A look into the future of direct comparison ambient temperature salinometry

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Salinometer FAQ

With my AutoSal™, can I:

1. Use it on a small boat? NO
2. Transport it in my suitcase? NO
3. Characterize different seawaters over temperature? NO
4. Test the salinity of Guacamole? NO
5. Run it off of a car battery? NO
6. Set it up and use within 1 hour? NO
Outline

• Why Salinometry?
• Standard Methods of Salinometry
• Basic limitations
• The future of Salinometry
• Conclusion/Discussion
Why Salinometry?

Salinity is a key property of seawater from which density and sound speed may be derived; these are fundamental to ocean science and climatology.

Salinometers provide a reference to the widely accepted Practical Salinity Scale.
Standard Method

CTD & Water Samples → AutoSAL

**Practical Salinity Scale (1978)**

\[
R = \frac{C(S, t, p)}{C(35, 15, 0)} = \frac{C(S, t, p)}{42.914}
\]

\[
R_t = \frac{R}{\eta R_p}
\]

\[
R_p = \frac{C(S, t, p)}{C(S, t, 0)} = 1 + \frac{p(e_1 + e_2 p + e_3 p^2)}{1 + d_1 t + d_2 t^2 + (d_3 + d_4 t)R}
\]

\[
S = \sum_{i=0}^{5} a_i R_t^{i/2} + \frac{t - 15}{1 + k(t - 15)} \sum_{i=0}^{5} b_i R_t^{i/2}
\]

\[
r_i = \frac{C(35, t, 0)}{C(35, 15, 0)} = \sum_{i=0}^{6} c_i t^i
\]

- \(a_0 = 0.0080\)
- \(b_0 = 0.0005\)
- \(c_0 = 0.6766097\)
- \(d_1 = 3.426e-2\)
- \(e_1 = 2.070e-5\)
- \(a_1 = -0.1692\)
- \(b_1 = -0.0056\)
- \(c_1 = 2.00564e-2\)
- \(d_2 = 4.464e-4\)
- \(a_2 = 25.3851\)
- \(b_2 = -0.0066\)
- \(c_2 = 1.104259e-4\)
- \(d_3 = 4.215e-1\)
- \(a_3 = 14.0941\)
- \(b_3 = -0.0375\)
- \(c_3 = -6.9698e-7\)
- \(d_4 = -3.107e-3\)
- \(a_4 = -7.0261\)
- \(b_4 = 0.0636\)
- \(c_4 = 1.0031e-9\)
- \(a_5 = 2.7081\)
- \(b_5 = -0.0144\)
- \(k = 0.0162\)
Standard Method - Standardization

- Salinometer
- referenced to
- Standard Seawater
- sequential samples
Limitations

- Temperature stabilized environment
- Sequential standardization
- Skilled staff
- SSW is expensive
- Warming samples may change apparent salinity
The Future...now

- High Performance
- Easy to Use
- Operates at *in situ* temperatures
- Small size
Concepts of the Small Salinometer:

1. Direct comparison of conductivity of sample and standard

2. Direct reading of $R_t$ over wide temperature range
Previous works

(a) China – Tienjin. in Collaboration with Tim Dauphinee, NSERC Canada
Two conductive cells

(b) Ukraine – Sevastopol
Inductive method
Dual chamber
Inductive system

Based on standard
RBR technology
Dual Chamber principle

- Oil Bath
- Fluid inlets
- Fluid outlets
- Sample Cell
- Reference Cell
Concepts of the Small Salinometer:

1. Direct comparison of conductivity of sample and standard

2. Direct reading of $R_t$ over wide temperature range
Salinometers measure $R_t$

\[
S = a_0 + a_1 R_t^{\frac{1}{3}} + a_2 R_t + a_3 R_t^2 + a_4 R_t^3 + a_5 R_t^5 + \frac{T - 15}{1 + k(T - 15)} \left( b_0 + b_1 R_t^{\frac{1}{3}} + b_2 R_t + b_3 R_t^2 + b_4 R_t^3 + b_5 R_t^5 \right)
\]

Practical Salinity Scale - 1978
Test Results

MS-310 Repeatability Using Samples of Constant Salinity

Temperature and Salinity measurements over time.
Test Results

Calibration of Temperature Sensor

Residuals Versus Temperature

Residuals °C

Temperature °C
Test Results

$R_t$ variation with temperature for samples of Standard Seawater
Test Results

MS-310 and AutoSal 8400B against OSIL Linearity pack (1 trial)
Salinometer Drift Comparison

Figure 4. D298 Autosal and MS-310 standardization drift

dS=Sssw(end)-Sssw(start), PSS-78

Station numbers
Performance data compared with PortaSal and AutoSal

<table>
<thead>
<tr>
<th></th>
<th>AutoSal 8400B</th>
<th>PortaSal 8410A</th>
<th>MicroSal MS-310</th>
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</thead>
<tbody>
<tr>
<td>Range</td>
<td>0.0001 to 1.15</td>
<td>0.0001 to 1.15</td>
<td>0.0001 to 2.00</td>
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<tr>
<td>Accuracy</td>
<td>0.002</td>
<td>0.003</td>
<td><strong>0.002</strong></td>
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<tr>
<td>Resolution</td>
<td>0.0002</td>
<td>0.0003</td>
<td><strong>0.0002</strong></td>
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<td>Room Temp</td>
<td>+0°; -2°</td>
<td>+0°; -2°</td>
<td><strong>15° to 30°</strong></td>
</tr>
<tr>
<td>Bath</td>
<td>16.8</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Weight</td>
<td>70</td>
<td>29</td>
<td>5</td>
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<tr>
<td>Power</td>
<td>400</td>
<td>200</td>
<td>10</td>
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<tr>
<td>Supply Voltage</td>
<td>110/220 AC</td>
<td>110/220 AC</td>
<td><strong>12 DC</strong></td>
</tr>
</tbody>
</table>
Easy to use

MS-310 User Interface

Windows®-based control panel streamlines And simplifies operation
Small Size

• 280mm x 280mm x 180mm
• 5kg
• 12VDC
What else can I do with the MS-310?

• Thermosalinograph
• Measure other fluids (guacamole?)
• Immerse in bath for direct calibration of CTDs
• Autosamplers
• Submersible ocean salinometer (ZEFICC)
• Investigate behaviour of seawater types
Characterization of various seawater types over temperature range

Dec06-Jan07 Different waters vs IAPSO SSW Salinity-Temperature test residuals

Temperature, deg.C

\( dS = S_{\text{Sample}} - S_{\text{SSW}} \), PSS-78
Conclusions

The MS-310 represents the future of scientific salinity measurement, allowing measurement of salinity samples directly after CTD retrieval, outside the lab; the nearest thing to *in situ* salinometry.

This offers a new perspective for understanding the nature of the conductivity measurements of seawater and opens doors beyond the PSS-78.

*Water samples should not have to be adjusted to a salinometer’s comfort conditions, rather the salinometer should adjust to the CTD measurement conditions – this is the future of salinity technology*