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Oskarshamn site investigation

Hydrological and meteorological monitoring at Oskarshamn, November 2004 until June 2005

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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, Äspö and Plittorp. Measured and calculated parameters at these stations are wind speed and direction, air humidity, precipitation, air pressure, global radiation and potential evapotranspiration. 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 fifteen 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. Hydrological measurements are performed at fifteen different places.

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

The quality of meteorological and hydrological measurements during the period concerned, starting 2004-11-01 and ending 2005-06-30 has showed to be rather good. It has been minor interrupts in measurements according to malfunctioning equipment. At hydrological stations intended for discharge measurements in watercourses, establishment of so-called rating curves or tables is needed 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 is made according to elevation system RT90-RHB70.

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 ställen, på Äspö och i Plittorp. Här har master med registrerade instrument monterats. De meteorologiska parametrar som mäts och bestäms är vind hastighet och riktning, luftfuktighet, nederbörd, lufttryck, globalstrålning och potentiell evapotranspiration. Sveriges Meteorologiska och Hydrologiska Institut, SMHI, har varit ansvariga för utformandet av de två meteorologiska mätstationerna. SMHI har också konstruerat och byggt 15 hydrologiska mätstationer. Vid dessa mäts vattennivåer i sjöar och i havet. Ytterligare parametrar som mäts är vattentemperatur och elektrisk konduktivitet samt bestämning av vattenföringar i vattendragen.

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.

Kvaliteten hos de meteorologiska och hydrologiska mätningarna utförda under perioden 2004-11-01 till och med 2005-06-30 har varit god. Det har endast förekommit några 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 i nuläget inte möjligt att beräkna någon avbördning för alla av dessa stationer. Vattenstånden registreras emellertid fortlöpande och då avbördningskurvor eller tabeller upprättats kan dessa vattenstånd i efterhand omräknas till vattenföring. Alla hydrologiska mätningar görs i höjdsystemet RT90-RHB70.

Contents

1 Introduction

This document reports the results of hydrological and meteorological measurements made in the area of Oskarshamn. The activities are 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 documents). 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 started in January 2004. Measured parameters are sea water level, water level in lakes and discharge in small creeks. Water temperature and conductivity are also measured at the runoff stations. At the moment hydrological measurements are made at fifteen different stations. Data presented in this document are quality checked and approved.

To characterise the investigation area regarding meteorological conditions SMHI has placed two stations with meteorological measuring equipment on the site. 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 period 2004-11-01 until 2005-06-30. The report also presents measurements made of winter parameters, depth of snow, depth of frost in ground and time for ice cover.

Controlling documents used in the activity presents in Table 1-1.

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
Registrering av snödjup, tjäldjup och tider för isläggning/islossning vintern 2002/2003	SKB AP PS 400-02-023	1.0
Installation av tjäldjupsmätare	Tillägg till SKB AP PS 400-02-023	–
Method descriptions	**Number**	**Version**
Meteorologiska mätningar	SKB MD 364.007	1.0
Ythydrologiska mätningar	SKB MD 364.008	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 two stations with meteorological measuring equipment at the site. The results will be used for calculations of hydrological parameters.

Hydrological measurements are performed at fifteen different places. At these places, measurements have been made during different times because building of stations has currently been going. The first stations was built in January 2004 and the last hydrological station where built in the end of January 2005. 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 winter parameters within the Oskarshamn area, during wintertime.

The objective with this report is to present quality checked results from hydrological and meteorological monitoring made during the period 2004-11-01 until 2005-06-30.

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, PSM345, PSM347 and PSM365 are constructed in concrete as V-notch weirs (triangular shaped outlet of water). At these stations, measurements are made with a Campbell CR10X data logger. A cellular phone and a GSM modem Siemens TC35, 9600 baud, establish communication. A dry cellular battery, CellTech (15 V, 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. Water level is measured in metres above sea level, m.a.s.l. Sensors and measured parameters are presented in Table 3-2.

Table 3-1. Sensors and measured parameters at stations PSM341, PSM343, PSM345, PSM347 and PSM365.

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 data logger. 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 14 V, 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.

The wind is measured at 10 metres above ground level, the other parameters at 2 metres.

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 warming 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 is 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.

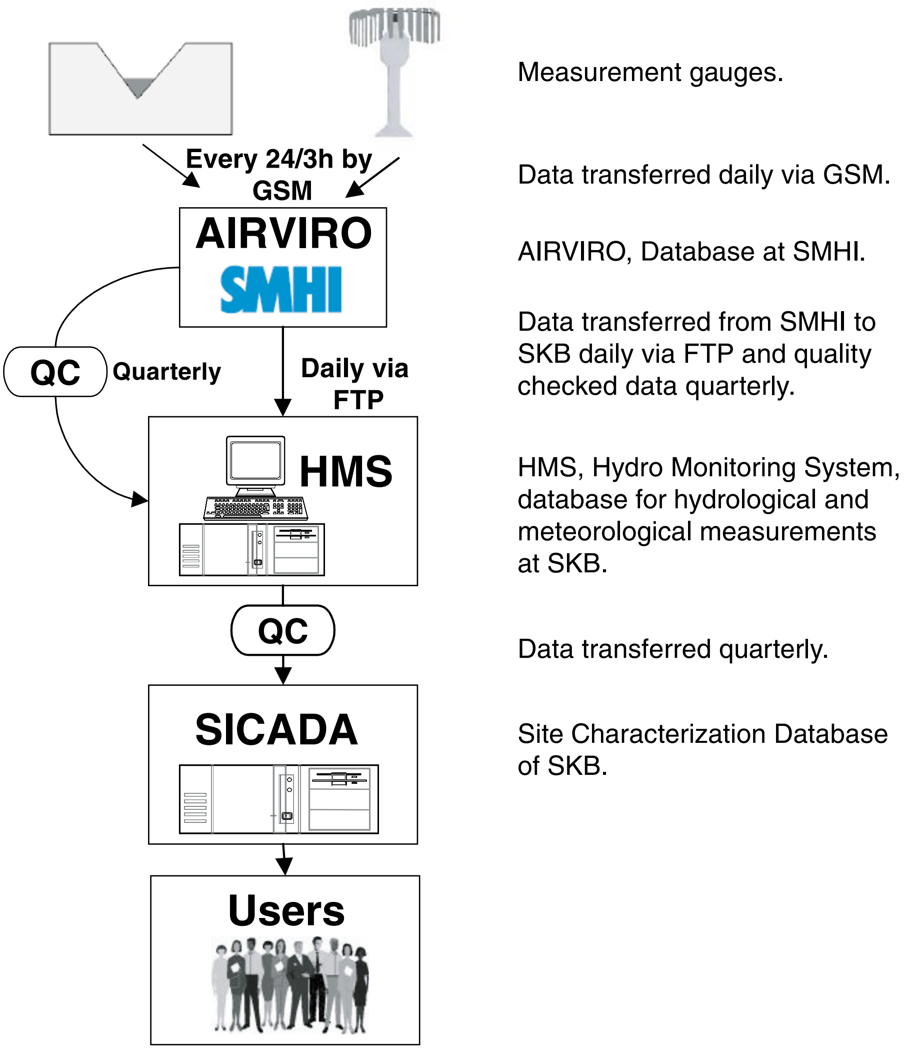


***Figure 4-1.** Flowchart – meteorological and hydrological data.*

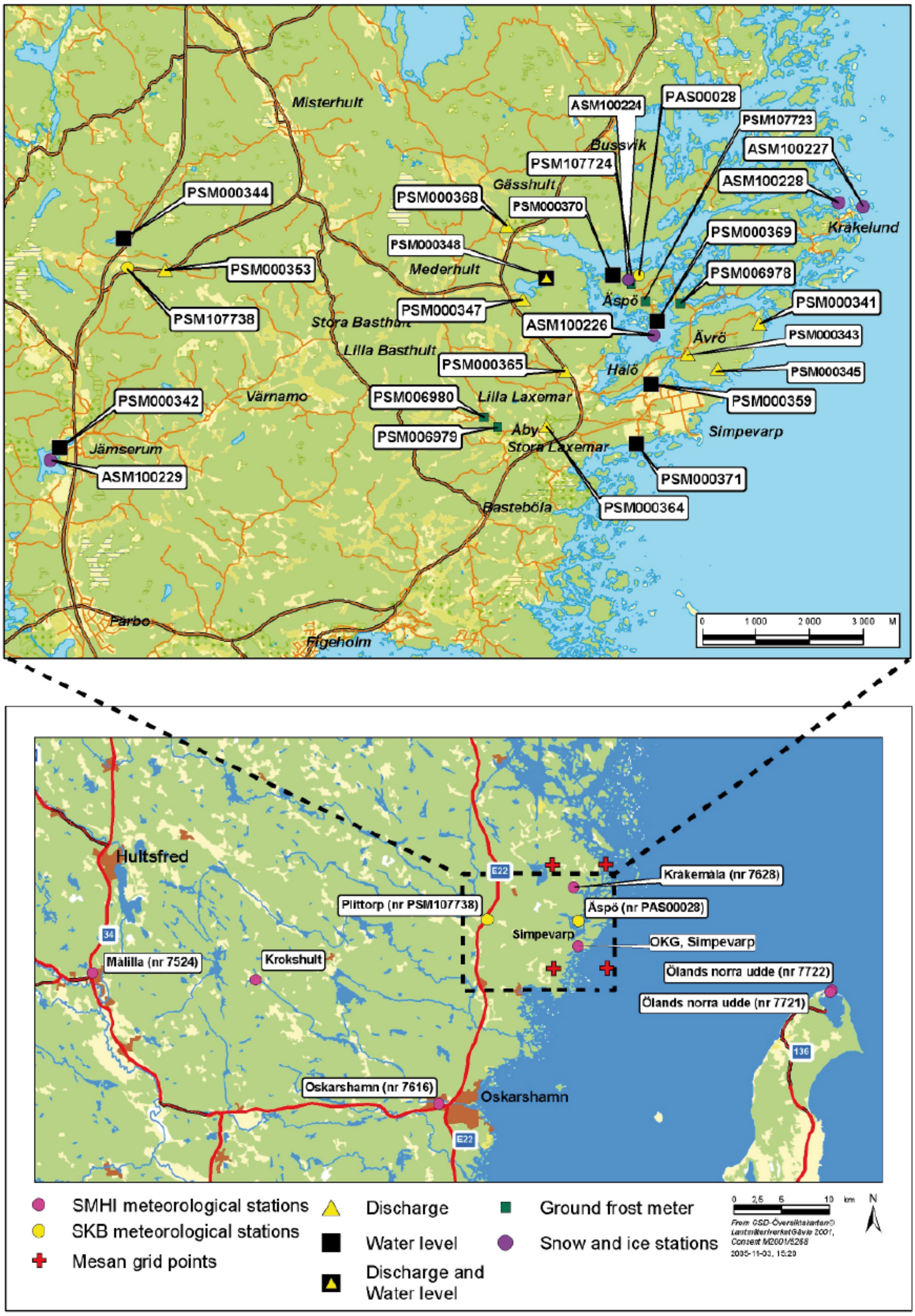


Figure 4-2. Map showing objects of all monitoring stations.

4.2 Hydrological measurements

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 and the actual water level is then set in the data logger.

At the runoff stations, the water head above the V-notch should be set in the data logger.

The probe used for measuring conductivity and water temperature should be tested in water with known conductivity. The water temperature should be measured with a reference thermometer. The measured value in the data logger 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 trough the V-notch is not blocked or influenced by ice, leaves or debris. For this reason SKB have established a scheduled standard procedure for regular inspection of the stations.

4.2.1 Discharge in water courses

Hourly measurements of discharge is made at nine stations but currently are discharges calculated only at five places where dams are built, PSM341, PSM343, PSM345, PSM347 and PSM365. At the other four stations, discharge is measured using a natural cross section in the watercourse and no reliable rating curves have yet been established. A rating curve describes the relationship between the measured water stage and the corresponding discharge. It usually takes some time to gain a reliable rating curve and until then measurements of water level are stored at these four stations.

At stations PSM341, PSM343, PSM345, PSM347 and PSM365 discharge is measured with a V-notch weir. It is a concrete dam with a triangular, V-notch, shaped outlet. The opening angle in the V-notch varies between these stations from 45°, 60° and 120° and theoretically, the discharge, Q, could be derived from a discharge formula. The upstream level 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/:

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

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 discharge 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.

At the moment discharges at station PSM341, PSM343 and PSM345 are calculated from rating curves established from control measurements made by SKB and SMHI. At station PSM347 and PSM365 discharges are calculated with the discharge formula. In calculations at these stations the value of the coefficient,μ have been set to a reasonable value of 0.60. Presently we do not now if this is a proper value of the coefficient,μ for both these 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 bee dried up during greater part of the year. The drainage area and the opening angle in V-notch for each dam are 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 metres above sea level (m.a.s.l.) in elevation system RT90-RHB70. The drainage area for each station is presented in Table 4-2.

Table 4-1. Drainage area and V-notch angle for the dams.

Station Id	Object	Measuring place	V-notch opening angle	Drainage area (km^2)
PSM341	Ävrö NE	Dam	45°	0.25
PSM343	Ävrö SW	Dam	45°	0.09
PSM345	Ävrö SE	Dam	45°	0.14
PSM347	Frisksjön (in)	Dam	60°	0.8
PSM365	Ekerumsån	Dam	120°	2.4

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 also 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 the sensor is placed as deep as possible in the creek or 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 are in elevation system RT90-RHB70. At one station, PSM359, the water level in the reservoir at Sörå is measured. 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 metres 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 min 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 Quality check of meteorological data

Before any data finally will be stored in SKB's database SICADA they have to be controlled and approved by SMHI. Every week a primary check for missing and incorrect values will be performed by SMHI and every third month the check will be performed by a meteorologist at SMHI that will approve data, calculate potential evapotranspiration and estimate the true precipitation before delivery for final storage in SKB's database, SICADA.

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 is stored and the quality assurance and check is done. After this check 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/.

4.4 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 received 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.

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

Measurement/observation	Id-code	Name
Snow depth	ASM100224	Grillplatsen
Frost in ground	PSM107724	Grillplatsen
	PSM006978	Löv1
	PSM006979	Grindstugan
	PSM006980	Åker
Ice cover	ASM100226	Äspö brygga
	ASM100227	Kråkelund
	ASM100228	Kråkelund inre
	ASM100229	Jämsen

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, see 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.

4.4.3 Frost in ground

For measurement of frost in the ground, equipment according to Section 3.3.2 was used. The measurements were carried out at four places representative for the local conditions, taking in consideration soil characteristics and topography (see Figure 4-2).

