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Äspö Hard Rock Laboratory

Hydro monitoring program

Report 1999

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Geosigma

August 2000

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Äspö Hard Rock Laboratory

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Abstract

The Äspö island is situated close to the nuclear power plant of Simpevarp in south-eastern Sweden. As part of the pre-investigations preceding excavation of the so called Äspö Hard Rock Laboratory, registrations of the groundwater levels and electrical conductivity in packed off borehole sections and levels in open boreholes started in 1987. The investigations are still ongoing and are planned to be continued for a long period after the termination of the tunnel construction. As the tunnel excavation went on from the autumn 1990 and onwards, new boreholes were drilled in the tunnel and instrumented to enable groundwater pressure monitoring in packed off sections. Also other hydro-related measurements such as water flow in the tunnel, electrical conductivity of tunnel water and inflow and outflow of water through tunnel pipes has been performed. This report is a presentation of the monitoring during 1999 and of the instrumentation and measurement methods used.

In order to allow for comparison with factors that may influence the groundwater level/pressure and flow, meteorological data and measurements of the level of the Baltic Sea are presented in the report. In one chapter, attention is paid also to the earth tide effect.

From the end of 1991 the disturbances from the tunnel are the dominating factors influencing groundwater levels in the area. In one chapter activities that may have an influence on the ground water situation are listed and briefly discussed.

Executive Summary

The construction of the Äspö Hard Rock Laboratory started in October 1990. The laboratory is an extensive tunnel system excavated down to a depth of 460 m below the ground surface. Äspö island is situated close to Simpevarp in south-eastern Sweden. A 3.6 km long entrance tunnel to the laboratory, starting at the ground surface close to the nuclear power plant on the Simpevarp peninsula, has been excavated. Vertical shafts, which connects the laboratory with the ground surface of Äspö, were also drilled. When excavating the last part of the tunnel, between 3.2 and 3.6 km, the traditional blasting technique was replaced by full face TBM-technique.

Extensive pre-investigations have been performed in the area, e.g. aerial and ground geophysical surveys, mapping of solid rocks and borehole investigations. These activities have been carried out on Äspö and four adjacent areas: on the islands of Ävrö, Bockholmen and Mjälen east and south of Äspö and in the Laxemar area at the mainland west of Äspö. A large number of core and percussion boreholes, varying in length between 20 m and 1 700 m, have been drilled in these areas. One important part of the pre-investigations has been geohydrological borehole measurements, such as different types of hydraulic tests, hydrochemical investigations, tracer tests and groundwater level registrations.

Along with the excavation of the tunnel, a number of boreholes in the tunnel have been included in the hydro-monitoring program. In addition, other groundwater-related measurements, such as water flow in the tunnel and electrical conductivity of tunnel water, have been performed.

The objectives of the geohydrological investigations are 1) to document the groundwater conditions before, during and after excavating the laboratory tunnel system, 2) to obtain a data set of hydraulic, transport and chemical parameters and 3) to meet the regulations imposed by the water rights court. The obtained parameters are essential in order to improve predictions of transient processes, e.g. predictions of groundwater level changes, which is one consequence of the tunnel excavation.

The groundwater level registrations were initiated in 1987, before the start of the tunnel excavation. The measurements have been ongoing during the whole period of construction and will be continued after the completion of the tunnel system. The results of these registrations have consecutively been presented in annual reports. However, the first report in this publication series comprised groundwater level data from three years: 1987-89 (Nyberg et al 1991). Earlier reports only comprised data collected in surface boreholes but as from the annual report for 1995, also data collected from measurements in the tunnel were included. The following data are described:

1) groundwater level data in surface boreholes,

2) electrical conductivity registrations of the groundwater in surface boreholes,

3) groundwater pressure in tunnel boreholes,

4) water flow in tunnel,

5) water flow in tunnel pipes,

6) electrical conductivity of tunnel water,

7) humidity transport in the ventilation air in the tunnel (only in report for 1995)

8) level registrations of the Baltic Sea,

9) precipitation,

10) air temperature and

11) potential evaporation.

The meteorological data is collected at the SMHI (Swedish Meteorological and Hydrological Institute) meteorological stations situated as close as possible to the investigation area.

During 1999, there were 107 boreholes involved in the hydro-monitoring program within the five investigation areas and in the tunnel. The boreholes are either core drilled (69 in number) or percussion drilled. Most of the boreholes are equipped with one or several rubber packers, which isolate up to ten borehole sections often representing different hydraulic units of the bedrock. The groundwater levels in many of the surface boreholes are gauged by pressure transducers, one for each borehole section. The transducers are planted in tubes connecting the sections with the ground surface. In certain boreholes, the design of the instrumentation is slightly different and in some cases, the measurements are performed by manual levelling. In a number of boreholes on the Äspö island that were excluded from the measurement program during 1995 manual levelling was resumed during 1997. In the tunnel, many sections are hydraulically connected to a multiplexer, controlling magnetic valves that opens to a pressure transducer. Therefore, the same transducer is used to measure a number of borehole sections. Other boreholes are, for special reasons, connected to individual transducers mounted on a panel.

Most core drilled surface boreholes on Äspö were initially equipped with two sensors to monitor electrical conductivity of the groundwater. One of the sensors is placed relatively close to the ground surface, the second rather deep in the borehole. Over time, most of these sensors has ceased to work and in the end of 1999 only one sensor was still measuring.

In the tunnel 21 gauging boxes equipped with a v-notch weir are installed for flow measurements. Electrical conductivity of tunnel water has been measured at eleven locations. Water flow out of the tunnel in the discharge pipe is measured at 0/700 m tunnel length. Until the end of June 1999 also inflow to the tunnel in a fresh water pipe was measured.

During the spring of 1991, the tunnel excavation began to affect the groundwater level in many surface boreholes. During 1992 and 1993 the effect of the tunnel is evident in all sub-areas except at Laxemar. In the areas on Äspö located near the tunnel spiral the drainage by the tunnel has caused dramatic effects in many boreholes. In some borehole sections the level has decreased up to 100 m. During 1995 the levels continued to decline a few metres in a number of borehole sections at Äspö. Levels were more stable during 1996 with changes within one metre in most boreholes. The results for 1997 indicated a somewhat greater decline of one or a few meters in the vicinity of the Äspö tunnel, but during 1998 and 1999 there have been only small changes. In the main part of the borehole sections the change over the year is within one metre, increasing in some boreholes and decreasing in others. One exception is HAS16 were the level decreased around 4 m in section 1 and nearly 16 m in section 2.

In most tunnel boreholes, the pressure was still decreasing during 1999. The average pressure decline has been approximately 50 kPa, with a maximum decrease of 150 kPa in borehole SA2338A. A pronounced drawdown in the pressure in many tunnel boreholes (also seen in the levels in many surface boreholes) occurs at the end of April as a result of the drilling of borehole KA2865A01 in the tunnel.

The flow changes in most gauging boxes are relatively small but at most locations a decline is observed when comparing mean flow for the period October – December for the latest five years. A few exceptions from this could be related to newly excavated parts of the tunnel and locations where fresh water, in connection to activities, has been added. During the same period 2105 m^3/24 h was pumped out from the tunnel, which is a decrease with approximately 165 m^3/24 h compared to 1998.

The total amount of precipitation during 1999 was 628 mm, which is 75 mm more than the mean for the comparison period 1961-90. Large amounts were measured in August and December whereas the precipitation figure was low for July.

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1 Introduction

Since October 1990 construction works for the Äspö Hard Rock Laboratory, situated a few kilometres north of the nuclear power plant of Simpevarp in south-eastern Sweden (Figure 1-1), are in progress. The laboratory is situated at a depth of maximum 460 m below the ground surface of the small island of Äspö (Figure 1-2). The entrance tunnel, starting at the ground surface on the mainland close to the nuclear power plant, has a length of about 3.6 km. Conventional blasting technique has been applied until about 3.2 km. Full face boring with TBM-technique was used to construct the remaining part of the main tunnel. The projection on the ground surface of the tunnel excavation is shown in Figures 1-2 and 2-1. Three vertical shafts (elevator shaft and two ventilation shafts), which connect the laboratory with the ground surface of Äspö, have been excavated.

Starting in 1987 extensive aerial and ground geophysical surveys, mapping of the rock outcrops and geohydrological investigations have been performed on Äspö, on the adjacent islands of Ävrö, Bockholmen and Mjälen and in the Laxemar area on the mainland west of Äspö (Figure 1-2). A large number of investigation boreholes have been drilled at these sites. The lengths of the boreholes vary between 22 m and 1 700 m and almost every borehole has, shortly after drilling, been instrumented with rubber packers, separating the borehole into two or more sections (maximum seven). The sections often represent different hydraulic units of the granitic bedrock. Most of the boreholes are also equipped with one or more pressure transducers, enabling ground-water pressure monitoring in the different borehole sections. In some sections the electrical conductivity of the groundwater is monitored. The deepest borehole in the investigated area, the 1 700 m long KLX02, is however not yet included in the ground-water monitoring program.

In March 1992 the first pressure measurements in tunnel boreholes were included in the hydro-monitoring program. Since then the tunnel measurements have been extended to comprise, except pressure measurements in several borehole sections, also flow measurements in the tunnel, measurements of electrical conductivity of tunnel water and flow in tunnel pipes. The pressure measurements are performed either with the aid of a hydraulic multiplexer, that makes it possible to measure up to 14 sections with the same pressure transducer, or with an individual transducer for each section. Water flow in the tunnel is measured with gauging boxes equipped with v-notch weirs and a pressure transducer to measure the water level in the box.

One important aim of the investigations has been to document the natural groundwater conditions regarding groundwater levels and groundwater chemistry, i.e. the prevailing conditions before excavation of the Äspö tunnel. Another purpose is to reveal hydraulic connections between different boreholes by analysing the pressure responses resulting from hydraulic disturbances of the aquifer (pumping or injection of water). Furthermore a goal has been to determine hydraulic, transport and chemical parameters in different units of the bedrock by analysing hydraulic tests, result from tracer tests and chemical sampling. With access to an extensive set of geological and geohydrological data, model predictions of different transient processes (e.g. pressure drawdown) which are a consequence of the tunnel excavation, have successively been tested and improved.

The groundwater level investigations from surface boreholes so far have been described in several progress reports. The groundwater level registrations are ongoing since 1987. The measurements have continued during the entire period of tunnel excavation and will go on for a long period afterwards. The registrations are successively presented in annual reports. The first report, however, contained groundwater level data from three years: 1987-89 (Nyberg et al 1991). Since the report for 1995, also tunnel data are included. The present paper is the annual report covering the year 1999. It contains data on:

1) groundwater level in surface boreholes

2) electrical conductivity of the groundwater in surface boreholes

3) groundwater pressure in tunnel boreholes

4) water flow in tunnel

5) water flow in tunnel pipes

6) electrical conductivity of tunnel water

Background data considered necessary for interpreting changes of groundwater levels are also presented in the report. This includes:

7) the water level of the Baltic Sea gauged by The Swedish Meteorological and Hydrological Institute (SMHI) at the harbour inlet of the city of Oskarshamn (Figure 1-2)

8) precipitation in Oskarshamn (SMHI)

9) air temperature in Oskarshamn (SMHI)

11) potential evapotranspiration calculated on data from the meteorological station at Gladhammar (southwest of Västervik), but with cloudiness (which is on of the input variables) from the Målilla station

Figure 1-1 Location of the Äspö Hard Rock Laboratory area and of the stations used to collect background data.

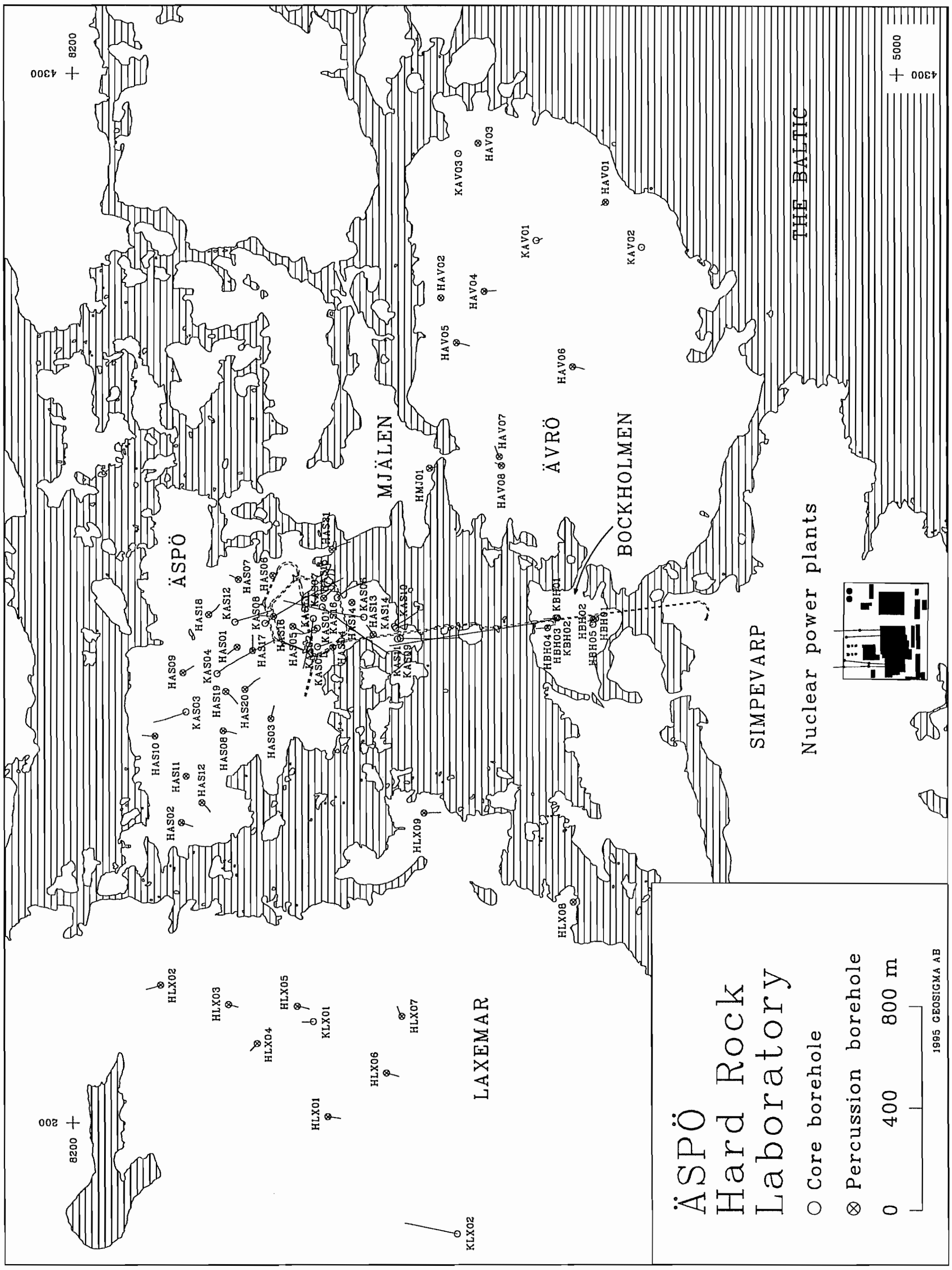


Figure 1-2 The investigation area with borehole locations

2 Geological and topographical overview of the investigation area

2.1 General

The near-coast areas of Äspö, Ävrö, Bockholmen, Mjälen and Laxemar (Figure 1-2) are characterised by small hills with an elevation range of a few meters or tens of meters, large areas of exposed crystalline bedrock and a thin and heavily abraded soil cover. Äspö, Ävrö, Bockholmen and Mjälen are islands, whereas Laxemar is part of the mainland. All five areas are forested, mainly with pine forest. However, especially on the islands of Äspö and Mjälen, the element of deciduous forest is apparent. The investigation area is almost uninhabitated.

The rocks in the investigation area, consisting of the five above mentioned sub-areas, belong to the extensive region of Småland-Värmland intrusions extending from south-eastern Sweden towards north and north-west to south-eastern Norway. Older, Sveco-carelian supracrustals and gneissic granites also occur as well as intrusions of anorogenic granites forming small massifs in the older bedrock, e.g. the Götemar granite. Datings of the Småland granites have yielded an age of > 1 700 Ma. The younger anorogenic granites range between 1 350 and 1 400 Ma in age (Kornfält, Wikman, 1988).

Concerning the structural conditions prevailing at the site of the Äspö Hard Rock Laboratory, much effort has been devoted to identification and characterisation of fractures and fracture zones. Since the fracture distribution governs the ground-water conditions of crystalline bedrock, the study of this subject is essential for implementation of reliable geohydrological predictions. To understand the variations with time of the ground-water levels studied in the present report, the spatial relation between the Äspö tunnel and the major fractures and fracture zones in the area is one of the key factors. Other important factors are climatic conditions, variations of the Baltic Sea level and the earth tide.

In sections 2.2-2.6 a brief description is given of the morphology, the petrography of the solid bedrock (based on mapping of outcrops) and of the structural conditions prevailing at the five subareas mentioned above. The structural model of the area is based on remote sensing, observation of outcrops as well as on tunnel and drill core mapping.

In earlier reports documenting the ground water level program at the Äspö Hard Rock Laboratory only boreholes drilled from the ground surface were accounted for. In the corresponding report from 1996 (Nyberg et al. 1996), data from boreholes drilled from the Äspö tunnel were included for the first time.

2.2 Äspö

The northern coastline of the triangular-shaped island of Äspö is rather straight (Figure 2-1), whereas the eastern and southwestern coasts are more irregular with several small islands and rocky islets at short distances from the coastline.

The bedrock of Äspö is dominated by so called Smålandsgranite: a finemedium-grained to medium-grained, reddish grey granitoid with megacrysts (1-3 cm) of red microcline. Dikes of fine-grained red to greyish granite intersect this older rock. At the southeastern part of the island, areas of Ävrö granite, a variety of the Smålandsgranite, are found. Minor intrusions of other rock types: greenstone, metavolcanics, aplite, pegmati-te, diabase and mylonite, are also scattered over the island (Kornfält, Wikman, 1988).

The altitude of the Äspö island exceeds 10 m.a.s.l. at the centre. Within a few small areas, e.g. close to the boreholes KAS04 and KAS08, small heights with an altitude of about 10 - 15 m.a.s.l. occur. The northern coastline is rather steep, especially in the central part.

Topographical maps and remote sensing reveal several more or less prominent lineaments intersecting the site of the Äspö Hard Rock Laboratory. The lineaments correspond to fracture zones of varying magnitude. In many cases, their existence at depth has been confirmed by borehole and tunnel observations.

Five major fracture zones have been identified by surface mapping of Äspö. One zone, denominated the mylonite zone and trending NE-SW, is approximately coinciding with a gully across the island between KAS04 and KAS12. In addition, a large number of minor fracture zones of various directions have been identified by surface mapping and confirmed by drilling.

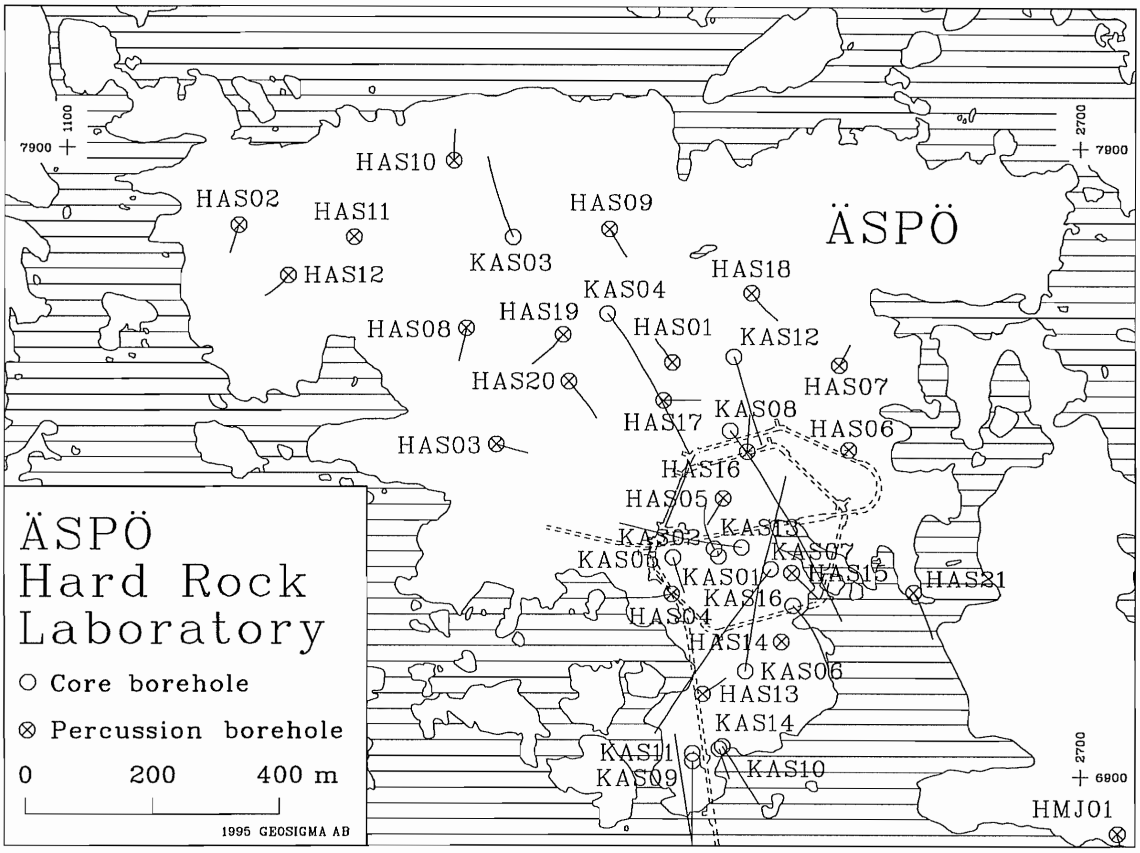


Figure 2-1 The Äspö area with borehole locations. Circles represent the intersection of the boreholes with the ground surface, the lines represent the projection on the ground surface of the respective boreholes. The tunnel is also shown in the figure.

2.3 Ävrö

The rectangular-like island of Ävrö (Figure 1-2) exhibits smoother coastlines than on Äspö. In addition, the topography of the Ävrö island is of different character. Ävrö consists of a plateau with a moderately undulating surface. The altitude varies between 6 and 15 m.a.s.l. A depression in the terrain, corresponding to a rock change, divides the plateau into a northwestern and a southeastern part. Most of the coastline is rather steep.

Granitic rocks dominate on Ävrö. The most frequent rocktype, denominated Ävrö granite, is greyish red and medium-grained. The above-mentioned NE-SW depression coincides with a fine-grained, grey metavolcanite (dacite to andecite) completely surrounded by the Ävrö granite (Kornfält, Wikman, 1987 a). Sparsely scattered remainders of other rock types also occur.

Two major fracture zones penetrated by the Äspö tunnel, a southern branch of zones found on the Äspö island, are trending ENE into the island of Ävrö at the northern part of its western coast (Gustafson et al., 1991 and Stanfors et al., 1994). A few other major fracture zones, however without contact with the Äspö tunnel, as well as several minor zones also intersect the island.

2.4 Bockholmen

Bockholmen is a small island (300 x 400 m) south of Äspö (Figure 1-2). Concerning geological character, Bockholmen can be described as a Southwest extension of the island of Ävrö, separated from the latter only by a narrow strait. Accordingly, the Ävrögranite is the dominating rock.

Only a few minor fracture zones have been identified at Bockholmen.

2.5 Mjälen

The postglacial land elevation has caused the Äspö, Mjälen and Ävrö islands to be almost connected to each other and to other islands further east (Figure 1-2). The long, narrow and curved island of Mjälen is situated between the Äspö and Ävrö islands and is geologically a part of both. The rocks of the major part of the island belong to the Småland granites. A minor part to the Southeast, close to Ävrö, is composed of the Ävrögranite. Only one investigation borehole has been drilled on Mjälen (Figure 1-2).

The island of Mjälen is in its southern part intersected by two major fracture zones, both penetrated by the Äspö tunnel. Further to the north, Mjälen is probably intersected by two other major fracture zones also found on the Äspö island.

2.6 Laxemar

The mainland to the west alongside the island of Äspö is called the Laxemar area. The coastline of Laxemar is somewhat irregular, especially to the south (Figure 1-2).

The predominant rocktype in the area is medium-grained, reddish grey, porphyritic granite with reddish augen (1-3 cm) of microcline. The granite is sometimes intruded by fine-grained, greyish red granite, both in smaller massifs and in dikes. Especially in the northeastern part of the area there exist xenoliths of mostly fine-grained, dark grey greenstone. The size of the xenoliths varies from a few meters to almost 50 meters (Kornfält, Wikman, 1987 b).

The Laxemar area exhibits a slightly more accentuated topography than the islands of Äspö, Ävrö, Mjälen and Bockholmen. In the southern and central parts the altitude exceeds 22 m.a.s.l.

During the autumn of 1992, a new borehole, KLX02, was drilled in the Laxemar area. The borehole, beeing the deepest core drilled borehole so far produced in Scandinavia, is almost vertical and has a length of 1 700 m. An extensive set of borehole loggings have been performed in KLX02. After this period of documentation, the borehole is planned to be included in the hydro-monitoring program described in this report. Three percussion boreholes were drilled in the vicinity of the core borehole KLX02, primarily for the production of cooling water. These boreholes are still not integrated into the official list of test boreholes.

Lineaments traversing the Laxemar area have been described by Munier, 1993. Munier correlates the most significant structure, here trending EW, to the mylonite zone at Äspö.

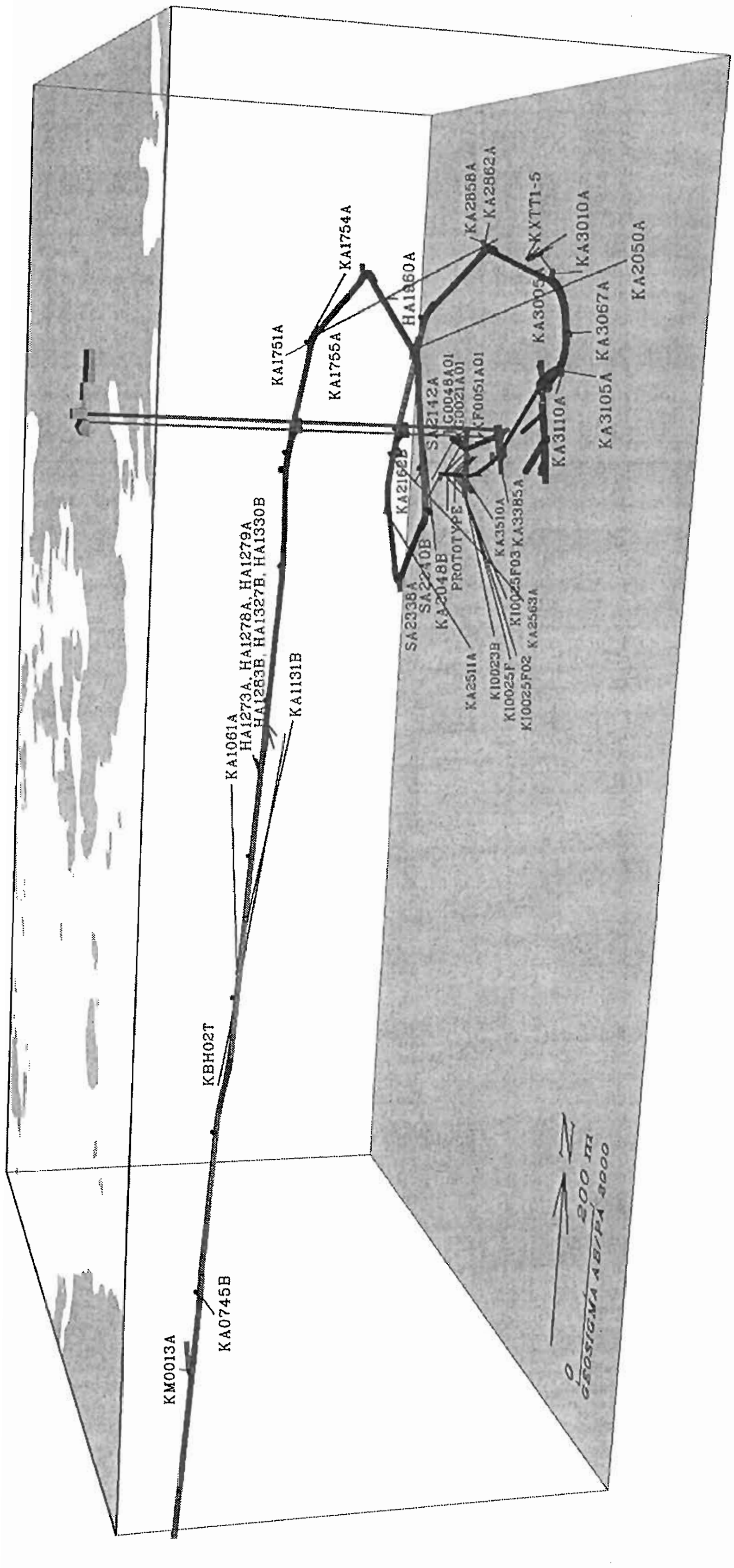


Figure 2-2 Outline of the Äspö Hard Rock Laboratory with a side-view of the access ramp, the tunnel spiral and boreholes.

2.7 The Äspö tunnel

The extension of the Äspö HRL tunnel is illustrated in Figures 2-2 and 2-3. The geoscientific conditions during excavation of the tunnel are described in a series of Progress Reports from the Äspö Hard Rock Laboratory: Stanfors et al., 1992, 1993, 1994a, 1994b and 1995 and Rhén ed., 1995. These reports, in which also evaluation of the geological predictions produced prior to the tunnel excavation is presented, cover the tunnel length 0/0-3/600 m.

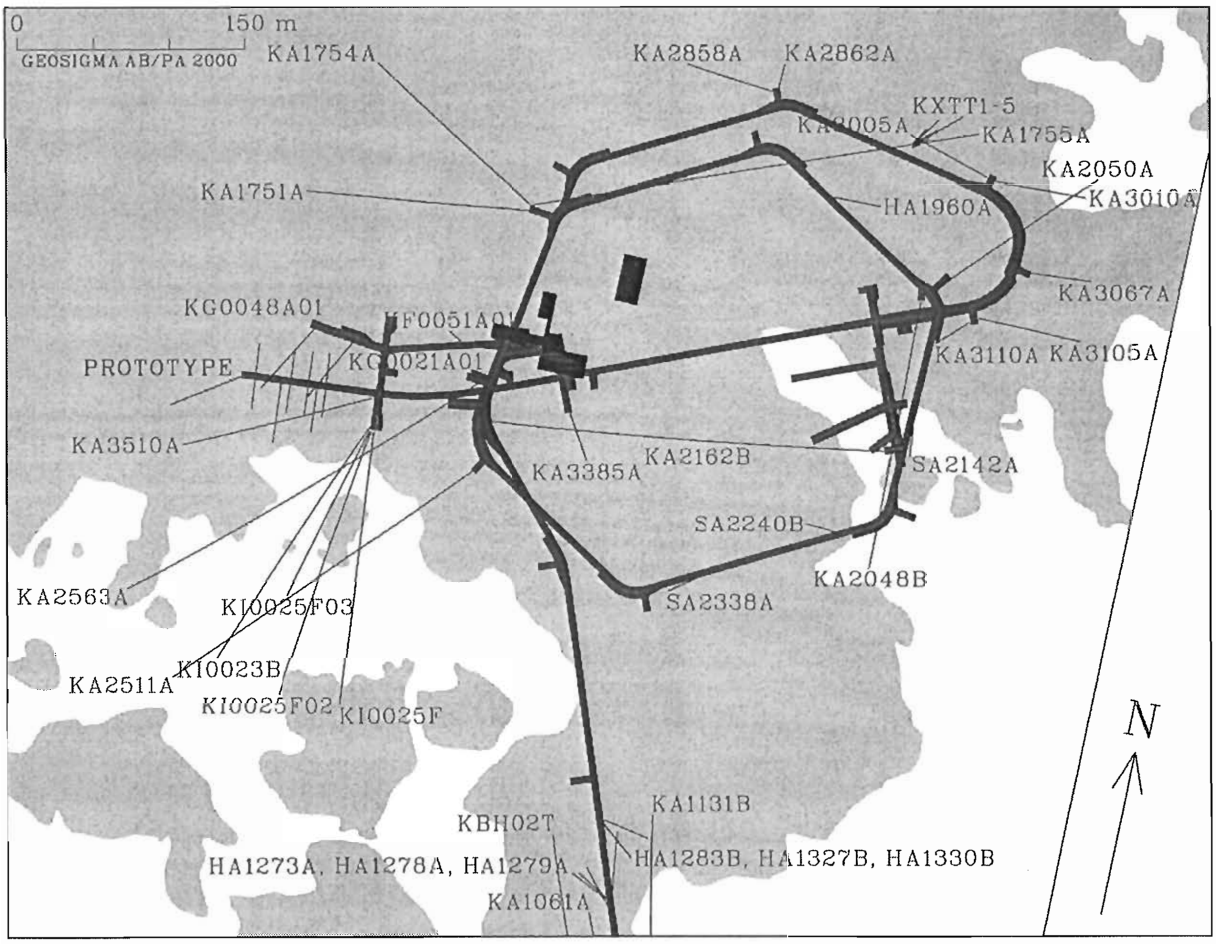


Figure 2-3 Plan view of the tunnel spiral with boreholes.

3 Boreholes

3.1 Surface boreholes

The location of the boreholes is shown in Figure 1-2. Of the five subareas mentioned above, the island of Äspö has the largest number of boreholes. The location of the Äspö boreholes is illustrated also in Figure 2-1.

The following number of boreholes existed at the end of 1999:

In the Äspö area:	16 core drilled boreholes and
	21 percussion drilled boreholes
In the Ävrö area:	3 core drilled boreholes and
	8 percussion drilled boreholes
In the Bockholmen area:	2 core drilled boreholes
	5 percussion drilled boreholes
In the Laxemar area:	2 core drilled borehole and
	9 percussion drilled boreholes
In the Mjälen area:	1 percussion drilled borehole

In some boreholes on Äspö and in most boreholes on Ävrö, Bockholmen and Laxemar the measurements were terminated during 1995 – 1996. The extent of the monitoring program for surface boreholes during 1999 is shown in Table 4-3.

The borehole deviation (inclination and bearing), borehole length, the elevation of the top of casing, length of casing and finally the date for completion of drilling are presented in Table 3-1.

The height above ground for the top of casing is normally less than half a meter, typically about 30 cm.

Table 3-1 Borehole deviation, length, elevation of top of casing, length of casing and date for the completion of drilling.

Borehole	Inclination at ground (°)	Bearing * at ground (°)	Borehole length (m)	Elevation at top of casing (m a s l)	Length of casing (m)	Drilling completed
HAS01	-60.7	327	100.00	6.38	1.20	870807
HAS02	-55.4	198	93.00	2.11	1.60	870801
HAS03	-55.6	107	100.00	2.34	1.60	870803
HAS04	-61.2	256	100			870804
			201.00	6.26	1.40	8904
HAS05	-58.1	207	100.00	6.31	1.40	870806
HAS06	-88.1	261	100.00	4.73	1.00	870806
HAS07	-61.5	30	100.00	3.76	2.00	870801
HAS08	-58.0	188	125.00	6.62	1.50	880319
HAS09	-59.3	149	125.00	7.84	1.50	880320
HAS10	-60.6	1	125.00	6.31	1.50	880322
HAS11	-89.3	355	125.00	5.59	1.50	880323
HAS12	-59.9	221	125.00	2.90	1.50	880325
HAS13	-60.3	59	100.00	2.05	3.00	881212
HAS14	-88.0	254	100.00	1.67	1.50	890118
HAS15	≈-60	≈ 136	120	4.19		890420
HAS16	≈-60	≈ 5	120	4.36		890416
HAS17	≈-60	≈ 90	120	7.89		890418
HAS18	-62.2	146	150	7.46	6.00	900303
HAS19	-57.3	219	150	8.97	6.00	900313
HAS20	-60.5	141	150	6.24	6.00	900319
HAS21	-61.5	151	148	3.04	3.00	911106
HAV01	-88.6	334	175.00	9.27		860813
HAV02	-89.1	137	163.00	6.08		860821
HAV03	-88.0	160	134.20	8.65		860824
HAV04	-60.1	180	100.00	7.53	0.40	870724
HAV05	-54.5	191	100.00	6.83	1.00	870728
HAV06	-59.5	190	100.00	11.93	1.20	870730
HAV07	-56.2	66	100.00	3.68	4.00	870728
HAV08	-61.9	28	63.00	6.98		Before 1984
HBH01	-59	351	50.6	4.71	3.0	910220
HBH02	-47.7	345	32.4	4.68	3.0	910221
HBH03	-59	355	100	5.92	1.2	910306
HBH04	-59.9	355	90.4	5.52	5.1	910307
HBH05	≈-45	≈335	22	2.97	6.7	9206(?)
HLX01	-59.4	187	100.00	8.5	3.00	871021
HLX02	-57.4	339	100			871027
			132.00	8.61	0.60	871110
HLX03	-62.4	197	100.00	10.43	1.40	871104
HLX04	-63.6	313	125.00	10.40	1.20	871106
HLX05	-57.7	187	100.00	15.5	0.60	871105
HLX06	-59.9	190	100.00	15.48	1.00	871030
HLX07	-59.4	59	100.00	8.61	1.00	871103
HLX08	-47.8	134	40	2.27	6.0	911114
HLX09	-61.3	178	151	3.43	3.0	911121
HMJ01	-60.0	197	46	1.45	6.0	911030

Borehole	Inclination at ground (°)	Bearing * at ground (°)	Borehole length (m)	Elevation at top of casing (m a s l)	Length of casing (m)	Drilling completed
KAS01	≈-85	≈ 330	101.00	8.18	1.00	871030
KAS02	-84.0	330	924.04	7.68	1.05	880126
KAS03	-82.9	338	1002.26	8.79	1.11	880407
KAS04	-59.9	140	480.98	11.66	100.80	880501
KAS05	-84.9	163	549.60	8.68	1.05	890227
KAS06	-59.6	7	602.17	5.16	1.30	890129
KAS07	-59.1	217	603.75	4.58	1.15	890131
KAS08	-59.0	145	601.49	7.66	100.80	890219
KAS09	-59.9	181	450.52	4.08	100.65	891122
KAS10	≈-60	≈ 162	99.93	3.72	2.50	891023
KAS11	-88.7	34	248.90	4.26	6.00	900221
KAS12	-69.9	161	380.40	4.83	6.00	900320
KAS13	-62.2	280	406.95	3.89	6.00	900314
KAS14	-61.3	148	211.85	3.35	6.00	900511
KAS16	-84.5	1138	548.46	3.66	6.00	920903
KAV01	-89.2	237	502			770516
			743.60	13.81	11.74	861113
KAV02	≈-90	137	97.10	7.54	12.40	770531
KAV03	-89.4	146	248.40	8.21	2.80	861005
KBH02	-45.0	348	706.35	5.50	5.50	900517
KLX01	-85.3	358	702.11		1.00	880205
			1077.99	16.81	≈ 101 + 1.00	900804
KLX02	-85.0	9	1700.50	18.31	203 + 3.00	921129

≈ Deviation in borehole is not measured. Value is intended deviation at start of drilling.

* Degrees (0-360) measured clockwise in local system. Magnetic bearing is achieved by subtracting 12.1°.

The borehole diameters are presented in Table 3-2. Most boreholes are enlarged in the uppermost part to allow for the installation of a casing. All core boreholes except six are "telescope drilled"; i.e. the diameter of the upper part is larger than below. The exceptions are KAS01, KAS10 and KBH01 where the drilling was not successful and therefore only the upper enlarged part was finished and the three core boreholes on Ävrö that were not telescope drilled. Normally this enlarged part has a length of approximately 100 m. All telescope drilled core boreholes also have an enlargement (approximately 1 m long) where the diameter is changing to make room for a funnel-shaped pipe which gives a smooth connection between the two borehole diameters.

Table 3-2 Borehole diameters.

Borehole	Borehole diameter (mm)	Length of borehole from (m)	to (m)
HAS01	115	0.00	100.00
HAS02	115	0.00	93.00
HAS03	115	0.00	100.00
HAS04	115	0.00	201.00
HAS05	115	0.00	100.00
HAS06	115	0.00	100.00
HAS07	115	0.00	100.00
HAS08	115	0.00	125.00
HAS09	115	0.00	125.00
HAS10	115	0.00	125.00
HAS11	115	0.00	125.00
HAS12	115	0.00	125.00
HAS13	115	0.00	100.00
HAS14	115	0.00	100.00
HAS15	115	0.00	120.00
HAS16	115	0.00	120.00
HAS17	115	0.00	120.00
HAS18	162	0.00	150.00
HAS19	158	0.00	150.00
HAS20	152	0.00	150.00
HAS21	115	0.00	148
HAV01	110	0.00	175.00
HAV02	110	0.00	163.00
HAV03	110	0.00	134.20
HAV04	115	0.00	100.00
HAV05	115	0.00	100.00
HAV06	115	0.00	100.00
HAV07	115	0.00	100.00
HAV08	76	0.00	63.00
HBH01	115	0.00	50.6
HBH02	115	0.00	32.4
HBH03	115	0.00	100
HBH04	115	0.00	90.4
HBH05	115	0.00	22
HLX01	115	0.00	100.00
HLX02	115	0.00	132.00
HLX03	115	0.00	100.00
HLX04	115	0.00	125.00
HLX05	115	0.00	100.00
HLX06	115	0.00	100.00
HLX07	115	0.00	100.00
HLX08	115	0.00	40
HLX09	115	0.00	151
HMJ01	115	0.00	46
KAS01	56	95.85	101.00
	155		95.85
KAS02	56	93.35	924.04
	155	0.00	93.35
KAS03	56	100.80	1002.06
	164	0.00	100.80
KAS04	56	100.70	480.98
	155	0.00	100.70
KAS05	76	150.00	549.60
	164	0.00	150.00
KAS06	56	100.00	602.17
	164	0.00	100.00
KAS07	56	100.00	603.75
	164	0.00	100.00
KAS08	56	100.00	601.49
	164	0.00	100.00
KAS09	56	101.45	450.52
	167	0.00	100.65
KAS10	56	0.00	99.93
KAS11	56	40.40	248.90
	160	0.00	40.40
KAS12	56	101.00	380.40
	167	0.00	100.05
KAS13	56	102.28	406.95
	162	0.00	100.20
KAS14	56	101.40	211.85
	164	0.00	100.44
KAS16	56	100.00	548.46
	165	0.00	100.00
KAV01	56	0.00	743.60
KAV02	56	0.00	97.10
KAV03	56	0.00	248.40
KBH02	56	101.50	706.35
	165	0.00	101.50
KLX01	76	101.30	702.11
	56	702.88	1077.99
	155	0.00	101.30
KLX02	92	201.00	202.95
	76	202.95	1700.50
	304	0.00	3.00
	215	3.00	200.80
	165	200.80	201.00

3.2 Tunnel Boreholes

A great number of boreholes are drilled in the tunnel. Pressure measurements from packed-off sections in 66 boreholes were connected to the monitoring system during 1999. The position of these boreholes in the tunnel is illustrated in Figures 2-2 and 2-3.

The borehole deviation (inclination and bearing), borehole length, borehole diameter, the elevation of the starting point at tunnel wall, length of casing and finally the date for completion of drilling are presented in Table 3-3. Only those boreholes that has been monitored within the HMS during 1999 are listed.

Most boreholes are enlarged in the outermost 2 - 2.5 metres to enable installation of a casing. Except for HA1283B, which was lengthened with a smaller diameter, the diameter inside the casing enlargement is unchanged.

Table 3-3 Borehole deviation, length, diameter, elevation at tunnel wall, length of casing and date for the completion of drilling.

Borehole	Inclination	Bearing *	Bore-	Bore-	Elevation	Length	Drilling completed
HA1273A	-10	332.7	30	57	-175.2	2.0	920423
HA1278A	1	307	29	57	-175.6	2.0	920910
HA1279A	1	312	24	57	-175.6	2.0	920910
HA1283B	-8	352.7	35.5	57	-176.5	2.0	920415
			40.2	51			
HA1327B	-0.5	140	29.5	57	-182.8	2.0	920911
HA1330B	-0.5	100	32.5	57	-183.0	No c.	920911
HA1960A	-7	89	32	57	-263.7	No c.	930121
HD0025A	7.0	88.7	?	?	-416.7	?	?
KA1061A	0.6	349.6	208.5	56	-144.9	2.0	920123
KA1131B	-12.9	0.5	203.1	56	-155.3	2.0	920212
KA1751A	-5.2	274.2	149.9	56	-237.5	2.0	930504
KA1754A	-26.2	299.9	159.9	56	-237.8	2.0	930519
KA1755A	-19.9	339.4	320.6	56	-237.8	2.5	940406
KA2048B	-10.6	190.9	184.5	56	-275.4	2.5	930216
KA2050A	-53.5	55.3	211.6	56	-275.8	2.5	931102
KA2162B	-15.2	272.2	288.1	56	-289.9	2.5	930401
KA2511A	-33.4	234.7	293	56	-335.8	2.5	930905
KA2563A	-42.5	237.2	363.43	56	-340.8	2.5	960924
KA2598A	-32.2	292.6	300.77	56	-342.4	?	?
KA2858A	-4.3	287.0	59.7	56	-379.4	2.5	950115
KA2862A	-8.0	16.0	16.0	56	-379.6	2.5	950125
KA3005A	-4.5	299.1	58.1	56	-399.9	2.5	941205
KA3010A	-4.7	99.5	60.7	56	-399.9	2.5	941208

Borehole	Inclination	Bearing *	Bore-	Bore-	Elevation	Length	Drilling completed
KA3067A	-4.7	98.4	40.1	56	-408.6	2.5	941211
KA3105A	-4.7	102.5	69.0	56	-413.7	2.5	941215
KA3110A	-5.4	238.3	26.8	56	-413.7	2.5	941217
KA3385A	-4.8	161.0	34.2	56	-446.0	No c.	950110
KA3510A	-30.15	255.3	150.06	76	-448.70	2.65	980909
KA3539G	-80.5	274.2	30.01	76	-449.19	No c.	980513
KA3542G01	-45	188.7	30.04	76	-449.07	No c.	980603
KA3542G02	-44.2	6.3	30.01	76	-449.07	No c.	980605
KA3544G01	-90	0	12	76	-448.95	No c.	980325
KA3546G01	-89.8	194	12	76	-448.89	No c.	980324
KA3548A01	-3.1	188.4	30	76	-446.58	2.65	980628
KA3548G01	-89.8	75.7	12.01	76	-449	No c.	980323
KA3550G01	-89.2	249	12.03	76	-448.77	No c.	980322
KA3552G01	-89.5	130.6	12.01	76	-448.77	No c.	980321
KA3554G01	-45	188.2	30.01	76	-448.83	No c.	980607
KA3554G02	-45	8.2	30.01	76	-448.82	No c.	980606
KA3557G	-81.5	271.2	30.04	76	-448.85	No c.	980512
KA3563G	-79.9	277.9	30	76	-448.69	No c.	980507
KA3566G01	-44.9	188.8	30.01	76	-448.57	No c.	980609
KA3566G02	-43.8	7.7	30.01	76	-448.57	No c.	980610
KA3572G01	-89.6	225	12	76	-448.51	No c.	980320
KA3573A	-2.1	188.3	40.07	76	-446.07	2.65	970911
KA3574G01	-89.2	249	12	76	-448.33	No c.	980428
KA3576G01	-89.2	213.7	12.01	76	-448.27	No c.	980426
KA3578G01	-89	252.6	12.58	76	-448.38	No c.	980319
KA3579G	-89.4	296.6	22.65	76	-448.37	No c.	971008
KA3584G01	-89.3	212.5	12	76	-448.25	No c.	980319
KA3590G01	-44.4	186.7	30.06	76	-448.06	No c.	980623
KA3590G02	-43.8	7.9	30.05	76	-448.08	No c.	980616
KA3593G	-79.9	275.2	30.02	76	-448.07	No c.	980504
KA3600F	-1.7	248.4	50.1	76	-445.58	2.65	970924
KF0051A01	29.9	310.3	11.70	76	-451.38	2.5	980527
KG0021A01	17.7	220.1	48.82	76	-445.15	No c.	980708
KG0048A01	14	222.4	54.69	76	-444.49	No c.	980804
KI0023B	-20.7	214.4	200.71	76	-447.69	2.65	971120
KI0025F	-20.1	187.1	193.8	76	-448.2	2.3	970425
KI0025F02	-25.5	200.0	204.18	76	-448.53	2.65	980825
KI0025F03	-29.8	206.9	141.72	76	-448.08	No c.	990813
KXTT1	-46.8	61.2	28.8	56	-392.1	2.5	950518
KXTT2	-45.2	61.4	18.3	56	-392.4	2.5	950928
KXTT3	-36.7	51.4	17.4	56	-391.1	2.5	950606
KXTT4	-36.5	61.5	49.3	56	-391.1	2.5	950616
KXTT5	-14.9	47.7	25.85	76	-390.3	No c.	990505
SA2142A	-9	174	20	57	-287.4	No c.	930223
SA2338A	-7	234	20	57	-313.1	No c.	930414

* Degrees (0-360) measured clockwise in local system. Magnetic bearing is achieved by subtracting 12.1°.

4 Measurements methods

4.1 Data collection

4.1.1 Data collecting system

The data collecting system, which is a part of the Hydro Monitoring System (HMS) at Äspö HRL, consists of a number of measurement stations (computers) connected by a computer network. One station is a host station to which all data from the other measurement stations are collected once a week. Each measurement station, except for the host station, communicate with and collect data from a number of dataloggers or datascan (in tunnel only) units. The host station is connected to the Ethernet LAN in the HRL, which in turn is connected to SKB corporate Ethernet in Stockholm. The host station and the measurement station collecting data from surface boreholes are situated at the site office, while three stations collecting data from tunnel measurements are located in the tunnel.

The on-line system is designed to handle breaks in the communication. Data can be stored in loggers and in measurement stations, in a logger for at least five days and in a measurement station for at least four weeks. However, data collected by the datascan unit, which is not a logger, is directly transferred to the measurement station. All data are finally stored on the host station. Backup of the host station is made on tape.

Data is transferred to the measurement stations in different ways:

Borre data network. Data from Borre loggers in the tunnel are transmitted via a logger network to the measurement stations in the tunnel.

Datascan network. Data from Datascan connected transducers are transmitted via a special network to the measurement stations in the tunnel.

Power line. Data from some surface boreholes at Äspö are transmitted via loggers and power line modems.

Radio. Data from some boreholes are collected via datalogger and radio to HMS.

Laptop. All loggers at the surface, not directly connected to HMS, are manually dumped into a portable PC and then transmitted to a measurement station

Manual. Manual readings are also entered into HMS. This is done either by editing a file directly or by using a portable PC with special written software, and then transferring the output to a measurement station.

All on-line dataloggers are frequently polled for new data by the measurement stations.

The surface part of the data collection system is illustrated in Figure 4-1.

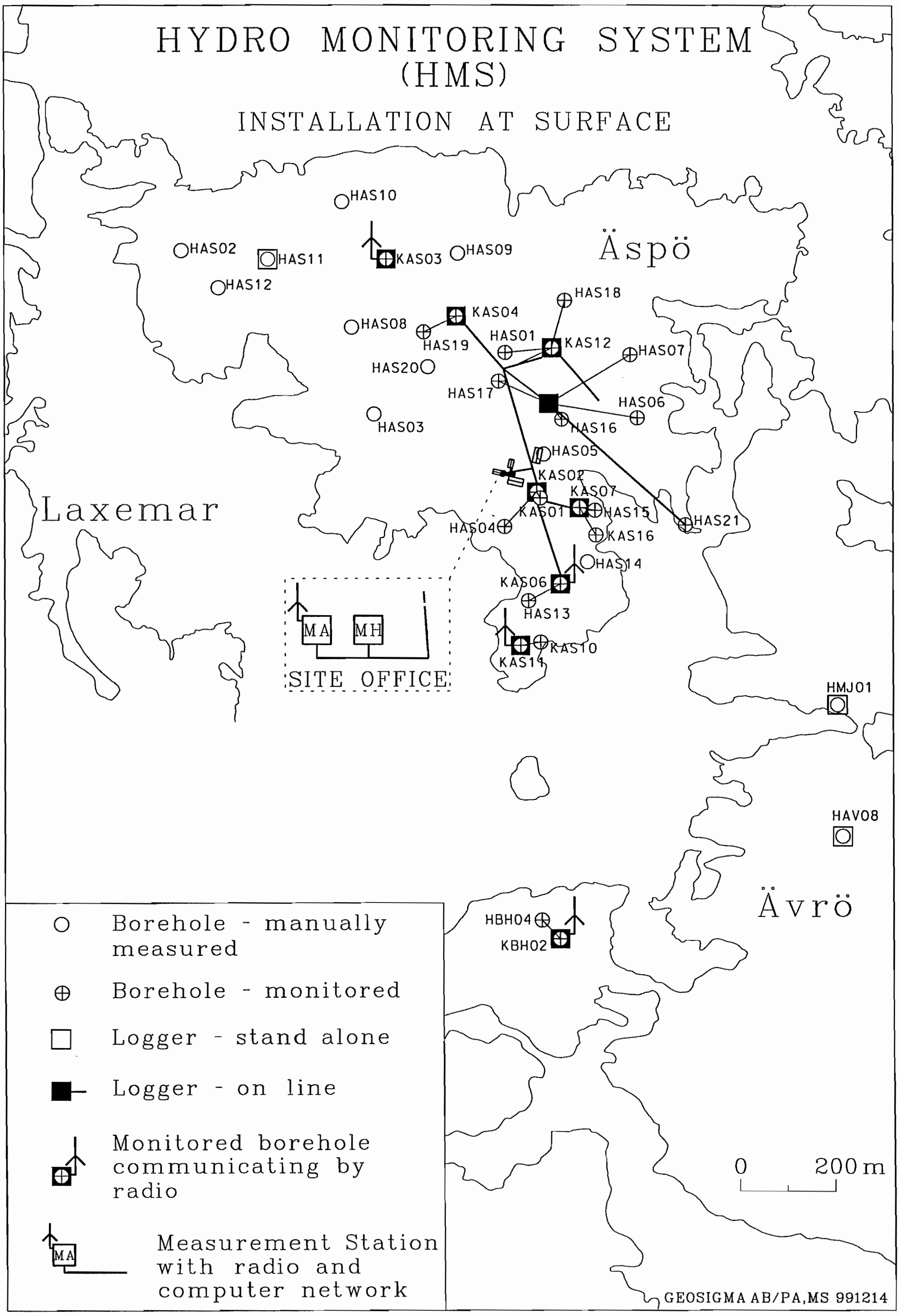


Figure 4-1 Surface part of the HMS showing the data logger network and radios.

4.1.2 Logger and Datascan units

Four different logger units are used to collect pressure data. The most important components of these units are a multiplexer (except in GRUND), an A/D converter, a data storing facility and a serial I/O port. They all have a battery power supply, either as the only supply or for safety.

The Datascan unit has a multiplexer, an A/D converter and a serial I/O port.

In the tunnel, pressure in borehole sections are measured either via a hydraulic multiplexer or by individual transducers for each section connected directly to a Borre logger or a Datascan unit. The hydraulic multiplexer holds a pressure transducer connected to a Borre logger of a type that can operate the magnetic valves on the multiplexer.

To sum up, the following units are used:

BorreF is a logger with a 16 bits A/D converter. This logger is a stand-alone type used at the surface only.

BorreR is a logger with a 16 bits A/D converter. This logger is communicating with a measurement station either by radio or via the power net. Used at the surface only.

BorreT is a logger with a 16 bits A/D converter communicating with a measurement station on a Borre data network. The logger, that can operate magnetic valves on a hydraulic multiplexer, is used in the tunnel only.

Grund is a single channel logger with a 13 bits A/D converter. This logger is a stand-alone type used at the surface only.

Datascan has a 16 bits A/D converter. This unit is connected directly to a measurement station and used in the tunnel only.

The logger types used for different boreholes on the surface are presented in Table 4-1.

Table 4-1 Monitoring equipment in surface boreholes.

Borehole	Section	Equipment	from	to
HAS01	1	BorreR	91-09	
HAS02	1	Manually	970320	
HAS03	1	Manually	981018	
HAS04	1-2	BorreR	91-09	
HAS05	1	Manually	970320	
HAS06	1-2	BorreR	91-09	
HAS07	1	BorreR	970218	
HAS08	1	Manually	970130	
HAS09	1	Manually	970320	
HAS10	1	Manually	970320	
HAS11	1-2	Manually	981201	
	1-2	BorreF	990401	
HAS12	1	Manually	970320	
HAS13	1-2	BorreR	91-09	
HAS14	1	Manually	970320	
HAS15	1-2	BorreR	970522	
HAS16	1-2	BorreR	91-09	
HAS17	1-2	BorreR	91-09	
HAS18	1	Manually	970227	
HAS19	1-2	BorreR	91-09	
HAS20	1-2	Manually	970130	
HAS21	1	BorreR	970130	
HAV02	1	Manually	970205	
HAV05	1	Grund	89-06	
HAV08	1	Grund	91-12	
HBH04	1	BorreR	91-12	
	2	Manually	91-03	
HLX04	1	Manually	970129	
HLX05	1	BorreR	950901	
HMJ01	1	Grund	91-12	
	2	Manually	92-01	
KAS01	1	BorreR	91-09	

Borehole	Section	Equipment	from	to	Borehole	Section	Equipment	from	to
KAS03	1-6	BorreR	91-09		KAS12	1-5	BorreR	971119	
KAS04	1	Manually	970320		KAS14	1	Manually	970320	
KAS07	1	Manually	970220		KAS16	2-4	BorreR	92-10	
KAS09	1-5	BorreR	91-09			1	Manually	92-10	
KAS10	1	BorreR	91-09		KBH02	3-6	BorreR	91-09	
KAS11	1	Manually	970320		KLX01	1-5	BorreR	950901	

Note - Data not relevant for 1999 is to be found in earlier annual reports.

In Table 4-2, the data-collecting units used for pressure measurements in different borehole sections in the tunnel are presented.

Table 4-2 Monitoring equipment in tunnel boreholes.

Borehole	Sect. no	Equipment	Date from	to	Borehole	Sect. no	Equipment	Date from	to
HA1273A	1	HM*+Borre			KA3548G01		Datascan	990525	99081
HA1278A	1	HM+BorreT			KA3550G01		Datascan	990217	
HA1279A	1	HM+BorreT			KA3552G01		Datascan	990217	
HA1283B	1	HM+BorreT			KA3554G01		Datascan	990217	
HA1327B	1	HM+BorreT			KA3554G02		Datascan	990217	
HA1330B	1	HM+BorreT			KA3557G		Datascan	990217	
HA1960A	1	HM+BorreT			KA3563G		Datascan	990217	
HD0025A	1	Datascan	990602		KA3566G01		Datascan	990217	
KA1061A	1	HM+BorreT			KA3566G02		Datascan	990217	
KA1131B	1	HM+BorreT			KA3572G01		Datascan	990217	
KA1751A	1-3	HM+BorreT	940426		KA3573A		Datascan	990217	
KA1754A	1-2	HM+BorreT	941025		KA3574G01		Datascan	990217	
KA1755A	1-4	HM+BorreT	940503		KA3576G01		Datascan	990217	
KA2048B	1-4	HM+BorreT			KA3578G01		Datascan	990217	
KA2050A	1-3	HM+BorreT			KA3579G		Datascan	990217	
KA2162B	1-4	HM+BorreT			KA3584G01		Datascan	990217	
KA2511A	1-5	Datascan	980218		KA3590G01		Datascan	990217	
KA2563A	1-7	Datascan	961120		KA3590G02		Datascan	990217	
KA2598A	1	Datascan	990512		KA3593G		Datascan	990217	
KA2858A	2	HM+BorreT	950223		KA3600F		Datascan	990217	
KA2862A	1	HM+BorreT	960912		KF0051A		Datascan	980612	
KA3005A	2-3	BorreT	951213		KG0021A01		Datascan	990217	
	4-5	HM+BorreT	951213		KG0048A0		Datascan	990217	
KA3010A	2	BorreT	950720		KI0023B		Datascan	980216	
KA3067A	1	HM+BorreT	980303	99110	KI0025F		Datascan	970710	
	1	BorreT	991103		KI0025F02		Datascan	981027	
	2-4	BorreT	950310		KI0025F03		Datascan	991013	
KA3105A	5	HM+BorreT	980303	99110	KXTT1	1,4	HM+BorreT	950720	
	1-4	BorreT	950310			2-3	BorreT	950720	
	5	BorreT	991103		KXTT2	1,4	HM+BorreT	950720	
KA3110A	1	BorreT	950310			2-3	BorreT	950720	
	2	HM+BorreT	980303	99110		5	HM+BorreT	951211	
	2	BorreT	991103		KXTT3	1	HM+BorreT	950720	
KA3385A	1-2	Datascan	970701			2-3	BorreT	950720	
KA3510A	1-3	Datascan	981027			4	HM+BorreT	950720	
KA3539G		Datascan	990217		KXTT4	1-2,5	HM+BorreT	951212	99121
KA3542G01		Datascan	990217			3-4	BorreT	951212	99121
KA3542G02		Datascan	990217		KXTT5	1-2,5	HM+BorreT	991214	
KA3544G01		Datascan	990525			3-4	BorreT	991214	
KA3546G01		Datascan	990525		SA2142A	1	HM+BorreT		
KA3548A01		Datascan	990217		SA2338A	1	HM+BorreT		

* HM=Hydraulic Multiplexer

4.2 Groundwater level measurements in surface bore-holes

4.2.1 Mechanical equipment in boreholes

A detailed description on instrumentation is given in "Manual för HMS (del 3:4), 1994".

Most boreholes were initially divided into different sections by rubber packers. Successively the packers have been removed in many boreholes and during 1999 less than half the boreholes were equipped with packers (see Figure 4-2 -- 4-4 and Table 4-3).

Boreholes without packers are called "open boreholes". The uppermost section in boreholes with one or several packers is an "open section". The measurement principles are somewhat different between percussion and core boreholes due to the different borehole diameters.

Most open boreholes have no equipment except a pressure transducer connected to a BORRE logger or a GRUND logger. At the end of 1999 HAV05, HAV08 and HMJ01 were the only boreholes equipped with the datalogger GRUND.

The hydraulic packers in **core boreholes** are inflated by means of a gas tube (N_2) and a water-filled pressure vessel connected to the packer-system.

During 1999 six core boreholes on Äspö, KLX01 at Laxemar and KBH02 on Bockholmen were instrumented with packers, dividing the boreholes into 4-6 sections. Each section has a hydraulic connection to the ground surface via a bypass plastic tube through the packers. The tubes have an inner diameter of 4 or 6 mm at depth, connected to wider tubes with an inner diameter of 23 or 54 mm at the uppermost part (see Figure 4-2). In two sections in KLX01 the inner diameter of the wider tube is only 12 mm.

Until the summer 1991 the length of these wider tubes were 40 - 50 m. In order to allow measurements at greater depths the tubes has been lengthened to 90 - 100 m in most boreholes on Äspö. Only KAS08 and KAS09 are still equipped with the shorter tubes.

In this upper wide tube, a pressure transducer is installed. To achieve a rapid response to pressure changes in the actual borehole section, a small packer is installed in each tube, a short distance below the pressure transducer. The latter is connected to the borehole section via a thin tube through the small packer. Since the beginning of 1993, due to problems with collapsing PEM-tubes, this small packer had to be removed in many sections to enable manual levelling.

One or two sections in the packer-equipped core boreholes has a second tube between the section and the ground surface (sections P2 and P4 in Figure 4-2). This tube has an inner diameter of 6 mm all the way to the surface. In the enlarged part of the borehole the tube is branching, and a third tube (inner diameter 4 mm) leads up to the surface. The wide PEM-tube to these sections has a diameter of 54 mm followed in the narrow part of the borehole by a plastic tube of 6 mm inner diameter. The purpose of this special equipment in some sections is to make possible circulation of section water during tracer tests.

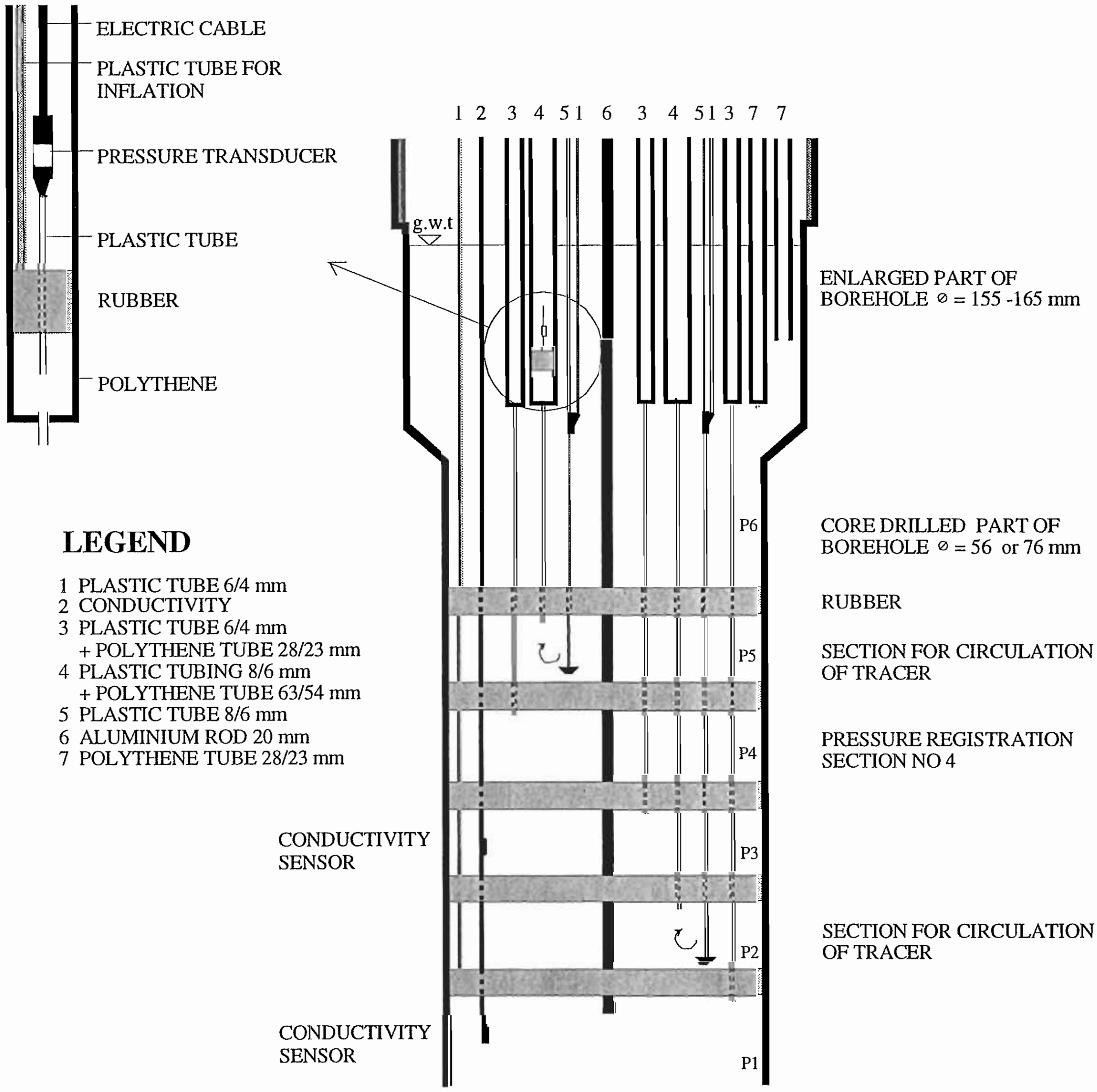


Figure 4-2 Instrumentation in core boreholes on Äspö.

Percussion boreholes are open or divided in two sections by rubber packers. See Figures 4-3 and 4-4.

Also the packed-off sections in the percussion boreholes have a hydraulic connection to the ground surface through tubes passing the packers. The tubes have an inner diameter of 4 mm at depth. The tubes in the uppermost 10 - 80 m of the borehole have an inner diameter of 23 or 28 mm. If the logger is of the BORRE type, only pressure transducers are installed in this wider part of the tubes. If on the other hand, the logger is of the GRUND type, the logger itself is installed in the borehole.

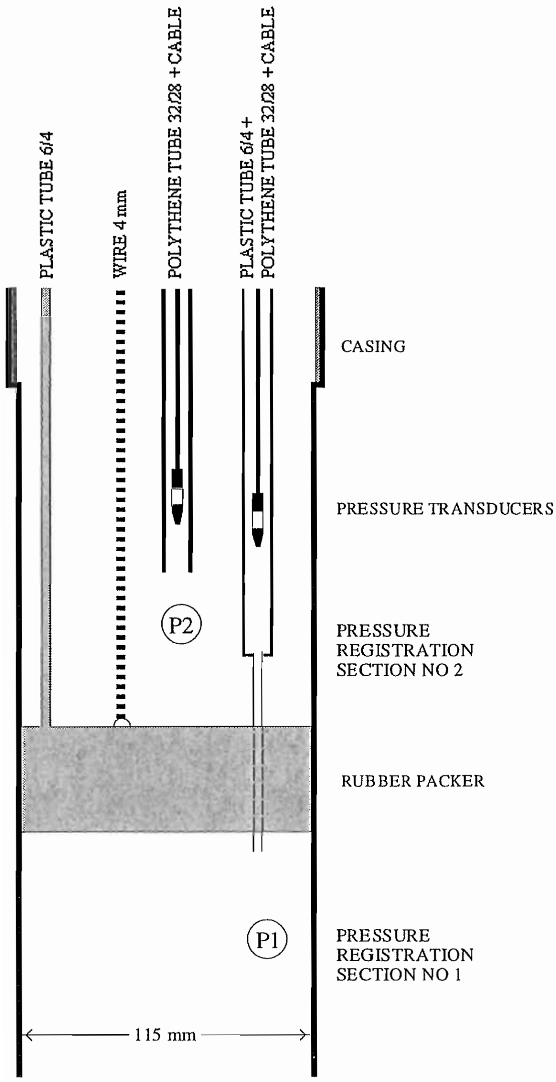


Figure 4-3 Instrumentation in percussion boreholes with the logger BORRE.

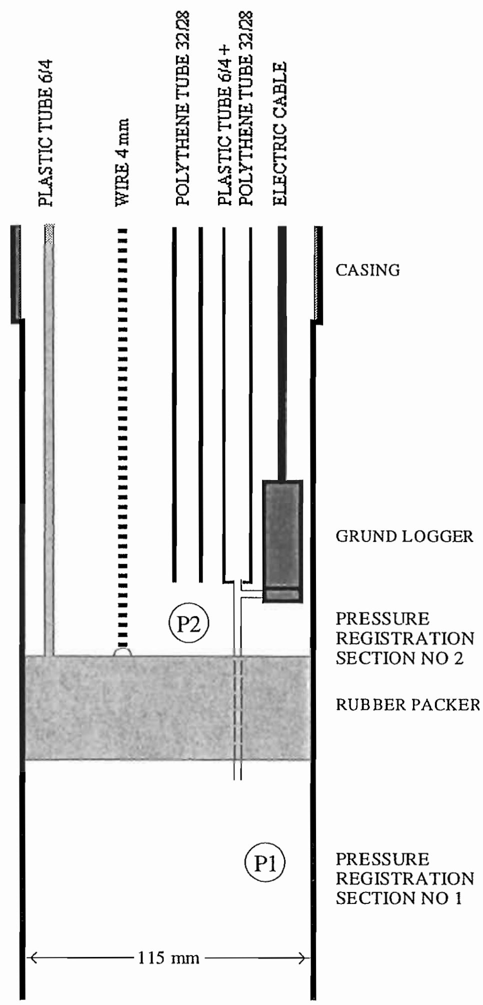


Figure 4-4 Instrumentation in percussion boreholes with the logger GRUND.

In Table 4-3 lengths along the borehole to top and bottom of each section as well as elevation of the top of section is presented. If no end date is given, the borehole is equipped in the same way at the end of 1999. However, the period when some of the boreholes were open to enable re-instrumentation (summer 1991) is not included in the table.

Table 4-3 Monitored sections in surface boreholes

Borehole	Section no	Date from	to	Borehole length from (m)	to (m)	Elevation of section at top (masl)	at middle (masl)
HAS01	1	1988-08-01		0	100	6.38	-37.41
HAS02	1	1995-08-25		0	93	2.11	-36.87
HAS03	1	1997-02-05		0	100	2.34	-39.42
HAS04	1	1989-05-12		101	201	-83.61	-129.99
	2	1989-05-12		0	100	6.26	-37.79
HAS05	1	1993-03-31		0	100	6.31	-36.70
HAS06	1	1996-01-17		57	100	-52.18	-73.61
	2	1996-01-17		0	56	4.73	-23.24
HAS07	1	1997-02-18		0	100	3.76	-41.45
HAS08	1	1997-01-30		0	125	6.62	-48.20
HAS09	1	1995-08-14		0	125	7.84	-47.69
HAS10	1	1995-08-14		0	125	6.31	-49.35
HAS11	1	1998-10-15	1999-04-01	0	125	5.59	-56.81
	1	1999-04-01		31	125	-25.39	-72.24
	2	1999-04-01		0	30	5.59	-9.41
HAS12	1	1995-08-15		0	125	2.90	-52.76
HAS13	1	1998-12-15	1999-05-18	0	100	2.05	-42.01
	1	1999-05-18		51	100	-42.91	-64.91
	2	1999-05-18		0	50	2.05	-19.81
HAS14	1	1995-08-14		0	100	1.67	-48.30
HAS15	1	1997-05-22		48	120	-37.38	-68.56
	2	1997-05-22		0	47	4.19	-16.16
HAS16	1	1989-05-12		41	120	-31.15	-65.36
	2	1989-05-12		0	40	4.36	-12.96
HAS17	1	1998-10-08	1999-02-24	0	120	7.89	-44.07
	1	1999-02-24		88	120	-68.32	-82.18
	2	1999-02-24		0	87	7.89	-29.78
HAS18	1	1997-02-27		0	150	7.46	-59.80
HAS19	1	1990-06-10		61	150	-43.30	-82.66
	2	1990-06-10		0	60	8.97	-16.47
HAS20	1	1990-12-12		69	150	-52.66	-86.55
	2	1990-12-12		0	68	6.24	-23.13
HAS21	1	1997-01-30		0	148	3.04	-60.98
HAV02	1	1997-02-05		0	163	6.08	-75.41
HAV05	1	1997-02-18		0	100	6.83	-34.48
HAV08	1	1987-09-05		0	63	6.98	-20.84
HBH04	1	1991-04-04		31	90.4	-21.27	-46.69
	2	1991-04-04		0	30	5.52	-7.45
HLX04	1	1997-01-29		0	125	10.40	-47.94
HLX05	1	1997-01-29		0	100	15.50	-28.68
HMJ01	1	1991-12-13		33	46	-26.21	-31.58
	2	1991-12-13		0	32	1.45	-12.08
KAS01	1	1987-10-30		0	101	8.18	-42.13
KAS03	1	1996-04-27		627	1002	-613.37	-798.89
	2	1996-04-27		533	626	-520.23	-566.30
	3	1996-04-27		377	532	-365.46	-442.37
	4	1996-04-27		253	376	-242.42	-303.44
	5	1996-04-27		107	252	-97.47	-169.46
	6	1996-04-27		0	106	8.79	-43.85
KAS04	1	1993-06-04		0	481	11.66	-193.59
KAS07	1	1997-02-20		0	604	4.58	-253.49

Borehole	Section no	Date from	to	Borehole length from (m)	to (m)	Elevation of section at top (masl)	at middle (masl)
KAS09	1	1990-04-09		261	450	-220.08	-301.03
	2	1990-04-09		241	260	-202.93	-211.08
	3	1990-04-09		151	240	-125.97	-163.99
	4	1990-04-09		116	150	-96.01	-110.58
	5	1990-04-09		0	115	4.08	-45.66
KAS10	1	1989-10-23		0	100	3.72	-39.58
KAS11	1	1995-10-23		0	249	4.26	-120.23
KAS12	1	1997-10-28		330	380	-299.84	-322.68
	2	1997-10-28		278	329	-252.25	-275.60
	3	1997-10-28		234	277	-211.95	-231.66
	4	1997-10-28		102	233	-90.23	-150.85
	5	1997-10-28		0	101	4.83	-42.44
KAS14	1	1995-10-24		0	212	3.35	-87.88
KAS16	1	1992-10-20		466	548.46	-452.91	-492.42
	2	1992-10-20		390	465	-379.59	-415.84
	3	1992-10-20		121	389	-116.36	-248.22
	4	1992-10-20		0	120	3.66	-55.96
KBH02	3	1991-09-19		261	326	-109.41	-117.30
	4	1991-09-19		151	260	-79.60	-95.04
	5	1991-09-19		106	150	-61.29	-71.08
	6	1991-09-19		0	105	5.50	-29.95
KLX01	1	1992-03-02		856	1078	-837.63	-948.47
	2	1992-03-02		695	855	-676.85	-756.74
	3	1992-03-02		272	694	-254.52	-465.15
	4	1992-03-02		141	271	-123.81	-188.66
	5	1992-03-02		0	140	16.81	-52.98

Note - Data not relevant for 1999 is to be found in earlier annual reports.

4.2.2 Pressure gauges

Until beginning of 1996 all BORRE loggers were equipped with a DRUCK PDCR 830 differential pressure transducer and/or with a DRUCK PTX 160/D differential pressure transducer. The pressure range has been 0-1, 0-3.5 or 0-10 bar. Sections 3 and 4 in KLX01 are equipped with a DRUCK PDCR 35 differential pressure transducer with the pressure range 0-10 bar.

Since there have been problems with moisture in the thin tube delivering air pressure to the differential pressure transducers, these has been successively replaced by absolute pressure transducers (DRUCK PDCR 35/D and PTX1830, 0-10 bar) from the beginning of 1996.

Air pressure, to enable subtraction from absolute pressure measurements, is measured with a DRUCK PDCR 930 with a pressure range of 0-1 bar.

The **GRUND** logger normally has a CRL951 differential pressure transducer with the pressure range 0-15 psi. In a few cases, a DRUCK PDCR 900 differential pressure transducer with a pressure range of 0-1.5 bar is used.

Accuracy for all **DRUCK** transducers is ±0.1% F.S. (B.S.L.) and for the CRL transducer ±2% F.S.

4.2.3 Absolute pressure in borehole sections

Sometimes it is of interest to determine the absolute pressure at the top of a packed off section. This value can be calculated if the vertical distance from top of section to the water table in the tube connecting the section with the ground surface and the density of water in the tube are known.

The altitude of the water table is presented in the diagrams in Appendix 2.

The altitude at top of section is to be found in Table 4-3.

Density

The density of the tube water is determined in the following way. When all packers in a core borehole are installed and inflated, water is flushed from all sections to the ground surface through the tubes. When at least the double tube volume has been discharged, a water sample from each tube is collected. The electrical conductivity of the sample is measured. On approximately 75 samples from 1988 and 1989 the density is laboratory-determined. The electrical conductivity of the density-determined samples range from 60 to 3400 mS/m. From these measurements a first degree equation is set up, by means of the least square method (by Ann-Chatrin Nilsson, KTH, 1990), which gives the density from the electrical conductivity (see note in Table 4-4). This equation is then used to calculate the density of any sample. The deviation from the straight line for a single value is at most 1.5 kg/m3, but normally less then 0.5 kg/m3.

A problem more difficult to handle is whether the water sample is representative for the water in the tube or not. For example, water with other density than the sample might have entered into a part of the tube when the flushing was interrupted. Considering even this possibility, the maximum error in the density is estimated at ±10 kg/m3, corresponding to ±1 m per 100 m water column.

Calculated density in the tubes and measured electrical conductivity is found in Table 4-4. Measurements of the electrical conductivity, from water samples, were performed only in the core boreholes on Äspö and in KLX01, beginning in 1988.

The values may differ from undisturbed values in the section. For example, if the sample was taken immediately after inflation of the packers, the electrical conductivity in the section may not have reached its natural value.

It can be mentioned that the electrical conductivity of the sea surface water east of Ävrö in august and september 1986 was 1180 and 1170 mS/m respectively.

Table 4-4 Electrical conductivity and calculated density (at 25° C) of water in tubes between section and ground.

Borehole	Sec.	Valid from	Electrical conduct. (mS/m)	Density (kg/m^3)
KAS03	1	1997-05-30	1805	1006
	2	1998-10-01	1500	1004
	2	1999-04-14	1260	1003
	2	1999-10-06	1920	1006
	3	1997-06-18	1790	1006
	4	1996-05-22	352	999
	5	1998-10-05	645	1000
	5	1999-04-12	650	1000
	5	1999-10-05	860	1001
	6	1996-05-22	47	998
KAS09	1	1990-04-07	1600	1005
	2	1990-04-07	1600	1005
	3	1990-04-07	1600	1005
	4	1998-10-01	767	1001
	4	1999-04-14	820	1001
	4	1999-10-06	1010	1002
	5	1990-04-07	1600	1005
KAS12	1	1997-11-12	990	1002
	2	1997-11-13	725	1001
	3	1994-04-06	720	1001
	4	1991-08-17	113	998
	4	1997-11-14	208	998
	5	1991-08-17	130	998
	5	1997-11-14	112	998
KAS16	1	1992-10-20	1450	1004
	2	1992-10-20	1350	1004
	3	1992-10-20	800	1001
	4	1992-10-20	750	1001
KBH02	3	1992-05-14	970	1002
	4	1992-05-14	1090	1002
	5	1992-05-14	870	1001
	6	1992-05-14	530	1000
KLX01	1	1998-06-17	1824	1006
	2	1998-06-17	503	1000
	3	1998-06-17	68	998
	4	1998-06-17	365	999
	5	1993-04-16	50	998

Density (kg/m^3) = 997.3 + 0.00467 · Electrical conductivity (mS/m).
Note - Data not relevant for 1999 is to be found in earlier annual reports.

4.2.4 Calibration method

To calibrate the registrations from the data loggers, manual levelling of all sections are made, normally once every month.

The logger data is converted to water levels by means of a linear calibration equation (if the pressure transducer is of the absolute type, subtracting the air pressure is also necessary). Converted logger data are compared with manual levellings, corrected to account for borehole deviation. If the two differs, calibration constants are changed and the procedure is repeated until an acceptable fit is achieved.

4.2.5 Recording interval

In some boreholes the recording interval is shortened during hydraulic test periods.

For loggers not directly connected to HMS the following recording intervals have normally been used:

Sections registered with a logger at Laxemar and on Ävrö 4 hours

Sections registered with a logger on Äspö and on Mjälen 2 hours

Most sections not connected to a logger are manually levelled once a month.

All directly connected boreholes have the following recording principle: Groundwater level is **measured** every 8th minute. The value is not stored unless it differs more than 0.2 m from the latest stored value. Regardless from this a value is stored every second hour.

4.2.6 Accuracy of groundwater level data

The results presented in the diagrams are the groundwater levels for each section expressed as metres above sea level. The total error in these values, consists of errors in the following measurements:

- Pressure transducer registrations
- Levelling of the borehole casing
- Levelling of the borehole groundwater surface
- Borehole deviation measurements
- Air pressure measurements (only sections with absolute pressure transducers)

(For more detailed information about the different errors see Ekman et al, 1989.)

When calculating the absolute pressure at the top of a packed off section, errors due to uncertainty in the density estimation of the water in the tube connecting the section with the ground surface must also be considered (see section 4.2.3).

The magnitude of the error in the groundwater level data is to a large degree varying with time, depending mainly on two factors, the frequency of manual levellings and the influence of activities in the boreholes. As the pressure gauges are calibrated against series of manually levelled values, the error due to erroneous levellings will in general be smaller than for a single levelled value. During tests, however, disturbances in the instrumentation may cause discontinuities in the data series. Some of these can be eliminated in the calibration process, while others are more difficult to identify and may remain for shorter periods.

Errors in determination of the altitude of the borehole casing and the borehole deviation are systematic. Errors in pressure gauge registrations and in levelling of the groundwater table, on the other hand, have a certain amount of randomness, while errors due to uncertainties in the density estimation can be of both types. (Note: There are new values for elevation of top of casing in some boreholes from July 1990, due to corrections after renewed levellings; see Table 3-1. Corrections for the new levellings are not made on data collected before July 1990.)

During the autumn 1992, because of the tunnel excavation, substantial drawdowns were observed in many boreholes on Äspö. This was especially noticed when the first of two raice-drilled ventilation shafts was drilled at the end of October 1992. Therefore, the manual levellings were more difficult to carry out. Consequently, in these boreholes, the error due to manual levellings may be significantly larger from the end of October 1992. Based on the above errors, a rough estimate of the total error in groundwater level under normal conditions has been estimated to ±0.2 m for ground water levels above approximately 50 m from ground surface. Below 50 m from ground surface the error was estimated to ±0.5 m.

Errors of a slightly different character are those caused by failure in the mechanical or electronic equipment in boreholes. To some extent data including these type of errors are eliminated from the diagrams, but sometimes (when data is trustworthy) they are difficult to recognise and may therefore decrease the reliability of data for shorter periods. Errors of this type are usually caused by one of the following failures:

- Leakage in the couplings connecting the hydraulic measurement system or in the system used to inflate the rubber packers.

- Insufficient communication between a section and the pressure transducer, due to clogging in the plastic tube.

- Failing pressure transducers.

4.3 Electrical conductivity in surface boreholes

4.3.1 Measurement equipment

To start with, electrical conductivity in two sections was measured in most core boreholes on Äspö. The deeper sensor in each borehole was connected to a BORRE logger and the upper sensor was read manually once a month. In course of time, the sensors have ceased to work and during 1999, electrical conductivity was measured only in section 2 in KAS09. Length along the borehole to this sensor is 249 m. Besides the sensor, the equipment consists of an electronic unit at ground and an electrical cable between the sensor and the logger. The sensor is of a two-electrode type, made of gold and with a cell constant of 2.0. The electronic unit is a commercial, type LX, made by Conducta GmbH & Co. The measurements are not temperature compensated.

4.3.2 Accuracy of the electrical conductivity data

The primary purpose with these measurements were not to measure electrical conductivity but rather to have an indicator on salinity changes that could be a result of the drawdown from the tunnel excavation. Therefore, the calibration procedure was very rough for most of the sensors.

The electrical conductivity sensors are strongly non-linear and the conductivity at measurement depth is not known when the calibration is performed. The calibration is carried out at the surface, with the cables connected, before installation in the borehole. Mostly, a two point linear method has been used. Conductivities for the two point calibration solutions are 666.8 and 5864 mS/m. Unfortunately this gives a poor result, since the calibration range is too wide in relation to the nonlinearity of the sensors. In KAS05 and KAS11 (from June 1992) a second degree polynomial was fitted to a four point calibration (127.4, 539, 1160 and 2231 mS/m), which gives a considerably better result. Unfortunately, KAS09 was calibrated with the two point method.

One can suspect that the error, under normal conditions, for those sensors calibrated with only two calibration points can amount to many thousands of mS/m. With the four point calibration technique the error is considerably lower and possibly some hundreds of mS/m.

4.4 Groundwater pressure in tunnel boreholes

4.4.1 Mechanical equipment in boreholes

For a detailed description on instrumentation, see "Manual för HMS (del 3:4), 1994".

Instrumentation in tunnel boreholes are mainly of three different types, see Figure 4-5. In boreholes with more than one section, the packers dividing the borehole are always of the hydraulic type (top in the Figure). Single-section boreholes have either a valve mounted on the borehole casing (bottom in the Figure) or a mechanical packer (middle in the Figure). The hydraulic packers are inflated by means of a gas tube (N_2) and a water-filled pressure vessel connected to the packer-system. The packed off sections have a hydraulic connection to the tunnel via plastic bypass tubes through the packers (essentially the same type of packers as in the surface boreholes). These tubes have an inner diameter of 4 or 6 mm. To some sections, prepared for circulation of tracer during tracer tests, there is an extra tube with an inner diameter of 6 or 8 mm. The borehole instrumentation is anchored to the tunnel wall.

In two boreholes (KI0023B and KI0025F02) a different type of packer system is used. The packers are connected by a large-diameter central tubing through which the smaller tubes building up the packer-, pressure- and circulation lines are drawn. The inner diameters on these small tubes are 2 mm for the packer- and pressure lines and 4 mm for the circulation line.

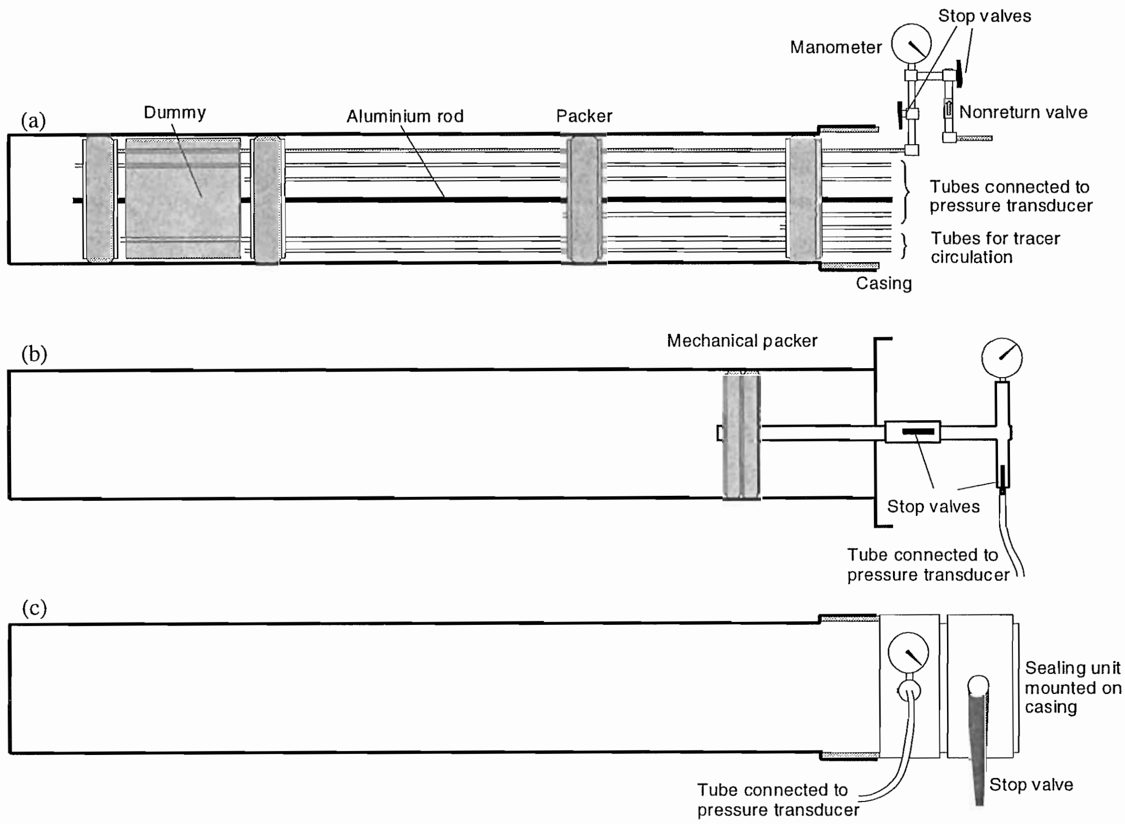


Figure 4-5 Instrumentation in tunnel boreholes with hydraulic packers (a), mechanical packer (b) and with a sealing mounted on casing (c).

4.4.2 Pressure measurements

The pressure in a borehole section is transmitted via a plastic tube, and a hydraulic multiplexer to a pressure transducer or directly to a pressure transducer. For many boreholes there is also a valve panel between the borehole and the pressure measuring equipment.

The multiplexer holds 16 magnetic valves that open to the pressure transducer one after another for all sections connected. Two of the inlets to the hydraulic multiplexer are reserved for reference pressure to enable in-situ calibrations of the pressure transducer. The data logger that collects data from the pressure transducer operates the valves.

The pressure reference system consists of calibration vessels at some carefully levelled locations and tubes connected to the hydraulic multiplexers. The system is filled with deionized water to give well-defined pressures. A tube connected on top of the calibration vessels, deliver air pressure from the surface.

A schematic outline of the pressure measurement system with a hydraulic multiplexer and the pressure reference system is shown in Figure 4-6.

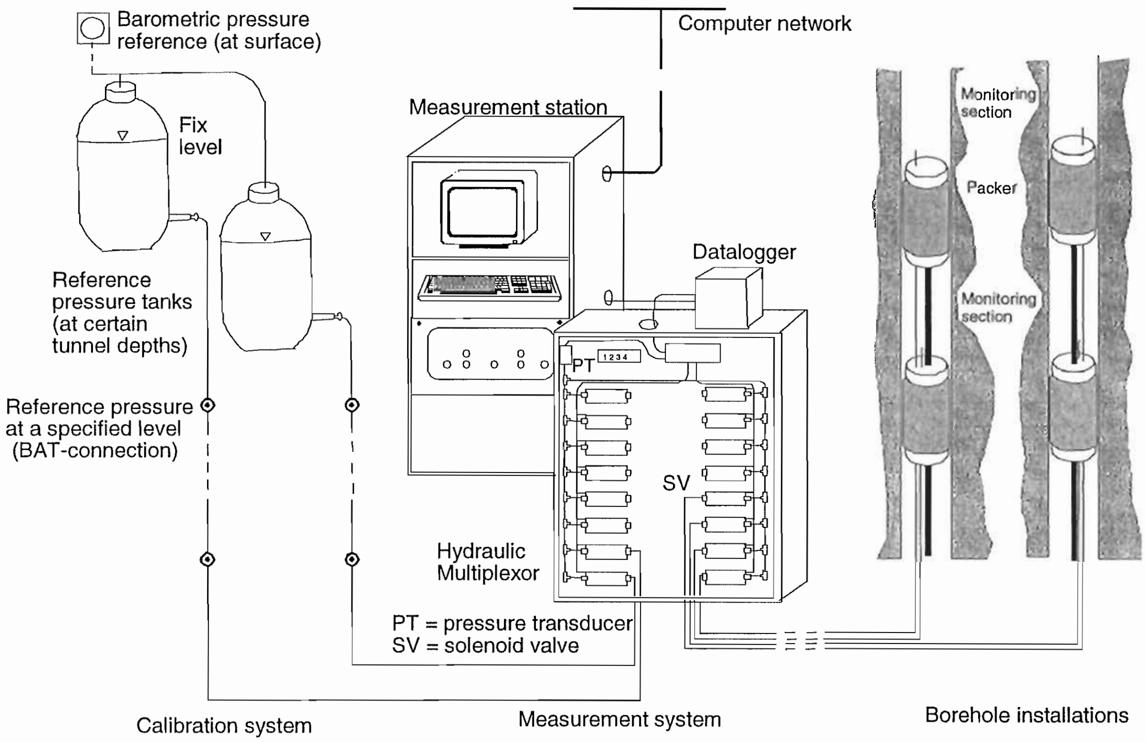


Figure 4-6 Equipment installations for groundwater pressure measurements with a hydraulic multiplexer.

During the last years most of the newly instrumented boreholes has been connected to individual pressure transducers. One reason for this is that the monitoring via the hydraulic multiplexer could not offer a measuring frequency that was high enough during hydraulic tests. In these cases, a number of transducers are mounted on a panel where also tubes from the pressure reference system are available to enable in-situ calibrations of the pressure transducers.

The pressure transducers are either of the type DRUCK PTX 5xx or 6xx (absolute) with a pressure range 0 - 50 bar.

According to the manufacturer the uncertainty for these transducers is ±0.2 % (type 5xx) and ±0.08 % (type 6xx) of full scale (F.S.) for the best straight line (B.S.L.). For the 6xx type the time drift is given to max. 0.05 % F.S., while no figure is given for the 5xx type.

Normally, a pressure value is scanned once every two second but if the pressure is measured with a hydraulic multiplexer every four minute. If the change since latest stored value exceeds a "change value" of approximately two kPa the newly scanned value is stored. A value is always stored once every second hour, unless the change.

In Table 4-5 the length along the boreholes to top and bottom of each section and the elevation at the middle of section is presented. To enable calculations of absolute pressure at the middle of section, also the level of the pressure transducer is given.

