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Hydrological and meteorological monitoring at Oskarshamn during 2003–2004

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Abstract

In the Simpevarp area nearby Oskarshamn meteorological monitoring has been going on since year 2003 and hydrological monitoring since the beginning of year 2004. Meteorological measurements are performed at two places. Measured and calculated parameters at these stations are temperature, wind speed and wind direction, air humidity, precipitation, air pressure and global radiation. The Swedish Meteorological and Hydrological Institute, SMHI, has been responsible for planning and designing of the two stations used for meteorological monitoring. Furthermore, SMHI has been responsible for planning and constructing thirteen hydrological measuring stations. At these hydrological stations, water levels in lakes and in the sea are taken. Additional water temperature and electrical conductivity are measured and discharges in watercourses decided. The order from the Swedish Nuclear Fuel and Waste Management Co, SKB, comprises fifteen hydrological monitoring stations. This means that there are still two more stations left to build.

This report also includes the registration and measurements of certain weather parameters that have been done within the area during the measurement period. Snowdepth, depth of frost and ice cover break up were registered during wintertime.

The quality of meteorological and hydrological measurements during the period concerned, starting 2003 and ending 2004-10-31 has showed to be rather good. There have only been minor interruptions in measurements due to malfunctioning equipment. At hydrological stations intended for discharge measurements in watercourses, the establishment of so-called rating curves or tables is required before calculation of reliable discharges can be executed. Because of this, it has not been possible to calculate discharge at all hydrological stations intended for this. However, the measured water level is stored at all discharge stations and discharges will be calculated later on, when rating curves are established.

Hydrological monitoring shall be made according to the elevation system RT90-RHB70 but at several hydrological stations, measurements are still in local elevation systems. The use of local elevation systems continues until surveying of all stations has been carried out by SKB.

Sammanfattning

I Simpevarpsområdet utanför Oskarshamn har meteorologiska mätningar pågått sedan år 2003 och hydrologiska mätningar sedan början av år 2004. De meteorologiska mätningarna sker på två platser, på Äspö och i Plittorp. Här har master med registrerande instrument monterats. De meteorologiska parametrar som mäts och bestäms är temperatur, vindhastighet och -riktning, luftfuktighet, nederbörd, lufttryck och globalstrålning. Sveriges Meteorologiska och Hydrologiska Institut, SMHI, har varit ansvariga för utformandet av de två meteorologiska mätstationerna. SMHI har också konstruerat och byggt 13 hydrologiska mätstationer. Vid dessa senare stationer mäts vattennivåer i sjöar och i havet. Ytterligare parametrar som mäts är vattentemperatur och elektrisk konduktivitet samt bestämning av vattenföringar i vattendragen. Svensk Kärnbränslehantering AB, SKB, har beställt totalt 15 hydrologiska mätstationer av SMHI. Två stationer återstår således att bygga.

Under perioden har det även skett en registrering av vissa väderrelaterade parametrar. Snödjup, frostdjup, tidpunkt för isläggning samt islossning har registrerats och finns inkluderade i denna rapport.

De meteorologiska och hydrologiska mätningarna utförda under perioden 2003 till och med 2004-10-31 har visat ganska hög kvalitet. Det har endast förekommit kortare avbrott i mätningarna orsakade av fel på mätutrustningen. Vid de hydrologiska mätstationer där vattenföringen skall bestämmas återstår fortfarande en del arbete med att upprätta tillförlitliga avbördningssamband. Därför är det inte i nuläget möjligt att beräkna någon avbördning vid flertalet av dessa stationer. Vattenstånden registreras emellertid fortlöpande och då avbördningskurvor eller tabeller upprättas kan dessa vattenstånd i efterhand omräknas till vattenföring.

Alla hydrologiska mätningar skall utföras i höjdsystemet RT90-RHB70 men för närvarande sker mätningarna vid ett flertal stationer i lokala höjdsystem. Detta kommer att fortgå tills SKB har mätt in samtliga stationer i ovan nämnda höjdsystem. Därefter kan historiska data omräknas till att gälla för höjdsystemet RT90-RHB70.

Contents

1 Introduction

This document reports the results of hydrological and meteorological measurements made in the area of Oskarshamn. The activities were performed within the site investigation at Oskarshamn and carried out in accordance to activity plan SKB AP PS 400-04-087 and SKB AP PS 400-04-088, (SKB internal controlling document). This document also reports the data gained in "Registration of snow depth, depth of frost in the ground and time for ice cover/ice break up " which was also one of the activities performed within the site investigation at Oskarshamn. The work was carried out according to activity plan AP PS 400-02-023 (SKB internal controlling document). The activity also comprised measurements and registrations of certain weather parameters within the Oskarshamn area, during wintertime. Three parameters, depth of snow, depth of frost in the ground and time for ice cover were measured and registered.

Hydrological measurements have been made since January 2004. Measured parameters are sea water level, water level in lakes and runoff in small creeks. Water temperature and conductivity are also measured at the runoff stations. At the moment hydrological measurements are made at thirteen different stations. All hydrological data presented in this document are quality checked and approved.

To characterise the investigation area regarding meteorological conditions SMHI has placed one more station with meteorological measuring equipment on the site. The new station, Plittorp, has been installed in the area and has been in progress since July 2004. It is located about 10 km west of the existing station at Äspö. The results will be used for calculations of hydrological parameters.

The geographical locations of the meteorological and hydrological measuring stations can be seen on the map in chapter 4.

The objective of this report is to present the hydrological and meteorological monitoring made during the years 2003 and 2004. The report also presents measurements made of winter parameters, depth of snow, depth of frost in ground and time for ice cover.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	Number	Version
Ythydrologiskt moniteringsprogram	SKB AP PS 400-04-087	1.0
Meteorologiskt moniteringsprogram	SKB AP PS 400-04-088	2.0
Method descriptions	**Number**	**Version**
Ythydrologiska mätningar	SKB MD 364.008	1.0
Meteorologiska mätningar	SKB MD 364.007	1.0

2 Objective and scope

SKB shall carry out site investigations at the Simpevarp area close to Oskarshamn. To characterise the investigation area regarding the meteorological conditions SMHI has installed a new station with meteorological measuring equipment at the site, Plittorp. The results will be used for calculations of hydrological parameters.

Hydrological measurements are performed at thirteen different places. At these places, measurements have been made during different times because building of stations has currently been going on during the year. The first stations were built in January 2004 and the last hydrological station was built in September 2004. Information about the hydrological stations and times of measurements are given in the table in Appendix 1.

This report also comprises measurements and registrations of certain weather parameters within the Oskarshamn area, during wintertime.

The objective with this report is to present results from hydrological and meteorological monitoring made during the years 2003 and 2004. Meteorological monitoring started at Plittorp in July 2004 and at Äspö in September 2003. The first hydrological measurements were made in January 2004. All meteorological and hydrological data are presented up to October 31, 2004.

3 Equipment

3.1 Hydrological measuring stations

Common for all stations is that the battery capacity is always measured and logged. This value is however only stored in the database at SMHI.

3.1.1 Runoff stations

The runoff stations PSM341, PSM343 and PSM345 are all situated at Ävrö. They are constructed in concrete as V-notch weirs (triangular shaped outlet of water). At these stations, measurements are made with a Campbell CR10X datalogger. A cellular phone and a GSM modem Siemens TC35, 9600 baud, establish communication. A dry cellular battery, CellTech (15V, 90 Ah) sustains power supply. Sensors and measured parameters are presented in Table 3-1.

At the runoff stations PSM348, PSM353, PSM364 and PSM368 discharge is measured according to a natural cross section in the watercourse. Equipment, sensors and measured parameters are the same as for the stations with constructed concrete dams. The only difference is that water level should be taken in metres above sea level, m a s l, instead of centimetres when these stations are surveyed. Sensors and measured parameters are presented in Table 3-2.

Table 3-1. Sensors and measured parameters at stations PSM341, PSM343 and PSM345.

Parameters	Sensors
Water level above V-notch (cm)	DRUCK PDCR1830, mV, range 1.5 m.
Conductivity and water temperature (mS/m and °C)	Campbell CS547, range 0.5–100 mS/m with interface CampbellA547.

Table 3-2. Sensors and measured parameters at stations PSM348, PSM353, PSM364 and PSM368.

Parameters	Sensors
Water level (m a s l)	DRUCK PDCR1830, mV, range 1.5 m.
Conductivity and water temperature (mS/m and °C)	Campbell CS547, range 0.5–100 mS/m with interface CampbellA547.

3.1.2 Water level stations

At the water level stations PSM359 and PSM371 measurements are carried out with a Campbell CR510 datalogger. A cellular phone and a GSM modem Siemens TC35, 9600 baud, establish communication. Power supply is sustained by a charger 1.5 A, 14 VDC connected to 230 VAC. The stations are connected to ground and equipped with a lightning conductor. Sensors and measured parameters are presented in Table 3-3.

At the water level stations PSM369 and PSM370 the equipment is almost the same as for PSM359 and PSM371 but a dry cellular battery, Celltech 14V, 90 Ah sustains power supply. Sensors and measured parameters are presented in Table 3-4.

Table 3-3. Sensors and measured parameters at stations PSM359 and PSM371.

Parameters	Sensors
Water level (m a s l)	DRUCK PDCR1830, mV, range 1.5 m.

Table 3-4. Sensors and measured parameters at stations PSM369 and PSM370.

Parameters	Sensors
Water level (m a s l)	DRUCK PDCR1830, mV, range 1.5 m.

3.1.3 Calibration of equipment used at hydrological measuring stations

The manufacturers calibrate the measuring equipment. DRUCK calibrates the level pressure probes and Campbell Scientific Inc. calibrates the conductivity and temperature probe. The function of every probe was thoroughly tested before deployment. These tests were performed by FDS mätteknik AB a sub-contractor to SMHI. Protocols from calibration have been delivered to SKB.

3.2 Meteorological measuring stations

The table below gives technical information about the equipment. Polycarbonate cupboards house data loggers (type Campbell CR10X), modem (Siemens TC35 and COM200E) and are earthed for lightening protection.

Wind is measured at 10 m above ground level, the other parameters at 2 m.

Table 3-5. Measuring equipment for collecting of meteorological data at the stations.

Parameters	Equipment
Wind speed and direction	RM Young Wind monitor
Air temperature	Pt100 sensor with radiation shield and ventilated Young 41004
Humidity	Rotronic HygroClip MP 100H
Precipitation	Geonor T200 complete with pedestal and wind shield
Pressure	PTB200
Global radiation at Äspö	Kipp&Zonen CM21 with heating and fan

3.2.1 Calibration of equipment used at meteorological measuring stations

Calibration of the instruments using data submitted by the manufactures was done by FDS along with the installation of the instruments. No further need of calibration has been required.

3.3 Winter parameters

3.3.1 Depth of snow

The snow depth has been measured according to SMHI's Handbook for observers (In Swedish: SMHI:s handbok för observatörer) /2/. The measuring device has been a measuring stick graded in centimetres.

3.3.2 Depth of frost in ground

The depth of frost in the ground has been measured according to SMHI:s Handbook for observers /2/. The measurements are performed with a specific measuring device. The device consists of a protective tube with a disc and a protective hood, including a measurement tube with solution. The solution consists of methylene blue and distilled water. When the water freezes the blue colour disappears and this is utilized when observing the position of frost in the ground. The measurement tube is graded in centimetres.

The ground level is marked and this together with the protective hood is what is usually seen above ground. When installing the device at Oskarshamn there were some difficulties because of the large numbers of boulders in the ground. Because of this a small part of the measuring tube is also present above ground, see Figure 3-1. This has no impact on the measurements, however.

3.3.3 Ice cover

The observation of ice freeze and break up was performed by visual inspection.

Figure 3-1. *Measuring device for registration of depth of frost in the ground at PSM6980.*

4 Execution

4.1 General

This execution chapter is intended to describe the complete course of events, from measuring, via quality check, data handling to the storage in SICADA. On the map in Figure 4-2 it is pointed out where all monitoring stations are geographically located.

Two terms that are frequently used in this context, HMS and SICADA, SKB´s data system, could therefore require a definition. HMS (Hydro Monitoring System) is SKB's network for the monitoring of hydrological, hydrogeological and meteorological parameters. This is a system for collection, calculation, and data check up and presentation. SICADA is the database that contains all of SKB's quality assured data. It is from these data the modelling and analyses are done, see Figure 4-1.

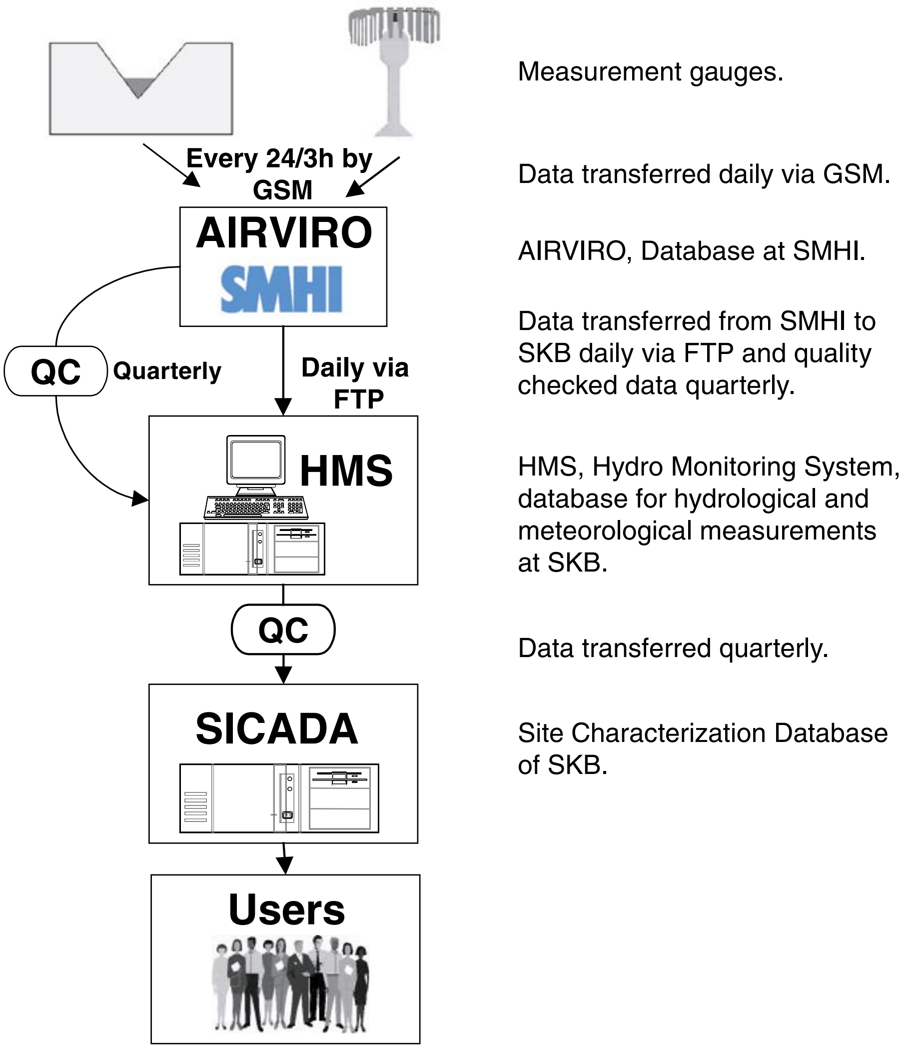


Figure 4-1. *Flowchart – meteorological and hydrological data.*

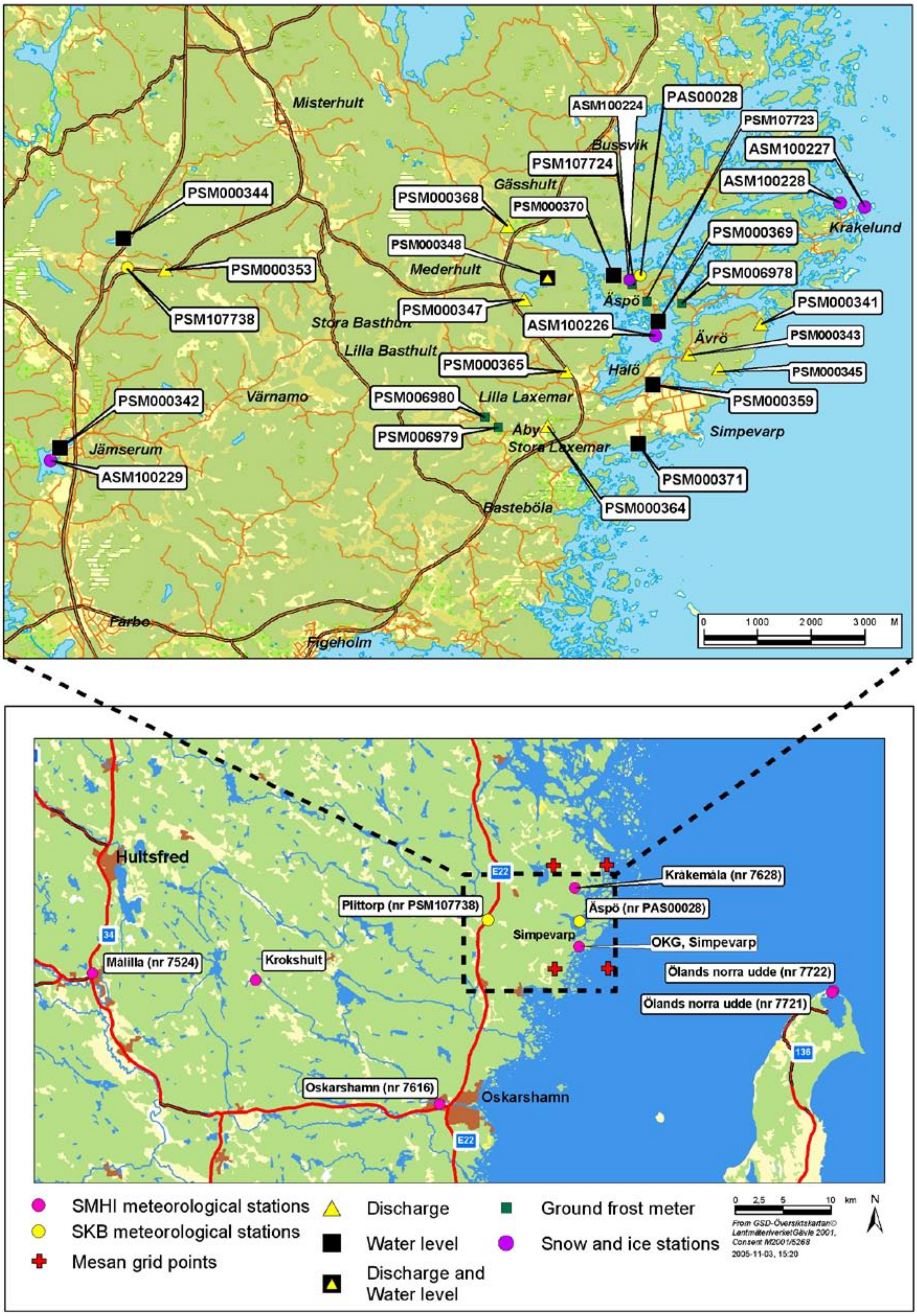


Figure 4-2. *Map showing objects of all monitoring stations.*

4.2 Hydrological measurements

Not all stations have yet been surveyed. This means that there are still measurements made in a local elevation system at some stations. However, in future all measurements should be made in elevation system RT90-RHB70. At the end of October 2004 the following stations remain to be surveyed, PSM342, PSM344, PSM353, PSM348 and PSM368.

All sensors, probes and other equipment shall be checked and serviced once a year or if needed as soon as possible. SMHIs sub contractor, FDS Mätteknik AB will handle malfunction of equipment.

The level pressure sensors are tested by measuring the water level at various known depths. After the test the sensor is fixed in the stainless pipe. The actual water level is then set in the datalogger.

At the runoff station, the water head above the V-notch should be set in the datalogger. It is the water head in centimetres above the V-notch point that is measured.

The probe used for measuring conductivity and water temperature should be tested against water with known conductivity. The water temperature should be measured with a reference thermometer. The measured values by the datalogger of conductivity and temperature are then compared with the reference values.

The runoff stations need some extra care because it is very important that the flow through the V-notch is not blocked or influenced by ice, leaves or debris. SMHI suggests that SKB establishes a scheduled standard procedure for regular inspection of the stations.

4.2.1 Discharge in water courses

Hourly measurements of discharge shall be made at nine stations all though currently such measurements are only made at three places, PSM341, PSM343 and PSM345. The reason why is that no proper rating curves have yet been made. A rating curve describes the relationship between the measured water stage and the corresponding discharge. It usually takes some time to gain a proper rating curve and until then the measurements of water level will be stored at all stations. Two stations PSM347 and PSM365 are under construction and no measurements are yet available.

At stations PSM341, PSM343 and PSM345 discharge is measured with a V-notch weir. It is a concrete dam with a triangular, V-notch, shaped outlet. The angle in the V-notch is 45° and theoretically, the discharge, Q, could be derived from a discharge formula. The upstream head is uniquely related to the discharge over the crest where the flow passes through critical conditions. For a V-notch weir, the discharge formula becomes /1/:

$Q = 8/15 \times \mu \times (2g)^{1/2} \times h^{5/2} \times \tan\alpha/2.$

Q = Discharge (m^3/s).

μ = Coefficient approximately constant, a value between 0.60 and 0.65.

g = Gravity constant (9.81 m/s^2).

h = Head above the V-notch (m).

α = Angle in V-notch.

The water level (head) above the V-notch point is measured. When the water stage is level with the V-notch discharge from the weir also equals zero i.e. the level of the V-notch point is set to zero. It should be pointed out that it is the water level that is measured at the runoff stations and not directly the discharge. The discharge has to be calculated from the discharge formula. Calculations with this equation are only reliable when the weirs are built with idealistic proportions. Due to conditions of local ground structure at the building site, idealistic dam proportions are sometimes hard to achieve. Therefore, a rating curve in most cases must be established before any reliable calculations of discharge can be made. Until then calculation of discharge has to be made with assumed values of parameters in the discharge formula and will be delivered as such.

In calculations of discharge at these stations the value of the coefficient,μ have been set to a reasonable value of 0.7. It is a slightly higher value than commonly used based on the results of a single discharge measurement made by SMHI. At present we do not now if this is a proper value of the coefficient,μ for all runoff stations. The discharge values presented in this report are for that reason affected with a degree of uncertainty and later on adjustments in accordance to rating curves will be made.

The drainage areas where dams are built are very small. Therefore, the creeks or ditches will be dried up during greater part of the year. The drainage area for each station is presented in Table 4-1.

At four stations PSM348, PSM353, PSM364 and PSM368 discharge should be measured according to a natural cross-section in the watercourse i.e. no dams are constructed. No rating curves are yet available and for this reason, it is impossible to present anything else but measured water levels at each station. All water levels are measured in local elevation systems because they have not yet been surveyed. Later on all measurements will be made in elevation system RT90-RHB70. The drainage area for each station is presented in Table 4-2.

Table 4-1. Drainage area for PSM341, PSM343, PSM345 and PSM347.

Station Id	Object	Measuring place	Drainage area (km^2)
PSM341	Ävrö NE	Dam	0.25
PSM343	Ävrö SW	Dam	0.09
PSM345	Ävrö SE	Dam	0.14
PSM347	Frisksjön (in)	Dam	0.8

Table 4-2. Drainage area for PSM348, PSM353, PSM364 and PSM368.

Station Id	Object	Measuring place	Drainage area (km^2)
PSM348	Frisksjön (out)	Lake and natural cross-section	1.8
PSM353	Laxemarån (upper)	Natural cross-section	13.5
PSM364	Laxemarån (lower)	Natural cross-section	40
PSM368	Kärrviksån	Natural cross-section	27

4.2.2 Water temperature and electrical conductivity, (EC)

At all stations monitoring discharge the water temperature and electrical conductivity, EC, are also measured. At stations where dams are constructed, temperature and EC are measured in the small basin upstream the concrete dam. At stations where natural cross-sections are used all sensors are placed in the creek or in the lake.

