BACKGROUND INFORMATION

Title is left blank because the Journal inserts it.

Code style based on https://google.github.io/styleguide/Rguide.xml (https://google.github.io/styleguide/Rguide.xml)

COPYRIGHT STATEMENT

Data Availability

Cefas data are available from the Cefas Data Hub - https://www.cefas.co.uk/cefas-data-hub/ (https://www.cefas.co.uk/cefas-data-hub/)

The data cited below are available from https://doi.org.10.14466/Cefasdatahub.4 (https://doi.org.10.14466/Cefasdatahub.4)

Software Used

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/ (https://www.R-project.org/). R version 3.3.2

RStudio (2016). RStudio: Integrated development environment for R (Version 0.99.903) [Computer software]. Boston, MA. Retrieved September 27, 2016. Available from http://www.rstudio.org/RStudio (http://www.rstudio.org/RStudio) version 1.0.44

AUTHOR COMMENT (David Morris)

This file contains the R code used to analyse the Quality Controlled data assembled from 17 diverse and disparate Cefas Data Systems for this Data Paper.

The data sources and an overview of the extensive data assembly processes involved are described in the accompanying publication. In summary, data were obtained from Cefas Data Owners / Stewards as folder/files and extracts from various operational databases and systems.

Data were processed to extract temperature records as described in the manuscript, with over 15,000 source files totalling ~ 15 G Bytes, reducing to some 100+ ‘summary’ files resulting from the extracts of the many and diverse, bespoke, usually Excel/.csv/.txt/.dat, data source files, each designed for the particular requirements of the data system involved.

Data processing included standardising formats, extracting reference fields, a minimum/maximum sense check process to detect system and sensor errors, a geographical sense check plot & Temperature .v. Time plots to examine outliers and data at inappropriate levels for the time of year.

FILE DESCRIPTION

The total data set from all 17 sources was saved as an R file (.Rda) and this is used for the following code.

Code is written within my limited R coding experience and for accessibility rather than computational elegance or efficiency. This approach inevitably evolved as the coding requirements emerged so there are different ways of doing things, especially around controlling plot outputs (I started with plot ended with ggplot and had to 'solve' issues around discrete & continuous scales and over plotting). Please accept my apologies for any inelegance & inconsistency.

Similarly, the code is verbose and repetitive, e.g. when dealing with monthly plots. I recognise the use of loops would reduce this but they came late to the party and I initially, as recommended on numerous websites, avoided them as something else new. Any potential for errors in the copying and editing is mitigated by the clarity of each line being clear as to what it is doing.

The code provides sections on what was done to select data for plotting (maps and plots) with a separate section (chunk) for plots to the files used in the manuscript. I encountered ggplot output issues with multiple plots; my solution means that they don't appear in the compiled Markdown document and my 'quick fix' (reimporting the files) seems unnecessary as the aim of this document s to present and explain the code and data workings. The file plots were set to the specified publication standards.

SOURCE & LIBRARY STATEMENTS

Local parameters

WINDOWS 10 (16 Gigabyte RAM) R 3.3.2 RStudio 1.0.44

ACQUIRE THE DATA

The main .csv file is provided as a .zip (~65 MBytes) which extracts to a ~900 MByte .csv file which takes a long time to "load" (faster R .csv read methods are available). The POSIXct conversion also takes time.

```
projectPath="C:/Users/djm00/OneDrive - CEFAS/SWT-MASTER"
# INSERT APPROPRIATE LOCAL PATH
setwd(projectPath)
load("CefasSWTdata20170707.Rda") # n = 10,680,821
SWTfinal <- CefasSWTdata20170707 # minimises my code editing arising from ch
anges in the data following systematic and detailed QC checks using tempreat
ure levels and month to remove anomalies that appeared in the plots as they
were developed.
rm(CefasSWTdata20170707) # reduces memory overheads and chances of changes t
o core file
```

The following section is text rather than an R chunk so it doesn't execute under *knitr*. It is included to allow re-creation of the .Rda file above from the downloaded .csv "all data" file.

Read from .csv files

CefasSWTdata20170707 <- read.csv("CefasSWTdata20170707.csv", header=TRUE, sep=",", stringsAsFactors = FALSE)

Create Time as DateTime (uses *lubridate* package)

library(lubridate) # 1.6.0 ymd_hms(CefasSWTdata20170707 $Time) * *CefasSWTdata20170707 Time <- as.POSIXct (CefasSWTdata20170707$Time) summary(CefasSWTdata20170707)*

A check using the "Summary" command shows the .Rda and .csv data frames are identical.

Libraries used in the assembly, checking & plotting processes

Maps have been created using the R package *marmap*.

sessionInfo() used for version numbers

```
library(data.table) # 1.10.4
library(ggmap) # 2.6.1
library(ggplot2) # 2.2.1
library(graphics)
library(gridExtra) # 2.2.1
library(lubridate) # 1.6.0
library(mapproj) # 1.2-4
library(marmap)  # 0.9.6
library(raster) # 2.5-8
library(rgdal) # 1.2-5
library(rgeos) # 0.3-22
library(sp)  # 1.2-3
library(lattice) # 0.20-34
library(scatterplot3d) # 0.3-40
```

Other libraries have been added as the manuscript progressed. These are inserted where they are needed.

FUNCTION DEFINITIONS

Multiple Plots

Uses http://www.cookbook-r.com/Graphs/Multiple_graphs_on_one_page_(ggplot2)/

(http://www.cookbook-r.com/Graphs/Multiple_graphs_on_one_page_(ggplot2)/)

```
# Multiple plot function
#
# ggplot objects can be passed in ..., or to plotlist (as a list of ggplot o
bjects)
# - cols:   Number of columns in layout
# - layout: A matrix specifying the layout. If present, 'cols' is ignored.
#
# If the layout is something like matrix(c(1,2,3,3), nrow=2, byrow=TRUE),
# then plot 1 will go in the upper left, 2 will go in the upper right, and
# 3 will go all the way across the bottom.
#
multiplot <- function(..., plotlist=NULL, file, cols=1, layout=NULL) {
  library(grid)

  # Make a list from the ... arguments and plotlist
  plots <- c(list(...), plotlist)

  numPlots = length(plots)

  # If layout is NULL, then use 'cols' to determine layout
  if (is.null(layout)) {
    # Make the panel
    # ncol: Number of columns of plots
    # nrow: Number of rows needed, calculated from # of cols
    layout <- matrix(seq(1, cols * ceiling(numPlots/cols)),
                     ncol = cols, nrow = ceiling(numPlots/cols))
  }

 if (numPlots==1) {
    print(plots[[1]])

  } else {
    # Set up the page
    grid.newpage()
    pushViewport(viewport(layout = grid.layout(nrow(layout), ncol(layout))))

    # Make each plot, in the correct location
    for (i in 1:numPlots) {
      # Get the i,j matrix positions of the regions that contain this subplo
t
      matchidx <- as.data.frame(which(layout == i, arr.ind = TRUE))

      print(plots[[i]], vp = viewport(layout.pos.row = matchidx$row,
                                      layout.pos.col = matchidx$col))
    }
  }
}
```

Sorting Scientific Notation

http://stackoverflow.com/questions/11610377/how-do-i-change-the-formatting-of-numbers-on-an-axis-with-ggplot (http://stackoverflow.com/questions/11610377/how-do-i-change-the-formatting-of-numbers-on-an-axis-with-ggplot)

```
fancy_scientific <- function(l) {
     # turn in to character string in scientific notation
     l <- format(l, scientific = TRUE)
     # quote the part before the exponent to keep all the digits
     l <- gsub("^(.*)e", "'\\1'e", l)
     # turn the 'e+' into plotmath format
     l <- gsub("e", "%*%10^", l)
     # return this as an expression
     parse(text=l)
}
```

LOCATION PARAMETERS

These specify to coordinates for maps and subsets of data; provided as NESW bounding boxes.

Bounding Boxes for maps

```
ukcs.north= 63
ukcs.east= 10
ukcs.south= 48
ukcs.west= -15
#
ukcsPlus.north= 82
ukcsPlus.east= 54
ukcsPlus.south= 37
ukcsPlus.west= -57
#
ices.north= 55
ices.east= 5
ices.south= 48
ices.west= -10
#
SNS.north = 54
SNS.east=6
SNS.south=51
SNS.west=0
```

Bounding Boxes for ICES areas

```
lpoolBay.north=54
lpoolBay.east=-3
lpoolBay.south=53
lpoolBay.west=-5
#
celticSea.north=51
celticSea.east=-7
celticSea.south=50
celticSea.west=-9
#
brixham.north=50.5
brixham.east=-2
brixham.south=49.5
brixham.west=-4
#
thames.north=52.5
thames.east=3
thames.south=51.5
thames.west=1
```

Bounding Boxes for the Southern North Sea area

```
SNSbb.north=53.5
SNSbb.east=4
SNSbb.south=51.5
SNSbb.west=2
```

Fix for Swiss GADM not plotting & Greenland/Turkey “tears”

Some “tears”, e.g. Russia generating a horizontal band from the Aleutian’s were dealt with by constraining the map size. These weren’t.

```
box.CHE <- data.frame(maxlat = 52, minlat = 48, maxlong = 20, minlong = 6, i
d="a")
box.CHE <- transform(box.CHE, laby=(maxlat +minlat )/2, labx=(maxlong+minlon
g)/2)
#
box.GRN <- data.frame(maxlat = 82, minlat = 72, maxlong = -25, minlong = -5
7, id="a")
box.GRN <- transform(box.GRN, laby=(maxlat +minlat )/2, labx=(maxlong+minlon
g)/2)
#
box.TUR.1 <- data.frame(maxlat = 41, minlat = 37, maxlong = 45, minlong = 2
8, id="a")
box.TUR.1 <- transform(box.TUR.1, laby=(maxlat +minlat )/2, labx=(maxlong+mi
nlong)/2)
#
box.TUR.2 <- data.frame(maxlat = 41.6, minlat = 41, maxlong = 38, minlong =
32, id="a")
box.TUR.2 <- transform(box.TUR.2, laby=(maxlat +minlat )/2, labx=(maxlong+mi
nlong)/2)
#
```

Base maps (uses marmap)

keep = TRUE retains the relevant .csv files downloaded from the NOAA database.

```
map.ukcs <- getNOAA.bathy(ukcs.west, ukcs.east, ukcs.south, ukcs.north, res
= 1, keep=TRUE)
```

```
## File already exists ; loading 'marmap_coord_-15;48;10;63_res_1.csv'
```

```
map.ukcsPlus <- getNOAA.bathy(ukcsPlus.west, ukcsPlus.east, ukcsPlus.south,
ukcsPlus.north, res = 4, keep=TRUE)
```

```
## File already exists ; loading 'marmap_coord_-57;37;54;82_res_4.csv'
```

```
map.ices <- getNOAA.bathy(ices.west, ices.east, ices.south, ices.north, res
= 1, keep=TRUE)
```

```
## File already exists ; loading 'marmap_coord_-10;48;5;55_res_1.csv'
```

```
map.SNS<-getNOAA.bathy(SNS.west, SNS.east, SNS.south, SNS.north, res = 1, ke
ep=TRUE)
```

```
## File already exists ; loading 'marmap_coord_0;51;6;54_res_1.csv'
```

All maps have used **marmap** plus darkgreen country overlays; this is consistent for all figures (the density plot does not allow a scaled fill for the data AND, e.g. an “etopo” fill for the topography), retains the bathymetry & over plots land, masking smear from point plots and the land components of the density plots.

