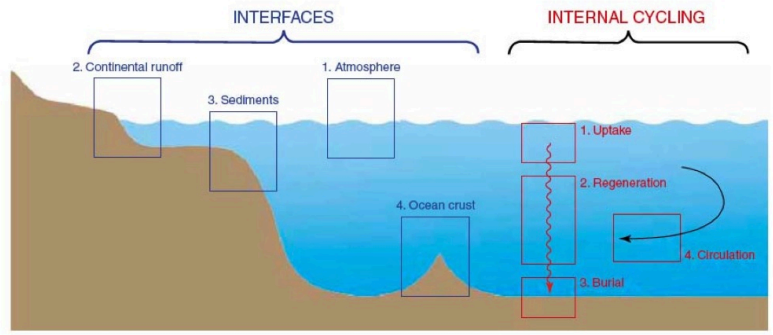
The program will survey oceans over a 10 year period

Copies of the Science plan are available at:

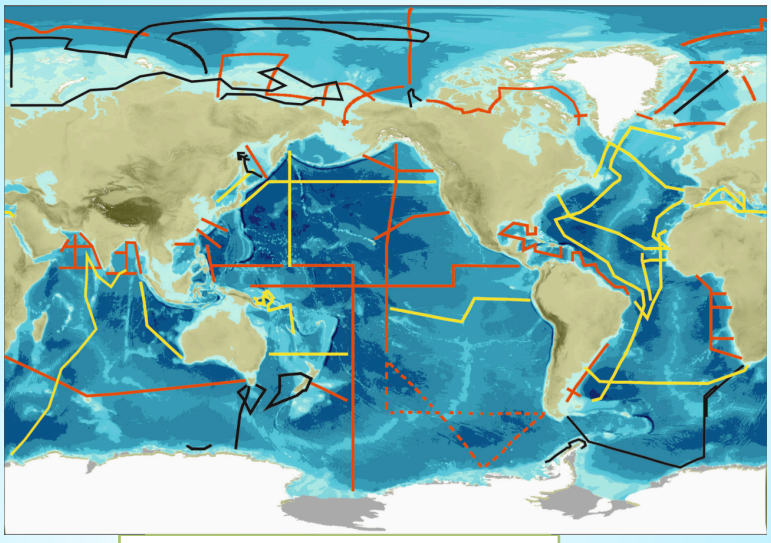
http://www.ldeo.columbia.edu/res/pi/geotraces/index.html



GEOTRACES Framework

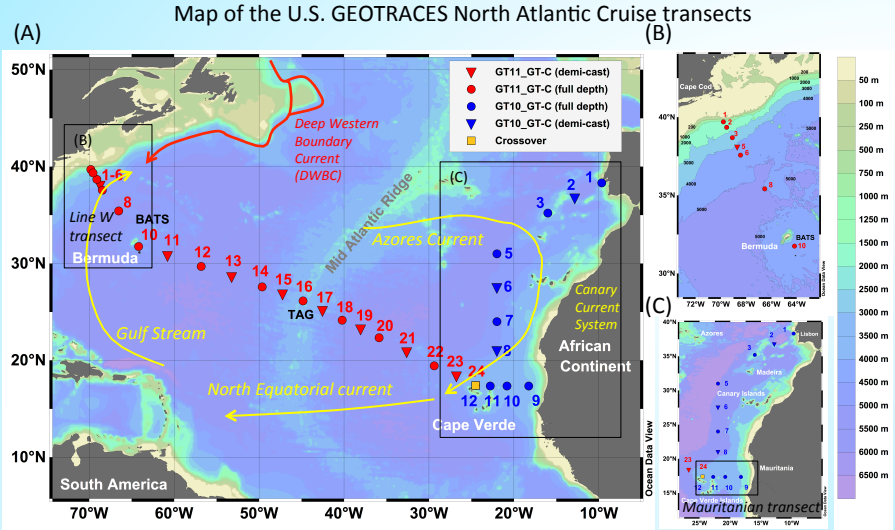


Define fluxes at four interfaces
and characterize four types of internal cycling.



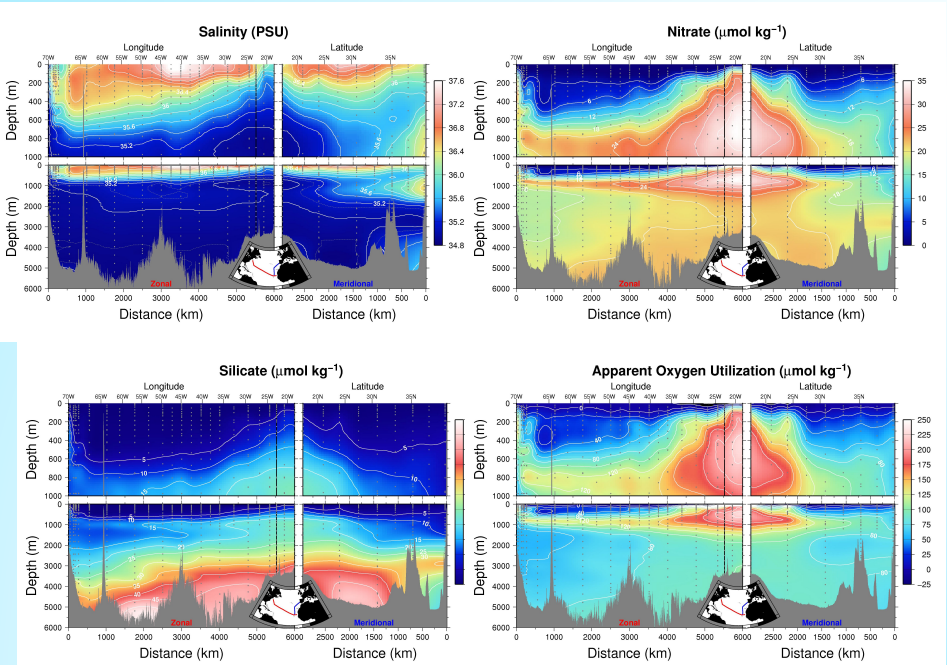
GEOTRACES Sections
Yellow: completed sections
Red: Planned sections
Black: Section completed as part of the IPY

Map of the U.S. GEOTRACES North Atlantic Cruise transects

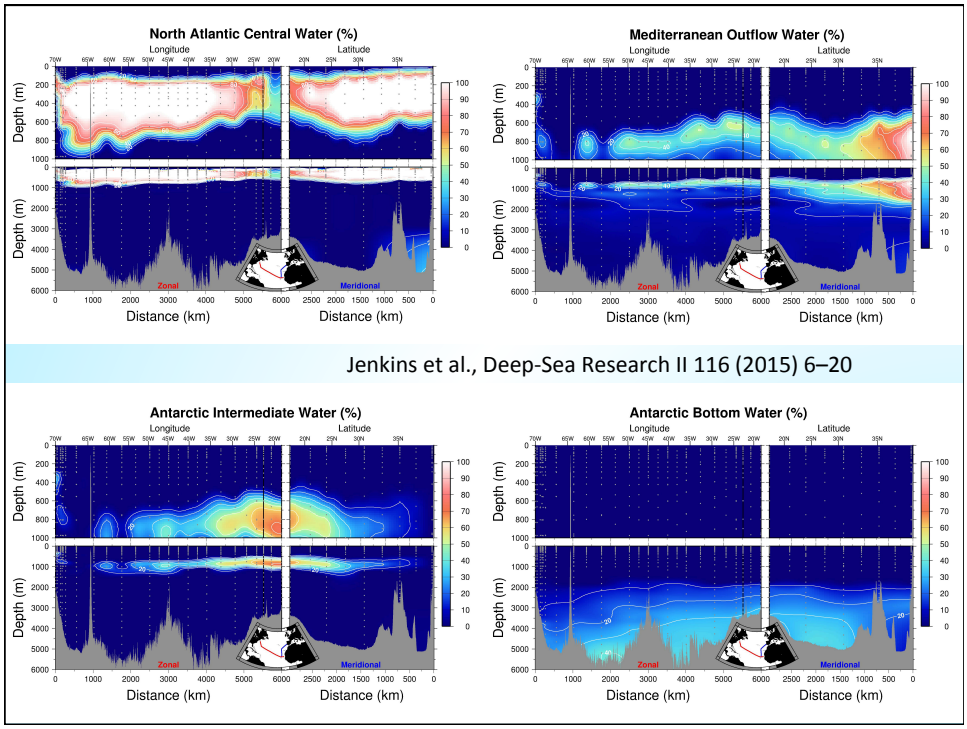


Full depth stations circle, and "demi" stations (samples were collected at the only upper 1000m) shows inverse triangle. (A) all transects (GT10 in blue and GT11 in red), (B) Western margin, and (C) Eastern margin. Crossover stations are shown as yellow squares (full depth station)

