# P-05-221

## Forsmark site investigation

# Meteorological monitoring at Forsmark, June 2003 until July 2005

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SMHI

November 2006

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*Keywords:* AP PF 400-03-14, AP PF 400-05-014, Meteorological stations, Precipitation, Air temperature, Barometric pressure, Wind speed, Wind direction, Air humidity, Global radiation, Calculated potential evapotranspiration.

# Abstract

In the Forsmark area meteorological monitoring has been going on since 2003. Meteorological measurements are performed at two locations, Högmasten and Storskäret. Measured and calculated parameters are precipitation, air temperature, barometric pressure, wind speed and direction, air humidity, global radiation and potential evapotranspiration. The Swedish Meteorological and Hydrological Institute, SMHI, has been responsible for planning and design of the two stations used for meteorological monitoring.

In general, the quality of the meteorological measurements during the period concerned, starting 2003-06-01 and ending 2005-07-31, has shown to be good. Only minor interruptions in measurements according to malfunctioning equipment have occurred. The accumulating precipitation gauges were not emptied after the winter 2004/2005, neither at Högmasten nor Storskäret. The gauges were full at 17 June 2005 and at 21 June 2005, respectively at the stations, entailing that all precipitation data are missing from these days until the end of July.

# Sammanfattning

I Forsmarksområdet har meteorologiska mätningar pågått sedan 2003. Dessa sker på två ställen, vid Högmasten och Storskäret. Här har master med registrerande instrument monterats. De meteorologiska parametrar som mäts och beräknas är nederbörd, temperatur, lufttryck, vindhastighet och -riktning, luftfuktighet, globalstrålning och potentiell evapotranspiration. Sveriges Meteorologiska och Hydrologiska Institut, SMHI, har varit ansvariga för utformandet av de två meteorologiska mätstationerna.

Kvaliteten hos de meteorologiska mätningarna utförda under perioden 2003-06-01 till och med 2005-07-31 har generellt varit god. Det har endast förekommit några kortare avbrott i mätningarna orsakade av fel på mätutrustningen. Nederbördskärlen i Högmasten och Storskäret tömdes ej efter vintern 2004/2005. Kärlen blev fulla 17 juni 2005 och 21 juni 2005 vid respektive station vilket medförde att alla nederbördsdata efter dessa datum saknas fram till slutet av juli.

# Contents

# 1 Introduction

This document reports the results of meteorological measurements made in the area of Forsmark. The activities are performed within the site investigation at Forsmark and carried out in accordance to activity plans SKB AP PF 400-03-14 and SKB AP PF 400-05-014, and to the method desciption SKB MD 364.007 (SKB internal controlling documents). The controlling documents used in the activity are listed in Table 1-1.

To characterise the investigation area regarding meteorological conditions, SMHI has placed two stations with meteorological measuring equipment on the site; Högmasten (Forsmark) and Storskäret. The results of the meteorological monitoring will be used for general site characterisation, water balance calculations and as input data for hydro(geo)logical modelling. The geographical locations of the meteorological monitoring stations are shown in Figure 1-1 together with nearby SMHI stations and MESAN-points referred to in the present report.

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

| Activity plans | Number | Version |
|---|---|---|
| Lokala meteorologiska mätningar till stöd för modellversion 1.2 | SKB AP PF 400-03-14 | 1.0 |
| Lokala meteorologiska mätningar till stöd för modellversion 2.1 | SKB AP PF 400-05-014 | 1.0 |
| **Method description** | **Number** | **Version** |
| Metodbeskrivning för meteorologiska mätningar | SKB MD 364.007 | 1.0 |

