Analysis of changes in water and particulate material chemistry during iron-enrichment experiments in the subarctic North Pacific (SEEDS, SERIES and SEEDS II)
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• NIES mission
  – pCO₂ measurement (with high time resolution & on board LAN) and nutrient analysis
  – DIC, AT for discrete samples (SEEDS)
  – POC/N, PIC analysis for water column particulate samples
  – Productivity (¹³C incubation, SEEDS)
  – Drifting sediment trap experiment for export flux measurement (C, N, P, Si, Fe and trace metals)
Observation Schedule (SEEDS)

6/28-7/10  Pre-survey
Tests of equipment
7/17   Pre-survey
7/18-19  Iron fertilization
7/19   Propeller survey (D1)
7/20   In-out survey (D2)
7/21   Prop. Survey & 2D (D3)
7/22   In-out survey (D4)
7/23
7/24   Propeller survey (D6)
7/25   In-out survey (D7)
7/26   Prop. Survey & 2D (D8)
7/27   In-out survey (D9)
7/28   Propeller survey (D10)
7/29   In-out survey (D11)
7/30   Prop. Survey & 2D (D12)
7/31   In-out survey (D13)
8/1    Trawl survey
Counter map of Dissolved Fe Concentration (nM)
Daily minimum and maximum values of pCO2, chlorophyll-a and nitrate concentration
pCO$_2$ draw down in SEEDS experiment
Correlation of Aquatracker fluorescence and pCO2
Patch survey in SEEDS (day 10)
Method for pCO$_2$ patch survey

- Water traveling and instrument response time give needs for delay correction of underway signal.
- Underway instruments take every minute record and every 5 minutes sampling for nutrient.
- Aquatracker (chlorophyll sensor) in wet laboratory has fastest response.
- One minute delay time for pCO2 and 2 minutes for filter chlorophyll and nutrient sampling gave best correlation results.
Parameters from patch survey (SEEDS)

Increasing component in patch

Left axis: Fe (pM), Chl-a (µg/l x 10), Right axis: SF₆ (fM)
Left axis: fCO₂ (µatm)

Decreasing component in patch

Left axis: fCO₂ (µatm), Right axis: Si (µM), nitrate (µM)
X:pCO2, without delay correction
Y:Aquatracker

Best fit pCO2-Aquatracker
X:pCO2 delay corrected (1min)
Y:Aquatracker

X:pCO2 delay over-corrected (3min)
Y:Aquatracker
Best fit Aquatracker-filter chlorophyll
X: Aquatracker
Y: filter chloropyll, delay over-corrected (4min)

X: Aquatracker
Y: filter chloropyll, delay corrected (2min)

X: Aquatracker
Y: filter chloropyll, without delay correction

\[
y = 2.0927x - 0.4041 \\
R^2 = 0.8309
\]

\[
y = 2.3169x - 0.6411 \\
R^2 = 0.912
\]

\[
y = 2.209x - 0.4228 \\
R^2 = 0.7548
\]
SERIES, July 26 (Day 18), short patch survey in SERIES
July 29 (Day 21), long patch survey in SERIES
Aug 3 (Day 26), long patch survey in SERIES
SERIES Fe fertilization experiment in 2002 July
July 29

August 4

Detailed patch survey may make it possible to estimate accurate mass balance.
Silicate (upper panel) and nitrate (lower panel) decrease in SERIES2002
Knauer type trap with 8 cylinders in SEEDS 2001
DST arrangement in SEEDS 2001

- Center buoy with 20 m traps
- Reference buoy with 20/40/60/100m traps
- Inside buoy with 40/60/100/200m trap
中心ブイ 漂流系図
パッチ内ブイ 漂流系図
Knauer type trap with 8 cylinders in SEEDS 2001

Density Gradient
Formalin 2% soln. (SEEDS), NaN3 (SERIES, SEEDSII)
Brine +5psu
Drifting period of each DST in SEEDS 2001

