Atmospheric Deposition of Trace Metals to the South Indian and Atlantic Oceans

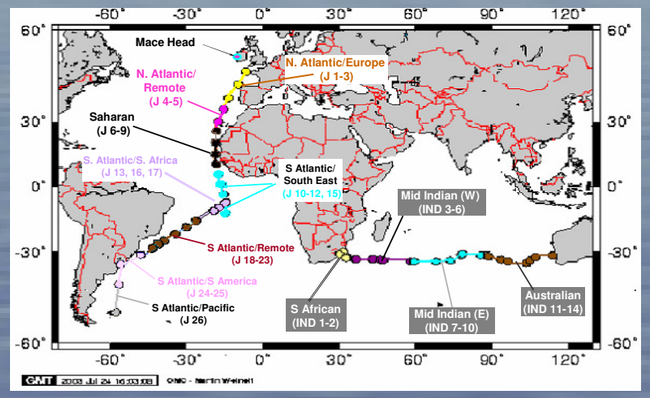
Melanie Witt [1,2*], Alex Baker [2] and Tim Jickells [2]

[1] Department of Earth Sciences, University of Oxford, Parks Road, Oxford, UK, OX1 3PR * **melanie.witt@earth.ox.ac.uk**

[2] School of Environmental Sciences, University of East Anglia, Norwich, UK, NR2 7TJ

Introduction

The atmosphere is recognised as an important source of trace metals to the oceans (Duce et al. 1991). However, there are few measurements of trace metal concentrations in remote marine regions, particularly in the Southern hemisphere. Aerosol samples were collected during cruises in the Indian and Atlantic Oceans and their metal content investigated. The lead isotope ratios in the aerosols were measured and used to assist in source apportionment of the samples. These are the first trace metal concentration data reported for aerosols over the South Indian Ocean.



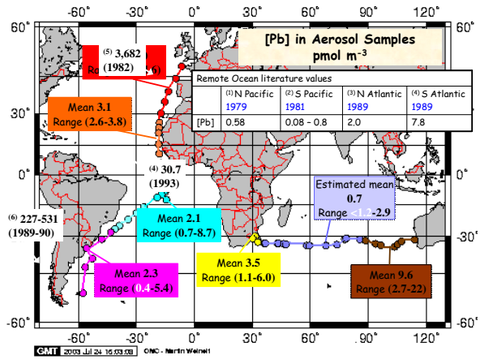
AMT Cruise on RRS James Clark Ross England to Falkland Islands September/October 2001

32°S Indian Ocean Transect on RRS Charles Darwin South Africa to Australia March/April 2002

Methods

Aerosol samples were collected during cruises in the Indian and Atlantic Oceans. High volume aerosol samplers were employed to collect aerosol particles on the surfaces of acid washed Whatman 41 filter papers. A 0.1 M Nitric Acid extraction solution was used followed by analysis for a suite of trace metals using Graphite Furnace Atomic Absorbance Spectroscopy. This enabled the readily soluble metals in the aerosols to be quantified. Lead isotope ratios were determined with multi-collector-inductively coupled plasma-mass spectrometry.

Lead Concentrations Measured in Aerosols in this Study (*coloured boxes*) and Literature Values (*white boxes*).



The lead data are presented here and similar trends were seen in other metals studies (Cu, Ni, Zn and Cd).

- Most samples in this study had air mass back trajectories suggesting they had a predominantly marine origin.
- Low lead concentrations were observed even fairly close to industrial regions such as Western Europe and South America.
- Similar concentrations were observed in the Northern and Southern hemispheres.
- In terms of metal concentrations in remote ocean regions, generally:

Pacific Ocean < Indian Ocean < Atlantic Ocean

Calculated Dry Deposition Fluxes of Trace Metals to Oceans Compared to Literature Data and River Fluxes