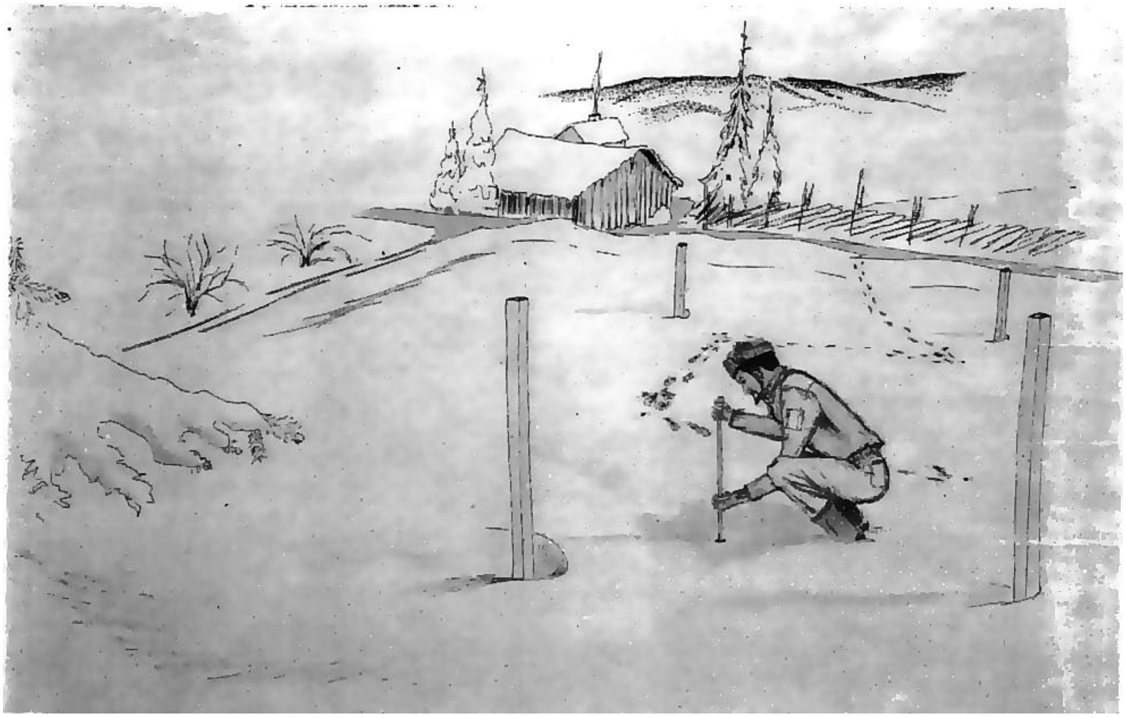


Figure 4-3. *Measurement of snow depth, from SMHI's Handbook for observers /2/.*

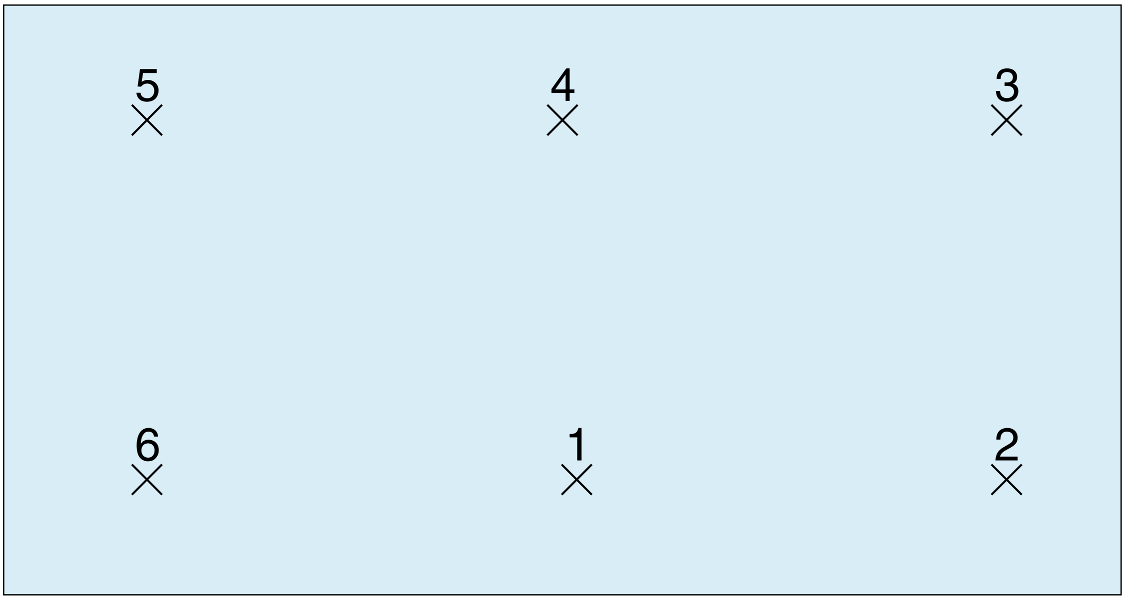


Figure 4-4. *Placement of the graded measuring stick in the area for measuring of snow depth. The distance between the measuring points is 1.5–2 m.*

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 all dams. Calculations are made for the period 2005-02-01 until 2005-06-30 because data are available for all stations during this period. Runoff in this part of Sweden based on measurements during the years 1961–1990 is about 5 $l/(s \cdot km^2)$. Discharge at PSM341, PSM343 and PSM345 is calculated using a rating curve based on control measurements made by SKB and SMHI. Compared to the long-term mean value the runoff at station PSM343 seems to be overestimated, Figure 4-5. It seems, as there still is a need of some more control measurements at this station. Continuously such control measurements carries out and historical measurements of discharge recalculates when reliable rating curves are established. Discharge at station PSM347 and PSM365 is calculated by the theoretical discharge formula.

4.5.2 Meteorological measurements

SMHI has continuously checked the collected data, i.e. checked that the data is within the limits of reason for each parameter. The data have also 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 has been stored in a special database. In Table 4-4 you can see the coordinates of the nearest grid points.

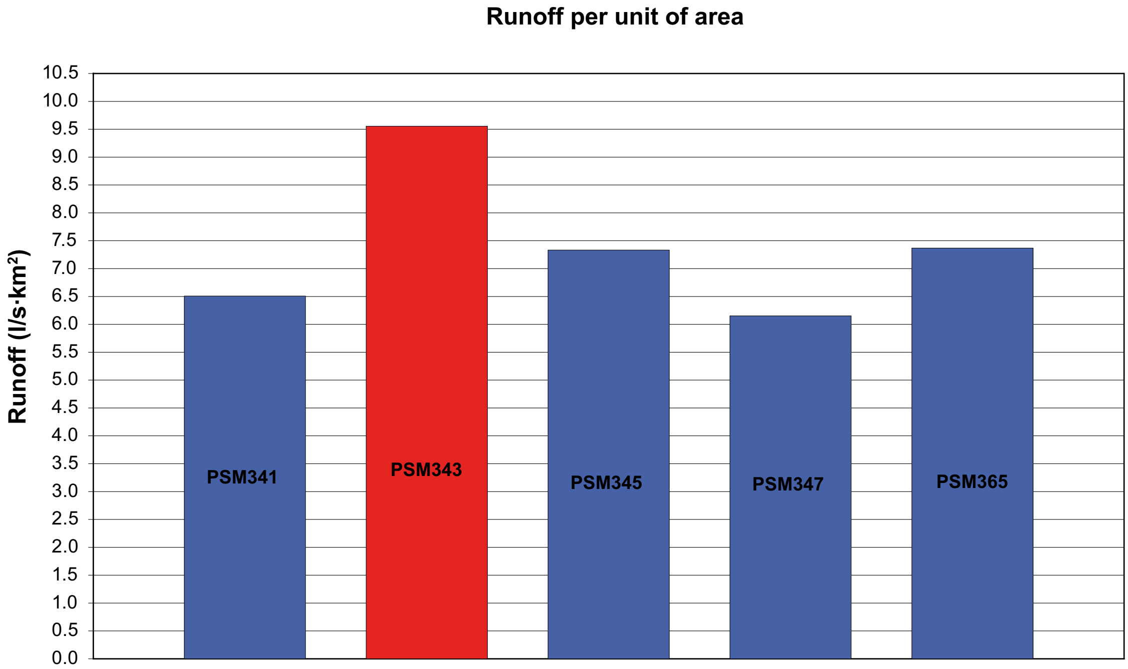


Figure 4-5. *Runoff expressed as l/s·km^2. Runoff at station PSM343 seem to be overestimated and more control measurements are needed.*

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

Discharge data can not be calculated until reliable rating curves are established. For the dams or V-notch stations, PSM341, PSM343, PSM345, PSM347 and PSM365 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 constructed before any discharge values can be calculated.

4.6.2 Meteorological measurements

There are no nonconformity’s that affect the result or nonconformity’s with respect to activity plan or method descriptions.

4.7 Missing data and system malfunctions

4.7.1 Hydrological measurements

At station PSM369, measuring sea water level the cable connecting the pressure probe to the data logger was cut off. Sabotage or not we actually do not know for sure. This caused an interruption in data during the period 2005-03-03 20:00 until 2005-03-21 16:00. All data registered by the data logger during this period have been deleted.

4.7.2 Meteorological measurements

Everything has been collected with good result during the last year. A minor problem with the communication between AIRVIRO to the logger occurred in the beginning of April for a short period, but no data was lost.

5 Results

5.1 Hydrological monitoring

Totally fifteen hydrological stations are built. Hydrological measurements at these stations have worked rather well during the period 2004-11-01 until 2005-06-30. It has only been minor interruptions in measurements caused by malfunctioning equipment. The quality of measurements regarding water levels in lakes, reservoirs and sea 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 depends on the maintenance of the basin upstream the dam. Therefore, it is very important that the dams are cleaned 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. At discharge stations, using a natural cross section most corrections of measured water levels are made during the time of ice break up. Ice in the watercourse is then building ice jams and measured water levels are not representative for discharge calculations. The water level in such situations have been interpolated between the level before and after the occasion of the peek caused by the ice jam.

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. It has turned out that it seems to be very important that the temperature and conductivity sensors are kept clean. During the vegetation period, the sensors seem to be covered with organic material and for that reason, it is necessary to clean the sensors at some occasions during this period. The smallest watercourses dry up a great part of the season and the sensors must be cleaned during such periods. Otherwise, there is a risk of erroneous values when the water starts to flow again.

5.1.1 Discharge

PSM341, PSM343, PSM345, PSM347 and PSM365

The quality checked values of discharge from the five stations with constructed dams are presented in Figure 5-1 and 5-2. Adjustment of measurements has been made to all stations at several occasions because the V-notches have been blocked.

PSM348, PSM353, PSM364 and PSM368

At four stations discharge is measured by using a natural cross section in the watercourse i.e. no dams are constructed. Presently no calculation of discharge is made because 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 elevation system RT90-RHB70. At station, PSM348 the discharge represents the outflow from lake Frisksjön. At all other places discharge is measured in the creek. The

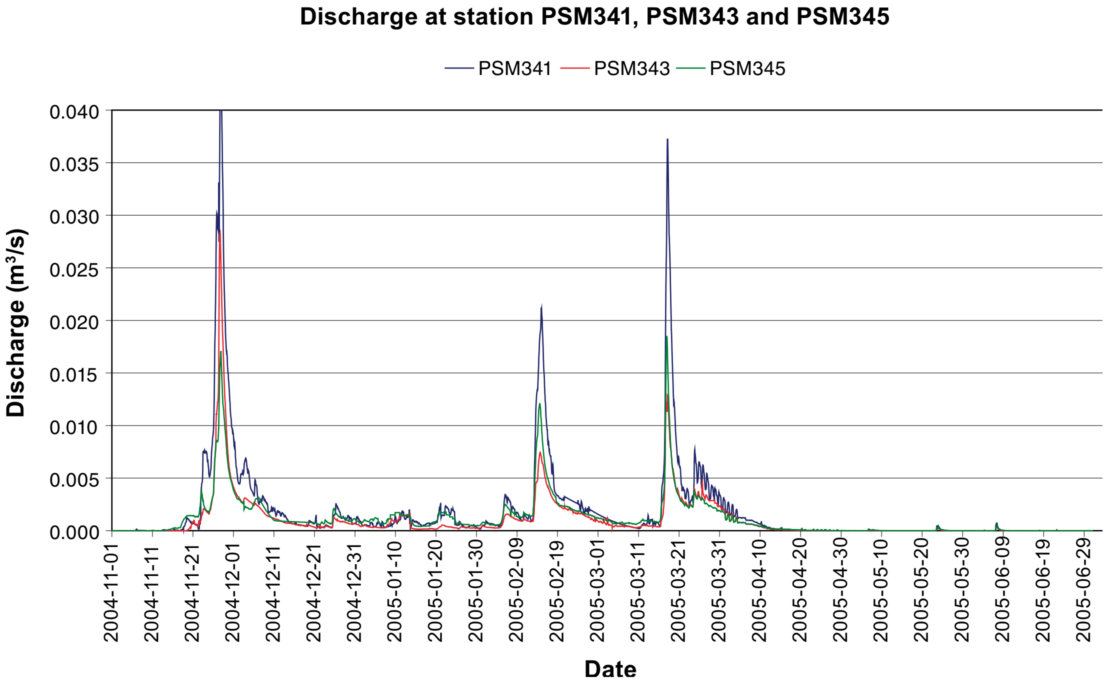


Figure 5-1. *Discharge calculated with preliminary rating curves, m³/s, at stations PSM341, PSM343 and PSM345.*

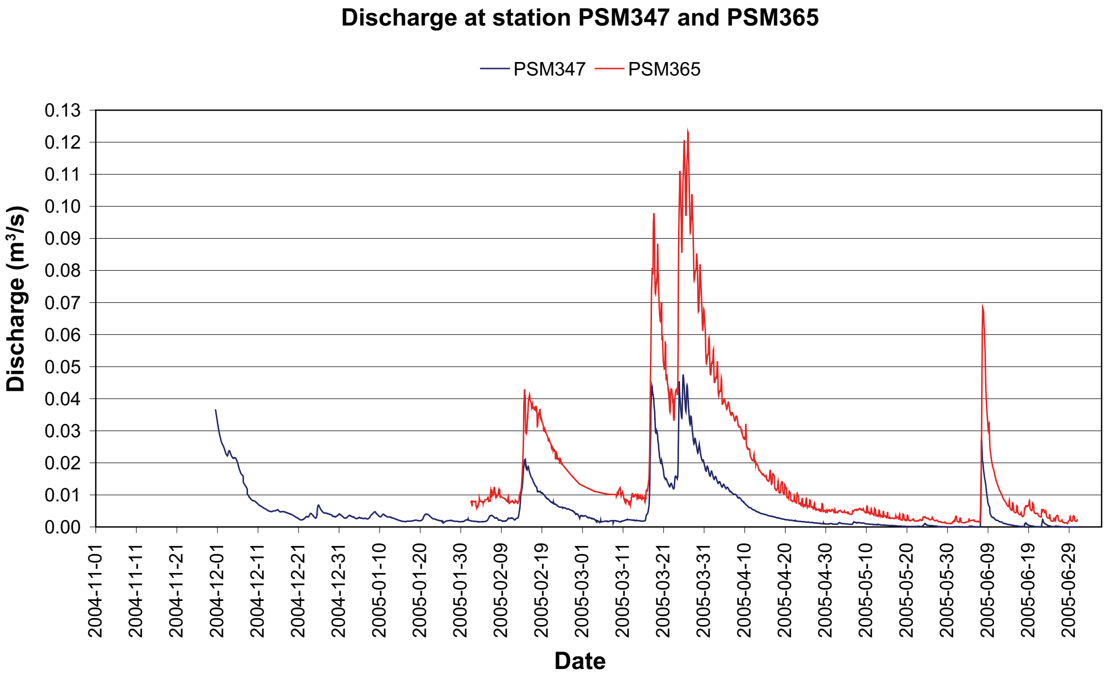


Figure 5-2. *Discharge calculated with preliminary rating curves, m³/s, for station PSM347 and PSM365.*

quality checked results from measurements of water level made so far could be seen in Figures 5-3 to 5-5. It has not been necessary to make any corrections of measured values during this period.