DST: Drifting Sediment Trap (Knauer type) experiment for SEED 2001

<table>
<thead>
<tr>
<th>DST(C) with Center bouy (20m depth)</th>
<th>Start</th>
<th>End</th>
<th>Drifting Period (day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>2001/7/17 15:19</td>
<td>2001/7/21 14:13</td>
<td>3.95</td>
</tr>
<tr>
<td>C2</td>
<td>2001/7/21 14:50</td>
<td>2001/7/24 10:50</td>
<td>2.83</td>
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<tr>
<td>C3</td>
<td>2001/7/24 12:33</td>
<td>2001/7/26 13:02</td>
<td>2.02</td>
</tr>
<tr>
<td>C4</td>
<td>2001/7/26 14:35</td>
<td>2001/7/28 14:11</td>
<td>1.98</td>
</tr>
<tr>
<td>C5</td>
<td>2001/7/28 15:49</td>
<td>2001/7/30 14:08</td>
<td>1.93</td>
</tr>
<tr>
<td>C6</td>
<td>2001/7/30 15:31</td>
<td>2001/8/1 16:46</td>
<td>2.05</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DST(I) inside enriched Fe patch (40, 60, 100, 200m depth)</th>
<th>Start</th>
<th>End</th>
<th>Drifting Period (day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1</td>
<td>2001/7/17 15:57</td>
<td>2001/7/21 15:38</td>
<td>3.99</td>
</tr>
<tr>
<td>I2</td>
<td>2001/7/21 16:29</td>
<td>2001/7/24 11:33</td>
<td>2.84</td>
</tr>
<tr>
<td>I3</td>
<td>2001/7/24 12:57</td>
<td>2001/7/26 13:43</td>
<td>2.03</td>
</tr>
<tr>
<td>I4</td>
<td>2001/7/26 14:57</td>
<td>2001/7/28 14:50</td>
<td>2.00</td>
</tr>
<tr>
<td>I5</td>
<td>2001/7/28 16:11</td>
<td>2001/7/30 15:04</td>
<td>1.95</td>
</tr>
<tr>
<td>I6</td>
<td>2001/7/30 15:51</td>
<td>2001/8/1 16:05</td>
<td>2.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DST(R) Reference bouy (20, 40, 60, 100m depth)</th>
<th>Start</th>
<th>End</th>
<th>Drifting Period (day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>2001/7/19 12:20</td>
<td>2001/7/24 16:21</td>
<td>5.17</td>
</tr>
<tr>
<td>R2</td>
<td>2001/7/24 18:45</td>
<td>2001/7/28 18:06</td>
<td>3.97</td>
</tr>
<tr>
<td>R3</td>
<td>2001/7/28 20:43</td>
<td>2001/8/1 6:43</td>
<td>3.42</td>
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</tbody>
</table>
Analysis of sediment trap samples

GF/F
• Organic Carbon and Nitrogen

Nuclepore Membrane (0.6 µm, weighed)
• Weight measurement
• Biogenic silica (alkaline dissolution)
• Inorganic Carbon from Ca analysis
 • Element analysis by ICP emission spectrometry (Al, Fe, Ca, Mg, Na, K, Mn, P, Sr, Zn, S, etc.)

All Fe experiment made just one DST survey in the patch!
Majority of trapped material was fecal pellet of zooplankton (SEEDS)
Majority of trapped material was phytoplankton (SERIES)
Total mass flux change in SEEDS 2001

(A) DST(C,I)
- Purple: 20m
- Red: 40m
- Blue: 60m
- Green: 100m

(B) DST(O)
- Purple: 20m
- Red: 40m
- Blue: 60m
- Green: 100m

Drifting Period

Day

Patch inside
Patch outside
Fe infusion
Carbon flux and Si flux change in SERIES 2002
Carbon flux and Si flux change in SERIES 2002
Carbon flux and Si flux change in SERIES 2002
Carbon flux and Si flux change in SERIES 2002
Total Mass Flux (SEEDS II)

In Patch

Out Patch

Fe Fertilization
Fe Fertilization II
Fe Fertilization
Fe Fertilization II
Total Mass Flux SEEDS vs SEEDS II
In Patch 40m

Out Patch 40m

In Patch 70m

Out Patch 70m

In Patch 100m

Out Patch 100m
Carbon budget in the patch

In patch

CO₂ exchange at sea surface
0.07 mol/m²

Decrease of DIC 1.23 mol/m²

Increase of DOM 0.11 mol/m²

Increase of POC 0.97 mol/m²

Mixed layer = 15–20 m

Sinking organic carbon flux 0.17 mol/m²

Inorganic C budget 1.23 + 0.07 = 1.30 mol/m²

Organic C budget = 0.97 + 0.17 + 0.11 = 1.26
<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>gross flux</td>
<td>0.24 mol/m²</td>
</tr>
<tr>
<td>DIC decrease est. from pCO2</td>
<td>1.7 mol/m²</td>
</tr>
<tr>
<td>50 m Part. C flux accounts</td>
<td>14 %</td>
</tr>
</tbody>
</table>

Tentative budget calculation for SERIES gives similar result with SEEDS 2001
NIES mission

- Supply of chemical data and accurate meta data to the participant
- Quantitative analysis of changing chemistry in the patch.