4.2.3 Water level

The logged water level is an arithmetic mean value calculated from measurements made every fifth second during one hour. Hourly mean values are stored.

Sea water level

Sea water level is measured at three places in the surroundings of Äspö. The stations are PSM369, PSM370 and PSM371. At these stations, measurements have been performed since January 2004. Measurements are taken in elevation system RT90-RHB70 and they are expressed as metres above sea level (m a s l).

Water level measured in lakes and reservoirs

Water level is also taken at station PSM342 and PSM344. At PSM342 water level in lake Jämsen is measured and at station PSM344 water level in lake Plittorpsgöl. All measurements at these two stations have so far been made in local elevation systems.

At one station, PSM359, water level is taken in the reservoir at Sörå. This is an artificial reservoir created as a backup for the freshwater supply to the power station. Water is pumped from Laxemarån about once a year to compensate for evaporation and leakage. Measurements are in metre above sea level, (m a s l), in elevation system RT90-RHB70.

4.2.4 Quality check of hydrological data

Before any data are finally stored in SKB's database SICADA they have to be approved. Each week SMHI performs a primary check for deviating values and every third month a senior hydrologist will check and approve data before delivery for final storage in SKB's database, SICADA. Delivery of checked and approved data to SKB is carried out quarterly.

Quality check of discharge stations

Weekly data is checked to limit possible disturbances and interruptions. Measurements of runoff are compared between neighbouring stations. Runoff from stations in nearby areas should mostly show the same pattern. Corrections of data are made if any disturbances or irregularities appear.

Water temperature and conductivity measurements are also compared between nearby stations. Even here, the same pattern is mostly expected. Disturbances or irregularities are corrected. Measurements of conductivity and water temperature are not approved when the water level is equal to or below the V-notch point in the dams. No water is then running in the creek and temperature and conductivity values are therefore not representative.

Quality check of water level stations

Data checks are made weekly to limit possible disturbances and interruptions.

Measurements from seawater level stations compare to each other because the same pattern is mostly expected. Corrections and adjustments of any disturbances or irregularities are made.

Water level at PSM359, being a reservoir, does not follow the same pattern as the sea level stations. For this reason, measurements of water level at this station are judged separately. Disturbances or irregularities are corrected.

Water levels taken in lakes are compared to each other because the same behaviour is expected.

4.3 Meteorological measurements

Data are collected every half-hour. The different parameters are valid for the following time period:

- Precipitation: Accumulated sum of precipitation every 30 min. The 30-min precipitation value is the difference between two adjacent accumulated precipitation sums.
- Temperature: Mean of 1-second values.
- Air pressure: Mean of 1-second values.
- Relative humidity: Mean of 1-second values.
- Wind speed and wind direction: The latest 10-minutes mean value for the actual half-hour, hence for the 10:00 data the measurement is from 09:51 to 10:00.

4.3.1 Preparations

The instruments were calibrated by FDS according to the instructions given by the manufacturer's. When mounting the wind direction sensor it was adjusted at the site for correct directions.

4.3.2 Data handling/post processing

The data logger at the station has an internal memory to secure the data in case of communication disturbances. The system is called upon every three hours through SMHI's air quality system AIRVIRO, where the data are stored and the quality assurance check is done. After this has been performed, data is delivered to the HMS database.

SMHI has constructed a homepage according to SKB's wishes, where the results of the measurements can be shown as graphs and from which data can be extracted. The address is: http://www.airviro.smhi.se/oskarshamn/.

4.3.3 Quality check of meteorological data

Before any data can finally be stored in SKB's database SICADA they have to be checked and approved by SMHI. Every week a primary check for missing and incorrect values is performed by SMHI and every third month the check is performed by a meteorologist at SMHI approving data, evapotranspiration calculations, and estimating the true precipitation before delivery for final storage in SKB's database, SICADA.

4.4 Winter parameters

4.4.1 Measurement of co-ordinates

Co-ordinates for each station (see Figure 1-1) were measured according to SKB's instruction SKB MD 110.001 /3/. The co-ordinates were then noted in a specific protocol. Each object recieved a specific ID code, see Table 4-3. For measurement of snow depth and observations of ice conditions the objects were registered as surfaces, while the objects for frost in the ground and ice conditions were registered as points.

4.4.2 Snow depth

Snow depth is in this case defined as the depth of snow from snow surface to ground. The characteristics of the site for execution of the measurement are of vital importance. The site should have a fairly smooth ground surface and the snow should not fall in drifts or be blown away. The sampling station has been a forest glade (see Figure 1-1). The chosen areas were marked with poles of such a length that they would be seen even at maximum snow depth, se Figure 4-3.

The measurement was executed once a week starting from the autumn's first snowfall until the snow surface was completely gone during springtime. The measurement was performed once a week, even if no snow had been falling, since packing, melting or evaporation should be considered as well.

The measurement was performed with a graded measuring stick, which was vertically squeezed through the snow layer until the ground was hit. The snow depth was read in centimetres. The measurement was performed at six places in the measuring area, Figure 4-4. The average snow depth was then calculated.

Table 4-3. Id-code numbers for the objects of this activity.

Measurement/observation	Id code	Name
Snow depth	ASM100224	Grillplatsen
Frost in ground	PSM107723	Äspö
	PSM107724	Grillplatsen
Ice cover	ASM100226	Äspö brygga
	ASM100227	Kråkelund
	ASM100228	Kråkelund inre
	ASM100229	Jämsen

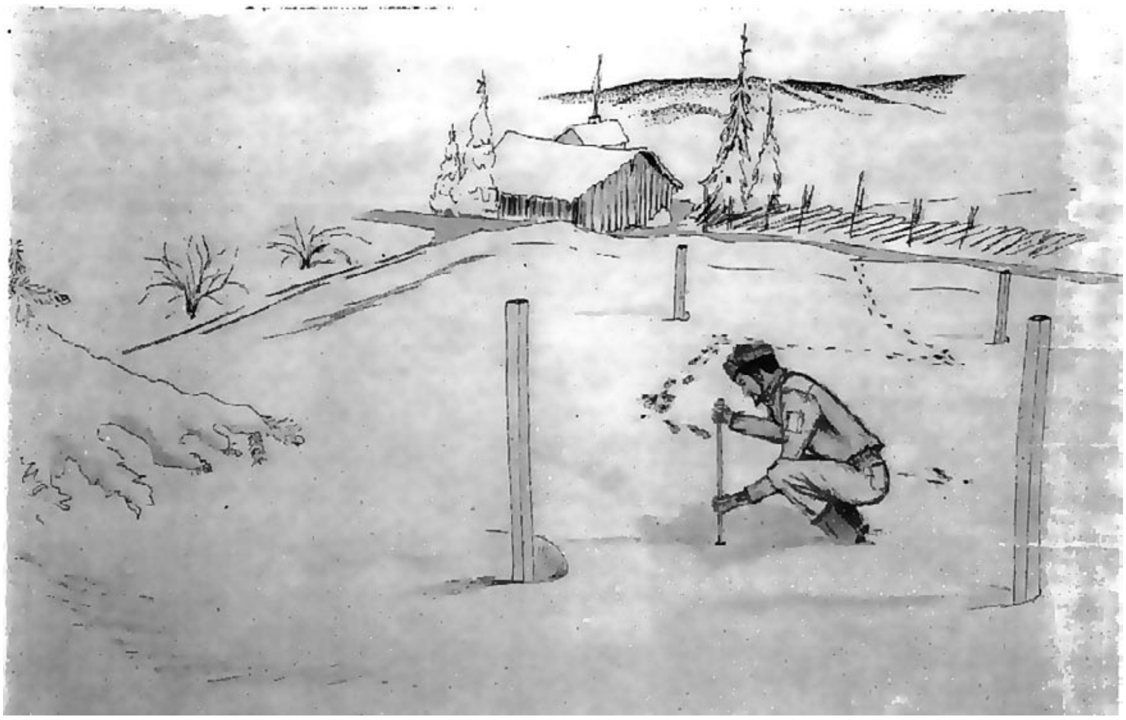


Figure 4-3. *Measurement of snow depth, from SMHI's Handbook for observers /3/.*

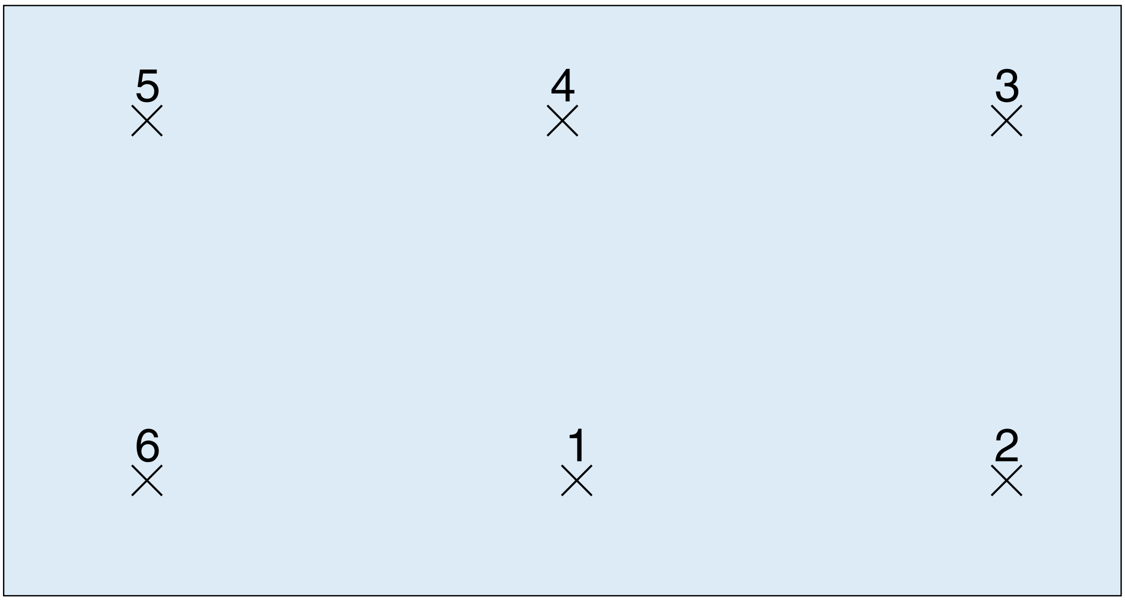


Figure 4-4. *Placement of the graded measuring stick in the area for measuring of snow depth. The distance between the measuring points is 1.5–2 m.*

4.4.3 Frost in ground

For measurement of frost in the ground, equipment according to section 3.3.2 was used. The measurement was carried out at two places representative for the local conditions, taking in consideration soil characteristics and topography (see Figure 1-1). Additional stations (PSM6978–6980) have been installed during January 2005, which are not included in this report.

The measuring device is read by observing the uncoloured part of the tube solution, i.e. the frozen part, which shows the border between ice and water. The distance from ground surface to the frost in the ground, was received by reducing the read values with the distance from the scale zero to the ground surface. The measurements were performed once a week in connection to registration of snow depth.

4.4.4 Ice cover

The time for ice freeze up/ice break was noted for sea bays (ASM100226–ASM100228) and for lakes in the area (ASM100229).

For the sea, ice conditions were registered every morning during working week and for the lake once a week. While ice freeze up was observed on the lake, the other lakes in the area were also observed, to check the representativety of the Lake (ASM100228).

The time for the first ice freeze up, which is important to register in the observations, is defined as the first time of the season when a lasting ice cover occurs. The time for the last ice break up, is defined as the time when the ice cover from the winter season finally breaks up. Short periods in early autumn, with thin ice covers were ignored, as well as partial ice during springtime.

4.4.5 Data handling and documentation

Field personnel from the SKB executed all measurements and observations of snow depth, frost in ground and ice cover in the activity. The primary data were registered in SICADA.

4.5 Analyses and interpretations

4.5.1 Hydrological measurements

Runoff per unit of area has been calculated for stations PSM341, PSM343 and PSM345. Calculations are made for the period 20040318 until 20041101. Runoff in this part of Sweden based on measurements during the years 1961–1990 is about 5 $l/s \times km^2$. Compared to the long-term mean value the runoff at station PSM341 seems to be underestimated, Figure 4-5. The reason why is that more water than expected flows through the dam. Difficulties appeared during construction of the dam at this site and therefore the dam was built with non-idealistic proportions. Water flows into this dam with a velocity too high for using the theoretically derived discharge formula for a V-notch weir. This formula requires that the water is stagnant, or at least nearly stagnant, on the upstream side of the dam. In this case, the same discharge formula was used when calculating discharge at the three stations (see 4.2.1). The result clearly points out the need of discharge measurements to verify the rating curve describing the hydraulic properties for the dam. Such measurements are carried out and historical measurements of discharge are recalculated on a regular basis when reliable rating curves are established.

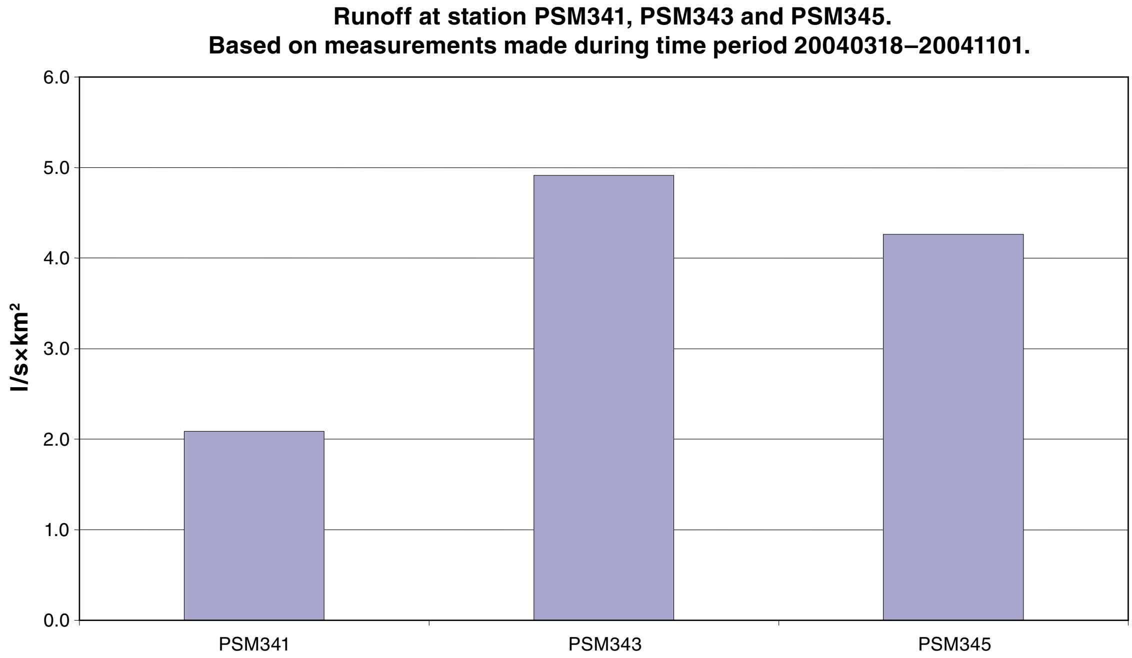


Figure 4-5. *Runoff expressed as l/s×km² at station PSM341, PSM343 and PSM345. Runoff at station PSM341 is underestimated when using the theoretically based discharge formula with assumed values of the parameter,μ.*

4.5.2 Meteorological measurements

SMHI has continuously checked the collected data, i. e. checked that the data are within the limits of reason for each parameter, and the data have been compared with data from SMHI's analysing system MESAN. MESAN is an automatic system for mesoscale analysis of meteorological parameters, built on manual as well as automatic observations and also including satellite- and radar information.

The values are interpolated from the nearest grid points in MESAN. The resolution of MESAN is 22×22 km and an analysis is made every hour. Corrected data have been stored in a special database. In Table 4-4 you can see the coordinates of the nearest grid points and in Figure 4-13 above you can see where the nearest points are located.

Table 4-4. Mesan grid points.

Latitude	Longitude
57.490	16.614
57.490	16.707
57.393	16.614
57.393	16.707

4.6 Nonconformities

4.6.1 Hydrological measurements

Water level measurements should be taken in accordance to the elevation system RT90-RHB70. At present, only some of the hydrological stations take measurements in accordance to this elevation system. In future all stations except V-notch discharge stations will take level measurements in this elevation system. At the V-notch discharge stations the water levels are given in centimetres above the lowest point in the V-notch.

Discharge data can not be calculated until rating curves are established. For the V-notch stations, PSM341, PSM343 and PSM345, it is possible to calculate approximate values of discharge. This will be done until proper rating curves are established. For all other discharge stations rating curves have to be made before any discharge values can be calculated.

4.6.2 Meteorological measurements

There are no nonconformities that affect the result, or nonconformities with respect to activity plan or method descriptions.

4.6.3 Winter parameters

During the year 2003, reading of the measuring device for frost in ground was not working, so the reported values are considered to be very uncertain for this period. The device for measuring frost in ground at PSM107723, was knocked over late in 2004 and is no longer monitored.

4.7 Missing data and system malfunctions

4.7.1 Hydrological measurements

At station PSM348 the sensor measuring electrical conductivity turned out to be defect. The sensor was removed and for that reason no conductivity data at all have been measured at this station. A new sensor will be installed at the station. This malfunction also affected the temperature measurements because temperature and conductivity are measured with the same sensor. Temperature measurements are for that reason only available for a shorter period.

At discharge station PSM364 no quality checked water level data (discharge data) have been available because changes have been made to the cross section intended to be used for discharge measurements. At this station an interruption according to measurements of electrical conductivity occurred between 2004-10-14 08:00 and 2004-10-15 12:00. This interruption occurred at the same time as work with changing the cross section was carried out.

4.7.2 Meteorological measurements

The barometric pressure has been erroneous until September 27, 2004.

A change in the filtering signal from the Geonor precipitation gauge was made by FDS September 29, 2004. Since then the quality of the measurements are much better. It has however been possible to correct data with good results.

5 Results

5.1 Hydrological monitoring

Hydrological measurements have turned out to work quite well during this first measuring period. So far thirteen hydrological stations have been built and two more will be built. All stations have worked well without almost any malfunctioning or interruptions in measurements. The quality of measurements regarding water levels is very good and no adjustments of data have been necessary.

At the discharge stations where constructed dams are built, quality of measured data almost exclusively are depends on the maintenance of the basin upstream the dam. SKB therefore has to make a scheduled program with the purpose of cleaning the dams from debris blocking the flow through the V-notches. Most of the corrections made to measurements according discharge have been made because the V-notches periodically have been obstructed by ice, leaves or debris floating in the water. **It is very important that a routine for this is established as soon as possible to secure proper measurements of discharge**.

Measurements of water temperature at the discharge stations seem so far to work well. Even here only a few measured values have been corrected when making quality check of data.

Measurements of electrical conductivity, EC, have also worked quite well. However more corrections according to obviously strange values have been necessary to make than for other measured parameters. One conductivity sensor, at station PSM348, showed an incorrect behaviour after installation. This sensor will therefore be replaced.

5.1.1 Discharge

PSM341, PSM343, PSM345 and PSM347

The quality checked values of discharge from the three constructed dams built at Ävrö are presented in Figure 5-1. For station PSM347 there is no data available yet. Adjustment of measurements has been made especially to station PSM345 where periodically something obstructed the flow through the V-notch. Also at station PSM343 some adjustments have been made due to the same reason.

PSM348, PSM353, PSM364 and PSM368

At these four stations discharge is measured by using a natural cross-section in the watercourse i.e. no dams are constructed. However rating curves have to be established before any discharge values can be derived and presented. For this reason measured water levels are presented at each station. All water levels are measured in local elevation systems because they have not been surveyed yet. Later on all measurements will be made in elevation system RT90-RHB70. At station PSM348 the discharge represents the outflow from lake, Friksjön. At all other places discharge is measured in the creek. The quality checked results from measurements of water level made so far can be seen in Figures 5-2 and 5-3. It has not been necessary to make any corrections of measured values during this time period.

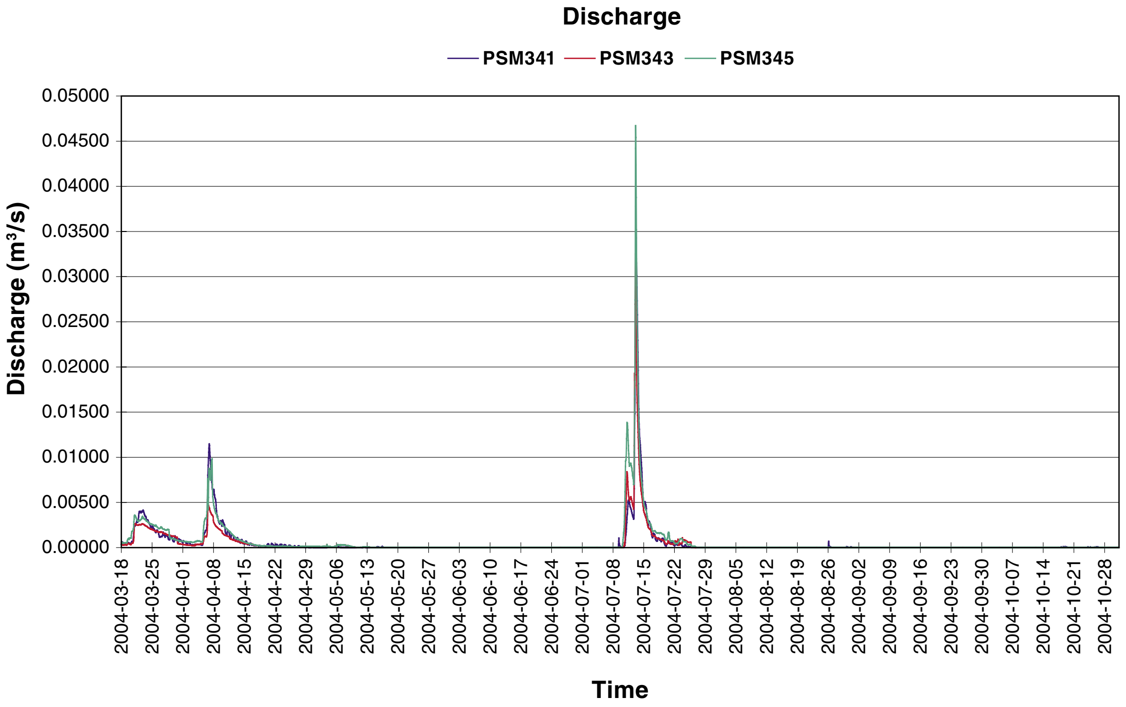


Figure 5-1. *Quality checked discharge, m³/s, at stations PSM341, PSM343 and PSM345 at Ävrö.*

