Trace element composition, solubility & flux estimates of aerosols from contrasting regions of the North Atlantic Ocean (GEOTRACES, GA01 & AWA project, offshore Senegal)

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SOLAS-France 2015 Open Meeting
Institut de Physiques du Globe de Paris
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Background image credit: http://coastal.er.usgs.gov/african_dust/documentary.html

Contrasting study regions

- UPSEN-2 (Feb. 2013)
- ECOAO (Mar. 2013)
- AWA (Mar. 2014)

GEOVIDE (15/05-30/06/2014)

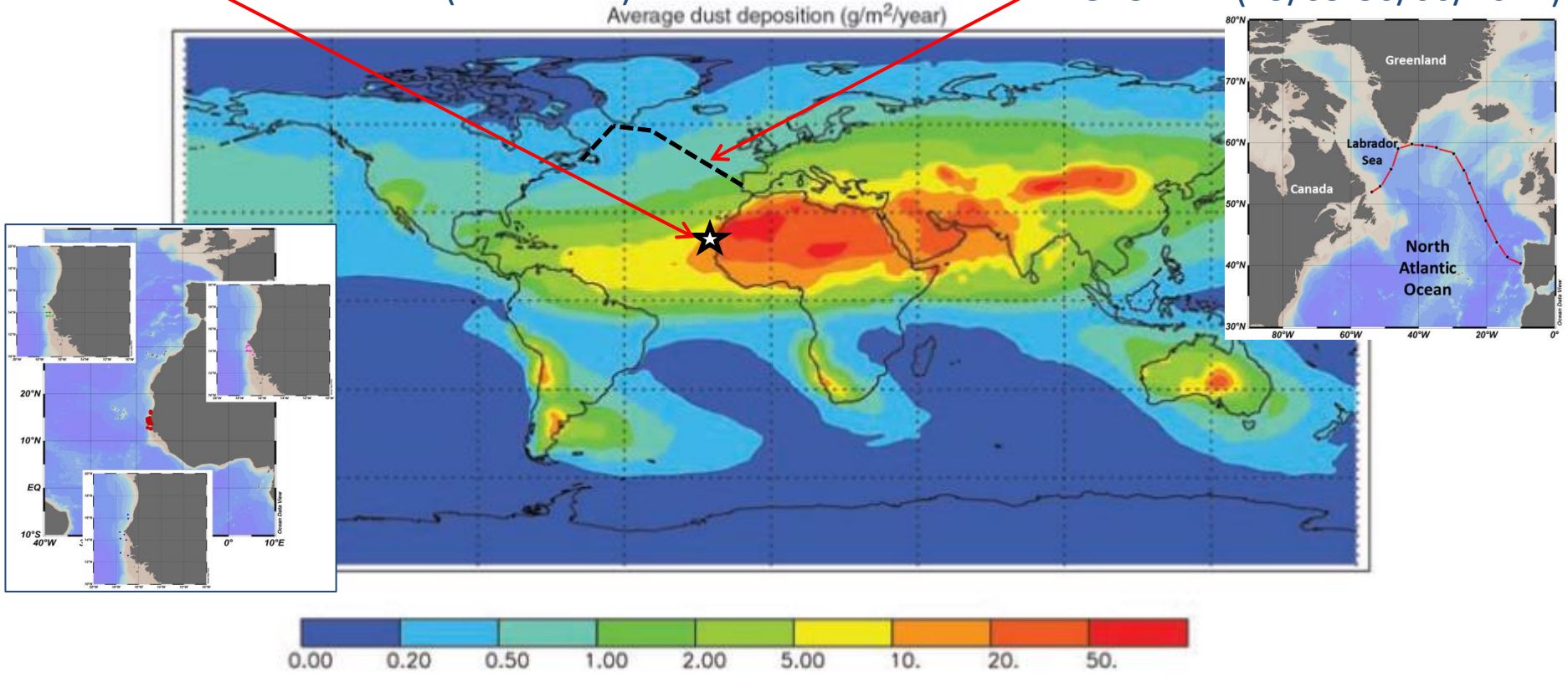
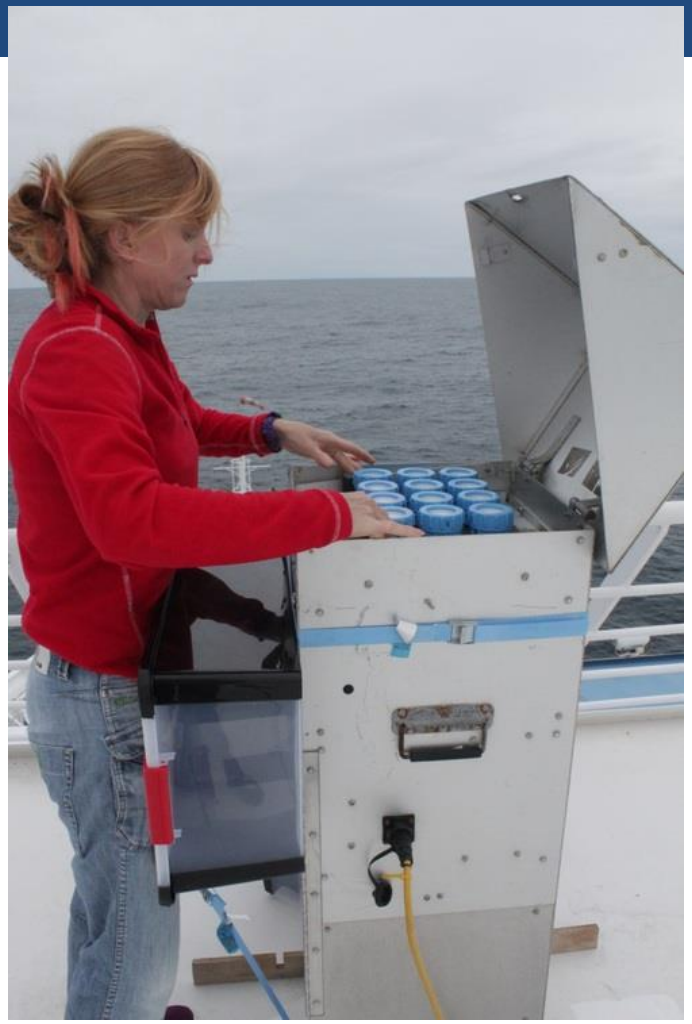


Image: Jickells et al. (2005)

Aerosol sampling



Aerosol trace element (TE) fractions

Total aerosol TEs

Digestion: HNO_3 + HF at 150 °C (Morton et al., 2013)

Leach 1: Labile, soluble TEs

Flow-through leach: UHP water

Soluble = < 0.45 µm (Buck et al., 2006)

Leach 2: Oxide/ carbonate fraction

Batch leach: 25 % HAc + reducing agent + heat (Berger et al., 2008)

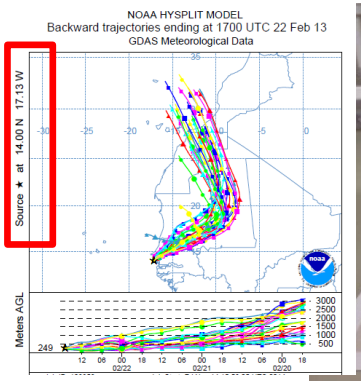
$$Sol\ \% = \frac{[TE_{Sol}]}{[TE_{Total}]} * 100$$

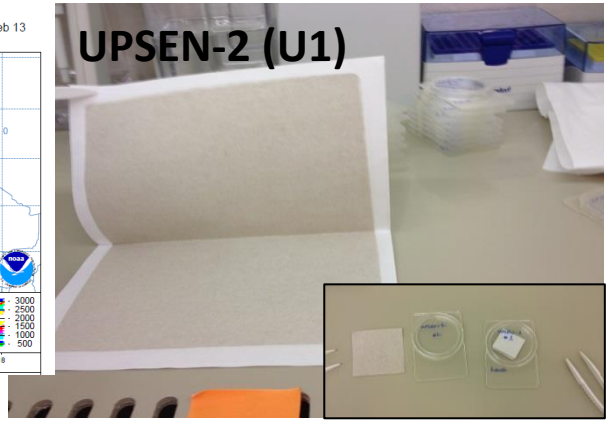
Aerosol TE solubility

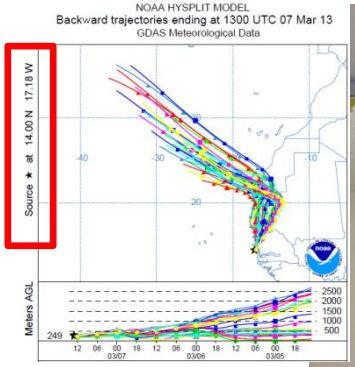
- Operationally-defined
- Fe solubility key parameter in models
- Analogue for bioavailability
- <0.1 - >90% ***!!!***

