Impact of marine mammal temperature and salinity data on ocean model fields

GODAE Ocean View Symposium, Baltimore, November 2013

Fiona Carse, Matt Martin and Alistair Sellar

Introduction

Temperature and salinity profiles are being obtained from instrumented marine mammals in near-real time. The mammals sample to depths of up to 2000 metres in high-latitude regions where there are few other in-situ profile observations.

Currently, most of the marine mammal profiles are not being assimilated into FOAM as they arrive more than 48 hours after their validity time. Most profiles arrive 3 - 5 days after the observation was made.

Using FOAM hindcasts, we aim to quantify the impact of mammal profiles on model temperature and salinity fields. If the mammal observations have a positive impact, it is hoped that evidence from this study will be used to encourage efforts to improve timeliness of data delivery.

Model details

Three hindcasts, with varying mammal data assimilation, have been run using the Met Office Global FOAM v12 system for the period 01 Dec 2010 to 31 Dec 2011:

- **SealTS**: seal temperature and salinity profiles assimilated
- **SealT**: seal temperature profiles only assimilated
- **NoSeals**: no seal data assimilated

The v12 version of Global FOAM uses the NEMO ORCA025L75 ocean model coupled to the CICE sea-ice model. Data assimilation is performed using the NEMOVAR 3D-Var system with profile observations from EN3-v2a (including mammals) as well as altimeter, SST and sea-ice data (Blockley et al., 2013).

Observations by marine mammals

Figure 1: CTD-SRDL deployed on a male southern elephant seal (*Mirounga leonina*). Around 90% of southern hemisphere mammal profiles are gathered by southern elephant seals.

Pressure	<1%
Position	2 km
Temperature	0.005 ºC
Salinity	0.02
Salinity bias	O(0.1)

Table 1: CTD-SRDL accuracy (Boehme, 2009)

CTD-SRDLs record temperature, salinity and pressure at 17 depth levels. Profiles are recorded from the deepest point of the seal's dive to the sea surface.

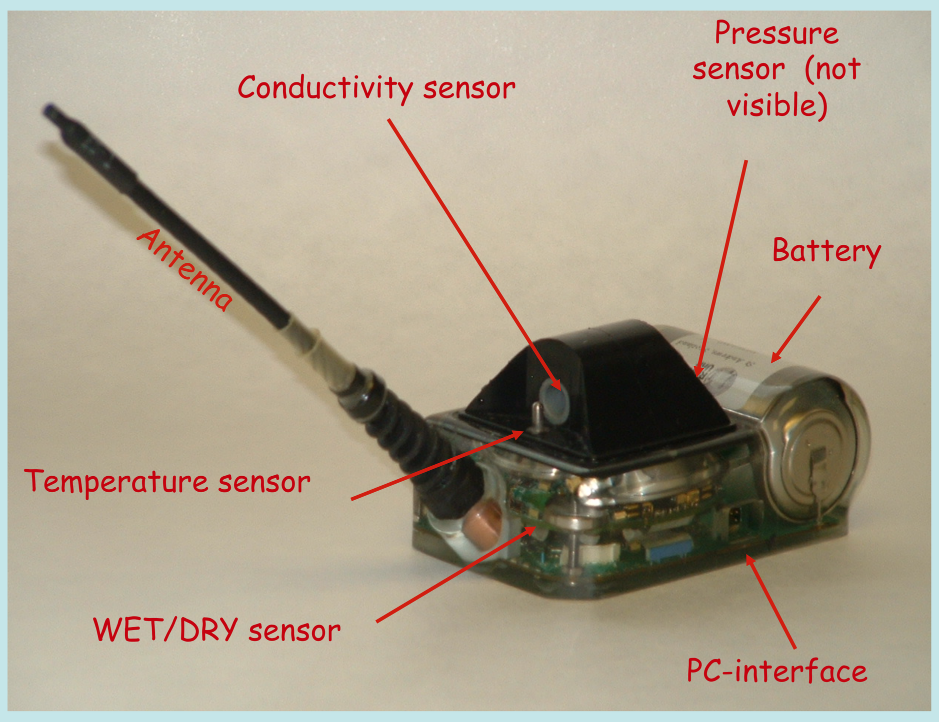


Figure 2: CTD Satellite Relay Data Logger (CTD-SRDL), designed and manufactured by Sea Mammal Research Unit (SMRU), St Andrews

