The GLOSCAL project and observations of near sea surface salinity variability

GLOSCAL : Global ocean sea surface salinity : calibration and validation of SMOS
P.I. F. Gaillard, IFREMER / Brest

Participant laboratories :
IFREMER/LPO, LOS, SISMER
IPSL/LOCEAN, LATMOS,
LEGOS,
Météo-France,
CLS,
ACRI-st

See also presentation by N. Reul and poster by B. Picard
Outline

• Large scale variability of the SSS from in-situ measurements

• Sea Surface Salinity drifters

• Salinity vertical gradients near sea surface
GLOSCAL: Large scale variability of the SSS from in-situ measurements

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Goals

• Produce monthly gridded fields of near surface temperature and salinity based on in-situ data over the Period: 2002-Present

• Compute the corresponding mean annual cycle and variances before SMOS launch date. To prepare the SMOS data validation

• Keep producing the monthly fields during the SMOS mission using as many validated data as possible
ISAS: In-Situ Analysis system/ Near Surface module

Grid:
- ½° Mercator
- Analysis performed at 5 m (representing 0-10m layer)
- Variances and Covariance scales defined at each grid point

Method: Optimal Interpolation

- \( y_0 \): data vector (observations)
- \( x_a \): state vector (T or S at grid points)
- \( P_a \): covariance matrix of analyzed field
- \( R \): data error covariance matrix
- \( C_0 \) and \( C_{ao} \): covariance matrices of obs-obs and analyzed-obs
- \( X_f \): first guess for \( x \) at analyzed points
- \( Y_f \): first guess at data point

\[
\begin{align*}
    d &= y^o - y^f \\
    x^a &= x^f + C_{ao} (C_0 + R)^{-1} d \\
    P^a &= P^f - C_{ao} (C_0 + R)^{-1} C_{ao}^T \\
    y^o - y^{ao} &= R(C_0 + R)^{-1} d
\end{align*}
\]

Data type and depth:
- Argo profilers (5-15 m)
- GOSUD: Thermosalinometer (3-20 m)
- Drifting buoys (0(1m))
Argo dataset

- Argo measurement starts between 4-5 m and 10m,
- Coverage is nominal since fall 2007 (see error map below)
- Data downloaded from Coriolis are checked against climatology before use

% of a-priori variance

<table>
<thead>
<tr>
<th>Year</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
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<tbody>
<tr>
<td>Error</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Producing validated TSG datasets

A Processing protocol has been defined for TSG data from French research vessels and VOS and will be implemented during 2009 by Coriolis datacenter

- Conversion to GOSUD – NetCDF format
- Adding water sample and instrument calibration information
- Visual check
- Correction using water samples or Argo data (TSG-QC software)

In order to produce salinity fields including TSG data and check the analysis tool we have processed the 2006, 2007 research vessels dataset
Results from ARGO data: Global ocean T-S variability

The mean 2003-2007 anomaly

- Argo data have been combined to produce gridded fields of temperature and salinity over the period 2002-2007 (ARIVO product). Horizontal maps of the difference between our estimation of the mean temperature (b) and salinity (d) at 10m depth during 2003-2007 and WOA5 shows the global warming of the northern hemisphere. The salinity change has a more complex pattern: warming of the north atlantic correspond to a saltening, except in the tropical band. In the North Pacific we observe strong zonal variability.

- On the left: zonal integrals of ARIVO T and S changes relative to WOA05 (blue curves) and differences between NOAA optimum Interpolation SST short-term (NSST, 2003-2007) and long-term (NSST_L, 1990-2007, red).
Schedule

- January-April 2009: Preparing ISAS-V4 surface module, testing
- Mai 2009: Analysis of surface layer from 2002-2008 V1 dataset.
- June 2009: Computing climatologies and variances
- September 2009: Full depth analysis and estimate of mixed layer depth
- October 2009: Real time SST/SSS/MLD and SMOS validations
- November 2009: Upgrade of in-situ dataset (adding surface buoys and new TSG data)
Salinity drifters

