EXAMPLES USING THE IMOS USER CODE LIBRARY (R VERSION)

Version 1.0

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IMOS – eMII

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Table of Contents

Revision History

Name	Date	Reason for Changes	Version

1. Introduction

This document describes how to use the NetCDF parser from the IMOS User Code Library to load IMOS NetCDF data files in an R environment, extract variables and produce a variety of plots including depth profiles, time-series, and raster plots.

1.1 Installation of the IMOS User Code Library (R)

The IMOS User Code Library for R can be downloaded from:
https://github.com/aodn/imos_user_code_library/tree/master/R/commons/NetCDF

The ncdf4 package needs to be downloaded and installed in R for use of the IMOS NetCDF parser function. It can be downloaded from:
http://cirrus.ucsd.edu/~pierce/ncdf/

1.2 Downloaded an IMOS NetCDF file

All IMOS datasets are available through the IMOS portal:
http://imos.aodn.org.au/imos

A guide showing how to use the IMOS portal and providing additional information on NetCDF files is available at:
http://portalhelp.aodn.org.au/Portal2_help/

For users familiar with the different IMOS facilities and datasets, IMOS NetCDF files are directly available via a Thredds catalog (*i.e.* inventory of datasets, organised into directories) at:
http://thredds.aodn.org.au/thredds/catalog/IMOS/catalog.html

Once users have selected a NetCDF dataset to work on, they are directed to a Thredds server page, from which several file download options are available, typically: **OPeNDAP**, **HTTP Server**, **WCS**, and **WMS**. For more details about those different options, refer to the 'Download via OPeNDAP' web page on the portal help forum:
http://portalhelp.aodn.org.au/Portal2_help/?q=node/112

The OPeNDAP access option is a link to an online OPeNDAP Dataset Access Form and allows users to work on the dataset they are interested in without necessarily downloading it on their local machine. The 'OPeNDAP Dataset Access Form' page lists the NetCDF global attributes and variables included in the NetCDF file. NetCDF files are commonly read remotely in R by copying the URL located in the 'Data URL' field. Alternatively, users can download a copy of the NetCDF file by clicking on the HTTP server link on the Thredds server page. More specifically, for IMOS NetCDF files that are large in volume, it is advised to either download NetCDF files on your

local machine and parse this local NetCDF file or select a subset of the NetCDF file on OPeNDAP that can be then read remotely in R.

2. General features

To parse a NetCDF file in R, load the ncdf4 package and NetCDF parser function ('ncParse.R') and specify into your R environment the local or remote location of the NetCDF file. This is achieved using the following script.

```
## Load the ncdf4 package and NetCDF parser function
library( ncdf4)
source( '/path/to/ncParse.R')

## Specify the location of the NetCDF file
# remotely
file <- 'http://thredds.aodn.org.au/thredds/dodsC/IMOS/SOOP/SOOP-
 XBT/aggregated_datasets/region/NW/IMOS_SOOP-XBT_T_19830603T000600Z_aggregated-
 profiles-NW_FV01_END-19860803T120000Z.nc'
# locally
file <- '/path/to/NetCDFfileName.nc'

## Parse the NetCDF of interest
dataset <- ncParse( file)
```

2.1 Metadata

To list all the global attributes of the NetCDF file, type dataset$metadata in the R console.

```
> dataset$metadata
$netcdf_filename
[1] "http://thredds.aodn.org.au/thredds/dodsC/IMOS/SOOP/SOOP-
XBT/aggregated_datasets/region/NW/IMOS_SOOP-XBT_T_19830603T000600Z_aggregated-
profiles-NW_FV01_END-19860803T120000Z.nc"

$title
[1] "SOOP-XBT Upper Ocean Thermal Data collected in the North-West region around Australia"

$abstract
[1] "This dataset contains all the XBT profiles collected in the North-West region around
Australia.This region has the following characteristics:Minimum Latitude -17Maximum Latitude
0Minimum Longitude 99Maximum Longitude 134"

$keywords
[1] "Oceans>Ocean Temperature>Sea Water Temperature ;Oceans>Bathymetry/Seafloor
Topography>Water Depth ;Bathythermographs>Expendable Bathythermographs
(XBT)"$file_version_quality_control
[1] "Data in this file has been through the IMOS quality control procedure (Reference Table C).
Every data point in this file has an associated quality flag"
```

2.2 Variables

To list all the variables of the NetCDF file, type summary(dataset$variables) in the R console.

```
> summary( dataset$variables)
                Length Class  Mode
TIME            20     -none- list
LATITUDE        21     -none- list
LONGITUDE       22     -none- list
DEPTH           22     -none- list
TEMP            20     -none- list
platform        4      -none- list
row_size        5      -none- list
trajectory_index 4     -none- list
profile_index   5      -none- list
xbt_unique_ID   3      -none- list
xbt_serialnumber 3     -none- list
xbt_probetype   5      -none- list
xbt_recorder    5      -none- list
calibration_offset 3   -none- list
calibration_scale 3    -none- list
xbt_line        3      -none- list
```

To list all the attributes of a variable, for instance TEMP, type str(dataset$variables$TEMP) in the R console.

```
> str( dataset$variables$TEMP)
List of 20
 $ dimensions                  : chr "observation"
 $ data                        : num [1:103525(1d)] NA NA 26.7 26.7 26.7 26.8 26.8 26.8 26.8 26.8 ...
 $ standard_name               : chr "sea_water_temperature"
 $ long_name                   : chr "sea water temperature"
 $ units                       : chr "Celsius"
 $ _FillValue                  : num -100
 $ valid_min                   : num 5
 $ valid_max                   : num 32.4
 $ quality_control_set         : num 1
 $ ancillary_variables         : chr "TEMP_quality_control"
 $ flags                       : int [1:103525(1d)] 1 1 1 1 1 1 1 1 1 1 ...
 $ flags_long_name             : chr "Quality control flag for temperature"
 $ flags_standard_name         : chr "sea_surface_temperature status_flag"
 $ flags_quality_control_conventions: chr "IMOS standard set using IODE flags"
 $ flags_quality_control_set   : num 1
 $ flags__FillValue            : int -1
 $ flags_flag_values           : int [1:10] 0 1 2 3 4 5 6 7 8 9
 $ flags_valid_min             : num 0
 $ flags_valid_max             : num 9
 $ flags_flag_meanings         : chr "no_qc_performed good_data probably_good_data
bad_data that_are_potentially_correctable bad_data value_changed not_used not_used"|
```

Then the value of each variable attribute, for instance dimensions, can be obtained by typing dataset$variables$TEMP$dimensions in the R console.

```
> dataset$variables$TEMP$dimensions
[1] "observation"
```

2.3 Dimensions

To list all the dimensions of the NetCDF file and their attributes, type str(dataset$dimensions) in the R console.

```
> str( dataset$dimensions)
List of 4
 $ length_char:List of 1
  ..$ data: int 15
 $ observation:List of 1
  ..$ data: int 103525
 $ profile    :List of 1
  ..$ data: int 501
 $ trajectory :List of 3
  ..$ data     : chr [1:27(1d)] "ane5983" "ane6083" "ane6183" "ane6283" ...
  ..$ long_name: chr "cruise identifier"
  ..$ cf_role  : chr "trajectory_id"
```

3. Dataset examples

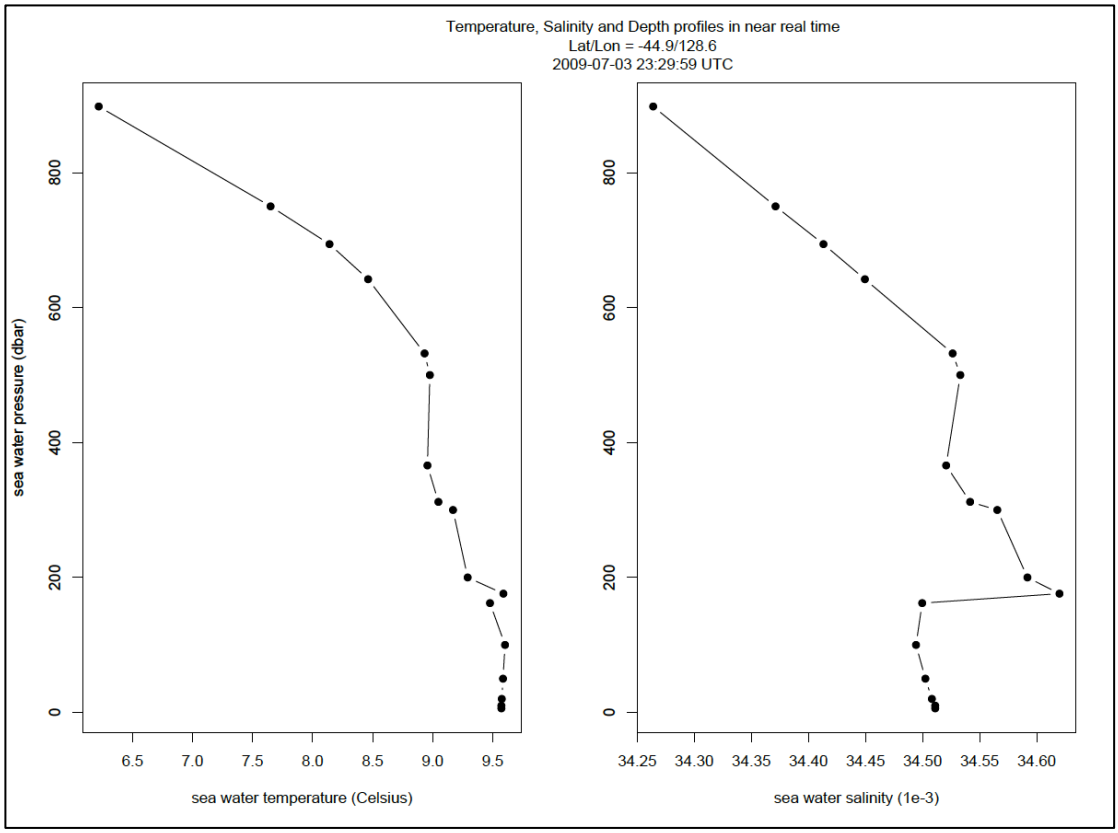
3.1 AATAMS – Animal Tagging and Monitoring

The Australian Animal Tagging And Monitoring System (AATAMS) is a coordinated marine animal tagging project. CTD Satellite Relay Data Loggers are used to explore how marine mammal behaviour relates to their oceanic environment.