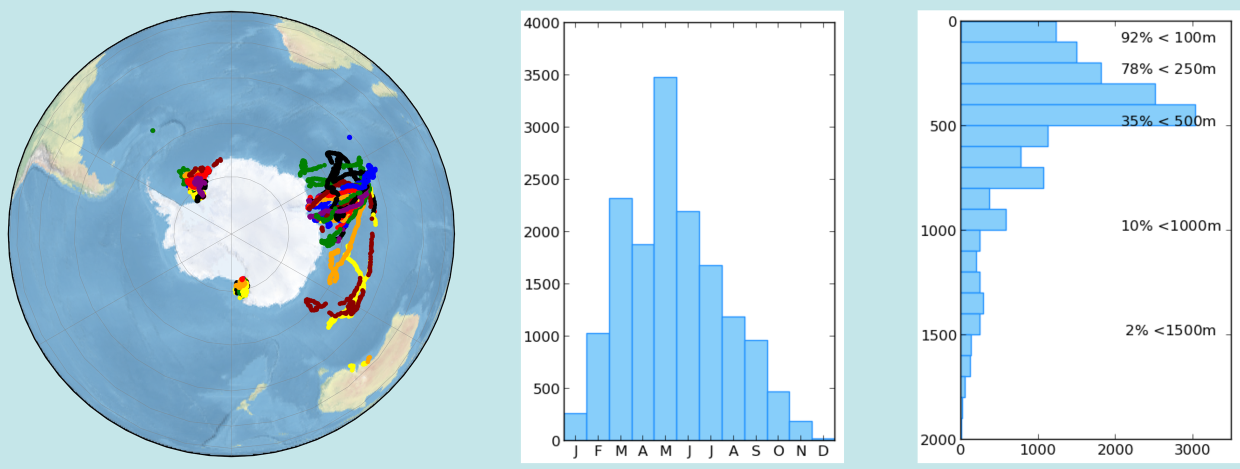


Figure 3: Southern hemisphere mammal temperature profile observations in 2011. 15,632 profiles by 76 individuals, shown by position, month and maximum depth. Mean (median) profile depth is 512m (426m).

Data quality problems

Profile splitting: Each profile is stored as four messages in the data logger.

Timeliness: When the seal surfaces, the CTD-SRDL transmits data to ARGOS satellites. Messages are selected for transmission at random from the previous 3 to 5 days, so often arrive outside the 48-hour validity window.

Incomplete data: The seals' brief time spent at the surface combined with poor satellite visibility often results in incomplete data transmission and imprecise position fixes. It is common to lose part of the profile if all four messages are not received together. Only 20% of surfacings in 2004/5 yielded full datasets (Boehme, 2009).

