International
Progress Report

IPR-01-29

Äspö Hard Rock Laboratory

Hydro Monitoring Program

Report for 2000

Göran Nyberg
Stig Jönsson
Eva Wass

GEOSIGMA AB

August 2001

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel +46 8 459 84 00
Fax +46 8 661 57 19

Äspö Hard Rock
Laboratory

Report no.	No.
IPR-01-29	F85K
Author	Date
Nyberg, Jönsson, Wass	01-05-23
Checked by	Date
Thomas Karlsson	01-08-23
Approved	Date
Christer Svemar	01-08-23

Äspö Hard Rock Laboratory

Hydro Monitoring Program

Report for 2000

Göran Nyberg
Stig Jönsson
Eva Wass

GEOSIGMA AB

August 2001

Keywords: Groundwater, borehole, instrumentation, tunnel, measurement methods, Äspö

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. In addition, 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 have been performed. This report is a summary of the monitoring during 2000 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 is the dominating factor influencing groundwater levels in the area. In one chapter activities that may have an influence on the ground water situation are listed and briefly di scussed.

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, connecting 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 going on during the whole period of construction and will continue 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 i n 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 2000, there were 119 boreholes involved in the hydro-monitoring program within the five investigation areas and in the tunnel. The boreholes are either core drilled (72 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 repr e-senting 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, the measurements are performed by manual levelling. A number of percussion boreholes on the surface were excluded from the measurement program during 1995 and 1996. However, manual levelling in these boreholes was resumed during 1997 on the Äspö island and during 2000 in the surrounding areas on Ävrö and Laxemar.

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 2000 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 metres. Since 1994 the levels have gradually stabilised and during the last years the level decrease in most boreholes have been less than two metres. For year 2000 more sections have had increasing levels then decrea s-ing, probably a result of relatively high precipitation figures combined with low evaporation.

In most tunnel boreholes, the pressure was still decreasing during 2000. Some borehole sections are strongly influenced by activities near the Prototype repository, resulting in large drawdowns. Boreholes located in the East – Northeast part of the tunnel spiral have shown increasing pressures at a magnitude of 10 – 30 kPa. In the main part of the tunnel borehole sections though, the pressure have decreased between zero and 100 kPa.

The flow in most gauging boxes have decreased when comparing mean flow for the period October – December for the latest six years. A few exceptions from this, especially in the deepest parts of the tunnel system, can be related to tunnel excavation, drilling of new boreholes and activities where external water has been added. During the same period (October – December) 1930 m^3/24 h was pumped out from the tunnel, which is a decrease with approx imately 175 m^3/24 h compared to 1999.

The total amount of precipitation during 2000 was 665 mm, which is 112 mm more than the mean for the comparison period 1961-90. Large amounts were measured in June – July and October – November whereas the precipitation figures were low in January – February, May and September.

Contents

List of Figures

List of Tables

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 groun d-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 groun d-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 2000. 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 1-1)

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.

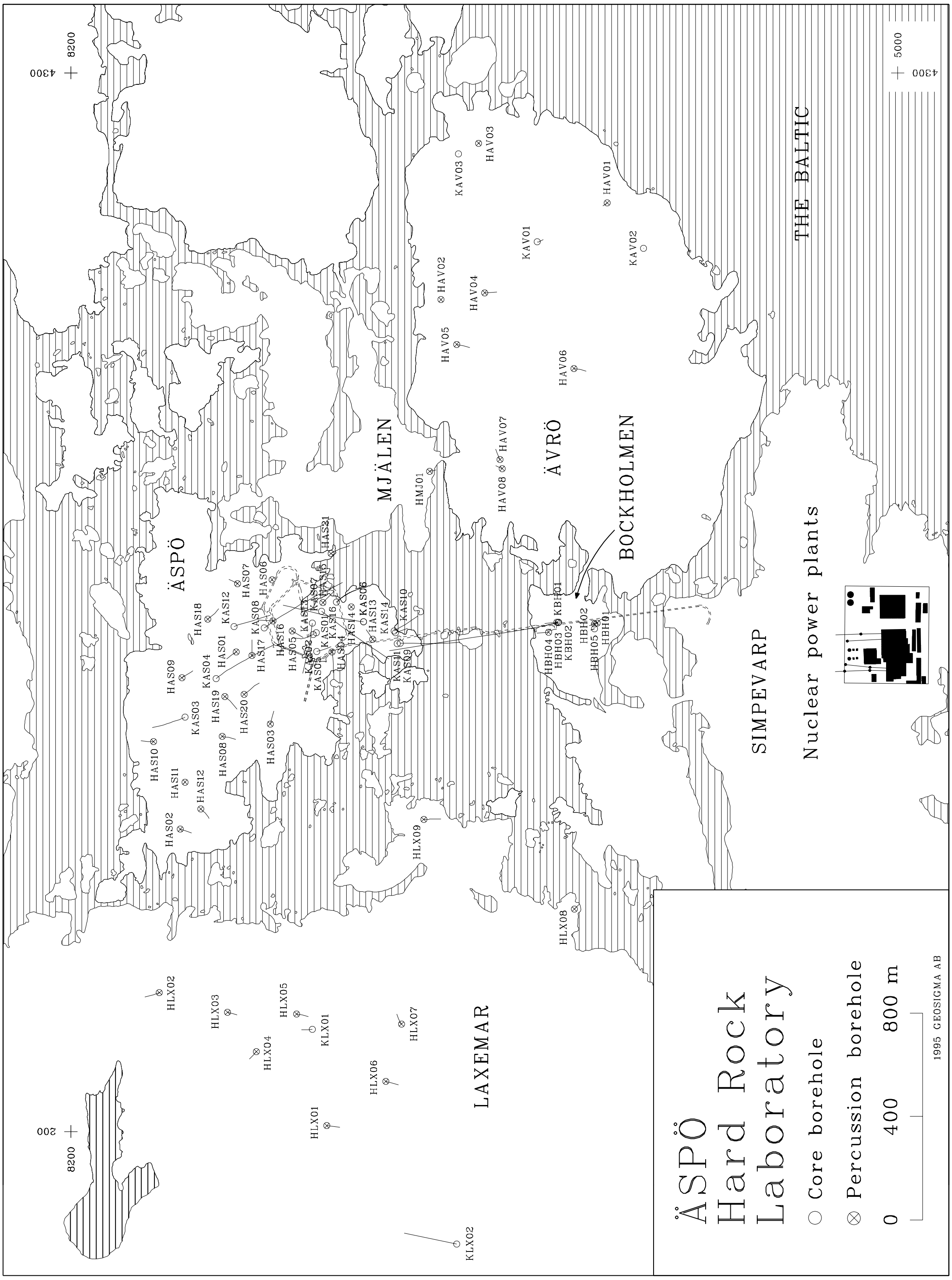


Figure 1-2 The investigation area with borehole locations.

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 have 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 uninhab ited.

The rocks in the investigation area, consisting of the five sub-areas mentioned above, belong to the extensive region of Småland-Värmland intrusions extending from south-eastern Sweden towards north and north-west to south-eastern Norway. Older, Svec o-carelian supracrustals and gneissic granites also occur as well as intrusions of anor o-genic 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 implement a-tion 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 south-western coasts are more irregular with several small islands and rocky islets at short di stances 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 south-eastern part of the island, areas of Ävrö granite, a variety of the Smålandsgranite, are found. Minor intrusions of other rock types: greenstone, metavolcanics, aplite, pegmatite, 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.

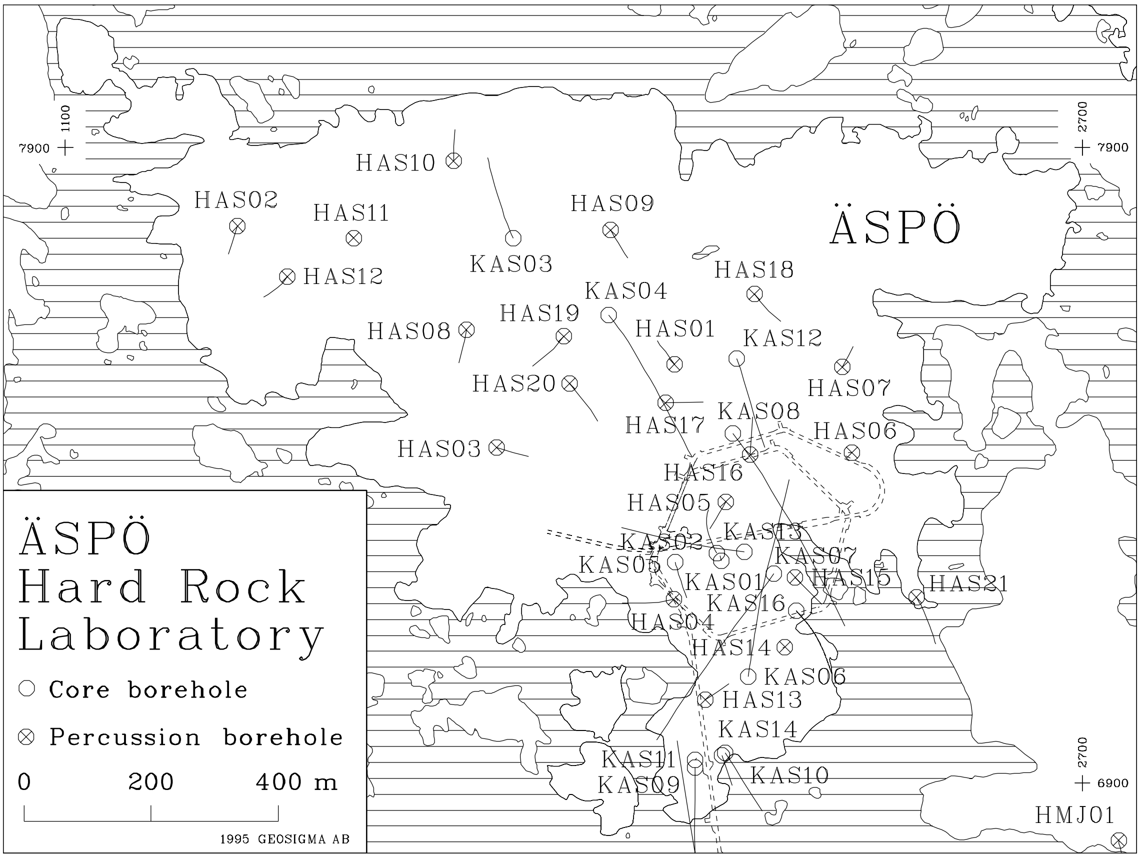


Figure 2-1 The Äspö area with borehole locations. Circles represent the intersection of the boreholes with the ground surface, the lines represent the projection on the ground surface of the respective boreholes. The tunnel is also shown in the figure.

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 north-western and a south-eastern 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 north-eastern 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.

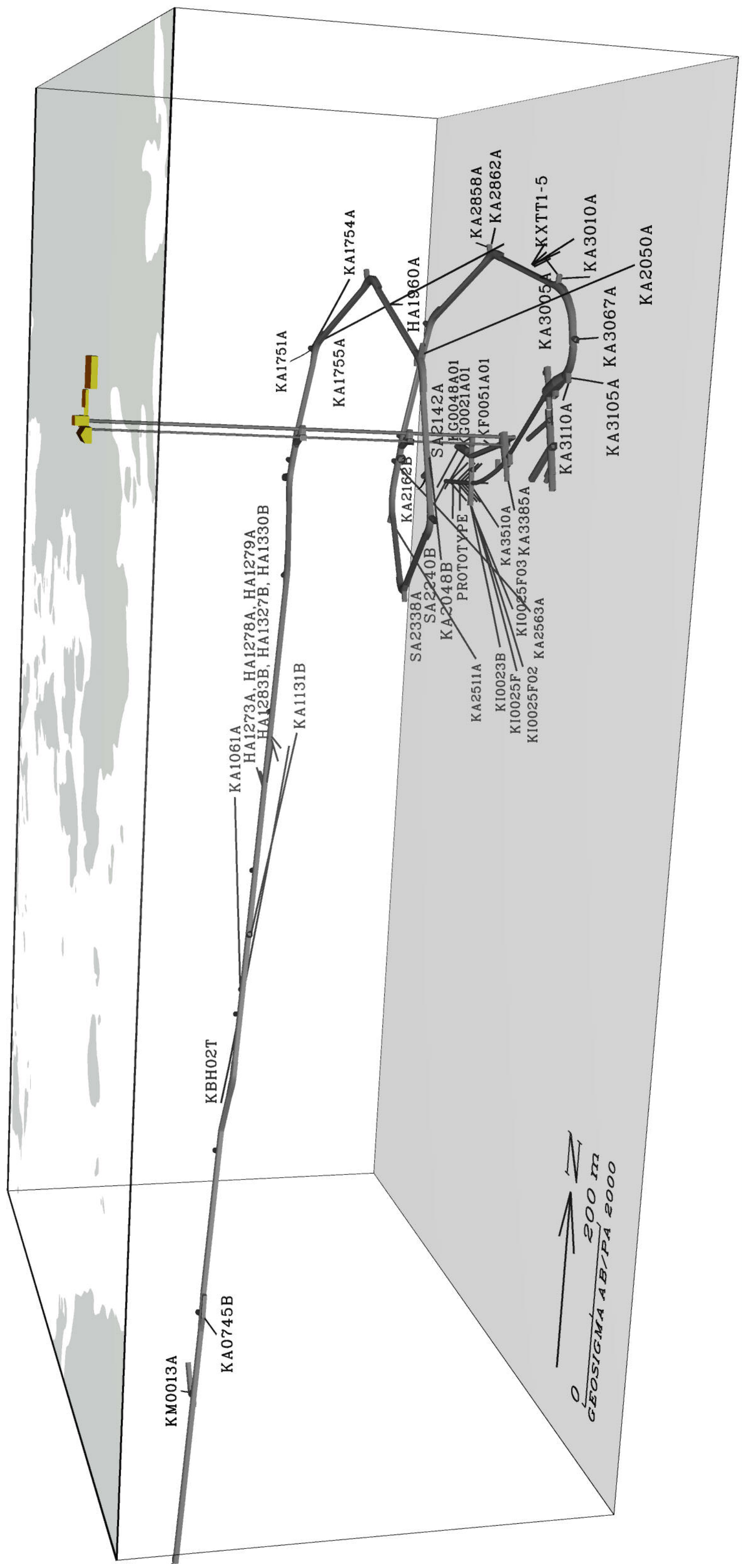


Figure 2-2 Outline of the Äspö Hard Rock Laboratory with a side-view of the access ramp, the tunnel spiral and boreholes.

2.7 The Äspö tunnel

The extension of the Äspö HRL tunnel is illustrated in Figures 2-2 and 2-3. The geo-scientific conditions during excavation of the tunnel are described in a series of Progress Reports from the Äspö Hard Rock Laboratory: Stanfors et al., 1992, 1993a, 1993b, 1994, Rhen and Stanfors, 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.

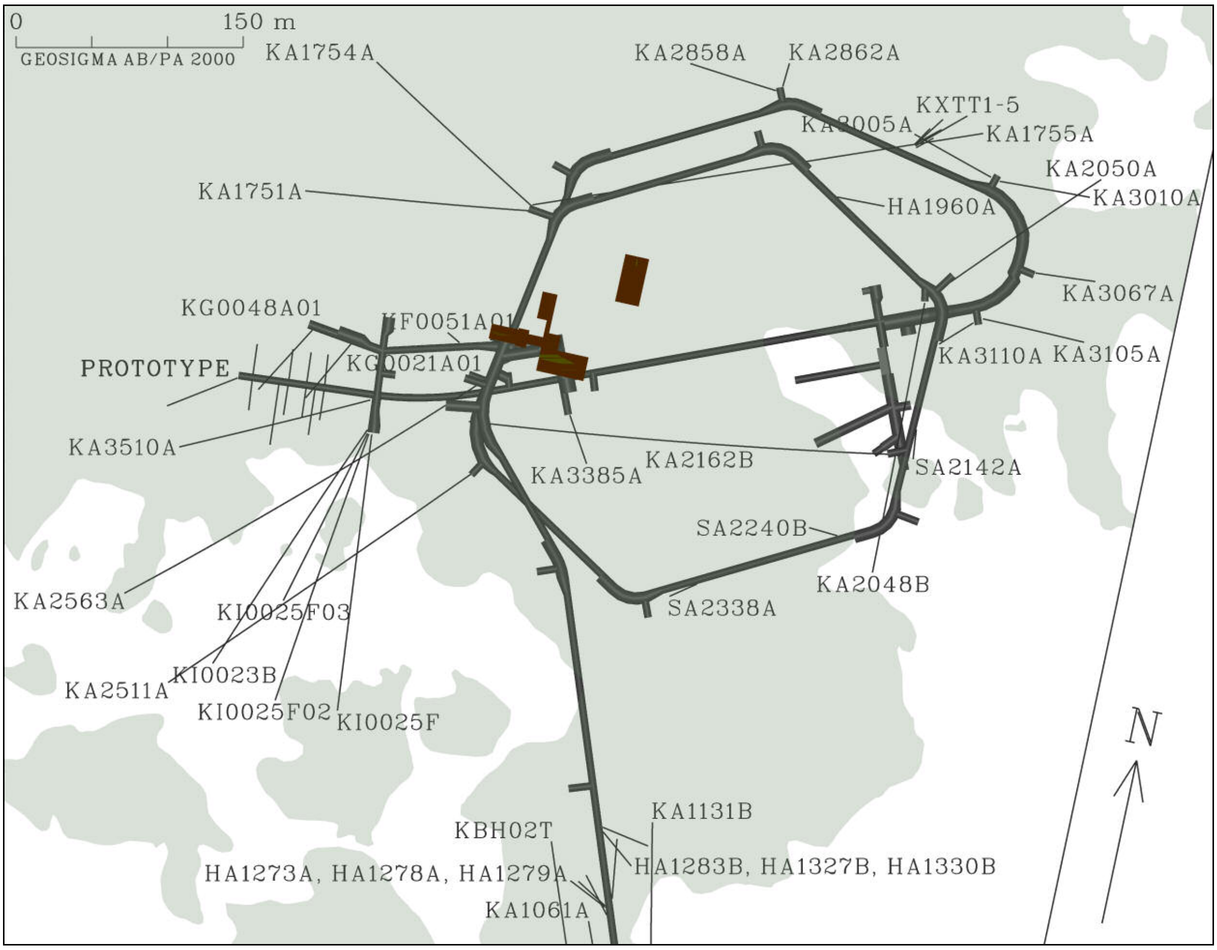


Figure 2-3 Plan view of the tunnel spiral with boreholes.

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 2000:

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 2000 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	-58.5	351	50.6	4.71	3.0	910220
HBH02	-47.7	345	32.4	4.68	3.0	910221
HBH03	-58.2	355	100	5.92	1.2	910306
HBH04	-59.7	355	90.4	5.52	5.1	910307
HBH05	≈-45	347	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	100.70	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	100.00	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	138	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	101.30	900804
KLX02	-85.0	9	1700.50	18.31	202.95 + 2.15	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 approx i-mately 100 m. All telescope drilled core boreholes also have an enlargement (approx i-mately 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	0.00	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	56	702.88	1077.99
	76	101.30	702.11
	155	0.00	101.30
KLX02	76	202.95	1700.50
	92	201.00	202.95
	165	200.80	201.00
	215	3.00	200.80
	304	0.00	3.00

3.2 Tunnel Boreholes

A great number of boreholes are drilled in the tunnel. Pressure measurements from packed-off sections in 68 boreholes were connected to the monitoring system during 2000. 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 have been monitored within the HMS during 2000 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, minimum diameter, elevation at tunnel wall, length of casing and date for the completion of drilling.

Borehole	Inclination at top of b.h. (º)	Bearing at top of b.h. (º) *	Bore-hole length (m)	Bore-hole min-diameter (mm)	Elevation at tunnel wall (m. a. s. l.)	Length of casing (m)	Drilling completed
HA1273A	10.7	351.3	30	57	-174.23	2.00	920423
HA1278A	4.3	304.8	29	57	-175.68	2.00	920910
HA1279A	2.8	311.6	24	57	-175.65	2.00	920910
HA1283B	-8.0	352.7	35.5	57	-176.55	2.00	920415
			40.2	51			
HA1327B	-0.5	140	29.5	57	-182.81	2.00	920911
HA1330B	-0.5	100	32.5	57	-182.99	No c.	920911
HA1960A	-7	89	32	57	-263.73	No c.	930121
HD0025A	7.0	88.7	15	57	-416.70	?	941111
KA1061A	0.6	349.6	208.5	56	-144.93	2.00	920123
KA1131B	-12.9	0.5	203.1	56	-155.30	2.00	920212
KA1751A	-5.2	274.2	149.9	56	-237.56	2.00	930504
KA1754A	-26.2	299.9	159.9	56	-237.84	2.00	930519
KA1755A	-19.9	339.4	320.6	56	-237.80	2.42	940406
KA2048B	-10.6	190.9	184.5	56	-275.43	2.00	930216
KA2050A	-53.5	55.3	211.6	56	-275.79	2.50	931102
KA2162B	-15.2	272.2	288.1	56	-289.87	2.50	930401
KA2511A	-33.4	234.7	293	56	-335.83	2.50	930905
KA2563A	-42.5	237.2	363.43	56	-340.79	2.05	960924
KA2598A	-32.1	292.6	300.77	56	-342.39	?	930928
KA2858A	-4.3	287.0	59.7	56	-379.38	2.50	950115
KA2862A	-8.0	16.0	16.0	56	-379.54	2.50	950125

Borehole	Inclination at top of b.h. (º)	Bearing * at top of b.h. (º)	Bore-hole length (m)	Bore-hole min-diame-ter (mm)	Elevation at tunnel wall (m. a. s. l.)	Length of casing (m)	Drilling completed
KA3005A	-4.5	299.1	58.1	56	-399.86	2.50	941205
KA3010A	-4.7	99.5	60.7	56	-399.87	2.50	941208
KA3067A	-4.7	98.4	40.1	56	-408.59	2.50	941211
KA3105A	-4.7	102.5	69.0	56	-413.68	2.50	941215
KA3110A	-5.4	238.3	26.8	56	-413.71	2.50	941217
KA3385A	-4.8	161.0	34.2	56	-446.01	No c.	950110
KA3510A	-30.2	255.3	150.06	76	-448.70	2.65	960909
KA3539G	-80.5	274.2	30.01	75.7	-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	2.50	980628
KA3548G01	-89.8	75.7	12.01	76	-449.00	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	75.7	-448.85	No c.	980512
KA3563G	-79.9	277.9	30	75.7	-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	75.7	-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	2.50	980527
KG0021A01	17.7	220.1	48.82	76	-445.15	2.50	980708
KG0048A01	14	222.4	54.69	76	-444.49	2.42	980804
KI0023B	-20.7	214.4	200.71	76	-447.69	2.65	971120
KI0025F	-20.1	187.1	193.8	75.6	-448.2	2.50	970425
KI0025F02	-25.5	200.0	204.18	76	-448.53	2.65	980825
KI0025F03	-29.8	206.9	141.72	76	-448.08	2.50	990813
KXTT1	-46.8	61.2	28.8	56	-392.12	2.50	950518
KXTT2	-45.2	61.4	18.3	56	-392.42	2.50	950522
KXTT3	-36.7	51.4	17.4	56	-391.07	2.50	950606

Borehole	Inclination at top of b.h. (º)	Bearing * at top of b.h. (º)	Bore-hole length (m)	Bore-hole min-diameter (mm)	Elevation at tunnel wall (m. a. s. l.)	Length of casing (m)	Drilling completed
KXTT4	-36.5	61.5	49.3	56	-391.10	2.50	950616
KXTT5	-14.9	47.7	25.85	76	-390.30	2.55	990505
SA2142A	-9	174	20	57	-287.41	No c.	930223
SA2338A	-7	234	20	57	-313.03	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.

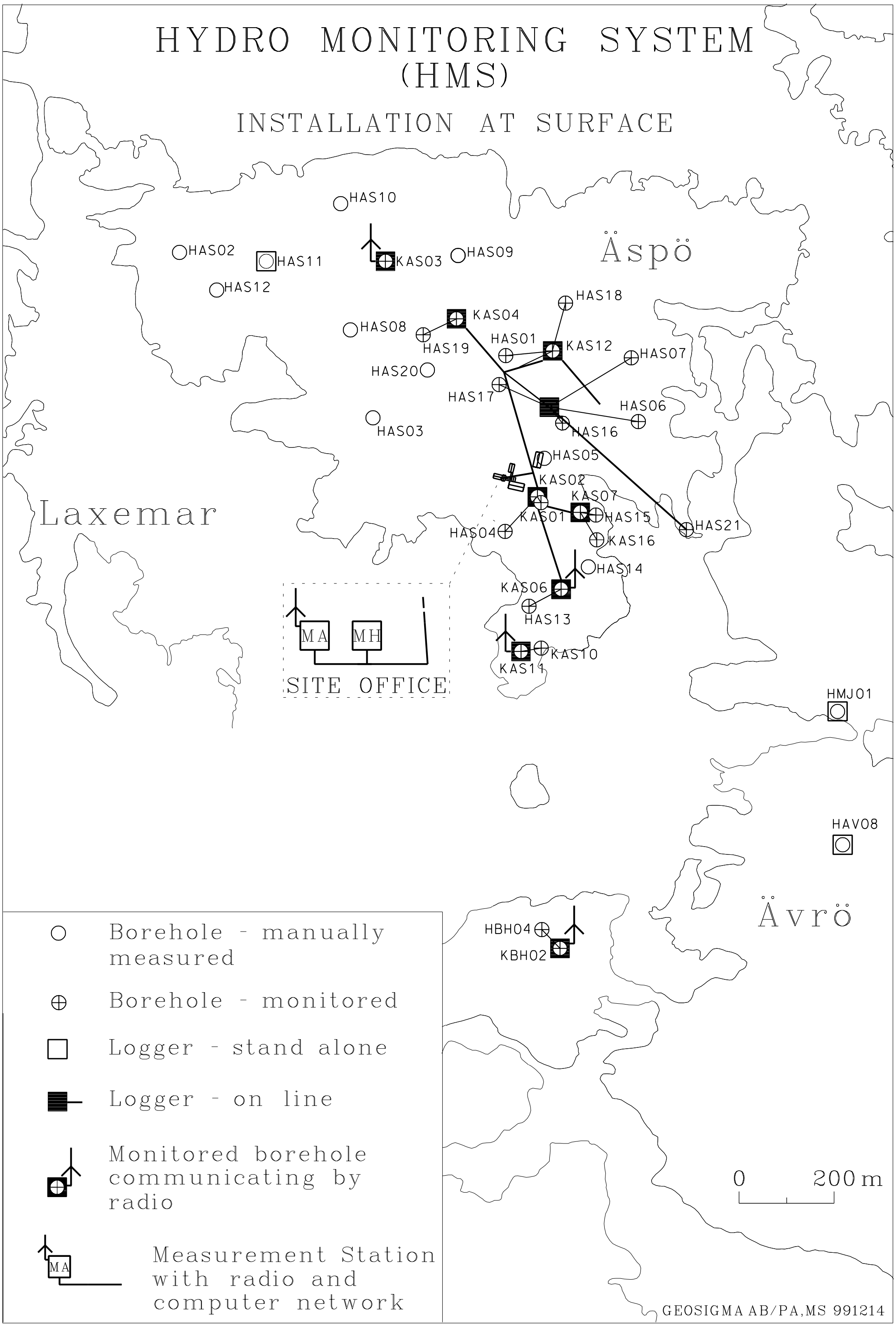


Figure 4-1 Surface part of the HMS showing the data logger network and radios.

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 s erial I/O port.

In the tunnel, pressure in borehole sections are measured either via a hydraulic mult i-plexer 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	990925	000912
	1-2	BorreF	000912	
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	

Borehole	Section	Equipment	from	to
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	
HAV01	1	Manually	000917	
HAV02	1	Manually	970205	
HAV03	1	Manually	000917	
HAV04	1	Manually	000917	
HAV05	1	Grund	89-06	
HAV06	1	Manually	000917	
HAV08	1	Grund	91-12	
HBH04	1	BorreR	91-12	
	2	Manually	91-03	
HLX01	1	Manually	000917	
HLX02	1	Manually	000917	
HLX03	1	Manually	000917	

Borehole	Section	Equipment	from	to
HLX04	1	Manually	970129	
HLX05	1	BorreR	950901	
HLX06	1	Manually	000917	
HLX07	1	Manually	000917	
HMJ01	1	Grund	91-12	
	2	Manually	92-01	
KAS01	1	BorreR	91-09	001130
KAS03	1-6	BorreR	91-09	
KAS04	1	Manually	970320	
KAS07	1	Manually	970220	
KAS09	1-5	BorreR	91-09	
KAS10	1	BorreR	91-09	
KAS11	1	Manually	970320	
KAS12	1-5	BorreR	971119	000120
KAS14	1	Manually	970320	
KAS16	2-4	BorreR	92-10	
	1	Manually	92-10	
KAV01	1	Manually	000917	
KAV02	1	Manually	000917	
KAV03	1	Manually	000917	
KBH02	3-6	BorreR	91-09	
KLX01	1-5	BorreR	950901	

Note - Data not relevant for 2000 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 pr esented.

Table 4-2 Monitoring equipment in tunnel boreholes.

Borehole	Sect. no	Equipment	Date from	to
HA1273A	1	HM*+Borre		
HA1278A	1	HM+BorreT		
HA1279A	1	HM+BorreT		
HA1283B	1	HM+BorreT		
HA1327B	1	HM+BorreT		
HA1330B	1	HM+BorreT		
HA1960A	1	HM+BorreT		
HD0025A	1	Datascan	990602	
KA1061A	1	HM+BorreT		
KA1131B	1	HM+BorreT		
KA1751A	1-3	HM+BorreT	940426	
KA1754A	1-2	HM+BorreT	941025	
KA1755A	1-4	HM+BorreT	940503	
KA2048B	1-4	HM+BorreT		
KA2050A	1-3	HM+BorreT		
KA2162B	1-4	HM+BorreT		
KA2511A	1-5	Datascan	980218	
KA2563A	1-7	Datascan	961120	
KA2598A	1	Datascan	990512	
KA2858A	2	HM+BorreT	950223	
KA2862A	1	HM+BorreT	960912	
KA3005A	2-3	BorreT	951213	
	4-5	HM+BorreT	951213	
KA3010A	2	BorreT	950720	
KA3067A	1	BorreT	991103	
	2-4	BorreT	950310	
KA3105A	1-4	BorreT	950310	
	5	BorreT	991103	
KA3110A	1	BorreT	950310	
	2	BorreT	991103	
KA3385A	1-2	Datascan	970701	
KA3510A	1-3	Datascan	981027	
KA3539G		Datascan	990217	
KA3542G01		Datascan	990217	
KA3542G02		Datascan	990217	
KA3544G01		Datascan	990525	
KA3546G01		Datascan	990525	
KA3548A01		Datascan	990217	
KA3550G01		Datascan	990217	
KA3552G01		Datascan	990217	
KA3554G01		Datascan	990217	
KA3554G02		Datascan	990217	
KA3557G		Datascan	990217	
KA3563G		Datascan	990217	
KA3566G01		Datascan	990217	
KA3566G02		Datascan	990217	
KA3572G01		Datascan	990217	
KA3573A		Datascan	990217	
KA3574G01		Datascan	990217	
KA3576G01		Datascan	990217	
KA3578G01		Datascan	990217	
KA3579G		Datascan	990217	
KA3584G01		Datascan	990217	
KA3590G01		Datascan	990217	
KA3590G02		Datascan	990217	
KA3593G		Datascan	990217	
KA3600F		Datascan	990217	
KF0051A		Datascan	980612	
KG0021A01		Datascan	990217	
KG0048A0		Datascan	990217	
KI0023B		Datascan	980216	
KI0025F		Datascan	970710	
KI0025F02		Datascan	981027	
KI0025F03		Datascan	991013	
KXTT2	1,4	HM+BorreT	950720	
	2-3	BorreT	950720	
	5	HM+BorreT	951211	
KXTT3	1	HM+BorreT	950720	
	2-3	BorreT	950720	
	4	HM+BorreT	950720	
KXTT4	1-2,5	HM+BorreT	951212	
	3-4	BorreT	951212	
KXTT5	1-2,5	HM+BorreT	991214	
	3-4	BorreT	991214	
SA2142A	1	HM+BorreT		
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 2000 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 2000 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 2000 measurements are carried out in four 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 P5 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.

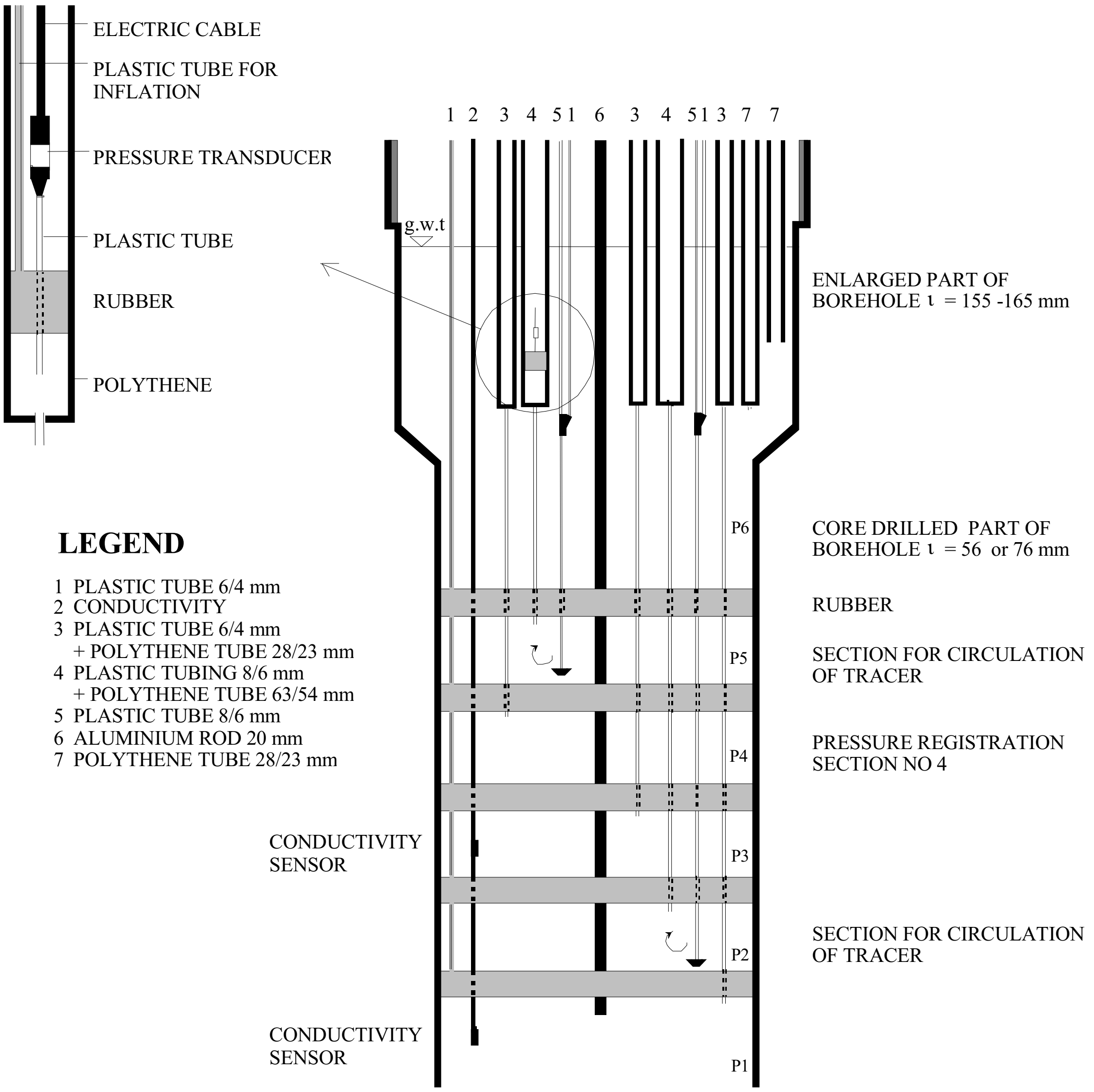


Figure 4-2 Instrumentation in core boreholes on Äspö.

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.

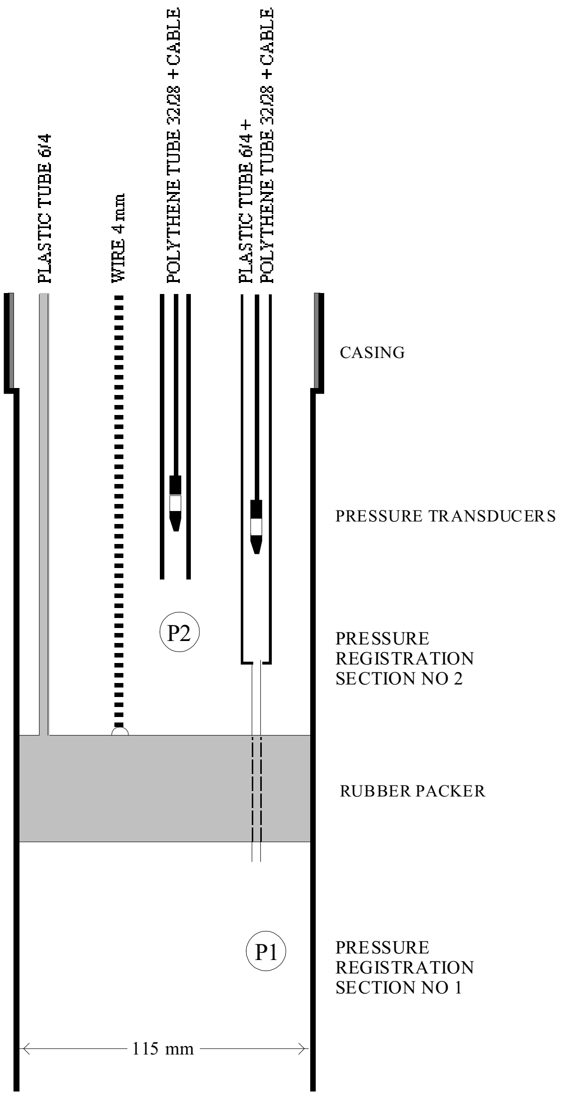


Figure 4-3 Instrumentation in percussion boreholes with the logger BORRE.

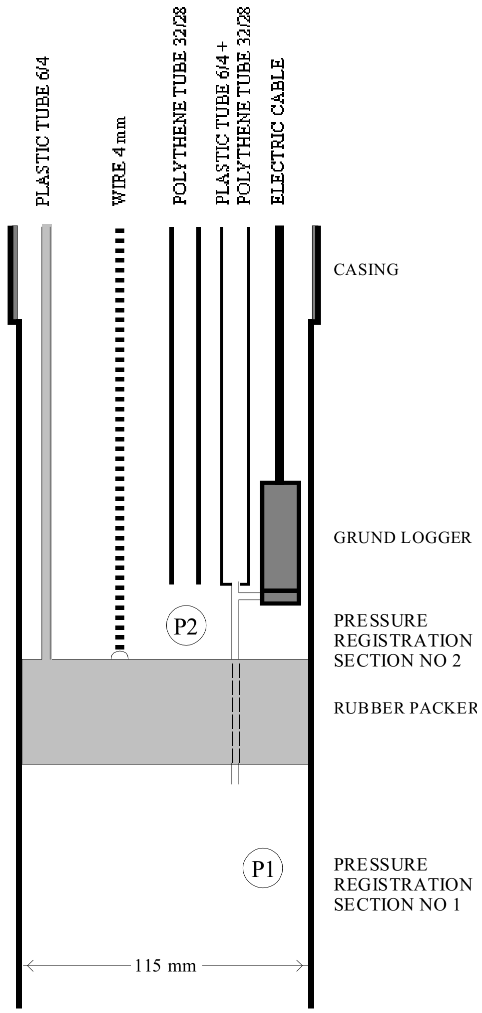


Figure 4-4 Instrumentation in percussion boreholes with the logger GRUND.

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 2000. 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	Section installed from	Section installed to	Borehole length from (m)	Borehole length to (m)	Elevation of section at top (masl)	Elevation of section 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	2000-03-23	101	201	-83.61	-129.99
	2	1989-05-12	2000-03-23	0	100	6.26	-37.79
	1	2000-03-23	2000-11-23	0	201	6.26	-83.15
	1	2000-11-23		101	201	-83.61	-129.99
	2	2000-11-23		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	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	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	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
HAV01	1	2000-09-17		0	175	9.27	-77.88
HAV02	1	1997-02-05		0	163	6.08	-75.41
HAV03	1	2000-09-17		0	134	8.65	-58.29
HAV04	1	2000-09-17		0	100	7.53	-36.21
HAV05	1	1997-02-18		0	100	6.83	-34.48
HAV06	1	2000-09-17		0	100	11.93	-31.13
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
HLX01	1	2000-09-17		0	100	8.50	-35.07

Borehole	Section no	Section installed from	to	Borehole length from (m)	to (m)	Elevation of section at top (masl)	at middle (masl)
HLX02	1	2000-09-17		0	132	8.61	-48.93
HLX03	1	2000-09-17		0	100	10.43	-35.04
HLX04	1	1997-01-29		0	125	10.40	-47.94
HLX05	1	1997-01-29		0	100	15.50	-28.68
HLX06	1	2000-09-17		0	100	15.48	-27.10
HLX07	1	2000-09-17		0	100	8.61	-35.67
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	2000-11-30	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
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	2000-01-20	330	380	-299.84	-322.68
	2	1997-10-28	2000-01-20	278	329	-252.25	-275.60
	3	1997-10-28	2000-01-20	234	277	-211.95	-231.66
	4	1997-10-28	2000-01-20	102	233	-90.23	-150.85
	5	1997-10-28	2000-01-20	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
KAV01	1	2000-09-17		0	744	13.81	-358.14
KAV02	1	2000-09-17		0	97	7.54	-40.96
KAV03	1	2000-09-17		0	248.4	8.21	-115.98
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 2000 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% of full scale (F.S.) for the best straight line (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, corr e-sponding 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 of 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	1999-10-06	1920	1006
	2	2000-09-18	1810	1006
	3	1997-06-18	1790	1006
	4	1996-05-22	352	999
	5	1999-10-05	860	1001
	5	2000-09-22	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	1999-10-06	1010	1002
	4	2000-09-21	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

Borehole	Sec.	Valid from	Electrical conduct. (mS/m)	Density (kg/m^3)
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 2000 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 is 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 transdu cers)

(For more detailed information about the different errors see E kman 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 raise-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 approx i-mately 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 2000, 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 2 or 4 mm. To some sections, prepared for circulation of tracer during tracer tests, there is an extra tube with an inner diameter of 4 or 6 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.

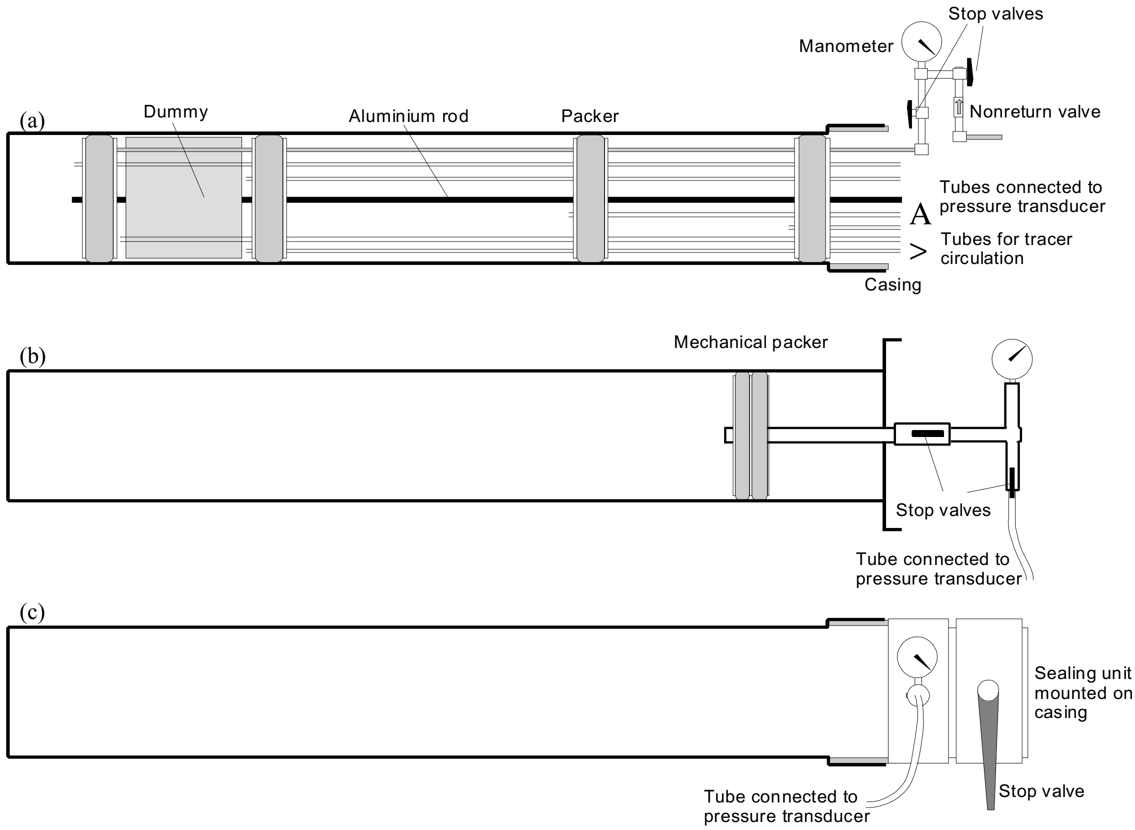


Figure 4-5 Instrumentation in tunnel boreholes with hydraulic packers (a), mechanical packer (b) and with a sealing mounted on casing (c).

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.

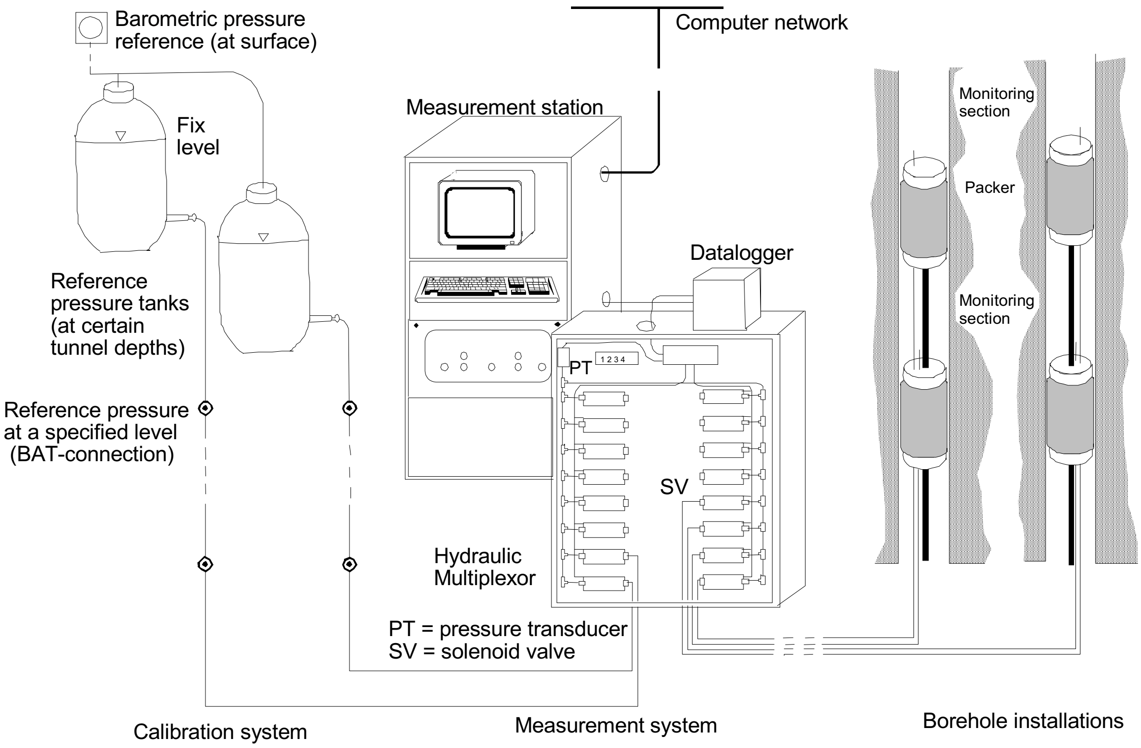


Figure 4-6 Equipment installations for groundwater pressure measurements with a hydraulic multiplexer.

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 seconds but if the pressure is measured with a hydraulic multiplexer every four minutes. 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	Section installed from	to	Borehole length from (m)	to (m)	Elevation of SecTop (masl)	SecMid (masl)	Transducer (masl)
HA1273A	1	1992-03-12		0	23	-174.23	-172.10	-163.34
HA1278A	1	1992-09-10		0	29	-175.68	-174.59	-163.34
HA1279A	1	1992-09-10		0	29	-175.65	-174.93	-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		?	?	-416.70	?	-416.42
KA1061A	1	1992-01-14		0	208.5	-144.93	-144.01	-163.34
KA1131B	1	1992-02-02		0	203.1	-155.30	-178.88	-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	-270.76	-289.21	-224.28
	2	1994-04-21		6	74	-240.49	-255.48	-224.28
KA1755A	1	1994-05-03		231	320.58	-318.23	-334.61	-224.28
	2	1994-05-03		161	230	-293.11	-305.47	-224.28
	3	1994-05-03		88	160	-267.53	-279.92	-224.28
	4	1994-05-03		6	87	-239.83	-253.50	-224.28
KA2048B	1	1994-12-12		150	184.45	-302.36	-305.35	-289.19
	2	1994-12-12		100	148.5	-293.69	-297.97	-289.19
	3	1994-12-12		50.5	99	-284.73	-289.16	-289.19
	4	1994-12-12		5	49.5	-276.35	-280.46	-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		202	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
KA2511A	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	1999-03-15		242	246	-501.36	-502.65	-334.61
	2	1999-03-15		236	241	-497.48	-499.10	-334.61
	3	1999-03-15		206	208	-478.00	-478.65	-334.61
	4	1999-03-15		187	190	-465.58	-466.56	-334.61
	5	1999-03-15		146	186	-438.64	-451.81	-334.61
KA2598A	1	1999-05-12		?	300.77	-342.69	?	-334.69
KA2858A	2	1995-02-23		39.8	40.77	-382.37	-382.40	-399.10
KA2862A	1	1996-09-12		7.37	15.98	-380.61	-381.20	-399.10

Borehole	Section no	Section installed from	to	Borehole length from (m)	to (m)	Elevation of SecTop (masl)	SecMid (masl)	Transducer (masl)
KA3005A	2	1995-12-07		46.8	50.03	-403.52	-403.64	-399.10
	3	1995-12-07		44.8	45.78	-403.37	-403.41	-399.10
	4	1995-12-07		39	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		34.6	40.05	-411.50	-411.74	-413.14
	2	1995-02-28		30.6	33.55	-411.16	-411.29	-413.14
	3	1995-02-28		28.1	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	68.95	-418.09	-418.81	-413.14
	2	1995-03-01		25.5	52.01	-415.78	-416.87	-413.14
	3	1995-03-01		22.5	24.51	-415.54	-415.62	-413.14
	4	1995-03-01		17	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		20.1	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		32.1	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	150.06	-509.75	-516.73	-447.96
	2	1998-10-20		114	121.02	-505.77	-507.51	-447.96
	3	1998-10-20		4.52	113.02	-450.97	-478.18	-447.96
KA3539G	1	1999-08-01	2000-06-05	19.3	30.01	-468.22	-473.51	-447.54
	2	1999-08-01	2000-06-05	9.8	18.3	-458.86	-463.05	-447.54
	3	1999-08-01	2000-06-05	1.3	8.8	-450.47	-454.17	-447.54
KA3542G01	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	1999-08-01	2000-06-07	22.3	30	-464.62	-467.30	-447.90
	2	1999-08-01	2000-06-07	13.8	21.3	-458.69	-461.31	-447.90
	3	1999-08-01	2000-06-07	8.8	12.8	-455.21	-456.60	-447.90
	4	1999-08-01	2000-06-07	1.3	7.8	-449.98	-452.24	-447.90
KA3544G01	1	1999-08-01	2000-01-19	6.3	12	-455.25	-458.10	-447.90
	2	1999-08-01	2000-01-19	1.3	5.3	-450.25	-452.25	-447.90
KA3546G01	1	1999-08-01	2000-01-19	6.8	12	-455.69	-458.29	-447.90
	2	1999-08-01	2000-01-19	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
KA3550G01	1	1999-08-01	2000-01-19	6.3	12	-455.07	-457.92	-447.90
	2	1999-08-01	2000-01-19	1.3	5.3	-450.07	-452.07	-448.25
KA3552G01	1	1999-08-01	2000-01-19	8.8	12	-457.57	-459.17	-447.90
	2	1999-08-01	2000-01-19	4.05	7.8	-452.82	-454.70	-447.90
	3	1999-08-01	2000-01-19	1.3	3.05	-450.07	-450.95	-447.90
KA3554G01	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	1999-08-01	2000-06-05	22.3	30	-464.59	-467.31	-447.90
	2	1999-08-01	2000-06-05	10.3	21.3	-456.10	-459.99	-447.90
	3	1999-08-01	2000-06-05	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

Borehole	Section no	Section installed from	to	Borehole length from (m)	to (m)	Elevation of SecTop (masl)	SecMid (masl)	Transducer (masl)
KA3563G	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	2000-06-06	19.3	30.01	-461.93	-465.63	-447.54
	2	1999-02-17	2000-06-06	12.3	18.3	-457.08	-459.16	-447.54
	3	1999-02-17	2000-06-06	7.8	11.3	-453.97	-455.18	-447.54
	4	1999-02-17	2000-06-06	1.3	6.8	-449.47	-451.37	-447.90
KA3572G01	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
KA3574G01	1	1999-08-01		0.3	12	-448.63	-454.48	-448.25
KA3576G01	1	1999-08-01		0.3	12	-448.57	-454.42	-448.25
KA3578G01	1	1999-08-01		0.3	12.6	-448.68	-454.83	-448.25
KA3579G	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	1999-08-01		0.3	30.1	-448.27	-458.70	-448.25
KA3590G02	1	1999-08-01		0.3	30.1	-448.29	-458.60	-448.25
KA3593G	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		10.6	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	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	1999-02-11		4	29	-443.52	-440.49	-447.03
KI0023B	1	1998-02-12		114	200.71	-488.30	-503.59	-448.21
	2	1998-02-12		111	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		84.8	86.2	-477.96	-478.22	-447.96
	5	1998-02-12		73	83.75	-473.73	-475.67	-447.96
	6	1998-02-12		71	71.95	-473.01	-473.19	-447.96
	7	1998-02-12		43.5	69.95	-463.15	-467.89	-447.96
	8	1998-02-12		41.5	42.45	-462.43	-462.61	-447.96
	9	1998-02-12		4.6	40.45	-449.32	-455.68	-447.96

Borehole	Section no	Section installed from	to	Borehole length from (m)	to (m)	Elevation of SecTop (masl)	SecMid (masl)	Transducer (masl)
KI0025F	1	1999-07-29		171	193.8	-502.58	-506.04	-448.21
	2	1999-07-29		166	169.5	-501.08	-501.68	-448.21
	3	1999-07-29		90.5	164.5	-478.18	-489.62	-448.21
	4	1999-07-29		87.5	89.5	-477.24	-477.55	-448.21
	5	1999-07-29		42.5	86.5	-462.70	-469.91	-448.21
	6	1999-07-29		5	41.5	-449.95	-456.23	-448.21
KI0025F02	1	1998-10-19		135	204.18	-504.43	-517.99	-447.35
	2	1998-10-19		100	134.15	-490.40	-497.27	-447.35
	3	1998-10-19		93.4	99.25	-487.58	-488.78	-447.35
	4	1998-10-19		78.3	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	141.72	-497.66	-507.42	-447.96
	2	1999-10-22		93.6	100.08	-494.04	-495.61	-447.96
	3	1999-10-22		89.1	92.58	-491.86	-492.71	-447.96
	4	1999-10-22		85.1	88.08	-489.92	-490.65	-447.96
	5	1999-10-22		66.6	74.08	-480.92	-482.75	-447.96
	6	1999-10-22		59.6	65.58	-477.49	-478.96	-447.96
	7	1999-10-22		55.1	58.58	-475.28	-476.14	-447.96
	8	1999-10-22		51.6	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		16.6	18.3	-404.01	-404.63	-399.10
	2	1995-12-06		14.6	15.55	-402.61	-402.96	-399.10
	3	1995-12-06		11.6	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		15.4	17.43	-400.33	-400.93	-399.10
	4	1995-07-08		3.17	7.92	-392.98	-394.41	-399.10
	2	1995-12-06		12.4	14.42	-398.53	-399.13	-399.10
	3	1995-12-06		8.92	11.42	-396.43	-397.18	-399.10
KXTT4	5	1995-07-18		3.17	7.42	-392.98	-394.24	-399.10
	3	1995-12-07		11.9	13.92	-398.17	-398.77	-399.10
	4	1995-12-07		8.42	10.92	-396.10	-396.84	-399.10
	2	1999-12-14		14.9	49.31	-399.95	-410.17	-399.10
KXTT5	1	1999-12-14		10.8	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	-391.10	-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 2000 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 multiple x-ers. 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 transmi ssivity.

Summarising the above mentioned errors one can estimate the uncertainty in pressure measurements, under normal conditions, to be approximately 10 kPa for measurements with individual 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 transmi t-ter, 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.

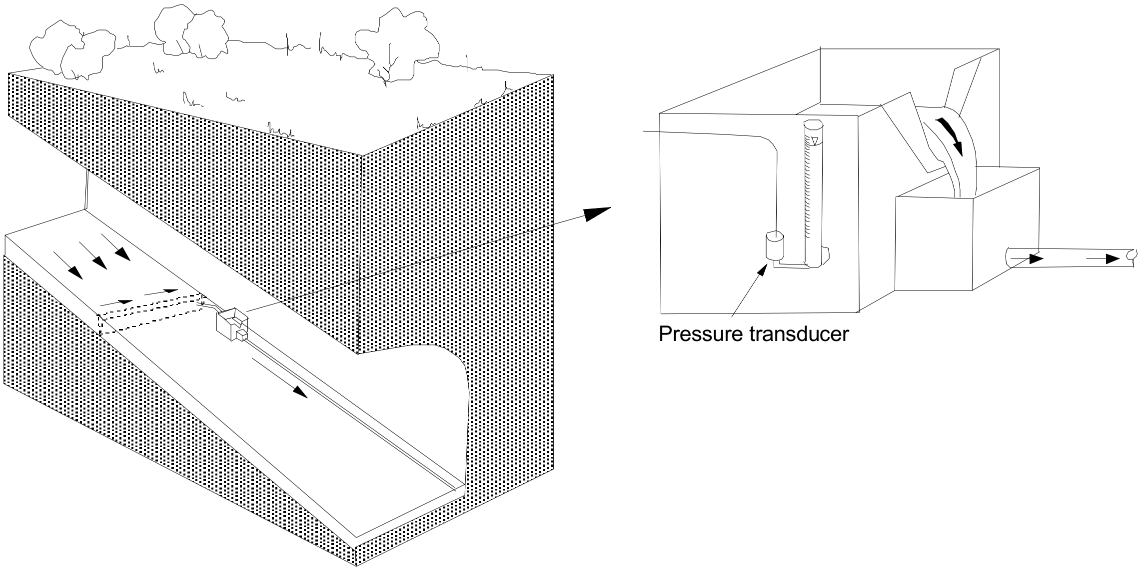


Figure 4-7 Water flow measurements in the tunnel.

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 2000 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	

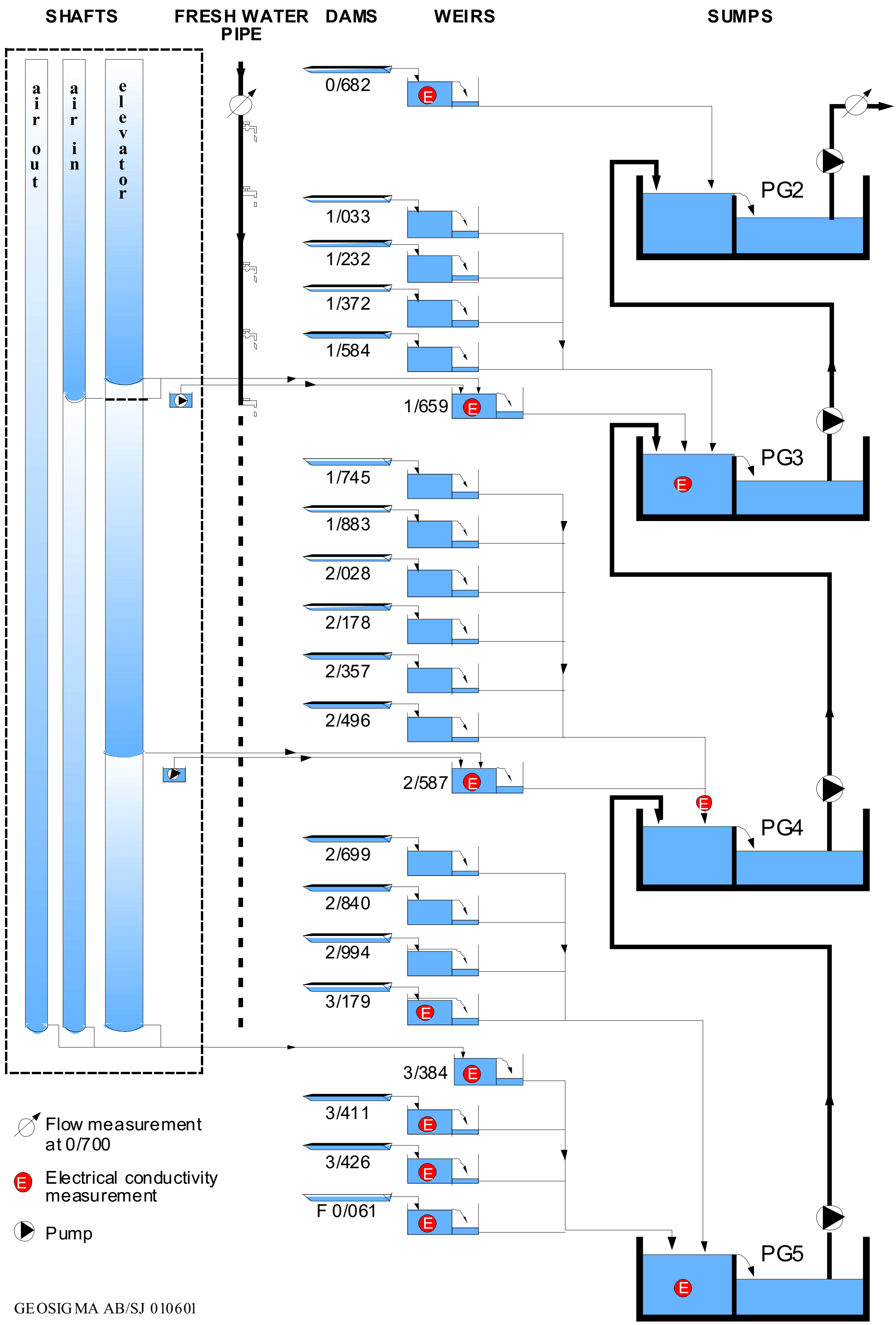


Figure 4-8 Tunnel drainage system.

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 calibr a-tion equation.

The levels in the gauging boxes are manually read ones every month to enable adjus t-ments 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. 2000).

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.

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.

The flowmeter measures very frequently, 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 percu s-sion 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 groun d-water surface, due to less relaxation than in the uppermost section.

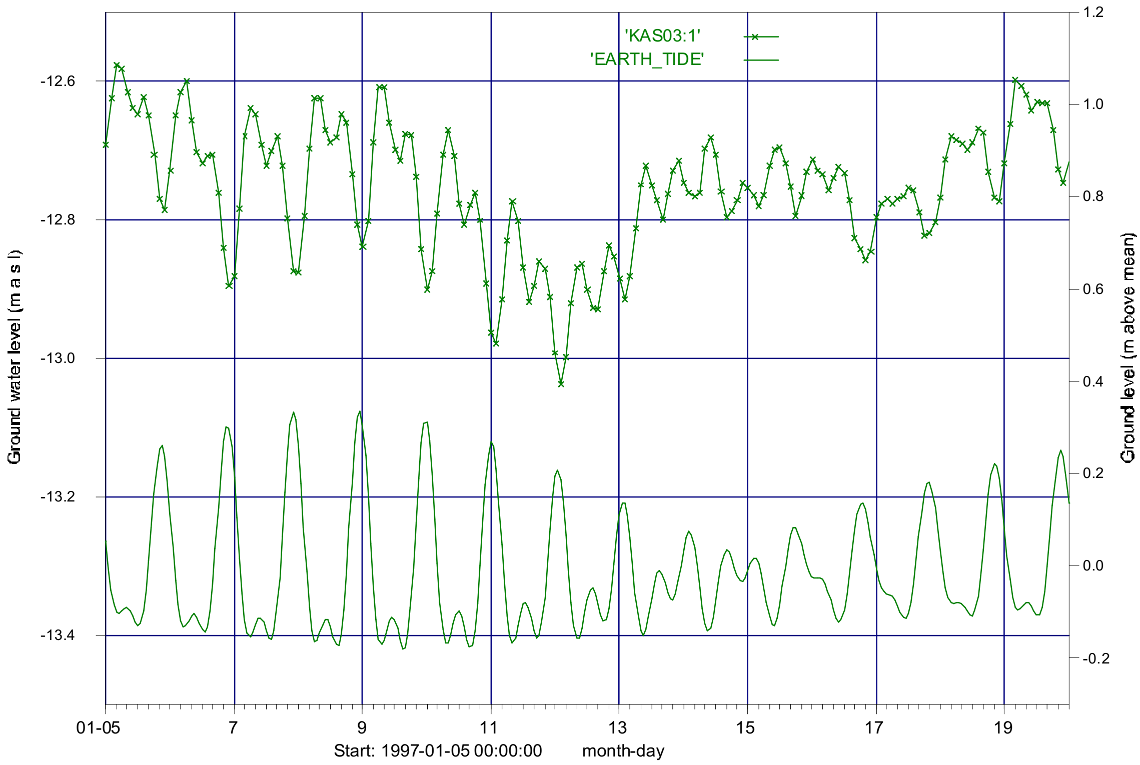


Figure 4-9 Earth tide (bottom curve, right axis) and groundwater level in KAS03:1 (top curve, left axis) during January 1997.

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 centimetres, 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, 1982) 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 to +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 representativity 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 represe n-tativity 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 cloud i-ness 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 groun d-water levels in the area. One single activity affecting the groundwater levels in many boreholes on Äspö was the drilling of the first of two raise-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 in most surface boreholes seems to have stabilised and the changes during 2000 were relatively small (within some metre), with both increasing and decreasing levels. Most sections in tunnel boreholes show decreasing pressures during 2000. A mean value is somewhere around 50 kPa but a much greater decline may be observed in some sections strongly influenced by drillings and other activities related to the Prototype repository.

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 2000. More than 3000 entries during 2000 are to be found in the activity table in the SKB database. One should also expect that there are activities influencing groundwater conditions that are missing 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 acti vity.

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
2000-01-03	2000-01-03	TASA	1650	1660	Additional scaling
2000-01-04	2000-01-04	TASA	1660	1670	Additional scaling
2000-01-06	2000-01-06	TASD	70	85	Additional scaling
2000-01-10	2000-01-10	TASB			Additional scaling
2000-01-11	2000-01-11	TASK			Bolting
2000-01-11	2000-01-11	TASK			Bolting
2000-01-13	2000-01-13	TASA	1645	1650	Bolting
2000-01-13	2000-01-13	TASB			Bolting
2000-01-14	2000-01-14	TASA	1655		Bolting
2000-01-14	2000-01-14	TASB	5	20	Bolting
2000-01-15	2000-01-15	TASA	2335	2348	Bolting
2000-01-19	2000-01-19	NASA3067A	3067		Bolting
2000-01-19	2000-01-19	NASA3067A			Bolting
2000-01-19	2000-01-19	TASD			Additional scaling
2000-01-31	2000-01-31	TASA	3500	3510	Additional scaling
2000-02-02	2000-02-02	TASA	1860	1880	Additional scaling
2000-02-02	2000-02-02	TASA	3512		Bolting
2000-02-02	2000-02-02	TASA	3515		Bolting
2000-02-02	2000-02-02	TASJ			Additional scaling
2000-02-03	2000-02-03	TASA	1880	1890	Additional scaling
2000-02-07	2000-02-07	TASA	3100	3140	Additional scaling
2000-02-08	2000-02-08	TASA	1750	1790	Additional scaling
2000-02-17	2000-02-17	TASR			Additional scaling
2000-02-22	2000-02-22	TASA	770	780	Additional scaling
2000-02-22	2000-02-22	TASM			Bolting
2000-02-23	2000-02-23	TASA	780	790	Additional scaling
2000-02-24	2000-02-24	TASA	790	820	Additional scaling
2000-02-28	2000-02-28	TASA	750		Bolting
2000-02-29	2000-02-29	NASA2156B			Additional scaling
2000-02-29	2000-02-29	TASA	730	750	Additional scaling
2000-03-03	2000-03-03	TASA	750	770	Additional scaling
2000-03-06	2000-03-06	TASA	825	835	Additional scaling
2000-03-07	2000-03-07	TASA	835	865	Additional scaling
2000-03-08	2000-03-08	TASA	865	870	Additional scaling
2000-03-13	2000-03-13	TASA	870	880	Additional scaling
2000-03-14	2000-03-14	TASA	880	890	Additional scaling
2000-03-15	2000-03-15	TASA	890	900	Additional scaling
2000-03-15	2000-03-15	TASA	670	685	Bolting
2000-03-16	2000-03-16	TASA	900	910	Additional scaling
2000-03-16	2000-03-16	TASA	500	510	Bolting
2000-03-20	2000-03-20	TASA	910	925	Additional scaling
2000-03-20	2000-03-20	TASA	910	925	Bolting

Start	Stop	Idcode	Secup (m)	Seclow (m)	Activity
2000-03-21	2000-03-21	TASA	925	930	Bolting
2000-03-22	2000-03-22	TASA	940	950	Bolting
2000-03-23	2000-03-23	NASA3106A			Additional scaling
2000-03-27	2000-03-27	NASA3106A			Additional scaling
2000-03-27	2000-03-27	TASA	925	935	Additional scaling
2000-03-27	2000-03-27	TASA	965	970	Bolting
2000-03-28	2000-03-28	TASA	935	950	Additional scaling
2000-03-28	2000-03-28	TASA	1010	1025	Bolting
2000-03-29	2000-03-29	TASA	1030	1040	Bolting
2000-03-30	2000-03-30	TASA	950	966	Additional scaling
2000-03-30	2000-03-30	TASA	740	745	Bolting
2000-04-03	2000-04-03	TASA	1010	1020	Additional scaling
2000-04-04	2000-04-04	TASA	1020	1030	Additional scaling
2000-04-04	2000-04-04	TASA	890	900	Bolting
2000-04-05	2000-04-05	TASA	1030	1040	Additional scaling
2000-04-06	2000-04-06	NASA0907A			Additional scaling
2000-04-10	2000-04-10	TASI			Additional scaling
2000-04-11	2000-04-11	TASA	900	925	Bolting
2000-04-12	2000-04-12	TASA	1040	1050	Bolting
2000-04-13	2000-04-13	TASA	1040	1060	Additional scaling
2000-04-18	2000-04-18	TASA	1050	1060	Bolting
2000-04-19	2000-04-19	TASA	1040	1070	Additional scaling
2000-04-20	2000-04-20	TASA	890	900	Bolting
2000-04-20	2000-04-20	TASA	900	910	Bolting
2000-05-02	2000-05-02	TASA	1070	1080	Additional scaling
2000-05-03	2000-05-03	TASM			Additional scaling
2000-05-04	2000-05-04	TASM			Additional scaling
2000-05-08	2000-05-08	TASM			Additional scaling
2000-05-08	2000-05-08	TASM			Bolting
2000-05-09	2000-05-09	TASM			Additional scaling
2000-05-10	2000-05-10	TASM			Additional scaling
2000-05-11	2000-05-11	TASM			Additional scaling
2000-05-15	2000-05-15	TASA	1080	1085	Additional scaling
2000-05-16	2000-05-16	TASA	1085	1095	Additional scaling
2000-05-16	2000-05-16	TASA	910	920	Bolting
2000-05-16	2000-05-16	TASA	920	930	Bolting
2000-05-17	2000-05-17	TASA	1085	1095	Bolting
2000-05-18	2000-05-18	TASM			Bolting
2000-05-22	2000-05-22	TASA	1650	1670	Bolting
2000-05-23	2000-05-23	TASA	1670	1680	Bolting
2000-05-24	2000-05-24	TASA	2325	2330	Bolting
2000-05-29	2000-05-29	NASA1194A			Additional scaling
2000-05-30	2000-05-30	NASA1049A			Additional scaling
2000-05-31	2000-05-31	NASA0907A			Additional scaling
2000-07-05	2000-07-05	NASA0115A			Shot creting
2000-07-05	2000-07-05	TASA	0	115	Shot creting
2000-07-07	2000-07-07	NASA0115A			Shot creting
2000-07-17	2000-07-17	TASA	1095	1100	Additional scaling
2000-07-18	2000-07-18	TASA	1100	1110	Additional scaling
2000-07-19	2000-07-19	TASA	1110	1117	Additional scaling
2000-07-20	2000-07-20	TASA	1117	1120	Additional scaling

Start	Stop	Idcode	Secup (m)	Seclow (m)	Activity
2000-07-24	2000-07-24	TASA	900		Additional scaling
2000-07-25	2000-07-25	TASA	900	915	Additional scaling
2000-07-26	2000-07-26	TASA	915	920	Additional scaling
2000-07-27	2000-07-27	TASA	920	935	Additional scaling
2000-07-31	2000-07-31	TASA	1120	1130	Additional scaling
2000-08-01	2000-08-01	TASA	1120	1130	Additional scaling
2000-08-02	2000-08-02	NASA1127B			Additional scaling
2000-08-03	2000-08-03	NASA1127B			Additional scaling
2000-08-04	2000-08-04	NASA1127B			Additional scaling
2000-08-07	2000-08-07	NASA0115A			Shot creting
2000-08-07	2000-08-07	TASA	1130	1140	Additional scaling
2000-08-07	2000-08-08	TASA	100	115	Shot creting
2000-08-08	2000-08-08	TASA	1140	1160	Additional scaling
2000-08-08	2000-08-09	TASA	33	100	Shot creting
2000-08-09	2000-08-09	TASA	1160	1170	Additional scaling
2000-08-09	2000-08-10	TASA	7	33	Shot creting
2000-08-10	2000-08-10	TASA	1170	1180	Additional scaling
2000-08-10	2000-08-10	TASA	93	120	Shot creting
2000-08-10	2000-08-10	TASA	93	115	Shot creting
2000-08-14	2000-08-14	TASA	1180	1190	Additional scaling
2000-08-14	2000-08-15	TASA	0	93	Shot creting
2000-08-15	2000-08-15	TASA	1190	1200	Additional scaling
2000-08-15	2000-08-15	TASA	201	225	Shot creting
2000-08-15	2000-08-15	TASA	210	230	Shot creting
2000-08-15	2000-08-16	TASA	210	225	Shot creting
2000-08-16	2000-08-16	TASA	1200	1225	Additional scaling
2000-08-21	2000-08-21	TASA	1225	1235	Additional scaling
2000-08-21	2000-08-22	TASA	740	770	Grouting
2000-08-22	2000-08-22	TASA	1235	1250	Additional scaling
2000-08-22	2000-08-22	TASA			Additional scaling
2000-08-22	2000-08-22	TASR			Round
2000-08-23	2000-08-23	TASA	1350	1370	Additional scaling
2000-08-23	2000-08-24	TASA	740	770	Grouting
2000-08-24	2000-08-24	TASR			Additional scaling
2000-08-24	2000-08-25	TASA	3537	3537	Round
2000-08-24	2000-08-24	TASA	740	770	Grouting
2000-08-28	2000-08-28	TASA	1370	1387	Additional scaling
2000-08-28	2000-08-31	TASA	3537	3537	Round
2000-08-29	2000-08-29	NASA1387A			Additional scaling
2000-08-29	2000-08-30	TASA	752	780	Shot creting
2000-08-30	2000-08-30	NASA1387A			Additional scaling
2000-08-31	2000-09-05	TASA	3560	3560	Round
2000-09-04	2000-09-04	TASA	730	752	Shot creting
2000-09-05	2000-09-05	KG0023A01			Round
2000-09-11	2000-09-11	TASA	1380	1390	Additional scaling
2000-09-12	2000-09-12	TASA	1390	1400	Additional scaling
2000-09-12	2000-09-12	TASA	742	780	Shot creting
2000-09-13	2000-09-13	TASA	1400	1410	Additional scaling
2000-09-13	2000-09-13	TASA	730	742	Shot creting
2000-09-14	2000-09-14	TASF			Additional scaling
2000-09-18	2000-09-18	TASF			Additional scaling

Start	Stop	Idcode	Secup (m)	Seclow (m)	Activity
2000-09-19	2000-09-19	TASA	34	38	Bolting
2000-09-20	2000-09-20	TASA	1410	1430	Additional scaling
2000-09-20	2000-09-20	TASA	470	486	Bolting
2000-09-20	2000-09-20	TASA	660.5	678.5	Bolting
2000-09-21	2000-09-21	TASA	1430	1440	Additional scaling
2000-09-25	2000-09-25	TASA	1430	1440	Additional scaling
2000-09-26	2000-09-26	TASA	1440	1450	Additional scaling
2000-09-27	2000-09-27	TASA	1440	1475	Additional scaling
2000-09-28	2000-09-28	TASA	1475	1500	Additional scaling
2000-10-01	2000-10-01	TASA	730	766	Bolting
2000-10-01	2000-10-01	TASA	768	780	Bolting
2000-10-02	2000-10-02	TASA	1475	1500	Additional scaling
2000-10-02	2000-10-02	TASA	892	920	Shot creting
2000-10-03	2000-10-03	TASA	1475	1500	Additional scaling
2000-10-04	2000-10-04	TASA	1500	1510	Additional scaling
2000-10-04	2000-10-04	TASA	3141	3165	Shot creting
2000-10-05	2000-10-05	TASA	1500	1500	Additional scaling
2000-10-05	2000-10-05	TASA	3120	3141	Shot creting
2000-10-09	2000-10-09	TASA	1500	1510	Additional scaling
2000-10-10	2000-10-10	TASA	1510	1520	Additional scaling
2000-10-12	2000-10-12	KG0021A01	2	2	Round
2000-10-12	2000-10-12	KG0033A01	2	2	Round
2000-10-16	2000-10-16	TASA	1520	1530	Additional scaling
2000-10-18	2000-10-18	TASA	1530	1550	Additional scaling
2000-10-23	2000-10-23	TASA	1550	1570	Additional scaling
2000-10-23	2000-10-23	TASA	957	970	Shot creting
2000-10-25	2000-10-25	TASA	1570	1600	Additional scaling
2000-10-25	2000-10-25	TASA	950	970	Shot creting
2000-10-30	2000-10-30	TASA	1600	1630	Additional scaling
2000-10-30	2000-10-30	TASA	940	970	Shot creting
2000-11-01	2000-11-01	NASA0408A	408		Additional scaling
2000-11-01	2000-11-13	TASA	3117	3164	Bolting
2000-11-06	2000-11-06	TASA	1622	1632.5	Bolting
2000-11-07	2000-11-07	TASA			Additional scaling
2000-11-07	2000-11-07	TASA	1756	1787	Bolting
2000-11-08	2000-11-08	TASA	1648	1668	Shot creting
2000-11-09	2000-11-09	HG0020A01	1	1.4	Round
2000-11-13	2000-11-13	HG0020A01			Round
2000-11-14	2000-11-14	TASA	950	1026	Shot creting
2000-11-15	2000-11-15	TASA	965	1013	Shot creting
2000-11-16	2000-11-16	HG0022A01	0.9	1.1	Round
2000-11-16	2000-11-16	HG0022A01	0.9	1.3	Round
2000-11-16	2000-11-16	HG0022A01	1.1	1.4	Round
2000-11-16	2000-11-16	HG0022A01	1	1.1	Round
2000-11-20	2000-11-20	HG0022A02	1	1.3	Round
2000-11-20	2000-11-20	HG0022A02	1.3	1.3	Round
2000-11-20	2000-11-20	HG0022A02	0.9	0.9	Round
2000-11-20	2000-11-20	HG0022A02	0.3	0.3	Round
2000-11-20	2000-11-20	HG0022A02	1	1	Round
2000-11-20	2000-11-20	HG0022A02	1.1	2	Round
2000-11-21	2000-11-21	TASA	1762	1790	Shot creting

Start	Stop	Idcode	Secup (m)	Seclow (m)	Activity
2000-11-21	2000-11-22	HG0023A01	0.8	1.5	Round
2000-11-22	2000-11-22	TASA	1758	1788	Shot creting
2000-11-23	2000-11-23	HG0023A01	0.8	1	Round
2000-11-23	2000-11-23	HG0023A01	0.8	1.1	Round
2000-11-23	2000-11-23	HG0023A01	1	1.3	Round
2000-11-23	2000-11-23	HG0023A01	1.1	1.3	Round
2000-11-23	2000-11-23	HG0023A01	0.9	1	Round
2000-11-23	2000-11-23	HG0023A01	0.8	0.9	Round
2000-11-27	2000-11-27	TASA	3114	3165	Shot creting
2000-11-27	2000-11-27	HG0023A02	1	1	Round
2000-11-27	2000-11-27	HG0023A02	1.2	1.2	Round
2000-11-27	2000-11-27	HG0023A02	1.3	1.3	Round
2000-11-27	2000-11-27	HG0023A02	1.2	1.2	Round
2000-11-27	2000-11-27	HG0023A02	1	1	Round
2000-11-27	2000-11-30	HG0024A01	0.9	1.3	Round
2000-12-04	2000-12-04	TASA	3114	3165	Shot creting
2000-12-04	2000-12-04	TASA	3116	3192	Shot creting
2000-12-04	2000-12-04	HG0025A02	0.9	1.4	Round
2000-12-05	2000-12-05	TASA	1098	1152	Shot creting
2000-12-05	2000-12-05	HG0025A03	0.9	1.4	Round
2000-12-06	2000-12-06	HG0026A02	0.9	1.4	Round
2000-12-06	2000-12-06	HG0026A01	0.9	1.5	Round
2000-12-07	2000-12-07	HG0027A01	1.1	1.1	Round
2000-12-07	2000-12-07	HG0027A01	1.3	1.4	Round
2000-12-07	2000-12-07	HG0027A01	1.5	1.6	Round
2000-12-07	2000-12-07	HG0027A01	1	1.4	Round
2000-12-08	2000-12-08	HG0027A01	1.1	1.3	Round
2000-12-08	2000-12-08	HG0027A01	1.3	1.6	Round
2000-12-08	2000-12-08	HG0027A01	1.4	1.7	Round
2000-12-11	2000-12-11	HG0029A02	1.1	1.2	Round
2000-12-11	2000-12-11	HG0029A02	1.2	1.4	Round
2000-12-11	2000-12-11	HG0029A02	1.4	1.6	Round
2000-12-11	2000-12-11	HG0029A02	1.2	1.4	Round
2000-12-11	2000-12-11	HG0029A01	1.1	1.2	Round
2000-12-11	2000-12-11	HG0029A01	1.2	1.6	Round
2000-12-11	2000-12-11	HG0029A01	1.2	1.3	Round
2000-12-11	2000-12-11	HG0028A02	1.1	1.2	Round
2000-12-11	2000-12-11	HG0028A02	1.1	1.4	Round
2000-12-11	2000-12-11	HG0028A02	1.4	1.7	Round
2000-12-11	2000-12-11	HG0028A01	1.2	1.4	Round
2000-12-11	2000-12-11	HG0028A02	1.4	1.7	Round
2000-12-11	2000-12-11	HG0028A01	1.4	1.7	Round
2000-12-11	2000-12-11	HG0028A02	1.3	1.4	Round
2000-12-11	2000-12-11	HG0028A02	1.1	1.2	Round
2000-12-12	2000-12-12	HG0028A01	1.3	1.7	Round
2000-12-12	2000-12-12	HG0028A01	1.1	1.3	Round
2000-12-13	2000-12-13	HG0030A01	1.1	1.4	Round
2000-12-13	2000-12-13	HG0030A01	1.4	1.8	Round
2000-12-13	2000-12-13	HG0030A01	1.1	1.4	Round
2000-12-13	2000-12-13	HG0030A01	1.2	1.4	Round
2000-12-14	2000-12-14	HG0030A02	1.1	1.2	Round

Start	Stop	Idcode	Secup (m)	Seclow (m)	Activity
2000-12-14	2000-12-14	HG0030A02	1.2	1.4	Round
2000-12-14	2000-12-14	HG0030A02	1.2	1.6	Round
2000-12-14	2000-12-14	HG0031A01	1	1.4	Round
2000-12-14	2000-12-14	HG0031A01	1.4	1.8	Round
2000-12-14	2000-12-14	HG0031A01	1.8	2	Round
2000-12-14	2000-12-14	HG0031A01	1.4	1.6	Round
2000-12-14	2000-12-14	HG0031A01	1.2	1.4	Round
2000-12-15	2000-12-15	HG0027A01	0.8	1	Round
2000-12-15	2000-12-15	HG0028A01	0.6	0.8	Round
2000-12-15	2000-12-15	HG0028A02	1	1.2	Round
2000-12-15	2000-12-15	HG0029A01	0.8	0.9	Round
2000-12-15	2000-12-15	HG0029A02	0.5	0.6	Round
2000-12-15	2000-12-15	HG0030A01	0.8	0.9	Round
2000-12-15	2000-12-15	HG0029A02	0.5	0.6	Round
2000-12-15	2000-12-15	HG0030A01	0.8	1.4	Round
2000-12-18	2000-12-18	HG0032A01	1	1.2	Round
2000-12-18	2000-12-18	HG0032A01	1.2	1.6	Round
2000-12-18	2000-12-18	HG0032A01	1	1.2	Round
2000-12-19	2000-12-19	HG0033A01	1.1	1.4	Round
2000-12-19	2000-12-19	HG0033A01	1.4	1.7	Round
2000-12-19	2000-12-19	HG0033A01	1.7	2.2	Round
2000-12-19	2000-12-19	HG0033A01	1.4	2.2	Round
2000-12-19	2000-12-19	HG0033A01	1	1.6	Round
2000-12-19	2000-12-19	HG0033A01	1.2	1.4	Round
2000-12-20	2000-12-20	TASF	0	105	Shot creting
2000-12-20	2000-12-20	HG0033A01	1.8	2.6	Round
2000-12-20	2000-12-20	HG0033A01	1.3	1.5	Round
2000-12-21	2000-12-21	HG0033A01	1.2	2	Round
2000-12-21	2000-12-21	KG0033A01	1.5	1.5	Round
2000-12-21	2000-12-21	HG0032A02	1.3	1.4	Round
2000-12-21	2000-12-21	HG0032A01	1.8	2.5	Round
2000-12-21	2000-12-21	HG0032A01	1	1.2	Round
2000-12-21	2000-12-21	HG0032A02	1	1.1	Round

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. Therefore, only openings and closure in borehole sections included in the monitoring program are listed in table 5-2, where dates when valves have been open are to be found. 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
2000-03-08	2000-03-08	HD0025A:
2000-03-09	2000-03-09	HD0025A:
2000-09-05	2000-09-05	HD0025A:
2000-09-19	2000-09-19	HD0025A:
2000-10-24	2000-10-24	HD0025A:
2000-10-24	2000-10-24	HD0025A:
2000-11-27	2000-11-27	HD0025A:
2000-12-28	2000-12-28	HD0025A:
2000-12-28	2000-12-28	HD0025A:
2000-09-20	2000-09-22	KA1061A:
2000-09-20	2000-09-21	KA1131B:1
2000-09-20	2000-09-21	KA1755A:3
2000-09-20	2000-09-21	KA2050A:1
2000-09-21	2000-09-21	KA2162B:1
2000-03-08	2000-03-08	KA2563A:1
2000-04-10	2000-04-11	KA2563A:1
2000-04-19	2000-04-19	KA2563A:1
2000-04-11	2000-04-11	KA2563A:5
2000-04-26	2000-05-22	KA2862A:
2000-08-29	2000-09-08	KA2862A:
2000-09-20	2000-09-20	KA2862A:1
2000-09-28	2000-10-06	KA2862A:1
2000-10-11	2000-10-23	KA2862A:1
2000-10-24		KA2862A:1
2000-01-26	2000-05-23	KA3065A02:
2000-05-30	2000-10-26	KA3065A02:
2000-10-26	2000-10-26	KA3065A02:
2000-09-20	2000-09-20	KA3110A:1
2000-03-09	2000-03-09	KA3385A:1
2000-03-09	2000-03-09	KA3385A:1
2000-03-14	2000-03-14	KA3385A:1
2000-03-14	2000-03-14	KA3385A:1
2000-03-15	2000-03-15	KA3385A:1
2000-03-15	2000-03-15	KA3385A:1
	2000-03-20	KA3385A:1
2000-03-21	2000-03-21	KA3385A:1
2000-03-24	2000-03-24	KA3385A:1
2000-03-27	2000-03-27	KA3385A:1
2000-03-29	2000-03-29	KA3385A:1
2000-03-29	2000-03-29	KA3385A:1
2000-03-29	2000-03-29	KA3385A:1
2000-03-30	2000-03-30	KA3385A:1
2000-03-30	2000-03-30	KA3385A:1
2000-03-31	2000-03-31	KA3385A:1
2000-04-03	2000-04-04	KA3385A:1
2000-04-05	2000-04-05	KA3385A:1
2000-04-06	2000-04-06	KA3385A:1
2000-04-06	2000-04-06	KA3385A:1
2000-04-10	2000-04-10	KA3385A:1
2000-04-12	2000-04-12	KA3385A:1
2000-04-13	2000-04-13	KA3385A:1
2000-04-18	2000-04-18	KA3385A:1
2000-04-18	2000-04-18	KA3385A:1
2000-05-03	2000-05-03	KA3385A:1
2000-05-09	2000-05-09	KA3385A:1
2000-05-10	2000-05-10	KA3385A:1
2000-05-15	2000-05-16	KA3385A:1
2000-05-22		KA3385A:1
2000-05-24		KA3385A:1
2000-05-25		KA3385A:1
2000-05-29	2000-05-30	KA3385A:1
2000-06-07	2000-06-07	KA3385A:1
2000-06-08	2000-06-08	KA3385A:1
2000-06-20	2000-06-20	KA3385A:1
2000-06-21	2000-06-21	KA3385A:1
2000-06-22	2000-06-22	KA3385A:1
2000-06-26	2000-06-26	KA3385A:1
2000-06-27	2000-06-27	KA3385A:1
2000-06-28	2000-06-28	KA3385A:1
2000-06-29	2000-06-29	KA3385A:1
2000-07-03	2000-07-03	KA3385A:1
2000-07-04		KA3385A:1
2000-07-10	2000-07-11	KA3385A:1
2000-07-12	2000-07-12	KA3385A:1
2000-07-12	2000-07-12	KA3385A:1
2000-07-14	2000-07-14	KA3385A:1
2000-07-18	2000-07-18	KA3385A:1
2000-07-25	2000-07-25	KA3385A:1
2000-07-26	2000-07-27	KA3385A:1
2000-08-01	2000-08-02	KA3385A:1
2000-08-02	2000-08-02	KA3385A:1
2000-08-09	2000-08-09	KA3385A:1
2000-08-10	2000-08-10	KA3385A:1
2000-08-17	2000-08-17	KA3385A:1
2000-08-23	2000-08-23	KA3385A:1
2000-08-29	2000-08-30	KA3385A:1
2000-09-07	2000-09-07	KA3385A:1
2000-09-08	2000-09-08	KA3385A:1
2000-09-08	2000-09-08	KA3385A:1
2000-09-12	2000-09-13	KA3385A:1
2000-09-13	2000-09-13	KA3385A:1
2000-09-19	2000-09-20	KA3385A:1
2000-09-20	2000-09-20	KA3385A:1
2000-09-26	2000-09-27	KA3385A:1

From	To	Borehole:sec
2000-09-28	2000-09-28	KA3385A:1
2000-10-02	2000-10-04	KA3385A:1
2000-10-05	2000-10-05	KA3385A:1
2000-10-06	2000-10-06	KA3385A:1
2000-10-10	2000-10-11	KA3385A:1
2000-10-16	2000-10-18	KA3385A:1
2000-10-18	2000-10-18	KA3385A:1
2000-10-24	2000-10-25	KA3385A:1
2000-05-11	2000-05-11	KA3542G02:4
1998-08-10	2000-12-05	KA3548A01:
2000-06-06	2000-06-06	KA3557G:
2000-06-06	2000-06-06	KA3563G:1
2000-06-06	2000-06-06	KA3572G01:1
	2000-12-05	KA3573A:
2000-06-06	2000-06-06	KA3574G01:1
2000-06-06	2000-06-06	KA3578G01:1
2000-06-06		KA3579G:
	2000-06-06	KA3579G:1
2000-06-06	2000-06-06	KA3584G01:
2000-06-06	2000-06-06	KA3590G01:1
2000-06-06	2000-06-06	KA3590G02:1
2000-06-06	2000-06-06	KA3593G:1
	2000-12-05	KA3600F:
2000-04-10	2000-04-10	KI0023B:2
2000-04-10	2000-04-10	KI0023B:4
2000-04-10	2000-04-10	KI0025F:4
2000-01-17	2000-01-17	KI0025F02:3
2000-01-17	2000-01-17	KI0025F02:3
2000-04-19	2000-04-19	KI0025F02:3
2000-04-19		KI0025F02:3
2000-03-08	2000-03-08	KI0025F02:5
2000-04-11	2000-04-11	KI0025F02:5
	2000-04-19	KI0025F02:7
2000-04-11	2000-04-11	KI0025F02:8
2000-04-11	2000-04-11	KI0025F02:9
2000-08-23	2000-08-23	KI0025F03:1
2000-04-12	2000-04-12	KI0025F03:3
2000-04-19	2000-04-19	KI0025F03:3
2000-04-12	2000-04-12	KI0025F03:4
2000-03-08	2000-03-08	KI0025F03:5
2000-03-08	2000-03-08	KI0025F03:6
2000-04-12	2000-04-12	KI0025F03:6
2000-04-19	2000-04-19	KI0025F03:6
2000-04-12	2000-04-12	KI0025F03:7
2000-04-19	2000-04-19	KI0025F03:7
2000-04-19	2000-04-19	KI0025F03:7
2000-04-12	2000-04-12	KXTT3:2
2000-09-20	2000-09-20	KXTT3:2

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. 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
HAS04	1989-05-12	2000-01-26
HAS04	2000-01-26	2000-02-08
HAS04	2000-02-08	2000-03-23
HAS04	2000-11-15	
HAS11	1999-04-01	
HAS13	1999-05-18	2000-02-08
HAS13	2000-02-08	
HAS16	1997-02-05	
HAS17	1999-02-24	
HAS19	1990-06-10	
HAS20	1990-12-12	
HAS23	1999-08-17	

Borehole	Expansion	Release
HAV08	1987-07-24	
HBH04	1991-12-11	
HMJ01	1991-12-13	
KAS02	1991-08-07	
KAS03	1996-04-27	2000-10-09
KAS03	2000-10-09	
KAS05	1991-11-24	
KAS08	1989-05-01	
KAS09	1990-04-05	2000-10-05
KAS09	2000-10-05	
KAS12	1999-12-15	
KAS13	1992-10-06	
KAS16	1992-10-20	
KBH02	1992-05-07	
KLX01	1992-03-02	2000-04-06
KLX01	2000-04-12	2001-05-16
KLX01	2001-05-16	

Table 5-4 Packer expansion and release in tunnel boreholes

Borehole	Expansion	Release
HA1960A	1993-07-13	
KA1131B	1994-10-25	
KA1751A	1994-04-26	
KA1754A	1994-04-21	
KA1755A	1994-05-03	
KA2048B	1994-12-12	
KA2050A	1994-11-22	
KA2162B	1999-10-28	
KA2511A	1999-03-17	
KA2563A	1999-03-15	
KA2598A	1998-03-04	
KA2858A	1995-09-27	
KA2862A	1997-09-22	
KA3005A	1999-12-14	2001-02-06
KA3005A	2001-02-06	
KA3010A	1995-09-28	1995-12-12
KA3010A		2001-02-06
KA3010A	2001-02-06	
KA3065A02	2000-01-26	2000-05-12
KA3065A02	2000-09-05	2000-09-05
KA3065A02	2000-09-05	
KA3067A	1995-02-28	
KA3105A	1995-09-19	
KA3110A	1995-09-19	
KA3385A	1995-09-25	
KA3510A	1998-11-23	2001-05-08
KA3510A	2001-05-09	
KA3539G	1999-08-04	
KA3542G01	1999-08-04	2000-11-29
KA3542G01	2000-12-06	
KA3542G02	1999-08-04	
KA3544G01	1999-08-04	2000-01-19
KA3546G01	1999-08-04	2000-01-19
KA3548G01	1999-02-03	
KA3550G01	1999-08-04	2000-01-19
KA3552G01	1999-08-04	2000-01-19
KA3554G01	1999-08-04	2000-12-05
KA3554G02	1999-08-04	
KA3557G	1999-02-03	
KA3563G	1999-08-05	
KA3566G01	1999-02-12	
KA3566G02	1999-02-12	
KA3572G01	1999-08-05	
KA3573A	1999-02-15	2000-12-05
KA3574G01	1999-08-05	
KA3576G01	1999-02-11	
KA3578G01	1999-08-05	2000-12-06
KA3579G	1999-08-05	
KA3584G01	1999-02-03	
KA3590G01	1999-08-05	
KA3590G02	1999-08-05	
KA3593G	1999-08-05	
KA3600F	1999-02-15	2000-12-05
KF0051A01	1998-06-12	
KG0021A01	1999-11-15	2000-03-06
KG0021A01	2000-03-06	2001-02-01
KG0021A01	2001-02-01	2001-02-06
KG0021A01	2001-02-06	
KG0048A01	1999-11-15	2001-02-01
KG0048A01	2001-02-01	2001-02-06
KG0048A01	2001-02-06	
KI0023B	1998-06-17	
KI0025F	1999-07-29	
KI0025F02	1998-10-23	
KI0025F03	1999-10-22	
KXTT1	1999-12-14	
KXTT2	1999-12-14	
KXTT3	1999-12-14	
KXTT4	1999-12-14	
KXTT5	1999-12-14	

5.5 Drilling

Only tunnel boreholes have been drilled during 2000.