AATAMS NetCDF files can be found at:
http://thredds.aodn.org.au/thredds/catalog/IMOS/AATAMS/marine_mammal_ctd-tag/catalog.html

In the example below, the ncParse function is used to extract temperature and salinity data. Those data are then used in conjunction with depth data to produce temperature and salinity profiles.

```
file <- 'http://thredds.aodn.org.au/thredds/dodsC/IMOS/AATAMS/marine_mammal_ctd-
 tag/2009_ct36_Kerguelen/ct36-B-09/profiles/IMOS_AATAMS-
 SATTAG_TSP_20090703T233000Z_ct36-B-09_FV00.nc'
dataset <- ncParse( file)

temp <- dataset$variables$TEMP$data
psal <- dataset$variables$PSAL$data
pres <- dataset$variables$PRES$data
lat <- round( dataset$variables$LATITUDE$data, 1)
lon <- round( dataset$variables$LONGITUDE$data, 1)
date <- dataset$variables$TIME$data
title <- dataset$metadata$title
templab <- gsub( '_', ' ', dataset$variables$TEMP$long_name)
psallab <- gsub( '_', ' ', dataset$variables$PSAL$long_name)
preslab <- gsub( '_', ' ', dataset$variables$PRES$long_name)
tempunit <- gsub( '_', ' ', dataset$variables$TEMP$units)
psalunit <- gsub( '_', ' ', dataset$variables$PSAL$units)
presunit <- gsub( '_', ' ', dataset$variables$PRES$units)

split.screen( c( 1, 2))
screen( 1)
plot( temp, pres, xlab = paste( templab, ' ', '(', tempunit, ')', sep = ''), ylab = paste( preslab, ' ', '(',
 presunit, ')', sep = ''), type = 'b', pch = 19)
mtext( paste( title, '
', 'Lat/Lon = ', lat, '/', lon, '
', date, ' UTC', sep = ''), side = 3, line = .5, at = 10.75)
screen( 2)
plot( psal, pres, xlab = paste( psallab, ' ', '(', psalunit, ')', sep = ''), ylab = '', type = 'b', pch = 19, bg =
 'transparent')
close.screen( all = TRUE)
```


Temperature, Salinity and Depth profiles in near real time
Lat/Lon = -44.9/128.6
2009-07-03 23:29:59 UTC
sea water pressure (dbar)
0
200
400
600
800
6.5
7.0
7.5
8.0
8.5
9.0
9.5
sea water temperature (Celsius)
34.25
34.30
34.35
34.40
34.45
34.50
34.55
34.60
sea water salinity (1e-3)

3.2 ABOS – Deep Water Moorings

The Southern Ocean Time Series (SOTS) sub-facility provides high temporal resolution observations in sub-Antarctic waters. Observations are broad and include measurements of physical, chemical and biogeochemical parameters from multiple deep-water moorings.

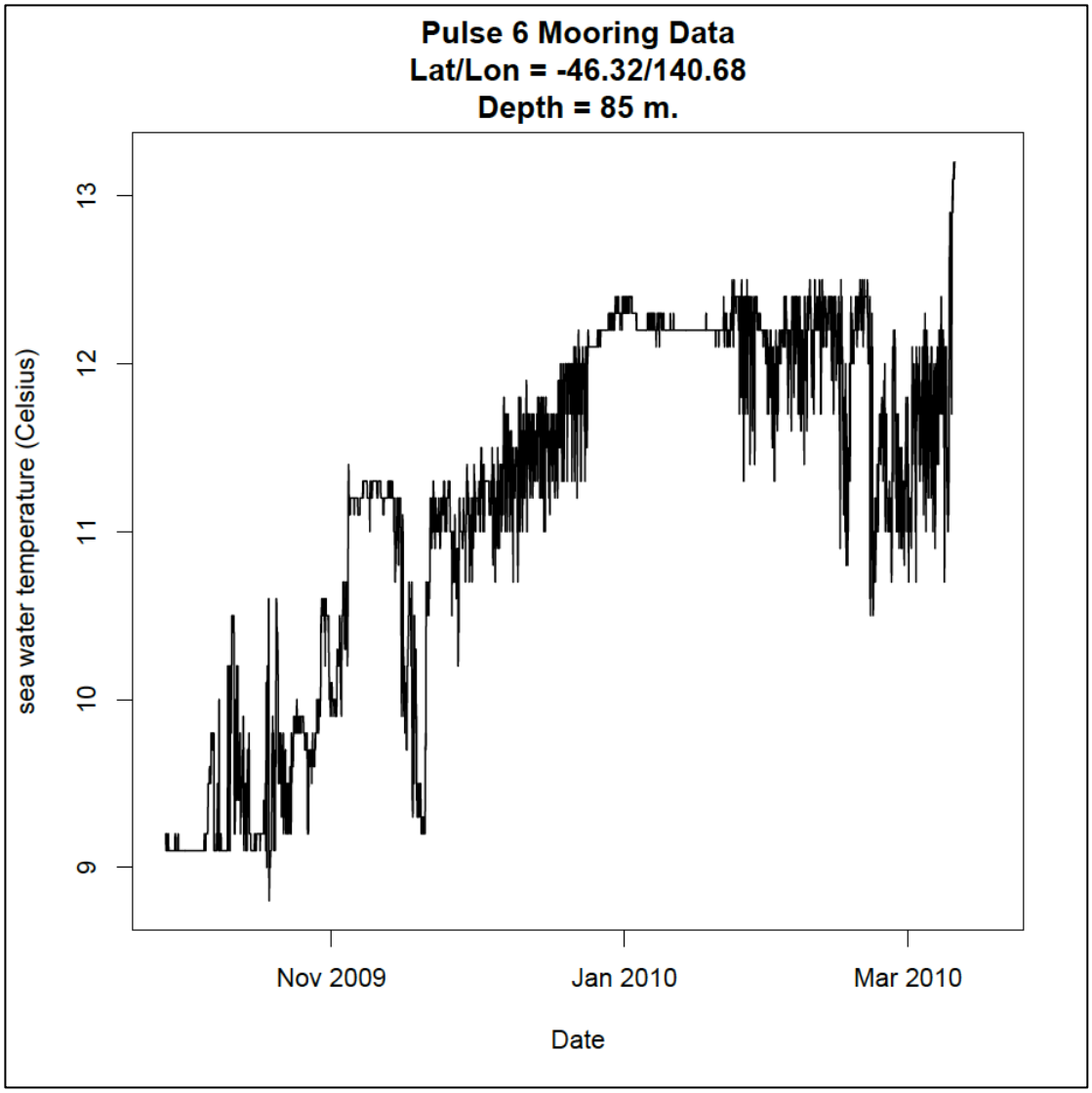
ABOS NetCDF files can be found at:
http://thredds.aodn.org.au/thredds/catalog/IMOS/ABOS/SOTS/catalog.html

In the example below, the ncParse function is used to extract temperature data from a Pulse mooring instrument and then produce a temperature time series plot.

```
file <- 'http://thredds.aodn.org.au/thredds/dodsC/IMOS/ABOS/SOTS/Pulse/IMOS_ABOS-
  SOTS_20090927T122500Z_PULSE_FV01_PULSE-6-2009_END-20100318T020500Z_C-
  20121009T214634Z.nc'
dataset <- ncParse( file)

temp <- dataset$variables$TEMP_85_1$data
date <- dataset$dimensions$TIME$data
pres <- dataset$variables$TEMP_85_1$sensor_depth
lat <- round( dataset$metadata$Latitude, 2)
lon <- round( dataset$metadata$Longitude, 2)
title <- dataset$metadata$title
templab <- gsub( '_', ' ', dataset$variables$TEMP_85_1 $standard_name)
tempunit <- gsub( '_', ' ', dataset$variables$TEMP_85_1 $units)

plot( date, temp, xlab = 'Date', ylab = paste( templab, ' ', '(', tempunit, ')', sep = ''), main = paste(
  title, '
', 'Lat/Lon = ', lat, '/', lon, '
', 'Depth = ', pres, ' m.', sep = ''), type = 'l', pch = 19, xaxt = 'n')
axis.POSIXct( 1, seq( date[1], date[length(date)], by = 'months'), format = '%b %Y')
```

To see the abstract of that NetCDF file, type dataset$metadata$abstract in the R console

```
> dataset$metadata$abstract
[1] "The Pulse 6 mooring was deployed from September 2009 to March 2010 at Lat -46.3224, Lon
  140.6776. Moored instruments are deployed by the IMOS Australian Bluewater Observing
  System (ABOS) Southern Ocean Time Series sub-facility for time-series observations of physical,
  biological, and chemical properties, in the Sub-Antarctic Zone southwest of Tasmania, with yearly
  servicing. The Southern Ocean Time Series (SOTS) Sub-Facility is responsible for the
  deployment of Pulse moorings. These time-series observations are crucial to resolving ecosystem
  processes that affect carbon cycling, ocean productivity and marine responses to climate
  variability and change, ocean acidification and other stresses. "
```


Pulse 6 Mooring Data
Lat/Lon = -46.32/140.68
Depth = 85 m.
sea water temperature (Celsius)
9
10
11
12
13
Nov 2009
Jan 2010
Mar 2010
Date