Contrasting impact of mammal T & S assimilation with T-only

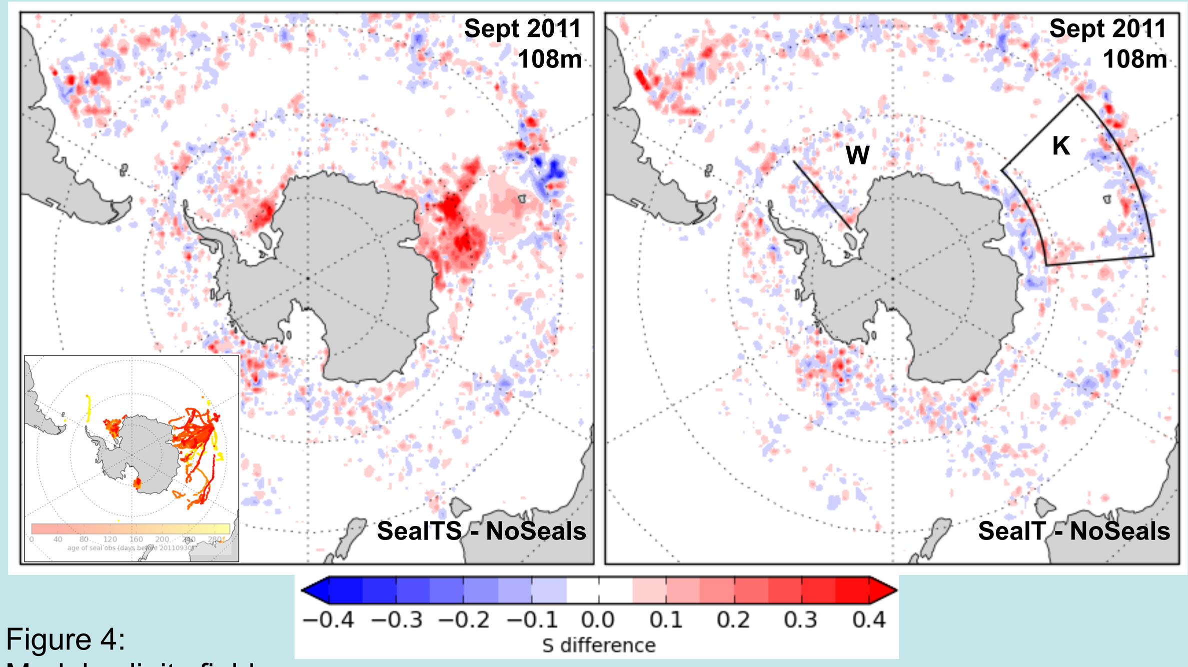


Figure 4: Model salinity field differences. The SealTS run is up to 0.4 psu too saline in regions where there are seal obs. SealT - NoSeals shows improvement in the salinity field when mammal salinity profiles are not assimilated.

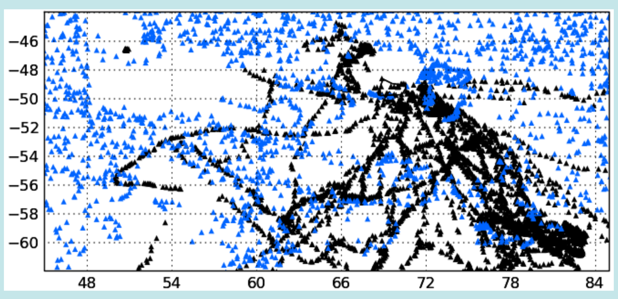


Figure 5: Kerguelen region with 2011 profile obs (K in figure 4). Seals (black), Argo (blue).

The impact of mammal profiles on model fields is difficult to verify as there are no collocated independent observations to compare against.

O-B statistics for Kerguelen (5) are used to compare the impact of mammal and Argo observations (6).

SealTS

Assimilating mammal T & S profiles has large impacts on RMS, up to 33% for S and 4% for T.

Reversal of impact in Kerguelen suggests S values are biased high: -6.2% Argo to +39.1% Seal (6i,j).

Biased S data is reducing the positive impact of T profiles due to the T-S balance used in the data assimilation scheme (Weaver 2005).

High S bias has been noted in lab testing of CTD-SRDLs. It is constant for each mammal, but cannot be corrected in real time (Boehme, 2009).

SealT

Assimilation of mammal T-only profiles gives up to 5.8% (2.5%) improvement in T (S) RMS statistics.