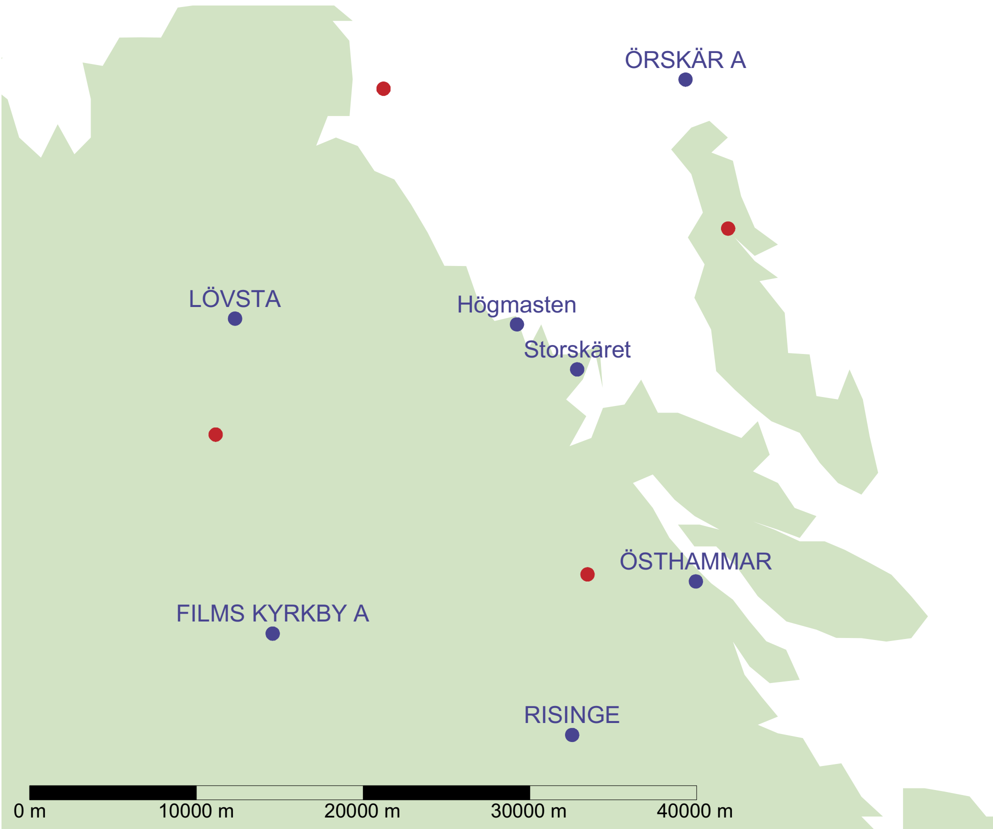


***Figure 1-1.*** *Map showing the location of SMHI's monitoring stations (capital letters), SKB's stations (lower-case letters) and the MESAN-points (red points).*

MESAN is an automatic system for mesoscale analysis of meteorological parameters built on manual as well as automatic observations, including satellite and radar information. Figure 1-2 shows a detailed map of the location of the two SKB stations and the coordinates of the two stations are given in Table 1-2.

**Table 1-2. SKB's monitoring stations. Coordinates in "RT 90 2,5 gon W 0:–15".**

| Identity | X | Y | Type | Name |
|---|---|---|---|---|
| PFM010700 | 6700525 | 1631046 | Meteorological station | Högmasten (Forsmark) |
| PFM010701 | 6697827 | 1634659 | Meteorological station | Storskäret |


*Figure 1-2. A detailed map showing the location of Högmasten and Storskäret.*

# 2 Objective and scope

SKB carries out site investigations in the Forsmark area. To characterise the meteorological conditions, SMHI has installed two stations with meteorological measuring equipment at the site. The results will also be used for water balance calculations and as input data for hydro(geo)logical modelling.

The objective of this report is to present quality checked results from the meteorological monitoring during the period from 2003-06-01 until 2005-07-31.

# 3 Equipment

## 3.1 Meteorological measuring stations

Table 3-1 gives technical information about the equipment. Polycarbonate cupboards house data loggers (type Campbell CR10X), a modem (Siemens TC35 and COM200E), and are earthed for lightning protection.

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

### 3.1.1 Calibration of equipment used at meteorological measuring stations

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

**Table 3-1. Measuring equipment for collecting meteorological data at the stations.**

| Parameters | Equipment |
|---|---|
| Precipitation | Geonor T200 complete with pedestal and wind shield |
| Air temperature | Pt100 sensor with radiation shield and ventilated Young 41004 |
| Barometric pressure (only at Högmasten) | PTB200 |
| Wind speed and direction | RM Young Wind monitor |
| Air humidity | Rotronic HygroClip MP 100H |
| Global radiation (only at Högmasten) | Kipp & Zonen CM21 with warming and fan |

# 4 Execution

## 4.1 General

This execution Chapter is intended to describe the complete course of events, from measuring at Högmasten and Storskäret, via quality check and data handling to the storage in SICADA.

Two abbreviations are frequently used in this context; HMS and SICADA. HMS (Hydro Monitoring System) is SKB's network for the monitoring of meteorological, hydrological and hydrogeological parameters. This is a system for collection, calculation, data check, and data presentation. SICADA is the database that contains all of SKB's quality assured data. Data in SICADA are traceable by the activity plan number. It is from data in SICADA that the modelling and analyses are performed.