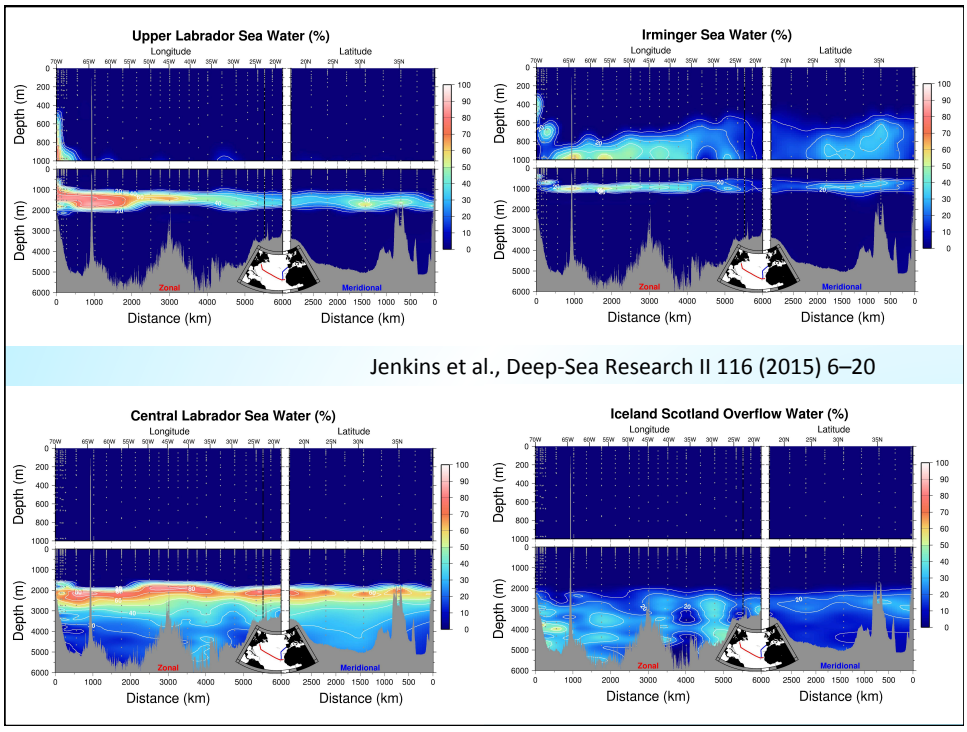
Hatta et al., Deep-Sea Research II 116 (2015) 117–129



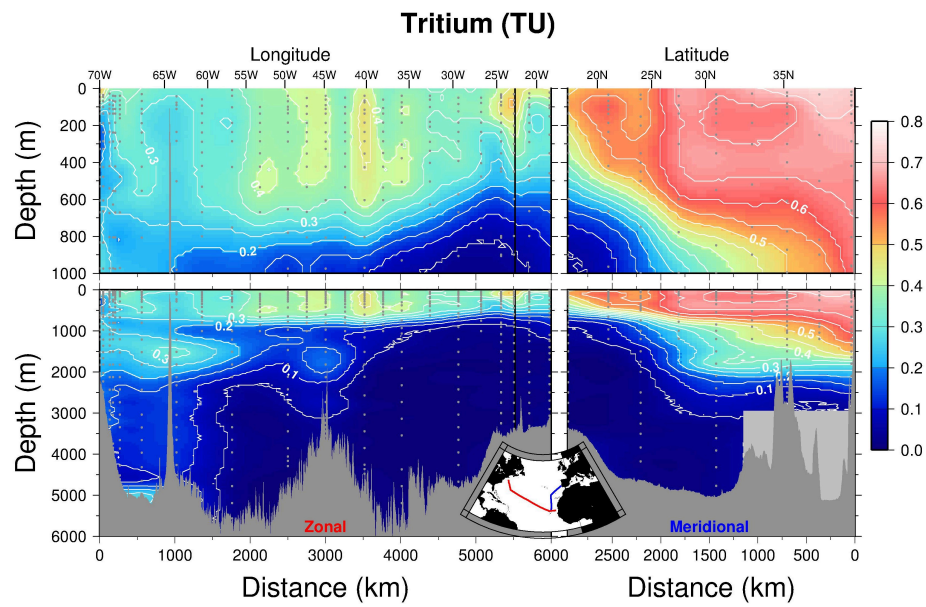
Jenkins et al., Deep-Sea Research II 116 (2015) 6–20



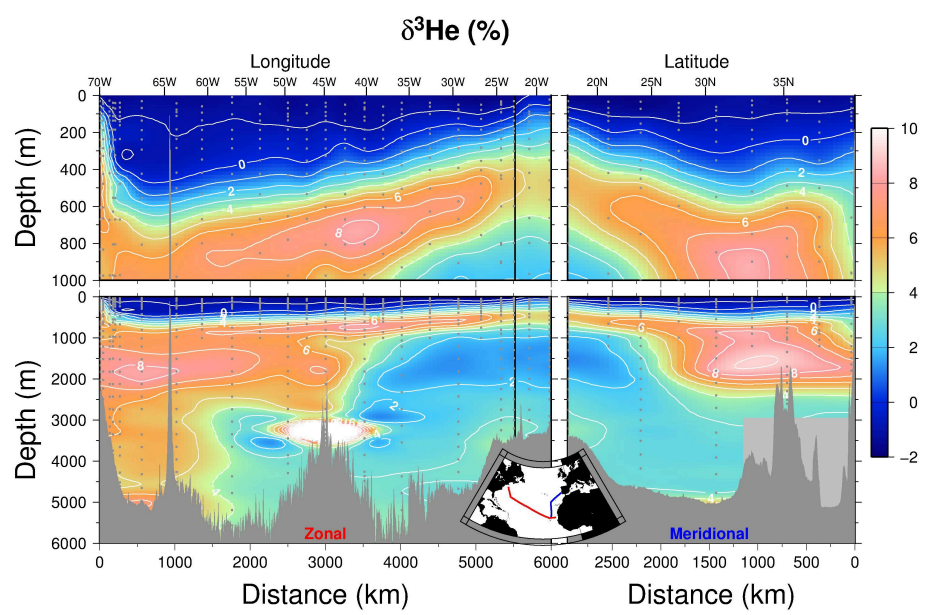
Jenkins et al., Deep-Sea Research II 116 (2015) 6–20



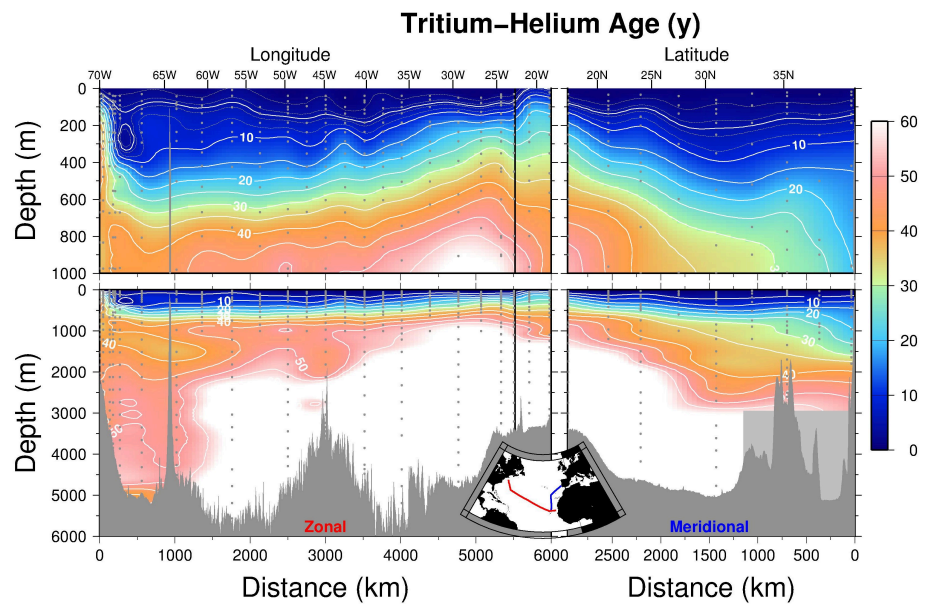
Jenkins et al., Deep-Sea Research II 116 (2015) 6–20



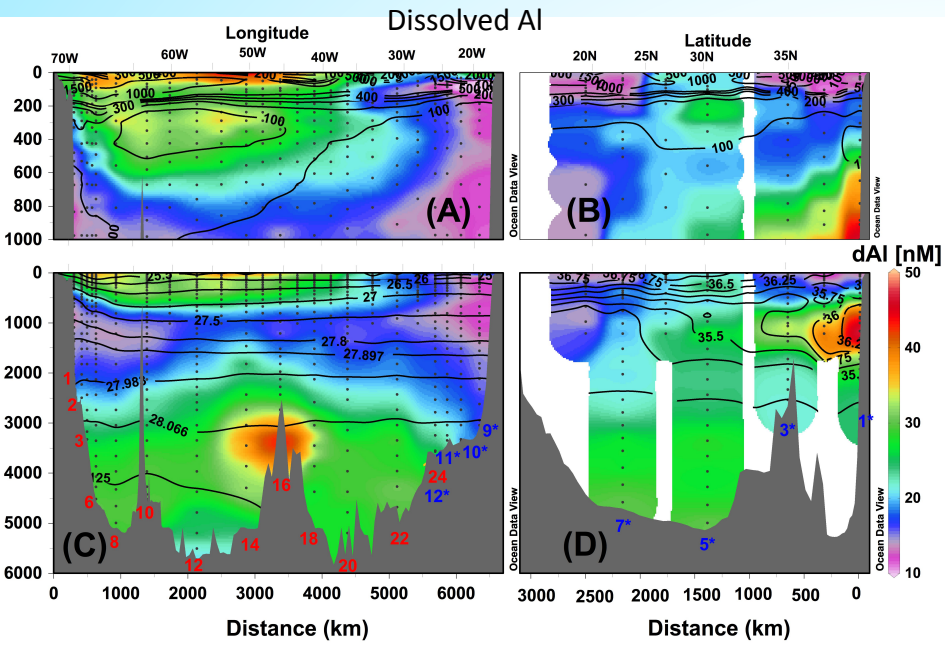
Jenkins et al., Deep-Sea Research II 116 (2015) 21–28