3.3 ACORN – Ocean Radar

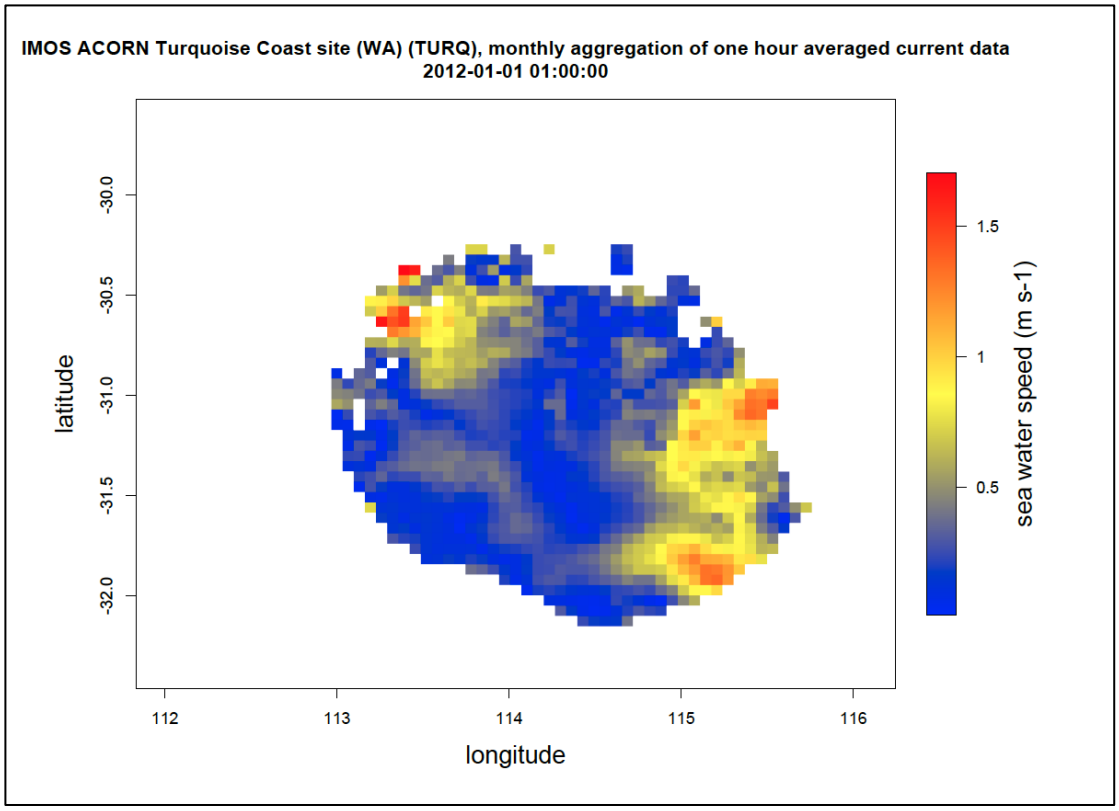
The Australian Coastal Ocean Radar Network (ACORN) facility comprises a coordinated network of HF radars delivering real-time, non-quality controlled and delayed-mode, quality controlled surface current data into a national archive.

ACORN NetCDF files can be found at:
http://thredds.aodn.org.au/thredds/catalog/IMOS/ACORN/catalog.html

Monthly aggregated files are also available in the following folders:
• monthly_gridded_1h-avg-current-map_QC
• monthly_gridded_1h-avg-current-map_non-QC

In the example below, the ncParse function is used to extract longitude, latitude, and velocity data for a single time value and then produce a raster plot of sea surface velocity on a longitude/latitude grid. To run the lines of commands below, the 'raster' package needs to be installed and loaded.

```
file <- 'http://thredds.aodn.org.au/thredds/dodsC/IMOS/ACORN/monthly_gridded_1h-avg-current-map_non-QC/TURQ/2012/IMOS_ACORN_V_20120101T000000Z_TUR_FV00_monthly-1-hour-avg_END-20120129T140000Z_C-20121030T160000Z.nc.gz'
dataset <- ncParse( file)

library(raster)

lat <- dataset$variables$LATITUDE$data
lon <- dataset$variables$LONGITUDE$data
speed <- dataset$variables$SPEED$data
date <- dataset$dimensions$TIME$data
title <- dataset$metadata$title
latlab <- gsub( '_', ' ', dataset$variables$LATITUDE$long_name)
lonlab <- gsub( '_', ' ', dataset$variables$LONGITUDE$long_name)
speedlab <- gsub( '_', ' ', dataset$variables$SPEED$long_name)
speedunits <- gsub( '_', ' ', dataset$variables$SPEED$units)

dat1 <- list()
dat1$x <- c( lon)
dat1$y <- c( lat)
dat1$z <- speed[,,2]  ## select sea surface velocity values for the 2nd time value.
raster <- raster( dat1$z, xmn = range( dat1[[1]])[1], xmx = range( dat1[[1]])[2], ymn = range( dat1[[2]])[1], ymx = range( dat1[[2]])[2])

plot( raster, col = colorRampPalette( c( "blue", "yellow", "red"))( 255), main = paste( title, '
', date[2], sep = ''), xlab = lonlab, ylab = latlab, cex.lab = 1.5,
xlim=c(min(lon),max(lon)), ylim = c ( min( lat), max( lat)), zlim = c( min( speed[,,2], na.rm = TRUE), max( speed[,,2], na.rm = TRUE)),
legend.width = 2, legend.shrink = .75, legend.args = list( text = paste( speedlab, ' ', '(', speedunits, ')', sep = ''), side = 4, line = 3, cex = 1.5),
axis.args=list(at=seq(round(min( speed[,,2], na.rm = TRUE),1), round(max( speed[,,2], na.rm = TRUE),1), .5), labels=seq(round(min( speed[,,2], na.rm = TRUE),1), round(max( speed[,,2], na.rm = TRUE),1), .5)))
```


IMOS ACORN Turquoise Coast site (WA) (TURQ), monthly aggregation of one hour averaged current data
2012-01-01 01:00:00
latitude
-30.0
-30.5
-31.0
-31.5
-32.0
112
113
114
115
116
longitude
1.5
1
0.5
sea water speed (m s-1)

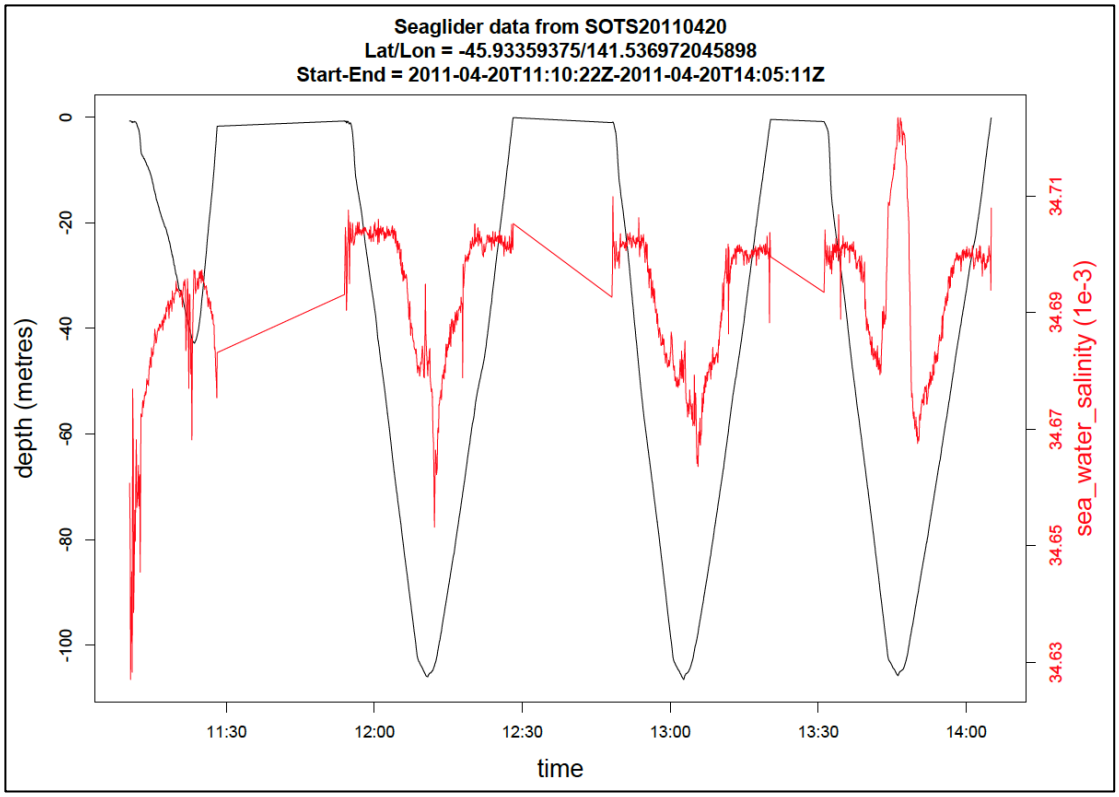
3.4 ANFOG – Ocean Gliders

The Australian National Facility for Ocean Gliders (ANFOG), with IMOS/NCRIS funding, deploys a fleet of eight gliders around Australia.

