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:
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
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., DSR II in press
Jenkins et al., DSR II in press

North Atlantic Central Water (%)

Mediterranean Outflow Water (%)

Antarctic Intermediate Water (%)

Antarctic Bottom Water (%)

Upper Labrador Sea Water (%)

Irminger Sea Water (%)

Central Labrador Sea Water (%)

Iceland Scotland Overflow Water (%)

Jenkins et al., DSR II in press
Jenkins et al., DSR II in press

Dissolved Al

Measures et al., DSR II in press
MADCOW model for calculating dust deposition

**DUST FLUX**

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

\( D = 3000 \ \mu\text{mol(AI g dust)}^{-1} \)

\( S = 1.5-5\% \ \text{AI Solubility} \)

\( [\text{AI}] \ \text{mol L}^{-1} \)

\( F = \text{Fractional Scavenging} \ 0.2 \ \text{yr}^{-1} \)

**MODEL ASSUMPTIONS**

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

From M Grand

Measures and Vink, 2000

Dissolved AI in surface waters with the surface water vectors overlaid

Measures et al., DSR II in press
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.
HNLC regions mostly correspond to low dust deposition regions.

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

Paleo records suggest large variations in dust deposition correspond to atmospheric CO$_2$ variations.
Global dust deposition patterns from CLIVAR Al data

$\text{gm mineral dust m}^{-2} \text{ yr}^{-1}$

Southern Ocean very limited deposition

Mineral dust deposition $g \text{ m}^{-2} \text{ yr}^{-1}$
Dissolved Fe (<2.5nM) 

Hatta et al., DSR II in press
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., DSR II, in press

Dissolved Mn  Hatta et al., DSR II in press
Greater particle flux at margins

Th preferentially scavenged Dissolved Pa/Th ratio higher
Highest ratio at margin

Lateral flux of Pa towards margins

Hayes et al., DSR II in press
Abiotic and biotic transformations between species

Hg$^0$ $\rightarrow$ Hg$^{2+}$

Hg$^0$ $\rightarrow$ Hg$^{2+}$ $\rightarrow$ CH$_3$Hg$^+$ $\leftrightarrow$ (CH$_3$)$_2$Hg

Hg-L, Hg-OM

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., DSR II in press
Particulate Total Hg

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

Filtered MMHg

- Maxima at OMZ, subsurface maxima central Atlantic
- No correlation with AOU or O₂, maxima in 40 to 220 μmol kg⁻¹ O₂ 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

**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
Elemental Hg

- 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
GEOTRACES sections are starting to change the way we view the oceans

Data synthesis and modelling workshops are being planned

UK December, 2015 — fluxes from boundaries
US Summer, 2016 — internal recycling processes

US has completed a Pacific section as well

An Arctic section is planned for August, 2015