Procedures for correcting in situ CTD data and results obtained during the NEAR-GOOS Cross-Basin Climate Monitoring Section project

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GOOS Regions

- NEAR-GOOS
- IOCARIBE-GOOS
- IO-GOOS
- GOOS AFRICA
- SEA-GOOS
- PI-GOOS
- GRASP
- MedGOOS
- BS-GOOS
- EuroGOOS
- AF
- Eu
Objectives for project:
- JES is semi-enclosed basin with the stable hydrographic structure e.g. cool deep water with the salinity and oxygene anomalies within the intermediate waters;
- The monitoring of these parameters gives a key for understanding of global warming the World Ocean;
- The main idea is to compare the temperature, salinity and oxygene observations made within the close locations which allow to suggest about data quality and compatibility of measurements made independently by the JMA and POI;
## Accuracy of SBE sensors

<table>
<thead>
<tr>
<th></th>
<th>SBE-35</th>
<th>Temp. SBE-3+</th>
<th>Cond. SBE 4C</th>
<th>O₂^(SBE-43)</th>
<th>O₂^(RINKO-III)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth measure</td>
<td>to 6800 m</td>
<td>to 7000 m</td>
<td>to 7000 m</td>
<td>to 7000 m</td>
<td>To 7000</td>
</tr>
<tr>
<td>Initial accuracy</td>
<td>± 0.001 °C</td>
<td>0.001 °C</td>
<td>0.0003 S/m</td>
<td>2% saturation</td>
<td>±2%</td>
</tr>
<tr>
<td>Stability</td>
<td>0.001 °C per year</td>
<td>0.0002 °C/month</td>
<td>0.0003 S/m/mon.</td>
<td>0.5% per 1000 hours</td>
<td>±5% (1 month)</td>
</tr>
<tr>
<td>Range:</td>
<td>-5 to +35 °C</td>
<td>-5 to 35 °C</td>
<td>0 to 7 S/m</td>
<td>Until 120% surf. sat.</td>
<td>0-200%</td>
</tr>
</tbody>
</table>

- During the study of East Sea deep waters structure within long time it necessary to pay attention on basic characteristics of used sensors for CTD-unit.
SBEDataProcessing: simple case

- Preliminary processing (SBEDataProcessing software.)
  - Data conversion (binary->ascii)
  - Align CTD (time lag correction, optional for SBE911)
  - Cell Thermal Mass correction (correction for warming of sensor cells)
  - Filtering (get rid of noise, bad data)
  - Loop edit (exclusion of ship waving, fluctuations)
  - Bin averaging (averaging data by: pressure/depth/time)
Data error assessment by NEAR-GOOS data

- Talley at al. 2004
- Cruise La58 R/V Akademik M.A. Lavrentyev”, Ga56 R/V “Professor Gagarinsky”, Op44 R/V “Akademik Oparin”
- R/V “Keifu Maru”
  - Ga56 St028 – 19/Jun/12
  - Op44 St033 – 24/Oct/12
  - KM-3141 – 30/Oct/12
  - KM-3169 – 4/Nov/12

La58-st98 (raw): 196 (calibrated 1000m-bottom): 210

Talley: 0.064
La58-st98: 0.086
Talley: 34.068
La58-st98: 34.072
Talley: 0.08
KS-3169-1: 0.086
Talley: 34.068
KS-3169-1: 34.068
Talley: 205
KS-3161-1: 195
La58-st98 (raw): 196
(calibrated 1000m-bottom): 210
Temperature and conductivity sensors in SBE

Expected time lag for
Thermistor – 0.07 sec
conductivity cell – 0.06 sec
With a pump performance 30 sm³/sec
or 1 m/sec²
Additional calibration of SBE


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Version 1, 2010
Each SBE-sensor is individual. Its deformation can be corrected at depths more than 2000 m by the calibration using SBE-35 (platinum thermometer).

Usual calibration formula for this case:

$$T_{cal} = T_{raw} - (C_0 + C_1 \times P)$$

- We used second sensors set (POI) for analysis due to the problem with the 1st one
Temperature Correction: without SBE35

Calibration based on PM-Line section, the data from R/V “Keifu Maru” have been compared with La-58 data (close locations), the SBE35 was not installed.
Temperature correction: with SBE35

Temperature correction on sensitivity to pressure may cause change of T value on +/- 0.003 C which may be important during the study of climatic changes.
Salinity correction

- to obtain high accuracy it is not enough a standard SBE-processing procedures
- it is necessary to consider pressure effect for SBE conductivity sensor by calibration with data from sampling bottles (together with SBE 35 measurements)