ANFOG NetCDF files can be found at:
http://thredds.aodn.org.au/thredds/catalog/IMOS/ANFOG/seaglider/catalog.html

In the example below, the ncParse function is used to extract depth, salinity, and time data and then produce a multiple time-series plot. Only the data points with a quality control flag of 1 (which means 'good data', see the IMOS NetCDF User Manual available at http://imos.org.au/facility_manuals.html).

```
file <-
 'http://thredds.aodn.org.au/thredds/dodsC/IMOS/ANFOG/seaglider/SOTS20110420/IMOS_ANF
 OG_BCEOSTUV_20110420T111022Z_SG517_FV01_timeseries_END-20110420T140511Z.nc'
dataset <- ncParse( file)

qcLevel1 <- 1
psal <- dataset$variables$PSAL$data[ which((dataset$variables$PSAL$flags) == qcLevel1)]
time <- dataset$dimensions$TIME$data[ which((dataset$variables$PSAL$flags) == qcLevel1)]
depth <- dataset$variables$DEPTH$data[ which((dataset$variables$PSAL$flags) == qcLevel1)]
title <- dataset$metadata$title
psallab <- dataset$variables$PSAL$standard_name
psalunit <- dataset$variables$PSAL$units
timelab <- dataset$dimensions$TIME$standard_name
depthlab <- dataset$variables$DEPTH$long_name
depthunit <- dataset$variables$DEPTH$units

par( mar = c( 4.5, 4.5, 4.5, 4.5))
plot( time, -depth, xlab = timelab, ylab = paste( depthlab, ' ', '(', depthunit, ')', sep = ''), main = paste(
  title, '
', 'Lat/Lon = ', dataset$metadata$geospatial_lat_min, '/', dataset$metadata$geospatial_lon_min, '
', 'Start-End = ', dataset$metadata$time_coverage_start, '-', dataset$metadata$time_coverage_end,
  sep = ''), type = 'l', pch = 19, xaxt = 'n', cex.lab = 1.5)
par( new = TRUE)
plot( time, psal, xlab = '', type = 'l', col = 'red', pch = 19, xaxt = 'n', ylab = '', main = '', yaxt = 'n')
axis.POSIXct( 1, seq( time[1], time[length(time)], by = 'hours'), format = '%H:%M')
axis( 4, at = seq( round( min( psal), 2), round( max( psal), 2), .02), labels = T, col.axis = 'red')
mtext( paste( psallab, ' ', '(', psalunit, ')', sep = ''), side = 4, line = 2.5, cex = 1.5, col = 'red')
```


Seaglider data from SOTS20110420
Lat/Lon = -45.93359375/141.536972045898
Start-End = 2011-04-20T11:10:22Z-2011-04-20T14:05:11Z
depth (metres)
0
-20
-40
-60
-80
-100
11:30
12:00
12:30
13:00
13:30
14:00
time
34.63
34.65
34.67
34.69
34.71
sea_water_salinity (1e-3)

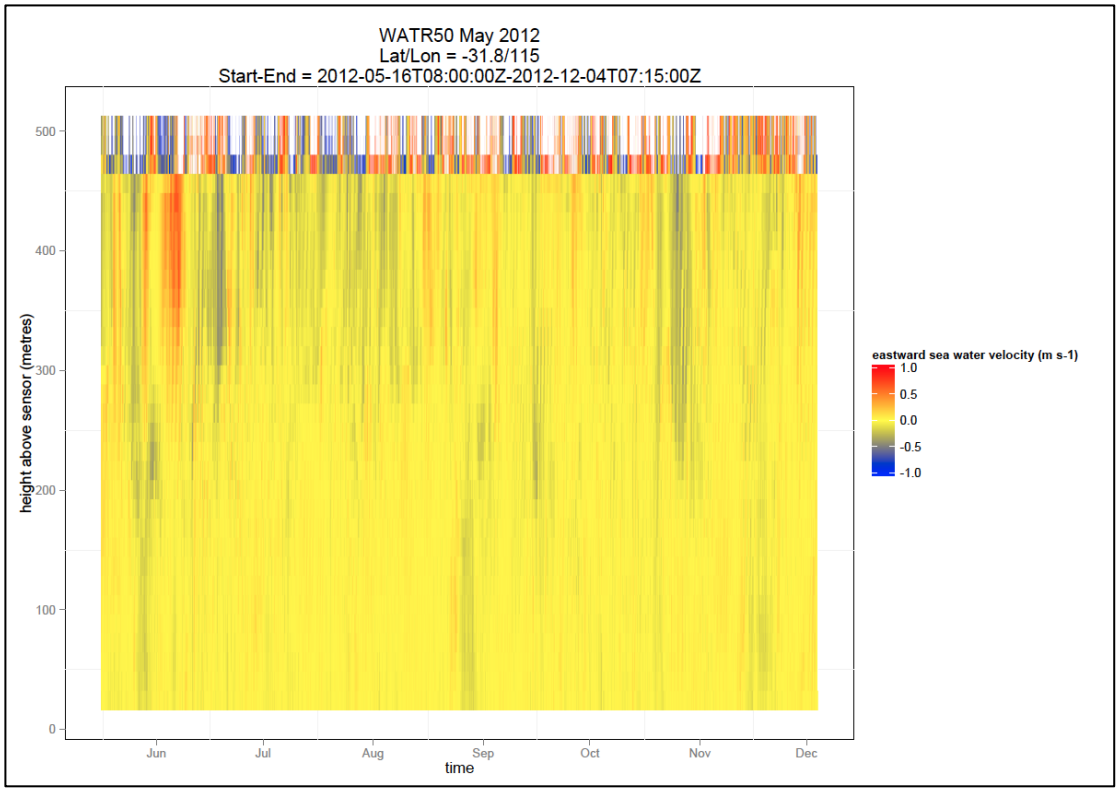
3.5 ANMN – National Mooring Network

The Australian National Mooring Network Facility is a series of national reference stations and regional moorings designed to monitor particular oceanographic phenomena in Australian coastal ocean waters.

ANMN NetCDF files can be found at:
http://thredds.aodn.org.au/thredds/catalog/IMOS/ANMN/catalog.html

In the example below, the ncParse function is used to extract depth, time and U current velocity data measured with an ADCP instrument (in Western Australia) and then produce a raster plot of U current velocity on a depth/time grid. To run the lines of commands below, the 'ggplot2' package needs to be installed and loaded.

```
file <-
 'http://thredds.aodn.org.au/thredds/dodsC/IMOS/ANMN/WA/WATR50/Velocity/IMOS_ANMN-
 WA_VATPE_20120516T040000Z_WATR50_FV01_WATR50-1205-Workhorse-ADCP-
 498_END-20121204T021500Z_C-20121207T023956Z.nc'
dataset <- ncParse( file)

library(ggplot2)

ucur <- dataset$variables$UCUR$data
depth <- dataset$dimensions$HEIGHT_ABOVE_SENSOR$data
date <- dataset$dimensions$TIME$data
title <- dataset$metadata$title
ucurlab <- gsub( '_', ' ', dataset$variables$UCUR$long_name)
ucurunit <- gsub( '_', ' ', dataset$variables$UCUR$units)
depthlab <- gsub( '_', ' ', dataset$dimensions$HEIGHT_ABOVE_SENSOR$long_name)
depthunit <- gsub( '_', ' ', dataset$dimensions$HEIGHT_ABOVE_SENSOR$units)
datelab <- dataset$dimensions$TIME$long_name

dat1 <- data.frame( rep( date, each = length(depth)),c( rep( depth, length( date))), c( ucur))
colnames( dat1) <- c( 'x', 'y', 'z')

ggplot( data = dat1, aes( x = x, y = y)) +
geom_raster( aes( fill = z)) +
scale_fill_gradient2( name = paste( ucurlab, ' ', '(', ucurunit, ')', sep = ''), limits = c( -1, 1), low =
 'blue' , mid = 'yellow', high = 'red', midpoint = 0, na.value = 'white')+
theme( panel.background = element_rect( fill = 'white', colour = 'black'), panel.grid.major =
 element_blank())+
labs( list( title = paste( title, '
', 'Lat/Lon = ', round( dataset$metadata$geospatial_lat_min, 1), '/', round(
 dataset$metadata$geospatial_lon_min, 1), '
', 'Start-End = ', dataset$metadata$time_coverage_start, '-', dataset$metadata$time_coverage_end,
 sep = ''), x = datelab, y = paste( depthlab, ' (', depthunit, ')', sep = '')))
```


WATR50 May 2012
Lat/Lon = -31.8/115
Start-End = 2012-05-16T08:00:00Z-2012-12-04T07:15:00Z
height above sensor (metres)
500
400
300
200
100
0
Jun
Jul
Aug
Sep
Oct
Nov
Dec
time
eastward sea water velocity (m s-1)
1.0
0.5
0.0
-0.5
-1.0

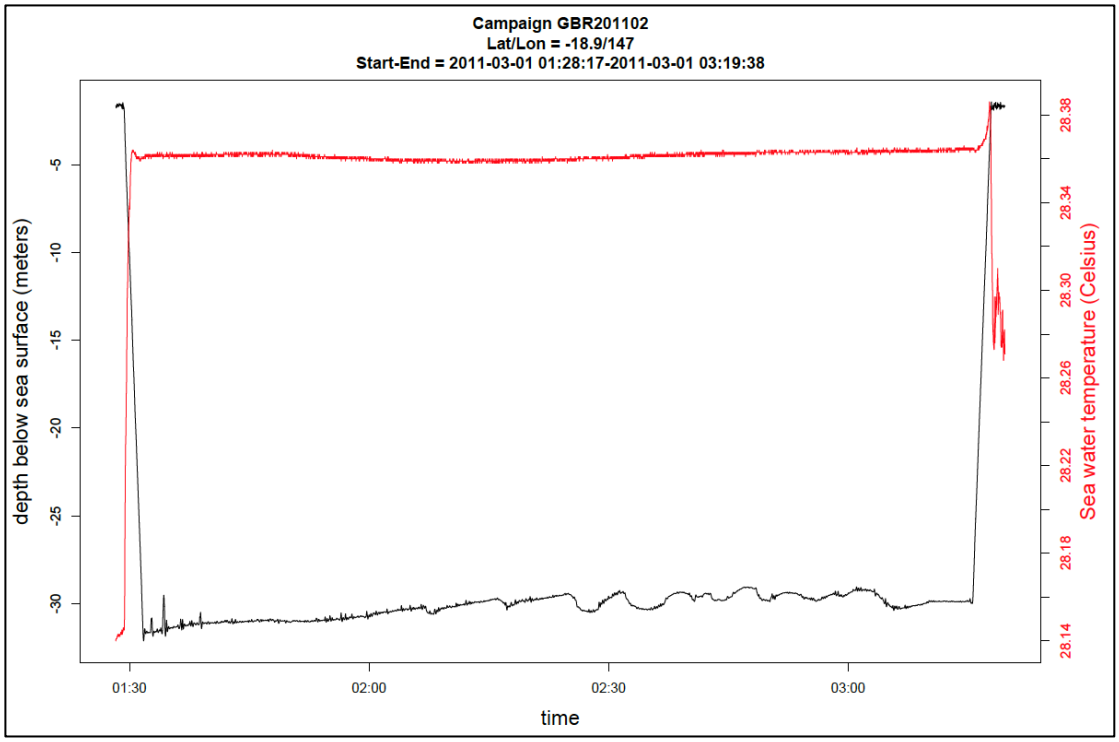
3.6 AUV – Autonomous Underwater Vehicle

The IMOS Autonomous Underwater Vehicle (AUV) Facility operates an ocean going AUV called Sirius capable of undertaking high resolution, geo-referenced survey work.

