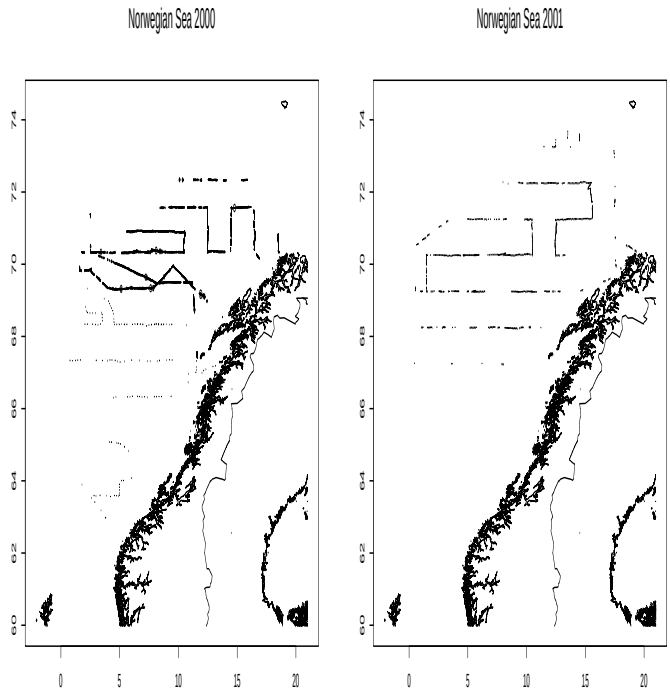
Initial analysis of data from Norwegian Spring Spawning Herring Survey in the Norwegian Sea, 2000 & 2001



SAMBA/21/02

Anders Løland
Gudmund Høst

July 2002

Norsk Regnesentral
ANVENDT DATAFORSKNING

NR-notat/NR Note

Tittel/Title: Initial analysis of data from Norwegian Spring Spawning Herring Survey in the Norwegian Sea, 2000 & 2001

Dato/Date: July
År/Year: 2002
Notat nr./Note no.: SAMBA/21/02

Forfatter/Author: Anders Løland
Gudmund Høst

Sammendrag/Abstract: This note sums up the initial analysis of the acoustic measurements of Norwegian Spring Spawning Herring (NSSH) in the Norwegian Sea 2000 & 2001. The data are corrected for shadow effect, avoidance effect and target strength effect and then integrated over the water column. One characteristic of the data is the large areas with 0 measurements. Generally, the variograms are increasing with distance, while there seems to be no trend for the variograms with respect to time.

Emneord/Keywords: Space-time data, empirical variograms, Norwegian Spring Spawning Herring

Målgruppe/Target group: Researchers in the project

Tilgjengelighet/Availability: Open

Prosjekt/Project: Absolute abundance estimation of fish

Prosjektnr./Project no.: 220140

Satsningsfelt/Research field: Marine Resources

Antall sider/No. of pages: 18

Norsk Regnesentral/Norwegian Computing Center
Gaustadalléen 23, Postboks 114 Blindern, 0314 Oslo, Norway
Telefon 22 85 25 00, telefax 22 69 76 60

Contents

1 Introduction **3**

2 Data **3**

3 Empirical Variograms **9**
3.1 Empirical Covariograms 9

4 Preliminary conclusion **10**

5 Future work **10**

List of Tables

1 Data start and stop locations with times. 3

List of Figures

1 Norwegian Sea 2000 transect (left) and measurements (right). 4
2 Histogram of measurements on original scale. Norwegian Sea 2000. The single bar on the left represents the (many) zeros. 5
3 Norwegian Sea 2001 transect (left) and measurements (right). 6
4 Histogram of measurements on original scale. Norwegian Sea 2001. The single bar on the left represents the (many) zeros. 7
5 Map of zero (black) and non-zero (red) observations. 8
6 Norwegian Sea 2000 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), variogram (middle left and middle centre), number of data points used in the variogram (middle right), data points used in variogram with no observations (lower left), variogram with time=0 (lower middle) and variogram with distance=0 (lower right). 11
7 Norwegian Sea 2001 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), variogram (middle left and middle centre), number of data points used in the variogram (middle right), data points used in variogram with no observations (lower left), variogram with time=0 (lower middle) and variogram with distance=0 (lower right). 12
8 Norwegian Sea 2000 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), variogram (middle left and middle centre), number of data points used in the variogram (middle right), data points used in variogram with no observations (lower left), variogram with time=0 (lower middle) and variogram with distance=0 (lower right). 13

9 Norwegian Sea 2001 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), variogram (middle left and middle centre), number of data points used in the variogram (middle right), data points used in variogram with no observations (lower left), variogram with time=0 (lower middle) and variogram with distance=0 (lower right). 14
10 Norwegian Sea 2000 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), covariogram (middle left and middle centre), number of data points used in the covariogram (middle right), data points used in covariogram with no observations (lower left), covariogram with time=0 (lower middle) and covariogram with distance=0 (lower right). 15
11 Norwegian Sea 2001 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), covariogram (middle left and middle centre), number of data points used in the covariogram (middle right), data points used in covariogram with no observations (lower left), covariogram with time=0 (lower middle) and covariogram with distance=0 (lower right). 16
12 Norwegian Sea 2000 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), covariogram (middle left and middle centre), number of data points used in the covariogram (middle right), data points used in covariogram with no observations (lower left), covariogram with time=0 (lower middle) and covariogram with distance=0 (lower right). 17
13 Norwegian Sea 2001 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), covariogram (middle left and middle centre), number of data points used in the covariogram (middle right), data points used in covariogram with no observations (lower left), covariogram with time=0 (lower middle) and covariogram with distance=0 (lower right). 18

1 Introduction

This note is meant to sum up the initial analysis of the acoustic measurements of Norwegian Spring Spawning Herring (NSSH) in the Norwegian Sea 2000 & 2001.

2 Data

The data are adjusted for shadow effect, avoidance effect and target strength effect (Zhao and Ona, 2002; Ona, 2001) and then integrated over the water column, so the locations are 2-dimensional, the time is 1-dimensional and the measurements are also 1-dimensional. We have measurements $Z(\boldsymbol{s}_i, t_i)$ of a spatial random field $Z(\boldsymbol{s}, t)$ at geographical locations $\boldsymbol{s}_i$ and times t_i, $i = 1, \ldots, n$.

In Table 1 we have summed up the start and stop times for the two surveys.

Survey	Start date & time	Start location	Stop date & time	Stop location
Norwegian Sea 2000	28.04 17:31	N61:17.5 E4:20.5	31.05 07:28	N67:05.2 E11:39.3
Norwegian Sea 2001	03.05 18:37	N60:41.1 E4:50.0	27.05 19:44	N70:21.3 E19:20.2

Table 1: Data start and stop locations with times.

This means that the 2000 survey started outside Bergen and ended up outside Mo i Rana and the 2001 survey also started outside Bergen but ended outside Tromsø. In the 2000 survey the distance between the measurement locations is 5 Nm (Nautical miles) to begin with and then 0.1 Nm. The 2001 survey has a resolution of 1 Nm for the locations throughout the entire survey.

In Figures 1-4 we have plotted the different transects and measurements. The axes are Longitude and Latitude *decimal* degrees. In the measurement plots, the abundance of herring in each measurement location is proportional to the area of the circle. We see that there are large areas where the measured abundance of herring equals zero, especially south of the 68th degree of Latitude. For each transect, we have produced histograms of the measurements. Since there are so many zero measurements, we have put the zeros in a single bar on the left of the other measurements.