Using the single world map from GADM requires dealing with shape files, another ‘extension’ that was time constrained and hence not used.

```
# Download relevant country polygons - see http://gadm.org/country UK & R Sp
atialPolygon - level 0 admin - Ver 2.8
#
#uses library(sp)
#
ALBcoast <- readRDS("ALB_adm0.rds")
ARMcoast <- readRDS("ARM_adm0.rds")
AUTcoast <- readRDS("AUT_adm0.rds")
AZEcoast <- readRDS("AZE_adm0.rds")
BELcoast <- readRDS("BEL_adm0.rds")
BGRcoast <- readRDS("BGR_adm0.rds")
BIHcoast <- readRDS("BIH_adm0.rds")
BLRcoast <- readRDS("BLR_adm0.rds")
CANcoast <- readRDS("CAN_adm0.rds")
CHEcoast <- readRDS("CHE_adm0.rds")
DEUcoast <- readRDS("DEU_adm0.rds")
DNKcoast <- readRDS("DNK_adm0.rds")
ESPcoast <- readRDS("ESP_adm0.rds")
ESTcoast <- readRDS("EST_adm0.rds")
FINcoast <- readRDS("FIN_adm0.rds")
FRAcoast <- readRDS("FRA_adm0.rds")
FROcoast <- readRDS("FRO_adm0.rds")
GBRcoast <- readRDS("GBR_adm0.rds")
GRCcoast <- readRDS("GRC_adm0.rds")
GEOcoast <- readRDS("GEO_adm0.rds")
GRLcoast <- readRDS("GRL_adm0.rds")
HRVcoast <- readRDS("HRV_adm0.rds")
HUNcoast <- readRDS("HUN_adm0.rds")
IMNcoast <- readRDS("IMN_adm0.rds")
IRLcoast <- readRDS("IRL_adm0.rds")
IRNcoast <- readRDS("IRN_adm0.rds")
ISLcoast <- readRDS("ISL_adm0.rds")
ITAcoast <- readRDS("ITA_adm0.rds")
KAZcoast <- readRDS("KAZ_adm0.rds")
LIEcoast <- readRDS("LIE_adm0.rds")
LTUcoast <- readRDS("LTU_adm0.rds")
LUXcoast <- readRDS("LUX_adm0.rds")
LVAcoast <- readRDS("LVA_adm0.rds")
MDAcoast <- readRDS("MDA_adm0.rds")
MKDcoast <- readRDS("MKD_adm0.rds")
MNEcoast <- readRDS("MNE_adm0.rds")
NLDcoast <- readRDS("NLD_adm0.rds")
NORcoast <- readRDS("NOR_adm0.rds")
POLcoast <- readRDS("POL_adm0.rds")
PRTcoast <- readRDS("PRT_adm0.rds")
ROUcoast <- readRDS("ROU_adm0.rds")
RUScoast <- readRDS("RUS_adm0.rds")
SJMcoast <- readRDS("SJM_adm0.rds")
SRBcoast <- readRDS("SRB_adm0.rds")
SVKcoast <- readRDS("SVK_adm0.rds")
SVNcoast <- readRDS("SVN_adm0.rds")
SWEcoast <- readRDS("SWE_adm0.rds")
```

```
TKMcoast <- readRDS("TKM_adm0.rds")
TURcoast <- readRDS("TUR_adm0.rds")
UKRcoast <- readRDS("UKR_adm0.rds")
XKOcoast <- readRDS("XKO_adm0.rds")
#
# proj4string(GBRcoast) # confirms WGS84
# GBRmerc <- spTransform(GBRcoast, CRS("+init=epsg:3395")) # not needed
#
ALB <- fortify(ALBcoast,id="id")
ARM <- fortify(ARMcoast,id="id")
AUT <- fortify(AUTcoast,id="id")
AZE <- fortify(AZEcoast,id="id")
BEL <- fortify(BELcoast,id="id")
BGR <- fortify(BGRcoast,id="id")
BIH <- fortify(BIHcoast,id="id")
BLR <- fortify(BLRcoast,id="id")
CAN <- fortify(CANcoast,id="id")
CHE <- fortify(CHEcoast,id="id")
DEU <- fortify(DEUcoast,id="id")
DNK <- fortify(DNKcoast,id="id")
ESP <- fortify(ESPcoast,id="id")
EST <- fortify(ESTcoast,id="id")
FIN <- fortify(FINcoast,id="id")
FRA <- fortify(FRAcoast,id="id")
FRO <- fortify(FROcoast,id="id")
GBR <- fortify(GBRcoast,id="id")
GRC <- fortify(GRCcoast,id="id")
GEO <- fortify(GEOcoast,id="id")
GRL <- fortify(GRLcoast,id="id")
HRV <- fortify(HRVcoast,id="id")
HUN <- fortify(HUNcoast,id="id")
IMN <- fortify(IMNcoast,id="id")
IRL <- fortify(IRLcoast,id="id")
IRN <- fortify(IRNcoast,id="id")
ISL <- fortify(ISLcoast,id="id")
ITA <- fortify(ITAcoast,id="id")
KAZ <- fortify(KAZcoast,id="id")
LIE <- fortify(LIEcoast,id="id")
LTU <- fortify(LTUcoast,id="id")
LVA <- fortify(LVAcoast,id="id")
LUX <- fortify(LUXcoast,id="id")
MDA <- fortify(MDAcoast,id="id")
MKD <- fortify(MKDcoast,id="id")
MNE <- fortify(MNEcoast,id="id")
NLD <- fortify(NLDcoast,id="id")
NOR <- fortify(NORcoast,id="id")
POL <- fortify(POLcoast,id="id")
PRT <- fortify(PRTcoast,id="id")
ROU <- fortify(ROUcoast,id="id")
RUS <- fortify(RUScoast,id="id")
SJM <- fortify(SJMcoast,id="id")
SRB <- fortify(SRBcoast,id="id")
```

```
SVK <- fortify(SVKcoast,id="id")
SVN <- fortify(SVNcoast,id="id")
SWE <- fortify(SWEcoast,id="id")
TKM <- fortify(TKMcoast,id="id")
TUR <- fortify(TURcoast,id="id")
UKR <- fortify(UKRcoast,id="id")
XKO <- fortify(XKOcoast,id="id")
```

Figures 1 & 2 are images of Research Vessels.

Common /Map & / or Plot parameters

```
PointColour="red3" # all maps and figures
```

Figure 3 Overview of the location of “all” Cefas seawater temperature measurements

The ESSD target journal requires images to be no less than 8cm wide and at 300 dpi, with vector formats (e.g. PDF) preferred. PNG are used for images (e.g. Research vessels) and maps. Plot file size is also a consideration. Point and text sizes are adjusted to suit the file output so may not look as good on screen/in the printed Notebook. Installation issues for PDF output unresolved so PNG is default format.

Create the required Labels for Lat & Long

Create the breaks- and label vectors

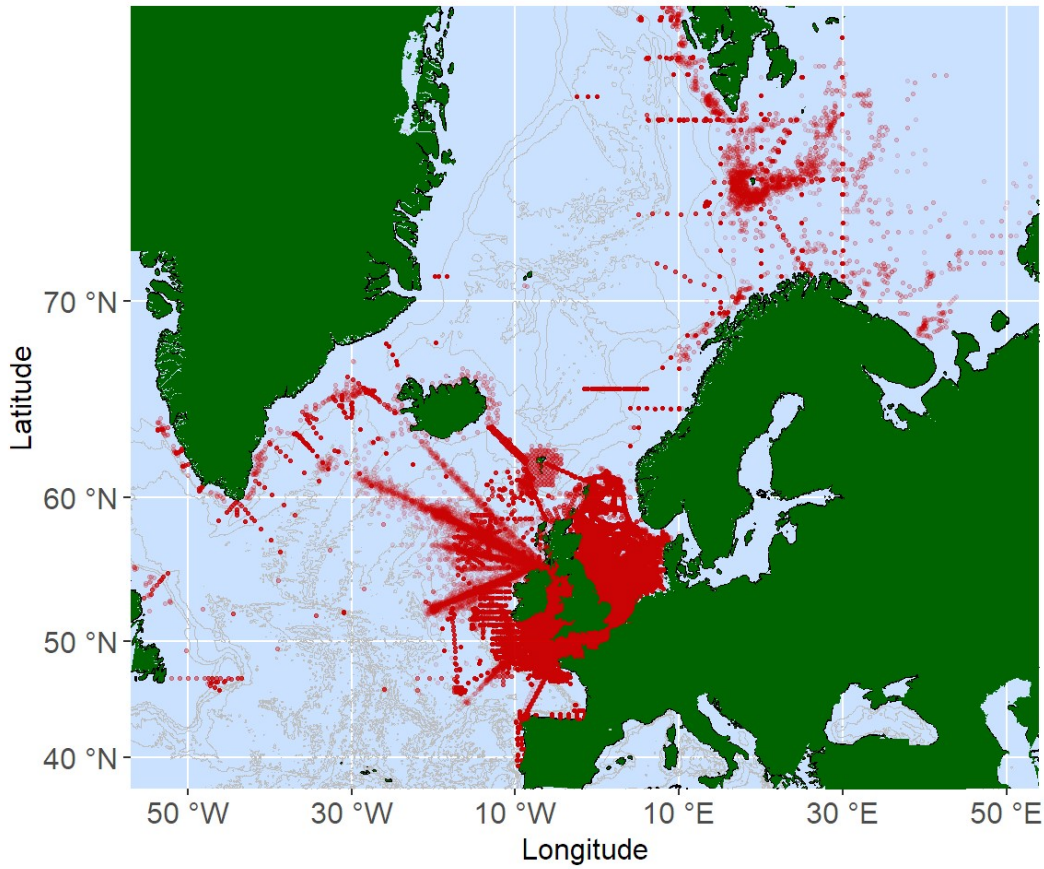
http://stackoverflow.com/questions/33302424/format-latitude-and-longitude-axis-labels-in-ggplot (http://stackoverflow.com/questions/33302424/format-latitude-and-longitude-axis-labels-in-ggplot)

```
ewbrks <- seq(-50,50,20) # 50 West to 50 East in 10 degree units
nsbrks <- seq(40,70,10) # differ from ukcsPlus etc as rounded to 5 and 10
ewlbls <- unlist(lapply(ewbrks, function(x) ifelse(x < 0, paste(x*-1, "°
W"), ifelse(x > 0, paste(x, "°E"),x))))
nslbls <- unlist(lapply(nsbrks, function(x) ifelse(x < 0, paste(x*-1, "°
S"), ifelse(x > 0, paste(x, "°N"),x))))
```

create the map

```
ppi=300
Figure.width = 16/2.54
Figure.height = 16/2.54
#
autoplot(map.ukcsPlus,geom="contour",colour="gray",size=0.1) +
scale_x_continuous(limits = c(ukcsPlus.west, ukcsPlus.east), breaks=ewbrks,
labels=ewlbls, expand = c(0, 0)) +
scale_y_continuous(limits = c(ukcsPlus.south, ukcsPlus.north), breaks=nsbrk
s, labels=nslbls, expand = c(0, 0)) +
coord_map(xlim=c(ukcsPlus.west,ukcsPlus.east),ylim=c(ukcsPlus.south,ukcsPlu
s.north)) +
theme(panel.background = element_rect(fill = "lightsteelblue1")) +
geom_point(aes(x=Long,y=Lat), data = SWTfinal, col=PointColour, size=0.5, al
pha = 1/10) +
  labs(x="Longitude", y="Latitude") +
  theme(axis.title = element_text(size = 12)) +
  theme(axis.text.x = element_text(size=12), axis.text.y = element_text(size
=12)) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=RUS) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=ALB) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=ARM) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=AUT) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=AZE) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=BEL) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=BGR) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=BIH) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=BLR) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=CAN) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=CHE) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=DEU) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=DNK) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=ESP) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=EST) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=FIN) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=FRA) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=FRO) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=GBR) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=GEO) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=GRC) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=GRL) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=HRV) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=HUN) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=IMN) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=IRL) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=IRN) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=ISL) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=ITA) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=KAZ) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=LIE) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=LTU) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=LUX) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=LVA) +
```

```
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=MDA) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=MKD) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=MNE) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=NLD) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=NOR) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=POL) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=PRT) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=ROU) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=SJM) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=SRB) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=SVK) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=SVN) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=SWE) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=TKM) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=TUR) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=UKR) +
 geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=XKO) +
  geom_rect(data=box.CHE, aes(xmin=minlong, xmax=maxlong, ymin=minlat, ymax=
maxlat), color="darkgreen", fill="darkgreen", inherit.aes=FALSE) +
  geom_rect(data=box.GRN, aes(xmin=minlong, xmax=maxlong, ymin=minlat, ymax=
maxlat), color="darkgreen", fill="darkgreen", inherit.aes=FALSE) +
  geom_rect(data=box.TUR.1, aes(xmin=minlong, xmax=maxlong, ymin=minlat, yma
x=maxlat), color="darkgreen", fill="darkgreen", inherit.aes=FALSE) +
  geom_rect(data=box.TUR.2, aes(xmin=minlong, xmax=maxlong, ymin=minlat, yma
x=maxlat), color="darkgreen", fill="darkgreen", inherit.aes=FALSE) +
    theme(axis.text = element_text(size=12))
```



```
#
# https://gis.stackexchange.com/questions/165974/r-fortify-causing-polygons-to-tear
# Greenland and Turkey 'tear' - fixed the image with polygons for now
ggsave("fig03.png", width=Figure.width, height = Figure.height, dpi=ppi)
```