## 4.2 Meteorological measurements

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

- Precipitation: Accumulated sum of precipitation every 30 minutes. The 30-minutes precipitation value is the difference between two adjacent accumulated precipitation sums.
- Temperature: 30-minutes mean of one-second values.
- Barometric pressure: 30-minutes mean of one-second values.
- Wind speed and wind direction: The latest 10-minutes mean value for the actual 30 minutes. Hence, for the 10:00 data the measurement is from 09:51 to 10:00.
- Relative humidity: 30-minutes mean of one-second values.
- Global radiation: 30-minutes mean of one-second values.

### 4.2.1 Quality check of meteorological data

Before any data are stored in SKB's database SICADA they are checked and approved by SMHI. Every week a primary check for missing and incorrect values is performed by SMHI and every month a check is made by a meteorologist at SMHI who approves data, calculates evapotranspiration and estimates the true (corrected) precipitation before delivery for final storage in SKB's database, SICADA.

### 4.2.2 Data handling/post processing

Unchecked data are transferred from SMHI to SKB daily via FTP (File Transfer Protocol), while quality checked data are transferred every month.

The data loggers at the stations have internal memories 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 data are stored and the monthly quality assurance and check is done. After this check has been performed, data are delivered to SKB's database.

SMHI has, commissioned by SKB, constructed a homepage 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/forsmark/.

## 4.3 Analyses and interpretations

### 4.3.1 Meteorological measurements

SMHI has continuously checked the collected data, i.e. checked that data are within the limits of reason for each parameter. Data have also been compared with data from SMHI's analysing system MESAN. 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 4-1, the coordinates of the nearest grid points are presented and in Figure 1-1 they are shown on a map.

## 4.4 Nonconformities

There are no nonconformities that affect the results or nonconformities with respect to the activity plan or the method description. However, some system malfunctions occurred and some data were lost.

A minor problem with the communication between AIRVIRO and the logger occurred in the beginning of April 2005 for a short period, but no data were lost.

There have been some problems with the precipitation measurements at both Högmasten and Storskäret. Precipitation data were lost from Storskäret for the periods July 5–9 and August 11–20, 2003. Furthermore, the precipitation gauges were not emptied after the winter 2005, entailing that the gauges were full at June 17 at Högmasten and at June 21 at Storskäret. The oily liquid, that prevents water to evaporate, flowed over. From that date, the evaporation was too large to allow accurate measurements. When some water had evaporated, new precipitation could fill the gauge. However, it was impossible to reconstruct data.

**Table 4-1. Mesan grid points.**

| Latitude | Longitude |
|---|---|
| 60.348 | 17.855 |
| 60.531 | 18.050 |
| 60.449 | 18.420 |
| 60.266 | 18.253 |

# 5 Results

## 5.1 Meteorological monitoring

The meteorological measurements have turned out to work very well during the period for all parameters. However, the 30-minutes value of precipitation still showed too high numbers. This occurs because of the high sensitivity of the instrument and that the precipitation is measured so often. The software in the data logger is improving the quality of the data afterwards at the station.

The locations of all monitoring stations, from which results are presented below, are shown in Figures 1-1 and 1-2. In Appendix 1 daily values are shown for all parameters except for precipitation and wind direction. As an example of the high-resolution variations during a month, data from January 2005 are presented for all parameters, including precipitation and wind direction.

### 5.1.1 Precipitation

The monthly precipitation for the SMHI stations is presented in Table 5-1 and Figure 5-1 below. "Films Kyrkby A" and "Örskär A" are automatic stations whereas the others are manual stations. The precipitation differs substantially between stations and between months. The presented precipitation values are all checked and approved by SMHI. However, the values are not corrected for wind, wetting and evaporation losses. The correction factors are listed in Table 5-2.

**Table 5-1. Monthly measured precipitation in mm at SMHI's stations. These values are not corrected for wind, wetting and evaporation losses.**

| | Jun -03 | Jul -03 | Aug -03 | Sep -03 | Oct -03 | Nov -03 | Dec -03 |
|---|---|---|---|---|---|---|---|
| Örskär A | 20.9 | 7.0 | 94.0 | 19.8 | 67.6 | 53.0 | 43.9 |
| Östhammar | 39.6 | 24.9 | 90.2 | 31.6 | 51.1 | 58.3 | 83.0 |
| Lövsta | 67.9 | 15.6 | 133.2 | 47.9 | 76.0 | 65.6 | 80.4 |
| Risinge | 55.7 | 26.7 | 118.3 | 28.4 | 53.8 | 56 | 80.8 |
| Films Kyrkby A | 49.0 | 16.3 | 97.4 | 68.7 | 76.6 | 63.8 | 101.3 |