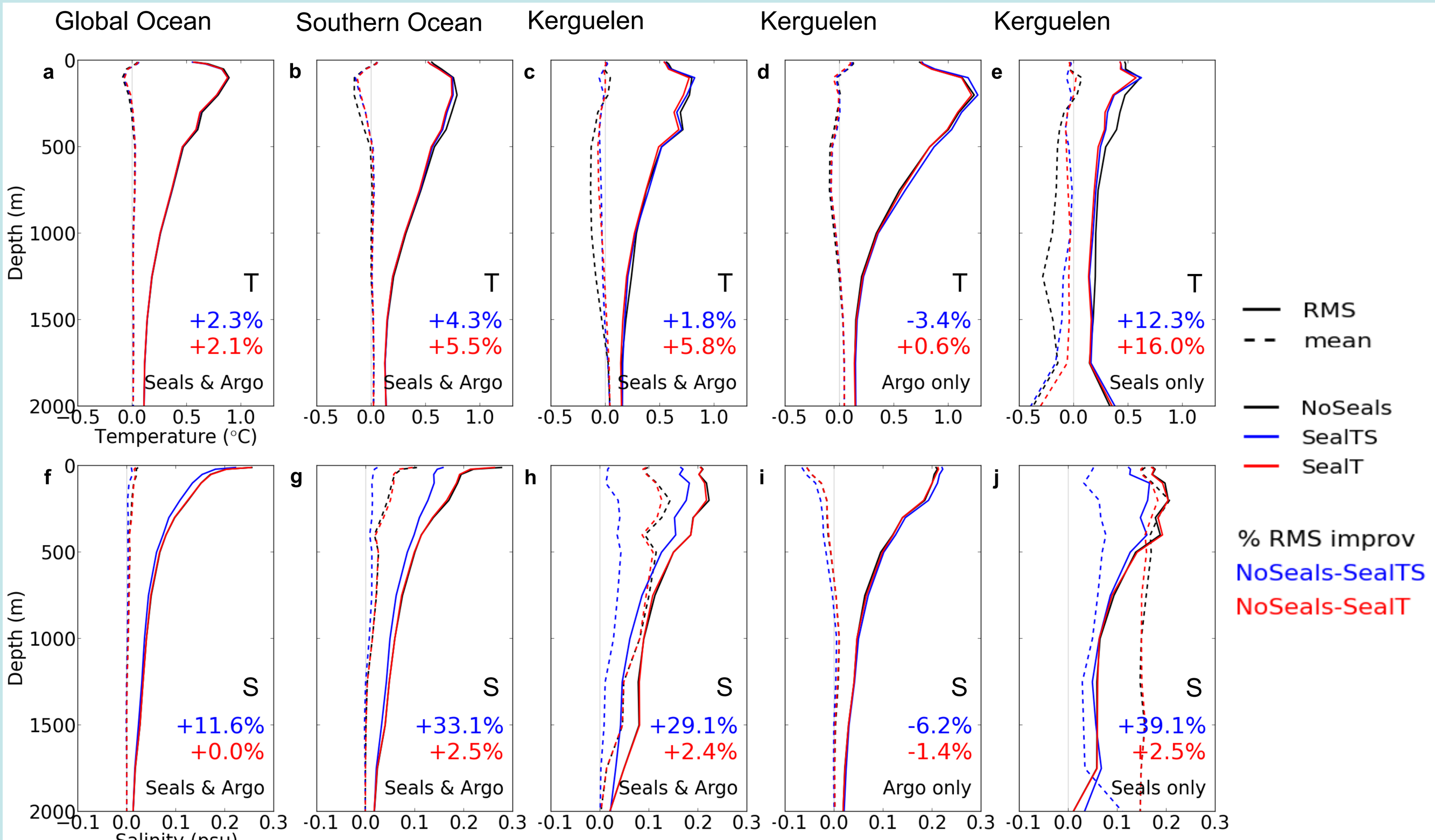


Figure 6: Observations minus background mean and RMS statistics for 3 ocean regions for temperature (a-e) and salinity (f-j) for 3 hindcast runs. O-B calculation uses all profiles (a-c, f-h), Argo profiles only (d, i) and mammal profiles only (e, j). Percent improvement in RMS difference between assimilating runs and NoSeals run are shown in each panel. %Improv = [$RMS_{NoSeals}$-$RMSD_{SealXX}$]/$RMSD_{NoSeals}$