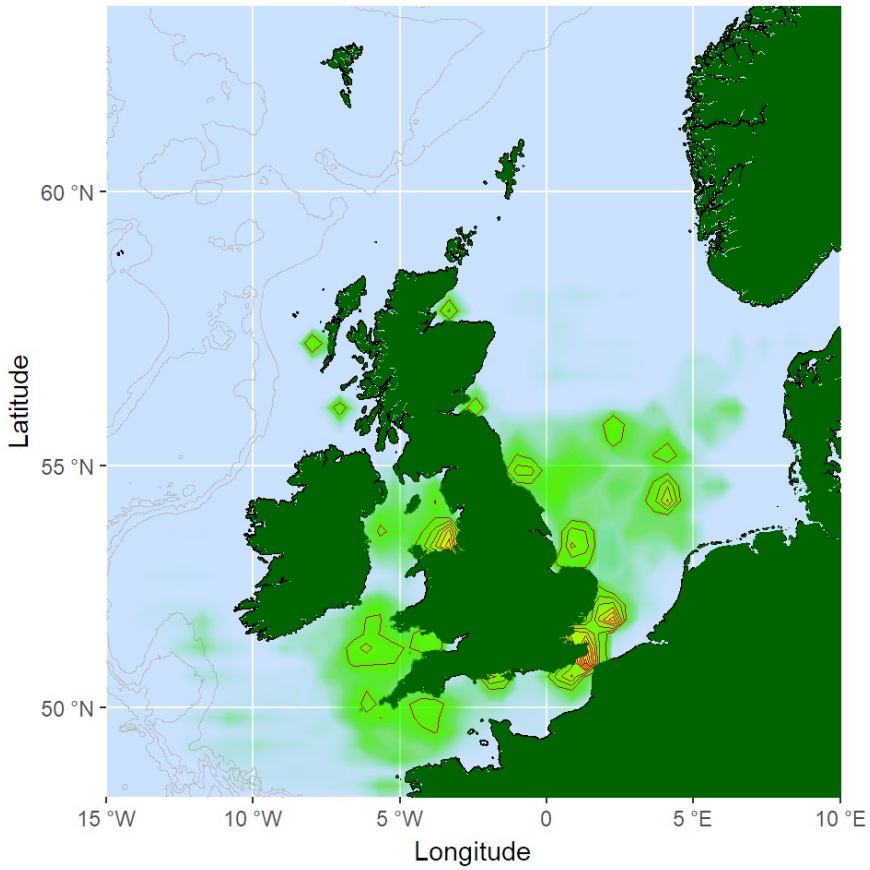
Figure 4 Data Density Plot - UKCS waters

```
ukcsAll <- subset(SWTfinal, Lat < ukcs.north)
ukcsAll <- subset(ukcsAll, Lat > ukcs.south)
ukcsAll <- subset(ukcsAll, Long < ukcs.east)
ukcsAll <- subset(ukcsAll, Long > ukcs.west)
ukcsLatLong <- ukcsAll[c("Lat","Long")]
LatLongTotal<-nrow(ukcsLatLong)
#
ReductionFactor = 5 # just fits into 16 Gbyte Cefas Windows 10 PC limit
#
ukcsSeq <-ukcsLatLong
ukcsSeq <- ukcsSeq[seq(1,LatLongTotal,ReductionFactor),]
```

```
#DENSITY PARAMETERS
# provide optimum plot to illustrate data coverage
#
binNum = 2000
denSize=0.1
#
# Data for Density calculations
d <- ukcsSeq
#
# SET UP OUTPUT FILE
ppi=300
Figure.width = 16/2.54
Figure.height = 16/2.54
#
# CALCULATE DENSITIES AND PLOT
#
# 16 Gbyte Windows Memory limits approached - auto memory clear by R insuffi
ciently reliable
gc()
```

```
##             used   (Mb) gc trigger   (Mb)   max used   (Mb)
## Ncells  13019274  695.4   20885653 1115.5   20885653 1115.5
## Vcells 355987520 2716.0 1105055247 8431.0 1105054542 8430.9
```

```
# LABELS
ewbrks <- seq(-15,10,5)
nsbrks <- seq(45,60,5)
ewlbls <- unlist(lapply(ewbrks, function(x) ifelse(x < 0, paste(x*-1, "°
W"), ifelse(x > 0, paste(x, "°E"),x))))
nslbls <- unlist(lapply(nsbrks, function(x) ifelse(x < 0, paste(x*-1, "°
S"), ifelse(x > 0, paste(x, "°N"),x))))
#
# Using the previous code does not work well. The density & contours result
in inland Norway & Europe not plotting andthe coastline of France plotting a
long the coast in a straight line from the border to the edge of the plot wt
h darkgreen fills acriss bats. Using scale_x_discrete (and for y) fixes thi
s but loses the background ligtsteelblue and the grid lines AND the axis ann
otations, although the degrre fix works.
# moving theme(panel.background...) to the end of the code makes no differen
ce.
# manually aligning the scales in the labels and the discrete scale works! d
uh!!!
# That will teach me to copy & paste too much.
autoplot(map.ukcs, geom="contour",colour="gray", size=0.1) +
  coord_map(xlim=c(ukcs.west,ukcs.east),ylim=c(ukcs.south,ukcs.north)) +
 scale_x_discrete(limits = c(-15,-10,-5,0,5,10), breaks=ewbrks, labels=ewlbl
s, expand = c(0, 0)) +
 scale_y_discrete(limits = c(45,50,55,60), breaks=nsbrks, labels=nslbls, exp
and = c(0, 0)) +
    labs(x="Longitude", y="Latitude") +
  stat_density2d(data = d, aes(x = Long, y = Lat, fill = ..level.., alpha
= ..level..), size = 10, bins = binNum, geom = "polygon") +
  geom_density2d(data = d, aes(x = Long, y = Lat, size = denSize), colour=Po
intColour, size=0.01) +
  scale_fill_gradient2(low = "cyan", mid="green",high = "yellow",guide = "co
lourbar") +
  scale_alpha(range = c(0, 0.3), guide = FALSE) +
  theme(legend.position="none") +
  geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=BEL) +
  #geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=CHE) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=DNK) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=DEU) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=FRA) +
  geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=FRO) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=GBR) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=IMN) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=IRL) +
  #geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=LIE) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=LUX) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=NLD) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=NOR)+
  theme(panel.background = element_rect(fill = "lightsteelblue1"))
```




```
  #
ggsave("fig04.png", width=Figure.width, height = Figure.height, dpi=ppi)
#
```

Figure 5 Overview of numbers of “all” Cefas seawater temperature measurements by year

Create Subsets

```
#
SWT.early<-subset(SWTfinal,SWTfinal$Time<"1960-01-01 00:00:00")
SWT.late<-subset(SWTfinal,SWTfinal$Time>="1940-01-01 00:00:00")
#
```

```
ppi=300
Figure.width = 16/2.54
Figure.height = 10/2.54
png("fig05.png", type = "cairo", width = Figure.width, height = Figure.heigh
t, units = "in", pointsize = 12, res = ppi)
p1 <- ggplot(data = SWT.early, aes(x=Time)) +
       geom_histogram() +
       scale_y_continuous(labels = fancy_scientific) +
       labs(x="Year", y="Count") +
       ggtitle("(a)") +
       theme_bw()
#
p2 <- ggplot(data = SWT.late, aes(x=Time)) +
  geom_histogram() +
  scale_y_continuous(labels = fancy_scientific) +
  labs(x="Year", y="Count") +
  ggtitle("(b)") +
  theme_bw()
#
multiplot(p1,p2, cols = 2)
dev.off()
```

```
## png
##   2
```

Figure 6 Overview of “all” Cefas seawater temperature measurements by depth - 1 m bin

Subset the Data

a <=10, b >10 <=100 c >100 <=250 d >250 (surface, thermocline/productive, shelf, rest)

Surface means top 10 m here - to display data distribution only - this changes for other, comparison based graphs below.

```
surface<-SWTfinal
surface<-subset(surface,Depth<=10)
#
productive<-SWTfinal
productive<-subset(productive,Depth>10)
productive<-subset(productive,Depth<=100)
#
shelf<-SWTfinal
shelf<-subset(shelf, Depth>100)
shelf<-subset(shelf, Depth<=250)
#
deepest<-SWTfinal
deepest<-subset(deepest, Depth>250)
#
# cross check
#
print(paste0("Surface           = ", NROW(surface)))
```

```
## [1] "Surface           = 5794209"
```

```
print(paste0("Productive        = ", NROW(productive)))
```

```
## [1] "Productive        = 4400299"
```

```
print(paste0("Shelf             = ", NROW(shelf)))
```

```
## [1] "Shelf             = 349008"
```

```
print(paste0("Deepest           = ", NROW(deepest)))
```

```
## [1] "Deepest           = 136924"
```

```
#
print(" ")
```

```
## [1] " "
```

```
print(paste0("Sum of above      = ", NROW(surface) + NROW(productive) + NROW
(shelf) + NROW(deepest)))
```

```
## [1] "Sum of above      = 10680440"
```

```
print(paste0("Total             = ", NROW(SWTfinal)))
```

```
## [1] "Total             = 10680440"
```

```
#
```

Plot to file

```
ppi=300
Figure.width = 16/2.54
Figure.height = 14/2.54
png("fig06.png", type = "cairo", width = Figure.width, height = Figure.heigh
t, units = "in", pointsize = 12, res = ppi)
#
p1 <- ggplot(data = surface, aes(x=Depth)) +
  geom_histogram() +
  scale_y_continuous(labels = fancy_scientific) +
  labs(x="Depth (m)", y="Count") +
  ggtitle("(a)") +
  theme(plot.title = element_text(hjust = 0.5)) +
  theme_bw()
p2 <- ggplot(data = productive, aes(x=Depth)) +
  geom_histogram() +
  scale_y_continuous(labels = fancy_scientific) +
  labs(x="Depth (m)", y="Count") +
  ggtitle("(b)") +
  theme(plot.title = element_text(hjust = 0.5)) +
  theme_bw()
p3 <- ggplot(data = shelf, aes(x=Depth)) +
  geom_histogram() +
  scale_y_continuous(labels = fancy_scientific) +
  labs(x="Depth (m)", y="Count") +
  ggtitle("(c)") +
  theme(plot.title = element_text(hjust = 0.5)) +
  theme_bw()
p4 <- ggplot(data = deepest, aes(x=Depth)) +
  geom_histogram() +
  scale_y_continuous(labels = fancy_scientific) +
  labs(x="Depth (m)", y="Count") +
  ggtitle("(d)") +
  theme(plot.title = element_text(hjust = 0.5)) +
  theme_bw()
#
multiplot(p1,p3,p2,p4, cols = 2)
dev.off()
```

```
## png
##   2
```

Figure 7 Location of Cefas temperature data by ICES Rectangle group - SURFACE (0-5m)

Subset Data

```
#
# 5m used to include intake data from Ferries (1.5) & RVs (4, 4.5)
#
upperdepth.threshold=0
lowerdepth.threshold=5
interimdepth.threshold = 1 # includes SmartBuouy & WaveNet data - 1m and 0.4
m nominal sensor depths respectively
```