Jenkins et al., Deep-Sea Research II 116 (2015) 21–28



Jenkins et al. Deep-Sea Research II 116 (2015) 21–28

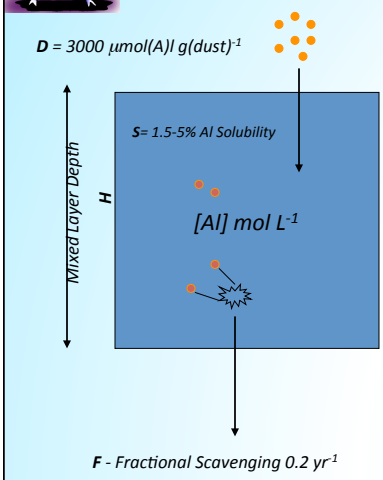


Measures et al., Deep-Sea Research II 116 (2015) 176–186

MADCOW model for calculating dust deposition

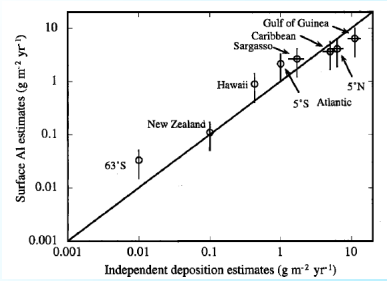
DUST FLUX

G (g m^{-2} yr^{-1})



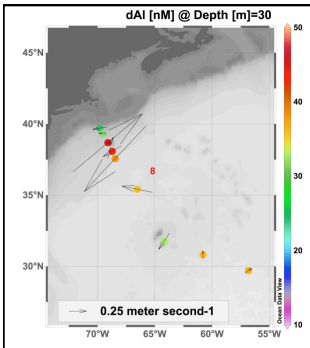
MODEL ASSUMPTIONS

- Dissolved Al is at steady-state
- Has a uniform 5yr residence time
- Al content of dust is 8%
- Fractional Al solubility: 1.5-5%
- No other sources of Al to surface

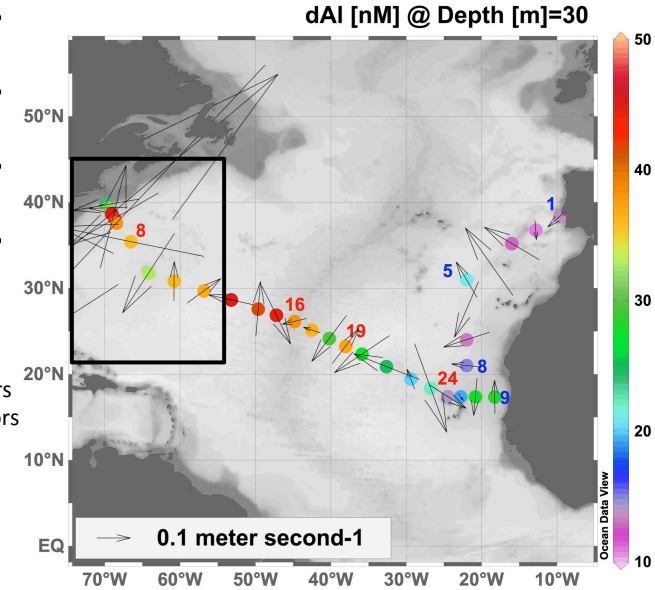


From M Grand

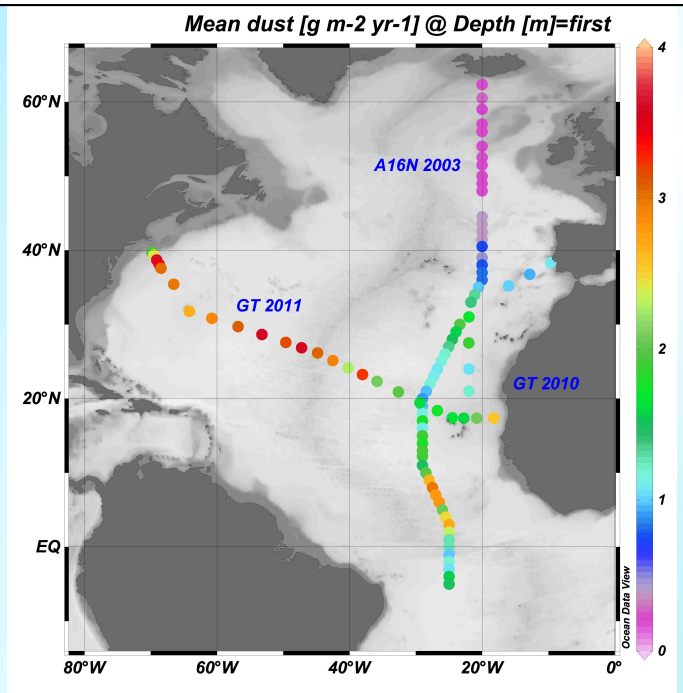
Measures and Vink, 2000



Dissolved Al in surface waters with the surface water vectors overlaid

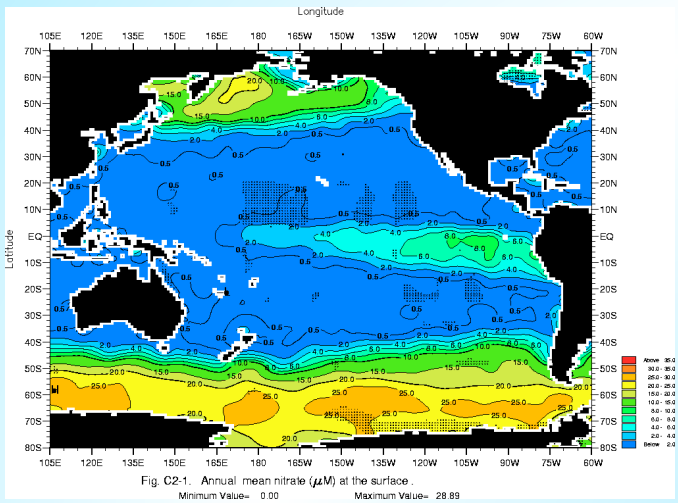


Measures et al., Deep-Sea Research II 116 (2015) 176–186



Measures et al., Deep-Sea Research II 116 (2015) 176–186

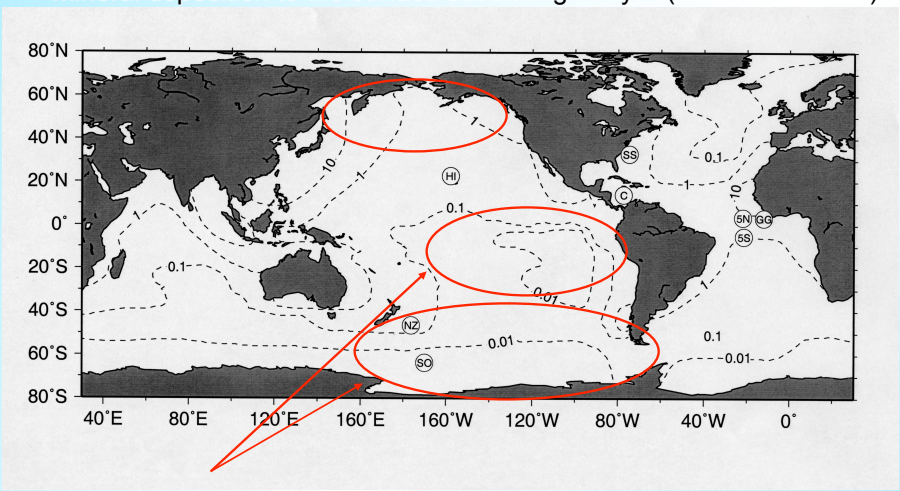
Surface water nitrate levels



HNLC regions are where upwelling/deep mixing occurs and eolian deposition is low

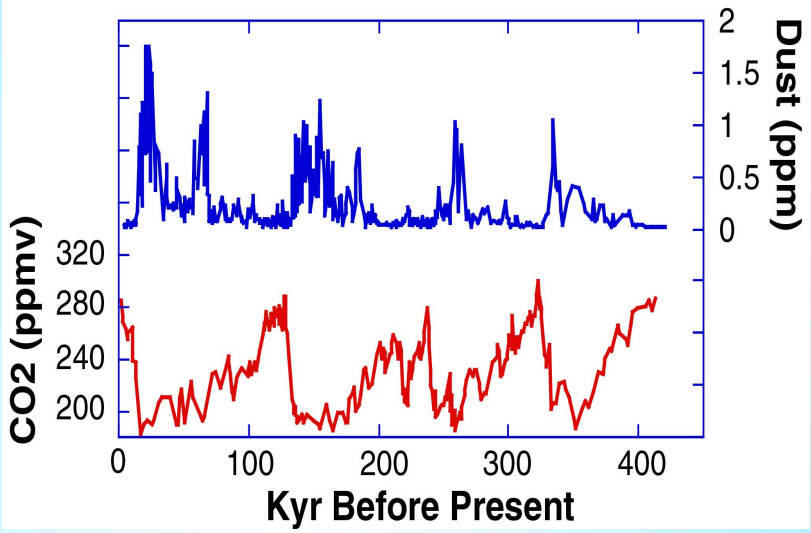
Surface water Fe is too low to allow full uptake of nutrients

Mineral deposition to the surface ocean in g m^{-2} yr^{-1} (Duce et al. 1991)



