# Veðurstofa Íslands
# Report

Kristján Ágústsson

# Overview of seismic activity in Iceland January 1995 - November 1996 Preliminary report on SIL data

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## Introduction

This report describes the seismic activity and its variations in time for different areas in Iceland from January 1995 to November 1996. The magnitude–frequency distribution and b–values have also been roughly estimated for most of the areas. Strain changes, as seen by the volumetric strainmeter network in southern Iceland, are also shown.

The report is based on the preliminary database of the SIL network.

## Procedure

The country is divided into areas around activity concentrations and lineaments. The areas are shown in Figure 1. For each area the number of earthquakes and strain-release is calculated. This is done for 30 days running averages with a week step and discrete week intervals. Strainrelease is calculated according to an ad hoc dimensionless relation, $strainrelease = 10^{(5+m)}$ where $m$ is magnitude (Bodvarsson et al. 1996).

The strain records shown are raw data and they are scaled to nanostrains.

The records of the seismicity, magnitude–frequency distribution and b–values are in appendix A. The strainmeter records are in appendix B.

## Data

The seismic dataset is complete in the sense that the network has been in continuous operation and all events that have been automatically detected are manually checked. Time stamping was based on a OMEGA transmitter in Norway until spring 1996 when it was replaced by a GPS clock. The OMEGA transmitter was not in function for a couple of days in August 1995 due to maintainance at the station.

The number of analyzed earthquakes during the period is 37500 and the epicentral distribution is shown in Figure 2. The detection level for different areas differs greatly because of uneven station distribution. This obviously affects the magnitude–number histograms.

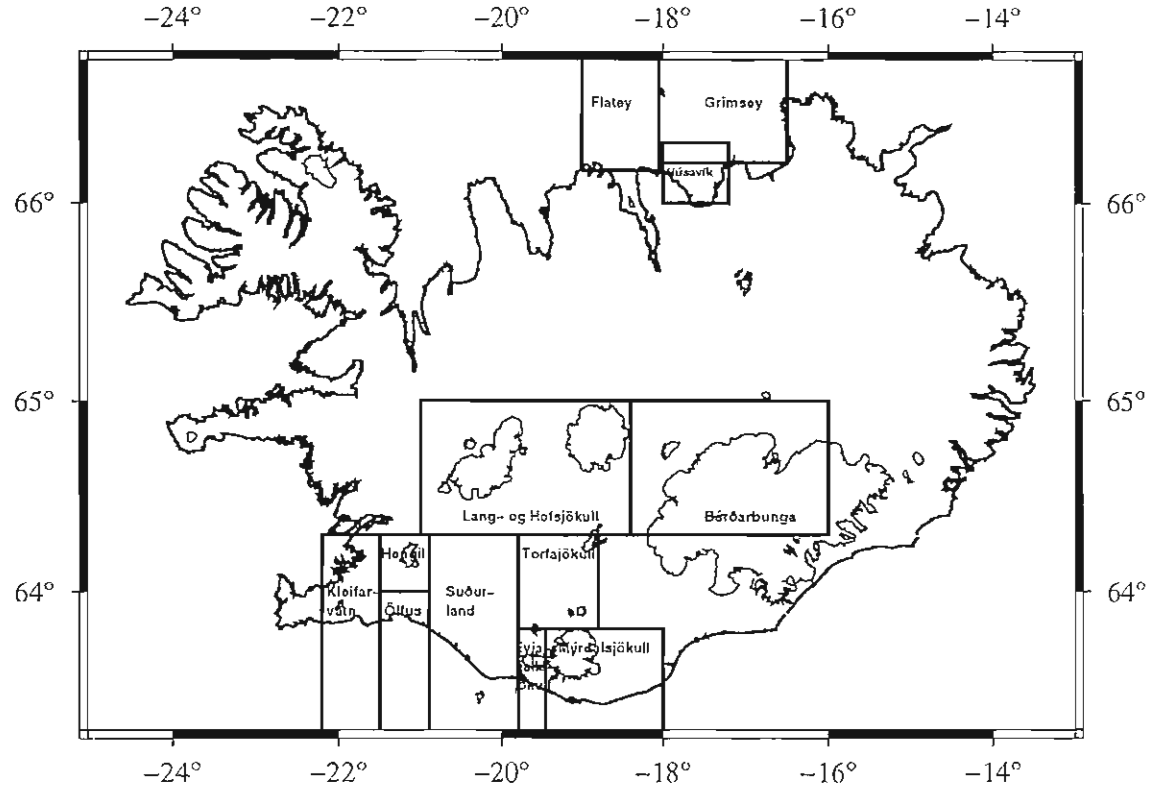



Figure 1: Areas of calculation.

Installation of new SIL stations also changes the detection level. The new stations either have 5 seconds or broadband seismometers, whose characteristics have not been taken fully into account in the magnitude calculation, which is based on 1 second sensors. This, as well as the installation of new stations, causes some inconsistency of the records which to some extent is reflected in the distribution and number plots.

The magnitude calculation's were originally based on comparison between magnitudes of earthquakes recorded by the previous seismic network and amplitudes of waveforms recorded with the 1 second Lennartz seismometers used in the initial phase of the SIL project. Later, during the buildup of the SIL network, new types of seismometers were used, 5 seconds Lennartz and broadband Guralp's (CMG-3T, CMG-3ESP). In the summer of 1995, 1 second seismometers were replaced by Guralp seismometers at three stations in northern Iceland and stations installed in late summer and autumn 1996 have 5 seconds Lennartz or Guralp seismometers.

In the magnitude calculations minimum and maximum amplitudes within a time window around the phases are estimated and a magnitude for each station is calulated. Then an average of magnitudes within a magnitude window of $\pm 0.5$ around the median of magnitudes from individual stations is formed. In the case of the longer period seismometers the presence of microseisms may cause overestimation of magnitudes. This is to some extent accounted for in the calculations (Gunnar Guðmundsson, personal communication).

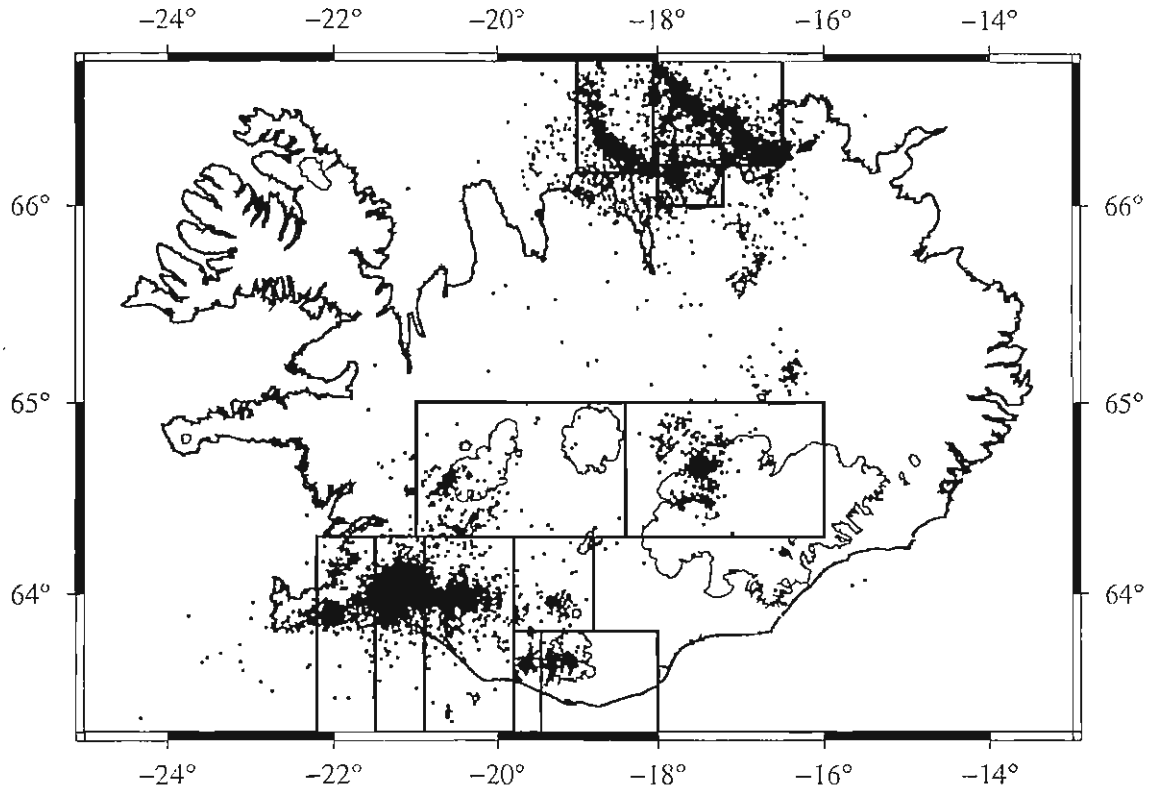



Figure 2: Hypocentral distribution of earthquakes in Iceland, January 1995 to November 1996, and the areas of calculation.

Records of earthquakes of magnitude 2.5 and above are complete for Central Iceland and in most other areas complete above magnitude 1.5. In Hengill, Ölfus and Suðurland the level is lower, close to magnitude 0.5.

The strainmeters are Sacks–Evertson's volumetric borehole strainmeters (Sacks et al. 1971).

# Discussion

Number of earthquakes each month varies between 1000 and 3000 for the whole of Iceland. The strainrelease increases slightly during the study period. In September 1996 there was an earthquke swarm in Bárðarbunga in Vatnajökull where the largest earthquakes during the period occurred.

In the following sections comments are made on the seismicity of each area and the strain changes on each of the strain stations.

## SEISMICITY

Kleifarvatn: Some increase in number is observed from May 1996 to the end of the period. Strainrelease is varying. (logN=3.9-1.1m)

Ölfus: Intense swarms in March 1995 and April 1996 and lower background activity in the middle of the period. (logN=4.5-1.0m)

Hengill: Several swarms are observed but the overall activity decreases during the period. The swarm in October 1996 is close to the eastern border of the area and separated from the area of more persistent activity farther west. (logN=4.5-1.0m)

Suðurland: Swarms in May to August 1996 but otherwise the number is rather constant while strainrelease varies more. (logN=3.6-1.2m)

Mýrdalsjökull: Activity increases constantly in Mýrdalsjökull until October 1996. (logN=3.6-1.2m)

Eyjafjallajökull: Swarm in February to March 1996 but otherwise one earthquake every other month on the average. (logN=4.6-2.0m)

Torfajökull: The number of earthquakes varies a little through the period but the earthquakes are generally larger in 1995. (logN=3.8-1.5m)

Langjökull and Hofsjökull: Swarms in April 1995 and 1996 but background activity is rather constant (labeled Lang– og Hofsjökull on the plots). (logN=4.2-1.7m)

Bárðarbunga: Increased activity during the period. A swarm in February 1996 and an intense swarm starts September 29, 1996 prior to an eruption between Grímsvötn and Bárðarbunga. It is assumed that the eruption starts just before midnight on September 30, and the swarm continues during the eruption with gradually decreased intensity. (logN=7.5-1.7m)

Flatey: Large swarms in September to October 1995, June 1996, September 1996 and several smaller swarms. Otherwise the number is constant but strainrelease increases (labeled Flateyjarbrotabeltið on the plots).

Húsavík: Swarms in January and June 1996 and activity rather increasing. (logN=4.6-1.3m)

Grímsey: Intense swarms in December 1995 and July 1996. Otherwise the number is constant but strainrelease increases (labeled Grímseyjarbrotabeltið on the plots). (logN=5.7-1.3m)

## VOLUMETRIC STRAIN

GEL shows continuous contraction on the order of 1 microstrain per year which is the average trend during the last ten years. Large pulses due to snow melting and rain are observed.

JAD has some technical problems and it is difficult to estimate the long term drift and changes therein and this has not been analyzed yet.

BUR is low–pass filtered (instrumental) and does not show variations of periods longer than a month.

SKA has its average trend of microstrain per year until March 1996 when the contraction rate increases approximately by a factor of four.

SAU has small trend in the beginning of the period but after March 1996 no trend is observed.

HEL a very large contractive step (120000 nanostrain) is observed from September to December 1995. The source of this signal must be local since it is not observed elsewhere. Probably some dislocation occurs in or close to the borehole where the instrument resides, possibly with simultaneous change in water flow and temperature.

STO shows contraction but in March 1996 the rate decreases approximately by a factor of 2.

# Conclusion

The increased activity in northern Iceland, which mainly manifests itself by larger earthquakes and increased strainrelease is a result of the change of seismometers in the summer of 1995. A new station, 30 km from Bárðarbunga, installed on the first day of the eruption there, lowers the detetction level of Central Iceland significantly. But the records prior to the installation are consistent. The areas that have better instrumental coverage have b–values between 1.0 and 1.3. Large b–values in Central Iceland and Eyjafjallajökull are possibly a result of overestimation of the magnitude of the smaller earthquakes.

To summarize, the most significant changes in the seismicity of Iceland are decrease of activity in the Hengill area and increase in Mýdalsjökull, Bárðarbunga and Húsavík. Slight increase in number is also observed in Grímsey and Kleifarvatn. No obvious pattern is recognized in the seismicity and to resolve such patterns finer division into areas and more time resolution might be needed. Regarding swarm activity, some tendency towards swarms in northern Iceland while southern Iceland remains almost swarmless and vice versa, is observed. The swarms in Bárðarbunga follow a swarm activity in northern Iceland.

After April 1996 strain changes show decreased strainrate south of the South Iceland seismic zone (SISZ) and increased to the north of it and no changes in the zone itself. This might indicate increased pressure in the eastern volcanic zone (EVZ) of Iceland to the north of SISZ. That could cause displacement close to the EVZ and strainaccumulation farther west, in a way pulling the eastern part of area to the south of SISZ along.

# References

Bödvarsson, R., S.Th. Rögnvaldsson, S.S. Jakobsdóttir, R. Slunga & R. Stefánsson 1996. The SIL data acquisition and monitoring system. *Seism. Res. Lett.* 67, 35–46.

Sacks, I.S., S. Suyehiro, D.W. Evertson & Y. Yamagishi 1971. Sacks–Evertson strainmeter, its installation in Japan and some preliminary results concerning strain steps. *Papers Meteorol. Geophys.* 22, 195–208.

# References

Bödvarsson, R., S.Th. Rögnvaldsson, S.S. Jakobsdóttir, R. Slunga & R. Stefánsson 1996. The SIL data acquisition and monitoring system. *Seism. Res. Lett.* 67, 35–46.

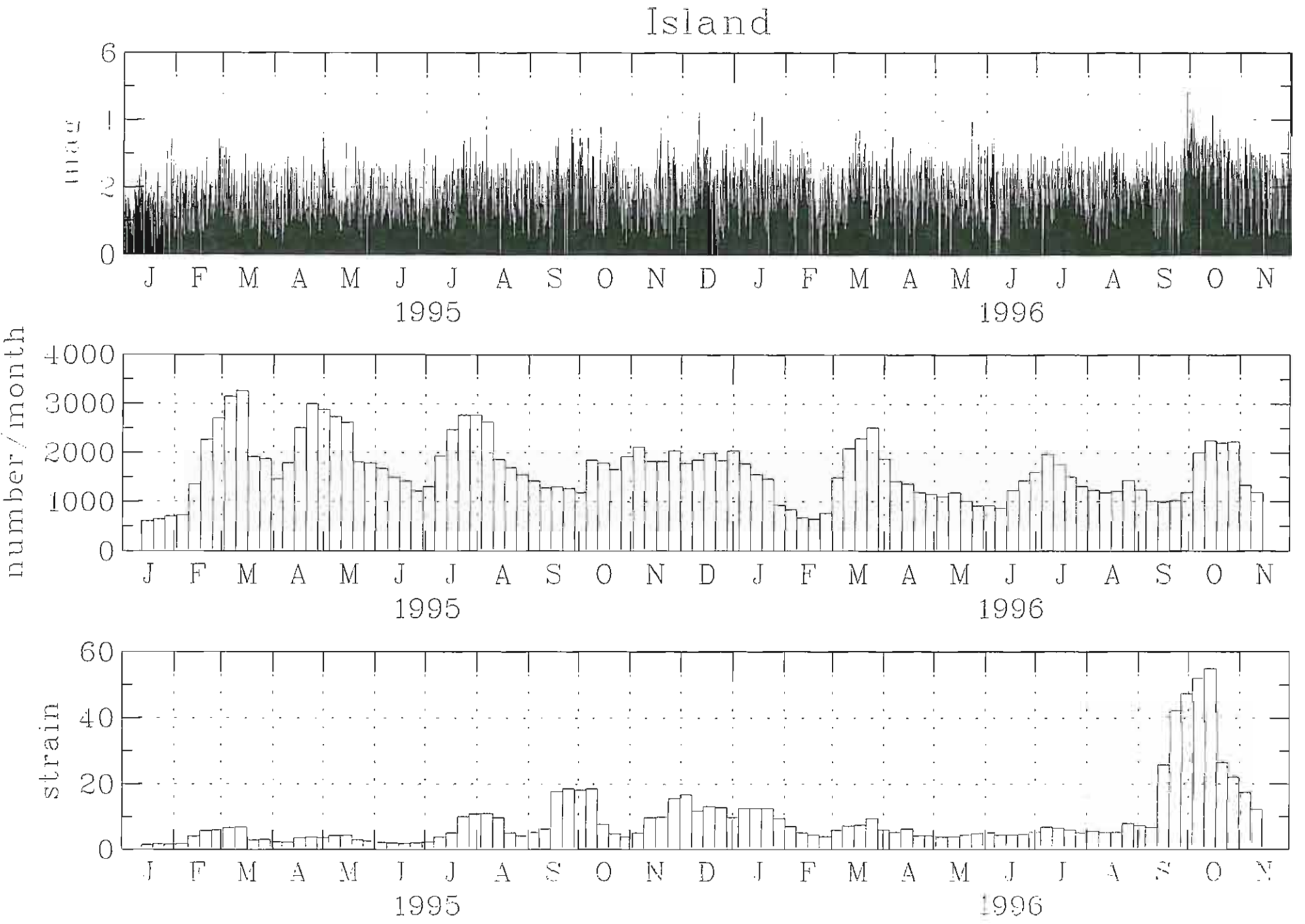
Sacks, I.S., S. Suyehiro, D.W. Evertson & Y. Yamagishi 1971. Sacks–Evertson strainmeter, its installation in Japan and some preliminary results concerning strain steps. *Papers Meteorol. Geophys.* 22, 195–208.