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
2000-01-19	2000-01-19	KA1673A01	1.03	Core drilling
2000-01-25	2000-02-06	KA3065A03	10.4	Core drilling
2000-02-23	2000-02-23	KA3065A03		Various drilling
2000-03-07	2000-03-07	KA3575G03	0.13	Core drilling
2000-03-07	2000-03-07	KA3575G02	0.41	Core drilling
2000-03-08	2000-03-08	KA3575G04	0.44	Core drilling
2000-03-08	2000-03-08	KA3575G05	0.38	Core drilling
2000-03-08	2000-03-08	KA3569G02	0.43	Core drilling
2000-03-08	2000-03-08	KA3569G03	0.43	Core drilling
2000-03-09	2000-03-09	KA3569G04	0.46	Core drilling
2000-03-09	2000-03-09	KA3569G05	0.41	Core drilling
2000-03-09	2000-03-09	KA3569G06	0.46	Core drilling
2000-03-09	2000-03-09	KA3569G07	0.47	Core drilling
2000-03-09	2000-03-09	KA3569G08	0.45	Core drilling
2000-03-09	2000-03-09	KA3569G09	0.44	Core drilling
2000-03-10	2000-03-10	KA3569G10	0.46	Core drilling
2000-03-10	2000-03-10	KA3569G11	0.37	Core drilling
2000-03-23	2000-03-24	KD0086G27	1.57	Core drilling
2000-03-24	2000-03-24	KD0086G26	1.57	Core drilling
2000-03-27	2000-03-27	KD0086G23	1.57	Core drilling
2000-03-27	2000-03-27	KD0086G20	1.57	Core drilling
2000-03-27	2000-03-27	KD0086G25	1.57	Core drilling
2000-03-28	2000-03-29	KD0086G22	1.57	Core drilling
2000-03-28	2000-03-28	KD0086G19	1.57	Core drilling
2000-03-28	2000-03-28	KD0086G24	1.57	Core drilling
2000-03-28	2000-03-28	KD0086G21	1.57	Core drilling
2000-03-29	2000-03-29	KD0086G18	1.57	Core drilling
2000-03-29	2000-03-30	KD0092G16	1.57	Core drilling
2000-03-30	2000-03-30	KD0092G15	1.57	Core drilling
2000-03-30	2000-03-30	KD0092G12	1.57	Core drilling
2000-03-30	2000-03-30	KD0092G09	1.57	Core drilling
2000-03-31	2000-03-31	KD0092G14	1.57	Core drilling
2000-03-31	2000-03-31	KD0092G11	1.57	Core drilling
2000-04-03	2000-04-03	KD0092G08	1.57	Core drilling
2000-04-03	2000-04-03	KD0092G13	1.57	Core drilling
2000-04-03	2000-04-03	KD0092G10	1.57	Core drilling
2000-04-04	2000-04-04	KD0092G07	1.57	Core drilling

Start	Stop	Borehole	Borehole length (m)	Type of drilling
2000-04-14	2000-04-27	KG0023A01	33.4	Core drilling
2000-05-02	2000-05-15	KG0033A01	56.9	Core drilling
2000-05-15	2000-05-21	TASA	3537	Slot drilling
2000-05-16	2000-05-24	KG0027A01	46.72	Core drilling
2000-05-23	2000-06-05	TASA	3537	Slot drilling
2000-06-01	2000-06-01	HD0092G05	10.2	Percussion drilling
2000-06-01	2000-06-01	HD0092G06	10.2	Percussion drilling
2000-06-01	2000-06-01	HD0092G04	10.2	Percussion drilling
2000-06-01	2000-06-01	HD0092G07	10.2	Percussion drilling
2000-06-01	2000-06-02	HD0092G03	10.2	Percussion drilling
2000-06-02	2000-06-02	HD0092G02	10.2	Percussion drilling
2000-06-02	2000-06-02	HD0092G01	10.2	Percussion drilling
2000-06-02	2000-06-02	HD0092G09	10.2	Percussion drilling
2000-06-02	2000-06-02	HD0092G08	10.2	Percussion drilling
2000-06-06	2000-06-15	TASA	3560	Slot drilling
2000-06-14	2000-06-15	KM0007B01	9.06	Core drilling
2000-06-15	2000-06-15	KM0008B01	9.04	Core drilling
2000-06-21	2000-06-21	TASA	3560	Slot drilling
2000-08-07	2000-08-15	TASA	3560	Slot drilling
2000-09-12	2000-10-04	HG0020A01	31.9	Percussion drilling
2000-09-19	2000-10-02	HG0021A01	31.8	Percussion drilling
2000-09-20	2000-09-20	KA3566C01	2.1	Core drilling
2000-09-21	2000-09-22	KA3563A01	2.06	Core drilling
2000-09-21	2000-09-22	KA3579D01	2	Core drilling
2000-09-22	2000-09-25	KA3563D01	2.01	Core drilling
2000-09-25	2000-09-25	KA3588D01	1.9	Core drilling
2000-09-25	2000-09-25	KA3568D01	2.03	Core drilling
2000-09-25	2000-09-26	KA3592C01	2.1	Core drilling
2000-09-26	2000-09-26	KA3574D01	2.05	Core drilling
2000-09-26	2000-10-02	HG0022A01	32.25	Percussion drilling
2000-09-26	2000-09-26	KA3588C01	2.04	Core drilling
2000-09-26	2000-09-26	KA3573C01	2.05	Core drilling
2000-09-26	2000-09-28	KA3578C01	2.09	Core drilling
2000-09-28	2000-09-28	KA3552A01	2.06	Core drilling
2000-09-28	2000-10-02	KA3578H01	1.9	Core drilling
2000-09-29	2000-10-04	KA3553B01	2.02	Core drilling
2000-10-04	2000-10-04	KA3597D01	2.22	Core drilling
2000-10-04	2000-10-05	KA3597H01	2.06	Core drilling
2000-10-05	2000-10-05	KA3543A01	2.06	Core drilling
2000-10-05	2000-10-11	KA3563I01	2.15	Core drilling
2000-10-06	2000-10-06	KA3548D01	2.06	Core drilling
2000-10-06	2000-10-08	HG0033A01	59	Percussion drilling
2000-10-09	2000-10-10	HG0032A02	57.7	Percussion drilling
2000-10-10	2000-10-11	KA3543I01	2.06	Core drilling
2000-10-11	2000-10-12	HG0022A02	32.6	Percussion drilling
2000-10-11	2000-10-12	KA3552H01	2.1	Core drilling
2000-10-16	2000-10-24	KG0023A01	33.4	Percussion drilling
2000-10-16	2000-10-16	HG0023A01	33.7	Percussion drilling
2000-10-17	2000-10-19	KA3571G01	10	Core drilling
2000-10-17	2000-11-03	HG0023A02	34.5	Percussion drilling
2000-10-18	2000-11-03	HG0024A01	35.05	Percussion drilling
2000-10-18	2000-10-19	KA3588I01	1.96	Core drilling

Start	Stop	Borehole	Borehole length (m)	Type of drilling
2000-10-19	2000-11-04	HG0024A02	35.25	Percussion drilling
2000-10-19	2000-10-20	KA3577G01	10	Core drilling
2000-10-23	2000-10-24	KA3578G02	10	Core drilling
2000-10-24	2000-11-05	HG0025A01	36.05	Percussion drilling
2000-10-25	2000-10-26	KA3552G04	3.1	Core drilling
2000-10-25	2000-11-06	HG0025A02	36.35	Percussion drilling
2000-10-26	2000-10-27	KA3589G01	10	Core drilling
2000-10-26	2000-10-31	HG0025A03	43.6	Percussion drilling
2000-10-27	2000-10-27	KA3551G05	3.1	Core drilling
2000-10-30	2000-10-30	KA3550G05	3	Core drilling
2000-10-30	2000-10-31	KA3592G01	10	Core drilling
2000-10-31	2000-10-31	DA3569G01	0.45	Various drilling
2000-10-31	2000-10-31	DA3569G01	0.35	Various drilling
2000-10-31	2000-11-01	KA3597G01	10	Core drilling
2000-10-31	2000-11-01	KA3550G04	7	Core drilling
2000-11-01	2000-11-01	KA3545G05	2.3	Core drilling
2000-11-01	2000-11-02	HG0026A01	44.4	Percussion drilling
2000-11-02	2000-11-02	KA3545G07	2.25	Core drilling
2000-11-02	2000-11-07	KA3549G01	7.05	Core drilling
2000-11-06	2000-11-09	KA3575G06	15.1	Core drilling
2000-11-06	2000-11-06	KA3545G08	2.3	Core drilling
2000-11-06	2000-11-07	HG0026A02	45.5	Percussion drilling
2000-11-07	2000-11-07	KA3545G06	2.3	Core drilling
2000-11-08	2000-11-08	KA3545G09	1	Core drilling
2000-11-08	2000-11-09	KG0027A01	46.7	Percussion drilling
2000-11-08	2000-11-13	KA3546G04	7	Core drilling
2000-11-09	2000-11-09	DA3545G01		Various drilling
2000-11-10	2000-11-15	KA3575G07	13.55	Core drilling
2000-11-13	2000-11-14	HG0027A01	48	Percussion drilling
2000-11-14	2000-11-15	KA3551G08	2.25	Core drilling
2000-11-14	2000-11-15	HG0028A01	48.6	Percussion drilling
2000-11-16	2000-11-20	HG0028A02	49.8	Percussion drilling
2000-11-17	2000-11-17	KA3551G06	2.25	Core drilling
2000-11-20	2000-11-20	KA3551G07	2.25	Core drilling
2000-11-20	2000-11-21	DA3581G01	2.4	Various drilling
2000-11-20	2000-11-20	KA3551G09	2.25	Core drilling
2000-11-20	2000-11-22	KM0007B01	3	Core drilling
2000-11-21	2000-11-22	DA3551G01		Various drilling
2000-11-21	2000-11-22	HG0029A01	50.7	Percussion drilling
2000-11-22	2000-11-22	KA3551G10	2.25	Core drilling
2000-11-22	2000-11-22	KM0007B02	3	Core drilling
2000-11-22	2000-11-23	HG0029A02	51.7	Percussion drilling
2000-11-22	2000-11-22	KM0007B03	3	Core drilling
2000-11-23	2000-11-23	DA3587G01		Various drilling
2000-11-23	2000-11-24	DA3575G01		Various drilling
2000-11-24	2000-11-27	HG0030A01	52	Percussion drilling
2000-11-27	2000-11-29	KG0033A01	56.8	Percussion drilling
2000-11-29	2000-11-30	HG0030A02	53.5	Percussion drilling
2000-12-01	2000-12-05	HG0031A01	53.9	Percussion drilling
2000-12-05	2000-12-06	HG0032A01	54.6	Percussion 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). The test is performed during either natural gradient or stressed gradient.

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 mean 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. Transient evaluation.

Steady state injection test. A hydraulic test performed in a similar way as transient injection test but generally of shorter duration. Steady state evaluation.

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
2000-01-10	2000-01-11	KXTT5:2	9.61	9.81	Dilution test stressed gradient
2000-01-11	2000-01-17	KXTT5:2	9.61	9.81	Radially converging Test Hole
2000-01-11	2000-01-17	KXTT4:3	8.42	10.92	Radially converging Test Hole
2000-03-09	2000-03-13	KI0025F02:5	73.3	77.25	Dilution test stressed gradient
2000-03-09	2000-03-13	KI0025F03:5	66.58	74.08	Dilution test stressed gradient
2000-03-09	2000-03-13	KI0025F03:6	59.58	65.58	Dilution test stressed gradient
2000-03-21	2000-04-06	KI0023B:6	70.95	71.95	Dipole: Test hole
2000-03-21	2000-04-06	KI0023B:6	70.95	71.95	Dipole: Test hole
2000-03-28	2000-05-22	KI0023B:6	70.95	71.95	Dipole: Test hole
2000-04-26	2000-06-07	KI0023B:6	70.95	71.95	Dipole: Test hole
2000-04-26	2000-06-07	KI0023B:6	70.95	71.95	Dipole: Test hole
2000-04-26	2000-05-23	KI0023B:6	70.95	71.95	Radially converging Test Hole
2000-04-26	2000-08-17	KI0023B:6	70.95	71.95	Radially converging Test Hole
2000-05-03	2000-05-22	KI0023B:6	70.95	71.95	Dipole: Test hole
2000-05-22	2000-05-30	KI0023B:6	70.95	71.95	Dipole: Test hole
2000-05-23	2000-06-07	KI0023B:6	70.95	71.95	Radially converging Test Hole
2000-06-05	2000-06-06	KG0027A01:	7	11	Pressure Build Up Test (PBT)
2000-06-06	2000-06-06	KG0033A01:	9	13	Pressure Build Up Test (PBT)
2000-06-07	2000-06-07	KG0033A01:	34	38	Pressure Build Up Test (PBT)
2000-06-07	2000-06-08	KG0023A01:	24	28	Pressure Build Up Test (PBT)
2000-06-15	2000-06-15	KI0023B:6	70.95	71.95	Dipole: Test hole
2000-06-15	2000-06-15	KI0025F03:5	66.58	74.08	Dipole: Test hole
2000-06-20	2000-06-20	KI0023B:6	70.95	71.95	Radially converging Test Hole
2000-06-20	2000-06-20	KI0025F02:3	93.35	99.25	Radially converging Test Hole
2000-06-21	2000-06-21	KI0023B:6	70.95	71.95	Dipole: Test hole
2000-06-21	2000-06-21	KI0025F03:7	55.08	58.58	Dipole: Test hole
2000-08-14	2000-08-15	KM0007B01:	1	9.06	Transient injection test
2000-08-15	2000-08-15	KM0007B01:	1	4.5	Steady state injection test
2000-08-15	2000-08-15	KM0007B01:	5	6.1	Steady state injection test
2000-08-16	2000-08-16	KM0007B01:	8	9.06	Steady state injection test
2000-08-16	2000-08-16	KM0008B01:	1	9.04	Transient injection test
2000-08-16	2000-08-16	KM0008B01:	1	9.04	Steady state injection test
2000-09-08	2000-09-20	KI0023B:6	70.95	71.95	Dipole: Test hole
2000-09-08	2000-09-20	KI0025F03:5	66.58	74.08	Tracer Injection
2000-10-24	2000-10-24	KA3065A03:	10.08	10.88	Single Packer Flow Logging
2000-11-29	2000-11-29	SA3045A:	17	20.7	Single Packer Flow Logging
2000-11-30	2000-11-30	SA3045A:	2	20.7	Single Packer Flow Logging
2000-12-01	2000-12-01	SA3045A:	1	20.7	Single Packer Flow Logging

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 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 2000. In the main part of the borehole sections, the change over the year is within some metre. In 21 sections out of 56, the levels have increased more than 0.5 metre. In 11 sections there have been a decrease greater than 0.5 metre. The level changes in the rest of the borehole sections have been between –0.5 and 0.5 metre. The groundwater levels in surface boreholes seems to be mainly influenced by variations in climate factors, no pronounced effects from tunnel activities can be seen. Most certainly though, there are such minor responses in some boreholes.

The response to precipitation varies from borehole to borehole. In some boreholes, there is a rather quick response with pronounced peeks after each rain (se for example HAS01). In others the response is dampened (se for example HAS07) and may be seen as two larger humps due to the relatively great precipitation figures in June-July and October-November. In a few borehole sections, neither the quick nor the dampened fluctuations are seen at all.

The great level increase in section 2 in HAS16 in January is an effect of repairing a leakage in the packer system, causing a shortcut between the two sections in the borehole.

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. However, since the main purpose of 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 1996-2000 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.)

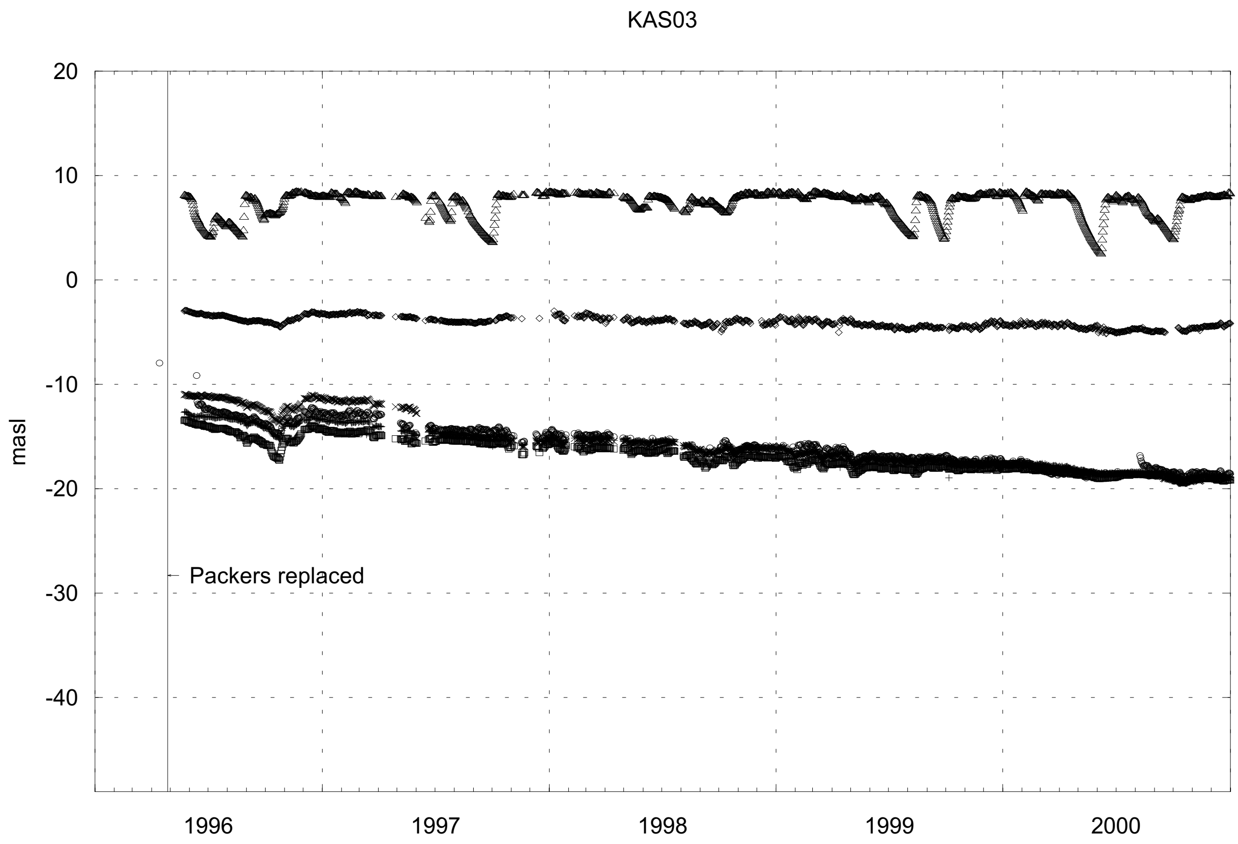


Figure 6-1 Groundwater levels in KAS03 on Äspö, 1996-2000.

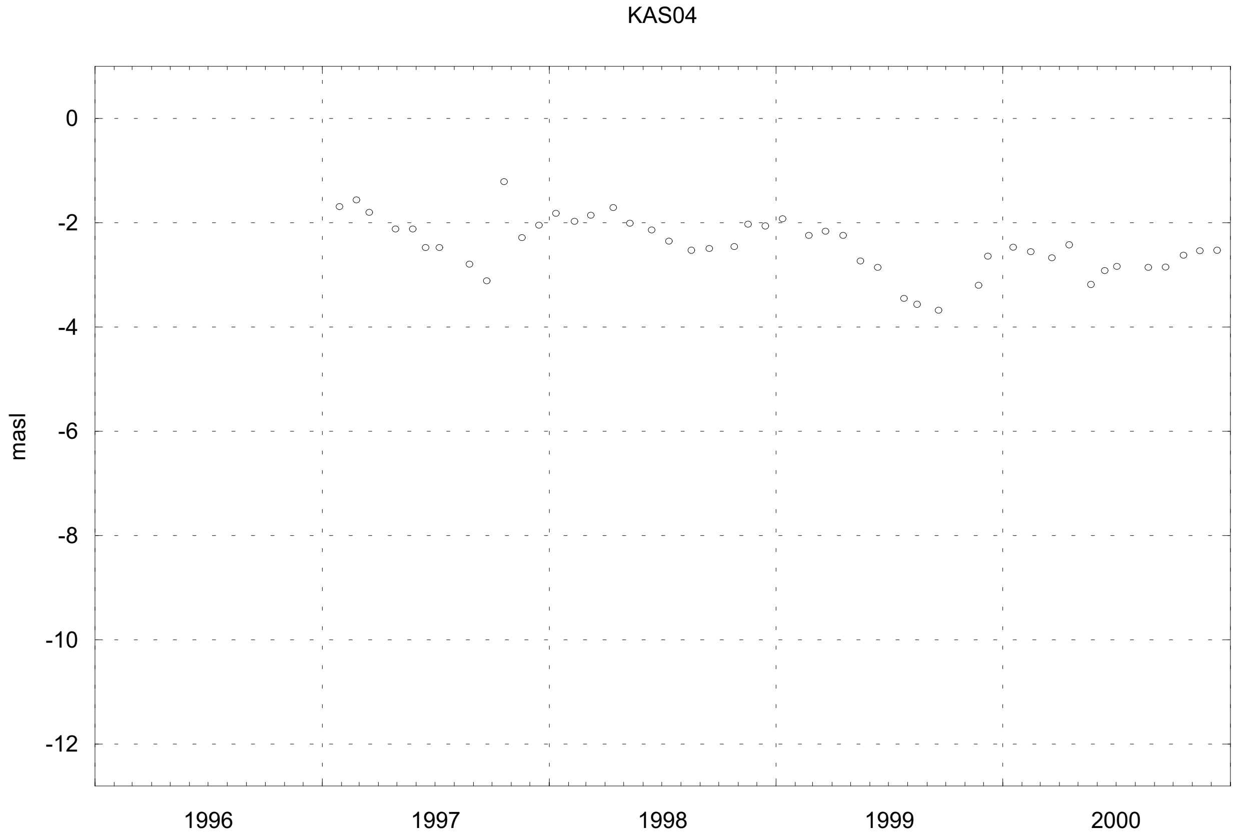


Figure 6-2 Groundwater levels in KAS04 on Äspö, 1996-2000.

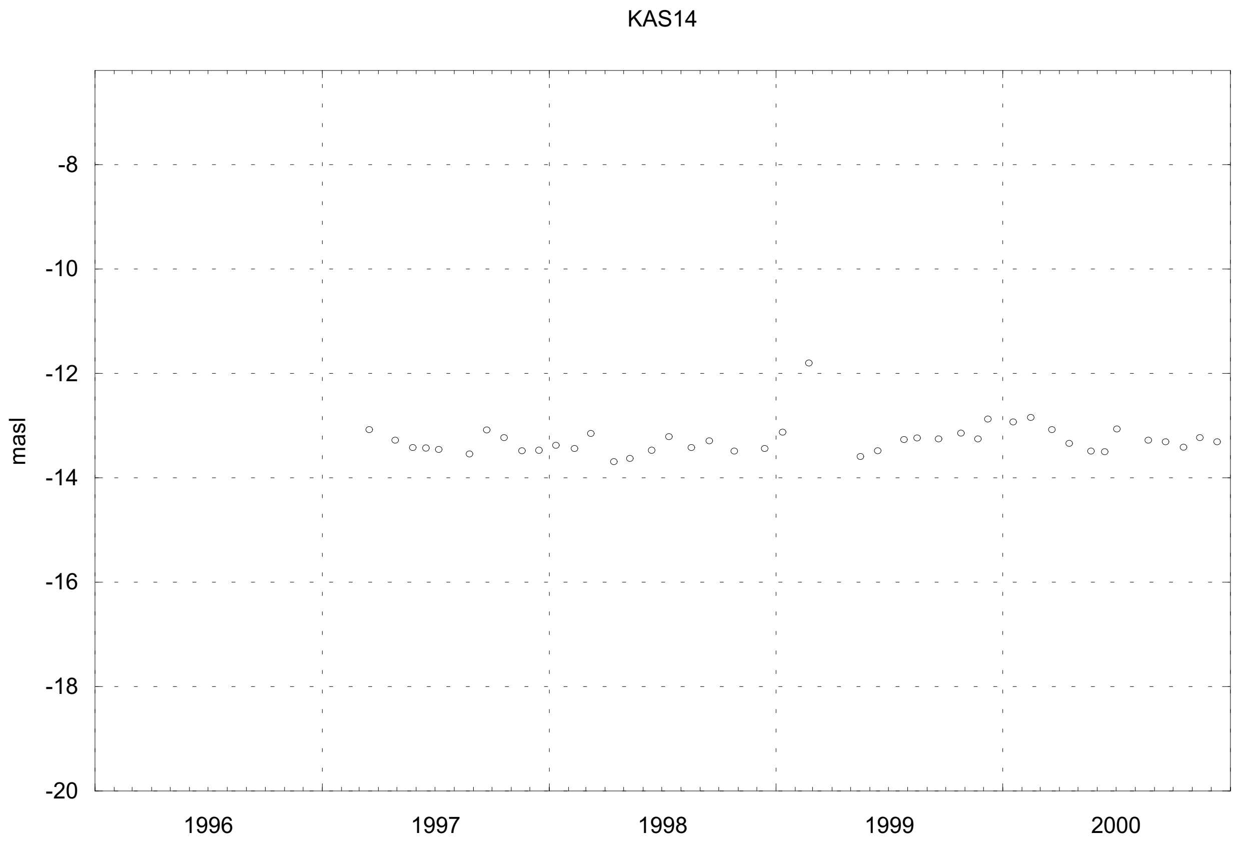


Figure 6-3 Groundwater levels in KAS14 on Äspö, 1996-2000.

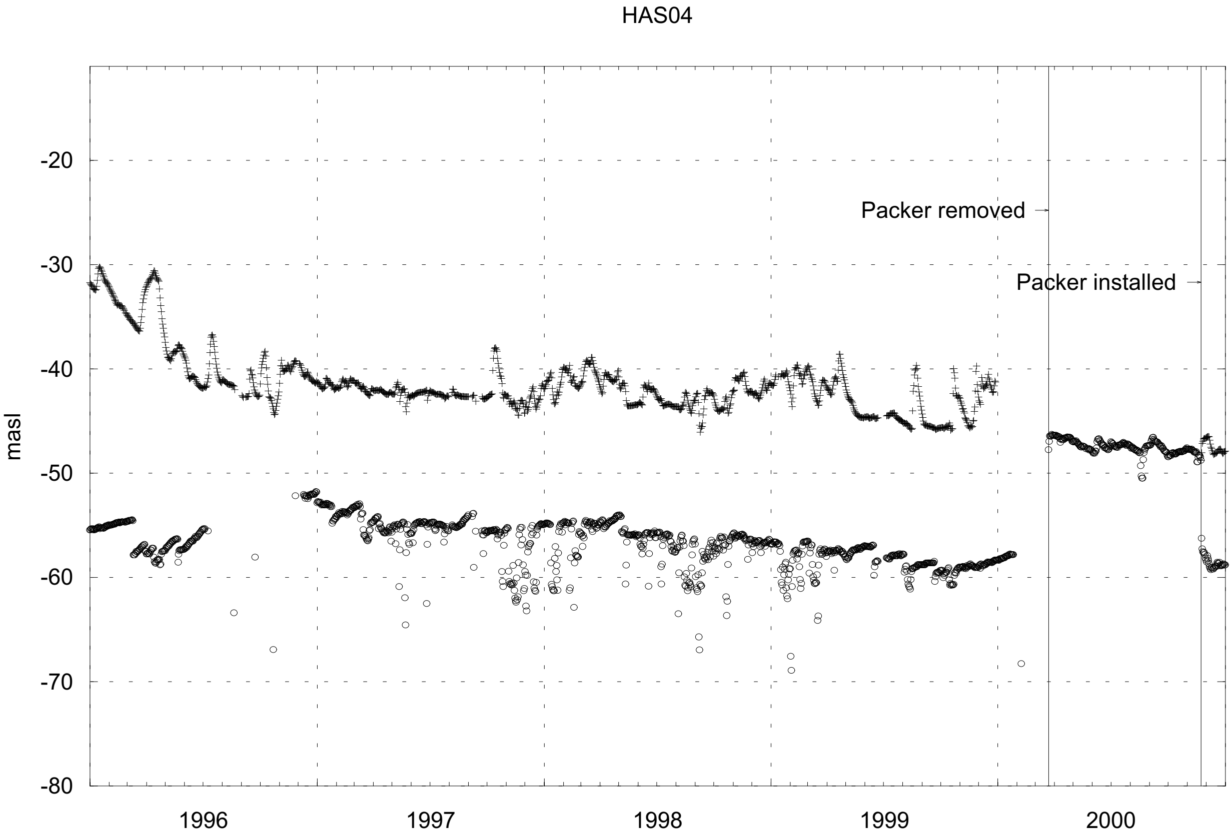


Figure 6-4 Groundwater levels in HAS04 on Äspö, 1996-2000.

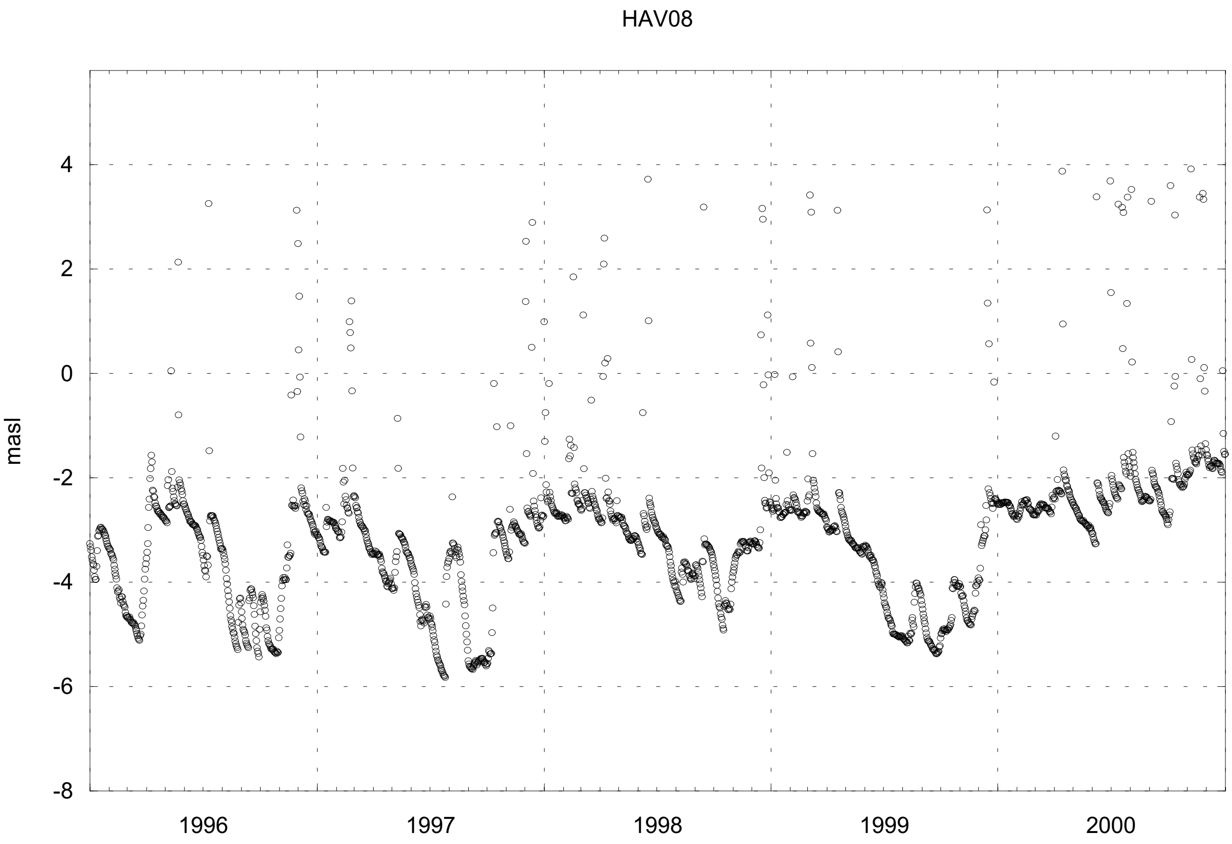


Figure 6-5 Groundwater levels in HAV08 on Ävrö, 1996-2000.

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 drawdowns 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 2000, PEM-packers were installed in the following sections: KAS03 (1-5), KAS09 (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 approx i-mately sea level than above. This means that a small amount of rain may cause a large and quick increase in the groundwater level.

HAS16: The low levels followed by a recovery in the beginning of the year are a result of too low pressure in the packer system causing the packer to deflate.

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

KAS10: The drawdown in the middle of August can be seen in some other surface boreholes and in many tunnel boreholes and is probably an effect of some activity in the tunnel.

KLX01: Due to a leakage in the packer line the packers were deflated for shorter periods in the middle of April and at the end of November. After repairing, the recovery in section 2 is very slow. This might depend on poor communication between the PEM-tube, where the transducer is located, and the borehole section.

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 2000.

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 the entrance tunnel, the pressure in almost all borehole sections was decreasing about 20 - 60 kPa during 2000. In the tunnel spiral boreholes located in the east – northeast part have shown increasing pressures at a magnitude of 10 – 30 kPa. Boreholes in the western part have had decreasing pressures of varying magnitude, mostly depending on the connectivity to prototype boreholes and lead-through boreholes from the G-tunnel to the prototype repository. A number of the Prototype repository boreholes were de-instrumented in December and drilling of lead-trough boreholes have been performed since the end of April. Pressures in many borehole section in the tunnel are influenced by these activities and very large drawdowns have occurred in some borehole sections in the I-tunnel, G-tunnel and in KA3510A (see for example KI0025F:6). A total of 3 core boreholes and 24 percussion boreholes were drilled between the G-tunnel and the Prototype repository during the year. The core boreholes were drilled in April and May and the percussion boreholes from September 9th to December 5th.

Some sections in boreholes KG0021A01 and KG0048A01 are strongly influenced by the drilling of three lead-trough boreholes from the G-tunnel to the Prototype repository from the end of April to the middle of May. The largest decrease found in the tunnel boreholes, nearly 2000 kPa and related to these drillings, occurs in section 4 in KG0048A01.

The measurements in all Prototype boreholes were terminated in the beginning of June, since the tubes connecting borehole sections to pressure transducers had to be removed to allow for construction works in the tunnel. At the same time hydraulic packers were removed in many boreholes and replaced by a mechanical packer at the borehole collar. In five boreholes, the hydraulic packers were remained inflated not to disturb a tracer experiment going on within the TRUE project.

In boreholes in the I-tunnel different pumping tests related to tracer experiments has affected the pressure in many sections during year 2000. A pumping in section 5 in KI0025F03 that started in December 1999 was finished in the middle of January 2000. A new pumping in section 6 in borehole KI0023B, starting in the beginning of March, was still going on in the end of the year. The effect of this experiments may be seen for example in section KI0025F:4 where a recovery occurs when the first pumping ended in January and a new drawdown occurs when the later pumping starts in March. Further drawdown occurs in the beginning of April when the pumping capacity is increased.

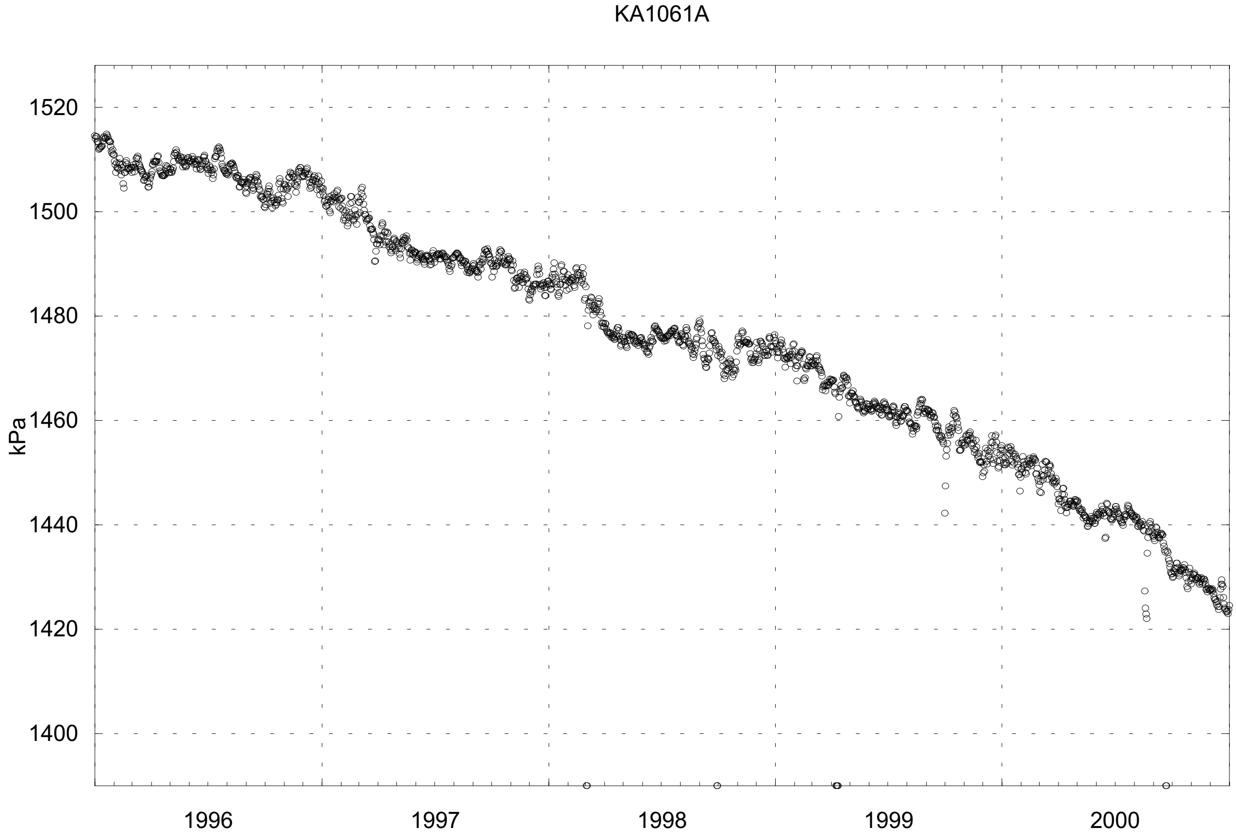
A drawdown may be seen in boreholes located in the eastern part of the tunnel spiral in the beginning of February. This is caused by borehole KA3065A03 that was left open, without sealing the casing. The borehole is sealed in the end of October when a recovery may be seen in the influenced boreholes; see for example borehole KA3067A. (No pressure registration has been performed in KA3065A03.)

A drawdown seen in many tunnel boreholes and also in some surface boreholes occurs 2000-08-17 with a corresponding recovery a few days later (see for example HA1273A). The activity database SICADA gives no explanation to this disturbance.

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, separate diagrams are normally made for sections 7 and higher. An exception is sections 7 and 8 in KA2511A presented in the same diagram, especially noted in the diagram, as sections 1 – 6.

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 1996-2000 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, 1996-2000.

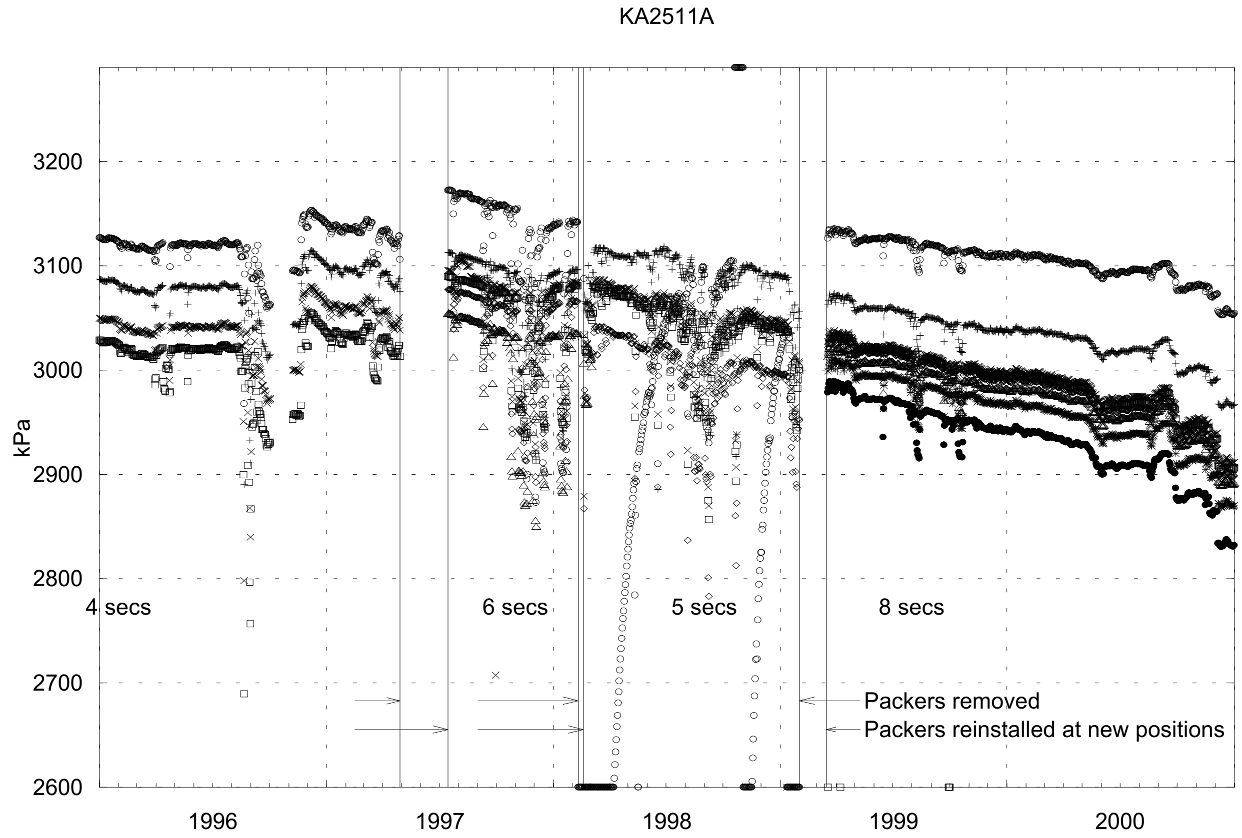


Figure 6-7 Groundwater pressure in tunnel borehole KA2511A, 1996-2000.

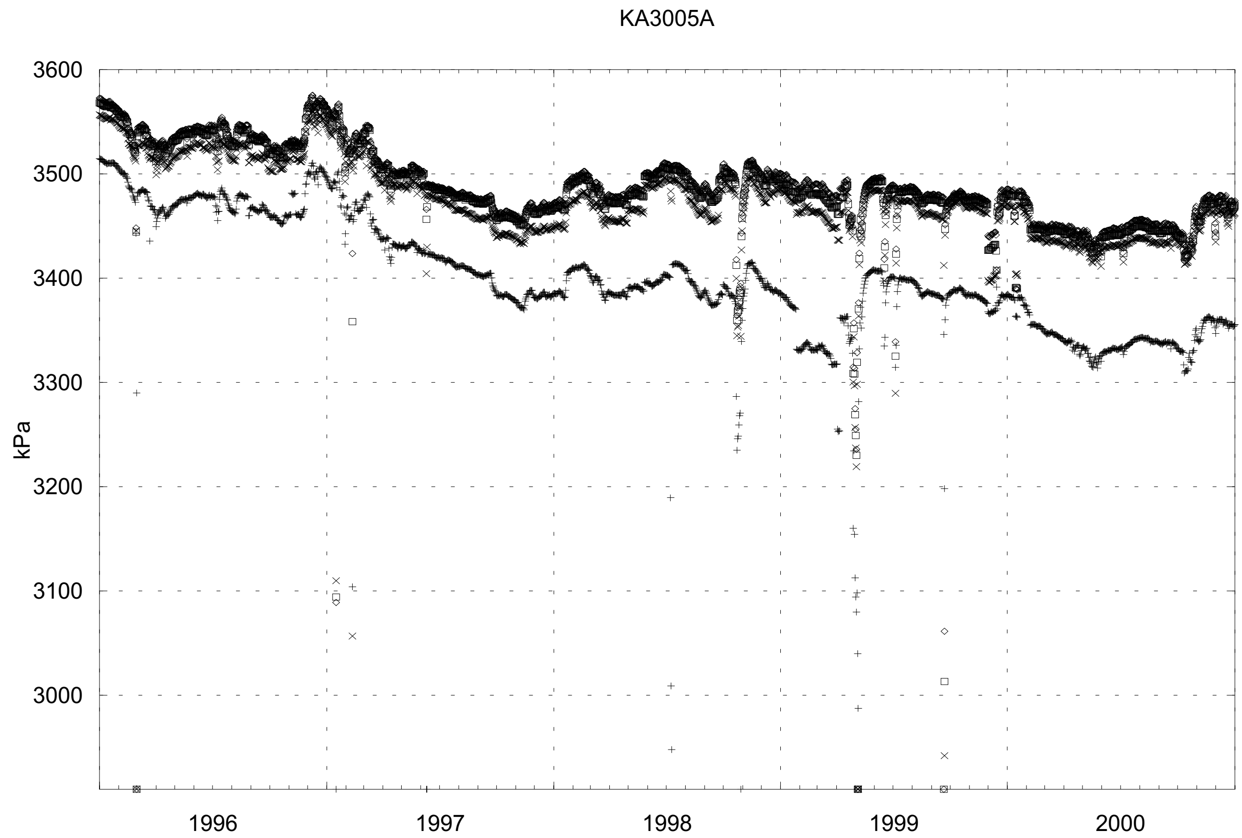


Figure 6-8 Groundwater pressure in tunnel borehole KA3005A, 1996-2000.

6.4.1 Comments on some of the diagrams

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

HD0025A: This borehole is frequently used for water supply purposes, which is the explanation to the deviating appearance.

KA2048B: After cleaning the hydraulic multiplexer to which the borehole is connected, the pressure in all sections receive a new level. Probably this change depends on imperfections in the technical installations, and it is not clear if the pressures measured after the cleaning is the correct pressure in the borehole sections.

KA3539G: After the re-instrumentation in the beginning of August 1999 sections 1 and 2 has the same pressure. This is due to a shortcut via the packer between the two sections.

KG0021A01: A leakage on the packer system has caused deflation of packers 2001-10-13. Since there is a separate packer for the outermost section, the borehole is not open toward the tunnel.

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 2000.

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 2000. For comparison purposes, also data for the corresponding period in 1995, 1996, 1997, 1998 and 1999 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, drilling of new boreholes, plus the addition of external 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.

During year 2000, relatively large decreases may be observed in the four uppermost gauging boxes in the entrance tunnel.

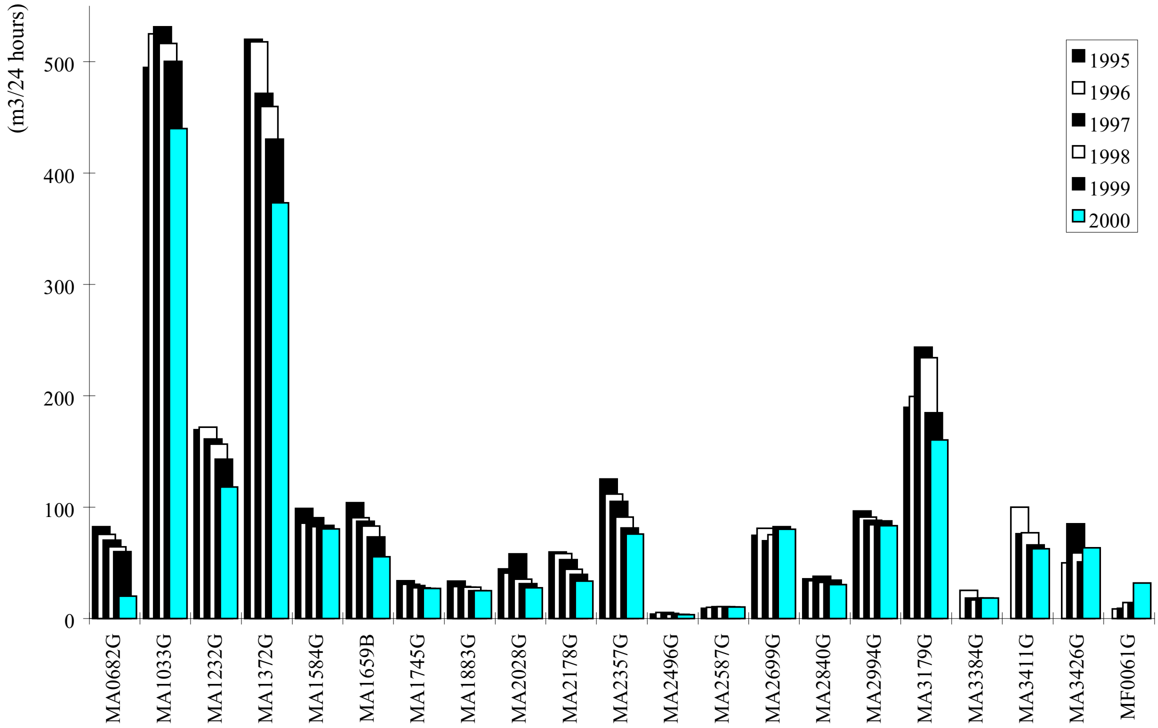


Figure 6-9 Water flow in all gauging boxes as a mean during October - December.

6.6 Water flow in tunnel pipes

The pumped flow out from the tunnel has been steady decreasing during 2000. The measurements of fresh water into the tunnel were terminated in the end of June 1999.

The mean daily flow of water in the pipes during October - December for the last six 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
2000	—	1930

The flow of water pumped out from the tunnel is presented in Appendix 6 as integrated daily values given in m^3/24 hours.

6.7 Electrical conductivity of tunnel water

Electrical conductivity of tunnel water has been measured in eight gauging boxes for flow measurements, at one location 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 2000, 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.

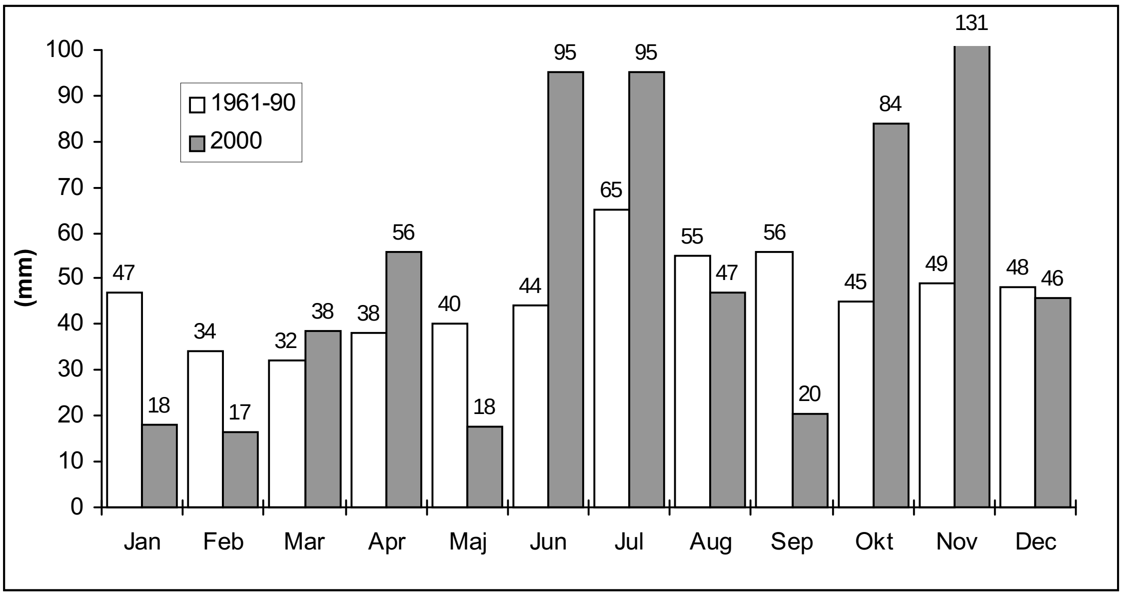


Figure 6-10 Precipitation at Oskarshamn. Monthly values 2000 and monthly means 1961 – 1990.

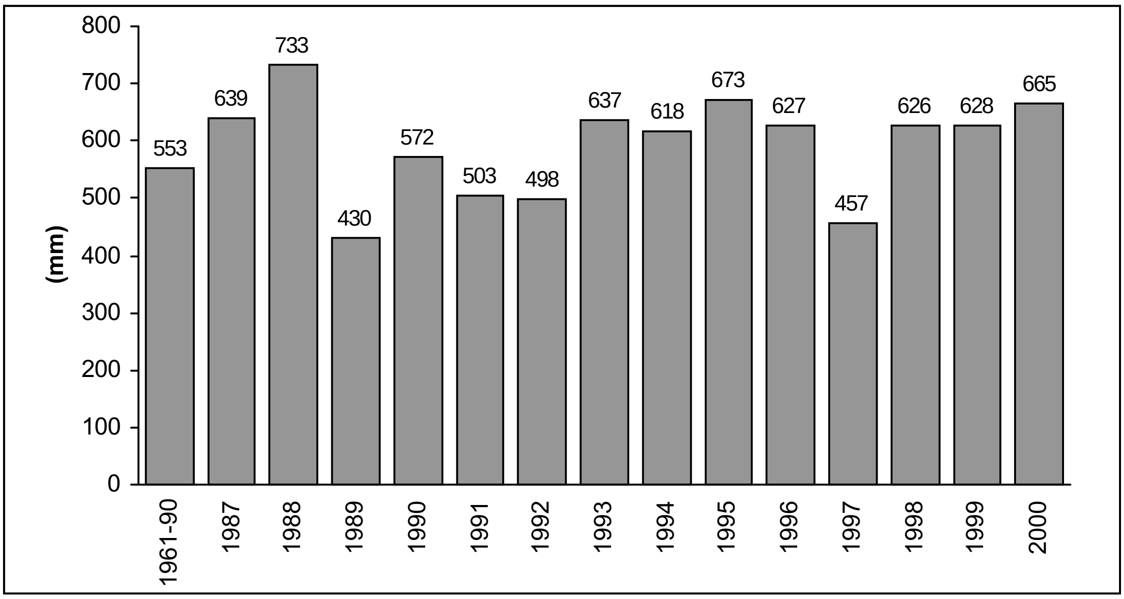


Figure 6-11 Precipitation at Oskarshamn. Yearly values 1987 - 2000 and yearly mean for the period 1961 - 1990.

6.10 Air temperature

Monthly mean temperature at the SMHI-station in Oskarshamn (see section 4.10.2) for 2000, 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 temperature during 2000 is demonstrated in Appendix 10.

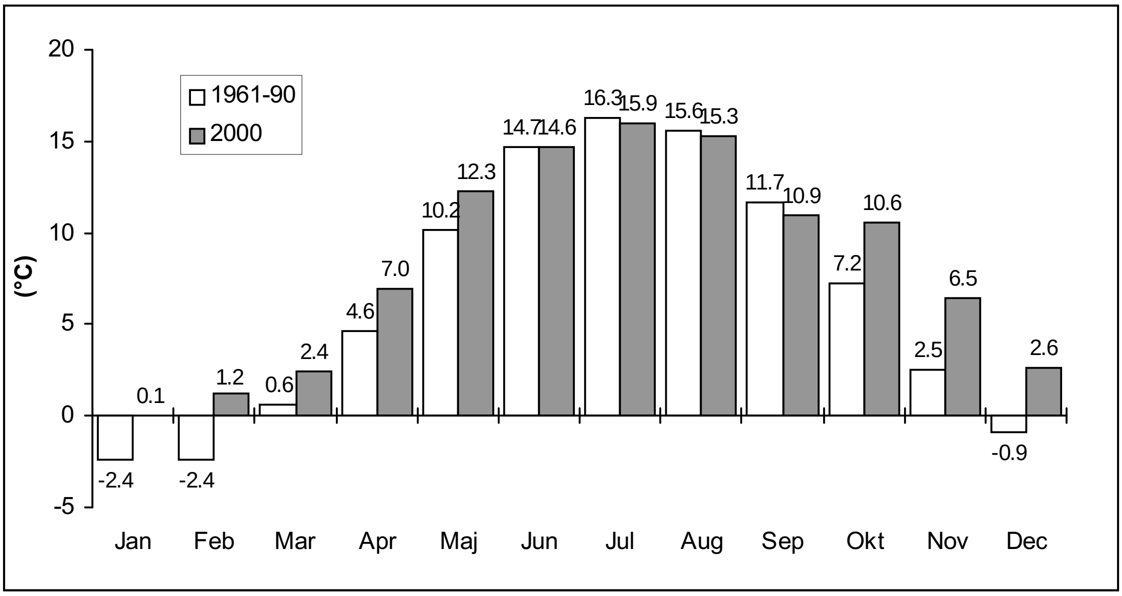


Figure 6-12 Temperature at Oskarshamn. Monthly values 2000 and monthly means 1961 – 1990

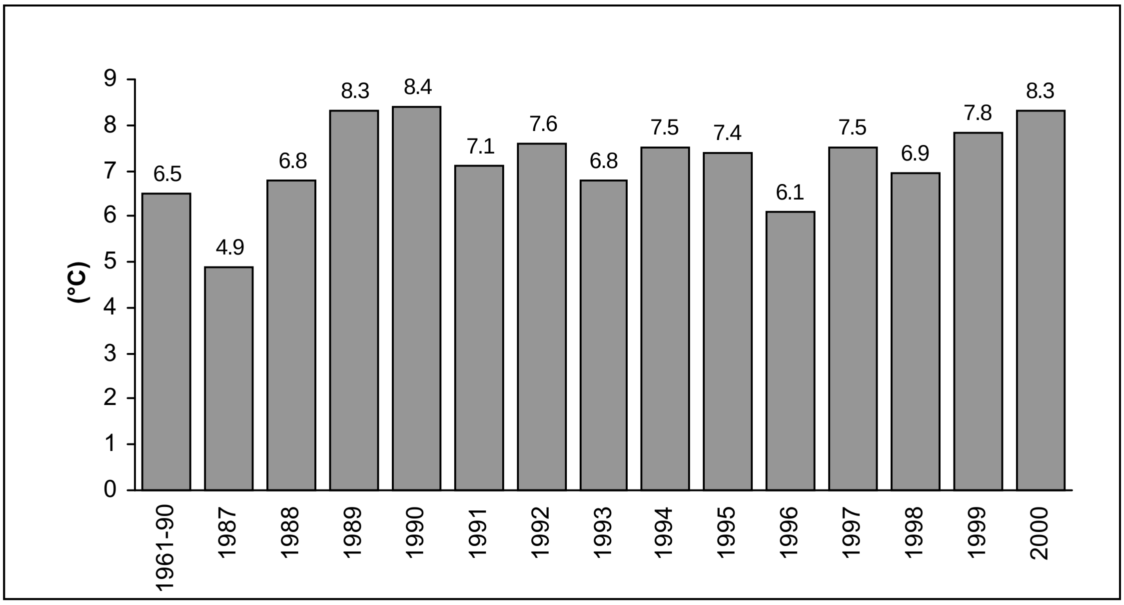


Figure 6-13 Temperature at Oskarshamn. Yearly values 1987 - 2000 and yearly mean for the period 1961 - 1990.

6.11 Potential evapotranspiration

The daily amount of potential evapotranspiration (see section 4.10.3) is presented in a diagram 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.

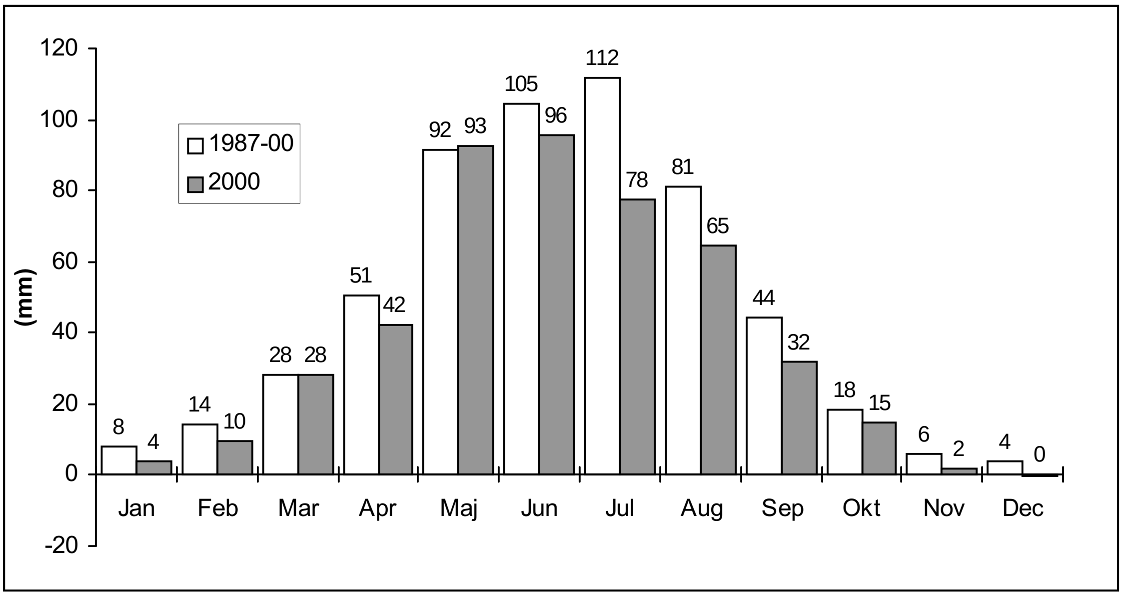


Figure 6-14 Potential evapotranspiration. Monthly values for Gladhammar 2000 and monthly means 1987 - 2000 (an average from Gladhammar and Ölands Norra Udde is used before 1 of August 1995).

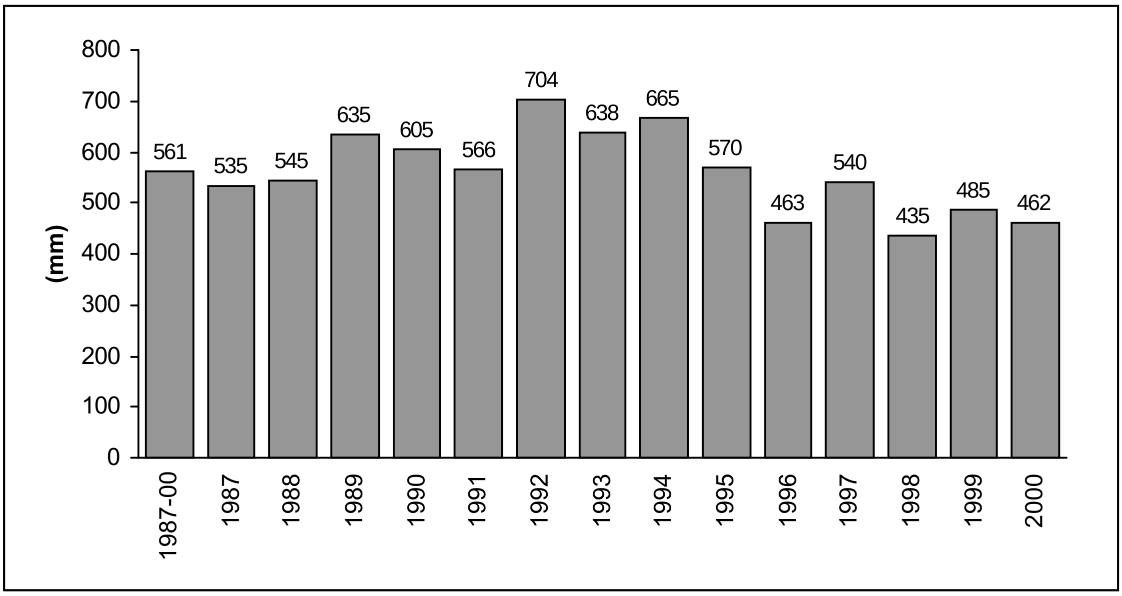


Figure 6-15 Potential evapotranspiration as average from Gladhammar and Ölands Norra Udde (only Gladhammar from 1 of August 1995). Yearly values 1987 - 2000 and yearly mean for the period 1987 - 2000.

References

Almén, Karl-Erik, et al, 1986: Site investigation Equipment for geological, geophysical, hydrogeological and hydrochemical characterization. SKB TR 86-16, SKB, Stockholm.

Almén, Karl-Erik and Zellman, Olle, 1991: Äspö Hard Rock Laboratory. Field investigation methodology and instruments used in the pre-investigation phase, 1986-1990. SKB TR 91-21, SKB, Stockholm.

Ekman, Lennart, et al, 1989: Erfarenheter från provpumpningar på Äspö 1989. Synpunkter på praktiskt genomförande och instrumentfunktioner. Noggrannheter vid mätning av nivå och tryck (in Swedish). SKB T PM NR. 25-89-006, SKB, Stockholm.

Ekman, Martin, 1987: Månen lyfter dej en kvarts meter två gånger om dygnet (in swedish). Forskning och Framsteg 4/87.

Eriksson, Bertil, 1980: The water balance of Sweden. Annual mean values (1931-60) of precipitation, evaporation and run-off (in Swedish). SMHI Nr RMK 18 and Nr RHO 21 (1980), SMHI, Norrköping.

Gottschalk, Lars, 1982: Hydrologi (in Swedish). Compendium in hydrology, Lund.

Gustafson, Gunnar, et al., 1991: Äspö Hard Rock Laboratory. Predictions prior to 2265-2874 m. SKB PR 25-94-19, SKB Stockholm.

Jönsson, Stig, et al., 2000: Äspölaboratoriet, Kalibrering av hydrosensorer 2000-02-14 – 2000-02-17. GRAP 00020, GEOSIGMA Uppsala.

Kornfält, Karl-Axel, and Wikman, Hugo, 1987a: Description of the map of solid rocks around Simpevarp. SKB PR 25-87-02, SKB, Stockholm.

Kornfält, Karl-Axel, and Wikman, Hugo, 1987b: Description of the map (No 4) of solid rocks of 3 small areas around Simpevarp. SKB PR 25-87-02a, SKB, Stockholm.

Kornfält, Karl-Axel, and Wikman, Hugo, 1988: The rocks of the Äspö island. Description to the detailed maps of solid rocks including maps of 3 uncovered trenches. SKB PR 25-88-12, SKB, Stockholm.

Manual för Hydro Monitoring System (HMS), 1994. SKB Tekniskt PM Nr. 25-94-014, SKB, Stockholm.

Munier, Raymond, 1993: Drilling KLX02 - Phase 2 Lilla Laxemar, Oskarshamn. Description of geological structures in and near boreholes KLX02 and KLX01, Laxemar. SKB Arbetsrapport 94-23, SKB Stockholm.

Nyberg, Göran, et al, 1991: Groundwater level program. Report for the Period 1987-1989. SKB PR 25-90-18, SKB, Stockholm.

Nyberg, Göran, et al, 1992a: Groundwater level program. Report for 1990. SKB PR 25-91-19, SKB, Stockholm.

Nyberg, Göran, et al, 1992b: Groundwater level program. Report for 1991. SKB PR 25-92-16, SKB, Stockholm.

Nyberg, Göran, et al, 1993: Groundwater level program. Report for 1992. SKB PR 25-93-09, SKB, Stockholm.

Nyberg, Göran, et al, 1994: Groundwater level program. Report for 1993. SKB PR 25-94-23, SKB, Stockholm.

Nyberg, Göran, et al, 1995: Hydro monitoring program. Report for 1994. SKB PR 25-95-08, SKB, Stockholm.

Nyberg, Göran, et al, 1996: Hydro monitoring program. Report for 1995. SKB PR HRL-96-17, SKB, Stockholm.

Nyberg, Göran, et al, 1997: Hydro monitoring program. Report for 1996. SKB PR HRL-97-17, SKB, Stockholm.

Nyberg, Göran, et al, 1998: Hydro monitoring program. Report for 1997. SKB PR HRL-98-19, SKB, Stockholm.

Nyberg, Göran, et al, 1999: Hydro monitoring program. Report for 1998. SKB IPR-99-20, SKB, Stockholm.

Nyberg, Göran and Jönsson, Stig, 2000: Hydro monitoring program. Report for 1999. SKB IPR-00-17, SKB, Stockholm.

Rhén, Ingvar, ed, 1995: Documentation of tunnel and shaft data; Tunnel section 2 874 - 3 600 m; Hoist and ventilation shafts 0 - 450 m. SKB PR 25-95-28, SKB, Stockholm

Rhén, Ingvar and Stanfors, Roy, 1995: Supplementary investigations of fracture zones in Äspö tunnel. SKB PR 25-95-20, SKB, Stockholm

Stanfors, Roy, et al., 1992: Evaluation of geological predictions in the access ramp 0 - 0/700 metres. SKB PR 25-92-02, SKB Stockholm.

Stanfors, Roy, et al., 1993a: Geological-structural evaluation of data from section 700-1475 m. SKB PR 25-93-05, SKB Stockholm.

Stanfors, Roy, et al., 1993b: Geological-structural evaluation of data from section 1475-2265 m. SKB PR 25-93-10, SKB Stockholm.

Stanfors, Roy, et al., 1994: Geological-structural evaluation of data from section excavation and the process of their validation. SKB TR 91-23, SKB Stockholm.

Appendices

Appendix 1: Statistics on missing data

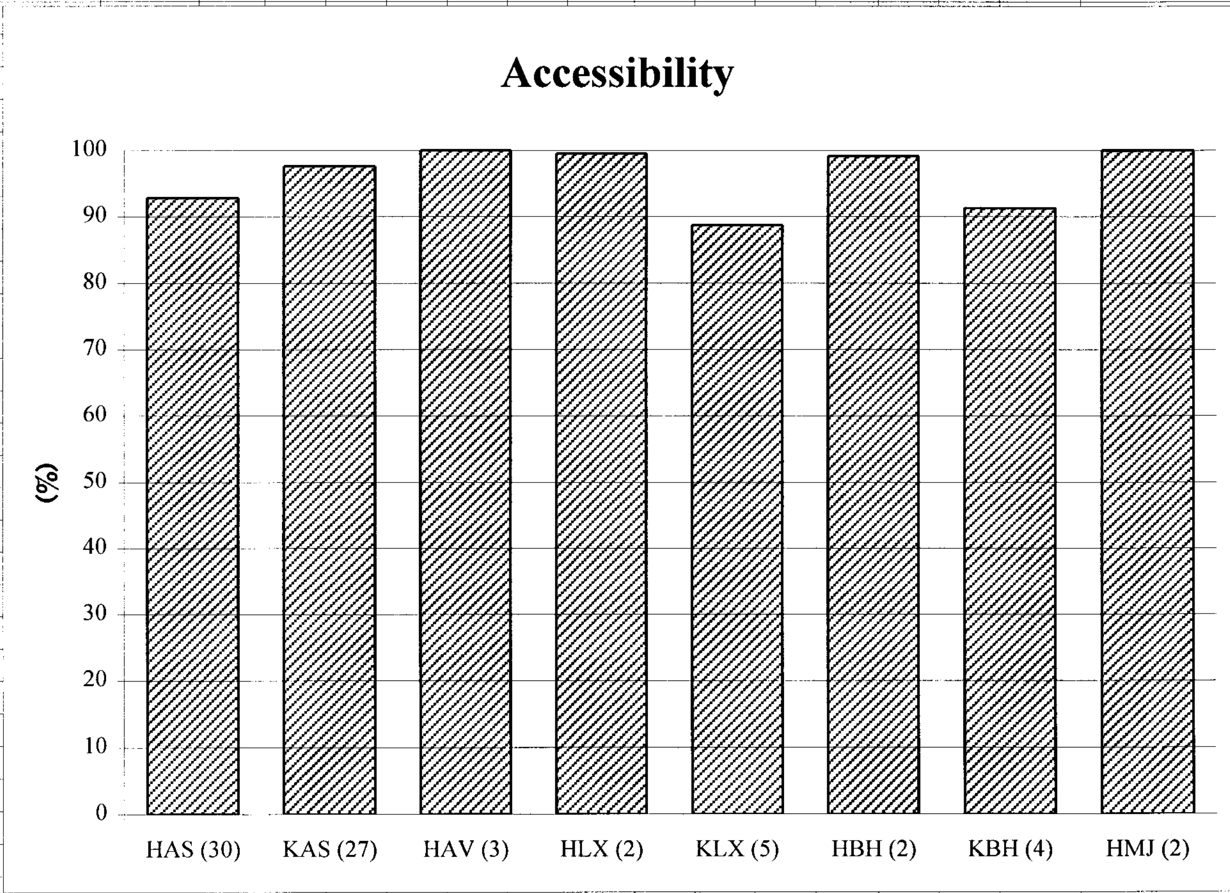
Äspö Hard Rock Laboratory		First date for statistics:	2000-01-01
Groundwater Level Program		Last date for statistics:	2000-12-31
Error statistics		Latest calibration date:	2001-05-20
		No of days in period:	366

Borehole	Section	Duration of error (days)														Accessibility
		TG	**TST**	**KOM**	**O**	**V**	**B**	**L**	**Å**	**ML**	**OP**	**G**	**K**	**?**	Sum	(%)
HAS01	1	3													3	99
HAS02	1														0	100
HAS03	1														0	100
HAS04	1				4					59					63	83
HAS04	2									329					329	10
HAS05	1														0	100
HAS06	1			13											13	96
HAS06	2			13											13	96
HAS07	1	6		13											19	95
HAS08	1														0	100
HAS09	1														0	100
HAS10	1														0	100
HAS11	1						61								61	83
HAS11	2						61								61	83
HAS12	1														0	100
HAS13	1														0	100
HAS13	2									51					51	86
HAS14	1														0	100
HAS15	1														0	100
HAS15	2														0	100
HAS16	1			13											13	96
HAS16	2			13											13	96
HAS17	1	56		13											69	81
HAS17	2													49	49	87
HAS18	1														0	100
HAS19	1														0	100
HAS19	2														0	100
HAS20	1														0	100
HAS20	2														0	100
HAS21	1			13		18									31	92
HAS		65	0	91	4	18	122	0	0	439	0	0	0	49	788	93

Borehole	Section	Duration of error (days)														Accessibility
		TG	**TST**	**KOM**	**O**	**V**	**B**	**L**	**Å**	**ML**	**OP**	**G**	**K**	**?**	Sum	(%)
KAS01	1	39													39	89
KAS02	1														0	100
KAS03	1	85													85	77
KAS03	2														0	100
KAS03	3														0	100
KAS03	4														0	100
KAS03	5	47													47	87
KAS03	6														0	100
KAS04	1														0	100
KAS07	1														0	100
KAS09	1														0	100
KAS09	2	16													16	96
KAS09	3														0	100
KAS09	4														0	100
KAS09	5														0	100
KAS10	1														0	100
KAS11	1														0	100
KAS12	1														0	100
KAS12	2														0	100
KAS12	3														0	100
KAS12	4	20													20	95
KAS12	5	20													20	95
KAS14	1														0	100
KAS16	1														0	100
KAS16	2														0	100
KAS16	3														0	100
KAS16	4	6													6	98
KAS		233	0	0	0	0	0	0	0	0	0	0	0	0	233	98

Borehole	Section	Duration of error (days)														Accessibility
		TG	**TST**	**KOM**	**O**	**V**	**B**	**L**	**Å**	**ML**	**OP**	**G**	**K**	**?**	Sum	(%)
HAV02	1														0	100
HAV05	1														0	100
HAV08	1														0	100
HAV		0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
HLX04	1														0	100
HLX05	1													3	3	99
HLX		0	0	0	0	0	0	0	0	0	0	0	0	3	3	100
KLX01	1													3	3	99
KLX01	2													3	3	99
KLX01	3	140									6			3	149	59
KLX01	4										23			3	26	93
KLX01	5	22												3	25	93
KLX		162	0	0	0	0	0	0	0	0	29	0	0	15	206	89
HBH04	1	6													6	98
HBH04	2														0	100
HBH		6	0	0	0	0	0	0	0	0	0	0	0	0	6	99
KBH02	3	12									9				21	94
KBH02	4	30									9				39	89
KBH02	5	51													51	86
KBH02	6	16													16	96
KBH		109	0	0	0	0	0	0	0	0	18	0	0	0	127	91
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)		65	0	91	4	18	122	0	0	439	0	0	0	49	788	93
KAS (27)		233	0	0	0	0	0	0	0	0	0	0	0	0	233	98
HAV (3)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
HLX (2)		0	0	0	0	0	0	0	0	0	0	0	0	3	3	100
KLX (5)		162	0	0	0	0	0	0	0	0	29	0	0	15	206	89
HBH (2)		6	0	0	0	0	0	0	0	0	0	0	0	0	6	99
KBH (4)		109	0	0	0	0	0	0	0	0	18	0	0	0	127	91
HMJ (2)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
TOTAL (80)		42%	0%	7%	0%	1%	9%	0%	0%	32%	3%	0%	0%	5%	100%	95

Borehole	Section	Duration of error (days)													Accessibility
		TG	**TST**	**KOM**	**O**	**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:	2000-01-01
Last date for statistics:	2000-12-31
Latest calibration date:	2001-04-16
No of days in period:	366

Idcode	Sec.	Duration of error (days)													Accessibility
		G	K	OP	TST	V	O	L	DS	ML	S	W	?	Sum	(%)
HA1273A	1													0	100
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													0	100
KA1131B	1													0	100
KA1751A	1													0	100
KA1751A	2													0	100
KA1751A	3													0	100
KA1754A	1													0	100
KA1754A	2													0	100
KA1755A	1													0	100
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

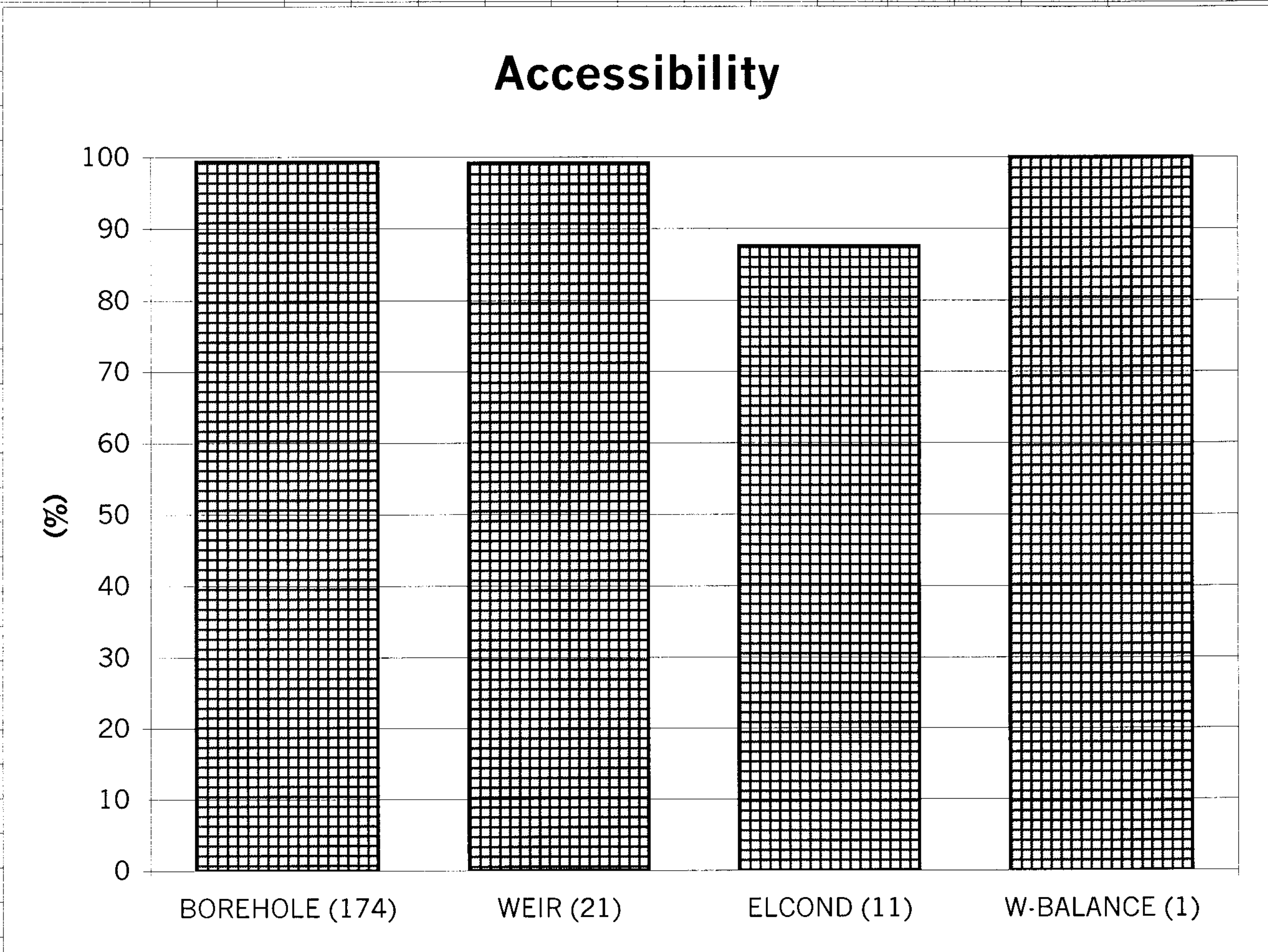
Idcode	Sec.	Duration of error (days)													Accessibility
		G	K	OP	TST	V	O	L	DS	ML	S	W	?	Sum	(%)
KA3067A	2													0	100
KA3067A	3													0	100
KA3067A	4													0	100
KA3105A	1													0	100
KA3105A	2													0	100
KA3105A	3													0	100
KA3105A	4													0	100
KA3105A	5													0	100
KA3110A	1													0	100
KA3110A	2													0	100
KA3385A	1								5					5	99
KA3385A	2								5					5	99
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													0	100
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													0	100
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	S	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													0	100
KA3600F	2													0	100
KF0051A	2													0	100
KF0051A	3													0	100
KF0051A	4													0	100
KG0021A01	1									80				80	78
KG0021A01	2									80				80	78
KG0021A01	3									80				80	78
KG0021A01	4									80				80	78
KG0021A01	5									80				80	78
KG0048A01	1		5											5	99
KG0048A01	2		5											5	99
KG0048A01	3		5											5	99
KG0048A01	4		5											5	99
KG0048A01	5		5											5	99
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	5												5	99
KI0025F	6													0	100

Idcode	Sec.	Duration of error (days)													Accessibility
		G	K	OP	TST	V	O	L	DS	ML	S	W	?	Sum	(%)
KI0025F02	1													0	100
KI0025F02	2													0	100
KI0025F02	3													0	100
KI0025F02	4													0	100
KI0025F02	5	14												14	96
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		**19**	**25**	**0**	**0**	**0**	**0**	**0**	**10**	**400**	**0**	**0**	**0**	**454**	**99**

Idcode	Sec.	Duration of error (days)													Accessibility
		G	K	OP	TST	V	O	L	DS	ML	S	W	?	Sum	(%)
MA0682G												5		5	99
MA1033G												2	2	4	99
MA1232G														0	100
MA1372G											18			18	95
MA1584G											18			18	95
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														0	100
MA3384G									5					5	99
MA3411G									5					5	99
MA3426G									5					5	99
MF0061G									5					5	99
Weir		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**20**	**0**	**36**	**7**	**2**	**65**	**99**
EA0682G												5		5	99
EA1584T														0	100
EA1659B														0	100
EA2496T														0	100
EA2587G														0	100
EA3179G													126	126	66
EA3384G									5					5	99
EA3411G														0	100
EA3426G														0	100
EF0061G														0	100
EPG5				366										366	0
ELCOND		**0**	**0**	**366**	**0**	**0**	**0**	**0**	**5**	**0**	**0**	**5**	**126**	**502**	**88**
QA0687O														0	100
W-BALANCE		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**100**

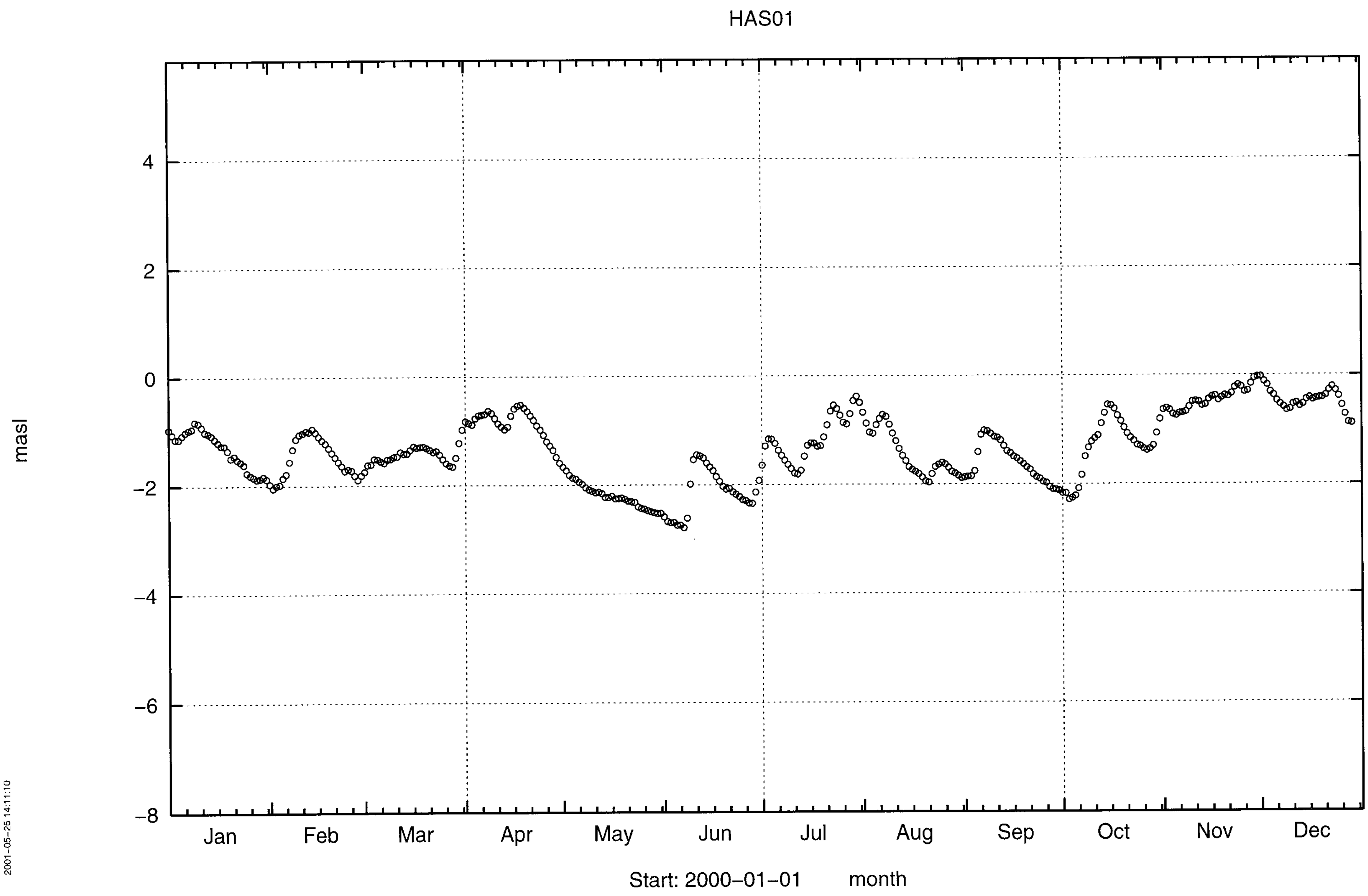
Idcode	Sec.	Duration of error (days)													Accessibility
		G	K	OP	TST	V	O	L	DS	ML	S	W	?	Sum	(%)
							SUMMARY								
BOREHOLE (174)		19	25	0	0	0	0	0	10	400	0	0	0	454	99
WEIR (21)		0	0	0	0	0	0	0	20	0	36	7	2	65	99
ELCOND (11)		0	0	366	0	0	0	0	5	0	0	5	126	502	88
W-BALANCE (1)		0	0	0	0	0	0	0	0	0	0	0	0	0	100
TOTAL		2%	2%	36%	0%	0%	0%	0%	3%	39%	4%	1%	13%	100%	99



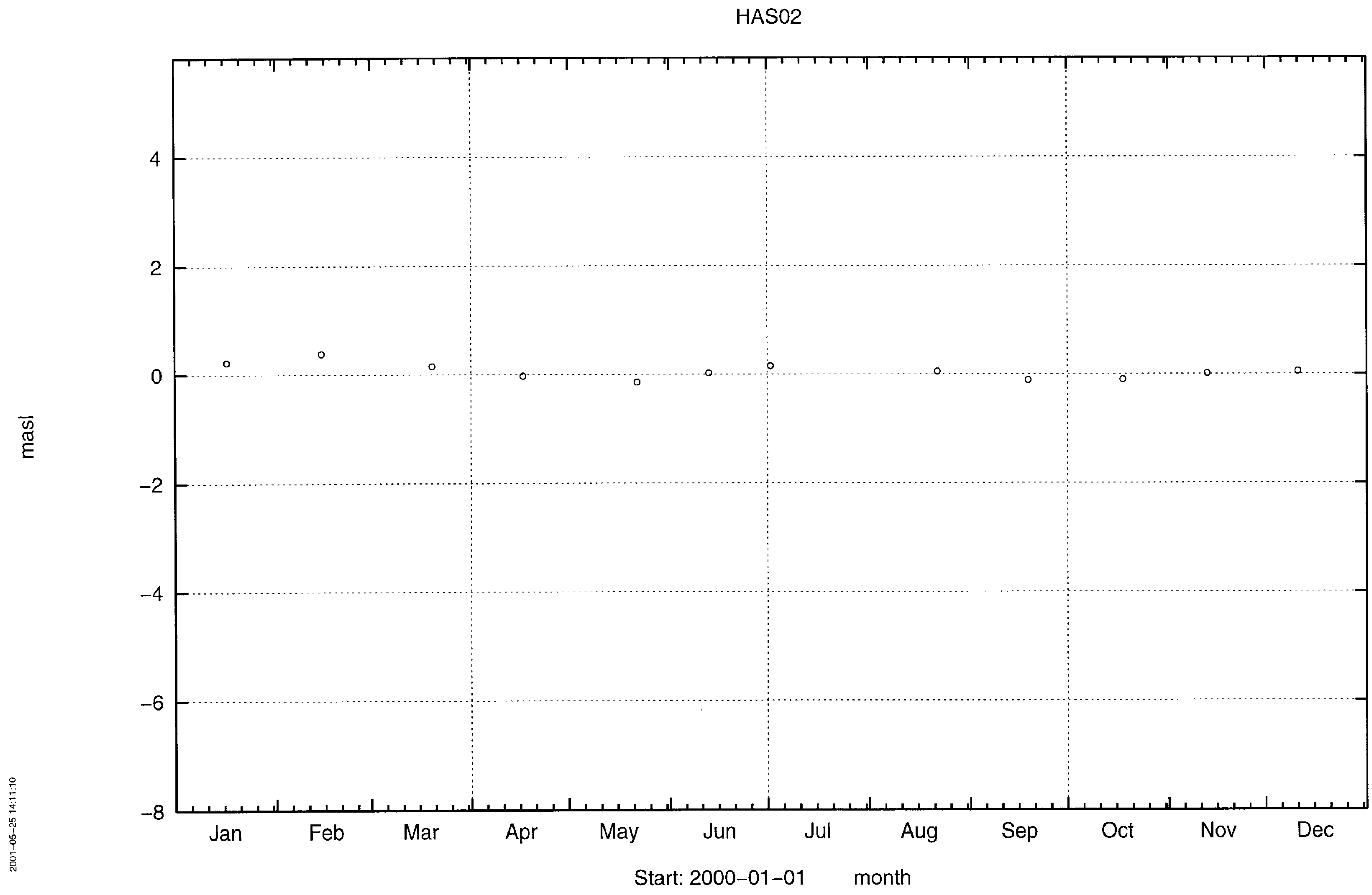
ERROR CODES

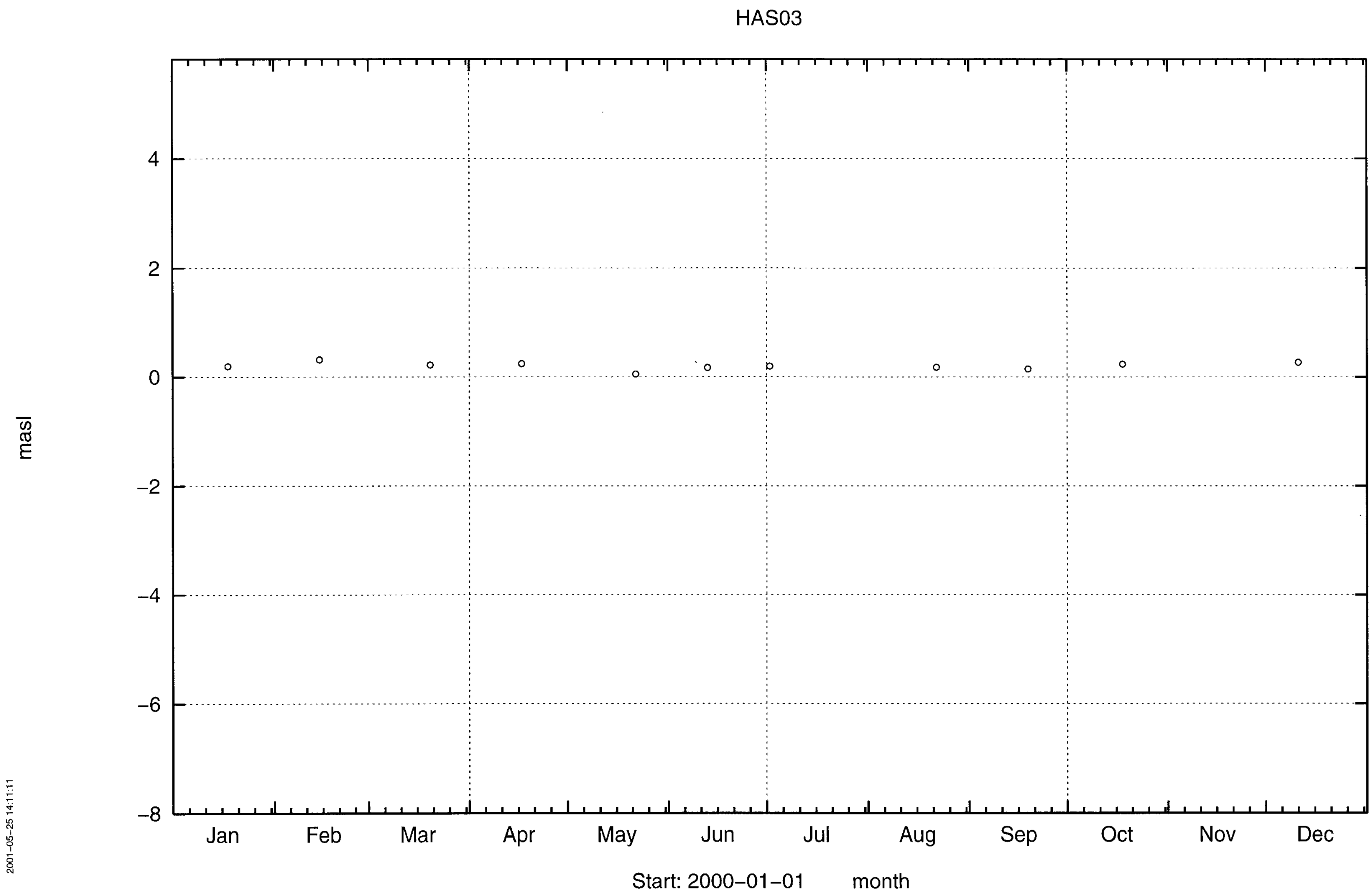
W:	Missing data due to work in vicinity
G:	Failing transducer
DS:	Missing data due to failure in Datascan Unit
TST:	Registration broken due to other tests or activities
K:	Broken signal cable
O:	Reinstrumentation
OP:	Mistake by the operator leading to a break in registration
V:	Failure in Hydraulic Multiplexer: 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