G. Reverdin, J. Boutin, F. Gaillard, J. Rolland, T. Delcroix
LOCEAN, LPO, Meteo-France, LEGOS

Both conductivity/salinity sensors from SeaBird

• SIO (SBE 37 SI)
• Metocean (SBE 47)
• SURFACT (ASD C/T sensor) (‘low cost’)
# Salinity drifters

## Characteristics

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Metocean</th>
<th>SIO/PacificGyre</th>
<th>SURFACT/LOCEAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time resolution</td>
<td>60 minutes</td>
<td>30 minutes</td>
<td>15 minutes</td>
</tr>
<tr>
<td>CT sensor</td>
<td>SBE 47</td>
<td>SBE 37 SI</td>
<td>ASD</td>
</tr>
<tr>
<td>Mean depth for conductivity measurement</td>
<td>50cm</td>
<td>40cm</td>
<td>26cm (recent 10cm)</td>
</tr>
<tr>
<td>Temp. depth</td>
<td>50cm &amp; 17 cm</td>
<td>40 cm</td>
<td>28cm (recent 10cm)</td>
</tr>
<tr>
<td>Duration</td>
<td>About 6months</td>
<td>&gt;12months</td>
<td>1-2months</td>
</tr>
</tbody>
</table>
Validation of SSS from drifters

- Extensive validation of Metocean/Pacific Gyre drifters in the Gulf of Biscay: SSS accuracy and drifts after 3 months < 0.03 pss78 (Reverdin et al., JAOT, 2007); C and T sensors not at the same depth may create artificial diurnal S signal (corrected); after 8 months at sea, no bias on a Pacific Gyre in the N. Atl.

- Validation of new SURFACT near Banyuls (to be used for process studies):

![Surface salinity measured by 2 SURFACT floats; samples taken close to the floats are indicated in blue. Low salinity values are due to freshwater coming from the coast, as confirmed by low salinity values on samples taken after the SURFACT time series. Accuracy < 0.05 pss over 1.5 months with strong biology.](image)
7 Drifters deployed since Sept. 2007 in the North Atlantic (21 months of meas.) in the Gulf of Biscay (30 months of meas.):
4 Drifters deployed since October 2007 in the tropical Atlantic (20 months of meas.)
Temperature measurements of a SURFACT tied up to a Metocean drifter

Temperature measurements performed by two surface floats in the southern part of the Gulf of Biscay (44.25N, 3.63W), at three depths (56cm in red, 30cm in black, 15cm in blue). The closer to the surface the measurement is, the larger the temperature peak recorded in the afternoon is. Also the increase of temperature starts earlier at 15cm than at 30 and 56cm.

Freshening event observed by a METOCEAN drifter in the tropical Atlantic Ocean

Trajectory of Metocean drifter (Oct 07-May 08) superimposed on rain rates from a) F14 SSM/I satellite (29 December 2007 at 2030) and b) F13 SSM/I satellite (29 December 2007 at 2111). Large dark dot = drifter position on 29 and 30 December 2007.

Salinity decrease recorded by Metocean buoy at 7°N, 48°W. The black curve represents the salinity measured at 66 cm depth and the gray curve the temperature at 56 cm depth.

Hénocq, Boutin et al., in revision, 2009
### Future deployments of PG and MO (depending on SMOS launch date)

<table>
<thead>
<tr>
<th>Date</th>
<th>Area</th>
<th>Number</th>
<th>Responsible</th>
<th>Campaign/ship</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 2009</td>
<td>Gulf of Biscay</td>
<td>2 PG 1 MO</td>
<td>LOCEAN</td>
<td>CAROLS-Gogasmos/Antéa</td>
</tr>
<tr>
<td>September 2009</td>
<td>Atlantic NE</td>
<td>3 MO</td>
<td>LPO</td>
<td>Podorange</td>
</tr>
<tr>
<td>October 2009</td>
<td>Atlantic eq.W</td>
<td>3 MO</td>
<td>LPO</td>
<td>Podorange</td>
</tr>
<tr>
<td>September 2009</td>
<td>Atlantic eq.E</td>
<td>2 MO 1 PG</td>
<td>LOCEAN</td>
<td>Pirata/Antéa</td>
</tr>
<tr>
<td>End 2009</td>
<td>Pacific W</td>
<td>5 PG</td>
<td>LEGOS</td>
<td>Commercial ship</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>May 2010</td>
<td>Indian equatorial</td>
<td>2 PG</td>
<td>LOCEAN</td>
<td>Tara</td>
</tr>
<tr>
<td>June 2010</td>
<td>Atlantic NE</td>
<td>2 MO 1 PG</td>
<td>LPO</td>
<td>Ovide/Thalassa</td>
</tr>
</tbody>
</table>