In Figure 5 we have made a map of zero (black) and non-zero (red) measurements. The zeros seem to be concentrated in certain areas and not spread out evenly, as we would expect if the distribution of the zeros had a very short correlation range.

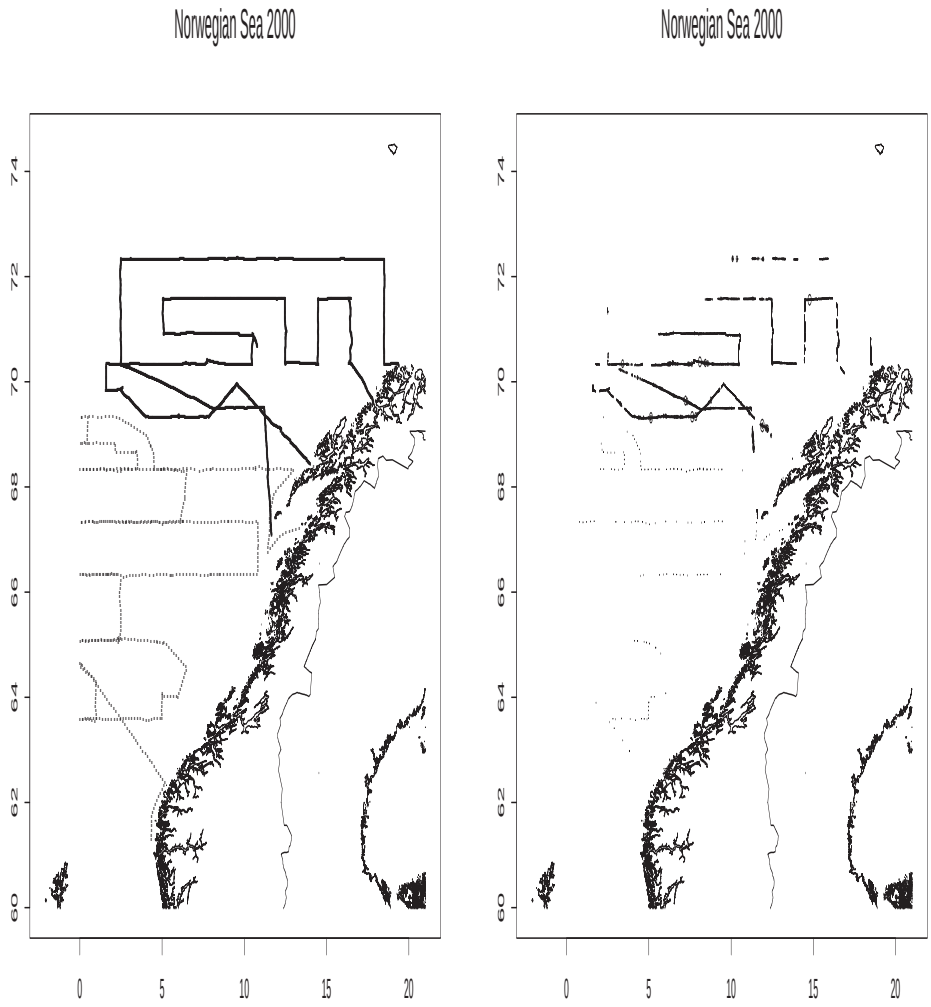


Figure 1: Norwegian Sea 2000 transect (left) and measurements (right).

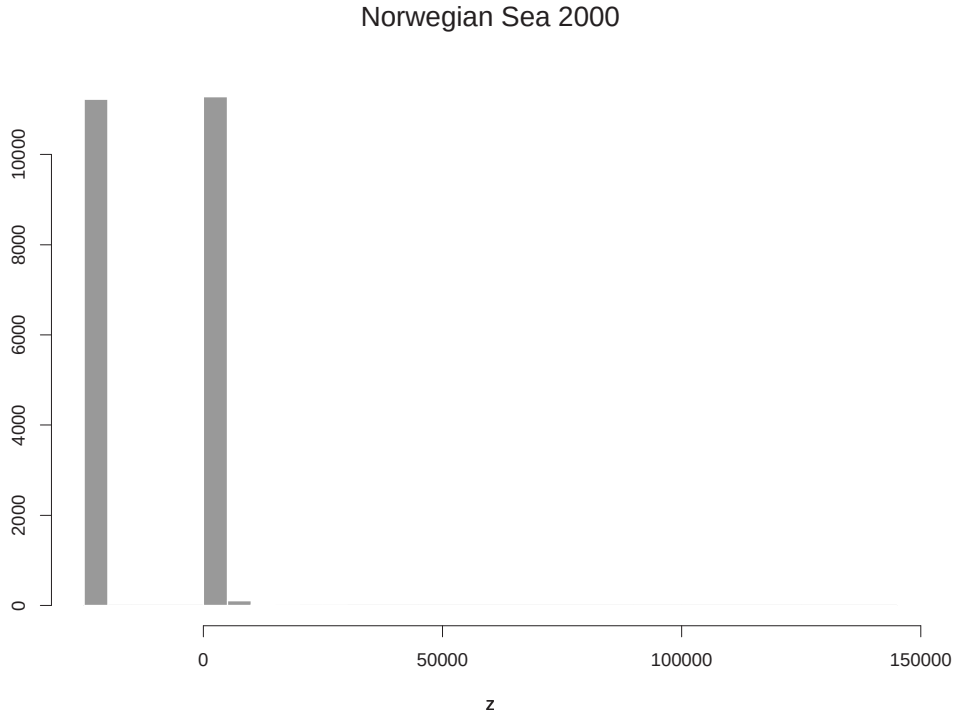


Figure 2: Histogram of measurements on original scale. Norwegian Sea 2000. The single bar on the left represents the (many) zeros.