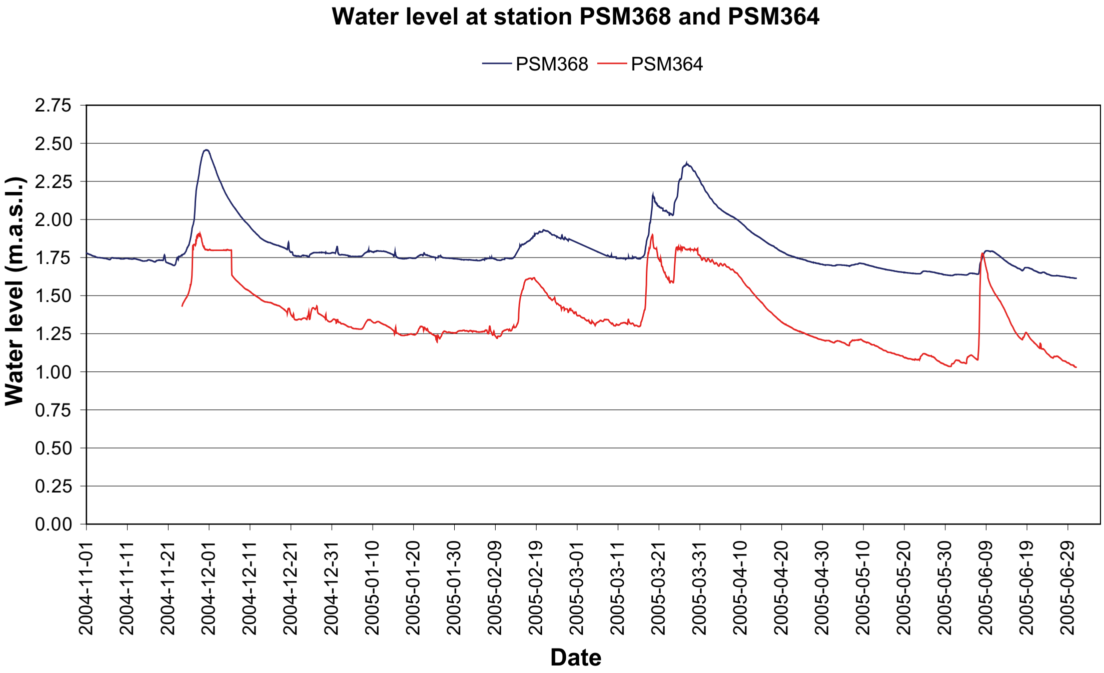


Figure 5-3. Water level measured at stations PSM364 and PSM368 in metres above sea level (m.a.s.l.).

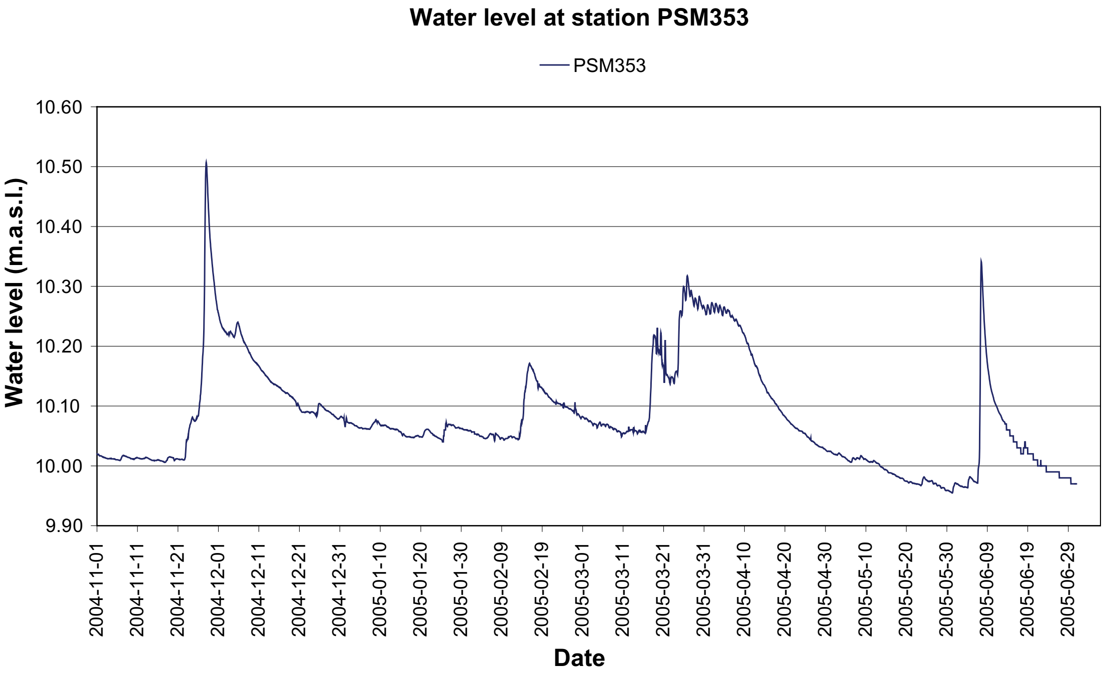


Figure 5-4. Water level measured at station PSM353 in metres above sea level (m.a.s.l.).

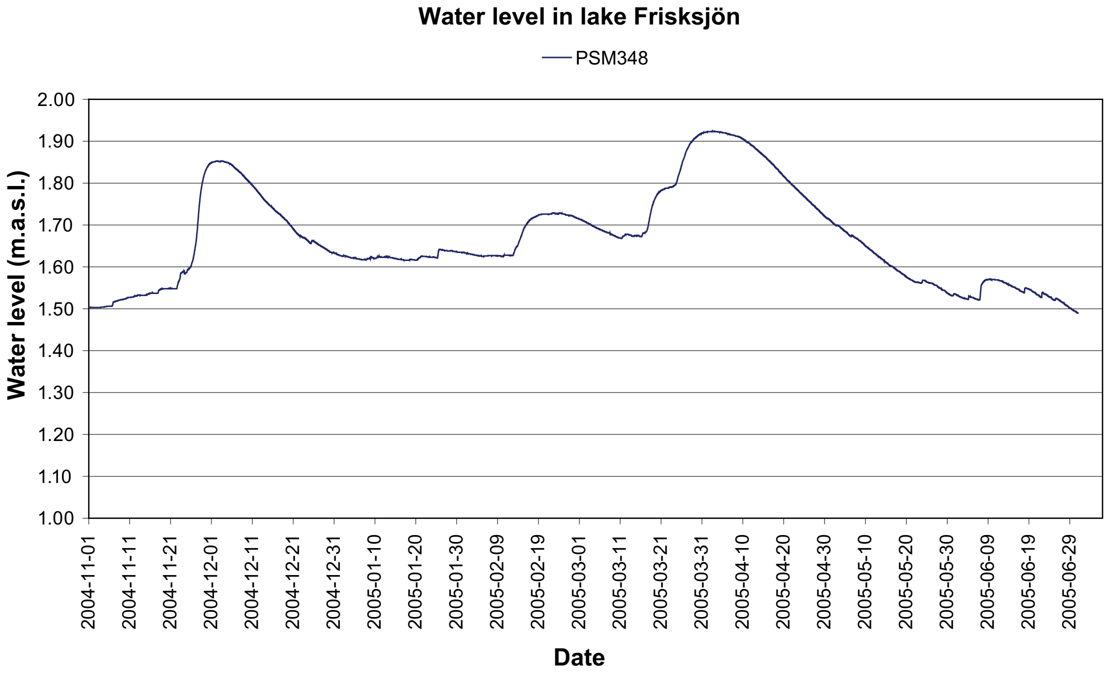


Figure 5-5. *Water level measured in lake Frisksjön in metres above sea level (m.a.s.l.).*

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. 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 5-6. 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 are in elevation system RT90-RHB70. It has not been necessary to make any corrections of data at all during this period. The measured water levels can bee seen in Figure 5-7.

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 level can bee seen in Figure 5-8. No corrections are made during time of measurements.

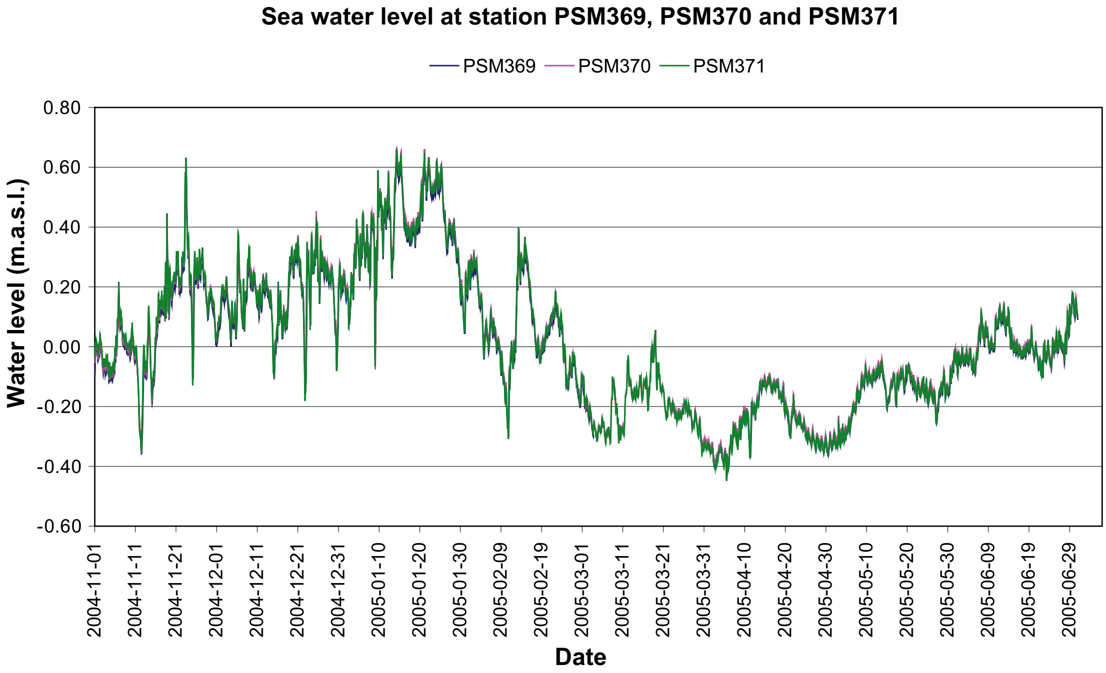


Figure 5-6. *Sea water level measured at station PSM369, PSM370 and PSM371. All measurements made in elevation system RT90-RHB70.*

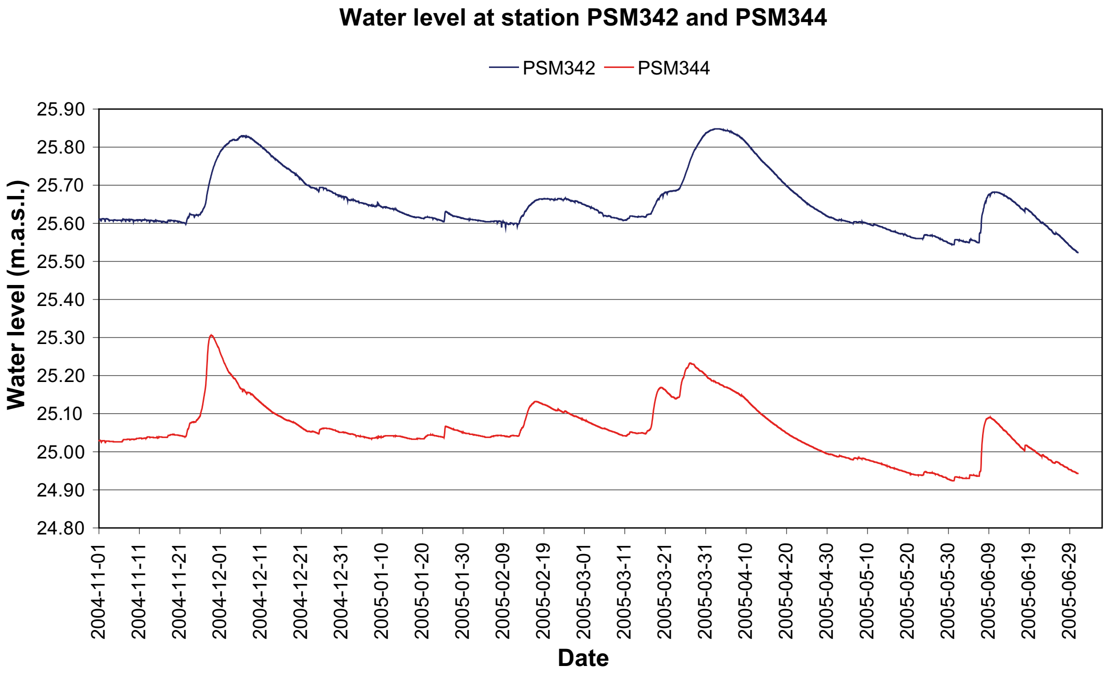


Figure 5-7. *Water level measured at station PSM342 and PSM344. The blue line shows the development of water level for lake Jämsen and the red line for lake Plittorpsgöl. Measurements made in metres above sea level (m.a.s.l.).*

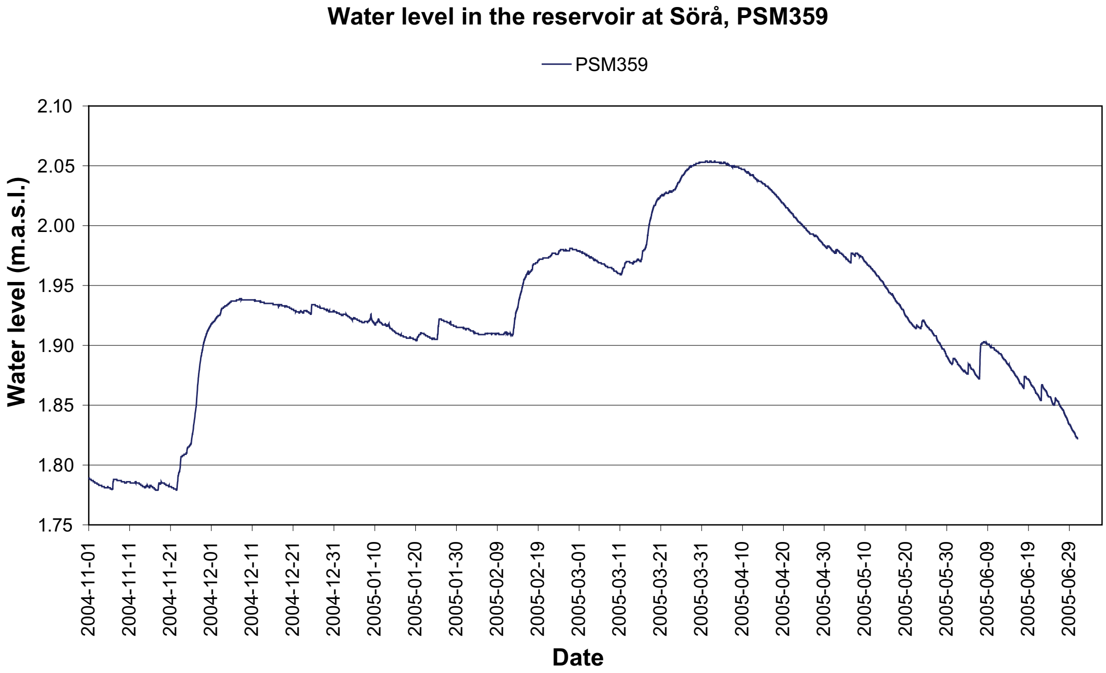


Figure 5-8. *Water level measured in m.a.s.l. at station PSM359. The blue line shows the development of water level in the reservoir at Sörå.*

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. Temperature measurements have worked well and no adjustments have been made. However, it has been necessary to adjust conductivity measurements when some deviating values occurred. At stations PSM348, PSM353, PSM364 and PSM368 all sensors are situated in a creek or in a lake. Also here, and especially at station PSM364 adjustments of conductivity has been necessary to make when some strange and deviating values occurred. The sensors seem to be covered with organic material during the vegetation period when the biological activity is high. Because of this, it is very important to keep the sensor clean during this part of season. All adjustments made have likely been caused by increasing growth of organic material on sensors. After cleaning the sensors, they have showed correct values. Quality checked measurements are presented in Figures 5-9 to 5-16.