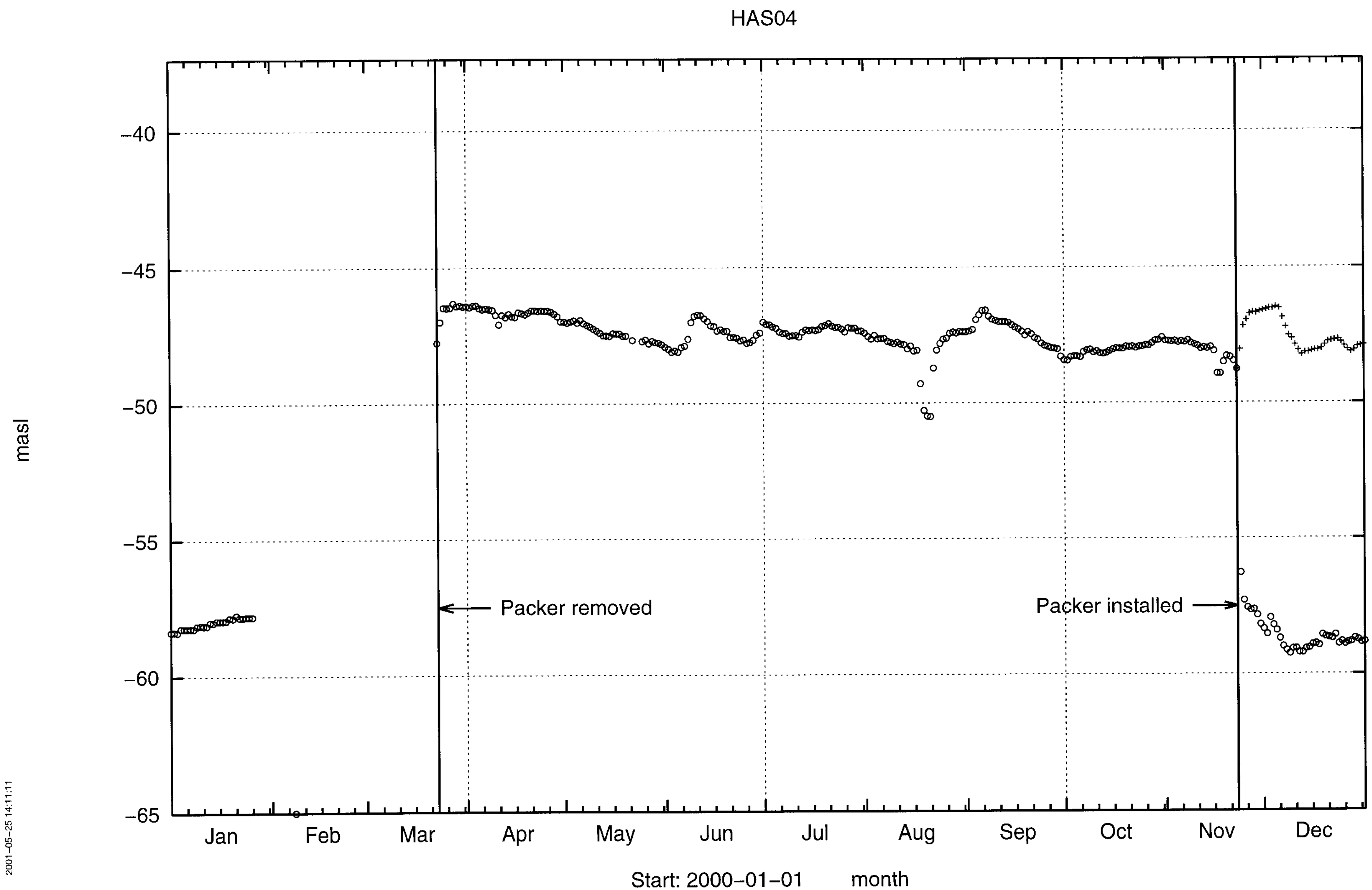
Appendix 2: Groundwater level

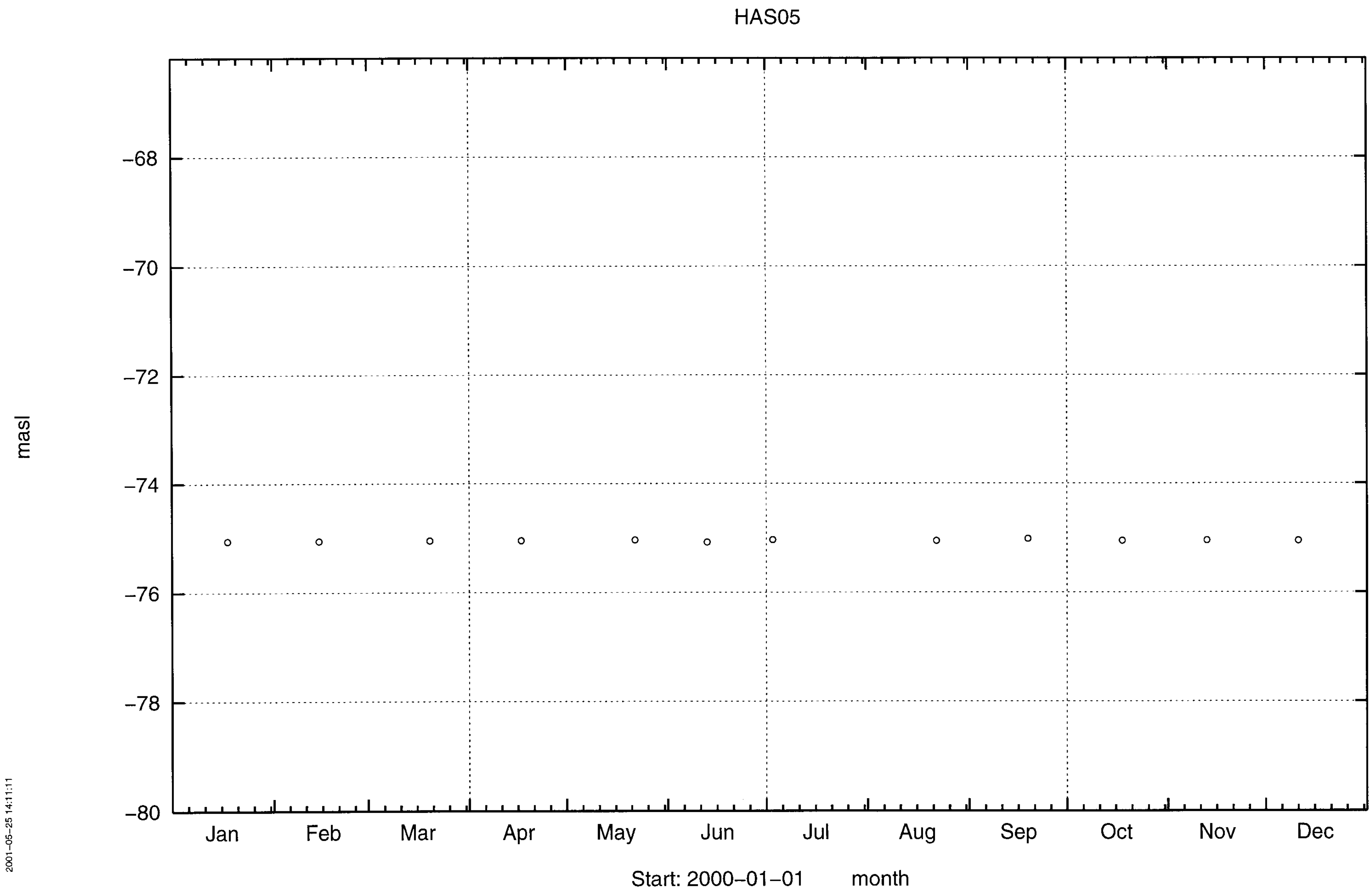


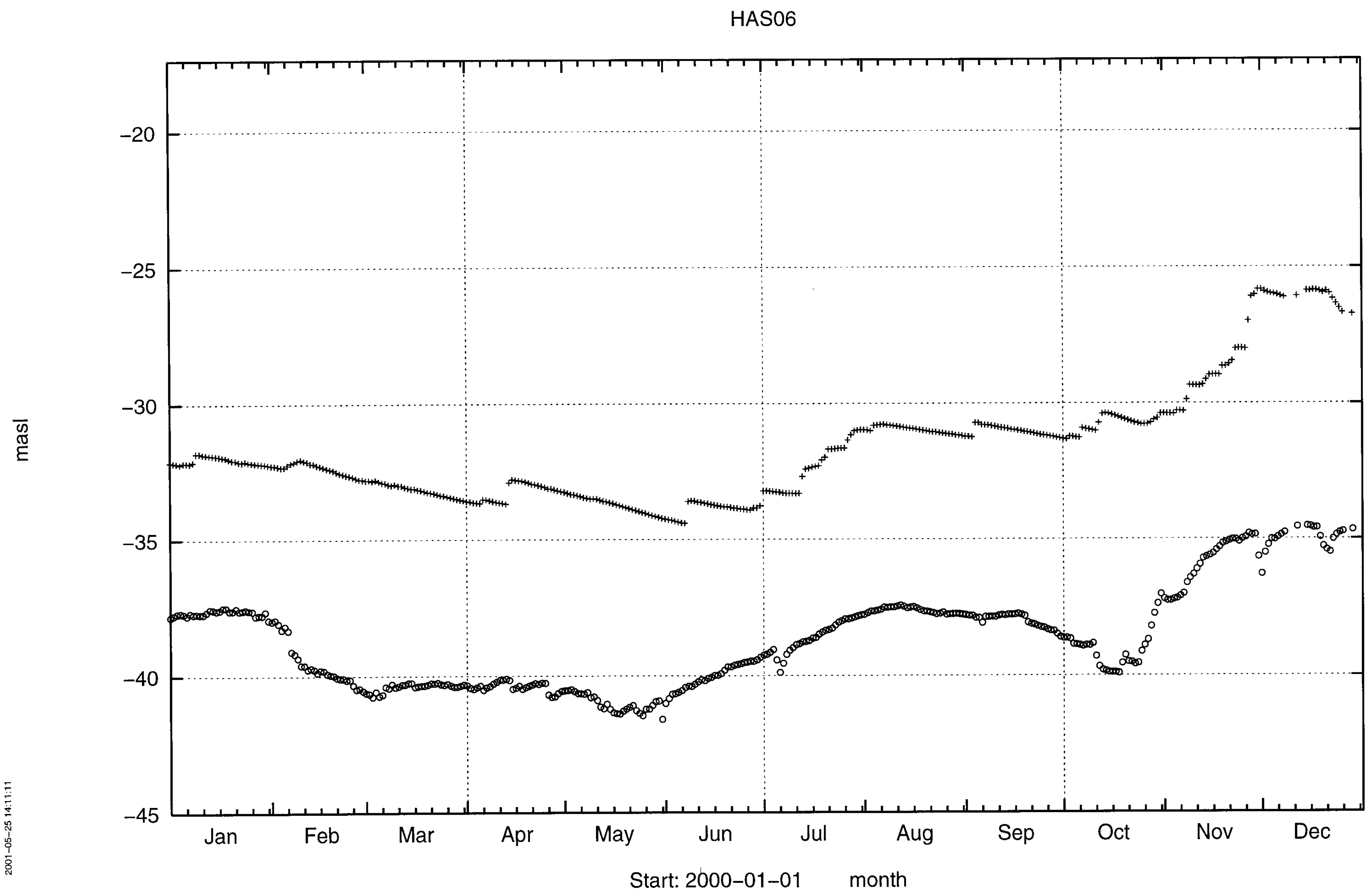
HAS01
masl
4
2
0
-2
-4
-6
-8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:10

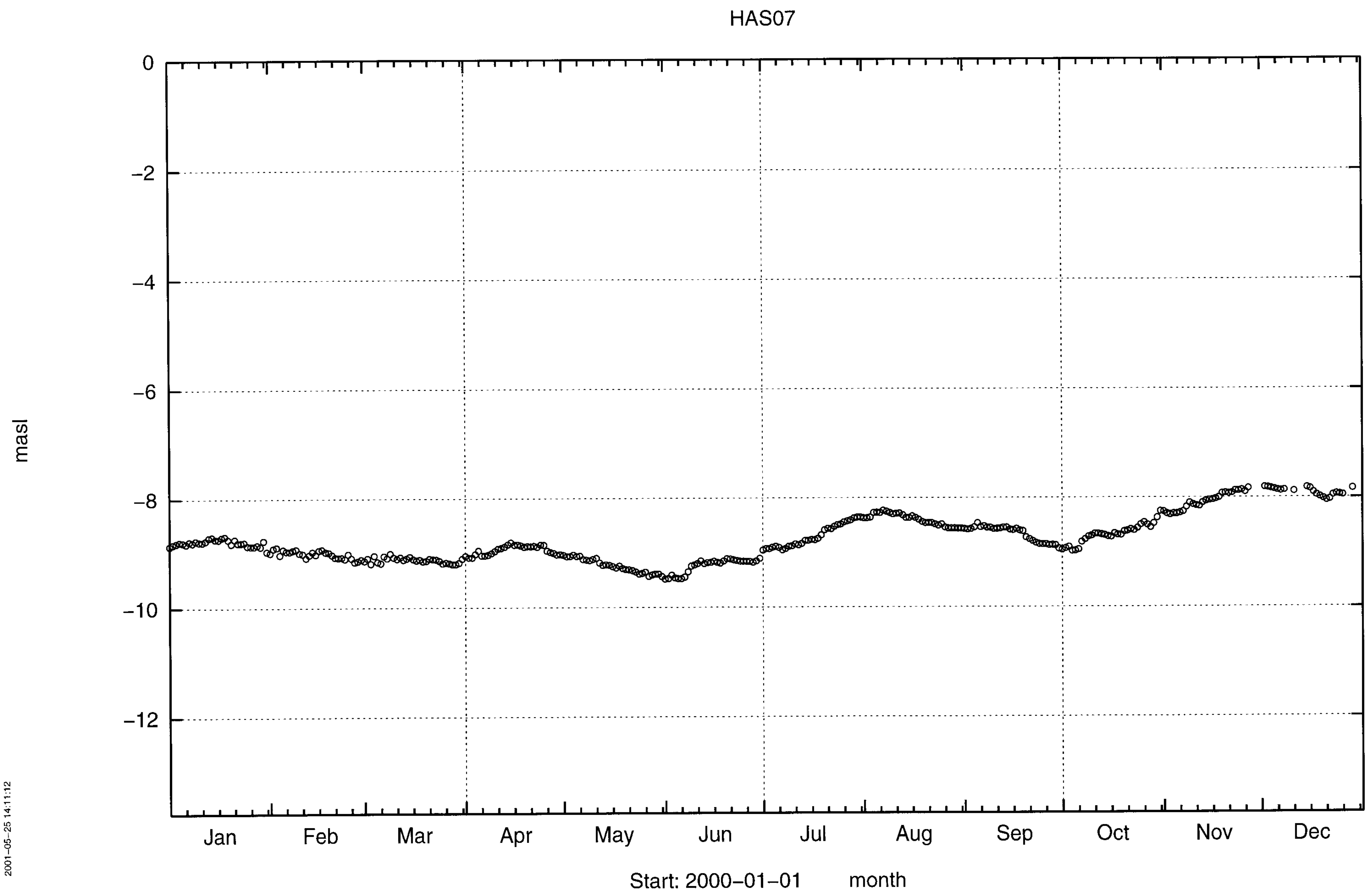

HAS02
masl
4
2
0
-2
-4
-6
-8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:10


HAS03
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:11

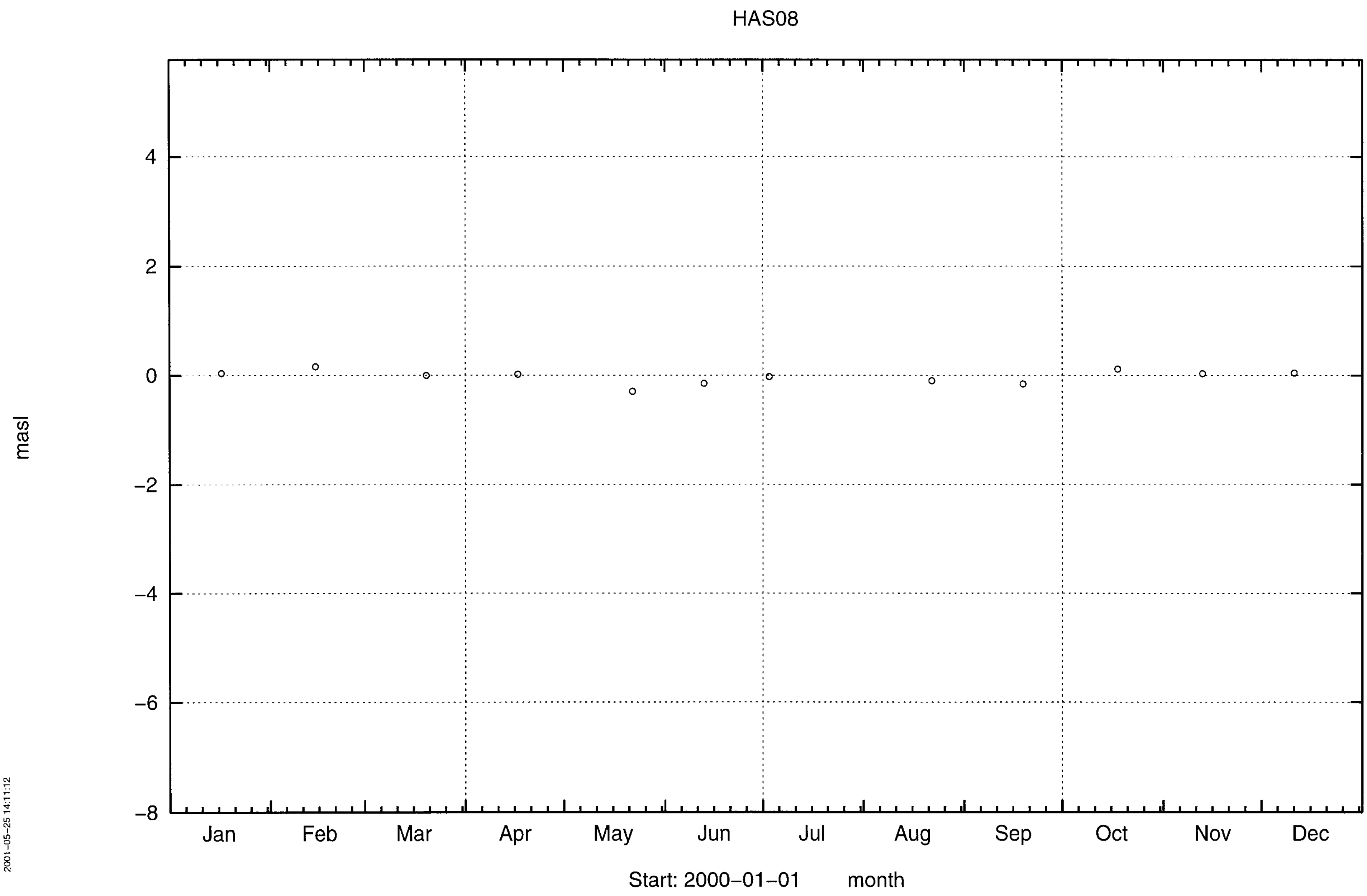

HAS04
masl
-40
-45
-50
-55
-60
-65
Packer removed
Packer installed
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:11

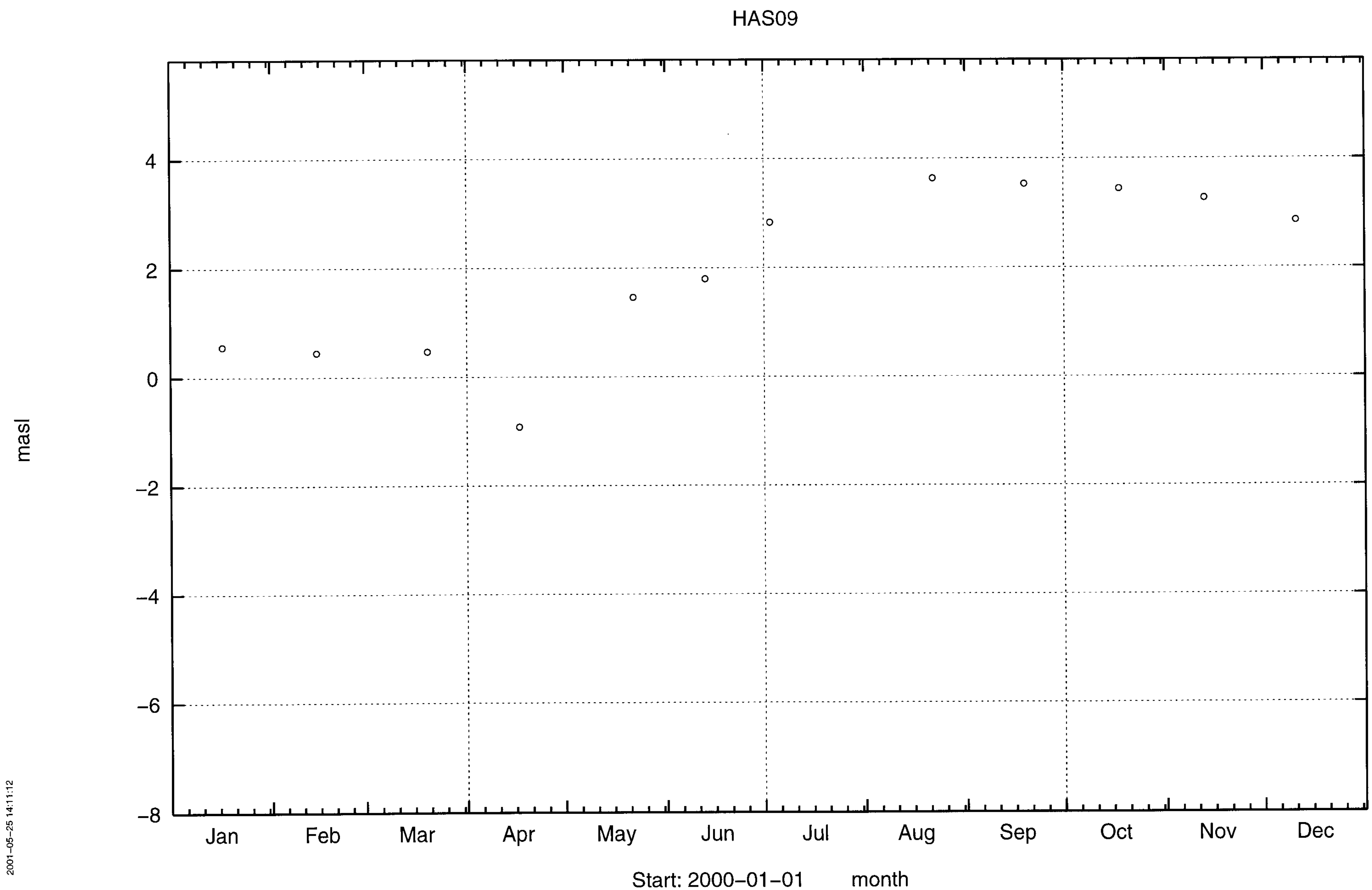

HAS05
masl
-68
-70
-72
-74
-76
-78
-80
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:11

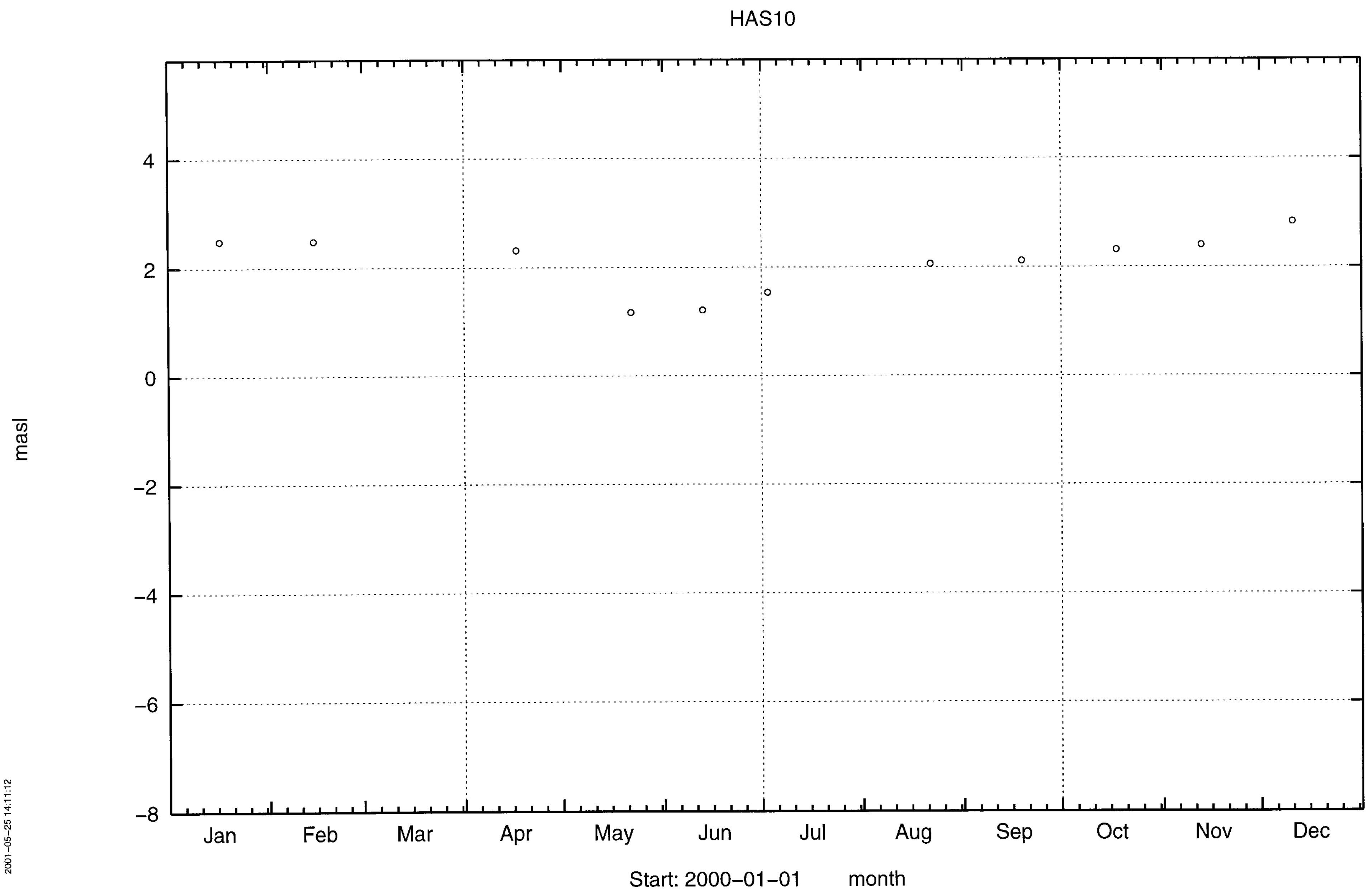

HAS06
masl
-20
-25
-30
-35
-40
-45
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01 month
2001-05-25 14:11:11

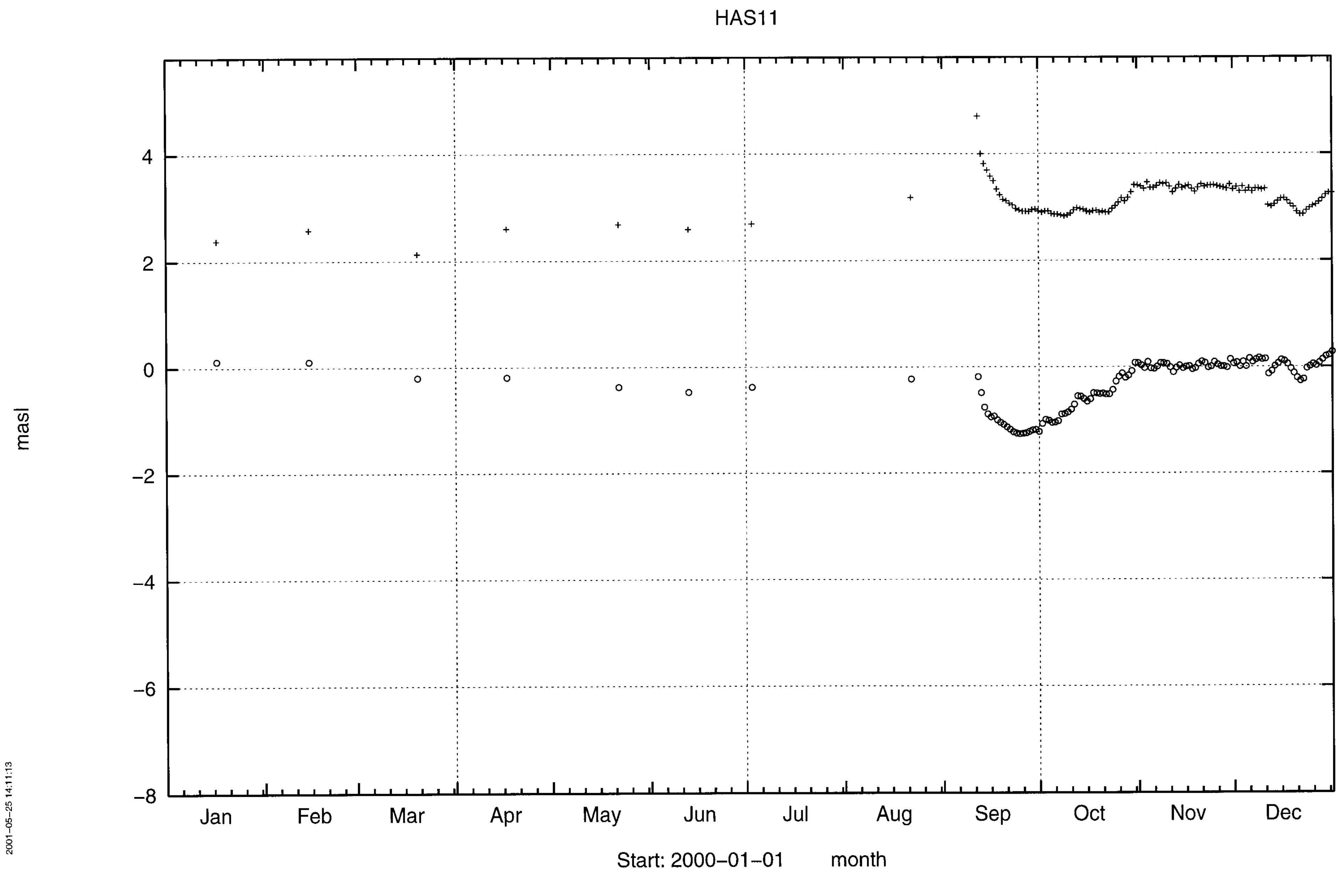


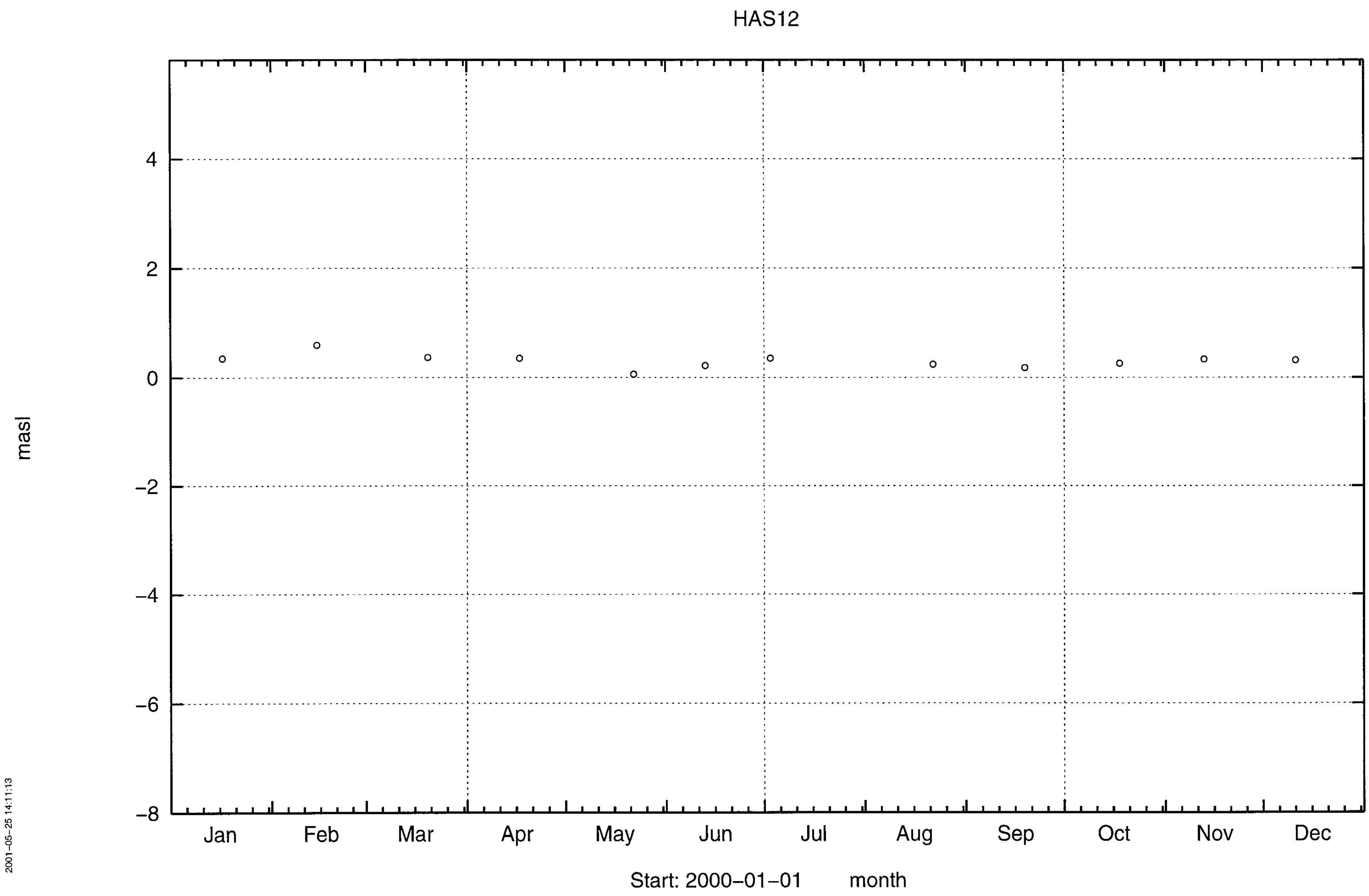
HAS07
masl
0
-2
-4
-6
-8
-10
-12
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:12

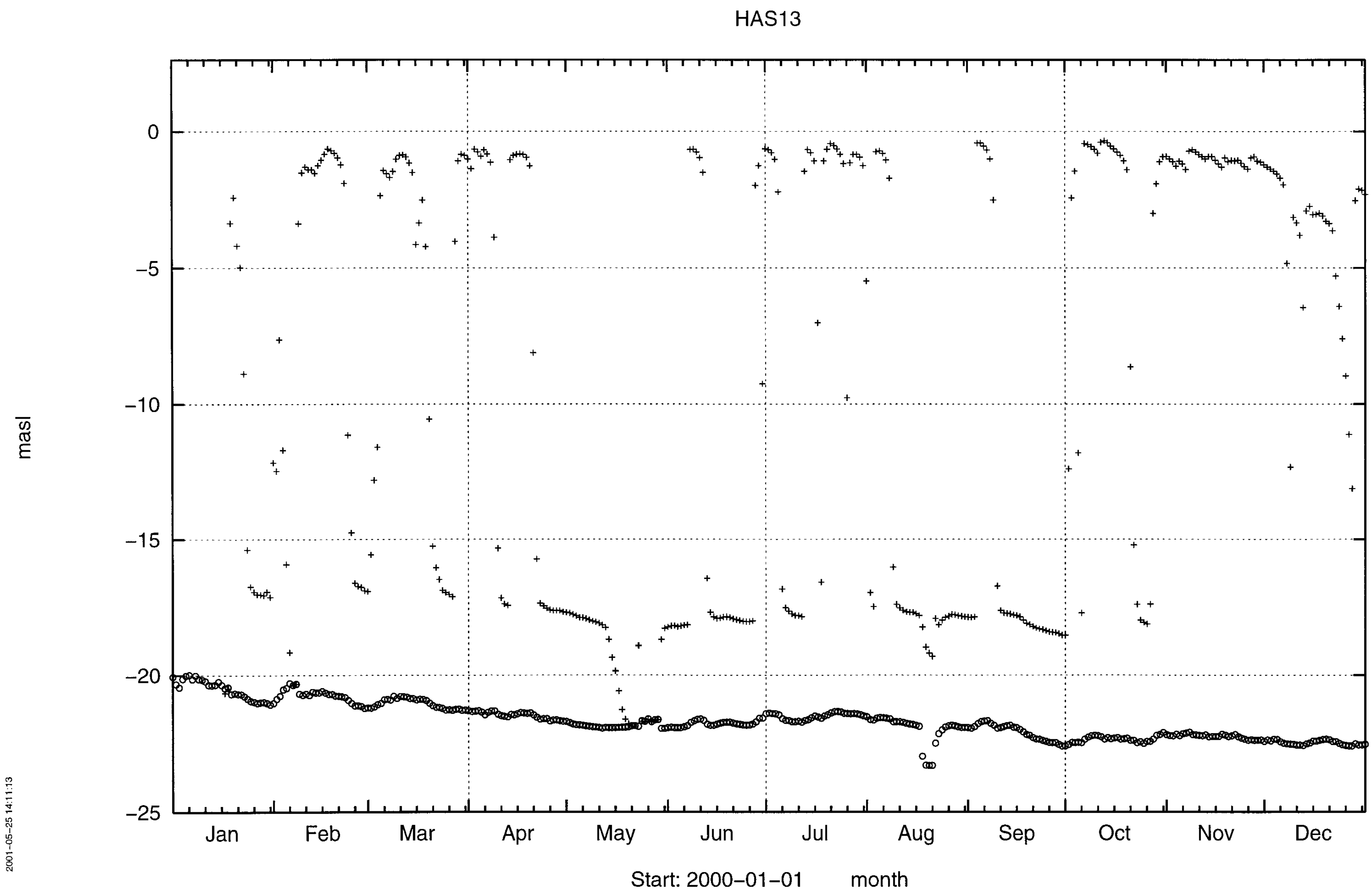

HAS08
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01 month
2001−05−25 14:11:12


HAS09
masl
4
2
0
-2
-4
-6
-8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:12

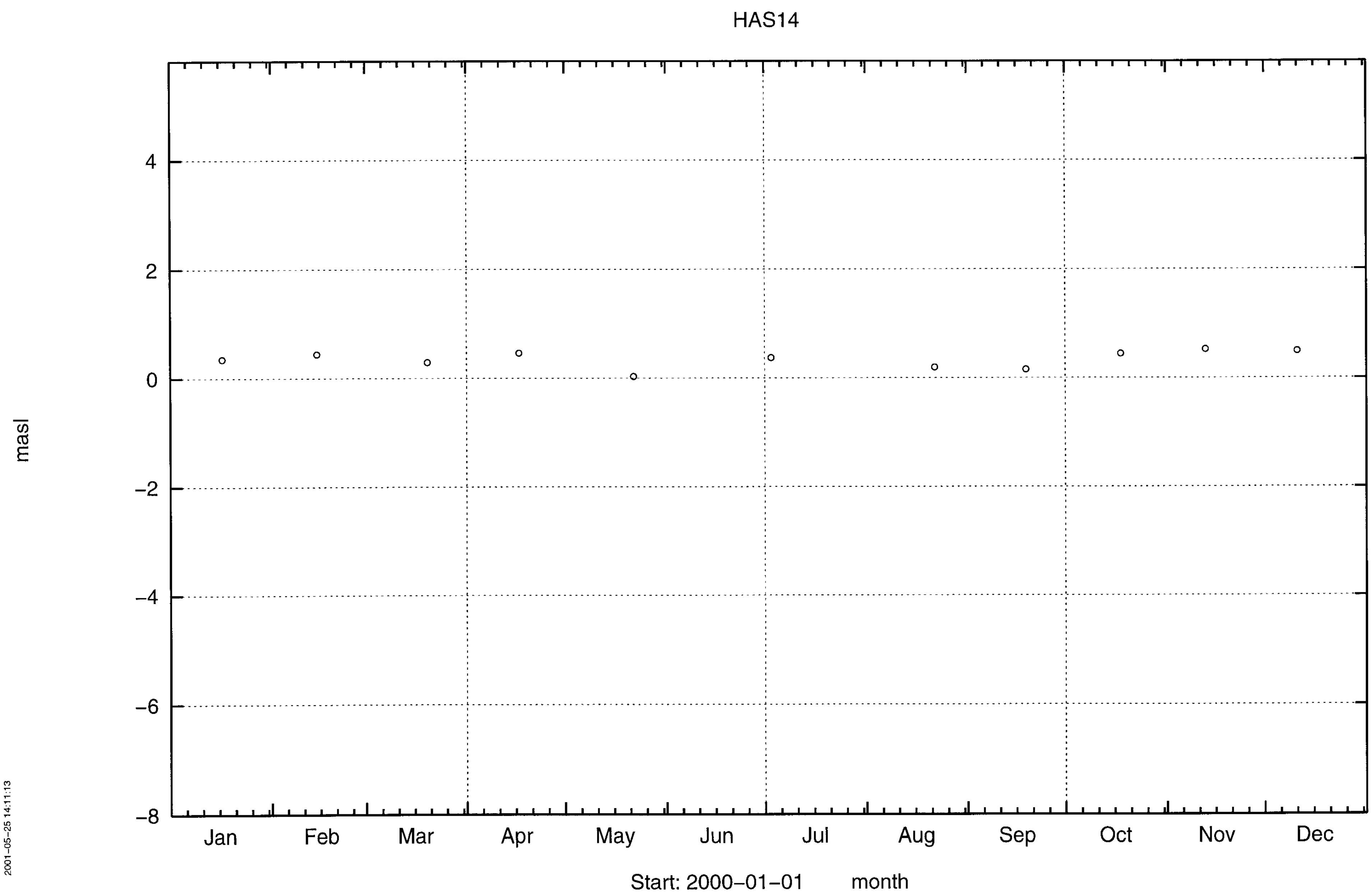

HAS10
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:12


HAS11
4
2
0
-2
-4
-6
-8
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:13


HAS12
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:13

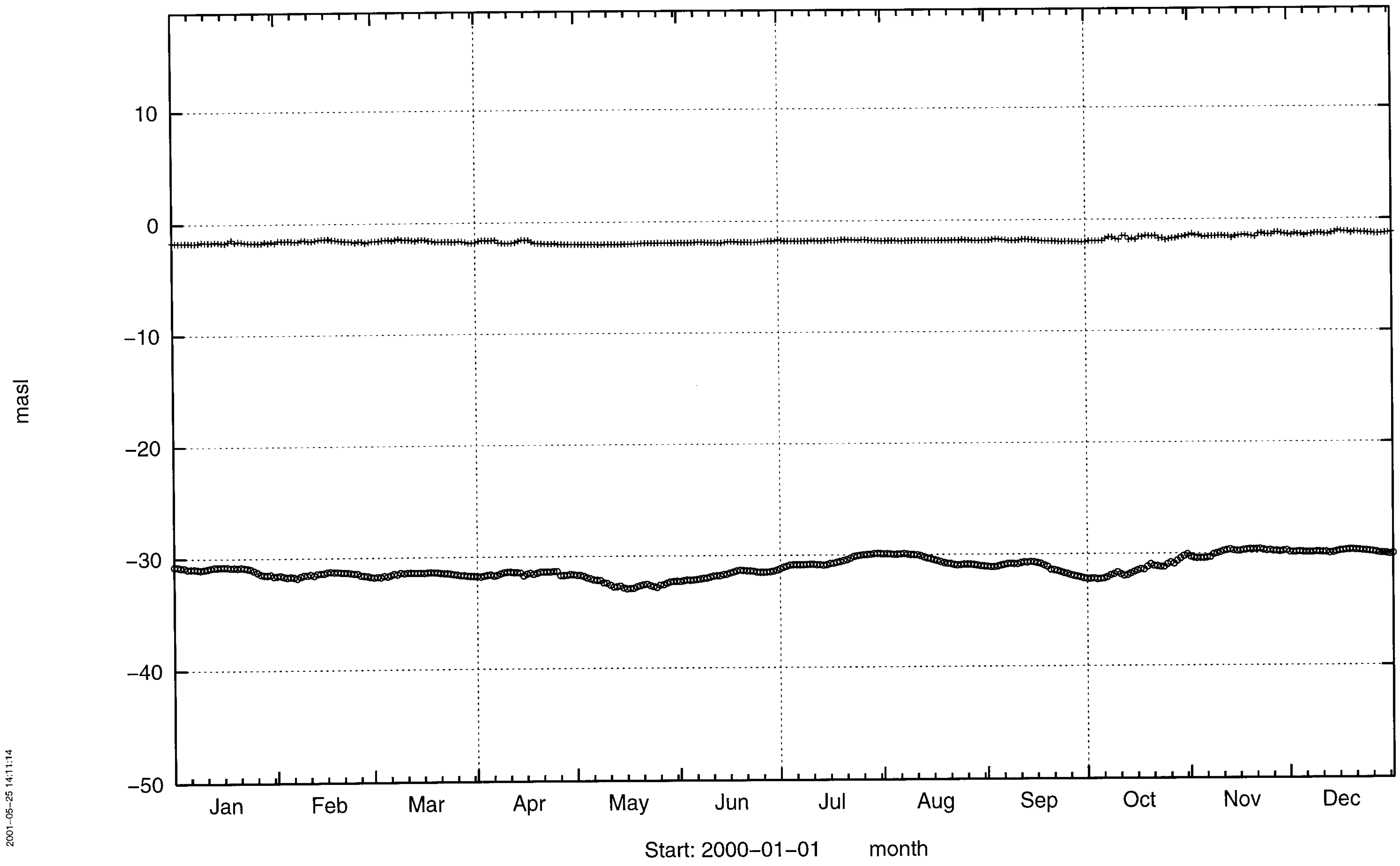


HAS13
masl
0
−5
−10
−15
−20
−25
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:13

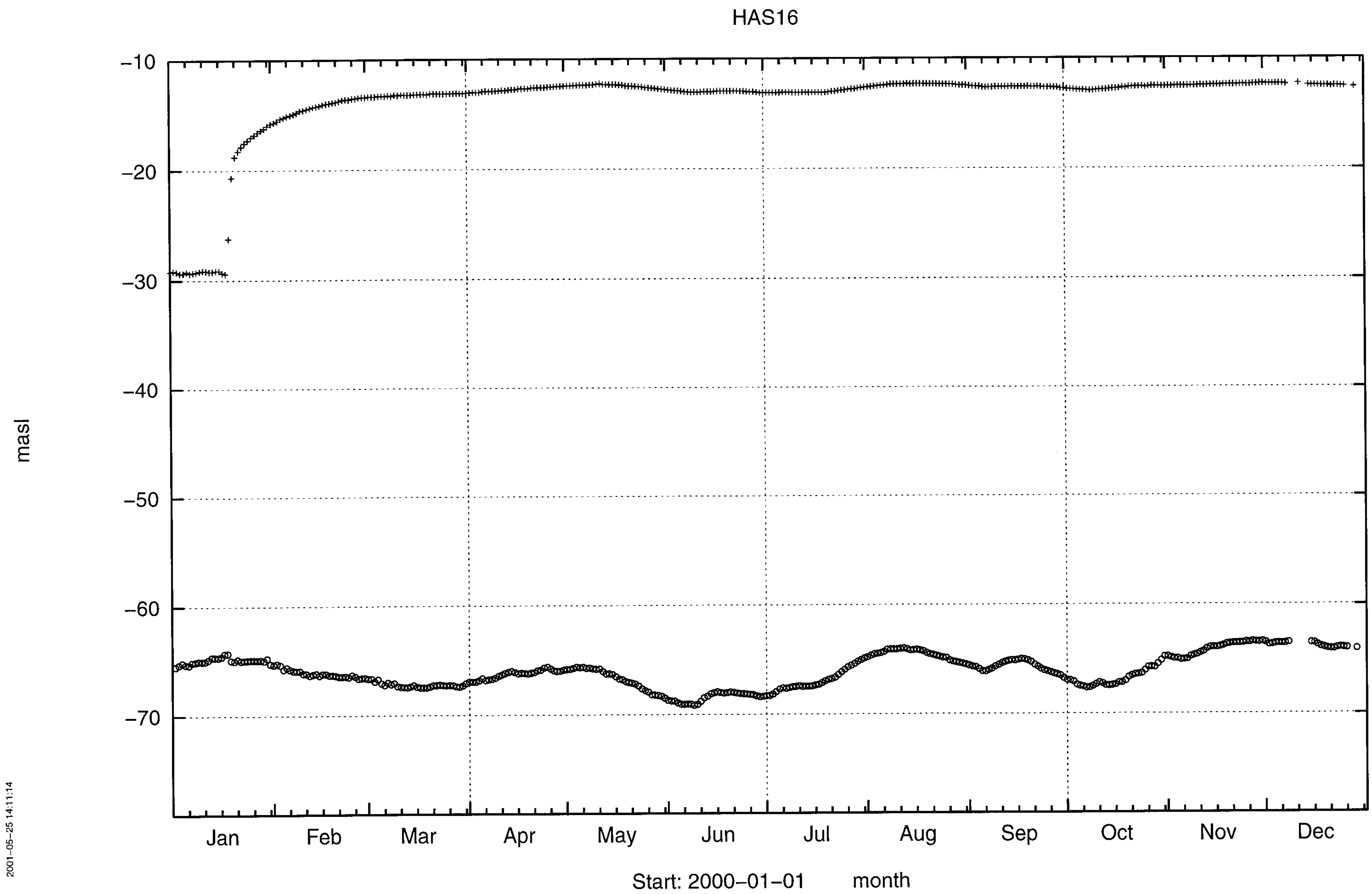


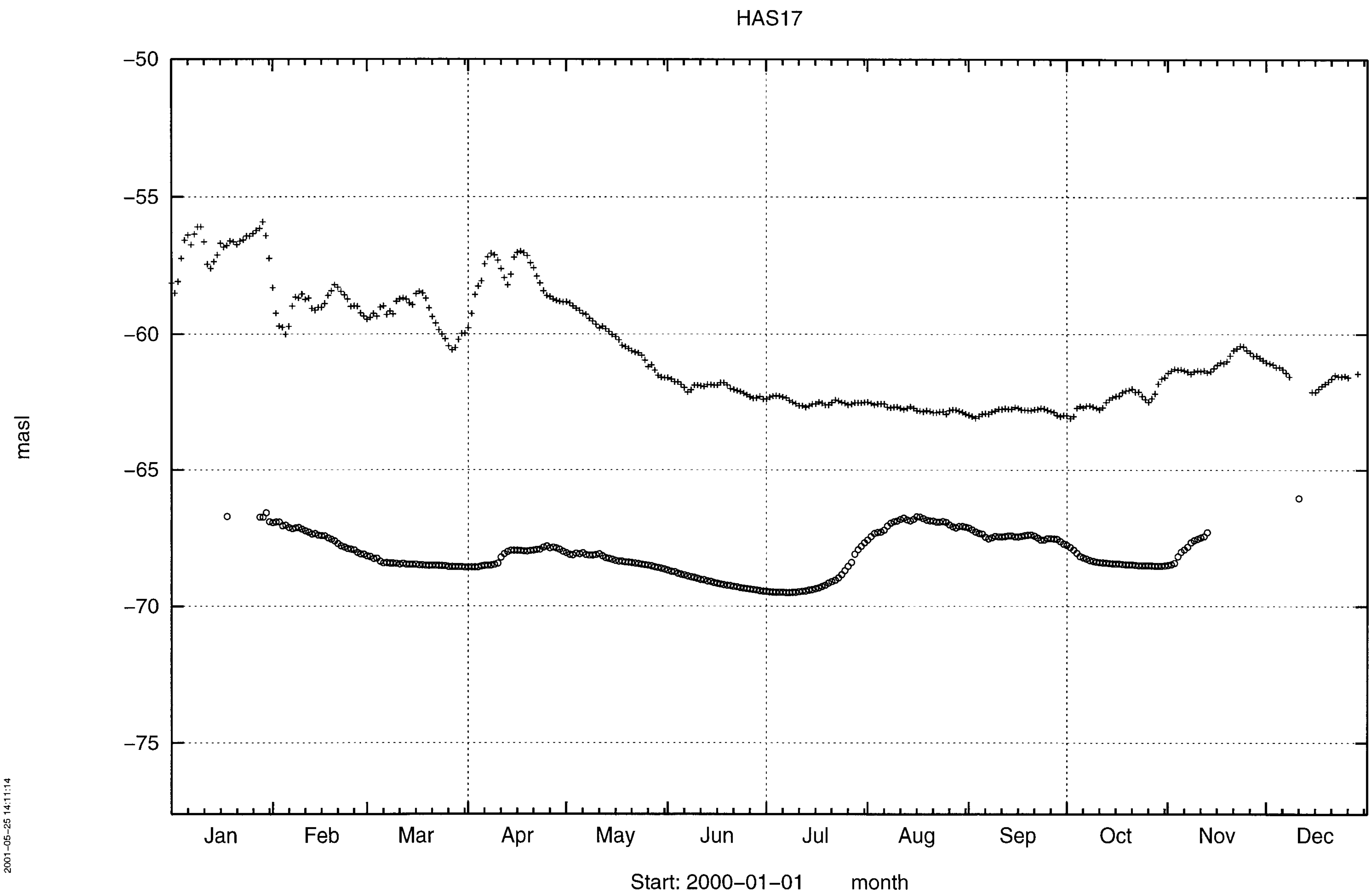
2001-05-25 14:11:13

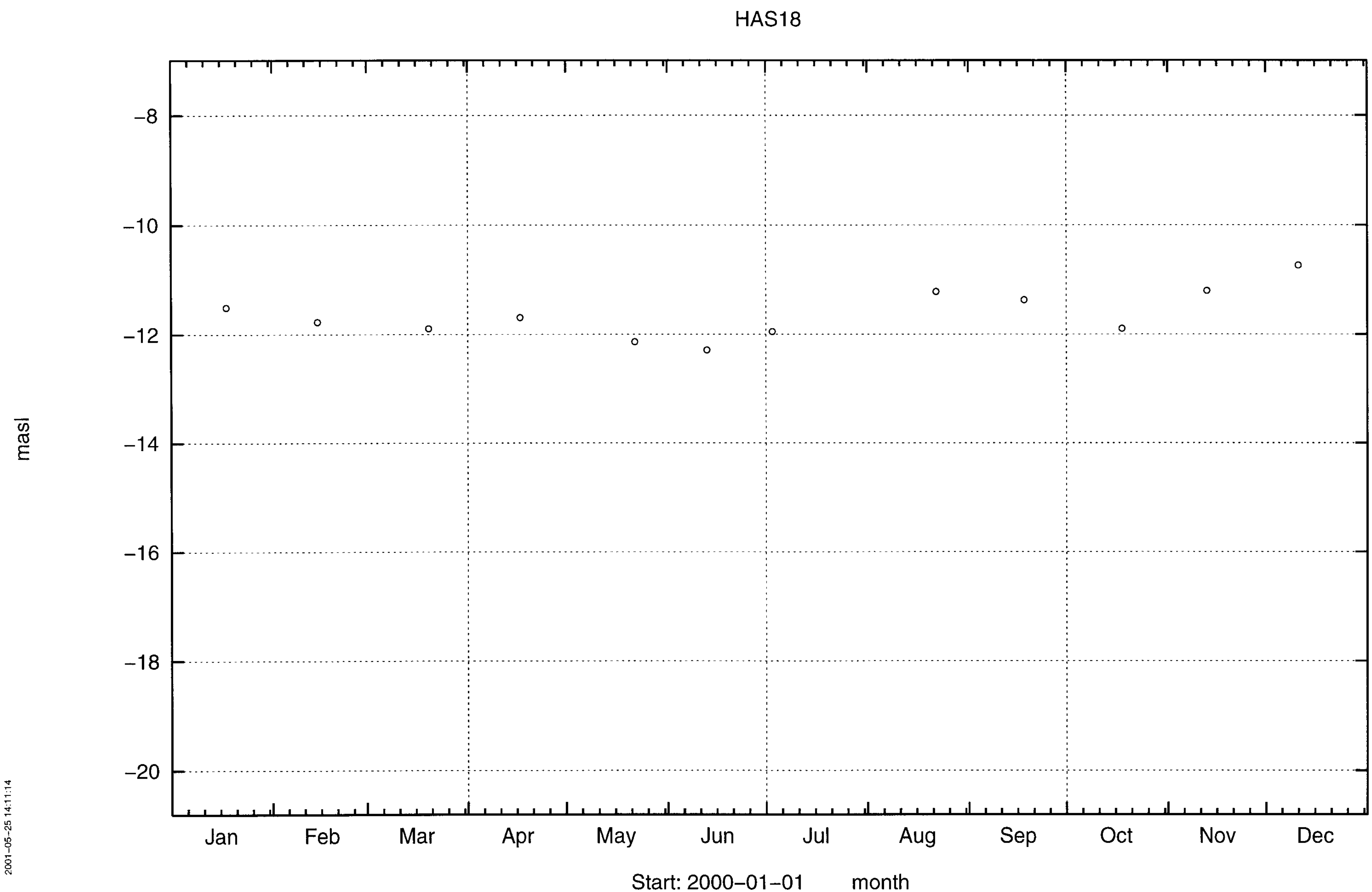
HAS15



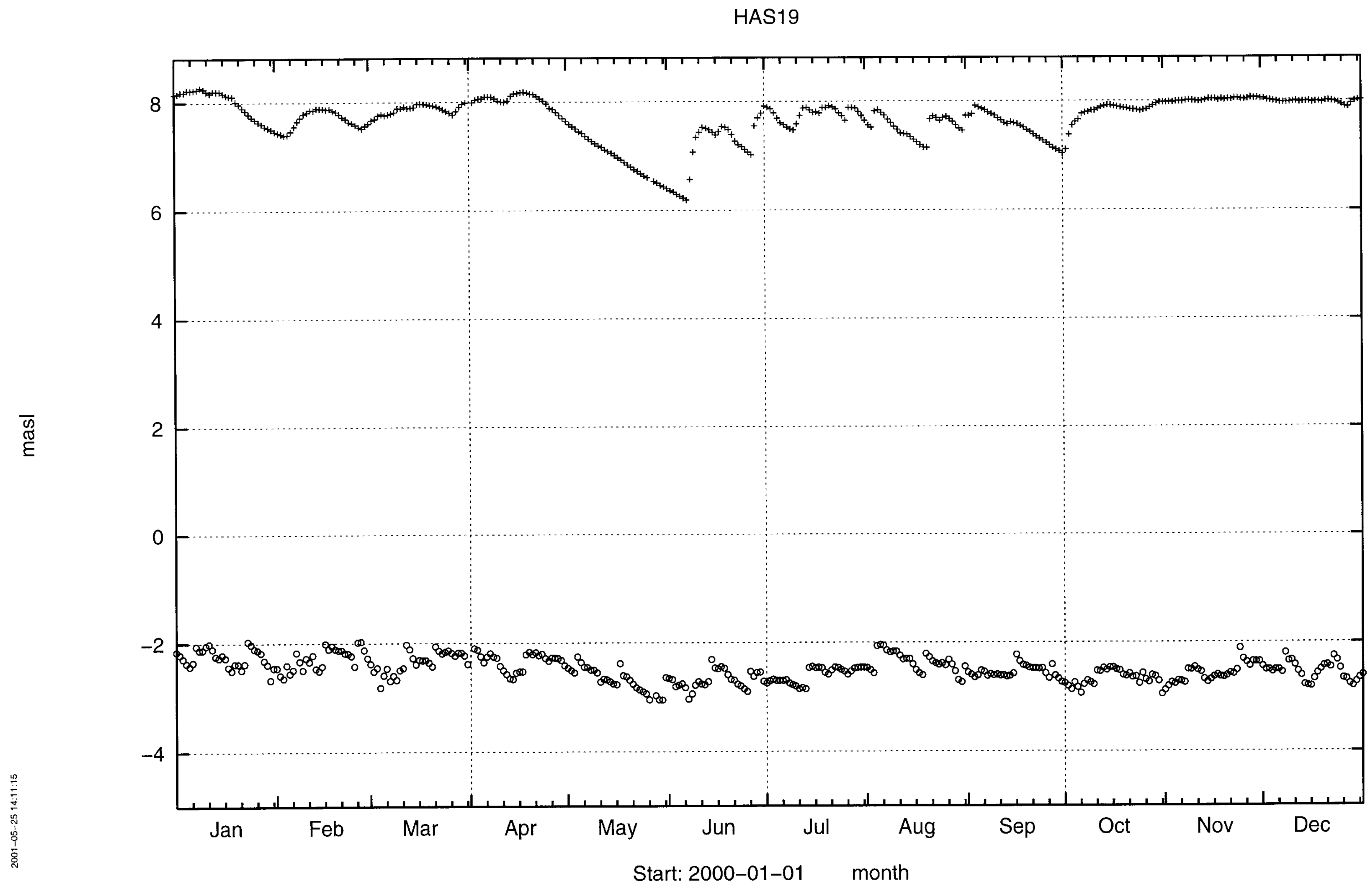
10
0
−10
−20
−30
−40
−50
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:14

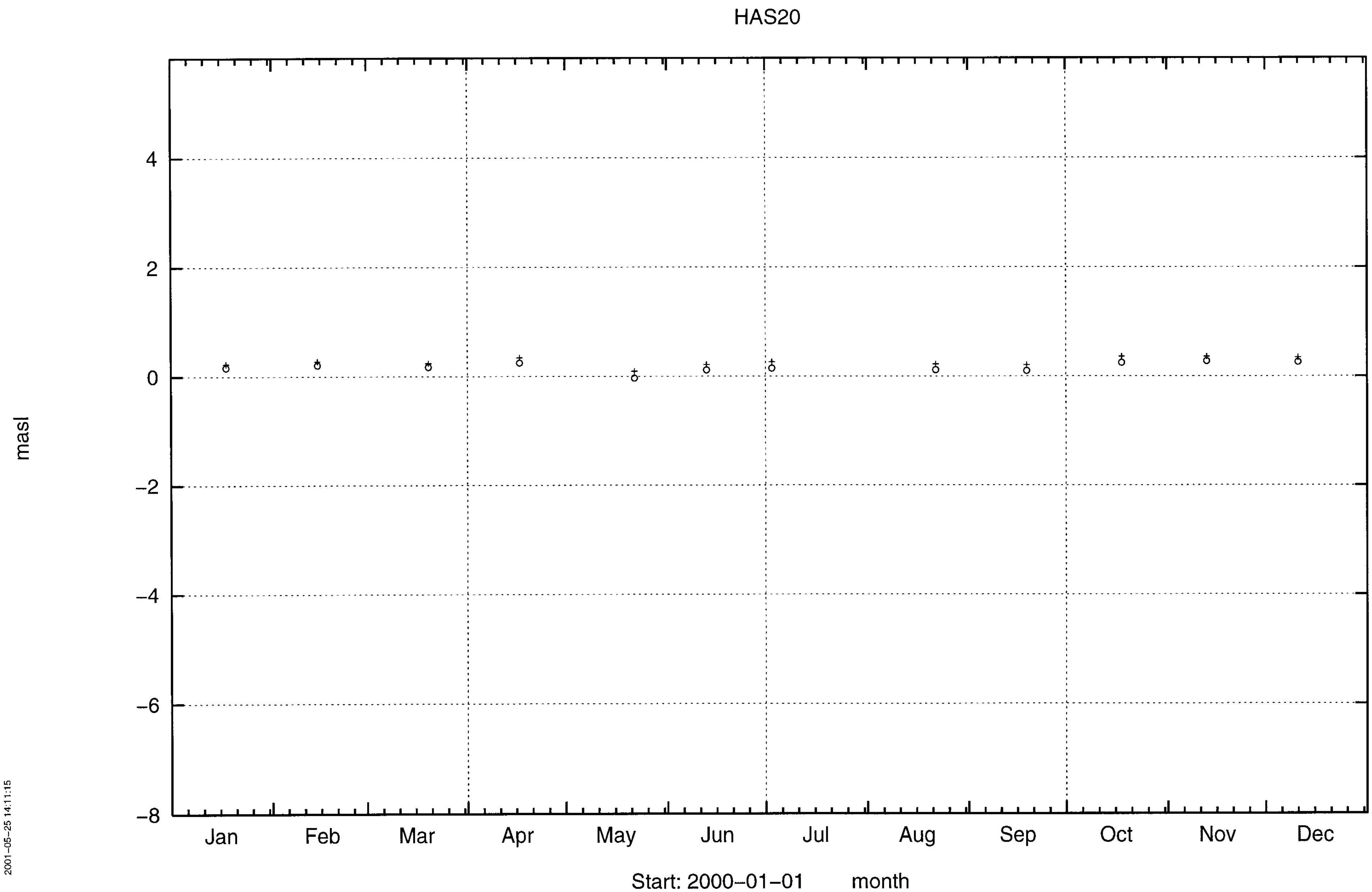

HAS16
masl
-10
-20
-30
-40
-50
-60
-70
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:14

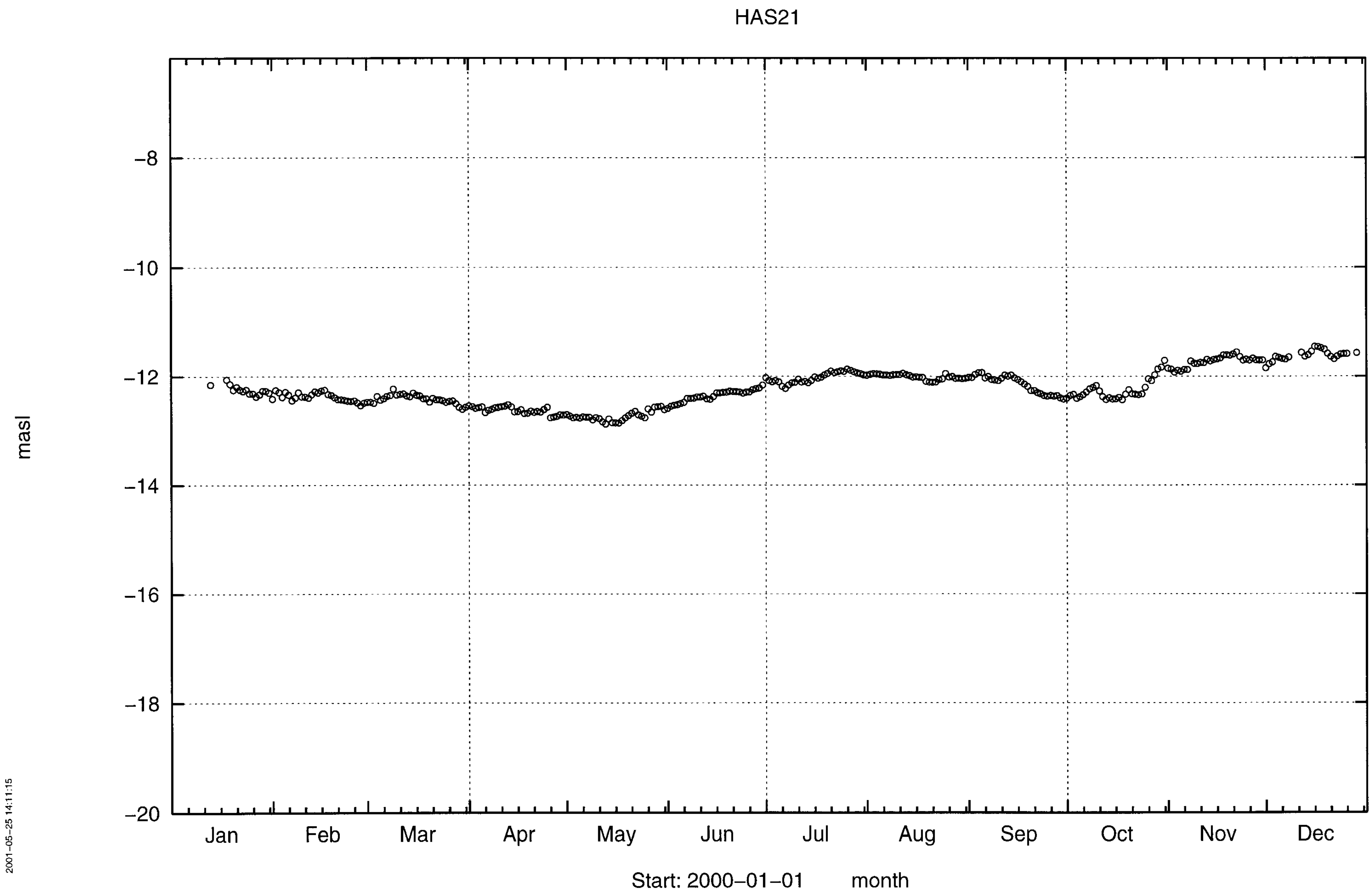

HAS17
masl
-50
-55
-60
-65
-70
-75
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:14



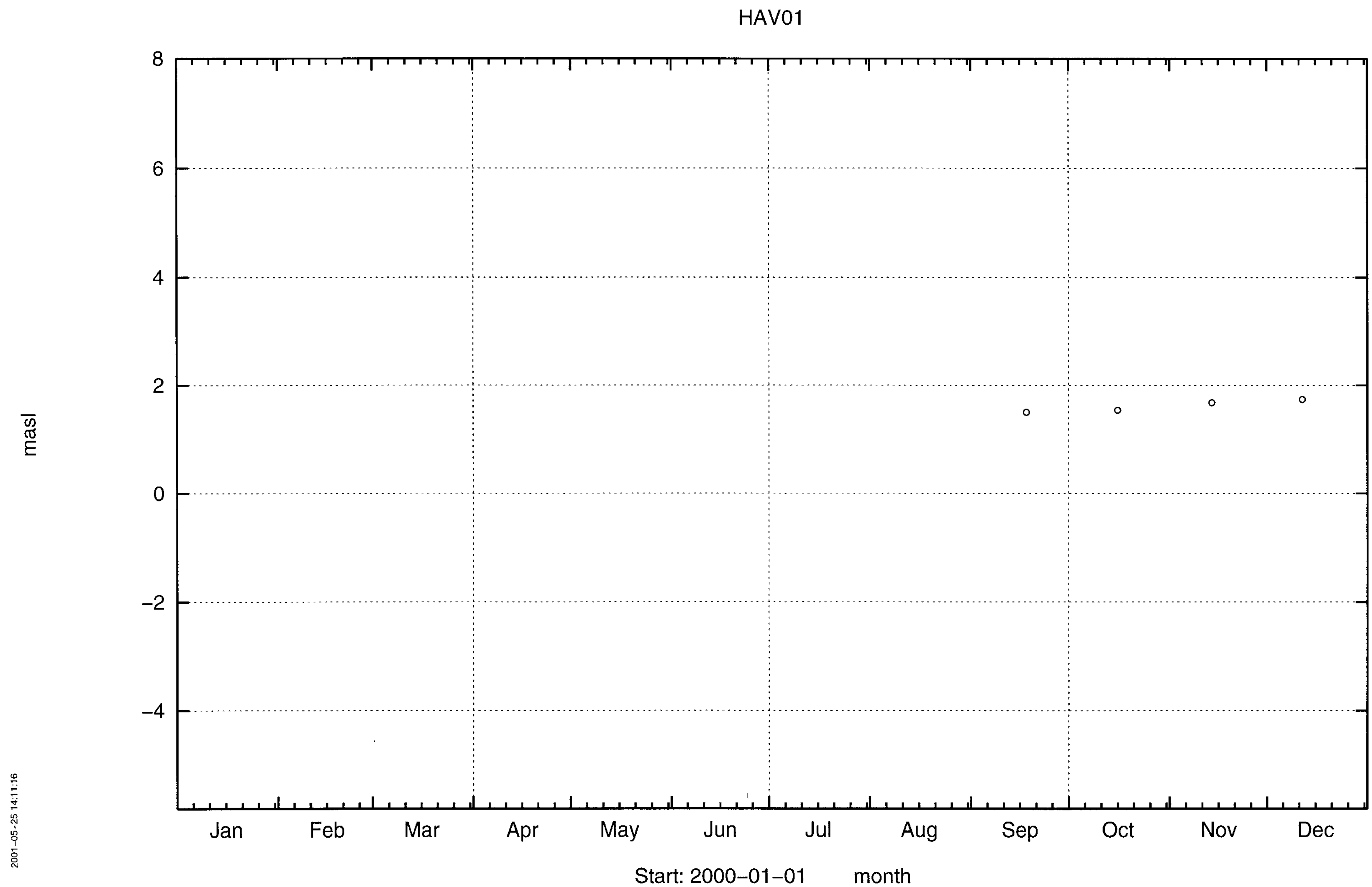
2001-05-25 14:11:14

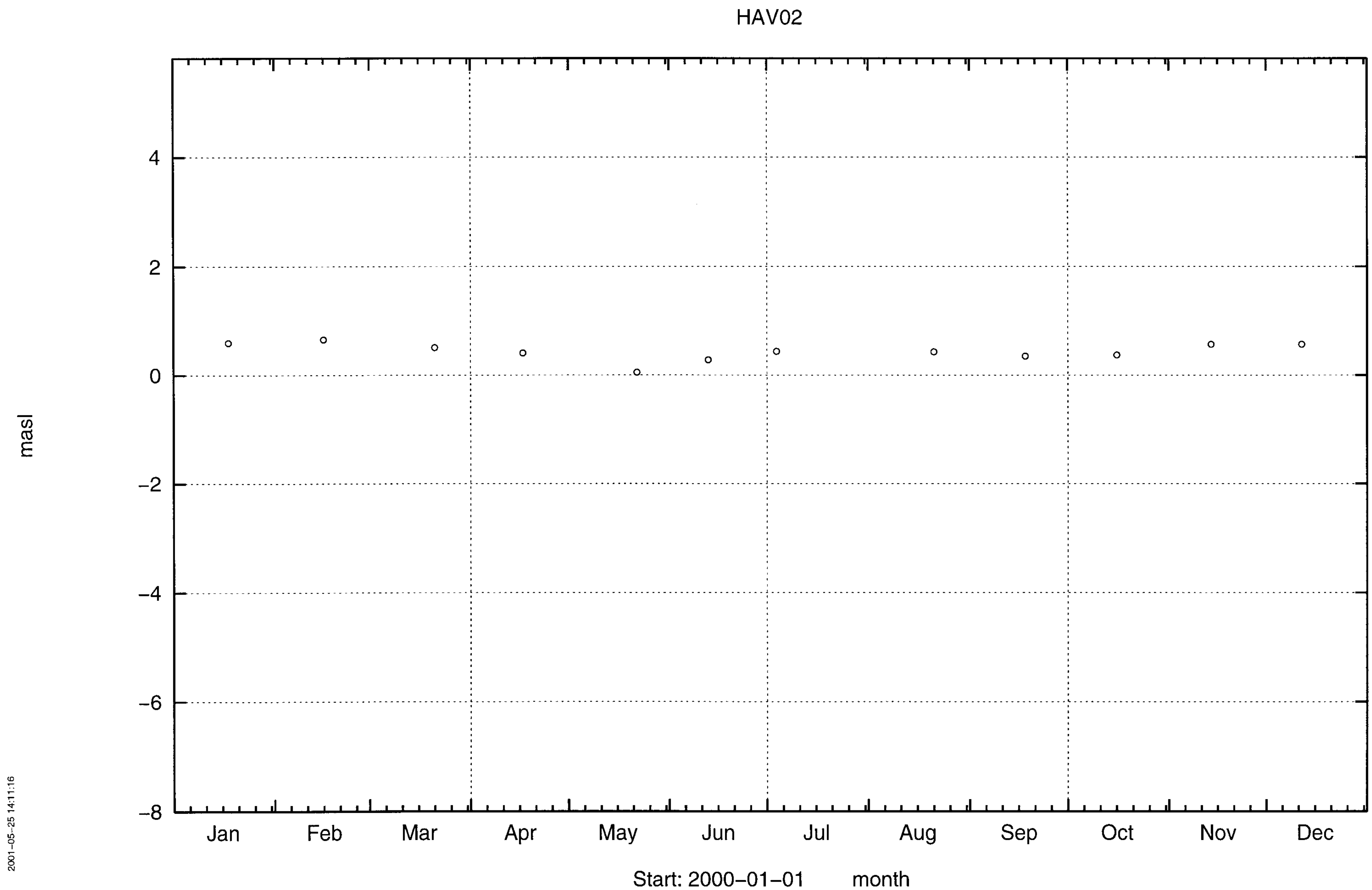

HAS19
masl
8
6
4
2
0
-2
-4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:15

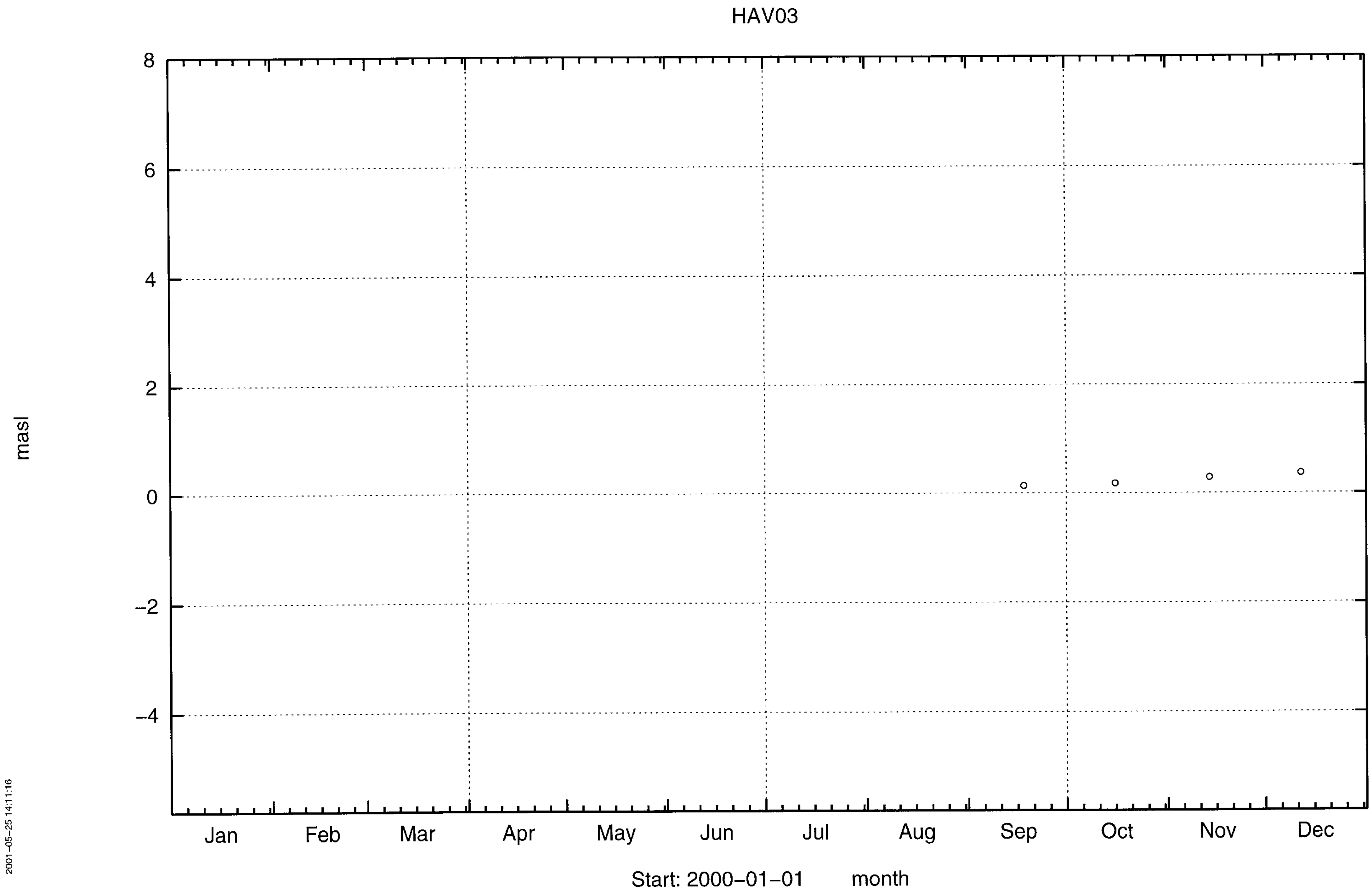

HAS20
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:15



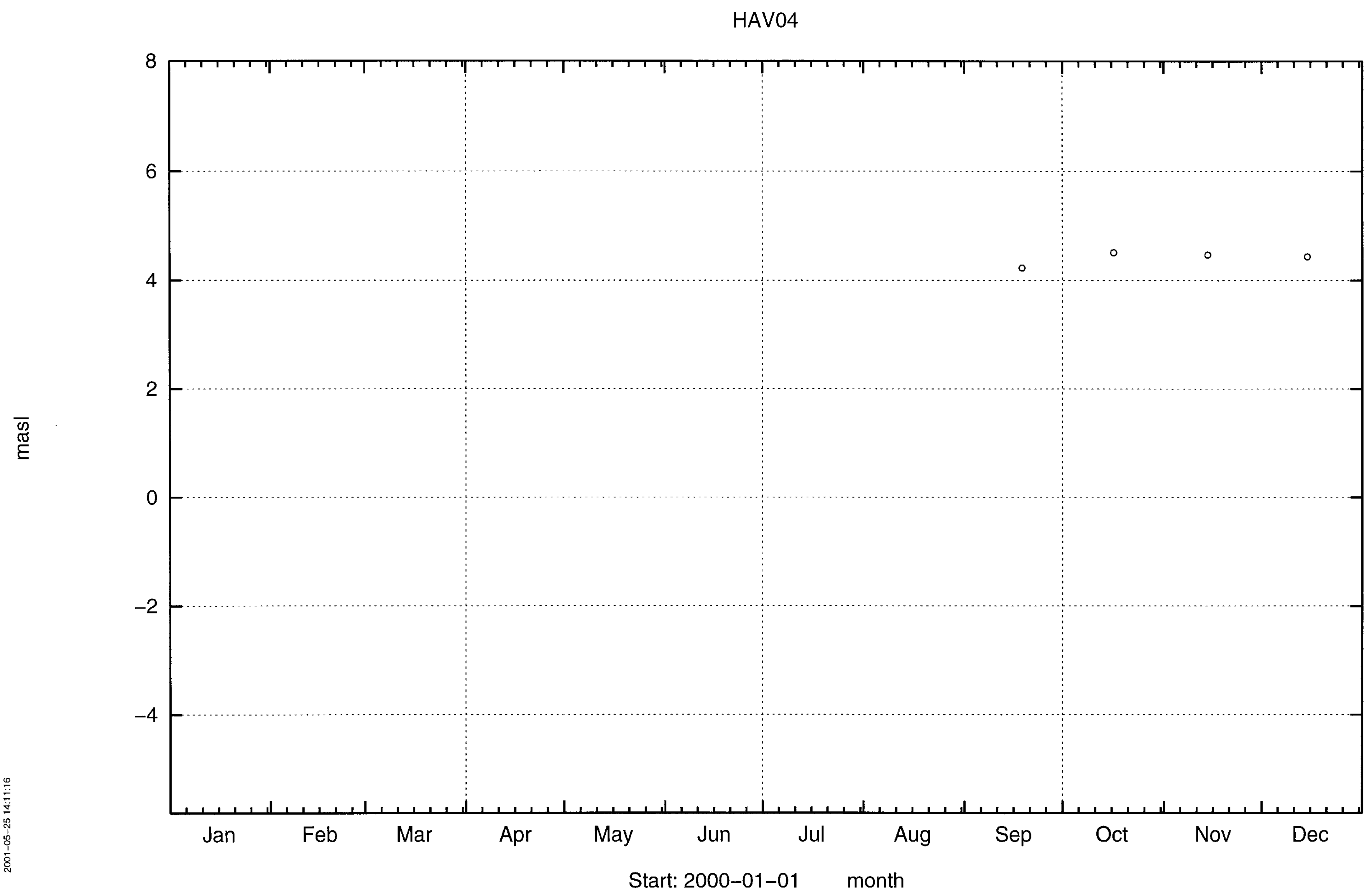
HAS21
masl
-8
-10
-12
-14
-16
-18
-20
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:15


HAV01
8
6
4
2
0
−2
−4
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001-05-25 14:11:16

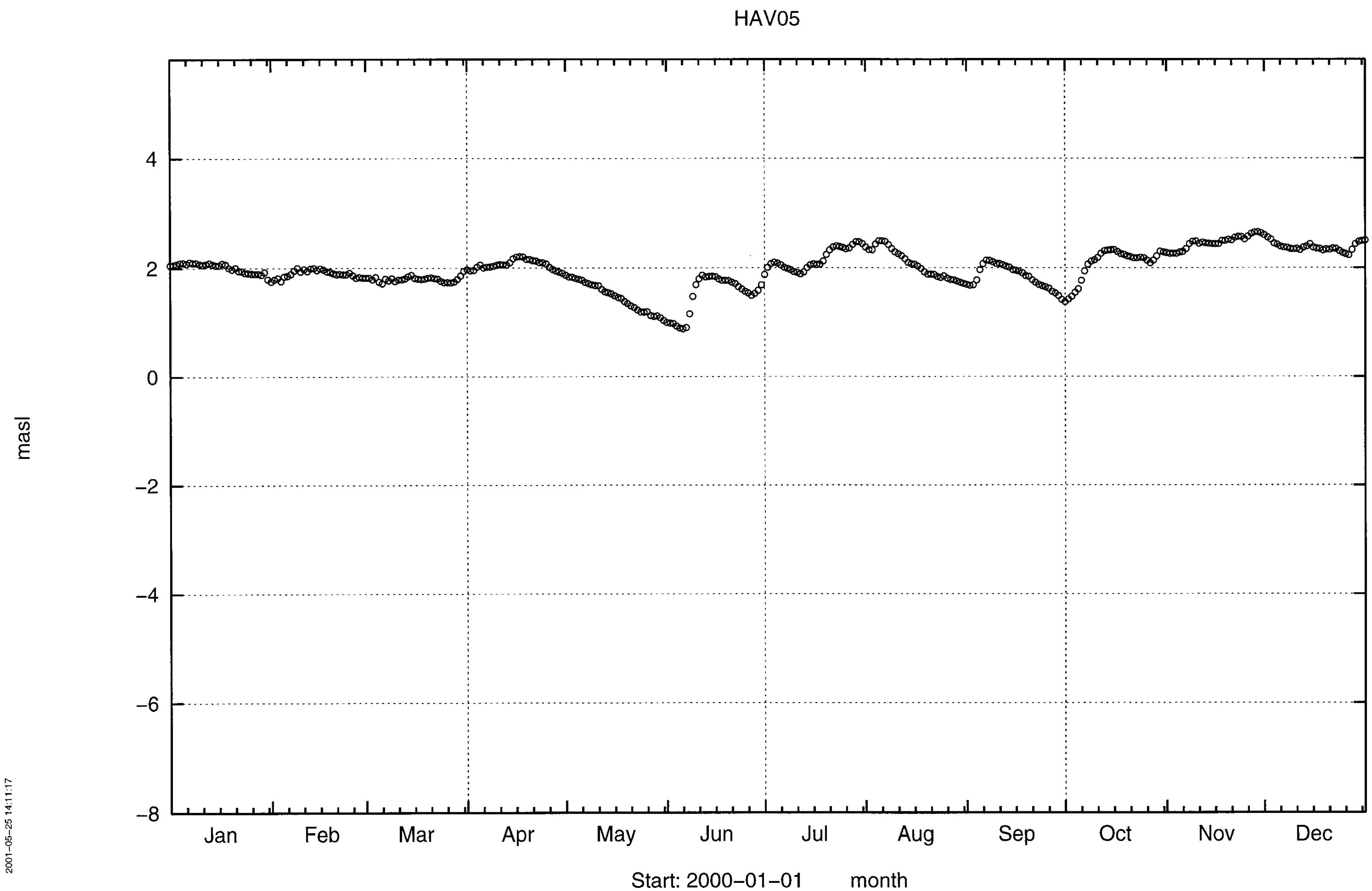

HAV02
4
2
0
−2
−4
−6
−8
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:16

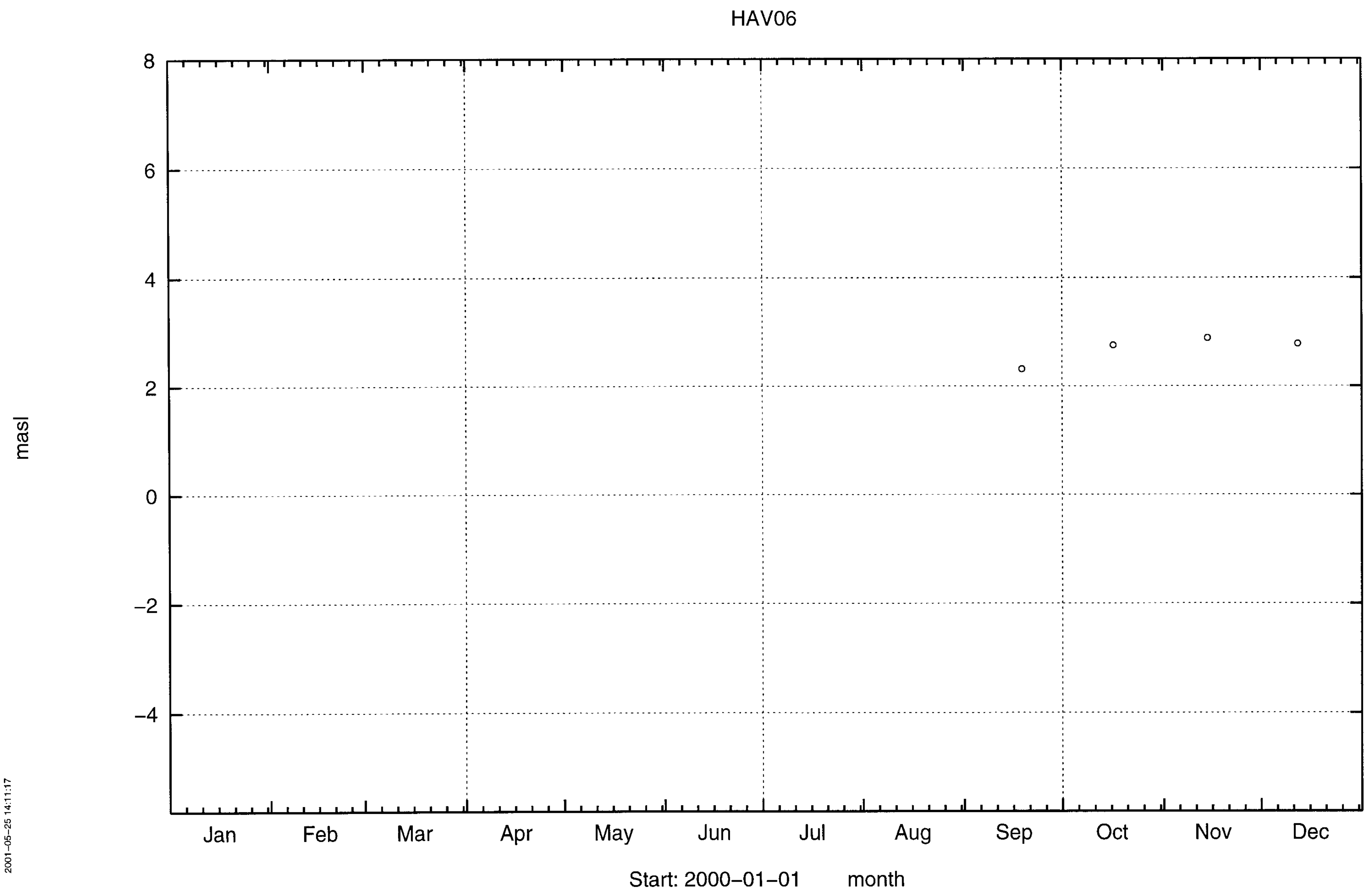


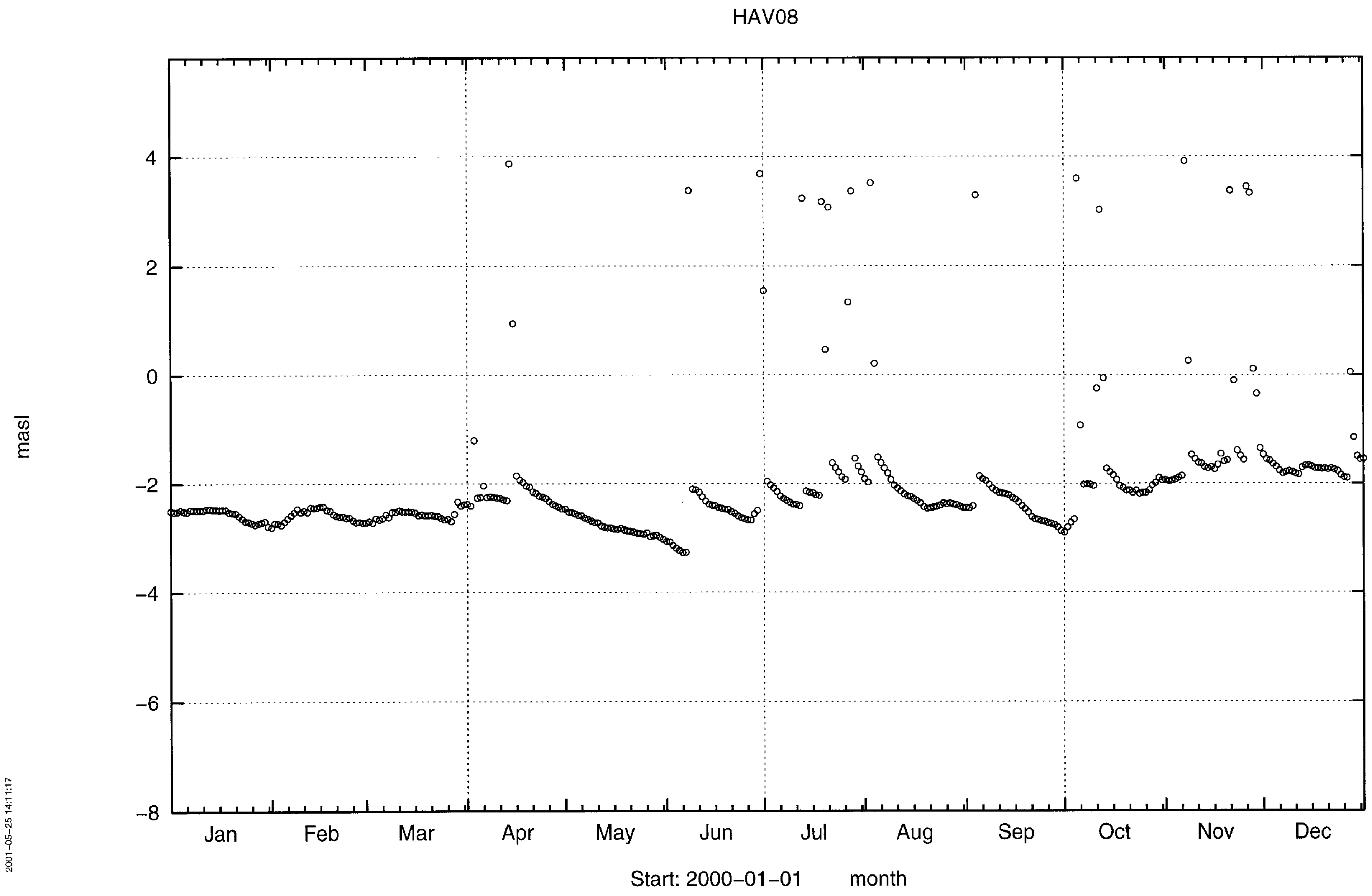
2001-05-25 14:11:16



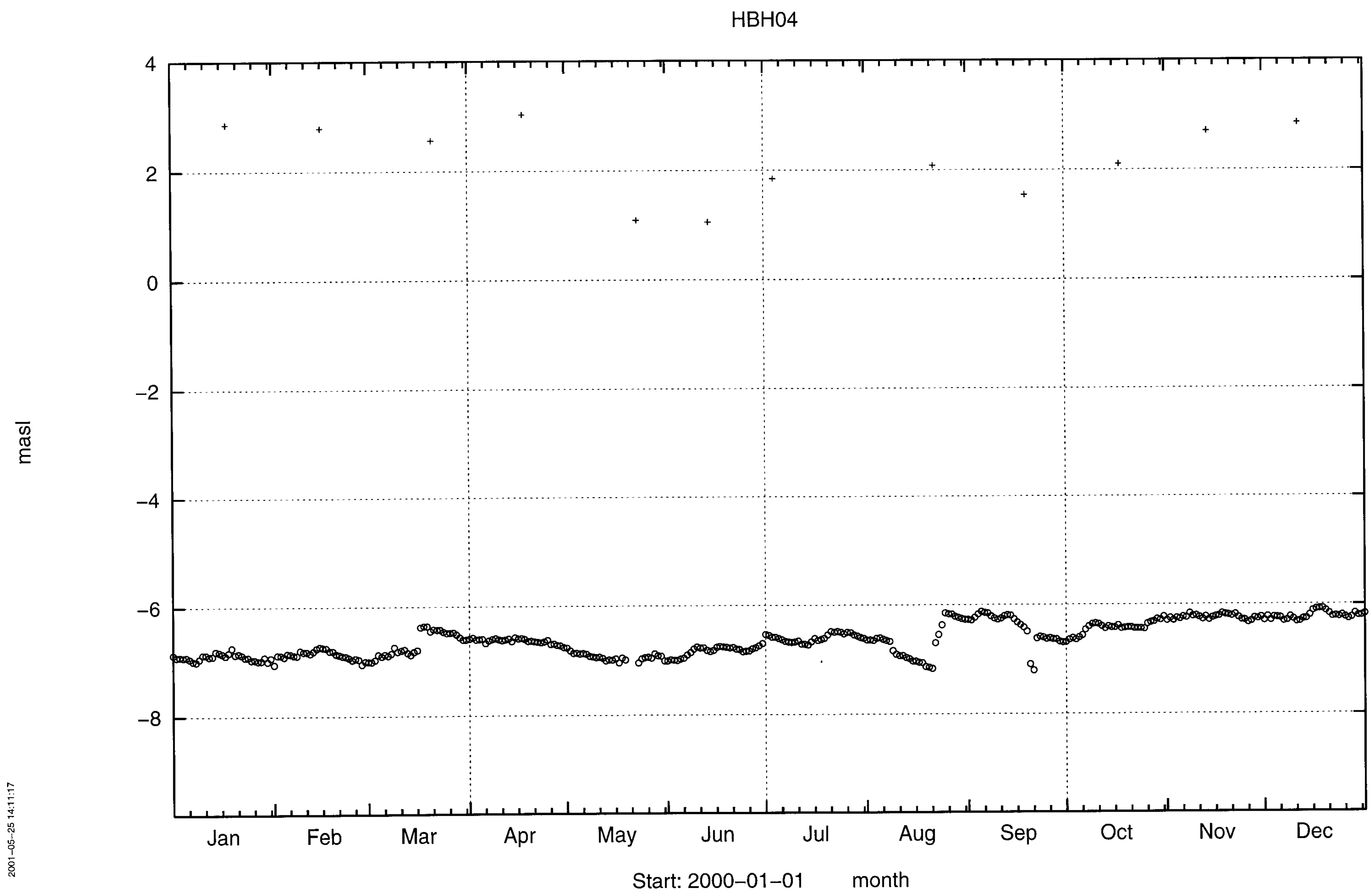
2001−05−25 14:11:16

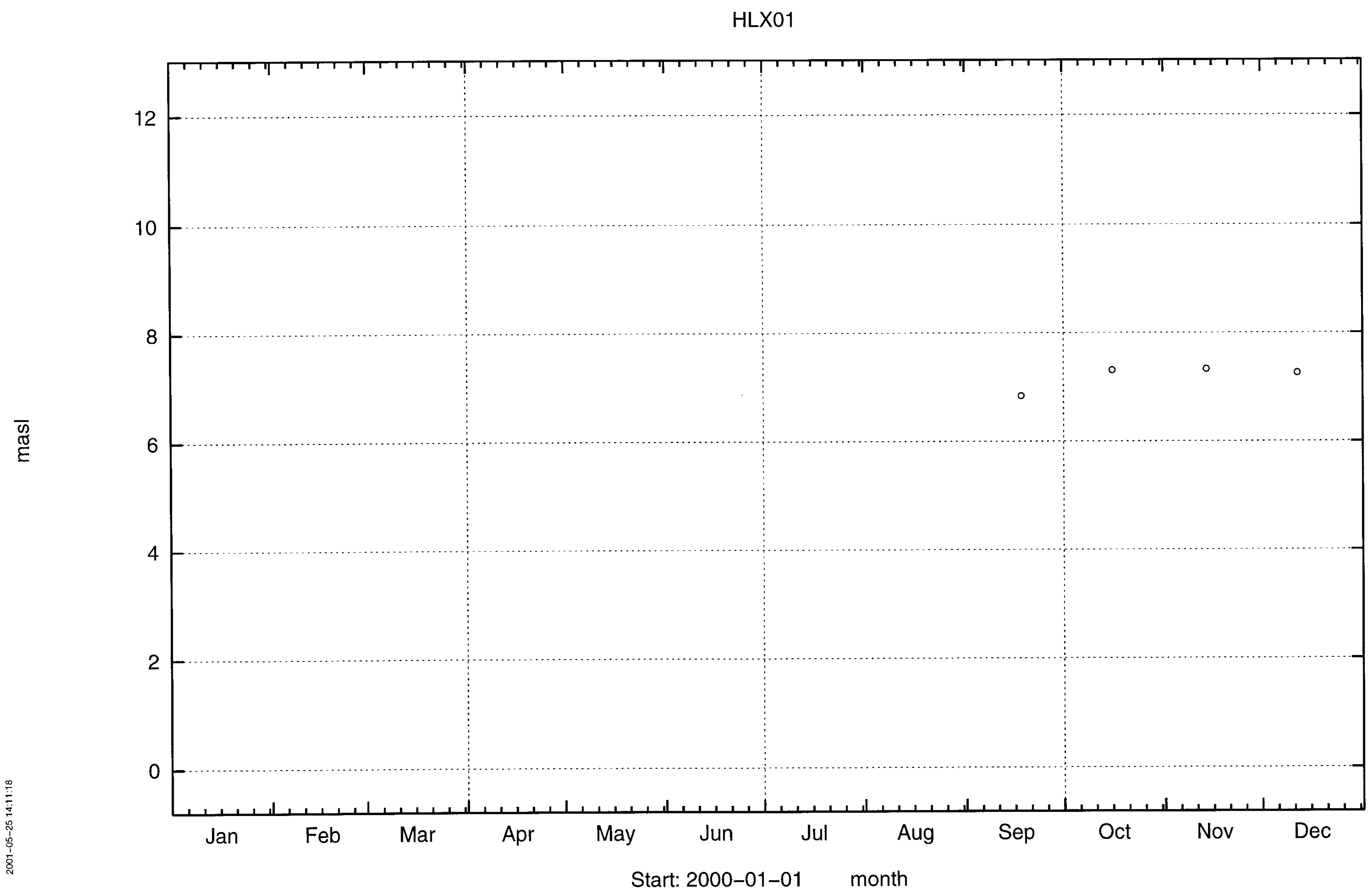

HAV05
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:17

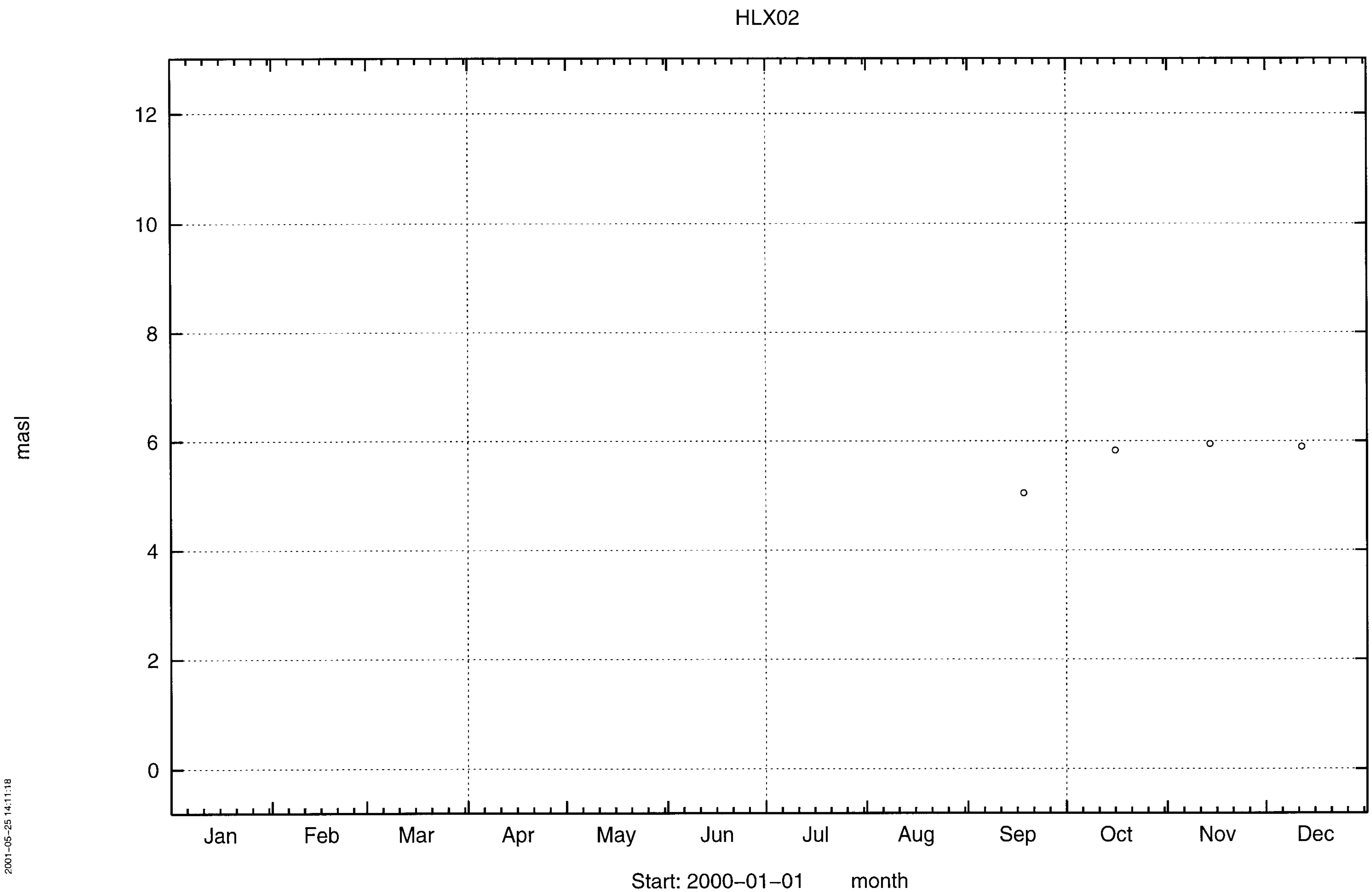

HAV06
masl
8
6
4
2
0
−2
−4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:17