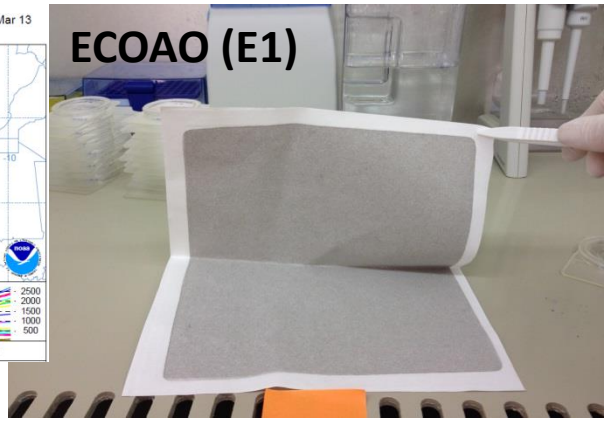
Leach 1 + leach 2

- Upper limit of aerosol TE solubility
- Comparisons with SPM solubility

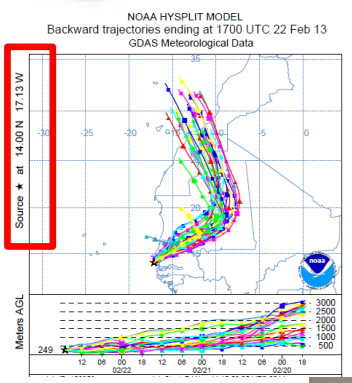


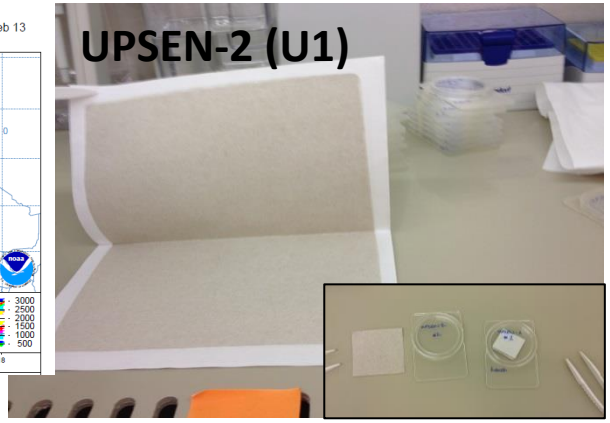


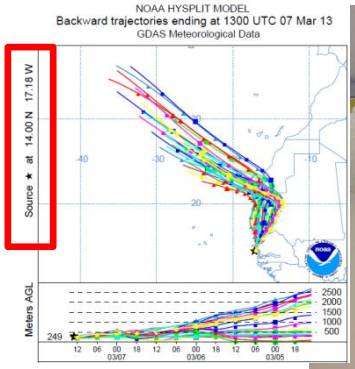


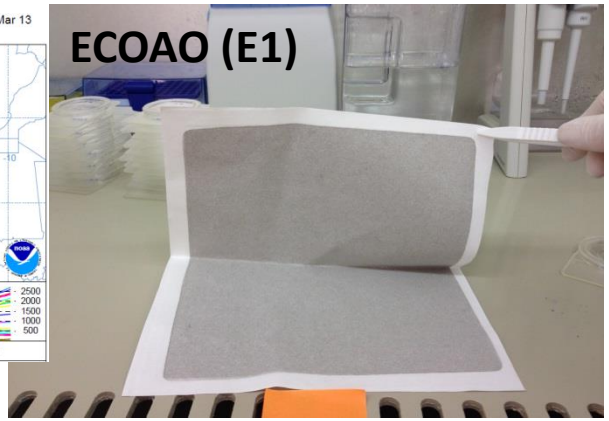


AWA cruises: Visible differences between aerosols with Saharan trajectories (top) and those without (bottom)









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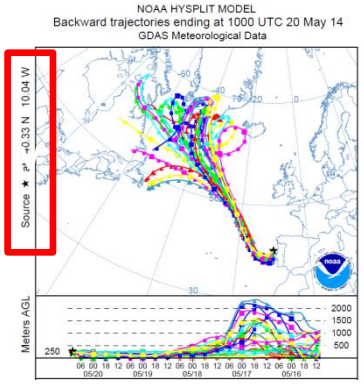
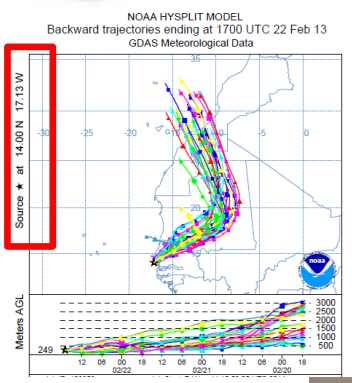
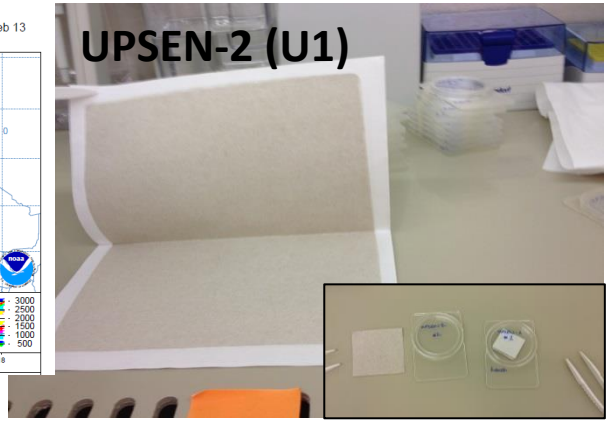
GEOVIDE
An international GEOTRACES study along the OVIDE section in the North Atlantic and Labrador Sea

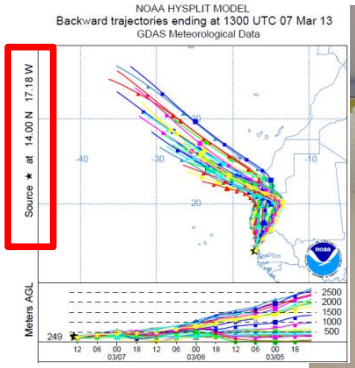


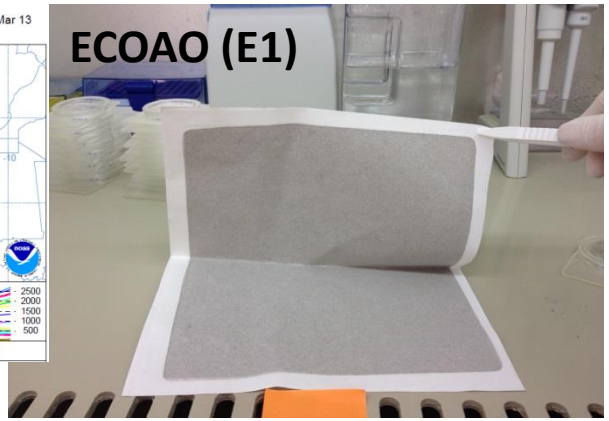
GEOVIDE:

- Sampled air masses with N-NW back trajectories
- Filters had very low aerosol loading









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GEOVIDE
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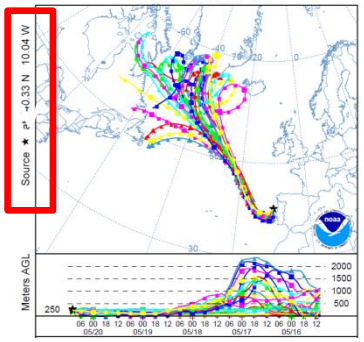
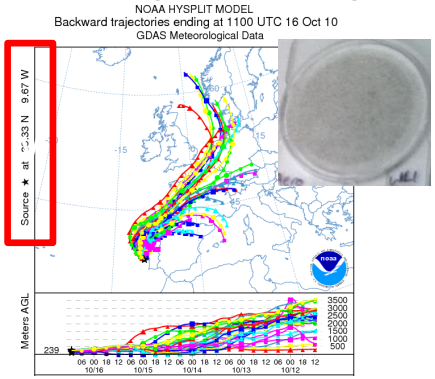
GEOVIDE, GA01 (20/05/14)



US-GEOTRACES, GA03 (16/10/10)



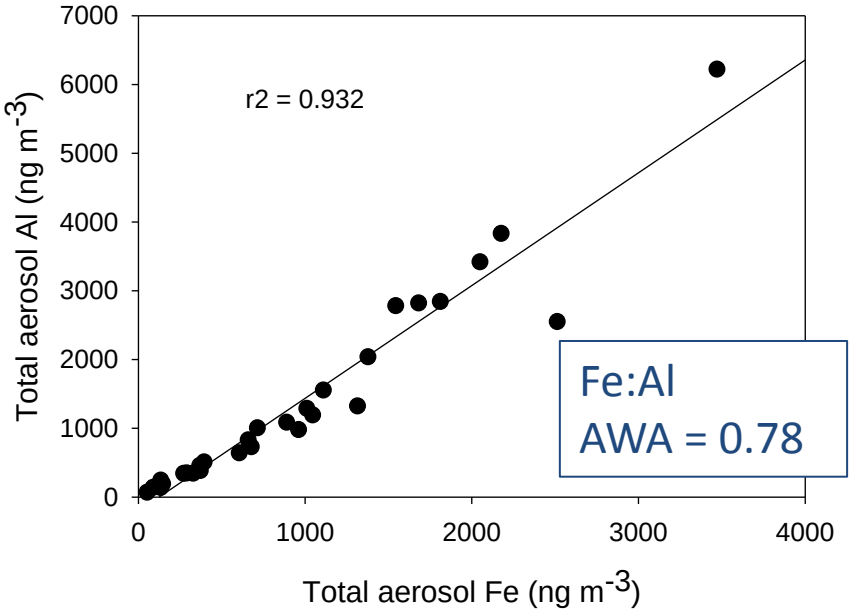
Aerosols collected near Lisbon differed visibly, dependent on air mass back trajectory

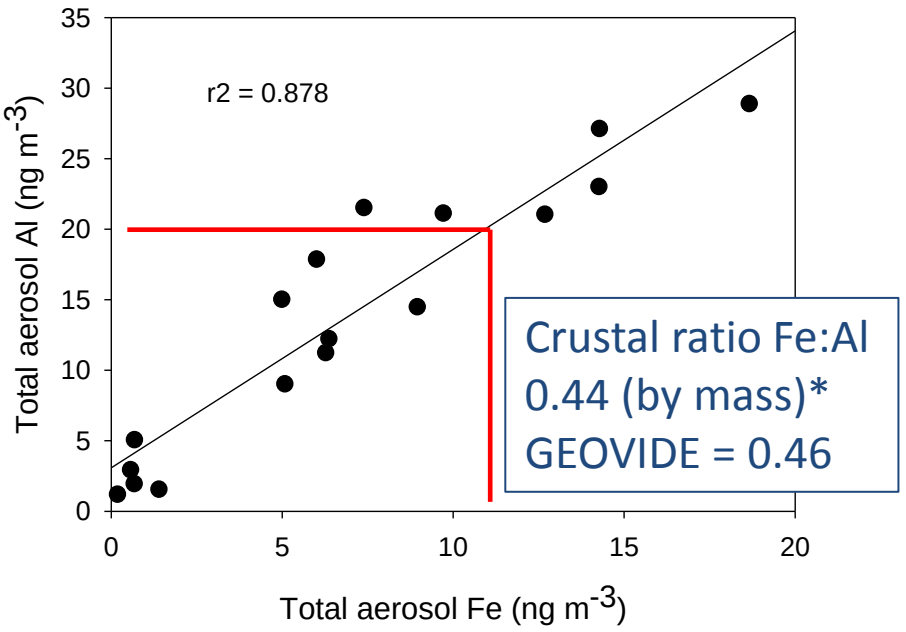
GEOVIDE:

