In-situ ocean observations: Building a research quality library for data assimilation in the CAFE climate forecasting system

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With the ocean carrying much of the memory for the global climate system, subsurface ocean observations hold the promise of longer-term climate forecasts. In the past decade there has been a revolution in our ability to observe the ocean including a growing array of near real-time profiling floats. Our efforts to collect and curate an ocean observations library is crucial for the assimilation of data into the CSIRO Climate Analysis Forecast Ensemble (CAFE) system delivering climate reanalyses and hindcasts/forecasts.

Assimilation of subsurface ocean data to improve decadal climate prediction

The ocean becomes the most influential source of memory in the climate system as the prediction effort moves past the seasonal horizon.

While the modes of decadal variability are often expressed in terms of Sea Surface Temperature (SST) observations, the underlying mechanisms include subsurface ocean circulation. Assimilation of in-situ subsurface ocean observations of temperature and salinity can positively impact forecast skill.

An ocean observing system sustained over climate change time scales is vital for the research community to improve longer-term predictions.[1,2]

A complete and consistent global ocean subsurface repository for Earth system, climate, and ocean studies

Despite dedicated independent efforts over decades by global research organisations assembling, rescuing, and quality-controlling (QC) subsurface ocean profiles, the global historical profile database still contains a relatively large fraction of biased, duplicated, and substandard quality data and metadata that can confound climate-related applications.[3]

The past decade has seen the ARGO float revolution with a surge of near real-time temperature and salinity data. However important regions are still poorly sampled including the deep ocean below 2000 m (Figure 1).

Database options with significant historical non-ARGO holdings

- **WOD** – World Ocean Database
- **CARS** – CSIRO Atlas of Regional Seas
- **EN4 –** UK MET office quality controlled subsurface ocean temperature and salinity profiles
- **CORA -** Coriolis Ocean database for ReAnalysis[4]
- **IQuOD -** International Quality Controlled Ocean Database[3]

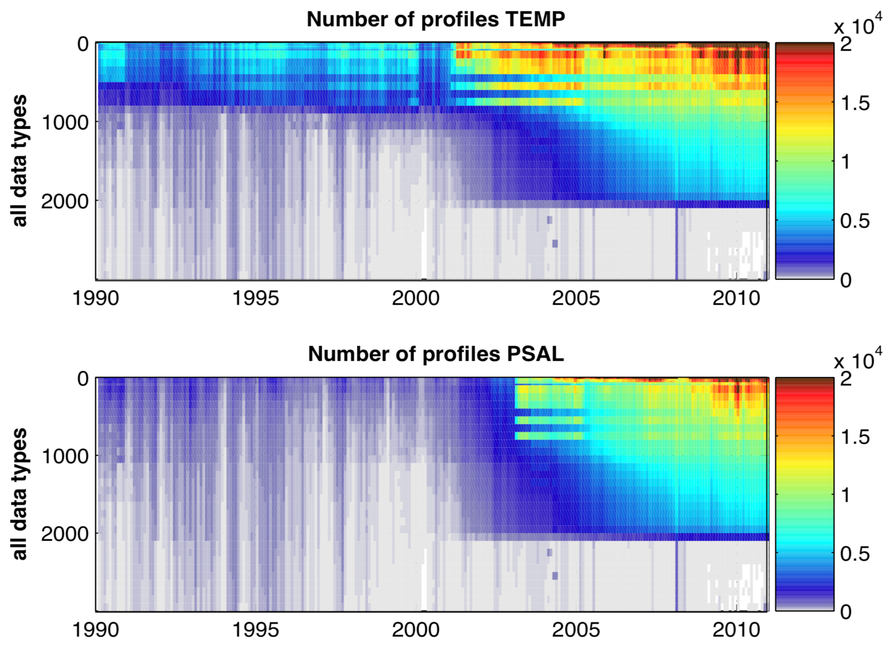

Figure 1: The number of temperature and salinity profiles for one of the global datasets (CORA3) per month across depths and as a function of time.[4]

