



## INTAROS – IMR Dataset

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## INTAROS – IMR Dataset

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INTAROS – IMR Dataset

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# Intaros - IMR Dataset

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*May 2nd 2018*

## Introduction

This paper is meant to demonstrate how to use a simple **Kriging interpolation** from the **RGeostats** package applied to the **Annual CTD datasets** from R/V Håkon Mosby (Norwegian research vessel).

## Download of NetCDF files

Use the following **bash** script for downloading the data files in the current directory:

```
lftp -c 'open -e "mget 58AA_CTD_2002.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2003.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2004.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2005.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2006.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2007.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2008.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2009.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2010.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2011.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2012.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2013.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2014.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2015.nc" ftp.nmdc.no/nmdc/IMR/CTD'
lftp -c 'open -e "mget 58AA_CTD_2016.nc" ftp.nmdc.no/nmdc/IMR/CTD'
```

## Definition of R functions

Definition of some functions:

- **load\_data**: Load the data set (all NetCDF files (\*.nc) from the given directory) into a *Db* RGeostats database. The data files must contain the following variables:
  - **LATITUDE**: Latitude (degrees) of the vessel position. 1D size = {Nb Positions}
  - **LONGITUDE**: Longitude (degrees) of the vessel position. 1D size = {Nb Positions}
  - **TIME**: Time of the position (number of days since January 1st, 1950). 1D size = {Nb Positions}
  - **DEPH**: Depth of each measure (m). 2D size = {Nb Positions, Nb Measures}
  - **TEMP**: Temperature (°C). 2D size = {Nb Positions, Nb Measures}
  - **CNDC**: Electrical conductivity (S m-1). 2D size = {Nb Positions, Nb Measures}
  - **PSAL**: Sea water practical salinity (0.001). 2D size = {Nb Positions, Nb Measures}
- **time2date**: Convert a time value from the dataset into a readable date (YYYY-MM-DD).
- **date2time**: Convert a readable date (YYYY-MM-DD) into a time value used by the dataset.
- **som**: Return the first day of the month from a given date

- **eom**: Return the last day of the month from a given date
- **apply\_sel**: Apply a selection on the *Db* by masking samples falling outside from a given interval (Depth, Longitude, Latitude, Dates, Variable values). Accepted variable names are: *Temperature*, *Conductivity* and *Salinity*.
- **remove\_sel**: Remove all selection variables from the *Db*.
- **get\_xlim**: Get integer Longitude limits of the given [filtered] *Db*
- **get\_ylim**: Get integer Latitude limits of the given [filtered] *Db*
- **get\_tlim**: Get time limits of the given [filtered] *Db*
- **get\_zlim**: Get range values for a given variable of the [filtered] *Db*
- **get\_title**: Return a suffix for plot titles which indicates the period covered by a [filtered] *Db*
- **create\_grid**: Create a grid centered on the data from the given [filtered] *Db* with a given square mesh
- **display\_grunit**: Display a grid centered on the data from the [filtered] *Db* with a given square mesh into the current plot
- **display\_var**: Display the variable of interest from the given [filtered] *Db*
- **display\_stat**: Display the statistics map coming from the function **stats\_grid**
- **display\_result**: Display the estimated results coming from the function **interpol\_var** and overlay data in the same plot
- **interpol\_var**: Interpolate a variable on a 2D grid at a given depth from a [filtered] *Db*
- **stats\_grid**: Generate a statistics map for a given variable from a [filtered] *Db*

## Quick example

- Here is a quick R script using these functions which performs:
  - Some simple display of available data
  - Some data selection and dates manipulation
  - An analysis of the correlation between Temperature and Conductivity for a given year
  - The display of data points density in each grid cell for a given month
  - Trimester interpolations of the Temperature data at the surface for a given year

Note that subsequent interpolation is performed in 2D (considering the 3D information would require a different script).

## Loading Data

First of all, we load the data from the current directory into a new RGeostats database *Db*. We check its contents and the number of active samples.

```
db = load_data(dir = ".")
```

```
## Reading 58AA_CTD_2002.nc : Number of positions = 54 , Maximum depth = 3433 m)
## Reading 58AA_CTD_2003.nc : Number of positions = 693 , Maximum depth = 2810 m)
## Reading 58AA_CTD_2004.nc : Number of positions = 1213 , Maximum depth = 2182 m)
## Reading 58AA_CTD_2005.nc : Number of positions = 1191 , Maximum depth = 2703 m)
## Reading 58AA_CTD_2006.nc : Number of positions = 1164 , Maximum depth = 3298 m)
## Reading 58AA_CTD_2007.nc : Number of positions = 1410 , Maximum depth = 3211 m)
## Reading 58AA_CTD_2008.nc : Number of positions = 1205 , Maximum depth = 2935 m)
```

```
## Reading 58AA_CTD_2009.nc : Number of positions = 960 , Maximum depth = 3011 m)
## Reading 58AA_CTD_2010.nc : Number of positions = 1413 , Maximum depth = 3390 m)
## Reading 58AA_CTD_2011.nc : Number of positions = 985 , Maximum depth = 3233 m)
## Reading 58AA_CTD_2012.nc : Number of positions = 1114 , Maximum depth = 3058 m)
## Reading 58AA_CTD_2013.nc : Number of positions = 1102 , Maximum depth = 2990 m)
## Reading 58AA_CTD_2014.nc : Number of positions = 966 , Maximum depth = 1714 m)
## Reading 58AA_CTD_2015.nc : Number of positions = 764 , Maximum depth = 3055 m)
## Reading 58AA_CTD_2016.nc : Number of positions = 559 , Maximum depth = 3654 m)
```

The following paragraph shows the contents of the newly created Db

```
db
```

```
##
## Data Base Characteristics
## =====
##
## Data Base Summary
## -----
## File is organized as a set of isolated points
## Space dimension          = 3
## Number of fields         = 8
## Maximum Number of attributes = 8
## Total number of samples   = 5080116
##
## Variables
## -----
## Field = 1 - Name      = rank - Locator = rank
## Field = 2 - Name      = Longitude - Locator = x1
## Field = 3 - Name      = Latitude - Locator = x2
## Field = 4 - Name      = Depth - Locator = x3
## Field = 5 - Name      = Temperature - Locator = NA
## Field = 6 - Name      = Conductivity - Locator = NA
## Field = 7 - Name      = Salinity - Locator = NA
## Field = 8 - Name      = Time - Locator = NA
```