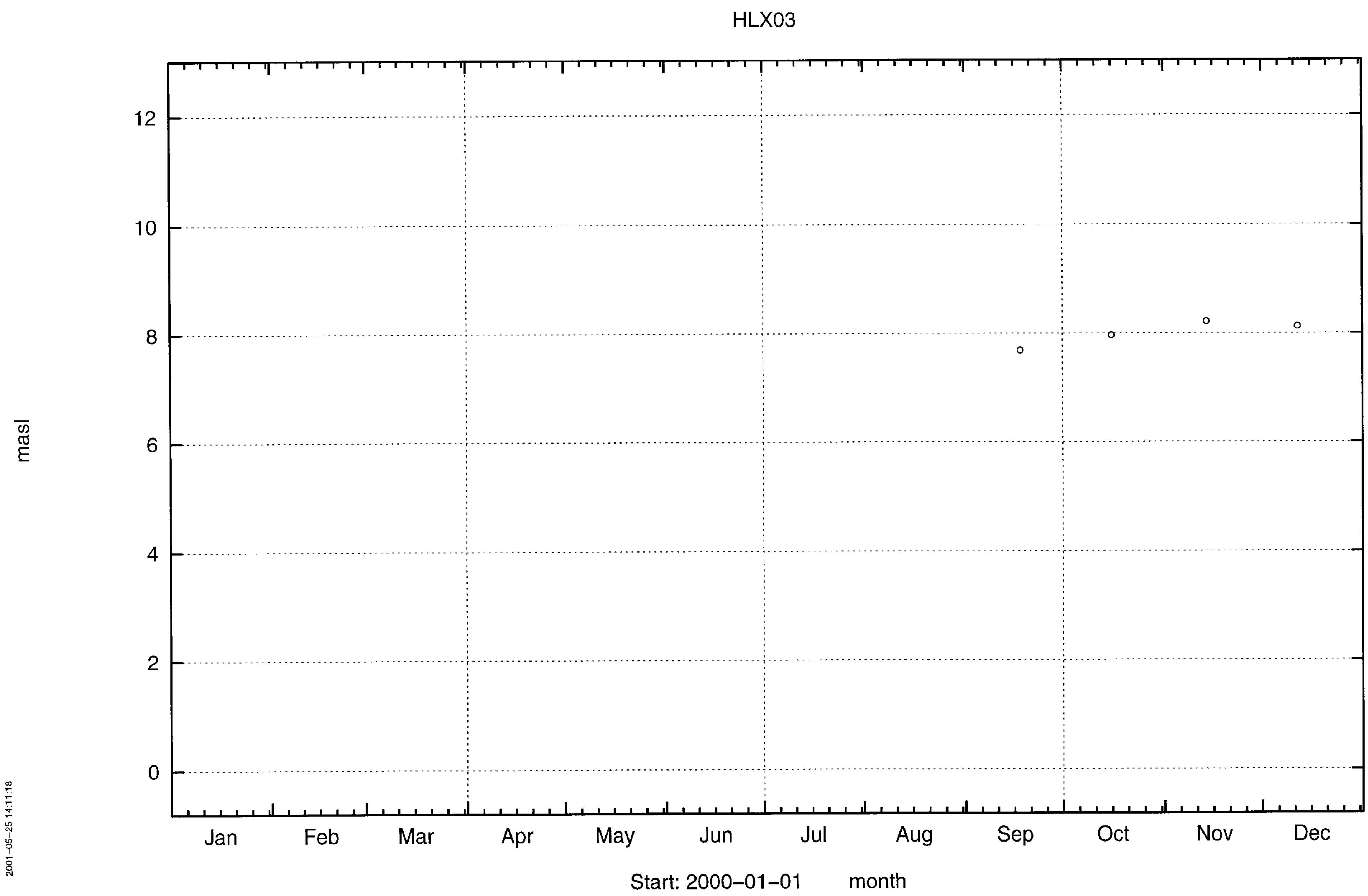
2001−05−25 14:11:17


HBH04
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:17

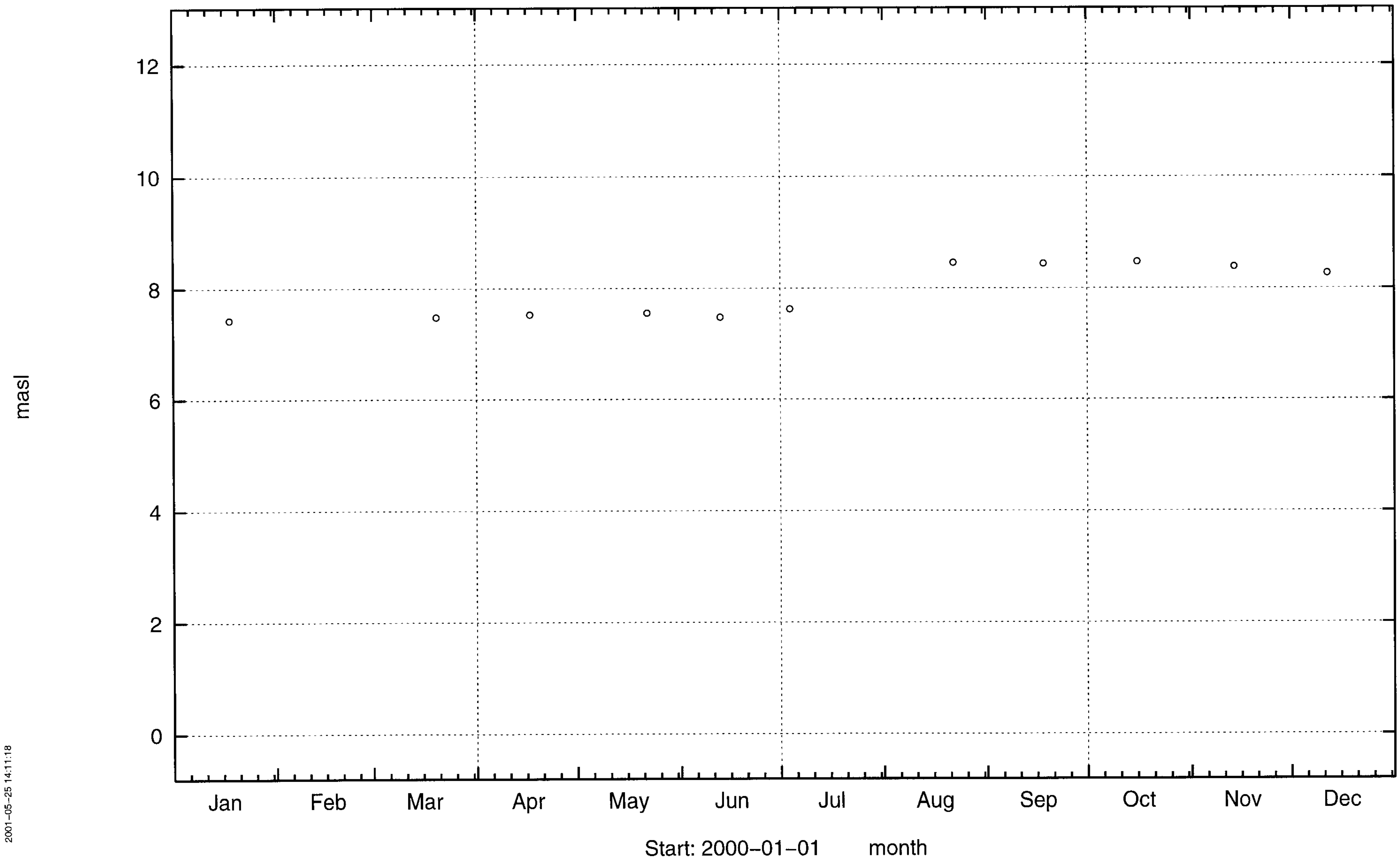

HLX01
masl
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:18



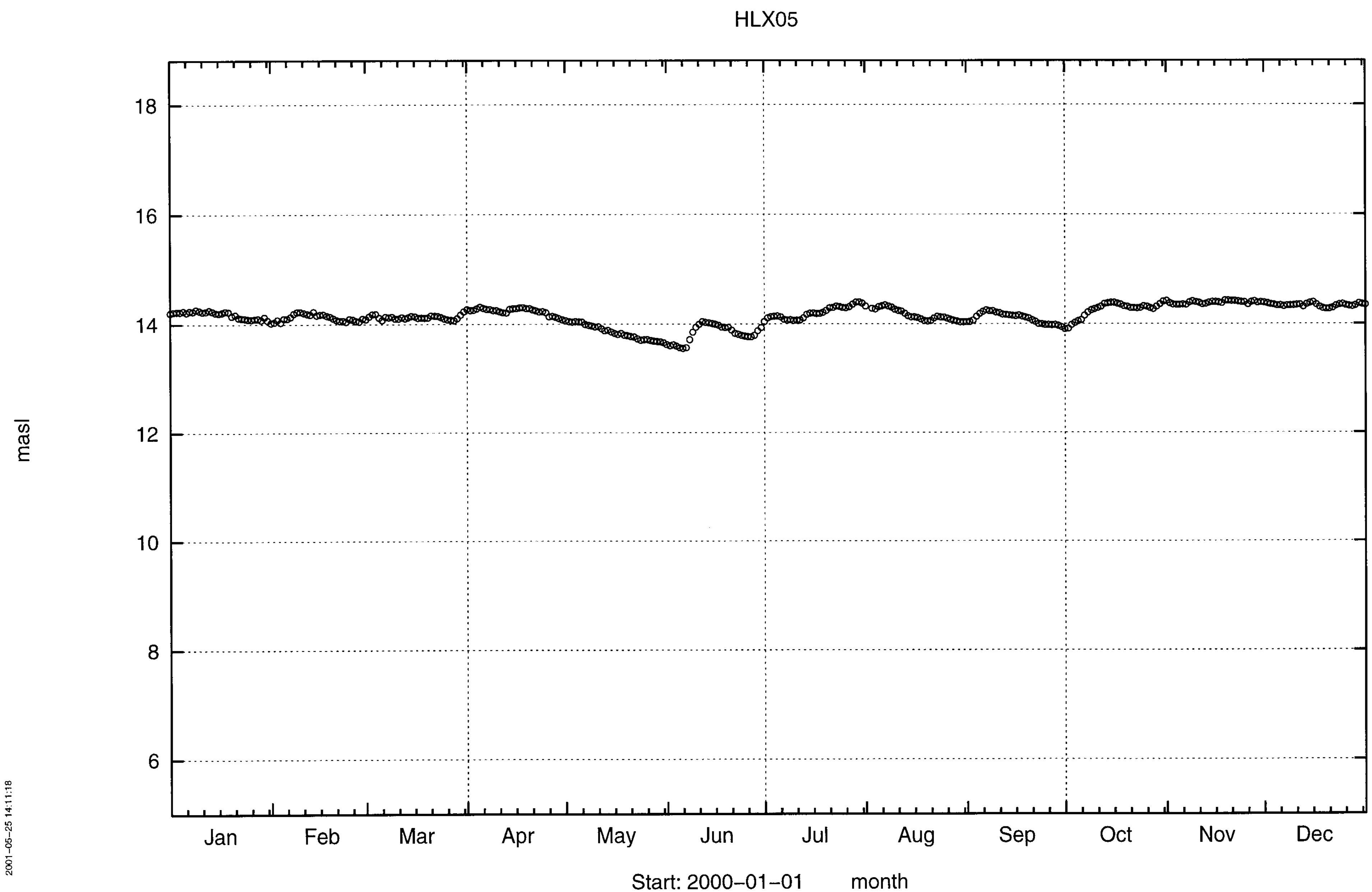
2001-05-25 14:11:18

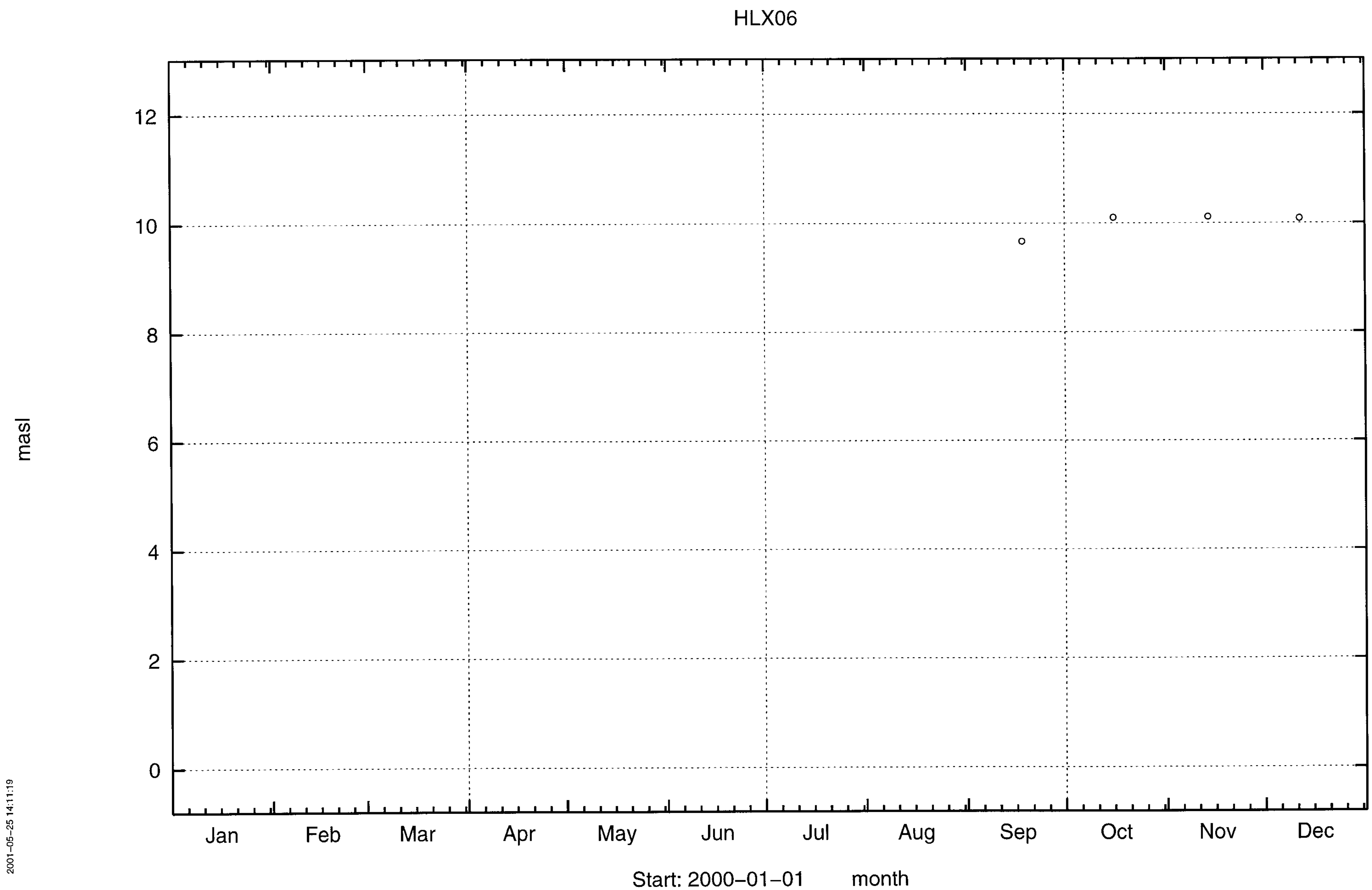

HLX03
masl
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:18

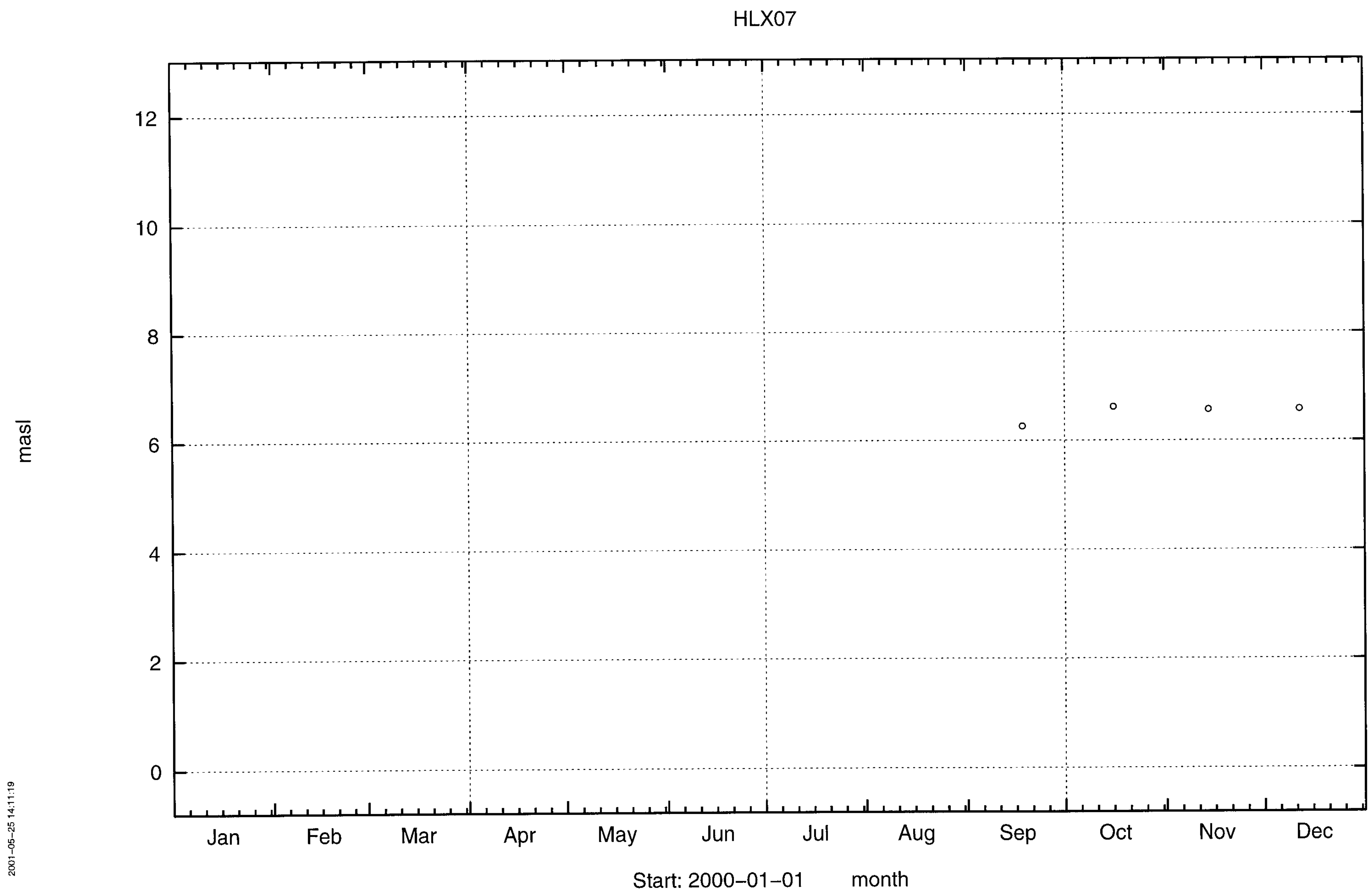
HLX04

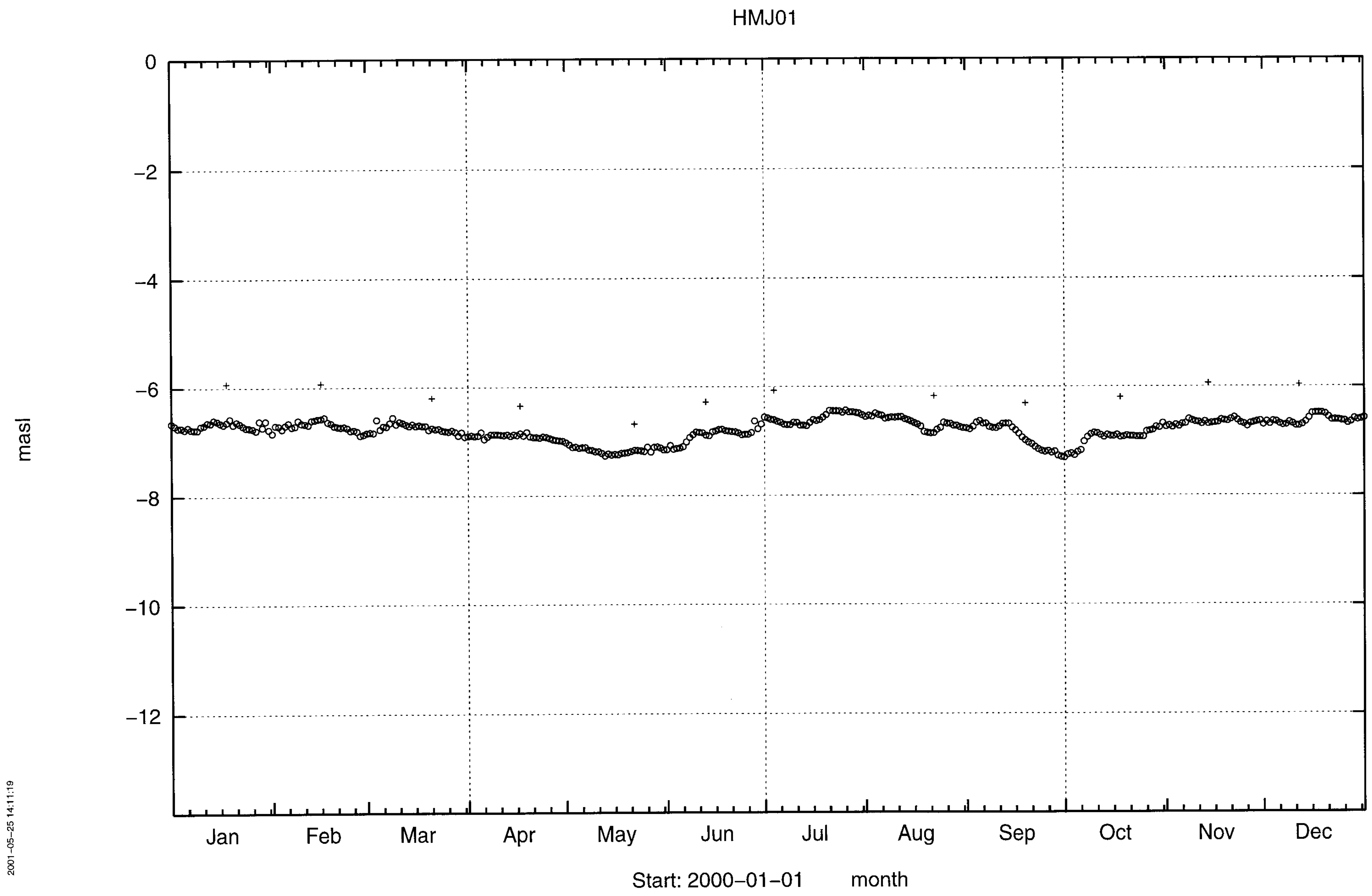


masl
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:18

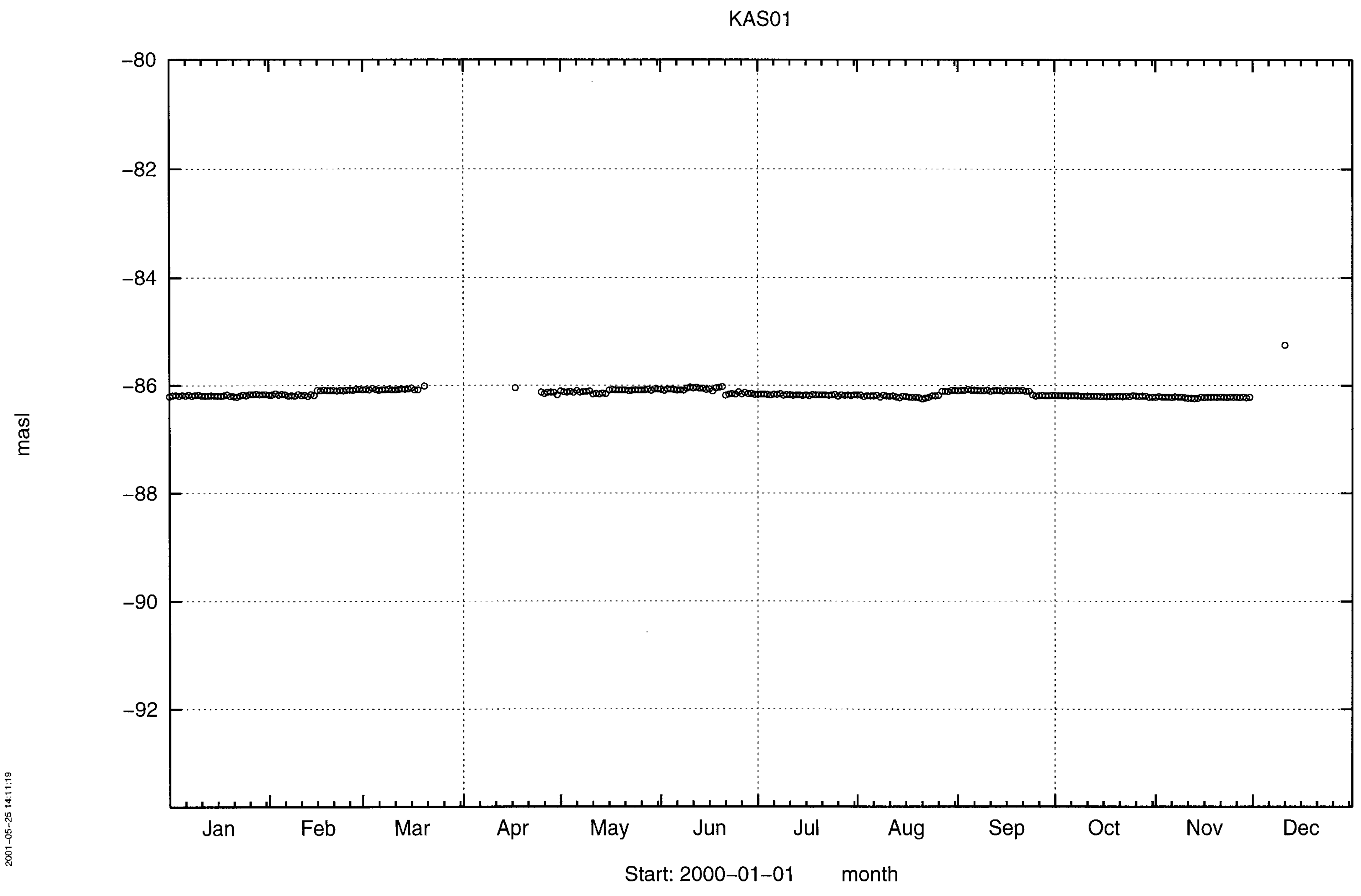

HLX05
masl
18
16
14
12
10
8
6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01 month
2001-05-25 14:11:18


HLX06
masl
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:19

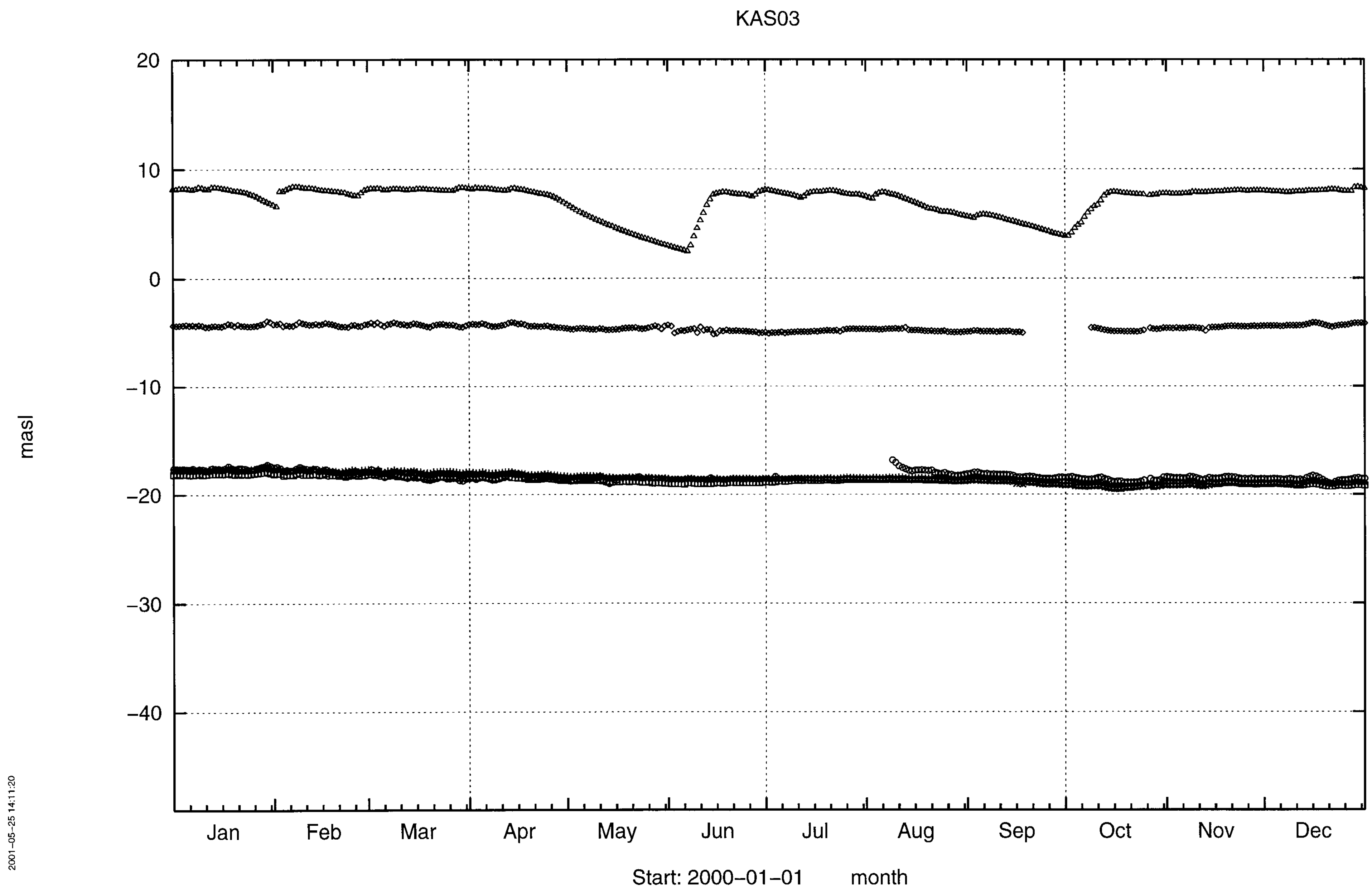

HLX07
masl
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:19

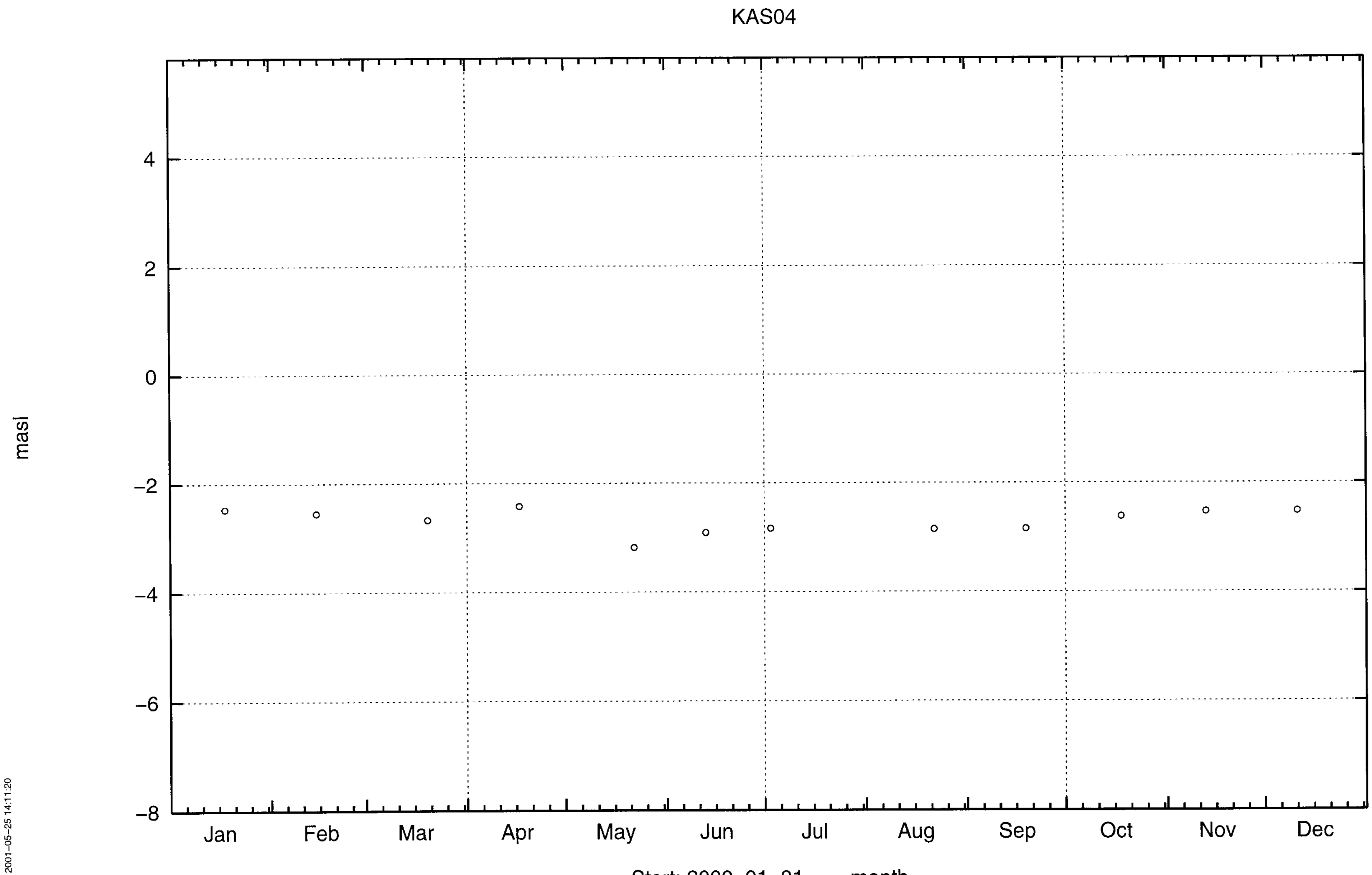


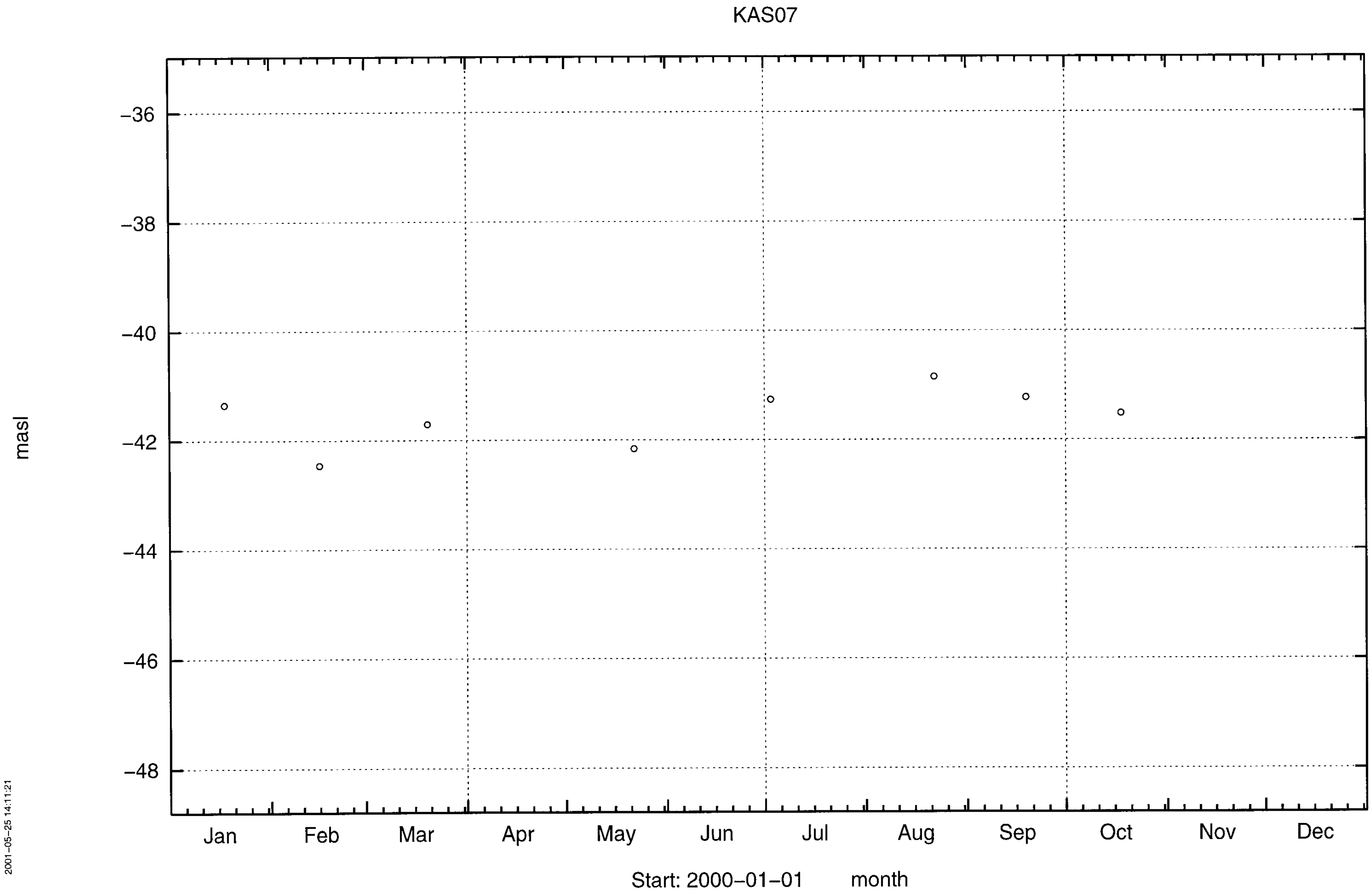
2001-05-25 14:11:19

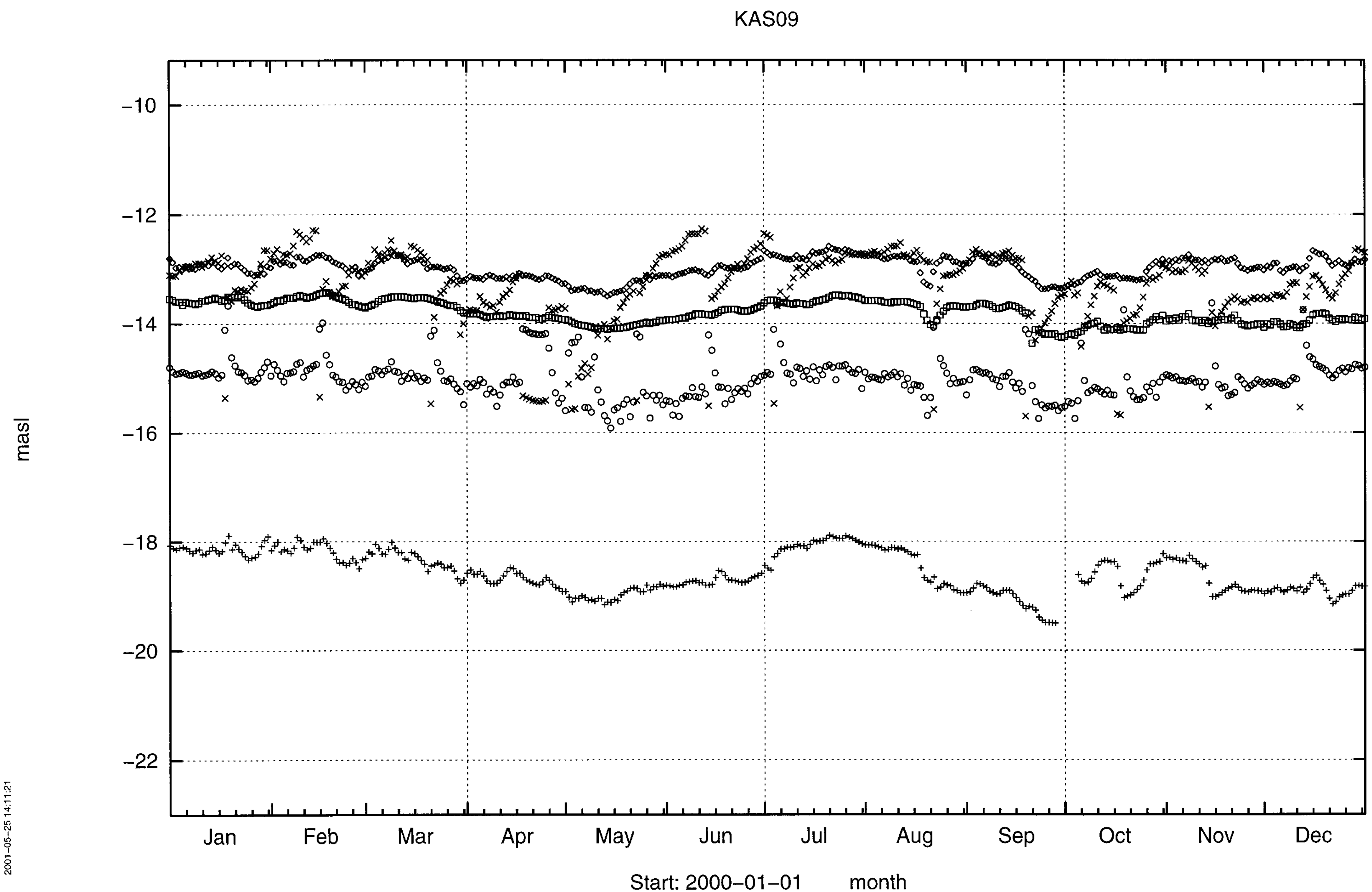


KAS01
masl
-80
-82
-84
-86
-88
-90
-92
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:19


KAS03
20
10
0
−10
−20
−30
−40
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:20

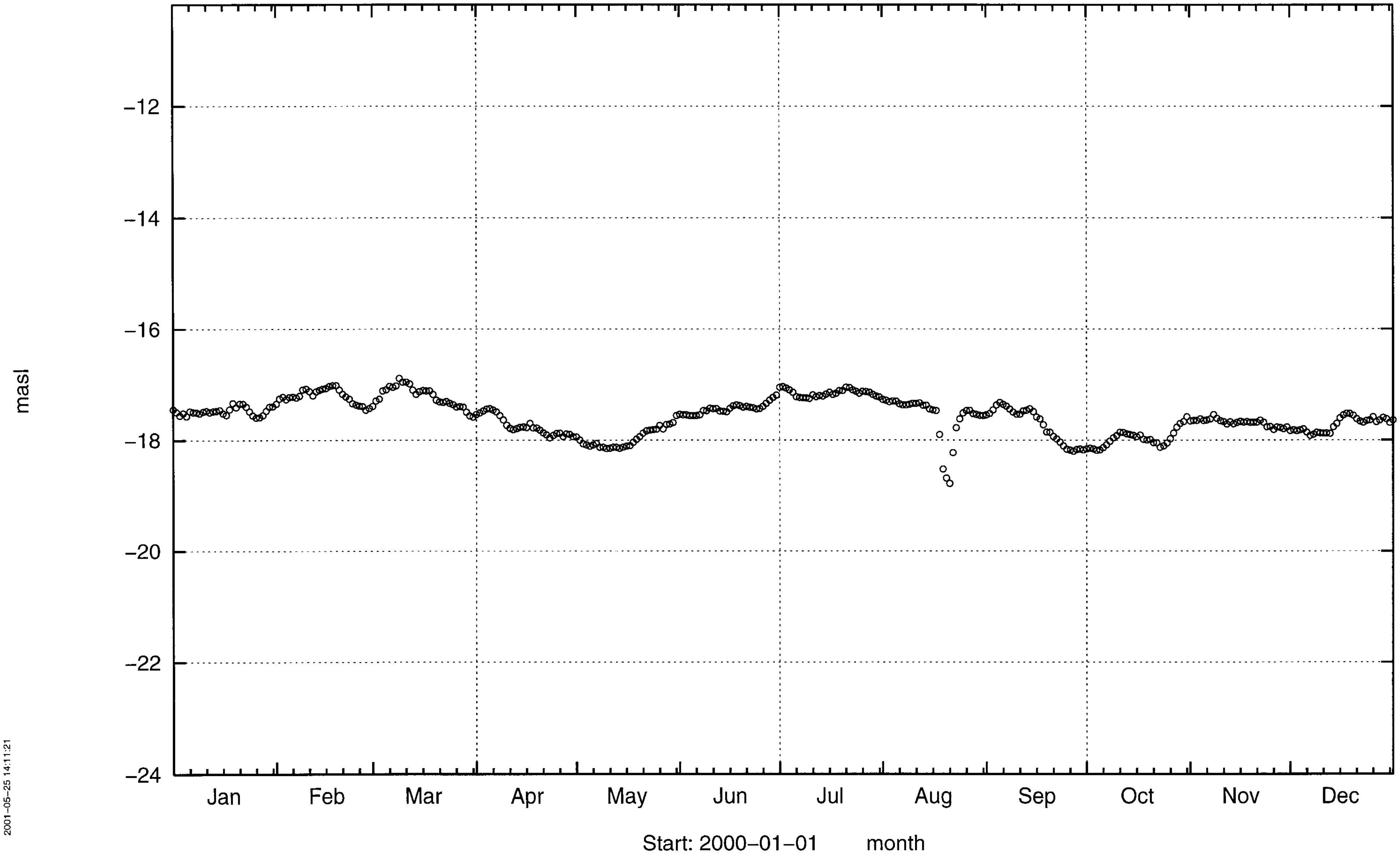

KAS04
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:20


KAS07
masl
-36
-38
-40
-42
-44
-46
-48
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:21

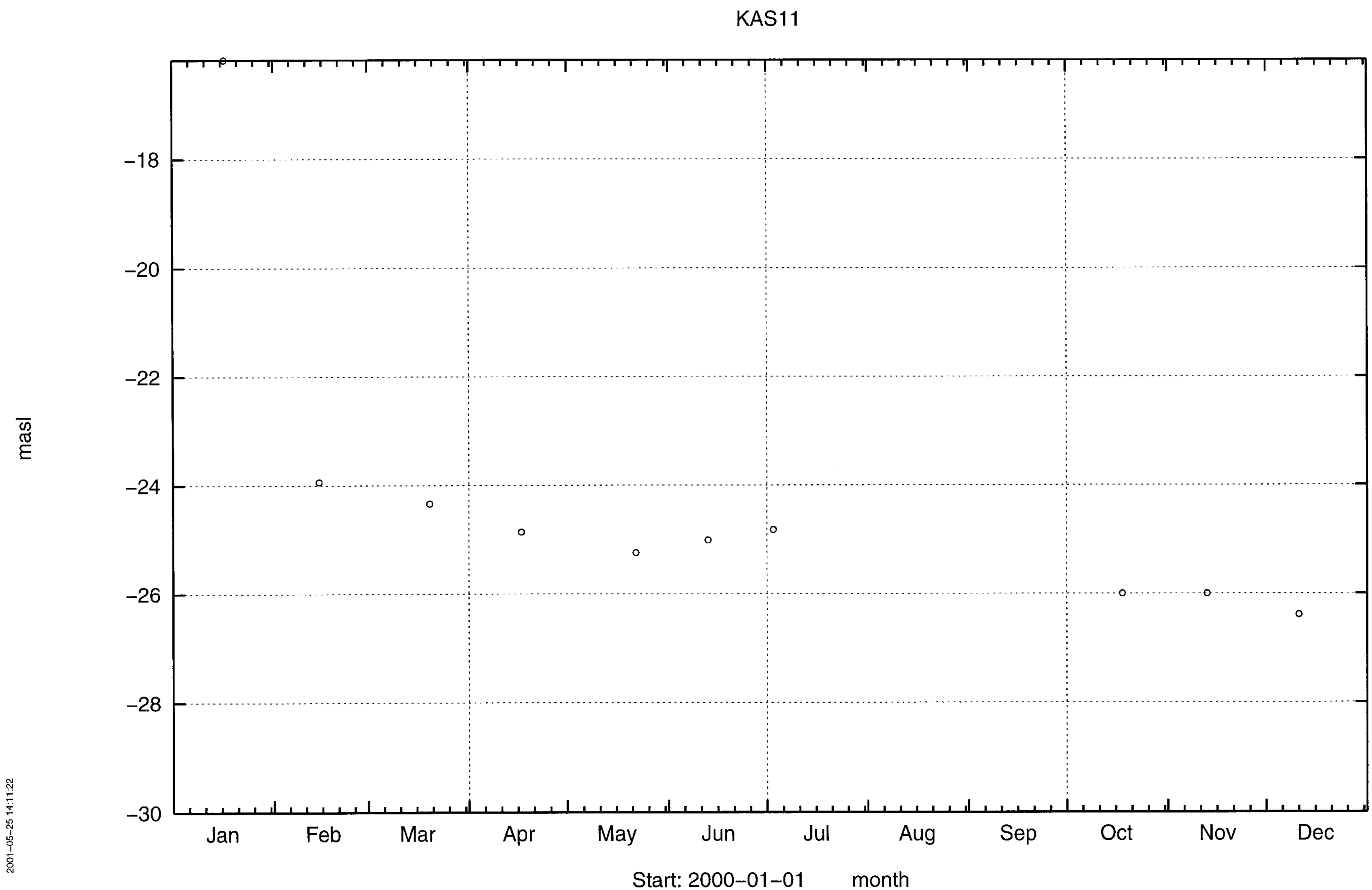


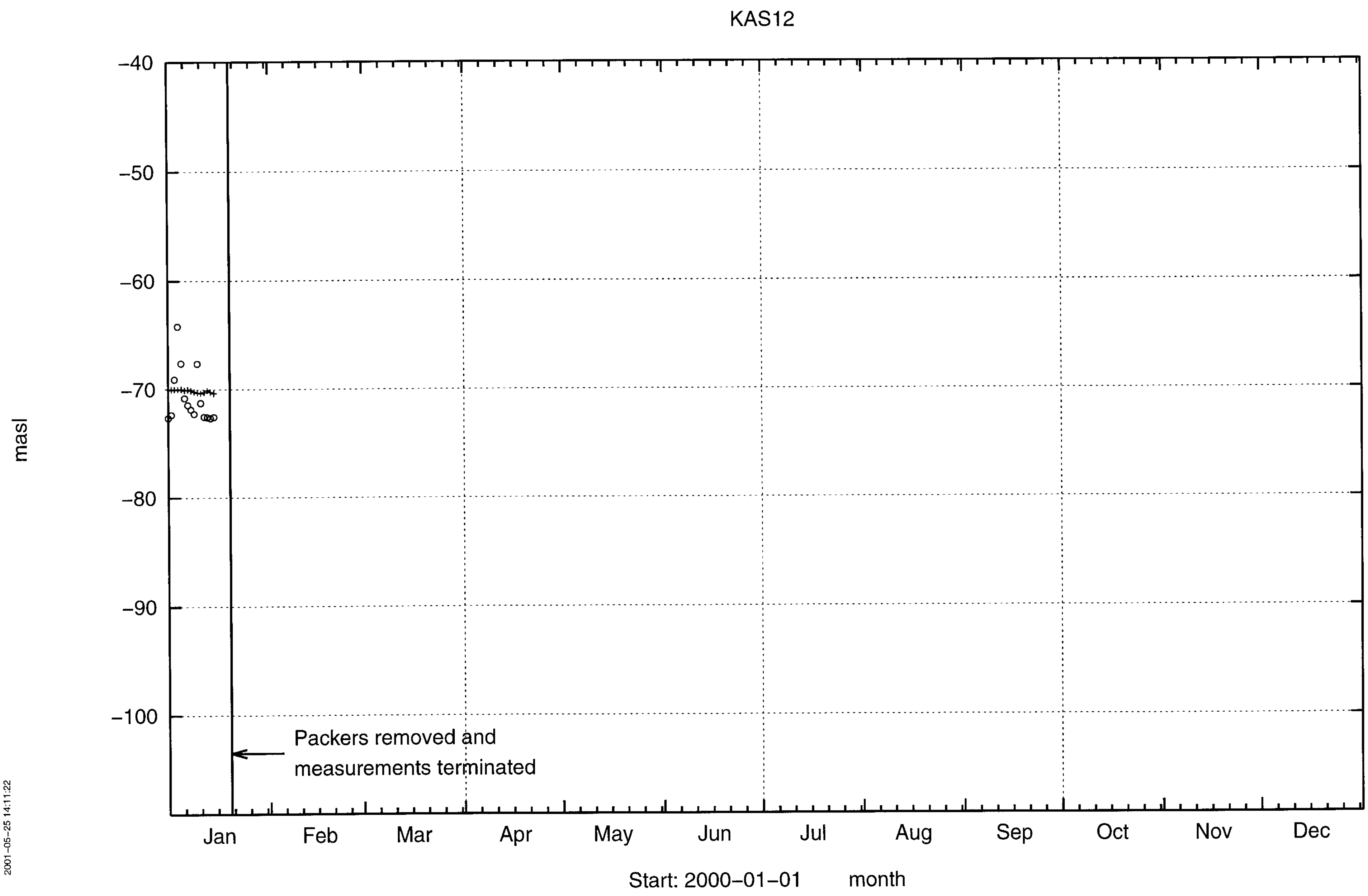
KAS09
masl
-10
-12
-14
-16
-18
-20
-22
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:21

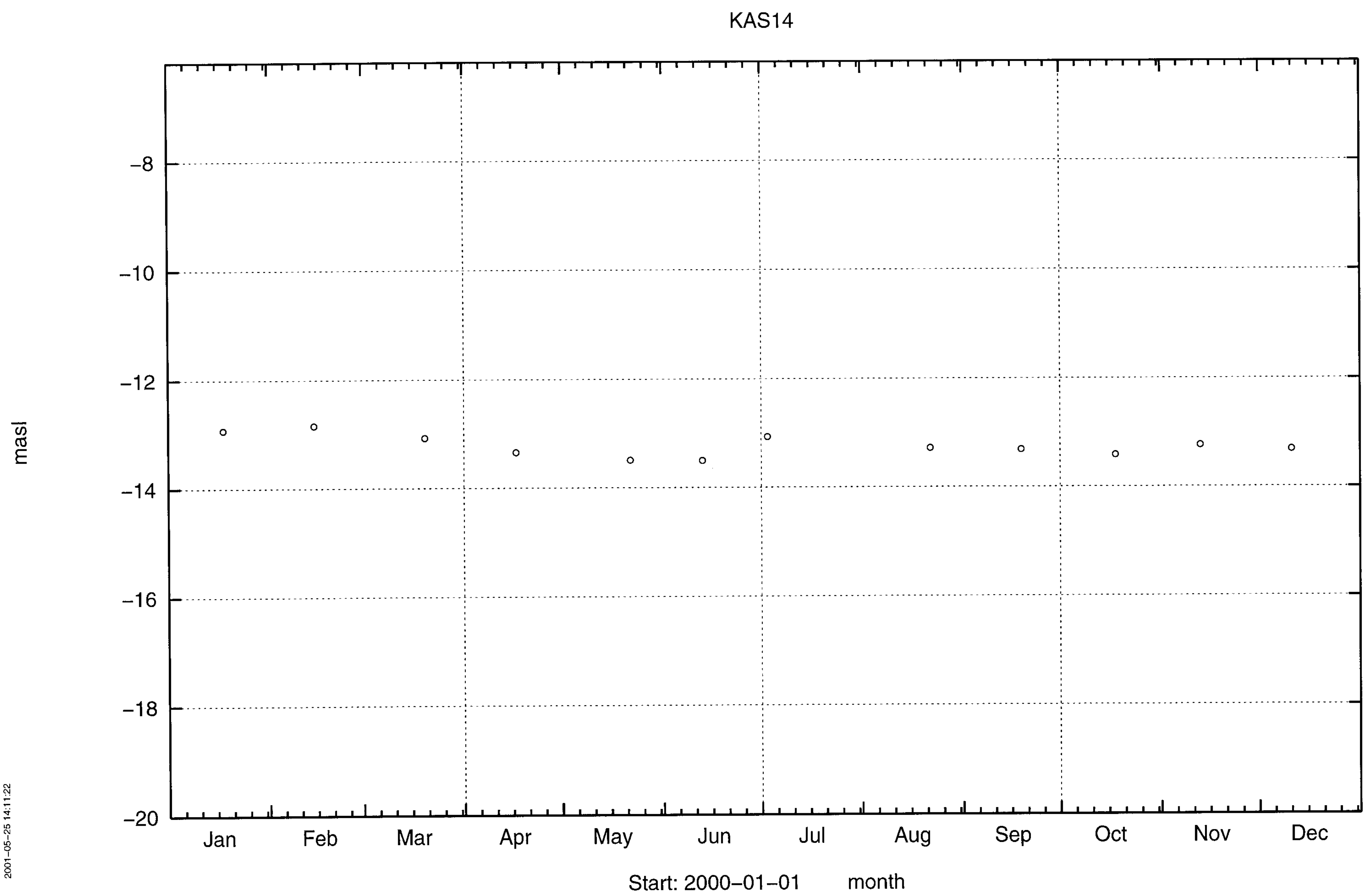
KAS10

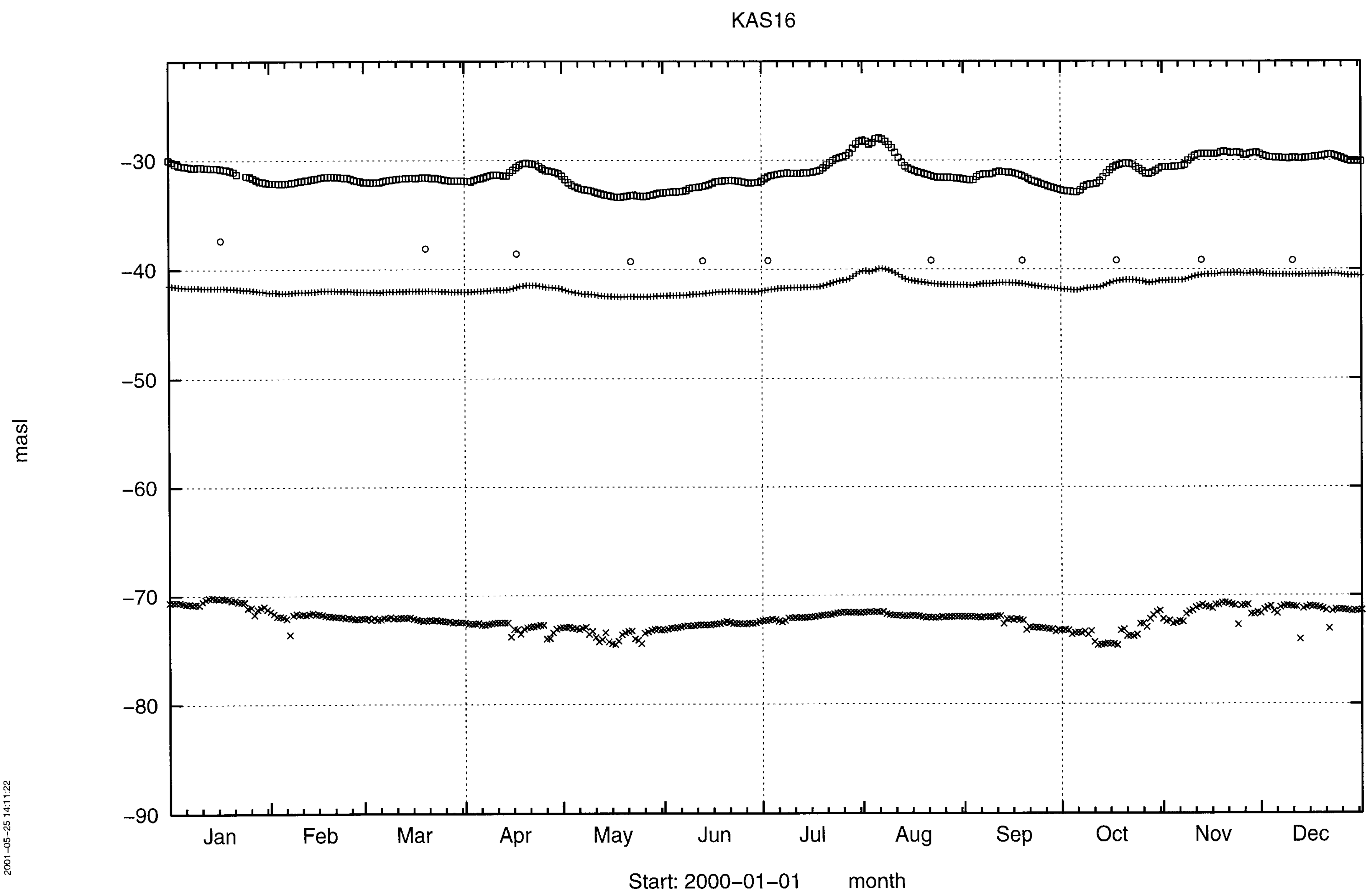


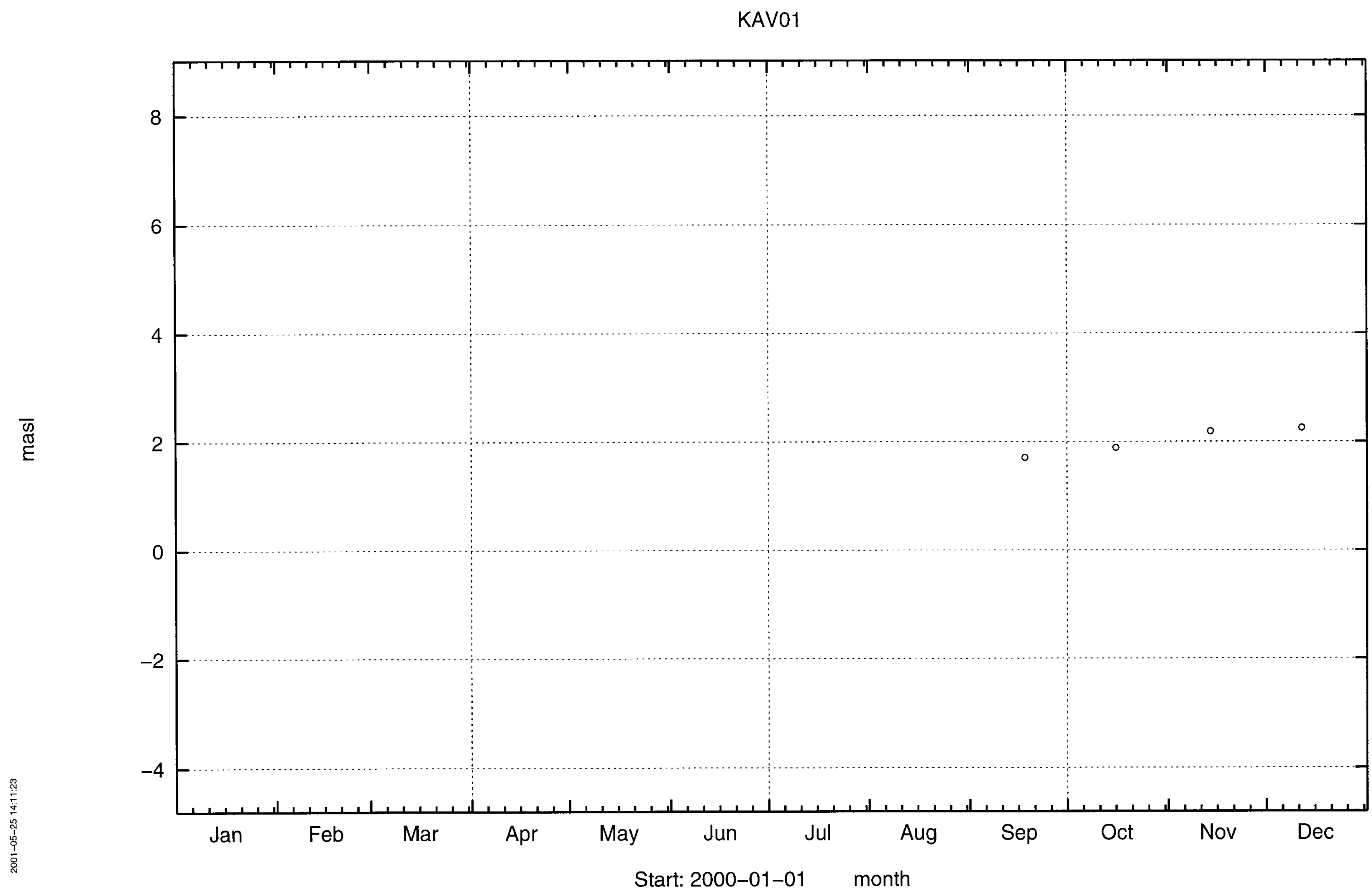
2001-05-25 14:11:21

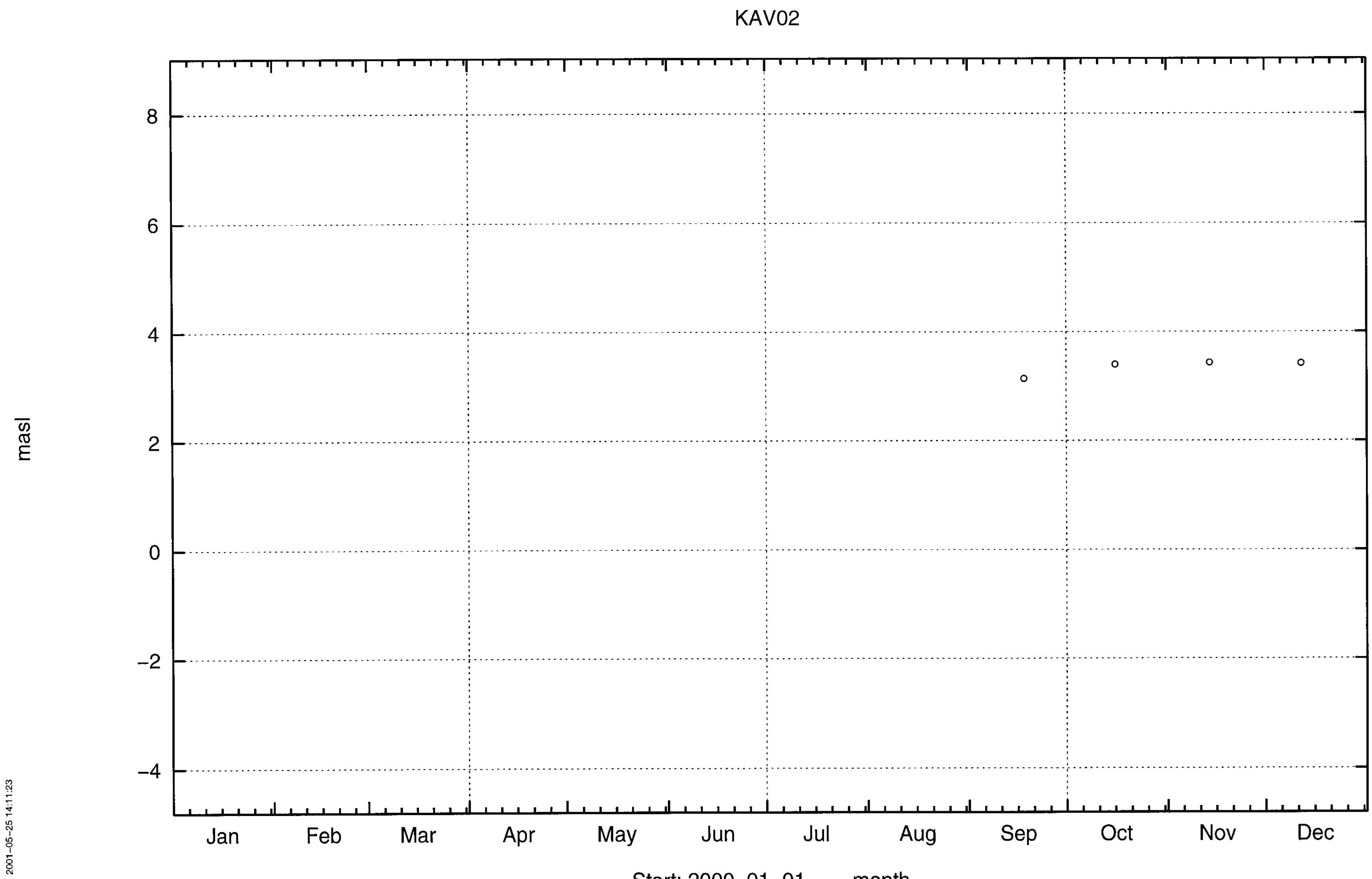

KAS11
masl
–18
–20
–22
–24
–26
–28
–30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–25 14:11:22

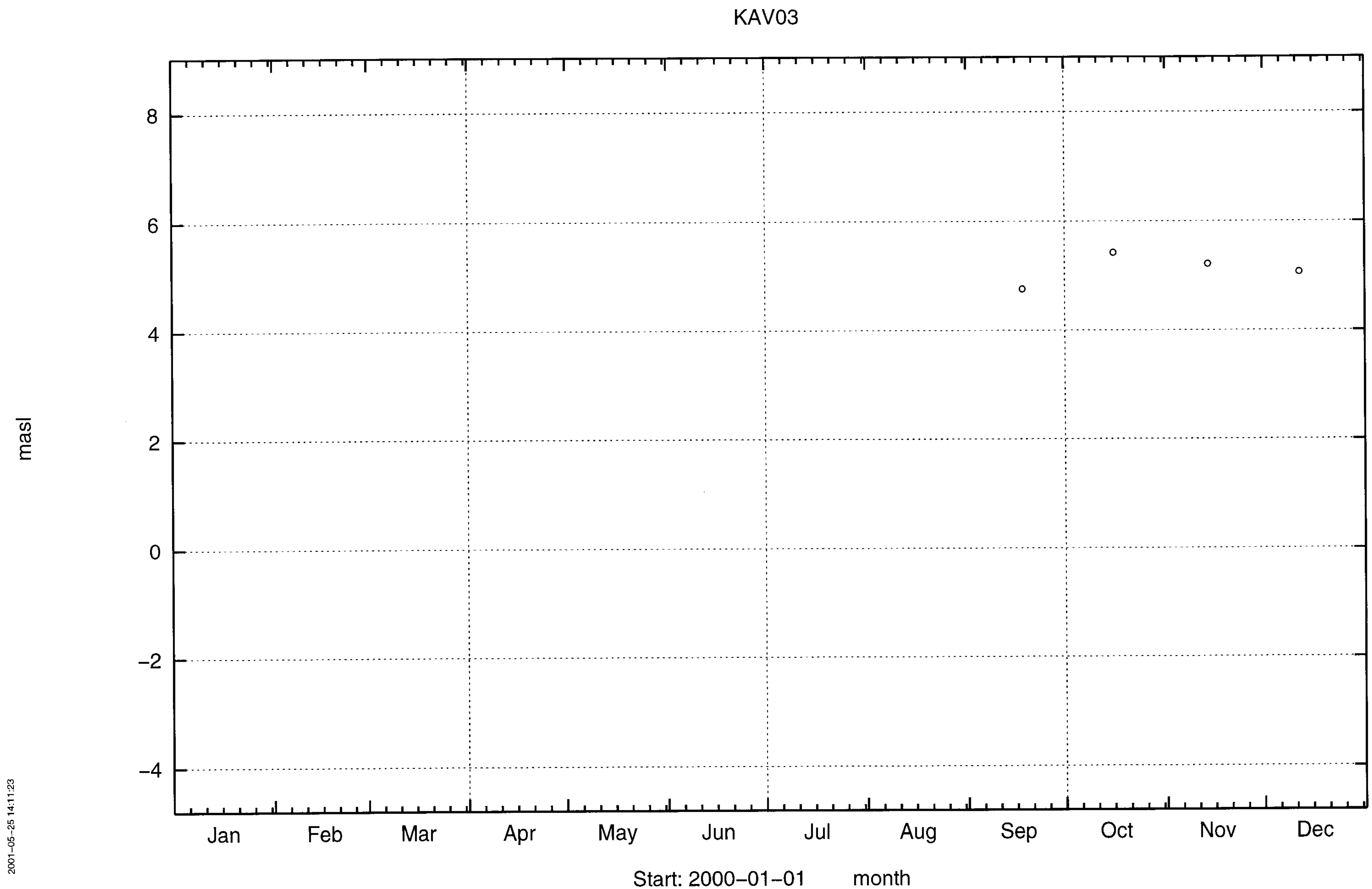

KAS12
-40
-50
-60
-70
-80
-90
-100
masl
Packers removed and
measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01 month
2001-05-25 14:11:22

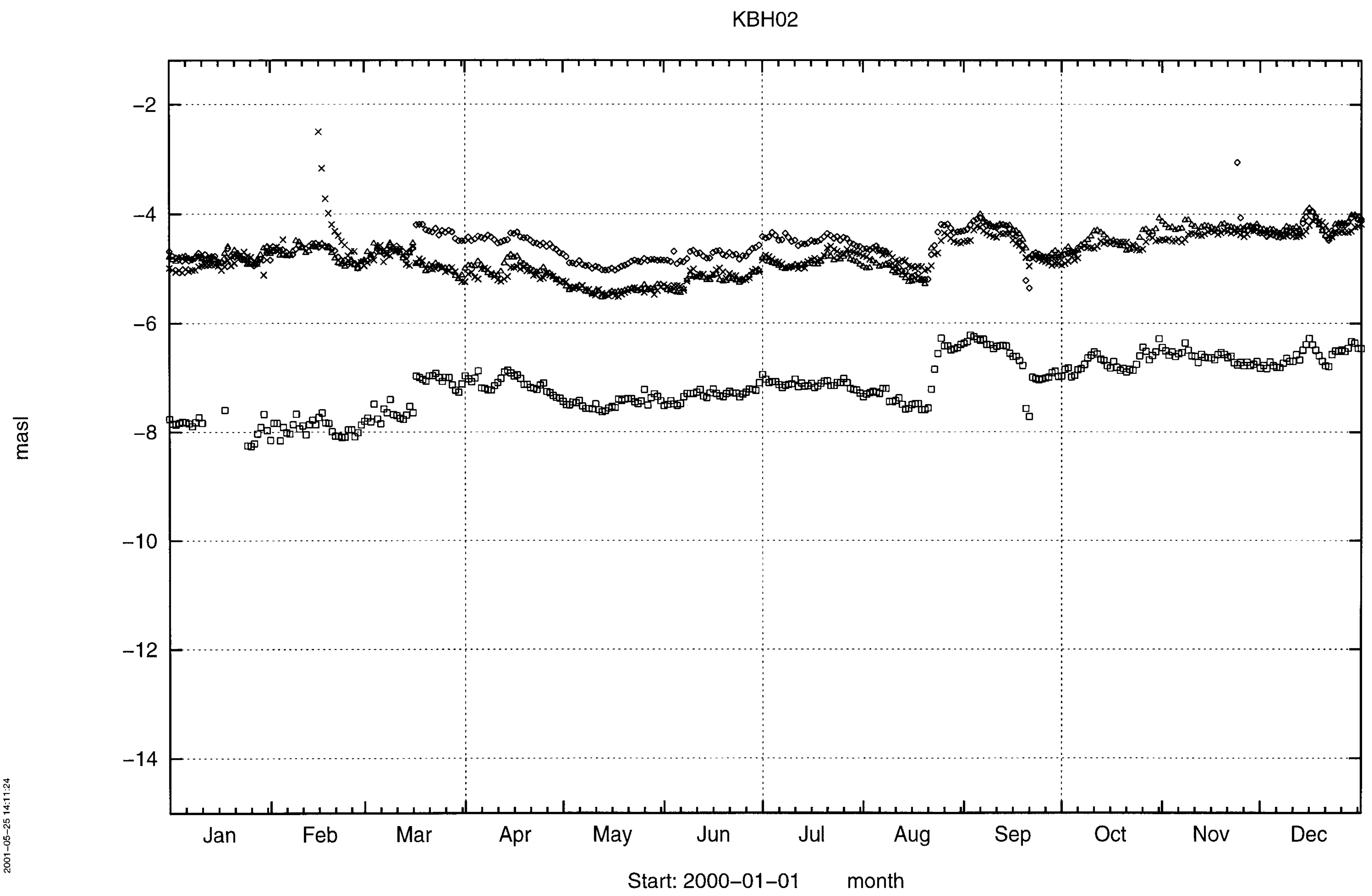

KAS14
masl
-8
-10
-12
-14
-16
-18
-20
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:22


KAS16
masl
-30
-40
-50
-60
-70
-80
-90
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:22

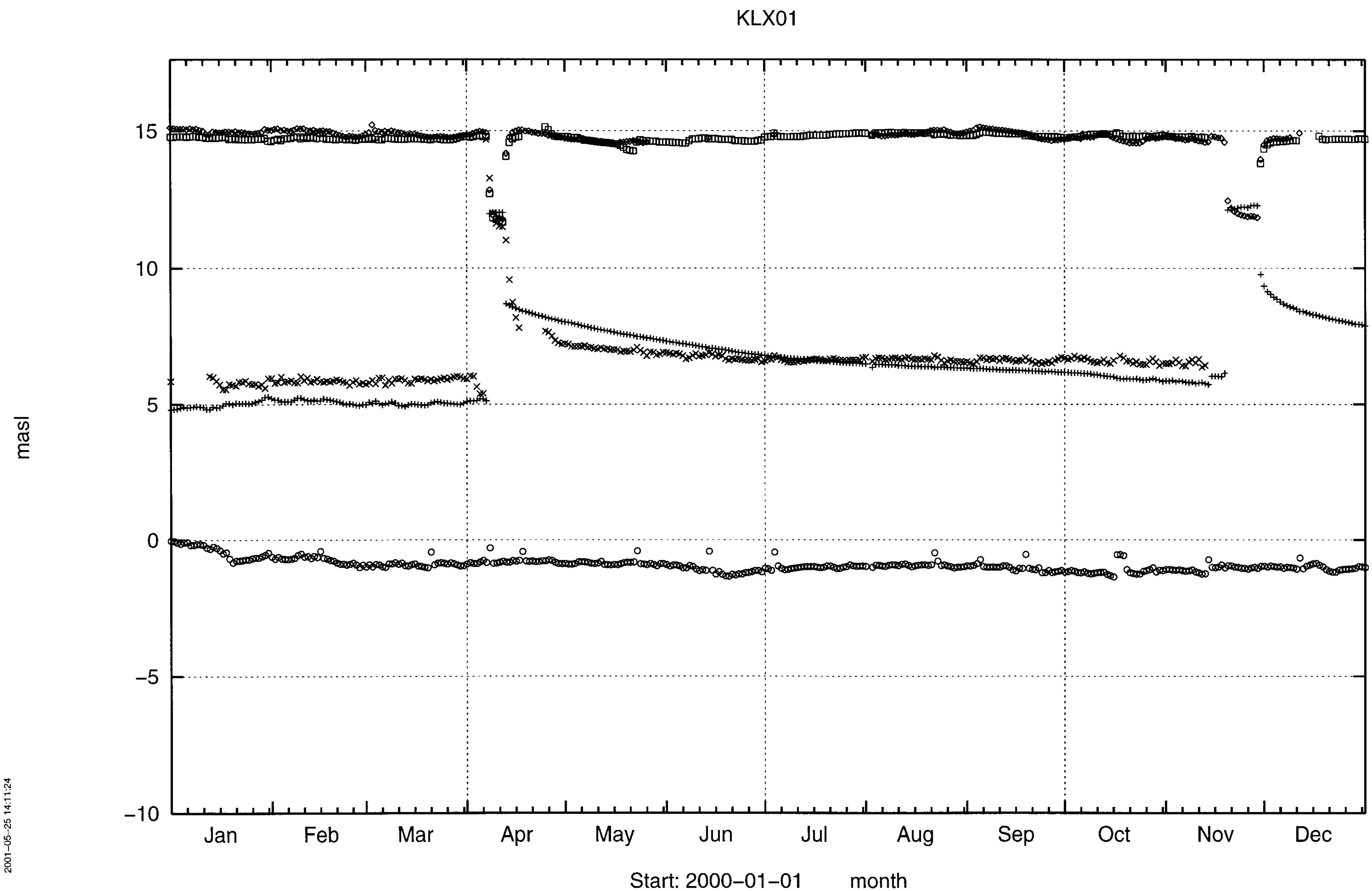

KAV01
masl
8
6
4
2
0
−2
−4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:23


KAV02
masl
8
6
4
2
0
−2
−4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:23


KAV03
8
6
4
2
0
−2
−4
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:23



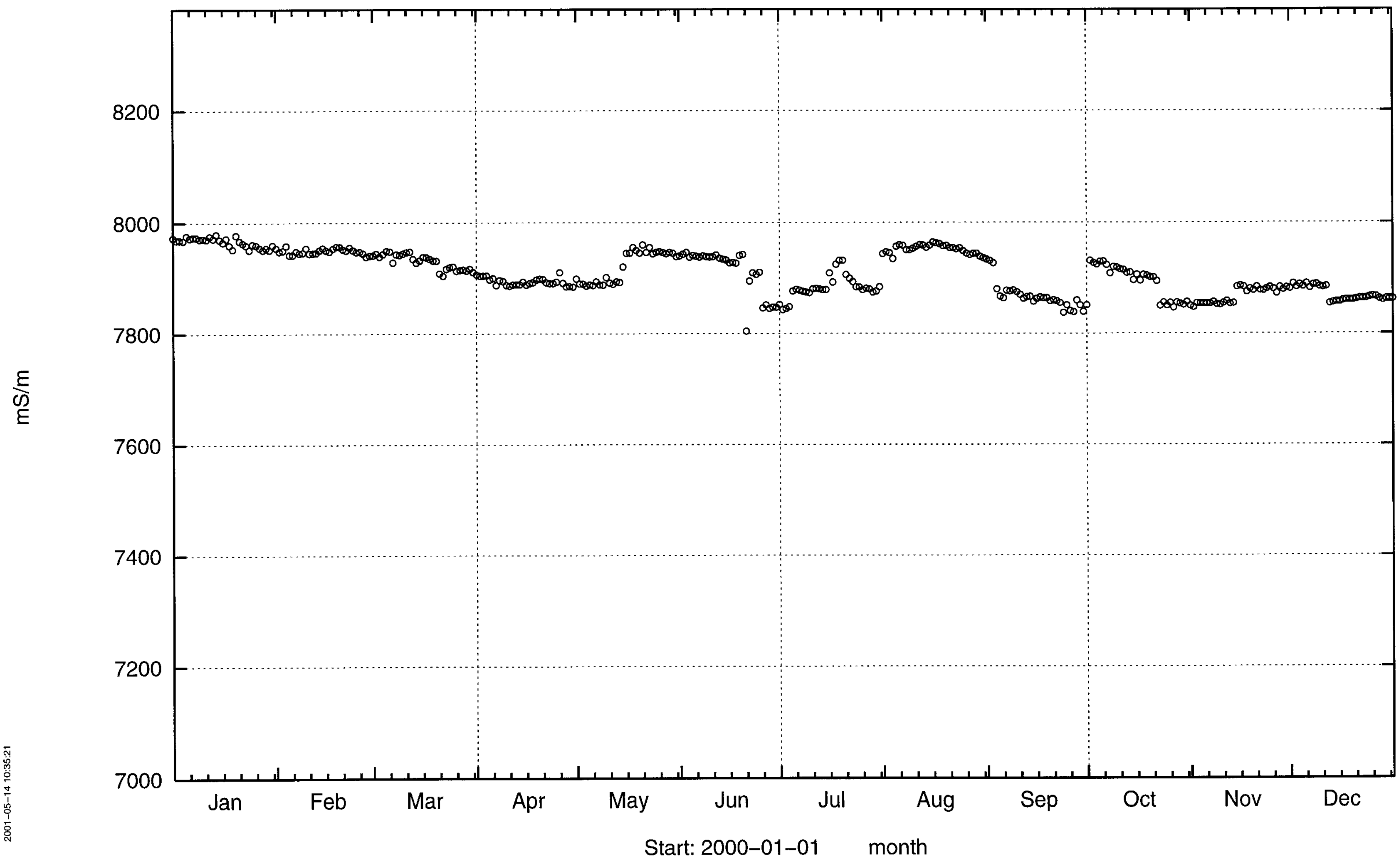
KBH02
masl
-2
-4
-6
-8
-10
-12
-14
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-25 14:11:24



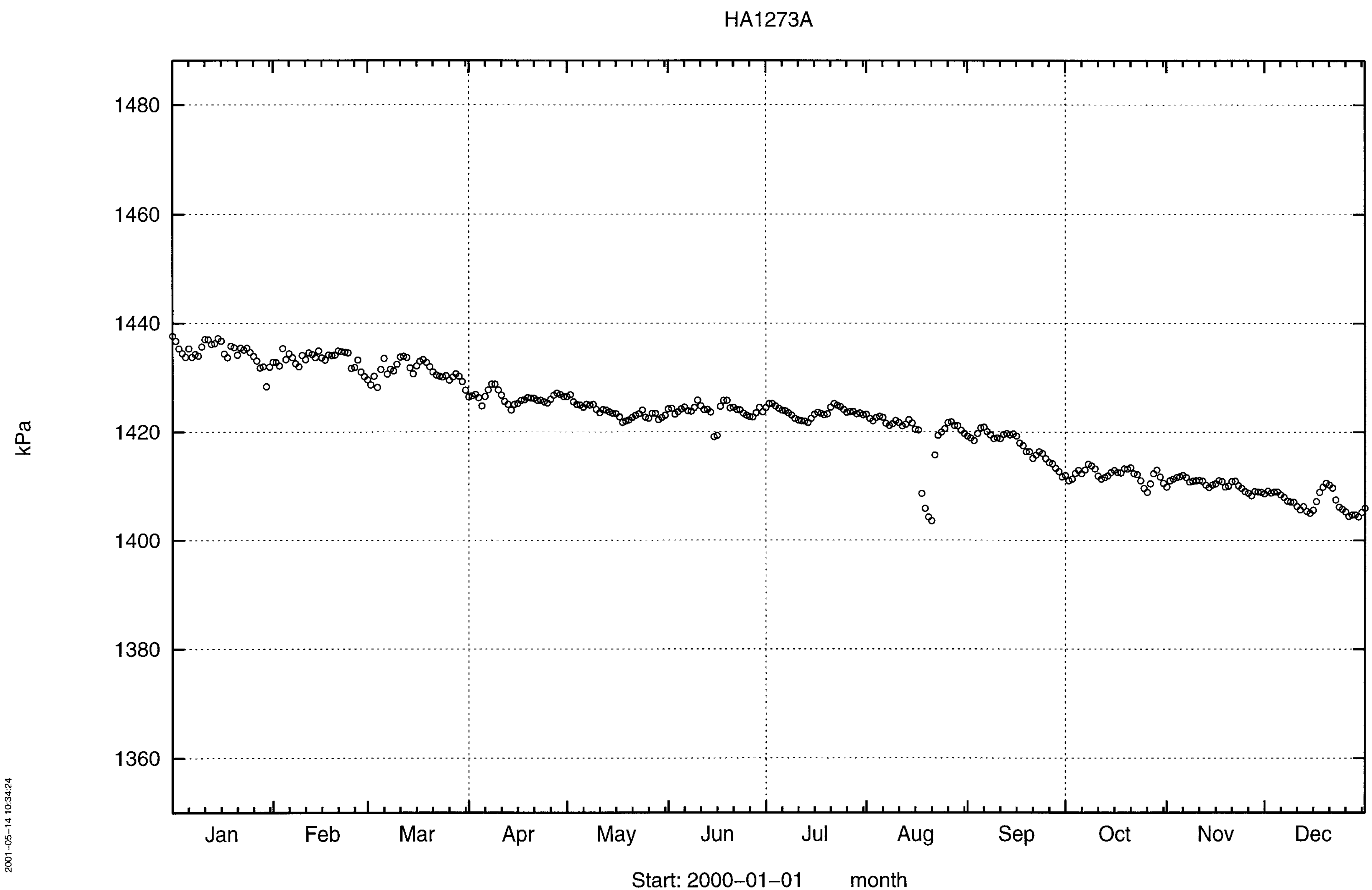
KLX01
masl
15
10
5
0
−5
−10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−25 14:11:24

Appendix 3: Electrical conductivity in surface boreholes

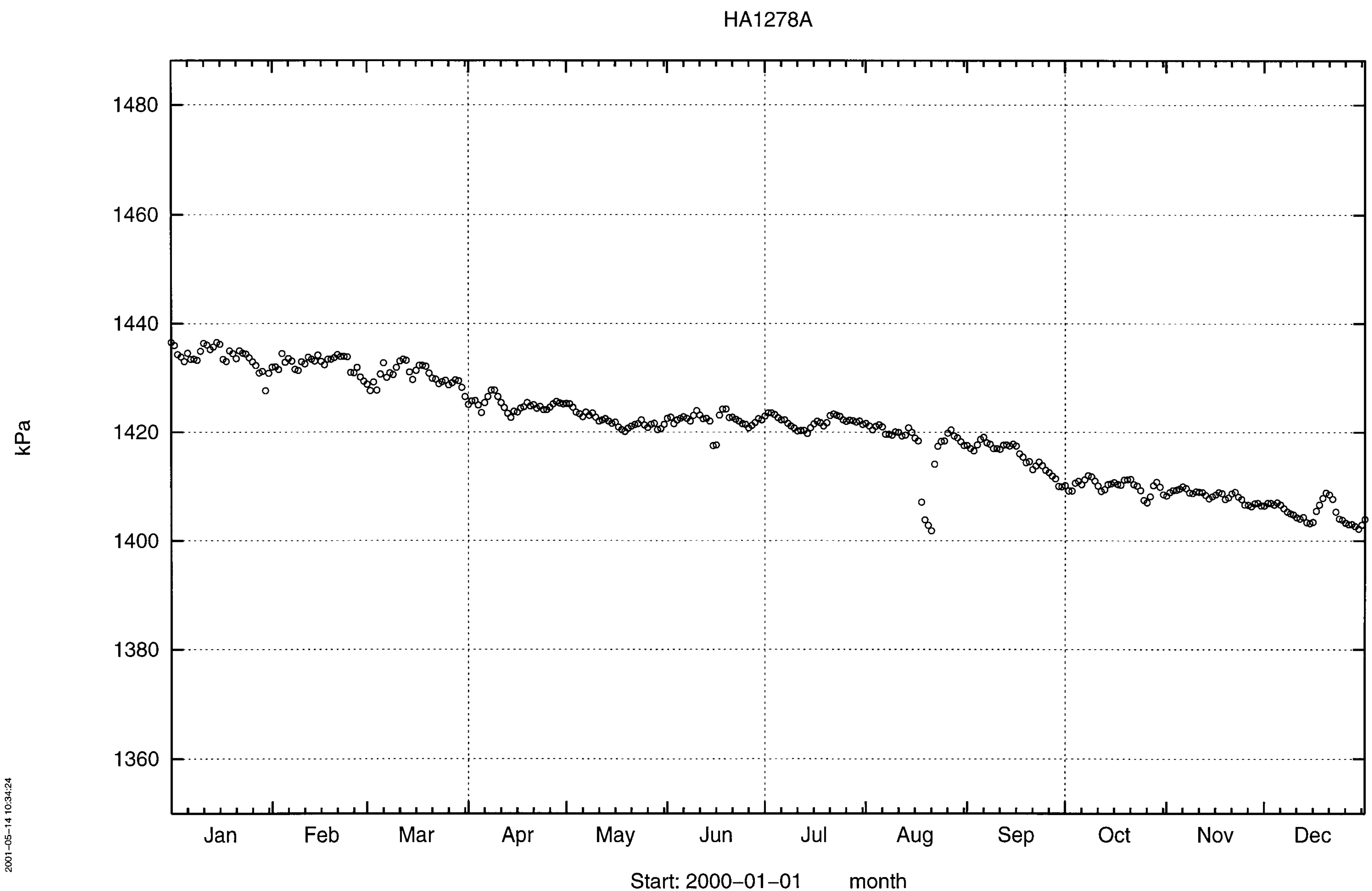
KAS09 Electrical Conductivity



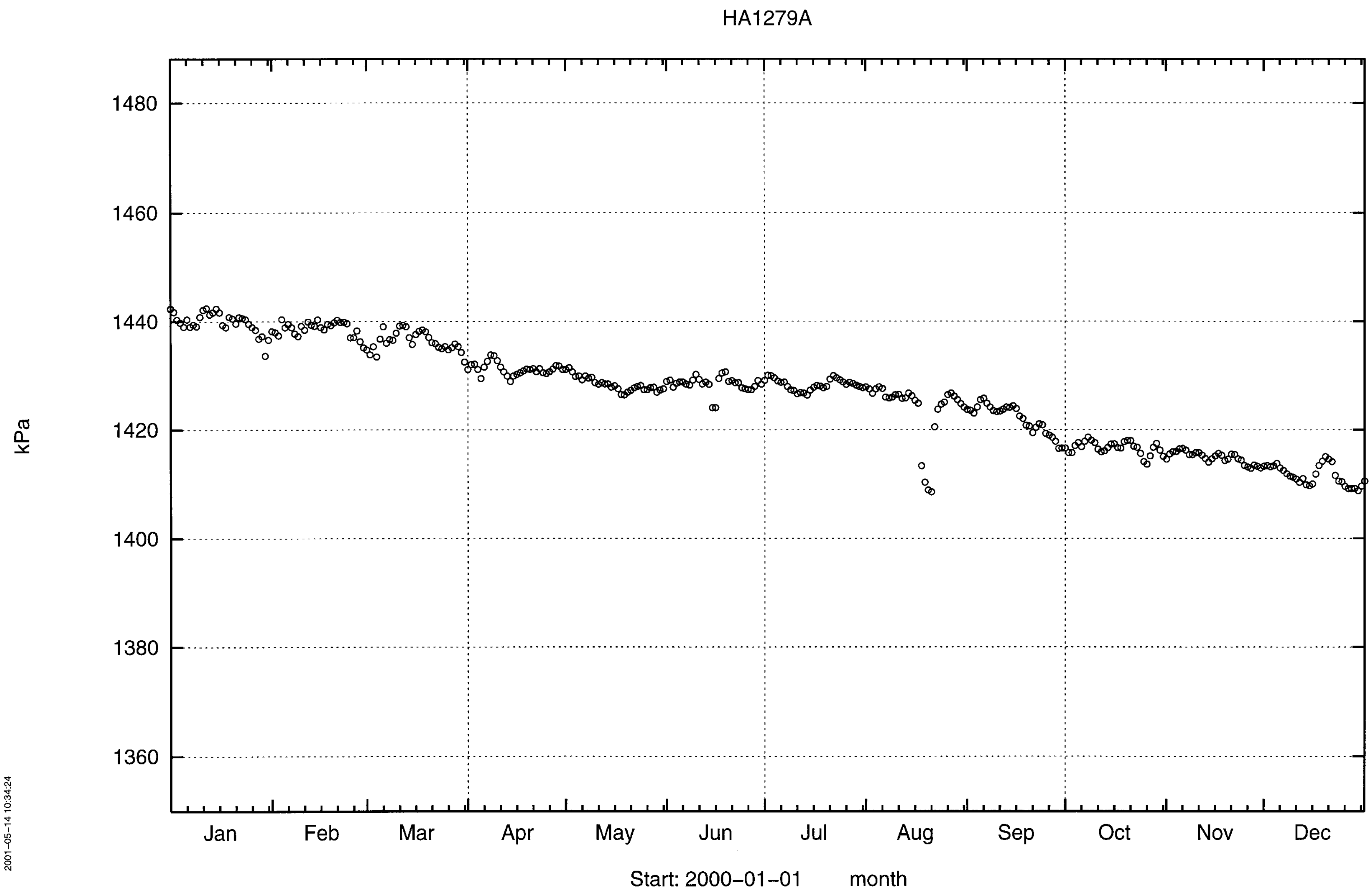
Appendix 4: Groundwater pressure in tunnel boreholes