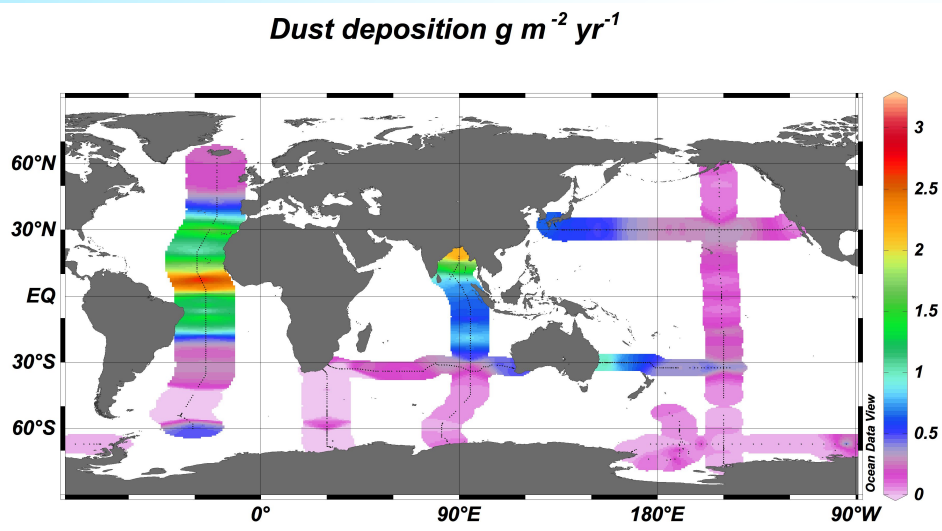
HNLC regions mostly correspond to low dust deposition regions

Paleo records suggest large variations in dust deposition correspond to atmospheric CO_2 variations

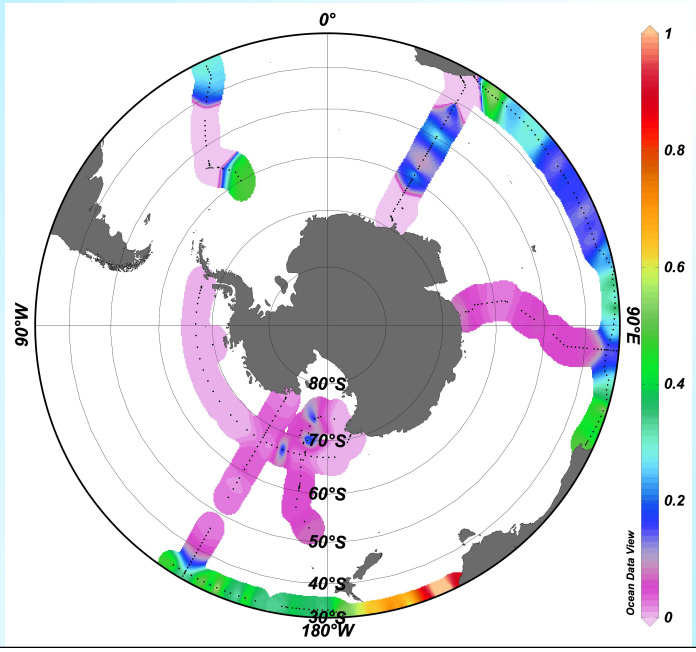


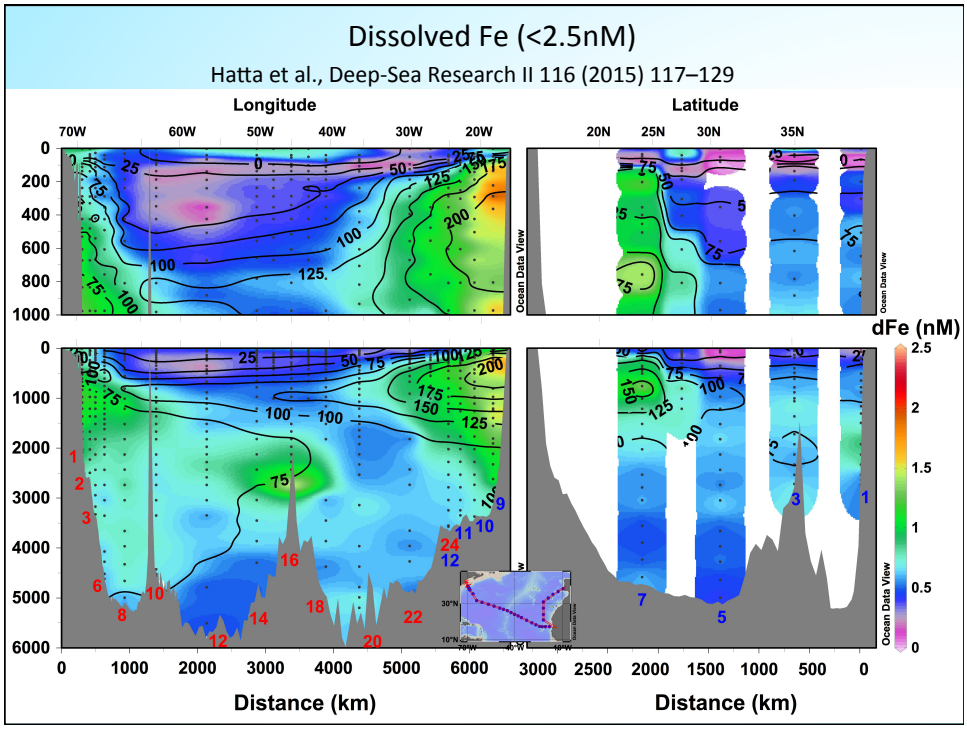
Global dust deposition patterns from CLIVAR Al data