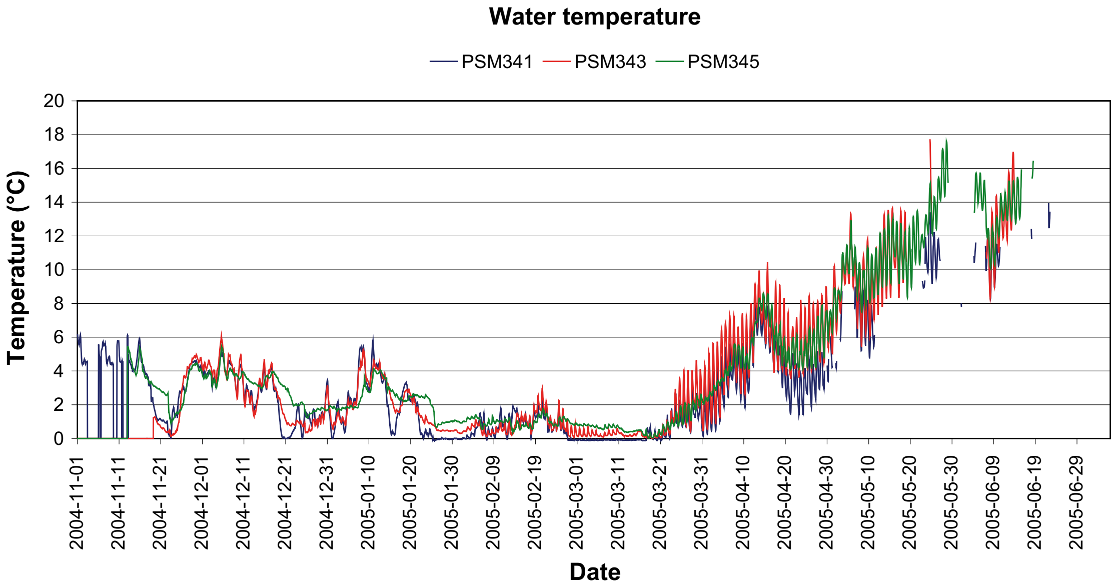


Figure 5-9. *Water temperature measured at stations PSM341, PSM343 and PSM345. Values are deleted during periods when the discharge equals zero or when the watercourse is dried up.*

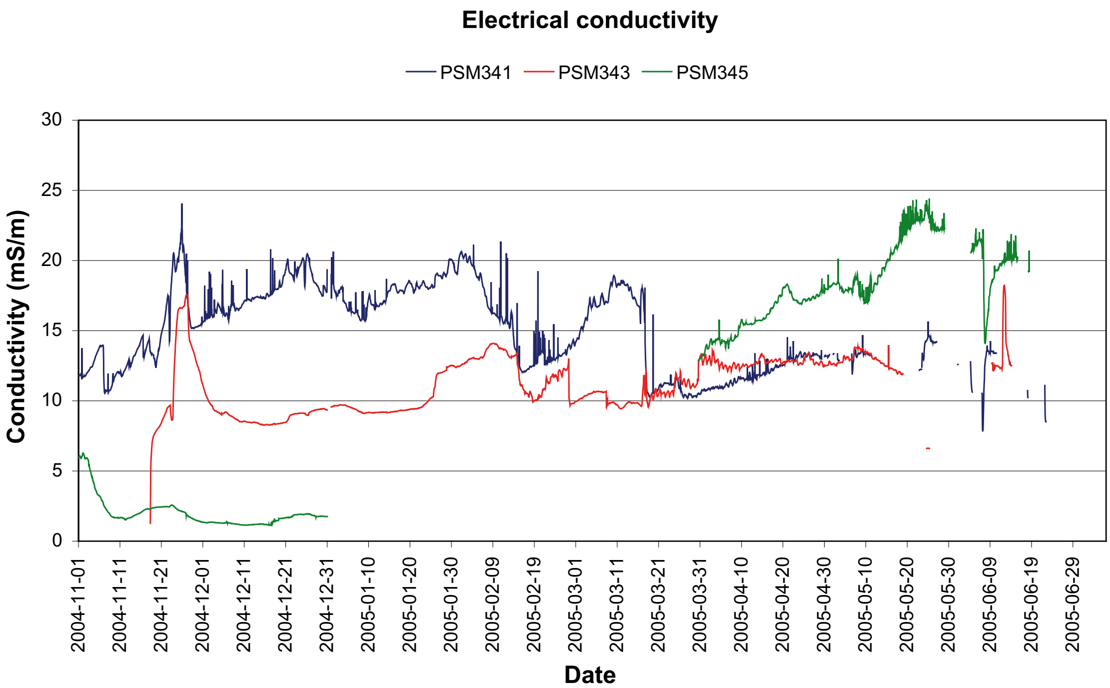


Figure 5-10. *Electrical conductivity, EC, measured at stations PSM341, PSM343 and PSM345. Values are deleted during periods when the discharge equals zero or when the watercourse is dried up.*

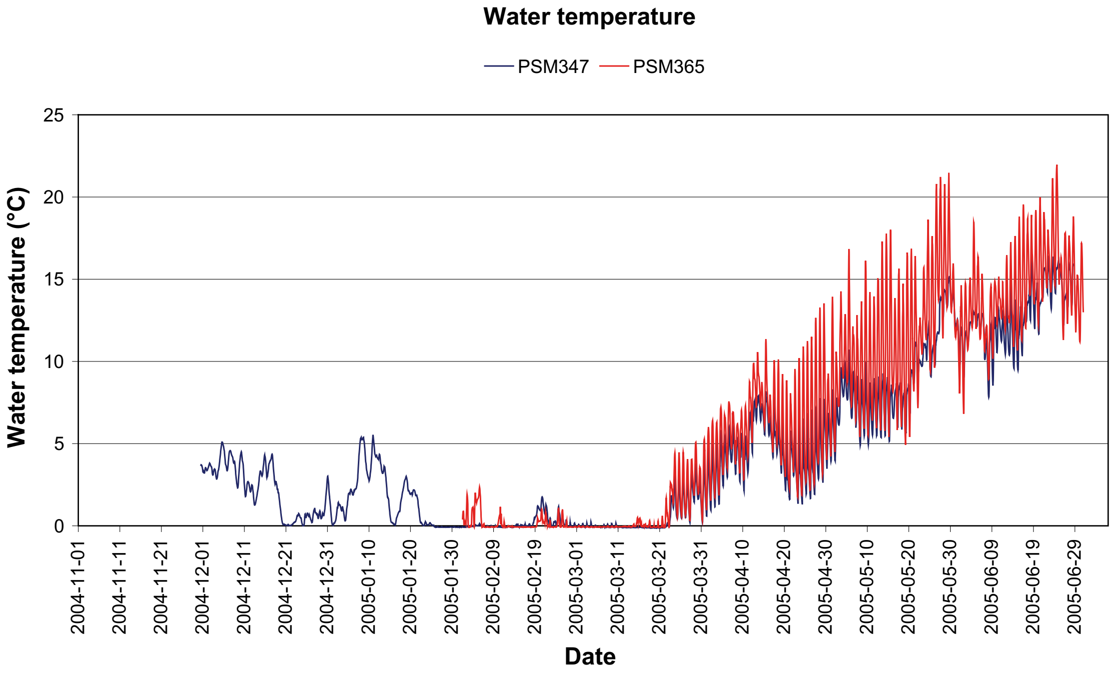


Figure 5-11. *Water temperature measured at stations PSM347 and PSM365.*

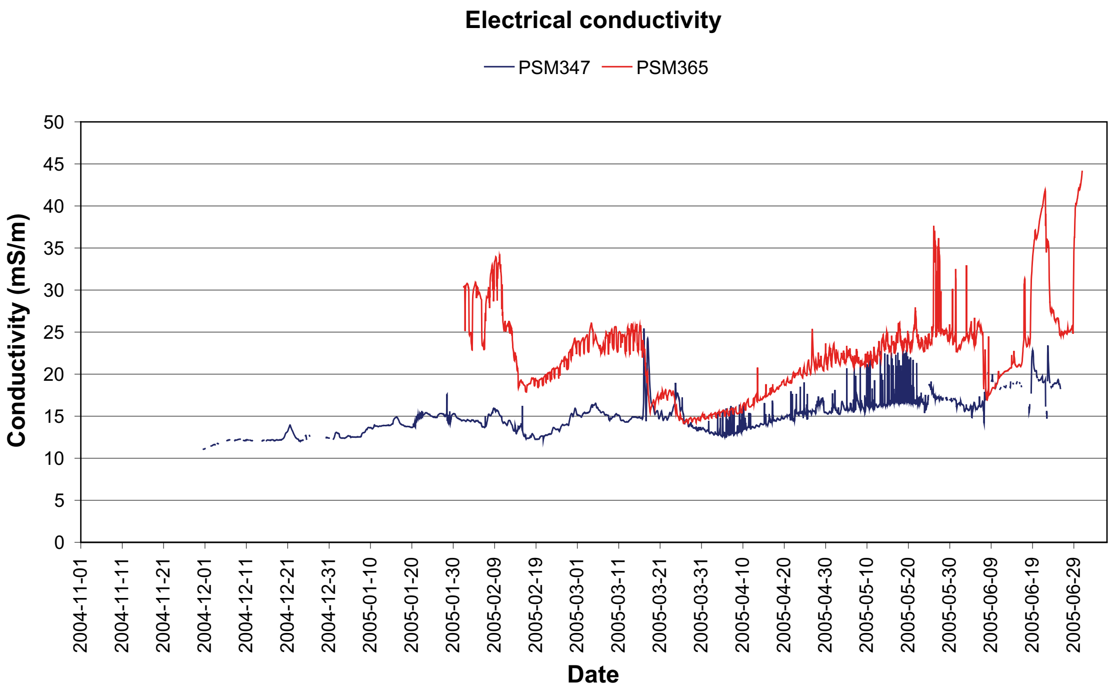


Figure 5-12. *Electrical conductivity, EC, measured at stations PSM347 and PSM365. At station PSM347, strange values are deleted in the end of the measuring period.*

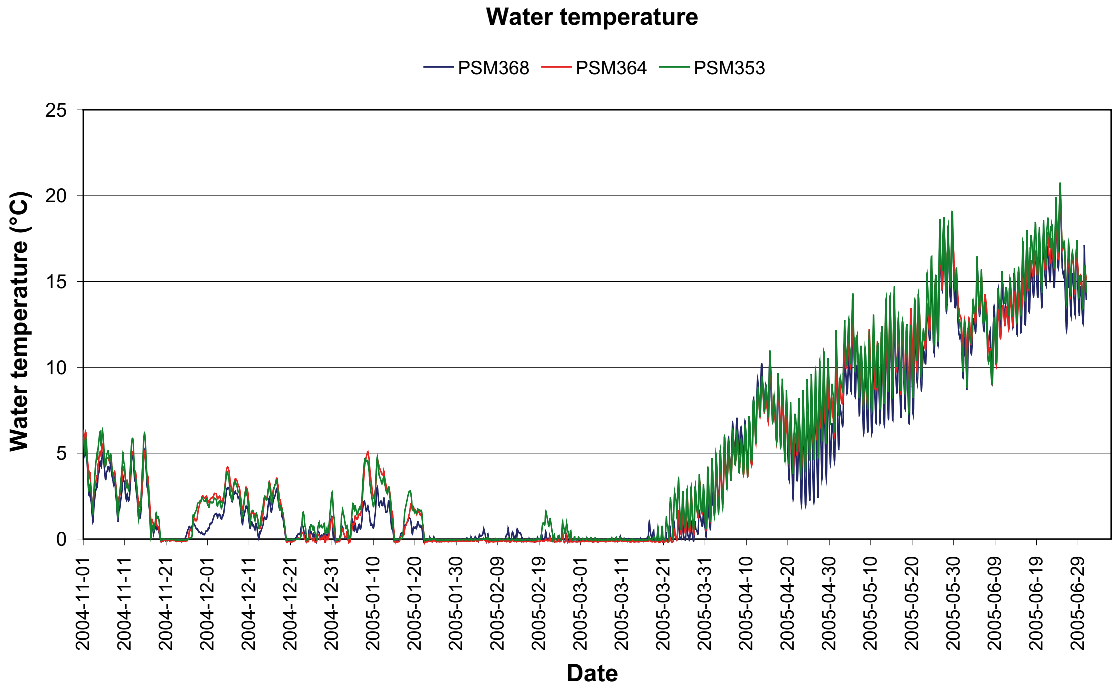


Figure 5-13. *Water temperature measured at stations PSM353, PSM364 and PSM368.*

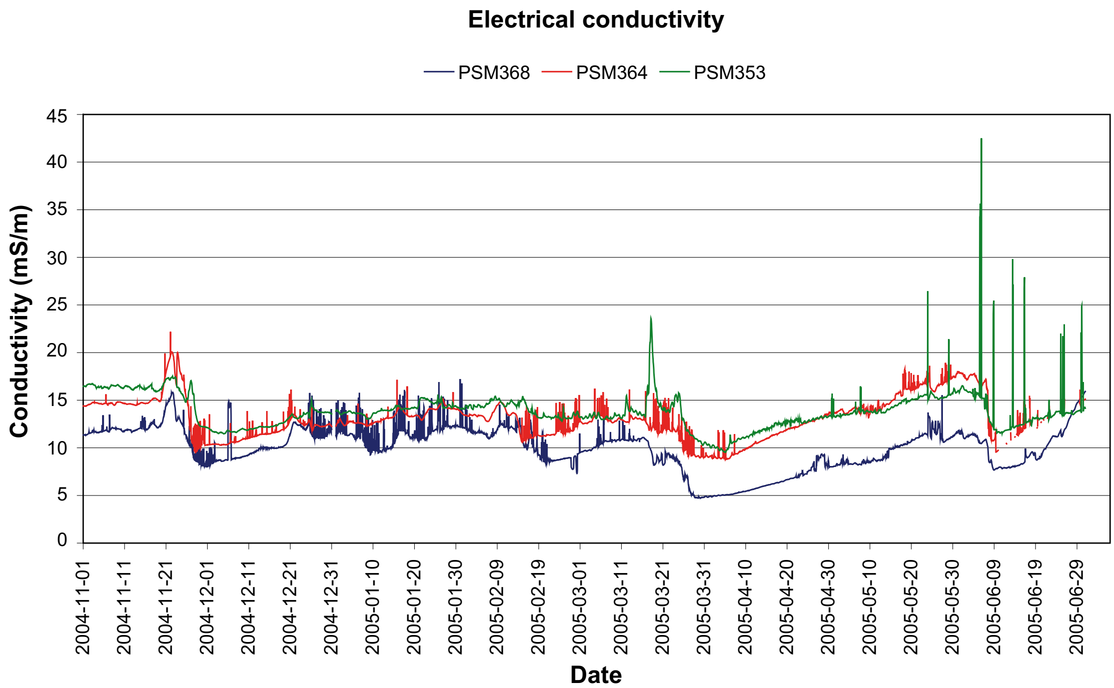


Figure 5-14. *Electrical conductivity measured at station PSM353, PSM364 and PSM368.*