Manipulate the dates:

```
dlim = time2date(get_tlim(db))
# Calculate first day of each month of the dataset
smon = seq(from = som(dlim[1]), to = eom(dlim[2]), by="1 month")
# Calculate last day of each month of the dataset
emon = do.call("c", lapply(smon,eom))
cat(get_title("The dataset period is:",dlim))
```

```
## The dataset period is: (2002-03-07 => 2016-10-16)
```

## Exploratory data Analysis

We apply a selection to mask all samples deeper than 10m depth:

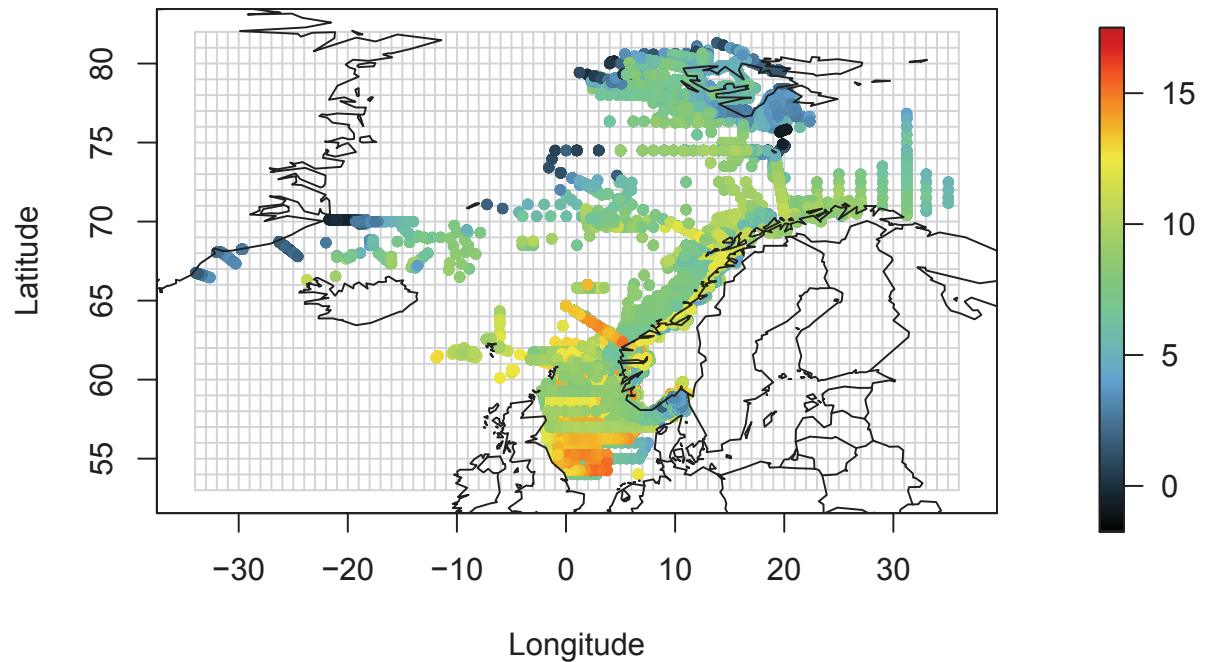
```
db = remove_sel(db)
db = apply_sel(db, depth_lim = c(0., 10))
```

```
## New number of active samples = 117756 ( out of 5080116 )
```

In a 2D aerial view, we display the previously selected *Temperature* values and the countries borders:

```
display_var(db, "Temperature")
```

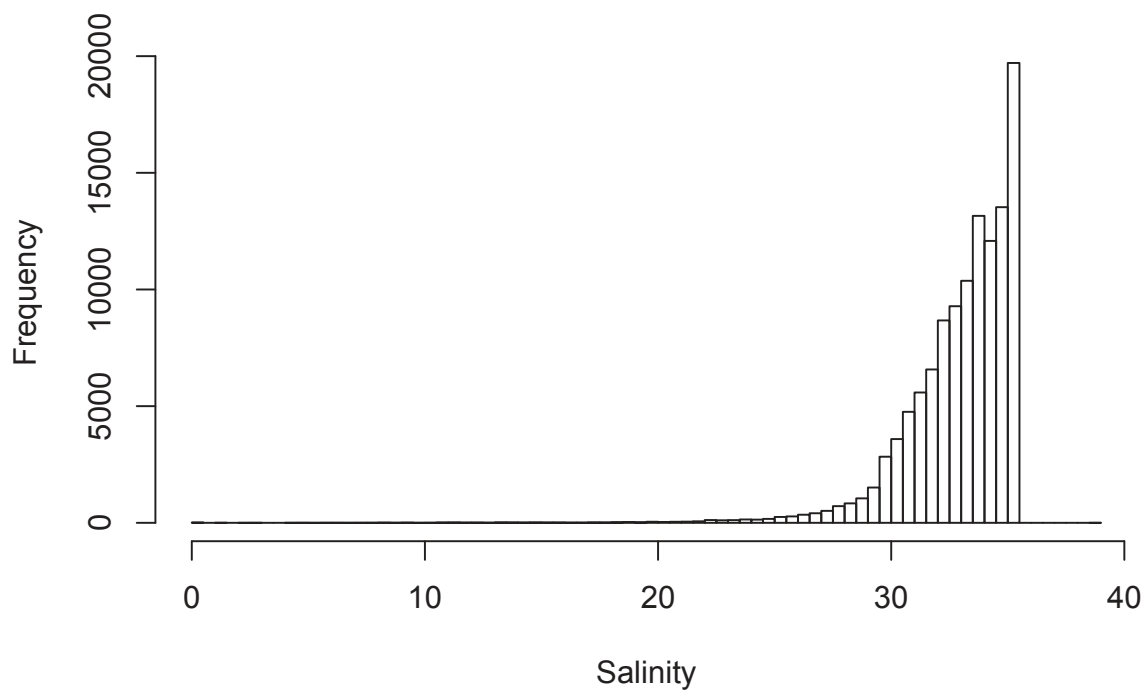
### Temperature (2002-03-07 => 2016-10-16)