Table 4-5 Monitored sections in tunnel boreholes

Borehole	Section no	Date from	to	Borehole length from (m)	to (m)	Elevation of SecTop (masl)	SecMid (masl)	Transducer (masl)
HA1273A	1	1992-03-12		0	23	-175.15	-177.15	-163.34
HA1278A	1	1992-09-10		0	29	-175.65	-175.40	-163.34
HA1279A	1	1992-09-10		0	29	-175.60	-175.35	-163.34
HA1283B	1	1992-04-15		0	40.2	-176.55	-179.35	-163.34
HA1327B	1	1992-09-11		0	29.5	-182.81	-182.93	-163.34
HA1330B	1	1992-09-11		6	32.5	-183.04	-183.15	-163.34
HA1960A	1	1993-01-21		4	32	-264.22	-265.92	-289.19
HD0025A	1	1999-06-02		?	?	-416.7	?	-416.42
KA1061A	1	1992-01-14		0	208.5	-144.93	-144.00	-163.34
KA1131B	1	1992-02-02		0	203.1	-155.30	-178.25	-163.34
KA1751A	1	1994-04-21		99	150	-246.10	-248.20	-224.28
	2	1994-04-21		56	98	-242.50	-244.23	-224.28
	3	1994-04-21		6	55	-238.10	-240.25	-224.28
KA1754A	1	1994-04-21		75	159.88	-267.40	-283.99	-224.28
	2	1994-04-21		6	74	-240.22	-253.67	-224.28
KA1755A	1	1994-05-03		231	320.58	-313.63	-329.03	-224.28
	2	1994-05-03		161	230	-290.00	-301.63	-224.28
	3	1994-05-03		88	160	-265.89	-277.58	-224.28
	4	1994-05-03		6	87	-239.72	-252.63	-224.28
KA2048B	1	1994-12-12		149.5	184.45	-301.91	-304.86	-289.19
	2	1994-12-12		100	148.5	-293.38	-297.59	-289.19
	3	1994-12-12		50.5	99	-284.57	-288.93	-289.19
	4	1994-12-12		5	49.5	-276.33	-280.38	-289.19
KA2050A	1	1994-04-14		155	211.57	-400.25	-422.84	-289.19
	2	1994-04-14		102	154	-357.81	-378.65	-289.19
	3	1994-04-14		6	101	-280.61	-318.81	-289.19
KA2162B	1	1994-04-15		201.5	288.1	-342.47	-353.24	-289.19
	2	1994-04-15		143	200.5	-327.48	-334.87	-289.19
	3	1994-04-15		80.5	142	-311.17	-319.19	-289.19
	4	1994-04-15		40	79.5	-300.49	-305.70	-289.19

Borehole	Section no	Date from	to	Borehole length from (m)	to (m)	Elevation of SecTop (masl)	SecMid (masl)	Transducer (masl)
KA2511A	1	1998-02-18	1999-02-01	242	244	-469.65	-470.20	-334.61
	2	1998-02-18	1999-02-01	217	241	-455.78	-462.43	-334.61
	3	1998-02-18	1999-02-01	110	216	-396.48	-425.90	-334.61
	4	1998-02-18	1999-02-01	92	109	-386.46	-391.19	-334.61
	5	1998-02-18	1999-02-01	52	54	-364.15	-364.70	-334.61
	1	1999-03-16		239	293	-467.98	-482.95	-334.61
	2	1999-03-16		171	238	-430.33	-448.88	-334.61
	3	1999-03-16		139	170	-412.60	-421.20	-334.61
	4	1999-03-16		111	138	-397.04	-404.54	-334.61
	5	1999-03-16		103	110	-392.59	-394.53	-334.61
	6	1999-03-16		96	102	-388.69	-390.36	-334.61
	7	1999-03-16		65	95	-371.40	-379.77	-334.61
	8	1999-03-16		6	64	-338.53	-354.67	-334.61
KA2563A	1	1998-02-25	1999-01-20	262	362	-514.25	-546.15	-334.61
	2	1998-02-25	1999-01-20	225	228	-490.36	-491.33	-334.61
	3	1998-02-25	1999-01-20	220	224	-487.11	-488.41	-334.61
	4	1998-02-25	1999-01-20	191	219	-468.20	-477.35	-334.61
	5	1998-02-25	1999-01-20	187	190	-465.58	-466.56	-334.61
	6	1998-02-25	1999-01-20	146	186	-438.64	-451.81	-334.61
	7	1998-02-25	1999-01-20	76	145	-392.08	-415.11	-334.61
	1	1999-01-20	1999-03-16	76	145	-392.08	-415.11	-334.61
	1	1999-03-16		242	362.43	-501.36	-539.94	-334.61
	2	1999-03-16		236	241	-497.48	-499.10	-334.61
	3	1999-03-16		206	208	-478.00	-478.65	-334.61
	4	1999-03-16		187	190	-465.58	-466.56	-334.61
	5	1999-03-16		146	186	-438.64	-451.81	-334.61
KA2598A	1	1999-05-12		?	300.77	-342.69	?	-334.69
KA2858A	2	1995-02-23		39.77	40.77	-382.37	-382.40	-399.10
KA2862A	1	1996-09-12		7.37	15.98	-380.61	-381.20	-399.10
KA3005A	2	1995-12-07		46.78	50.03	-403.52	-403.64	-399.10
	3	1995-12-07		44.78	45.78	-403.37	-403.41	-399.10
	4	1995-12-07		39.03	43.78	-402.94	-403.12	-399.10
	5	1995-12-07		6.53	38.03	-400.38	-401.64	-399.10
KA3010A	2	1995-02-23		8.56	15.06	-400.58	-400.86	-399.10
KA3067A	1	1995-02-28		34.55	40.05	-411.50	-411.74	-413.14
	2	1995-02-28		30.55	33.55	-411.16	-411.29	-413.14
	3	1995-02-28		28.05	29.55	-410.95	-411.01	-413.14
	4	1995-02-28		6.55	27.05	-409.14	-410.00	-413.14
KA3105A	1	1995-03-01		53.01	68.95	-418.09	-418.81	-413.14
	2	1995-03-01		25.51	52.01	-415.78	-416.87	-413.14
	3	1995-03-01		22.51	24.51	-415.54	-415.62	-413.14
	4	1995-03-01		17.01	19.51	-415.09	-415.19	-413.14
	5	1995-03-01		6.51	16.01	-414.21	-414.61	-413.14
KA3110A	1	1995-02-23		20.05	28.63	-415.61	-416.02	-413.14
	2	1995-02-23		6.55	19.05	-414.32	-414.91	-413.14
KA3385A	1	1995-03-02		32.05	34.18	-448.74	-448.83	-416.42
	2	1995-03-02		7.05	31.05	-446.61	-447.62	-416.42
KA3510A	1	1998-10-20		122.02	150.06	-509.75	-516.73	-447.96
	2	1998-10-20		114.02	121.02	-505.77	-507.51	-447.96
	3	1998-10-20		4.52	113.02	-450.97	-478.18	-447.96
KA3539G	1	1999-02-17	1999-08-01	0.3	30.01	-449.49	-464.14	-448.25
	1	1999-08-01		19.3	30.01	-468.22	-473.51	-447.54
	2	1999-08-01		9.8	18.3	-458.86	-463.05	-447.54
	3	1999-08-01		1.3	8.8	-450.47	-454.17	-447.54

Borehole	Section no	Date from	to	Borehole length from (m)	to (m)	Elevation of SecTop (masl)	SecMid (masl)	Transducer (masl)
KA3542G01	1	1999-02-17	1999-08-01	0.3	30.04	-449.29	-459.79	-448.25
	1	1999-08-01		25.8	30	-467.30	-468.79	-447.90
	2	1999-08-01		8.8	24.8	-455.29	-460.94	-447.90
	3	1999-08-01		1.3	7.8	-449.99	-452.29	-447.90
KA3542G02	1	1999-02-17	1999-08-01	0.3	30.01	-449.28	-459.64	-448.25
	1	1999-08-01		22.3	30	-464.62	-467.30	-447.90
	2	1999-08-01		13.8	21.3	-458.69	-461.31	-447.90
	3	1999-08-01		8.8	12.8	-455.21	-456.60	-447.90
	4	1999-08-01		1.3	7.8	-449.98	-452.24	-447.90
KA3544G01	1	1999-02-17	1999-08-01	0.3	12	-449.25	-455.10	-448.25
	1	1999-08-01		6.3	12	-455.25	-458.10	-447.90
	2	1999-08-01		1.3	5.3	-450.25	-452.25	-447.90
KA3546G01	1	1999-02-17	1999-08-01	0.3	12	-449.19	-455.04	-448.25
	1	1999-08-01		6.8	12	-455.69	-458.29	-447.90
	2	1999-08-01		1.3	5.8	-450.19	-452.44	-447.90
KA3548A01	1	1999-02-17		15	30	-447.39	-447.80	-448.25
	2	1999-02-17		10	14	-447.12	-447.23	-448.25
KA3548G01	1	1999-02-17	1999-08-18	0.3	12.01	-449.30	-455.15	-448.25
KA3550G01	1	1999-02-17	1999-08-01	0.3	12.03	-449.07	-454.93	-448.25
	1	1999-08-01		6.3	12	-455.07	-457.92	-447.90
	2	1999-08-01		1.3	5.3	-450.07	-452.07	-448.25
KA3552G01	1	1999-02-17	1999-08-01	0.3	12.01	-449.07	-454.93	-448.25
	1	1999-08-01		8.8	12	-457.57	-459.17	-447.90
	2	1999-08-01		4.05	7.8	-452.82	-454.70	-447.90
	3	1999-08-01		1.3	3.05	-450.07	-450.95	-447.90
KA3554G01	1	1999-02-17	1999-08-01	0.3	30.01	-449.05	-459.56	-448.25
	1	1999-08-01		22.3	30	-464.61	-467.34	-447.90
	2	1999-08-01		12.3	21.3	-457.54	-460.72	-447.90
	3	1999-08-01		1.3	11.3	-449.75	-453.29	-447.90
KA3554G02	1	1999-02-17	1999-08-01	0.3	30.01	-449.03	-459.53	-448.25
	1	1999-08-01		22.3	30	-464.59	-467.31	-447.90
	2	1999-08-01		10.3	21.3	-456.10	-459.99	-447.90
	3	1999-08-01		1.3	9.3	-449.74	-452.57	-447.90
KA3557G	1	1999-02-17		0.3	30.04	-449.14	-463.85	-448.25
KA3563G	1	1999-02-17	1999-08-01	9.3	30	-457.85	-468.04	-447.54
	2	1999-02-17	1999-08-01	3.8	8.3	-452.44	-454.65	-447.54
	3	1999-02-17	1999-08-01	1.3	2.8	-449.97	-450.71	-447.54
	1	1999-08-01		0.3	30	-448.99	-463.61	-448.25
KA3566G01	1	1999-02-17		20.7	30.01	-463.17	-466.45	-447.54
	2	1999-02-17		12.2	19.8	-457.17	-459.85	-447.54
	3	1999-02-17		7.3	11.3	-453.72	-455.13	-447.54
	4	1999-02-17		1.3	6.3	-449.48	-451.25	-447.54
KA3566G02	1	1999-02-17		19.3	30.01	-461.93	-465.63	-447.54
	2	1999-02-17		12.3	18.3	-457.08	-459.16	-447.54
	3	1999-02-17		7.8	11.3	-453.97	-455.18	-447.54
	4	1999-02-17		1.3	6.8	-449.47	-451.37	-447.90
KA3572G01	1	1999-02-17	1999-08-01	6.3	12	-454.81	-457.66	-447.90
	2	1999-02-17	1999-08-01	1.3	5.3	-449.81	-451.81	-447.90
	1	1999-08-01		0.3	12	-448.81	-454.66	-448.25
KA3573A	1	1999-02-17		18	40.07	-446.73	-447.14	-448.25
	2	1999-02-17		4.5	17	-446.23	-446.46	-448.25

Borehole	Section no	Date from	to	Borehole length from (m)	to (m)	Elevation of SecTop (masl)	SecMid (masl)	Transducer (masl)
KA3574G01	1	1999-02-17	1999-08-01	8.8	12	-457.13	-458.73	-447.90
	2	1999-02-17	1999-08-01	5.3	7.8	-453.63	-454.88	-447.90
	3	1999-02-17	1999-08-01	1.3	4.3	-449.63	-451.13	-447.90
	1	1999-08-01		0.3	12	-448.63	-454.48	-448.25
KA3576G01	1	1999-02-17	1999-08-01	8.8	12.01	-457.07	-458.68	-447.90
	2	1999-02-17	1999-08-01	3.8	7.8	-452.07	-454.07	-447.90
	3	1999-02-17	1999-08-01	1.3	2.8	-449.57	-450.32	-447.90
	1	1999-08-01		0.3	12	-448.57	-454.42	-448.25
KA3578G01	1	1999-02-17	1999-08-01	6.8	12.58	-455.18	-458.07	-447.90
	2	1999-02-17	1999-08-01	1.3	5.8	-449.68	-451.93	-447.90
	1	1999-08-01		0.3	12.6	-448.68	-454.83	-448.25
KA3579G	1	1999-02-17	1999-08-01	9.3	22.65	-457.67	-464.34	-447.90
	2	1999-02-17	1999-08-01	5.3	8.2	-453.67	-455.12	-447.90
	3	1999-02-17	1999-08-01	1.3	4.3	-449.67	-451.12	-447.90
	1	1999-08-01		0.3	22.7	-448.67	-459.87	-448.25
KA3584G01	1	1999-02-17		0.3	12	-448.55	-454.40	-448.25
KA3590G01	1	1999-02-17	1999-08-01	17.3	30.06	-460.17	-464.63	-447.90
	2	1999-02-17	1999-08-01	7.8	16.3	-453.52	-456.49	-447.90
	3	1999-02-17	1999-08-01	1.3	6.8	-448.97	-450.90	-447.90
	1	1999-08-01		0.3	30.1	-448.27	-458.70	-448.25
KA3590G02	1	1999-02-17	1999-08-01	23.3	30.05	-464.21	-466.55	-447.90
	2	1999-02-17	1999-08-01	17.3	22.3	-460.06	-461.79	-447.90
	3	1999-02-17	1999-08-01	8.3	16.3	-453.83	-456.60	-447.90
	4	1999-02-17	1999-08-01	1.3	7.3	-448.98	-451.06	-447.90
	1	1999-08-01		0.3	30.1	-448.29	-458.60	-448.25
KA3593G	1	1999-02-17	1999-08-01	8.3	30.02	-456.24	-466.93	-447.90
	2	1999-02-17	1999-08-01	1.3	7.3	-449.35	-452.31	-448.25
	1	1999-08-01		0.3	30	-448.37	-462.99	-448.25
KA3600F	1	1999-02-17		22	50.1	-446.24	-446.66	-448.25
	2	1999-02-17		4.5	21	-445.73	-445.97	-448.25
KF0051A01	1	1998-06-12		10.55	11.8	-446.12	-445.81	-450.9±0.3
	2	1998-06-12		8.85	9.55	-446.97	-446.80	-450.9±0.3
	3	1998-06-12		6.26	7.85	-448.26	-447.87	-450.9±0.3
	4	1998-06-12		4.66	5.26	-449.06	-448.91	-450.9±0.3
KG0021A01	1	1998-10-16	1999-06-15	-0.1	48.82		-437.76	-446.78
	1	1999-06-15		42.5	48.82	-432.25	-431.29	-446.78
	2	1999-06-15		35	41.5	-434.53	-433.54	-446.78
	3	1999-06-15		25	34	-437.57	-436.20	-446.78
	4	1999-06-15		17	24	-440.00	-438.93	-446.78
	5	1999-06-15		4	16	-443.94	-442.12	-446.78
KG0048A01	1	1998-11-24		49	54.69	-432.63	-431.95	-446.78
	2	1998-11-24		41	48	-434.57	-433.72	-446.78
	3	1998-11-24		30	40	-437.23	-436.02	-447.03
	4	1998-11-24	1999-01-18	13	29	-441.34	-439.40	-447.03
	5	1998-11-24	1999-01-18	4	12	-443.52	-442.55	-447.03
	4	1999-02-11		4	29	-443.52	-440.49	-447.03

Borehole	Section no	Date from	to	Borehole length from (m)	to (m)	Elevation of SecTop (masl)	SecMid (masl)	Transducer (masl)
KI0023B	1	1998-02-12		200.71	113.7	-518.68	-503.59	-448.21
	2	1998-02-12		111.25	112.7	-487.43	-487.69	-447.96
	3	1998-02-12		87.2	110.25	-478.84	-482.97	-447.96
	4	1998-02-12		84.75	86.2	-477.96	-478.22	-447.96
	5	1998-02-12		72.95	83.75	-473.73	-475.67	-447.96
	6	1998-02-12		70.95	71.95	-473.01	-473.19	-447.96
	7	1998-02-12		43.45	69.95	-463.15	-467.89	-447.96
	8	1998-02-12		41.45	42.45	-462.43	-462.61	-447.96
	9	1998-02-12		4.6	40.45	-449.32	-455.68	-447.96
KI0025F	1	1998-03-04	1999-07-29	169	193.8	-502.04	-505.72	-448.21
	2	1998-03-04	1999-07-29	164	168	-500.55	-501.15	-448.21
	3	1998-03-04	1999-07-29	89	163	-477.66	-489.09	-448.21
	4	1998-03-04	1999-07-29	86	88	-476.72	-477.03	-448.21
	5	1998-03-04	1999-07-29	41	85	-462.18	-469.39	-448.21
	6	1998-03-04	1999-07-29	3.5	40	-449.43	-455.70	-448.21
	1	1999-07-29		170.5	193.8	-502.49	-505.94	-448.21
	2	1999-07-29		165.5	169.5	-501.00	-501.59	-448.21
	3	1999-07-29		90.5	164.5	-478.13	-489.55	-448.21
	4	1999-07-29		87.5	89.5	-477.19	-477.50	-448.21
	5	1999-07-29		42.5	86.5	-462.68	-469.87	-448.21
	6	1999-07-29		5	41.5	-449.95	-456.22	-448.21
KI0025F02	1	1998-10-19		135.15	204.18	-504.43	-517.99	-447.35
	2	1998-10-19		100.25	134.15	-490.40	-497.27	-447.35
	3	1998-10-19		93.35	99.25	-487.58	-488.78	-447.35
	4	1998-10-19		78.25	92.95	-481.36	-484.39	-447.35
	5	1998-10-19		73.3	77.25	-479.31	-480.13	-447.35
	6	1998-10-19		64	72.9	-475.45	-477.30	-447.35
	7	1998-10-19		56.1	63	-472.17	-473.61	-447.35
	8	1998-10-19		51.7	55.1	-470.34	-471.05	-447.35
	9	1998-10-19		38.5	50.7	-464.85	-467.39	-447.35
	10	1998-10-19		3.4	37.5	-450.00	-457.26	-447.35
KI0025F03	1	1999-10-22		101.08	141.72	-497.66	-507.42	-447.96
	2	1999-10-22		93.58	100.08	-494.04	-495.61	-447.96
	3	1999-10-22		89.08	92.58	-491.86	-492.71	-447.96
	4	1999-10-22		85.08	88.08	-489.92	-490.65	-447.96
	5	1999-10-22		66.58	74.08	-480.92	-482.75	-447.96
	6	1999-10-22		59.58	65.58	-477.49	-478.96	-447.96
	7	1999-10-22		55.08	58.58	-475.28	-476.14	-447.96
	8	1999-10-22		51.58	54.08	-473.56	-474.18	-447.96
	9	1999-10-22		3.58	50.58	-449.85	-461.49	-447.96
KXTT1	1	1995-07-07		17	28.76	-404.27	-408.48	-399.10
	2	1995-07-07		15	16	-402.84	-403.20	-399.10
	3	1995-12-07		7.5	11.5	-397.48	-398.91	-399.10
	4	1995-12-07		3	6.5	-394.26	-395.51	-399.10
KXTT2	1	1995-12-06		16.55	18.3	-404.01	-404.63	-399.10
	2	1995-12-06		14.55	15.55	-402.61	-402.96	-399.10
	3	1995-12-06		11.55	13.55	-400.51	-401.21	-399.10
	4	1995-12-06		7.55	10.55	-397.72	-398.77	-399.10
	5	1995-12-06		3.05	6.55	-394.56	-395.79	-399.10
KXTT3	1	1995-07-08		15.42	17.43	-400.33	-400.93	-399.10
	2	1995-12-06		12.42	14.42	-398.53	-399.13	-399.10
	3	1995-12-06		8.92	11.42	-396.43	-397.18	-399.10
	4	1995-07-08		3.17	7.92	-392.98	-394.41	-399.10

Borehole	Section no	Date from	to	Borehole length from (m)	to (m)	Elevation of SecTop (masl)	SecMid (masl)	Transducer (masl)
KXTT4	1	1995-07-18	1999-12-14	24.42	49.31	-405.59	-413.01	-399.10
	2	1995-07-18	1999-12-14	14.92	23.42	-399.95	-402.47	-399.10
	2	1999-12-14		14.92	49.31	-399.95	-410.17	-399.10
	3	1995-12-07		11.92	13.92	-398.17	-398.77	-399.10
	4	1995-12-07		8.42	10.92	-396.10	-396.84	-399.10
	5	1995-07-18		3.17	7.42	-392.98	-394.24	-399.10
KXTT5	1	1999-12-14		10.81	25.8	-393.09	-395.05	-399.10
	2	1999-12-14		9.61	9.81	-392.78	-392.81	-399.10
	3	1999-12-14		6.11	8.61	-391.88	-392.20	-399.10
	4	1999-12-14		3.11	5.11	-391.62	-391.36	-399.10
SA2142A	1	1993-02-23		6	20	-288.35	-289.44	-289.19
SA2338A	1	1993-04-14		6	20	-313.76	-314.61	-334.61

Note - Data not relevant for 1999 is to be found in earlier annual reports.

4.4.3 Accuracy of pressure measurements

No systematic estimation of different errors in the pressure measurements has been performed.

One source of error is the determination of the calibration constants. This is related to the status of the pressure reference system, i.e. the accuracy of the estimated levels of the calibration vessels and pressure transducers, the density of the water in the tubes and occurrence of air in the system. Also errors in the air pressure measured at the ground surface and the value used for acceleration of gravity can contribute to smaller errors in the pressure values.

Another error is related to the measurement method itself when measuring via a hydraulic multiplexer. The main dilemma is the delay time in the hydraulic multiplexers. When a magnetic valve opens towards a new section it will take some time before a deviating pressure inside the multiplexer, resulting from the previously measured section, has decayed and a correct pressure from the new section is obtained. Therefore, a delay time of 30 seconds between valve opening and measurement is used (Before March 1998 a delay time of 10 seconds have been used). However, the needed delay time depends on a number of factors such as hydraulic transmissivity and length of section and the length of the tube between a section and the hydraulic multiplexer. Since the value used is a compromise between the wish to be able to measure with relatively high frequency and the need of a delay time long enough, a certain error will be involved. This is especially valid in sections with low hydraulic transmissivity.

Summarising the above mentioned errors one can estimate the uncertainty in pressure measurements, under normal conditions, to be approximately 10 kPa for measurements with individul pressure transducers and 10-30 kPa for measurements via the hydraulic multiplexer.

If one wants to calculate absolute pressure at the section location, one must consider errors in density estimates of the water in the tubes between the section and the pressure transducer. The accuracy of the estimated levels of the section and the pressure transducer also has to be regarded.

4.5 Water flow in tunnel

4.5.1 Instrumentation

For a detailed description on instrumentation, see "Manual för HMS (del 3:4), 1994".

The water flow along the tunnel is collected at certain locations by concrete ditches across the tunnel and diverted to a gauging box equipped with a v-notch weir. The water level in the box is measured with either a pressure transducer or an ultrasonic transmitter, connected to the HMS, that are calibrated against a ruler mounted on the box. After passage through the gauging box, the flow is diverted to a discharge pipe common for a number of gauging boxes, which finally leads into one of the sumps in the tunnel. See Figure 4-7.

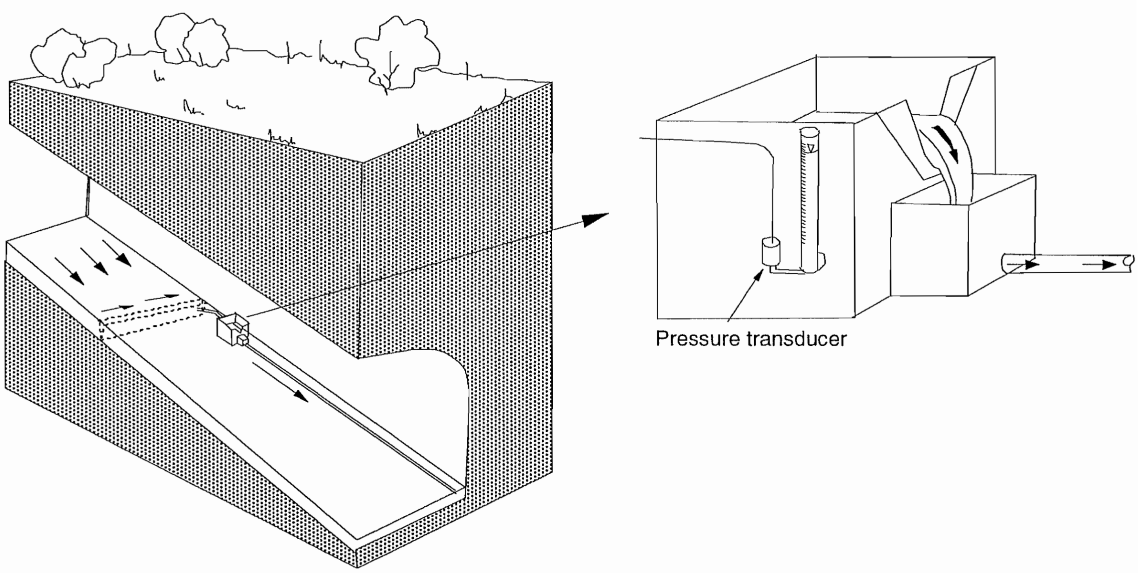


Figure 4-7 Water flow measurements in the tunnel.

Before autumn 1998 the levels in all flow weirs were measured with DRUCK PTX 510, relative pressure transducers with a pressure range of 0 - 100 mbar.

Since there have been some problems with the pressure transducers (incomplete compensation for air pressure, drift in the offset and sudden jumps in the registration), a number of ultrasonic transmitters of the type EXAC- /STA-270 replaced some of the pressure transducers during the autumn 1998. The remaining pressure transducers have been successively replaced, and at the end of 1999 pressure transducers were in use only in four gauging boxes at the very bottom of the tunnel system. This is because of the risk for overflow in this part of the tunnel. The ultrasonic transmitter is placed above the water surface in the box and measures the level by means of an ultrasonic signal. The measuring range is 0.2 – 0.7 m.

The tunnel sections, in metres from tunnel entrance, between which water is drained to the different measuring ditches, are listed in Table 4-6. The tunnel drainage system is graphically presented in Figure 4-8. Normally the gauging box is placed some 10 metres downward from the measuring ditch crossing the tunnel. Special arrangements are used to collect the water from the side tunnels containing the elevator and the ventilation shafts.

Table 4-6 Water flow measurements in tunnel segments

Gauging box	Upper section (m)	Lower section (m)
MA0682G	0	682
MA1033G	682	1033
MA1232G	1033	1232
MA1372G	1232	1372
MA1584G	1372	1584
MA1659G	Water from the elevator shaft (TH: 0-213 m), from the ventilation shaft for incoming air (TV: 0-213 m) and from a sump inside the gate in the side tunnel.	
MA1745G	1584	1745
	Water from the side tunnel collected at MA1659G is not included.	
MA1883G	1745	1883
MA2028G	1883	2028
MA2178G	2028	2178
MA2357G	2178	2357
MA2496G	2357	2496
MA2587G	Water from the elevator shaft (TH: 220-333 m) and from a sump inside the gate in the side tunnel.	
MA2699G	2496	2699
	Water from the side tunnel collected at MA2587G is not included.	
MA2840G	2699	2840
MA2994G	2840	2994
MA3179G	2994	3179
MA3385G	Water from the elevator shaft (TH: 340-450 m), from the ventilation shaft for incoming air (TV: 220-450 m) and from the ventilation shaft for outgoing air (TW: 0-450 m)	
MA3411G	3179	3426
	Water from the side tunnel collected at MA3385G is not included.	
MA3426G	3426	3600
	Water from parts of tunnel J at approximately 3510 m is included	
MF0061G	Water from tunnel F 0-61 m, parts of tunnel J and tunnel G	

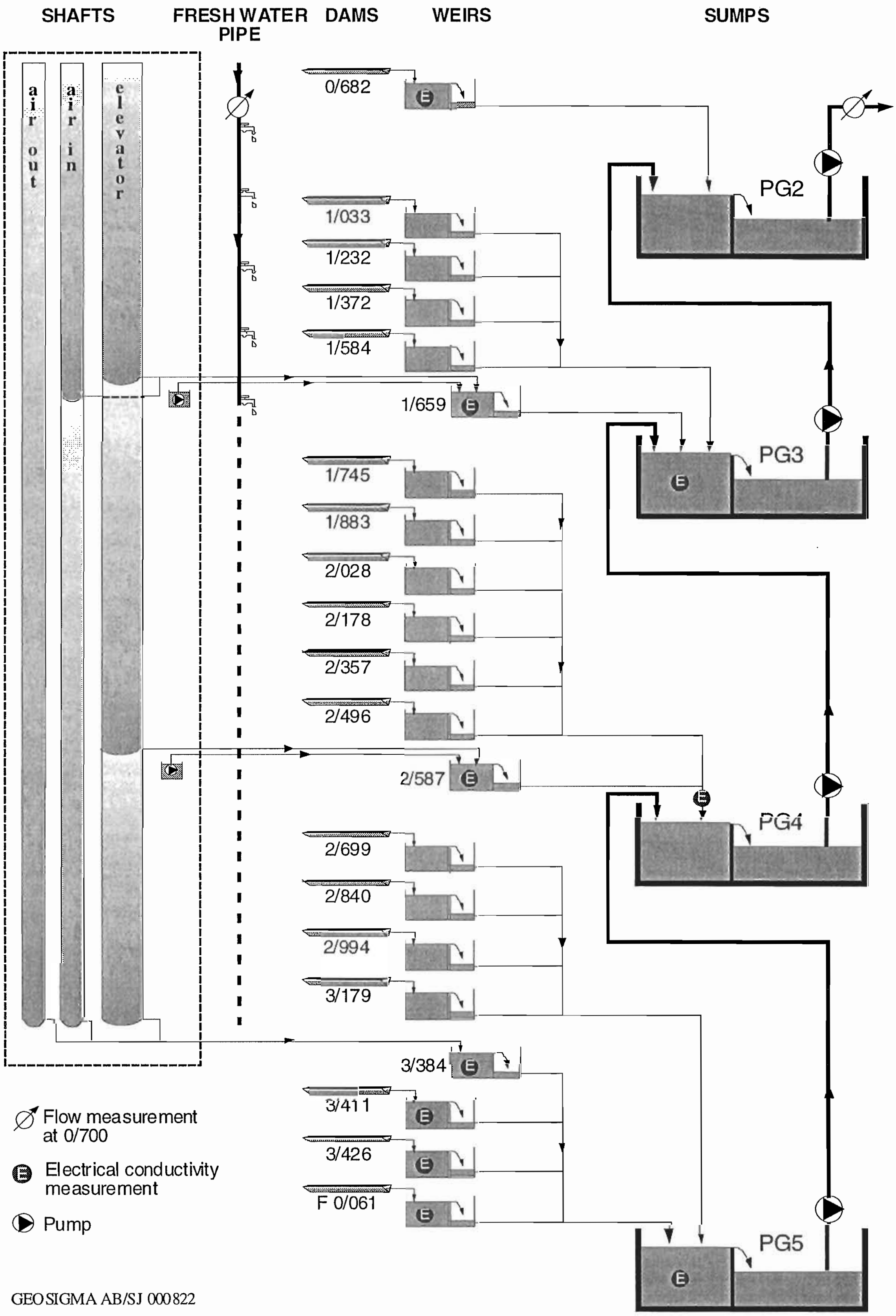


Figure 4-8 Tunnel drainage system.

4.5.2 Methodology

Water levels in the gauging boxes are used on the HMS to calculate flow rates by means of a discharge equation expressing flow rate as a function of level. Normally, the level is scanned every 10th second but stored only every 30th minute unless the change since latest stored value exceeds a predefined amount (change value). The change value is usually 1 mm, but due to oscillating levels in some gauging boxes it has been necessary to increase this value to avoid sampling too much data.

Initially the discharge equation for a weir is determined. The flow rate is measured at four different levels on the ruler. The level indicator is then calibrated against the ruler by altering the level in the box. This two-step procedure is used to avoid a new determination of the discharge equation every time a level indicator has to be replaced and to make the discharge equation independent to changes in the transducers calibration equation.

The levels in the gauging boxes are manually read ones every month to enable adjustments of the calibration constants for the level indicators. Once a year the discharge equation is checked through a field measurement of the existing flow rate and, if necessary, a new discharge equation is determined (see for example Jönsson et al. 1999).

4.5.3 Accuracy

If the flow rate does not differ too much from the interval where the measuring points were selected to determine the calibration equation, the error due to the equation is within approximately five percent.

However, the maintenance of the v-notch weir is important. If there are obstacles or coatings on the weir the relation between level and flow rate is disturbed.

4.6 Water flow in tunnel pipes

For a detailed description on instrumentation, see "Manual för HMS (del 3:4), 1994".

The flow in the pipe for pumped out drainage water is measured with an acoustic "clamp-on" type flow meter. The sensor is situated approximately 700 m from the tunnel entrance. Until 1999-06-26, the flow of incoming consumption water was measured in the same way, but after a failure in the flow meter a decision was taken not to continue this measurement.

4.6.1 Methodology

It is not enough to use calibration constants given by the manufacturer. Using some material constants for different pipes is then necessary and the errors caused by using wrong constants are unknown. The pipes consist of different material layers, and can be coated at the inside. The flow meters are therefore calibrated using a "watch and bucket" method.

If the flow values are used as a part of the water balance for the tunnel one shall be aware that some of the incoming water is used for consumption at the Site office. However, this portion is a very small part of the total water balance of the tunnel.

The drainage water is pumped from one sump to the sump upward (there are five sumps in the tunnel). From the top sump the water is pumped out of the tunnel. The pump in every sump is working at max capacity until the sump is emptied and starts again when the sump is filled to a certain level. The flow is measured at one location only, some 10 metres upwards the top sump. This means that the flow rate is either zero or at the maximum capacity of the pump. The flow meter is calibrated by measuring the level changes per time in the sump. Since the area of the sump at different levels is known one can calculate the discharged water.

Both flowmeters measure very frequently, every ten seconds for incoming and every five seconds for discharged water, but the values are stored only if a certain change has taken place.

4.6.2 Accuracy

No systematic estimation of different errors has been performed but comparisons of the annual calibrations indicates an uncertainty around 10 % for both incoming and outgoing flow measurements.

4.7 Electrical conductivity of tunnel water

For a detailed description on instrumentation, see "Manual för HMS (del 3:4), 1994".

Electrical conductivity is measured with a 4-electrode conductivity meter, consisting of a housing with an electronic unit and an integrated sensor. The manufacturer gives a figure of max. 0.5 % of measured value plus 0.5 % of measuring range. This gives at maximum 20 mS/m for most of the sensors.

The meter is mounted either in a gauging box for flow measurements or on the common discharge pipe leading water from the gauging boxes to the pumping sumps.

In Table 4-7 the tunnel parts from which water originates at the different measuring points are listed. Length to section is given in metres from the tunnel entrance.

Table 4-7 Electrical conductivity of water in tunnel segments

Mearuring point	Upper section (m)	Lower section (m)
EA0682G	0	682
EA1584T	1033	1584
EA1659B	Water from the elevator shaft, from the ventilation shaft for incoming air (TV: 0-220 m) and from a sump inside the gate in the side tunnel.	
EA2496T	Water between section 1584 m and section 2496 m, and from the gauging box MA2587G (see below).	
EA2587G	Water from the elevator shaft and from a sump inside the gate in the side tunnel at 2587 m.	
EA3179G	2994	3179
EA3384G	Water from the elevator shaft (TH: 340-450 m), from the ventilation shaft for incoming air (TV: 220-450 m) and from the ventilation shaft for outgoing air (TW: 0-450 m)	
EA3411G	3179	3426
EA3426G	3426	3600
	Water from parts of tunnel J at approximately 3510 m is included	
EF0061G	Water from tunnel F 0-61 m, parts of tunnel J and tunnel G	
EPG5	Water below section 2496 m, including the water from the gauging box MA3384G (see above)	

4.7.1 Methodology

The electric conductivity meter is connected to a logger on the HMS. A value is measured and stored once every hour. The four gauging boxes MA3384G, MA3411G, MA3426G and MF0061G are all situated near the sump PG5 in the bottom part of the tunnel, and the same electrical conductivity meter is used for periods in the different boxes and the sump.

Once a year the meters are calibrated by measuring on three buffer fluids having well-defined electrical conductivity.

4.7.2 Accuracy

No careful calculations on errors have been done, but a rough estimate gives a figure around some tens mS/m. From the annual calibrations the uncertainty can be estimated to be approximately 5 % of measured values. This includes all types of errors, for example coatings on the sensor, drift in calibration constants, error in the electrical conductivity of the buffer solutions etc.

4.8 Earth tide

Depending on the tidal forces of the moon and the sun, the earth is periodically deformed. Because of this deformation, the earth's surface moves up and down with an amplitude of 15-30 centimetres every day. The tide effect also causes volume changes in compressible material in the earth's crust, an effect termed tidal volumetric dilatation. This phenomenon can be observed as a nearly semidiurnal sinusoidal fluctuation in some groundwater pressure registrations (see example in Figure 4-9). In fact, the tidal wave is composed of two longwave (half a month and half a year) and two shortwave (nearly half diurnal and half diurnal) oscillations.

Hourly values on earth tide, expressed as level above mean, have been calculated with an analytical model by Hans-Georg Scherneck at Chalmers University of Technology, Onsala Space Observatory, for the Äspö location. Since the earth tide mainly is a global phenomenon affecting the whole earth crust, local conditions are of minor importance and the relative error in the calculated values is less then a few percent.

At Äspö the effect can be seen in nearly all core boreholes and in many of the percussion boreholes. The groundwater pressure increases when the Earth crust is depressed and decreases when the crust rises. Therefore the oscillations in the pressure registration are almost an image of the Earth tide expressed as a level above mean (Figure 4-9). Furthermore, the amplitude is greater in sections not in direct contact with the groundwater surface, due to less relaxation than in the uppermost section.

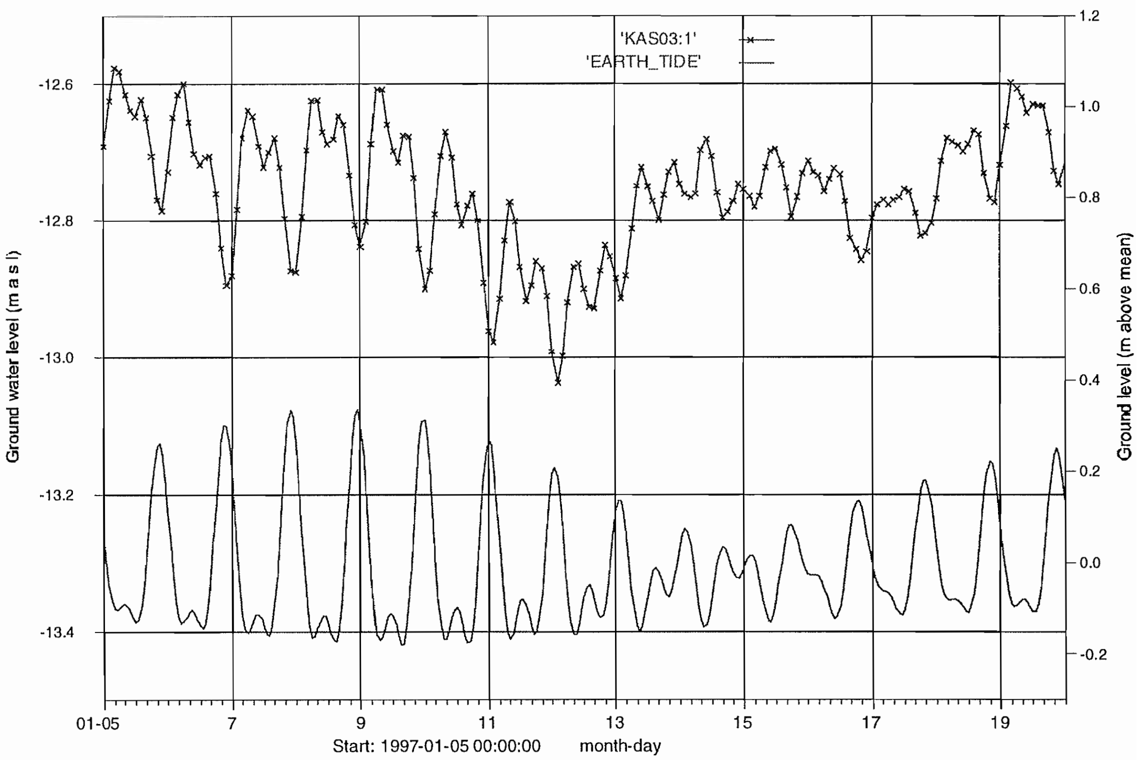


Figure 4-9 Earth tide (bottom curve, right axis) and groundwater level in KAS03:1 (top curve, left axis) during January 1997.

4.9 Level data from the Baltic Sea

The Swedish Meteorlogical and Hydrological Institute (SMHI) record the sea level at the city of Oskarshamn (some 25 km from the Simpevarp area). A writing recorder is connected to a float in a gauge well. Data is digitized and transferred to computer media (by SMHI) on an hourly basis. The influence of oscillations with short frequency (waves) is filtered, both by the gauge well and when digitizing data. Sea levels are adjusted to the national elevation system (RH70), which gives approximately 6 centimetres higher values than the local system on Äspö.

The errors in the data presented in the diagrams are, according to SMHI, less than one hour in time notation and less than a few centimetres in elevation.

For shorter periods, during quickly changing weather conditions, the difference in sea level between Oskarshamn and the Äspö area can be a few centimeters, but is normally much less.

4.10 Meteorological data

4.10.1 Precipitation

Precipitation is obtained from the Oskarshamn station (SMHI no 7616). The station is a regular SMHI-station, where a precipitation gauge with a wind shield (SMHI-type) is emptied at 0700 hours every day. Precipitation amounts are always referred to the day before emptying the gauge.

The most important error in point measurements of precipitation is due to the wind. The wind error varies with type of precipitation, wind speed and site, but always results in a deficiency of catch. The error due to evaporation from the gauge is largest during warm summer days with showers. The loss is estimated to some 1.5 mm/month (Gottschalk, 1980) as a mean, although much depending on meteorological factors. All types of errors cause precipitation to be underestimated. For the Oskarshamn station the total correction needed have been estimated at +18 % (Eriksson, 1980) for the annual precipitation amount. All precipitation values in this report are measured values, without any corrections.

A much more difficult problem when dealing with precipitation data is the poor areal representativeness of precipitation measurements, especially during showery conditions in the summer.

4.10.2 Temperature

Daily mean temperatures are obtained from the Oskarshamn station. These are, by SMHI, evaluated as a weighted mean of temperatures measured at 0700, 1300 and 1900 hours and the maximum and minimum temperatures.

Temperature is an easier variable to measure than precipitation, and the areal representativeness is normally much better. Therefore the Oskarshamn measurements some 25 km away can be regarded as good estimates of the temperature at Äspö, especially since both sites are near-coastal and at nearly the same altitude.

4.10.3 Potential Evapotranspiration

Potential evapotranspiration[1] is calculated with the Penman formula. This demands meteorological data available only at a few synoptical stations. Until 31 July 1995 , when the station at Ölands Norra Udde was closed, all presented values were means of potential evaporation calculated for Gladhammar and Ölands Norra Udde. Furthermore, the observation of cloudiness, which is used to obtain incoming short wave radiation in Penmans formula, was ended for Gladhammar 30 June 1995. Therefore, from 31 July 1995, the potential evaporation is calculated with data from Gladhammar but with cloudiness from Målilla some 50 km west from the Simpevarp area. Since the cloudiness at Målilla is greater than at the near coastal station in Gladhammar this will result in lower calculated potential evapotranspiration.

Ölands Norra Udde and Gladhammar are situated approximately 25 and 35 km respectively from the study site.

Although actual evapotranspiration can show a rather great aerial variation on the local scale, the potential evapotranspiration, depending mainly upon meteorological factors, does not vary that much. For long periods the actual evapotranspiration is almost the same as the potential, but during the summer months it does not reach the potential rate. The difference between the two very much depends upon vegetation, ground conditions and the wetness situation in an area.

[1] The theoretical evapotranspiration from a surface completely covered by a homogenous surface of green vegetation (crop) experiencing no lack of soil water.

5 Summary of activities influencing groundwater levels, pressure and flow

5.1 General

One main purpose of this report is to give an overview of the long-term effect of the tunnel excavations on the groundwater situation in the area. Therefore activities that might influence the groundwater pressure, groundwater levels and groundwater inflow to the tunnel are presented. The character and magnitude of the disturbances are different for different activities. Some might influence the groundwater pressure/level in many surrounding boreholes while others have influence only in the borehole where the activity takes place.

During the spring of 1991, the tunnel excavation began to have a visible effect on the groundwater level in many boreholes, especially on Äspö and Bockholmen. Later on most boreholes, except those on Laxemar, were influenced by the tunnel activities. From late 1991, the disturbances from the tunnel had a dominating influence on the groundwater levels in the area. One single activity affecting the groundwater levels in many boreholes on Äspö was the drilling of the first of two raice-drilled ventilation shafts to the tunnel at the end of October 1992. After this event, the groundwater levels continued to decline in many borehole sections, but nothing as spectacular as in the late 1992 has occurred. Since 1996, the level/pressure in most boreholes seems to have stabilised and in most of the surface borehole sections the changes during 1999 were small (within one metre), with both increasing and decreasing levels. The greatest change occurred in borehole HAS16 where the level decreased around 4 m in section 1 and nearly 16 m in section 2. Almost all sections in tunnel boreholes show decreasing pressures during 1999. A mean value is somewhere around 50 kPa but the greatest decline, observed in borehole SA2338A, was almost 150 kPa.

A large number of activities, which may or may not have influenced the groundwater level/pressure and inflow to the tunnel, have been carried out during 1999. A total of more than 3300 entries during 1999 are to be found in the activity table in the SKB database. One should also expect that there are activities that have influenced groundwater conditions that are not included in the database. Because of the great number of activities in the database, only a selection of activities is presented in the following tables.

The activities are listed in Tables 5-1 - 5-6. The dates stated in the tables are the dates for the actual activity. However, the influence on groundwater levels/pressures may last 5-10 times the length of the activity.

5.2 Tunnel excavation and permanent reinforcement

These activities, presented in Table 5-1, may have a substantial influence on ground water levels and pressures.

Table 5-1 Tunnel excavation and permanent reinforcements

Start	Stop	Idcode	Secup (m)	Seclow (m)	Activity
1999-01-03	1999-01-03	NASA3009A			Additional scaling
1999-01-12	1999-01-14	TASA	2710	2728	Bolting
1999-01-18	1999-01-21	TASA	2720	2735	Bolting
1999-02-02	1999-02-05	KK0045G01			Grouting
1999-02-02	1999-02-04	TASA	3000	3015	Bolting
1999-02-08	1999-02-11	TASA	3022	3053	Bolting
1999-02-15	1999-02-15	TASA	3058	3065	Bolting
1999-02-18	1999-02-18	NASA3419B			Additional scaling
1999-03-02	1999-03-02	TASA	2770	2780	Additional scaling
1999-03-04	1999-03-04	TASA	2780	2790	Additional scaling
1999-03-08	1999-03-09	TASA	2790	2815	Additional scaling
1999-03-11	1999-03-11	TASA	2815	2830	Additional scaling
1999-03-16	1999-03-18	TASA	2858	2910	Bolting
1999-03-16	1999-03-16	TASZ			Additional scaling
1999-03-22	1999-03-24	TASA	2910	2940	Bolting
1999-04-12	1999-04-12	NASA3067A			Additional scaling
1999-04-12	1999-04-12	TASG			Additional scaling
1999-04-13	1999-04-13	TASF	1	20	Additional scaling
1999-04-13	1999-04-13	TASJ			Additional scaling
1999-04-14	1999-04-15	TASD			Additional scaling
1999-04-15	1999-04-15	TASG			Additional scaling
1999-04-15	1999-04-15	TASZ			Additional scaling
1999-04-19	1999-04-22	TASF	1	80	Additional scaling
1999-04-26	1999-04-26	TASC			Additional scaling
1999-04-26	1999-04-26	TASE			Additional scaling
1999-05-03	1999-05-03	TASC			Bolting
1999-06-24	1999-06-24	TASA	2360	2375	Additional scaling
1999-06-28	1999-06-28	TASA	2375	2390	Additional scaling
1999-06-30	1999-06-30	TASA	2405	2420	Additional scaling
1999-07-01	1999-07-01	TASA	2490	2500	Additional scaling
1999-07-05	1999-07-05	TASA	2500	2510	Additional scaling
1999-07-06	1999-07-07	TASA	2190	2225	Additional scaling
1999-08-03	1999-08-05	TASA	2200	2250	Additional scaling
1999-08-09	1999-08-10	TASA	2250	2290	Additional scaling
1999-08-10	1999-08-11	TASA	2290	2340	Additional scaling
1999-08-19	1999-08-19	TASA	2340	2360	Additional scaling
1999-08-26	1999-08-26	TASA	2035	2150	Additional scaling
1999-09-07	1999-09-07	TASA	2050	2070	Additional scaling
1999-09-14	1999-09-16	TASA	2110	2190	Additional scaling
1999-09-14	1999-09-14	TASD			Additional scaling
1999-09-27	1999-09-27	TASA	1890	1910	Additional scaling
1999-09-30	1999-09-30	TASA	1910	1925	Additional scaling
1999-10-06	1999-10-06	TASA	1925	1935	Additional scaling
1999-10-07	1999-10-07	TASJ			Additional scaling
1999-10-11	1999-10-14	TASA	1935	1995	Additional scaling
1999-10-18	1999-10-21	TASF	0	72	Additional scaling

5.3 Opening of valves in tunnel boreholes

The main reason for valve openings in boreholes is water sampling for chemical analyses. Usually, before water samples are taken from a tunnel borehole section, a certain amount of water is discharged to assure that the water is representative for that section. Typically for chemical sampling, a volume corresponding to five section volumes is discharged. When a valve is opened, the flow rate may vary a lot from section to section due to different transmissivities and pressures. Normally these type of valve openings have only a minor influence in other boreholes and therefore only borehole sections included in the monitoring program are listed in the table. Dates when valves have been open are to be found in Table 5-2. In some cases, due to missing data records, only start- or stop-date is noted. Since the opening and closing of a valve are uncoupled activities in the database is also possible, if two successive data records are missing, that the "from"- and "to"-dates are mismatching.

Table 5-2 Open valves in tunnel boreholes.

From	To	Borehole:sec	From	To	Borehole:sec	From	To	Borehole:sec
991214	991214	HA1273A:	990929	990930	KA1755A:3	990112		KA2563A:4
991214	991214	HA1278A:	990407	990408	KA2050A:1		990122	KA2563A:
991214	991214	HA1279A:	990929	990930	KA2050A:	990128	990128	KA2563A:
991214	991214	HA1283B:	990408	990408	KA2162B:1	990129	990129	KA2563A:
990922	990922	HA1327B:		990930	KA2162B:	990129	990129	KA2563A:
990929	990929	HA1327B:	991201	991201	KA2162B:1	990129	990129	KA2563A:
991203	991203	HA1327B:		991209	KA2377A01:	990129	990129	KA2563A:
991206	991206	HA1327B:	990111	990112	KA2511A:3	990130	990130	KA2563A:
991214	991214	HA1327B:	990111	990115	KA2511A:1	990130	990130	KA2563A:
991214	991214	HA1330B:		990112	KA2511A:5	990130	990130	KA2563A:
990922	990922	HA2743A:	990112		KA2511A:5	990131		KA2563A:
990929	990929	HA2743A:		990112	KA2511A:4	990303		KA2563A:
991201	991201	HA2743A:	990112		KA2511A:4	990407	990408	KA2563A:4
990929	990929	HA3289B:		990112	KA2511A:2	990408	990408	KA2563A:3
990930	990930	HA3289B:	990112		KA2511A:2	990408	990615	KA2563A:1
991203	991203	HA3289B:	990316		KA2511A:	990408	990615	KA2563A:1
990412	990412	HD0025A:1	990407	990408	KA2511A:4		990408	KA2563A:1
991021	991021	HD0025A:	990408	990408	KA2511A:5		990408	KA2563A:1
	990929	HG0038B01:	990929	991001	KA2511A:4	990408	990408	KA2563A:3
990930	990930	HG0038B01:	990930	990930	KA2511A:5	990408	990408	KA2563A:3
991006	991006	HG0038B01:	990412	990412	KA2512A:		990408	KA2563A:3
000119	000119	HG0038B01:	990426	990426	KA2512A:	990408	990408	KA2563A:4
990408	990409	KA1061A:	990111	990115	KA2563A:2	990408	990408	KA2563A:4
990409		KA1061A:	990111	990115	KA2563A:3	990615		KA2563A:4
	990412	KA1061A:1	990111	990112	KA2563A:1	990615	990615	KA2563A:4
990929	991001	KA1061A:	990112	990112	KA2563A:5		990615	KA2563A:4
991214	991214	KA1061A:	990112	990112	KA2563A:5		990615	KA2563A:1
990408	990409	KA1131B:		990112	KA2563A:6	990928	990928	KA2563A:1
990929	990930	KA1131B:	990112		KA2563A:6	990928	990928	KA2563A:3
991214	991214	KA1131B:		990112	KA2563A:7	990928	990928	KA2563A:4
990407	990408	KA1755A:3	990112		KA2563A:7	991021	991021	KA2563A:4
990920	990921	KA1755A:3		990112	KA2563A:4	991021	991021	KA2563A:4

From	To	Borehole:sec
991021	991021	KA2563A:1
991021	991021	KA2563A:1
	991021	KA2563A:1
991021	991021	KA2563A:3
991021	991021	KA2563A:3
	991021	KA2563A:3
980304	980304	KA2598A:
990518		KA2598A:
	990518	KA2598A:
990218	990218	KA2861A:
990811		KA2861A:
990412	990412	KA2862A:1
990811	990811	KA2862A:2
990920	990921	KA2862A:
990929	990929	KA2862A:1
991006	991126	KA2862A:
	991006	KA2862A:
991201	991201	KA2862A:1
990617	990617	KA2865A01:
990704	990704	KA2865A01:
990705	990705	KA2865A01:
990921	990921	KA2865A01:
990922	990922	KA3010A:2
990929	990929	KA3010A:2
991130	991130	KA3010A:2
990614	990616	KA3065A02:
990704	990704	KA3065A02:
990705	990705	KA3065A02:
990920	990920	KA3065A02:
990929	990929	KA3067A:2
991130	991130	KA3067A:2
990922	990922	KA3105A:3
990929	990929	KA3105A:3
991130	991130	KA3105A:3
990412	990412	KA3110A:1
991001	991001	KA3110A:
991130	991130	KA3110A:1
990406	990406	KA3385A:2
990923	990923	KA3385A:1
990929	990929	KA3385A:1
990929	990929	KA3385A:1
991203	991203	KA3385A:1
990115	990115	KA3510A:3
	990115	KA3510A:2
990115	991203	KA3510A:2
990822	990822	KA3539G:2
990817	990817	KA3542G01:2
990107	990107	KA3542G02:
	990816	KA3542G02:2
990819	990819	KA3542G02:4
990519	990525	KA3544G01:1
990519	990520	KA3546G01:1
	990112	KA3548A01:2

From	To	Borehole:sec
	990112	KA3548A01:1
990112	990113	KA3548A01:1
	990112	KA3548A01:2
990112		KA3548A01:2
990112	990113	KA3548A01:2
	990113	KA3548A01:1
990113		KA3548A01:1
	990113	KA3548A01:2
990113		KA3548A01:2
990519	990525	KA3548G01:1
990816	990816	KA3554G01:1
990818	990818	KA3554G01:1
990816		KA3554G02:2
990318	990318	KA3563G:2
990318	990318	KA3563G:3
990222	990222	KA3566G01:2
990318	990409	KA3566G01:2
	990318	KA3566G01:2
990318	990318	KA3566G01:3
990318	990318	KA3566G01:4
990323	990416	KA3566G01:1
	990323	KA3566G01:1
	990409	KA3566G01:2
990224	990224	KA3566G02:2
990318	990318	KA3566G02:2
990318	990318	KA3566G02:3
990318	990318	KA3566G02:4
990323	990415	KA3566G02:1
	990323	KA3566G02:1
990329	990503	KA3566G02:3
990407		KA3566G02:2
990407	990608	KA3566G02:4
990408	990408	KA3566G02:2
990318	990318	KA3572G01:2
990406	990608	KA3572G01:2
	990115	KA3573A:2
990115		KA3573A:2
	990115	KA3573A:1
990115		KA3573A:1
990407	990929	KA3573A:1
	990407	KA3573A:1
990407	990407	KA3573A:2
990929	990929	KA3573A:2
990318	990318	KA3578G01:1
990406	990416	KA3578G01:1
	971103	KA3579G:
990116	990116	KA3579G:
	980420	KA3584G01:
990225	990225	KA3590G01:3
990226	990226	KA3590G01:2
990406	990406	KA3590G01:3
990226	990226	KA3590G02:1
990318	990318	KA3590G02:2

From	To	Borehole:sec
990318	990318	KA3590G02:3
990409	990413	KA3590G02:2
990409	990413	KA3590G02:3
990323	990323	KA3593G:2
990414	990415	KA3593G:2
	990113	KA3600F:2
990113		KA3600F:2
	990113	KA3600F:1
990113		KA3600F:1
990408	990409	KA3600F:1
990408	990409	KA3600F:2
990928	990929	KA3600F:1
990928	990929	KA3600F:2
990525	990525	KG0021A01:1
990615		KG0021A01:
990820	990820	KG0021A01:3
990821	990821	KG0021A01:1
990317	990317	KG0033G01:
	990407	KG0033G01:
990317	990317	KG0037G01:
990408	990409	KG0037G01:
990317	990409	KG0042G01:
	990317	KG0042G01:
990412		KG0042G01:
990317	990317	KG0046G01:
990412	990412	KG0046G01:
990525	990525	KG0048A01:1
990525	990525	KG0048A01:2
990525	990525	KG0048A01:3
990525	990525	KG0048A01:4
990617	990617	KG0048A01:
990317	990317	KG0051G01:
990412	990412	KG0051G01:
	980617	KI0023B:
	990111	KI0023B:8
990111		KI0023B:8
	990111	KI0023B:6
990111	990128	KI0023B:6
	990111	KI0023B:9
990111		KI0023B:9
	990111	KI0023B:5
990111		KI0023B:5
	990111	KI0023B:2
990111		KI0023B:2
	990111	KI0023B:7
990111		KI0023B:7
	990111	KI0023B:4
990111		KI0023B:4
	990111	KI0023B:1
990111		KI0023B:1
990111		KI0023B:8
990128	990129	KI0023B:6
990129	990129	KI0023B:6

From	To	Borehole:sec	From	To	Borehole:sec	From	To	Borehole:sec
990130	990130	KI0023B:6	990408		KI0025F:2	990408	990408	KI0025F02:5
990130	990130	KI0023B:6	990408	990408	KI0025F:4	990408	990408	KI0025F02:3
990131	990131	KI0023B:6	990408	990408	KI0025F:4	990408	990928	KI0025F02:6
990407	990407	KI0023B:4	990728	990728	KI0025F:4		990408	KI0025F02:5
990407		KI0023B:6	990729	990729	KI0025F:	990408	990408	KI0025F02:5
990407	990407	KI0023B:8	990729	990729	KI0025F:4		990408	KI0025F02:6
990407	990407	KI0023B:9	990730	990730	KI0025F:3	990429		KI0025F02:5
990408	990408	KI0023B:2	990730	990730	KI0025F:5	990429		KI0025F02:5
	990408	KI0023B:2	990929	990929	KI0025F:2		990615	KI0025F02:3
	990408	KI0023B:2	990929	990929	KI0025F:4		990615	KI0025F02:3
990408		KI0023B:2		990114	KI0025F02:5		990615	KI0025F02:6
990408	990408	KI0023B:4	990114		KI0025F02:5		990615	KI0025F02:6
990408	990408	KI0023B:4		990114	KI0025F02:8	990927	990928	KI0025F02:7
990408	990408	KI0023B:5		990114	KI0025F02:6	990928	990928	KI0025F02:3
990408	990408	KI0023B:5	990114		KI0025F02:6	990928	990928	KI0025F02:5
990408	990408	KI0023B:6		990114	KI0025F02:2	991025	991025	KI0025F02:5
990408	990408	KI0023B:6	990114		KI0025F02:2	991025	991025	KI0025F02:5
990408	990408	KI0023B:7		990114	KI0025F02:10	991025	991025	KI0025F02:6
	990408	KI0023B:7	990114		KI0025F02:8	991025	991025	KI0025F02:6
990408	990408	KI0023B:6	990114		KI0025F02:10	000117	000117	KI0025F02:3
990408	990408	KI0023B:6		990114	KI0025F02:7	000117	000117	KI0025F02:3
990408	990408	KI0023B:6		990114	KI0025F02:3		000117	KI0025F02:3
990408	990408	KI0023B:6	990114		KI0025F02:3	990921		KI0025F03:
990408		KI0023B:7	990114	990114	KI0025F02:9	991004	991004	KI0025F03:
990415	990416	KI0023B:4	990114		KI0025F02:7	991004	991004	KI0025F03:
990415	990416	KI0023B:4		990114	KI0025F02:9	991004	991004	KI0025F03:
990421	990423	KI0023B:6	990114		KI0025F02:9	991005	991005	KI0025F03:
990421	990423	KI0023B:6		990114	KI0025F02:1	991006	991006	KI0025F03:
990517	990615	KI0023B:7	990114		KI0025F02:1	991007	991007	KI0025F03:
990517	990615	KI0023B:7	990407	990407	KI0025F02:7	991012	991012	KI0025F03:
990518	990615	KI0023B:6	990408	990408	KI0025F02:2	991014	991021	KI0025F03:
990518	990615	KI0023B:6		990408	KI0025F02:2	991022	991022	KI0025F03:3
	990518	KI0023B:7	990408	990408	KI0025F02:2	991022	991022	KI0025F03:3
	990518	KI0023B:7	990408	990408	KI0025F02:2		991022	KI0025F03:3
990927	990927	KI0023B:4	990408	990408	KI0025F02:2	991022	991022	KI0025F03:4
990927	990927	KI0023B:6		990408	KI0025F02:2	991022	991022	KI0025F03:4
990927	990927	KI0023B:7	990408	990408	KI0025F02:3	991022	991022	KI0025F03:5
990112	990113	KI0025F:1	990408	990408	KI0025F02:3	991022	991022	KI0025F03:5
990112	990113	KI0025F:3		990408	KI0025F02:3	991022	991022	KI0025F03:6
990112	990113	KI0025F:6	990408	990408	KI0025F02:5	991022	991022	KI0025F03:6
	990113	KI0025F:2	990408	990408	KI0025F02:5	991022	991022	KI0025F03:7
990113		KI0025F:2	990408	990408	KI0025F02:6	991022	991022	KI0025F03:7
	990113	KI0025F:4	990408	990408	KI0025F02:6	991022	991022	KI0025F03:5
990113		KI0025F:4	990408	990408	KI0025F02:7	991022	991022	KI0025F03:5
	990113	KI0025F:5	990408	990408	KI0025F02:7		990319	KJ0044F01:
990113		KI0025F:5	990408	990408	KI0025F02:8	990703	990703	KJ0044F01:
990407	990407	KI0025F:2	990408	990408	KI0025F02:8	991014	991015	KJ0044F01:
990407	990407	KI0025F:4	990408		KI0025F02:3	000119	000119	KJ0044F01:
990408	990408	KI0025F:2	990408	990408	KI0025F02:3		990319	KJ0050F01:
990408	990408	KI0025F:2		990408	KI0025F02:3	000119	000119	KJ0050F01:
	990408	KI0025F:2	990408	990408	KI0025F02:3	000124		KJ0050F01:
990408	990408	KI0025F:2	990408	990408	KI0025F02:3	990704	990704	KJ0052F01:
	990408	KI0025F:2		990408	KI0025F02:3	990928	990928	KJ0052F01:

From	To	Borehole:sec
991013	991013	KJ0052F01:
991213	991213	KJ0052F01:
000119	000119	KJ0052F01:
000125	000126	KJ0052F01:
000127	000127	KJ0052F01:
	990326	KJ0052F02:
990703	990703	KJ0052F02:
990704	990704	KJ0052F03:
000119	000119	KJ0052F03:
000124		KJ0052F03:
990406	990406	KR0012B:1
990415	990415	KR0012B:
990804	990804	KR0012B:1
990927	990927	KR0012B:
990927	990927	KR0013B:
990406	990406	KR0015B:1
990415	990415	KR0015B:
990804	990804	KR0015B:
990927	990927	KR0015B:
990224	990224	KXP24BGR:
990224	990224	KXP24BGR:
990224	990224	KXP24BGR:
990225	990226	KXP24BGR:
	990225	KXP24BGR:
990226	990226	KXP24BGR:
990226		KXP24BGR:
990226		KXP24BGR:
990301		KXP24BGR:
990302		KXP24BGR:
990303	990303	KXP24BGR:
990303		KXP24BGR:
990303	990303	KXP24BGR:
	990303	KXP24BGR:
990303		KXP24BGR:
990303	990304	KXP24BGR:
990304	990304	KXP24BGR:
990304	990304	KXP24BGR:
	990714	KXP24BGR:
990224	990224	KXP26BGR:
990224	990224	KXP26BGR:
990224	990224	KXP26BGR:
990225	990225	KXP26BGR:
990225		KXP26BGR:
990226	990226	KXP26BGR:
990226	990226	KXP26BGR:
990226	990301	KXP26BGR:
990301	990301	KXP26BGR:

From	To	Borehole:sec
990301	990301	KXP26BGR:
990301	990301	KXP26BGR:
	990301	KXP26BGR:
990303		KXP26BGR:
990303	990303	KXP26BGR:
	990303	KXP26BGR:
	990303	KXP26BGR:
990303		KXP26BGR:
990304	990304	KXP26BGR:
990304	990304	KXP26BGR:
	990714	KXP26BGR:
991103		KXP26BGR:
990225	990225	KXP27BGR:
991129	991129	KXTT1:2
991129	991129	KXTT1:2
	991129	KXTT1:2
991215	991215	KXTT1:2
991215	991215	KXTT1:3
991215	991215	KXTT1:1
991215	991215	KXTT1:4
	990303	KXTT3:3
990303	990304	KXTT3:3
990304	990304	KXTT3:3
990304	990304	KXTT3:3
990304	990305	KXTT3:3
990305	990317	KXTT3:3
990413	990413	KXTT3:2
990928	990928	KXTT3:2
991004	991004	KXTT3:2
991013	991013	KXTT3:2
991209	991209	KXTT3:2
991209	991209	KXTT3:2
	991209	KXTT3:2
991213	991213	KXTT3:3
991214	991214	KXTT3:3
990305	990317	KXTT4:4
990317	990406	KXTT4:4
	990317	KXTT4:3
991215	991215	KXTT4:3
991215	991215	KXTT4:4
	991215	KXTT4:4
991215	991215	KXTT4:1
991215	991215	KXTT4:1
991215		KXTT4:2
	991215	KXTT4:1
991215	991215	KXTT4:2
990616	990616	KXTT5:

From	To	Borehole:sec
990704	990704	KXTT5:
990705	990705	KXTT5:
990921	990921	KXTT5:
991213	991213	KXTT5:
991214		KXTT5:
991216	991216	KXTT5:2
991130		KXZA4:
991130		KXZA5:
991130		KXZA7:
990108	990108	KZ0082F01:
990109	990109	KZ0082F01:
990110	990110	KZ0082F01:
990412	990415	SA0813B:
991001	991006	SA0813B:
990412	990413	SA1009B:
991004	991005	SA1009B:
991129	991202	SA1009B:
990413	990413	SA1229A:
991004	991004	SA1229A:
990412	990413	SA1420A:
	991005	SA1420A:
990413	990413	SA1730A:
990920	990921	SA1730A:
990923	990923	SA1730A:
991005	991005	SA1730A:
990412	990413	SA2074A:
991004	991005	SA2074A:
990406	990406	SA2273A:
991006	991006	SA2273A:
990407	990407	SA2338A:
990406		SA2600A:
990630	990630	SA2600A:
990630	990630	SA2600A:
	991006	SA2600A:
991006		SA2600A:
990922	990922	SA2718A:
990930	990930	SA2718A:
991201	991201	SA2718A:
990413	990414	SA2783A:
991004	991005	SA2783A:
990929	990930	SA2783B:
991201	991202	SA2783B:
990414	990414	SA2880A:
990920	990921	SA2880A:
991001	991001	SA2880A:
990414	990414	SA3045A:
991006	991006	SA3045A:

5.4 Packer expansion and release

Packers often isolate different fractures or fracture zones from each other in order to prevent flow along the borehole, which otherwise may act as a connection between fractures or zones. Therefore, release and expansion of packers may have an influence on the groundwater system. The dates for packer expansion/release in surface boreholes are listed in Table 5-3 (This refers to the large borehole packers and not the PEM - packers). Surface boreholes not included in the table have no packers.

In Table 5-4 packer expansion and release in tunnel boreholes are presented. This table only includes entries found in the database for 1999. In a few cases, data on expansion/release is missing in the database, which means that two entries on packer expansion or release may occur after one another.

Table 5-3 Packer expansion and release in surface boreholes.

Borehole	Expansion	Release
HAS03	89-05-12	97-02-05
HAS04	89-05-12	
HAS06	89-05-12	
HAS07	89-05-16	97-02-18
HAS08	89-05-12	97-01-30
HAS11	89-05-16	
HAS13	89-11-23	98-12-15
HAS13	99-05-18	
HAS15	89-05-11	97-02-18
HAS15	97-05-22	
HAS16	89-05-12	97-01-29
HAS17	95-08-12	97-03-04
HAS17	97-05-29	98-10-08
HAS18	93-09-30	97-02-27
HAS19	90-06-09	

Borehole	Expansion	Release
HAS20	90-12-12	
HAS21	91-12-10	97-01-30
HAV02	89-05-17	97-02-05
HAV05	89-05-17	97-02-18
HBH04	91-12-11	
HLX04	89-05-17	97-01-29
HLX05	89-05-17	97-01-29
HMJ01	91-12-13	
KAS02	91-08-06	
KAS03	96-04-27	

Borehole	Expansion	Release
KAS05	91-11-24	
KAS07	91-07-07	97-02-20
KAS08	89-05-12	
KAS09	90-04-05	
KAS12	97-10-28	99-11-23
KAS12	99-11-23	99-12-07
KAS12	99-12-15	
KAS16	92-10-20	
KBH02	92-05-07	
KLX01	92-02-26	

Table 5-4 Packer expansion and release in tunnel boreholes

Idcode	Expand	Release
HA1960A	93-07-13	
KA1131B	94-10-25	
KA1750A	93-06-07	
KA1750A	93-06-07	
KA1750A	99-11-19	
KA1751A	94-04-26	
KA1754A	94-04-21	
KA1755A	94-05-03	
KA2048B	94-12-12	
KA2050A	94-11-22	
KA2162B	95-10-09	99-10-24
KA2162B	99-10-28	
KA2511A	98-10-19	99-02-01
KA2511A	99-03-17	
KA2563A	98-12-22	99-01-20
KA2563A	99-01-21	99-01-22
KA2563A	99-03-04	99-03-04
KA2563A	99-03-04	99-03-05
KA2563A	99-03-05	99-03-08
KA2563A	99-03-15	
KA2598A	98-03-04	
KA2858A	95-09-27	
KA2862A	97-09-22	
KA3005A	95-12-13	99-12-14
KA3005A	99-12-14	
KA3010A	95-09-28	95-12-12
KA3067A	95-02-28	
KA3105A	95-09-19	
KA3110A	95-09-19	
KA3385A	95-09-25	
KA3510A	98-11-23	
KA3539G	97-11-10	
KA3539G	99-02-03	99-07-27
KA3539G	99-08-04	
KA3542G01	99-02-03	99-07-27
KA3542G01	99-08-04	
KA3542G02	99-02-03	99-07-27

Idcode	Expand	Release
KA3542G02	99-08-04	
KA3544G01		98-04-08
KA3544G01	99-02-03	99-07-27
KA3544G01	99-08-04	00-01-19
KA3546G01	99-02-03	99-07-27
KA3546G01	99-08-04	00-01-19
KA3548A01	98-11-24	
KA3548G01		98-04-15
KA3548G01	99-02-03	
KA3550G01	98-04-16	
KA3550G01	99-02-03	99-07-27
KA3550G01	99-08-04	00-01-19
KA3552G01	99-02-03	99-07-27
KA3552G01	99-08-04	00-01-19
KA3554G01	99-02-03	99-07-27
KA3554G01	99-08-04	
KA3554G02	99-02-03	99-07-27
KA3554G02	99-08-04	
KA3557G		97-11-26
KA3557G	99-02-03	
KA3563G	97-11-12	97-11-26
KA3563G	99-02-11	99-07-27
KA3563G	99-08-05	
KA3566G01	99-02-12	
KA3566G02	99-02-12	
KA3572G01	98-04-18	
KA3572G01	99-02-12	99-07-27
KA3572G01	99-08-05	
KA3573A	98-03-05	99-02-15
KA3573A	99-02-15	
KA3574G01	99-02-11	99-07-27
KA3574G01	99-08-05	
KA3576G01	99-02-11	
KA3578G01	98-04-18	
KA3578G01	99-02-11	99-07-27
KA3578G01	99-08-05	
KA3579G	97-11-03	97-11-26

Idcode	Expand	Release
KA3579G	99-02-12	99-07-27
KA3579G	99-08-05	
KA3584G01	98-04-20	
KA3584G01	99-02-03	
KA3590G01	99-02-12	99-07-27
KA3590G01	99-08-05	
KA3590G02	99-02-12	99-07-27
KA3590G02	99-08-05	
KA3593G	97-11-03	97-11-18
KA3593G	99-02-12	99-07-27
KA3593G	99-08-05	
KA3600F	98-03-05	99-02-15
KA3600F	99-02-15	
KG0021A01		98-10-16
KG0021A01	99-06-16	99-11-12
KG0021A01	99-11-15	
KG0048A01	98-11-24	99-01-18
KG0048A01	99-01-18	99-02-11
KG0048A01	99-02-11	99-02-16
KG0048A01	99-02-16	99-11-04
KG0048A01	99-11-15	
KI0023B	98-06-17	
KI0025F	98-03-04	99-07-28
KI0025F	99-07-29	
KI0025F02	98-10-23	
KI0025F03	99-10-21	
KM0013A	97-01-29	
KXTT1	95-12-12	99-12-14
KXTT1	99-12-14	
KXTT2	95-12-06	99-12-14
KXTT2	99-12-14	
KXTT3	96-10-21	99-12-14
KXTT3	99-12-14	
KXTT4	95-12-12	99-12-14
KXTT4	99-12-14	
KXTT5	99-12-14	

5.5 Drilling

Only tunnel boreholes have been drilled during 1999.

During drilling water is injected into the borehole with high pressure, and the effect at different locations in the borehole may be either injection or removal of water. During drilling interruptions, water is flowing out of the borehole and the net result on pressure registrations mainly seems to be a pumping effect. In Table 5-5 dates when boreholes were drilled, borehole length and type of drilling are presented. Drilling before rounds and drilling for bolting are not included in the table.

Table 5-5 Drilling

Start	Stop	Borehole	Borehole length (m)	Type of drilling
1999-01-26	1999-02-05	DA3153G01	2.5	Deposit hole boring
1999-03-02	1999-03-02	KG0046G01	8.05	Core drilling
1999-03-02	1999-03-02	KG0051G01	8.05	Core drilling
1999-03-03	1999-03-03	KG0037G01	8.05	Core drilling
1999-03-03	1999-03-03	KG0042G01	8.05	Core drilling
1999-03-04	1999-03-04	KG0033G01	8.05	Core drilling
1999-03-09	1999-03-12	KJ0050F01	46.79	Core drilling
1999-03-15	1999-03-17	KJ0044F01	17.26	Core drilling
1999-03-16	1999-03-24	DK0051G01	8.83	Deposit hole boring
1999-03-18	1999-03-23	KJ0052F02	21.42	Core drilling
1999-03-24	1999-03-30	KJ0052F01	50.06	Core drilling
1999-03-29	1999-03-31	DK0045G01	8.83	Deposit hole boring
1999-04-07	1999-04-12	KA2377A01	41.17	Core drilling
1999-04-08	1999-04-12	DK0031G01	8.83	Deposit hole boring
1999-04-14	1999-04-22	KA3065A02	69.95	Core drilling
1999-04-16	1999-04-18	DK0025G01	8.8	Deposit hole boring
1999-04-19	1999-04-20	TASD	0.95	Various drilling
1999-04-20	1999-04-22	HG0008A01	24	Percussion drilling
1999-04-23	1999-04-27	KA2865A01	27.73	Core drilling
1999-04-26	1999-04-26	KG0032G01	4.03	Core drilling
1999-04-26	1999-04-27	KG0051G01	4.15	Core drilling
1999-04-27	1999-04-27	KG0046G01	4.15	Core drilling
1999-04-28	1999-05-04	DD0092G01	8.83	Deposit hole boring
1999-04-28	1999-04-28	KG0037G01	4.15	Core drilling
1999-04-28	1999-04-28	KG0042G01	4.15	Core drilling
1999-04-29	1999-04-29	KG0033G01	4.15	Core drilling
1999-04-29	1999-05-05	KXTT5	25.85	Core drilling
1999-05-03	1999-05-04	TASD	0.35	Various drilling
1999-05-04	1999-05-04	TASA	190	Various drilling
1999-05-06	1999-05-10	KJ0052F03	10.6	Core drilling
1999-05-07	1999-05-07	HA3145G01	6.95	Percussion drilling
1999-05-08	1999-06-10	HK0025G01	7.85	Percussion drilling
1999-05-08	1999-05-10	HK0031G01	8.11	Percussion drilling
1999-05-08	1999-06-10	HK0045G01	7.08	Percussion drilling
1999-05-08	1999-06-10	HK0051G01	7.38	Percussion drilling
1999-05-17	1999-06-02	DD0086G01	8.79	Deposit hole boring
1999-06-19	1999-06-22	DA3587G01	8.37	Deposit hole boring

Start	Stop	Borehole	Borehole length (m)	Type of drilling
1999-06-30	1999-07-02	DA3581G01	8.37	Deposit hole boring
1999-07-05	1999-07-08	DA3575G01	8.37	Deposit hole boring
1999-07-12	1999-07-13	KZ0035G01	0.69	Core drilling
1999-07-12	1999-07-13	KZ0035G02	0.69	Core drilling
1999-07-12	1999-07-13	KZ0035G03	0.72	Core drilling
1999-07-13	1999-07-15	DA3569G01	8.37	Deposit hole boring
1999-08-05	1999-08-13	KI0025F03	141.72	Core drilling
1999-08-26	1999-09-01	DA3551G01	8.37	Deposit hole boring
1999-09-14	1999-09-18	DA3545G01	8.37	Deposit hole boring
1999-09-20	1999-09-28	KK0051B01	0.54	Core drilling
1999-09-20	1999-09-28	KK0051B02	0.5	Core drilling
1999-09-20	1999-09-28	KK0052B01	0.49	Core drilling
1999-09-20	1999-09-28	KK0053B01	0.53	Core drilling
1999-09-29	1999-09-29	HG0038B01	3.6	Percussion drilling
1999-10-19	1999-10-19	KD0086G05	0.9	Core drilling
1999-10-19	1999-10-19	KD0086G06	0.9	Core drilling
1999-10-19	1999-10-19	KD0086G07	0.9	Core drilling
1999-10-19	1999-10-19	KD0086G08	0.9	Core drilling
1999-10-19	1999-10-19	KD0086G16	0.9	Core drilling
1999-10-19	1999-10-19	KD0086G17	0.9	Core drilling
1999-10-20	1999-10-20	KD0086G10	0.9	Core drilling
1999-10-20	1999-10-20	KD0086G12	0.9	Core drilling
1999-10-20	1999-10-20	KD0086G14	0.9	Core drilling
1999-10-20	1999-10-20	KD0086G15	0.9	Core drilling
1999-10-21	1999-10-21	KD0086G09	0.9	Core drilling
1999-10-21	1999-10-21	KD0086G11	0.9	Core drilling
1999-10-21	1999-10-21	KD0086G13	0.9	Core drilling
1999-10-21	1999-10-21	KD0092G05	0.3	Core drilling
1999-10-21	1999-10-21	KD0092G06	0.3	Core drilling
2000-01-19	2000-01-19	KA1673A01	1.03	Core drilling
2000-01-25	2000-02-06	KA3065A03	10.4	Core drilling

5.6 Tests

All tests in Table 5-6 have been performed in tunnel boreholes.

Tracer tests are performed in a number of different ways:

Dilution test is a single hole test where the tracer is circulated in one section. No water is withdrawn or added to the circulation section (except for a small amount of tracer solution).

During ***radially converging or dipole tests*** water is pumped out of one section and tracer injected in another section. In radially converging tests there is usually no excess pressure in the injection section while during dipole tests a certain injection flow is maintained during the test. In Table 5-6 the sections that were pumped during the tests are listed.

Flow logging means that a single or a pair of packers is expanded at certain intervals in the borehole and the flow rate from inside/between the packers is measured.

Flow logging with the UCM probe. Water is pumped or flowed out of the borehole while the probe is moved along the borehole to measure the flow.

Flow logging with thermal probe. Water is pumped or flowed out of the borehole while the probe is moved along the borehole to measure the flow.

Interference tests means that pumping or flowing is done in one section to induce and study a response in other sections. The length of such a test and the magnitude of flow may vary over a wide range.

Constant pressure test. A hydraulic test where water is either injected or withdrawn from a test section of a borehole under constant pressure. At Äspö HRL, constant pressure tests in the tunnel are generally performed as withdrawal tests. Normally, a constant pressure test is followed by a pressure build-up test.

Constant flow test. A hydraulic test performed in the same way as a constant pressure test, but instead of pressure the flow rate is held constant.

Pressure build up test. The borehole is discharged between 45 minutes and a few hours before the valve is closed and the pressure recovery is studied.

Outflow tests with constant flow or constant pressure are equivalent to pumping tests in surface borehole.

Recovery test. A hydraulic test where the recovery after withdrawal of water is studied.

Transient injection test. A hydraulic test where water is injected under constant pressure. The same as a constant pressure test with injection.

Pulse injection test is a type of water injection test where the test section is short (50 mm) and the injection under constant pressure is performed during a few minutes (a pulse).

Table 5-6 Tests

From	To	Borehole:sec	Borehole length (m) from	to	Activity
98-01-28	99-02-17	KI0023B	109.5	110.5	Pressure Build Up Test UHT sonde
98-12-16	99-02-18	KA3579G	0.7	22.65	Pressure Build Up Test (BUP)
98-12-16	99-02-17	KA3579G	1	22.65	Double packer flow logging
99-01-07	99-01-09	KA3542G02	0.25	1.75	Transient injection test
99-01-09	99-01-10	KA3542G01	0.25	1.75	Transient injection test
99-01-10	99-01-10	KA3544G01	0.25	1.75	Transient injection test
99-01-10	99-01-11	KA3546G01	0.25	1.75	Transient injection test
99-01-11	99-01-12	KA3548G01	0.25	1.75	Transient injection test
99-01-12	99-01-12	KA3550G01	0.25	1.75	Transient injection test
99-01-12	99-01-13	KA3552G02	0.25	1.75	Transient injection test
99-01-13	99-01-13	KA3554G02	0.25	1.75	Transient injection test
99-01-13	99-01-14	KA3554G01	0.25	1.75	Transient injection test

From	To	Borehole:sec	Borehole length (m) from	to	Activity
99-01-14	99-01-14	KA3572G01	0.25	1.75	Transient injection test
99-01-14	99-01-15	KA3574G01	0.25	1.75	Transient injection test
99-01-15	99-01-15	KA3576G01	0.25	1.75	Transient injection test
99-01-15	99-01-16	KA3578G01	0.25	1.75	Transient injection test
99-01-16	99-01-18	KA3579G	0.7	22.65	Pressure Build Up Test (BUP)
99-01-21	99-01-22	KA2563A	230	300	Double packer flow logging
99-01-26	99-02-01	KXTT4:4	8.42	10.92	Radially converging
99-02-02	99-02-04	KXTT3:3	8.92	11.42	Radially converging
99-02-17	99-02-17	KA3579G	0.5	22.65	Single Packer Flow Logging
99-02-17	99-02-18	KA2563A	188	267.5	Double packer flow logging
99-02-22	99-02-23	KA3566G01:2	12.3	19.8	Interference test
99-02-24	99-02-25	KA3566G02:2	12.3	18.3	Interference test
99-02-25	99-02-26	KA3590G01:3	1.3	6.8	Interference test
99-02-25	99-02-25	KXP26BGR	5.2	5.7	Constant Pressure Test - CPT
99-02-26	99-02-26	KA3590G01:2	7.8	16.3	Interference test
99-02-26	99-02-26	KA3590G02:1	23.3	30.05	Interference test
99-03-01	99-03-01	KXP26BGR	6.2	8.35	Constant Pressure Test - CPT
99-03-01	99-03-02	KXP26BGR	6.2	5.7	Constant Pressure Test - CPT
99-03-02	99-03-03	KXP26BGR	5.2	5.7	Constant Pressure Test - CPT
99-03-03	99-03-03	KXP24BGR	3.2	3.7	Constant Pressure Test - CPT
99-03-03	99-03-03	KXP24BGR	3.2	3.7	Recovery test
99-03-03	99-03-03	KXP26BGR	5.2	5.7	Constant Pressure Test - CPT
99-03-03	99-03-04	KXP24BGR	3.2	3.7	Constant Pressure Test - CPT
99-03-04	99-03-04	KXP24BGR	3.2	3.7	Recovery test
99-03-04	99-03-04	KXP24BGR	3.2	5.7	Recovery test
99-03-04	99-03-04	KXP24BGR	3.2	3.7	Constant Pressure Test - CPT
99-03-15	99-03-17	KXTT4:4	8.42	10.92	Radially converging
99-04-06	99-04-07	KA3590G01:3	1.3	6.8	Interference test
99-04-07	99-04-08	KG0033G01	1	8.05	Double packer flow logging
99-04-08	99-04-09	KG0037G01	1.4	8.5	Double packer flow logging
99-04-09	99-04-09	KG0042G01	1	8.05	Double packer flow logging
99-04-12	99-04-12	KG0046G01	1	8.05	Double packer flow logging
99-04-12	99-04-12	KG0051G01	1	8.05	Double packer flow logging
99-04-13	99-04-16	KI0023B:6	70.95	71.95	Dilution test
99-04-13	99-04-16	KI0025F:4	86	88	Dilution test
99-04-13	99-04-16	KI0025F02:5	73.3	77.25	Dilution test
99-04-14	99-04-16	KI0025F02:3	93.35	99.25	Dilution test
99-04-14	99-04-16	KXP27BGR			Pulse injection test
99-04-14	99-04-16	KA2563A:3	206	208	Dilution test
99-04-14	99-04-16	KA2563A:4	187	190	Dilution test
99-04-15	99-04-16	KI0023B:4	84.75	86.2	Interference test
99-04-19	99-04-20	KA2563A:3	206	208	Dilution test
99-04-19	99-04-20	KA2563A:1	242	246	Dilution test
99-04-19	99-04-20	KI0025F:4	86	88	Dilution test
99-04-19	99-04-20	KI0025F02:3	93.35	99.25	Dilution test
99-04-19	99-04-20	KI0025F02:5	73.3	77.25	Dilution test
99-04-19	99-04-20	KI0023B:4	84.75	86.2	Dilution test
99-04-20	99-04-21	KXP27BGR			Pulse injection test
99-04-20	99-04-22	KI0023B:7	43.45	69.95	Dilution test
99-04-20	99-04-22	KI0025F02:8	51.7	55.1	Dilution test
99-04-20	99-04-22	KI0025F02:7	56.1	63	Dilution test
99-04-20	99-04-22	KA2563A:4	187	190	Dilution test

From	To	Borehole:sec	Borehole length (m) from	to	Activity
99-04-21	99-04-23	KI0023B:6	70.95	71.95	Interference test
99-04-22	99-04-23	KI0025F:4	86	88	Dilution test
99-04-22	99-04-23	KI0023B:4	84.75	86.2	Dilution test
99-04-22	99-04-23	KI0025F02:3	93.35	99.25	Dilution test
99-04-22	99-04-23	KI0025F02:5	73.3	77.25	Dilution test
99-04-22	99-04-23	KA2563A:3	206	208	Dilution test
99-04-22	99-04-23	KA2563A:1	242	246	Dilution test
99-04-27	99-04-28	KA2563A:3	206	208	Dilution test
99-04-27	99-04-28	KI0023B:4	84.75	86.2	Dilution test
99-04-27	99-04-28	KI0025F:4	86	88	Dilution test
99-04-27	99-04-28	KI0025F02:8	51.7	55.1	Dilution test
99-04-27	99-04-28	KI0025F02:3	93.35	99.25	Dilution test
99-04-27	99-04-28	KI0023B:6	70.95	71.95	Dilution test
99-04-28	99-04-30	KI0023B:7	43.45	69.95	Dilution test
99-04-28	99-04-30	KI0025F02:6	64	72.3	Dilution test
99-04-28	99-04-30	KI0023B:5	72.95	83.75	Dilution test
99-04-28	99-04-30	KI0025F02:7	56.1	63	Dilution test
99-04-28	99-04-30	KI0023B:2	111.25	112.7	Dilution test
99-04-28	99-04-30	KA2563A:4	187	190	Dilution test
99-04-29	99-11-30	KI0025F02:5	73.3	77.25	Interference test
99-04-30	99-05-01	KI0025F:4	86	88	Dilution test
99-04-30	99-05-01	KI0023B:4	84.75	86.2	Dilution test
99-04-30	99-05-01	KI0023B:6	70.95	71.95	Dilution test
99-04-30	99-05-01	KI0025F02:3	93.35	99.25	Dilution test
99-04-30	99-05-01	KI0025F02:8	51.7	55.1	Dilution test
99-04-30	99-05-01	KA2563A:3	206	208	Dilution test
99-05-17	99-05-19	KI0023B:5	72.95	83.75	Dilution test
99-05-17	99-05-19	KI0025F02:7	56.1	63	Dilution test
99-05-17	99-05-19	KI0025F02:8	51.7	55.1	Dilution test
99-05-18	99-05-19	KI0023B:7	43.45	69.95	Dilution test
99-05-19	99-05-20	KI0023B:7	43.45	69.95	Radially converging
99-05-19	99-05-20	KI0023B:6	70.95	71.95	Radially converging
99-05-26	99-06-04	KI0023B:6	70.95	71.95	Radially converging
99-05-26	99-11-30	KI0023B:6	70.95	71.95	Radially converging
99-05-26	99-11-30	KI0023B:7	43.45	69.95	Dilution test
99-05-27	99-05-27	KI0023B:6	70.95	71.95	Radially converging
99-06-02	99-11-30	KI0023B:6	70.95	71.95	Radially converging
99-06-15	99-06-15	KA2563A:1	242	246	Radially converging
99-06-15	99-06-15	KI0025F02:6	64	72.3	Radially converging
99-06-15	99-06-15	KI0025F02:3	93.35	99.25	Radially converging
99-06-15	99-06-15	KI0023B:7	43.45	69.95	Dilution test
99-06-17	99-06-17	KG0048A01	49	54.69	Interference test
99-08-16	99-08-17	KA3554G02:2	10.3	21.3	Interference test
99-08-17	99-08-18	KA3542G01:2	8.8	24.8	Interference test
99-08-18	99-08-19	KA3554G01:1	22.3	30.01	Interference test
99-08-19	99-08-20	KA3542G02:4	1.3	7.8	Interference test
99-08-20	99-08-21	KG0021A01:3	25	34	Interference test
99-08-21	99-08-22	KG0021A01:1	42.5	48.8	Interference test
99-08-22	99-08-22	KA3539G:2	9.8	18.3	Interference test
99-09-16	99-09-16	KXP26BGR			Constant Flow Test
99-10-05	99-10-05	KI0025F03	42.5	44.5	Constant Flow Test
99-10-05	99-10-05	KI0025F03	42.5	44.5	Constant Flow Test

From	To	Borehole:sec	Borehole length (m) from	to	Activity
99-10-05	99-10-06	KI0025F03	52	54	Constant Flow Test
99-10-06	99-10-06	KI0025F03	51.5	53.5	Constant Flow Test
99-10-06	99-10-06	KI0025F03	54	56	Constant Flow Test
99-10-06	99-10-06	KI0025F03	56	58	Constant Flow Test
99-10-07	99-10-07	KI0025F03	60	62	Constant Flow Test
99-10-07	99-10-07	KI0025F03	62	64	Constant Flow Test
99-10-07	99-10-07	KI0025F03	72	74	Constant Flow Test
99-10-07	99-10-07	KI0025F03	72	74	Constant Flow Test
99-10-07	99-10-08	KI0025F03	85	87	Constant Flow Test
99-10-08	99-10-08	KI0025F03	87	89	Constant Flow Test
99-10-08	99-10-08	KI0025F03	90.5	92.5	Constant Flow Test
99-10-11	99-10-11	KI0025F03	98	100	Constant Flow Test
99-10-11	99-10-11	KI0025F03	124	126	Constant Flow Test
99-10-25	99-10-26	KI0023B:7	43.45	69.95	Dilution test
99-10-25	99-10-26	KI0025F02:3	93.35	99.25	Dilution test
99-10-25	99-10-26	KI0023B:4	84.75	86.2	Dilution test
99-10-25	99-10-26	KI0025F02:5	73.3	77.25	Dilution test
99-10-25	99-10-26	KI0025F02:6	64	72.3	Dilution test
99-10-25	99-10-26	KA2563A:3	206	208	Dilution test
99-10-26	99-10-28	KI0025F02:7	56.1	63	Dilution test
99-10-26	99-10-28	KI0023B:6	70.95	71.95	Dilution test
99-10-26	99-10-28	KI0025F03:3	89	92.5	Dilution test
99-10-26	99-10-28	KI0025F03:4	85	88	Dilution test
99-10-26	99-10-28	KI0025F03:6	66.5	74	Dilution test
99-10-26	99-10-28	KA2563A:4	187	190	Dilution test
99-10-28	99-10-29	KI0023B:7	43.45	69.95	Dilution test
99-10-28	99-10-29	KI0025F02:6	64	72.3	Dilution test
99-10-28	99-10-29	KI0023B:4	84.75	86.2	Dilution test
99-10-28	99-10-29	KI0025F02:3	93.35	99.25	Dilution test
99-10-28	99-10-29	KI0025F02:5	73.3	77.25	Dilution test
99-10-28	99-10-29	KA2563A:3	206	208	Dilution test
99-10-29	99-10-31	KI0023B:5	72.95	83.75	Dilution test
99-10-29	99-10-31	KI0025F02:7	56.1	63	Dilution test
99-10-29	99-10-31	KI0025F:4	87.5	89.5	Dilution test
99-10-29	99-10-31	KI0025F02:8	51.7	55.1	Dilution test
99-10-29	99-10-31	KI0023B:2	111.25	112.7	Dilution test
99-10-29	99-10-31	KA2563A:1	242	246	Dilution test
99-10-31	99-11-01	KI0025F02:5	73.3	77.25	Dilution test
99-10-31	99-11-01	KI0025F02:6	64	72.3	Dilution test
99-10-31	99-11-01	KA2563A:3	206	208	Dilution test
99-10-31	99-11-01	KI0023B:7	43.45	69.95	Dilution test
99-10-31	99-11-01	KI0023B:4	84.75	86.2	Dilution test
99-10-31	99-11-01	KI0025F02:3	93.35	99.25	Dilution test
99-11-01	99-11-03	KI0023B:6	70.95	71.95	Dilution test
99-11-01	99-11-03	KI0025F03:3	89	92.5	Dilution test
99-11-01	99-11-03	KI0025F03:5	75	84	Dilution test
99-11-01	99-11-03	KI0025F03:6	66.5	74	Dilution test
99-11-01	99-11-03	KI0025F02:7	56.1	63	Dilution test
99-11-01	99-11-03	KA2563A:4	187	190	Dilution test
99-11-03	99-11-04	KA2563A:3	206	208	Dilution test
99-11-03	99-11-04	KI0023B:7	43.45	69.95	Dilution test
99-11-03	99-11-04	KI0025F02:6	64	72.3	Dilution test

From	To	Borehole:sec	Borehole length (m) from	to	Activity
99-11-03	99-11-04	KI0025F02:3	93.35	99.25	Dilution test
99-11-03	99-11-04	KI0023B:4	84.75	86.2	Dilution test
99-11-03	99-11-04	KI0025F02:5	73.3	77.25	Dilution test
99-11-04	99-11-08	KA2563A:1	242	246	Dilution test
99-11-04	99-11-08	KI0025F03:7	59.5	65.5	Dilution test
99-11-04	99-11-08	KI0025F:4	87.5	89.5	Dilution test
99-11-04	99-11-08	KI0025F02:9	38.5	50.7	Dilution test
99-11-04	99-11-08	KI0023B:2	111.25	112.7	Dilution test
99-11-04	99-11-08	KI0023B:5	72.95	83.75	Dilution test
99-11-08	99-11-09	KI0025F03:7	59.5	65.5	Dilution test
99-11-08	99-11-09	KI0023B:5	72.95	83.75	Dilution test
99-11-08	99-11-09	KI0023B:4	84.75	86.2	Dilution test
99-11-08	99-11-09	KI0023B:4	84.75	86.2	Dilution test
99-11-08	99-11-09	KA2563A:3	206	208	Dilution test
99-11-08	99-11-09	KI0023B:7	43.45	69.95	Dilution test
99-11-09	99-11-11	KI0025F02:7	56.1	63	Dilution test
99-11-09	99-11-11	KI0025F03:3	89	92.5	Dilution test
99-11-09	99-11-11	KI0025F03:5	75	84	Dilution test
99-11-09	99-11-11	KI0025F03:4	85	88	Dilution test
99-11-09	99-11-11	KI0025F02:3	93.35	99.25	Dilution test
99-11-09	99-11-11	KI0025F03:6	66.5	74	Dilution test
99-11-11	99-11-12	KI0025F03:7	59.5	65.5	Dilution test
99-11-11	99-11-12	KI0023B:5	72.95	83.75	Dilution test
99-11-11	99-11-12	KI0025F:4	87.5	89.5	Dilution test
99-11-11	99-11-12	KI0023B:4	84.75	86.2	Dilution test
99-11-11	99-11-12	KI0023B:7	43.45	69.95	Dilution test
99-11-11	99-11-12	KA2563A:3	206	208	Dilution test
99-11-17	99-11-19	KI0025F03:4	85	88	Dilution test
99-11-17	99-11-19	KI0025F03:6	66.5	74	Dilution test
99-11-17	99-11-19	KI0025F03:5	75	84	Dilution test
99-11-17	99-11-19	KI0025F03:7	59.5	65.5	Dilution test
99-11-17	99-11-19	KI0025F03:3	89	92.5	Dilution test
99-11-23	99-11-30	KI0025F03:6	66.5	74	Radially converging
99-11-23	99-11-30	KI0025F03:7	59.5	65.5	Radially converging
99-11-23	99-11-30	KI0025F03:5	75	84	Radially converging
99-12-06	99-12-06	KI0025F03:7	59.5	65.5	Interference test
99-12-06	99-12-06	KI0025F03:4	85	88	Interference test
99-12-07	99-12-07	KI0025F03:3	89	92.5	Interference test
99-12-07	99-12-07	KI0025F03:6	66.5	74	Interference test
99-12-07	99-12-07	KI0025F03:5	75	84	Interference test
99-12-08	99-12-08	KI0025F03:3	89	92.5	Radially converging
99-12-08	99-12-08	KI0025F03:5	75	84	Radially converging
99-12-08	99-12-08	KI0025F03:6	66.5	74	Radially converging
99-12-15	99-12-15	KI0025F03:6	66.5	74	Radially converging
99-12-15	99-12-15	KA2563A:4	187	190	Radially converging
99-12-16	99-12-16	KXTT5:2	9.61	9.81	Dilution test
99-12-20	99-12-20	KXTT5:2	9.61	9.81	Dilution test
00-01-10	00-01-11	KXTT5:2	9.61	9.81	Dilution test
00-01-11	00-01-17	KXTT5:2	9.61	9.81	Radially converging
00-01-11	00-01-17	KXTT4:3	8.42	10.92	Radially converging

6 Results

6.1 General

Results from the measurements in surface boreholes and in the tunnel are presented in annually based diagram Appendices. Brief descriptions of the different variables are given in the following chapters. In some cases comments are given when data is missing or if the registration has a deviating appearance. Meteorological background data (precipitation, temperature and potential evapotranspiration) are also summarised in monthly and yearly values.

Due to failures in the mechanical or electronic equipment, data sometimes is missing for longer or shorter periods. This is not specifically commented on below. In Appendix 1, statistics on missing registrations for different reasons are summarised for each measuring point.

6.2 Groundwater levels

In most surface boreholes, there have been small changes in groundwater levels during 1999. In the main part of the borehole sections, the change over the year is within one metre. One exception is HAS16 were the level decreased around 4 m in section 1 and nearly 16 m in section 2. In many boreholes a pronounced drawdown occurs at the end of April as a result of the drilling of borehole KA2865A01 in the tunnel (see for example the diagram for KAS12). In the beginning of May a recovery occured when the borehole was sealed. Many boreholes show their minimum levels during the summer and early autumn months while in some boreholes season fluctuations are hardly seen at all.

Annual diagrams of groundwater levels are presented in Appendix 2. All levels in the diagrams are given as meters above sea level (local system). The local system on Äspö results in approximately 6 centimetres lower values than the national elevation system (RH70). In these diagrams, at most one data point per day and section is displayed. When registration is missing, manually levelled data, if available, are inserted.

The levels from all sections in one borehole are presented in the same diagram. The symbols used in the diagrams are:

The lowest section = Section 1 ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
Section 2 + + + + + + + + + +
Section 3 × × × × × × × × × × × ×
Section 4 □ □ □ □ □ □ □ □ □ □
Section 5 ◇ ◇ ◇ ◇ ◇ ◇ ◇ ◇ ◇ ◇
Section 6 △ △ △ △ △ △ △ △ △ △

In the diagrams there are vertical lines with a text indicating changes in packer configuration (for example "Packers removed").

Sometimes it is difficult to differentiate registrations from the individual sections in the diagrams, but since the main purpose with this report is to present an overall view of the long term level changes, it was not found to be advantageous to separate sections from one borehole into different diagrams. More detailed groundwater level diagrams during test periods are presented in reports from the different tests.

In Figures 6-1 to 6-5 an overview over the 5-year period 1995-1999 for some of the boreholes is presented. The diagrams are of the same type as the annual diagrams described above. (For the sake of continuity the same boreholes that were presented in earlier annual reports have been chosen, even if data is missing for shorter or longer periods.)

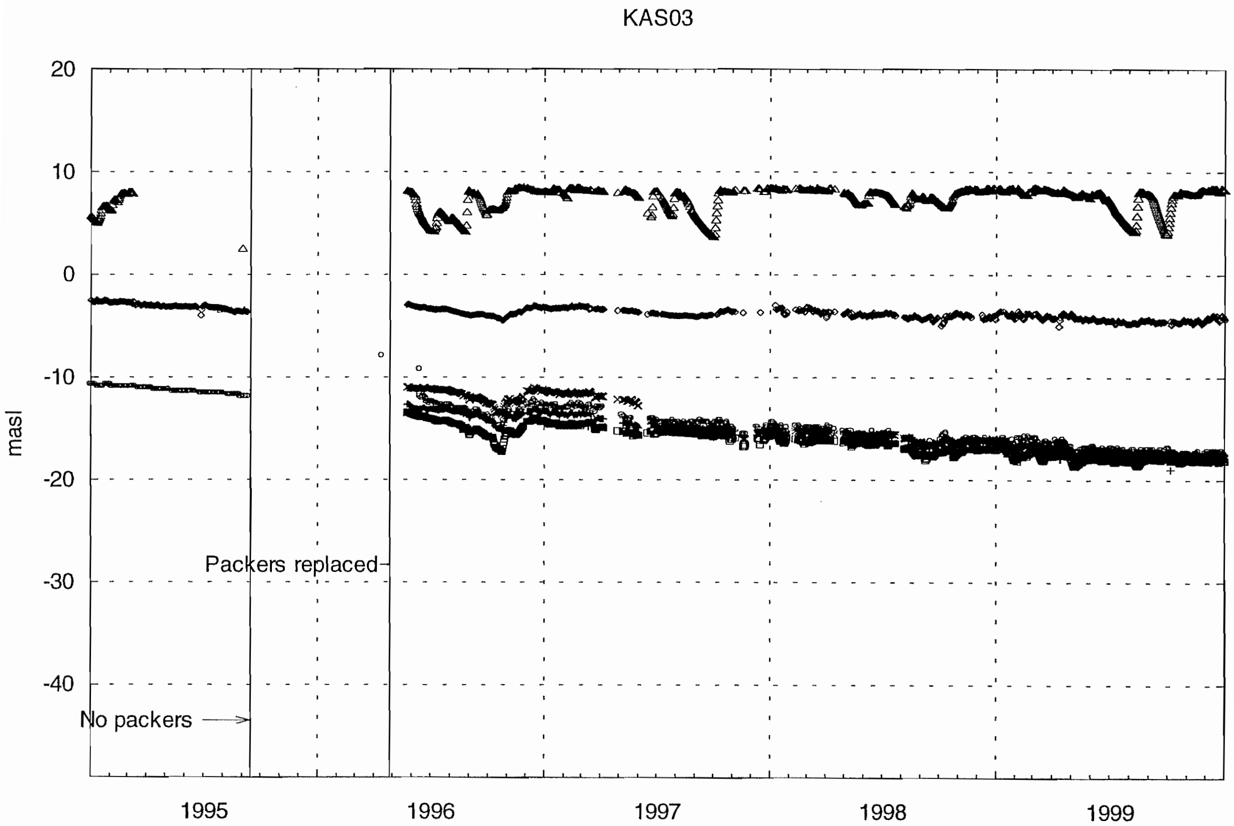


Figure 6-1 Groundwater levels in KAS03 on Äspö, 1995-1999.

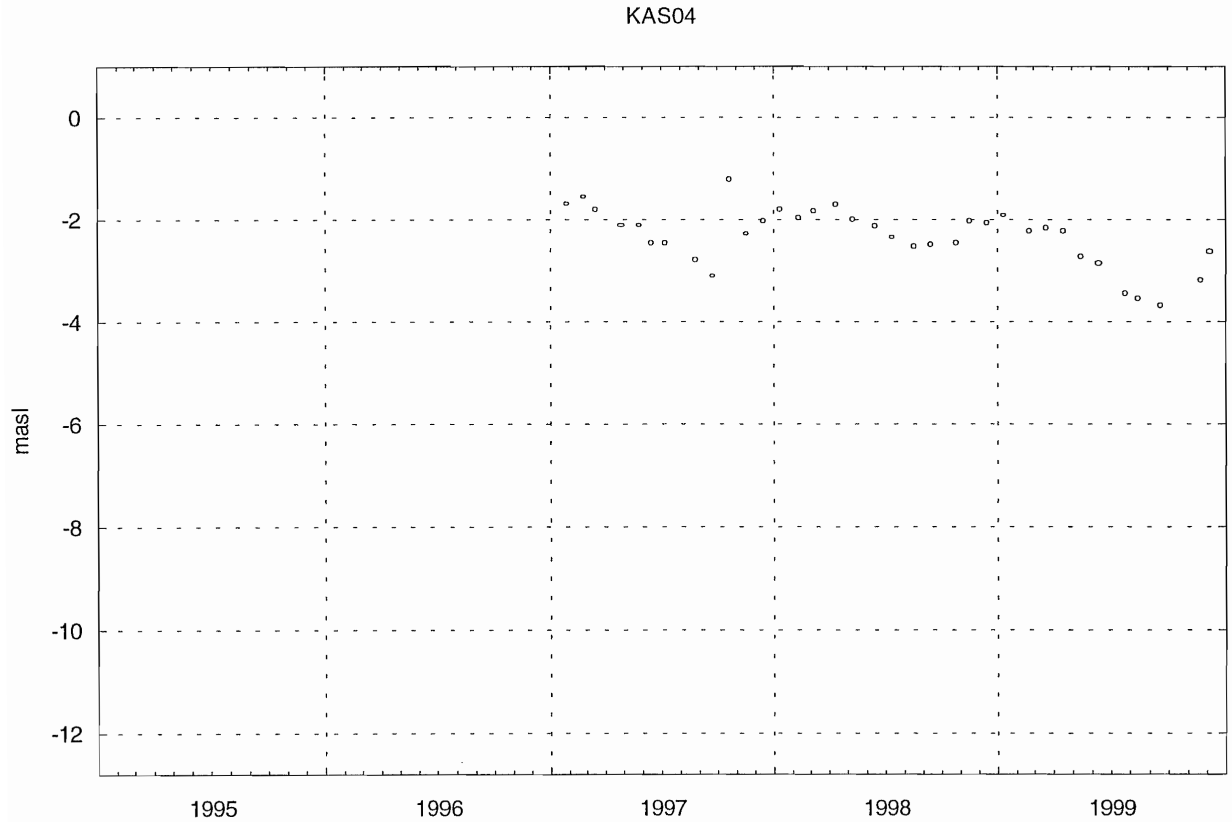


Figure 6-2 Groundwater levels in KAS04 on Äspö, 1995-1999.

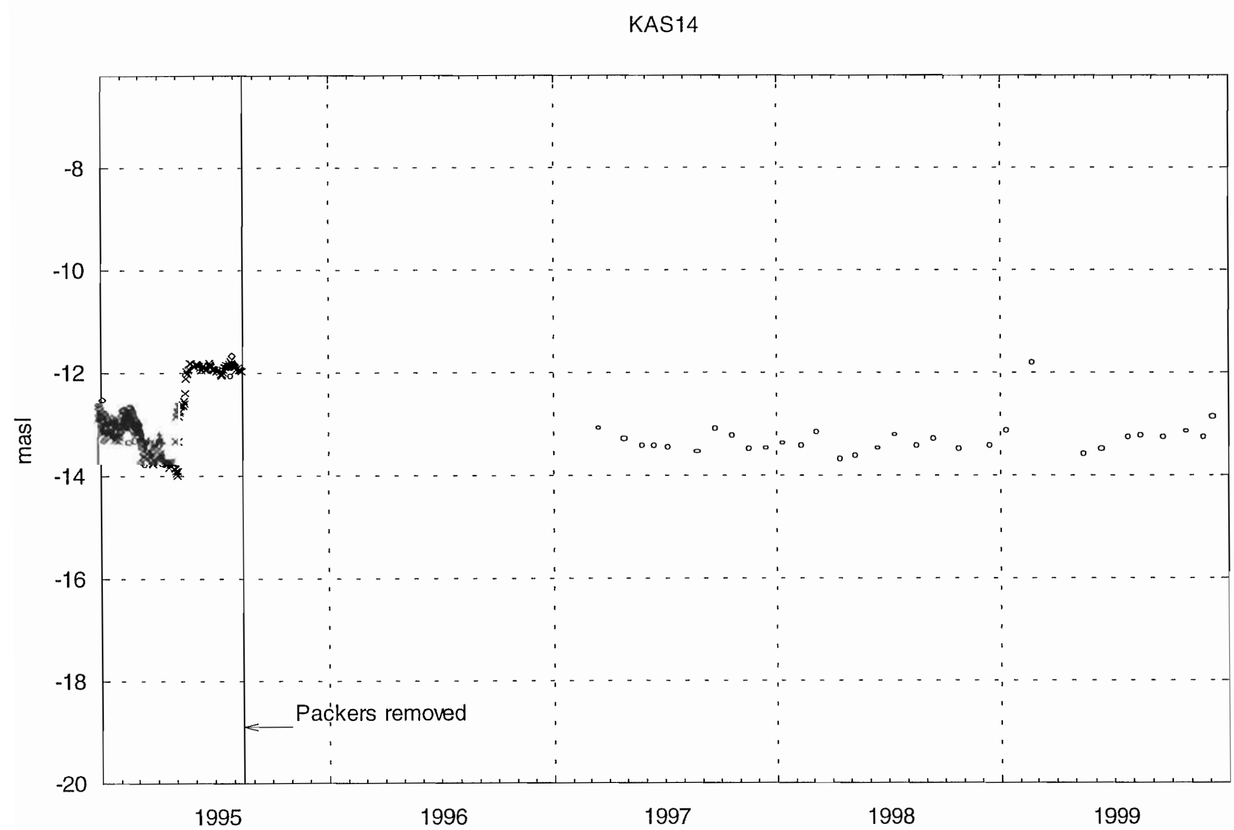


Figure 6-3 Groundwater levels in KAS14 on Äspö, 1995-1999.

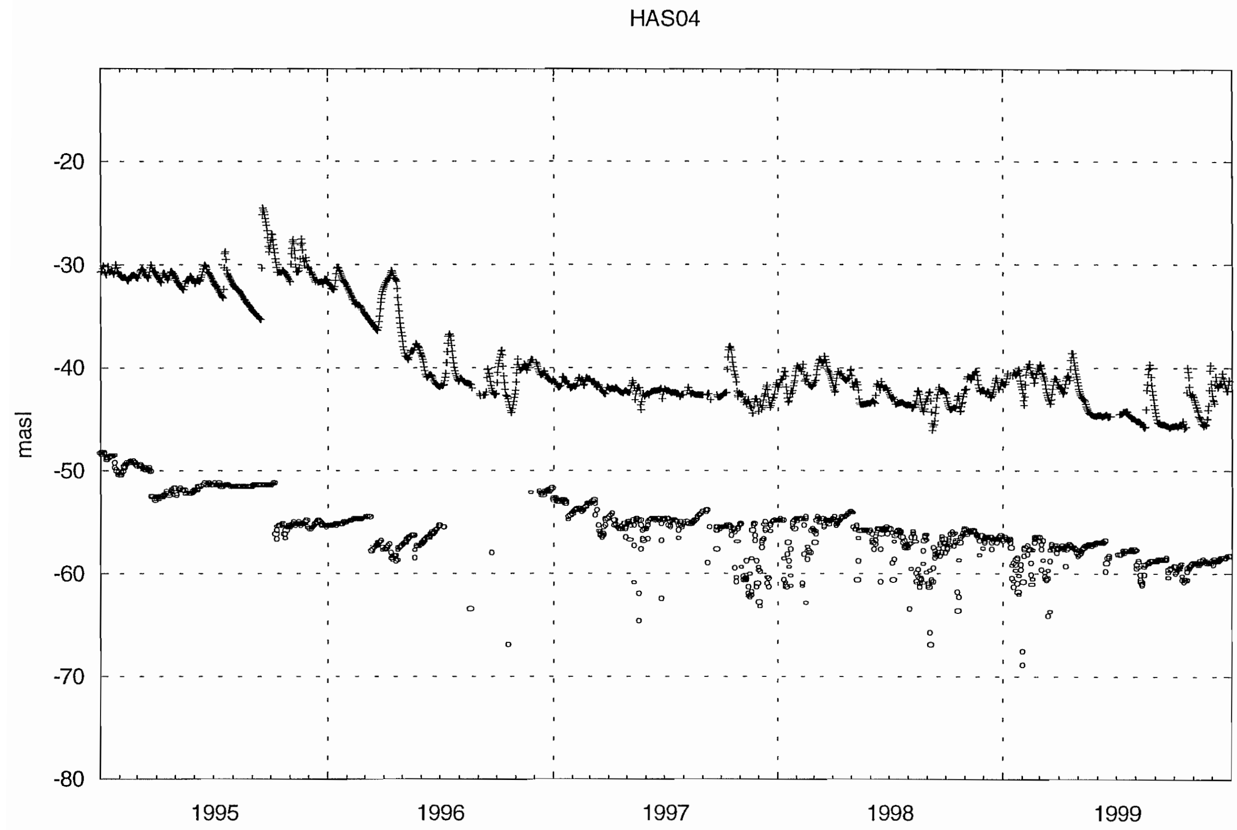


Figure 6-4 Groundwater levels in HAS04 on Äspö, 1995-1999.