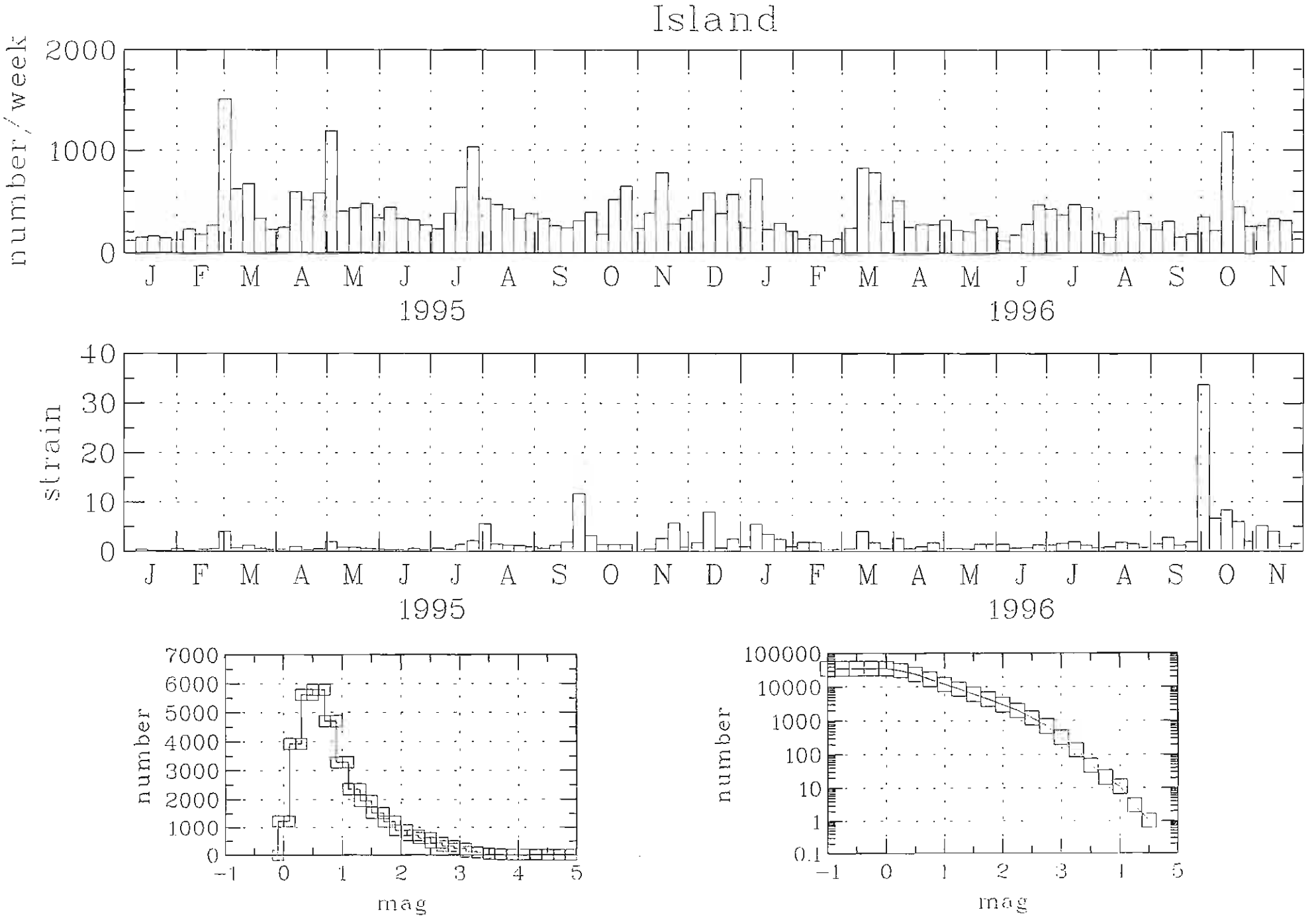
# Appendix A

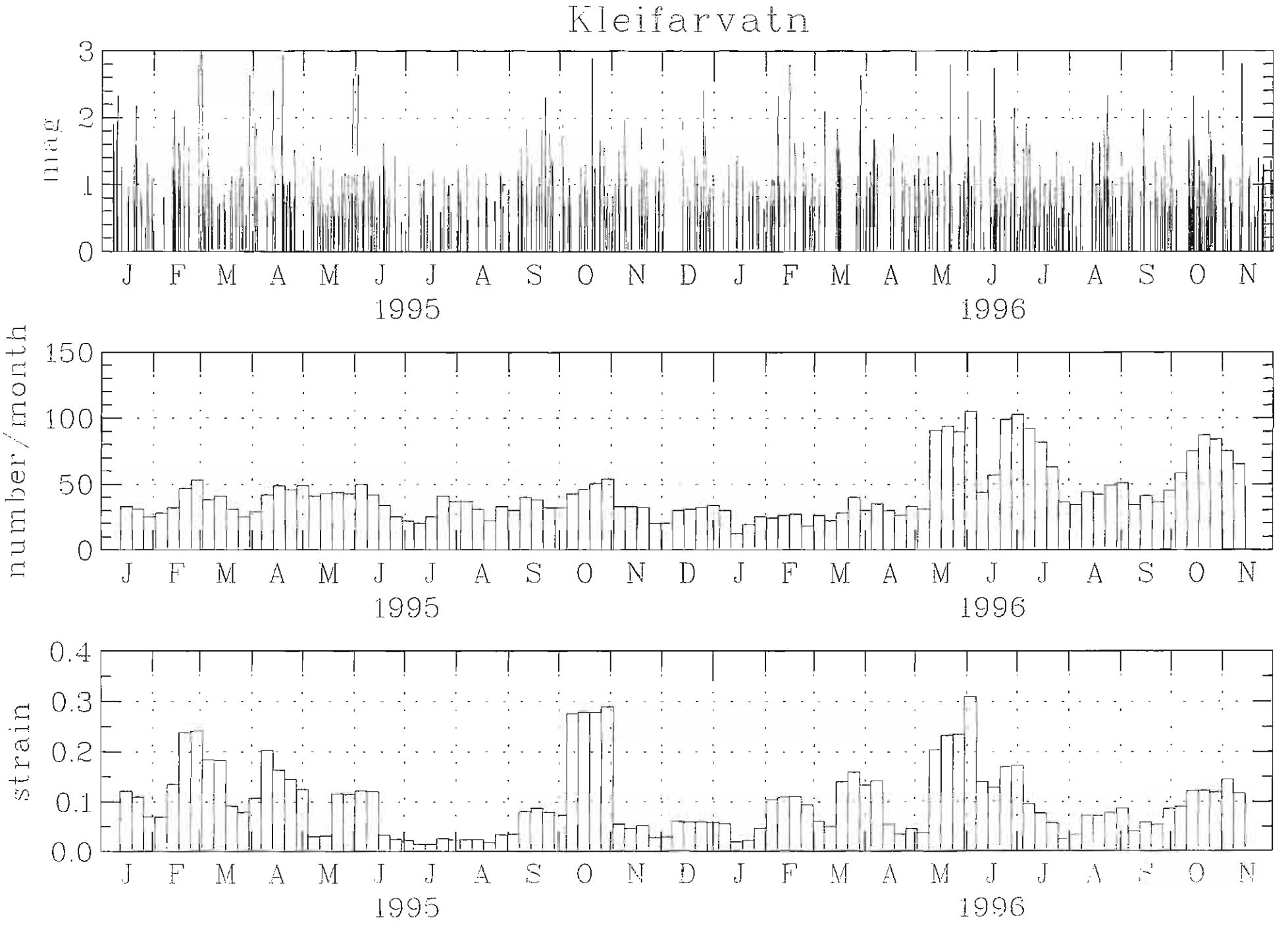
In the following there are two pages for each area. On the first the magnitude and 30 days running averages of number and strainrelease with 7 days steps are plotted. On the second 7 days discrete averages of number and strainrelease as well as frequency distribution and cumulative number of eartquakes are plotted. The units of the strainrelease plots are Gigastrain. The bin size of the frequency distribution is 0.2. The cumulative number is plotted on logarithmic scale and crude estimate of logN as a function of magnitude (m), where N is the cumulative number, is given for most of the areas.

The order is:

Iceland (Ísland)
Kleifarvatn
Ölfus
Hengill
Suðurland
Mýrdalsjökull
Eyjafjallajökull
Torfajökull
Lang- and Hofsjökull (Lang- og Hofsjökull)
Bárðarbunga
Flatey (Flateyjarbrotabeltið)
Húsavík
Grímsey (Grímseyjarbrotabeltið)


Island
6
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number/month
4000
3000
2000
1000
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
60
40
20
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996


Island
number / week
2000
1000
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
40
30
20
10
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
7000
6000
5000
4000
3000
2000
1000
0
−1 0 1 2 3 4 5
mag
number
100000
10000
1000
100
10
1
0.1
−1 0 1 2 3 4 5
mag


Kleifarvatn
mag
3
2
1
0
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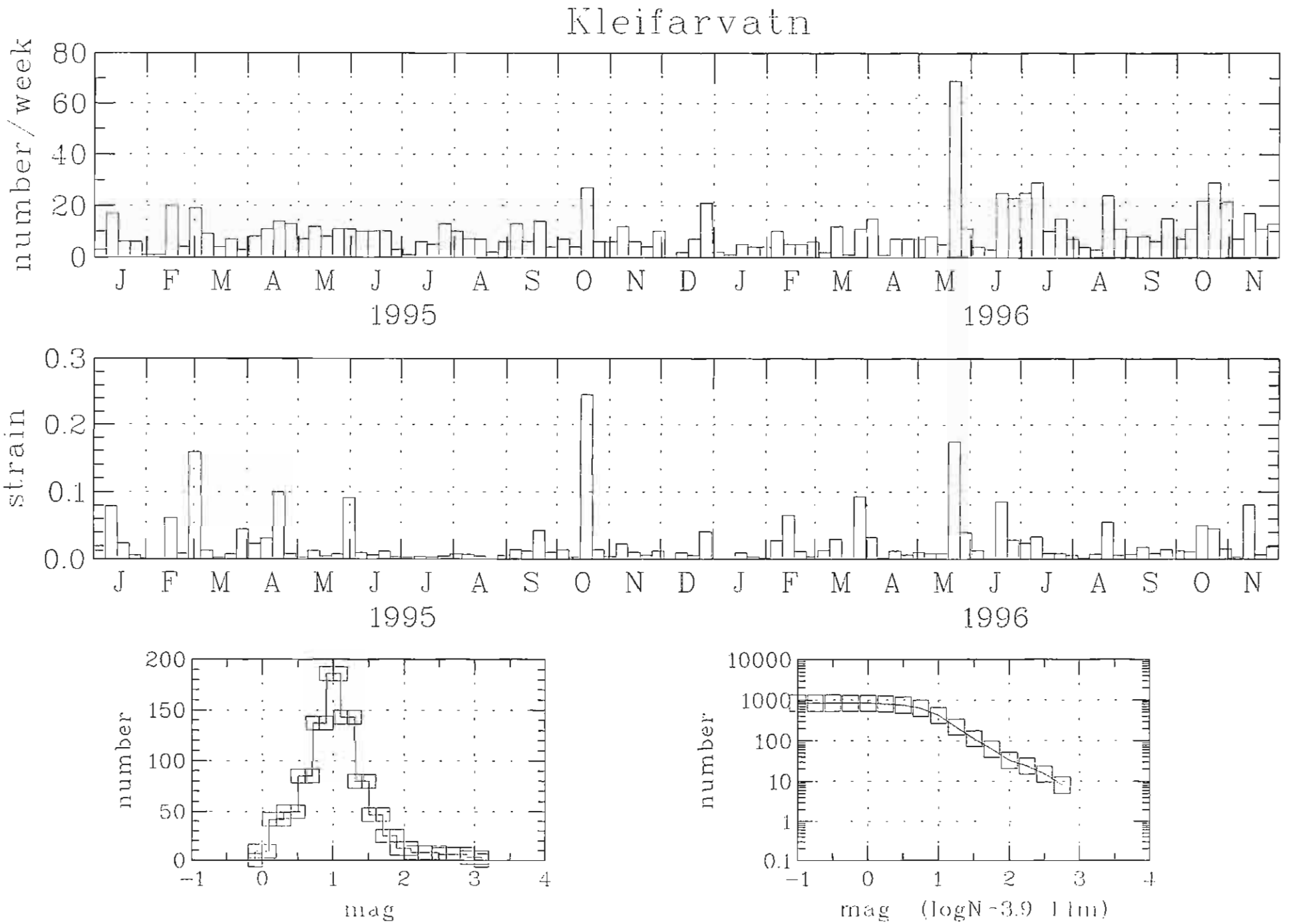
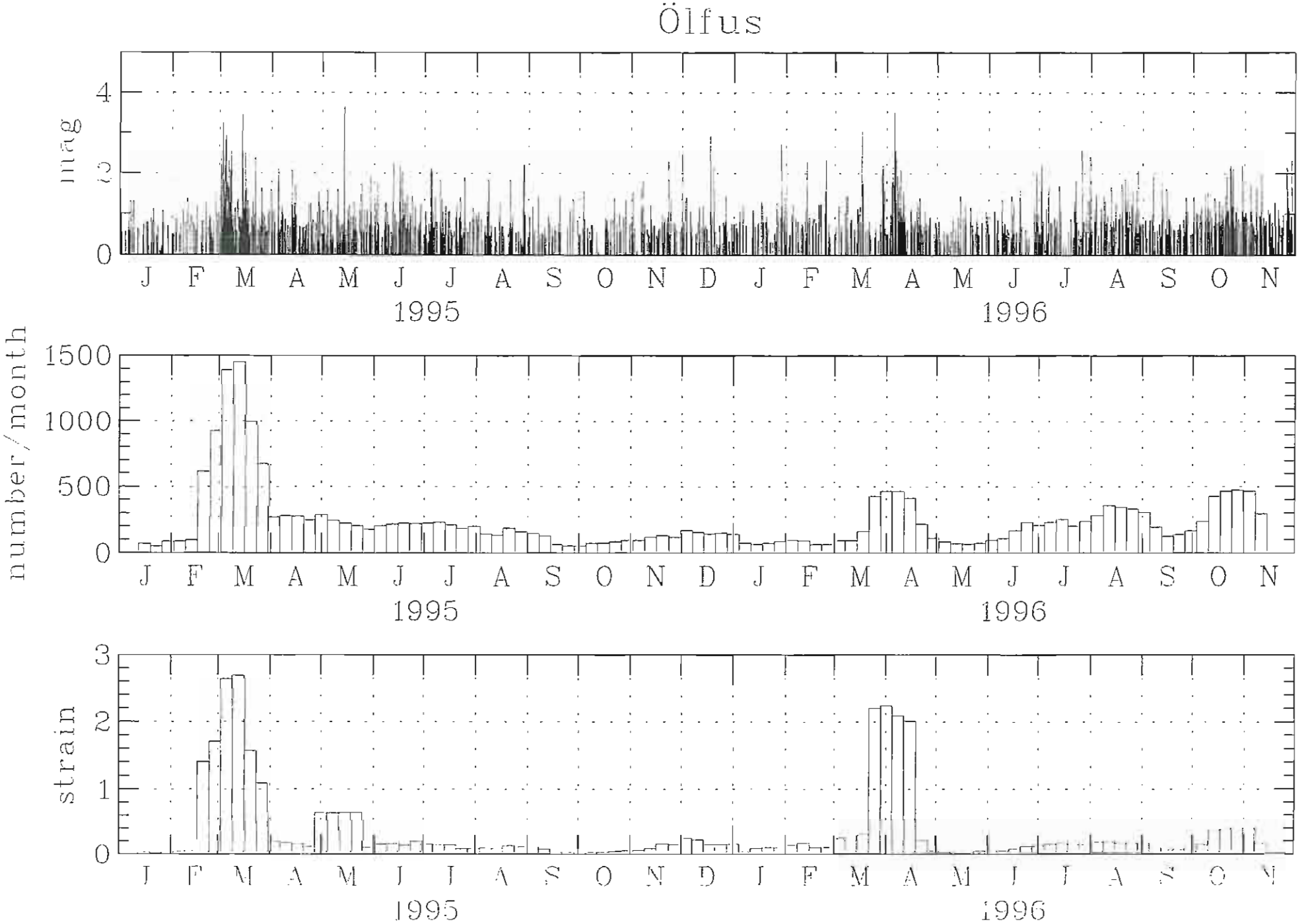
1995
1996
number/month
150
100
50
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
0.4
0.3
0.2
0.1
0.0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996