Then, we inquire the database for the range of *Salinity* values:

```
Salinity = db.extract(db, "Salinity", flag.compress = TRUE)  
hist(Salinity, breaks = 100, main = "Histogram of Salinity")
```

## Histogram of Salinity



```
cat("Range of values = ", range(Salinity, na.rm = TRUE), "\n")
```

```
## Range of values = 0.1694 38.7109
```

We combine the previous selection with a new selection for removing *Salinity* outliers:

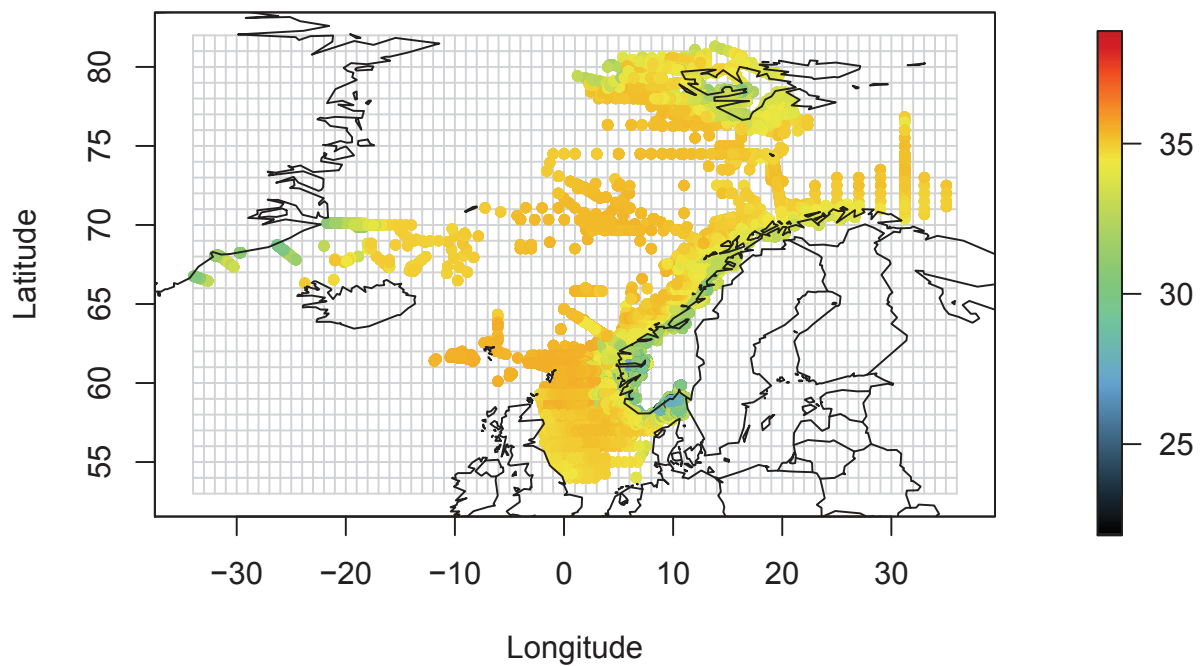
```
db = apply_sel(db, z_lim = c(22, 39), z_var = "Salinity")
```

```
## New number of active samples = 116836 ( out of 5080116 )
```

```
display_var(db, "Salinity")
```



### Salinity (2002-03-07 => 2016-10-16)



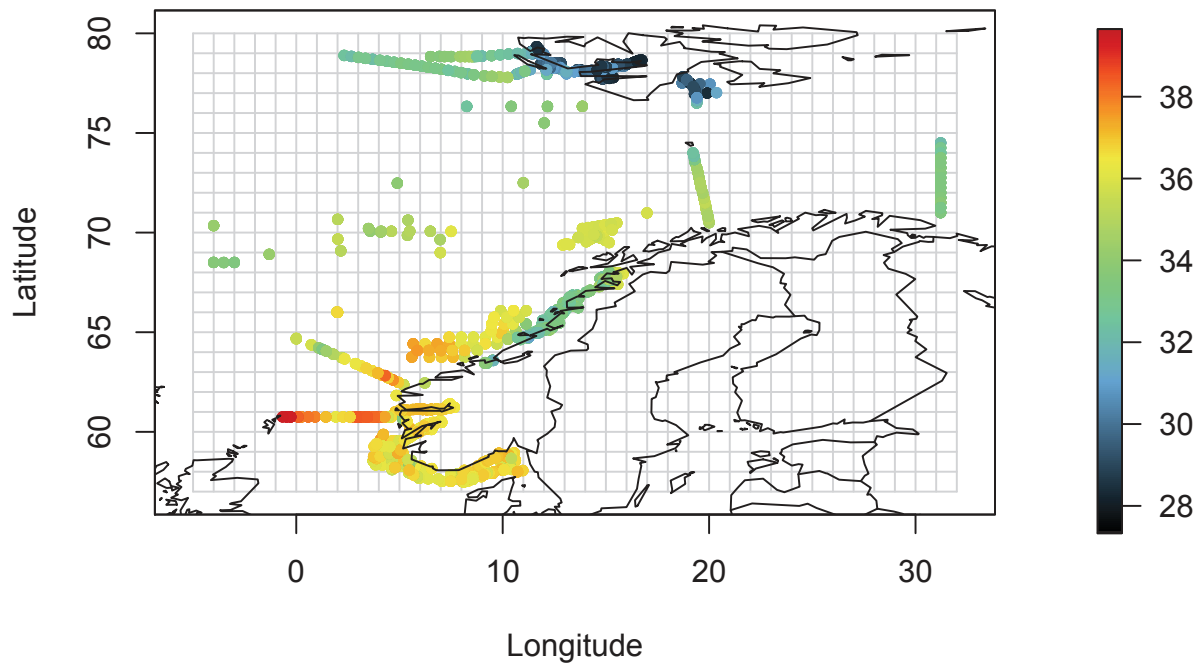
We display *Conductivity* for 2010's measures at a depth around 100m (previous selection is cancelled first):

```
datelim = c("2010-01-01", "2010-12-31")
db       = remove_sel(db)
db       = apply_sel(db, depth_lim = c(95., 105),
                     dates_lim = datelim)
```

```
## New number of active samples = 9454 ( out of 5080116 )
```

```
display_var(db, "Conductivity")
```