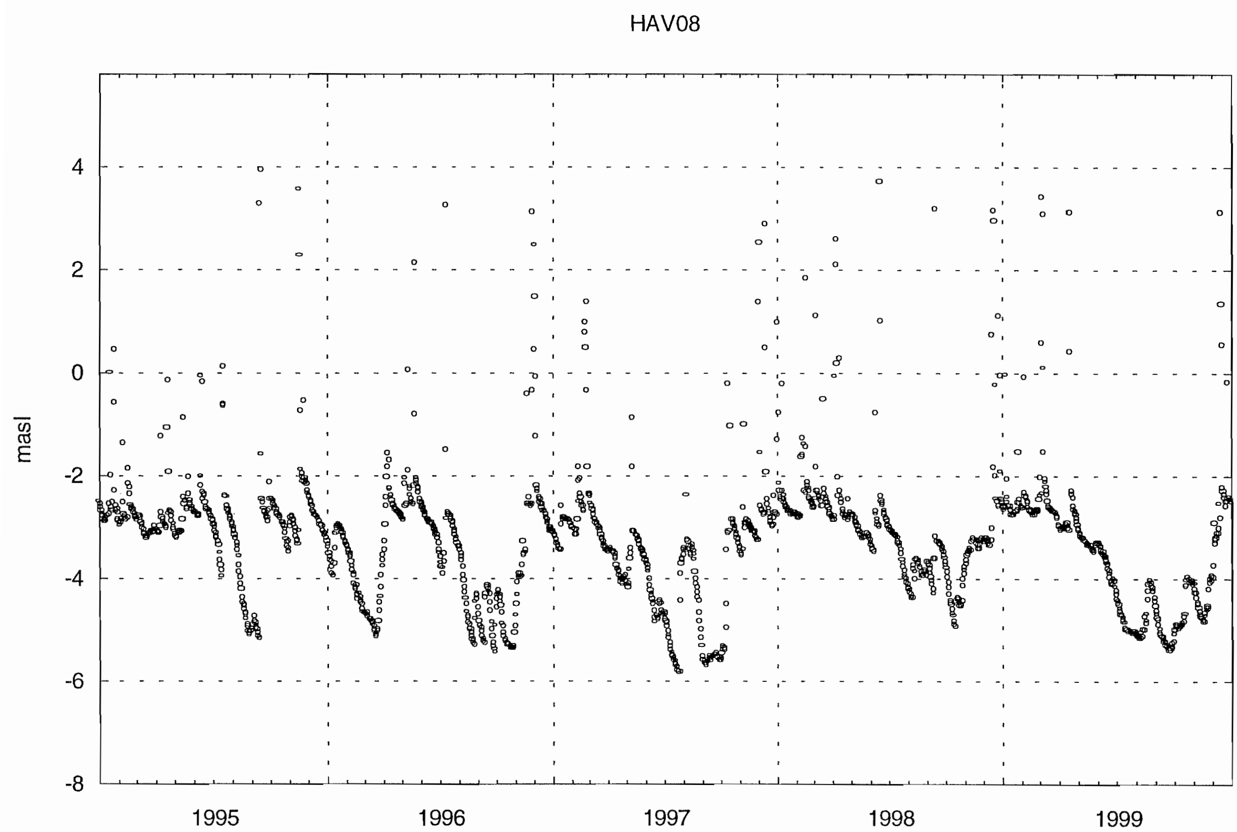


Figure 6-5 Groundwater levels in HAV08 on Ävrö, 1995-1999.

6.2.1 Comments on some of the diagrams

Remarks are given when the registration for some reason has a deviating appearance. When registration is missing manually levelled data, if available, are inserted.

Packers may deflate, due to leakage in the packer system, which can be difficult to discover. If one section in a borehole suddenly shows a pressure that is close to the pressure in a neighbouring section, the reason might be deflated packers.

Considerable draw-downs have complicated the manual levellings in many sections in boreholes at Äspö. Some sections have not been possible to level at all, while others have been difficult to level. In other sections, the actual groundwater level for some periods is uncertain while relative changes during short periods are fairly certain even during these periods.

To facilitate/enable manual levellings the PEM-packers has been removed in some sections. At the end of 1999 PEM-packers were installed in the following sections: KAS03 (1-5), KAS09 (1-4), KAS12 (1-4), KBH02 (3-5) and KLX01 (1,2).

The removal or deflation of a PEM-packer will dampen pressure changes due to water transport between the PEM-tube and the section. In sections with low hydraulic transmissivity this may cause the response to pressure changes to be very slow.

HAS13: After the considerable drawdown in June 1992 the groundwater level in section 2 responds quickly to rain. The reason for this is probably that the effective porosity in the aquifer communicating with the borehole is considerably lower below approximately sea level than above. This means that a small amount of rain may cause a large and quick increase in the groundwater level.

HAV08: The groundwater level in this borehole responds quickly to rain.

KAS09: The PEM-packers have been deflated between July 26 and August 17. This is the reason for the deviating levels in sections 1 and 3 during this period.

KAS12: It is not possible to perform manual levelling in this borehole. Therefore the absolute levels are very uncertain and no levelled values are available when the transducers stops working in sections 4 and 5.

KLX01: Due to a leakage in the packer line the packers were deflated in most sections between March 7 and 23. The sporadic deviating values for section 1 occur when the PEM-packers are deflated to enable manual levelling.

6.3 Electrical conductivity of the groundwater

To start with, electrical conductivity in two sections was measured in most core boreholes on Äspö. In course of time, the sensors have ceased to work and since they have not been replaced, electrical conductivity was measured only in section 2 in KAS09 during 1999.

Because of the poor calibration and other problems with the electrical conductivity sensors, one must be very careful when interpreting the diagram in Appendix 3. The values are very uncertain.

6.4 Ground water pressure in tunnel boreholes

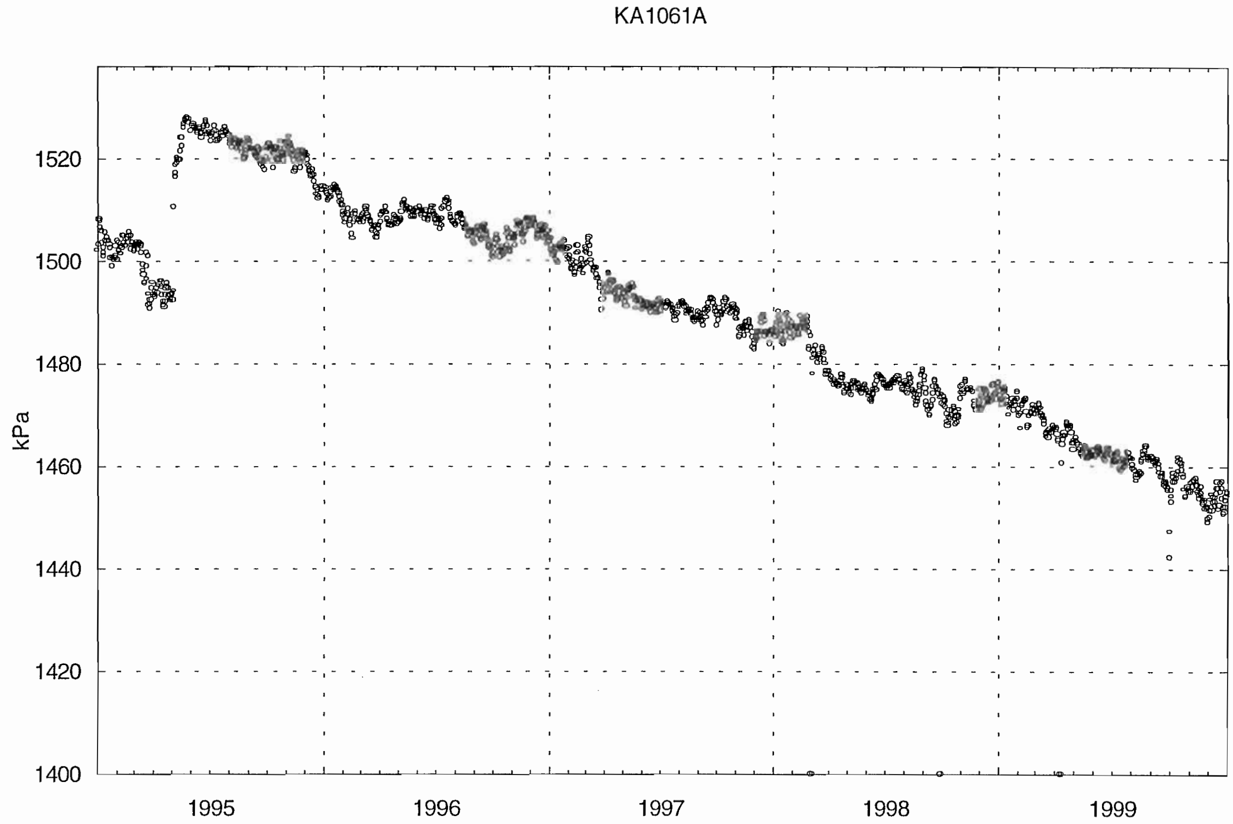
In almost all sections in tunnel boreholes the pressures was decreasing about 20 - 60 kPa during 1999. Exceptions are two sections in borehole KA2048B where the pressure decline is 95 kPa, KA3110A with a drop of 70 kPa, and some sections in the KXTT-boreholes where there is no change or a small increase seen over the year. The largest decrease, 150 kPa, is observed in borehole SA2338A. Most of this pressure drop, approximately 100 kPa, occurs on the 30th of March when the equipment was damaged during scaling in the tunnel. After reparation the pressure is established at a lower level.

Many activities have influenced groundwater pressure in borehole sections during 1999 (see chapter 5). One that have influenced many boreholes and caused substantial drawdowns in many sections from the end of April to the middle of May is the drilling of borehole KA2865A01. A tracer test with pumping in KXTT4 has caused drawdowns in the other KXTT-boreholes and in KA3005A from the end of January to beginning of April. Another tracer test with pumping in KI0023B has resulted in drawdowns in the boreholes in the I-tunnel and in KA2563A from May 18 to June 15. The same boreholes were affected by the drilling of borehole KI0025F03 from beginning of August to October 21.

Twenty-six new boreholes were instrumented in the Prototype tunnel in February and most of them were re-instrumented in the beginning of August. Many activities in the Prototype tunnel has affected the pressure registrations in these boreholes. For instance has the drilling of six deposit boreholes in the tunnel influenced the pressure in many boreholes.

Groundwater pressures from tunnel borehole sections are presented in Appendix 4. The same symbol convention as for surface boreholes is used (see section 6.2). If a borehole has more than 6 sections the symbols are repeated from section 7, meaning that section 7 has a circle, section 8 a plus and so on. In these cases sections 7 and up (in number) are presented in a separate diagram. An exception is a 7th section in borehole KA2563A before, and sections 7 and 8 in KA2511A after, the re-instrumentation in the beginning of the year. These sections are presented in the same diagram as sections 1 – 6, which also is especially noted in the diagrams. For tunnel boreholes, as for surface boreholes, section 1 means the innermost section, section 2 the next section towards the tunnel/surface and so on.

In Figures 6-6 to 6-8 an overview over the 5-year period 1995-1999 for some of the boreholes is presented. The diagrams are of the same type as the annual diagrams described above.



Figur 6-6 Groundwater pressure in tunnel borehole KA1061A, 1995-1999.

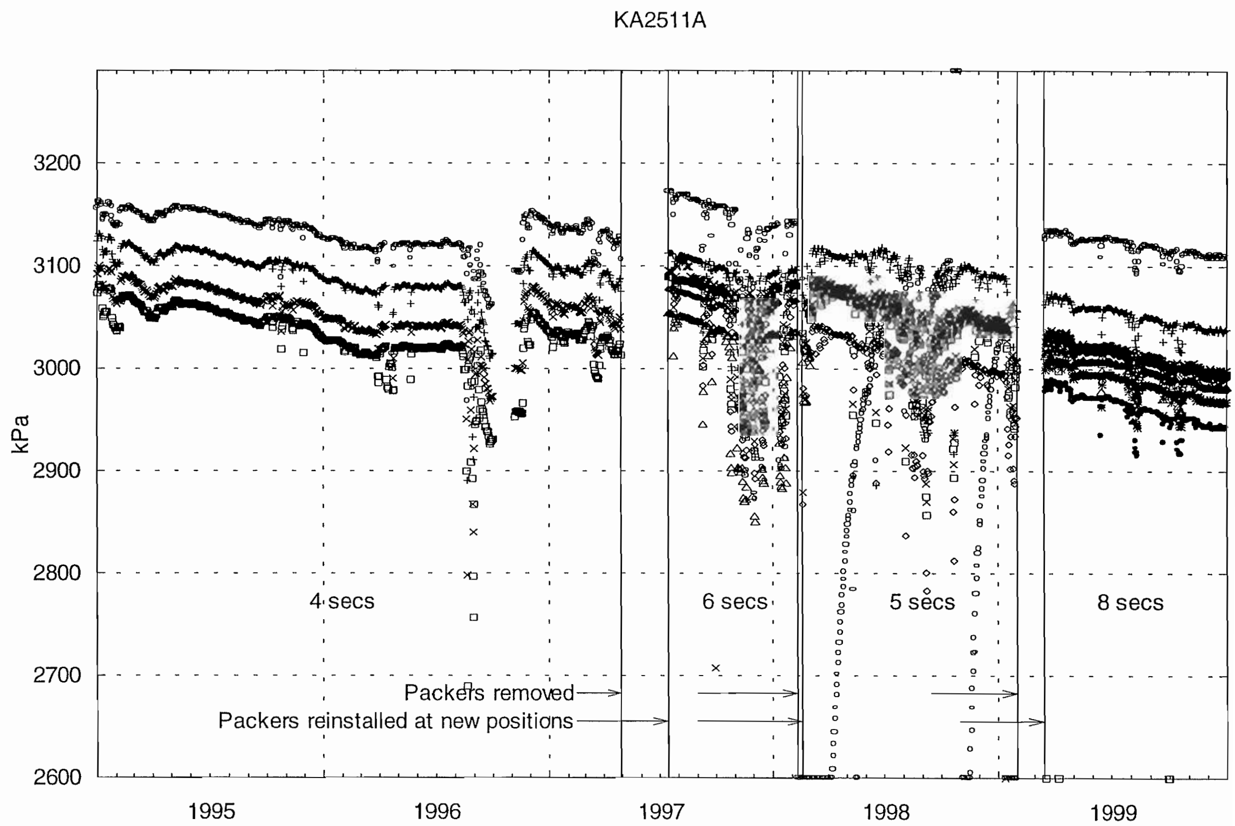


Figure 6-7 Groundwater pressure in tunnel borehole KA2511A, 1995-1999.

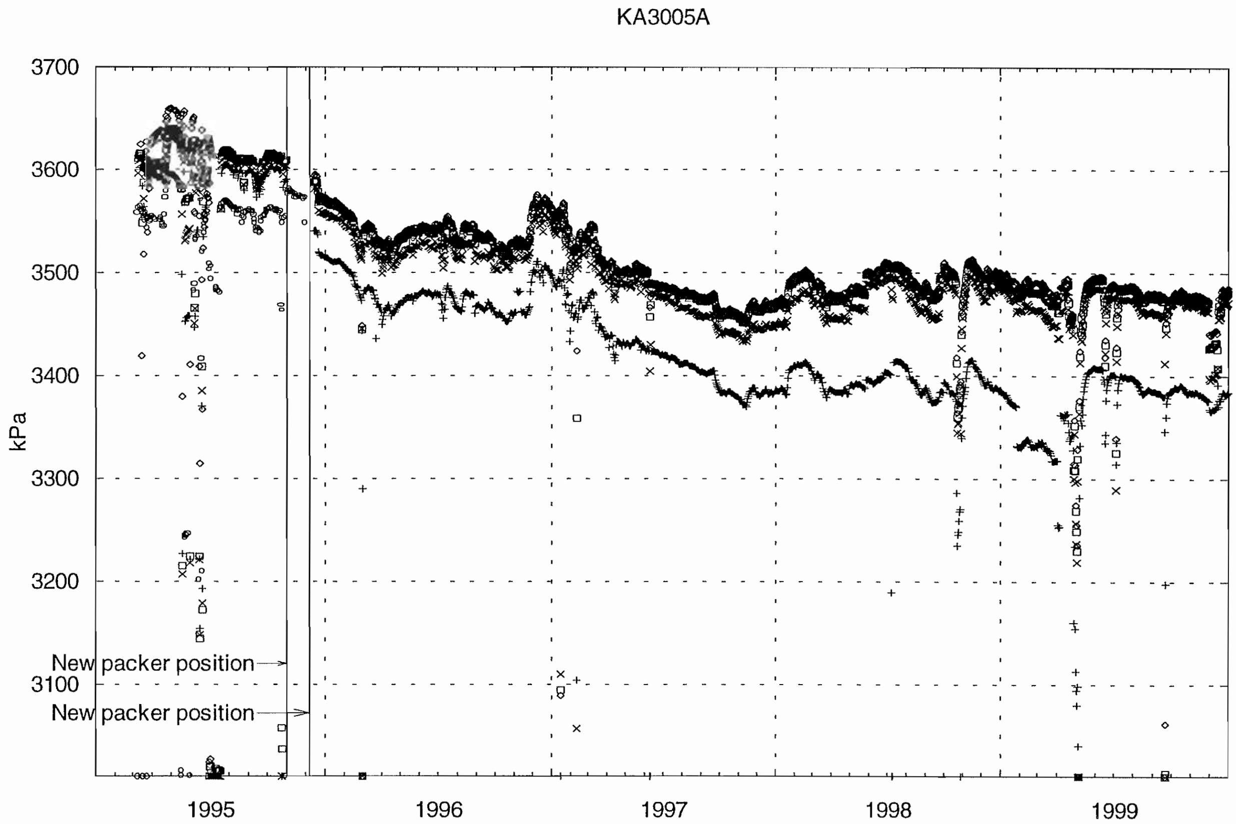


Figure 6-8 Groundwater pressure in tunnel borehole KA3005A, 1995-1999.

6.4.1 Comments on some of the diagrams

The activities affecting many boreholes mentioned in preceding section 6.4 is not further commented on below.

KA3105A, section 5: A jump in the registration may be seen November 3 when the hydraulic multiplexer to which this section was connected is replaced by individual transducers for each section. This is probably an effect of too short delay time between measurements with the multiplexer, especially affecting sections with low transmissivity (see 4.4.3).

KA3110A, section 2: See KA3105A above.

KA3510A: Due to low transmissivity the pressure build-up in section 1 is very slow after the instrumentation in October 1998.

KA3539G: After the re-instrumentation in the beginning of August sections 1 and 2 has the same pressure. This is probably due to a shortcut via the packer between the two sections.

KA3563G: Before the re-instrumentation the equipment in KA3539G was mounted in this borehole and the shortcut via the packer (see above) has had the same effect in this borehole.

KA3574G01: The high pressure peaks, particularly in section 2, occur when the packers are expanded. This is likely an effect of very low transmissivity in this section. After the packer expansion the pressure decreases very slow towards the real section pressure. The repeated packer expansions are a result of reparations of damages on the packer line caused by welding in the vicinity.

KA3576G01: See comment for KA3574G01.

KA3578G01:In section 1 the pressure build-up is slow after packer expansion. See comment for KA3574G01.

KA3579G01: See comment for KA3574G01.

KA3590G01: Due to leakage on the packer line the packer between sections 2 and 3 has been deflated until March 25.

KG0048A01: The pressure drop in section 4 in June occurs when borehole KG0021A01 is re-instrumented.

6.5 Water flow in tunnel

Water flow in the tunnel, measured at the gauging boxes at different tunnel lengths is presented in Appendix 5. The flow is integrated to daily values given as $m^3/24$ hours. The flow changes in most boxes are relatively small over the year 1999.

For periods, the flow at some gauging boxes increases as a result of water added in connection to work using water in the tunnel, especially in the deepest part of the tunnel system, from the assembly hall and downward. Water from the assembly hall is collected by the gauging box MA3179G.

The flow in all gauging boxes is shown in Figure 6-9 as a mean during October - December 1999. For comparison purposes, also data for the corresponding period in 1995, 1996, 1997 and 1998 is illustrated. Although data is missing in some boxes for certain periods (especially during 1995 and 1996), the diagram gives realistic values because the flow has been fairly constant during the period presented.

Figure 6-9 shows that the mean flow for the comparison period October – December decreases from year to year at most locations. One exception is MA1033G and some measuring locations in the deeper parts of the tunnel system. The latter may be a result of new excavations of side tunnels plus the addition of fresh water in connection to these and other activities.

Because of the changed installation 1997 and the uncertainty due to missing data for 1996, one should be careful when interpreting the flow changes observed in MA1033G before 1997.

The relatively large decrease in flow in gauging box MA3179G from 1998 to 1999 may be a result of less fresh water added in connection to activities in the assembly hall and the surrounding side-tunnels.

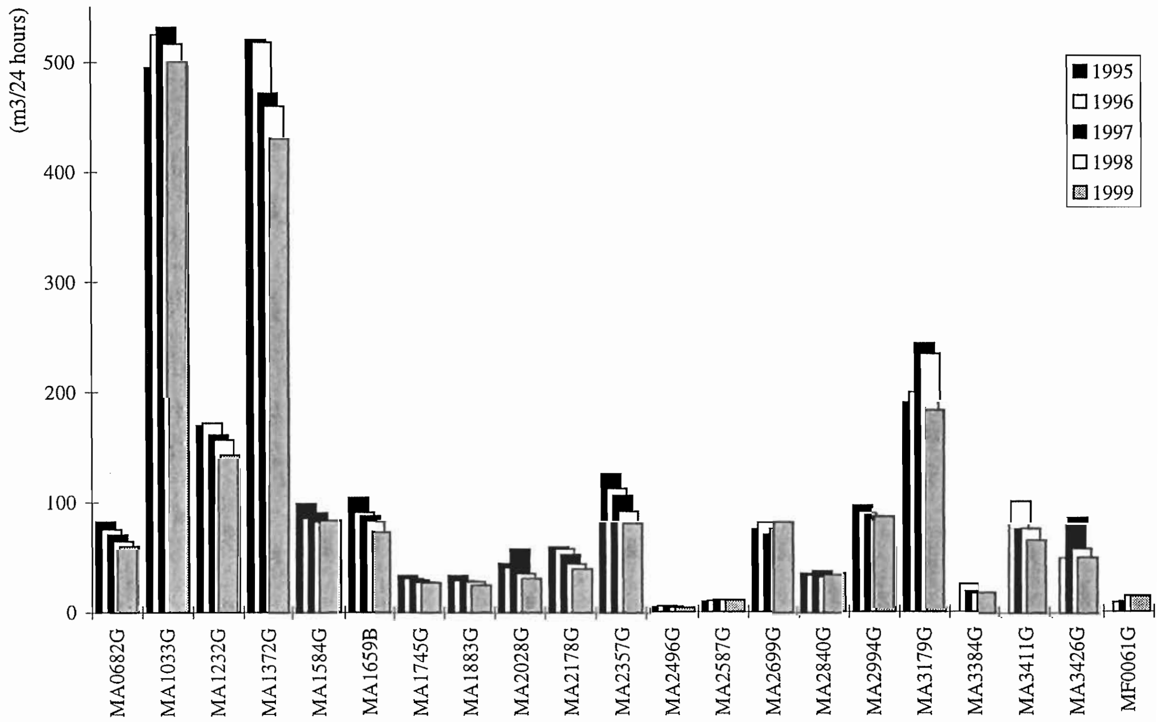


Figure 6-9 Water flow in all gauging boxes as a mean during October - December.

6.6 Water flow in tunnel pipes

The pumped flow out from the tunnel has been steady decreasing during 1999. The measurements of fresh water into the tunnel were terminated in the end of June.

The mean daily flow of water in the pipes during October - December for the last four years are found in Table 6-1.

Table 6-1 Water flow in tunnel pipes, October - December.

Year	Water in (m^3/24 hours)	Water out (m^3/24 hours)
1995	4.4	2479
1996	9.6	2438
1997	11.0	2393
1998	9.2	2268
1999	—	2105

The flow of water pumped out from the tunnel and water flow in pipes into the tunnel are presented in Appendix 6 as integrated daily values given in m^3/24 hours. Data on pumped out water is missing in August 4 – 18, depending on a defect transmitter. For four days in the end of August a malfunctioning logger caused a drop out of data for both incoming and pumped out water.

6.7 Electrical conductivity of tunnel water

Electrical conductivity of tunnel water has been measured in eight gauging boxes for flow measurements, at one locations on the discharge pipe leading water from the gauging boxes to one of the sumps, and in two of the sumps (see section 4.7).

The same electrical conductivity meter is used for periods in the four gauging boxes MA3384G, MA3411G, MA3426G, MF0061G and in the sump PG5, all in the deepest part of the tunnel system.

The results, one data point per day, are presented in Appendix 7.

6.8 Levels of the Baltic Sea

The sea level varies in the approximate range -0.5 - +0.5 m.a.s.l. during the year. Sea levels are adjusted to the national elevation system (RH70), which gives approximately 6 centimetres higher values than the local system on Äspö.

On some occasions, there are very fast level changes. This happens when weather conditions, i.e. wind direction and air pressure, changes rapidly.

Hourly values of the sea level in Oskarshamn are presented in a diagram in Appendix 8.

6.9 Precipitation

Monthly precipitation at the SMHI-station in Oskarshamn (see section 4.10.1) for 1999, as well as monthly mean for the period 1961-1990 and yearly values are presented in Figures 6-10 and 6-11. All precipitation values are measured values without any corrections. A diagram of daily totals is shown in Appendix 9.

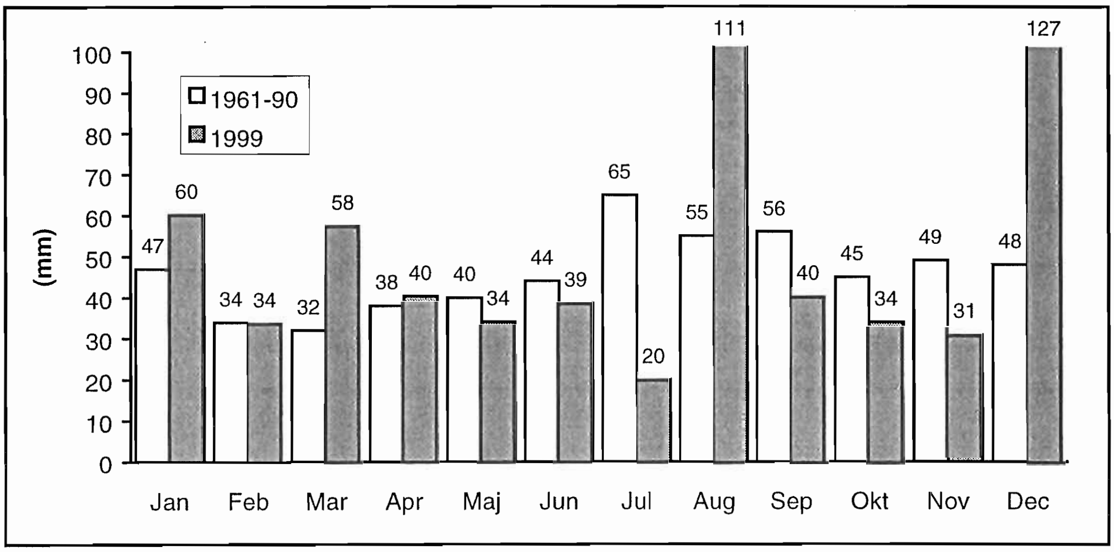


Figure 6-10 Precipitation at Oskarshamn. Monthly values 1999 and monthly means 1961 – 1990.

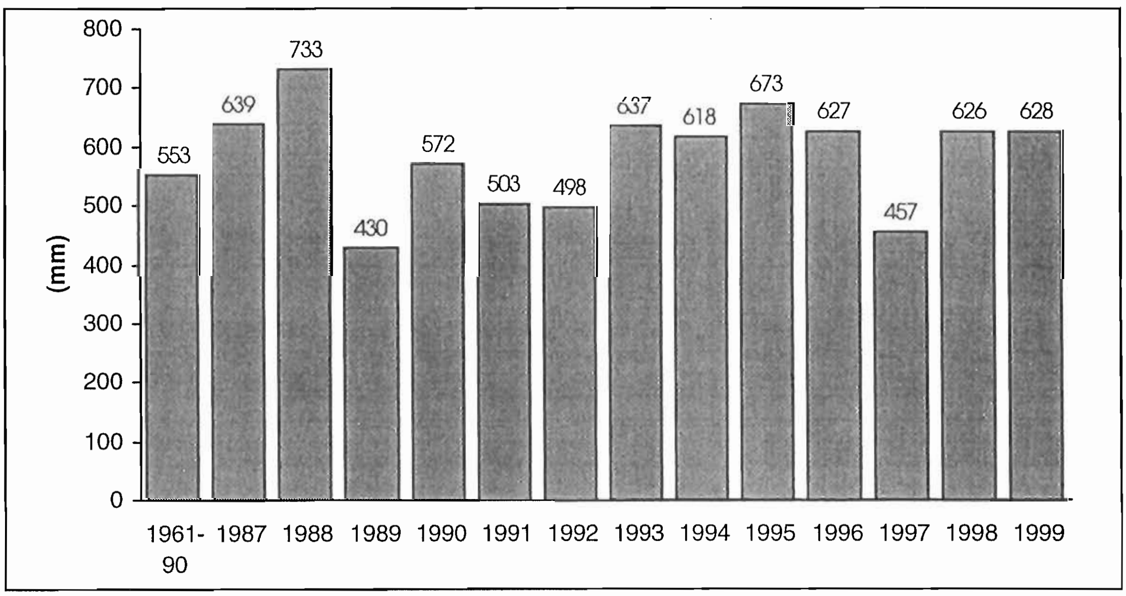


Figure 6-11 Precipitation at Oskarshamn. Yearly values 1987 - 1999 and yearly mean for the period 1961 - 1990.

6.10 Air temperature

Monthly mean temperature at the SMHI-station in Oskarshamn (see section 4.10.2) for 1999, as well as monthly mean for the period 1961-1990 and yearly values are presented in Figures 6-12 and 6-13. The daily mean temperatures during 1999 is demonstrated in Appendix 10.

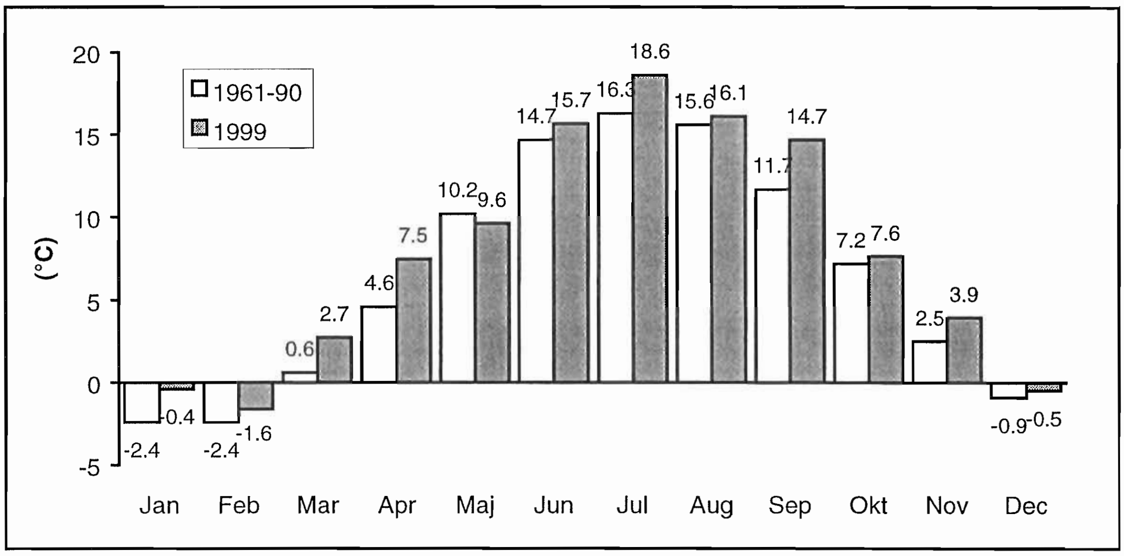


Figure 6-12 Temperature at Oskarshamn. Monthly values 1999 and monthly means 1961 – 1990

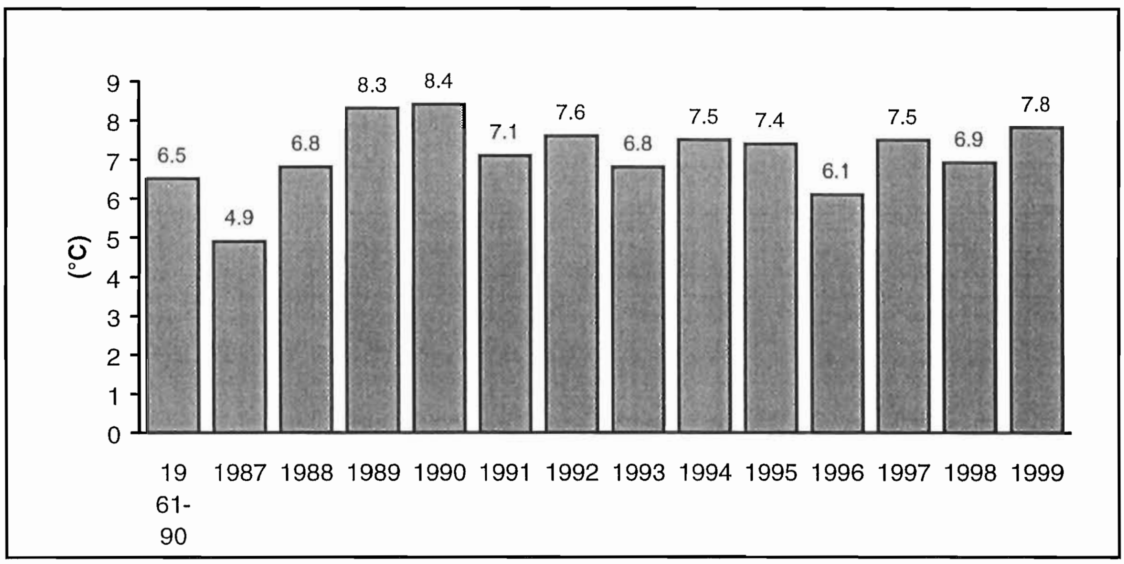


Figure 6-13 Temperature at Oskarshamn. Yearly values 1987 - 1999 and yearly mean for the period 1961 - 1990.

6.11 Potential evapotranspiration

The daily amount of potential evapotranspiration (see section 4.10.3) is presented in diagrams in Appendix 11. Monthly and yearly amounts are presented in Figures 6-14 and 6-15. Since evaporation is not normally calculated by SMHI, there are no mean values for the period 1931-1990 available. Due to changes of the origin of the involved variables (see section 4.10.3), the calculated potential evapotranspiration seems to be considerably lower from August 1995 and onwards. Data from the end of June, beginning of July and from November 1999 are missing. When calculating a yearly mean for 1999, mean values from the years 1996-1998 were used for the missing periods.

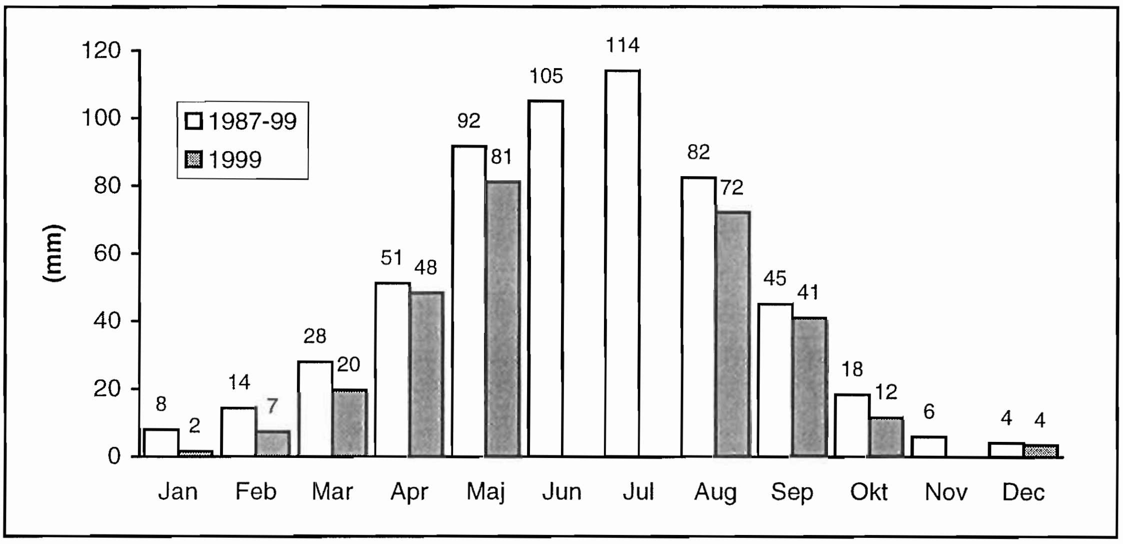


Figure 6-14 Potential evapotranspiration. Monthly values for Gladhammar 1999 and monthly means 1987 - 1999 (an average from Gladhammar and Ölands Norra Udde is used before 1 of August 1995).

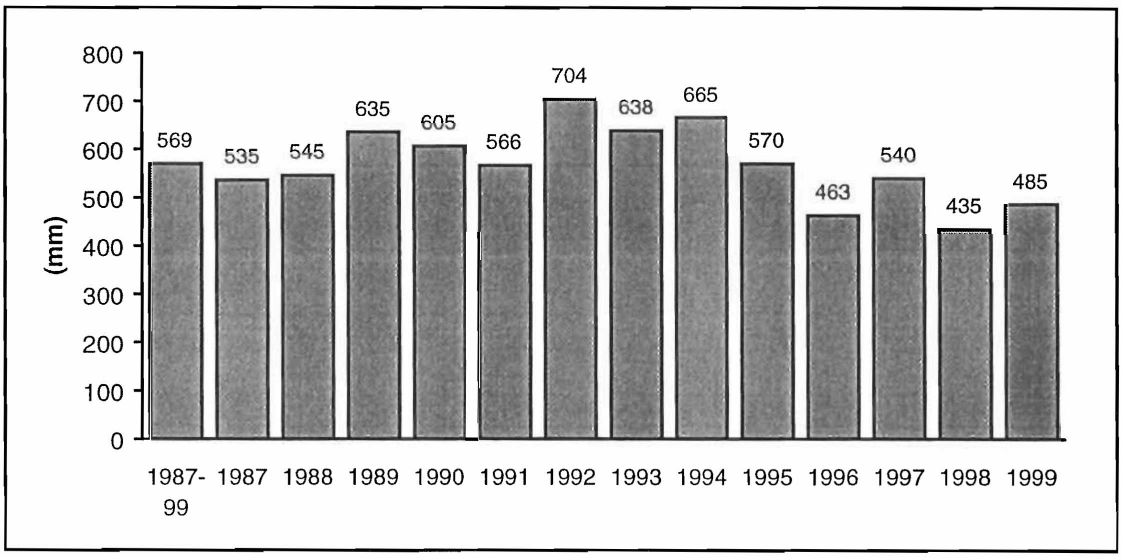


Figure 6-15 Potential evapotranspiration as average from Gladhammar and Ölands Norra Udde (only Gladhammar from 1 of August 1995). Yearly values 1987 - 1999 and yearly mean for the period 1987 - 1999.

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Appendices

Appendix 1: Statistics on missing data

Äspö Hard Rock Laboratory

Groundwater Level Program

Error statistics

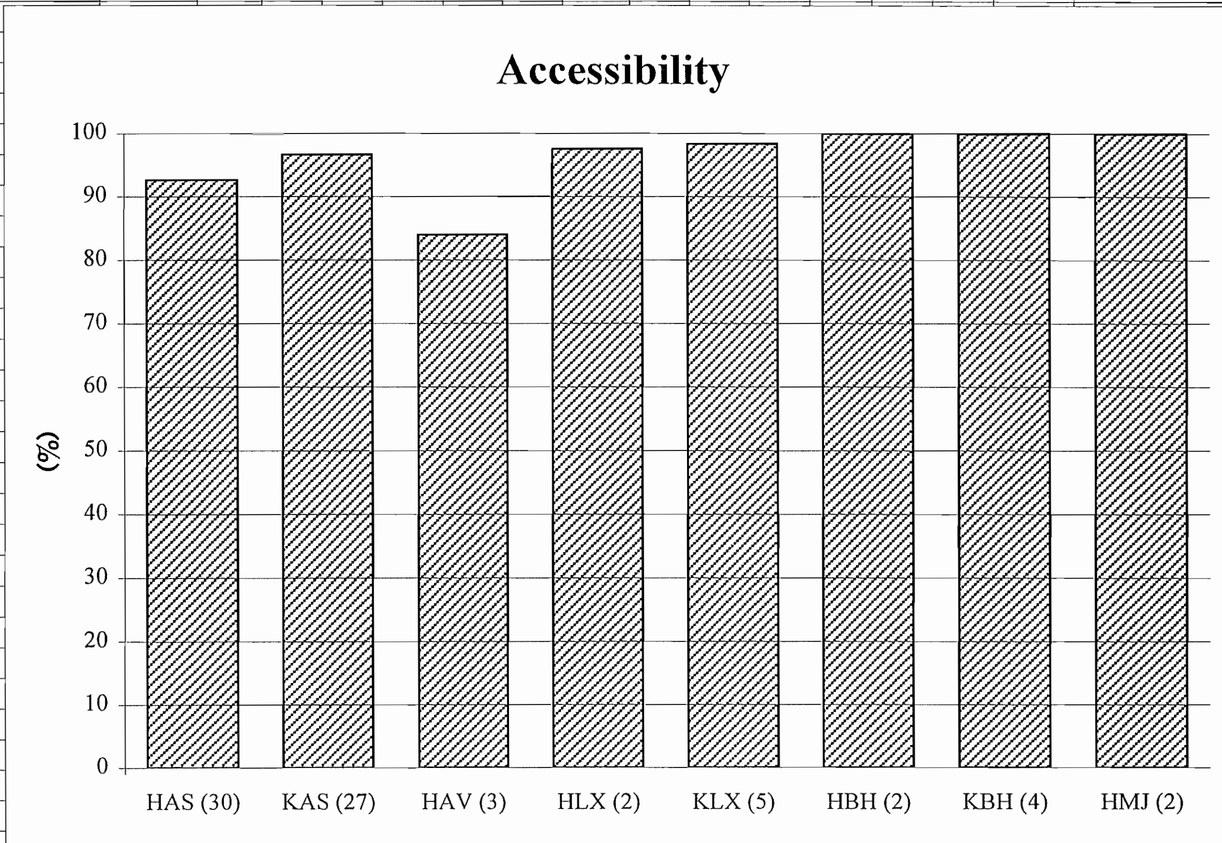
First date for statistics:	1999-01-01
Last date for statistics:	1999-12-31
Latest calibration date:	2000-06-01
No of days in period:	365

Borehole	Section	Duration of error (days)														Accessibility
		TG	**TST**	**KOM**	**I**	**V**	**B**	**L**	**Å**	**ML**	**OP**	**G**	**K**	**?**	Sum	(%)
HAS01	1			10									14		24	93
HAS02	1														0	100
HAS03	1														0	100
HAS04	1			14											14	96
HAS04	2			14						4	8				26	93
HAS05	1														0	100
HAS06	1					6									6	98
HAS06	2					6									6	98
HAS07	1					6									6	98
HAS08	1														0	100
HAS09	1														0	100
HAS10	1														0	100
HAS11	1	80					139								219	40
HAS11	2						115								115	68
HAS12	1														0	100
HAS13	1		8												8	98
HAS13	2		8							168					176	52
HAS14	1														0	100
HAS15	1														0	100
HAS15	2														0	100
HAS16	1					6									6	98
HAS16	2					6									6	98
HAS17	1	116													116	68
HAS17	2					6				55					61	83
HAS18	1														0	100
HAS19	1														0	100
HAS19	2														0	100
HAS20	1														0	100
HAS20	2														0	100
HAS21	1					14									14	96
HAS		196	16	38	0	50	254	0	0	227	8	0	14	0	803	93

Borehole	Section	Duration of error (days)														Accessibility
		TG	**TST**	**KOM**	**I**	**V**	**B**	**L**	**Å**	**ML**	**OP**	**G**	**K**	**?**	Sum	(%)
KAS01	1			14											14	96
KAS02	1														0	100
KAS03	1	29													29	92
KAS03	2														0	100
KAS03	3														0	100
KAS03	4														0	100
KAS03	5														0	100
KAS03	6														0	100
KAS04	1														0	100
KAS07	1														0	100
KAS09	1														0	100
KAS09	2														0	100
KAS09	3														0	100
KAS09	4														0	100
KAS09	5														0	100
KAS10	1								8						8	98
KAS11	1														0	100
KAS12	1			10											10	97
KAS12	2			10											10	97
KAS12	3														0	100
KAS12	4	88													88	76
KAS12	5	149													149	59
KAS14	1														0	100
KAS16	1														0	100
KAS16	2														0	100
KAS16	3	23													23	94
KAS16	4														0	100
KAS		289	0	34	0	0	0	0	8	0	0	0	0	0	331	97

Borehole	Section	Duration of error (days)														Accessibility
		TG	**TST**	**KOM**	**I**	**V**	**B**	**L**	**Å**	**ML**	**OP**	**G**	**K**	**?**	Sum	(%)
HAV02	1														0	100
HAV05	1											175			175	52
HAV08	1														0	100
HAV		0	0	0	0	0	0	0	0	0	0	175	0	0	175	84
HLX04	1														0	100
HLX05	1	18													18	95
HLX		18	0	0	0	0	0	0	0	0	0	0	0	0	18	98
KLX01	1	21													21	94
KLX01	2														0	100
KLX01	3										9				9	98
KLX01	4														0	100
KLX01	5														0	100
KLX		21	0	0	0	0	0	0	0	0	9	0	0	0	30	98
HBH04	1														0	100
HBH04	2														0	100
HBH		0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
KBH02	3														0	100
KBH02	4														0	100
KBH02	5														0	100
KBH02	6														0	100
KBH		0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
HMJ01	1														0	100
HMJ01	2														0	100
HMJ		0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
						SUMMARY										
HAS (30)		196	16	38	0	50	254	0	0	227	8	0	14	0	803	93
KAS (27)		289	0	34	0	0	0	0	8	0	0	0	0	0	331	97
HAV (3)		0	0	0	0	0	0	0	0	0	0	175	0	0	175	84
HLX (2)		18	0	0	0	0	0	0	0	0	0	0	0	0	18	98
KLX (5)		21	0	0	0	0	0	0	0	0	9	0	0	0	30	98
HBH (2)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
KBH (4)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
HMJ (2)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
TOTAL (80)		39%	1%	5%	0%	4%	19%	0%	1%	17%	1%	13%	1%	0%	100%	95

Borehole	Section	Duration of error (days)													Accessibility
		TG	TST	KOM	I	V	B	L	Å	ML	OP	G	K	?	Sum	(%)



ERROR CODES

TG:	Failing pressure transducer
M:	Leakage in the PEM-packer system leading to wrong level registration
KOM:	Failure in the communication with on-line loggers
I:	Communication tube clogged
U:	Ground water level below pressure transducer
B:	Failure in datalogger Borre
L:	Levellings were not possible to perform
Å:	Failure in lightning protector
ML:	Leakage in the packer system
OP:	Mistake by the operator leading to a break in registration
O:	Reinstrumentation
K:	Broken signal cable
?:	Unknown error
G:	Failure in datalogger Grund
V:	Failure in power supply
Ö:	Misc. errors
TST:	Registration broken due to other activities

Äspö Hard Rock Laboratory
Monitoring in tunnel
Error statistics

First date for statistics:	99-01-01
Last date for statistics:	99-12-31
Latest calibration date:	00-08-08
No of days in period:	365

Idcode	Sec.	Duration of error (days)													Accessibility
		G	K	OP	TST	V	O	L	DS	ML	TG	W	?	Sum	(%)
HA1273A	1			10										10	97
HA1278A	1													0	100
HA1279A	1													0	100
HA1283B	1													0	100
HA1327B	1													0	100
HA1330B	1													0	100
HA1960A	1													0	100
KA1061A	1				3									3	99
KA1131B	1				2									2	99
KA1751A	1													0	100
KA1751A	2													0	100
KA1751A	3													0	100
KA1754A	1													0	100
KA1754A	2													0	100
KA1755A	1					27								27	93
KA1755A	2													0	100
KA1755A	3													0	100
KA1755A	4													0	100
KA2048B	1													0	100
KA2048B	2													0	100
KA2048B	3													0	100
KA2048B	4													0	100
KA2050A	1													0	100
KA2050A	2													0	100
KA2050A	3													0	100
KA2162B	1													0	100
KA2162B	2													0	100
KA2162B	3													0	100
KA2162B	4													0	100
KA2511A	1													0	100
KA2511A	2													0	100
KA2511A	3													0	100
KA2511A	4													0	100
KA2511A	5													0	100
KA2511A	6													0	100
KA2563A	1													0	100
KA2563A	2													0	100
KA2563A	3													0	100
KA2563A	4													0	100
KA2563A	5													0	100
KA2563A	6													0	100
KA2563A	7													0	100
KA2858A	2													0	100
KA2862A	1													0	100
KA3005A	2													0	100
KA3005A	3													0	100
KA3005A	4													0	100
KA3005A	5													0	100
KA3010A	2													0	100
KA3067A	1													0	100
KA3067A	2													0	100

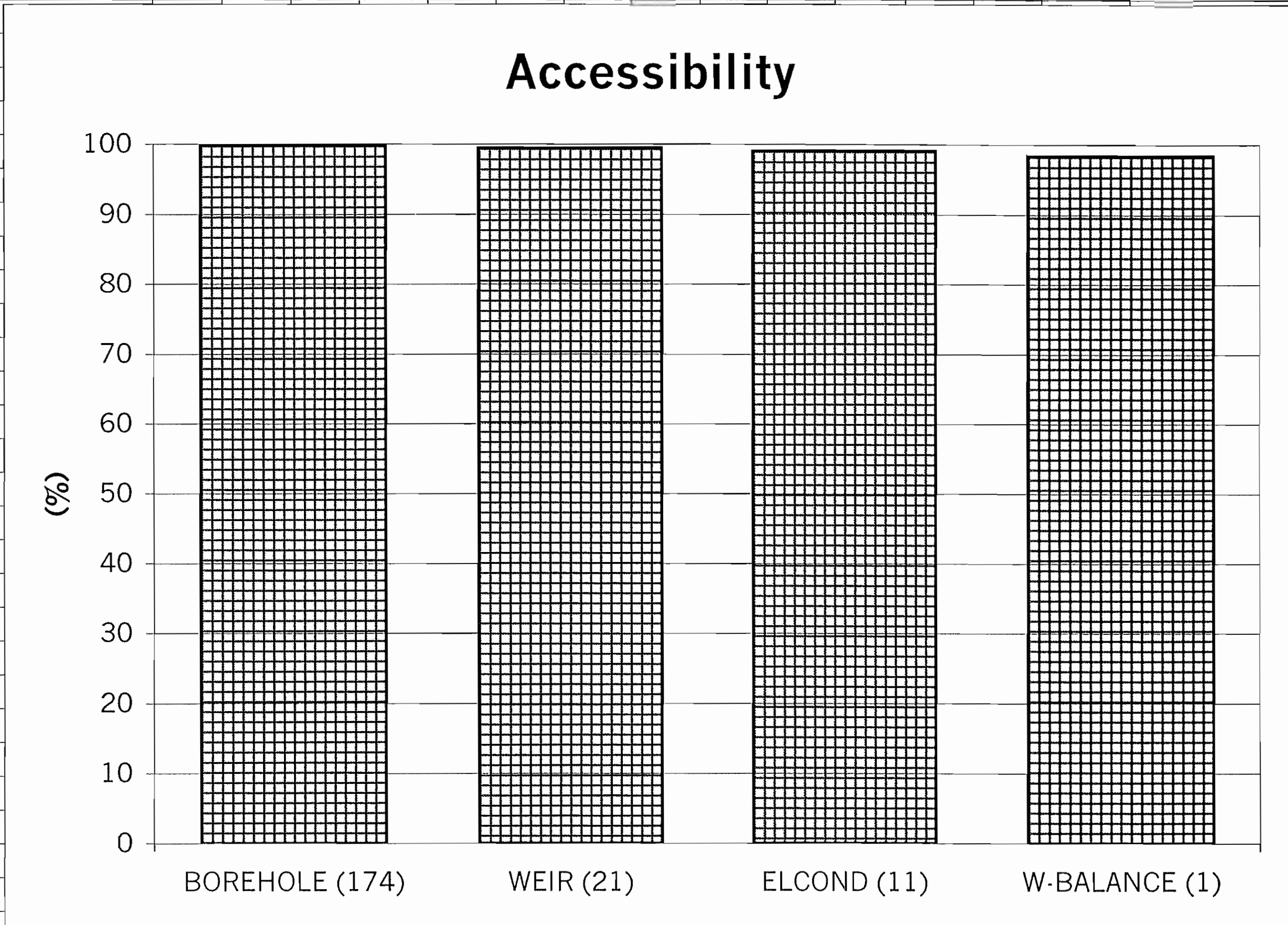
Idcode	Sec.	Duration of error (days)													Accessibility
		G	K	OP	TST	V	O	L	DS	ML	TG	W	?	Sum	(%)
KA3067A	3													0	100
KA3067A	4													0	100
KA3105A	1													0	100
KA3105A	2													0	100
KA3105A	3													0	100
KA3105A	4													0	100
KA3105A	5					9								9	98
KA3110A	1													0	100
KA3110A	2													0	100
KA3385A	1													0	100
KA3385A	2													0	100
KA3510A	1													0	100
KA3510A	2													0	100
KA3510A	3													0	100
KA3539G	1													0	100
KA3539G	2													0	100
KA3539G	3													0	100
KA3542G01	1										19			19	95
KA3542G01	2													0	100
KA3542G01	3													0	100
KA3542G02	1													0	100
KA3542G02	2													0	100
KA3542G02	3													0	100
KA3542G02	4													0	100
KA3544G01	1													0	100
KA3544G01	2													0	100
KA3546G01	1													0	100
KA3546G01	2													0	100
KA3548A01	1													0	100
KA3548A01	2													0	100
KA3548G01	1				10									10	97
KA3550G01	1													0	100
KA3550G01	2													0	100
KA3552G01	1													0	100
KA3552G01	2													0	100
KA3552G01	3													0	100
KA3554G01	1													0	100
KA3554G01	2													0	100
KA3554G01	3													0	100
KA3554G02	1													0	100
KA3554G02	2													0	100
KA3554G02	3													0	100
KA3557G	1													0	100
KA3563G01	1													0	100
KA3566G01	1													0	100
KA3566G01	2													0	100
KA3566G01	3													0	100
KA3566G01	4													0	100

Idcode	Sec.	Duration of error (days)													Accessibility
		G	K	OP	TST	V	O	L	DS	ML	TG	W	?	Sum	(%)
KA3566G02	1													0	100
KA3566G02	2													0	100
KA3566G02	3													0	100
KA3566G02	4													0	100
KA3572G01	1													0	100
KA3573A	1													0	100
KA3573A	2													0	100
KA3574G01	1													0	100
KA3576G01	1													0	100
KA3578G01	1													0	100
KA3579G	1													0	100
KA3584G01	1													0	100
KA3590G01	1													0	100
KA3590G02	1													0	100
KA3593G	1													0	100
KA3600F	1										19			19	95
KA3600F	2													0	100
KF0051A	2													0	100
KF0051A	3												23	23	94
KF0051A	4													0	100
KG0021A01	1													0	100
KG0021A01	2													0	100
KG0021A01	3													0	100
KG0021A01	4													0	100
KG0021A01	5													0	100
KG0048A01	1													0	100
KG0048A01	2													0	100
KG0048A01	3													0	100
KG0048A01	4													0	100
KG0048A01	5													0	100
KI0023B	1													0	100
KI0023B	2													0	100
KI0023B	3													0	100
KI0023B	4													0	100
KI0023B	5													0	100
KI0023B	6													0	100
KI0023B	7													0	100
KI0023B	8													0	100
KI0023B	9													0	100
KI0025F	1													0	100
KI0025F	2													0	100
KI0025F	3													0	100
KI0025F	4													0	100
KI0025F	5													0	100
KI0025F	6													0	100

Idcode	Sec.	Duration of error (days)													Accessibility
		G	K	OP	TST	V	O	L	DS	ML	TG	W	?	Sum	(%)
KI0025F02	1													0	100
KI0025F02	2													0	100
KI0025F02	3													0	100
KI0025F02	4													0	100
KI0025F02	5													0	100
KI0025F02	6													0	100
KI0025F02	7													0	100
KI0025F02	8													0	100
KI0025F02	9													0	100
KI0025F02	10													0	100
KXTT1	1													0	100
KXTT1	2													0	100
KXTT1	3													0	100
KXTT1	4													0	100
KXTT2	1													0	100
KXTT2	2													0	100
KXTT2	3													0	100
KXTT2	4													0	100
KXTT2	5													0	100
KXTT3	1													0	100
KXTT3	2													0	100
KXTT3	3													0	100
KXTT3	4													0	100
KXTT4	1													0	100
KXTT4	2													0	100
KXTT4	3													0	100
KXTT4	4													0	100
KXTT4	5													0	100
SA2142A	1													0	100
SA2338A	1													0	100
BOREHOLE		**0**	**0**	**10**	**15**	**36**	**0**	**0**	**0**	**0**	**38**	**0**	**23**	**122**	**100**

Idcode	Sec.	Duration of error (days)													Accessibility
		G	K	OP	TST	V	O	L	DS	ML	TG	W	?	Sum	(%)
MA0682G														0	100
MA1033G													5	5	99
MA1232G							23							23	94
MA1372G														0	100
MA1584G														0	100
MA1659G														0	100
MA1745G														0	100
MA1883G														0	100
MA2028G														0	100
MA2178G														0	100
MA2357G														0	100
MA2496G														0	100
MA2587G														0	100
MA2699G														0	100
MA2840G														0	100
MA2994G														0	100
MA3179G												14		14	96
MA3384G				2										2	99
MA3411G														0	100
MA3426G														0	100
MF0061G														0	100
Weir		**0**	**0**	**2**	**0**	**0**	**23**	**0**	**0**	**0**	**0**	**14**	**5**	**44**	**99**
EA0682G														0	100
EA1584T														0	100
EA1659B														0	100
EA2496T														0	100
EA2587G														0	100
EA3179G													16	16	96
EA3384G														0	100
EA3411G				22										22	94
EA3426G														0	100
EF0061G														0	100
EPG5														0	100
ELCOND		**0**	**0**	**22**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**16**	**38**	**99**
QA0687O													6	6	98
W-BALANCE		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6**	**6**	**98**

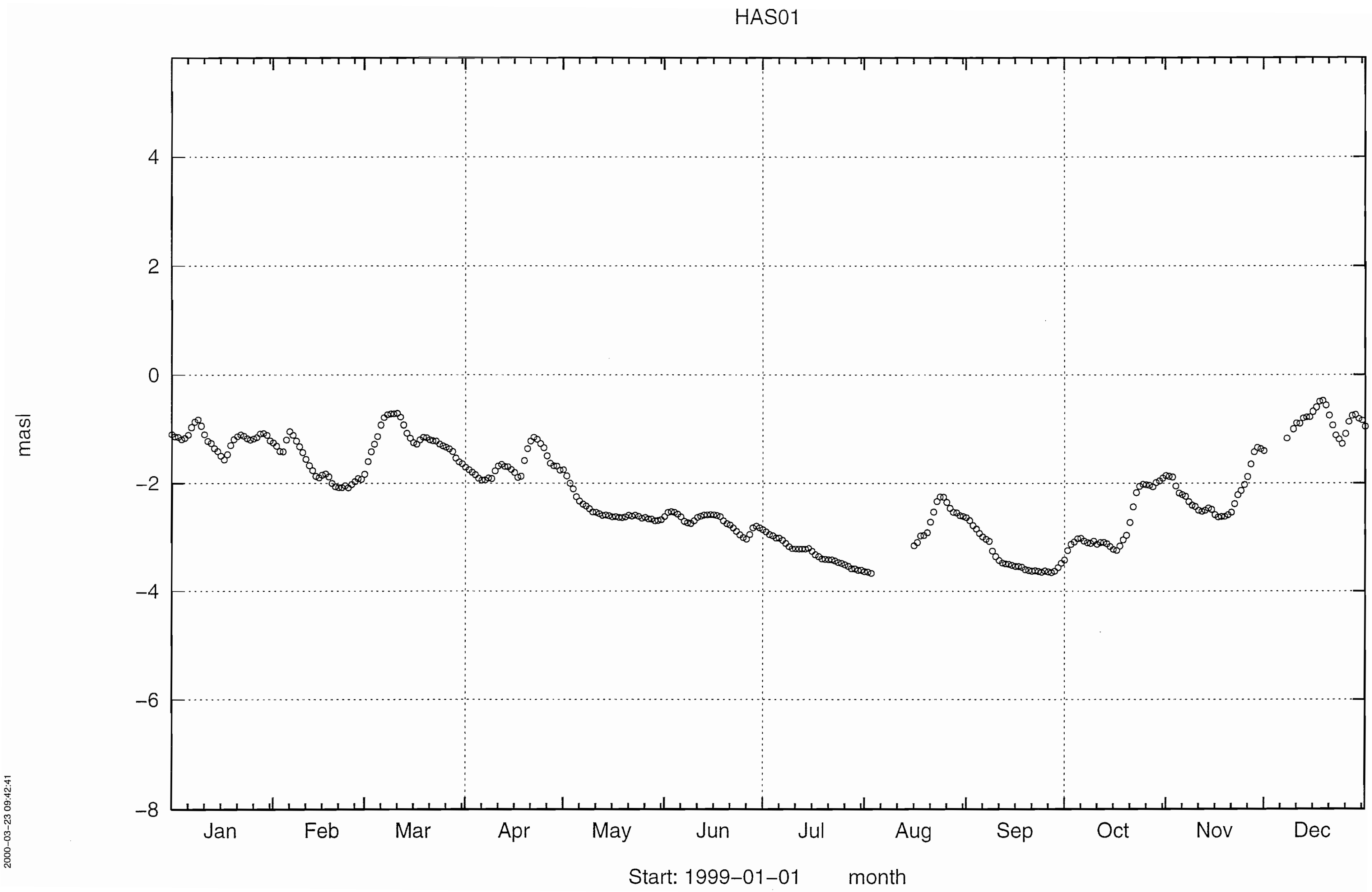
Idcode	Sec.	Duration of error (days)													Accessibility
		G	K	OP	TST	V	O	L	DS	ML	TG	W	?	Sum	(%)
							SUMMARY								
BOREHOLE (174)		0	0	10	15	36	0	0	0	0	38	0	23	122	100
WEIR (21)		0	0	2	0	0	23	0	0	0	0	14	5	44	99
ELCOND (11)		0	0	22	0	0	0	0	0	0	0	0	16	38	99
W-BALANCE (1)		0	0	0	0	0	0	0	0	0	0	0	6	6	98
TOTAL		0%	0%	16%	7%	17%	11%	0%	0%	0%	18%	7%	24%	100%	100



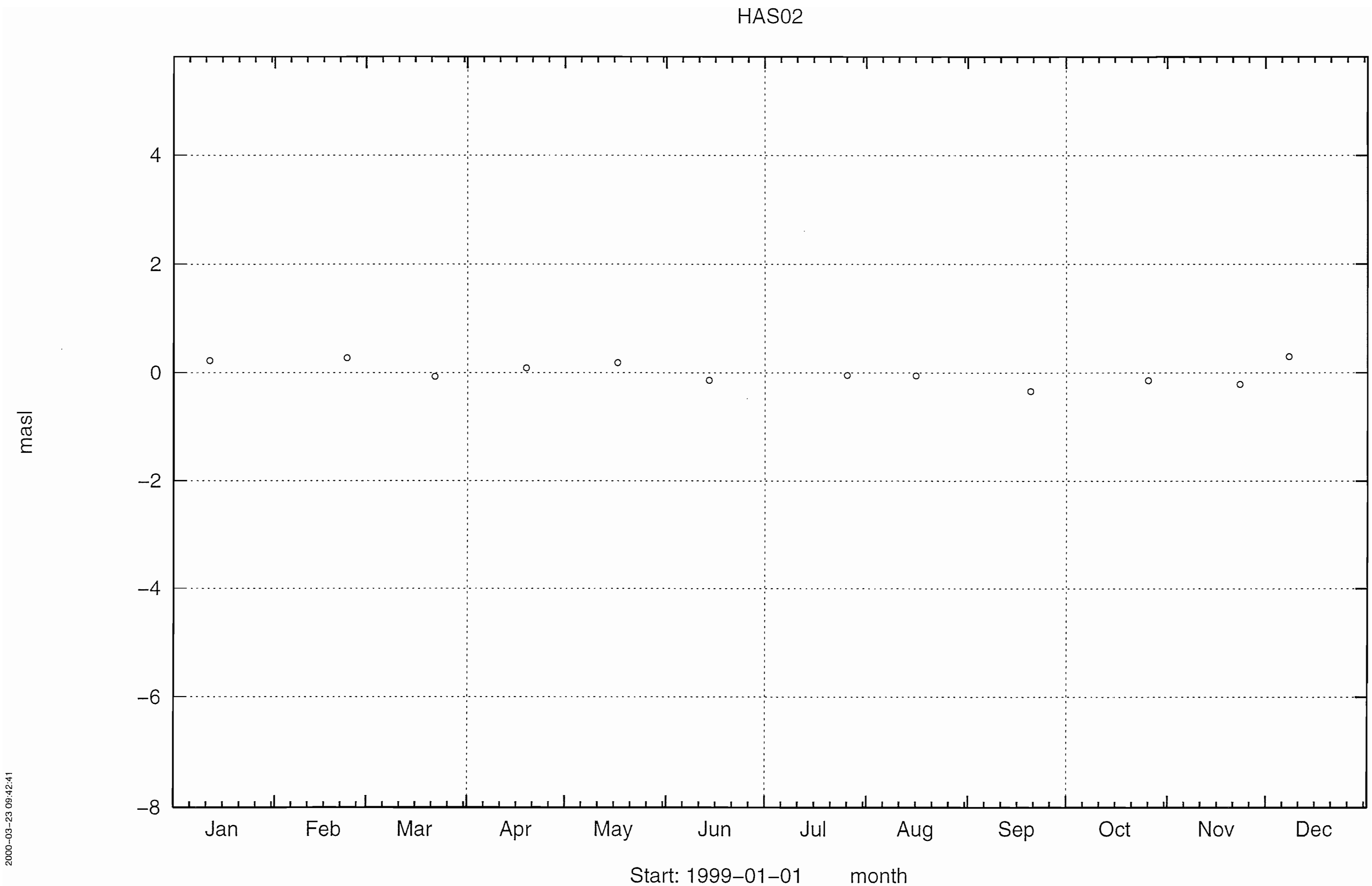
ERROR CODES

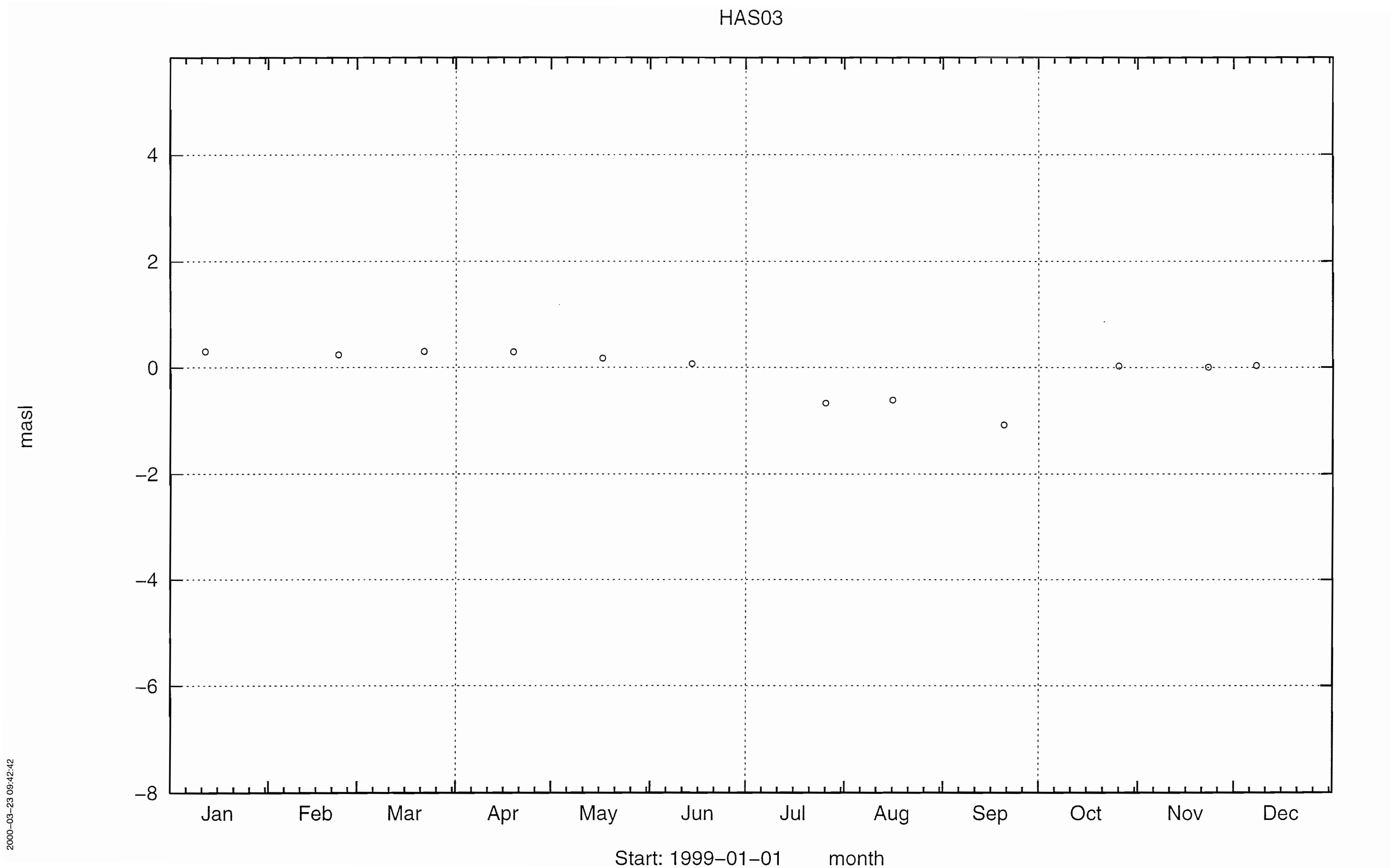
W:	Missing data due to work in vicinity
G:	Failing transducer
DS:	Missing data due to failure in Datascan Unit
TST:	Registration broken due to other tests or activities
K:	Broken signal cable
O:	Reinstrumentation
OP:	Mistake by the operator leading to a break in registration
V:	Failure in Hydraulic Multiplexer: jammed magnetic valve or clogged tubes
L:	Leakage or broken communicating tubes
B:	Failure in datalogger Borre
S:	Ditch and/or gauging box filled with sediment
D:	Computer error that leads to a break in registration
ML:	Leakage in the packer system
?:	Unknown error

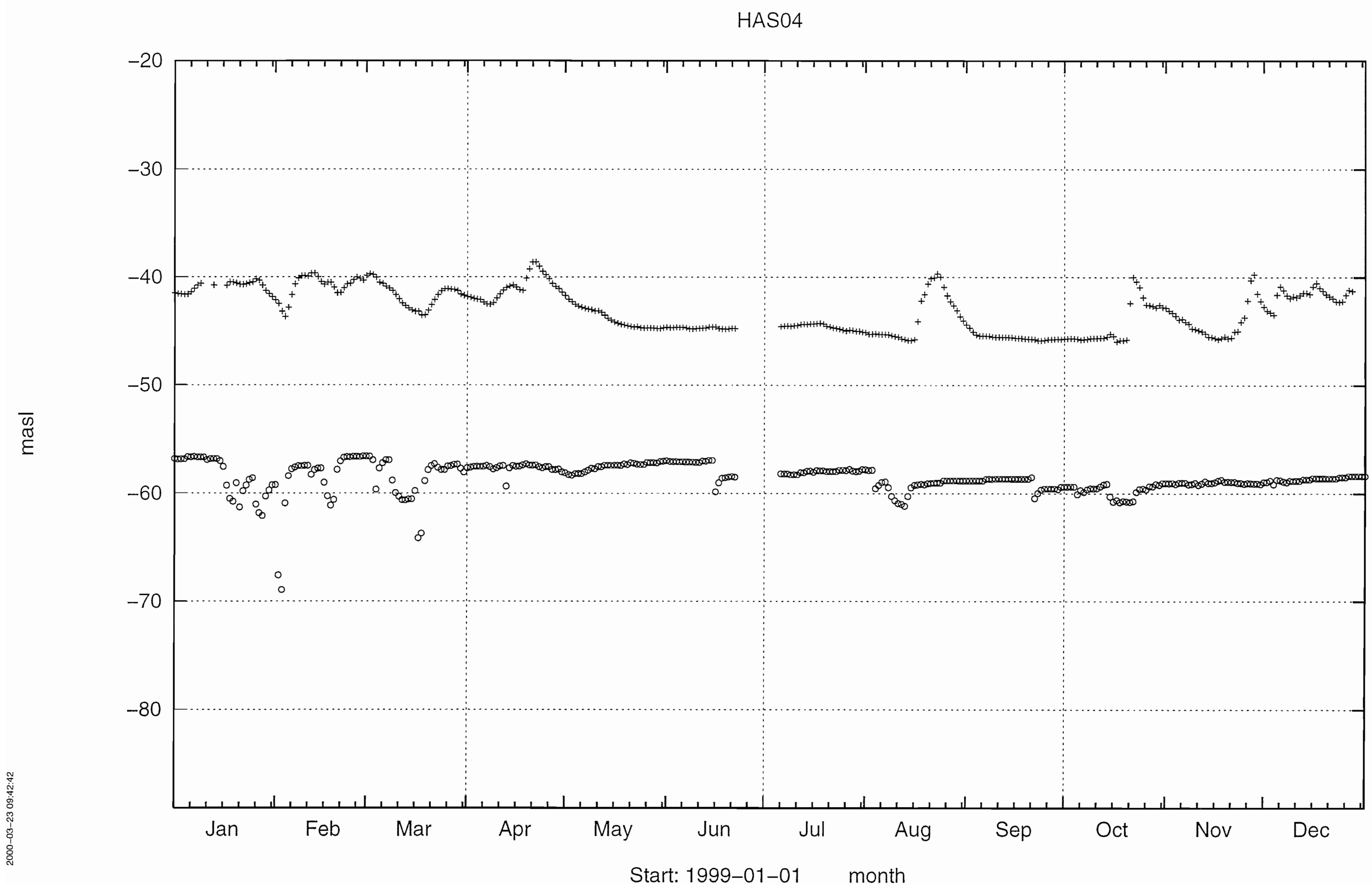
Appendix 2: Groundwater level

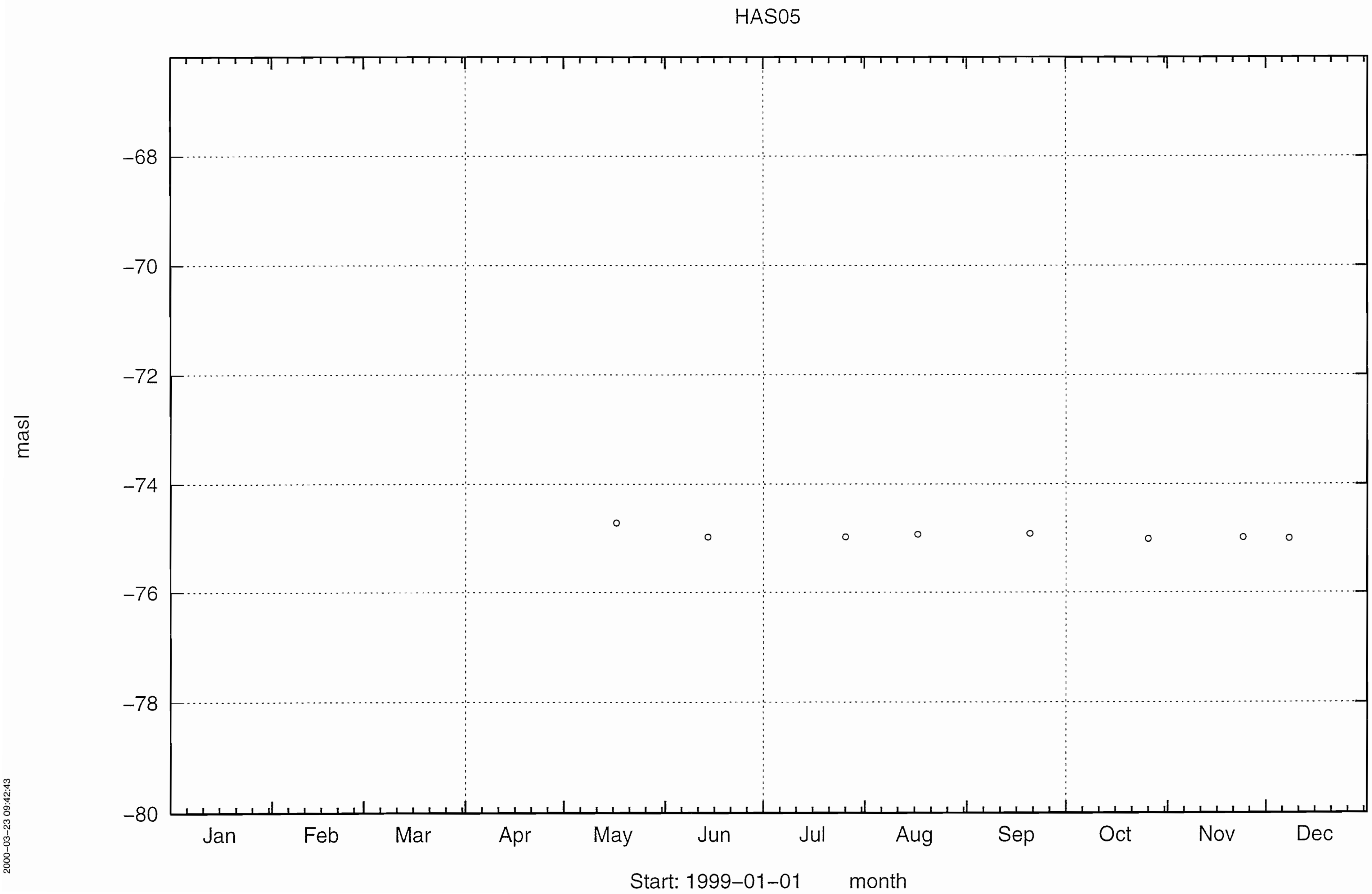


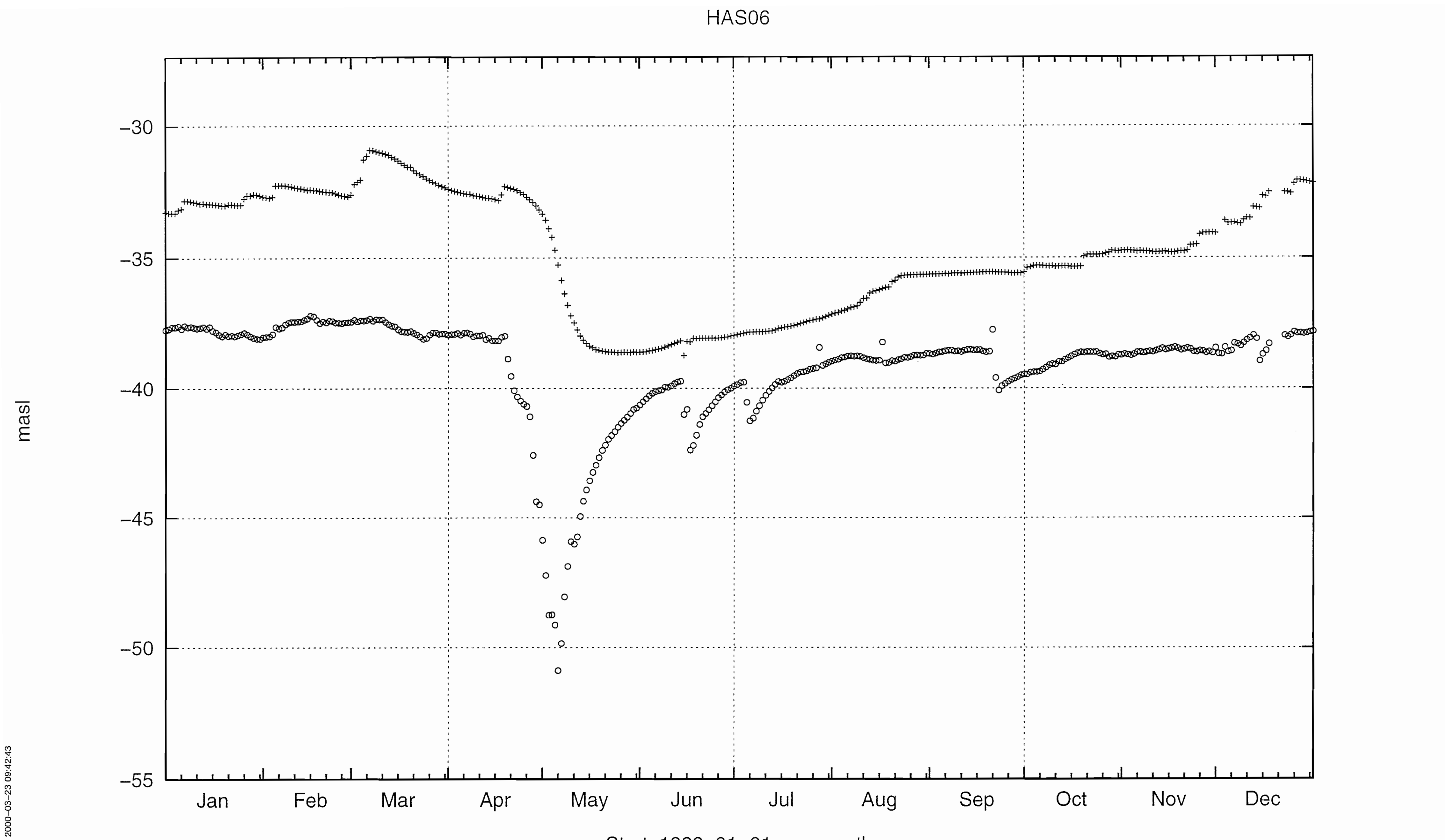
HAS01
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−03−23 09:42:41

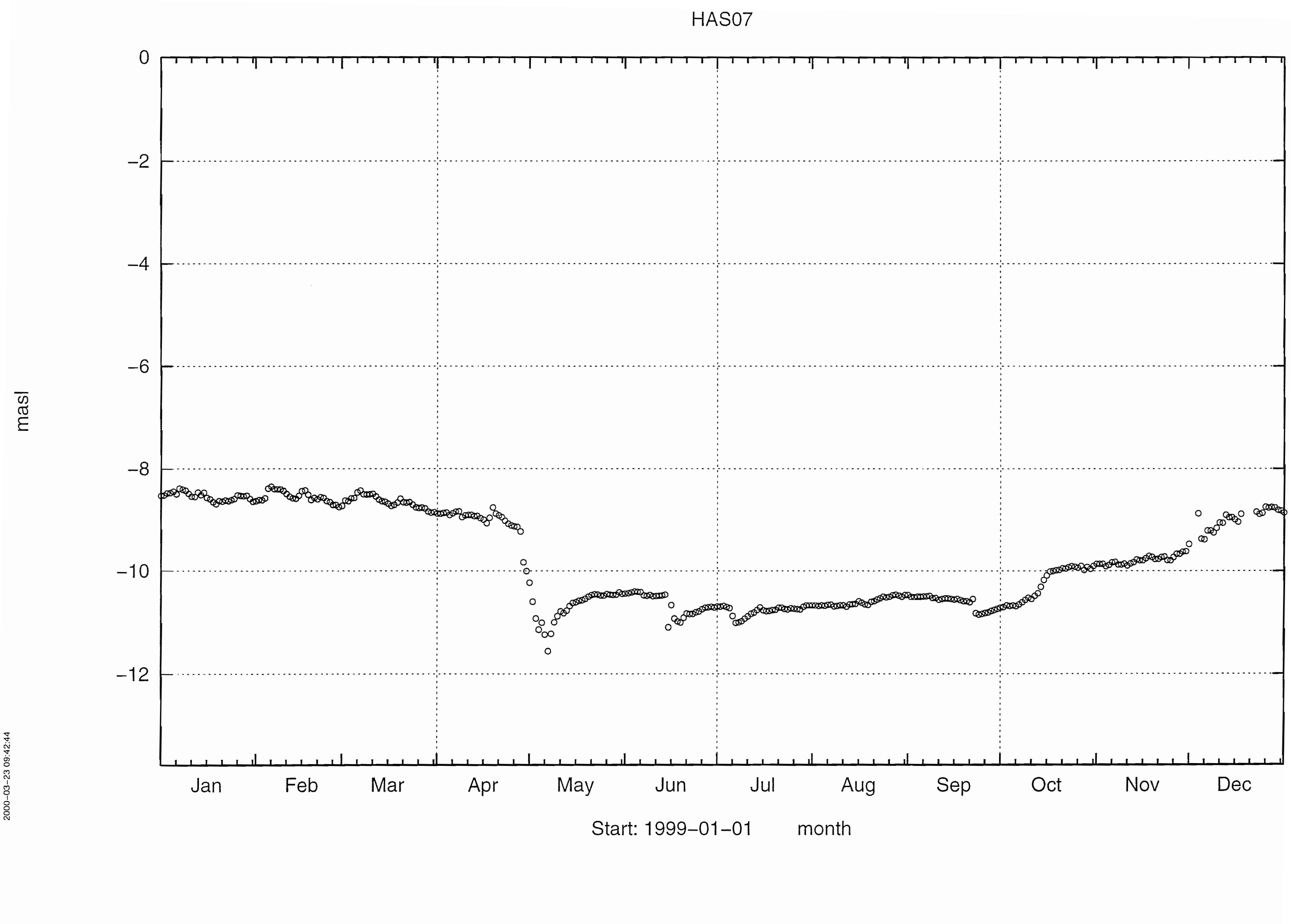

HAS02
4
2
0
−2
−4
−6
−8
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−03−23 09:42:41


HAS03
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−03−23 09:42:42

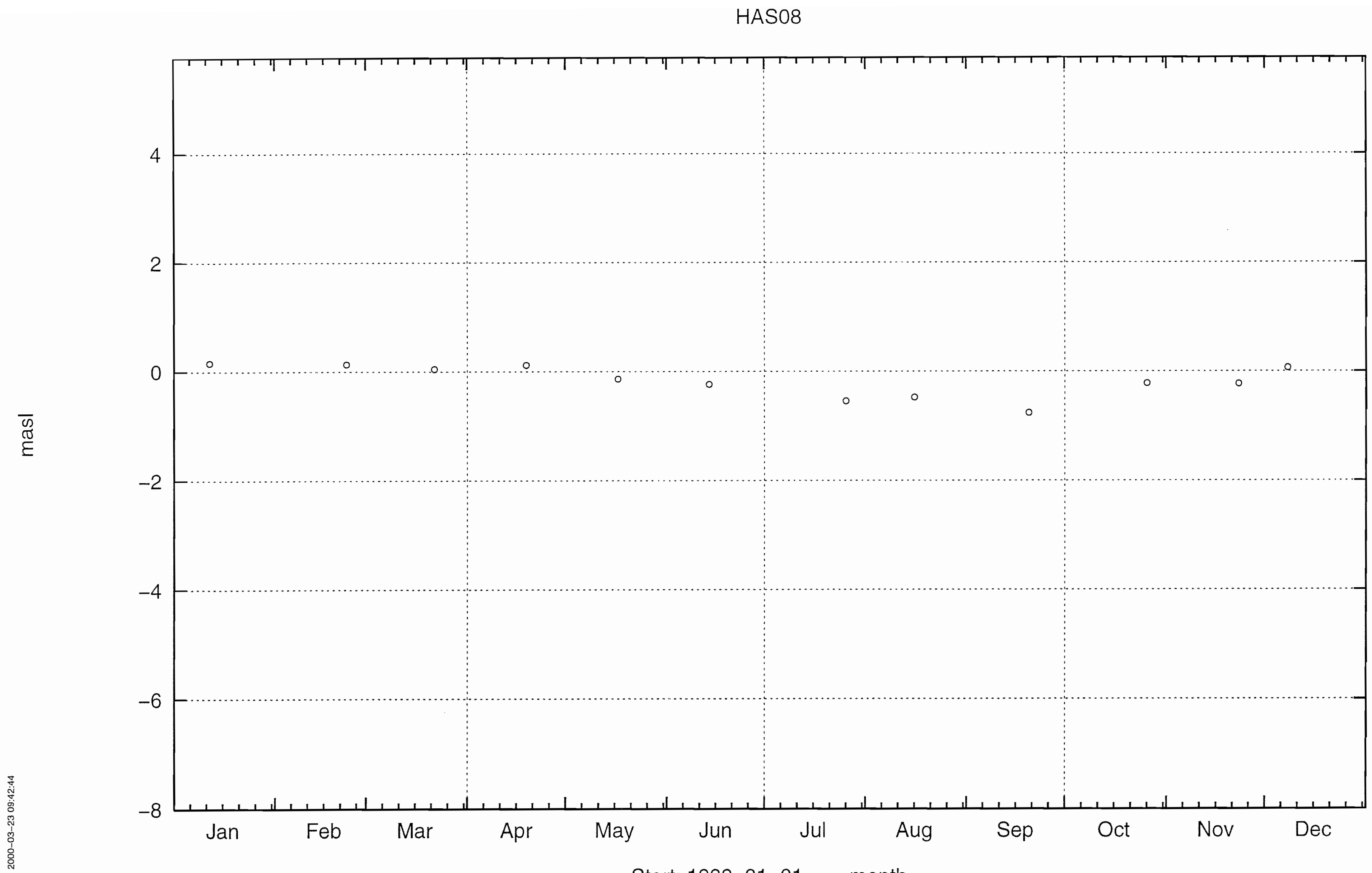

HAS04
masl
−20
−30
−40
−50
−60
−70
−80
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−03−23 09:42:42


HAS05
masl
−68
−70
−72
−74
−76
−78
−80
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−03−23 09:42:43


HAS06
masl
−30
−35
−40
−45
−50
−55
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−03−23 09:42:43



HAS07
0
−2
−4
−6
−8
−10
−12
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−03−23 09:42:44


HAS08
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
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May
Jun
Jul
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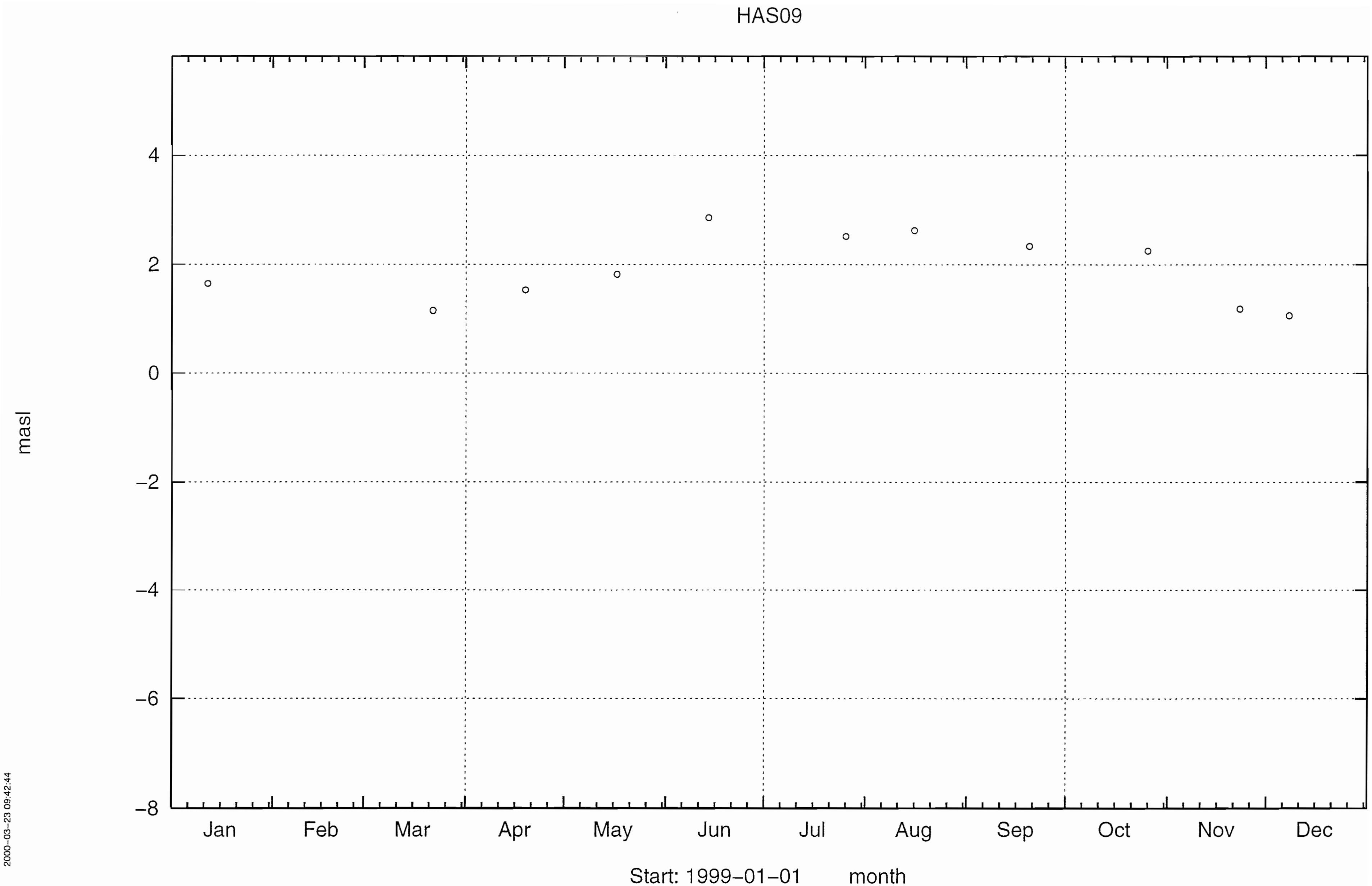
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−03−23 09:42:44



HAS09
masl
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Jun
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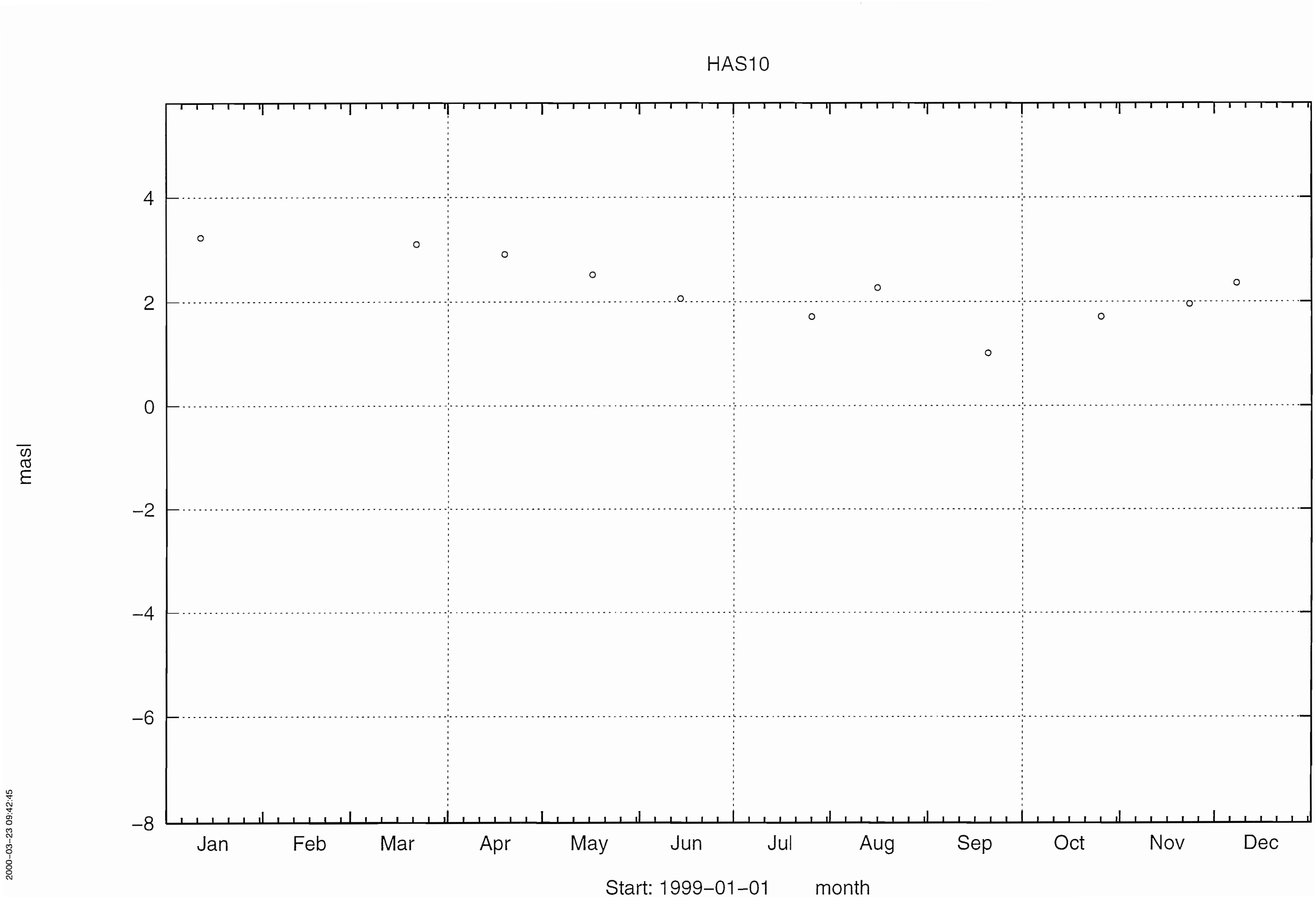
Oct
Nov
Dec
Start: 1999−01−01 month
2000−03−23 09:42:44



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Jun
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Oct
Nov
Dec
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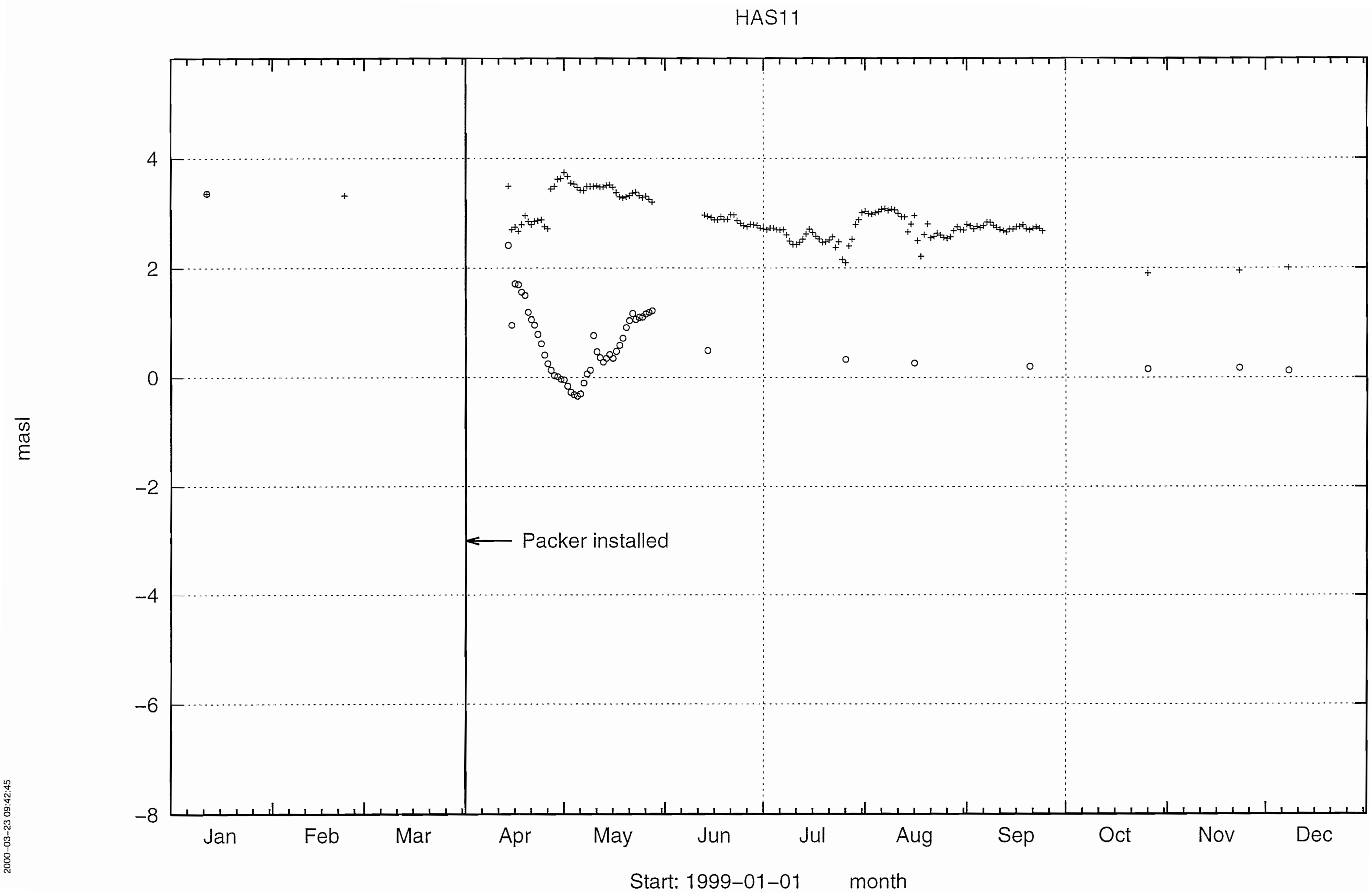
2000−03−23 09:42:45


HAS11
masl
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−2
−4
−6
−8
Packer installed
Jan
Feb
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May
Jun
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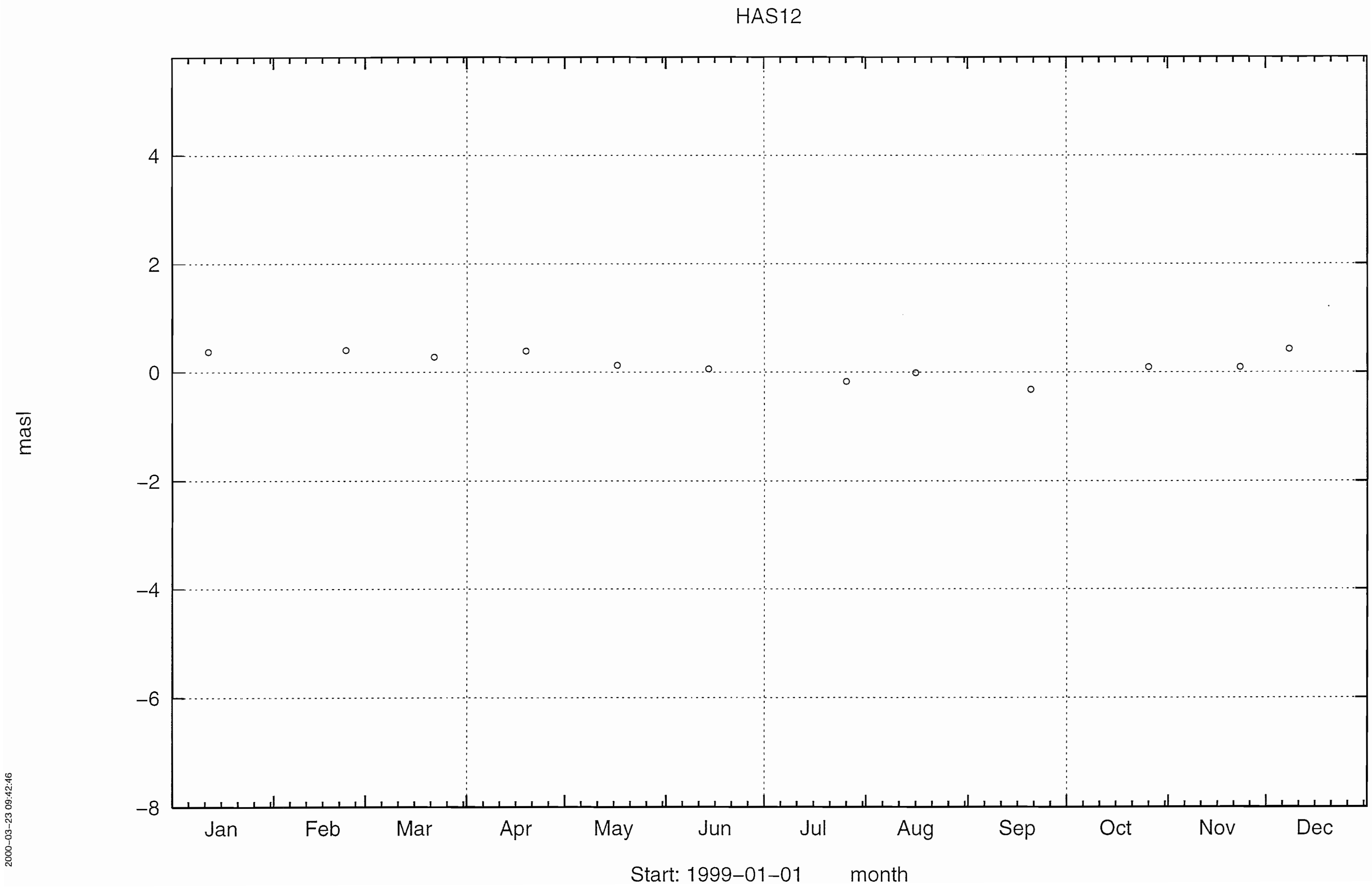
month
2000−03−23 09:42:45



