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Äspö Hard Rock Laboratory

Hydro Monitoring Program

Report for 2002

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August 2003

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Abstract

The Äspö island is situated close to the nuclear power plant of Simpevarp in south-eastern Sweden. As part of the pre-investigations preceding excavation of the so called Äspö Hard Rock Laboratory, registrations of the groundwater levels and electrical conductivity in packed off borehole sections and levels in open boreholes started in 1987. The investigations are still ongoing and are planned to be continued for a long period of time. 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 2002 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 discussed.

Sammanfattning

Äspö ligger nära Oskarshamns kärnkraftverk i sydöstra Sverige. Som en del av förundersökningarna inför anläggningen av Äspölaboratoriet påbörjades 1987 registrering av grundvattennivå och elektrisk konduktivitet i avmanschetterade borrhålssektioner och nivå i öppna borrhål. Mätningarna pågår fortfarande och planeras fortgå under lång tid framöver. Från hösten 1990, under det att tunneln drevs, borrades nya hål i tunneln som instrumenterades för att möjliggöra mätningar av grundvattentrycket i avmanschetterade sektioner. Därtill har andra hydrorelaterade mätningar gjorts i tunneln såsom: vattenflöde i tunneln, grundvattnets elektriska ledningsförmåga samt in- och utflöde av vatten i tunnelledningar. Denna rapport sammanfattar alla mätningar som gjorts under 2002 och beskriver instrumenteringar och mätmetoder som använts.

För att kunna relatera förändringar till faktorer som kan påverka grundvattnets nivå/tryck och flöde presenteras meteorologiska data och mätningar av Östersjöns nivå i rapporten. Ett kapitel behandlar även effekter av jordskorpans regelbundna rörelser till följd av solens och månens inverkan (den s.k. tidaleffekten).

Från och med 1991, ett år efter det att tunneldrivningen startade, är störningen från tunneldrivningen den faktor som har störst påverkan på grundvattenytan i området. I ett kapitel redovisas och diskuteras översiktligt sådana aktiviteter som kan påverka grundvattnet.

Executive Summary

The construction of the Äspö Hard Rock Laboratory started in October 1990. The laboratory consists of an extensive tunnel system excavated down to a depth of 460 m below the ground surface. The 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 a 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, data collected from measurements in the tunnel were also included. The following data are described:

1. Groundwater level data in surface boreholes

2. Electrical conductivity registrations of the groundwater in surface boreholes

3. Groundwater pressure in tunnel boreholes
4. Water flow in tunnel
5. Water flow in tunnel pipes
6. Electrical conductivity of tunnel water
7. Humidity transport in the ventilation air in the tunnel (only in the report for 1995)
8. Level registrations of the Baltic Sea
9. Precipitation
10. Air temperature
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 2002, there were 127 boreholes involved in the hydro-monitoring program within the five investigation areas and in the tunnel. The boreholes are either core-drilled (78 in number) or percussion-drilled. Most of the boreholes are equipped with one or several rubber packers, which isolate up to ten borehole sections. The isolated sections often represent 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 instrumentation design differs slightly compared with above and in some boreholes levels are obtained by manual levelling. A number of percussion-drilled 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, some 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 was placed relatively close to the ground surface, the second rather deep in the borehole. Over time these sensors have ceased to work and in May 2002 the last one in KAS09 stopped functioning.

In the tunnel, 22 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 inflow to the tunnel in the fresh water pipe was also 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 caused by the tunnel has resulted in dramatic effects in many boreholes. In some borehole sections, the level has declined as much as 100 metres. Since 1994 the levels have gradually stabilised and during the last years the level decline in most boreholes has been less than a few metres. During 2002, the level changes have been within ±0.5 m in 36 sections out of 73. In 32 sections, the levels were declining more than 0.5 m and in the remaining five there was an increase greater than 0.5 m. Even if the changes are rather small, the long term overall picture is that a small decrease is still ongoing in many boreholes on the Äspö island as a result of the excavation of the Äspö HRL. During certain periods this decrease may be balanced by meteorological conditions resulting in increasing groundwater levels.

In most tunnel boreholes, the pressure was still decreasing during 2002. In some borehole sections in the Prototype repository, pressure recovery is still ongoing after the re-instrumentation, grouting works and backfilling of the inner section of the repository carried out during 2001. In the entrance tunnel and in the tunnel spiral, the pressure decreased 30-120 kPa during 2002. Generally, the decrease is somewhat higher further down in the tunnel system. In some borehole sections in the Prototype repository (in the I-tunnel and the two boreholes in the G-tunnel), there has been a rather great decrease (hundreds of kPa). This is partly due to a sudden pressure drop that occurred 2002-05-06 for which no explanation has been found.

The flow in most gauging boxes has 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 various activities. For example, two new boreholes drilled between MA3384G and MA3411G caused the high flow rates for the latter. During the comparison period October – December, 1821 m^3/d was pumped out from the tunnel, which is approximately 27 m^3/d less than during the same period year 2001.

The total amount of precipitation during 2002 was 685 mm, which is 132 mm more than the mean for the comparison period 1961-90. Large amounts were measured in May and October (210 mm) while there were no precipitation at all in August and only 17 mm in September.

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1 Introduction

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

Starting in 1987 extensive aerial and ground geophysical surveys, mapping of the rock outcrops and geohydrological investigations have been performed on Äspö, on the adjacent islands of Ävrö, Bockholmen and Mjälen and in the Laxemar area on the mainland west of Äspö (Figure 1-2). A large number of investigation boreholes have been drilled at these sites. The lengths of the boreholes vary between 22 m and 1 700 m and almost every borehole has, shortly after drilling, been instrumented with rubber packers, separating the borehole into two or more sections (maximum seven). The sections often represent different hydraulic units of the granitic bedrock. Most of the boreholes are also equipped with one or more pressure transducers, enabling groundwater 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 groundwater 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. To measure the water level in the gauging boxes either a pressure transducer or an ultrasonic transmitter located above the water surface is used.

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 presented in annual reports. The first report, however, contained groundwater level data from three years: 1987-89 (Nyberg et al 1991). As from the report for 1995, also tunnel data are included. The present paper is the annual report covering the year 2002. 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 one 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.

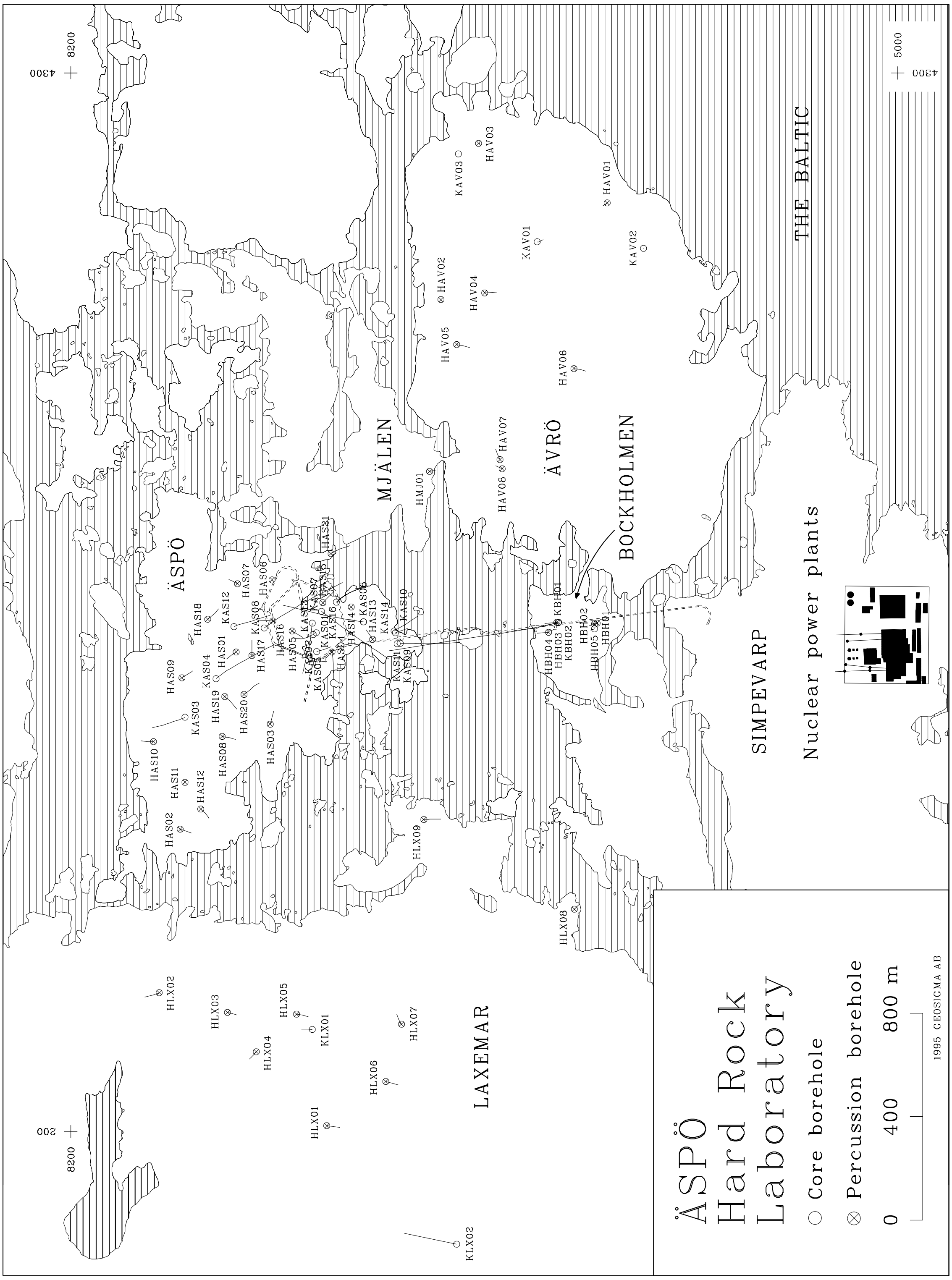

Figure 1-2 The investigation area with borehole locations.

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 uninhabited.

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, Sveco-carelian supracrustals and gneissic granites also occur as well as intrusions of anorogenic granites forming small massifs in the older bedrock, e.g. the Götemar granite. Datings of the Småland granites have yielded an age of > 1 700 Ma. The younger anorogenic granites range between 1 350 and 1 400 Ma in age (Kornfält, Wikman, 1988).

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

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

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

2.2 Äspö

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

The bedrock of Äspö is dominated by so called Smålandsgranite: a finemedium-grained to medium-grained, reddish grey granitoid with megacrysts (1-3 cm) of red microcline. Dikes of fine-grained red to greyish granite intersect this older rock. At the 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.

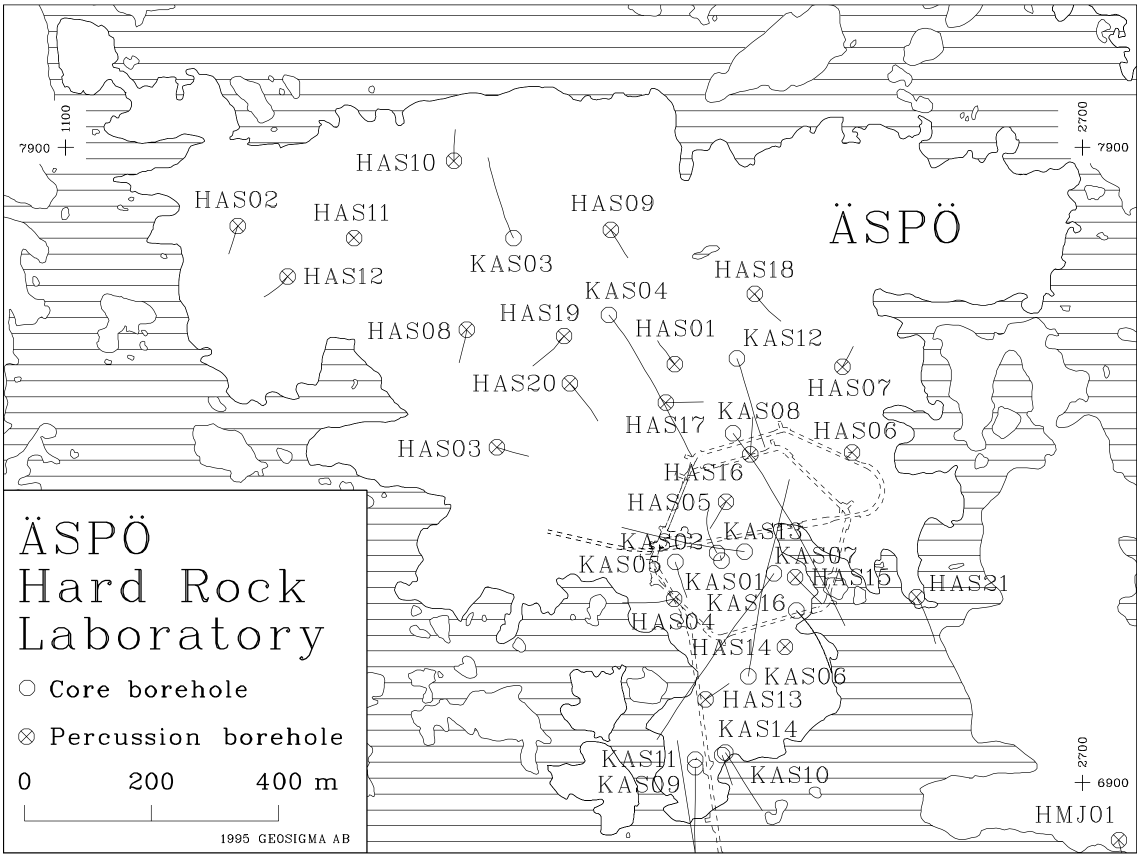

Figure 2-1 The Äspö area with borehole locations. Circles represent the intersection of the boreholes with the ground surface, the lines represent the projection on the ground surface of the respective boreholes. The tunnel is also shown in the figure.

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, 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.

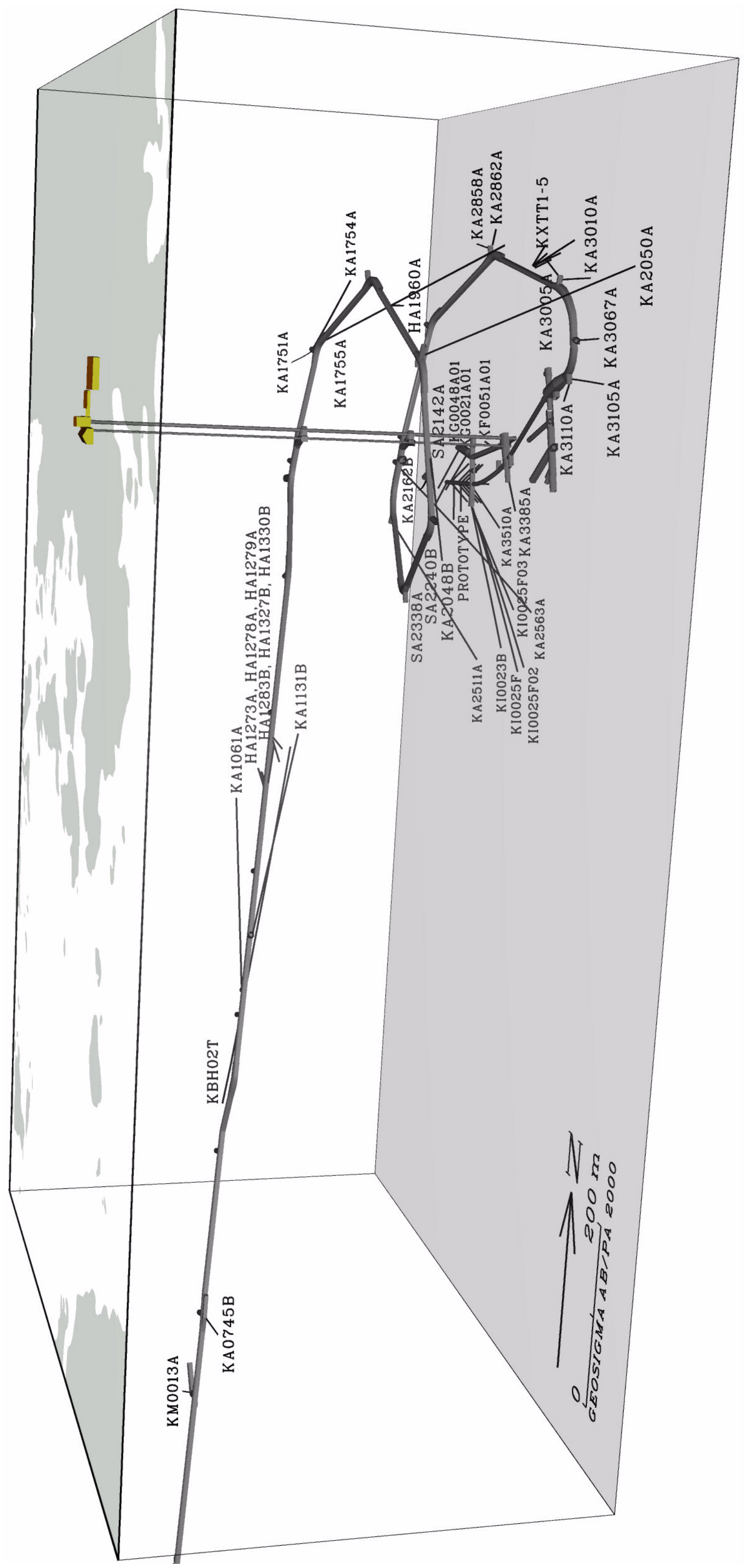

Figure 2-2 Outline of the Äspö Hard Rock Laboratory with a side-view of the access ramp, the tunnel spiral and boreholes.

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.

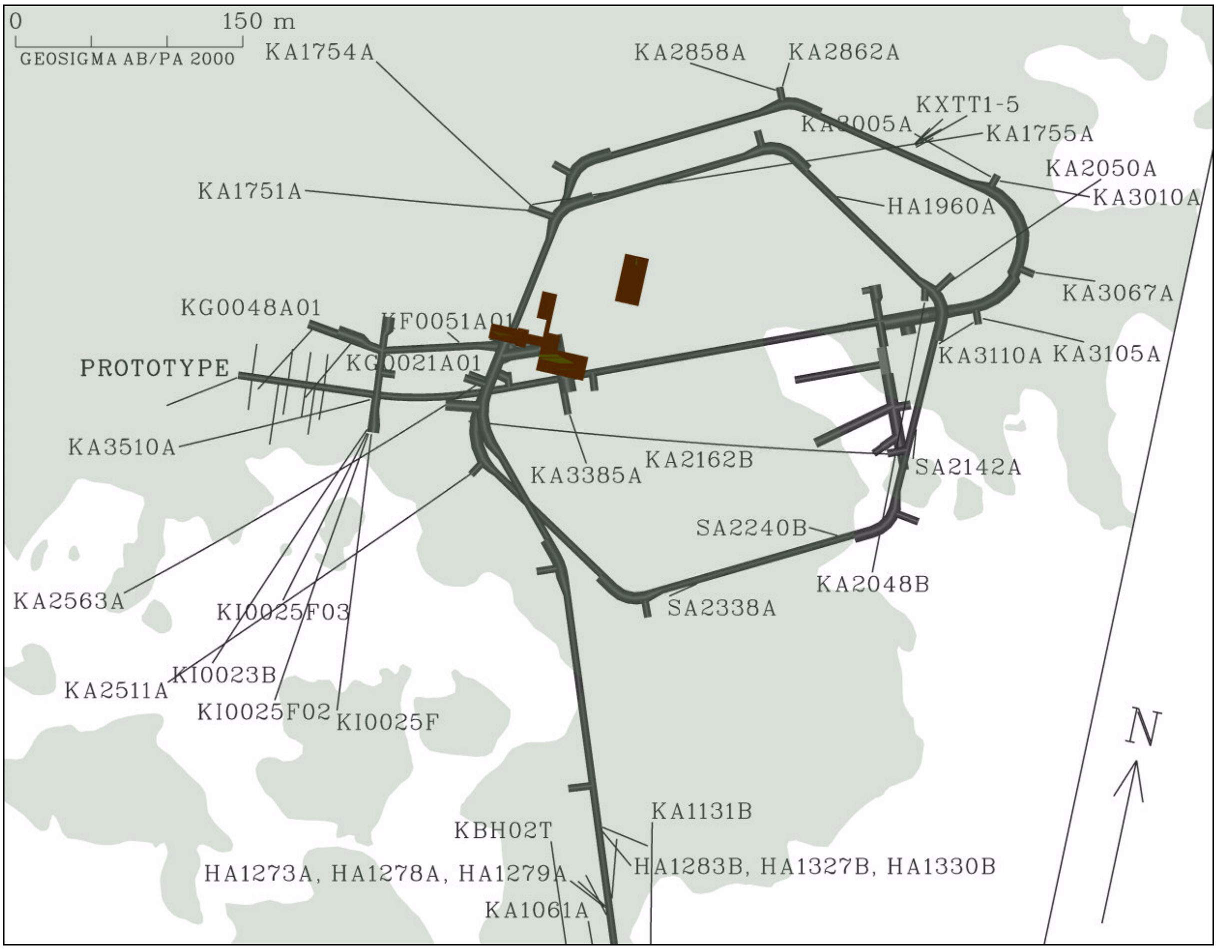

Figure 2-3 Plan view of the tunnel spiral with boreholes.

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 2002:

In the Äspö area:	16 core drilled boreholes and
	25 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
	12 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. 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. The extent of the monitoring program for surface boreholes during 2002 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	2.38	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	4.83	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	6.38	1.50	880322
HAS11	-89.3	355	125.00	5.59	1.50	880323
HAS12	-59.9	221	125.00	2.91	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	7.56	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	9.20		860824
HAV04	-60.1	180	100.00	7.99	0.40	870724
HAV05	-54.5	191	100.00	6.83	1.00	870728
HAV06	-59.5	190	100.00	12.42	1.20	870730
HAV07	-56.2	66	100.00	4.17	4.00	870728
HAV08	-61.9	28	63.00	7.08		*Before 1984*
HBH01	-58.5	351	50.6	4.71	3.0	910220
HBH02	-47.5	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(01?)
HLX01	-59.4	187	100.00	8.90	3.00	871021
HLX02	-57.4	339	100			871027
			132.00	9.04	0.60	*871110*
HLX03	-62.4	197	100.00	10.45	1.40	871104
HLX04	-63.6	313	125.00	10.36	1.20	871106
HLX05	-57.7	187	100.00	15.71	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	2.22	6.0	911114
HLX09	-61.3	178	151	3.31	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	450.62	4.08	100.65	891122
KAS10	≈-60	≈ 162	99.93	3.72	2.50	891023
KAS11	-88.7	34	248.90	4.25	6.00	900221
KAS12	-69.9	161	380.40	4.83	6.00	900320
KAS13	-62.2	278	406.95	3.84	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	14.10	11.74	861113
KAV02	≈-90	137	97.10	7.82	12.40	770531
KAV03	-89.4	146	248.40	8.74	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	16.77	101.30	900804
KLX02	-85.0	9	1700.50	18.40	202.95	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°.
Italics = This information is not found in the Sicada database or the information is questioned.

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 unsuccessful and terminated before a telescope drilled borehole was complete and the three core boreholes on Ävrö that were not telescope drilled. Normally this enlarged part has a length of approximately 100 m. All telescope drilled core boreholes also have an enlargement (approximately 1 m long) where the diameter is changing to make room for a funnel-shaped pipe which gives a smooth connection between the two borehole diameters.

Table 3-2 Borehole diameters.

Borehole	Borehole diameter (mm)	Length of borehole from (m)	to (m)
HAS01	115	0.00	100.00
HAS02	115	0.00	93.00
HAS03	115	0.00	100.00
HAS04	115	0.00	201.00
HAS05	115	0.00	100.00
HAS06	115	0.00	100.00
HAS07	115	0.00	100.00
HAS08	115	0.00	125.00
HAS09	115	0.00	125.00
HAS10	115	0.00	125.00
HAS11	115	0.00	125.00
HAS12	115	0.00	125.00
HAS13	115	0.00	100.00
HAS14	115	0.00	100.00
HAS15	115	0.00	120.00
HAS16	115	0.00	120.00
HAS17	115	0.00	120.00
HAS18	162	6.00	150.00
	250	0.00	6.00
HAS19	158	6.00	150.00
	250	0.00	6.00
HAS20	152	6.00	150.00
	250	0.00	6.00
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	115	95.85	101.00
	115	0.00	95.85
KAS02	56	93.35	924.04
	155	0.00	93.35
KAS03	56	100.80	1002.26
	164	?	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	100.65	450.62
	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
	164	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	?	101.30
KLX02	76	202.95	1700.50
	92	201.00	202.95
	165	200.80	201.00
	215	3.00	200.80
	340	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 75 boreholes were connected to the monitoring system during 2002. 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 2002 are listed.

Many 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. (°)	Bearing * at top of b.h. (°)	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	149.91	56	-237.56	2.00	930504
KA1754A	-26.2	299.9	159.88	56	-237.84	2.00	930519
KA1755A	-19.9	339.4	320.58	56	-237.80	2.42	940406
KA2048B	-10.6	190.9	184.45	56	-275.43	2.00	930216
KA2050A	-53.5	55.3	211.57	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	15.98	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-diameter (mm)	Elevation at tunnel wall (m. a. s. l.)	Length of casing (m)	Drilling completed
KA3005A	-4.5	299.1	58.11	56	-399.86	2.50	941205
KA3010A	-4.7	99.5	60.66	56	-399.87	2.50	941208
KA3067A	-4.7	98.4	40.05	56	-408.59	2.50	941211
KA3105A	-4.7	102.5	68.95	56	-413.68	2.50	941215
KA3110A	-5.4	238.3	26.83	56	-413.71	2.50	941217
KA3385A	-4.8	161.0	34.18	56	-446.01	No c.	950110
KA3510A	-30.2	255.3	150.06	76	-448.70	*2.35*	960909
KA3563A01	-7.7	233.8	2.06	56	-447.06	No c.	000922
KA3563D01	2.5	53.7	2.01	56	-446.15	No c.	000925
KA3563G	-79.9	277.9	30	76	-448.69	No c.	980507
KA3563I01	73	235.9	2.15	56	-443.64	No c.	001011
KA3566C01	3.5	232.3	2.1	56	-445.56	No c.	000920
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
KA3568D01	-2.3	54.4	2.3	56	-445.83	No c.	000925
KA3572G01	-89.6	225	12	76	-448.51	No c.	980320
KA3573A	-2.1	188.3	40.07	76	-446.07	2.65	970911
KA3573C01	34.9	232.3	2.05	56	-445.13	No c.	000926
KA3574D01	12.6	55.5	2.05	56	-445.12	No c.	000926
KA3574G01	-89.2	249	12	76	-448.33	No c.	980428
KA3576G01	-89.2	213.7	12.01	76	-448.27	No c.	980426
KA3578C01	-5.4	232.4	2.09	56	-445.34	No c.	000928
KA3578G01	-89	252.6	12.58	76	-448.38	No c.	980319
KA3578H01	59.1	266.7	1.9	56	-443.38	No c.	001002
KA3579D01	-1	54.2	2	56	-445.43	No c.	000922
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
KA3588C01	-4	232.8	2.04	56	-445.44	No c.	000926
KA3588D01	-1.8	55	1.9	56	-445.24	No c.	000925
KA3588I01	65.6	5.2	1.96	56	-443.34	No c.	001019
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
KA3592C01	4.4	233.8	2.1	56	-445.25	No c.	000926
KA3593G	-79.9	275.2	30.02	76	-448.07	No c.	980504
KA3597D01	3.1	53.5	2.22	56	-445.1	No c.	001004
KA3597H01	55.1	248.8	2.06	56	-443.18	No c.	001005
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	76	-448.23	2.50	970425
KI0025F02	-25.5	200.0	204.18	76	-448.53	2.65	980825

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
KI0025F03	-29.8	206.9	141.72	76	-448.08	2.50	990813
KR0012B	-1	315	10.57	38	-69.06	No c.	910503
KR0013B	-1	296	16.94	38	-69.06	No c.	910430
KR0015B	-1	289	30.31	38	-69.1	No c.	910504
KXTT1	-46.8	61.2	28.76	56	-392.12	2.50	950518
KXTT2	-45.2	61.4	18.3	56	-392.42	2.50	950522
KXTT3	-36.7	51.4	17.43	56	-391.07	2.50	950606
KXTT4	-36.5	61.5	49.31	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 is transmitted via a special network to the measurement stations in the tunnel.

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

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

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

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

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

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

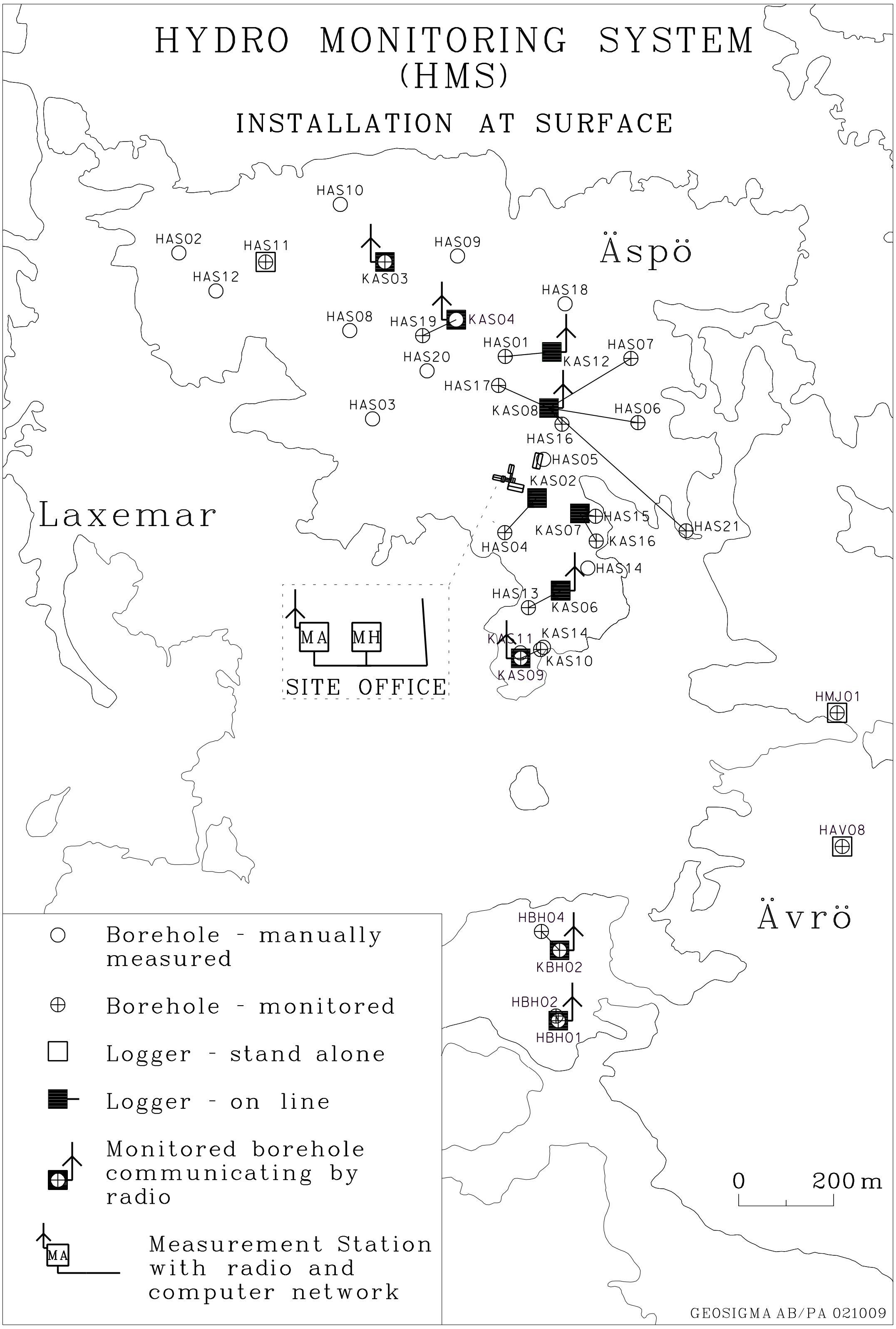

Figure 4-1 Surface part of the HMS showing the data logger network and radios.

4.1.2 Logger and Datascan units

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

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

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

To sum up, the following units are used:

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

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

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

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

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

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

Table 4-1 Monitoring equipment in surface boreholes.

Borehole	Section	Equipment	from	To
HAS01	1	BorreR	91-09	
HAS02	1	Manually	970320	
HAS03	1	Manually	981018	
HAS04	1-2	BorreR	91-09	
HAS05	1	Manually	970320	
HAS06	1-2	BorreR	91-09	
HAS07	1	BorreR	970218	
HAS08	1	Manually	970130	
HAS09	1	Manually	970320	
HAS10	1	Manually	970320	
HAS11	1-2	BorreF	000912	
HAS12	1	Manually	970320	
HAS13	1-2	BorreR	91-09	
HAS14	1	Manually	970320	
HAS15	1	BorreR	970522	
HAS16	1-2	BorreR	91-09	
HAS17	1-2	BorreR	91-09	
HAS18	1	Manually	970227	
HAS19	1-2	BorreR	91-09	
HAS20	1-2	Manually	970130	
HAS21	1	BorreR	970130	
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	
HBH01	1-2	BorreR	011130	
HBH02	1-2	BorreR	011130	
HBH04	1	BorreR	91-12	
	2	Manually	91-03	
HLX01	1	Manually	000917	
HLX02	1	Manually	000917	

Borehole	Section	Equipment	from	To
HLX03	1	Manually	000917	
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	
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	
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 2002 is to be found in earlier annual reports.

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

Table 4-2 Monitoring equipment in tunnel boreholes.

Borehole	Sect. no	Equipment	Date from	to
HA1273A	1	HM*+BorreT		
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	1-6	Datascan	970701	
	7-8	Datascan	990316	
KA2563A	1-5	Datascan	961120	
KA2598A	1	Datascan	990512	
KA2858A	2	Datascan	011024	
KA2862A	1	Datascan	011024	
KA3005A	2-5	Datascan	011024	
KA3010A	2	Datascan	011024	
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	
	4-5	Datascan	010518	
KA3563A01	1	Datascan	011219	
KA3563D01	1	Datascan	011219	
KA3563G	1-4	Datascan	011219	
KA3563I01	1	Datascan	010921	
KA3566C01	1	Datascan	011114	
KA3566G01	1-5	Datascan	011217	

Borehole	Sect. no	Equipment	Date from	to
KA3566G02	1-5	Datascan	011217	
KA3568D01	1	Datascan	010926	
KA3572G01	1-2	Datascan	011217	
KA3573A	1-5	Datascan	011217	
KA3573C01	1	Datascan	011219	
KA3574D01	1	Datascan	011219	
KA3574G01	1-3	Datascan	011217	
KA3576G01	1-3	Datascan	010918	
KA3578C01	1	Datascan	011106	
KA3578G01	1-2	Datascan	010918	
KA3578H01	1	Datascan	011219	
KA3579D01	1	Datascan	010920	
KA3579G	1-3	Datascan	011217	
KA3584G01	1-2	Datascan	010918	
KA3588C01	1	Datascan	011101	
KA3588D01	1	Datascan	011219	
KA3588I01	1	Datascan	011101	
KA3590G01	1-3	Datascan	011217	
KA3590G02	1-4	Datascan	011217	
KA3592C01	1	Datascan	011219	
KA3593G	1-4	Datascan	011015	
KA3597D01	1	Datascan	010918	
KA3597H01	1	Datascan	011015	
KA3600F	1-4	Datascan	011015	
KF0051A01	1-4	Datascan	980612	
KG0021A01	1-5	Datascan	010530	
KG0048A01	1-5	Datascan	010529	
KI0023B	1-9	Datascan	980216	
KI0025F	1-6	Datascan	970710	
KI0025F02	1-10	Datascan	981027	
KI0025F03	1-9	Datascan	991013	
KR0012B	1	BorreT	011115	
KR0013B	1	BorreT	011115	
KR0015B	1	BorreT	011115	
KXTT1	1-4	Datascan	011024	
KXTT2	1-5	Datascan	011024	
KXTT3	1-4	Datascan	011024	
KXTT4	1-5	Datascan	011024	
KXTT5	1-4	Datascan	011024	
SA2142A	1	HM+BorreT		
SA2338A	1	HM+BorreT		

* HM=Hydraulic Multiplexer

4.2 Groundwater level measurements in surface boreholes

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 2002 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 2002 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 2002 three core boreholes on Äspö, KBH02 on Bockholmen and KLX01 at Laxemar (under re-instrumentation during entire 2002) were equipped 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.

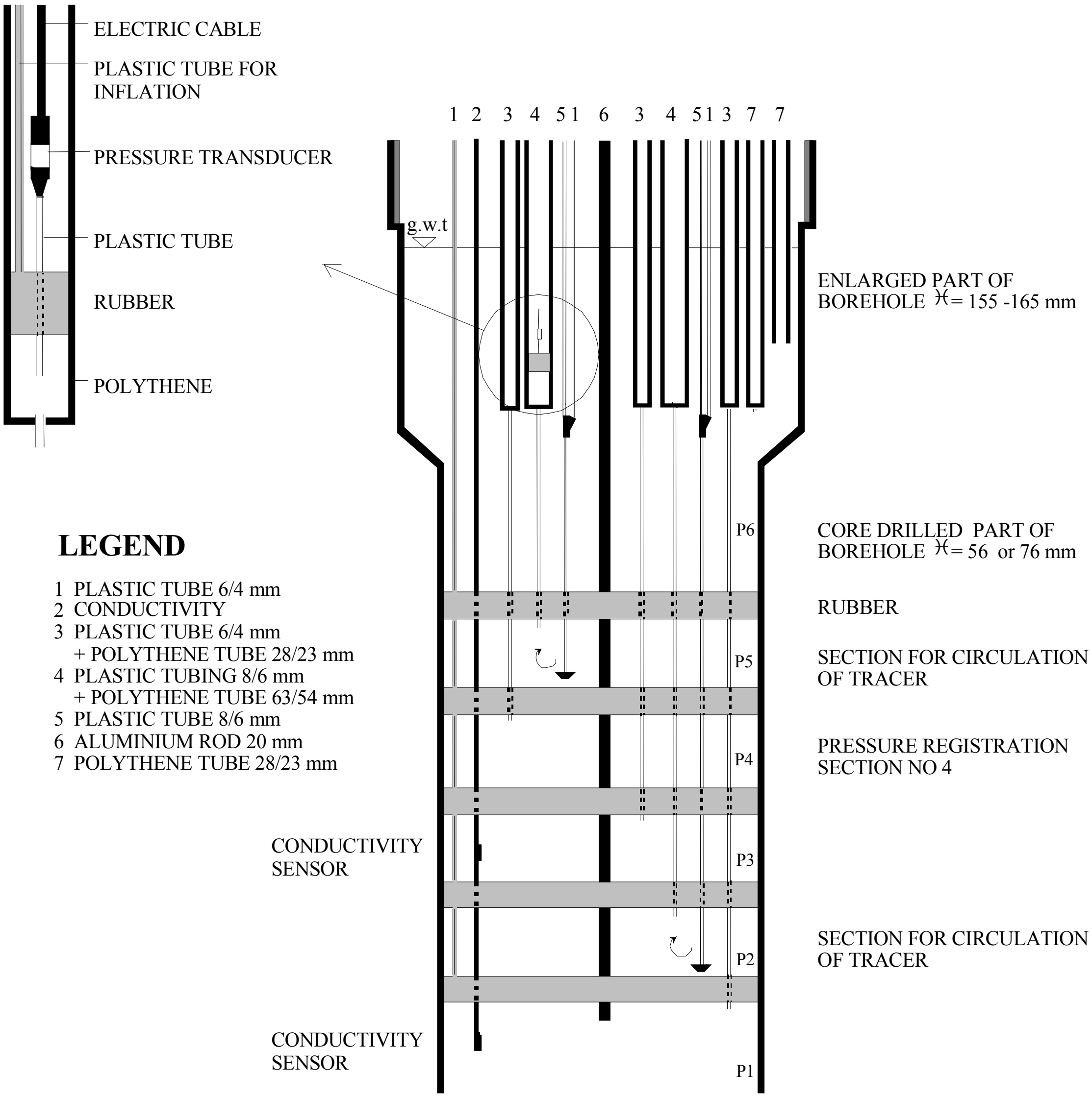

Figure 4-2 Instrumentation in core boreholes on Äspö.

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.

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.

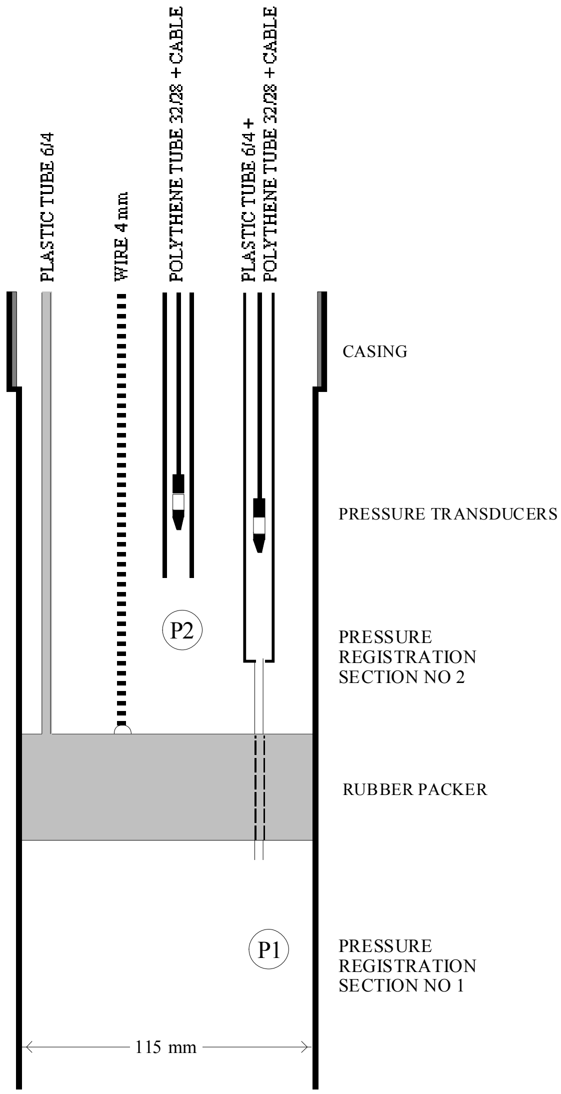

Figure 4-3 Instrumentation in percussion boreholes with the logger BORRE.

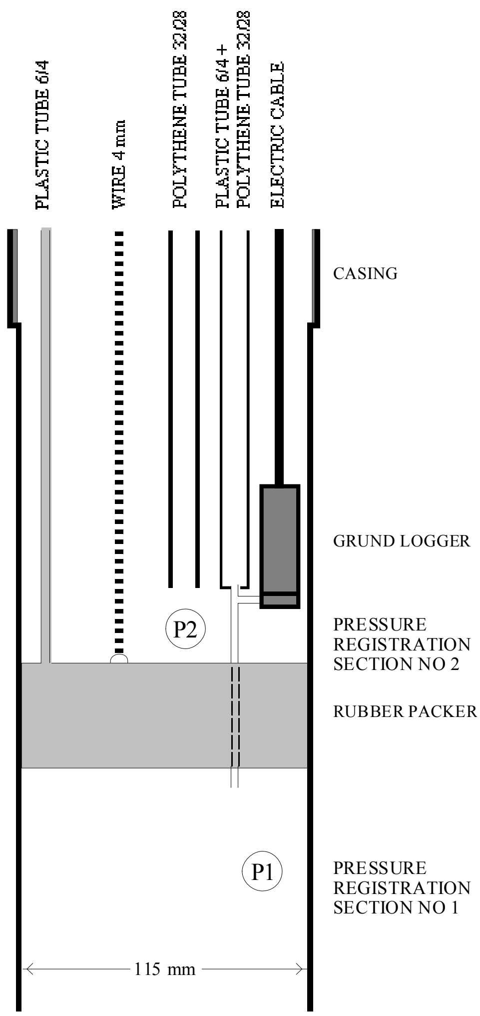

Figure 4-4 Instrumentation in percussion boreholes with the logger GRUND

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 2002. 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	Section installed		Borehole length		Elevation of section	
	no	from	to	from (m)	to (m)	at top (masl)	at middle (masl)
HAS01	1	1988-08-01		0	100	6.38	-37.41
HAS02	1	1995-08-25		0	93	2.11	-36.87
HAS03	1	1997-02-05		0	100	2.34	-39.42
HAS04	*1*	*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	2001-08-18	*2002-06-26*	0	125	5.59	-56.81
	1	2002-06-26		31	125	-25.39	-72.24
	2	2002-06-26		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	2001-05-15		0	120	4.19	-47.77
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	9.2	-57.75
HAV04	1	*2000-09-17*		0	100	7.99	-35.75
HAV05	1	1997-02-18		0	100	6.83	-34.48
HAV06	1	*2000-09-17*		0	100	12.42	-30.64
HAV08	1	1987-09-05		0	63	7.08	-20.74
HBH01	1	2001-11-17	2002-04-09	43	50.6	-32.86	-36.28
	2	*2001-11-17*	*2002-04-09*	*0*	*42*	*4.71*	*-13.39*
	1	*2002-04-09*	*2002-06-25*	*0*	*50.6*	*4.71*	*-17.16*
	1	2002-06-25		43	50.6	-32.86	-36.28
	2	2002-06-25		0	42	4.71	*-13.39*

Borehole	Section no	Section installed from	to	Borehole length from (m)	to (m)	Elevation of section at top (masl)	at middle (masl)
HBH02	1	2001-11-15	2002-04-09	25	32.4	-14	-16.82
	2	*2001-11-15*	*2002-04-09*	*0*	*24*	*4.68*	*-4.21*
	1	*2002-04-09*	*2002-06-26*	*0*	*32.4*	*4.68*	*-7.34*
	1	*2002-06-26*	*2002-09-10*	*?*	*32.4*		
	2	*2002-06-26*	*2002-09-10*	*0*	*?*	*4.68*	
	1	*2002-09-10*	*2002-10-23*	*0*	*32.4*	*4.68*	*-7.34*
	1	2002-10-23		25	32.4	-14	16.82
	2	2002-10-23		0	24	4.68	-4.21
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	8.9	-34.67
HLX02	1	*2000-09-17*		0	132	9.04	-48.5
HLX03	1	*2000-09-17*		0	100	10.45	-35.02
HLX04	1	1997-01-29		0	125	10.36	-47.98
HLX05	1	1997-01-29		0	100	15.71	-28.47
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
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
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	14.1	-357.85
KAV02	1	*2000-09-17*		0	97	7.82	-40.69
KAV03	1	*2000-09-17*		0	248.4	8.74	-115.45
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	-837.67	-948.51
	2	1992-03-02		695	855	-676.89	-756.78
	3	1992-03-02		272	694	-254.56	-465.19
	4	1992-03-02		141	271	-123.85	-188.7
	5	1992-03-02		0	140	16.77	-53.02

Note - Data not relevant for 2002 is to be found in earlier annual reports.

Italics=This information is not found in the Sicada database or the information is questioned.

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 was laboratory-determined. The electrical conductivity of the density-determined samples range from 60 to 3400 mS/m. From these measurements a first degree equation is set up, by means of the least square method (by Ann-Chatrin Nilsson, KTH, 1990), which gives the density from the electrical conductivity (see note in Table 4-4). This equation is then used to calculate the density of any sample. The deviation from the straight line for a single value is at most 1.5 kg/m3, but normally less then 0.5 kg/m3.

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

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

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

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

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

Borehole	Sec.	Valid from	Electrical conduct. (mS/m)	Density (kg/m^3)
KAS03	1	1997-05-30	1805	1006
	2	2001-09-27	1700	1005
	2	2002-09-18	1564	1005
	3	1997-06-18	1790	1006
	4	1996-05-22	352	999
	5	2001-09-25	850	1001
	5	2002-09-27	830	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	2001-09-26	870	1001
	4	2002-09-17	930	1002
	5	1990-04-07	1600	1005
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

Density (kg/m^3) = 997.3 + 0.00467 × Electrical conductivity (mS/m).
Note - Data not relevant for 2002 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 two hours.

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 groundwater surface in borehole section tubes
- Borehole deviation measurements
- Air pressure measurements (only sections with absolute pressure transducers)

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

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

The magnitude of the error in the groundwater level data is to a large degree varying with time, depending mainly on two factors, the frequency of manual levellings and the influence of activities in the boreholes. Since 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, in these boreholes, the manual levellings were more difficult to carry out. Consequently, the error due to manual levellings may be significantly larger from the end of October 1992.

Based on the errors above, a rough estimate of the total error in groundwater level under normal conditions has been estimated to ±0.2 m for ground water levels above approximately 50 m from ground surface. Below 50 m from ground surface the error was estimated to ±0.5 m.

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

- Leakage in the couplings connecting the hydraulic measurement system or in the system used to inflate the rubber packers.
- Insufficient communication between a section and the pressure transducer, due to clogging in the plastic tube.
- Failing pressure transducers.

4.3 Electrical conductivity in surface boreholes

4.3.1 Measurement equipment

To start with, electrical conductivity was measured in two sections 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 2002, electrical conductivity was measured only in section 2 in KAS09 until May when also this last sensor stopped working. 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 absolute values on 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 bottle (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.

Since beginning of 2001, 14 boreholes in the inner part of the Prototype Repository are equipped with bentonite packers. The sealing between the borehole sections are achieved through wetting the bentonite filled rubber packers, causing the bentonite to swell.

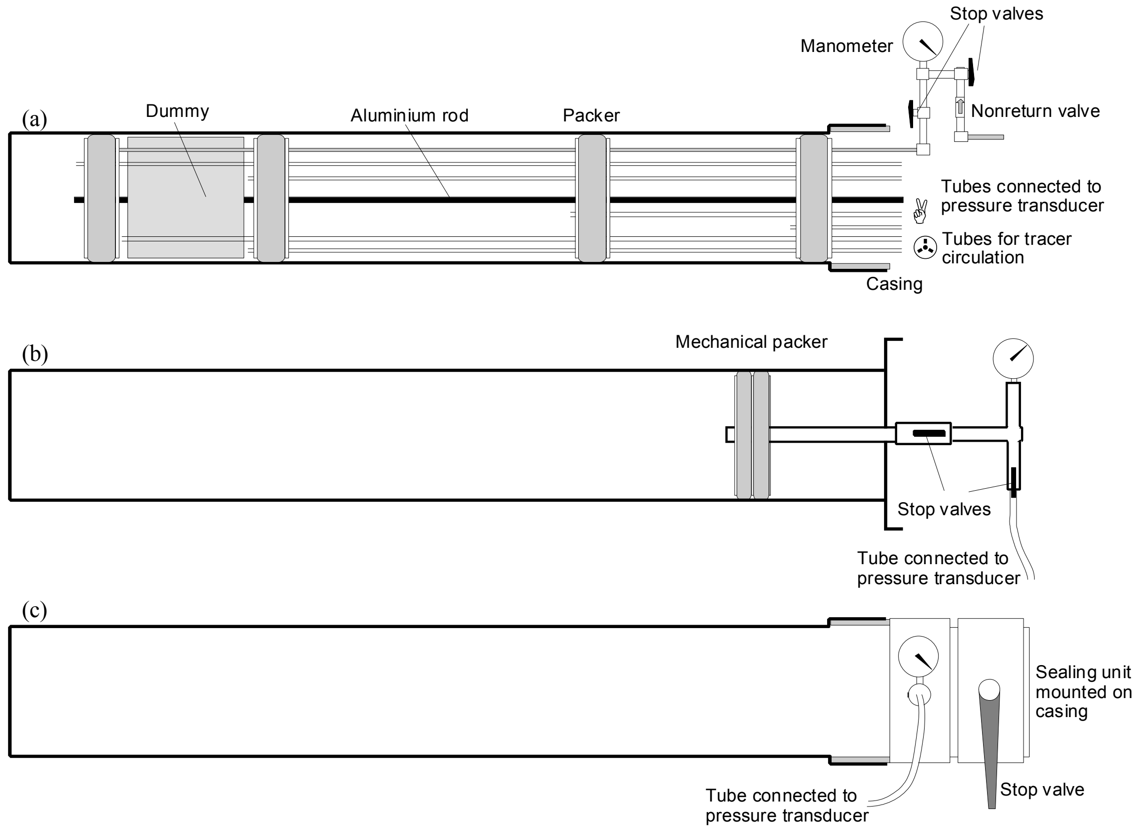

Figure 4-5 Instrumentation in tunnel boreholes with hydraulic packers (a), mechanical packer (b) and with a sealing mounted on casing (c).

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 deionised 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.

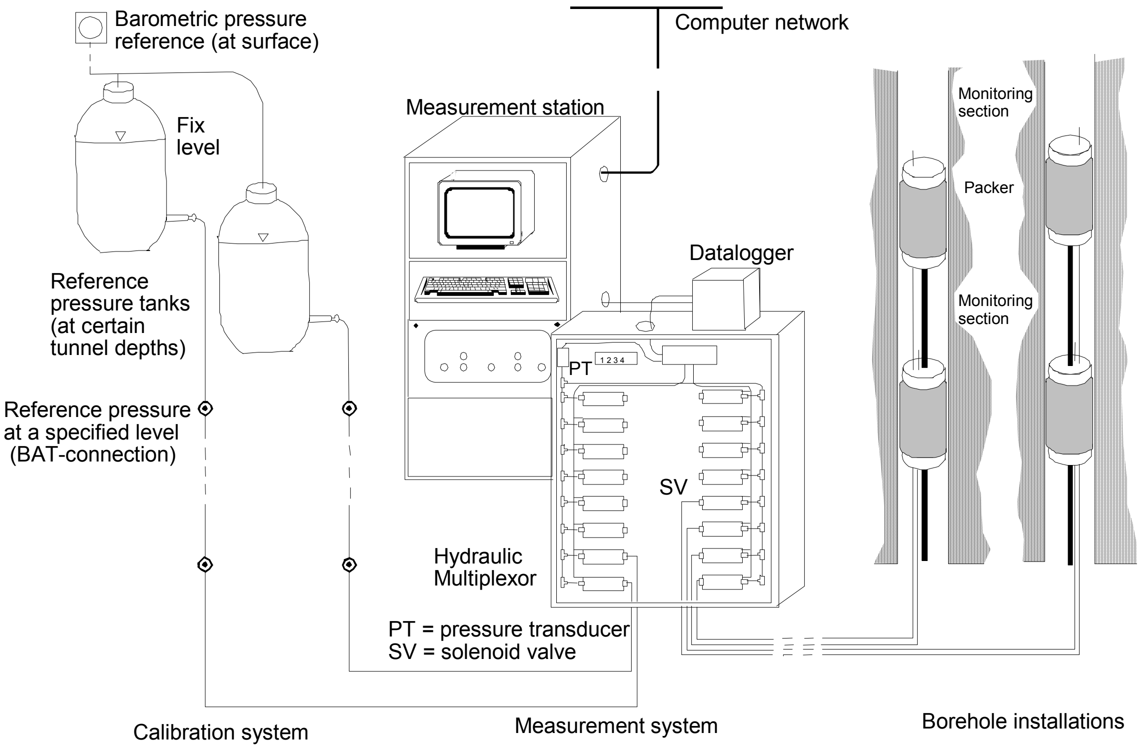

Figure 4-6 Equipment installations for groundwater pressure measurements with a hydraulic multiplexer.

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	Se tion 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*		*0*	*15*	*-416.70*	*-415.79*	-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		149.5	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		201.5	288.1	-342.47	-353.24	-289.19
	2	1994-04-15		143.0	200.5	-327.48	-334.87	-289.19
	3	1994-04-15		80.5	142.0	-311.17	-319.19	-289.19
	4	1994-04-15		40.0	79.5	-300.49	-305.70	-289.19
KA2511A	1	1999-03-16		239.0	293	-467.14	-481.94	-335.20
	2	1999-03-16		171.0	238.0	-429.93	-448.25	-335.20
	3	1999-03-16		139.0	170.0	-412.40	-420.90	-335.20
	4	1999-03-16		111.0	138.0	-397.01	-404.44	-335.20
	5	1999-03-16		103.0	110.0	-392.62	-394.54	-335.20
	6	1999-03-16		96.0	102.0	-388.77	-390.42	-335.20
	7	1999-03-16		65.0	95.0	-371.67	-379.95	-335.20
	8	1999-03-16		6.0	64.0	-339.17	-355.13	-335.43
KA2563A	1	1999-03-15		242.0	246.0	-501.36	-502.65	-335.43
	2	1999-03-15		236.0	241.0	-497.48	-499.10	-335.43
	3	1999-03-15		206.0	208.0	-478.00	-478.65	-335.43
	4	1999-03-15		187.0	190.0	-465.58	-466.56	-335.43
	5	1999-03-15		146.0	186.0	-438.64	-451.81	-335.43
KA2598A	*1*	*1999-05-12*		*0*	*300.77*	*-342.39*	*-421.96*	-334.69
KA2858A	2	1995-02-23		39.77	40.77	-382.34	-382.37	-399.00
KA2862A	1	1996-09-12	2002-03-22	6.82	6.92	-380.50	-380.51	-399.00
	1	2002-03-22		0	15.98	-379.54	-380.66	-399.00

Borehole	Se tion no	Section installed from	To	Borehole length from (m)	to (m)	Elevation of SecTop (masl)	SecMid (masl)	Transducer (masl)
KA3005A	2	1995-12-07		46.78	50.03	-403.52	-403.64	-399.67
	3	1995-12-07		44.78	45.78	-403.37	-403.41	-399.67
	4	1995-12-07		39.03	43.78	-402.94	-403.12	-399.67
	5	1995-12-07		6.53	38.03	-400.38	-401.64	-399.67
KA3010A	2	1995-02-23		8.56	15.06	-400.58	-400.86	-399.67
KA3067A	1	1995-02-28		34.55	40.05	-411.50	-411.74	-413.14
	2	1995-02-28		30.55	33.55	-411.16	-411.29	-413.14
	3	1995-02-28		28.05	29.55	-410.95	-411.01	-413.14
	4	1995-02-28		6.55	27.05	-409.14	-410.00	-413.14
KA3105A	1	1995-03-01		53.01	68.95	-418.09	-418.81	-413.14
	2	1995-03-01		25.51	52.01	-415.78	-416.87	-413.14
	3	1995-03-01		22.15	24.51	-415.54	-415.62	-413.14
	4	1995-03-01		17.01	19.51	-415.09	-415.19	-413.14
	5	1995-03-01		6.51	16.01	-414.21	-414.61	-413.14
KA3110A	1	1995-02-23		20.05	*28.63*	-415.61	*-416.02*	-413.14
	2	1995-02-23		6.55	19.05	-414.32	-414.91	-413.14
KA3385A	1	1995-03-02		32.05	34.18	-448.74	-448.83	-416.42
	2	1995-03-02		7.05	31.05	-446.61	-447.62	-416.42
KA3510A	1	2001-05-08		125	150.06	-511.24	-517.48	-447.96
	2	2001-05-08		110	124	-503.77	-507.26	-447.96
	3	2001-05-08		75	109	-486.30	-494.79	-447.96
	4	2001-05-08		51	74	-474.28	-480.04	-447.54
	5	2001-05-08		4.5	50	-450.96	-462.38	-447.54
KA3563A01	1	2001-04-02		0.63	2.06	-447.15	-447.24	-445.49
KA3563D01	1	2001-04-02		0.63	2.01	-446.13	-446.10	-445.49
KA3563G	1	2001-03-27		15.0	30.0	-463.46	-470.85	-445.93
	2	2001-03-27		10.0	13.0	-458.54	-460.02	-445.72
	3	2001-03-27		4.0	8.0	-452.63	-454.60	-445.94
	4	2001-03-27		1.5	3.0	-450.17	-450.91	-445.72
KA3563I	1	2001-04-03		0.63	2.15	-443.02	-442.30	-455.70
KA3566C01	1	2001-04-02		0.63	2.10	-445.52	-445.48	-445.92
KA3566G01	1	2001-03-20		23.5	30.1	-465.14	-467.47	-447.00
	2	2001-03-20		20.0	21.5	-462.68	-463.20	-446.78
	3	2001-03-20		12.0	18.0	-457.03	-459.15	-446.57
	4	2001-03-20		7.3	10.0	-453.72	-454.67	-446.36
	5	2001-03-20		1.5	6.3	-449.62	-451.32	-446.14
KA3566G02	1	2001-03-20		19.0	30.01	-461.72	-465.53	-446.56
	2	2001-03-20		16.0	18.0	-459.64	-460.34	-446.35
	3	2001-03-20		12.0	14.0	-456.87	-457.57	-446.14
	4	2001-03-20		8.0	11.0	-454.11	-455.14	-445.93
	5	2001-03-20		1.5	6.0	-449.61	-451.16	-445.71
KA3568D01	1	2001-04-02		0.63	2.3	-445.86	-445.89	-445.49
KA3572G01	1	2001-03-21		7.3	12.03	-455.81	-458.18	-446.99
	2	2001-03-21		2.7	5.3	-451.21	-452.51	-446.78
KA3573A	1	2001-03-29		26.0	40.07	-447.03	-447.29	-446.35
	2	2001-03-29		21.0	24.0	-446.84	-446.90	-446.14
	3	2001-03-29		14.5	19.0	-446.60	-446.68	-445.93
	4	2001-03-29		10.5	12.5	-446.45	-446.49	-445.71
	5	2001-03-29		3.4	8.5	-446.19	-446.28	-445.50

Borehole	Se tion	Section installed		Borehole length		Elevation of		
	no	from	To	from	to	SecTop	SecMid	Transducer
				(m)	(m)	(masl)	(masl)	(masl)
KA3573C01	1	2001-04-02		0.63	2.05	-444.76	-444.36	-445.71
KA3574D01	1	2001-04-02		0.63	2.05	-444.98	-444.83	-445.92
KA3574G01	1	2001-03-07		8.0	*12.00*	-456.33	*-458.33*	-446.99
	2	2001-03-07		5.1	7.0	-453.43	-454.38	-446.78
	3	2001-03-07		1.8	4.1	-450.13	-451.28	-446.56
KA3576G01	1	2001-03-07		*7.87*	*12.01*	*-456.14*	*-458.21*	-446.56
	2	2001-03-07		*3.87*	*5.87*	*-452.14*	*-453.14*	-446.34
	3	2001-03-07		*1.37*	*2.87*	*-449.64*	*-450.39*	-446.13
KA3578C01	1	2001-04-03		0.63	2.09	-445.4	-445.47	-445.49
KA3578G01	1	2001-03-08		6.5	12.58	-454.88	-457.92	-446.98
	2	2001-03-08		4.3	5.5	-452.68	-453.28	-446.77
KA3578H01	1	2001-04-03		0.63	1.9	-442.82	-442.28	-445.70
KA3579D01	1	2001-04-03		0.63	2.0	-445.44	-445.45	-445.91
KA3579G	1	2001-03-08		14.7	22.65	-463.07	-467.04	-446.56
	2	2001-03-08		12.5	13.7	-460.87	-461.47	-446.35
	3	2001-03-08		2.5	11.5	-450.87	-455.37	-446.13
KA3584G01	1	2001-03-19		7	12.00	-455.25	-457.75	-446.98
	2	2001-03-19		1.4	5	-449.65	-451.45	-446.77
KA3588C01	1	2001-04-03		0.63	2.04	-445.49	-445.54	-445.49
KA3588D01	1	2001-04-03		0.63	1.9	-445.26	-445.28	-445.70
KA3588I01	1	2001-04-03		0.63	1.96	-442.75	-442.15	-445.91
KA3590G01	1	2001-02-28		16	*30.06*	-459.26	*-464.18*	-446.98
	2	2001-02-28		*7*	*15*	*-452.96*	*-455.76*	-446.78
	3	2001-02-28		*1.5*	*6*	*-449.11*	*-450.69*	-446.56
KA3590G02	1	2001-03-06		*25.65*	*30.05*	*-465.84*	*-467.36*	-446.98
	2	2001-03-06		*15.35*	*23.65*	*-458.71*	*-461.58*	-446.77
	3	2001-03-06		*12.05*	*13.35*	*-456.42*	*-456.87*	-446.55
	4	2001-03-06		*1.65*	*10.05*	*-449.22*	*-452.13*	-446.34
KA3592C01	1	2001-04-03		0.63	2.1	-445.2	-445.15	-445.49
KA3593G	1	2001-02-27		25.2	30.02	-472.88	-475.25	-446.98
	2	2001-02-27		23.5	24.2	-471.21	-471.55	-446.76
	3	2001-02-27		9	22.5	-456.93	-463.58	-446.55
	4	2001-02-27		3	7	-451.03	-452.99	-446.34
KA3597D01	1	2001-04-03		0.63	2.22	-445.06	-445.02	-445.70
KA3597H01	1	2001-04-03		0.63	2.06	-442.64	-442.07	-445.91
KA3600F	1	2001-03-28		43	50.1	-446.86	-446.96	-446.98
	2	2001-03-28		40.5	42	-446.79	-446.81	-446.76
	3	2001-03-28		20	39.5	-446.18	-446.47	-446.55
	4	2001-03-28		3.4	18	-445.69	-445.91	-446.34
KF0051A01	1	1998-06-12	2003-02-13	10.55	11.8	-446.12	-445.81	-452.23
	1	2003-02-13		9.65	11.8	-446.57	-446.03	-452.23
	2	1998-06-12	2003-02-13	8.85	9.55	-446.97	-446.80	-452.23
	2	2003-02-13		7.95	8.65	-447.42	-447.24	-452.23
	3	1998-06-12	2003-02-13	6.26	7.85	-448.26	-447.87	-452.23
	3	2003-02-13		5.36	6.95	-448.71	-448.31	-452.23
	4	1998-06-12	2003-02-13	4.66	5.26	-449.06	-448.91	-452.23
	4	2003-02-13		3.76	4.36	-449.51	-449.36	-452.23

Borehole	**Se tion no**	**Section installed from**	**To**	**Borehole length from (m)**	**to (m)**	**Elevation of SecTop (masl)**	**SecMid (masl)**	**Transducer (masl)**
KG0021A01	1	2001-05-30		42.5	48.8	-432.25	-431.3	-447.00
	2	2001-05-30		37	41.5	-433.92	-433.24	-446.79
	3	2001-05-30		35	36	-434.53	-434.38	-446.58
	4	2001-05-30		19	34	-439.39	-437.11	-446.36
	5	2001-05-30		5.0	18	-443.64	-441.67	-446.15
KG0048A01	1	2001-05-29		49.0	54.69	-432.63	-431.95	-447.00
	2	2001-05-29		34.8	48.0	-436.07	-434.47	-446.79
	3	2001-05-29		32.8	33.8	-436.55	-436.43	-446.58
	4	2001-05-29		13.0	31.8	-441.34	-439.07	-446.36
	5	2001-05-29		5.0	12.0	-443.27	-442.43	-446.15
KI0023B	1	1998-02-12		113.70	200.71	-488.30	-503.59	-448.21
	2	1998-02-12		111.25	112.70	-487.43	-487.69	-447.96
	3	1998-02-12		87.20	110.25	-478.84	-482.97	-447.96
	4	1998-02-12		84.75	86.20	-477.96	-478.22	-447.96
	5	1998-02-12		72.95	83.75	-473.73	-475.67	-447.96
	6	1998-02-12		70.95	71.95	-473.01	-473.19	-447.96
	7	1998-02-12		43.45	69.95	-463.15	-467.89	-447.96
	8	1998-02-12		41.45	42.45	-462.43	-462.61	-447.96
	9	1998-02-12		4.60	40.45	-449.32	-455.68	-447.96
KI0025F	1	1999-07-29		170.5	193.8	-502.58	-506.04	-448.21
	2	1999-07-29		165.5	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		5.0	41.5	-449.95	-456.23	-448.21
KI0025F02	1	1998-10-19		135.15	204.18	-504.43	-517.99	-447.35
	2	1998-10-19		100.25	134.15	-490.40	-497.27	-447.35
	3	1998-10-19		93.35	99.25	-487.58	-488.78	-447.35
	4	1998-10-19		78.25	*92.35*	-481.36	*-484.26*	-447.35
	5	1998-10-19		73.30	77.25	-479.31	-480.13	-447.35
	6	1998-10-19		64.00	*72.30*	-475.45	*-477.18*	-447.35
	7	1998-10-19		56.10	63.00	-472.17	-473.61	-447.35
	8	1998-10-19		51.70	55.10	-470.34	-471.05	-447.35
	9	1998-10-19		38.50	50.70	-464.85	-467.39	-447.35
	10	1998-10-19		3.40	37.50	-450.00	-457.26	-447.35
KI0025F03	1	1999-10-22		101.08	141.72	-497.66	-507.42	-447.96
	2	1999-10-22		93.58	100.08	-494.04	-495.61	-447.96
	3	1999-10-22		89.08	92.58	-491.86	-492.71	-447.96
	4	1999-10-22		85.08	88.08	-489.92	-490.65	-447.96
	5	1999-10-22		66.58	74.08	-480.92	-482.75	-447.96
	6	1999-10-22		59.58	65.58	-477.49	-478.96	-447.96
	7	1999-10-22		55.08	58.58	-475.28	-476.14	-447.96
	8	1999-10-22		51.58	54.08	-473.56	-474.18	-447.96
	9	1999-10-22		3.58	50.58	-449.85	-461.49	-447.96
KR0012B	1	2001-11-08	2002-04-09	4	10.57	-69.13	-69.19	-69.06
	1	*2002-04-09*	*2002-06-13*	*0*	*10.57*	*-69.06*	*-69.15*	-69.06?
	1	*2002-06-13*		*4.0*	*10.57*	*-69.13*	*-69.19*	-69.06?

Borehole	Se tion	Section installed		Borehole length		Elevation of		
	no	from	To	from	to	SecTop	SecMid	Transducer
				(m)	(m)	(masl)	(masl)	(masl)
KR0013B	1	2001-11-08	2002-04-09	6	16.94	-69.16	-69.26	-69.06
	1	*2002-04-09*	*2002-06-13*	*0*	*16.94*	*-69.06*	*-69-21*	-69.06?
	1	*2002-06-13*		*6.0*	*16.94*	*-69.16*	*-69.26*	-69.06?
KR0015B	1	2001-11-08	2002-04-09	18.8	30.31	-69.43	-69.53	-69.06
	1	*2002-04-09*	*2002-06-13*	*0*	*30.31*	*-69.10*	*-69.36*	-69.06?
	1	*2002-06-13*		*18.8*	*30.31*	*-69.43*	*-69.53*	-69.06?
KXTT1	1	2001-11-22		17.00	28.76	-404.27	-408.48	-399.00
	2	2001-11-22		15.00	16.00	-402.84	-403.20	-399.00
	3	2001-11-22		7.50	11.50	-397.48	-398.91	-399.00
	4	2001-11-22		3.00	6.50	-394.26	-395.51	-399.00
KXTT2	1	2001-10-25		16.55	18.30	-404.01	-404.63	-399.00
	2	2001-10-25		14.55	15.55	-402.61	-402.96	-399.00
	3	2001-10-25		11.55	13.55	-400.51	-401.21	-399.00
	4	2001-10-25		7.55	10.55	-397.72	-398.77	-399.00
	5	2001-10-25		3.05	6.55	-394.56	-395.79	-399.00
KXTT3	1	2001-10-25		15.42	17.43	-400.33	-400.93	-399.67
	2	2001-10-25		12.42	14.42	-398.53	-399.13	-399.67
	3	2001-10-25		8.92	11.42	-396.43	-397.18	-399.67
	4	2001-10-25		3.17	7.92	-392.98	-394.41	-399.67
KXTT4	1	2001-11-06		14.92	49.31	-399.95	-410.17	-399.67
	2	2001-11-06		12.92	13.92	-398.77	-399.06	-399.67
	3	2001-11-06		11.92	12.42	-398.17	-398.32	-399.67
	4	2001-11-06		8.42	10.92	-396.1	-396.84	-399.67
	5	2001-11-06		3.17	7.42	-392.98	-394.24	-399.67
KXTT5	1	2001-10-25		10.81	*25.85*	-393.09	-395.05	-399.67
	2	2001-10-25		9.61	9.81	-392.78	-392.81	-399.67
	3	2001-10-25		6.11	8.61	-391.88	-392.20	-399.67
	4	2001-10-25		3.11	5.11	-391.10	-391.36	-399.67
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 2002 is to be found in earlier annual reports.

Italics=This information is not found in the Sicada database or the information is questioned.

4.4.3 Accuracy of pressure measurements

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

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

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

Summarising the above mentioned errors one can estimate the uncertainty in pressure measurements, under normal conditions, to be approximately 10 kPa for measurements with 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 transmitter, connected to the HMS, that is 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.

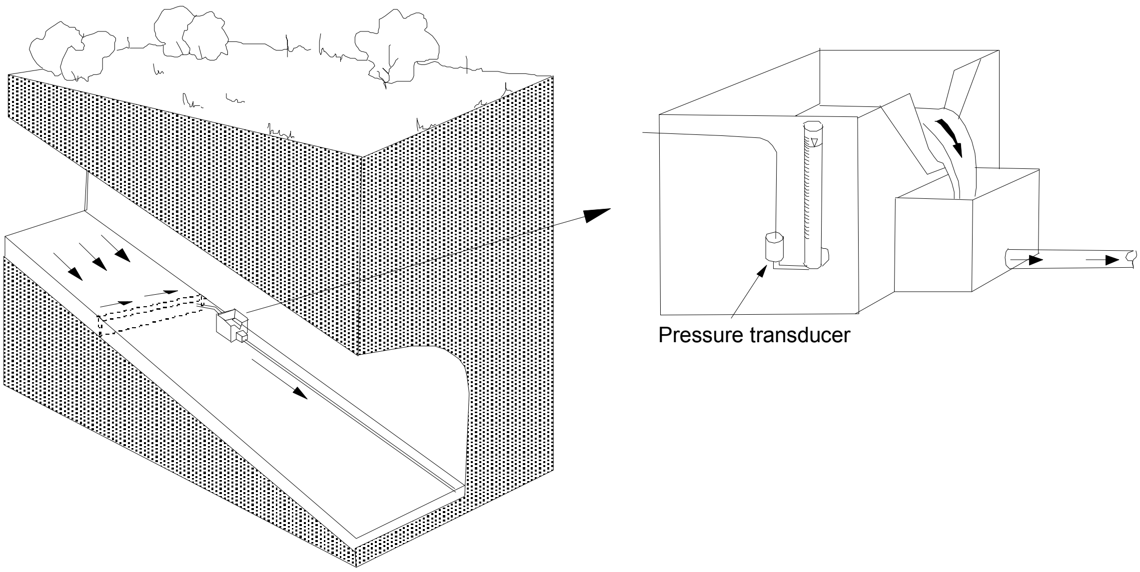

Figure 4-7 Water flow measurements in the tunnel.

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 SBA-270 replaced some of the pressure transducers during the autumn 1998. The remaining pressure transducers have been successively replaced, the last ones during 2002. 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 except for the transmitters in the five gauging boxes at the very bottom of the tunnel system where the measuring range is 0.25 – 0.75 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
MA3384G	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 MA3384G is not included.	
MA3426G	3426	3600
	Water from tunnel I and parts of tunnel J is included	
MF0061G	Water from tunnel F 0-61 m and parts of tunnel J	
MG0004G	Water from tunnel G	

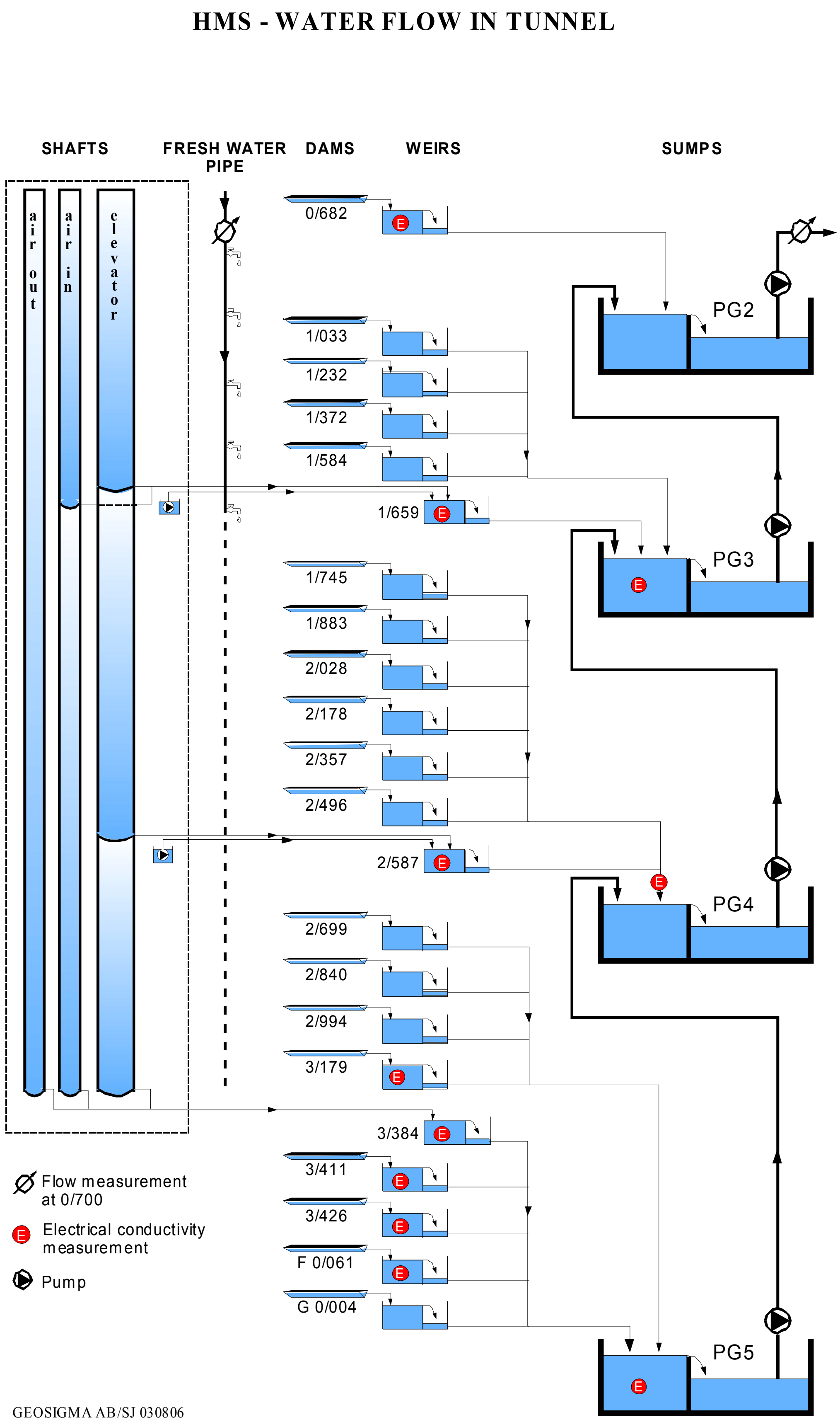

Figure 4-8 Schematic picture showing the tunnel drainage system.

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 10^{th} second but stored only every 30^{th} minute unless the change since latest stored value exceeds a predefined amount (change value). The change value is usually 1 mm, but due to oscillating levels in some gauging boxes it has been necessary to increase this value to avoid sampling too much data.

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

The levels in the gauging boxes are manually read once every month to enable adjustments of the calibration constants for the level indicators. Once a year the discharge equations are checked through field measurements and, if necessary, a new discharge equation is determined (see for example Jönsson et al. 2002).

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. Therefore, due to these uncertainties, the flow meter is calibrated by measuring level changes in the uppermost pumping sump. (There are five sumps in the tunnel and the drainage water is pumped from one sump to the sump upward until it is pumped out of the tunnel).

The flow is measured at a location some 10 metres upwards the top sump. 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. This means that the flow rate is either zero or at the maximum capacity of the pump. The flow meter is calibrated by measuring level changes per time in the sump. Knowing the area of the sump at different levels one can calculate the discharged water.

The flow meter 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 on inaccuracy 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, on the common discharge pipe leading water from the gauging boxes to the pumping sumps, or in a sump.

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	682	1584
	Water from the gauging box MA1659G is included (see below).	
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	1584	2496
	Water from the gauging box MA2587G is included (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
	Water from the gauging box MA3384G is excluded (see above).	
EA3426G	3426	3600
	Water from tunnel I and parts of tunnel J is included.	
EF0061G	Water from tunnel F 0-61 m and parts of tunnel J.	
EPG5	Water below section 2496 m, excluding the water from the gauging box MA2587G, including the water from the gauging box MA3384G (see above).	

4.7.1 Methodology

A value is measured and stored once every hour at the HMS. 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 From the annual calibrations the uncertainty can be estimated to be approximately ±5 % of measured values. This includes all types of errors, for example coatings on the sensor, drift in calibration constants, error in the electrical conductivity of the buffer solutions etc.

4.8 Earth tide

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

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

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

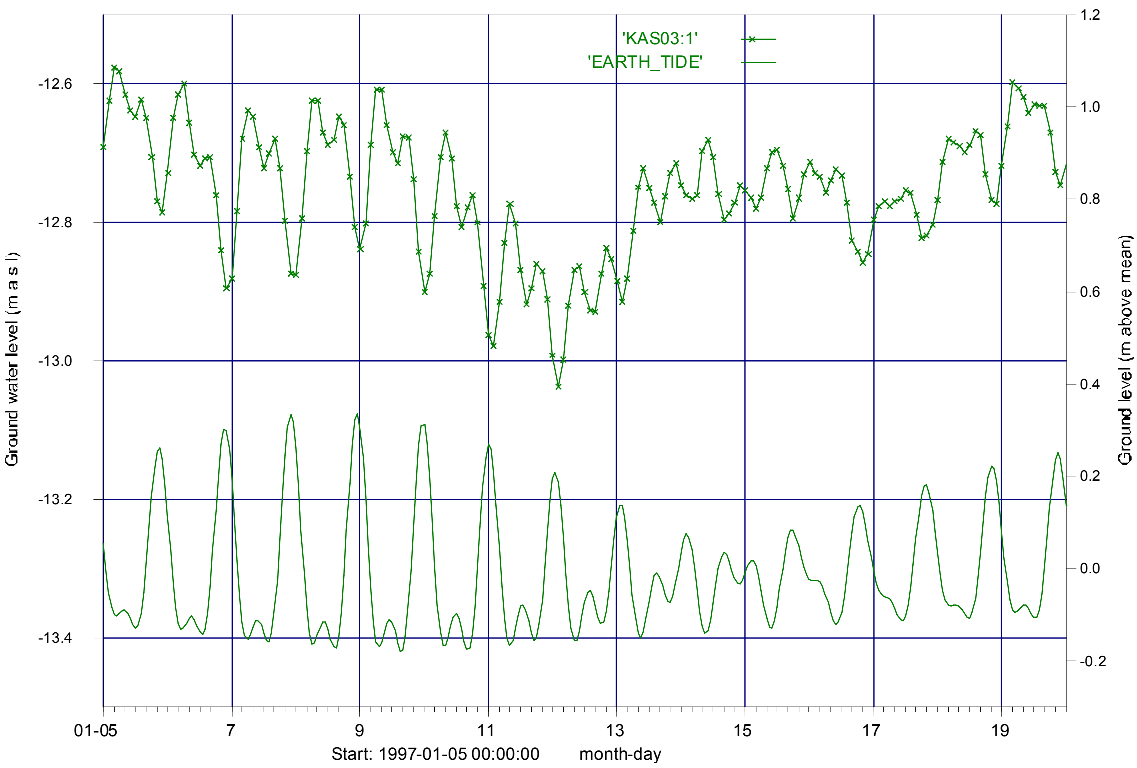

Figure 4-9 Earth tide (bottom curve, right axis) and groundwater level in KAS03:1 (top curve, left axis) during January 1997.

4.9 Level data from the Baltic Sea

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

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

For shorter periods, during quickly changing weather conditions, the difference in sea level between Oskarshamn and the Äspö area can be a few 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 representativity 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 evapotranspiration 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 evapotranspiration is calculated with data from Gladhammar but with cloudiness from Målilla some 50 km west from the Simpevarp area. Since the cloudiness at Målilla is greater than at the near coastal station in Gladhammar this will result in lower calculated potential evapotranspiration.

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

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

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

5 Summary of activities influencing groundwater levels, pressure and flow

5.1 General

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

During the spring of 1991, the tunnel excavation began to have a visible effect on the groundwater level in many surface boreholes, especially on Äspö and Bockholmen. Later on most boreholes, except those on Laxemar, were influenced by the tunnel activities. From late 1991, the disturbances from the tunnel had a dominating influence on the groundwater levels in the area. One single activity affecting the groundwater levels in many boreholes on Äspö was the drilling of the first of two 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 2002 were relatively small (within some metre in most boreholes), with both increasing and decreasing levels. In the tunnel, the pressure in most borehole sections decreased about 30 - 120 kPaduring 2002.

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 2002. Almost 2500 entries during 2002 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 activity.

5.2 Tunnel excavation and permanent reinforcement

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

Table 5-1 Tunnel excavation and permanent reinforcements

Start	Stop	Idcode	Secup (m)	Seclow (m)	Activity
2002-03-05	2002-03-05	NASA3419B	3419	3419	Bolting
2002-03-11	2002-03-11	TASA	2930	2940	Bolting
2002-03-12	2002-03-12	TASA	2920	2930	Bolting
2002-03-13	2002-03-13	TASA	2910	2920	Bolting
2002-03-14	2002-03-14	TASA	2910	2940	Additional scaling
2002-03-18	2002-03-18	TASA	2930	2940	Bolting
2002-03-19	2002-03-19	TASA	2920	2930	Bolting
2002-03-20	2002-03-20	TASA	2910	2920	Bolting
2002-03-21	2002-03-21	TASA	2890	2910	Bolting
2002-03-26	2002-03-26	TASA	2900	2920	Additional scaling
2002-04-03	2002-04-03	TASA	2900	2920	Additional scaling
2002-04-08	2002-04-08	TASA	2880	2900	Additional scaling
2002-04-09	2002-04-09	TASA	2840	2880	Additional scaling
2002-04-10	2002-04-10	TASA	2840	2870	Additional scaling
2002-04-15	2002-04-15	TASA	2800	2840	Additional scaling
2002-04-16	2002-04-16	TASA	2700	2700	Additional scaling
2002-04-17	2002-04-17	TASA	2720	2800	Additional scaling
2002-04-18	2002-04-18	TASA	2700	2800	Additional scaling
2002-04-22	2002-04-22	TASA	2790	2810	Additional scaling
2002-04-29	2002-04-29	TASA	2760	2790	Additional scaling
2002-05-14	2002-05-14	TASA	2645	2670	Additional scaling
2002-05-15	2002-05-15	TASA	2635	2645	Additional scaling
2002-05-16	2002-05-16	TASA	2600	2635	Additional scaling
2002-05-23	2002-05-23	TASA	2650	2670	Additional scaling
2002-05-29	2002-05-29	TASA	2540	2560	Additional scaling
2002-06-10	2002-06-10	TASA	2490	2540	Additional scaling
2002-06-12	2002-06-12	TASA	2930	2940	Additional scaling
2002-06-17	2002-06-17	TASA	2995	2995	Additional scaling
2002-06-25	2002-06-25	NASA2514A	2514	2514	Additional scaling
2002-06-26	2002-06-26	NASA2514A	2514	2514	Bolting
2002-07-08	2002-07-08	TASA	2510	2510	Additional scaling
2002-07-10	2002-07-10	TASA	2490	2510	Additional scaling
2002-07-22	2002-07-22	TASA	2490	2510	Additional scaling
2002-07-23	2002-07-23	TASA	2480	2490	Additional scaling
2002-07-24	2002-07-24	TASA	2470	2480	Additional scaling
2002-07-25	2002-07-25	TASA	2470	2480	Additional scaling
2002-07-29	2002-07-29	NASA1504A			Additional scaling
2002-07-30	2002-07-30	NASA1504A			Additional scaling
2002-07-31	2002-07-31	TASA	1504	1510	Additional scaling
2002-07-31	2002-07-31	NASA1504A	1504	1510	Additional scaling
2002-08-01	2002-08-01	TASA	1510	1530	Additional scaling
2002-08-06	2002-08-06	TASA	2460	2470	Additional scaling

Start	Stop	Idcode	Secup (m)	Seclow (m)	Activity
2002-08-07	2002-08-07	TASA	2420	2460	Additional scaling
2002-08-08	2002-08-08	TASM			Additional scaling
2002-08-12	2002-08-12	TASM			Additional scaling
2002-08-14	2002-08-14	NASA3384A			Additional scaling
2002-08-15	2002-08-15	TASA	2410	2420	Additional scaling
2002-08-15	2002-08-15	TASF			Additional scaling
2002-08-15	2002-08-15	TASF			Additional scaling
2002-08-19	2002-08-19	TASA	2400	2430	Additional scaling
2002-08-20	2002-08-20	TASA	2400	2420	Additional scaling
2002-08-21	2002-08-21	TASA	2420	2440	Additional scaling
2002-08-22	2002-08-22	TASA	2430	2500	Additional scaling
2002-09-02	2002-09-02	TASA	2240	2460	Additional scaling
2002-09-03	2002-09-03	TASA	2460	2480	Additional scaling
2002-09-04	2002-09-04	TASA	2480	2510	Additional scaling
2002-09-09	2002-09-09	TASA	2510	2530	Additional scaling
2002-09-10	2002-09-10	TASA	2530	2560	Additional scaling
2002-09-11	2002-09-11	TASA	2390	2410	Additional scaling
2002-09-12	2002-09-12	TASA	2370	2390	Additional scaling
2002-09-16	2002-09-16	TASA	2390	2410	Additional scaling
2002-09-17	2002-09-17	TASA	2370	2390	Additional scaling
2002-09-18	2002-09-18	TASA	2340	2370	Additional scaling
2002-09-19	2002-09-19	TASA	2310	2340	Additional scaling
2002-09-23	2002-09-23	TASA	2290	2310	Additional scaling
2002-09-24	2002-09-24	TASA	2270	2290	Additional scaling
2002-09-25	2002-09-25	TASA	2260	2270	Additional scaling
2002-09-30	2002-09-30	TASA	2240	2260	Additional scaling
2002-10-02	2002-10-02	TASA	2220	2240	Additional scaling
2002-10-03	2002-10-03	TASA	2210	2220	Additional scaling
2002-10-07	2002-10-07	TASA	2220	2240	Additional scaling
2002-10-08	2002-10-08	TASA	2210	2220	Additional scaling
2002-10-09	2002-10-09	TASA	2210	2220	Additional scaling
2002-10-15	2002-10-15	TASA	2220	2220	Additional scaling
2002-10-16	2002-10-16	TASA	2220	2240	Addtional scaling
2002-10-17	2002-10-17	TASA	2240	2260	Additional scaling
2002-10-21	2002-10-21	TASA	2260	2275	Additional scaling
2002-10-22	2002-10-22	TASA	2275	2290	Additional scaling
2002-10-23	2002-10-23	TASA	2290	2305	Additional scaling
2002-10-24	2002-10-24	TASA	2305	2320	Additional scaling
2002-10-28	2002-10-28	TASA	2320	2340	Additional scaling
2002-10-29	2002-10-29	TASA	2340	2360	Additional scaling
2002-10-30	2002-10-30	TASA	2360	2380	Additional scaling
2002-10-31	2002-10-31	TASA	450	450	Additional scaling
2002-11-04	2002-11-04	TASA	2175	2200	Additional scaling
2002-11-05	2002-11-05	TASA	2160	2175	Additional scaling
2002-11-06	2002-11-06	TASA	2145	2160	Additional scaling
2002-11-11	2002-11-11	TASA	2130	2145	Additional scaling
2002-11-12	2002-11-12	TASA	2110	2130	Additional scaling
2002-11-13	2002-11-13	TASA	2090	2110	Additional scaling
2002-11-14	2002-11-14	TASA	2080	2090	Additional scaling
2002-11-18	2002-11-18	TASA	2060	2080	Additional scaling
2002-11-21	2002-11-21	TASA	2040	2060	Addtional scaling

Start	Stop	Idcode	Secup (m)	Seclow (m)	Activity
2002-11-25	2002-11-25	TASA	2040	2080	Additional scaling
2002-11-26	2002-11-26	TASA	2040	2070	Additional scaling
2002-11-27	2002-11-27	TASA	2070	2100	Additional scaling
2002-11-28	2002-11-28	TASA	2010	2040	Additional scaling
2002-12-04	2002-12-04	TASA	2100	2120	Additional scaling
2002-12-09	2002-12-09	TASA	2120	2140	Additional scaling
2002-12-16	2002-12-16	TASA			Additional scaling
2002-12-19	2002-12-19	TASA	2140	2160	Additional scaling

5.3 Opening of valves in tunnel boreholes

The main reason for valve openings in boreholes is water sampling for chemical analyses. Usually, before water samples are taken from a tunnel borehole section, a certain amount of water is discharged to assure that the water is representative for that section. Typically, for chemical sampling, a volume corresponding to five section volumes is discharged. When a valve is opened, the flow rate may vary a lot from section to section due to different transmissivities and pressures. Normally this type of valve openings has 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 it 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
2002-01-04	2002-01-04	HD0025A:
2002-01-16	2002-01-16	KXTT4:3
2002-01-16	2002-01-17	KR0012B:
2002-01-17	2002-01-17	KXTT1:2
2002-01-17	2002-01-17	KXTT1:3
2002-01-17	2002-01-17	KXTT1:3
2002-01-17	2002-01-17	KXTT2:2
2002-01-17	2002-01-17	KXTT2:3
2002-01-17	2002-01-17	KXTT3:2
2002-01-17	2002-01-17	KXTT3:3
2002-01-17	2002-01-17	KXTT4:2
2002-01-17	2002-01-17	KXTT4:4
2002-01-17	2002-01-17	KXTT5:2
2002-01-17	2002-01-18	KR0015B:
2002-01-18	2002-01-18	KA3005A:2
2002-01-18	2002-01-18	KA3005A:3
2002-01-18	2002-01-18	KA3010A:2
2002-01-21	2002-01-21	HD0025A:
2002-01-21	2002-01-22	KA3005A:3
2002-01-21	2002-01-22	KXTT4:2
2002-01-21	2002-01-22	KXTT4:4
2002-01-21	2002-01-22	KXTT5:2
2002-01-22	2002-01-22	HD0025A:
2002-01-22	2002-01-23	KA3005A:2
2002-01-22	2002-01-23	KXTT2:2
2002-01-22	2002-01-23	KXTT3:2
2002-01-22	2002-01-23	KXTT3:3
2002-01-23	2002-01-24	KA3005A:3
2002-01-23	2002-01-24	KXTT4:2
2002-01-23	2002-01-24	KXTT4:4
2002-01-23	2002-01-24	KXTT5:2
2002-01-24	2002-01-28	KA3010A:2
2002-01-24	2002-01-28	KXTT1:2
2002-01-24	2002-01-28	KXTT1:3
2002-01-24	2002-01-28	KXTT2:3
2002-01-28	2002-01-30	KA3005A:2
2002-01-28	2002-01-30	KXTT2:2
2002-01-28	2002-01-30	KXTT3:3

From	To	Borehole:sec
2002-01-28	2002-01-30	KXTT4:3
2002-01-30	2002-01-30	KA1755A:3
2002-01-30	2002-01-31	KA3010A:2
2002-01-30	2002-01-31	KXTT1:2
2002-01-30	2002-01-31	KXTT1:3
2002-01-30	2002-01-31	KXTT2:3
2002-01-31	2002-02-04	KA3005A:3
2002-01-31	2002-02-04	KXTT3:2
2002-01-31	2002-02-04	KXTT4:2
2002-01-31	2002-02-04	KXTT5:2
2002-02-01	2002-02-01	HD0025A:
2002-02-04	2002-02-04	HD0025A:
2002-02-11	2002-02-11	HD0025A:
2002-02-18	2002-02-18	HD0025A:
2002-02-25	2002-02-25	HD0025A:
2002-03-01	2002-03-01	HD0025A:
2002-03-05	2002-03-05	HD0025A:
2002-03-25	2002-03-25	HD0025A:
2002-04-02	2002-04-02	HD0025A:
2002-04-03	2002-04-03	KXTT4:2
2002-04-03	2002-04-03	KXTT4:3
2002-04-04	2002-04-04	KXTT4:2
2002-04-11	2002-04-11	HD0025A:
2002-04-17	2002-04-17	HD0025A:
2002-04-26	2002-04-26	HD0025A:
2002-05-07	2002-05-07	HD0025A:
2002-05-10	2002-05-10	HD0025A:
2002-05-13	2002-05-13	KXTT1:3
2002-05-13	2002-05-13	KXTT4:3
2002-05-13	2002-05-13	KXTT4:4
2002-05-14	2002-05-14	HD0025A:
2002-05-15	2002-05-15	HD0025A:
2002-05-15	2002-05-15	HD0025A:
2002-05-15	2002-05-15	HD0025A:
2002-05-17	2002-05-17	HD0025A:
2002-05-17	2002-05-17	HD0025A:
2002-05-18	2002-05-18	HD0025A:
2002-05-19	2002-05-19	HD0025A:
2002-05-20	2002-05-20	HD0025A:
2002-05-21	2002-05-21	HD0025A:
2002-05-22	2002-05-22	HD0025A:
2002-06-05	2002-06-05	HD0025A:
2002-06-14	2002-06-14	HD0025A:
2002-06-18	2002-06-18	HD0025A:
2002-06-28	2002-06-28	HD0025A:
2002-07-05	2002-07-05	HD0025A:
2002-07-15	2002-07-15	HD0025A:
2002-07-15	2002-07-15	HD0025A:
2002-07-22	2002-07-22	HD0025A:
2002-07-29	2002-07-29	HD0025A:
2002-08-08	2002-08-08	KR0012B:

From	To	Borehole:sec
2002-08-16	2002-08-16	HD0025A:
2002-08-26	2002-08-26	HD0025A:
2002-09-11	2002-09-11	HD0025A:
2002-09-18	2002-09-18	KA2862A:
2002-09-18	2002-09-18	KA3110A:1
2002-09-18	2002-09-19	KA2563A:4
2002-09-20	2002-09-23	KA2511A:4
2002-09-23	2002-09-23	KA2162B:1
2002-09-23	2002-09-23	KA2511A:5
2002-09-24	2002-09-24	HD0025A:
2002-09-24	2002-09-24	KA3385A:1
2002-09-24	2002-09-24	KA3573A:1
2002-09-24	2002-09-24	KA3573A:2
2002-09-24	2002-09-25	KA1755A:3
2002-09-24	2002-09-25	KA2050A:1
2002-09-24	2002-09-25	KA3600F:1
2002-09-24	2002-09-25	KA3600F:2
2002-09-24	2002-09-26	KA1061A:1
2002-09-24	2002-09-26	KA1131B:1
2002-09-25	2002-09-26	HA1330B:
2002-09-30	2002-09-30	HD0025A:
2002-10-04	2002-10-04	KR0013B:
2002-10-04	2002-10-04	KR0015B:
2002-10-04	2002-10-08	KR0012B:
2002-10-18	2002-10-18	HD0025A:
2002-10-31	2002-10-31	HD0025A:
2002-11-18	2002-11-18	HD0025A:
2002-11-27	2002-11-27	HD0025A:
2002-12-03	2002-12-03	KI0025F02:1
2002-12-03	2002-12-03	KI0025F02:2
2002-12-03	2002-12-03	KI0025F02:2
2002-12-03	2002-12-03	KI0025F02:3
2002-12-03	2002-12-03	KI0025F02:3
2002-12-03	2002-12-03	KI0025F02:5
2002-12-03	2002-12-03	KI0025F02:5
2002-12-03	2002-12-03	KI0025F02:6
2002-12-03	2002-12-03	KI0025F02:6
2002-12-03	2002-12-03	KI0025F02:7
2002-12-03	2002-12-03	KI0025F02:8
2002-12-03	2002-12-03	KI0025F02:9
2002-12-04	2002-12-04	KI0025F:1
2002-12-04	2002-12-04	KI0025F:2
2002-12-04	2002-12-04	KI0025F:2
2002-12-04	2002-12-04	KI0025F:3
2002-12-04	2002-12-04	KI0025F:4
2002-12-04	2002-12-04	KI0025F:4
2002-12-04	2002-12-04	KI0025F:5
2002-12-04	2002-12-04	KI0025F:6
2002-12-04	2002-12-04	KI0025F03:1
2002-12-04	2002-12-04	KI0025F03:3
2002-12-04	2002-12-04	KI0025F03:4

From	To	Borehole:sec
2002-12-04	2002-12-04	KI0025F03:5
2002-12-04	2002-12-04	KI0025F03:5
2002-12-04	2002-12-04	KI0025F03:6
2002-12-04	2002-12-04	KI0025F03:6
2002-12-04	2002-12-04	KI0025F03:7
2002-12-04	2002-12-04	KI0025F03:7
2002-12-04	2002-12-04	KI0025F03:8
2002-12-04	2002-12-04	KI0025F03:9
2002-12-04	2002-12-05	KI0023B:1
2002-12-05	2002-12-05	KI0023B:2
2002-12-05	2002-12-05	KI0023B:4
2002-12-05	2002-12-05	KI0023B:4
2002-12-05	2002-12-05	KI0023B:5
2002-12-05	2002-12-05	KI0023B:6
2002-12-05	2002-12-05	KI0023B:6
2002-12-05	2002-12-05	KI0023B:7
2002-12-05	2002-12-05	KI0023B:7
2002-12-05	2002-12-05	KI0023B:8
2002-12-05	2002-12-05	KI0023B:9
2002-12-05	2002-12-05	KI0023B:9
2002-12-06	2002-12-06	KA2563A:1
2002-12-06	2002-12-06	KA2563A:3

From	To	Borehole:sec
2002-12-06	2002-12-06	KA2563A:4
2002-12-06	2002-12-09	KA2563A:2
2002-12-06	2002-12-17	KA2563A:5
2002-12-09	2002-12-12	KI0025F:5
2002-12-09	2002-12-13	KI0025F:3
2002-12-10	2002-12-10	KI0023B:5
2002-12-10	2002-12-10	KI0023B:8
2002-12-10	2002-12-11	KI0025F:1
2002-12-10	2002-12-11	KI0025F02:1
2002-12-10	2002-12-11	KI0025F03:2
2002-12-10	2002-12-12	KA3510A:5
2002-12-10	2002-12-12	KI0025F:6
2002-12-10	2002-12-12	KI0025F03:1
2002-12-10	2002-12-12	KI0025F03:9
2002-12-11	2002-12-11	KA3510A:1
2002-12-11	2002-12-11	KA3510A:4
2002-12-11	2002-12-11	KI0025F02:9
2002-12-11	2002-12-11	KI0025F02:10
2002-12-11	2002-12-12	KA3510A:2
2002-12-11	2002-12-12	KA3510A:3
2002-12-16	2002-12-16	HD0025A:
2002-12-20	2002-12-20	HD0025A:

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	2000-11-15	2002-03-01
HAS04	2002-03-04	
HAS06	1987-06-06	1996-01-18
HAS11	1999-04-01	2001-08-18
HAS11		2002-05-29
HAS11	2002-06-26	

Borehole	Expansion	Release
HAS13	2000-02-08	
HAS15		2001-05-15
HAS16	1997-02-05	
HAS17	1999-02-24	
HAS19	1990-06-10	
HAS20	1990-12-12	

Borehole	Expansion	Release
HAV08	1987-07-24	
HBH01	2001-11-17	2001-12-23
HBH01	2002-01-08	2002-02-07
HBH01	2002-02-11	2002-04-09
HBH01	2002-06-26	
HBH02	2001-11-15	2001-12-24
HBH02	2002-01-08	2002-02-07
HBH02	2002-02-11	
HBH04	1991-12-11	2002-02-28
HBH04	2002-02-28	
HMJ01	1991-12-13	
KAS02	1991-08-07	
KAS03	2000-10-09	
KAS08	1989-05-01	
KAS09	2000-10-05	
KAS12	1999-12-15	
KAS16	1992-10-20	
KBH02	1992-05-07	
KLX01	2001-05-16	2001-11-22

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	2002-01-30
KA1751A	2002-01-30	
KA1754A	1994-04-21	2002-01-30
KA1754A	2002-01-30	
KA1755A	1994-05-03	2002-01-25
KA1755A	2002-01-25	2002-01-30
KA1755A	2002-01-30	2003-01-14
KA1755A	2003-01-14	
KA2048B	1994-12-12	2002-01-11
KA2048B	2002-01-11	
KA2050A	2001-12-13	
KA2162B	1999-10-28	
KA2511A	1999-03-17	
KA2563A	1999-03-15	
KA2598A	1998-03-04	
KA2858A	1995-09-27	2002-01-11
KA2858A	2002-01-11	
KA2862A	1997-09-22	
KA3005A	2001-11-07	
KA3010A	2001-12-13	2002-06-10
KA3010A	2002-06-17	2002-06-27
KA3010A	2002-06-29	
KA3067A	2001-12-19	2002-06-10
KA3067A	2002-06-17	2002-06-27
KA3067A	2002-06-29	
KA3105A	2001-12-19	
KA3110A	2001-12-19	
KA3385A	1995-09-25	2002-01-11
KA3385A	2002-01-11	2003-01-13
KA3385A	2003-01-13	
KA3510A	2001-05-09	
KA3563A01	2001-04-02	
KA3563D01	2001-04-02	
KA3563G	1999-08-05	
KA3563I01	2001-04-03	
KA3566C01	2001-04-02	
KA3566G01	1999-02-12	
KA3566G02	1999-02-12	
KA3568D01	2001-04-02	
KA3572G01	1999-08-05	
KA3573A	1999-02-15	2000-12-05
KA3573A	2000-12-05	2000-12-05
KA3573C01	2001-04-02	
KA3574D01	2001-04-02	
KA3574G01	1999-08-05	
KA3576G01	1999-02-11	
KA3578C01	2001-04-03	
KA3578G01	1999-08-05	2000-12-06
KA3578H01	2001-04-03	
KA3579D01	2001-04-03	
KA3579G	1999-08-05	
KA3584G01	1999-02-03	
KA3588C01	2001-04-03	
KA3588D01	2001-04-03	
KA3588I01	2001-04-03	
KA3590G01	1999-08-05	
KA3590G02	1999-08-05	
KA3592C01	2001-04-03	
KA3593G	1999-08-05	
KA3597D01	2001-04-03	
KA3597H01	2001-04-03	
KA3600F	1999-02-15	2000-12-05
KA3600F	2000-12-05	2000-12-05
KF0051A01	1998-06-12	
KG0021A01	2001-05-30	
KG0048A01	2001-05-29	
KI0023B	1998-06-17	
KI0025F	1999-07-29	
KI0025F02	1998-10-23	
KI0025F03	1999-10-22	
KR0012B	2000-03-15	2001-12-27
KR0012B	2002-01-08	2002-04-09
KR0013B		2001-12-27
KR0013B	2002-01-08	2002-04-09

Borehole	Expansion	Release
KR0015B	2000-03-15	2001-12-27
KR0015B	2002-01-08	2002-04-09
KXTT1	2001-11-07	
KXTT2	2001-11-07	

Borehole	Expansion	Release
KXTT3	2001-11-07	
KXTT4	2001-11-06	
KXTT5	1999-12-14	
KXTT5	1999-12-14	

5.5 Drilling

Only tunnel boreholes have been drilled during 2002.