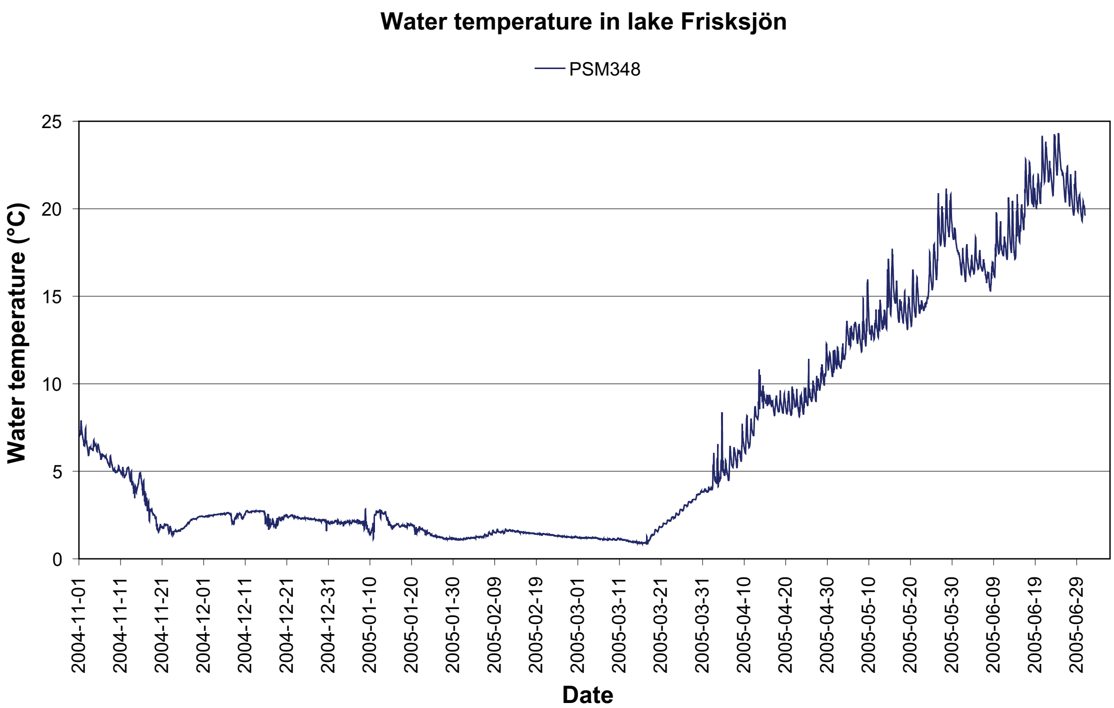


Figure 5-15. *Water temperature measured at lake Frisksjön station PSM348.*

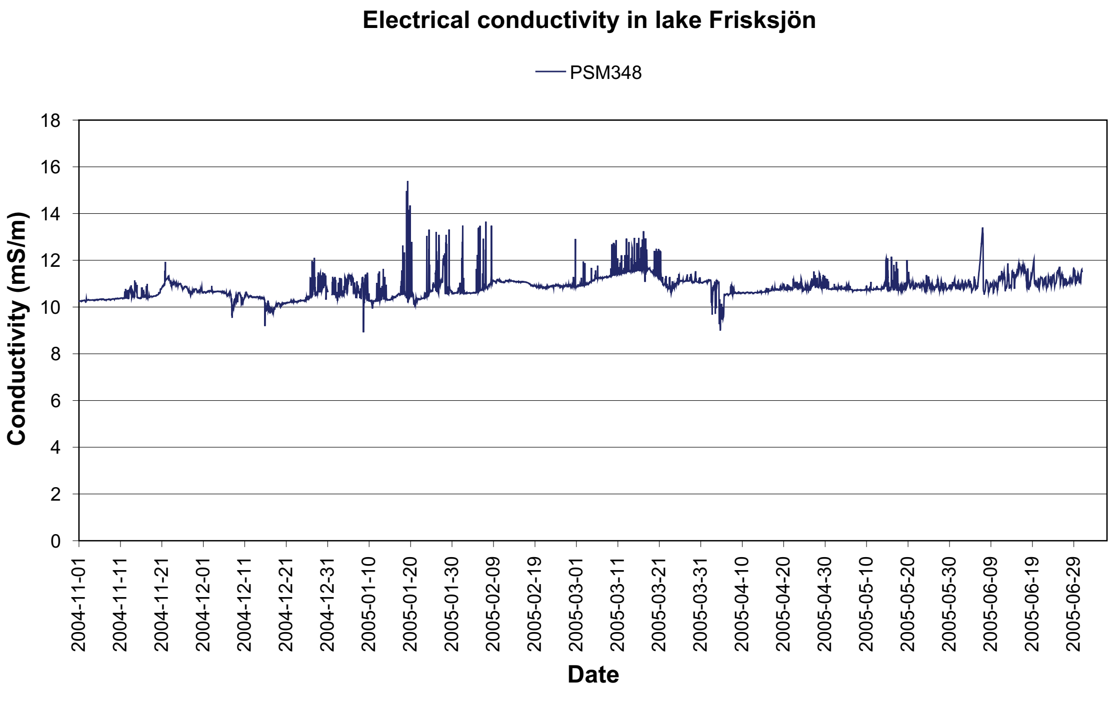


Figure 5-16. *Electrical conductivity measured at lake Frisksjön station PSM348.*

5.2 Meteorological monitoring

Meteorological measurements have turned out to work very well during the period for all parameters. The 30 min value of precipitation still shows too high values. 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. This error can be corrected afterwards, and that is a part of the measurement procedure for the precipitation gauge (GEONOR).

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 are presented in Table 5-2 and Figure 5-17 below. "Ölands Norra Udde A" is an automatic station and the others are manual stations. These precipitation values are all controlled and approved by SMHI. There are no correction for wind errors, wetting and evaporation in these values. The correction of precipitation is listed below in Table 5-1.

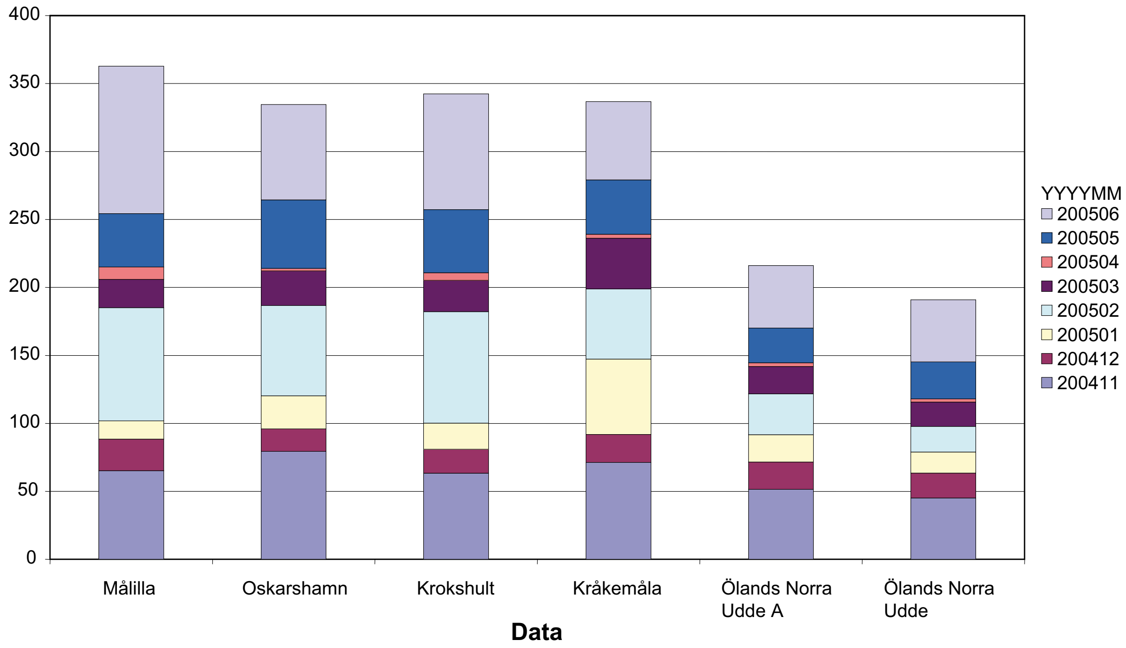
We see that the precipitation differs a lot between stations and between months.

Table 5-1. Corrections in percent of SMHI's stations according to reference /5/.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Målilla	7	9	6	8	7	8	6	7	7	6	6	6	7
Oskarshamn	6	6	6	8	8	11	8	7	7	7	6	6	7
Krokshult	9	11	9	8	10	12	9	10	8	8	8	8	9
Kråkemåla	7	9	9	8	9	10	8	9	8	8	7	6	8
Ölands norra udde A	18	22	16	16	13	16	15	16	16	16	18	18	17
Ölands norra udde	13	14	17	12	13	16	15	11	12	14	11	11	13

Table 5-2. Monthly precipitation in mm at SMHI's stations.

	2004-11	2004-12	2005-01	2005-02	2005-03	2005-04	2000-05	2005-06	Total
Målilla	65.2	23.2	13.5	83.2	20.8	9.1	39.3	108.5	362.8
Oskarshamn	79.4	16.6	24.2	66.5	25.4	1.9	50.4	70.1	334.5
Krokshult	63.3	17.7	19.2	82.0	23	5.6	46.4	85.2	342.4
Kråkemåla	71.3	20.5	55.5	51.7	37.1	3.0	39.9	57.7	336.7
Ölands norra udde A	51.5	20.1	20.1	30.0	20.1	2.7	25.6	46.0	216.1
Ölands norra udde	45.1	18.3	15.5	18.8	18	2.3	27.2	45.7	190.9



Figur 5-17. *Monthly precipitation in mm at SMHI's stations.*

The precipitation at Plittorp and Äspö are presented in Table 5-4. "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. ALX is the new correction for wind errors, wetting and evaporation.

The true precipitation (KOR), i.e. precipitation corrected for wind errors, wetting and evaporation, is also estimated. For this site and instrument, we have been estimating that the precipitation is 10% more than the measured if the temperature is below +1°C, or else 6% more. More information about true precipitation can be found in reference /5/.

During the year a new method for estimating the true precipitation were implemented (ALX). It is based on photographs of the surroundings and maps of the stations and the same method is used as for the other SMHI stations. It gives higher values than the KOR-method described above. The Table 5-3 below gives the corrections in percent for each month. More information about the estimated true precipitation can be found in reference /6/.

The registered 30 min precipitation values have to be filtered before storing. That is because the instrument is very sensitive and registers incorrect small values of precipitation.

If we compare the corrected values from Plittorp and Äspö (357 and 291), with the values from the closest SMHI stations Kråkemåla and Oskarshamn (337 mm and 334 mm) we see that they correspond quite well with each other.

Figure A4-1 in Appendix 4 shows the accumulated sum of precipitation during the period. From the figure we see that the precipitation gauge was emptied in December and April.

Table 5-3. Corrections in percent of SKB's stations according to reference /6/.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Äspö	21	21	19	16	14	14	14	14	14	16	17	20	17
Plittorp	12	13	12	10	10	9	9	10	10	10	10	12	11

Table 5-4. 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 and "MES" means analysed values from Mesan. ALX is the new estimation of the true precipitation.

	2004-11	2004-12	2005-01	2005-02	2005-03	2005-04	2005-05	2005-06	Total
Äspö 001	136.2	22.4	48.0	38.1	27.0	3.6	30.0	63.0	368.3
Äspö COR	74.6	18.6	36.1	38.1	27.2	3.6	30.0	62.9	291.1
Äspö KOR	80.0	20.0	39.4	41.7	29.8	3.8	31.8	66.7	313.1
Äspö MES	39.2	7.6	12.3	51.1	17.4	4.0	33.0	32.3	197.1
Äspö ALX	87.3	22.3	43.7	46.1	32.4	4.2	34.2	71.7	341.8
Plittorp 001	79.1	19.9	48.2	61.7	28.8	4.4	31.8	85.5	359.4
Plittorp COR	76.5	19.8	48.5	61.7	28.9	4.4	31.8	85.5	357.1
Plittorp KOR	82.2	21.2	53.0	67.6	31.7	4.7	33.7	90.6	384.8
Plittorp ALX	84.1	22.2	54.3	69.7	32.4	4.8	35.0	93.2	395.7

5.2.2 Barometric pressure

Graphs of the barometric pressure are presented in Figure A4-2 in Appendix 4. Values from Plittorp, Äspö and Mesan-values are presented. Figure A4-10 shows 30 min values for January 2005 where we can see that the measured value from Plittorp is 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 daily temperature are presented in the Figure A4-3 in Appendix 4. Values from Plittorp, Äspö and Mesan-values are presented. We see that the three curves follow each other very well.

Figure A4-11 shows 30 min values for January 2005. We notice that Äspö is more influenced of the sea because the lowest temperatures are several degrees higher compared to Plittorp.

5.2.4 Relative humidity

Graphs of daily relative humidity are presented in the Figure A4-4 in Appendix 4. Values from Plittorp, Äspö and Mesan-values are presented. We see that the three curves follow each other very well. In Figure A4-12, 30 min values for January 2005 are presented.

5.2.5 Wind speed

Graphs of the wind speed (daily mean) are presented in the Figure A4-5 in Appendix 4. Values from Plittorp, Äspö and Mesan-values are presented. We see that the wind speeds are 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 depends on 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.

Figure A4-13 shows measurements for January 2005 for the 30 min mean wind speed. We notice the peak of the wind speed the night 8–9 January when the severe storm was ravaging. The gust wind speed is approximately 2–3 times higher than the mean wind speed presented here.

5.2.6 Wind direction

Graphs of the wind direction are presented in the Figure A4-6 in Appendix 4. Values from Äspö, Plittorp and Mesan-values are presented. We see that the two curves follow each other very well. Figure A4-14 shows 30 min values for January 2005.

5.2.7 Global radiation

Graphs of the daily sum of global radiation are presented in the Figure A4-7 in Appendix 4. Global radiation is measured only at Äspö. 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. 30 min values for January 2005 are presented in Figure A4-15.

5.2.8 Calculated evapotranspiration

The potential evapotranspiration are calculated with the Pennman formula:

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

The method is described in reference /4/, Bertil Eriksson (1981, RMK 28).

Graph of the potential evapotranspiration is presented in the Figure A4-8 in Appendix 4. The 30 min values are presented in Figure A4-16.

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 5-18. The complete set of primary data is presented in Appendix 2, Table A2-1.

5.3.2 Frost in ground

The frost in ground together with snow depth at Grillplatsen (PSM107724) is shown in Figure 5-19. The complete sets of primary data are shown in Appendix 3, Table A3-1 and Table A3-2.

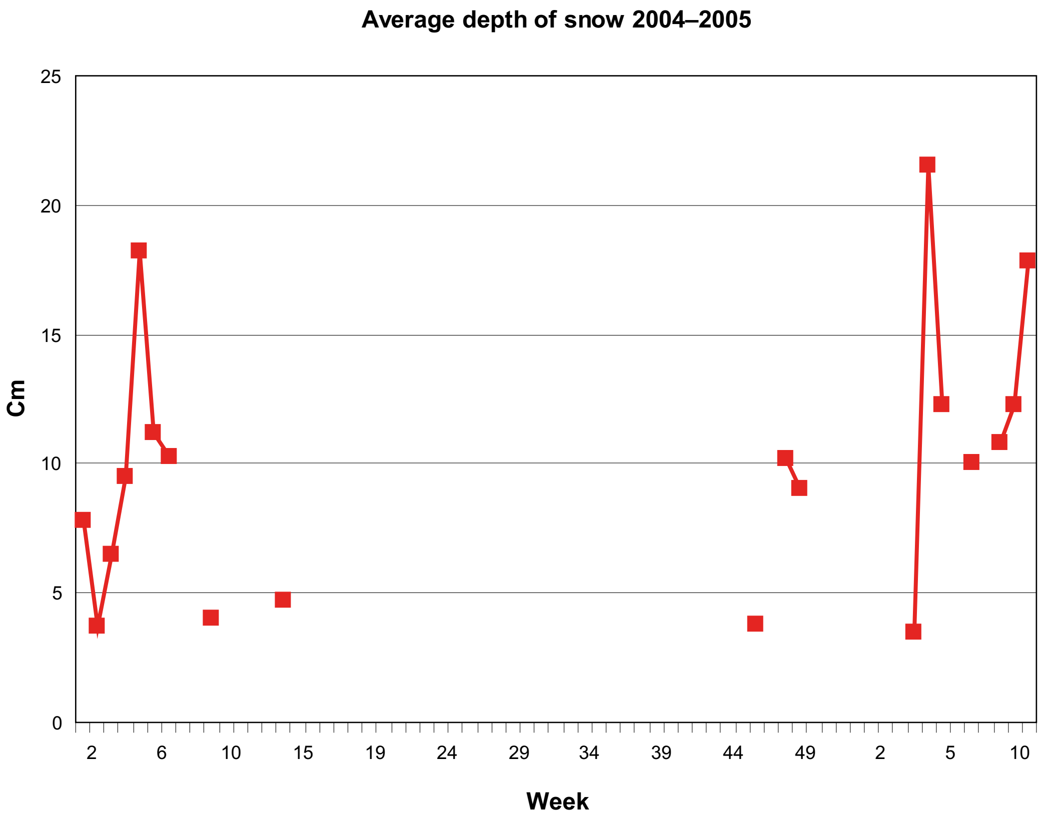


Figure 5-18. Average snow depth at Äspö 2 (ASM100224) during the winter 2004/2005.

