3.5 TOWARDS AN OCEANOGRAPHIC CLIMATOLOGY OF THE AOTEAROA – NEW ZEALAND REGION

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1. INTRODUCTION

1.1. Motivation

A variety of global, sub-global, and regional oceanographic climatologies (or hydrographic atlases) exist with coverage of the western South Pacific Ocean and Tasman Sea. However, the motivation for this work is to develop a regional oceanographic climatology (OCAANZ[2]) customised for particular research needs, for which we control the spatial and temporal domains, the included input data, the interpolation algorithms, the output grid resolution and the visualisation methodology. A further key motivation is to design a system that can be updated as new input data continue to become available.

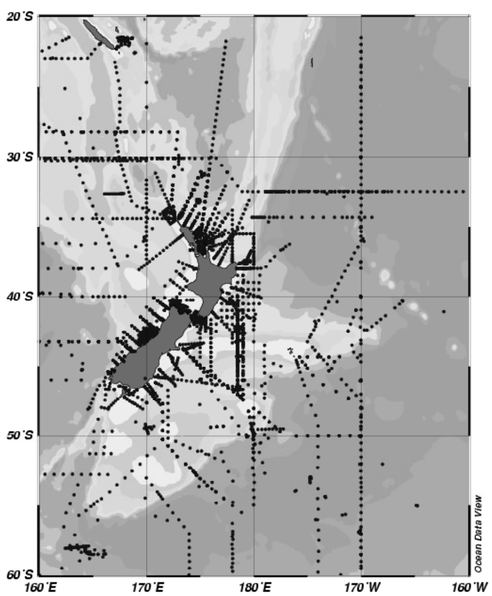

Figure 1: Spatial Distribution of NIWA and World Ocean Database 2001 CTD Casts

1.2. Spatial Domain

Figure 1 shows the "OCAANZ region" -- the default spatial domain chosen for the climatology: latitude 20°S to 60°S, longitude 160°E to 200°E. To allow for future flexibility, the initial input data collation spans a larger region: latitude 10°S to 70°S, longitude 150°E to 210°E.

1.3. Hydrographic Variables

As it stands, the climatology restricts itself to the basic scalar hydrographic fields: pressure- or depth-referenced temperature and salinity. High vertical resolution input data are sub-sampled at fifty-six standard depths, chosen to coincide with the standard depths used by several well-known oceanographic climatologies with coverage of the region. From the temperature and salinity fields, it is possible to calculate corresponding fields for various derived hydrographic variables, including surface mixed-layer depth.

2. INPUT DATA

2.1. Sources

The principal source of data for the climatology is the collection of high quality, high vertical resolution CTD data that has been collected by NIWA and its predecessors since the mid-1980s. This includes in excess of 3300 CTD casts in the default spatial domain and is presently growing by the rate of about 300 to 400 casts per year. In addition to the NIWA collection, the climatology optionally incorporates data sets from several international data sources:

- The WOCE Hydrographic Program One-time Survey[3]
- The WOCE Hydrographic Program Repeat Surveys[4]
- NODC's World Ocean Database 2001[5]
- The CSIRO Archive of Australian Hydrographic Data [6]
- AWI's Southern Ocean Database[7]

These data sets are all freely and easily available for downloading from public access web sites. We are indebted to these organisations and their excellent data access policies and implementations.

Initial work towards the climatology considers only high quality, high vertical resolution CTD data for inclusion as input data. This has the advantages of consistently high data quality, simplified quality control, greater uniformity of data formats, and simplified pre-processing -- but obviously has potential to significantly reduce the spatial and temporal coverage of the composite data set. A subsequent development will be to investigate the inclusion of data collected with earlier and

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[2] Oceanographic Climatology Around Aotearoa – New Zealand