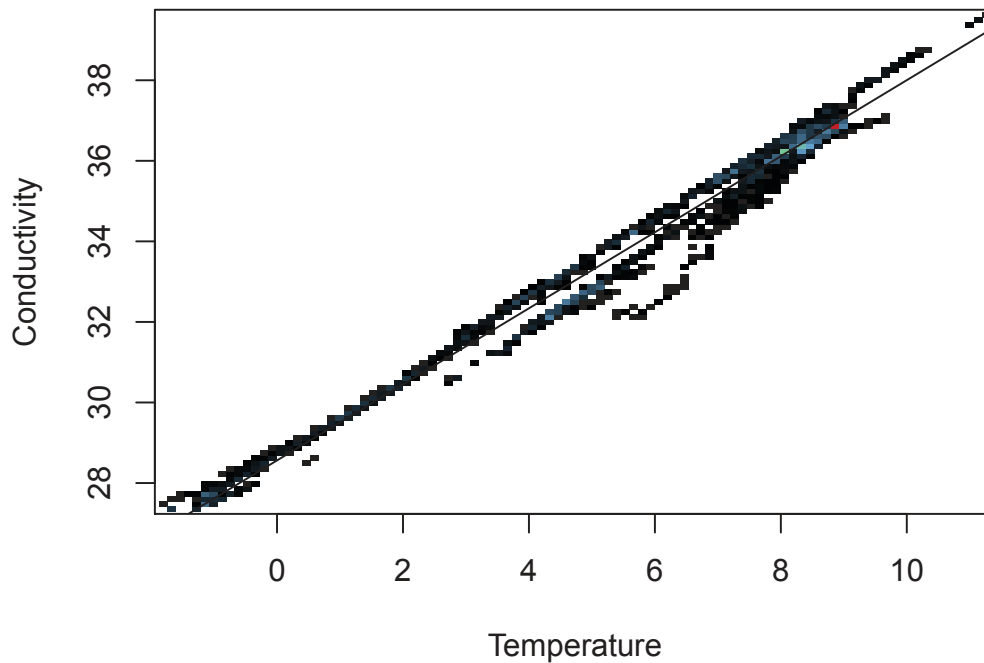
### Conductivity (2010-01-15 => 2010-10-29)



We show the correlation between *Conductivity* and *Temperature*. As a result, we also obtain the correlation coefficient.

```
title = "Correlation between Temperature and Conductivity\n(Year 2010 at 100m depth)"  
corval = correlation(db, "Temperature", "Conductivity", flag.regr = TRUE, title = title)
```

## Correlation between Temperature and Conductivity (Year 2010 at 100m depth)



```
cat("Correlation Coefficient = ", corval, "\n")
```

```
## Correlation Coefficient = 0.9936022
```

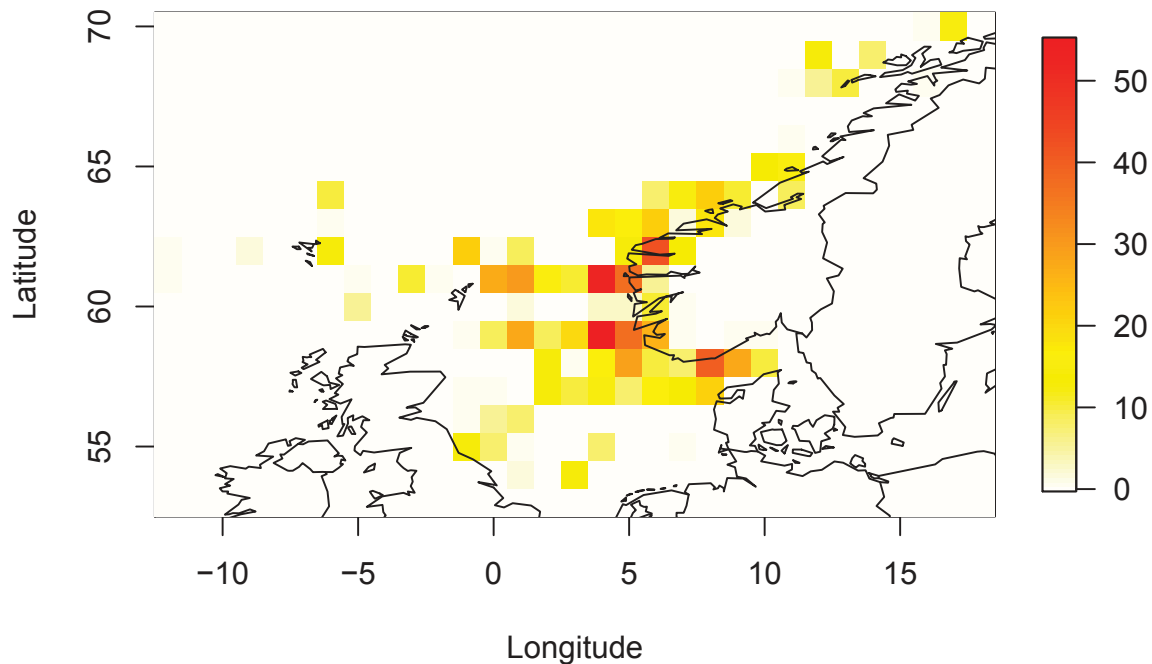
We display the number of data points (<50m depth) that fall in each grid cell (with a mesh equal to 1 degree) for a given month:

```
datelim = c(smon[20], emon[20])
db       = remove_sel(db)
db       = apply_sel(db, depth_lim = c(0., 50), dates_lim = datelim)
```

```
## New number of active samples = 1082 ( out of 5080116 )
```

```
dbstat = stats_grid(db, "Temperature", fun = "count")
title  = get_title("# data points by cell (<50m)", datelim)
display_stat(dbstat, title = title)
```

