INTAROS – IMR Dataset

Didier Renard, Fabien Ors

▶ **To cite this version:**

Didier Renard, Fabien Ors. INTAROS – IMR Dataset. [Research Report] MINES ParisTech - PSL Research University. 2018. hal-01820877

HAL Id: hal-01820877

https://minesparis-psl.hal.science/hal-01820877

Submitted on 22 Jun 2018

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Didier Renard, Fabien Ors

Mai 2018

N° R180502FORS

MINES ParisTech - CENTRE DE GÉOSCIENCES
35, Rue Saint Honoré – 77305 Fontainebleau - France
Secrétariat : +33 (0)1 64 69 47 78, Fax : +33 (0)1 64 69 47 05 - http://www.geosciences.mines-paristech.fr

MINES ParisTech - Centre de Géosciences

Equipe Géostatistique

35, rue Saint Honoré

77300 Fontainebleau, France

Tél. 01 64 69 47 81

Fax 01 64 69 47 05

Didier Renard, Fabien Ors

INTAROS – IMR Dataset

Equipe	Géostatistique
Visa	J. Rivoirard

Intaros - IMR Dataset

D. Renard, F. Ors

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

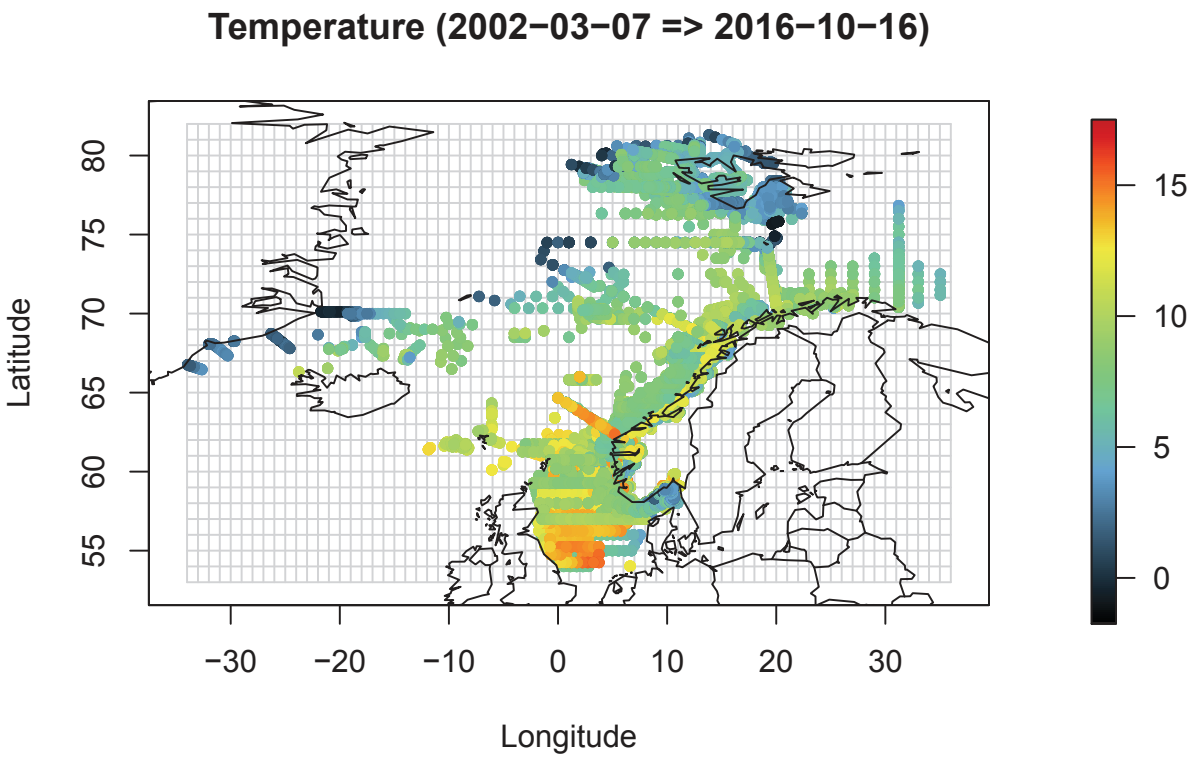
We apply a selection to mask all samples deeper than 10m depth:

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

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

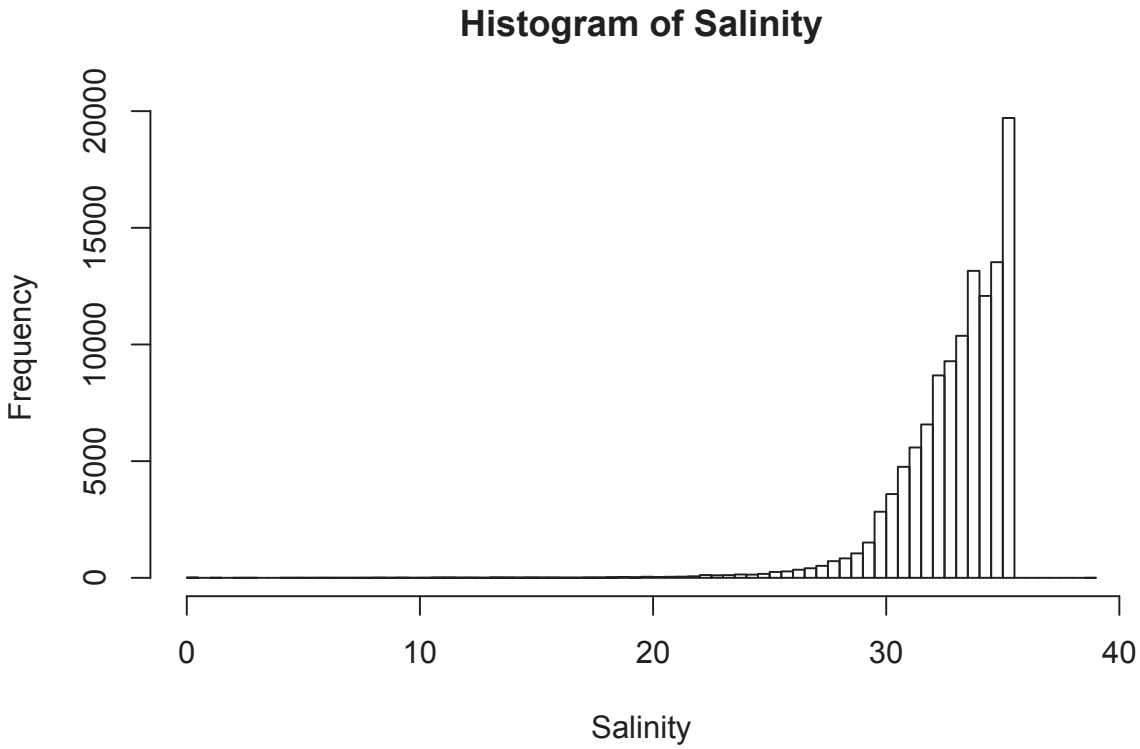
In a 2D aerial view, we display the previously selected *Temperature* values and the countries borders:

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



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

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




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

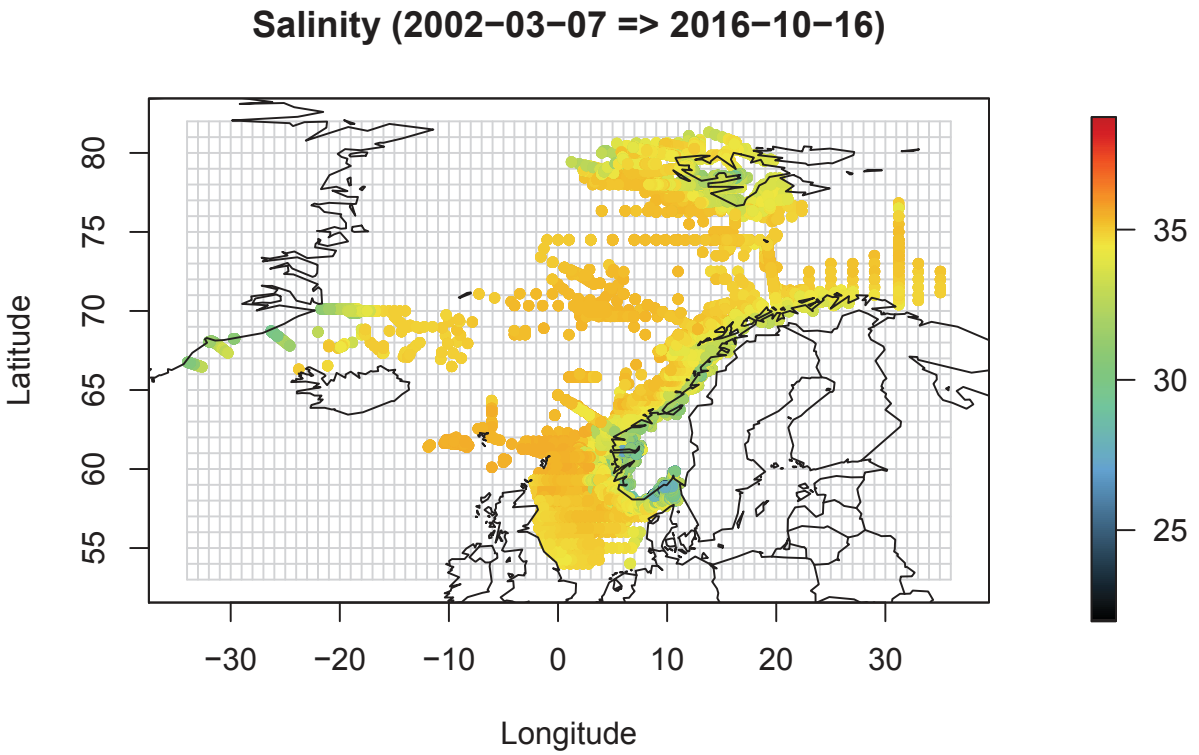
```
## Range of values =  0.1694 38.7109
```