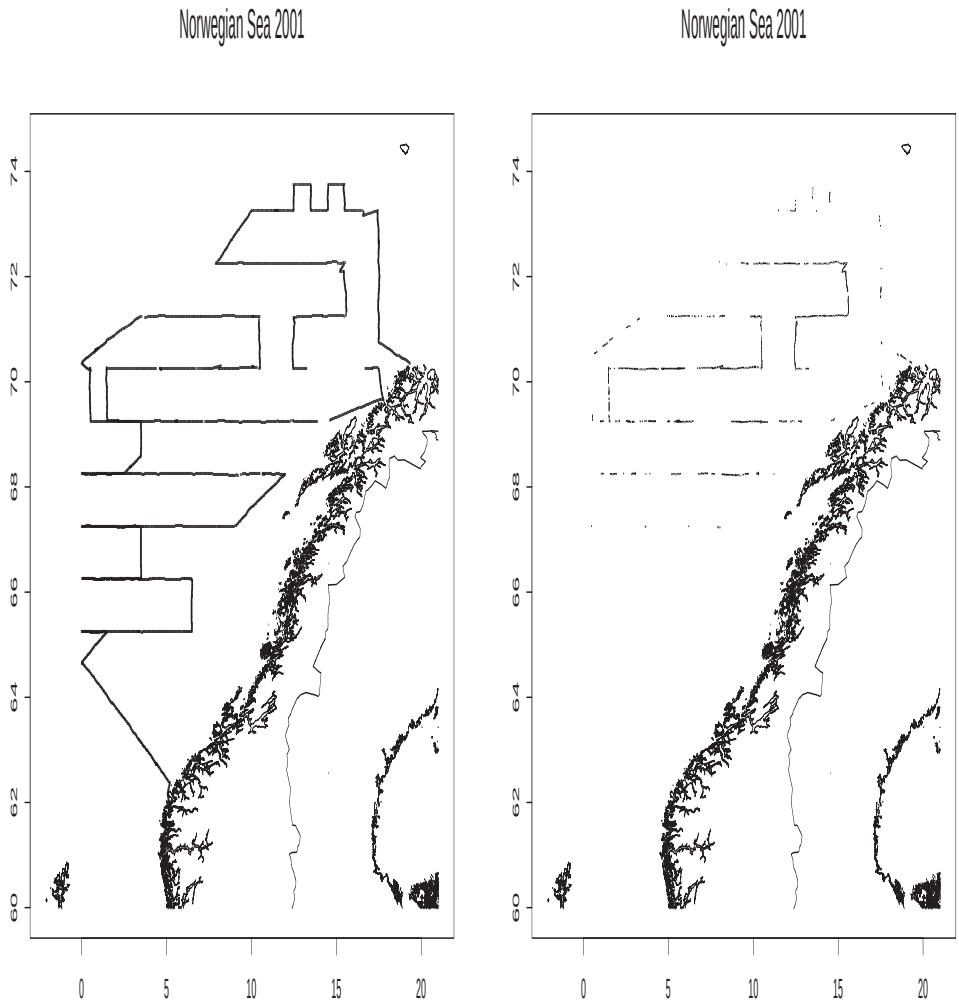


Figure 3: Norwegian Sea 2001 transect (left) and measurements (right).

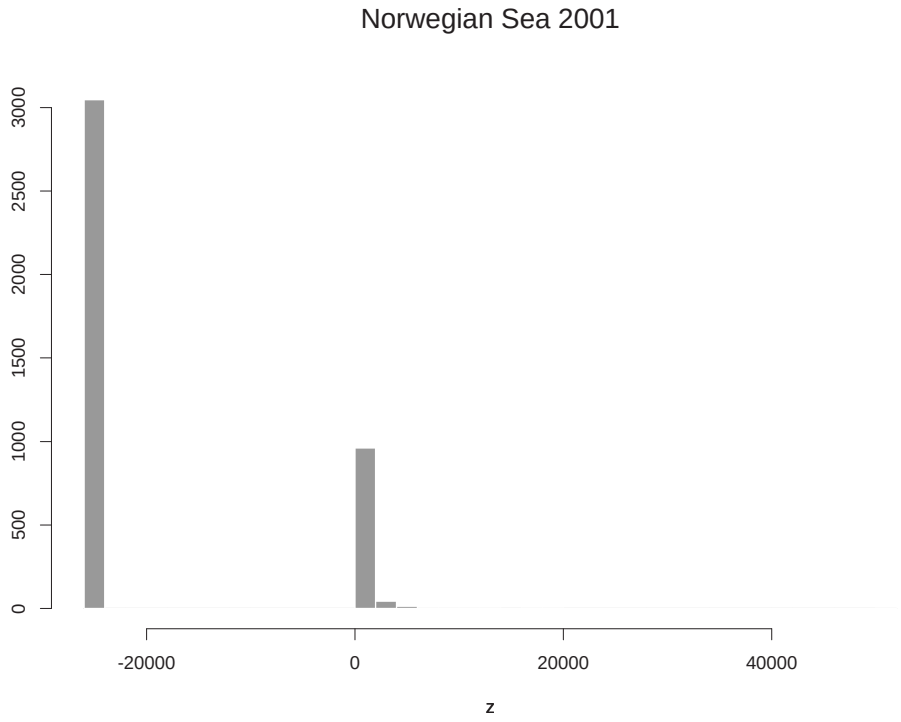


Figure 4: Histogram of measurements on original scale. Norwegian Sea 2001. The single bar on the left represents the (many) zeros.

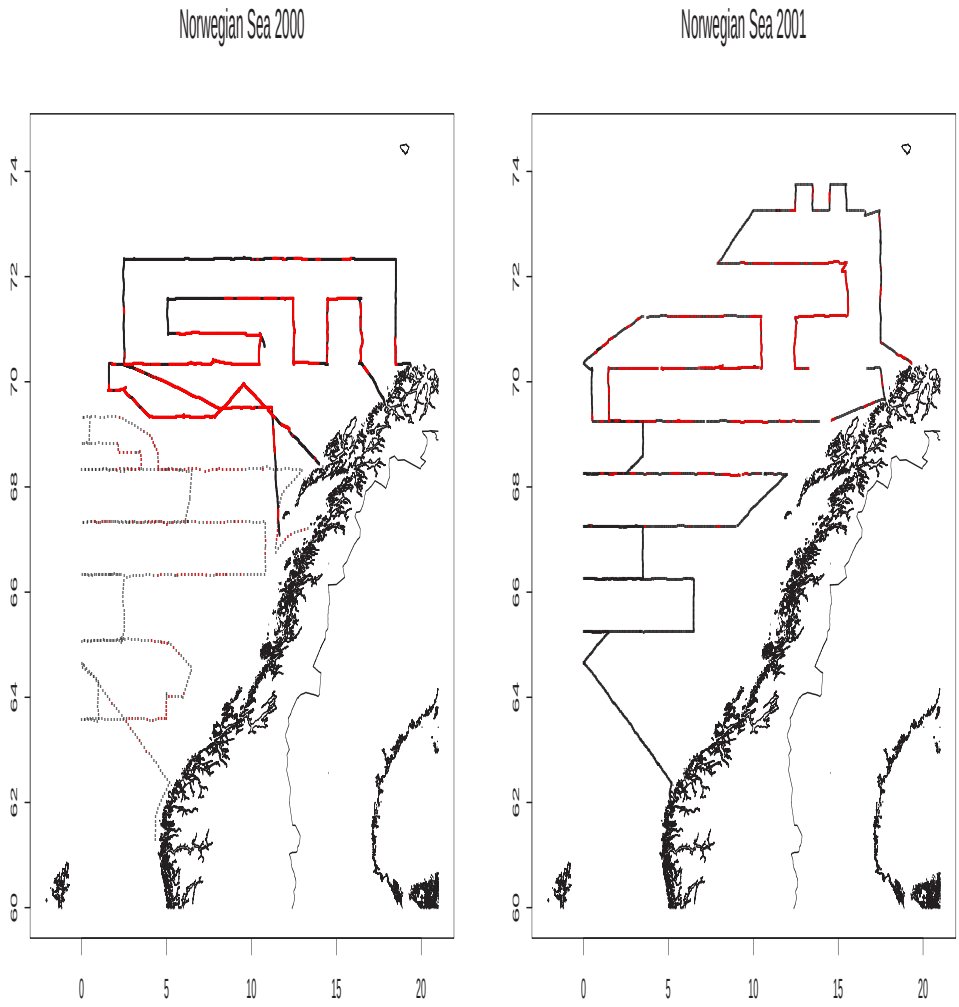


Figure 5: Map of zero (black) and non-zero (red) observations.