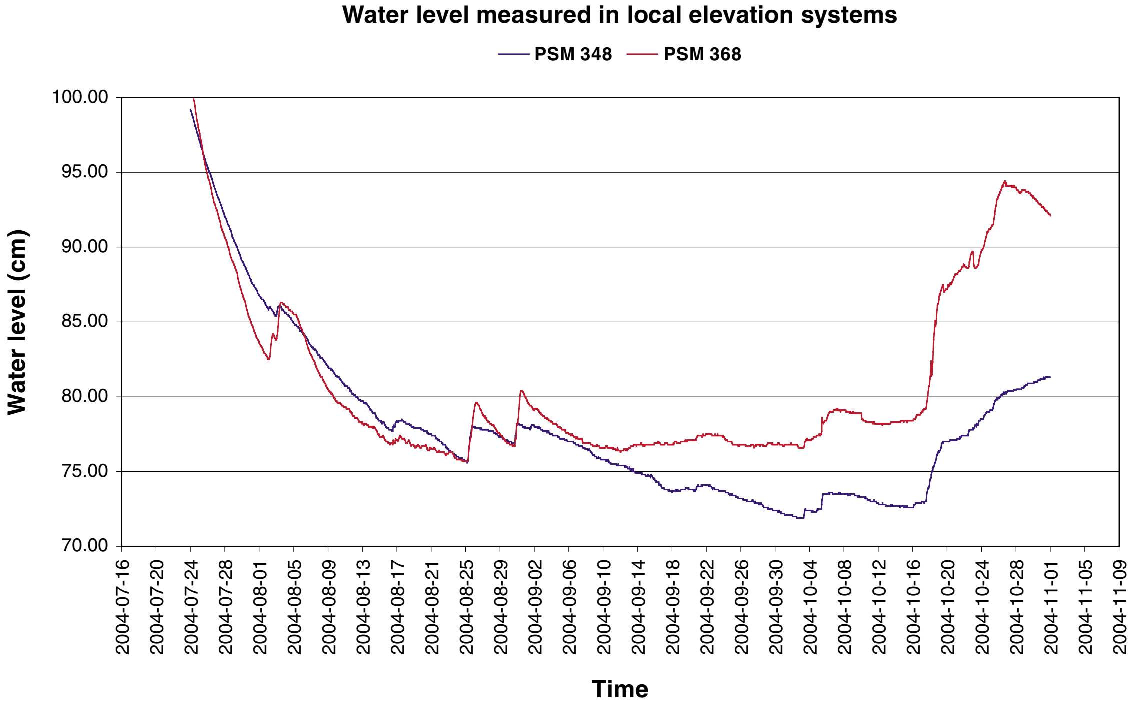


Figure 5-2. *Water level measured at stations PSM348 and PSM368. The blue line shows the variation in water level for the lake Frisksjön and the red line variation in water level in the creek Kärrviksån. Measurements made in centimetres in local elevation systems.*

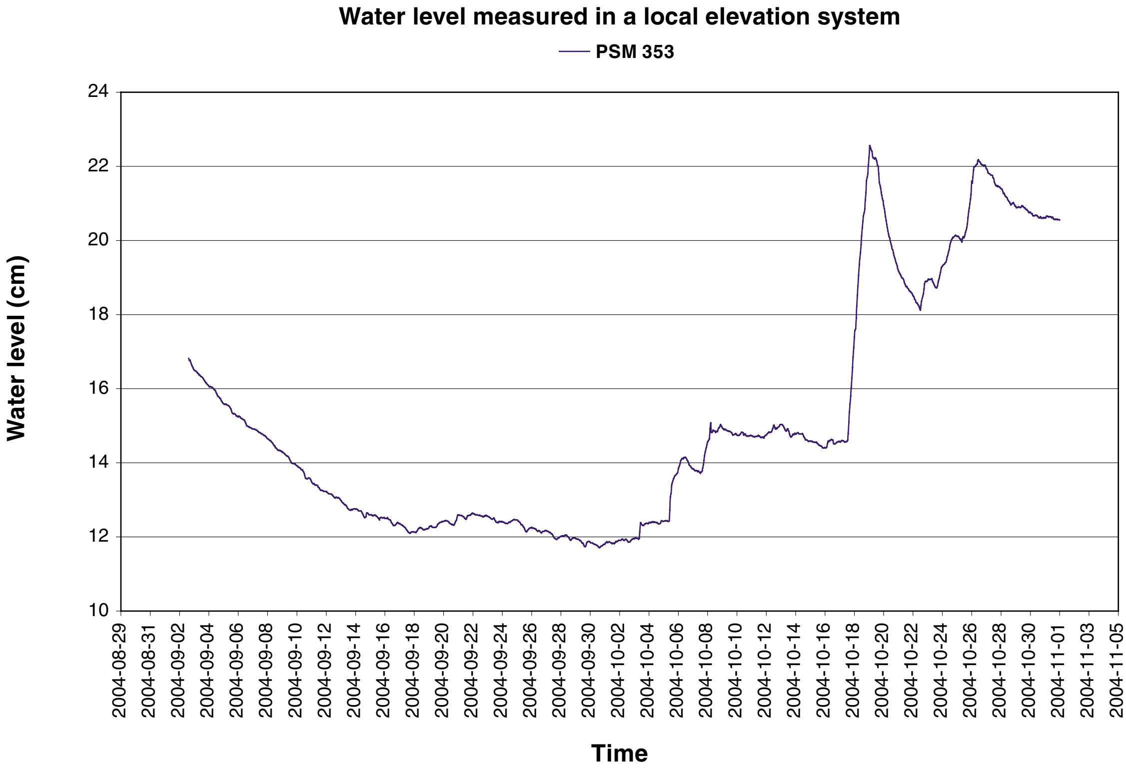


Figure 5-3. *Water level measured at station PSM353. The blue line shows the variation in centimetres in the upper part of the creek Laxemarån. Measurements made in centimetres in a local elevation system.*

For station PSM364 no quality checked water level data are delivered because changes to the cross-section have recently been made. An agreement has been made between SMHI and SKB that no quality approved data will be stored in any database before work with the cross section is finished.

5.1.2 Water level

Sea water level

Sea water level is measured at three places in the surroundings of Äspö. The stations are PSM369, PSM370 and PSM371. At these stations measurements have been made since January 2004. Measurements are made in elevation system RT90-RHB70 and expressed as metres above sea level (m a s l). The similarity between measurements at the three stations is good. The results are presented in Figure 5-4. It has not been necessary to make any corrections of measured values during time of measurements.

Water level measured in lakes and reservoirs

Water level is also taken at station PSM342 and PSM344. At PSM342 water level in lake Jämsen is measured and at station PSM344 water level in lake Plittorpsgöl. All measurements at these two stations have so far been made in local elevation systems. It has not been necessary to make any corrections of data at all according to these measurements. The measurements can be seen in Figure 5-5.

At station PSM359 water level is taken in the reservoir at Sörå. Measurements are in metres above sea level, (m a s l), in elevation system RT90-RHB70. The measured water levels can be seen in Figure 5-6. No corrections are made during time of measurements.

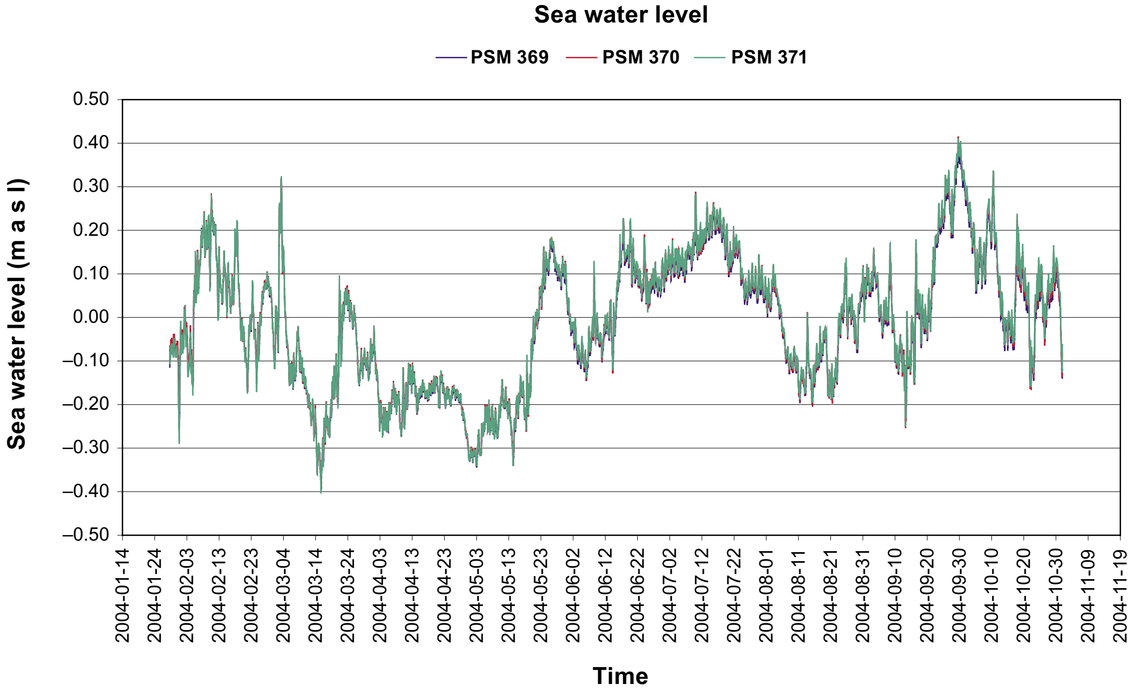


Figure 5-4. *Measured sea water level at station PSM369, PSM370 and PSM371. All measurements made in elevation system RT90-RHB70.*

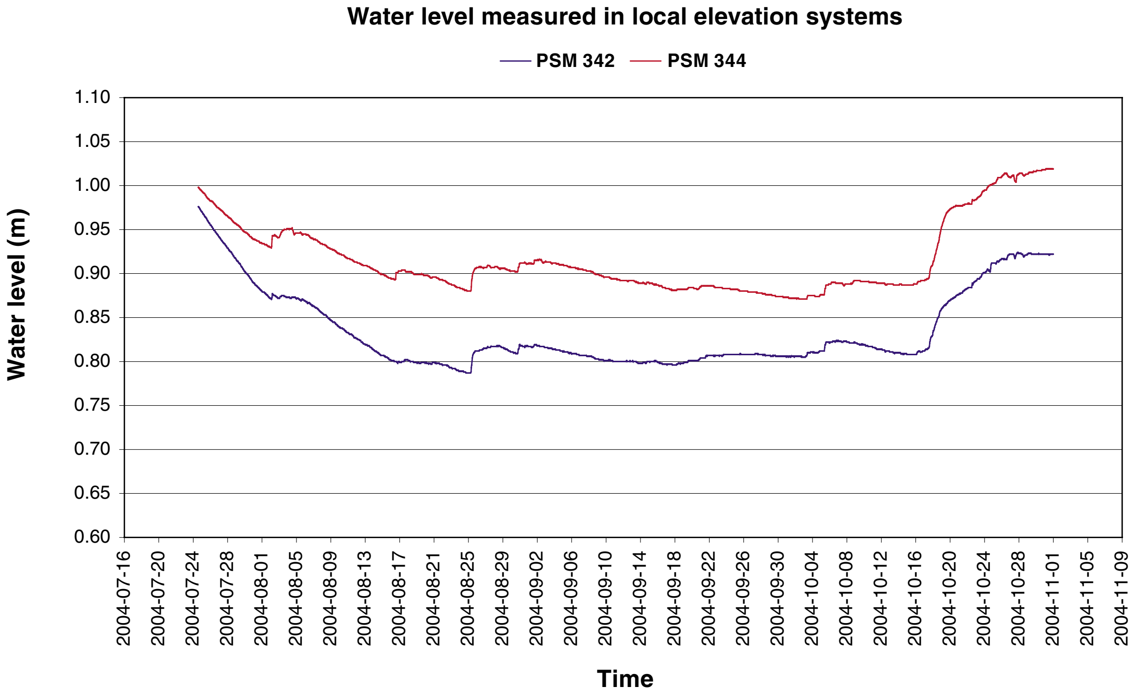


Figure 5-5. *Water level measured in metres at station PSM342 and PSM344. The blue line shows the variation in water level for lake Jämsen and the red line variation in water level for lake Plittorpsgöl. Measurements made in local elevation systems.*

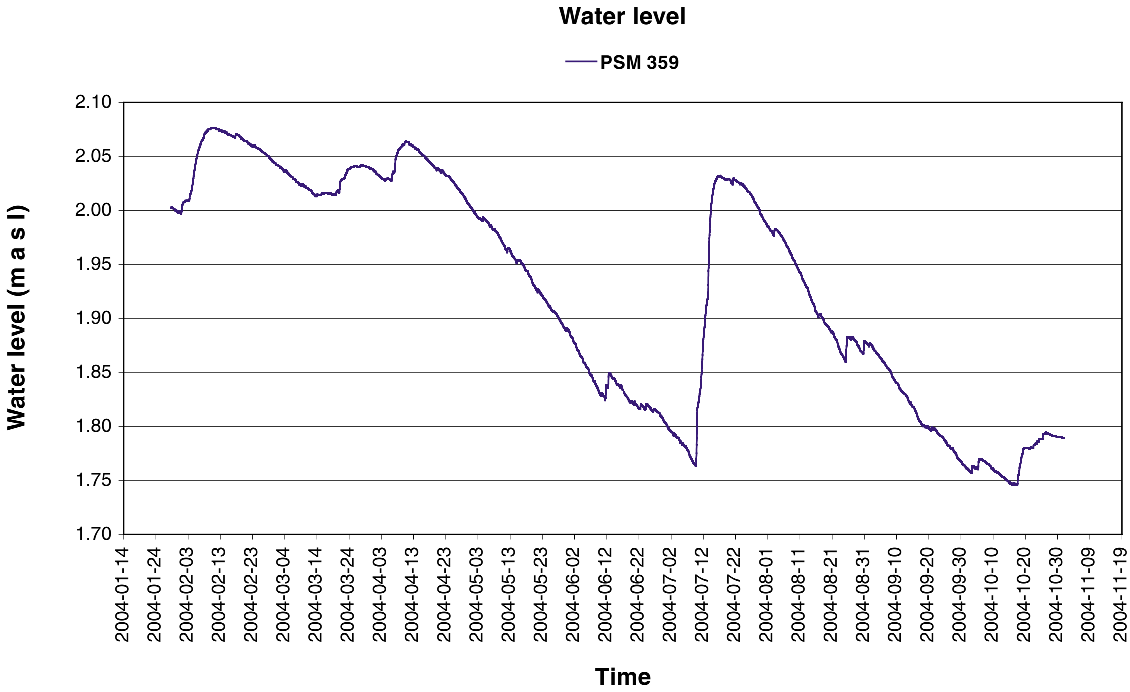


Figure 5-6. *Water level measured in m a s l at station PSM359. The blue line shows the variation in water level in the reservoir at Sörå. Measurements made in elevation system RT90-RHB70.*

5.1.3 Water temperature and electrical conductivity, (EC)

At all stations monitoring discharge the water temperature and electrical conductivity, EC, are also measured. At three stations PSM341, PSM343 and PSM345 where constructed dams are made, temperature and EC is measured in the small basin upstream the concrete dam. During drought periods when discharge in creeks equals zero the water in the basins will be warmed up and measured temperature and EC values will because of this not be representative. For this reason all quality checked temperature and EC values are deleted when the discharge equals zero. It has only been necessary to make adjustments to conductivity measurements when some odd values occurred. Quality approved measurements are presented in Figures 5-7 and 5-8. At stations PSM348, PSM353, PSM364 and PSM368 all sensors are situated in a creek or in a lake. Therefore measurements of temperature and EC could be made all the time except when, or if, the creek was dried up. Even here it has only been necessary to make adjustments to conductivity measurements when some strange and deviating values occurred. Quality checked measurements are presented in Figures 5-9 to 5-12. At station PSM364 an interruption in data occurred between 2004-10-14 08:00 and 2004-10-15 12:00. This interruption was most likely caused by the work with the cross section in the creek carried out at this time. At station PSM348 the conductivity sensor malfunctioned shortly after installation, and was therefore removed 2004-09-02. Temperature and electrical conductivity are measured with the same sensor and as a result temperature measurements are missing after 2004-09-02.

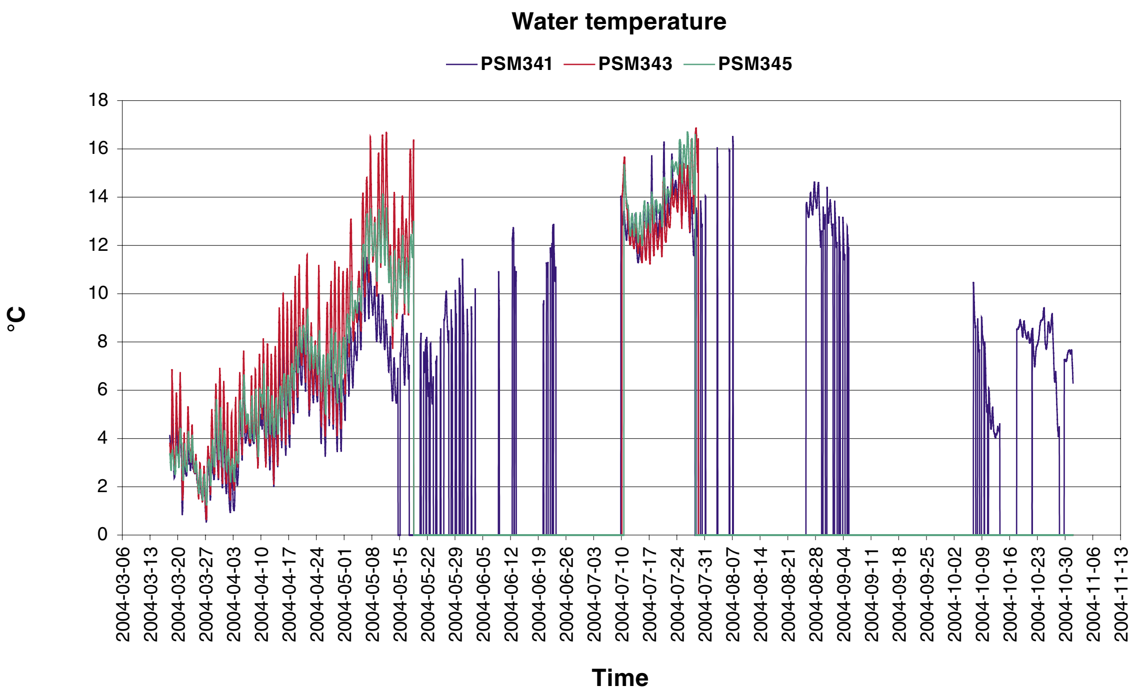


Figure 5-7. Water temperature measured at stations PSM341, PSM343 and PSM345. Values are deleted during periods when the discharge equals zero or when the watercourse is dried up.

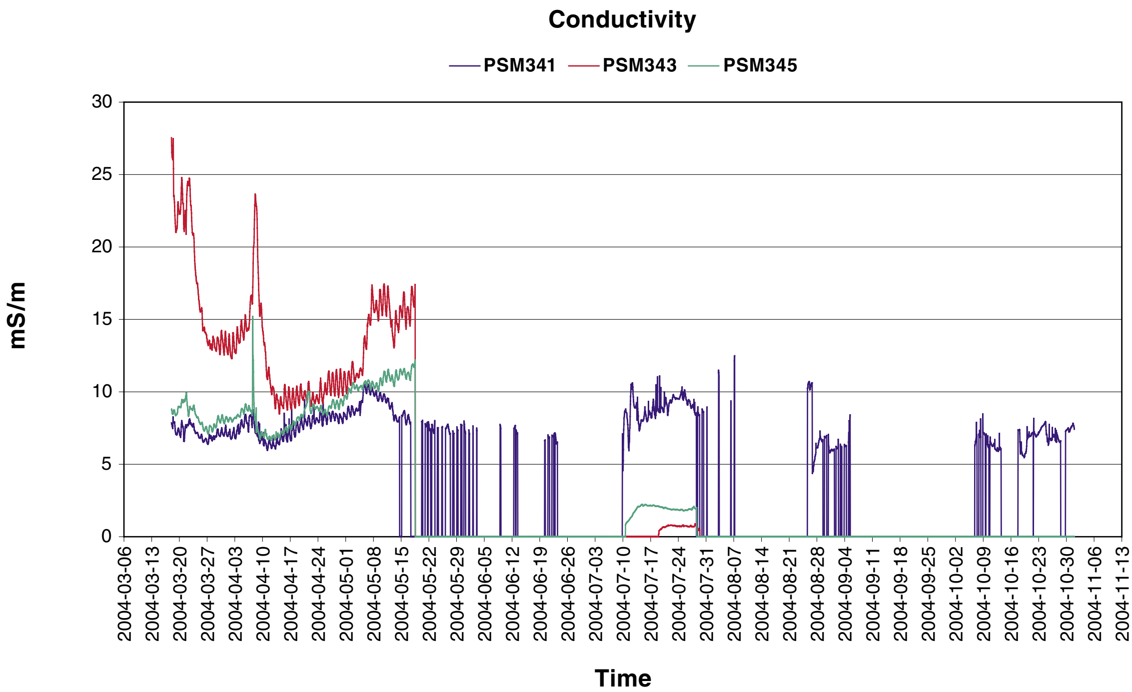


Figure 5-8. Electrical conductivity, EC, measured at stations PSM341, PSM343 and PSM345. Values are deleted during periods when the discharge equals zero or when the watercourse is dried up.