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
2002-02-04	2002-02-04	KA3545G09	1.1	Core drilling
2002-02-05	2002-02-05	KA3551G10	1.1	Core drilling
2002-04-17	2002-04-17	HA3533I01	6.5	Percussion drilling
2002-04-18	2002-04-18	HA3533H01	6.5	Percussion drilling
2002-04-18	2002-04-19	HA3532B02	6.5	Percussion drilling
2002-04-22	2002-04-24	HA3532B01	6.5	Percussion drilling
2002-04-25	2002-04-25	HA3532A01	6.5	Percussion drilling
2002-04-25	2002-04-25	HA3532A02	6.5	Percussion drilling
2002-04-25	2002-04-25	HA3538B02	3	Percussion drilling
2002-04-29	2002-04-29	HA3538B01	2.1	Percussion drilling
2002-04-29	2002-04-29	HA3538A01	2.4	Percussion drilling
2002-05-15	2002-05-21	KF0069A01	70.09	Core drilling
2002-05-28	2002-06-01	KF0066A01	60.11	Core drilling
2002-06-04	2002-06-15	KA3386A01	65.11	Core drilling
2002-11-08	2002-11-26	KA3376B01	80.19	Core drilling
2002-12-09	2002-12-09	KA1598A01	0.46	Core drilling
2002-12-10	2002-12-10	KA1598A03	0.74	Core drilling
2002-12-10	2002-12-10	KA1598A02	0.32	Core drilling
2002-12-11	2002-12-11	HD0086G05	10	Percussion drilling
2002-12-11	2002-12-11	HD0086G04	10	Percussion drilling
2002-12-11	2002-12-11	HD0086G03	10	Percussion drilling
2002-12-11	2002-12-11	HD0086G02	10	Percussion drilling
2002-12-11	2002-12-11	HD0086G06	10	Percussion drilling
2002-12-11	2002-12-12	HD0086G07	10	Percussion drilling
2002-12-12	2002-12-12	HD0086G08	10	Percussion drilling
2002-12-12	2002-12-12	HD0086G09	10	Percussion drilling
2002-12-12	2002-12-12	HD0086G01	10	Percussion drilling

5.6 Tests

A number of different tests are described below. However, this year only a few of the tests have been performed.

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 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).

Slug test is a type of disturbance test**.** This type of slug test is performed by expanding a double packer at certain intervals in the borehole. The pressure in the section between the packers is increased momentary and the recovery is then studied during 5-20 minutes.

Table 5-6 Tests

From	To	Borehole:sec	Borehole length (m) from	to	Activity
2002-01-21	2002-01-22	KXTT5:2	9.61	9.81	Dilution test stressed gradient
2002-01-21	2002-01-22	KXTT4:2	12.92	13.92	Dilution test stressed gradient
2002-01-21	2002-01-22	KXTT4:4	8.42	10.92	Dilution test stressed gradient
2002-01-21	2002-01-22	KA3005A:3	44.78	45.78	Dilution test stressed gradient
2002-01-22	2002-01-23	KXTT3:3	8.92	11.42	Dilution test stressed gradient
2002-01-22	2002-01-23	KXTT3:2	12.42	14.42	Dilution test stressed gradient
2002-01-22	2002-01-23	KXTT2:2	14.55	15.55	Dilution test stressed gradient
2002-01-22	2002-01-23	KA3005A:2	46.78	50.03	Dilution test stressed gradient
2002-01-23	2002-01-24	KXTT4:4	8.42	10.92	Dilution test stressed gradient
2002-01-23	2002-01-24	KXTT4:2	12.92	13.92	Dilution test stressed gradient
2002-01-23	2002-01-24	KXTT5:2	9.61	9.81	Dilution test stressed gradient
2002-01-23	2002-01-24	KA3005A:3	44.78	45.78	Dilution test stressed gradient
2002-01-23	2002-04-05	HBH02:1	25	32.4	Radially converging Test Hole
2002-01-24	2002-01-28	KXTT1:2	15	16	Dilution test stressed gradient
2002-01-24	2002-01-28	KXTT1:3	7.5	11.5	Dilution test stressed gradient
2002-01-24	2002-01-28	KXTT2:3	11.55	13.55	Dilution test stressed gradient
2002-01-24	2002-01-28	KA3010A:2	8.56	15.06	Dilution test stressed gradient
2002-01-28	2002-01-30	KXTT3:3	8.92	11.42	Dilution test stressed gradient
2002-01-28	2002-01-30	KXTT4:3	11.92	12.42	Dilution test stressed gradient
2002-01-28	2002-01-30	KXTT2:2	14.55	15.55	Dilution test stressed gradient
2002-01-28	2002-01-30	KA3005A:2	46.78	50.03	Dilution test stressed gradient
2002-01-30	2002-01-31	KXTT1:2	15	16	Dilution test stressed gradient
2002-01-30	2002-01-31	KXTT2:3	11.55	13.55	Dilution test stressed gradient
2002-01-30	2002-01-31	KXTT1:3	7.5	11.5	Dilution test stressed gradient
2002-01-30	2002-01-31	KA3010A:2	8.56	15.06	Dilution test stressed gradient
2002-01-31	2002-02-04	KXTT3:2	12.42	14.42	Dilution test stressed gradient
2002-01-31	2002-02-04	KXTT4:2	12.92	13.92	Dilution test stressed gradient
2002-01-31	2002-02-04	KXTT5:2	9.61	9.81	Dilution test stressed gradient
2002-01-31	2002-02-04	KA3005A:3	44.78	45.78	Dilution test stressed gradient
2002-02-04	2002-02-05	KA3005A:3	44.78	45.78	Dilution test stressed gradient
2002-02-04	2002-02-05	KXTT5:2	9.61	9.81	Dilution test stressed gradient
2002-02-04	2002-02-05	KXTT4:2	12.92	13.92	Dilution test stressed gradient
2002-02-04	2002-02-05	KXTT4:4	8.42	10.92	Dilution test stressed gradient
2002-02-05	2002-02-06	KXTT3:3	8.92	11.42	Dilution test stressed gradient
2002-02-05	2002-02-06	KXTT2:2	14.55	15.55	Dilution test stressed gradient
2002-02-05	2002-02-06	KXTT4:3	11.92	12.42	Dilution test stressed gradient
2002-02-05	2002-02-06	KA3005A:2	46.78	50.03	Dilution test stressed gradient
2002-02-06	2002-02-06	KXTT4:4	8.42	10.92	Dilution test stressed gradient
2002-02-06	2002-02-06	KXTT5:2	9.61	9.81	Dilution test stressed gradient
2002-02-06	2002-02-06	KXTT4:2	12.92	13.92	Dilution test stressed gradient

From	To	Borehole:sec	Borehole length (m) from	to	Activity
2002-02-06	2002-02-07	KA3005A:3	44.78	45.78	Dilution test stressed gradient
2002-02-06	2002-02-08	KXTT1:3	7.5	11.5	Dilution test stressed gradient
2002-02-06	2002-02-08	KXTT1:2	15	16	Dilution test stressed gradient
2002-02-06	2002-02-08	KXTT2:3	11.55	13.55	Dilution test stressed gradient
2002-02-07	2002-02-08	KA3010A:2	8.56	15.06	Dilution test stressed gradient
2002-02-12	2002-03-08	KXTT4:3	11.92	12.42	Radially converging Test Hole
2002-02-12	2002-03-08	KXTT4:2	12.92	13.92	Radially converging Test Hole
2002-03-12	2002-04-04	KXTT4:2	12.92	13.92	Radially converging Test Hole
2002-03-12	2002-04-03	KXTT4:3	11.92	12.42	Radially converging Test Hole
2002-04-16	2002-04-17	KXTT1:2	15	16	Radially converging Test Hole
2002-04-16	2002-05-14	KXTT4:3	11.92	12.42	Radially converging Test Hole
2002-04-16	2002-05-14	KXTT4:4	8.42	10.92	Radially converging Test Hole
2002-04-17	2002-05-14	KXTT1:3	7.5	11.5	Radially converging Test Hole
2002-05-28	2002-05-28	KA2865A01:	10.1	11.1	Pressure Build Up Test (PBT)
2002-05-28	2002-05-28	KA2865A01:	14	15	Pressure Build Up Test (PBT)
2002-05-29	2002-05-29	KA2865A01:	17	18	Pressure Build Up Test (PBT)
2002-05-29	2002-05-29	KA2865A01:	23	24	Pressure Build Up Test (PBT)
2002-05-29	2002-05-29	KA2865A01:	25	26	Pressure Build Up Test (PBT)
2002-05-29	2002-05-29	KA2865A01:	17	18	Pressure Build Up Test (PBT)
2002-05-30	2002-05-30	KA2865A01:	4	27.7	Pressure Build Up Test (PBT)
2002-05-30	2002-05-30	KA2865A01:	26	27.7	Pressure Build Up Test (PBT)
2002-05-30	2002-05-30	KA2865A01:	27	27.7	Pressure Build Up Test (PBT)
2002-06-28	2002-06-28	HBH01:			Dipole: Test hole
2002-06-28	2002-06-28	KR0013B:			Dipole: Test hole
2002-07-03	2002-07-17	HBH01:			Dipole: Test hole
2002-07-03	2002-07-17	KR0013B:			Dipole: Test hole
2002-08-27	2002-09-06	HBH01:			Dipole: Test hole
2002-08-27	2002-09-06	KR0013B:			Dipole: Test hole
2002-09-16	2002-09-26	KR0013B:1			Dipole: Test hole
2002-10-25	2002-10-25	HBH02:1			Dilution test stressed gradient
2002-11-06	2002-11-06	HBH02:1			Tracer Injection
2002-11-19	2002-11-22	HBH02:1			Dilution test stressed gradient
2002-12-03	2002-12-05	HBH02:1			Dilution test stressed gradient
2002-12-17	2002-12-19	HBH02:1			Dilution test stressed gradient

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 is sometimes 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.

Level data and pressure data, respectively, from all sections in each borehole are presented in one single diagram. The symbols used in the diagrams are:

The lowest/innermost section =	Section 1	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
	Section 2	+ + + + + + + + + +
	Section 3	× × × × × × × × ×
	Section 4	□ □ □ □ □ □ □ □ □ □
	Section 5	◇ ◇ ◇ ◇ ◇ ◇ ◇
	Section 6	△ △ △ △ △ △ △ △ △ △
	Section 7	◁ ◁ ◁ ◁ ◁ ◁ ◁ ◁ ◁ ◁ ◁
	Setion 8	▽ ▽ ▽ ▽ ▽ ▽ ▽ ▽ ▽ ▽
	Section 9	▷ ▷ ▷ ▷ ▷ ▷ ▷ ▷ ▷ ▷ ▷
	Section 10	⤫ ⤫ ⤫ ⤫ ⤫ ⤫ ⤫ ⤫
	Section 11	⤪ ⤪ ⤪ ⤪ ⤪ ⤪ ⤪ ⤪
	Section 12	∘∘∘∘∘∘∘∘∘∘∘∘∘∘∘∘∘∘∘∘∘

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 changes, it was not found to be advantageous to separate sections from one borehole into different diagrams. More detailed diagrams during test periods are presented in reports from the different tests.

6.2 Groundwater levels

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 registrations are missing, manually levelled data, if available, are inserted.

In Figures 6-1 to 6-5, an overview over the 5-year period 1998-2002 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.)

6.2.1 Comments on the year 2002

In most surface boreholes, there have been small changes in groundwater levels seen over the year 2002. In the main part of the borehole sections, the change over the year is within some metre. In 32 sections out of 78, the levels have decreased more than 0.5 metre. In 5 sections there has been an increase of more than 0.5 meter. The level changes in the rest of the borehole sections were between –0.5 and 0.5 metre. The largest decrease may be found for the deep sections in boreholes HAS06, HAS17 (both 5 metres) and HAS16 (6 metres).

A typical seasonal variation may be seen in many boreholes, see for example HAS01 or HAS07. From April to the beginning of October the levels are decreasing, followed by a rather quick recovery during October. This seasonal variation during 2002 is pronounced by very low precipitation during August - September followed by high figures for October and November (see figure 6-10). 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 and the upper sections in HAS04 and HAS19). In others, the response is more or less dampened (se for example HAS07), while in some sections it is difficult to se any responses to rain at all.

In the short term, the groundwater level in surface boreholes mainly seems to be influenced by variations in climate factors. Only in the borehole HAS06 (and to some extent also boreholes HAS07, HAS16 and HAS21) a pronounced effect from tunnel activities can be seen. In March, a drawdown due to the opening of the tunnel borehole KA3065A03 occurred. The drawdown in June was caused by the re-instrumentation of borehole KA3065A03 when the packers in some neighbouring tunnel boreholes (KA3010A, KA3065A02, KA3067A and SA3045A) also were deflated. Most certainly though, there are minor responses also in other boreholes.

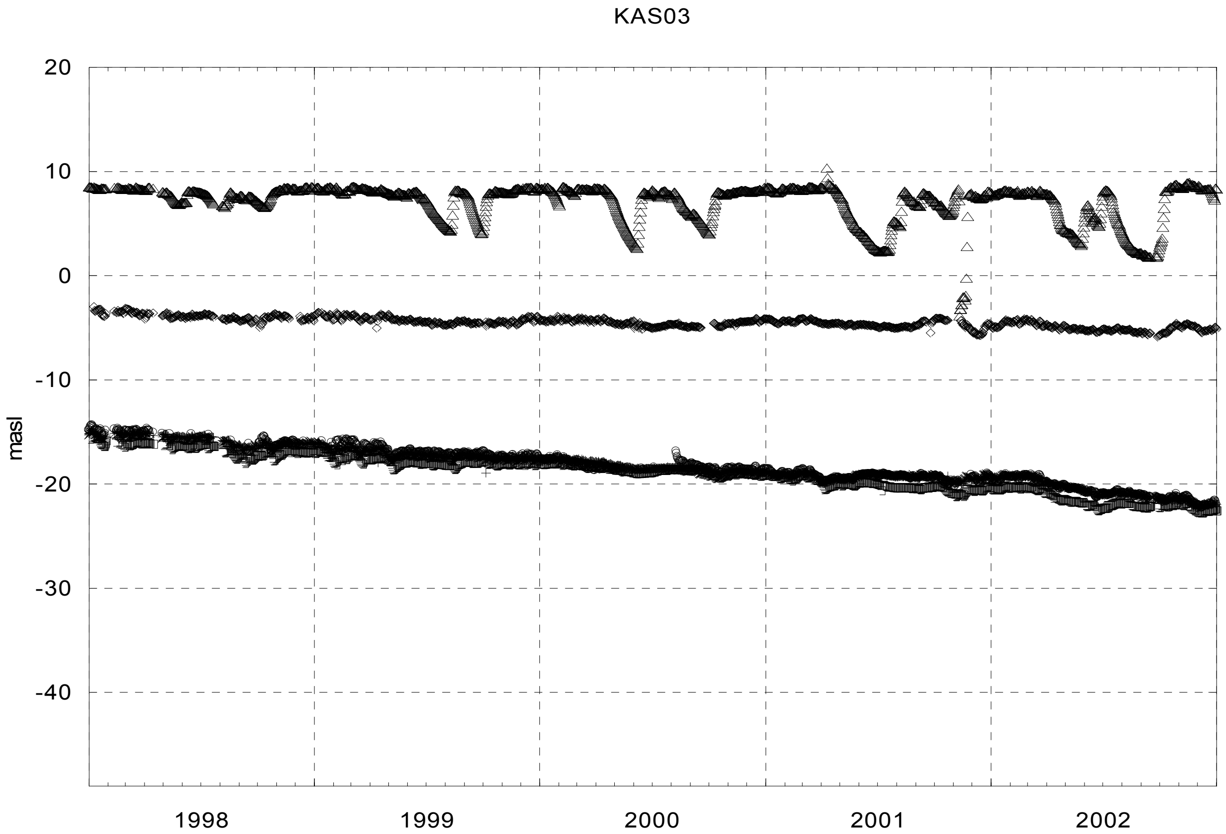

Figure 6-1 Groundwater levels in KAS03 on Äspö, 1998-2002.

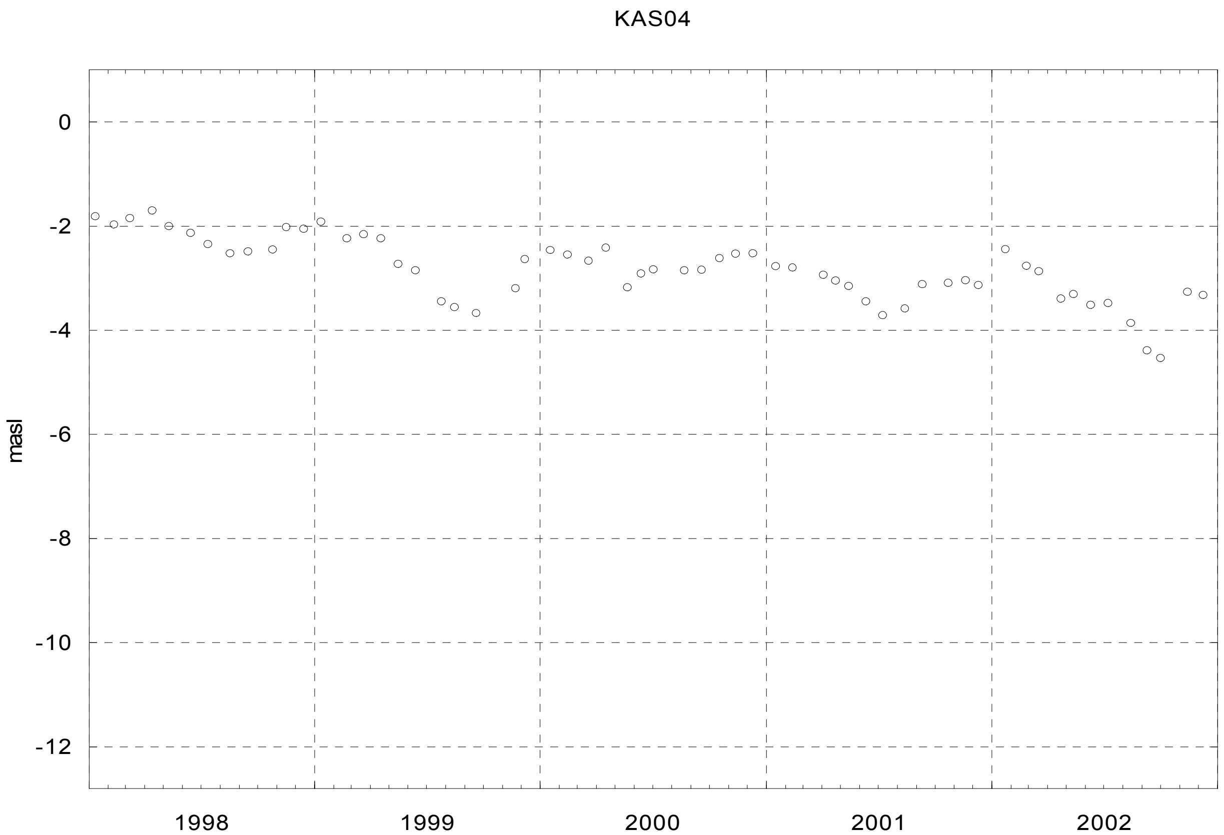

Figure 6-2 Groundwater levels in KAS04 on Äspö, 1998-2002.

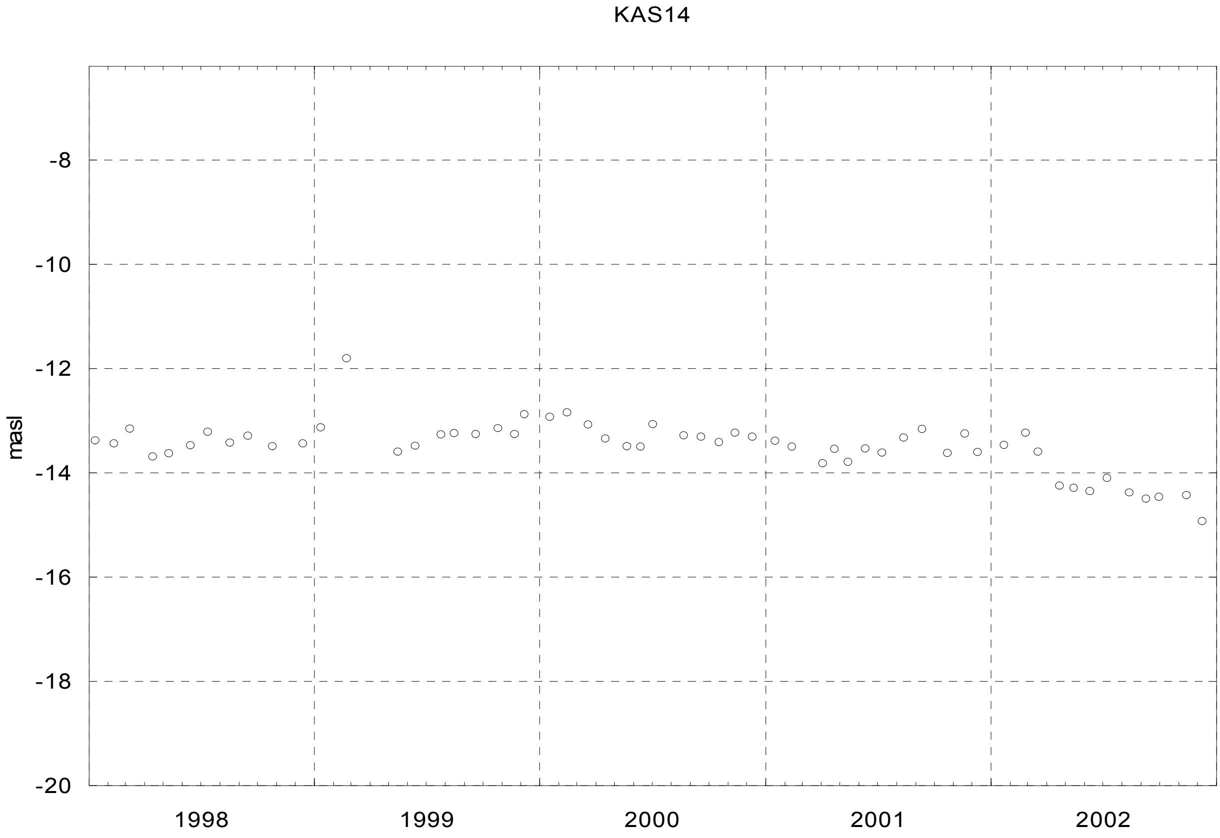

Figure 6-3 Groundwater levels in KAS14 on Äspö, 1998-2002.

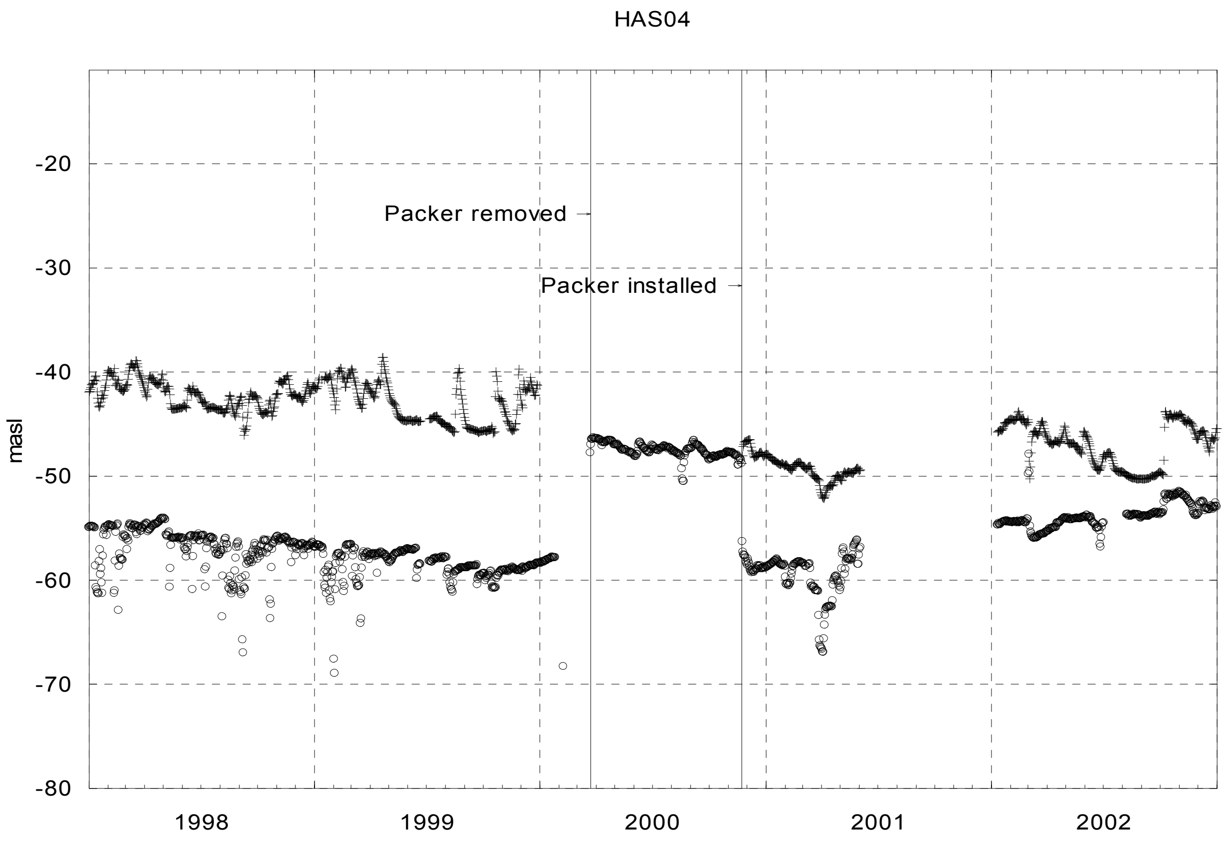

Figure 6-4 Groundwater levels in HAS04 on Äspö, 1998-2002.

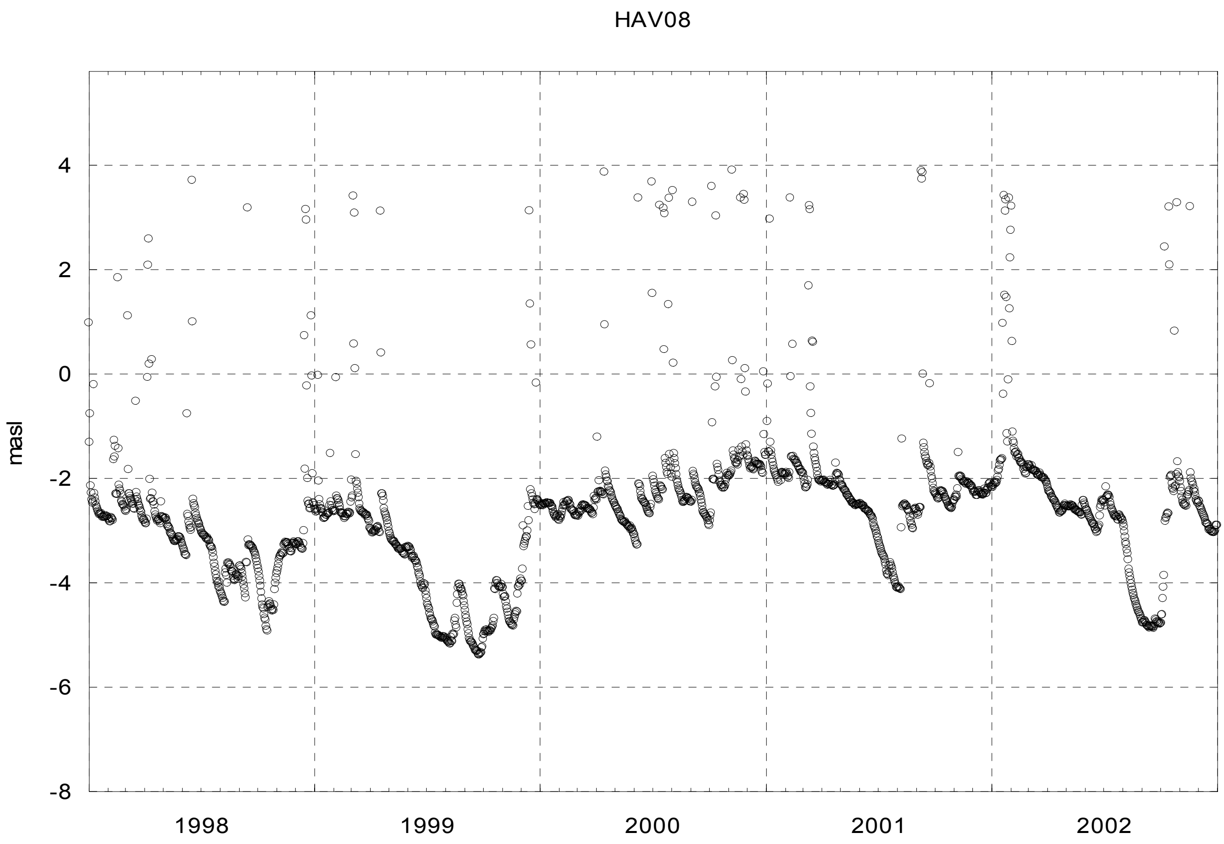

Figure 6-5 Groundwater levels in HAV08 on Ävrö, 1998-2002.

6.2.2 Comments on some of the diagrams

Remarks are given when the registration for some reason has a deviating appearance. When registrations are 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 enable manual levellings the PEM-packers has been removed in some sections. At the end of 2002, PEM-packers were installed in the following sections: KAS03 (1-5), KAS09 (1-4) and KBH02 (3-5).

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 a 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 in an approximate interval from 0 to -18 masl. This means that a small amount of rain may cause a large and quick increase in the groundwater level. The packer was deflated from the end of December and onwards.

HAS15: The packer was removed from the borehole at the end of February.

HAV05: The pressure transducer ceased to work at the end of September.

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

HBH01 and HBH02: Tracer tests were performed in these boreholes during 2002. Packers were removed and re-installed, deflated and inflated several times during the year. The frequent peaks in HBH02 (section 1) occurring from November and onwards are due to tracer injections.

HBH04: After cleaning of tubes and renovation of couplings at the end of February the levels in the two sections were separated.

KAS07: Due to difficulties when performing manual levelling in the borehole no values are available from 2002.

KAS09: The deviating appearance for sections one, two and three depends on very low transmissivities (or poor communication between the PEM standpipe and the section).

6.3 Electrical conductivity of the groundwater

To start with, electrical conductivity was measured in two sections in most of the core-drilled 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 KAS09 during 2002. However, this last sensor also stopped working in May 2002.

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

Groundwater pressures in tunnel borehole sections are presented in Appendix 4.

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 1998-2002 for some of the boreholes is presented. The diagrams are of the same type as the annual diagrams described above.

In the tunnel, the pressure in most borehole sections decreased about 30 - 120 kPa during 2002. The decrease is somewhat greater in boreholes further down in the spiral tunnel. Seen over the last few years, the pressure is steadily decreasing in these boreholes (see the 5-year plot in figure 6-6).

In the prototype repository, the pressure is still increasing in many borehole sections after the re-instrumentation, grouting works and back-filling of the inner section of the repository performed during 2001. Some sections in the Prototype boreholes, the two boreholes in the G-tunnel and the boreholes in the I-tunnel show decreasing pressures of a rather great magnitude (some hundreds kPa). This is partly related to a sudden pressure drop occurring 2002-05-06. No explanation for this pressure drawdown has been found.

6.4.1 Comments on some major disturbances

Some activities during the year causing major disturbances seen in many boreholes in the tunnel were:

From the **end of January to the beginning of February** the packer in borehole KG0021A01 was released which affected many boreholes in the lower part of the tunnel.

From **mid-January to mid-May** tracer tests were performed in the TRUE-1 boreholes (KXTT1-5, KA3005A and KA3010A). After a period of shorter pumping phases in different sections, a longer period of pumping in KXTT3 was started in the beginning of February and the withdrawal rate was then increased two months later and finally stopped in the middle of May.

From the **middle of March until early April** borehole KA3065A03 was open.

In the **beginning of May** a drop in pressure in many borehole sections occurred in the lower part of the tunnel. The reason for this is unknown. A minor drawdown can also be seen in the same boreholes at the **end of June** which can not be explained by the re-instrumentation of KA3065A03.

Atthe **end of May** hydraulic tests and water sampling were performed in KA2865A01.

In **mid-June** a new borehole, KA3386A01, was drilled. Packer installation and other activities were performed in the borehole at the **beginning of July and in August.**

In the **middle and at the end of June** borehole KA3065A03 was re-instrumented. Some neighboring boreholes (KA3010A, KA3065A02, KA3067A, KA3068A and SA3045A) were also opened during this time.

At the **end of September** a packer release in the Prototype repository borehole KA3548A01 (not yet connected to the HMS-system) occurred.

In **September** and in **December** water sampling was performed in many tunnel boreholes.

During **November** a new borehole, KA3376B01, was drilled and packer installation in the borehole was performed in **December**.

During **November-December** some boreholes in the Prototype area (not yet connected to the HMS-system) were instrumented.

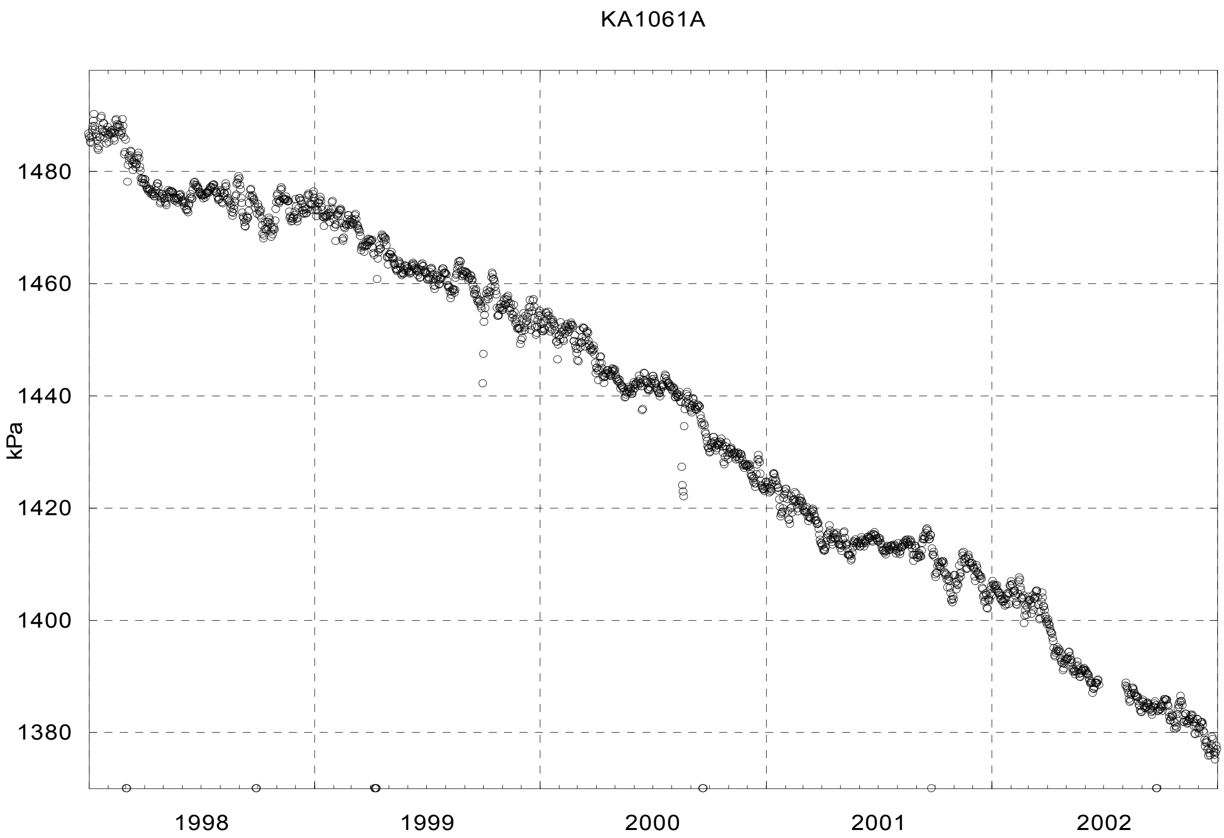

Figure 6-6 Groundwater pressure in tunnel borehole KA1061A, 1998-2002.

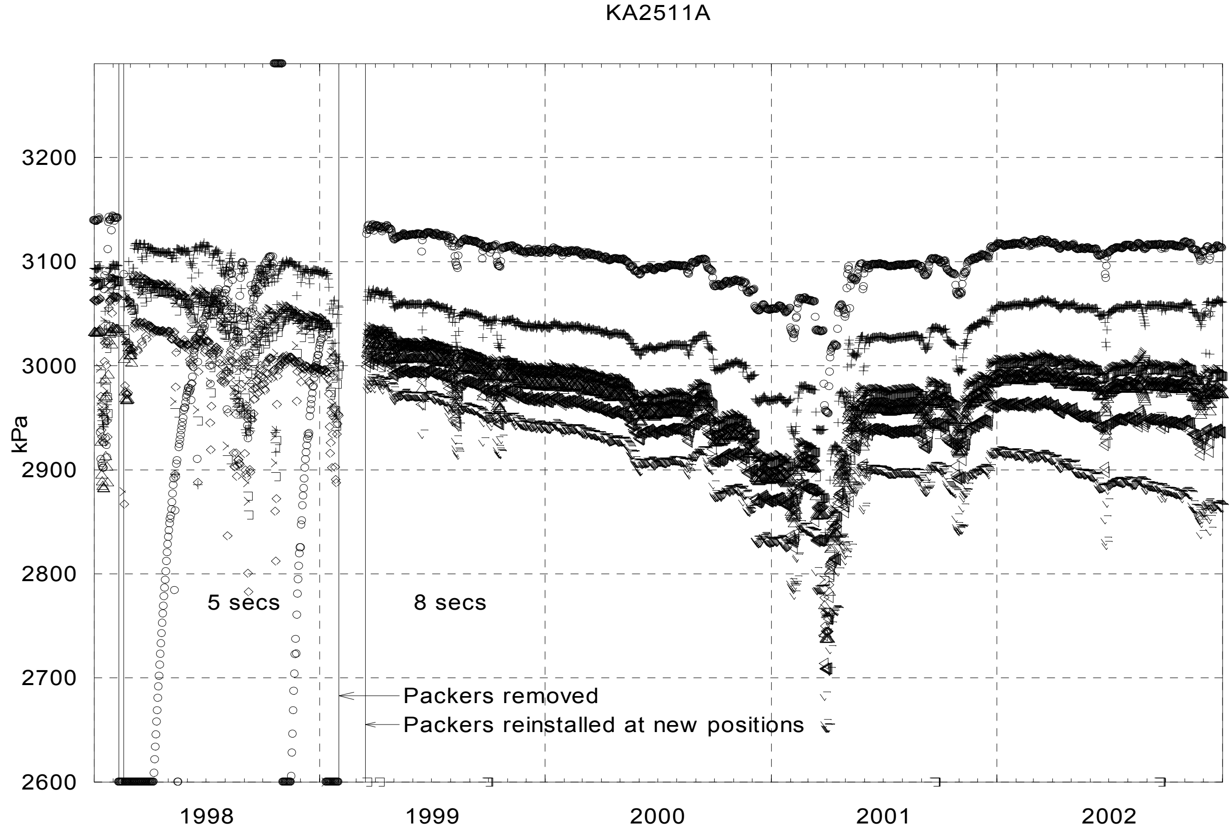

Figure 6-7 Groundwater pressure in tunnel borehole KA2511A, 1998-2002.

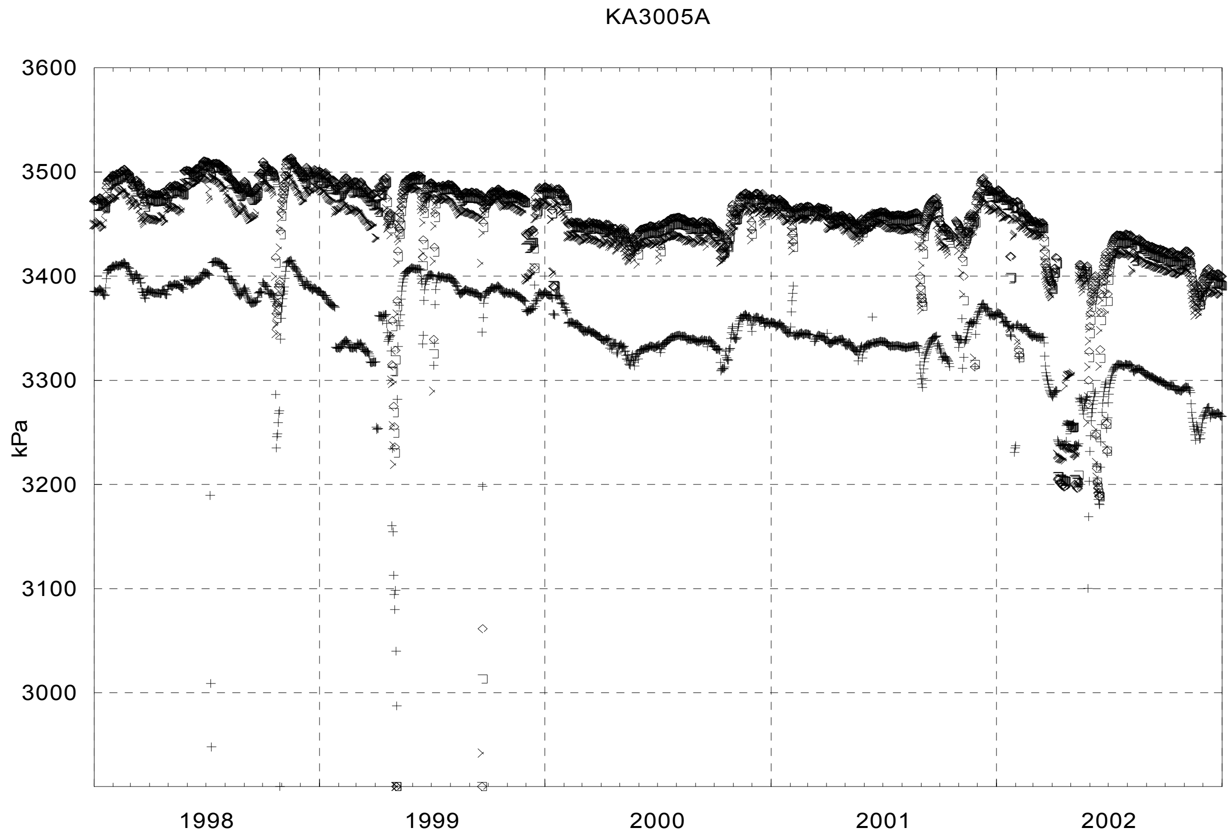

Figure 6-8 Groundwater pressure in tunnel borehole KA3005A, 1998-2002.

6.4.2 Comments on some of the diagrams

The activities affecting many boreholes mentioned in proceeding section 6.4.1 are not further commented on below.

The pressure in some borehole sections in the Prototype repository is very low, almost air pressure, indicating very tight sections and/or poorly degassed tubes. The pressure build-up after the installation in the autumn 2001 or after a disturbance is also very slow in some sections.

HD0025A: This borehole is sometimes used for water supply purposes.

KA1755A: The packers were deflated during some days at the end of January when couplings were changed.

KA2048A and KA2162B: Maintenance of the hydraulic multiplexer caused the pressure disturbances seen during January in some sections in these boreholes.

KA2511A: A leakage in the packer system occurred in August and was repaired at the end of the month.

KA2563A: Section 5 was left open after water sampling at the beginning of December and was closed about ten days later.

KA2598A: This borehole is sometimes used for water supply purposes.

KA3566G02: At the very beginning of January, the pressure in section 4 started to rise and reached a new level some days later. The reason for this behaviour is unknown.

KI0023B: Section 6 has been open and flowing since March 2000 due to tracer tests.

KR0012, KR0013B and KR0015B: The packers in the boreholes were inflated at the beginning of January. Tracer tests were performed during the year with pumping in KR0013B. Water sampling was performed in KR0012B at the beginning of October. Due to malfunctioning pressure transducers, data is missing for longer periods for KR0012B and KR0013B.

KXTT1: A leakage in a tube to section 2 occurred during a couple of days in August.

KXTT5: The packers were deflated from the end of April to the beginning of May.

SA2338A: A tube was damaged during August due to scaling.

6.5 Water flow in tunnel

Water flow in the tunnel, measured at gauging boxes at different tunnel lengths is presented in Appendix 5. The flow is integrated to daily values given as m^3/d.

For periods, the flow at some gauging boxes increases as a result of water added in connection to work carried out in the tunnel.

The flow in all gauging boxes is shown in Figure 6-9 as a mean during October - December 2002. For comparison purposes, data for the corresponding period in 1995, 1996, 1997, 1998, 1999, 2000 and 2001 is also illustrated. Although data is missing in some boxes for certain periods (especially during 1995 and 1996), the diagram gives realistic values since the flow has been fairly constant during the period presented. During 2002 no data was missing for the period.

Figure 6-9 shows that, seen over all years, the mean flow for the comparison period October – December has decreased at most locations. In 2002, however, the mean flow at many of the locations has increased slightly or is nearly the same as for the previous year.

One exception to the long term trend 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 2000, the ditch collecting water to the gauging box MA0682G was partly filled with sprayed concrete during tunnel work. As a result some of the water normally colleted by this ditch flowed over to the next gauging box MA1033G. The concrete was removed in December 2001 and the flow rates returned to normal. This is the reason for the low figures for MA0682G for the years 2000 and 2001. As a consequence, the figures for MA1033G should have been lower for the same years.

The low figure for MA1232G during 2001, accompanied by a high figure for MA1372G, also depends on sprayed concrete in the ditch collecting water to MA1232G. In this case the concrete was spread in December 2000 and removed on the 17th of January 2002, which means that the figures for 2000 also are partly influenced.

In January 2002, a new gauging box, MG0004G, was installed. The water from the G-tunnel, earlier collected in the gauging box MF0061G, is now lead to MG0004G. As a result, a decrease in flow in MF0061G could be seen (Appendix 5) and this also explains the low figure for year 2002 in Figure 6-9.

Data is missing from the end of June until the beginning of August for MA1033G, MA1232G and MA1372G due to failure in the datalogger Borre.

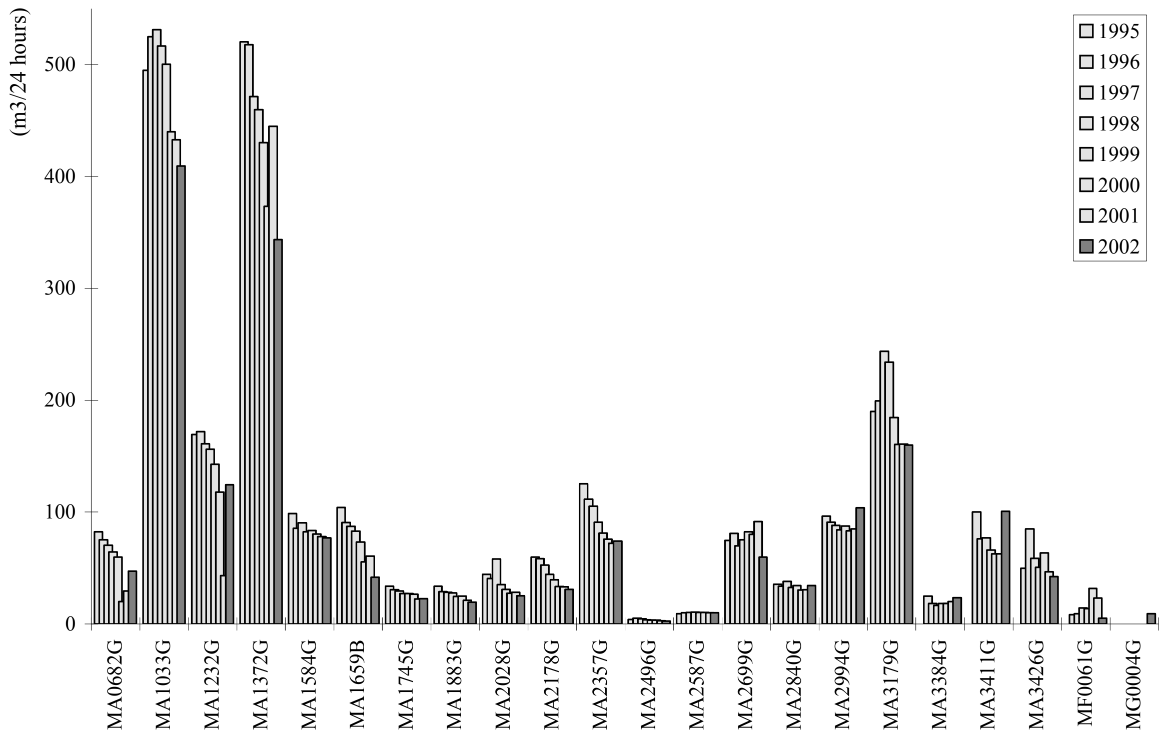

Figure 6-9 Water flow in all gauging boxes as a mean during October - December.

6.6 Water flow in tunnel pipes

The pumped flow rate out from the tunnel has been steadily decreasing since 1995. The measurements of fresh water entering 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 eight years are found in Table 6-1.

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

Year	Water in (m^3/d)	Water out (m^3/d)
1995	4.4	2479
1996	9.6	2438
1997	11.0	2393
1998	9.2	2268
1999	—	2105
2000	—	1930
2001	—	1848
2002	—	1821

The flow rates of water pumped out from the tunnel are presented in Appendix 6 as integrated daily values given in m^3/d.

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 along 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 -0.6 - +0.8 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 2002, 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.

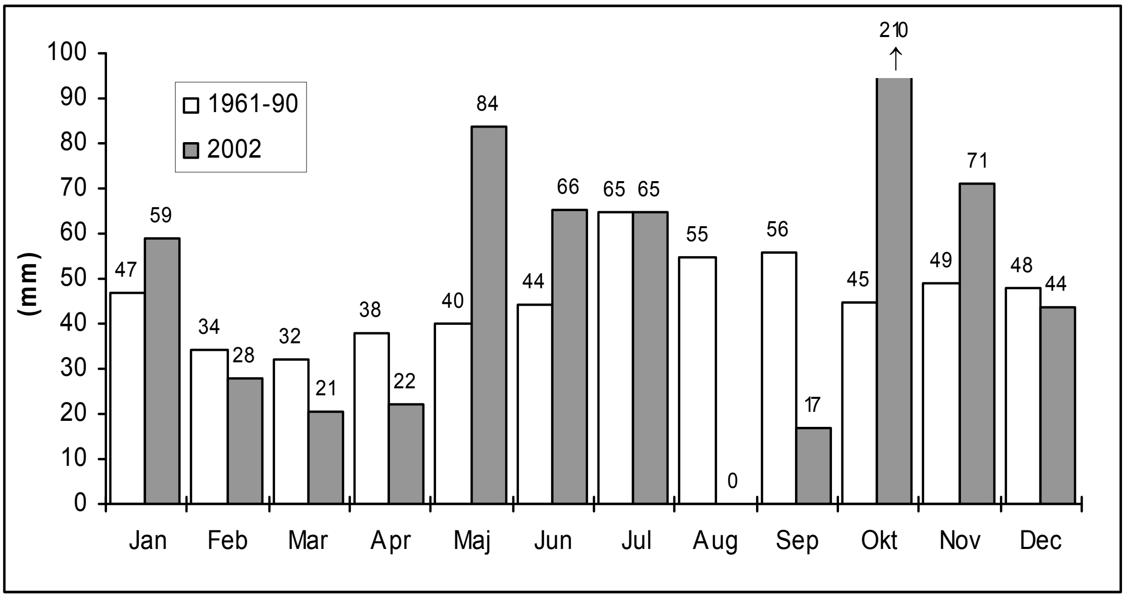

Figure 6-10 Precipitation at Oskarshamn: Monthly values 2002 and monthly means 1961 – 1990.

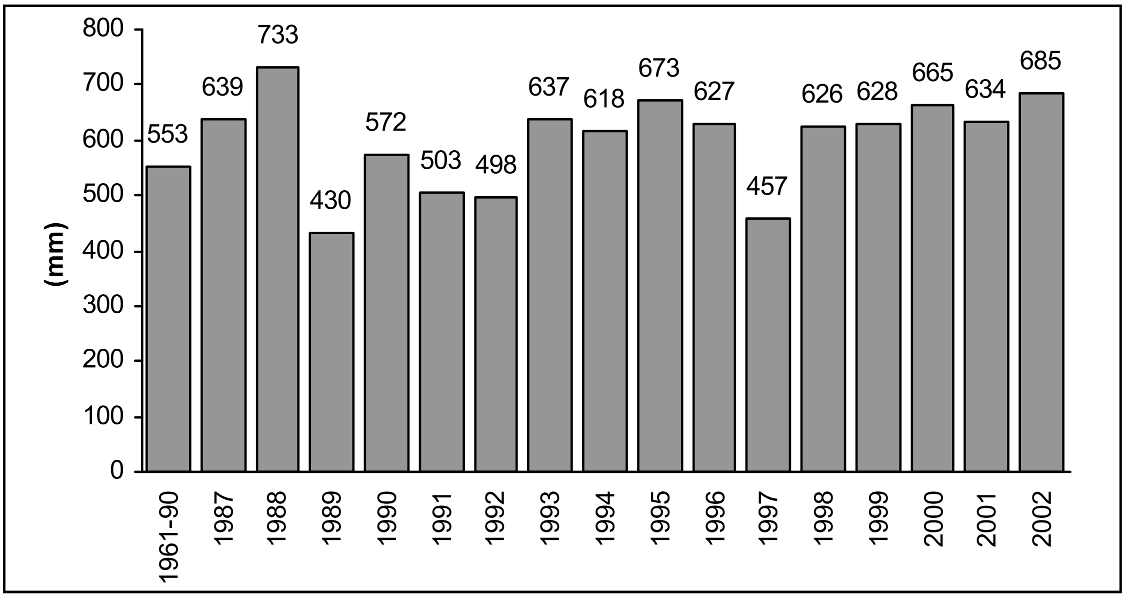

Figure 6-11 Precipitation at Oskarshamn. Yearly values 1987 - 2002 and yearly mean for the period 1961 - 1990.

6.10 Air temperature

Monthly mean temperature at the SMHI-station in Oskarshamn (see section 4.10.2) for 2002, 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 2002 is shown in Appendix 10.

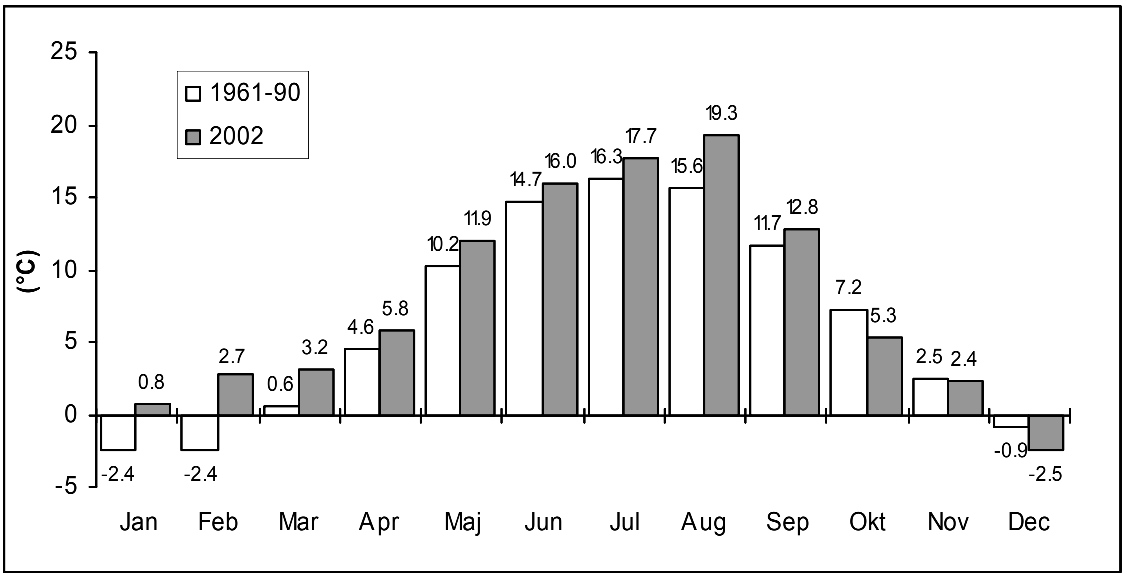

Figure 6-12 Temperature at Oskarshamn: Monthly values 2002 and monthly means 1961 – 1990.

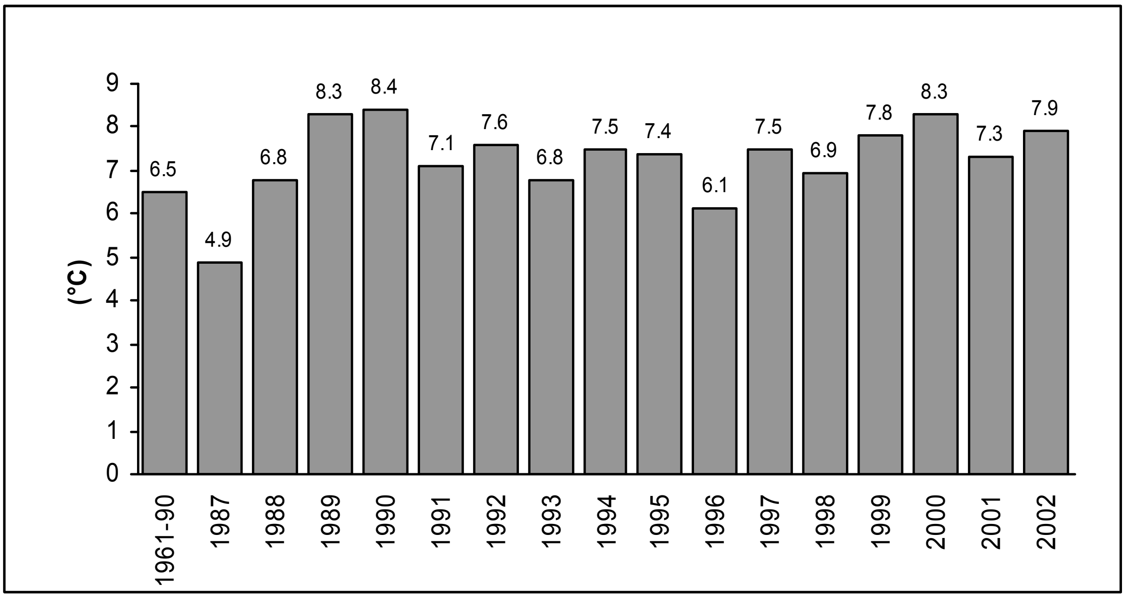

Figure 6-13 Temperature at Oskarshamn. Yearly values 1987 - 2002 and yearly mean for the period 1961 - 1990.

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.

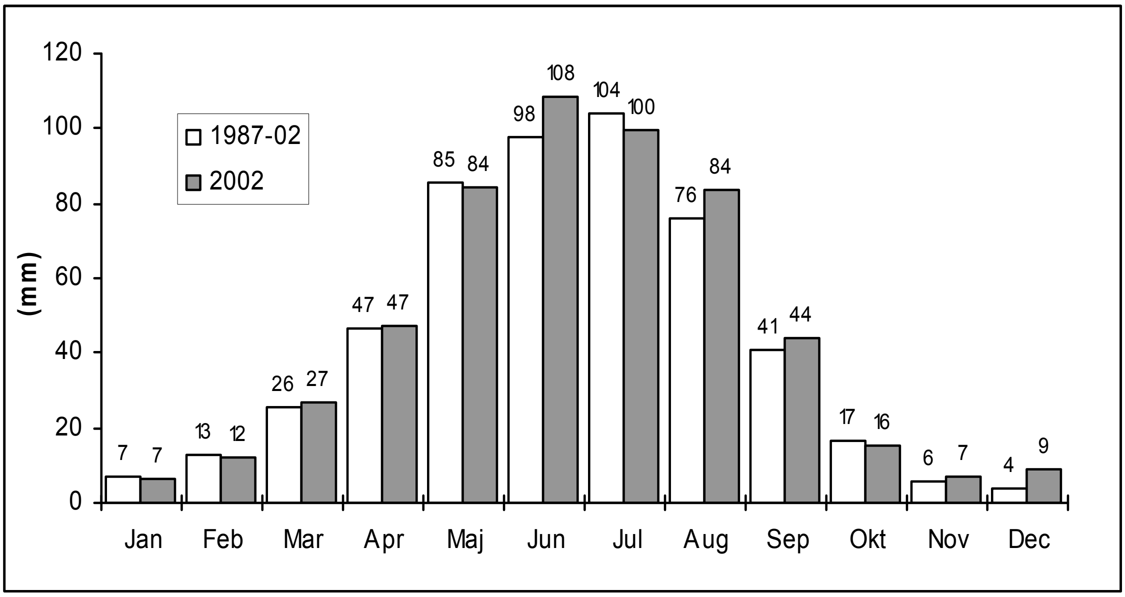

Figure 6-14 Potential evapotranspiration. Monthly values for Gladhammar 2002 and monthly means 1987 - 2002 (an average from Gladhammar and Ölands Norra Udde is used before 1 of August 1995).

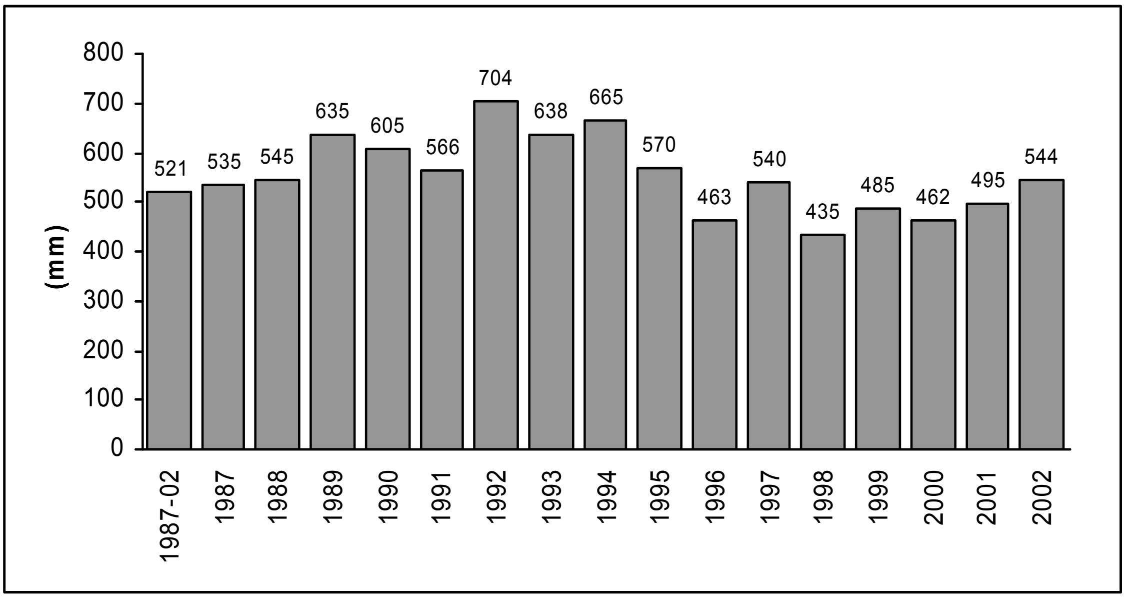

Figure 6-15 Potential evapotranspiration as average from Gladhammar and Ölands Norra Udde (only Gladhammar from 1 of August 1995). Yearly values 1987 - 2002 and yearly mean for the period 1987 - 2002.

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Appendices

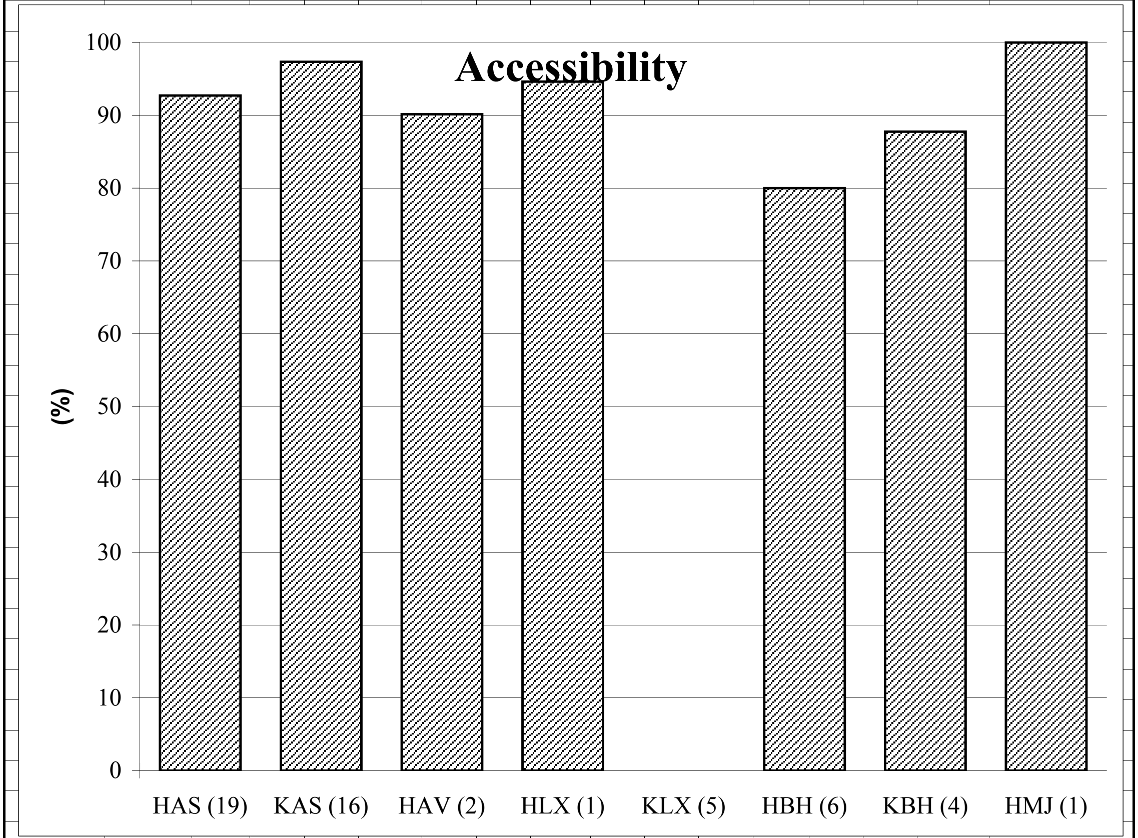
Appendix 1: Statistics on missing data

Äspö Hard Rock Laboratory	First date for statistics:	2002-01-01
Groundwater Level Program	Last date for statistics:	2002-12-01
Error statistics	Latest calibration date:	2003-06-01
	No of days in period:	335

Borehole	Section	Duration of error (days)														Accessibility
		TG	**TST**	**KOM**	**O**	**V**	**B**	**L**	**Å**	**ML**	**OP**	**G**	**K**	**?**	Sum	(%)
HAS01	1														0	100
HAS04	1	36					11								47	86
HAS04	2						11								11	97
HAS06	1														0	100
HAS06	2														0	100
HAS07	1	5													5	99
HAS11	1									177					177	47
HAS11	2	37								177					214	36
HAS13	1														0	100
HAS13	2														0	100
HAS15	1	5		4											9	97
HAS15	2														0	100
HAS16	1														0	100
HAS16	2														0	100
HAS17	1														0	100
HAS17	2														0	100
HAS19	1														0	100
HAS19	2														0	100
HAS21	1														0	100
HAS		83	0	4	0	0	22	0	0	354	0	0	0	0	463	93
KAS03	1					10									10	97
KAS03	2					10									10	97
KAS03	3	13				10									23	93
KAS03	4					10									10	97
KAS03	5					10									10	97
KAS03	6					10									10	97
KAS09	1	35		5											40	88
KAS09	2			5										1	6	98
KAS09	3	4		5											9	97
KAS09	4			5											5	99
KAS09	5			5											5	99
KAS10	1			4											4	99
KAS16	1														0	100
KAS16	2														0	100
KAS16	3														0	100
KAS16	4														0	100
KAS		52	0	29	0	60	0	0	0	0	0	0	0	1	142	97

Borehole	Section	Duration of error (days)														Accessibility
		TG	**TST**	**KOM**	**O**	**V**	**B**	**L**	**Å**	**ML**	**OP**	**G**	**K**	**?**	Sum	(%)
HAV05	1											66			66	80
HAV08	1														0	100
HAV		0	0	0	0	0	0	0	0	0	0	66	0	0	66	90
HLX05	1	1		17											18	95
HLX		1	0	17	0	0	0	0	0	0	0	0	0	0	18	95
KLX01	1				335										335	0
KLX01	2				335										335	0
KLX01	3				335										335	0
KLX01	4				335										335	0
KLX01	5				335										335	0
KLX		0	0	0	1675	0	0	0	0	0	0	0	0	0	1675	0
HBH01	1			83											83	75
HBH01	2	25		83											108	68
HBH02	1			83										4	87	74
HBH02	2			75						45				4	124	63
HBH04	1														0	100
HBH04	2														0	100
HBH		25	0	324	0	0	0	0	0	45	0	0	0	8	402	80
KBH02	3	68													68	80
KBH02	4														0	100
KBH02	5														0	100
KBH02	6	96													96	71
KBH		164	0	0	0	0	0	0	0	0	0	0	0	0	164	88
HMJ01	1														0	100
HMJ		0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
							SUMMARY									
HAS (19)		83	0	4	0	0	22	0	0	354	0	0	0	0	463	93
KAS (16)		52	0	29	0	60	0	0	0	0	0	0	0	1	142	97
HAV (2)		0	0	0	0	0	0	0	0	0	0	66	0	0	66	90
HLX (1)		1	0	17	0	0	0	0	0	0	0	0	0	0	18	95
KLX (5)		0	0	0	1675	0	0	0	0	0	0	0	0	0	1675	0
HBH (6)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	80
KBH (4)		164	0	0	0	0	0	0	0	0	0	0	0	0	164	88
HMJ (1)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
TOTAL (80)		12%	0%	2%	66%	2%	1%	0%	0%	14%	0%	3%	0%	0%	100%	85

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:	2002-01-01
Last date for statistics:	2002-12-31
Latest calibration date:	2003-04-03
No of days in period:	365

Idcode	Sec.	Duration of error (days)													Accessibility
		B	K	OP	TST	V	O	L	DS	ML	G	W	?	Sum	(%)
HA1273A	1	44												44	88
HA1278A	1	44												44	88
HA1279A	1	44												44	88
HA1283B	1	44												44	88
HA1327B	1	44												44	88
HA1330B	1	44												44	88
HA1960A	1						51							51	86
HD0025A	1			2										2	99
KA1061A	1	44												44	88
KA1131B	1	44		6										50	86
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							1						1	100
KA2050A	2							1						1	100
KA2050A	3							1						1	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
KA2511A	7													0	100
KA2511A	8													0	100
KA2563A	1													0	100
KA2563A	2													0	100
KA2563A	3													0	100
KA2563A	4													0	100
KA2563A	5													0	100
KA2598A	1													0	100
KA2858A	2													0	100
KA2862A	1													0	100
KA3005A	2													0	100
KA3005A	3													0	100
KA3005A	4													0	100
KA3005A	5													0	100
KA3010A	2													0	100
KA3067A	1													0	100
KA3067A	2													0	100

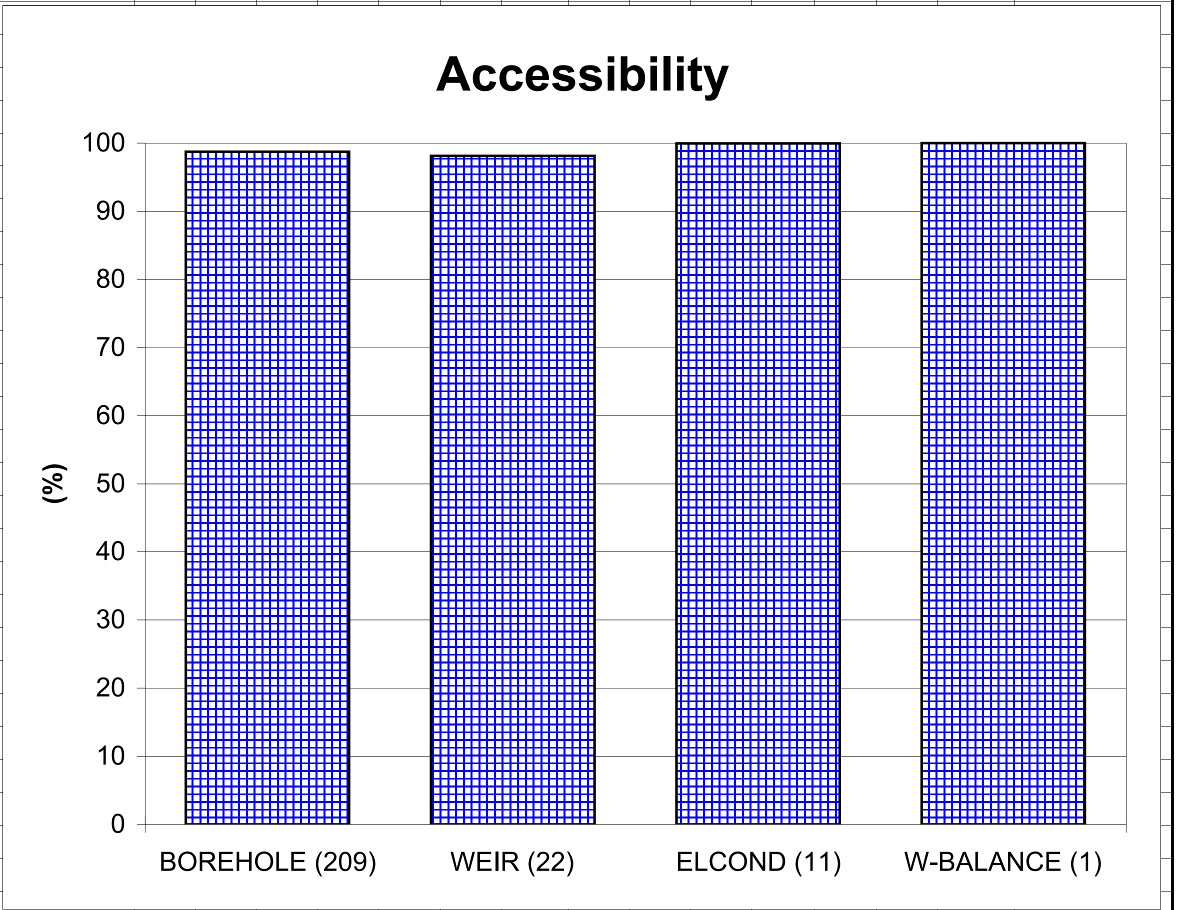
Idcode	Sec.	Duration of error (days)													Accessibility
		B	K	OP	TST	V	O	L	DS	ML	G	W	?	Sum	(%)
KA3067A	3													0	100
KA3067A	4													0	100
KA3105A	1													0	100
KA3105A	2													0	100
KA3105A	3													0	100
KA3105A	4													0	100
KA3105A	5													0	100
KA3110A	1													0	100
KA3110A	2										12			12	97
KA3385A	1			2										2	99
KA3385A	2			2										2	99
KA3510A	1			2										2	99
KA3510A	2			2										2	99
KA3510A	3			2										2	99
KA3510A	4			2										2	99
KA3510A	5			2										2	99
KA3563A01	1													0	100
KA3563D01	1													0	100
KA3563G01	1													0	100
KA3563G01	2													0	100
KA3563G01	3													0	100
KA3563G01	4													0	100
KA3563I01	1													0	100
KA3566C01	1													0	100
KA3566G01	1													0	100
KA3566G01	2													0	100
KA3566G01	3													0	100
KA3566G01	4													0	100
KA3566G01	5													0	100
KA3566G02	1													0	100
KA3566G02	2													0	100
KA3566G02	3													0	100
KA3566G02	4													0	100
KA3566G02	5													0	100
KA3568D01	1													0	100
KA3572G01	1													0	100
KA3572G01	2													0	100
KA3573A	1													0	100
KA3573A	2													0	100
KA3573A	3													0	100
KA3573A	4													0	100
KA3573A	5													0	100
KA3573C01	1													0	100
KA3574D01	1													0	100
KA3574G01	1		19										9	28	92
KA3574G01	2													0	100
KA3574G01	3													0	100
KA3576G01	1													0	100
KA3576G01	2													0	100
KA3576G01	3													0	100
KA3578C01	1													0	100
KA3578G01	1													0	100
KA3578G01	2													0	100
KA3578H01	1													0	100
KA3579D01	1													0	100
KA3579G	1													0	100
KA3579G	2													0	100

Idcode	Sec.	Duration of error (days)													Accessibility
		B	K	OP	TST	V	O	L	DS	ML	G	W	?	Sum	(%)
KA3579G	3													0	100
KA3584G01	1													0	100
KA3584G01	2													0	100
KA3588C01	1													0	100
KA3588D01	1													0	100
KA3588I01	1													0	100
KA3590G01	1													0	100
KA3590G01	2													0	100
KA3590G01	3													0	100
KA3590G02	1													0	100
KA3590G02	2													0	100
KA3590G02	3													0	100
KA3590G02	4													0	100
KA3592C01	1													0	100
KA3593G	1													0	100
KA3593G	2													0	100
KA3593G	3													0	100
KA3593G	4													0	100
KA3597D01	1													0	100
KA3597H01	1													0	100
KA3600F	1													0	100
KA3600F	2													0	100
KA3600F	3													0	100
KA3600F	4													0	100
KF0051A	1			2										2	99
KF0051A	2			2										2	99
KF0051A	3			2										2	99
KF0051A	4			2										2	99
KG0021A01	1													0	100
KG0021A01	2													0	100
KG0021A01	3													0	100
KG0021A01	4													0	100
KG0021A01	5													0	100
KG0048A01	1													0	100
KG0048A01	2													0	100
KG0048A01	3													0	100
KG0048A01	4													0	100
KG0048A01	5													0	100
KI0023B	1			2										2	99
KI0023B	2			2										2	99
KI0023B	3			2										2	99
KI0023B	4			2										2	99
KI0023B	5		10	2									4	16	96
KI0023B	6			2										2	99
KI0023B	7			2										2	99
KI0023B	8			2										2	99
KI0023B	9			2										2	99

Idcode	Sec.	Duration of error (days)													Accessibility
		B	K	OP	TST	V	O	L	DS	ML	G	W	?	Sum	(%)
KI0025F	1			2										2	99
KI0025F	2			2										2	99
KI0025F	3			2										2	99
KI0025F	4			2										2	99
KI0025F	5			2										2	99
KI0025F	6			2										2	99
KI0025F02	1			2										2	99
KI0025F02	2			2										2	99
KI0025F02	3			2										2	99
KI0025F02	4			2										2	99
KI0025F02	5			2										2	99
KI0025F02	6			2										2	99
KI0025F02	7			2										2	99
KI0025F02	8			2										2	99
KI0025F02	9			2										2	99
KI0025F02	10			2										2	99
KI0025F03	1			2										2	99
KI0025F03	2			2										2	99
KI0025F03	3			2										2	99
KI0025F03	4			2										2	99
KI0025F03	5			2										2	99
KI0025F03	6			2										2	99
KI0025F03	7			2										2	99
KI0025F03	8			2										2	99
KI0025F03	9			2										2	99
KR0012B	1										63			63	83
KR0013B	1										259			259	29
KR0015B	1													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
KXTT5	1													0	100
KXTT5	2													0	100
KXTT5	3													0	100
KXTT5	4													0	100
SA2142A	1						51							51	86
SA2338A	1						51							51	86
BOREHOLE		352	29	98	0	0	153	3	0	0	334	0	13	982	99

Idcode	Sec.	Duration of error (days)													Accessibility
		B	K	OP	TST	V	O	L	DS	ML	G	W	?	Sum	(%)
MA0682G														0	100
MA1033G		44												44	88
MA1232G		44												44	88
MA1372G		44												44	88
MA1584G														0	100
MA1659G														0	100
MA1745G														0	100
MA1883G														0	100
MA2028G														0	100
MA2178G														0	100
MA2357G														0	100
MA2496G														0	100
MA2587G														0	100
MA2699G														0	100
MA2840G														0	100
MA2994G														0	100
MA3179G														0	100
MA3384G				4										4	99
MA3411G				4										4	99
MA3426G				4										4	99
MF0061G				4										4	99
MG0004G				2										2	99
Weir		132	0	18	0	0	0	0	0	0	0	0	0	150	98
EA0682G														0	100
EA1584T														0	100
EA1659B														0	100
EA2496T														0	100
EA2587G														0	100
EA3179G														0	100
EA3384G														0	100
EA3411G														0	100
EA3426G														0	100
EF0061G				2										2	99
EPG5														0	100
ER0013B														0	100
ELCOND		0	0	2	0	0	0	0	0	0	0	0	0	2	100
QA0687O														0	100
W-BALANCE		0	0	0	0	0	0	0	0	0	0	0	0	0	100

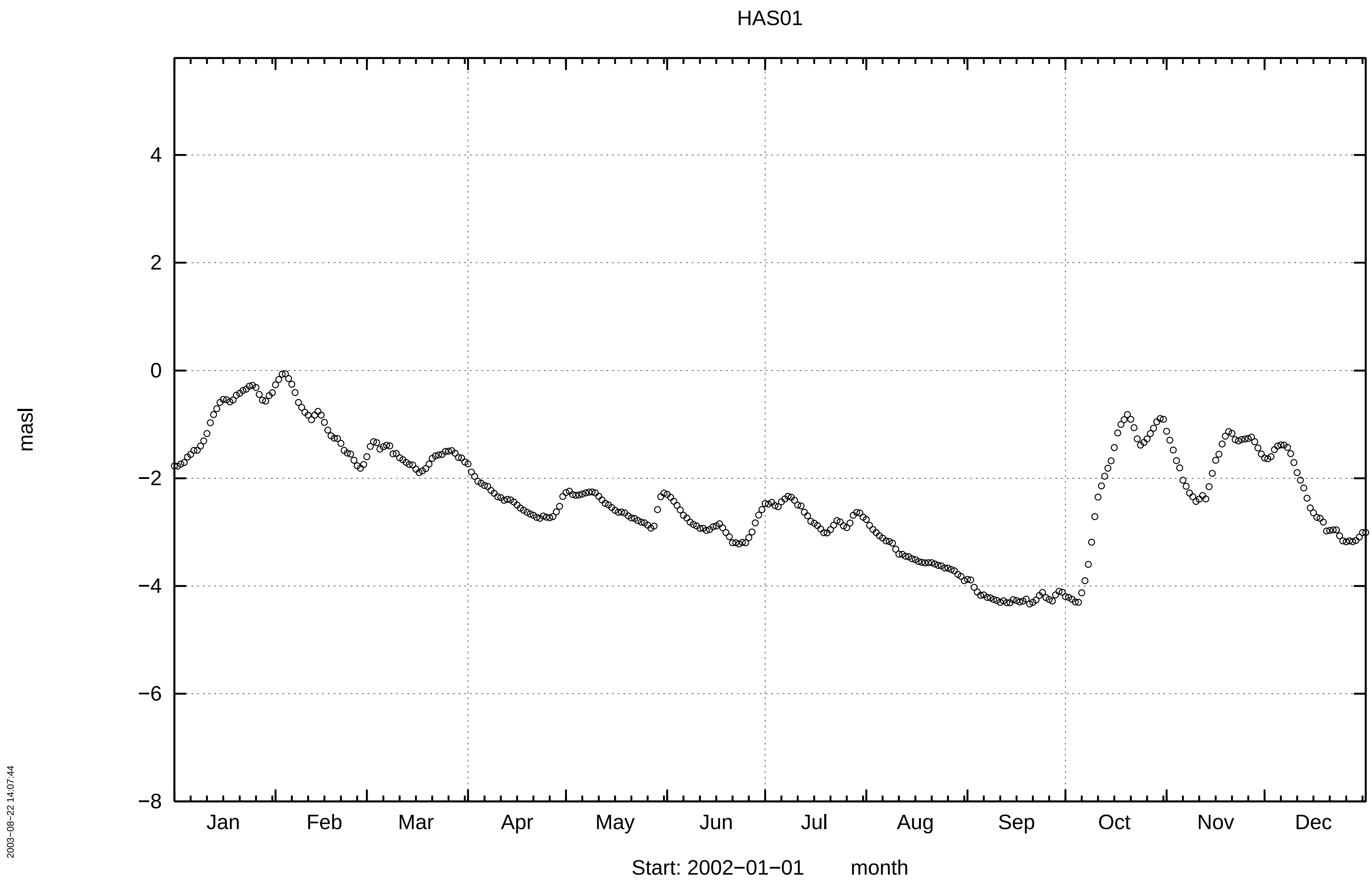
Idcode	Sec.	Duration of error (days)													Accessibility
		B	K	OP	TST	V	O	L	DS	ML	G	W	?	Sum	(%)
							SUMMARY								
BOREHOLE (209)		352	29	98	0	0	153	3	0	0	334	0	13	982	99
WEIR (22)		132	0	18	0	0	0	0	0	0	0	0	0	150	98
ELCOND (11)		0	0	2	0	0	0	0	0	0	0	0	0	2	100
W-BALANCE (1)		0	0	0	0	0	0	0	0	0	0	0	0	0	100
TOTAL		43%	3%	10%	0%	0%	13%	0%	0%	0%	29%	0%	1%	100%	99

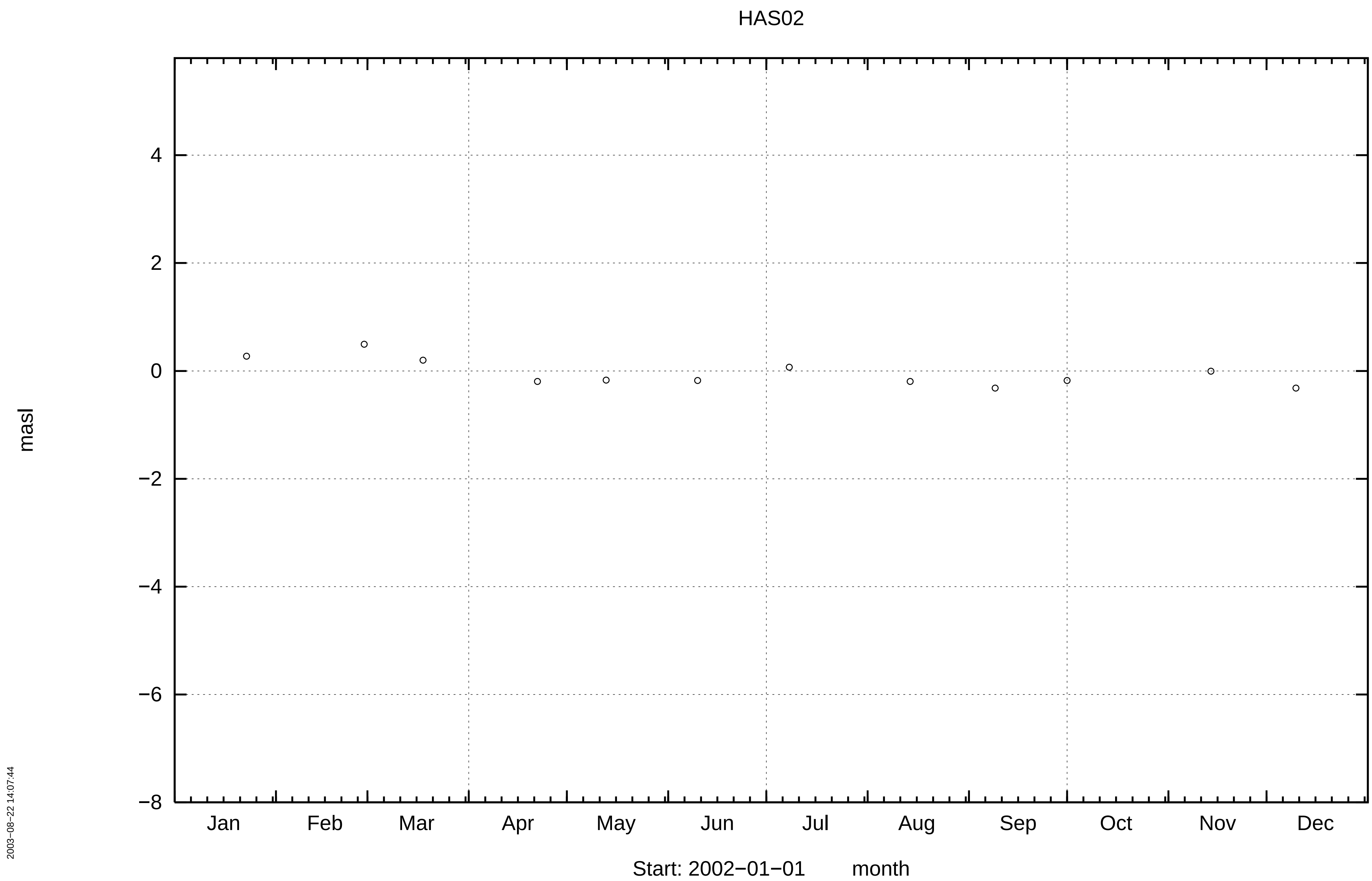


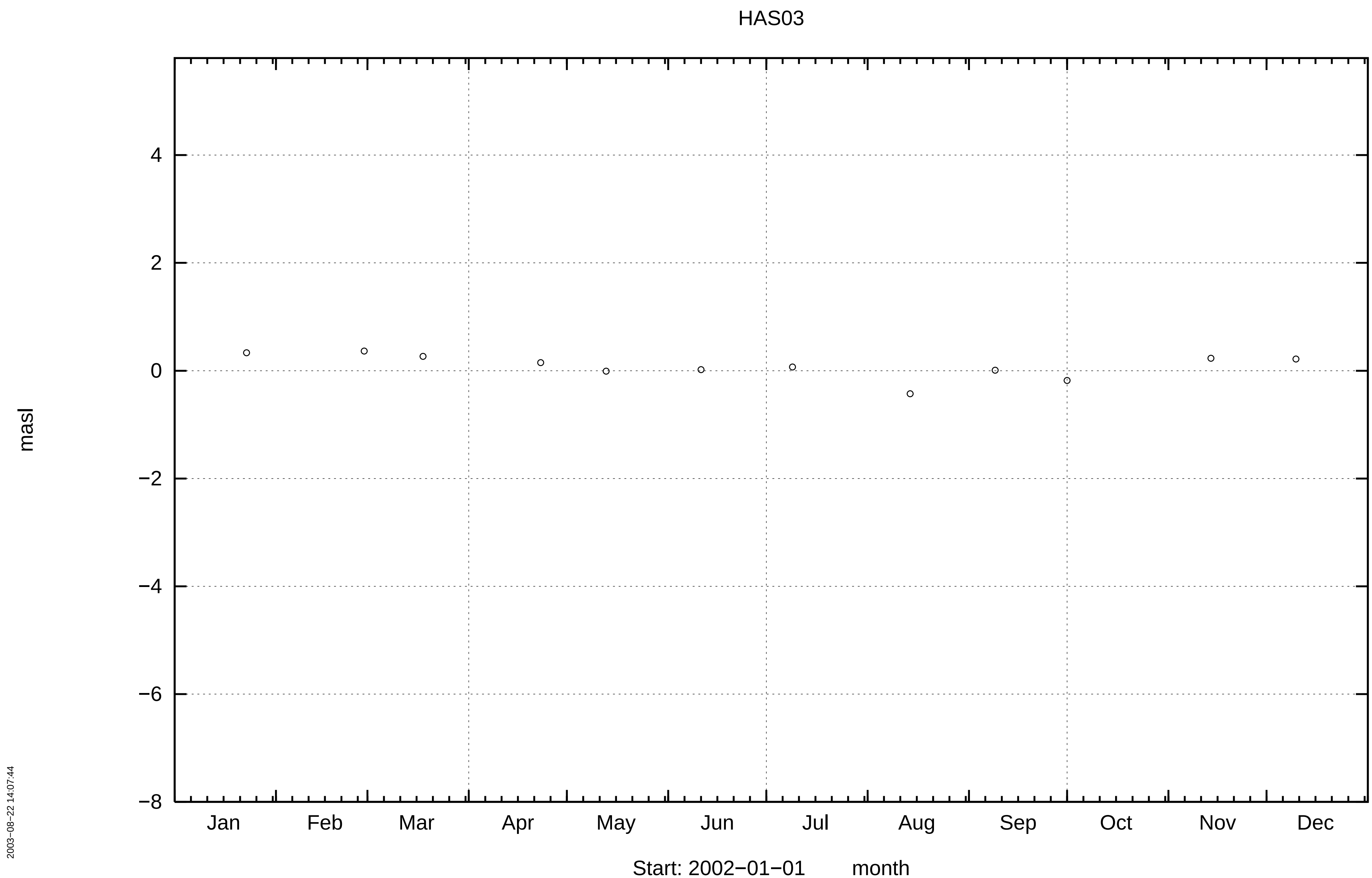
ERROR CODES

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 or inaccurate 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