AUV NetCDF files can be found at:
http://thredds.aodn.org.au/thredds/catalog/IMOS/AUV/catalog.html

In the example below, the ncParse function is used to extract depth, temperature, and time data and then produce a multiple time-series plot showing the variation of water temperature with depth and time during the robot's dive.

```
file <-
 'http://thredds.aodn.org.au/thredds/dodsC/IMOS/AUV/GBR201102/r20110301_012810_station11
 95_09_transect/hydro_netcdf/IMOS_AUV_ST_20110301T012815Z_SIRIUS_FV00.nc'
dataset <- ncParse( file)

temp <- dataset$variables$TEMP$data
depth <- dataset$variables$DEPTH$data
time <- dataset$dimensions$TIME$data
title <- dataset$metadata$title
templab <- dataset$variables$TEMP$long_name
tempunit <- dataset$variables$TEMP$units
depthlab <- dataset$variables$DEPTH$long_name
depthunit <- dataset$variables$DEPTH$units
timelab <- dataset$dimensions$TIME$standard_name

par( mar = c( 4.5, 4.5, 4.5, 4.5))
plot( time, -depth, xlab = timelab, ylab = paste( depthlab, ' ', '(', depthunit, ')', sep = ''), main = paste(
 'Campaign ',title, '
', 'Lat/Lon = ', round( dataset$metadata$geospatial_lat_min, 1), '/', round(
 dataset$metadata$geospatial_lon_min, 1), '
', 'Start-End = ', time[1], '-', time[length(time)], sep = ''), type = 'l', pch = 19, xaxt = 'n', cex.lab =
 1.5)
par( new = TRUE)
plot( time, temp, xlab = '', type = 'l', col = 'red', pch = 19, xaxt = 'n', ylab = '', main = '', yaxt = 'n')
axis.POSIXct( 1, seq( time[1], time[length(time)], by = 'hours'), format = '%H:%M')
axis( 4, at = seq( round( min( temp), 2), round( max( temp), 2), .02), labels = T, col.axis = 'red')
mtext( paste( templab, ' ', '(', tempunit, ')', sep = ''), side = 4, line = 2.5, cex = 1.5, col = 'red')
```


Campaign GBR201102
Lat/Lon = -18.9/147
Start-End = 2011-03-01 01:28:17-2011-03-01 03:19:38
depth below sea surface (meters)
-5
-10
-15
-20
-25
-30
Sea water temperature (Celsius)
28.38
28.34
28.30
28.26
28.22
28.18
28.14
01:30
02:00
02:30
03:00
time

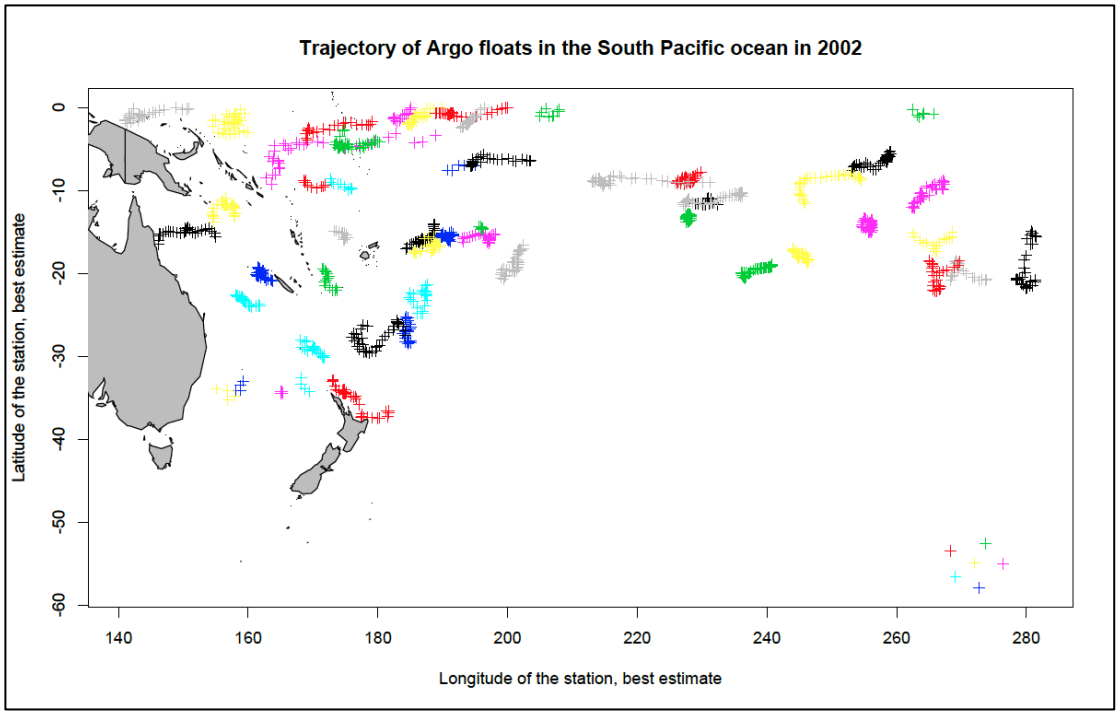
3.7 Argo – Argo Floats Program

Argo floats have revolutionised our understanding of the broad scale structure of the oceans to 2000 m depth. In the past 10 years more high resolution hydrographic profiles have been provided by Argo floats then from the rest of the observing system put together. Each Argo float is identified by a unique identification number, called a WMO ID.

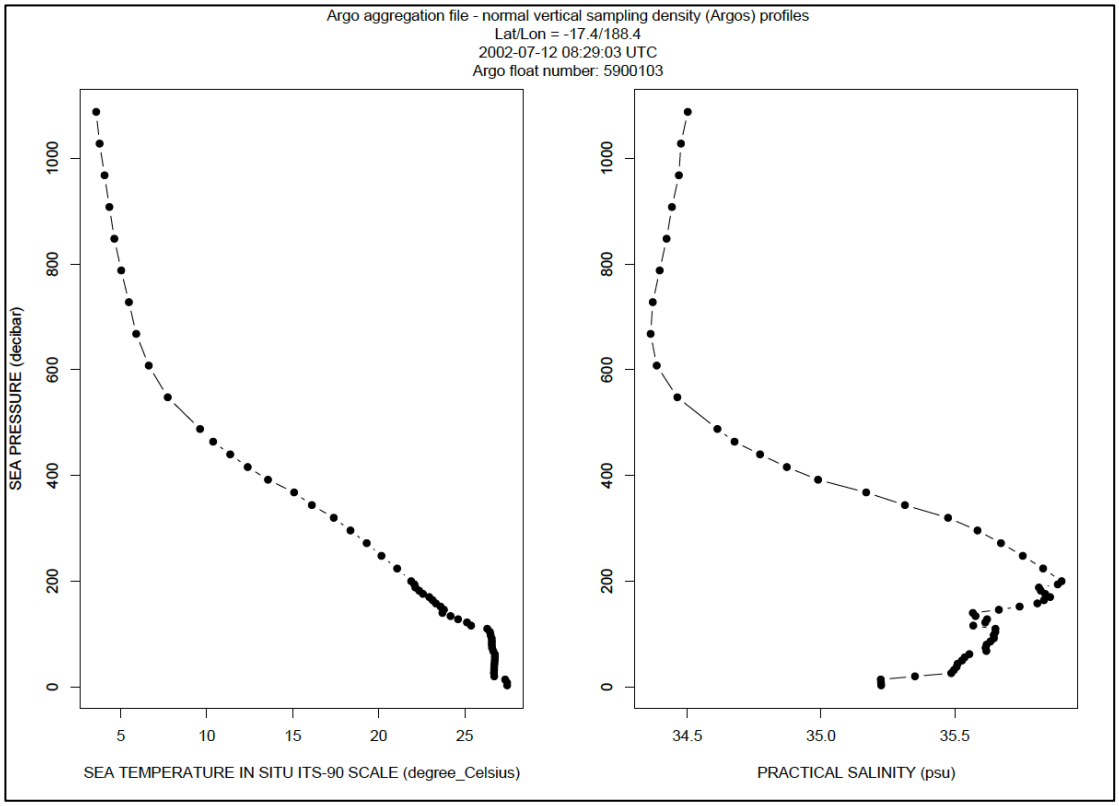
Argo NetCDF files can be found at:
http://thredds.aodn.org.au/thredds/catalog/IMOS/Argo/aggregated_datasets/catalog.html

In the example below, the ncParse function is used to extract and then plot temperature and salinity data from an aggregated file (one file per year per basin: Atlantic, Indian, Pacific North, Pacific South), along with all the surface locations of all the Argo floats. The 'maps' package needs to be installed and loaded to be able to plot a world map.

```
file <-
 'http://thredds.aodn.org.au/thredds/dodsC/IMOS/Argo/aggregated_datasets/south_pacific/IMOS_
 Argo_TPS-20020101T000000_FV01_yearly-aggregation-South_Pacific_C-
 20121102T220000Z.nc'
dataset <- ncParse( file)

nprof <- dataset$dimensions$N_PROF$data # Number of profiles in the NetCDF file
profile <- sample( seq( 1, nprof), 1) # Random selection of a profile number
temp <- dataset$variables$TEMP_ADJUSTED$data[,profile]
psal <- dataset$variables$PSAL_ADJUSTED$data[,profile]
depth <- dataset$variables$PRES_ADJUSTED$data[,profile]
lat <- dataset$variables$LATITUDE$data[profile]
lon <- dataset$variables$LONGITUDE$data[profile]
date <- dataset$variables$JULD$data[profile]
templab <- dataset$variables$TEMP_ADJUSTED$long_name
psallab <- dataset$variables$PSAL_ADJUSTED$long_name
depthlab <- dataset$variables$PRES_ADJUSTED$long_name
latlab <- dataset$variables$LATITUDE$long_name
lonlab <- dataset$variables$LONGITUDE$long_name
tempunit <- dataset$variables$TEMP_ADJUSTED$units
psalunit <- dataset$variables$PSAL_ADJUSTED$units
depthunit <- dataset$variables$PRES_ADJUSTED$units

alllat <- dataset$variables$LATITUDE$data
alllon <- dataset$variables$LONGITUDE$data

# Argo floats' trajectories
library( maps)
plot( alllon, alllat, pch = 3, col = dataset$variables$PLATFORM_NUMBER$data, xlab = lonlab,
  ylab = latlab, main = 'Trajectory of Argo floats in the South Pacific ocean in 2002')
map('world',fill=TRUE,add=T,col='grey')
```




```
# Temperature and salinity profiles
split.screen( c( 1, 2))
screen( 1)
par( mar = c( 5, 4, 4.5, 2))
plot( temp, depth, xlab = paste( templab, ' ', '(', tempunit, ')', sep = ''), ylab = paste( depthlab, ' ', '(',
  depthunit, ')', sep = ''), type = 'b', pch = 19)
mtext( paste( dataset$metadata$description, '
', 'Lat/Lon = ', round( lat, 1), '/', round( lon, 1), '
', date, ' UTC','
Argo float number: ', dataset$variables$PLATFORM_NUMBER$data[profile], sep = ''), side = 3,
  line = .5, at = 31)
screen( 2)
par( mar = c( 5, 4, 4.5, 2))
plot( psal, depth, xlab = paste( psallab, ' ', '(', psalunit, ')', sep = ''), ylab = '', type = 'b', pch = 19, bg
  = 'transparent')
close.screen( all = TRUE)
```