- Sampled air masses with N-NW back trajectories
- Filters had very low aerosol loading

labex MER

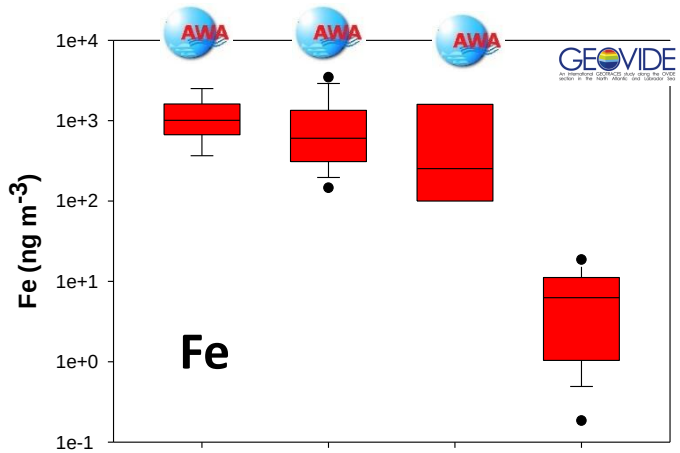
Total aerosol Fe vs Al

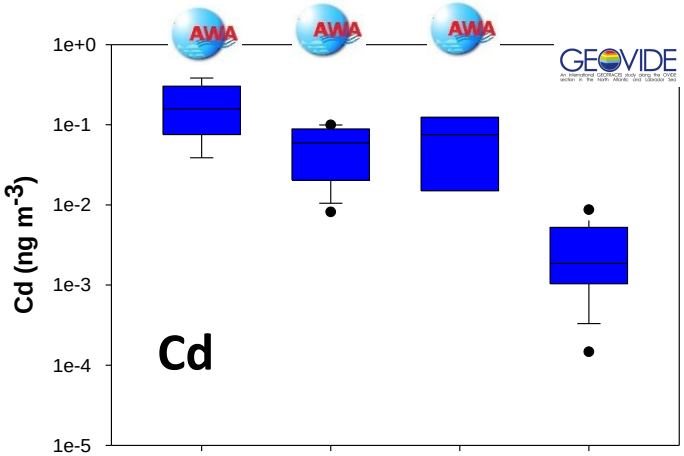


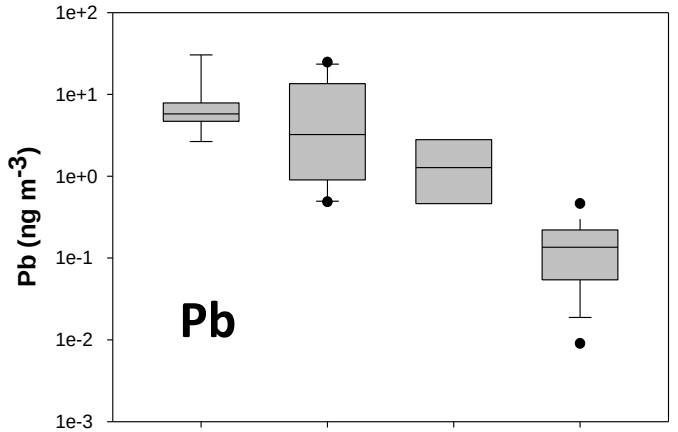


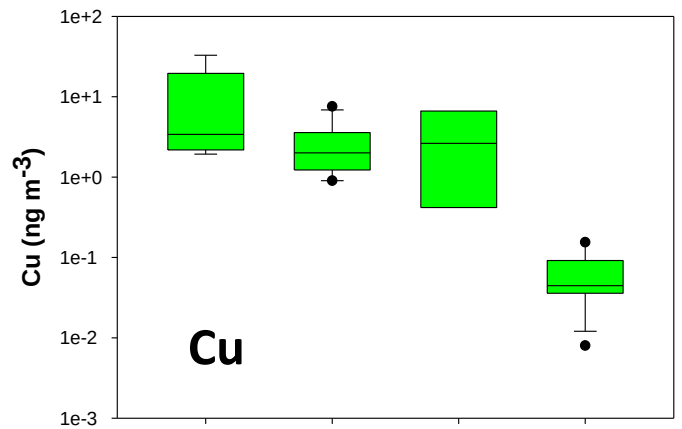
*= Taylor & McLennan (1995)

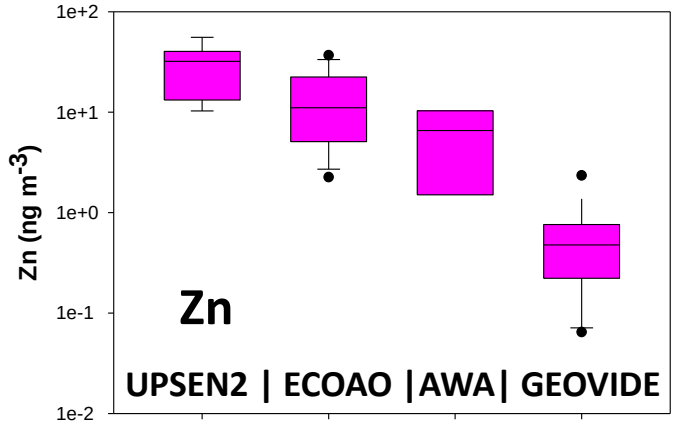
- Al is a proxy for total aerosol deposition
  - AWA had high aerosol deposition relative to GEOVIDE
- Strong correlation between Al & Fe – suggests common source(s) – 3rd & 4th most abundant crustal elements, respectively
- GEOVIDE Fe:Al ≈ crustal; AWA ≈ 'Saharan'

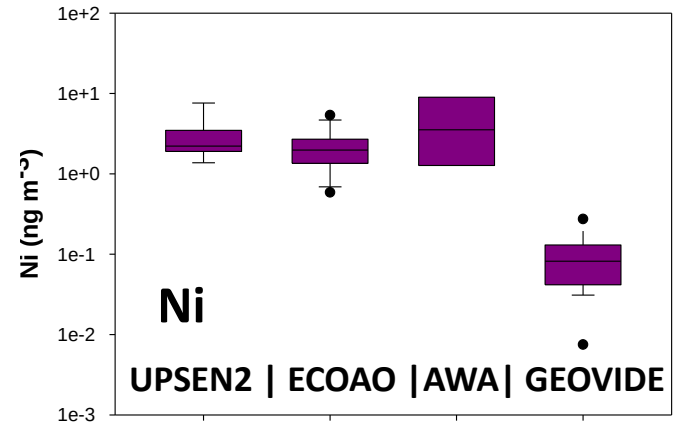






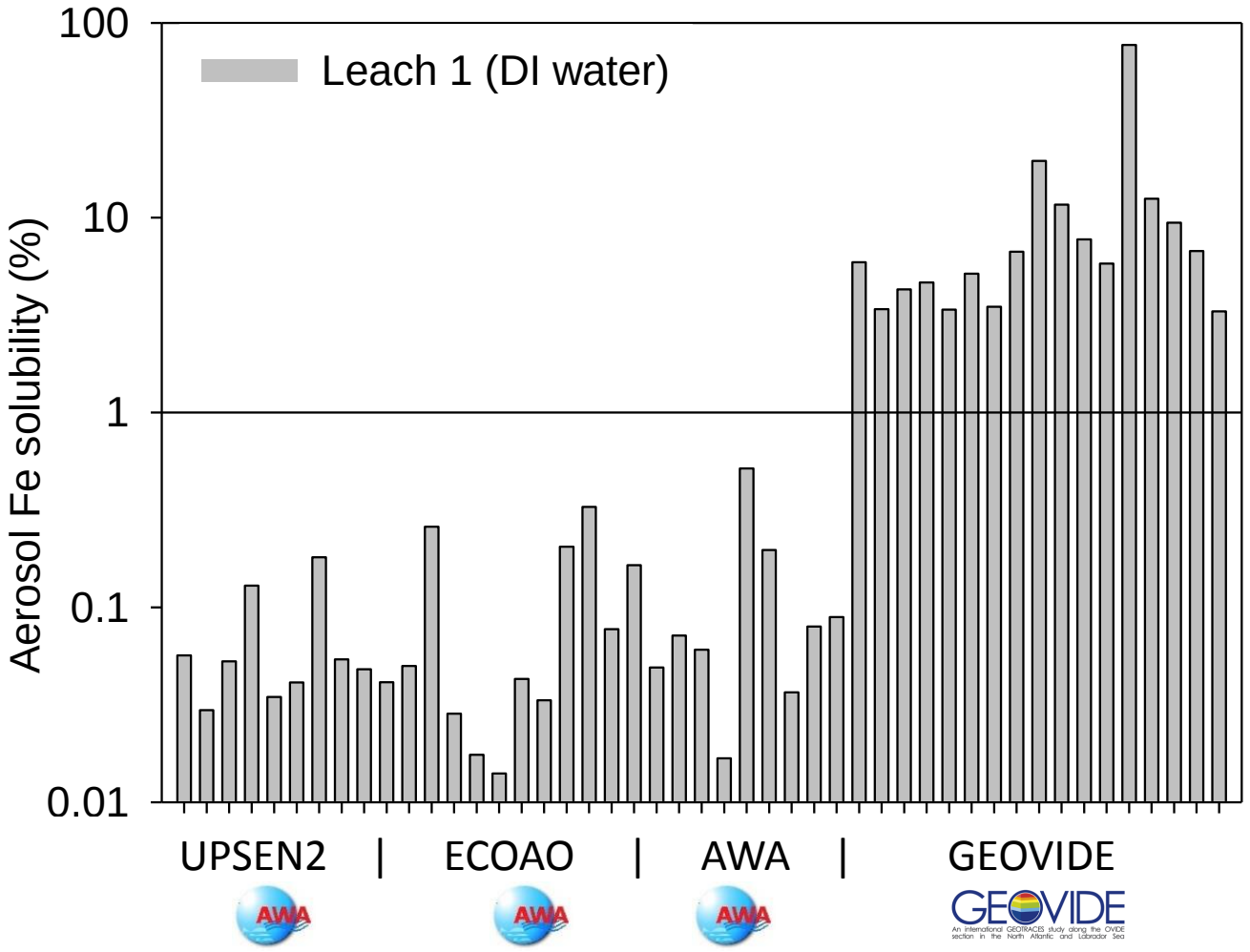






- No significant difference between metal concentrations for *AWA* cruises
- *GEOVIDE* metals are significantly different to *AWA* at $p = 0.01$ level
- *AWA* cruises: Similar Fe concentrations - prevalence of Saharan dust
- Similar 'pollution-derived' metal concentrations - brown dust is not pure end member Saharan dust

