Mercury in the Southern Ocean
GEOTRACES (SR3)
R/V Aurora Australis
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Why studying Mercury in the Southern Ocean?

- Very few available data

- Polar zones exhibit unique characteristic, the rapid oxidation of atmospheric Hg\(^0\) in the polar springtime by sea-salt-derived bromine released into the atmosphere during sea ice formation.

- These Hg depletion events (MDE) were observed in coastal Antarctica along the Antarctic sea ice edge, in polynyas, and between pack ice and fast ice.

- The very high RGHg concentrations (up to 5.0 pmol m\(^{-3}\)) are likely to result in Hg deposition onto coastal snow packs leading to elevated Hg\(_T\) concentrations (up to 2 nmol L\(^{-1}\)) in the surface snow at the fast-ice edge adjacent to the freezing ocean.

- The lack of Hg observations in the Antarctic environment has prevented identification of the factors controlling the distribution and speciation of mercury in the SO, including the high MeHg bioaccumulation in open-ocean and coastal ecosystems.

Ref.: Ebinghaus et al., 1999; Pontgraz & Heumann, 1998; Brooks et al., 2008; Sprovieri et al., 2002; Dommergue et al., 2010; etc.
Questions

• What are the level and general distribution of \( Hg_T \) concentrations in the waters of the SO, and is there any indication for sources and sinks?

• What are the characteristics of the Hg speciation in the waters, which may shed light on Hg cycling specificity of the SO?

• What is the role of the sea ice (formation and melting) in the \( Hg_T \) distribution, speciation and cycling in the SO?

• How do our findings contribute to explaining the high Hg bioaccumulation in Antarctic food webs?
SR3 Geotraces transect
27 stations with
8 to 12 sampling depths

Casey coastal station

Ocean

Tasmania

New Zealand

Hobart

Southern

Antarctica
Potential sources of Hg in the Southern Ocean:
- NADW
- Atmosphere
- Continental shelf
Maximal OM oxidation zone
High concentrations in the SZ first 400m and within the AABW.

Low conc in surface SAZ.

Deposition? / Evasion?
Total Methylated Mercury
\[ \text{MeHg}_T = \text{MMHg} + \text{DMHg} \]

Maximum concentrations in the AZ + SZ at 1000-1500 m
Methylmercury vertical profiles in the Upper Southern Ocean Water Column
Vertical distribution of total methylated mercury (MeHg$_T$) and Apparent Oxygen Utilization (AOU) against potential density evidencing latitudinal gradient along isopycnals.

MeHg$_T$ is maximum between SPF and SACCF where AOU is also high. This means that a fraction of MeHg is not imported from North with NADW, but in situ methylated in the AZ.
Hg enrichment at the fast-ice edge adjacent to the freezing ocean, the type of environment where Brooks and al. (2008) found elevated $\text{Hg}_T$ (up to 2 nM) in the surface snow.
The overall correlation between MeHg$_T$ and AOU is given by the equation:

\[ \text{MeHg}_T (\text{pmol}) = 0.0031 \times \text{AOU (\mu mol)} + 0.119 \quad (R^2 = 0.72, n=236) \]

Is the slope of the MeHg vs AOU depending on the abundance of substratum?
Southern Ocean GEOTRACES SR3 Transect

**Y:**
Slope MeHgT vs AOU within the 0-1000m;

**X:**
Average HgR within the maximum concentration layer (200-400m).

**SZ**: Southern Zone;

**AZ**: Antarctic Zone;

**PFZ**: Polar Frontal Zone;

**SAZ**: Southern Sub-Antarctic Zone;

**SCZ**: Subtropical Convergence Zone.
Maximum methylation occurs within the SZ where \( \text{iHg}^{II} \) (\( \text{HgR} \)) substratum for methylation and bacterial fuel are maximum.

**Abbreviations:**
- **SZ:** Southern Zone;
- **AZ:** Antarctic Zone;
- **PFZ:** Polar Frontal Zone;
- **SAZ:** Southern Sub-Antarctic Zone;
- **SCZ:** Subtropical Convergence Zone
Coastal Sea-Ice System off Casey Station (Antarctica)

- Hgₜ enrichment within snow and brine suggests atmospheric inputs and Hg rejection during sea-ice formation;
- MeHg is enriched at the base of the sea-ice where biological production is abundant.
Coastal Sea-Ice System off Casey Station (Antarctica)

Principal Component Analysis on salinity POC, Chla, HgT, HgR and MeHgT within the snow, ice, brine and seawater

- MeHg linked to biological parameters
- Inorganic Hg linked to salinity (salt exclusion)

\[ \text{Hg}_{\text{Tp}} = 0.21 \times \text{Salinity} + 3.6, \quad R^2 = 0.69 \]
Is there any difference in mercury mean concentrations between water masses?

<table>
<thead>
<tr>
<th></th>
<th>$Hg_T$</th>
<th>$Hg_R$</th>
<th>$MeHg_T$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± sd</td>
<td>(min – max)</td>
<td>n</td>
</tr>
<tr>
<td>CDW</td>
<td>1.19 ± 0.27</td>
<td>(0.95-1.80)</td>
<td>11</td>
</tr>
<tr>
<td>AAIW</td>
<td>1.15 ± 0.22</td>
<td>(0.82-1.56)</td>
<td>10</td>
</tr>
<tr>
<td>AABW</td>
<td>1.35 ± 0.39</td>
<td>(0.98-1.99)</td>
<td>14</td>
</tr>
</tbody>
</table>

Significance of the differences:
- $P < 0.12$
- $P < 0.01$
Summary

Main results

- 50% $Hg_T$ concentrations range 1.1 – 1.5 pM
- $Hg_T$ (and $Hg_R$) in surface waters increases poleward: >2 pM in the AZ-SZ and up to 44 pM below the coastal sea ice
- $Hg_T$, $Hg_R$ and $MeHg_T$ concentrations \textit{tend} to be higher in the AABW compared to the CDW and/or AAIW
- High proportions of methylated mercury (50% of $Hg_T$) occur in the hypoxic part of the water column, up to 78% in Divergence area

These distribution characteristics suggest three main drivers of the SO Hg cycle:

- A net Hg input to the ocean surface near the Antarctic continent from an atmospheric source,
- A role of sea ice formation in the transfer of Hg enriched waters to depth,
- A net methylation of Hg south of the SPF as a result of the co-location of atmospheric Hg$^{II}$ input and the bacterial decomposition of OM, which are superimposed with the advection of MeHg-enriched NADW-CDW deep water by the upwelling at the Antarctic divergence.
Thanks from the Mercury Team

Delphine

Lars

and Steve
Data obtained on a « dry ship »!