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")
```

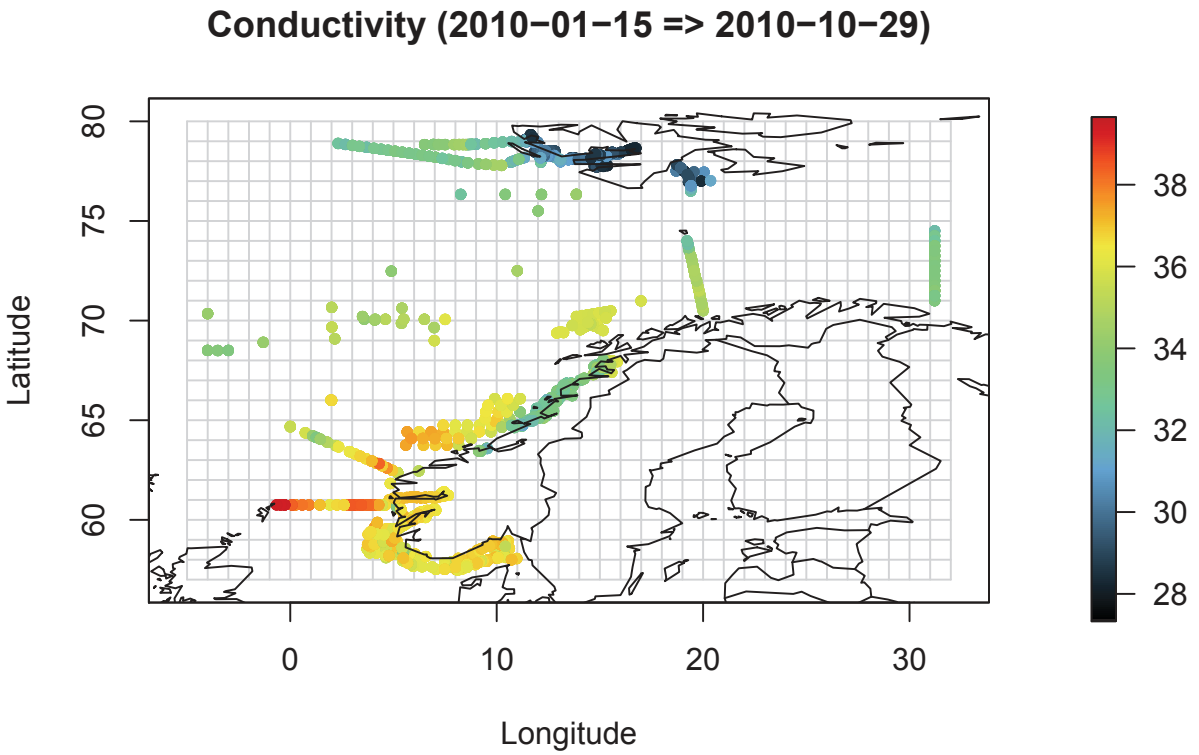


We display *Conductivity* for 2010's measures at a depth around 100m (previous selection is cancelled first):

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

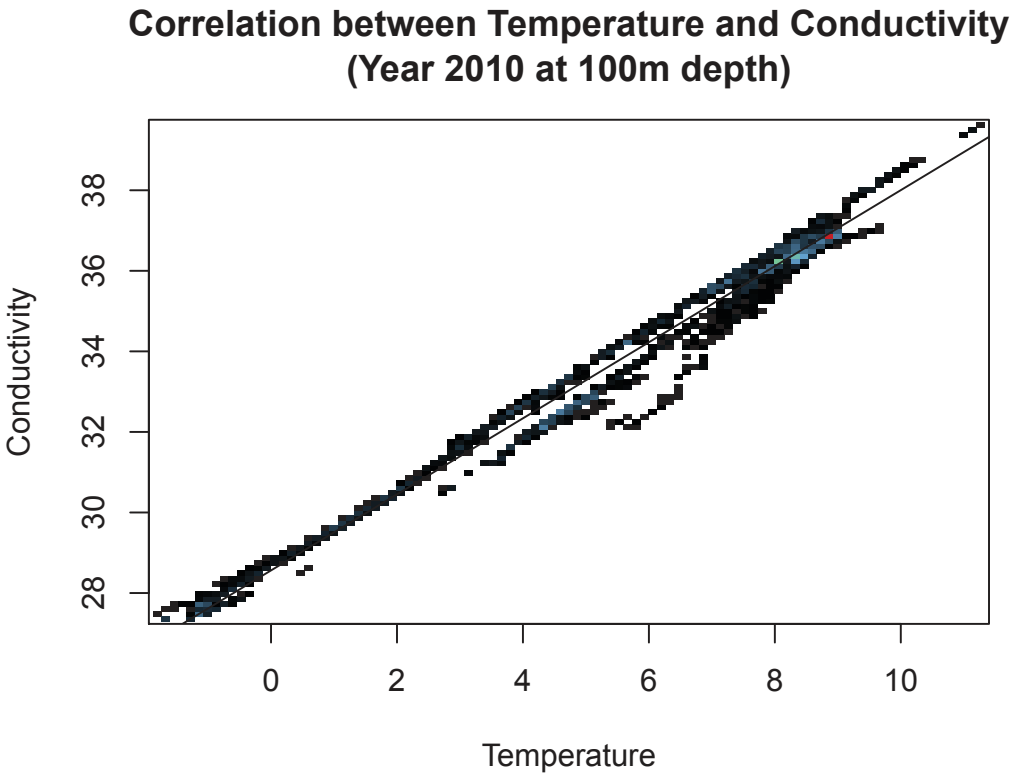
```
## New number of active samples =  9454 ( out of 5080116 )
```

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



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)
```