3 Empirical Variograms

In Figures 6-9 we have plotted classical variogram estimates (Cressie, 1993).

$$2\hat{\gamma}(\boldsymbol{h}_s, h_t) = \frac{1}{|N(\boldsymbol{h}_s, h_t)|} \sum_{N(\boldsymbol{h}_s, h_t)} \big(Z(\boldsymbol{s}_i, t_i) - Z(\boldsymbol{s}_j, t_j)\big)^2.$$

Here, $N(\boldsymbol{h}_s, h_t) = \{(\boldsymbol{s}_i, \boldsymbol{s}_j) : \boldsymbol{s}_i - \boldsymbol{s}_j = \boldsymbol{h}_s; (t_i, t_j) : t_i - t_j = h_s; i, j = 1, \ldots, n\}$ and $|N(\boldsymbol{h}_s, h_t)|$ is the number of distinct pairs in $N(\boldsymbol{h}_s, h_t)$. The empirical variograms are computed using both distance and time lags, and we thus get a 3-dimensional plot of the empirical variogram (with the 3 dimensions being distance lag, time lag and empirical variogram values). In the variogram plots the bins with no data points are excluded (and an image plot is given to show exactly where the observations are missing).

Since the survey ship moves from one part of the to another part of the Norwegian Sea in a predestined pattern, we have either a good resolution on the distance scale or a good resolution on the time scale , but not a simultaneously good resolution of both distance and time. The survey ship can not, for instance, be at two locations 10 Nm apart in less than 1 hour when it is cruising at 10 knots (1 Nm = 1852 m and 1 knot = 1 Nm/hour).

In Figures 6 and 7 we have plotted empirical variograms for data from the area north of the 68th degree of Latitude. We see that in neither of them we have coverage of locations 0-20 Nm and 40-60 hours apart. Holding the time fixed, we see that the empirical variogram for the 2000 survey is much steeper than the one for the 2001 survey and the other way around; holding the distance fixed. This may be due to the spatial trend in the data from the selected region from the 2000 survey.

Figures 8 and 9 show variograms for the same areas, but using a much bigger maximum time and distance lag (200 hours and 400 Nm, respectively). Holding the distance fixed, the variogram seems to reach a steady state. Holding the time fixed, there does not seem to be a clear trend.

3.1 Empirical Covariograms

In Figures 10 - 13 we have plotted classical covariogram estimates (Cressie, 1993).

$$\hat{C}(\boldsymbol{h}_s, h_t) = \frac{1}{|N(\boldsymbol{h}_s, h_t)|} \sum_{N(\boldsymbol{h}_s, h_t)} \big(Z(\boldsymbol{s}_i) - \bar{Z}\big)\big(Z(\boldsymbol{s}_j) - \bar{Z}\big),$$

where $\bar{Z} = \sum_{i=1}^{n} Z(\boldsymbol{s}_i)/n$, $N(\boldsymbol{h}_s, h_t) = \{(\boldsymbol{s}_i, \boldsymbol{s}_j) : \boldsymbol{s}_i - \boldsymbol{s}_j = \boldsymbol{h}_s; (t_i, t_j) : t_i - t_j = h_s; i, j = 1, \ldots, n\}$ and $|N(\boldsymbol{h}_s, h_t)|$ is the number of distinct pairs in $N(\boldsymbol{h}_s, h_t)$.

In Figure 10 and 11 we have plotted covariogram for the 2000 and 2001 survey and in Figure 12 and 13 we have plotted covariogram for all the data. Generally we see that in the time domain, the covariance is more or less constant, while it is decreasing with increasing distance. This might be what we expect: If the fish moves around in the very slowly, maybe we would have discovered that it has moved in a few weeks or so, but not in 20-30 hours. The falling covariance with distance might be either due to a spatial trend of some sort or that the random field is non-stationary.

4 Preliminary conclusion

The problem with *non-water distances*: "distances between two sites *not* traversed entirely over water" is not a big problem here, since we are mostly out on the open sea. If it is a problem, maybe it is so for distances above 100 Nm.

Generally we have quite good coverage of both the time and the distance domain.

5 Future work

We have several problems to work with:

1. In the observations where we measure 0 fish special care has to be taken to model the abundance. Maybe we can model the probability of measuring 0 in a particular location/time? Then, given a measurement greater than zero, model the amount.

   How do we deal with migration between the areas?

2. What covariance or kernel function are we going to choose for space-time?

References

Cressie, N. A. C. (1993). *Statistics for Spatial Data*. Wiley-Interscience, revised edition.

Ona, E. (2001). About avoidance effect and target strength effect. Personal comment.

Zhao, X. and Ona, E. (2002). Models for estimation of the σ_e/σ ratio of fish: Compensation for the shadowing effect in dense fish aggregations. *Unpublished*. Yellow Sea Fisheries Research Institute, 106 Nanjing Road, Qingdao 266071, P. R. China.

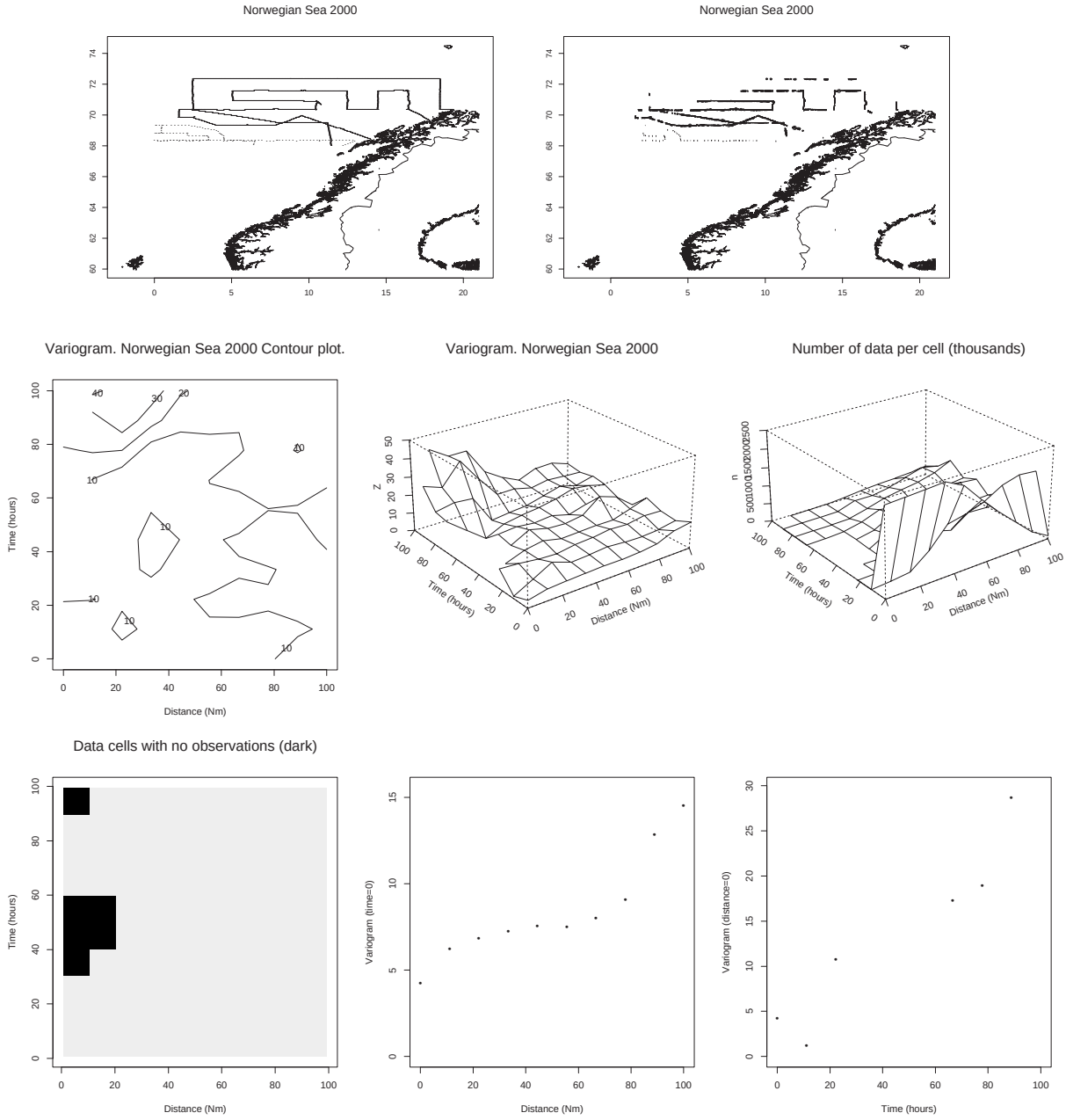


Figure 6: Norwegian Sea 2000 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), variogram (middle left and middle centre), number of data points used in the variogram (middle right), data points used in variogram with no observations (lower left), variogram with time=0 (lower middle) and variogram with distance=0 (lower right).