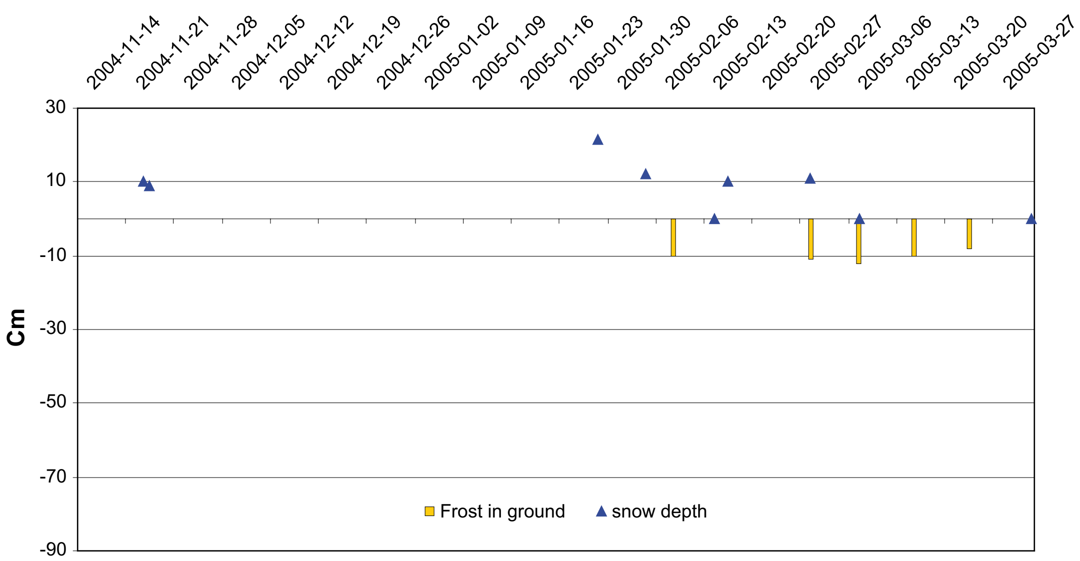


Figure 5-19. Calculated frost in ground and snow depth at PSM107724 during 2004 and 2005.

5.3.3 Ice cover

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

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

	Ice freeze up	Ice break up	Period with ice cover (days)
Äspös brygga (ASM10226)	2002-12-19	2003-03-27	99
	2004-01-07	2004-03-10	62
	2005-03-08	2005-04-01	25
Kråkelund (ASM100227)	2003-01-10	2003-03-21	71
	no ice cover during 2004–2005		
Kråkelund inre (ASM100228)	2003-01-10	2003-03-21	71
	no ice cover during 2004–2005		
Jämsen (ASM100229)	2002-11-19	2002-11-22	3
	2002-12-19	2003-03-28	100
	2004-01-07	2004-03-10	64
	2004-11-22	2005-03-30	129

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.

/5/ **Alexandersson, 2003.** Meteorologi, Nr111. Korrektion av nederbörd enligt enkel klimatologisk metodik.

/6/ **Alexandersson, 2005.** Enkel bedömning av nederbördsmätförluster på fyra automatstationer.

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 Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-03-18 00:00 Stop: 2005-07-01 00:00	OK
PSM342	Jämsen	Lake	Water level	Logger: Campbell CR510 Pressure sensor: DRUCK PDCR 1830	Start: 2004-07-24 14:00 Stop: 2005-07-01 00:00	OK
PSM343	Ävrö SW	Dam	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-03-18 00:00 Stop: 2005-07-01 00:00	OK
PSM344	Plittorpsgöl	Lake	Water level	Logger: Campbell CR510 Pressure sensor: DRUCK PDCR 1830	Start: 2004-07-24 14:00 Stop: 2005-07-01 00:00	OK
PSM345	Ävrö SE	Dam	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-03-18 00:00 Stop: 2005-07-01 00:00	OK
PSM347	Frisksjön (in)	Dam	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-11-30 10:00 Stop: 2005-07-01 00:00	OK
PSM348	Frisksjön (out)	Lake, Natural section	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-07-24 00:00 Stop: 2005-07-01 00:00	OK
PSM353	Laxemarån (upper)	Natural section	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-09-02 15:00 Stop: 2005-07-01 00:00	OK
PSM359	Sörå-magasinet	Lake	Water level	Logger: Campbell CR510 Pressure sensor: DRUCK PDCR 1830	Start: 2004-01-28 17:00 Stop: 2005-07-01 00:00	OK
PSM364	Laxemarån (lower)	Natural section	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-09-02 11:00 Stop: 2005-07-01 00:00	OK

Station Id	Object	Place	Variables	Instrumentation	Time interval of measurements	QC_OK
PSM365	Ekerumsån	Dam	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2005-02-01 13:00 Stop: 2005-07-01 00:00	OK
PSM368	Kärrviksån	Natural section	Discharge, T, EC	Logger: Campbell CR10X Pressure sensor: DRUCK PDCR 1830 Temp. and EC: Campbell CS547	Start: 2004-07-24 09:00 Stop: 2005-07-01 00:00	OK
PSM369	Äspö S	Sea	Water level	Logger: Campbell CR510 Pressure sensor: DRUCK PDCR 1830	Start: 2004-01-28 17:00 Stop: 2005-07-01 00:00	OK
PSM370	Äspö N	Sea	Water level	Logger: Campbell CR510 Pressure sensor: DRUCK PDCR 1830	Start: 2004-01-28 17:00 Stop: 2005-07-01 00:00	OK
PSM371	Clab	Sea	Water level	Logger: Campbell CR510 Pressure sensor: DRUCK PDCR 1830	Start: 2004-07-28 17:00 Stop: 2005-07-01 00:00	OK

Appendix 2

Measurements of snow cover

Primary data from snow depth measurements during the winter 2004/2005

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 2004/2005.

Start date	Stop date	Point 1 (cm)	Point 2 (cm)	Point 3 (cm)	Point 4 (cm)	Point 5 (cm)	Point 6 (cm)	Average snow cover (cm)	Snow coverage
2004-11-14	2004-11-14	3	5	4	4	3	4	3.8	S
2004-11-17	2004-11-17								S
2004-11-23	2004-11-23	11	10	10	10	9	11	10.2	S
2004-11-24	2004-11-24	7	7	9	7	8	9	9.0	S
2005-01-24	2005-01-24	4	3	3	4	4	3	3.5	S
2005-01-28	2005-01-28	22	22	23	20	21	21	21.5	S
2005-02-04	2005-02-04	12	13	13	12	12	12	12.3	S
2005-02-16	2005-02-16	11	8	11	10	10	10	10.0	S
2005-02-28	2005-02-28	13	10	10	10	11	11	10.8	S
2005-03-11	2005-03-11	12	11	10	12	10	12	12.3	S
2005-03-15	2005-03-15	17	16	21	20	17	16	17.8	S

Appendix 3

Measurements of ground frost

Primary data from measurement of frost in the ground during the winter 2004/2005

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 2004/2005 at Grillplatsen (PSM107724).

Start date	Stop date	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)
2004-11-17	2004-11-17	100					
2004-11-19	2004-11-19	100					
2004-11-24	2004-11-24	100					
2005-02-08	2005-02-08	100	102	112	2	12	10.0
2005-02-14	2005-02-14	100					
2005-02-28	2005-02-28	100		111		11	11.0
2005-03-07	2005-03-07	100	72	112	0	12	12.0
2005-03-15	2005-03-15	100	992	110	0	10	10.0
2005-03-23	2005-03-23	100	105	113	5	13	8.0
2005-04-01	2005-04-01	100					

Table A3-2. Frost in ground during the winter 2004/2005 at Äspö (PSM6978).

Start date	Stop date	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)
2005-01-17	2005-01-17	95					
2005-01-28	2005-01-28	95					
2005-02-08	2005-02-08	95	95	102	0.0	7	7.0
2005-02-15	2005-02-15	95	91	100	0.0	5	5.0
2005-02-28	2005-02-28	95	92	102	0.0	2	2.0
2005-03-07	2005-03-07	95	102	116	7.0	21	14.0
2005-03-15	2005-03-15	95	88	113	0.0	18	18.0
2005-03-23	2005-03-23	95	97	108	2.0	13	11.0
2005-04-01	2005-04-01	95					

Table A3-3. Frost in ground during the winter 2004/2005 at Grindstugan (PSM6979).

Start date	Stop date	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)
2005-01-27	2005-01-17	100	100	103	0	3	3.0
2005-02-08	2005-01-24	100	0	104	0	4	4.0
2005-02-14	2005-01-27	100	0	103	0	3	3.0
2005-02-28	2005-02-08	100		104		4	4.0
2005-03-07	2005-02-10	100					
2005-03-15	2005-02-11	100					
2005-03-23	2005-02-14	100	94	104	0	4	4.0
	2005-02-28	100	79	102	0	2	2.0
	2005-03-07	100	70	105	0	5	5.0
	2005-03-15	100	72	105	0	5	5.0
	2005-03-23	100	0	103	0	3	3.0
	2005-04-01	100					

Table A3-4. Frost in ground during the winter 2004/2005 at Åkern (PSM6980).

Start date	Stop date	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)
2005-01-27	2005-01-27	92					
2005-02-08	2005-02-08	92	94	102	2	10	8.0
2005-02-14	2005-02-14	92	92	98	0.0	6	6.0
2005-02-28	2005-02-28	92	95	97	3	5	2.0
2005-03-07	2005-03-07	92	0.0	101	0.0	9	9.0
2005-03-15	2005-03-15	92	72	103	0.0	11	11.0
2005-03-23	2005-03-23	92	90	115	0.0	23	23.0

Appendix 4

Meteorological monitoring

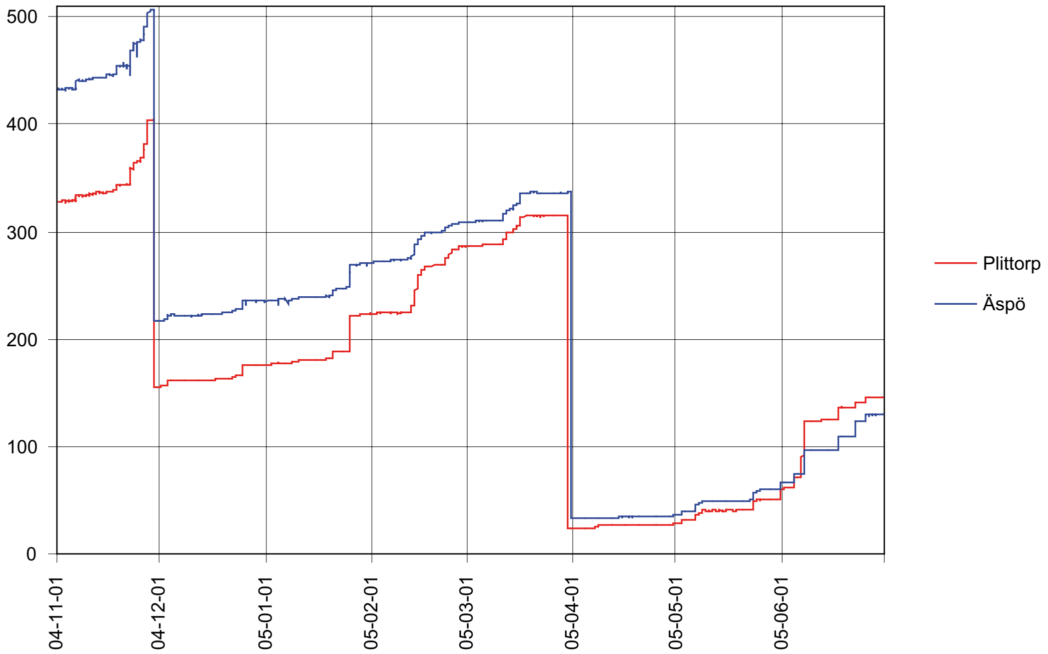


Figure A4-1. *Precipitation in mm, 30 min values. November 2004–June 2005.*

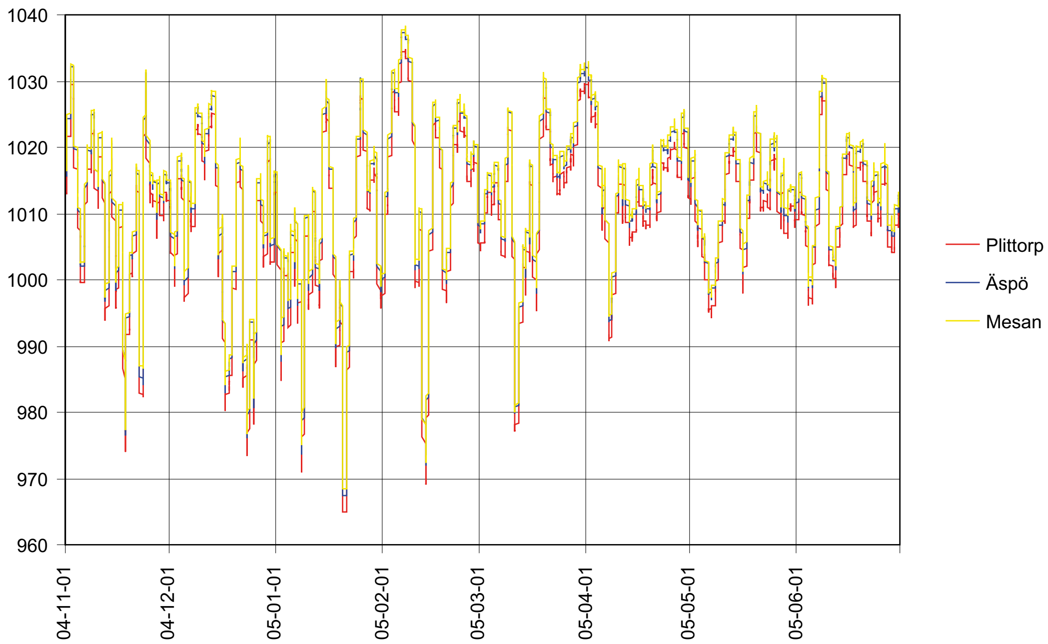


Figure A4-2. *Barometric pressure in Pa, 30 min values. November 2004–June 2005.*