| | Jan -04 | Feb -04 | Mar -04 | Apr -04 | May -04 | Jun -04 | Jul -04 | Aug -04 | Sep -04 | Oct -04 | Nov -04 | Dec -04 | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Örskär A | 21.5 | 9.9 | 16.7 | 15.1 | 38.3 | 38.0 | 57.5 | 27.0 | 19.1 | 32.8 | 41.2 | 18.3 | 335.4 |
| Östhammar | 27.0 | 18.3 | 22.5 | 25.6 | 47.9 | 55.5 | 87.3 | 60.4 | 48.0 | 68.4 | 75.2 | 30.8 | 566.9 |
| Lövsta | 34.0 | 14.3 | 29.1 | 22.4 | 48.5 | 74.3 | 64.4 | 69.4 | 60.2 | 52.3 | 57.1 | 27.5 | 553.5 |
| Risinge | 35.4 | 19.8 | 20.4 | 18.0 | 54.6 | 71.2 | 95.1 | 74.2 | 81.3 | 49.5 | 78.4 | 33.0 | 630.9 |
| Films Kyrkby A | 30.9 | 18.0 | 26.7 | 19.5 | 49.9 | 61.2 | 68.4 | 59.3 | 43.5 | 49.4 | 49.5 | 25.4 | 501.7 |

| | Jan -05 | Feb -05 | Mar -05 | Apr -05 | May -05 | Jun -05 | Jul -05 |
|---|---|---|---|---|---|---|---|
| Örskär | 33.0 | 24.4 | 9.6 | 3.0 | 39.8 | 62.2 | 30.7 |
| Östhammar | 44.6 | 40.9 | 10.3 | 5.1 | 41.4 | 73.9 | 59.2 |
| Lövsta | 51.7 | 38.4 | 17.2 | 8.3 | 39.0 | 90.2 | 93.4 |
| Risinge | 57.0 | 42.1 | 13.1 | 9.0 | 40.1 | 83.6 | 116.4 |
| Films Kyrkby A | 58.2 | 46.7 | 18.3 | 8.2 | 50.5 | 61.7 | 96.2 |

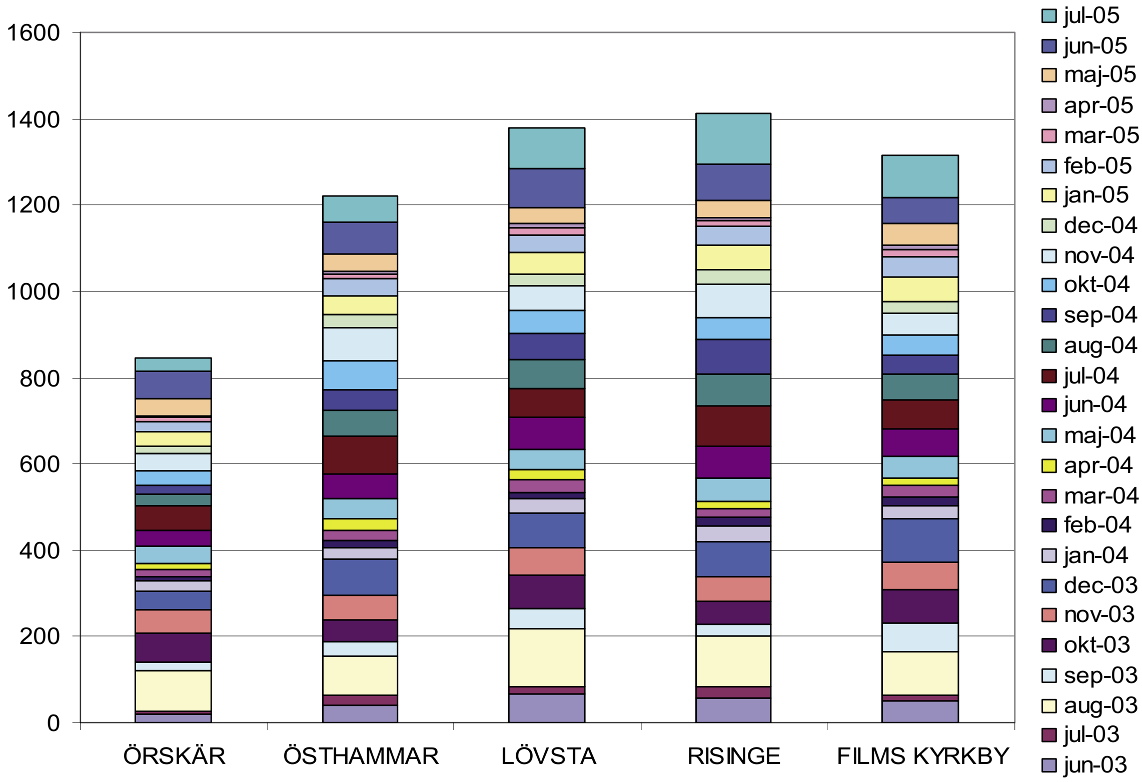


***Figure 5-1.*** *Monthly precipitation in mm at SMHI's stations. The values are not corrected for wind, wetting and evaporation losses.*