Argo aggregation file - normal vertical sampling density (Argos) profiles
Lat/Lon = -17.4/188.4
2002-07-12 08:29:03 UTC
Argo float number: 5900103
SEA PRESSURE (decibar)
0
200
400
600
800
1000
5
10
15
20
25
SEA TEMPERATURE IN SITU ITS-90 SCALE (degree_Celsius)
34.5
35.0
35.5
PRACTICAL SALINITY (psu)

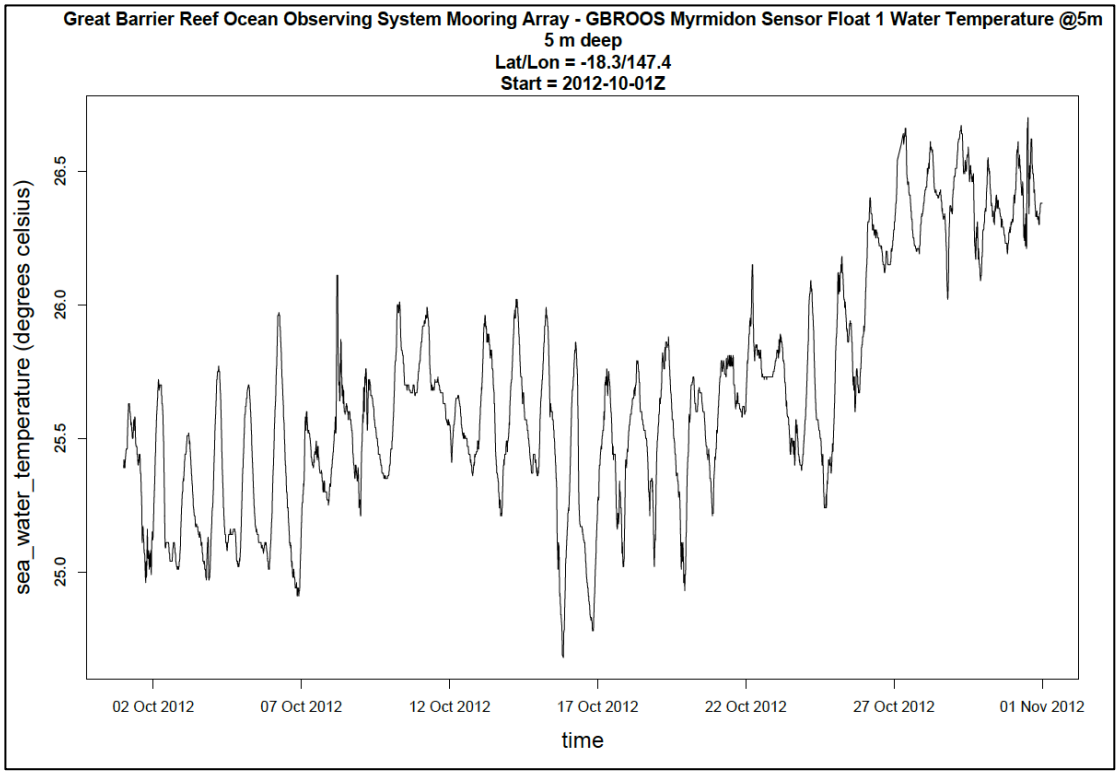
3.8 FAIMMS – Wireless Sensor Networks

The IMOS Facility for Intelligent Monitoring of Marine Systems is a sensor network established in the Great Barrier Reef off the coast of Queensland, Australia. A 'sensor network' is an array of small, wirelessly interconnected sensors that collectively stream sensor data to a central data aggregation point. Sensor networks can be used to provide spatially dense bio-physical measurements in real-time.

FAIMMS NetCDF files can be found at:
http://thredds.aodn.org.au/thredds/catalog/IMOS/FAIMMS/catalog.html

In the example below, the ncParse function is used to extract temperature and time data and then produce a temperature time-series plot. Only the data points with a quality control flag of 1 (which means 'good data', see the IMOS NetCDF User Manual available at http://imos.org.au/facility_manuals.html).

```
file <-
 'http://thredds.aodn.org.au/thredds/dodsC/IMOS/FAIMMS/Myrmidon_Reef/Sensor_Float_1/water
 _temperature/sea_water_temperature@5.0m_channel_114/2012/QAQC/IMOS_FAIMMS_T_201
 21001T000000Z_FV01_END-20121101T000000Z_C-20130426T102454Z.nc'
dataset <- ncParse( file)

qcLevel1 <- 1
temp <- dataset$variables$TEMP$data[ which((dataset$variables$TEMP$flags) == qcLevel1)]
date <- dataset$dimensions$TIME$data[ which((dataset$variables$TEMP$flags) == qcLevel1)]
title <- dataset$metadata$title
templab <- dataset$variables$TEMP$long_name
tempunit <- dataset$variables$TEMP$units
datelab <- dataset$dimensions$TIME$long_name

par( mar = c( 5, 4.5, 5, 2))
plot( date, temp, xlab = datelab, ylab = paste( templab, ' ', '(', tempunit, ')', sep = ''), main = paste(
 title, '
', dataset$metadata$geospatial_vertical_min, ' m deep', '
', 'Lat/Lon = ', round( dataset$metadata$geospatial_lat_min, 1), '/', round(
 dataset$metadata$geospatial_lon_min, 1), '
', 'Start = ', dataset$metadata$time_coverage_start, sep = ''), type = 'l', pch = 19, xaxt = 'n', cex.lab =
 1.5)
axis.POSIXct( 1, seq( date[1], date[length(date)], by = 'weeks'), format = '%d %b %Y')
```


Great Barrier Reef Ocean Observing System Mooring Array - GBROOS Myrmidon Sensor Float 1 Water Temperature @5m
5 m deep
Lat/Lon = -18.3/147.4
Start = 2012-10-01Z
sea_water_temperature (degrees celsius)
25.0
25.5
26.0
26.5
02 Oct 2012
07 Oct 2012
12 Oct 2012
17 Oct 2012
22 Oct 2012
27 Oct 2012
01 Nov 2012
time

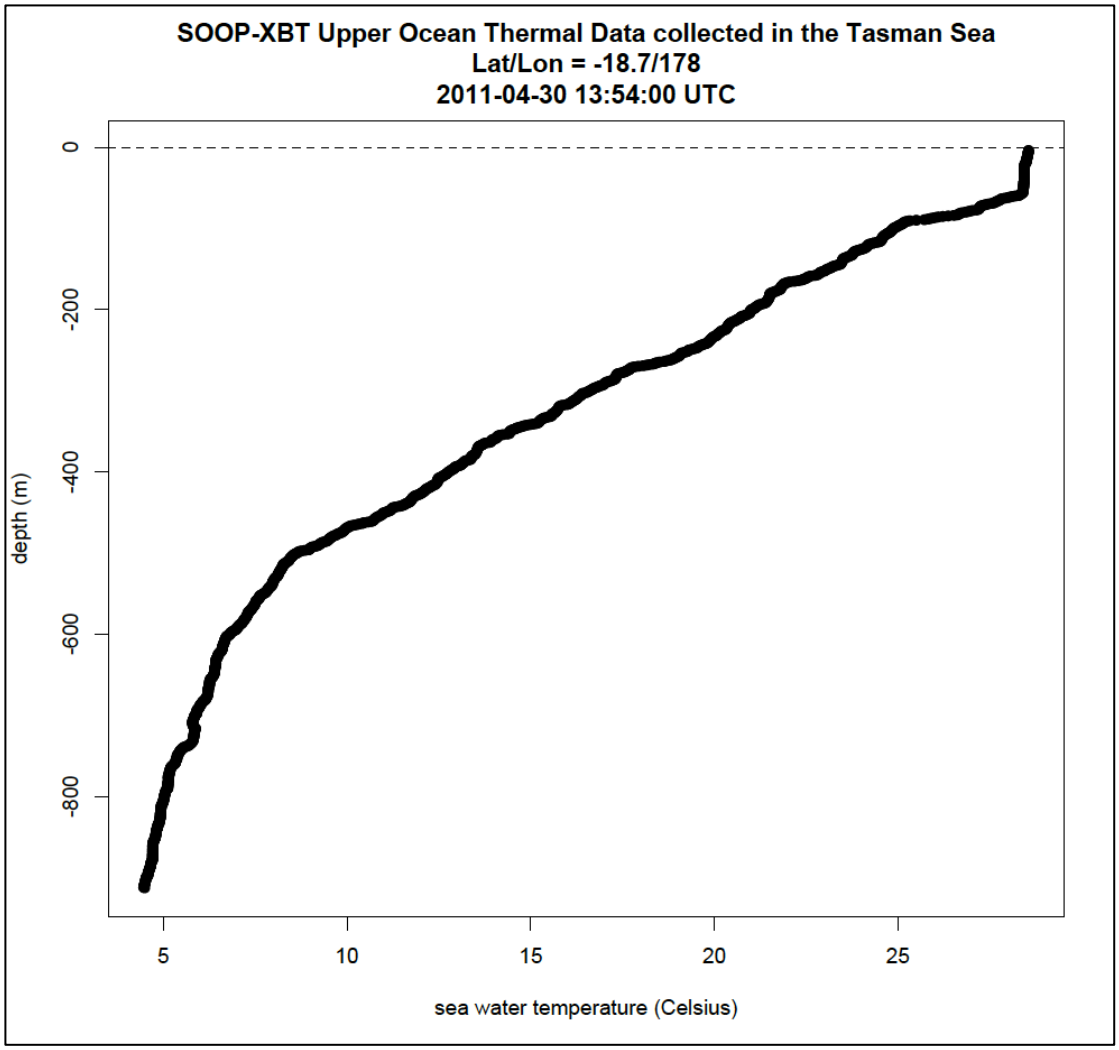
3.9 SOOP – Ship Of Opportunities

IMOS Ship of Opportunity Underway Expandable Bathythermographs (XBT) group is a research and data collection project working within the IMOS Ship of Opportunity Multi-Disciplinary Underway Network sub-facility.