HAS12
4
2
0
−2
−4
−6
−8
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
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month
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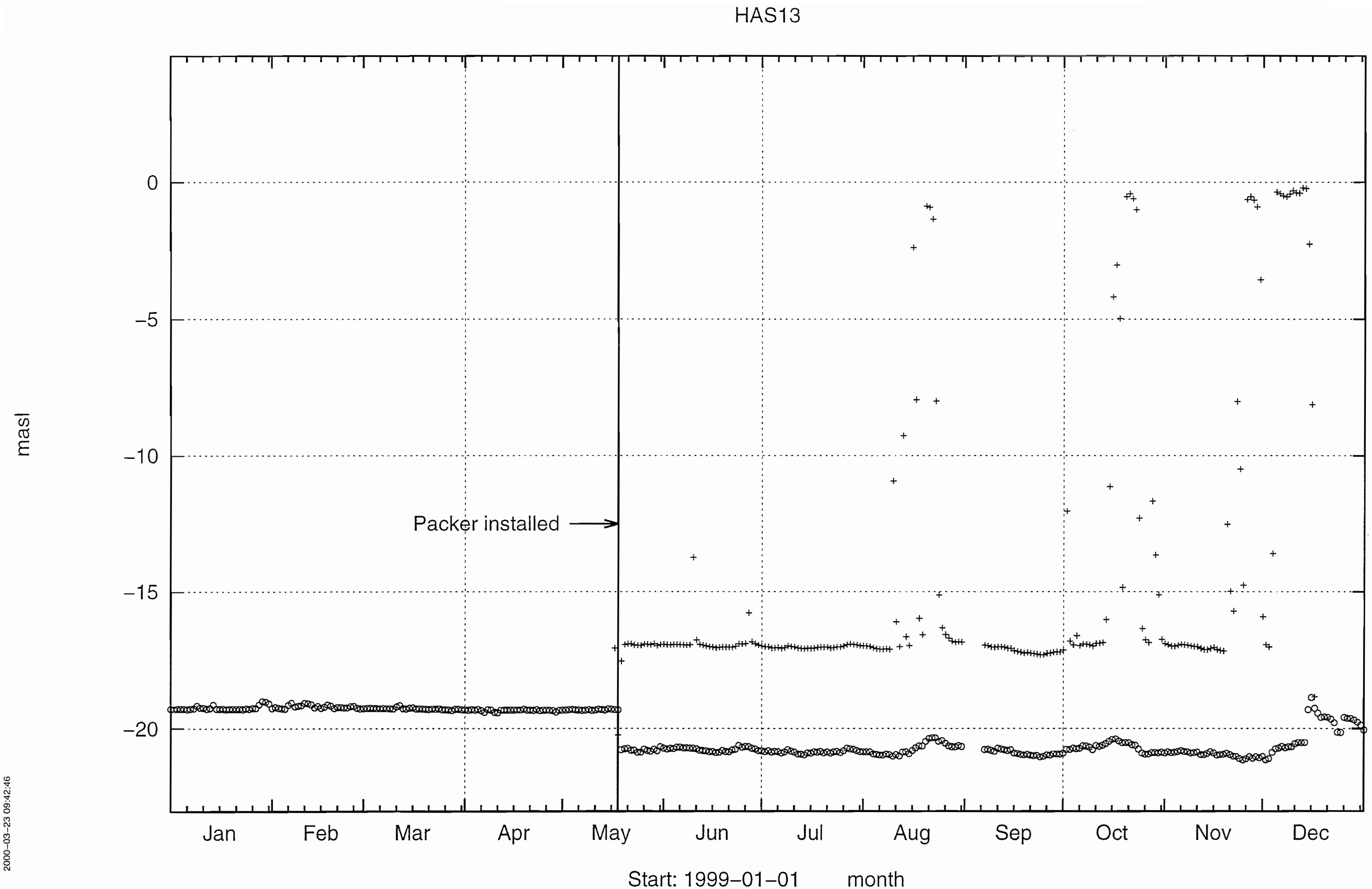
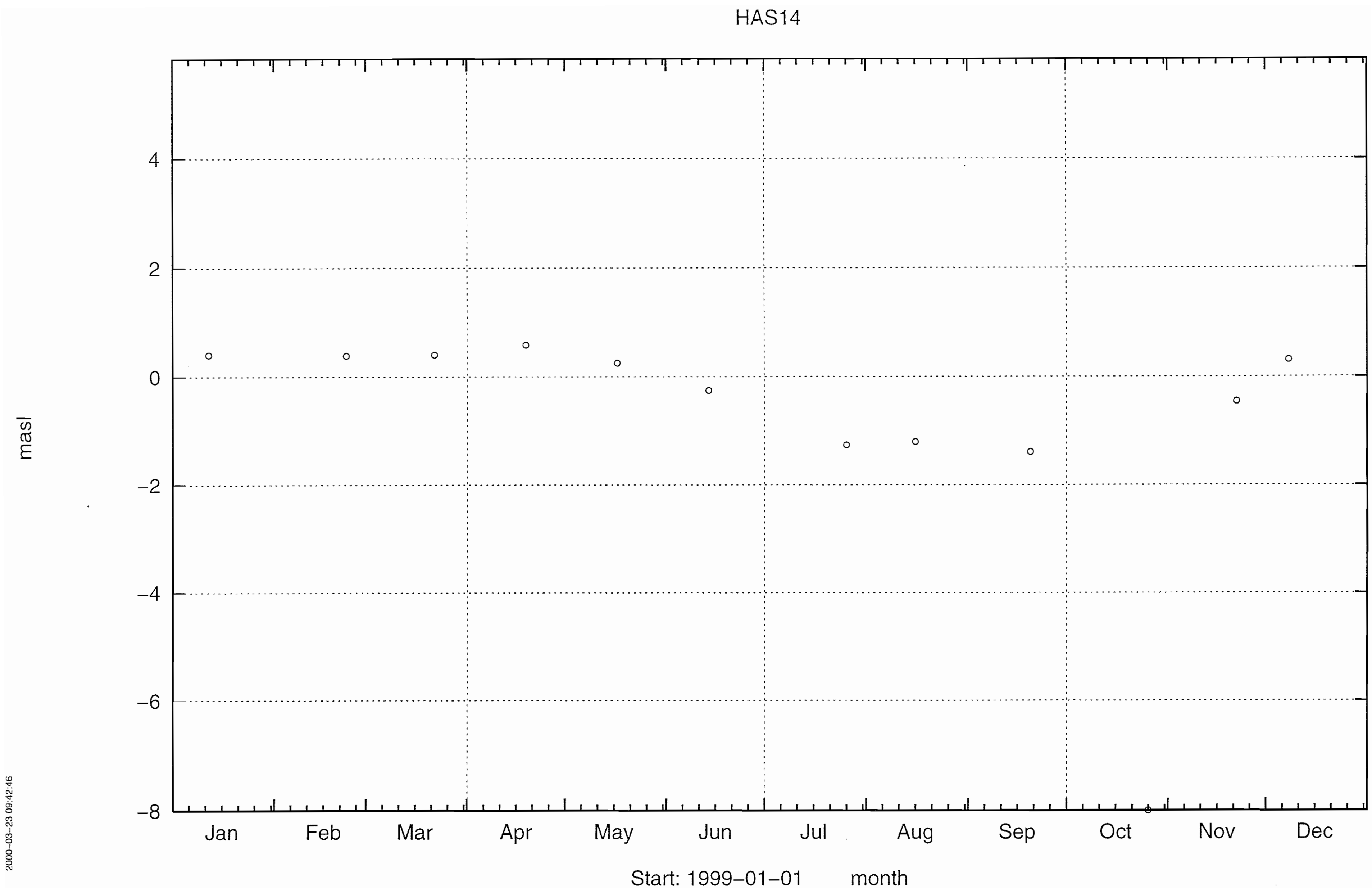


HAS13
masl
0
−5
−10
−15
−20
Packer installed
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−03−23 09:42:46



HAS14
masl
4
2
0
-2
-4
-6
-8
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Jun
Jul
Aug
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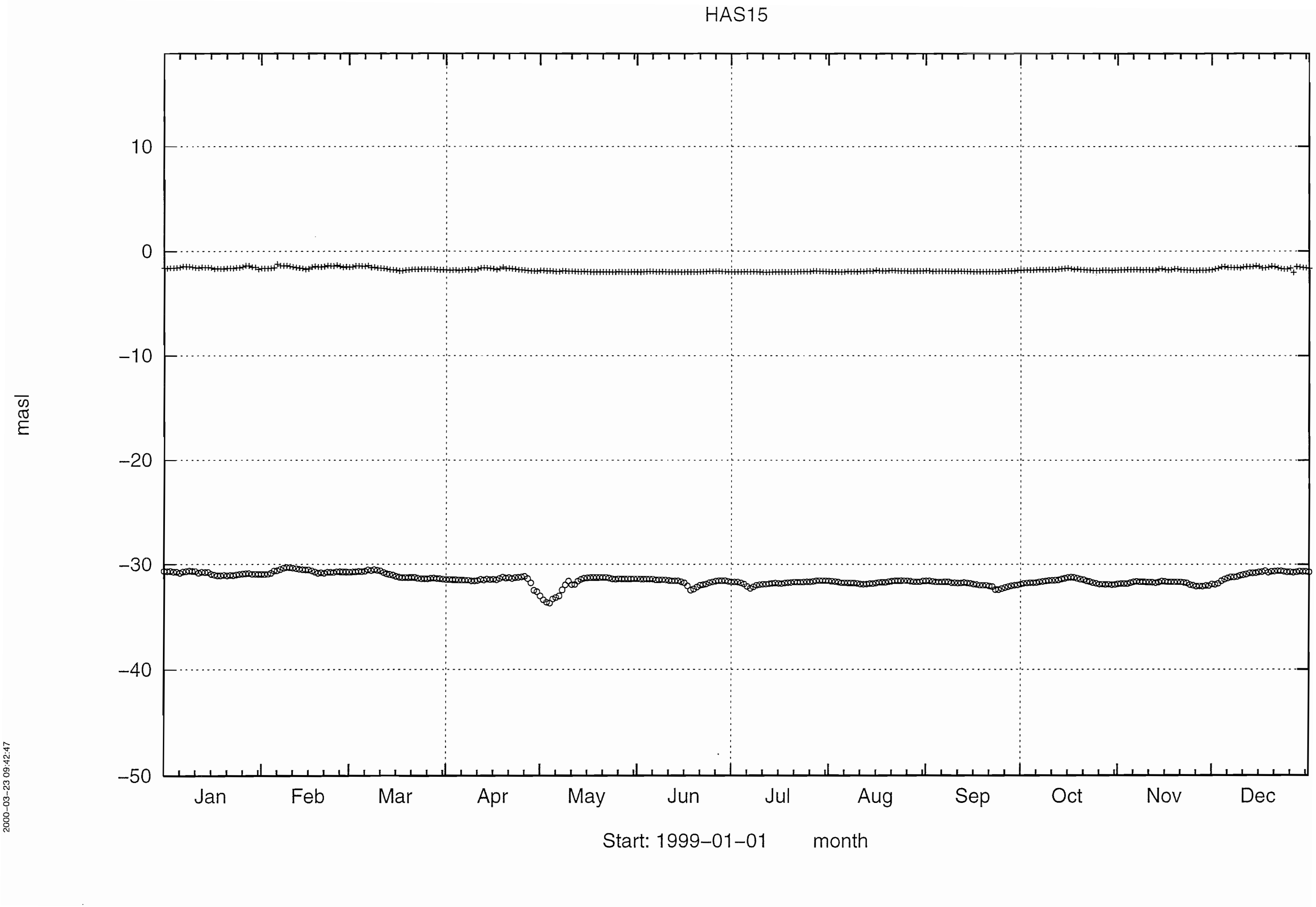
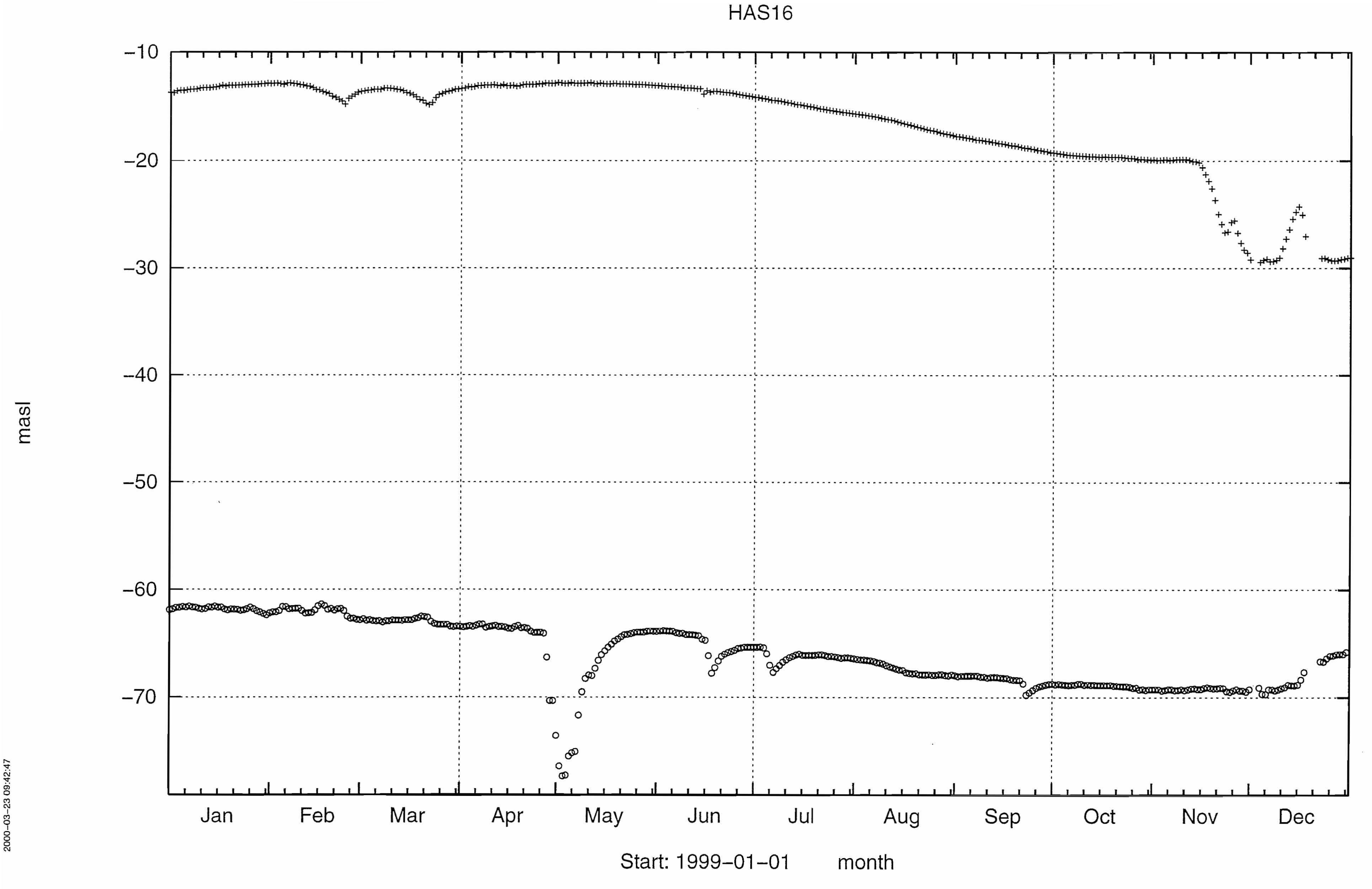
month
2000-03-23 09:42:46


HAS15
masl
10
0
−10
−20
−30
−40
−50
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−03−23 09:42:47



HAS16
-10
-20
-30
-40
-50
-60
-70
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
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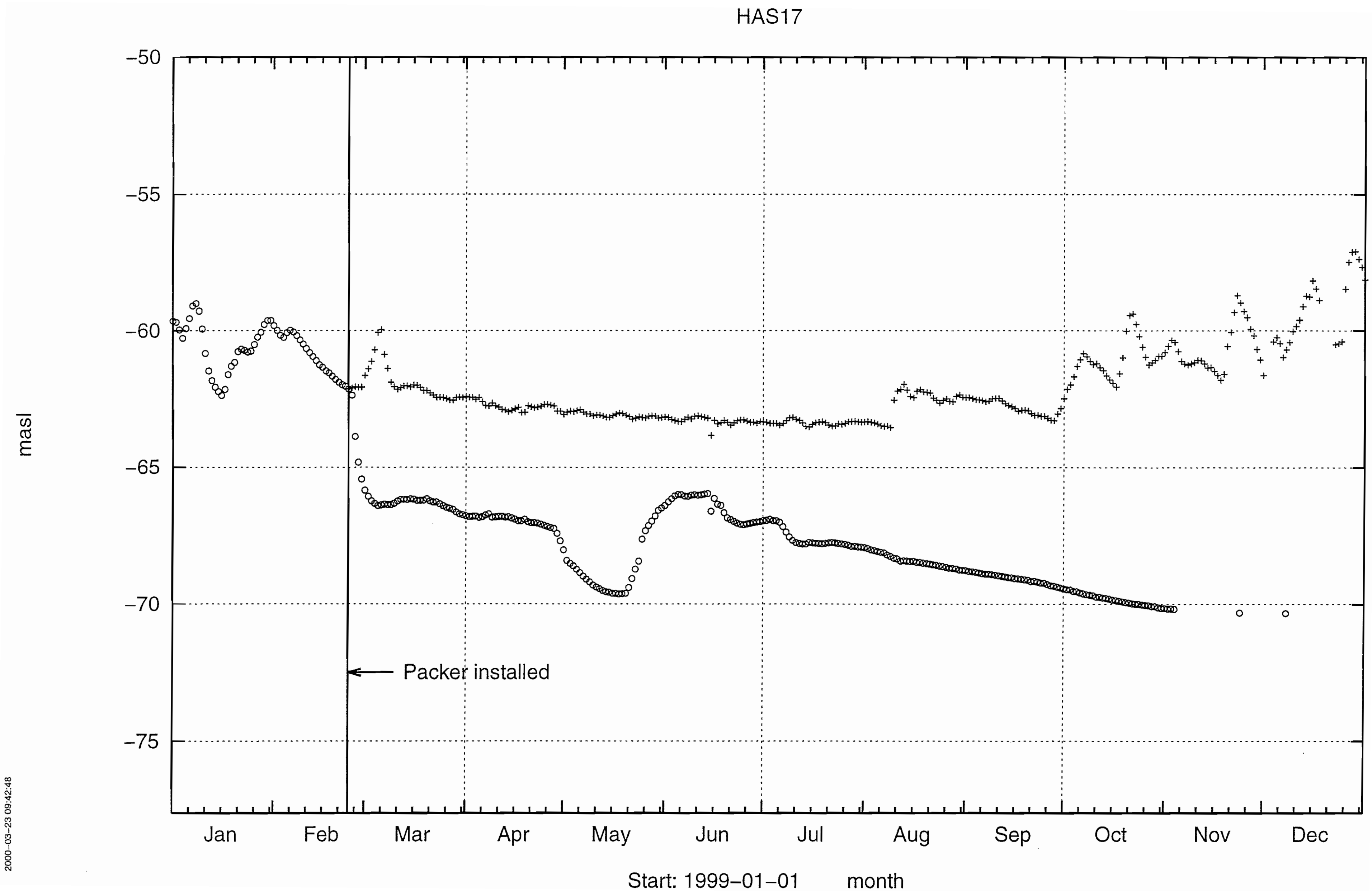
Oct
Nov
Dec
Start: 1999-01-01
month
2000-03-23 08:42:47



HAS17
masl
-50
-55
-60
-65
-70
-75
Packer installed
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Mar
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May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
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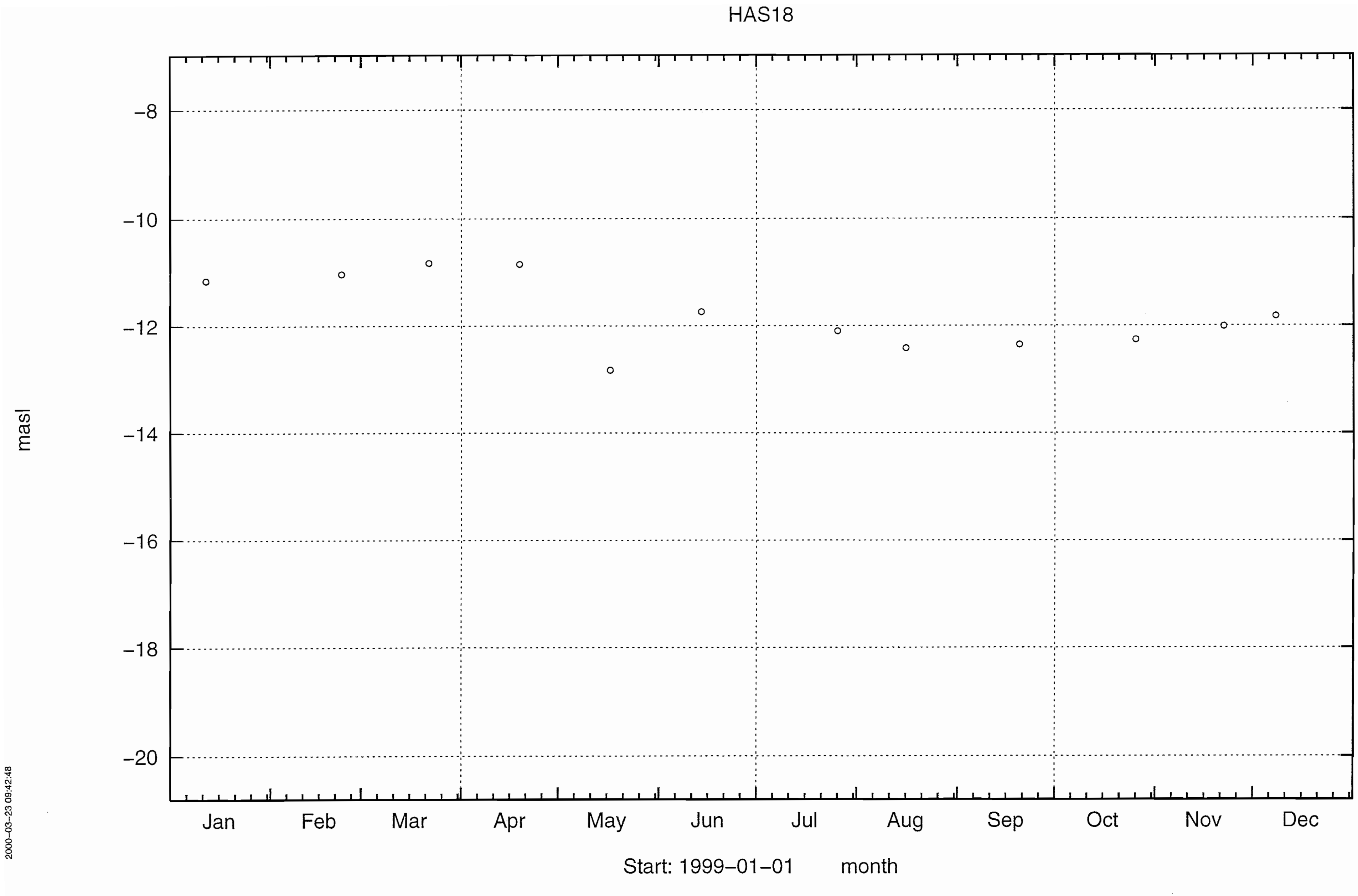
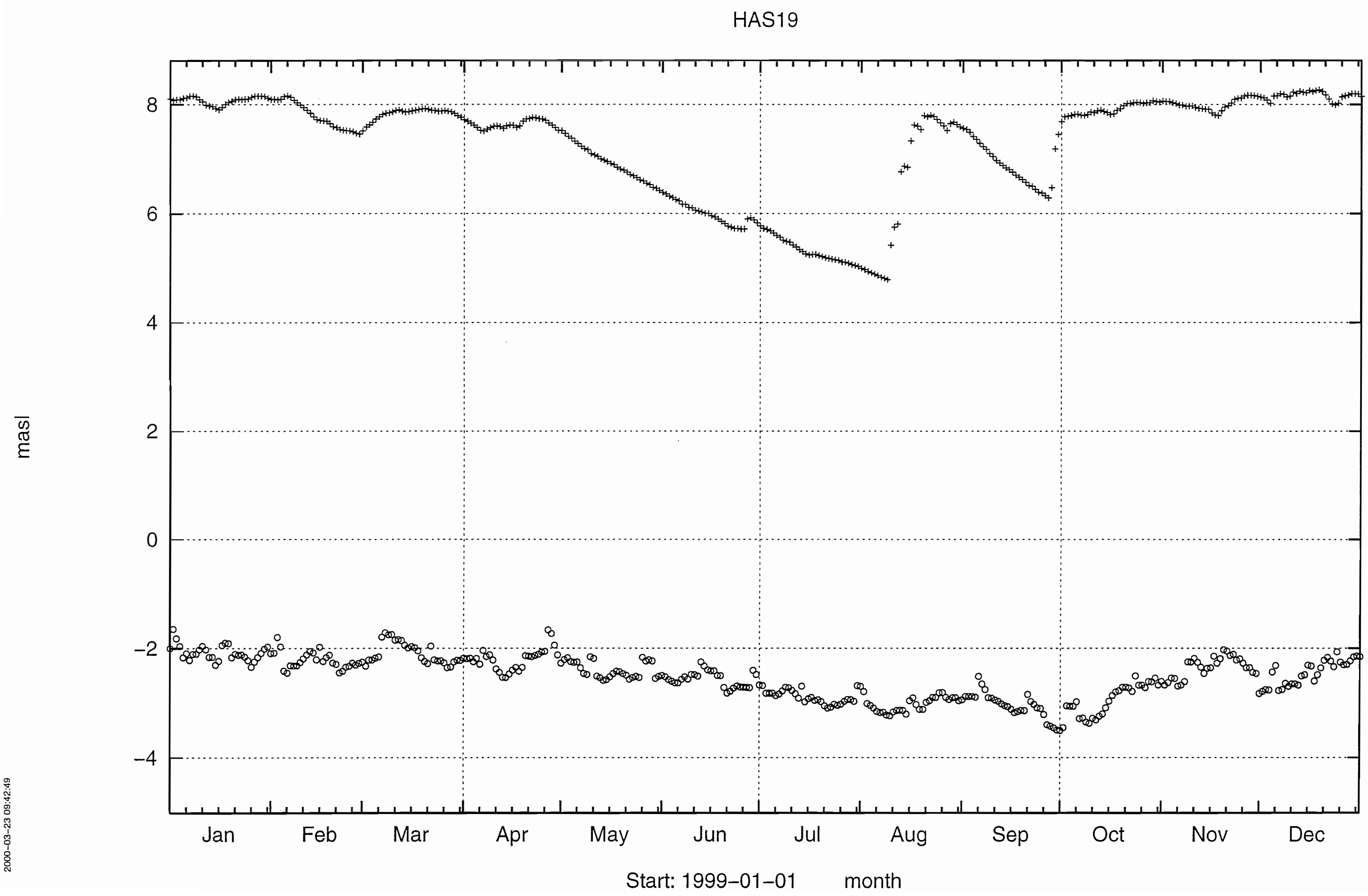
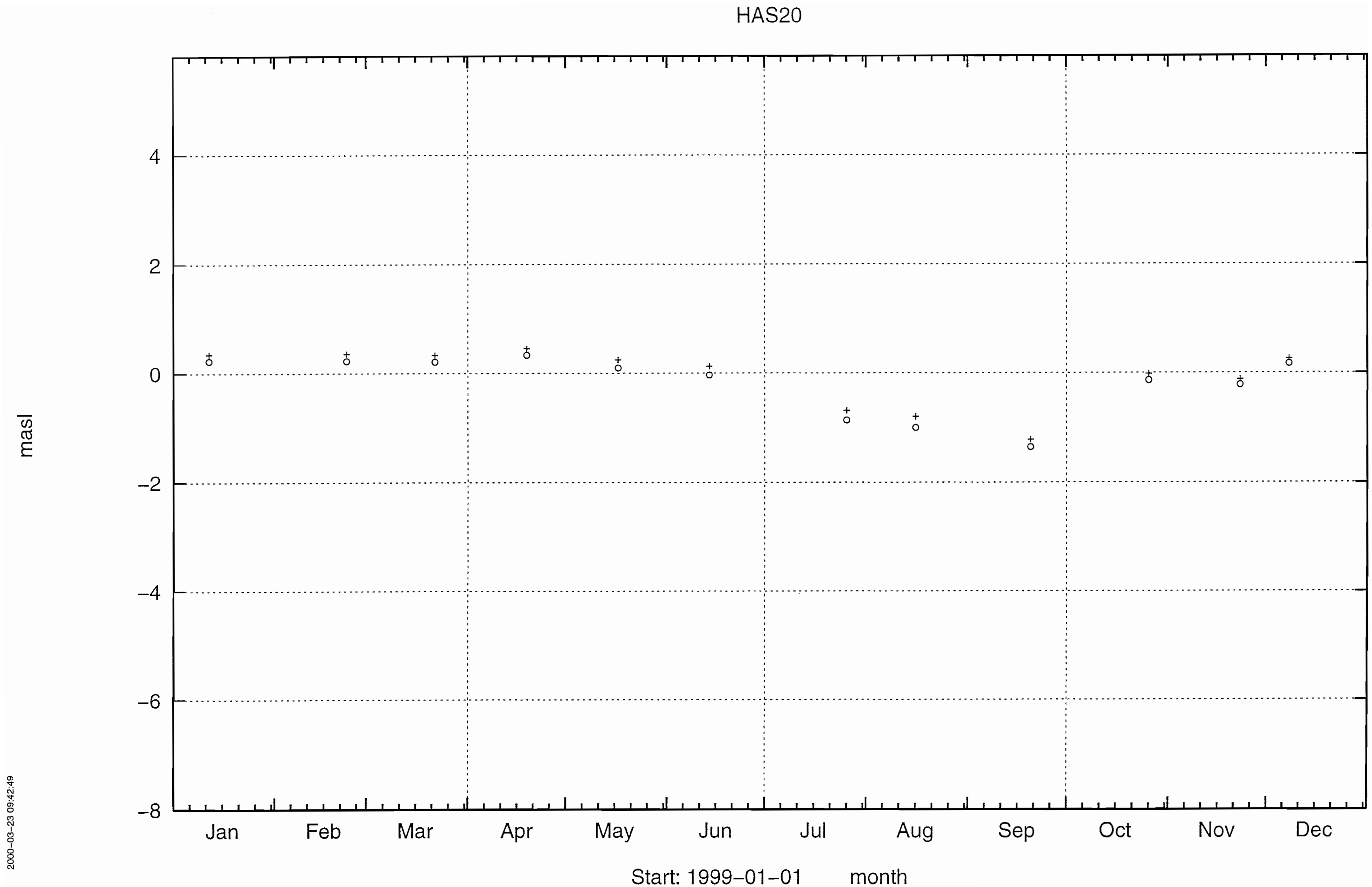
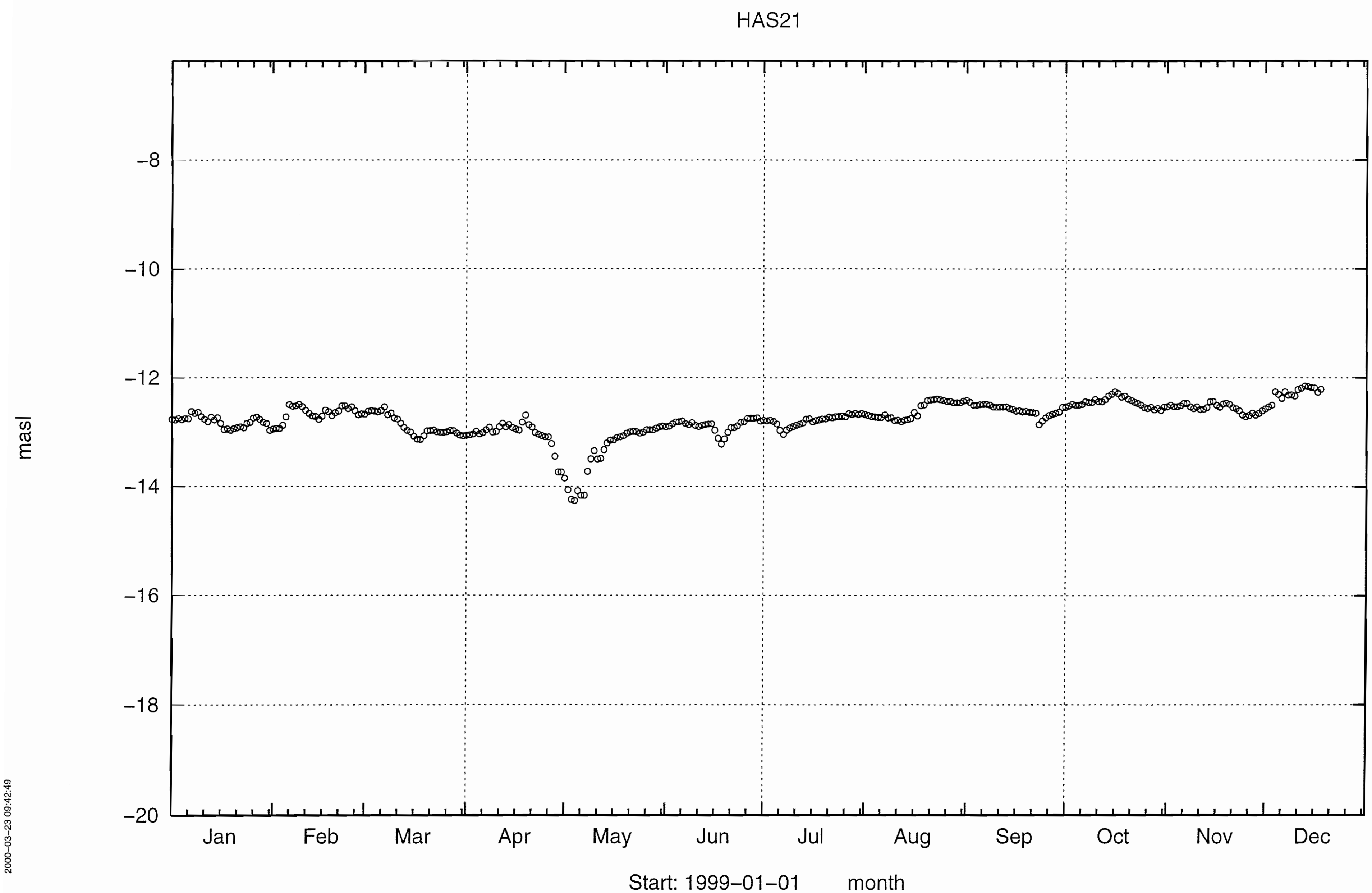

HAS18
masl
−8
−10
−12
−14
−16
−18
−20
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−03−23 09:42:48



HAS19
masl
8
6
4
2
0
-2
-4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-03-23 09:42:49



HAS20
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−03−23 09:42:49


HAS21
masl
-8
-10
-12
-14
-16
-18
-20
Jan
Feb
Mar
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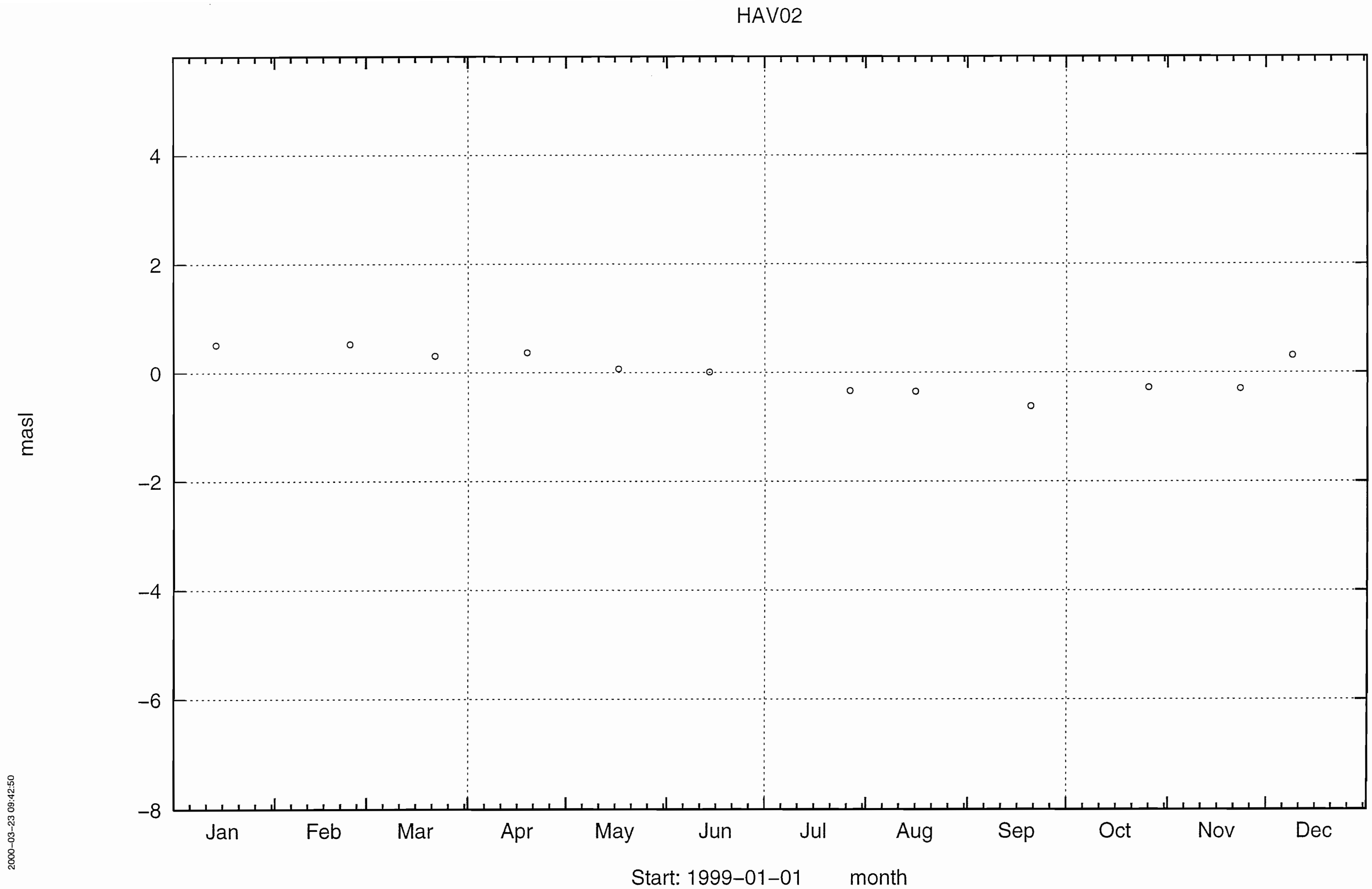
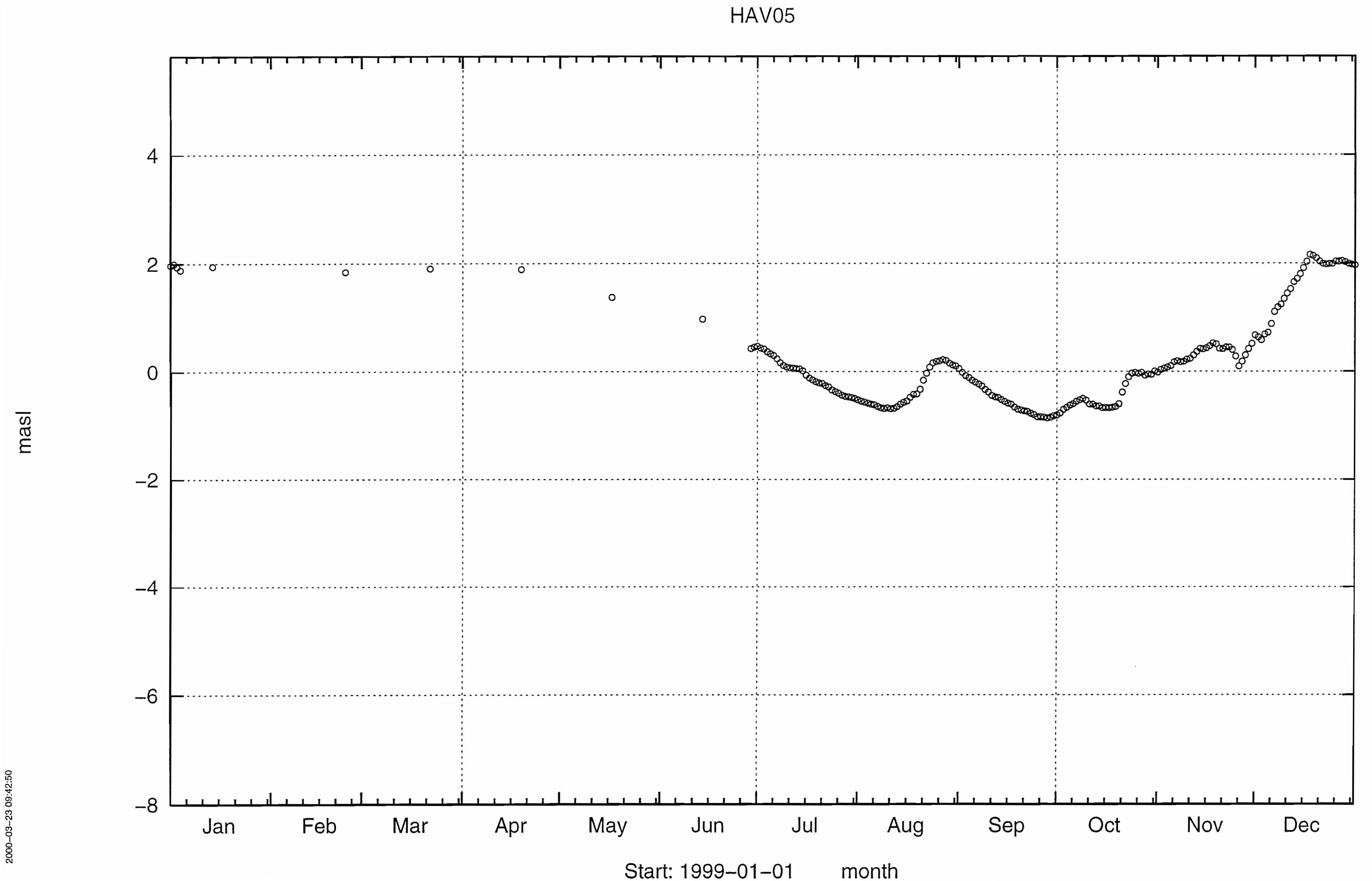
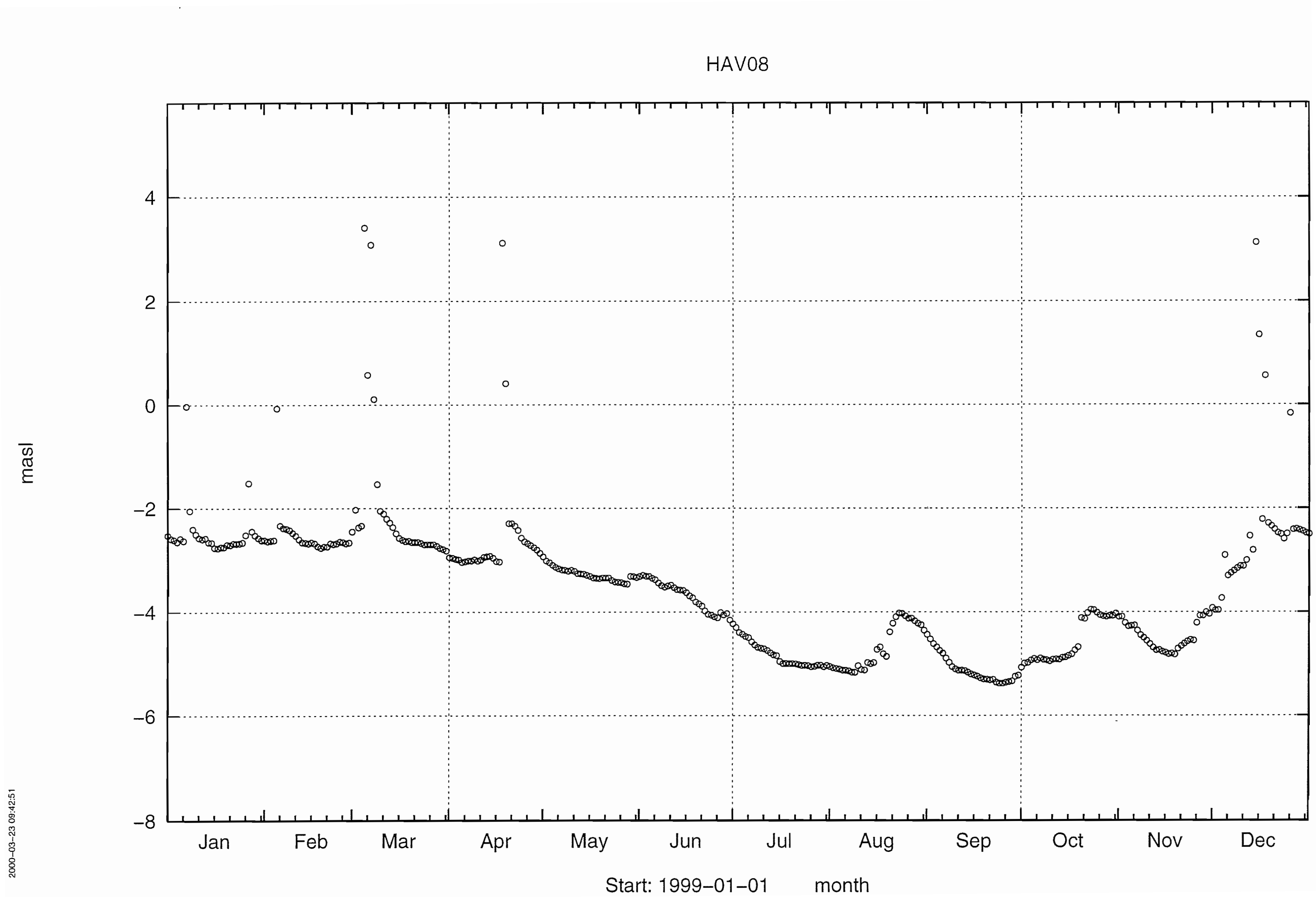
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-03-23 09:42:49

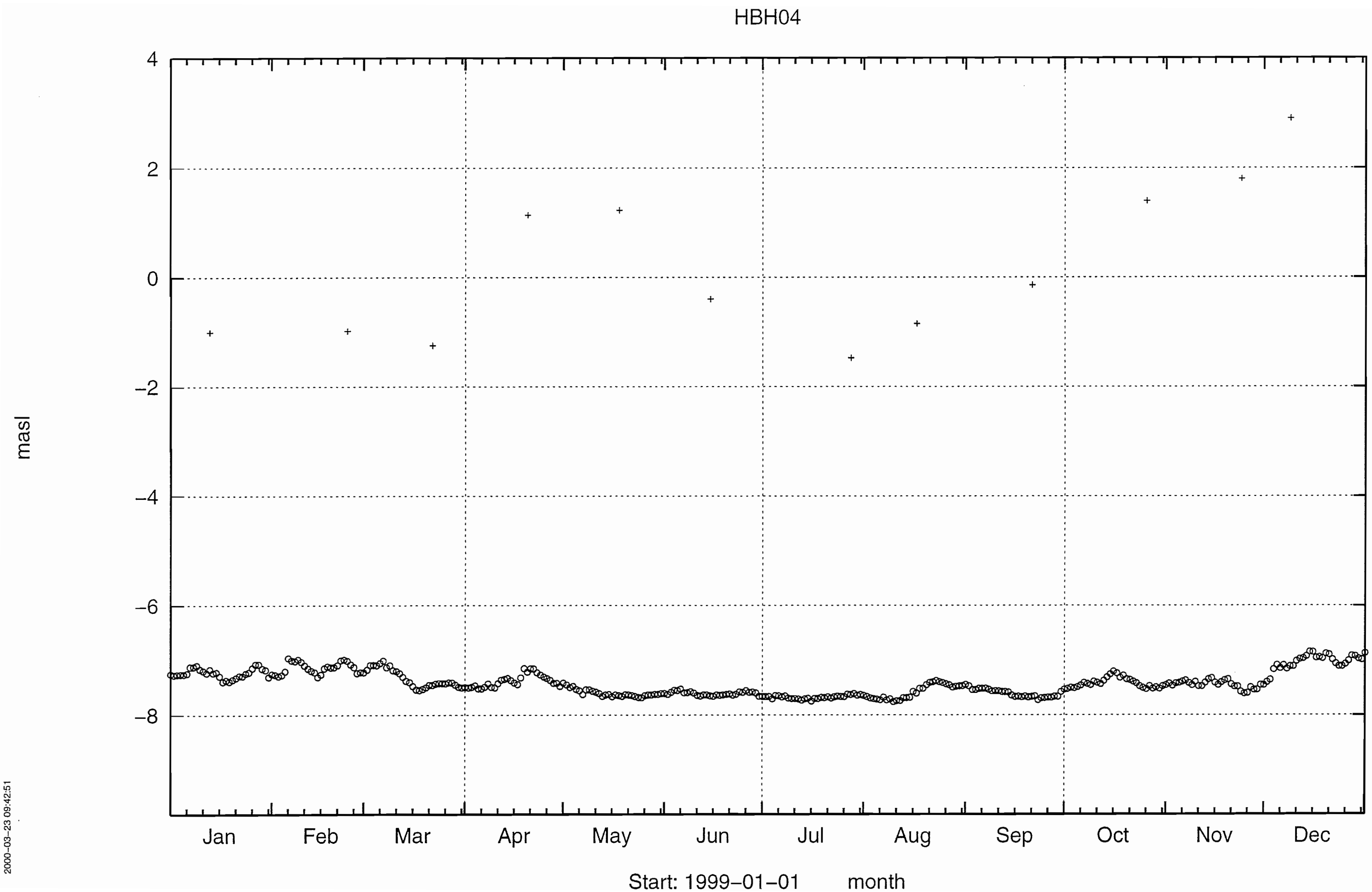

HAV02
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−03−23 09:42:50

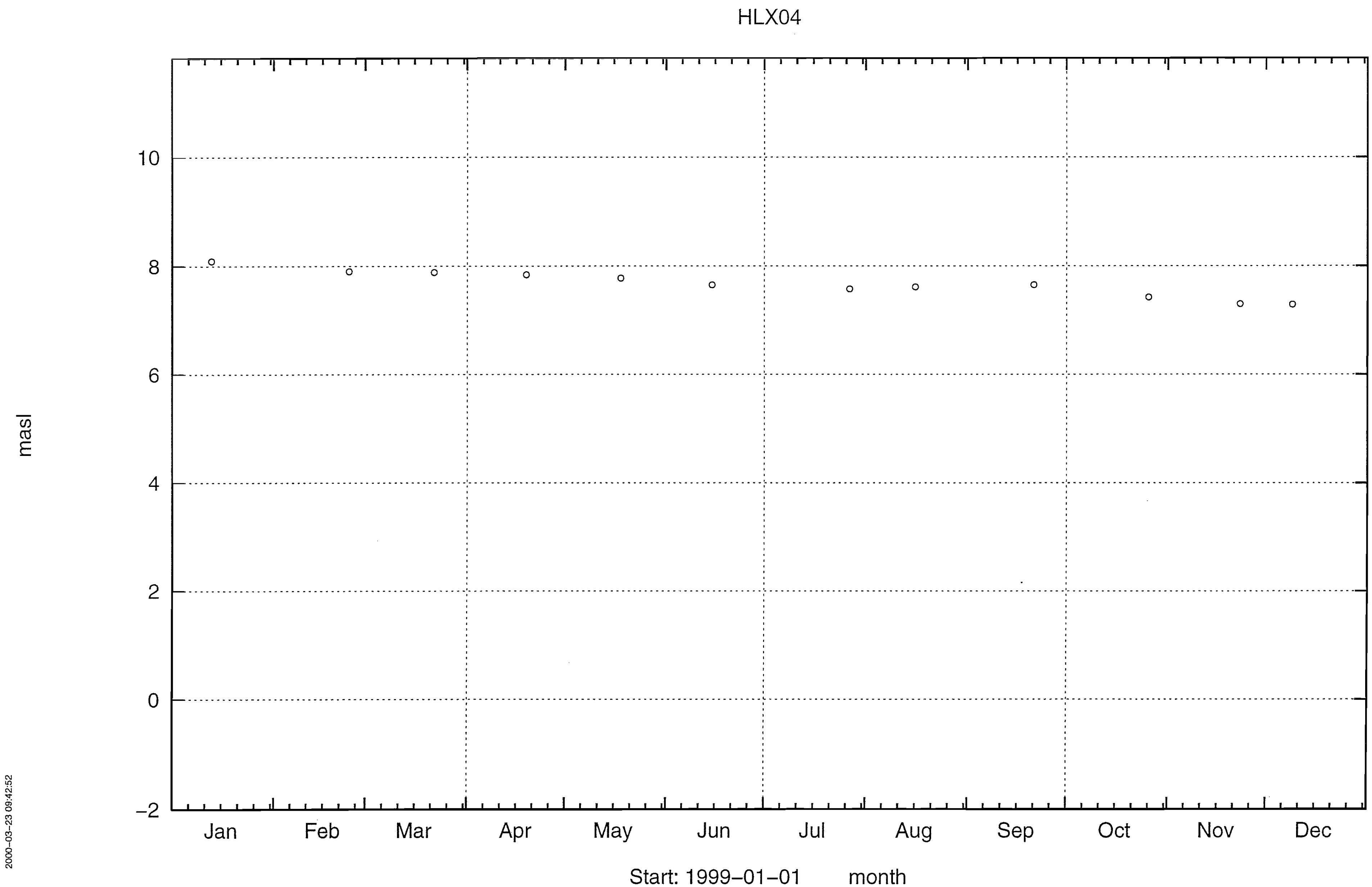


HAV05
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−03−23 09:42:50



HAV08
masl
4
2
0
-2
-4
-6
-8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-03-23 09:42:51


HBH04
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000-03-23 09:42:51


HLX04
masl
10
8
6
4
2
0
−2
Jan
Feb
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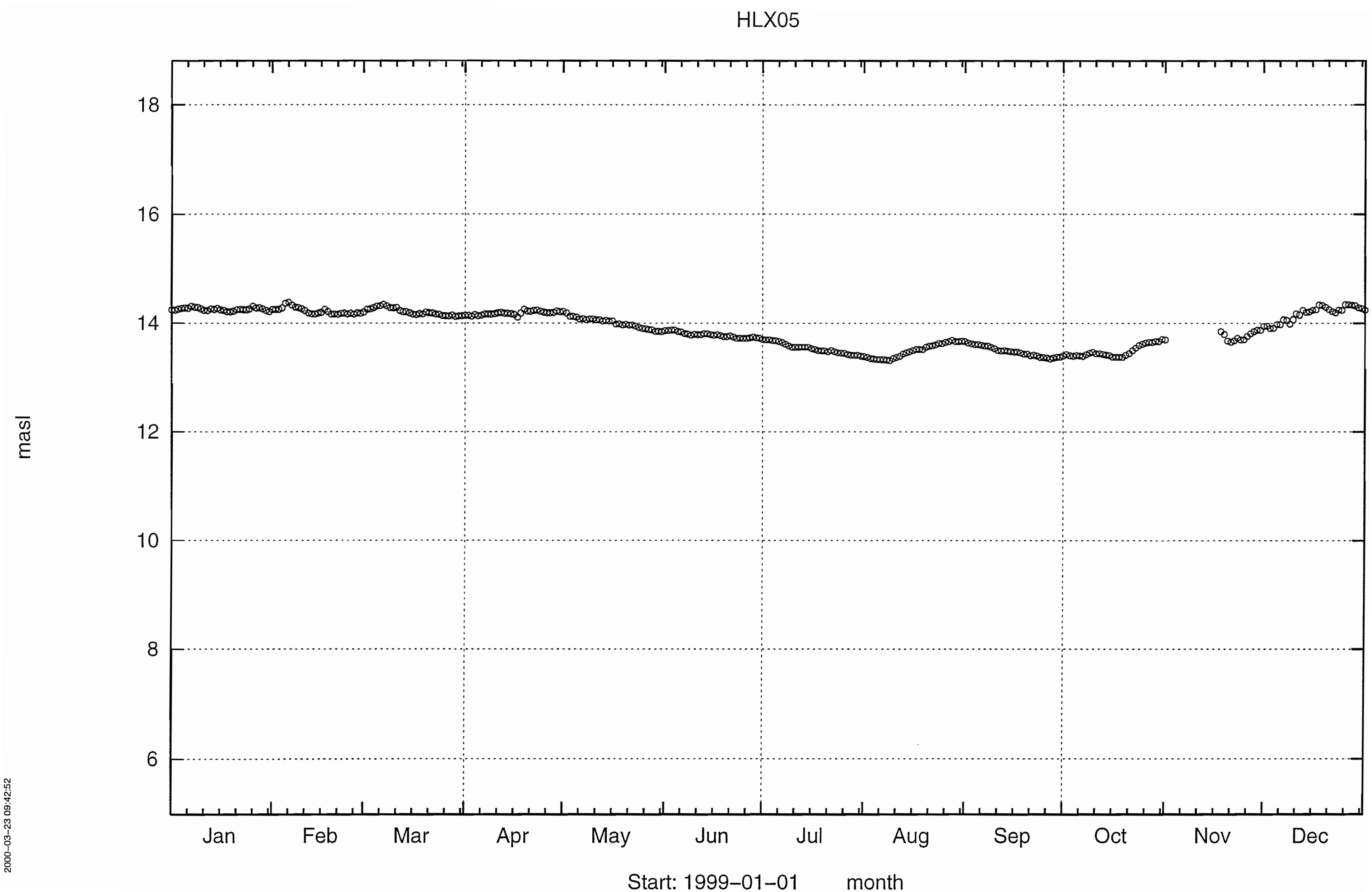
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−03−23 09:42:52


HLX05
masl
18
16
14
12
10
8
6
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Feb
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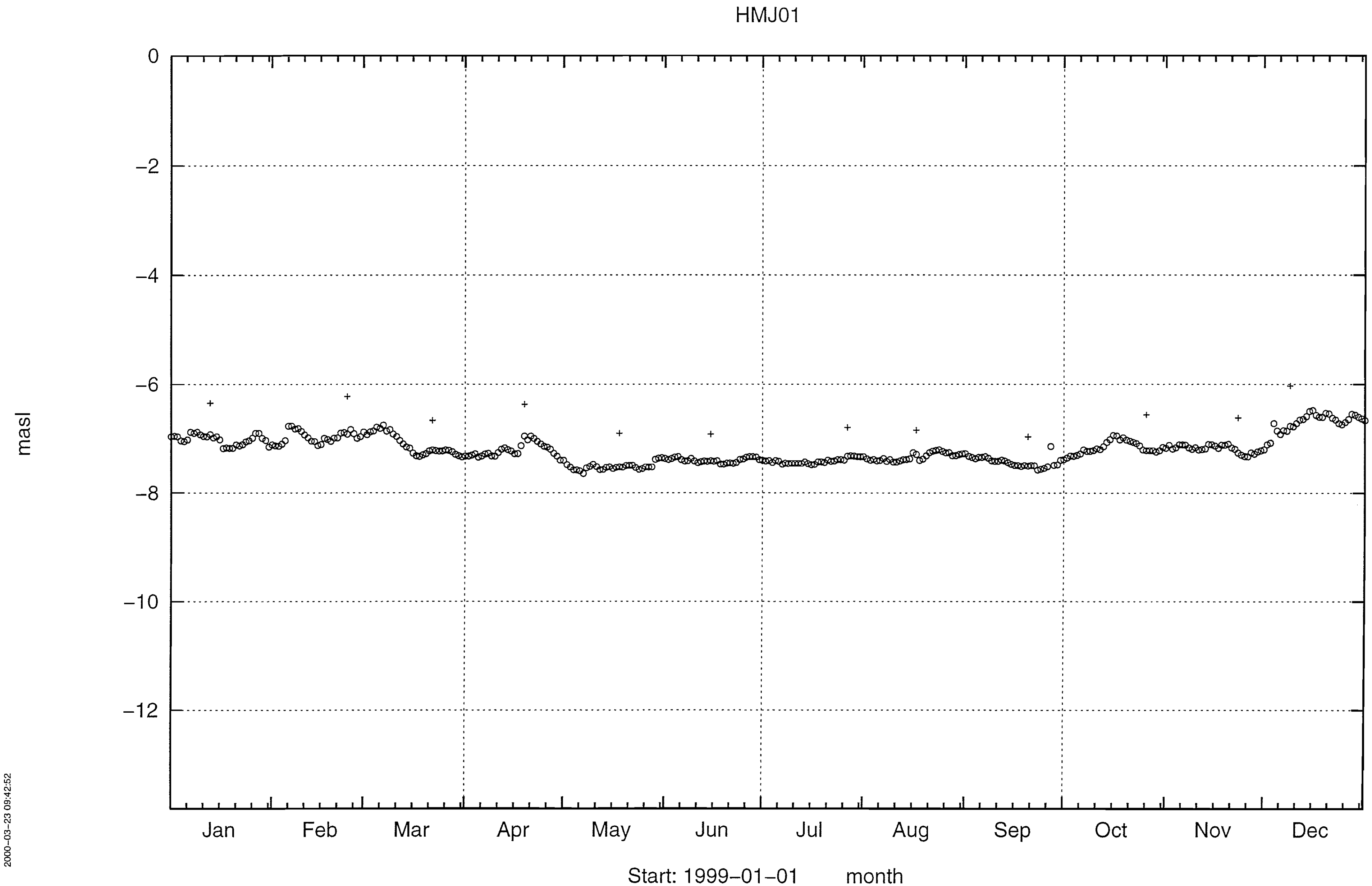
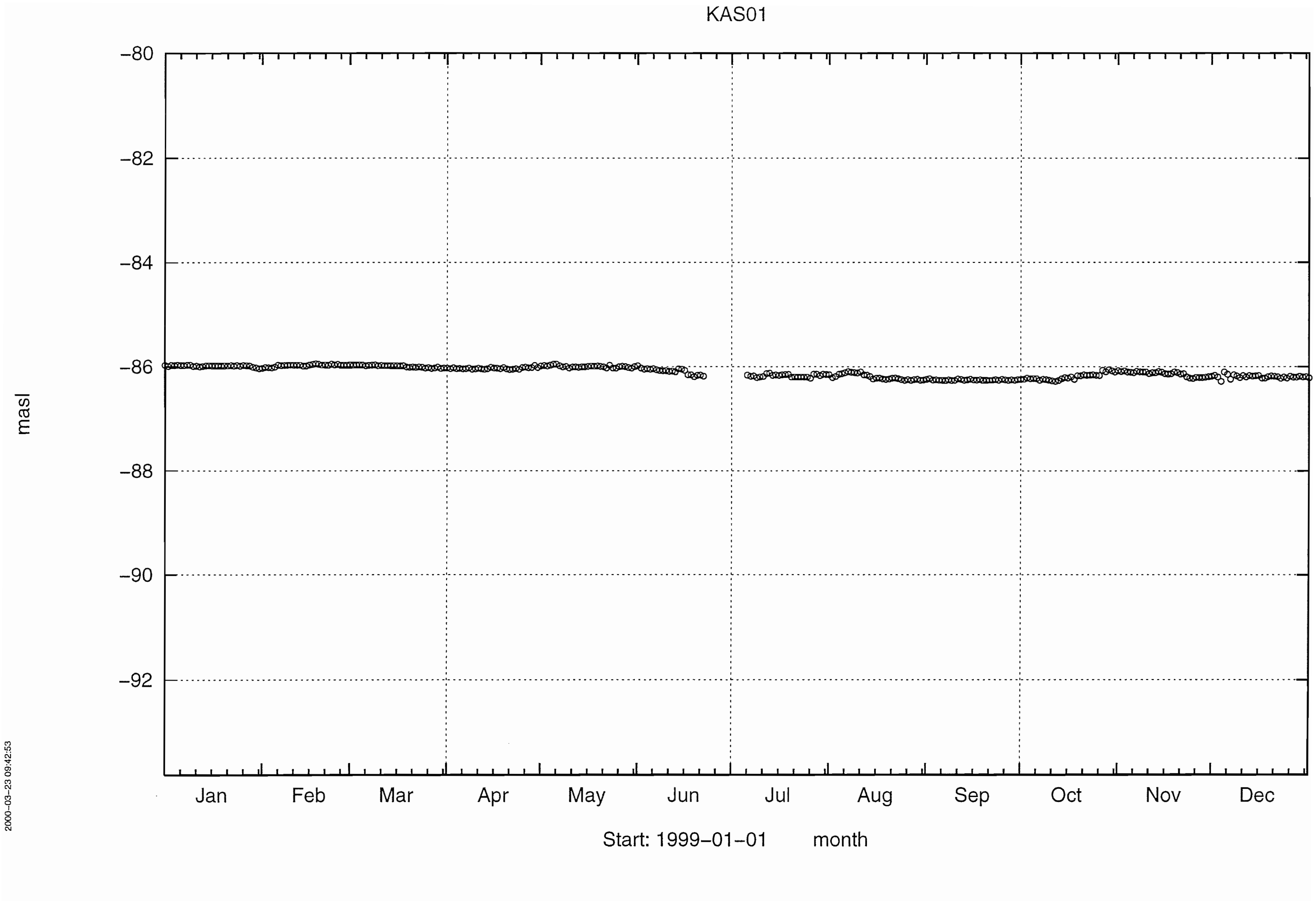
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−03−23 09:42:52


HMJ01
masl
0
−2
−4
−6
−8
−10
−12
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−03−23 09:42:52


KAS01
-80
-82
-84
-86
-88
-90
-92
masl
Jan
Feb
Mar
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May
Jun
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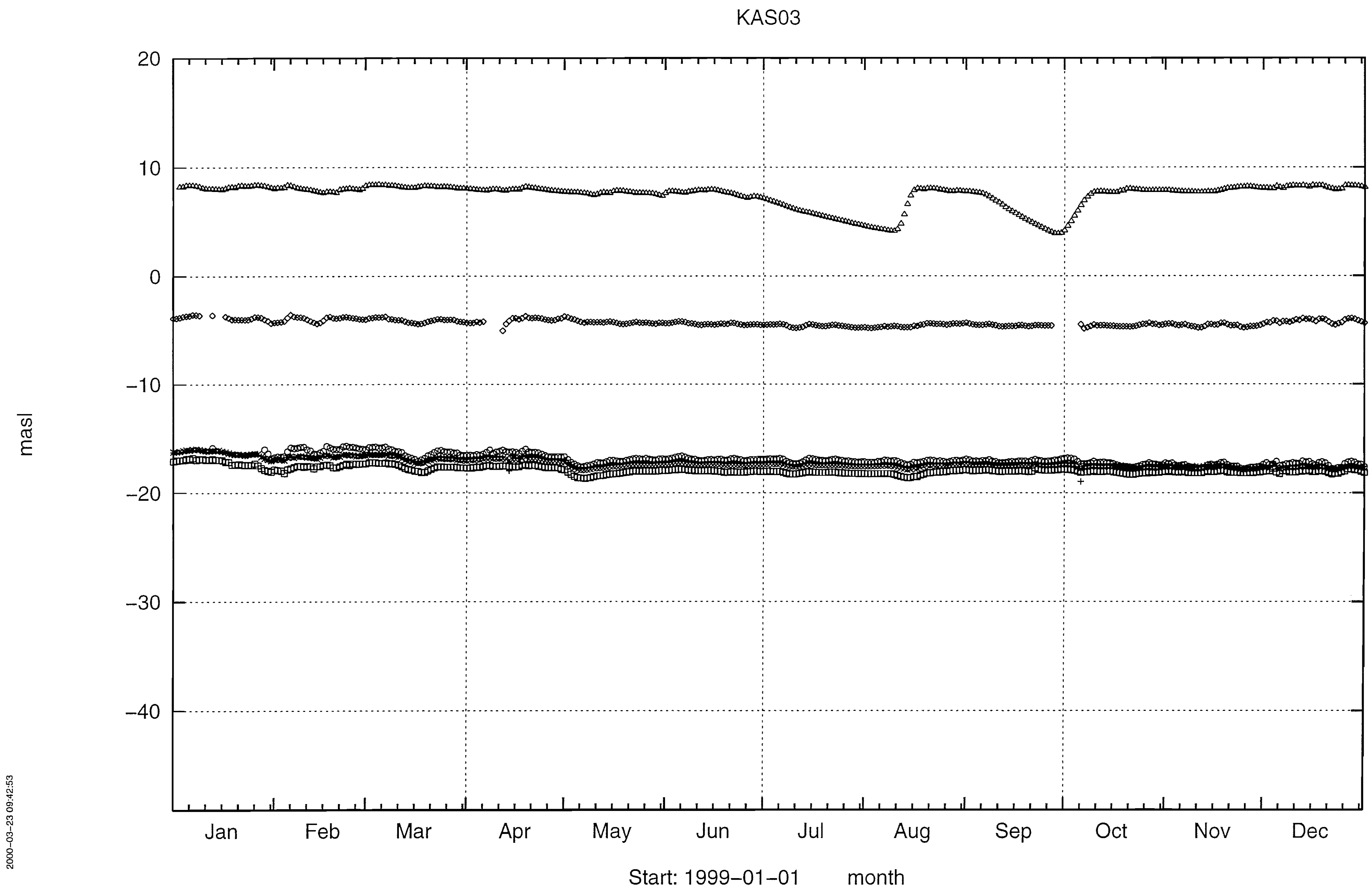
Nov
Dec
Start: 1999-01-01
month
2000-03-23 09:42:53


KAS03
20
10
0
−10
−20
−30
−40
masl
Jan
Feb
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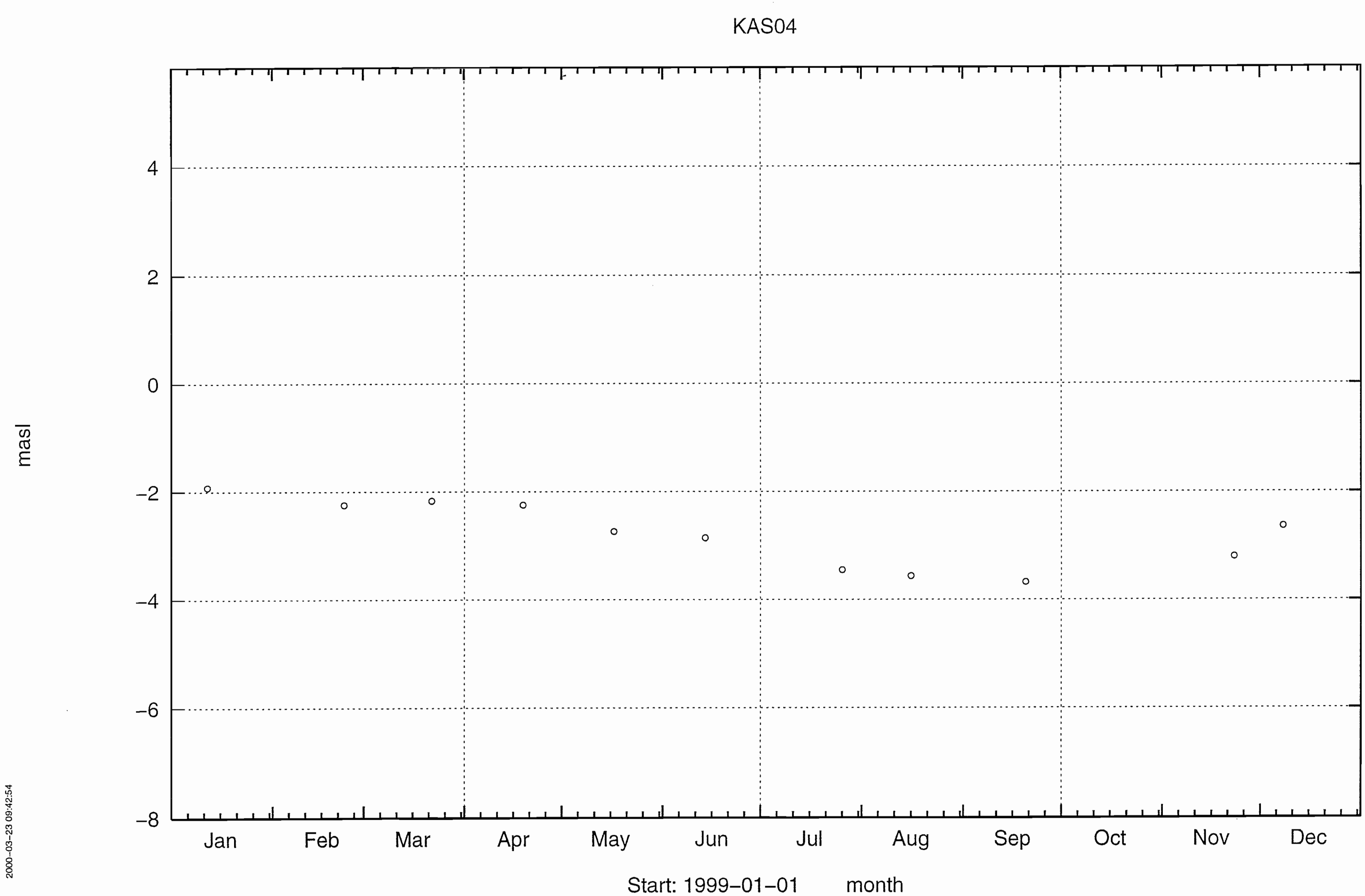
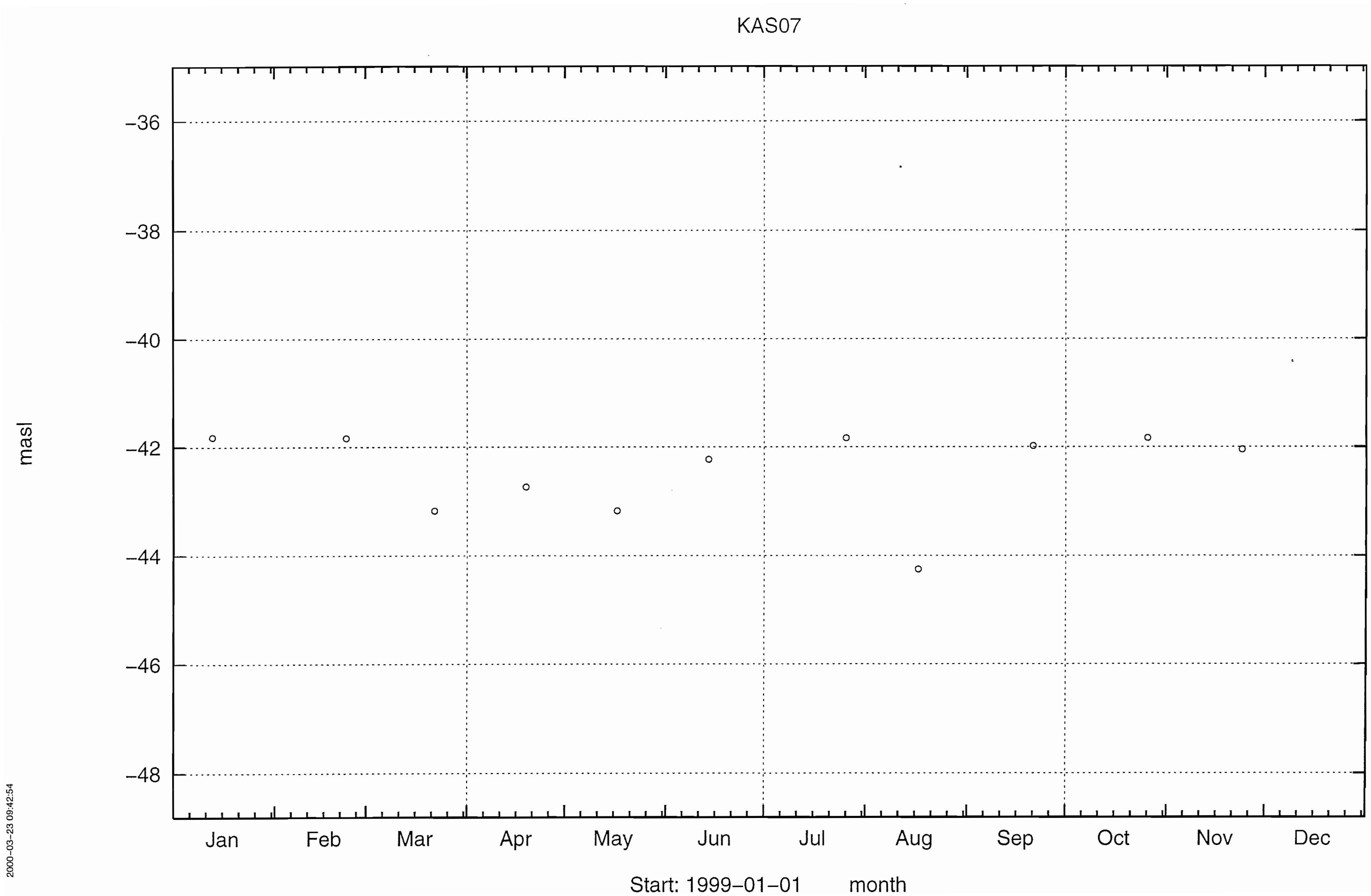
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−03−23 09:42:53


KAS04
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−03−23 09:42:54


KAS07
masl
-36
-38
-40
-42
-44
-46
-48
Jan
Feb
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Apr
May
Jun
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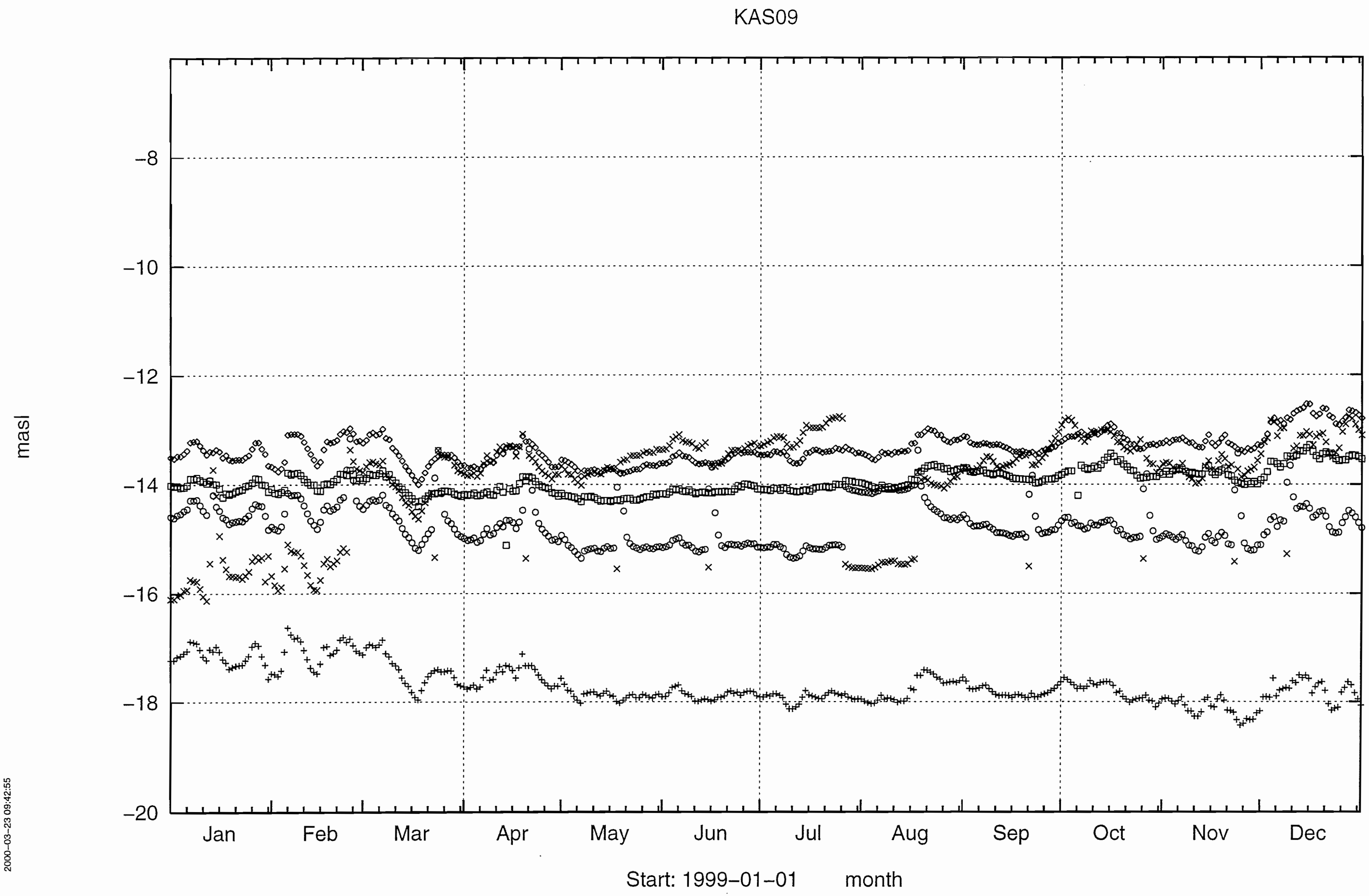
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-03-23 09:42:54



KAS09
masl
-8
-10
-12
-14
-16
-18
-20
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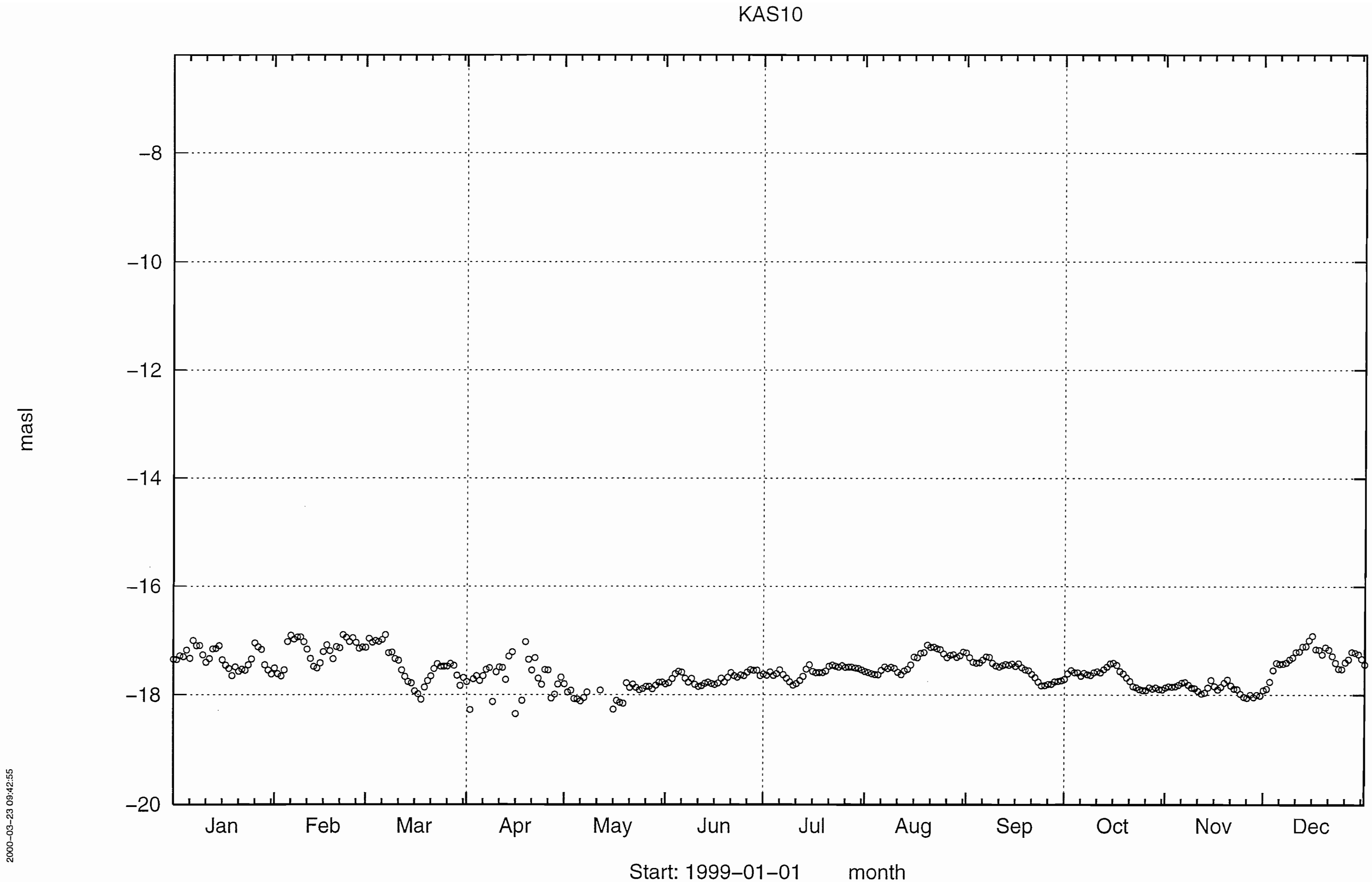
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-03-23 09:42:55


KAS10
masl
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-10
-12
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-20
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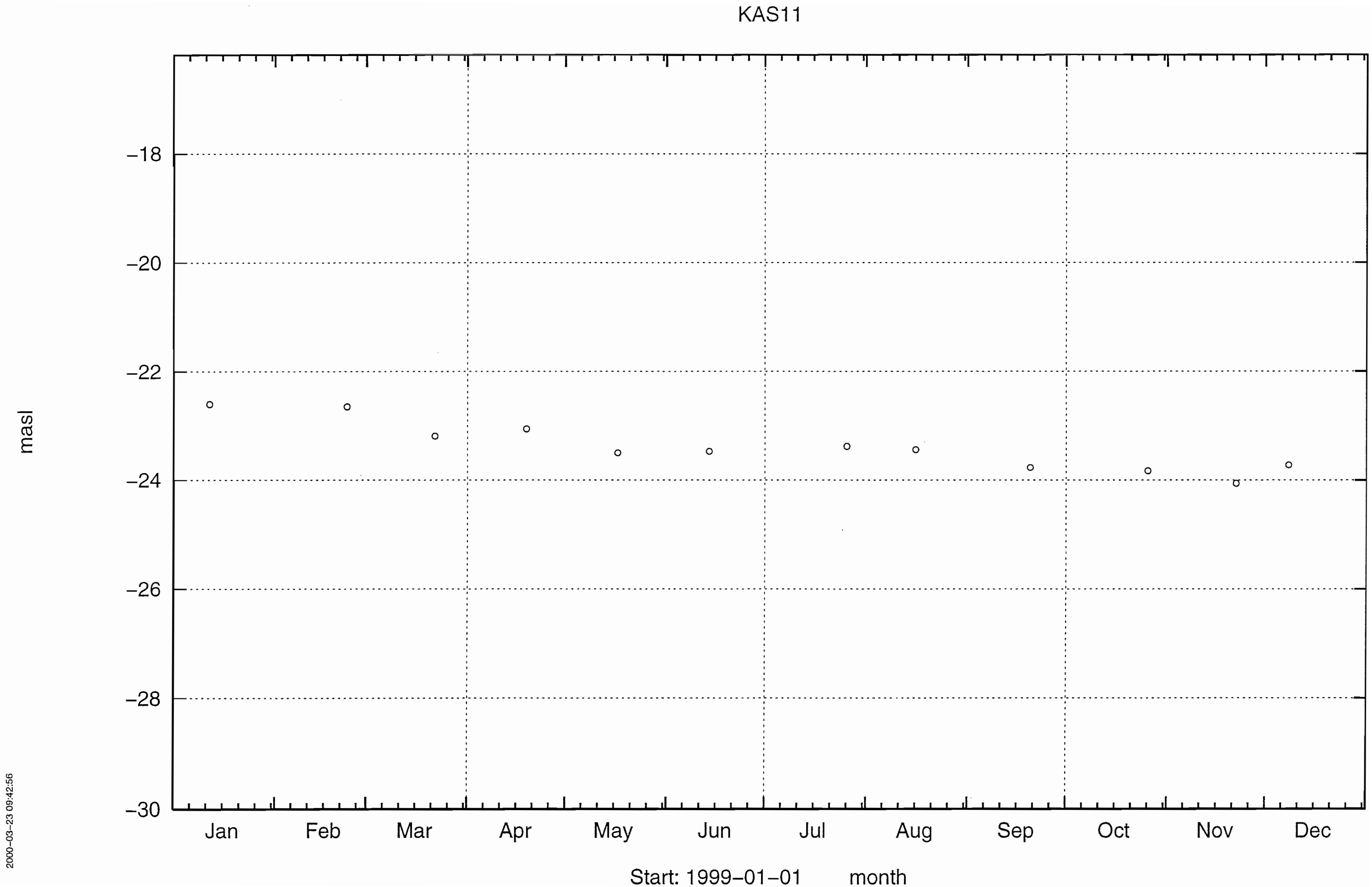
Nov
Dec
Start: 1999-01-01
month
2000-03-23 09:42:55



KAS11
masl
−18
−20
−22
−24
−26
−28
−30
Jan
Feb
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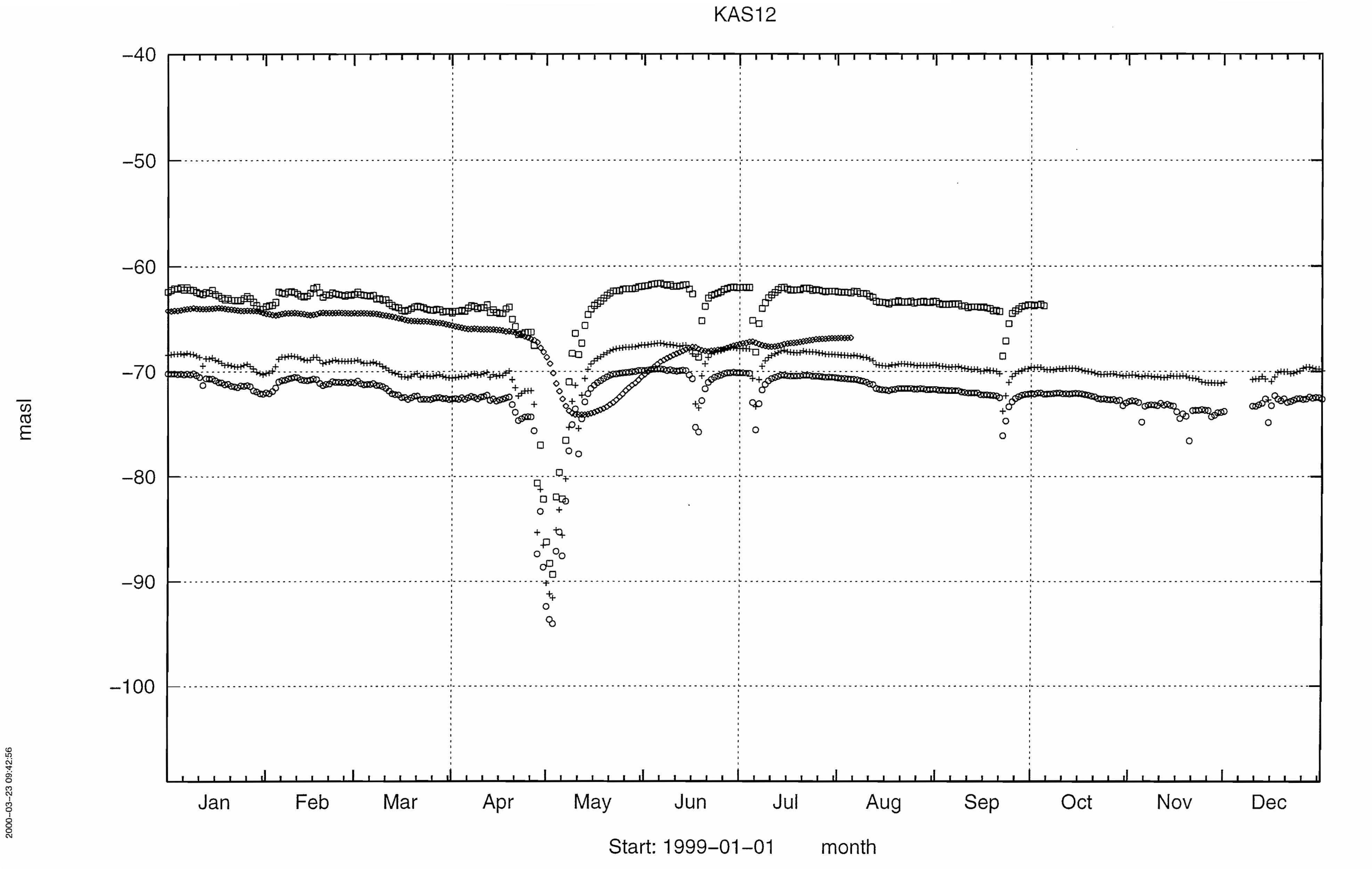
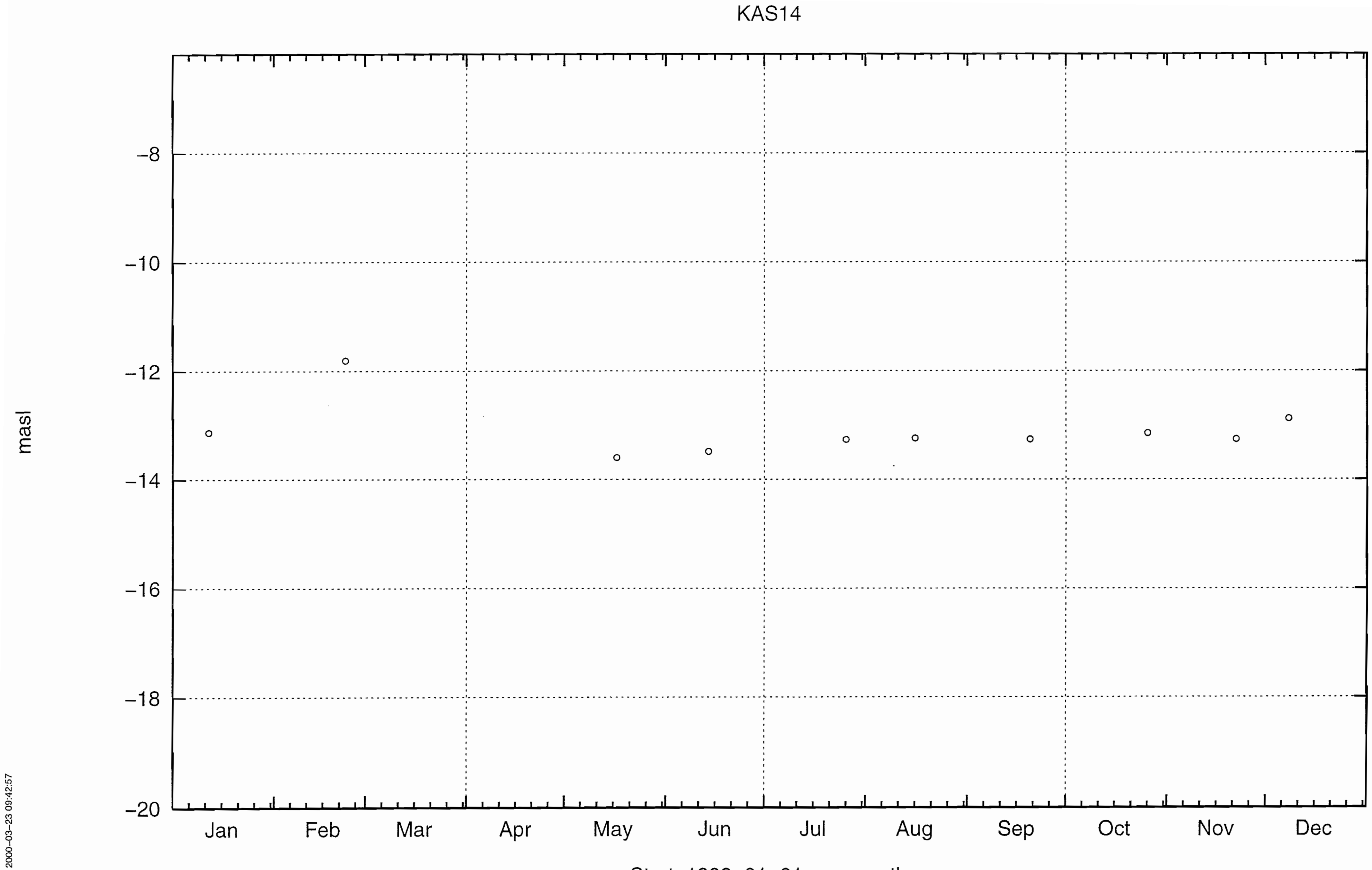
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000-03-23 09:42:56


KAS12
−40
−50
−60
−70
−80
−90
−100
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−03−23 09:42:56


KAS14
masl
-8
-10
-12
-14
-16
-18
-20
Jan
Feb
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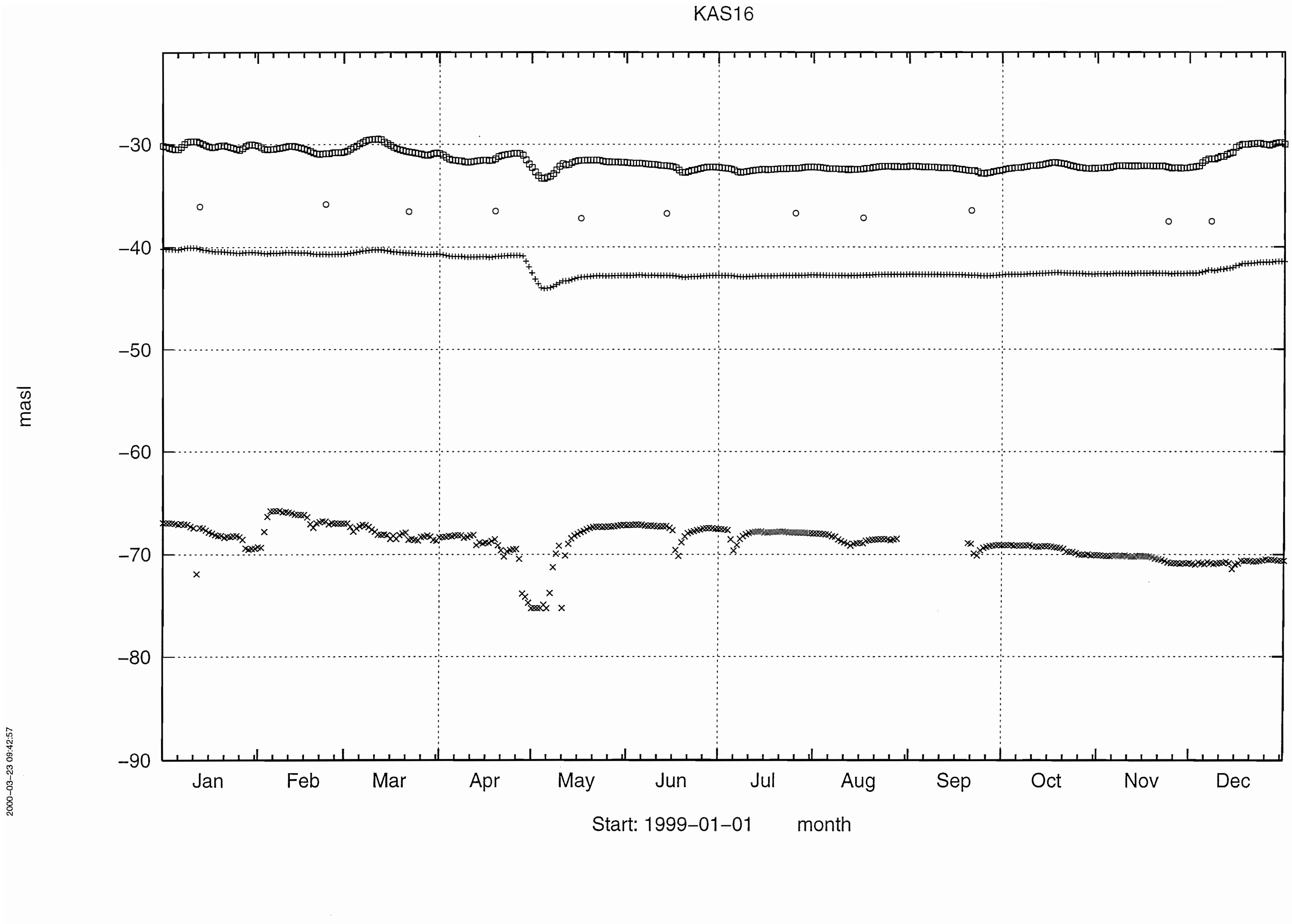
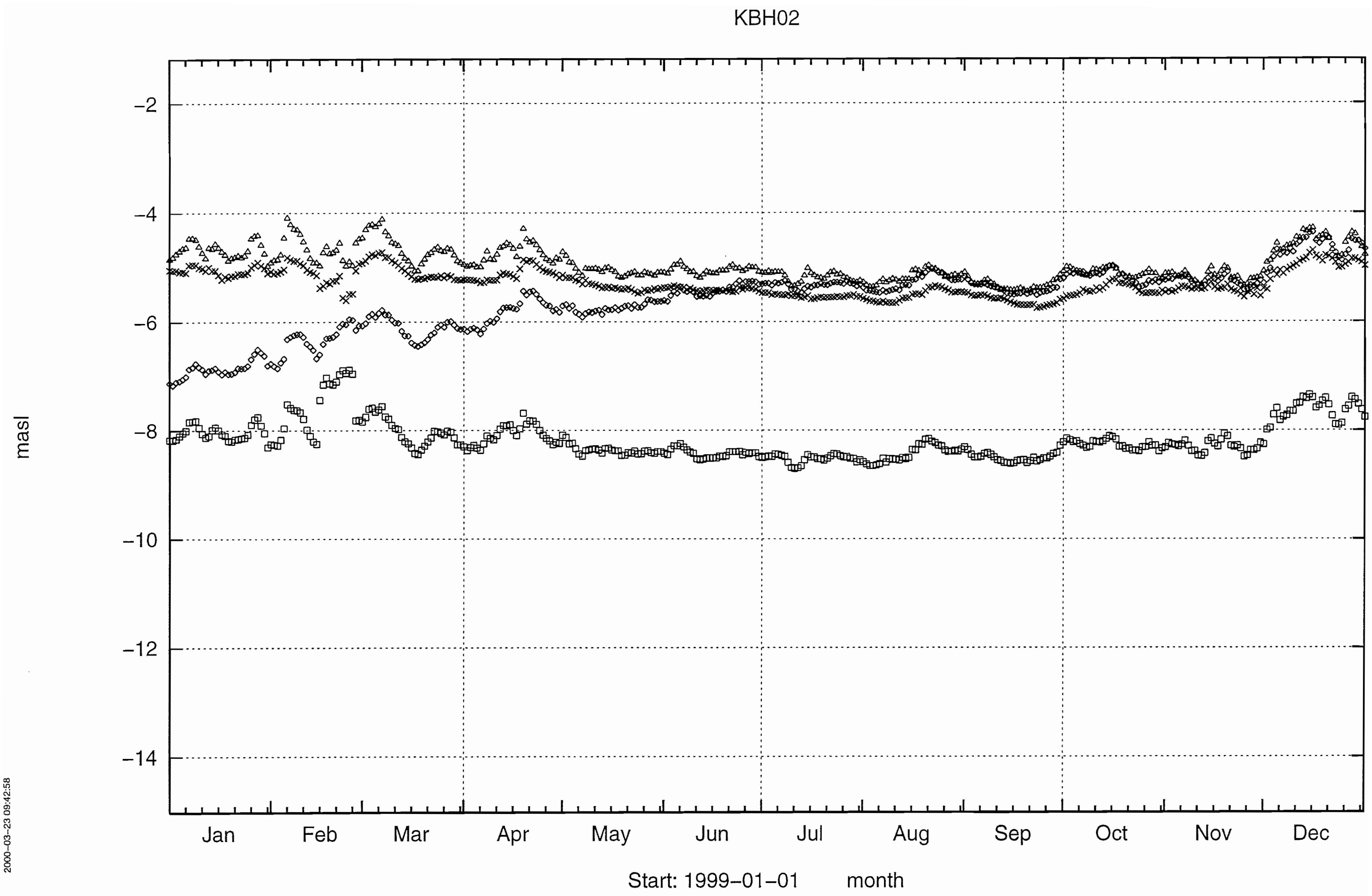
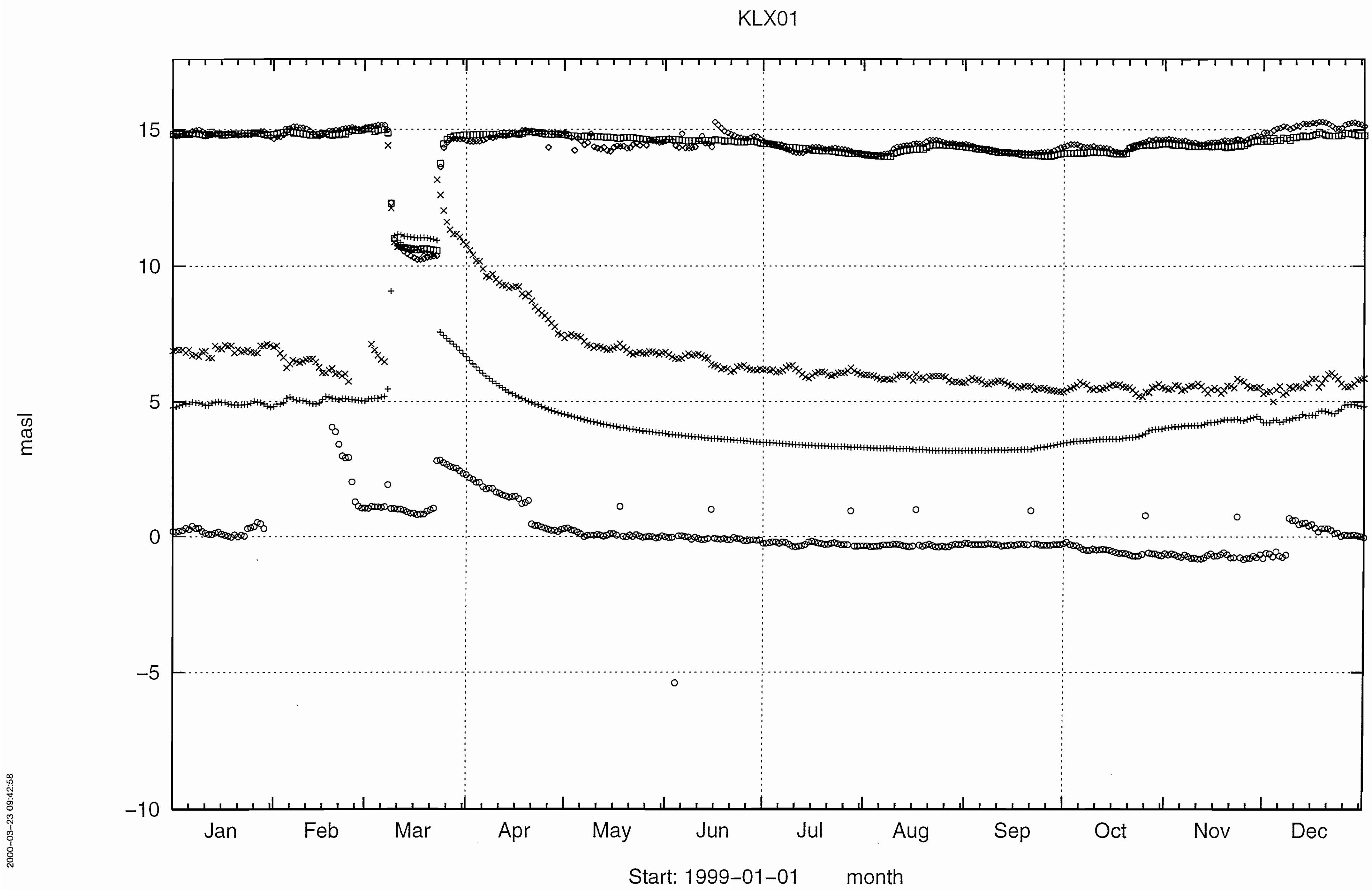
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-03-23 09:42:57