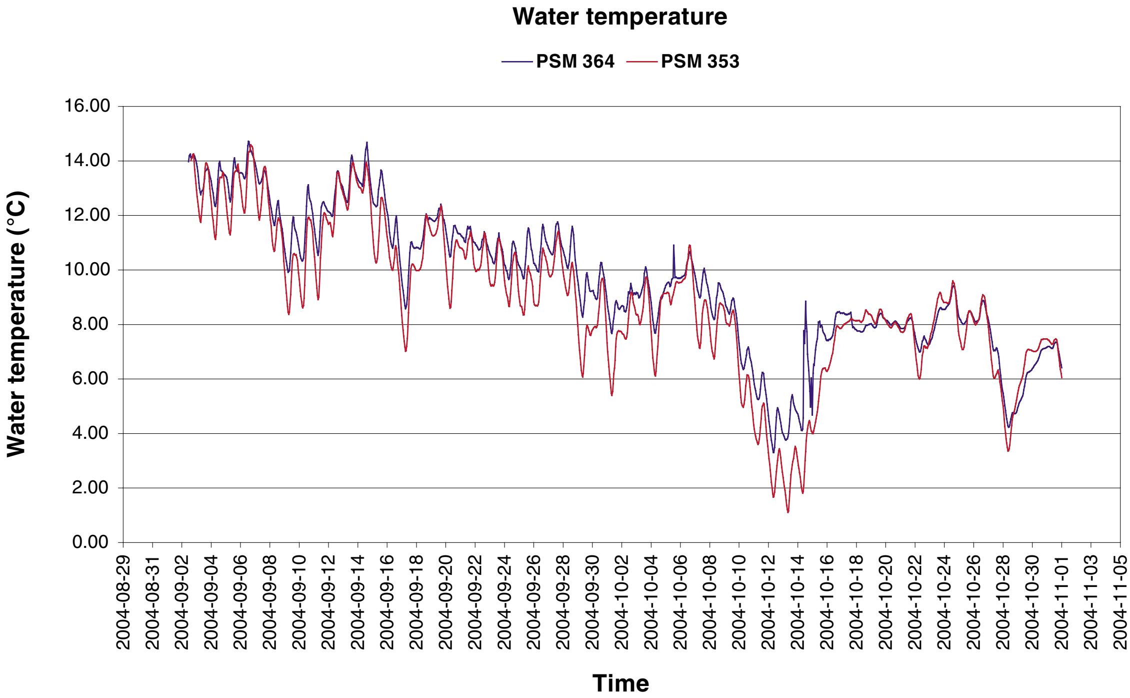


Figure 5-9. *Water temperature measured at stations PSM353 and PSM364. The blue line shows the fluctuation in water temperature in the lower part of creek Laxemarån. The red line shows the fluctuation in water temperature in the upper part of creek Laxemarån.*

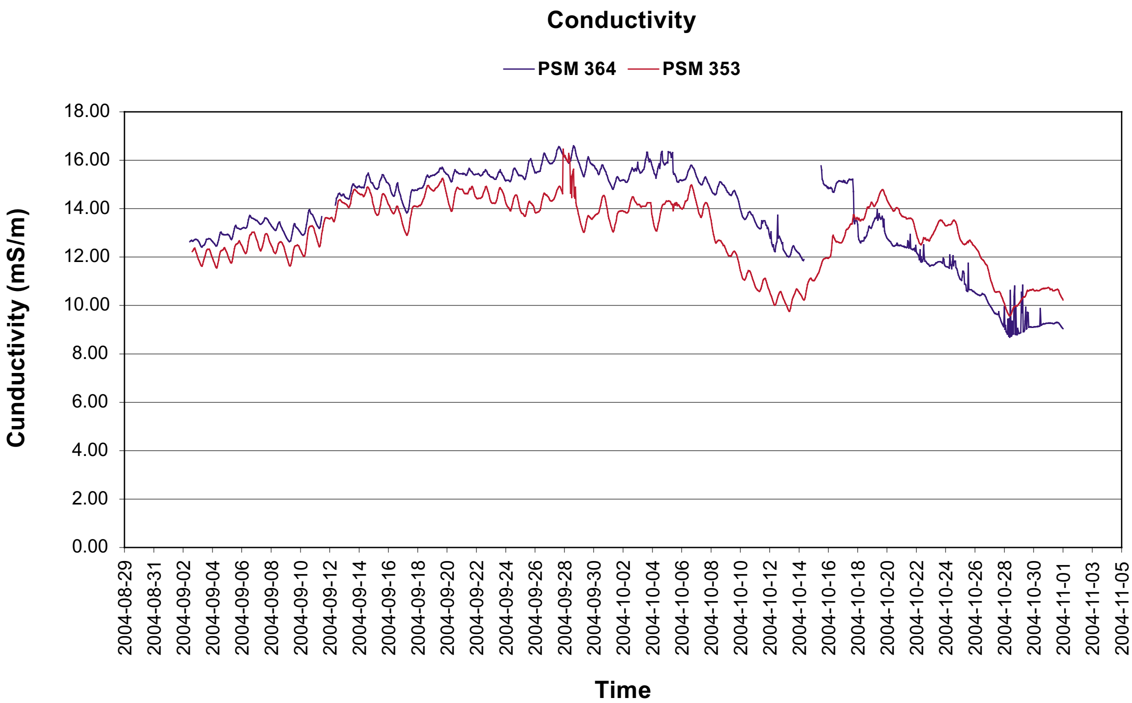


Figure 5-10. *Electrical conductivity measured at station PSM353 and PSM364.*

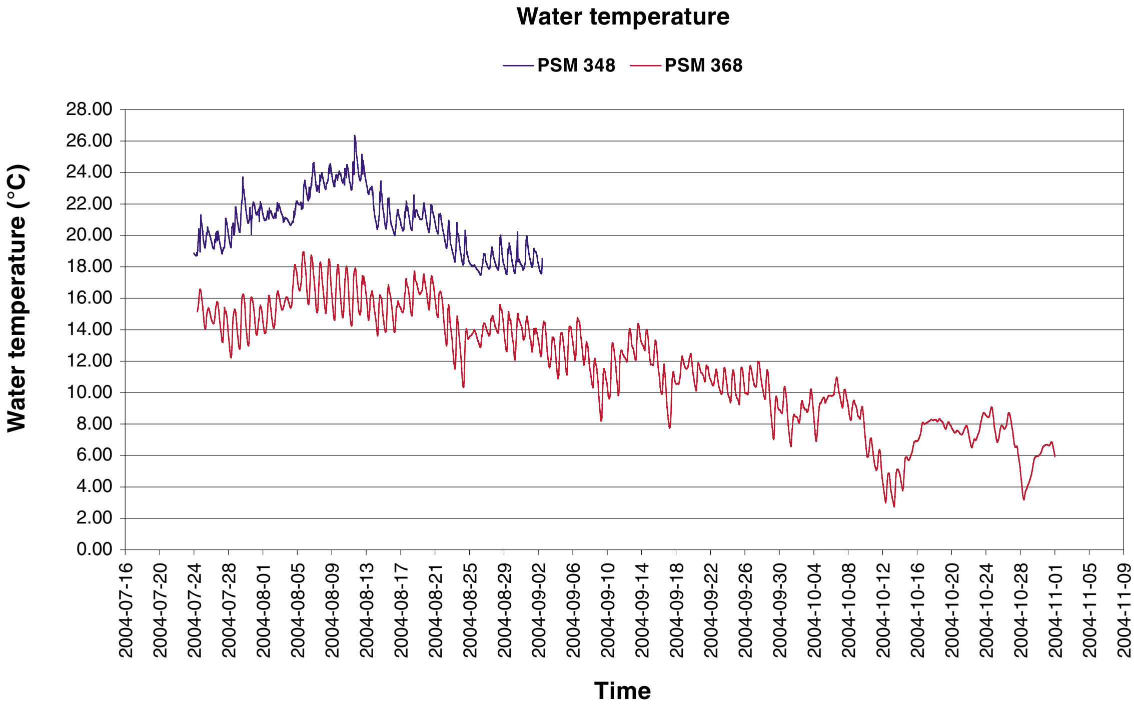


Figure 5-11. *Water temperature measured at station PSM348 and PSM368. Blue line is water temperature at the lake Frisksjön, PSM348, and red line is water temperature in the creek Kärrviksån, PSM368.*

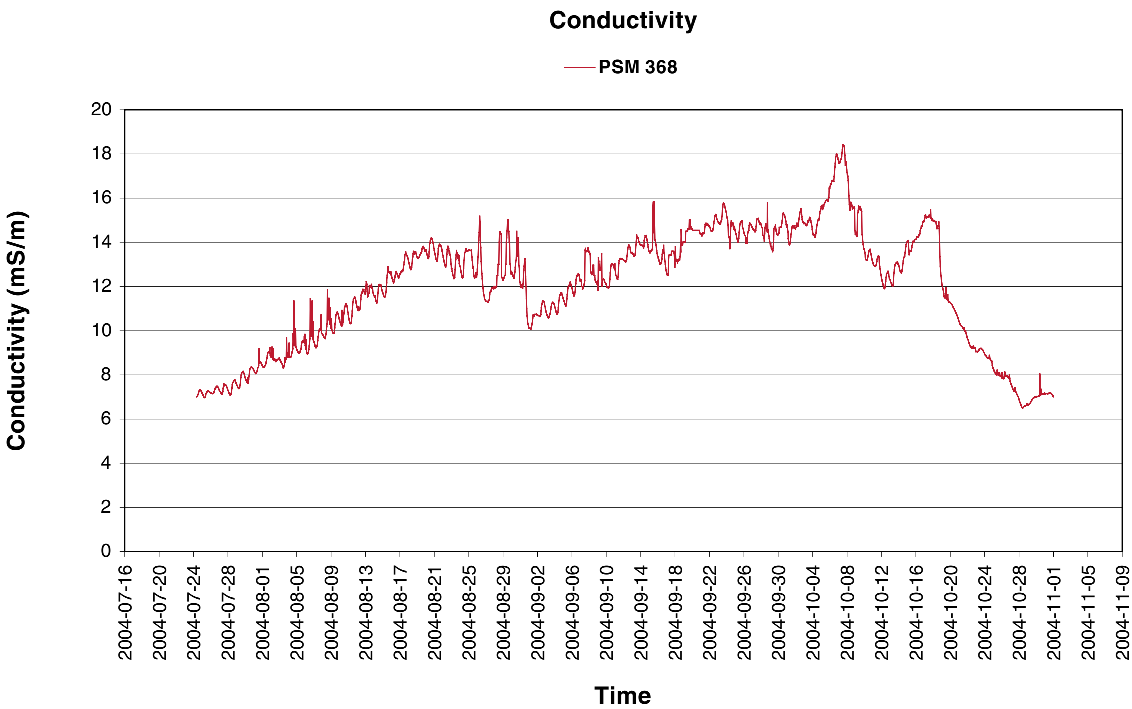


Figure 5-12. *Electrical conductivity measured at station PSM368. For station PSM348 no data are available because of malfunction of the sensor.*

5.2 Meteorological monitoring

Meteorological measurements have turned out to work quite well during this first measuring period for the measurements of temperature, wind direction and wind speed and relative humidity. However, some errors regarding the air pressure have been found. The errors occurred due to problems with the logger and were corrected in September. The 30-minute value of precipitation shows too high numbers, particularly for Plittorp in September. This occurs because of the sensitivity of the instrument and that the precipitation is measured so often. The data logger is now adjusted but still the errors continue, all though far fewer than before. These errors can be corrected afterwards.

A new station Plittorp has been installed. The measurements have been in progress since July 2004. This report aims to illustrate the function of the measuring equipment and to show that it is working according to the way it was intended. The purpose is also to take measures needed to improve the results. The following parameters are measured at this new station:

- Wind speed and direction at 10 m above ground level.
- Air temperature (2 m).
- Humidity (2 m).
- Precipitation (2 m).
- Air pressure (2 m).

Global radiation is only measured at the Äspö Station. Below are given graphs and comments about the parameters mentioned above and the calculated parameter potential evapotranspiration.

Figure 4-2 shows where the two monitoring stations Plittorp and Äspö are situated. The figure also shows where the SMHI precipitation stations presented in this report below are located.

5.2.1 Precipitation

The monthly precipitation for SMHI's stations is presented in Table 5-1 and Figure 5-13 below. "Ölands Norra Udde A" is an automatic station and the others are manual stations. These precipitation values are all checked and approved by SMHI. There are no correction for wind errors, wetting and evaporation in these values. The true precipitation is estimated to be 7–17% higher as year average.

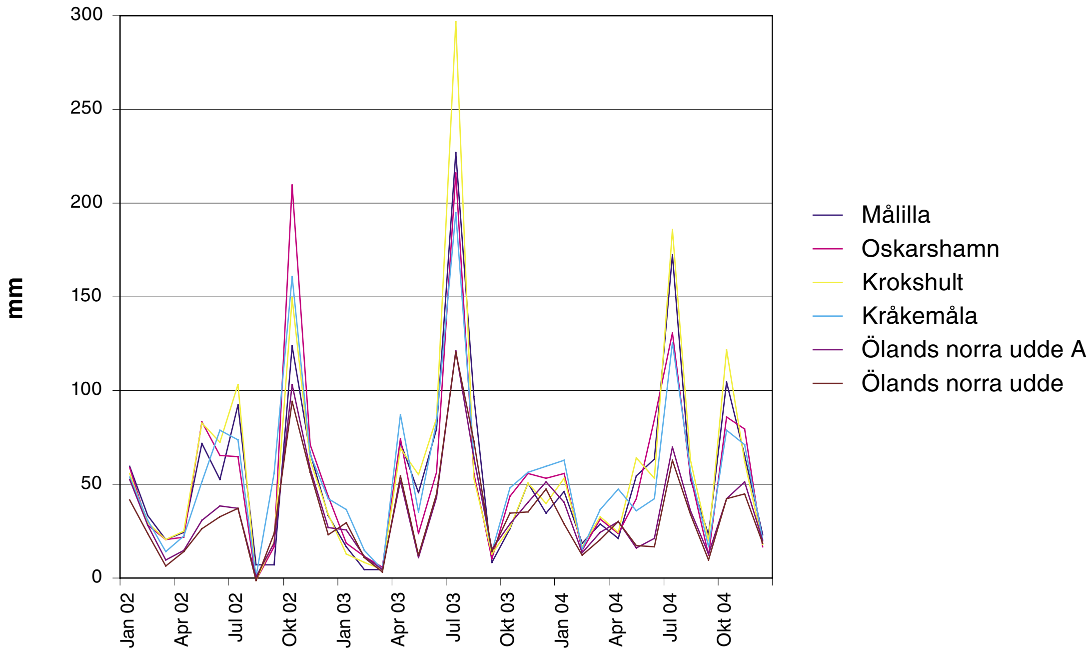
One can see that the precipitation differs a lot between stations and between months.

The precipitation at Plittorp and Äspö is presented in Table 5-2. "001" in the table means originally measured value, "COR" means corrected and approved value by SMHI, "KOR" is an estimation of the true precipitation, "BUC" means values from a precipitation gauge of the type tipping bucket and "MES" means analysed values from SMHI's analysing system Mesan. Mesan is an automatic system for mesoscale analysis of meteorological parameters, built on manual as well as automatic observations and also including satellite- and radar information.

The true precipitation (KOR), i.e. precipitation corrected for wind errors, wetting and evaporation, is also estimated. For this site and instrument we estimate that the precipitation is 10% more than that measured, if the temperature is below +1°C, otherwise 6% more. More information about true precipitation can be found in reference /4/.

Table 5-1. Monthly precipitation in mm at SMHI's stations.

	Målilla	Oskarshamn	Krokshult	Kråkemåla	Ölands norra udde A	Ölands norra udde
Estimated correction	**7%**	**7%**	**9%**	**8%**	**17%**	**13%**
Jan 02	60	59	56	54	52	42
Feb 02	34	28	29	31	28	24
Mar 02	21	21	21	14	10	7
Apr 02	24	22	25	22	15	14
May 02	72	84	83	51	31	27
Jun 02	53	66	72	79	38	33
Jul 02	92	65	103	74	37	37
Aug 02	7	0	0	1	1	0
Sep 02	7	17	20	56	19	24
Oct 02	124	210	149	161	103	94
Nov 02	67	71	63	66	59	56
Dec 02	34	44	34	42	27	23
Sum	592	684	653	650	419	379
Jan 03	17	19	13	37	26	30
Feb 03	5	12	8	15	11	11
Mar 03	5	6	4	4	5	3
Apr 03	73	74	69	87	52	54
May 03	45	24	55	35	11	12
Jun 03	80	56	85	83	43	45
Jul 03	227	216	297	195	121	121
Aug 03	97	56	53	65	64	73
Sep 03	8	10	13	14	15	14
Oct 03	26	44	27	48	29	35
Nov 03	50	56	51	56	41	35
Dec 03	34	53	40	60	51	47
Sum	666	625	716	700	470	480
Jan 04	46	56	53	63	41	29
Feb 04	19	15	17	16	14	12
Mar 04	29	31	32	37	24	20
Apr 04	21	24	25	47	30	30
May 04	54	42	64	36	16	17
Jun 04	64	85	53	42	21	17
Jul 04	173	131	186	126	70	63
Aug 04	52	55	63	57	36	34
Sep 04	23	12	20	17	13	10
Oct 04	105	86	122	79	43	42
Nov 04	65	79	62	71	52	45
Dec 04	23	17	18	21	20	18
Sum	674	631	714	611	379	338



Figur 5-13. *Monthly precipitation in mm at SMHI's stations.*

Table 5-2. Monthly precipitation in mm at SKB's stations. "001" in the table means originally measured value, "COR" means corrected and approved value by SMHI, "KOR" is an estimation of the true precipitation, "BUC" means values from a precipitation gauge of the type tipping bucket and "MES" means analysed values from Mesan.

	Plittorp 001	Plittorp COR	Plittorp KOR	Äspö 001	Äspö COR	Äspö KOR	Äspö BUC	Äspö MES
Aug	137	65	69	87	58	62	59	43
Sep	363	14	15	74	13	14	14	15
Oct	86	81	86	87	70	74	73	54
Sum	587	160	170	247	141	149	147	112

The registered 30-minute precipitation values has to be filtered before storing. This is because the instrument is very sensitive and registers incorrect small values of precipitation. September 29, 2004 FDS Mätteknik made a change in this filtering to improve the quality of the stored value. We see in Table 4-4 that the measured values are much higher than the corrected values in August and September. After the improvement the "001"-values are in better agreement with the corrected values.

If we compare the corrected values from Plittorp and Äspö for three months, 160 mm and 141 mm, with the values from the closest SMHI stations Kråkemåla and Oskarshamn (153 mm and 153 mm) we see that they correspond well with each other.

Graphs of the precipitation are presented in the Figures A4-1 to A4-4 in Appendix 4, one graph per month. Values from Plittorp and Äspö are presented. We see that they correspond well with each other and that Plittorp had more rain.

5.2.2 Barometric pressure

Graphs of the barometric pressure are presented in the Figures A4-5 to A4-8 in Appendix 4, one graph per month. Values from Plittorp, Äspö and Mesan-values are presented. We notice that there have been problems with the Plittorp measurements. Some extremely low values are reported from start until September 27.

There were two problems with the logger. First the instrument only registered values with no decimals and sometimes values were missing but were registered as 899 hPa. After an adjustment of the data logger by FDS Mätteknik September 27 the measurements are corrected and we see no more erroneous values.

Until September 24 the pressure from Plittorp was reported as an integer. After that date the pressure is reported with decimals.

We also notice that the measured value from Plittorp is on average in October 3.2 hPa lower than the Mesan-value which is valid for the sea surface. The pressure decreases in theory about 1 hPa per 8 m and the value from Plittorp is therefore correct.

5.2.3 Air temperature

Graphs of the temperature are presented in the Figures A4-9 to A4-12 in Appendix 4, one graph per month. Values from Plittorp, Äspö and Mesan-values are presented. We see that the three curves follow each other very well. We notice that the diurnal variation is biggest at Plittorp. This is correct because the station is situated about 10 km from the coast and the sea effects the temperature.

5.2.4 Relative humidity

Graphs of the temperature are presented in the Figures A4-13 to A4-16 in Appendix 4, one graph per month. Values from Plittorp, Äspö and Mesan-values are presented. We see that the three curves follow each other very well.

5.2.5 Wind speed

Graphs of the wind speed are presented in the Figures A4-17 to A4-20 in Appendix 4, one graph per month. Values from Plittorp, Äspö and Mesan-values are presented. We see that the wind speed is higher at Äspö compared to Plittorp but that the curves follow each other quite well.

The measured wind speed at Plittorp is clearly lower than the Mesan analysis. This is due to the surroundings of the site (not very open area) and that Mesan overestimates the wind speed at sites close to the sea. The measured wind speed at Plittorp is also lower than the values from Äspö. The reason is of course that Äspö is closer to the sea.

5.2.6 Wind direction

Graphs of the wind direction are presented in the Figures A4-21 to A4-24 in Appendix 4, one graph per month. Values from Plittorp and Mesan-values are presented. We see that the two curves follow each other very well. There are no data from Äspö because of errors.

5.2.7 Global radiation

Graphs of the global radiation are presented in the Figures A4-25 to A4-28 in Appendix 4, one graph per month. Global radiation is only measured at the Äspö Station. Values from Äspö and Strång-values are presented. Analysed global radiation from the SMHI radiation model Strång, which uses data from Mesan, corresponds well to measured global radiation at Äspö.

5.2.8 Calculated evapotranspiration

The potential evapotranspiration is calculated with the Pennman formula:

$$E_P = \left(\frac{\Delta \times (R_n - G)}{(\Delta + \gamma) \times L} + \frac{\gamma \times f(u) \times (e_s - e)}{(\Delta + \gamma)}\right) \times tstep$$

The method for doing so is described in Bertil Eriksson (1981, RMK 28) /5/.

Graphs of the evapotranspiration are presented in the Figures A4-29 to A4-32 in Appendix 4, one graph per month.

5.3 Winter parameters

5.3.1 Snow depth

The average snow depth at the one station for snow depth measurement is shown in Figure 5-14. The complete set of primary data is presented in Appendix 2, Table A2-1.

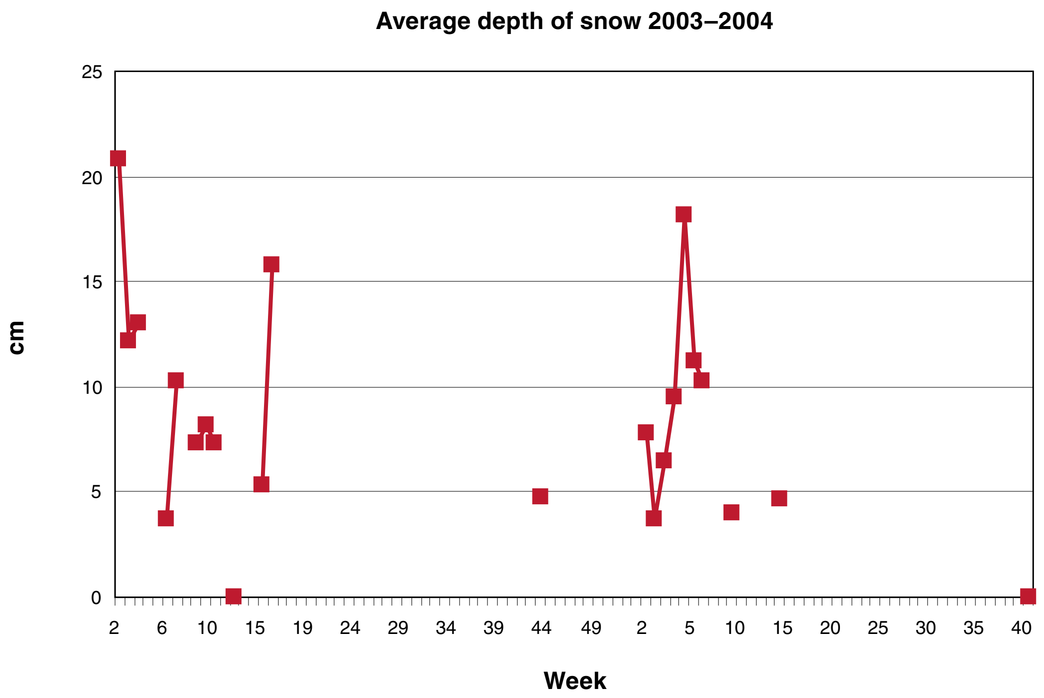


Figure 5-14. *Average snow depth at Äspö 2 (ASM100224) during the winter 2003/2004.*

5.3.2 Frost in ground

The frost in ground together with snow depth at "Grillplatsen" (PSM107724) is shown in Figure 5-15. However, values for frost in ground during 2003 are to be considered as uncertain due to problems with the reading of the instruments. The complete sets of primary data are shown in Appendix 3, Table A3-1.

5.3.3 Ice cover

Ice conditions observed in the Oskarshamn area are shown in Table 5-3.

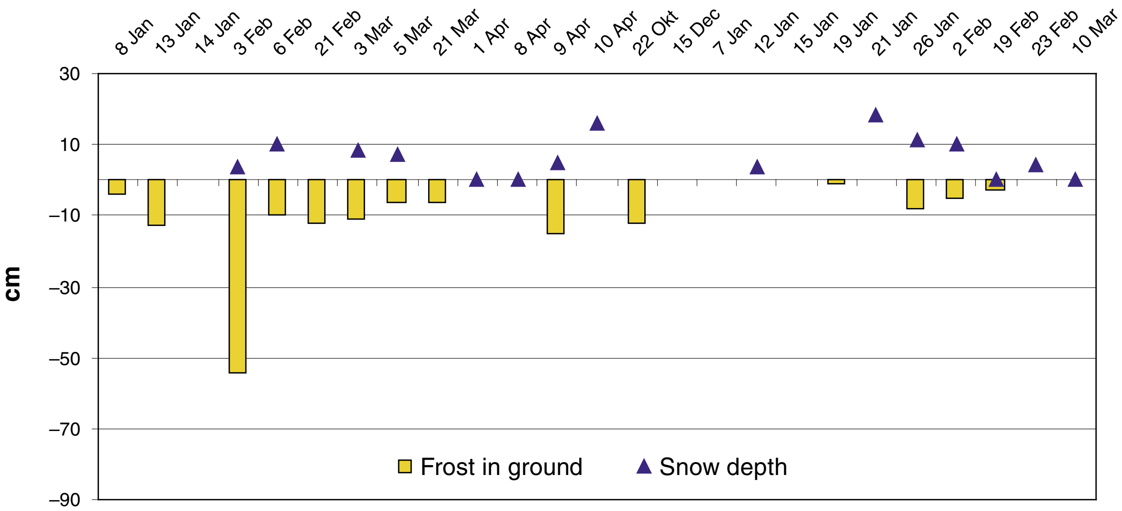


Figure 5-15. *Calculted frost in ground and snow depth at PSM107724 during 2003 and 2004.*

Table 5-3. Time for ice freeze up and ice break up in a lake and sea at the Forsmarks area.