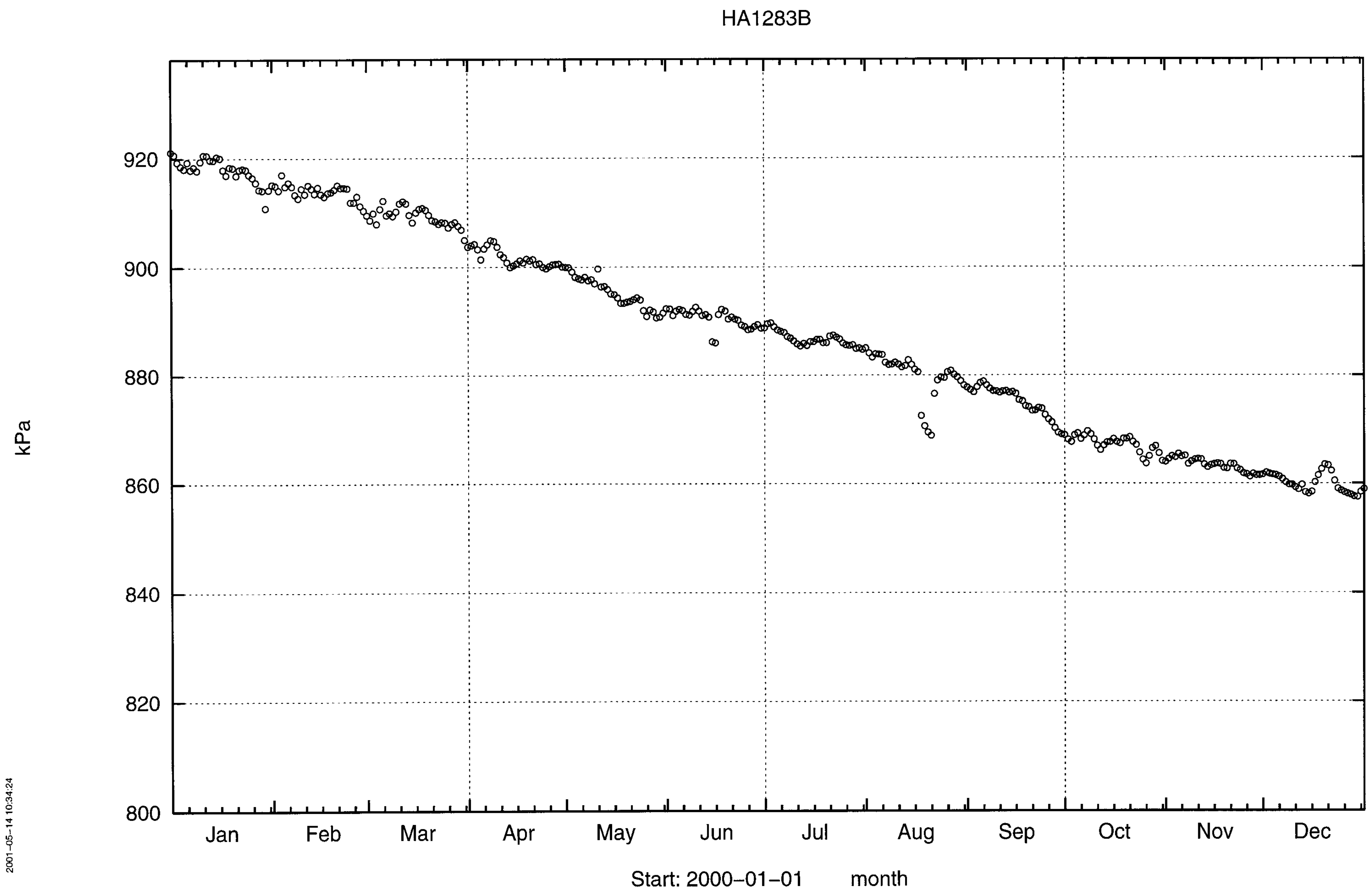
HA1273A
kPa
1480
1460
1440
1420
1400
1380
1360
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−14 10:34:24



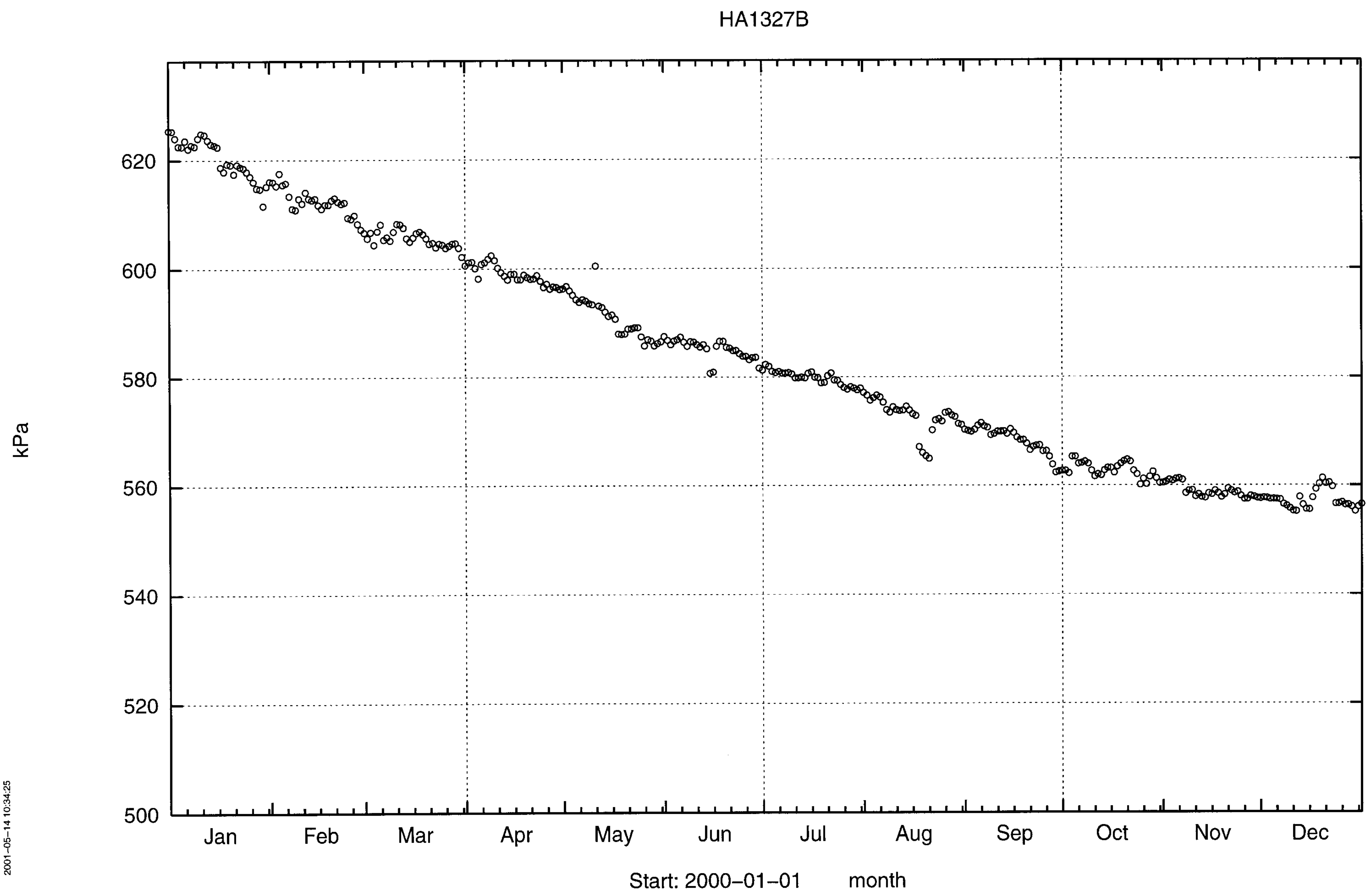
2001−05−14 10:34:24



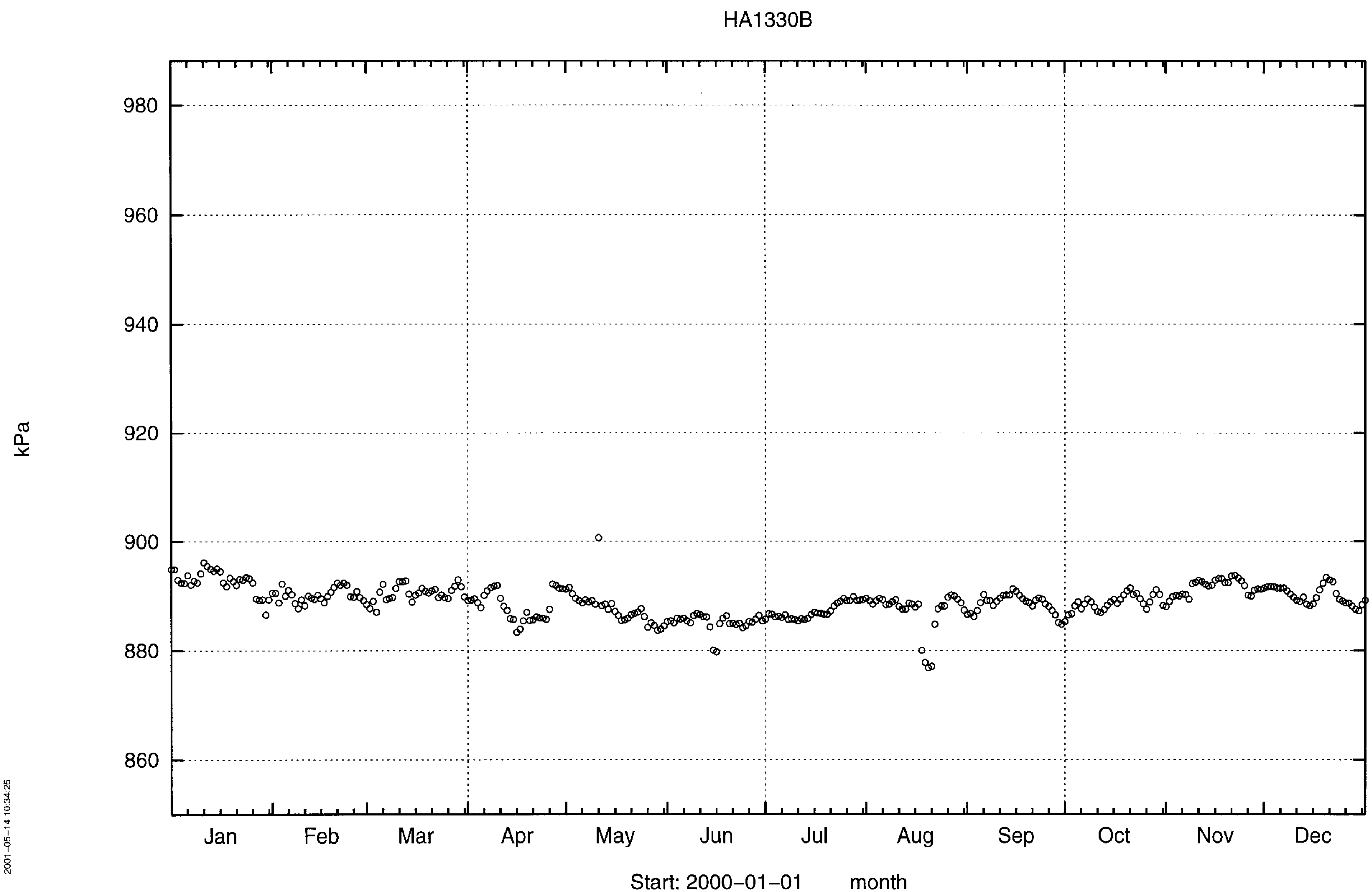
HA1279A
kPa
1480
1460
1440
1420
1400
1380
1360
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:24



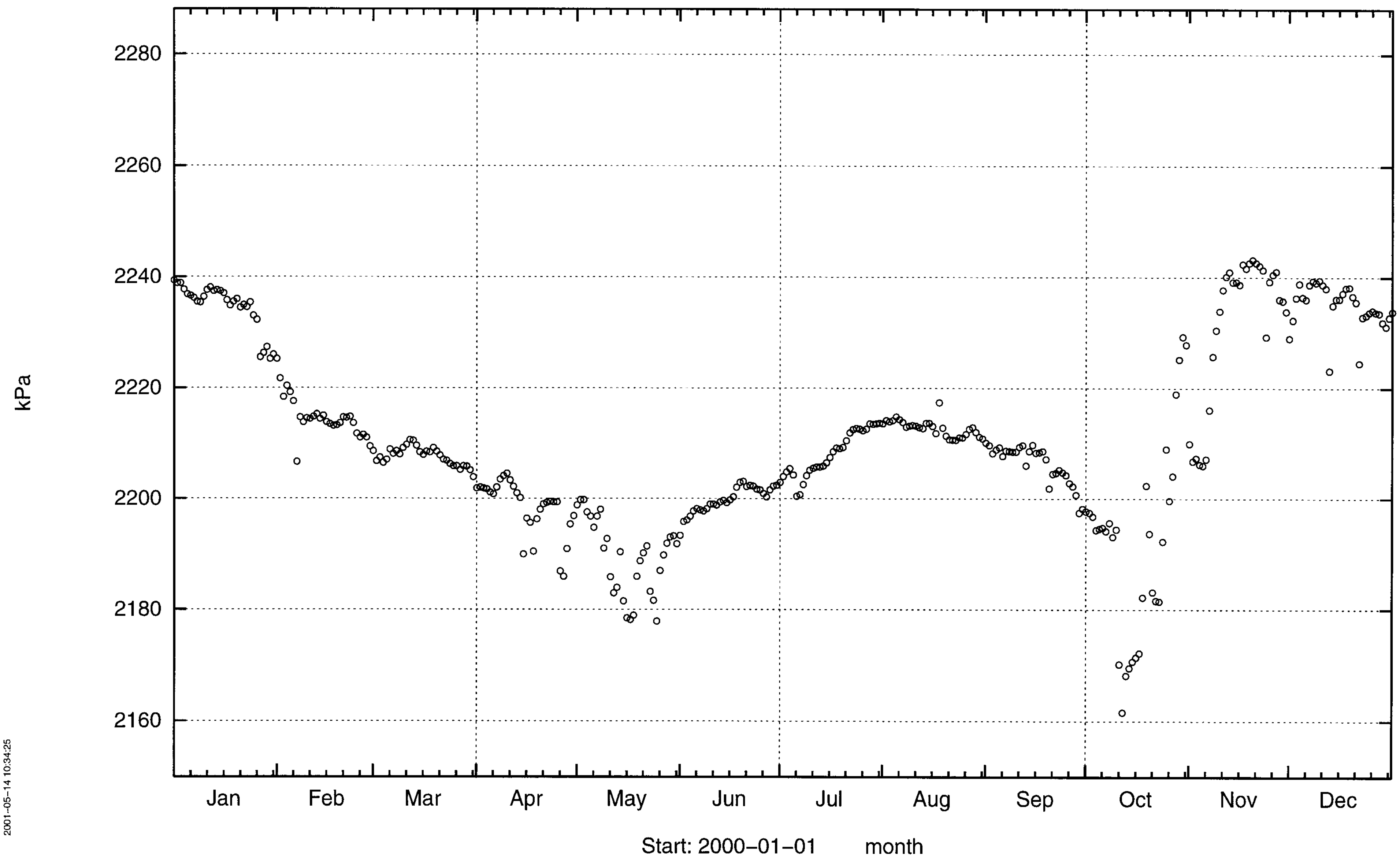
HA1283B
kPa
920
900
880
860
840
820
800
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:24



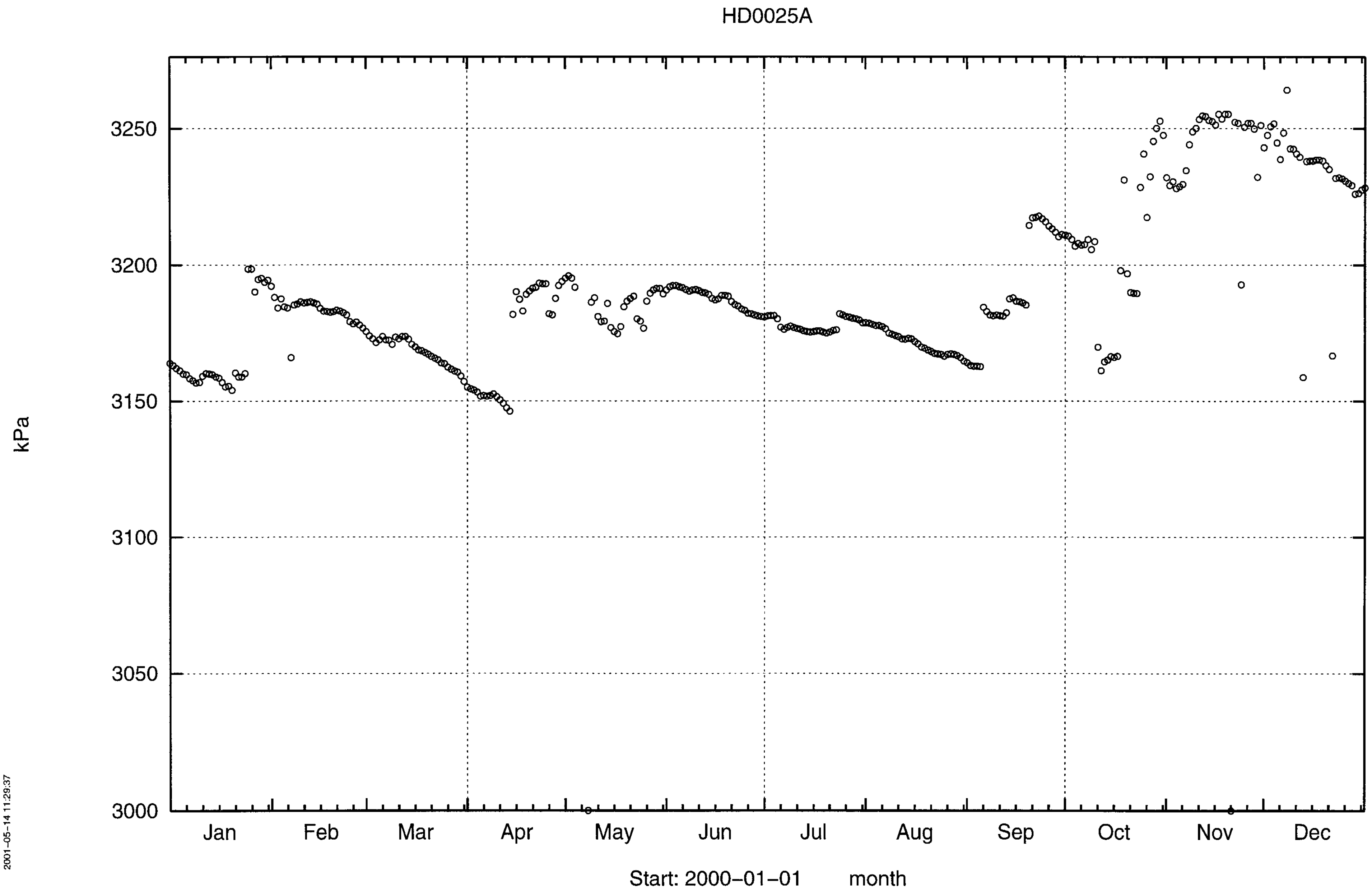
2001–05–14 10:34:25


HA1330B
kPa
980
960
940
920
900
880
860
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:25

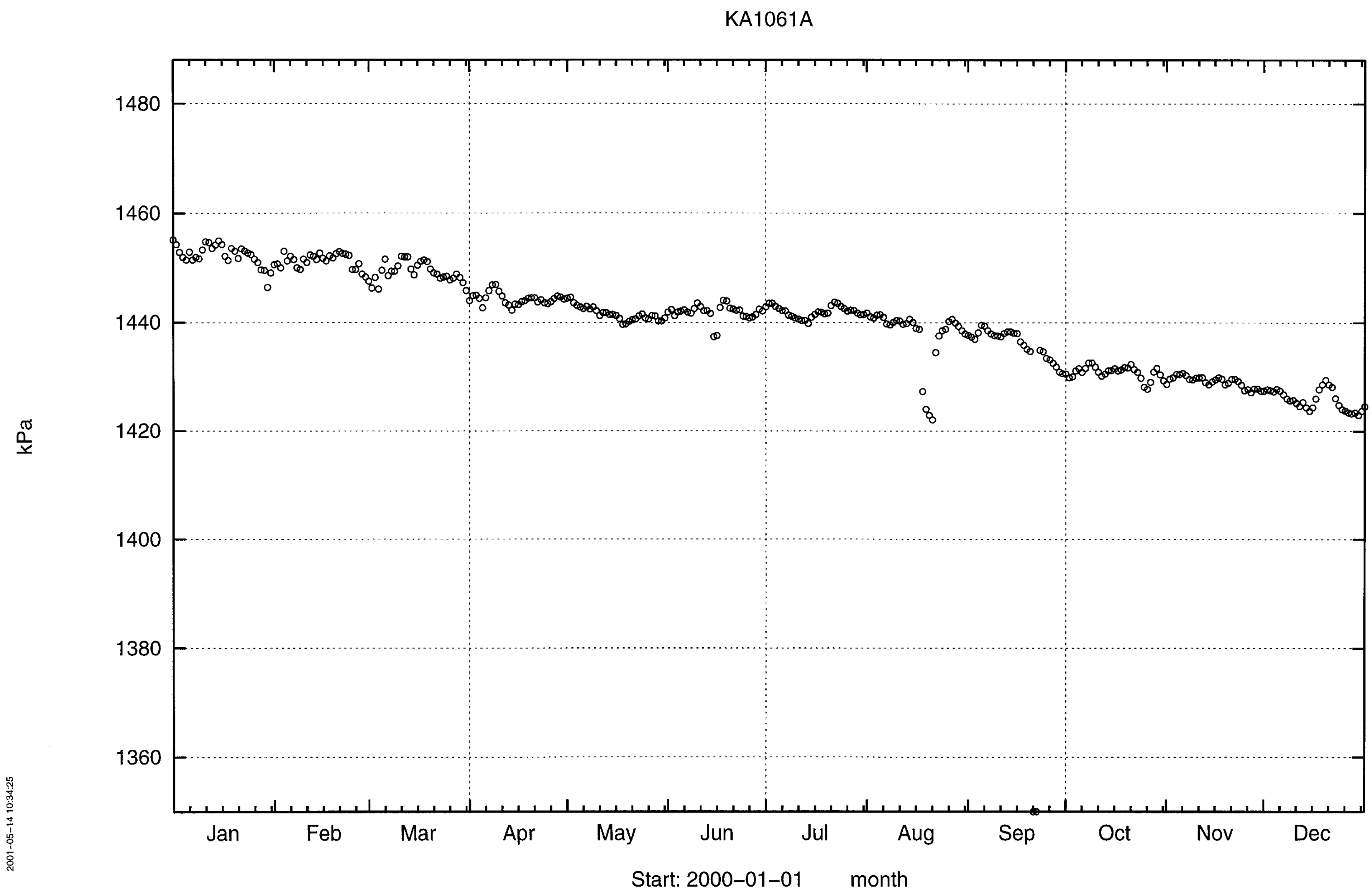
HA1960A

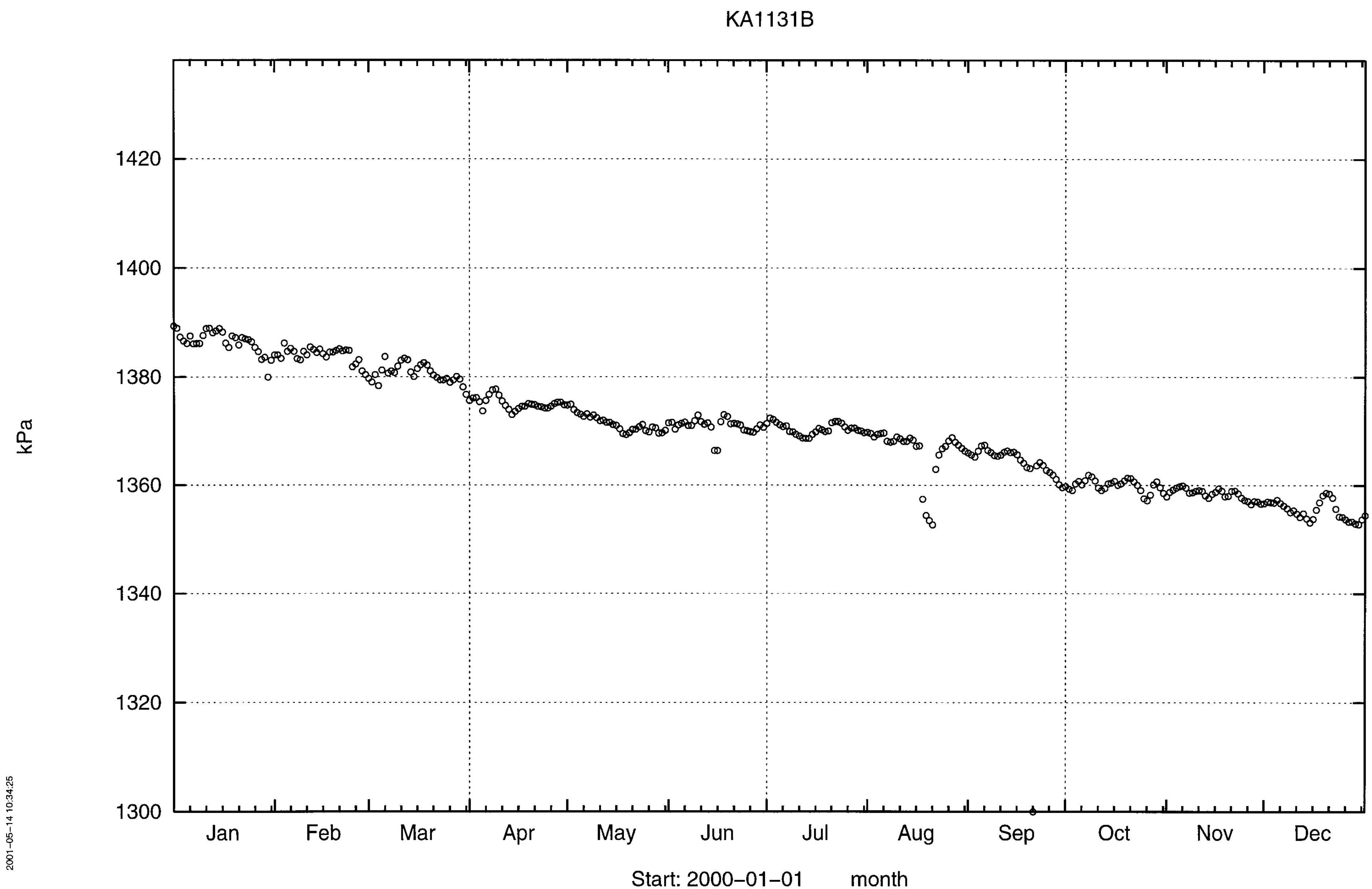


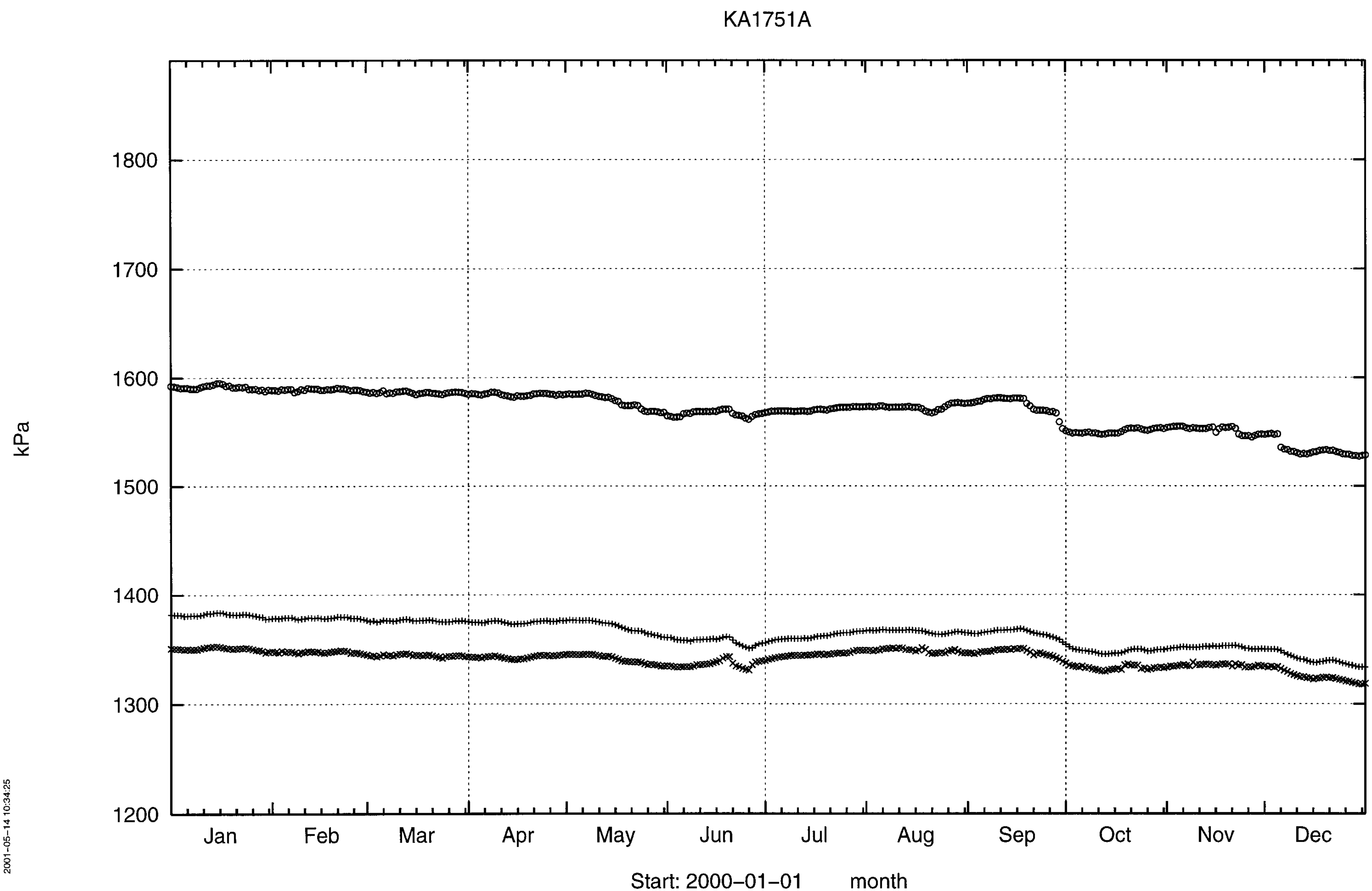
2001-05-14 10:34:25

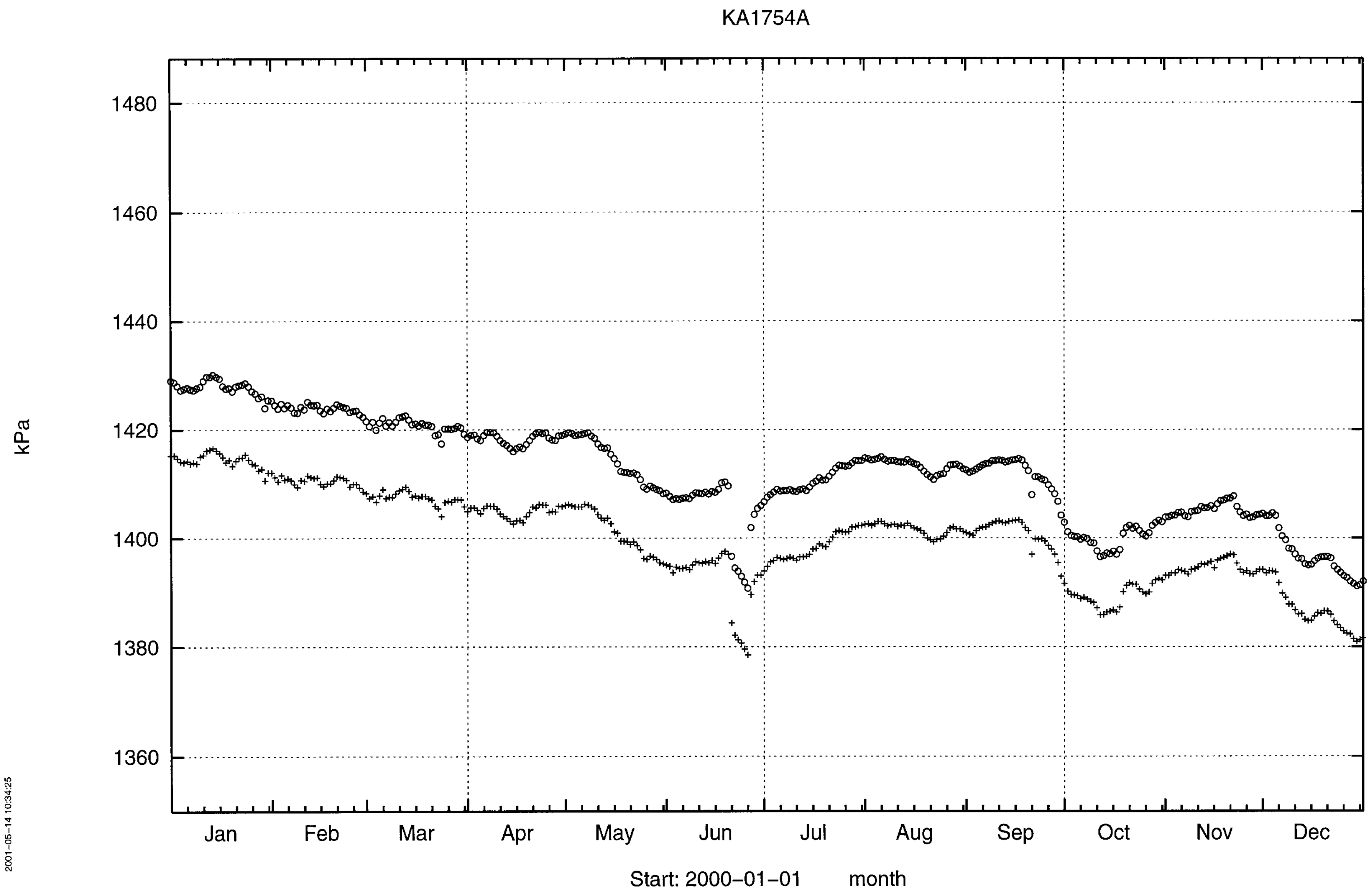


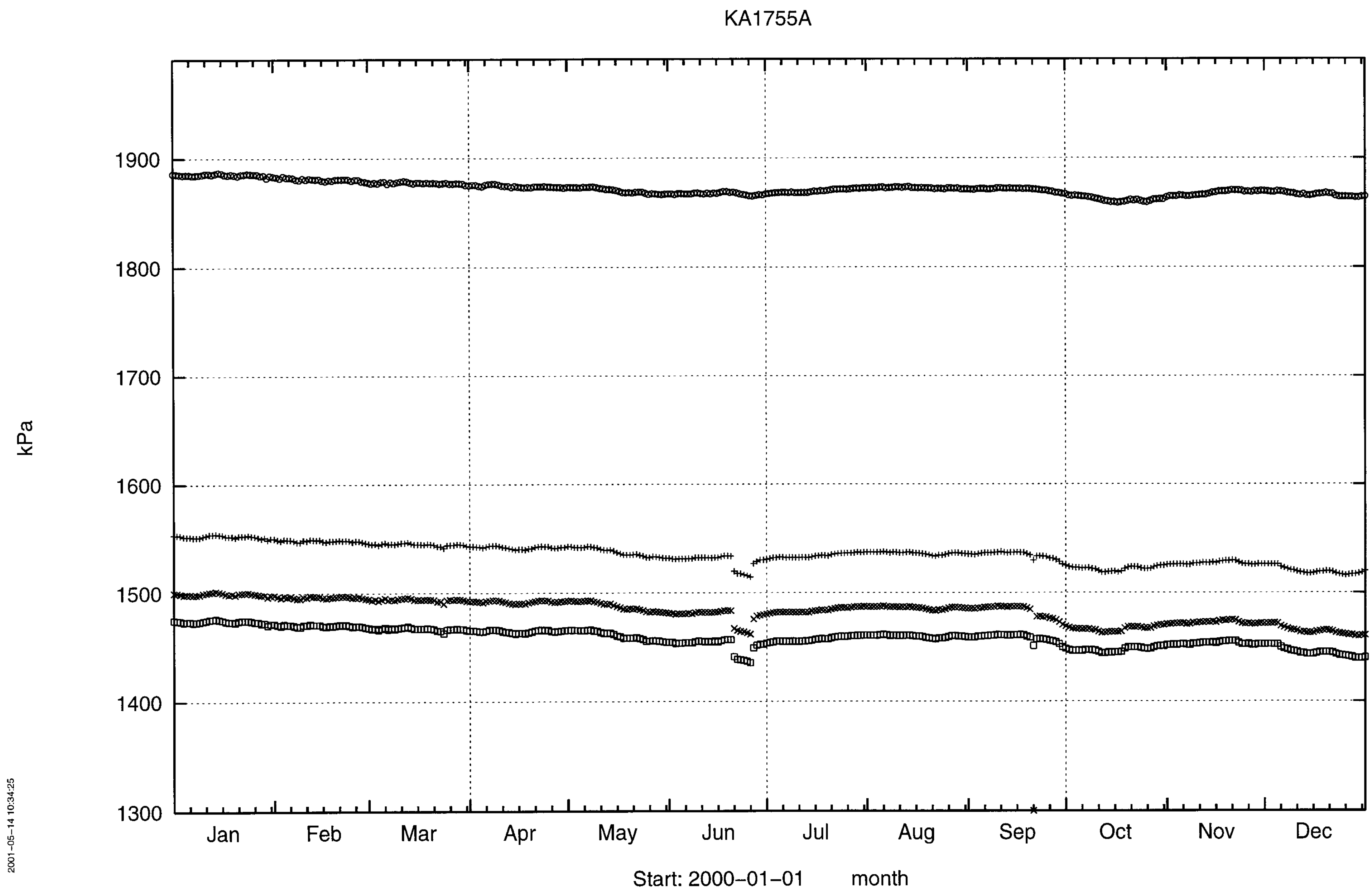
2001−05−14 11:29:37


KA1061A
1480
1460
1440
1420
1400
1380
1360
kPa
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:25

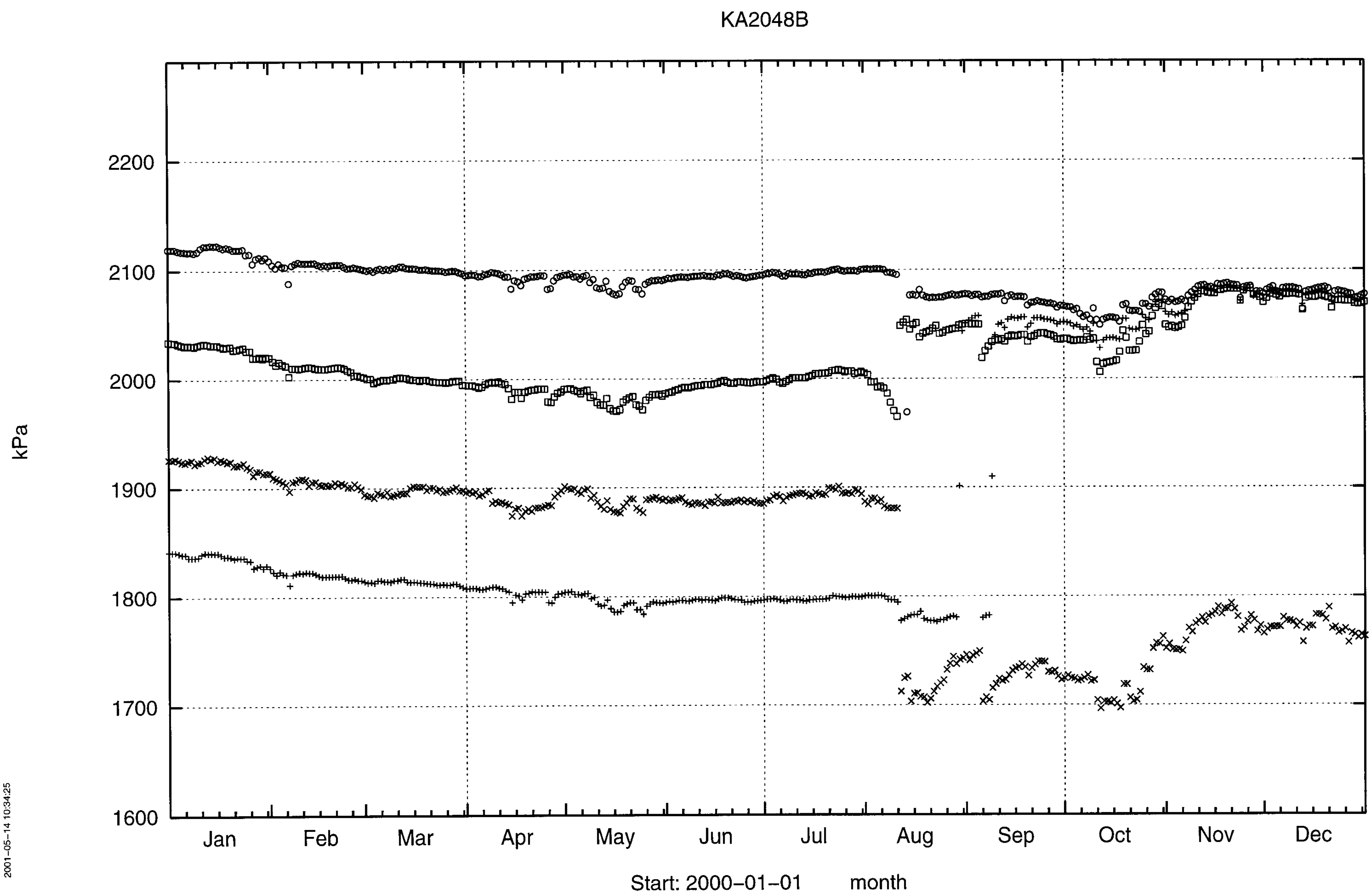

KA1131B
kPa
1420
1400
1380
1360
1340
1320
1300
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:25


KA1751A
kPa
1800
1700
1600
1500
1400
1300
1200
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001-05-14 10:34:25

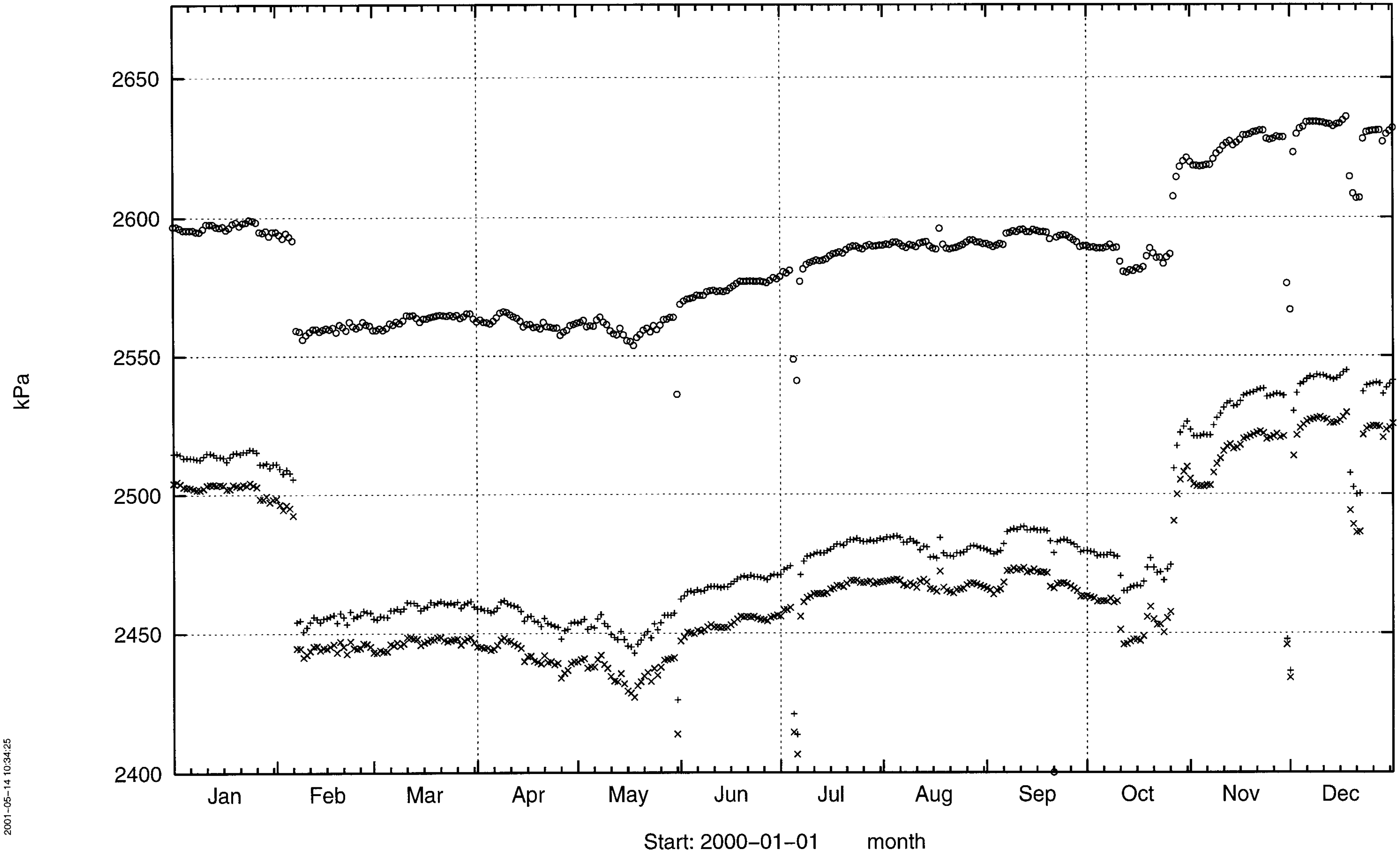

KA1754A
1480
1460
1440
1420
1400
1380
1360
kPa
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:25



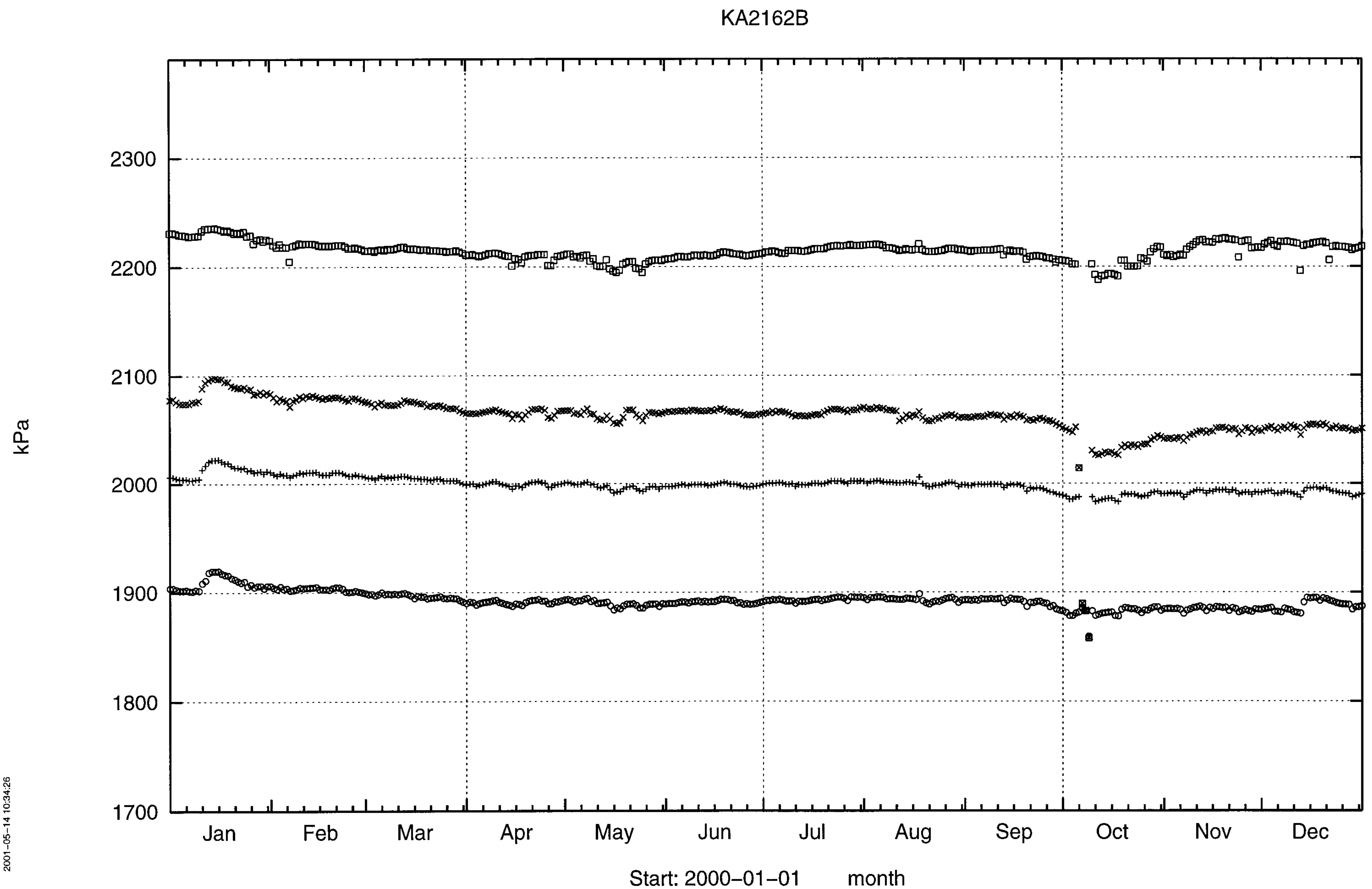
KA1755A
kPa
1900
1800
1700
1600
1500
1400
1300
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:25

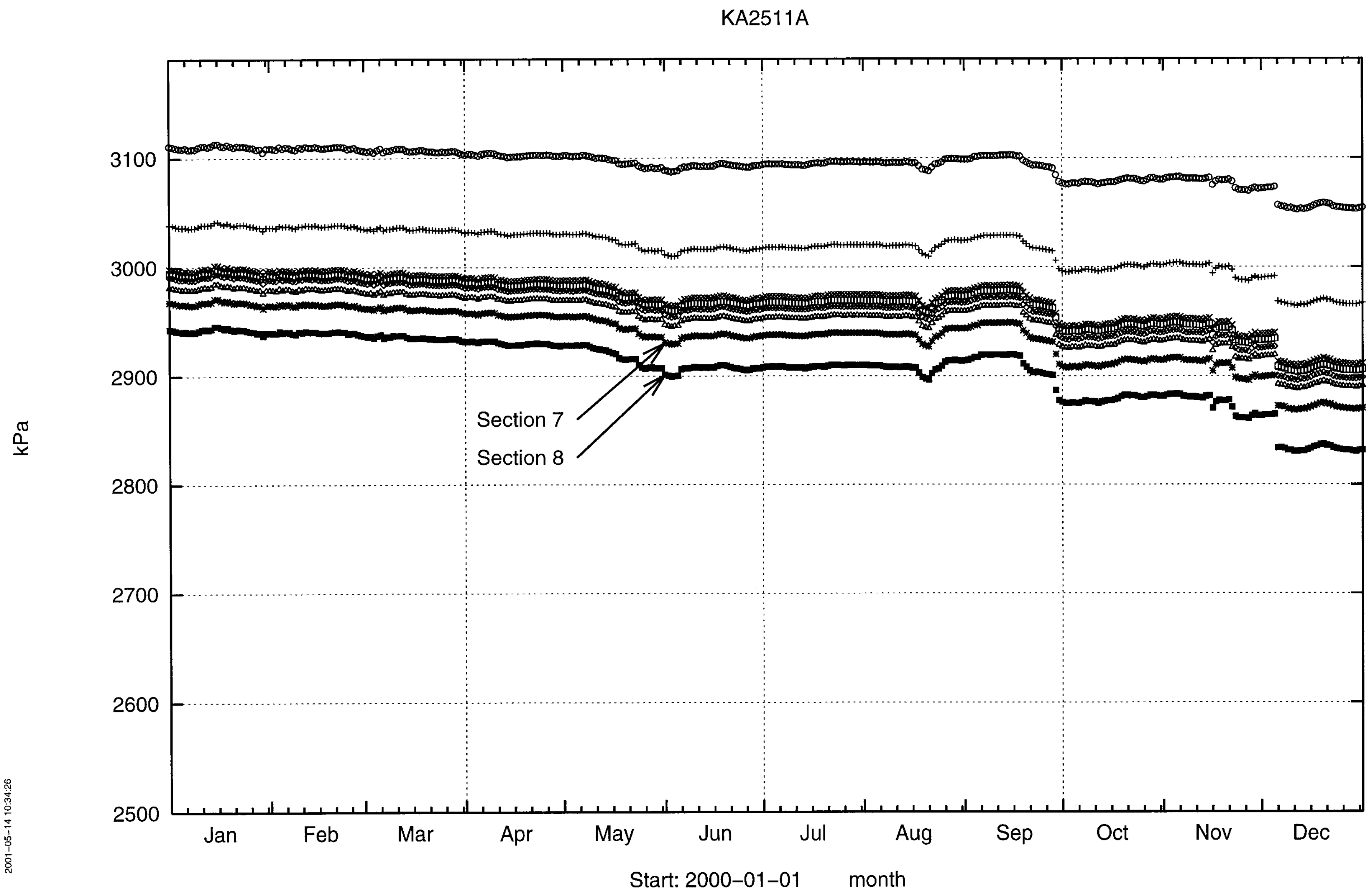

KA2048B
kPa
2200
2100
2000
1900
1800
1700
1600
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:25

KA2050A

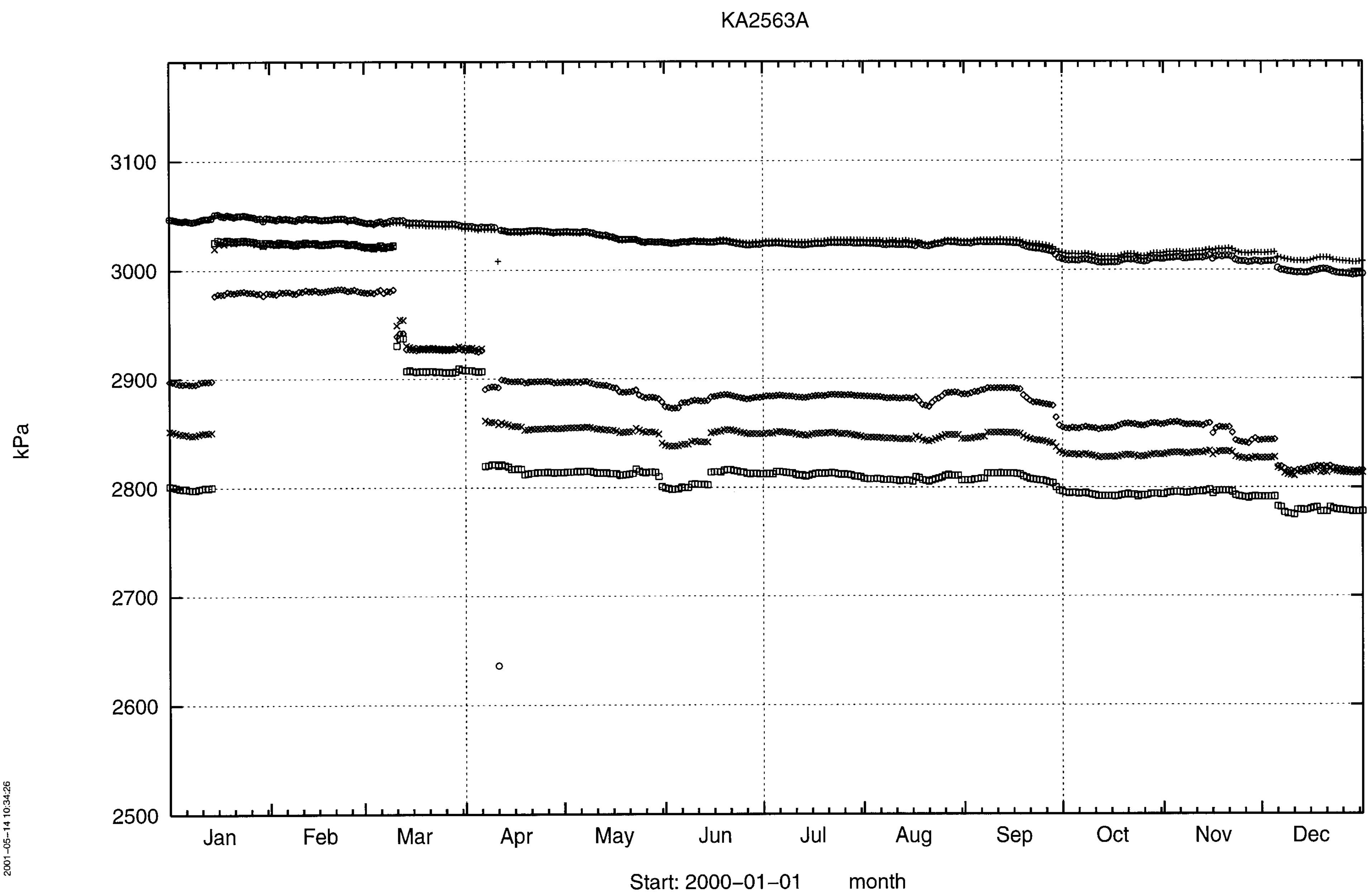


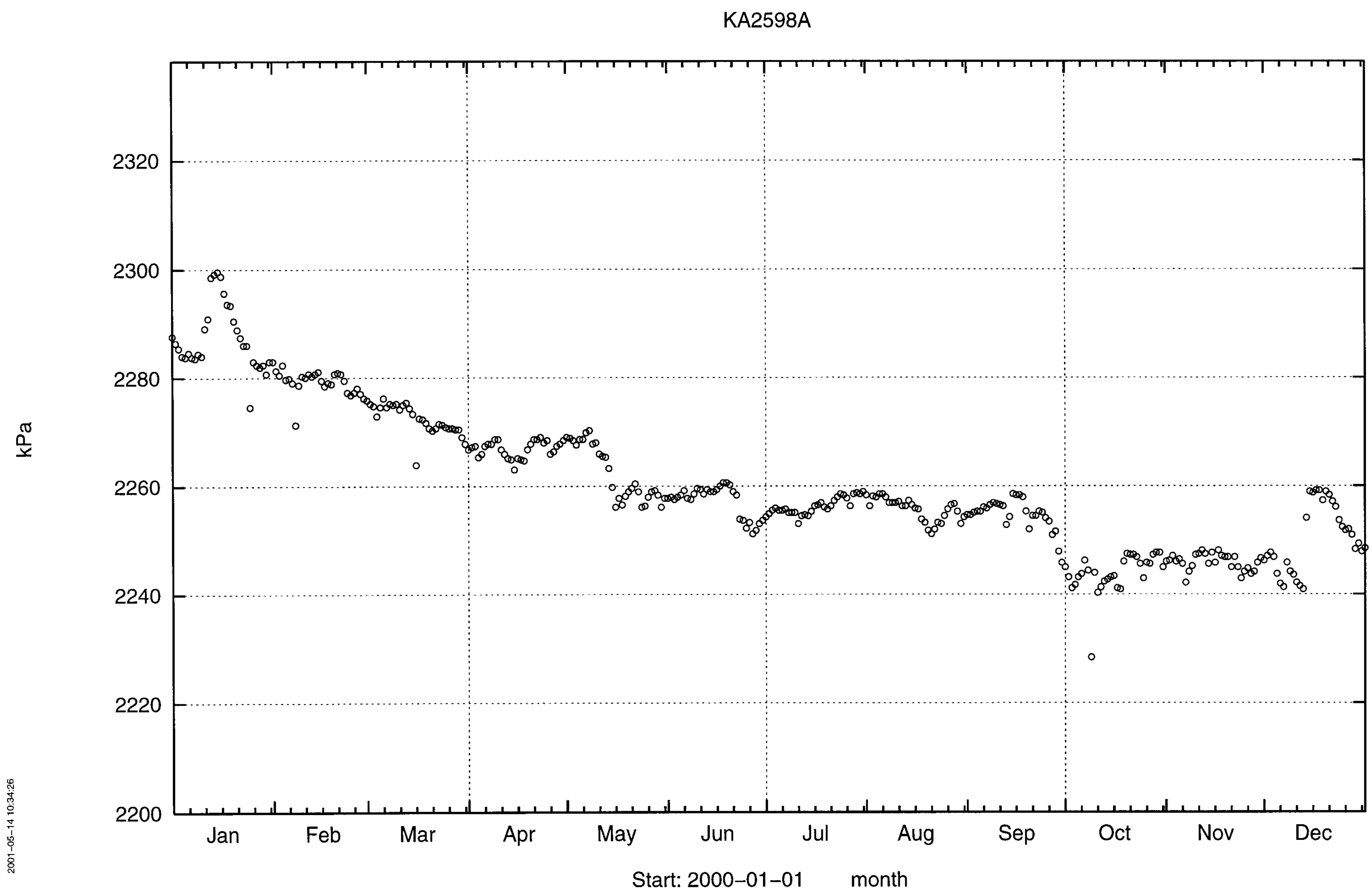
2001-05-14 10:34:25

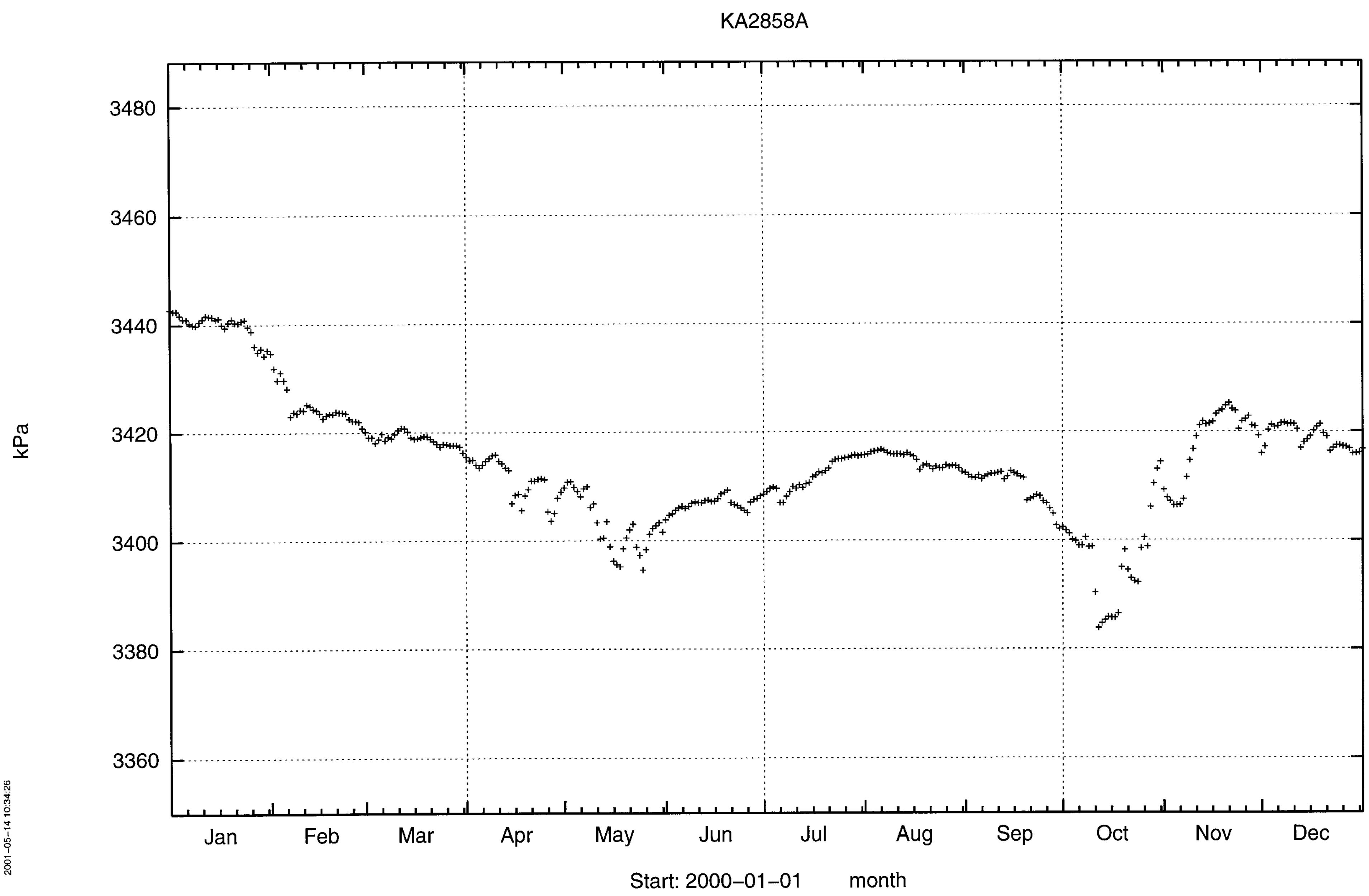

KA2162B
kPa
2300
2200
2100
2000
1900
1800
1700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:26



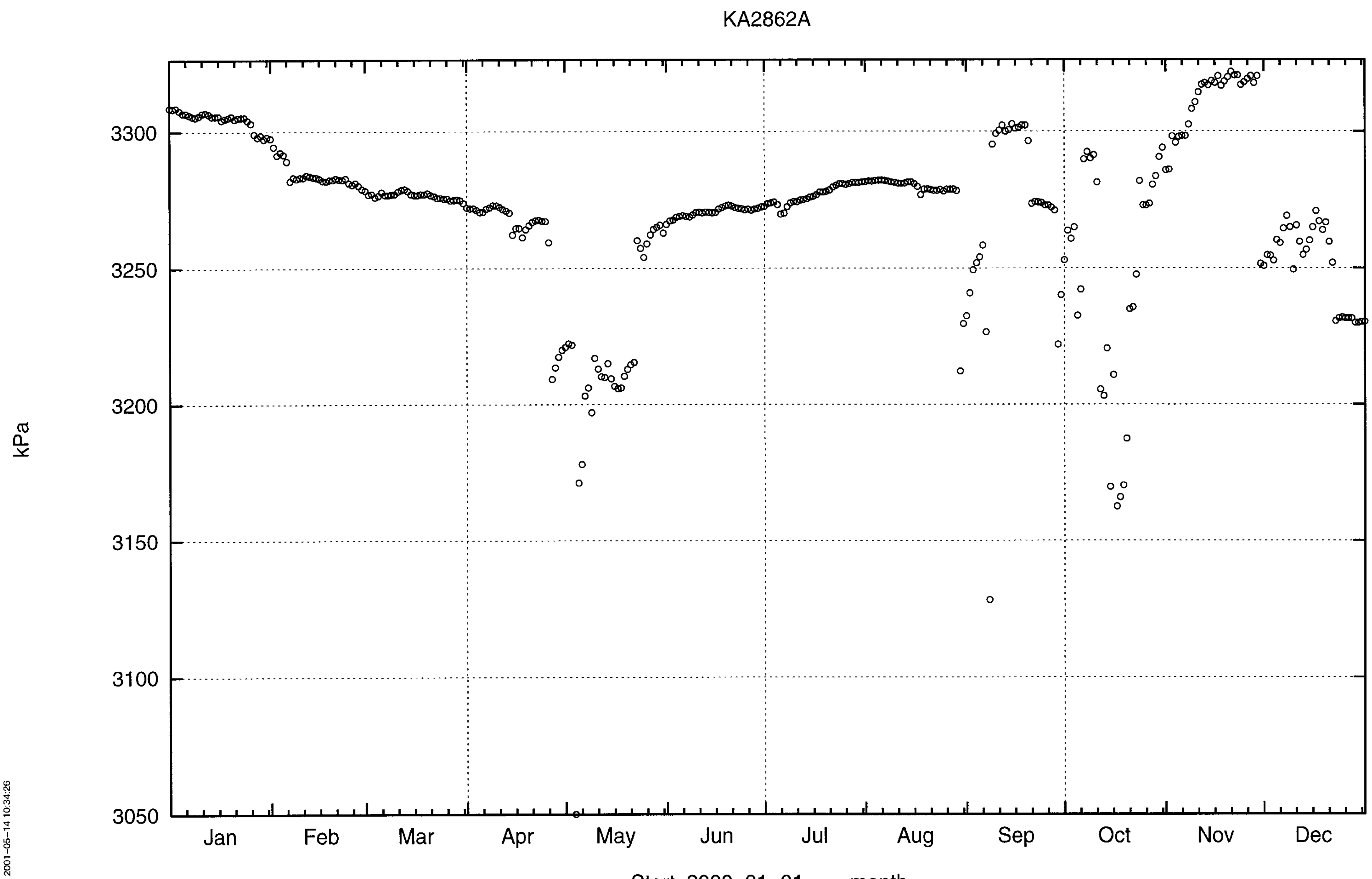
KA2511A
kPa
3100
3000
2900
2800
2700
2600
2500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01 month
Section 7
Section 8
2001−05−14 10:34:26

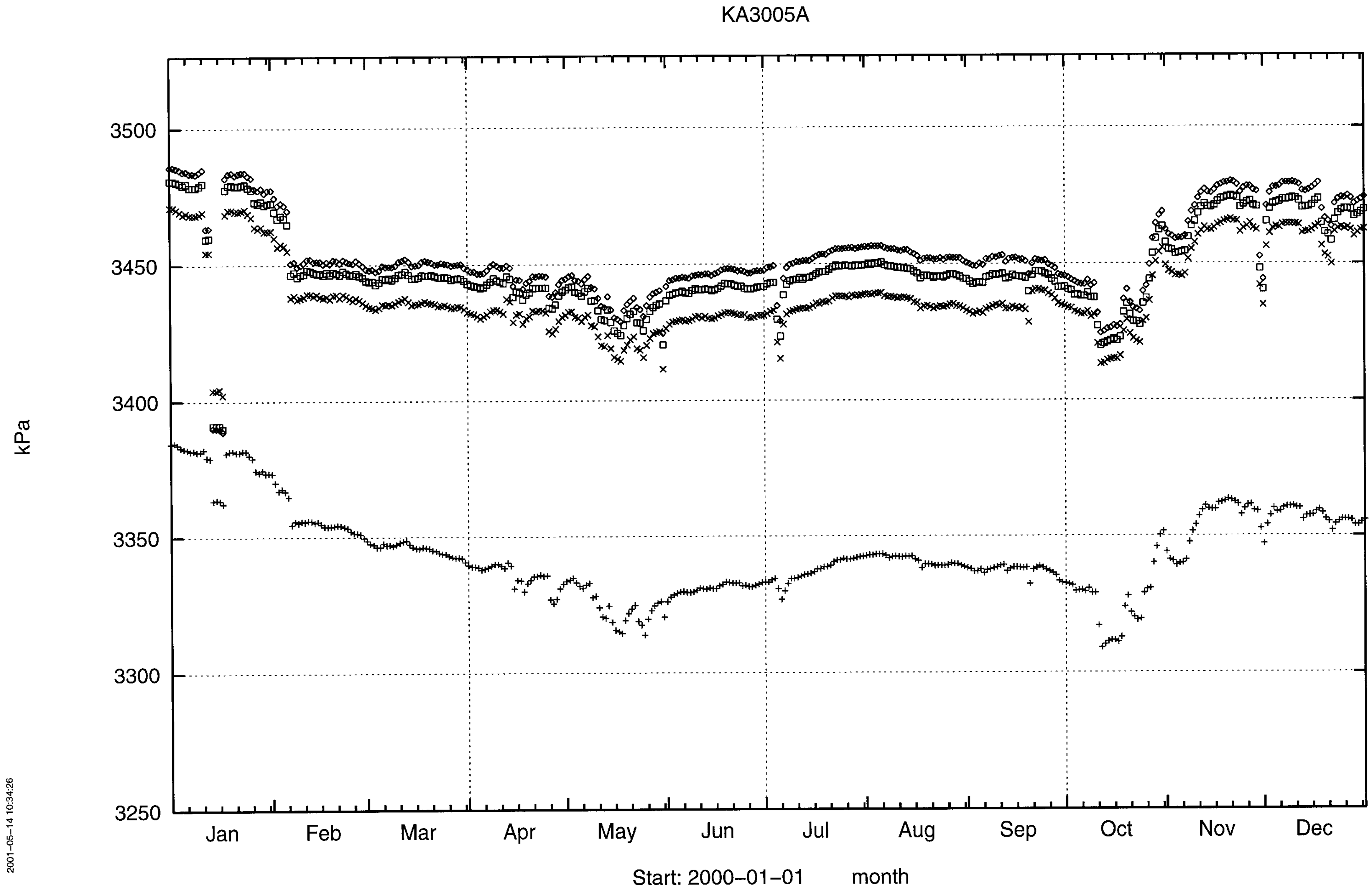

KA2563A
kPa
3100
3000
2900
2800
2700
2600
2500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:26

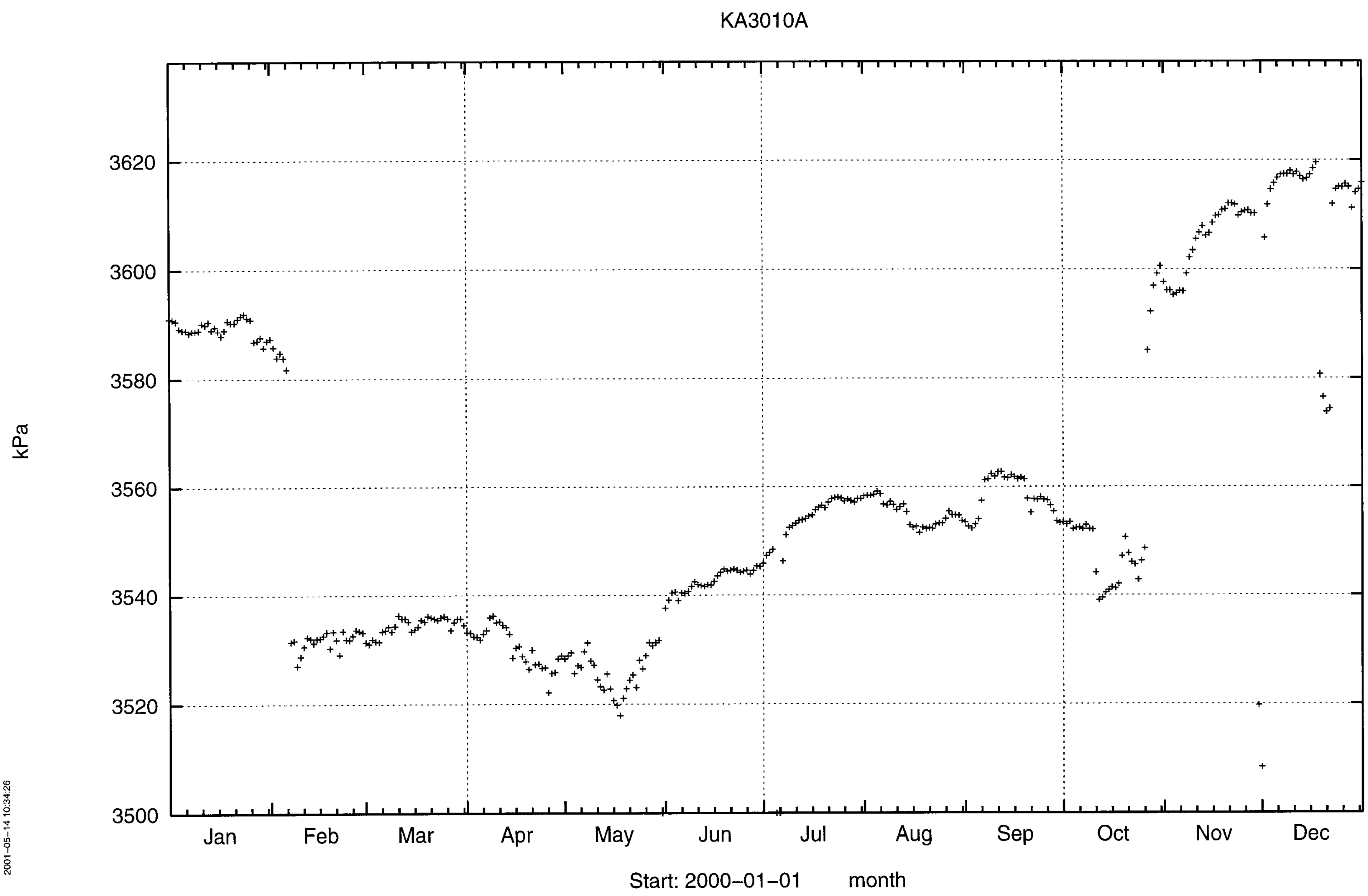

KA2598A
kPa
2320
2300
2280
2260
2240
2220
2200
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:26

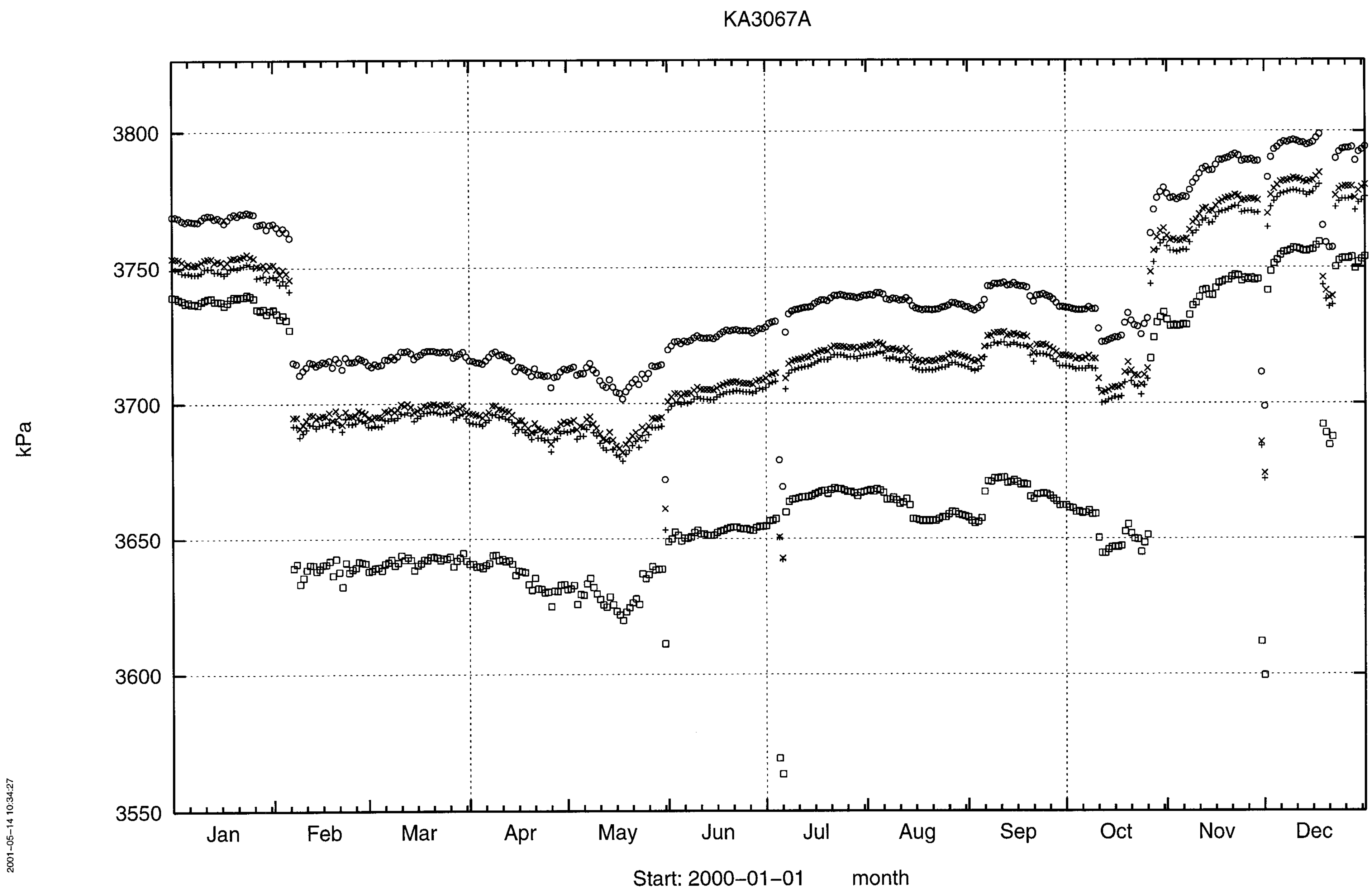


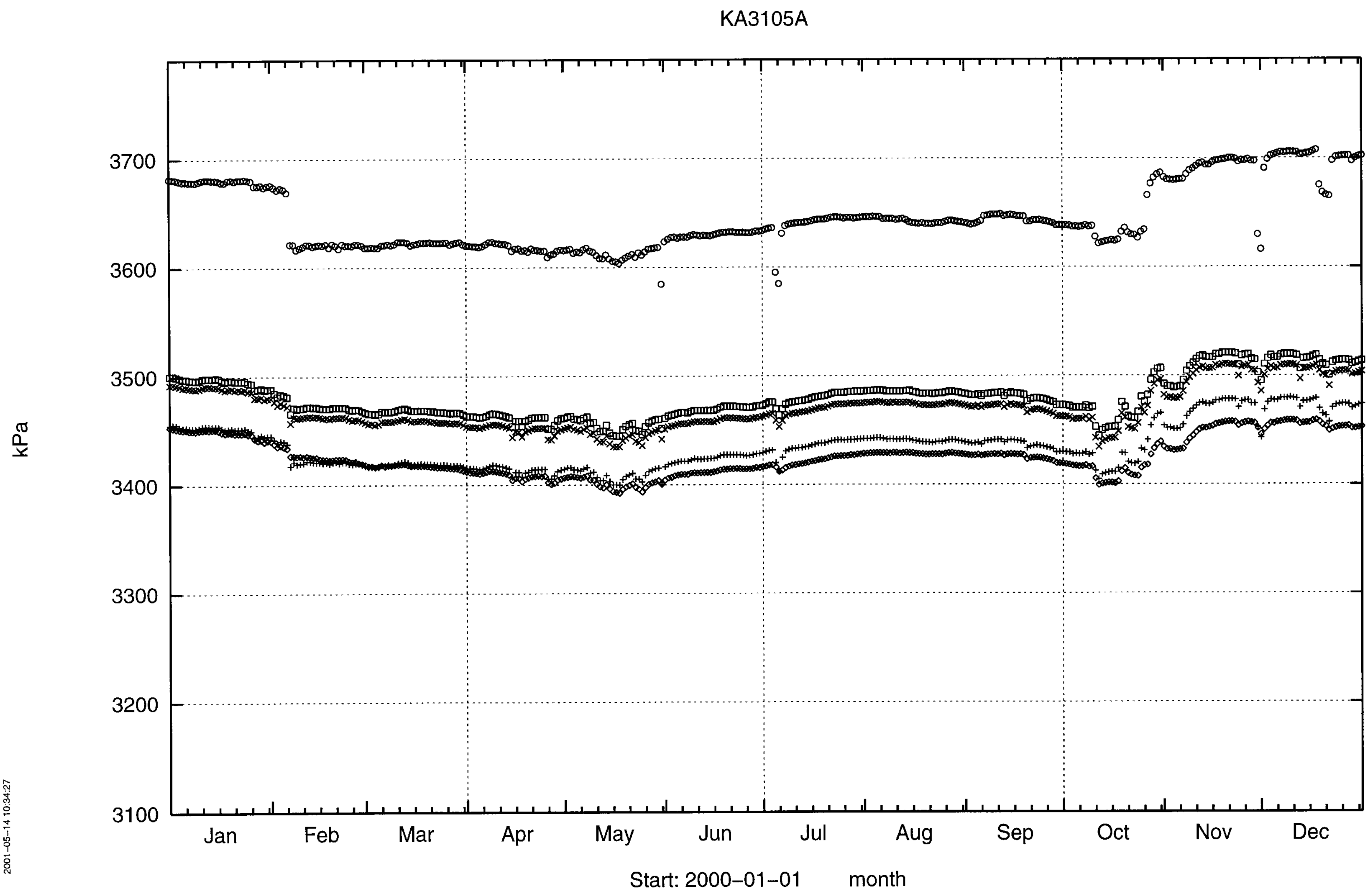
2001−05−14 10:34:26

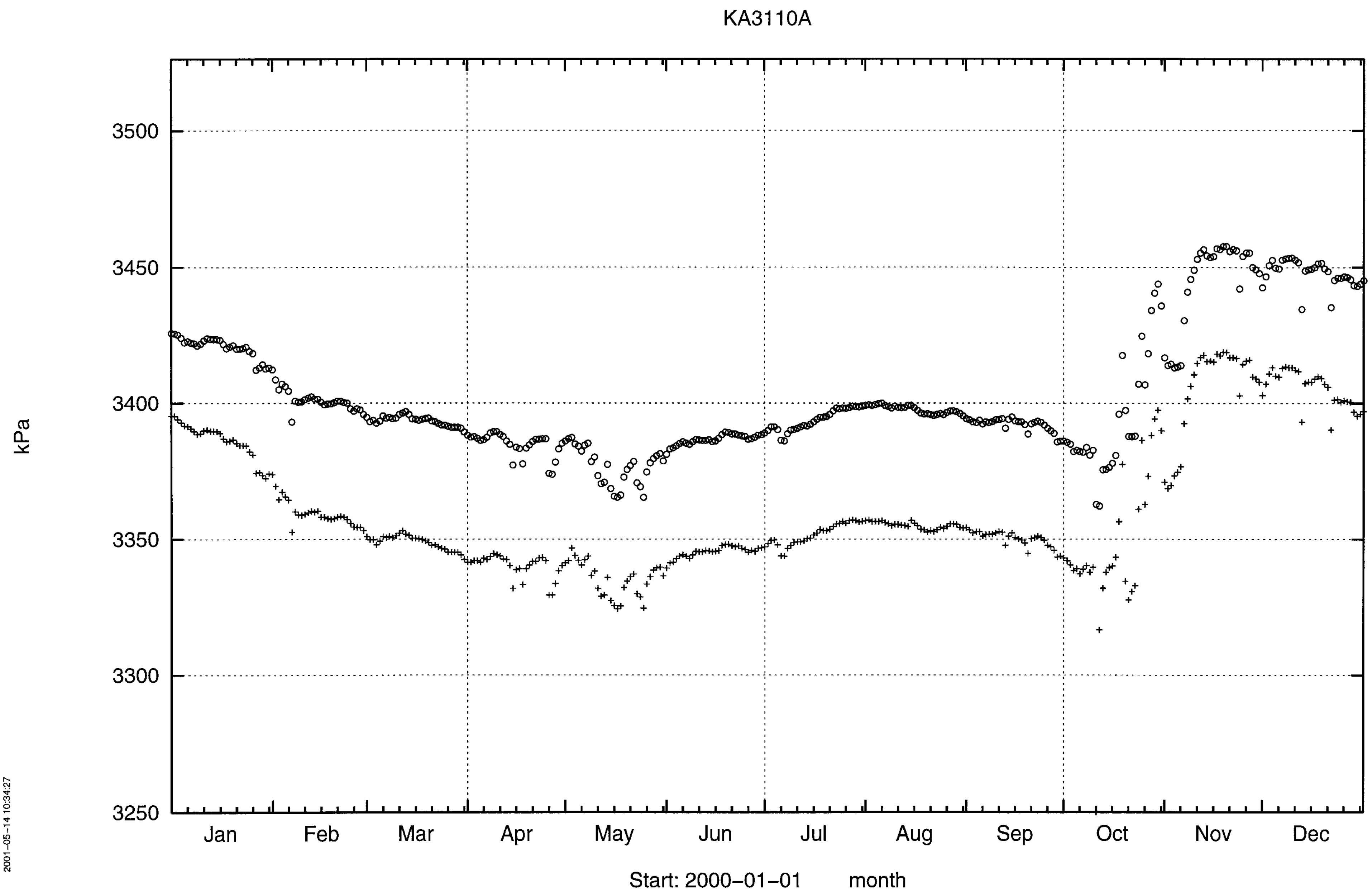

KA2862A
kPa
3300
3250
3200
3150
3100
3050
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:34:26

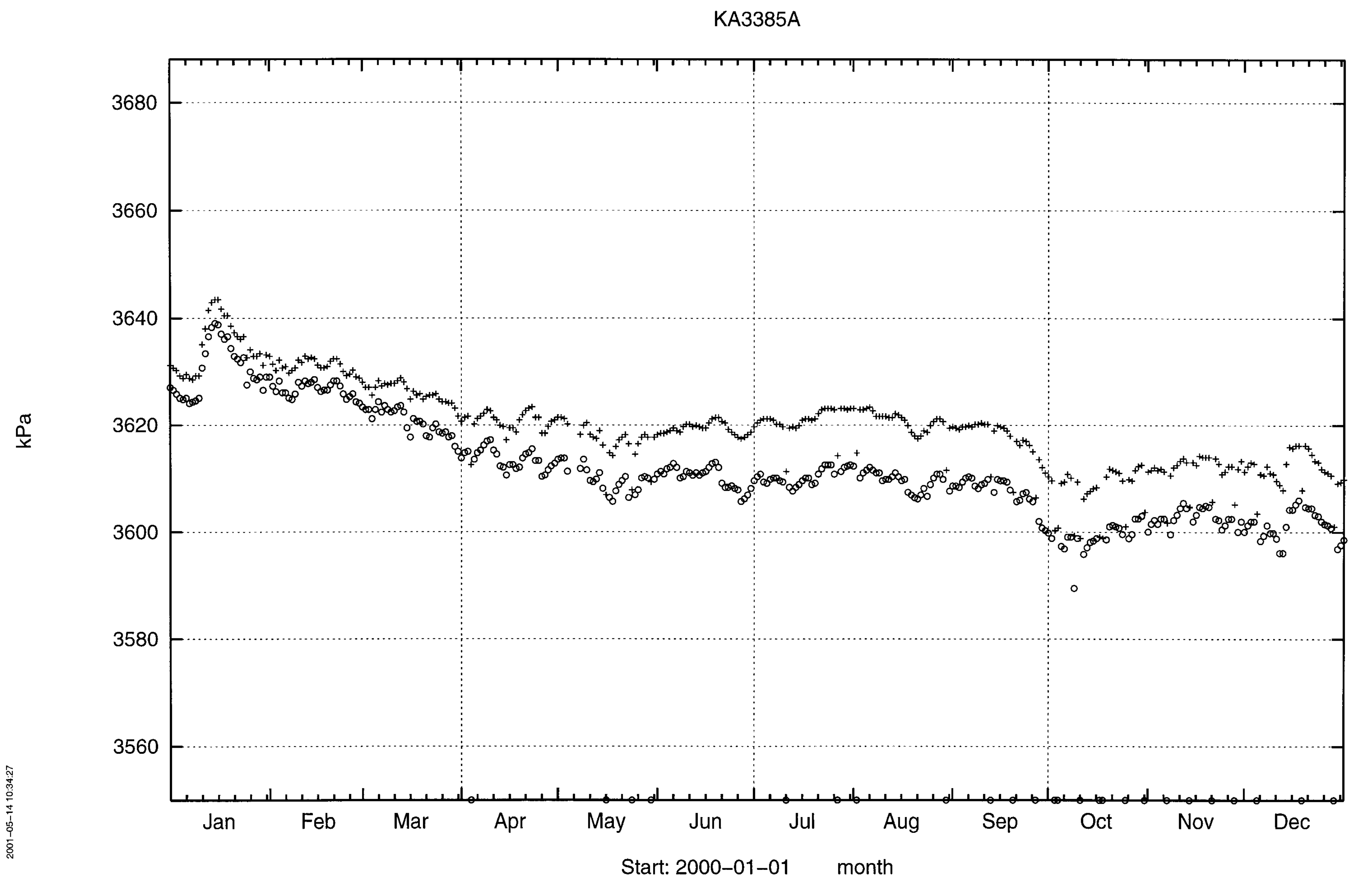

KA3005A
kPa
3500
3450
3400
3350
3300
3250
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:26

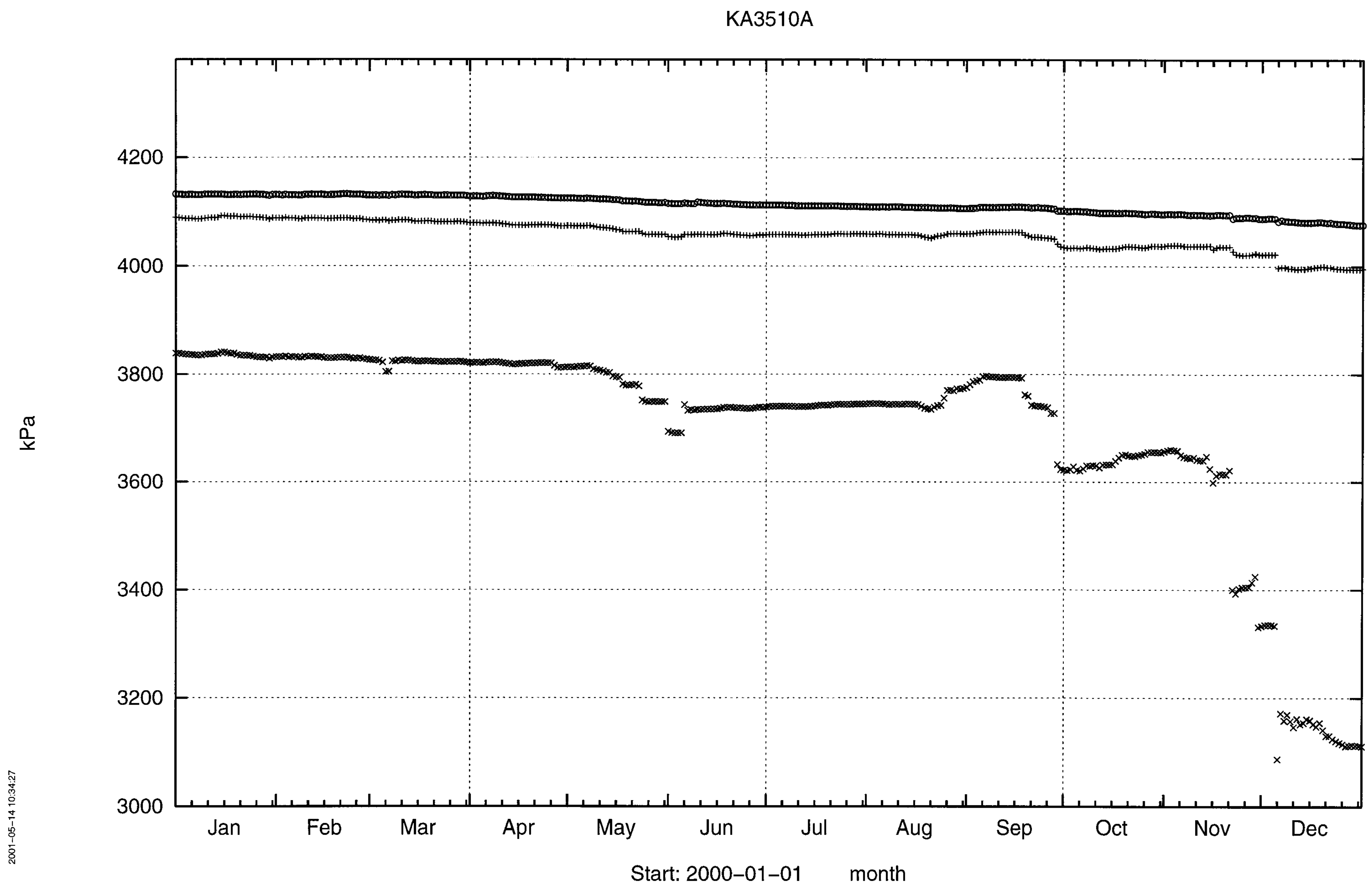

KA3010A
kPa
3620
3600
3580
3560
3540
3520
3500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:26