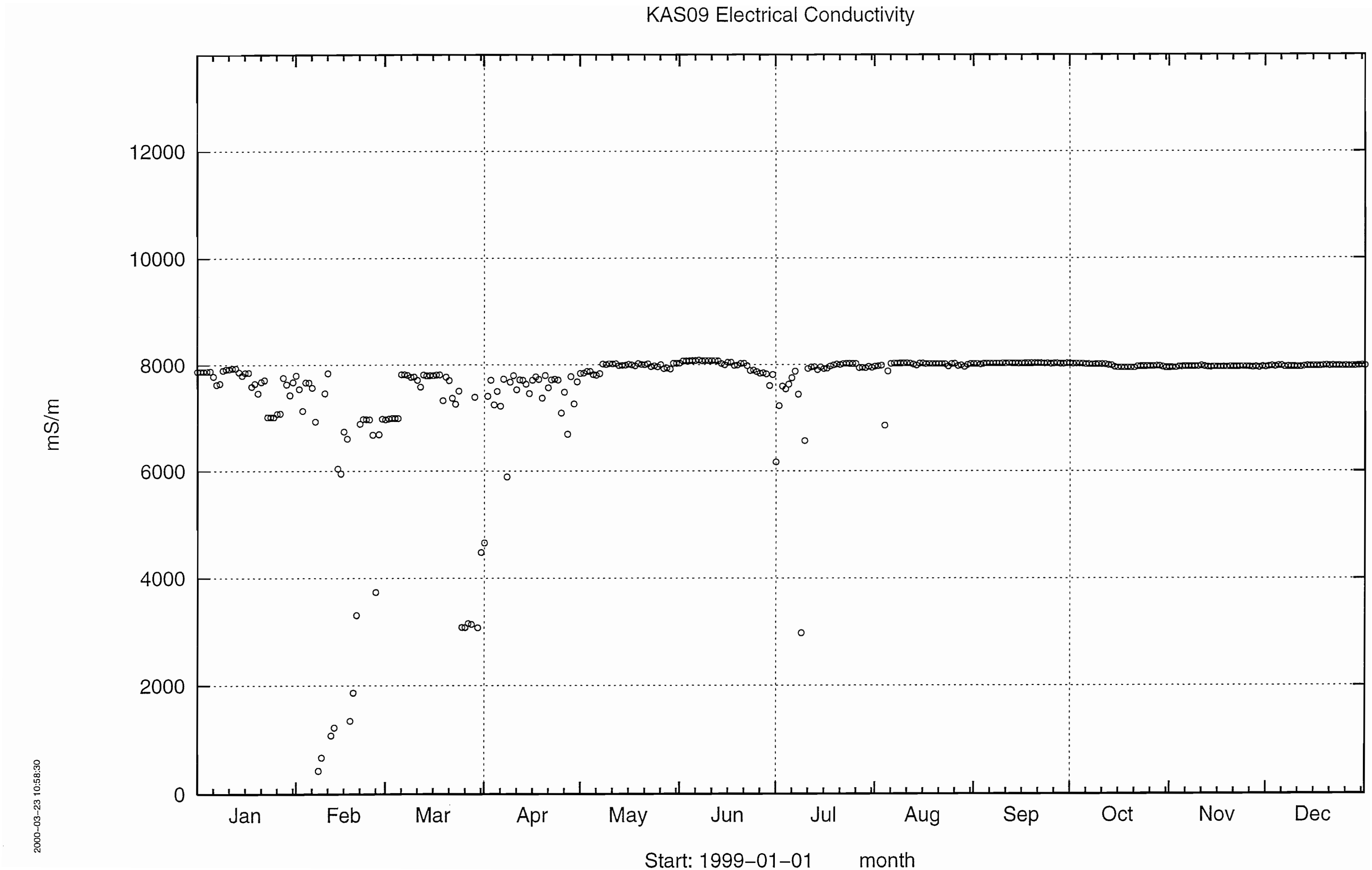


KAS16
masl
-30
-40
-50
-60
-70
-80
-90
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-03-23 09:42:57

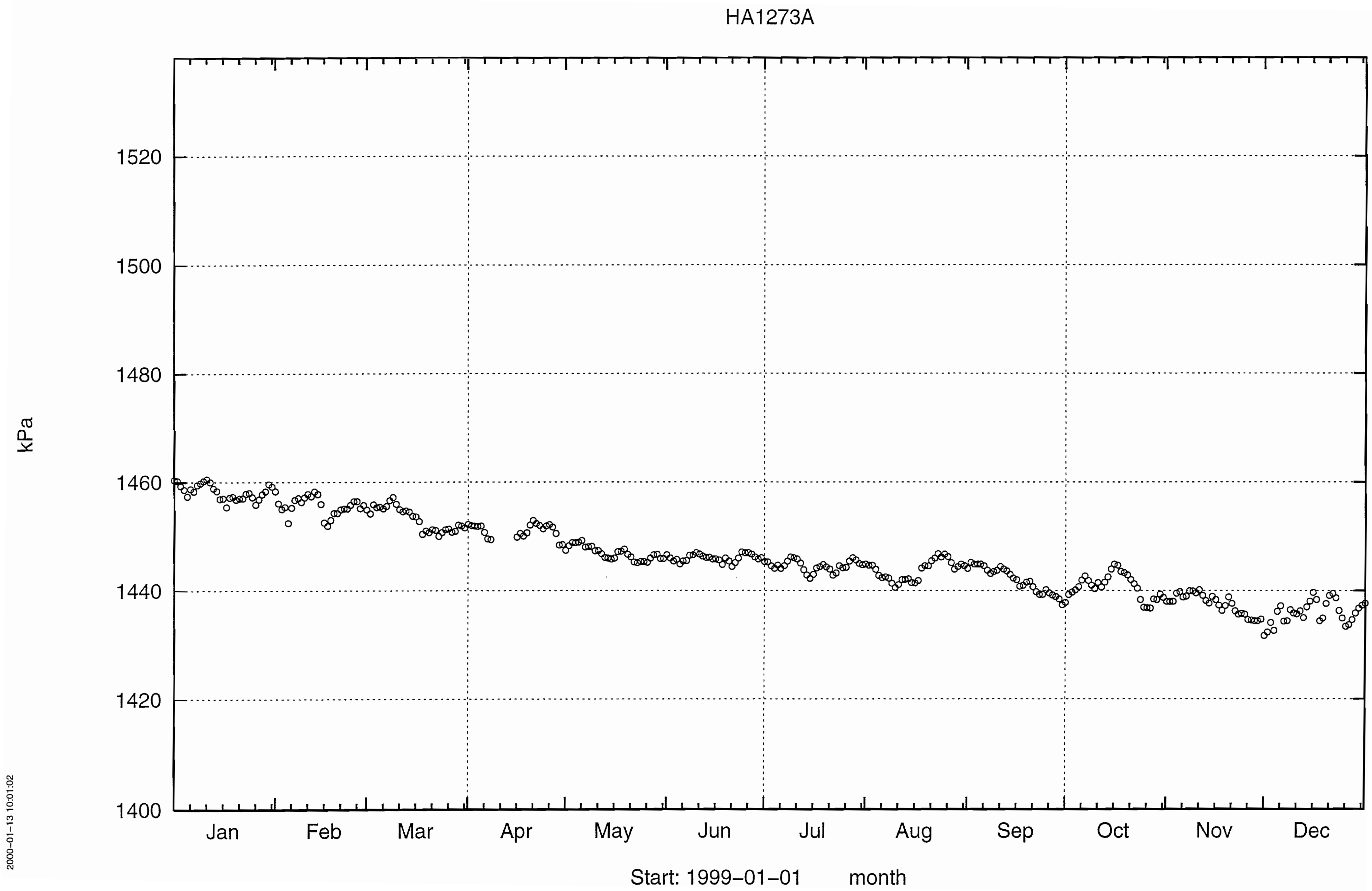

KBH02
masl
-2
-4
-6
-8
-10
-12
-14
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-03-23 09:42:58


KLX01
masl
15
10
5
0
−5
−10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−03−23 09:42:58

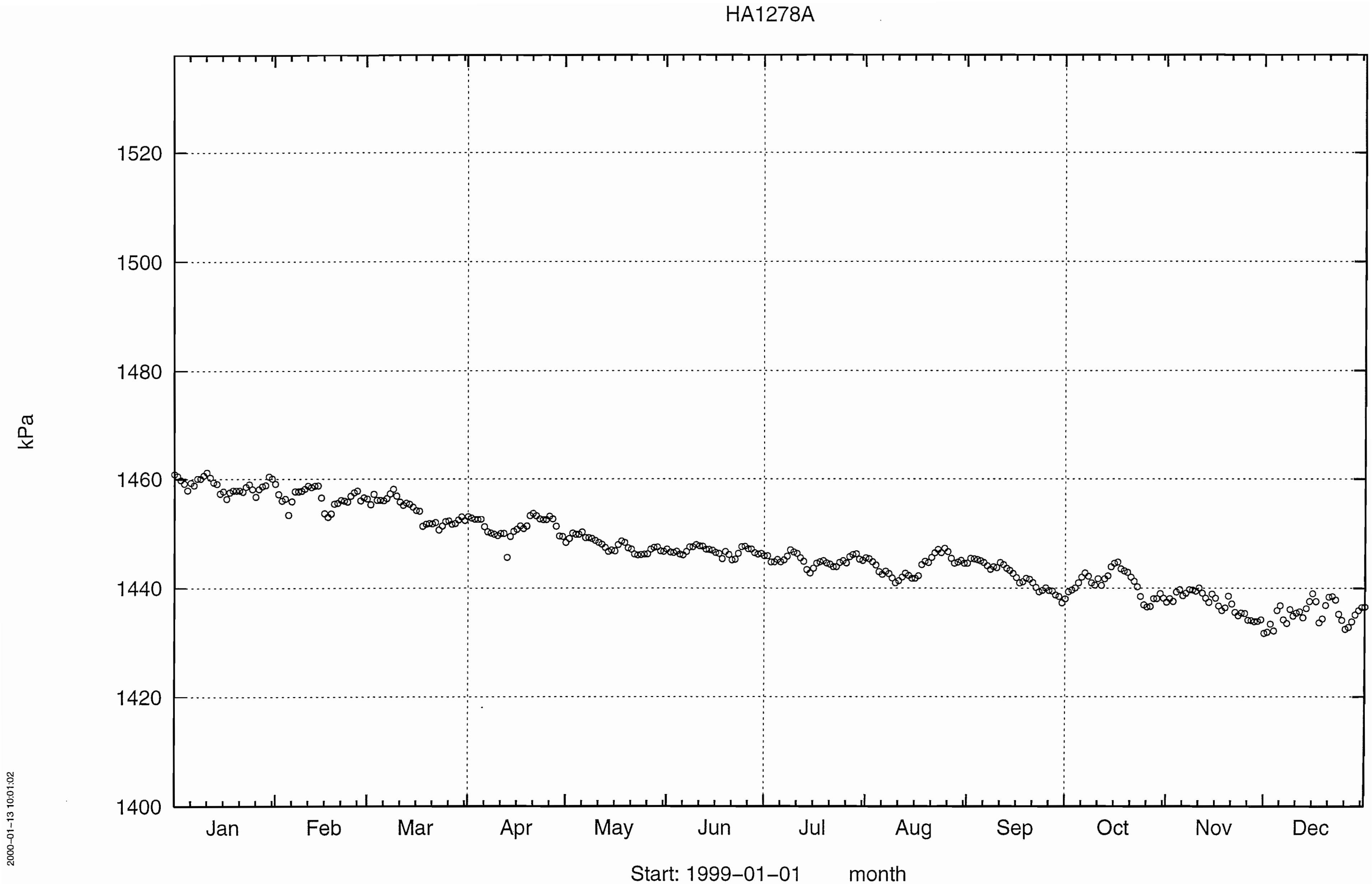
Appendix 3: Electrical conductivity in surface boreholes


KAS09 Electrical Conductivity
mS/m
12000
10000
8000
6000
4000
2000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−03−23 10:58:30

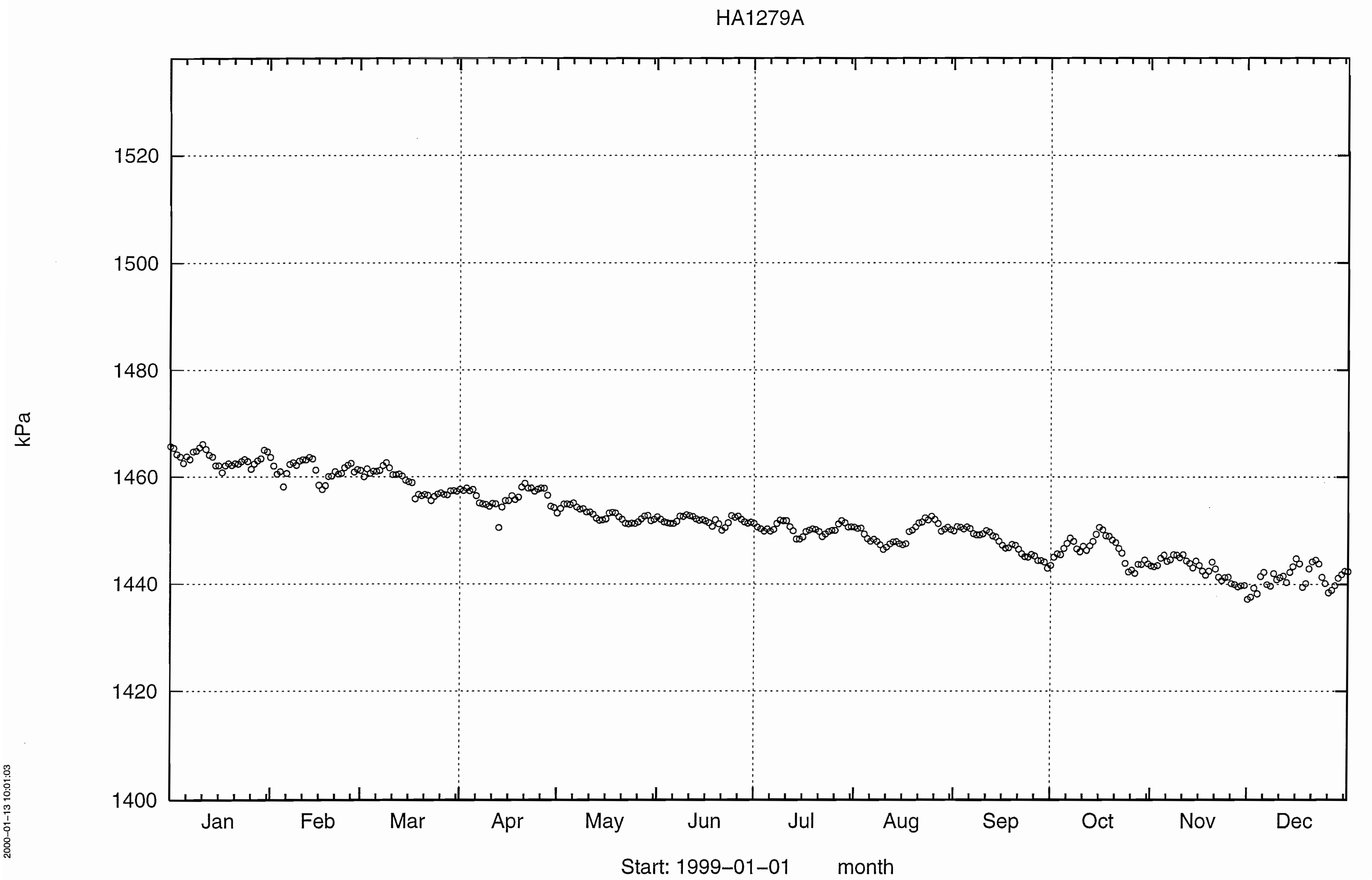
Appendix 4: Groundwater pressure in tunnel boreholes



HA1273A
kPa
1520
1500
1480
1460
1440
1420
1400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−01−13 10:01:02



HA1278A
kPa
1520
1500
1480
1460
1440
1420
1400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:02



HA1279A
kPa
1520
1500
1480
1460
1440
1420
1400
Jan
Feb
Mar
Apr
May
Jun
Jul
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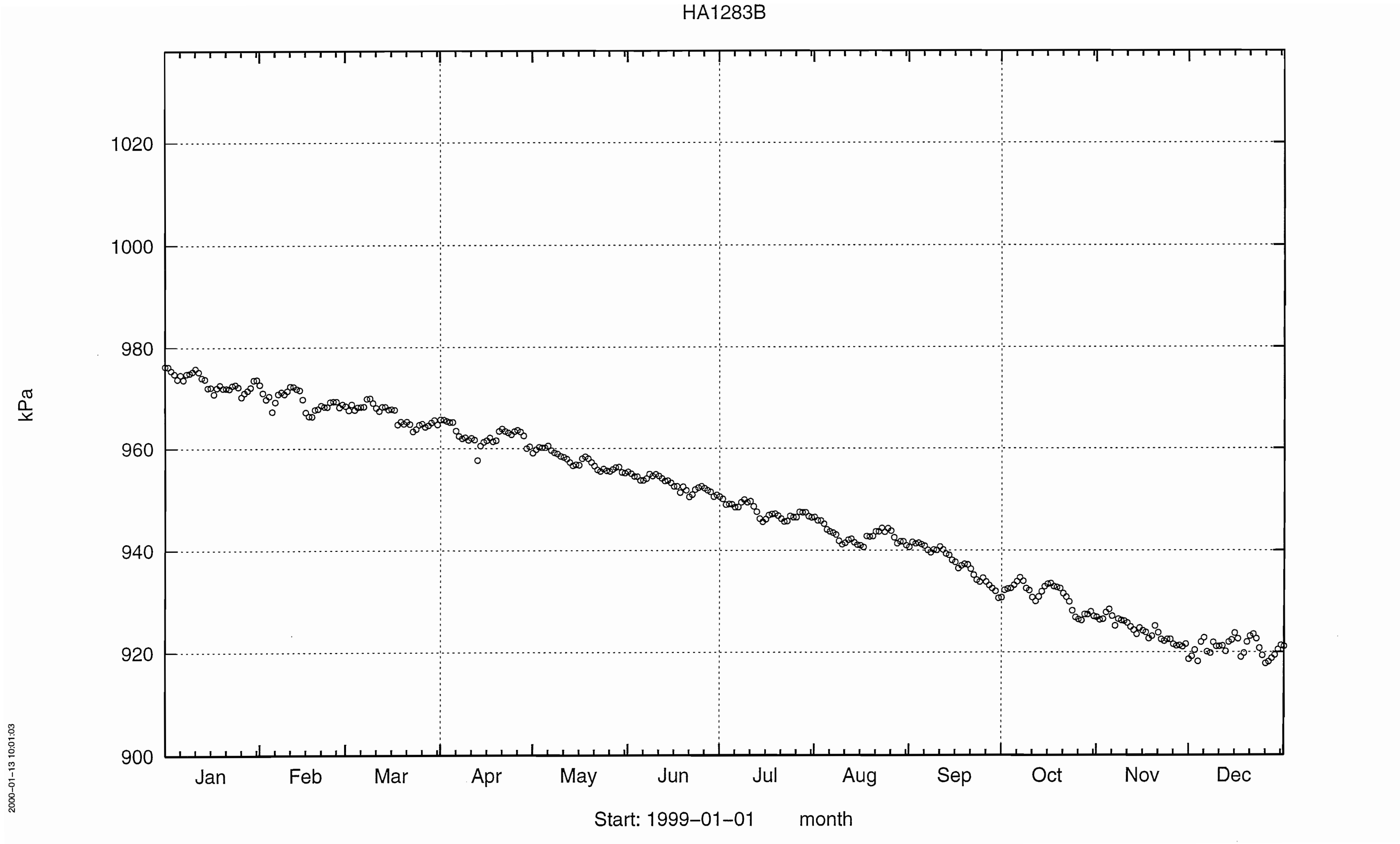
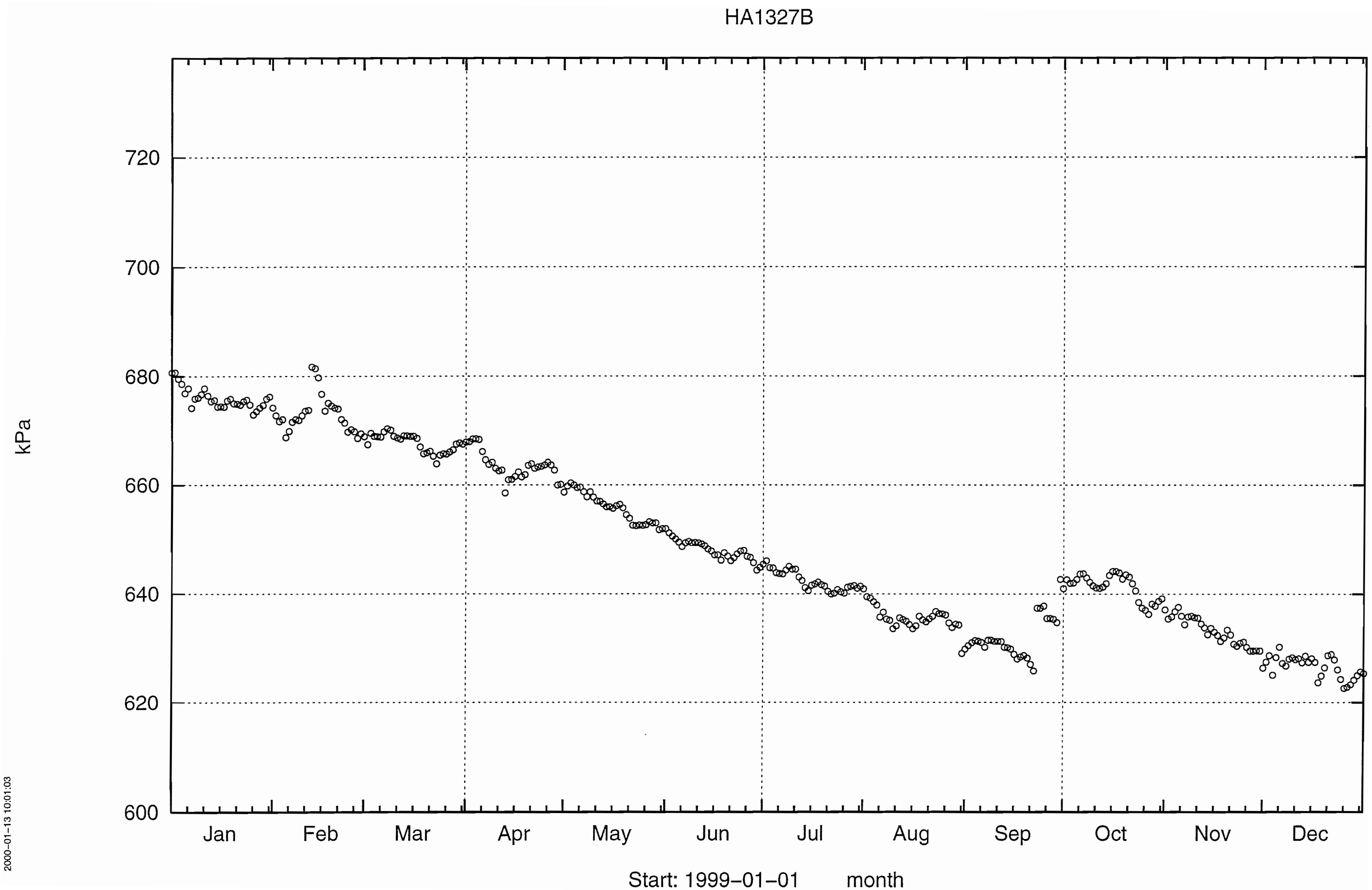
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000-01-13 10:01:03



HA1283B
kPa
1020
1000
980
960
940
920
900
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:03


HA1327B
kPa
720
700
680
660
640
620
600
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
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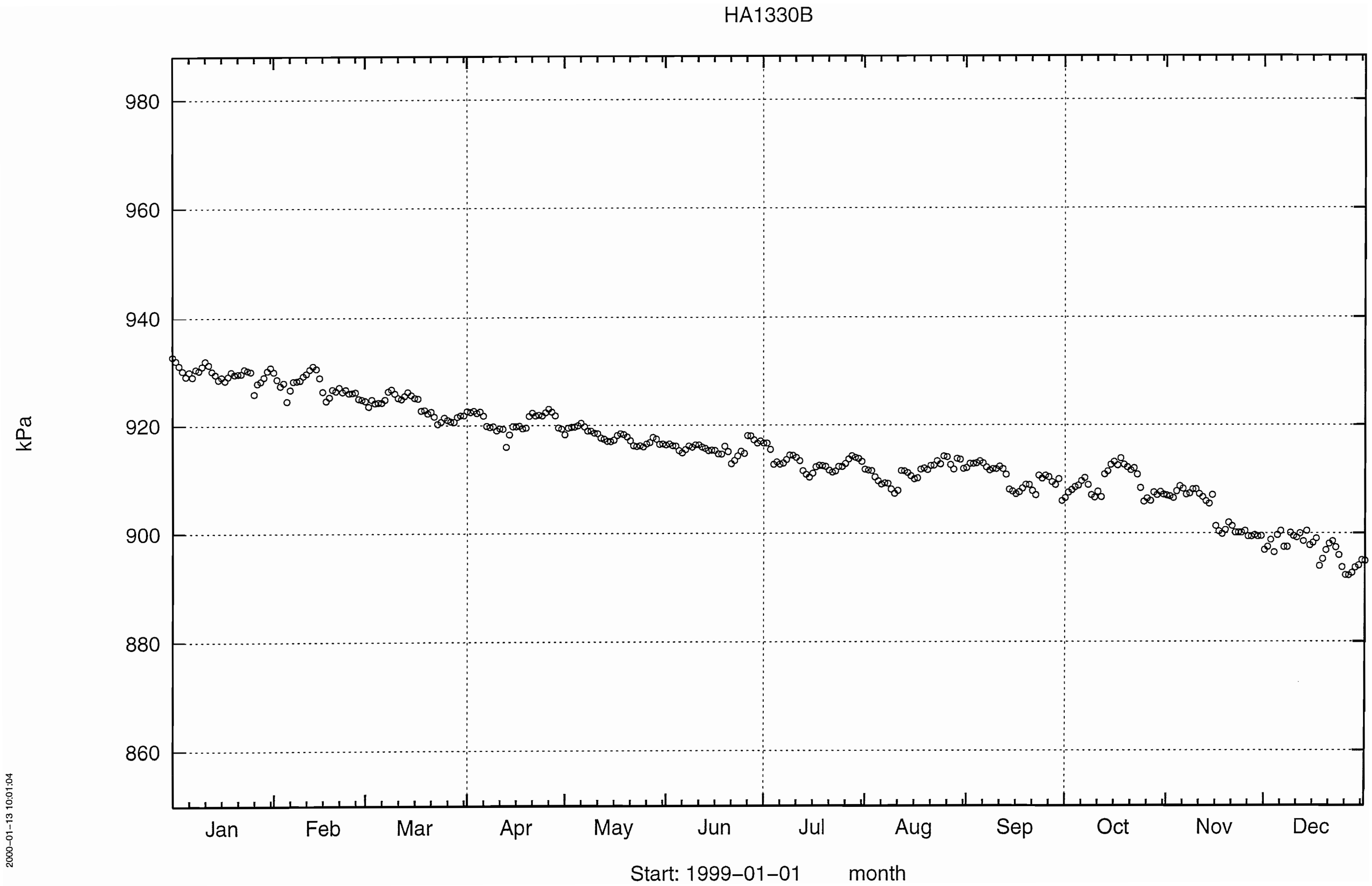
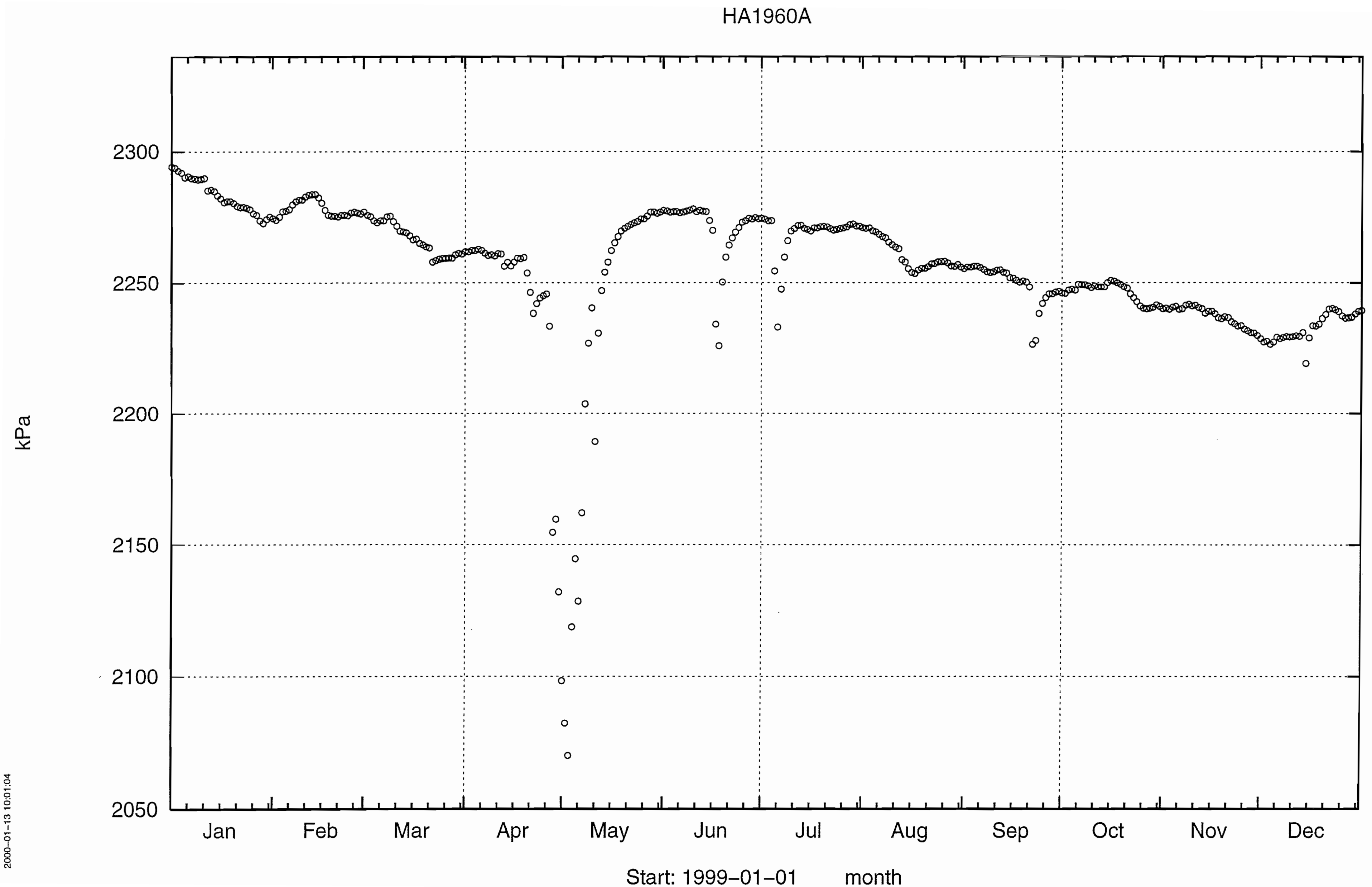
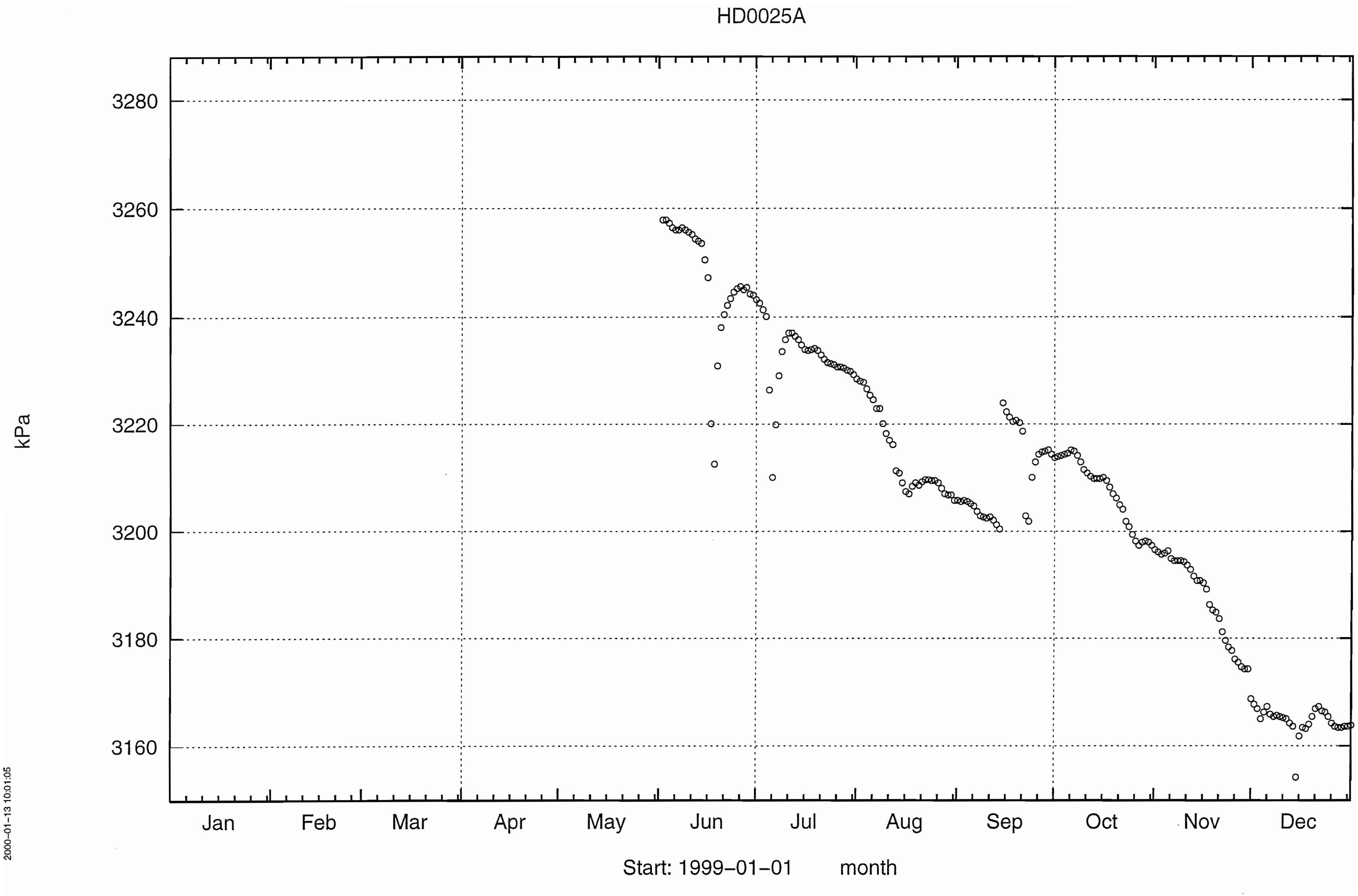
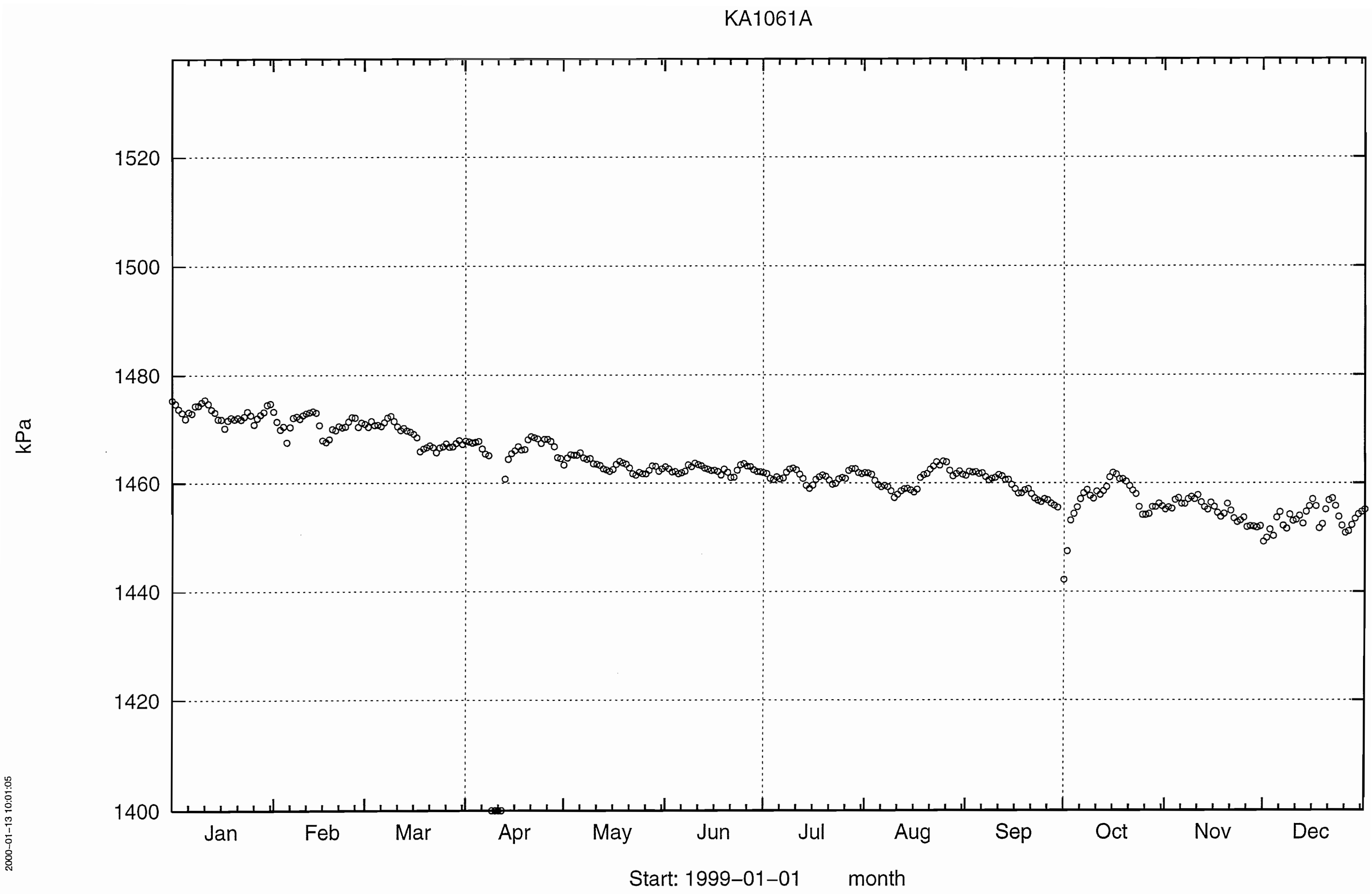
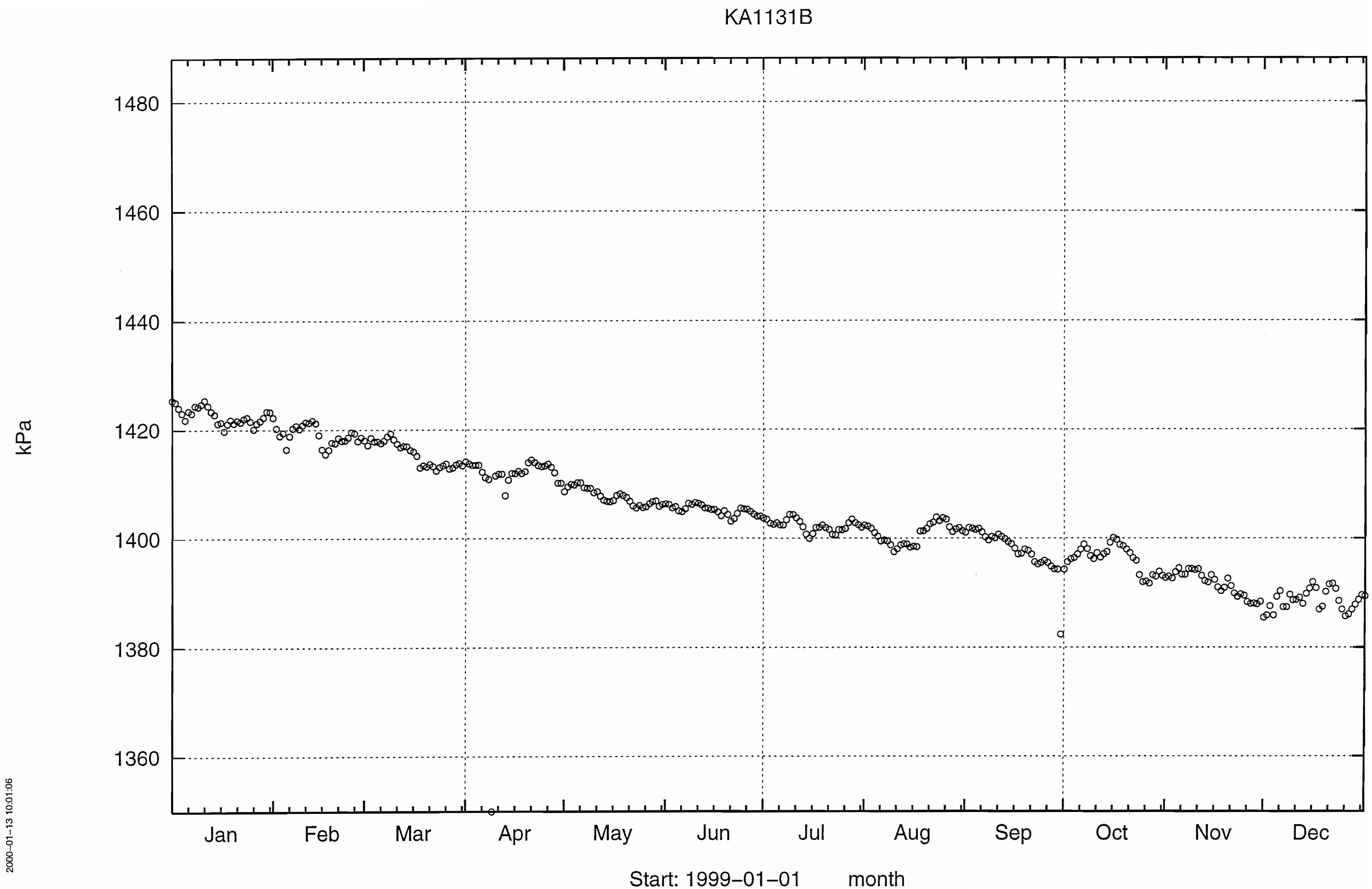
Dec
Start: 1999−01−01 month
2000−01−13 10:01:03

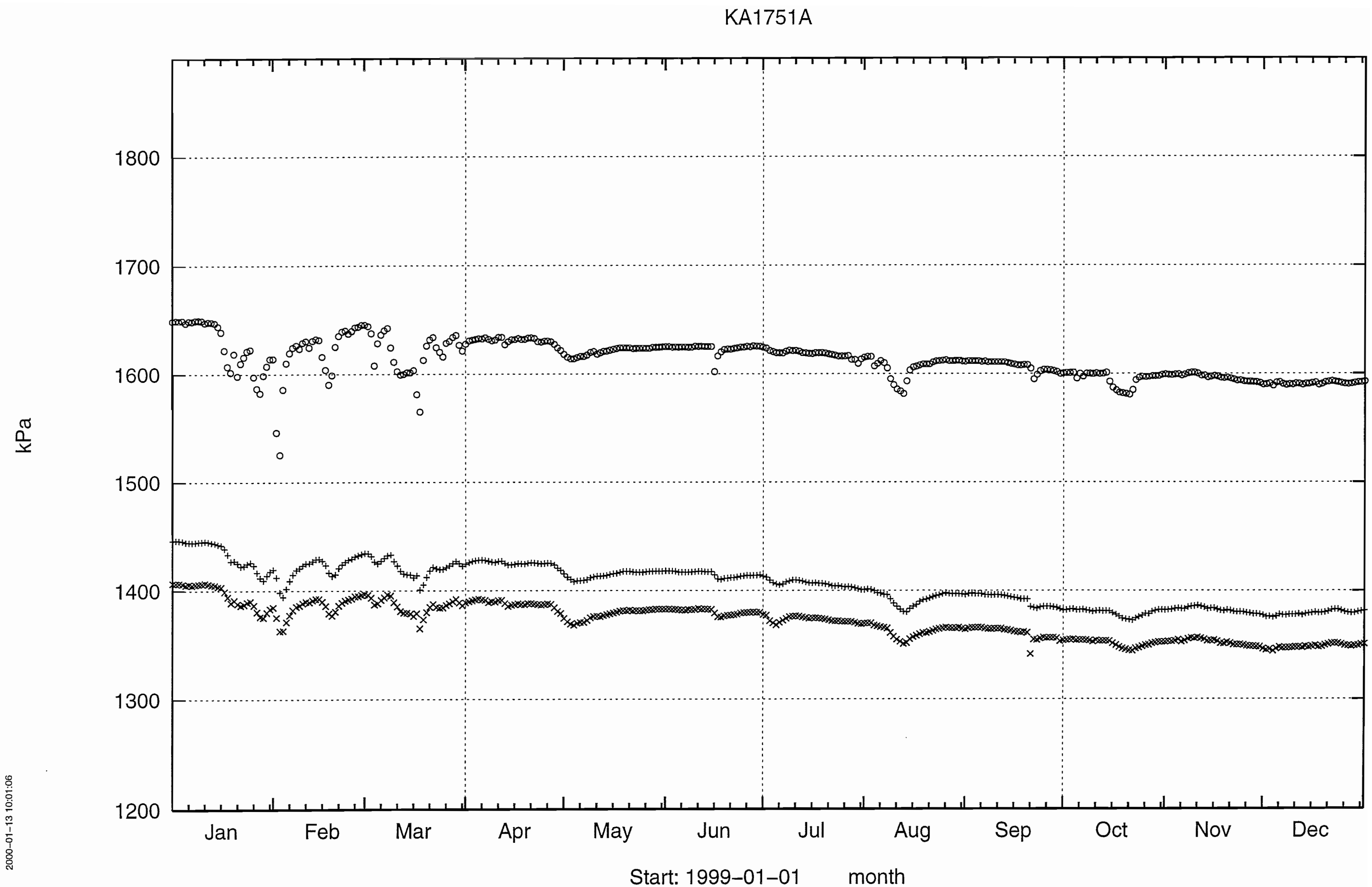

HA1330B
kPa
980
960
940
920
900
880
860
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:04


HA1960A
kPa
2300
2250
2200
2150
2100
2050
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:04

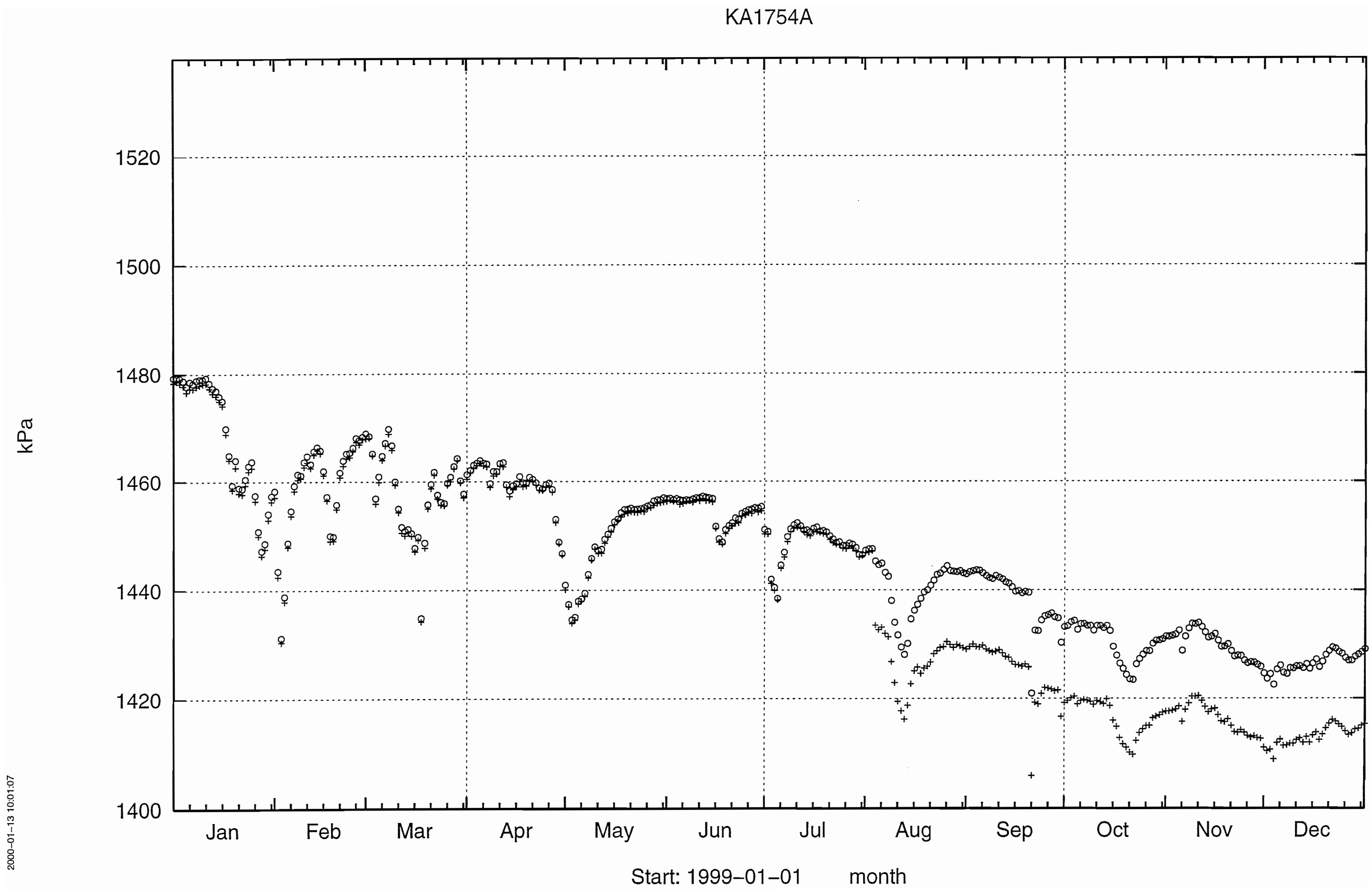

HD0025A
kPa
3280
3260
3240
3220
3200
3180
3160
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:05


KA1061A
kPa
1520
1500
1480
1460
1440
1420
1400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:05


KA1131B
kPa
1480
1460
1440
1420
1400
1380
1360
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:06



KA1751A
kPa
1800
1700
1600
1500
1400
1300
1200
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:06


KA1754A
kPa
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1480
1460
1440
1420
1400
Jan
Feb
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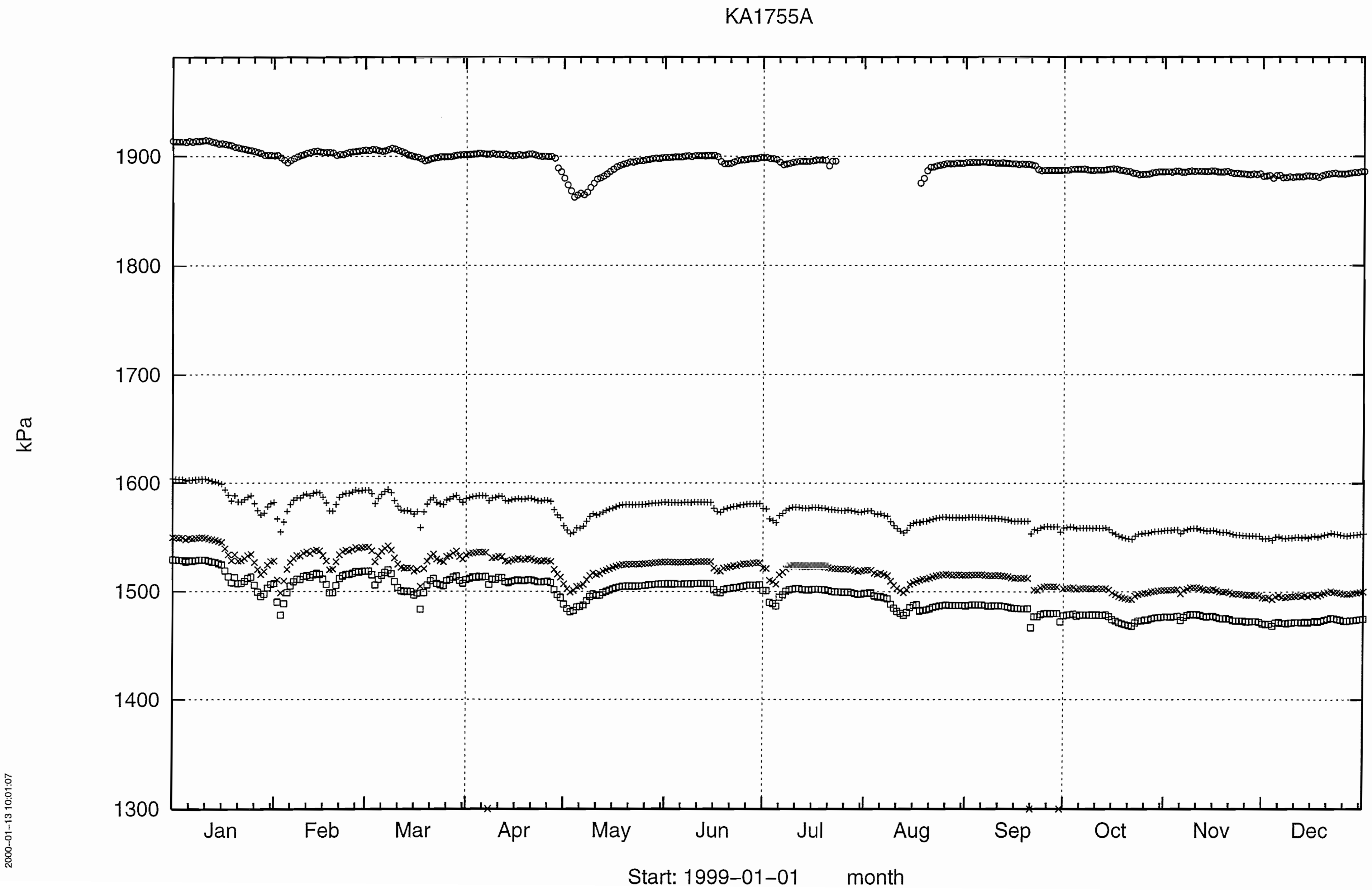
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:07


KA1755A
kPa
1900
1800
1700
1600
1500
1400
1300
Jan
Feb
Mar
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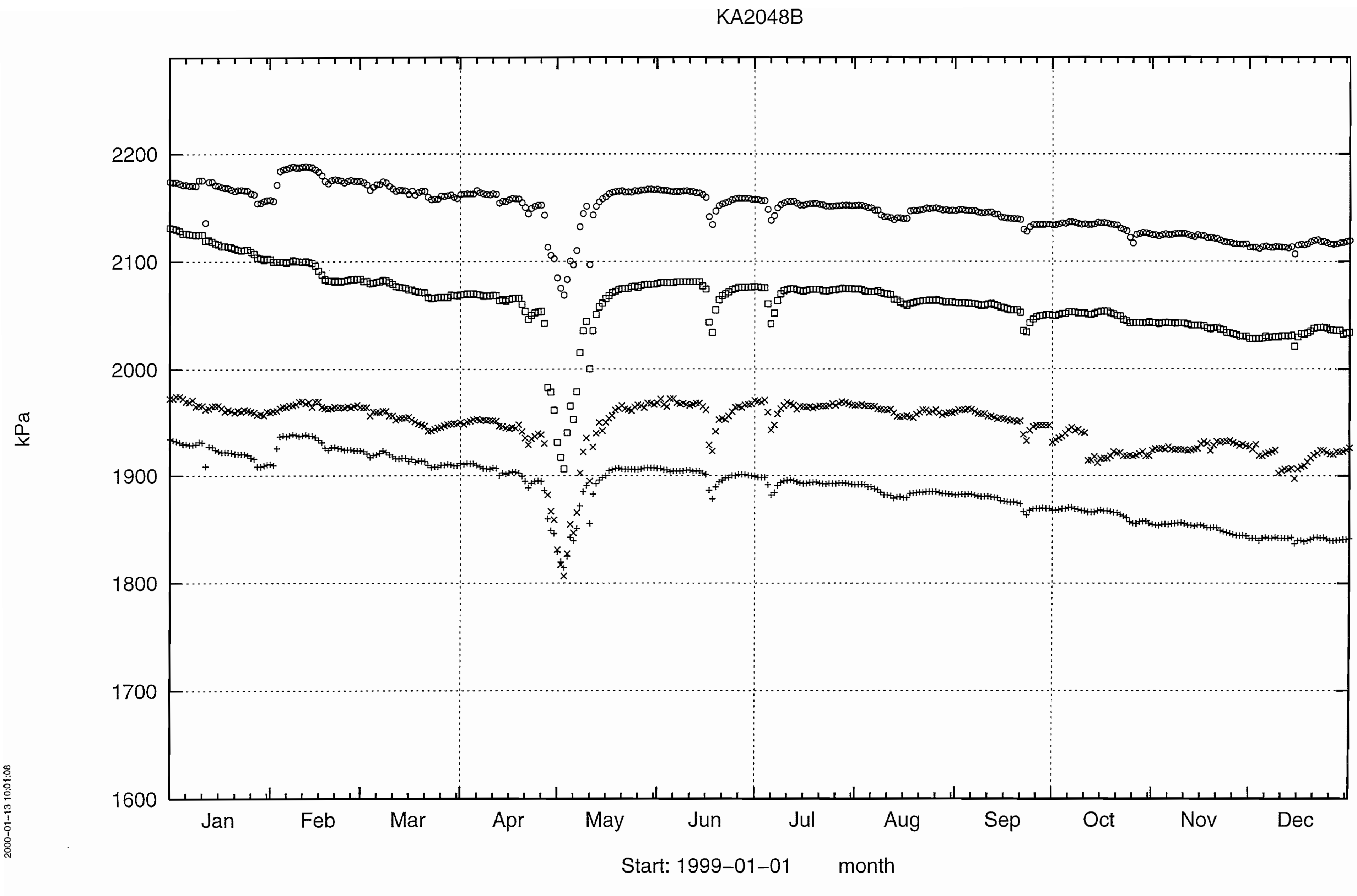
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:07


KA2048B
kPa
2200
2100
2000
1900
1800
1700
1600
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
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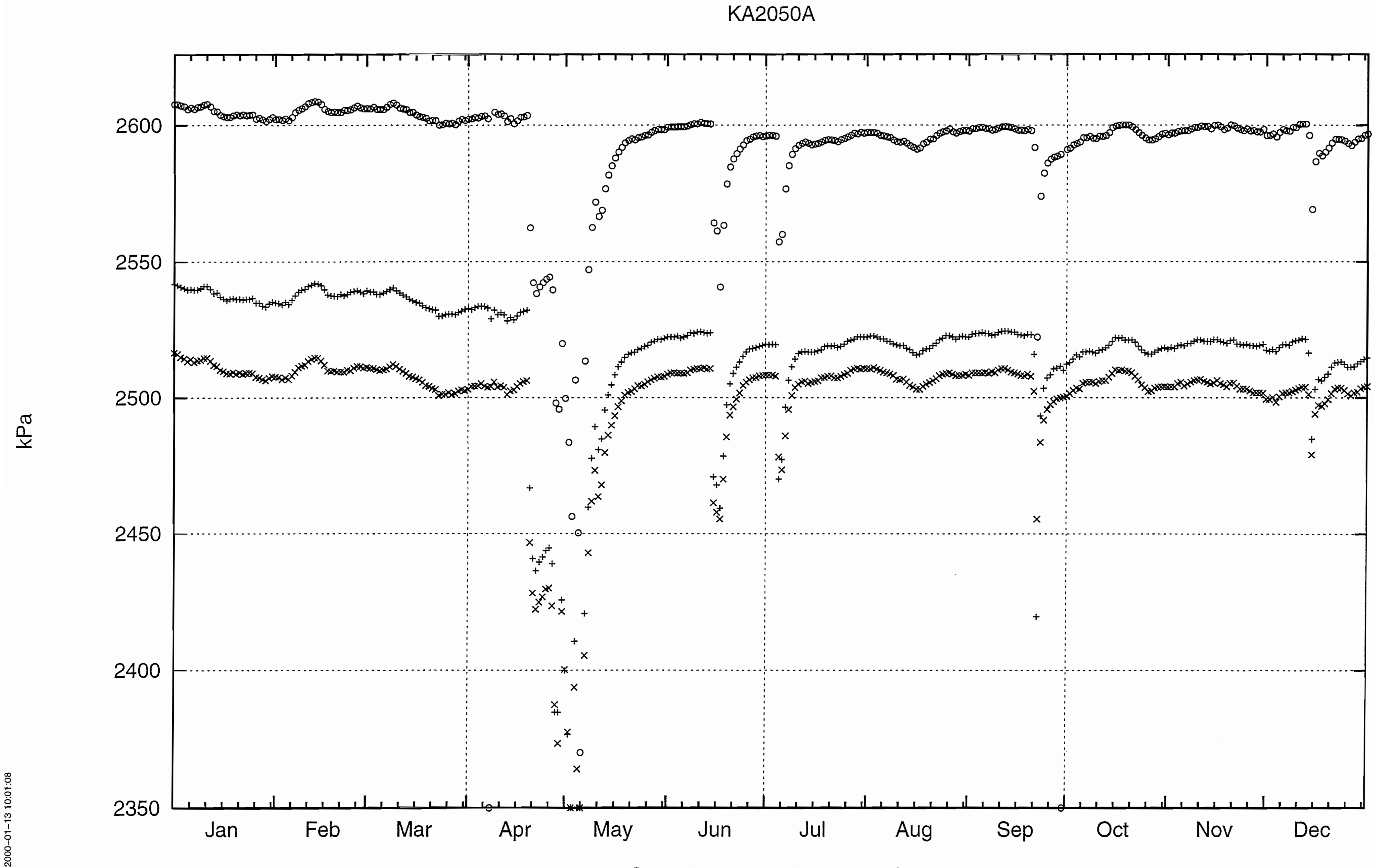
Dec
Start: 1999-01-01 month
2000-01-13 10:01:08


KA2050A
kPa
2600
2550
2500
2450
2400
2350
Jan
Feb
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Apr
May
Jun
Jul
Aug
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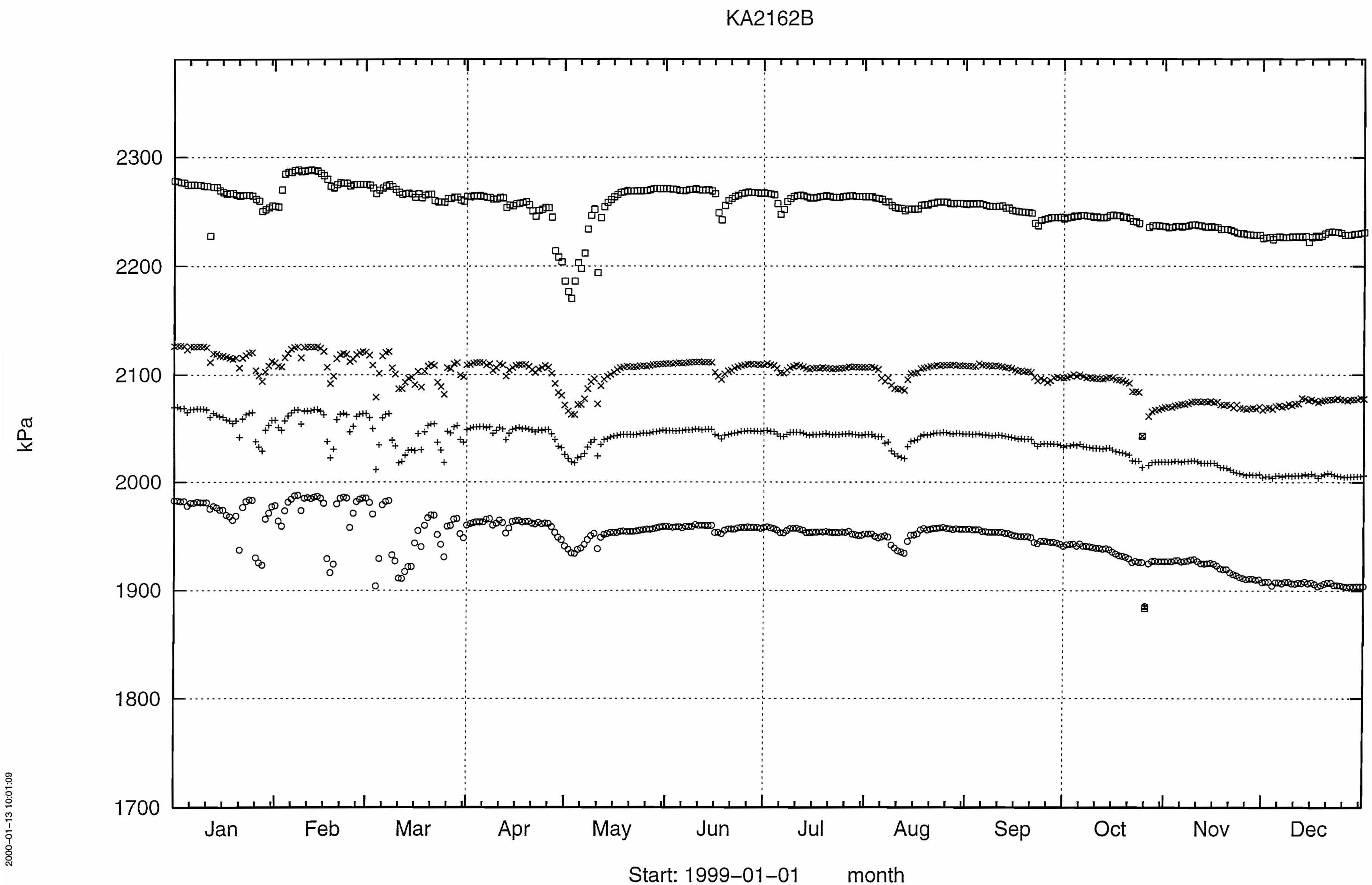
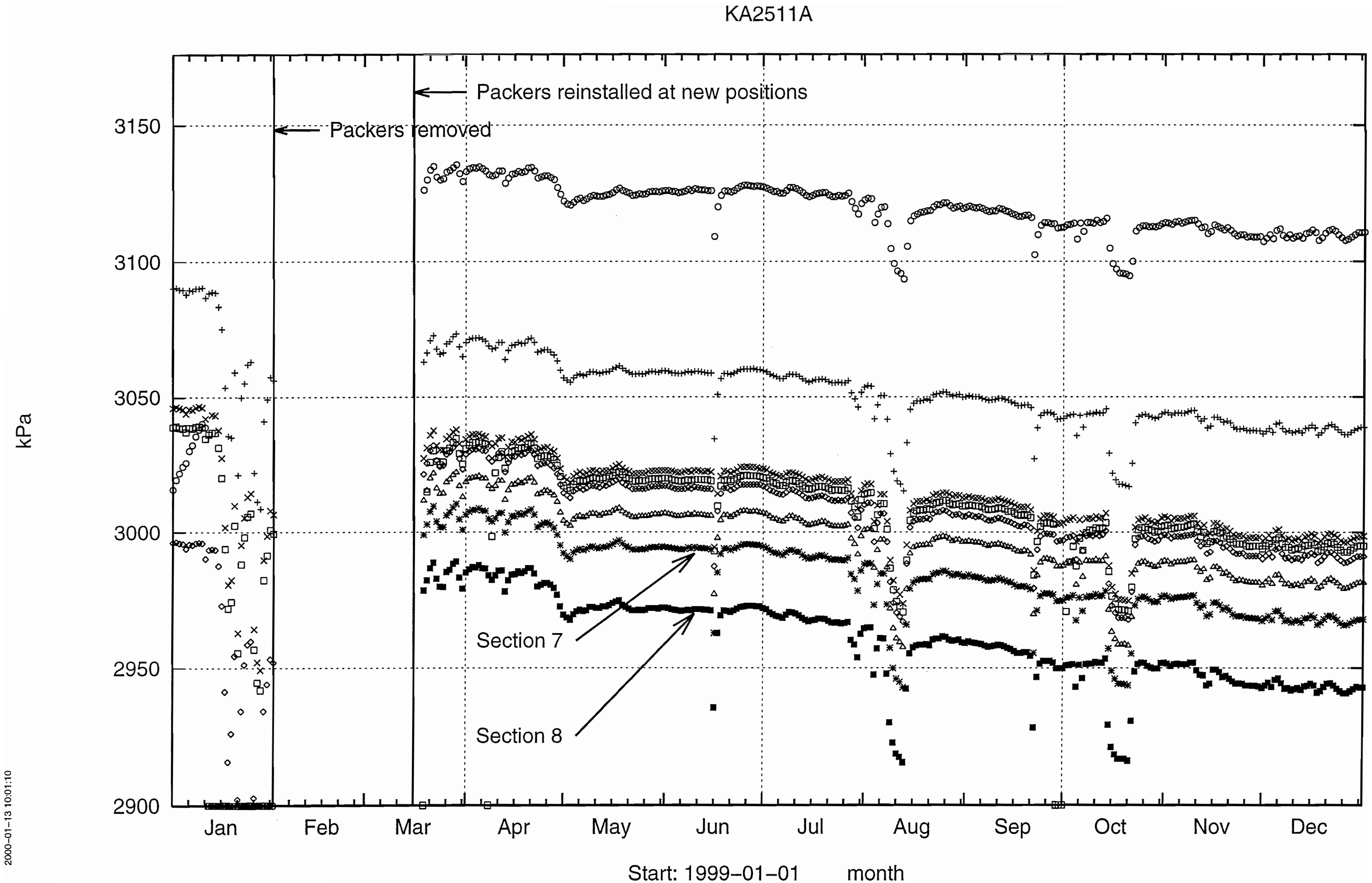
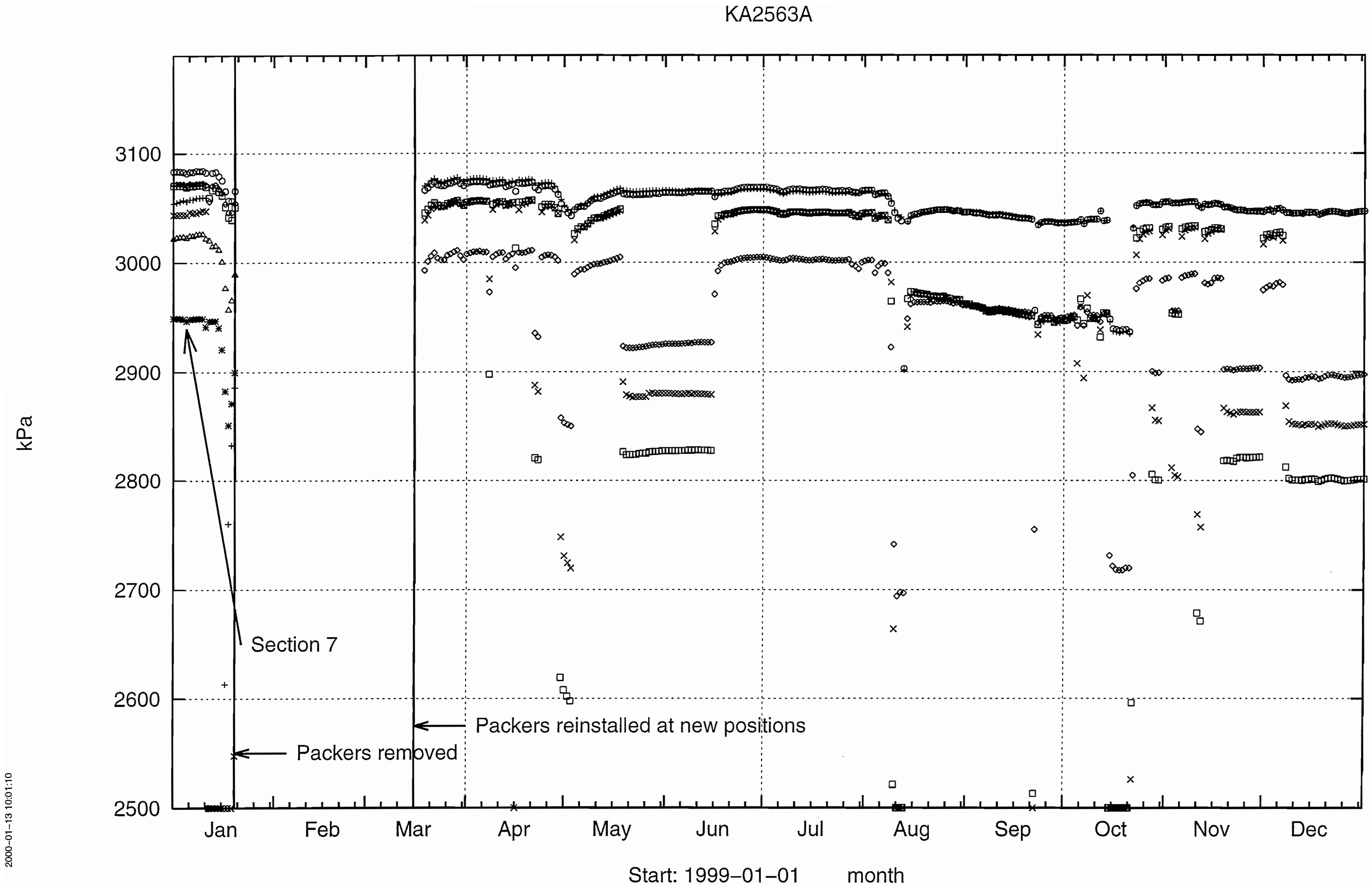
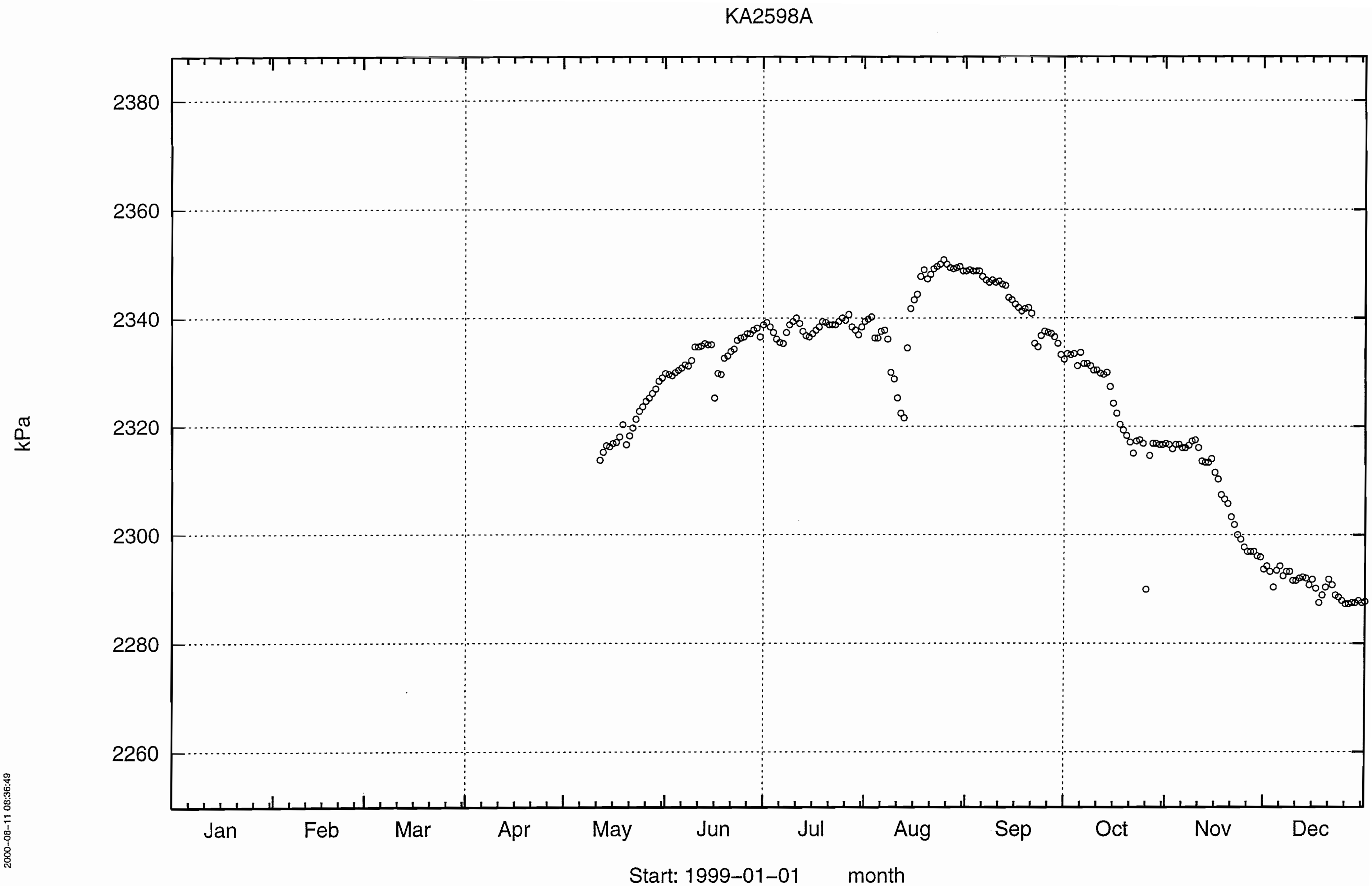
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:08

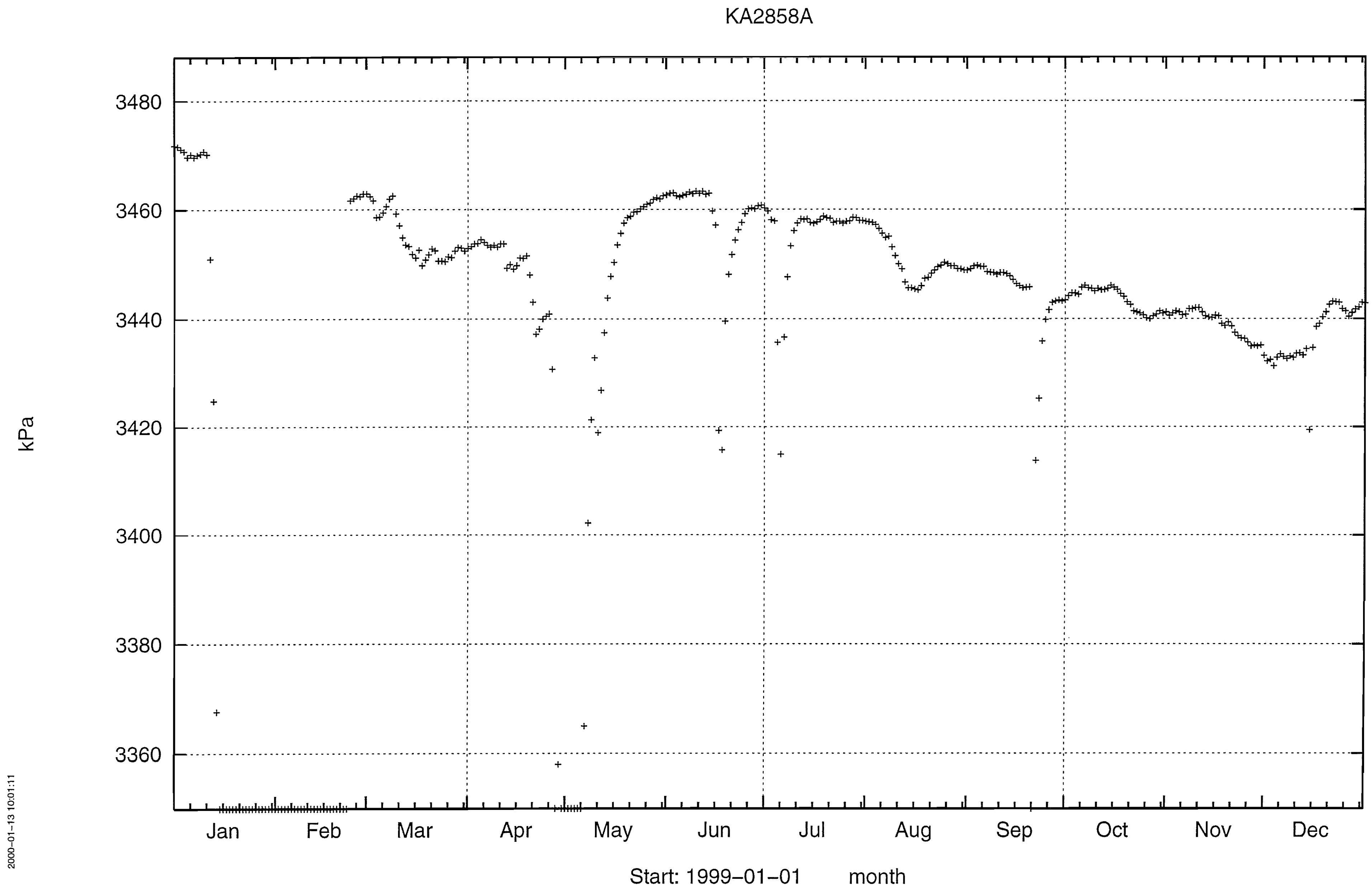

KA2162B
kPa
2300
2200
2100
2000
1900
1800
1700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:09


KA2511A
Packers reinstalled at new positions
Packers removed
3150
3100
3050
3000
2950
2900
kPa
Section 7
Section 8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:10

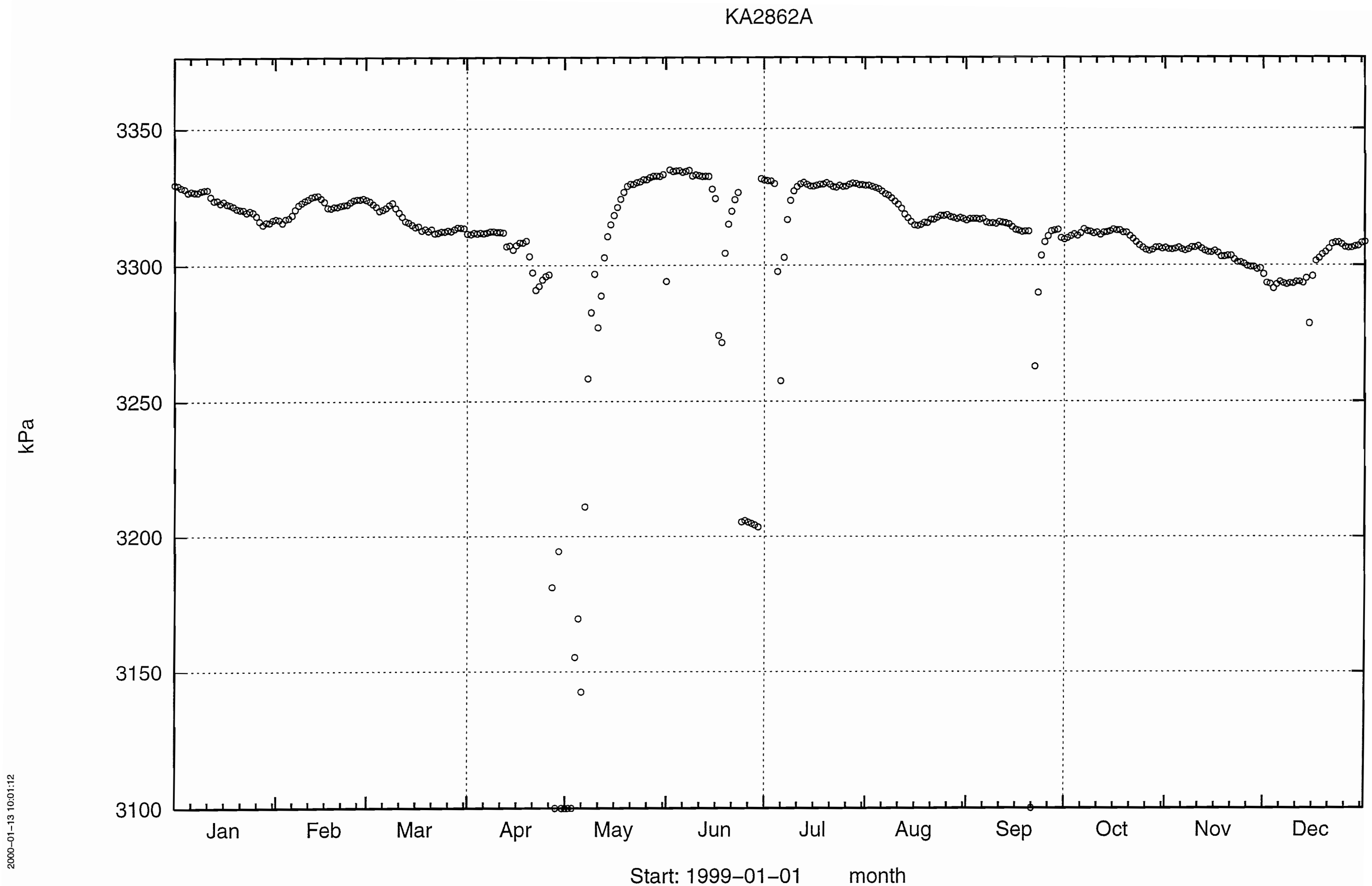

KA2563A
kPa
3100
3000
2900
2800
2700
2600
2500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
Section 7
Packers removed
Packers reinstalled at new positions
2000−01−13 10:01:10

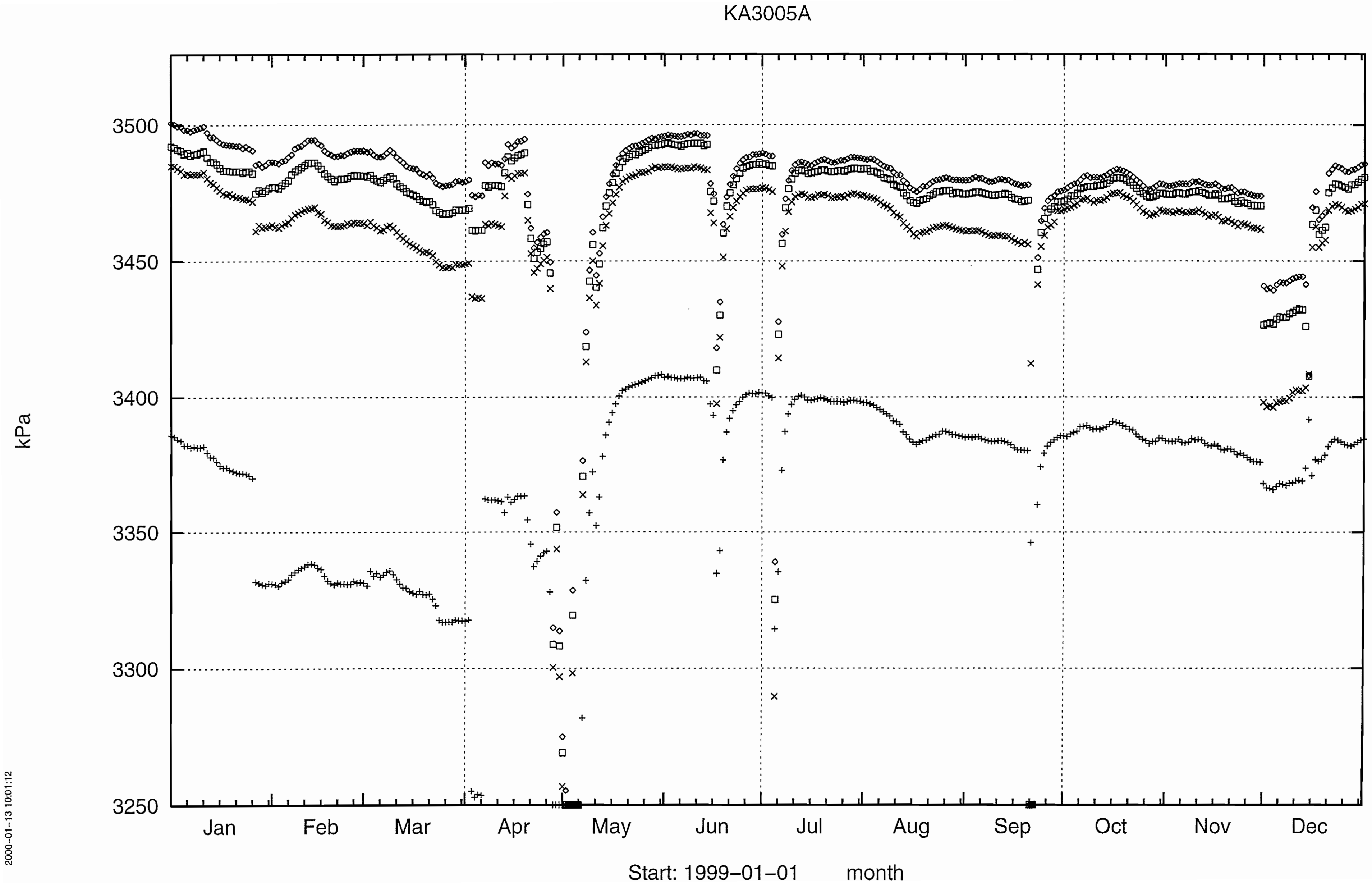


KA2598A
kPa
2380
2360
2340
2320
2300
2280
2260
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-08-11 08:36:49

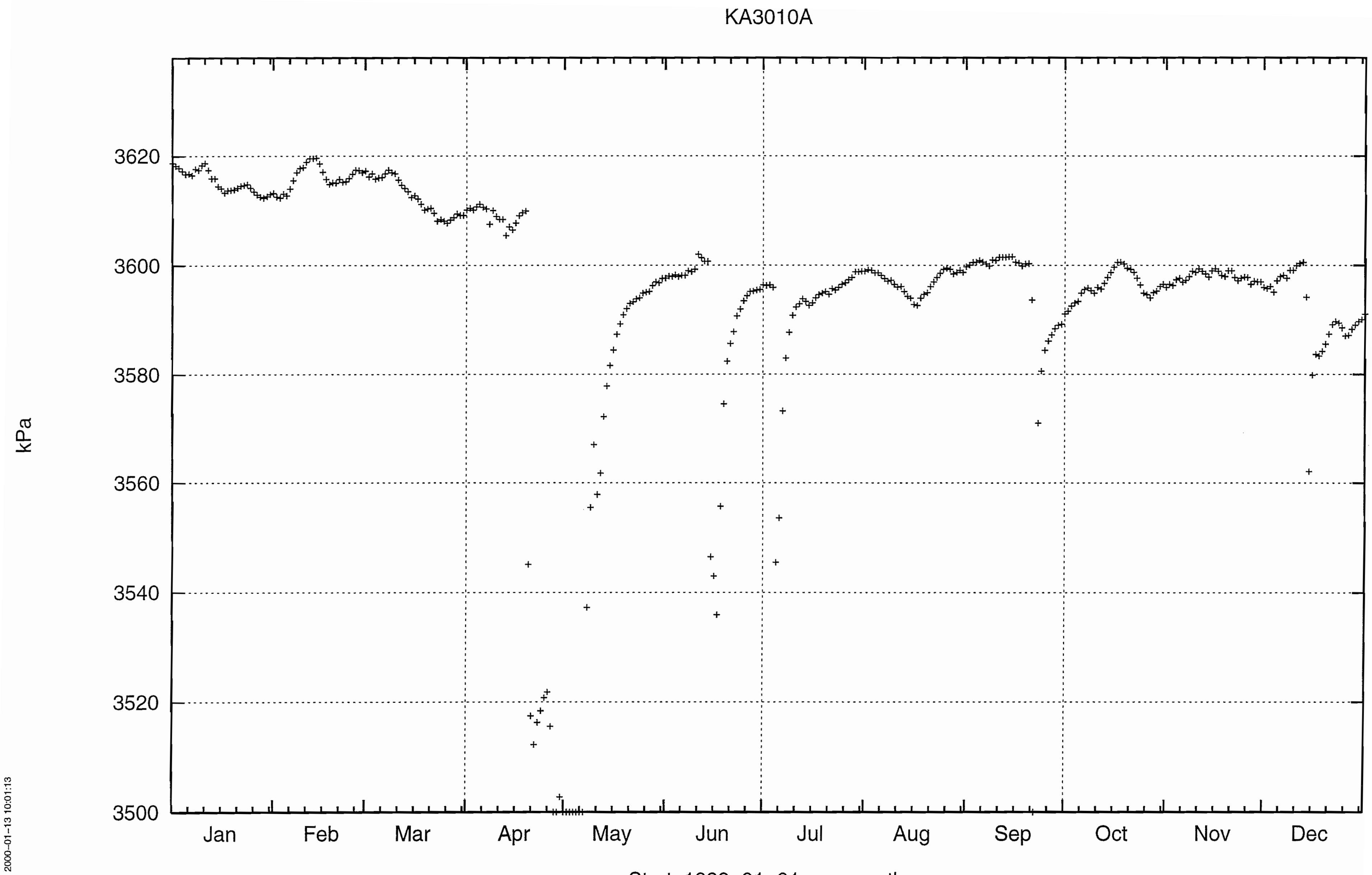


KA2858A
kPa
3480
3460
3440
3420
3400
3380
3360
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:11

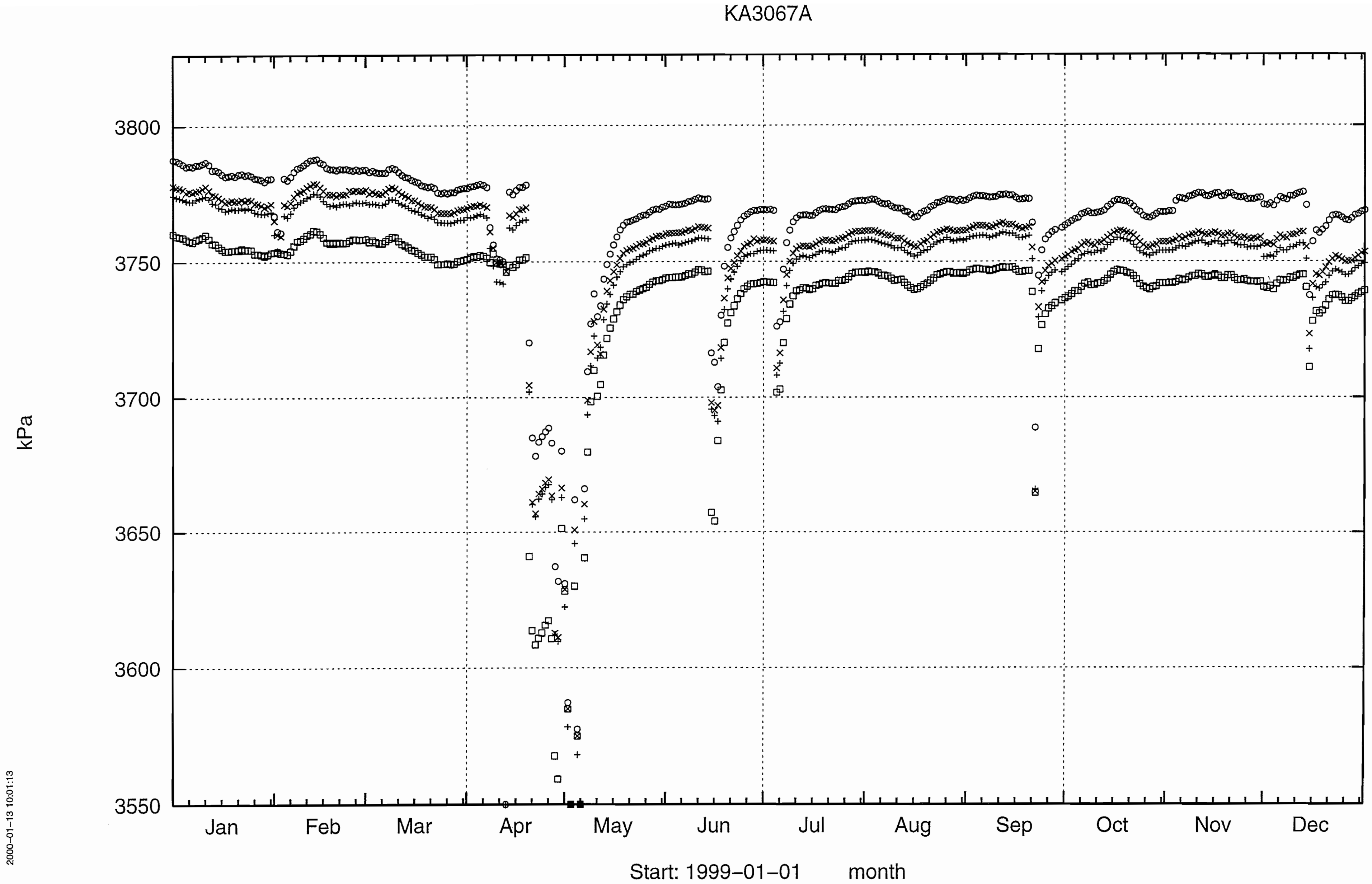

KA2862A
kPa
3350
3300
3250
3200
3150
3100
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:12



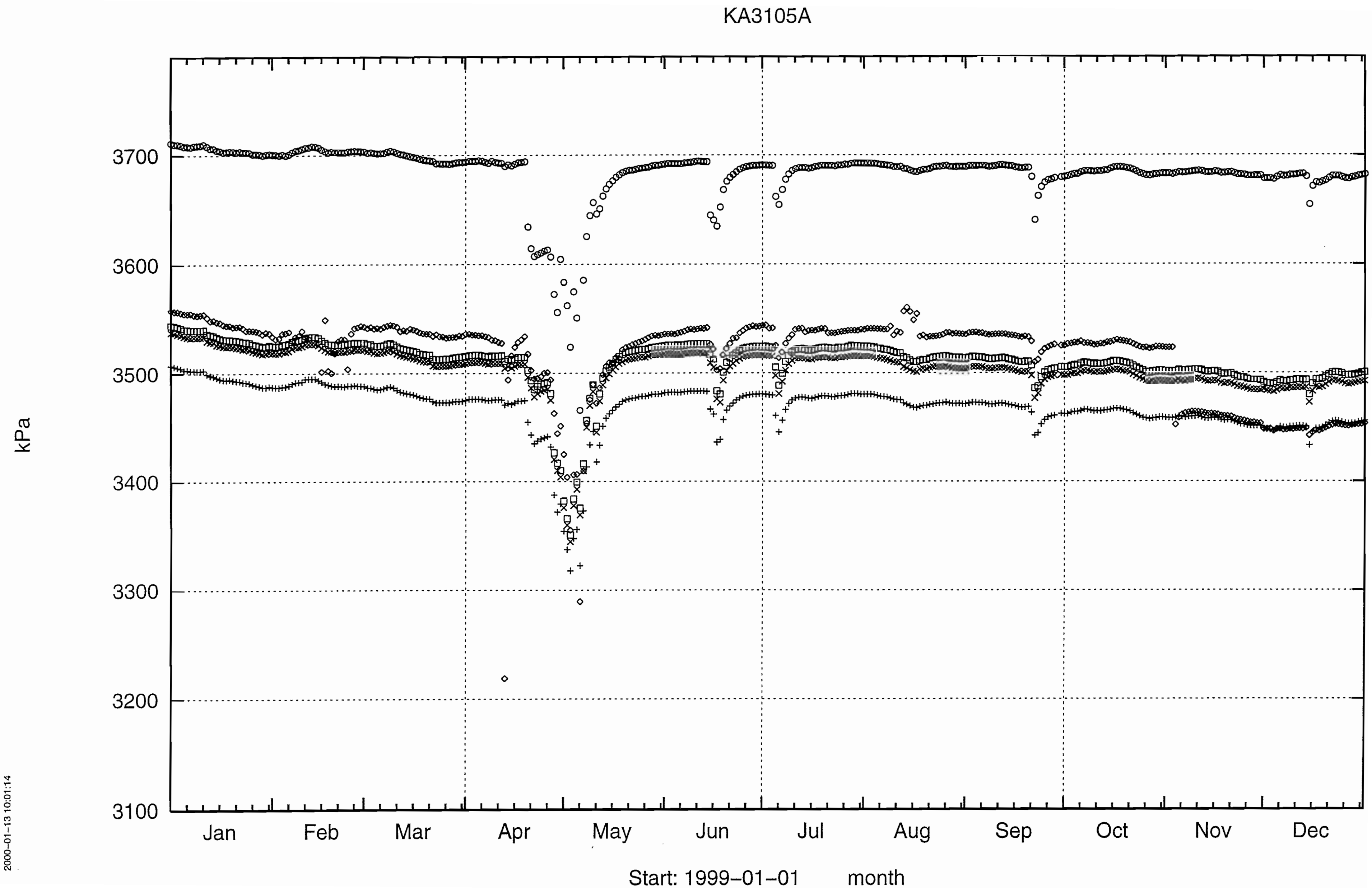
KA3005A
kPa
3500
3450
3400
3350
3300
3250
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:12



KA3010A
kPa
3620
3600
3580
3560
3540
3520
3500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−01−13 10:01:13



KA3067A
kPa
3800
3750
3700
3650
3600
3550
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:13