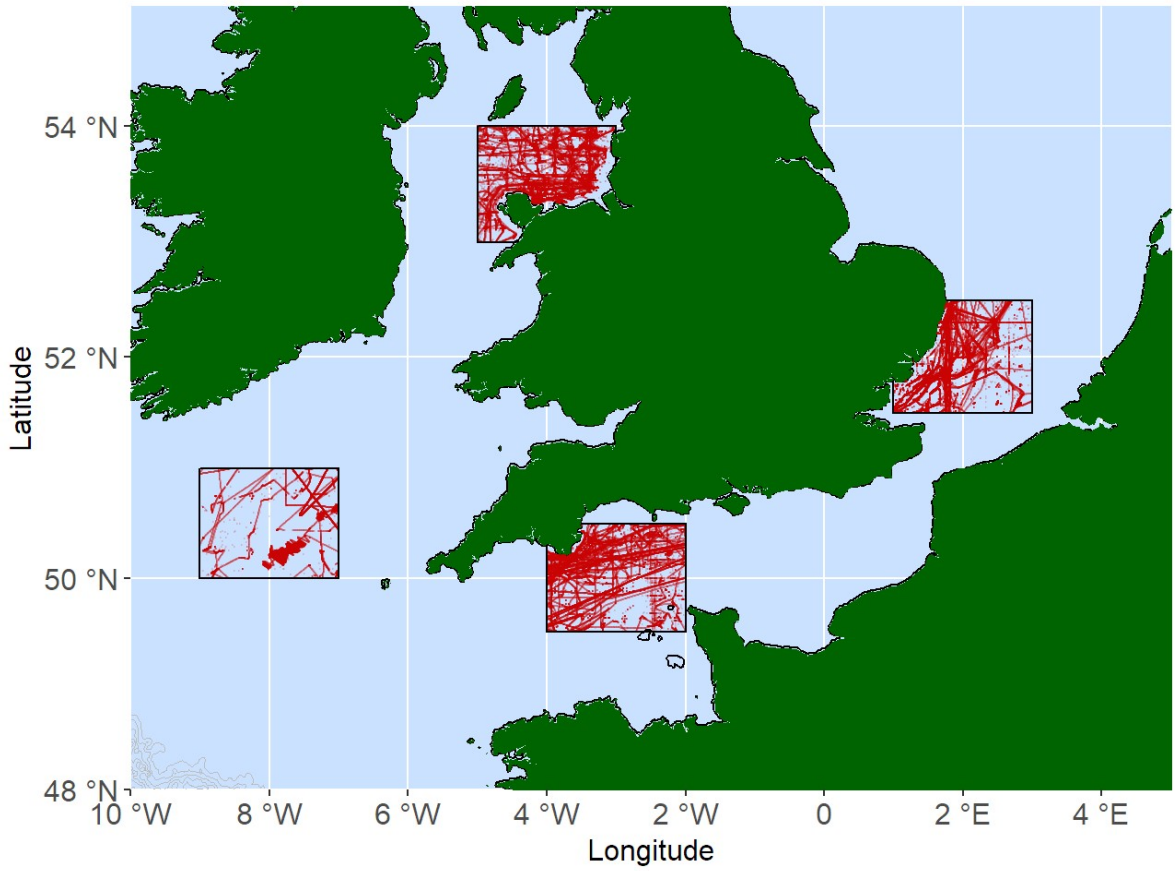
```
#
SWTfinalSURFACE<-subset(SWTfinal, Depth>=upperdepth.threshold & Depth<=lower
depth.threshold)
#
swt.lpoolBay<-SWTfinalSURFACE
swt.lpoolBay<-subset(swt.lpoolBay, Lat <= lpoolBay.north)
swt.lpoolBay<-subset(swt.lpoolBay, Lat >= lpoolBay.south)
swt.lpoolBay<-subset(swt.lpoolBay, Long >= lpoolBay.west)
swt.lpoolBay<-subset(swt.lpoolBay, Long <= lpoolBay.east)
#
swt.celticSea<-SWTfinalSURFACE
swt.celticSea<-subset(swt.celticSea, Lat <= celticSea.north)
swt.celticSea<-subset(swt.celticSea, Lat >= celticSea.south)
swt.celticSea<-subset(swt.celticSea, Long >= celticSea.west)
swt.celticSea<-subset(swt.celticSea, Long <= celticSea.east)
#
swt.brixham<-SWTfinalSURFACE
swt.brixham<-subset(swt.brixham, Lat <= brixham.north)
swt.brixham<-subset(swt.brixham, Lat >= brixham.south)
swt.brixham<-subset(swt.brixham, Long >= brixham.west)
swt.brixham<-subset(swt.brixham, Long <= brixham.east)
#
swt.thames<-SWTfinalSURFACE
swt.thames<-subset(swt.thames, Lat <= thames.north)
swt.thames<-subset(swt.thames, Lat >= thames.south)
swt.thames<-subset(swt.thames, Long >= thames.west)
swt.thames<-subset(swt.thames, Long <= thames.east)
#
```

Plot to file

```
ewbrks <- seq(-10,4,2)
nsbrks <- seq(48, 54,2)
ewlbls <- unlist(lapply(ewbrks, function(x) ifelse(x < 0, paste(x*-1, "°
W"), ifelse(x > 0, paste(x, "°E"),x))))
nslbls <- unlist(lapply(nsbrks, function(x) ifelse(x < 0, paste(x*-1, "°
S"), ifelse(x > 0, paste(x, "°N"),x))))
```

```
box.Lpool <- data.frame(maxlat = 54, minlat = 53, maxlong = -3, minlong =
-5, id="(a)")
box.Lpool <- transform(box.Lpool, laby=(maxlat +minlat )/2, labx=(maxlong+mi
nlong)/2)
box.Celtic <- data.frame(maxlat = 51, minlat = 50, maxlong = -7, minlong =
-9, id="(b)")
box.Celtic <- transform(box.Celtic, laby=(maxlat +minlat )/2, labx=(maxlong+
minlong)/2)
box.Brixham <- data.frame(maxlat = 50.5, minlat = 49.5, maxlong = -2, minlon
g = -4, id="(c)")
box.Brixham <- transform(box.Brixham, laby=(maxlat +minlat )/2, labx=(maxlon
g+minlong)/2)
box.Thames <- data.frame(maxlat = 52.5, minlat = 51.5, maxlong = 3, minlong
= 1, id="(d)")
box.Thames <- transform(box.Thames, laby=(maxlat +minlat )/2, labx=(maxlong+
minlong)/2)
```

```
ppi=300
Figure.width = 16/2.54
Figure.height = 16/2.54
#
autoplot(map.ices, geom="contour", colour="gray", size=0.1) +
scale_x_continuous(limits = c(ices.west, ices.east), breaks=ewbrks, labels=e
wlbls, expand = c(0, 0)) +
scale_y_continuous(limits = c(ices.south, ices.north), breaks=nsbrks, labels
=nslbls, expand = c(0, 0)) +
coord_map(xlim=c(ices.west,ices.east),ylim=c(ices.south,ices.north)) +
theme(panel.background = element_rect(fill = "lightsteelblue1")) +
  theme(legend.position = "none") +
  geom_point(aes(x=Long,y=Lat), data = swt.lpoolBay, col=PointColour, size=
0.1, alpha = 1/10) +
  geom_point(aes(x=Long,y=Lat), data = swt.celticSea, col=PointColour, size=
0.1, alpha = 1/10) +
  geom_point(aes(x=Long,y=Lat), data = swt.brixham, col=PointColour, size=0.
1, alpha = 1/10) +
  geom_point(aes(x=Long,y=Lat), data = swt.thames, col=PointColour, size=0.
1, alpha = 1/10) +
  labs(x="Longitude", y="Latitude") +
  theme(axis.title = element_text(size = 12)) +
  theme(axis.text.x = element_text(size=12), axis.text.y = element_text(size
=12)) +
  theme(axis.text = element_text(size=12)) +
  scale_x_continuous(breaks = ewbrks, labels = ewlbls, expand = c(0, 0)) +
  scale_y_continuous(breaks = nsbrks, labels = nslbls, expand = c(0, 0)) +
  geom_rect(data=box.Lpool, aes(xmin=minlong, xmax=maxlong, ymin=minlat, yma
x=maxlat ), color="black", fill="transparent", inherit.aes=FALSE) +
  geom_text(data=box.Lpool, aes(x=labx, y=laby), color="black",label=" ") +
  geom_rect(data=box.Celtic, aes(xmin=minlong, xmax=maxlong, ymin=minlat, ym
ax=maxlat ), color="black", fill="transparent", inherit.aes=FALSE) +
  geom_text(data=box.Celtic, aes(x=labx, y=laby), color="black",label=" ")
+
  geom_rect(data=box.Brixham, aes(xmin=minlong, xmax=maxlong, ymin=minlat, y
max=maxlat ), color="black", fill="transparent", inherit.aes=FALSE) +
  geom_text(data=box.Brixham, aes(x=labx, y=laby), color="black",label=" ")
+
  geom_rect(data=box.Thames, aes(xmin=minlong, xmax=maxlong, ymin=minlat, ym
ax=maxlat ), color="black", fill="transparent", inherit.aes=FALSE) +
  geom_text(data=box.Thames, aes(x=labx, y=laby), color="black",label=" ")
+
  geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=BEL) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=DEU) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=FRA) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=GBR) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=IMN) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=IRL) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=LIE) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=LUX) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=NLD)
```




```
ggsave("fig07.png", width=Figure.width, height = Figure.height, dpi=ppi)
```

Figure 8 Southern North Sea - Data Availability - NEAR SURFACE

Subset the Data

```
# NEAR SURFACE DATA
#
SNS<-SWTfinal
SNSsurface=lowerdepth.threshold
SNS<-subset(SNS,Depth<=SNSsurface)
SNS<-subset(SNS,Lat>=SNSbb.south)
SNS<-subset(SNS,Lat<=SNSbb.north)
SNS<-subset(SNS,Long<=SNSbb.east)
SNS<-subset(SNS,Long>=SNSbb.west)
```