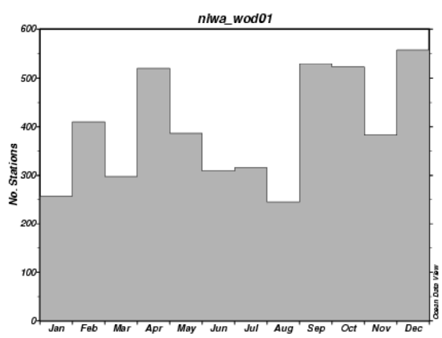
[3] http://whpo.ucsd.edu/
[4] http://whpo.ucsd.edu/
[5] http://www.nodc.noaa.gov/
[6] http://www.marine.csiro.au/
[7] http://www.awi-bremerhaven.de/

alternative technologies, such as hydrographic water bottles, XBTs, and profiling floats.

2.2. Spatial Distribution

Figure 1 shows the CTD cast positions of the NIWA collection and the NODC's World Ocean Database 2001, some 4700 or more casts in all. Primarily, the spatial distribution reflects two factors: (1) the focus of oceanographic research programs of NIWA and its predecessors; and (2) the design of the WOCE HP one-time and repeat surveys.

A detailed analysis of the spatial distribution shows that ~70% of these casts are situated in just three or four relatively restricted research locales, corresponding to factor (1) above. Also, the NIWA casts tend to locate closer to the landmass, while the non-NIWA casts tend to occupy the open ocean. A further significant characteristic is that there are large areas, particularly towards the eastern and northeastern edges of the region, where there are essentially no casts.



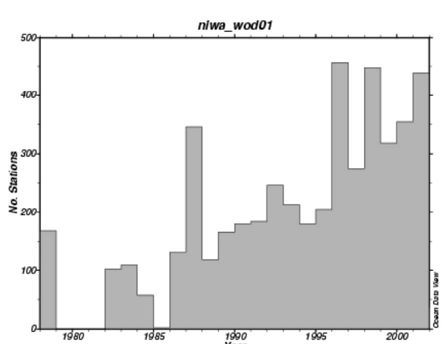


Figure 2: Temporal Distribution of NIWA and World Ocean Database 2001 CTD Casts

2.3. Temporal Distribution

Figure 2 shows the temporal distribution of the CTD casts. The temporal distribution by year indicates a concentration in the last decade or fifteen years (with some earlier international observations in the late 1970s and early 1980s). It also shows the increasing rate of data collection, from 100 to 200 casts per year in the early 1990s to the present 300 to 400.

The temporal distribution by month shows a reasonable uniformity with some bias towards the months of April, September, October and December -- or in terms of Southern Hemisphere seasonality, away from winter and later summer.

2.4. Quality Control

"Careful selection of source" underpins data quality control for the climatology. This notion is reflected in the initial choice to consider for inclusion as input data only high quality, high-resolution CTD casts. These observations have largely been obtained with stable, high precision instrumentation and have been properly processed, calibrated and quality controlled by their originators.

Then, too, with respect to the NIWA collection, we are able to revisit in detail the raw data and related records, and the data processing and calibration procedures. In addition, certain general properties of the observation method can apply to quality control. For example, all NIWA CTD casts prior to 1993 were collected using instrumentation with intrinsically less accurate conductivity sensors.

There is still, however, a necessity to implement data quality control specifically for the climatology. A variety of validation methods, objective and subjective, are available, each of value in a particular situation for identifying a particular type of questionable data.

3. FIRST THOUGHTS ABOUT ADEQUACY AND REPRESENTATIVENESS

Simple arguments based on the spatial density of CTD casts provide some insight into the likely adequacy and representativeness of the climatology. At one-degree resolution, the default domain totals 40 x 40 or 1600 grid cells. Consequently, the average spatial density of the 4700 casts is ~2.9 per grid cell. Supposing a near uniform spatial distribution of casts and a static ocean that varies only slowly with horizontal position on the scale of one-degree, 4700 casts would seem to be entirely adequate. Unfortunately, neither of those assumptions applies. As Figure 1 shows, the spatial distribution is highly non-uniform, and supposing the ocean realistically complies with such a simple model completely ignores features such as diurnal cycles and other short time-scale variability; annual and sub-annual cycles; inter-annual and decadal cycles; fronts and mesoscale variability.