Kleifarvatn
number / week
80
60
40
20
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
0.3
0.2
0.1
0.0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
200
150
100
50
0
−1 0 1 2 3 4
mag
number
10000
1000
100
10
1
0.1
−1 0 1 2 3 4
mag (logN=3.9 1m)


Ölfus
mag
4
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number/month
1500
1000
500
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
3
2
1
0
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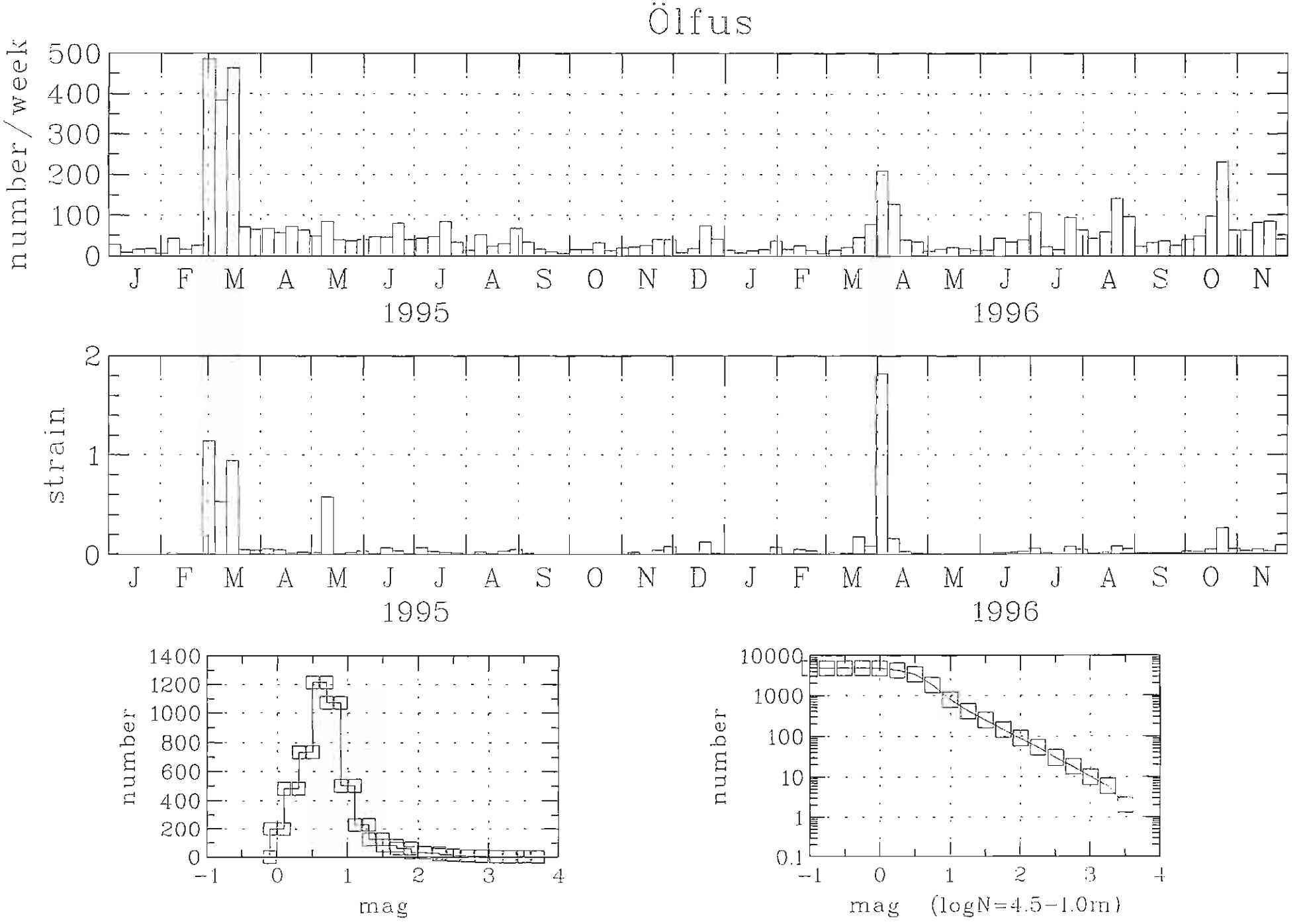
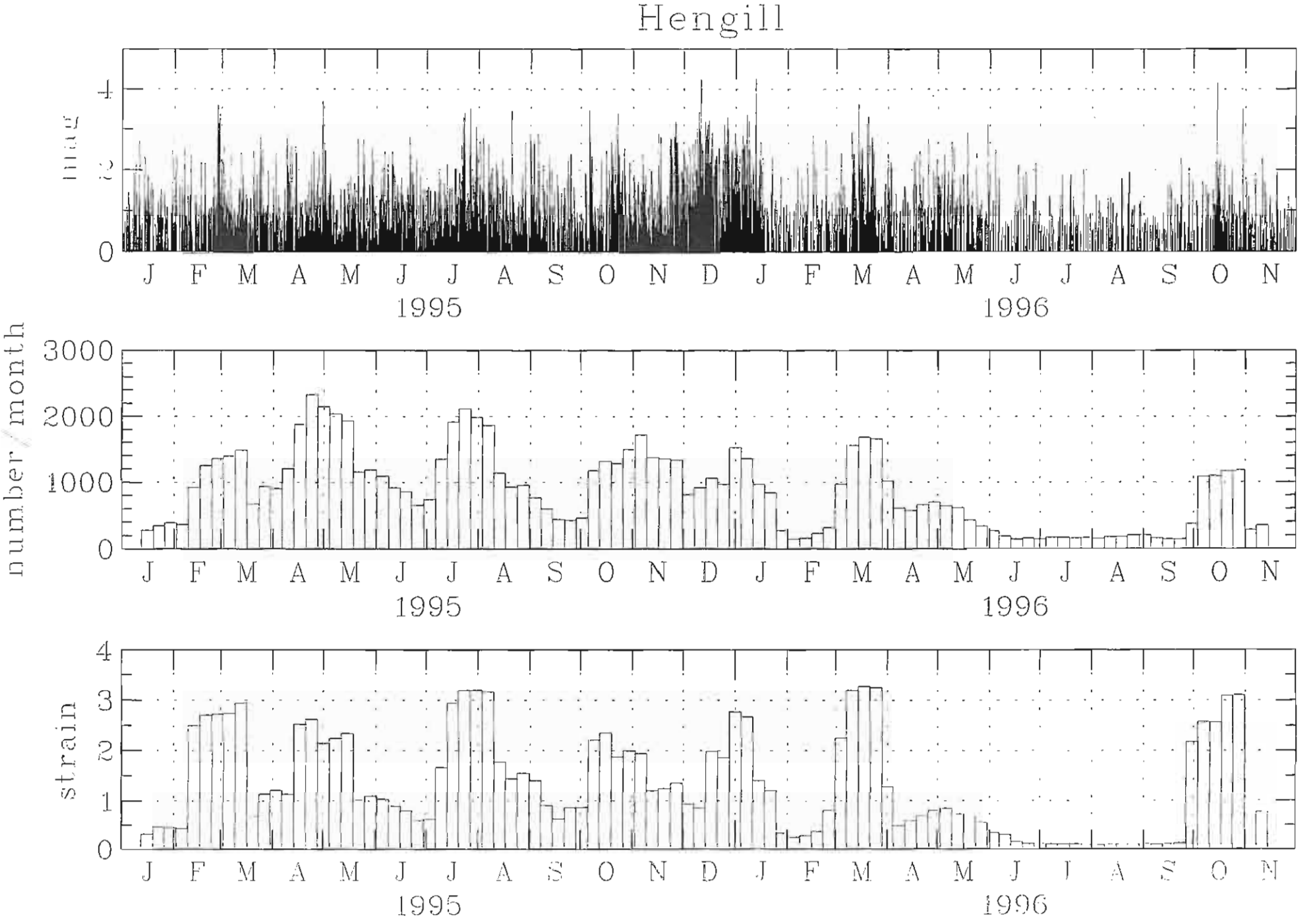
1995
1996


Ölfus
number/week
500
400
300
200
100
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
2
1
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
1400
1200
1000
800
600
400
200
0
−1 0 1 2 3 4
mag
number
10000
1000
100
10
1
0.1
−1 0 1 2 3 4
mag (logN=4.5−1.0m)


Hengill
number / month
strain
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1000
2000
3000
1
2
3
4
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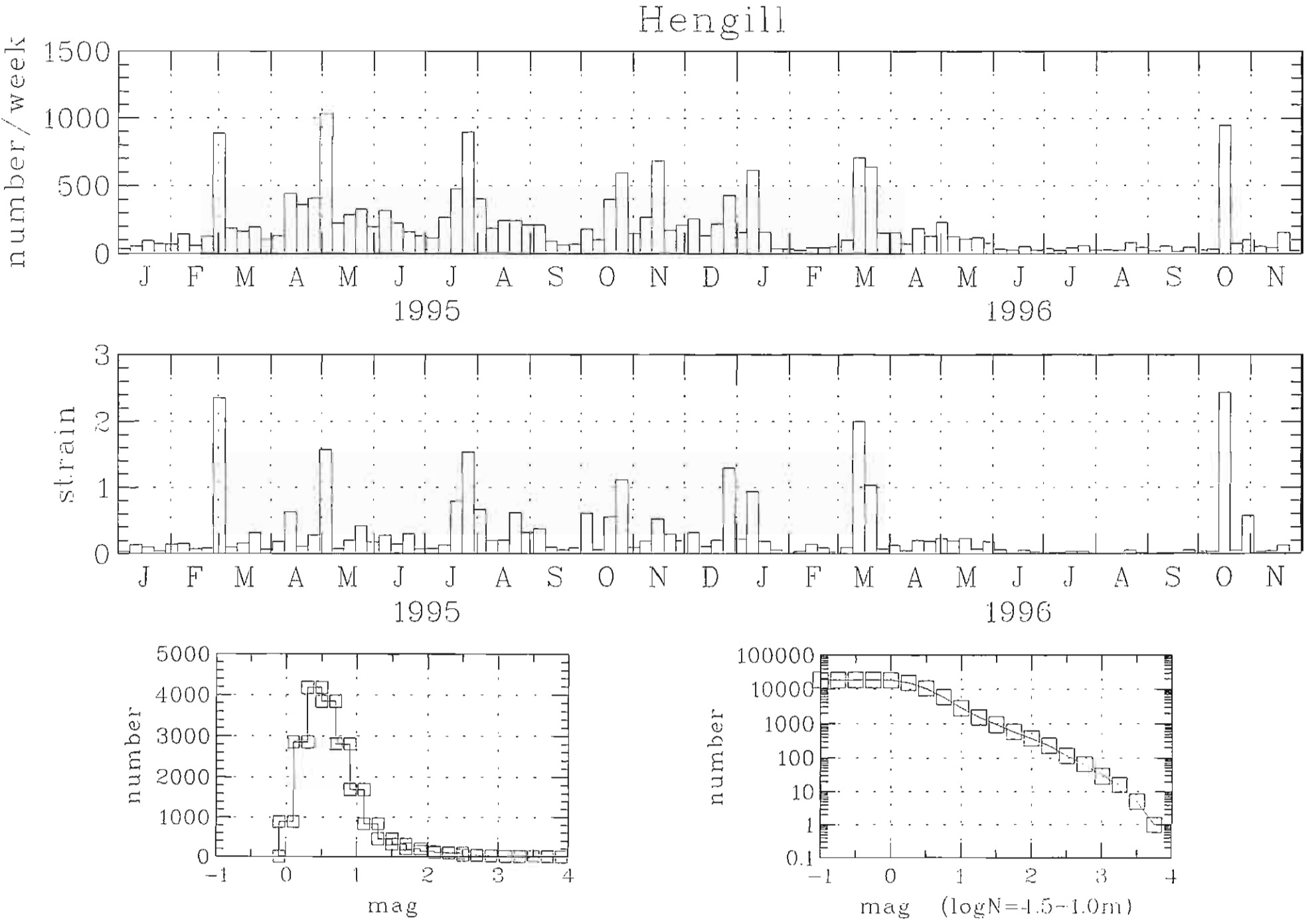
1995
1996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number/week
1500
1000
500
0
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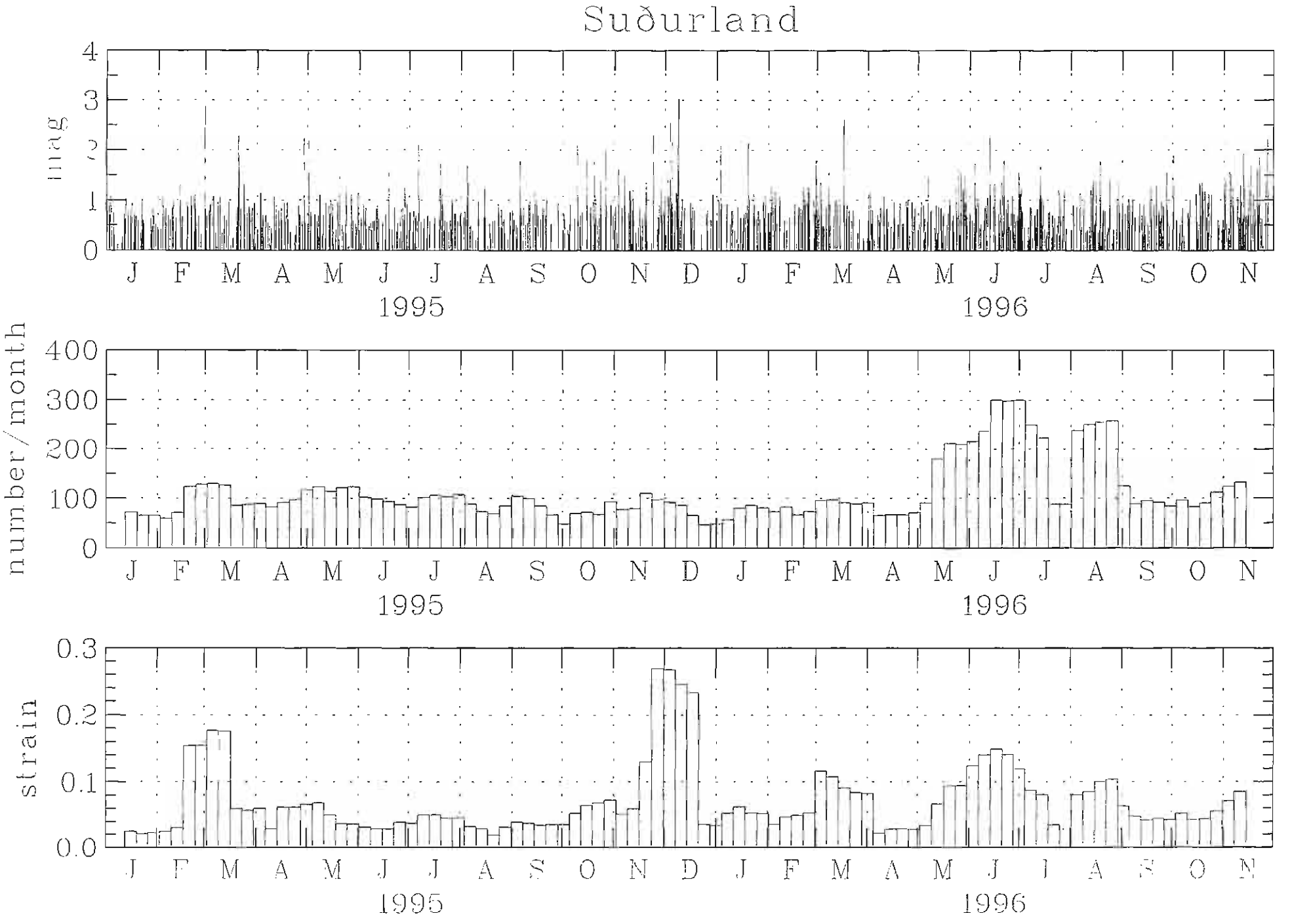
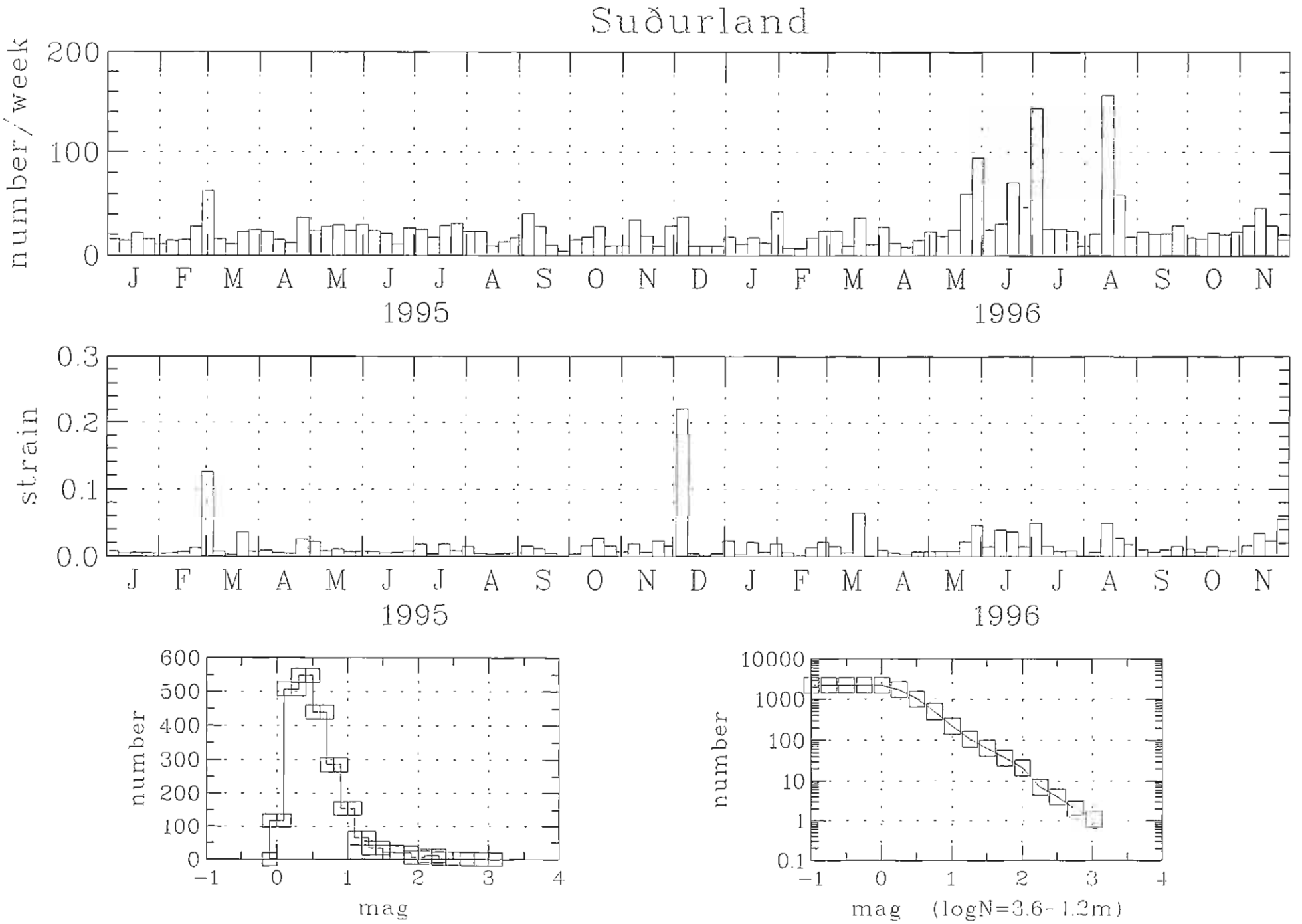
1995
1996
strain
3
2
1
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
5000
4000
3000
2000
1000
0
−1 0 1 2 3 4
mag
number
100000
10000
1000
100
10
1
0.1
−1 0 1 2 3 4
mag (logN=4.5-1.0m)