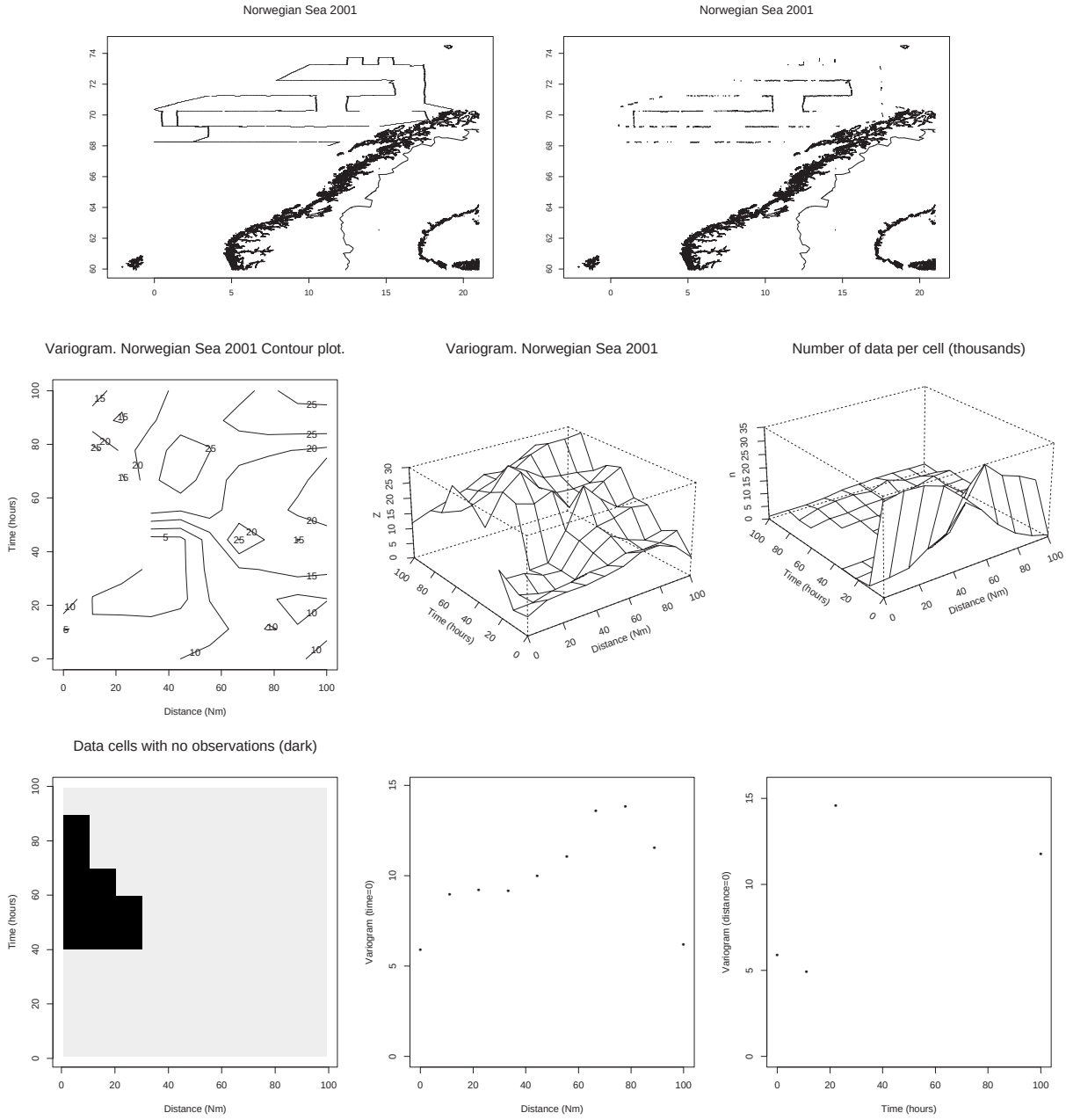


Figure 7: Norwegian Sea 2001 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), variogram (middle left and middle centre), number of data points used in the variogram (middle right), data points used in variogram with no observations (lower left), variogram with time=0 (lower middle) and variogram with distance=0 (lower right).