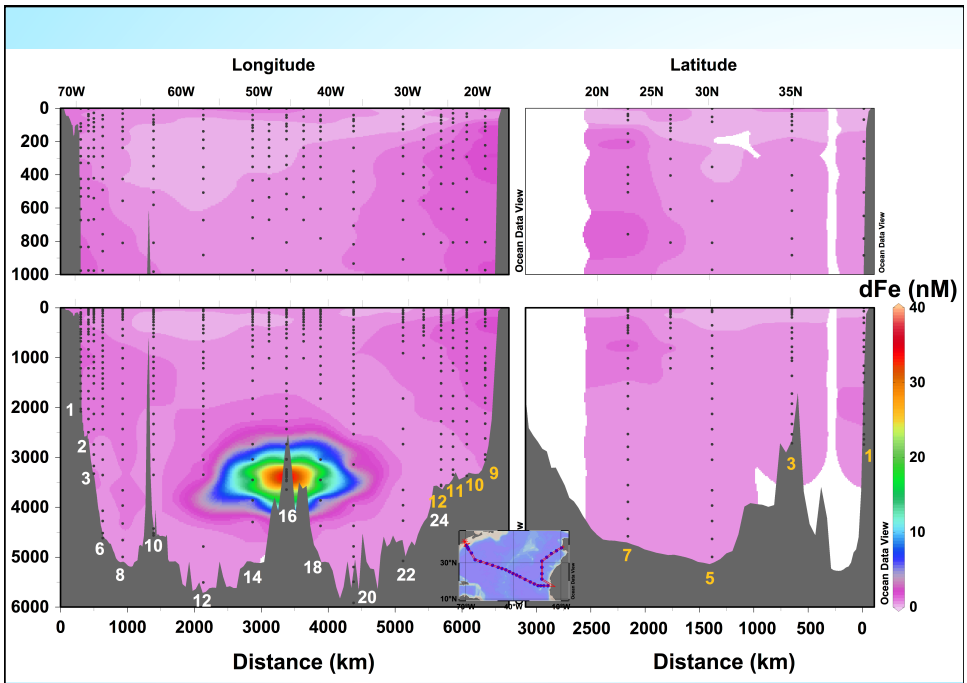
gm mineral dust m^{-2} yr^{-1}



Southern Ocean very limited deposition

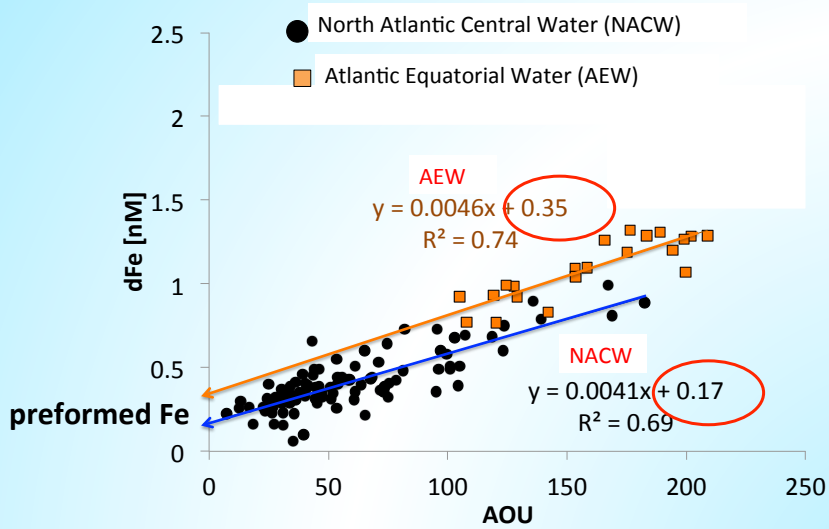


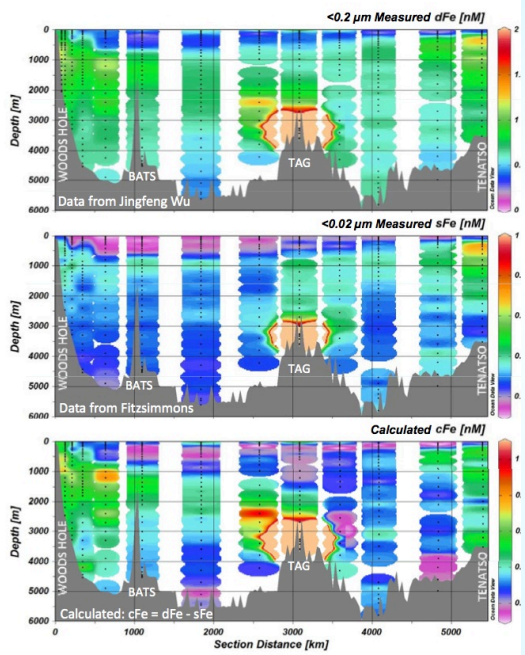




Hatta et al., Deep-Sea Research II 116 (2015) 117–129

Fe-supply mechanism in subsurface water





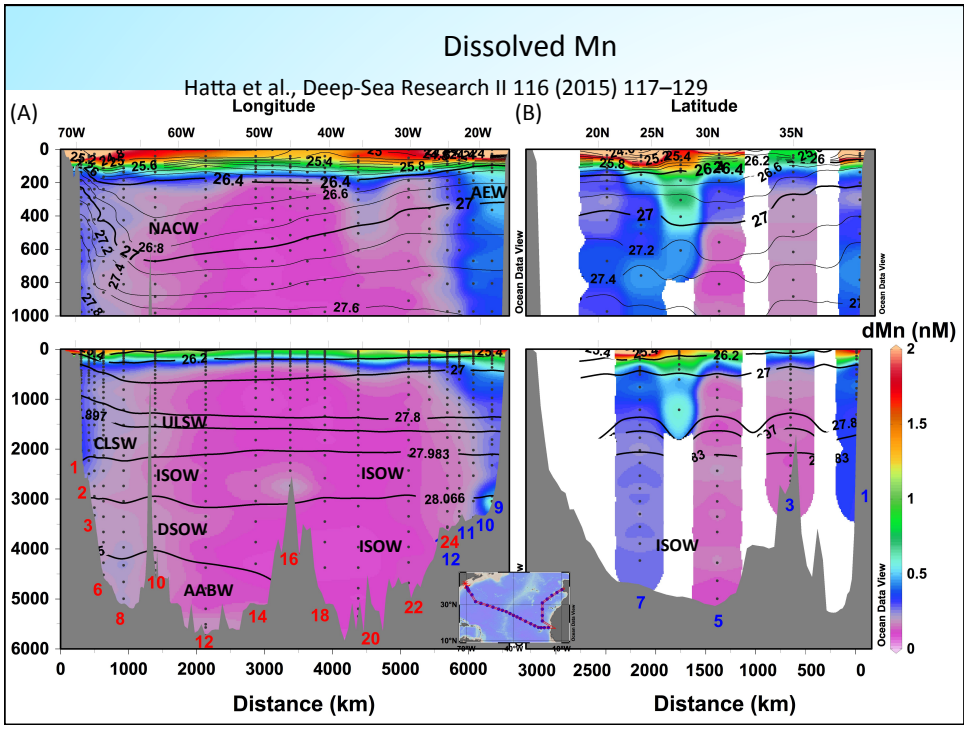
Size speciation is appearing to be important

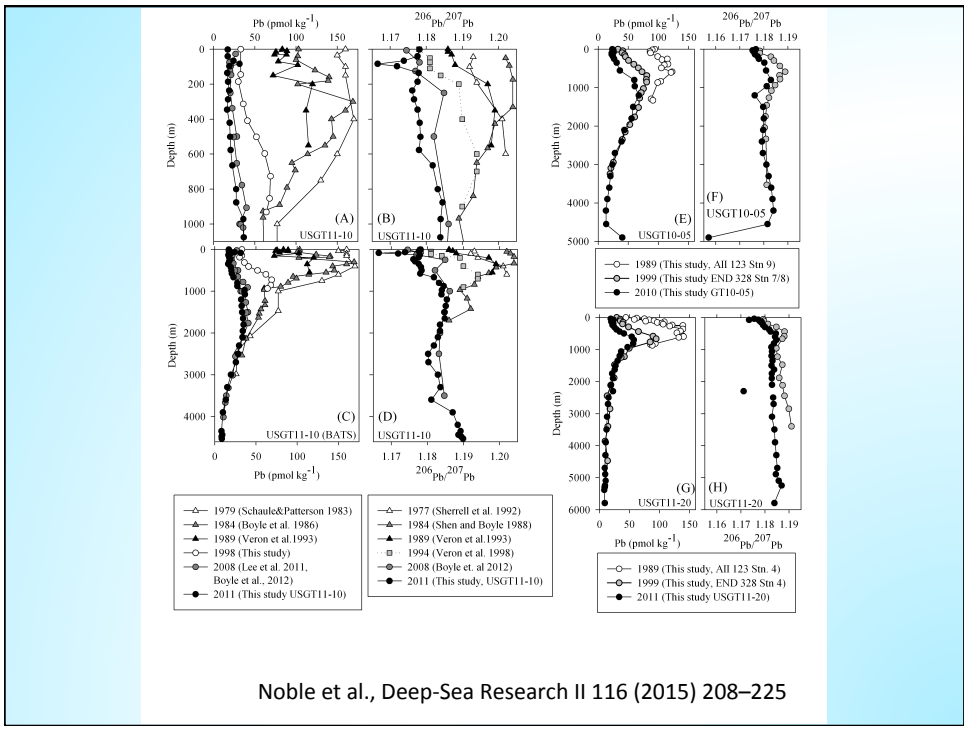
Dissolved Fe (dFe) is <0.2 µm (Acropak)

Soluble Fe (sFe) is <0.02 µm (Anodisc)

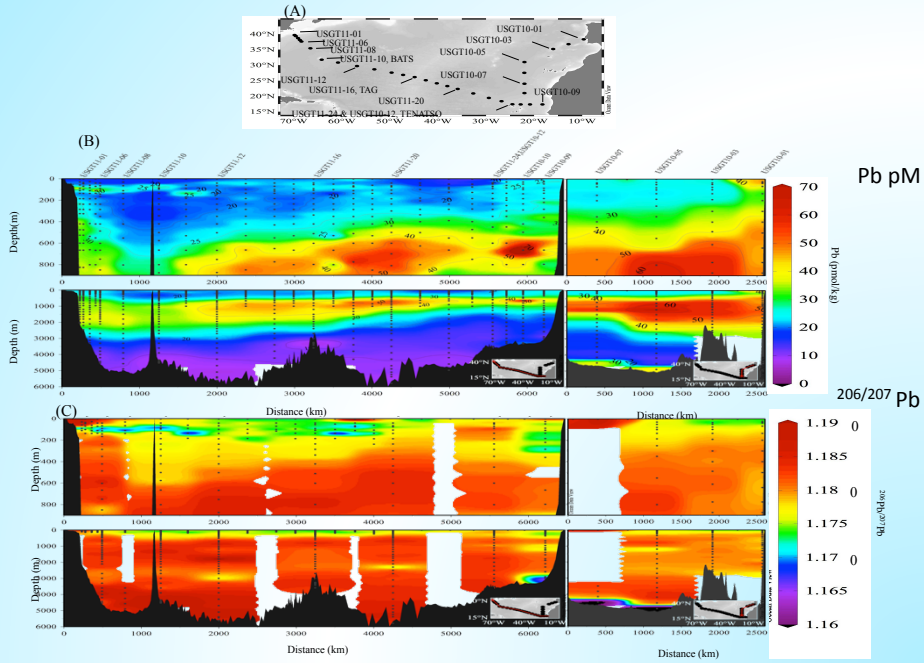
Colloidal Fe (cFe) = dFe – sFe

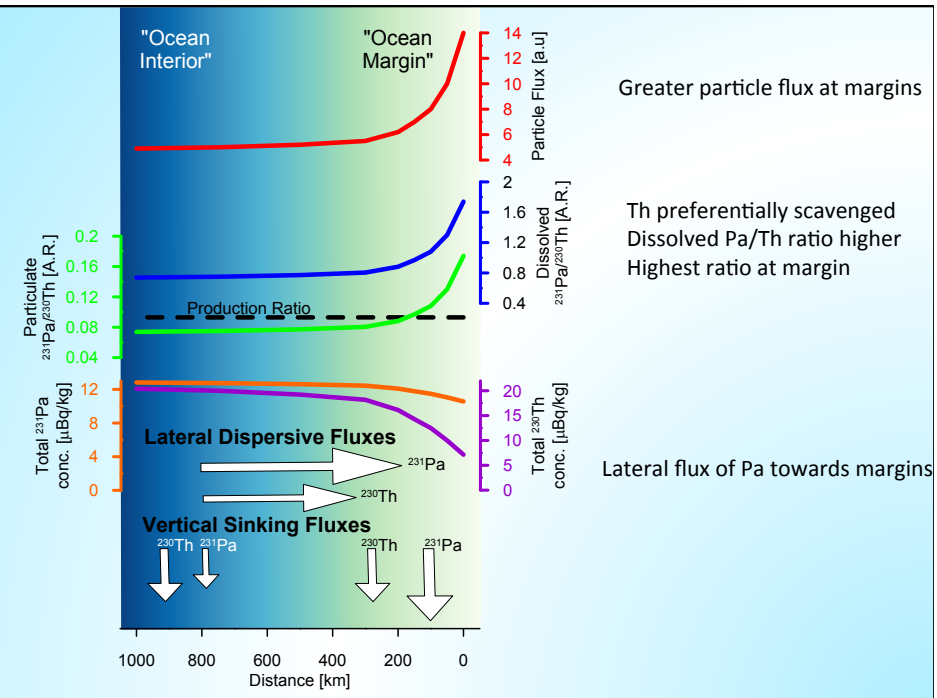
Fitzsimmons et al., Deep-Sea Research II 116 (2015) 130–151