Suðurland
mag
0
1
3
4
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number/month
0
100
200
300
400
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
0.0
0.1
0.2
0.3
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996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number/week
200
100
0
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1995
1996
strain
0.3
0.2
0.1
0.0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
600
500
400
300
200
100
0
−1 0 1 2 3 4
mag
number
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100
10
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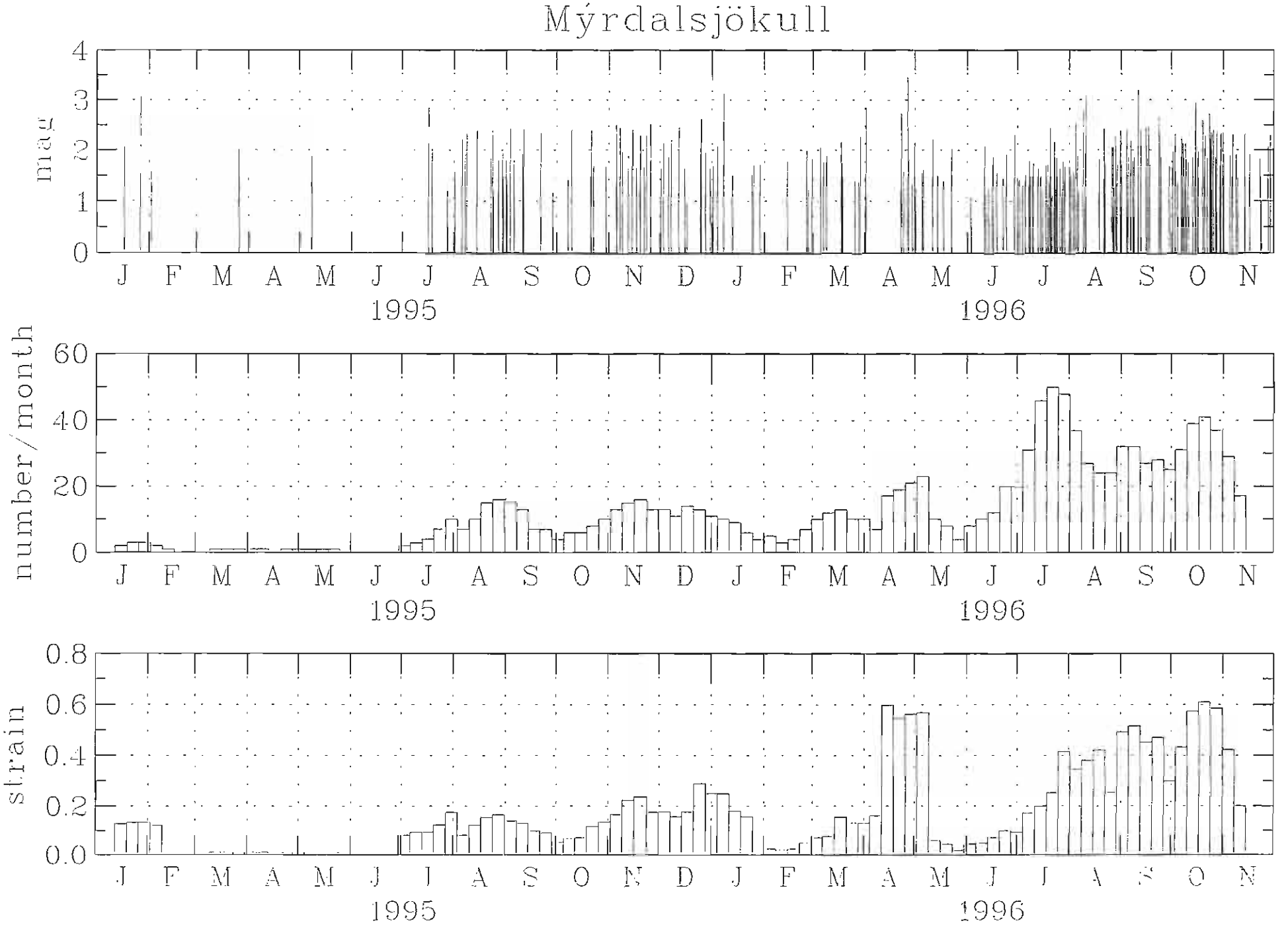
0.1
−1 0 1 2 3 4
mag (logN=3.6-1.2m)


Mýrdalsjökull
mag
0
1
2
3
4
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1995
1996
number/month
0
20
40
60
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
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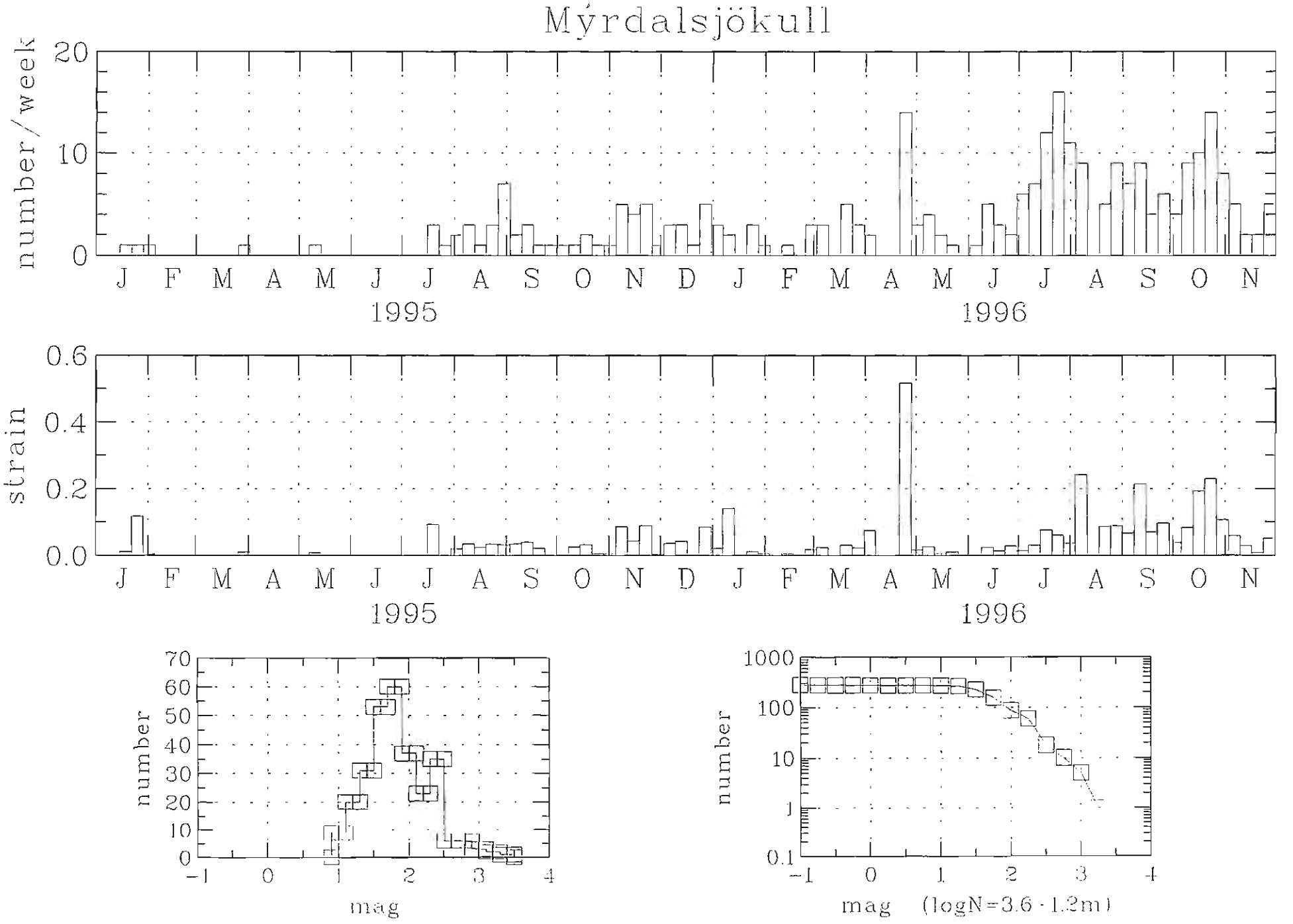
1995
1996


Mýrdalsjökull
number/week
20
10
0
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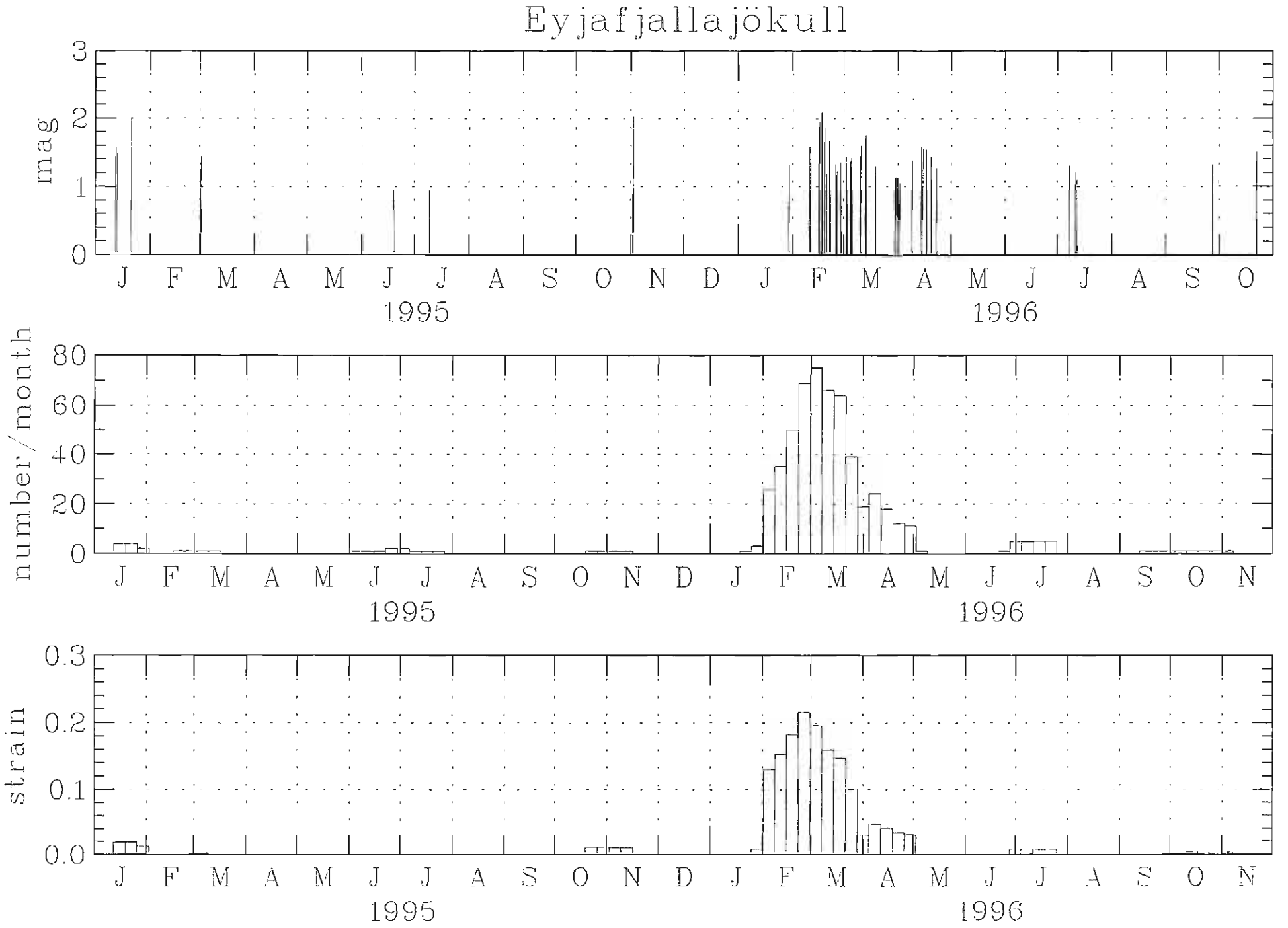
1995
1996
strain
0.6
0.4
0.2
0.0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
70
60
50
40
30
20
10
0
−1 0 1 2 3 4
mag
number
1000
100
10
1
0.1
−1 0 1 2 3 4
mag (logN=3.6 - 1.2m)