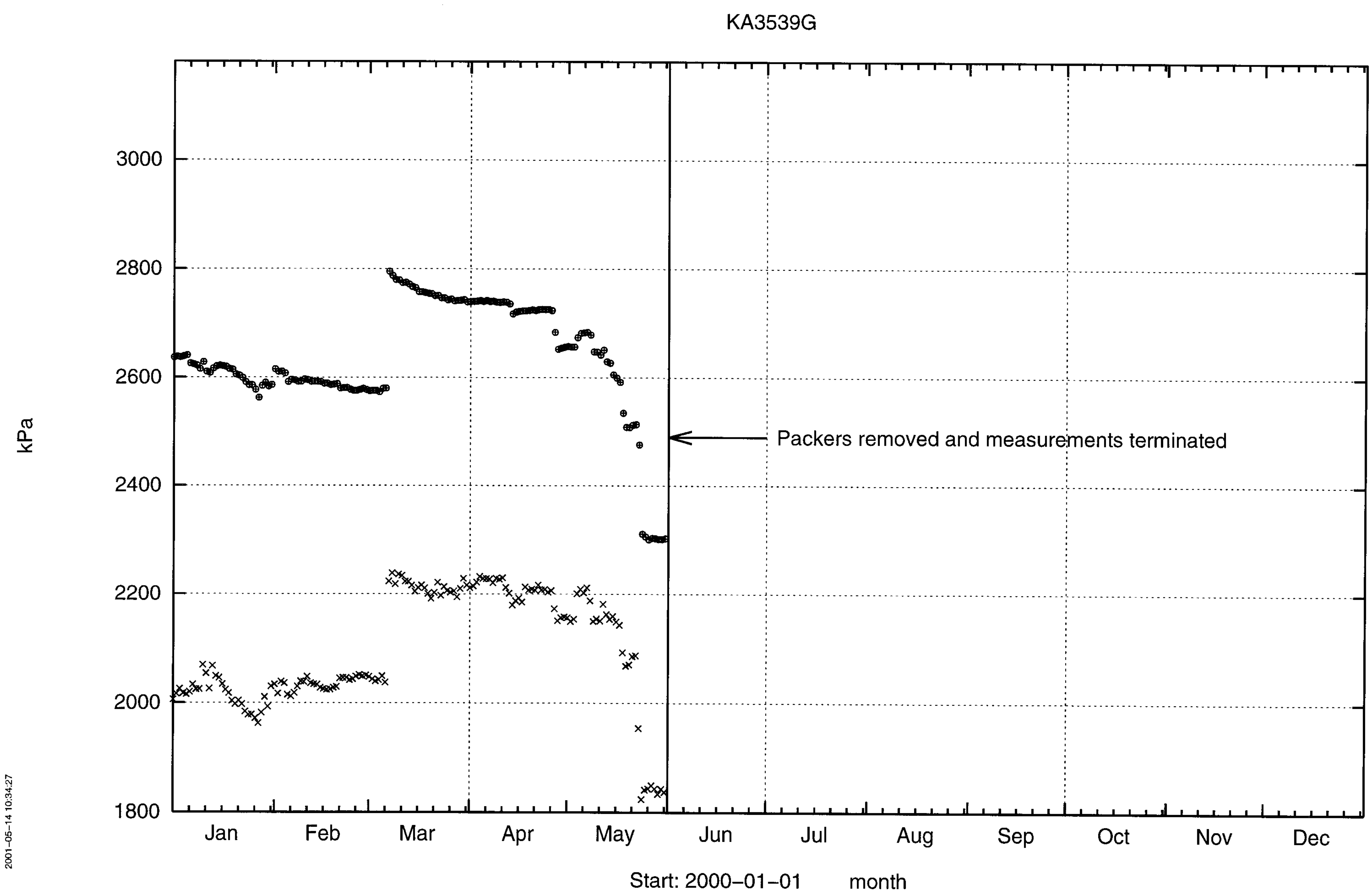

KA3067A
kPa
3800
3750
3700
3650
3600
3550
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:27

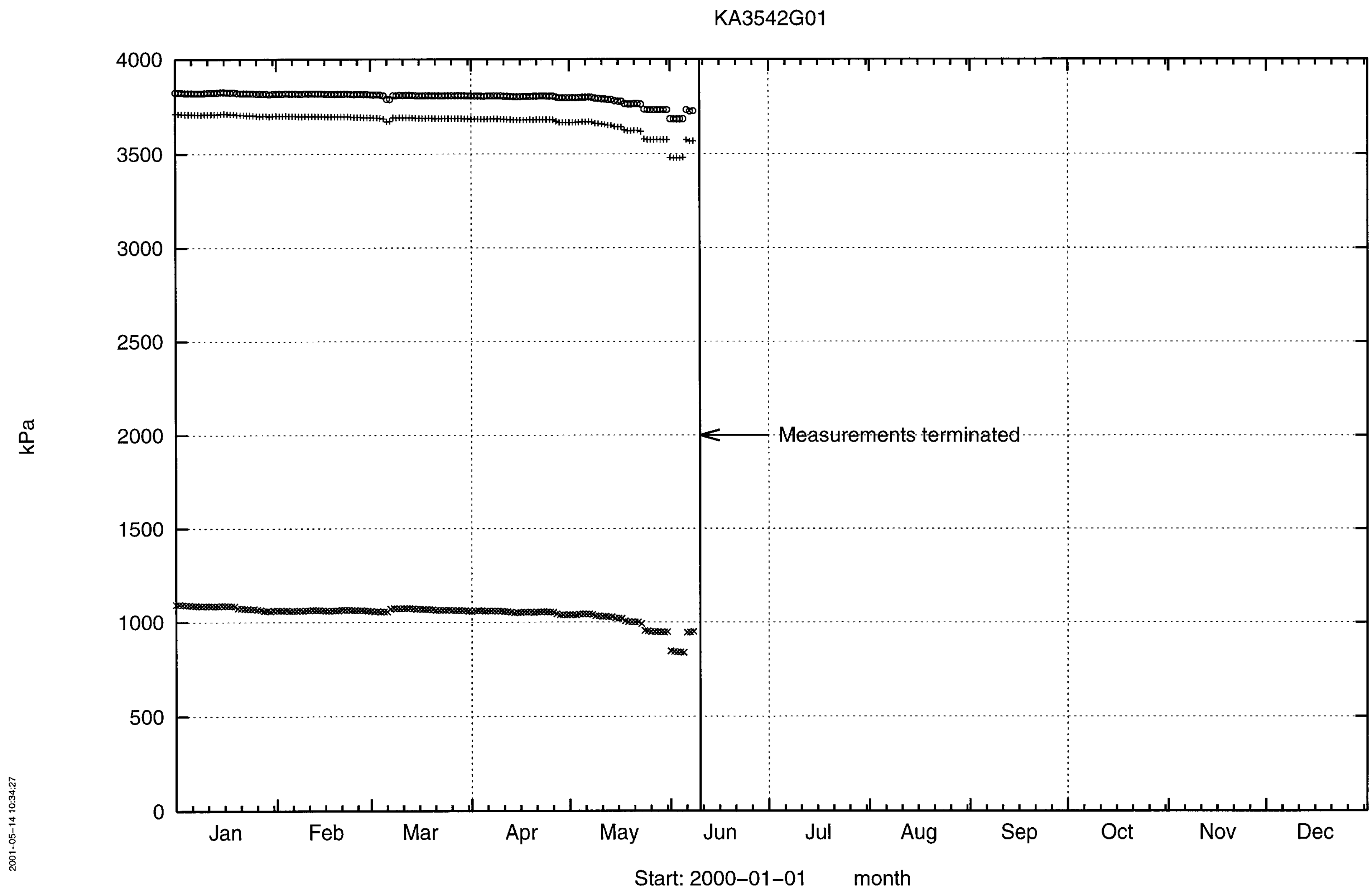

KA3105A
kPa
3700
3600
3500
3400
3300
3200
3100
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:27


KA3110A
3500
3450
3400
3350
3300
3250
kPa
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:27

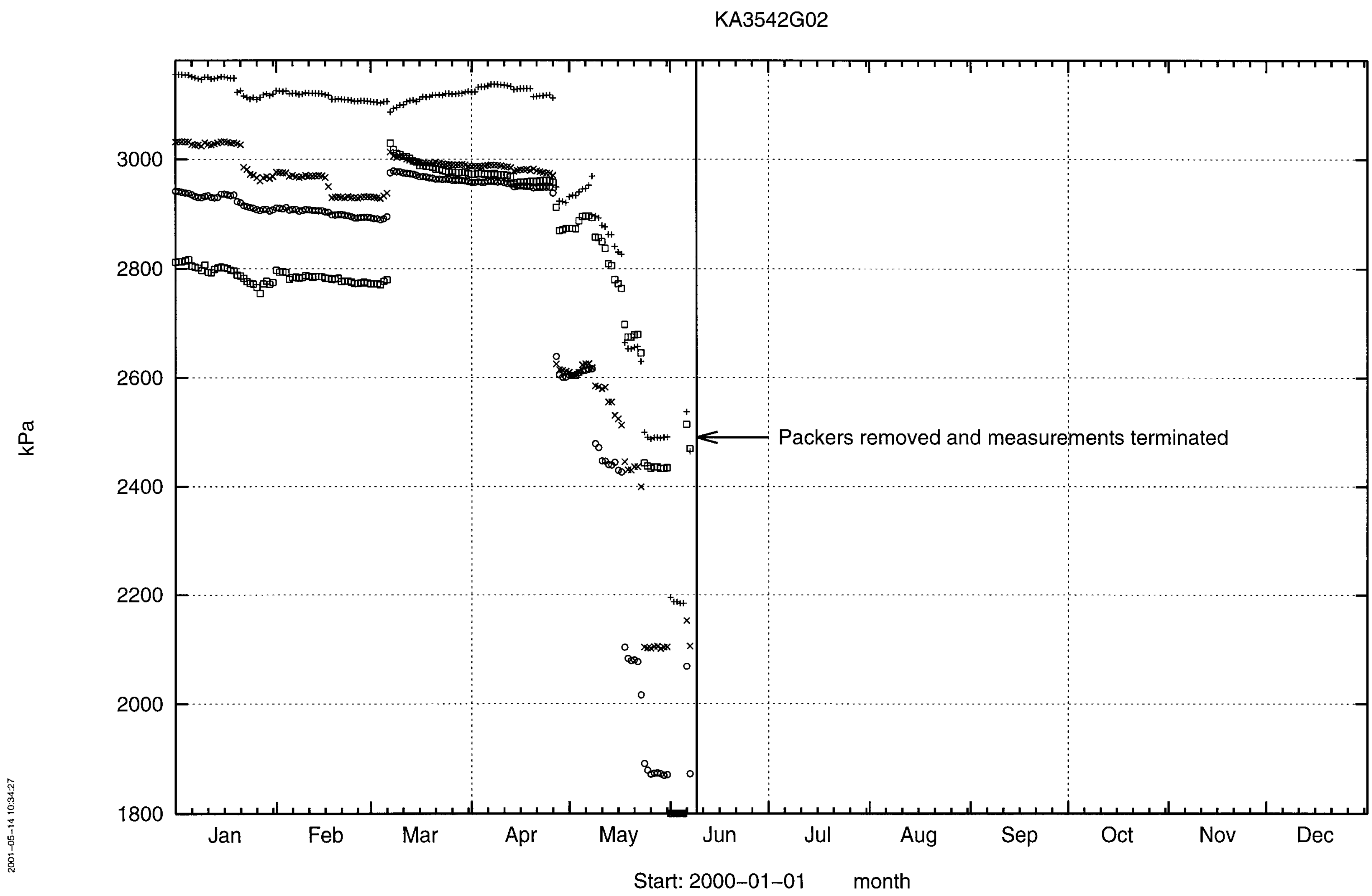

KA3385A
kPa
3680
3660
3640
3620
3600
3580
3560
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:27


KA3510A
kPa
4200
4000
3800
3600
3400
3200
3000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:27

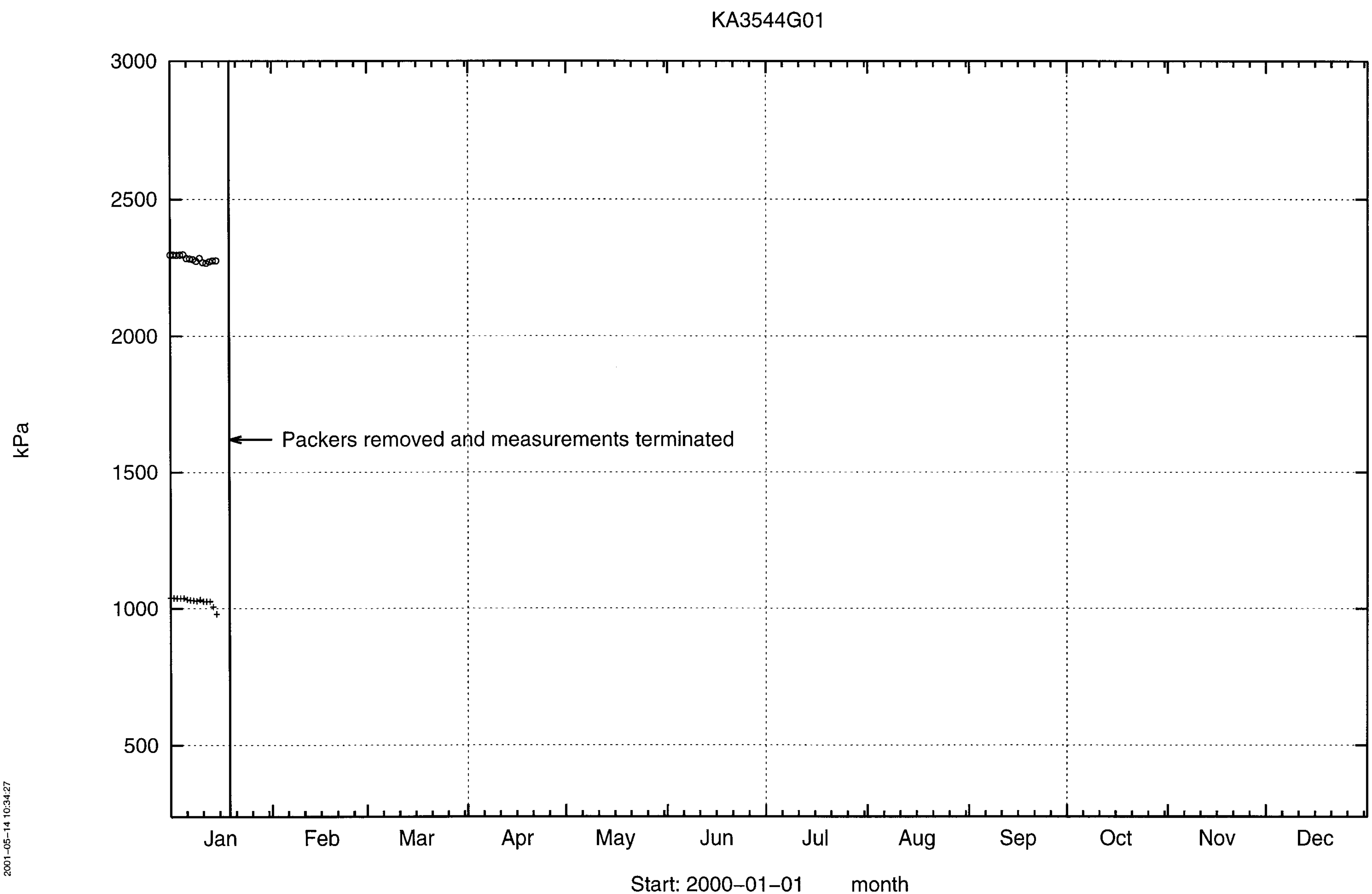

KA3539G
kPa
3000
2800
2600
2400
2200
2000
1800
Packers removed and measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:27

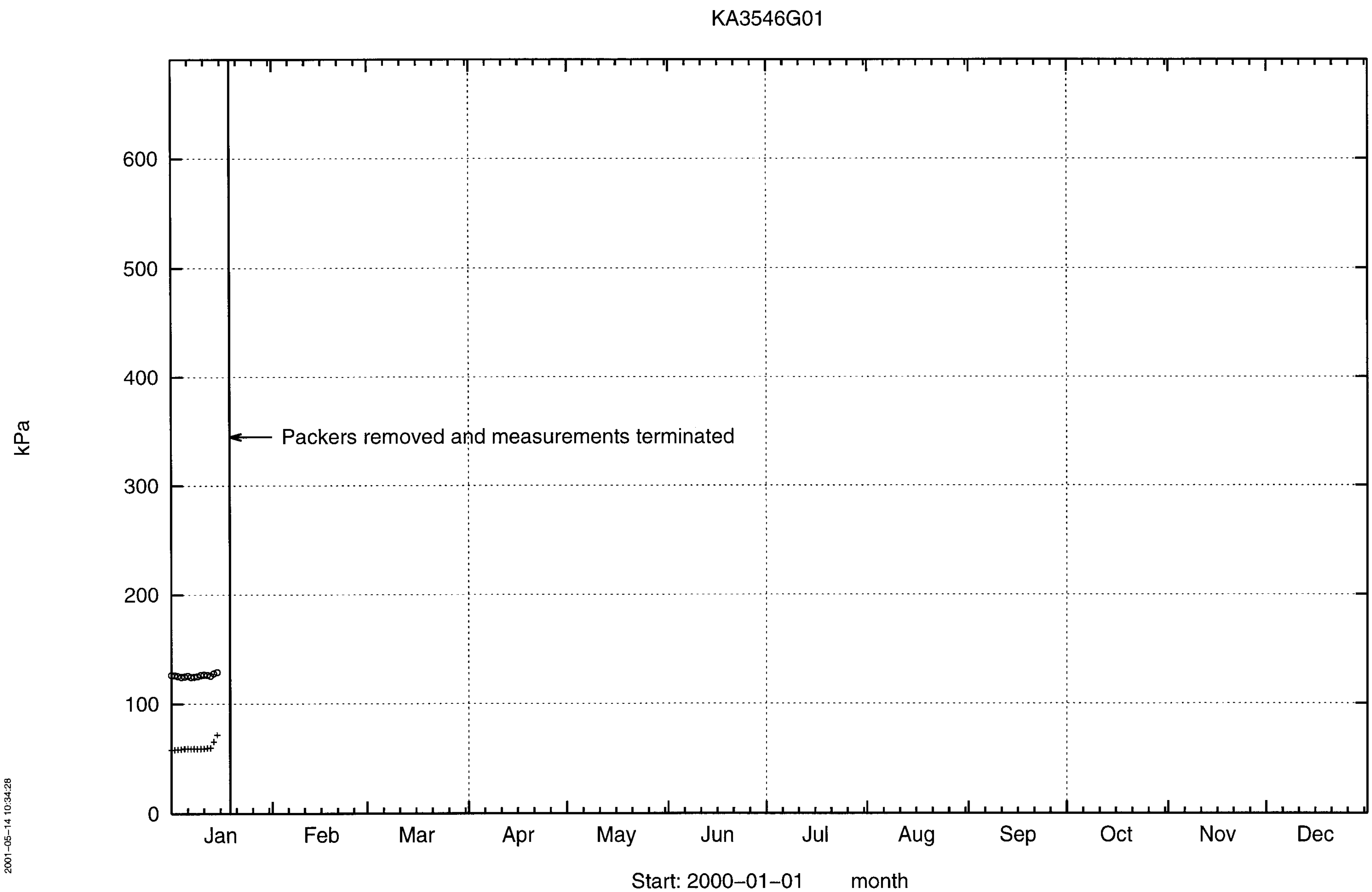


KA3542G01
kPa
4000
3500
3000
2500
2000
1500
1000
500
0
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−14 10:34:27

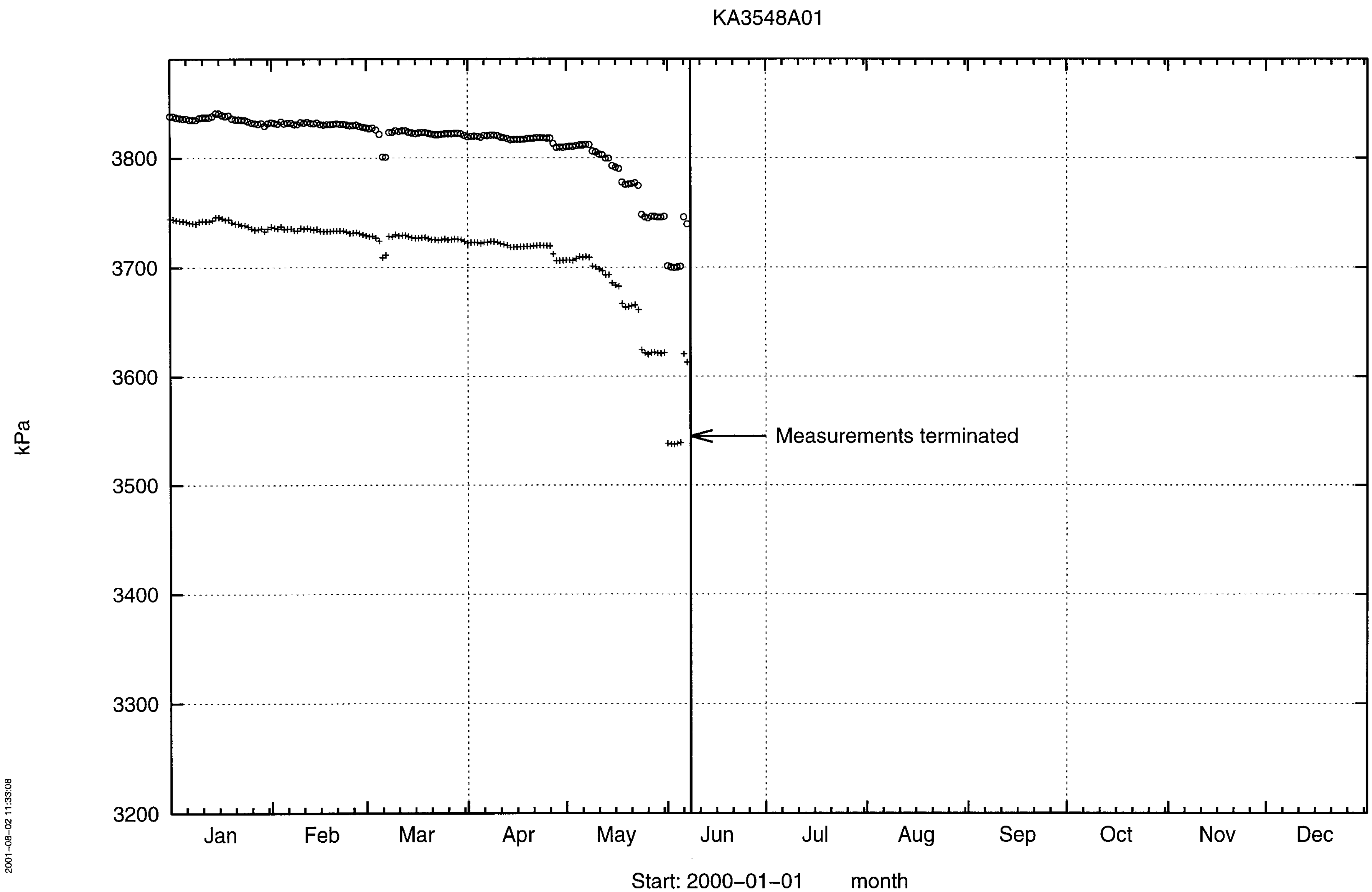


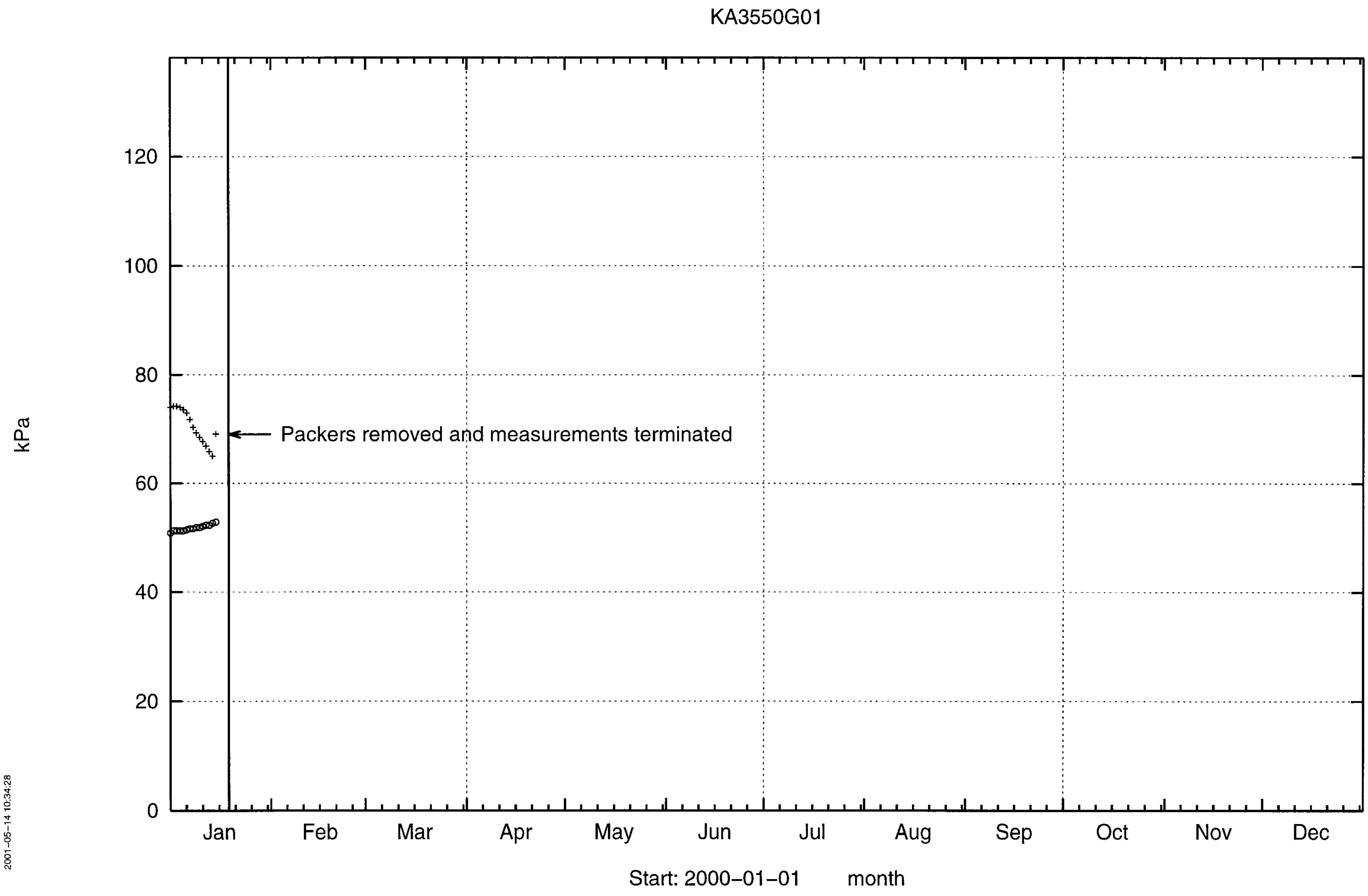
KA3542G02
kPa
3000
2800
2600
2400
2200
2000
1800
Packers removed and measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:27


KA3544G01
kPa
3000
2500
2000
1500
1000
500
Packers removed and measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:27

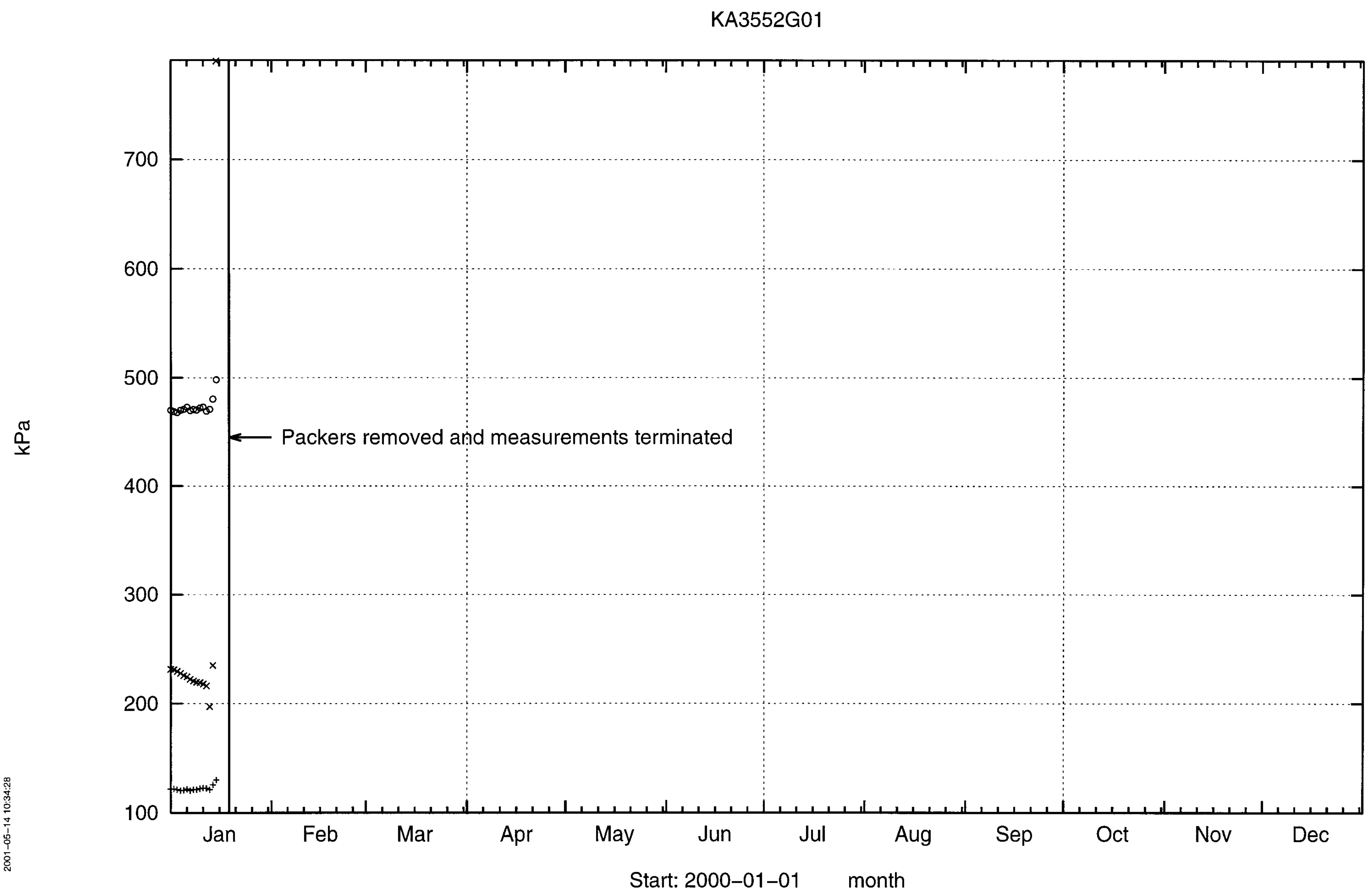


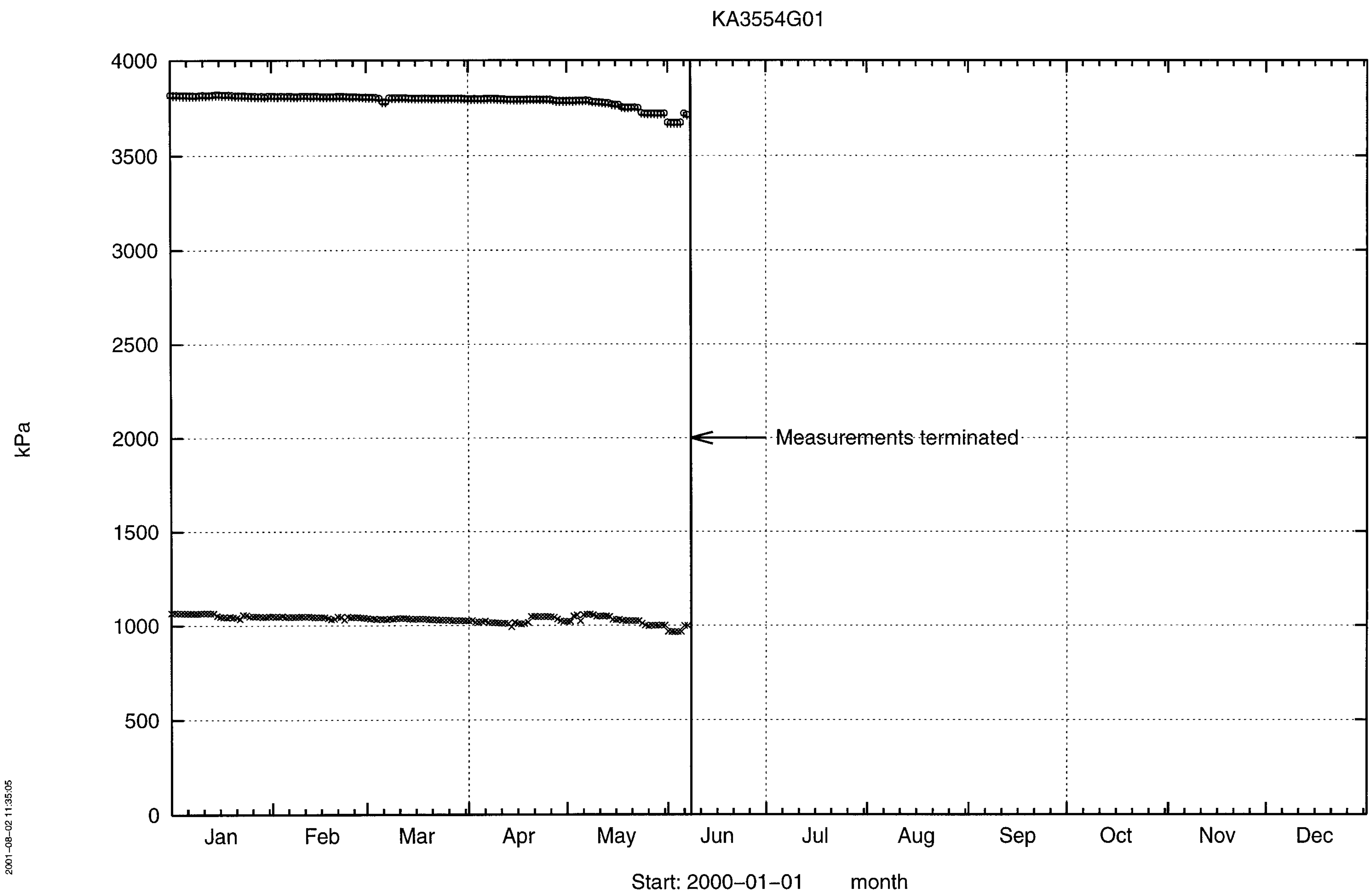
KA3546G01
kPa
600
500
400
300
200
100
0
Packers removed and measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:28

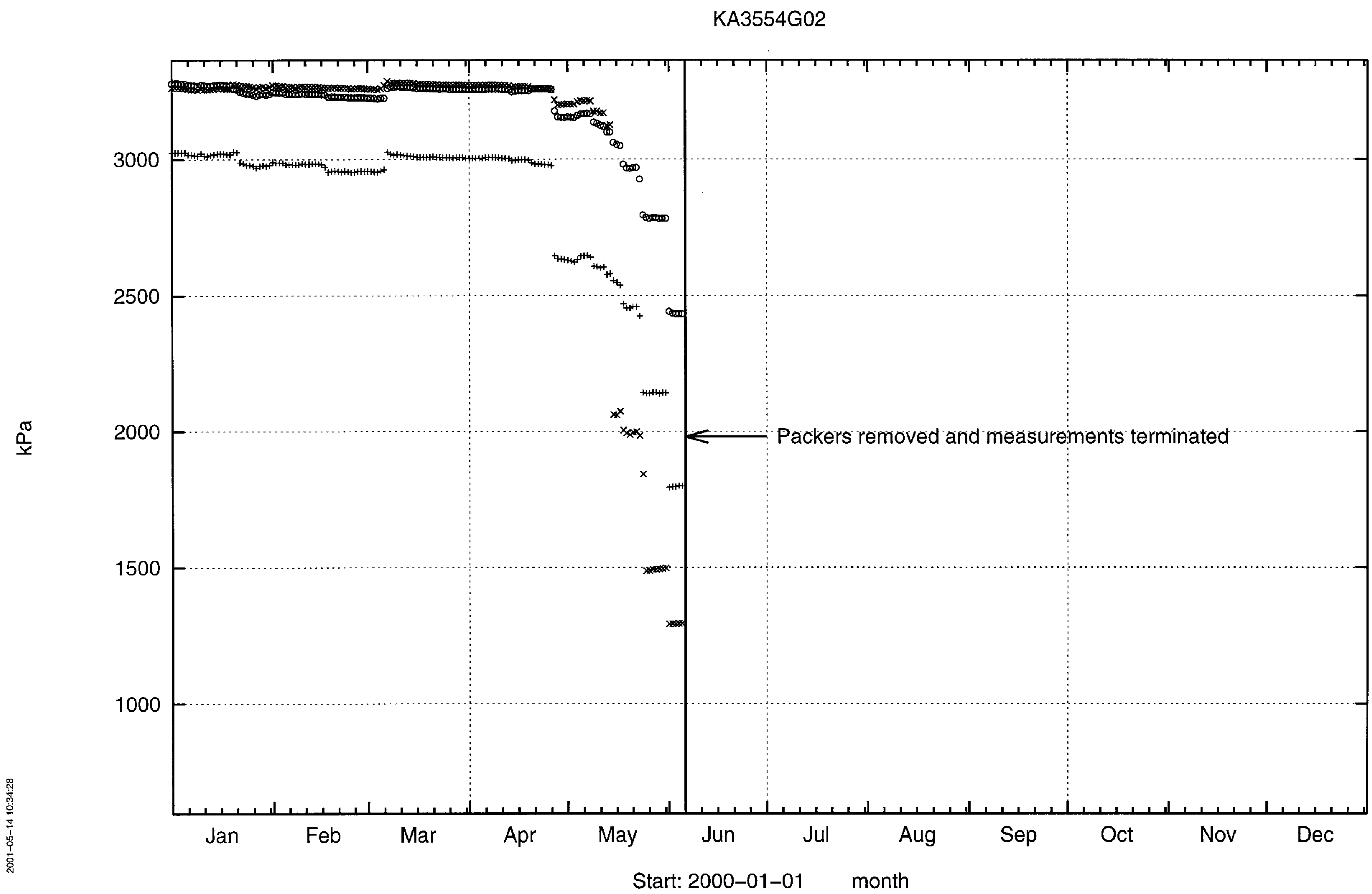

KA3548A01
kPa
3800
3700
3600
3500
3400
3300
3200
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-08-02 11:33:08



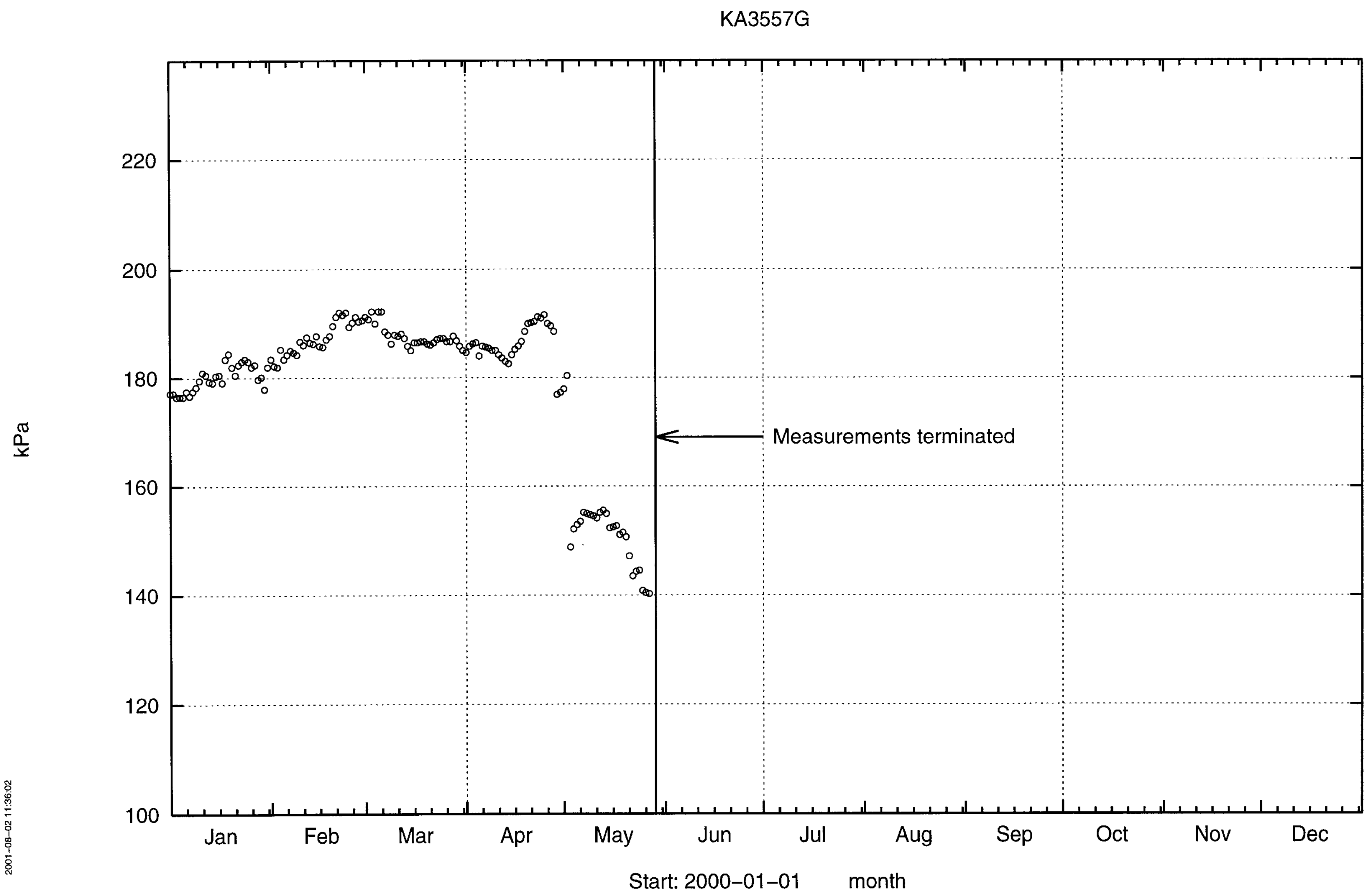
KA3550G01
kPa
0
20
40
60
80
100
120
Packers removed and measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−14 10:34:28

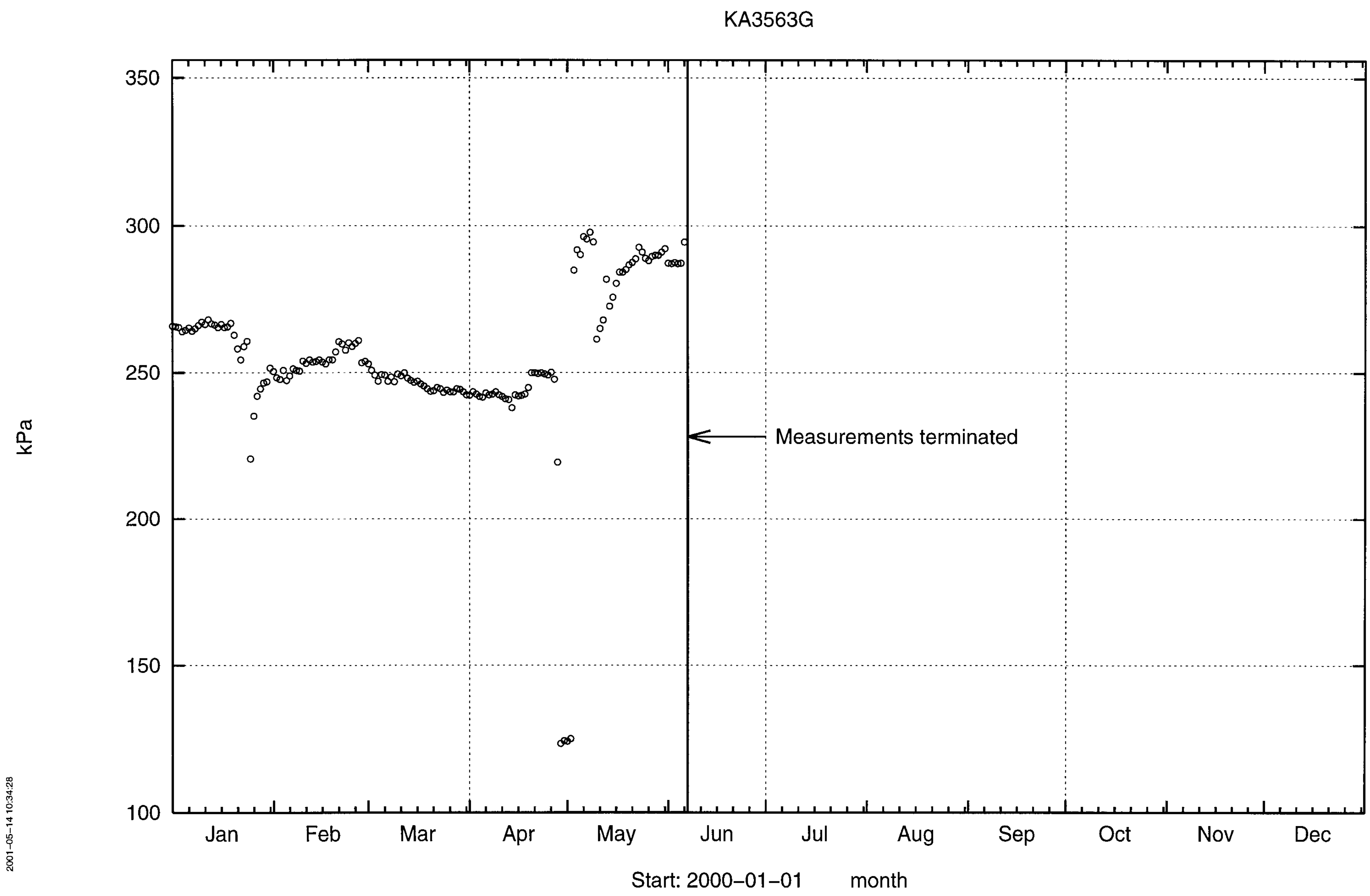

KA3552G01
kPa
700
600
500
400
300
200
100
Packers removed and measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:28


KA3554G01
kPa
4000
3500
3000
2500
2000
1500
1000
500
0
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-08-02 11:35:05

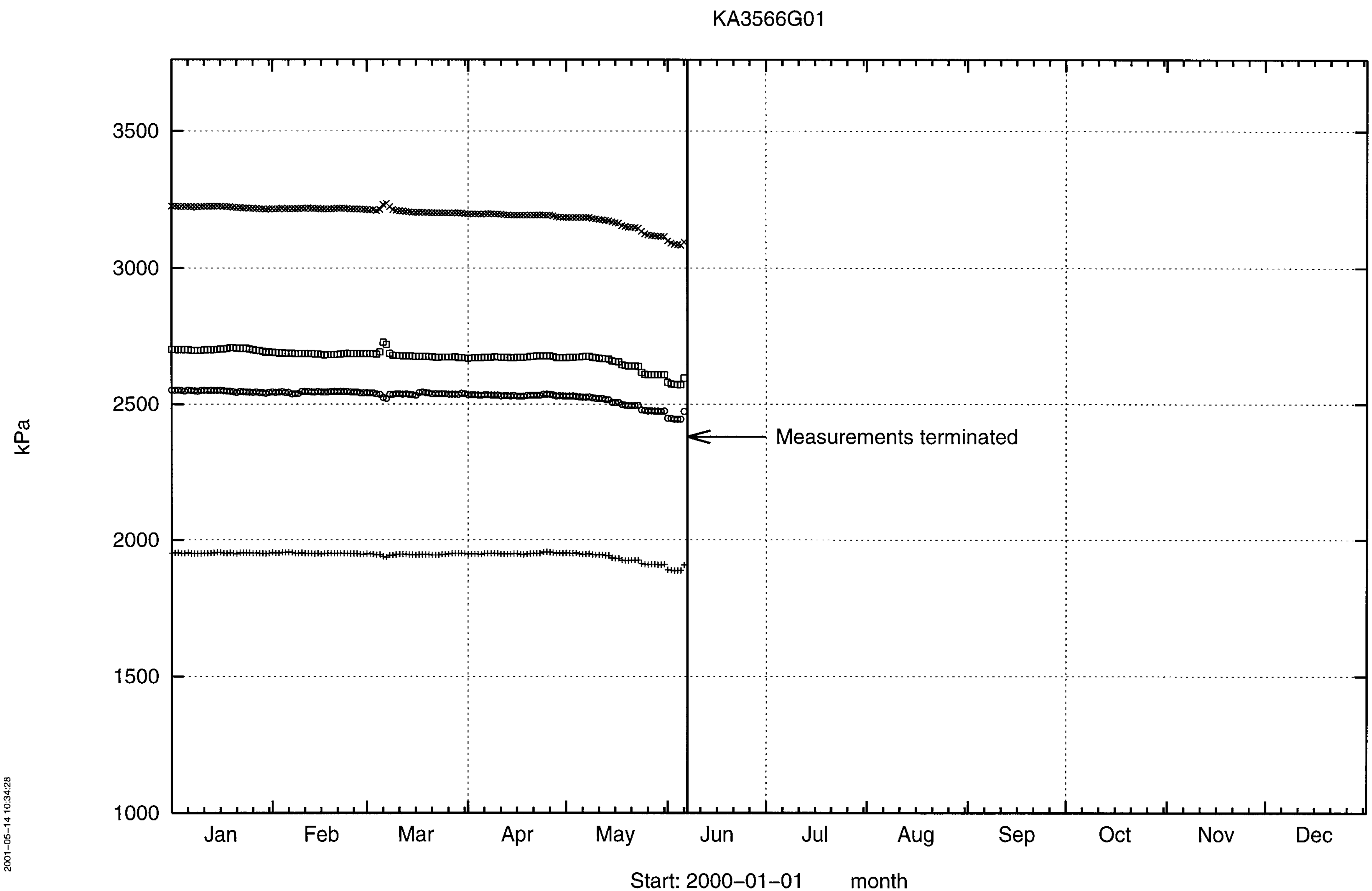


KA3554G02
kPa
3000
2500
2000
1500
1000
Packers removed and measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01 month
2001-05-14 10:34:28

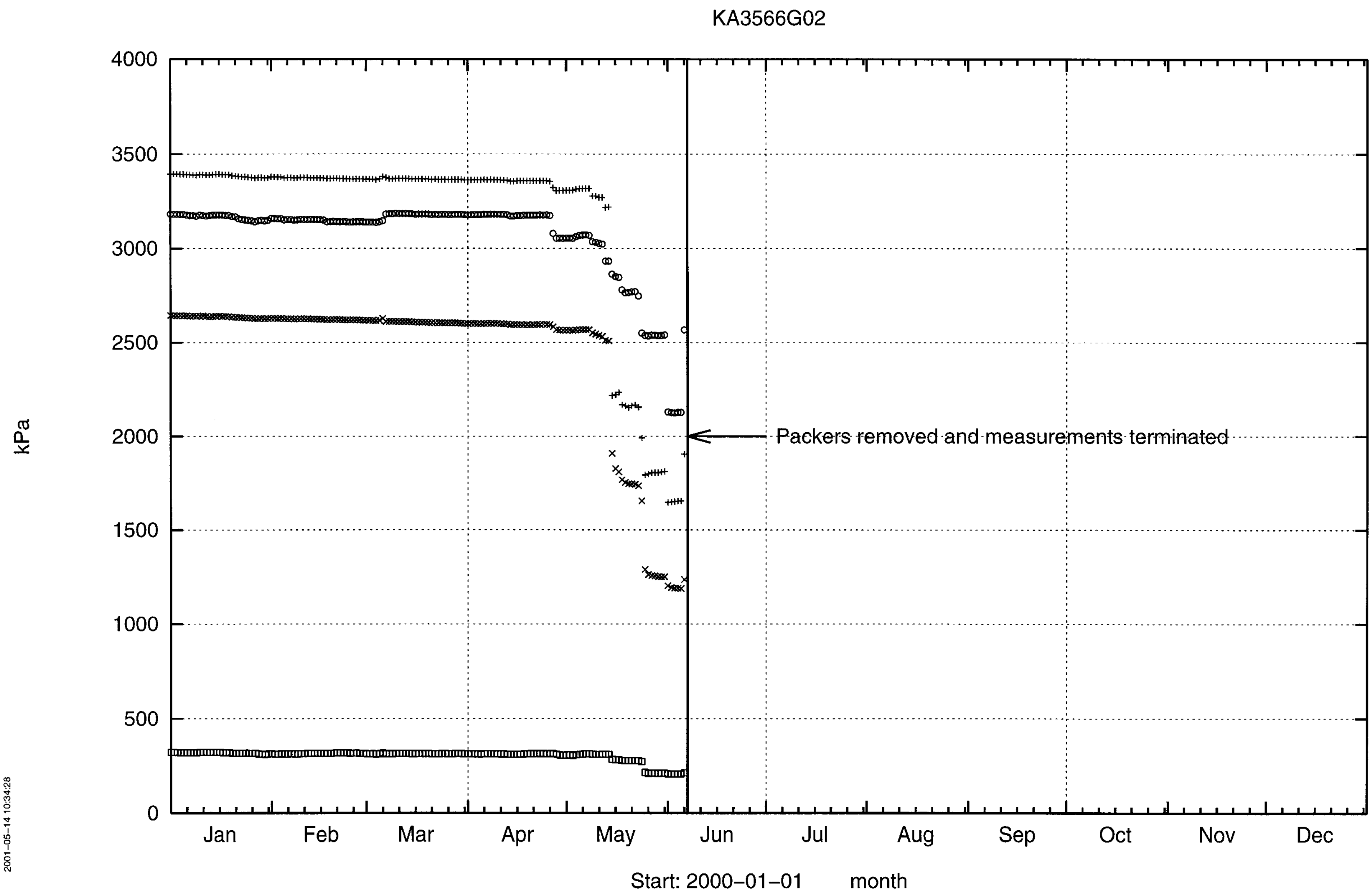

KA3557G
kPa
220
200
180
160
140
120
100
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-08-02 11:36:02



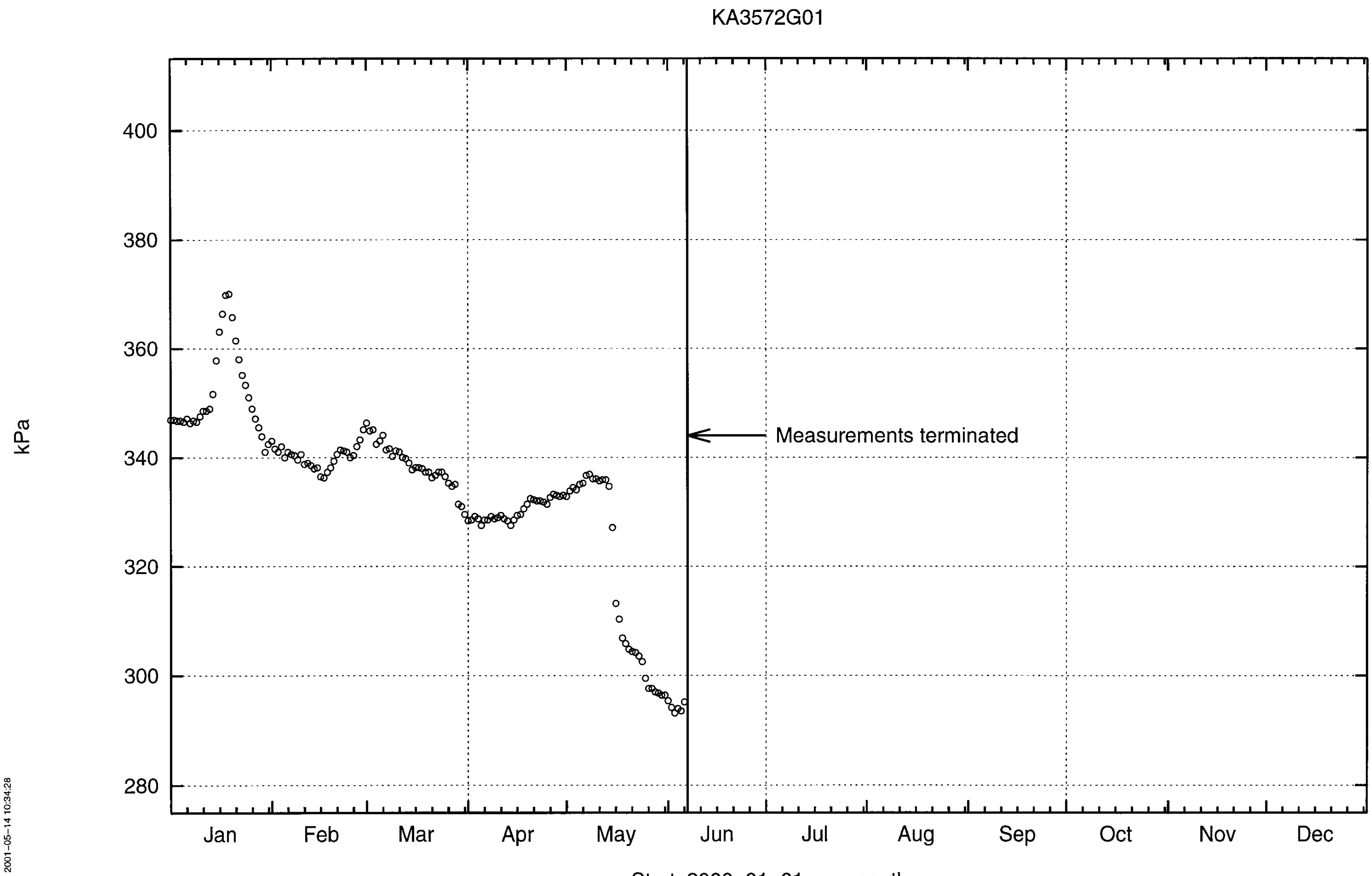
KA3563G
kPa
350
300
250
200
150
100
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:28

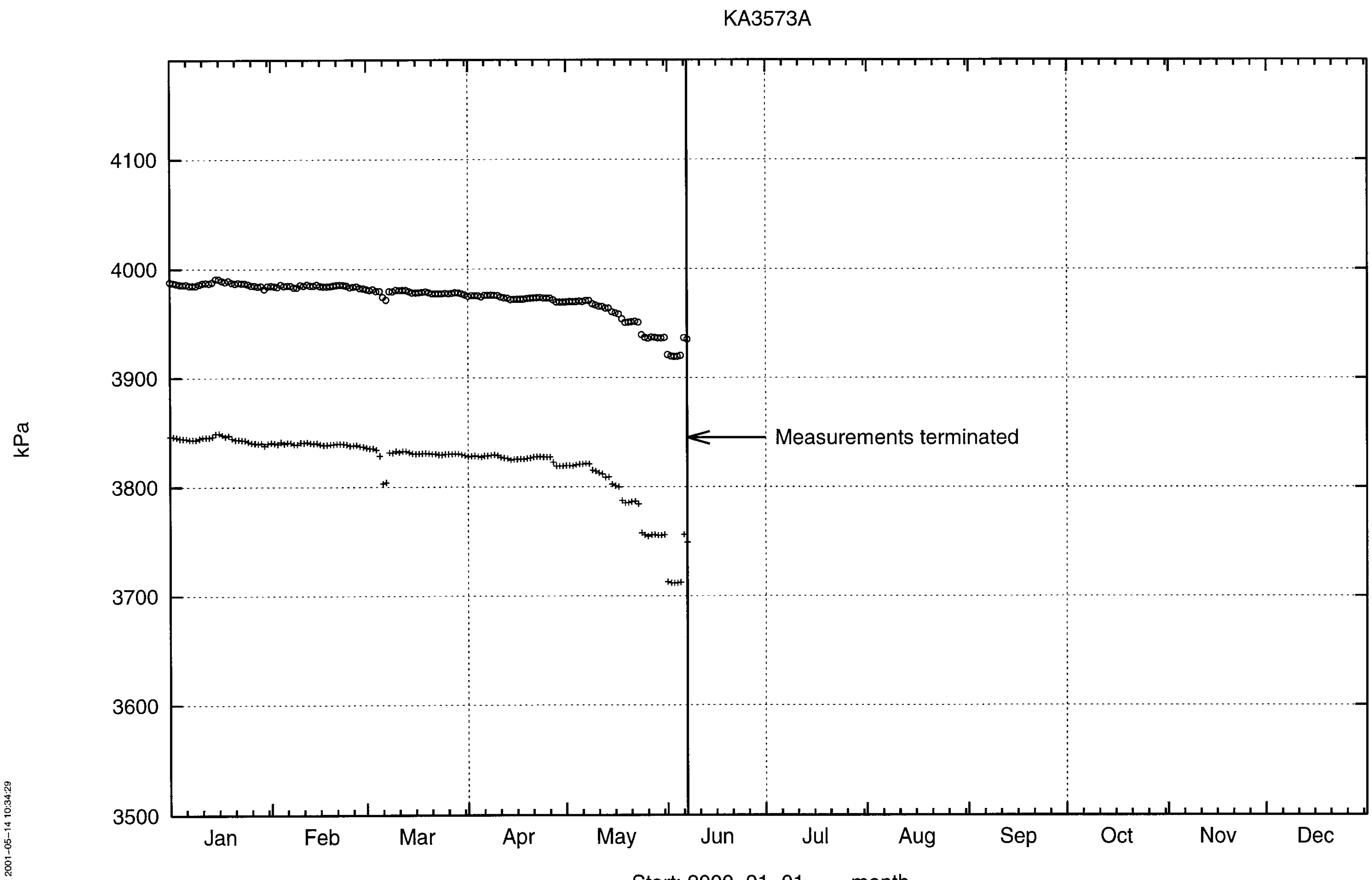


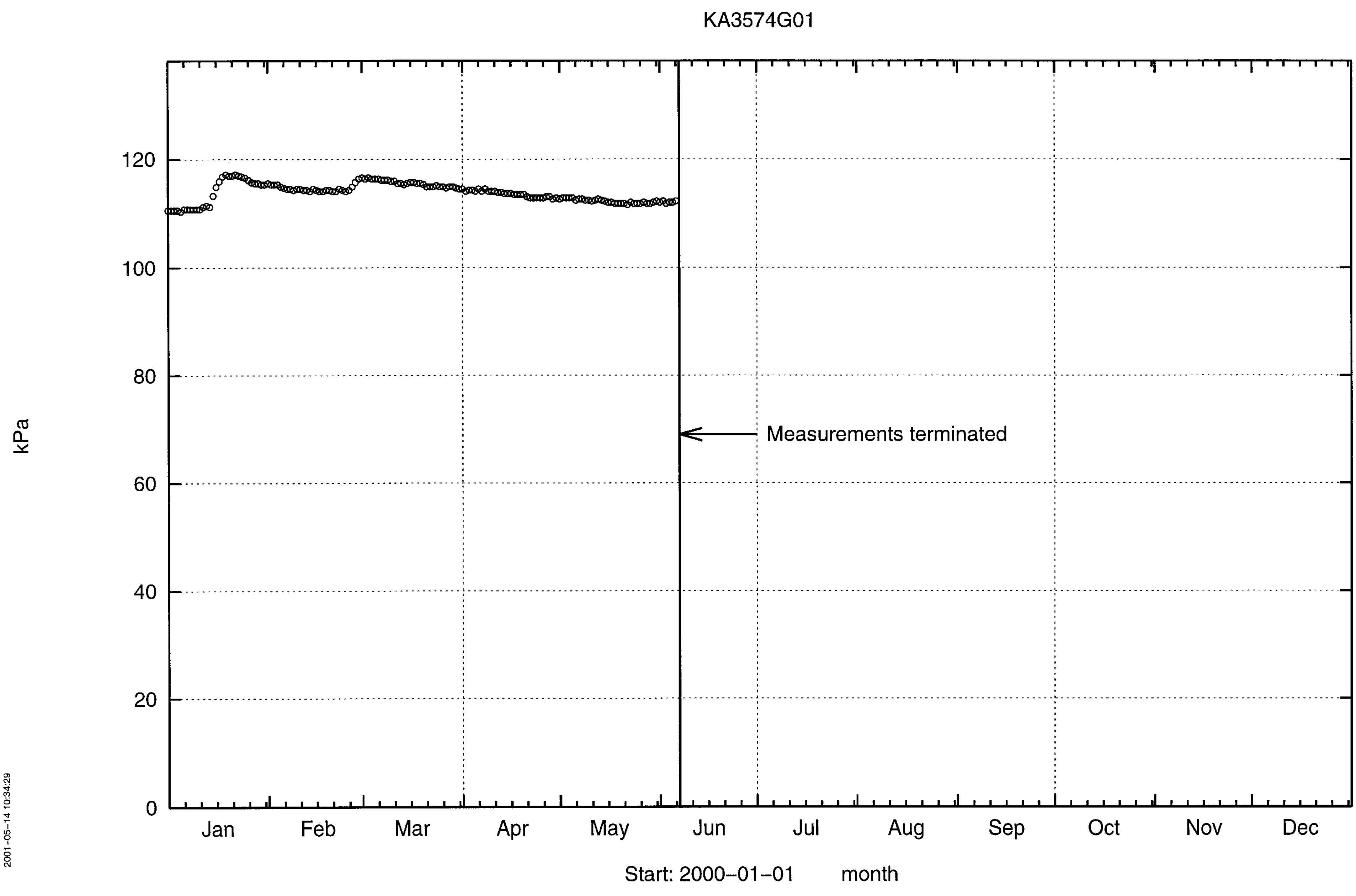
KA3566G01
kPa
3500
3000
2500
2000
1500
1000
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:28

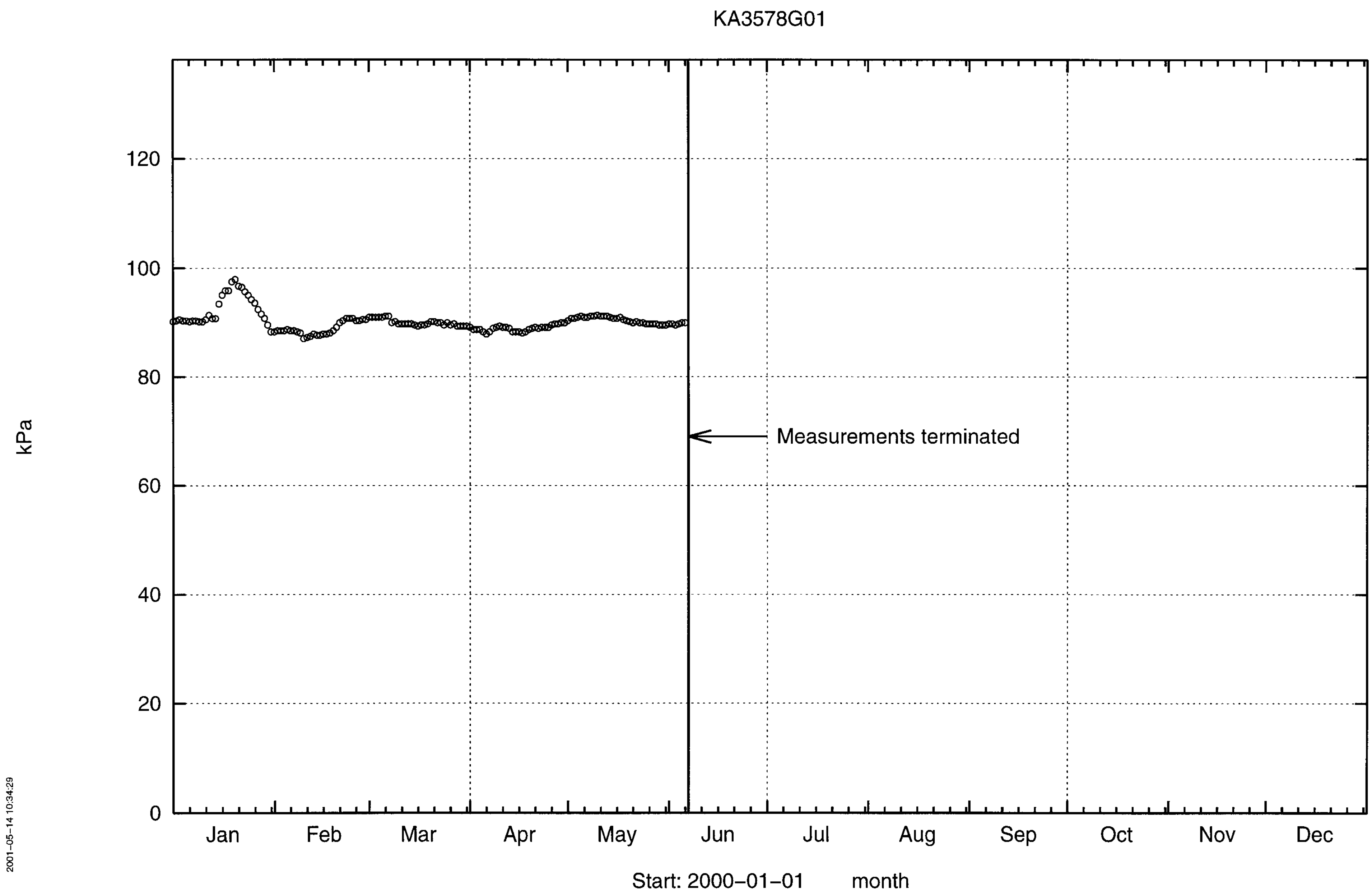


KA3566G02
kPa
4000
3500
3000
2500
2000
1500
1000
500
0
Packers removed and measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:28

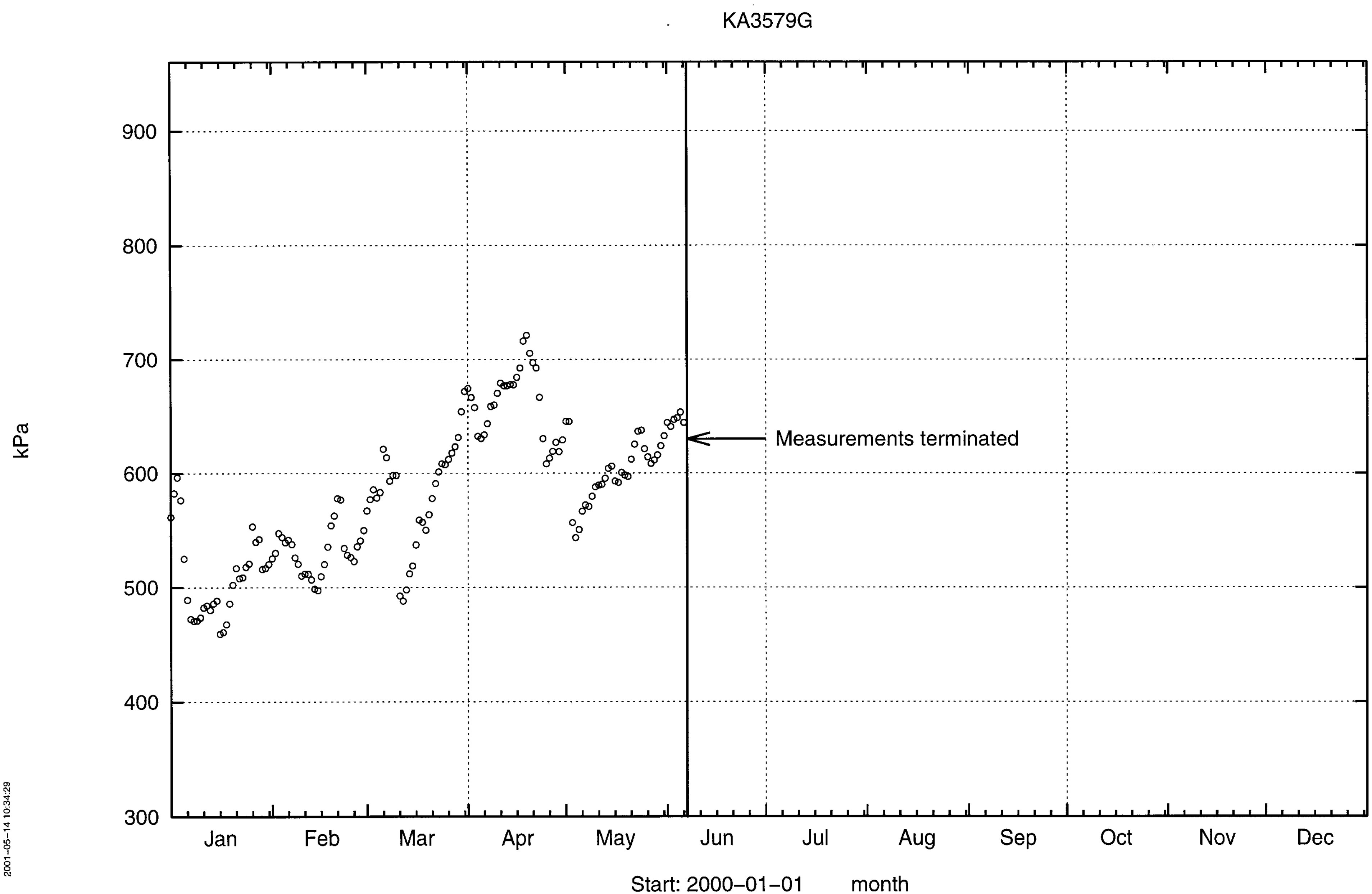

KA3572G01
kPa
400
380
360
340
320
300
280
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−14 10:34:28

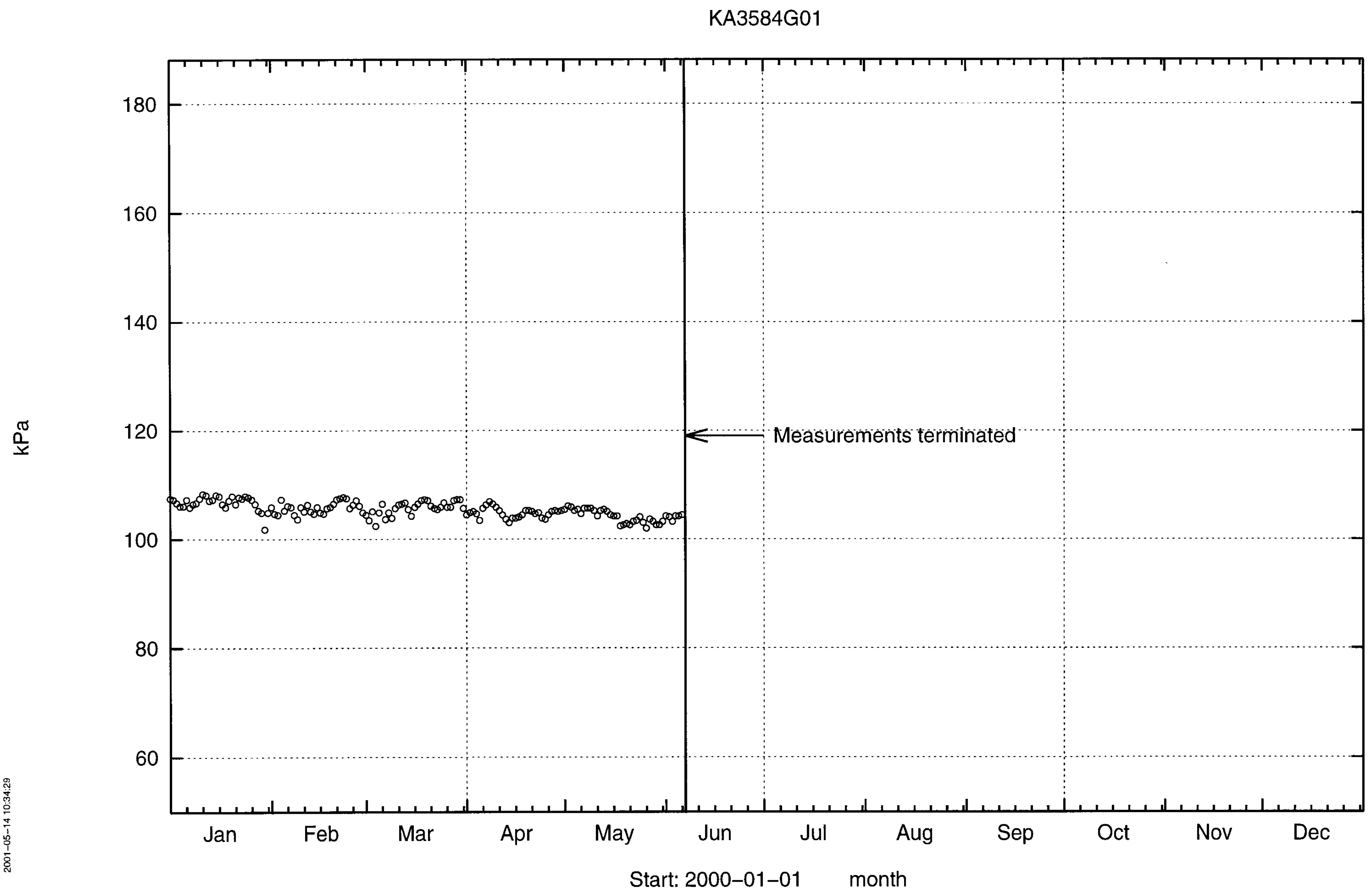

KA3573A
kPa
4100
4000
3900
3800
3700
3600
3500
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:29


KA3574G01
kPa
120
100
80
60
40
20
0
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:29

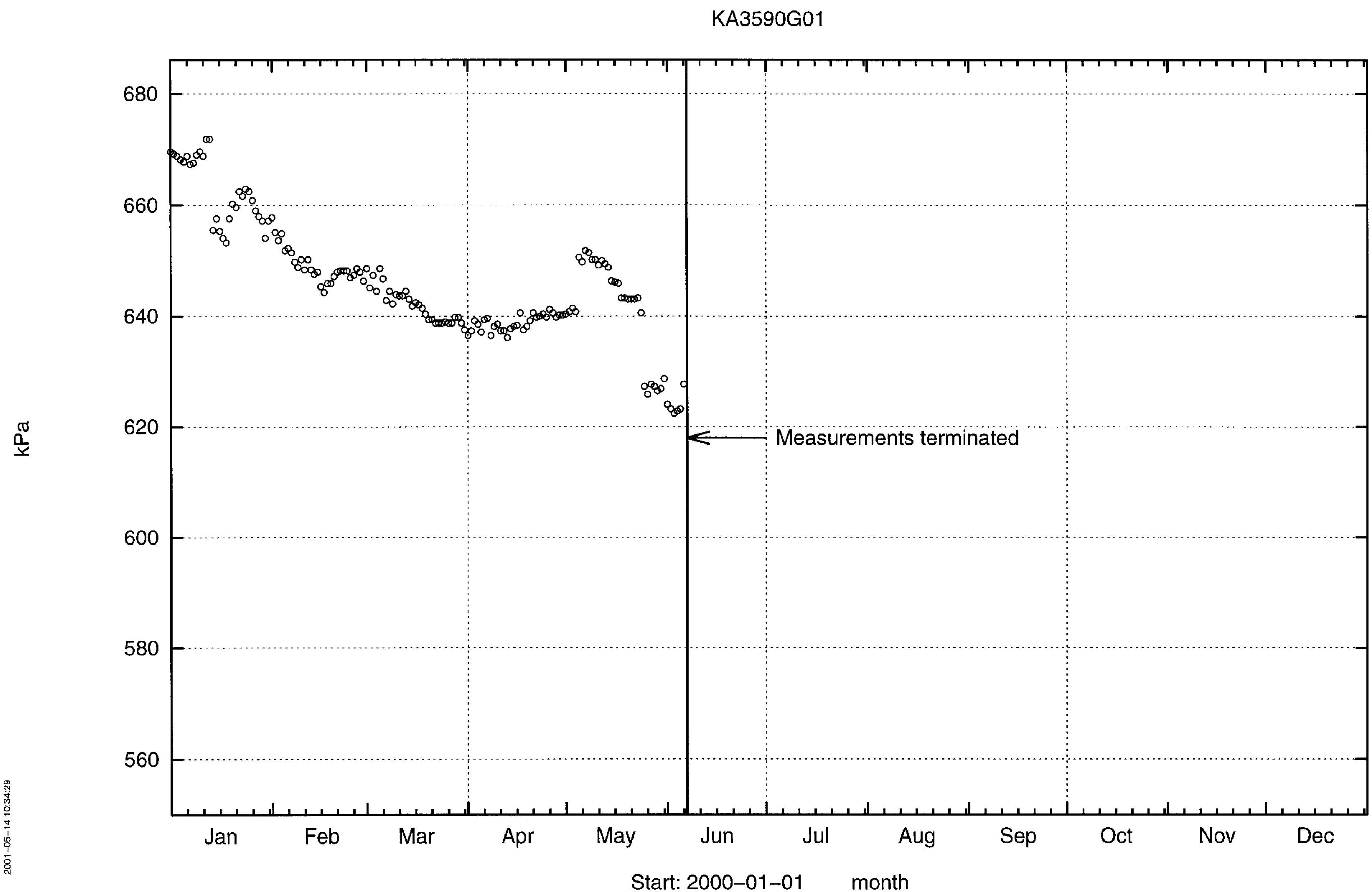


KA3578G01
kPa
120
100
80
60
40
20
0
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:29

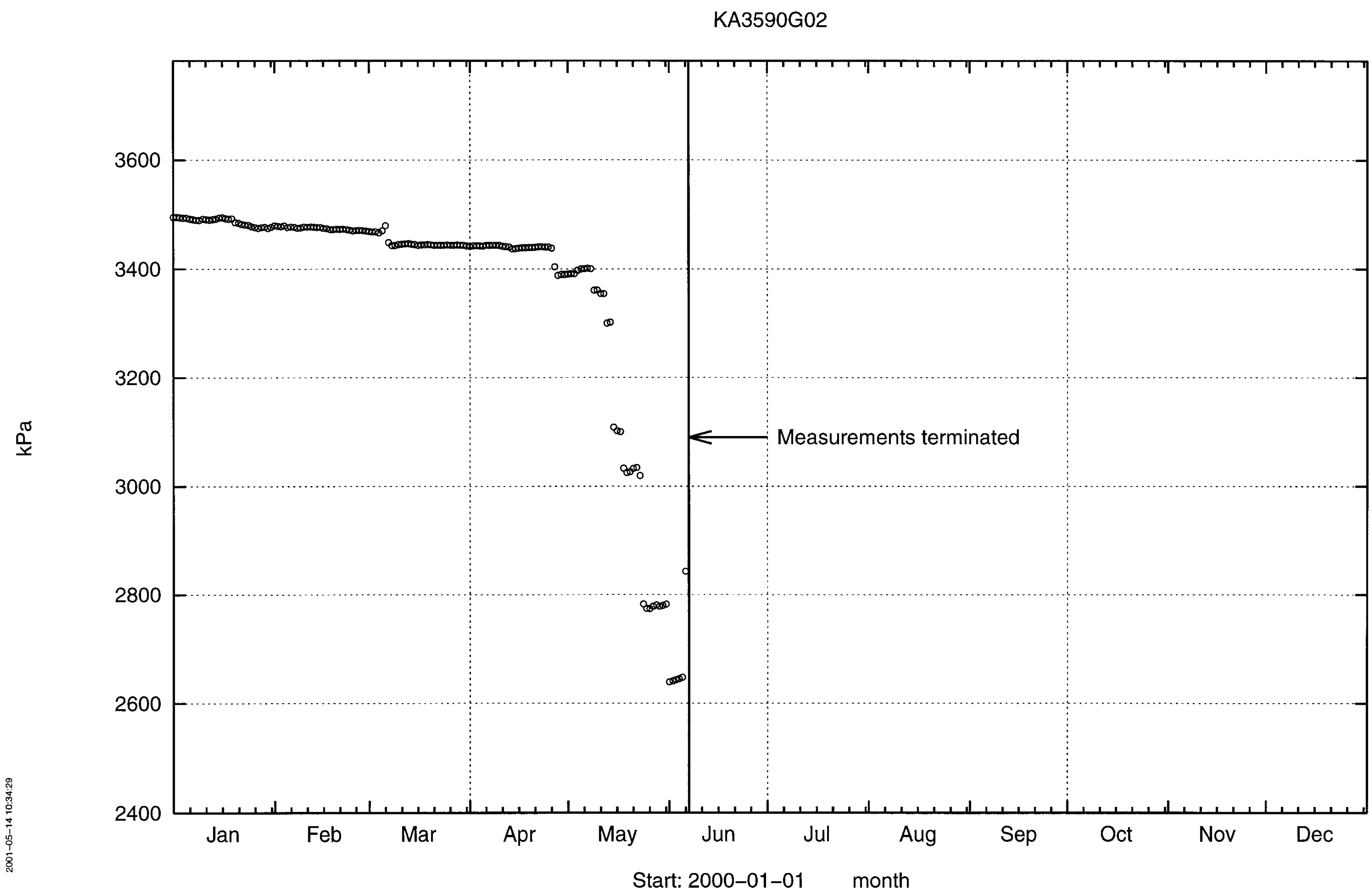

KA3579G
kPa
900
800
700
600
500
400
300
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:29

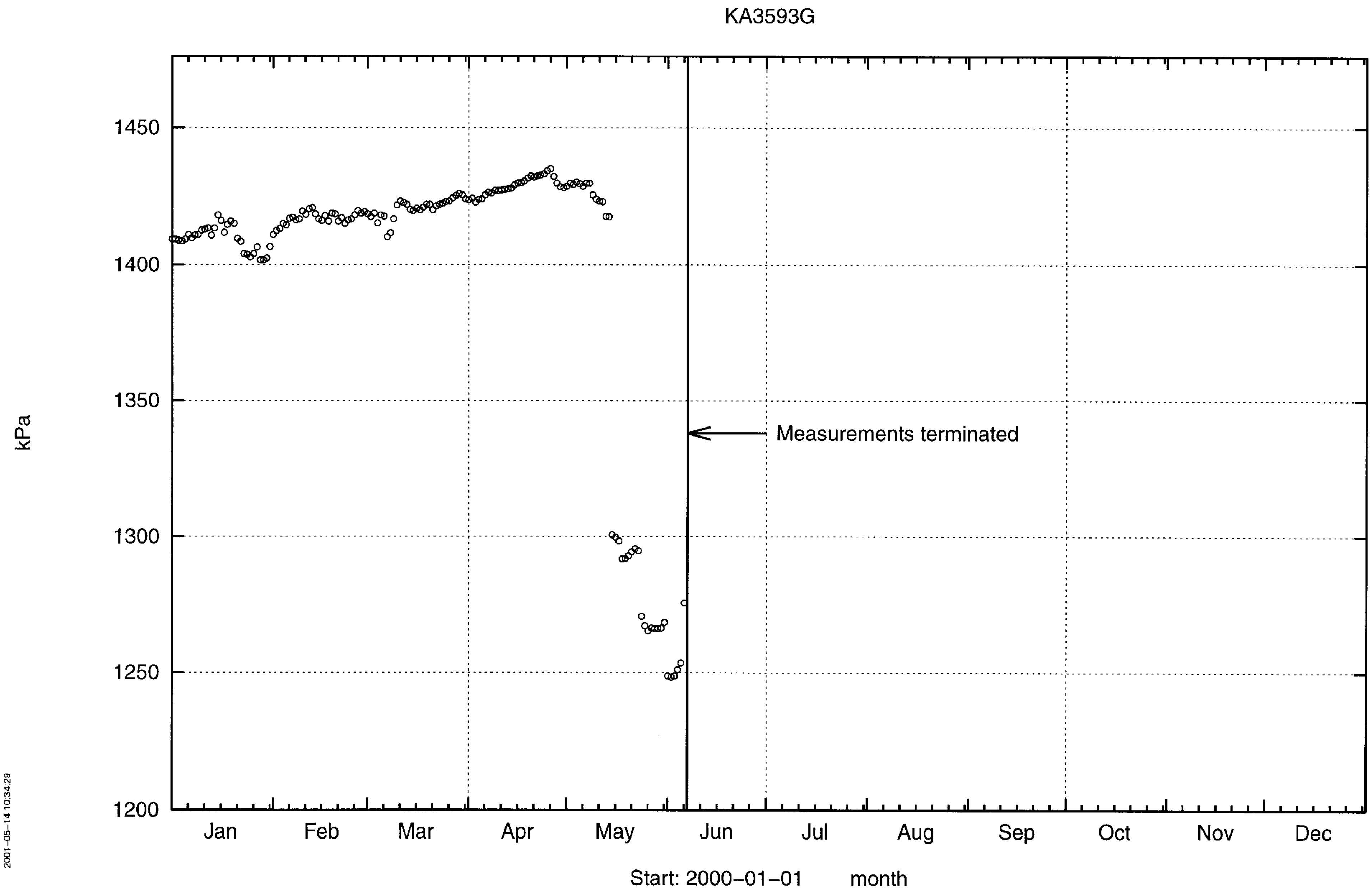


KA3584G01
kPa
180
160
140
120
100
80
60
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:29

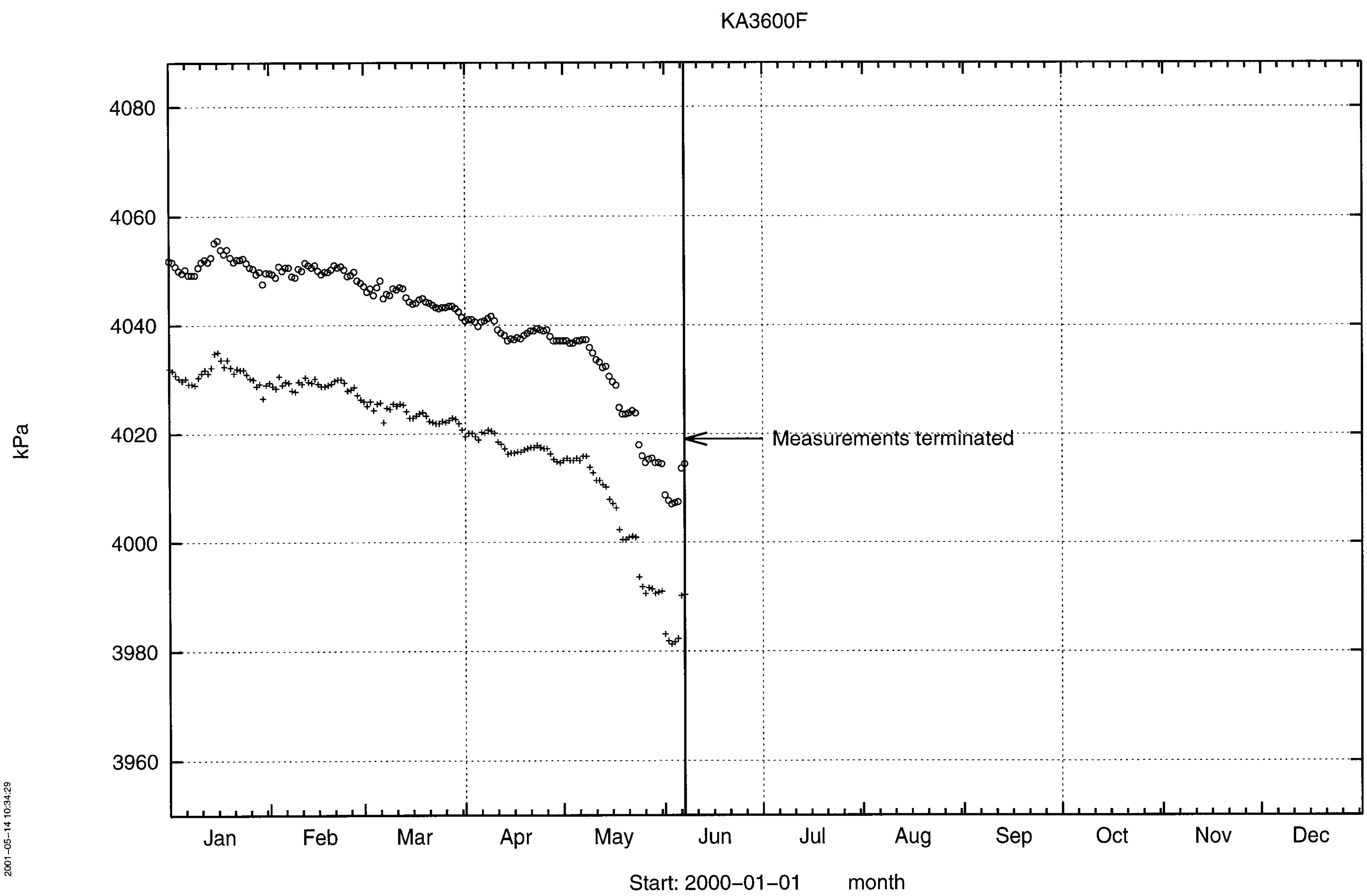


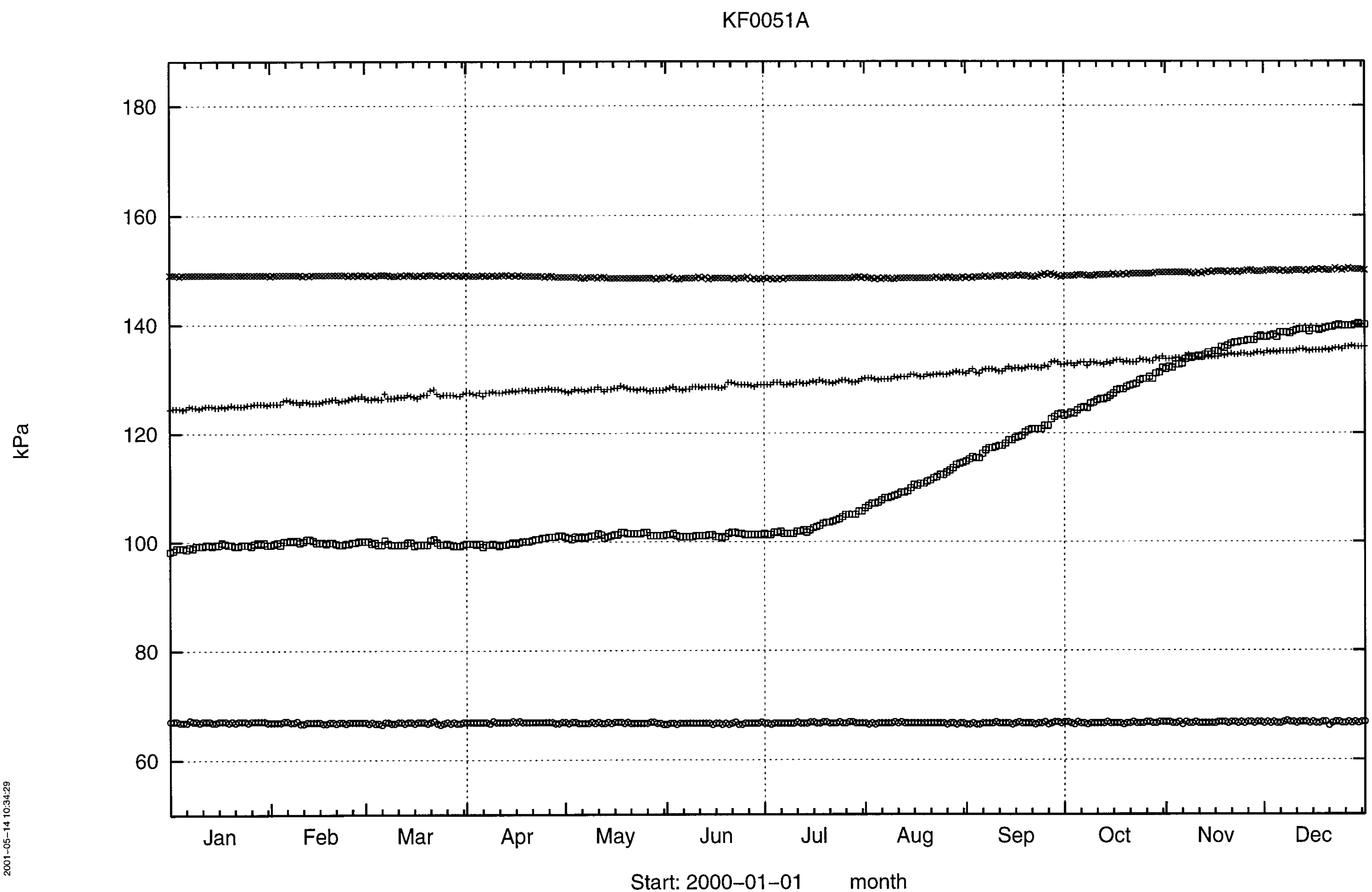
KA3590G01
kPa
680
660
640
620
600
580
560
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:29


KA3590G02
kPa
3600
3400
3200
3000
2800
2600
2400
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:29