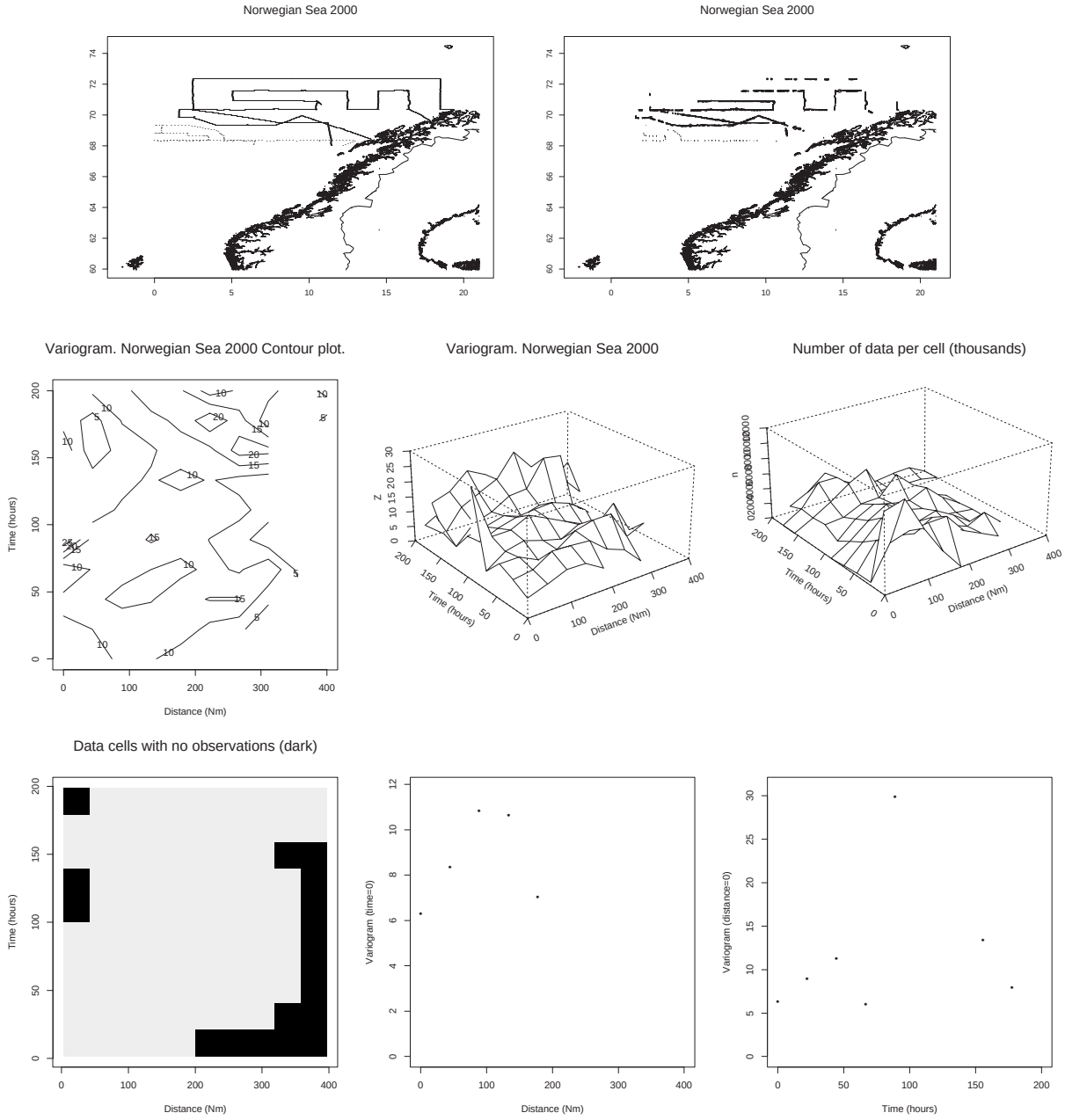


Figure 8: Norwegian Sea 2000 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), variogram (middle left and middle centre), number of data points used in the variogram (middle right), data points used in variogram with no observations (lower left), variogram with time=0 (lower middle) and variogram with distance=0 (lower right).

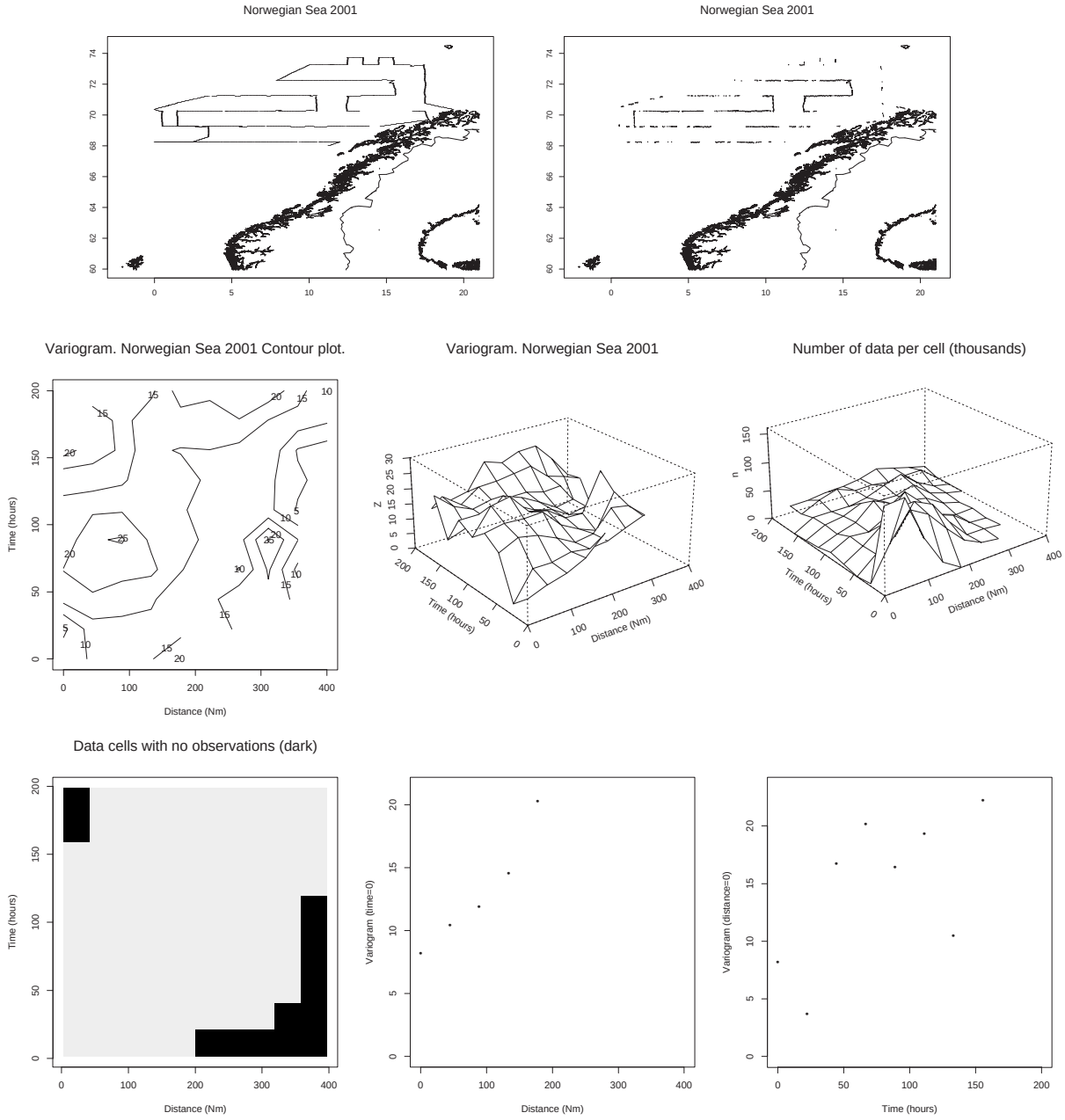


Figure 9: Norwegian Sea 2001 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), variogram (middle left and middle centre), number of data points used in the variogram (middle right), data points used in variogram with no observations (lower left), variogram with time=0 (lower middle) and variogram with distance=0 (lower right).