Eyjafjallajökull
mag
0
1
2
3
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1995
1996
number/month
0
20
40
60
80
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
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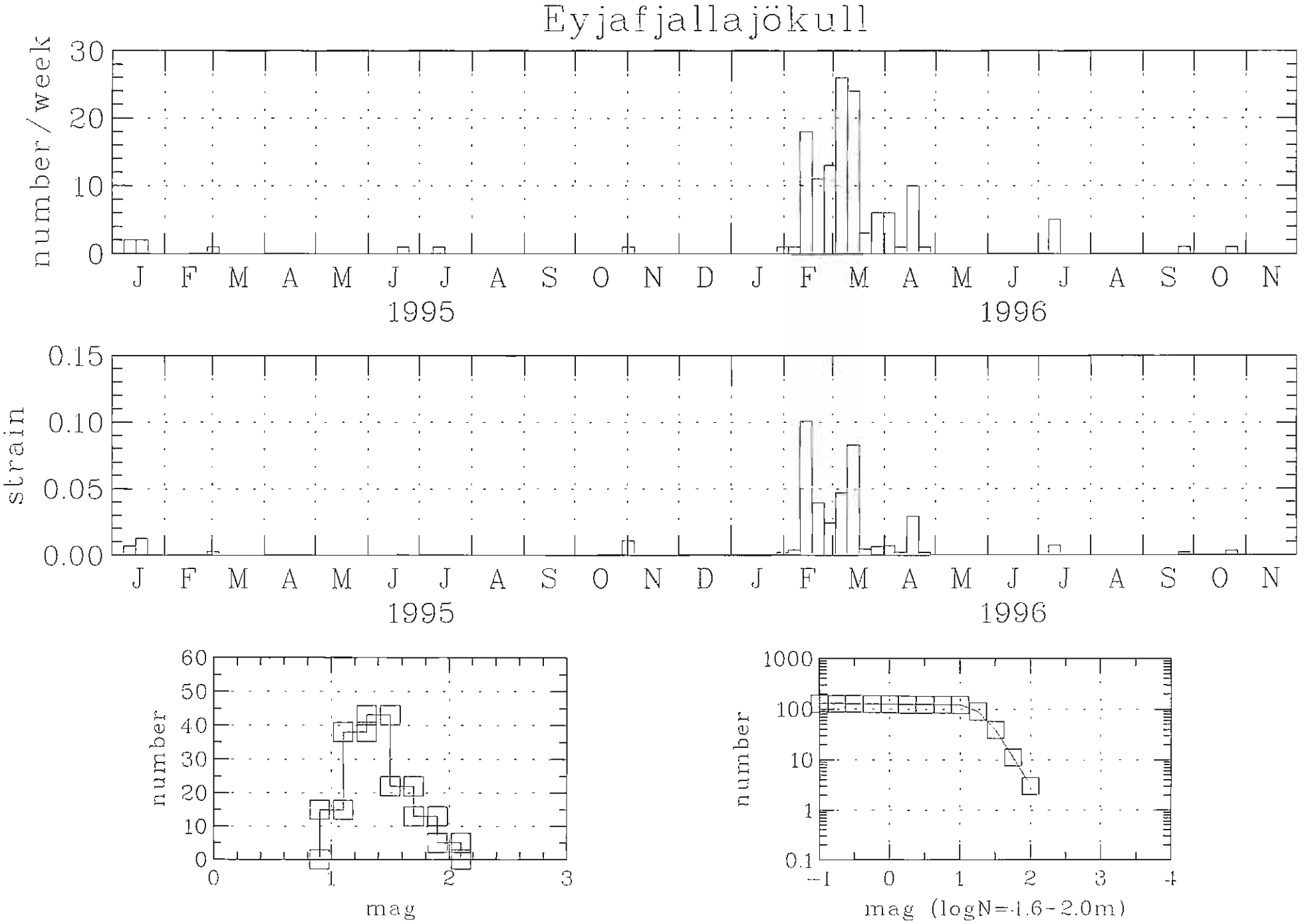
1995
1996


Eyjafjallajökull
number/week
30
20
10
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
0.15
0.10
0.05
0.00
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
60
50
40
30
20
10
0
0 1 2 3
mag
number
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100
10
1
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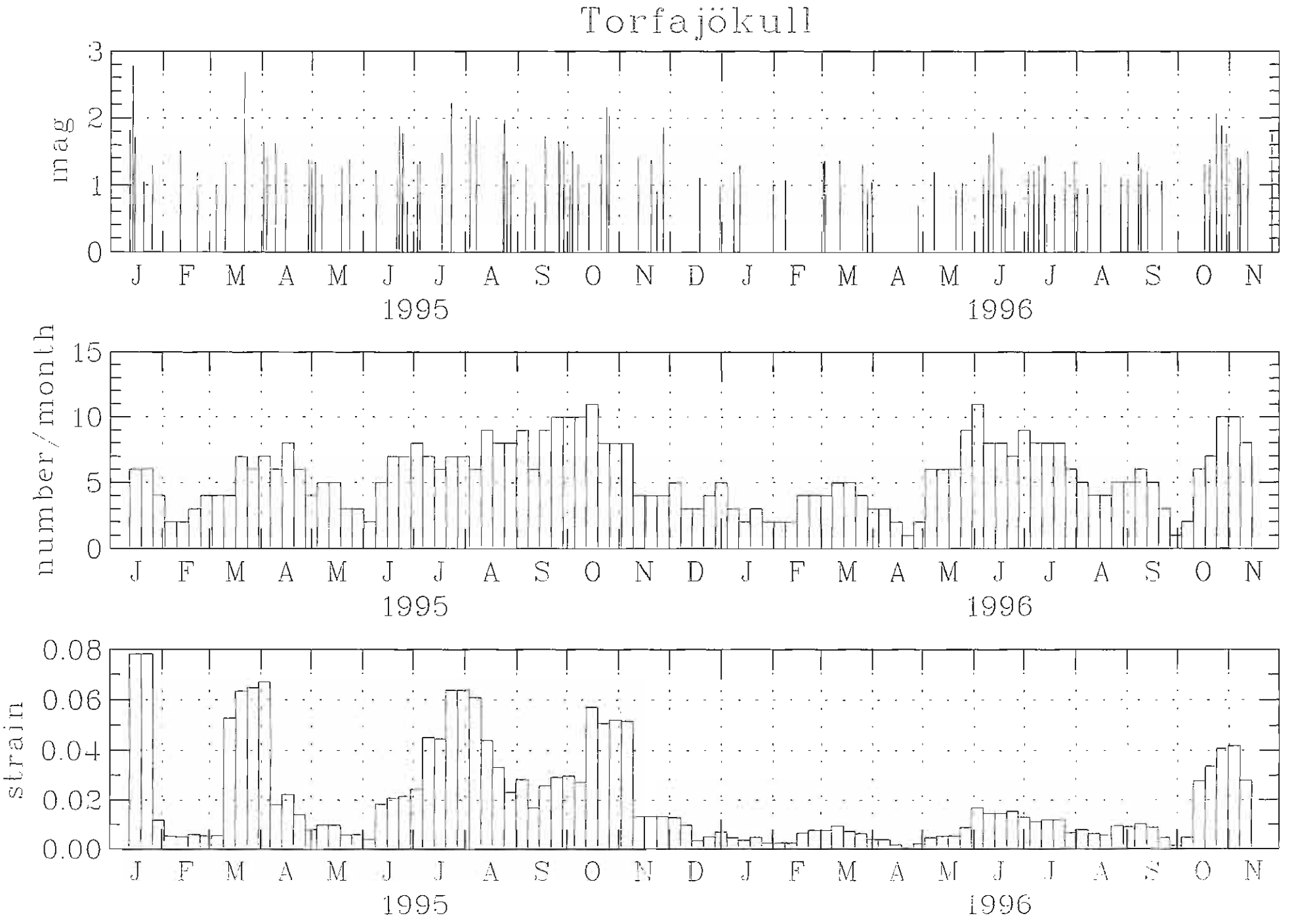
-1 0 1 2 3 4
mag (logN=-1.6-2.0m)


Torfajökull
mag
0
1
2
3
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1995
1996
number / month
0
5
10
15
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
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0.04
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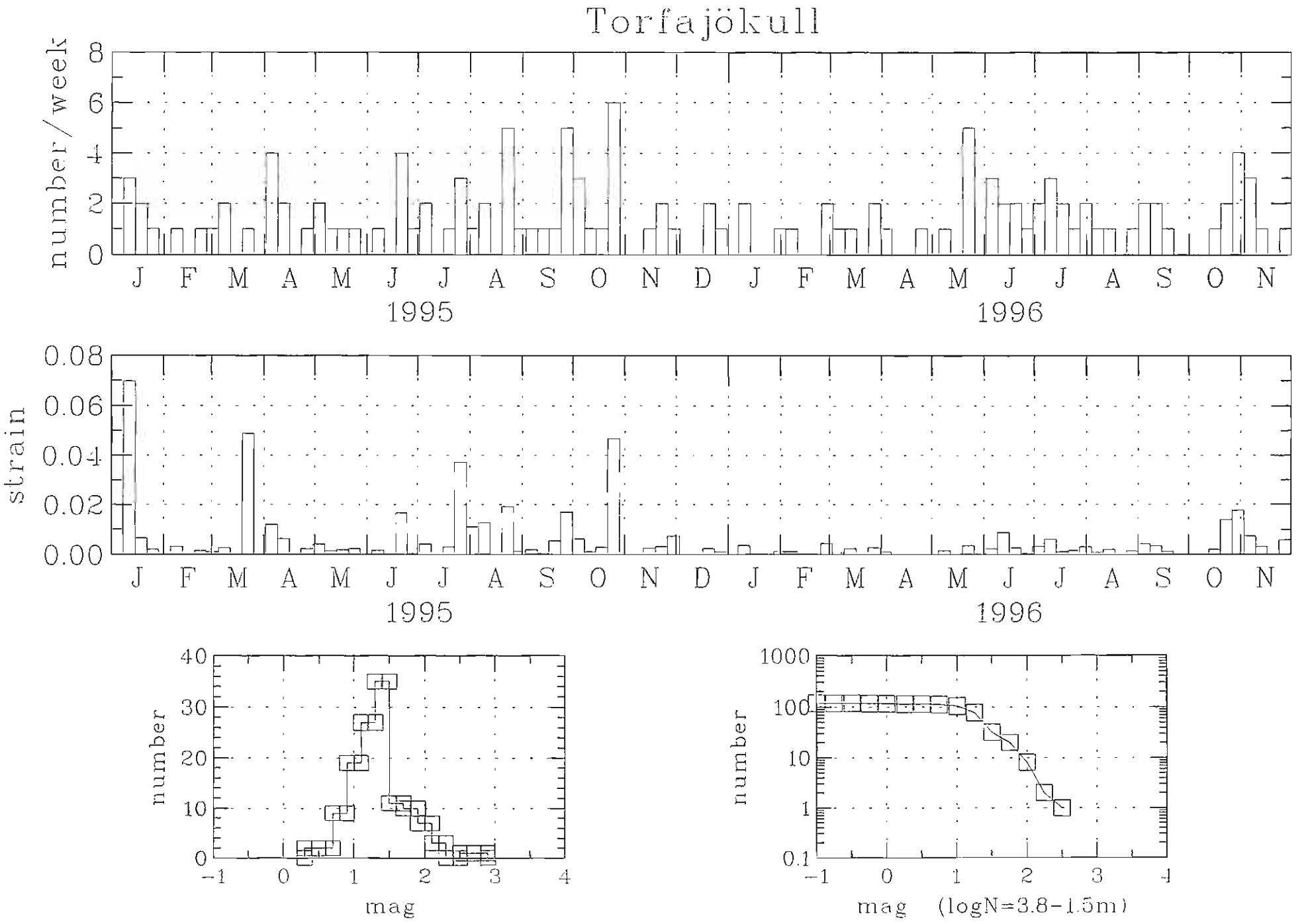
1995
1996