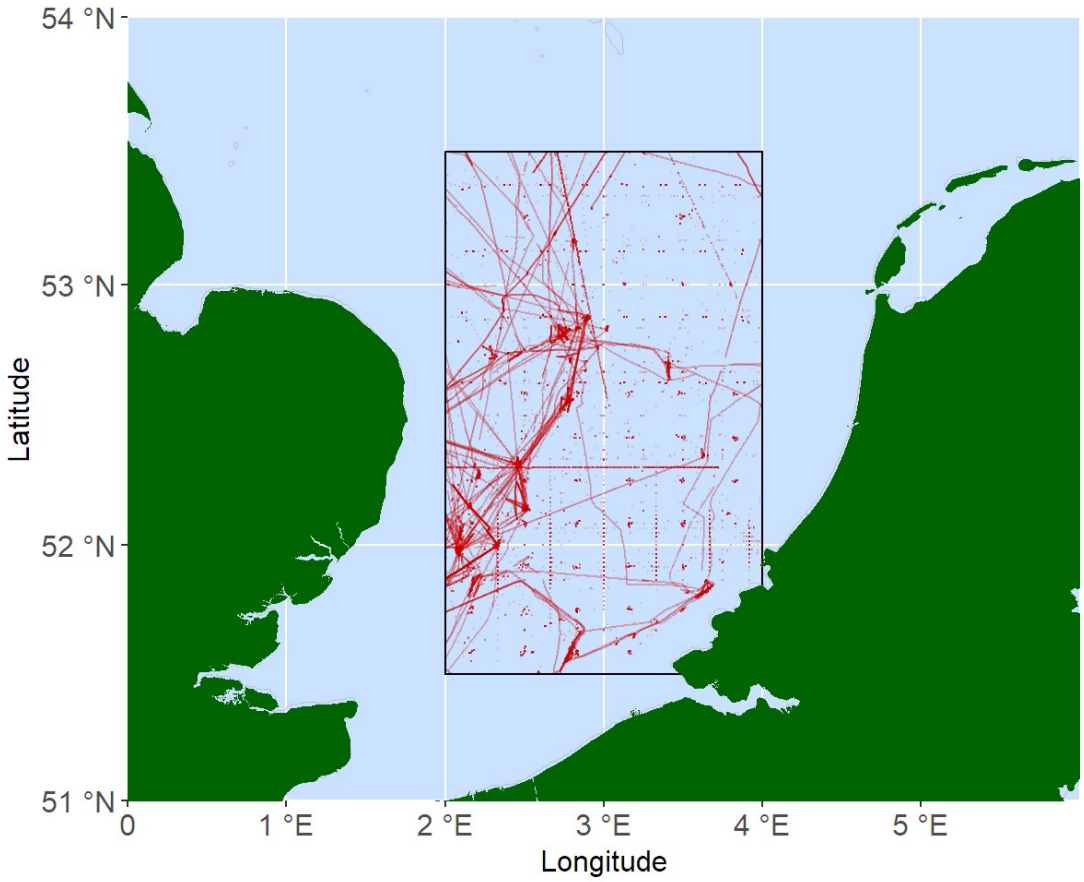
Plot to file

```
box.SNS <- data.frame(maxlat = SNSbb.north, minlat = SNSbb.south, maxlong =
SNSbb.east, minlong = SNSbb.west, id=" ")
box.SNS <- transform(box.SNS, laby=(maxlat +minlat )/2, labx=(maxlong+minlon
g)/2)
```

```
ewbrks <- seq(-1,5,1)
nsbrks <- seq(51,54,1)
ewlbls <- unlist(lapply(ewbrks, function(x) ifelse(x < 0, paste(x*-1, "°
W"), ifelse(x > 0, paste(x, "°E"),x))))
nslbls <- unlist(lapply(nsbrks, function(x) ifelse(x < 0, paste(x*-1, "°
S"), ifelse(x > 0, paste(x, "°N"),x))))
```

create the map

```
ppi=300
Figure.width = 16/2.54
Figure.height = 16/2.54
#
autoplot(map.SNS, coast=FALSE,geom="contour",colour="gray", size=0.1) +
scale_x_continuous(limits = c(SNS.west, SNS.east), breaks=ewbrks, labels=ewl
bls, expand = c(0, 0)) +
scale_y_continuous(limits = c(SNS.south, SNS.north), breaks=nsbrks, labels=n
slbls, expand = c(0, 0)) +
coord_map(xlim=c(SNS.west,SNS.east),ylim=c(SNS.south,SNS.north)) +
theme(panel.background = element_rect(fill = "lightsteelblue1")) +
  theme(legend.position = "none") +
  geom_point(aes(x=Long,y=Lat), data = SNS, col=PointColour, size=0.1, alph
a = 1/10) +
  labs(x="Longitude", y="Latitude") +
  theme(axis.title = element_text(size = 12)) +
  theme(axis.text.x = element_text(size=12), axis.text.y = element_text(size
=12)) +
  theme(axis.text = element_text(size=12)) +
  scale_x_continuous(breaks = ewbrks, labels = ewlbls, expand = c(0, 0)) +
  scale_y_continuous(breaks = nsbrks, labels = nslbls, expand = c(0, 0)) +
   geom_rect(data=box.SNS, aes(xmin=minlong, xmax=maxlong, ymin=minlat,   ym
ax=maxlat ), color="black", fill="transparent", inherit.aes=FALSE) +
  geom_text(data=box.SNS, aes(x=labx, y=laby, label=id), color="black") +
  geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=BEL) +
  #geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=DEU) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=FRA) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=GBR) +
  #geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=IMN) +
  #geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=LIE) +
 # geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=LUX) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=NLD)
```




```
#
ggsave("fig08.png", width=Figure.width, height = Figure.height, dpi=ppi)
```

Figure 9 - SNS Temperature .v. Time by key sources

SEPARATE BY SOURCE - use top 9 by number

```
#
SNS01<- subset(SNS, Source=="1") #exclude - low number <1000
SNS02<- subset(SNS, Source=="2") #exclude - low number <1000
SNS03<- subset(SNS, Source=="3")
SNS04<- subset(SNS, Source=="4")
SNS05<- subset(SNS, Source=="5") #exclude - low number <1000
SNS06<- subset(SNS, Source=="6")
SNS07<- subset(SNS, Source=="7")
SNS08<- subset(SNS, Source=="8")
SNS09<- subset(SNS, Source=="9") #exclude - low number <1000
SNS10<- subset(SNS, Source=="10") #exclude - low number <1000
SNS11<- subset(SNS, Source=="11")
SNS12<- subset(SNS, Source=="12") ##exclude - low number <1000
SNS13<- subset(SNS, Source=="13") #exclude - low number <1000
SNS14<- subset(SNS, Source=="14") #exclude - low number <1000
SNS15<- subset(SNS, Source=="15")
SNS16<- subset(SNS, Source=="16")
SNS17<- subset(SNS, Source=="17")
#
SNS03$year <- year(SNS03$Time)
SNS04$year <- year(SNS04$Time)
SNS06$year <- year(SNS06$Time)
SNS07$year <- year(SNS07$Time)
SNS08$year <- year(SNS08$Time)
SNS11$year <- year(SNS11$Time)
SNS15$year <- year(SNS15$Time)
SNS16$year <- year(SNS16$Time)
SNS17$year <- year(SNS17$Time)
#
```

Plot to file

```
ppi=300
Figure.width = 16/2.54
Figure.height = 16/2.54
png("fig09.png", type = "cairo", width = Figure.width, height = Figure.heigh
t, units = "in", pointsize = 12, res = ppi)
#
p1 <- ggplot(data = SNS03, aes(x=Time, y=tC)) +
  geom_point(color="blue",size=0.2) +
  labs(x="Year", y="Temperature °C") +
  ggtitle("Source 3") +
  # theme(plot.title = element_text(size=5, face = "bold")) +
  scale_y_continuous(limits = c(-2, 25),breaks = seq(0,25,5)) +
  theme_bw() +
  theme(axis.title.x = element_text(face="plain", size=10),
          axis.text.x  = element_text(angle=90, vjust=0.5, size=10))
#
p2 <- ggplot(data = SNS04, aes(x=Time, y=tC)) +
  geom_point(color="gray64",size=0.2) +
  labs(x="Year", y="Temperature °C") +
  ggtitle("Source 4") +
  theme(plot.title = element_text(size=5, face = "bold")) +
  scale_y_continuous(limits = c(-2, 25),breaks = seq(0,25,5)) +
  theme_bw() +
  theme(axis.title.x = element_text(face="plain", size=10),
          axis.text.x  = element_text(angle=90, vjust=0.5, size=10))
#
p3 <- ggplot(data = SNS06, aes(x=Time, y=tC)) +
  geom_point(color="orange",size=0.1) +
  labs(x="Year", y="Temperature °C") +
  ggtitle("Source 6") +
  theme(plot.title = element_text(size=5, face = "bold")) +
  scale_y_continuous(limits = c(-2, 25),breaks = seq(0,25,5)) +
  theme_bw() +
  theme(axis.title.x = element_text(face="plain", size=10),
          axis.text.x  = element_text(angle=90, vjust=0.5, size=10))
#
p4 <- ggplot(data = SNS07, aes(x=Time, y=tC)) +
  geom_point(color="orange",size=0.1) +
  labs(x="Year", y="Temperature °C") +
  ggtitle("Source 7") +
  theme(plot.title = element_text(size=5, face = "bold")) +
  scale_y_continuous(limits = c(-2, 25),breaks = seq(0,25,5)) +
  theme_bw() +
  theme(axis.title.x = element_text(face="plain", size=10),
          axis.text.x  = element_text(angle=90, vjust=0.5, size=10))
#
p5 <- ggplot(data = SNS08, aes(x=Time, y=tC)) +
  geom_point(color=PointColour,size=0.1) +
  labs(x="Year", y="Temperature °C") +
  ggtitle("Source 8") +
  theme(plot.title = element_text(size=5, face = "bold")) +
  scale_y_continuous(limits = c(-2, 25),breaks = seq(0,25,5)) +
```

```
  theme_bw() +
  theme(axis.title.x = element_text(face="plain", size=10),
          axis.text.x  = element_text(angle=90, vjust=0.5, size=10))
#
p6 <- ggplot(data = SNS11, aes(x=Time, y=tC)) +
  geom_point(color="magenta",size=0.2) +
  labs(x="Year", y="Temperature °C") +
  ggtitle("Source 11") +
  theme(plot.title = element_text(size=5, face = "bold")) +
  scale_y_continuous(limits = c(-2, 25),breaks = seq(0,25,5)) +
  theme_bw() +
  theme(axis.title.x = element_text(face="plain", size=10),
          axis.text.x  = element_text(angle=90, vjust=0.5, size=10))
#
p7 <- ggplot(data = SNS15, aes(x=Time, y=tC)) +
  geom_point(color="orange",size=0.1) +
  labs(x="Year", y="Temperature °C") +
  ggtitle("Source 15") +
  theme(plot.title = element_text(size=5, face = "bold")) +
  scale_y_continuous(limits = c(-2, 25),breaks = seq(0,25,5)) +
  theme_bw() +
  theme(axis.title.x = element_text(face="plain", size=10),
          axis.text.x  = element_text(angle=90, vjust=0.5, size=10))
#
p8 <- ggplot(data = SNS16, aes(x=Time, y=tC)) +
  geom_point(color="green",size=0.2) +
  labs(x="Year", y="Temperature °C") +
  ggtitle("Source 16") +
  theme(plot.title = element_text(size=5, face = "bold")) +
  scale_y_continuous(limits = c(-2, 25),breaks = seq(0,25,5)) +
 theme_bw() +
  theme(axis.title.x = element_text(face="plain", size=10),
          axis.text.x  = element_text(angle=90, vjust=0.5, size=10))
#
p9 <- ggplot(data = SNS17, aes(x=Time, y=tC)) +
  geom_point(color="turquoise3",size=0.2) +
  labs(x="Year", y="Temperature °C") +
  ggtitle("Source 17") +
  theme(plot.title = element_text(size=5, face = "bold")) +
  scale_y_continuous(limits = c(-2, 25),breaks = seq(0,25,5)) +
 theme_bw() +
  theme(axis.title.x = element_text(face="plain", size=10),
          axis.text.x  = element_text(angle=90, vjust=0.5, size=10))
#
multiplot(p1,p4,p7,p2,p5,p8,p3,p6,p9, cols = 3)
#
dev.off()
```

```
## png
##   2
```

Figure 10 SNS - Temperature .v. Date - All Surface Data - coloured by Source

red > 100,000 points (Sources 6 & 7 - SmartBuoy & WaveNet) blue 30,000 - 50,000 (8 & 15) green 2,000 - 6,000 (3,4,11,16,17)

```
ppi=300
Figure.width = 16/2.54
Figure.height = 12/2.54
png("fig10.png", type = "cairo", width = Figure.width, height = Figure.heigh
t, units = "in", pointsize = 12, res = ppi)

p1 <- ggplot(data = SNS, aes(x=Time)) +
       geom_histogram() +
       scale_y_continuous(labels = fancy_scientific) +
       labs(x="Year", y="Count") +
       ggtitle("(a)") +
       theme_bw()
#
p2 <- ggplot(data = SNS03, aes(x=Time, y=tC)) +
  geom_point(data=SNS03, color="blue",size=0.1) +
  geom_point(data=SNS04, color="gray64",size=0.1) +
  geom_point(data=SNS08, color=PointColour,size=0.1) +
  geom_point(data=SNS11, color="magenta",size=0.1) +
  geom_point(data=SNS15, color="orange",size=0.1) +
  geom_point(data=SNS16, color="green",size=0.1) +
  geom_point(data=SNS17, color="turquoise3",size=0.1) +
  geom_point(data=SNS06, color="orange",size=0.1, alpha = .5) +
  geom_point(data=SNS07, color="orange",size=0.1, alpha = .5) +
  labs(x="Year", y="Temperature °C") +
  ggtitle("(b)") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(-2, 25),breaks = seq(0,25,5)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
#
multiplot(p1,p2, cols = 1)
dev.off()
```

```
## png
##   2
```

The question arising from Fig 10 (b) is *“there looks to be a change in the minimum values after 2000, with no values < ~ 5C. Is this an artefact of data source?”*. The following few figures explore this.