	Ice freeze up	Ice break up	Period with ice cover (days)
Äspös brygga (ASM10226)	2002-12-19	2003-03-27	99
Äspös brygga (ASM10226)	2004-01-07	2004-03-10	62
Kråkelund (ASM100227)	2003-01-10	2003-03-21	71
Kråkelund inre (ASM100228)	2003-01-10	2003-03-21	71
Jämsen (ASM100229)	2002-11-19	2002-11-22	3
Jämsen (ASM100229)	2002-12-19	2003-03-28	100
Jämsen (ASM100229)	2004-01-07	2004-03-10	64

References

/1/ **SMHI/Naturvårdsverket, 1979.** Vattenföringsbestämning vid vattenundersökningar.

/2/ **SMHI.** Handbok för observatörer. Internt document.

/3/ **SKB, 2002.** Instruktion för inmätning och avvägning av objekt. SKB MD 110.001, Svensk Kärnbränslehantering AB.

/4/ **Eriksson B, 1981.** Den "potentiella" evapotranspirationen i Sverige. Eriksson B (1981).

/5/ **Alexandersson, 2003.** Meteorologi, Nr 111. Korrektion av nederbörd enligt enkel klimatologisk metodik.

Appendix 1

Hydrological monitoring stations

Station Id	Object	Place	Variables	Instrumentation	Time interval of measurements	QC_OK
PSM341	Ävrö NE	Dam	Discharge, T, EC	Logger: Campbell CR10X	Start: 2004-03-18 00:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	
				Temp. and EC: Campbell CS547		
PSM342	Jämsen	Lake	Water level	Logger: Campbell CR510	Start: 2004-07-24 14:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	
PSM343	Ävrö SW	Dam	Discharge, T, EC	Logger: Campbell CR10X	Start: 2004-03-18 00:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	
				Temp. and EC: Campbell CS547		
PSM344	Plittorpsgöl	Lake	Water level	Logger: Campbell CR510	Start: 2004-07-24 14:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	
PSM345	Ävrö SE	Dam	Discharge, T, EC	Logger: Campbell CR10X	Start: 2004-03-18 00:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	
				Temp. and EC: Campbell CS547		
PSM347	Frisksjön (in)	Dam	Discharge, T, EC	No instrumentation yet.	No data yet.	No data yet
PSM348	Frisksjön (out)	Lake, Natural section	Discharge, T, EC	Logger: Campbell CR10X	Start: 2004-07-24 00:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	
				Temp. and EC: Campbell CS547		
PSM353	Laxemarån (upper)	Natural section	Discharge, T, EC	Logger: Campbell CR10X	Start: 2004-09-02 15:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	
				Temp. and EC: Campbell CS547		
PSM359	Sörå-magasinet	Lake	Water level	Logger: Campbell CR510	Start: 2004-01-28 17:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	

Station Id	Object	Place	Variables	Instrumentation	Time interval of measurements	QC_OK
PSM364	Laxemarån (lower)	Natural section	Discharge, T, EC	Logger: Campbell CR10X	Start: 2004-09-02 11:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	
				Temp. and EC: Campbell CS547		
PSM365	Ekerumsån	Dam	Discharge, T, EC	Not built yet.	No data yet.	No data yet
PSM368	Kärrviksån	Natural section	Discharge, T, EC	Logger: Campbell CR10X	Start: 2004-07-24 09:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	
				Temp. and EC: Campbell CS547		
PSM369	Äspö S	Sea	Water level	Logger: Campbell CR510	Start: 2004-01-28 17:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	
PSM370	Äspö N	Sea	Water level	Logger: Campbell CR510	Start: 2004-01-28 17:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	
PSM371	CLAB	Sea	Water level	Logger: Campbell CR510	Start: 2004-07-28 17:00	OK
				Pressure sensor: DRUCK PDCR 1830	Stop: 2004-11-01 00:00	

Appendix 2

Measurements of snow cover

Primary data from snow depth measurements during the winter 2003/2004

The data collected during the snow depth measurements are presented below as individual measurements as well as the calculated average snow depth and a visual estimate of the coverage degree. S = completely or almost covered ground, SB = more than half of the ground snow covered but not completely covered, BS = more than half of the ground free of snow but not completely, B = the ground completely or almost completely free of snow.

Table A2-1. Snow depth at "Grillplatsen" (ASM100224) during the winter 2003/2004.

Start date/time	Stop date/time	Point 1 (cm)	Point 2 (cm)	Point 3 (cm)	Point 4 (cm)	Point 5 (cm)	Point 6 (cm)	Average snow cover (cm)	Snow coverage
2003-01-08	2003-01-08	16.0	25.0	21.0	22.0	22.0	23.0	20.8	S
2003-01-13	2003-01-13	10.0	11.0	11.5	11.0	11.5	18.0	12.2	S
2003-01-14	2003-01-14	14.0	11.0	18.0	15.0	10.0	10.0	13.0	S
2003-02-03	2003-02-03	2.0	5.0	5.0	3.0	4.0	3.0	3.7	S
2003-02-06	2003-02-06	11.0	10.0	11.0	10.0	10.0	10.0	10.3	S
2003-02-21	2003-02-21	9.0	9.0	7.0	6.0	7.0	6.0	7.3	S
2003-02-28	2003-02-28	7.0	8.0	9.0	9.0	8.0	8.0	8.2	S
2003-03-05	2003-03-05	8.0	8.0	5.0	7.0	8.0	8.0	7.3	S
2003-03-21	2003-03-21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	B
2003-04-09	2003-04-09	7.0	5.0	5.0	7.0	5.0	3.0	5.3	S
2003-04-10	2003-04-10	15.0	16.0	17.0	17.0	15.0	15.0	15.8	S
2003-10-22	2003-10-22	7.0	5.0	5.0	4.0	4.0	4.0	4.8	–
2004-01-07	2004-01-07	7.0	9.0	.0	8.0	8.0	8.0	7.8	–
2004-01-12	2004-01-12	4.0	4.0	5.0	4.	2.0	3.0	3.7	–
2004-01-15	2004-01-15	5.0	7.0	10.0	7.0	5.0	5.0	6.5	–
2004-01-19	2004-01-19	9.0	10.0	9.0	9.0	10.0	10.0	9.5	–
2004-01-21	2004-01-21	19.0	18.0	18.0	22.0	15.0	17.0	18.2	–
2004-01-26	2004-01-26	11.0	12.0	12.0	12.0	10.0	10.0	11.2	–
2004-02-02	2004-02-02	8.0	10.0	10.0	10.0	10.0	14.0	10.3	–
2004-02-23	2004-02-23	5.0	4.0	4.0	3.0	4.0	4.0	4.0	–
2004-03-04	2004-03-04	6.0	5.0	4.0	5.0	4.0	4.0	4.7	–
2004-03-10	2004-03-10								B

Measurements of ground frost

Primary data from measurement of frost in the ground during the winter 2003/2004

The data collected during the measurements of ground frost are presented below. As the whole device was not situated within the ground, the levels for ground surface are above the 0-level. The upper registration is the level of the upper border of the ground frost read from the device whereas the lower registration is the lower border. The upper and lower levels of ground frost are calculated using the level of the ground surface and the upper and lower registrations, respectively. From these two levels the distribution of ground frost has been calculated.

Table A3-1. Frost in ground during the winter 2003/2004 at Äspö (PSM107723).

Start date/time	Stop date/time	Ground surface (cm)	Upper reg (cm)	Lower reg (cm)	Upper level of ground frost (cm)	Lower level of ground frost (cm)	Ground frost distribution (cm)
2003-01-14	2003-01-14	100.0	95.0	100.0	–5.0	0.0	
2003-01-24	2003-01-24	100.0	96.0	107.0	–4.0	7.0	
2003-02-03	2003-02-03	100.0	0.0	110.0		10.0	
2003-02-21	2003-02-21	100.0	80.0		–20.0		
2003-02-27	2003-02-27	100.0		114.0		14.0	
2003-03-03	2003-03-03	100.0	102.0	114.0	2.0	14.0	
2003-03-05	2003-03-05	100.0	102.0	114.0	2.0	14.0	
2003-03-21	2003-03-21	100.0	105.0	107.0	5.0	7.0	
2003-04-01	2003-04-01	100.0		106.0		6.0	
2003-04-09	2003-04-09	59.0		70.0		11.0	
2004-02-19	2004-02-19	34.0	31.0	37.0	3.0	6.0	3.0
2004-02-23	2004-02-23	34.0	32.0	39.0	2.0	7.0	5.0
2004-03-04	2004-03-04	34.0	31.0	42.0	3.0	8.0	5.0
2004-03-10	2004-03-10	34.0	35.0	41.0	1.0	7.0	6.0