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

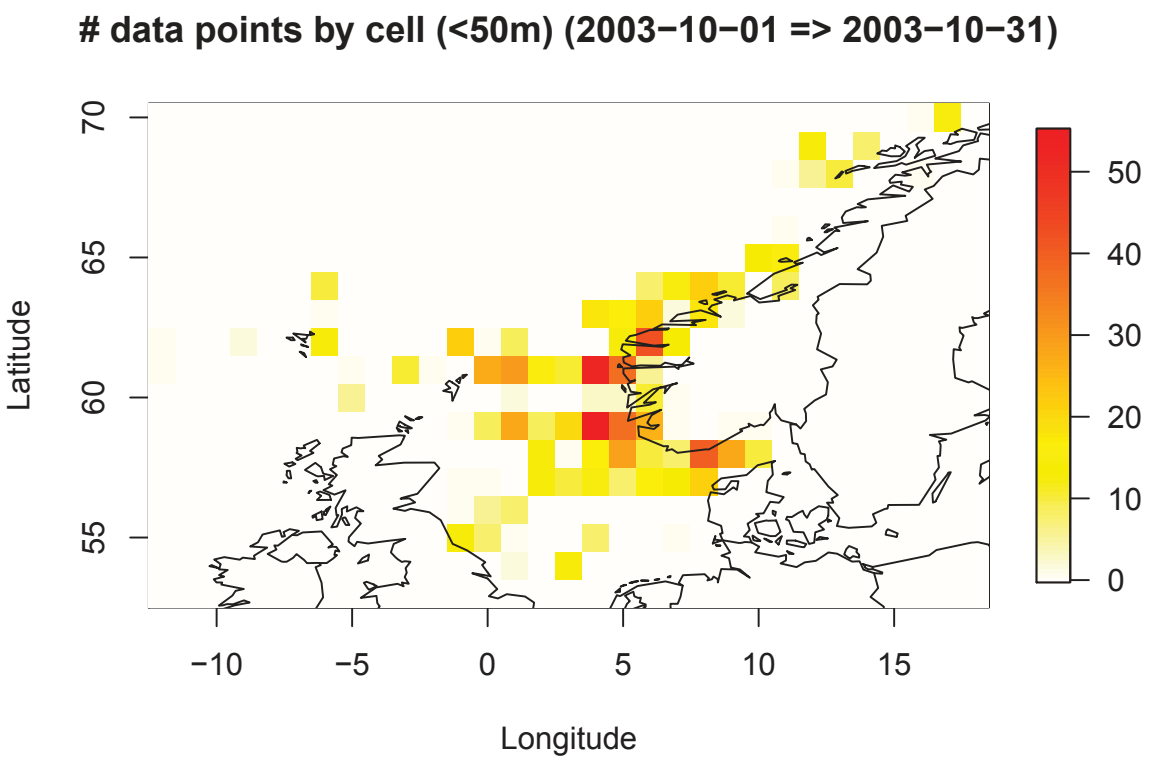
```
## Correlation Coefficient =  0.9936022
```

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)
```



Estimation

We estimate the 2007 *Temperature* season maps at sea surface (1m depth +-1m) on a refined grid (mesh = 0.5°) which covers all data available. The geostatistical model is automatically fitted using default parmaters: 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
```

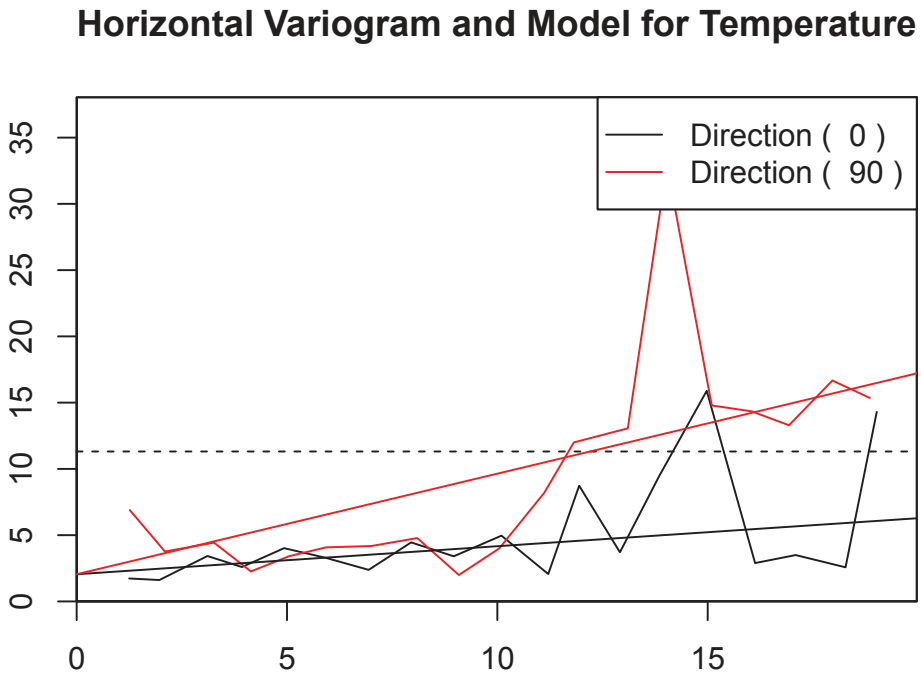
First three months of the year

```
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")
```