Torfajökull
number/week
0
2
4
6
8
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1995
1996
strain
0.00
0.02
0.04
0.06
0.08
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
0
10
20
30
40
−1 0 1 2 3 4
mag
number
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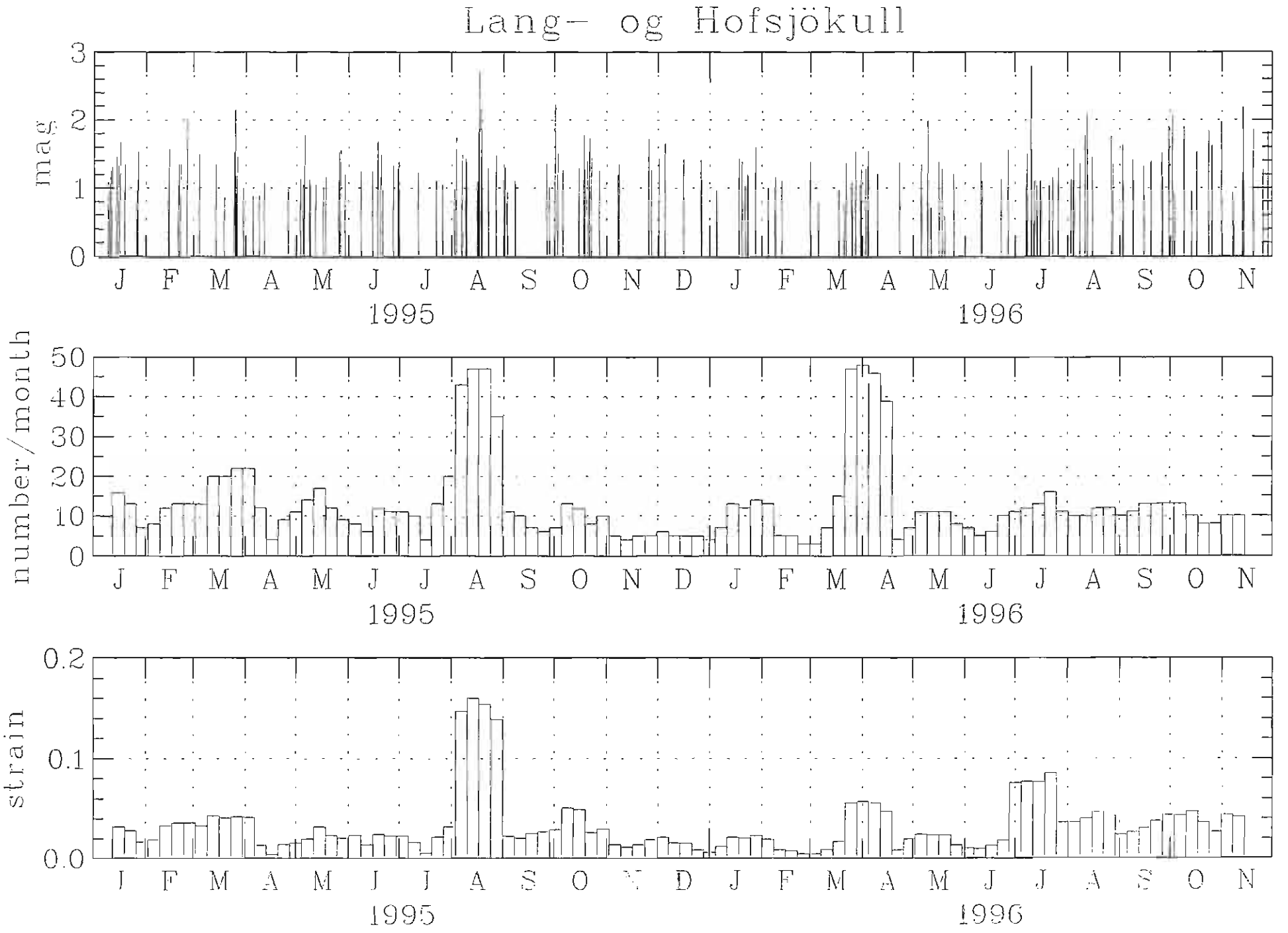
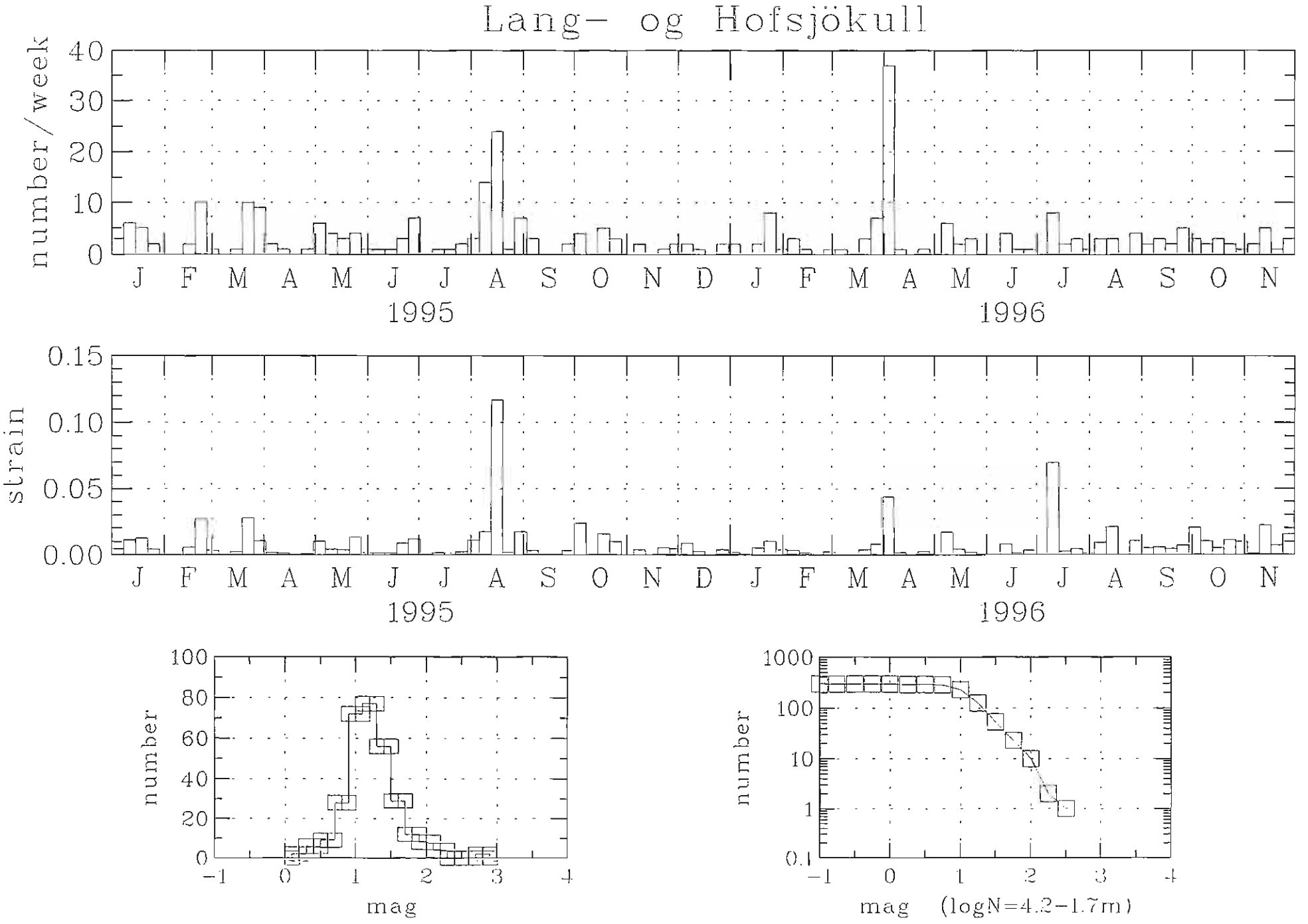
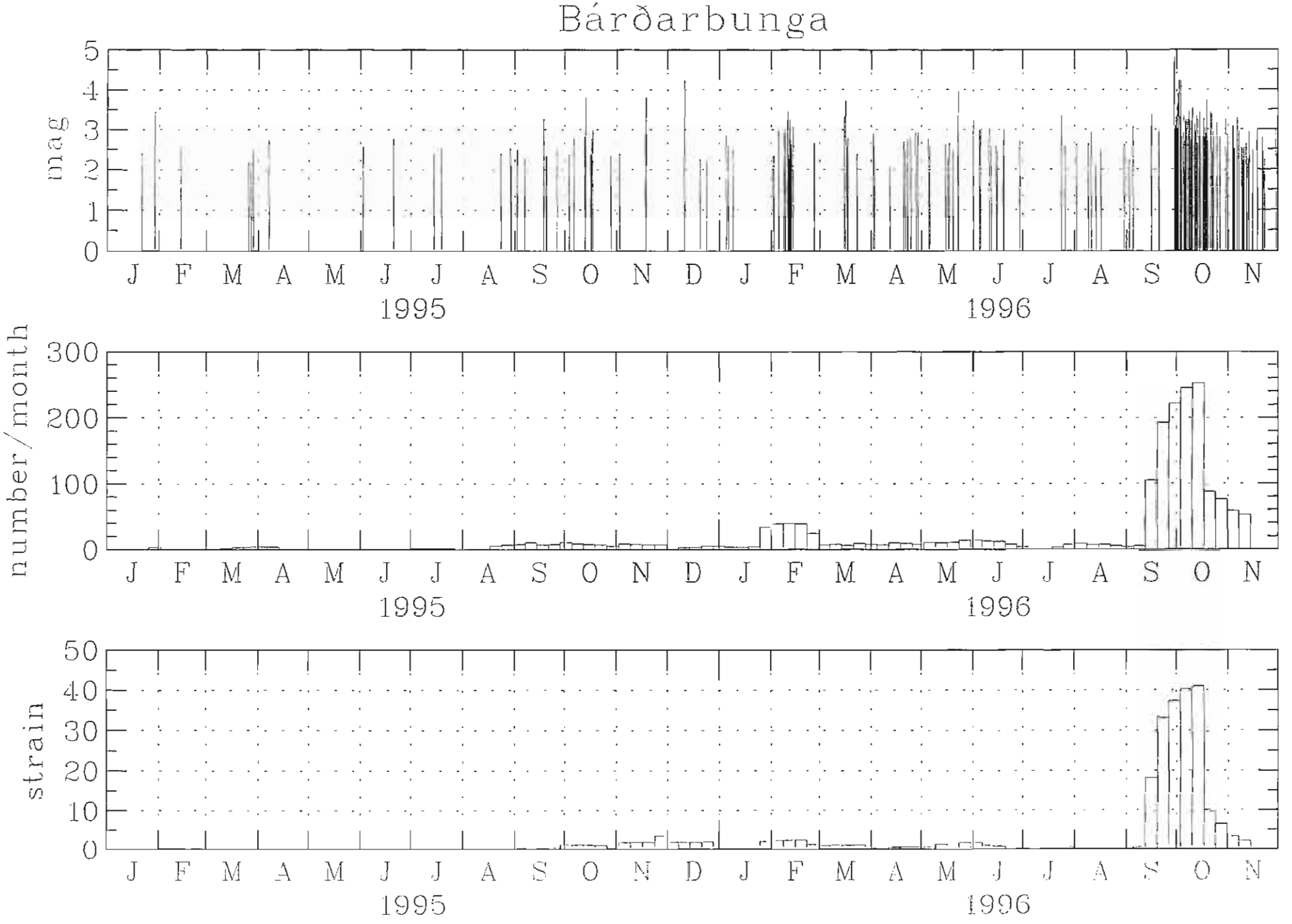
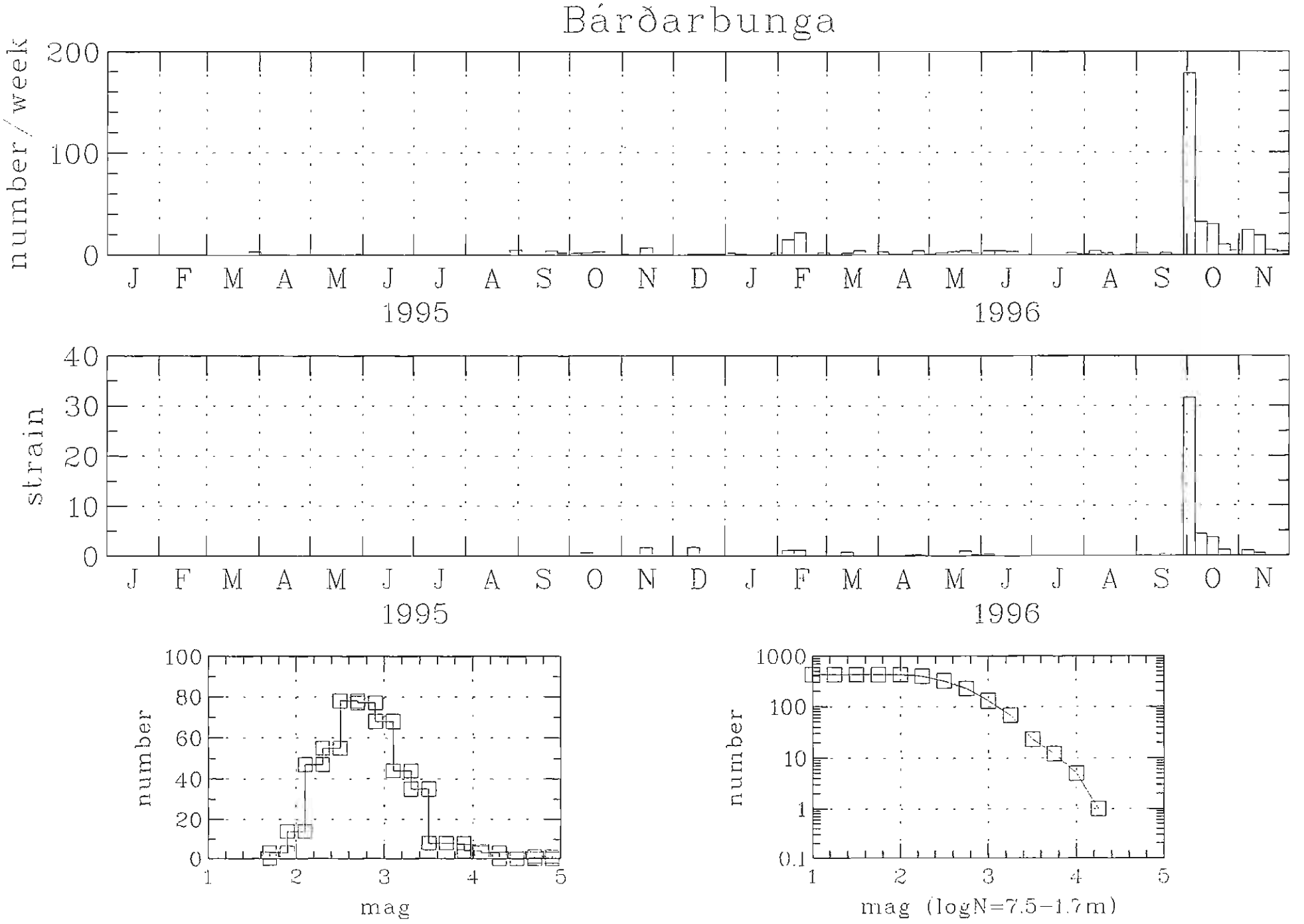
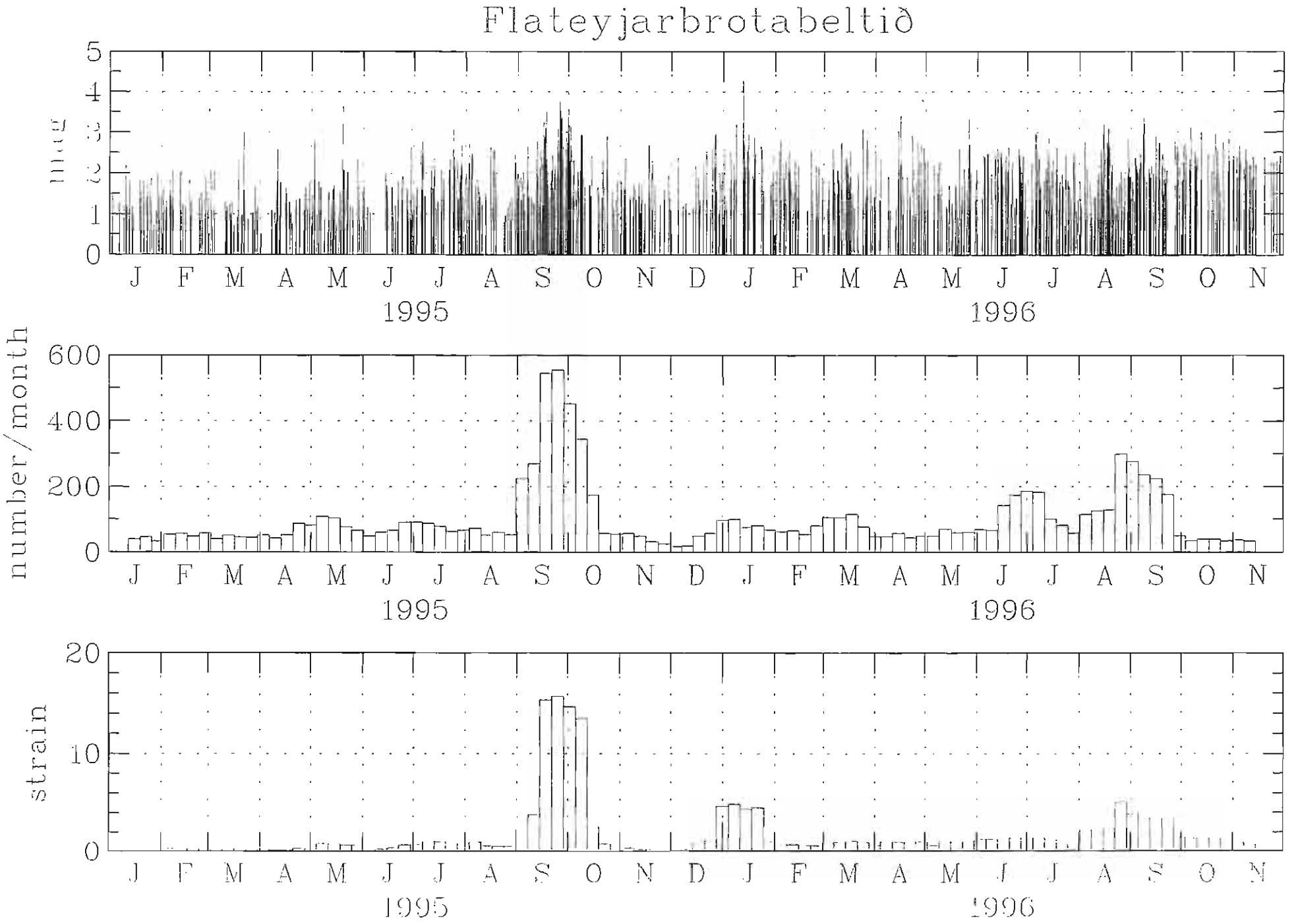
1
10
100
1000
−1 0 1 2 3 4
mag (logN=3.8−1.5m)

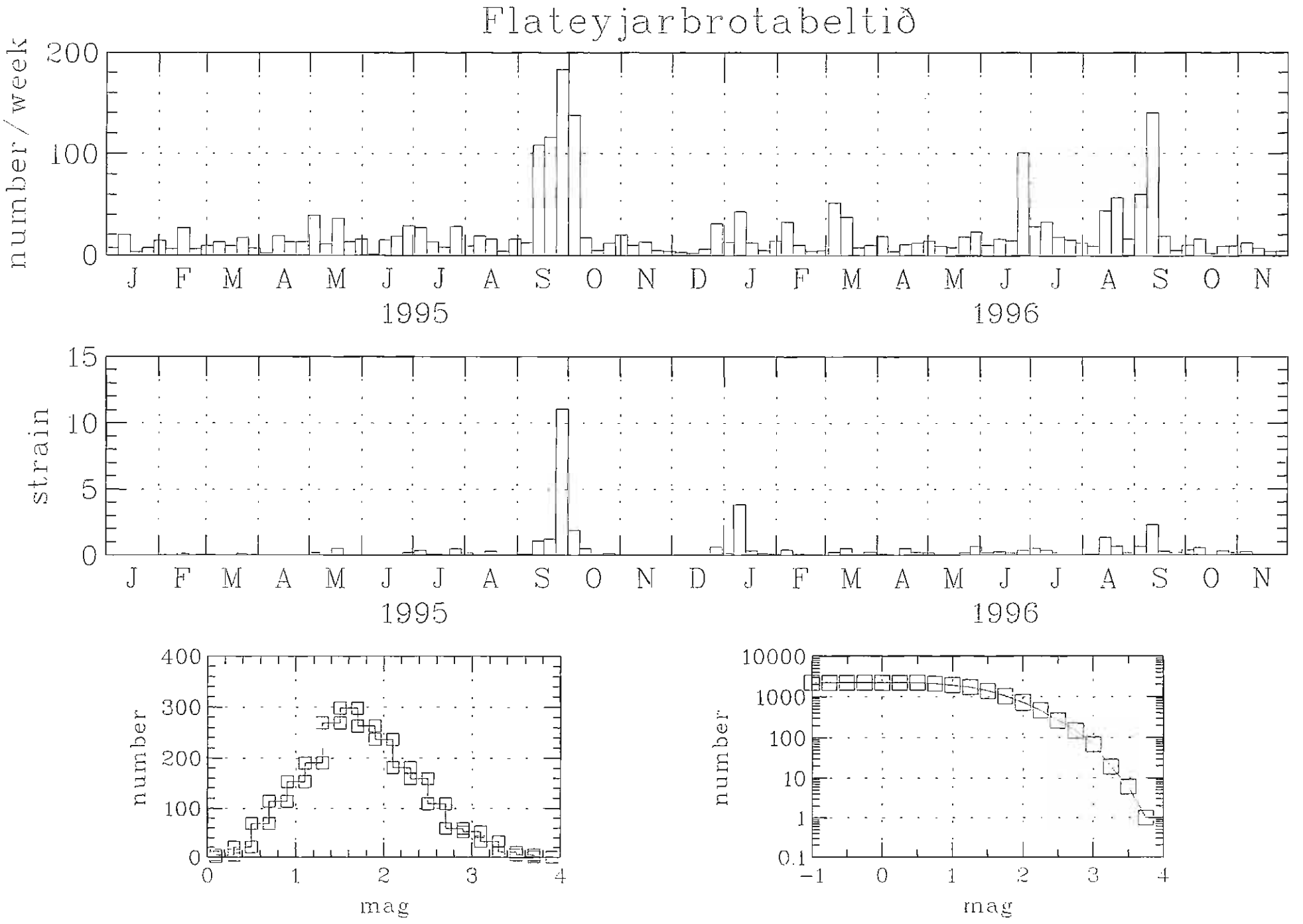

Lang- og Hofsjökull
mag
3
2
1
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number/month
50
40
30
20
10
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
0.2
0.1
0.0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996