Fraction solubility (aerosol Fe)



AWA

DI soluble:

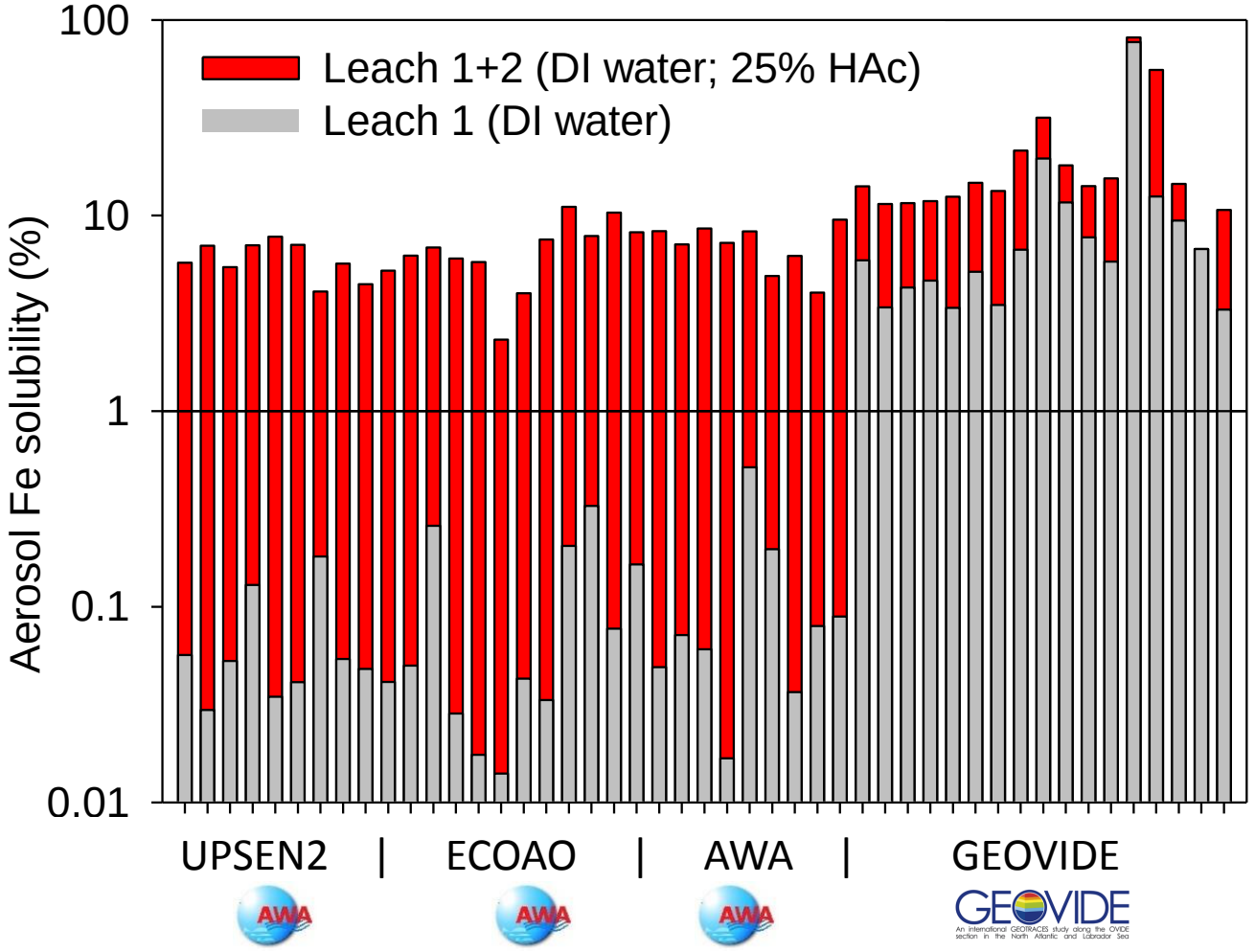
0.01-0.52%

GEOVIDE

DI soluble:

3.3-20% (77%)

Fraction solubility (aerosol Fe)



AWA

DI soluble:

0.01-0.52%

HAc soluble:

2.3-11%

GEOVIDE

DI soluble:

3.3-20% (77%)

HAc soluble:

6.7-32%

Aerosol deposition flux estimation

Dry deposition flux

$$F_{dry} = C_a \times V_d$$

C_a = concentration in aerosol
V_d = deposition velocity

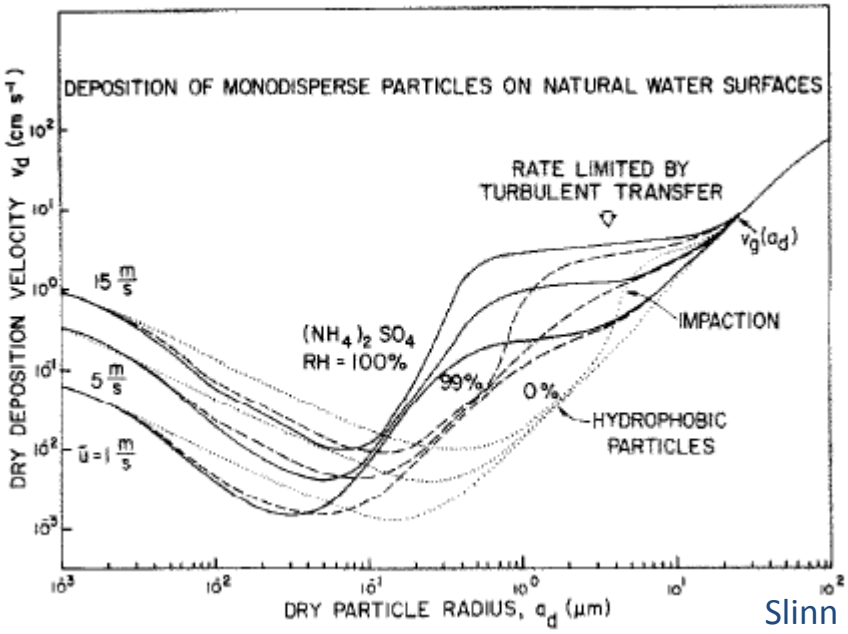
Aerosol deposition flux estimation

Dry deposition flux

$$F_{dry} = C_a \times V_d$$

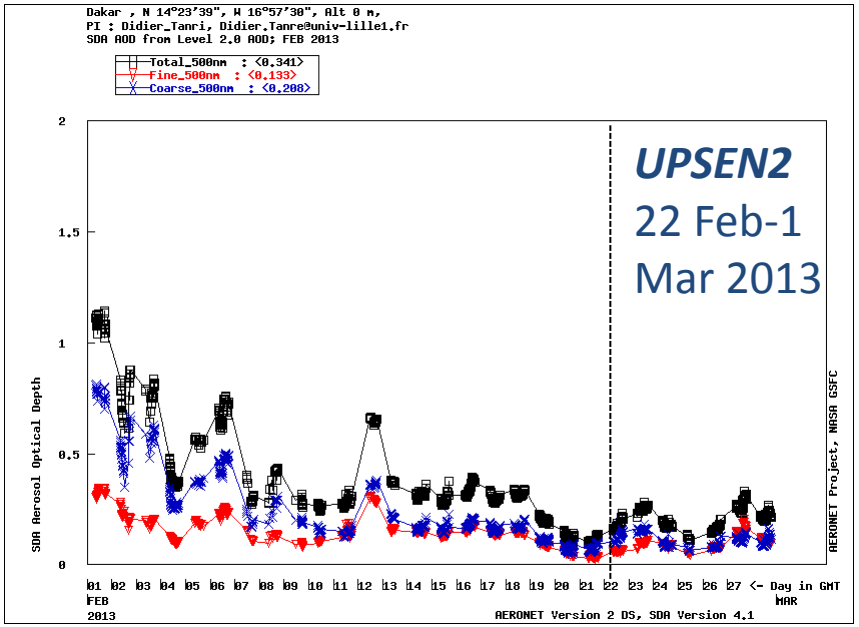
C_a = concentration in aerosol
V_d = deposition velocity

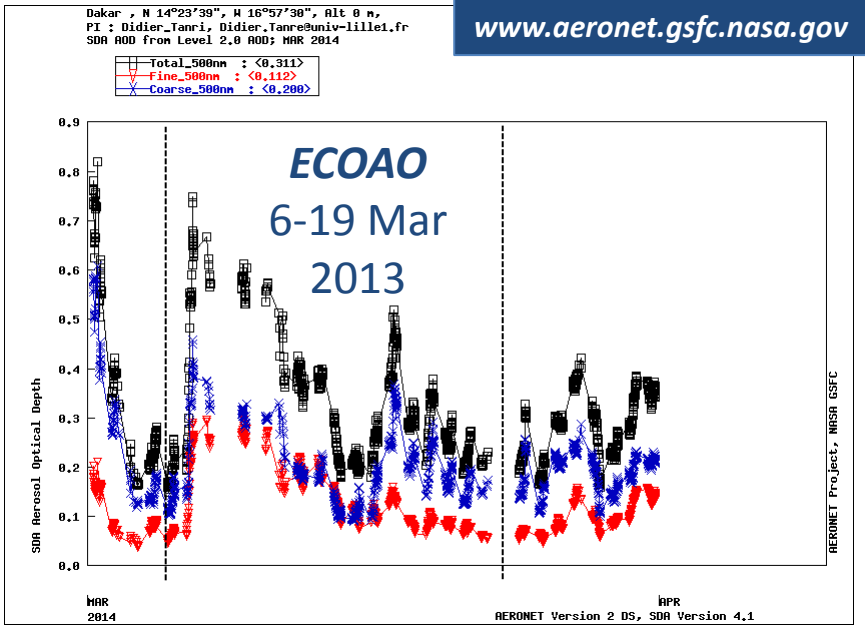
- Wind speed
- Relative humidity
- Particle size
- Particle type