Dissolved Mn
Hatta et al., Deep-Sea Research II 116 (2015) 117–129
(A)
Longitude
(B)
Latitude
NACW
AEW
ULSW
CLSW
ISOW
DSOW
AABW
dMn (nM)
Distance (km)
Distance (km)
Ocean Data View


Pb (pmol kg-1)
206Pb/207Pb
Depth (m)
USGT11-10
USGT11-10 (BATS)
USGT10-05
USGT11-20
1979 (Schaule&Patterson 1983)
1984 (Boyle et al. 1986)
1989 (Veron et al.1993)
1998 (This study)
2008 (Lee et al. 2011, Boyle et al., 2012)
2011 (This study USGT11-10)
1977 (Sherrell et al. 1992)
1984 (Shen and Boyle 1988)
1989 (Veron et al.1993)
1994 (Veron et al. 1998)
2008 (Boyle et. al 2012)
2011 (This study, USGT11-10)
1989 (This study, All 123 Stn 9)
1999 (This study END 328 Stn 7/8)
2010 (This study GT10-05)
1989 (This study, All 123 Stn. 4)
1999 (This study, END 328 Stn 4)
2011 (This study USGT11-20)
Noble et al., Deep-Sea Research II 116 (2015) 208–225

Noble et al., Deep-Sea Research II 116 (2015) 208–225





Hayes et al., Deep-Sea Research II 116 (2015) 29–41

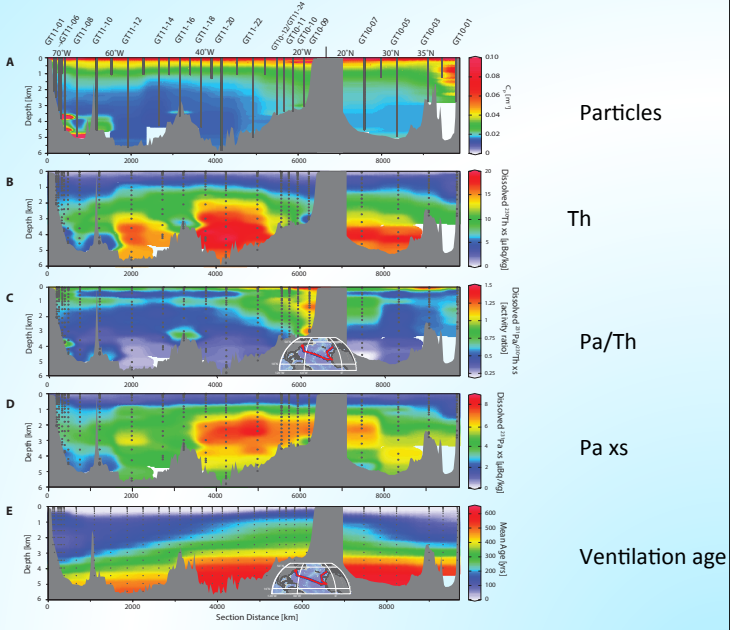
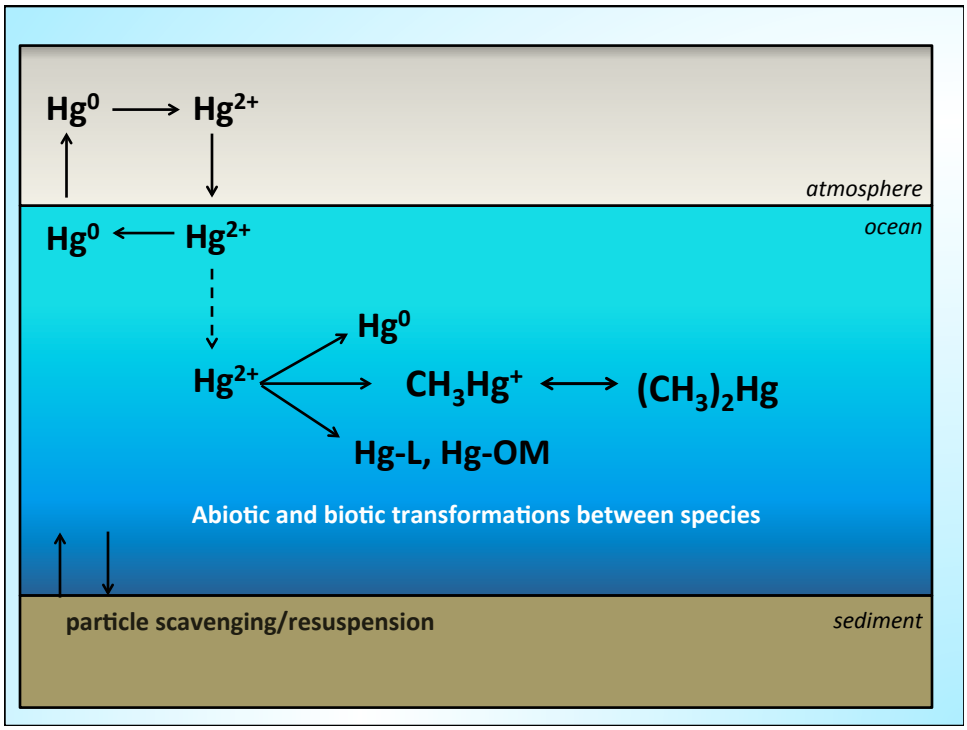


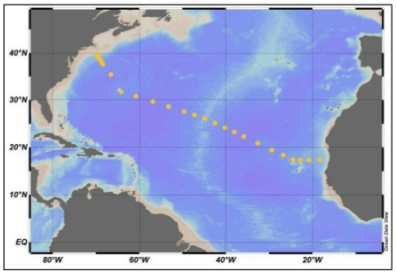
Figure 3.

Hayes et al., Deep-Sea Research II 116 (2015) 29–41

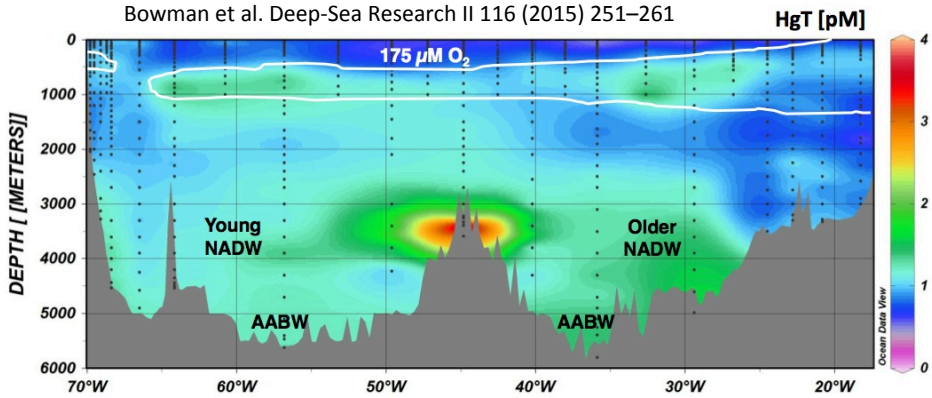


Total Hg

- Increase in OMZ (particle remineralization)
- Scavenging near Africa (dust, upwelling)
- Horizontal enrichment in NADW
- **13 pM** in hydrothermal vent plume



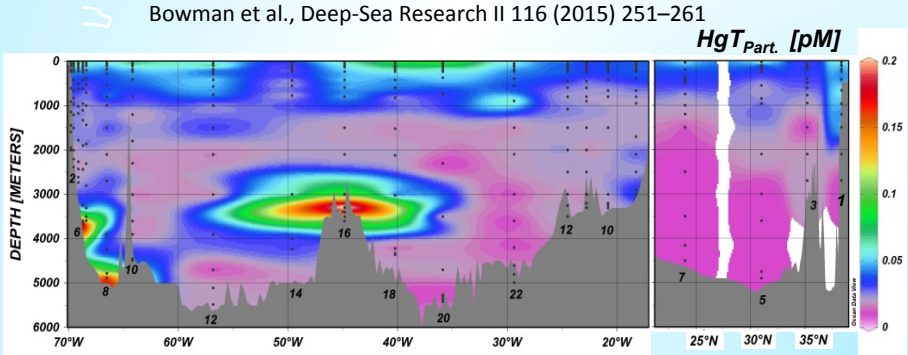
Bowman et al. Deep-Sea Research II 116 (2015) 251–261



Particulate Total Hg

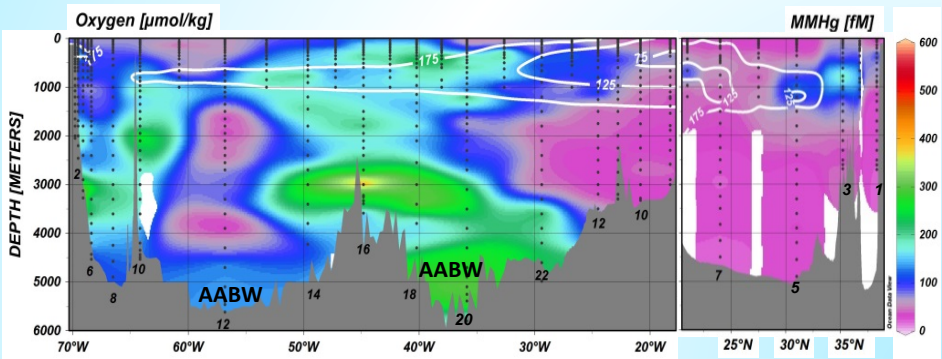
- Suspended particles (1-51 µm)
- 10 ± 5% HgT in surface
- Generally <0.1 pM HgT
- Elevated in benthic nephloid layers