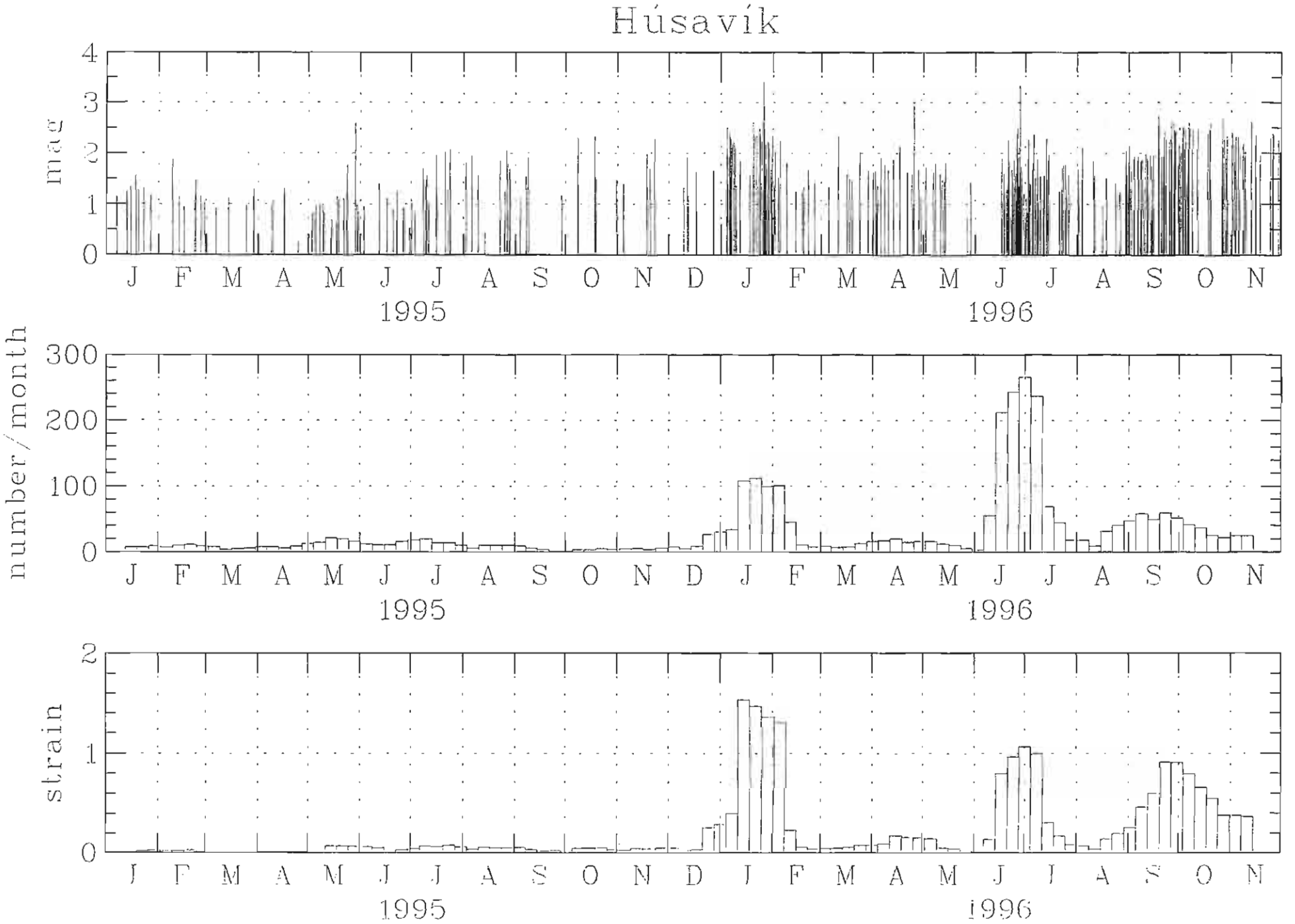

Lang- og Hofsjökull
number/week
0
10
20
30
40
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
0.00
0.05
0.10
0.15
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
0
20
40
60
80
100
−1 0 1 2 3 4
mag
number
0.1
1
10
100
1000
−1 0 1 2 3 4
mag (logN=4.2−1.7m)

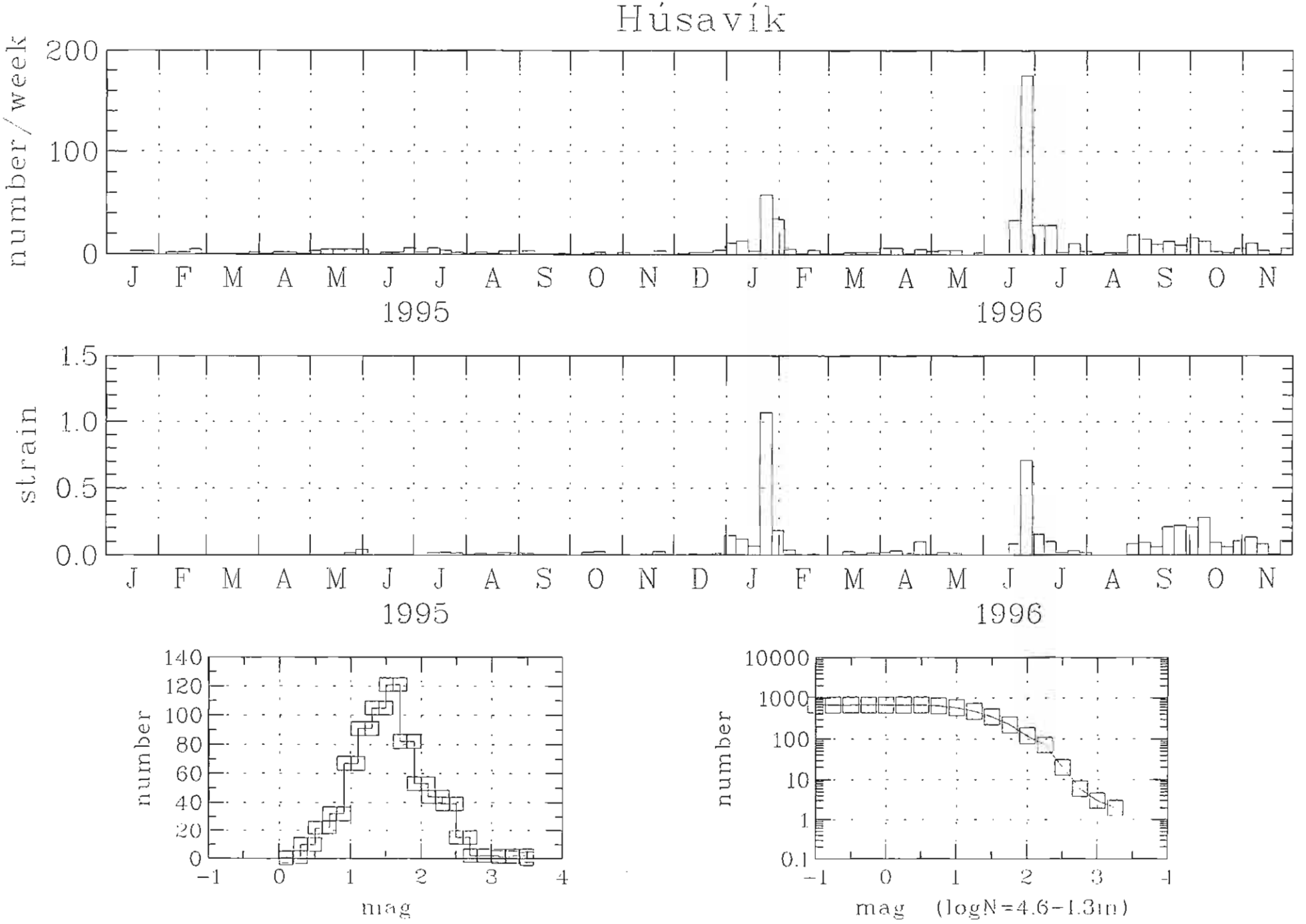

Bárðarbunga
mag
0
1
2
3
4
5
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number/month
0
100
200
300
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
0
10
20
30
40
50
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996

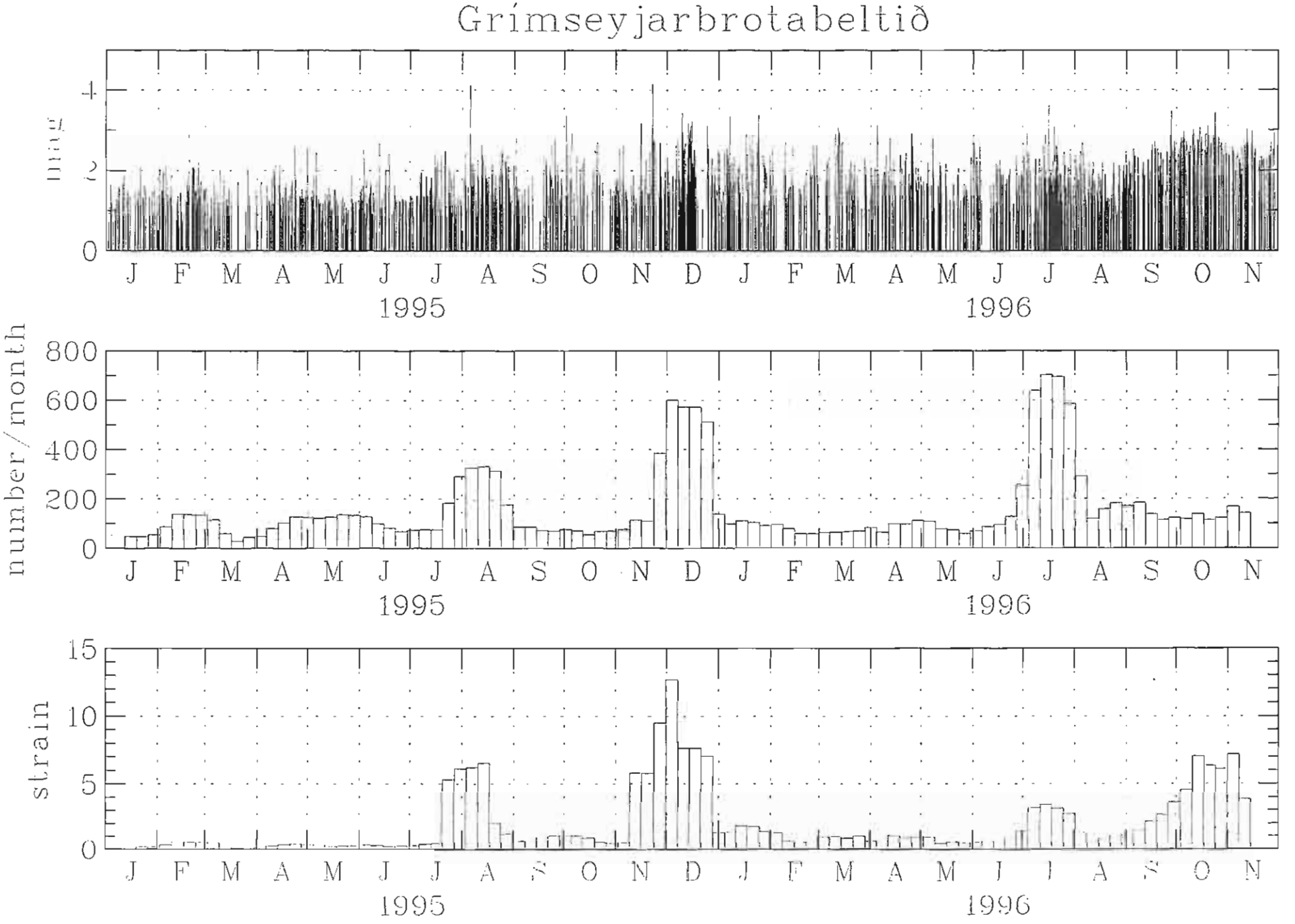

Bárðarbunga
number / week
200
100
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
40
30
20
10
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
100
80
60
40
20
0
1 2 3 4 5
mag
number
1000
100
10
1
0.1
1 2 3 4 5
mag (logN=7.5-1.7m)

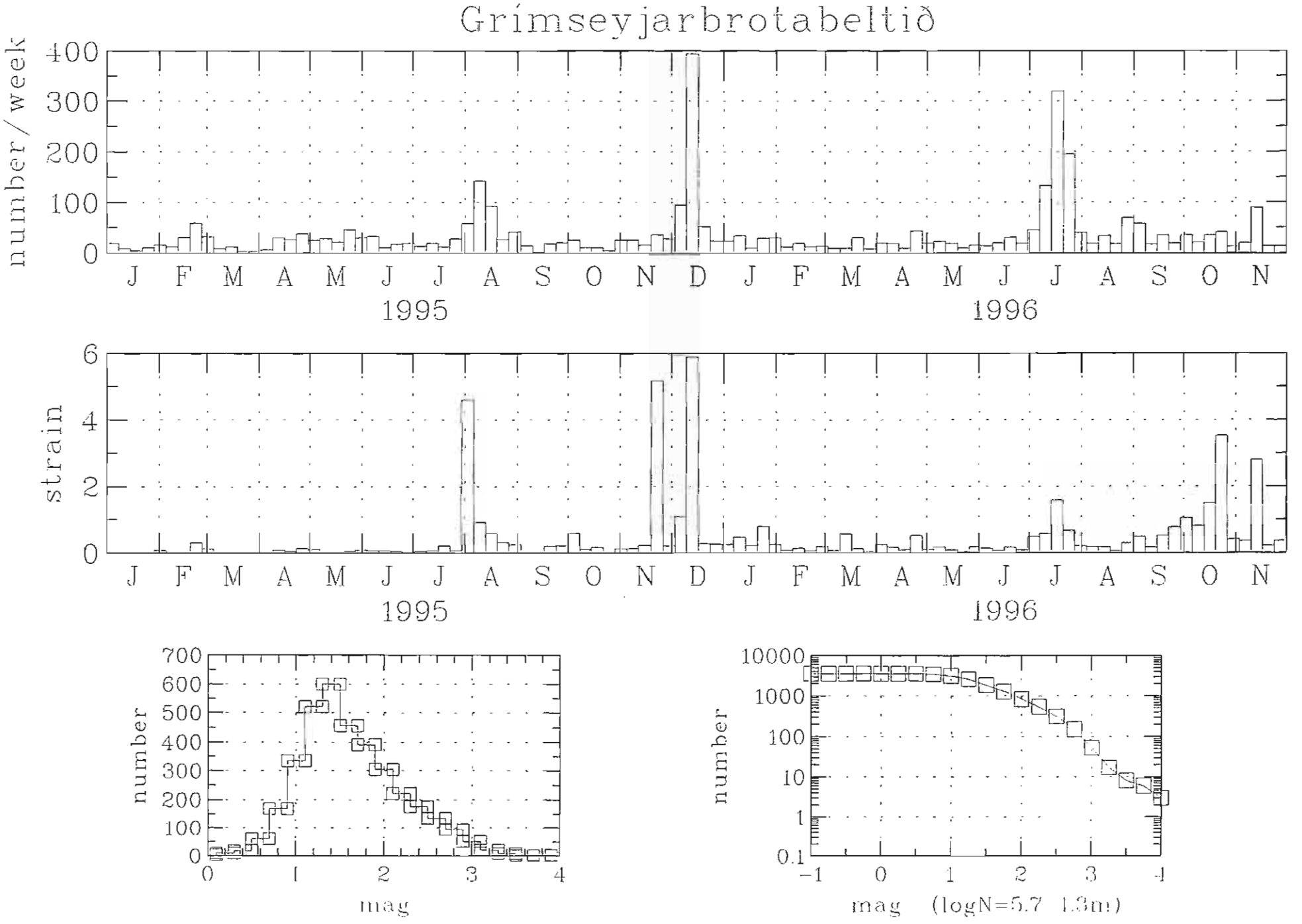

Flateyjarbrotabeltið
5
4
1
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number/month
600
400
200
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
20
10
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996