## # data points by cell (<50m) (2003-10-01 => 2003-10-31)



## Estimation

We estimate the 2007 *Temperature* season maps at sea surface (1m depth  $\pm$  1m) on a refined grid (mesh = 0.5°) which covers all data available. The geostatistical model is automatically fitted using default parameters. It could be improved using more expertise and providing additional parameters to function **interpol\_var**. For comparison purpose, the maps are displayed using the same colorscale, latitude and longitude limits.

```
year      = 2007
var       = "Temperature"
mesh      = 0.5
depth     = 1
depthtol  = 1
datelim   = c(paste(year, "-01-01", sep = ""), paste(year, "-12-31", sep = ""))
db        = remove_sel(db)
db        = apply_sel(db, dates_lim = datelim)
```

```
## New number of active samples = 546718 ( out of 5080116 )
```

```
xlim      = get_xlim(db)
ylim      = get_ylim(db)
zlim      = get_zlim(db, var = var)
cat("Range of Temperatures for", year, "=", zlim, "\n")
```

```
## Range of Temperatures for 2007 = -1.8927 13.7984
```

First three months of the year

```

datelim = c(paste(year, "-01-01", sep = ""), paste(year, "-03-31", sep = ""))
db      = remove_sel(db)
db      = apply_sel(db, dates_lim = datelim, verbose=FALSE)
cat("Temperature in First trimester of", year, "\n")

```

```

## Temperature in First trimester of 2007

```

```

res      = interpol_var(db, depth = depth, depth_tol = depthtol,
                        var = var, mesh = mesh)

```

```

## New number of active samples = 142 ( out of 5080116 )

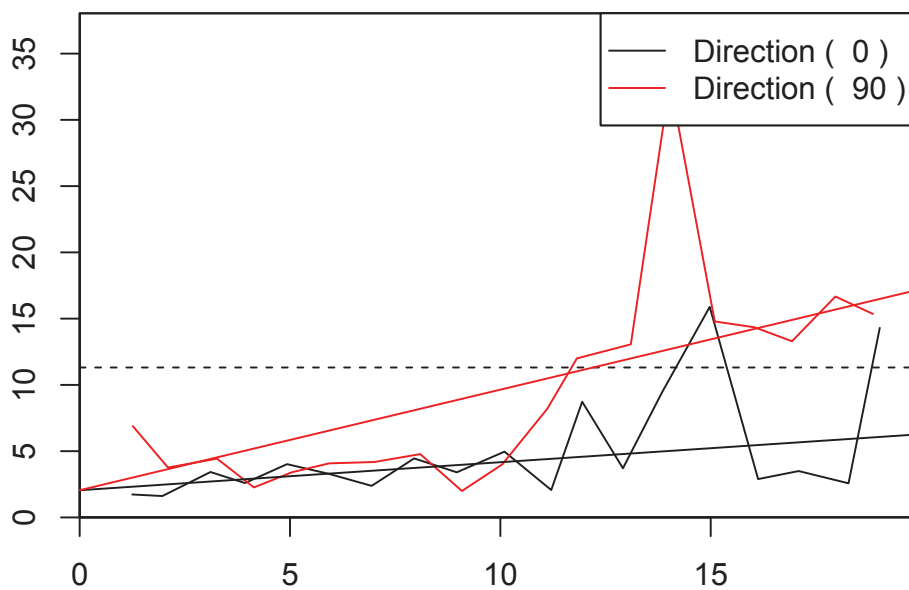
```

```

## Range of Information = -1.8725 13.7984

```

## Horizontal Variogram and Model for Temperature

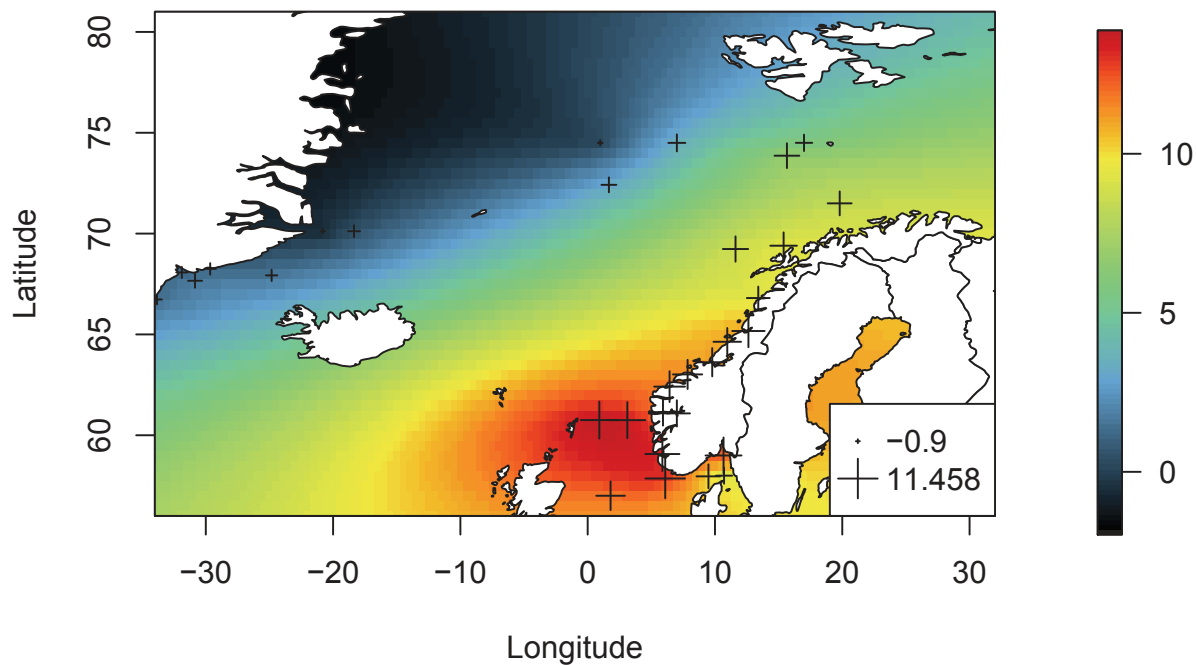


```

display_result(res = res, flag.estim = TRUE,
               xlim = xlim, ylim = ylim, zlim = zlim)

```

### Estimated Temperature at 1m depth (2007-01-06 => 2007-03-30)



Second trimester of the year

```
datelim = c(paste(year, "-04-01", sep = ""), paste(year, "-06-30", sep = ""))
db       = remove_sel(db)
db       = apply_sel(db, dates_lim = datelim, verbose=FALSE)
```

```
cat("Temperature in Second trimester of", year, "\n")
```