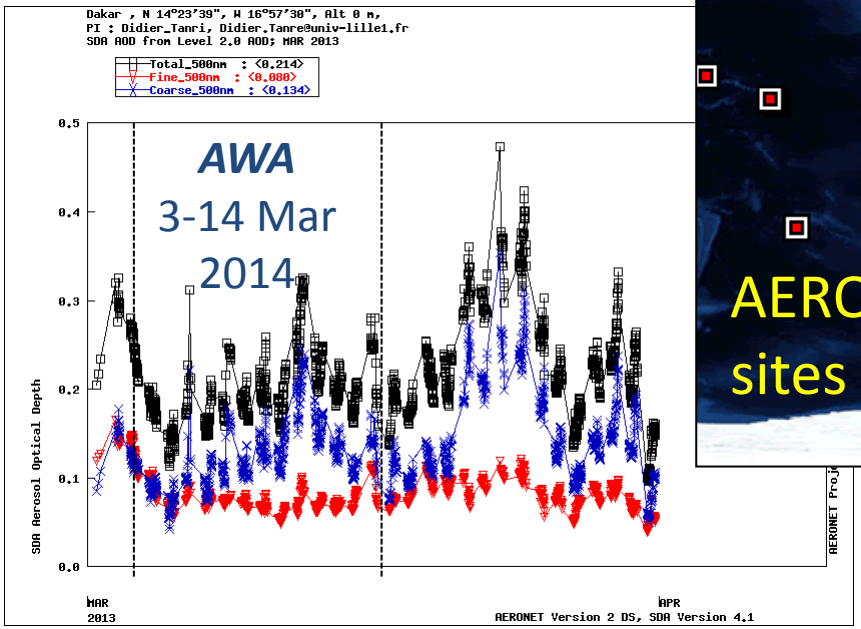


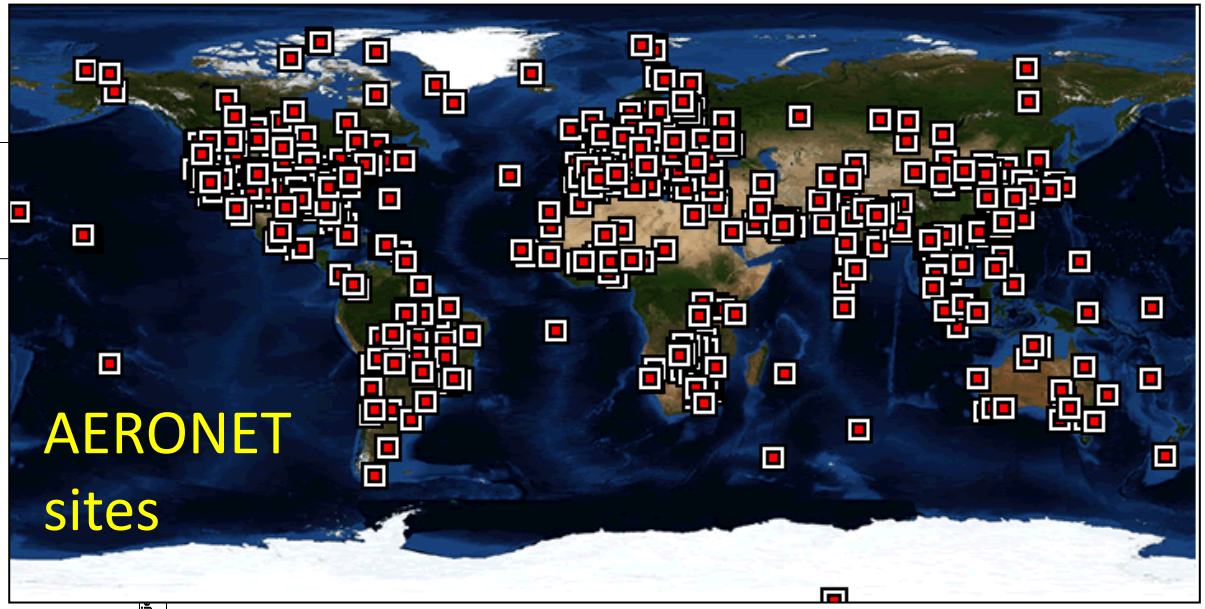
Slinn & Slinn (1980)