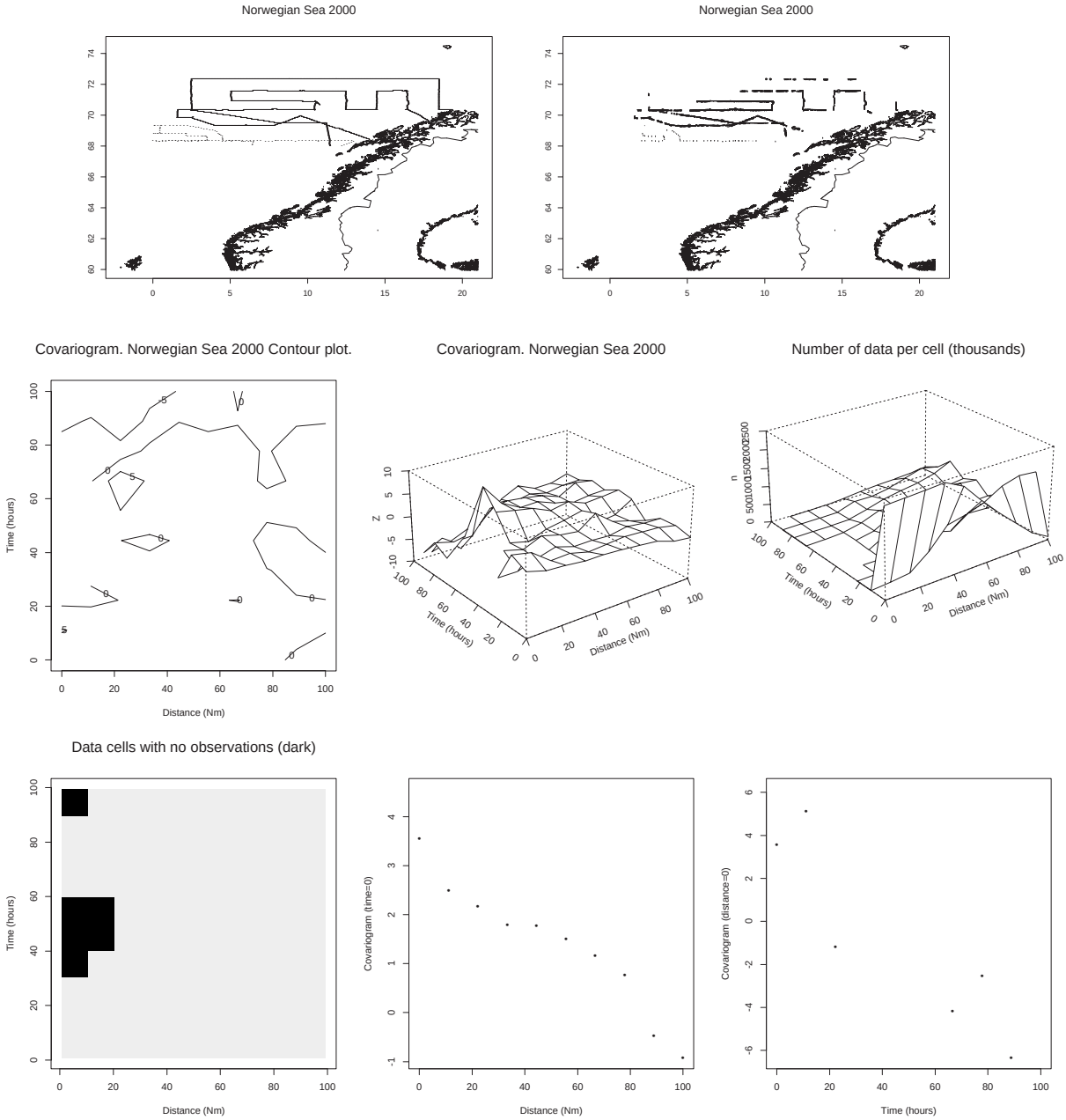


Figure 10: Norwegian Sea 2000 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), covariogram (middle left and middle centre), number of data points used in the covariogram (middle right), data points used in covariogram with no observations (lower left), covariogram with time=0 (lower middle) and covariogram with distance=0 (lower right).

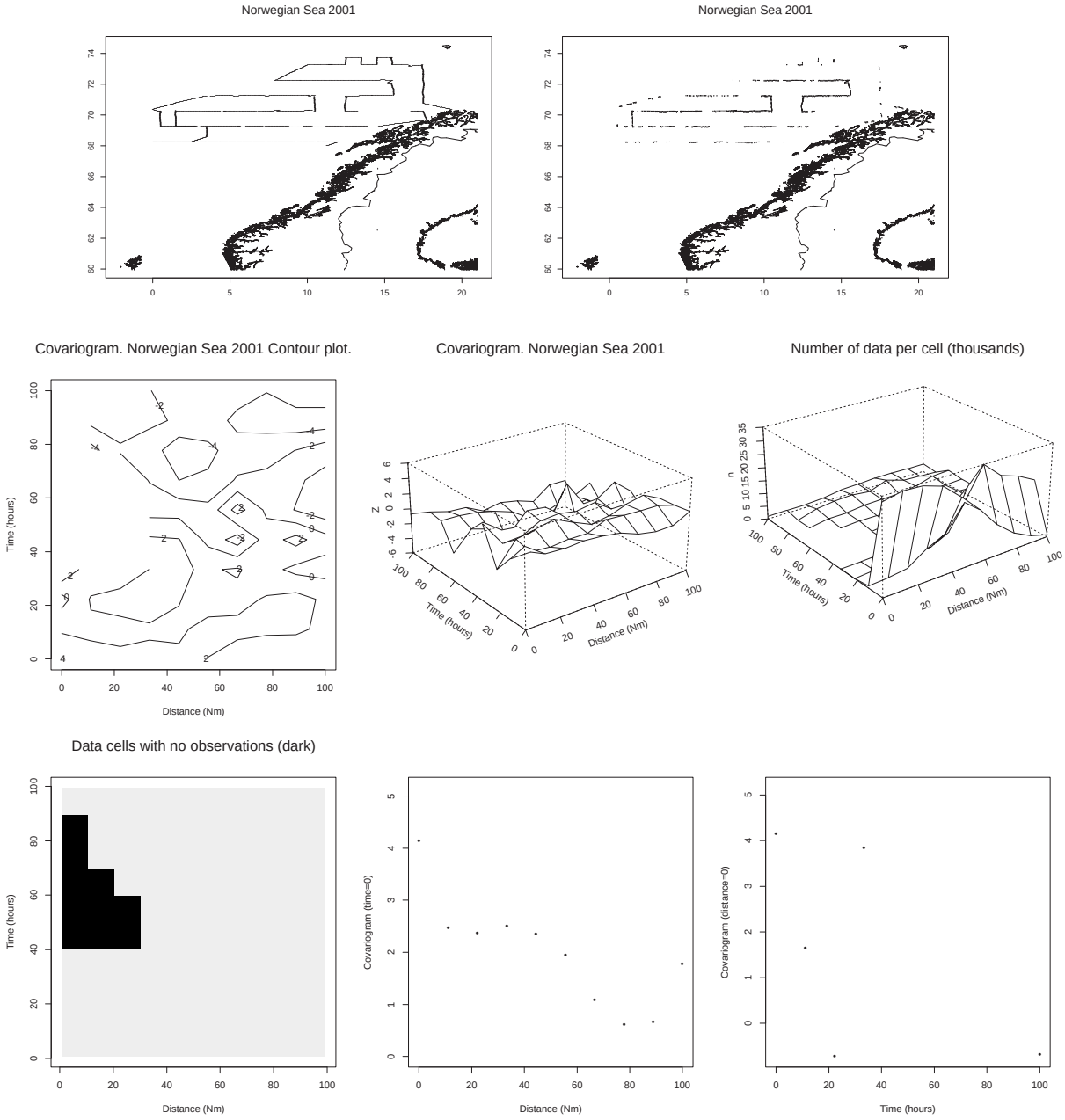


Figure 11: Norwegian Sea 2001 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), covariogram (middle left and middle centre), number of data points used in the covariogram (middle right), data points used in covariogram with no observations (lower left), covariogram with time=0 (lower middle) and covariogram with distance=0 (lower right).