Mammal temperature-only assimilation: impacts on model fields

Northern hemisphere impacts: West Spitsbergen Current at 108m, April 2011

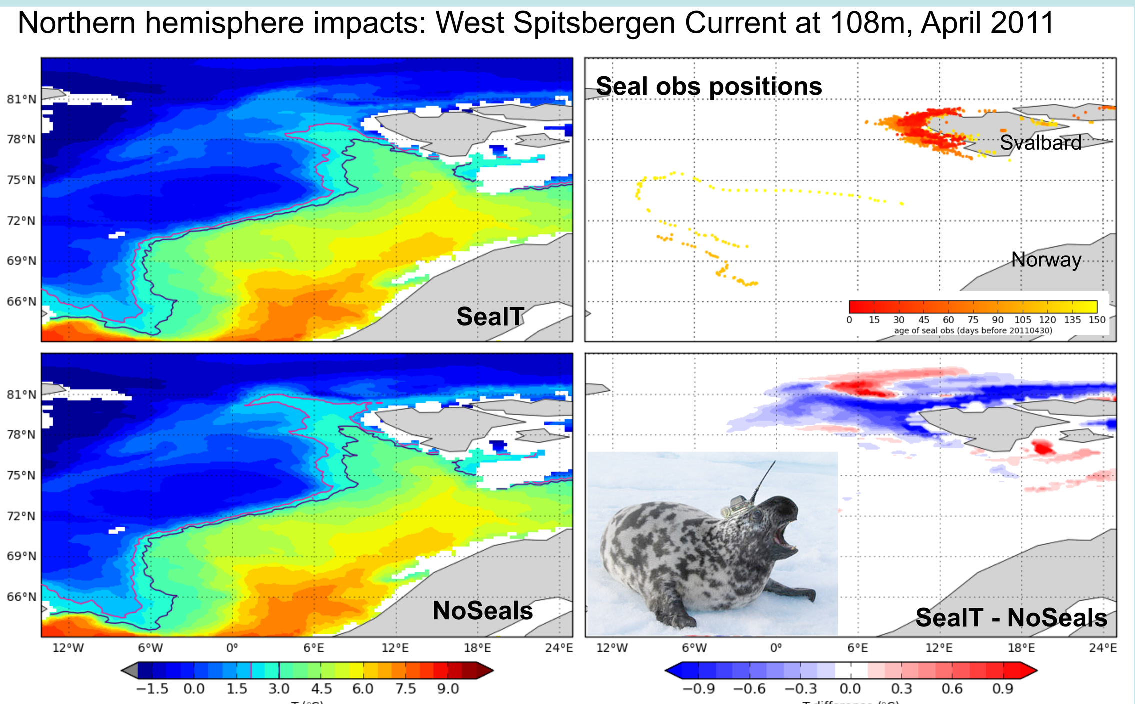
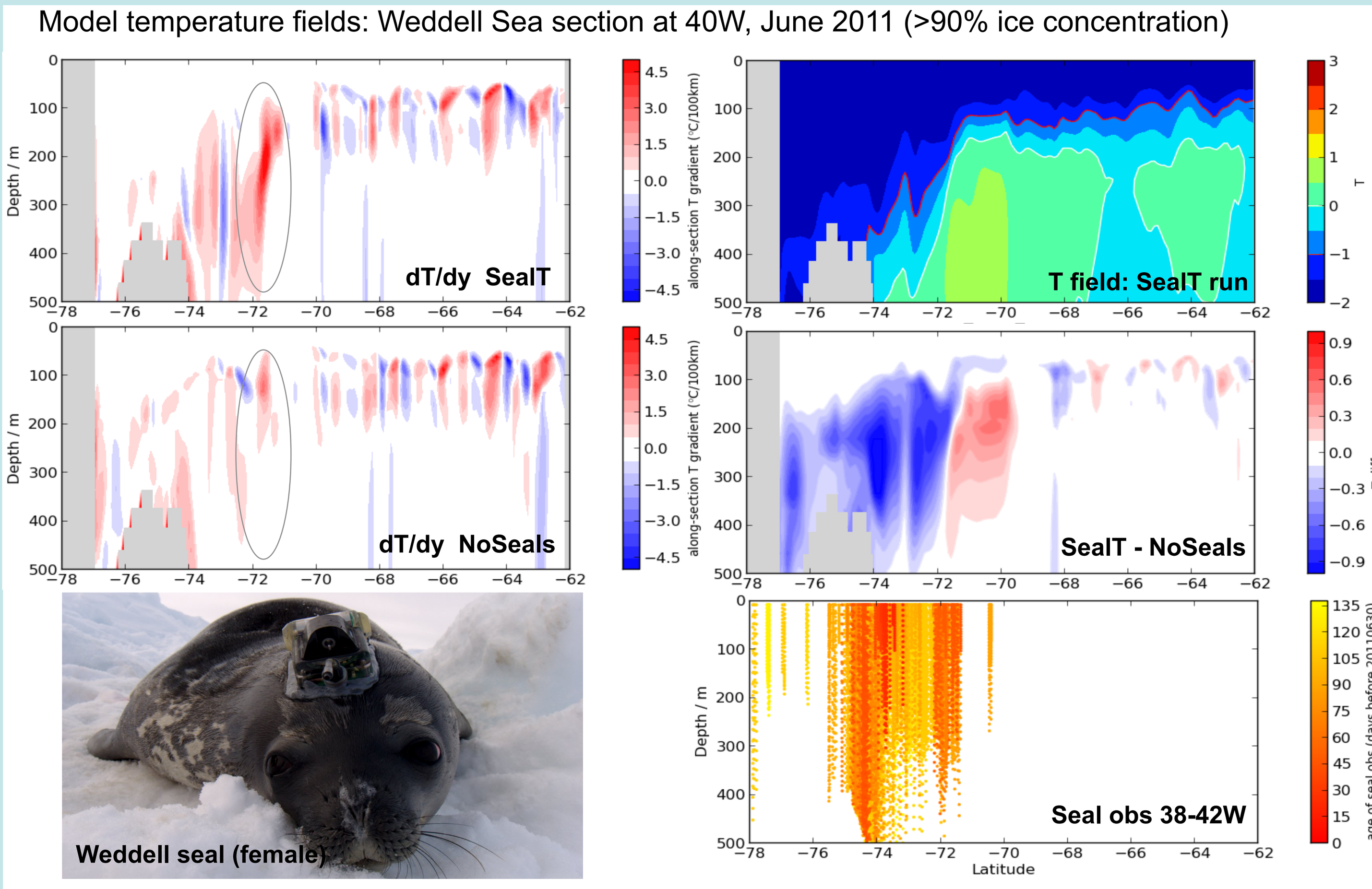