Fig 11 SNS after 2000 - Distribution of data for Surface 0-5m and 0-1m & E/W - point/vessel

This explores potential bias in the data related to numbers, depth and location. 0-1m is chosen to "isolate" the fixed mooring point, high data number, sources 6 & 7 (SmartBuoy & WaveNet).

Subset Data

```
#
SNS2000 <- subset(SNS, year(Time) >= 2000)
#
SNS2000.1 <- subset(SNS2000, Depth <= interimdepth.threshold)
SNS2000.5 <- subset(SNS2000, Depth > interimdepth.threshold & Depth <=  lowe
rdepth.threshold)
#
SBuoyWNet <- subset(SNS2000.1, Source == 6 | Source == 7) # OR
```

Calculate Percentages

```
#
PercentPost2000 <- 100-(NROW(SNS)-NROW(SNS2000))*100/NROW(SNS)
#
PercentPost2000.1 <- 100-(NROW(SNS2000)-NROW(SNS2000.1))*100/NROW(SNS2000)
#
specify_decimal <- function(x, k) format(round(x, k), nsmall=k)
#
cat((paste0("Percentage of all SNS data in SNS Surface (0-5m), post 2000, i
s ", specify_decimal(PercentPost2000,1)))); cat("\n"); cat((paste0("Percenta
ge of the 0-5m, post 2000 SNS data that is in the 0-1m range [encompassing a
utonomous buouys but excluding vessel mounted pump systems] is ", specify_de
cimal(PercentPost2000.1,1))))
```

```
## Percentage of all SNS data in SNS Surface (0-5m), post 2000, is 95.3
```

```
## Percentage of the 0-5m, post 2000 SNS data that is in the 0-1m range [enc
ompassing autonomous buouys but excluding vessel mounted pump systems] is 8
8.9
```

```
#
```

Plot to file

```
box.SNSa <- data.frame(maxlat = SNSbb.north, minlat = SNSbb.south, maxlong
= SNSbb.east, minlong = SNSbb.west, id="a")
box.SNSa <- transform(box.SNSa, laby=(maxlat +minlat )/2, labx=(maxlong+minl
ong)/2)
#
box.SNSb <- data.frame(maxlat = SNSbb.north, minlat = SNSbb.south, maxlong
= SNSbb.east, minlong = SNSbb.west, id="b")
box.SNSb <- transform(box.SNSb, laby=(maxlat +minlat )/2, labx=(maxlong+minl
ong)/2)
```

```
ewbrks <- seq(0,5,1)
nsbrks <- seq(51,54,1)
ewlbls <- unlist(lapply(ewbrks, function(x) ifelse(x < 0, paste(x*-1, "°
W"), ifelse(x > 0, paste(x, "°E"),x))))
nslbls <- unlist(lapply(nsbrks, function(x) ifelse(x < 0, paste(x*-1, "°
S"), ifelse(x > 0, paste(x, "°N"),x))))
```

```
ppi=300
Figure.width = 16/2.54
Figure.height = 8/2.54
#
png("fig11.png", type = "cairo", width = Figure.width, height = Figure.heigh
t, units = "in", pointsize = 12, res = ppi)
#
p1 <- autoplot(map.SNS, coast=FALSE,geom=("contour"),colour="gray", size=0.0
1) +
  theme(legend.position = "none") +
  geom_point(aes(x=Long,y=Lat), data = SNS2000.5, col=PointColour, size=0.
1, alpha = 1/10) +
  coord_map(xlim=c(SNS.west,SNS.east),ylim=c(SNS.south,SNS.north)) +
  labs(x="Longitude", y="Latitude") +
  theme(axis.title = element_text(size = 12)) +
  theme(axis.text.x = element_text(size=12), axis.text.y = element_text(size
=12)) +
  theme(axis.text = element_text(size=12)) +
  scale_x_continuous(breaks = ewbrks, labels = ewlbls, expand = c(0, 0)) +
  scale_y_continuous(breaks = nsbrks, labels = nslbls, expand = c(0, 0)) +
   geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=BEL) +
  #geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=DEU) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=FRA) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=GBR) +
  #geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=IMN) +
  #geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=LIE) +
 # geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=LUX) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=NLD) +
   geom_rect(data=box.SNSa, aes(xmin=minlong, xmax=maxlong, ymin=minlat,   y
max=maxlat ), color="black", fill="transparent", inherit.aes=FALSE) +
  geom_text(data=box.SNSa, aes(x=labx, y=laby, label=id), color="black")+
  theme(panel.background = element_rect(fill = "lightsteelblue1"))
p2 <- autoplot(map.SNS, coast=FALSE, geom=("contour"),colour="gray", size=0.
01) +
  #scale_fill_etopo() +
  theme(legend.position = "none") +
    coord_map(xlim=c(SNS.west,SNS.east),ylim=c(SNS.south,SNS.north)) +
  geom_point(aes(x=Long, y=Lat), data = SNS2000.1, col=PointColour, size=0.
1, alpha = 1/10) +
  geom_point(aes(x=Long, y=Lat), data = SBuoyWNet, shape=18, col = "orang
e", size = 2) +
  labs(x="Longitude", y="Latitude") +
  theme(axis.title = element_text(size = 12)) +
  theme(axis.text.x = element_text(size=12), axis.text.y = element_text(size
=12)) +
  theme(axis.text = element_text(size=12)) +
  scale_x_continuous(breaks = ewbrks, labels = ewlbls, expand = c(0, 0)) +
  scale_y_continuous(breaks = nsbrks, labels = nslbls, expand = c(0, 0)) +
   geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=BEL) +
  #geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=DEU) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=FRA) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=GBR) +
```

```
  #geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=IMN) +
  #geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=LIE) +
 # geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=LUX) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=NLD) +
   geom_rect(data=box.SNSb, aes(xmin=minlong, xmax=maxlong, ymin=minlat,   y
max=maxlat ), color="black", fill="transparent", inherit.aes=FALSE) +
  geom_text(data=box.SNSb, aes(x=labx, y=laby, label=id), color="black") +
  theme(panel.background = element_rect(fill = "lightsteelblue1"))
# ggsave and multiplot issues so
#
multiplot(p1,p2, cols = 2)
dev.off()
```

```
## png
##   2
```

```
#
```

This illustrates a numerical and a geographic bias for the point sources, south and west.

```
specify_decimal <- function(x, k) format(round(x, k), nsmall=k)
Percent.Moored <- 100-(NROW(SNS2000.1)-NROW(SBuoyWNet))*100/NROW(SNS2000.1)
print(paste0("Percentage of point source data (Sources 6 & 7) in SNS Surfac
e (0-1m), post 2000 is ", specify_decimal(Percent.Moored,1)))
```

```
## [1] "Percentage of point source data (Sources 6 & 7) in SNS Surface (0-1
m), post 2000 is 99.8"
```

```
Percent.Moored <- 100-(NROW(SNS2000.1)-NROW(SBuoyWNet))*100/NROW(SNS2000.5)
print(paste0("Percentage of point source data (Sources 6 & 7) in SNS Surfac
e (0-5m), post 2000 is ", specify_decimal(Percent.Moored,1)))
```

```
## [1] "Percentage of point source data (Sources 6 & 7) in SNS Surface (0-5
m), post 2000 is 98.5"
```

Figure 12 SNS post 2000 - Surface (0-1m) Temperature .v. Time for non-point and point data

Subset Data

```
NOTSBuoyWNet <- subset(SNS2000.1, Source != 6 & Source != 7) # NOT

print(NROW(NOTSBuoyWNet))
```

```
## [1] 787
```

```
#
print(NROW(SBuoyWNet))
```

```
## [1] 426443
```

Plot to file

```
ppi=300
Figure.width = 16/2.54
Figure.height = 8/2.54
png("fig12.png", type = "cairo", width = Figure.width, height = Figure.heigh
t, units = "in", pointsize = 12, res = ppi)
#
p1 <- ggplot(data = NOTSBuoyWNet, aes(x=Time, y=tC)) +
  geom_point(color=PointColour,size=0.05) +
  labs(x="Year", y="Temperature °C") +
  ggtitle("(a)") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(-2, 25),breaks = seq(0,25,5)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
p2 <- ggplot(data = SBuoyWNet, aes(x=Time, y=tC)) +
  geom_point(color="orange",size=0.05) +
  labs(x="Year", y="Temperature °C") +
  ggtitle("(b)") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(-2, 25),breaks = seq(0,25,5)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
#
multiplot(p1,p2, cols=2)
#
dev.off()
```

```
## png
##   2
```

Fig 13 Plot of min, mean & max for SNS surface data (0-5m)

Having established that there don't seem to be any location, number or depth effects in the SNS surface data subset, this section looks at a plot of the Min, Mean and Max for the data to see if this sheds light on the plot in Fig 9(b).

Create the stats data

```
# stats by year
# create a new Variable called Year
SNS$Year <- year(SNS$Time)
#
SNS1925on <- subset(SNS, Year >= 1925 & Year <= 2015)
#
# use Data Table for easy extraction of descriptive statistics
# recreate a simple data frame of year and tC
Year.tC <- data.frame(SNS1925on$Year, SNS1925on$tC)
setnames(Year.tC, old=c("SNS1925on.Year", "SNS1925on.tC"), new=c("Year","Tem
perature"))
#
# now convert to data.table for quick summary stats
#
Simple.Data <- data.table(Year.tC)
tC.stats <- Simple.Data[,list(mean=mean(Temperature),
                              min=min(Temperature),
                              max=max(Temperature)),
                        by='Year']

# revert to data frames to keep plotting consistenmt and reduce data.table p
lot learning curve to 0
#
#e.g. tC.stats[, matplot(SNS.sub.Year, mean, type="p", ylab="Temperature sta
ts", xlab="Year"), .SDcols = !"SNS.sub.Year"]
#
class(as.data.frame(tC.stats))
```

```
## [1] "data.frame"
```

```
#
# generate a subset for lines as overplot
#
line.data <- subset(tC.stats, Year >= 1955)
line.data <- line.data[order(line.data$Year),]
#
```

Fig13 Plot to file

```
#
ppi=300
Figure.width = 16/2.54
Figure.height = 16/2.54 # height increased to show more tC detail
png("fig13.png", type = "cairo", width = Figure.width, height = Figure.heigh
t, units = "in", pointsize = 12, res = ppi)
#
ggplot(data = tC.stats, aes(x=Year, y=mean)) +
  geom_point(color="green") +
  geom_line(data=line.data, aes(x=Year, y=mean), colour = "green") +
  geom_point(data = tC.stats, aes(x=Year, y=max),color=PointColour) +
  geom_line(data= line.data, aes(x=Year, y=max), color=PointColour) +
  geom_point(data = tC.stats, aes(x=Year, y=min),color="blue") +
  geom_line(data= line.data, aes(x=Year, y=min), color="blue") +
  labs(x="Year", y="Annual Average Temperature °C") +
  scale_y_continuous(breaks = seq(0,20,5)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
dev.off()
```

```
## png
##   2
```

```
#
```

Fig 14 3d Plot of Data Sources in SNS

A selected smaller ‘belt’ to illustrate multiple sources and how they are represented in a depth profile. SNS sub-area & small to make plot look clearer - ALL depths.