Figure A4-3. *Temperature in °C, daily values. November 2004–June 2005.*

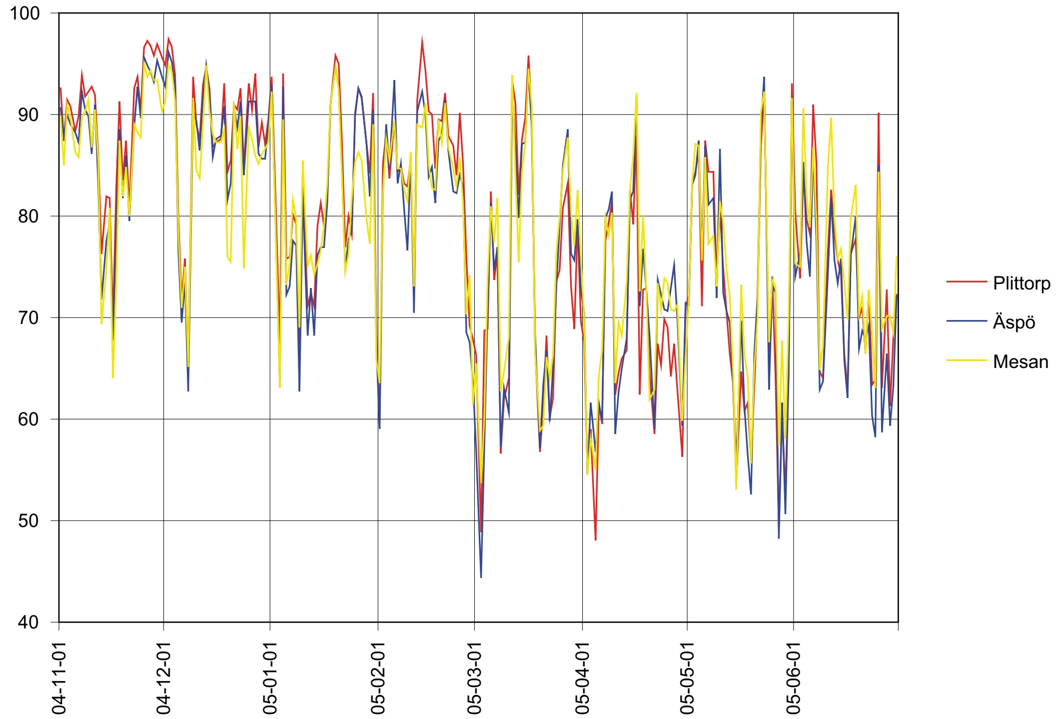


Figure A4-4. *Relative humidity in %, daily values. November 2004–June 2005.*

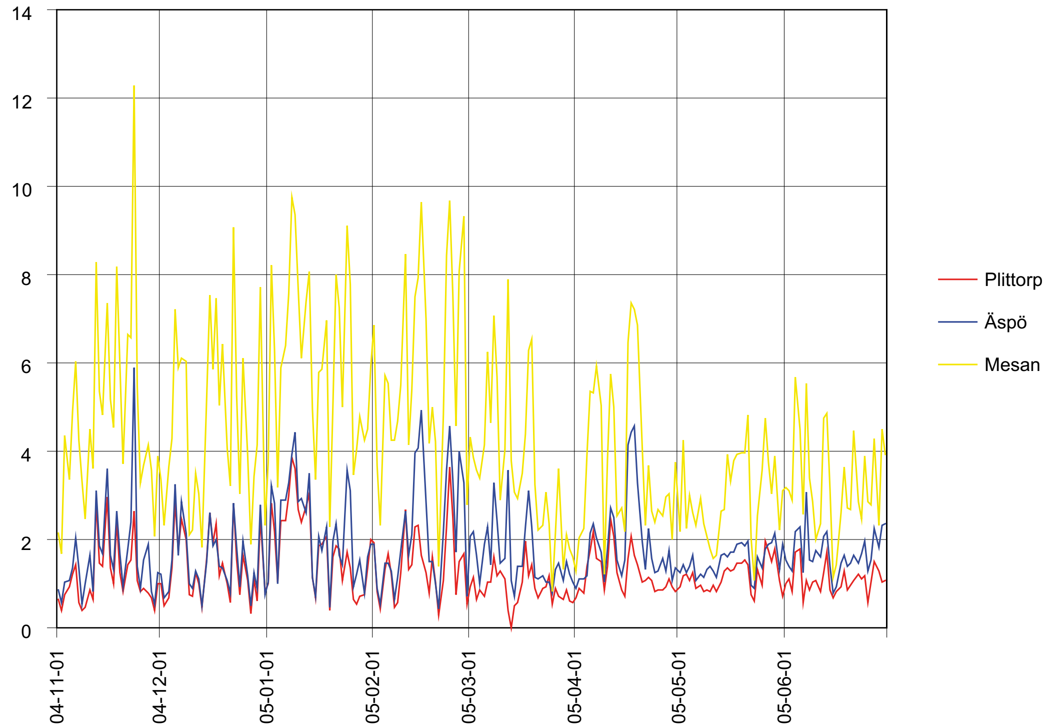


Figure A4-5. *Wind speed in m/s, daily values. November 2004–June 2005.*

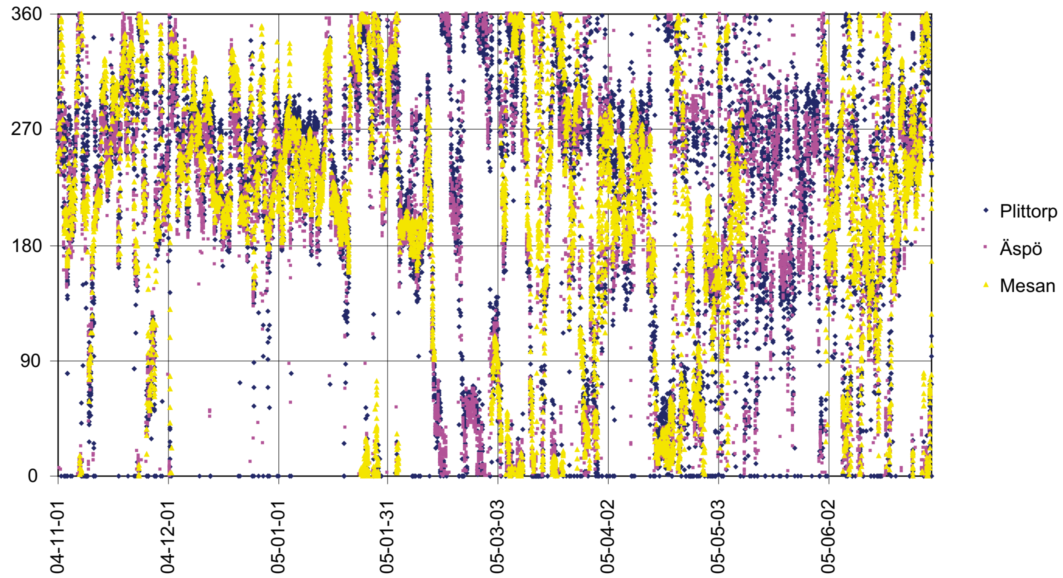


Figure A4-6. *Wind direction in °, 30 min values. November 2004–June 2005.*

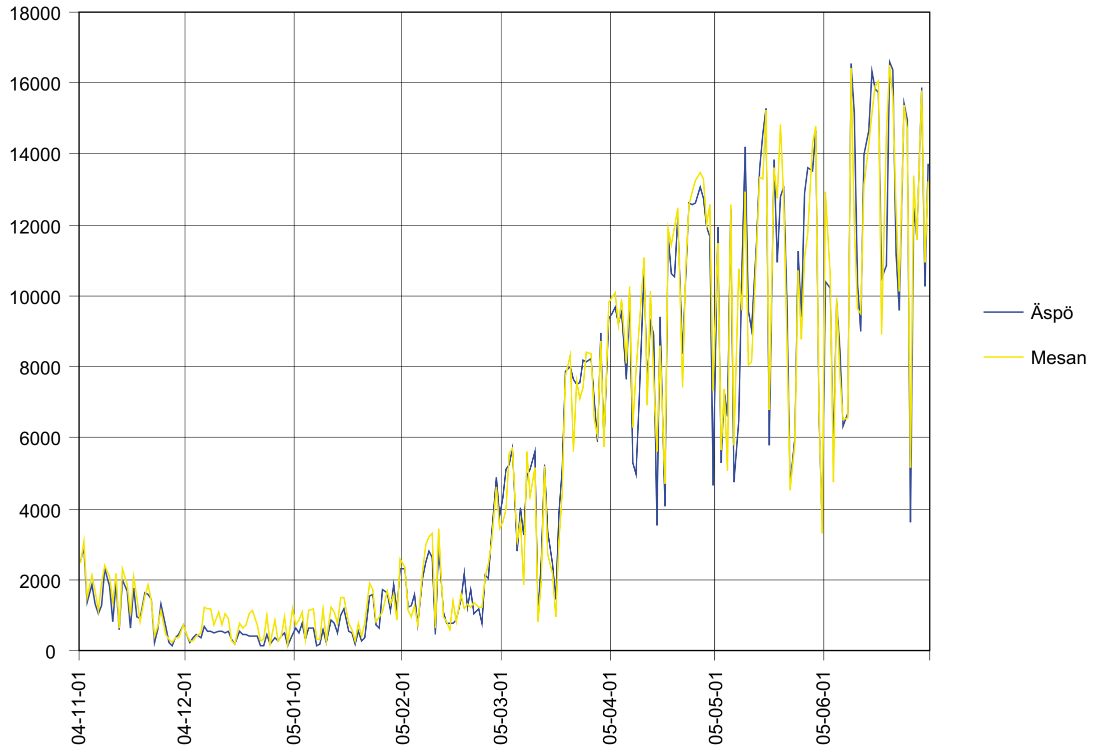


***Figure A4-7.** Global radiation in Wh/m², daily sum. November 2004–June 2005.*

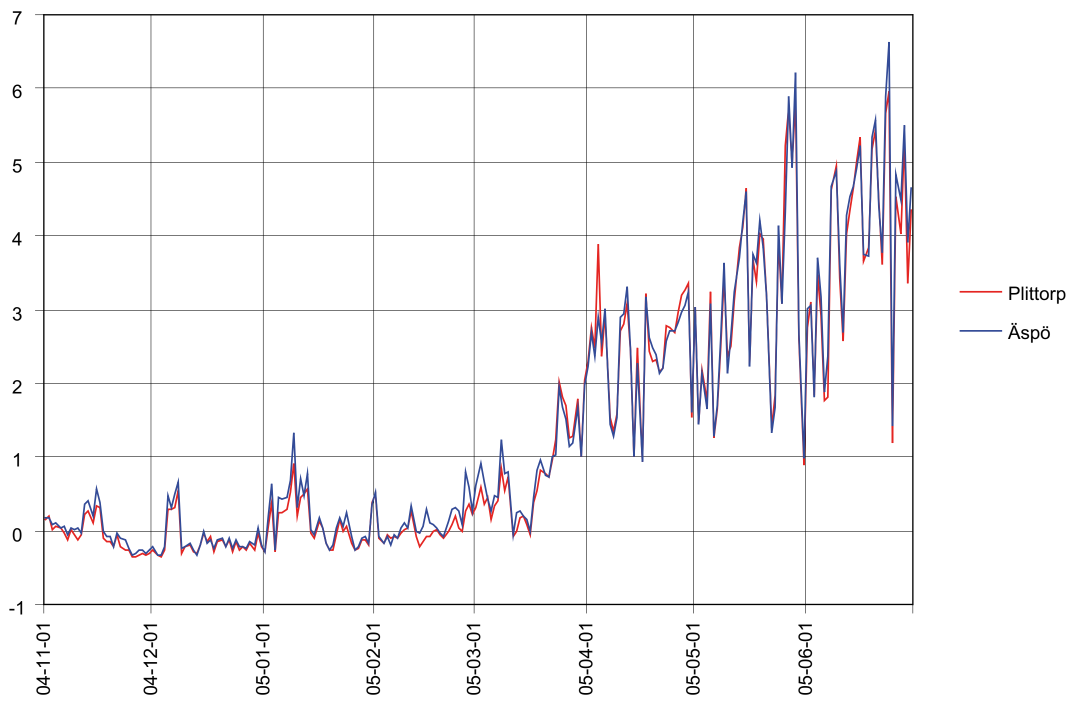


***Figure A4-8.** Evapotranspiration in mm, daily sum. November 2004–June 2005.*

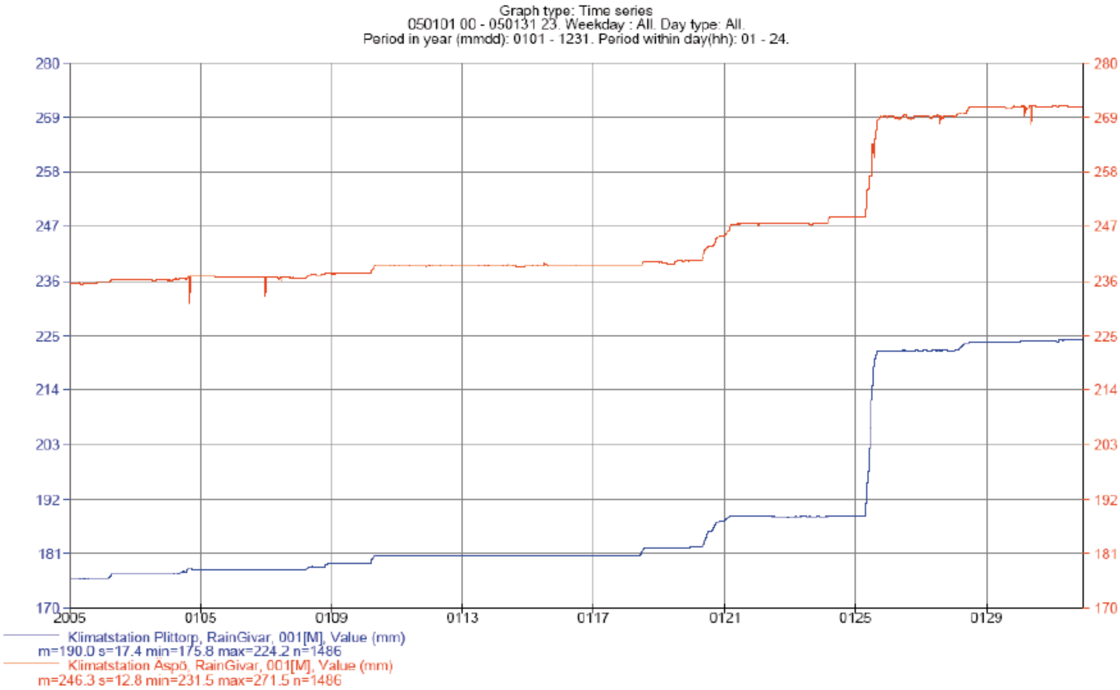


Figure A4-9. *Precipitation in mm, 30 min values. January 2005.*