**Correction may be defined using the following formula:**

\[
C_{cal} = C - \left( \sum_{i=0}^{I} c_i \times C^i + \sum_{j=1}^{J} p_j \times P^j \right)
\]
Mysterious Deep Salinity Minimum

- Due to polynomial equation of second order sometimes slope and curl is not correctly obtained for intermediate and deep waters of JES
Salinity correction

JMA data of cruises of R/V “Keifu Maru” (blue line on map):

http://www.data.kishou.go.jp/kaiyou/db/vessel_obs/
data-report/html/ship/ship_e.php

- During the cruise the Laboratory Salinometer was available onboard, which allowed one to make a calibration;

### Laboratory Salinometer
Autosal 8400B

**Table C.1.2. Conductivity Calibration Coefficient Summary.**

<table>
<thead>
<tr>
<th>S/N</th>
<th>Num</th>
<th>( c_0 ) (mS/m)</th>
<th>( c_1 )</th>
<th>( c_2 ) (mS/m)</th>
<th>Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>3670</td>
<td>1274</td>
<td>1.5107e-3</td>
<td>-7.4144e-5</td>
<td>0.0000e-0</td>
<td>Stn. 1 – 67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6.6856e-7</td>
<td></td>
<td>-8.3866e-11</td>
<td></td>
</tr>
<tr>
<td>3670</td>
<td>308</td>
<td>2.2680e-3</td>
<td>-8.0696e-5</td>
<td>0.0000e 0</td>
<td>Stn. 68 – 83,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-1.2437e-8</td>
<td></td>
<td>0.5038e-11</td>
<td>Stn. 105 – 107,</td>
</tr>
<tr>
<td>3670</td>
<td>698</td>
<td>1.0048e-3</td>
<td>-7.6991e-5</td>
<td>0.0000e-0</td>
<td>Stn. 84 – 104,</td>
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<tr>
<td></td>
<td></td>
<td>3.9031e-7</td>
<td></td>
<td>-4.2466e-11</td>
<td>Stn. 108 – 124,</td>
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<tr>
<td>2849</td>
<td>2195</td>
<td>2.1693e-3</td>
<td>-5.5359e-5</td>
<td>0.0000e-0</td>
<td>Stn. 1 124</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.3709e-7</td>
<td></td>
<td>7.6495e11</td>
<td></td>
</tr>
</tbody>
</table>
Salinity correction

Ga56 and Op44 data before correction
KM3141 – corrected data for reference
Ga56 and Op44 data after correction
KM3141 – corrected data for reference

Temporal drift of conductivity sensor is shown for 127 calendar (36 operated) days
Dissolved Oxygen Measurements

SBE 43 – O₂ sensor with polarographic membrane

\[ O_2 = S_{oc} \cdot \left( V + V_{off} + \tau_{20} \cdot e^{(Di\cdot P + D2\cdot (T-20))} \cdot dV/dt \right) \]

\[ \cdot O_{sat} \cdot (1 + A \cdot T + B \cdot T^2 + C \cdot T^3) \cdot e^{[(E\cdot P)/(273.15+T)]} \]


Ref: Gordon, Garcia
Ref: Uchida et al.
DO correction: no samples
Optical (Rinko)/ Membrane (SBE43) correction

La 64 – steps of choice with 2sigma criteria for RINKO III

La 66 – steps of choice with 2sigma criteria for RINKO III

The analysis showed different behavior of sensor during two different cruises
Comparatively with the SBE43 RinkoIII has a temporal drift which is not similar for different cruises. This cause us to use only 30% of obtained data for calibration in the La66 cruise. According with this the RinkoIII sensors needs to be inspected and controlled during the further cruises.

Optical (Rinko)/ Membrane (SBE43) correction
Calibrated data comparison (2009-2014)

Finally were defined:
- Temperature corrected in the same manner for the last 5 years essentially increases;
- The temperature growth is not regular from year to year;
- The salinity minimum is stable within the frames of instrument sensitivity;
- The oxygen in the deep layer has some variations and now is lower than 3 years before, but rather oscillate than increases;
Conclusions

1. To identify interannual and spatial variations of deep and bottom water parameters in the JES an accuracy of ±0.001 is required for temperature and salinity.

2. T, S and dissolved oxygen intercalibration and correction of data is important.

3. Calibration of SBE43 and RINKO-III DO-sensors is available by samples analysis (Winkler chemical method) and by comparison of POI and JMA data.

4. Optical sensor (RINKO-III) sensor has some peculiarities which need to take into account during the oxygen calibration.

5. Continuation of NEAR-GOOS Cross-Basin Section will provide reliable data on deep and bottom water response of the sea to climate changes.
Thank you for your attention!