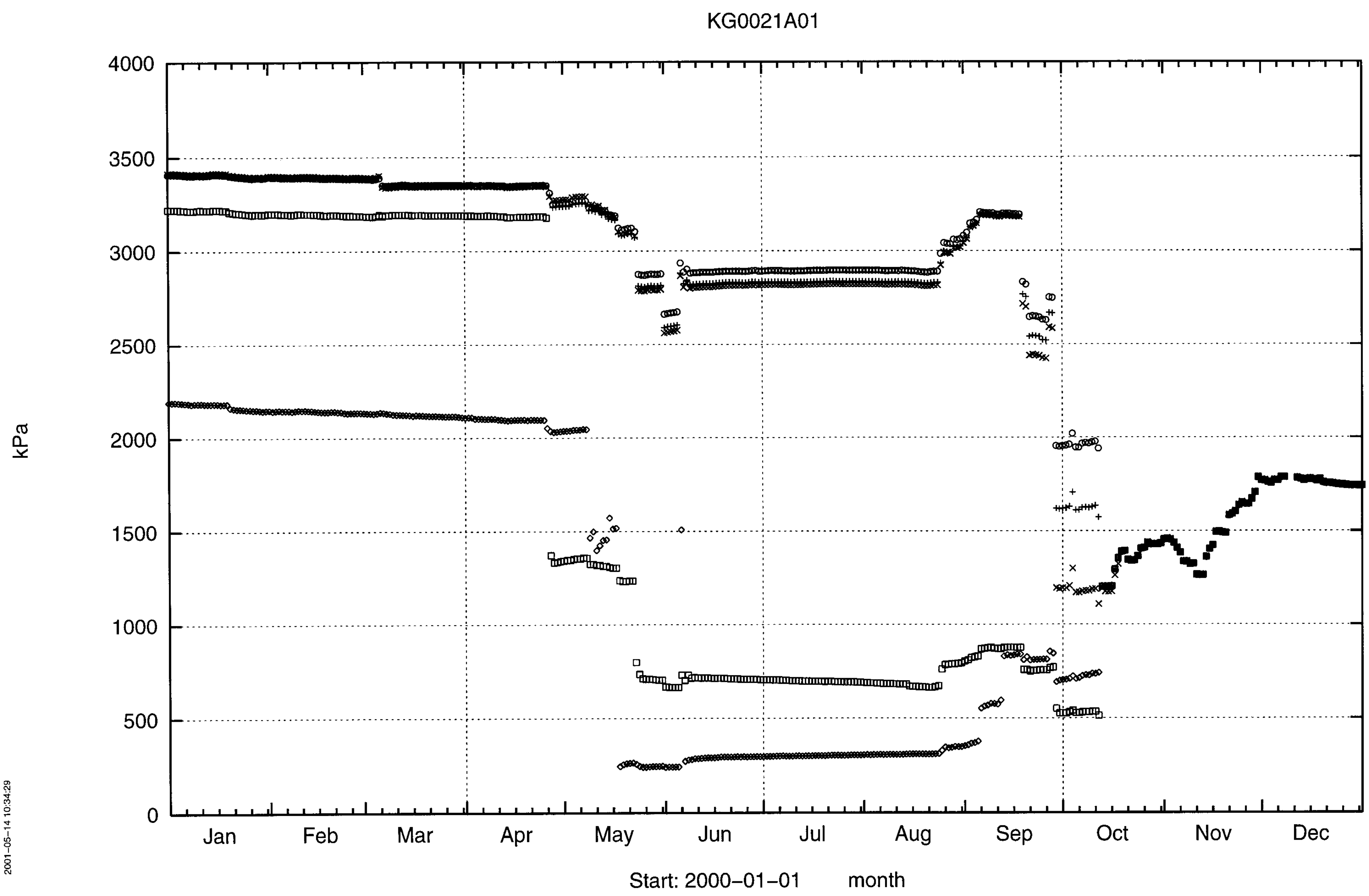


2001-05-14 10:34:29

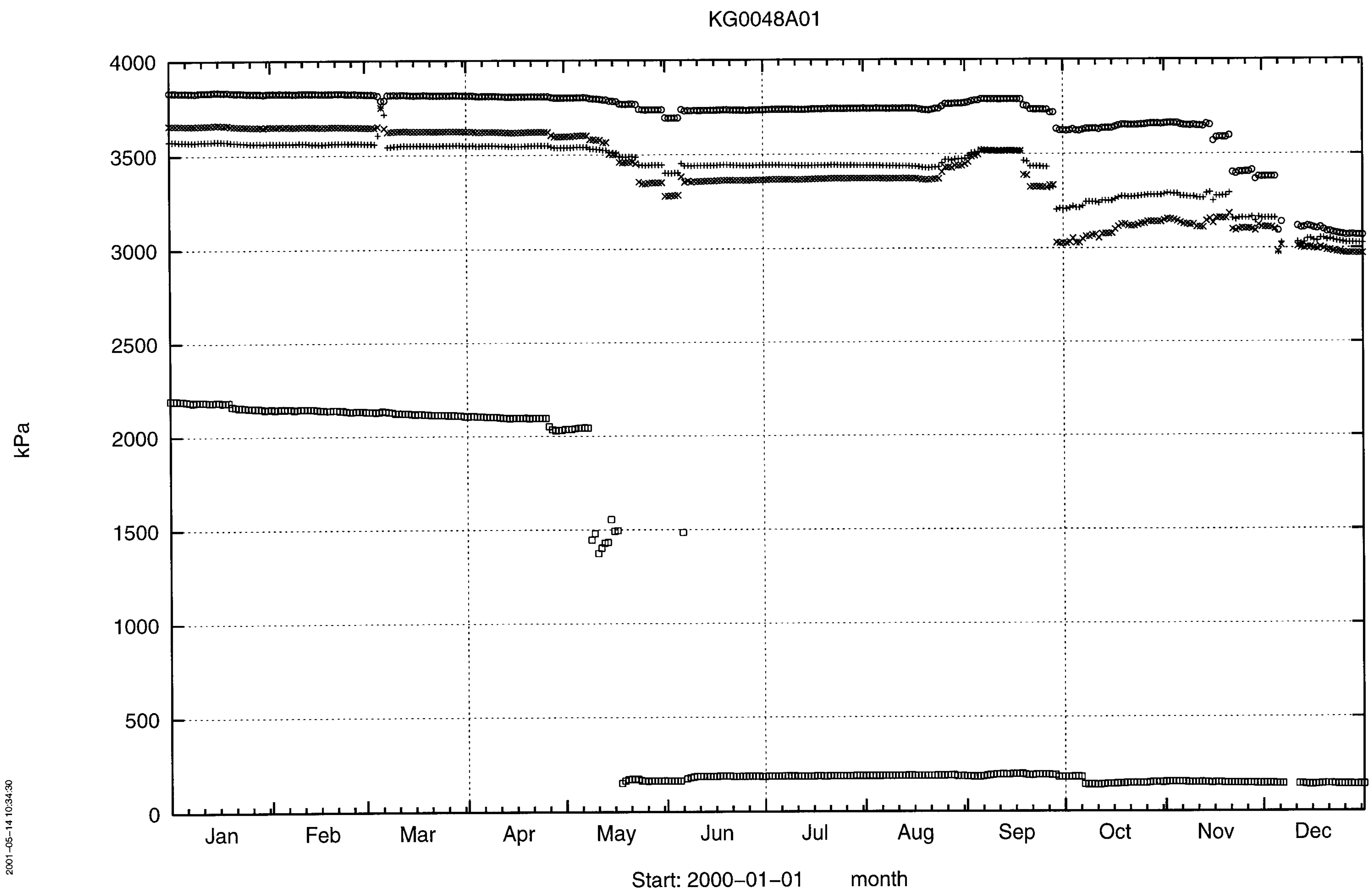

KA3600F
kPa
4080
4060
4040
4020
4000
3980
3960
Measurements terminated
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:29

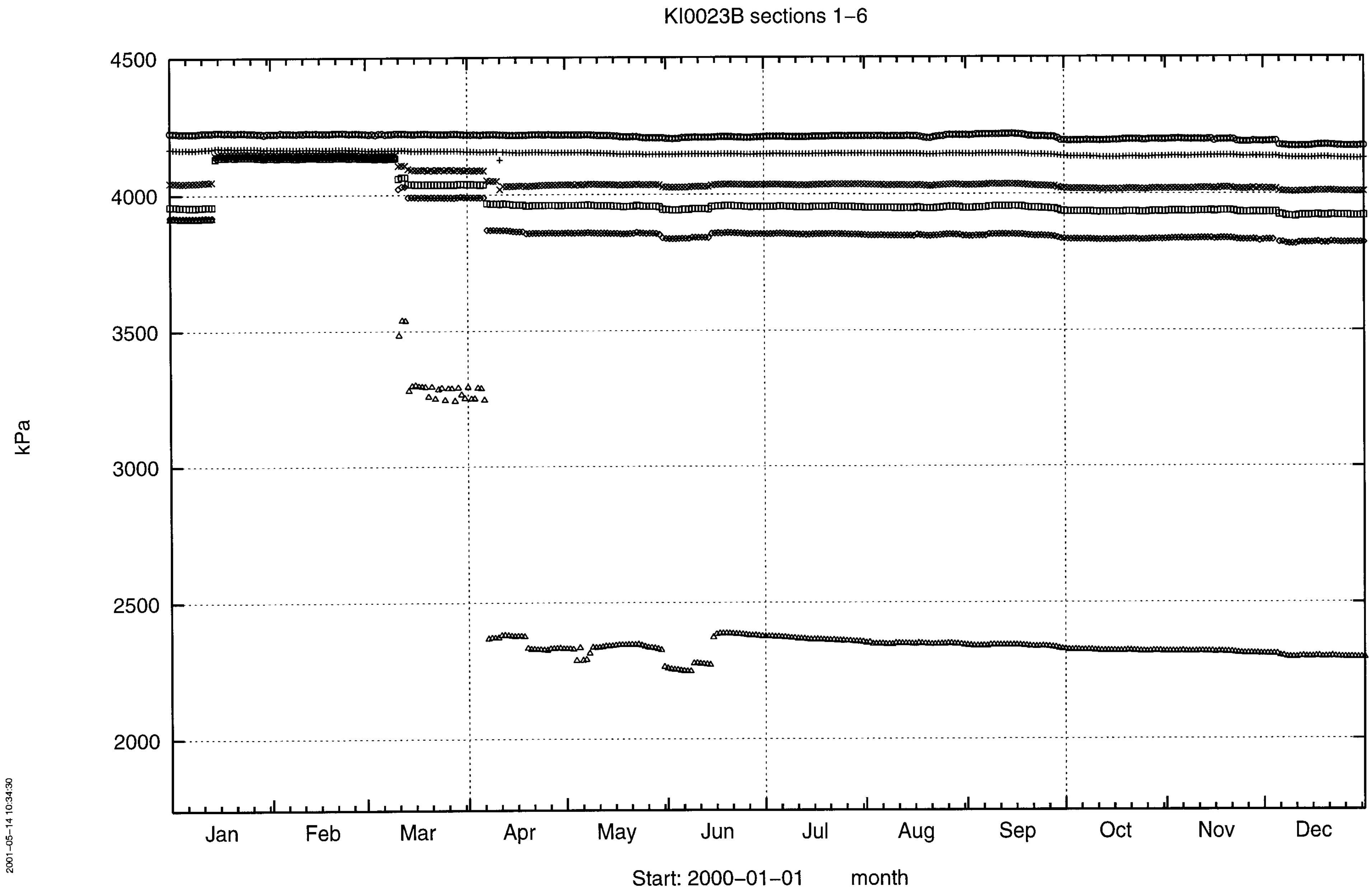


2001-05-14 10:34:29

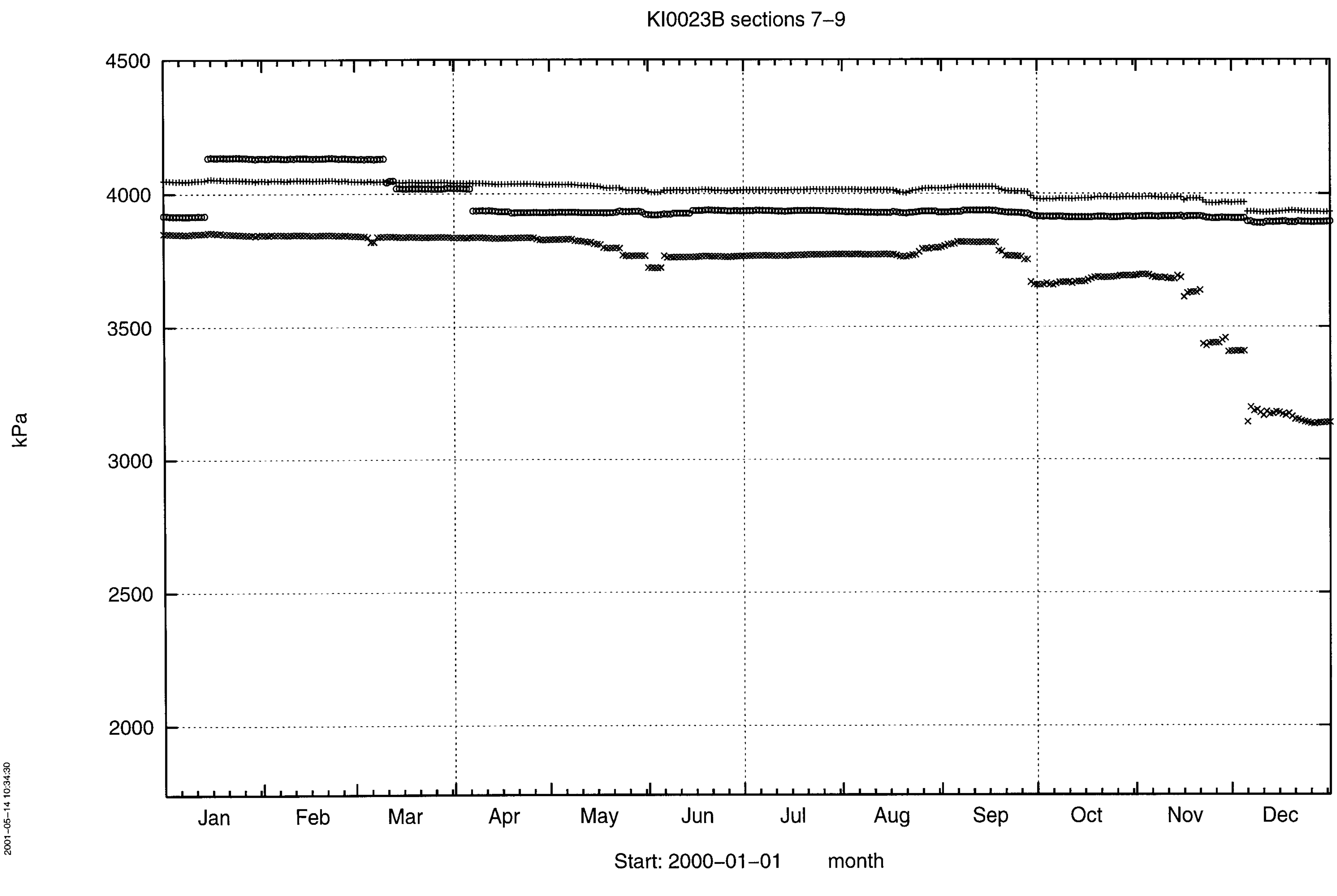


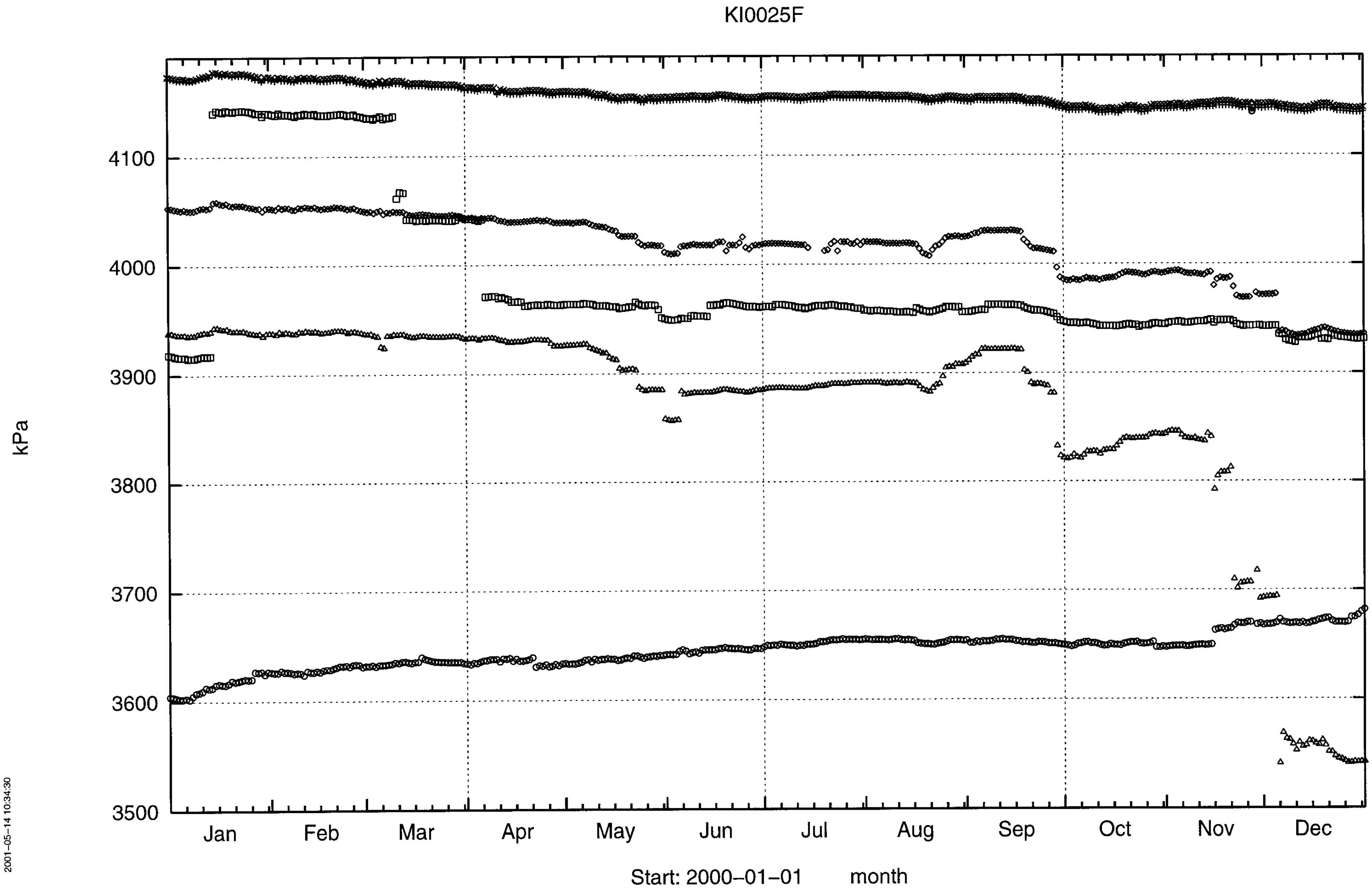
KG0021A01
kPa
4000
3500
3000
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:29


KG0048A01
kPa
4000
3500
3000
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:30

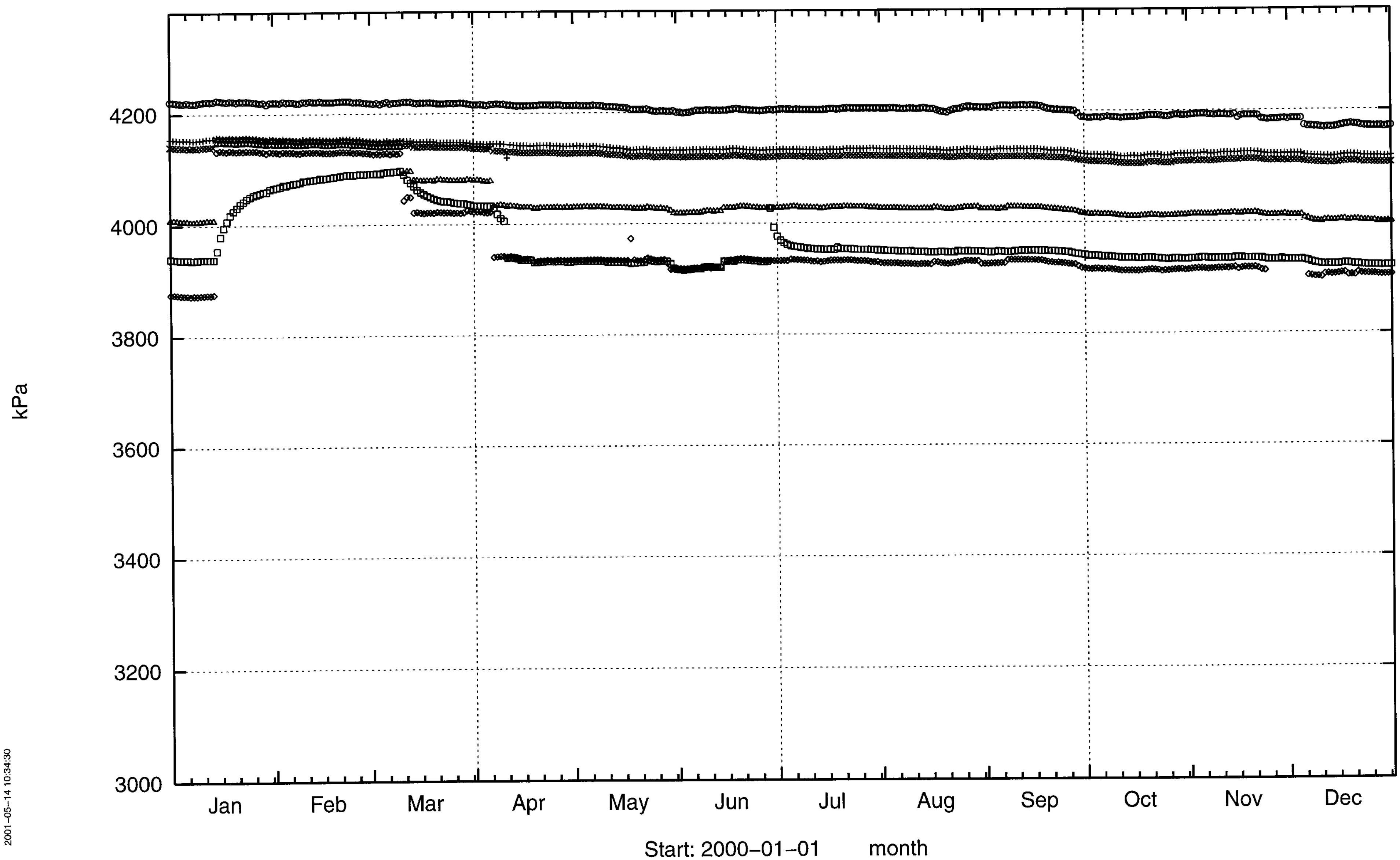


KI0023B sections 1–6
4500
4000
3500
3000
2500
2000
kPa
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:34:30

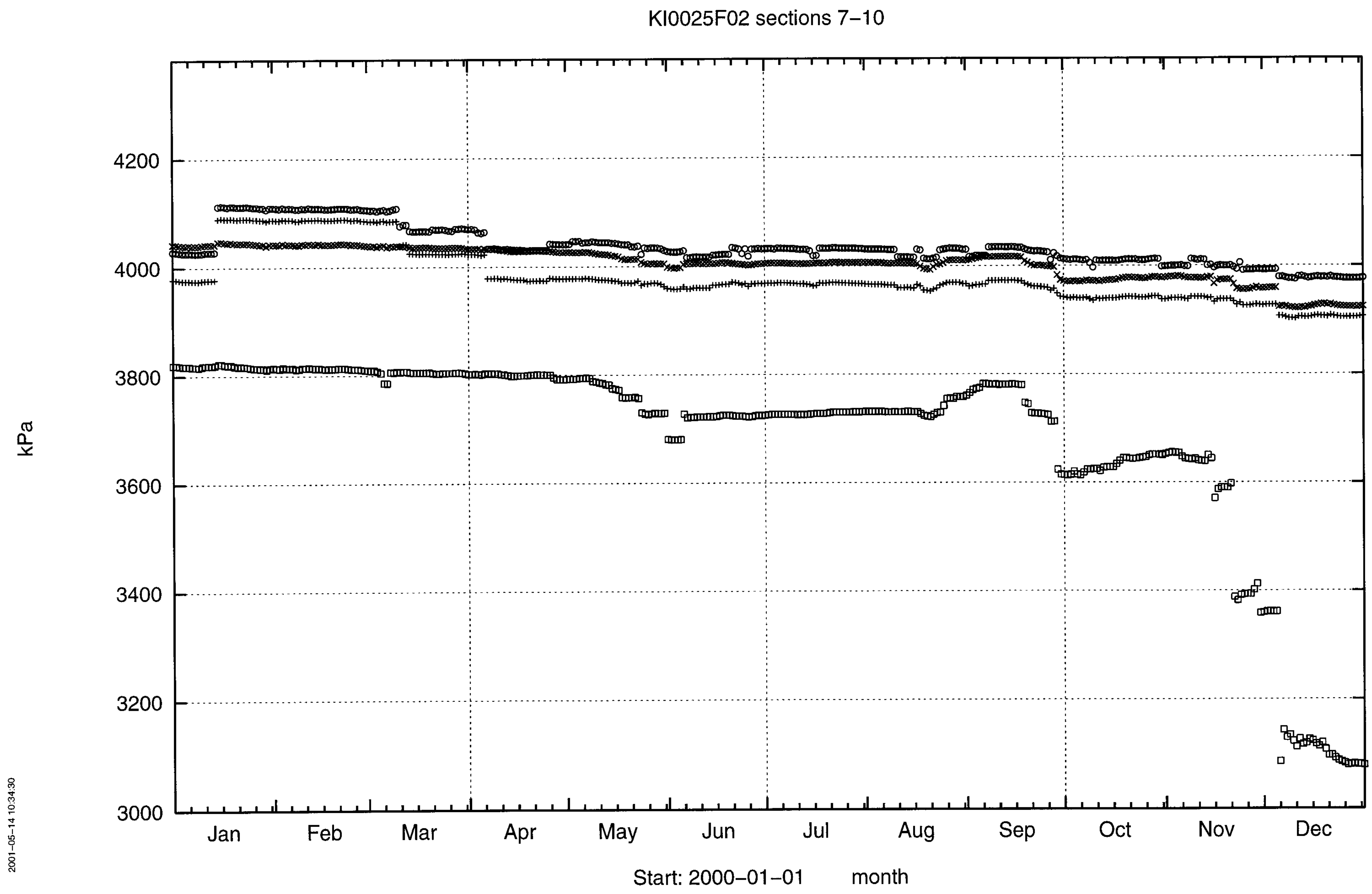

KI0023B sections 7–9
4500
4000
3500
3000
2500
2000
kPa
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:34:30


KI0025F
kPa
4100
4000
3900
3800
3700
3600
3500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:34:30

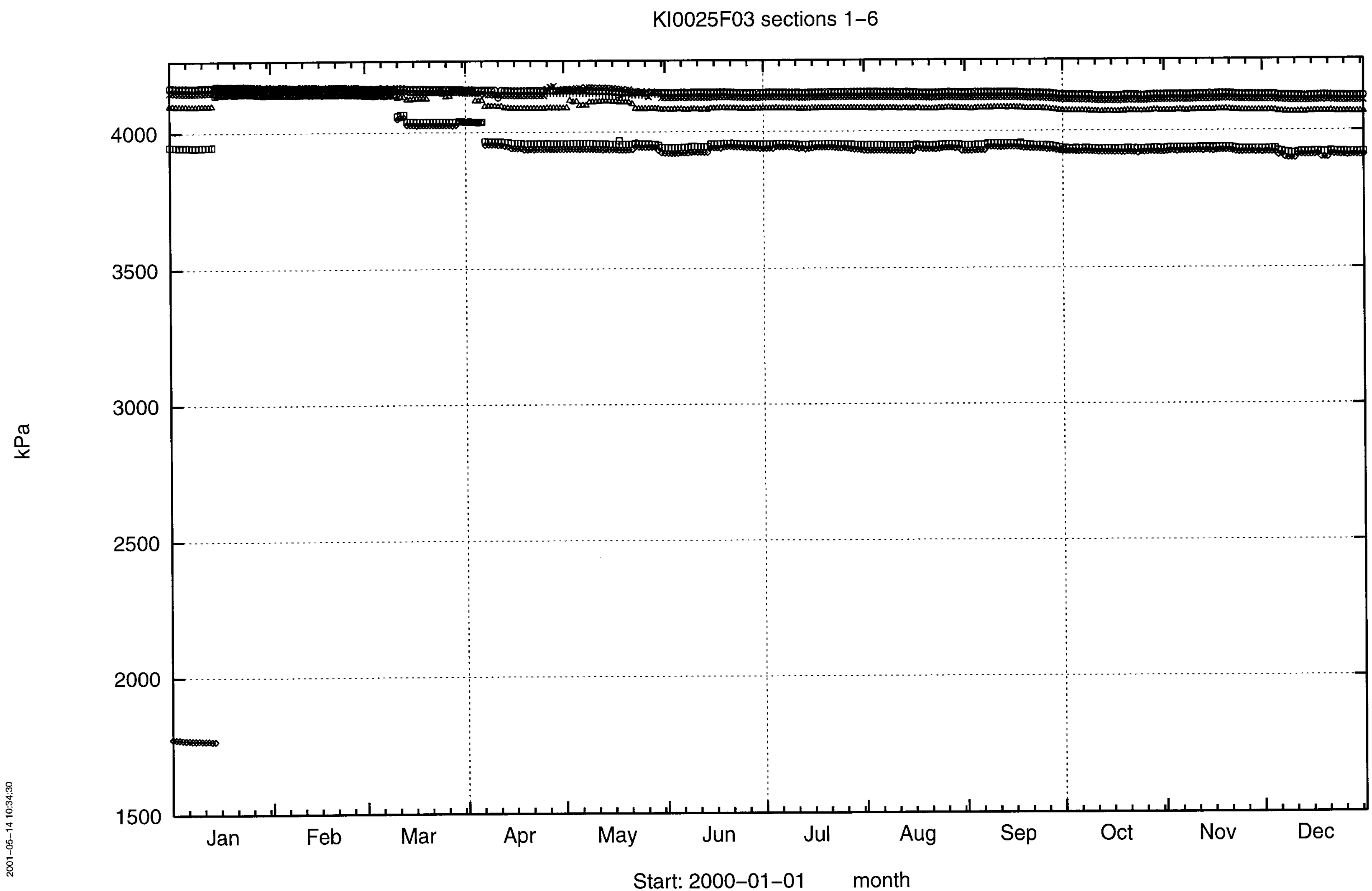
KI0025F02 sections 1–6



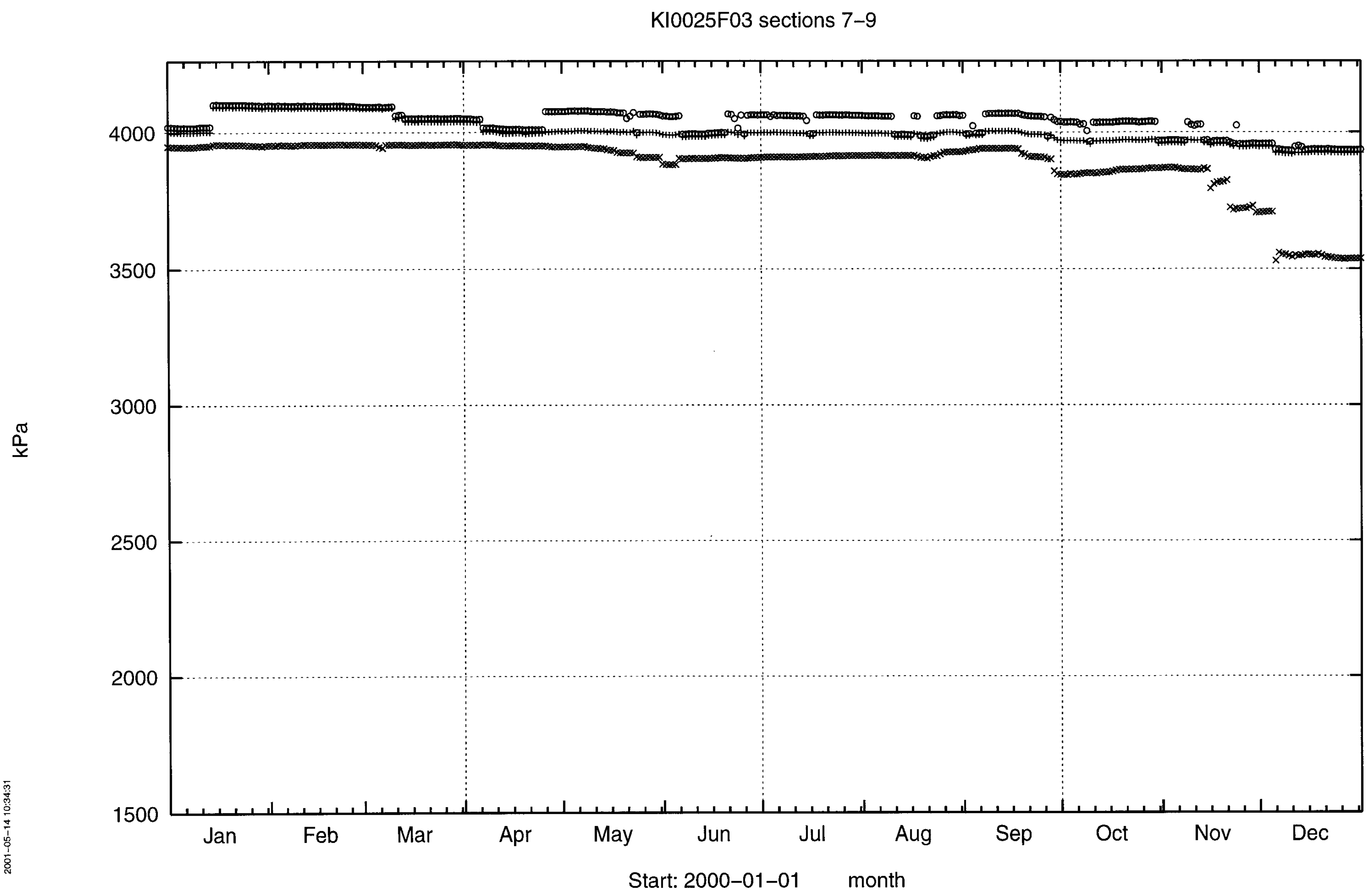
2001–05–14 10:34:30



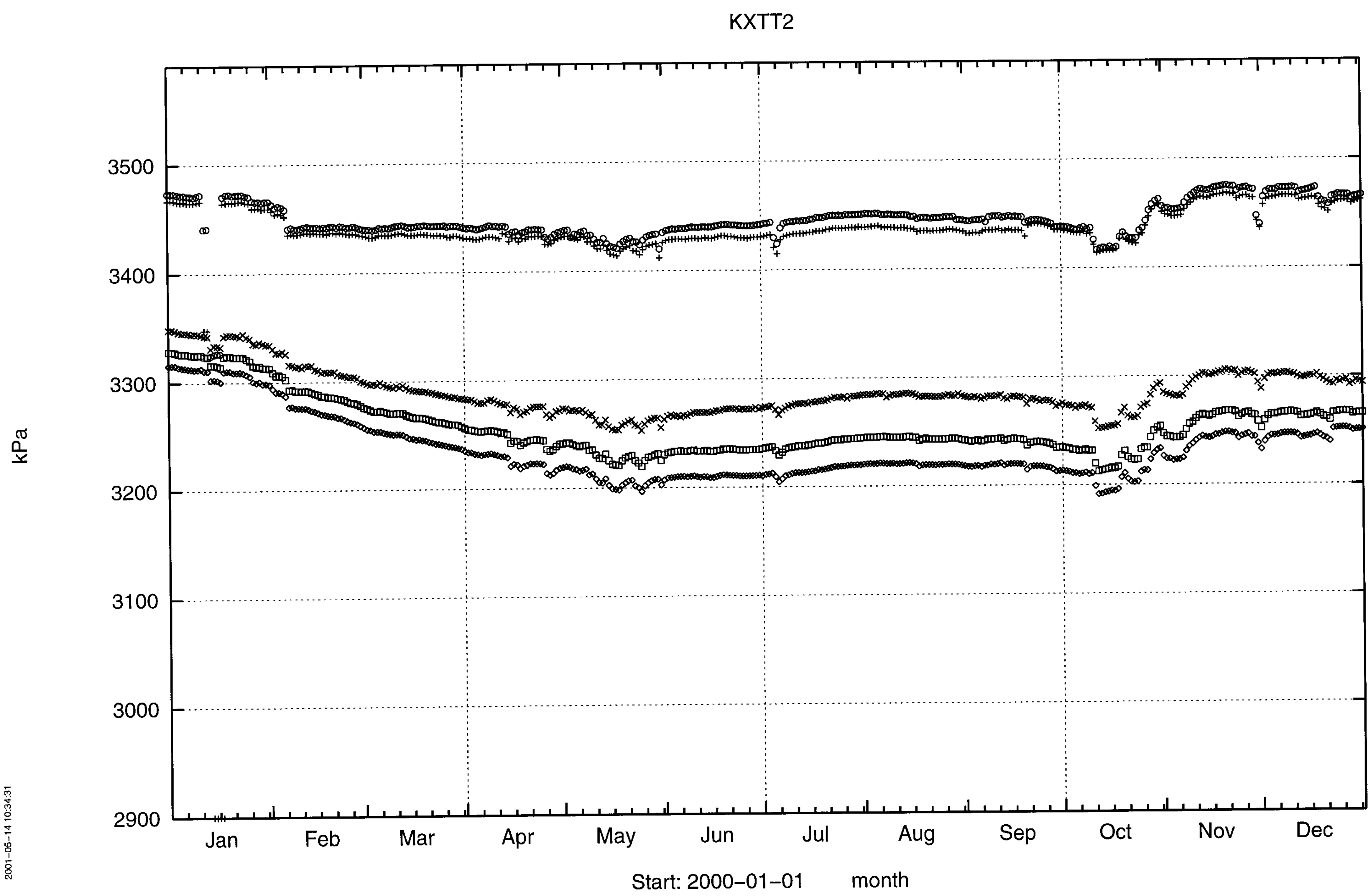
KI0025F02 sections 7–10
kPa
4200
4000
3800
3600
3400
3200
3000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01 month
2001–05–14 10:34:30

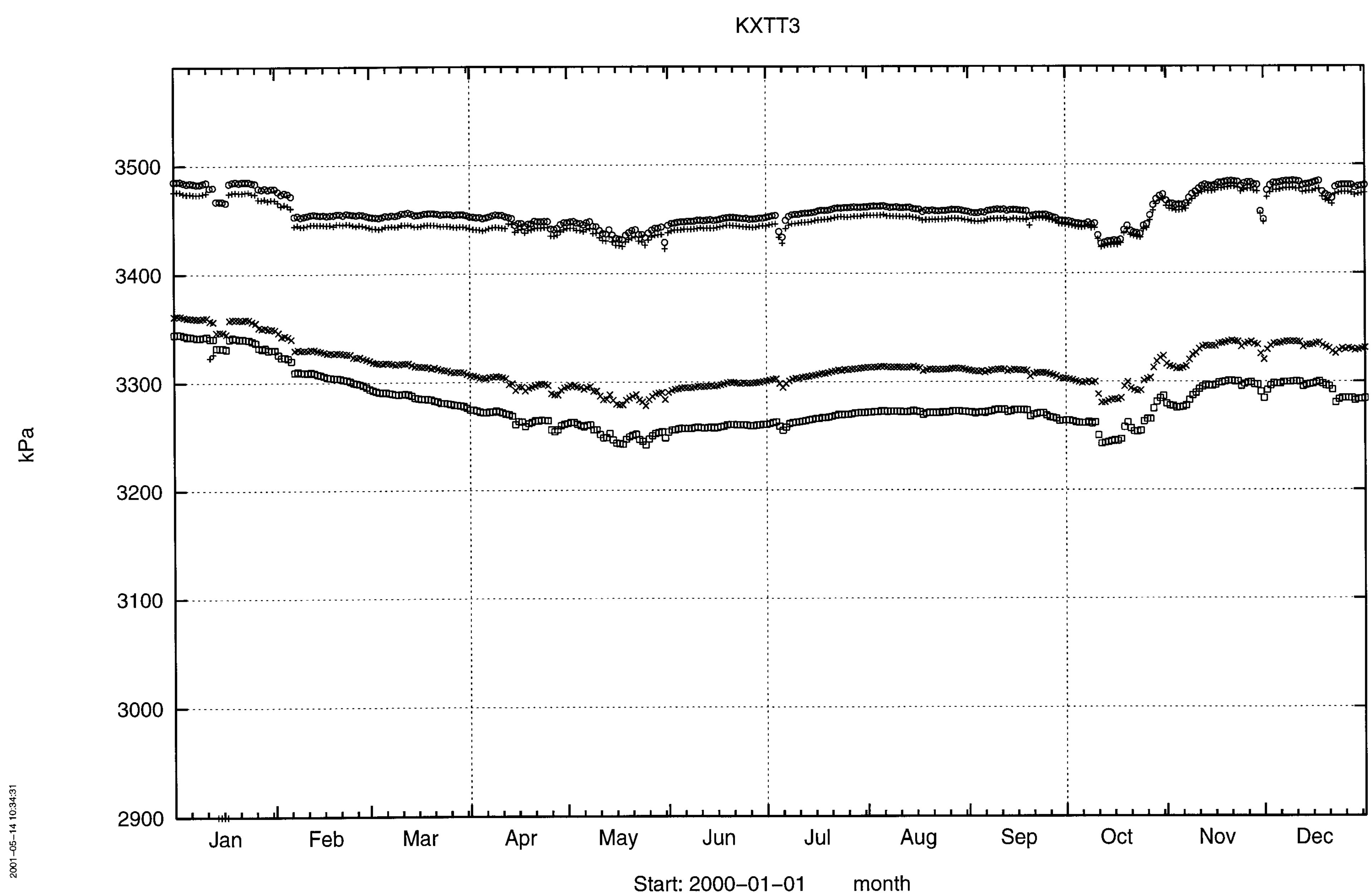


KI0025F03 sections 1–6
kPa
4000
3500
3000
2500
2000
1500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001-05-14 10:34:30

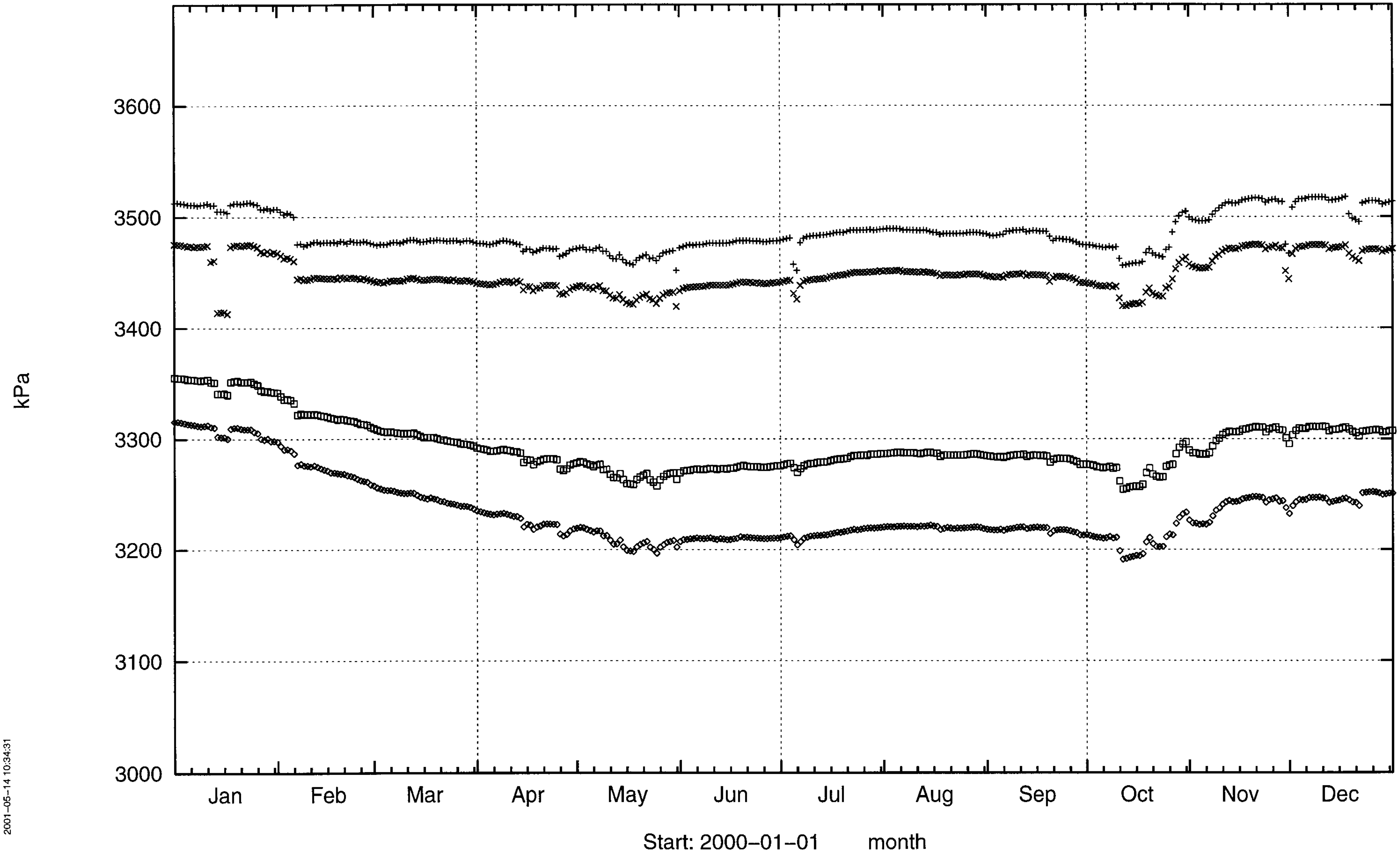


KI0025F03 sections 7–9
kPa
4000
3500
3000
2500
2000
1500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:34:31

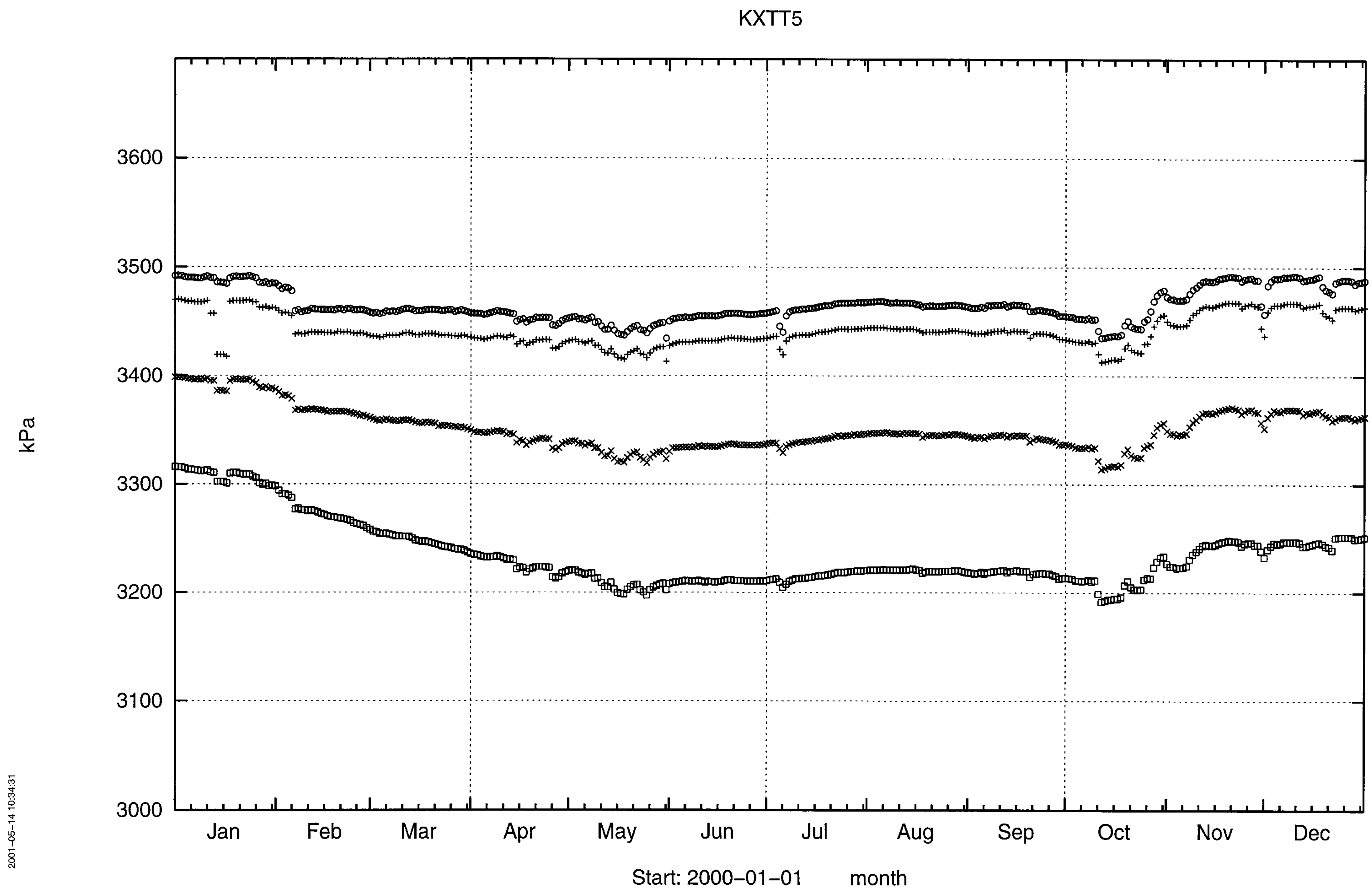

KXTT2
kPa
3500
3400
3300
3200
3100
3000
2900
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:31

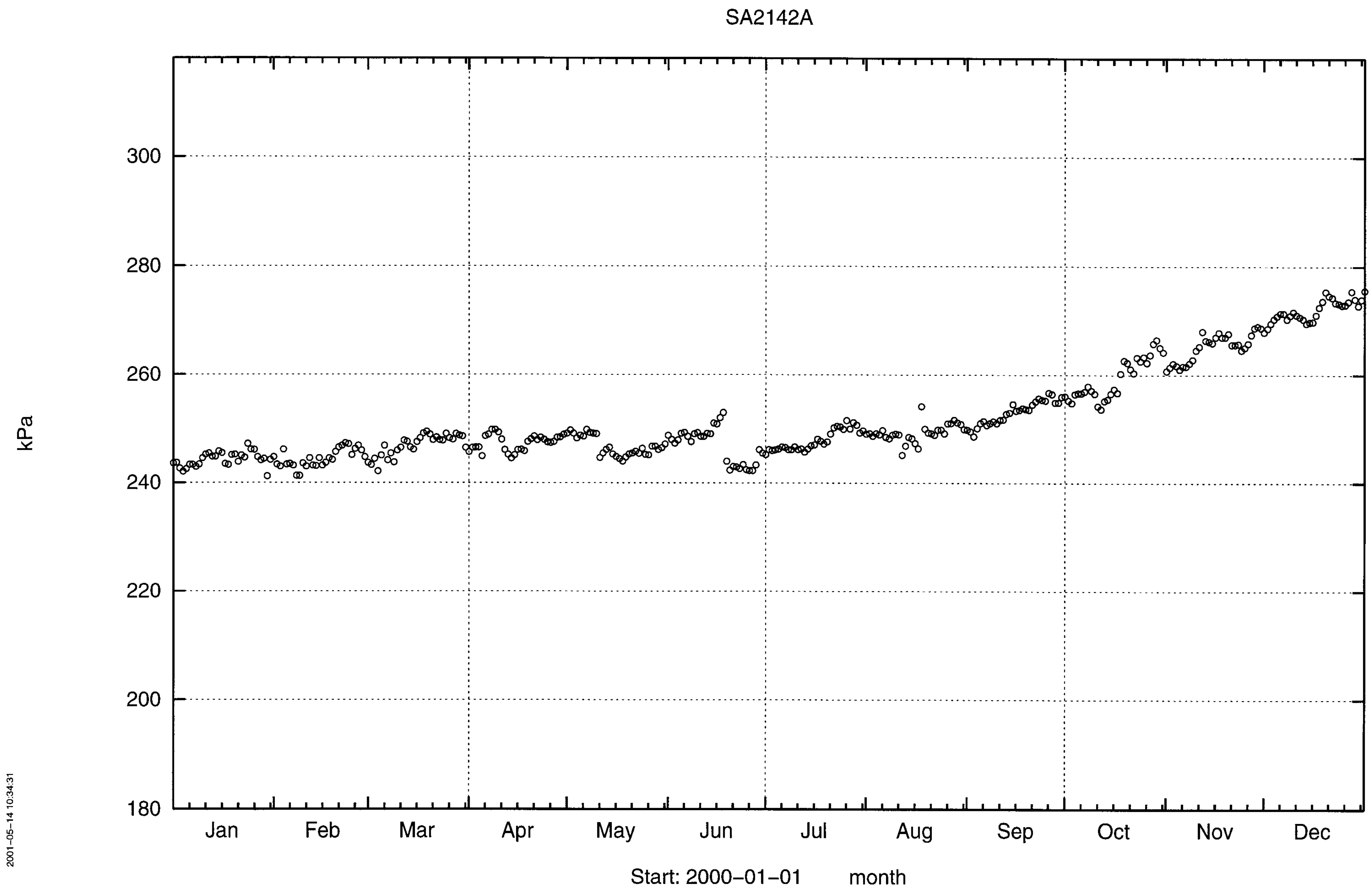

KXTT3
kPa
3500
3400
3300
3200
3100
3000
2900
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01 month
2001-05-14 10:34:31

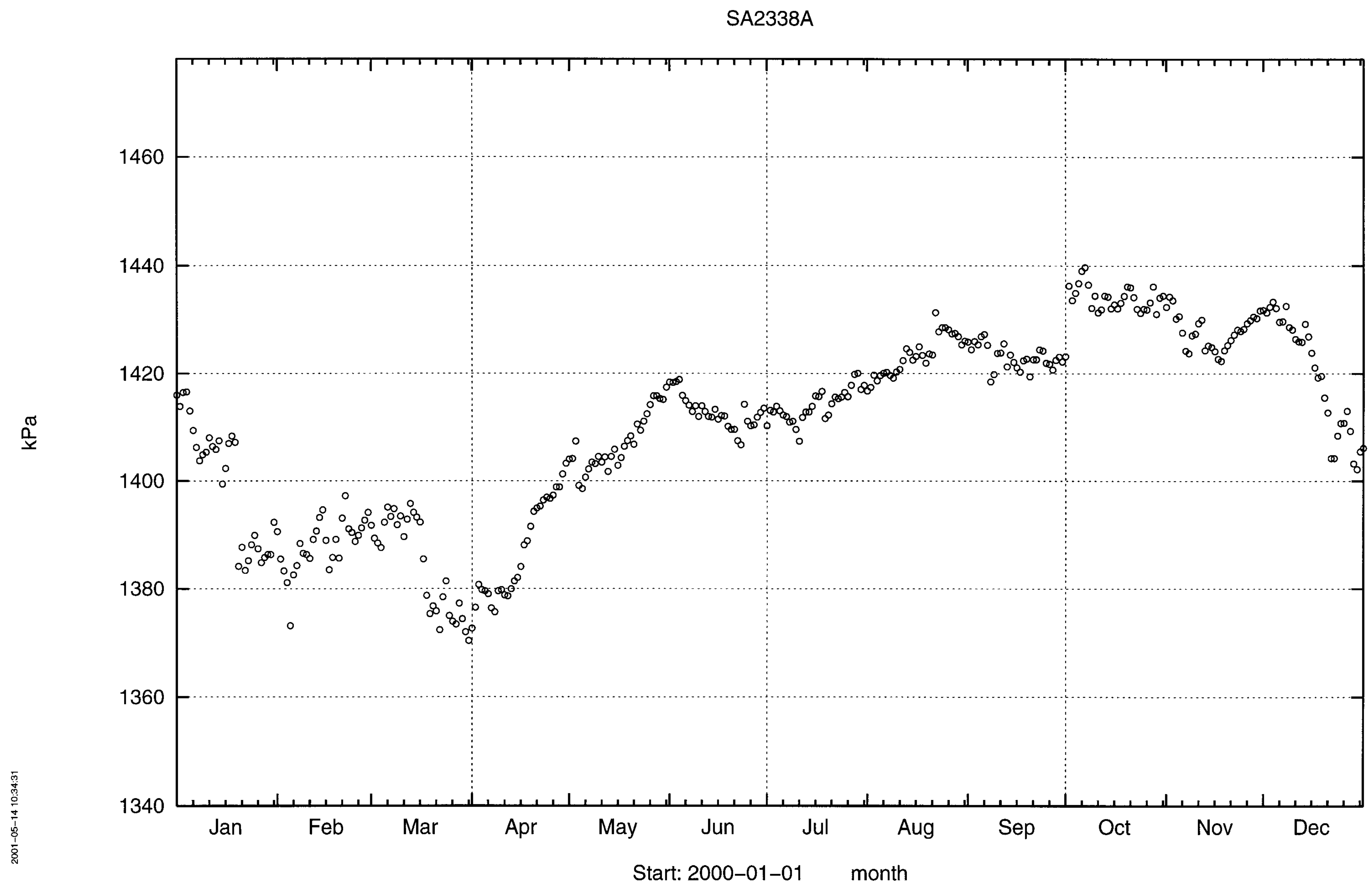
KXTT4



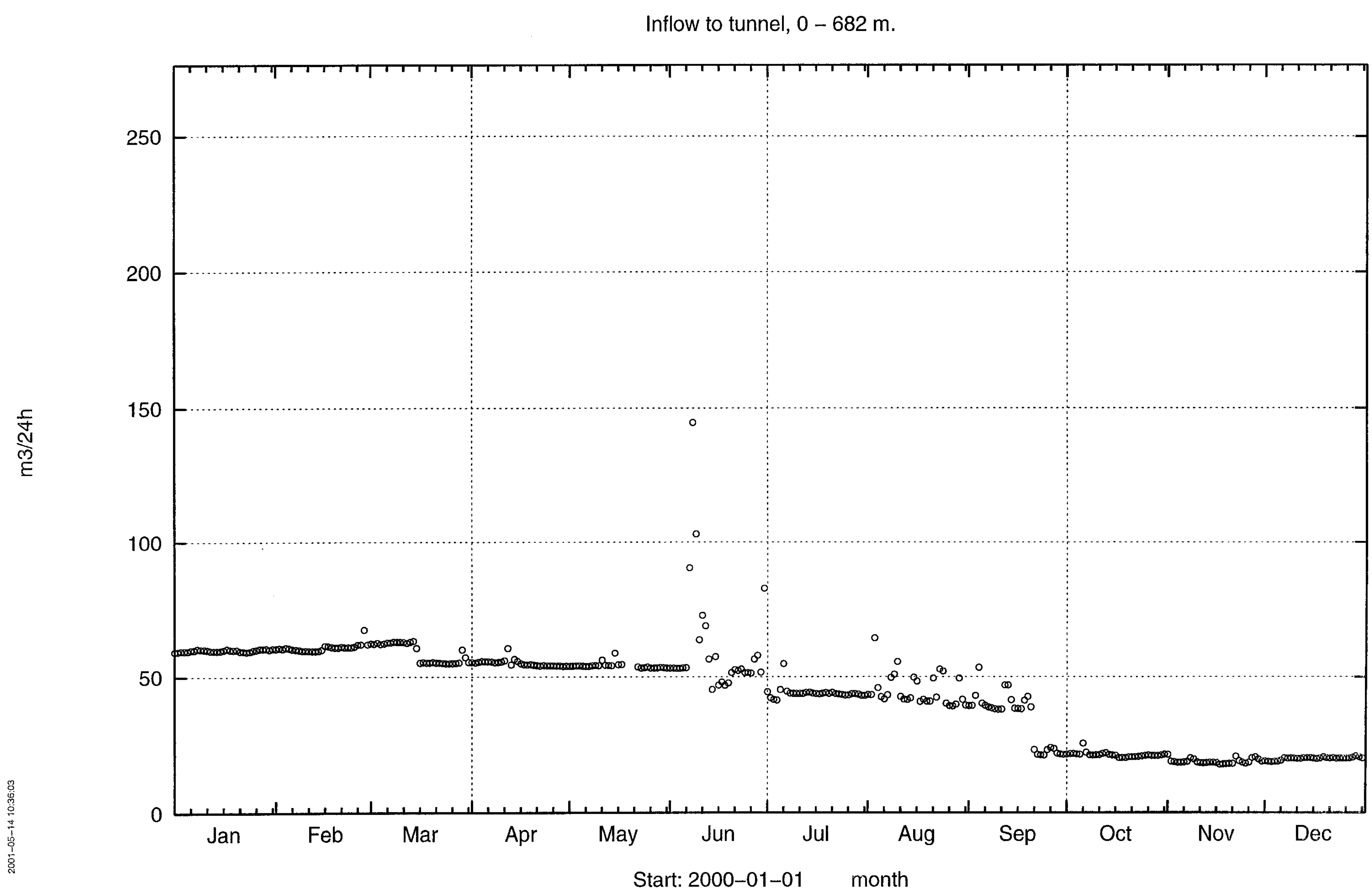
2001-05-14 10:34:31

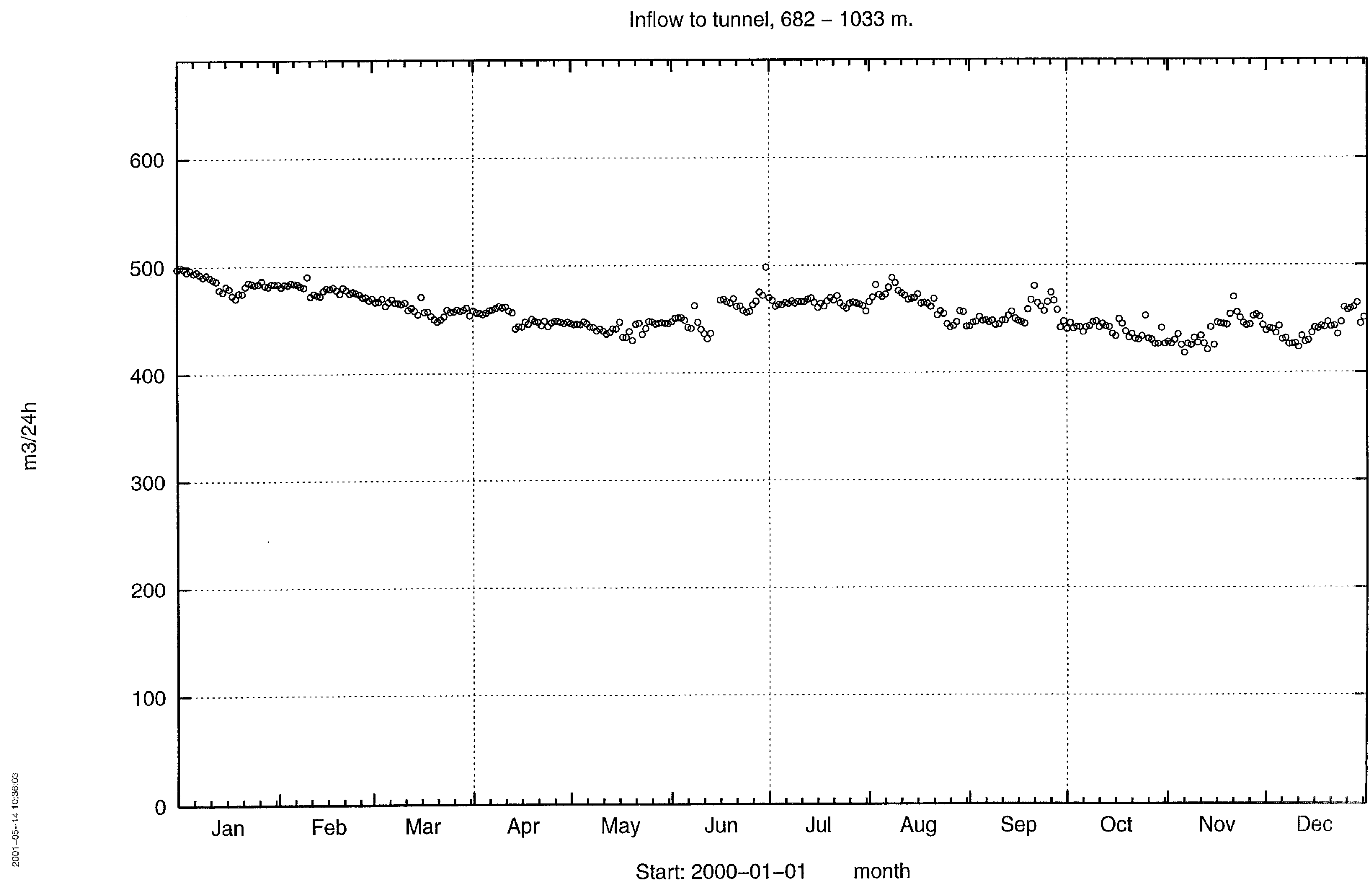

KXTT5
kPa
3600
3500
3400
3300
3200
3100
3000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:31


SA2142A
kPa
300
280
260
240
220
200
180
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:34:31

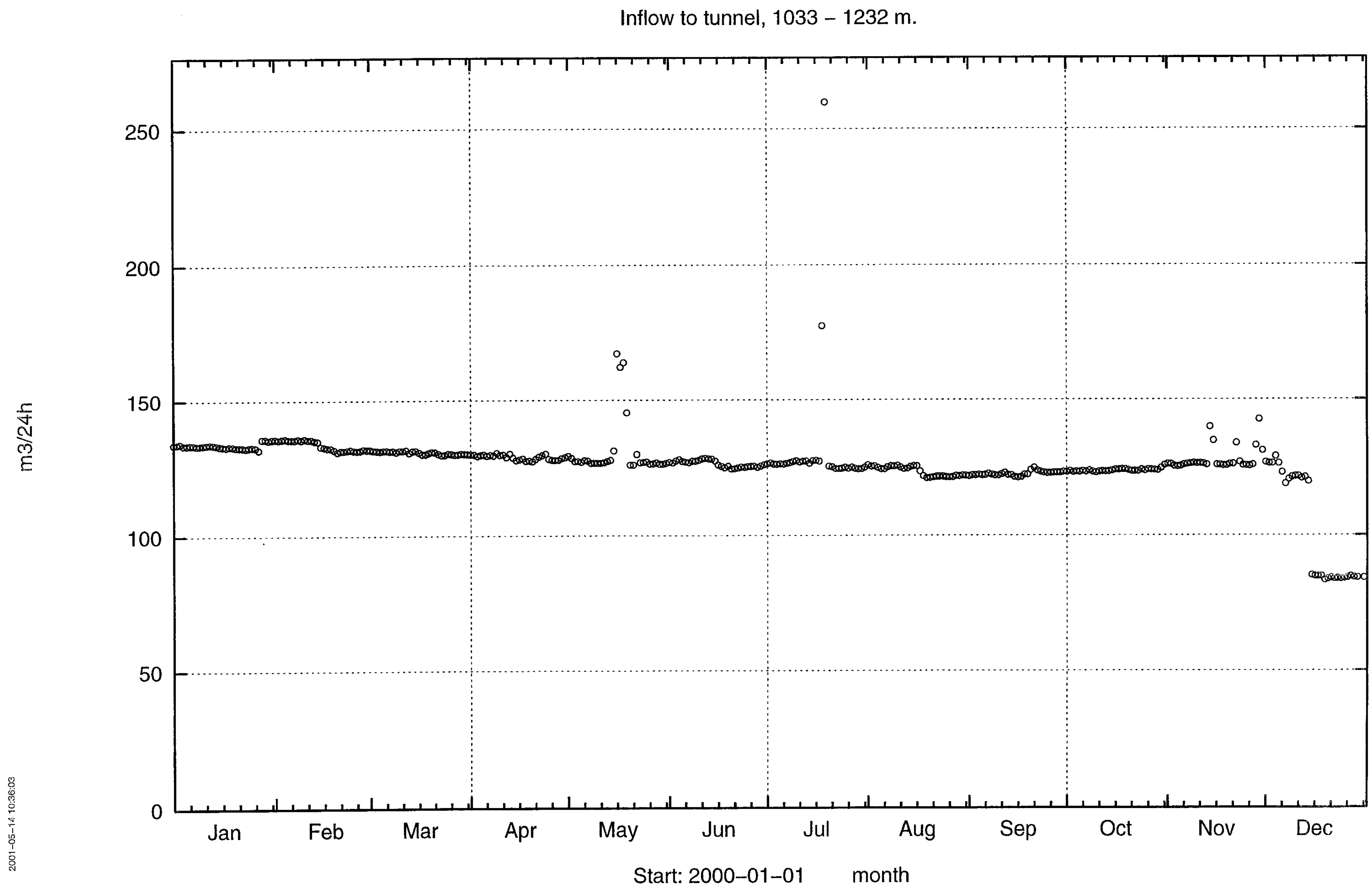

SA2338A
kPa
1460
1440
1420
1400
1380
1360
1340
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−14 10:34:31

Appendix 5: Water flow in tunnel

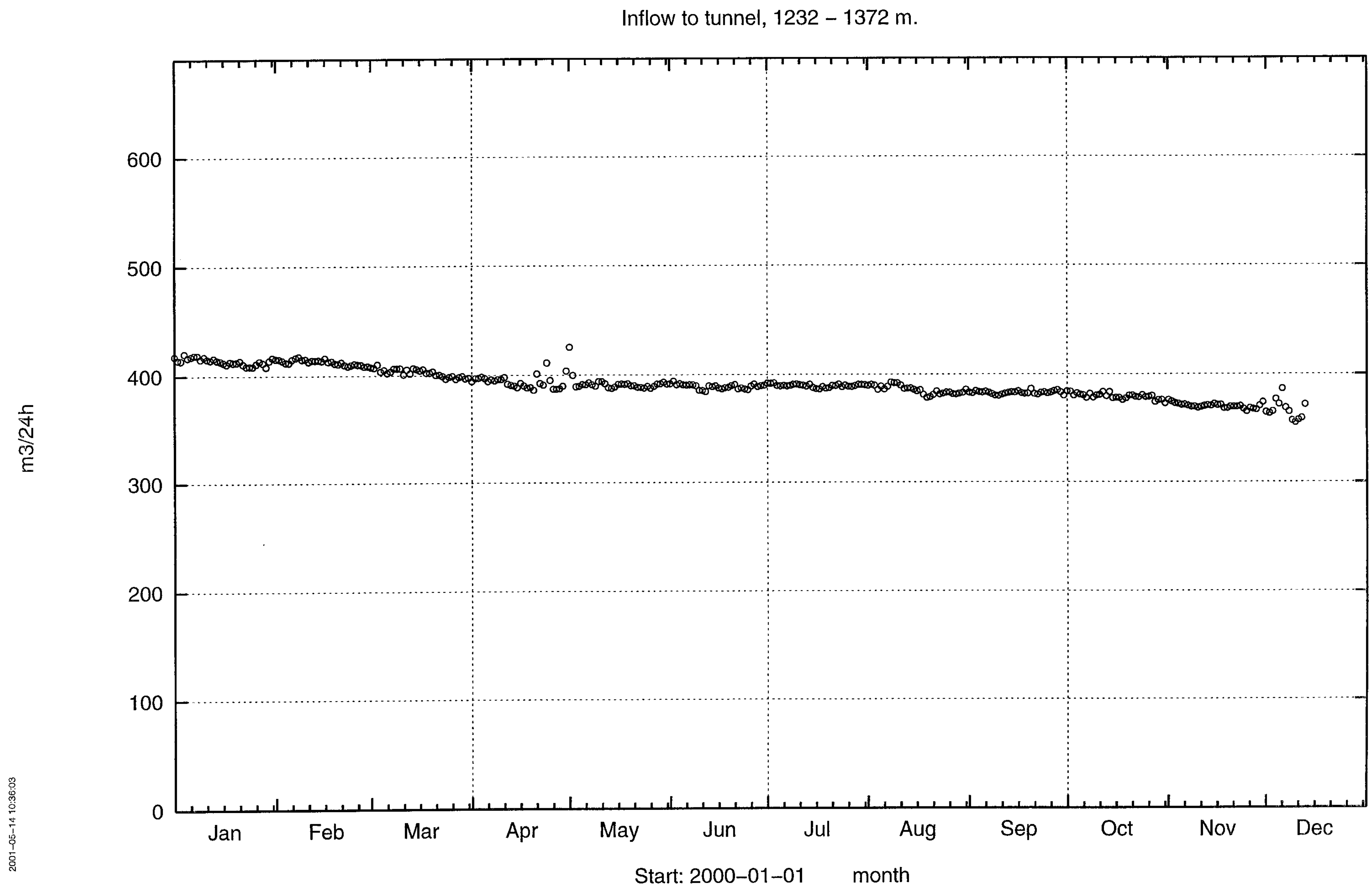

Inflow to tunnel, 0 – 682 m.
m3/24h
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:36:03



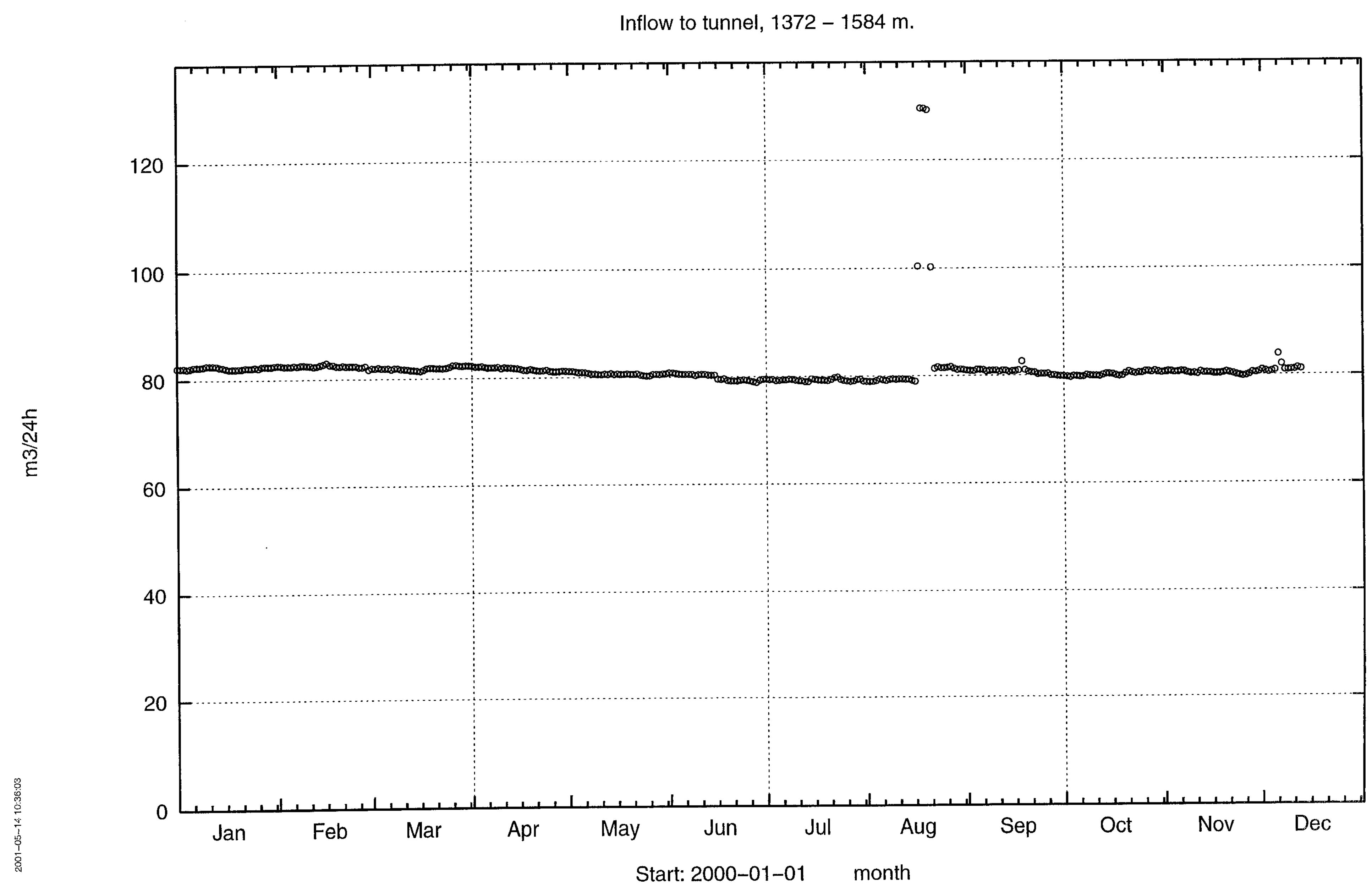
Inflow to tunnel, 682 – 1033 m.
m3/24h
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:36:03

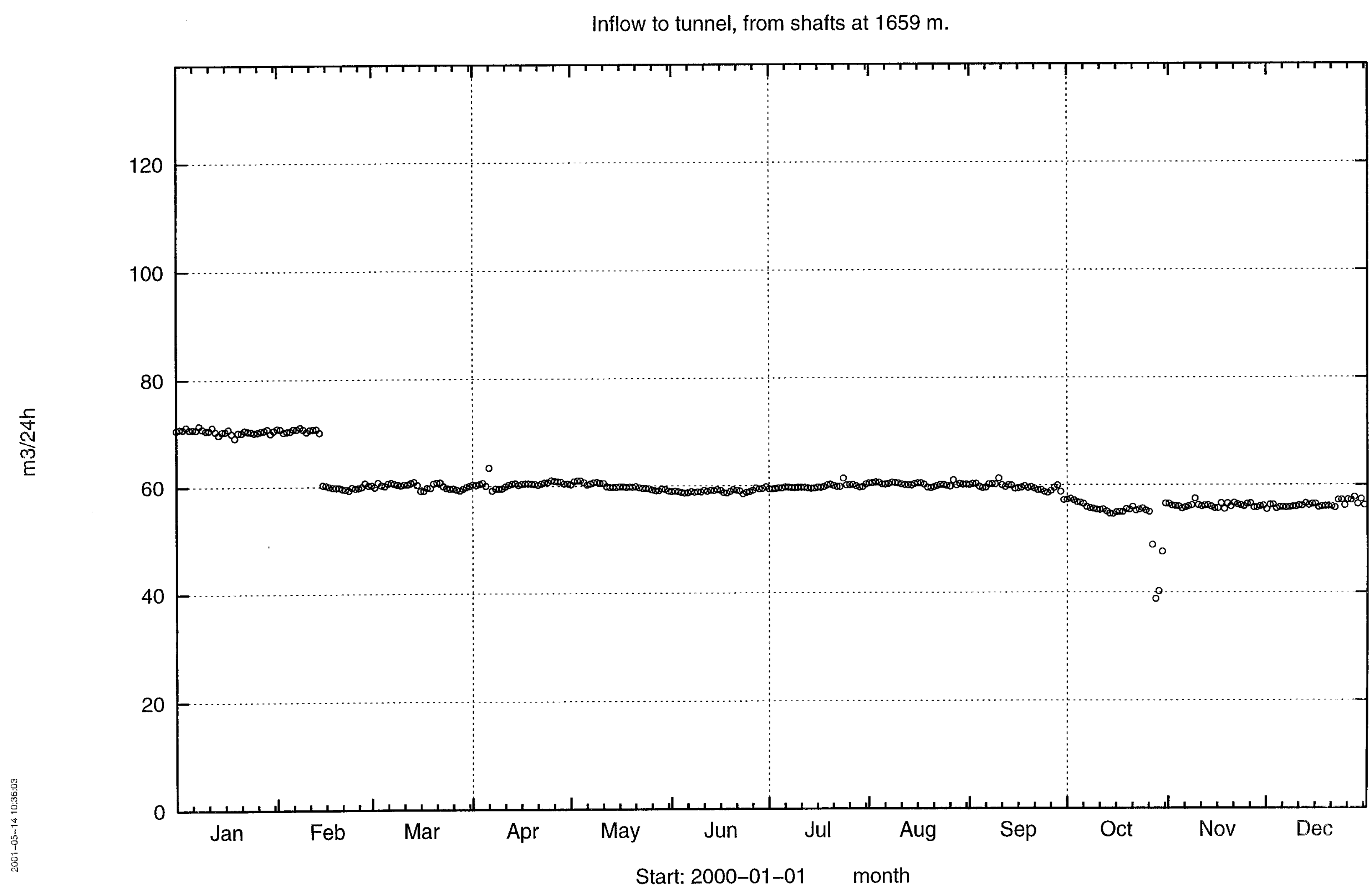


Inflow to tunnel, 1033 – 1232 m.
m3/24h
0
50
100
150
200
250
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:36:03

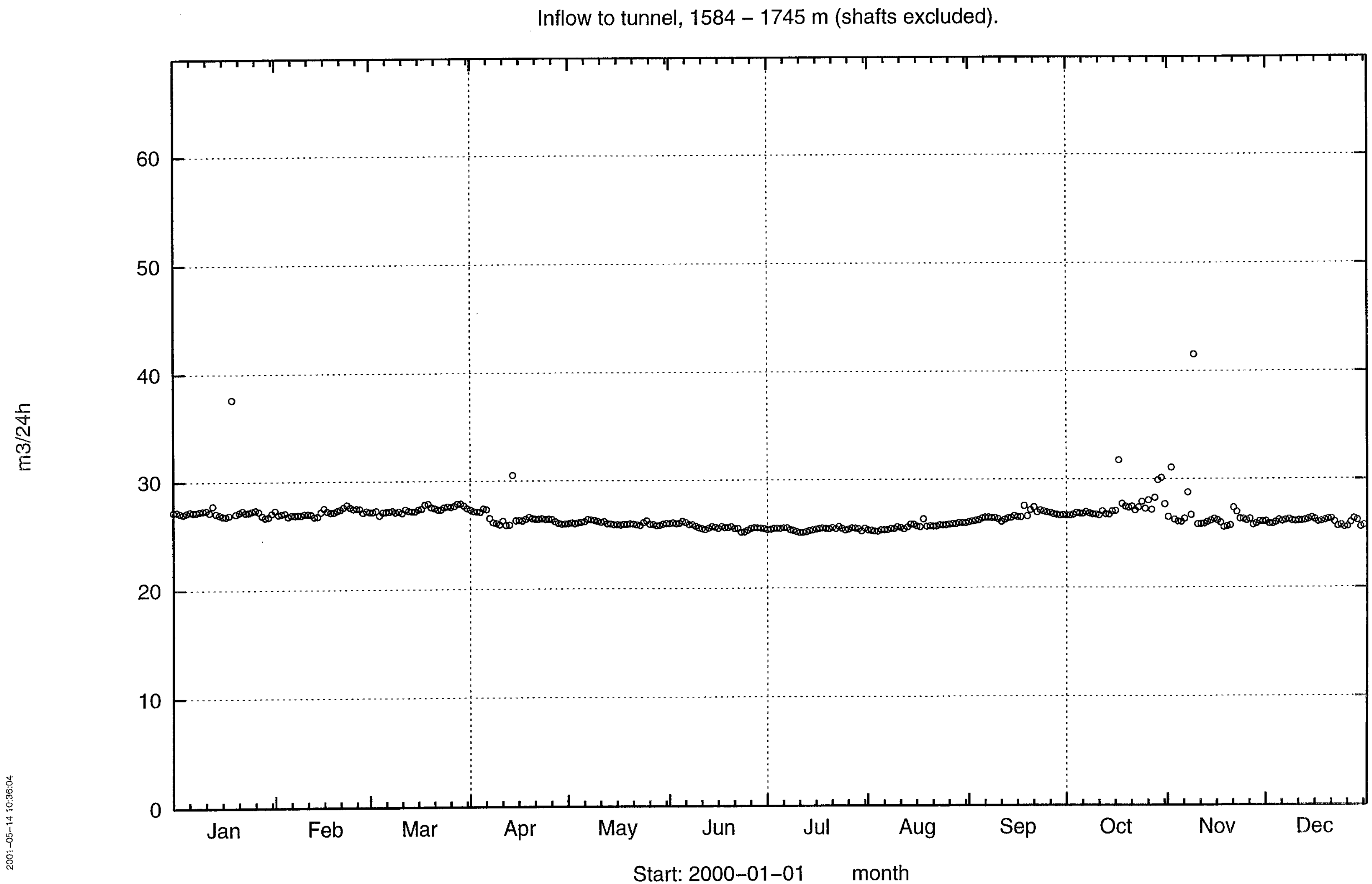


Inflow to tunnel, 1232 – 1372 m.
m3/24h
0
100
200
300
400
500
600
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:36:03


Inflow to tunnel, 1372 – 1584 m.
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:36:03

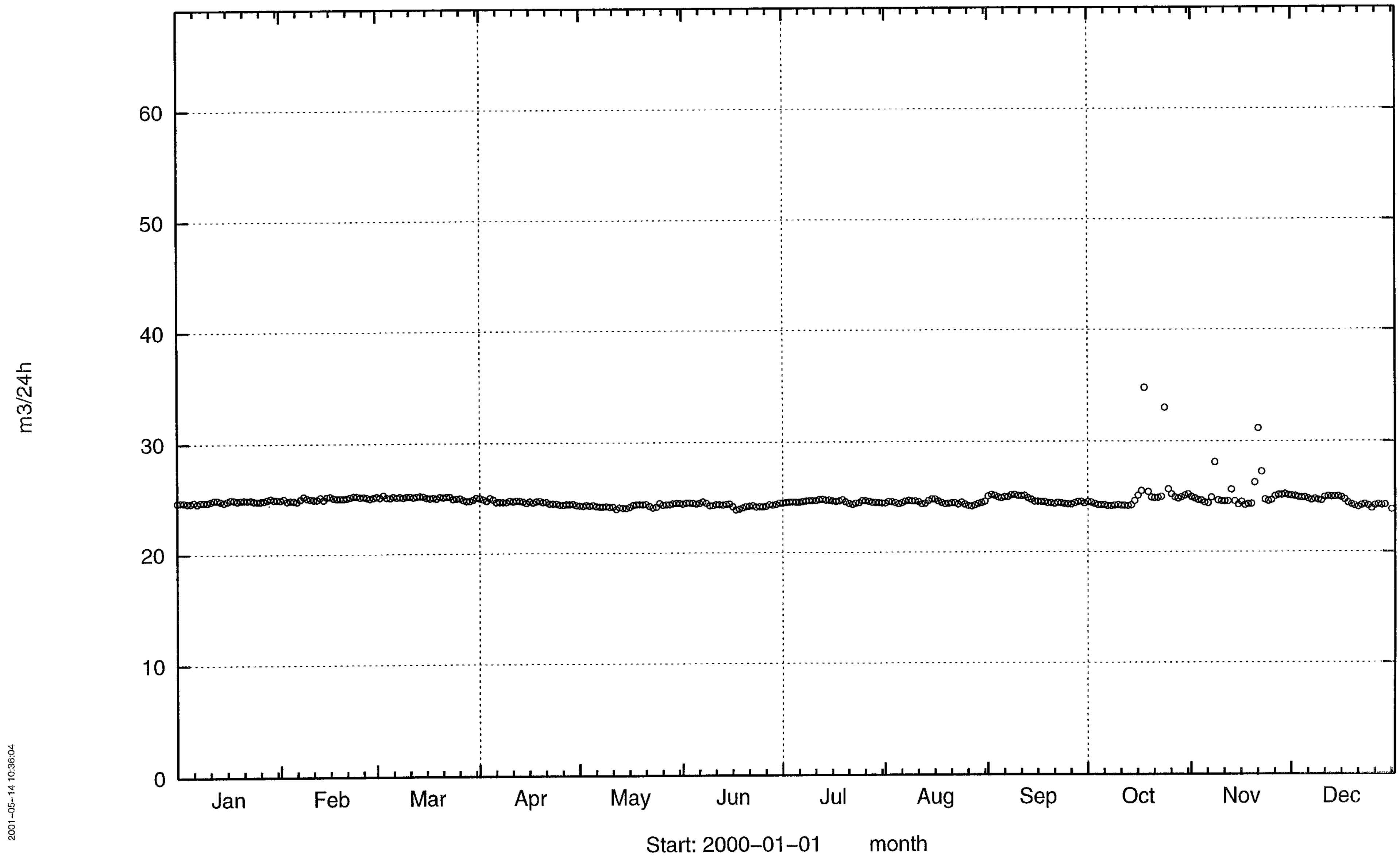


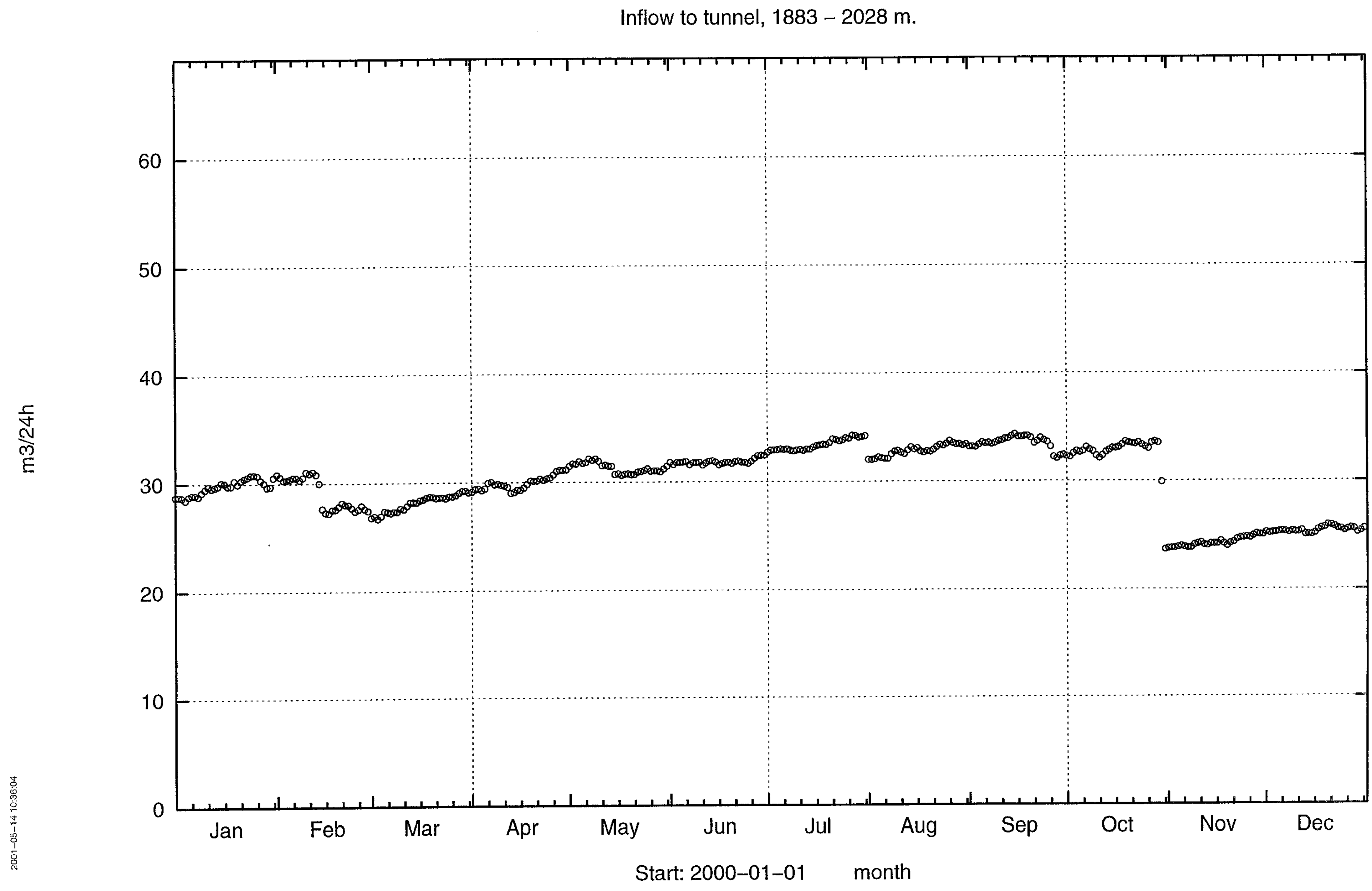
Inflow to tunnel, from shafts at 1659 m.
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:36:03



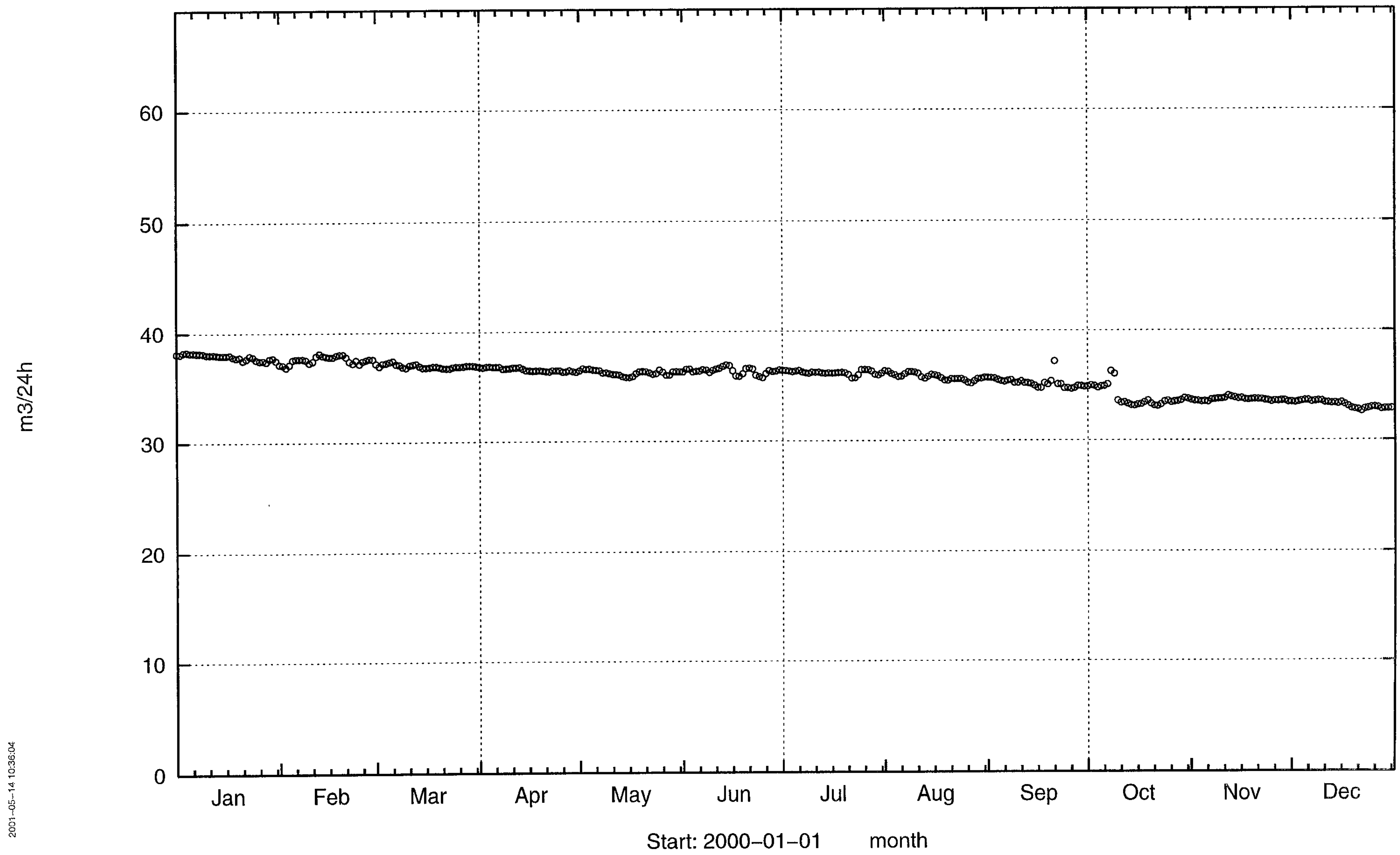
Inflow to tunnel, 1584 – 1745 m (shafts excluded).
m3/24h
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:36:04

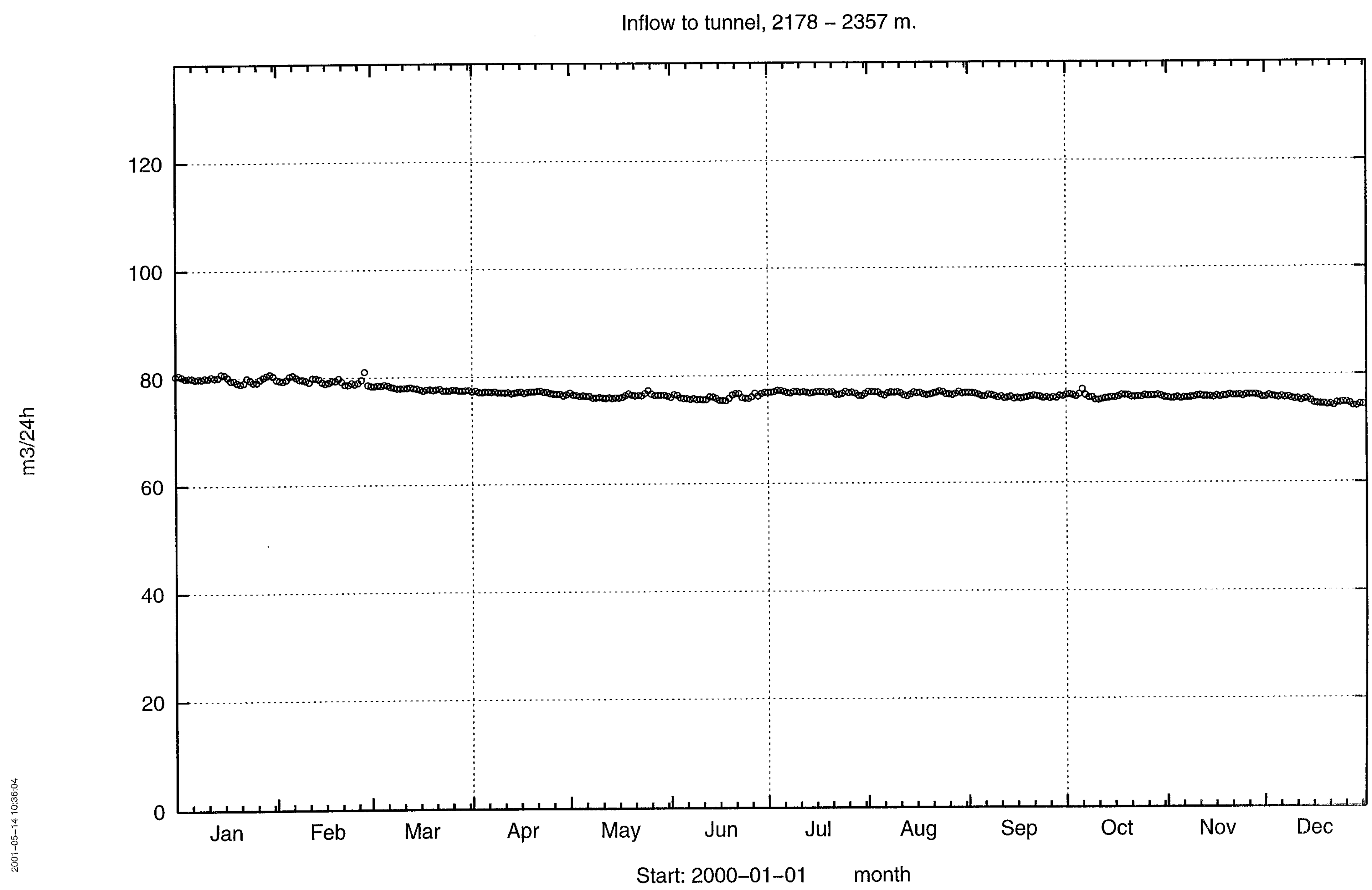
Inflow to tunnel, 1745 – 1883 m.