Units 10^9g year^{-1}

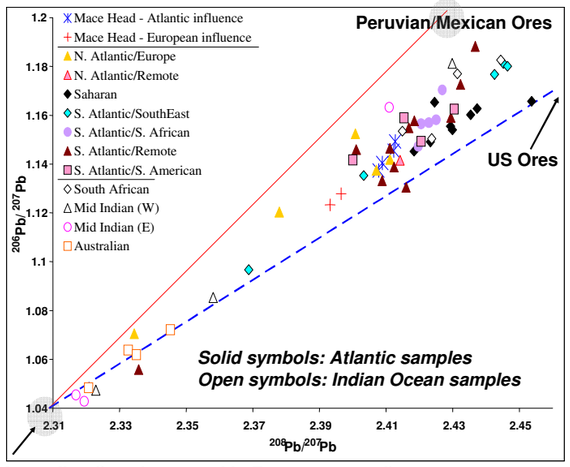
This Study	Pb	Cu	Cd	Ni	Zn
North Atlantic	8.3	14.1	0.16	2.6	24.4
South Atlantic	6.7	9.7	0.12	1.3	27.2
South Indian	3.7	27.3	0.07	0.7	16.1

Duce et al. [7]					
North Atlantic	9.6	6.6	0.2	3.2	29
South Atlantic	1.1	0.8	0.03	0.4	3.3
South Indian	0.3	0.2	0.01	0.1	0.9

Dissolved River Inputs [8]					
North Atlantic	0.5	36	3.7	44	21
South Atlantic	0.2	20	1.4	16	13

- The fluxes to the North Atlantic in this study are of a similar magnitude to those calculated by Duce et al[7] and Spokes et al. [9].
- The values are higher than those of Duce et al. for the South Atlantic and South Indian Oceans. This may reflect an increase in industrialisation in the Southern hemisphere in recent years.
- **The input of trace metals to the North and South Atlantic are of a similar magnitude.**
- Atmospheric flux of lead more important than river fluxes. For other metals, river fluxes are a similar magnitude or larger than atmospheric but;
- The atmosphere likely to deliver several times the dry deposition flux through wet deposition processes.
- Rivers only deliver material in continental regions, **the atmosphere is the most important source in remote ocean areas.**

Lead Isotope Ratios in Aerosol Samples



Australian Ores (was used in European petrol)

- All of the lead isotope ratios in the aerosols collected fall within classic mixing lines between older less radiogenic Australian lead ores (Bottom left of figure) and younger more radiogenic ores from Mississippi valley (top of dashed blue line) and Peruvian/Mexican ores (top of solid red line).
- Different sized fractions of the same sample show differences in Pb isotope ratios although these are not systematic. The enriched lead in the coarse mode may reflect earlier lead emissions resuspended on soil particles, leading to isotopic differences in size fractions as trends in lead use evolve.
- There is a marked difference between on shore and off shore flow at Mace Head, possibly due to the difference between US and European lead sources.
- Samples collected under Saharan dust influence have similar Pb isotope ratios which are typical of Saharan dust, even though the Pb is enriched above crustal values.
- Aerosols collected in the Indian Ocean close to South Africa has a similar lead isotope ratio to those collected in the mid Atlantic Ocean with South Easterly air mass back trajectories (S. Atlantic/S. Africa). These ratios suggest southern African signal has changed. The Pb signal was more radiogenic than previously detected implying S African Pb is now dominated by mining and coal burning activities.
- Throughout much of the mid and eastern and Indian Ocean air mass back trajectories suggested a westerly source. The isotopic signature of the lead in the samples imply Australian ores are important throughout this regions, as well as over parts of the South Atlantic.

Summary

- Even close to industrial centres such as Montevideo and Buenos Aries, low trace metal concentrations were observed reflecting the importance of sample history when assessing aerosol data.
- Calculation of Enrichment factors (using Al and Na as reference elements) showed that trace metals were enriched above both crustal and oceanic sources in aerosols collected close to land and in remote ocean regions 1000s of km from emission sources. This confirms that continental emissions of trace metals can impact even very remote parts of the ocean.
- Aerosols over the remote Pacific Ocean appear to have the lowest trace metal content, followed by the remote Indian Ocean with higher concentrations found in the remote Atlantic Ocean.
- Atmospheric deposition of trace metals to oceans in the Northern and Southern hemisphere are now of a similar magnitude possibly resulting from the increase in industrialisation in many countries in the southern hemisphere.
- Although lead isotope ratios are less region specific since the phase out of leaded petrol and the growing homogeneity in the global lead market, many ocean regions show distinct Pb isotope signals consistent with those measured in adjacent continental areas.
- The long range transport of metal emitted in South Africa and Australia appear to influence large areas of the South Indian and South Atlantic Oceans.
- This work confirms the atmosphere as an important source of metals even in remote oceanic regions.

University of Oxford
Department of Earth Sciences
Mathematical, Physical and Life Sciences Division

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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