**Table 5-2. Corrections for losses in percent at SMHI's precipitation stations according to /Alexandersson 2003/.**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Örskär A | 19 | 22 | 23 | 15 | 15 | 13 | 13 | 15 | 14 | 15 | 17 | 20 | 16 |
| Östhammar | 9 | 13 | 10 | 9 | 9 | 12 | 8 | 9 | 8 | 7 | 8 | 10 | 9 |
| Lövsta | 10 | 9 | 12 | 10 | 11 | 12 | 8 | 8 | 8 | 8 | 9 | 9 | 9 |
| Risinge | 11 | 12 | 10 | 11 | 13 | 12 | 8 | 8 | 8 | 9 | 8 | 9 | 9 |
| Film Kyrkby A | 13 | 16 | 19 | 15 | 13 | 14 | 11 | 13 | 13 | 13 | 14 | 16 | 14 |

The precipitation at Högmasten and Storskäret is presented in Table 5-3. "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.

The true precipitation (KOR) is the precipitation corrected for wind, wetting and evaporation losses. For this site and instrument it was estimated that the true precipitation exceeded the measured precipitation by 10% if the temperature was below +1°C and 6% more if the temperature was equal to or above +1°C. More information about true precipitation can be found in /Alexandersson 2003/.

**Table 5-3. 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, "ALX" is the new estimation of the true precipitation, and "MES" means values from the MESAN-analyses.**

| | Jun -03 | Jul -03 | Aug -03 | Sep -03 | Oct -03 | Nov -03 | Dec -03 |
|---|---|---|---|---|---|---|---|
| Forsmark 001 | 37.7 | 13.5 | 94.7 | 49.2 | 74.7 | 53.7 | 65.6 |
| Forsmark COR | 37.7 | 13.5 | 94.7 | 49.2 | 74.7 | 53.7 | 65.6 |
| Forsmark KOR | 40.0 | 14.3 | 100.4 | 52.2 | 80.7 | 57.3 | 71.6 |
| Forsmark ALX | 41.5 | 14.8 | 104.2 | 54.1 | 82.2 | 59.6 | 73.5 |
| MESAN | 39.4 | 9.1 | 51.3 | 20.4 | 38.6 | 35.9 | 69.9 |
| Storskäret 001 | 33.2 | 18.4 | 111.7 | 41.9 | 60.2 | 54.7 | 64.7 |
| Storskäret COR | 33.2 | 18.4 | 103.5 | 41.9 | 60.2 | 54.7 | 64.7 |
| Storskäret KOR | 35.2 | 19.5 | 109.7 | 44.4 | 64.9 | 58.6 | 70.7 |
| Storskäret ALX | 36.5 | 20.2 | 122.9 | 46.1 | 66.2 | 60.7 | 72.5 |

| | Jan -04 | Feb -04 | Mar -04 | Apr -04 | May -04 | Jun -04 | Jul -04 | Aug -04 | Sep -04 | Oct -04 | Nov -04 | Dec -04 | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forsmark 001 | 36.9 | 14.3 | 24.5 | 28.7 | 39.0 | 41.7 | 69.7 | 54.7 | 28.6 | 33.8 | 245.9 | 26.5 | 644.3 |
| Forsmark COR | 36.9 | 14.3 | 24.5 | 28.7 | 39.0 | 40.4 | 64.6 | 48.6 | 27.8 | 33.8 | 55.0 | 26.5 | 440.1 |
| Forsmark KOR | 40.6 | 15.7 | 26.6 | 30.4 | 41.3 | 42.8 | 68.5 | 51.5 | 29.5 | 35.8 | 59.8 | 28.5 | 471.0 |
| Forsmark ALX | 41.7 | 16.3 | 27.7 | 31.9 | 42.9 | 44.4 | 71.1 | 53.5 | 30.6 | 37.2 | 61.1 | 29.7 | 487.9 |
| Mesan | 29.9 | 14.0 | 13.9 | 13.3 | 24.0 | 47.1 | 51.8 | 30.6 | 26.0 | 38.3 | 41.8 | 16.1 | 346.9 |
| Storskäret 001 | 39.0 | 13.3 | 22.0 | 27.1 | 40.9 | 43.2 | 87.8 | 50.9 | 24.6 | 38.8 | 240.1 | 30.6 | 658.3 |
| Storskäret COR | 39.0 | 13.3 | 22.0 | 27.1 | 40.9 | 43.2 | 87.8 | 50.9 | 24.6 | 38.8 | 50.4 | 30.6 | 468.6 |
| Storskäret KOR | 42.9 | 14.5 | 23.9 | 28.7 | 43.4 | 45.8 | 93.1 | 54.0 | 26.1 | 41.1 | 54.6 | 32.9 | 500.9 |
| Storskäret ALX | 44.1 | 15.2 | 24.9 | 30.1 | 45.0 | 47.5 | 96.6 | 56.0 | 27.1 | 42.7 | 55.9 | 34.3 | 519.2 |