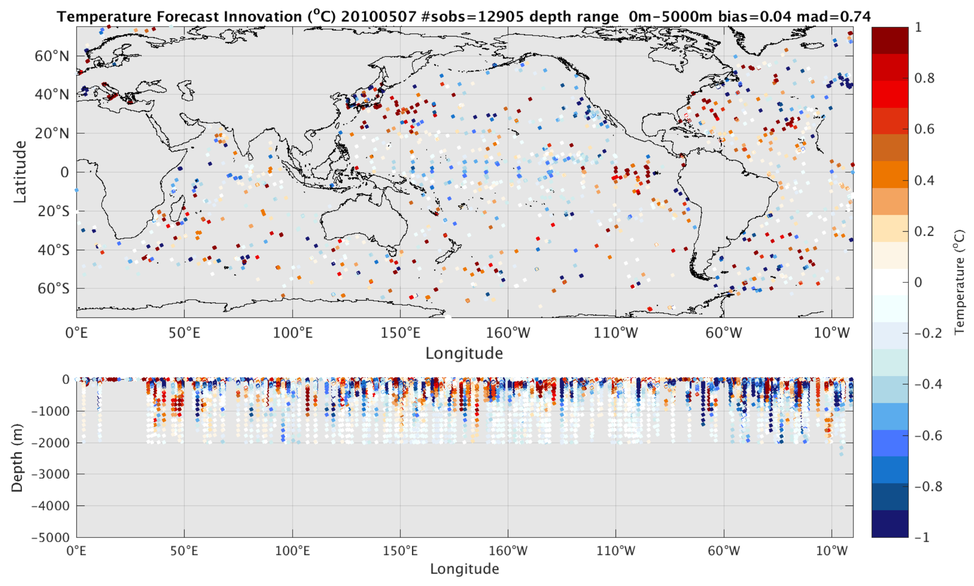

Figure 2: In-situ temperature innovations (color bar, °C) for 2010/05/07 (top) spatial coverage and (bottom) longitude vertical distribution assimilated by CSIRO's CAFE system. The bias and mean absolute deviation (MAD) are shown. The observations come from a variety of observing platforms including Argo, Ocean Sites (including Tropical Moored Buoy program), XBT, ships (research and volunteer), and animal tags and in this case were taken from the CORA 5.0 dataset.

Climate Analysis Forecast Ensemble (CAFE) system

The CAFE system developed by the Decadal Climate Forecasting Project modelling team[5] at CSIRO utilises:

- A current generation climate model - a variant of the GFDL CM2.1 ocean (MOM5) - atmosphere (AM2) - land (LM2) - sea ice (SIS).
- Coupled data assimilation applying the EnKF-C software of Sakov[6] which allows for easy implementation of EnOI, ETKF and DEnKF variants and assimilation of a diverse range of surface and subsurface ocean observations (Figure 2) as well as sea-ice and atmospheric products.
- An ensemble prediction system capable of generating initial perturbations specific to a given dynamical process at a given lead time.

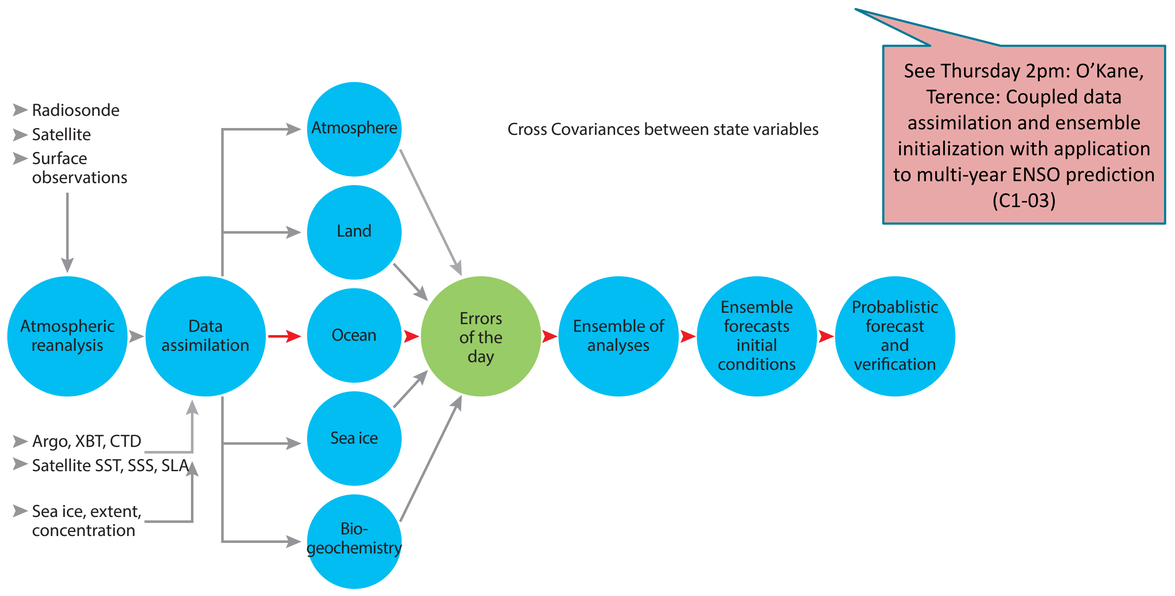

Figure 3: Schematic of variants of the CSIRO Climate Analysis Forecast Ensemble (CAFE) system [5]

Plans for reanalyses and hindcasts / forecasts

Subsurface ocean observations from the 1980's through to the present day are required to feed the data assimilation system underpinning a 30 year reanalysis effort that will begin in late 2018.

The 1988 – 2018 coupled reanalysis will include a 96 member ensemble and will also provide the initial conditions for seasonal hindcasts / forecasts with a 5 year leadtime, 30 ensemble members, and multiscale breeding.

FOR FURTHER INFORMATION

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REFERENCES

1. Dunstone NJ. Philosophical transactions Series A, Mathematical, physical, and engineering sciences. 2014;372(2025):20130340. doi:10.1098/rsta.2013.0340.
2. Dunstone & Smith. GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L02709, doi:10.1029/2009GL041609, 2010.
3. IQuOD - International Quality Controlled Ocean Database - http://www.iquod.org/
4. Cabanes, C., A. et al , 2013: The CORA dataset: validation and diagnostics of in-situ ocean temperature and salinity measurements. Ocean Science, 9, 1-18, doi:10.5194/os-9-1-2013.
5. O'Kane et al., 2018. Coupled data assimilation and ensemble initialization with application to multi-year ENSO prediction. Journal of Climate, under review.
6. Sakov, P. (2017) EnKF-C user guide, version 1.65.4, arXiv:1410.1233, 1–48.

CLIMATE ANALYSIS FORECAST ENSEMBLE system

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