THE IMPORTANCE OF SALINITY MEASUREMENTS IN THE HEAT STORAGE ESTIMATION FROM TOPEX/POSEIDON

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OUTLINE

Heat storage anomaly (HS) is derived from altimeter data through the relation between thermosteric variations in the upper layer and variations in the sea surface height.

This study compares in situ and satellite heat storage estimates. The discrepancies between the two estimates are mostly related to haline effects.

The objectives of this study are:

1. to investigate if a haline height correction significantly improves the satellite-derived heat storage anomaly signal, and
2. if this correction should be based on in situ salinity measurements or climatological estimates.

HEAT STORAGE

The in situ heat storage is

\[ HEAT\ STORAGE = \int \left( \rho C_p \right) dz \]

\[ \left( T \right) \] temperature
\[ \left( \alpha \right) \] thermal expansion coefficient
\[ \left( \psi \right) \] filtered height
\[ \left( \eta \right) \] haline correction

\[ \rho, C_p, \alpha, \psi, \eta \] are estimated from the WOA94 climatology as a function of \( \eta, z \) and \( T \), \( \eta \) is weight-averaged by temperature and layer thickness.

\[ q_s \] is the integral of the product of the climatological haline contraction coefficient, \( \eta \), and the salinity anomaly (residual after subtracting the annual mean) profiles from the surface to a depth \( h \).

\[ q_s = \int_0^h S \eta dz \]

SEA SURFACE HEIGHT

The TOPEX/POSEIDON (T/P) sea surface height anomaly is decomposed using 2D finite impulse response filtering as

\[ H_S = \left( \frac{1}{1 - \alpha T} \right) H_T \]

\[ \alpha \] is the basin-wide non-propagating variability, mostly due to mesoscale heating, and cooling and advections by the broad oceanic currents.

\[ \eta \] is composed mainly of first-mode barotropic Munk waves, with periods of 24, 12, 6, 3 and 1.5 months.

\[ \psi \] includes a variety of signals among them equatorial Kelvin waves and meso-scale eddies variability.

The small-scale, non-propagating signals are filtered out.

CONCLUSIONS

<table>
<thead>
<tr>
<th>Source</th>
<th>No sal. rms</th>
<th>corr.</th>
<th>WOA94 rms</th>
<th>corr.</th>
<th>in situ rms</th>
<th>corr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CalCOFI</td>
<td>67</td>
<td>.49</td>
<td>68</td>
<td>.49</td>
<td>56</td>
<td>.67</td>
</tr>
<tr>
<td>Hy5</td>
<td>71</td>
<td>.75</td>
<td>69</td>
<td>.67</td>
<td>64</td>
<td>.86</td>
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<tr>
<td>HOT</td>
<td>65</td>
<td>.63</td>
<td>73</td>
<td>.57</td>
<td>56</td>
<td>.75</td>
</tr>
</tbody>
</table>

- The use of in situ salinity estimates significantly augmented the correlations (up to 0.15) and decreased the rms differences (up to 11 × 10^-7 J m^-2) in the HS' estimates from in situ and satellite measurements.
- The correlations based on climatological salinities are equal or worse than not including haline effects at all.
- These results stress the importance of having salinity measurements concurrent with satellite altimeter measurements to study sub-surface processes.
- Although in situ salinity measurements are sparse the lack of a relatively small haline correction does not preclude the use of altimeter data for oceanic heat storage estimation.

LOCATION OF THE STATIONS

Bermuda

This time series has an average one measurement every 15 days and the HS' from both sources were interpolated to one month resolution.

The T/P HS' is in better agreement (lower rms difference and higher correlation (52% and 0.90) are obtained for the 1995–97 period compared to 1993–94 (75% and 0.75). This time series coincides with a T/P cross-over latitude where the time series were interpolated to monthly resolution for comparison.

This station coincides with a T/P cross-over latitude where the in situ heat storage is in better agreement (lower rms difference and correlation (52% and 0.90) are obtained than not including haline effects at all.

Hawai’i

This time series has an average sampling rate of 40 days. Both time series were interpolated to monthly resolution for comparison.

The results when including in situ salinity are significantly better than using the climatology.

In fact, when the salinity is not used, the rms and the correlation are better than using climatology.

California

The CalCOFI array time series has a temporal resolution of 90 days. The T/P time series was interpolated to match this resolution.

Salinity measurements of the sea surface height degrade near the coast due to local tides that are inadequately removed from the T/P data and spread seaward by the filter. Thus, correlations decrease and rms difference increase toward the coast. Only eleven stations west of this gradient were considered.

The top row shows comparisons for two stations. The inclusion of salinity effects from in situ measurements improved significantly the T/P estimates. As observed in other regions the inclusion of a climatological salinity correction is detrimental to the results.

W O D A T A S T E R

- Hydrographic sections from the California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruises at the California coast.
- The hydrostation ALOHA from the Hawaii Ocean Time series Program (HOT) in Hawaii.
- The hydrographic time series in Bermuda (Hy5) in the western Atlantic.

RESULTS

The in situ HS is calculated from temperature profiles integrated between the surface and a depth below the main thermocline.

For each time series the long term mean is computed with the maximum number of complete years of data. The in situ HS is estimated by removing this mean.

To evaluate the role of \( \eta \) in determining the T/P HS', three cases are studied:

- no salinity,
- climatological (WOA94) salinity,
- in situ salinity.

For each of these cases the T/P HS' is compared with the in situ HS' when the haline correction is based on in situ rather than climatological salinity.

When the haline correction is not included, the rms difference and correlation are about the same as when the climatological salinity is used.

Results are better after 1995 as the dominant signal in the heat storage spectrum shifts from semi-annual to annual. Lower rms difference and higher correlation (12.2 × 10^-7 J m^-2 and 0.80) are obtained for the 1995–97 period compared to 1993–94 (15.2 × 10^-7 J m^-2 and 0.80).

This station coincides with a T/P cross-over latitude where the spatial aliasing and degradation of the correlation.

The small-scale, non-propagating signals are filtered out.

- The use of in situ salinity estimates significantly augmented the correlations (up to 0.15) and decreased the rms differences (up to 11 × 10^-7 J m^-2) in the HS' estimates from in situ and satellite measurements.
- The correlations based on climatological salinities are equal or worse than not including haline effects at all.
- These results stress the importance of having salinity measurements concurrent with satellite altimeter measurements to study sub-surface processes.
- Although in situ salinity measurements are sparse the lack of a relatively small haline correction does not preclude the use of altimeter data for oceanic heat storage estimation.

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