Figure 7: Mammal observations constrain the north and westward extent of the West Spitsbergen Current when seal temperature profiles are assimilated, compared to the NoSeals run (left panels). The assimilation of seal T data results in model temperatures up to 1 ºC colder than NoSeals to the west and north of Svalbard (lower right). Northern hemisphere mammal observations are made by hooded seals (inset, lower right), bearded seals and ringed seals (not shown).

Figure 8: Under ice: the ACC Southern Boundary front is sharper and extends deeper when seal temperature profiles are assimilated, compared to the NoSeals run. Model T south of 72S are up to 1 ºC colder than when seal T profiles are assimilated (W, figure 4).

Model temperature fields: Weddell Sea section at 40W, June 2011 (>90% ice concentration)



Conclusions & further work

Assimilation of marine mammal temperature and salinity profiles into FOAM v12 has large impacts on all ocean regions where seal observations are available.

The salinity data is biased high. We conclude that only mammal temperature profiles should be assimilated in operational models until a salinity correction can be achieved in near-real time.

Ocean fronts and currents appear different in model fields when seal T is assimilated, compared to no seal data.

We aim to work with SMRU to improve the timeliness of data arrival and investigate whether salinity values can be corrected in near-real time.

References

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Acknowledgements

We thank Lars Boehme (SMRU) for helpful discussions and for the photographs in figures 1, 2, 7 and 8.
SEAOS project website: www.biology.st-and.ac.uk/seaos/

Met Office FitzRoy Road, Exeter, Devon, EX1 3PB United Kingdom
Tel: +44 (0)1392 885680 Fax: +44 (0)1392 885681
Email: fiona.carse@metoffice.gov.uk