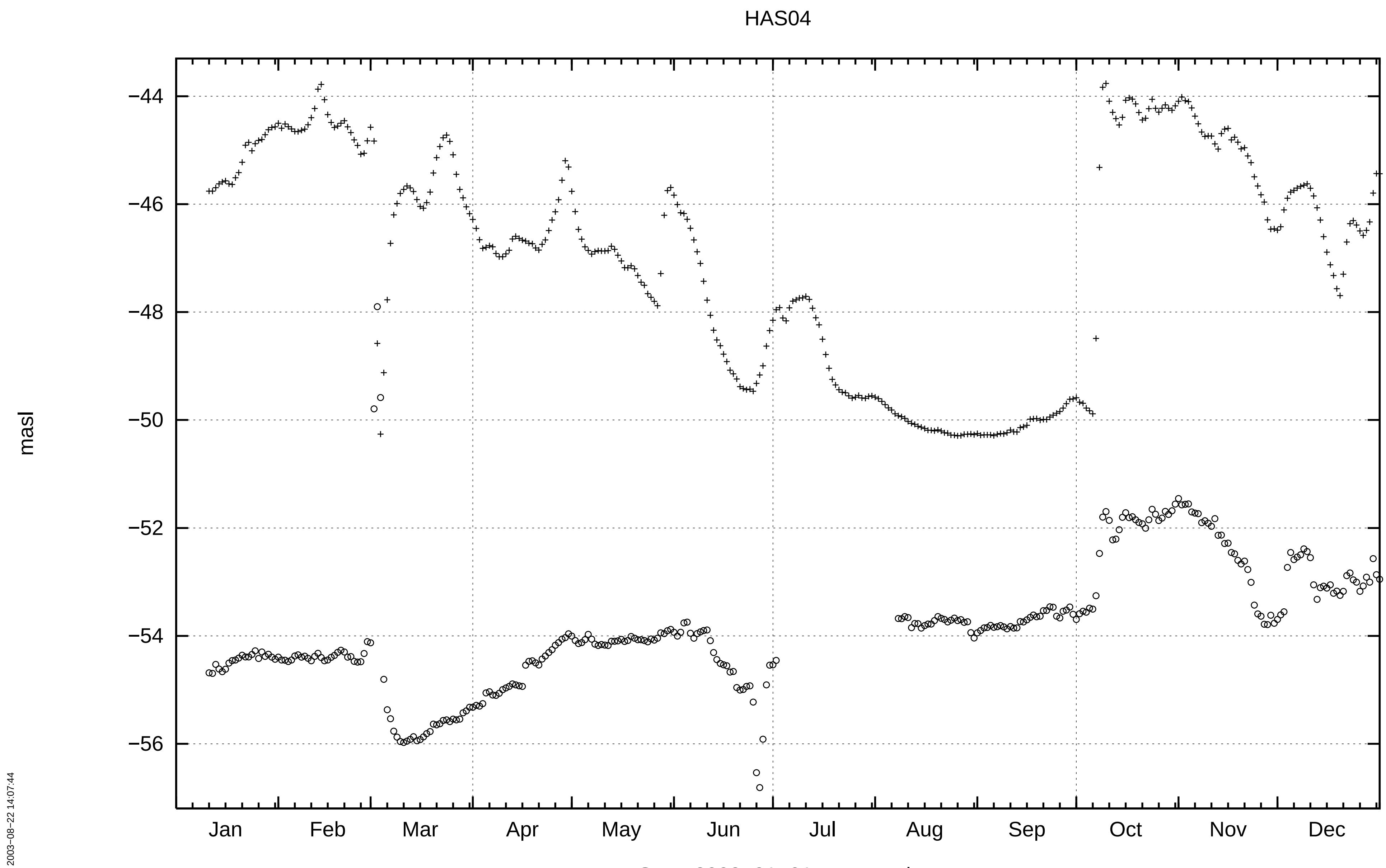
Appendix 2: Groundwater level

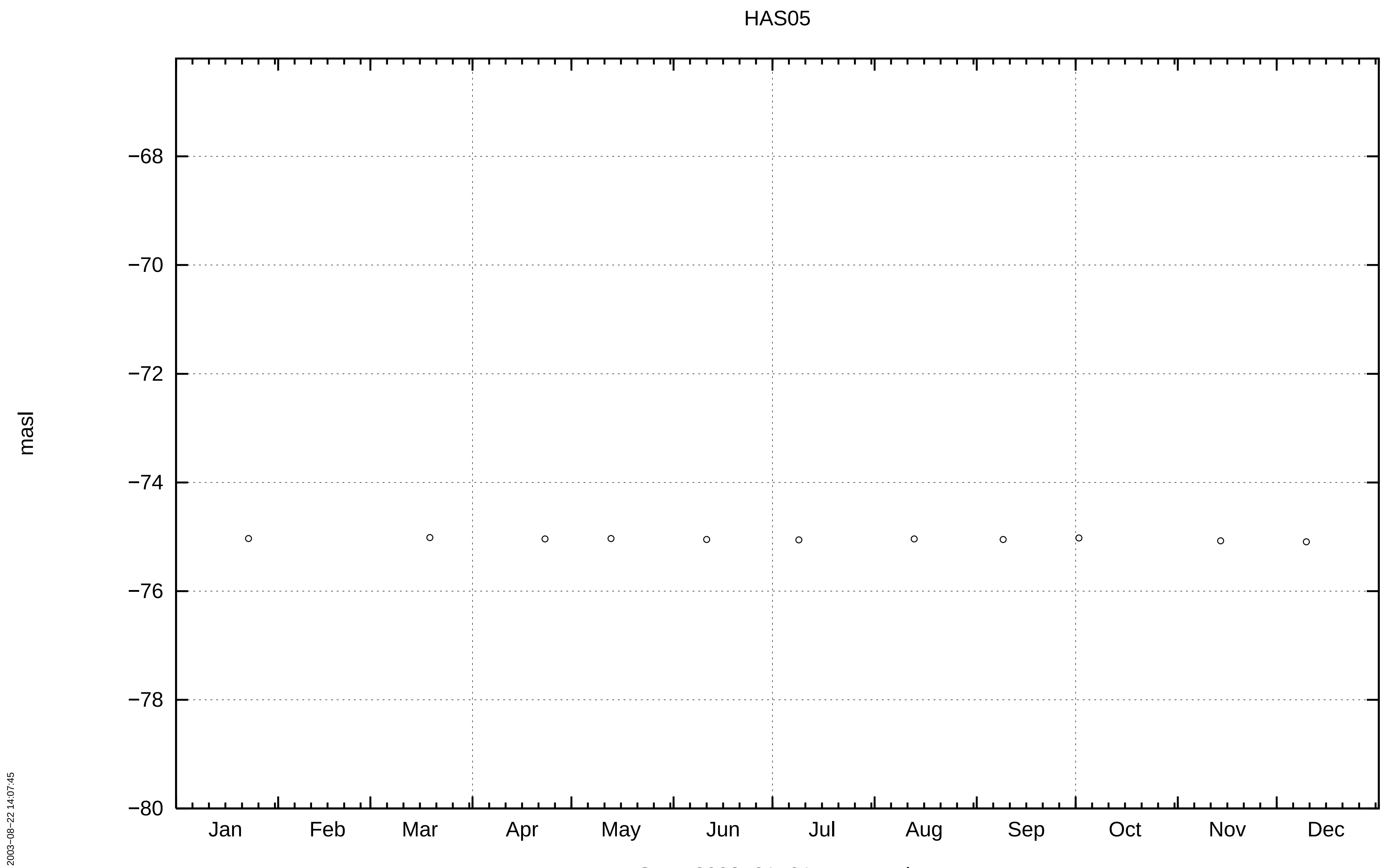

HAS01
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:44

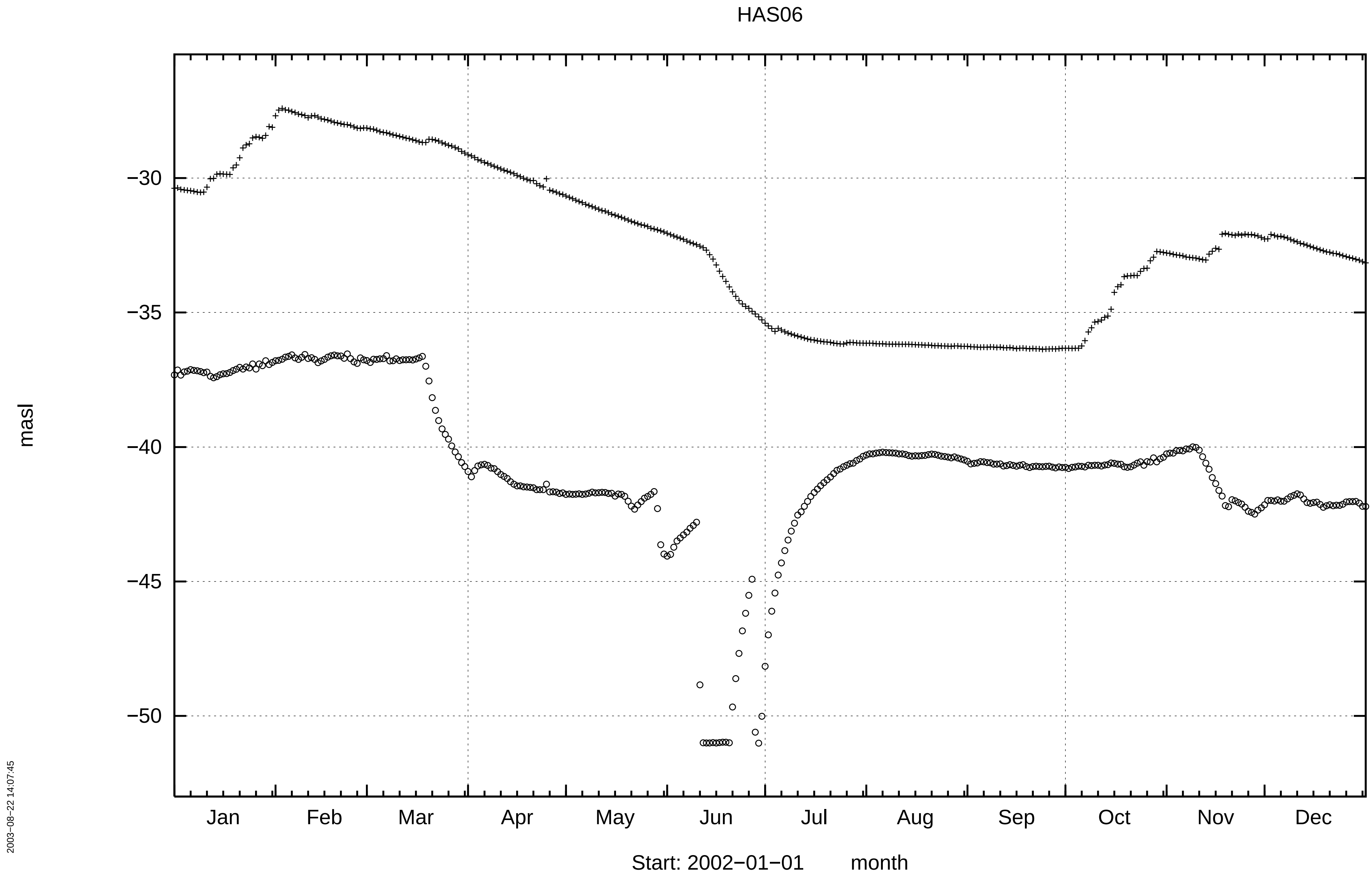

HAS02
4
2
0
−2
−4
−6
−8
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:44

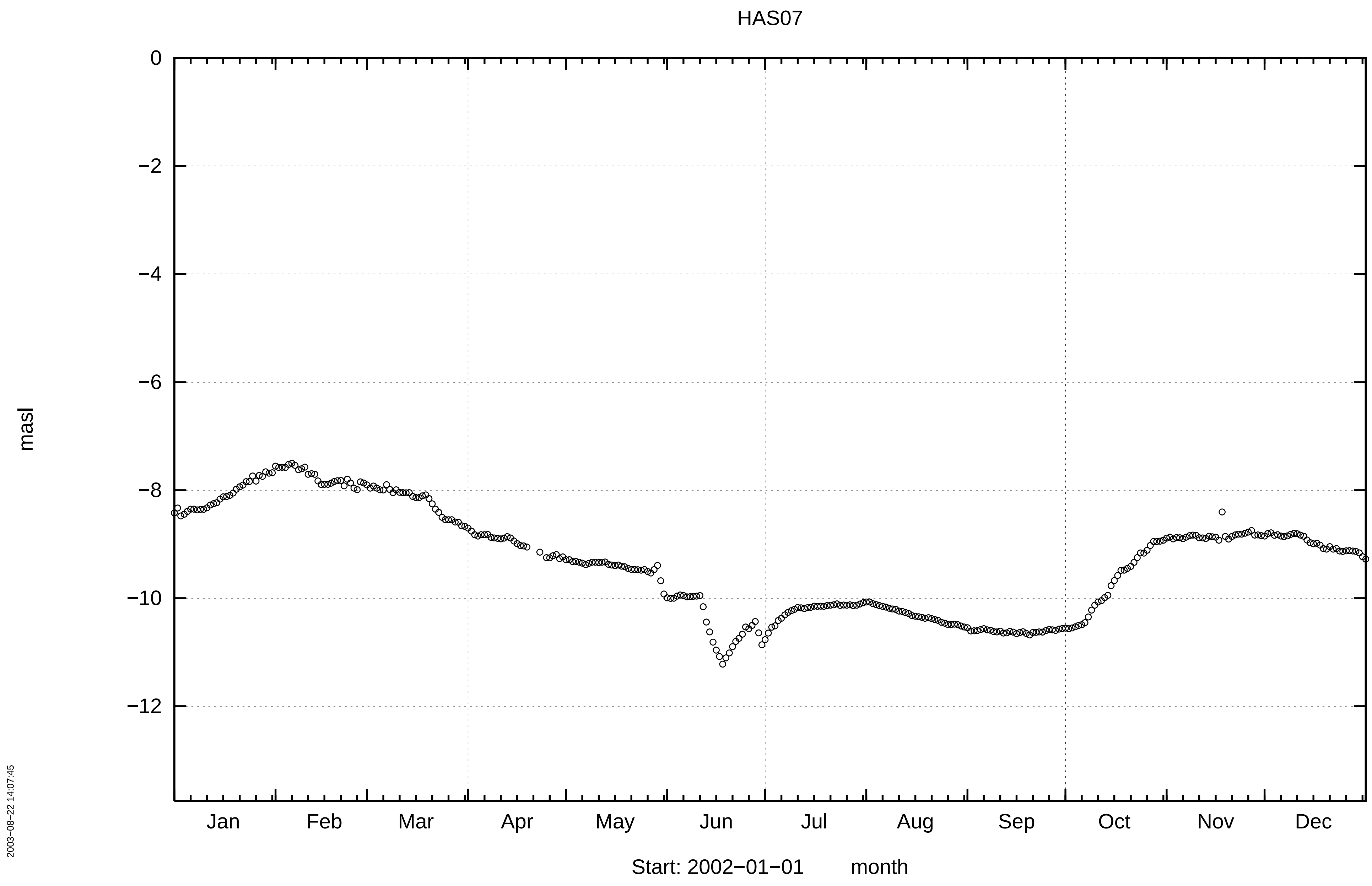


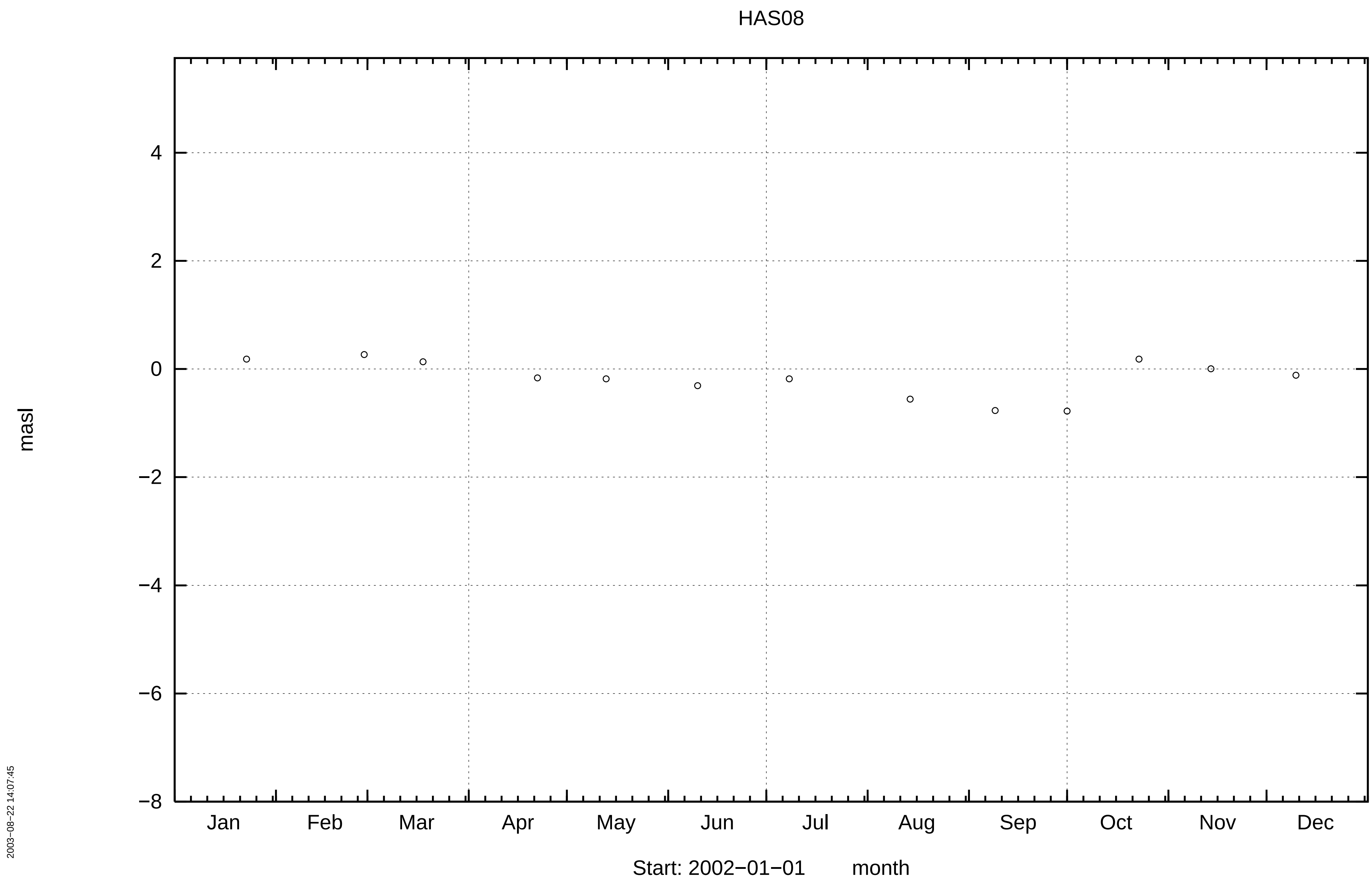
HAS03
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:44

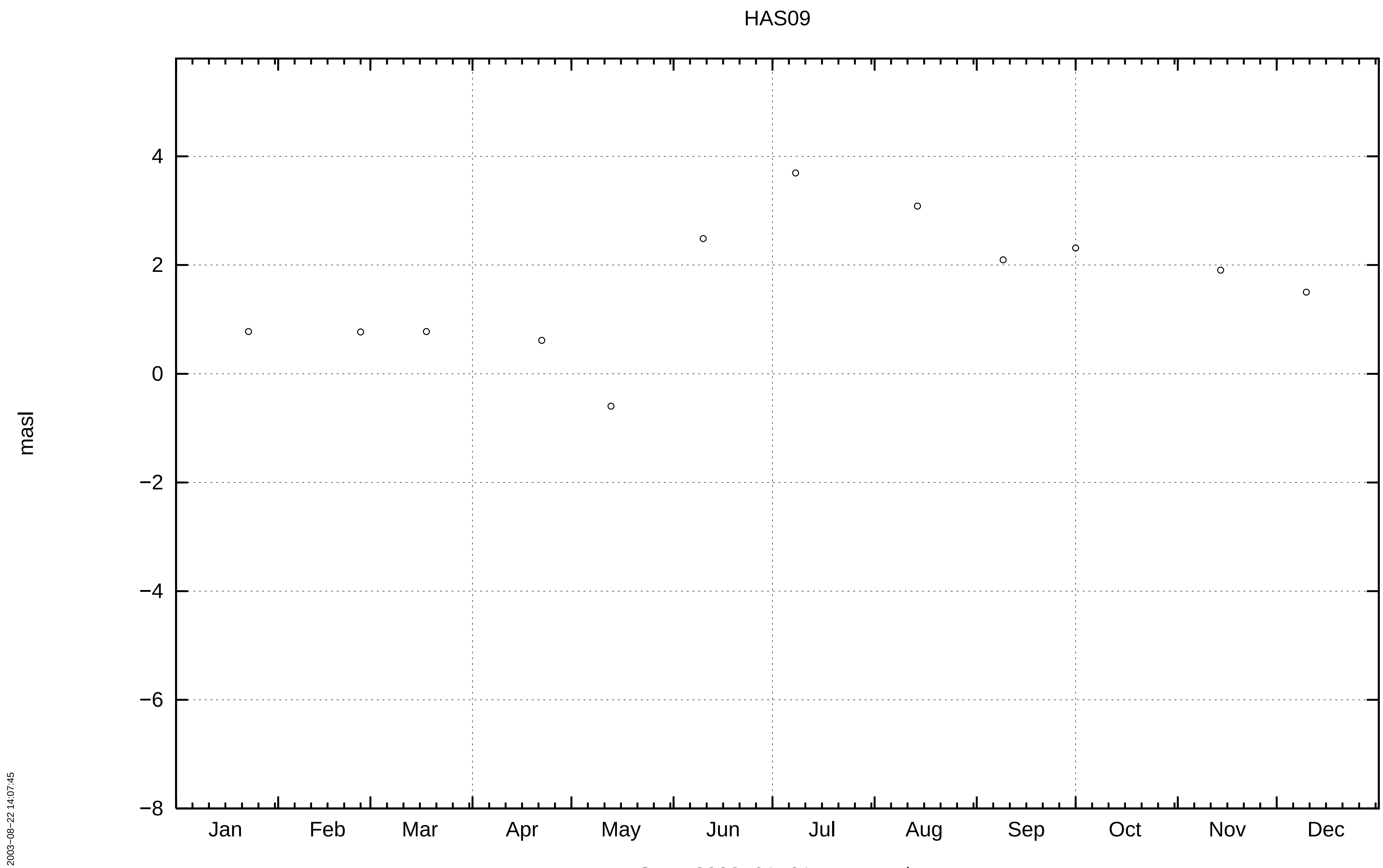

HAS04
masl
−44
−46
−48
−50
−52
−54
−56
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:44

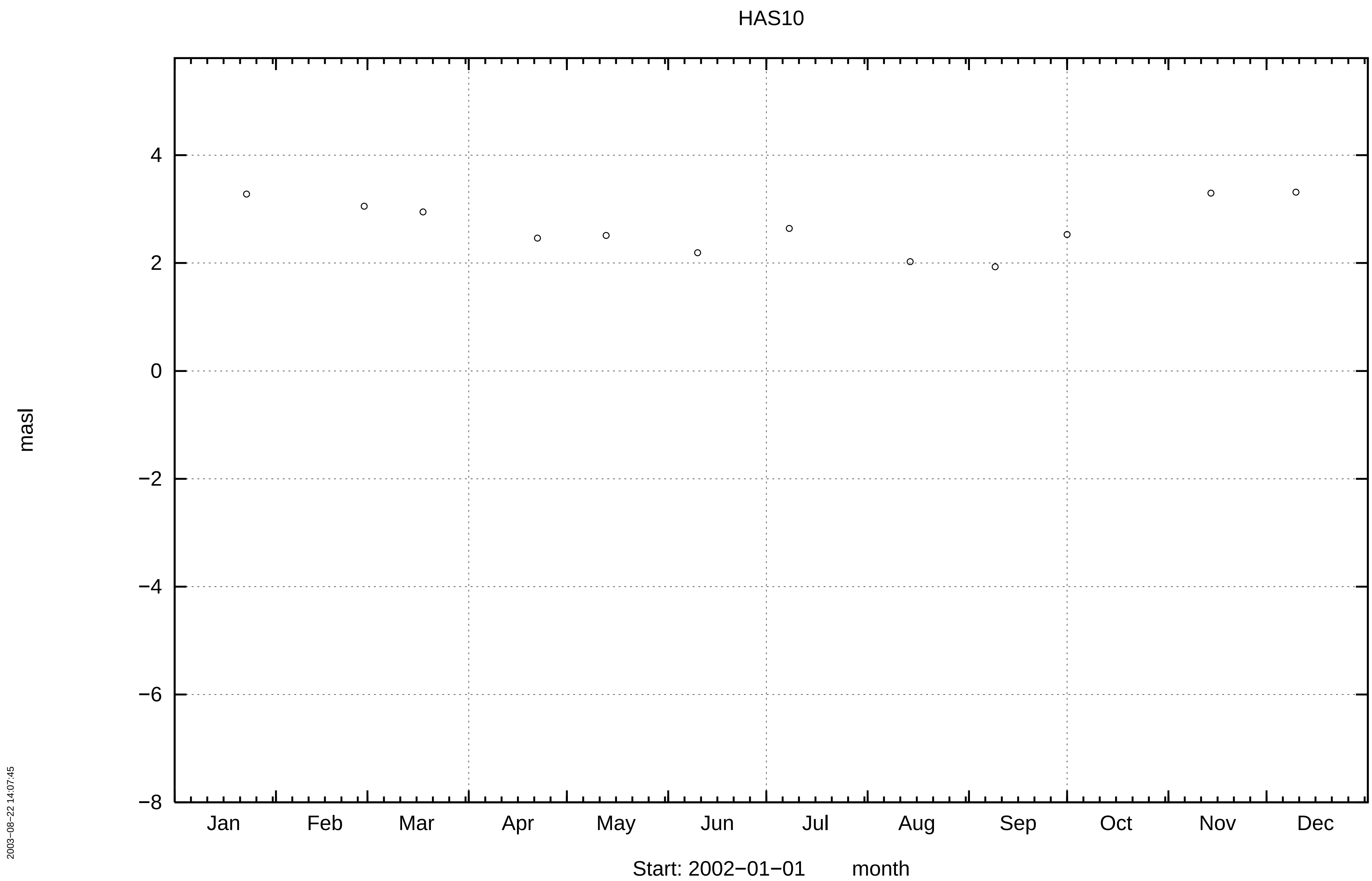

HAS05
masl
−68
−70
−72
−74
−76
−78
−80
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:45


HAS06
masl
-30
-35
-40
-45
-50
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:45


HAS07
masl
0
−2
−4
−6
−8
−10
−12
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:45


HAS08
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:45


HAS09
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:45



HAS10
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
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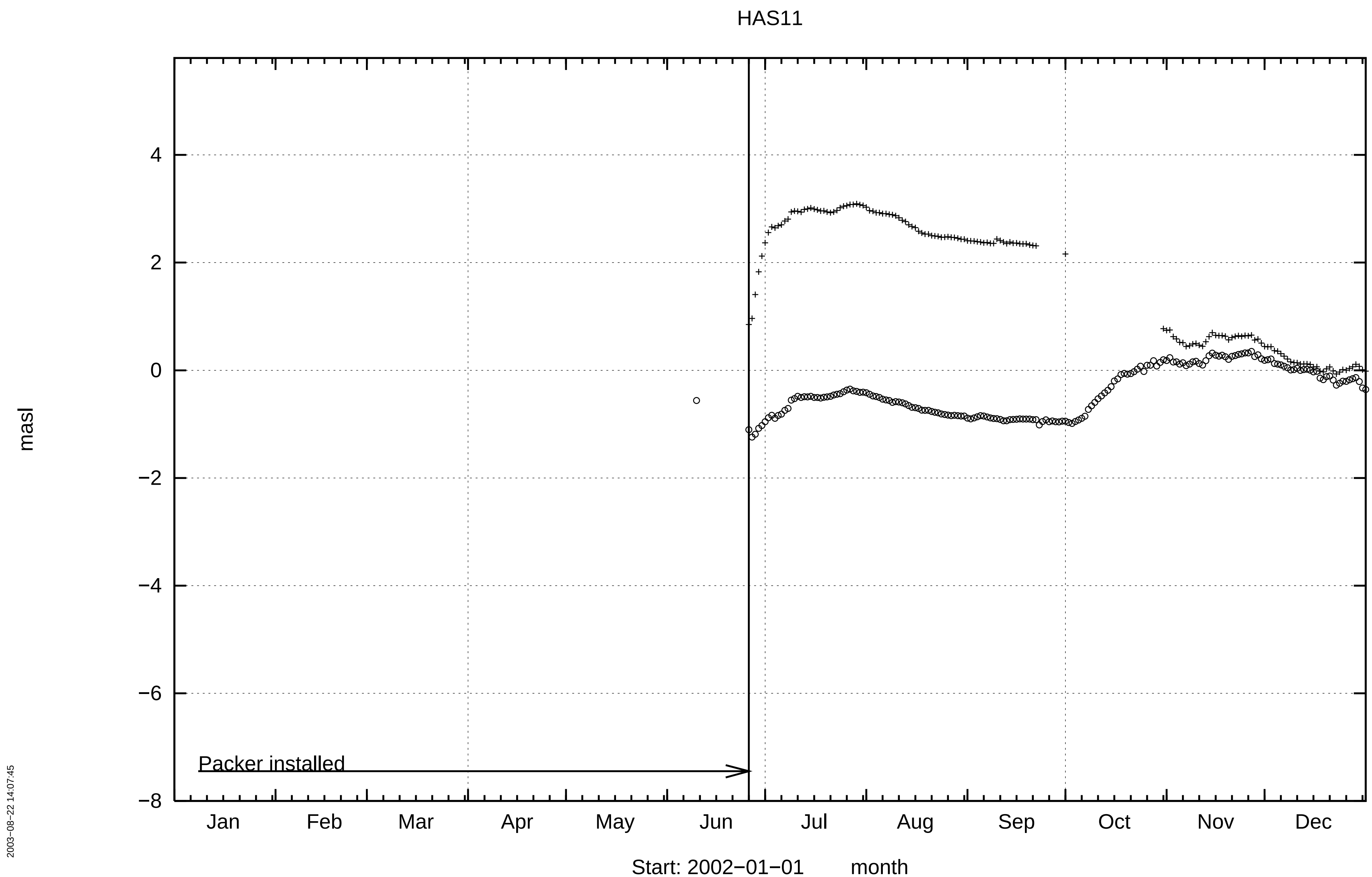
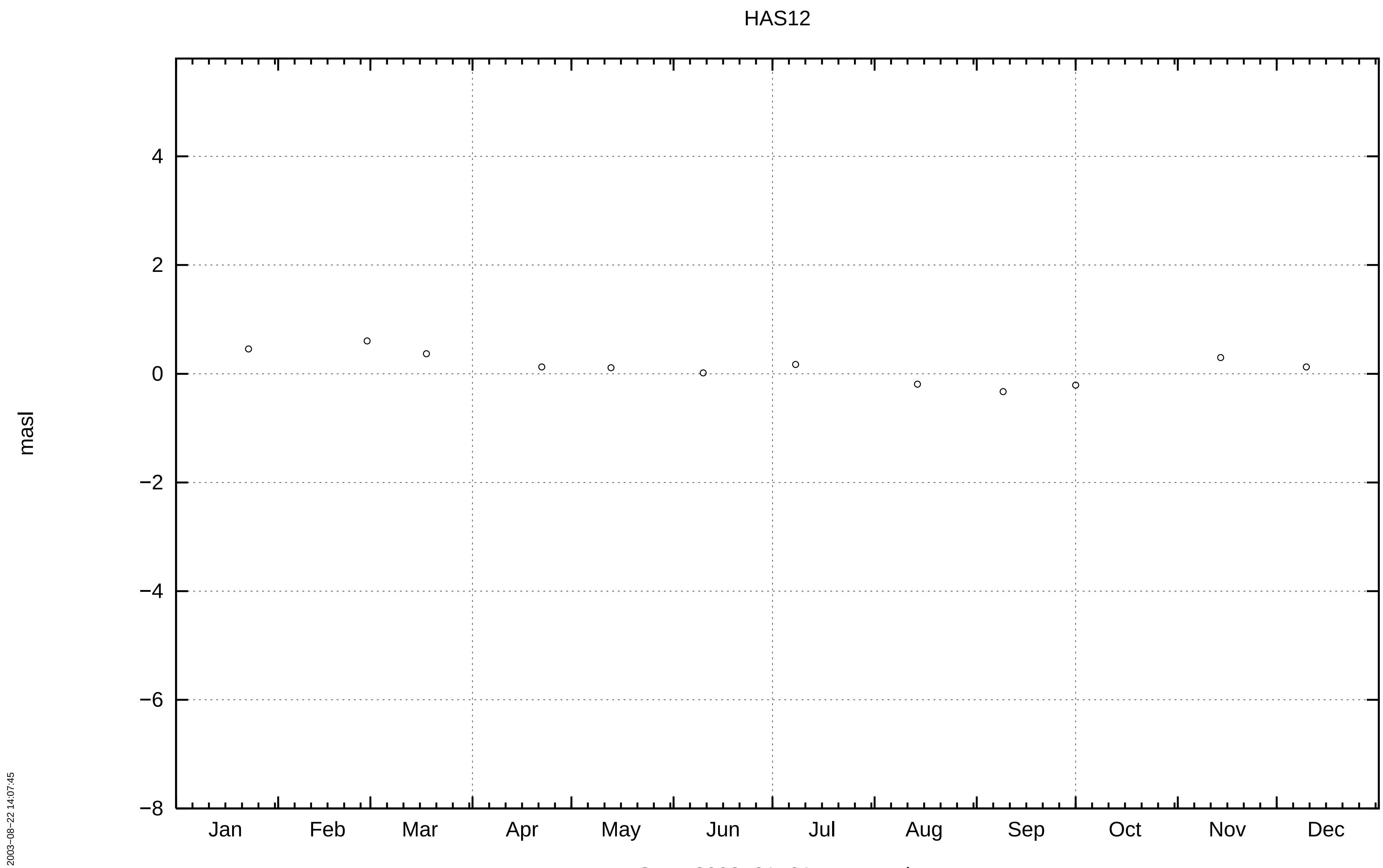
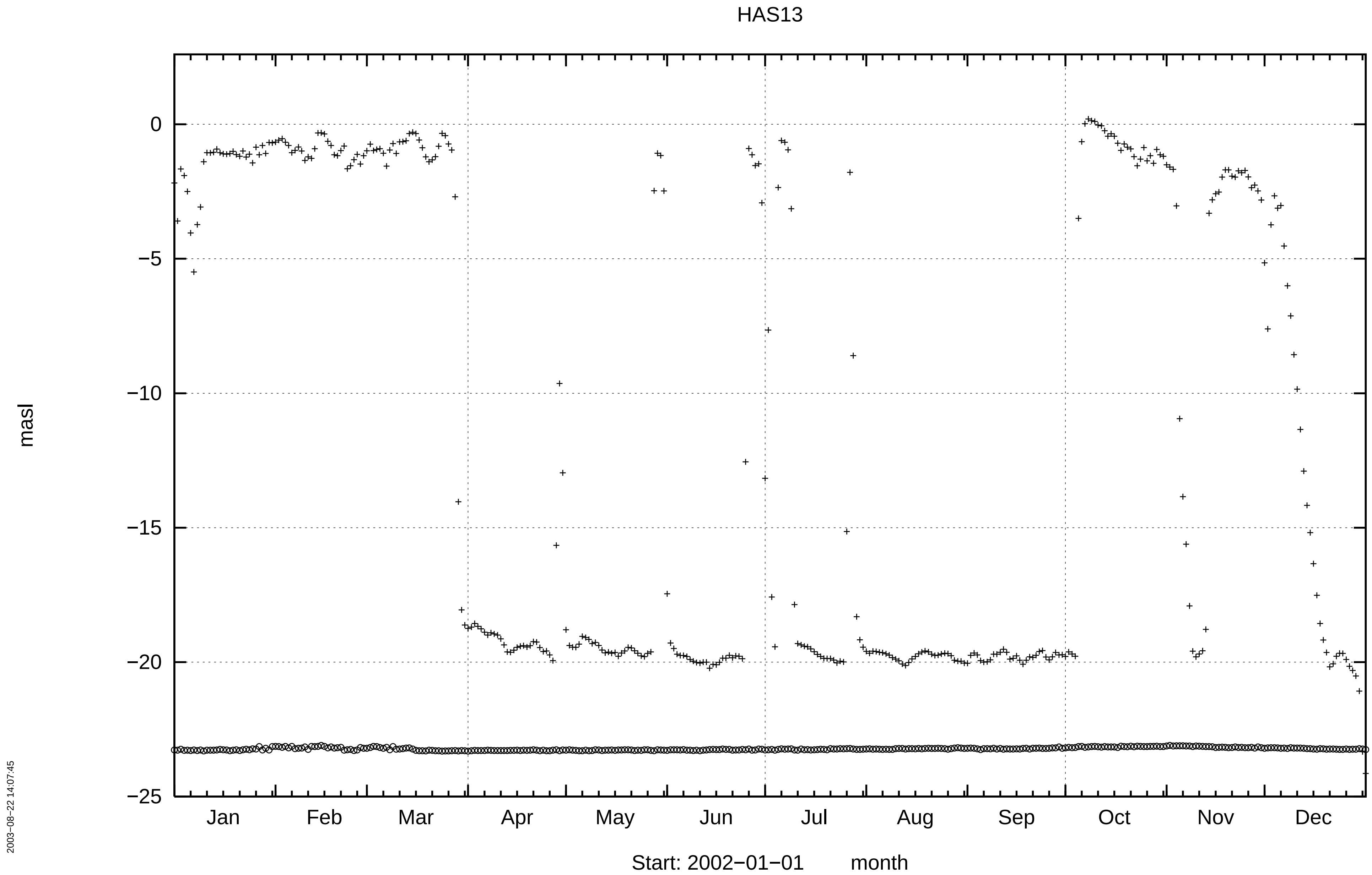
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:45


HAS11
masl
4
2
0
−2
−4
−6
−8
Packer installed
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:45


HAS12
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:45


HAS13
masl
0
−5
−10
−15
−20
−25
Jan
Feb
Mar
Apr
May
Jun
Jul
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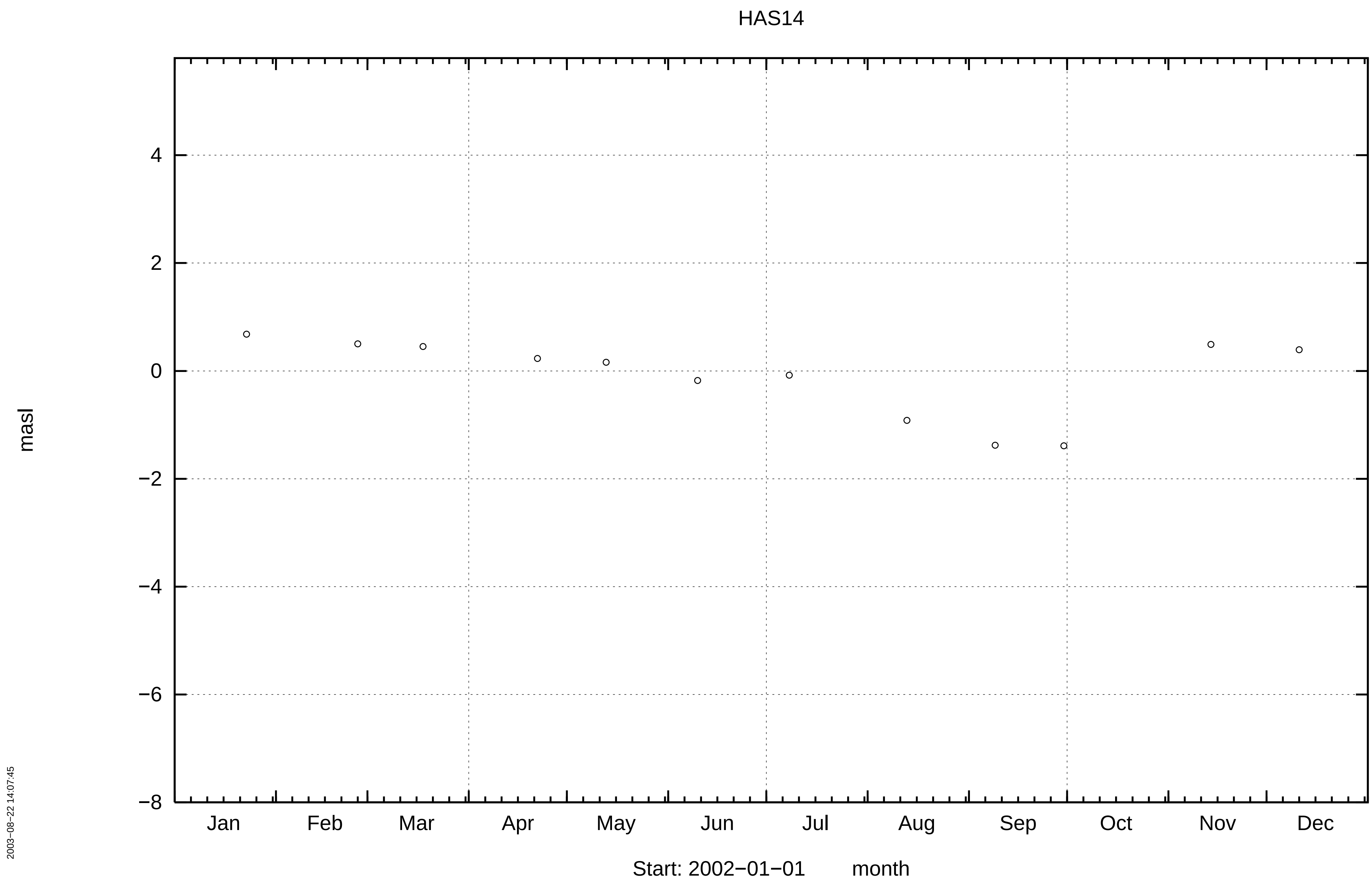
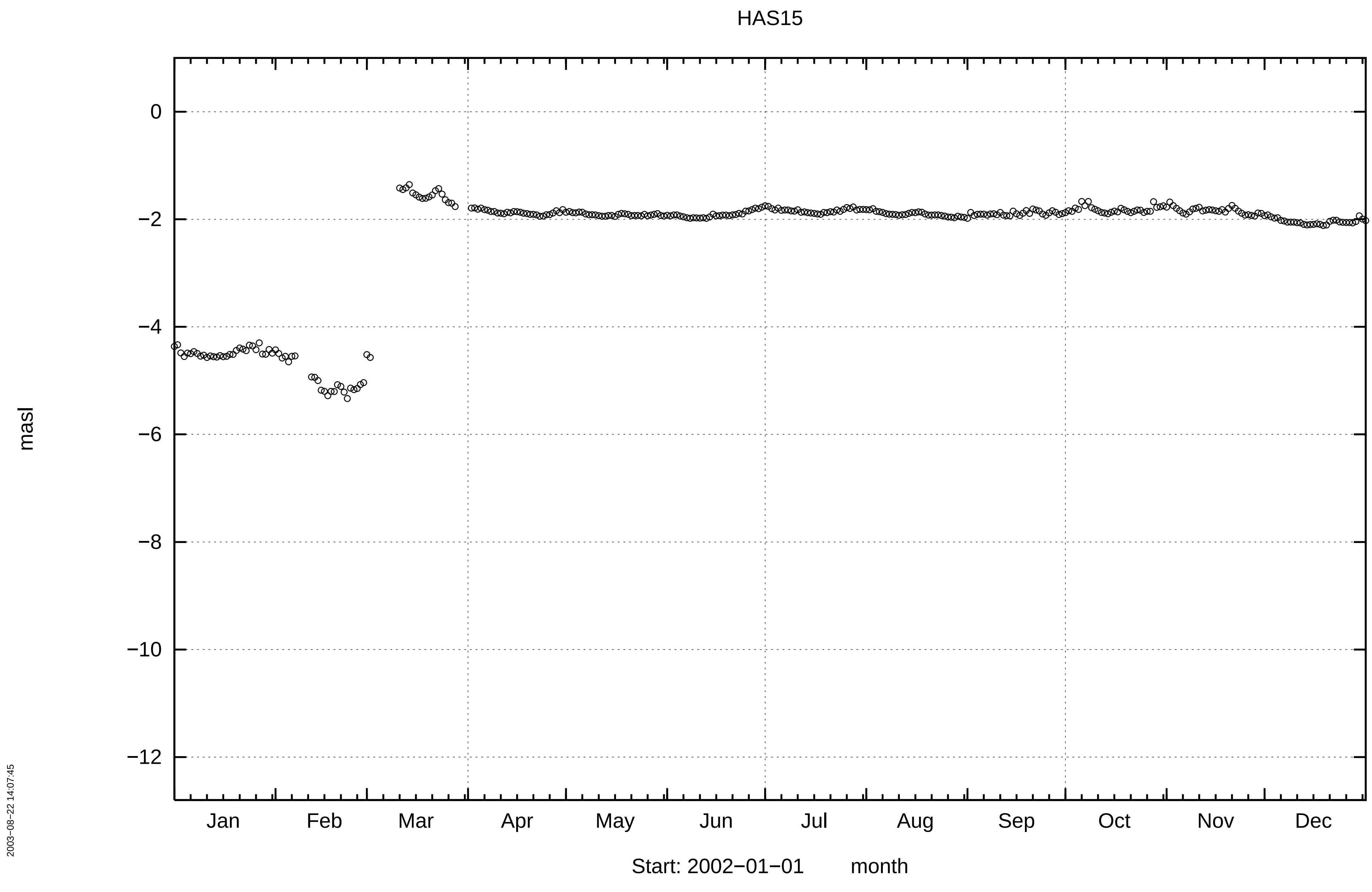
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:45



HAS14
4
2
0
−2
−4
−6
−8
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:45


HAS15
masl
0
−2
−4
−6
−8
−10
−12
Jan
Feb
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May
Jun
Jul
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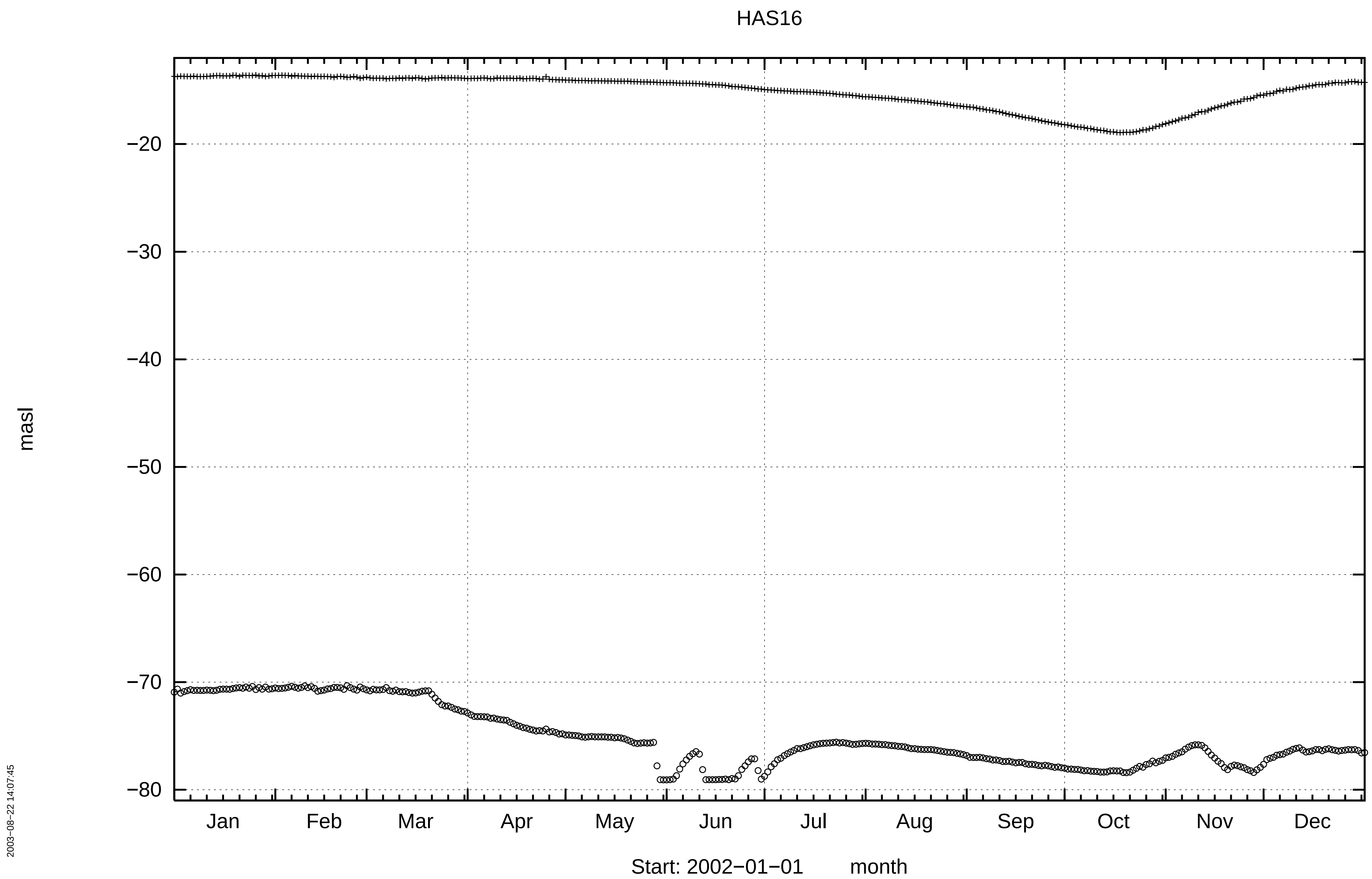
month
2003−08−22 14:07:45


HAS16
masl
−20
−30
−40
−50
−60
−70
−80
Jan
Feb
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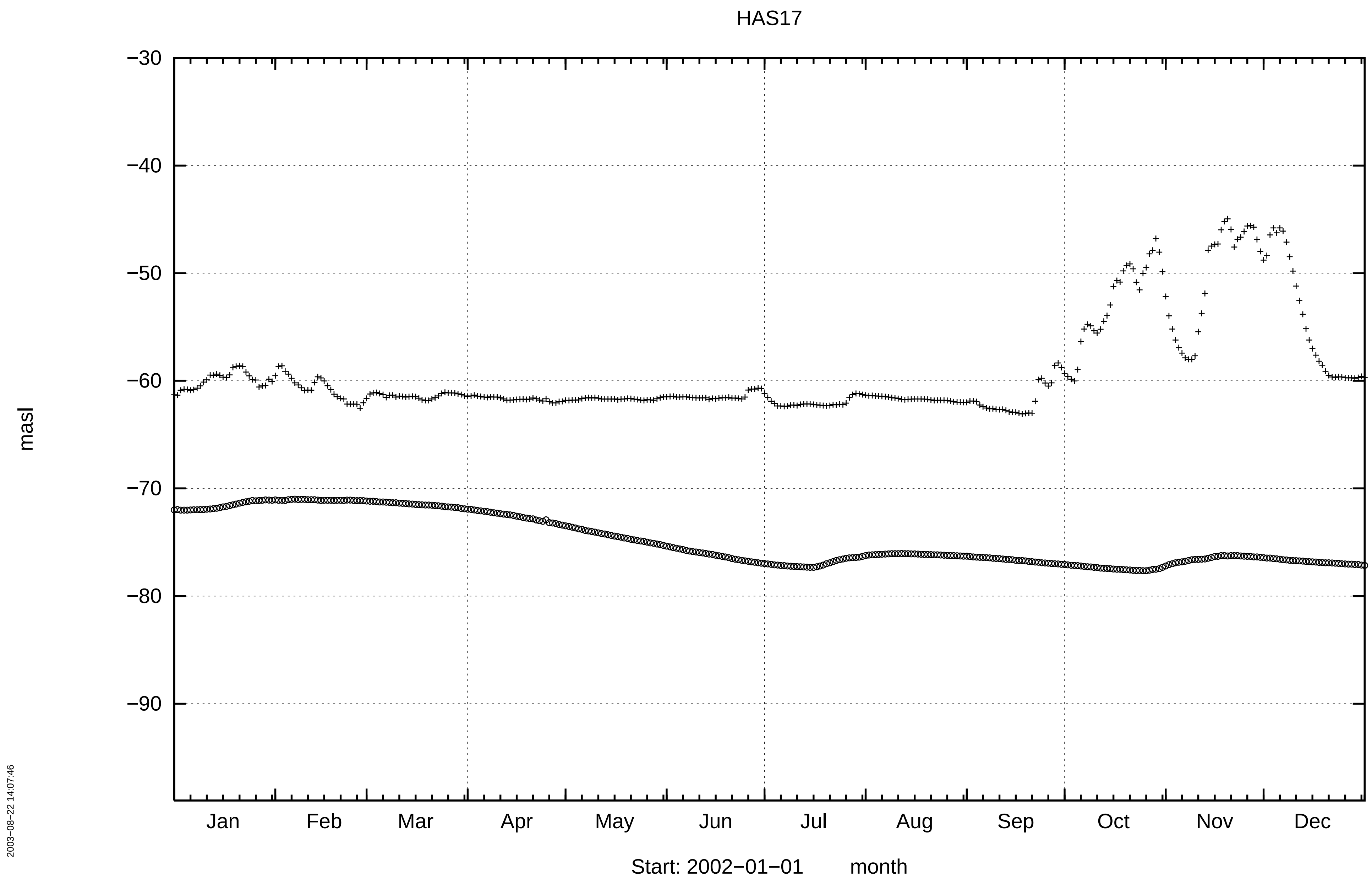
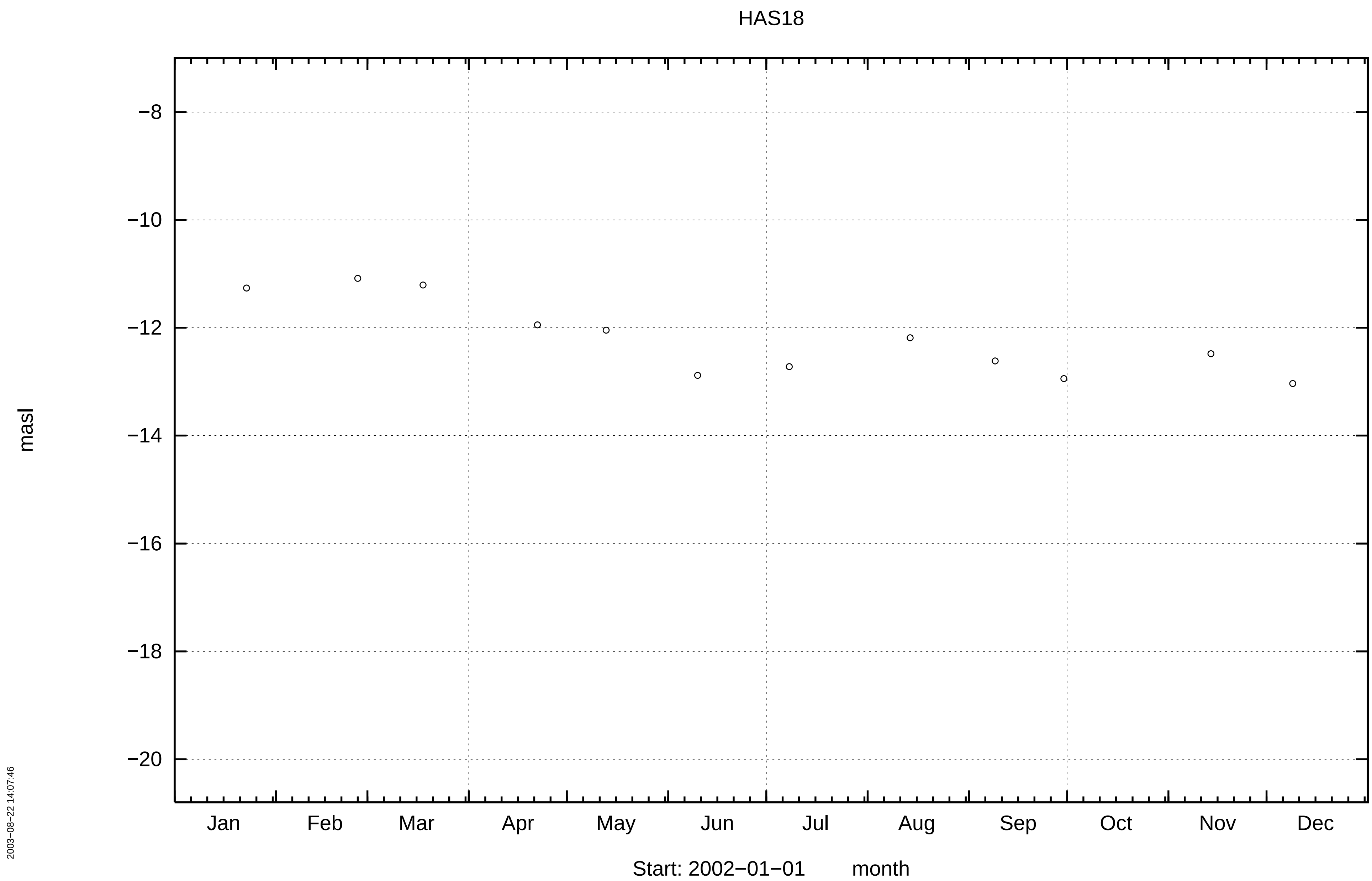
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:45


HAS17
masl
−30
−40
−50
−60
−70
−80
−90
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:46


HAS18
masl
−8
−10
−12
−14
−16
−18
−20
Jan
Feb
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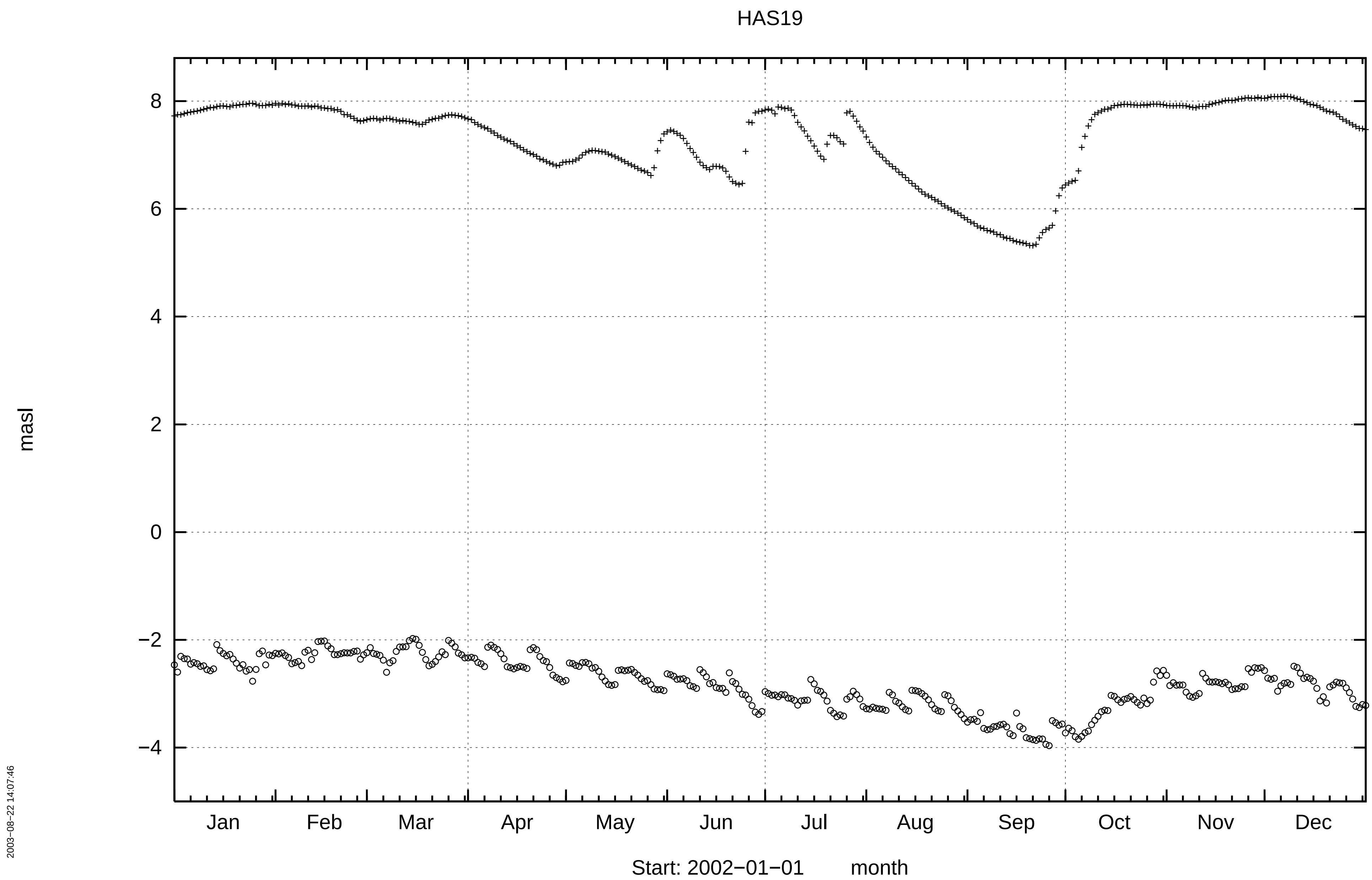
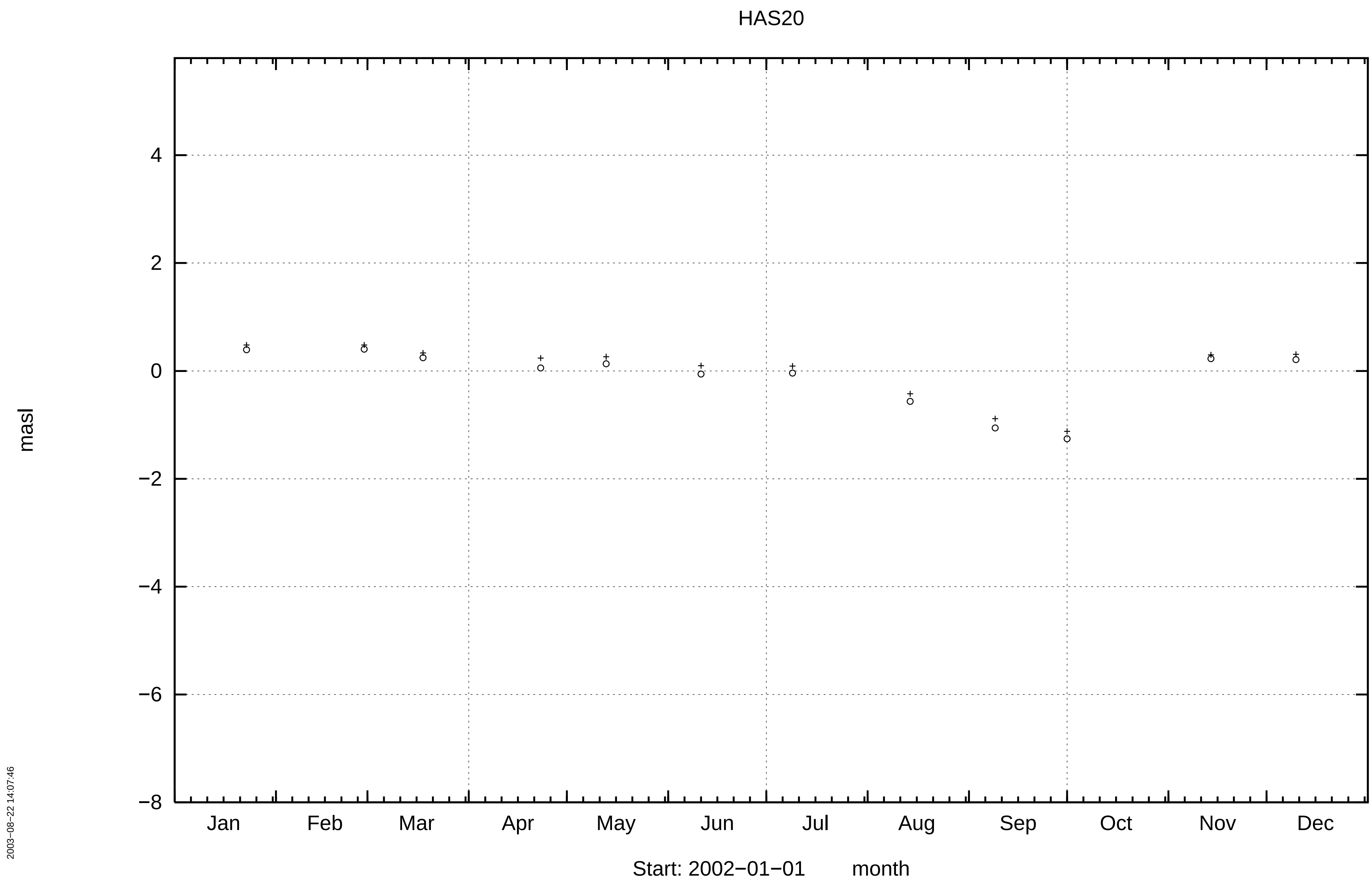
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:46


HAS19
masl
8
6
4
2
0
−2
−4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:46


HAS20
masl
4
2
0
−2
−4
−6
−8
Jan
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Sep
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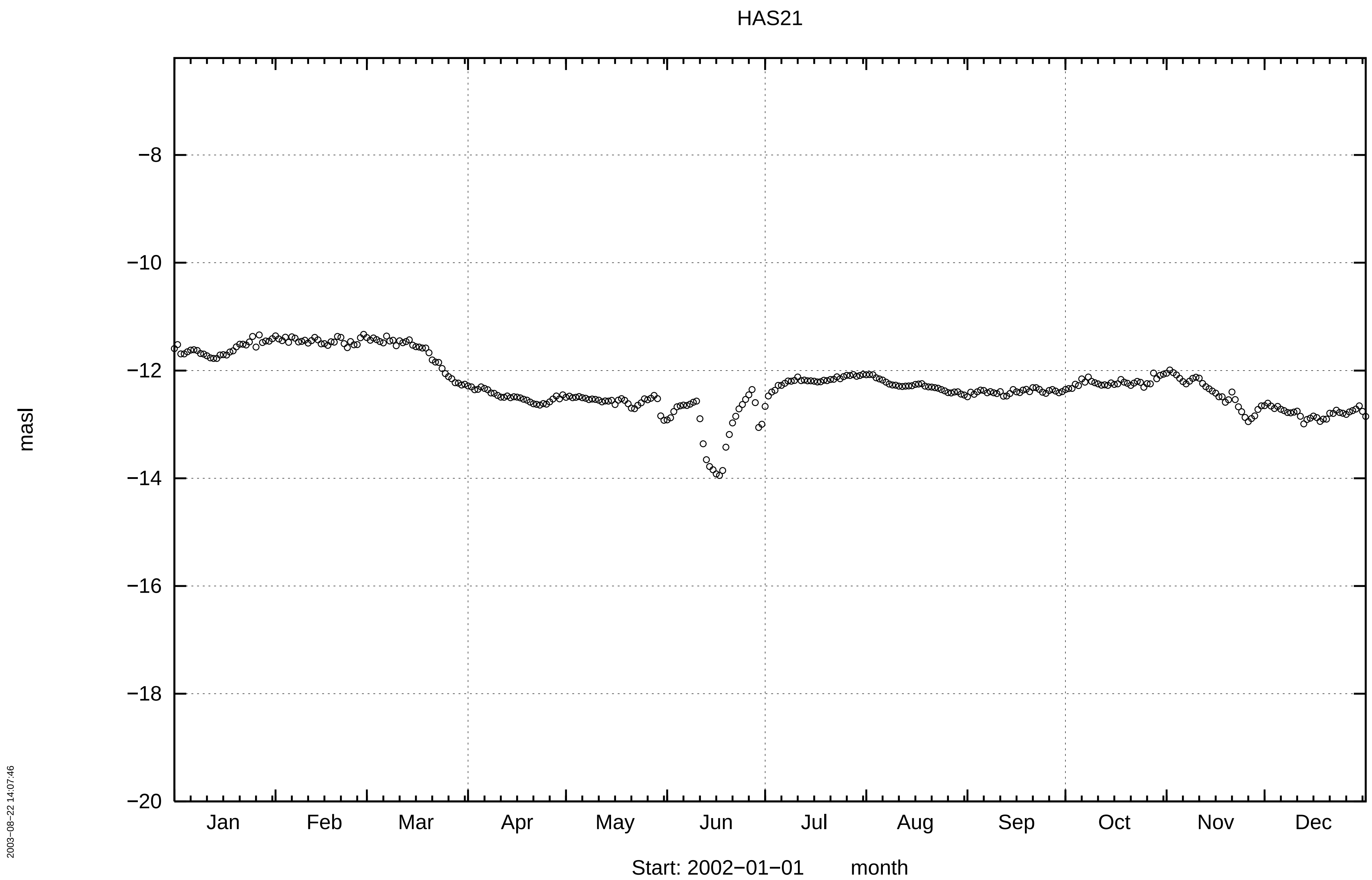
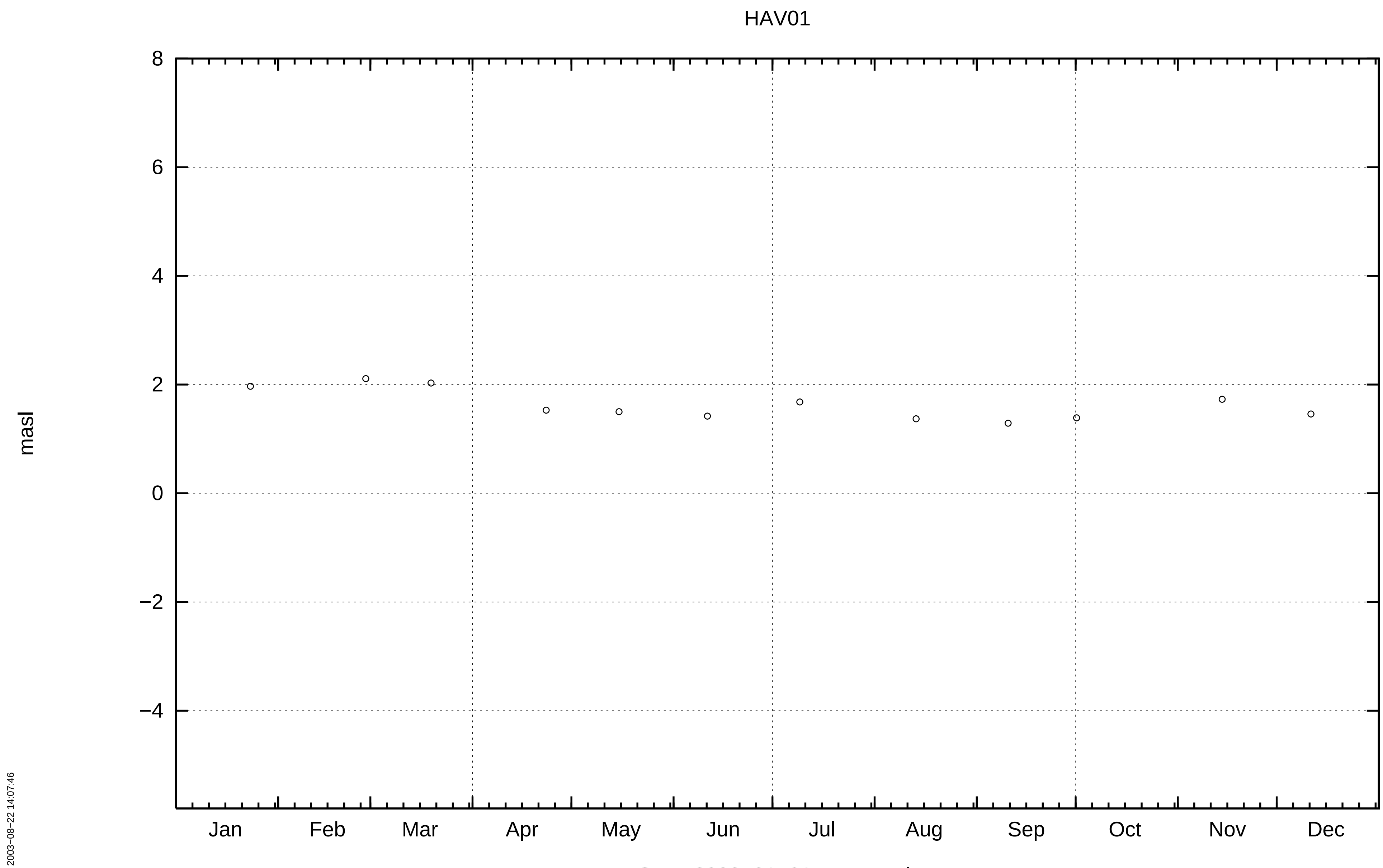
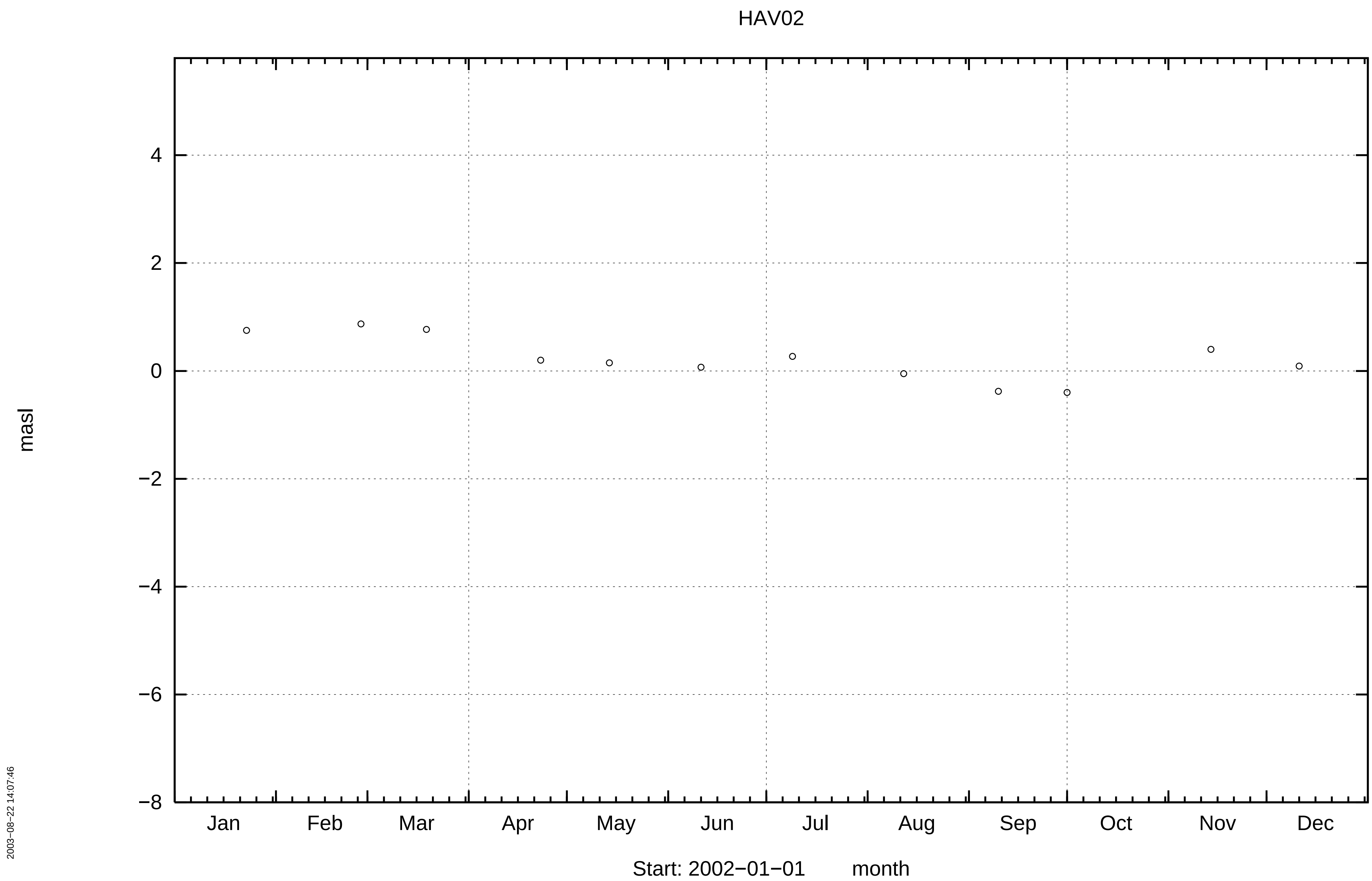
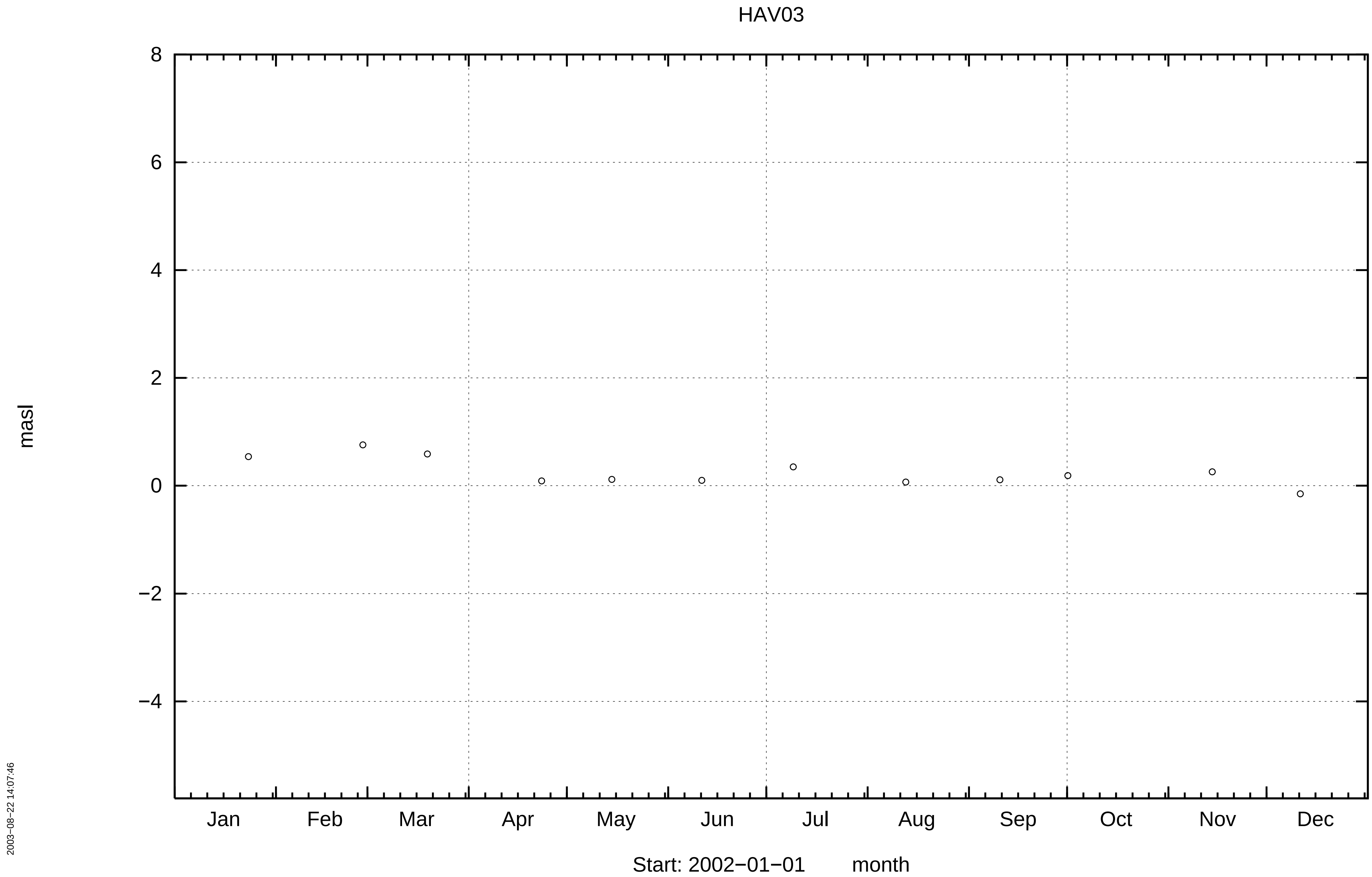
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:46

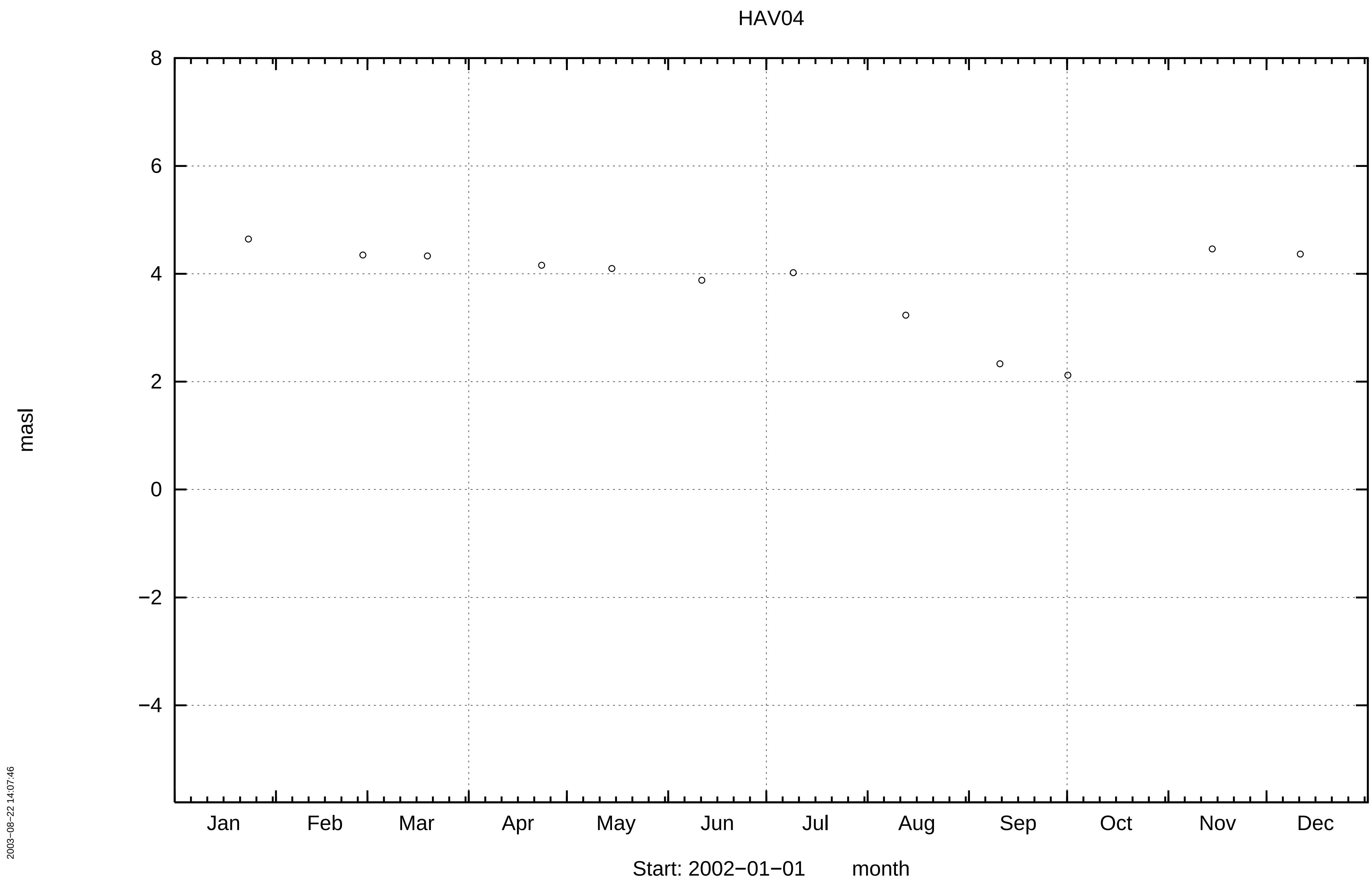


HAS21
masl
−8
−10
−12
−14
−16
−18
−20
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:46


HAV01
8
6
4
2
0
−2
−4
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:46


HAV02
4
2
0
−2
−4
−6
−8
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:46


HAV03
8
6
4
2
0
−2
−4
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:46


HAV04
masl
8
6
4
2
0
−2
−4
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Feb
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May
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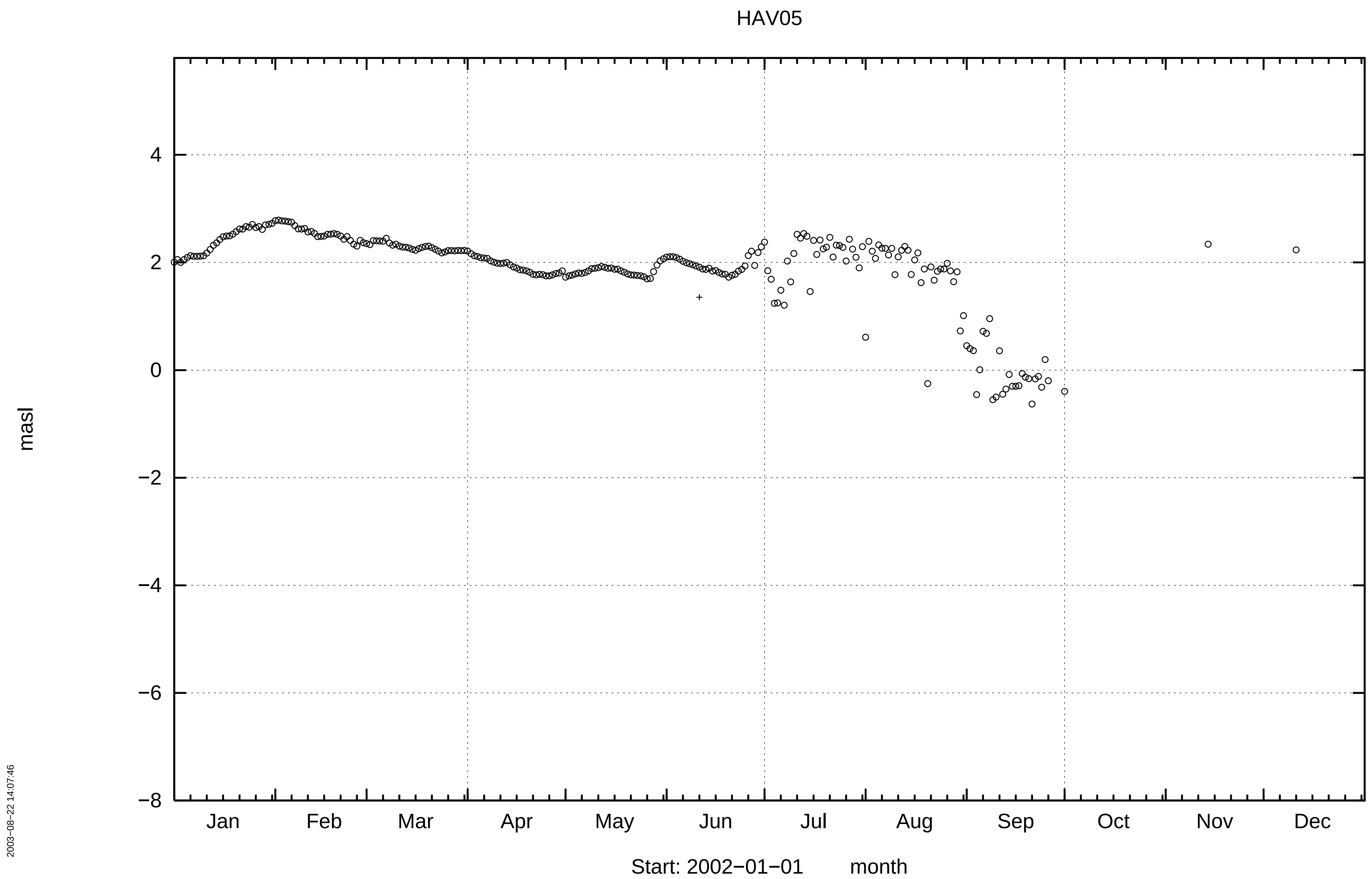
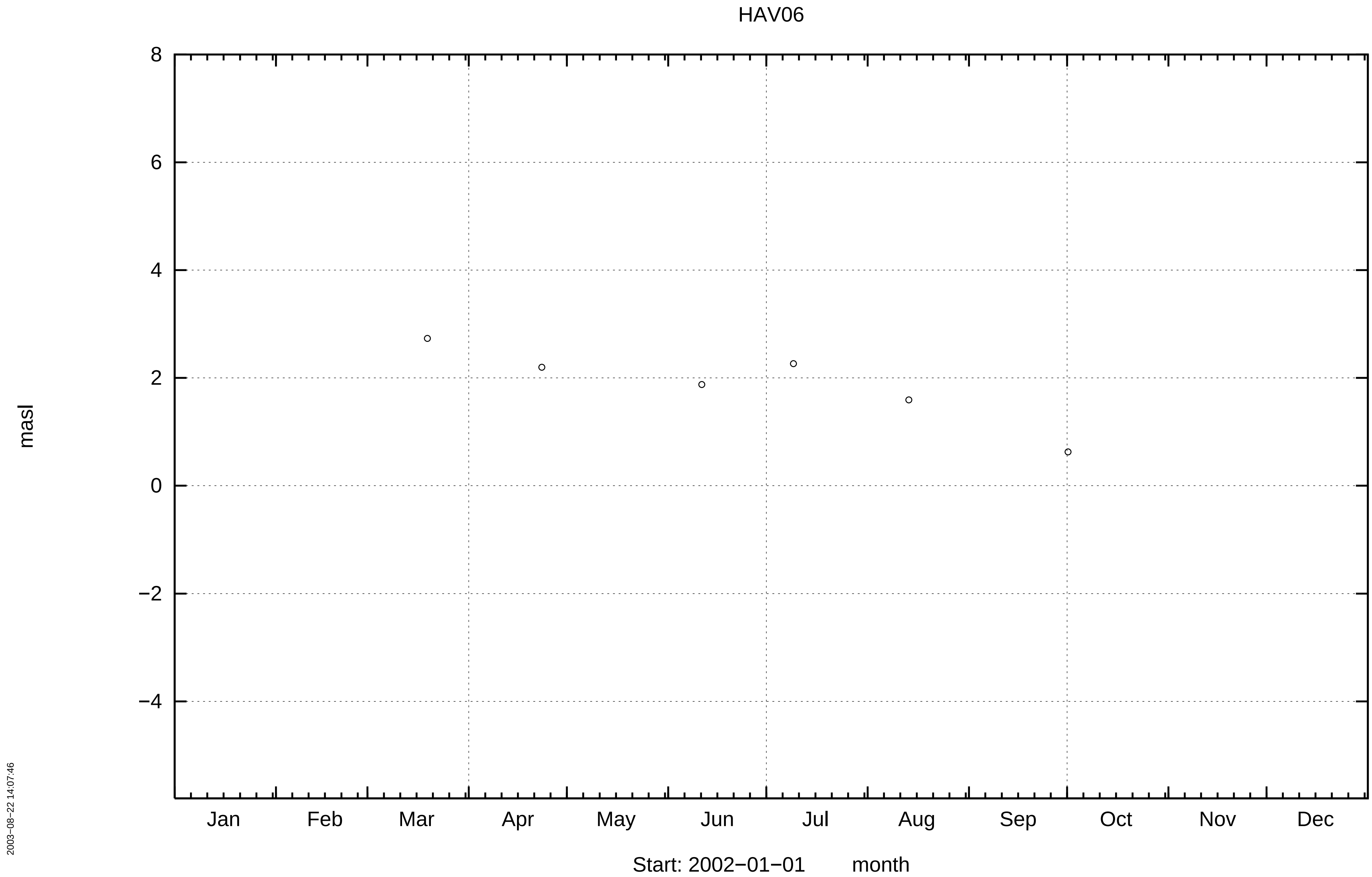
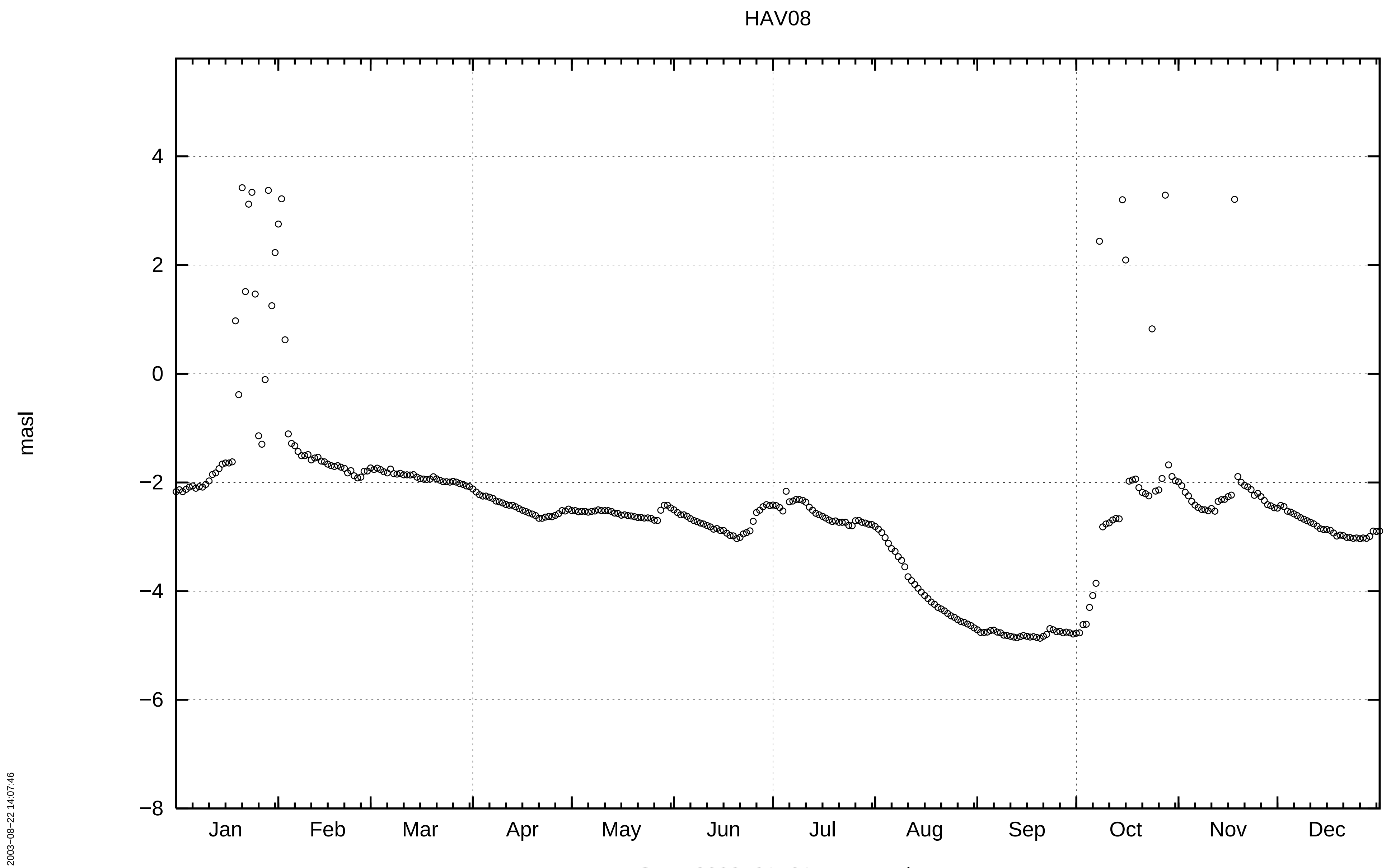
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:46

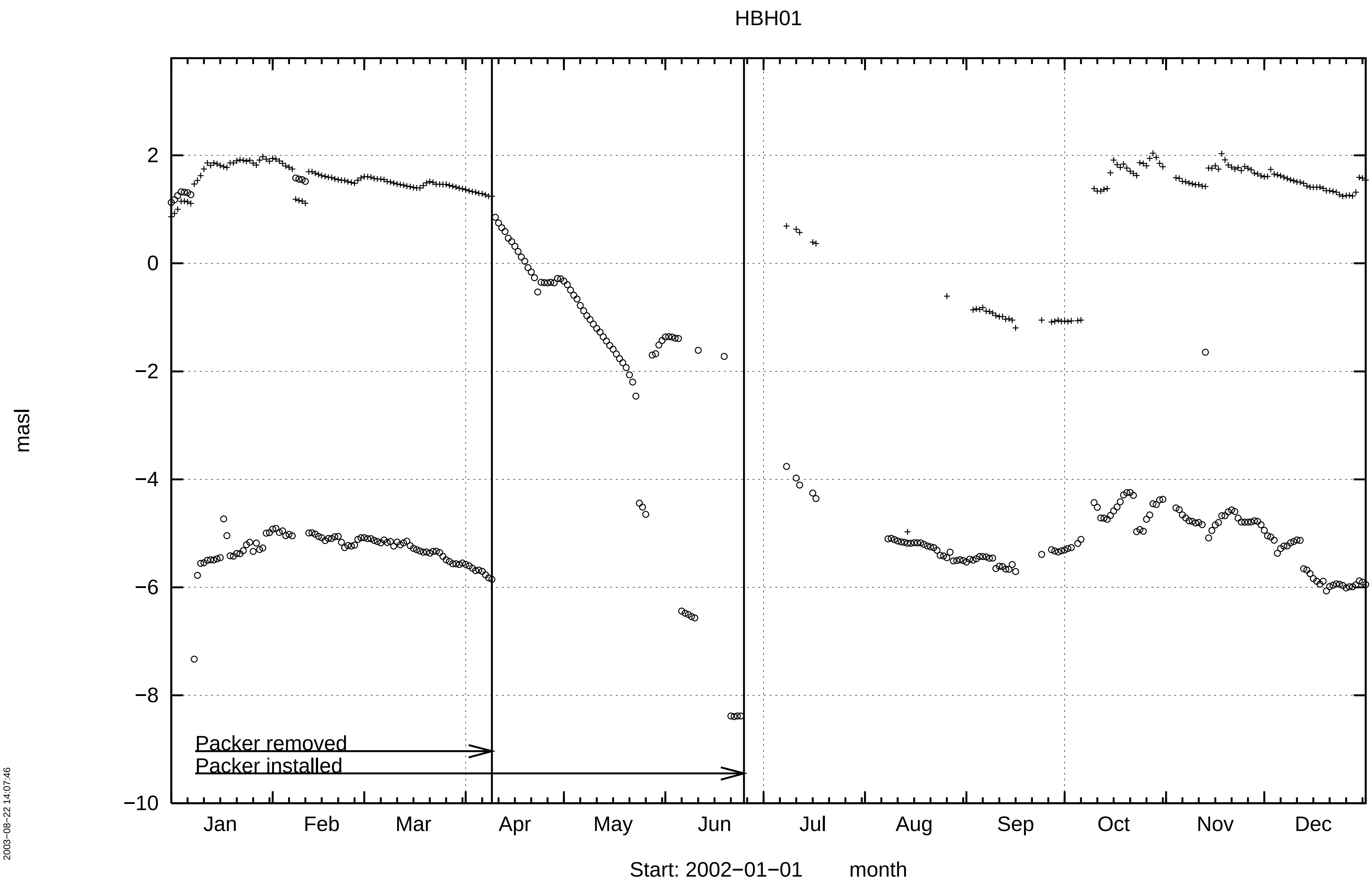

HAV05
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:46

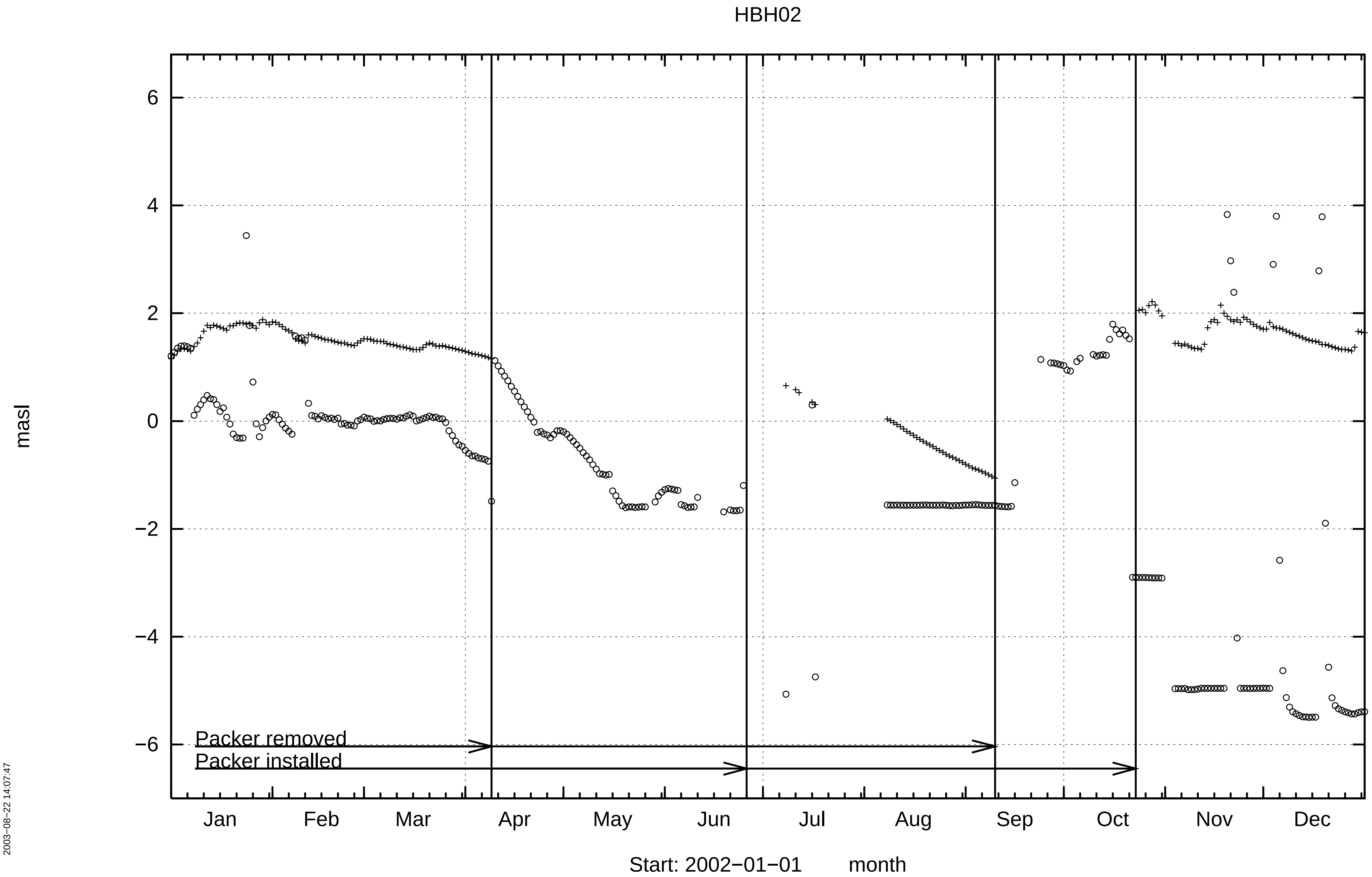


HAV06
8
6
4
2
0
−2
−4
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:46



HAV08
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:46


HBH01
masl
2
0
−2
−4
−6
−8
−10
Packer removed
Packer installed
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:46


HBH02
masl
6
4
2
0
−2
−4
−6
Packer removed
Packer installed
Jan
Feb
Mar
Apr
May
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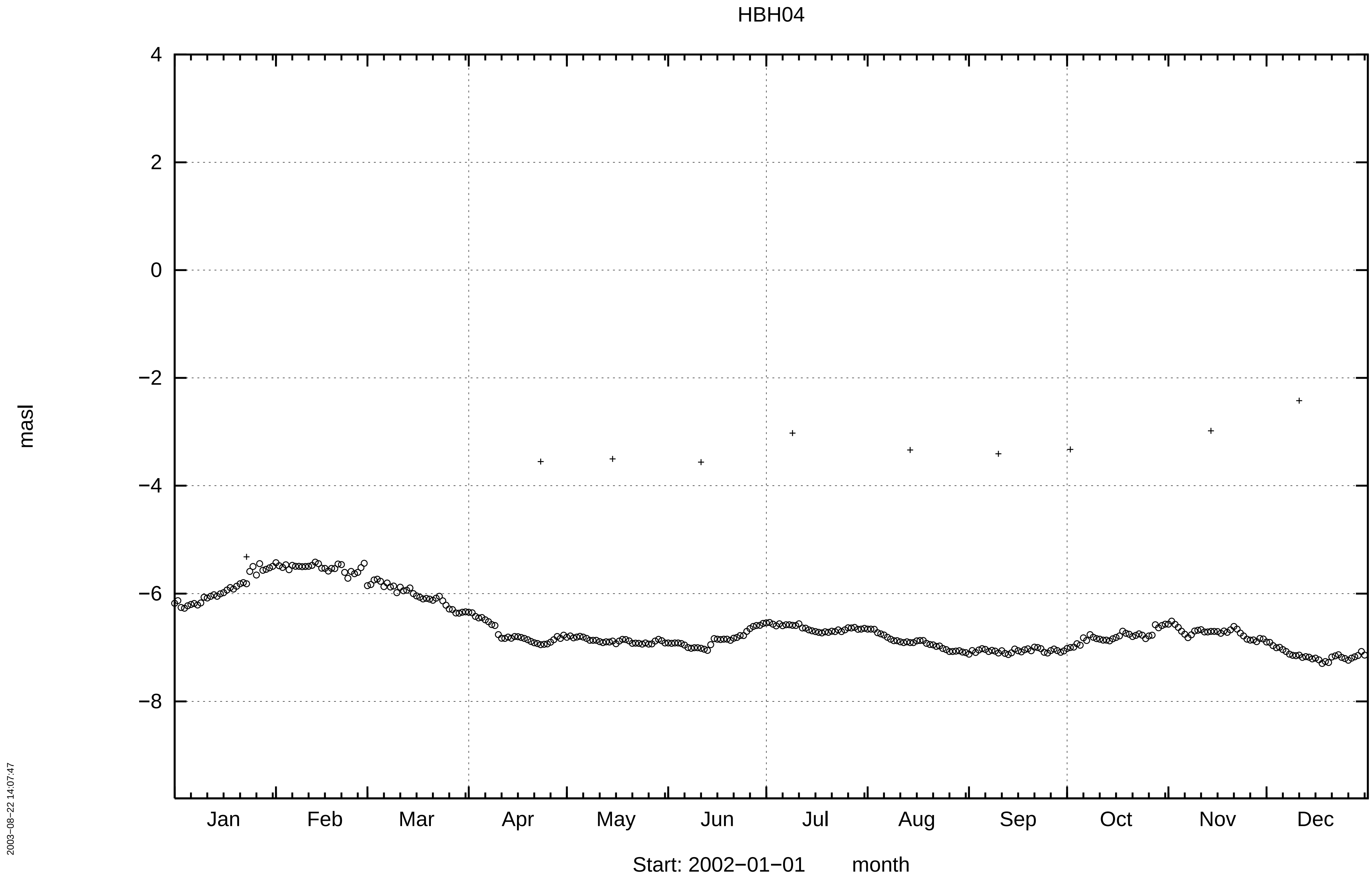
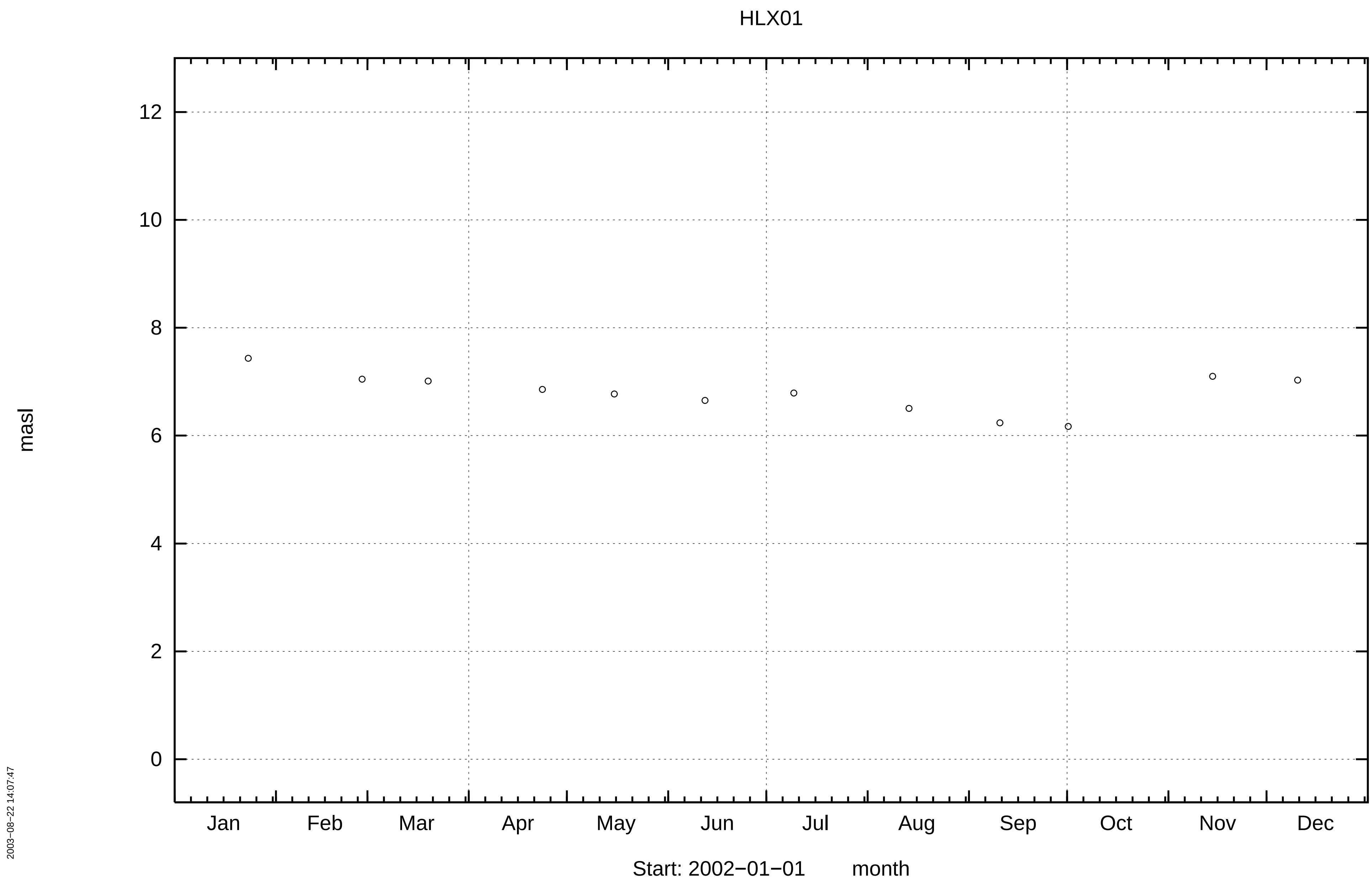
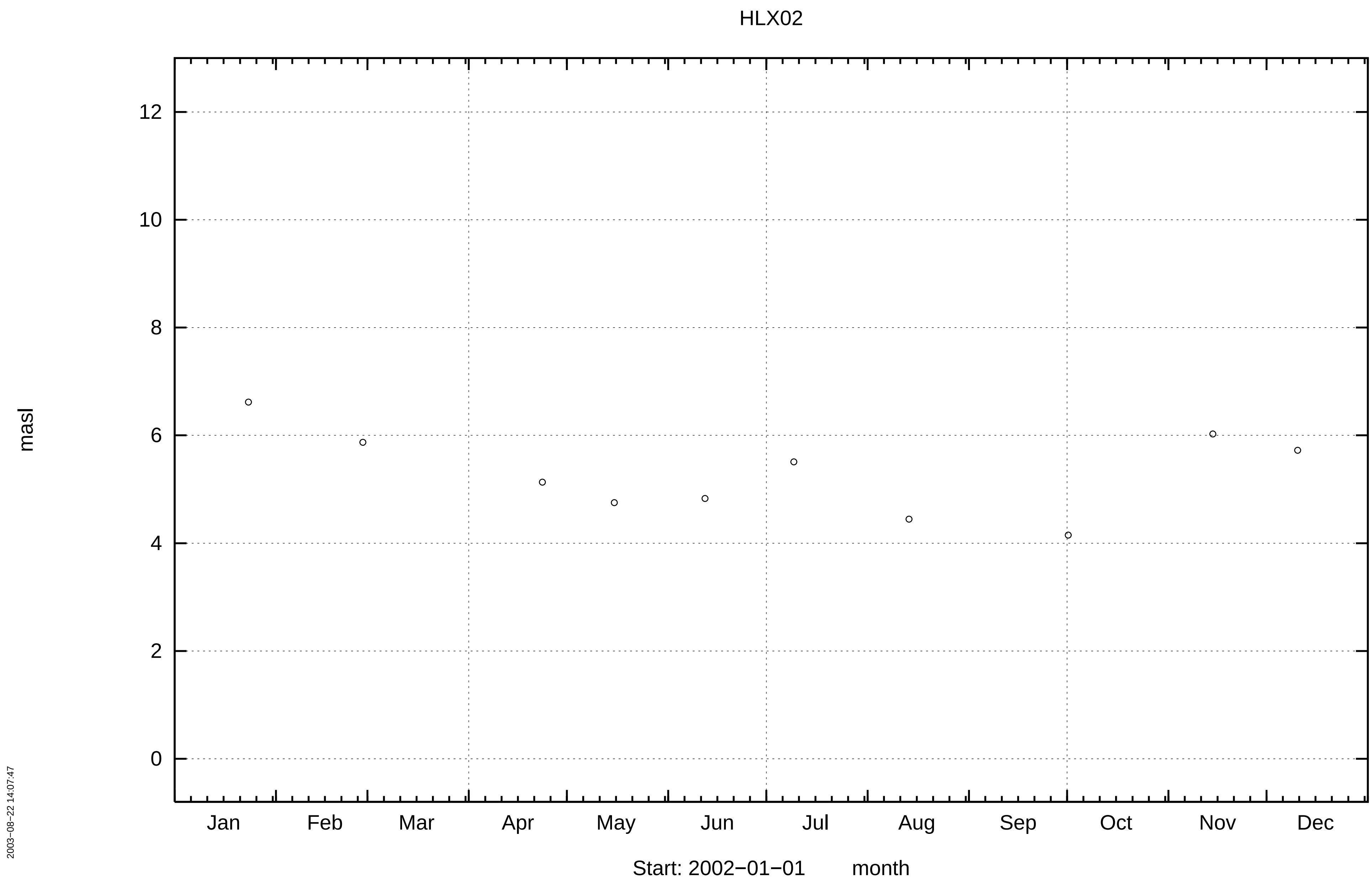
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:47