SOOP NetCDF files can be found at:
http://thredds.aodn.org.au/thredds/catalog/IMOS/SOOP/SOOP-XBT/catalog.html

In the example below, the ncParse function is used to extract and then plot temperature and depth data from an XBT profile. Only the data points with a quality control flag of 1 (which means 'good data', see the IMOS NetCDF User Manual available at http://imos.org.au/facility_manuals.html).

```
file <- 'http://thredds.aodn.org.au/thredds/dodsC/IMOS/SOOP/SOOP-
 XBT/aggregated_datasets/region/Tasman-Sea/IMOS_SOOP-
 XBT_T_20110217T022600Z_aggregated-profiles-TasmanSea_FV01_END-
 20110430T190400Z.nc'
dataset <- ncParse( file)

nprof <- dataset$dimensions$profile$data # Number of profiles in the NetCDF file
profile <- sample( seq( 1, nprof), 1) # Random selection of a profile number
profindex <- which(( dataset$variables$profile_index$data) == profile)

temp <- dataset$variables$TEMP$data[profindex]
depth <- dataset$variables$DEPTH$data[profindex]
tempflags <- dataset$variables$TEMP$flags[profindex]
qcLevel1 <- 1
temp <- temp[which(( tempflags) == qcLevel1)]
depth <- depth[which(( tempflags) == qcLevel1)]
lat <- round( dataset$variables$LATITUDE$data[profile], 1)
lon <- round( dataset$variables$LONGITUDE$data[profile], 1)
date <- dataset$variables$TIME$data[profile]
title <- dataset$metadata$title
templab <- dataset$variables$TEMP$long_name
depthlab <- dataset$variables$DEPTH$long_name
tempunit <- dataset$variables$TEMP$units
depthunit <- dataset$variables$DEPTH$units

par( mar = c( 5, 4, 4.5, 2))
plot( temp, -depth, main = paste( title, '
', 'Lat/Lon = ', lat, '/', lon, '
', date, ' UTC', sep = ''), xlab = paste( templab, ' ', '(', tempunit, ')', sep = ''), ylab = paste( depthlab, '
 ', '(', depthunit, ')', sep = ''), type = 'b', pch = 19)
abline( h = 0, lty = 'dashed')
```


SOOP-XBT Upper Ocean Thermal Data collected in the Tasman Sea
Lat/Lon = -18.7/178
2011-04-30 13:54:00 UTC
depth (m)
0
-200
-400
-600
-800
5
10
15
20
25
sea water temperature (Celsius)

3.10 SRS – Satellite Remote Sensing

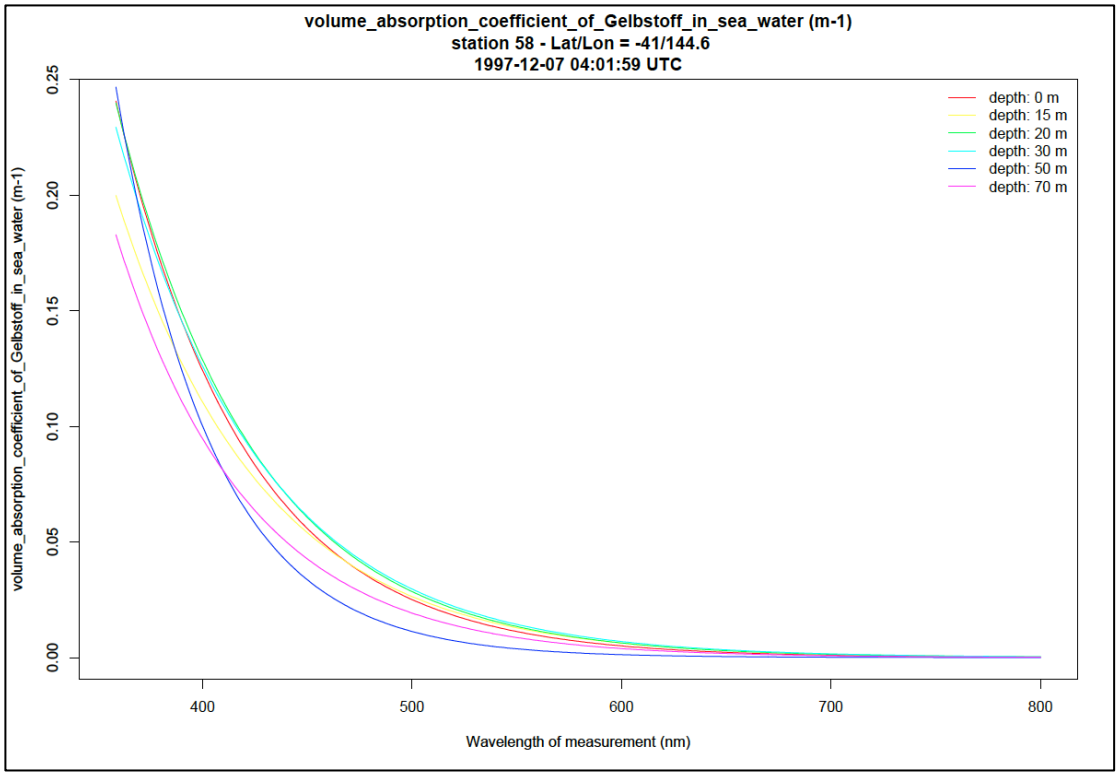
3.10.1 Bio-Optical dababase – Absorption data

The bio-optical database underpins the assessment of ocean colour products in the Australian region (e.g. chlorophyll a concentrations, phytoplankton species composition and primary production).

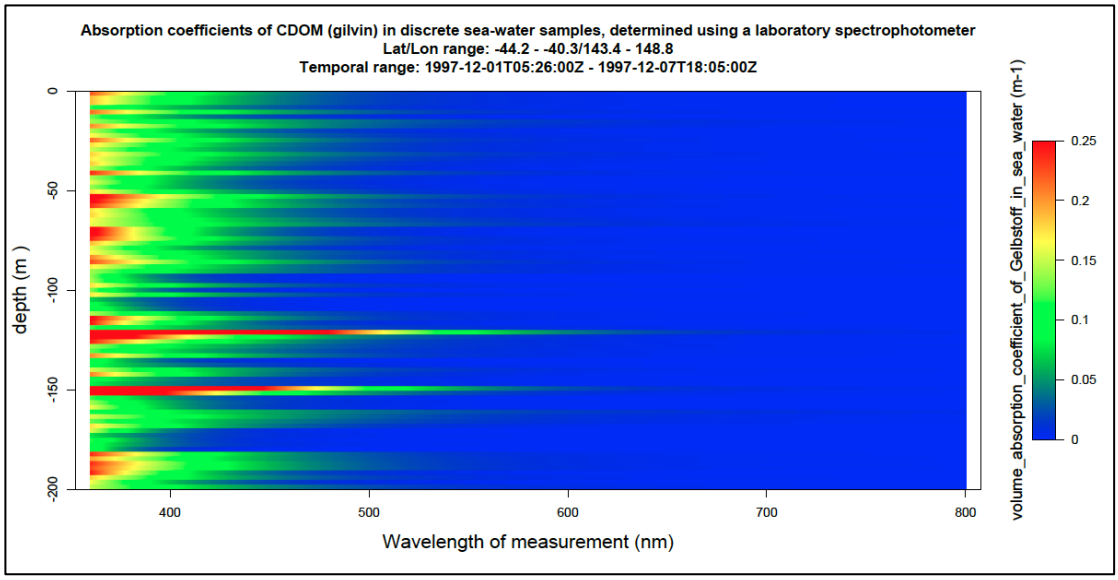
SRS Bio-Optical database NetCDF files can be found at:
http://thredds.aodn.org.au/thredds/catalog/IMOS/SRS/BioOptical/catalog.html