KA3105A
kPa
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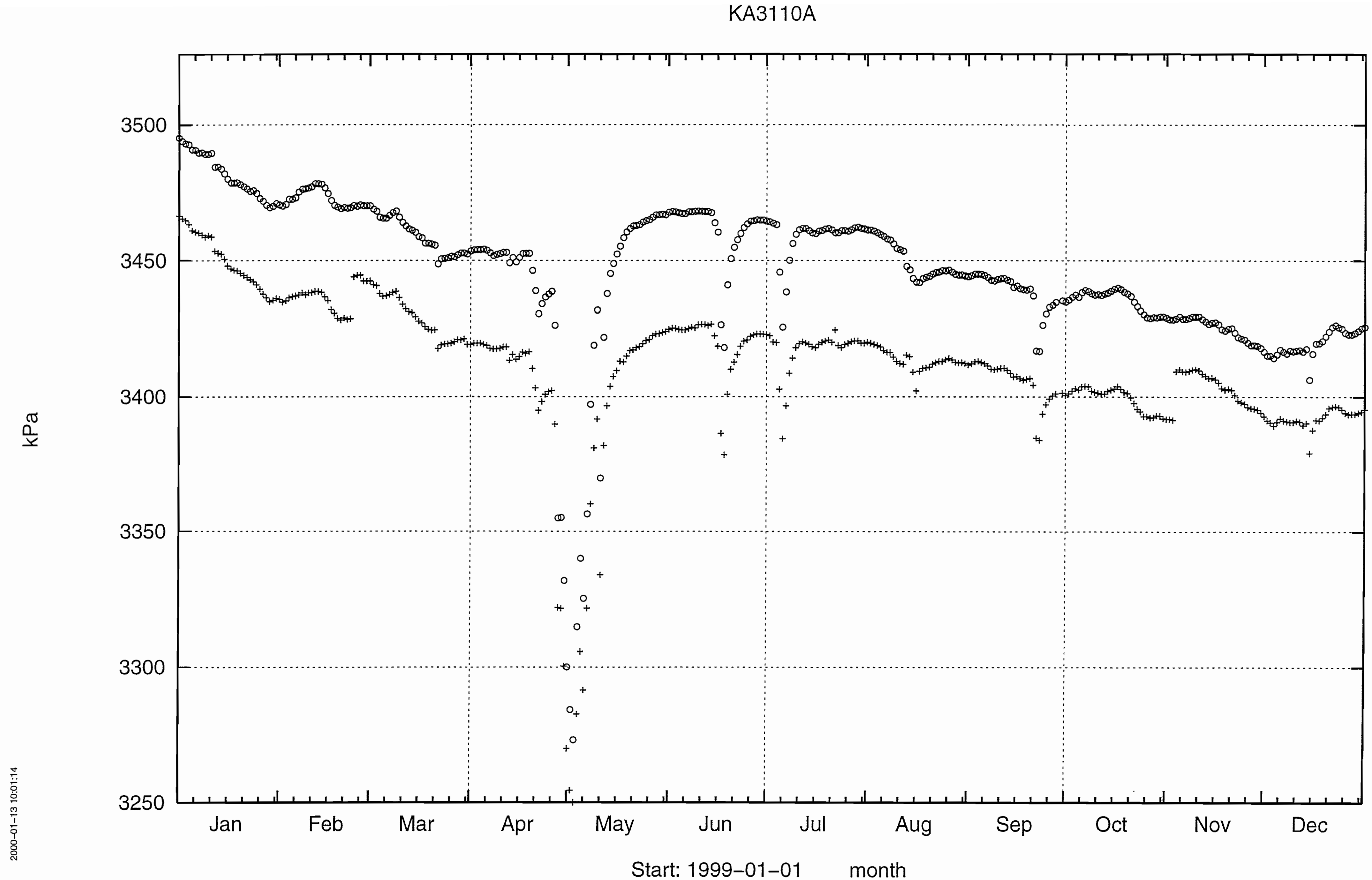
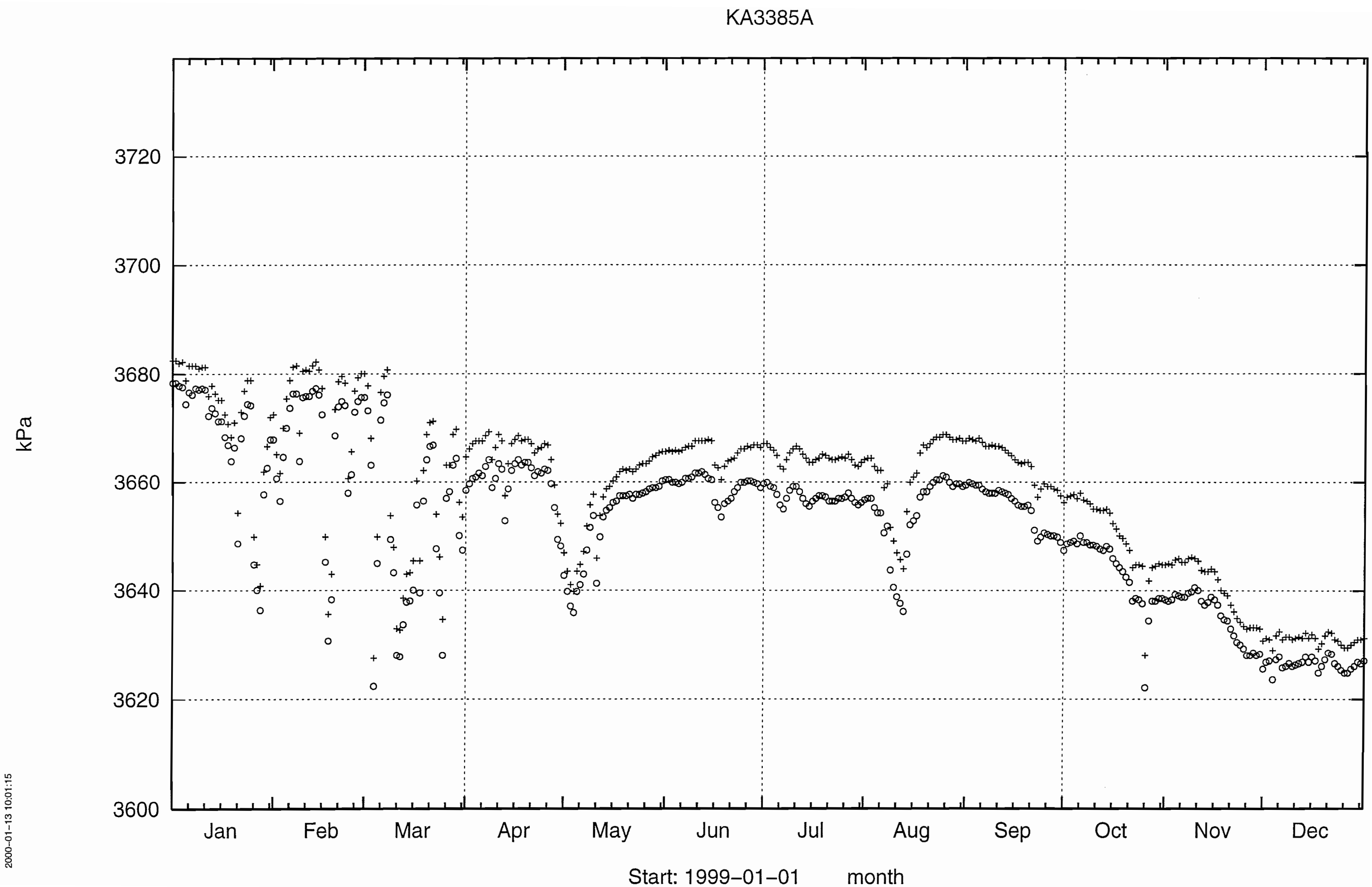
3600
3500
3400
3300
3200
3100
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:14


KA3110A
kPa
3500
3450
3400
3350
3300
3250
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:14


KA3385A
kPa
3720
3700
3680
3660
3640
3620
3600
Jan
Feb
Mar
Apr
May
Jun
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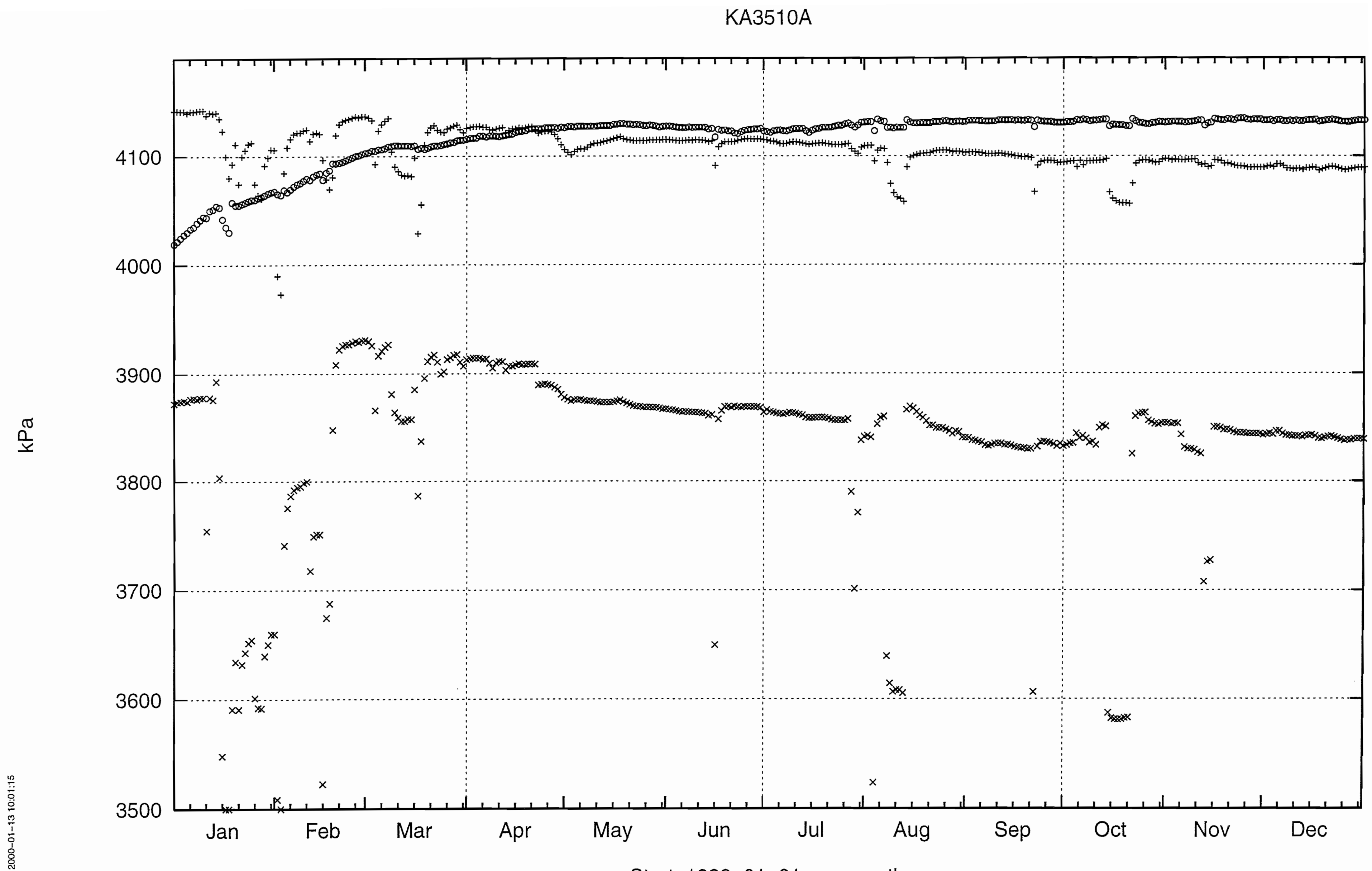
Dec
Start: 1999-01-01 month
2000-01-13 10:01:15



KA3510A
kPa
4100
4000
3900
3800
3700
3600
3500
Jan
Feb
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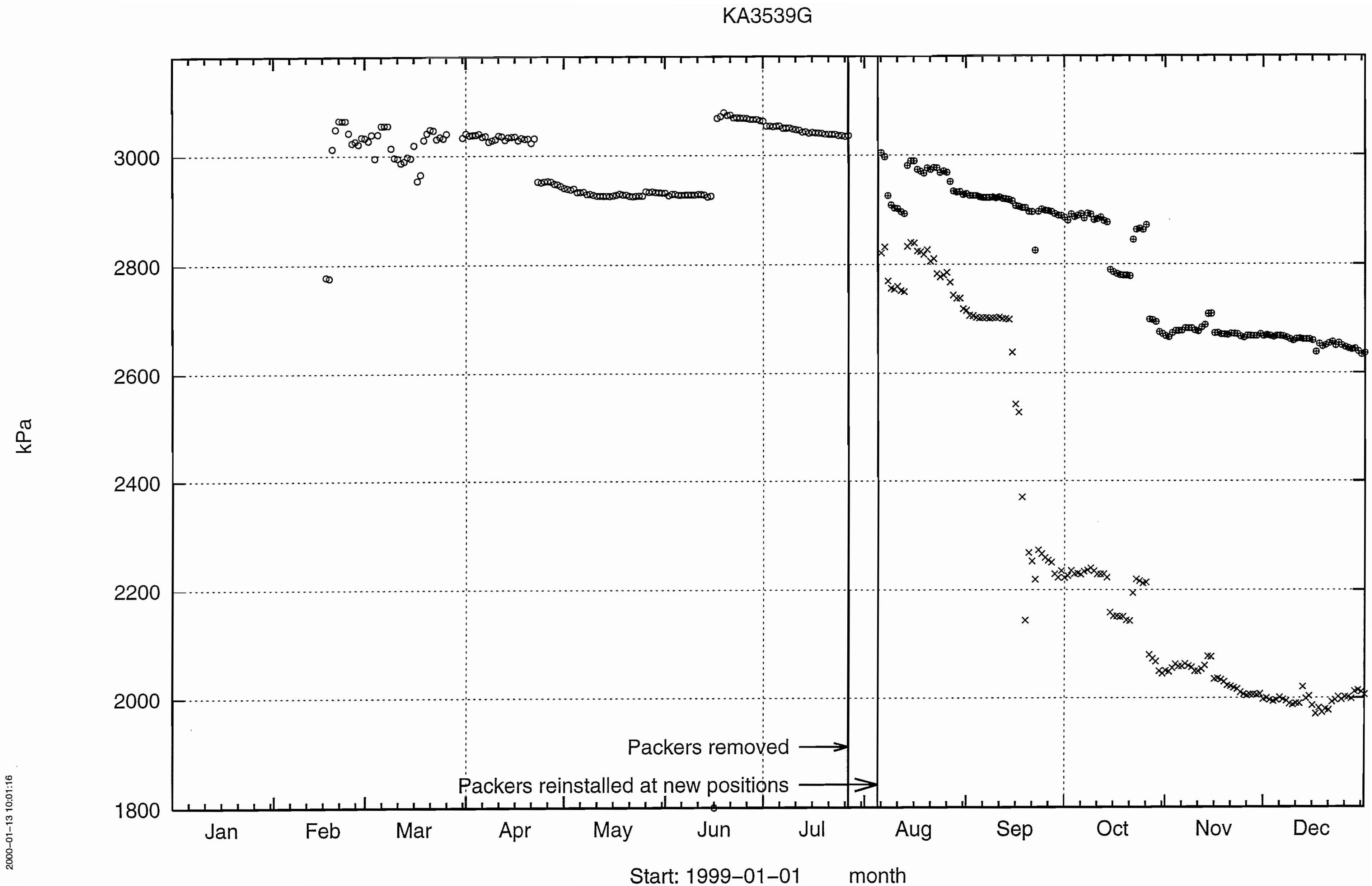
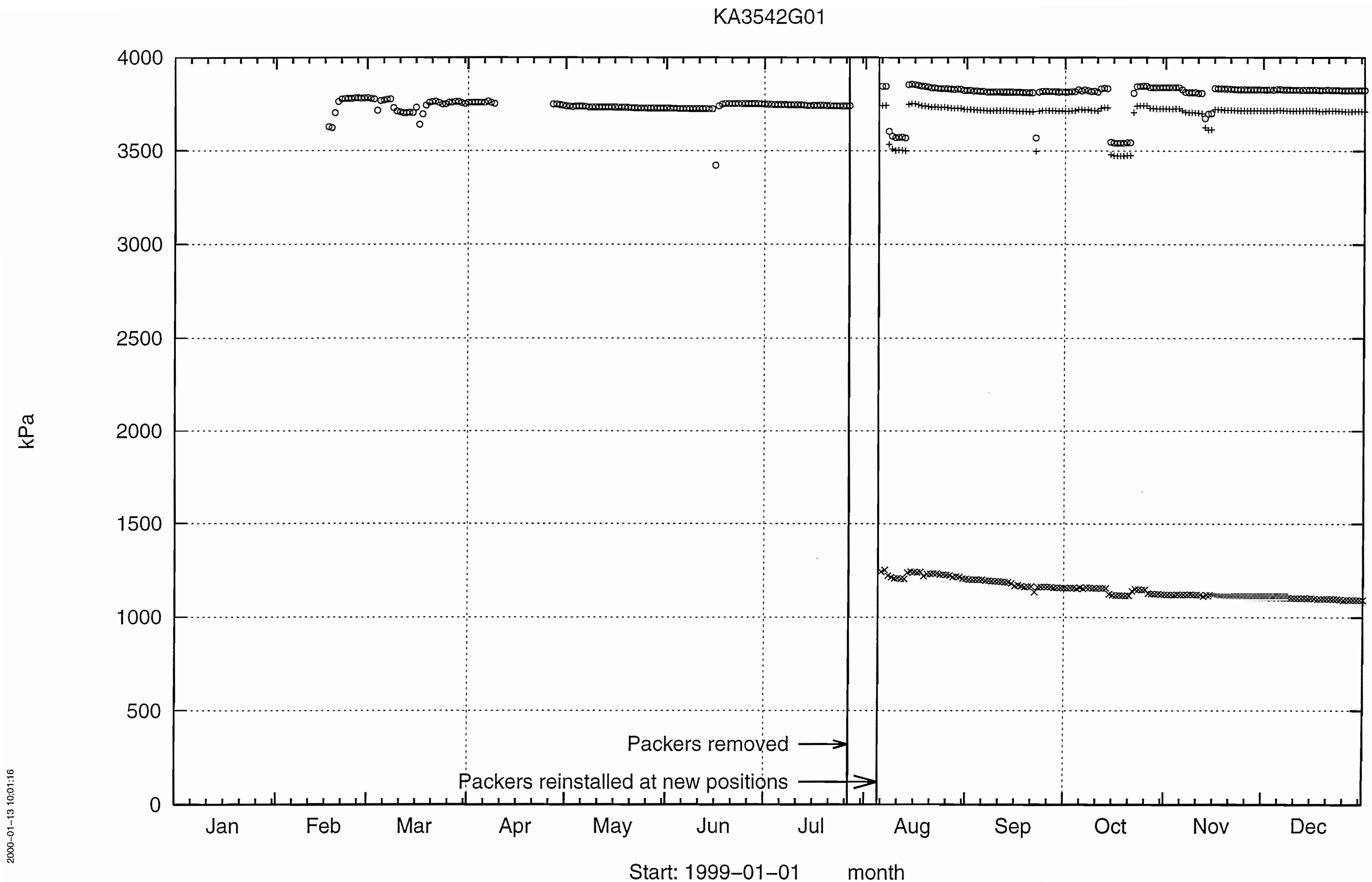
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:15



KA3539G
kPa
3000
2800
2600
2400
2200
2000
1800
Packers removed
Packers reinstalled at new positions
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:16



KA3542G01
kPa
4000
3500
3000
2500
2000
1500
1000
500
0
Packers removed
Packers reinstalled at new positions
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Feb
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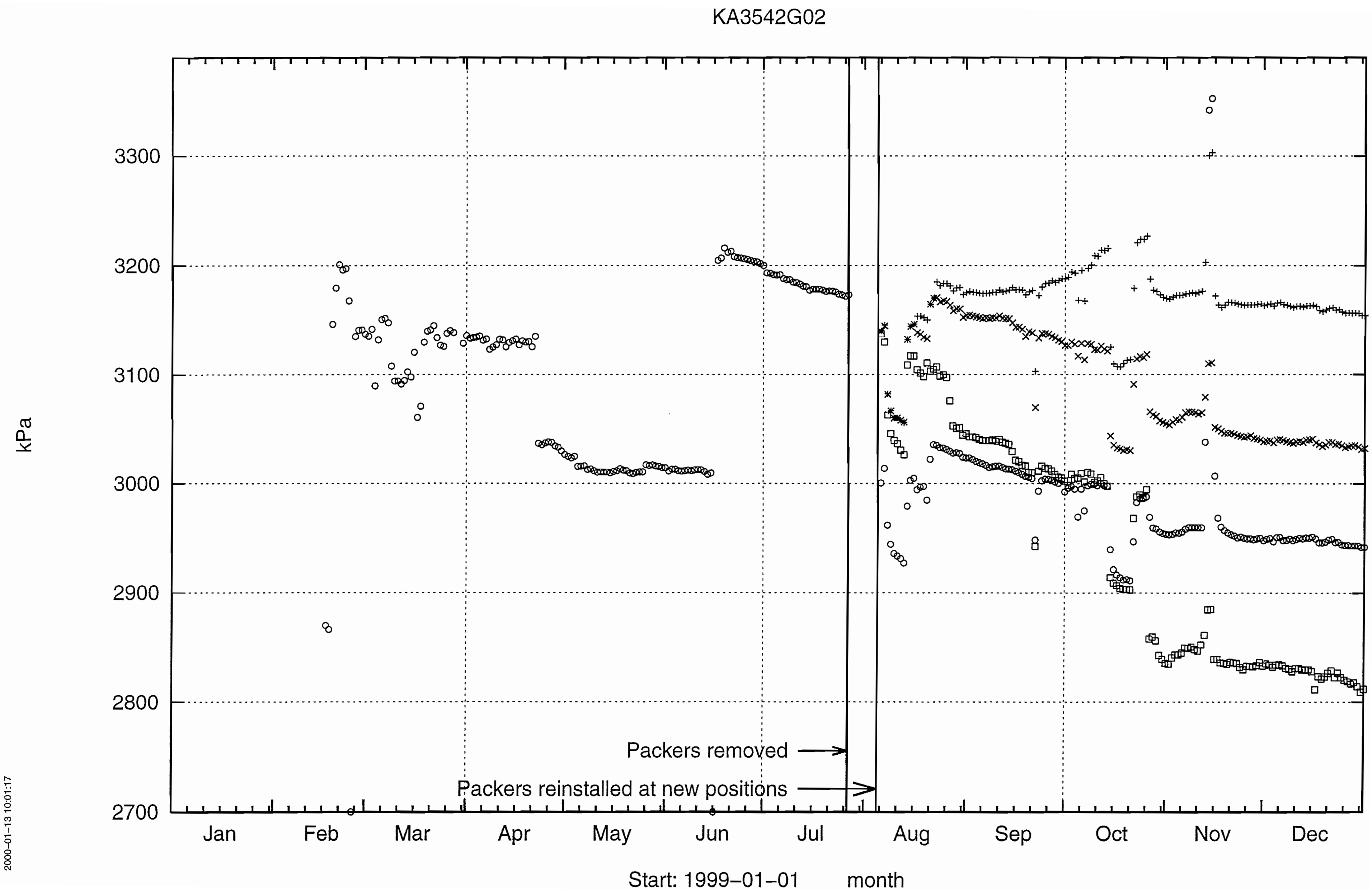
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–01–13 10:01:16


KA3542G02
kPa
3300
3200
3100
3000
2900
2800
2700
Jan
Feb
Mar
Apr
May
Jun
Jul
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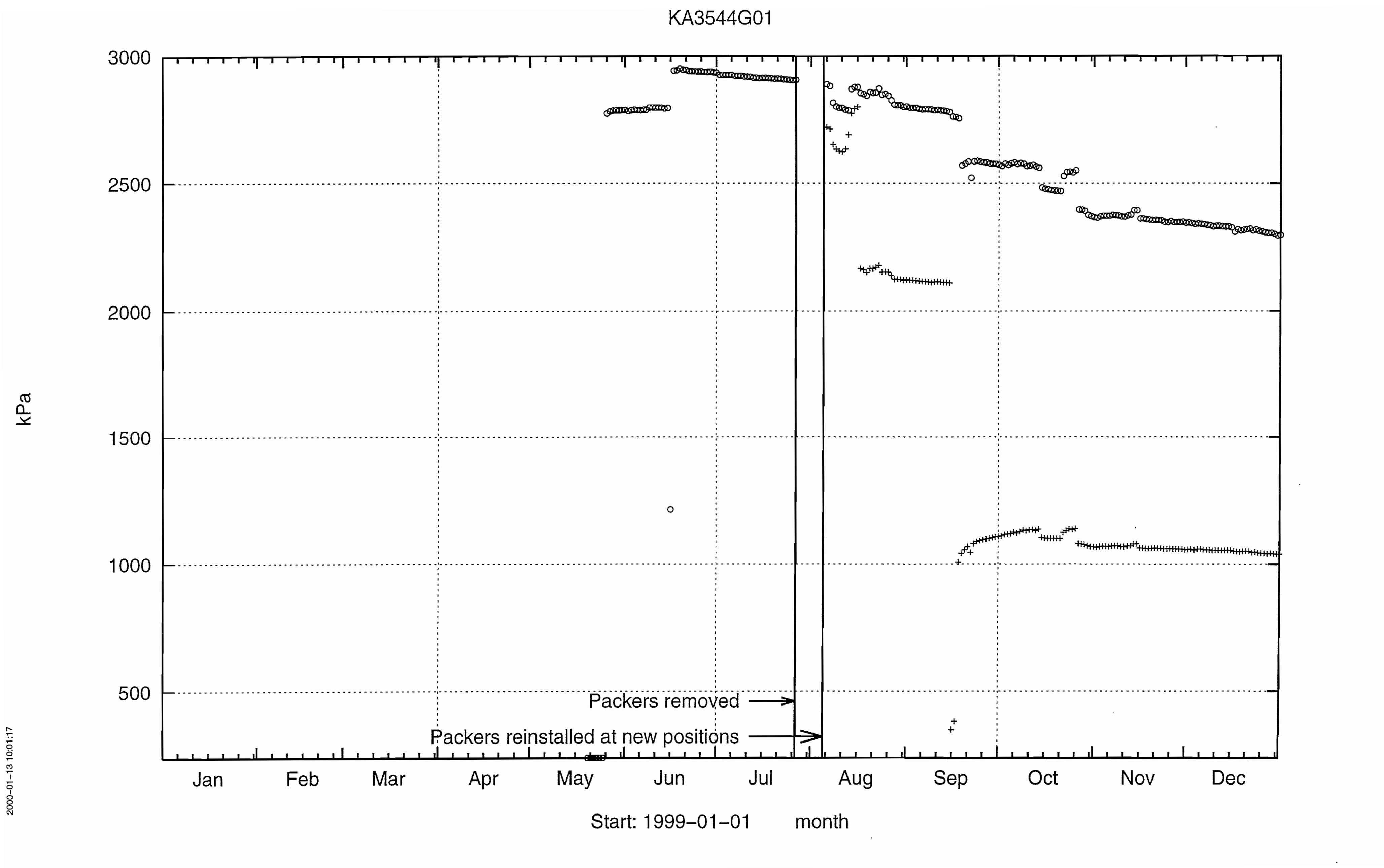
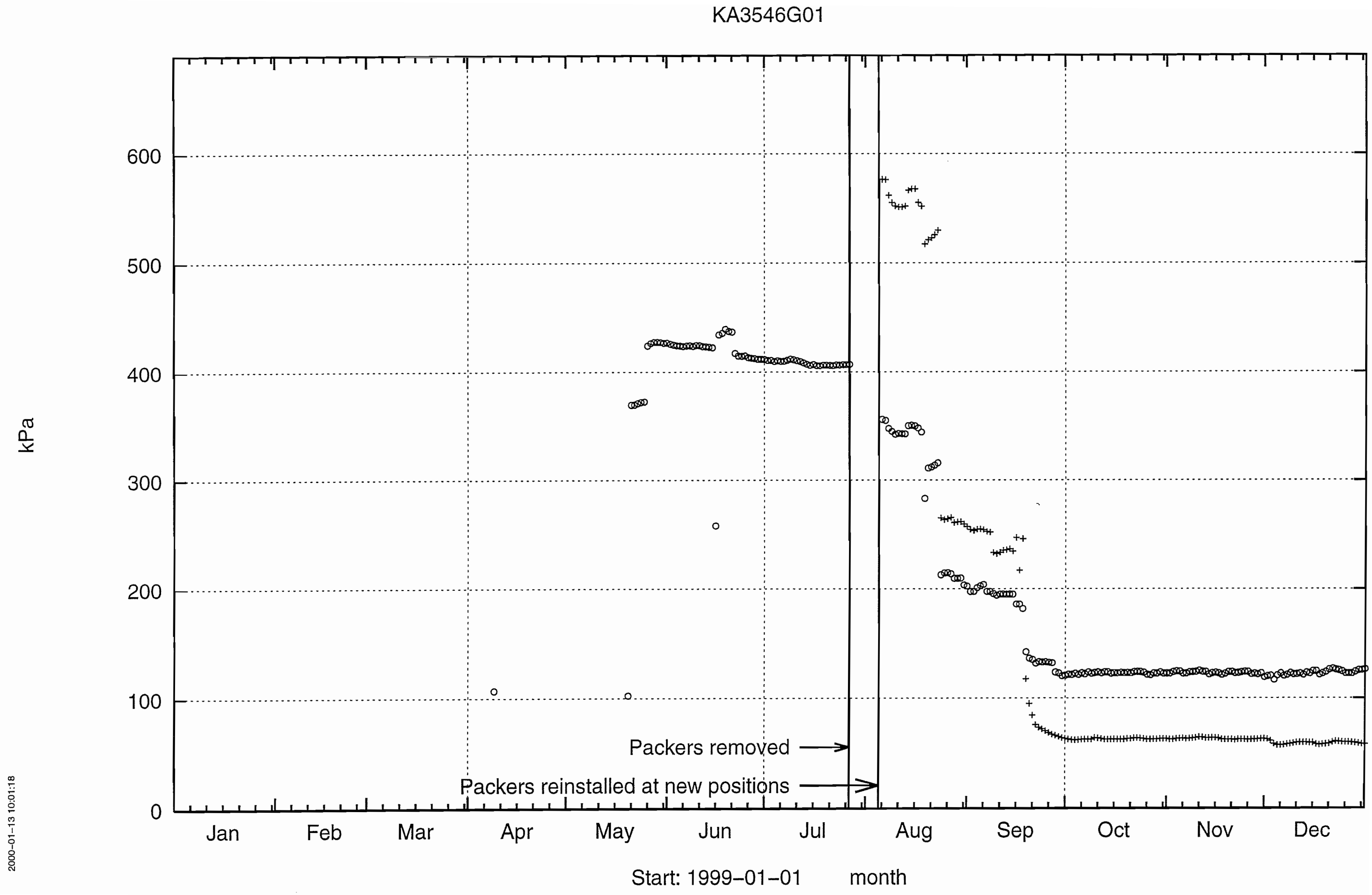
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
Packers removed
Packers reinstalled at new positions
2000-01-13 10:01:17


KA3544G01
3000
2500
2000
1500
1000
500
kPa
Packers removed
Packers reinstalled at new positions
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:17


KA3546G01
kPa
600
500
400
300
200
100
0
Packers removed
Packers reinstalled at new positions
Jan
Feb
Mar
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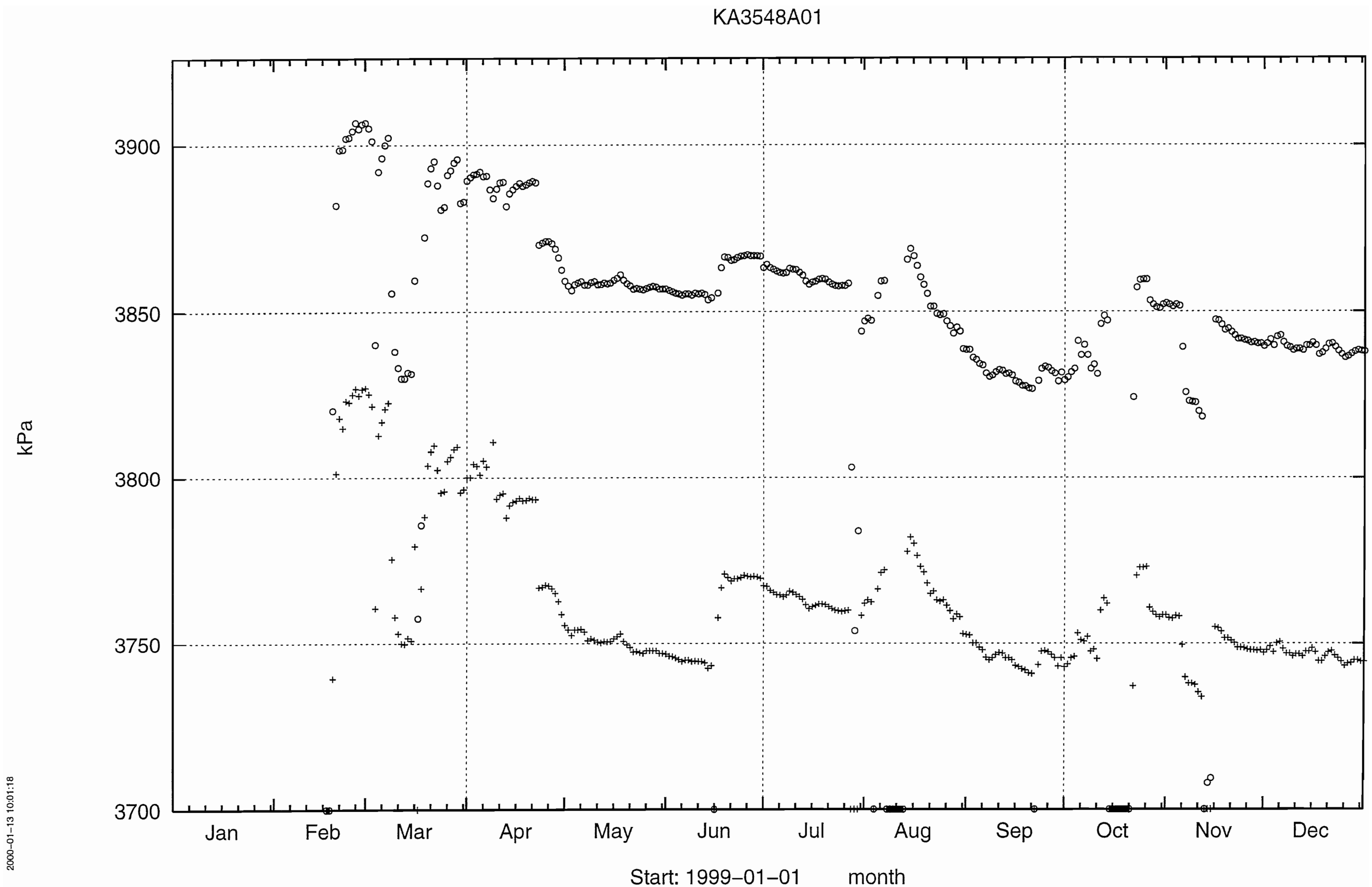
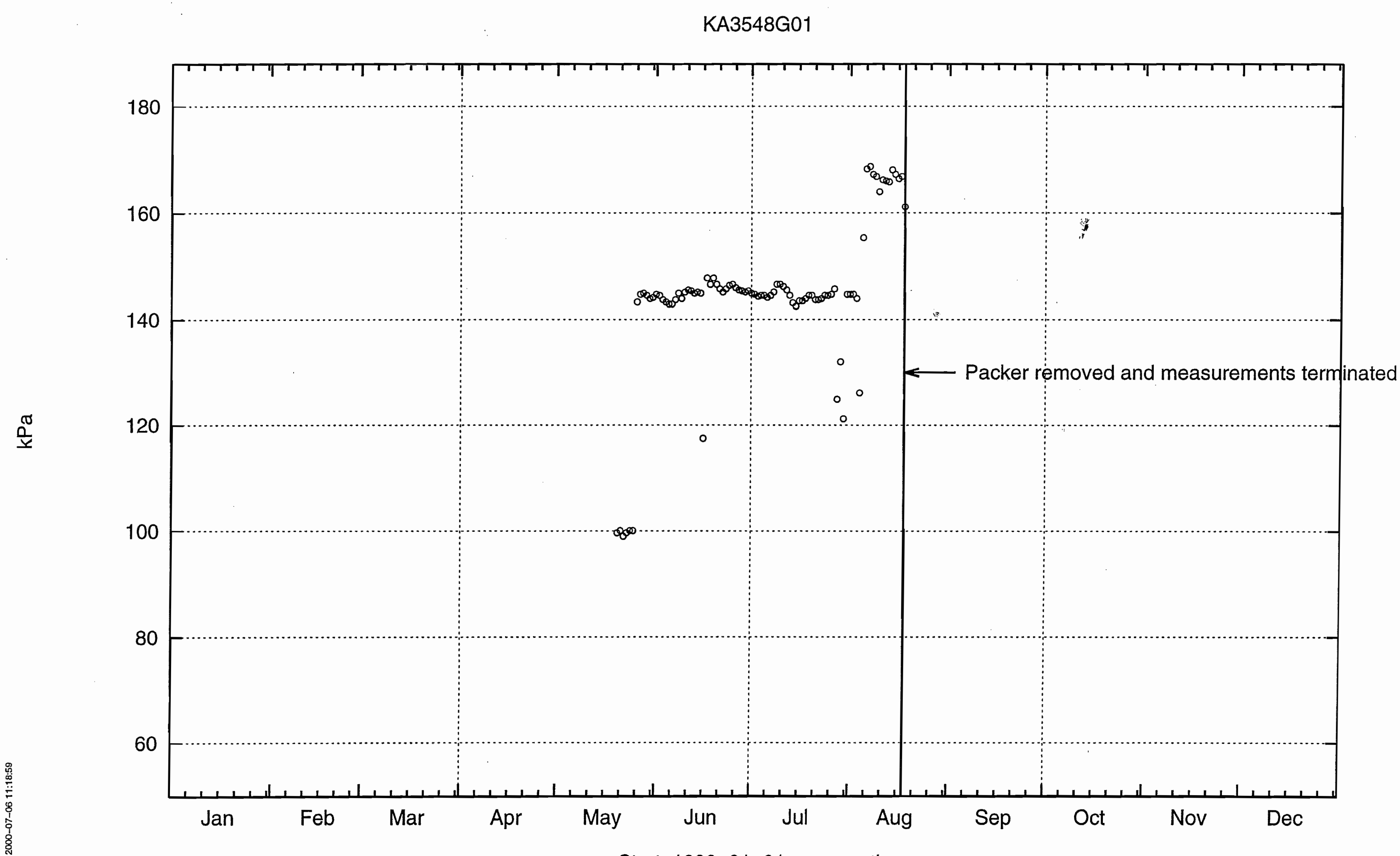
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:18



KA3548A01
kPa
3900
3850
3800
3750
3700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:18


KA3548G01
kPa
180
160
140
120
100
80
60
Packer removed and measurements terminated
Jan
Feb
Mar
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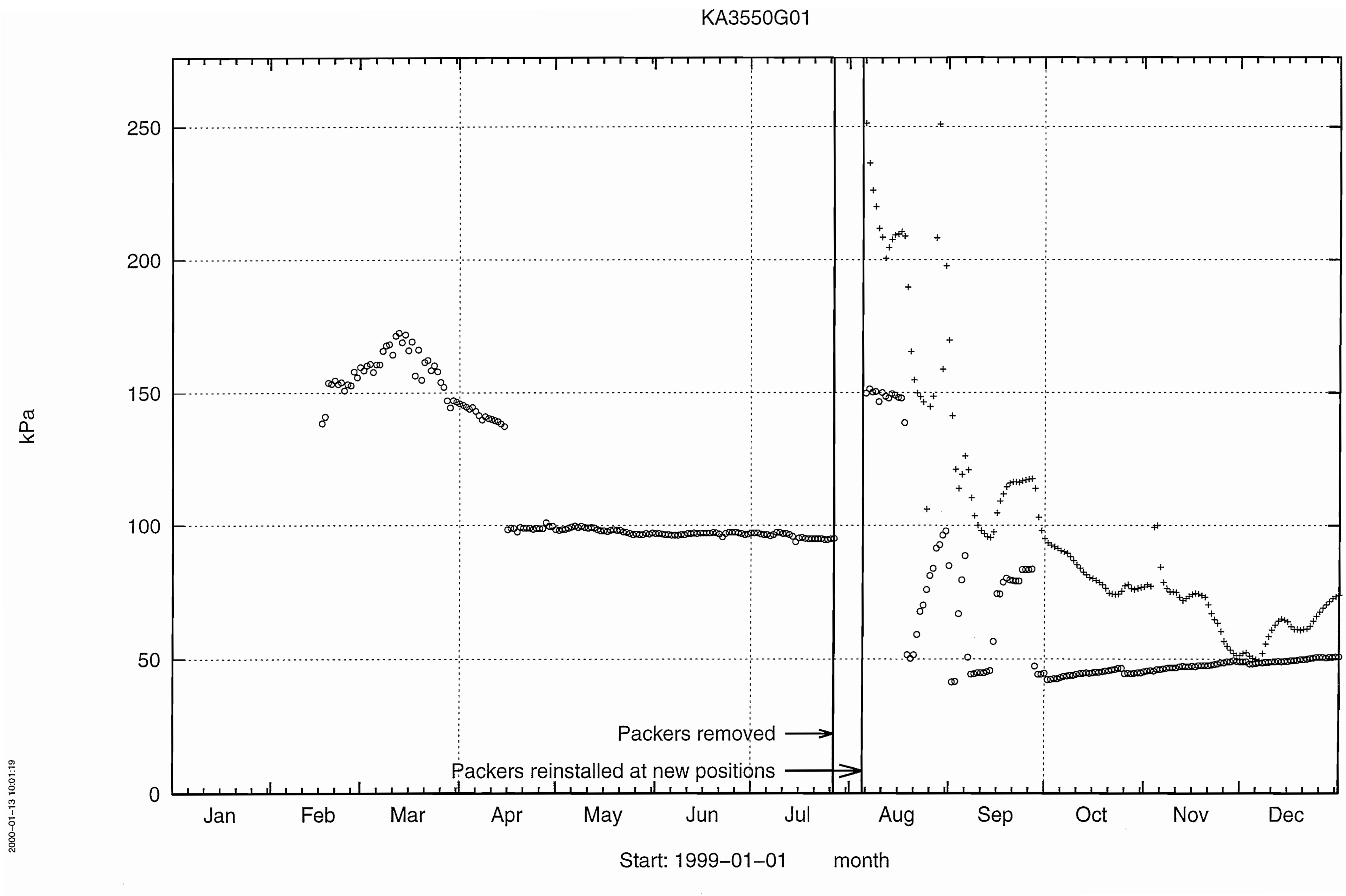
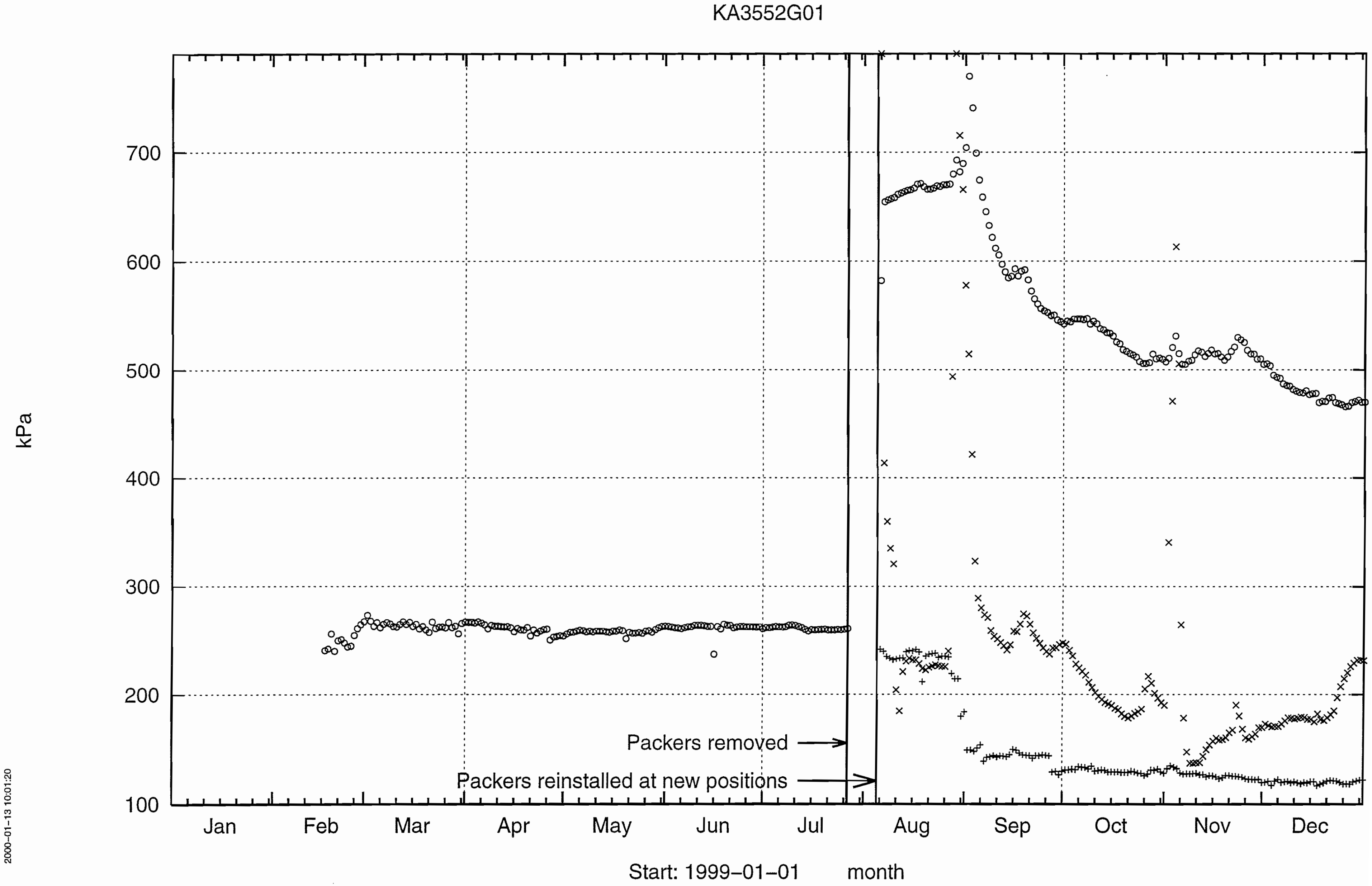
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-07-06 11:18:59



KA3550G01
kPa
250
200
150
100
50
0
Packers removed
Packers reinstalled at new positions
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:19



KA3552G01
kPa
700
600
500
400
300
200
100
Packers removed
Packers reinstalled at new positions
Jan
Feb
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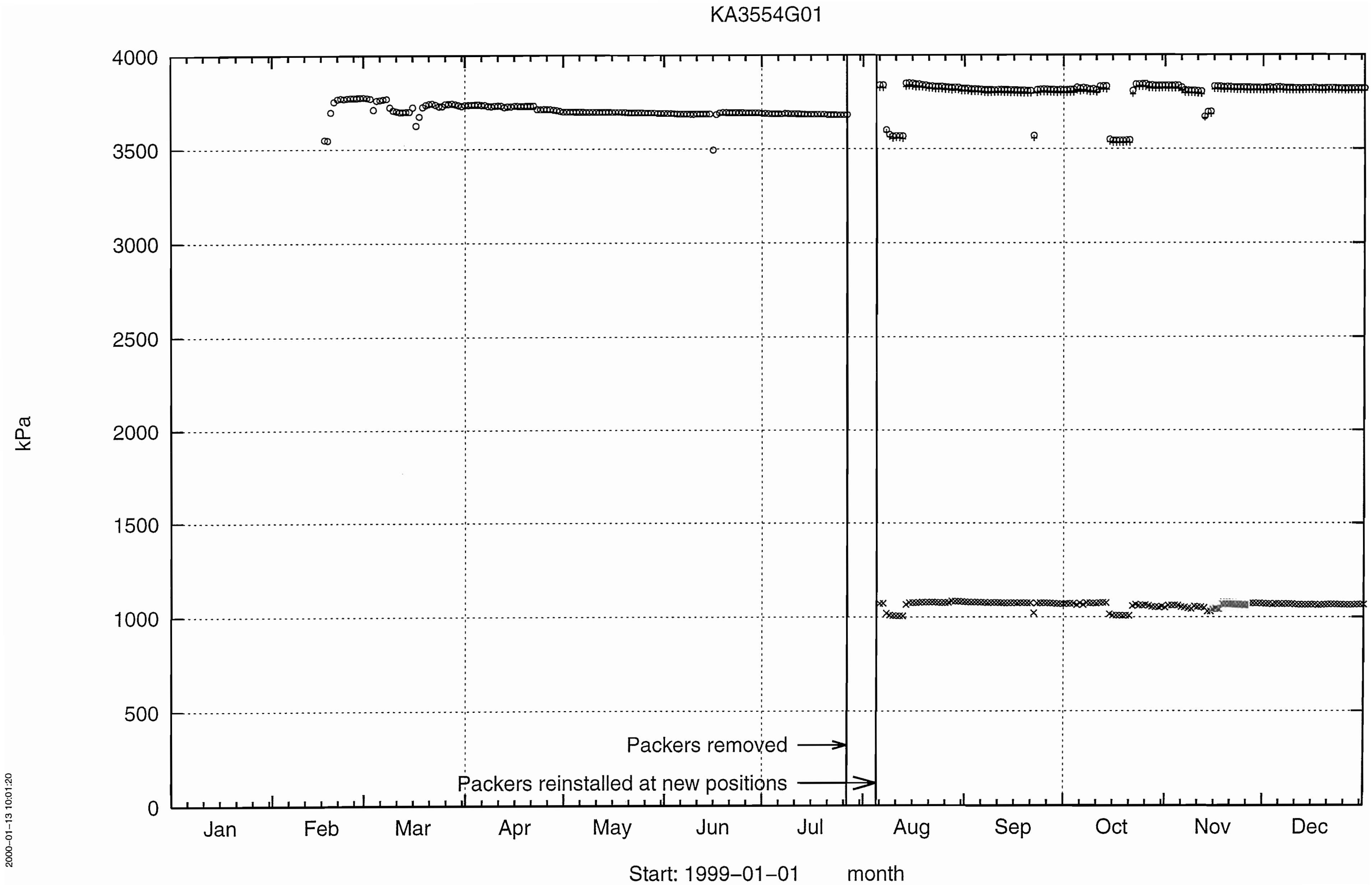
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:20



KA3554G01
kPa
4000
3500
3000
2500
2000
1500
1000
500
0
Packers removed
Packers reinstalled at new positions
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Feb
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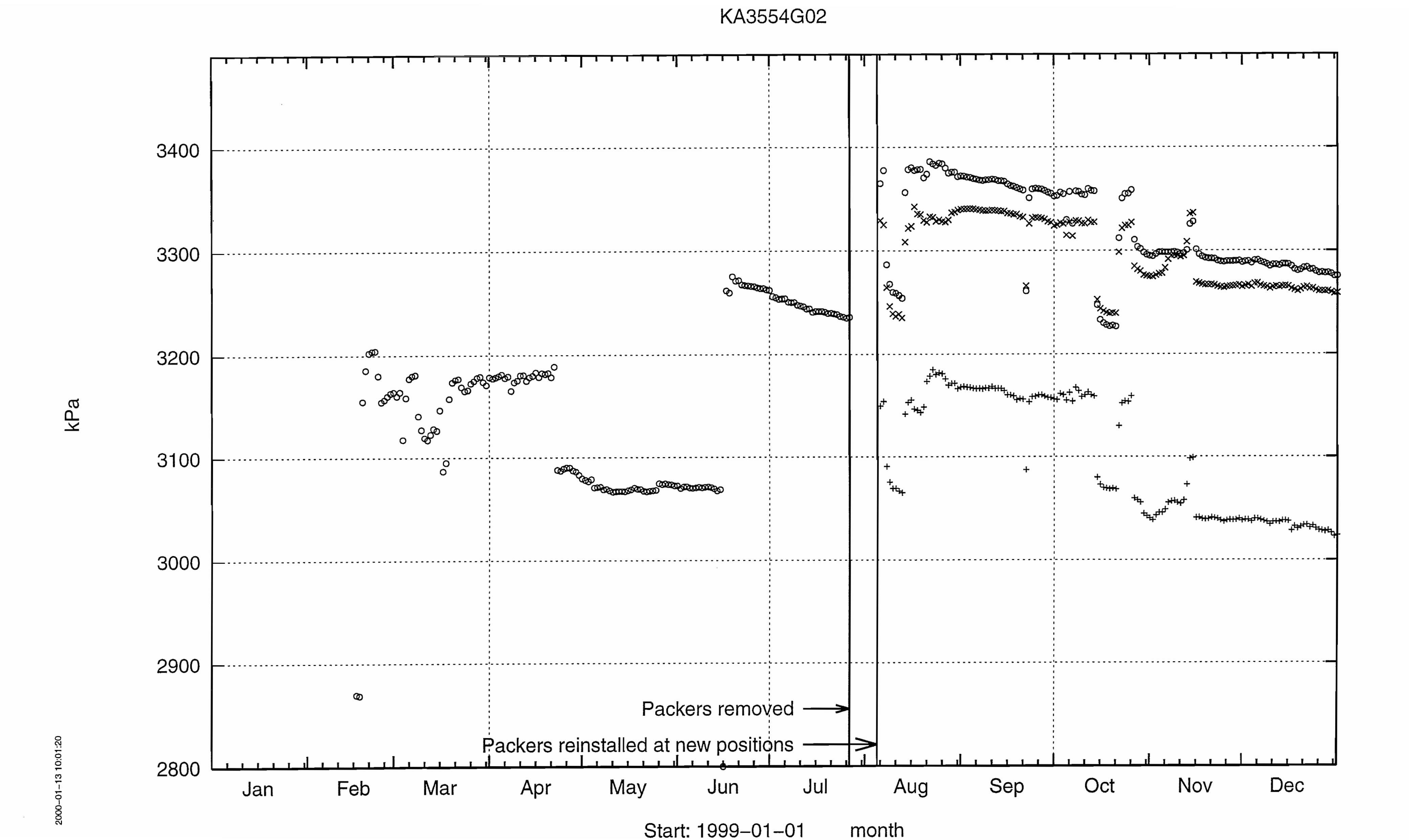
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–01–13 10:01:20



KA3554G02
kPa
3400
3300
3200
3100
3000
2900
2800
Packers removed
Packers reinstalled at new positions
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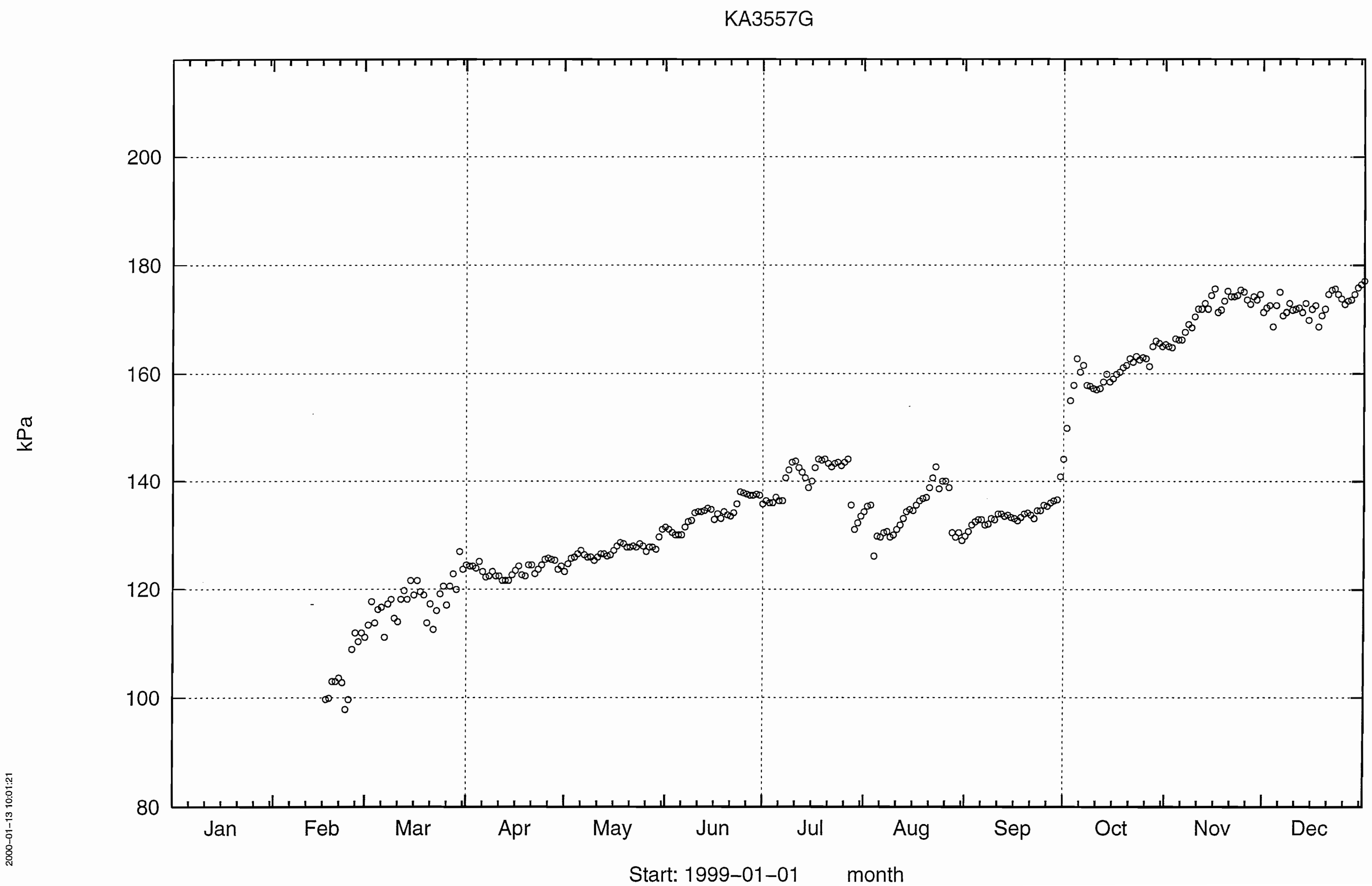
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:20


KA3557G
kPa
200
180
160
140
120
100
80
Jan
Feb
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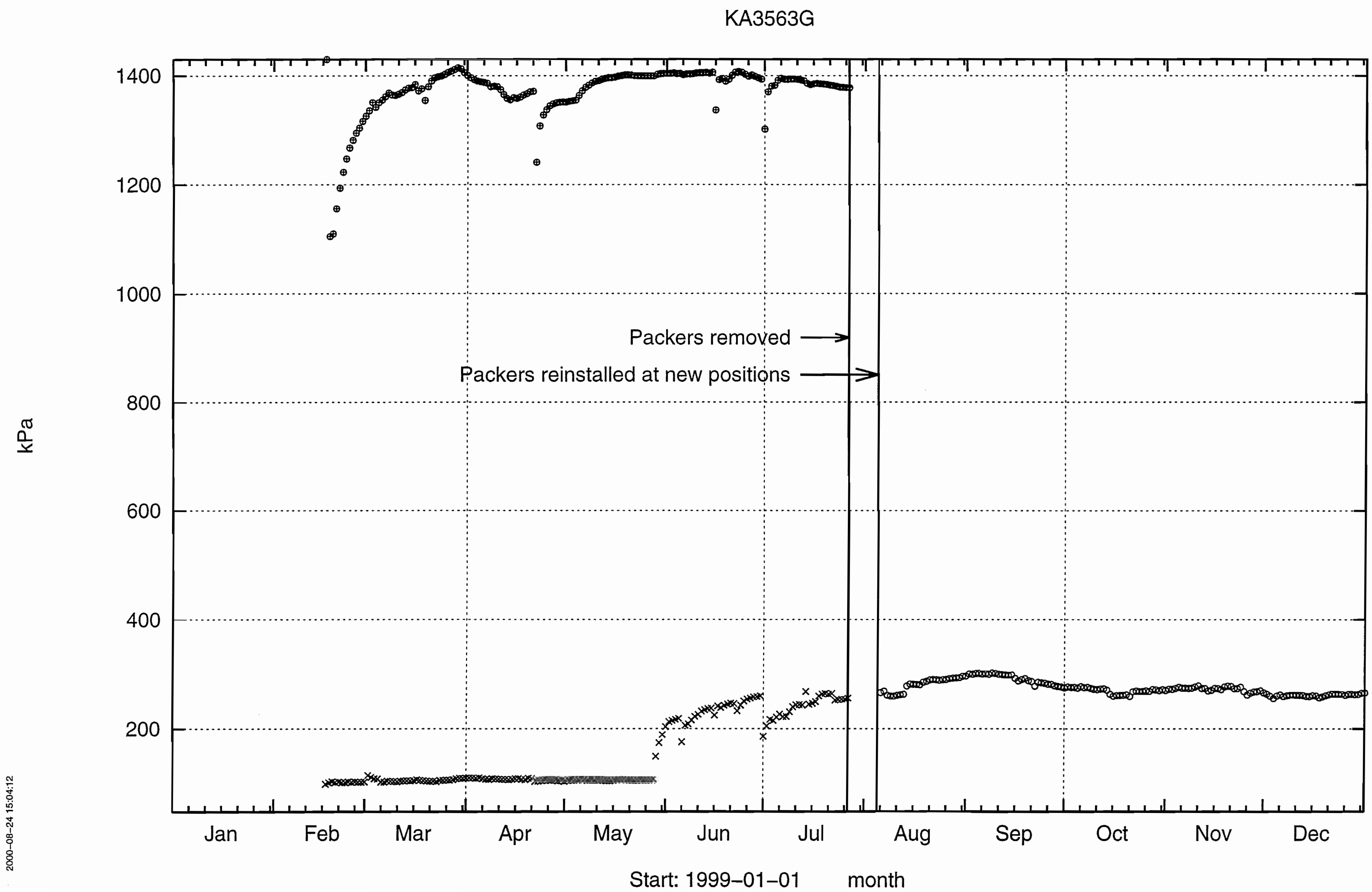
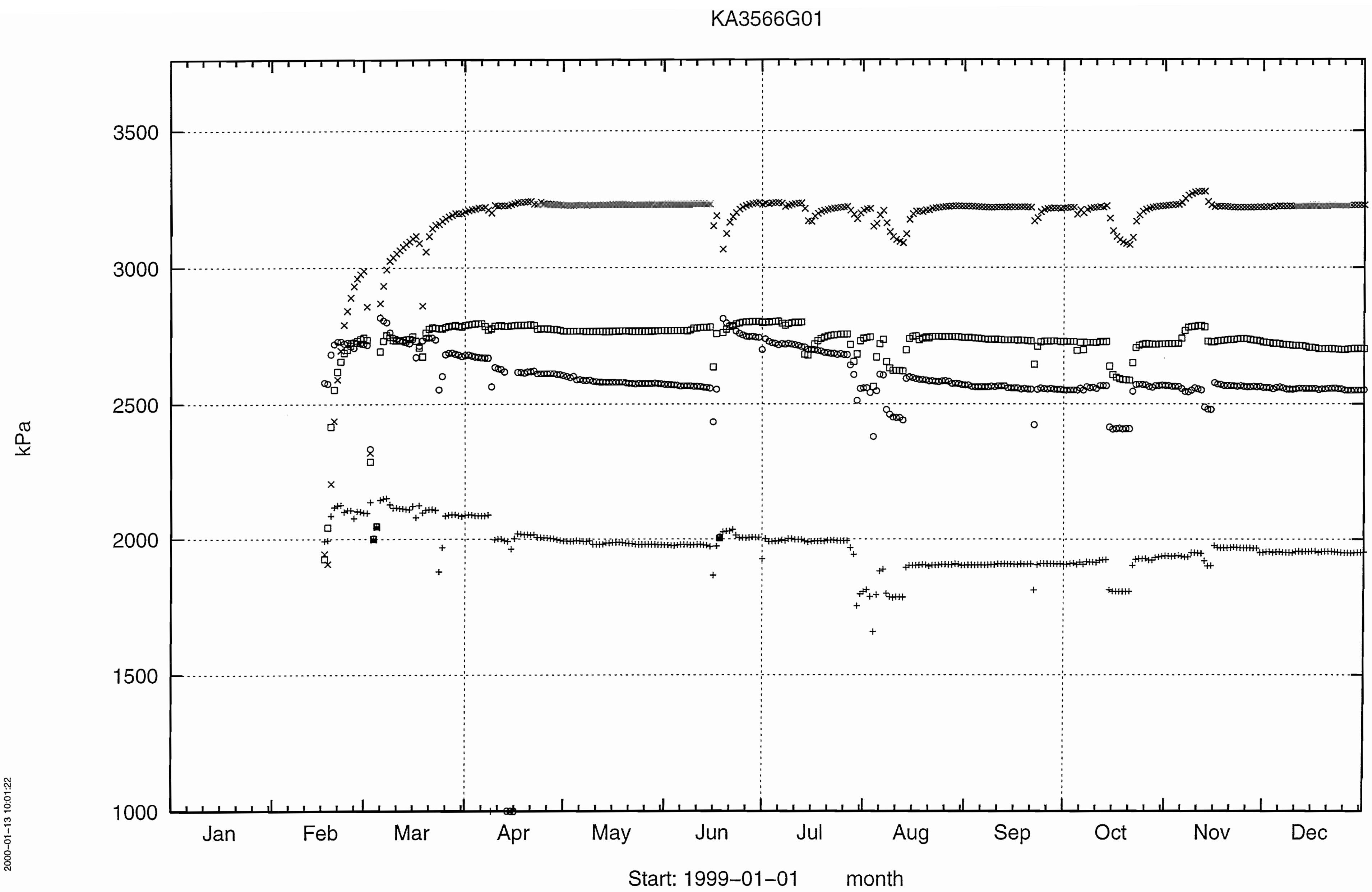
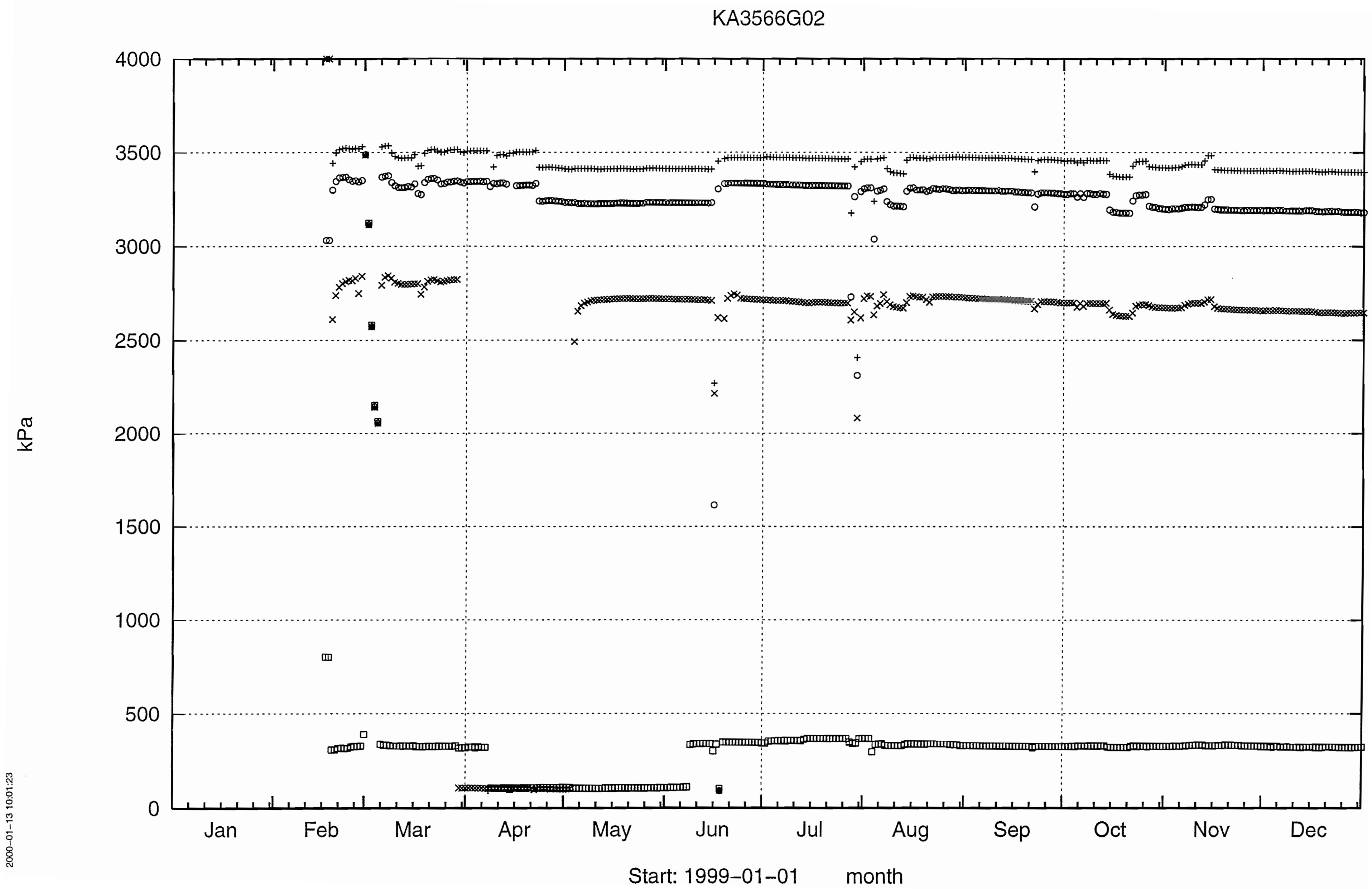
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:21



KA3563G
kPa
1400
1200
1000
800
600
400
200
Packers removed
Packers reinstalled at new positions
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-08-24 15:04:12


KA3566G01
kPa
3500
3000
2500
2000
1500
1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:22


KA3566G02
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3500
3000
2500
2000
1500
1000
500
0
kPa
Jan
Feb
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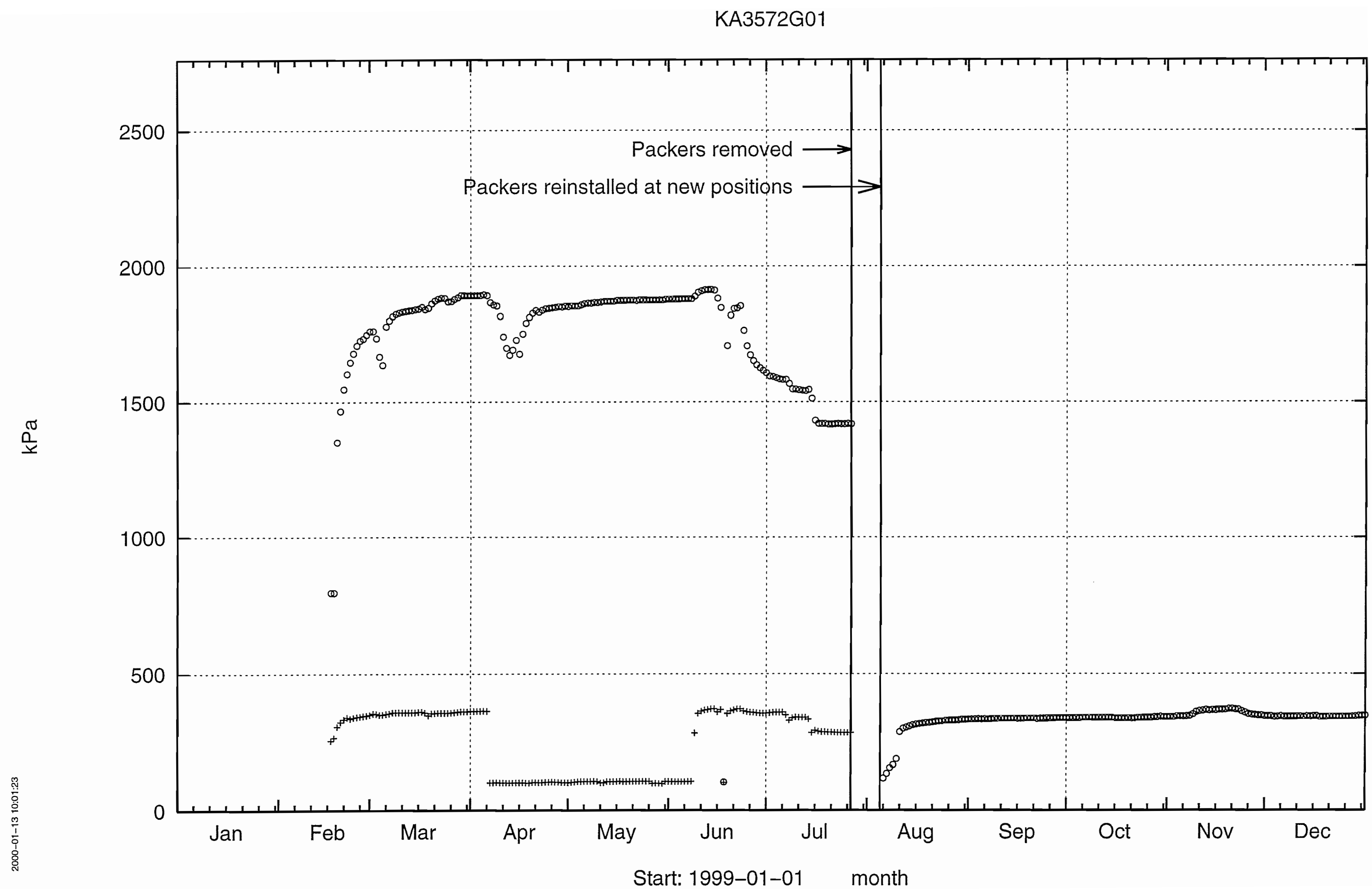
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:23


KA3572G01
kPa
2500
2000
1500
1000
500
0
Packers removed
Packers reinstalled at new positions
Jan
Feb
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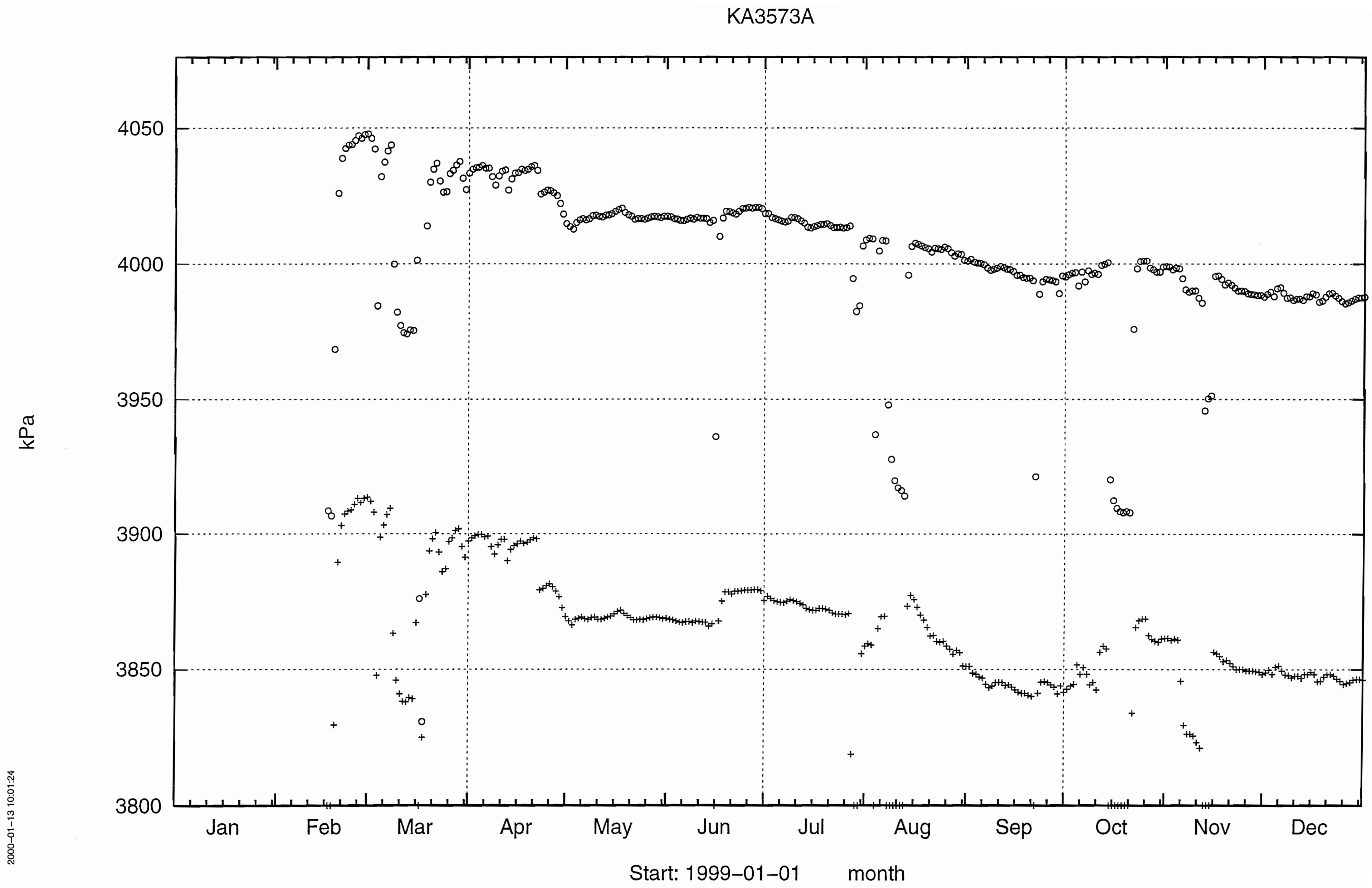
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:23


KA3573A
kPa
4050
4000
3950
3900
3850
3800
Jan
Feb
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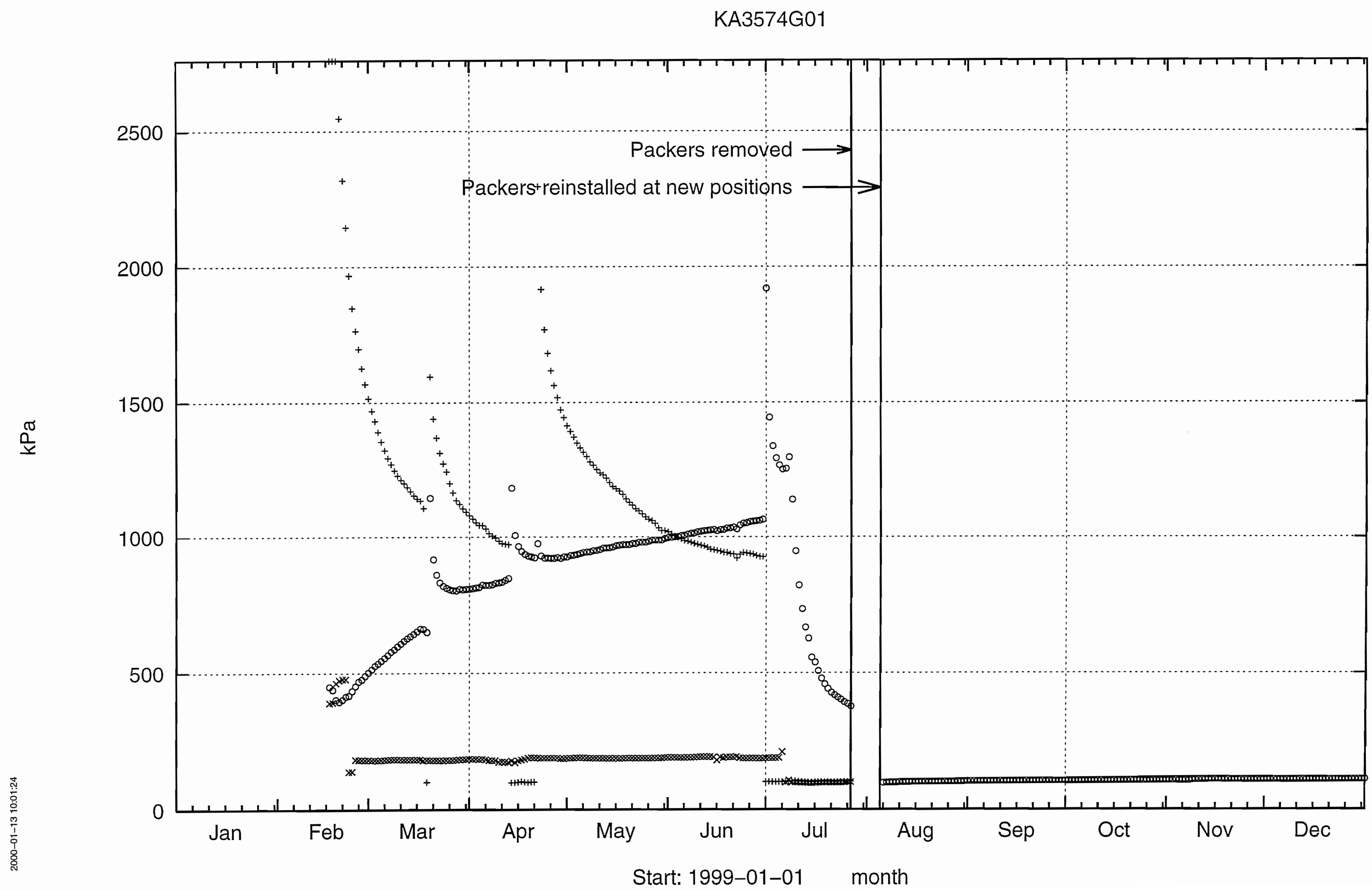
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:24


KA3574G01
kPa
0
500
1000
1500
2000
2500
Packers removed
Packers reinstalled at new positions
Jan
Feb
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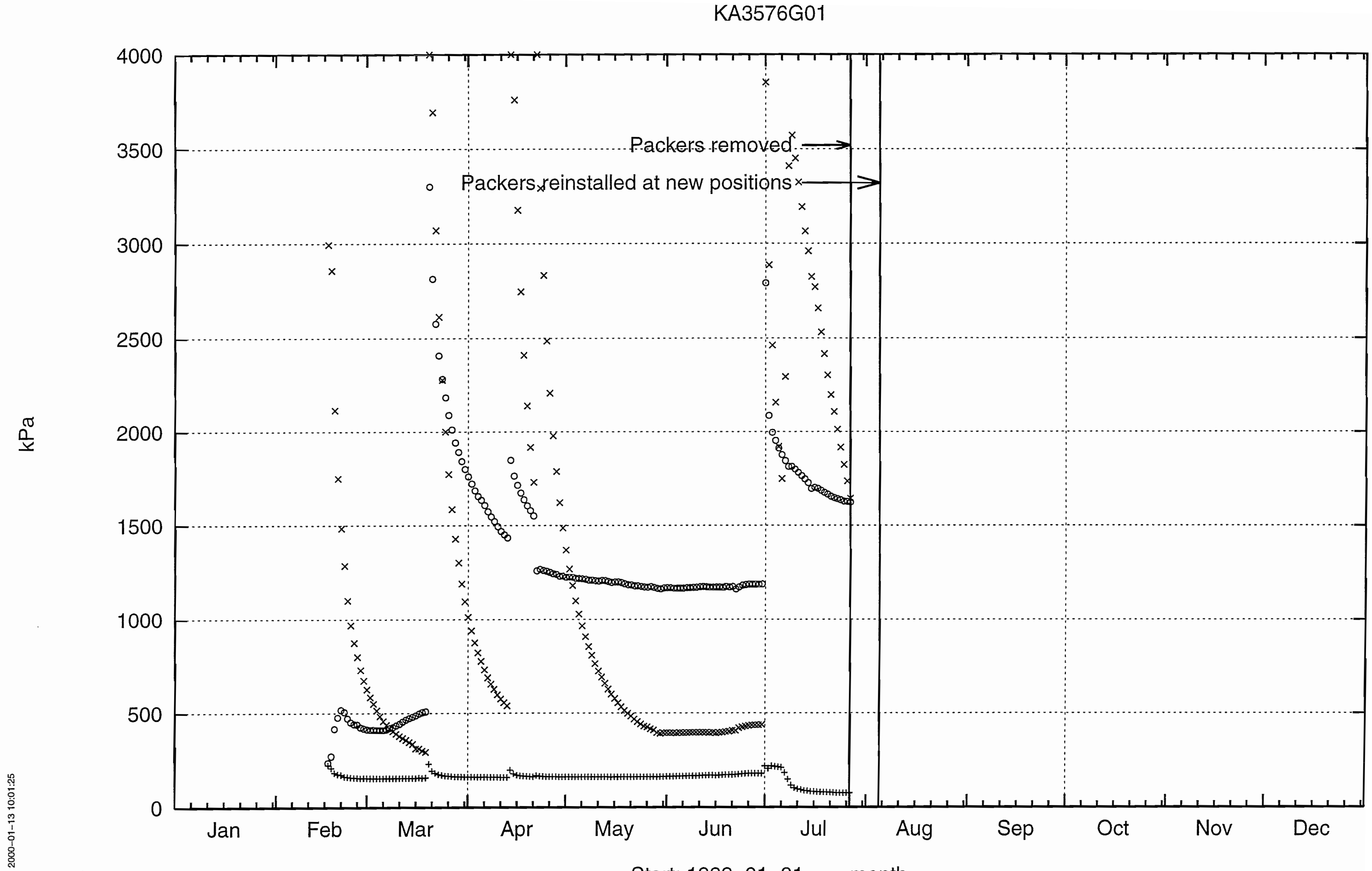
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:24



KA3576G01
kPa
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3500
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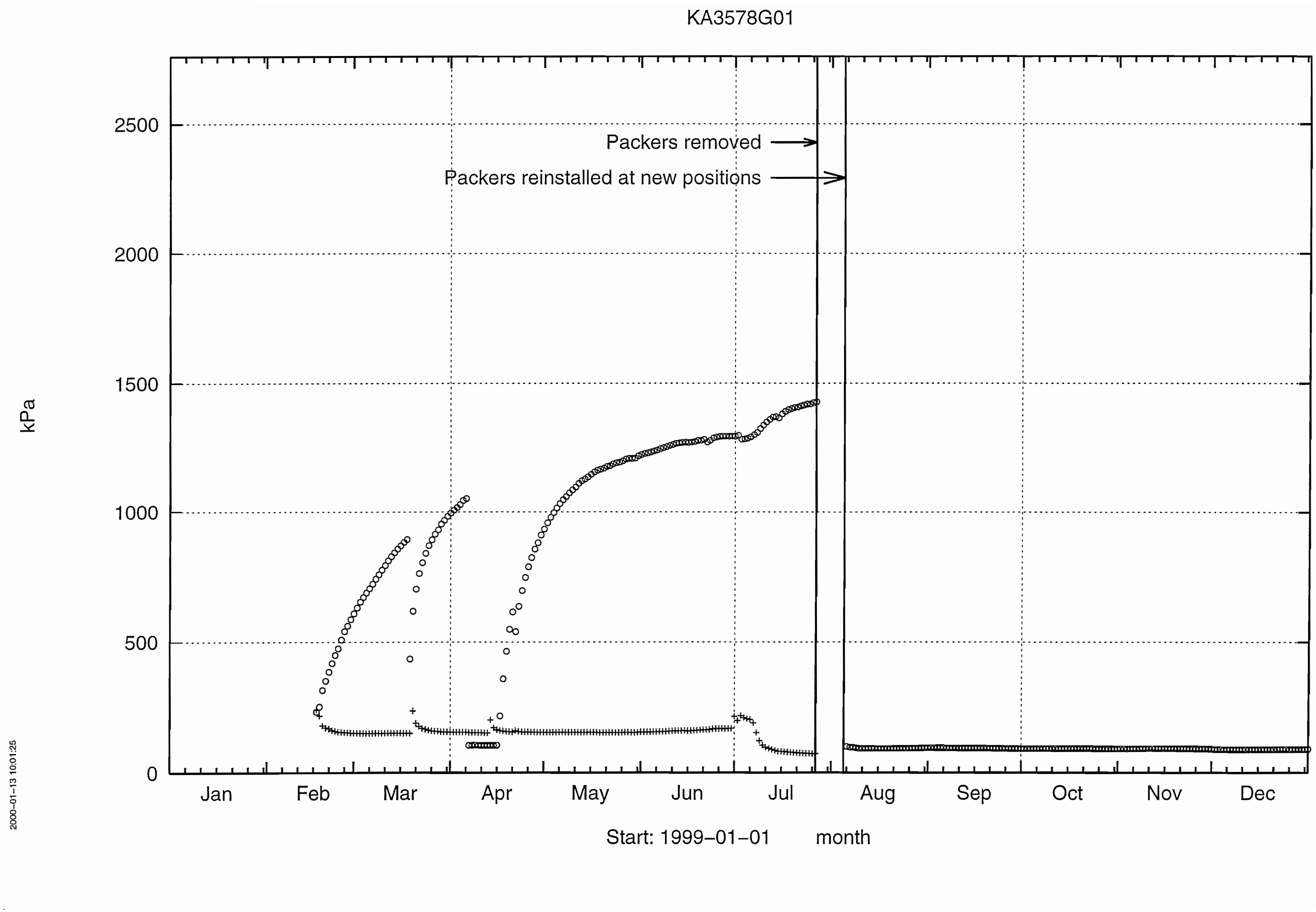
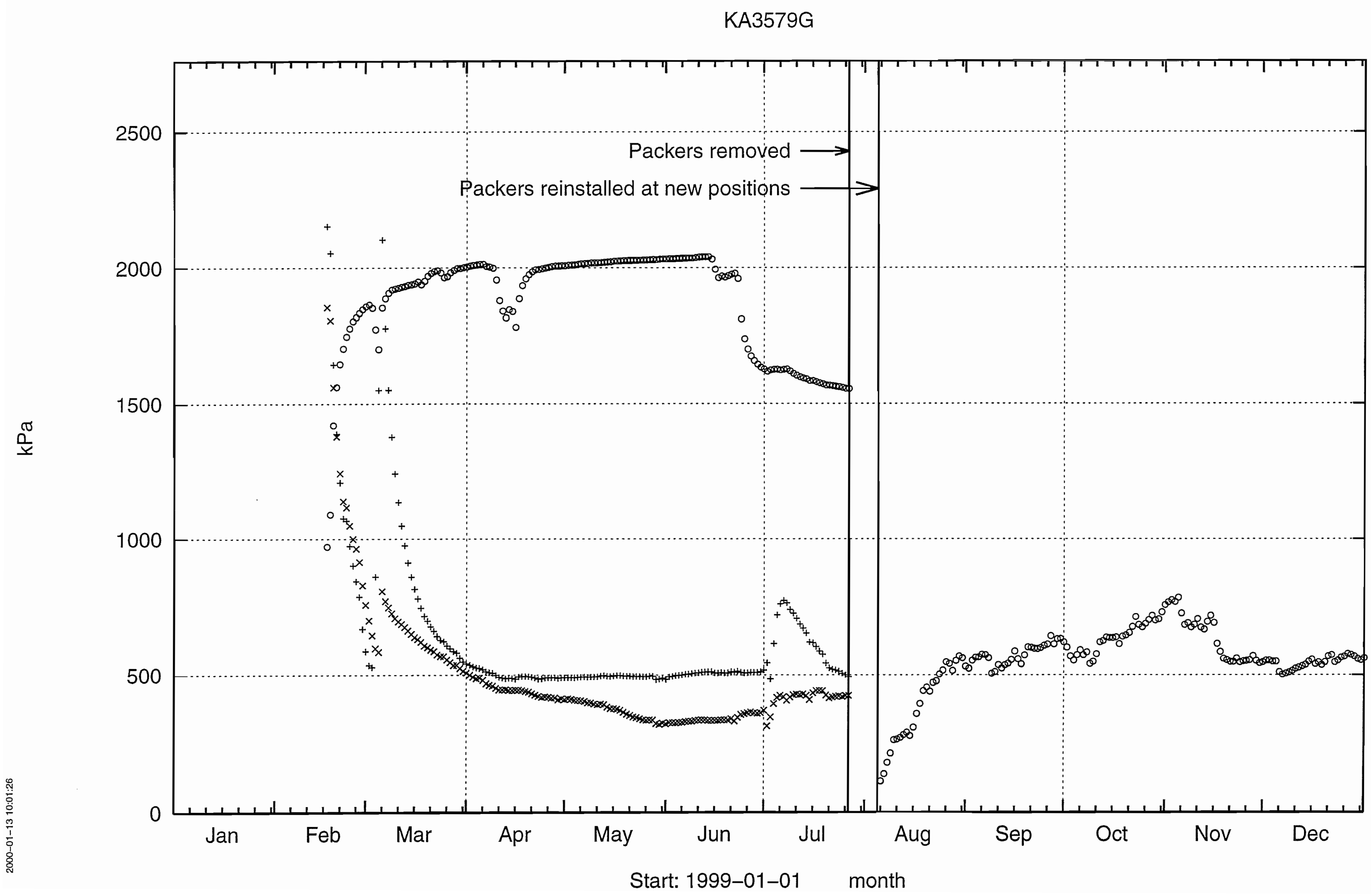
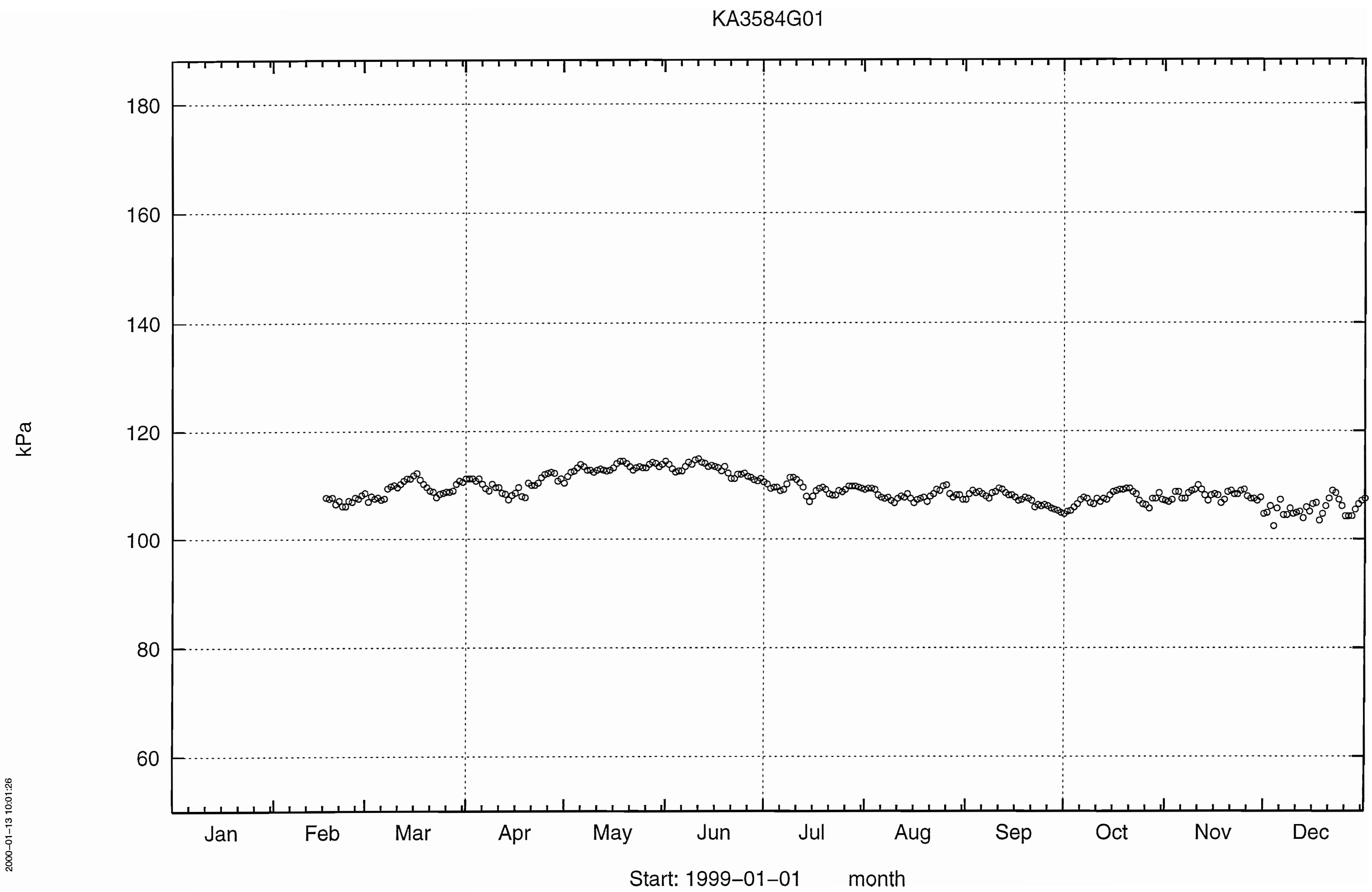
2500
2000
1500
1000
500
0
Packers removed
Packers reinstalled at new positions
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:25

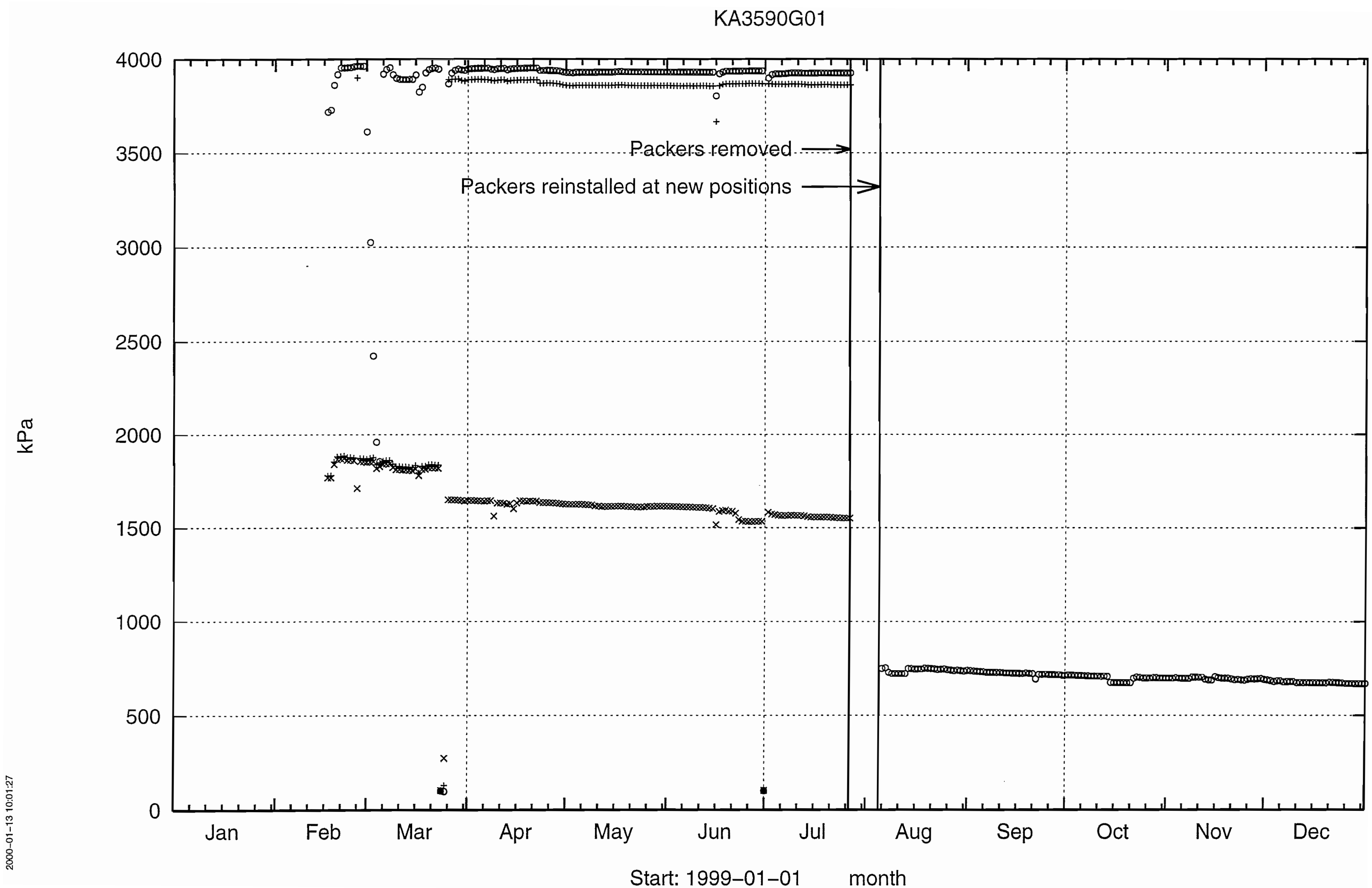


KA3578G01
Packers removed
Packers reinstalled at new positions
kPa
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:25

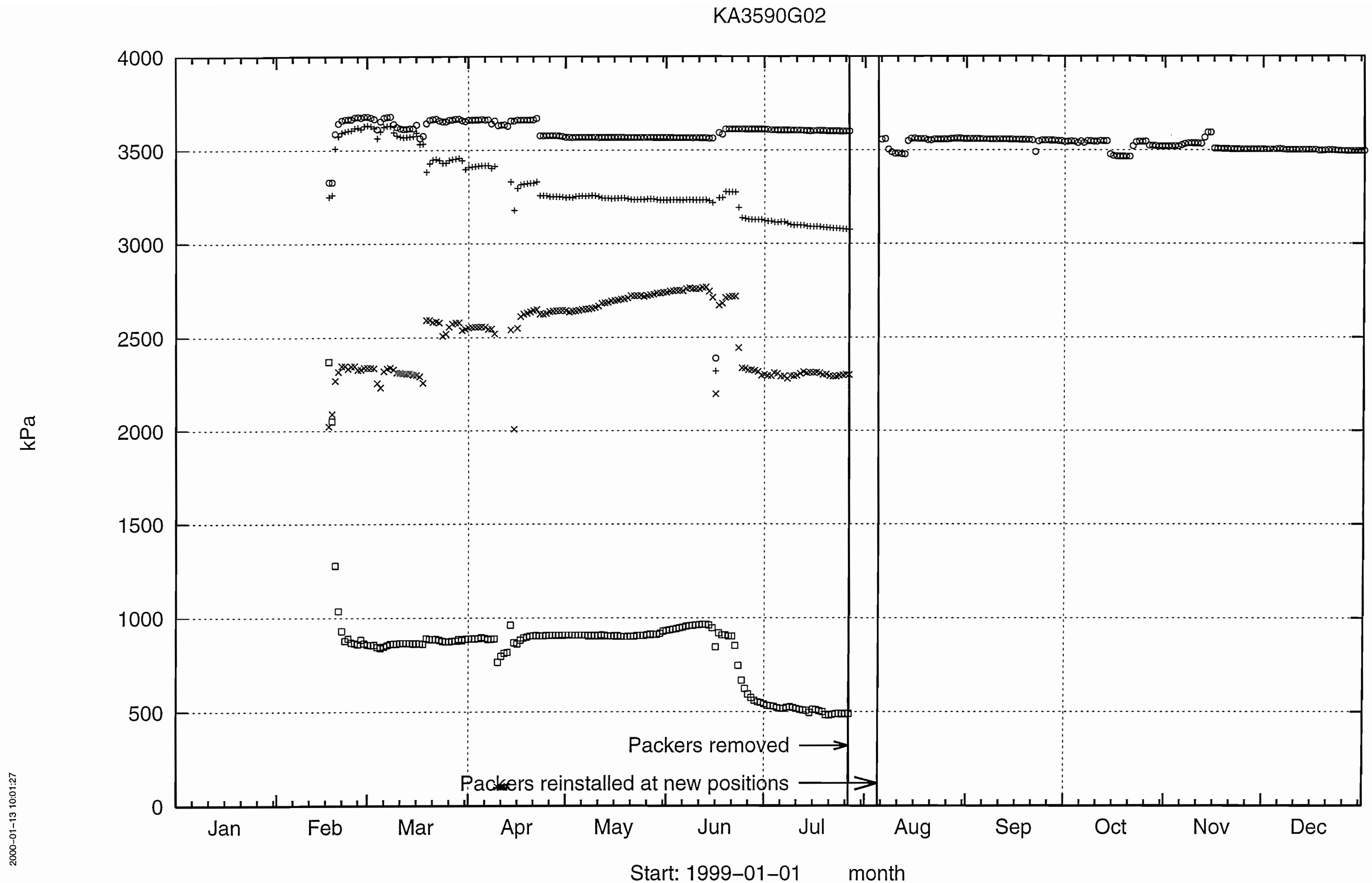

KA3579G
Packers removed
Packers reinstalled at new positions
kPa
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−01−13 10:01:26



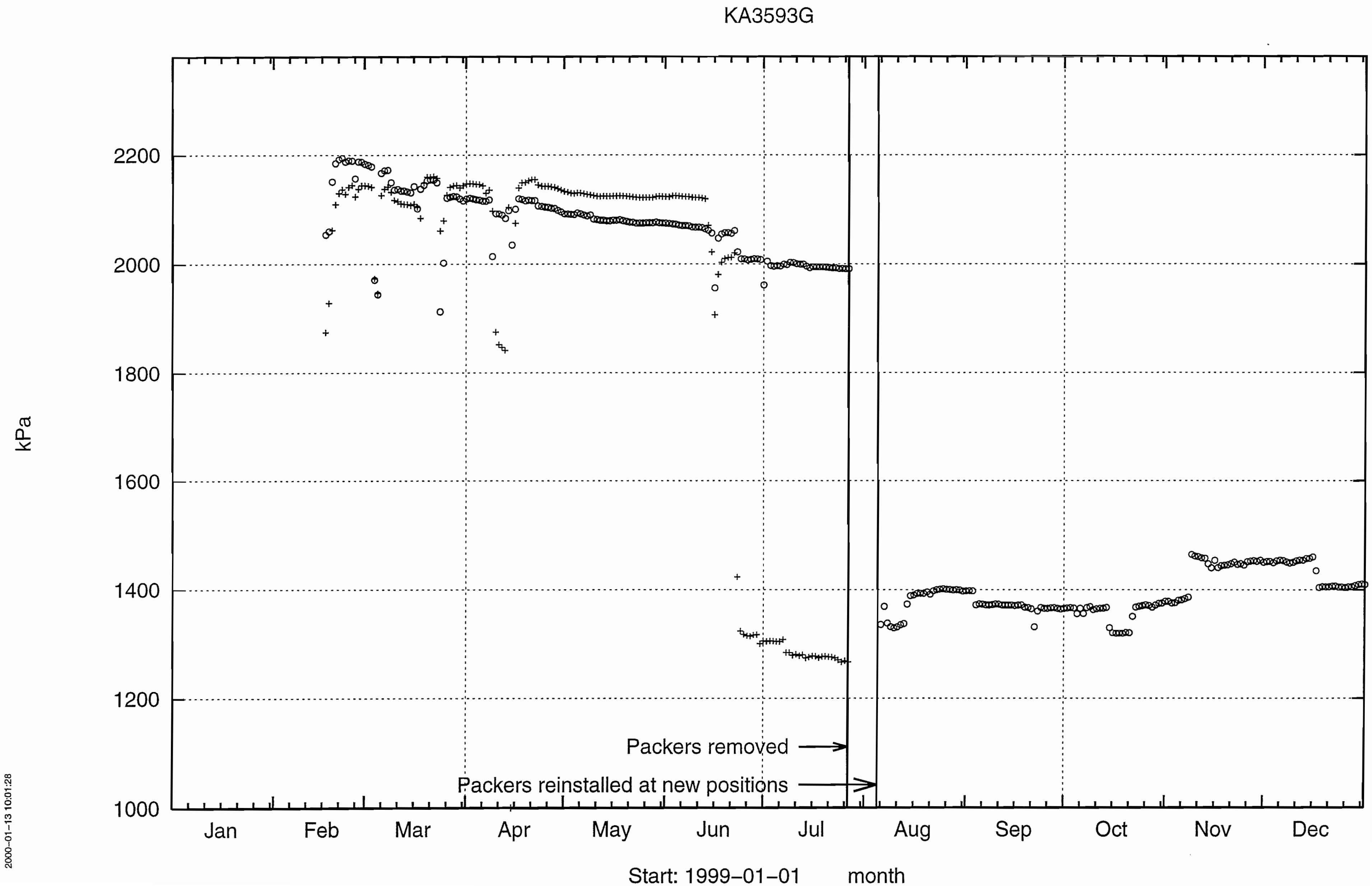
KA3584G01
kPa
180
160
140
120
100
80
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:26