HBH04
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:47


HLX01
masl
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:47



HLX02
masl
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
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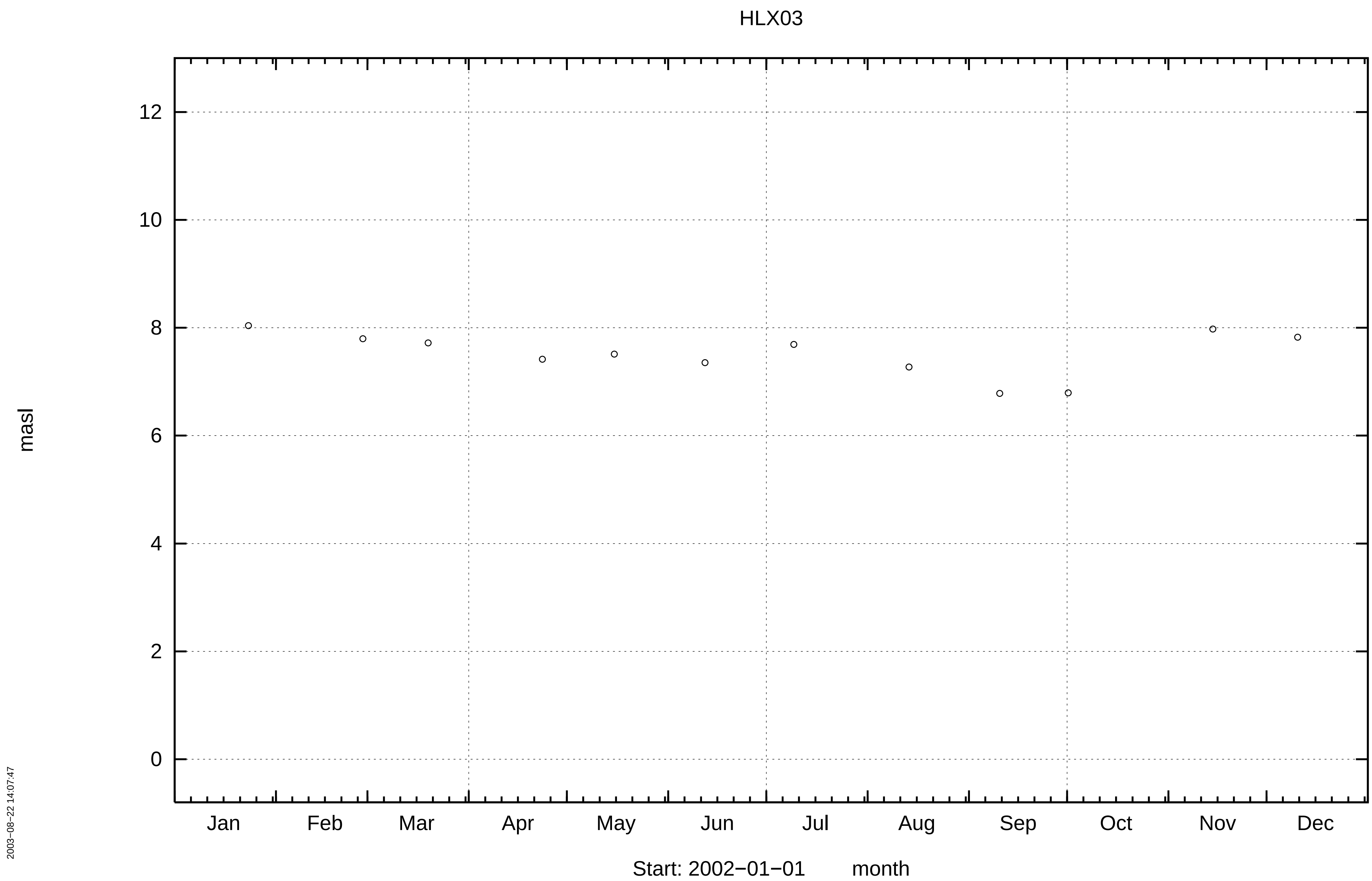
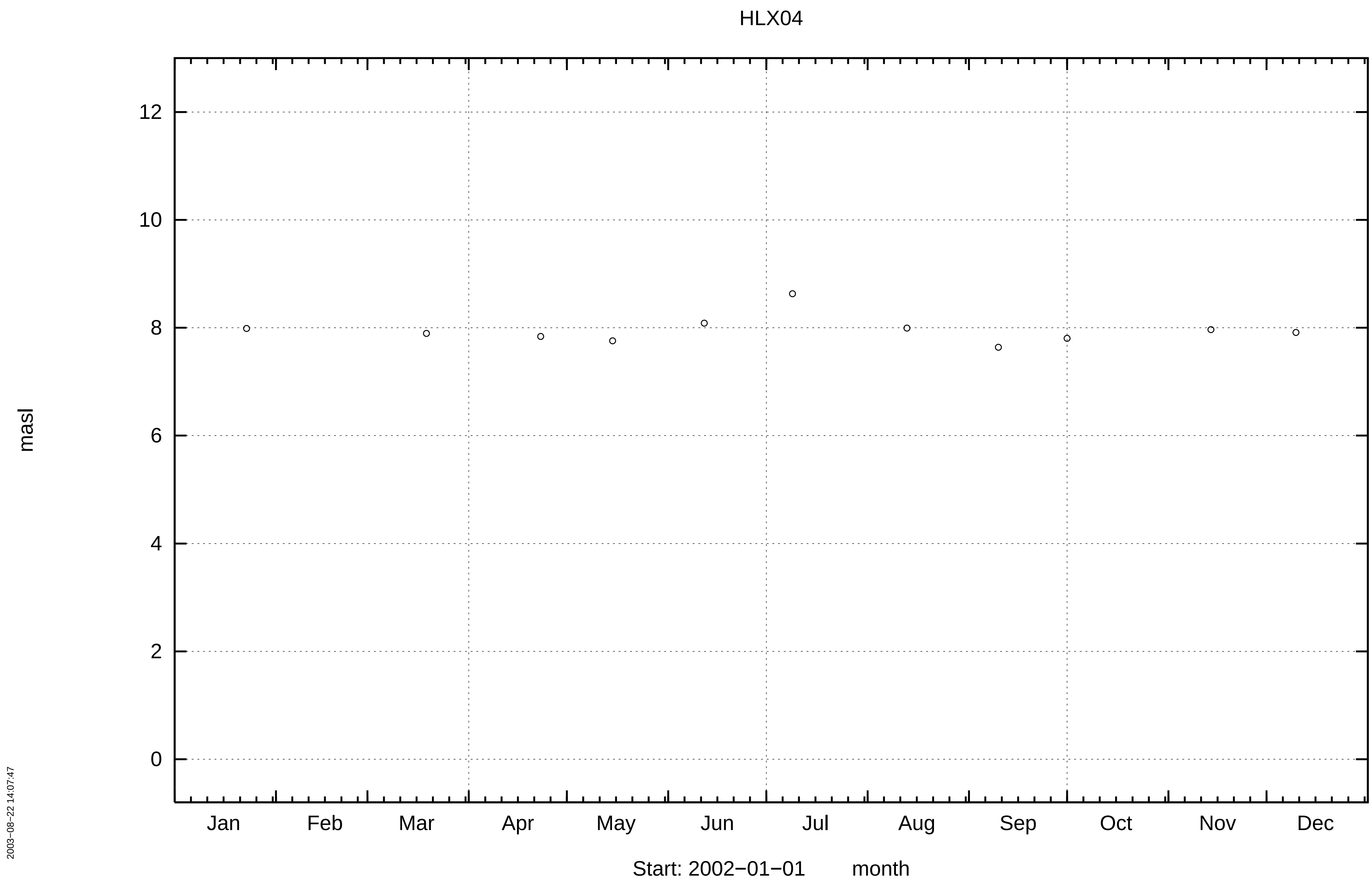
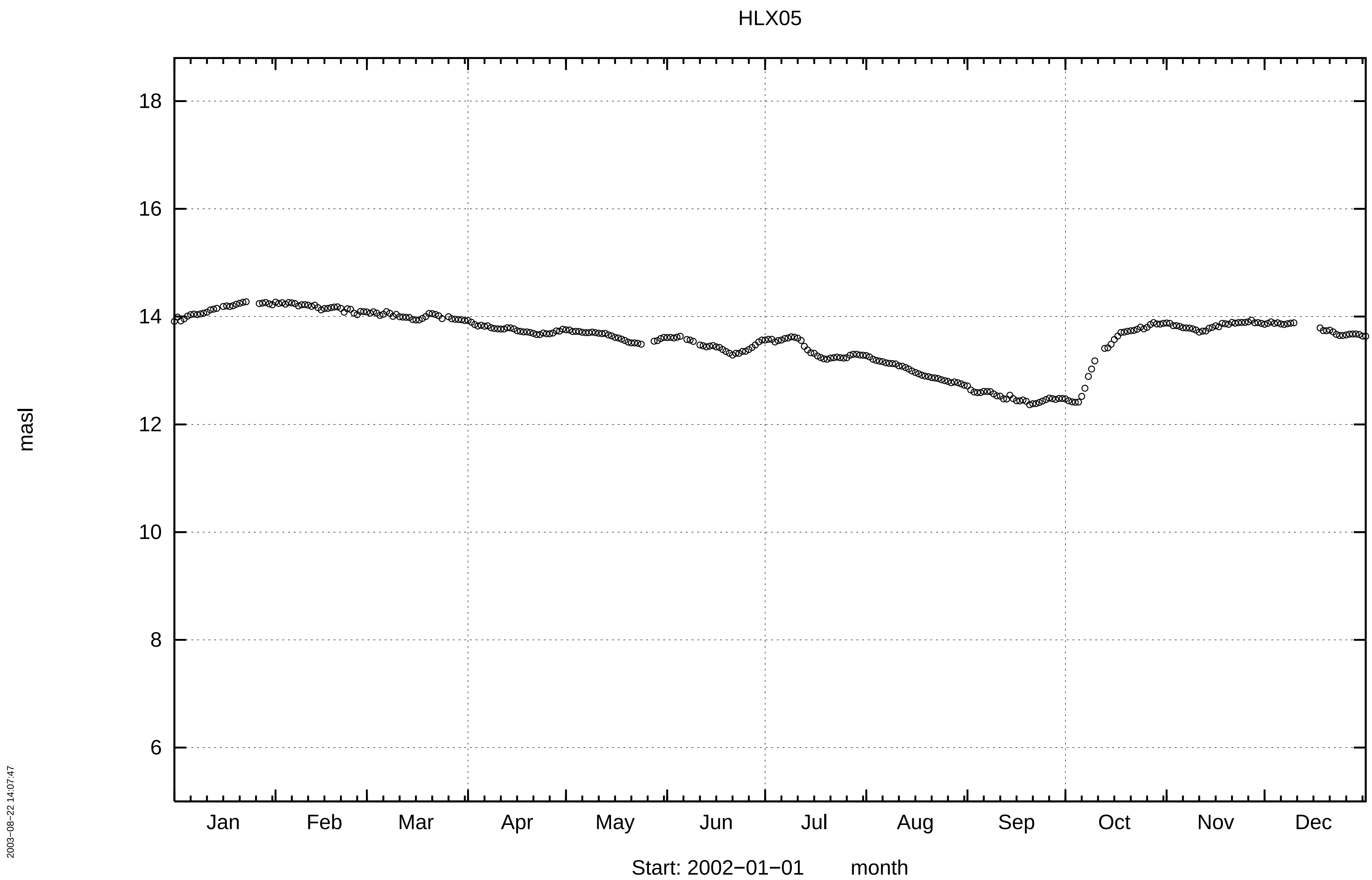
Dec
Start: 2002−01−01
month
2003−08−22 14:07:47


HLX03
masl
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:47


HLX04
masl
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:47



HLX05
18
16
14
12
10
8
6
masl
Jan
Feb
Mar
Apr
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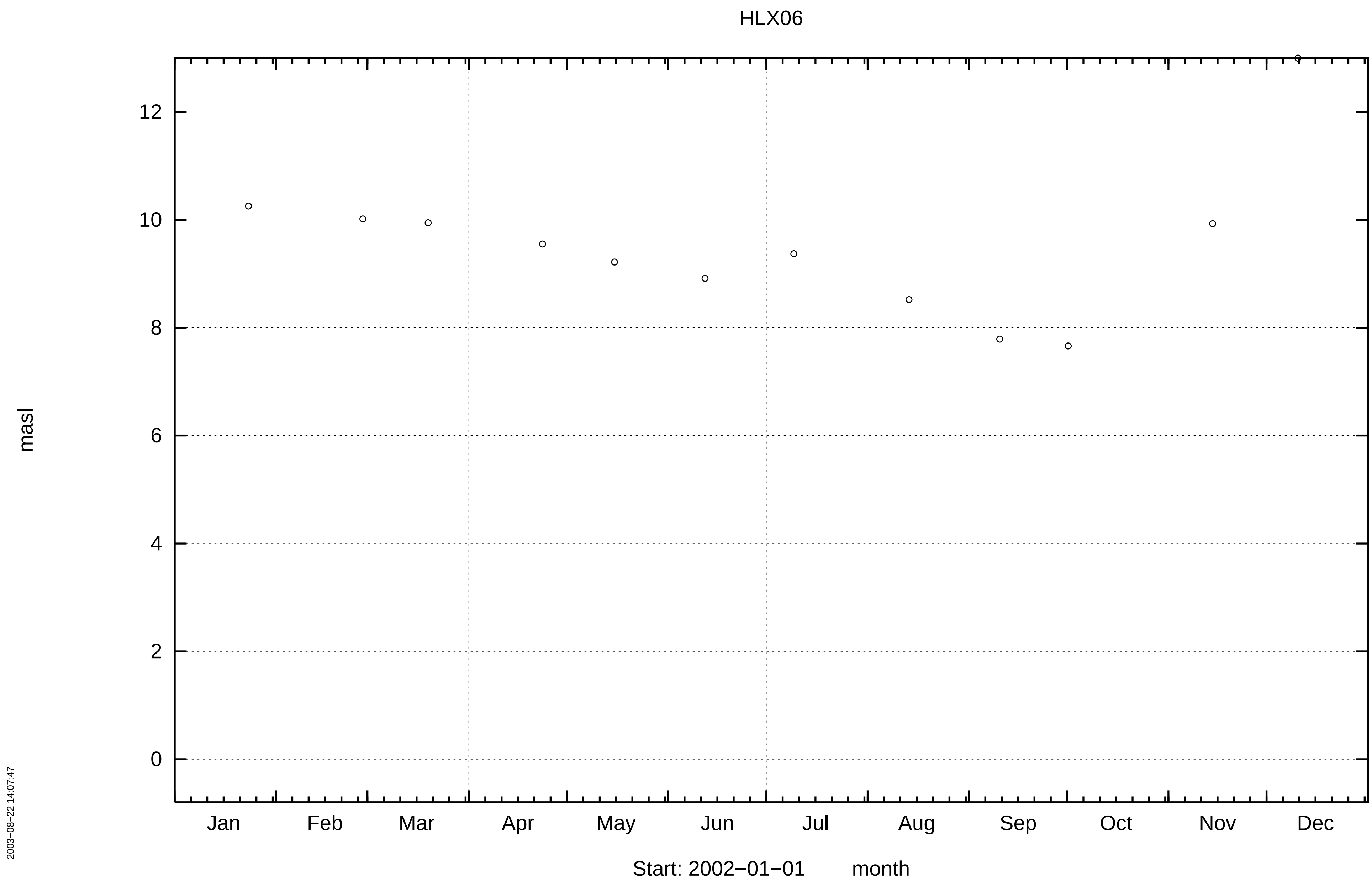
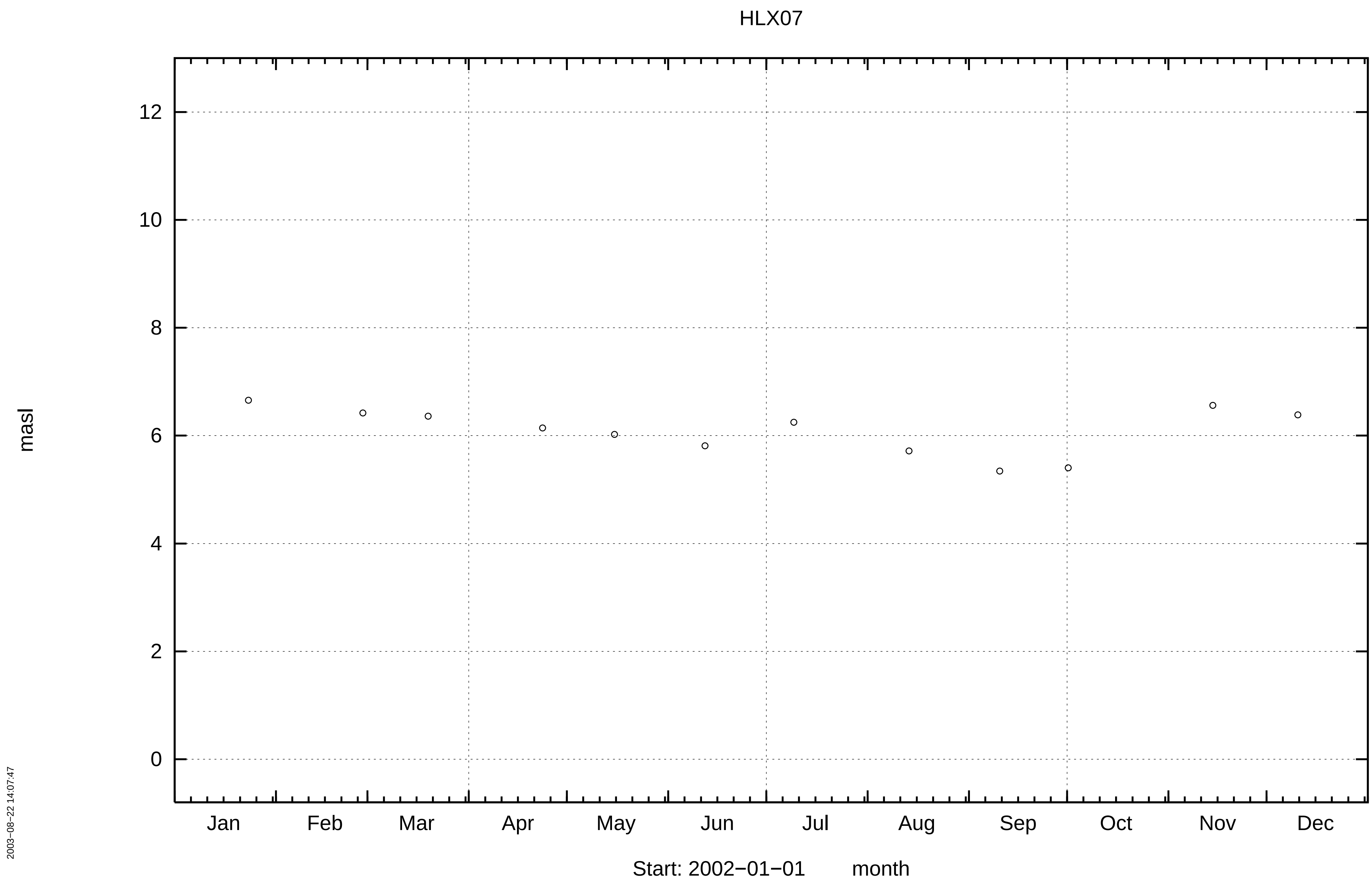
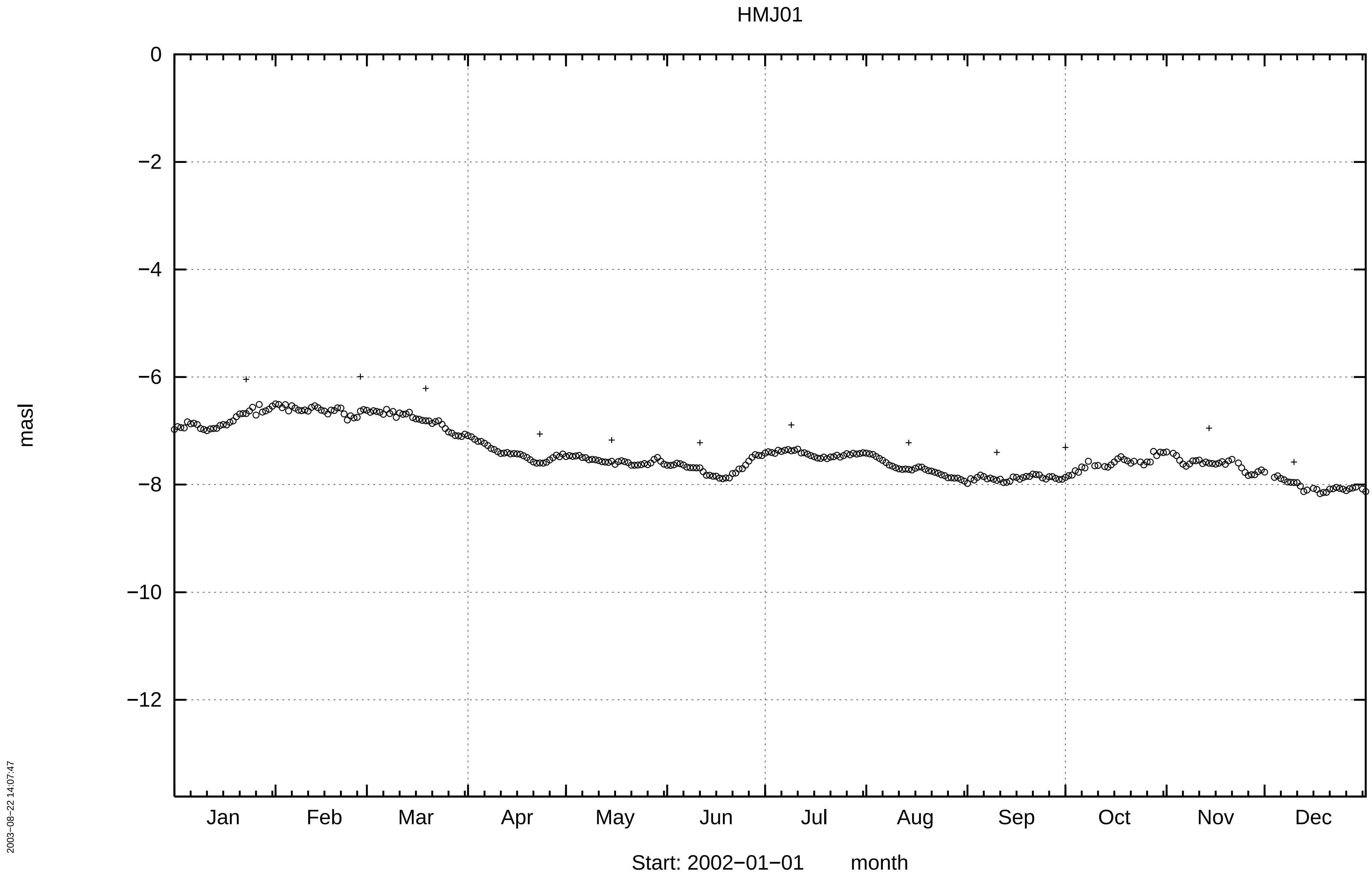
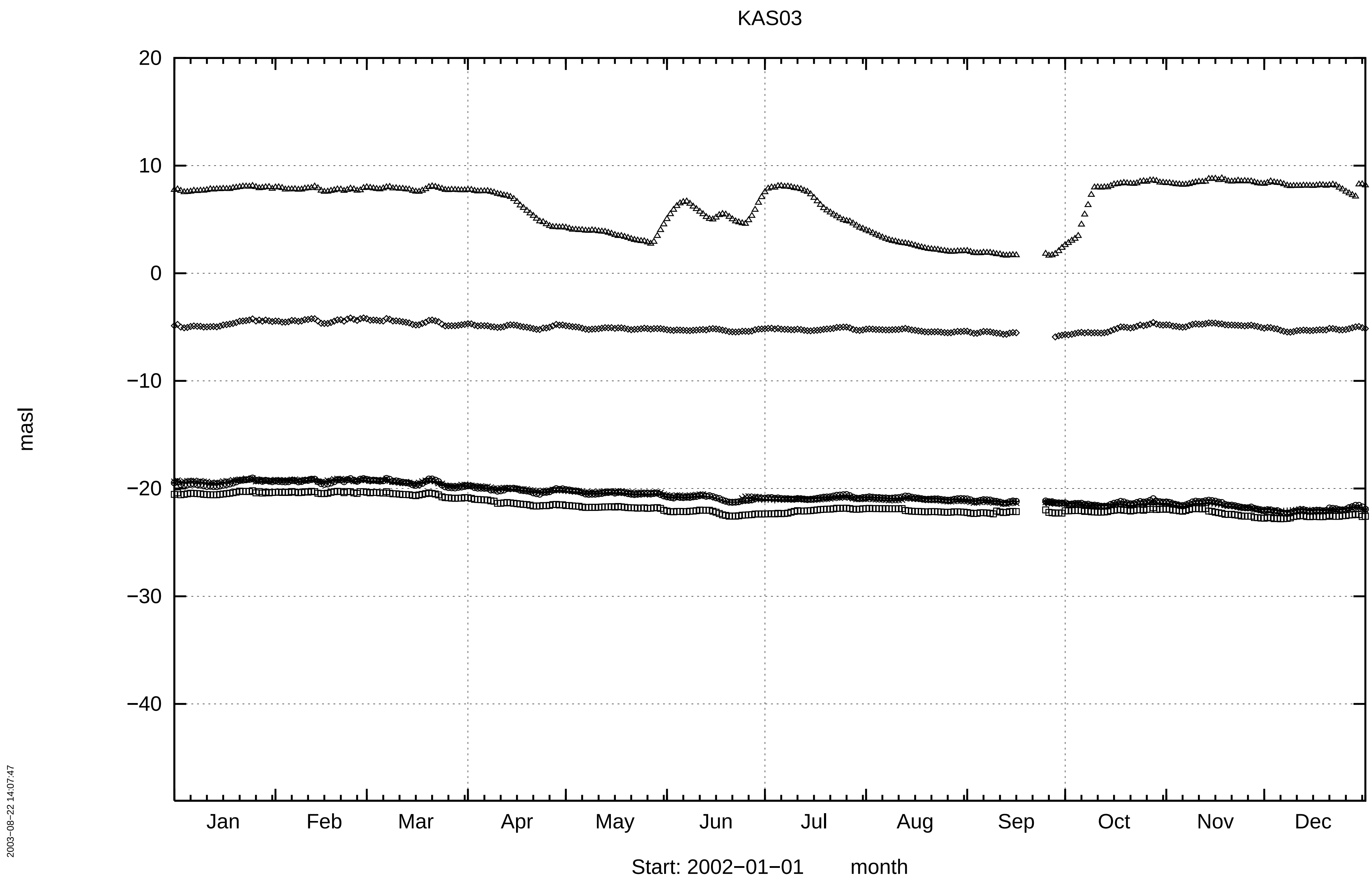
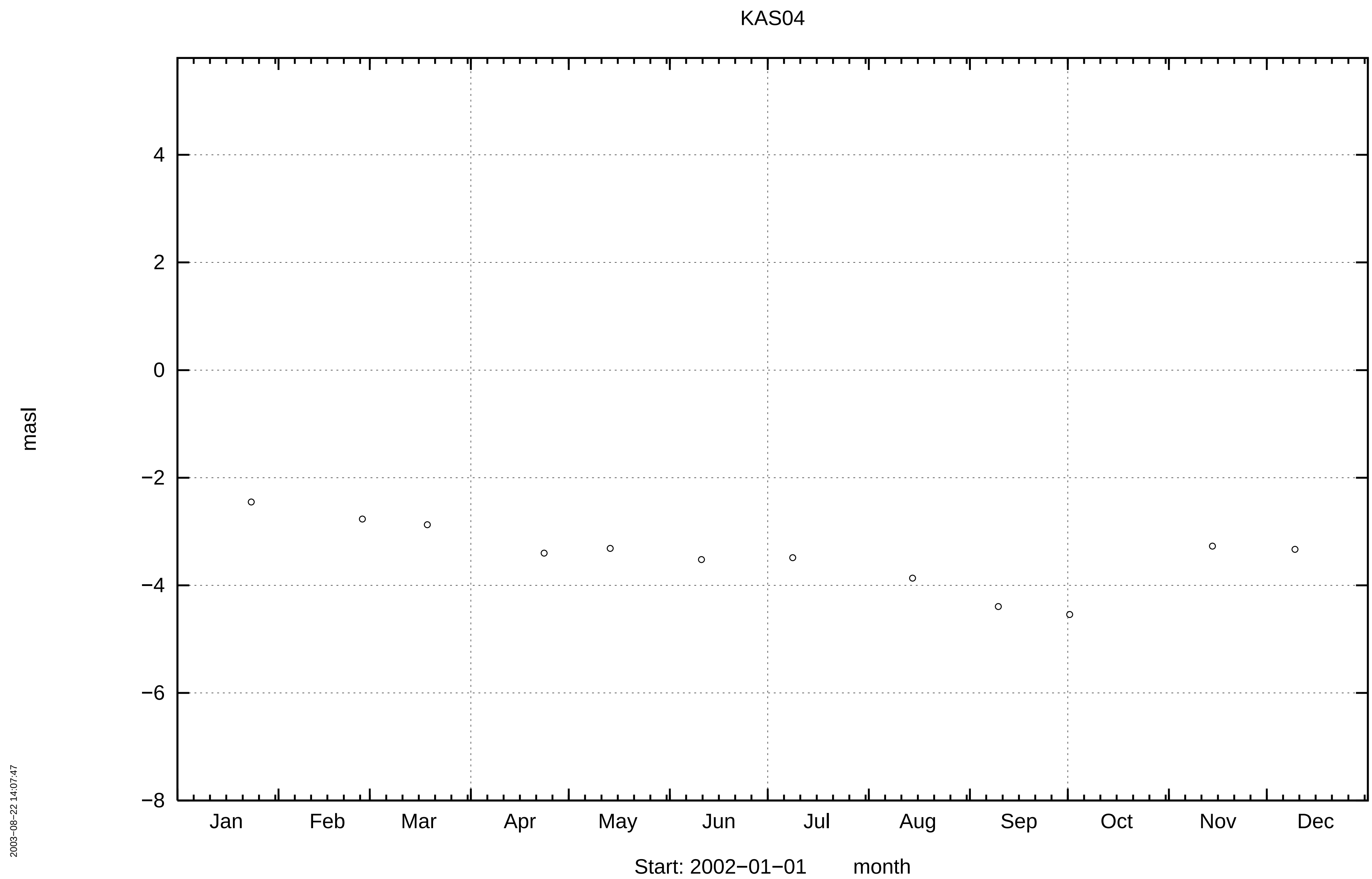
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:47


HLX06
masl
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:47


HLX07
masl
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:47


HMJ01
masl
0
−2
−4
−6
−8
−10
−12
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:47


KAS03
20
10
0
−10
−20
−30
−40
masl
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:47



KAS04
masl
4
2
0
−2
−4
−6
−8
Jan
Feb
Mar
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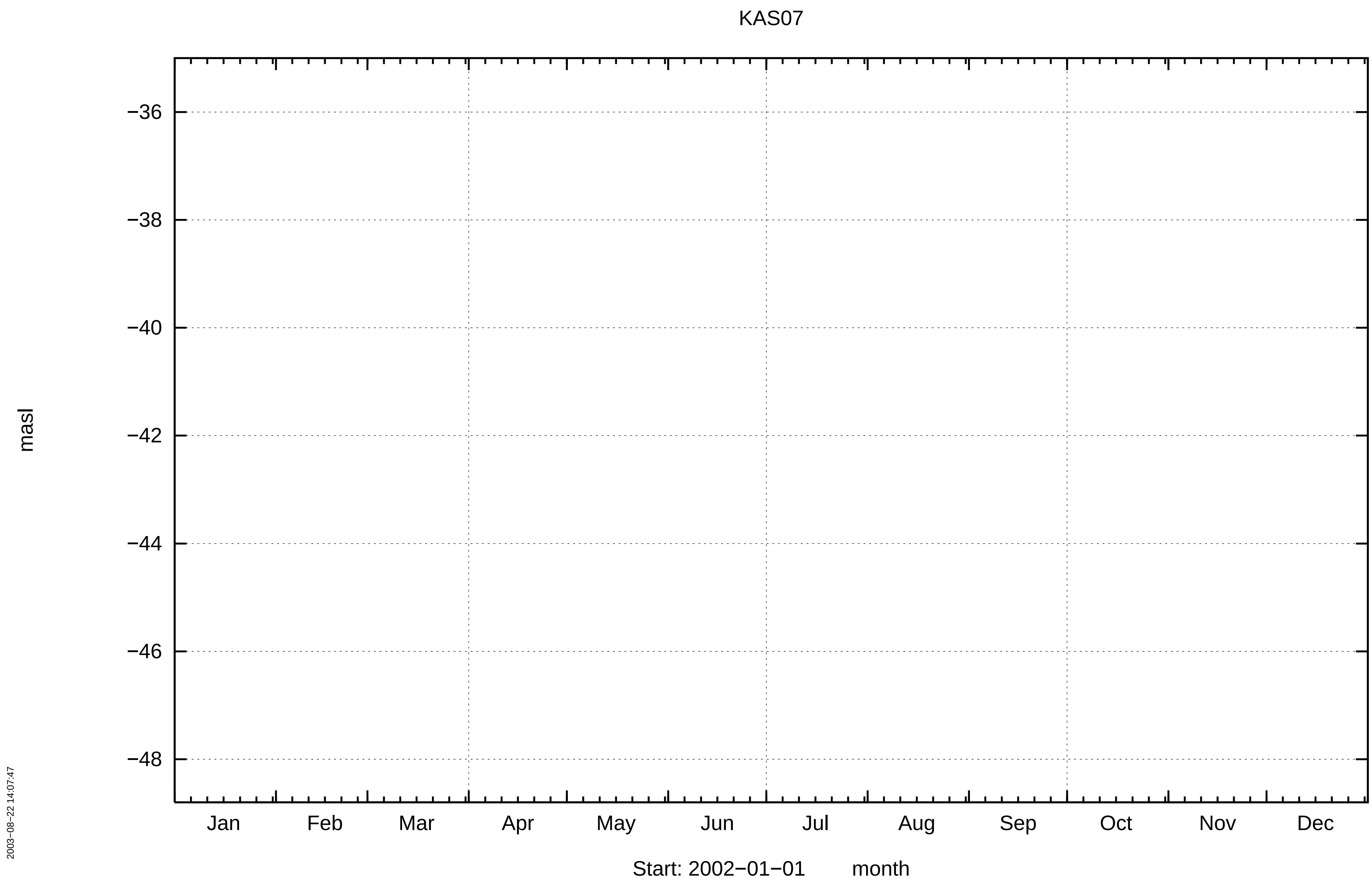
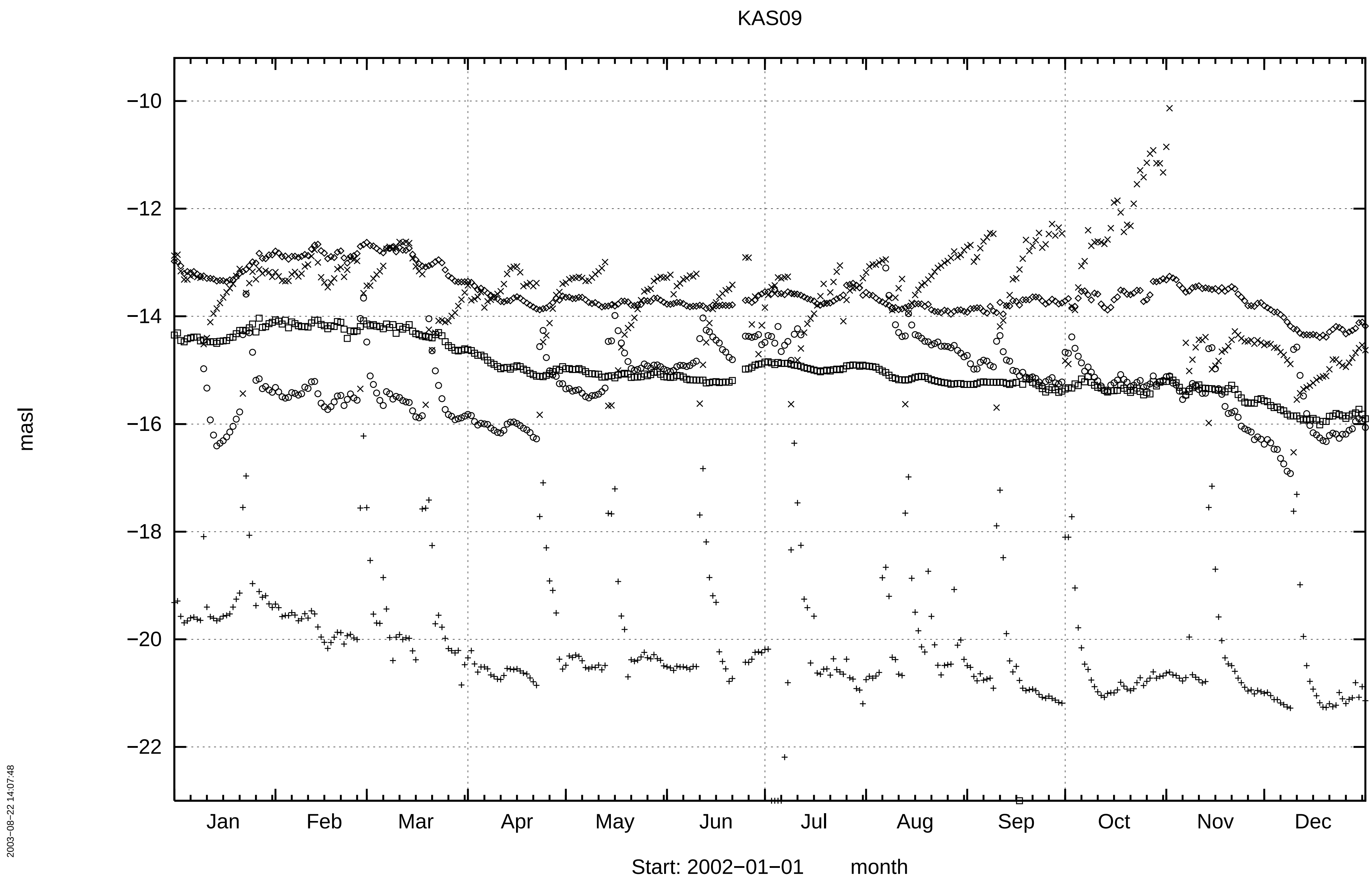
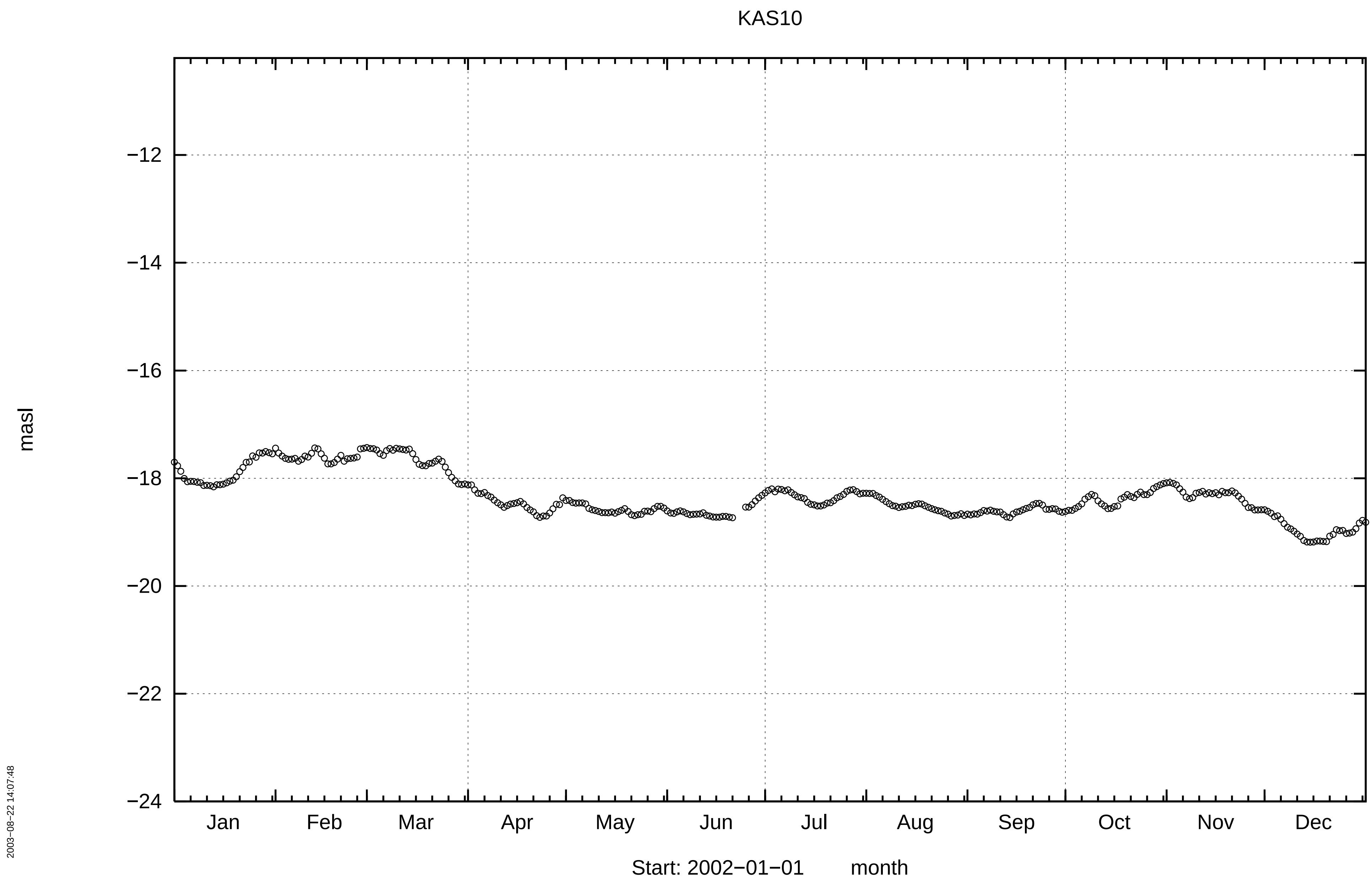
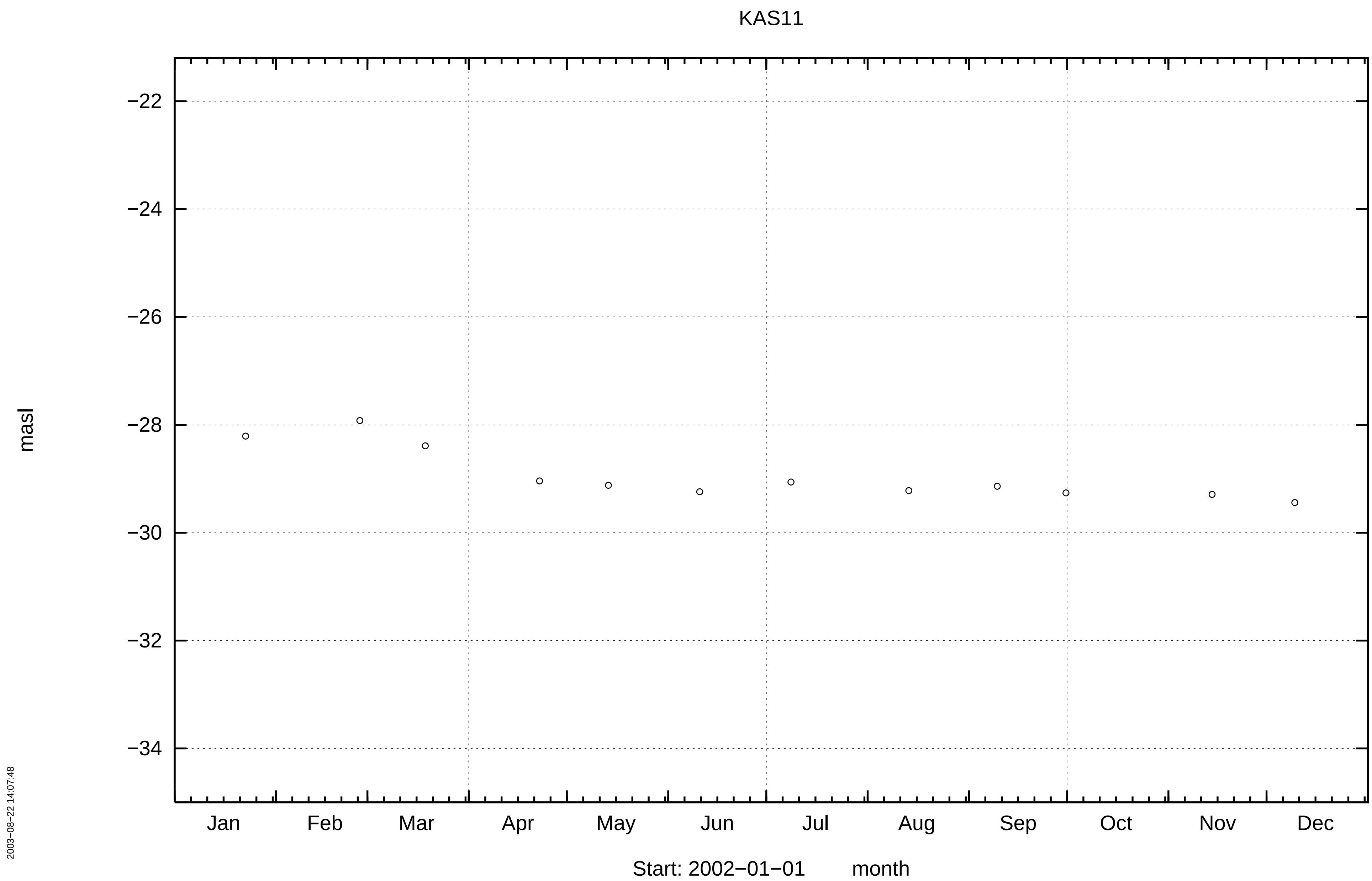
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:47

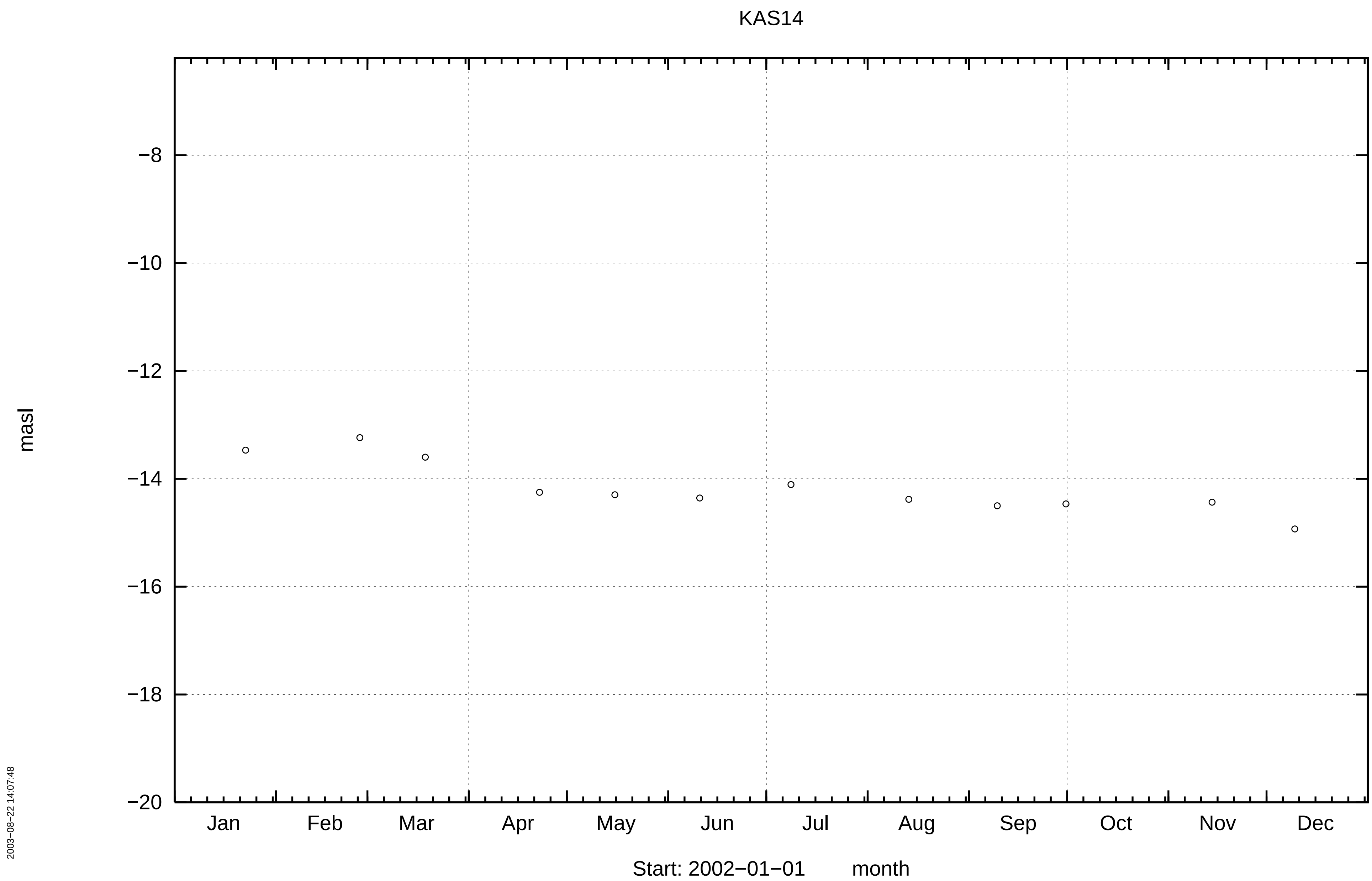

KAS07
masl
−36
−38
−40
−42
−44
−46
−48
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:47



KAS09
masl
−10
−12
−14
−16
−18
−20
−22
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:48


KAS10
masl
−12
−14
−16
−18
−20
−22
−24
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:48


KAS11
masl
−22
−24
−26
−28
−30
−32
−34
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:48


KAS14
masl
−8
−10
−12
−14
−16
−18
−20
Jan
Feb
Mar
Apr
May
Jun
Jul
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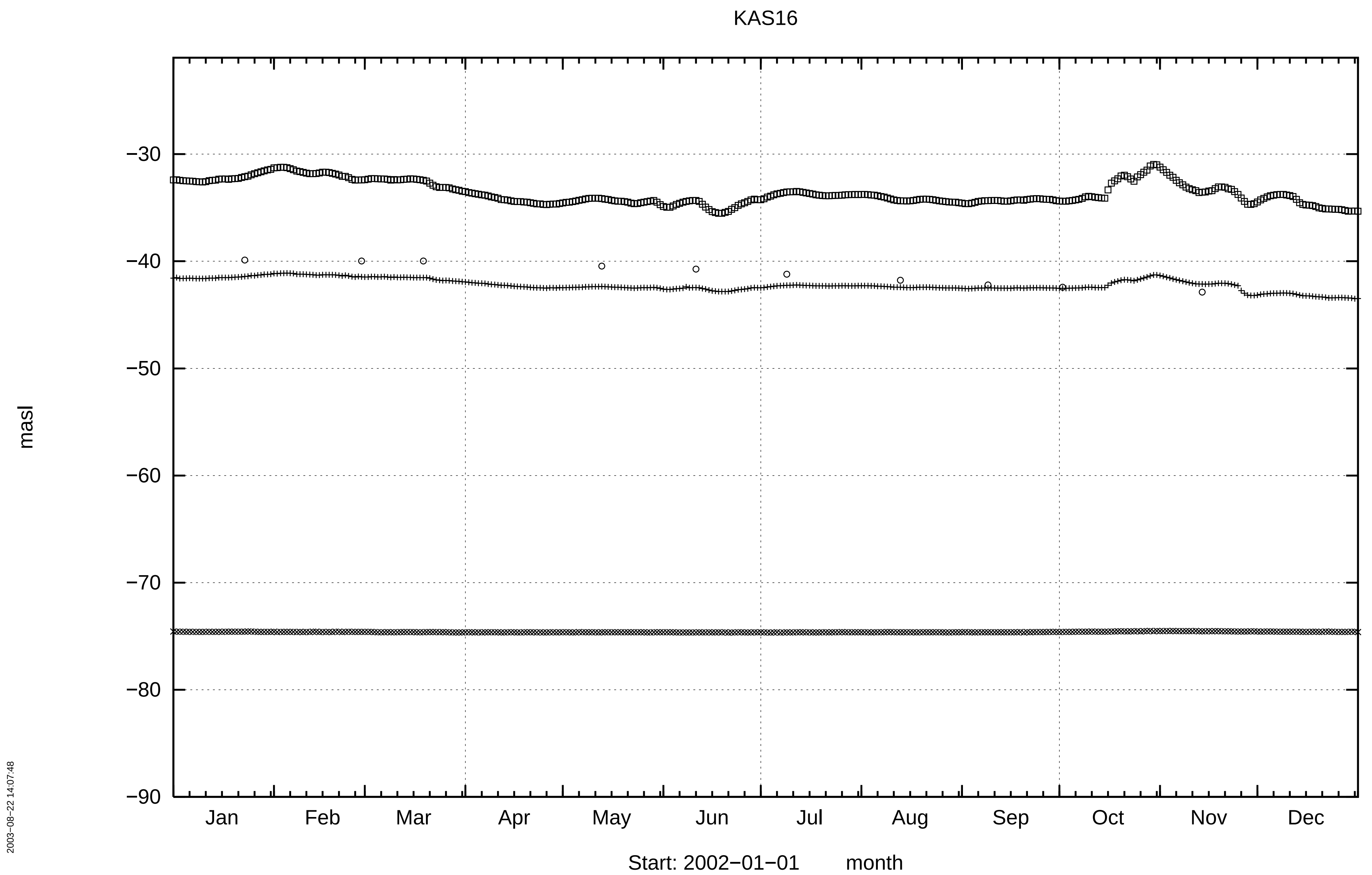
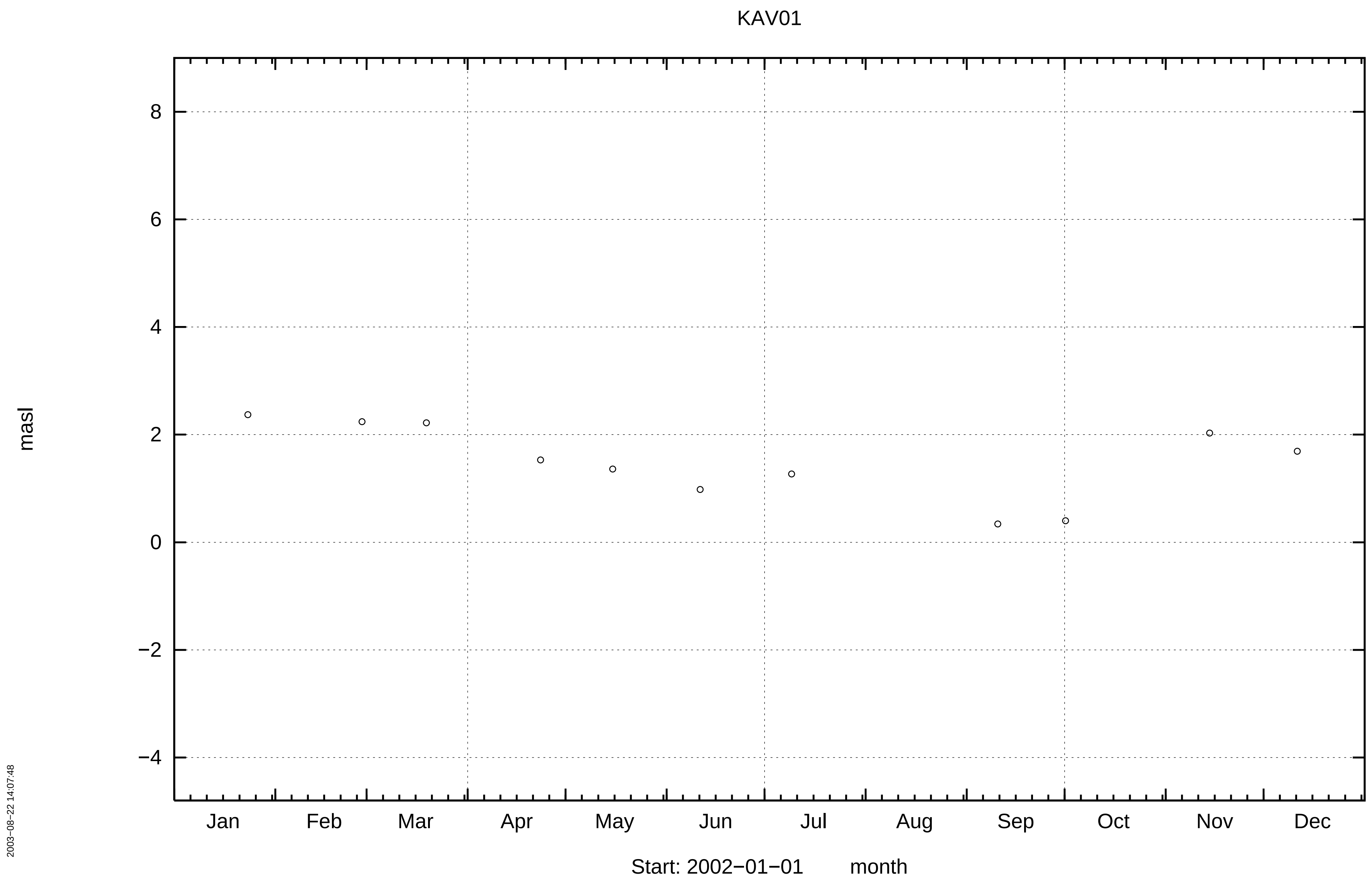
month
2003−08−22 14:07:48



KAS16
masl
−30
−40
−50
−60
−70
−80
−90
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:48


KAV01
masl
8
6
4
2
0
−2
−4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
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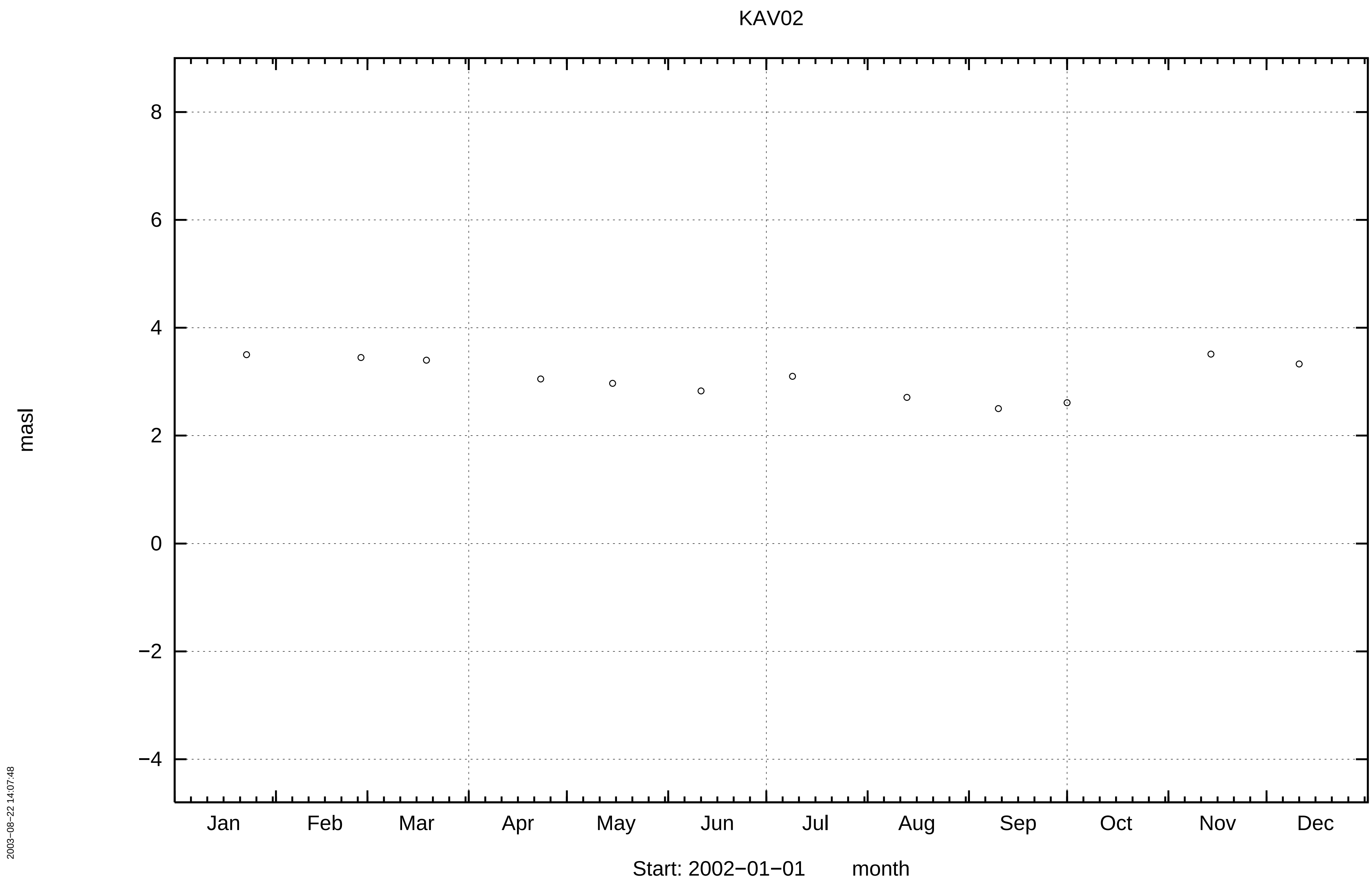
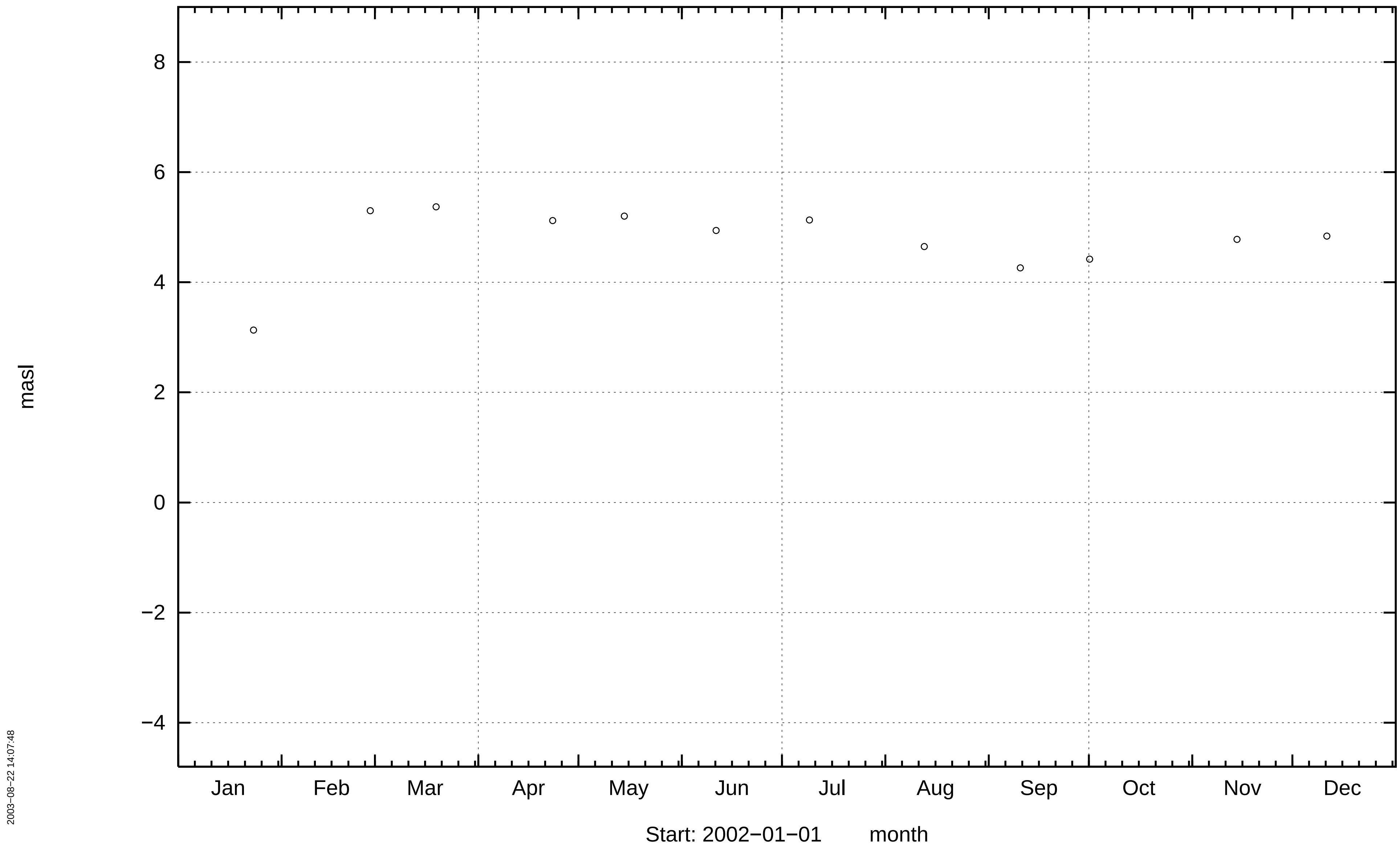
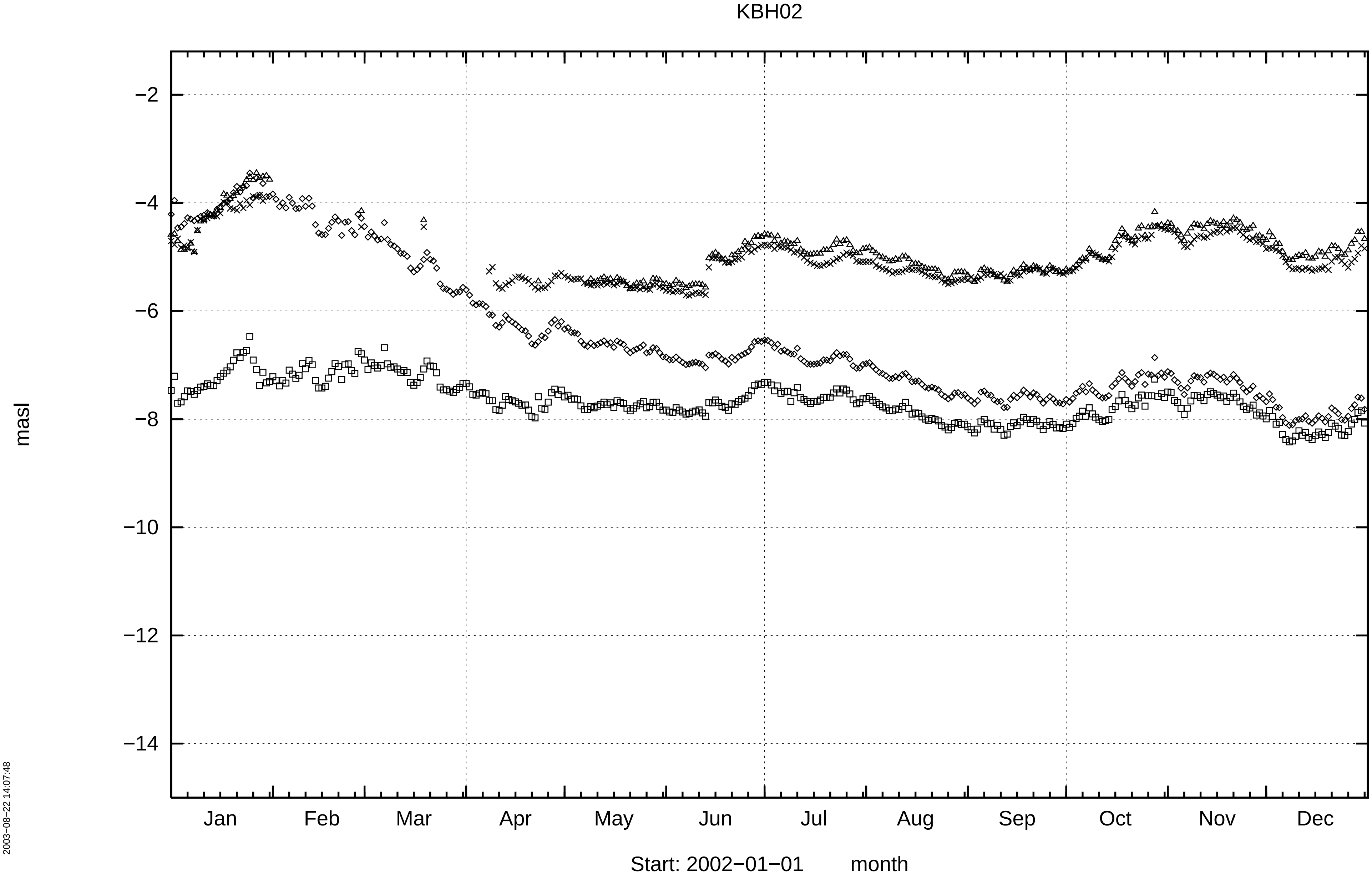
Start: 2002−01−01
month
2003−08−22 14:07:48


KAV02
masl
8
6
4
2
0
−2
−4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:48

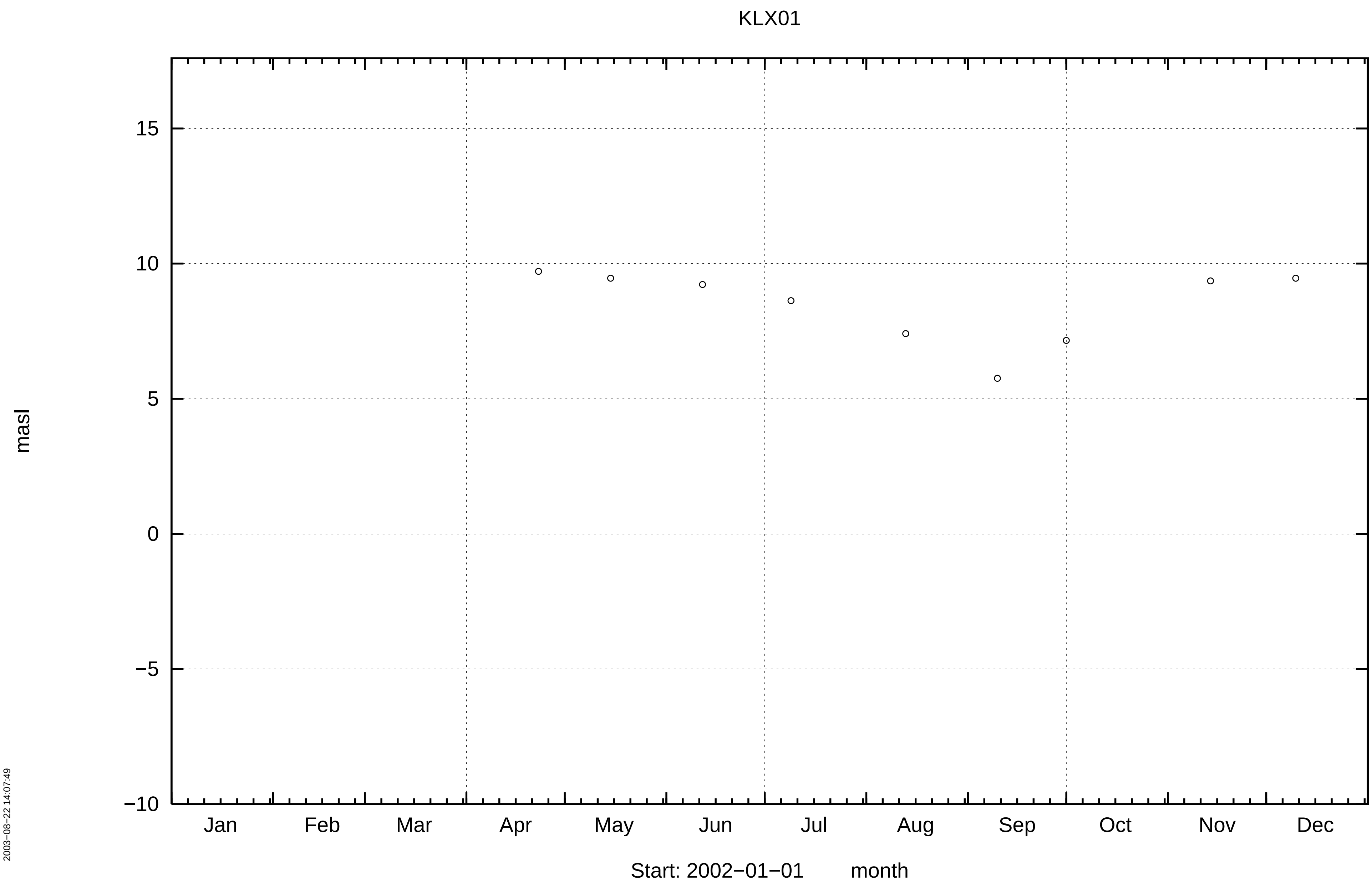
KAV03



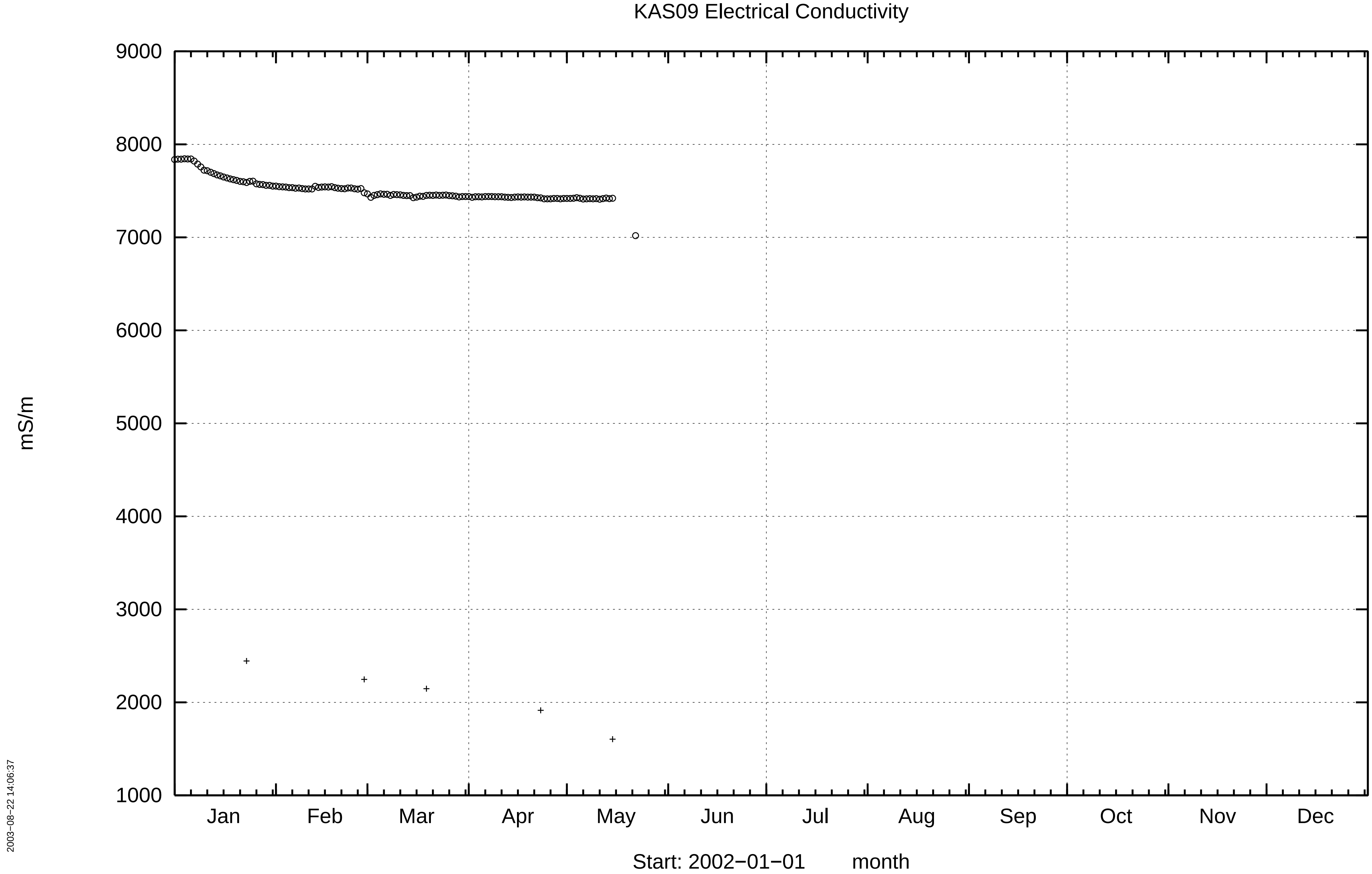
masl
8
6
4
2
0
−2
−4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:48



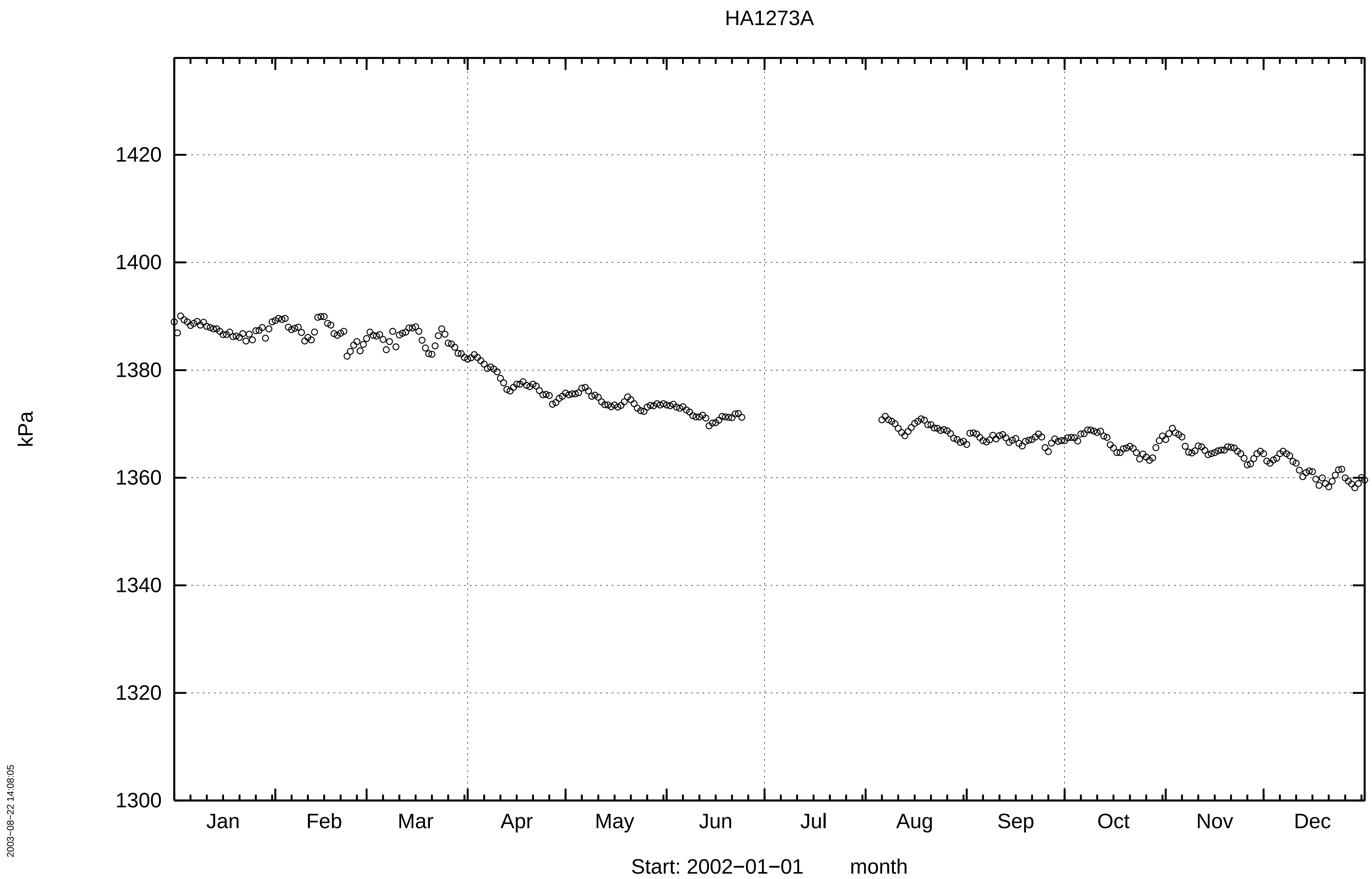
KBH02
masl
−2
−4
−6
−8
−10
−12
−14
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:07:48

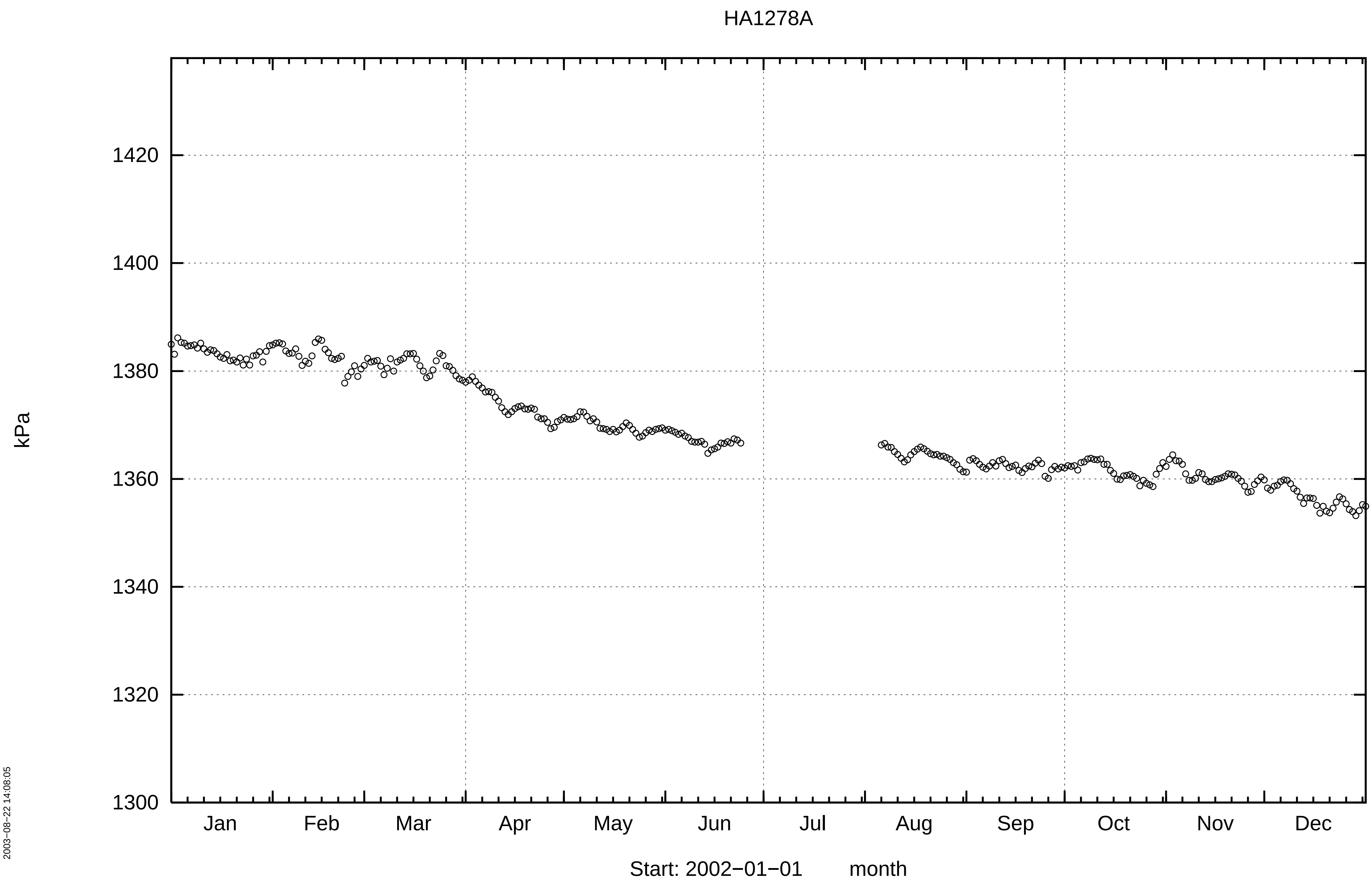

KLX01
masl
15
10
5
0
−5
−10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:49

Appendix 3: Electrical conductivity in surface boreholes

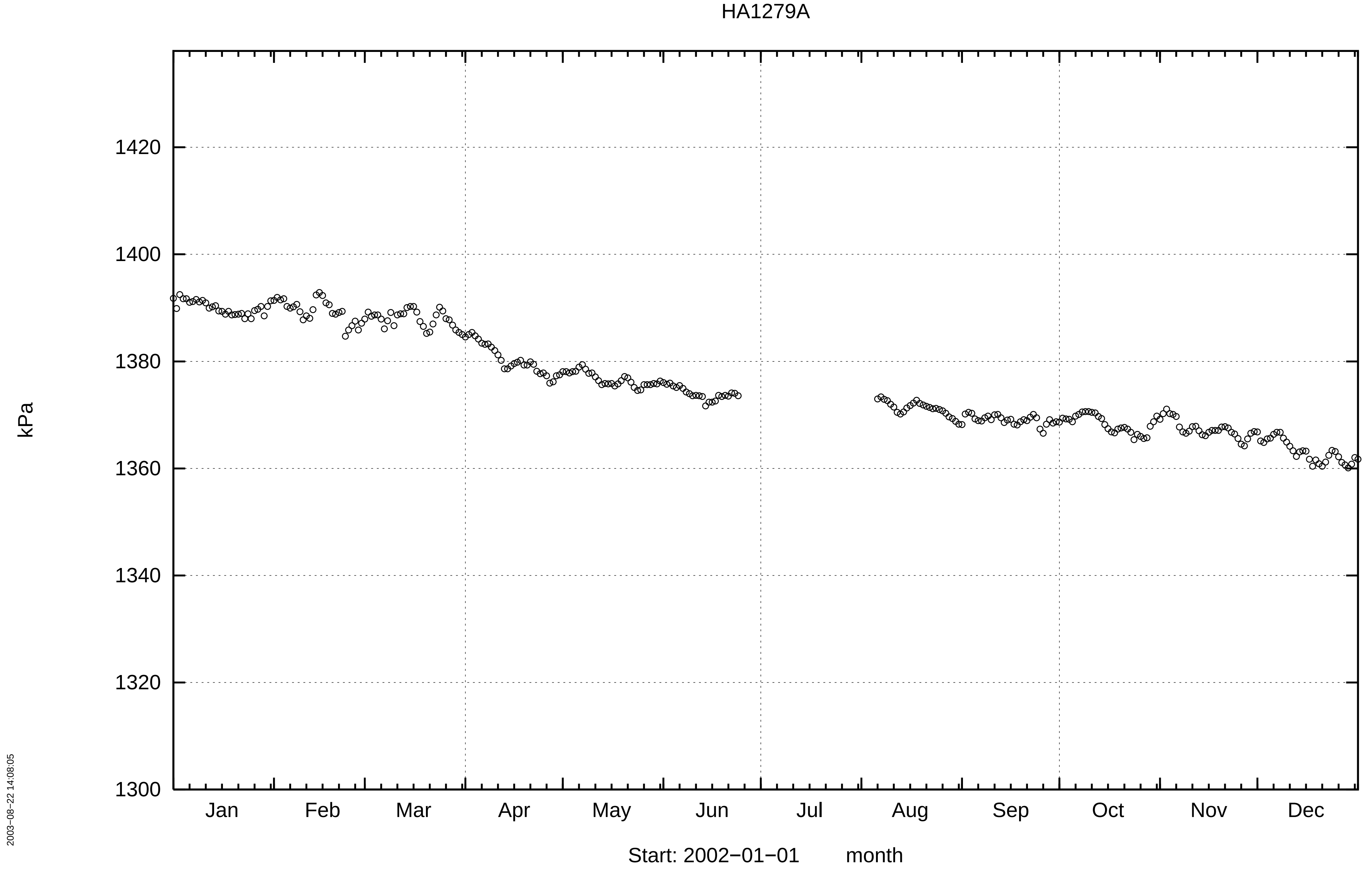

KAS09 Electrical Conductivity
mS/m
9000
8000
7000
6000
5000
4000
3000
2000
1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:06:37

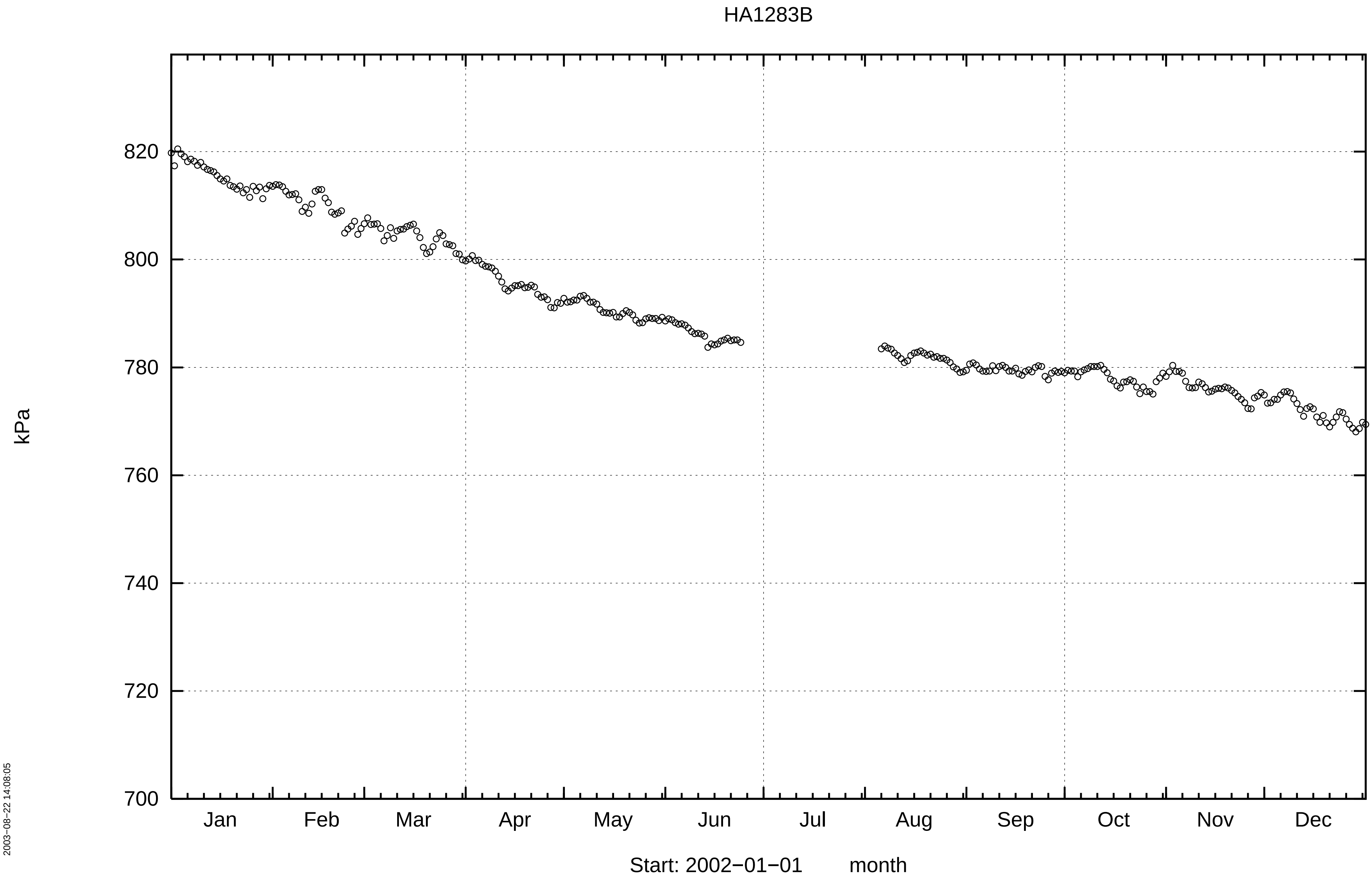
Appendix 4: Groundwater pressure in tunnel boreholes

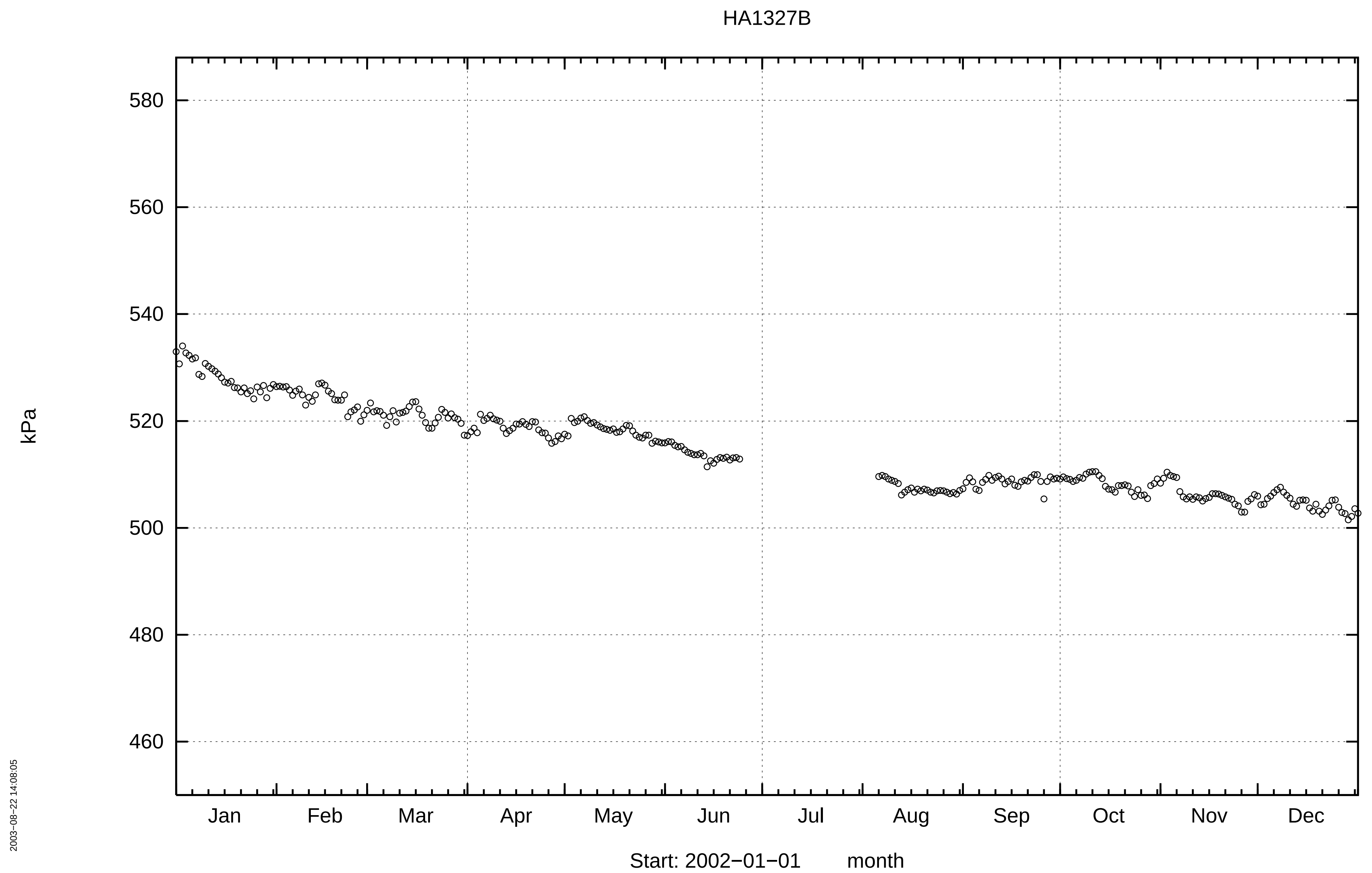

HA1273A
kPa
1420
1400
1380
1360
1340
1320
1300
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:05