www.aeronet.gsfc.nasa.gov

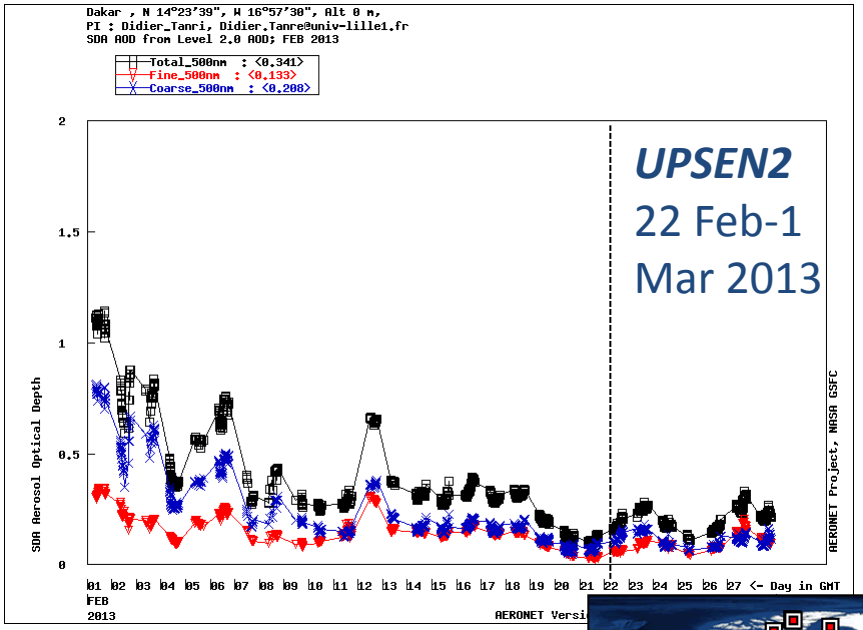


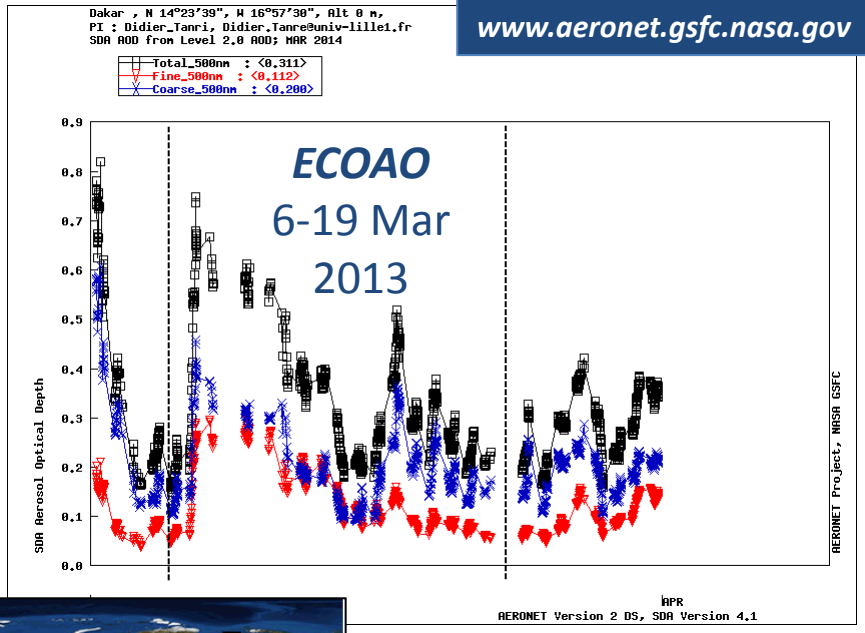


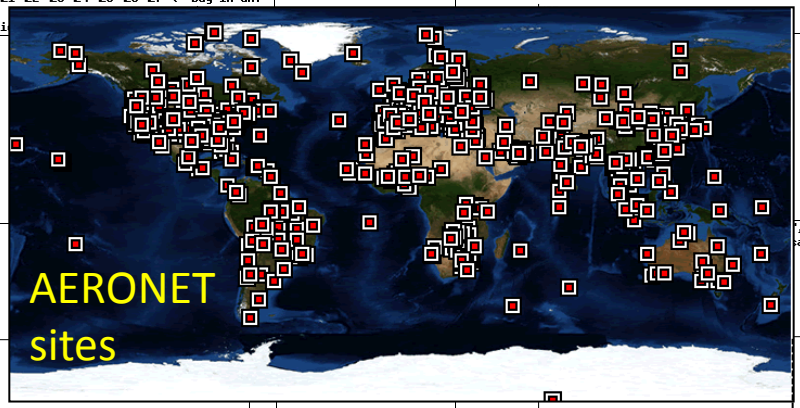


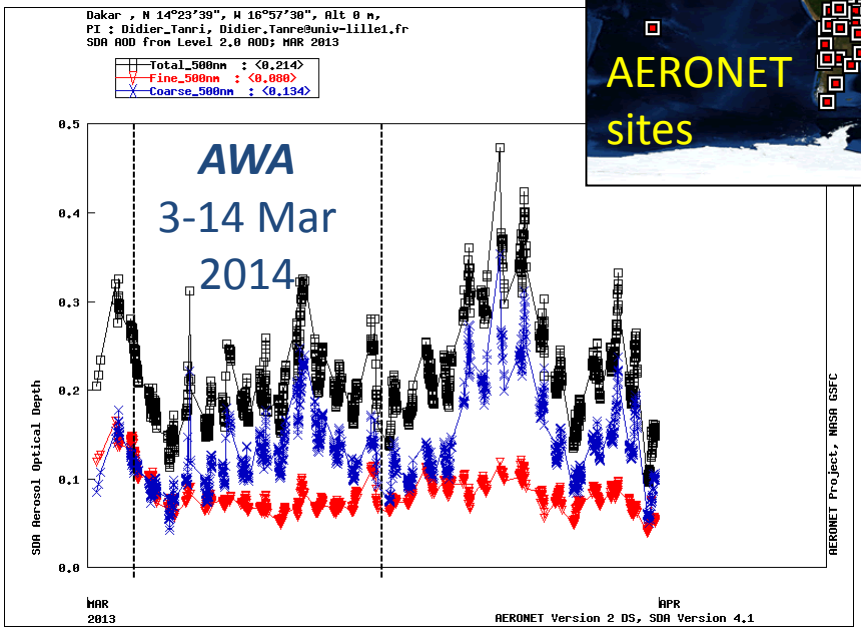


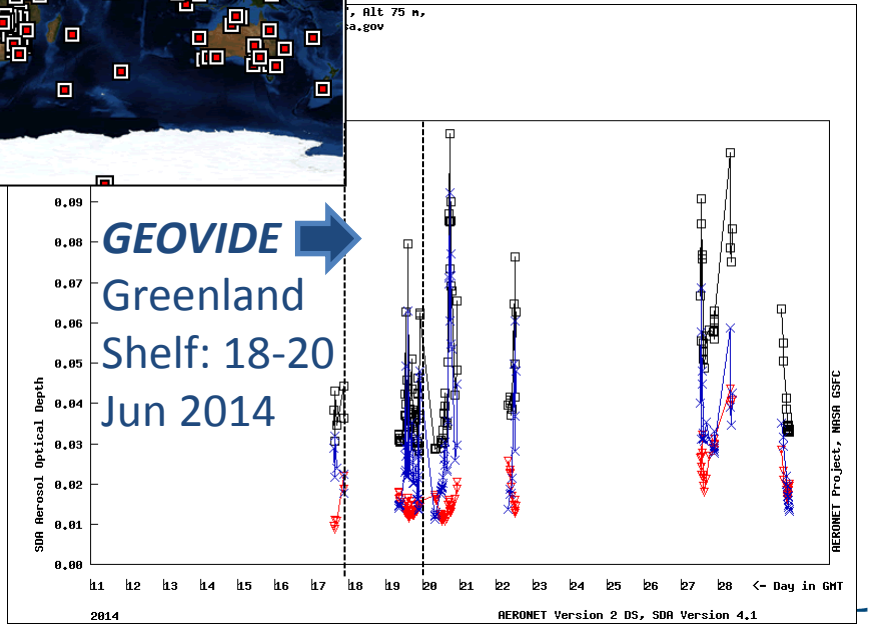
www.aeronet.gsfc.nasa.gov











Aerosol deposition flux estimation

Wet deposition flux

$$F_{wet} = C_r \times P_r \times S$$

C_r = concentration in rain
P_r = precipitation rate
S = scavenging ratio (200; Jickells & Spokes, 2001)

Aerosol deposition flux estimation…

…^{7}Be method

^{7}Be
- Cosmogenically-formed
- $T_{1/2}$ = 53.3 days

Total (wet + dry) flux*

$$F_{total,\,atmos} \cong F_{total\,Be7} \times \frac{C_a}{C_{Be7}}$$

C_a = concentration of metal in aerosol
C_a = concentration of ^{7}Be

* = Kadko et al. (2015)

Aerosol deposition flux estimation…

…^{7}Be method

^{7}Be

- Cosmogenically-formed
- $T_{1/2}$ = 53.3 days
- Tracer to estimate atmospheric deposition of metals analogous to ^{234}Th as a tracer of particle flux for estimating POC export from surface ocean

Total (wet + dry) flux

$$F_{total,\,atmos} \cong F_{total,Be7} \times \frac{C_a}{C_{Be7}}$$

$$F_{total,\,atmos} \cong \left[Ocean \sum Be7\right] \times \frac{C_a}{C_{Be7}}$$

C_a = concentration of metal in aerosol

C_a = concentration of ^{7}Be

Aerosol deposition flux estimation…

…^{7}Be method

Total (wet + dry) flux

Assumptions:

- As the open ocean is a low particle regime, $T_{1/2}$ of ^{7}Be is short & atmospheric inputs are relatively large, losses via particle scavenging assumed negligible (i.e. they are ignored)

Aerosol deposition flux estimation…

…^{7}Be method

Total (wet + dry) flux

$$\frac{F_{total,atmos}}{F_{total,Be7}} = \frac{C_a \times (P_r \times S \times \rho + V_d)_{atmos}}{C_{Be7} \times (P_r \times S \times \rho + V_d)_{Be7}}$$

C_a = concentration in aerosol (or ^{7}Be)
P_r = precipitation rate
S = Scavenging ratio ([rain]/[air])
ρ = ($denisty_{water}$/$density_{air}$ ≈ 833)
V_d = deposition velocity

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Aerosol deposition flux estimation…

…^{7}Be method

Total (wet + dry) flux

$$\frac{F_{total,aerosol}}{F_{total,Be7}} = \frac{C_a \times (P_r \times S \times \rho + V_d)_{aerosol}}{C_{Be7} \times (P_r \times S \times \rho + V_d)_{Be7}}$$

✓ C_a = concentration in aerosol (or ^{7}Be)

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C_a = concentration in aerosol (or ^{7}Be)

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V_d = deposition velocity

Assumptions:

- As the open ocean is a low particle regime, $T_{1/2}$ of ^{7}Be is short & atmospheric inputs are relatively large, losses via particle scavenging assumed negligible (i.e. they are ignored)
- For ^{7}Be, S is large (~400-600) & V_d is small (~0.1 cm s^{-1})
- For mineral dust, S is smaller (~150-300) & V_d is larger (~1 cm s^{-1})
  - → terms in brackets roughly cancel

Aerosol deposition flux estimation…

…^{7}Be method

Total (wet + dry) flux

$$\frac{F_{total,aerosol}}{F_{total,Be7}} = \frac{C_a}{C_{Be7}}$$

C_a = concentration in aerosol (or ^{7}Be)

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- For ^{7}Be, S is large (~400-600) & V_d is small (~0.1 cm s^{-1})
- For mineral dust, S is smaller (~150-300) & V_d is larger (~1 cm s^{-1})
  - → terms in brackets roughly cancel