Create Subset

```
belt.north = 54.8
belt.south = 54.3
belt.east = 3.28
belt.west = 3.24
#
##Subset Belt data
NSdata <- subset(SWTfinal, Lat < belt.north)
NSdata <- subset(NSdata, Lat > belt.south)
NSdata <- subset(NSdata, Long < belt.east)
NSdata <- subset(NSdata, Long > belt.west)
summary(NSdata)
```

```
##      Source             Time                          Lat
##  Min.   : 3.000   Min.   :1960-11-19 20:00:00   Min.   :54.31
##  1st Qu.: 4.000   1st Qu.:2002-08-21 22:03:17   1st Qu.:54.58
##  Median : 8.000   Median :2004-03-08 05:21:38   Median :54.75
##  Mean   : 9.173   Mean   :2004-02-20 15:46:54   Mean   :54.63
##  3rd Qu.:16.000   3rd Qu.:2004-03-08 05:31:13   3rd Qu.:54.75
##  Max.   :17.000   Max.   :2013-08-10 05:44:00   Max.   :54.80
##       Long            Depth             tC           Sample
##  Min.   :3.240   Min.   : 0.00   Min.   : 4.50   Length:2764
##  1st Qu.:3.253   1st Qu.: 4.50   1st Qu.: 5.60   Class :character
##  Median :3.263   Median :17.70   Median :13.06   Mode  :character
##  Mean   :3.262   Mean   :17.71   Mean   :10.96
##  3rd Qu.:3.270   3rd Qu.:28.23   3rd Qu.:14.66
##  Max.   :3.280   Max.   :43.90   Max.   :18.10
##    Measure              Ref1               Ref2
##  Length:2764        Length:2764        Length:2764
##  Class :character   Class :character   Class :character
##  Mode  :character   Mode  :character   Mode  :character
##
##
##
##        ID
##  Min.   : 1148832
##  1st Qu.: 1529821
##  Median : 7516150
##  Mean   : 5379971
##  3rd Qu.: 9279090
##  Max.   :10568496
```

Create columns indicating point color, shape and size

```
NSdata$pcolour[NSdata$Source==3] <- "blue"
NSdata$pcolour[NSdata$Source==4] <- "gray64"
NSdata$pcolour[NSdata$Source==8] <- PointColour
NSdata$pcolour[NSdata$Source==9] <- "black"
NSdata$pcolour[NSdata$Source==11] <- "magenta"
NSdata$pcolour[NSdata$Source==15] <- "orange"
NSdata$pcolour[NSdata$Source==16] <- "green"
NSdata$pcolour[NSdata$Source==17] <- "turquoise3"
#
NSdata$ppch[NSdata$Source==3] <- 20
NSdata$ppch[NSdata$Source==4] <- 20
NSdata$ppch[NSdata$Source==8] <- 20
NSdata$ppch[NSdata$Source==9] <- 8
NSdata$ppch[NSdata$Source==11] <- 17
NSdata$ppch[NSdata$Source==15] <- 20
NSdata$ppch[NSdata$Source==16] <- 20
NSdata$ppch[NSdata$Source==17] <- 20
#
NSdata$pcex[NSdata$Source==3] <- 0.1
NSdata$pcex[NSdata$Source==4] <- 0.1
NSdata$pcex[NSdata$Source==8] <- 0.1
NSdata$pcex[NSdata$Source==9] <- 1
NSdata$pcex[NSdata$Source==11] <- 0.5
NSdata$pcex[NSdata$Source==15] <- 0.1
NSdata$pcex[NSdata$Source==16] <- 0.1
NSdata$pcex[NSdata$Source==17] <- 0.1
```

Plot 3d Scatterplot

```
pts <-
  data.frame(x = NSdata$Long,
             y = NSdata$Lat,
             z = NSdata$Depth* -1)
# pts$ppch <- as.numeric(pts$ppch) # needed as was 'chr' in development stag
es
pts$pcolour <- NSdata$pcolour
pts$ppch <- NSdata$ppch
pts$pcex <- NSdata$pcex
#
ppi=300
Figure.width = 16/2.54
Figure.height = 10/2.54 # height increased to show more tC detail
png("fig14.png", type = "cairo", width = Figure.width, height = Figure.heigh
t, units = "in", pointsize = 12, res = ppi)
#
with(pts, {
     s3d <- scatterplot3d(pts$x,pts$y,pts$z,
               color=pts$pcolour, pch=pts$ppch, cex.symbols=pts$pcex, type
="p",
               scale.y=1,
               scale.x=1,
               cex.lab=0.75,
               cex.axis=0.5,
               x.ticklabs = c("3.24°E","3.25°E","3.26°E","3.27°E","3.28°
E","3.29°E"),
               xlab="Longitude",
               y.ticklabs = c("54.3°N","54.4°N","54.5°N","54.6°N","54.7°N","
"),
               ylab="Latitude",
               z.ticklabs = c(50,40,30,20,10,0),
               zlab="Depth (m)")
               #add legend
               legend("topright", bty="y",cex=0.5,"Data by Source", c("Sourc
e = 3","Source = 4","Source = 8","Source = 9","Source = 11","Source = 15","S
ource = 16","Source = 17"), fill = c("blue","gray64", PointColour, "black",
"magenta", "orange", "green", "turquoise3"))
               })
dev.off()
```

```
## png
##   2
```

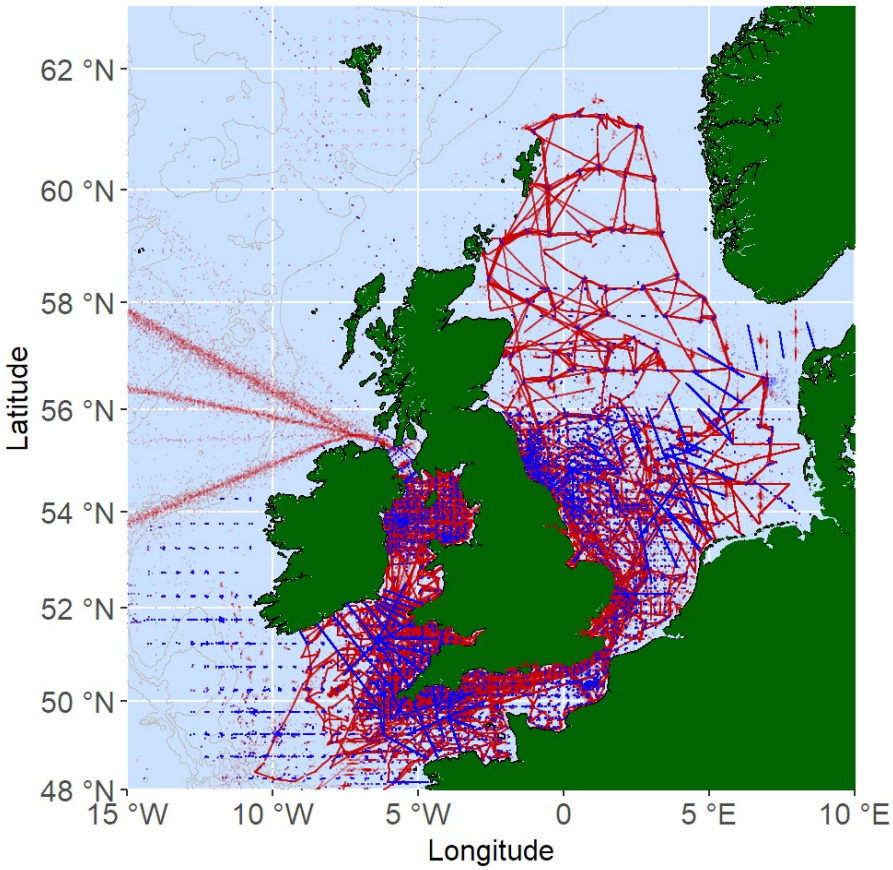
Figure 15 UKCS map and Data Availablity - Surface and Mid water

Subset Data

```
#restrict to UKCS
ukcs <- subset(SWTfinal, Lat < ukcs.north)
ukcs <- subset(ukcs, Lat > ukcs.south)
ukcs <- subset(ukcs, Long < ukcs.east)
ukcs <- subset(ukcs, Long > ukcs.west)
#
# restrict by depth
Dupperdepth.threshold=20
Dlowerdepth.threshold=25
#
ukcs.surface <- subset(ukcs,Depth <=lowerdepth.threshold)
ukcs.mid <- subset(ukcs,Depth >=Dupperdepth.threshold & Depth <=Dlowerdepth.
threshold)
```

```
ewbrks <- seq(-15,10,5)
nsbrks <- seq(48,63,2)
ewlbls <- unlist(lapply(ewbrks, function(x) ifelse(x < 0, paste(x*-1, "°
W"), ifelse(x > 0, paste(x, "°E"),x))))
nslbls <- unlist(lapply(nsbrks, function(x) ifelse(x < 0, paste(x*-1, "°
S"), ifelse(x > 0, paste(x, "°N"),x))))
```

```
ppi=300
Figure.width = 16/2.54
Figure.height = 16/2.54
#
autoplot(map.ukcs, geom="contour",colour="gray", size=0.1) +
  scale_x_continuous(limits = c(ukcs.west, ukcs.east), breaks=ewbrks, labels
=ewlbls, expand = c(0, 0)) +
scale_y_continuous(limits = c(ukcs.south, ukcs.north), breaks=nsbrks, labels
=nslbls, expand = c(0, 0)) +
coord_map(xlim=c(ukcs.west,ukcs.east),ylim=c(ukcs.south,ukcs.north)) +
  theme(legend.position = "none") +
  theme(panel.background = element_rect(fill = "lightsteelblue1")) +
  geom_point(aes(x=Long,y=Lat), data = ukcs.surface, col=PointColour, size=
0.1, alpha = 1/10) +
  geom_point(aes(x=Long,y=Lat), data = ukcs.mid, col="blue", size=0.1, alph
a = 1/10) +
  labs(x="Longitude", y="Latitude") +
  theme(axis.title = element_text(size = 12)) +
  theme(axis.text.x = element_text(size=12), axis.text.y = element_text(size
=12)) +
  theme(axis.text = element_text(size=12)) +
  scale_x_continuous(breaks = ewbrks, labels = ewlbls, expand = c(0, 0)) +
  scale_y_continuous(breaks = nsbrks, labels = nslbls, expand = c(0, 0)) +
  geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=BEL) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=CHE) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=DNK) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=DEU) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=FRA) +
  geom_polygon(aes(x=long,y=lat, group=group),fill="darkgreen",data=FRO) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=GBR) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=IMN) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=IRL) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=LIE) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=LUX) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=NLD) +
  geom_polygon(aes(x=long,y=lat,group=group),fill="darkgreen",data=NOR)
```




```
#
ggsave("fig15.png", width=Figure.width, height = Figure.height, dpi=ppi)
```

Figure 16 UKCS Surface and Mid Water Temperature by 14 YEAR periods

Mid Water data extends from 1970 so that is the time range selected for comparison of surface and mid water data

Partition data

```
ukcs.surface.7084 <- subset(ukcs.surface, Time >= "1970-01-01 00:00:00" & Ti
me <= "1984-12-31 23:59:59")
ukcs.surface.8599 <- subset(ukcs.surface, Time >= "1985-01-01 00:00:00" & Ti
me <= "1999-12-31 23:59:59")
ukcs.surface.0015 <- subset(ukcs.surface, Time >= "2000-01-01 00:00:00" & Ti
me <= "2015-12-31 23:59:59")
#
ukcs.mid.7084 <- subset(ukcs.mid, Time >= "1970-01-01 00:00:00" & Time <= "1
984-12-31 23:59:59")
ukcs.mid.8599 <- subset(ukcs.mid, Time >= "1985-01-01 00:00:00" & Time <= "1
999-12-31 23:59:59")
ukcs.mid.0015 <- subset(ukcs.mid, Time >= "2000-01-01 00:00:00" & Time <= "2
015-12-31 23:59:59")
#
```