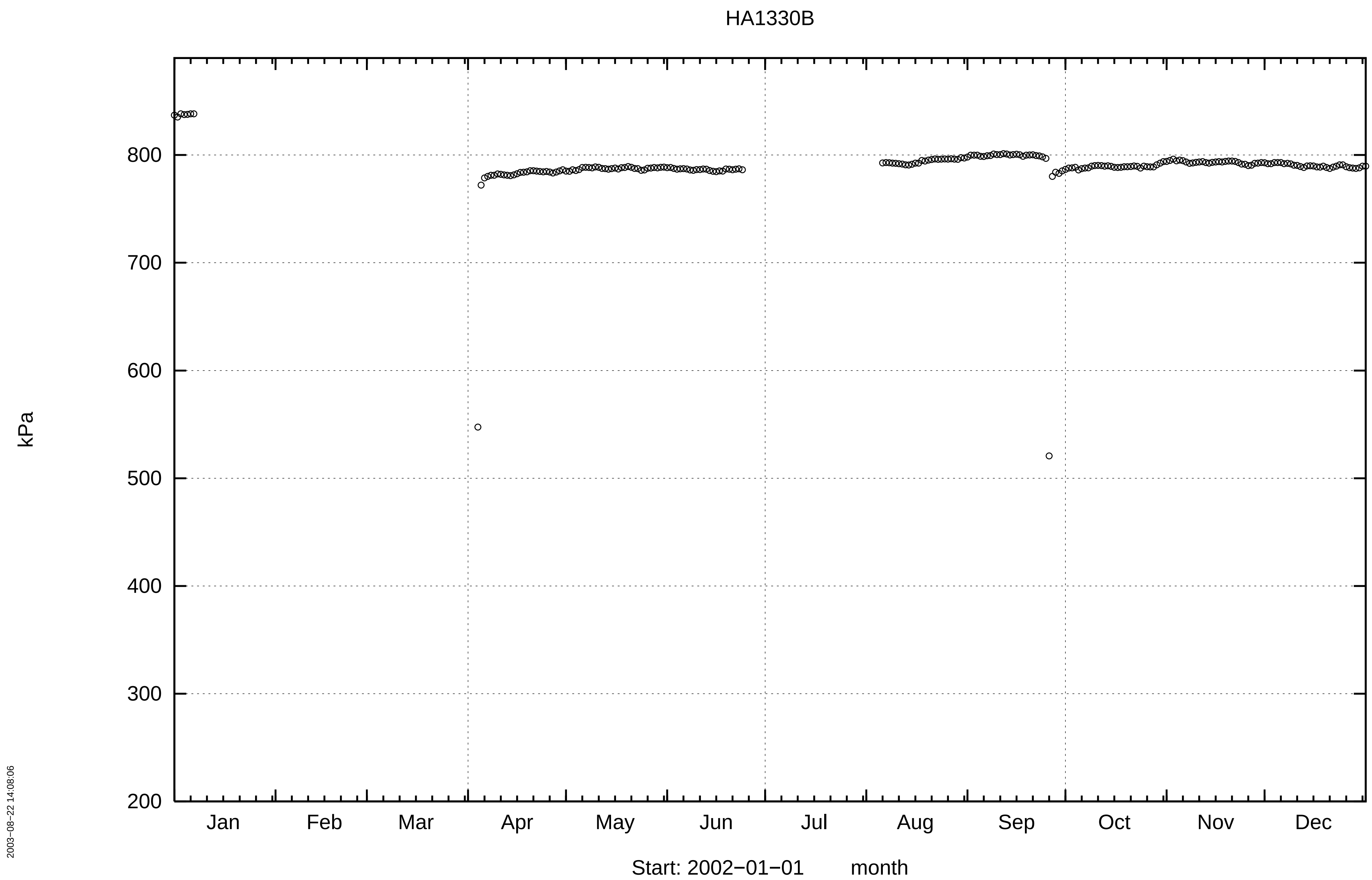
HA1278A
kPa
1420
1400
1380
1360
1340
1320
1300
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:05


HA1279A
kPa
1420
1400
1380
1360
1340
1320
1300
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:05

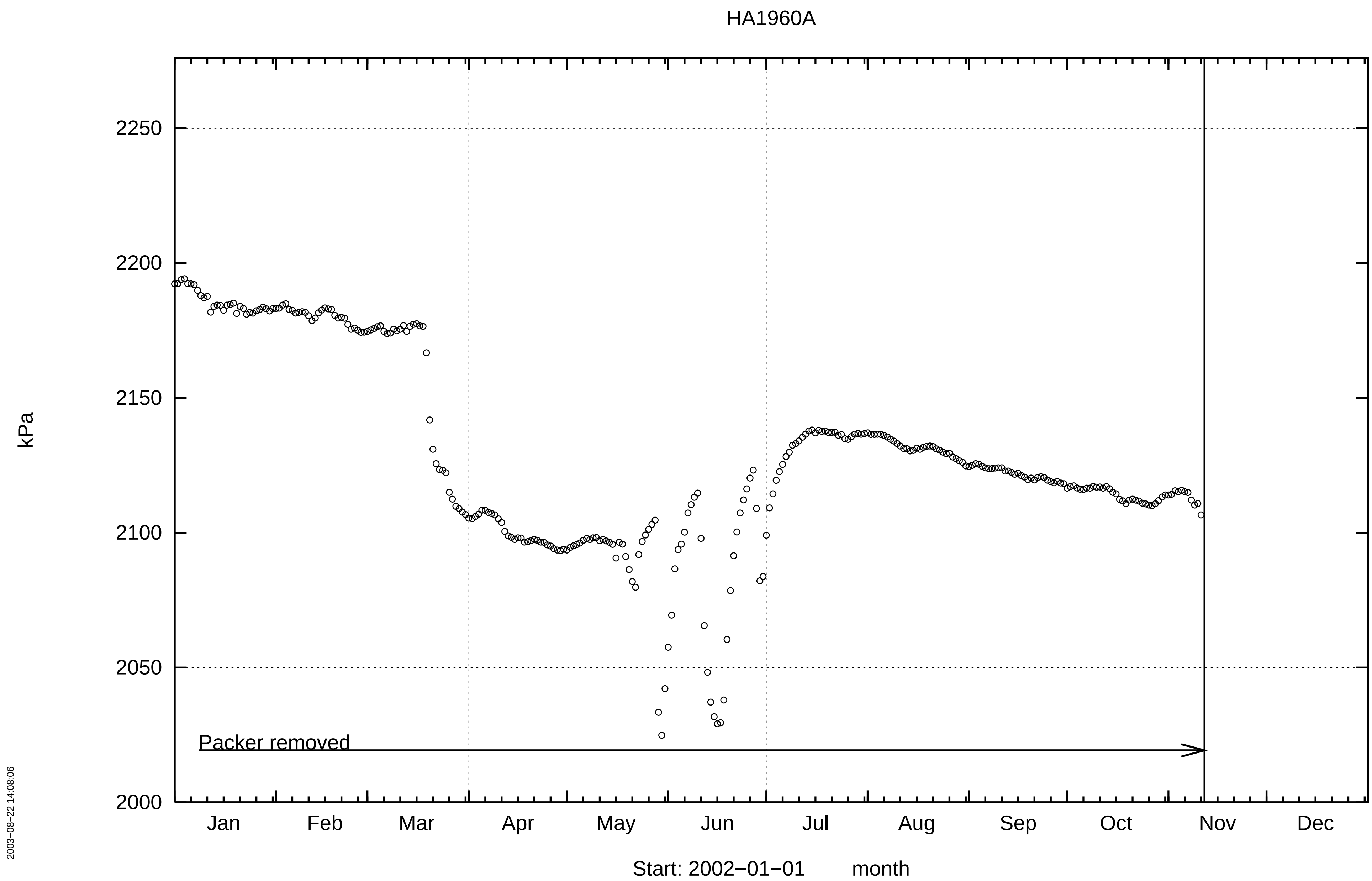

HA1283B
kPa
820
800
780
760
740
720
700
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:05



HA1327B
kPa
580
560
540
520
500
480
460
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:05



HA1330B
kPa
800
700
600
500
400
300
200
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:06


HA1960A
kPa
2250
2200
2150
2100
2050
2000
Packer removed
Jan
Feb
Mar
Apr
May
Jun
Jul
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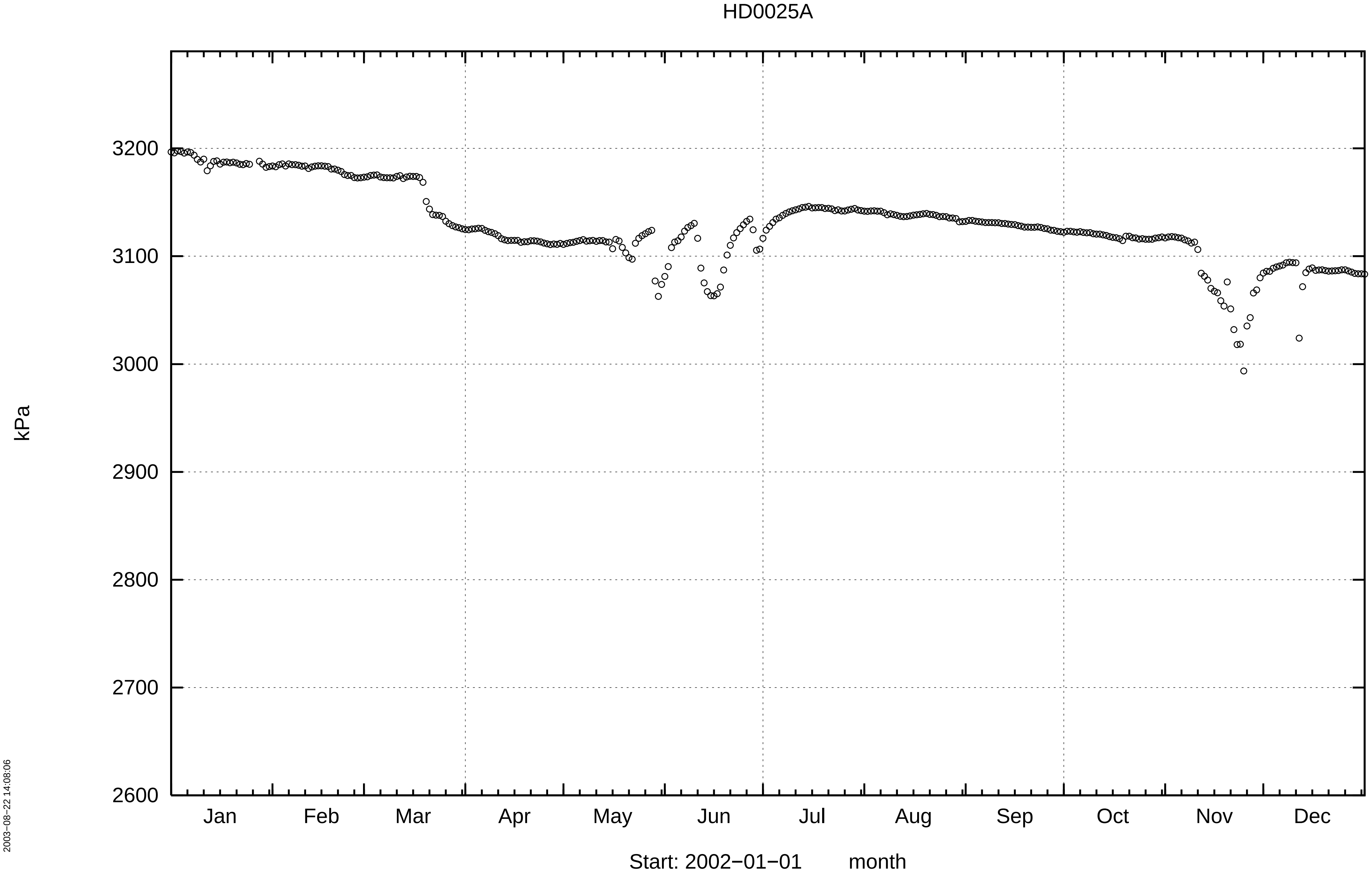
Start: 2002−01−01
month
2003−08−22 14:08:06


HD0025A
kPa
3200
3100
3000
2900
2800
2700
2600
Jan
Feb
Mar
Apr
May
Jun
Jul
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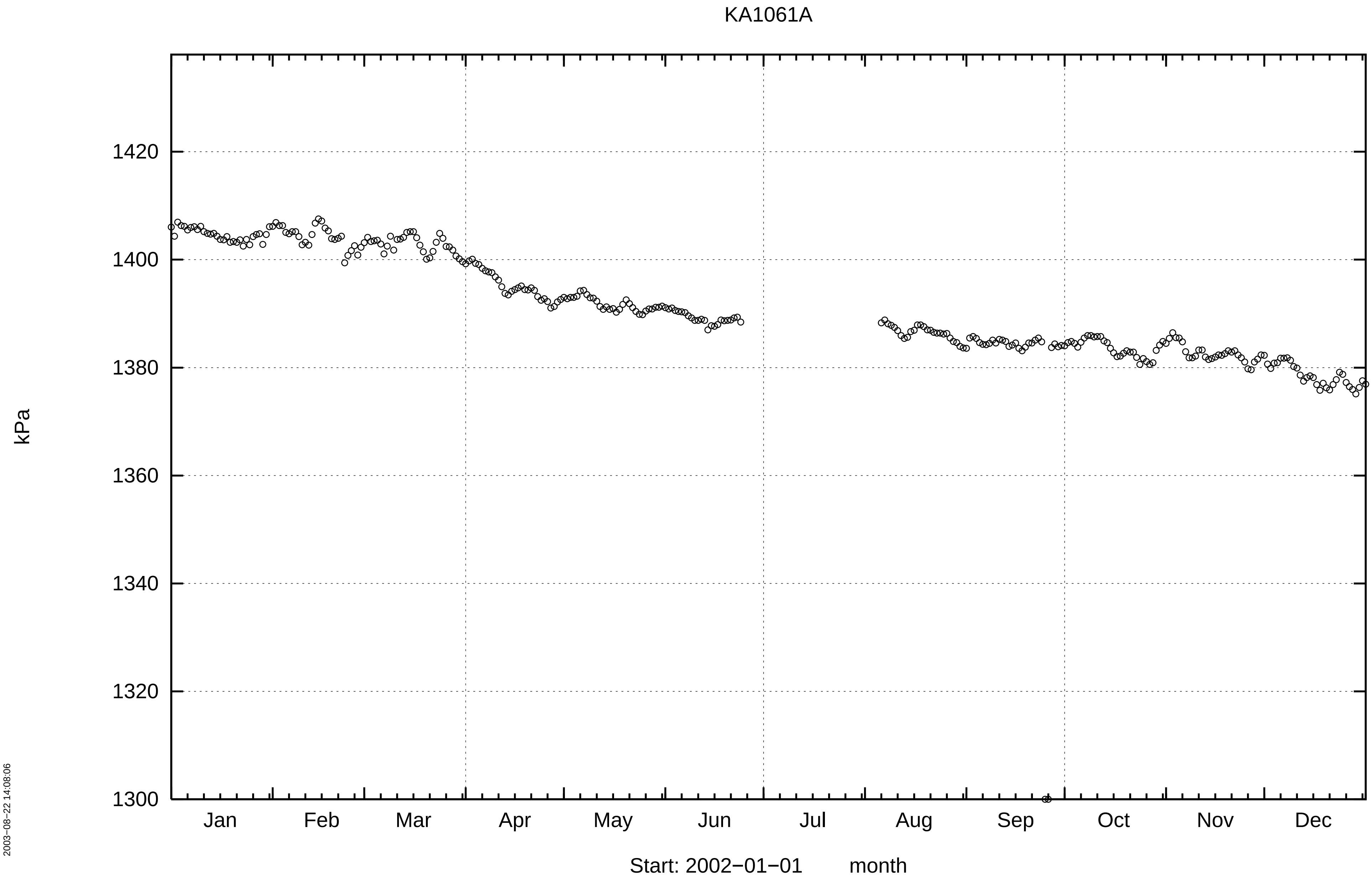
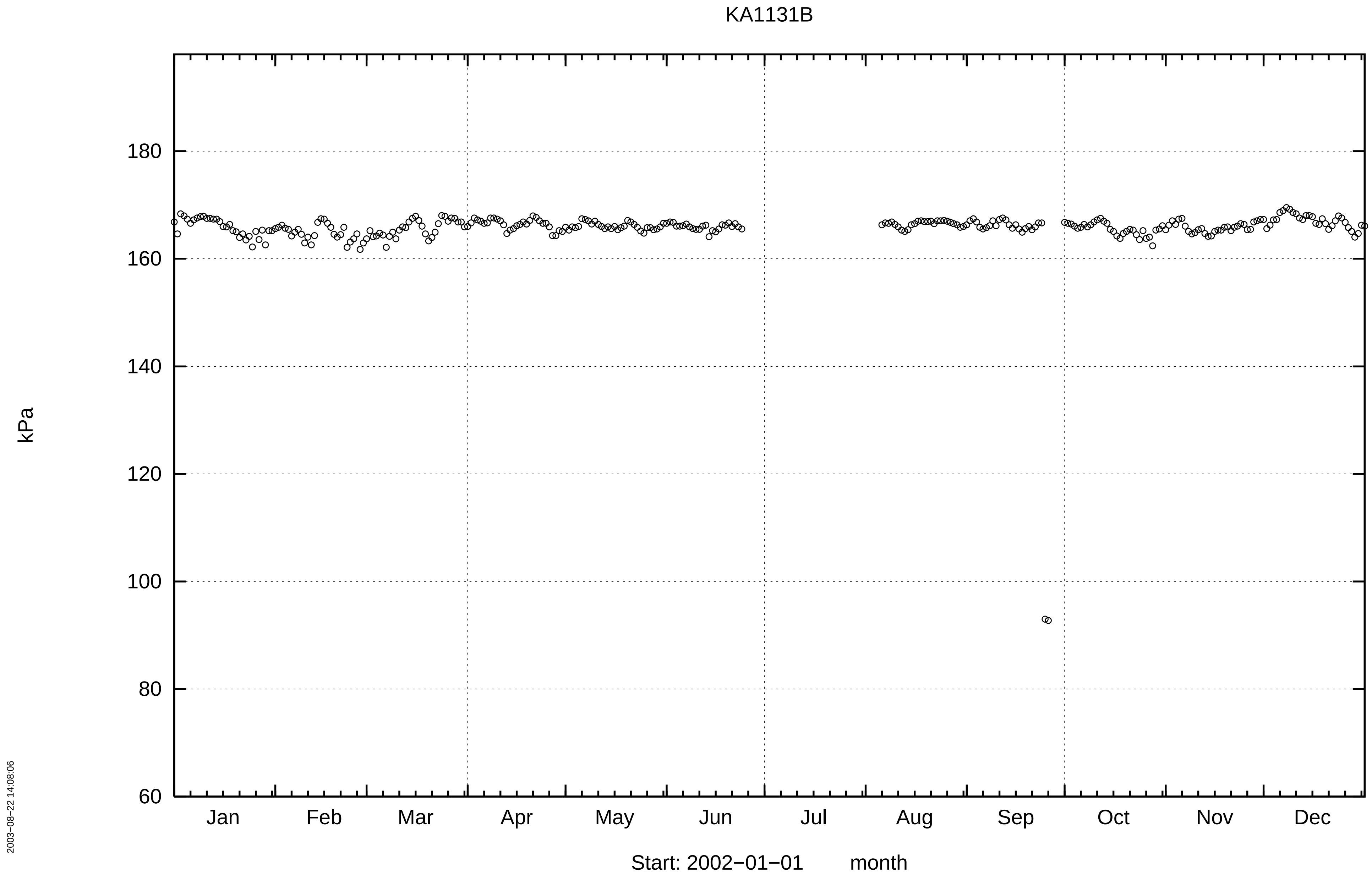
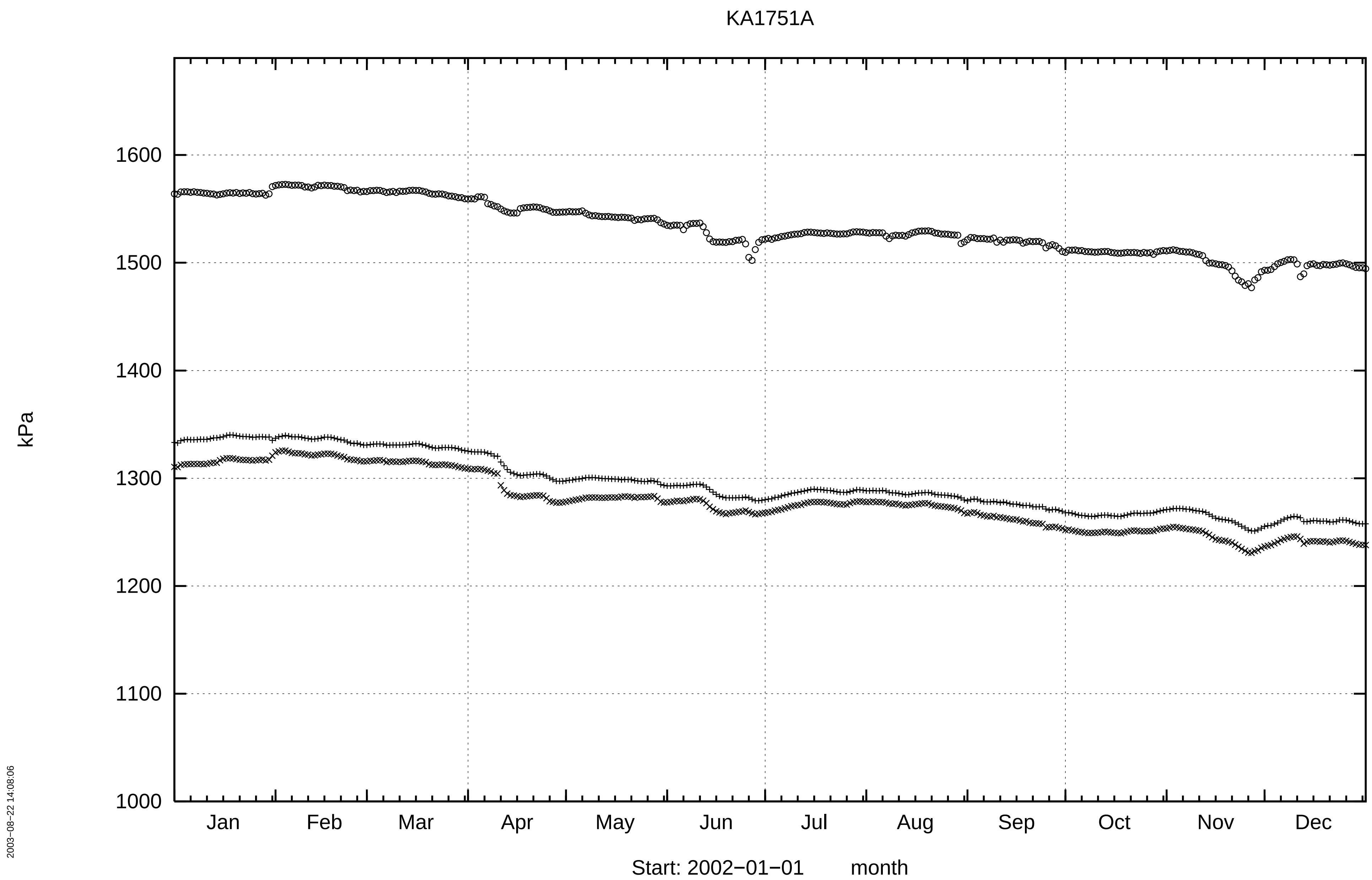
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:06



KA1061A
kPa
1420
1400
1380
1360
1340
1320
1300
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:06



KA1131B
kPa
180
160
140
120
100
80
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:06



KA1751A
kPa
1600
1500
1400
1300
1200
1100
1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
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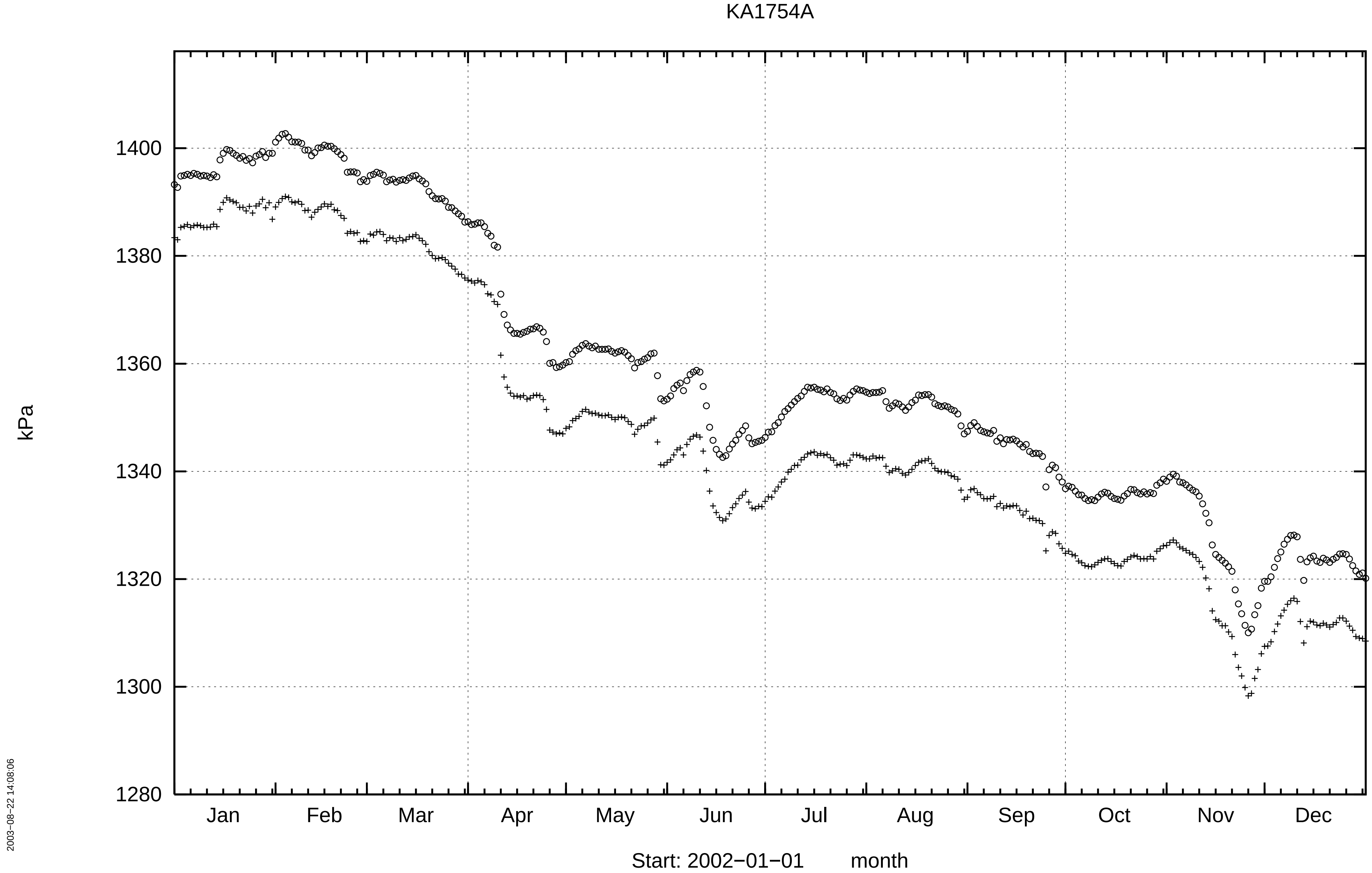
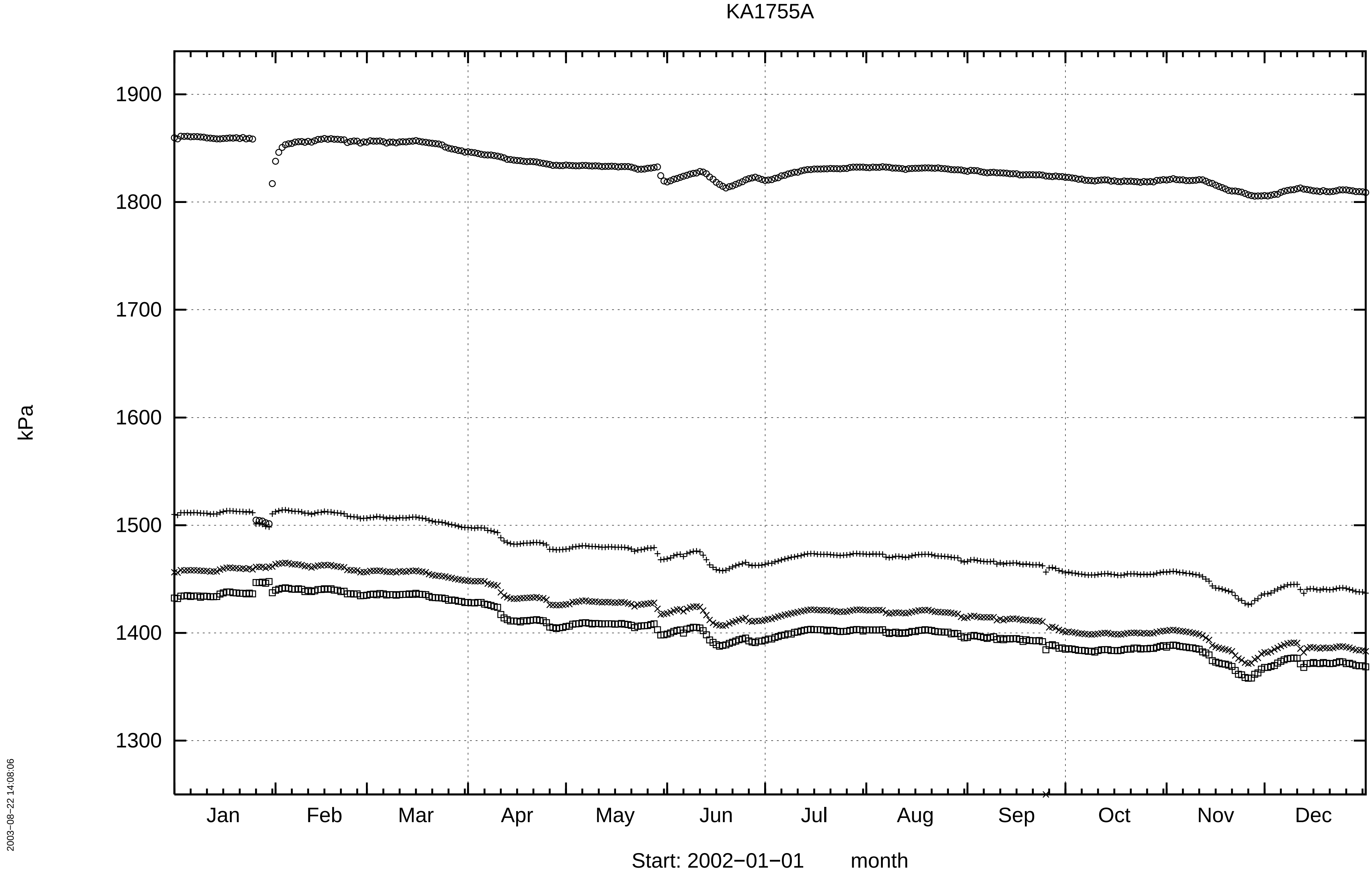
Start: 2002−01−01
month
2003−08−22 14:08:06



KA1754A
kPa
1400
1380
1360
1340
1320
1300
1280
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:06



KA1755A
kPa
1900
1800
1700
1600
1500
1400
1300
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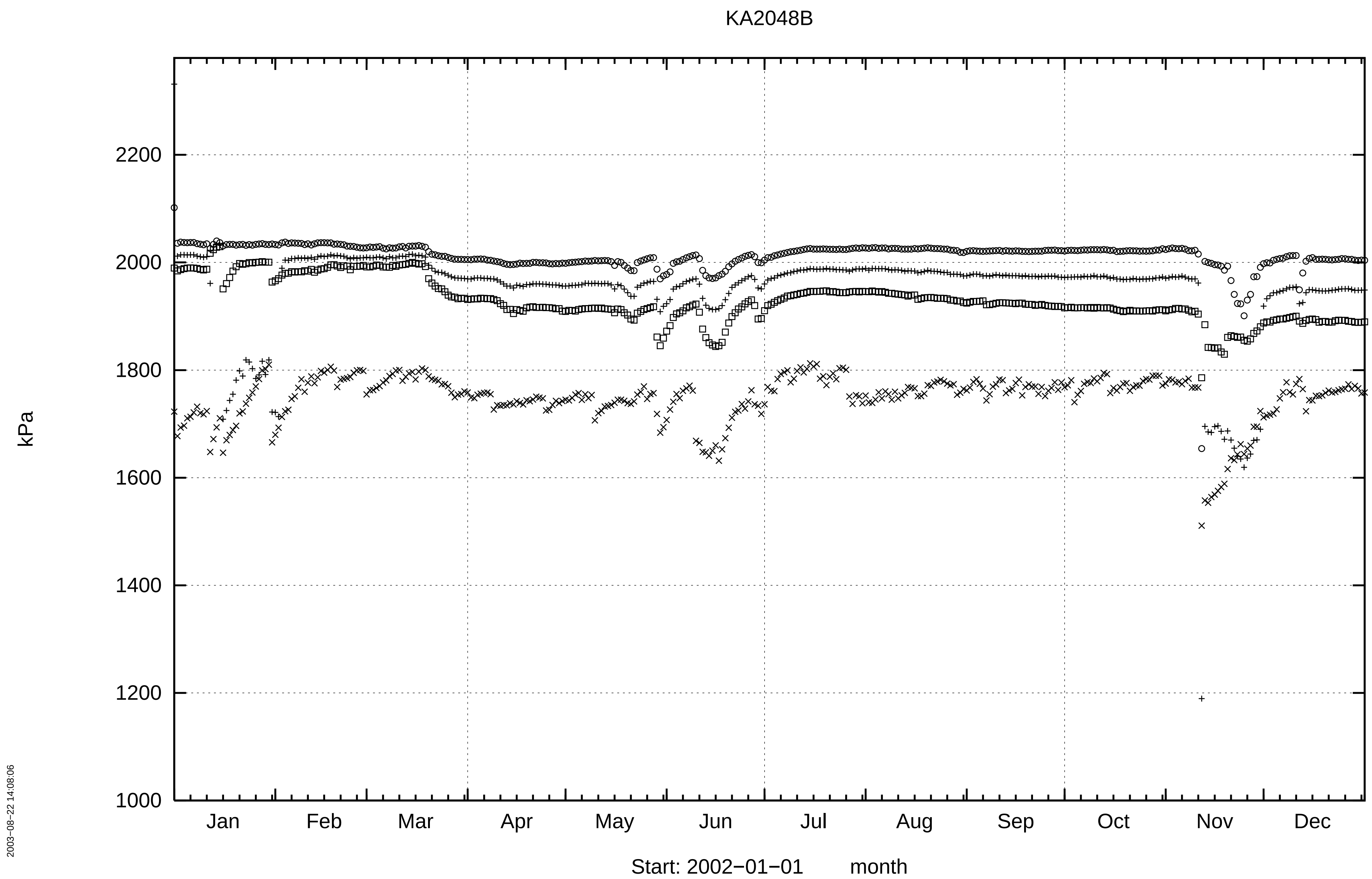
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:06


KA2048B
kPa
2200
2000
1800
1600
1400
1200
1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
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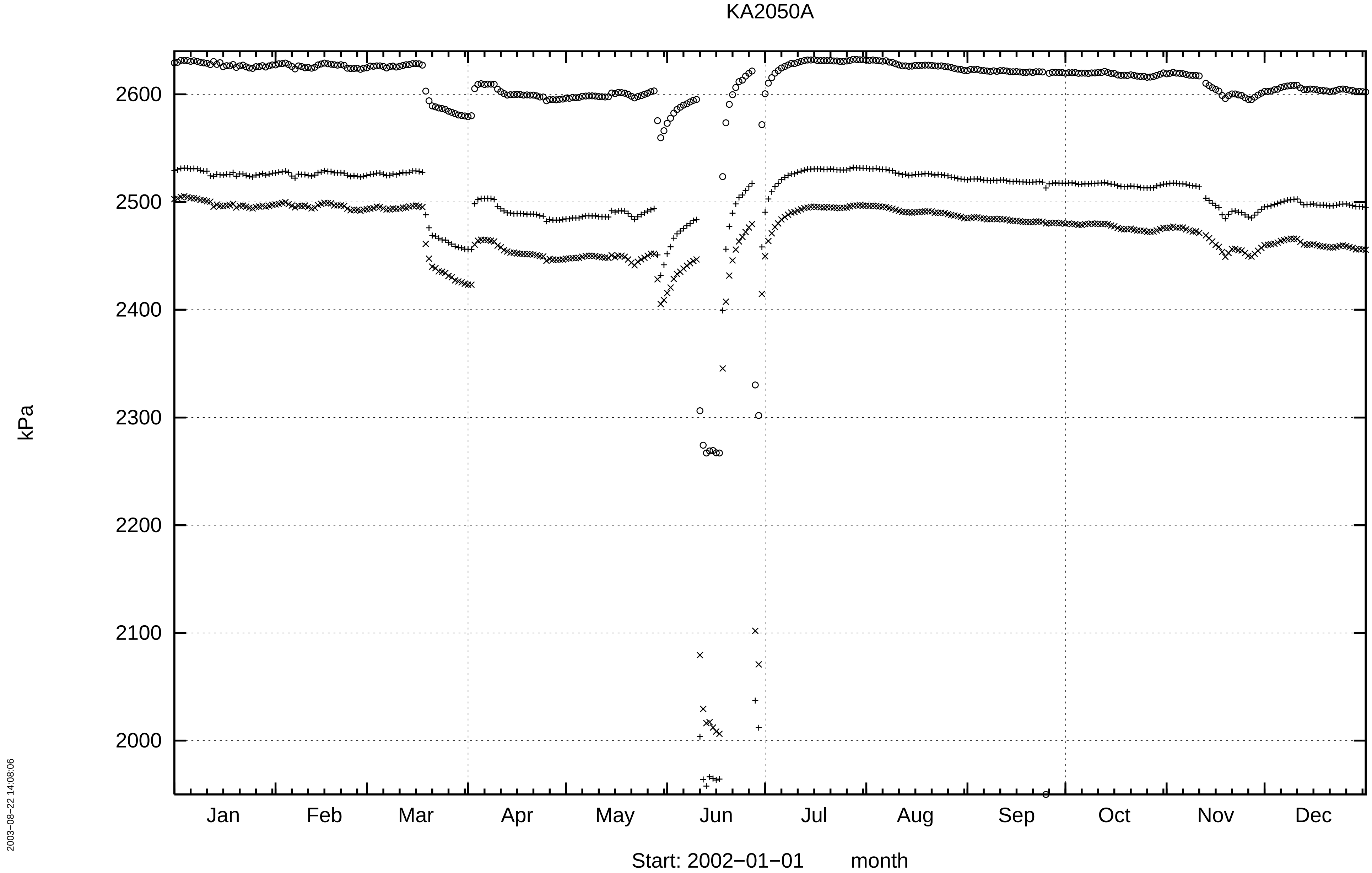
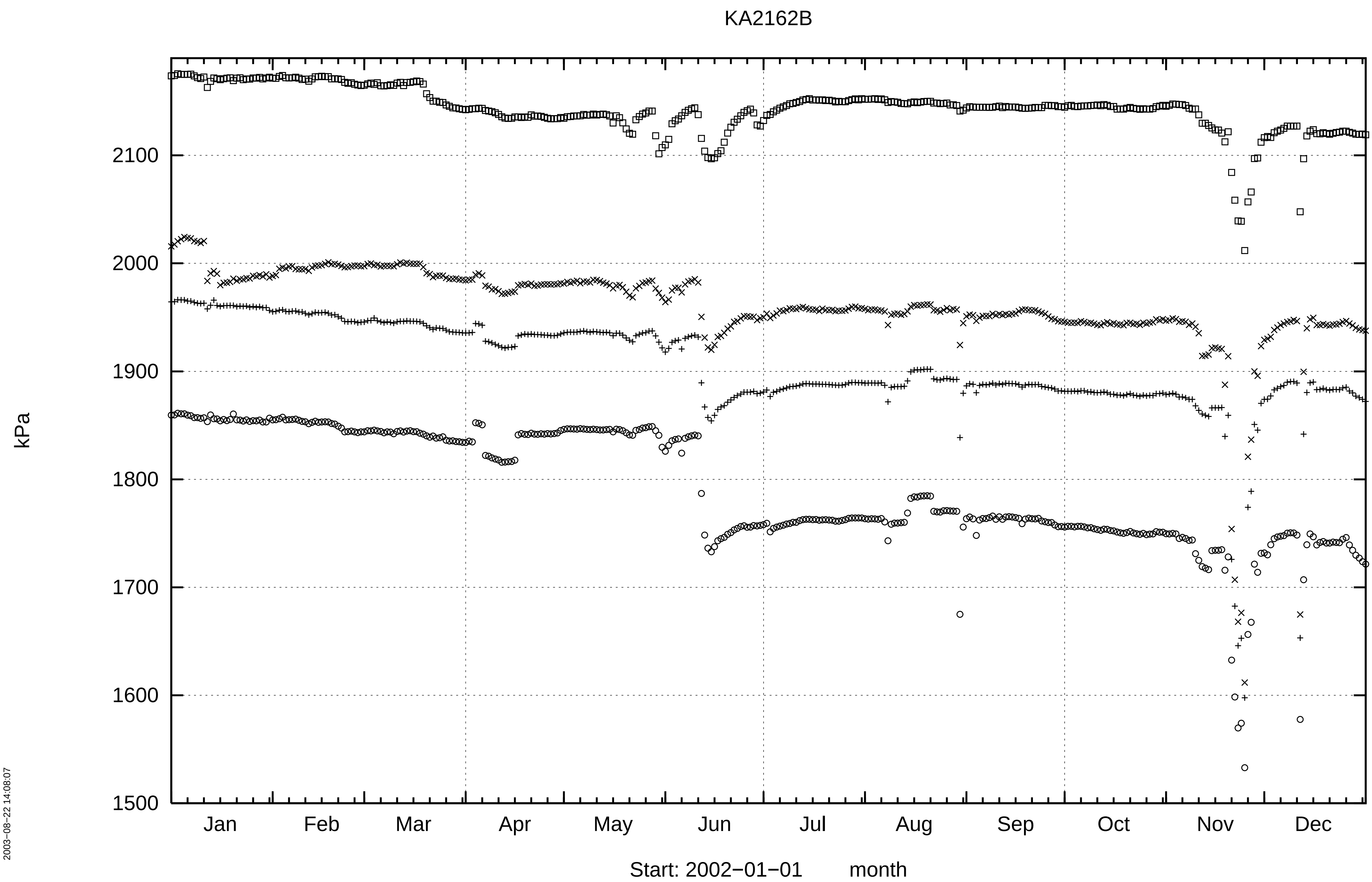
month
2003−08−22 14:08:06



KA2050A
kPa
2600
2500
2400
2300
2200
2100
2000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:06


KA2162B
kPa
2100
2000
1900
1800
1700
1600
1500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
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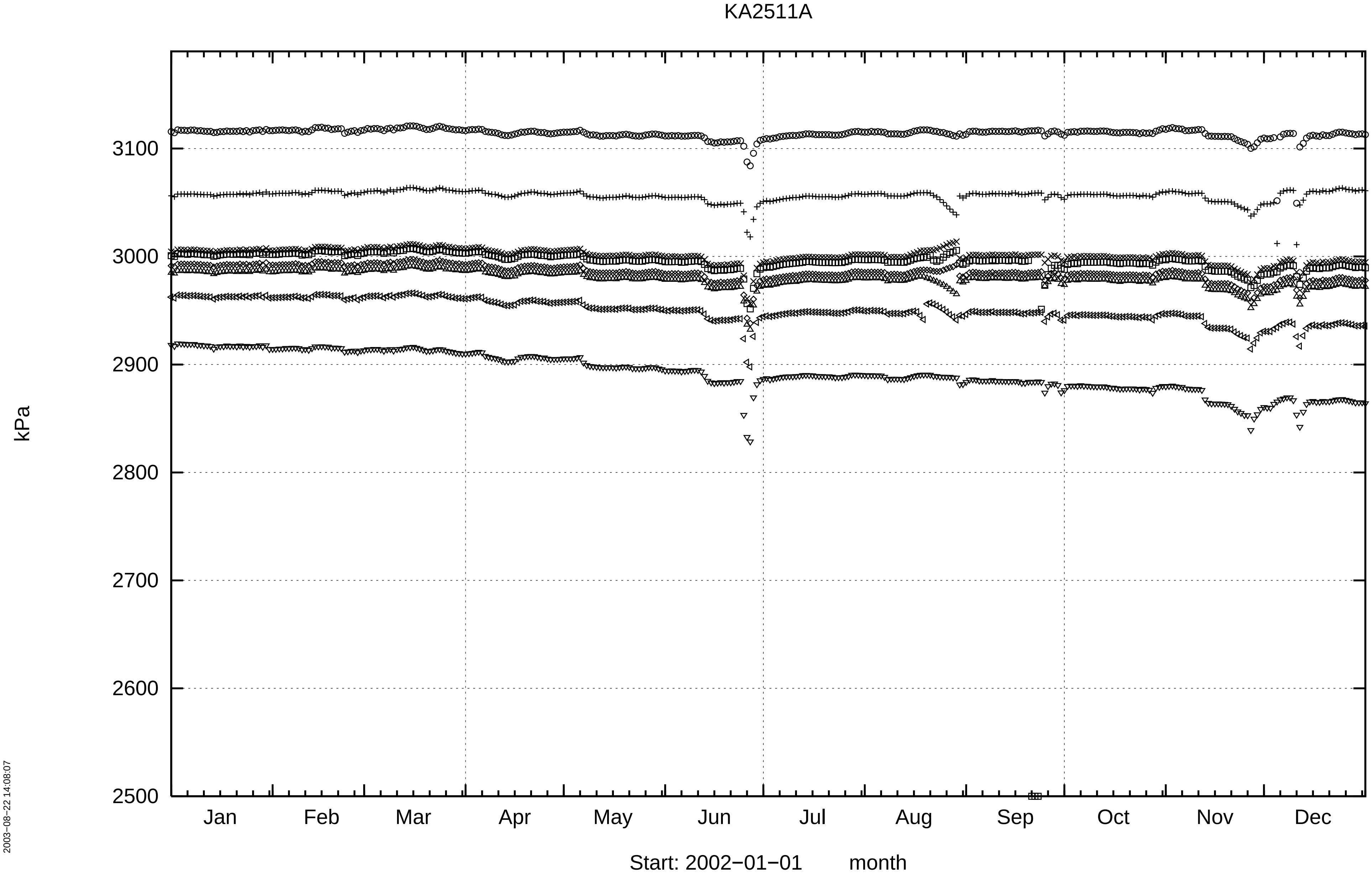
Start: 2002−01−01
month
2003−08−22 14:08:07


KA2511A
kPa
3100
2900
3000
2800
2700
2600
2500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
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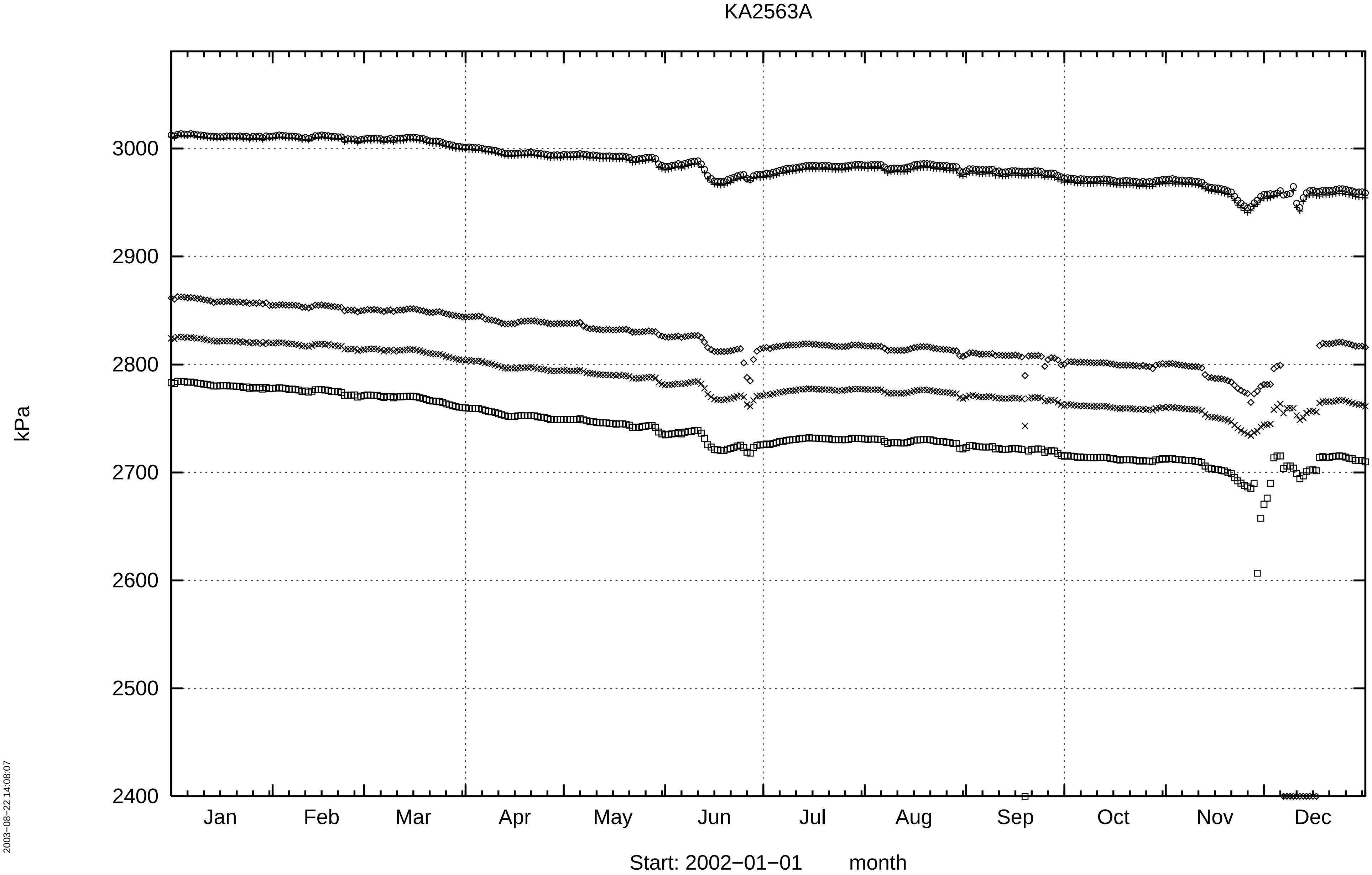
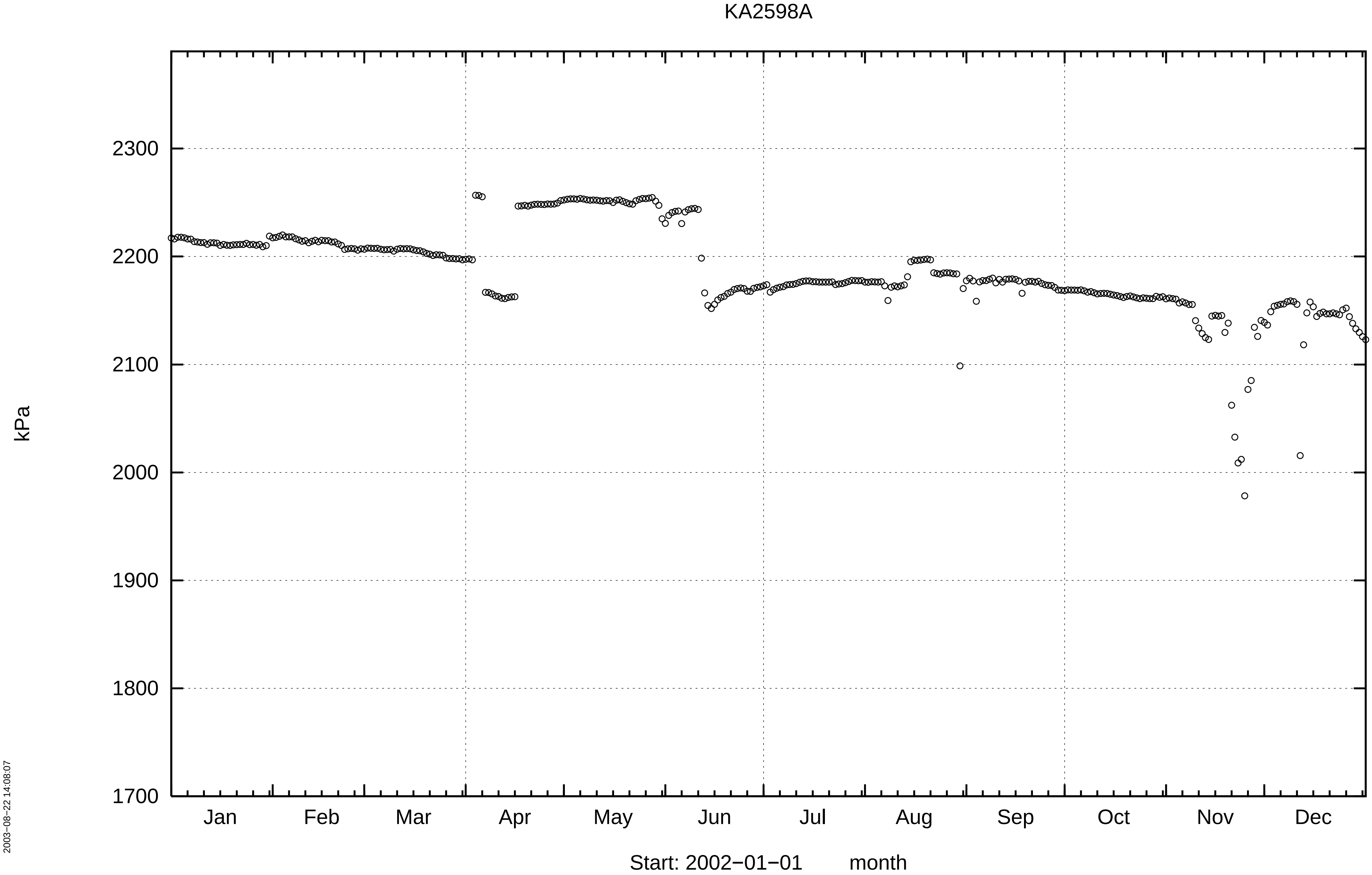
Dec
Start: 2002−01−01 month
2003−08−22 14:08:07



KA2563A
kPa
3000
2900
2800
2700
2600
2500
2400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:07


KA2598A
kPa
2300
2200
2100
2000
1900
1800
1700
Jan
Feb
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Apr
May
Jun
Jul
Aug
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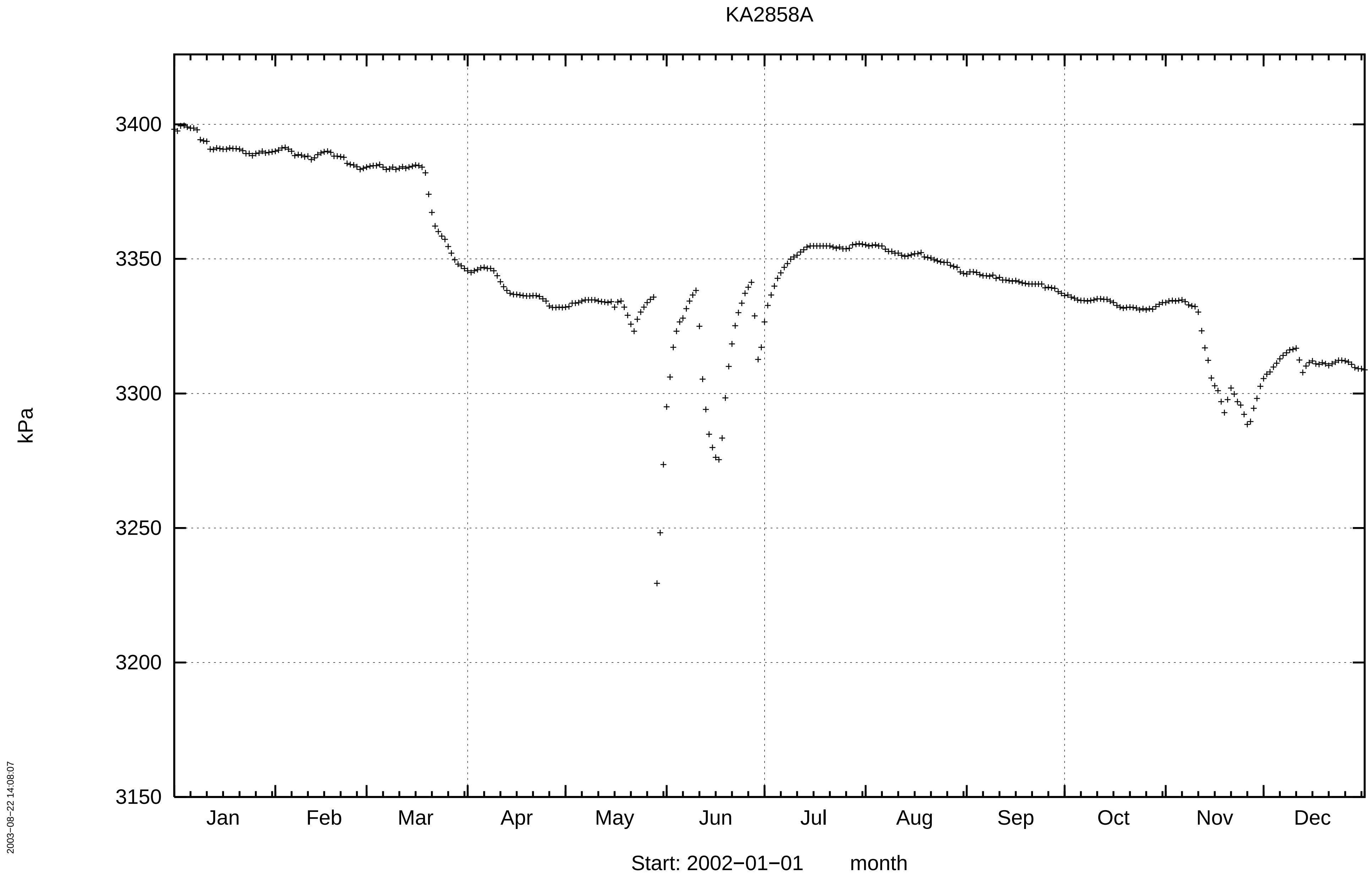
2003−08−22 14:08:07



KA2858A
kPa
3400
3350
3300
3250
3200
3150
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
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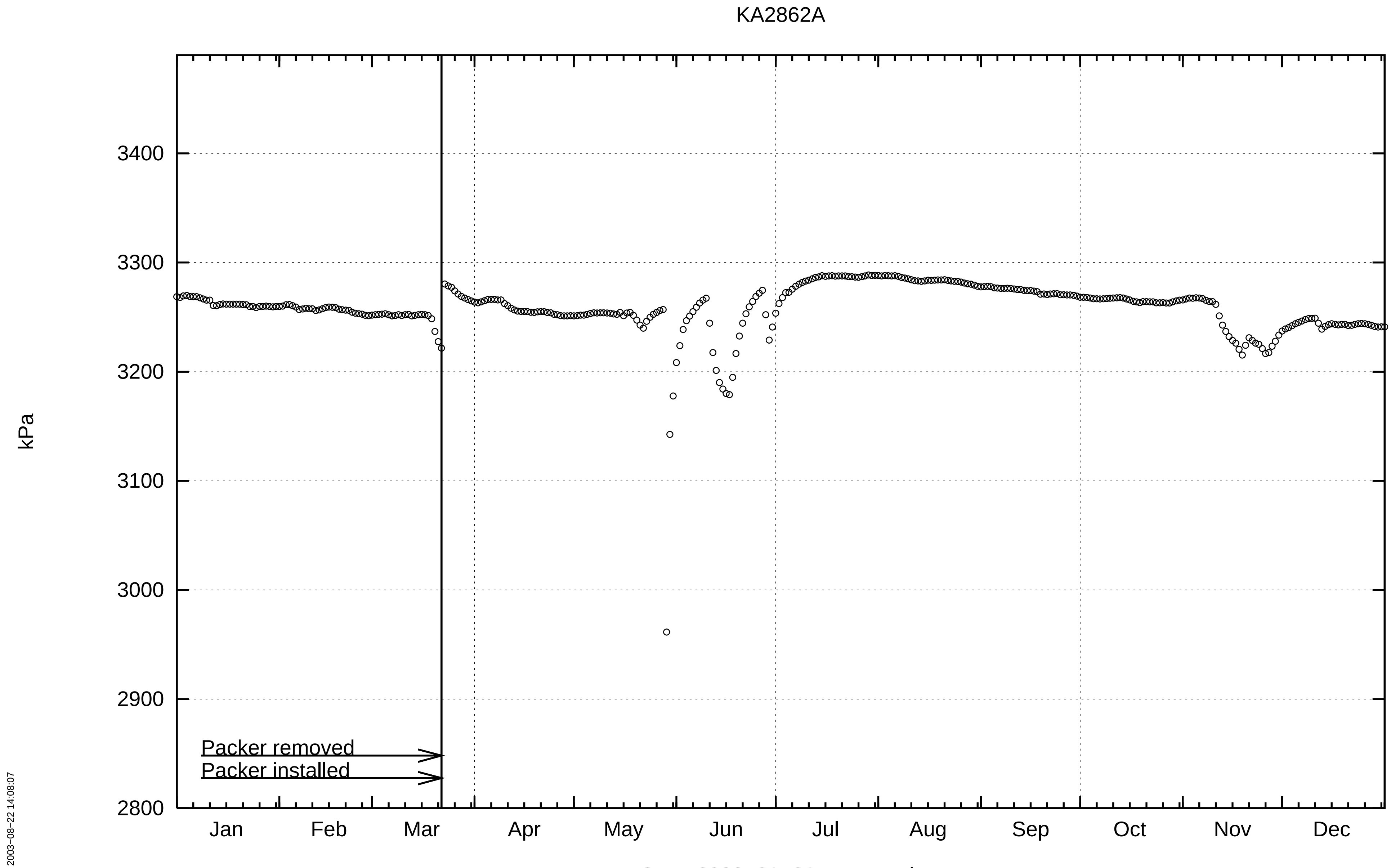
Start: 2002−01−01
month
2003−08−22 14:08:07



KA2862A
kPa
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3300
3200
3100
3000
2900
2800
Packer removed
Packer installed
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Feb
Mar
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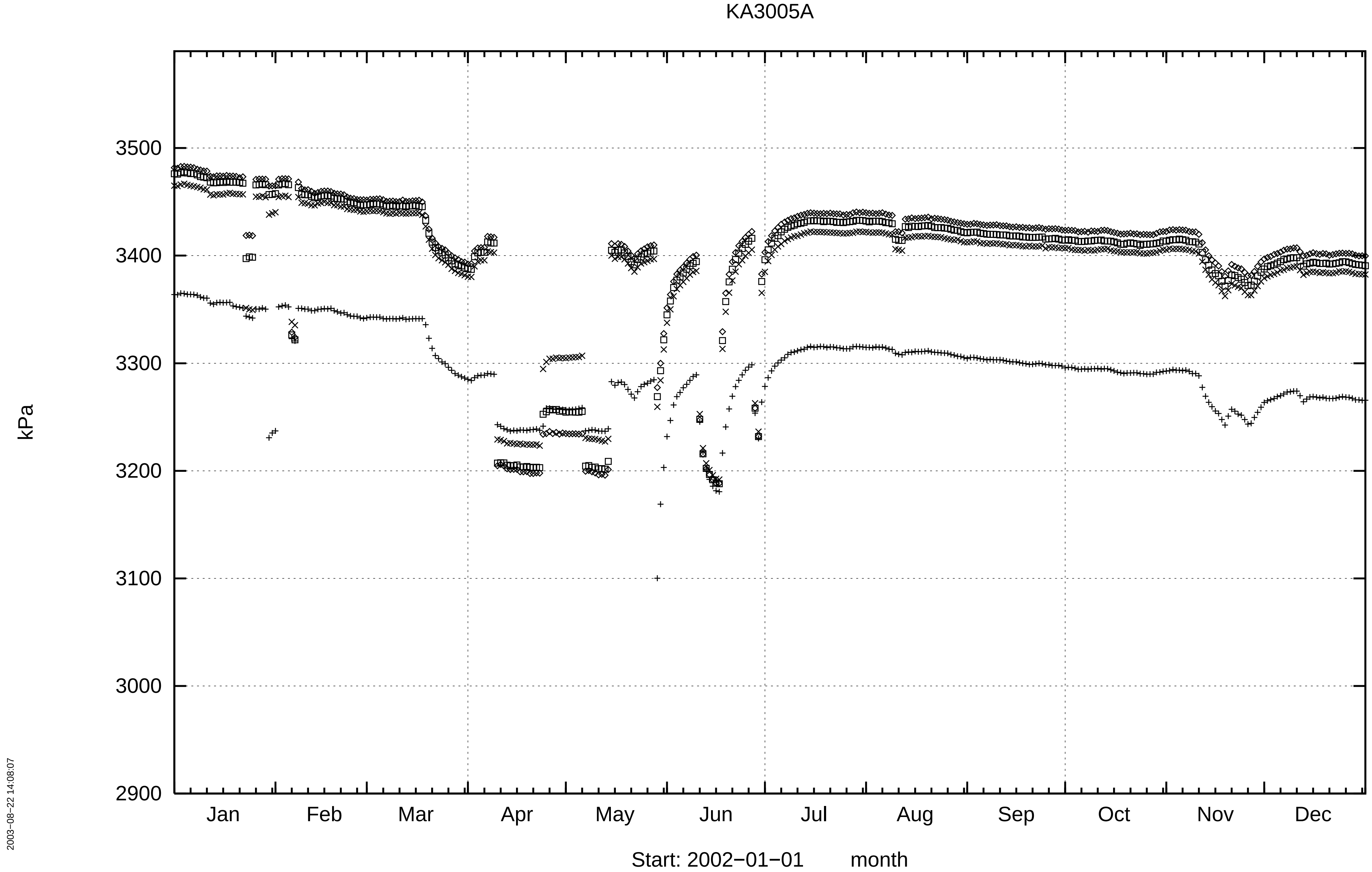
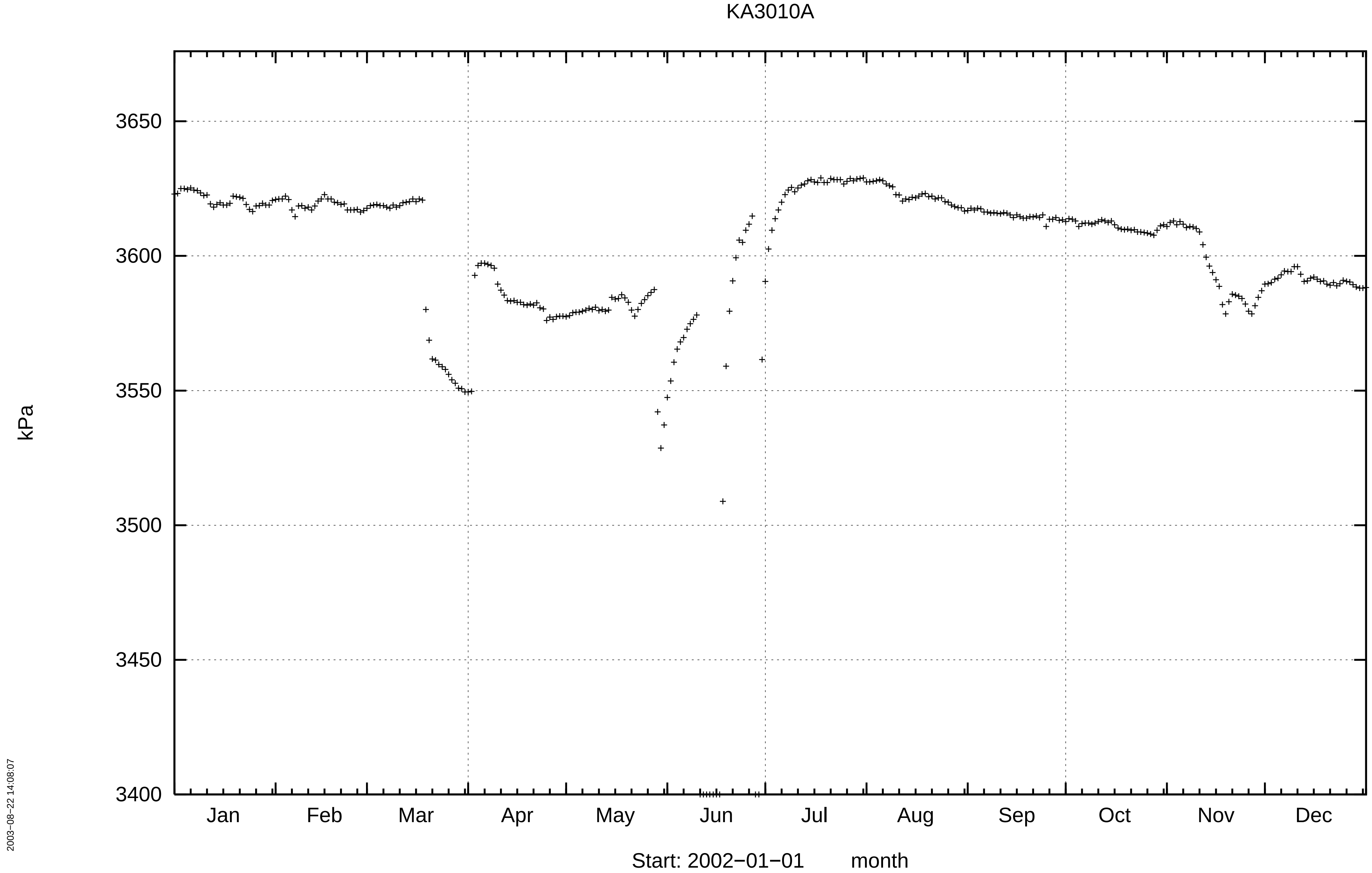
month
2003−08−22 14:08:07



KA3005A
kPa
3500
3400
3300
3200
3100
3000
2900
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:07


KA3010A
3650
3600
3550
3500
3450
3400
kPa
Jan
Feb
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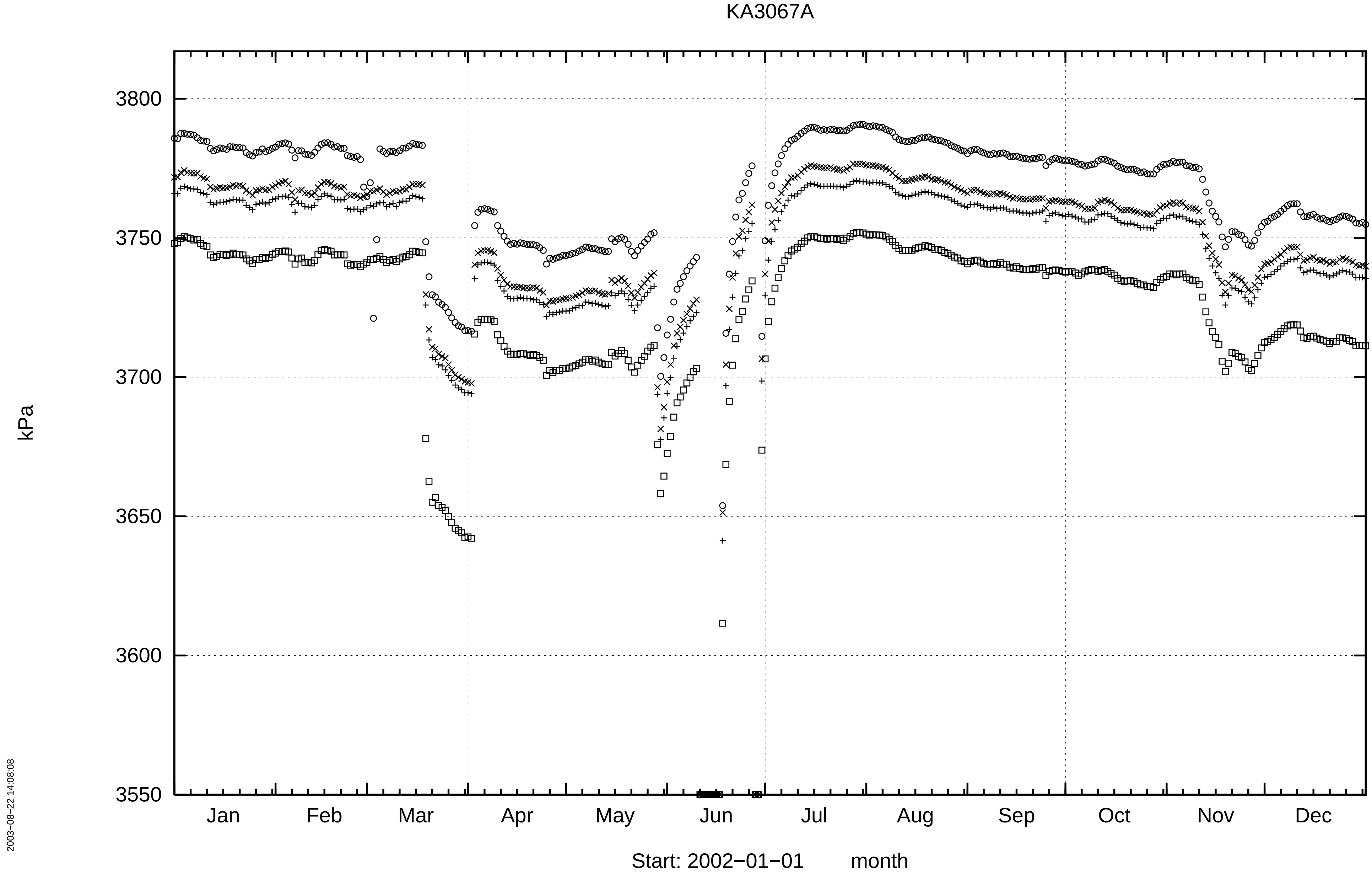
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:07



KA3067A
kPa
3800
3750
3700
3650
3600
3550
Jan
Feb
Mar
Apr
May
Jun
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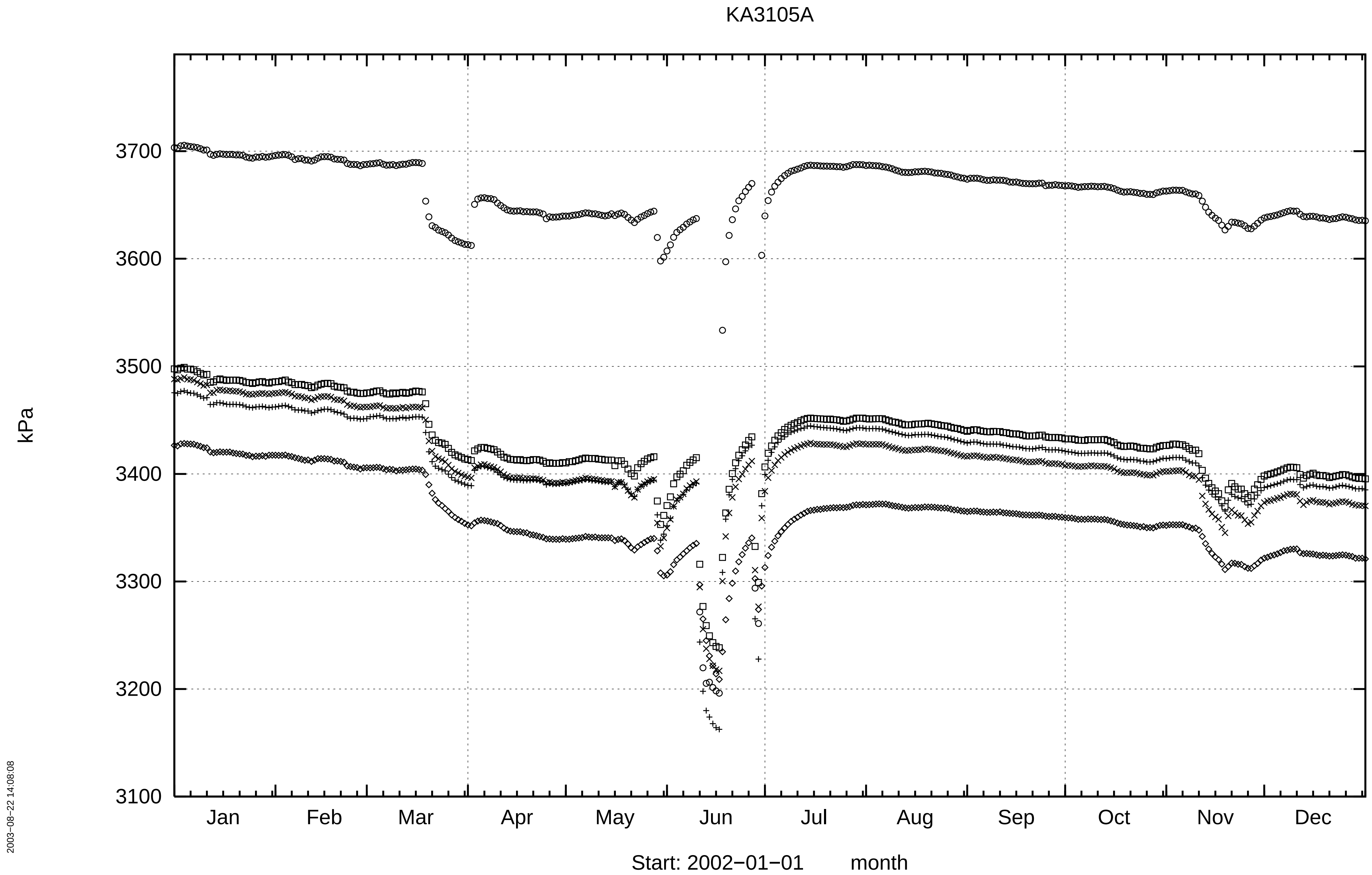
2003−08−22 14:08:08


KA3105A
kPa
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3600
3500
3400
3300
3200
3100
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Feb
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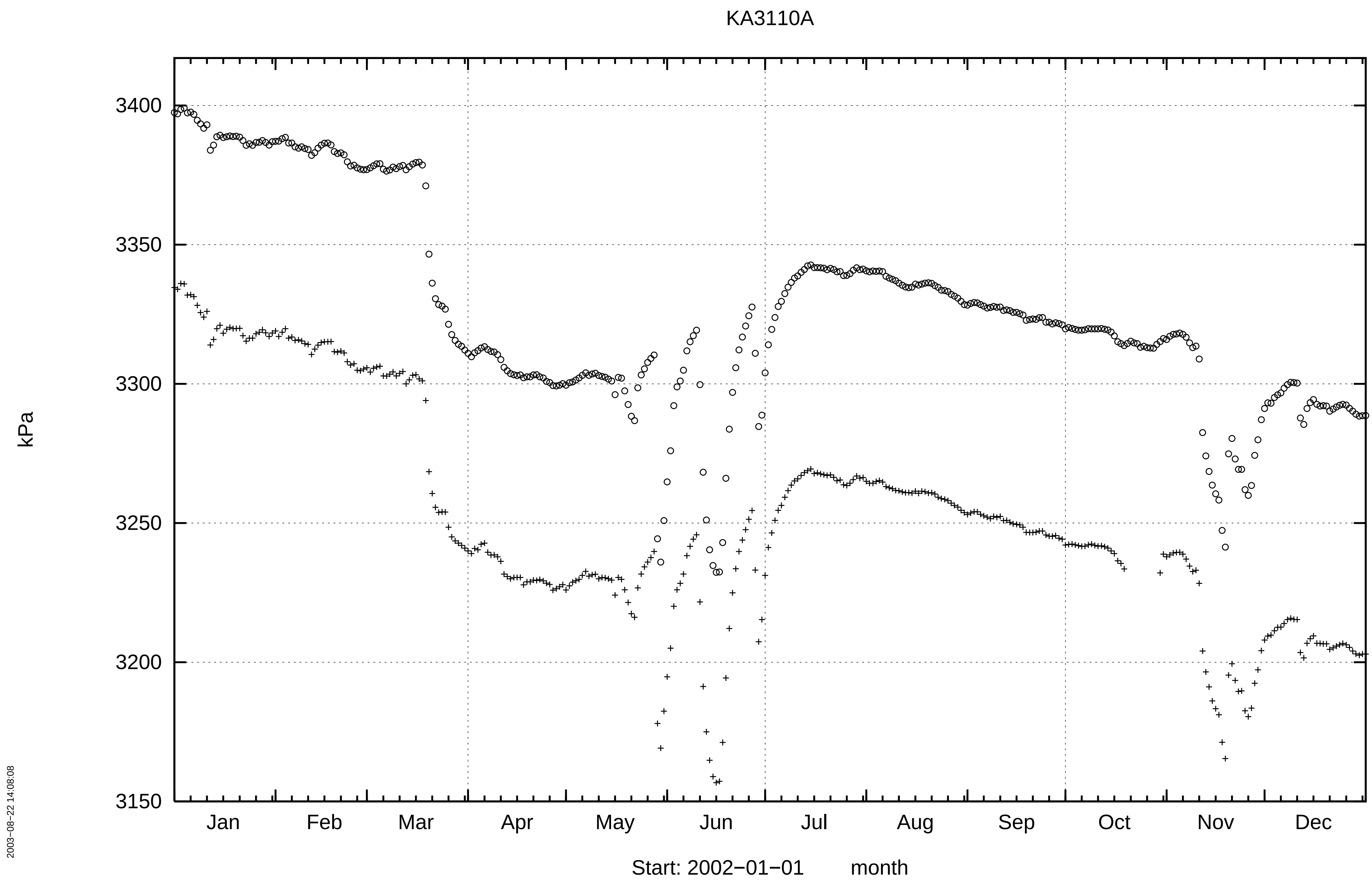
Dec
Start: 2002−01−01
month
2003−08−22 14:08:08


KA3110A
kPa
3400
3350
3300
3250
3200
3150
Jan
Feb
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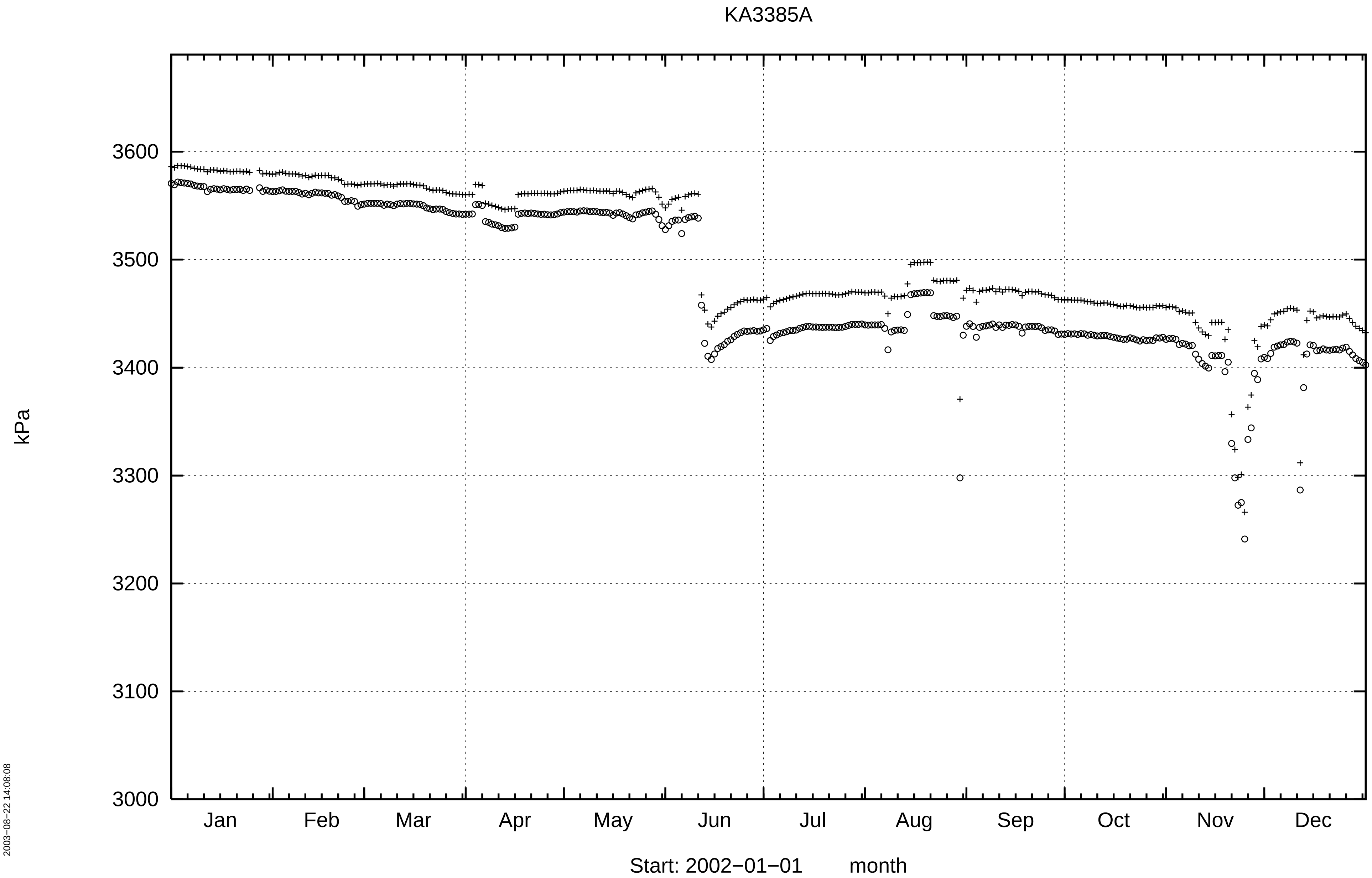
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:08



KA3385A
kPa
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3500
3400
3300
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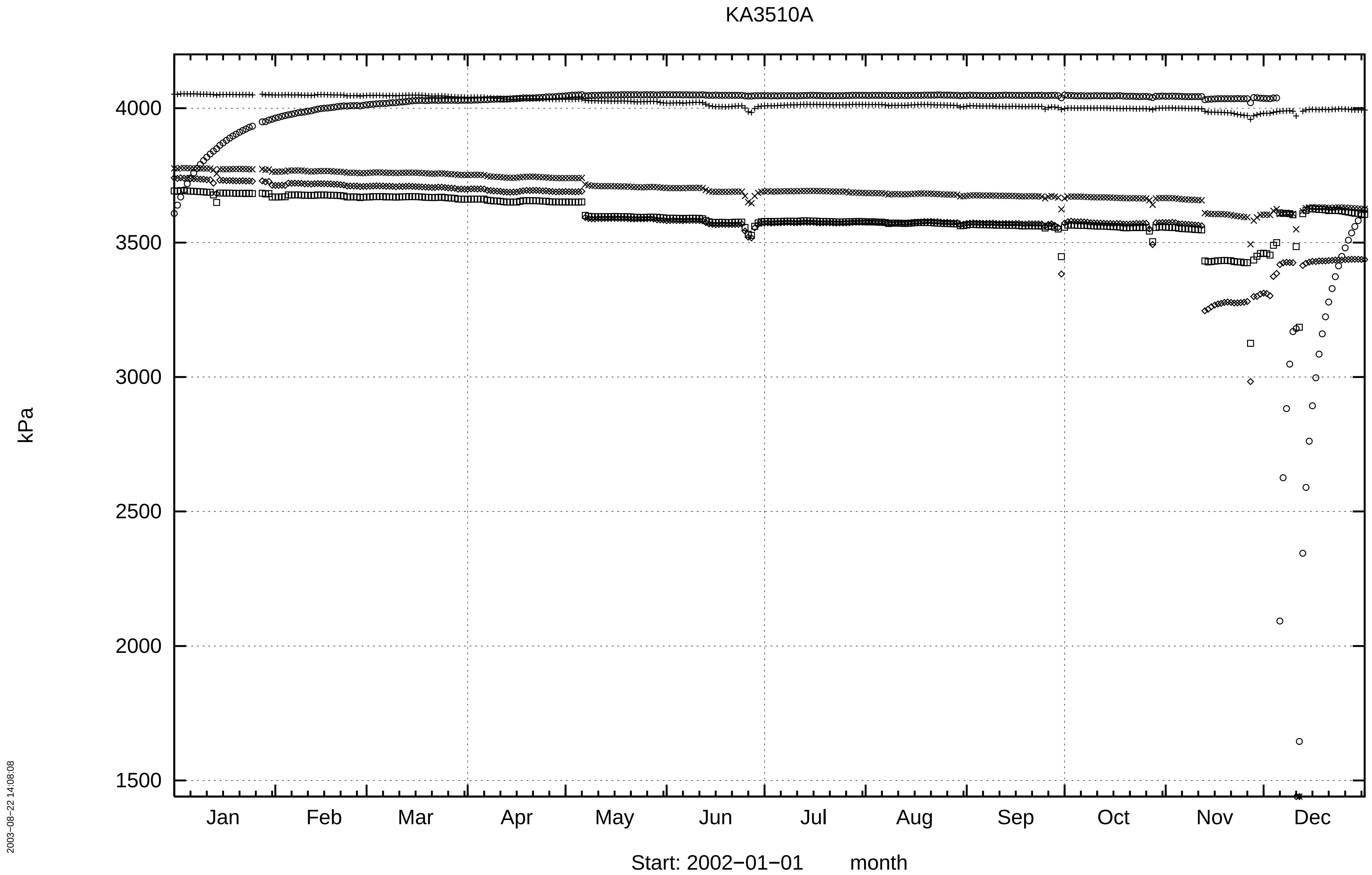
3100
3000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:08



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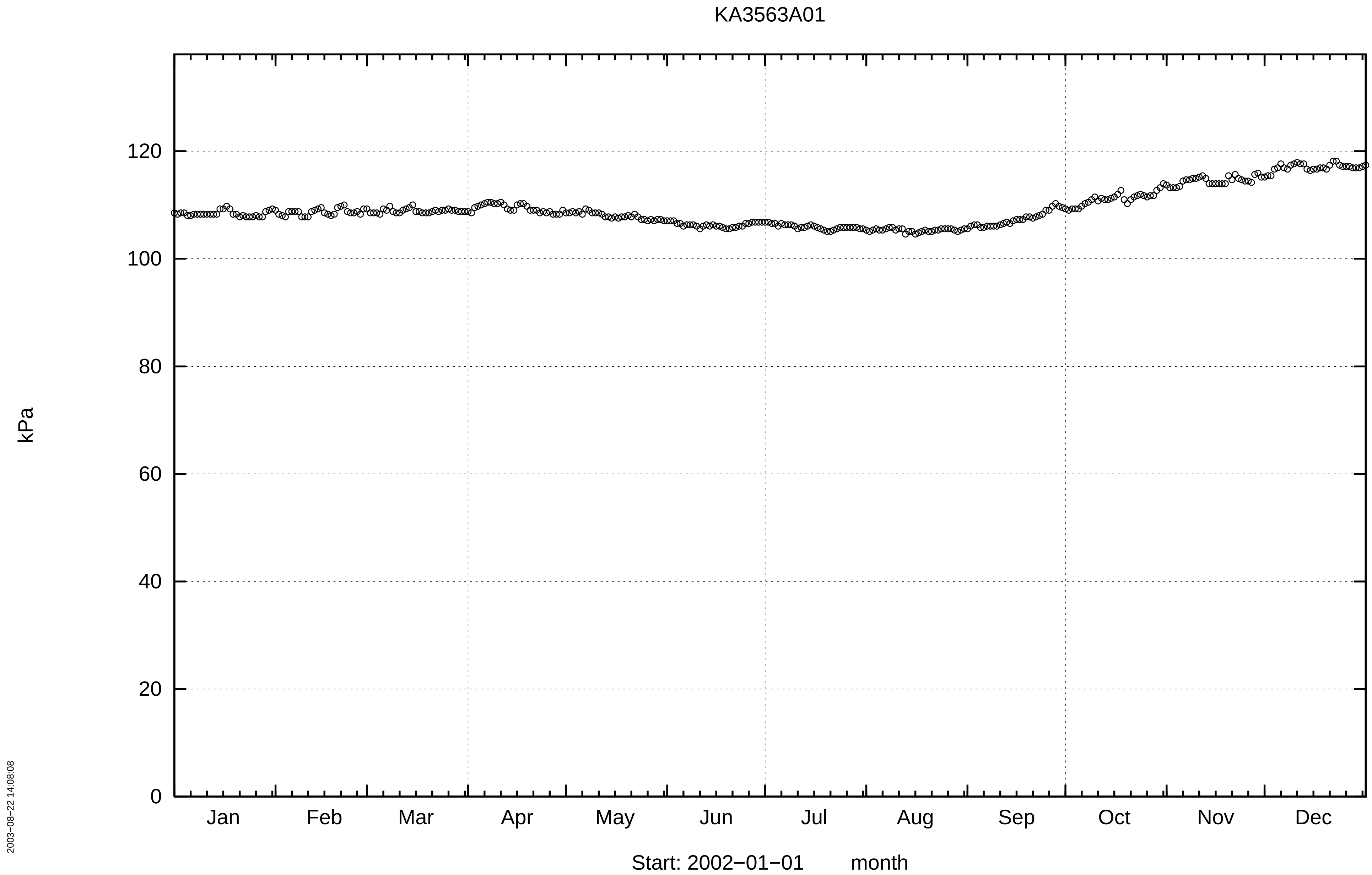

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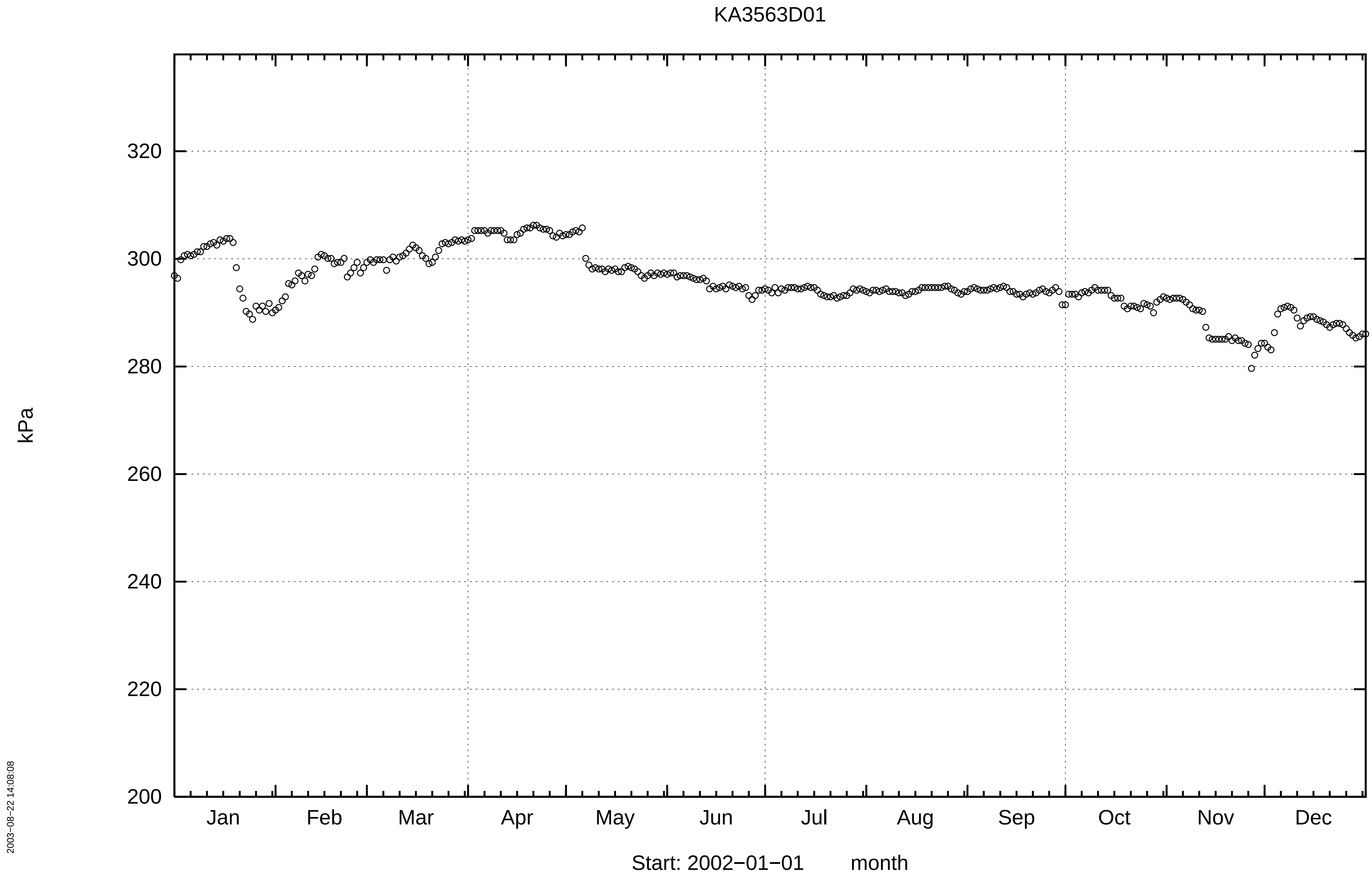

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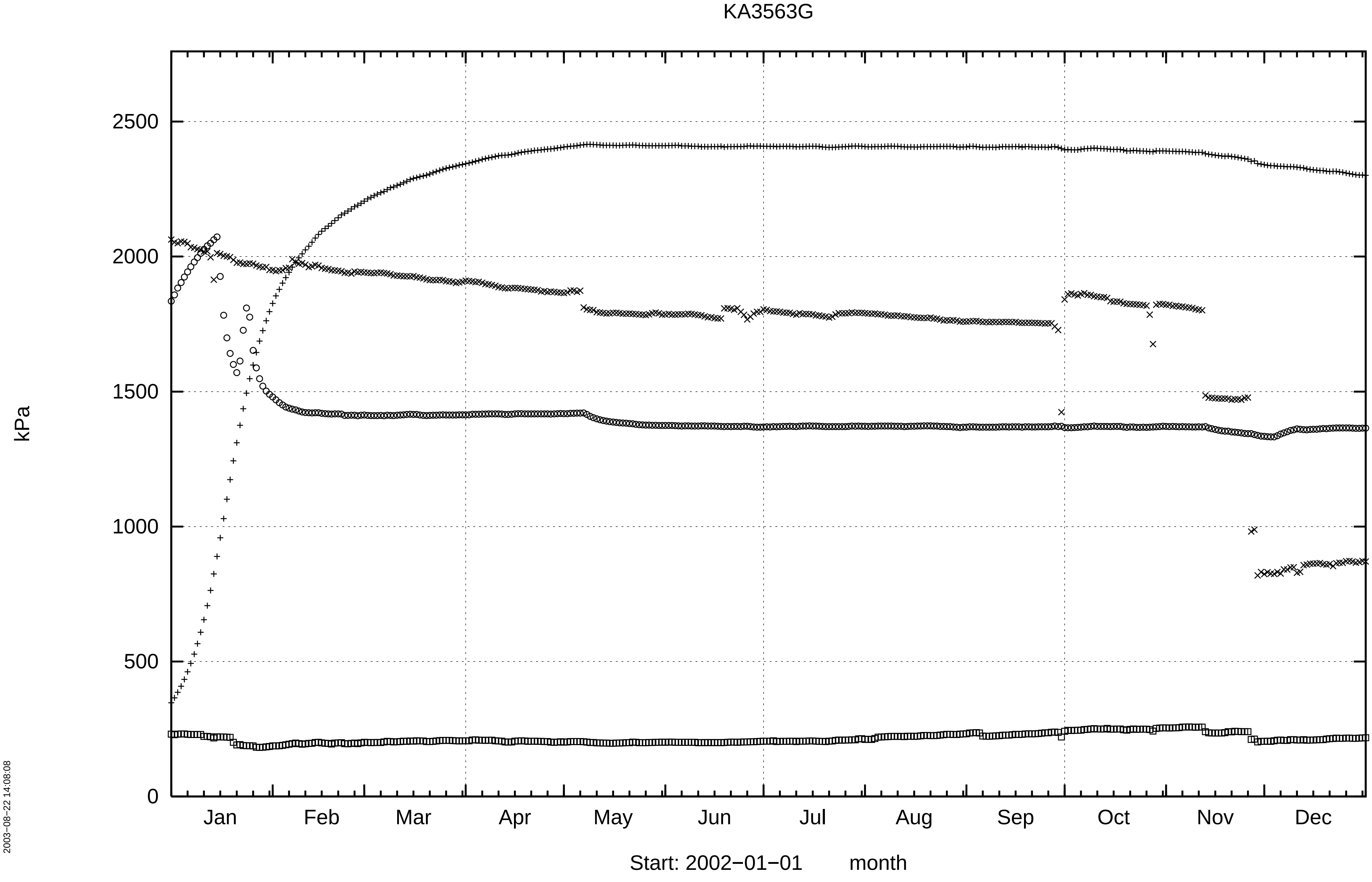
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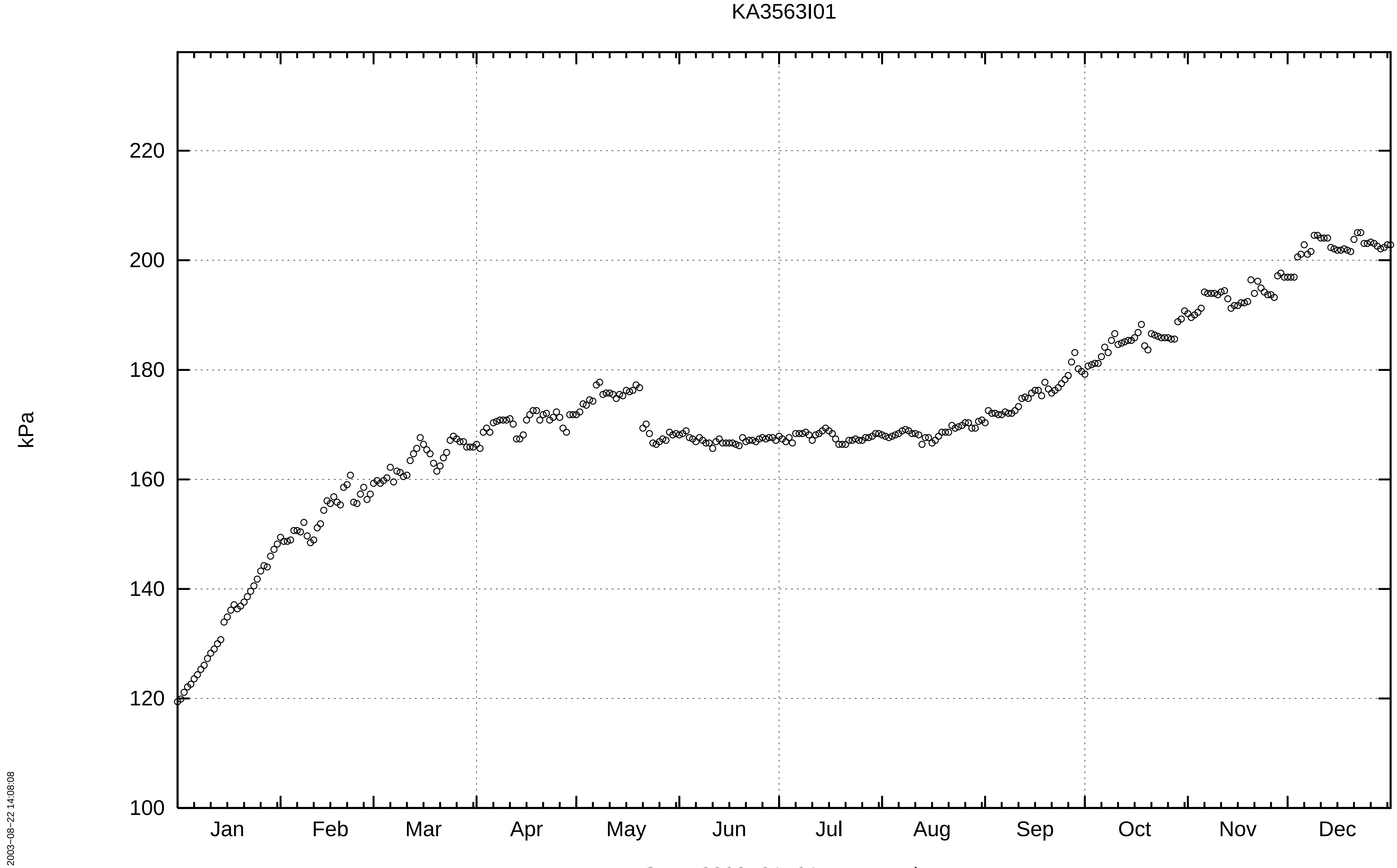
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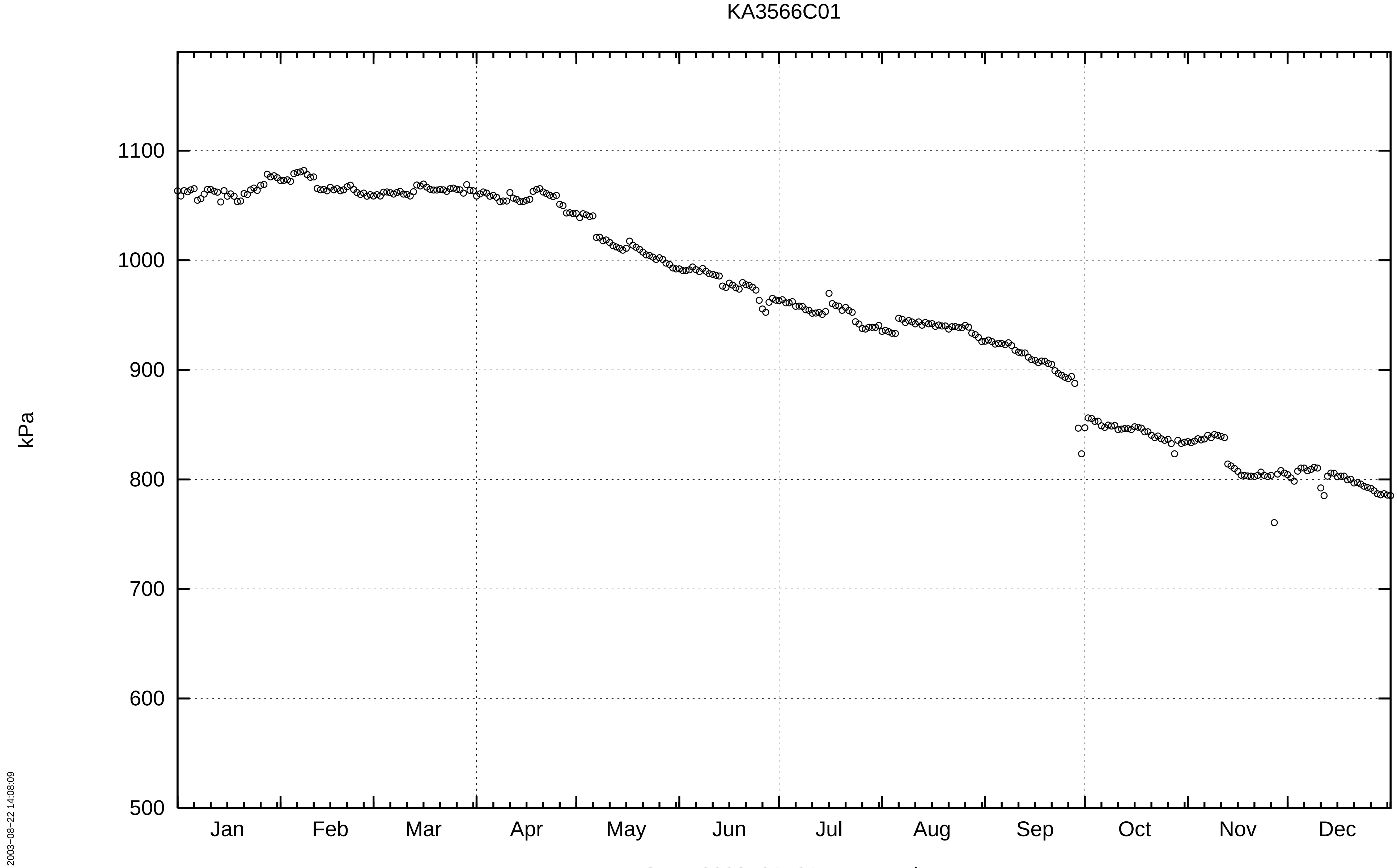
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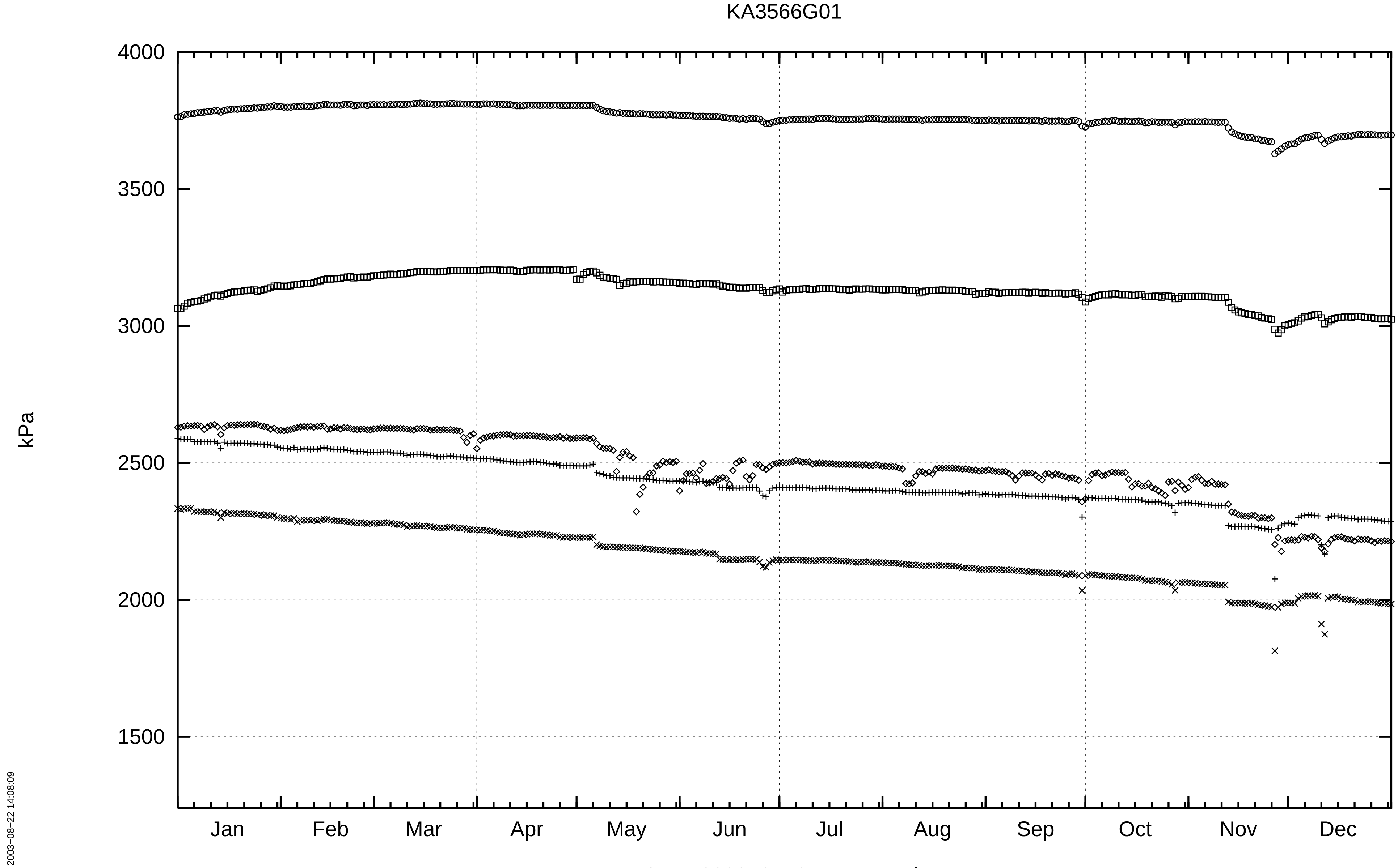