Bowman et al., Deep-Sea Research II 116 (2015) 251–261



Filtered MMHg

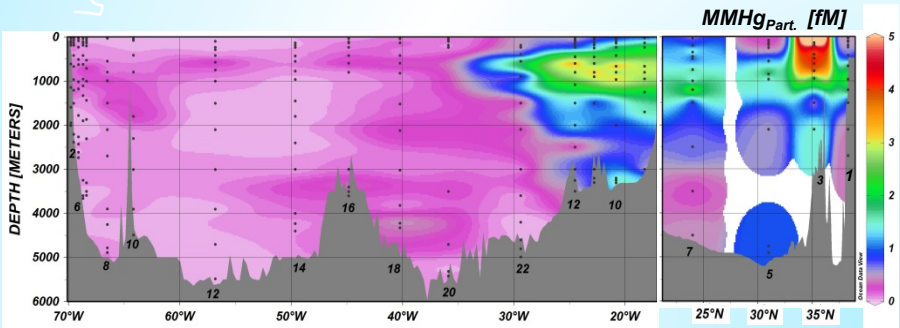
- Maxima at OMZ, subsurface maxima central Atlantic
- No correlation with AOU or O_2, maxima in 40 to 220 µmol kg^{-1} O_2 water
- No increase at sediment-water interface
- Elevated at northwest Atlantic slope and near Bermuda
- AABW enrichment, no enrichment in MOW or NADW



Particulate MMHg

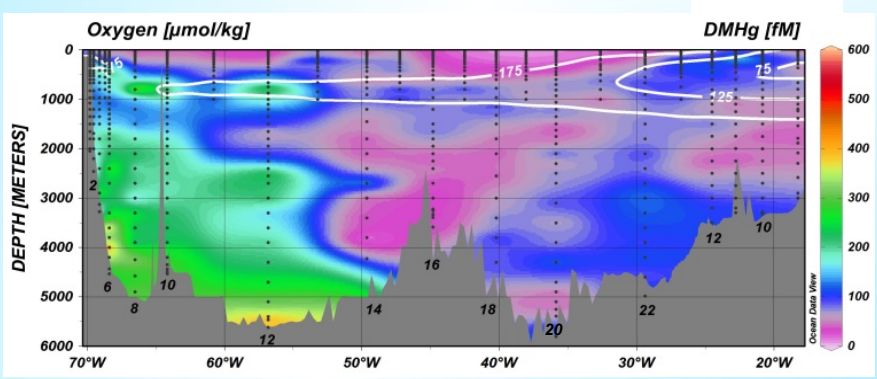
- Suspended particles (1-51 µm), 80% of particle mass
- Low MMHg (0.82 ± 1.4 fM MMHg)
  - Particles should have little impact on MMHg in water column
- Particle and filtered maxima at same depths

Bowman et al., Deep-Sea Research II 116 (2015) 251–261



Dimethylmercury

- Absent at surface (evasion), maxima at OMZ
- Distribution independent of MMHg
- Elevated in young NADW, decreases with age
- DMHg production during deep water formation

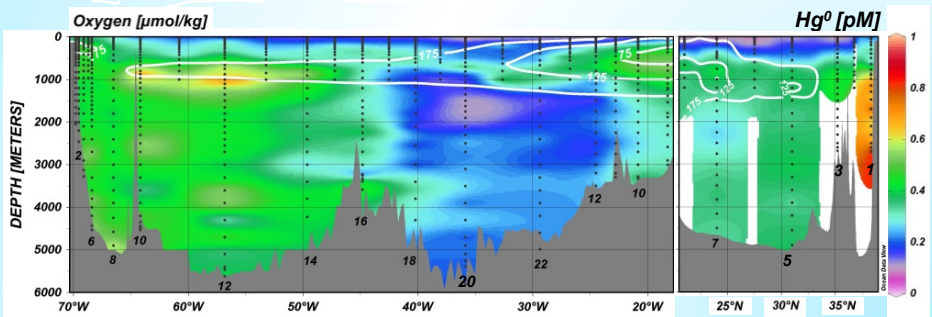


Bowman et al., Deep-Sea Research II 116 (2015) 251–261

Elemental Hg

Bowman et al., Deep-Sea Research II 116 (2015) 251–261

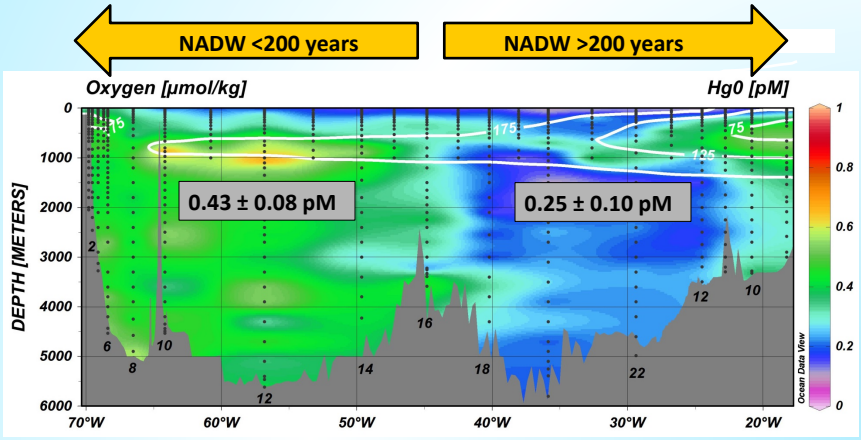
- Increase at OMZ
- Nutrient-like profiles near continents, similar to NO_3
- No nutrient-like profiles >900 km from land
- Microbial production different in open-ocean versus coastal?
- ↑ western basin, ↓ eastern basin



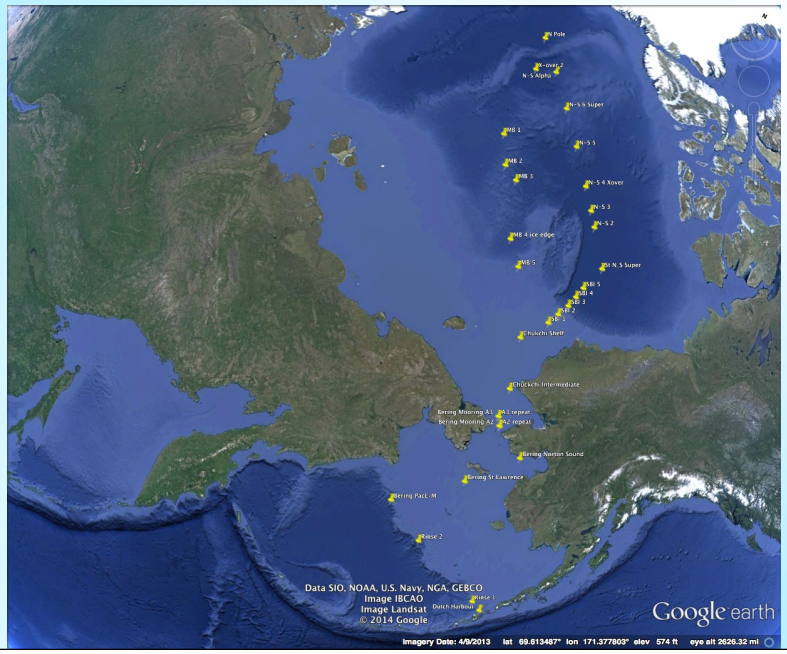
Anthropogenic Hg

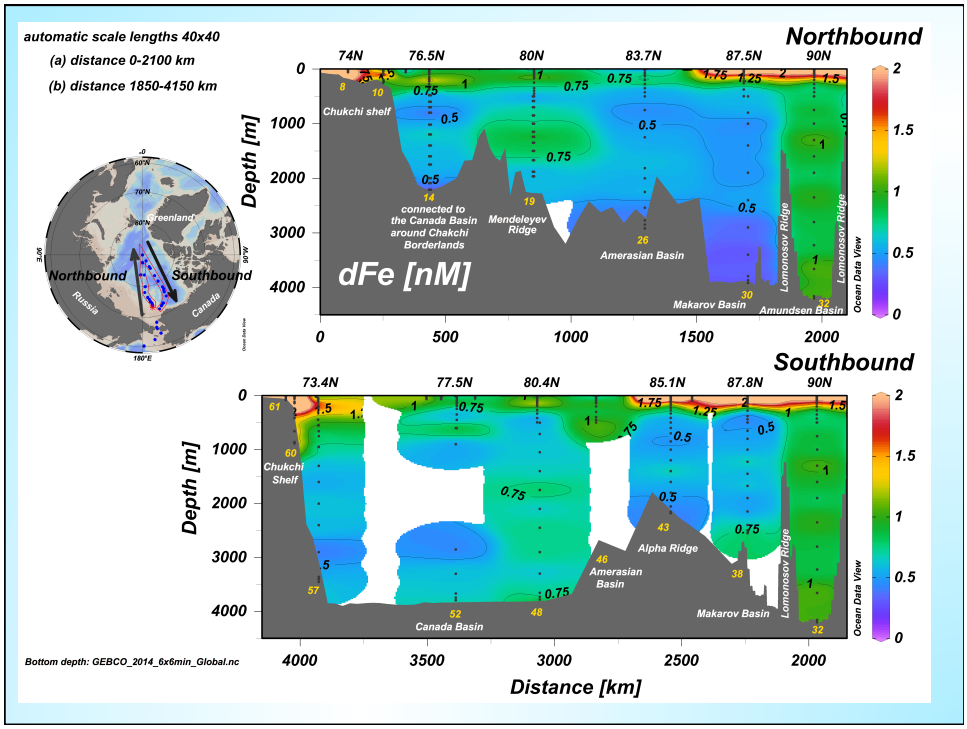
- Significantly more HgT and Hg^0 in NADW <200 years old in western Atlantic
  (t-test, p<0.001)
- **2x** Hg^0, **1.3x** HgT