Aerosol deposition flux estimation

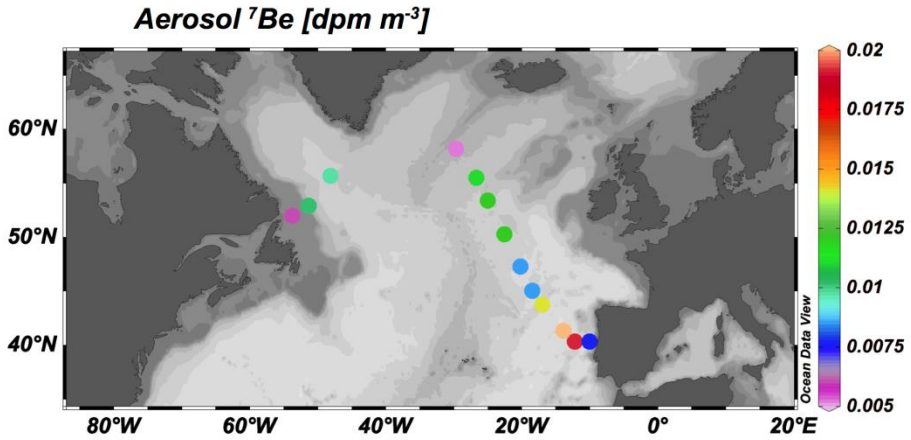
…^{7}Be method

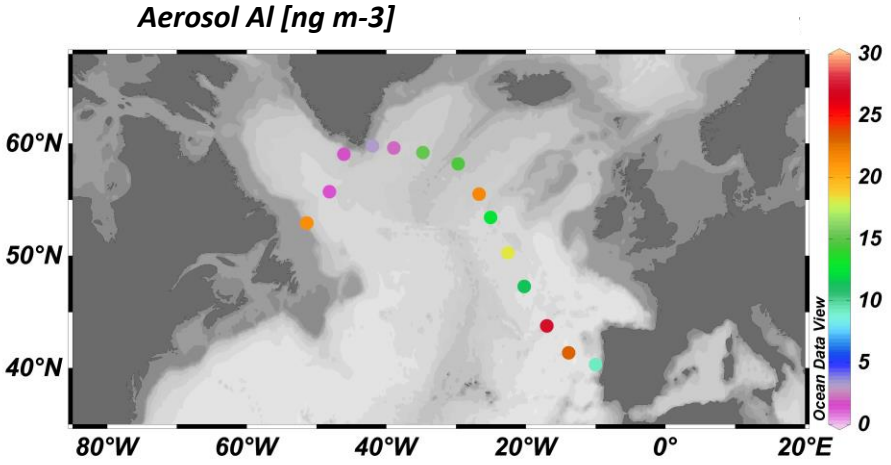
Total (wet + dry) flux

$$F_{total,\,aerosol} \cong F_{total,Be7} \times \frac{C_a}{C_{Be7}}$$

Aerosol deposition flux estimation…

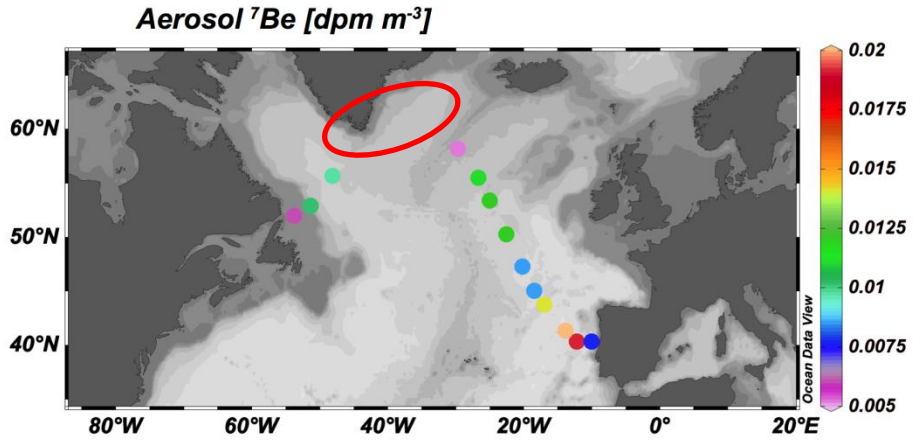
…^{7}Be method

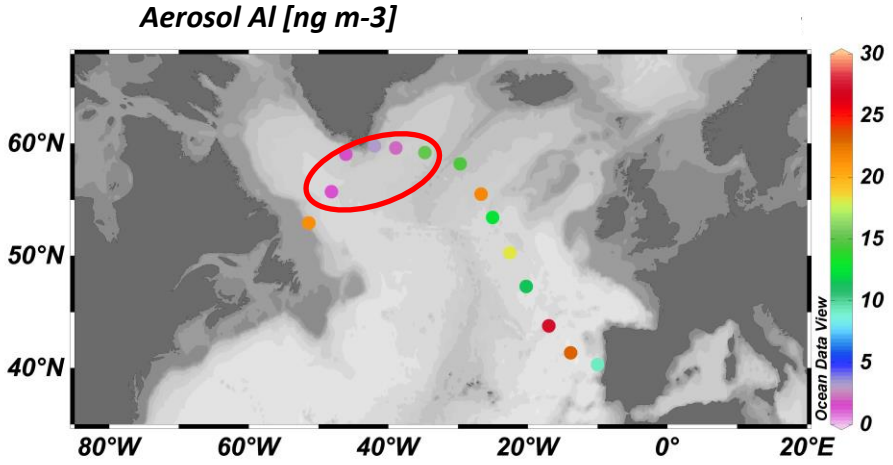




Aerosol deposition flux estimation…

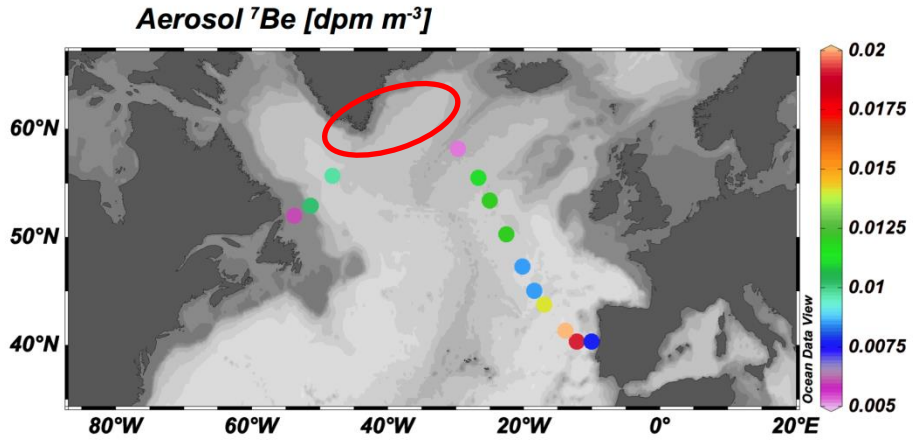
…^{7}Be method

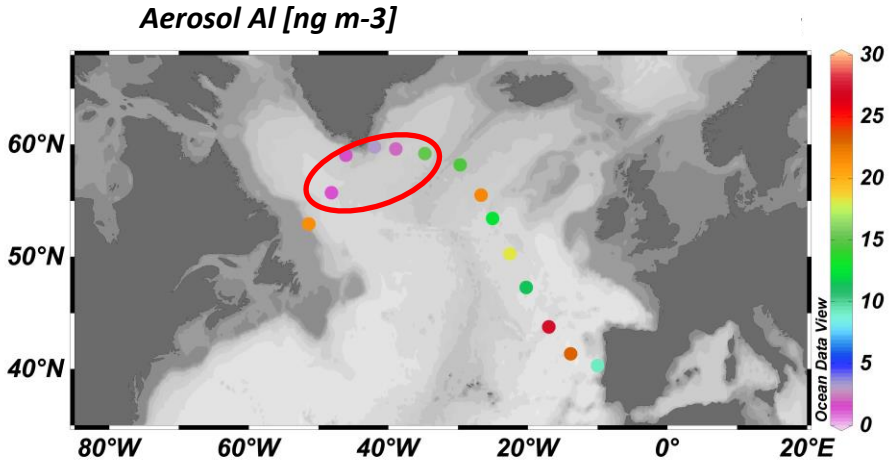


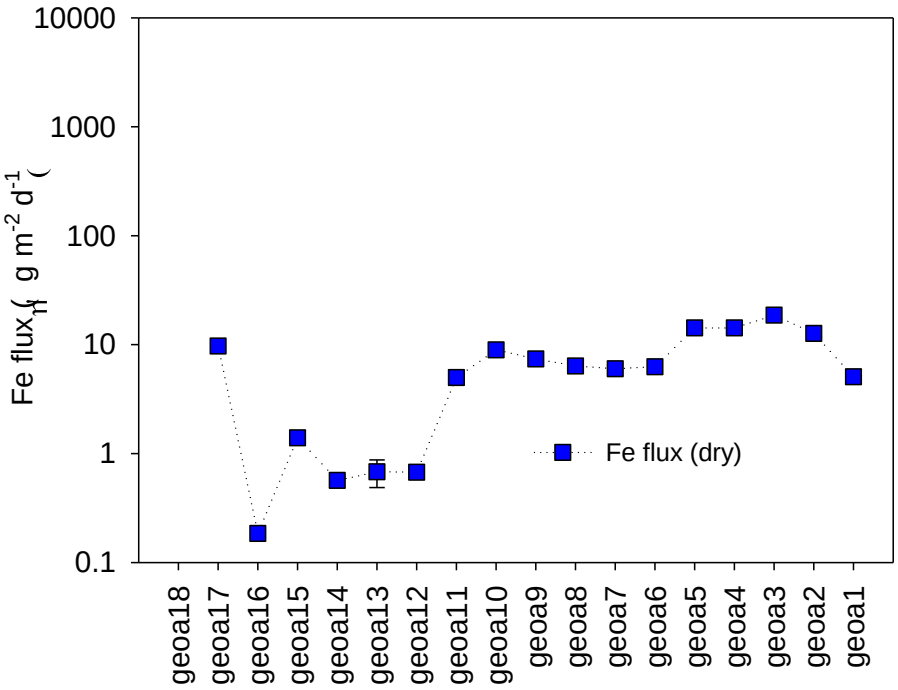


Aerosol deposition flux estimation…

…^{7}Be method vs ‘classic’ method

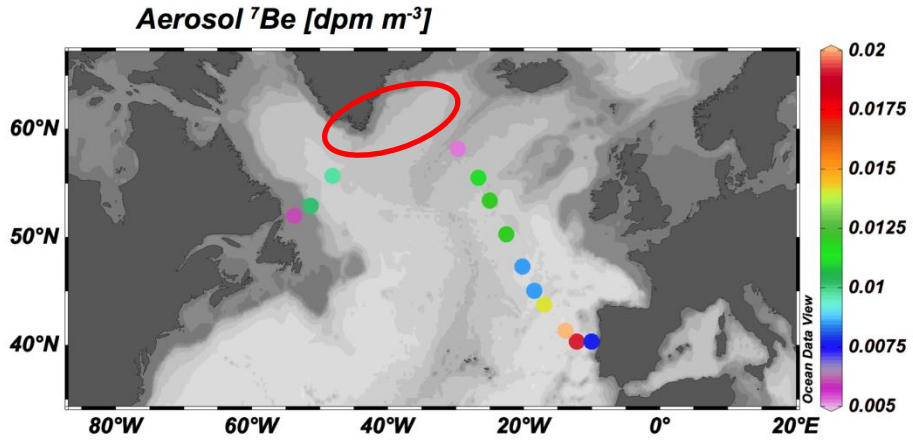


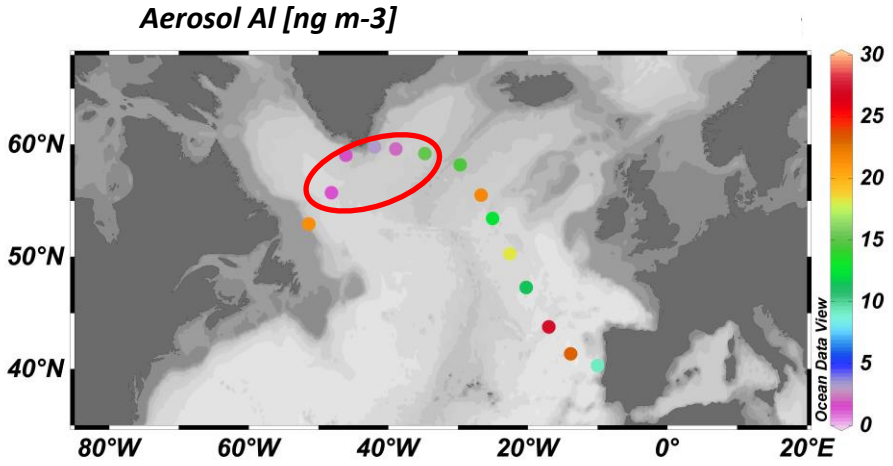


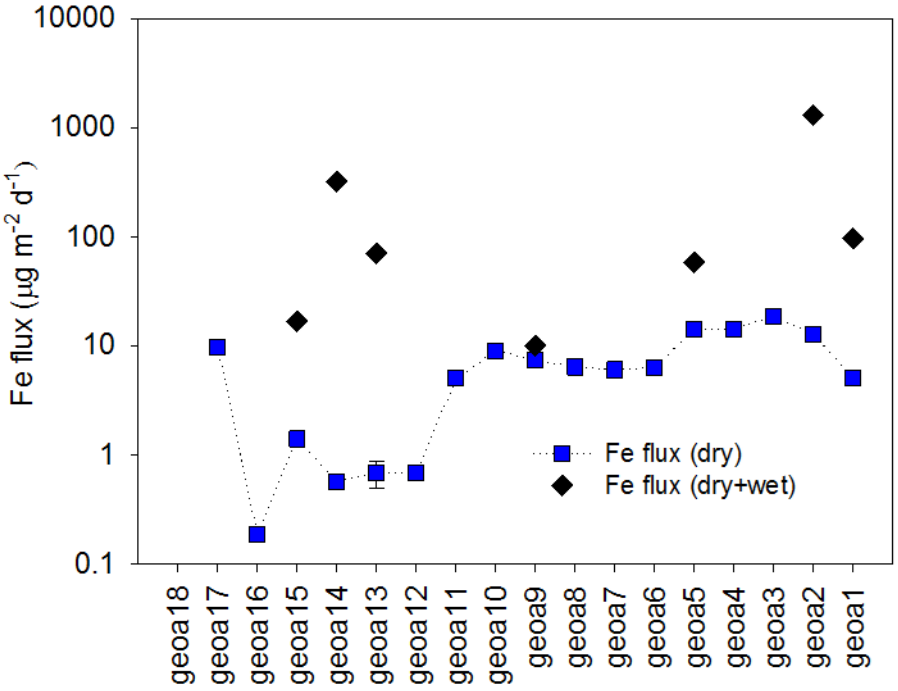


Aerosol deposition flux estimation…

…^{7}Be method vs ‘classic’ method

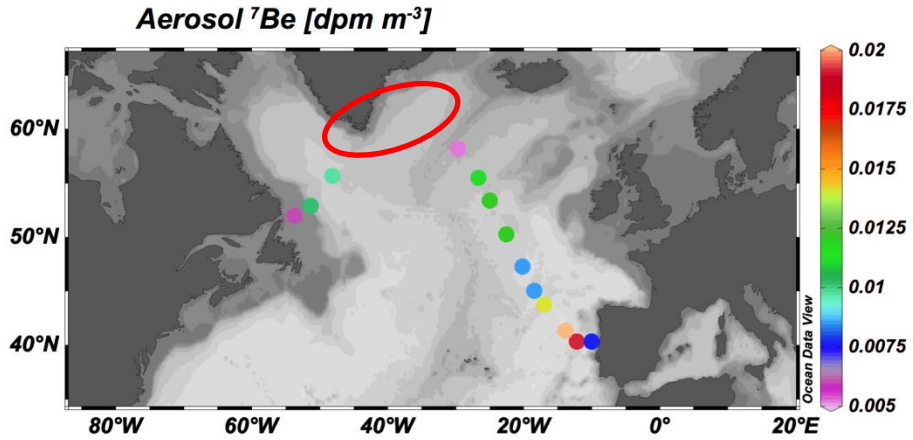


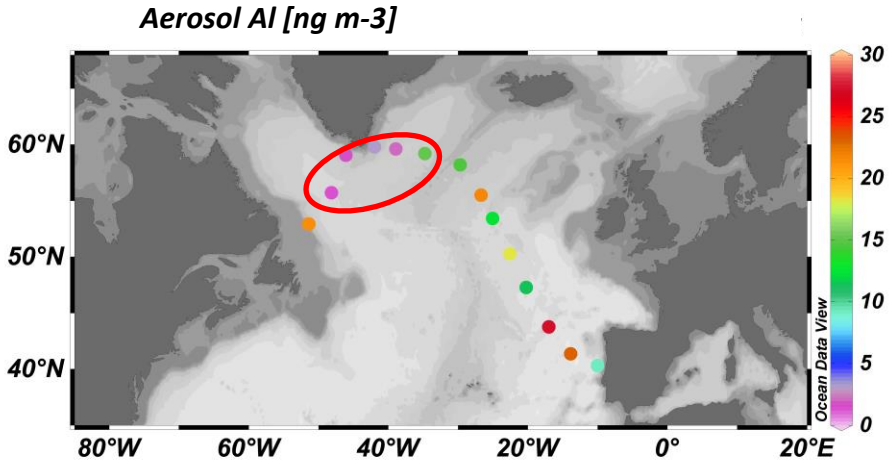


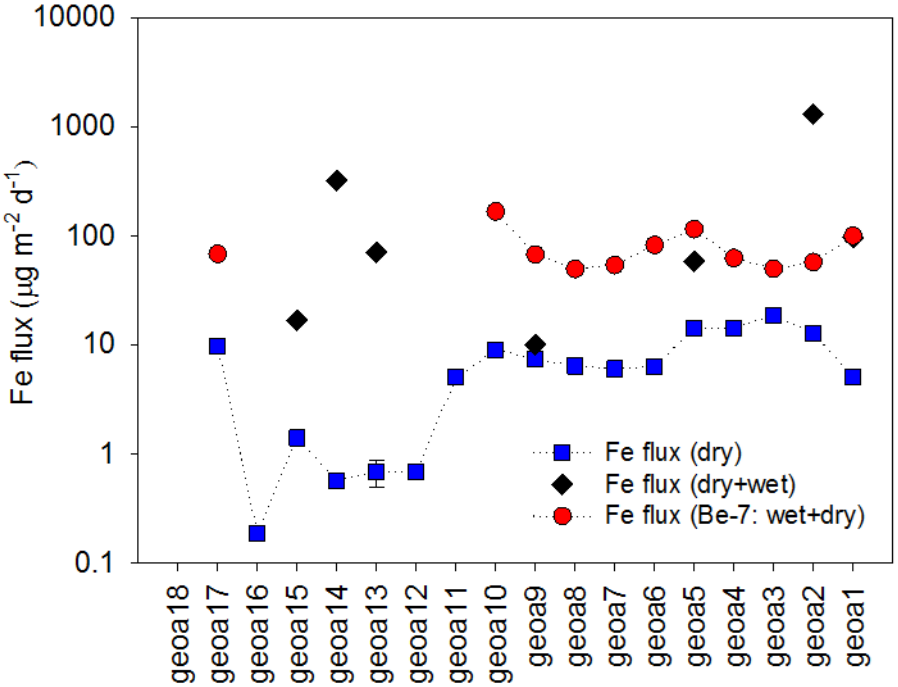


Aerosol deposition flux estimation…

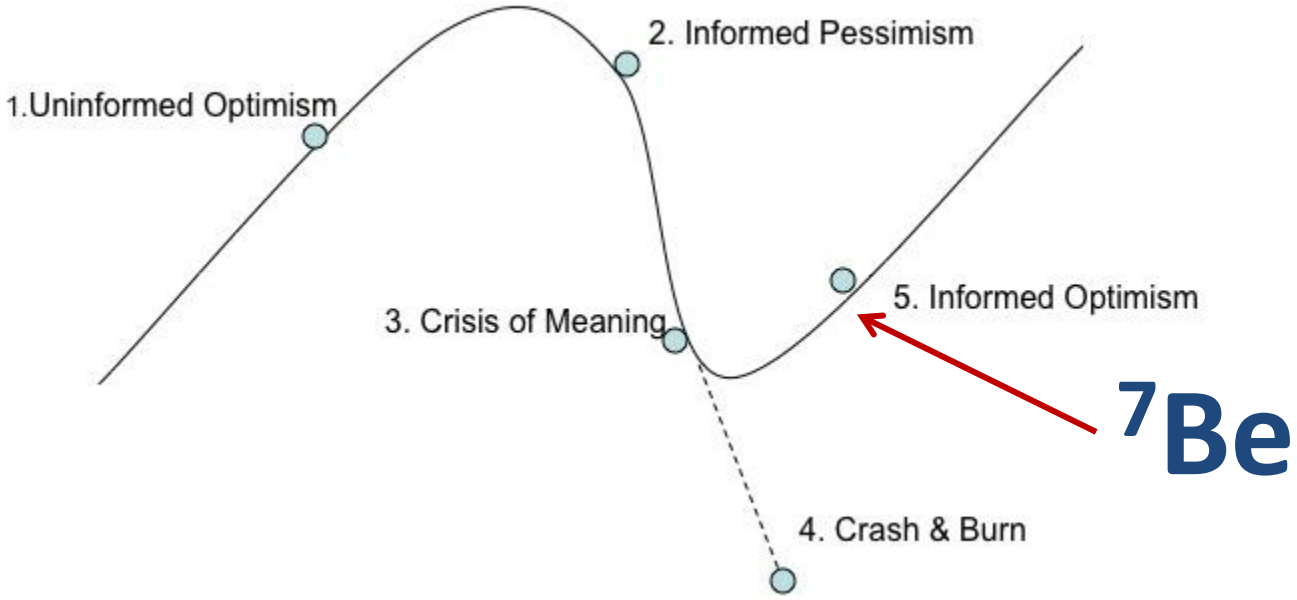
…^{7}Be method vs ‘classic’ method







The tracer rollercoaster



http://fourhourworkweek.com/2008/10/03/harnessing-entrepreneurial-manic-depression-making-the-rollercoaster-work-for-you/

Summary

- 'Saharan' dust dominates metal composition of AWA aerosols, but not GEOVIDE
  - AWA: higher aerosol loadings for all metals
  - GEOVIDE: very low aerosol loading in Irminger Basin & Labrador Sea
- Fe solubility in DI water was higher in GEOVIDE samples (non-Saharan; up to 20%), but a much smaller proportion dissolved after the second leach (25% HAc) compared to the AWA samples
  - Differences in solubility between leach media → standard leaching protocols
- Trace metal deposition fluxes are difficult to constrain because of uncertainties with :
  - Deposition velocity (dry deposition)
  - Precipitation rate (wet deposition)
- ^{7}Be/trace metal ratios should allow us to better constrain the flux (total)…but there's work to be done

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