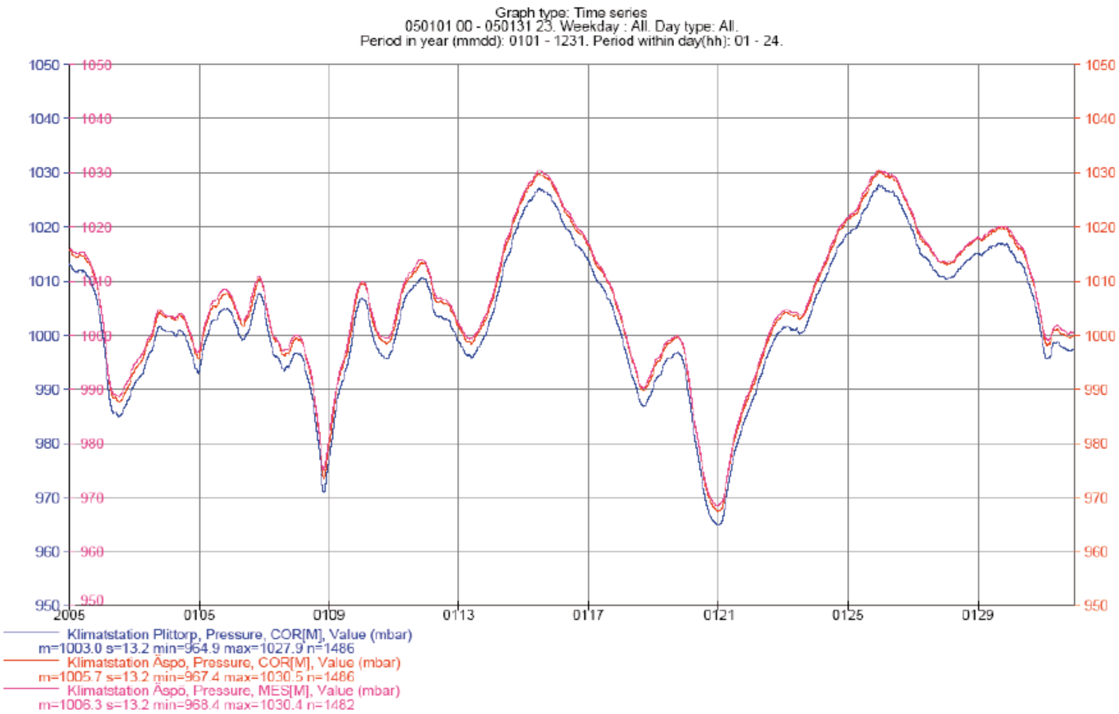


Figure A4-10. *Barometric pressure in Pa, 30 min values. January 2005.*

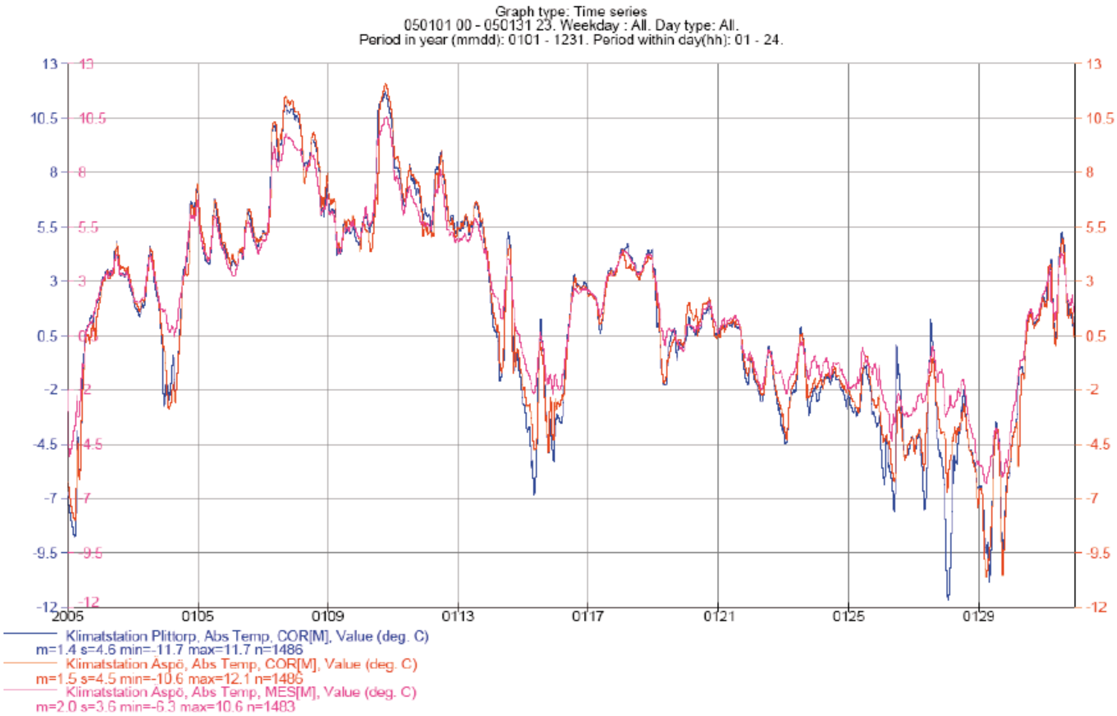


Figure A4-11. *Temperature in °C, 30 min values. January 2005.*

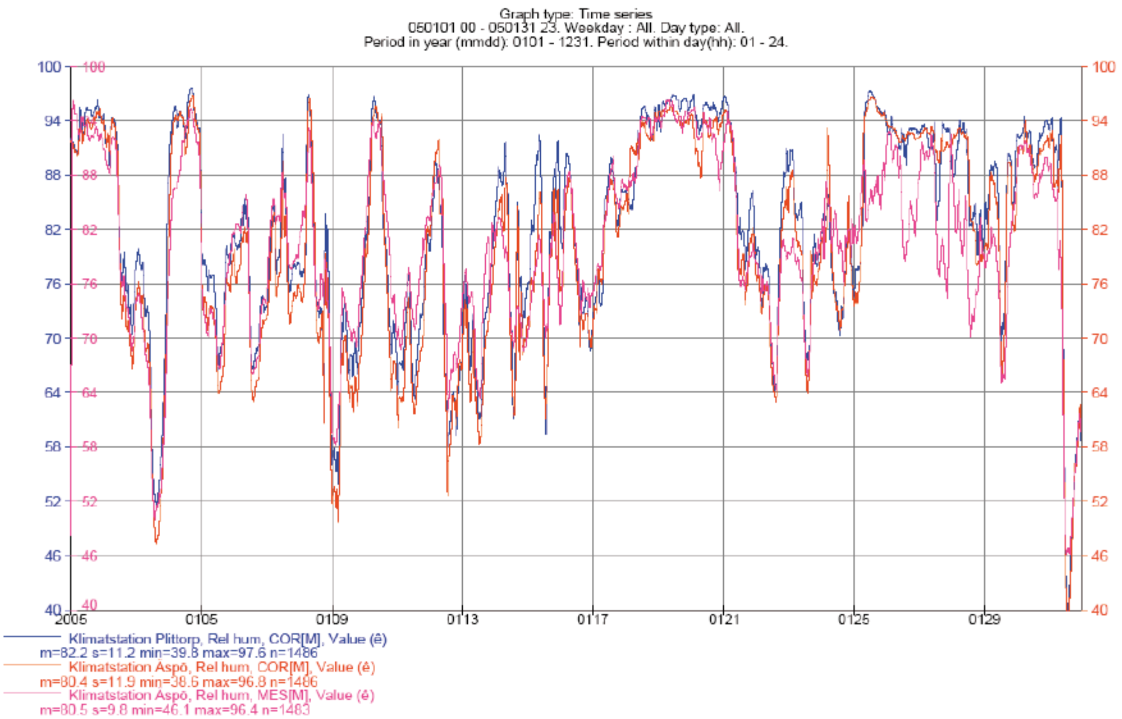


Figure A4-12. *Relative humidity in %, 30 min values. January 2005.*

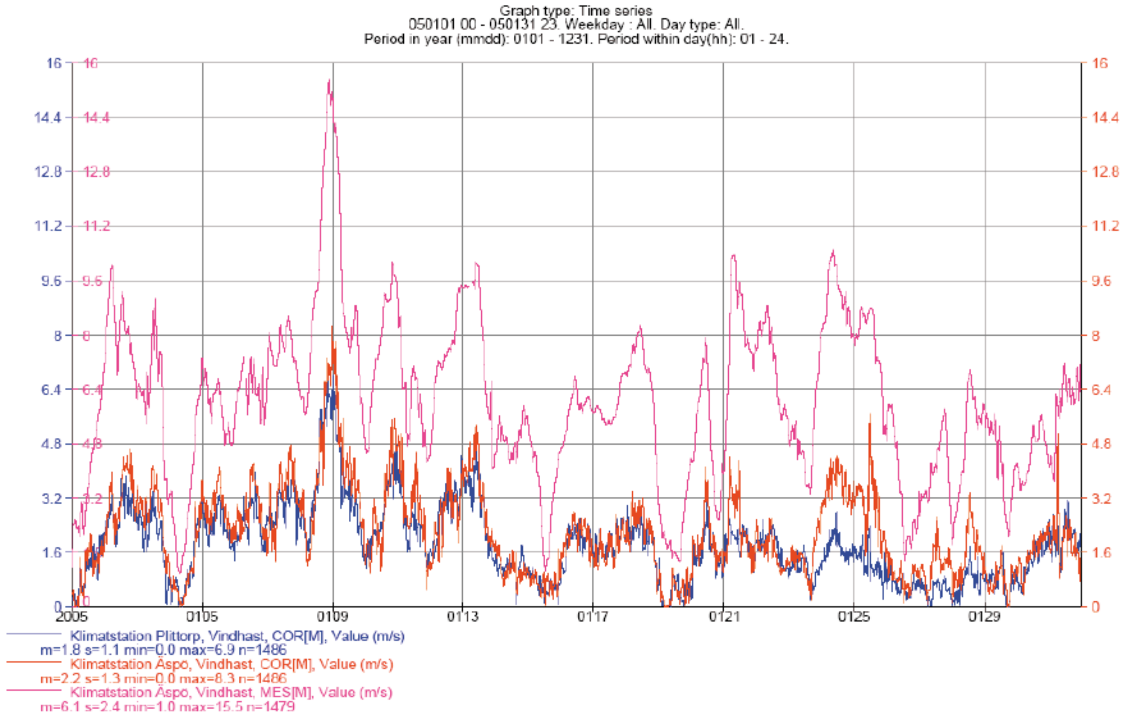


Figure A4-13. *Wind speed in m/s, 30 min values. January 2005.*

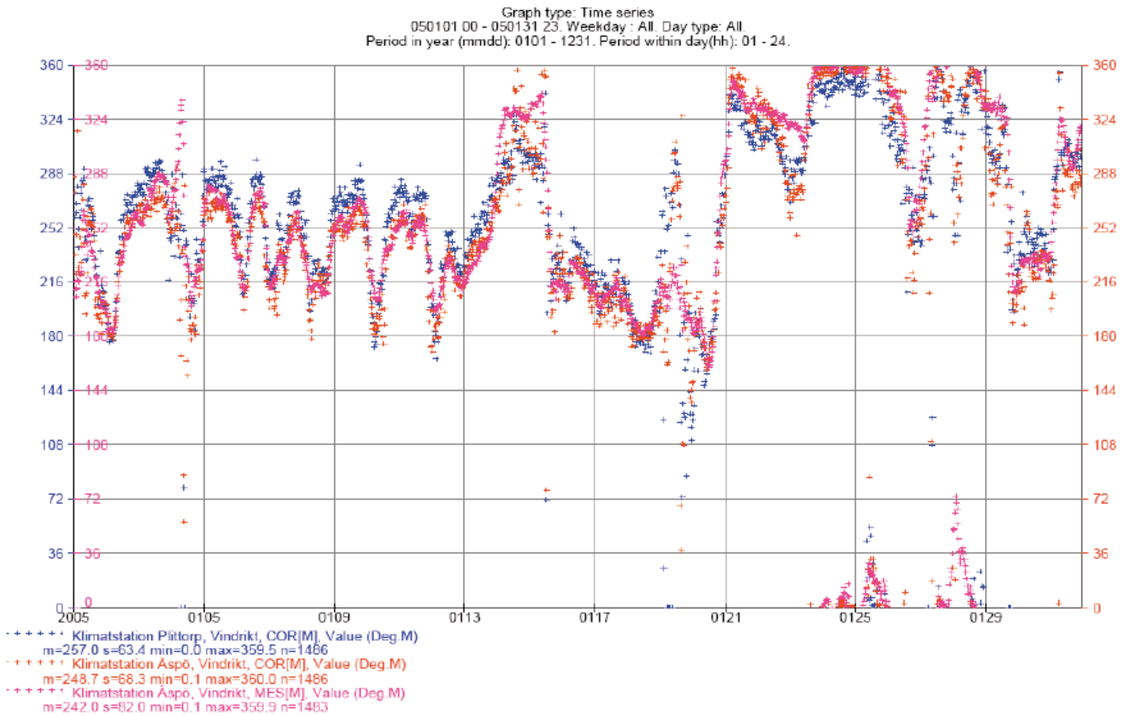


Figure A4-14. *Wind direction in °, 30 min values. January 2005.*

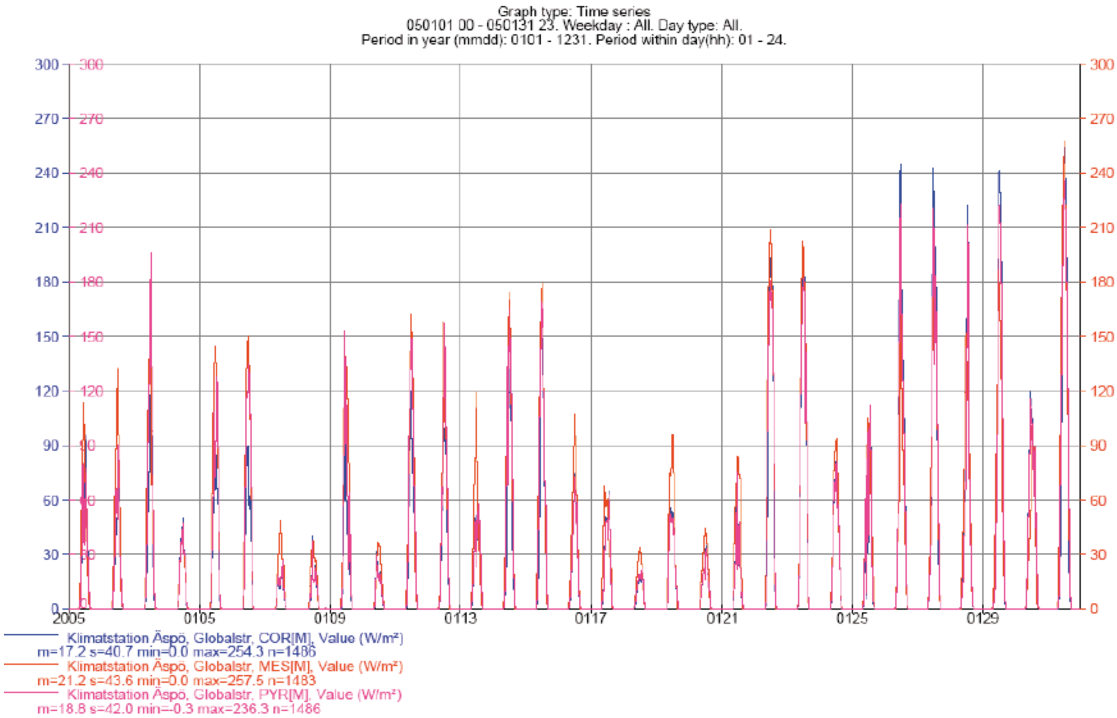


Figure A4-15. *Global radiation in W/m², 30 min values. January 2005.*

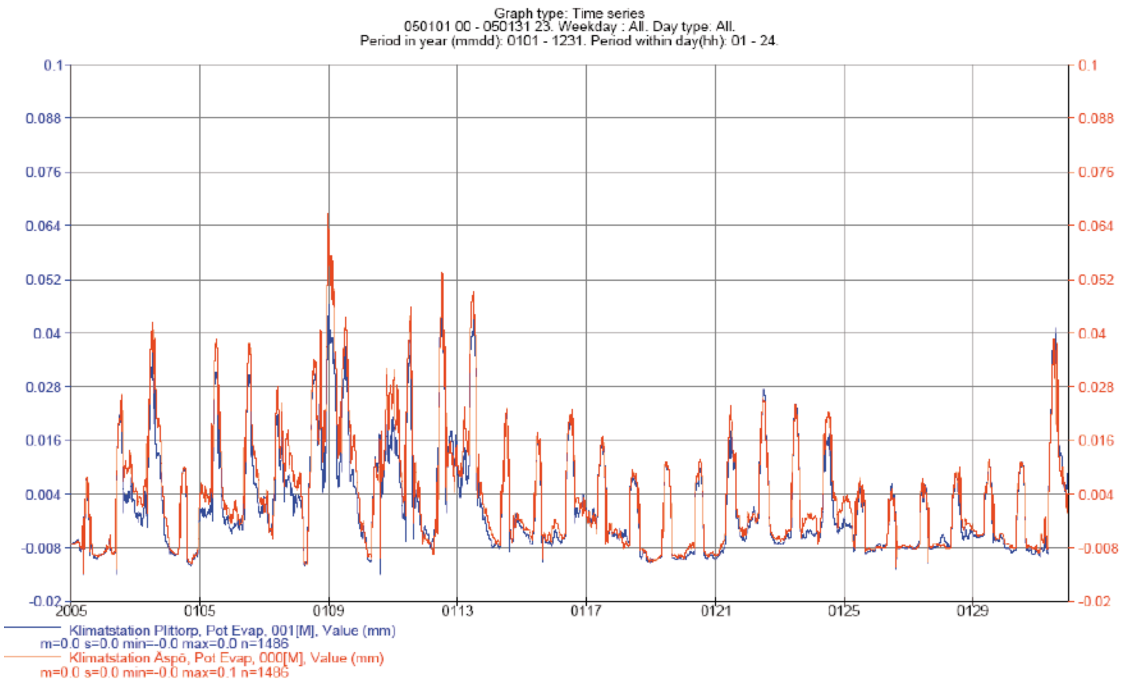


Figure A4-16. *Evapotranspiration in mm, 30 min values. January 2005.*