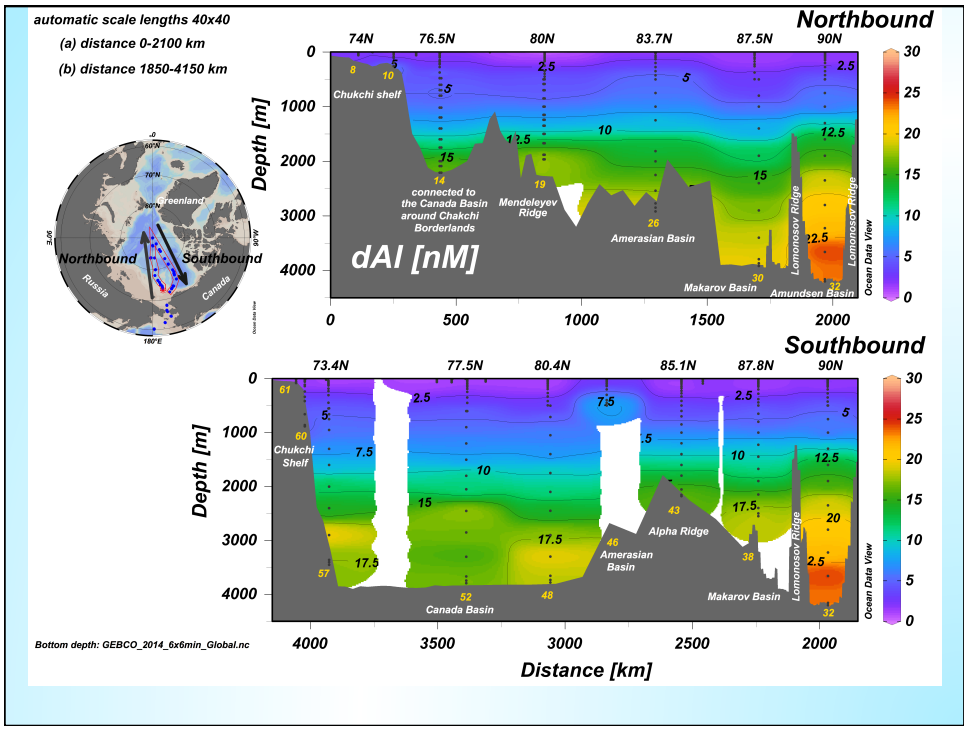
Bowman et al., Deep-Sea Research II 116 (2015) 251–261

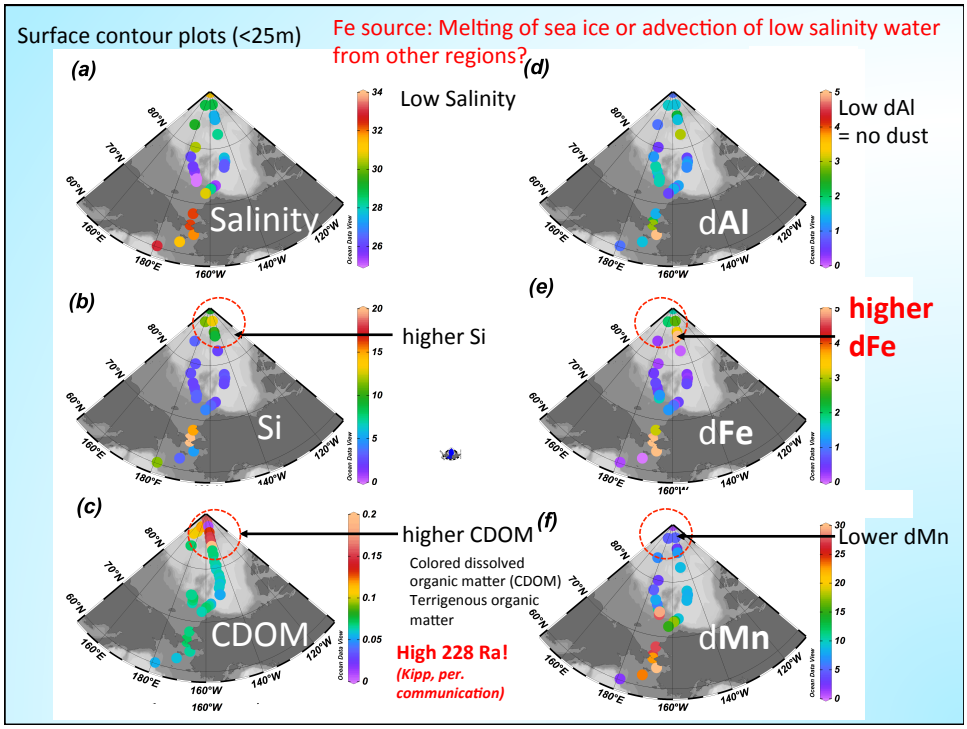


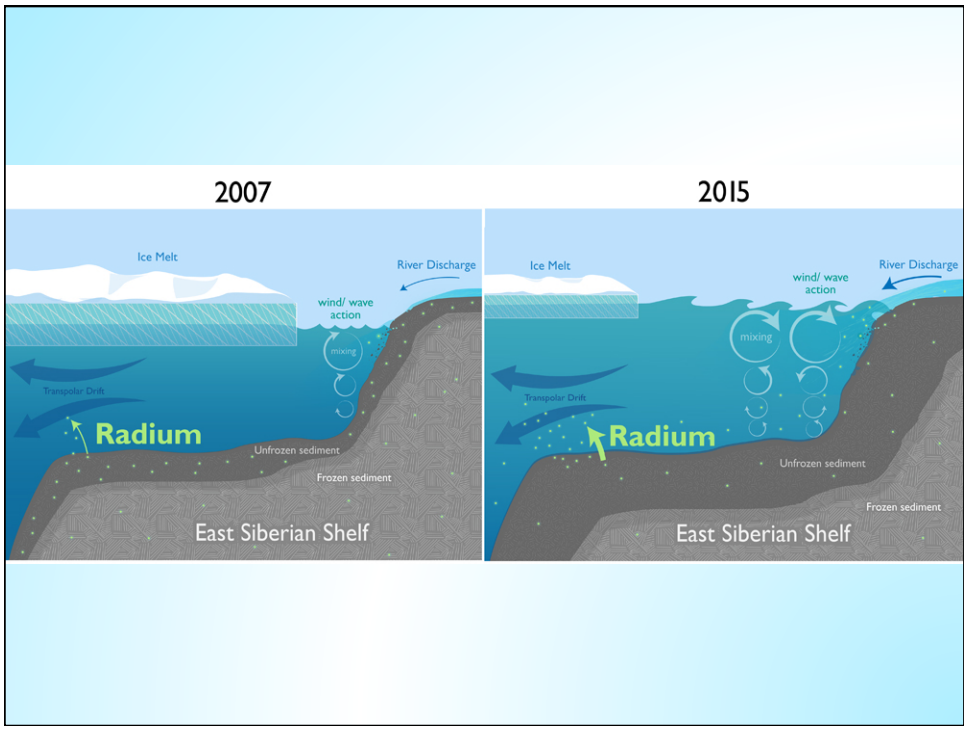
Arctic section August 9-October 12, 2015




automatic scale lengths 40x40
(a) distance 0-2100 km
(b) distance 1850-4150 km
Northbound
Southbound
Greenland
Russia
Canada
Chukchi shelf
connected to the Canada Basin around Chakchi Borderlands
Mendeleyev Ridge
Amerasian Basin
Lomonosov Ridge
Makarov Basin
Amundsen Basin
dFe [nM]
Depth [m]
Ocean Data View
Chukchi Shelf
Alpha Ridge
Canada Basin
Bottom depth: GEBCO_2014_6x6min_Global.nc
Distance [km]


automatic scale lengths 40x40
(a) distance 0-2100 km
(b) distance 1850-4150 km
Northbound
Southbound
Greenland
Russia
Canada
Chukchi shelf
connected to the Canada Basin around Chakchi Borderlands
Mendeleyev Ridge
Amerasian Basin
Lomonosov Ridge
Makarov Basin
Amundsen Basin
dAl [nM]
Depth [m]
Ocean Data View
Chukchi Shelf
Alpha Ridge
Canada Basin
Bottom depth: GEBCO_2014_6x6min_Global.nc
Distance [km]


Surface contour plots (<25m)
Fe source: Melting of sea ice or advection of low salinity water from other regions?
(a)
Salinity
Low Salinity
(d)
dAl
Low dAl
= no dust
(b)
Si
higher Si
(e)
dFe
higher dFe
(c)
CDOM
higher CDOM
Colored dissolved organic matter (CDOM)
Terrigenous organic matter
High 228 Ra!
(Kipp, per. communication)
(f)
dMn
Lower dMn


2007
2015
Ice Melt
River Discharge
wind/ wave action
mixing
Transpolar Drift
Radium
Unfrozen sediment
Frozen sediment
East Siberian Shelf