In the example below, the ncParse function is used to extract depth, wavelength, and absorption coefficients of CDOM data. Two plots are then produced: (1) the variation of absorption coefficients of CDOM at different wavelengths, and (2) the variation of absorption coefficients of CDOM at different wavelengths and different depths. To run the lines of commands below, the 'raster' package need to be installed and loaded.

```
file <- 'http://thredds.aodn.org.au/thredds/dodsC/IMOS/SRS/BioOptical/1997_cruise-
 FR1097/absorption/IMOS_SRS-OC-BODBAW_X_19971201T052600Z_FR1097-absorption-
 CDOM_END-19971207T180500Z_C-20121129T130000Z.nc'
dataset <- ncParse( file)

nprof <- dataset$dimensions$profile$data # Number of profiles in the NetCDF file
profile <- sample( seq(1, max( nprof)), 1) # Random selection of a profile number
nobs <- dataset$variables$rowSize$data[profile] # Number of observations for this profile
startobs <- sum( dataset$variables$rowSize$data[1 : ( profile - 1)]) + 1
endobs <- startobs + ( nobs -1)

date <- dataset$variables$TIME$data[profile]
lon <- dataset$variables$LONGITUDE$data[profile]
lat <- dataset$variables$LATITUDE$data[profile]
depth <- dataset$variables$DEPTH$data[startobs:endobs]
abscoeff <- dataset$variables$ag$data[,startobs:endobs]
wavelength <- dataset$dimensions$wavelength$data
abscoefflab <- dataset$variables$ag$long_name
wavelengthlab <- dataset$dimensions$wavelength$long_name
depthlab <- dataset$variables$DEPTH$long_name
abscoeffunit <- dataset$variables$ag$units
wavelengthunit <- dataset$dimensions$wavelength$units
depthunit <- dataset$variables$DEPTH$units

# Absorption coefficient vs. wavelength
plot( wavelength, abscoeff[,1], type = 'l', col = rainbow( n = ncol( abscoeff))[1],
xlab = paste( wavelengthlab, ' (', wavelengthunit, ')', sep = ''), ylab = paste( abscoefflab, ' (',
 abscoeffunit, ')', sep = ''), main = paste( abscoefflab, ' (', abscoeffunit, ')', '
', ' station ', dataset$variables$station_name$data[profile], ' - Lat/Lon = ', round( lat, 1), '/', round(
 lon, 1), '
', date, ' UTC', sep = ''))
for (i in 2 : ncol( abscoeff)){
 lines( wavelength, abscoeff[,i], col = rainbow( n = ncol( abscoeff))[i])
}
legend( 750, 0.25, bty = 'n', paste( depthlab, ': ', depth, ' ', depthunit, sep =''),
lty = c(rep( 'solid', 6)), col = rainbow( n = ncol( abscoeff))[1:6])
```




```
# Absorption coefficient vs. wavelength and depth
library(raster)
dat1 <- list()
dat1$x <- - dataset$variables$DEPTH$data
dat1$y <- dataset$dimensions$wavelength$data
dat1$z <- dataset$variables$ag$data  ## select sea surface velocity values for the 2nd time value.
raster <- raster( dat1$z, xmn = range( dat1[[1]])[1], xmx=range( dat1[[1]])[2], ymn= range(
 dat1[[2]])[1], ymx = range( dat1[[2]])[2])
raster <- flip( t( raster), direction = 'x')

par( mar = c(5.5, 4.5, 5.5, 4.5))
plot( raster, col = colorRampPalette( c( "blue", 'green', "yellow", "red"))( 255),
main = paste( dataset$metadata$source, '
Lat/Lon range: ', round( dataset$metadata$geospatial_lat_min, 1), ' - ', round(
 dataset$metadata$geospatial_lat_max, 1), '/', round( dataset$metadata$geospatial_lon_min, 1), ' -
 ', round( dataset$metadata$geospatial_lon_max, 1), '
Temporal range: ', dataset$metadata$time_coverage_start, ' - ',
 dataset$metadata$time_coverage_end, sep = ''),
xlab = paste( wavelengthlab, ' (', wavelengthunit, ')', sep = ''), ylab = paste( depthlab, ' (', depthunit,
 ')', sep = ''), cex.lab = 1.5,
xlim = c( 360, 800), ylim = c( 0, 200), zlim = c( 0, 0.25),
legend.width = 2, legend.shrink = .75, legend.args = list( text = paste( abscoefflab, ' ', '(',
 abscoeffunit, ')', sep = ''), side = 4, line = -3, cex = 1.25),
axis.args=list(at = seq( 0, 0.25, 0.05), labels =  seq( 0, 0.25, 0.05)))
```


Absorption coefficients of CDOM (gilvin) in discrete sea-water samples, determined using a laboratory spectrophotometer
Lat/Lon range: -44.2 - -40.3/143.4 - 148.8
Temporal range: 1997-12-01T05:26:00Z - 1997-12-07T18:05:00Z
depth (m)
0
-50
-100
-150
-200
400
500
600
700
800
Wavelength of measurement (nm)
volume_absorption_coefficient_of_Gelbstoff_in_sea_water (m-1)
0.25
0.2
0.15
0.1
0.05
0

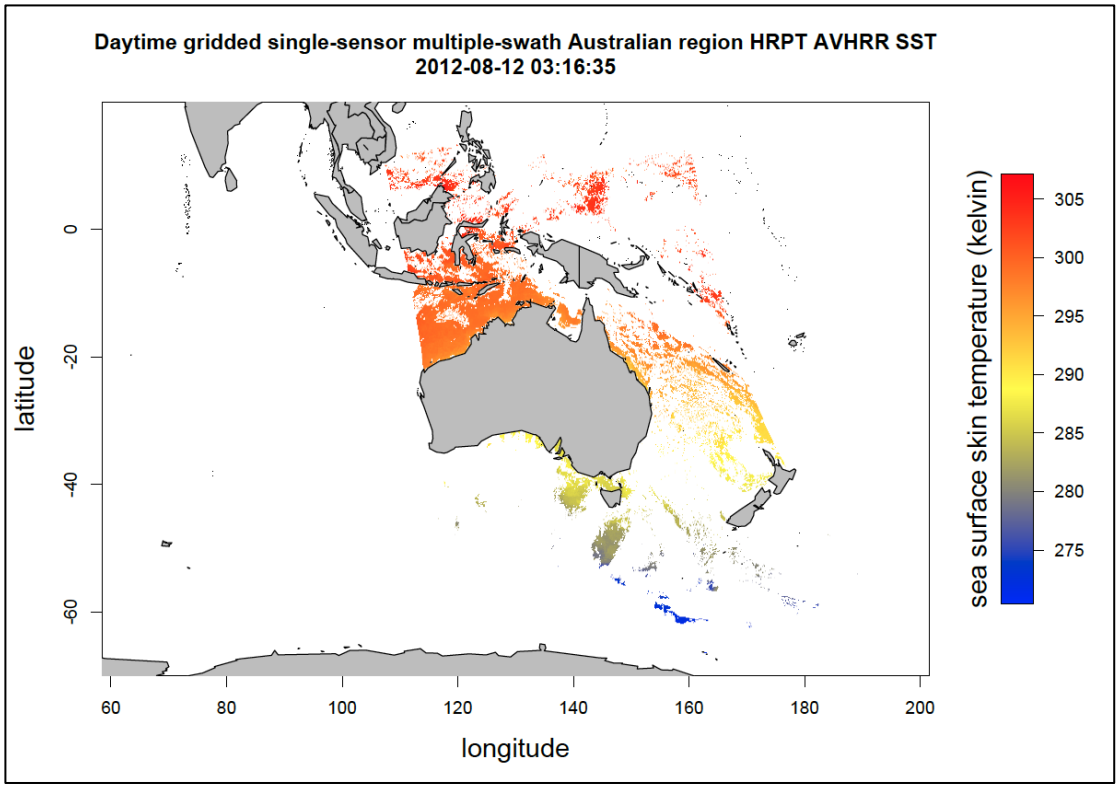
3.10.2 GHRSST – L3C – multi swath, single sensor

As part of IMOS, the Australian Bureau of Meteorology produces high-resolution satellite SST products over the Australian region. All these products follow the latest International Group for High Resolution Sea Surface Temperature (GHRSST: www.ghrsst.org) file formats. For more information about SRS SST products, refer to: http://portalhelp.aodn.org.au/Portal2_help/?q=node/149

SRS – SST NetCDF files can be found at:
http://thredds.aodn.org.au/thredds/dodsC/IMOS/SRS/SRS-SST/L3C-01day/

In the example below, the ncParse function is used to extract longitude, latitude, and sea surface temperature data for a single time value and then produce a raster plot of sea surface temperature on a longitude/latitude grid. To run the lines of commands below, the 'raster' and 'maps' packages need to be installed and loaded.

```
file <- '/path/to/20120812032000-ABOM-L3C_GHRSST-SSTskin-AVHRR19_D-1d_day-v02.0-
  fv01.0_ncWMS.nc'
dataset <- ncParse( file)

library(raster)
library(maps)

lat <- dataset$dimensions$lat$data
lon <- dataset$dimensions$lon$data
temp <- dataset$variables$sea_surface_temperature$data
date <- dataset$dimensions$time$data
title <- dataset$metadata$title
latlab <- gsub( '_', ' ', dataset$dimensions$lat$long_name)
lonlab <- gsub( '_', ' ', dataset$dimensions$lon$long_name)
templab <- gsub( '_', ' ', dataset$variables$sea_surface_temperature$long_name)
tempunit <- gsub( '_', ' ', dataset$variables$sea_surface_temperature$units)

dat1<- list()
dat1$x <- c( lon)
dat1$y <- c( lat)
dat1$z <- t( temp)
raster <- raster( dat1$z, xmn = range( dat1[[1]])[1], xmx = range( dat1[[1]])[2], ymn = range(
  dat1[[2]])[1], ymx = range(dat1[[2]])[2])

par( mar = c(5, 4.5, 4.5, 4.5))
plot( raster, col = colorRampPalette( c( "blue", "yellow", "red"))( 255), main = paste( title, '
', date, sep = ''), xlab = lonlab, ylab = latlab, cex.lab = 1.5,
xlim=c( min( lon), max( lon)), ylim = c ( min( lat), max( lat)), zlim = c( min( temp, na.rm =
  TRUE), max( temp, na.rm = TRUE)),
legend.width = 2, legend.shrink = .75, legend.args = list( text = paste( templab, ' ', '(', tempunit, ')',
  sep = ''), side = 4, line = -3, cex = 1.5),
axis.args=list(at=seq(round(min( temp, na.rm = TRUE),0), round(max( temp, na.rm = TRUE),0),
  5), labels=seq(round(min( temp, na.rm = TRUE),0), round(max( temp, na.rm = TRUE),0), 5)))
map('world',fill=TRUE,add=T,col='grey')
```


Daytime gridded single-sensor multiple-swath Australian region HRPT AVHRR SST
2012-08-12 03:16:35
latitude
0
-20
-40
-60
60
80
100
120
140
160
180
200
longitude
sea surface skin temperature (kelvin)
305
300
295
290
285
280
275