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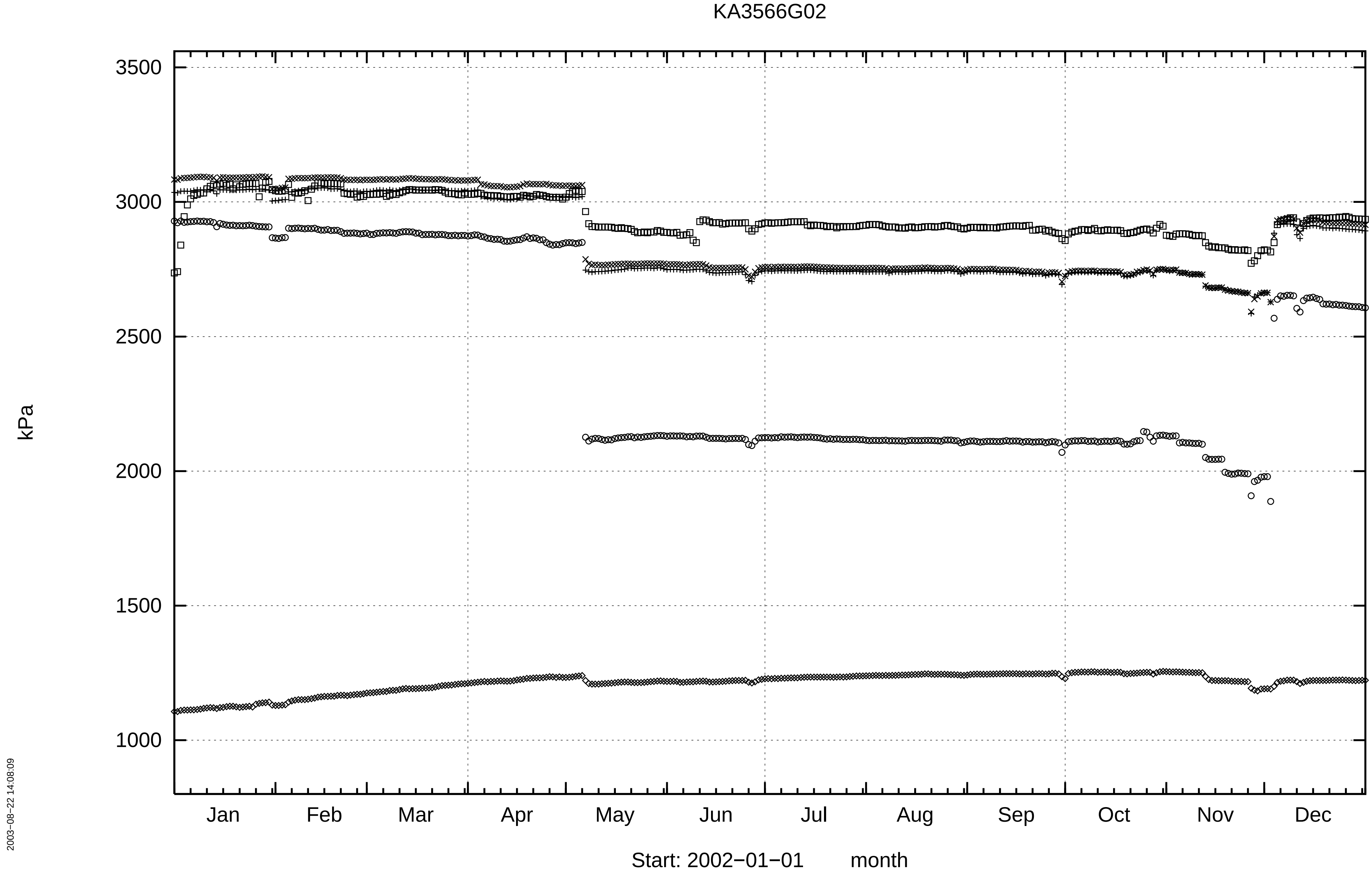
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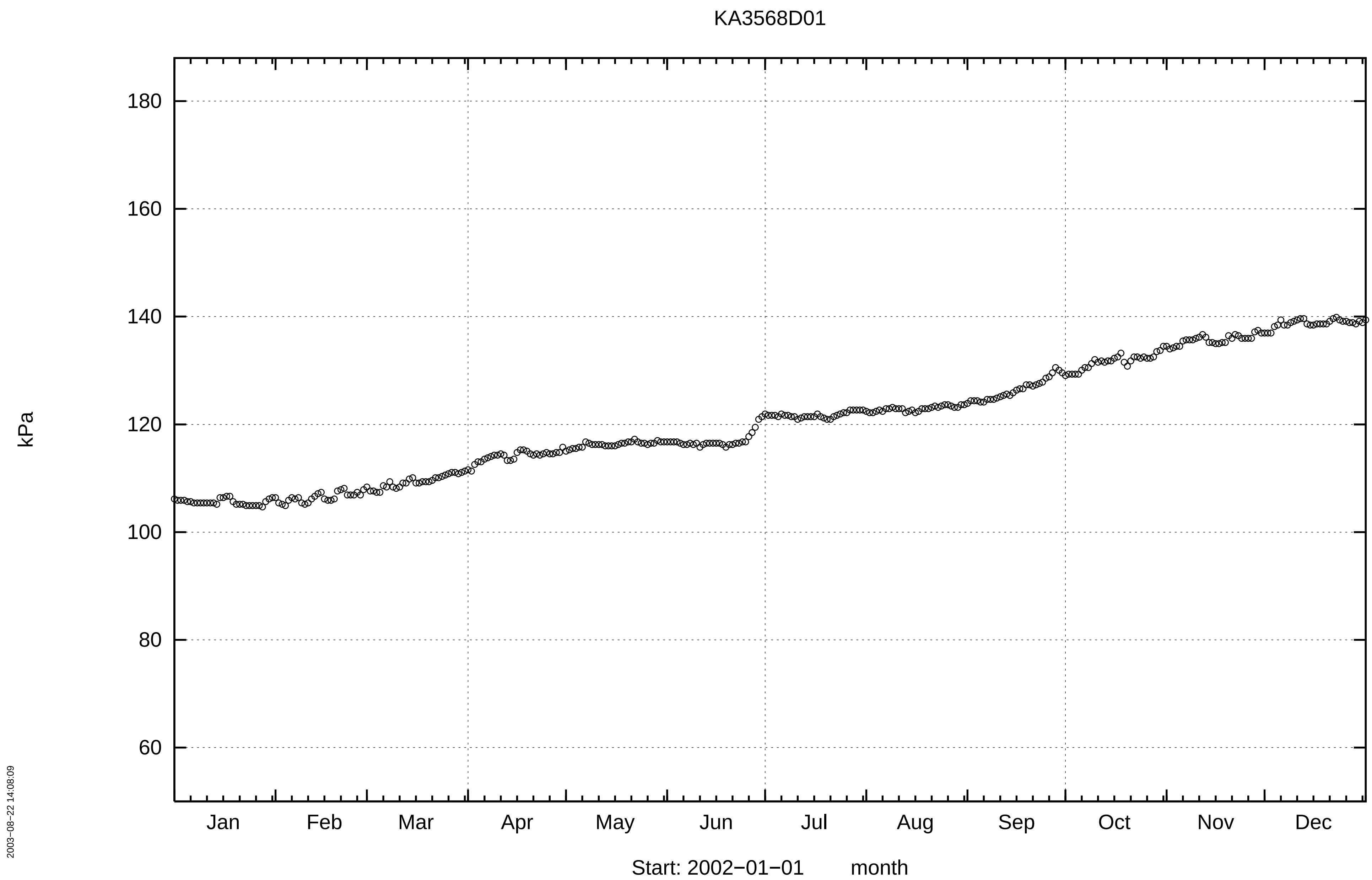

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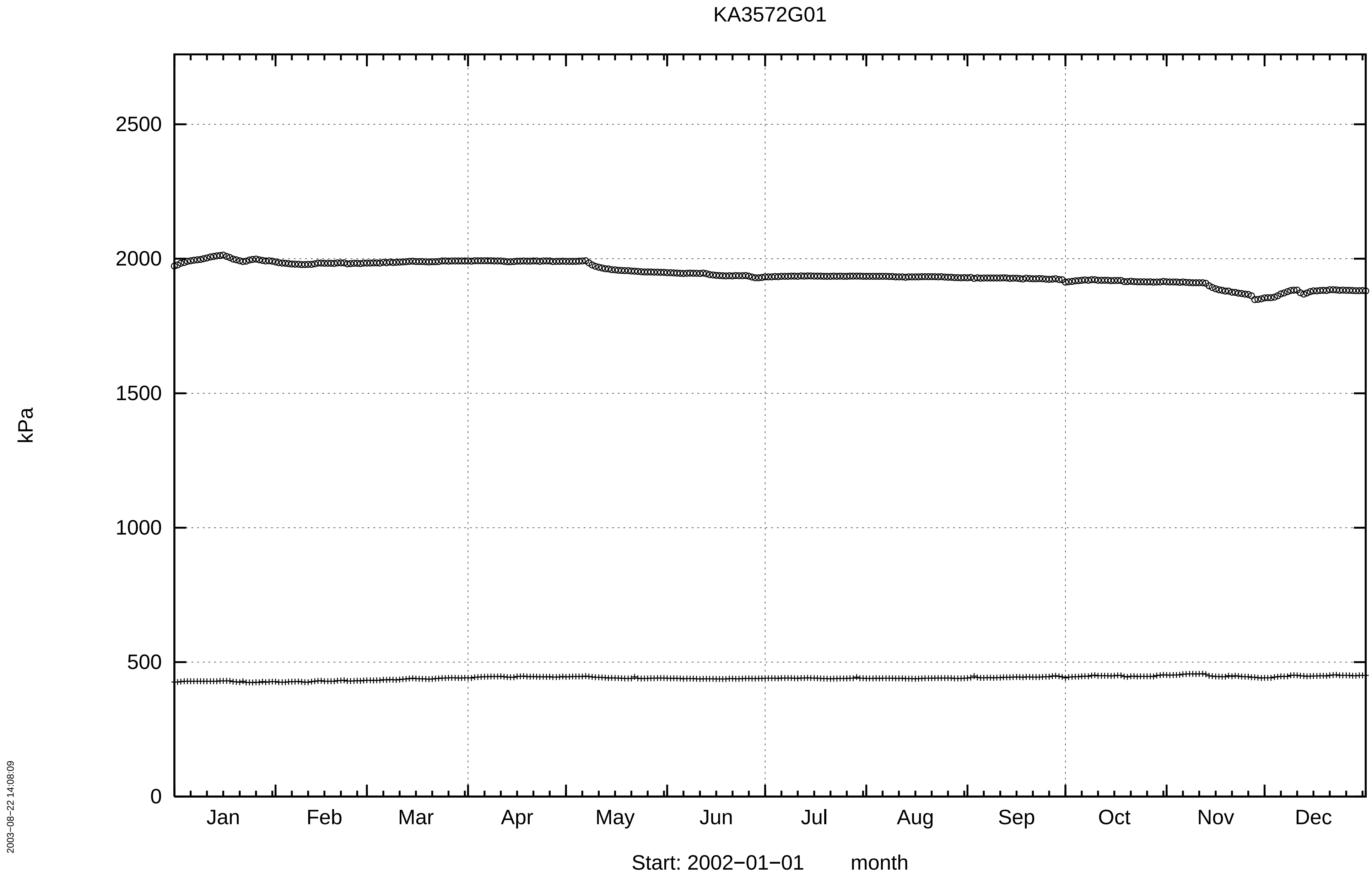

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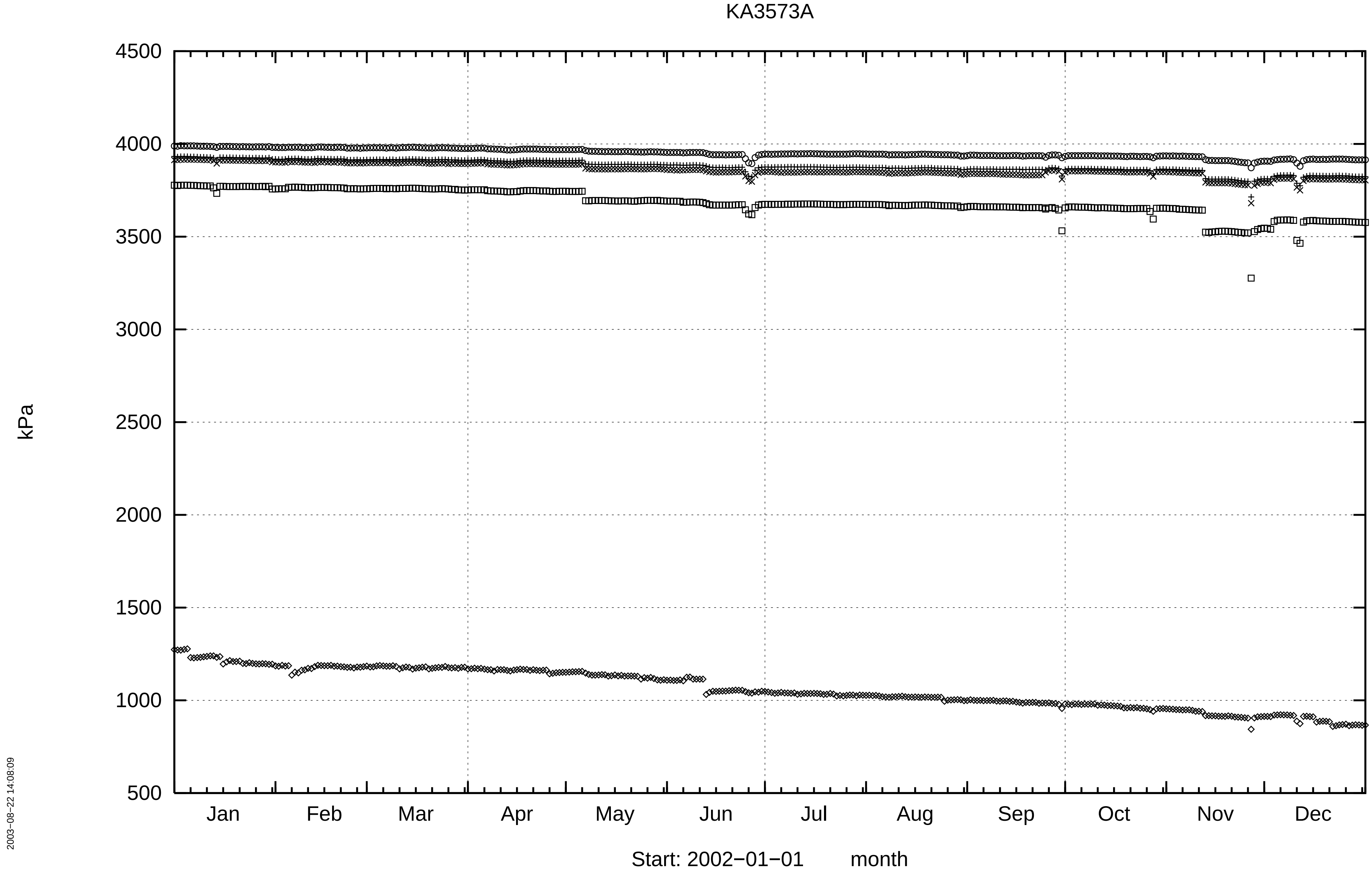
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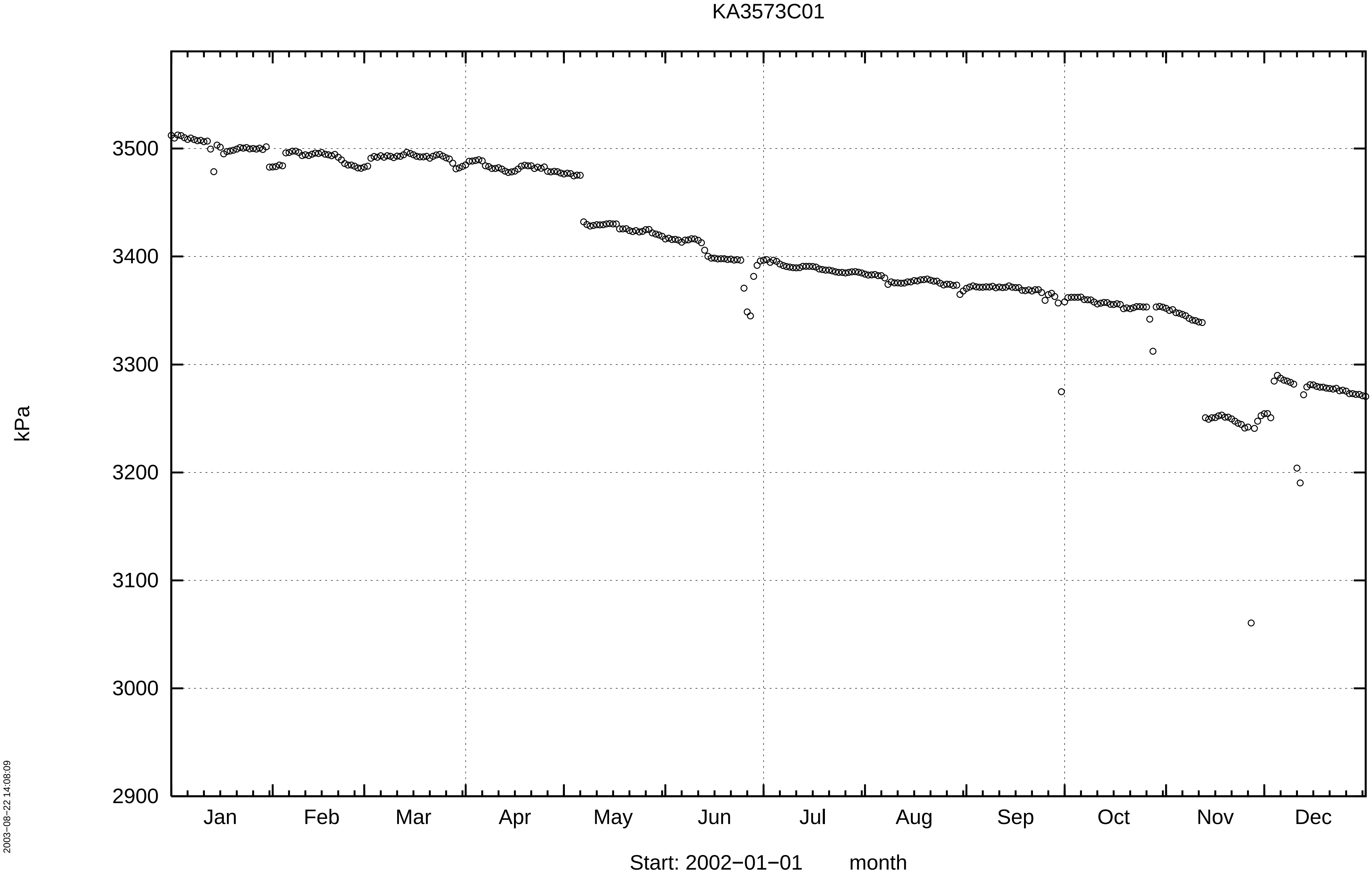

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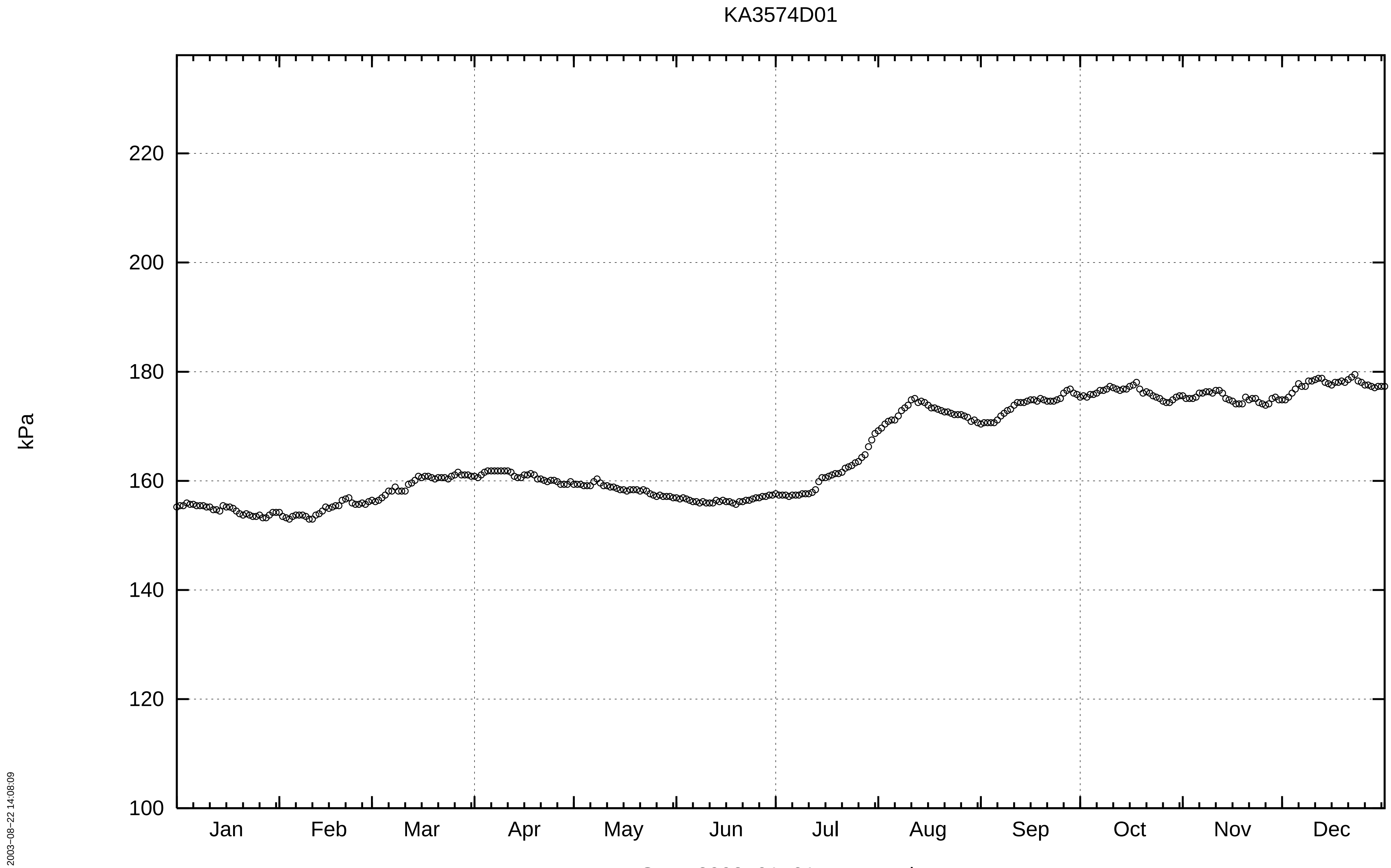

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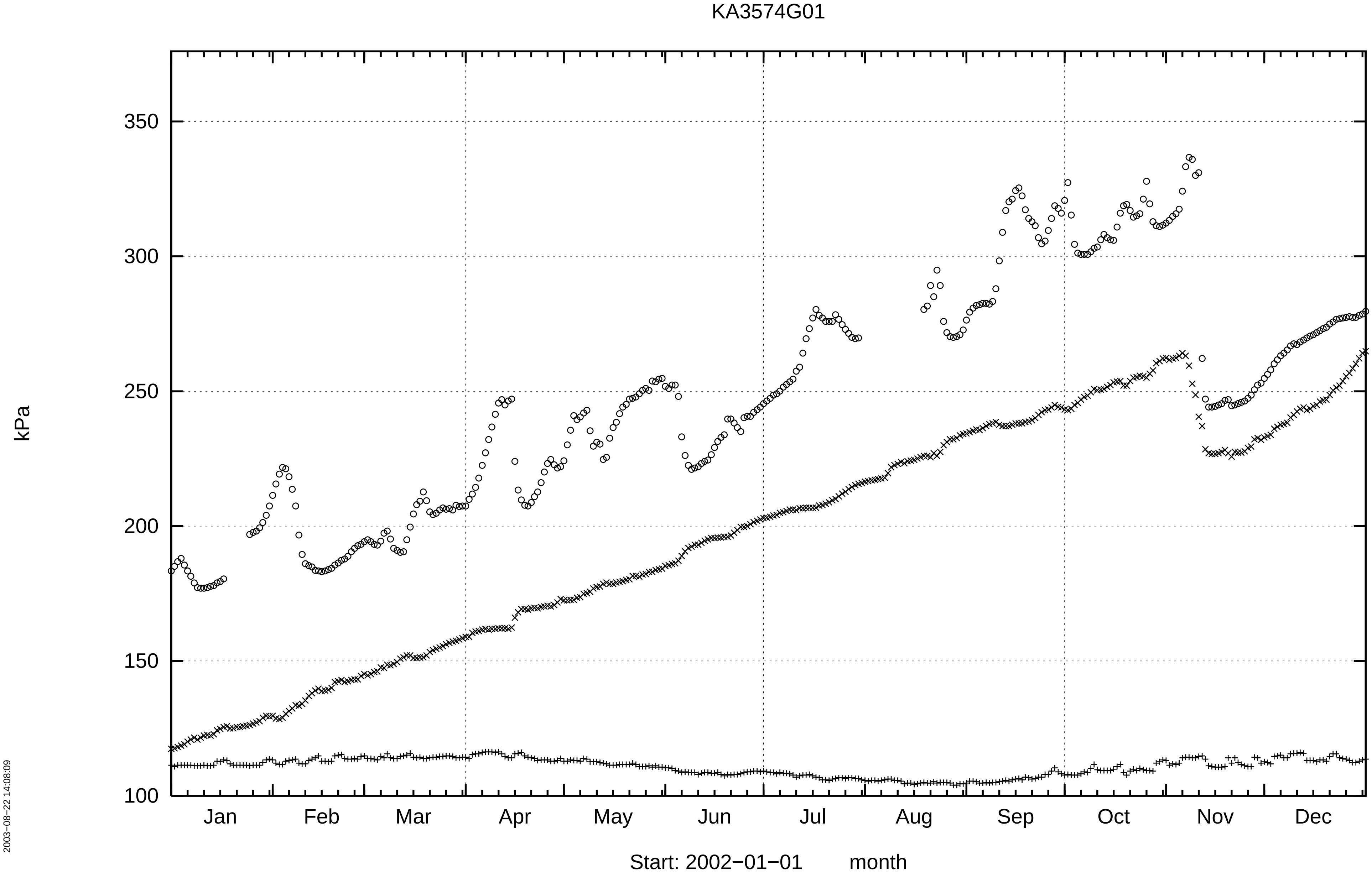
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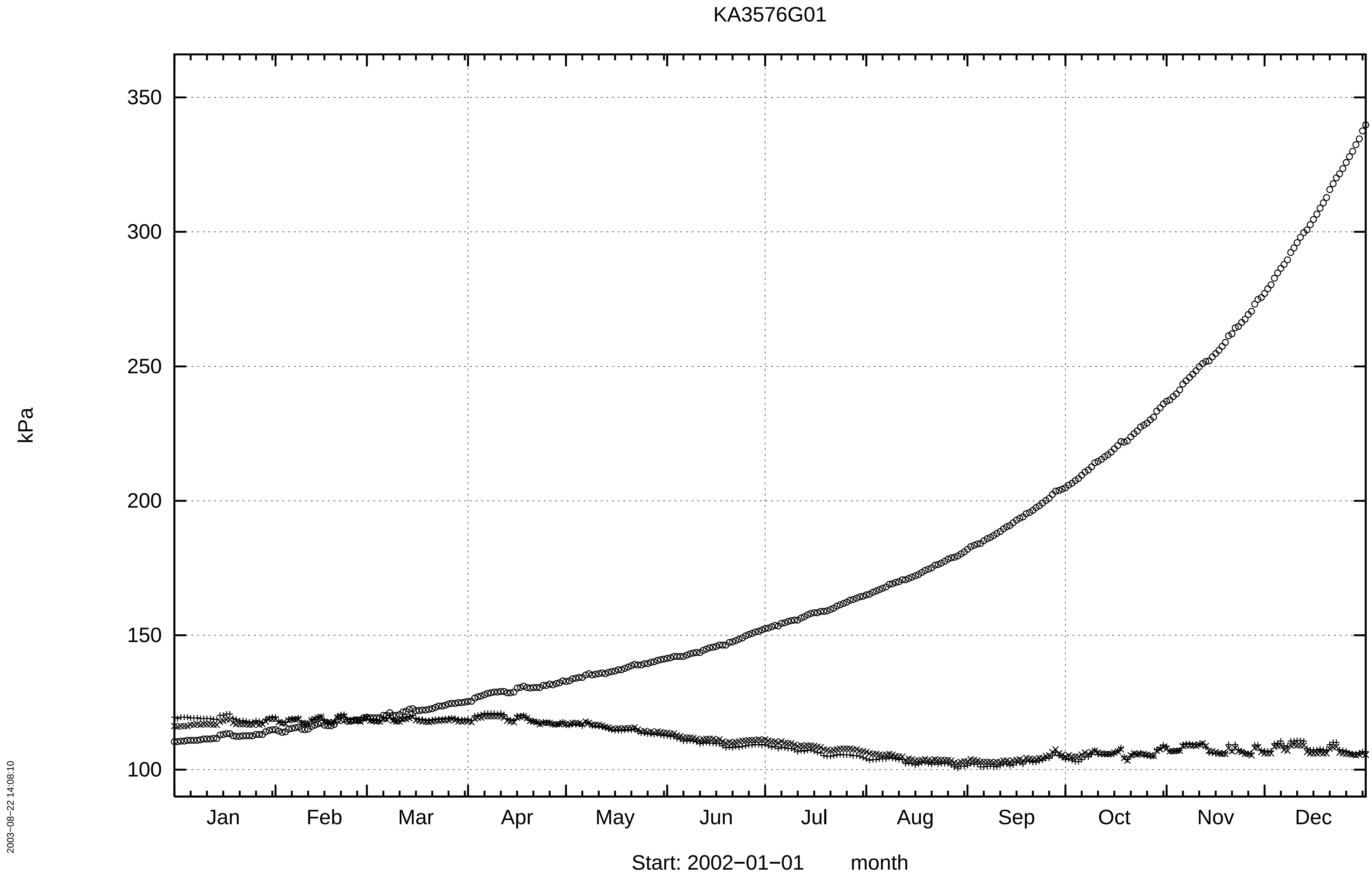

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month
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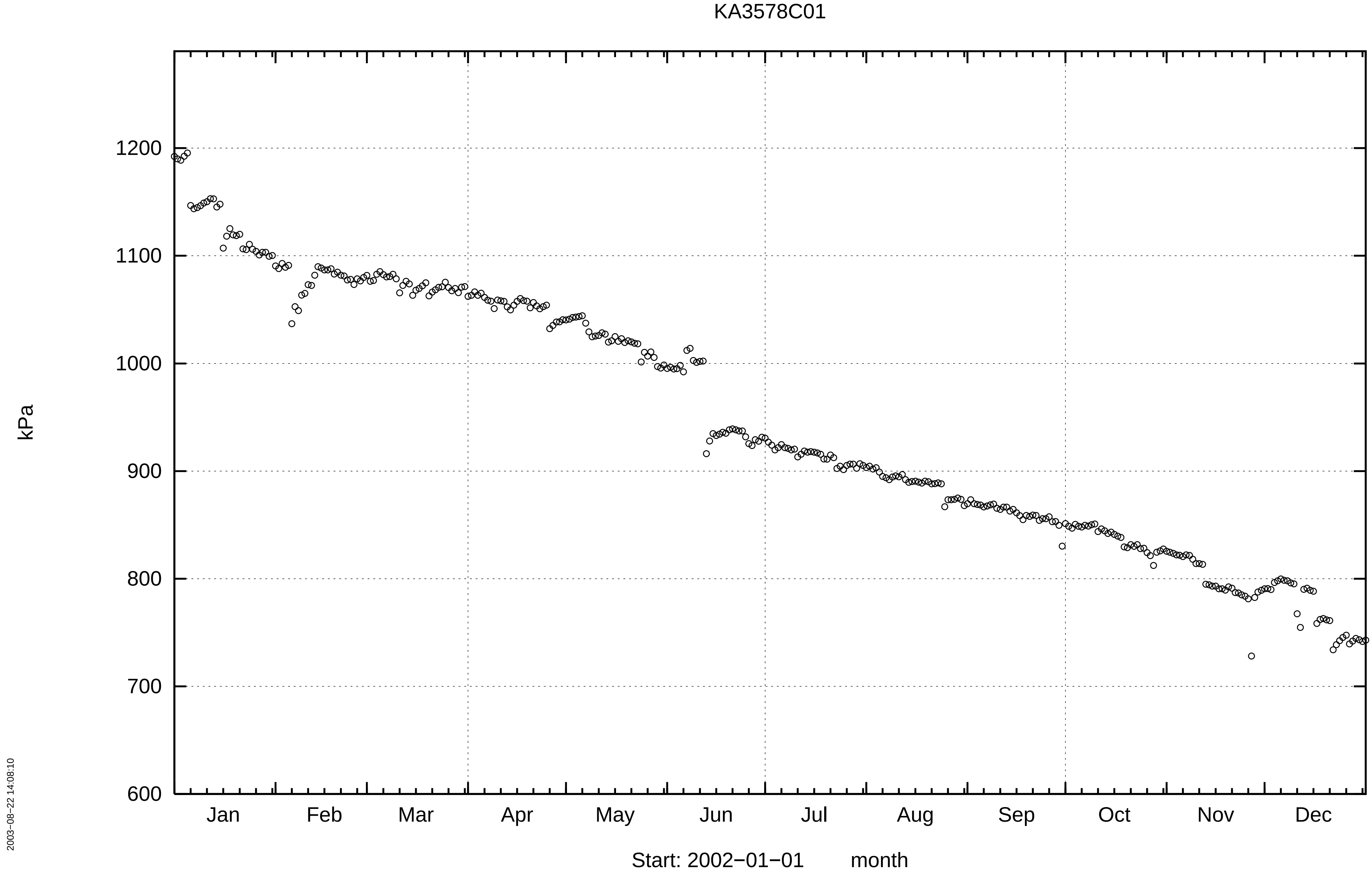

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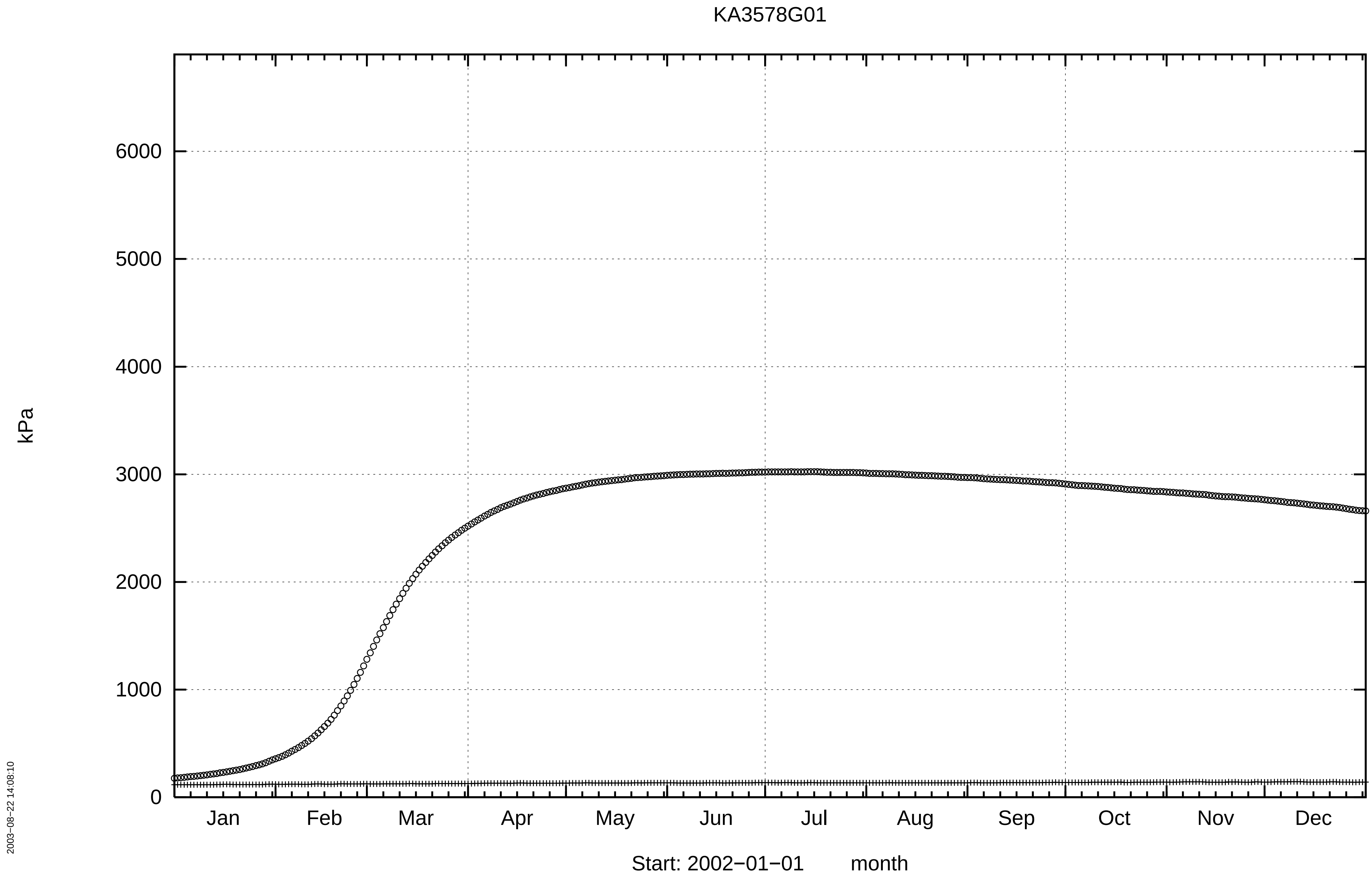

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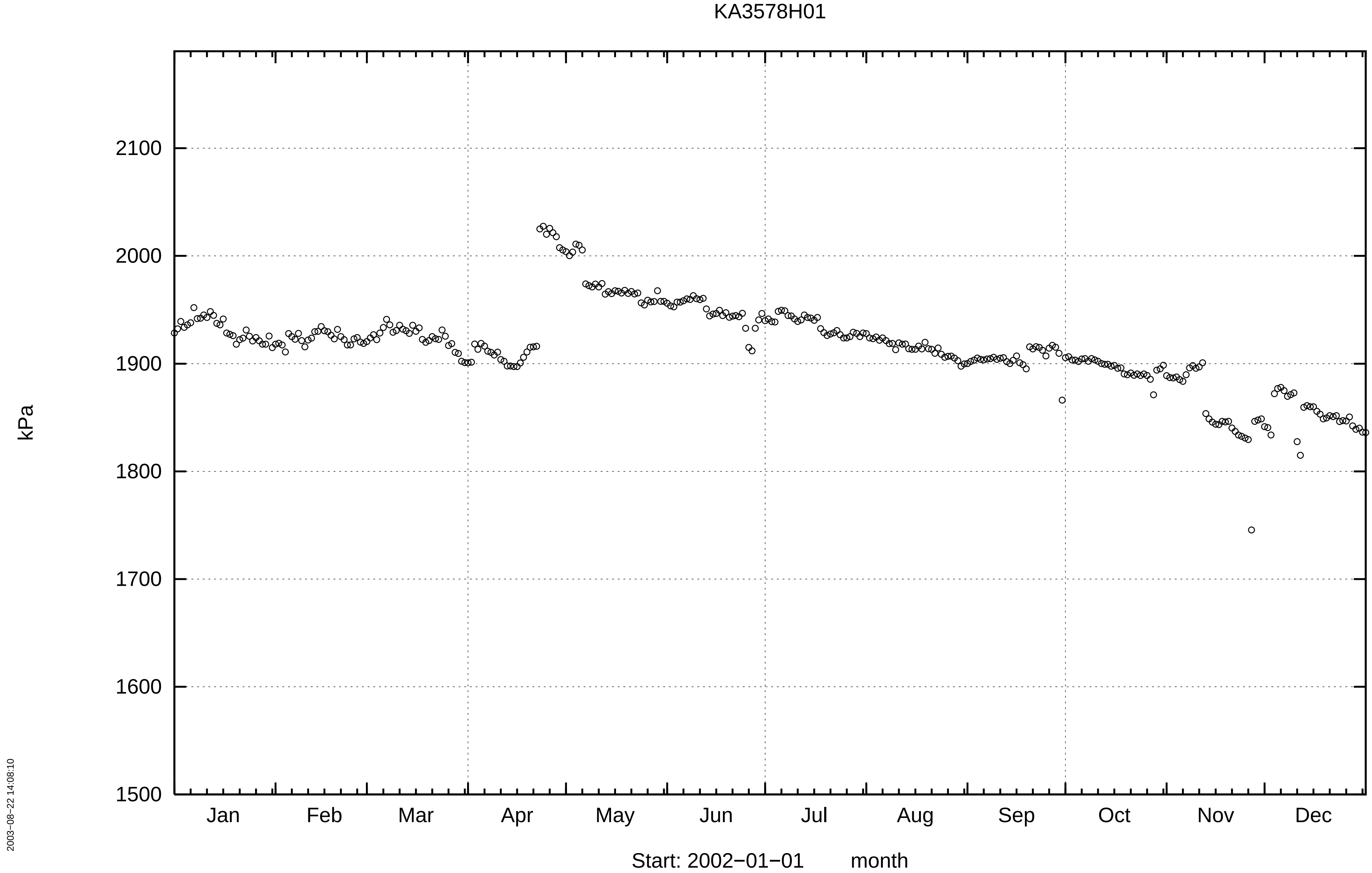
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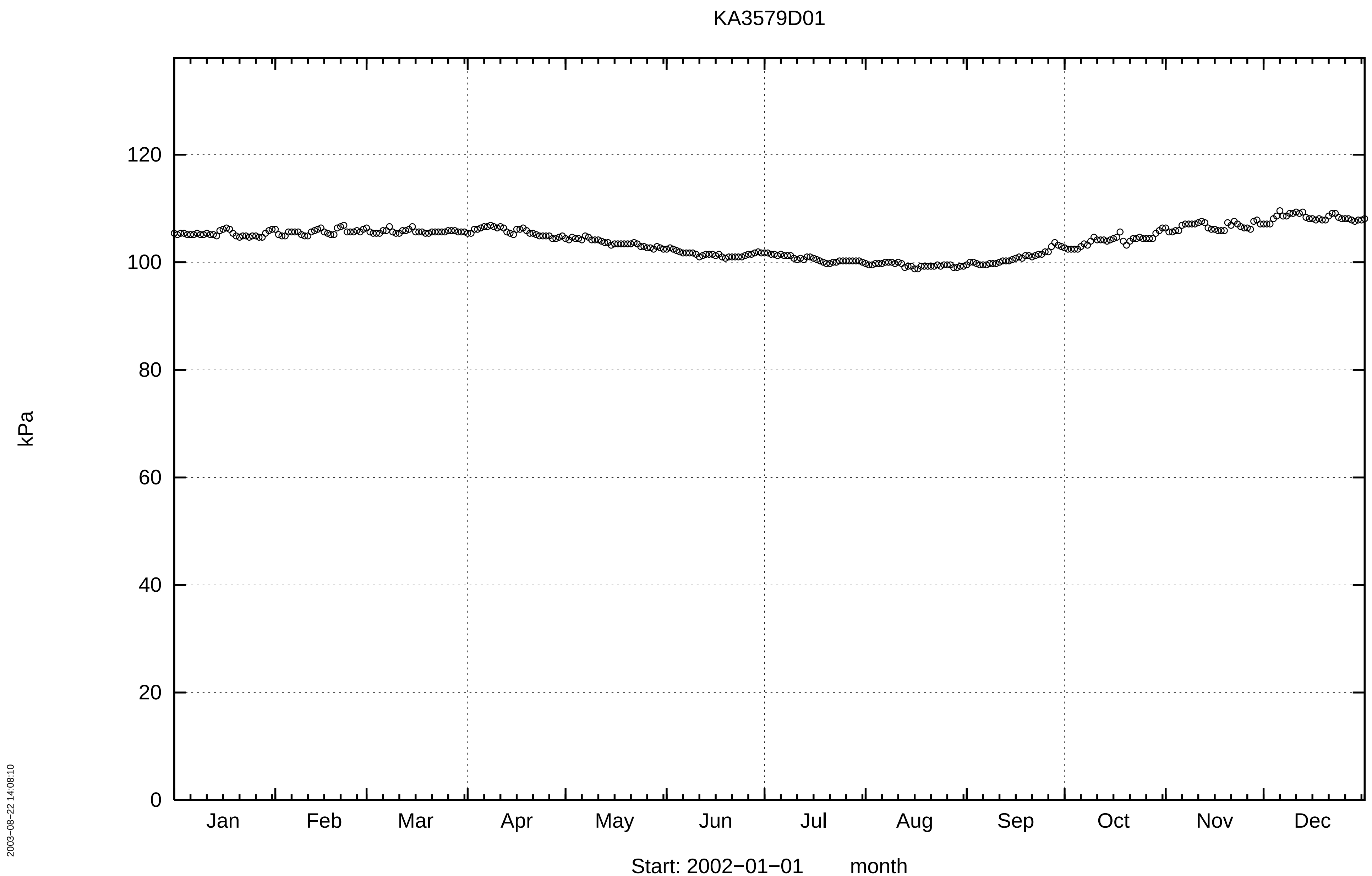

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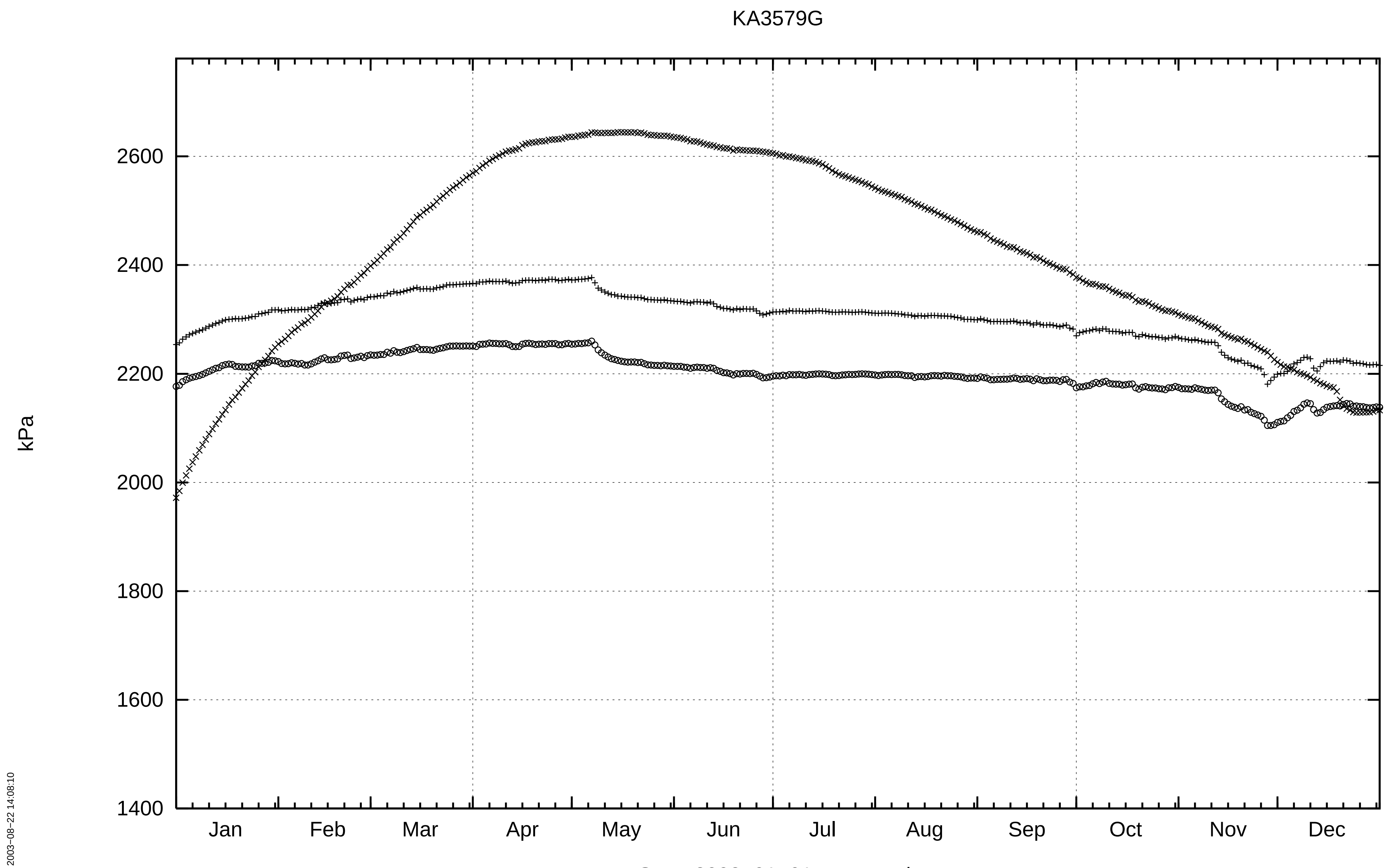

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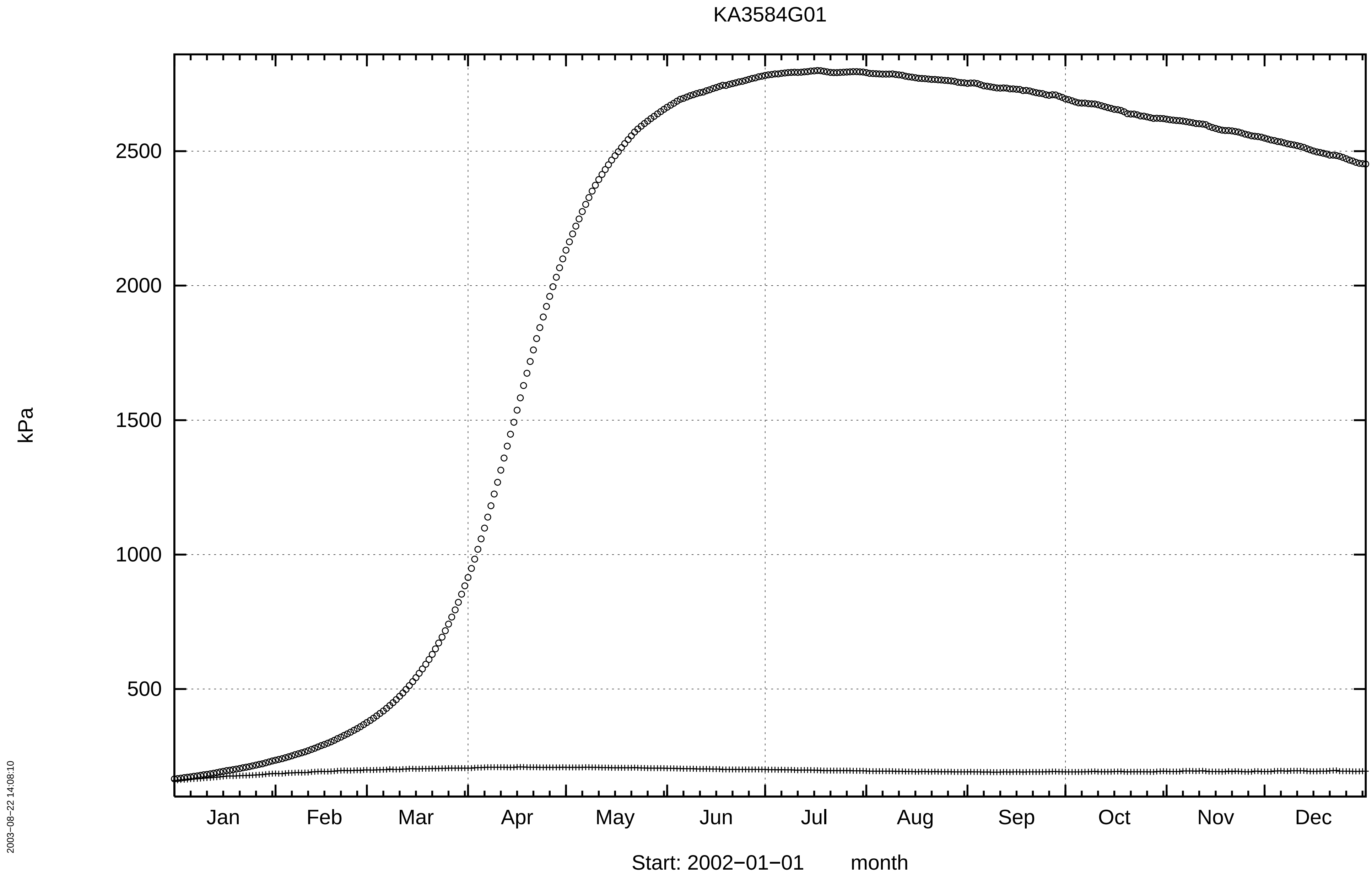

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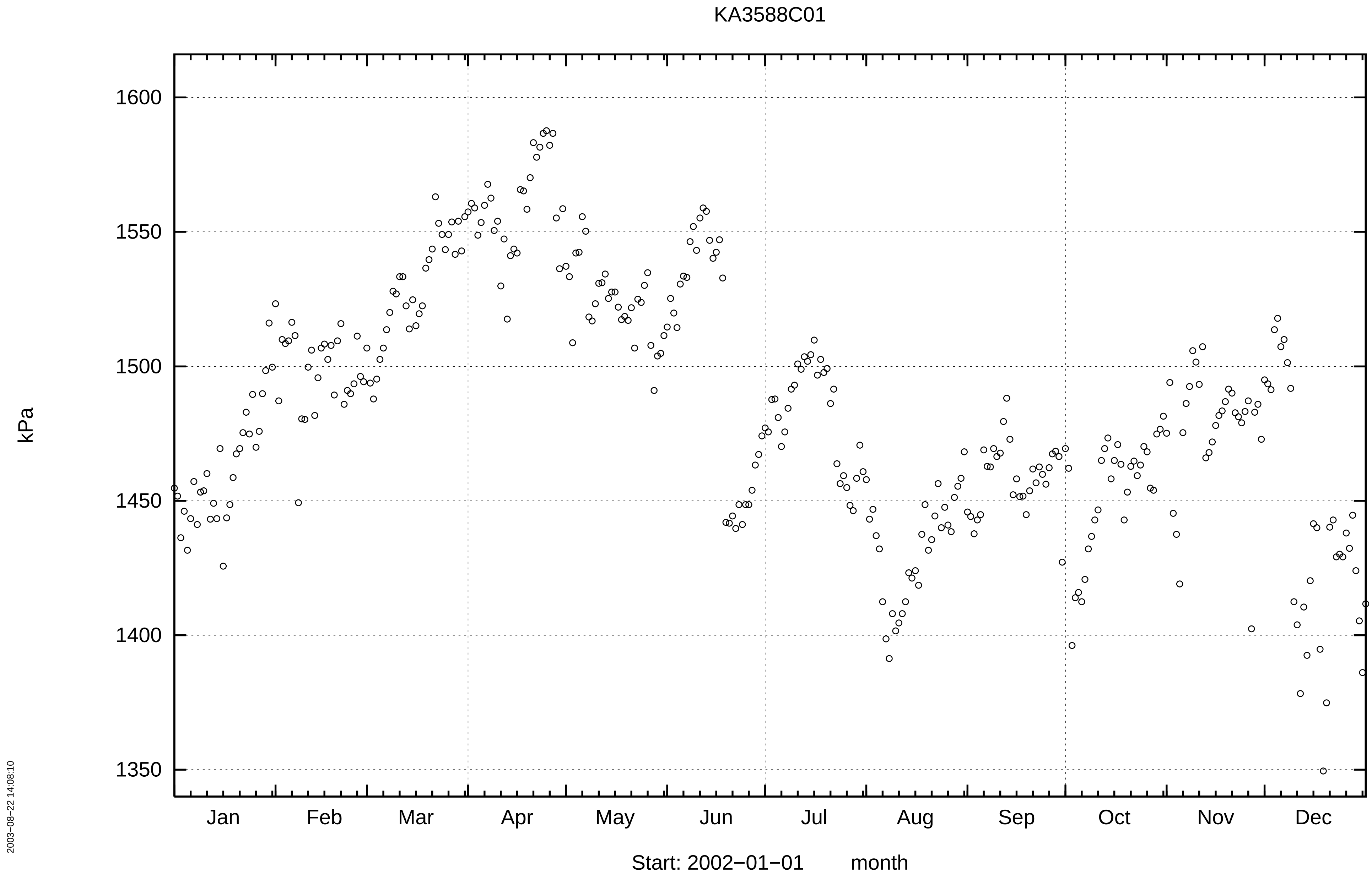
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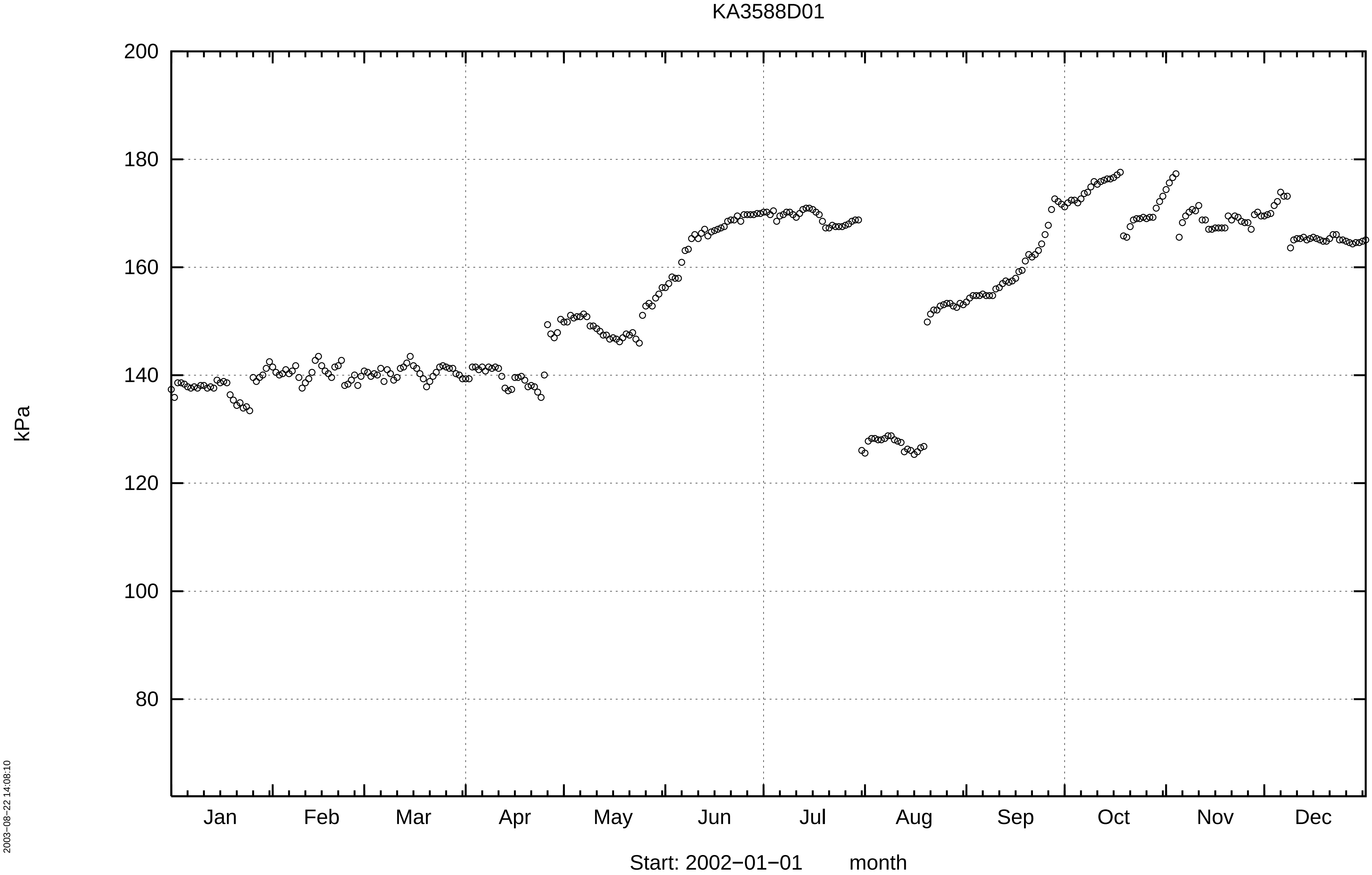

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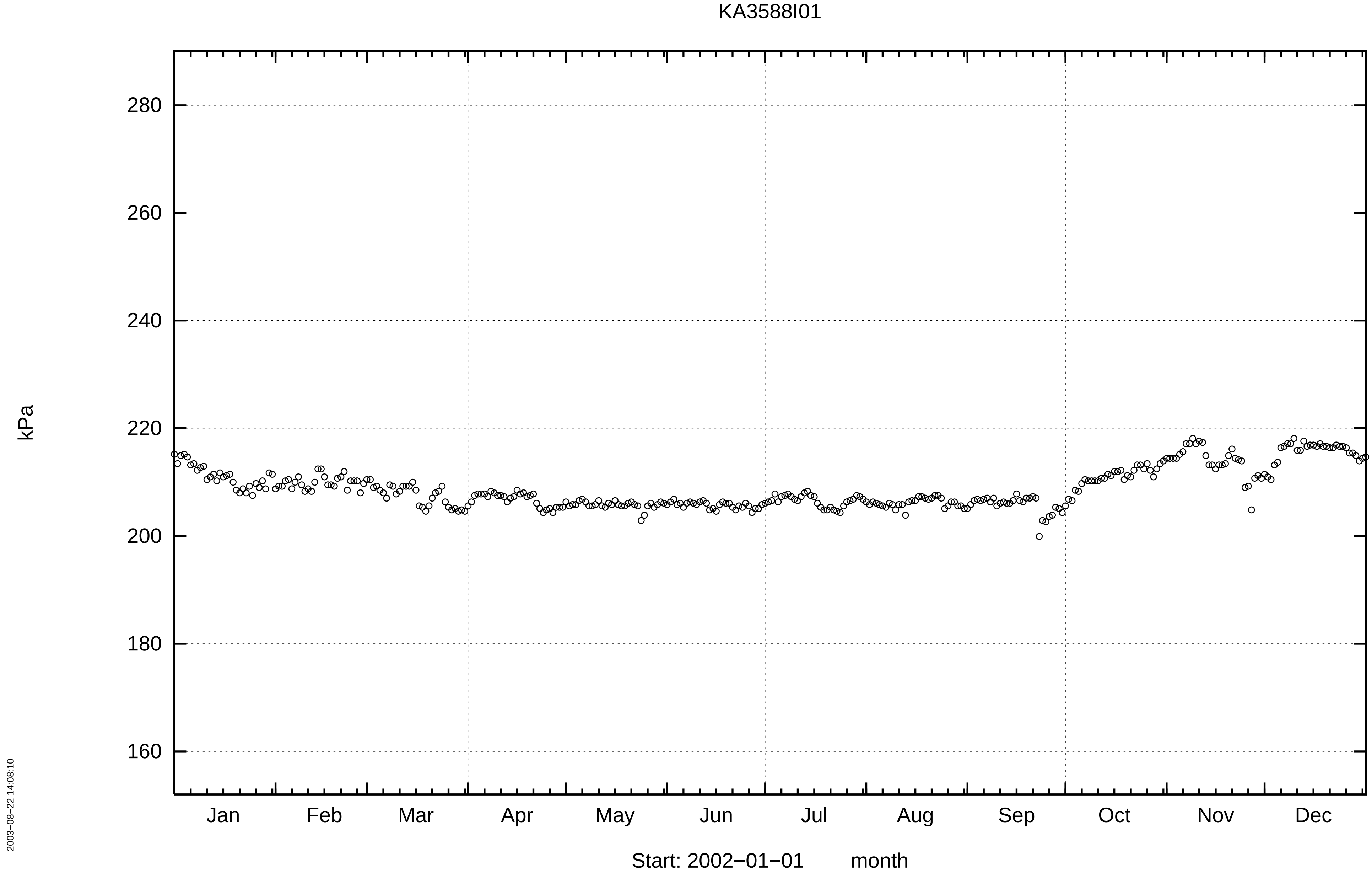

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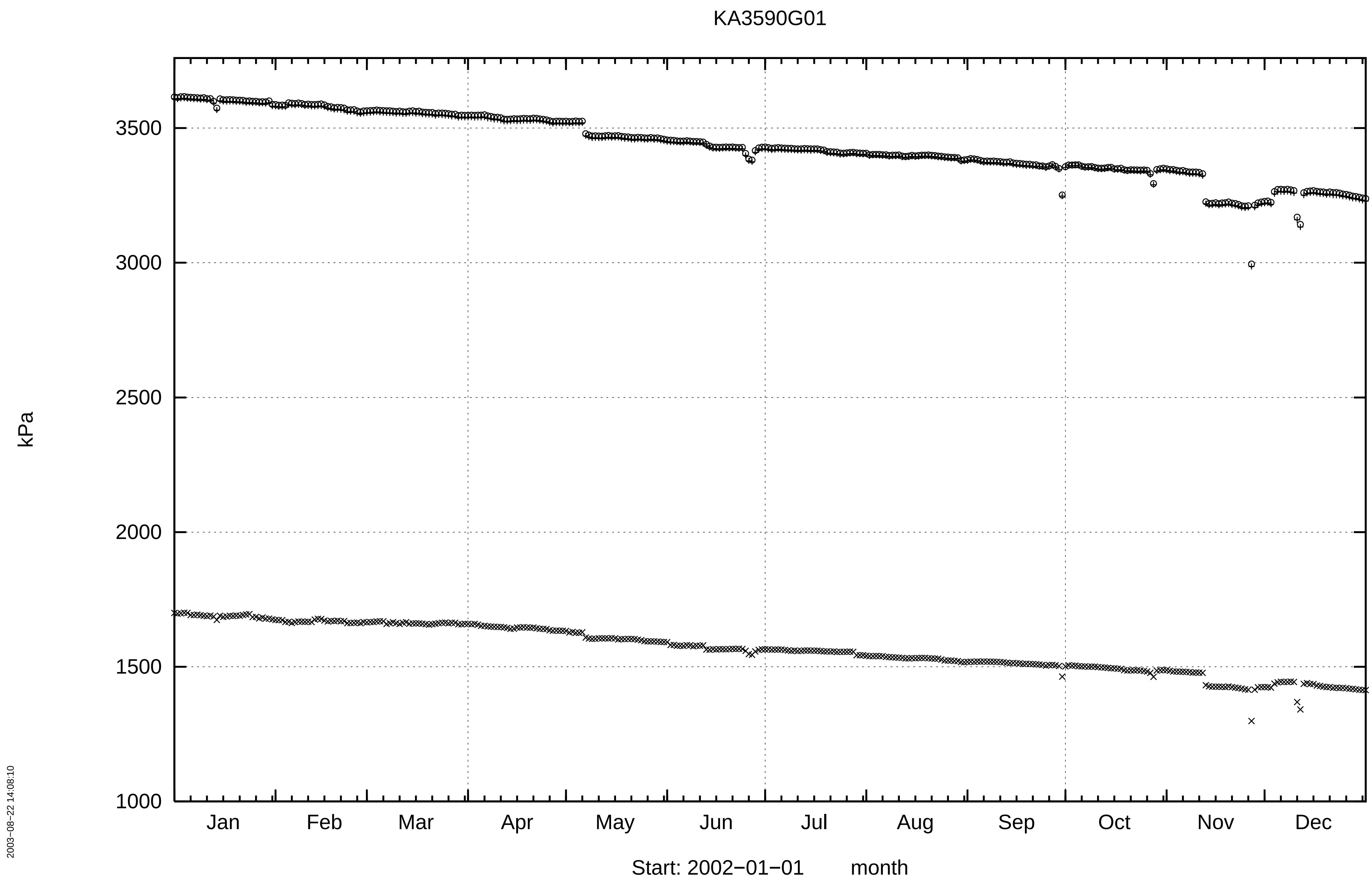
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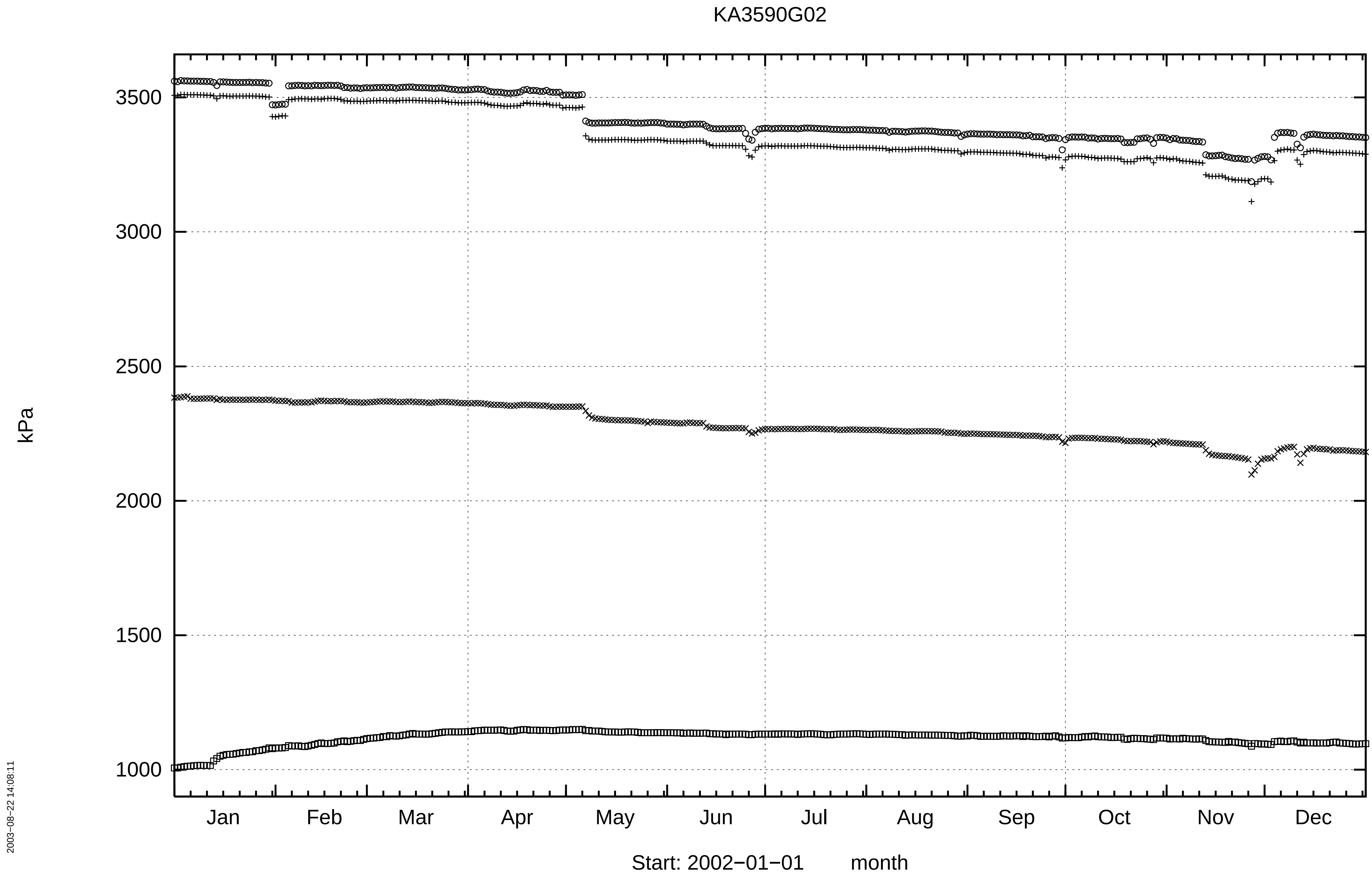

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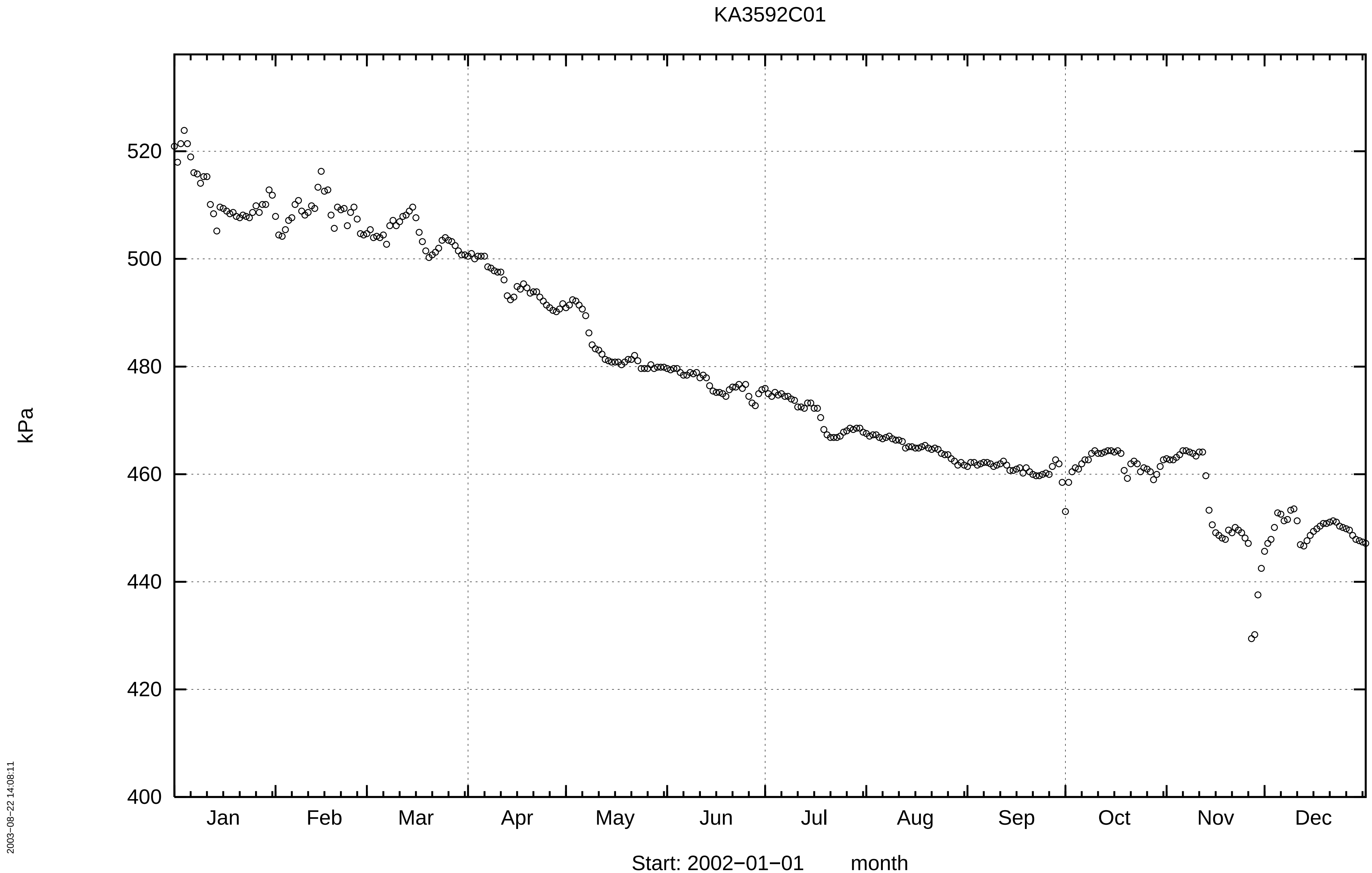

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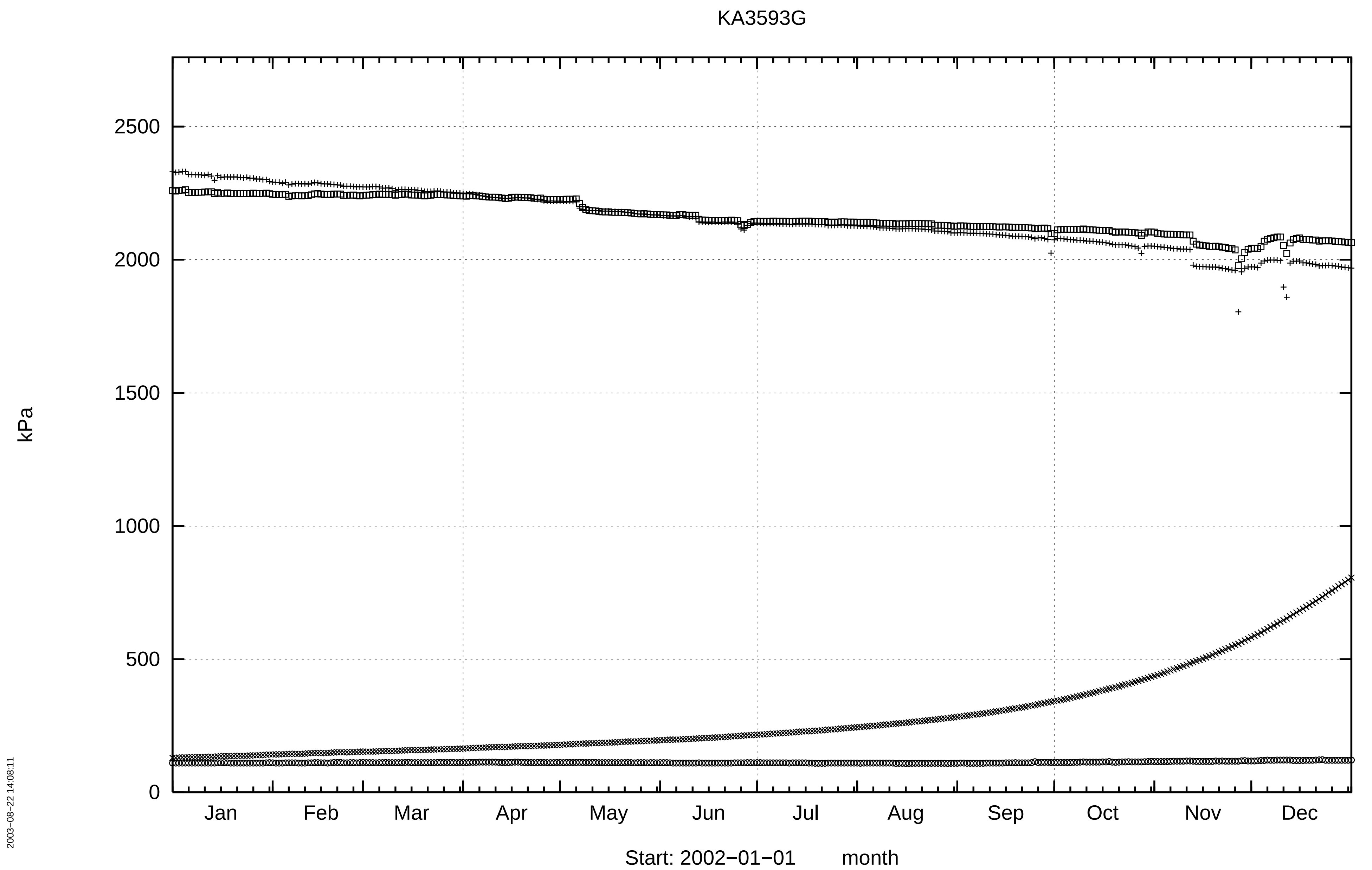

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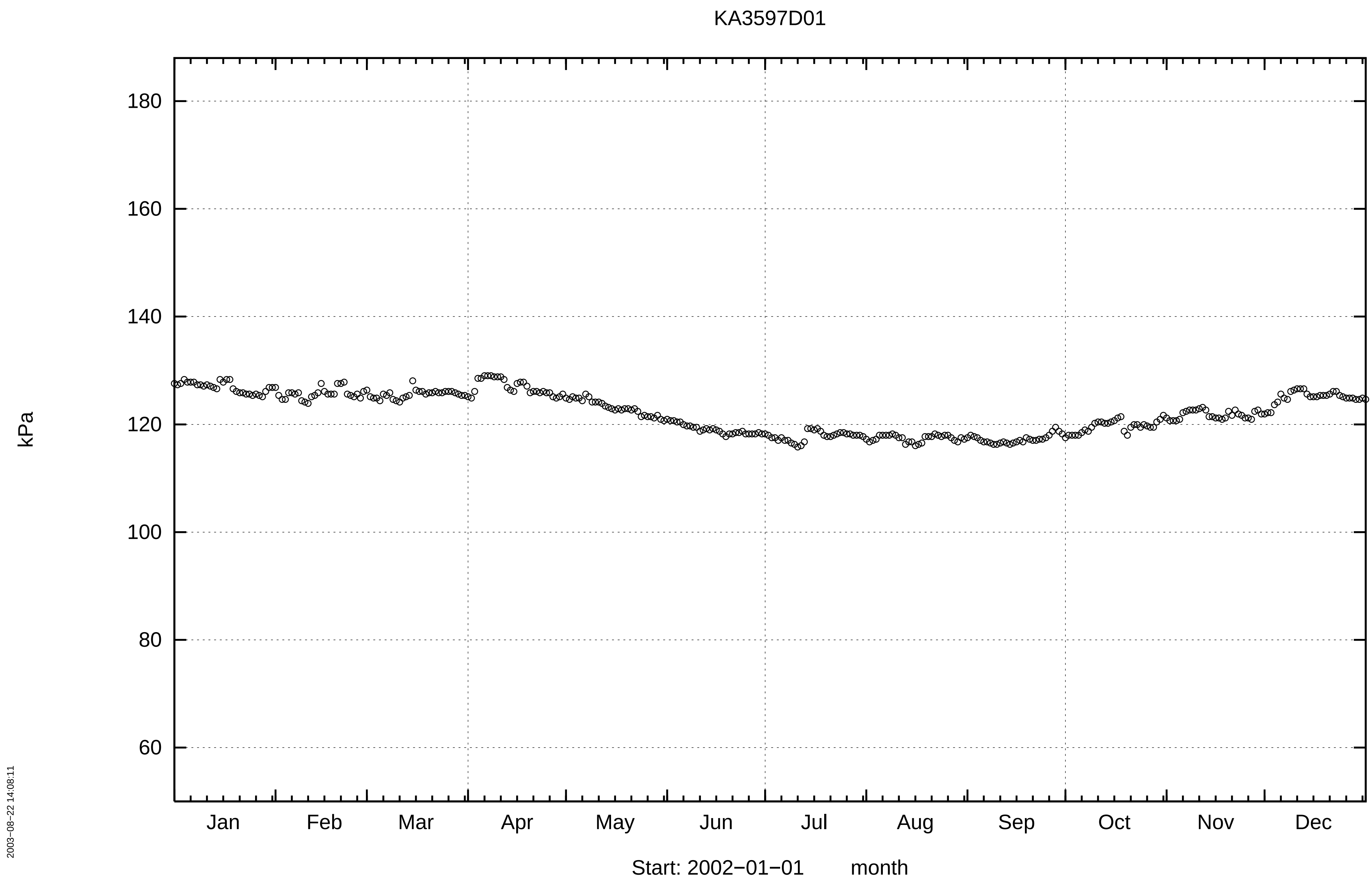

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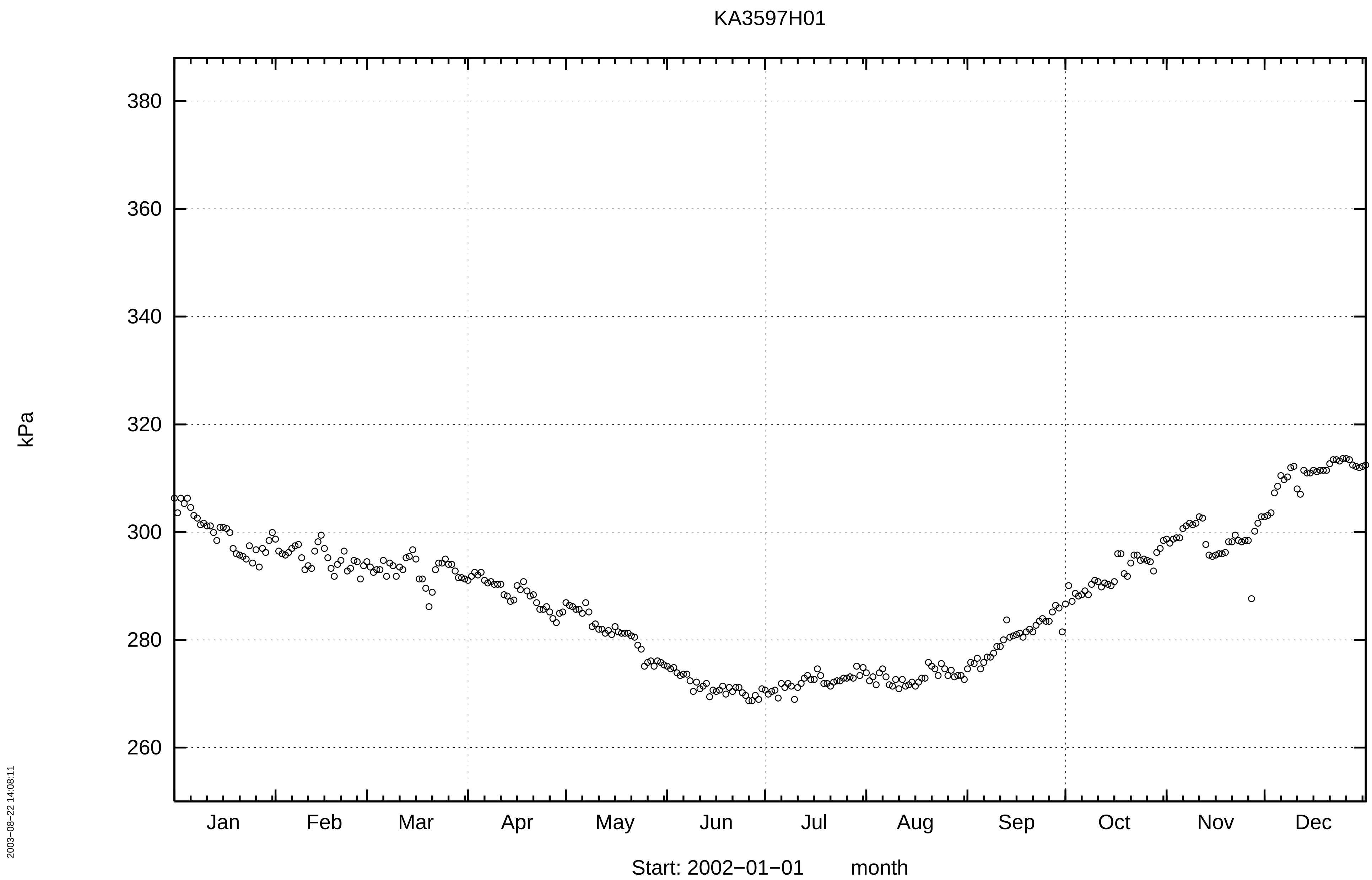
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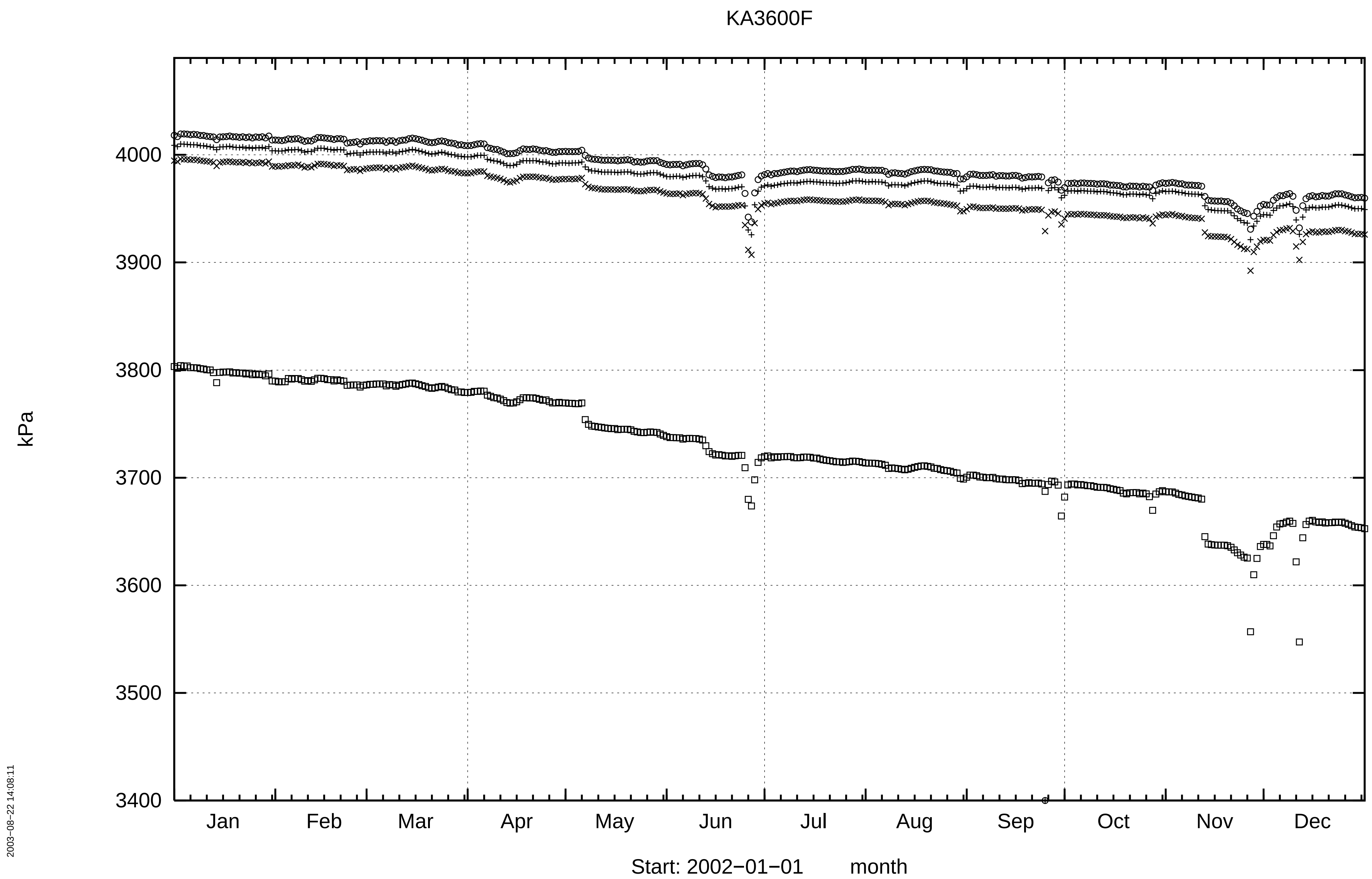

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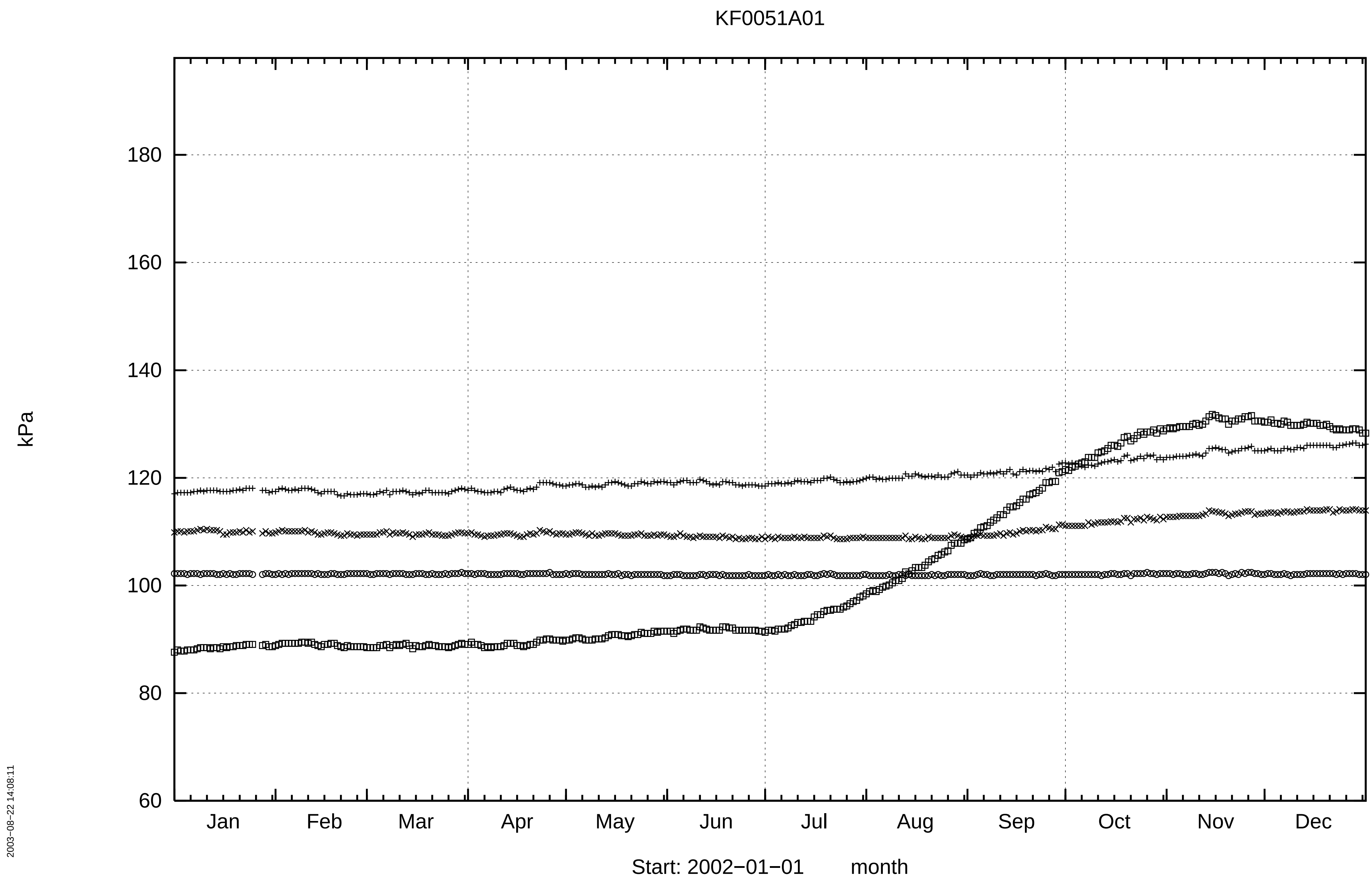
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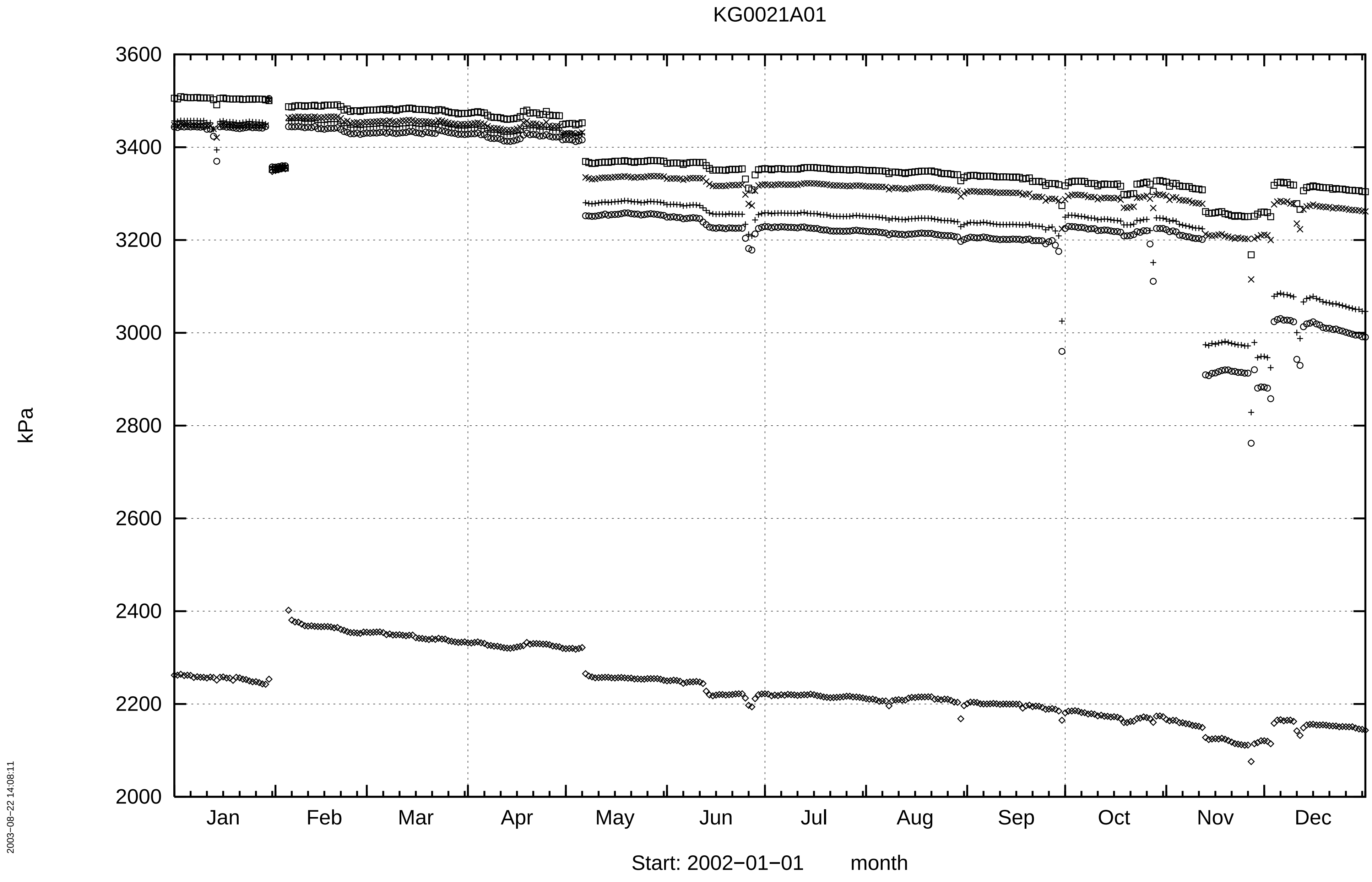