Focusing on the desire to obtain an output climatology with a grid cell size or spatial resolution finer than one degree, however, reveals a significant shortage of input data. Each doubling of resolution or halving of grid size, introduces a factor of four to the input data requirement, so that if the climatology was to attain three casts per grid cell coverage at the 1/4 degree level, 4 x 4 x 4700 or 75200 near-uniformly distributed casts would be needed. At the present rate of acquisition, this would take until the year 2190.

Turning attention to the question "how much better can the climatology expect to do in regions of higher cast density", a similar line of reasoning applies. In the sub-region "North New Zealand", defined as latitude 30°S to 37.5°S, longitude 170°E to 180°E, there are some 1400 casts in 75 one-degree grid cells or nearly twenty casts per grid cell, compared with the average density for the entire OCAANZ region of just about three. This cast density suggests that the climatology might accurately characterise an ocean that varies slowly over a one-degree grid cell and that has a simple annual cycle. If, however, significantly better than one-degree resolution is required, or as again is the case, the CTD casts are non-uniformly distributed over this sub-region, then the situation is again one of a significant shortage of input data.

4. INTERPOLATION ALGORITHM

Although based on similar concepts, available objective-analysis or related methodologies vary significantly in the way they interpolate or map spatially scattered input data onto a regular grid (Stephens et al (2001), Ridgeway et al (2002)). The objective analysis for OCAANZ will use horizontal length scales based on ocean dynamics (i.e. the Rossby radius) or on input data spacing. The final output climatology will likely involve an optimised combination of these approaches depending on input data coverage.

5. VISUALISATION OF THE OUTPUT CLIMATOLOGY

Possibilities for output visualisation include: station distribution maps; hydrographic parameters on standard levels, on density surfaces, on core layers, at the sea floor, and on vertical sections; and objective interpolation error maps.

6. COMPARISON WITH EXISTING CLIMATOLOGIES

Four hydrographic atlases or climatologies with coverage of the OCAANZ region are:

1) NODC's World Ocean Atlas 2001[8]
2) Texas A&M University's WOCE Southern Ocean Atlas[9]
3) AWI's Hydrographic Atlas of the Southern Ocean[10]
4) CSIRO's Atlas of Regional Seas (CARS2000)[11]

These, and possibly other, climatologies provide a benchmark for the output of the new work.

7. WORK IN PROGRESS

Development will continue beyond the conference. Please visit:
http://homepages.ihug.co.nz/~matt-w/ocaanz.html
for progress updates.

8. REFERENCES

Ridgway K.R., J.R. Dunn, and J.L. Wilkin, 2002: Ocean interpolation by four-dimensional least squares -Application to the waters around Australia, *J. Atmos. Ocean. Tech.*, **19** (9), 1357-1375.

Stephens C., J.I. Antonov, T.P. Boyer, M.E. Conkright, R.A. Locarnini, T.D. O'Brien, and H.E. Garcia, 2002: *World Ocean Atlas 2001, Volume 1: Temperature.* S. Levitus, Ed., NOAA Atlas NESDIS 49, U.S. Government Printing Office, Wash., D.C.

9. ACKNOWLEDGEMENTS

From the perspective of this work, no end of thanks and recognition are due to the multitude of research and support workers from Aotearoa – New Zealand and other parts of the globe who's collective contribution is that the input data exist and are so easily available to the climatology.

9.1. Software

Portions of this work use the following software: Schlitzer, R., Ocean Data View, http://www.awi-bremerhaven.de/GEO/ODV, 2002.

[8] http://www.nodc.noaa.gov/OC5/WOA01/
[9] http://woceatlas.tamu.edu/
[10] http://www.awi-bremerhaven.de/Atlas/SO/
[11] http://www.marine.csiro.au/~dunn/eez_data/atlas.html