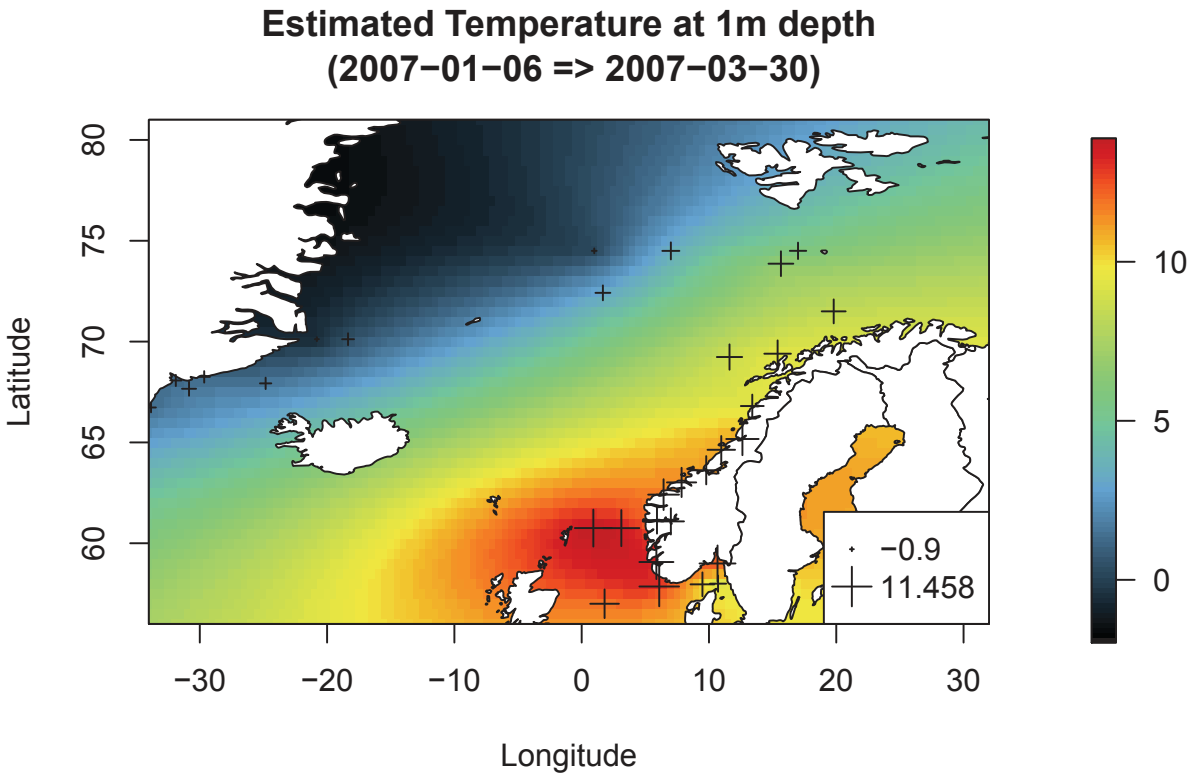
```
## Temperature in First trimester of 2007
```

```
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
```




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



Second trimester of the year

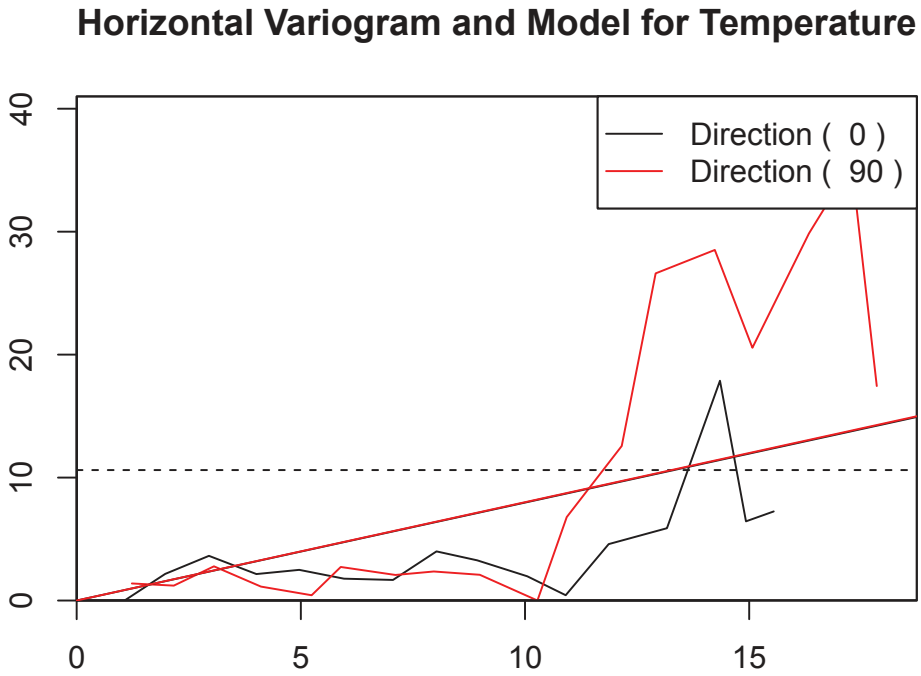
```
datelim  = c(paste(year, "-04-01", sep = ""), paste(year, "-06-30", sep = ""))
db       = remove_sel(db)
db       = apply_sel(db, dates_lim = datelim, verbose=FALSE)

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

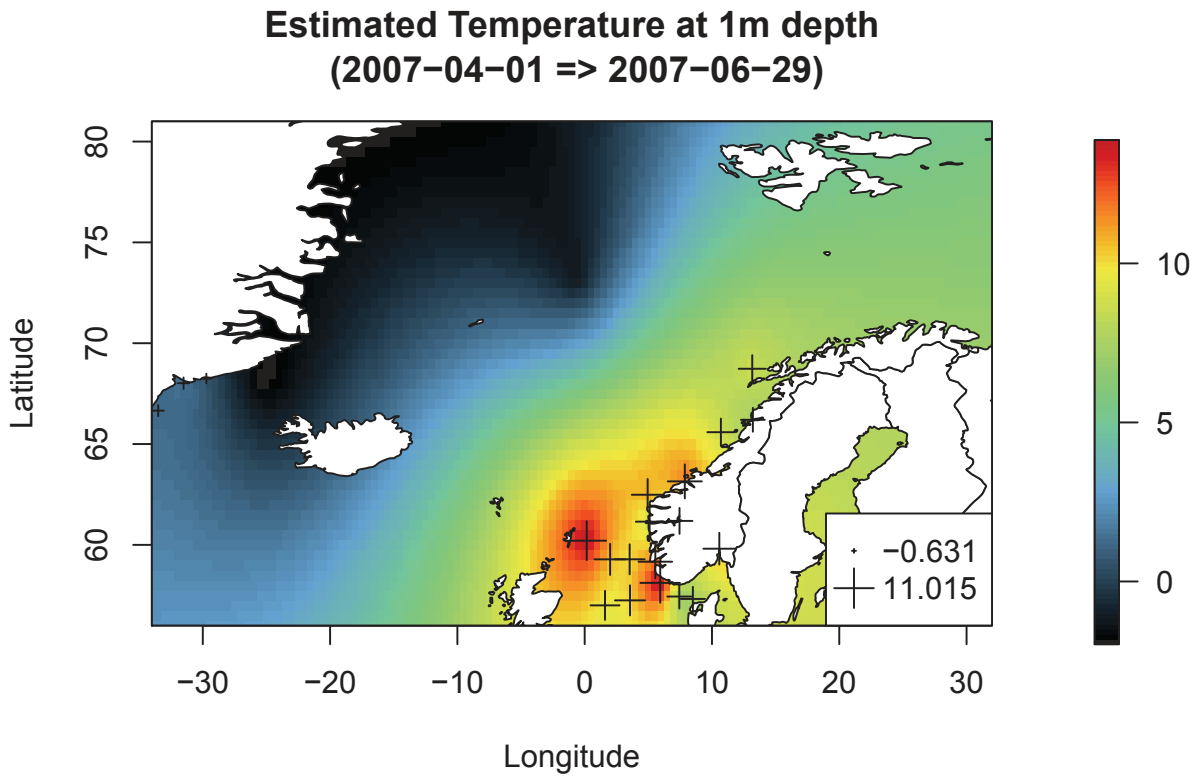
```
## Temperature in Second trimester of 2007
```