Meteorological monitoring

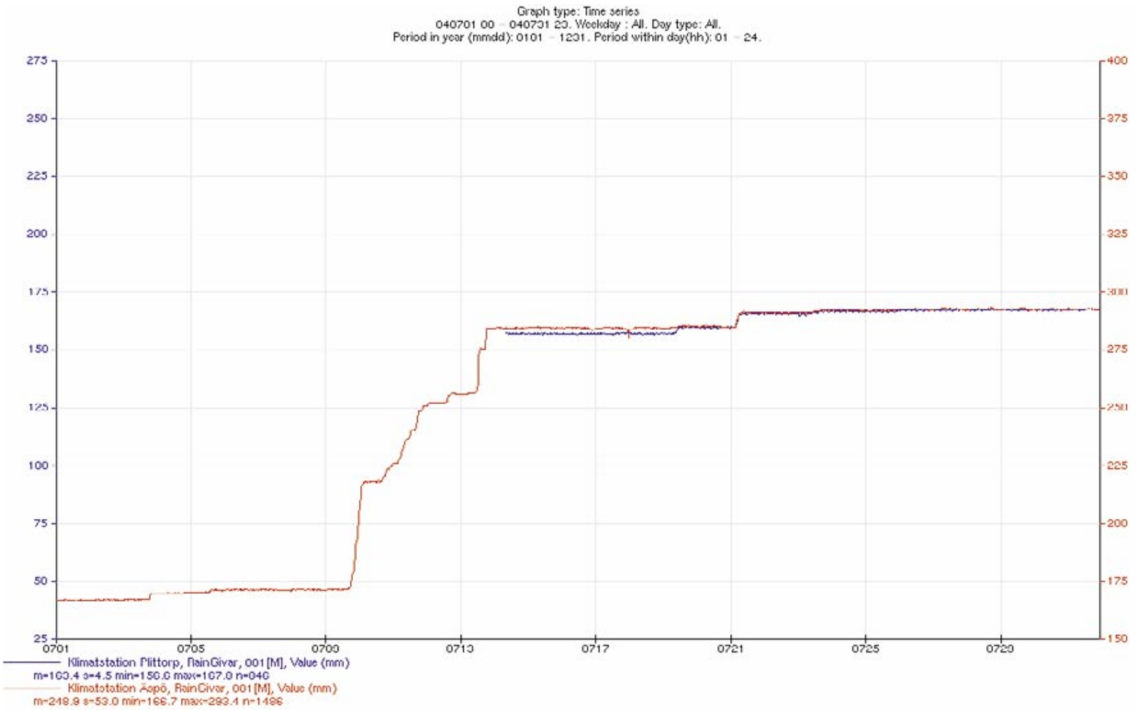


Figure A4-1. *July precipitation.*

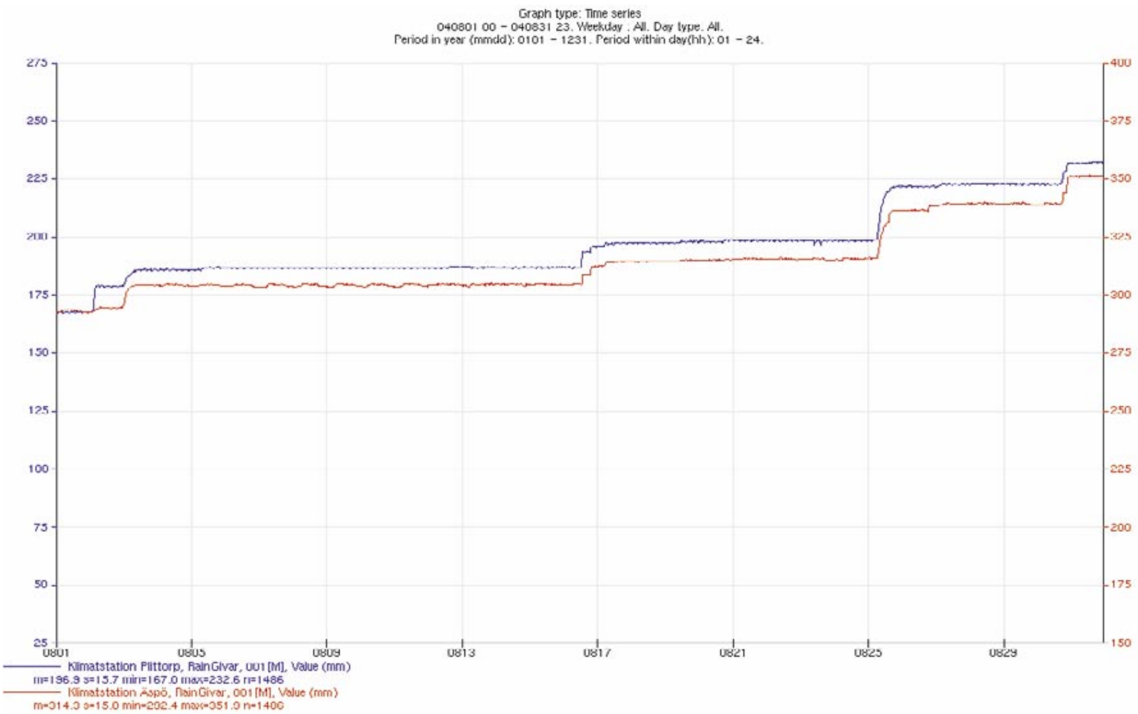


Figure A4-2. *August precipitation.*

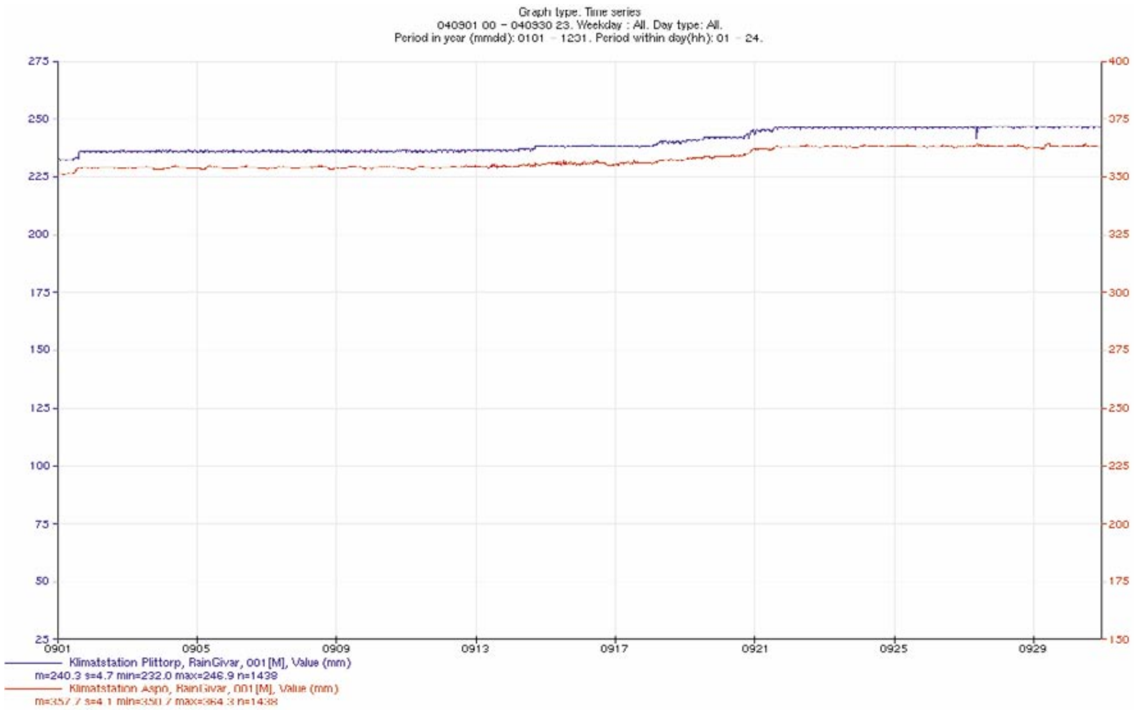


__Figure A4-3.__ September precipitation.

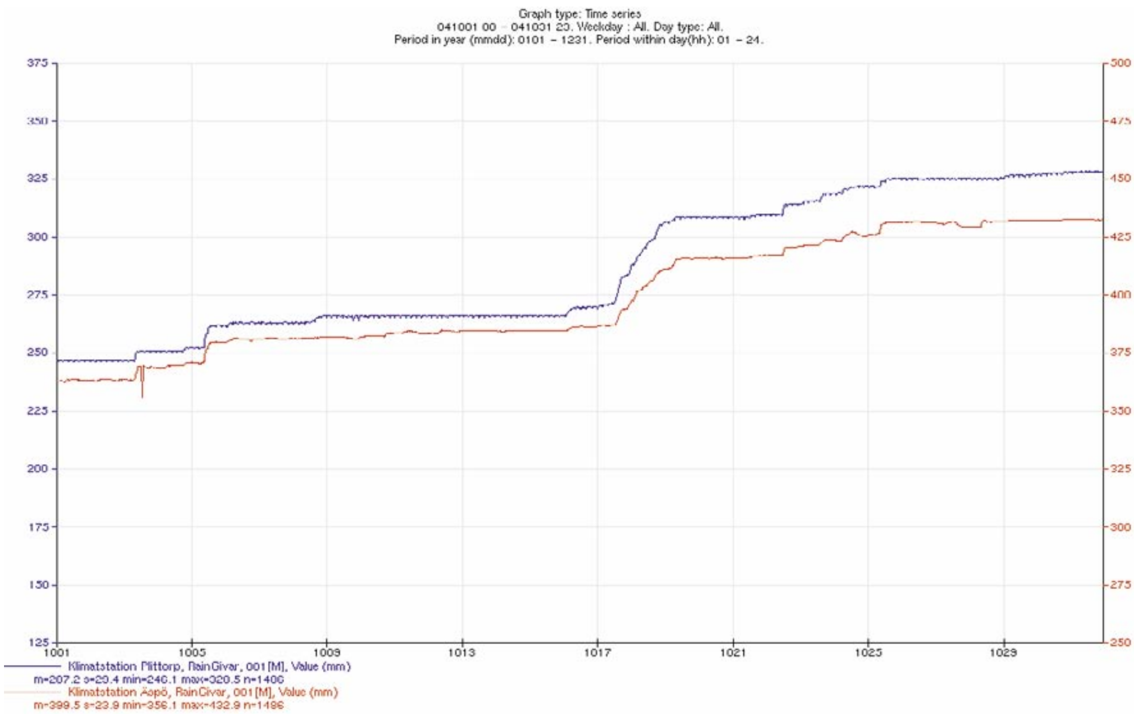


__Figure A4-4.__ October precipitation.

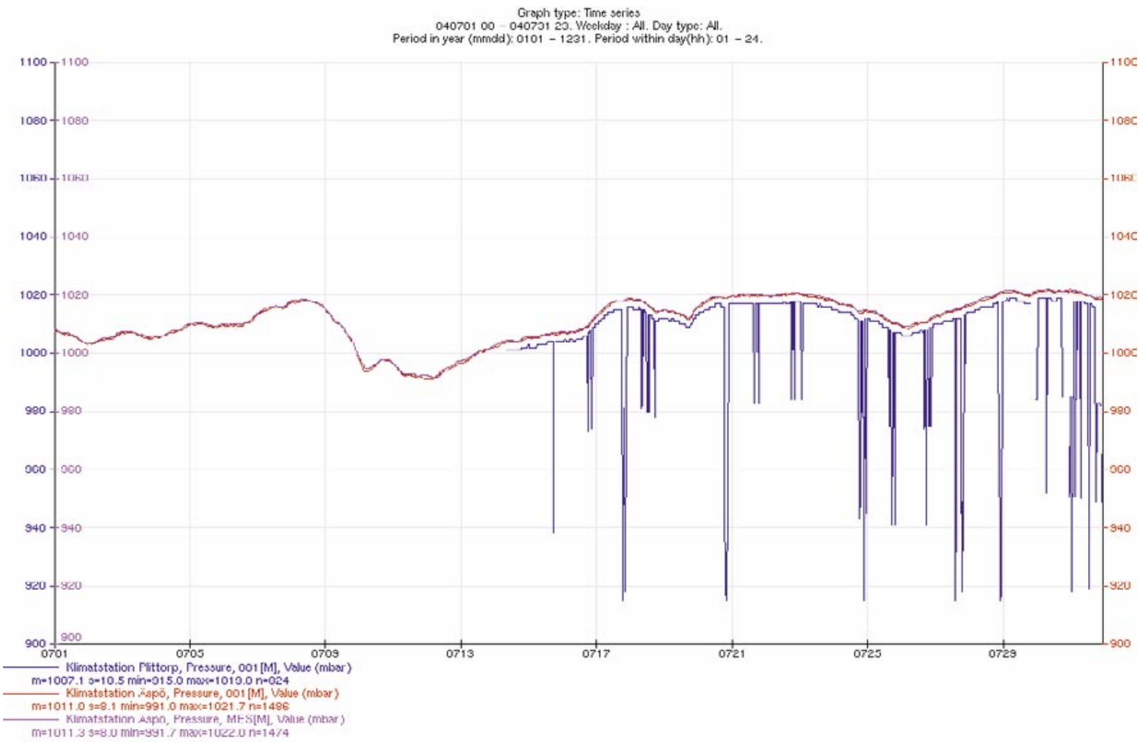


Figure A4-5. *July barometric pressure.*

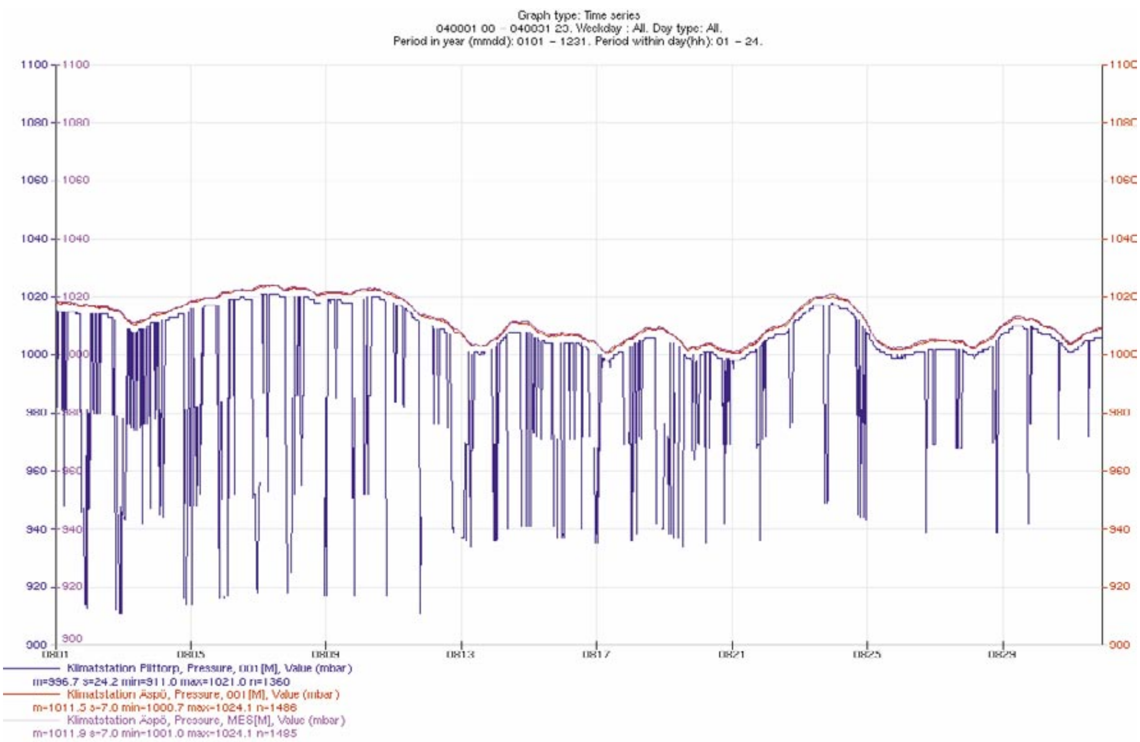


Figure A4-6. *August barometric pressure.*

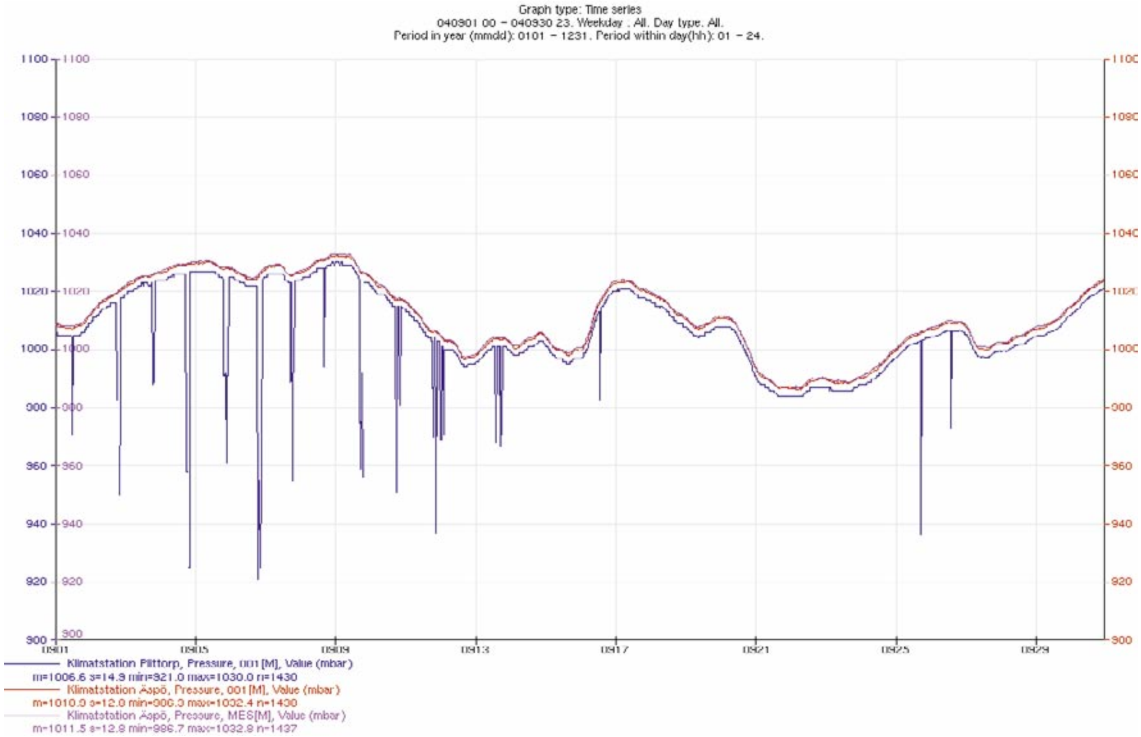


Figure A4-7. *September barometric pressure.*

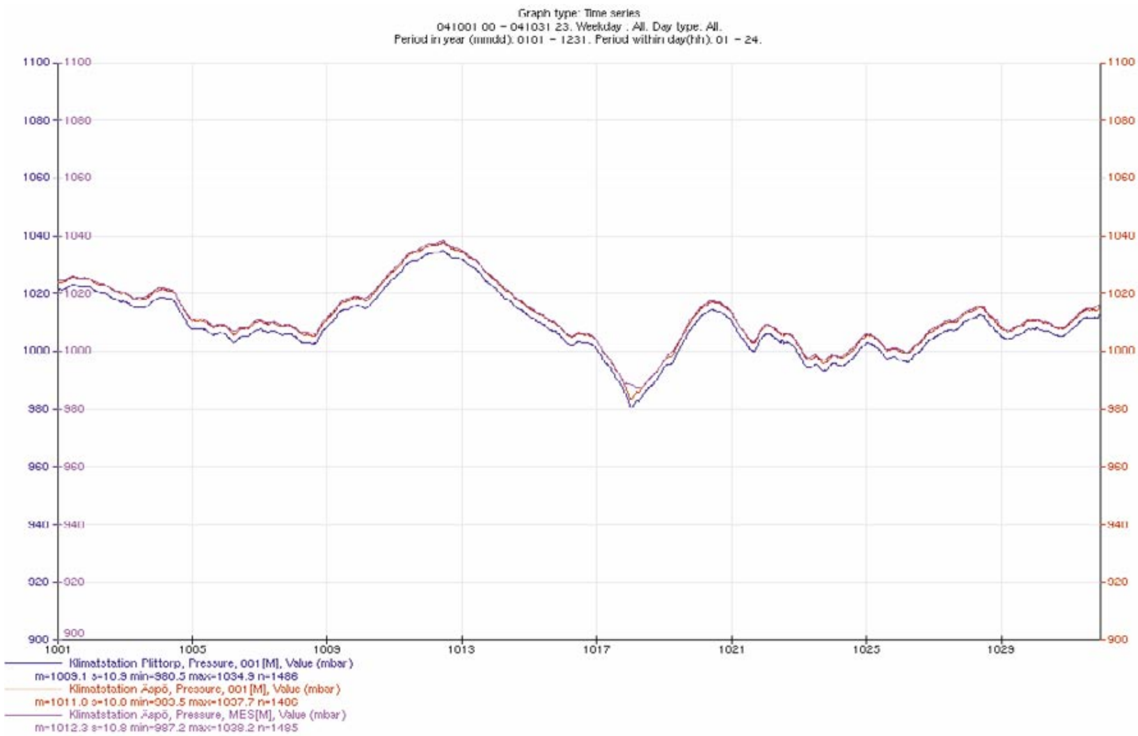


Figure A4-8. *October barometric pressure.*

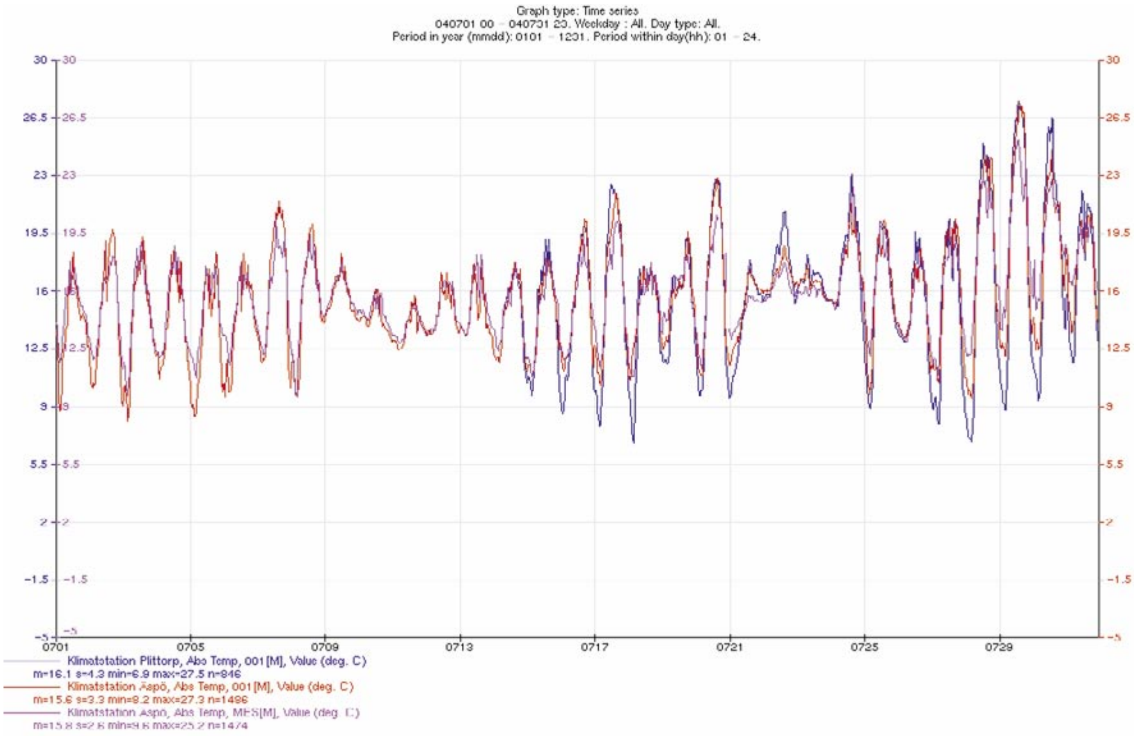


Figure A4-9. *July temperature.*

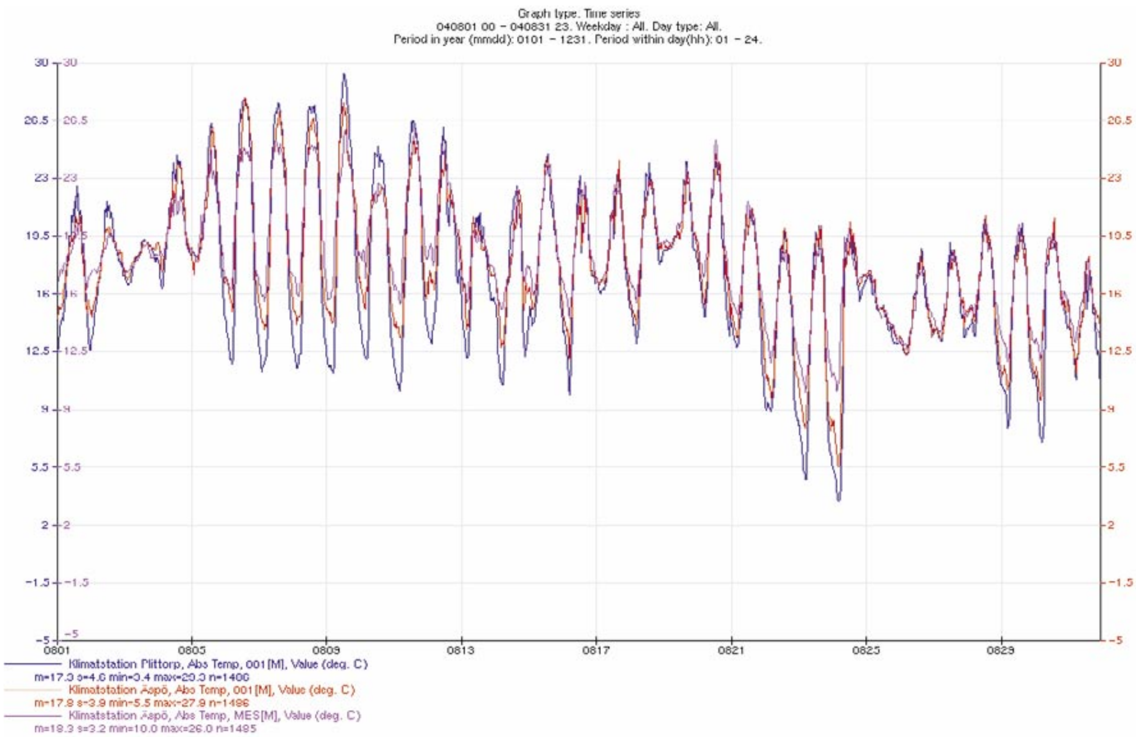


Figure A4-10. *August temperature.*

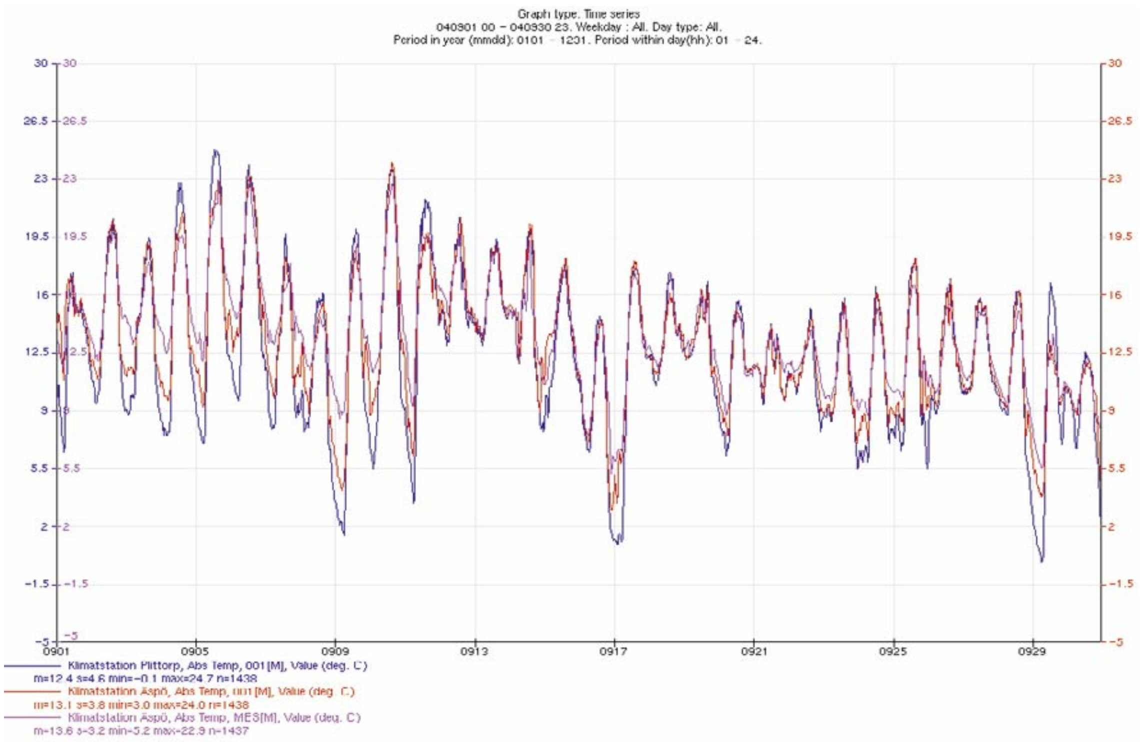