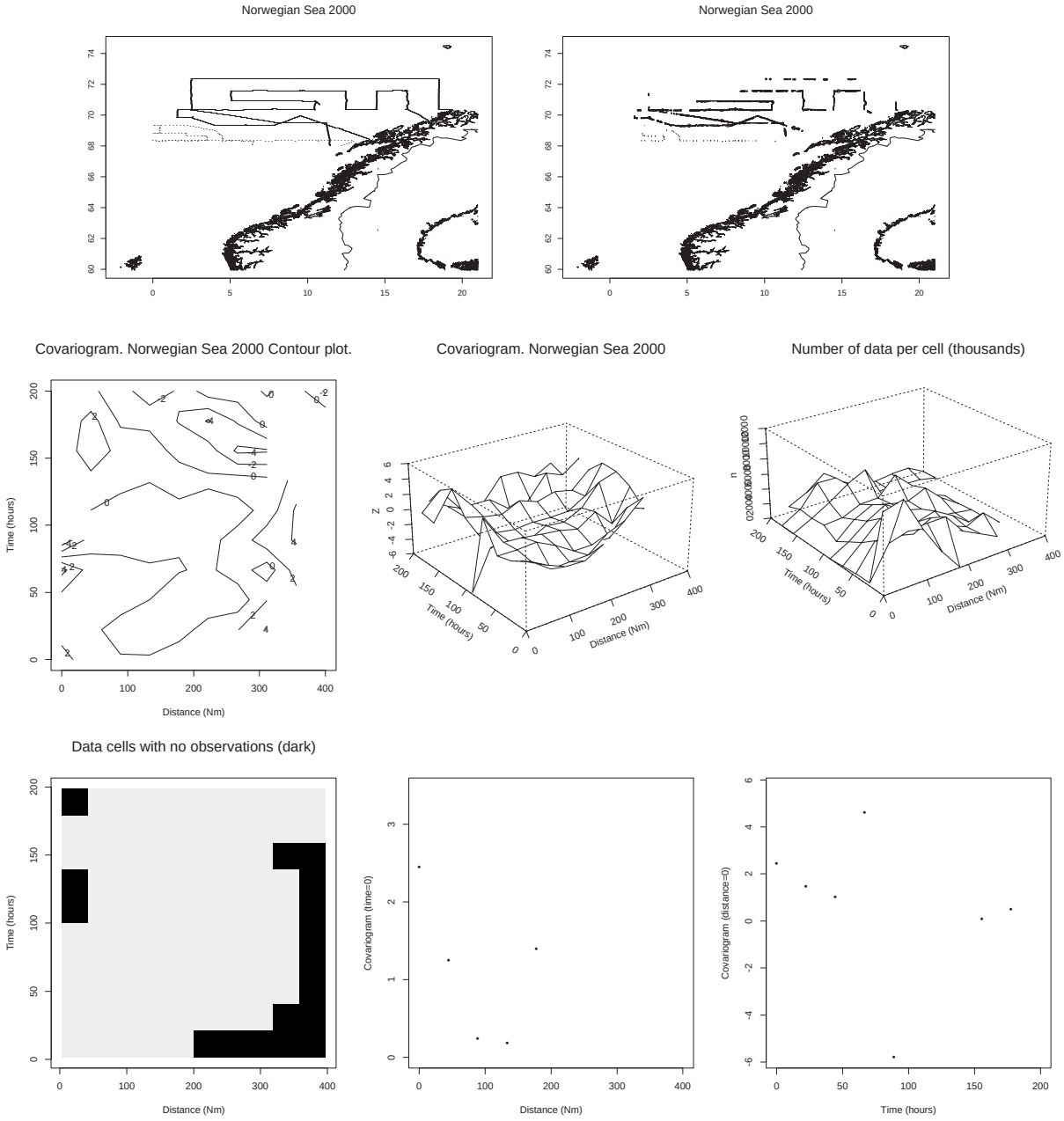


Figure 12: Norwegian Sea 2000 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), covariogram (middle left and middle centre), number of data points used in the covariogram (middle right), data points used in covariogram with no observations (lower left), covariogram with time=0 (lower middle) and covariogram with distance=0 (lower right).

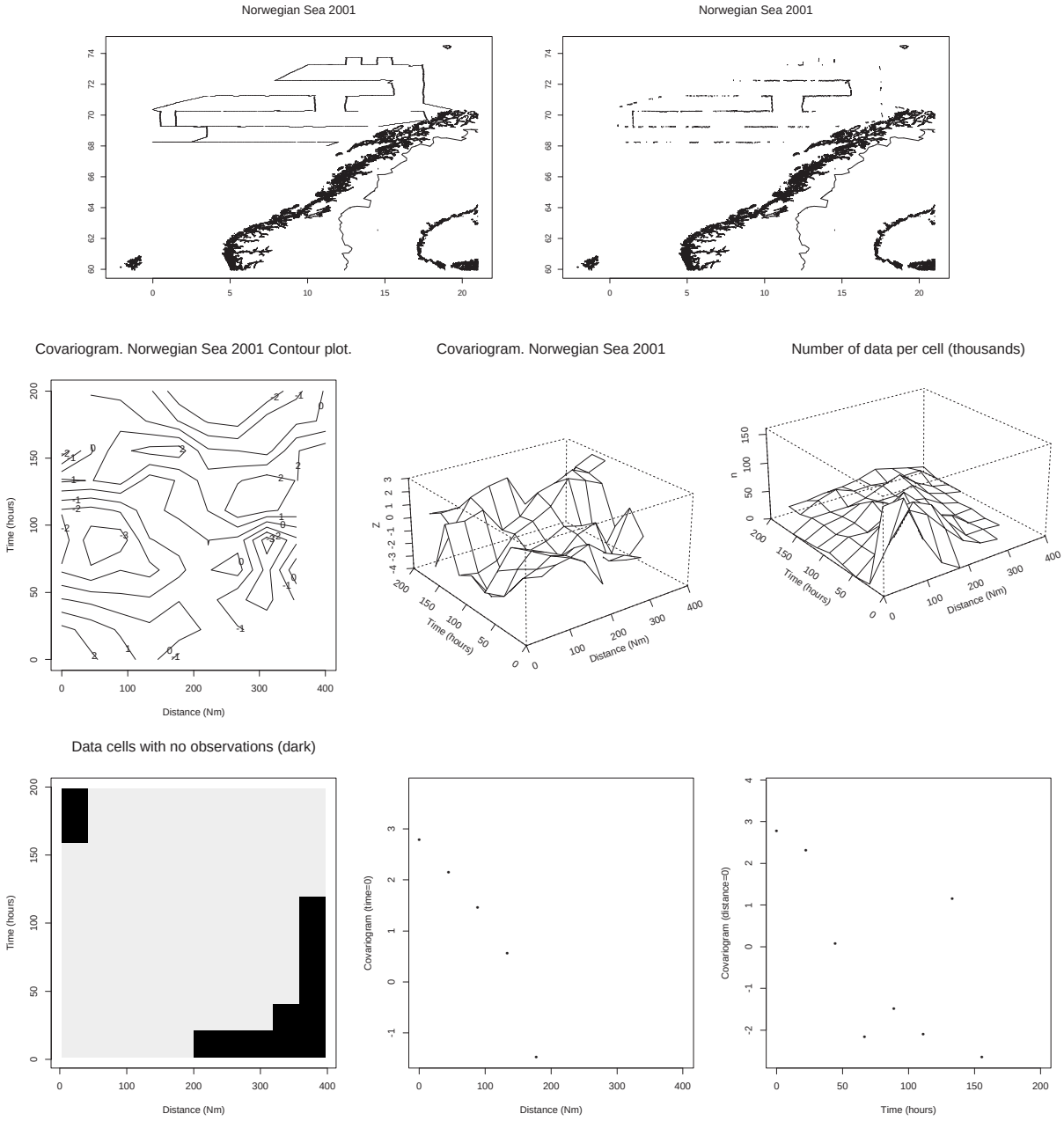


Figure 13: Norwegian Sea 2001 – data located north of the 68th degree Latitude. Transect (upper left), data (upper right), covariogram (middle left and middle centre), number of data points used in the covariogram (middle right), data points used in covariogram with no observations (lower left), covariogram with time=0 (lower middle) and covariogram with distance=0 (lower right).