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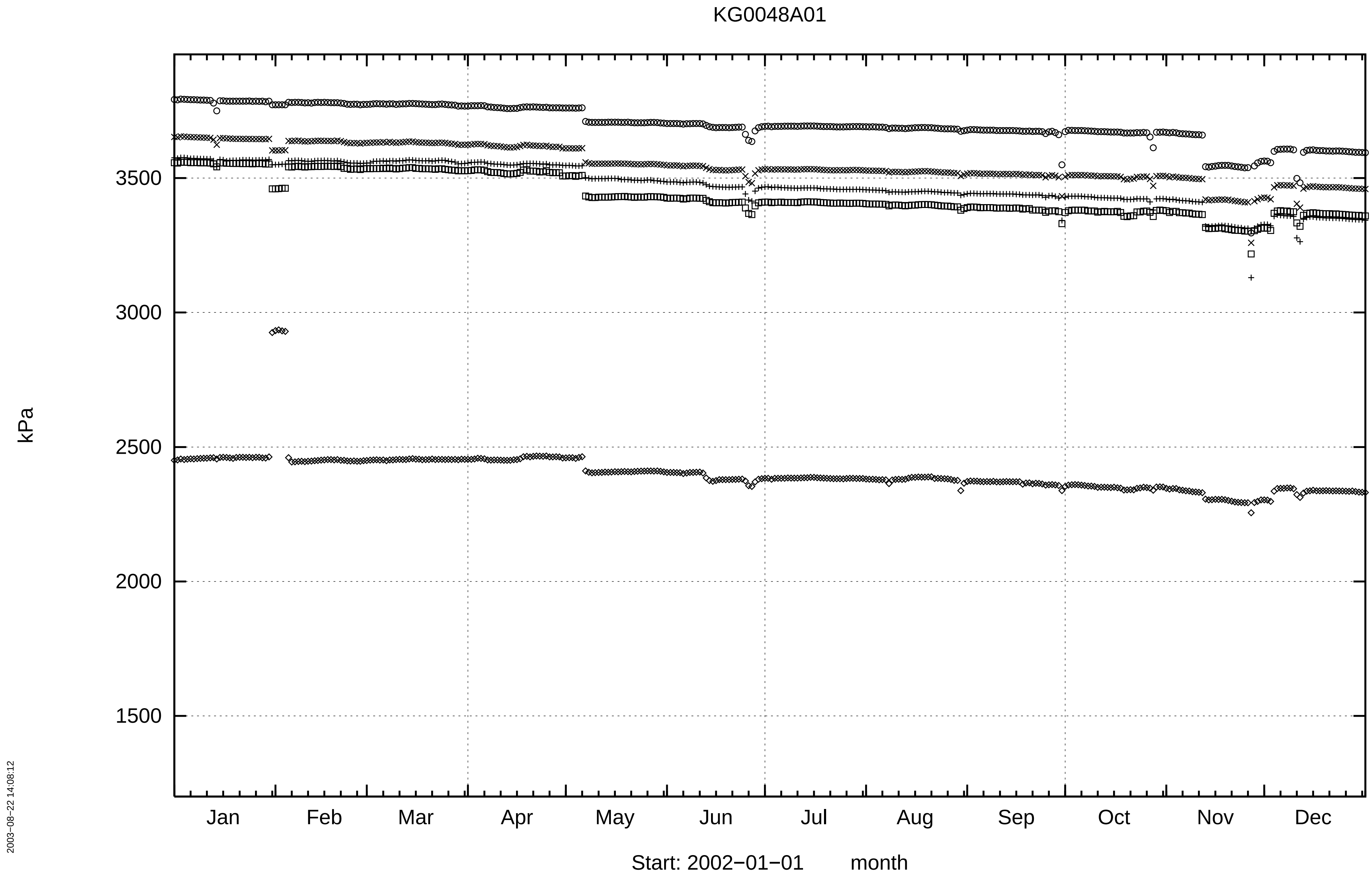
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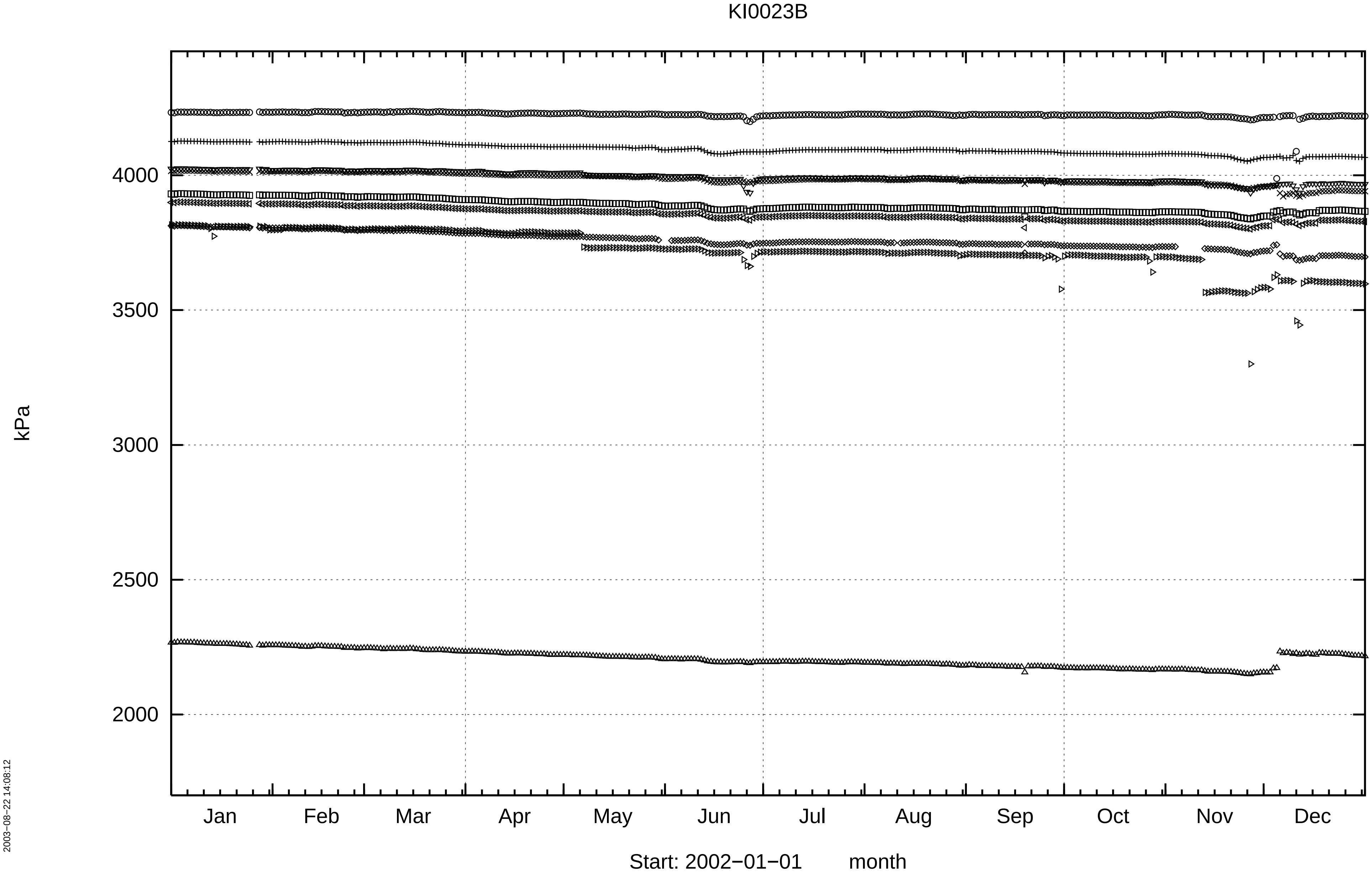

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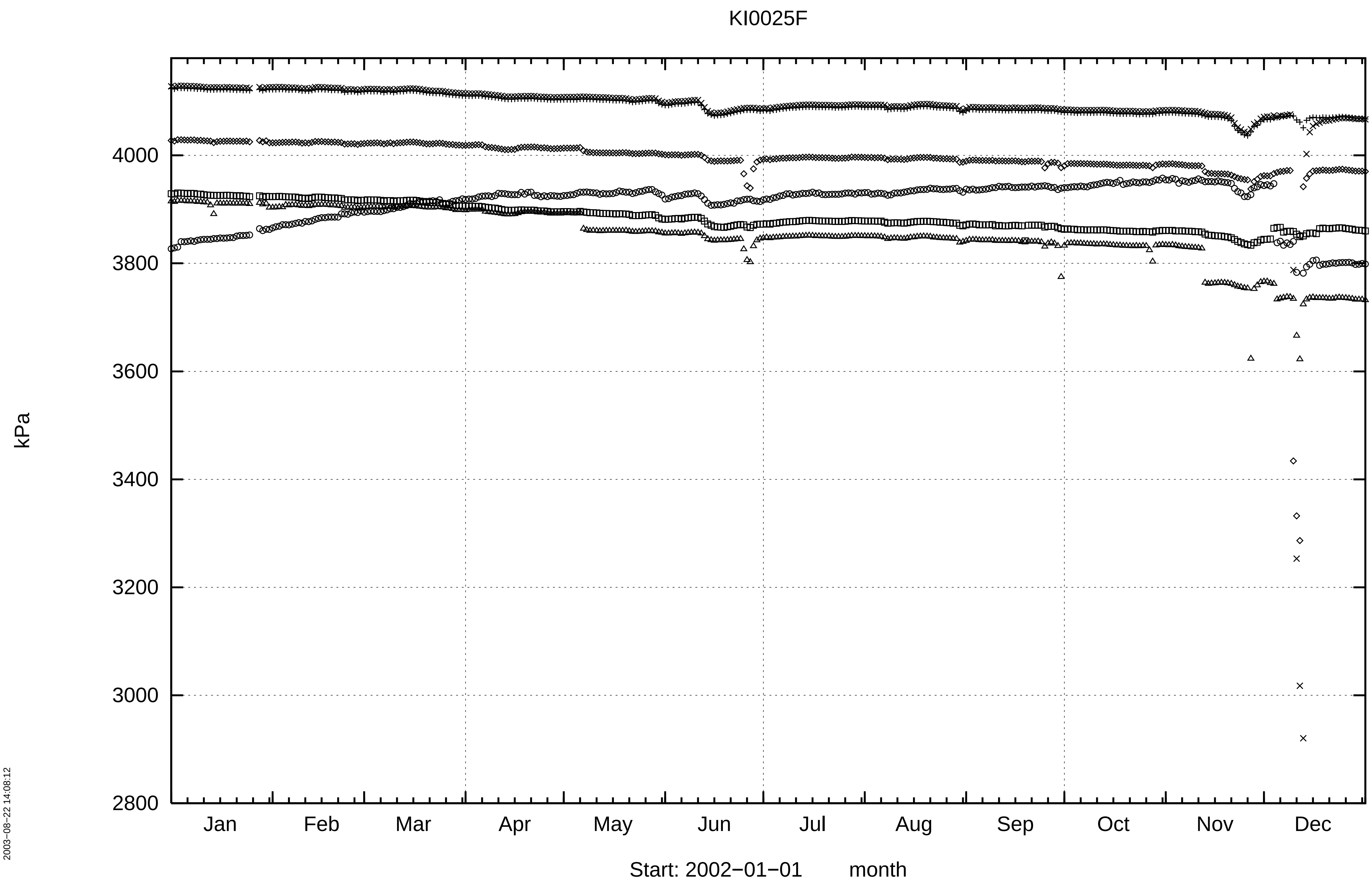
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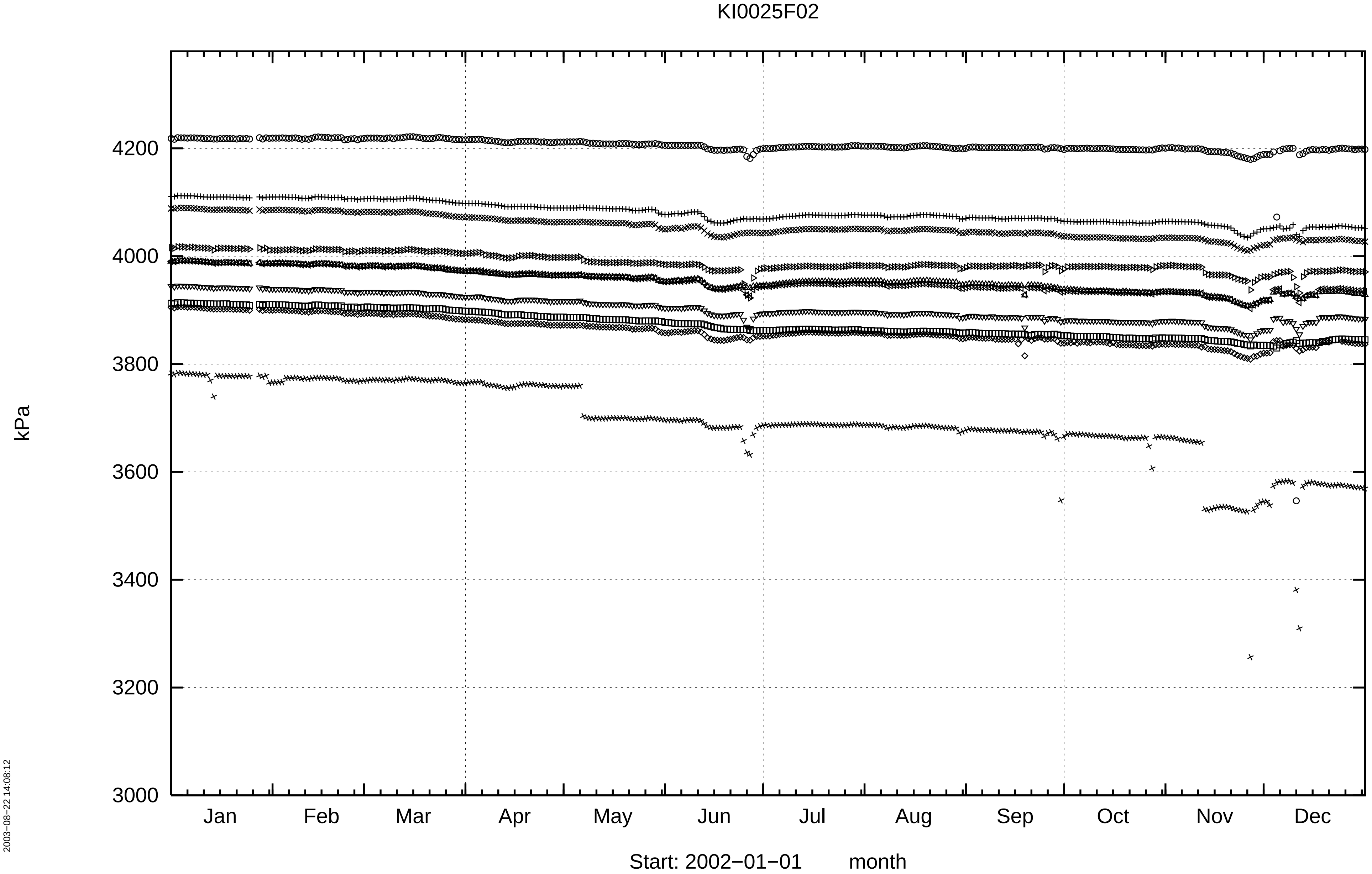
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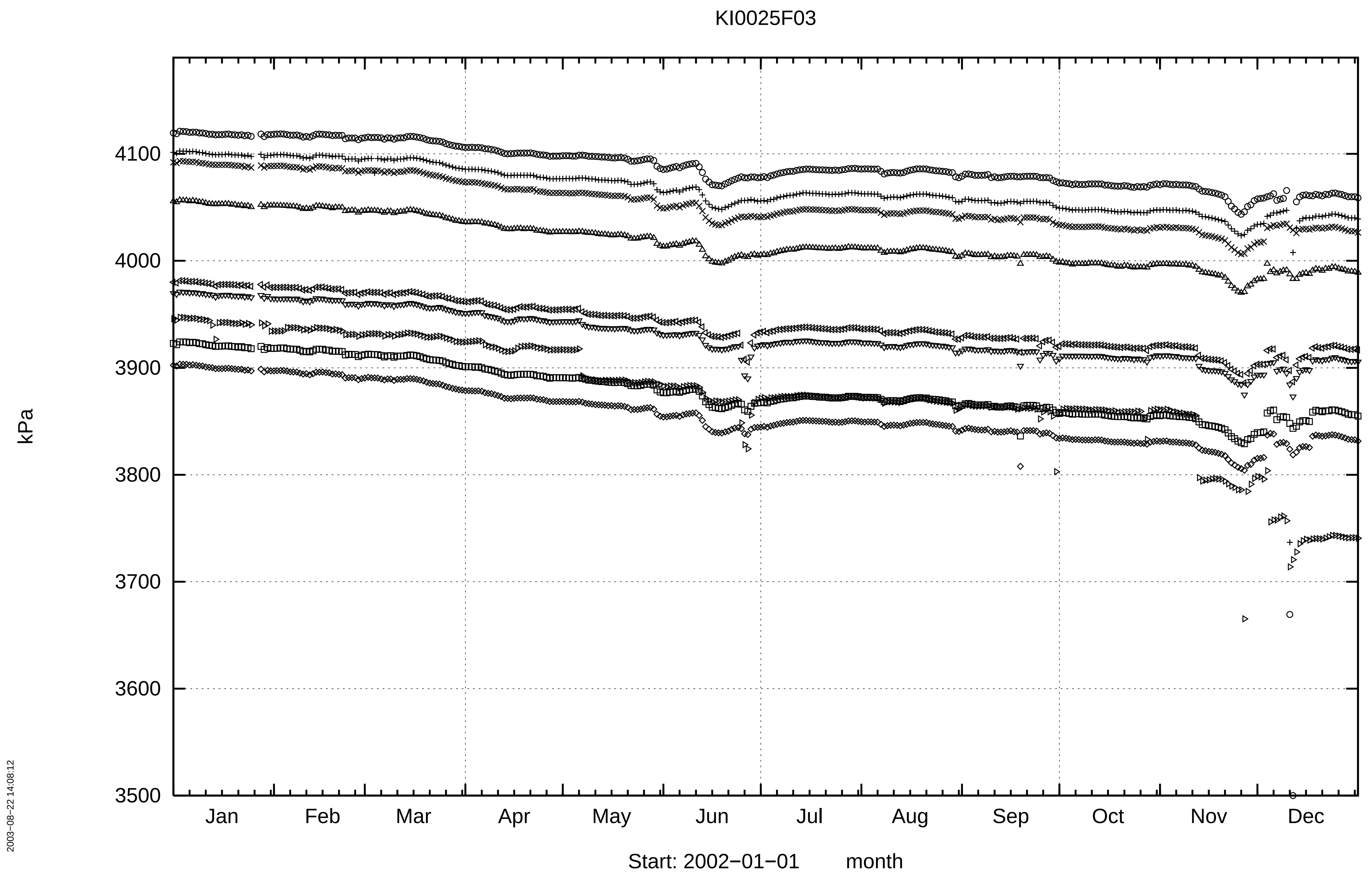

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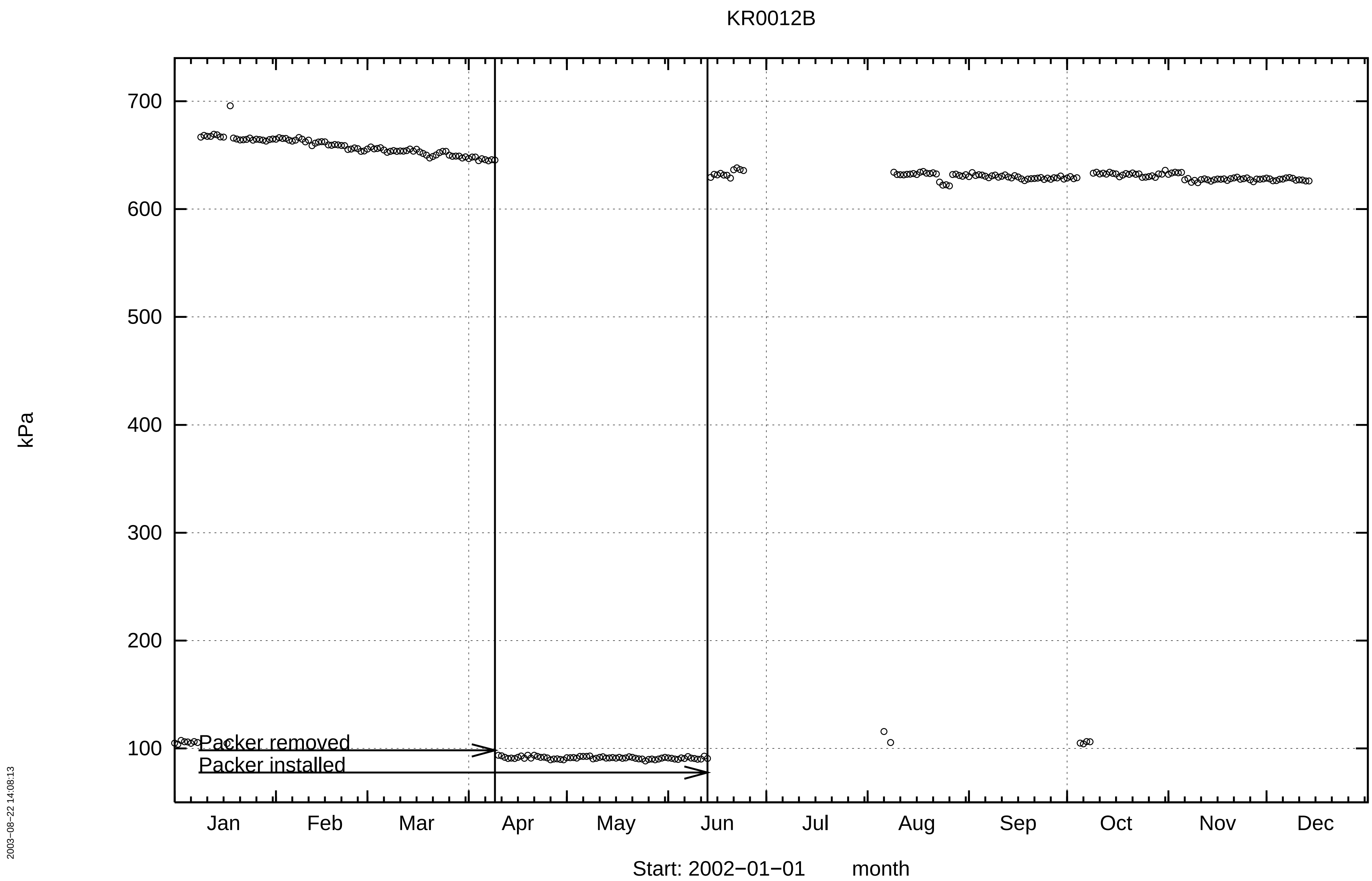
2003−08−22 14:08:12



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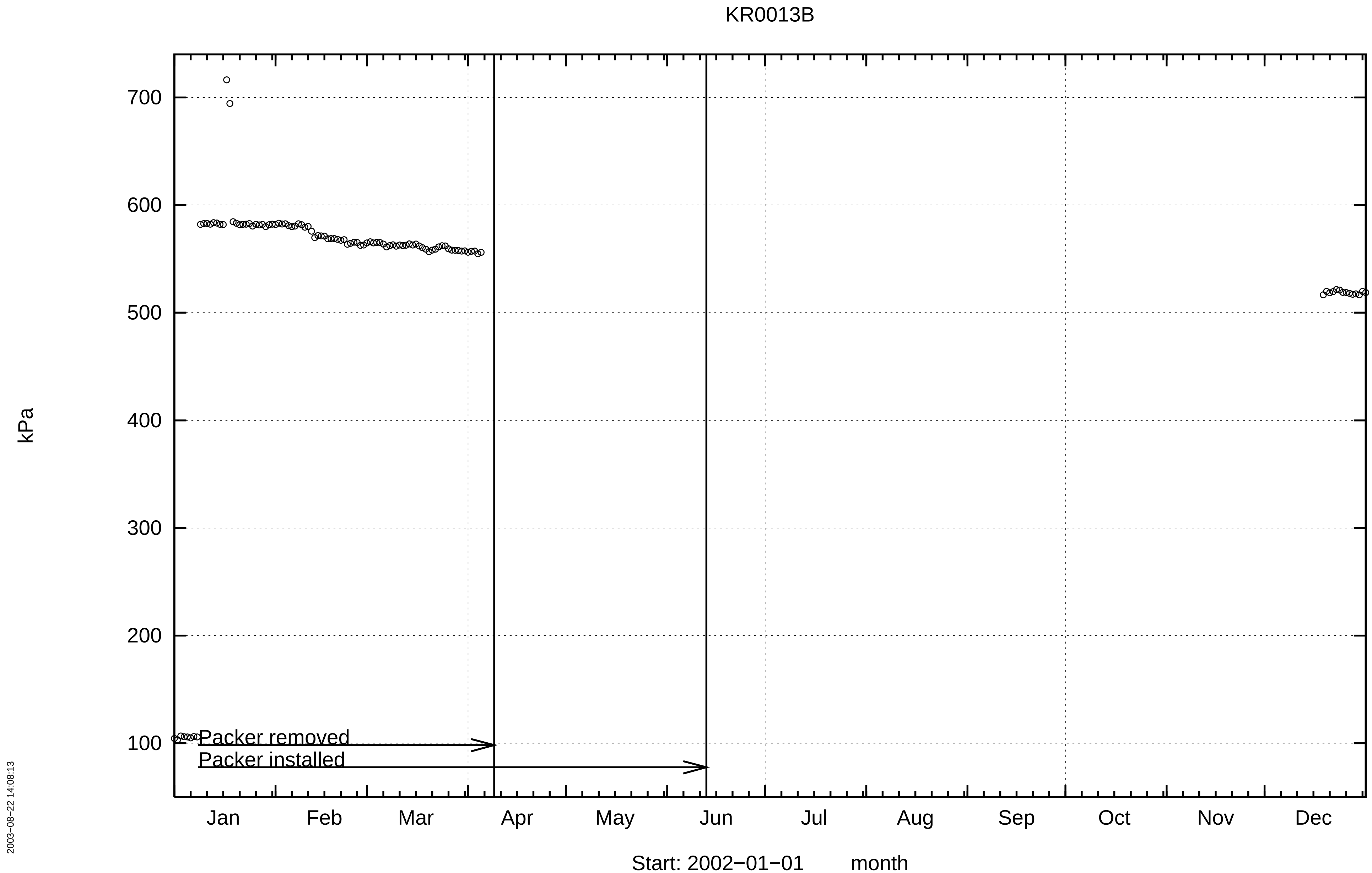
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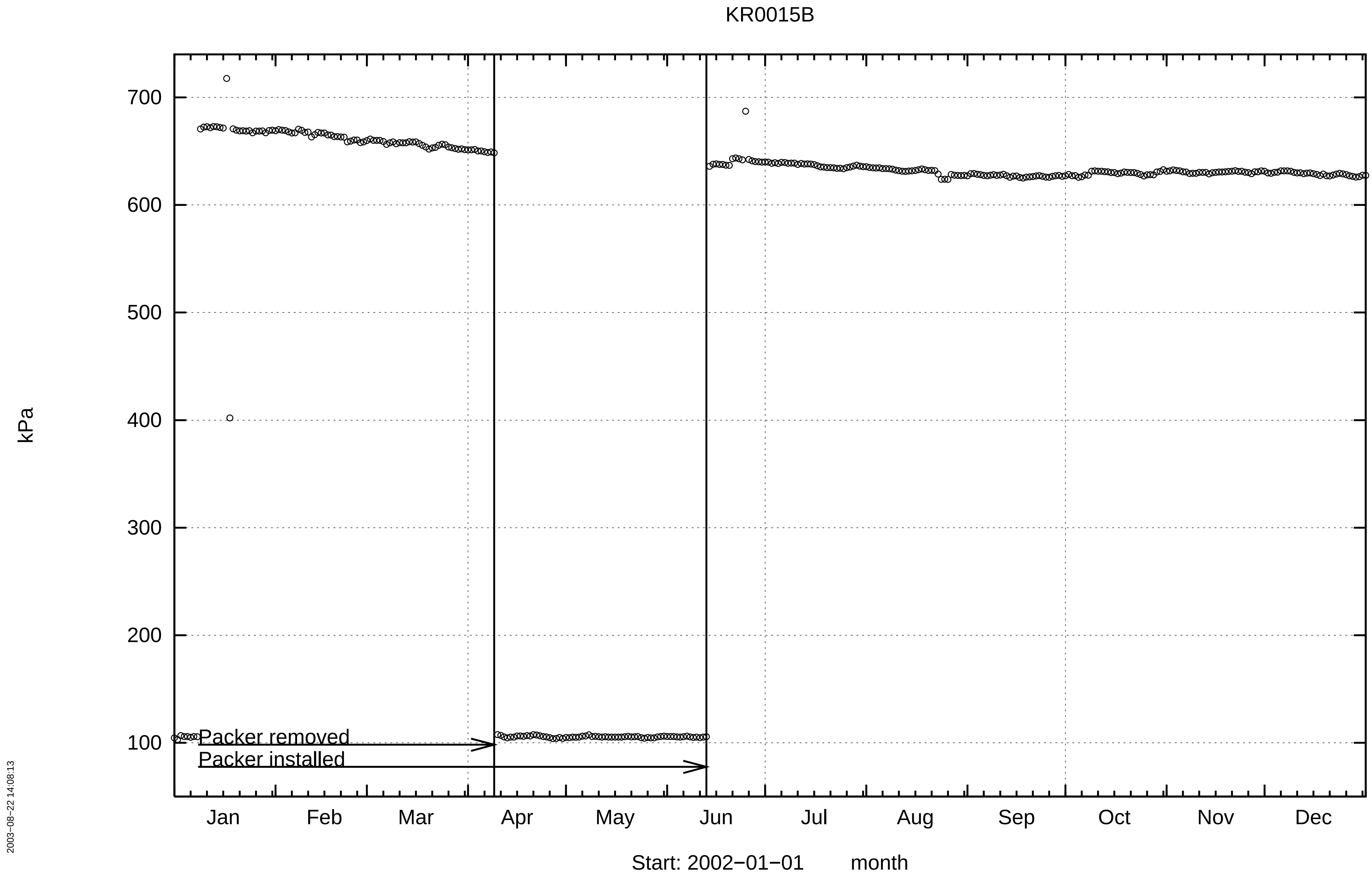

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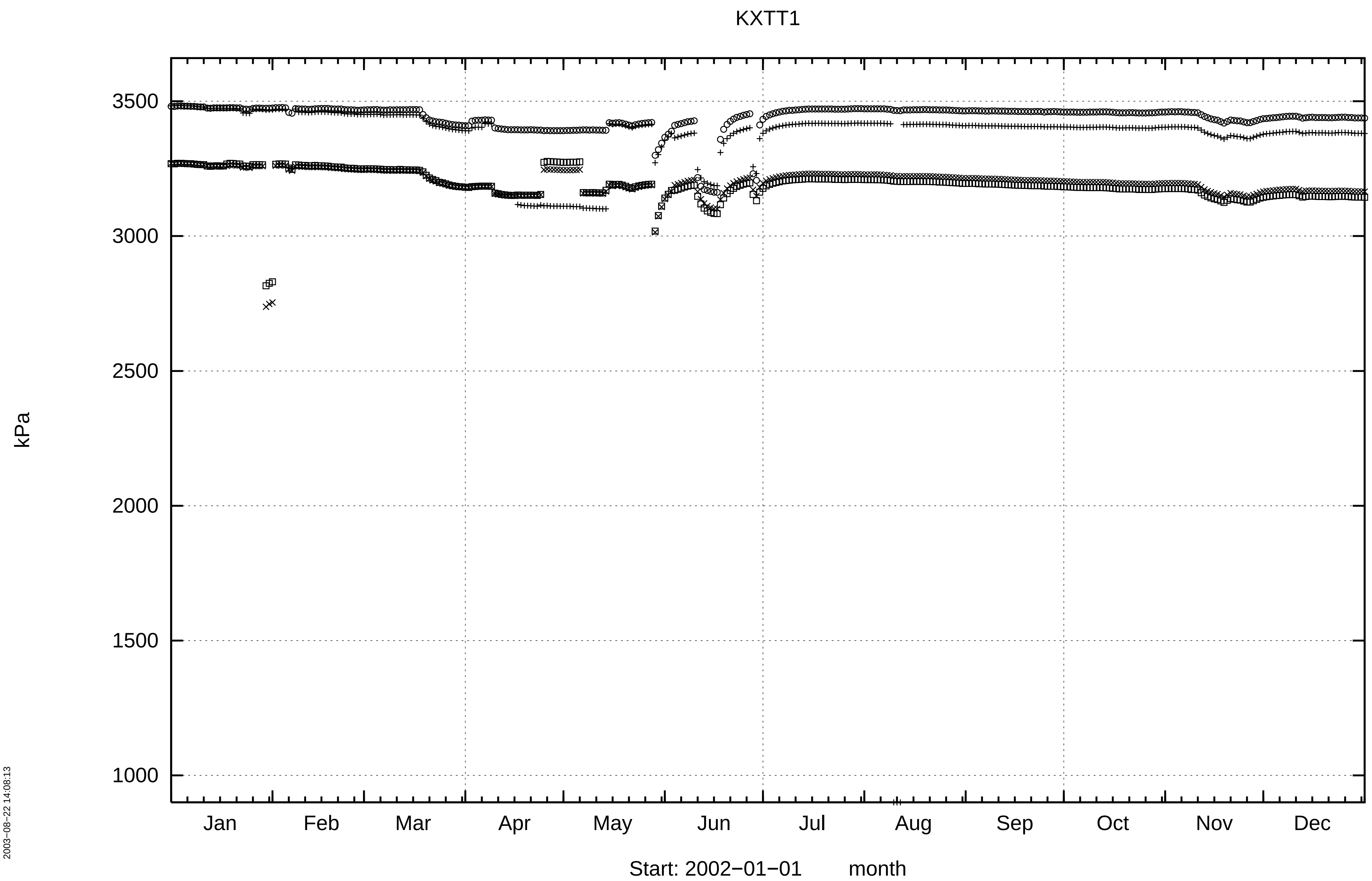
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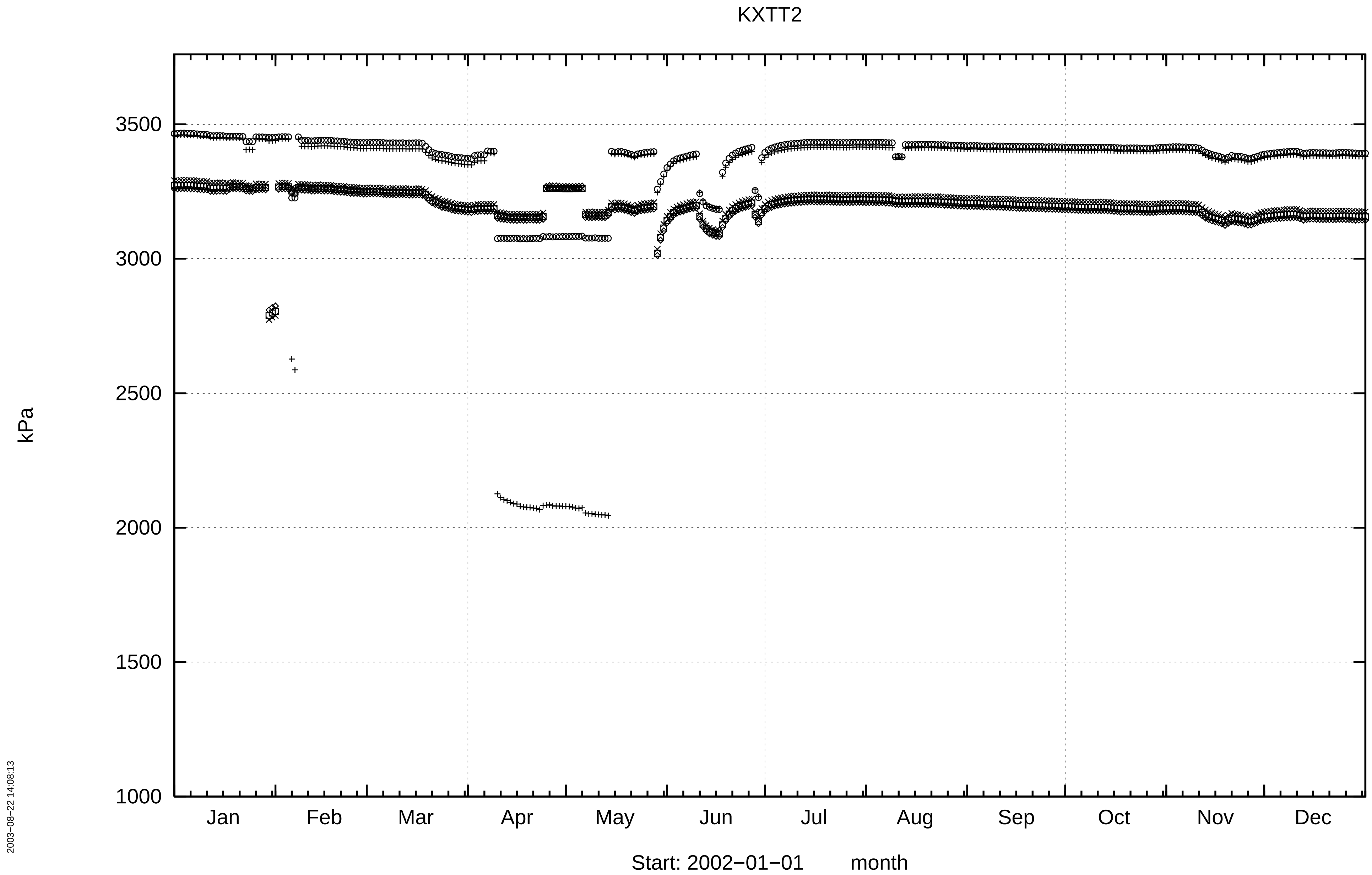
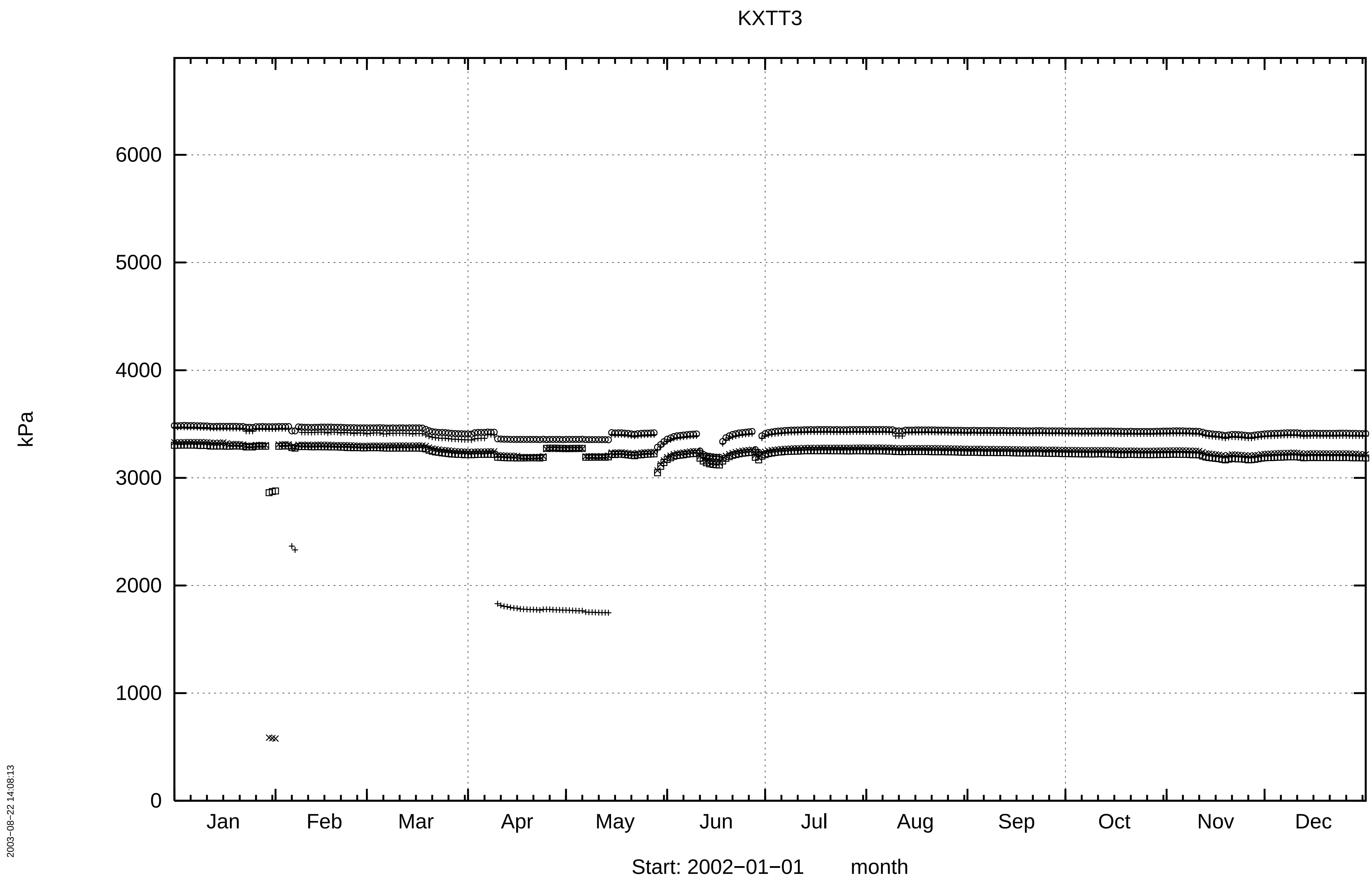
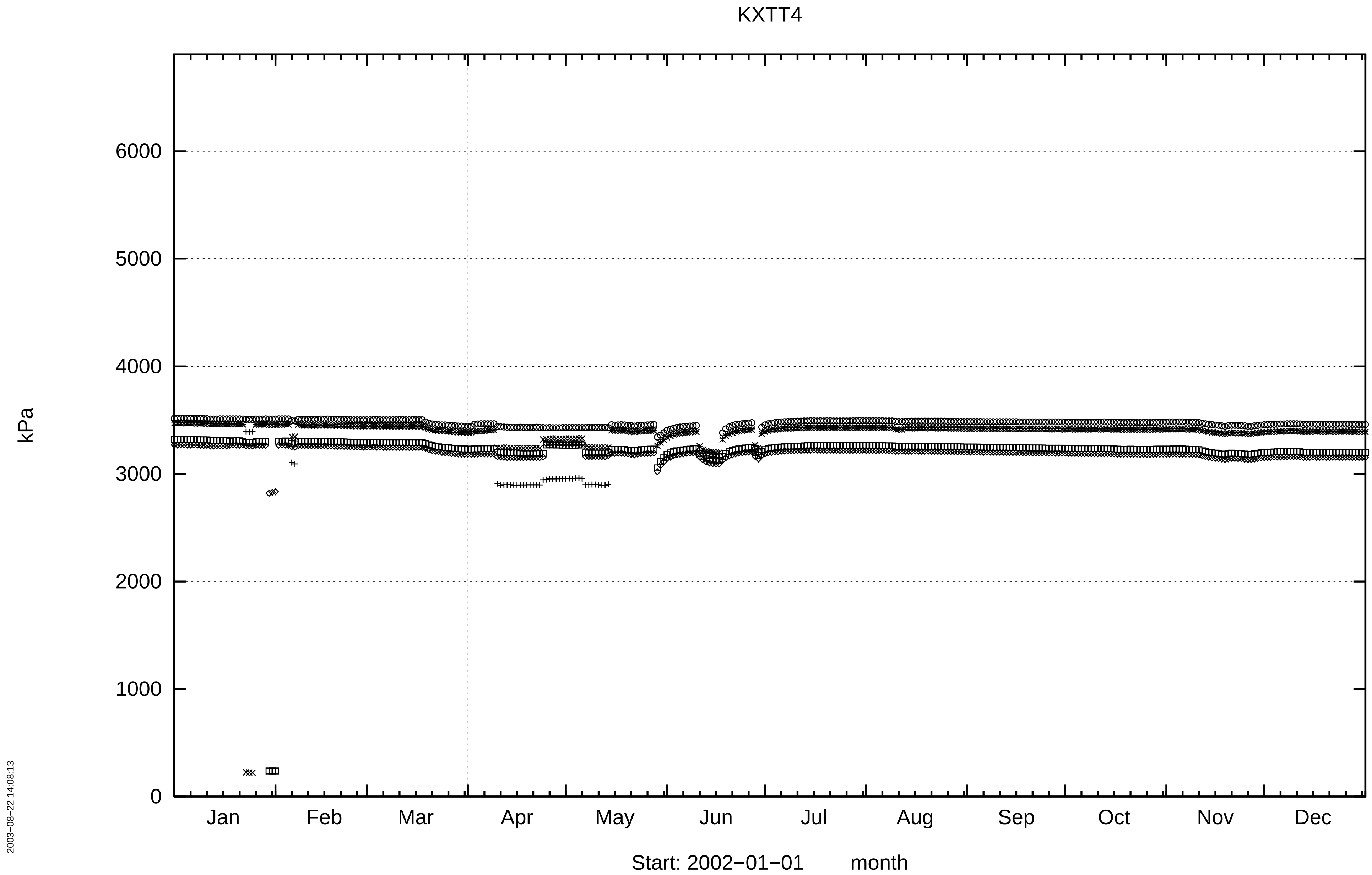
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:13

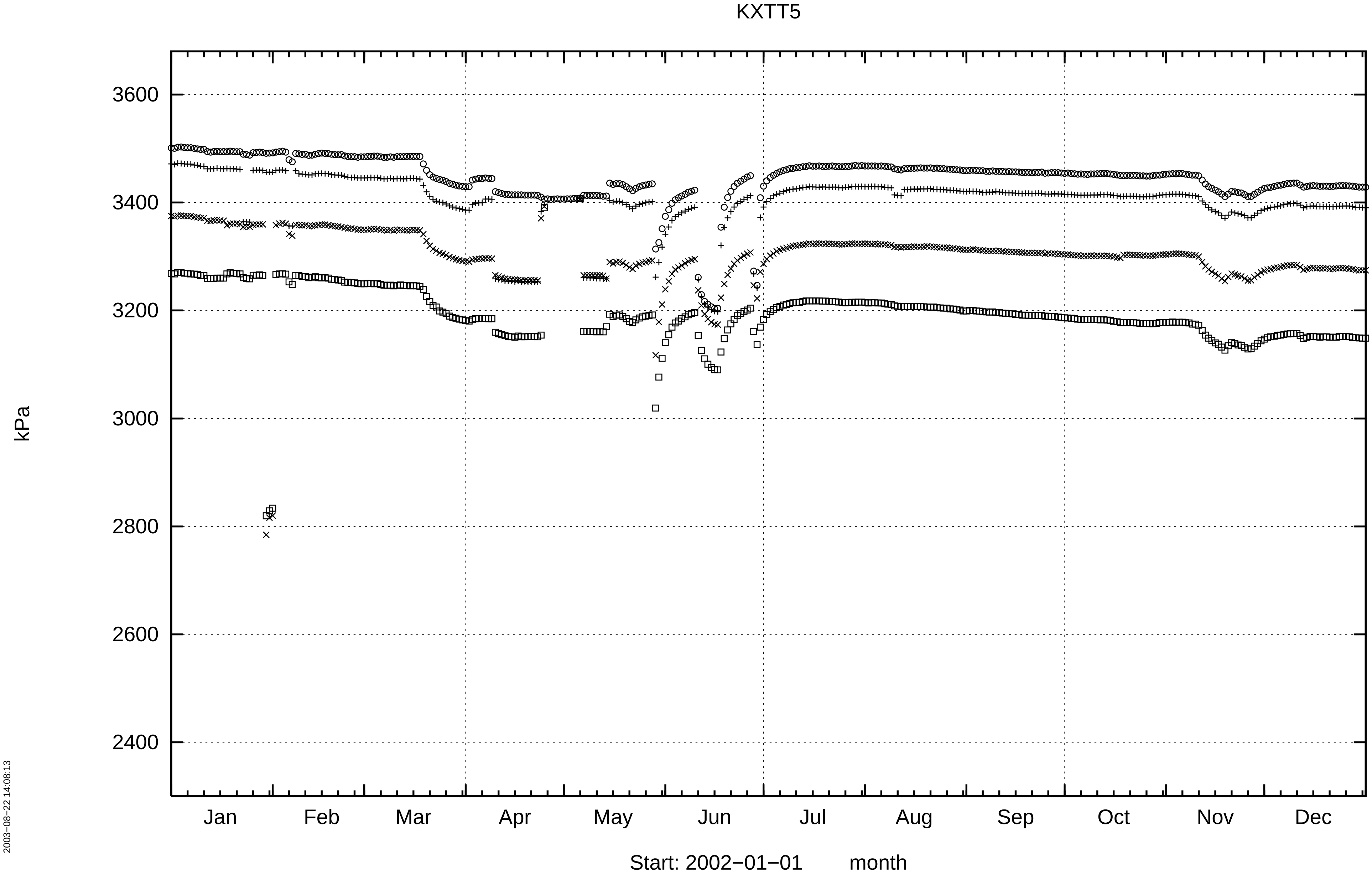


KXTT2
kPa
3500
3000
2500
2000
1500
1000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:13

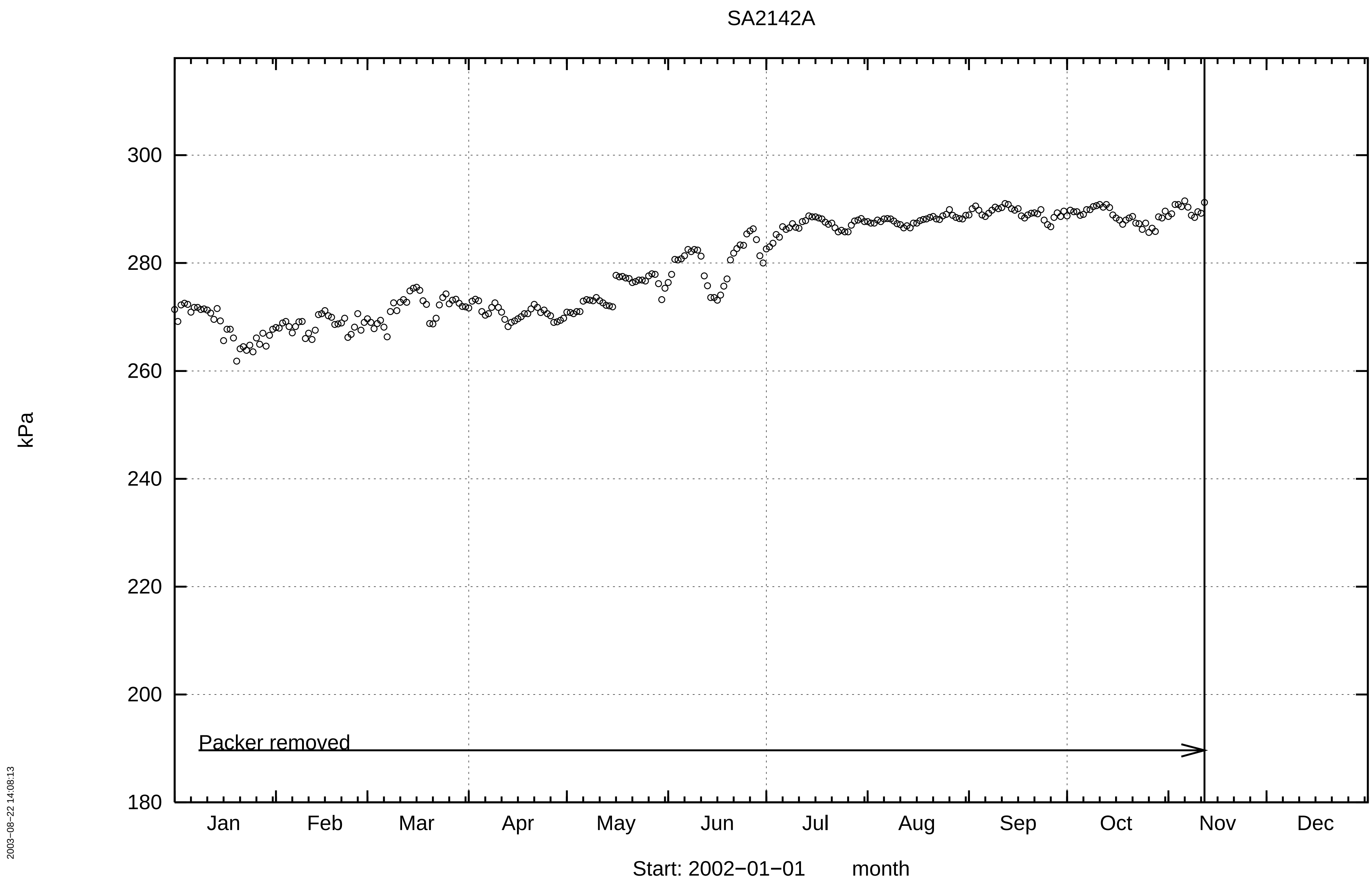

KXTT3
kPa
6000
5000
4000
3000
2000
1000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:13

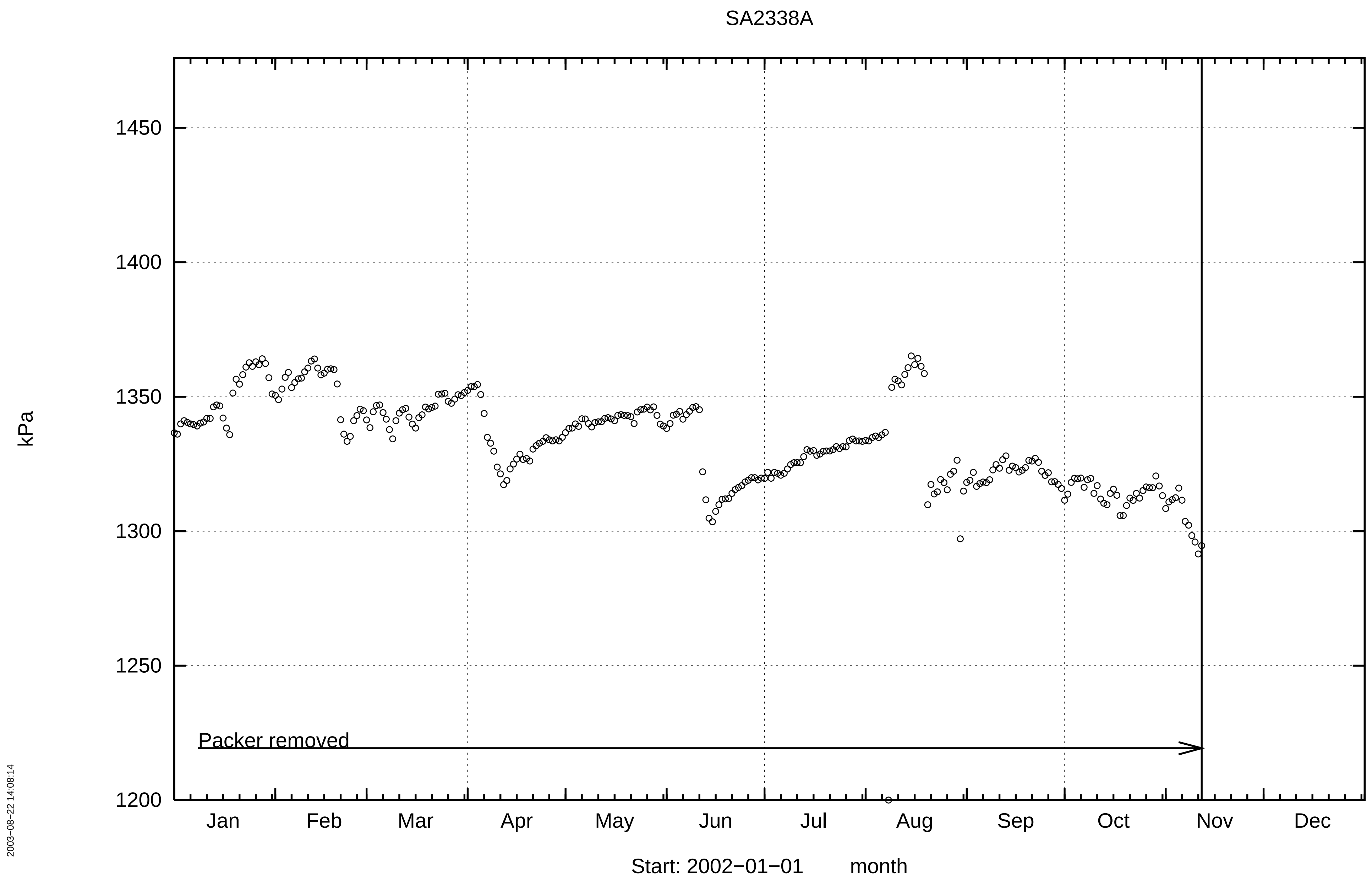


KXTT4
kPa
6000
5000
4000
3000
2000
1000
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:13

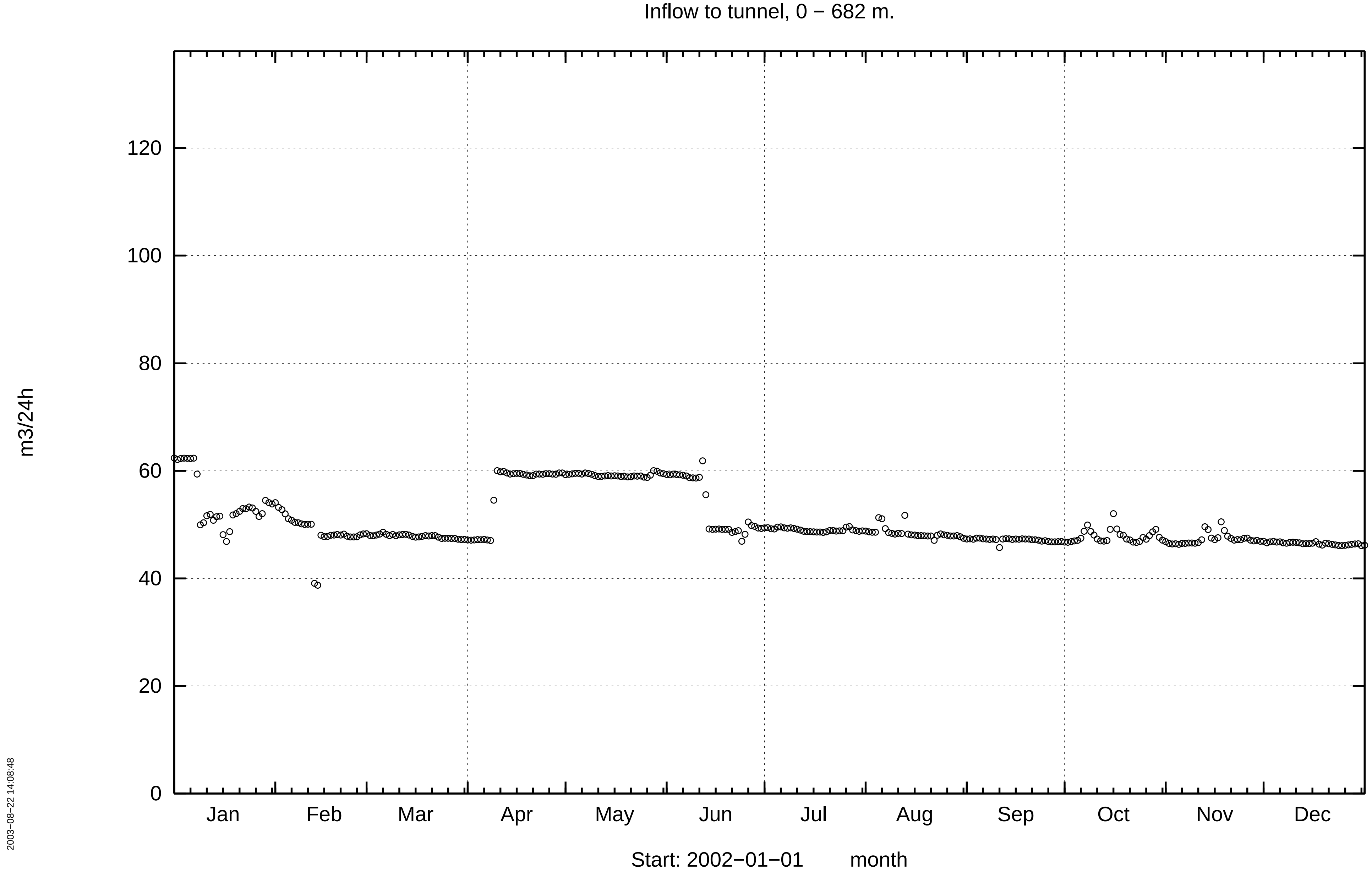


KXTT5
kPa
3600
3400
3200
3000
2800
2600
2400
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:13

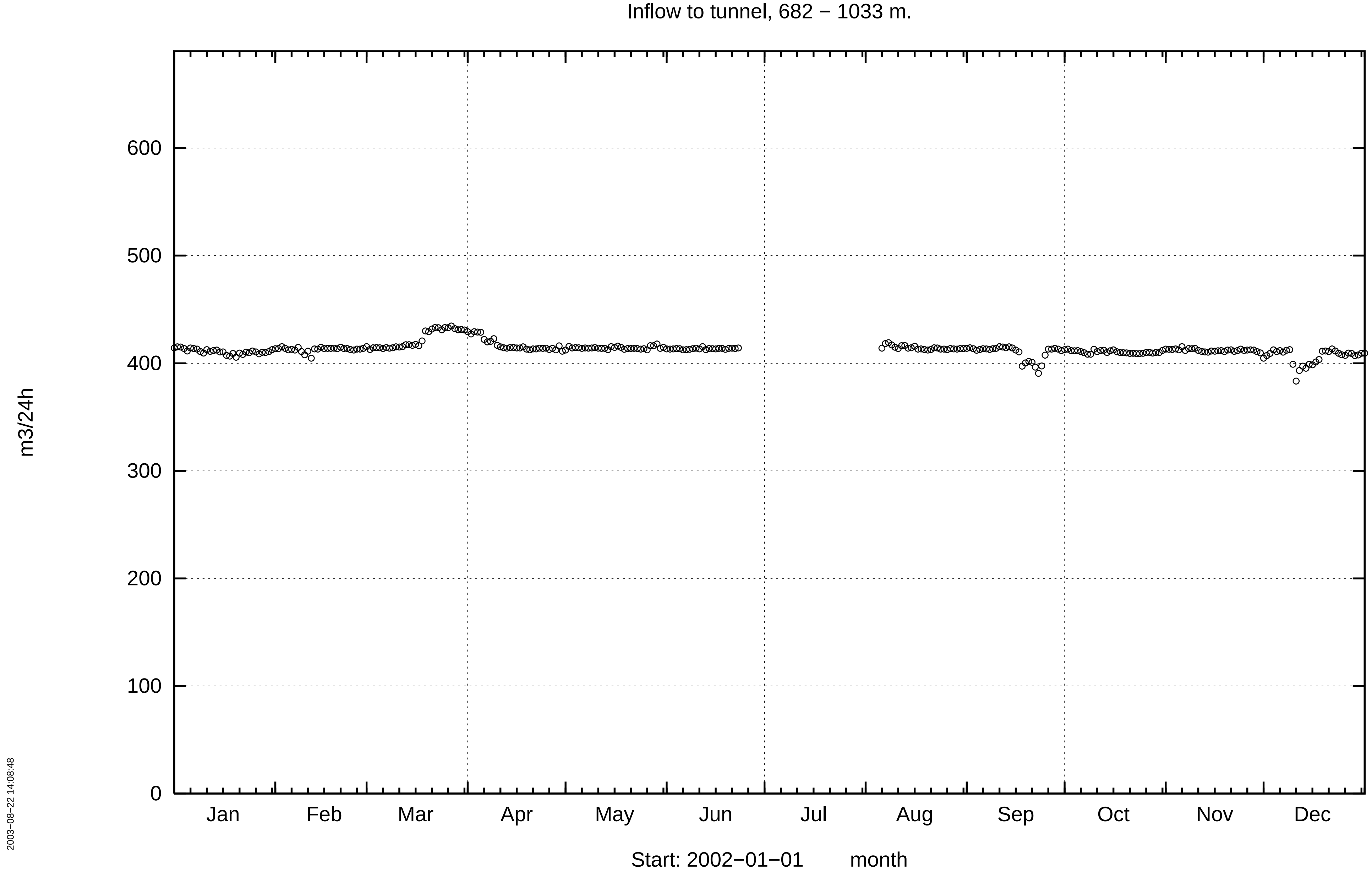

SA2142A
kPa
300
280
260
240
220
200
180
Packer removed
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:13


SA2338A
kPa
1450
1400
1350
1300
1250
1200
Packer removed
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:14

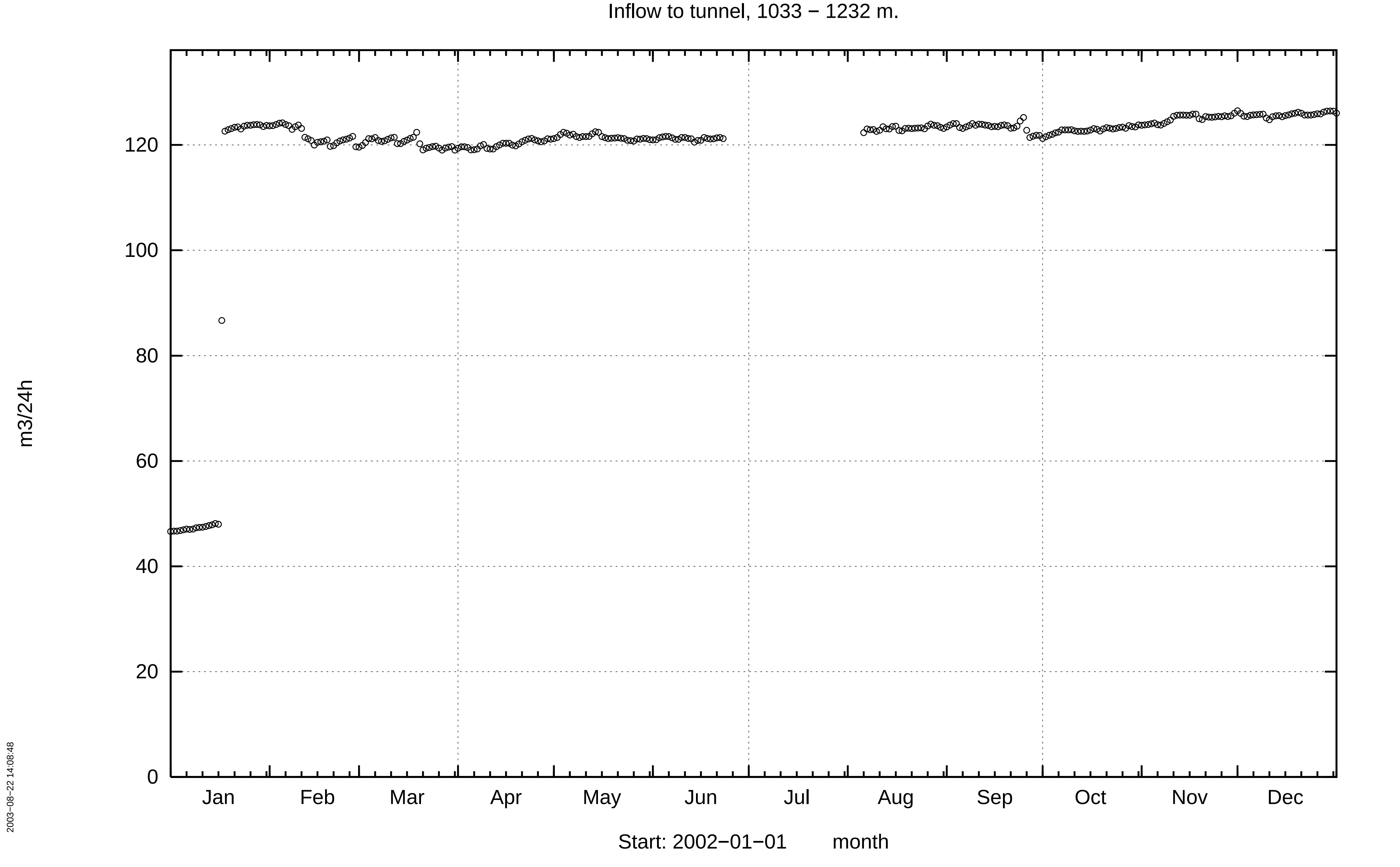
Appendix 5: Water flow in tunnel



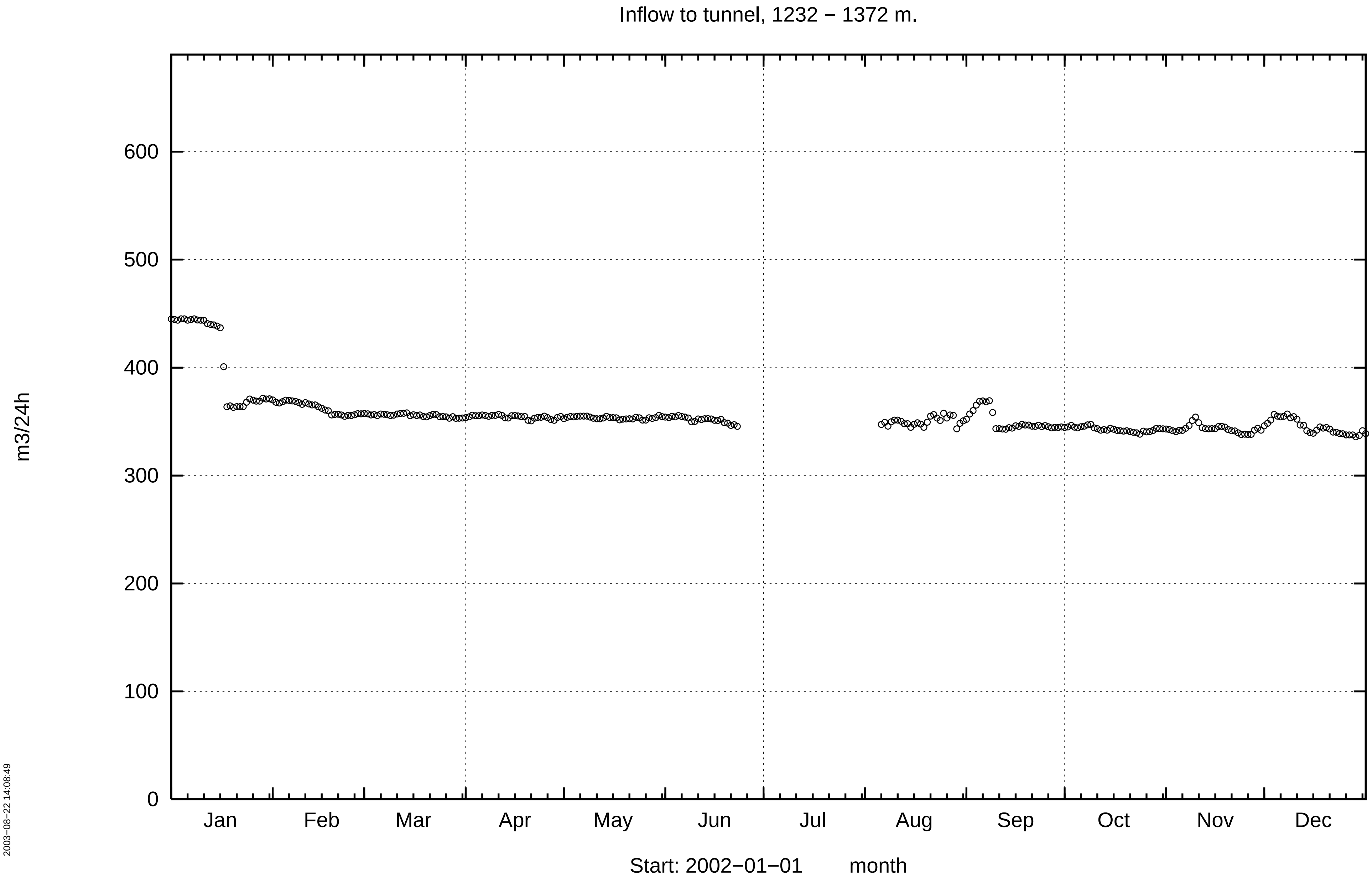
Inflow to tunnel, 0 − 682 m.
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:48



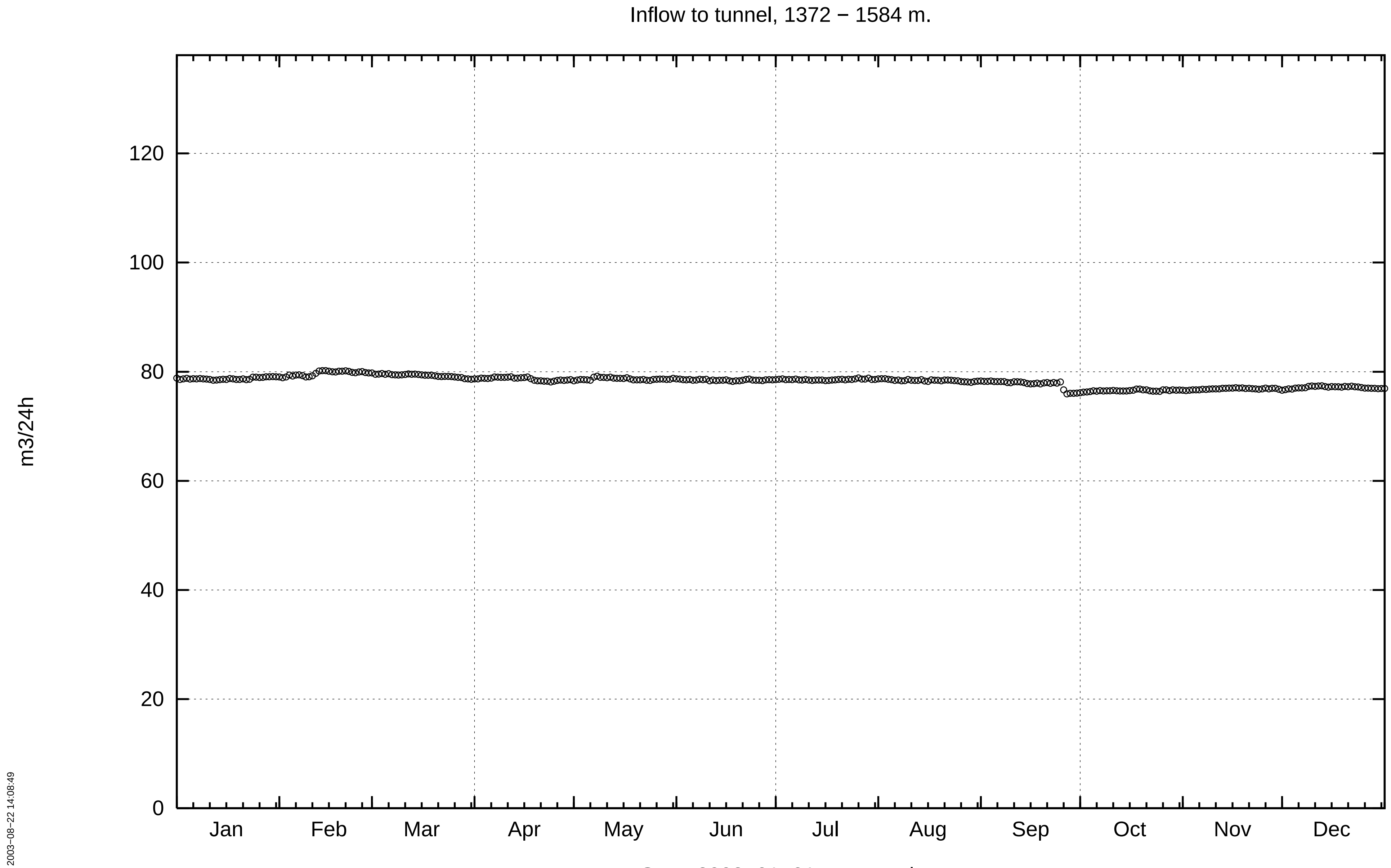
Inflow to tunnel, 682 − 1033 m.
m3/24h
0
100
200
300
400
500
600
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:48



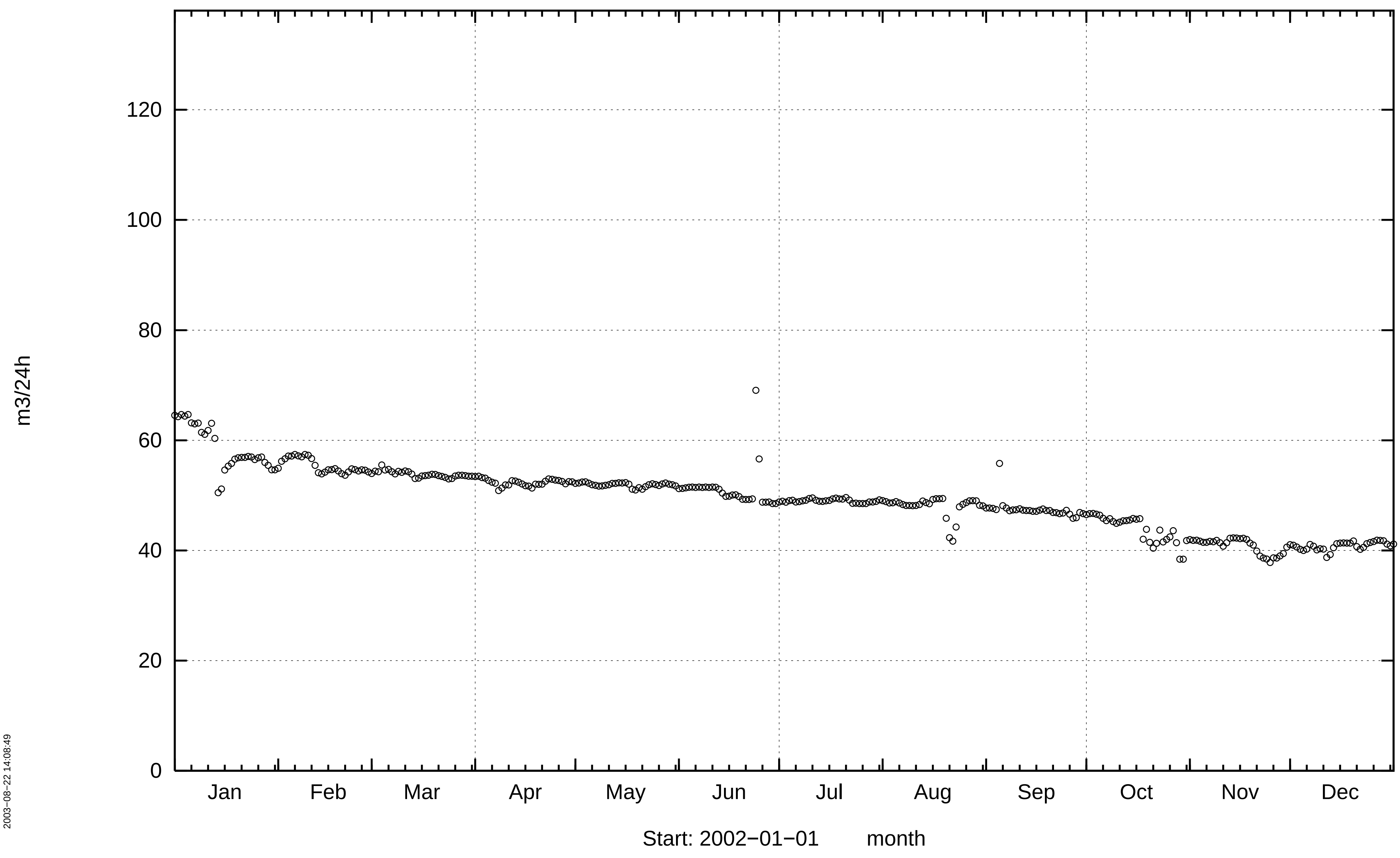
Inflow to tunnel, 1033 − 1232 m.
m3/24h
120
100
80
60
40
20
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:48



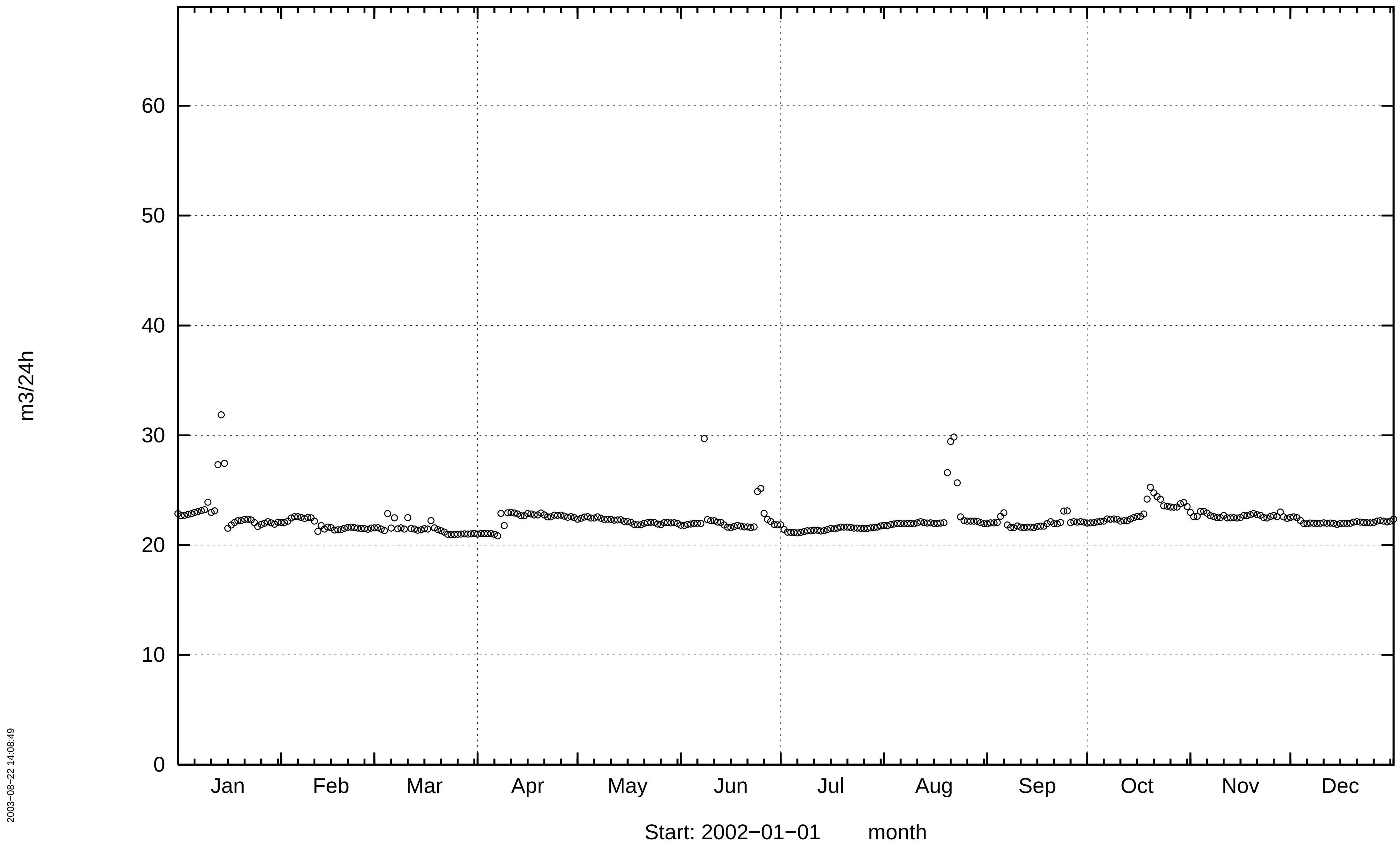
Inflow to tunnel, 1232 − 1372 m.
m3/24h
0
100
200
300
400
500
600
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:49

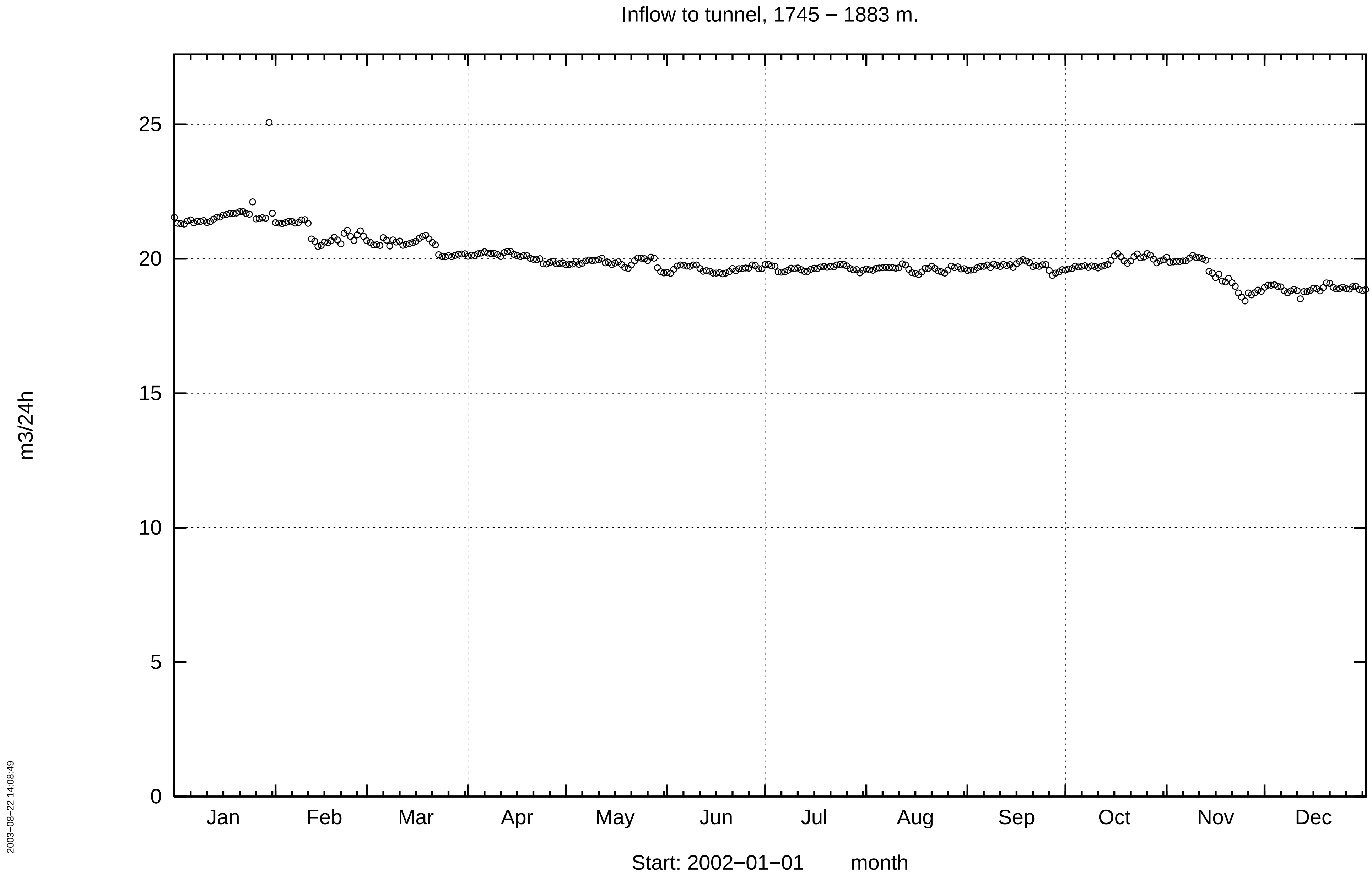

Inflow to tunnel, 1372 − 1584 m.
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:49

Inflow to tunnel, from shafts at 1659 m.

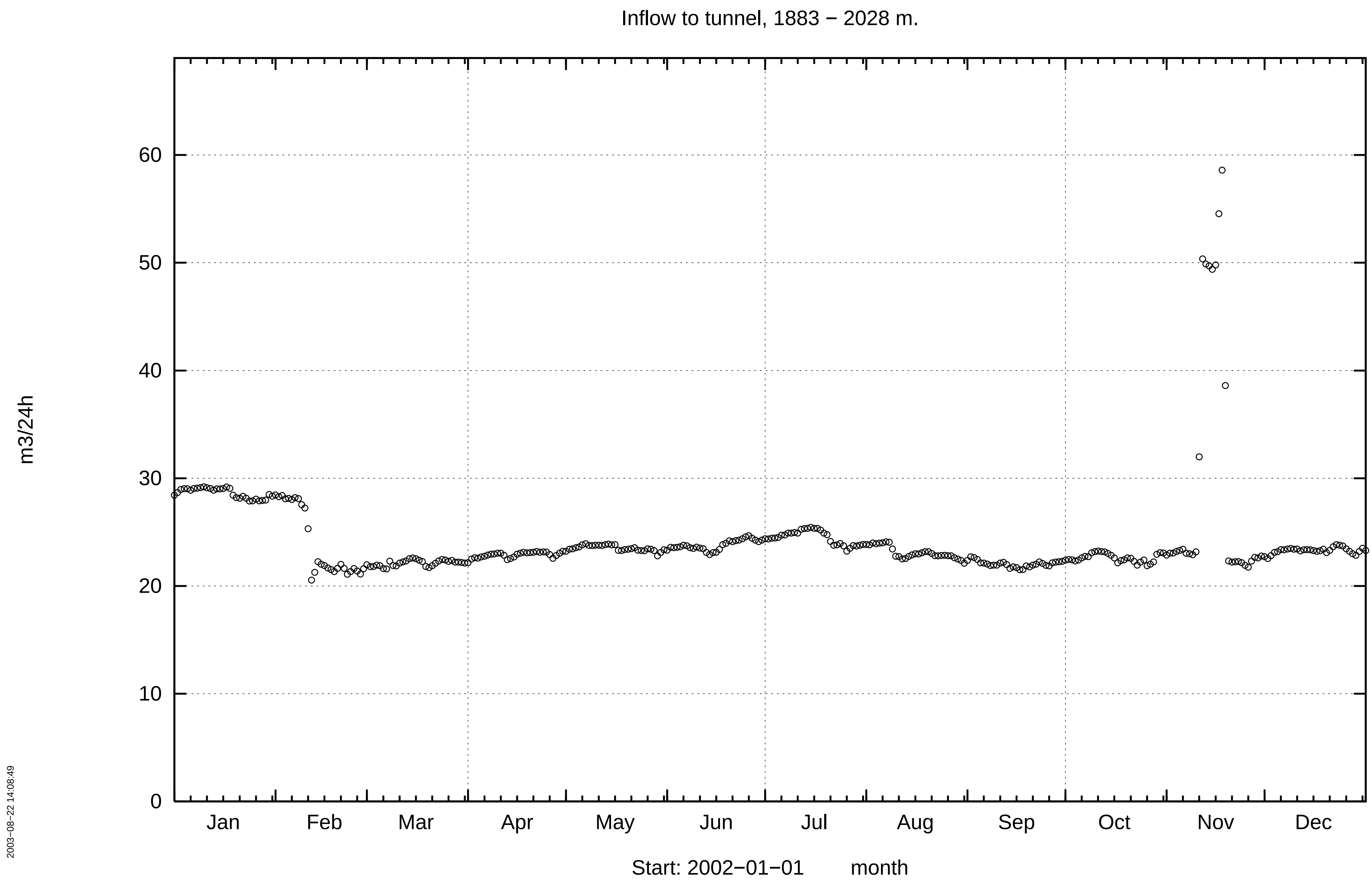


Inflow to tunnel, 1584 − 1745 m (shafts excluded).



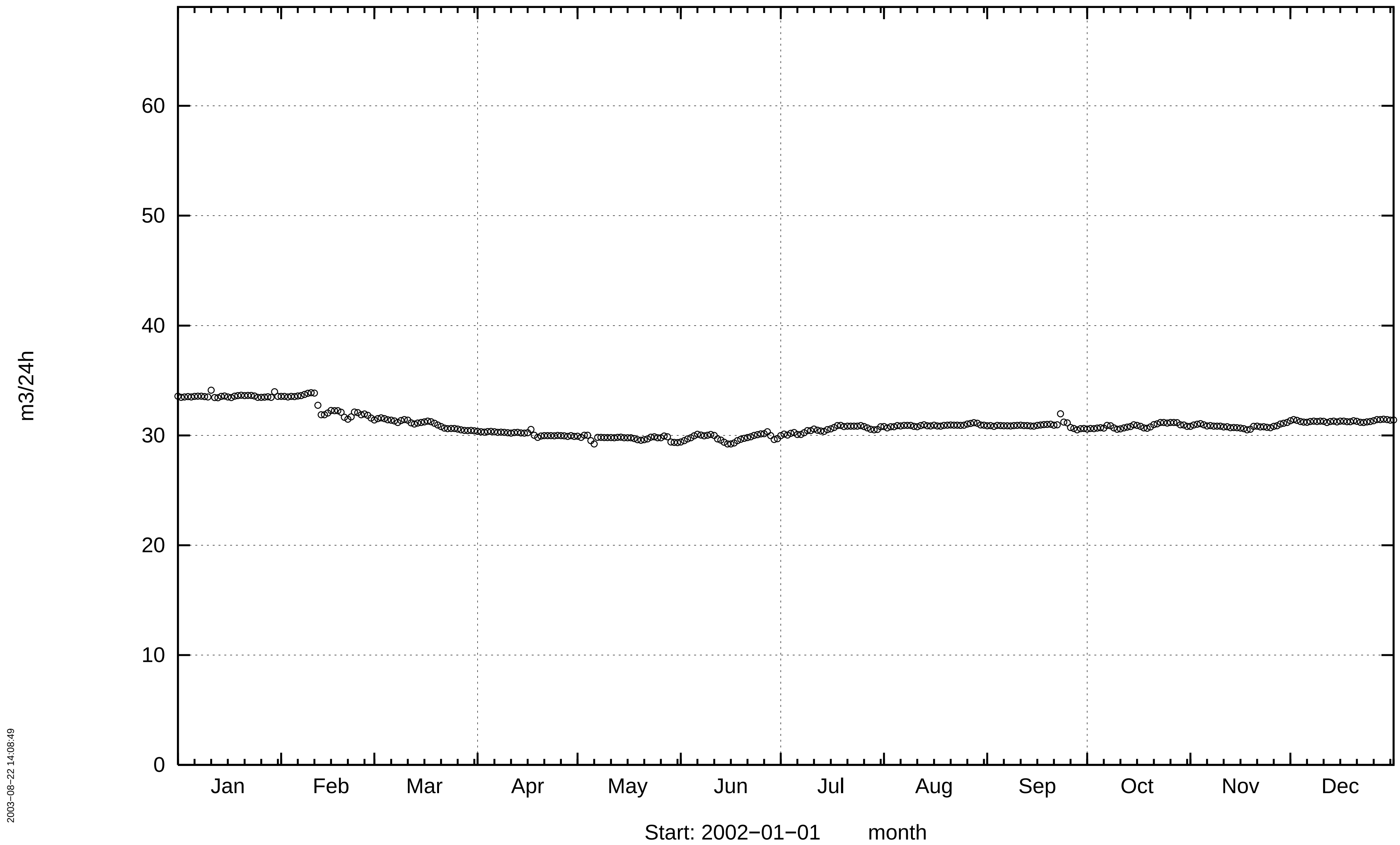


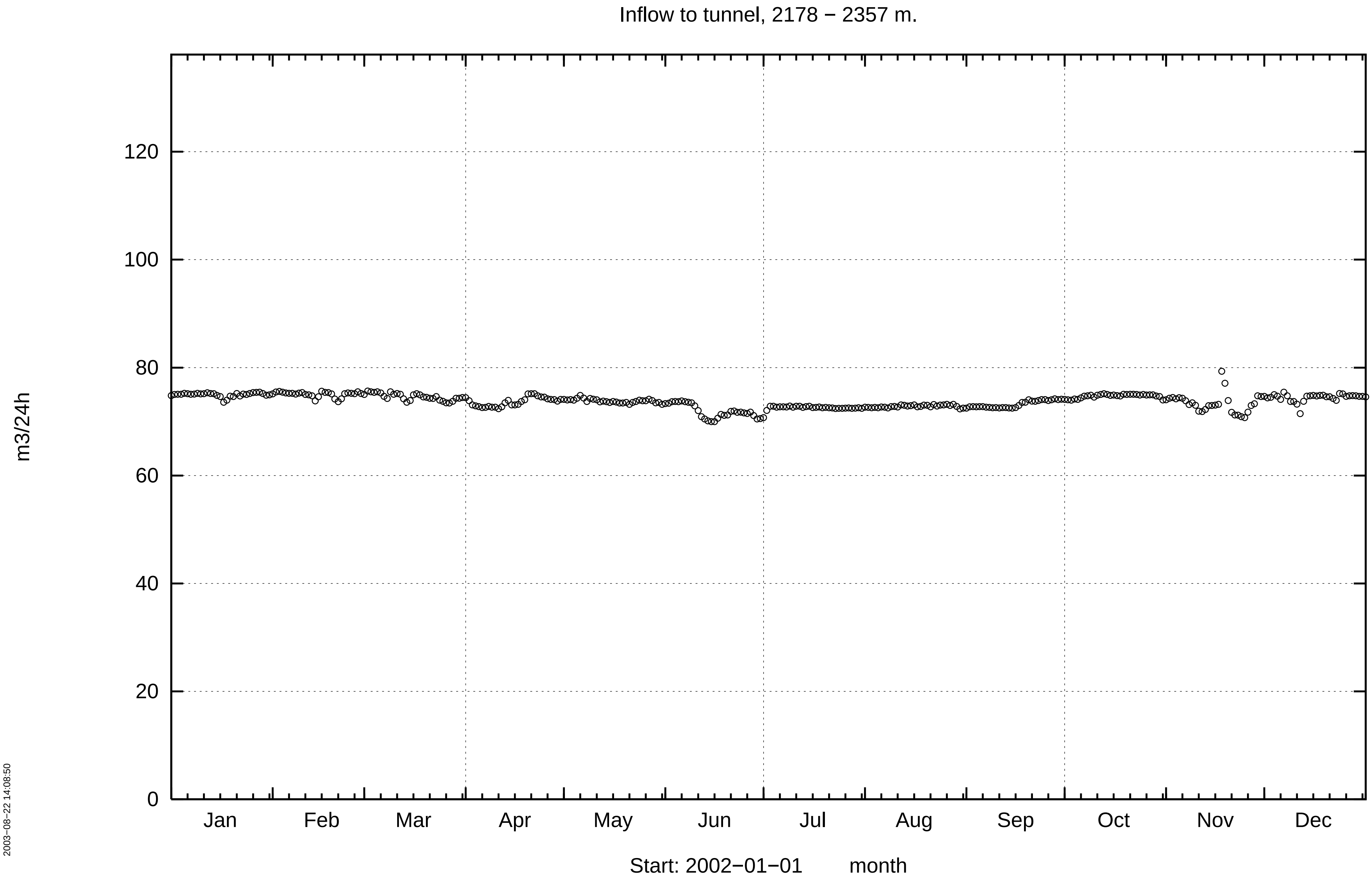
Inflow to tunnel, 1745 − 1883 m.
m3/24h
0
5
10
15
20
25
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:49



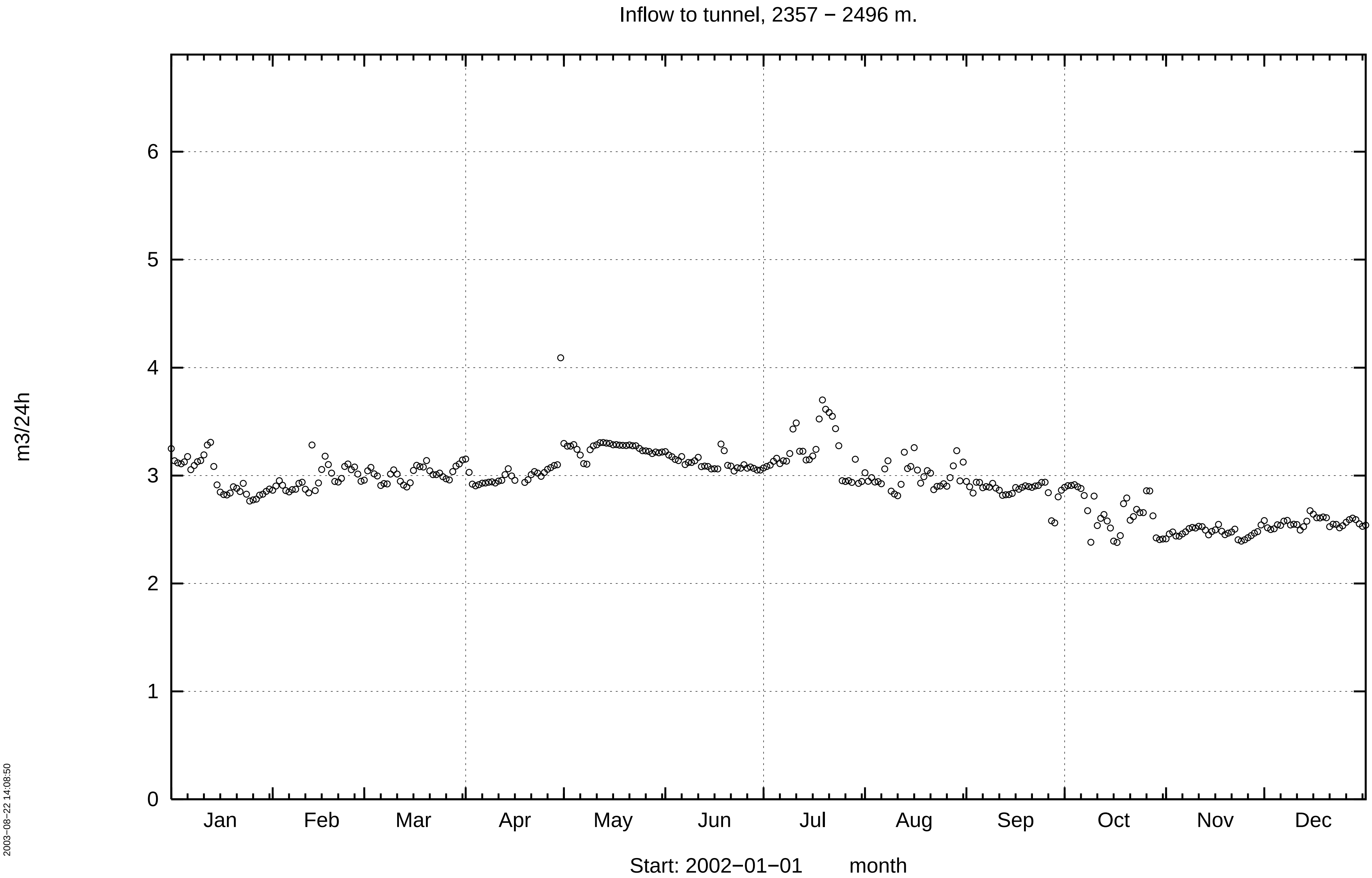
Inflow to tunnel, 1883 − 2028 m.
m3/24h
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:49

Inflow to tunnel, 2028 − 2178 m.