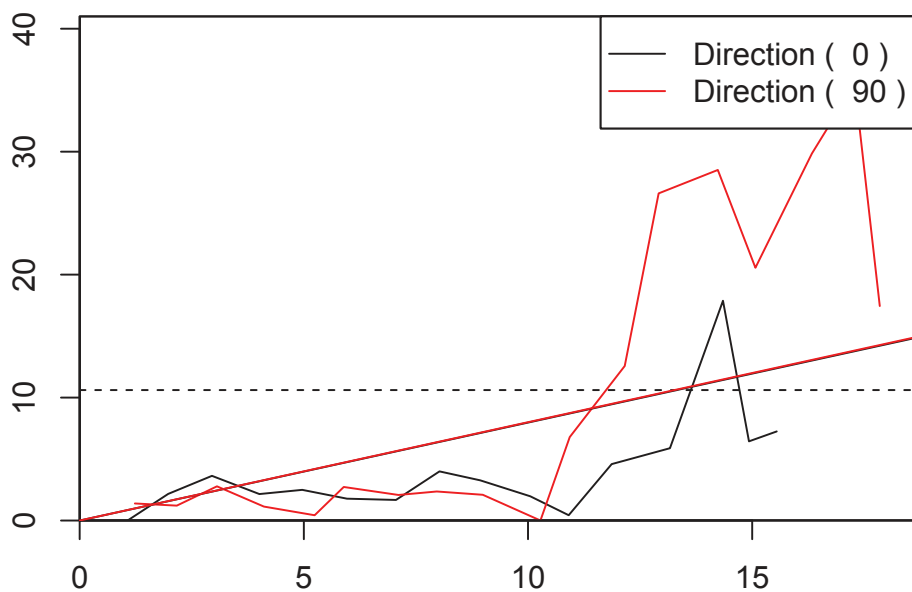
```
## Temperature in Second trimester of 2007
```

```
res      = interpol_var(db, depth = depth, depth_tol = depthtol,
                        var = var, mesh = mesh)
```

```
## New number of active samples = 53 ( out of 5080116 )
```

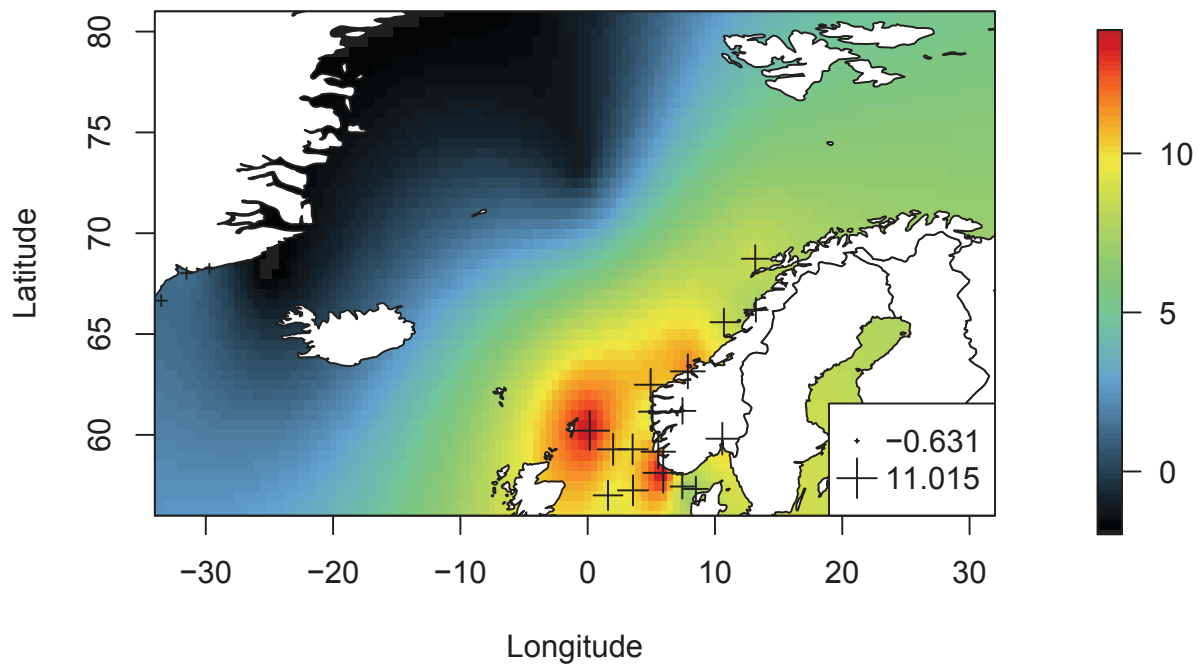
```
## Range of Information = -1.8927 13.4265
```

## Horizontal Variogram and Model for Temperature



```
display_result(res = res, flag.estim = TRUE,
               xlim = xlim, ylim = ylim, zlim = zlim)
```

## Estimated Temperature at 1m depth (2007-04-01 => 2007-06-29)



Third trimester of the year

```
datelim = c(paste(year, "-07-01", sep = ""), paste(year, "-09-30", sep = ""))
db      = remove_sel(db)
db      = apply_sel(db, dates_lim = datelim, verbose=FALSE)
cat("Temperature in Third trimester of", year, "\n")
```