Flateyjarbrotabeltið
number / week
200
100
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
15
10
5
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
400
300
200
100
0
0 1 2 3 4
mag
number
10000
1000
100
10
1
0.1
−1 0 1 2 3 4
mag


Húsavík
mag
number/month
strain
0
1
2
3
4
100
200
300
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996


Húsavík
number/week
200
100
0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
1.5
1.0
0.5
0.0
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
140
120
100
80
60
40
20
0
−1 0 1 2 3 4
mag
number
10000
1000
100
10
1
0.1
−1 0 1 2 3 4
mag (logN=4.6−1.3m)


Grímseyjarbrotabeltið
mag
0
2
4
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number/month
0
200
400
600
800
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
0
5
10
15
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996

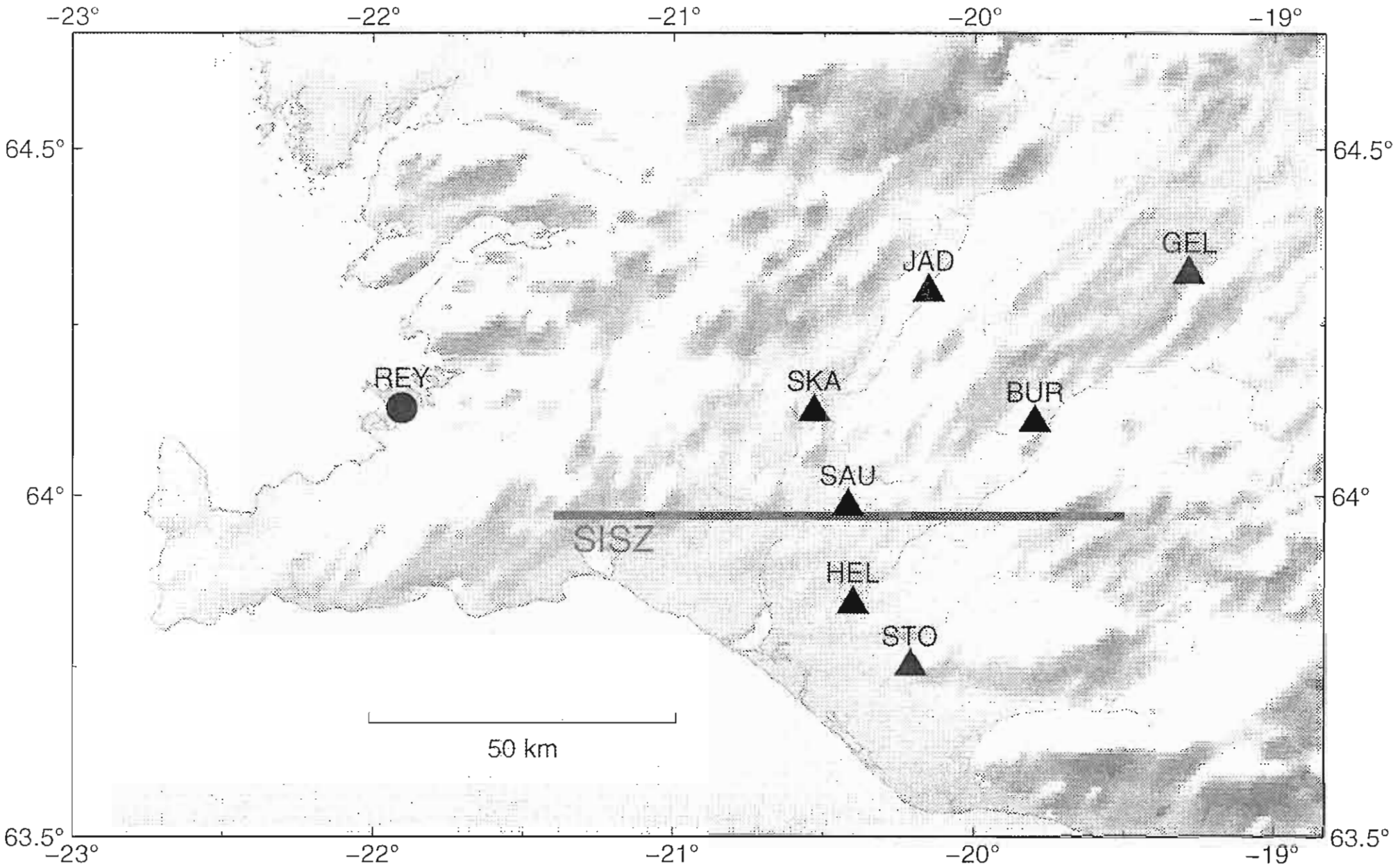

Grímseyjarbrotabeltið
number / week
0
100
200
300
400
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
strain
0
2
4
6
J F M A M J J A S O N D J F M A M J J A S O N
1995
1996
number
0
100
200
300
400
500
600
700
0 1 2 3 4
mag
number
0.1
1
10
100
1000
10000
−1 0 1 2 3 4
mag (logN=5.7 1.3m)

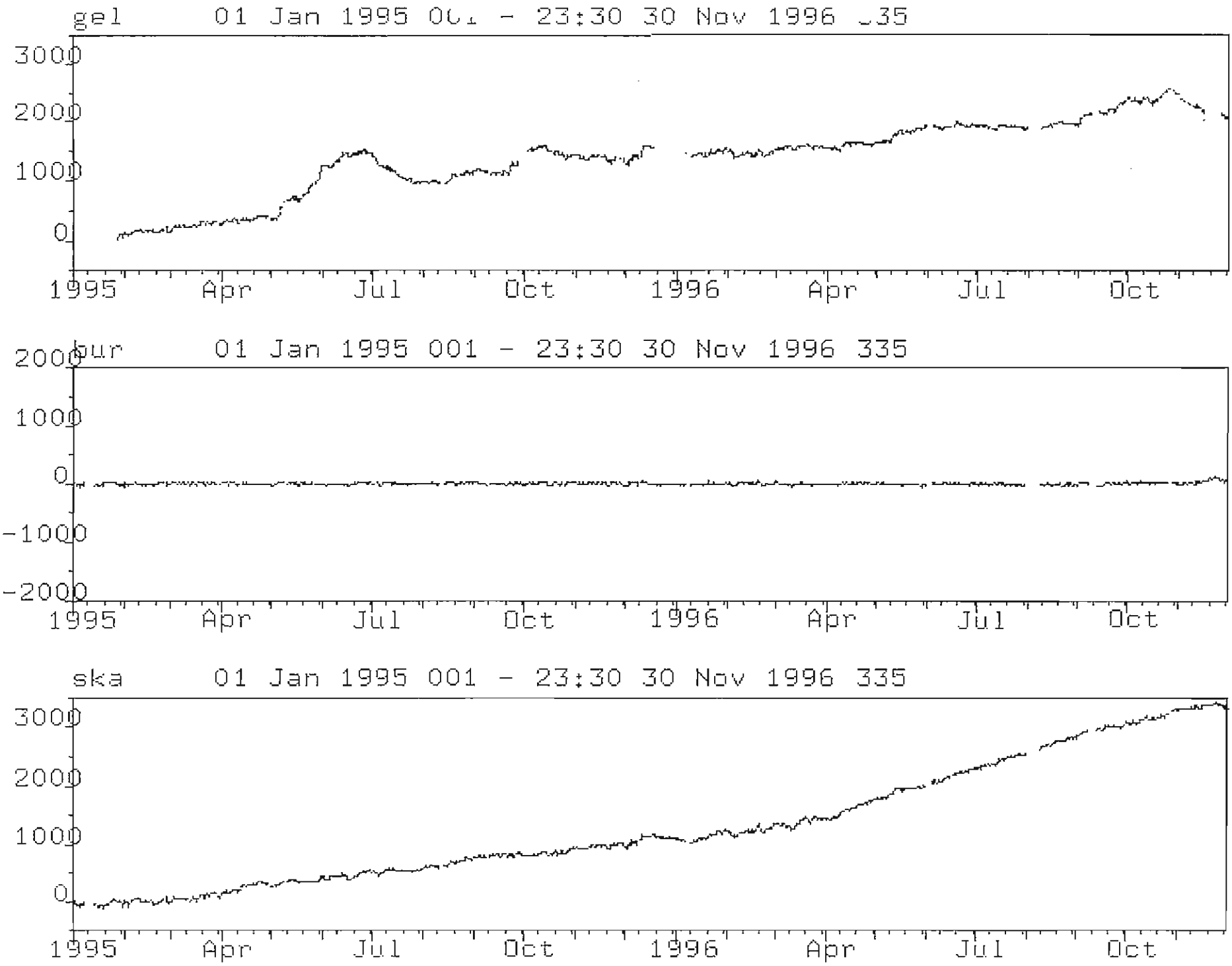
# Appendix B

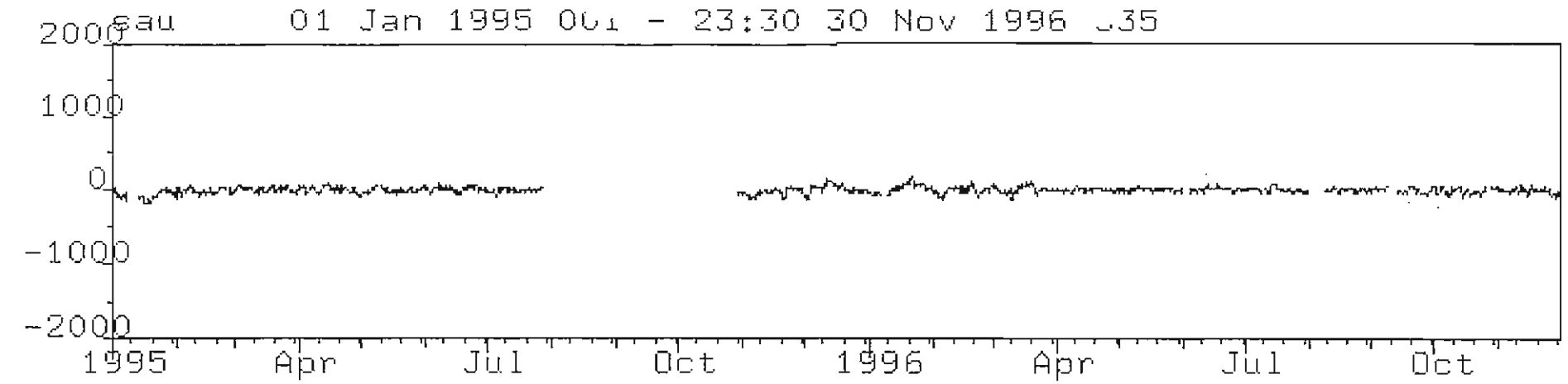
Location of strainmeters and strainmeter records. The records are scaled to nanostrain and contraction is up.

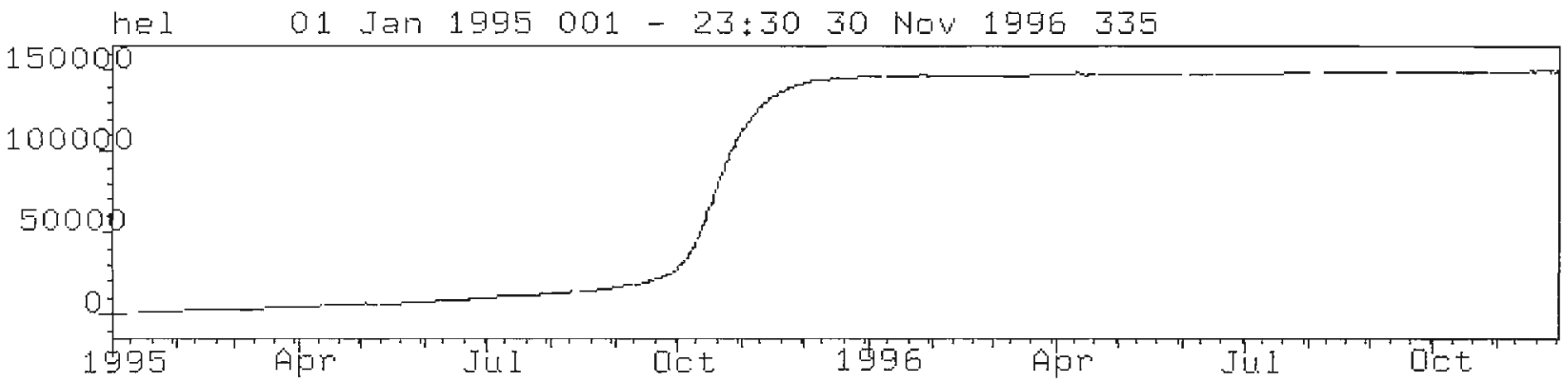
The order is:

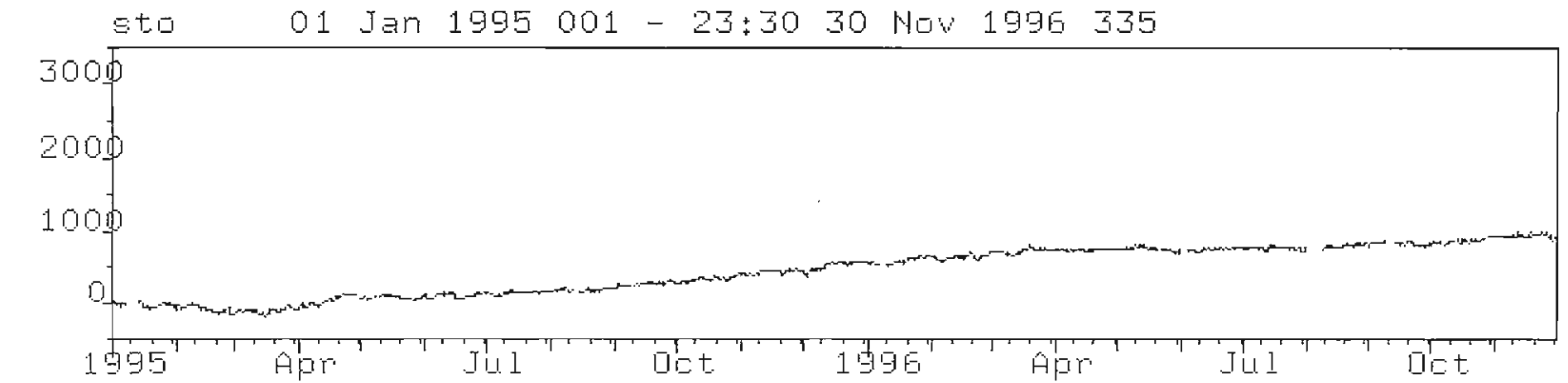
Location of the strainmeters and the South Iceland seismic zone (SISZ)
GEL, BUR, SKA
SAU, HEL, STO


−23°
−22°
−21°
−20°
−19°
64.5°
64°
63.5°
JAD
GEL
REY
SKA
BUR
SAU
SISZ
HEL
STO
50 km


gel 01 Jan 1995 001 - 23:30 30 Nov 1996 335
3000
2000
1000
0
1995 Apr Jul Oct 1996 Apr Jul Oct
bur 01 Jan 1995 001 - 23:30 30 Nov 1996 335
2000
1000
0
-1000
-2000
1995 Apr Jul Oct 1996 Apr Jul Oct
ska 01 Jan 1995 001 - 23:30 30 Nov 1996 335
3000
2000
1000
0
1995 Apr Jul Oct 1996 Apr Jul Oct


sau 01 Jan 1995 001 - 23:30 30 Nov 1996 335
2000
1000
0
-1000
-2000
1995
Apr
Jul
Oct
1996
Apr
Jul
Oct


hel 01 Jan 1995 001 - 23:30 30 Nov 1996 335
150000
100000
50000
0
1995
Apr
Jul
Oct
1996
Apr
Jul
Oct


sto 01 Jan 1995 001 - 23:30 30 Nov 1996 335
3000
2000
1000
0
1995
Apr
Jul
Oct
1996
Apr
Jul
Oct