```
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
```




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



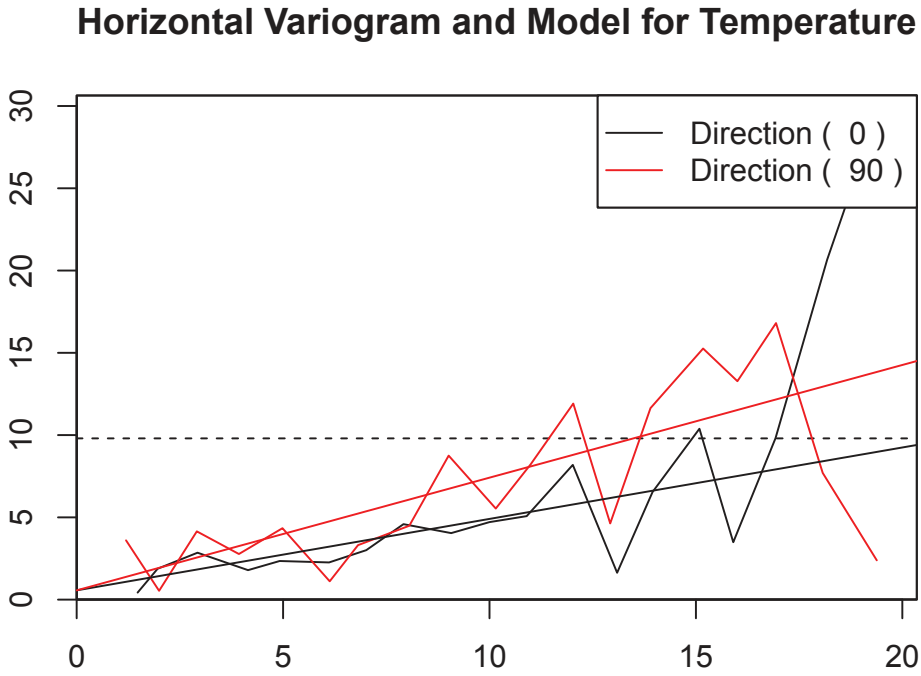
Third trimester of the year