**Total 2009-2010**

22 (11PG + 11MO)

Need to be coordinated with J. Font/J. Pelegri and D. Stammer

17 remaining drifters to be deployed in 2011
Salinity vertical gradients near sea surface

Claire HENOCQ*, Jacqueline Boutin, Gilles Reverdin, Sabine Arnault**
*LOCEAN / ACRI-St
**LOCEAN

Objectives:
- quantify the vertical variability of the salinity above 10m depth
- rain influence?
- determine highly variable specific areas
Observation of rain impact at local scale

- TAO mooring in the equatorial Pacific (5S, 95W); hourly measurements of salinity at 1, 5 and 10m, sea surface wind speed, rain rate measured every 1 à minutes

\[ S_{10m} - S_{1m} = 0.93 \text{ pss} \]

Henocq et al (JAOT, 2009, in revision)
10m-1m salinity vertical difference averaged over 10 days: still large differences (>>0.1 psu)

- 4 TAO moorings (Eastern Equatorial Pacific, 95W)
- In case of large rain rate, differences >>0.1 psu remain

Henocq et al (JAOT, 2009, in revision)
Data

• ARGO floats (Coriolis data base) ➔ various depth (>4m)

• Thermosalinographs:
  from ships ➔ 5 and 11 m depth
  from fixed moorings (TAO/PIRATA) ➔ 1, 5 and 10 m depth

• CTD / XCTD
  ARAMIS project
  SISMER data base ➔ Measurements every meter between 4 and 10 m
  World Ocean Database 2005

• Correction and sorting of data according to quality coefficients (e.g. CORIOLIS data flagged 3 ou 4 discarded)

• Classification of the differences according to vertical depths:
  \[ \Delta S_{10-5} = S([8; 11]m) - S([4; 6]m) \]
  \[ \Delta S_{5-1} = S([4; 6]m) - S([0; 2]m) \]
  \[ \Delta S_{10-1} = S([8; 11]m) - S([0; 2]m) \]
Large differences (>0.2 psu) observed close to intertropical convergence zones:

Henocq et al. (JAOT, 2009, in revision)
Influence of rain

1. Colocation of salinity vertical differences with satellite rain rates measured the same day and the 2 days before in a 12.5km radius: Satellites : AMSR-E, TMI, SSMI (F10, 11, 13, 14, 15)

2. Compute a « 3 days accumulation of maximum rain rate» ( = sum of daily maximum rain) (« 3D max rain rate ») parameter

3. Correlate vertical salinity differences with 3D max rain rate ; compute and mean and std of salinity vertical differences in classes of 3D max rain rate
Influence of rain for 3D max rain rate < or >= 10 mm/hr

Henocq et al (JAOT, 2009, in revision)
Statistical relationship between vertical salinity differences and 3D max rain rate

- Vertical difference increases with 3D max rain rate
- Larger dependency obtained for vertical difference computed with salinity

Henocq et al (JAOT, 2009, in revision)
On average over large data set, vertical variability (up to 1m) is less than 0.1psu

In rainy regions, signature of rain history on surface salinity is expected to be on average >0.15psu => this suggests to classify the differences between SMOS SSS \textit{(at $1\text{cm depth}$)} and 5m or 10m in situ SSS as a function of 3Dmax rain rate:

- To look for better than 0.2 psu accuracy in rainy regions
- To validate SMOS SSS by testing its sensitivity to rain history. This criteria could be used to validate SMOS SSS.

Need measurements of salinity close to the surface (depth $<$ 50cm), especially in tropical regions.