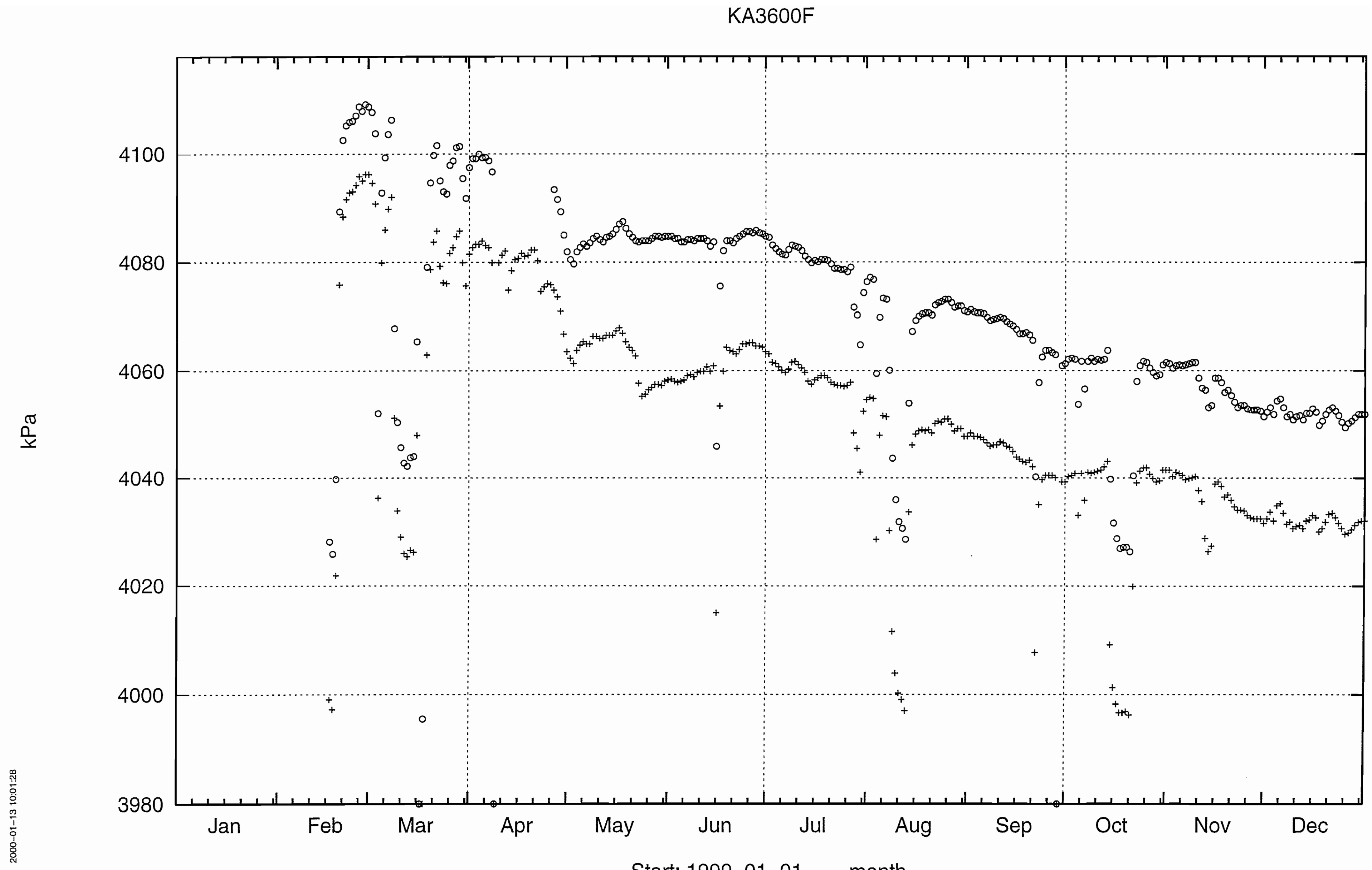


KA3590G01
kPa
4000
3500
3000
2500
2000
1500
1000
500
0
Packers removed
Packers reinstalled at new positions
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–01–13 10:01:27

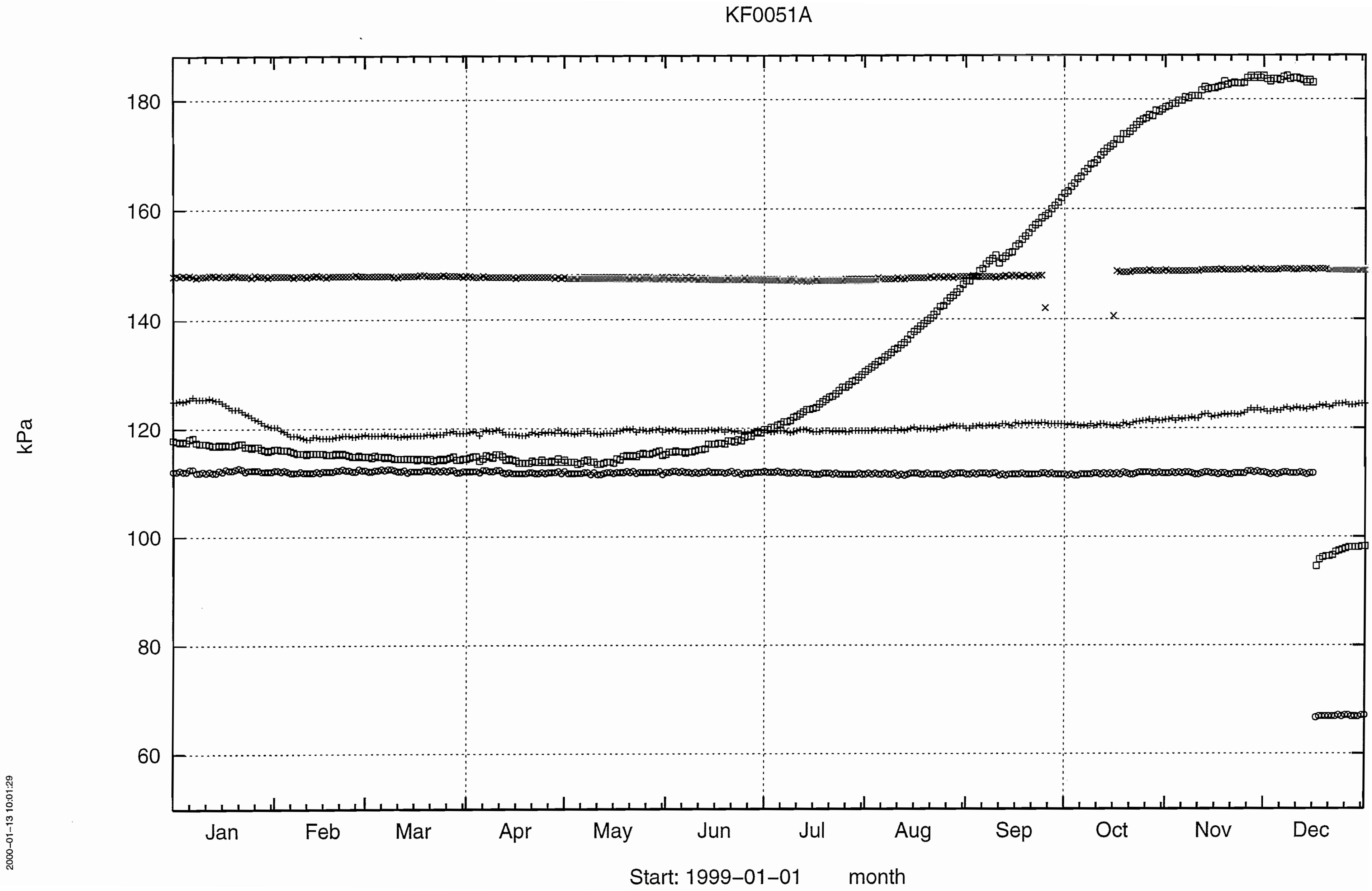


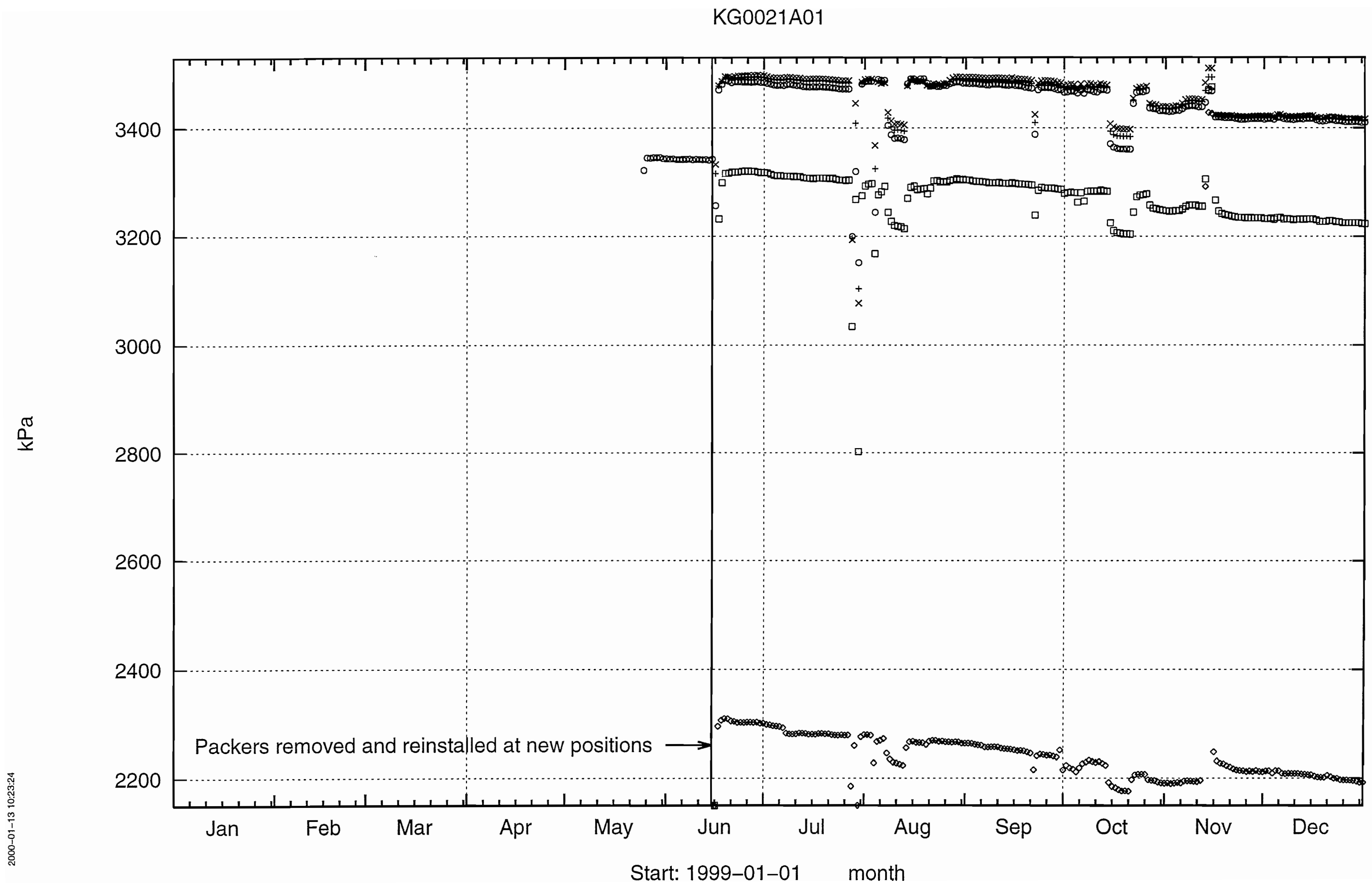
KA3590G02
4000
3500
3000
2500
2000
1500
1000
500
0
kPa
Packers removed
Packers reinstalled at new positions
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:27

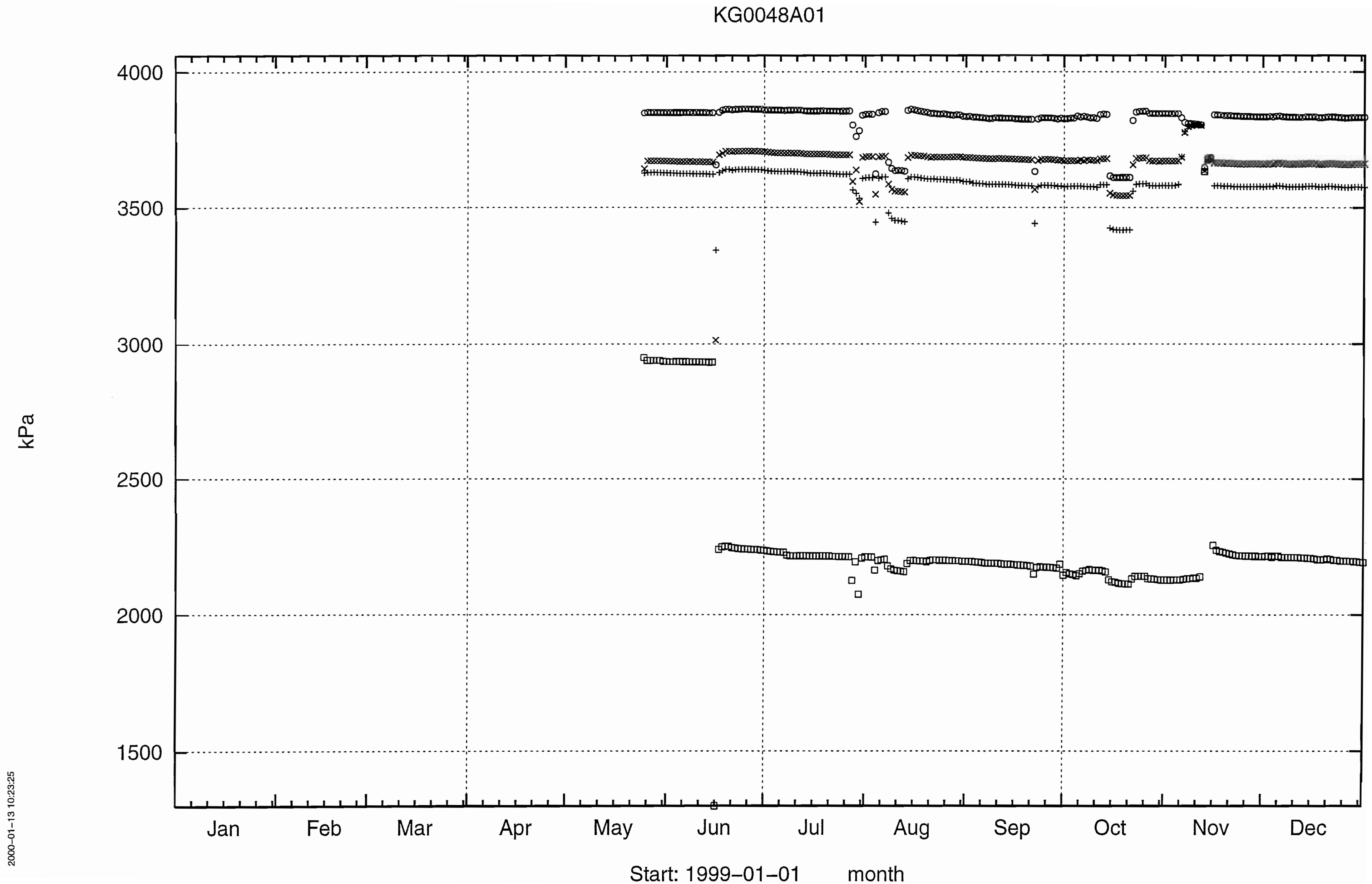

KA3593G
kPa
2200
2000
1800
1600
1400
1200
1000
Packers removed
Packers reinstalled at new positions
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:01:28

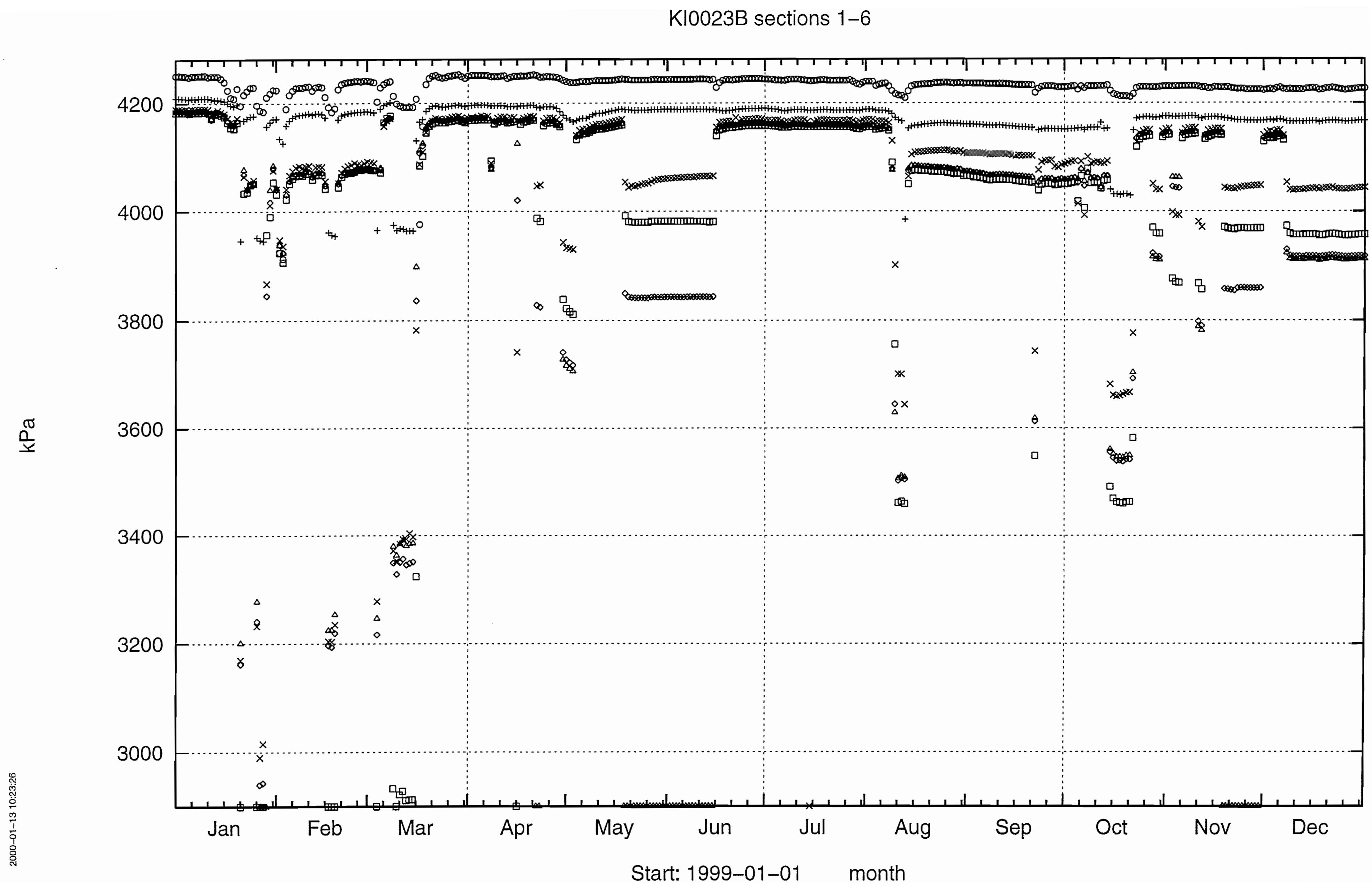


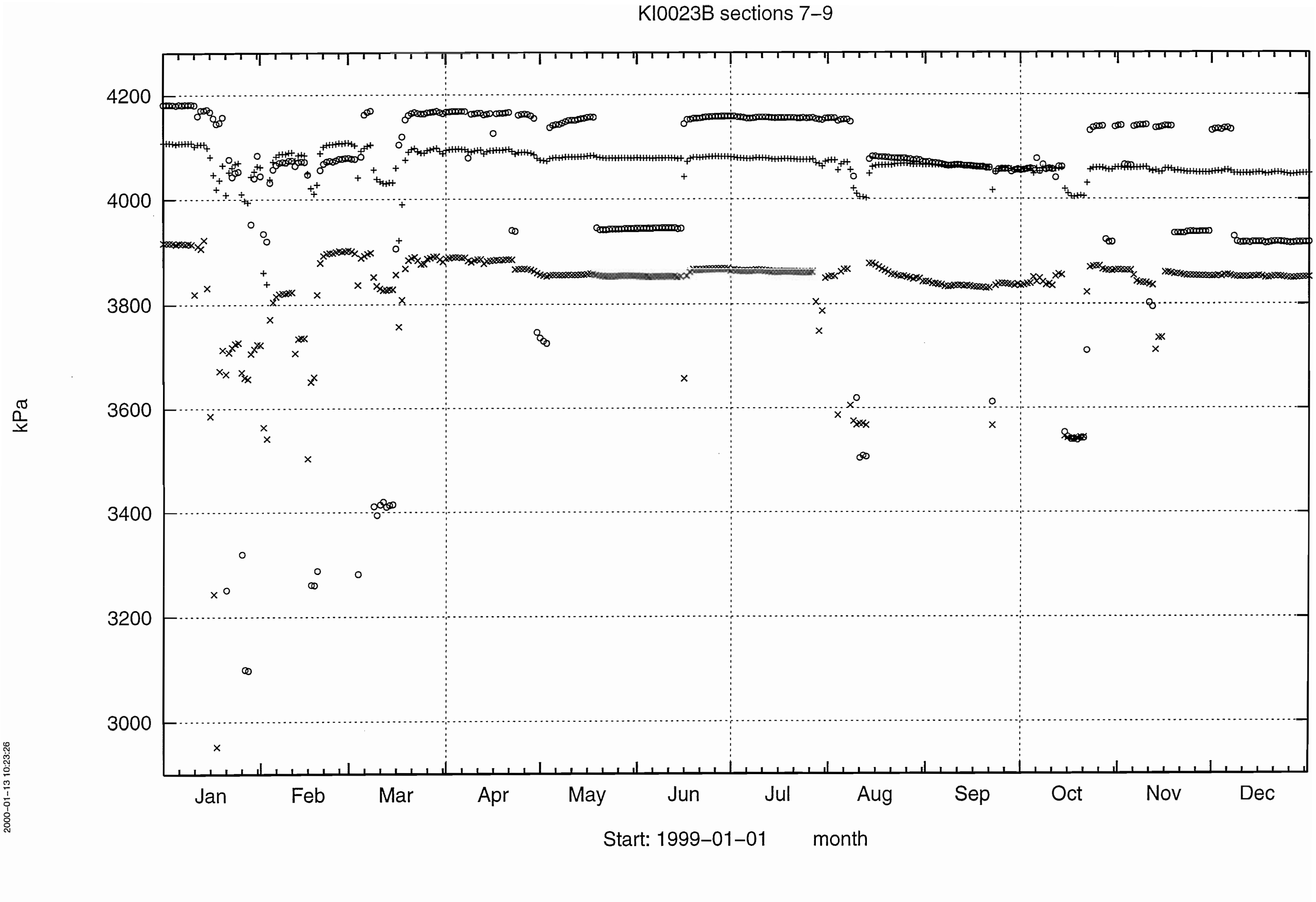
KA3600F
kPa
4100
4080
4060
4040
4020
4000
3980
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:01:28


KF0051A
kPa
180
160
140
120
100
80
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−01−13 10:01:29

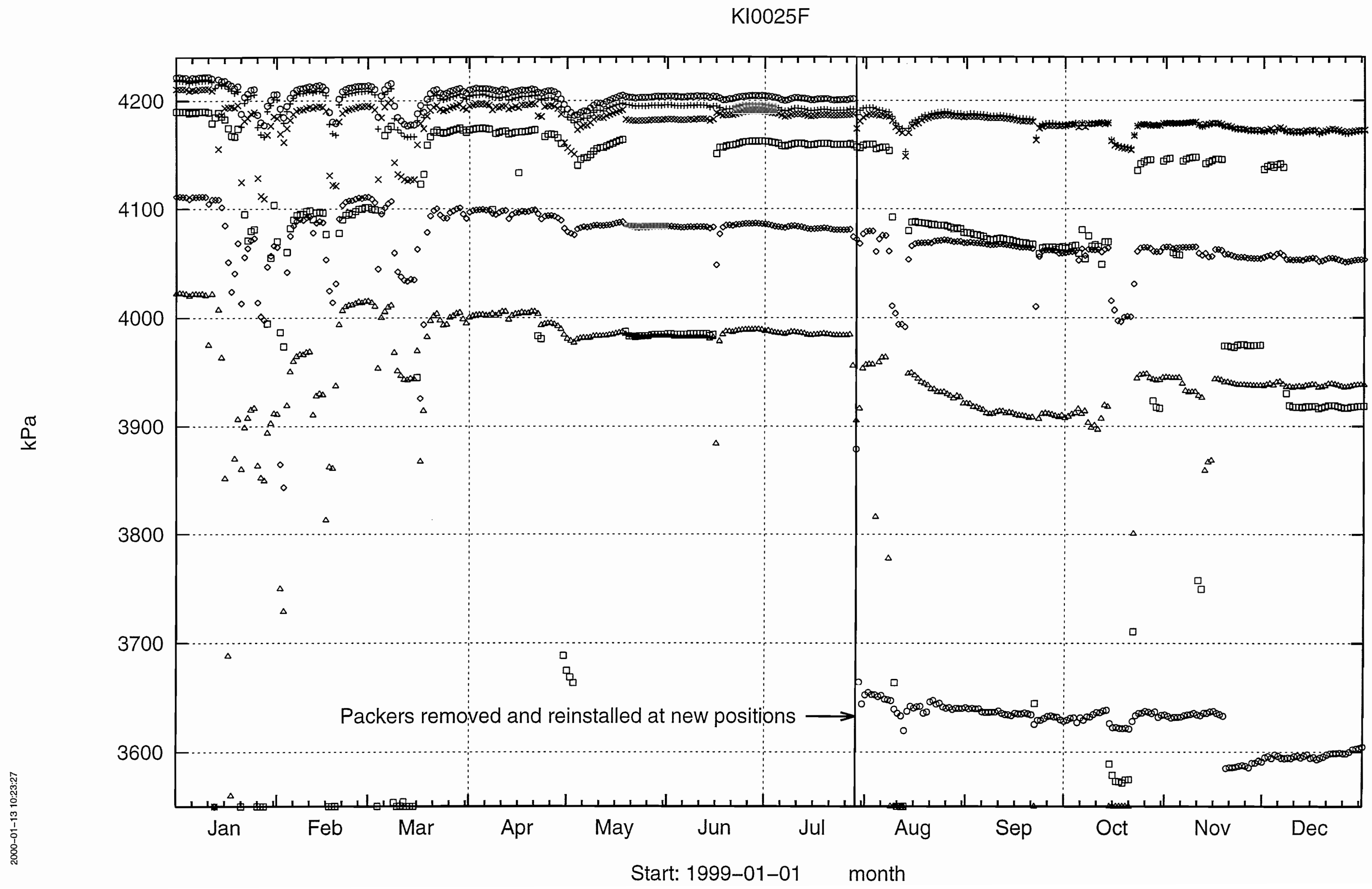

KG0021A01
kPa
3400
3200
3000
2800
2600
2400
2200
Packers removed and reinstalled at new positions
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–01–13 10:23:24


KG0048A01
4000
3500
3000
2500
2000
1500
kPa
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:23:25

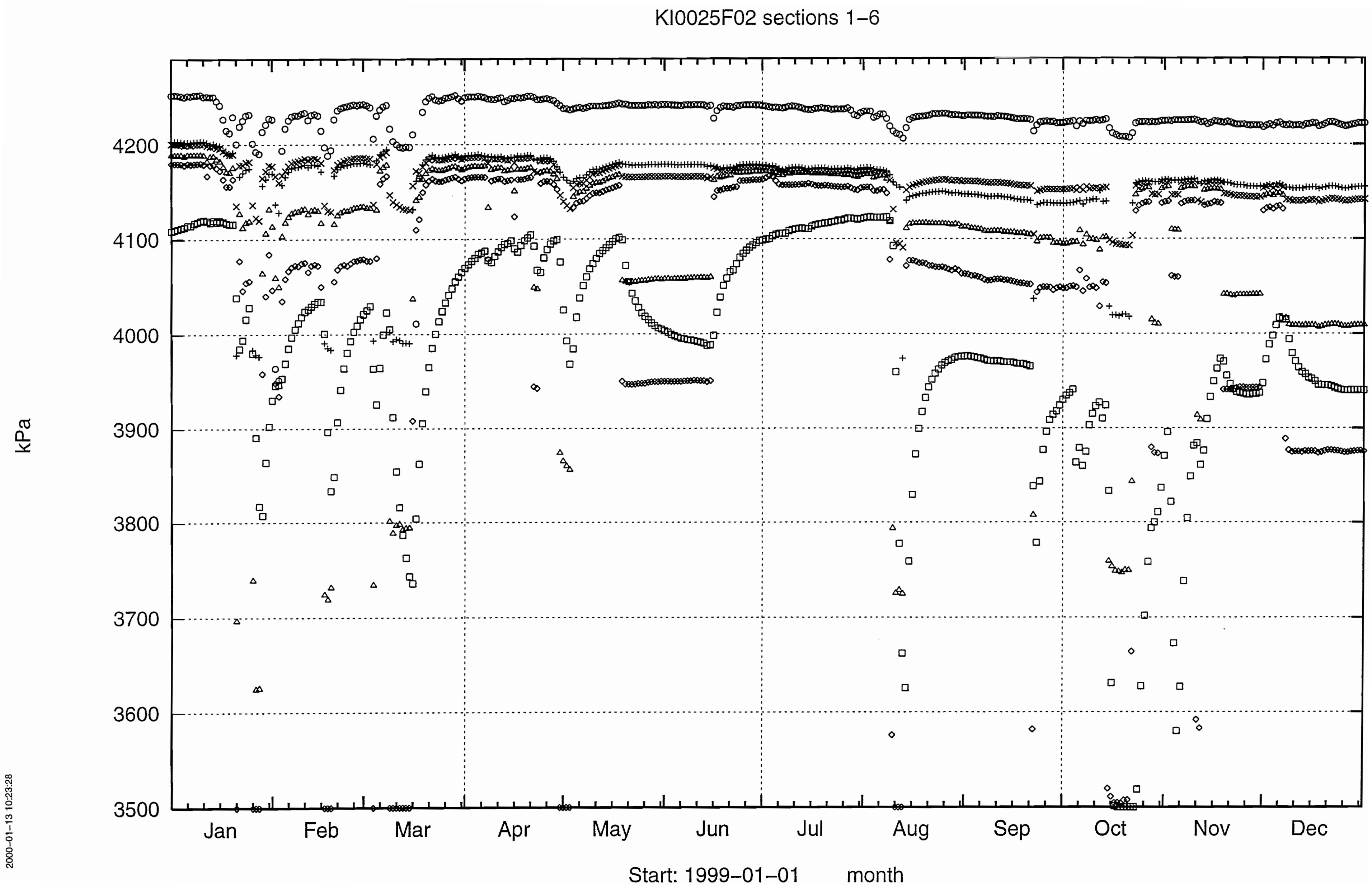

KI0023B sections 1-6
kPa
4200
4000
3800
3600
3400
3200
3000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:23:26

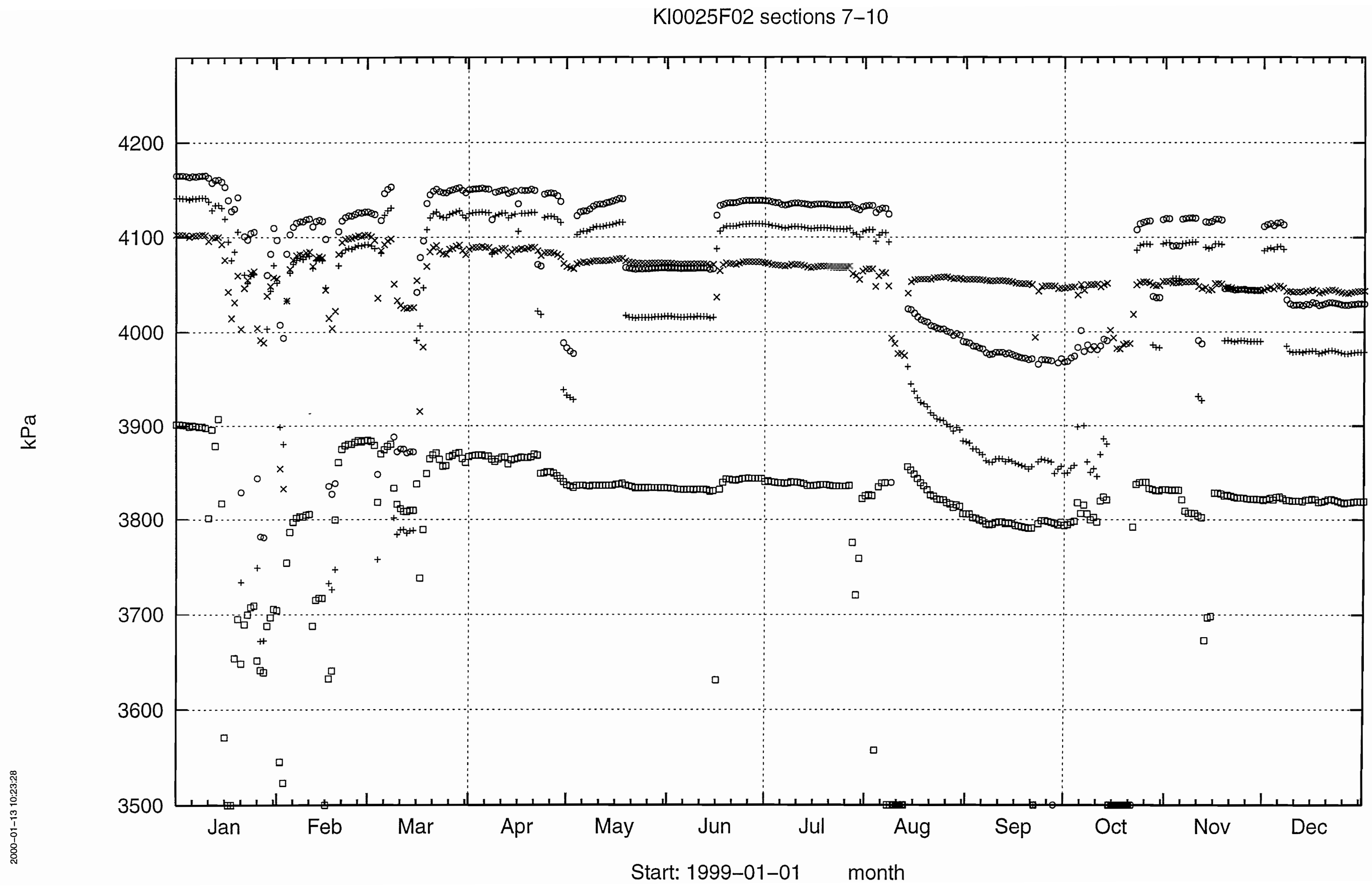


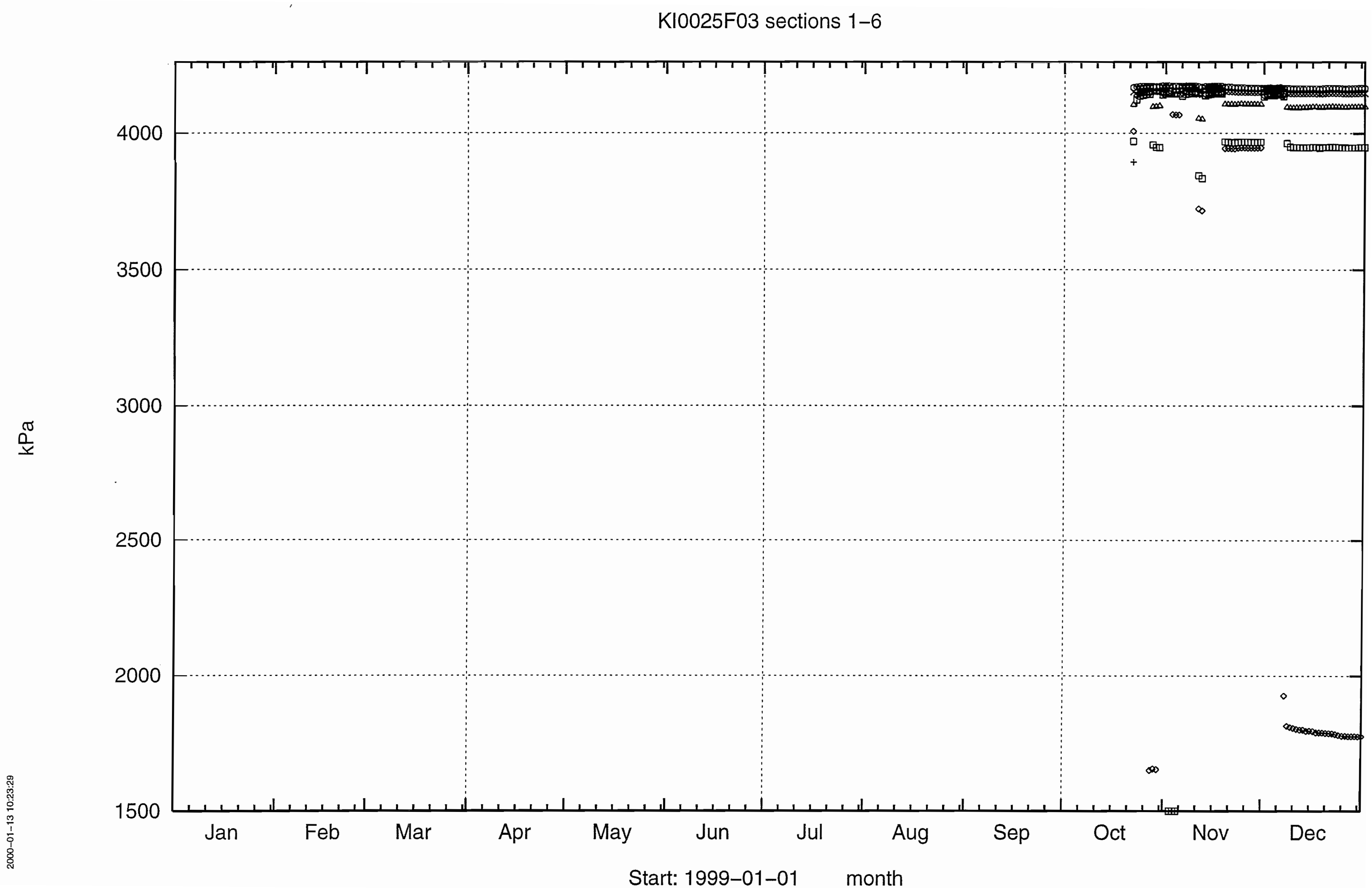
KI0023B sections 7-9
4200
4000
3800
3600
3400
3200
3000
kPa
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:23:26

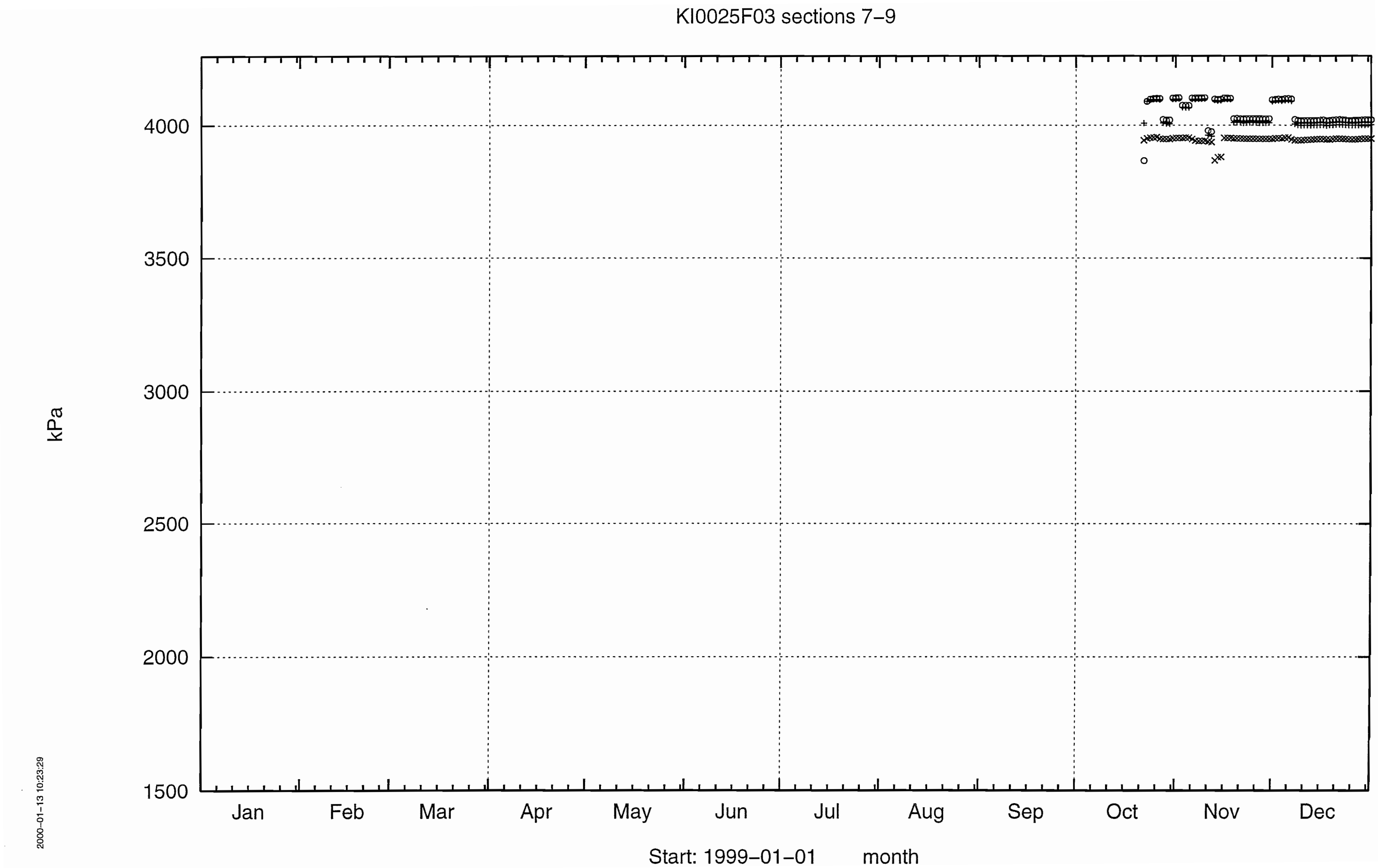


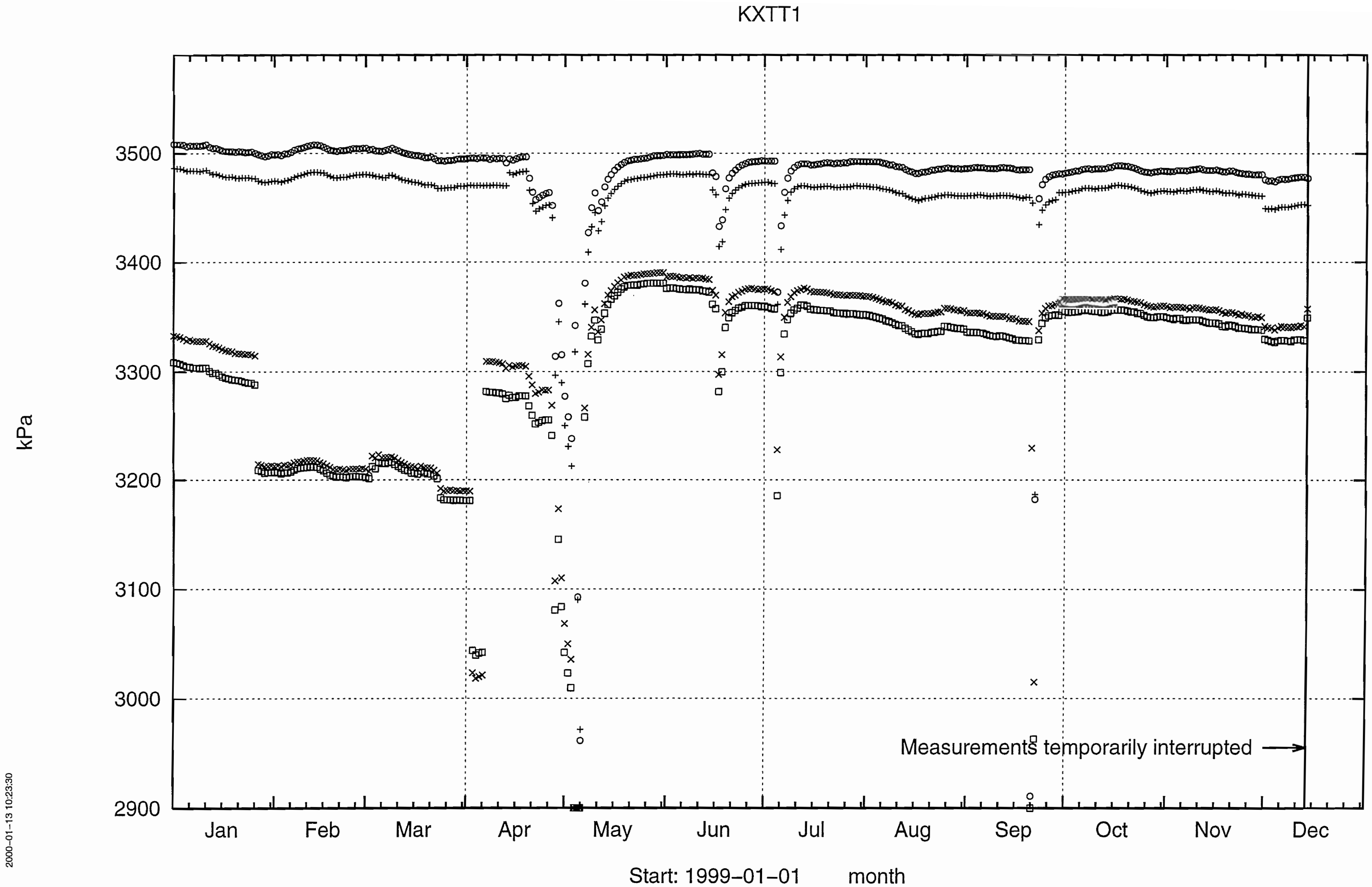
KI0025F
kPa
4200
4100
4000
3900
3800
3700
3600
Packers removed and reinstalled at new positions
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:23:27

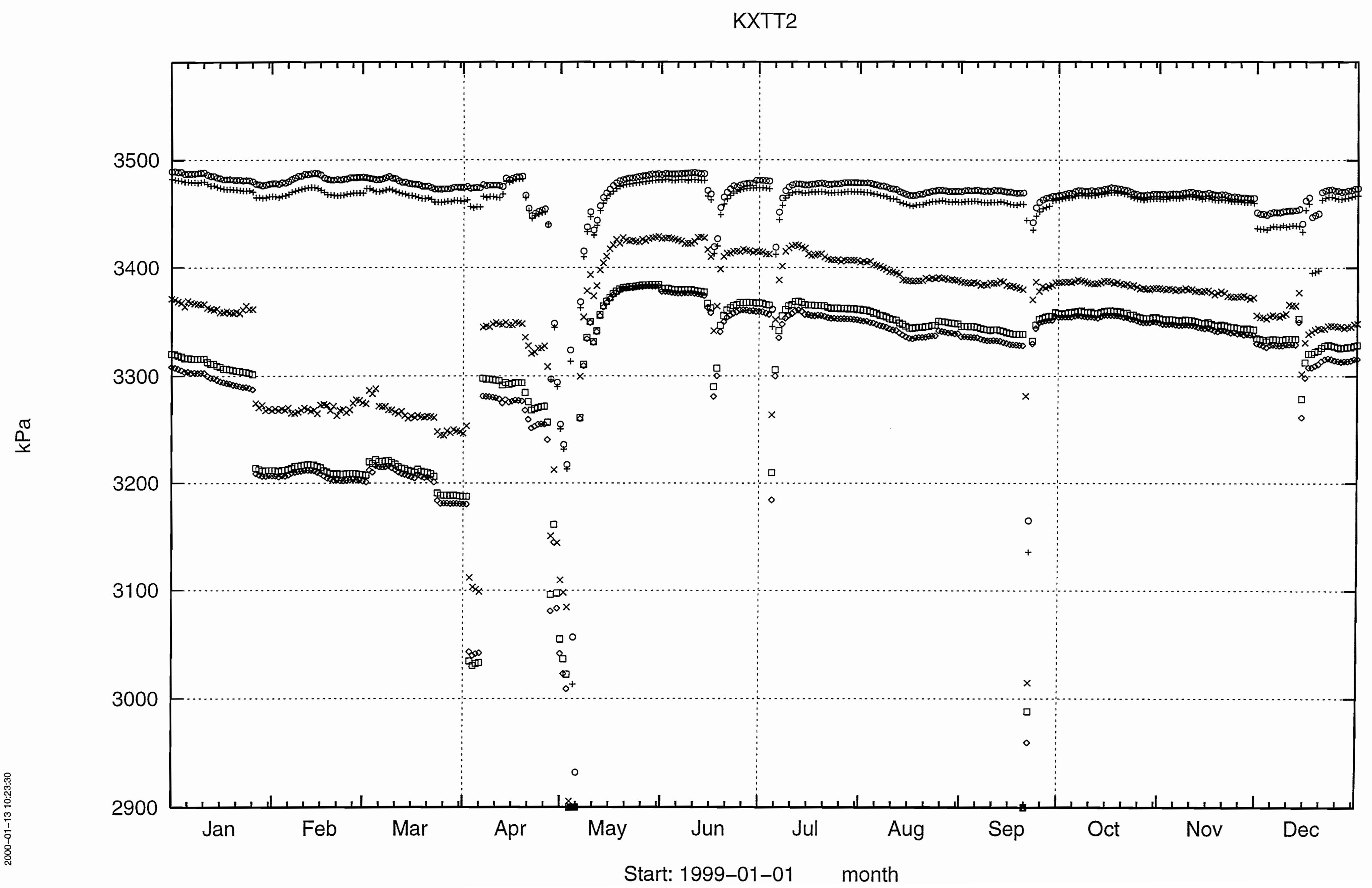

KI0025F02 sections 1–6
kPa
4200
4100
4000
3900
3800
3700
3600
3500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01 month
2000–01–13 10:23:28

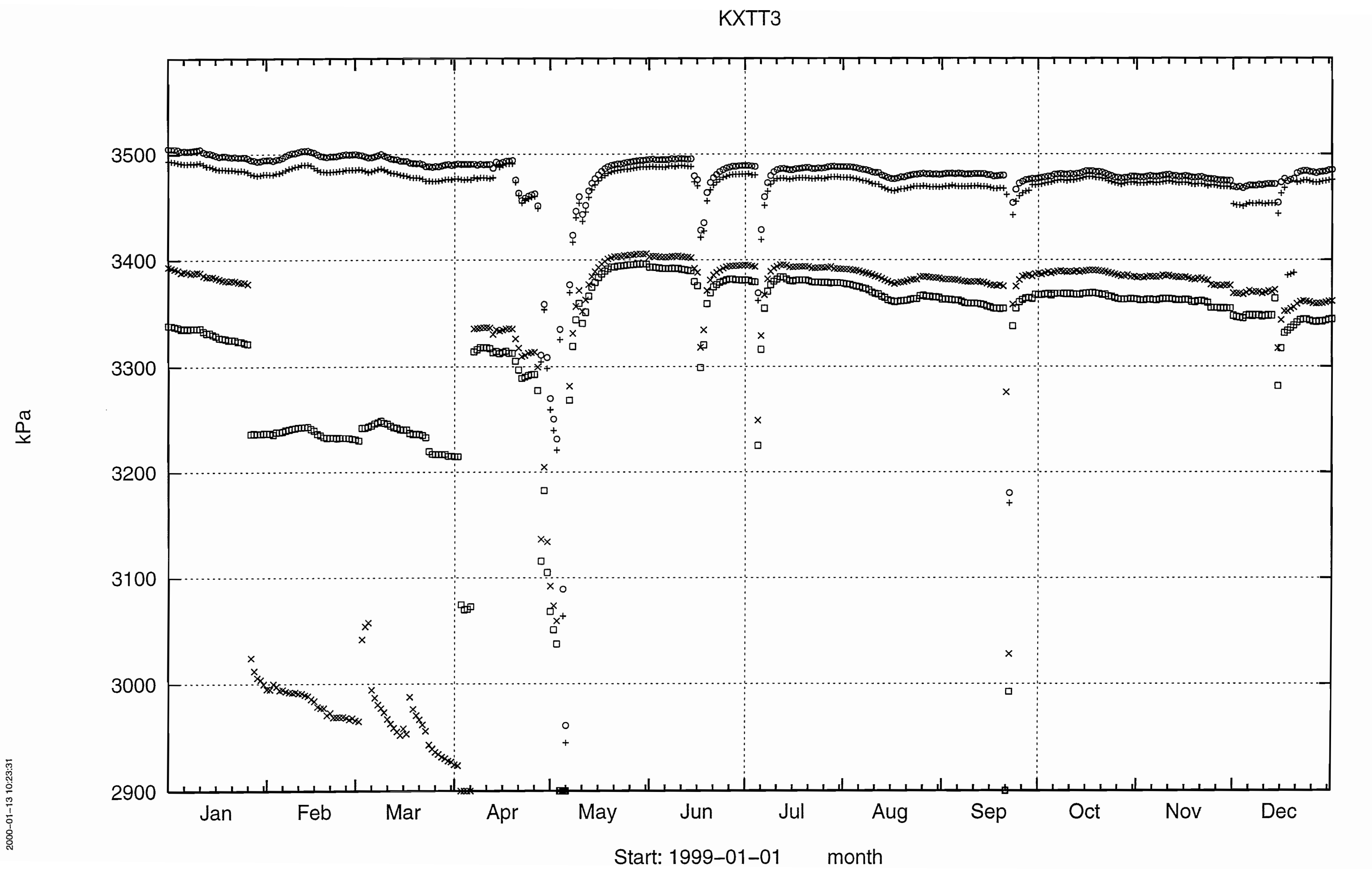

KI0025F02 sections 7–10
kPa
4200
4100
4000
3900
3800
3700
3600
3500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01 month
2000–01–13 10:23:28

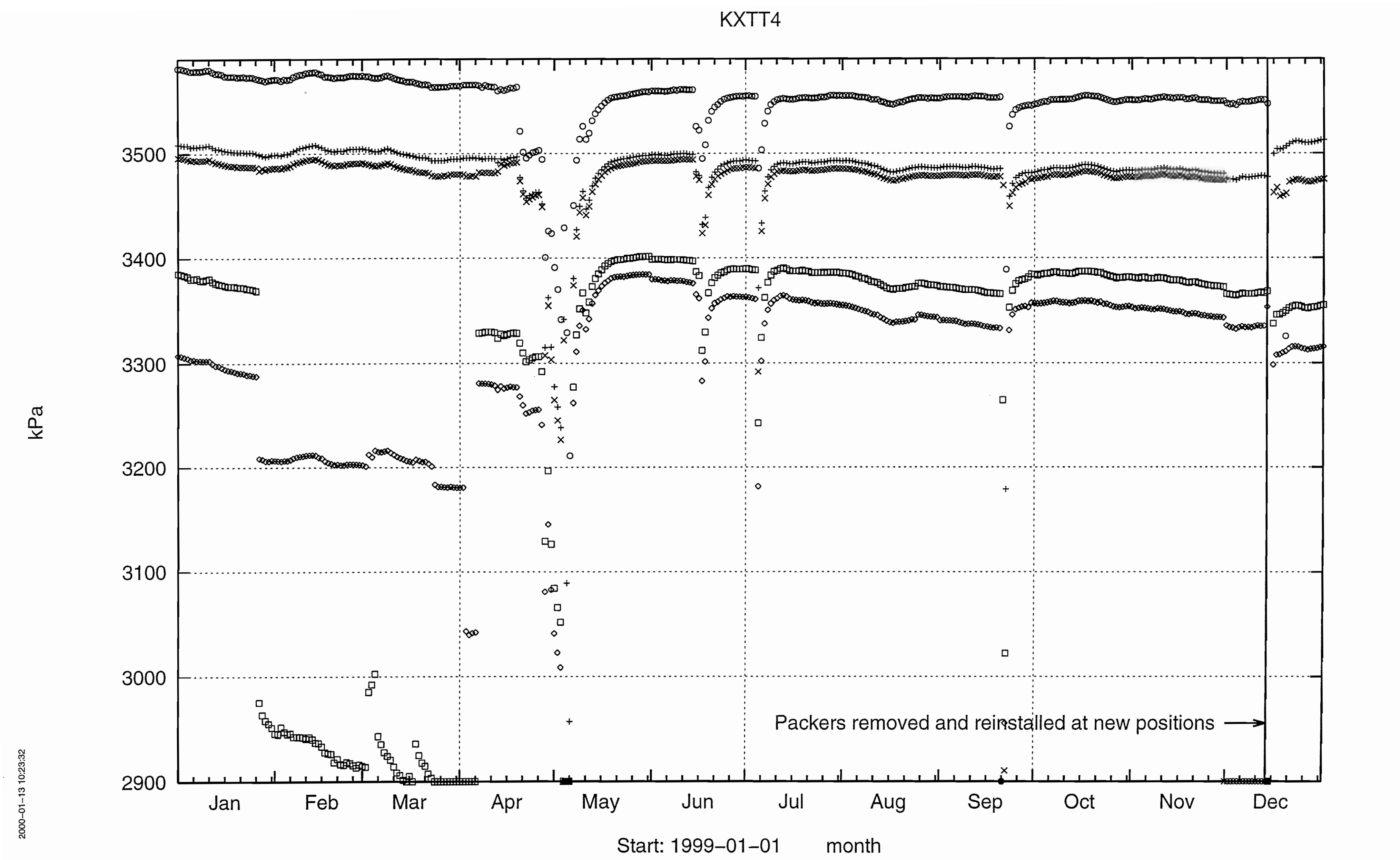

KI0025F03 sections 1–6
kPa
4000
3500
3000
2500
2000
1500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–01–13 10:23:29


KI0025F03 sections 7–9
kPa
4000
3500
3000
2500
2000
1500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–01–13 10:23:29

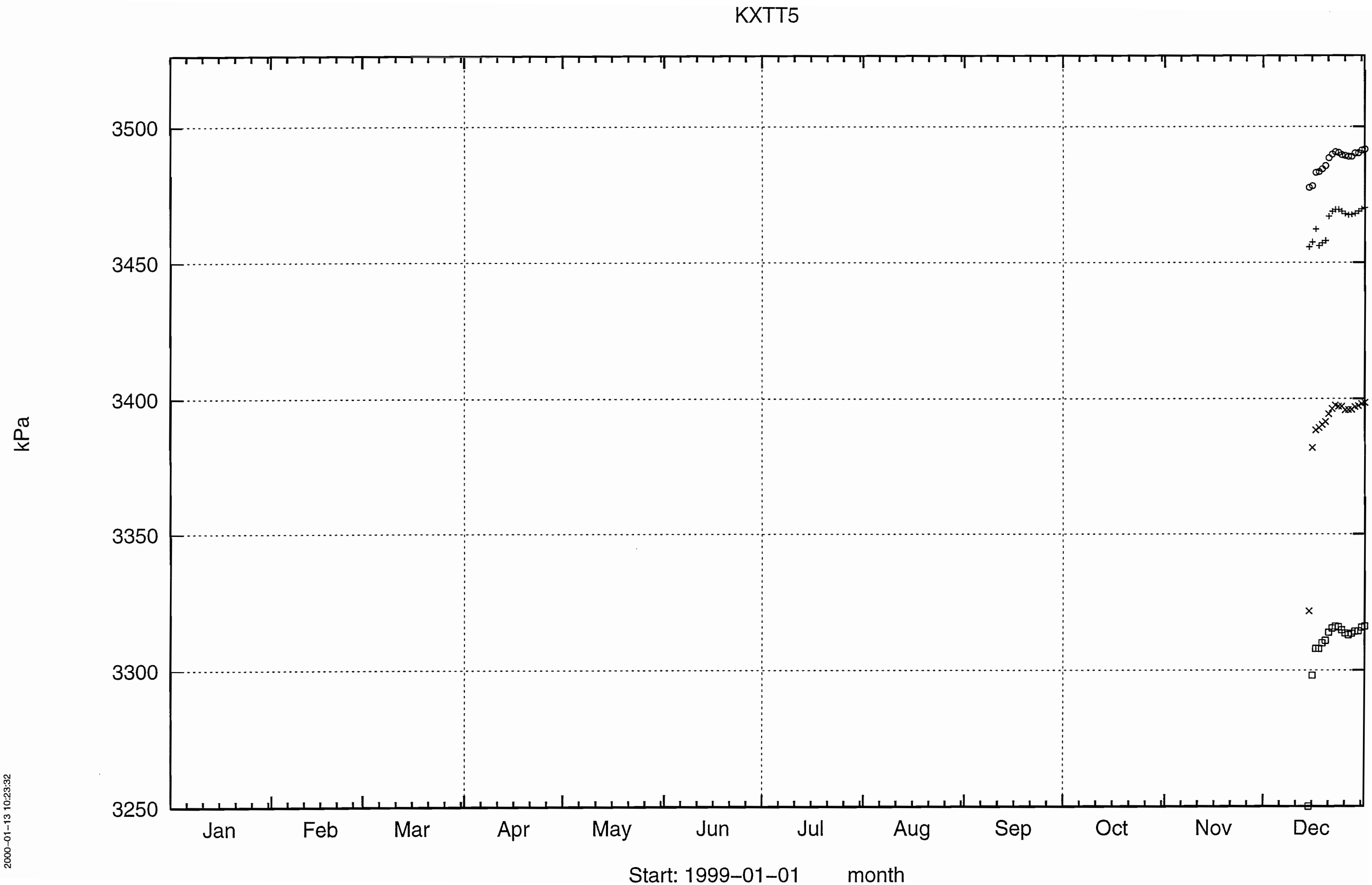

KXTT1
kPa
3500
3400
3300
3200
3100
3000
2900
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
Measurements temporarily interrupted
2000-01-13 10:23:30


KXTT2
3500
3400
3300
3200
3100
3000
2900
kPa
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:23:30

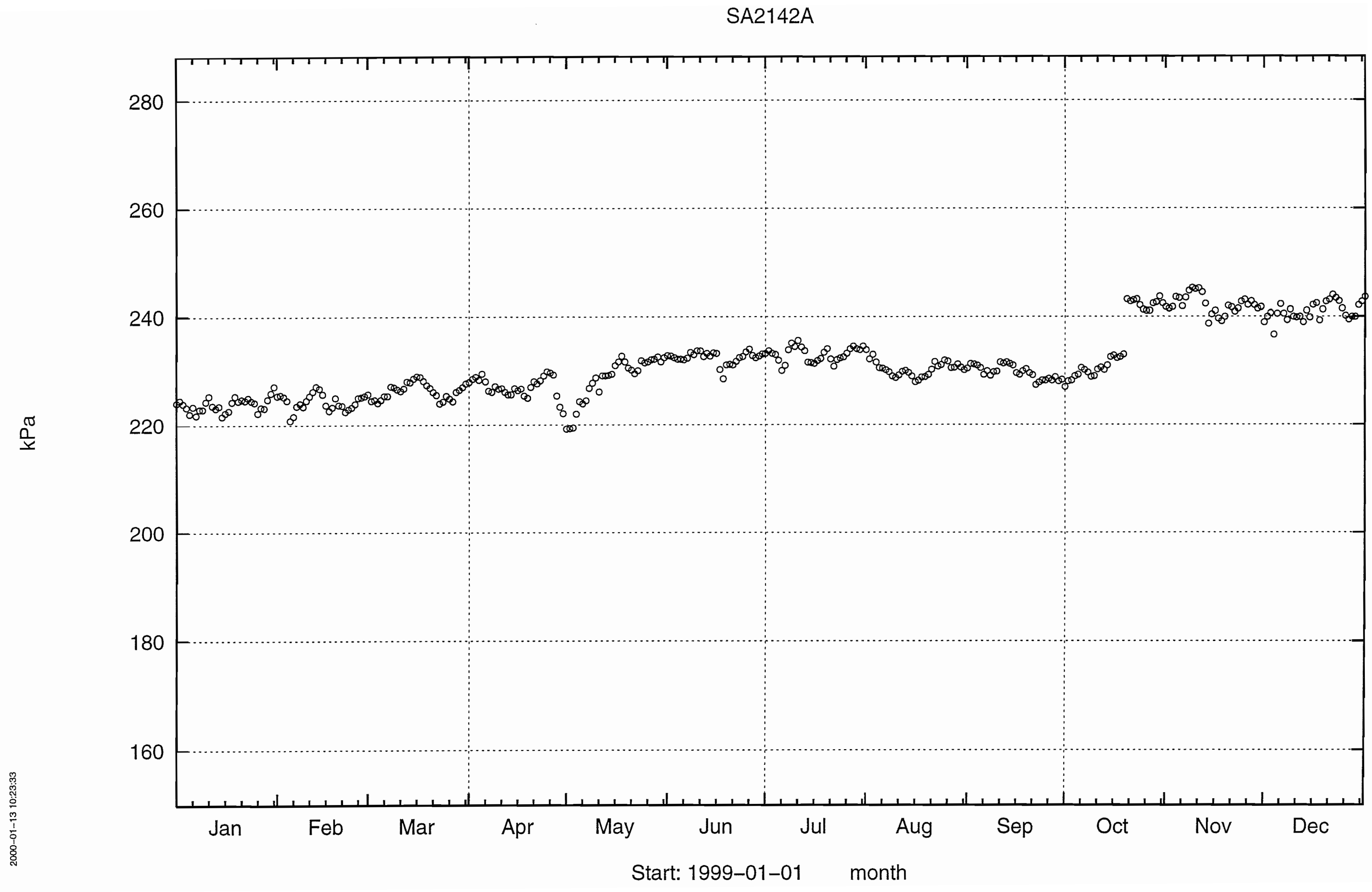

KXTT3
kPa
3500
3400
3300
3200
3100
3000
2900
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:23:31

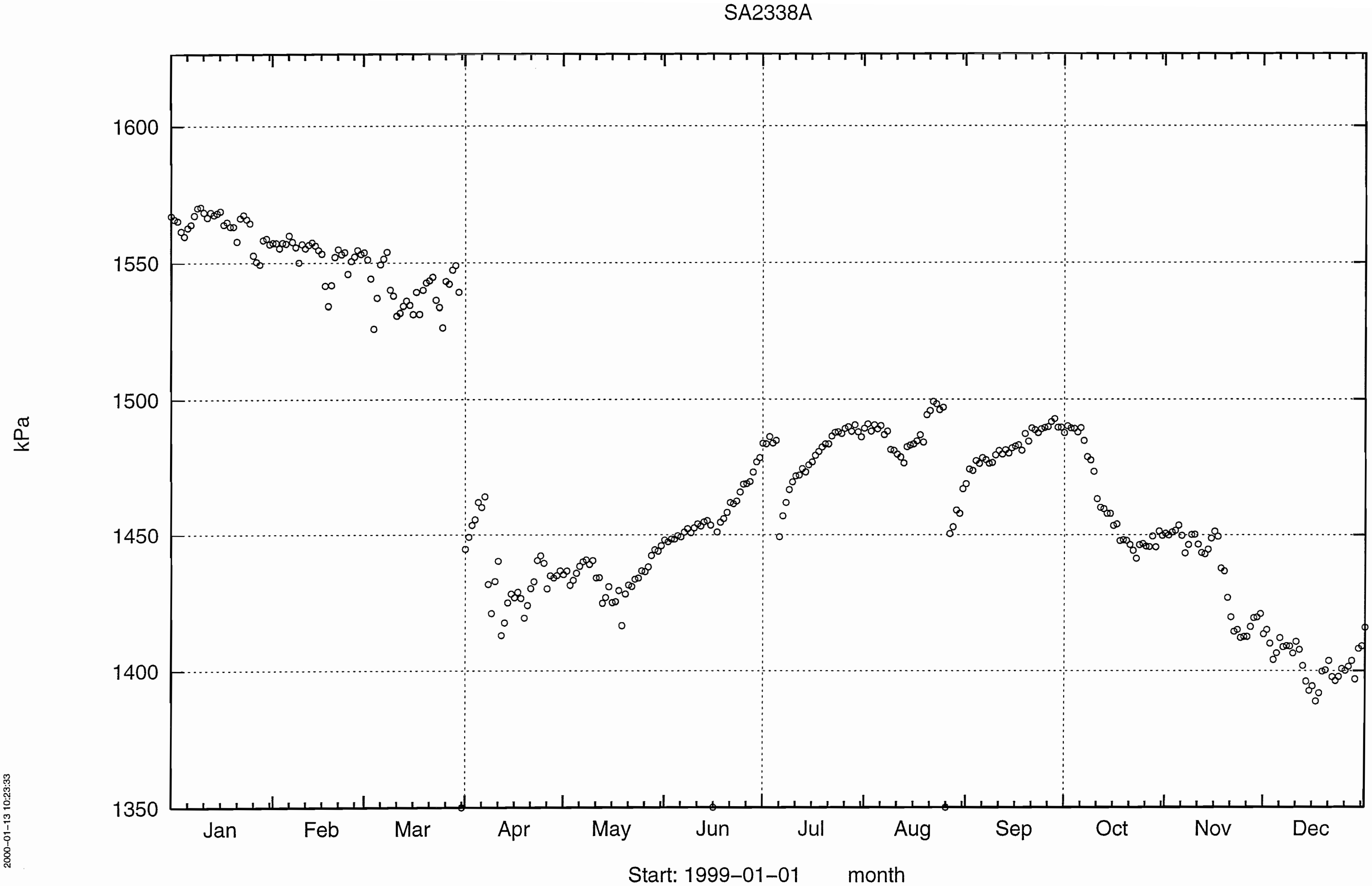


KXTT4
kPa
3500
3400
3300
3200
3100
3000
2900
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
Packers removed and reinstalled at new positions
2000-01-13 10:23:32

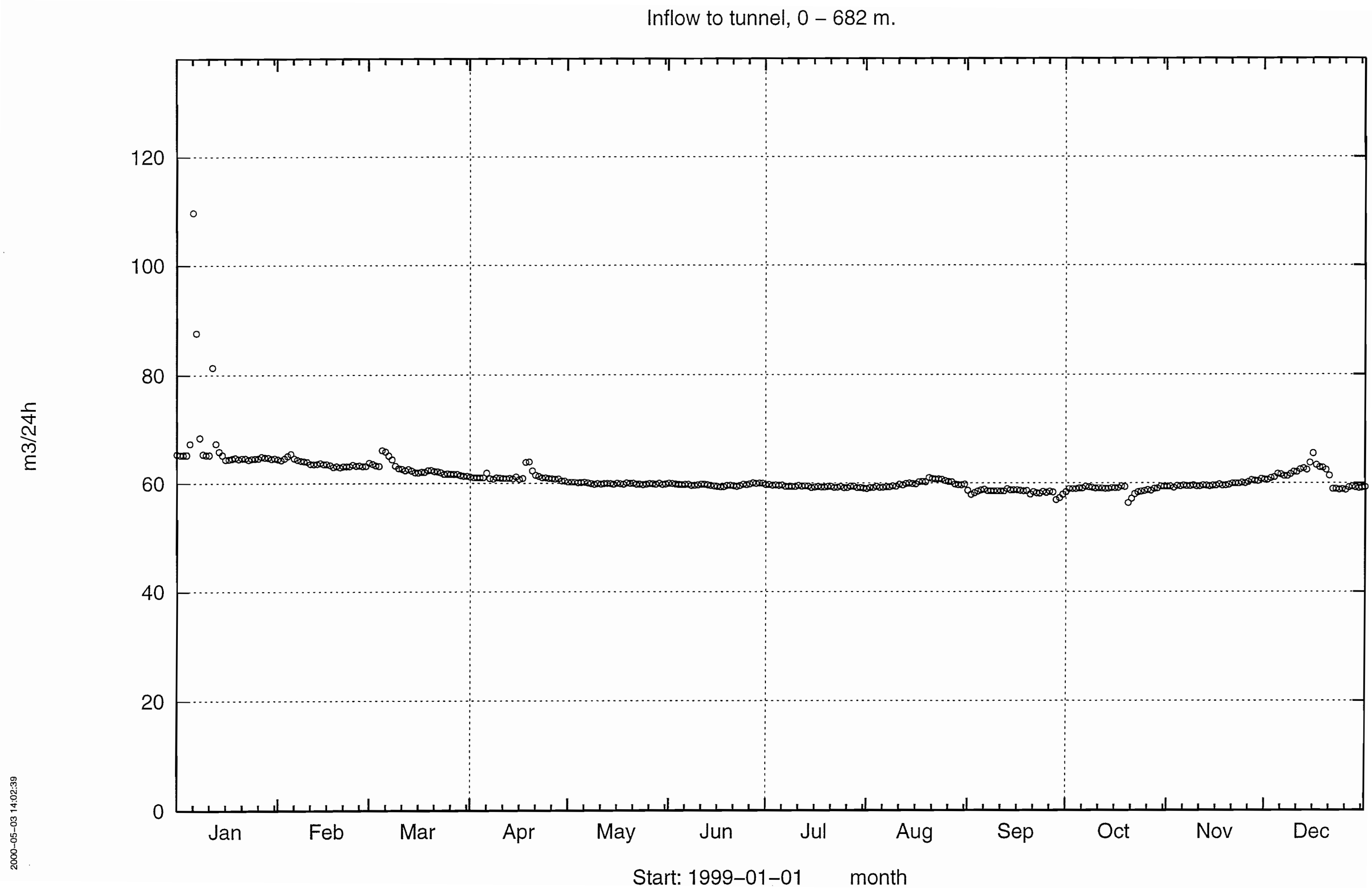


KXTT5
kPa
3500
3450
3400
3350
3300
3250
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-01-13 10:23:32

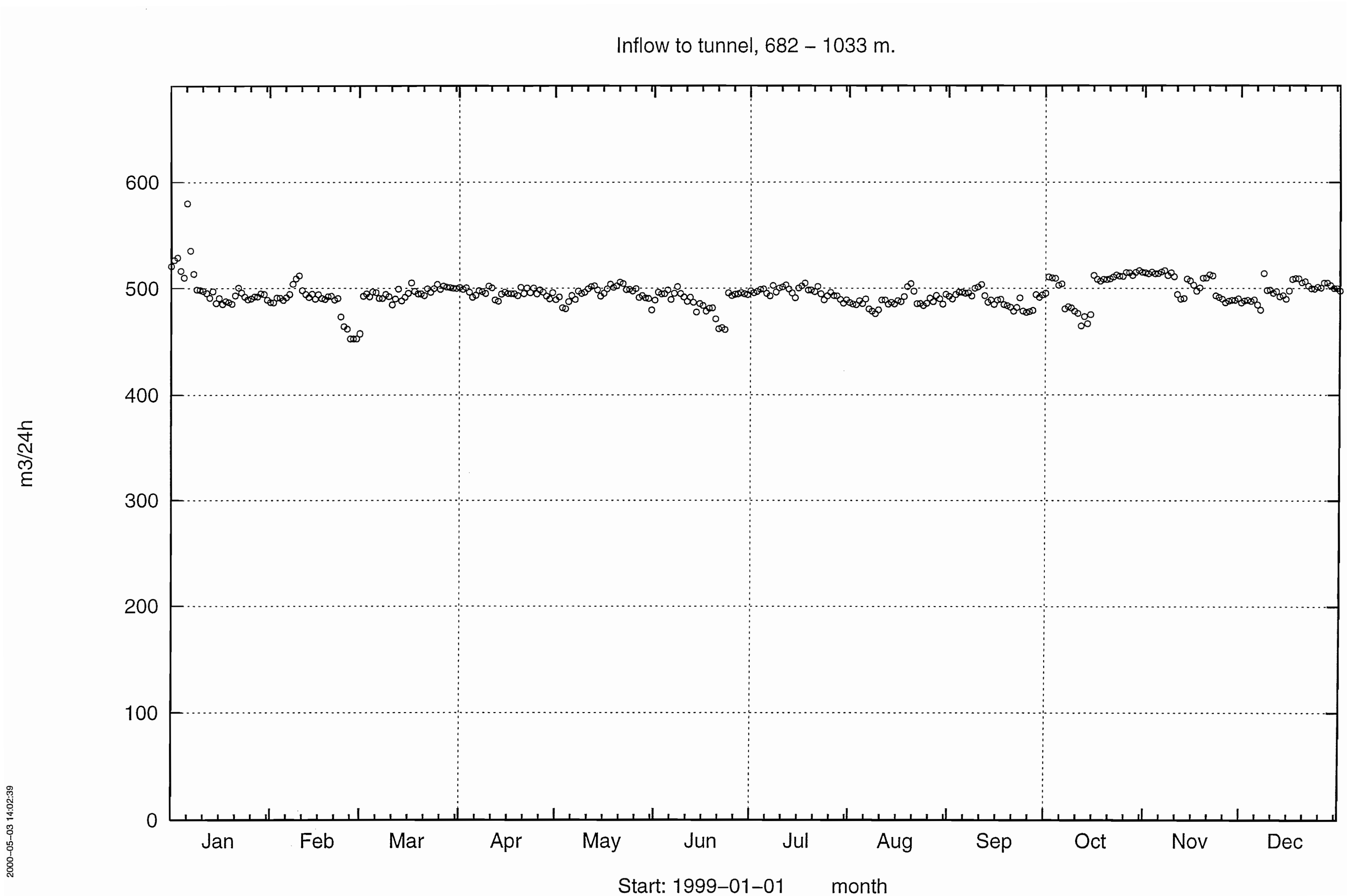

SA2142A
kPa
280
260
240
220
200
180
160
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-01-13 10:23:33

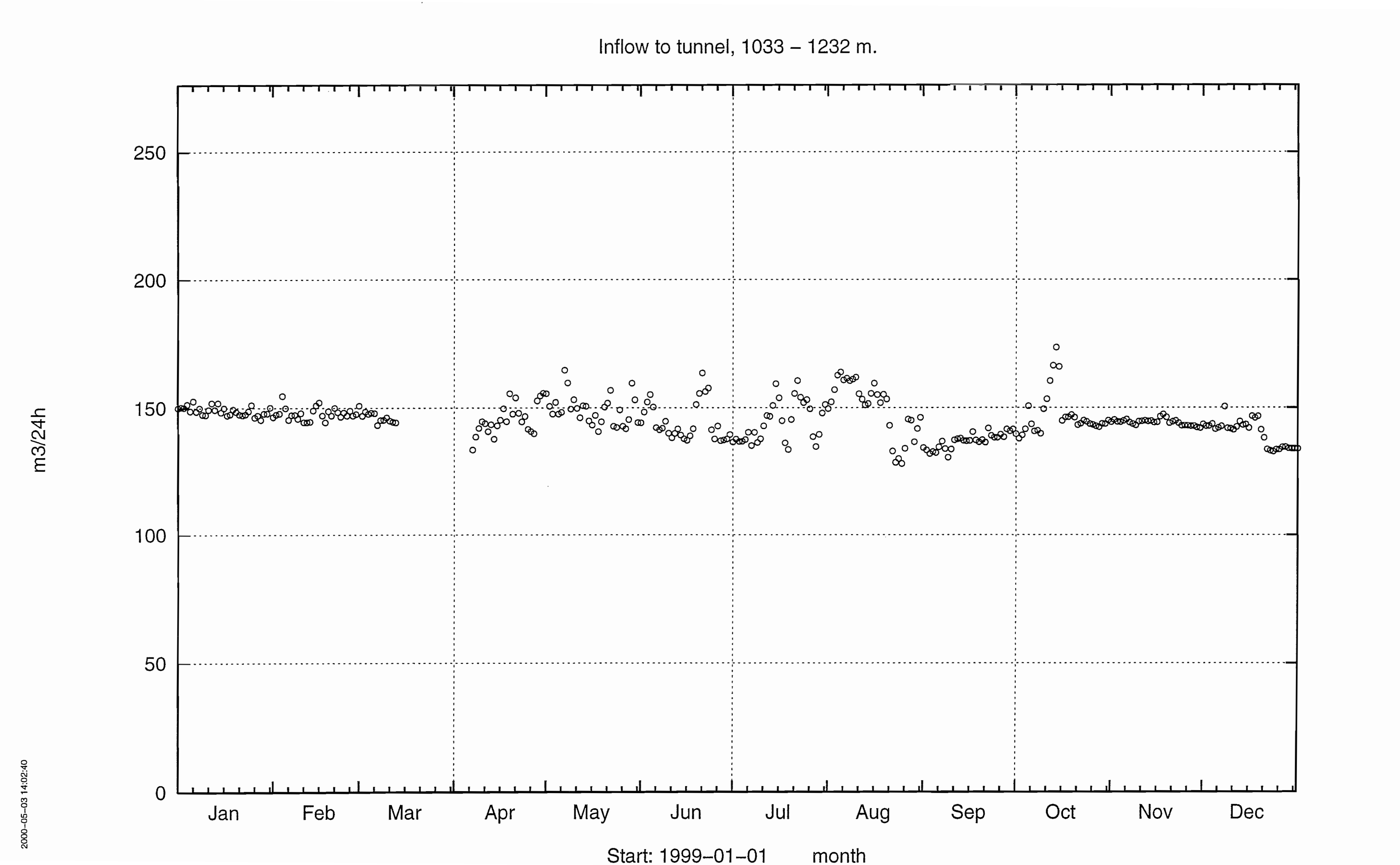

SA2338A
kPa
1600
1550
1500
1450
1400
1350
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−01−13 10:23:33

Appendix 5: Water flow in tunnel

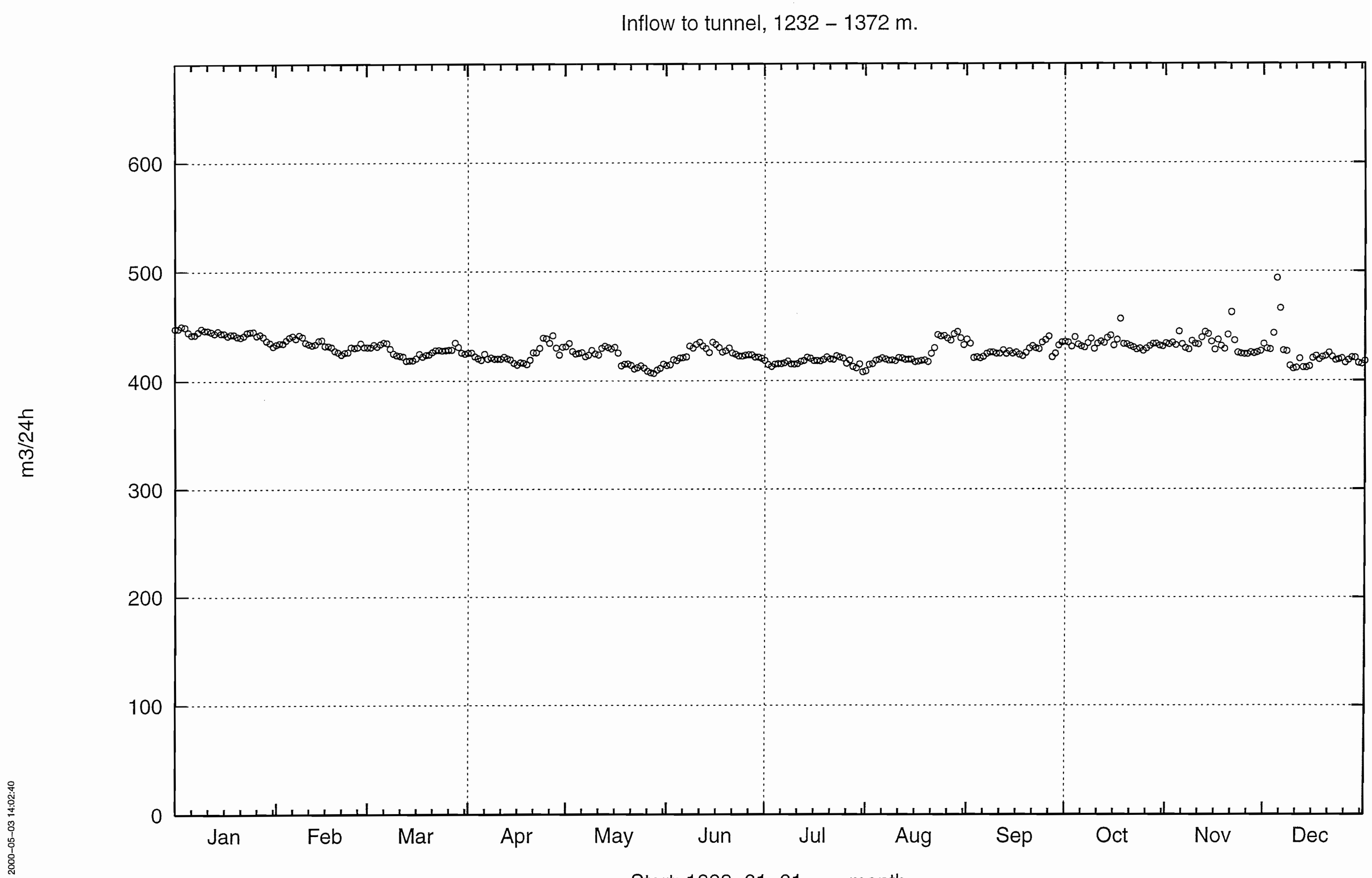


Inflow to tunnel, 0 – 682 m.
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01 month
2000–05–03 14:02:39

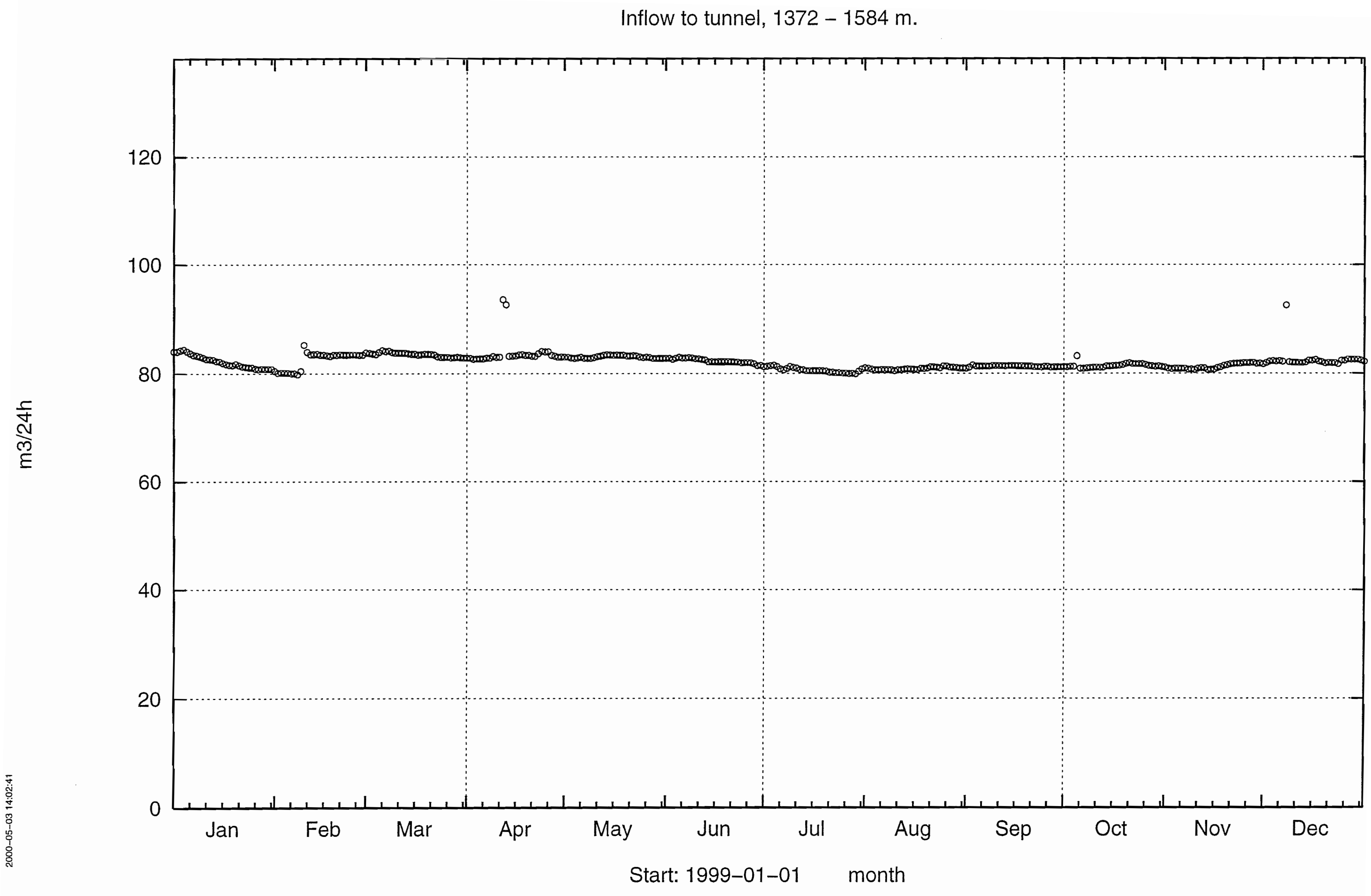

Inflow to tunnel, 682 – 1033 m.
m3/24h
0
100
200
300
400
500
600
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–05–03 14:02:39



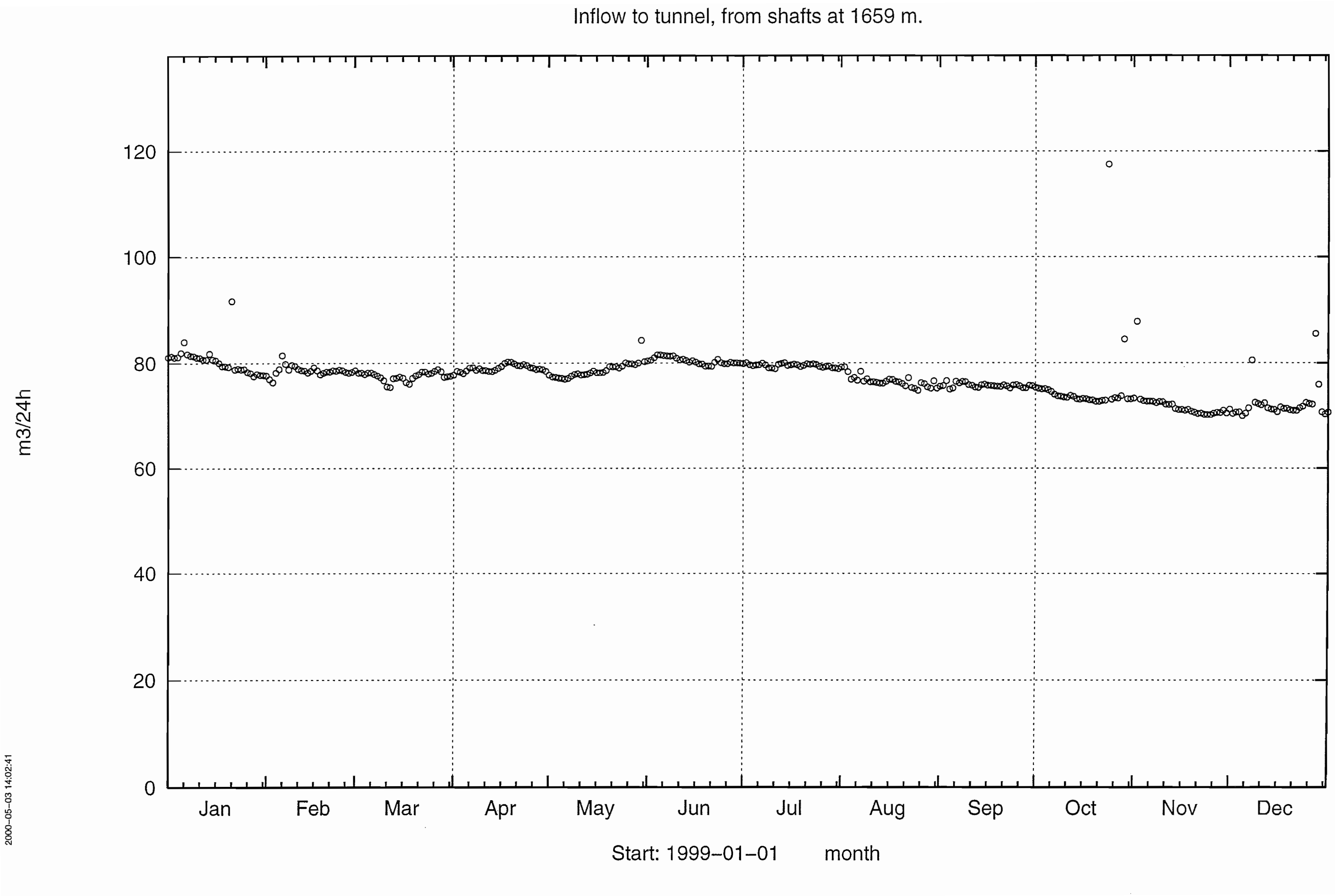
Inflow to tunnel, 1033 – 1232 m.
m3/24h
0
50
100
150
200
250
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-05-03 14:02:40



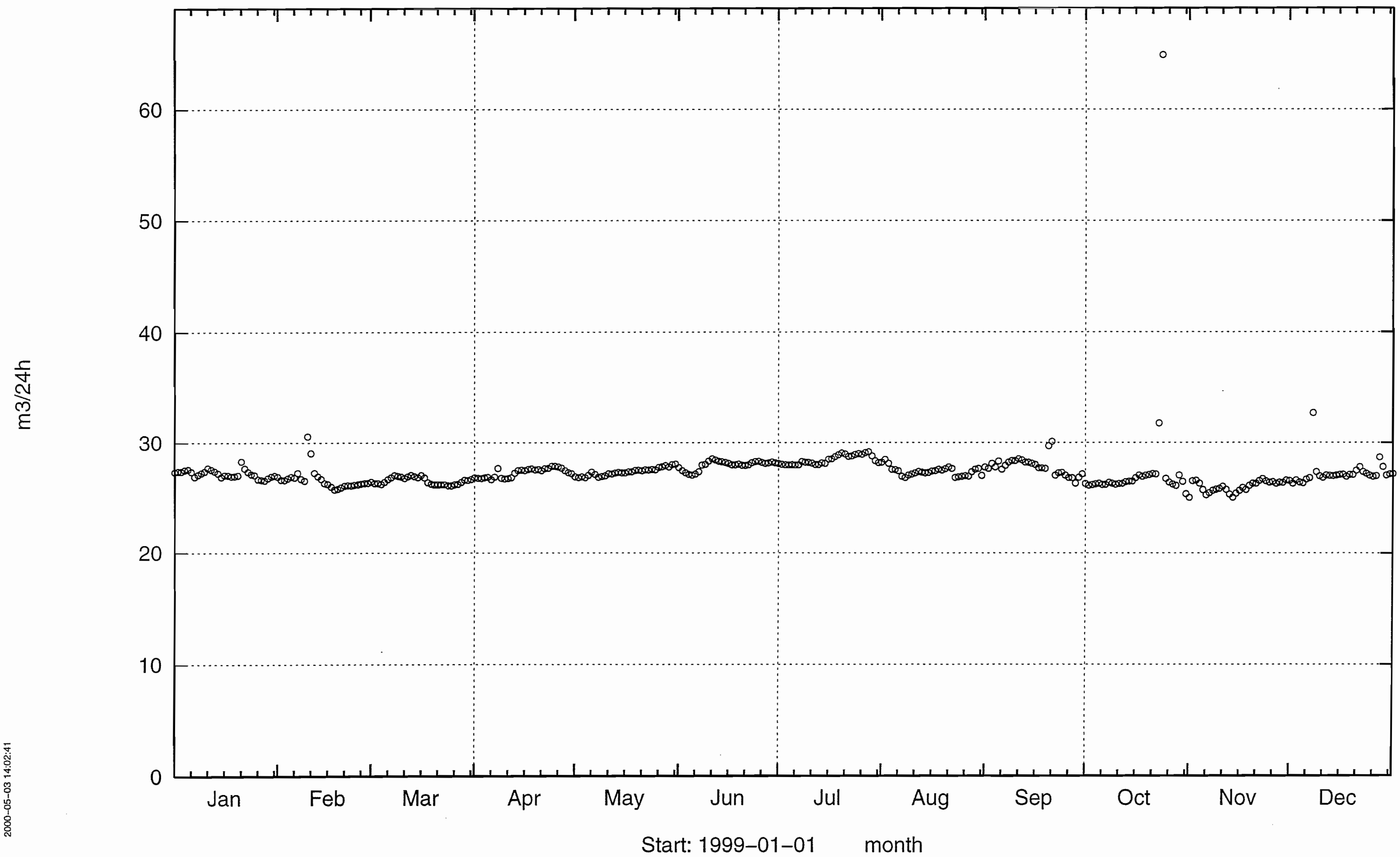
Inflow to tunnel, 1232 – 1372 m.
m3/24h
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–05–03 14:02:40



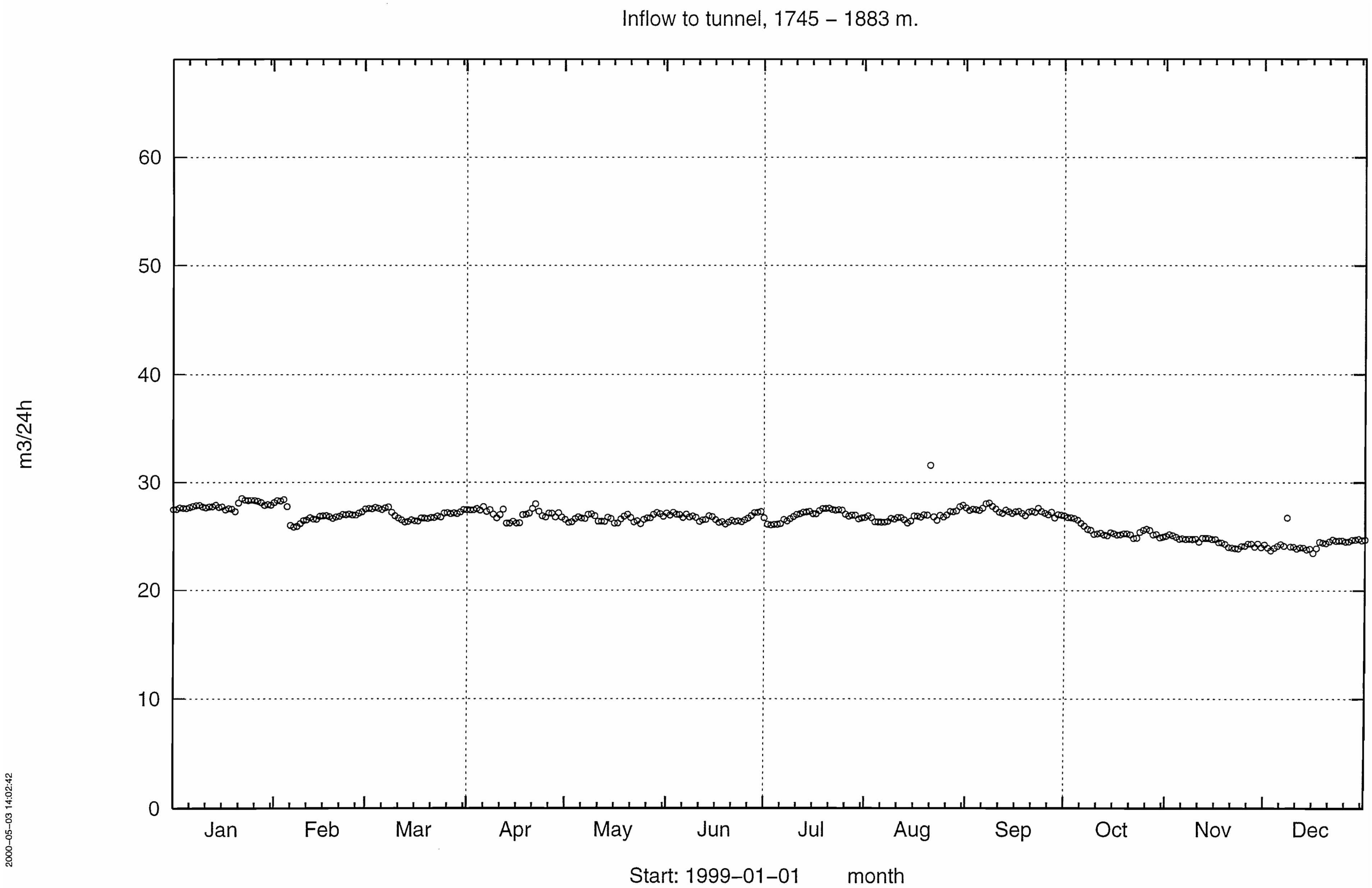
Inflow to tunnel, 1372 – 1584 m.
m3/24h
120
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–05–03 14:02:41

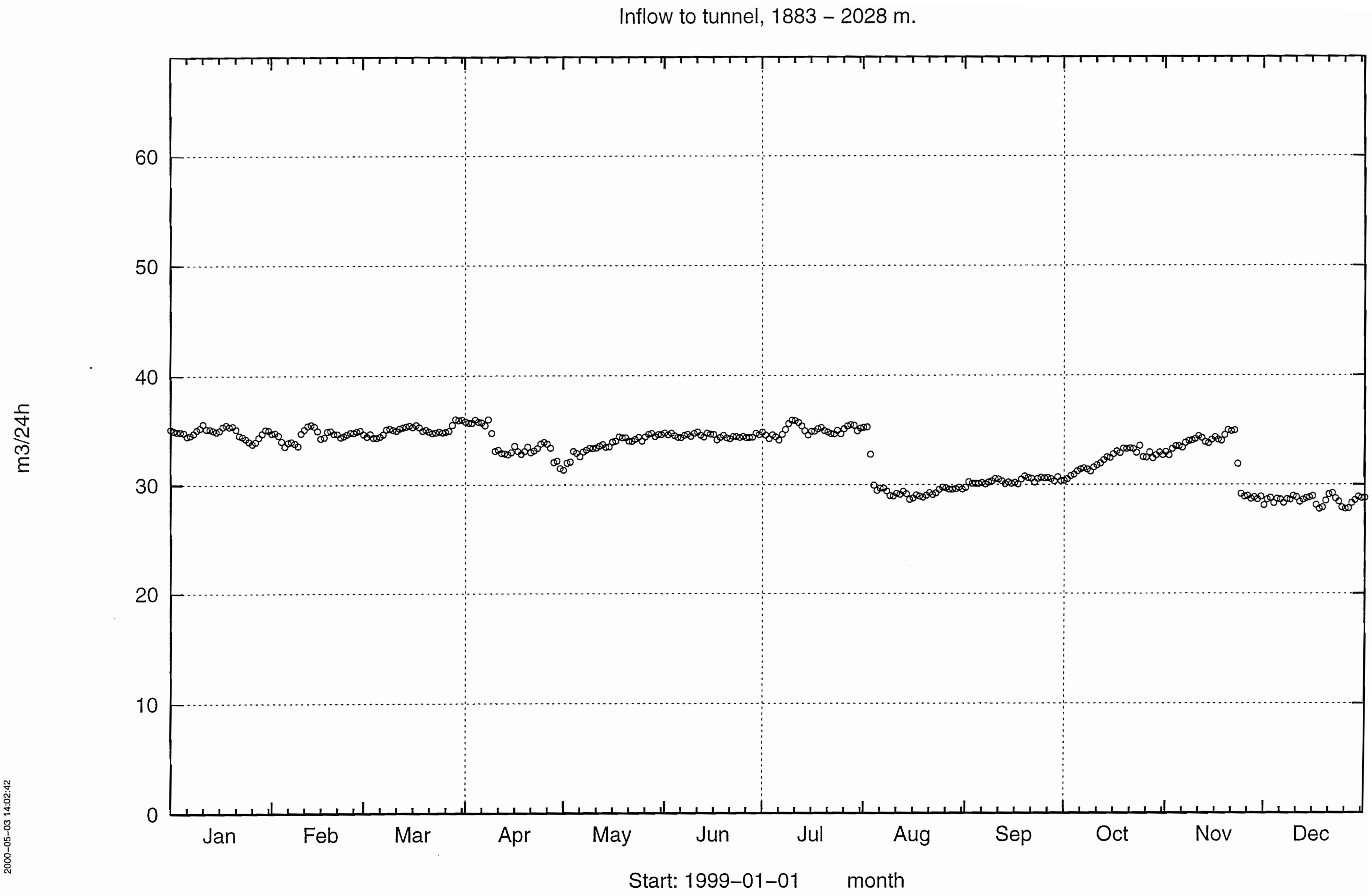

Inflow to tunnel, from shafts at 1659 m.
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-05-03 14:02:41

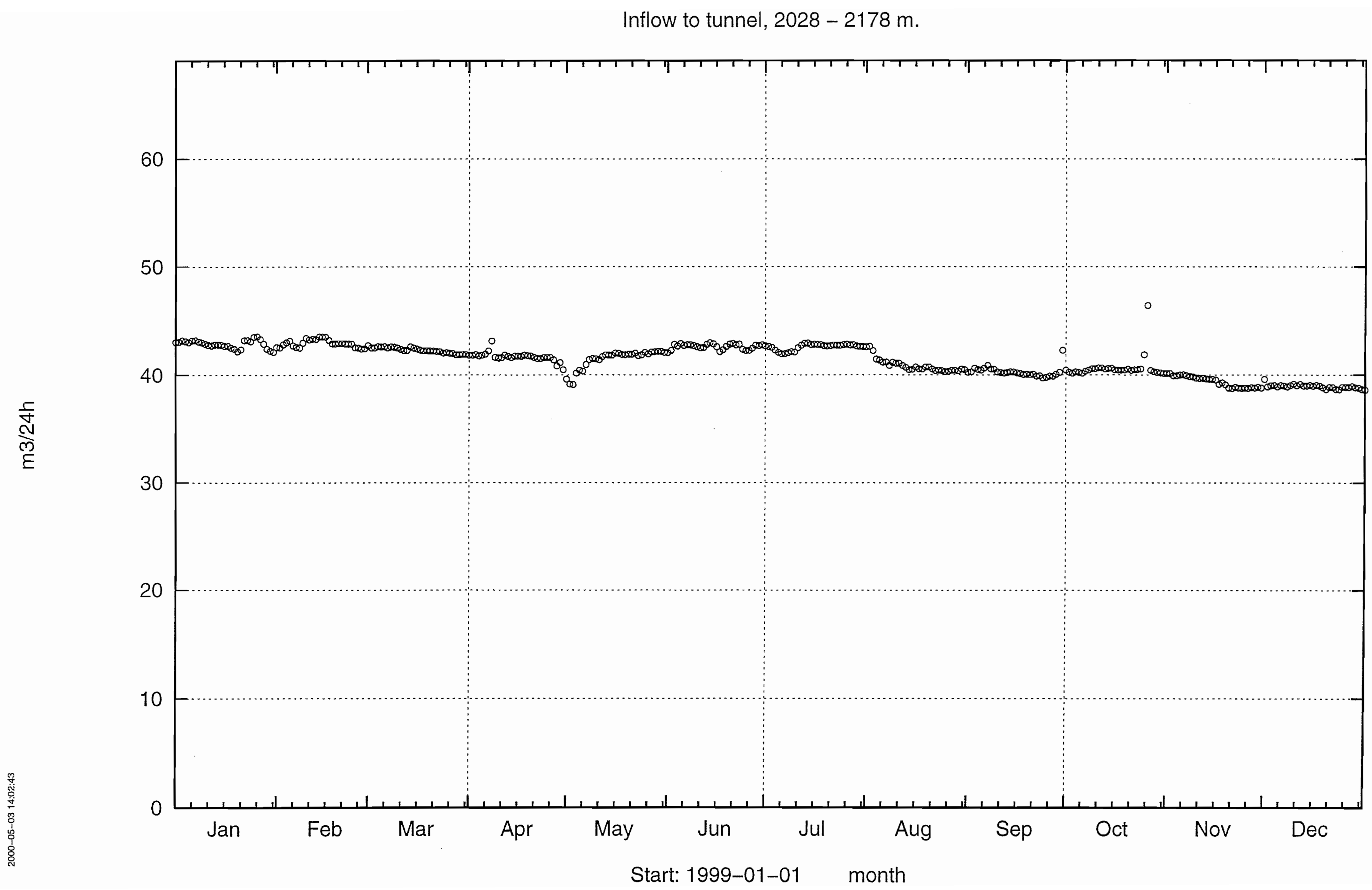
Inflow to tunnel, 1584 – 1745 m (shafts excluded).