```
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")
```

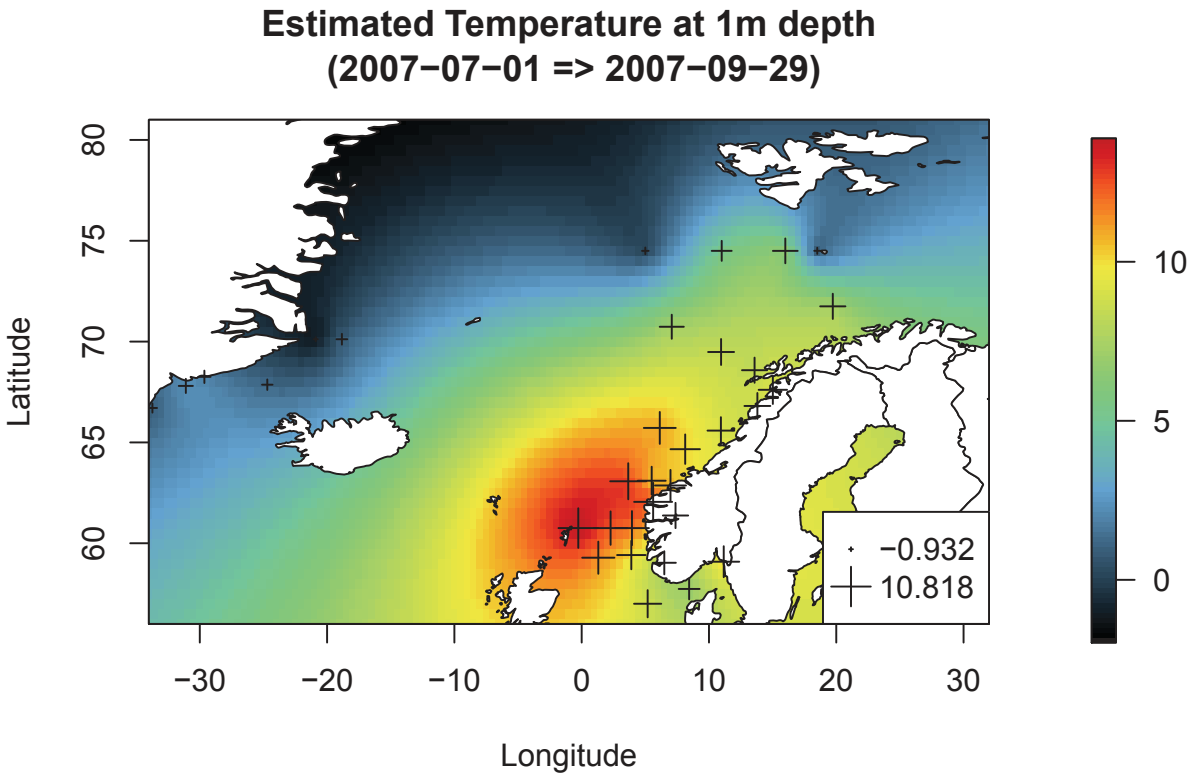
```
## Temperature in Third trimester of 2007
```

```
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
```




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



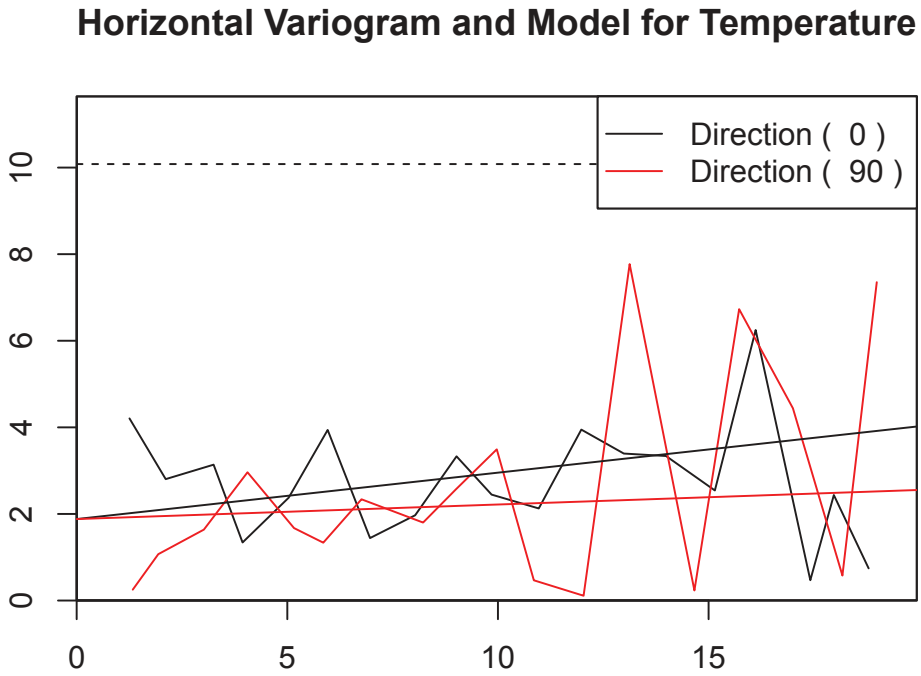
Fourth trimester of the year