Figure A4-11. *September temperature.*

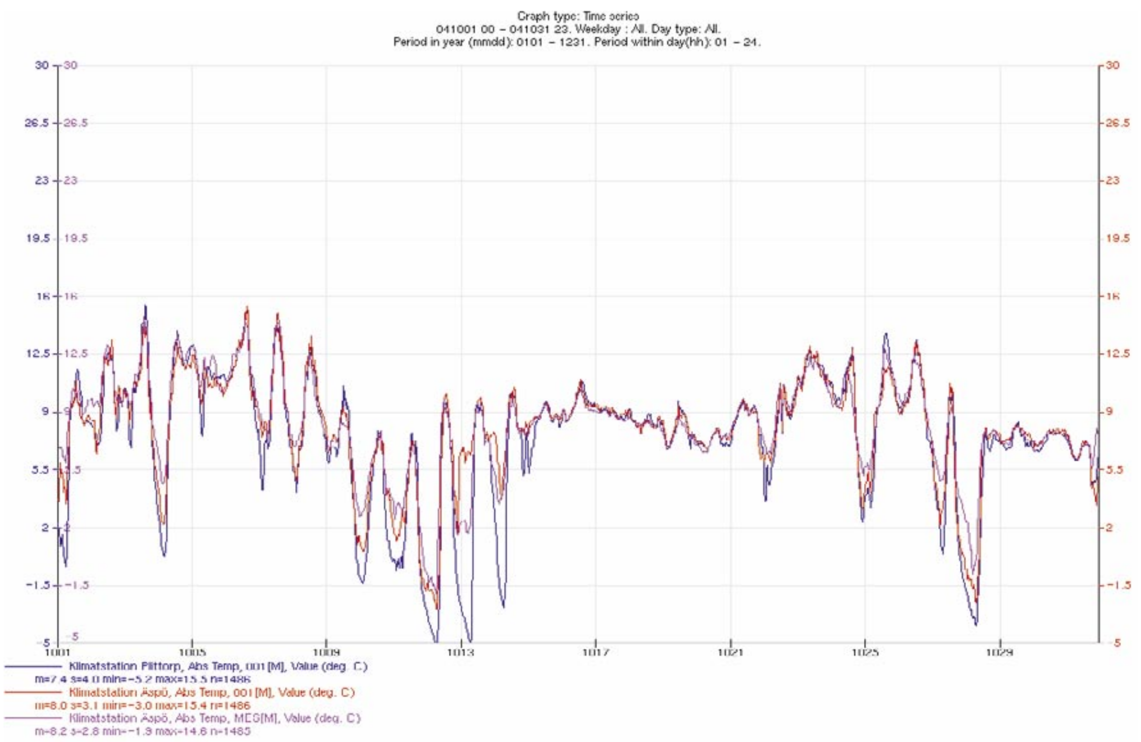


Figure A4-12. *October temperature.*

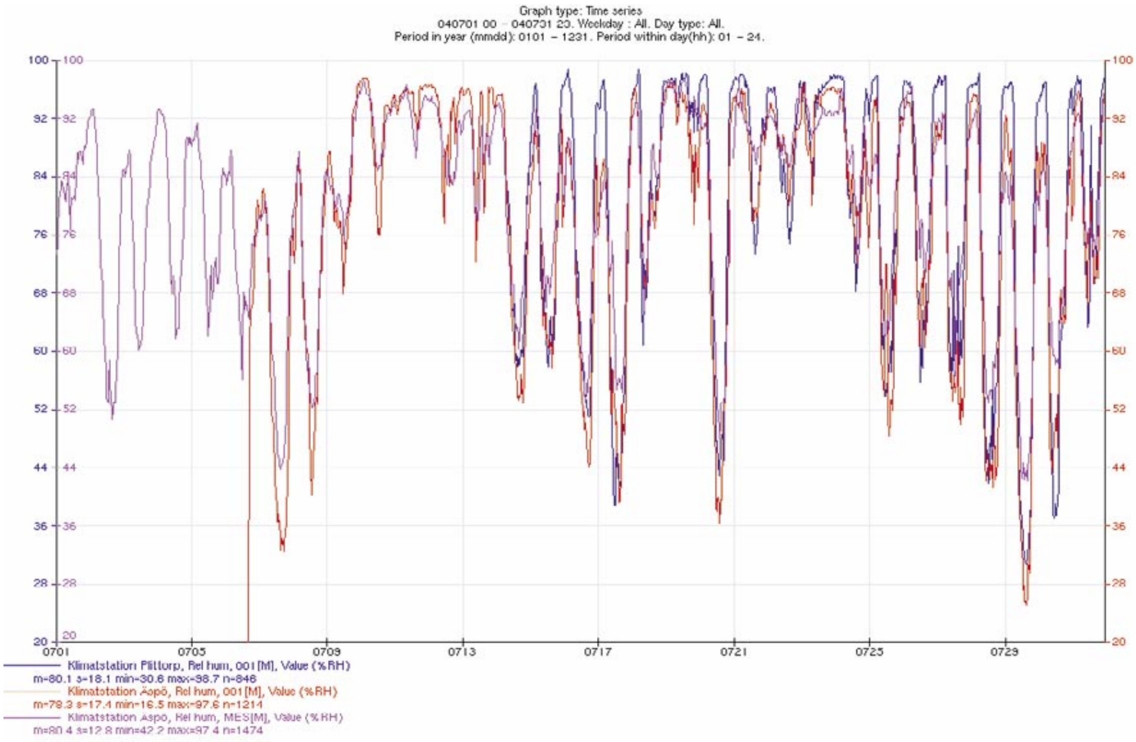


Figure A4-13. *July relative humidity.*

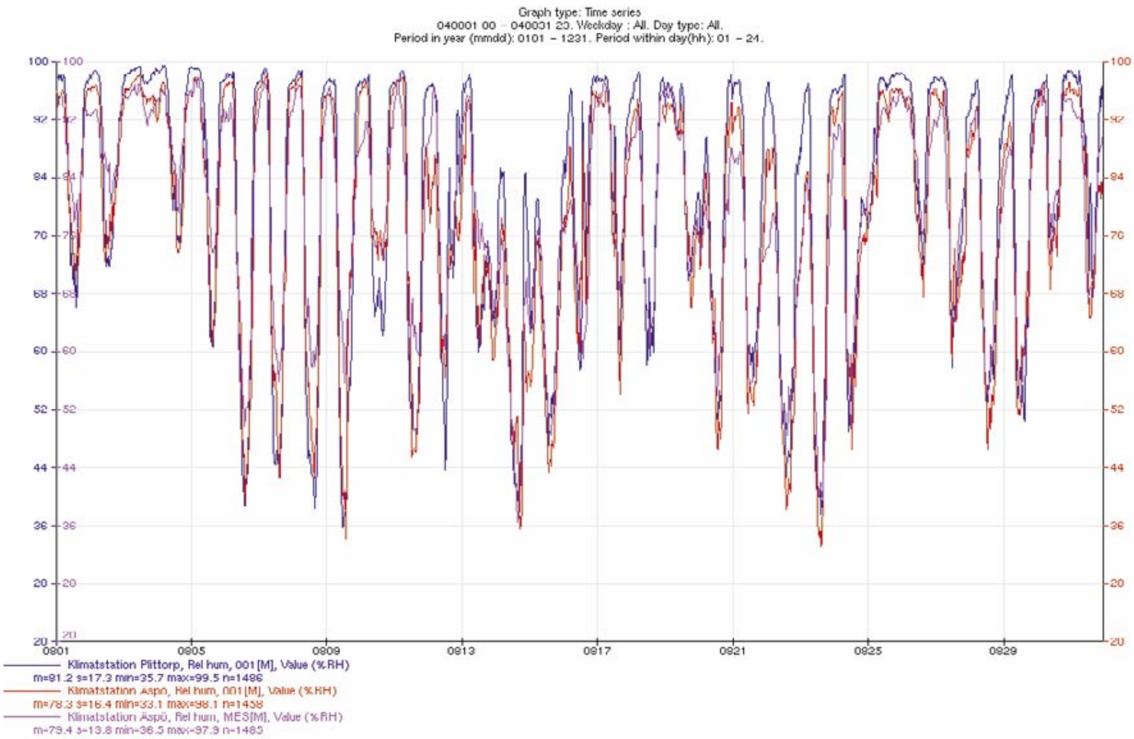


Figure A4-14. *August relative humidity.*

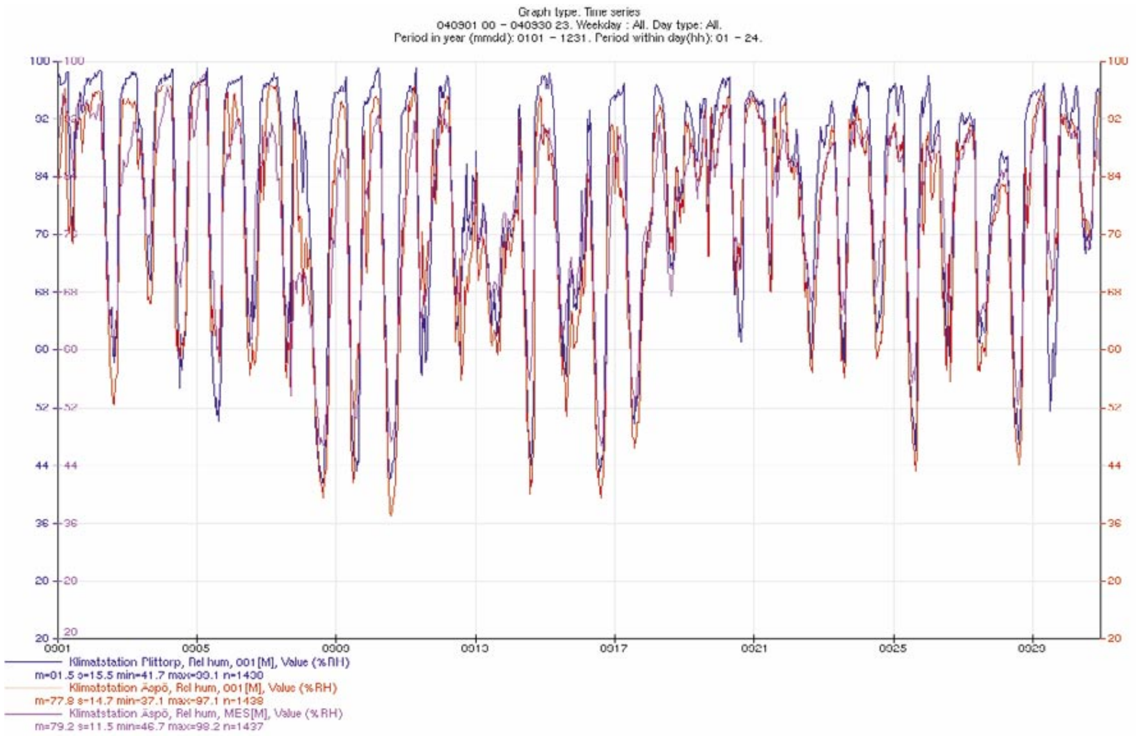


Figure A4-15. *September relative humidity.*

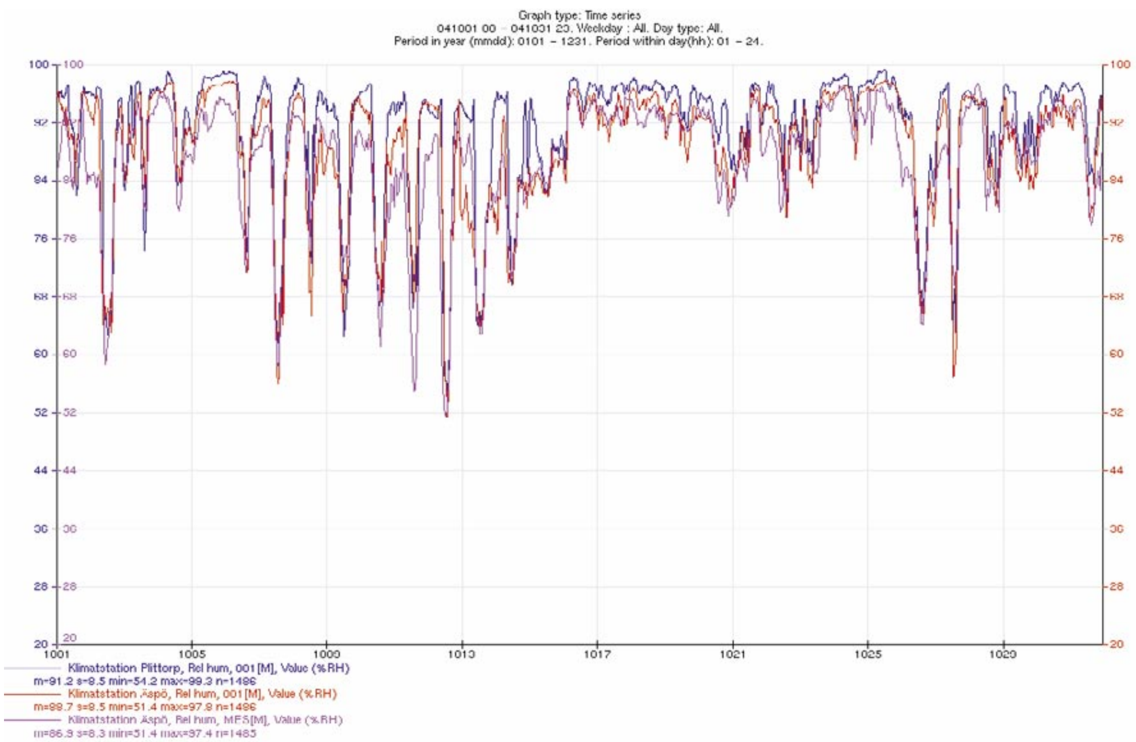


Figure A4-16. *October relative humidity.*

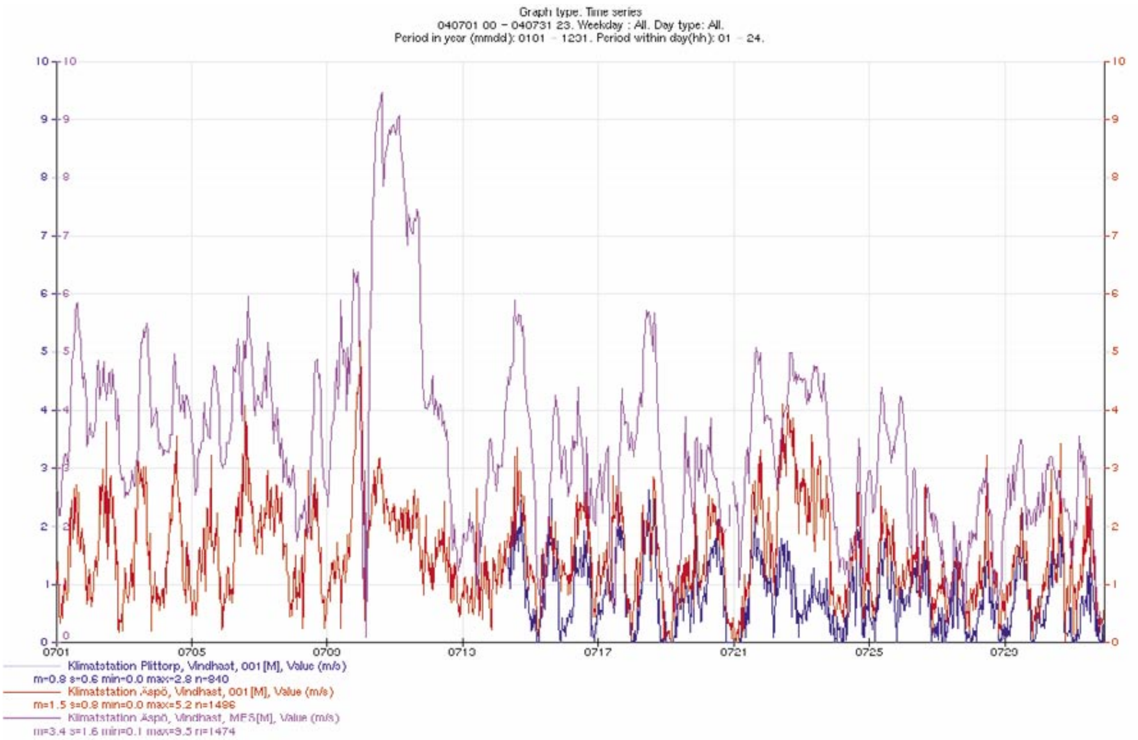


Figure A4-17. *July wind speed.*

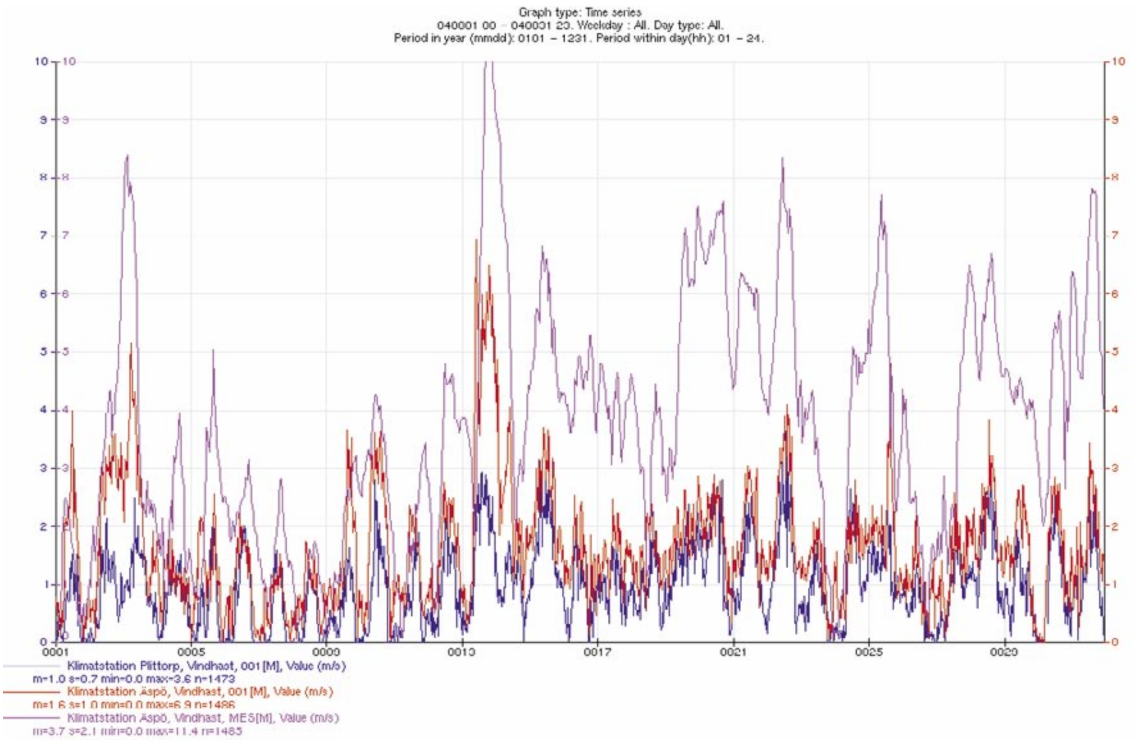


Figure A4-18. *August wind speed.*

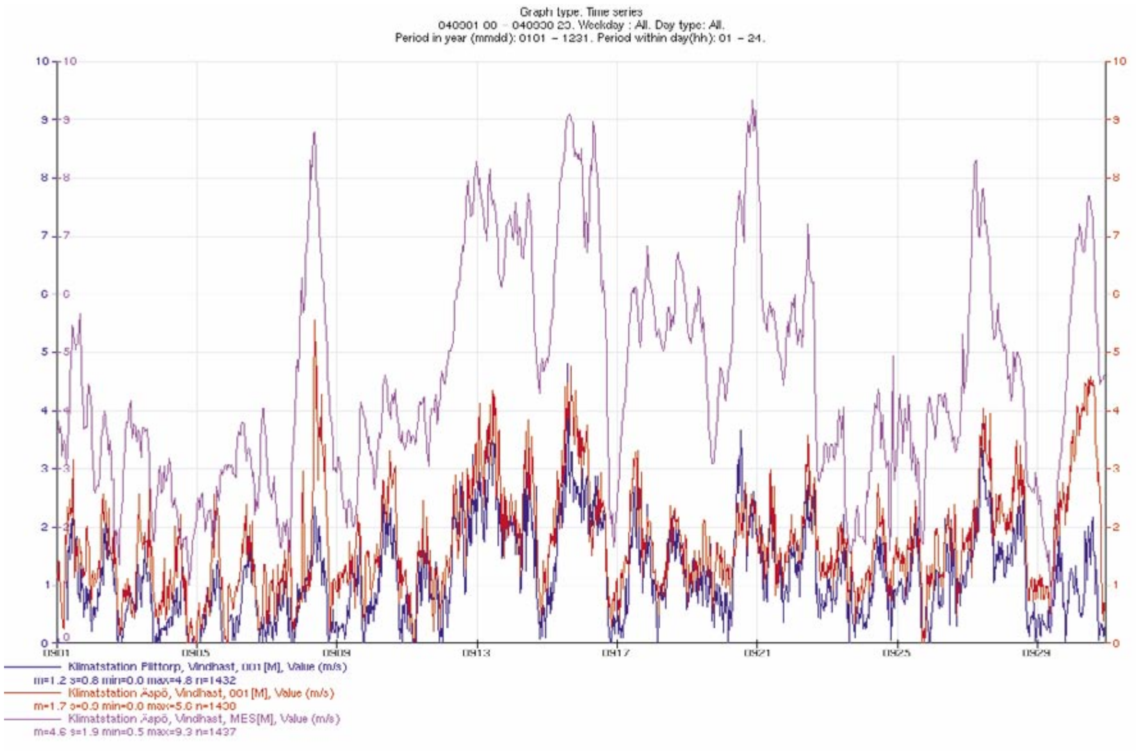


Figure A4-19. *September wind speed.*

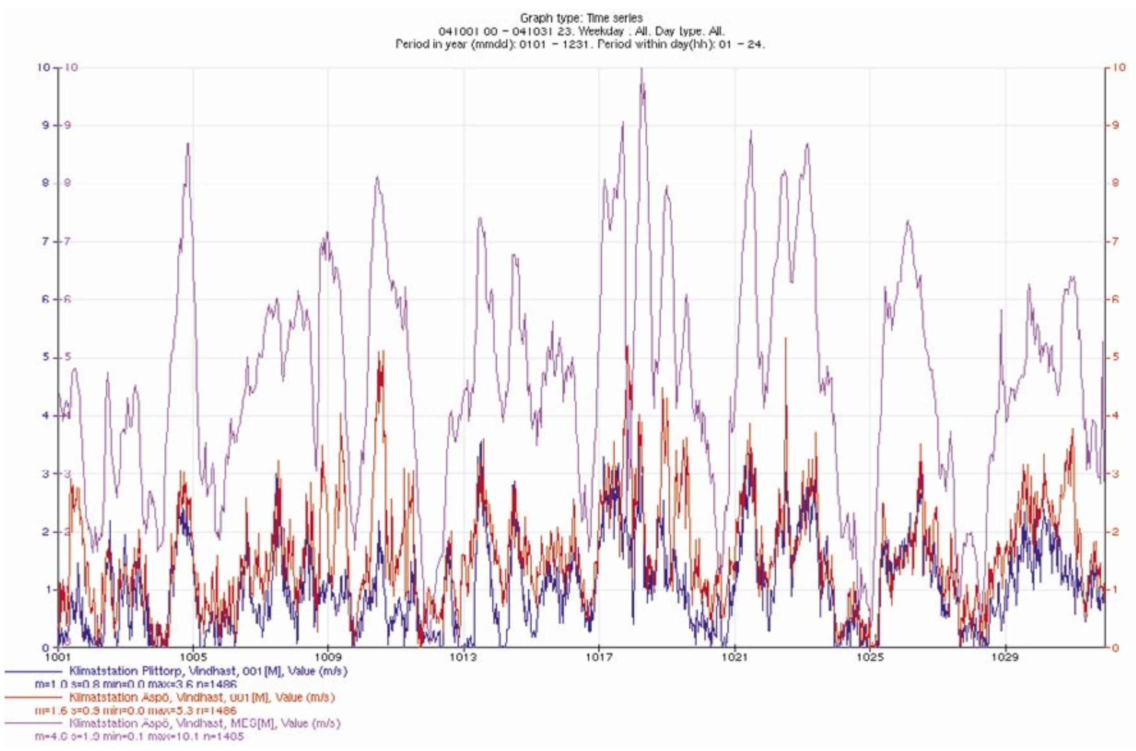


Figure A4-20. *October wind speed.*

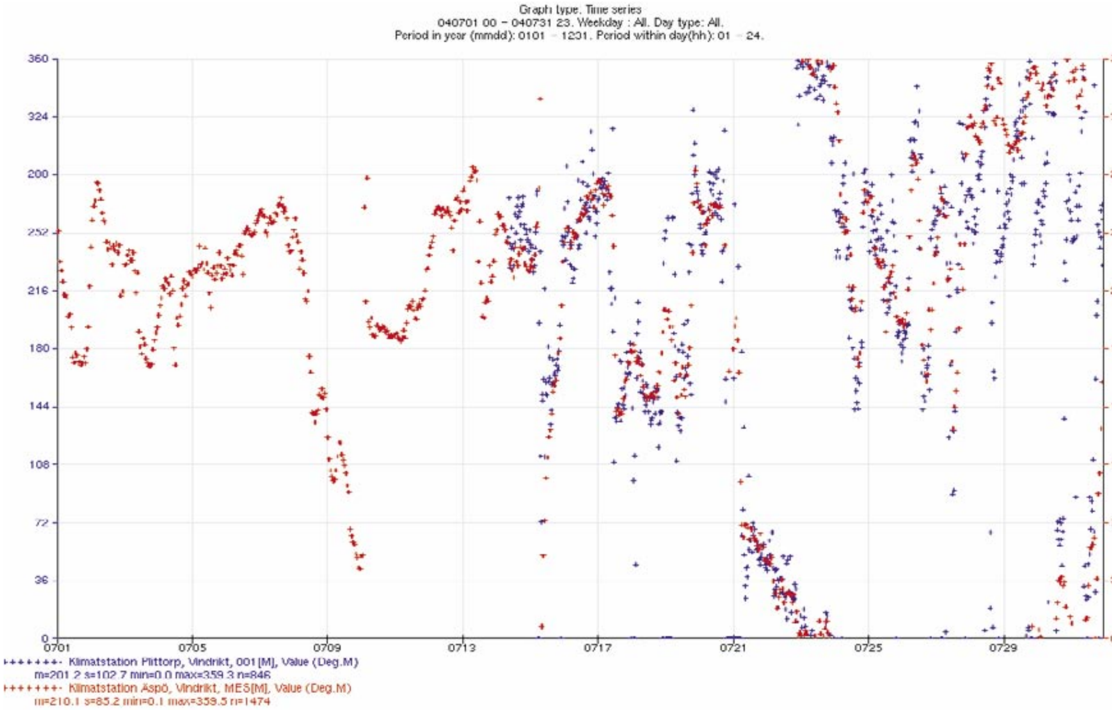


Figure A4-21. *July wind direction.*

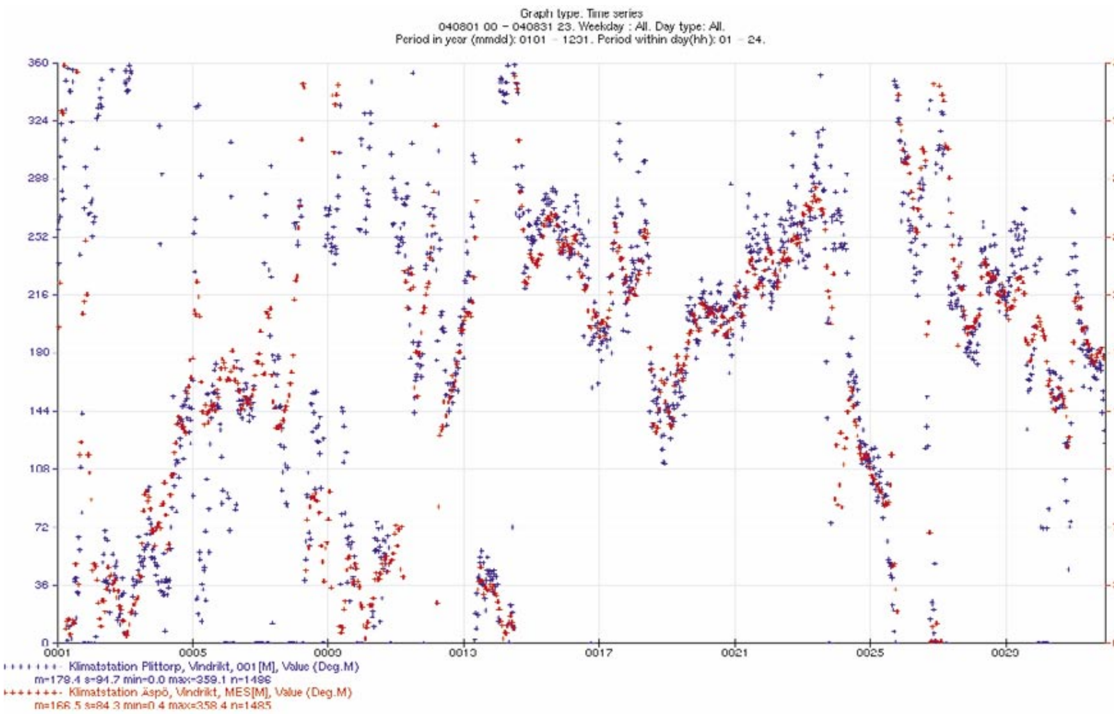