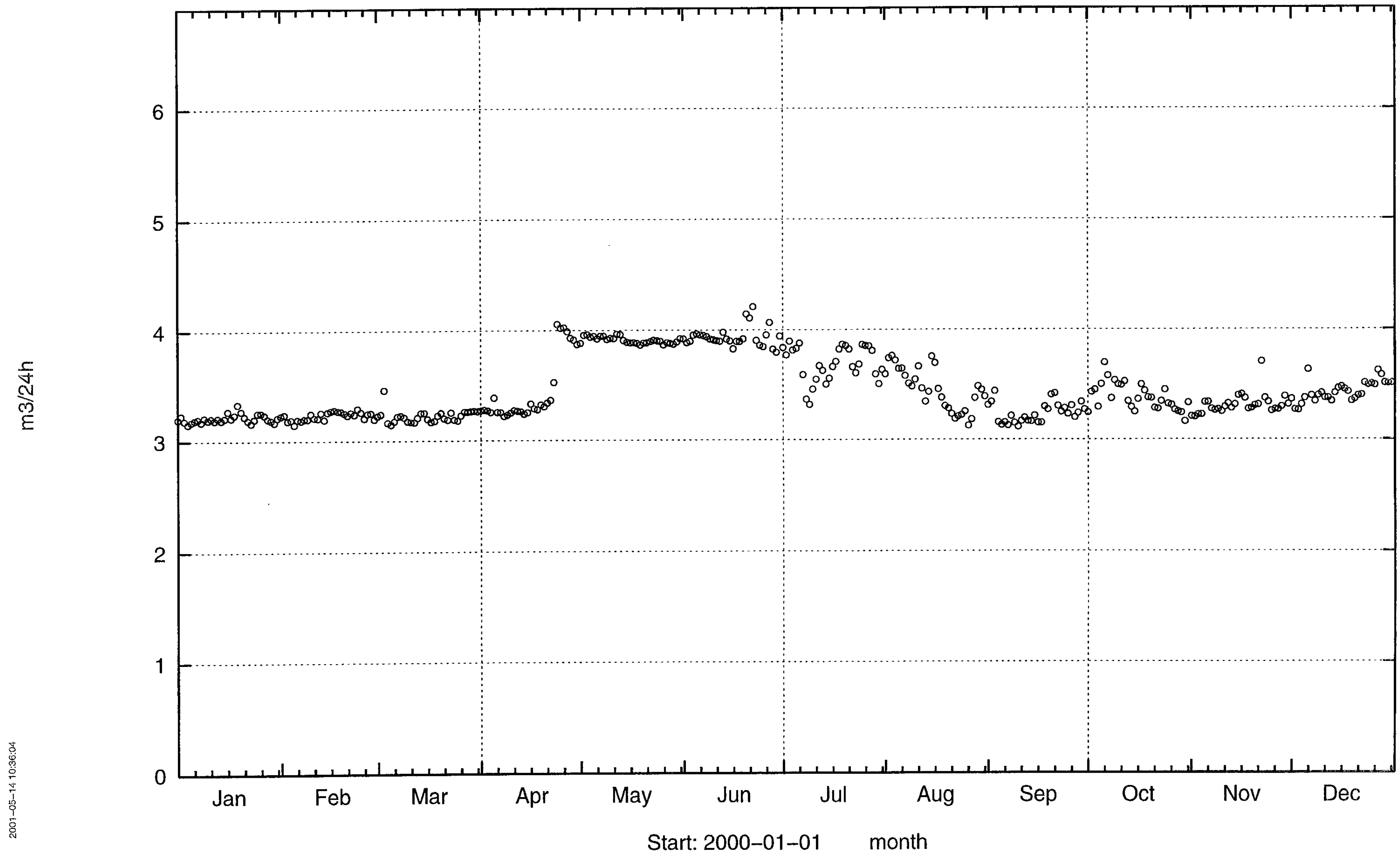

Inflow to tunnel, 1883 – 2028 m.
m3/24h
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:36:04

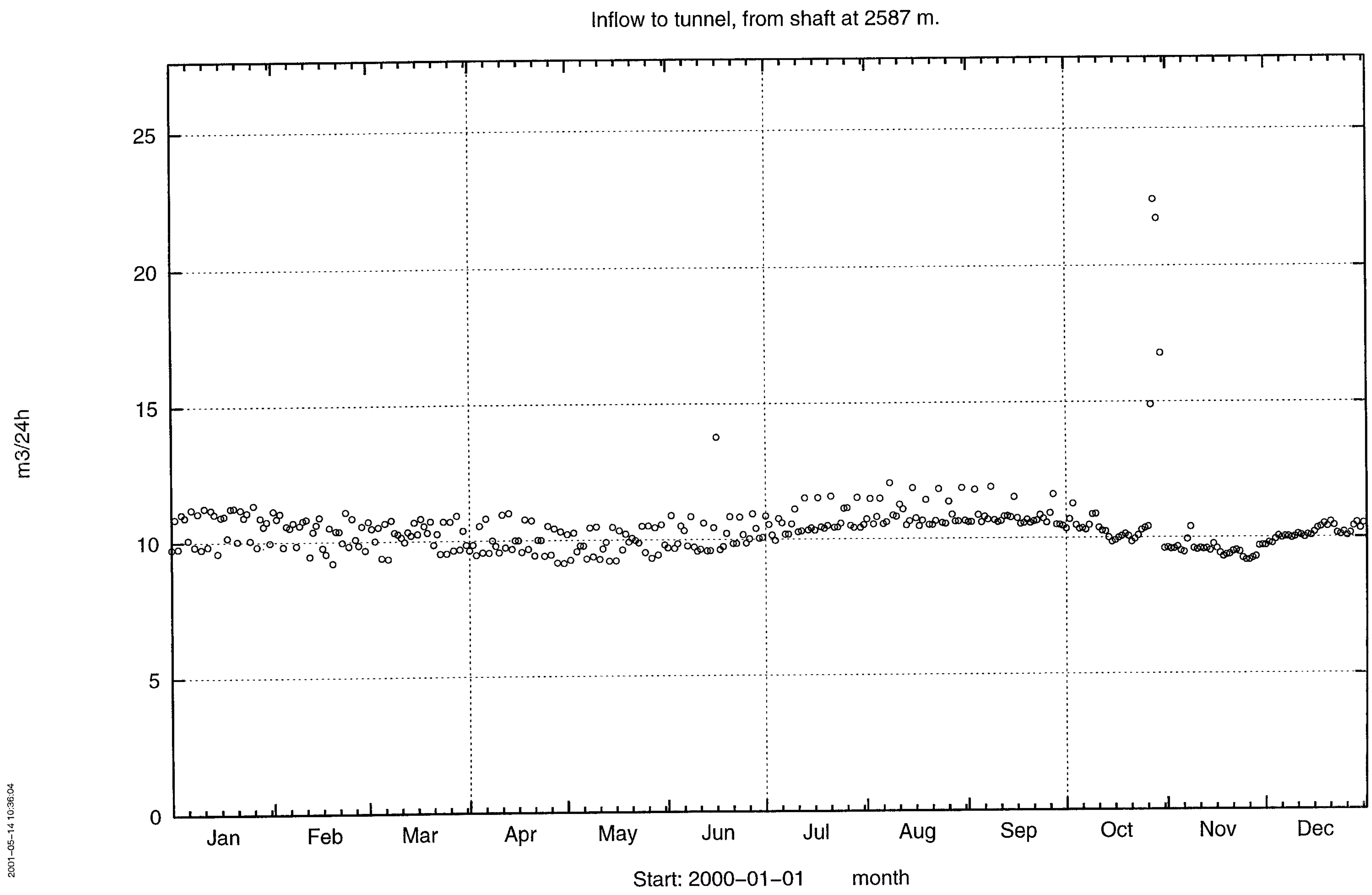
Inflow to tunnel, 2028 – 2178 m.




Inflow to tunnel, 2178 – 2357 m.
120
100
80
60
40
20
0
m3/24h
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:36:04

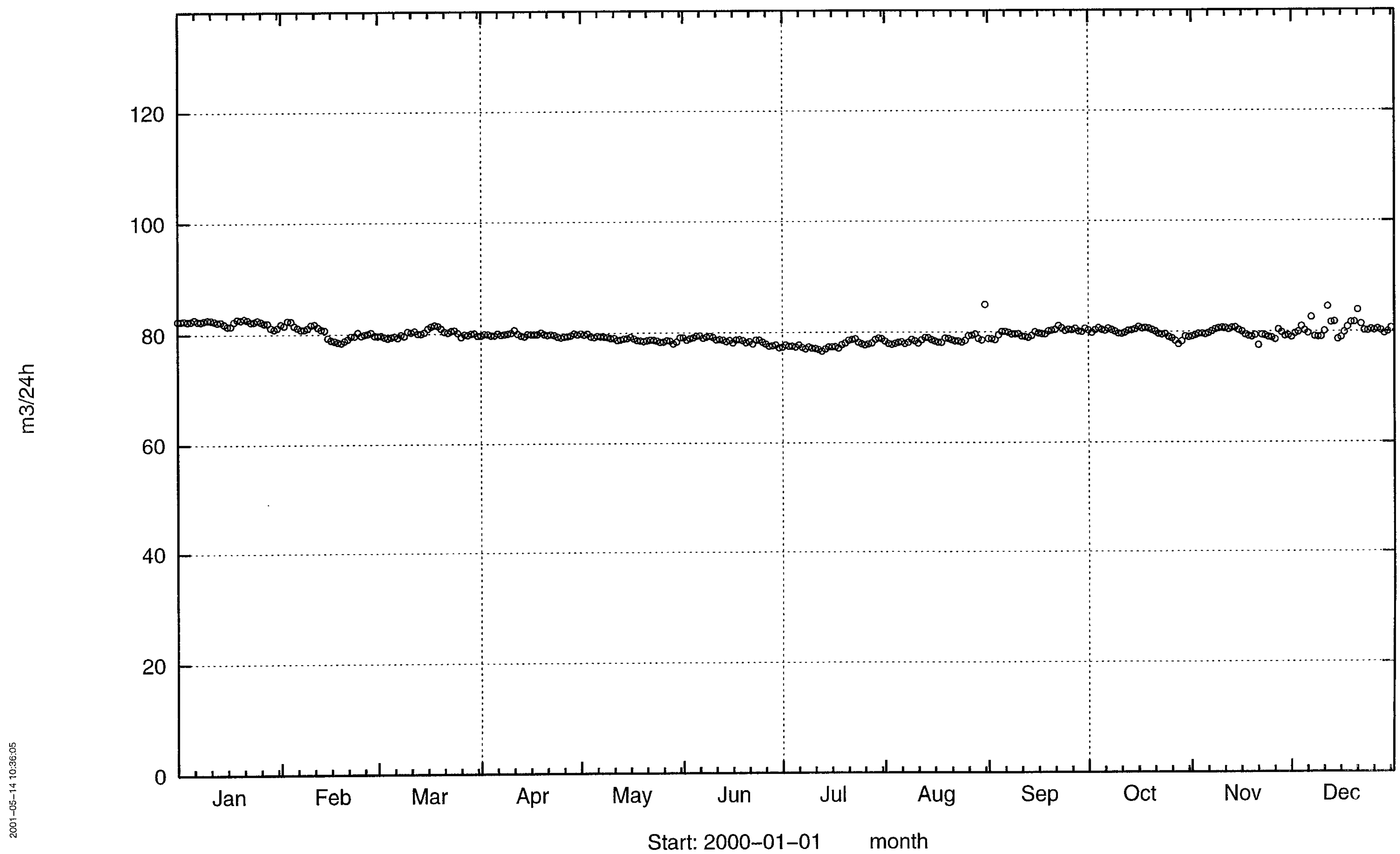
Inflow to tunnel, 2357 – 2496 m.



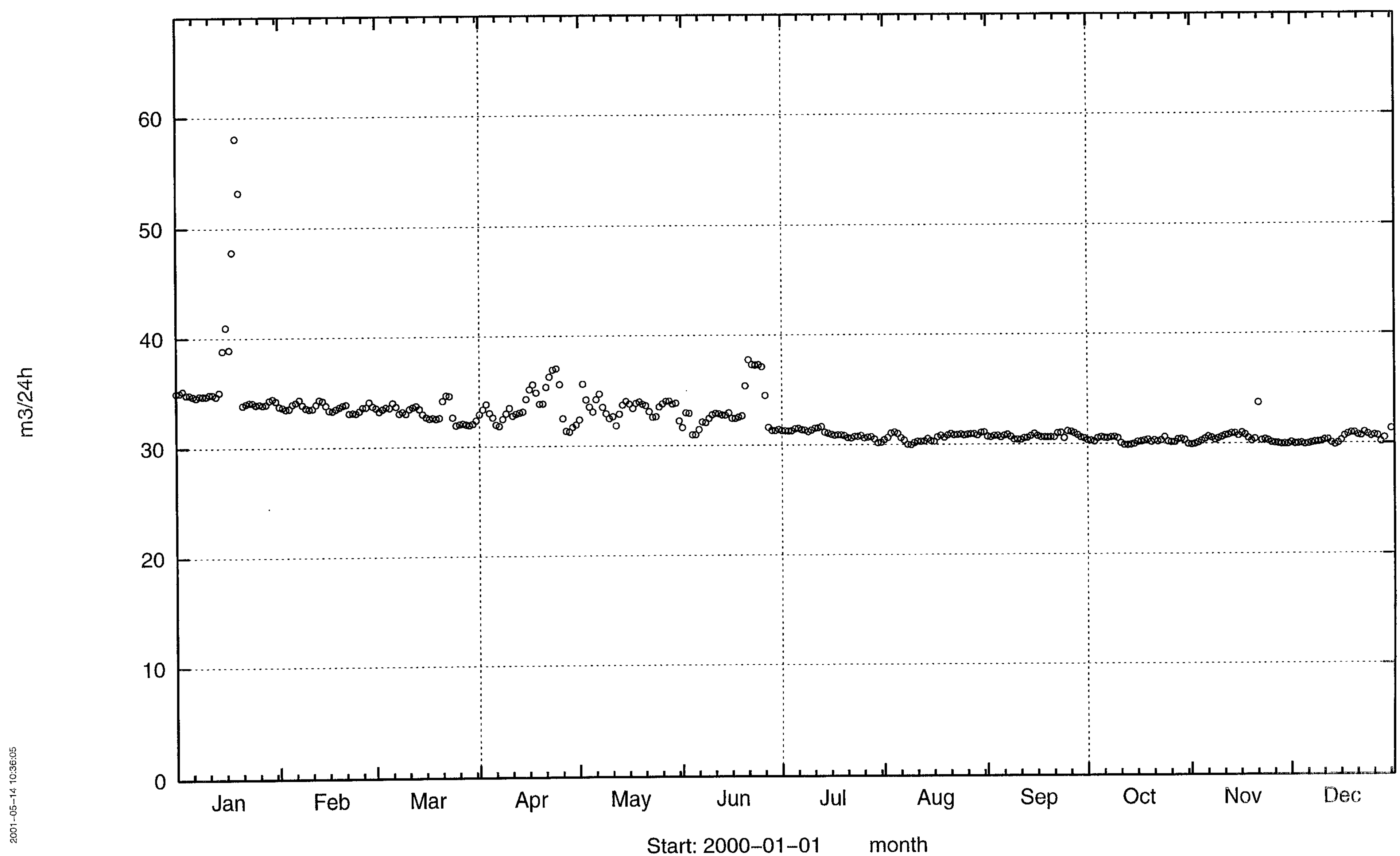


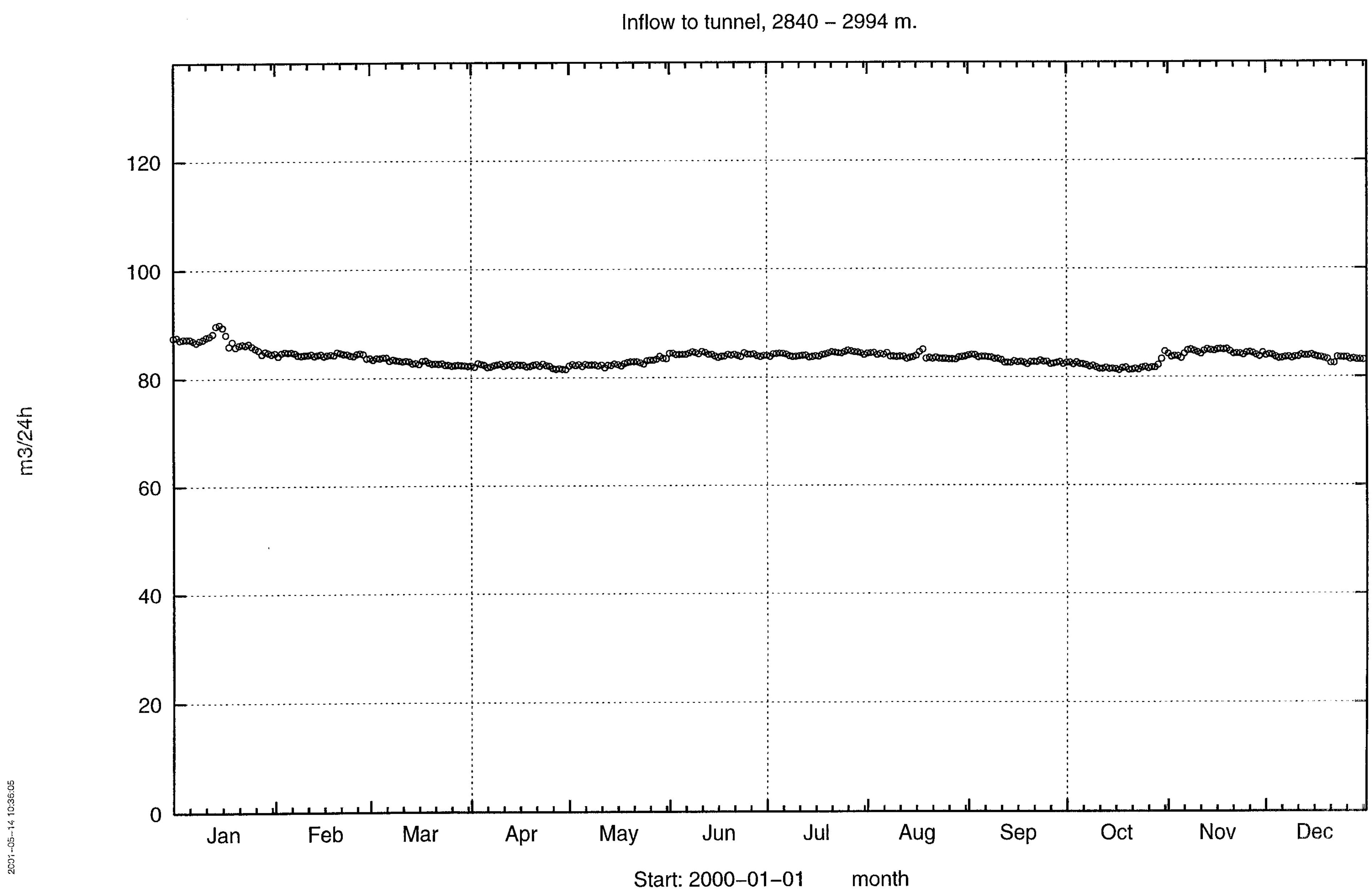
Inflow to tunnel, from shaft at 2587 m.
m3/24h
0
5
10
15
20
25
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:36:04

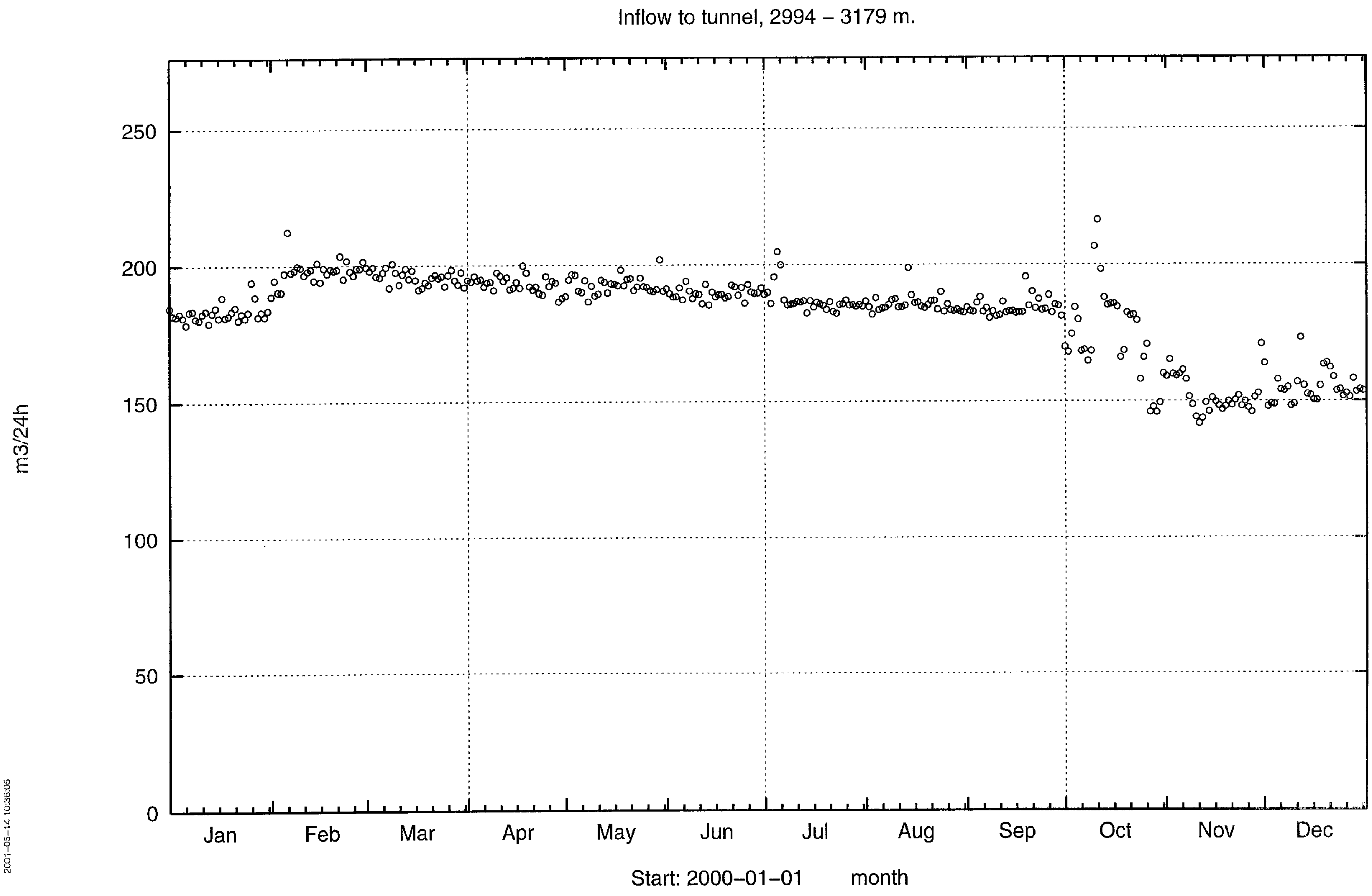
Inflow to tunnel, 2496 – 2699 m (shaft excluded).



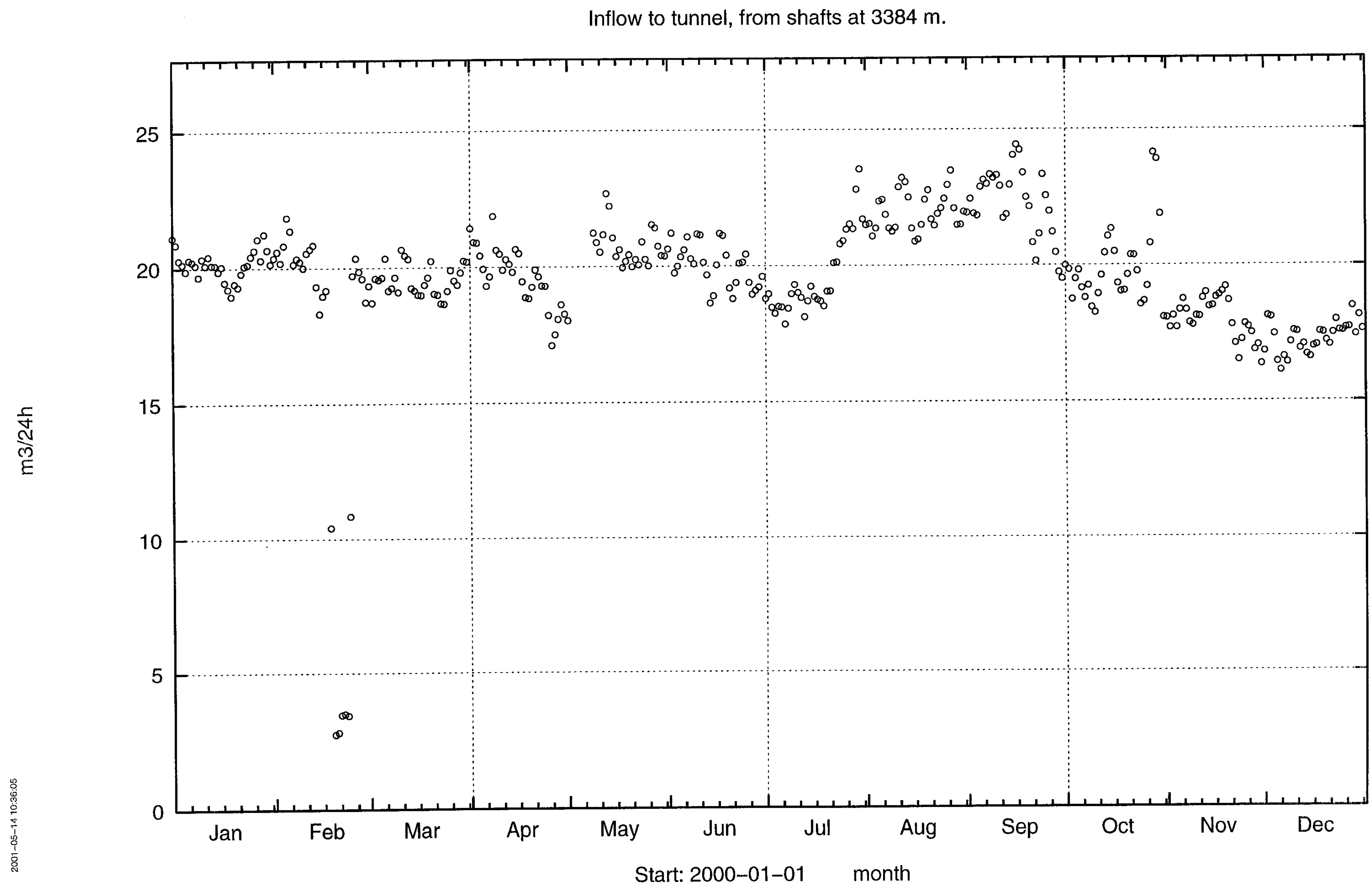
Inflow to tunnel, 2699 – 2840 m.

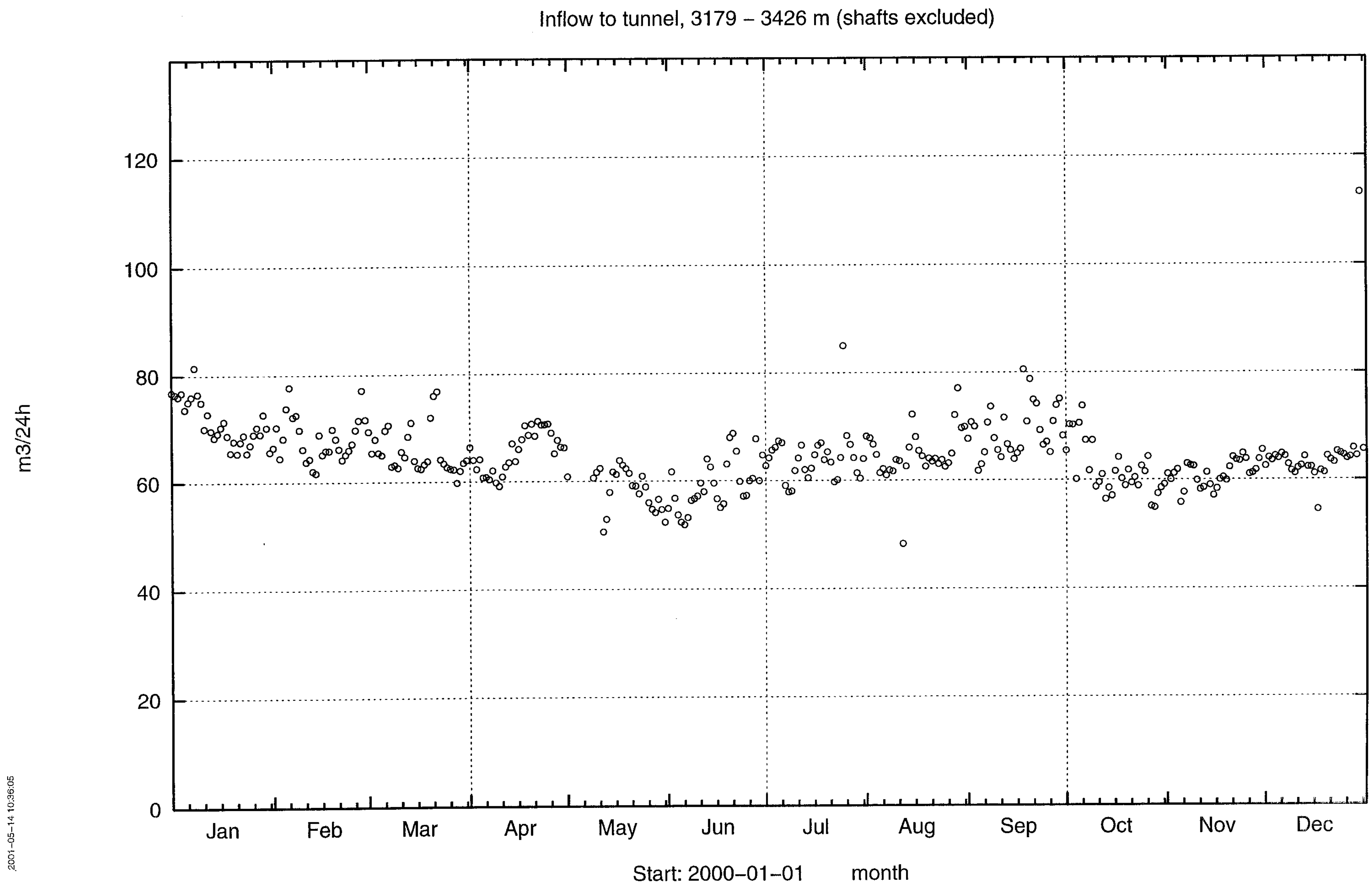



Inflow to tunnel, 2840 – 2994 m.
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001-05-14 10:36:05



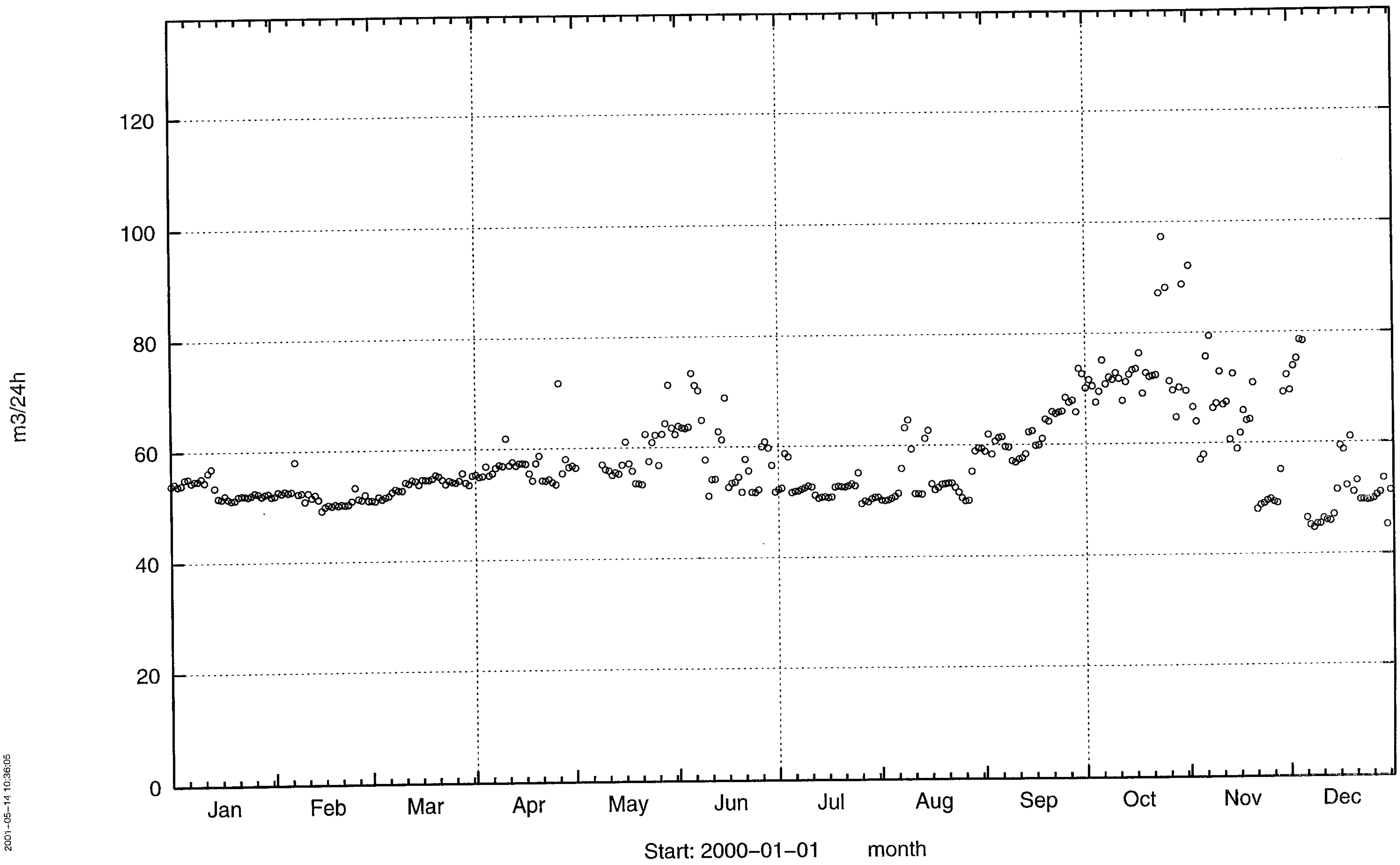
Inflow to tunnel, 2994 – 3179 m.
m3/24h
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:36:05


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: 2000-01-01
month
2001-05-14 10:36:05

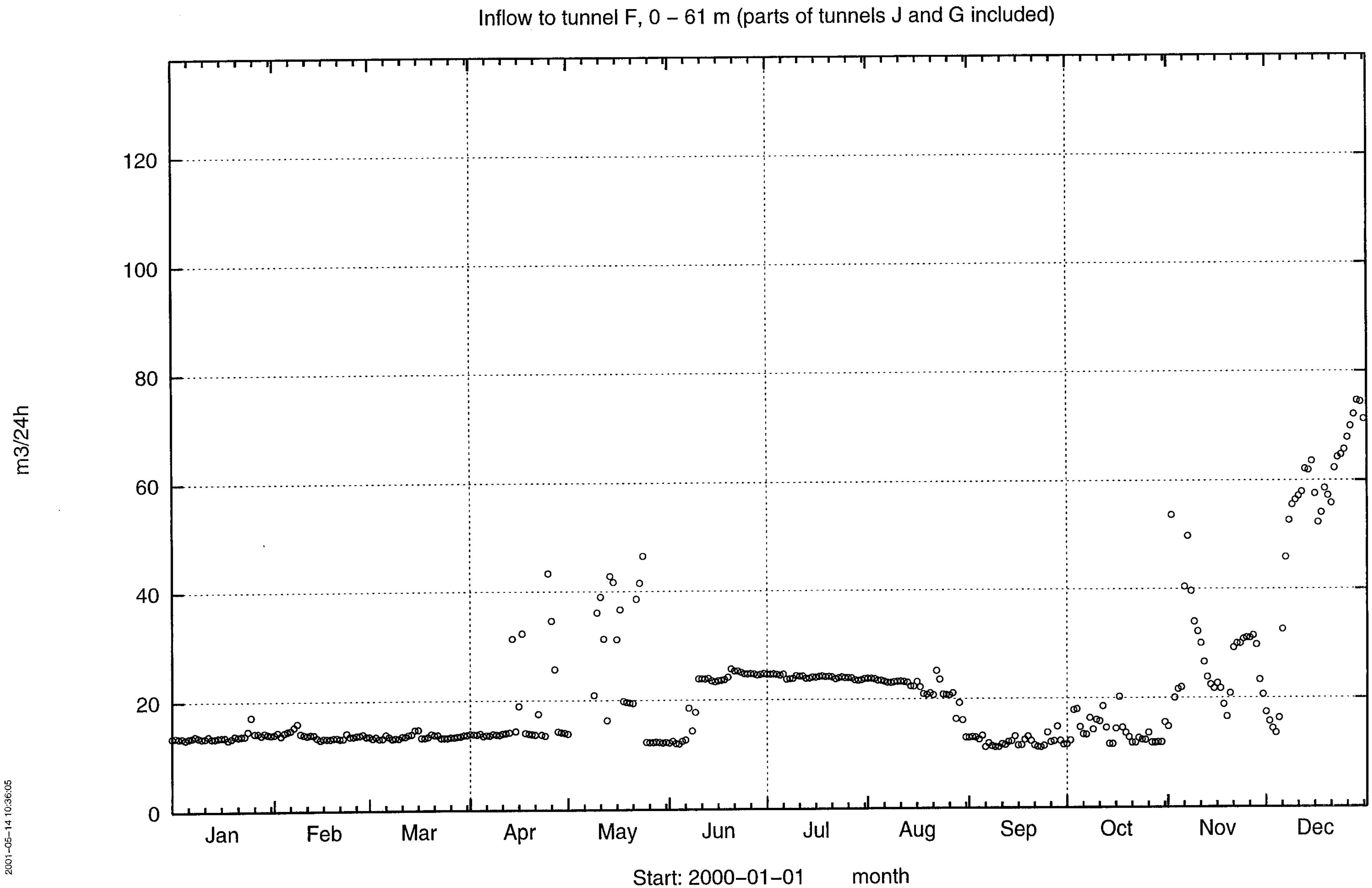


Inflow to tunnel, 3179 – 3426 m (shafts excluded)
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:36:05

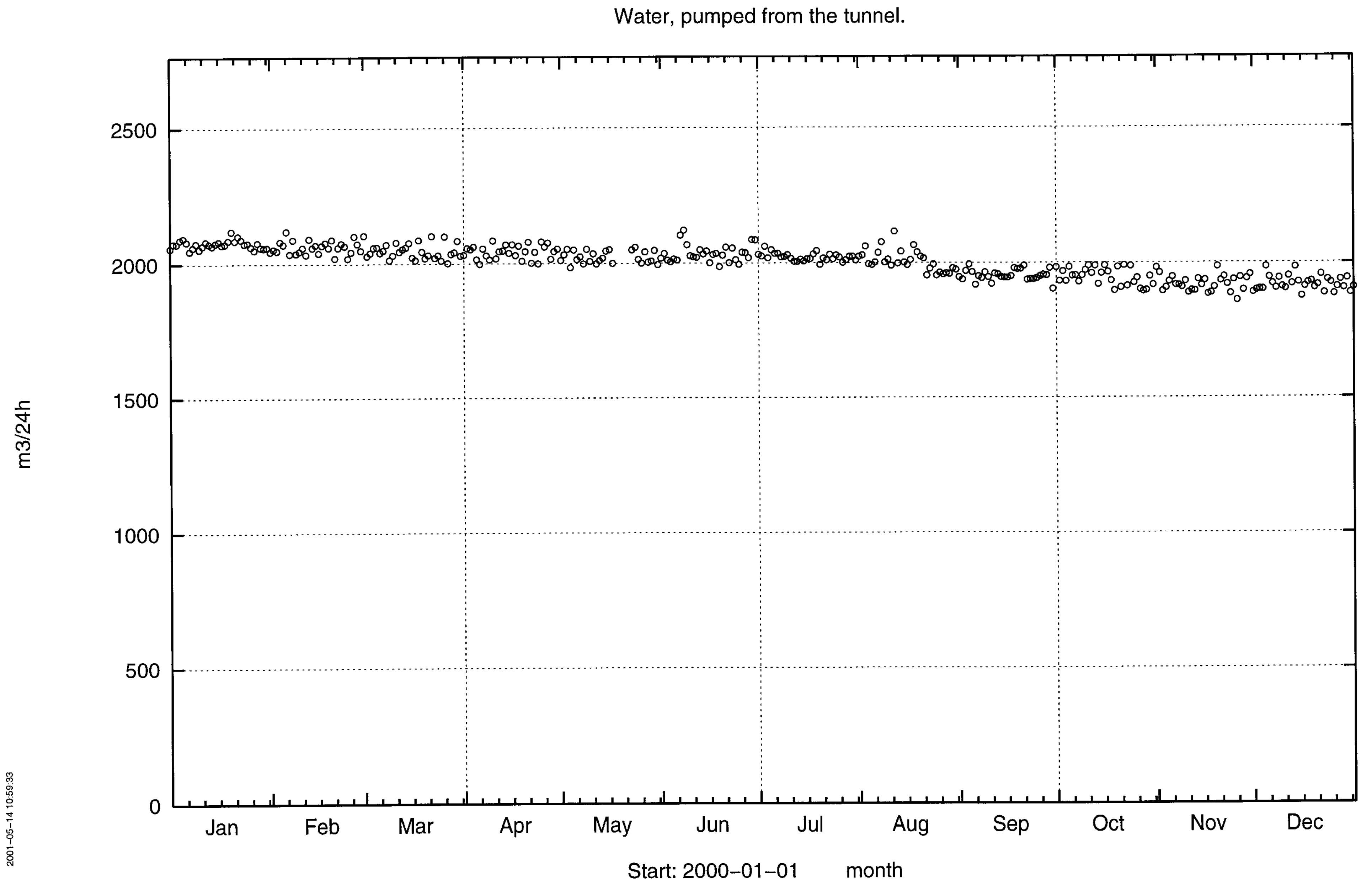
Inflow to tunnel, 3426 – 3600 m (parts of tunnel J included)



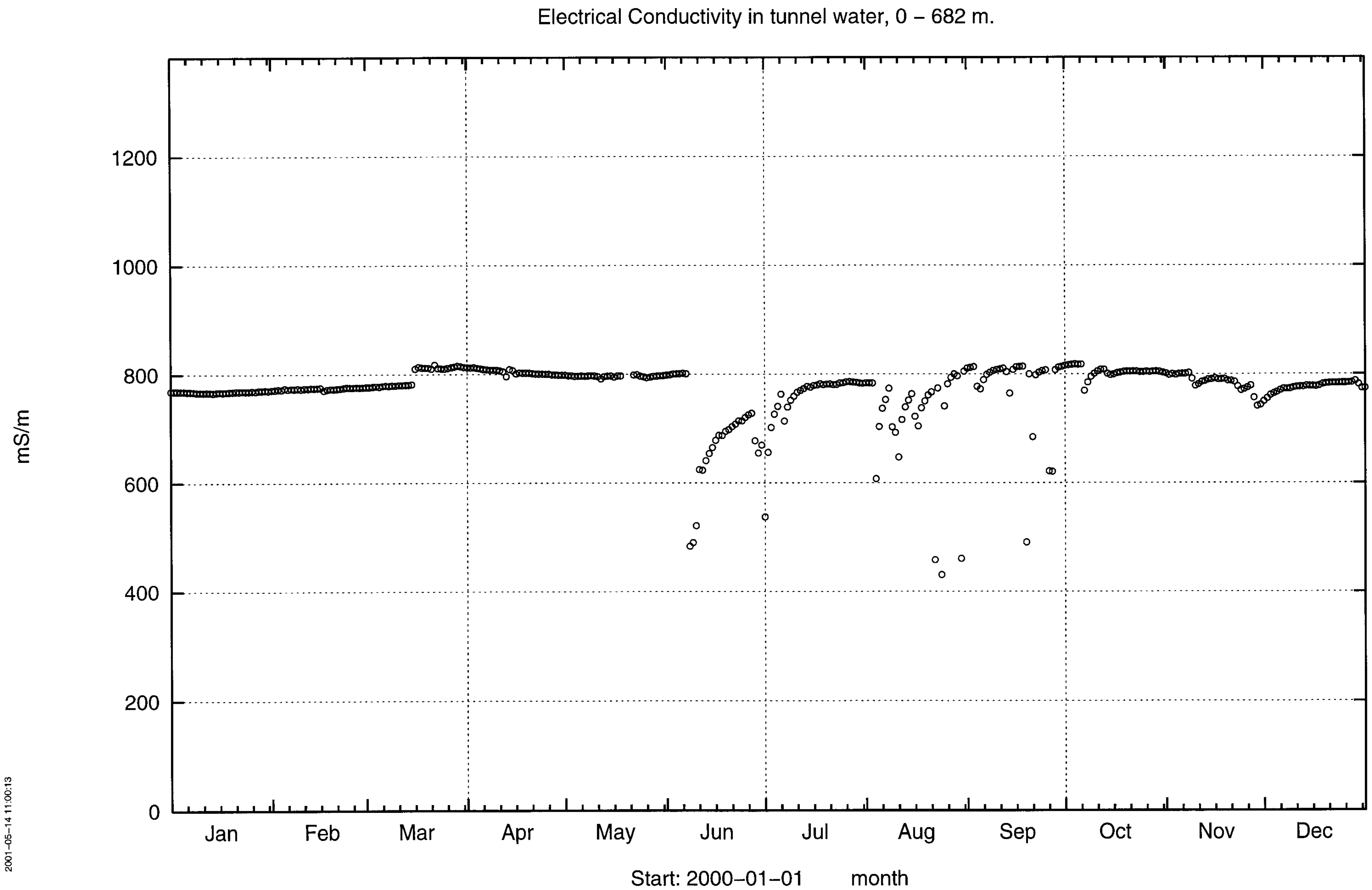
2001-05-14 10:36:05


Inflow to tunnel F, 0 – 61 m (parts of tunnels J and G included)
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 10:36:05

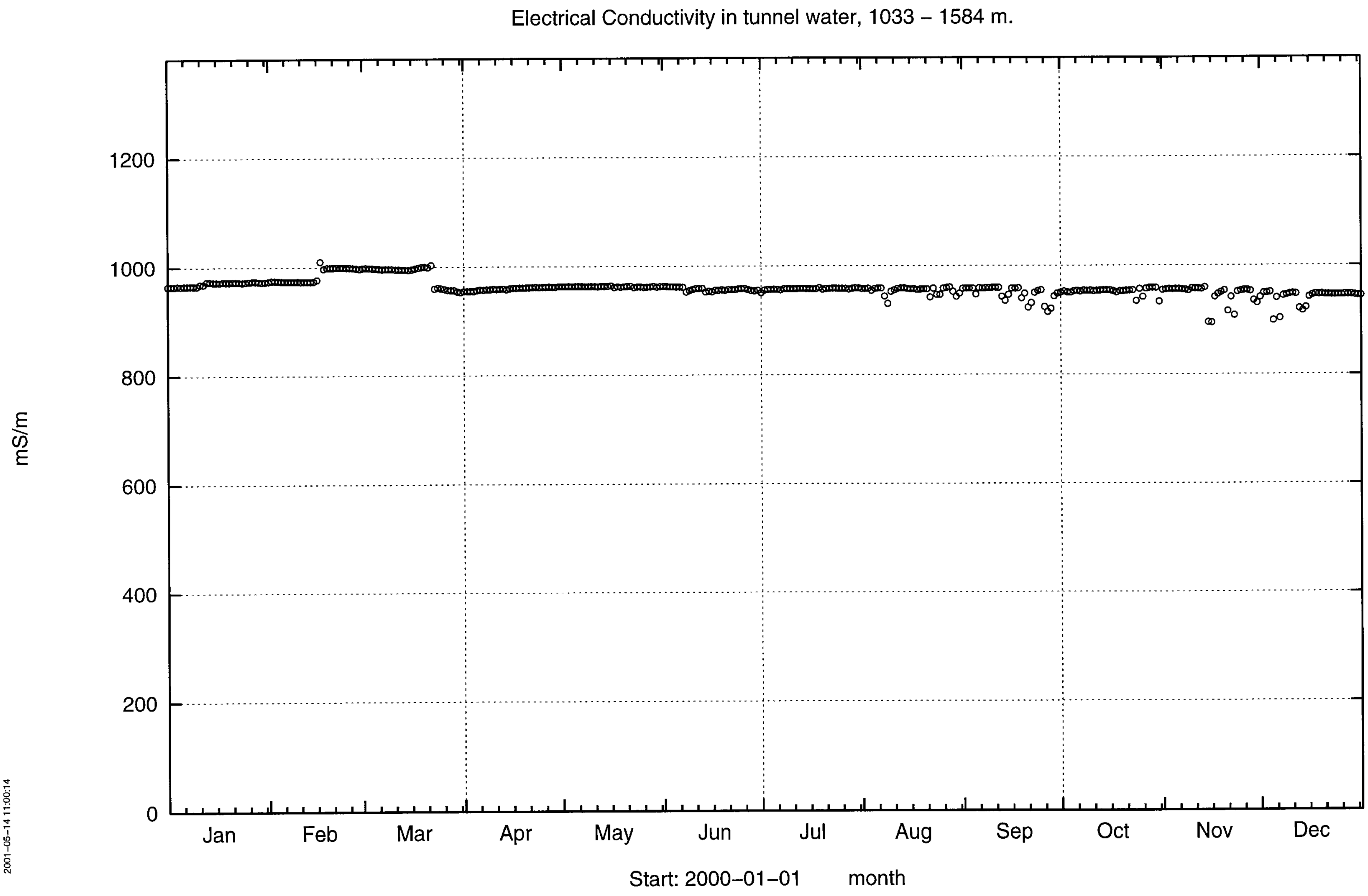
Appendix 6: Water flow in tunnel pipes


Water, pumped from the tunnel.
m3/24h
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000-01-01
month
2001-05-14 10:59:33

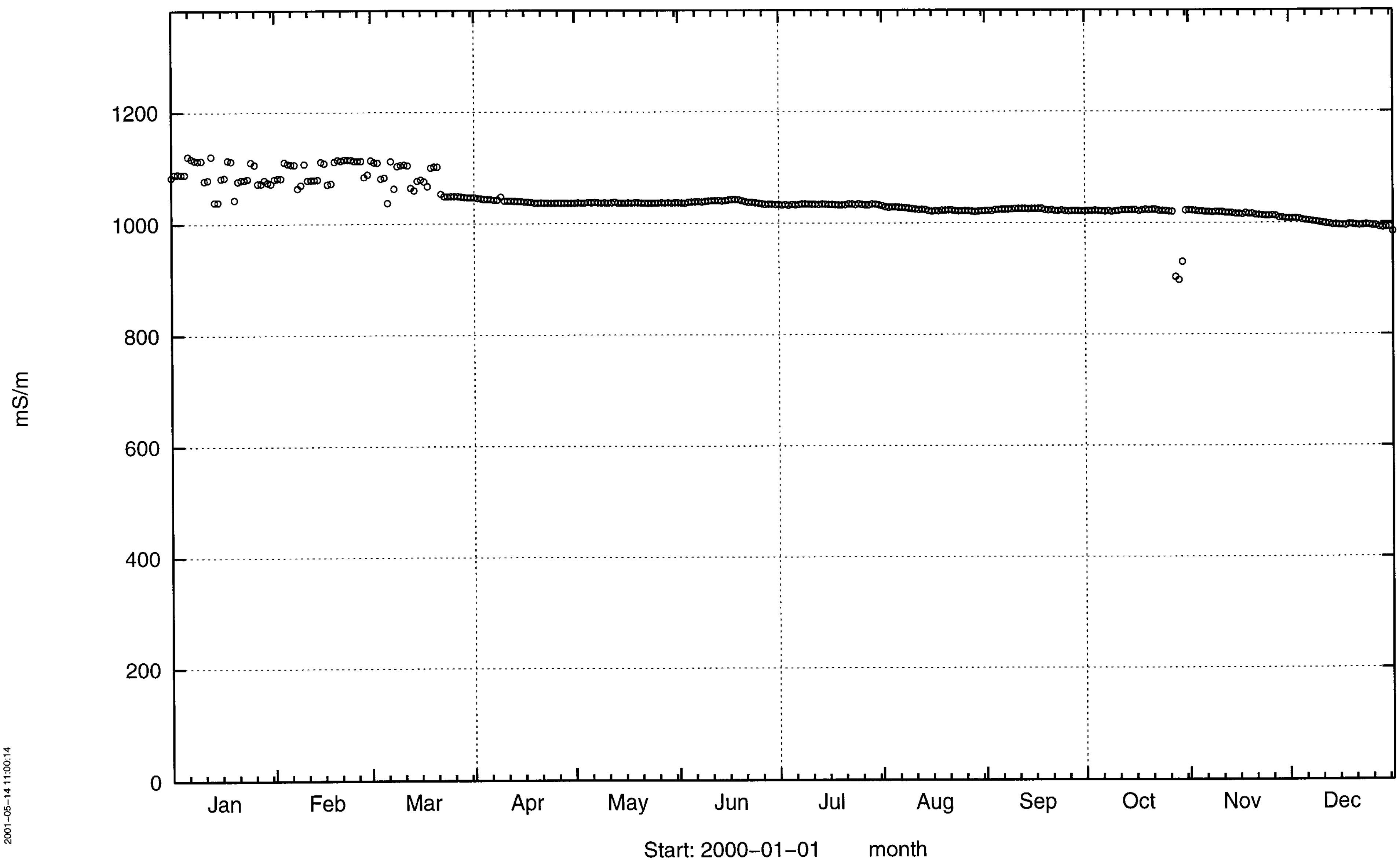
Appendix 7: Electrical conductivity of tunnel water

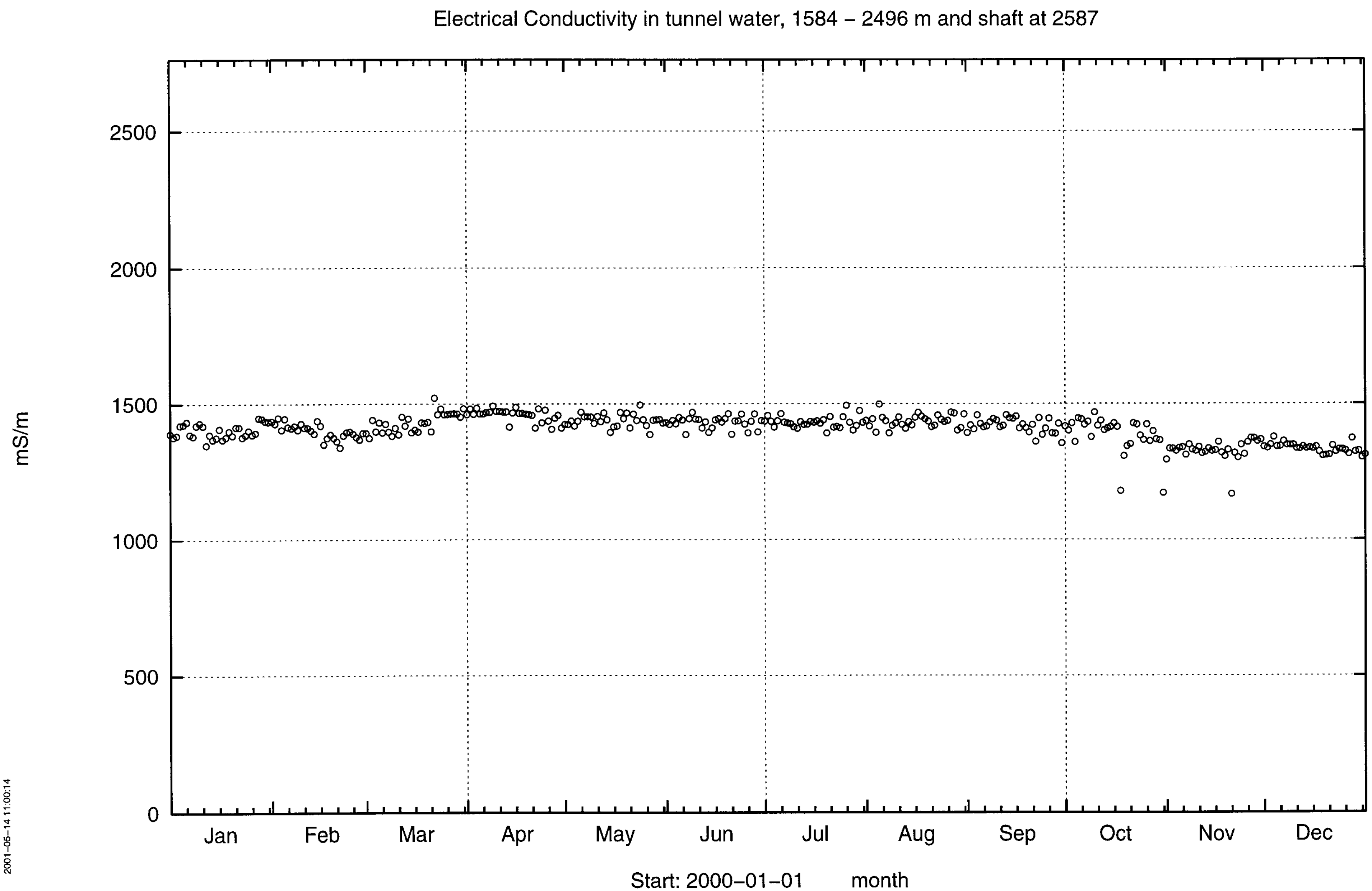


Electrical Conductivity in tunnel water, 0 – 682 m.
mS/m
1200
1000
800
600
400
200
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 11:00:13


Electrical Conductivity in tunnel water, 1033 – 1584 m.
mS/m
1200
1000
800
600
400
200
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 11:00:14

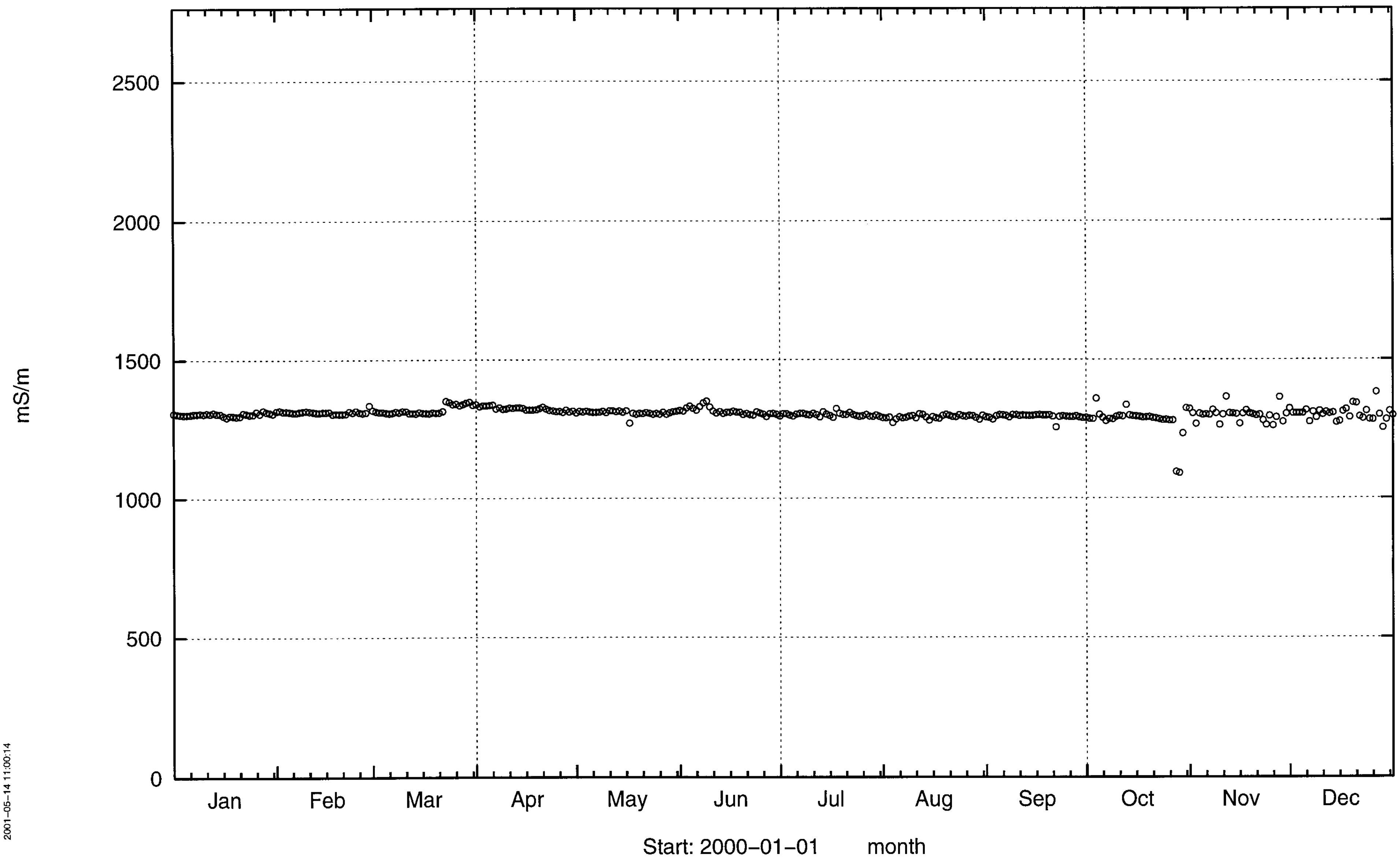
Electrical Conductivity in tunnel water, from shafts at 1659 m.



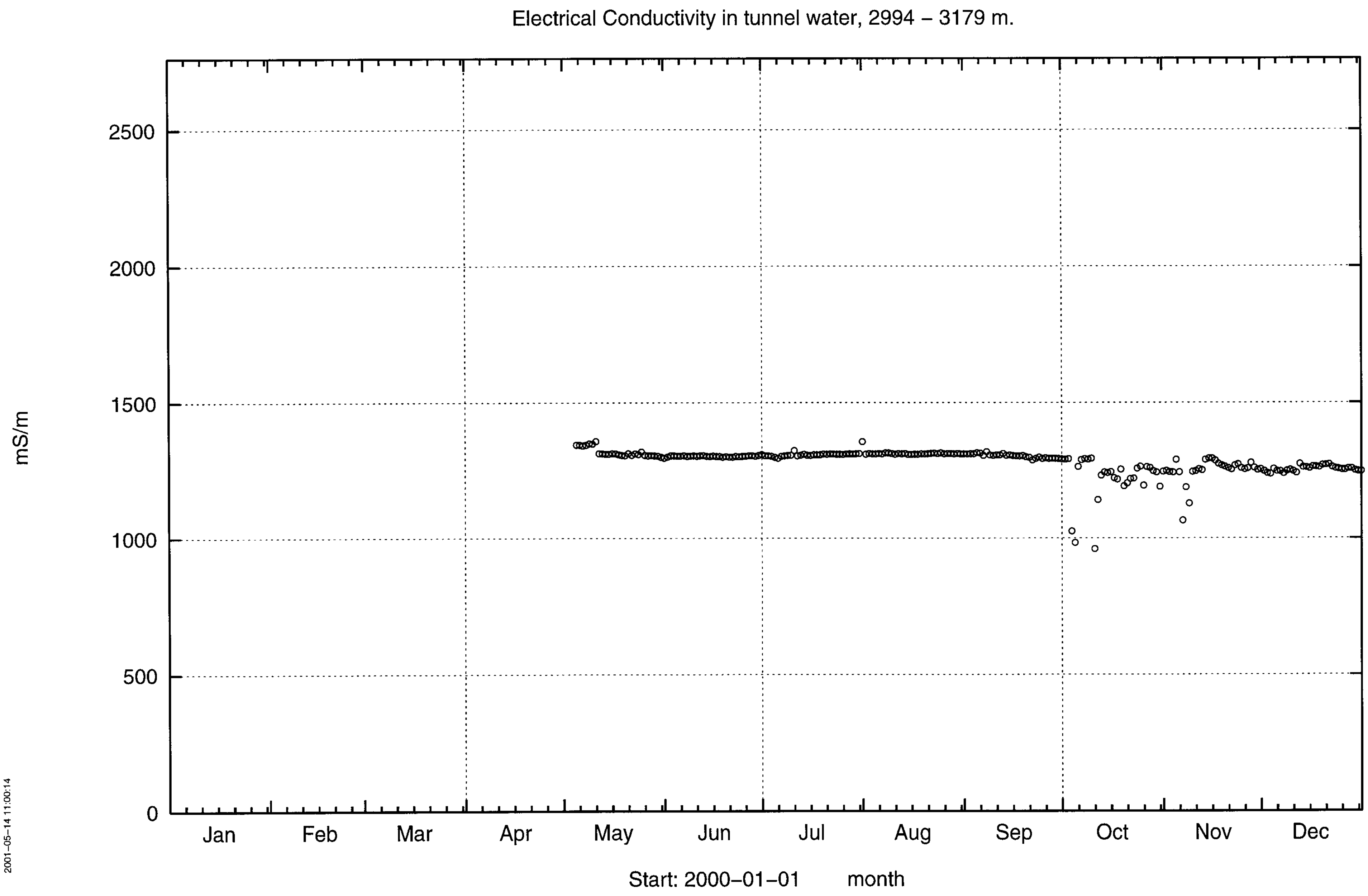


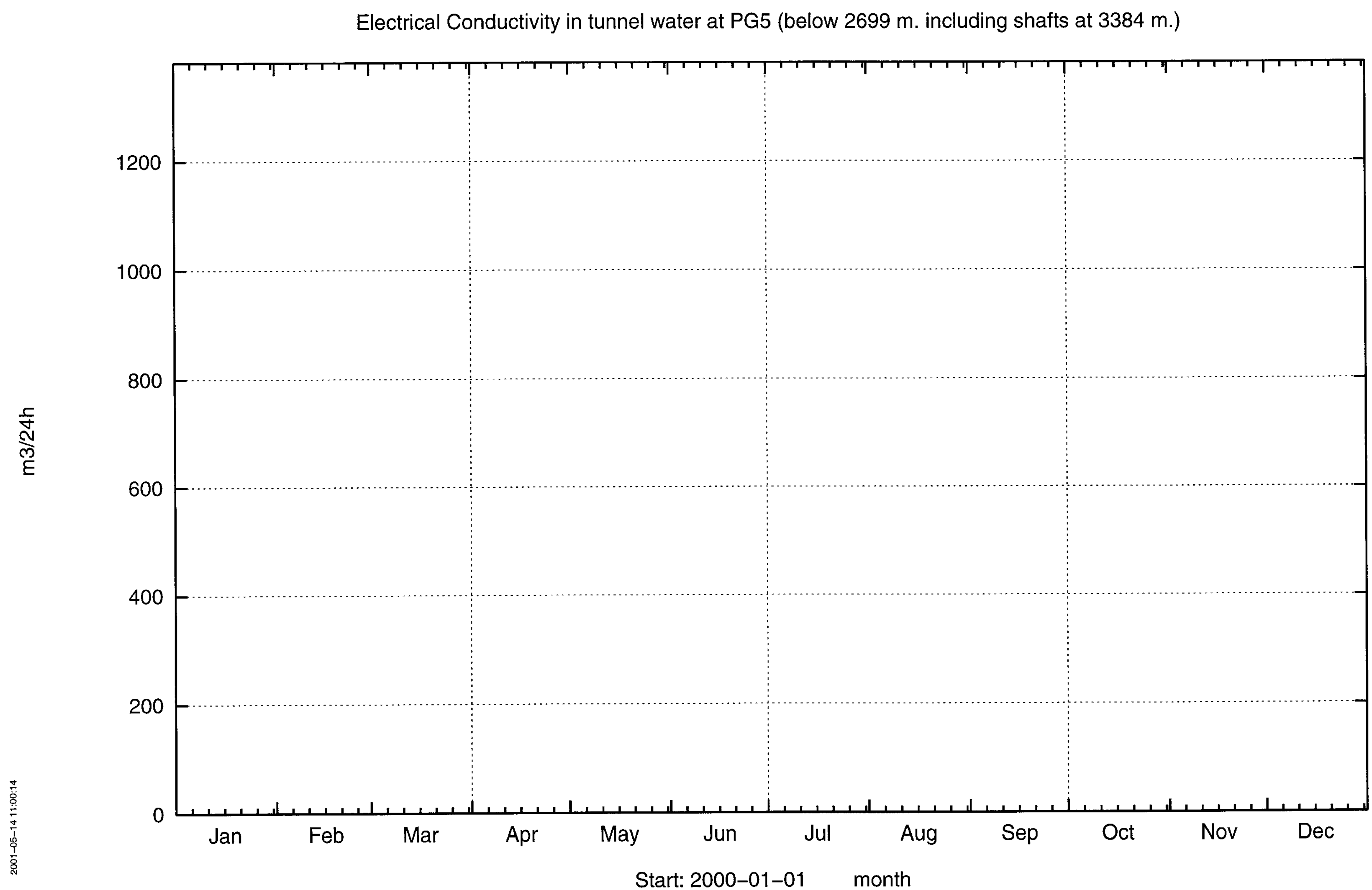
Electrical Conductivity in tunnel water, 1584 – 2496 m and shaft at 2587
mS/m
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 11:00:14

Electrical Conductivity in tunnel water, from shaft at 2587 m.

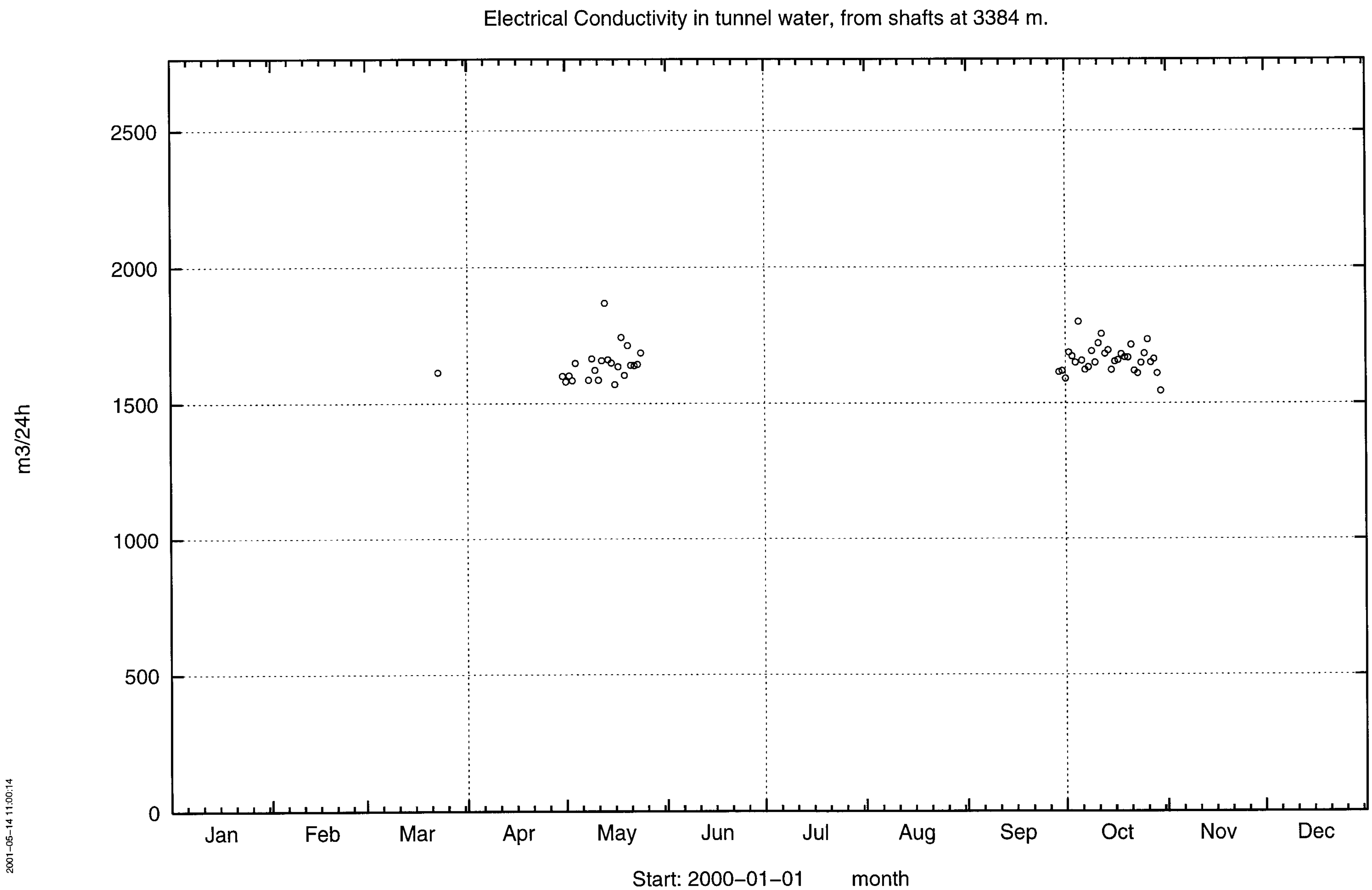


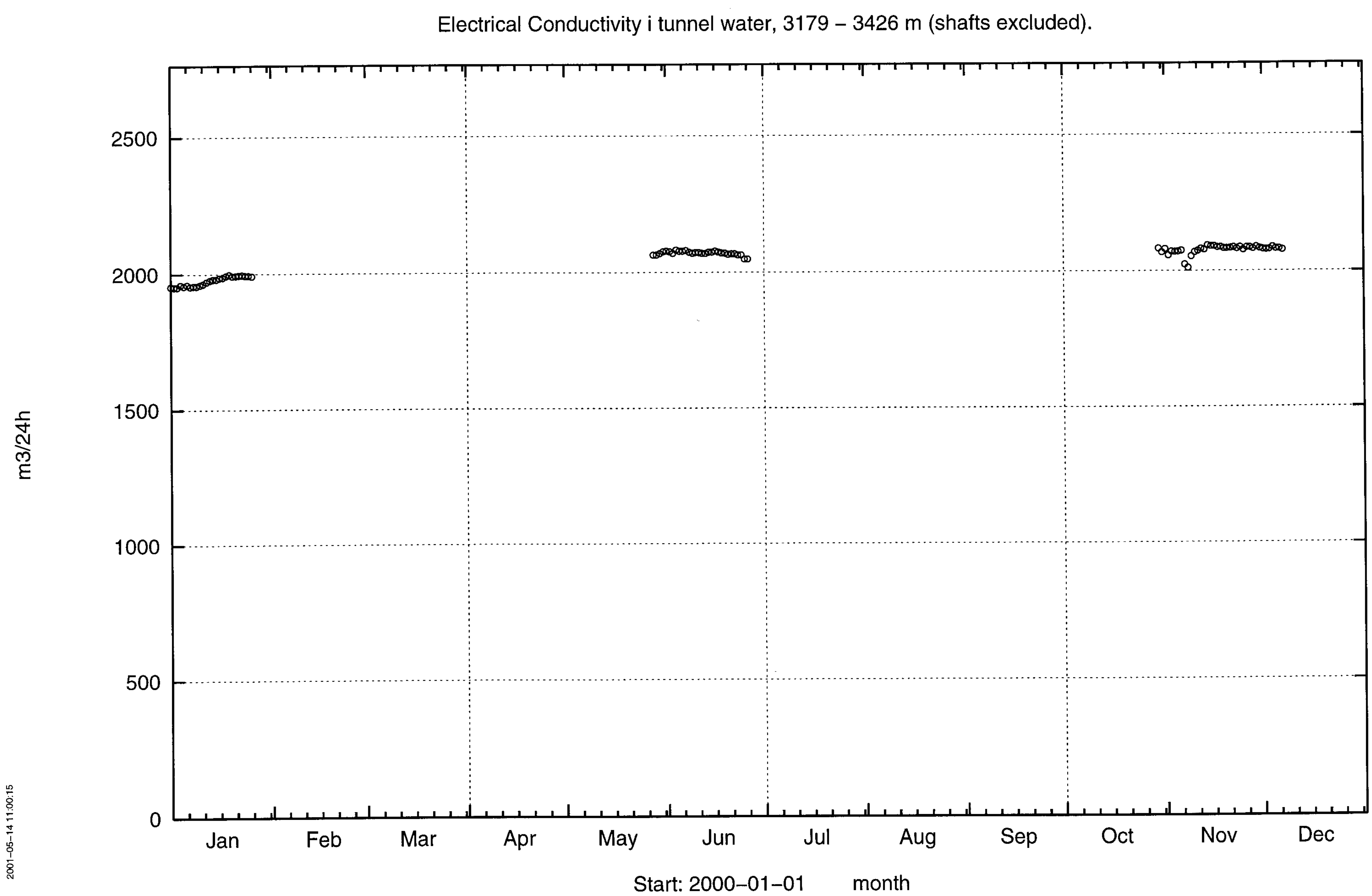
2001−05−14 11:00:14


Electrical Conductivity in tunnel water, 2994 – 3179 m.
mS/m
0
500
1000
1500
2000
2500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 11:00:14

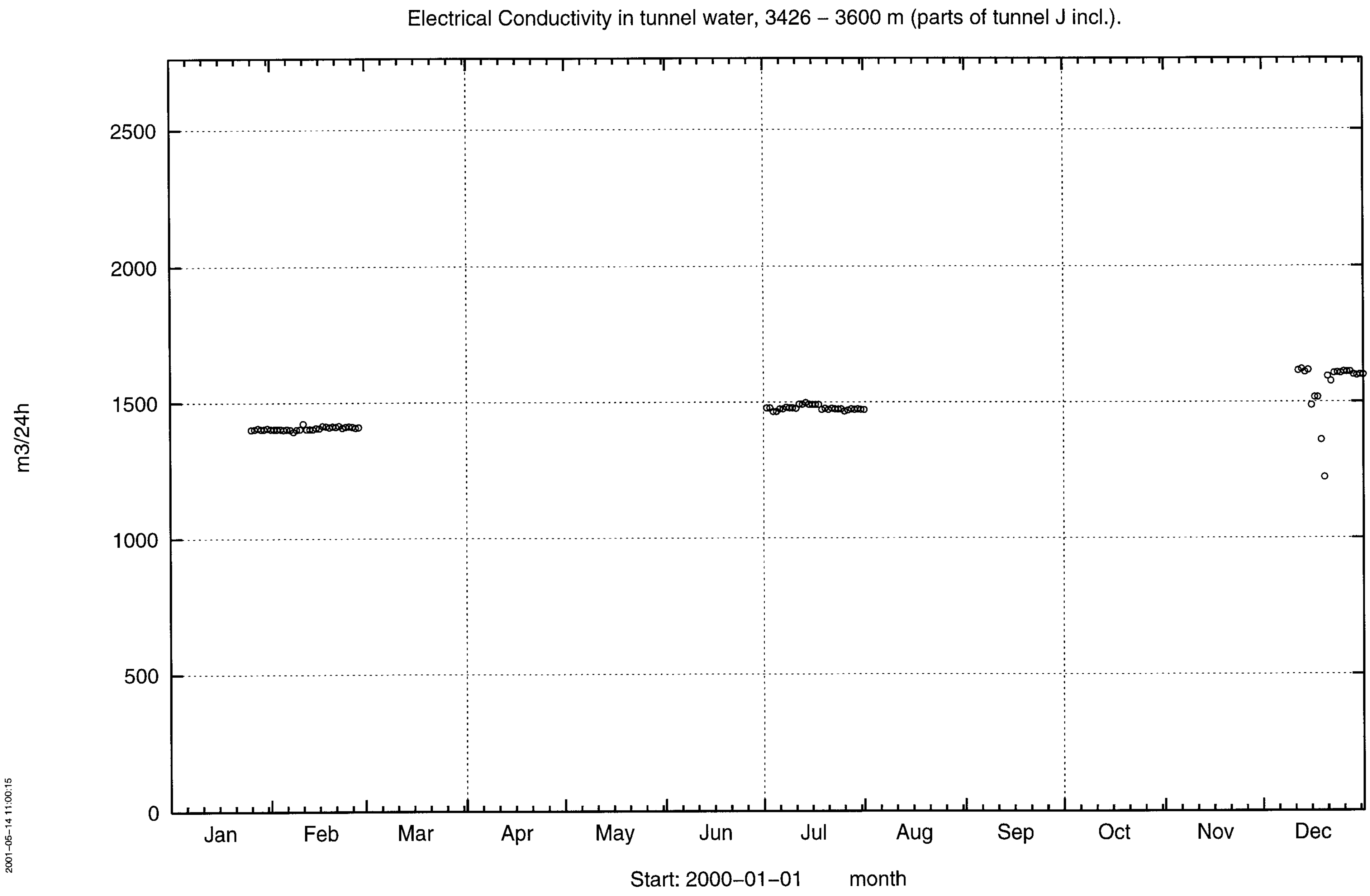


Electrical Conductivity in tunnel water at PG5 (below 2699 m. including shafts at 3384 m.)
m3/24h
1200
1000
800
600
400
200
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−14 11:00:14

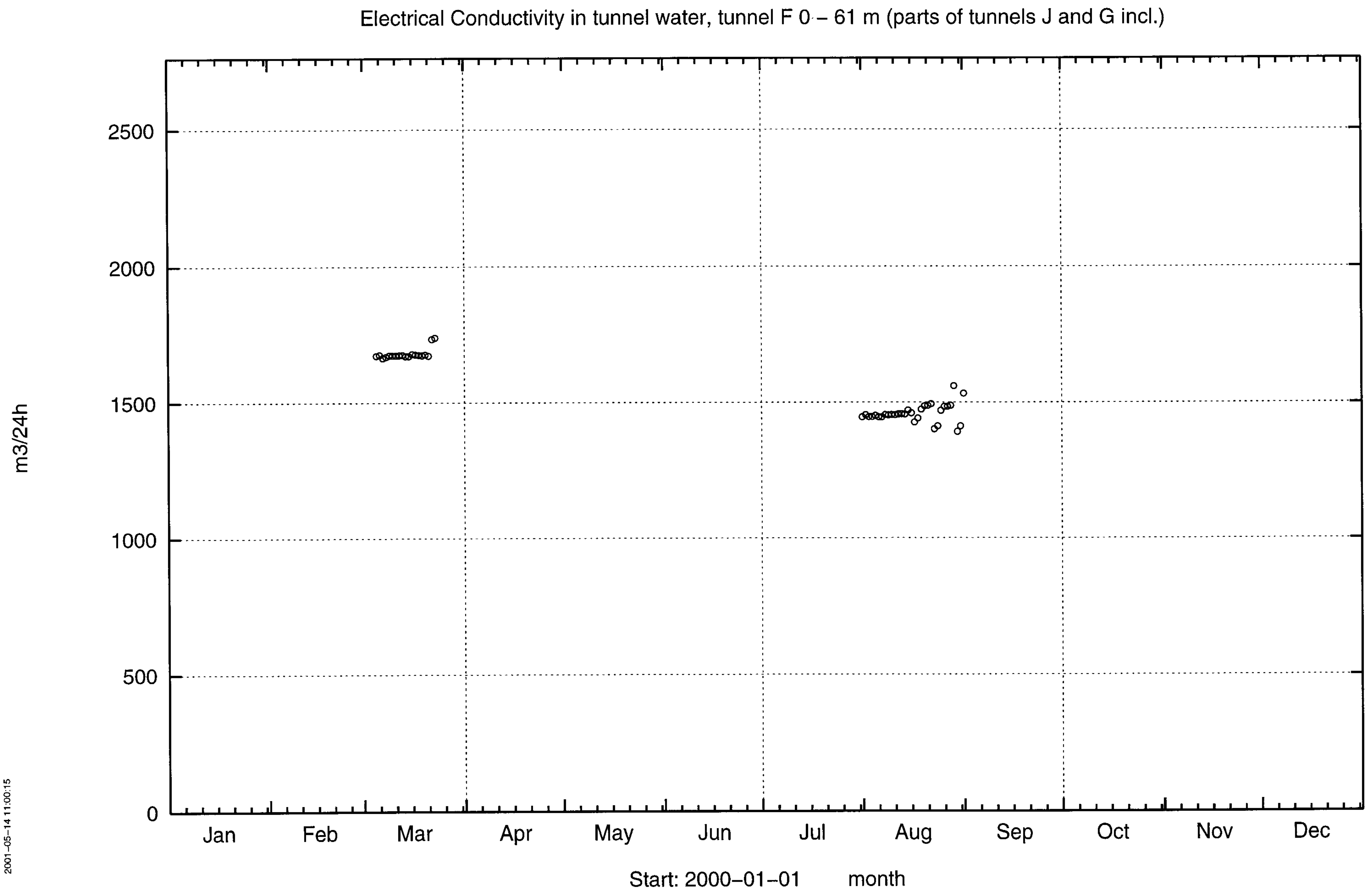

Electrical Conductivity in tunnel water, from shafts at 3384 m.
m3/24h
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−14 11:00:14



Electrical Conductivity i tunnel water, 3179 – 3426 m (shafts excluded).
m3/24h
0
500
1000
1500
2000
2500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 11:00:15

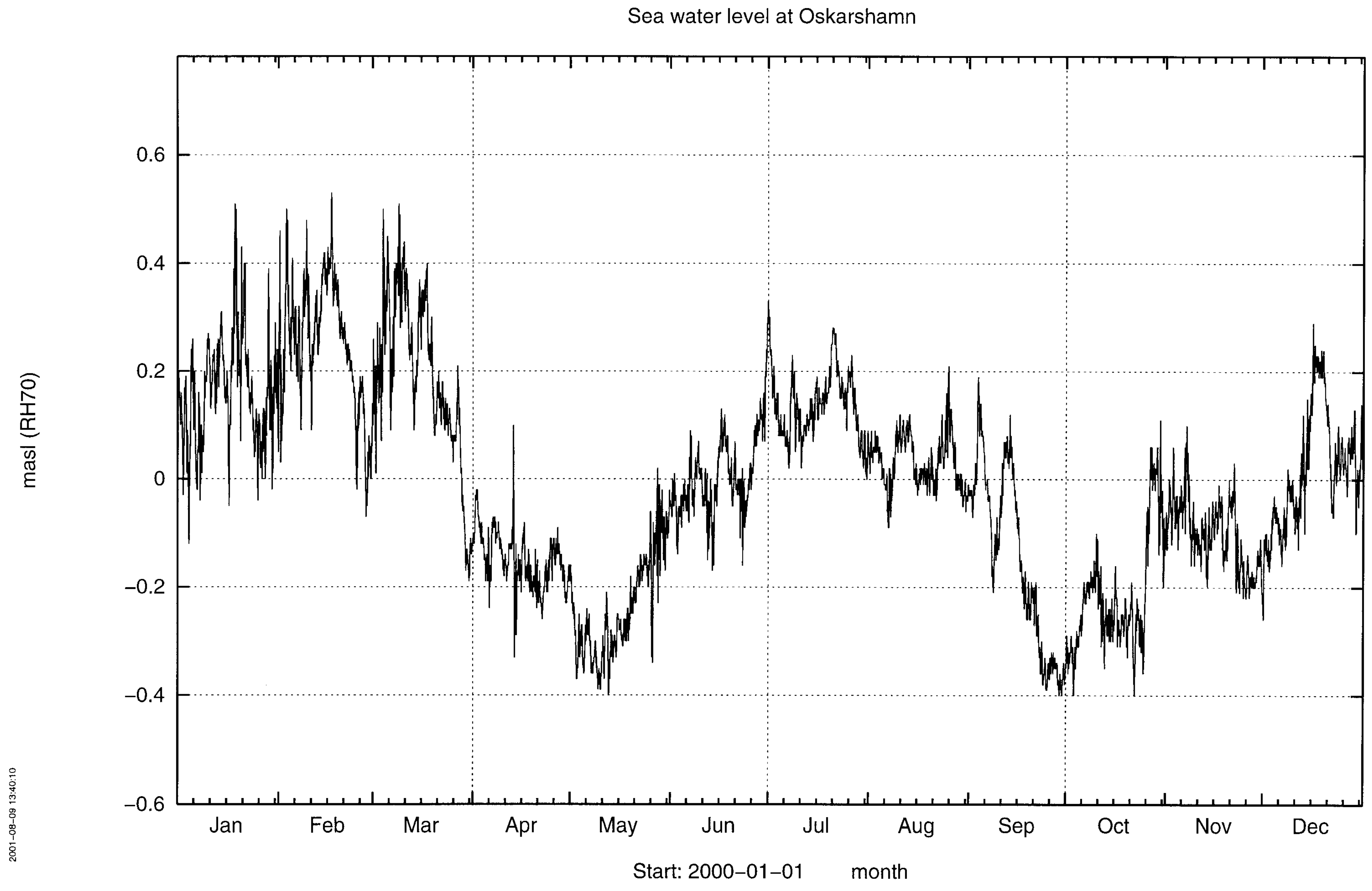


Electrical Conductivity in tunnel water, 3426 – 3600 m (parts of tunnel J incl.).
m3/24h
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01 month
2001–05–14 11:00:15

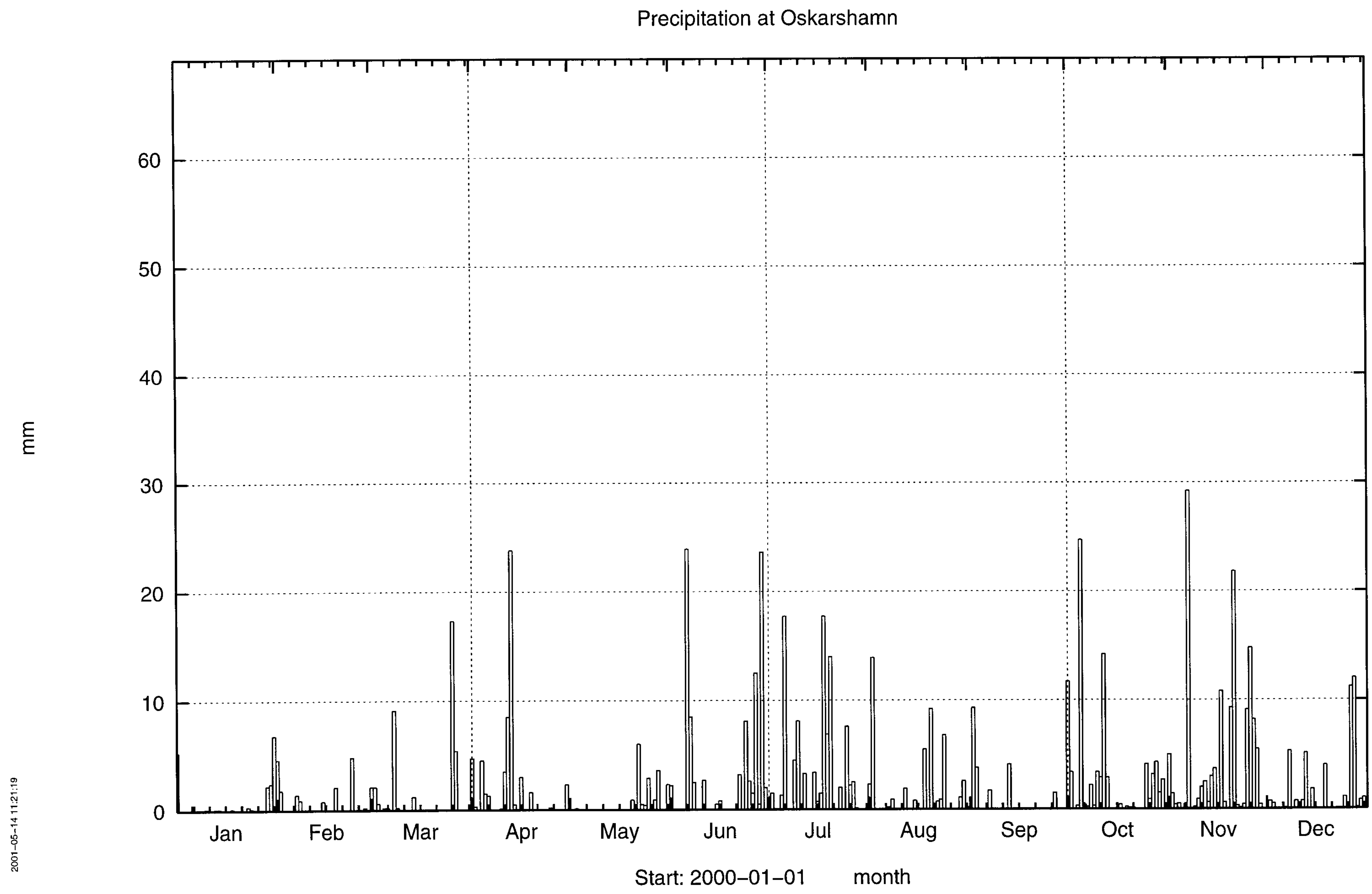


Electrical Conductivity in tunnel water, tunnel F 0 – 61 m (parts of tunnels J and G incl.)
m3/24h
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000–01–01
month
2001–05–14 11:00:15

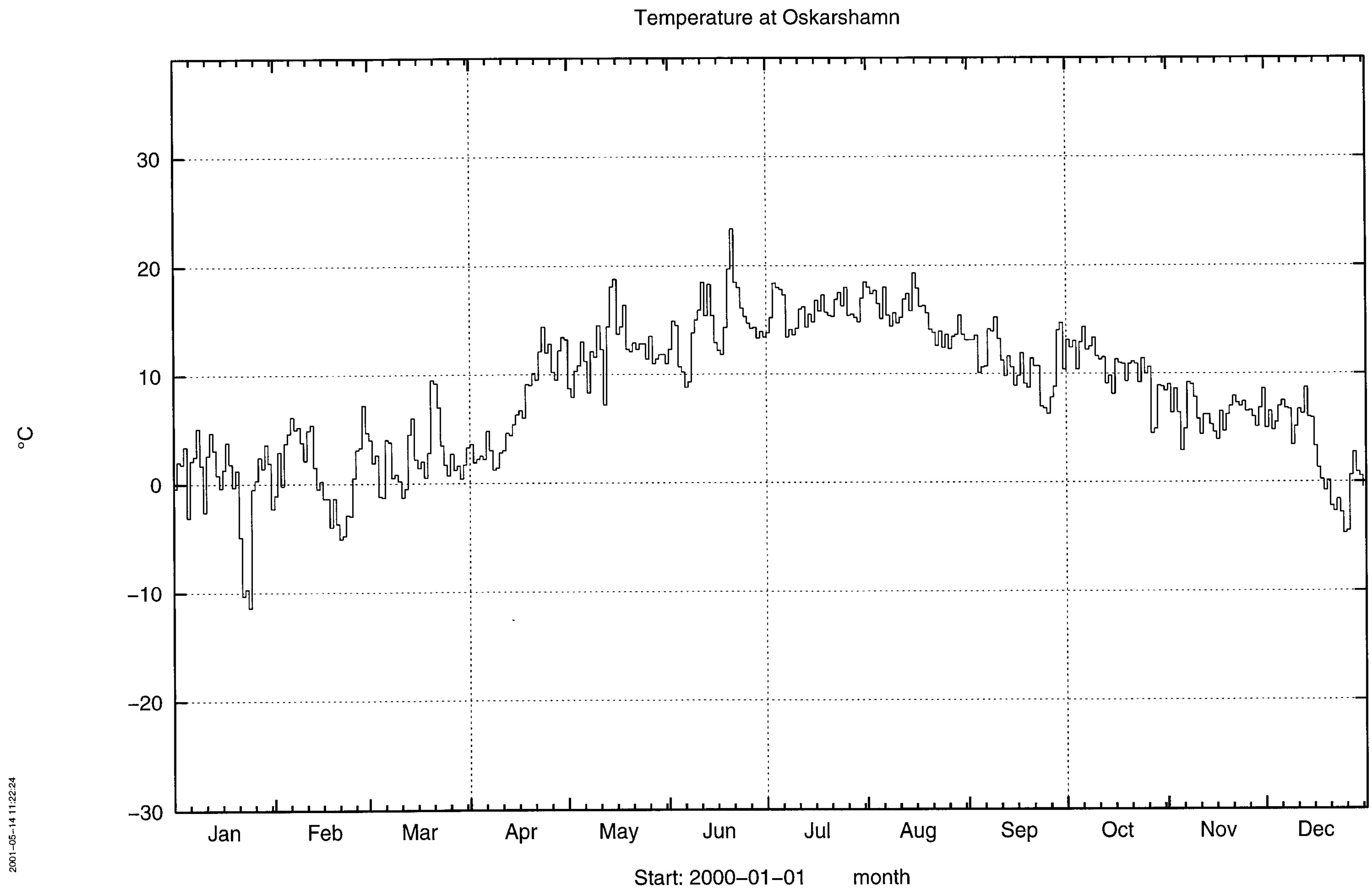
Appendix 8: Level of the Baltic Sea


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: 2000−01−01
month
2001−08−09 13:40:10

Appendix 9: Precipitation

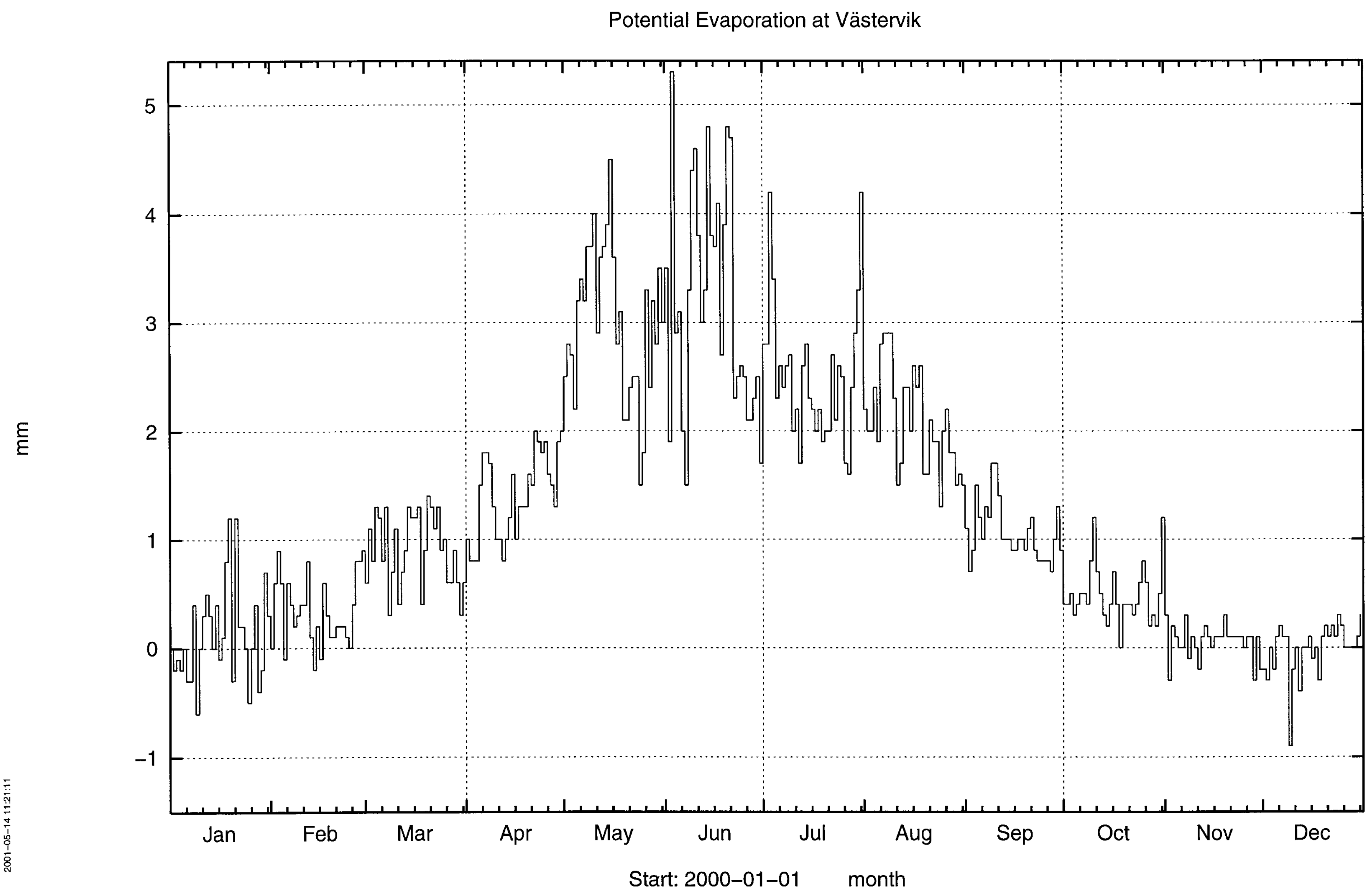

Precipitation at Oskarshamn
mm
60
50
40
30
20
10
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−14 11:21:19

Appendix 10: Air temperature



Temperature at Oskarshamn
°C
30
20
10
0
−10
−20
−30
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−14 11:22:24

Appendix 11: Potential evapotranspiration



Potential Evaporation at Västervik
mm
5
4
3
2
1
0
−1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2000−01−01
month
2001−05−14 11:21:11