```
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")
```

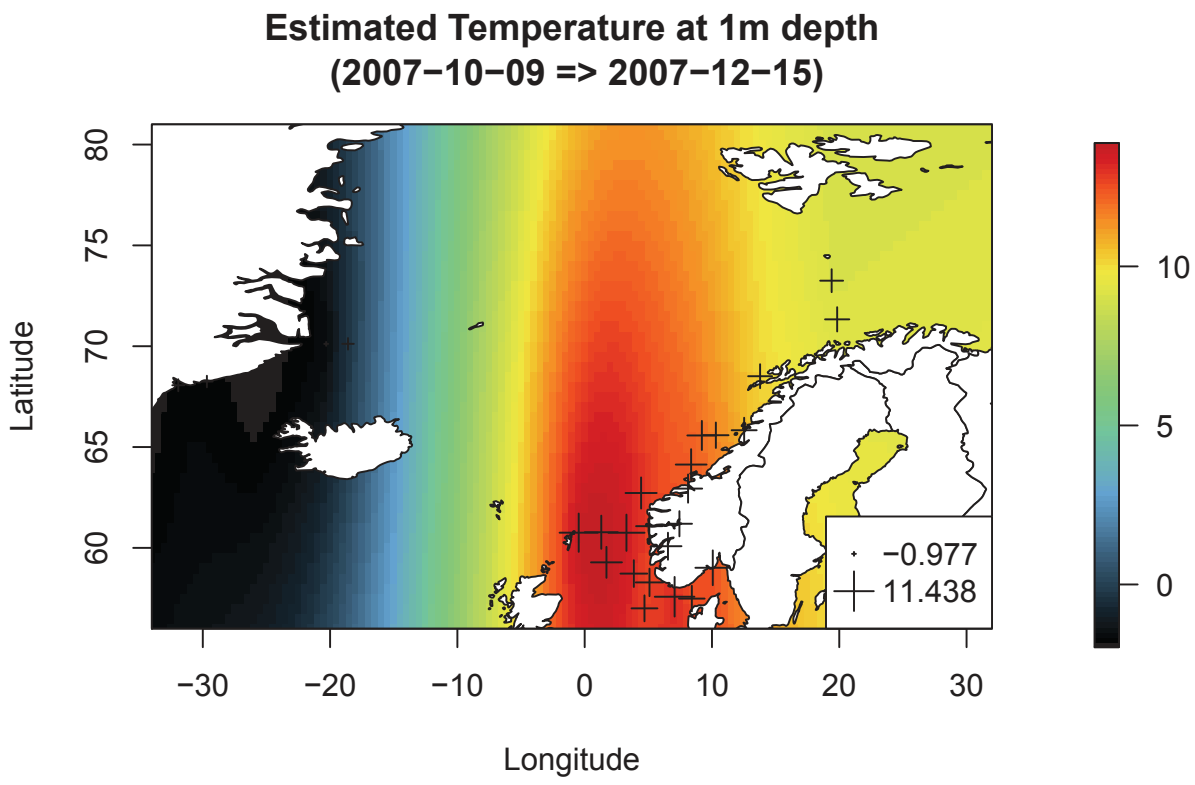
```
## Temperature in Fourth trimester of 2007
```

```
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
```

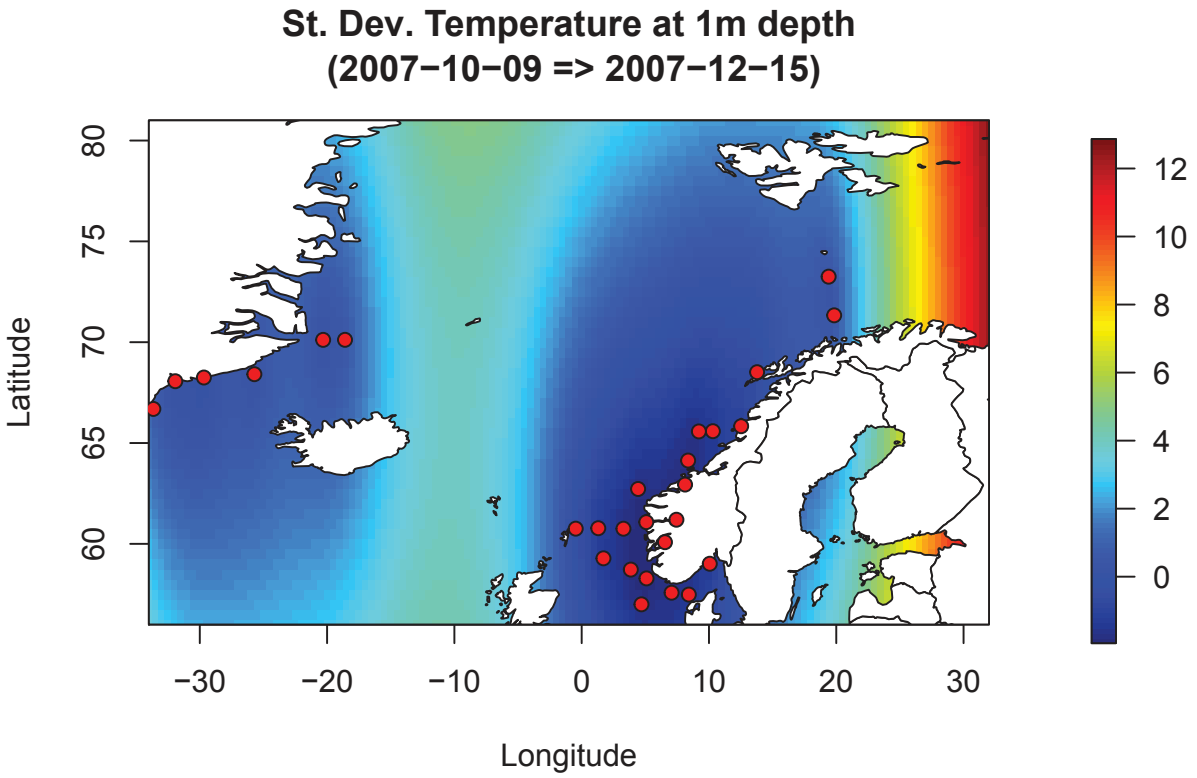



```
display_result(res = res, flag.estim = TRUE,
               xlim = xlim, ylim = ylim, zlim = zlim)
```



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)
```



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