| | Jan -05 | Feb -05 | Mar -05 | Apr -05 | May -05 | Jun -05 | Jul -05 |
|---|---|---|---|---|---|---|---|
| Forsmark 001 | 51.8 | 41.9 | 16.4 | 3.1 | 38.8 | 73.4 | 15.8 |
| Forsmark COR | 51.7 | 41.9 | 16.3 | 3.2 | 38.8 | 61.0 | |
| Forsmark KOR | 55.9 | 46.0 | 17.9 | 3.4 | 41.1 | 64.7 | |
| Forsmark ALX | 58.4 | 47.8 | 18.4 | 3.6 | 42.7 | 67.1 | |
| Mesan | 29.9 | 30.9 | 12.9 | 4.3 | 33.0 | 56.2 | 29.9 |
| Storskäret 001 | 159.0 | 42.5 | 17.2 | 2.5 | 34.7 | 87.8 | 16.6 |
| Storskäret COR | 53.1 | 42.4 | 17.5 | 2.5 | 34.8 | 70.9 | |
| Storskäret KOR | 57.5 | 46.5 | 19.2 | 2.6 | 36.9 | 75.2 | |
| Storskäret ALX | 60.0 | 48.3 | 19.8 | 2.8 | 38.3 | 78.0 | |

During 2005, a new method for estimating the true precipitation was implemented (ALX). This new method is judged to be better than the previously applied method because it is based on photographs of the surroundings of the stations. Furthermore, it is the same method as used for the SMHI stations. The new method gives higher values than the method above. Table 5-4 gives the corrections (percentage) for each month. More information about the estimated true precipitation can be found in /Alexandersson 2005/ (Appendix 2).

The registered 30-minutes precipitation values have to be filtered before storage. That is because the instrument is very sensitive and registers incorrectly small values of precipitation.

In the end of June 2005 problems with the precipitation gauges occurred. The precipitation from June 17 until the end of July is not counted for at Högmasten, and not from June 21 until the end of July at Storskäret.

Figure 5-2 shows the accumulated sum of precipitation from August 2004 to July 2005, where it can be seen that the gauges reached the maximum values in June. (The gauges were emptied on September 14, 2004).

If the accumulated uncorrected precipitation from June 2003 to May 2005 from the different stations is compared, it can be seen that the SMHI-station at Örskär only got 751 mm, wheras the other SMHI stations got between 1,090 and 1,212 mm (Table 5-5). These values can be compared with the COR-values from Forsmark and Storskäret in the same table. The values correspond well with each other.

As an example of high-resolution precipitation data, Figure 7 in Appendix 1 shows the 30-minutes precipitation values for January 2005 for Forsmark and Storskäret.

**Table 5-4. Corrections for losses in percent at SKB's stations according to /Alexandersson 2005/ (Appendix 2).**

| | J | F | M | A | M | J | J | A | S | O | N | D | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Högmasten | 13 | 14 | 13 | 11 | 10 | 10 | 10 | 10 | 10 | 10 | 11 | 12 | 11 |
| Storskäret | 13 | 14 | 13 | 11 | 10 | 10 | 10 | 10 | 10 | 10 | 11 | 12 | 11 |