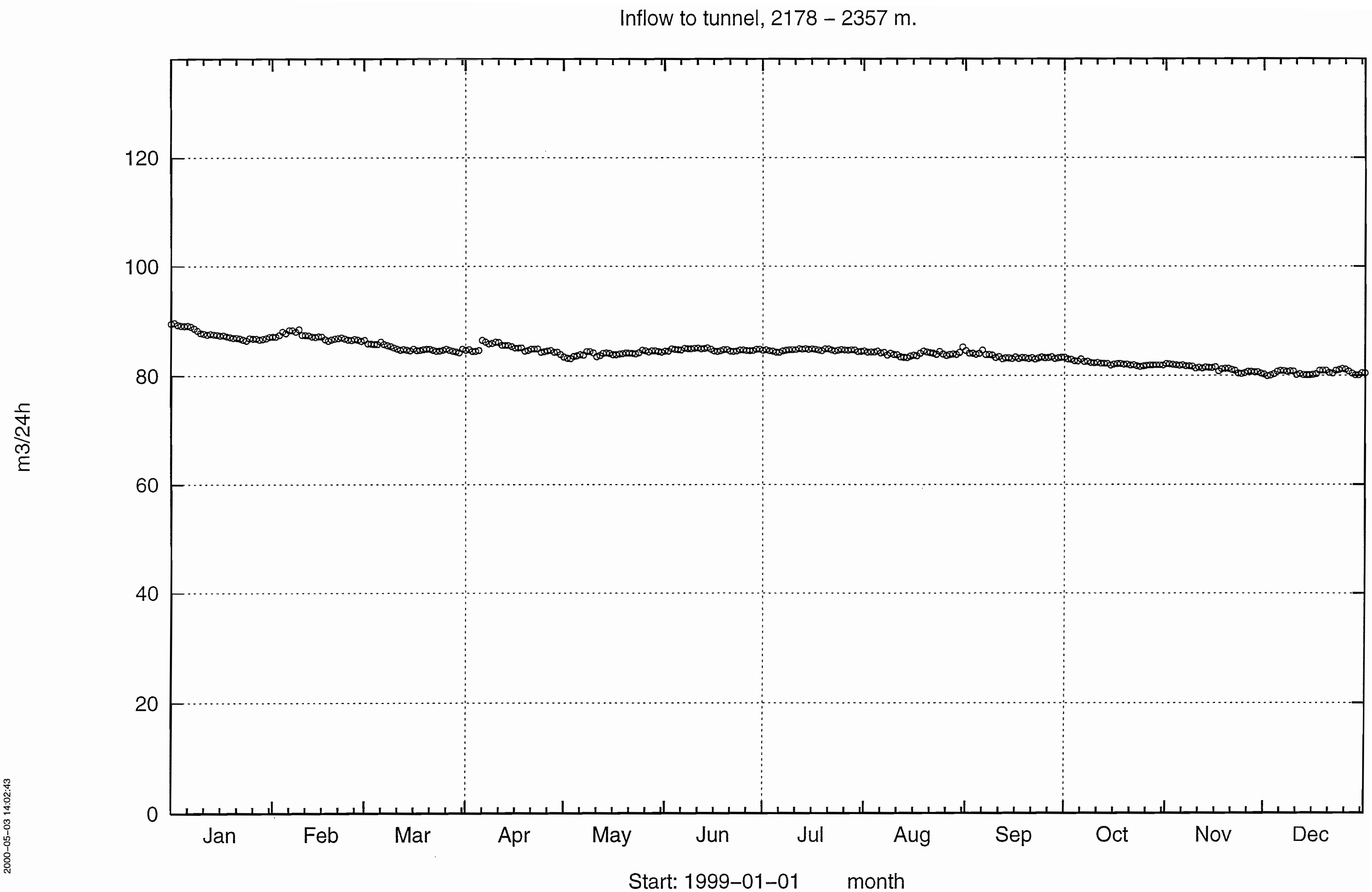


2000–05–03 14:02:41

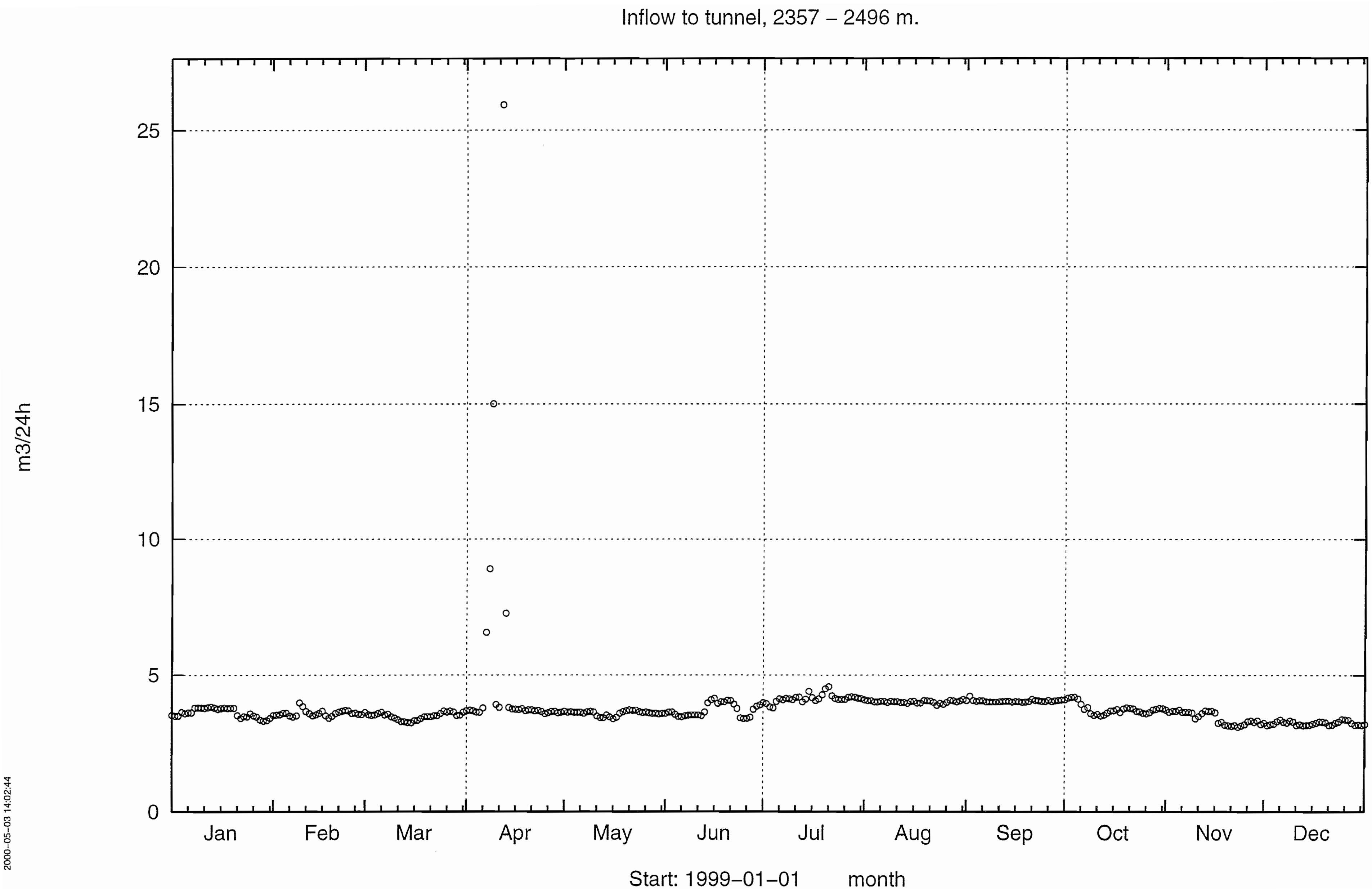

Inflow to tunnel, 1745 – 1883 m.
m3/24h
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–05–03 14:02:42


Inflow to tunnel, 1883 – 2028 m.
m3/24h
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01 month
2000–05–03 14:02:42

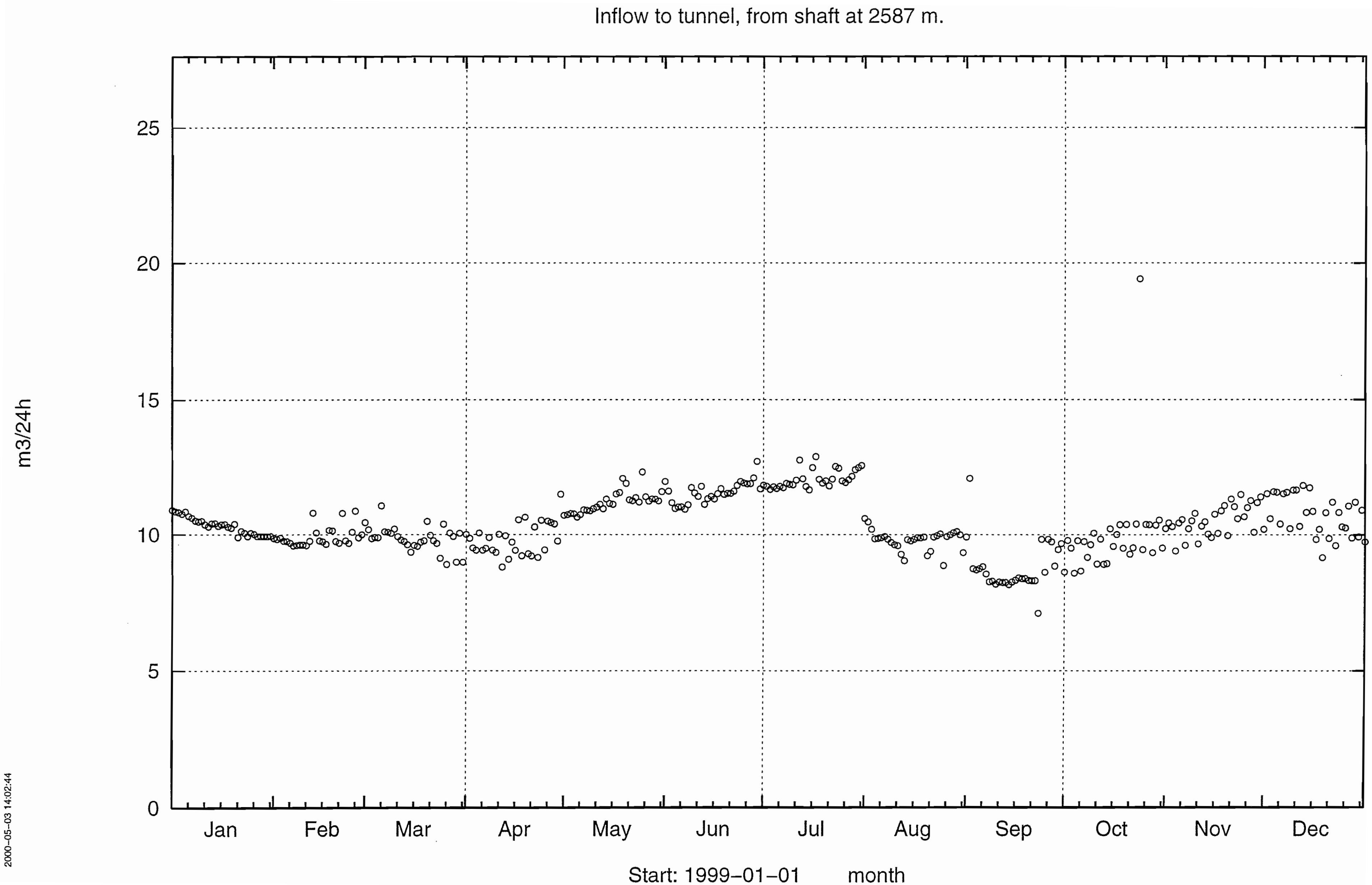

Inflow to tunnel, 2028 – 2178 m.
m3/24h
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–05–03 14:02:43

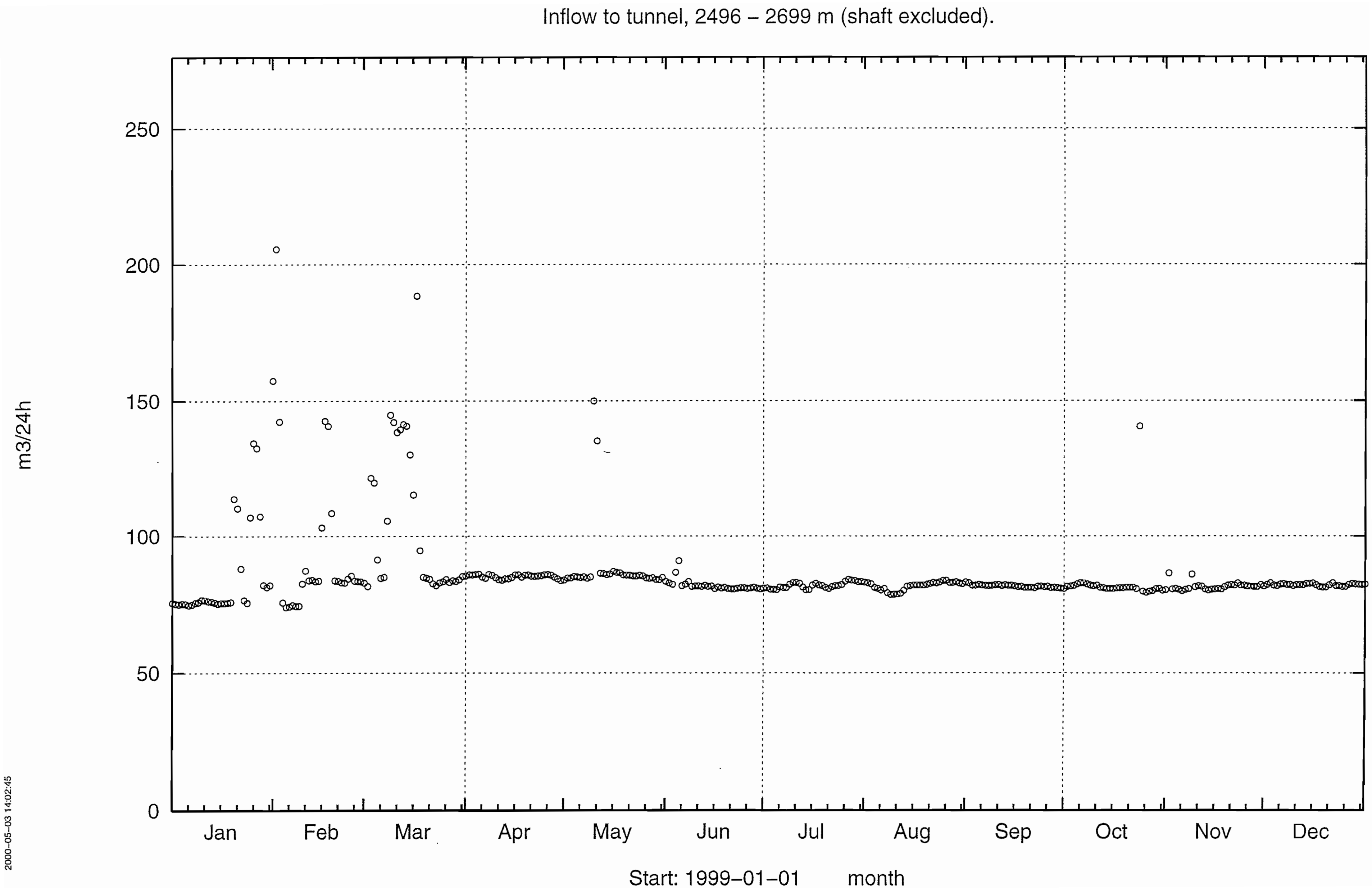


Inflow to tunnel, 2178 – 2357 m.
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01 month
2000–05–03 14:02:43

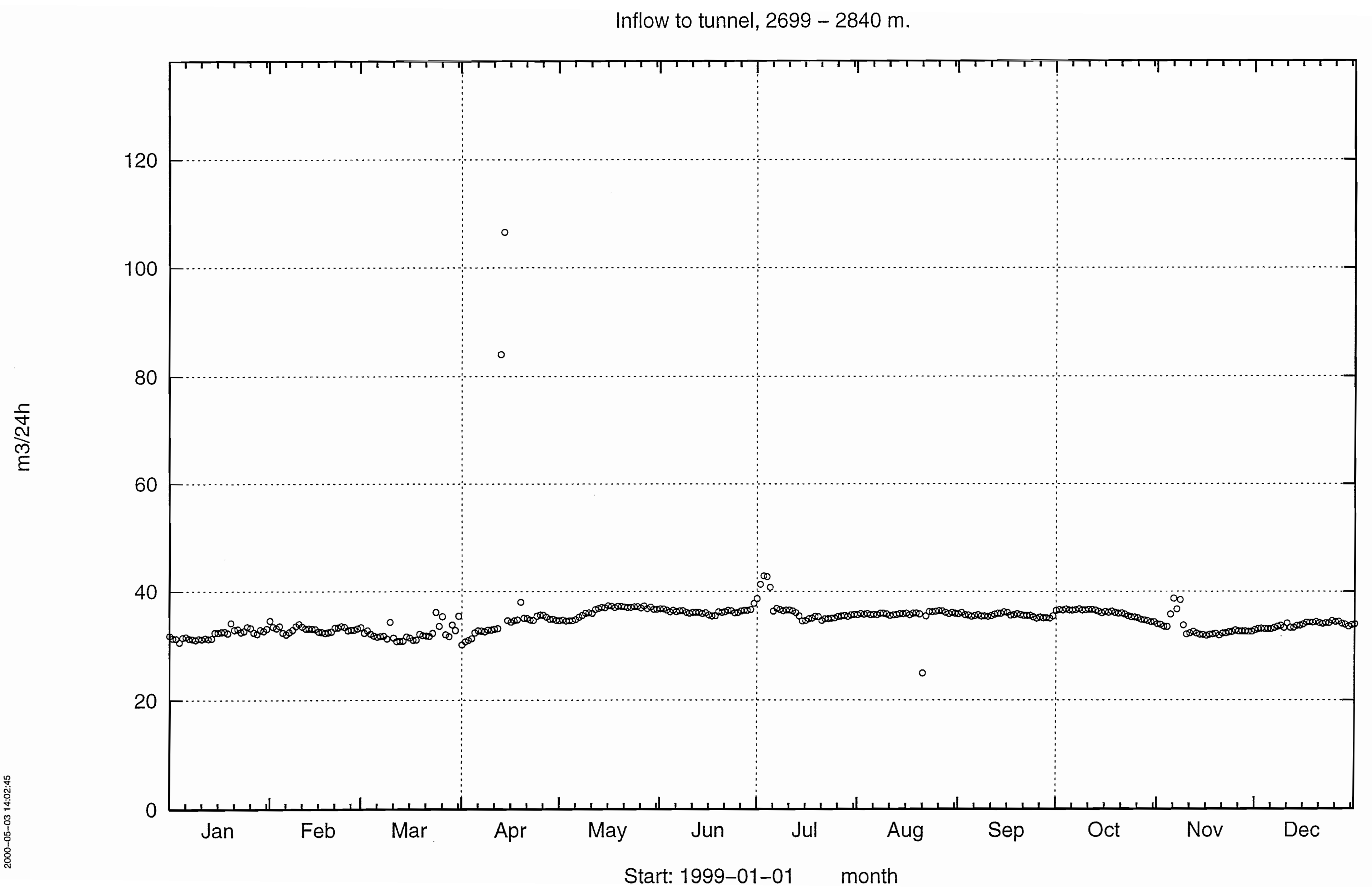


Inflow to tunnel, 2357 – 2496 m.
m3/24h
0
5
10
15
20
25
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-05-03 14:02:44

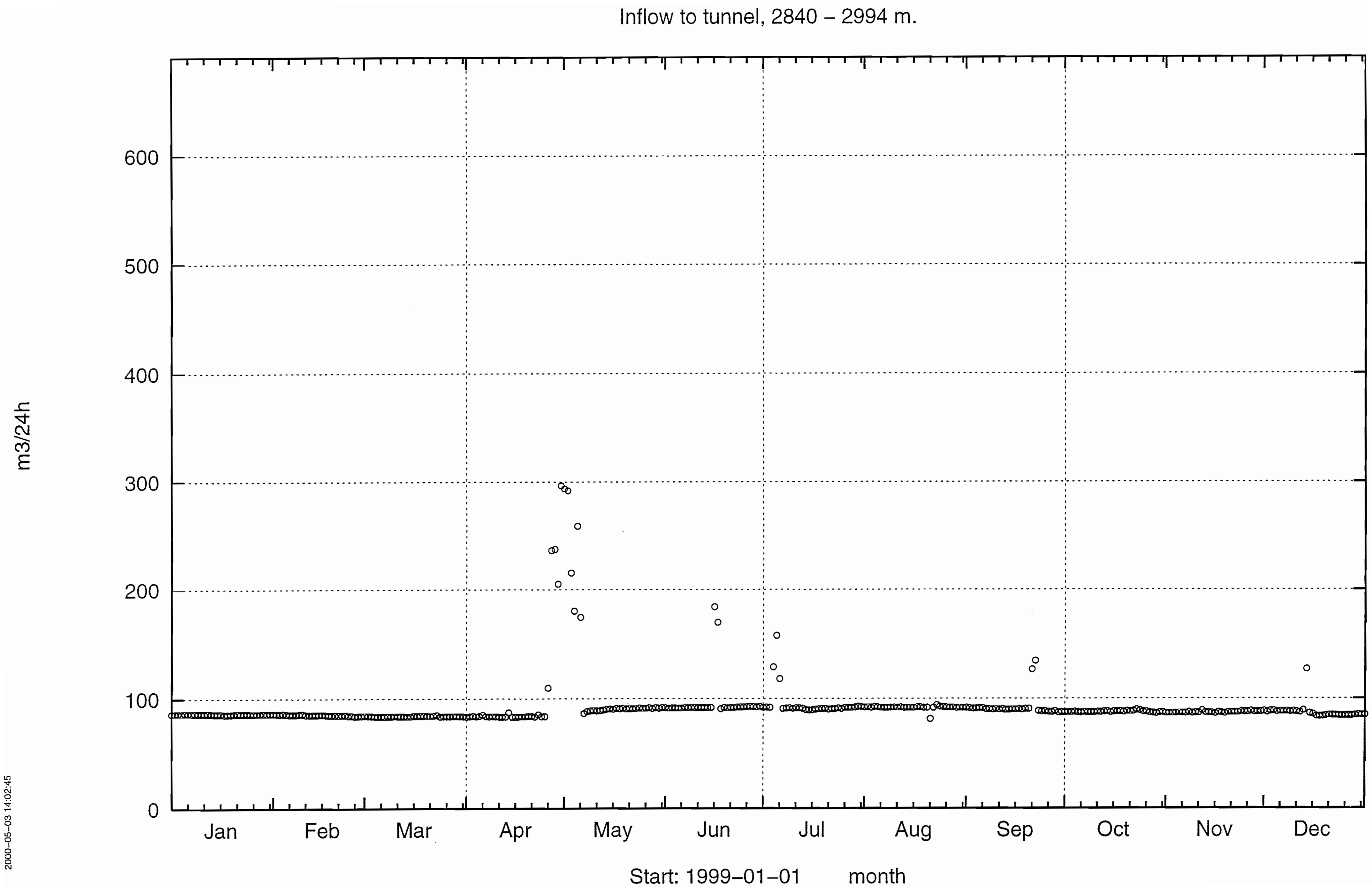

Inflow to tunnel, from shaft at 2587 m.
m3/24h
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−05−03 14:02:44



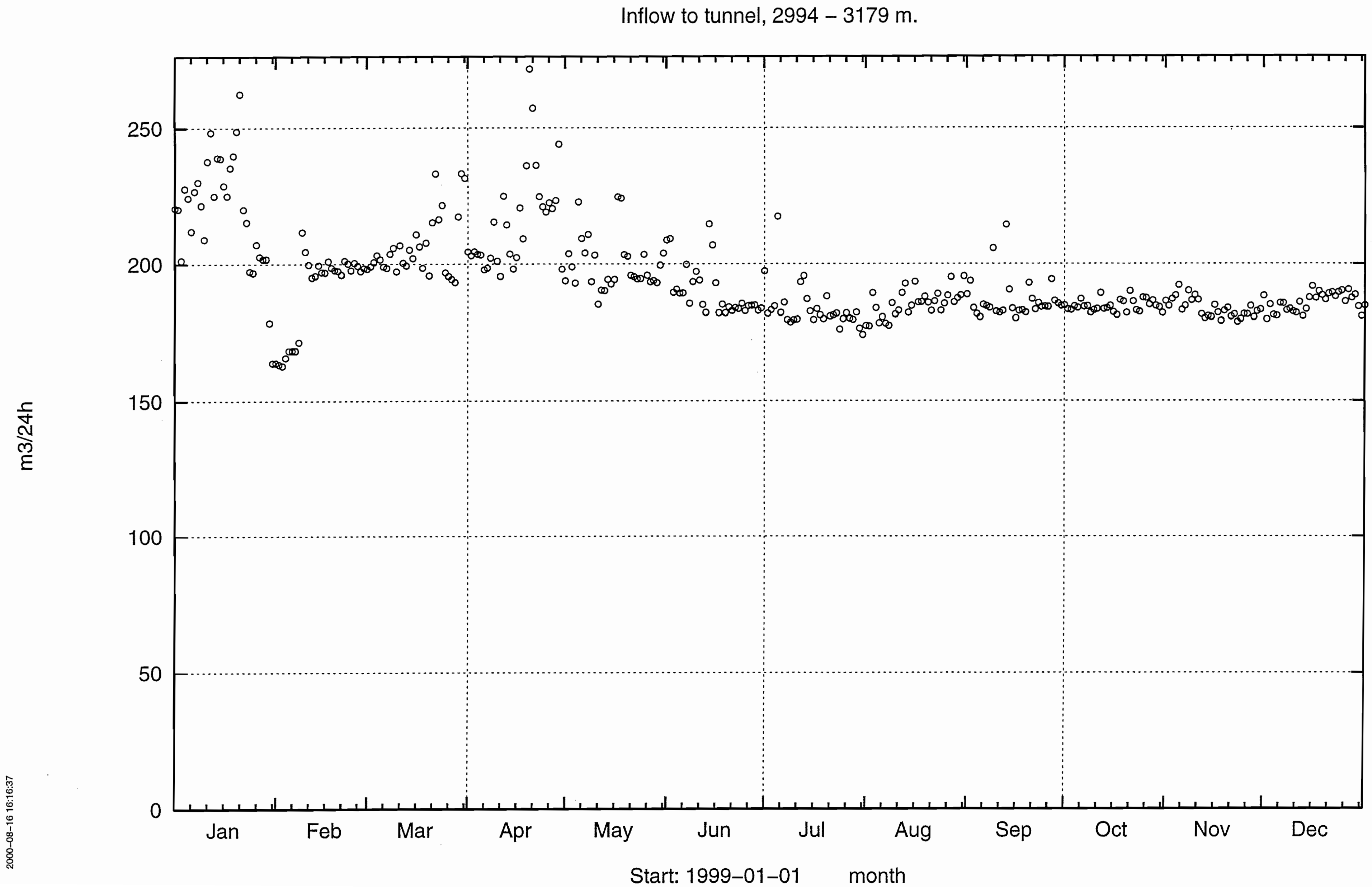
Inflow to tunnel, 2496 – 2699 m (shaft excluded).
m3/24h
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01 month
2000–05–03 14:02:45

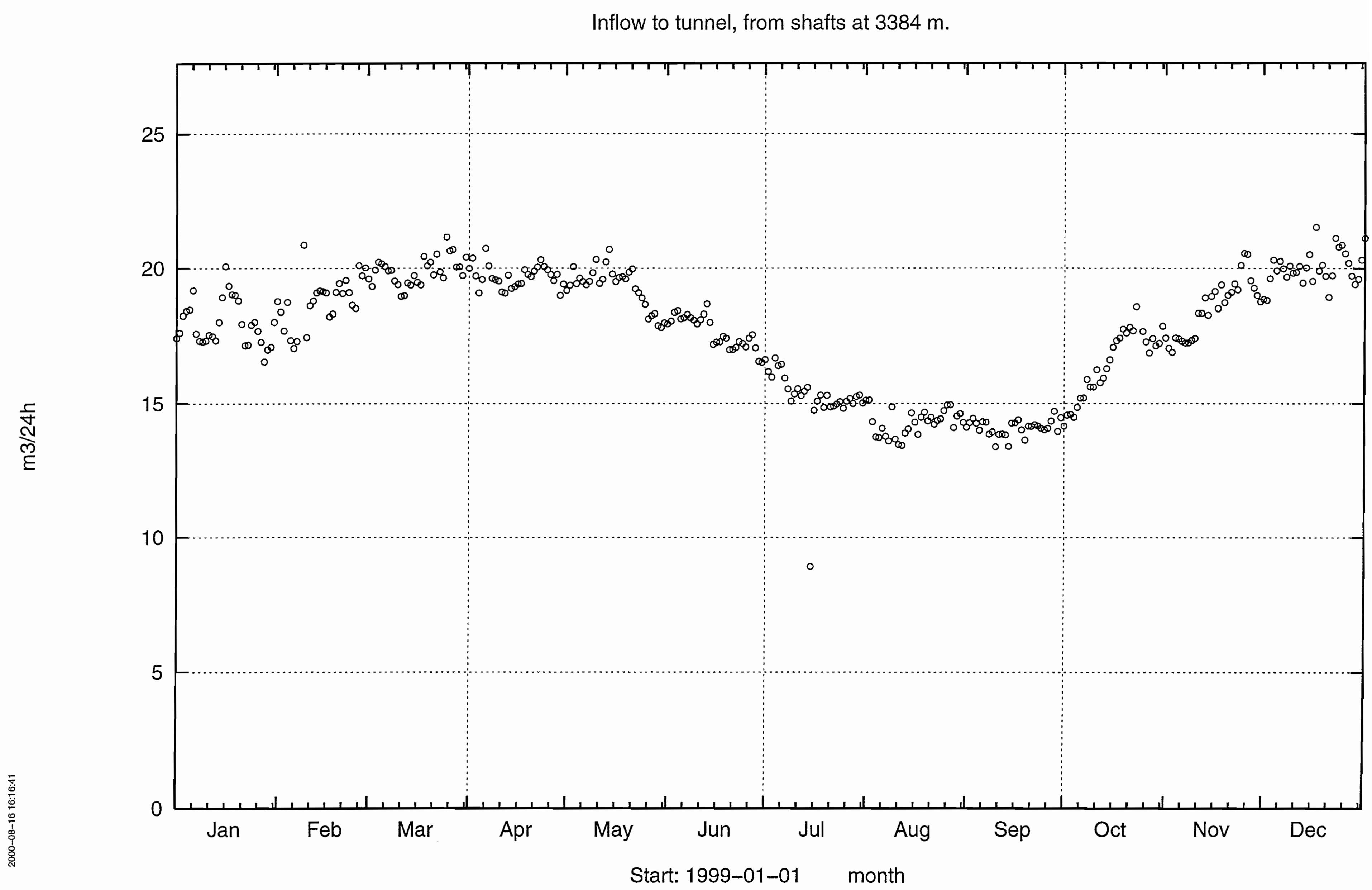


Inflow to tunnel, 2699 – 2840 m.
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01 month
2000–05–03 14:02:45

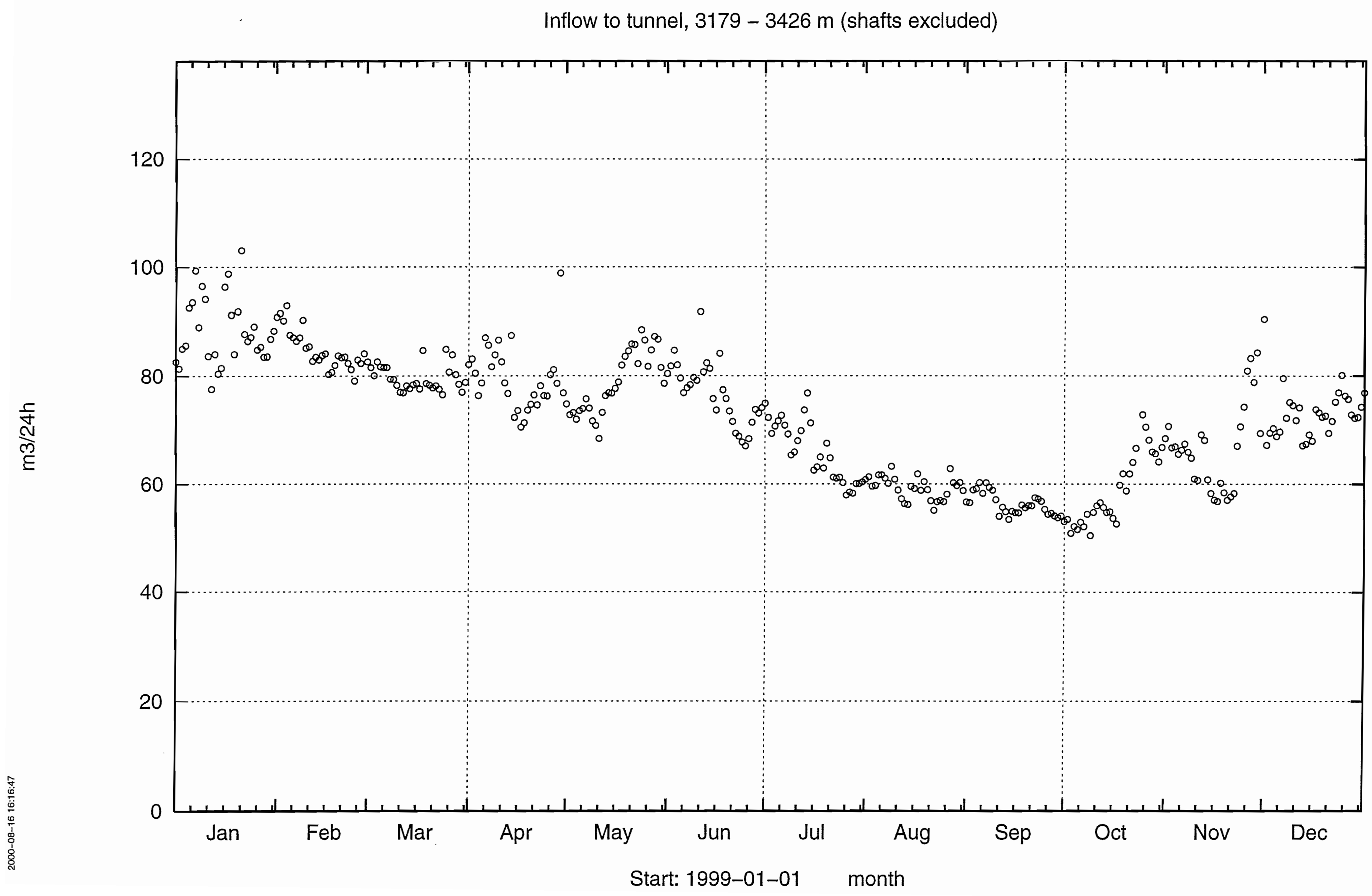


Inflow to tunnel, 2840 – 2994 m.
m3/24h
0
100
200
300
400
500
600
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01 month
2000–05–03 14:02:45


Inflow to tunnel, 2994 – 3179 m.
m3/24h
0
50
100
150
200
250
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–08–16 16:16:37

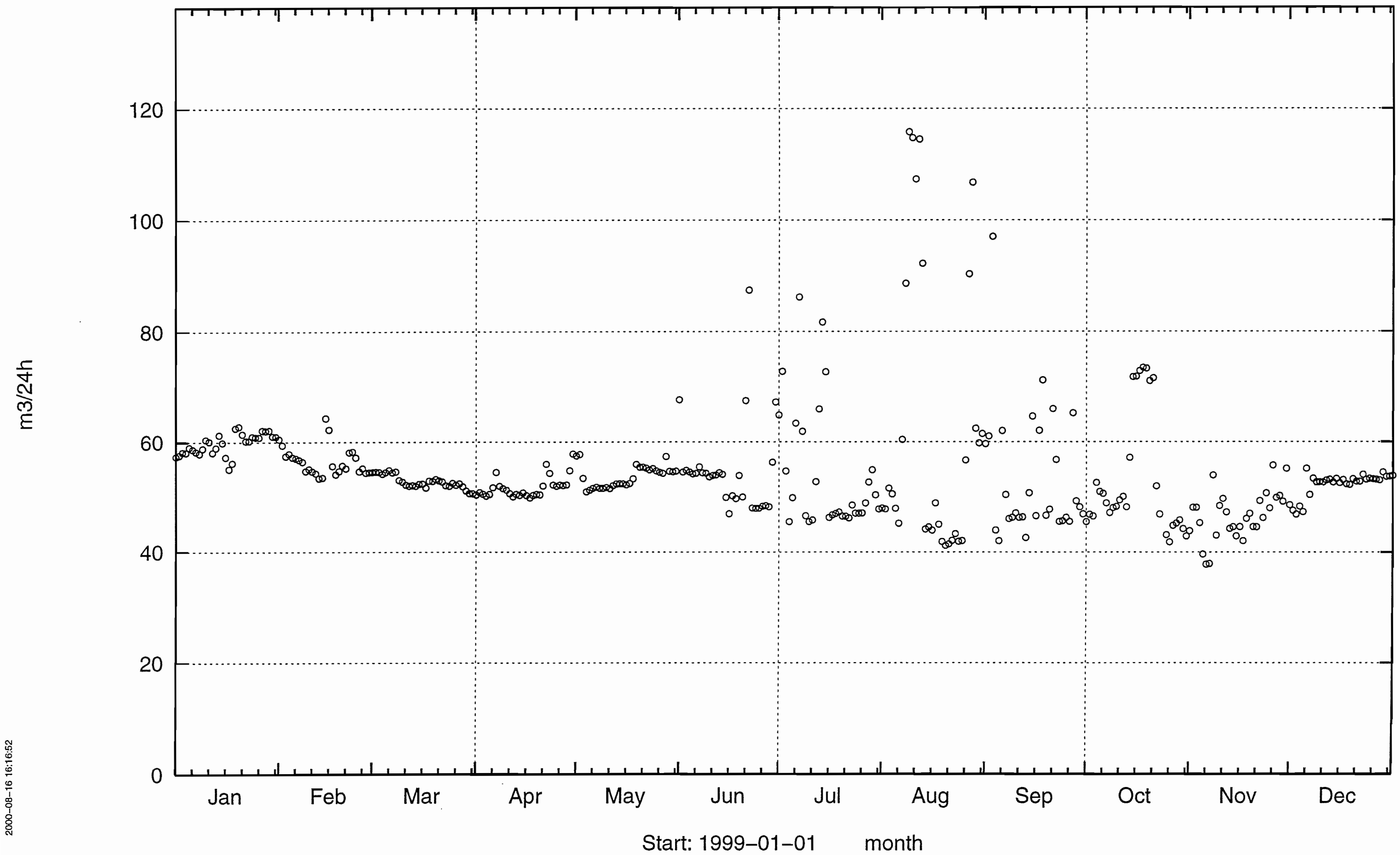


Inflow to tunnel, from shafts at 3384 m.
m3/24h
0
5
10
15
20
25
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-08-16 16:16:41

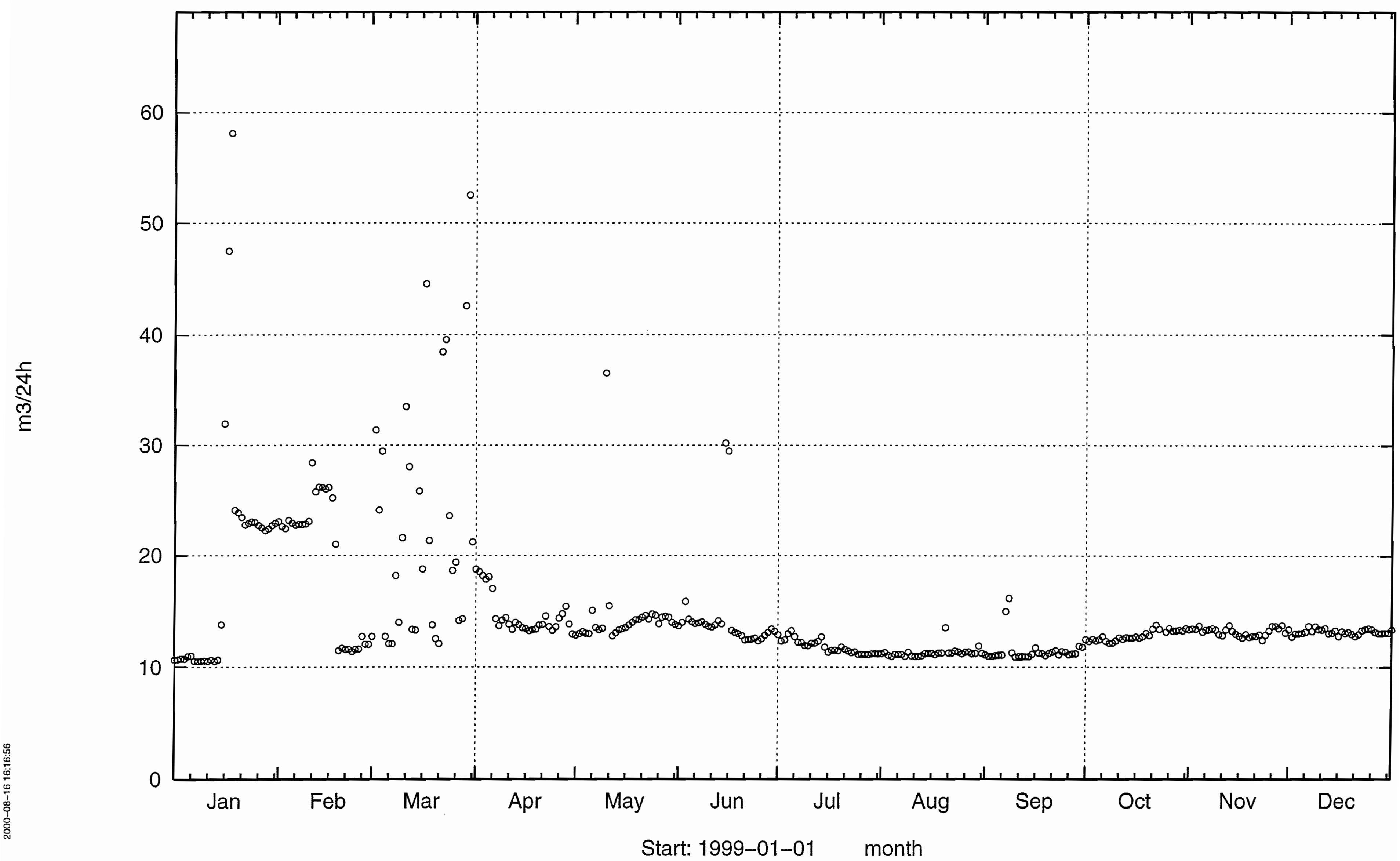


Inflow to tunnel, 3179 – 3426 m (shafts excluded)
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01 month
2000–08–16 16:16:47

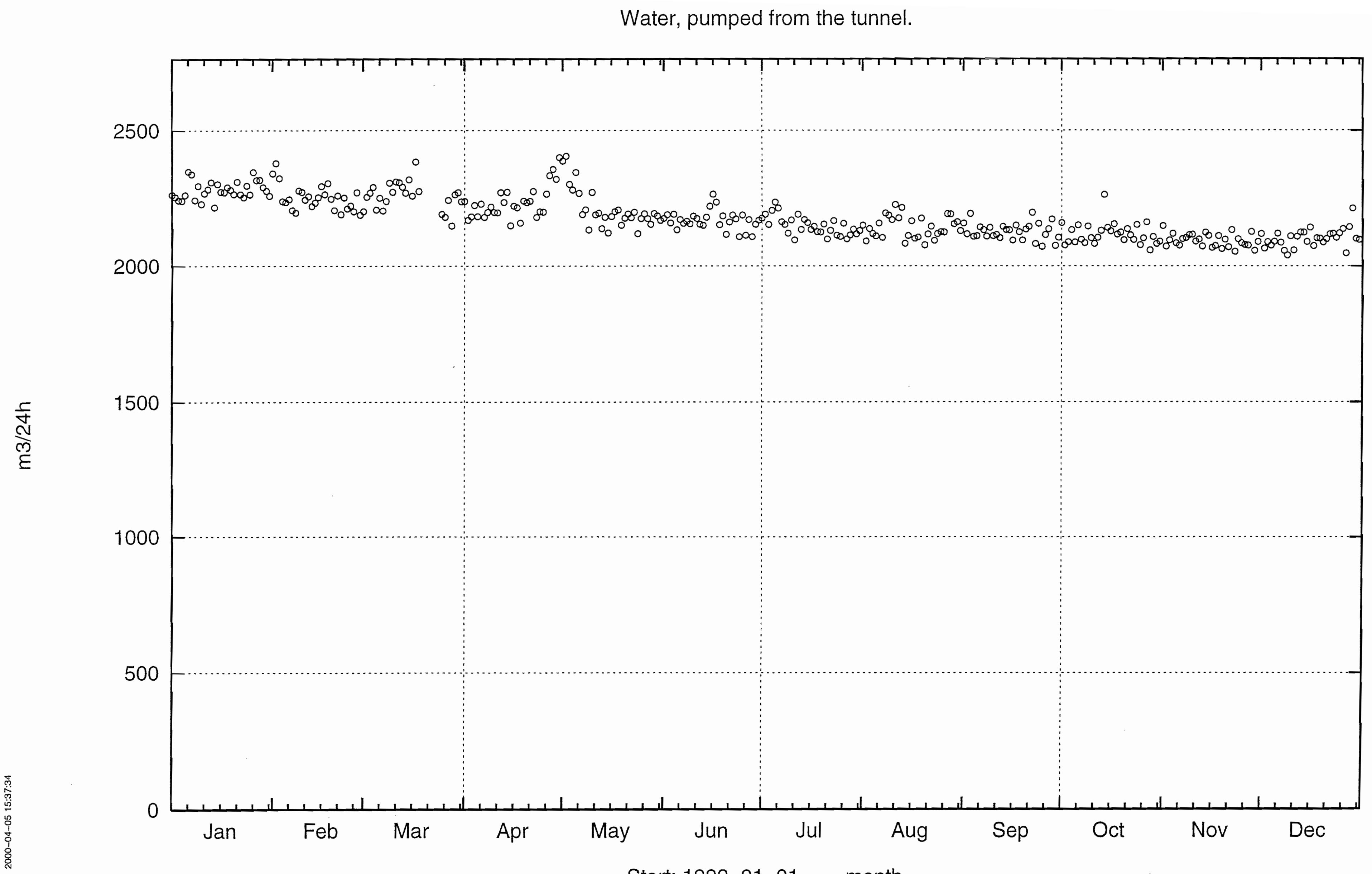
Inflow to tunnel, 3426 – 3600 m (parts of tunnel J included)



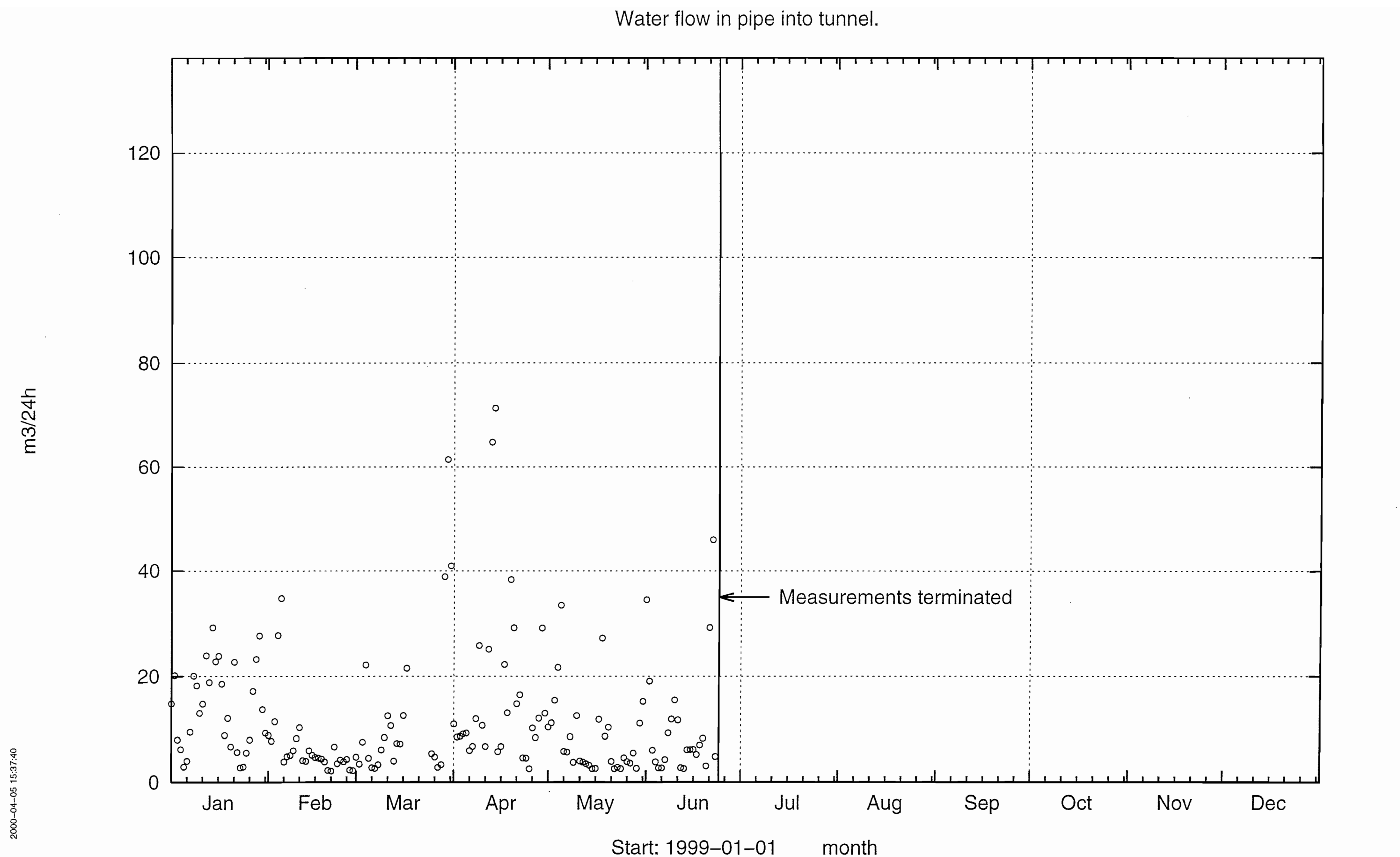
Inflow to tunnel F, 0 – 61 m (parts of tunnels J and G included)



Appendix 6: Water flow in tunnel pipes

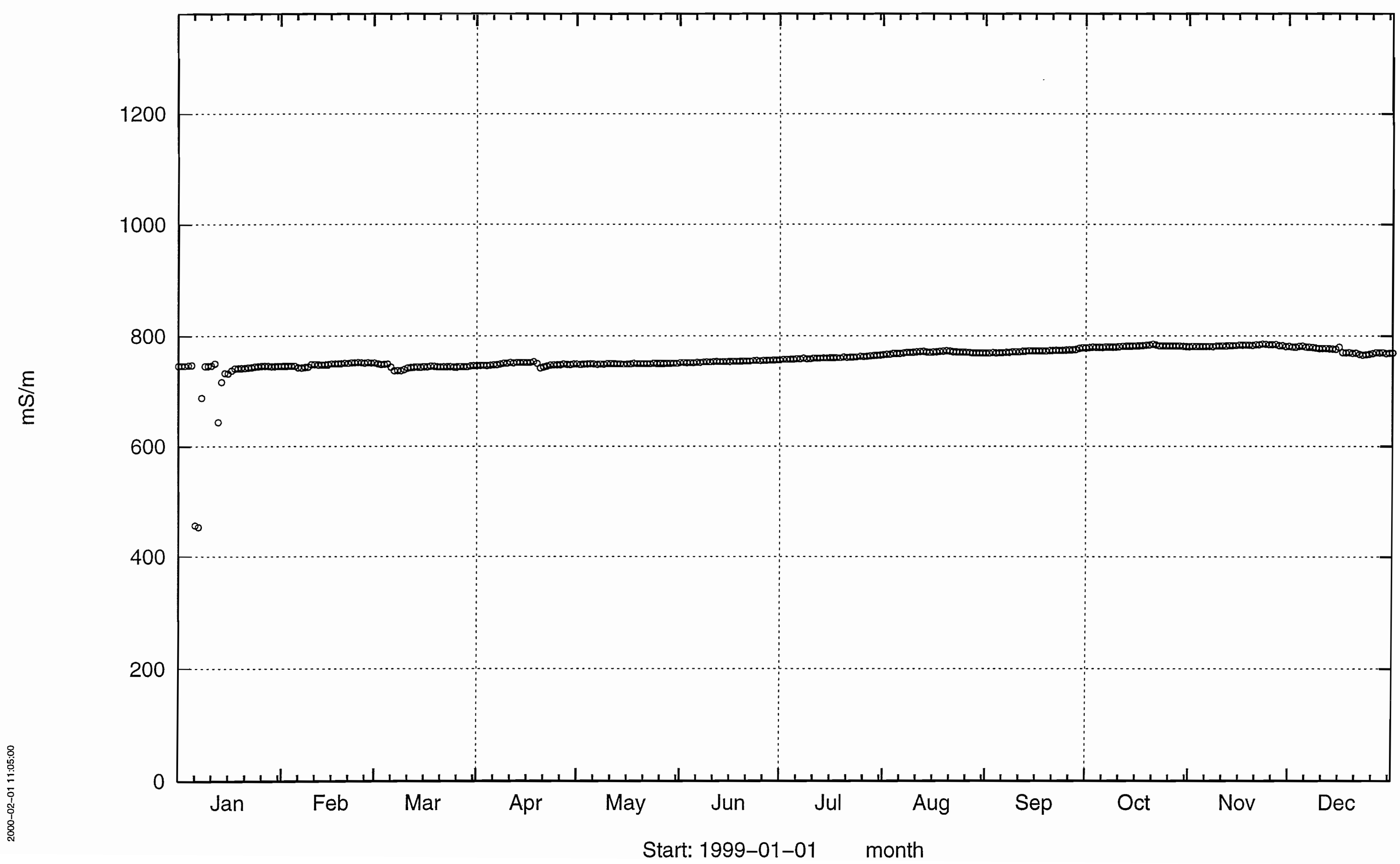


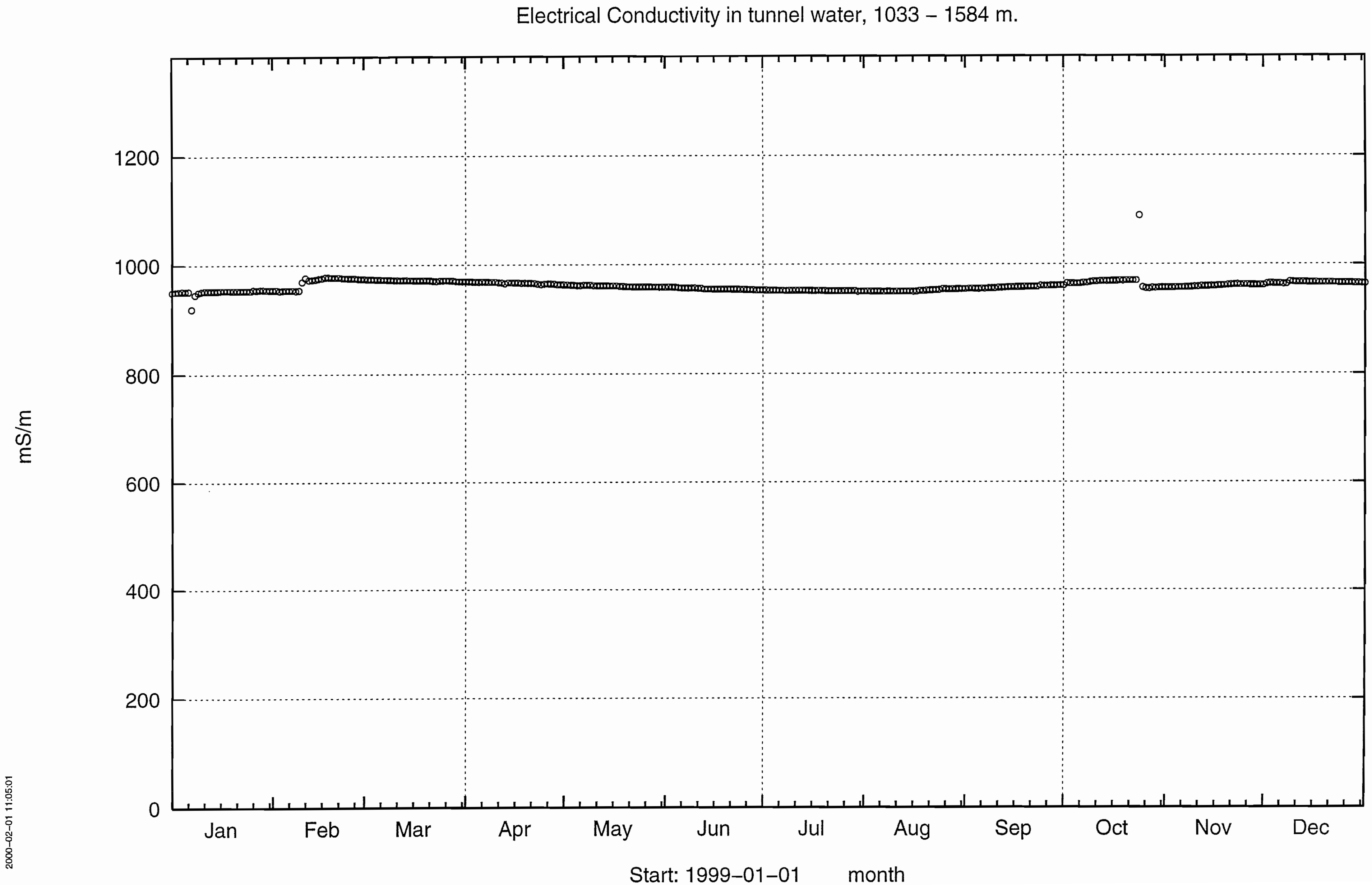
Water, pumped from the tunnel.
m3/24h
0
500
1000
1500
2000
2500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000-04-05 15:37:34


Water flow in pipe into tunnel.
m3/24h
0
20
40
60
80
100
120
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-04-05 15:37:40

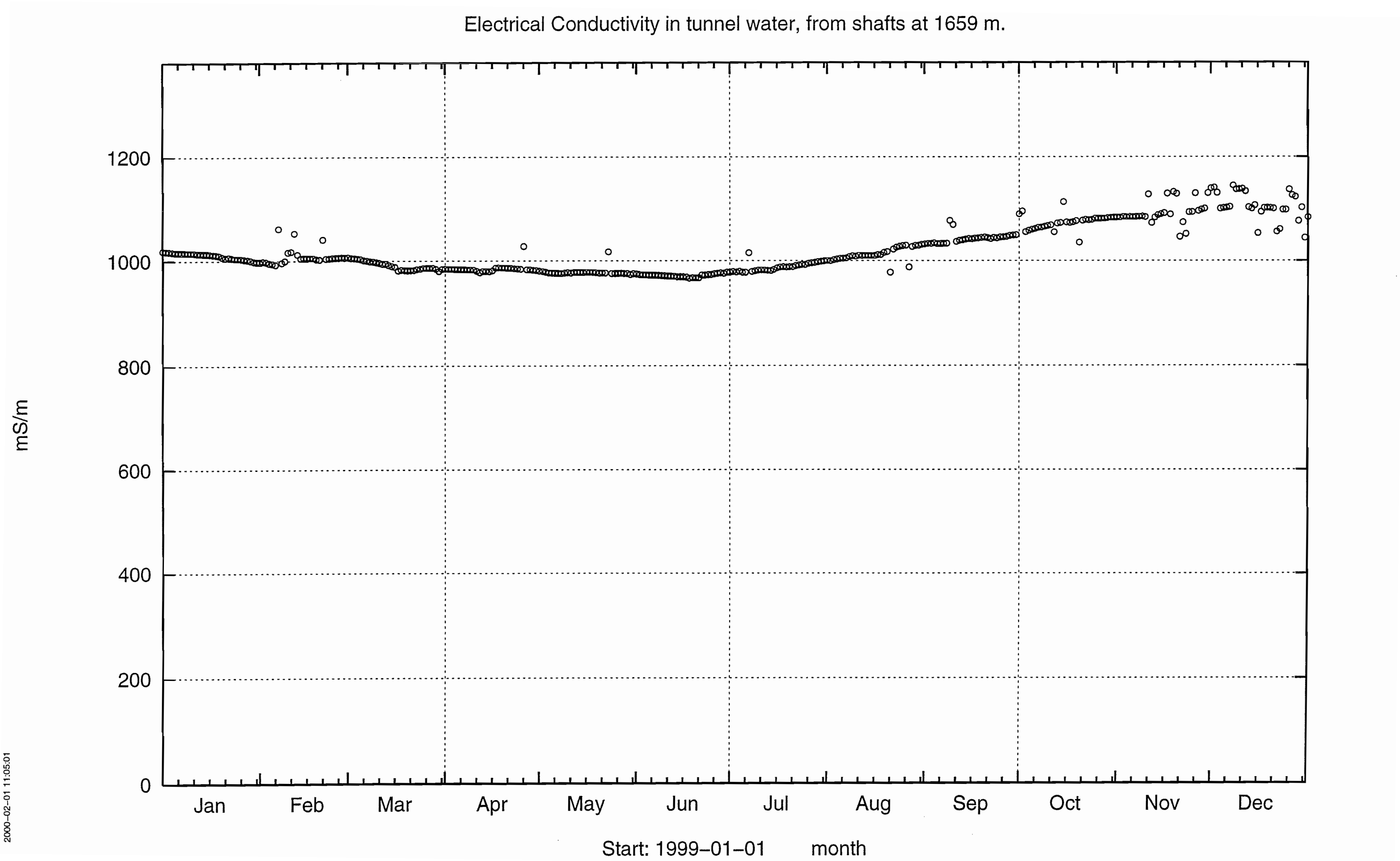
Appendix 7: Electrical conductivity of tunnel water

Electrical Conductivity in tunnel water, 0 – 682 m.

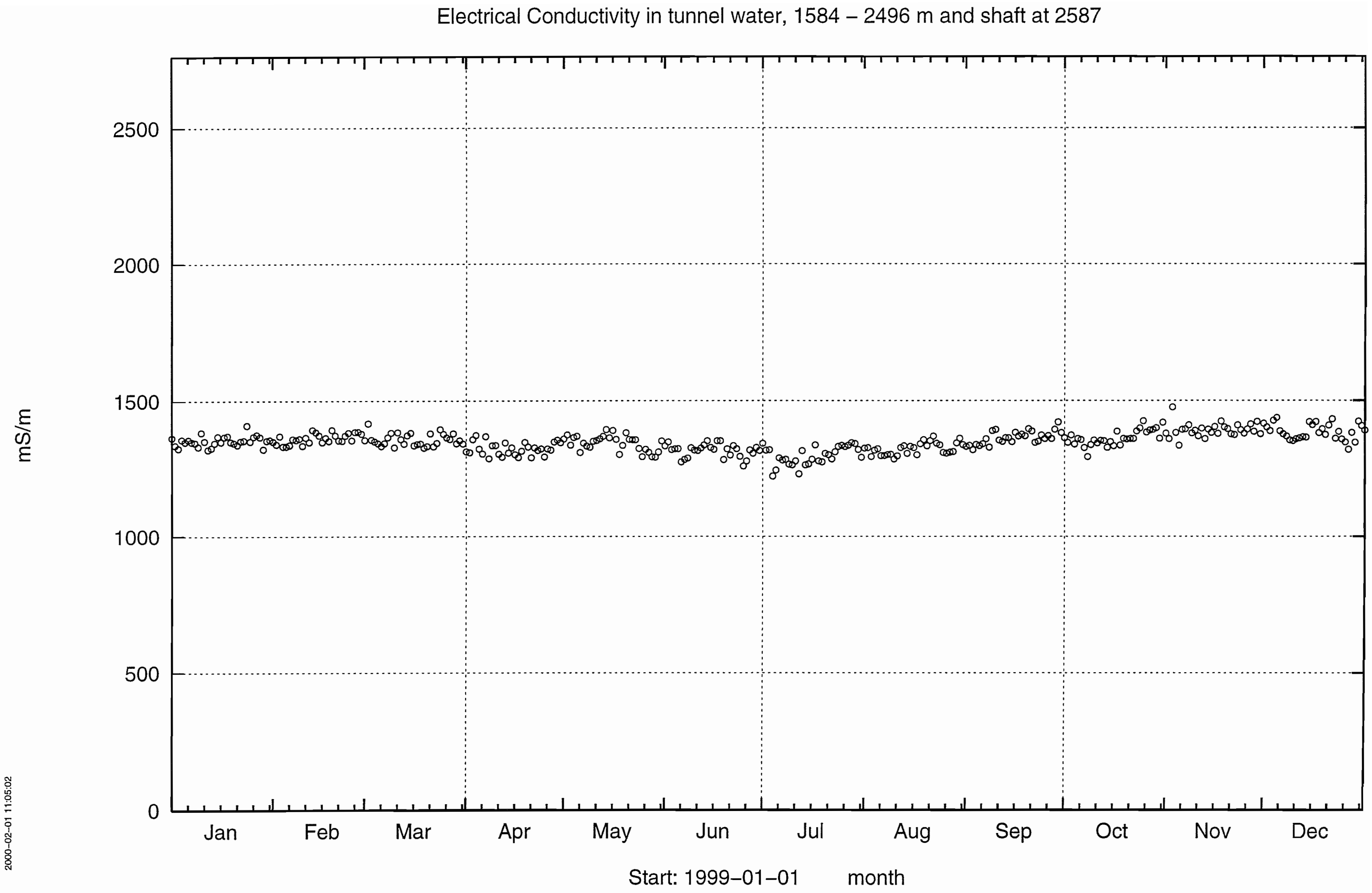


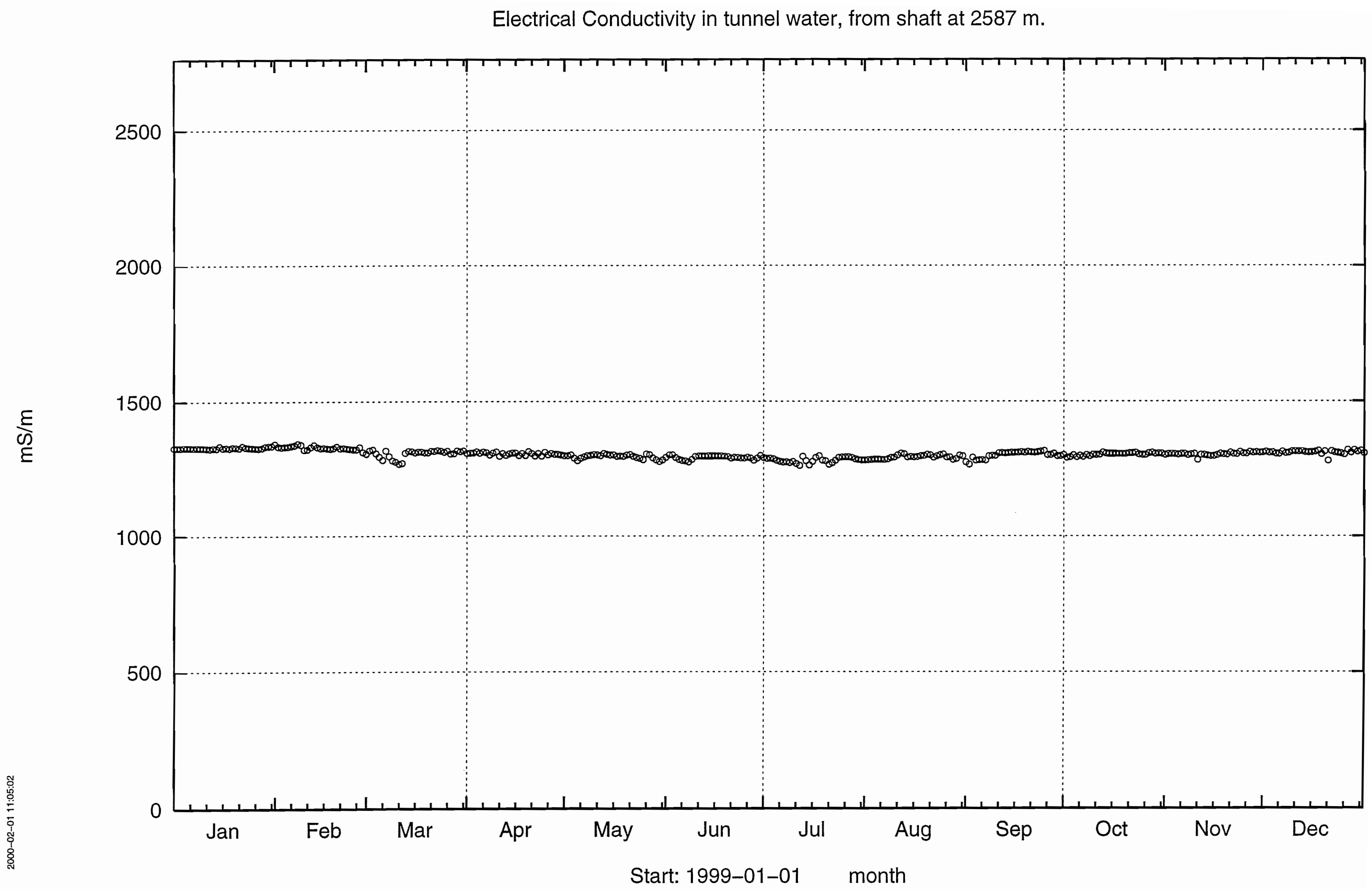


Electrical Conductivity in tunnel water, 1033 – 1584 m.
mS/m
0
200
400
600
800
1000
1200
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-02-01 11:05:01

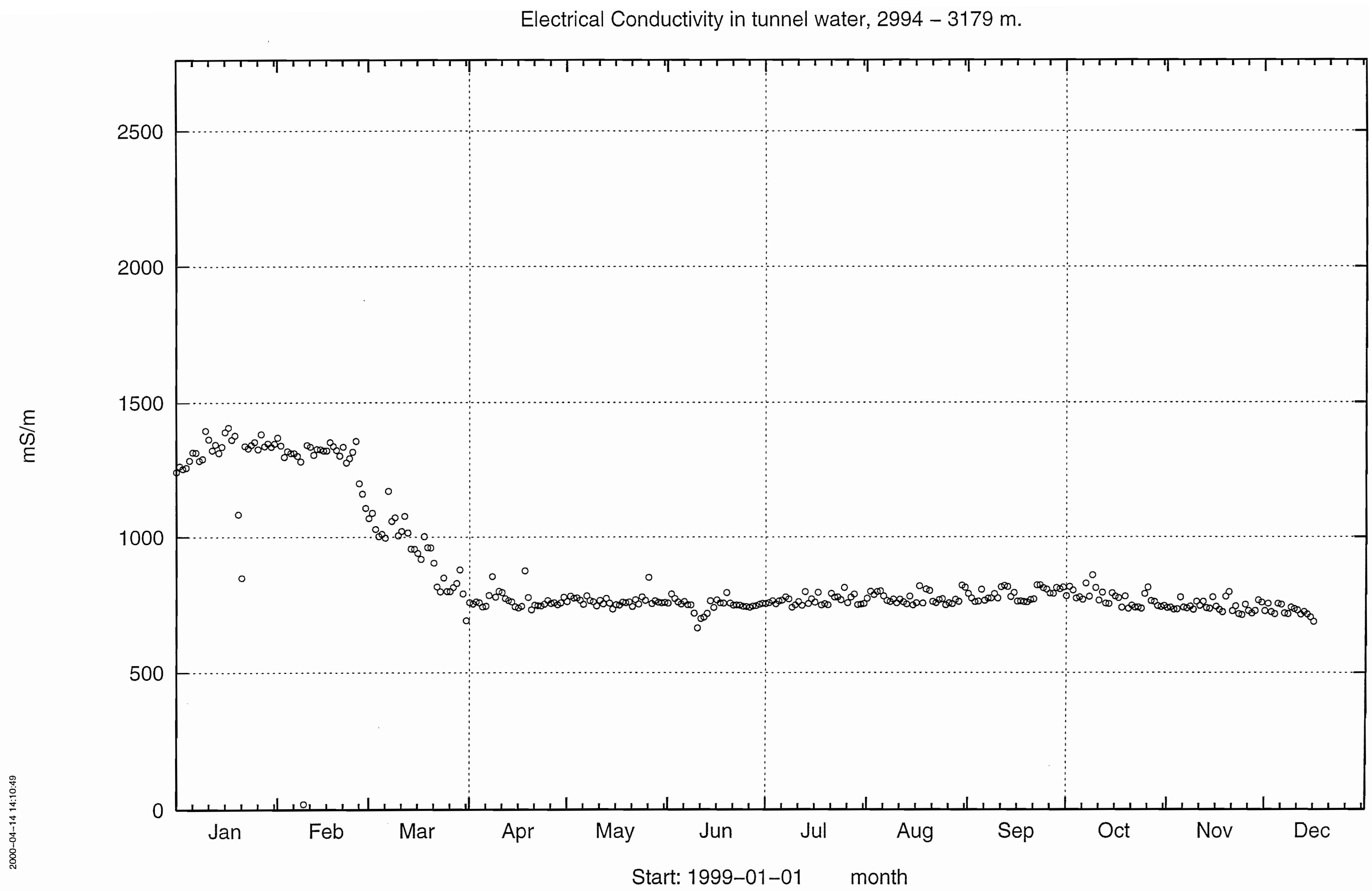


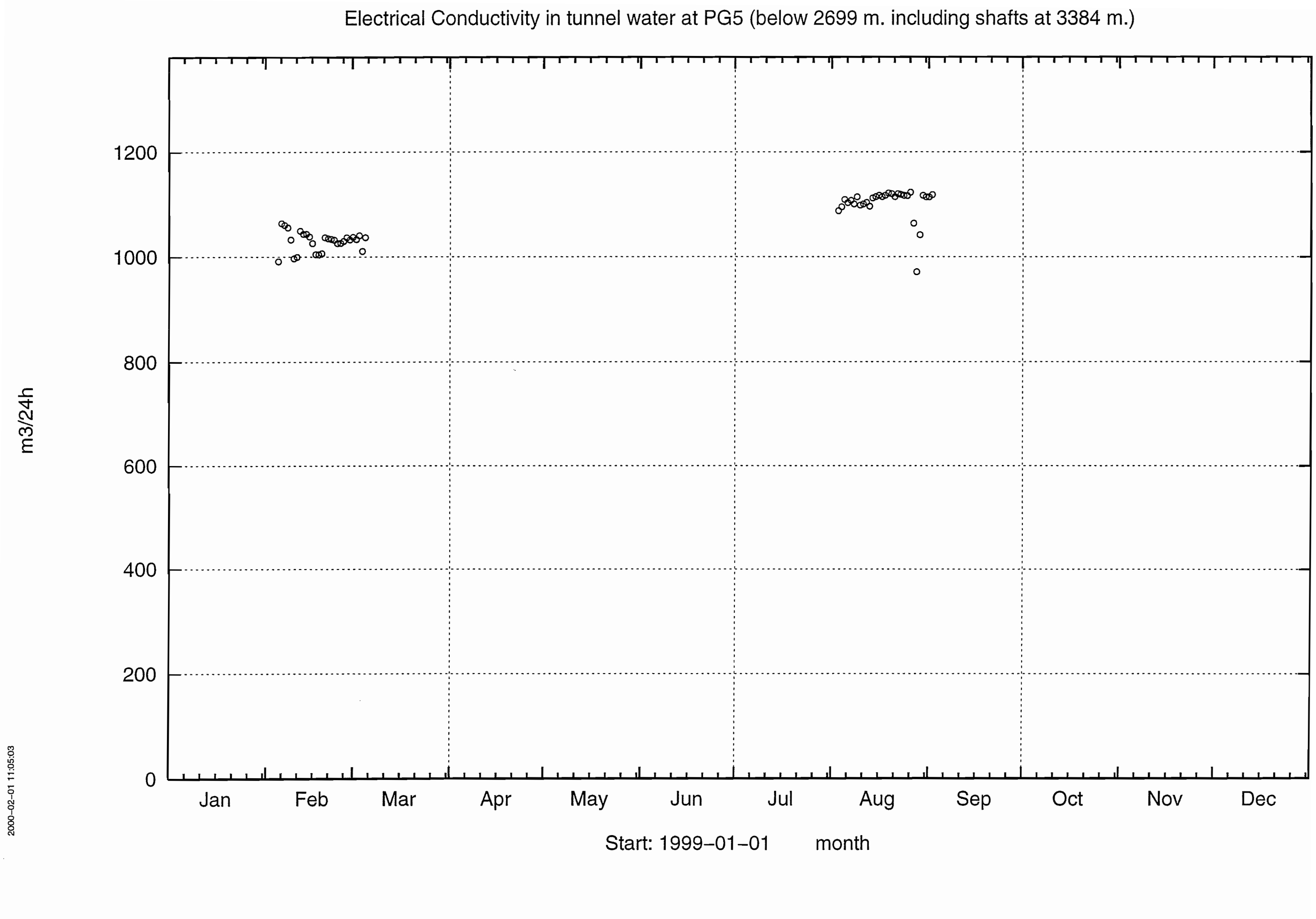
Electrical Conductivity in tunnel water, from shafts at 1659 m.
mS/m
0
200
400
600
800
1000
1200
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01 month
2000–02–01 11:05:01

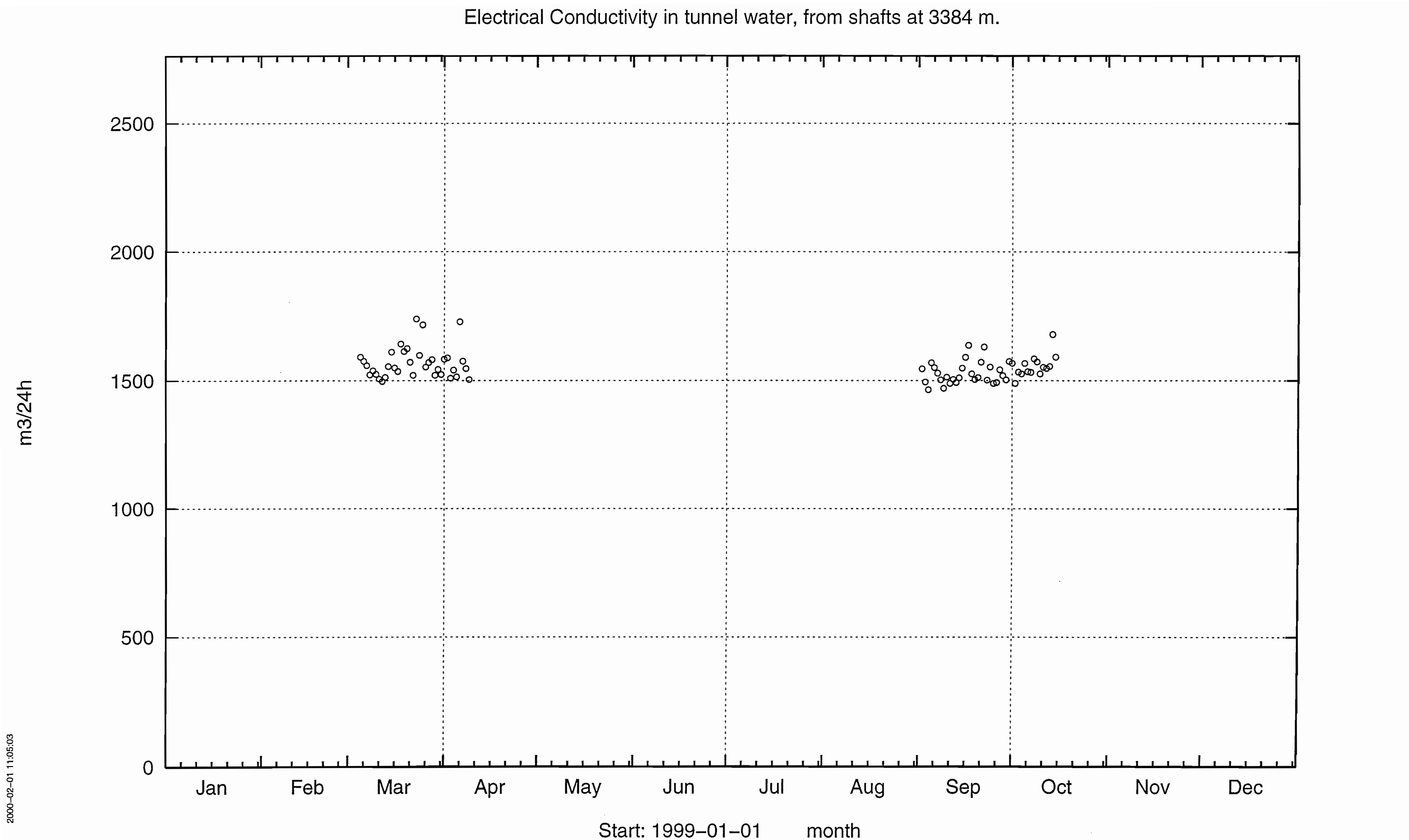

Electrical Conductivity in tunnel water, 1584 – 2496 m and shaft at 2587
mS/m
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-02-01 11:05:02



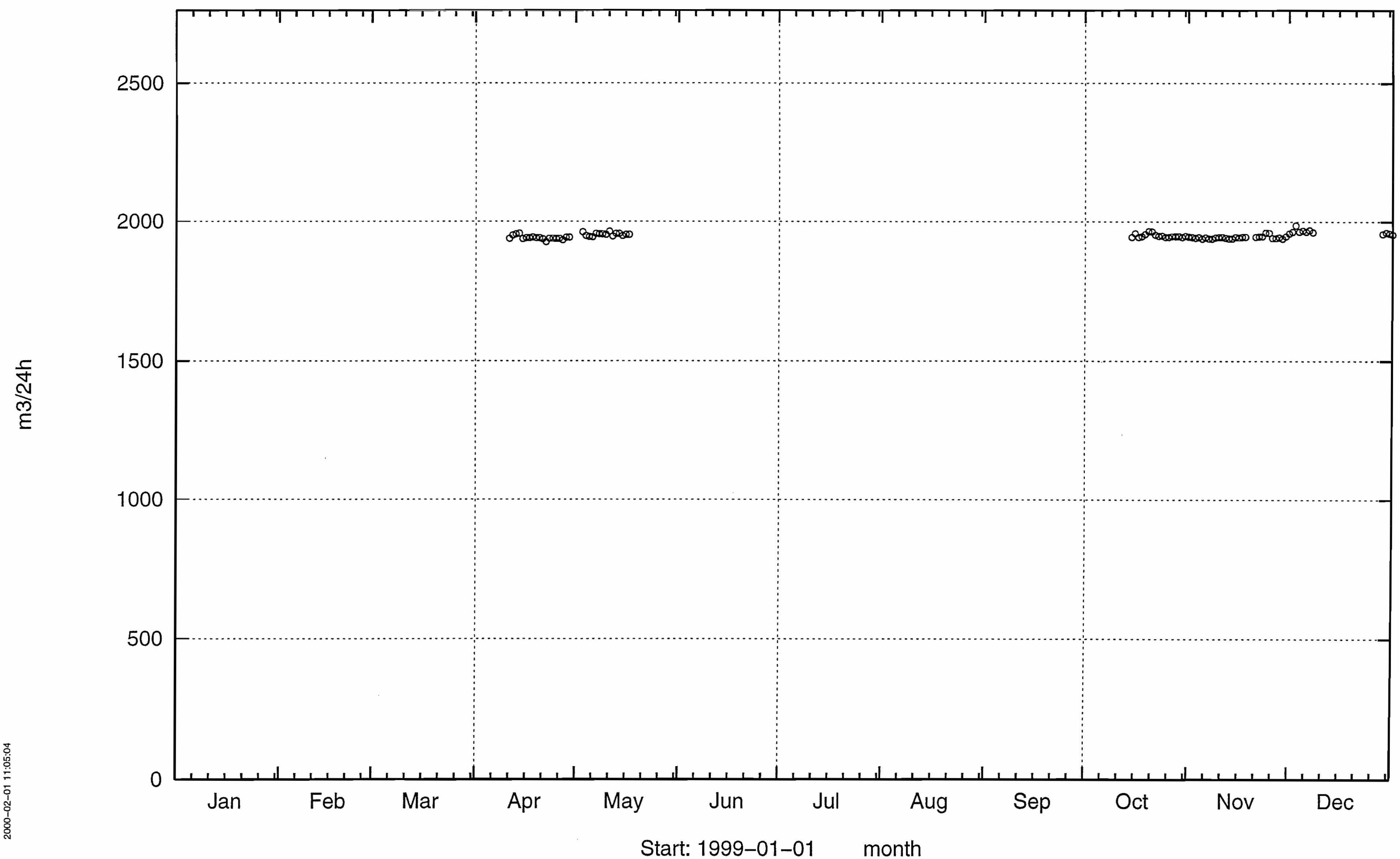
Electrical Conductivity in tunnel water, from shaft at 2587 m.
mS/m
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−02−01 11:05:02

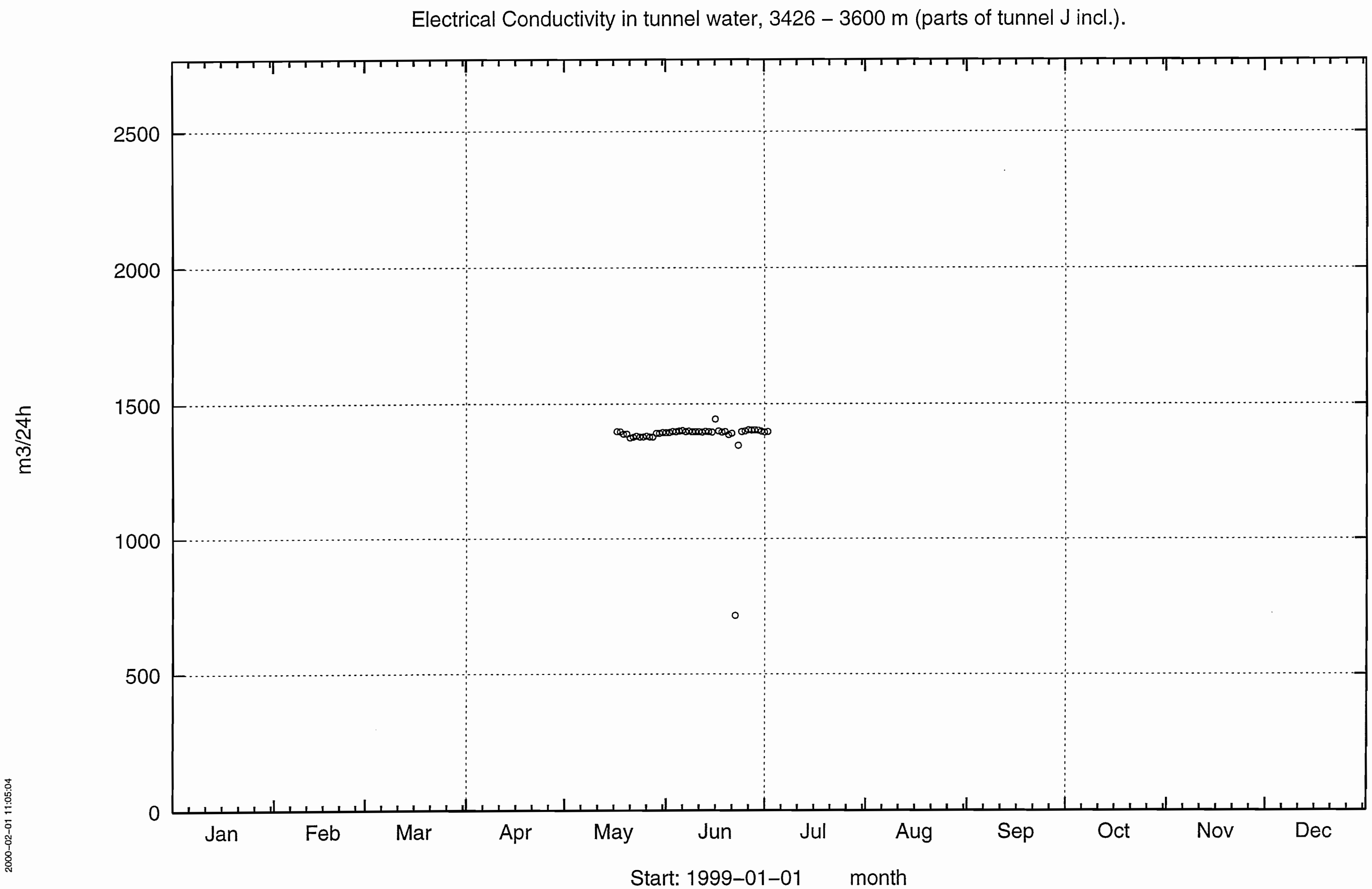

Electrical Conductivity in tunnel water, 2994 – 3179 m.
mS/m
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-04-14 14:10:49


Electrical Conductivity in tunnel water at PG5 (below 2699 m. including shafts at 3384 m.)
1200
1000
800
600
400
200
0
m3/24h
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–02–01 11:05:03

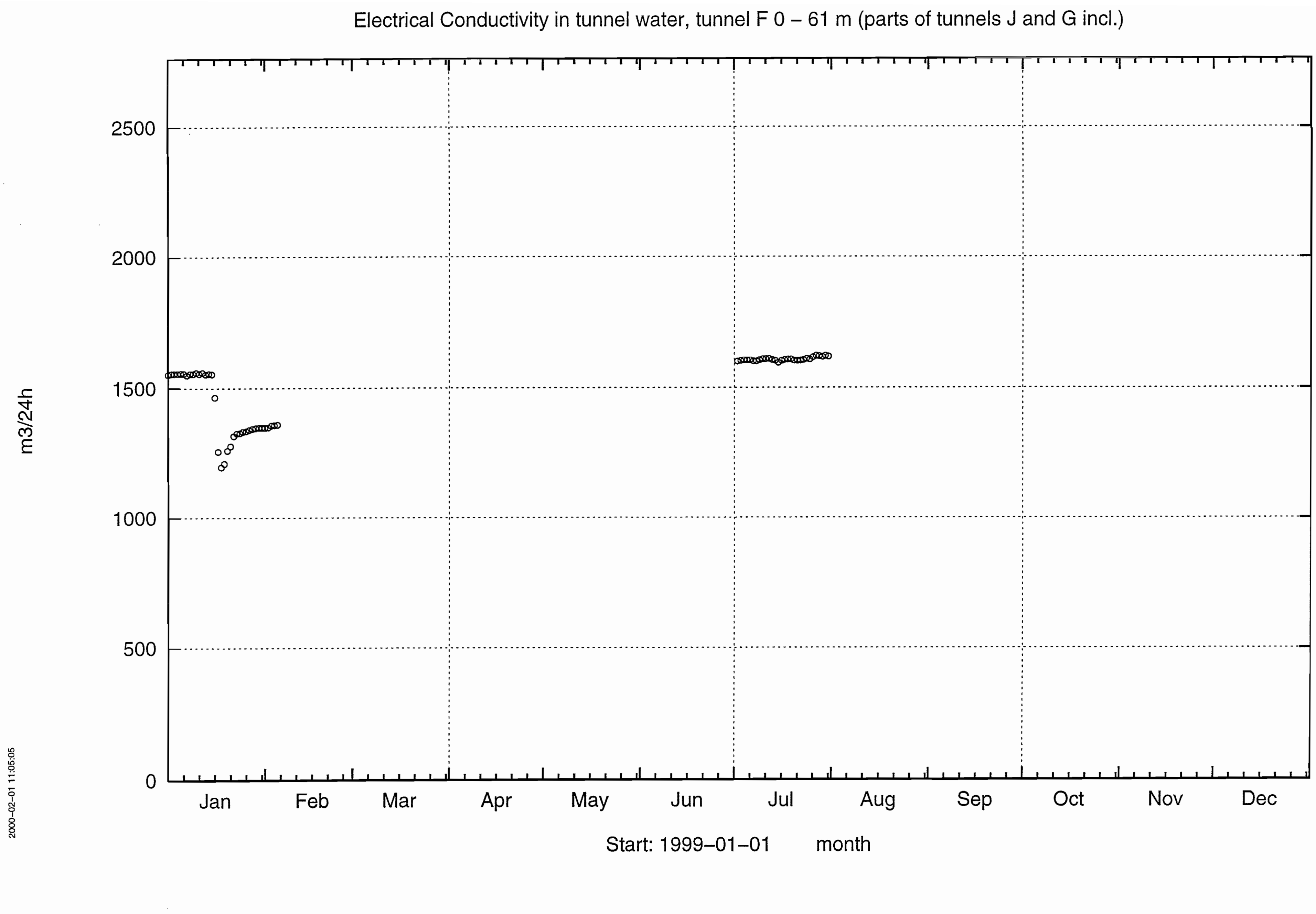

Electrical Conductivity in tunnel water, from shafts at 3384 m.
m3/24h
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01 month
2000-02-01 11:05:03

Electrical Conductivity i tunnel water, 3179 – 3426 m (shafts excluded).

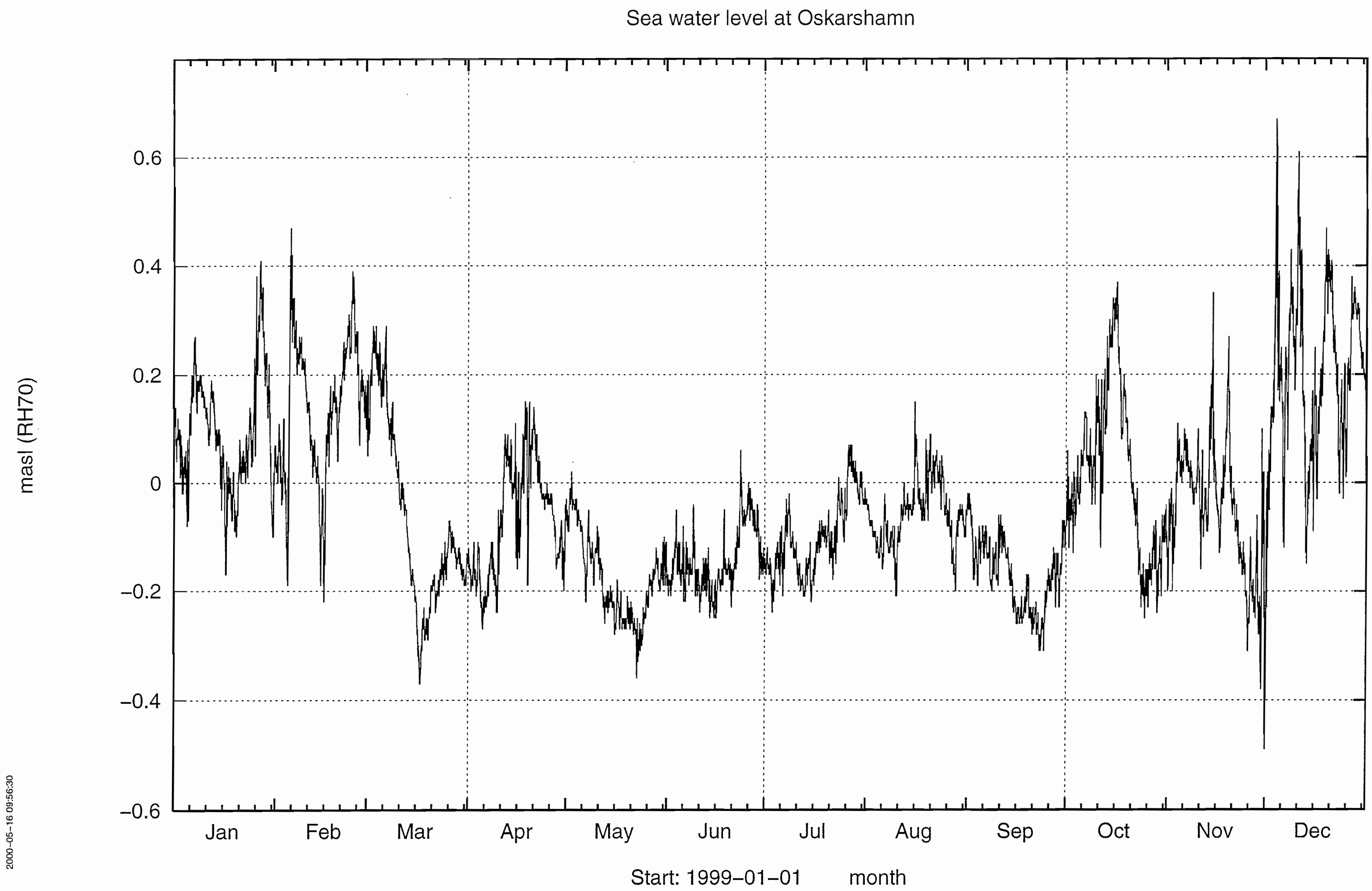




Electrical Conductivity in tunnel water, 3426 – 3600 m (parts of tunnel J incl.).
m3/24h
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01 month
2000–02–01 11:05:04

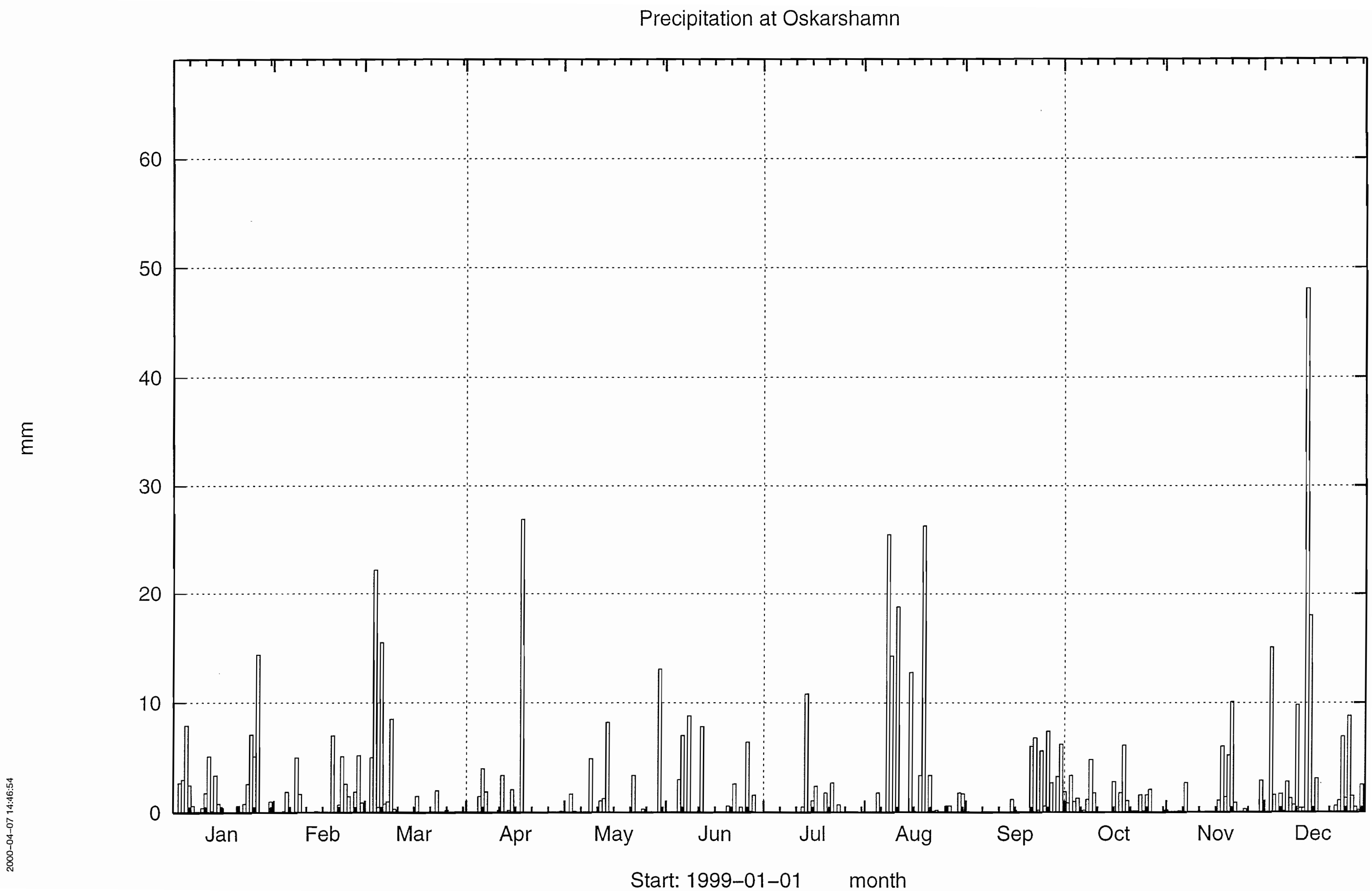

Electrical Conductivity in tunnel water, tunnel F 0 – 61 m (parts of tunnels J and G incl.)
m3/24h
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999–01–01
month
2000–02–01 11:05:05

Appendix 8: Level of the Baltic Sea



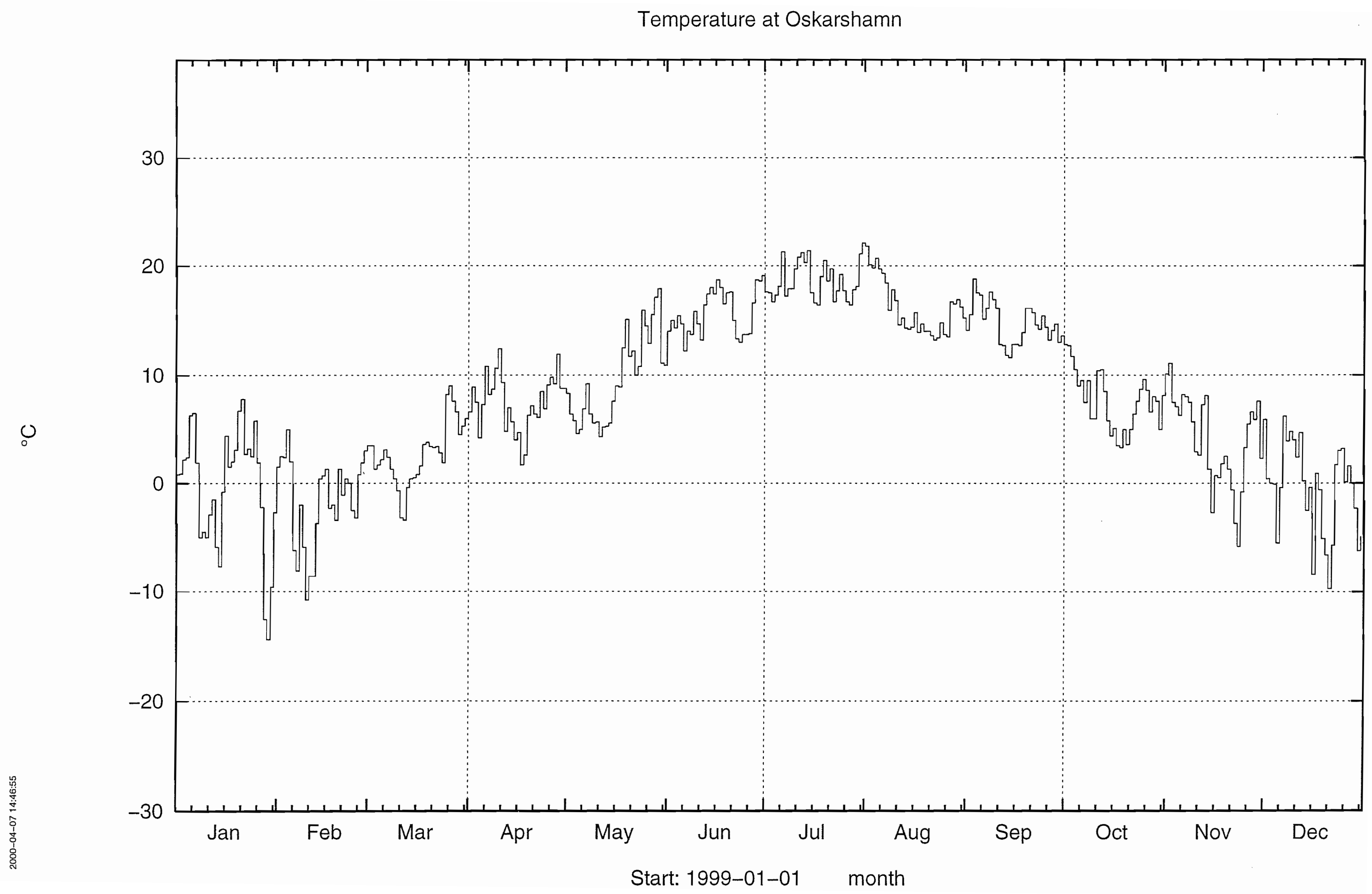
Sea water level at Oskarshamn
masl (RH70)
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01
month
2000−05−16 09:56:30

Appendix 9: Precipitation



Precipitation at Oskarshamn
mm
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999-01-01
month
2000-04-07 14:46:54

Appendix 10: Air temperature



Temperature at Oskarshamn
30
20
10
0
−10
−20
−30
°C
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 1999−01−01 month
2000−04−07 14:46:55

Appendix 11: Potential evapotranspiration

Potential Evaporation at Västervik