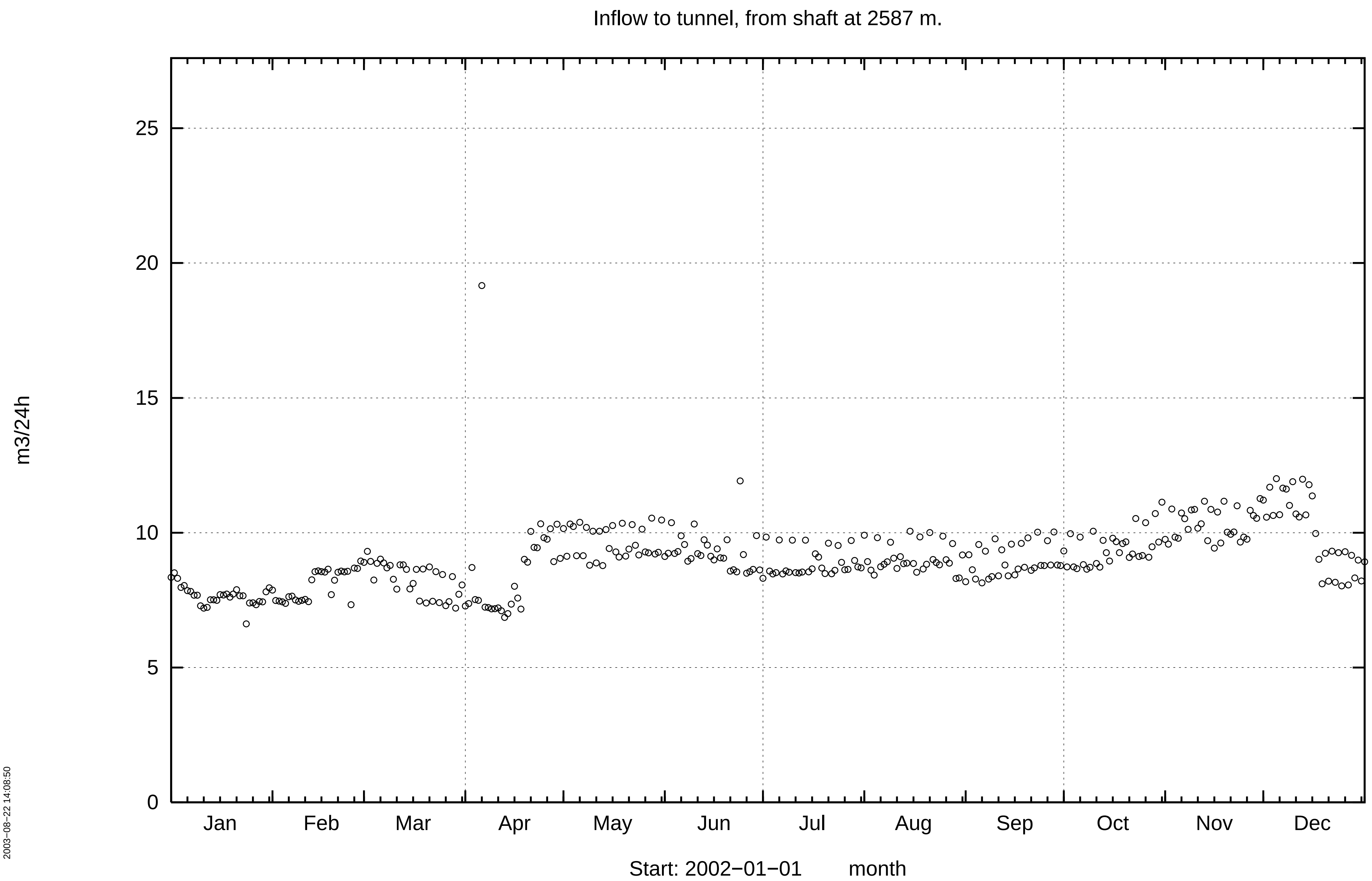




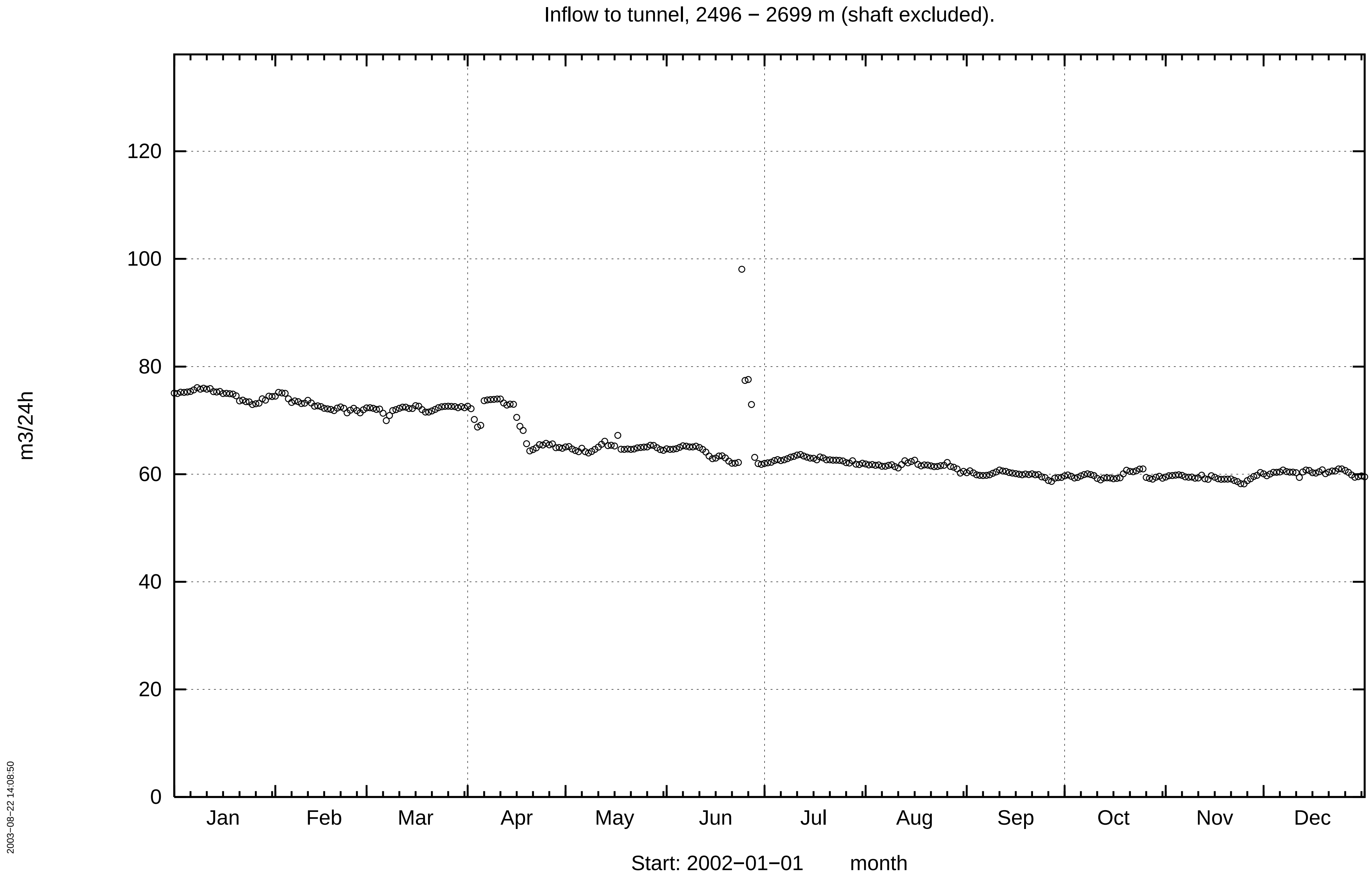
Inflow to tunnel, 2178 − 2357 m.
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:50



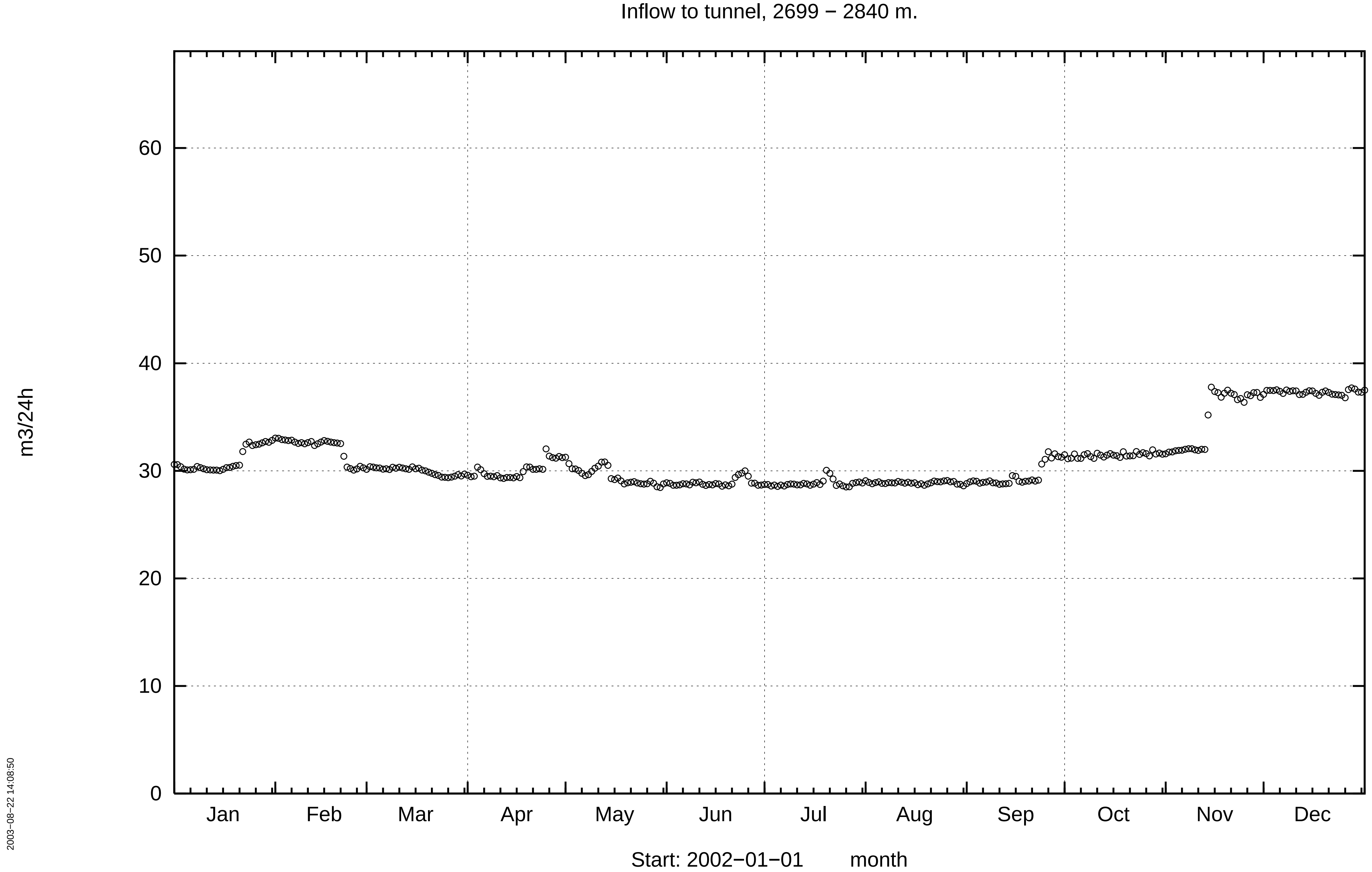
Inflow to tunnel, 2357 − 2496 m.
m3/24h
0
1
2
3
4
5
6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:50



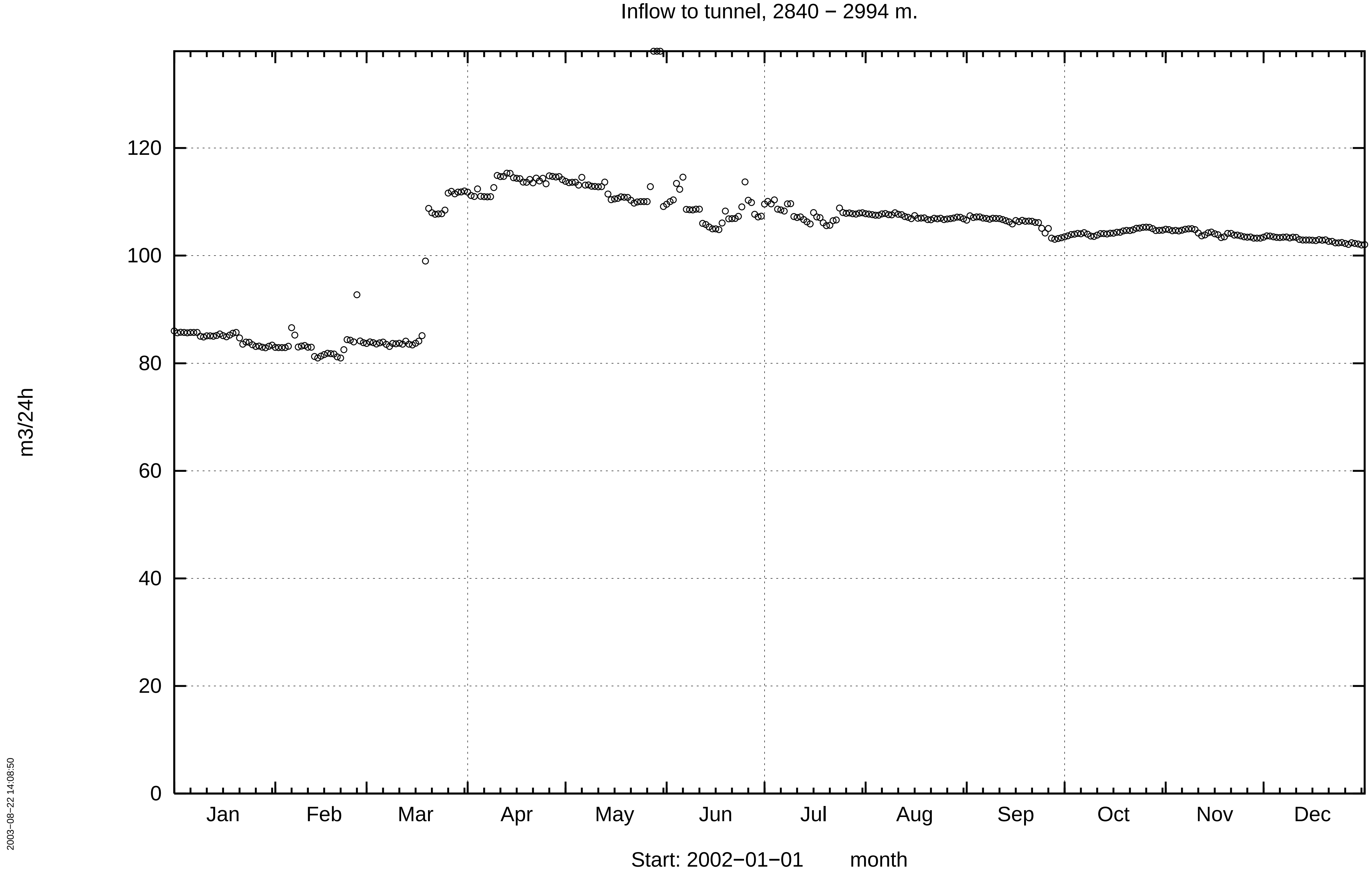
Inflow to tunnel, from shaft at 2587 m.
m3/24h
25
20
15
10
5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:50



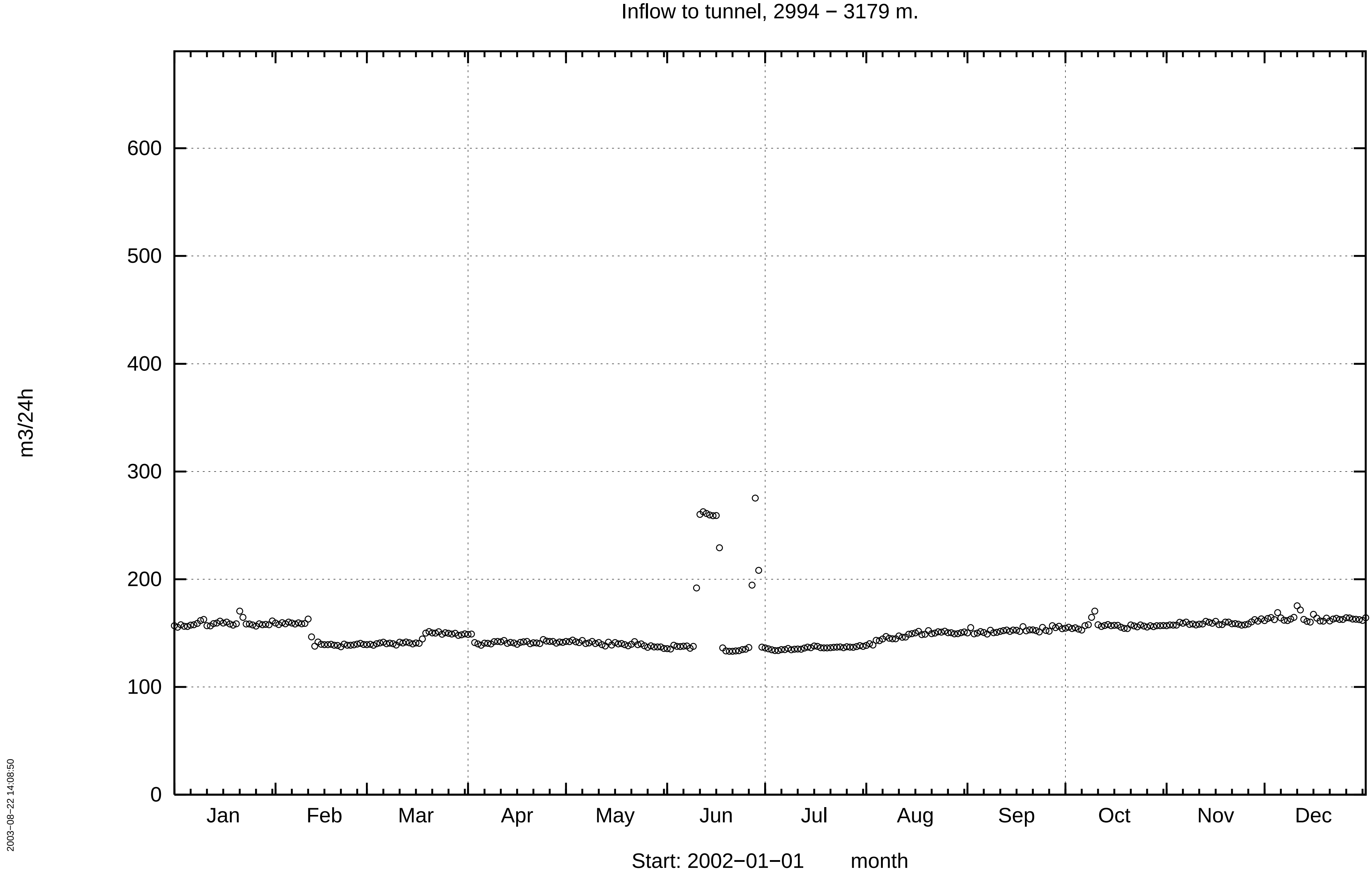
Inflow to tunnel, 2496 − 2699 m (shaft excluded).
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:50

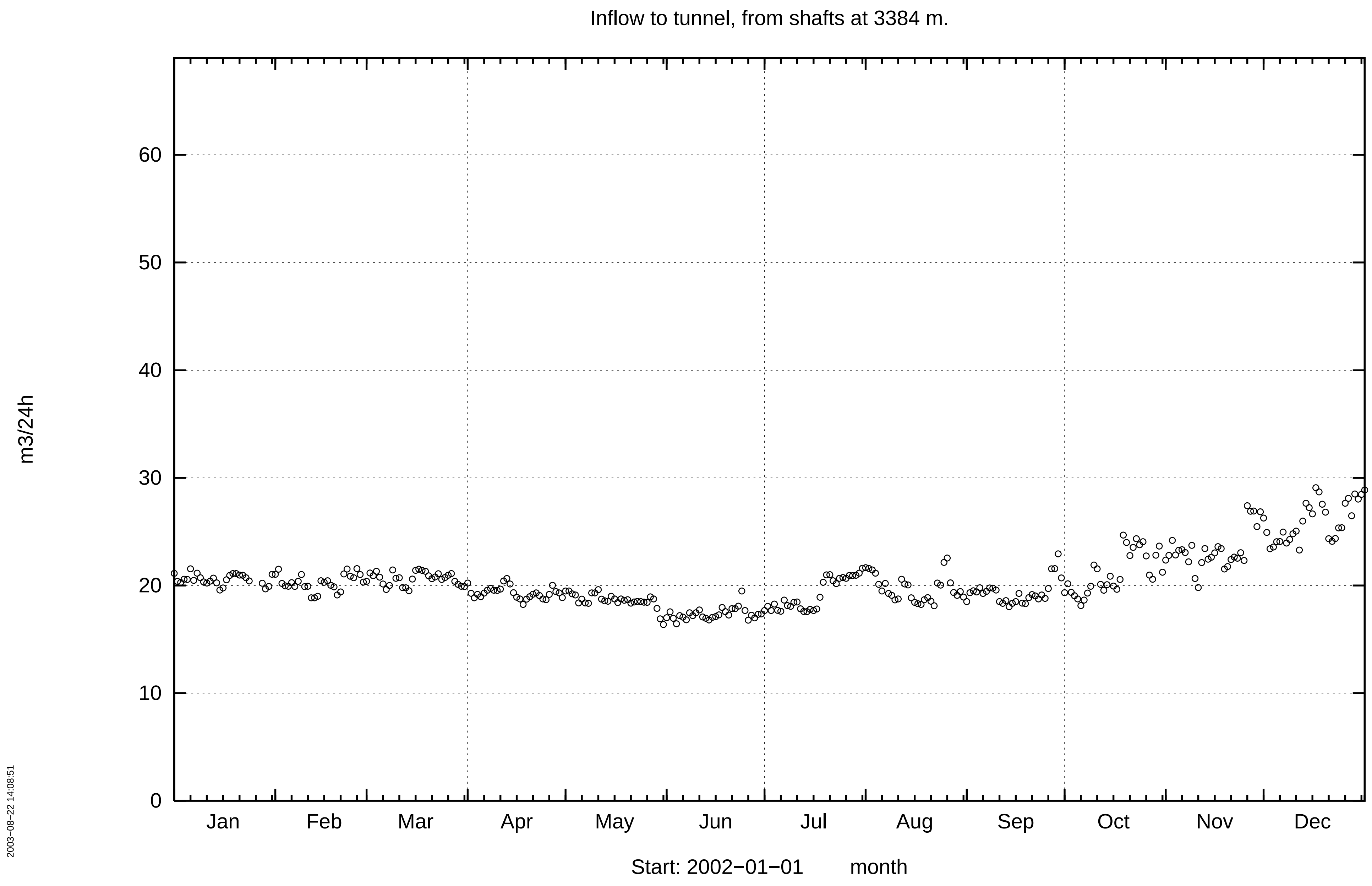


Inflow to tunnel, 2699 − 2840 m.
m3/24h
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:50

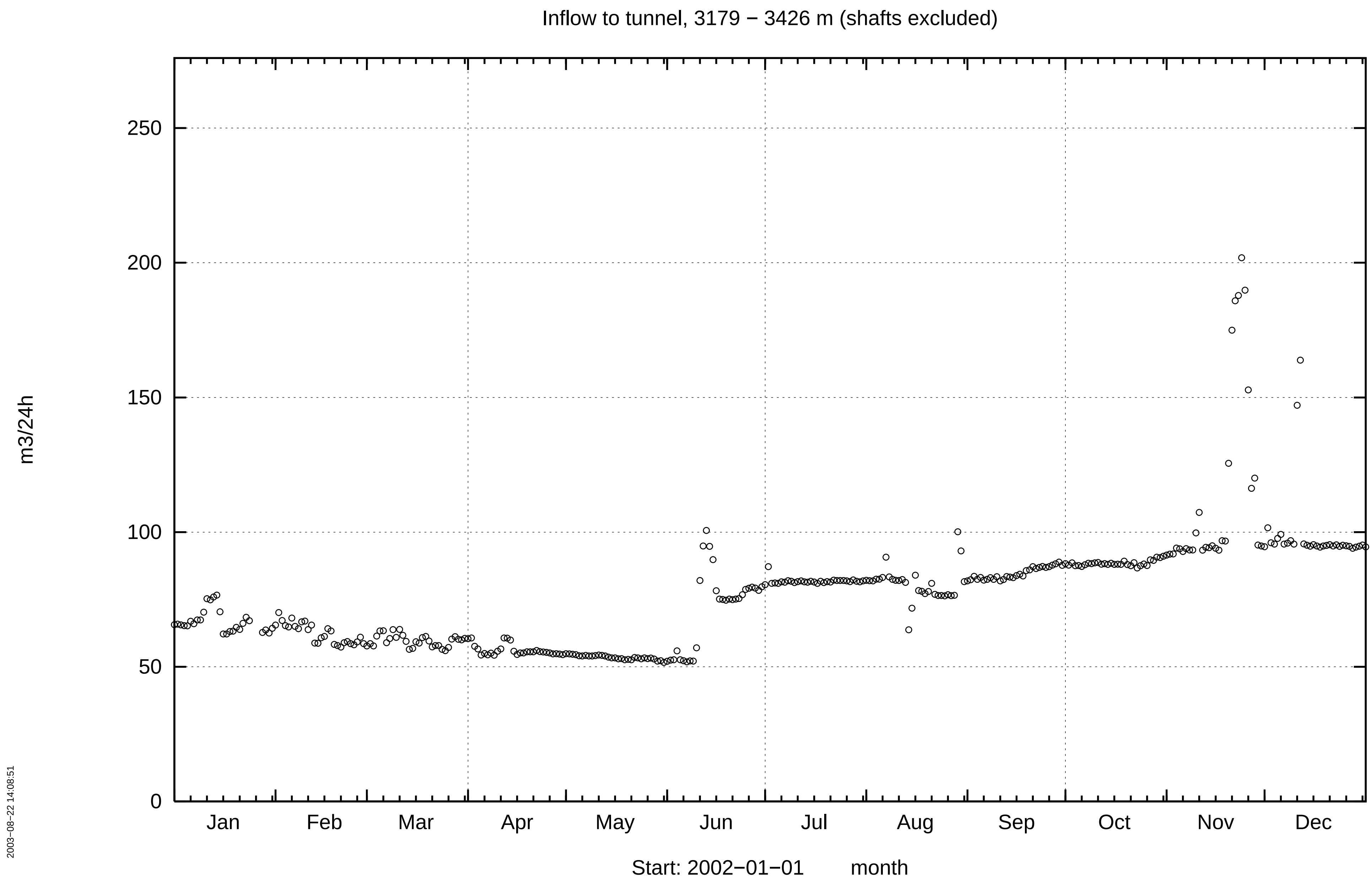


Inflow to tunnel, 2840 − 2994 m.
m3/24h
0
20
40
60
80
100
120
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:50

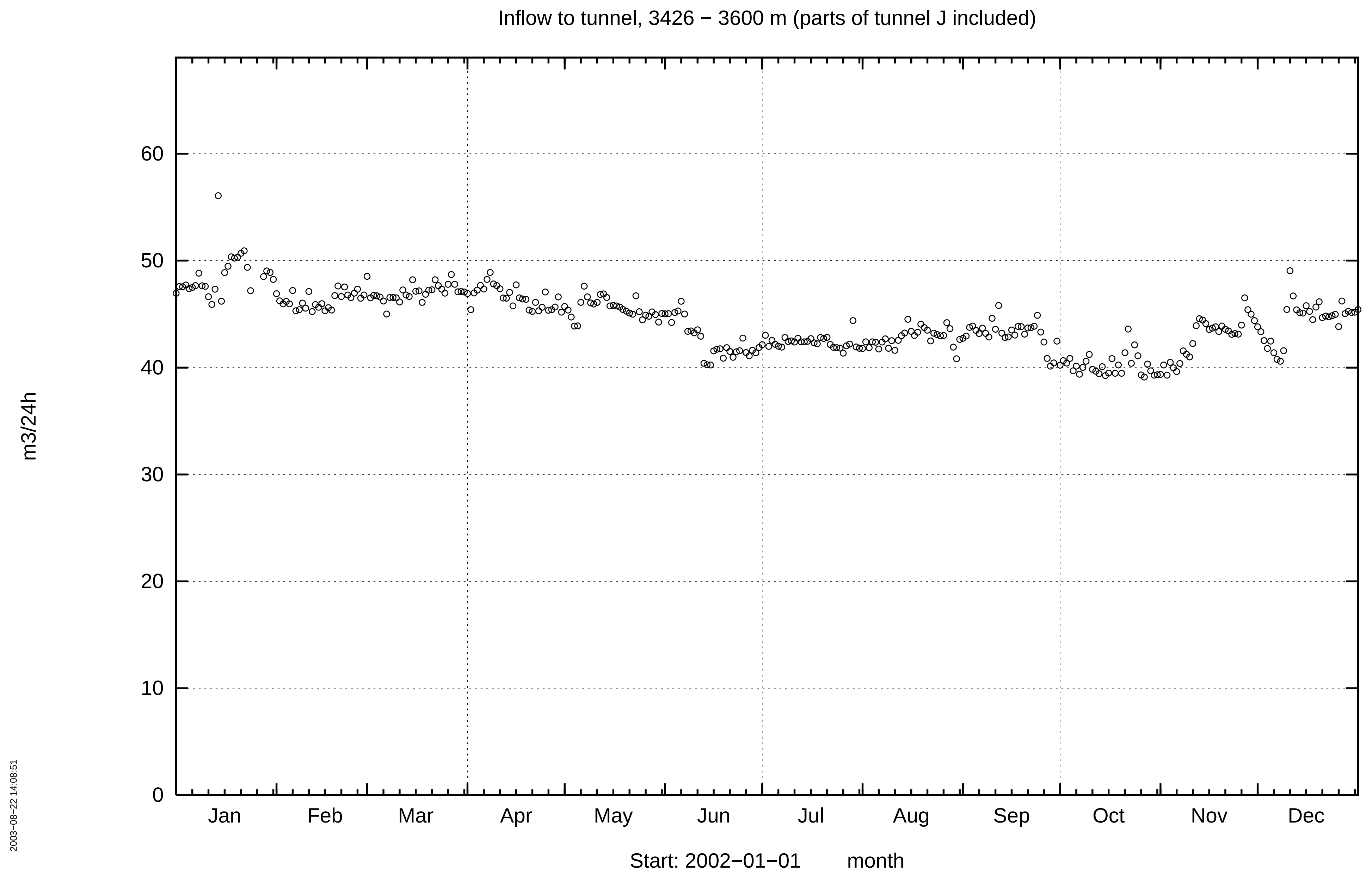

Inflow to tunnel, 2994 − 3179 m.
m3/24h
0
100
200
300
400
500
600
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:50

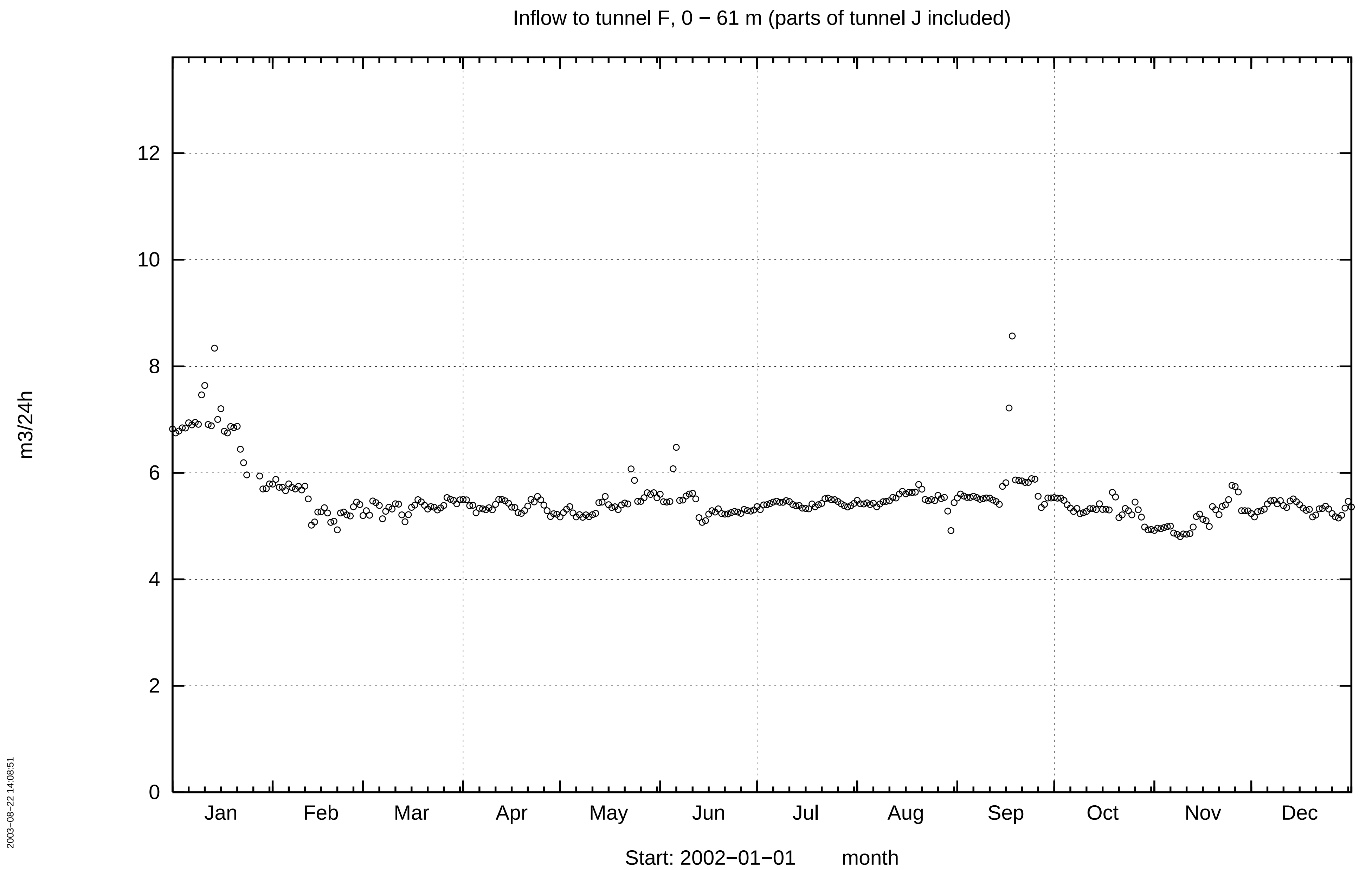


Inflow to tunnel, from shafts at 3384 m.
m3/24h
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:51

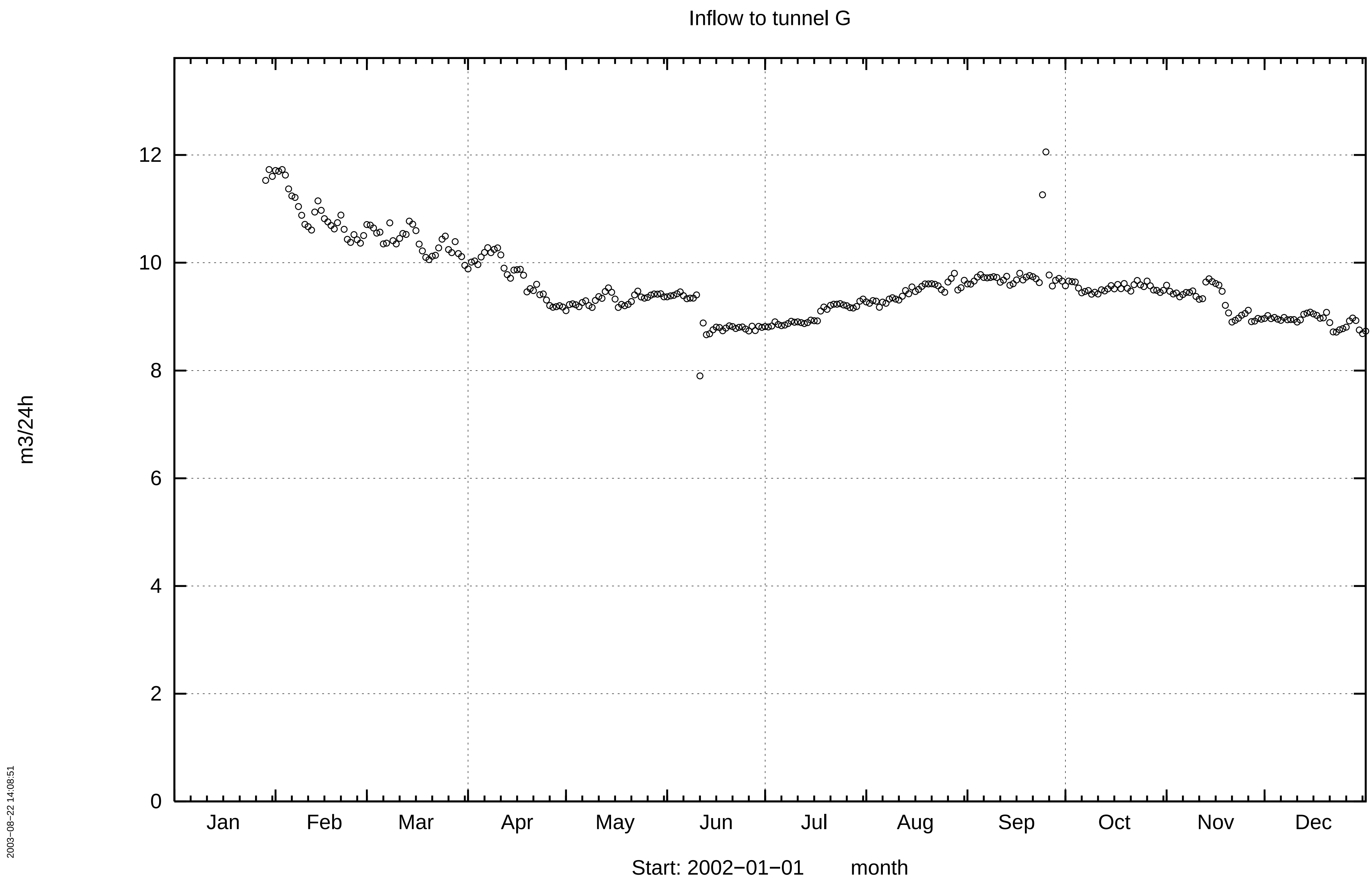


Inflow to tunnel, 3179 − 3426 m (shafts excluded)
m3/24h
0
50
100
150
200
250
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:51

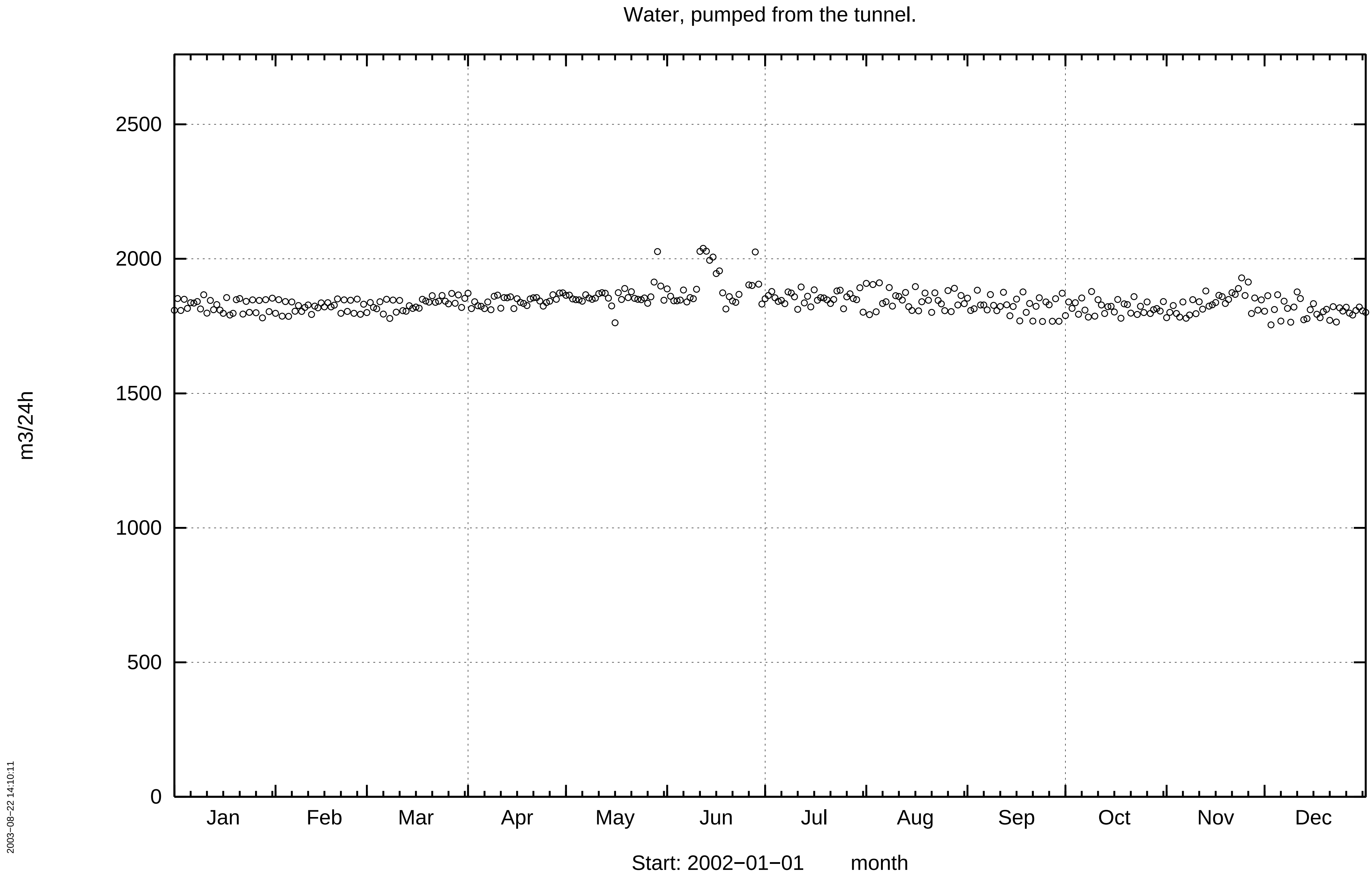

Inflow to tunnel, 3426 − 3600 m (parts of tunnel J included)
m3/24h
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:51



Inflow to tunnel F, 0 − 61 m (parts of tunnel J included)
m3/24h
0
2
4
6
8
10
12
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:51

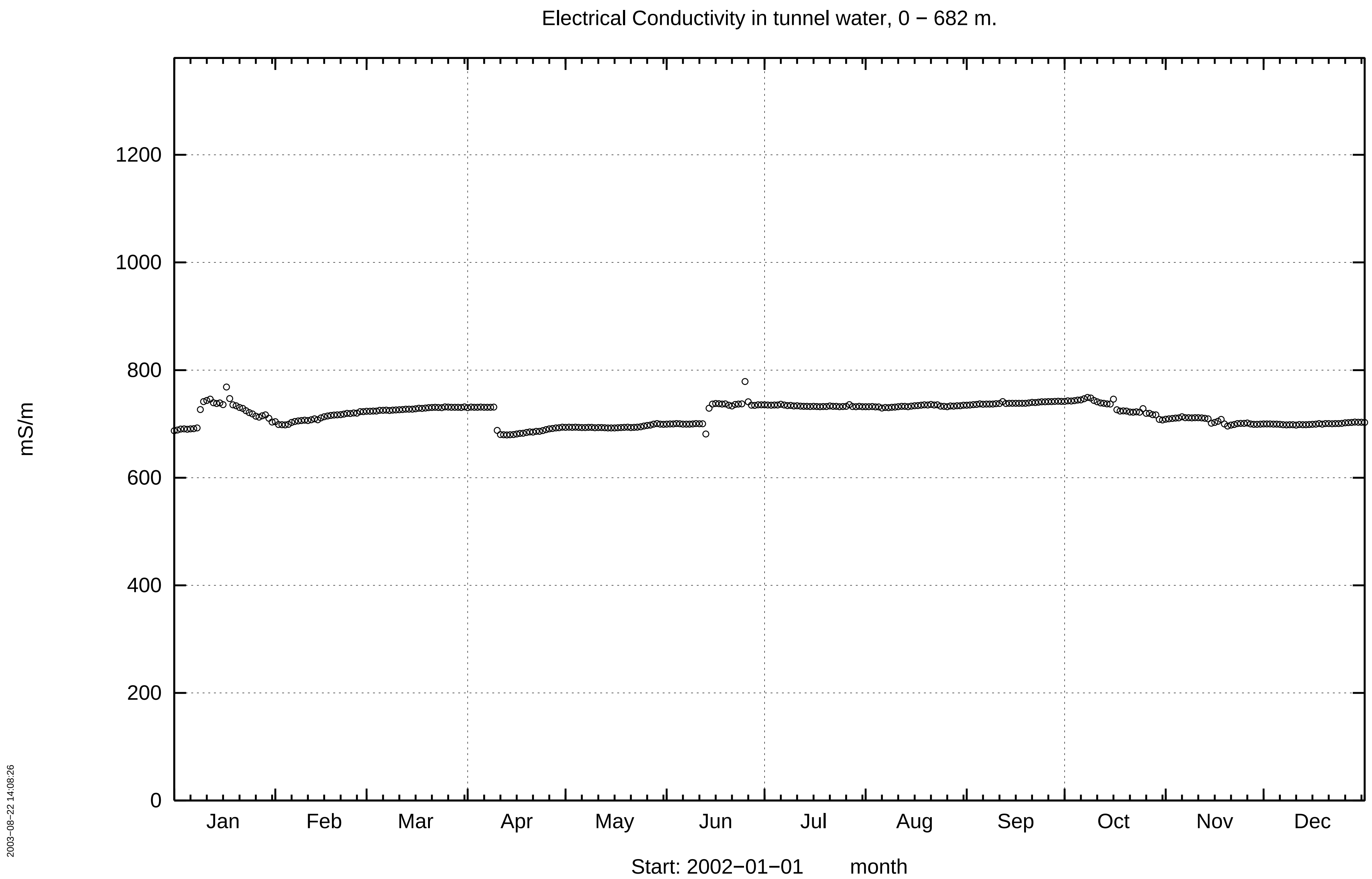

Inflow to tunnel G
m3/24h
0
2
4
6
8
10
12
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:51

Appendix 6: Water flow in tunnel pipes



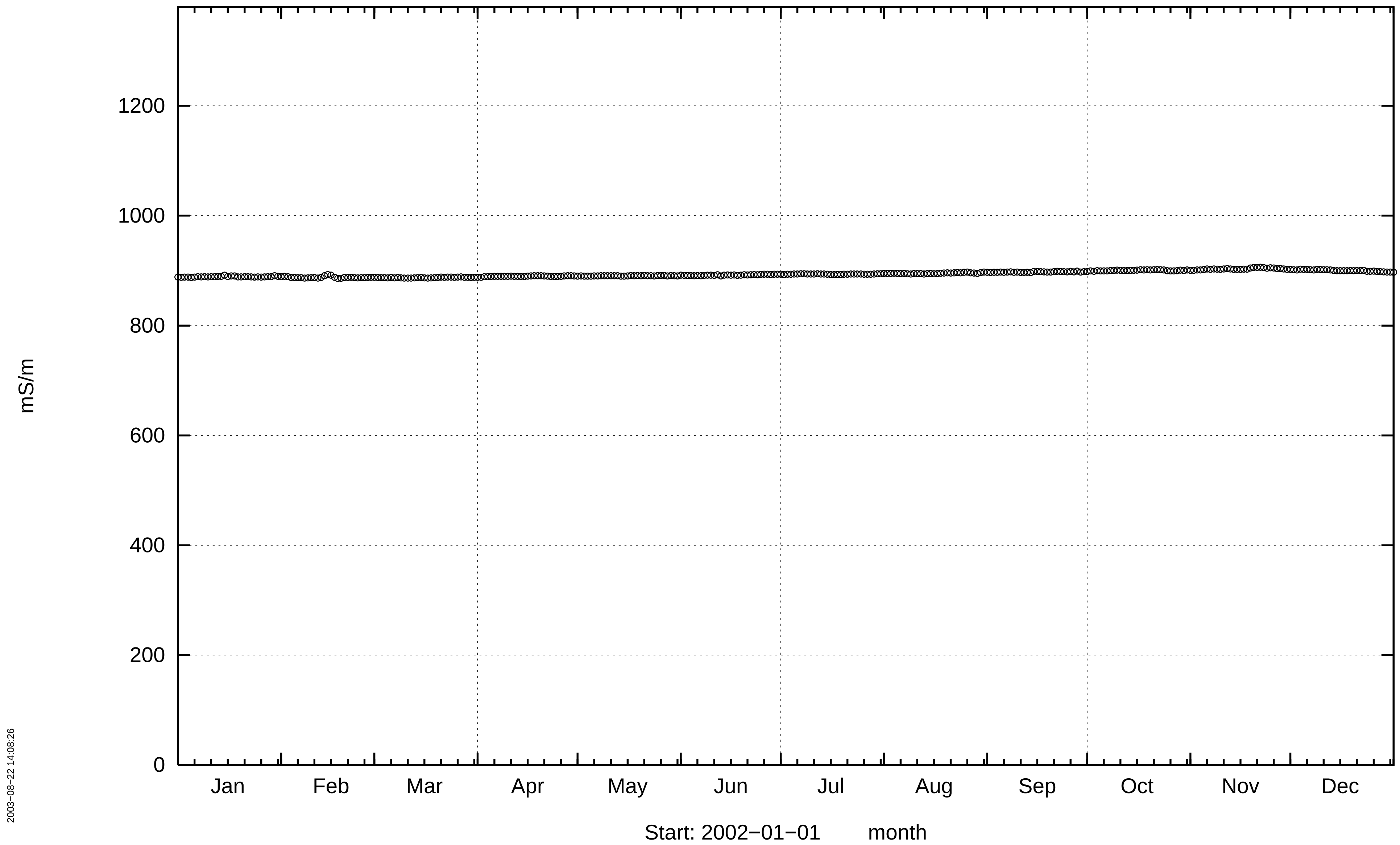
Water, pumped from the tunnel.
m3/24h
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:10:11

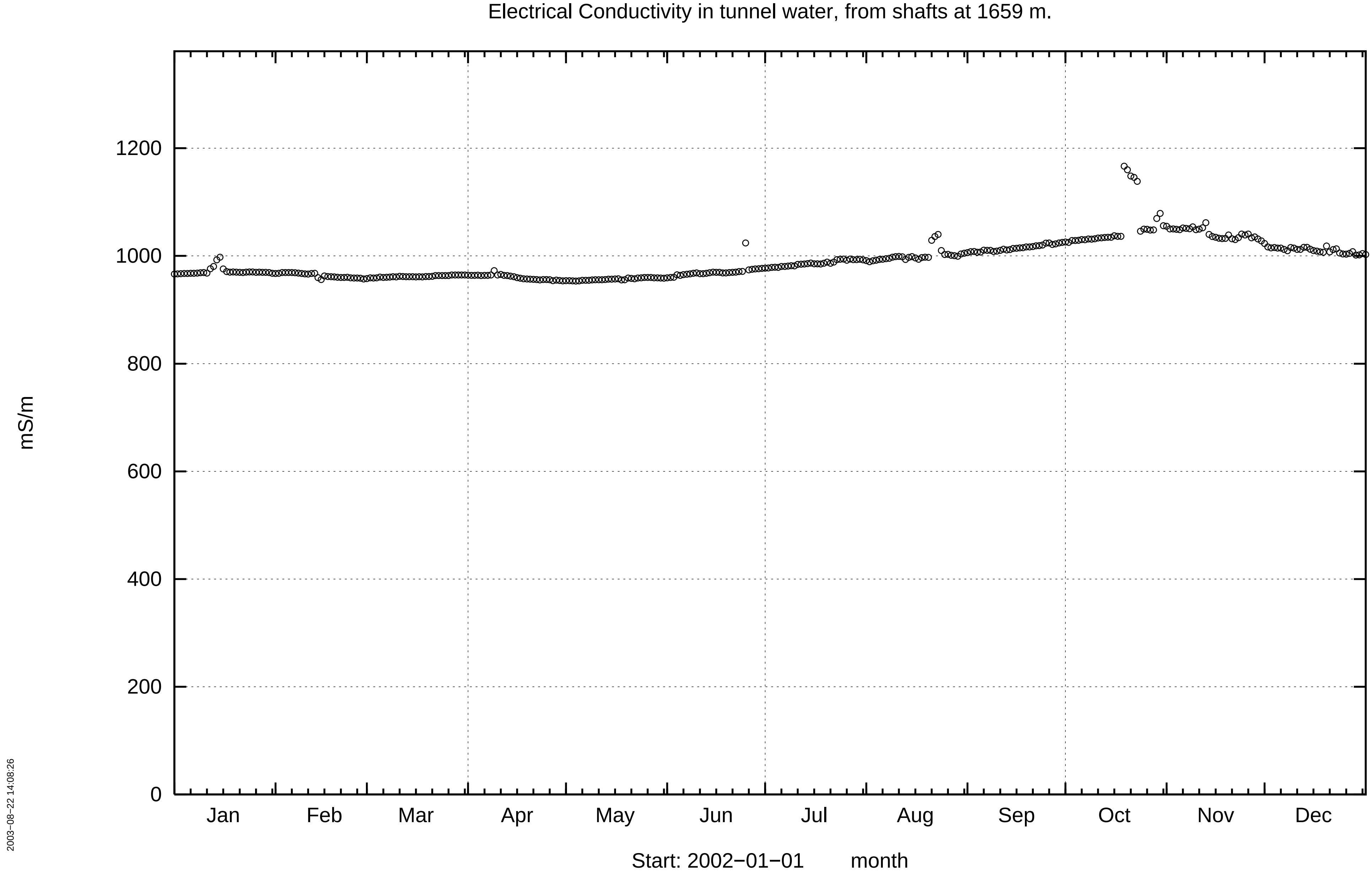
Appendix 7: Electrical conductivity of tunnel water



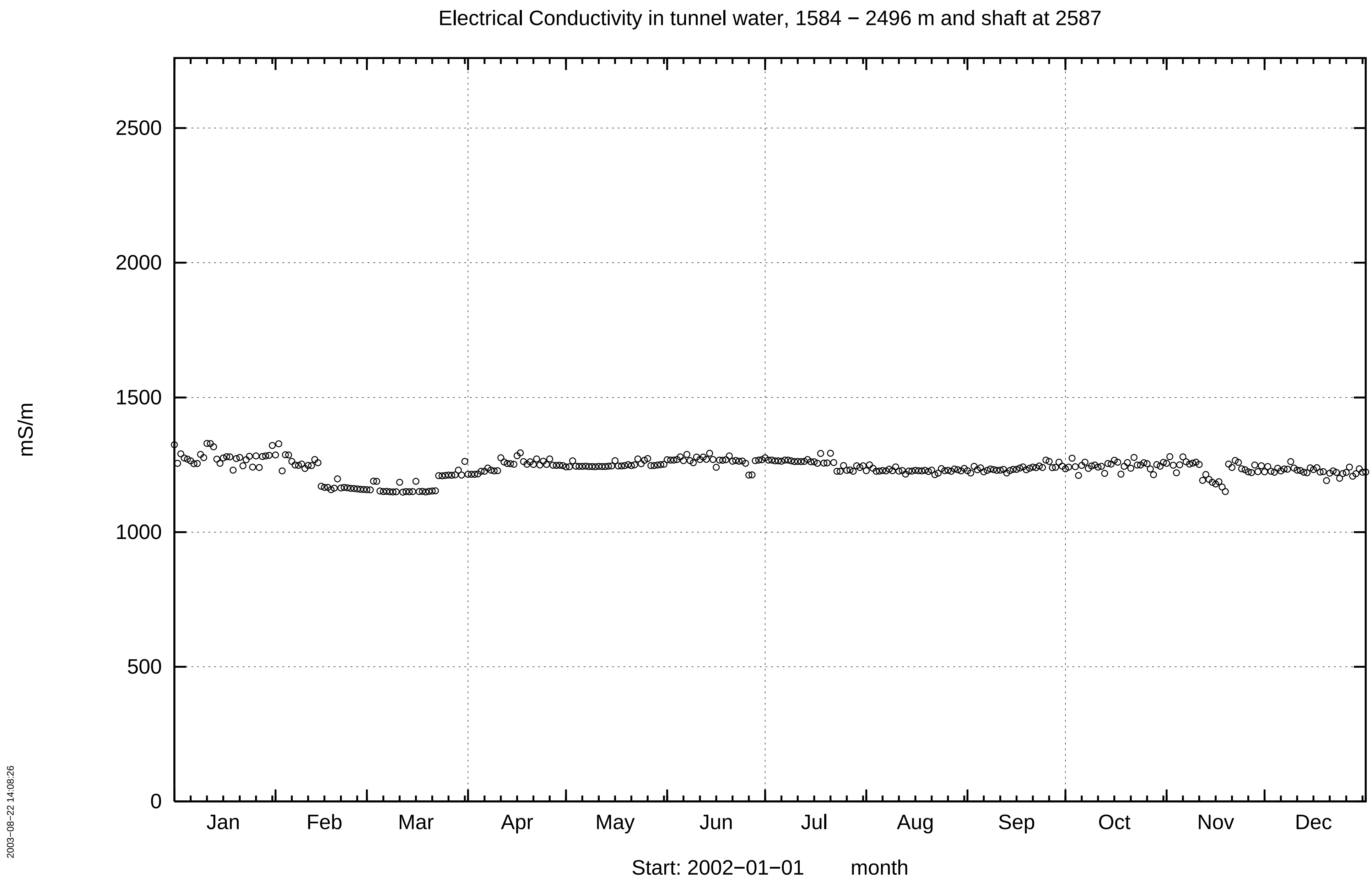
Electrical Conductivity in tunnel water, 0 − 682 m.
mS/m
1200
1000
800
600
400
200
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01 month
2003−08−22 14:08:26

Electrical Conductivity in tunnel water, 682 − 1584 m and from shafts at 1659.

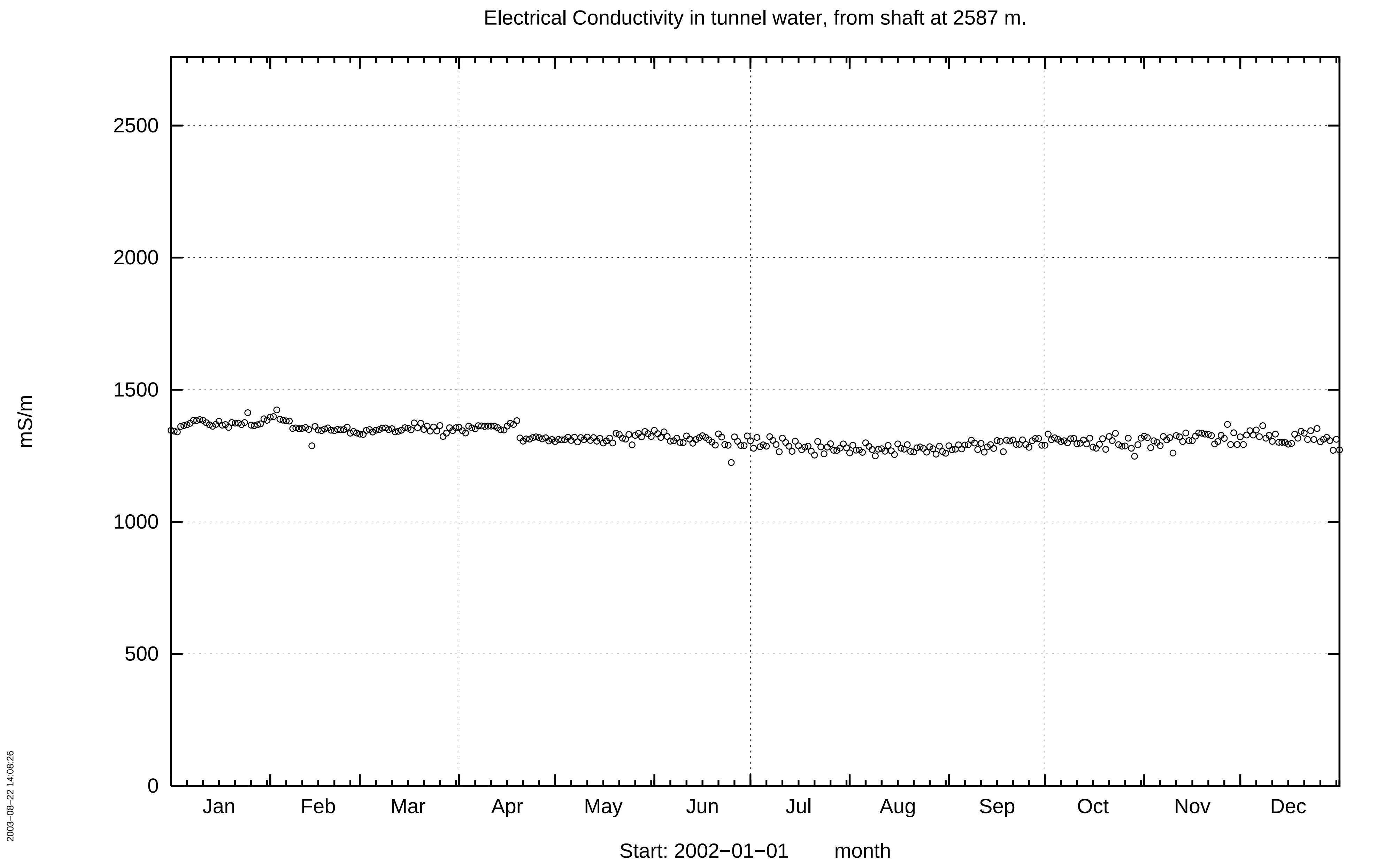




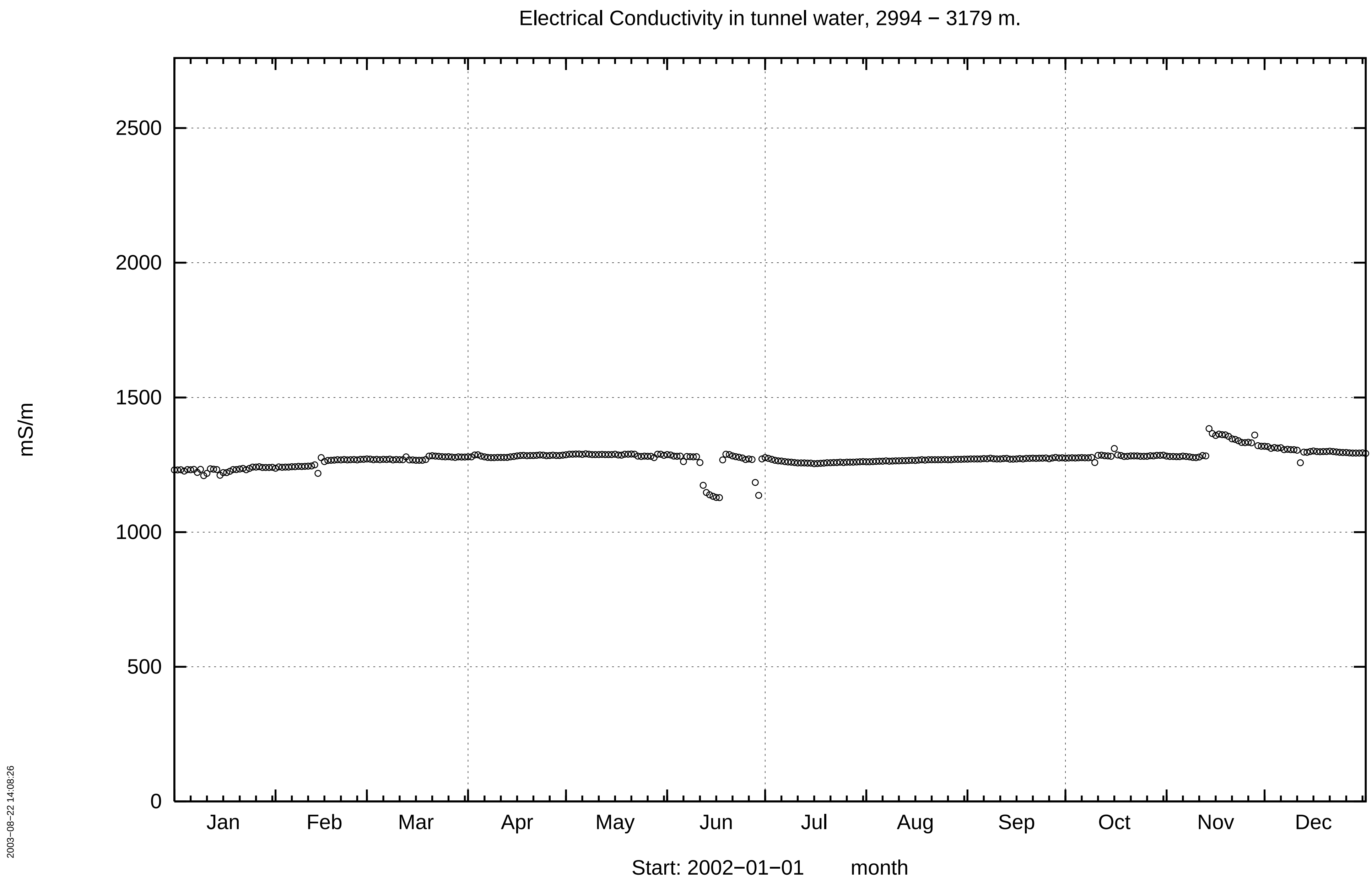
Electrical Conductivity in tunnel water, from shafts at 1659 m.
mS/m
0
200
400
600
800
1000
1200
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:26



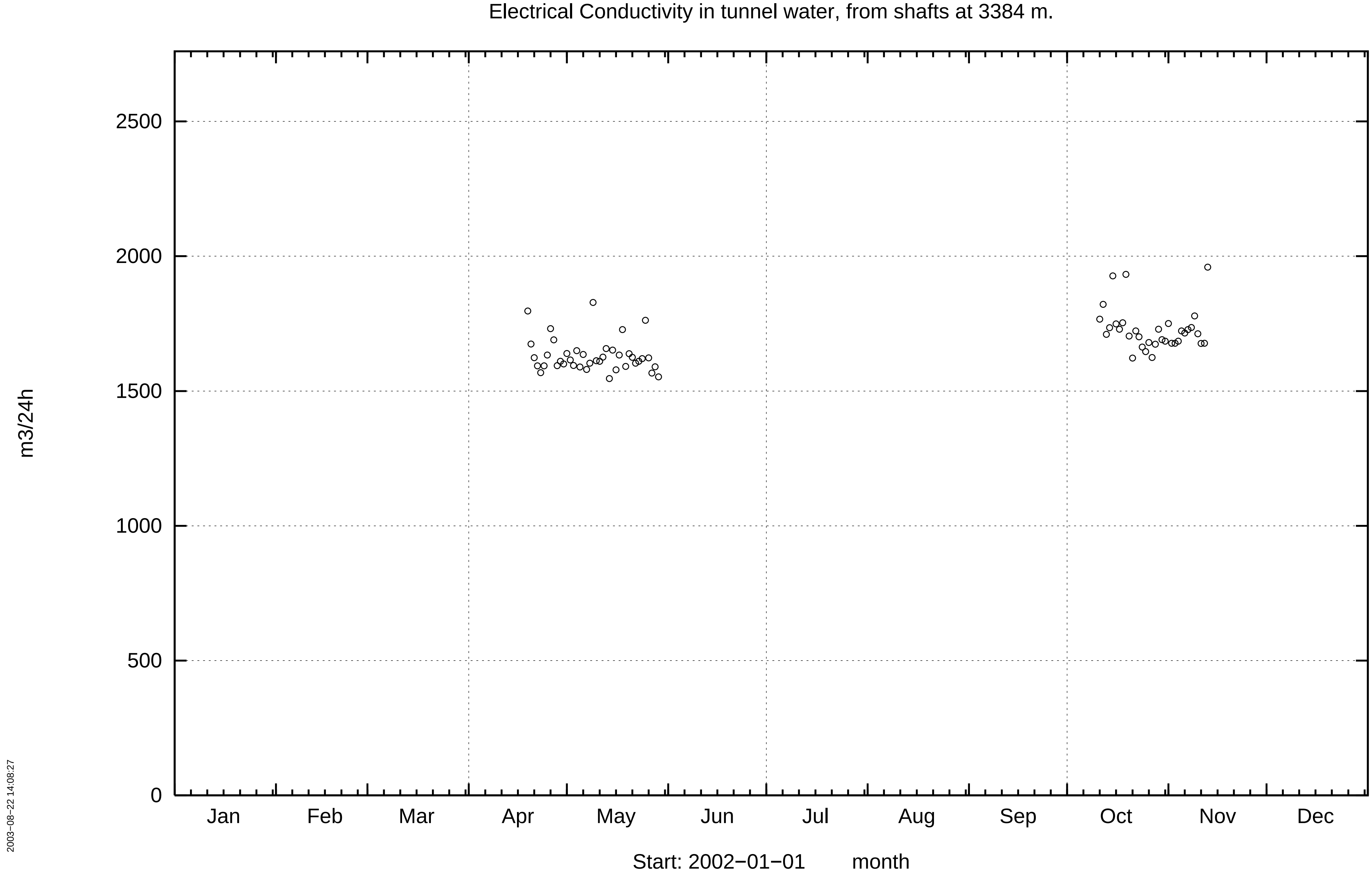
Electrical Conductivity in tunnel water, 1584 − 2496 m and shaft at 2587
mS/m
0
500
1000
1500
2000
2500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:26



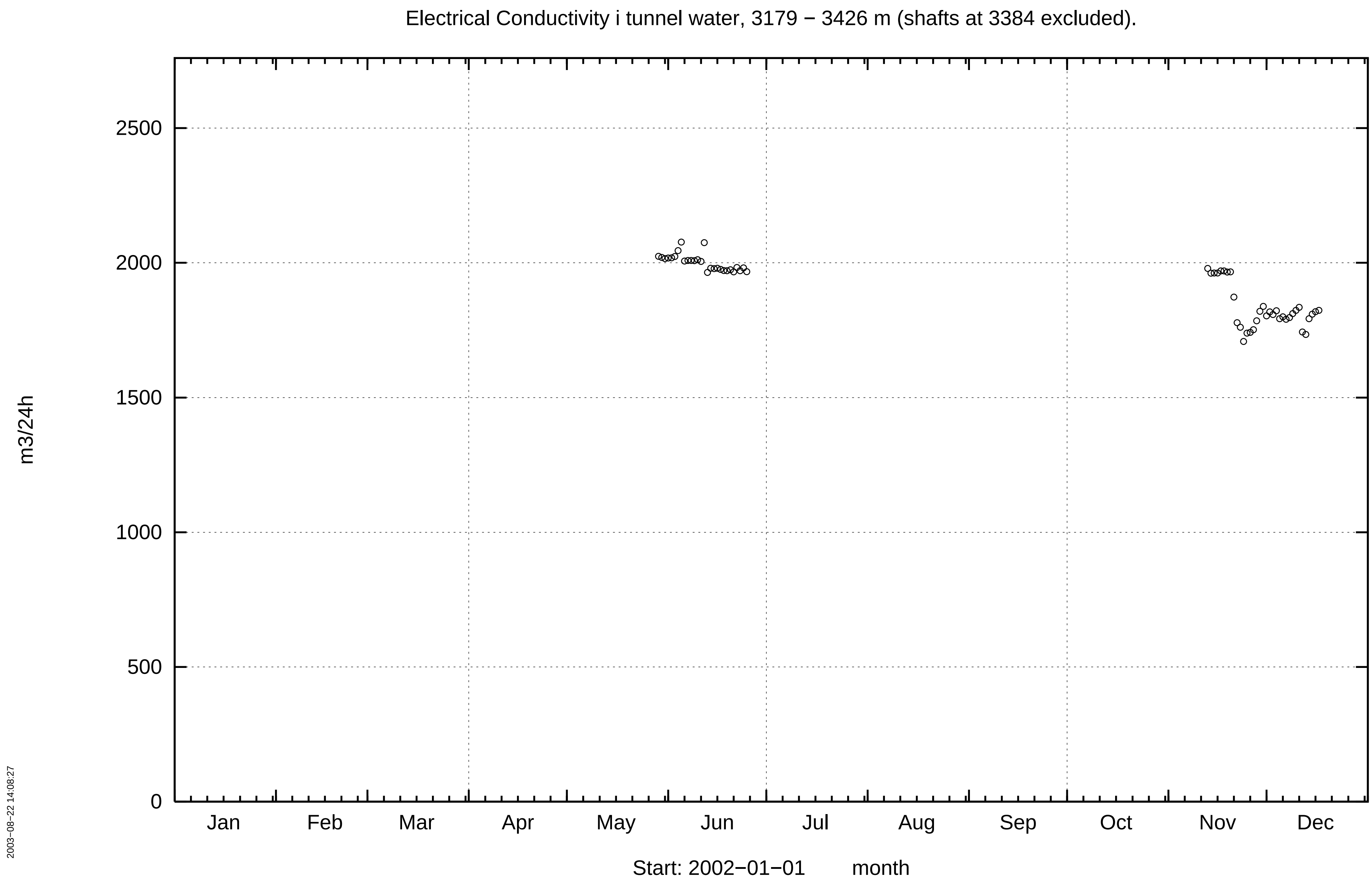
Electrical Conductivity in tunnel water, from shaft at 2587 m.
mS/m
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:26



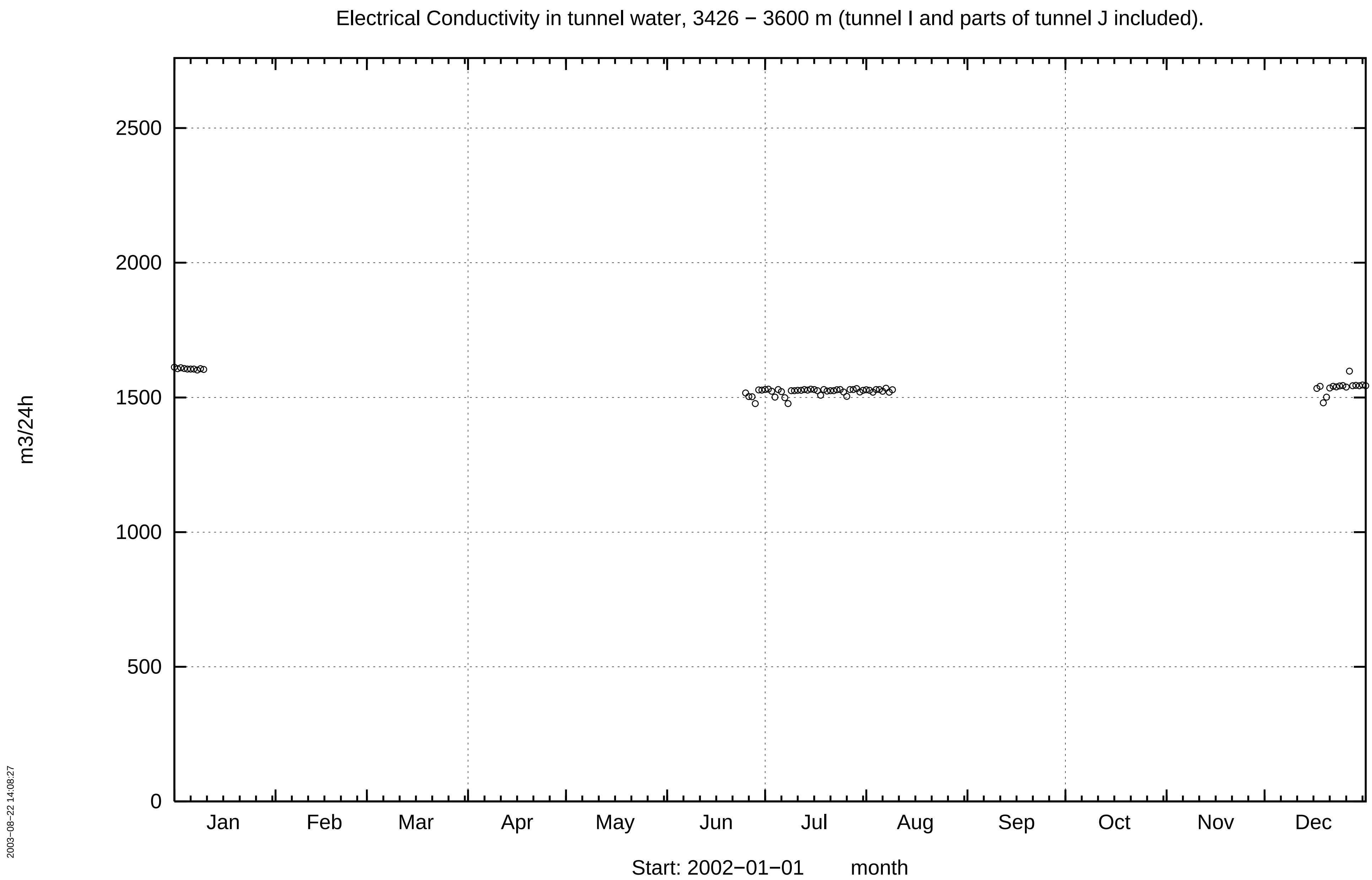
Electrical Conductivity in tunnel water, 2994 − 3179 m.
mS/m
0
500
1000
1500
2000
2500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:26



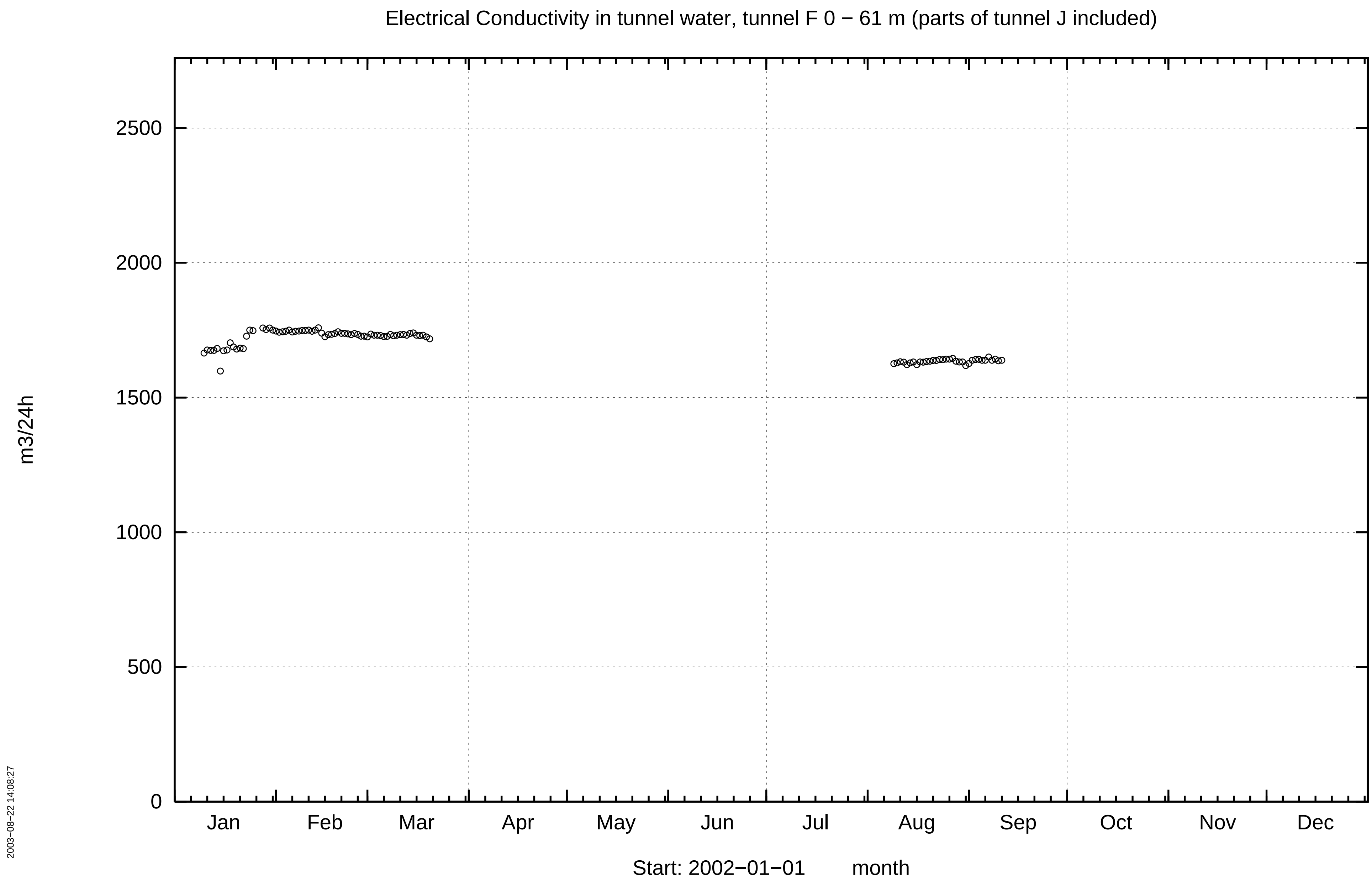
Electrical Conductivity in tunnel water, from shafts at 3384 m.
m3/24h
0
500
1000
1500
2000
2500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:27



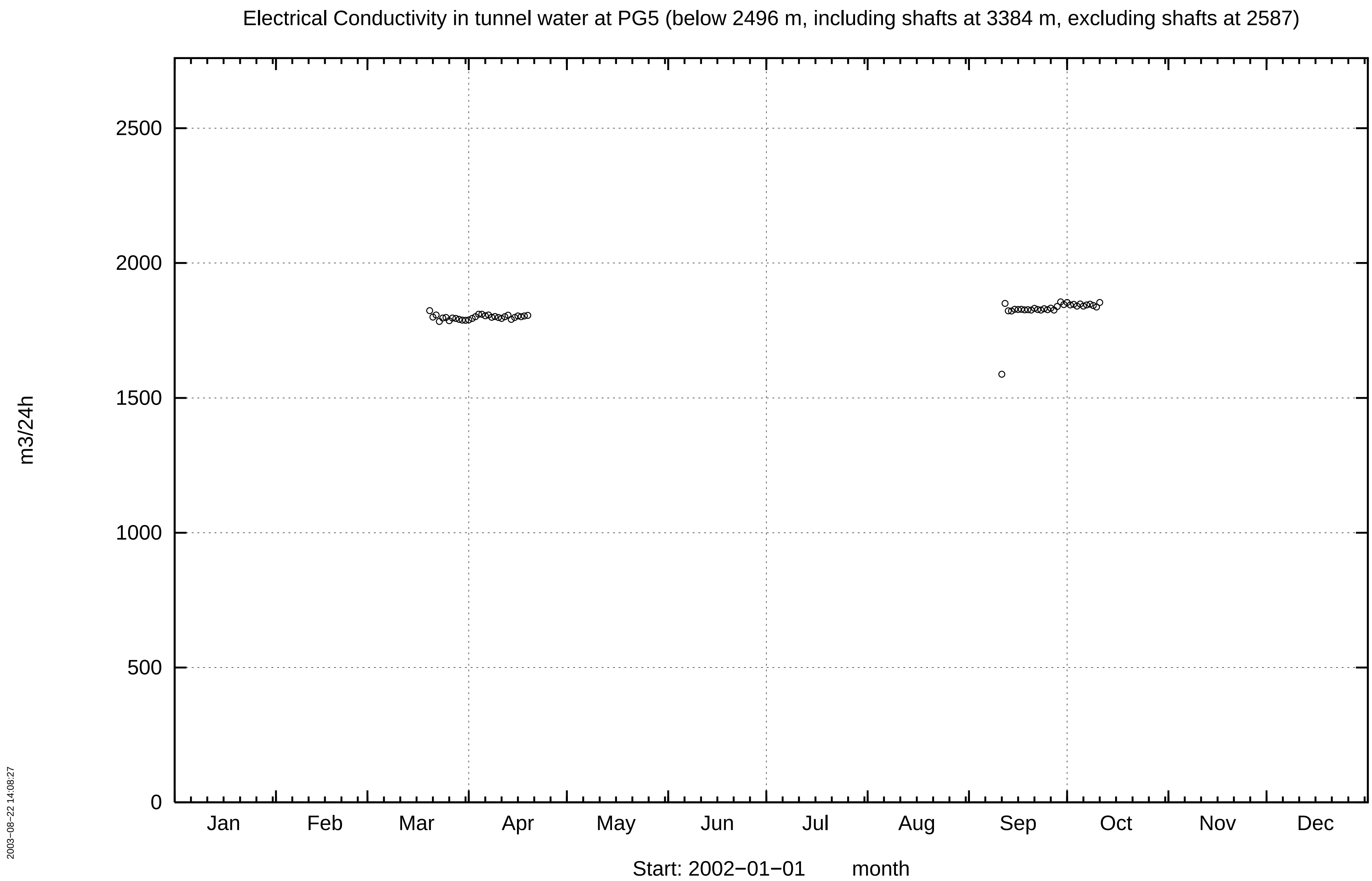
Electrical Conductivity i tunnel water, 3179 − 3426 m (shafts at 3384 excluded).
m3/24h
0
500
1000
1500
2000
2500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:27



Electrical Conductivity in tunnel water, 3426 − 3600 m (tunnel I and parts of tunnel J included).
m3/24h
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:27

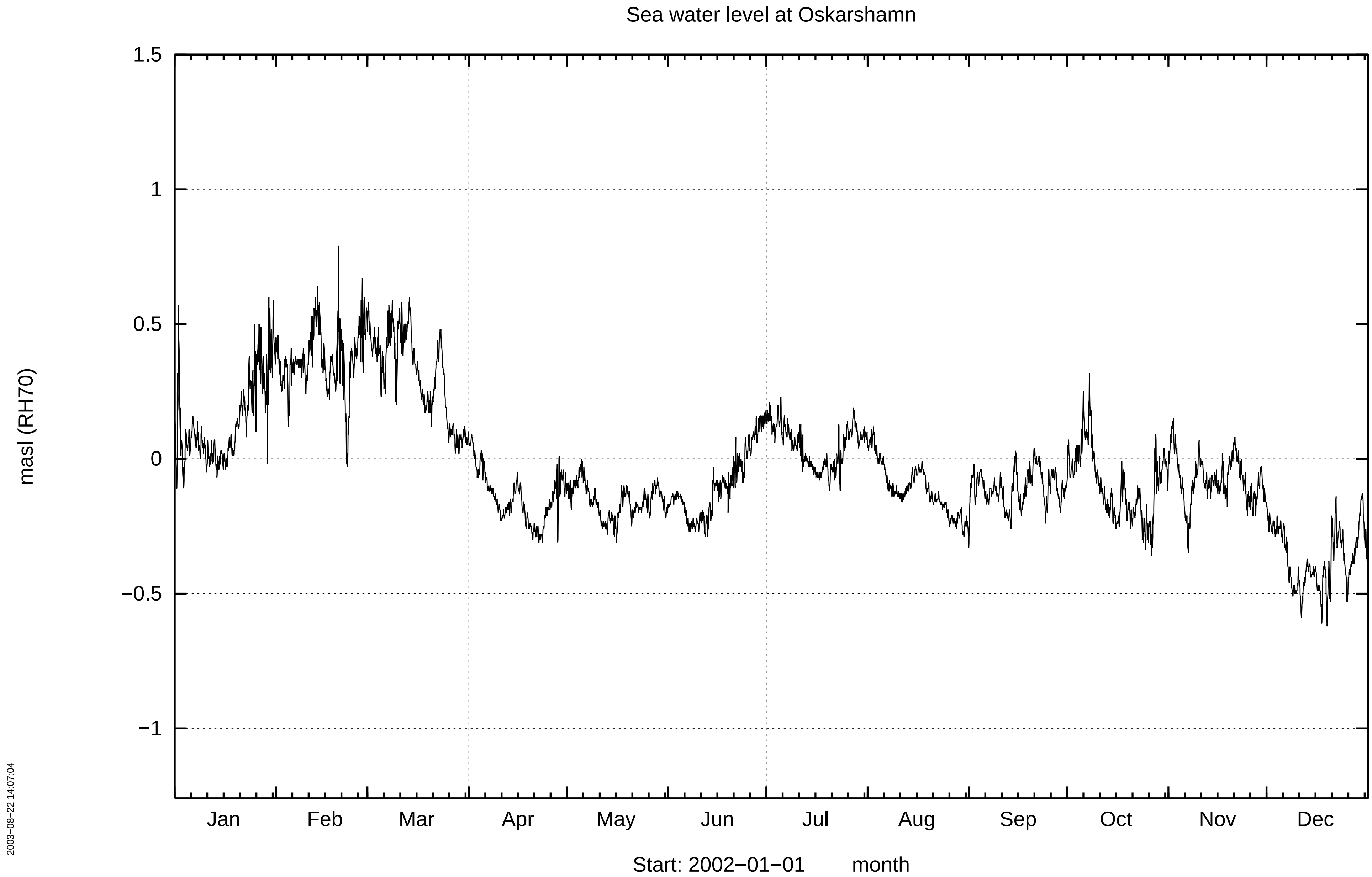


Electrical Conductivity in tunnel water, tunnel F 0 − 61 m (parts of tunnel J included)
m3/24h
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:27

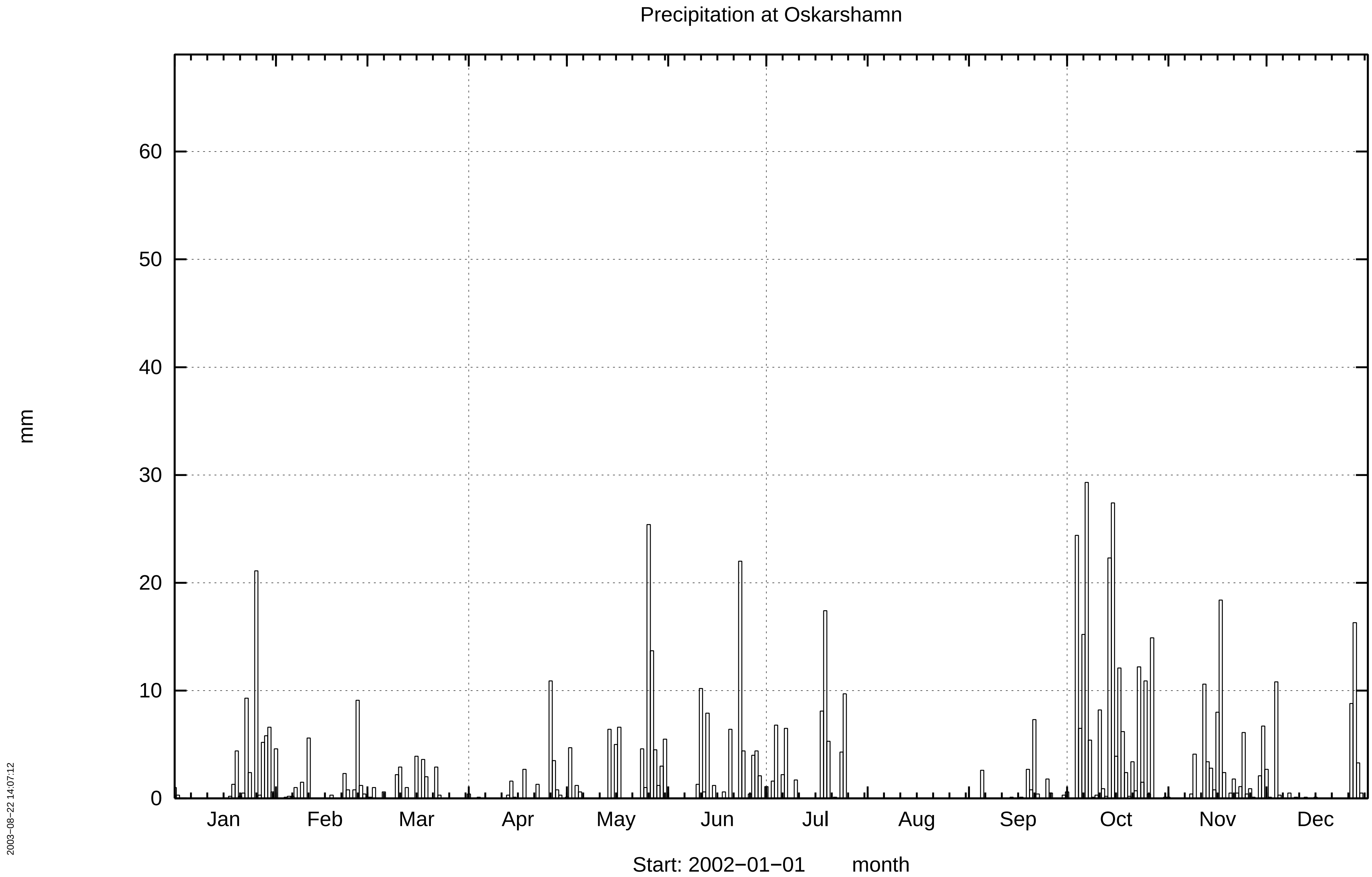


Electrical Conductivity in tunnel water at PG5 (below 2496 m, including shafts at 3384 m, excluding shafts at 2587)
m3/24h
2500
2000
1500
1000
500
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:08:27

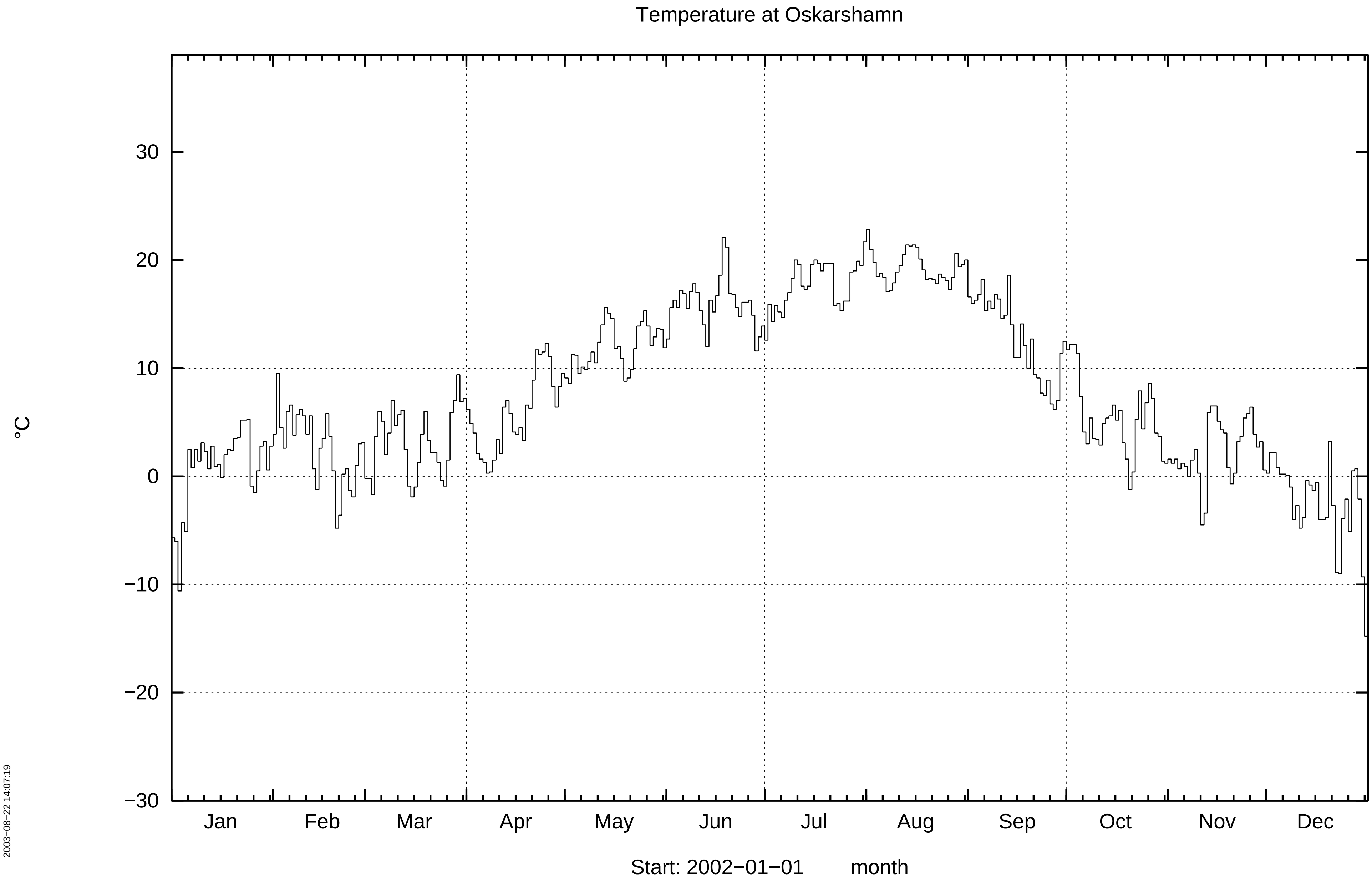
Appendix 8: Level of the Baltic Sea


Sea water level at Oskarshamn
masl (RH70)
1.5
1
0.5
0
−0.5
−1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:04

Appendix 9: Precipitation

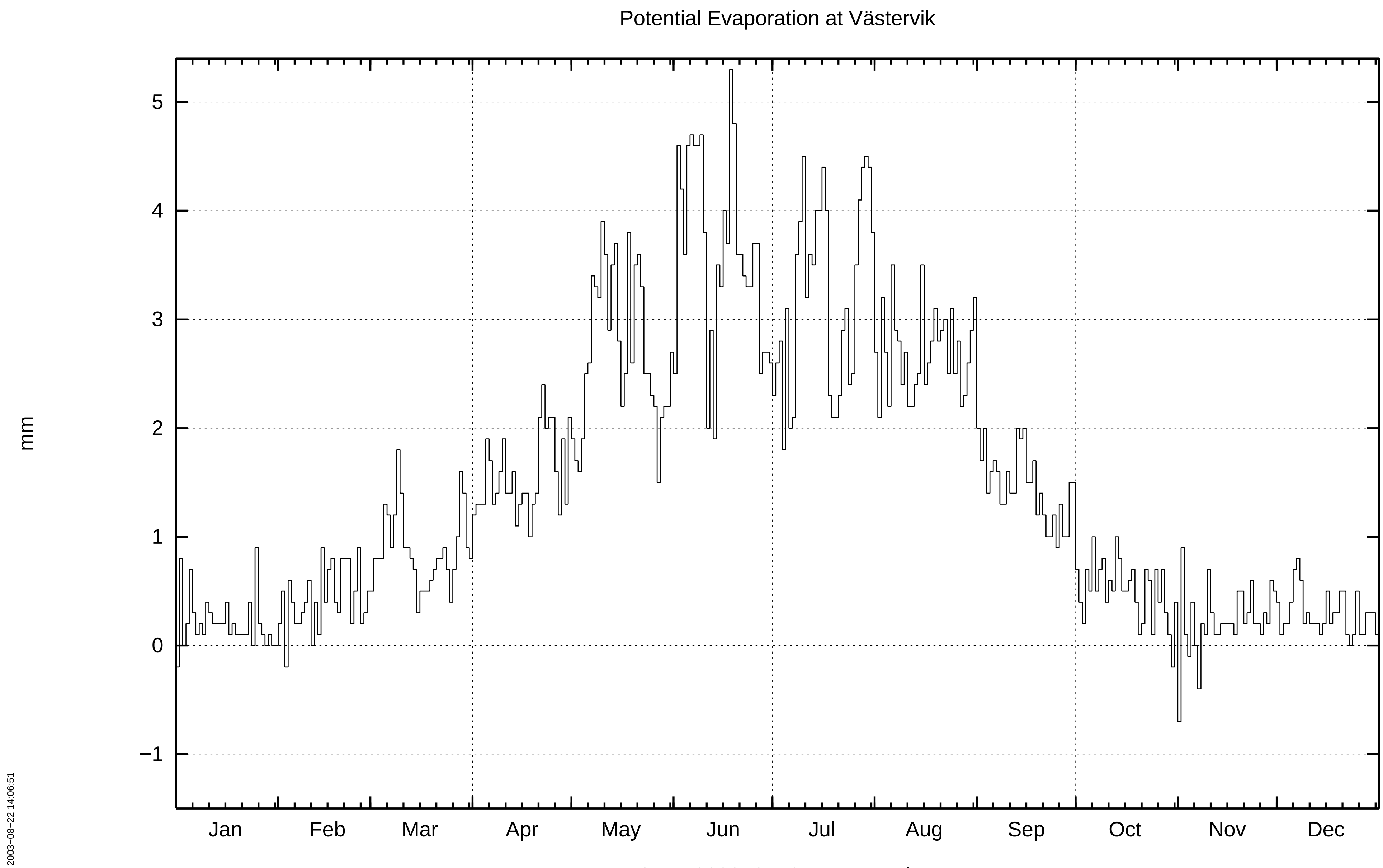

Precipitation at Oskarshamn
mm
0
10
20
30
40
50
60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Start: 2002−01−01
month
2003−08−22 14:07:12

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: 2002−01−01
month
2003−08−22 14:07:19

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: 2002−01−01
month
2003−08−22 14:06:51