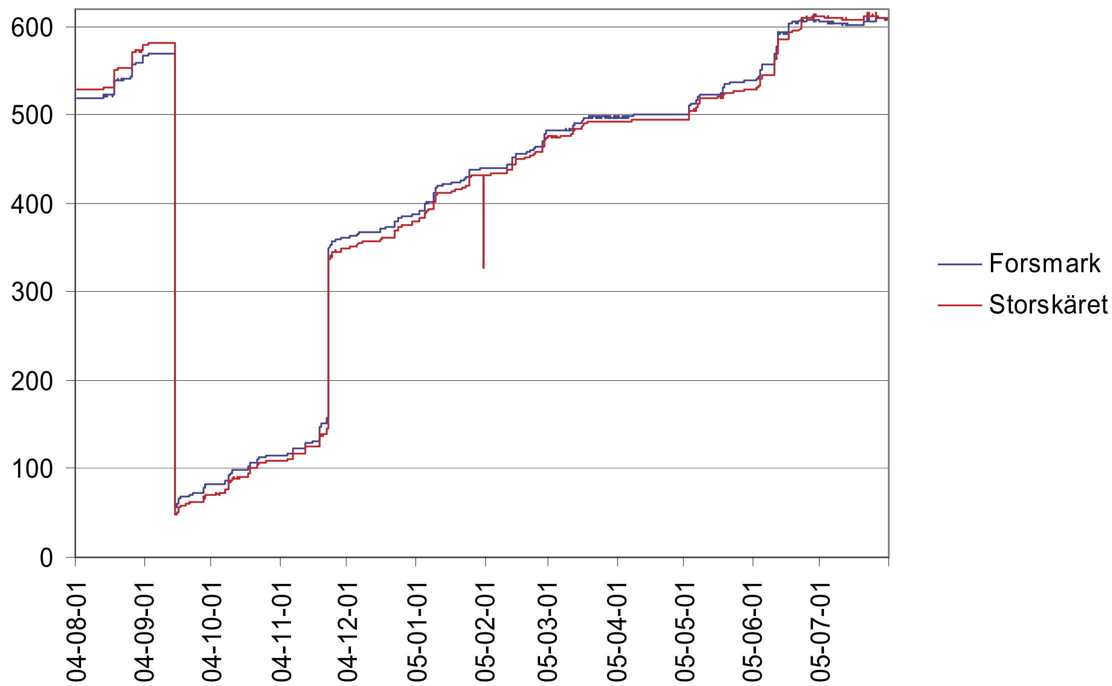


***Figure 5-2.*** *Precipitation in mm, 30-minutes values. August 2004–July 2005.*

**Table 5-5. Precipitation in mm from June 2003 to May 2005. Only uncorreced values are given for the SMHI stations (corresponding to the COR-values at SKB's stations).**

| | |
|---|---|
| Forsmark 001 | 1,185 |
| Forsmark COR | 981 |
| Forsmark KOR | 1,052 |
| Forsmark ALX | 1,089 |
| Mesan | 813 |
| Storskäret 001 | 1,299 |
| Storskäret COR | 996 |
| Storskäret KOR | 1,066 |
| Storskäret ALX | 1,113 |
| Örskär | 751 |
| Östhammar | 1,090 |
| Lövsta | 1,195 |
| Risinge | 1,212 |
| Films Kyrkby A | 1,158 |

### 5.1.2 Air temperature

A graph of daily temperature is presented in Figure 1 in Appendix 1. Values from Forsmark (Högmasten), Storskäret and MESAN-values are exposed. Figure 8 shows the 30-minutes values for January 2005. The three curves follow each other very well.

### 5.1.3 Barometric pressure

A graph of the daily barometric pressure is presented in Figure 2 in Appendix 1. Values from Forsmark (Högmasten) and MESAN-values are presented. Figure 9 shows the 30-minutes values for January 2005. The three curves are nearly identical.

### 5.1.4 Wind speed and wind direction

A graph of the wind speed (daily mean) is illustraded in Figure 3 in Appendix 1. Values from Forsmark (Högmasten), Storskäret and MESAN-values are presented. Figure 10 shows the 30-minutes values for January 2005. The wind speeds are higher from MESAN compared to Högmasten and Storskäret.

From Figure 1-1, it can be seen that two of the MESAN-points are situated at sea and therefore provide very high wind speeds. The other mesan-points give values closer to Forsmark, especially when the wind is from west. When interpolating the wind speed to the location of Forsmark, MESAN overestimates the wind speed. The wind speed curves from Högmasten and Storskäret follow each other quite well.

In Figure 11 in Appendix 1, the wind directions for the same stations are compared for January 2005. The data correspond well to each other.

### 5.1.5 Relative humidity

A graph of relative humidity is presented in Figure 4 in Appendix 1. Values from Forsmark (Högmasten), Storskäret and MESAN-values are displayed. Figure 12 shows the 30-minutes values for January 2005. The three curves follow each other very well.