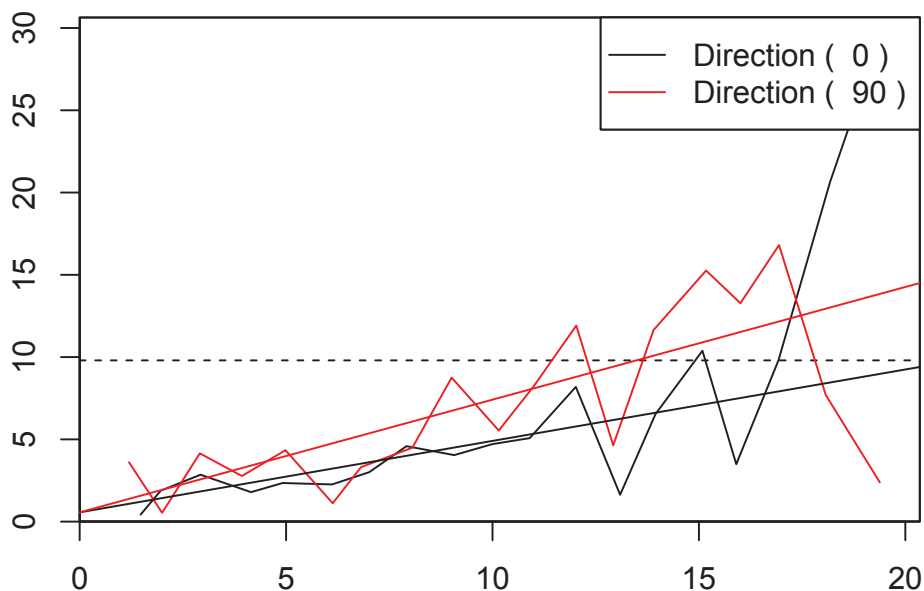
```
## Temperature in Third trimester of 2007
```

```
res      = interpol_var(db, depth = depth, depth_tol = depthtol,
                        var = var, mesh = mesh)
```

```
## New number of active samples = 186 ( out of 5080116 )
```

```
## Range of Information = -1.8803 12.8682
```

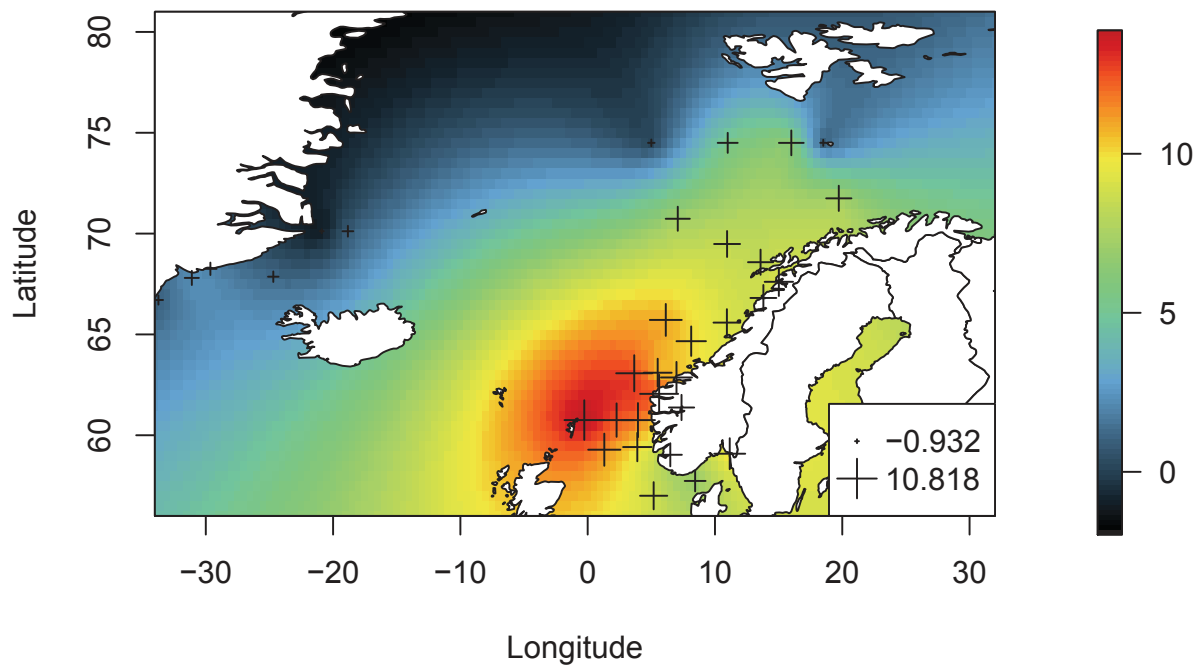
## Horizontal Variogram and Model for Temperature



```
display_result(res = res, flag.estim = TRUE,
               xlim = xlim, ylim = ylim, zlim = zlim)
```



### Estimated Temperature at 1m depth (2007-07-01 => 2007-09-29)



Fourth trimester of the year

```
datelim = c(paste(year, "-10-01", sep = ""), paste(year, "-12-31", sep = ""))
db      = remove_sel(db)
db      = apply_sel(db, dates_lim = datelim, verbose=FALSE)
cat("Temperature in Fourth trimester of", year, "\n")
```

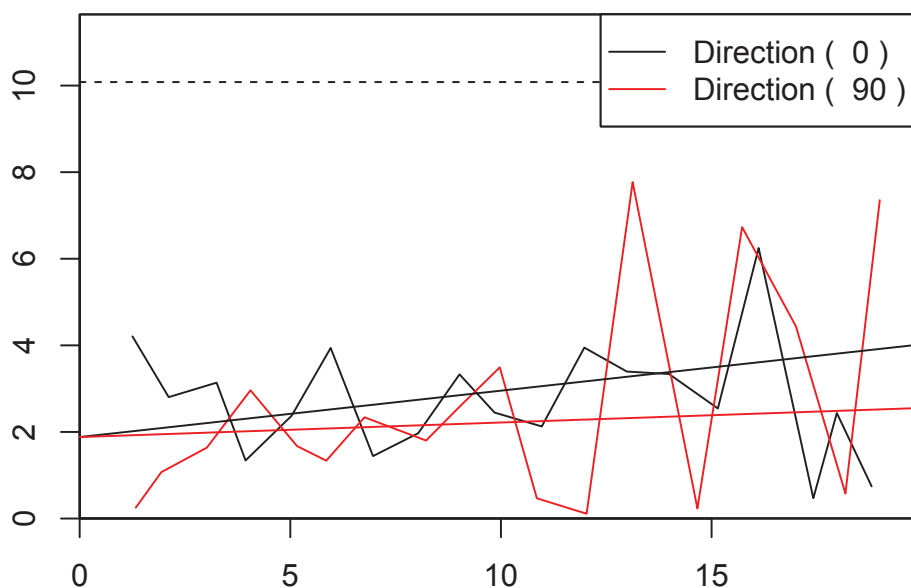
## Temperature in Fourth trimester of 2007

```
res      = interpol_var(db, depth = depth, depth_tol = depthtol,
                        var = var, mesh = mesh)
```