Plot to file

```
ppi=300
Figure.width = 16/2.54
Figure.height = 16/2.54
png("fig16.png", type = "cairo", width = Figure.width, height = Figure.heigh
t, units = "in", pointsize = 12, res = ppi)
#
p1 <- ggplot(data = ukcs.surface.7084, aes(x=Time, y=tC)) +
  geom_point(color=PointColour,size=0.1) +
  geom_point(data=ukcs.mid.7084, aes(x=Time, y=tC), colour = "blue",size=0.
5)+
  labs(x="Year", y="Temperature °C") +
  ggtitle("(a)") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(-2, 32),breaks = seq(0,25,5)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
#
p2 <- ggplot(data = ukcs.surface.8599, aes(x=Time, y=tC)) +
  geom_point(color=PointColour,size=0.1) +
  geom_point(data=ukcs.mid.8599, aes(x=Time, y=tC), colour = "blue",size=0.
5)+
  labs(x="Year", y="Temperature °C") +
  ggtitle("(b)") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(-2, 32),breaks = seq(0,25,5)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
#
p3 <- ggplot(data = ukcs.surface.0015, aes(x=Time, y=tC)) +
  geom_point(color=PointColour,size=0.1) +
  geom_point(data=ukcs.mid.0015, aes(x=Time, y=tC), colour = "blue",size=0.
5)+
  labs(x="Year", y="Temperature °C") +
  ggtitle("(c)") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(-2, 32),breaks = seq(0,25,5)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
#
multiplot(p1,p2,p3, cols=1)
dev.off()
```

```
## png
##   2
```

Figure 17 UKCS Monthly Average Temperature .v. Year - SURFACE

Calculate Monthly averages

```
#
#http://stackoverflow.com/questions/6052631/aggregate-daily-data-to-month-year-in-r
#
# SURFACE
#
Mon.avg <- setDT(ukcs.surface)[, .(MonthlyMeans = mean(tC)), by = .(year(Time), month(Time))]
#
# to see counts for means
# Mon.count <- setDT(ukcs.surface)[, .(COUNT = .N), by = .(year(Time), month(Time))]
#
#convert to dates
Mon.avg$year <- as.character(Mon.avg$year)
Mon.avg$month <- as.character(Mon.avg$month)
#combine chr
Mon.avg$YearMon <- paste(Mon.avg$year, Mon.avg$month, sep = "-0")
# replace 010 011 and 012 with 10 11 12
Mon.avg$YearMon <- gsub('-010', '-10',Mon.avg$YearMon)
Mon.avg$YearMon <- gsub('-011', '-11',Mon.avg$YearMon)
Mon.avg$YearMon <- gsub('-012', '-12',Mon.avg$YearMon)
#convert to date - add day 01
Mon.avg$YearMon <- as.Date(paste(Mon.avg$YearMon,"-01",sep=""))
#
Mon.avg.SURFACE <- Mon.avg
#
# MID WATER
#
Mon.avg <- setDT(ukcs.mid)[, .(MonthlyMeans = mean(tC)), by = .(year(Time), month(Time))]
#
#Mon.count <- setDT(ukcs.mid)[, .(COUNT = .N), by = .(year(Time), month(Time))]
#
#convert to dates
Mon.avg$year <- as.character(Mon.avg$year)
Mon.avg$month <- as.character(Mon.avg$month)
#combine chr
Mon.avg$YearMon <- paste(Mon.avg$year, Mon.avg$month, sep = "-0")
# replace 010 011 and 012 with 10 11 12
Mon.avg$YearMon <- gsub('-010', '-10',Mon.avg$YearMon)
Mon.avg$YearMon <- gsub('-011', '-11',Mon.avg$YearMon)
Mon.avg$YearMon <- gsub('-012', '-12',Mon.avg$YearMon)
#convert to date - add day 01
Mon.avg$YearMon <- as.Date(paste(Mon.avg$YearMon,"-01",sep=""))
#
Mon.avg.MID <- Mon.avg
```

Subset Data

```
JanS.avg <- subset(Mon.avg.SURFACE,month == "1")
JanM.avg <- subset(Mon.avg.MID,month == "1")
JanS.avg$year <- as.numeric(JanS.avg$year)
JanM.avg$year <- as.numeric(JanM.avg$year)
#
FebS.avg <- subset(Mon.avg.SURFACE,month == "2")
FebM.avg <- subset(Mon.avg.MID,month == "2")
FebS.avg$year <- as.numeric(FebS.avg$year)
FebM.avg$year <- as.numeric(FebM.avg$year)
#
MarS.avg <- subset(Mon.avg.SURFACE,month == "3")
MarM.avg <- subset(Mon.avg.MID,month == "3")
MarS.avg$year <- as.numeric(MarS.avg$year)
MarM.avg$year <- as.numeric(MarM.avg$year)
#
AprS.avg <- subset(Mon.avg.SURFACE,month == "4")
AprM.avg <- subset(Mon.avg.MID,month == "4")
AprS.avg$year <- as.numeric(AprS.avg$year)
AprM.avg$year <- as.numeric(AprM.avg$year)
#
MayS.avg <- subset(Mon.avg.SURFACE,month == "5")
MayM.avg <- subset(Mon.avg.MID,month == "5")
MayS.avg$year <- as.numeric(MayS.avg$year)
MayM.avg$year <- as.numeric(MayM.avg$year)
#
JunS.avg <- subset(Mon.avg.SURFACE,month == "6")
JunM.avg <- subset(Mon.avg.MID,month == "6")
JunS.avg$year <- as.numeric(JunS.avg$year)
JunM.avg$year <- as.numeric(JunM.avg$year)
#
JulS.avg <- subset(Mon.avg.SURFACE,month == "7")
JulM.avg <- subset(Mon.avg.MID,month == "7")
JulS.avg$year <- as.numeric(JulS.avg$year)
JulM.avg$year <- as.numeric(JulM.avg$year)
#
AugS.avg <- subset(Mon.avg.SURFACE,month == "8")
AugM.avg <- subset(Mon.avg.MID,month == "8")
AugS.avg$year <- as.numeric(AugS.avg$year)
AugM.avg$year <- as.numeric(AugM.avg$year)
#
SepS.avg <- subset(Mon.avg.SURFACE,month == "9")
SepM.avg <- subset(Mon.avg.MID,month == "9")
SepS.avg$year <- as.numeric(SepS.avg$year)
SepM.avg$year <- as.numeric(SepM.avg$year)
#
OctS.avg <- subset(Mon.avg.SURFACE,month == "10")
OctM.avg <- subset(Mon.avg.MID,month == "10")
OctS.avg$year <- as.numeric(OctS.avg$year)
OctM.avg$year <- as.numeric(OctM.avg$year)
#
NovS.avg <- subset(Mon.avg.SURFACE,month == "11")
NovM.avg <- subset(Mon.avg.MID,month == "11")
```

```
NovS.avg$year <- as.numeric(NovS.avg$year)
NovM.avg$year <- as.numeric(NovM.avg$year)
#
DecS.avg <- subset(Mon.avg.SURFACE,month == "12")
DecM.avg <- subset(Mon.avg.MID,month == "12")
DecS.avg$year <- as.numeric(DecS.avg$year)
DecM.avg$year <- as.numeric(DecM.avg$year)
```

Plot to file

```
# lowess
#https://ww2.coastal.edu/kingw/statistics/R-tutorials/simplelinear.html
#
PointSize = 0.5
ppi=300
Figure.width = 16/2.54
Figure.height = 24/2.54
# size increased to allow for margins - 16/10 gave plot error margins too sm
all
png("fig17.png", type = "cairo", width = Figure.width, height = Figure.heigh
t, units = "in", pointsize = 12, res = ppi)
#
p1 <- ggplot(data = JanS.avg, aes(x=year, y=MonthlyMeans)) +
  geom_point(color=PointColour, size = PointSize) +
  geom_point(data=JanM.avg, aes(x=year, y=MonthlyMeans), colour = "blue", si
ze = PointSize) +
    labs(x="Year", y="Temperature °C") +
  ggtitle("Jan") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(0, 20)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
p2 <- ggplot(data = FebS.avg, aes(x=year, y=MonthlyMeans)) +
  geom_point(color=PointColour, size = PointSize) +
  geom_point(data=FebM.avg, aes(x=year, y=MonthlyMeans), colour = "blue", si
ze = PointSize) +
    labs(x="Year", y="Temperature °C") +
  ggtitle("Feb") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(0, 20)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
p3 <- ggplot(data = MarS.avg, aes(x=year, y=MonthlyMeans)) +
  geom_point(color=PointColour, size = PointSize) +
  geom_point(data=MarM.avg, aes(x=year, y=MonthlyMeans), colour = "blue", si
ze = PointSize) +
    labs(x="Year", y="Temperature °C") +
  ggtitle("Mar") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(0, 20)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
p4 <- ggplot(data = AprS.avg, aes(x=year, y=MonthlyMeans)) +
  geom_point(color=PointColour, size = PointSize) +
  geom_point(data=AprM.avg, aes(x=year, y=MonthlyMeans), colour = "blue", si
ze = PointSize) +
    labs(x="Year", y="Temperature °C") +
  ggtitle("Apr") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(0, 20)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
```

```
p5 <- ggplot(data = MayS.avg, aes(x=year, y=MonthlyMeans)) +
  geom_point(color=PointColour, size = PointSize) +
  geom_point(data=MayM.avg, aes(x=year, y=MonthlyMeans), colour = "blue", si
ze = PointSize) +
    labs(x="Year", y="Temperature °C") +
  ggtitle("May") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(0, 20)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
p6 <- ggplot(data = JunS.avg, aes(x=year, y=MonthlyMeans)) +
  geom_point(color=PointColour, size = PointSize) +
  geom_point(data=JunM.avg, aes(x=year, y=MonthlyMeans), colour = "blue", si
ze = PointSize) +
    labs(x="Year", y="Temperature °C") +
  ggtitle("Jun") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(0, 20)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
p7 <- ggplot(data = JulS.avg, aes(x=year, y=MonthlyMeans)) +
  geom_point(color=PointColour, size = PointSize) +
  geom_point(data=JulM.avg, aes(x=year, y=MonthlyMeans), colour = "blue", si
ze = PointSize) +
    labs(x="Year", y="Temperature °C") +
  ggtitle("Jul") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(0, 20)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
p8 <- ggplot(data = AugS.avg, aes(x=year, y=MonthlyMeans)) +
  geom_point(color=PointColour, size = PointSize) +
  geom_point(data=AugM.avg, aes(x=year, y=MonthlyMeans), colour = "blue", si
ze = PointSize) +
    labs(x="Year", y="Temperature °C") +
  ggtitle("Aug") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(0, 20)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
p9 <- ggplot(data = SepS.avg, aes(x=year, y=MonthlyMeans)) +
  geom_point(color=PointColour, size = PointSize) +
  geom_point(data=SepM.avg, aes(x=year, y=MonthlyMeans), colour = "blue", si
ze = PointSize) +
    labs(x="Year", y="Temperature °C") +
  ggtitle("Sep") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(0, 20)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
p10 <- ggplot(data = OctS.avg, aes(x=year, y=MonthlyMeans)) +
  geom_point(color=PointColour, size = PointSize) +
```

```
  geom_point(data=OctM.avg, aes(x=year, y=MonthlyMeans), colour = "blue", si
ze = PointSize) +
    labs(x="Year", y="Temperature °C") +
  ggtitle("Oct") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(0, 20)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
p11 <- ggplot(data = NovS.avg, aes(x=year, y=MonthlyMeans)) +
  geom_point(color=PointColour, size = PointSize) +
  geom_point(data=NovM.avg, aes(x=year, y=MonthlyMeans), colour = "blue", si
ze = PointSize) +
    labs(x="Year", y="Temperature °C") +
  ggtitle("Nov") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(0, 20)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
p12 <- ggplot(data = DecS.avg, aes(x=year, y=MonthlyMeans)) +
  geom_point(color=PointColour, size = PointSize) +
  geom_point(data=DecM.avg, aes(x=year, y=MonthlyMeans), colour = "blue", si
ze = PointSize) +
    labs(x="Year", y="Temperature °C") +
  ggtitle("Dec") +
  theme(plot.title = element_text(size=10, face = "bold")) +
  scale_y_continuous(limits = c(0, 20)) +
  theme(axis.text.x=element_text(angle = 90, hjust = 0)) +
  theme_bw()
#
multiplot(p1,p3,p5,p7,p9,p11,p2,p4,p6,p8,p10,p12, cols=2)
dev.off()
```

```
## png
##   2
```

END