Figure A4-22. *August wind direction.*

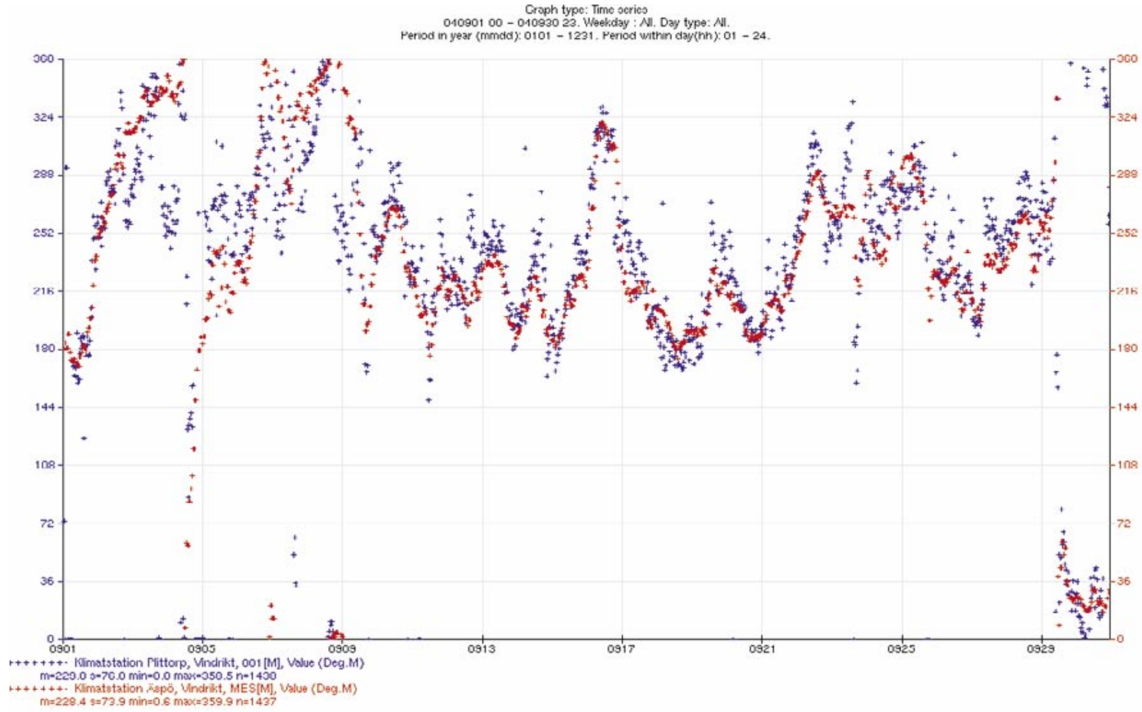


Figure A4-23. *September wind direction.*

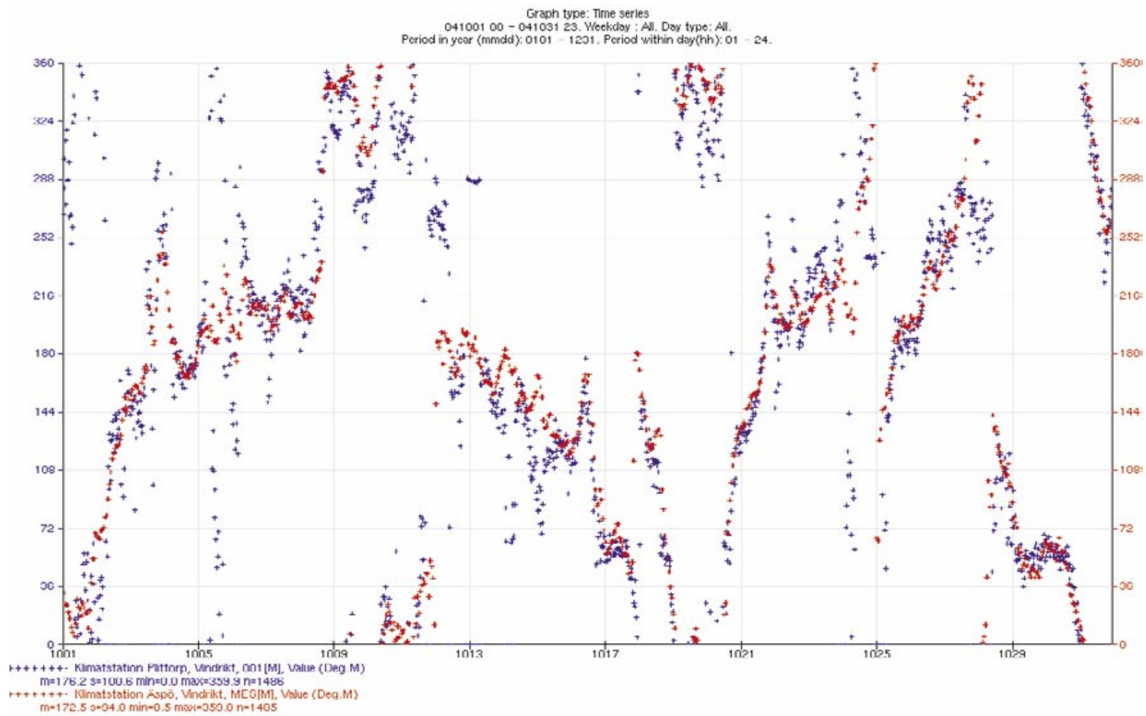


Figure A4-24. *October wind direction.*

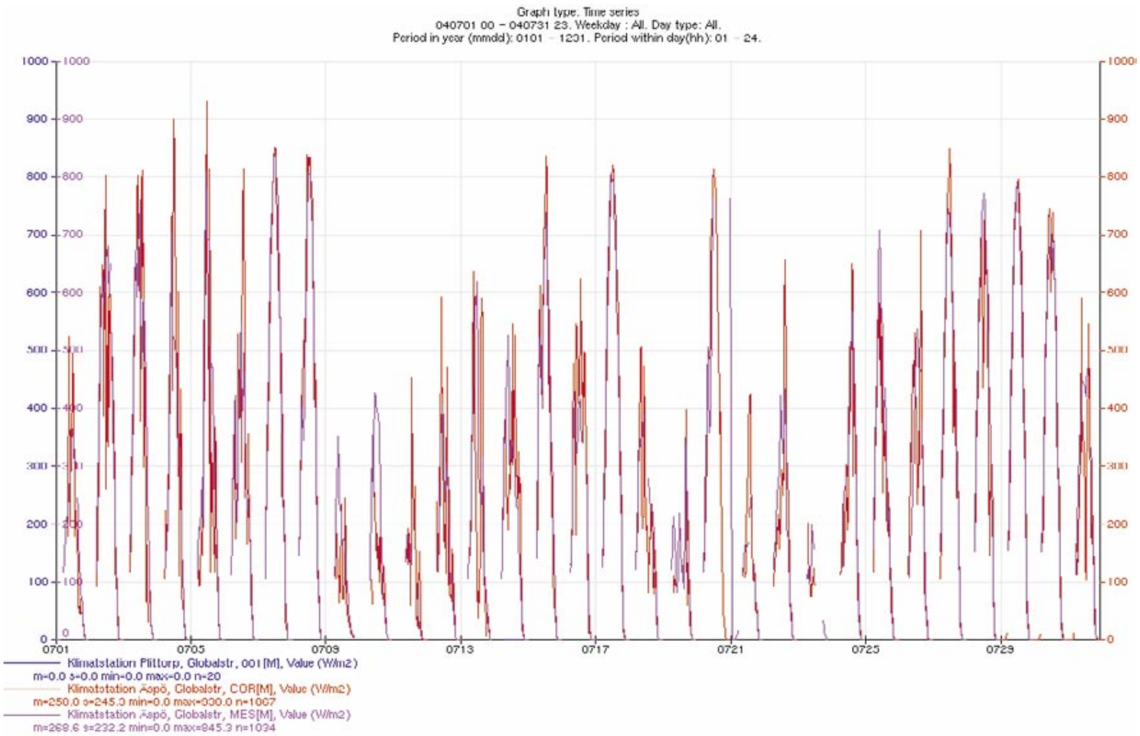


Figure A4-25. July global radiation.

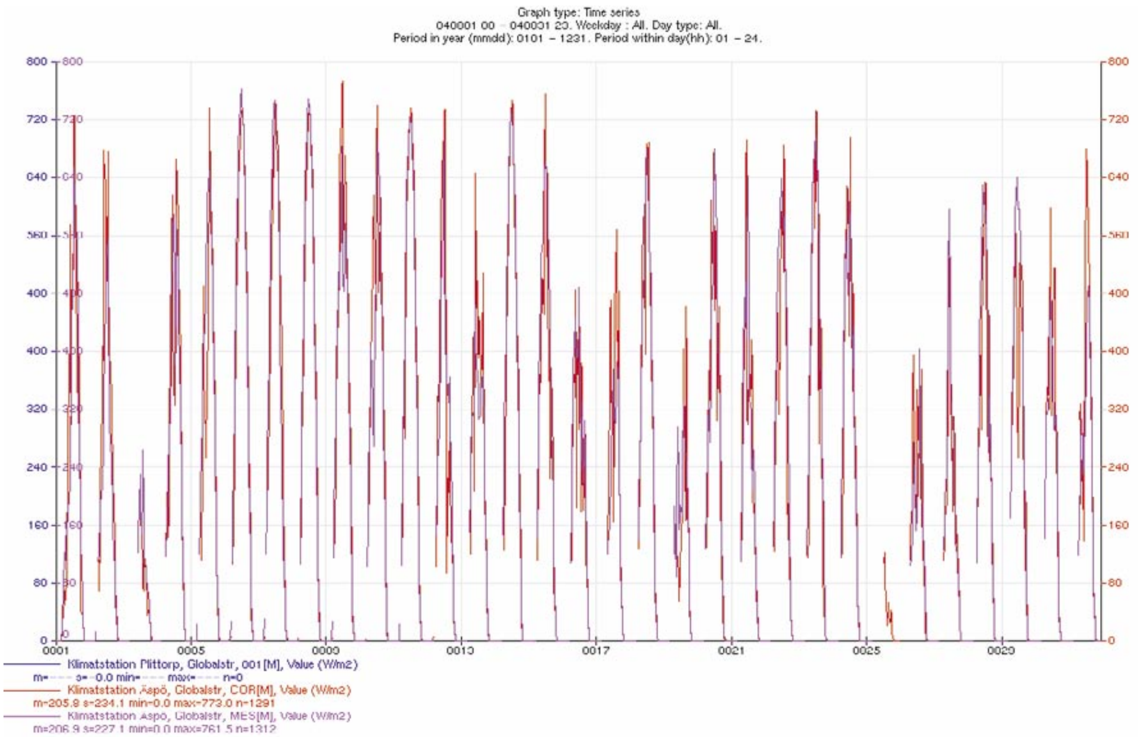


Figure A4-26. August global radiation.

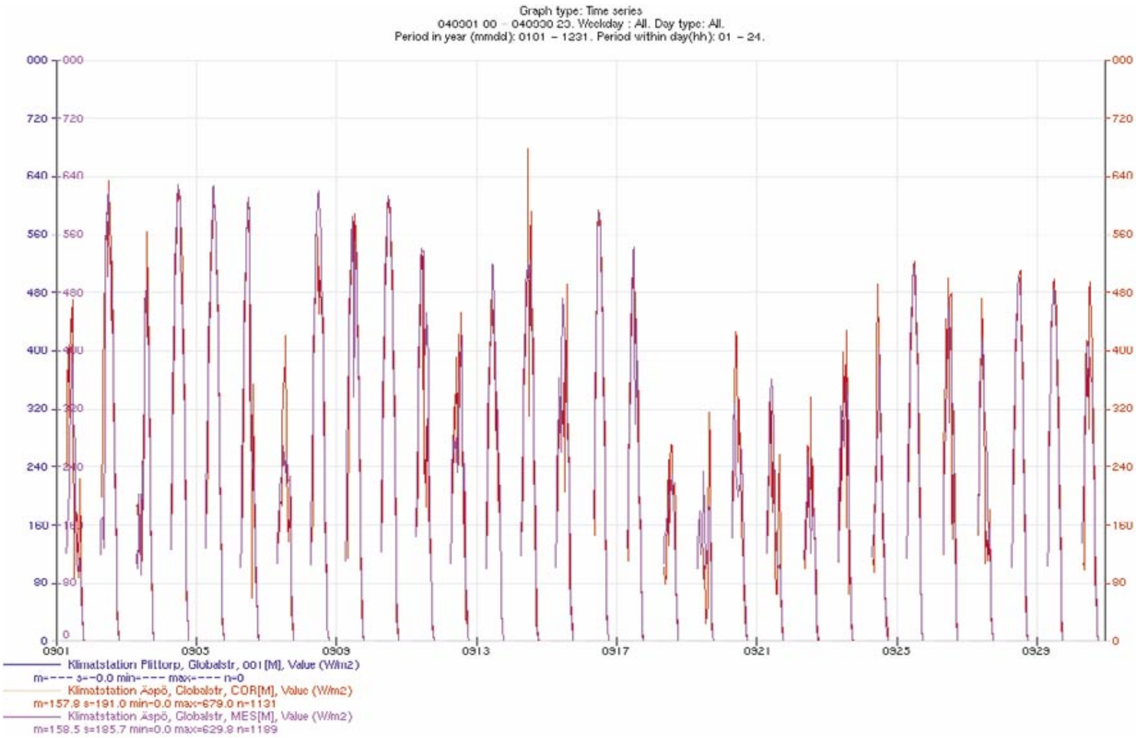


Figure A4-27. *September global radiation.*

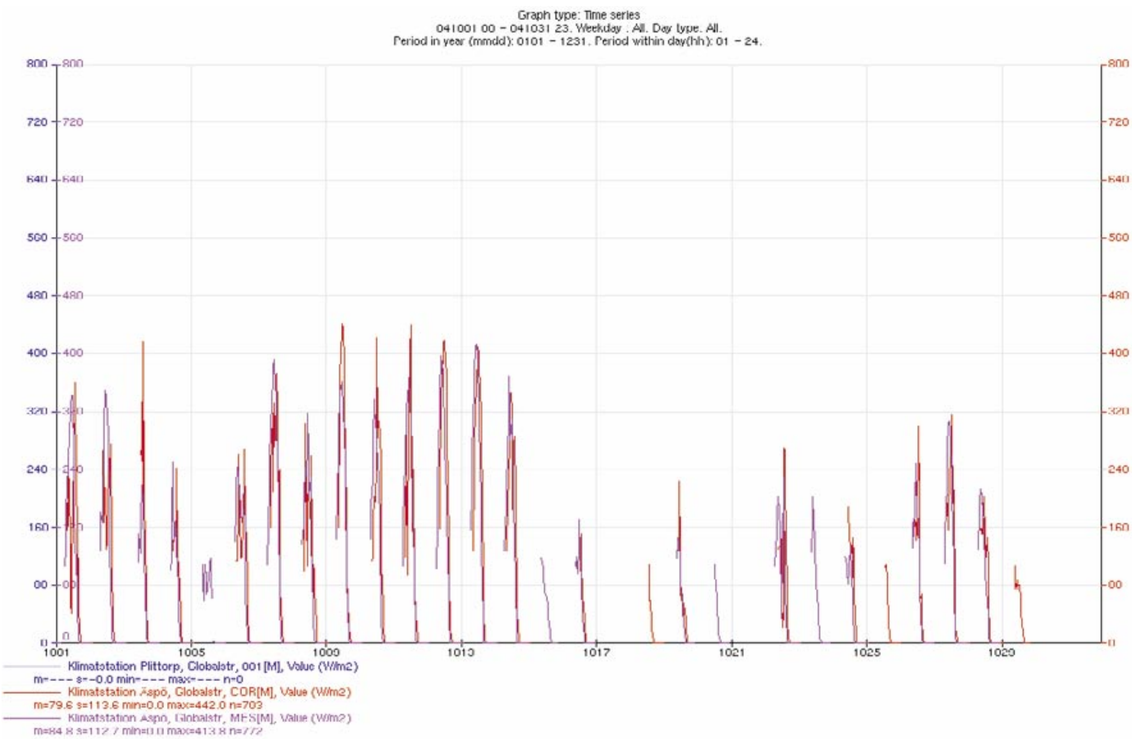


Figure A4-28. *October global radiation.*

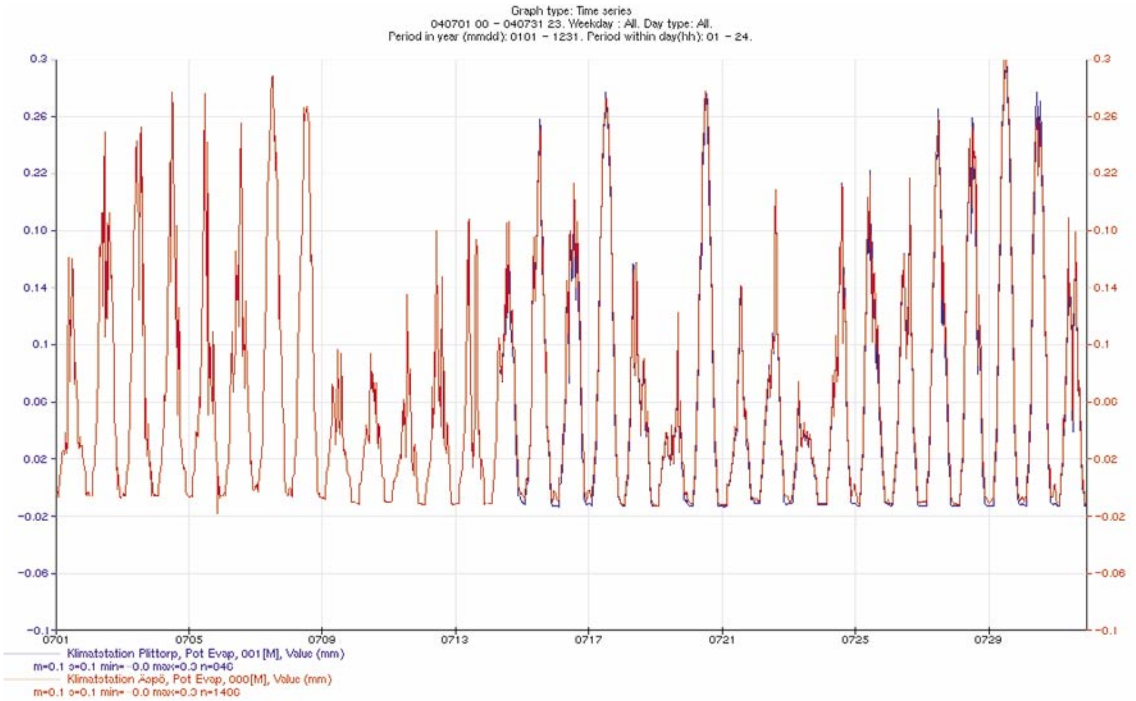


Figure A4-29. *July evapotranspiration.*

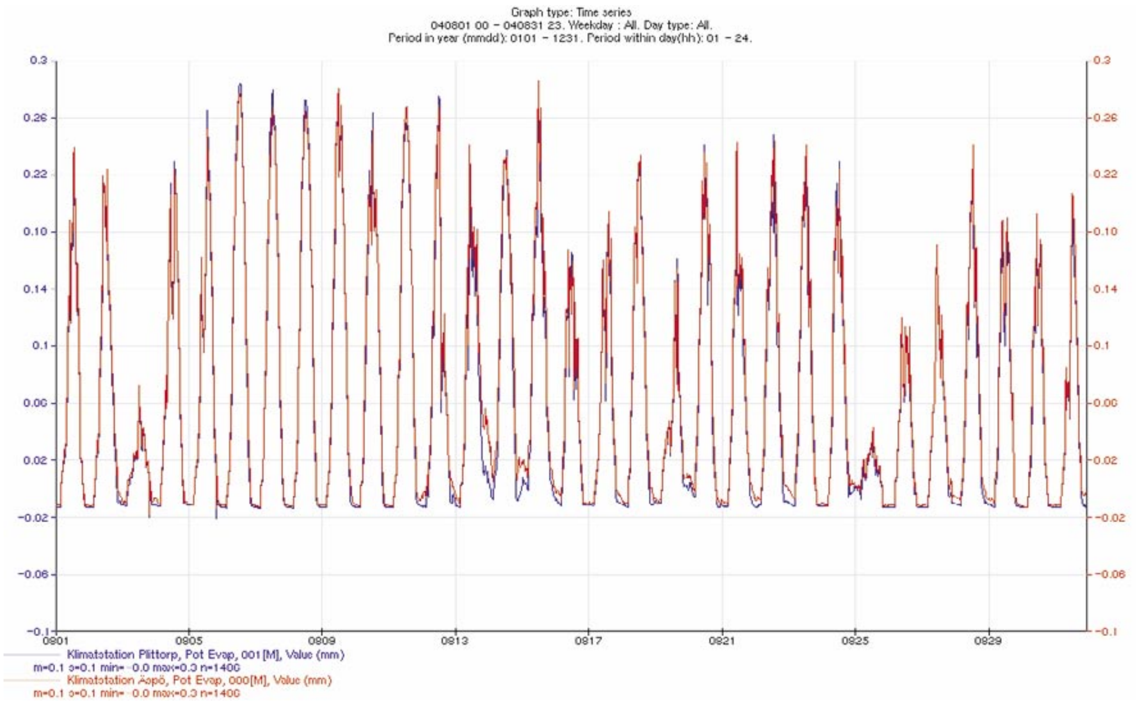


Figure A4-30. *August evapotranspiration.*

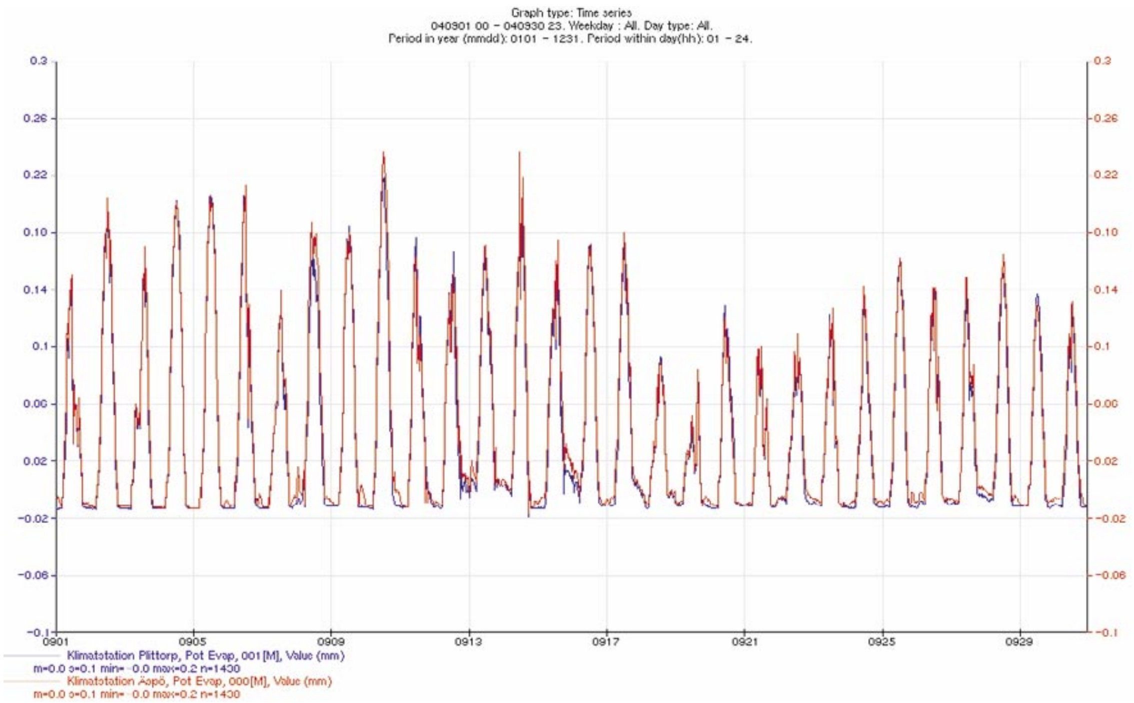


Figure A4-31. *September evapotranspiration.*

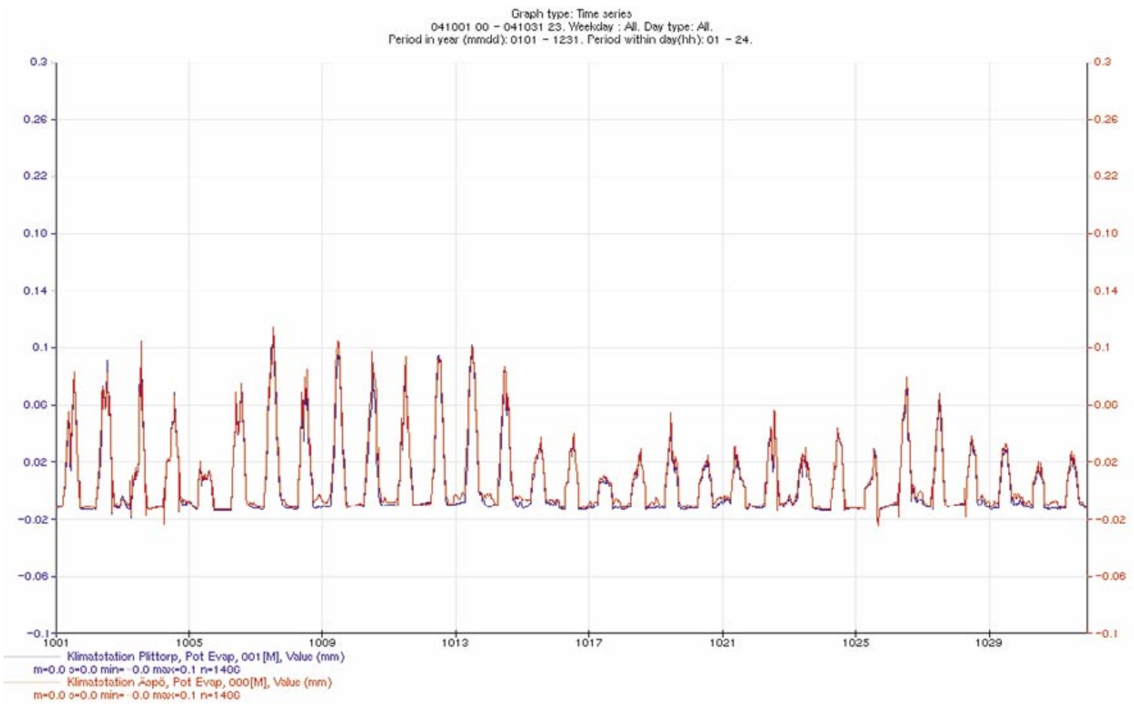


Figure A4-32. *October evapotranspiration.*