## New number of active samples = 69 ( out of 5080116 )

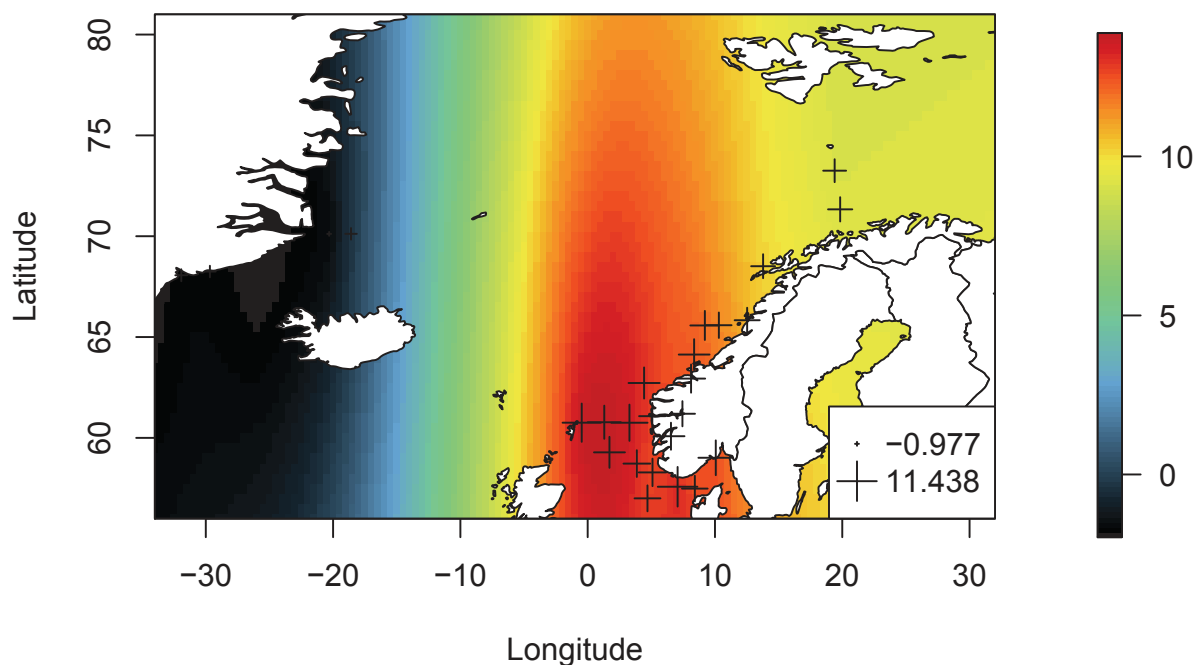
## Range of Information = -1.8804 12.7919

## Horizontal Variogram and Model for Temperature



```
display_result(res = res, flag.estim = TRUE,
               xlim = xlim, ylim = ylim, zlim = zlim)
```

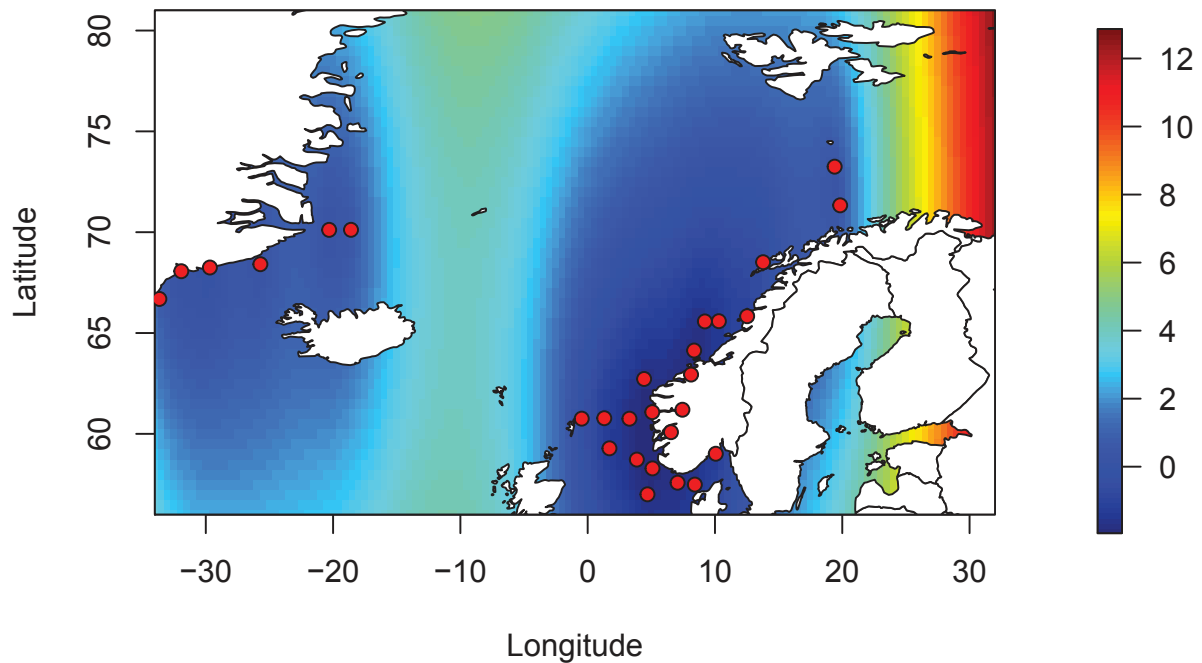
## Estimated Temperature at 1m depth (2007-10-09 => 2007-12-15)



Finally, we display the *Standard Deviation of the Estimation Error* for the previous last trimester interpolation (could be done after each interpolation and would give different results).

```
display_result(res = res, flag.estim = FALSE)
```

### St. Dev. Temperature at 1m depth (2007-10-09 => 2007-12-15)



### Perspectives

- Several perspectives can be imagined for this showcase script:
  - Tackling the data in a 3D approach in order to account for any possible vertical trend. Specific display would be welcomed.
  - Using a secondary exhaustive information (i.e. satellite image) in order to improve the knowledge provided by the measures: external drift concept.
  - Using simulations (instead of kriging) in order to derive maps of quantities which are not linearly related to the data: Probability that the temperature passes a given limit