### 5.1.6 Global radiation

A graph of the daily sum of global radiation is presented in Figure 5 in Appendix 1. Figure 13 in Appendix 1 shows the 30-minutes values for January 2005. Global radiation is measured only at Forsmark (Högmasten). Values from Forsmark (Högmasten) and Strång-values are presented. Strång is the analysed global radiation from the SMHI radiation model, which uses data from MESAN. Values from Strång (MESAN) correspond well to measured global radiation at Forsmark (Högmasten).

During days with a clear sky, for example July 1–4 2005, it can be seen that something blocks the view of the sensor (Figure 5-3). Every day at about 08:00 there is a notch in the graph. It is the high mast of the nuclear plant that is blocking the sensor.

### 5.1.7 Calculated potential evapotranspiration

The potential evapotranspiration $E_p$ is calculated from the Penman equation:

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

where

$\Delta$ proportionality constant

$R_n$ net radiation flux density

$G$ heat flux density into ground

$\gamma$ psychrometric constant

$f(u)$ function of wind speed

$e_s$ saturated water vapor pressure

$e$ water vapor pressure

$L$ latent heat of vaporization

$tstep$ time step

The method is described in detail in /Eriksson 1981/.

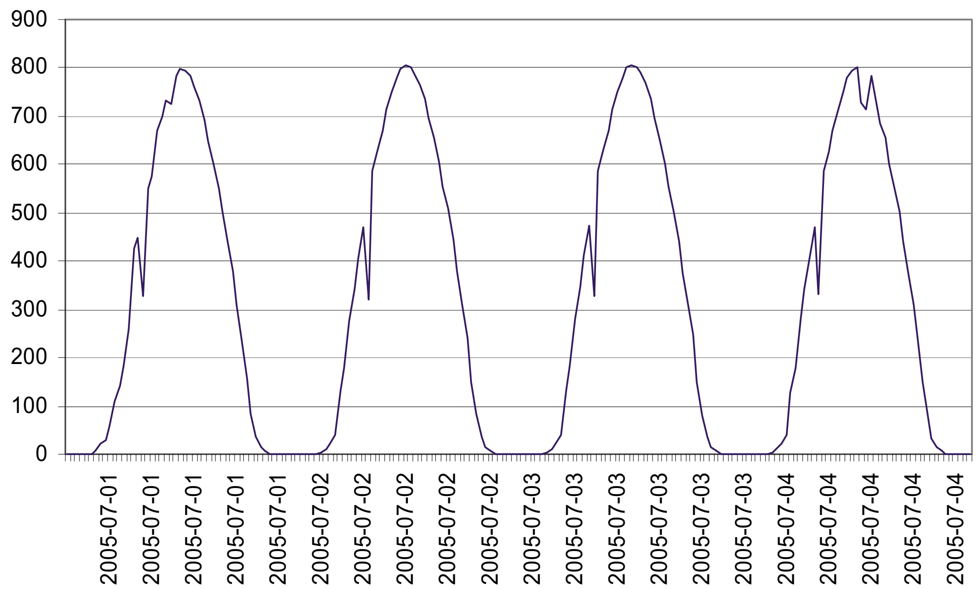


***Figure 5-3.*** *Global radiation July 1–4, 2005.*

Measured data every 30-minutes of temperature, relative humidity, wind speed and global radiation are required as input data to the equation to calculate the potential evapotranspiration. The potential evapotranspiration is much higher at Örskär compared to Forsmark and Films Kyrkby. During 2004 the calculated potential evaporation at Högmasten was 494 mm and at Films Kyrkby 538 mm, while it was 688 mm at Örskär. The reason for this difference is mainly that the wind speed is much higher at Örskär (sea station).

A graph of the potential evapotranspiration for Högmasten is presented in Figure 6 in Appendix 1. Figure 14 shows the 30-minutes values for January 2005.

# References

**Alexandersson H, 2003.** Korrektion av nederbörd enligt enkel klimatologisk metodik. SMHI, Meteorologi, Nr 111.

**Alexandersson H, 2005.** Enkel bedömning av nederbördsförluster på fyra automatstationer (see Appendix 2).

**Eriksson B, 1981.** Den ”potentiella” evapotranspirationen i Sverige. SMHI, RMK 28.

**Førland E J, Allerup P, Dahlström B, Elomaa E, Jónsson T, Madsen H, Perälä J, Rissanen P, Vedin H, Vejen F, 1996.** Manual for operational correction of Nordic precipitation data. DNMI Klima 24/96, 66 pages.

## Meteorological monitoring

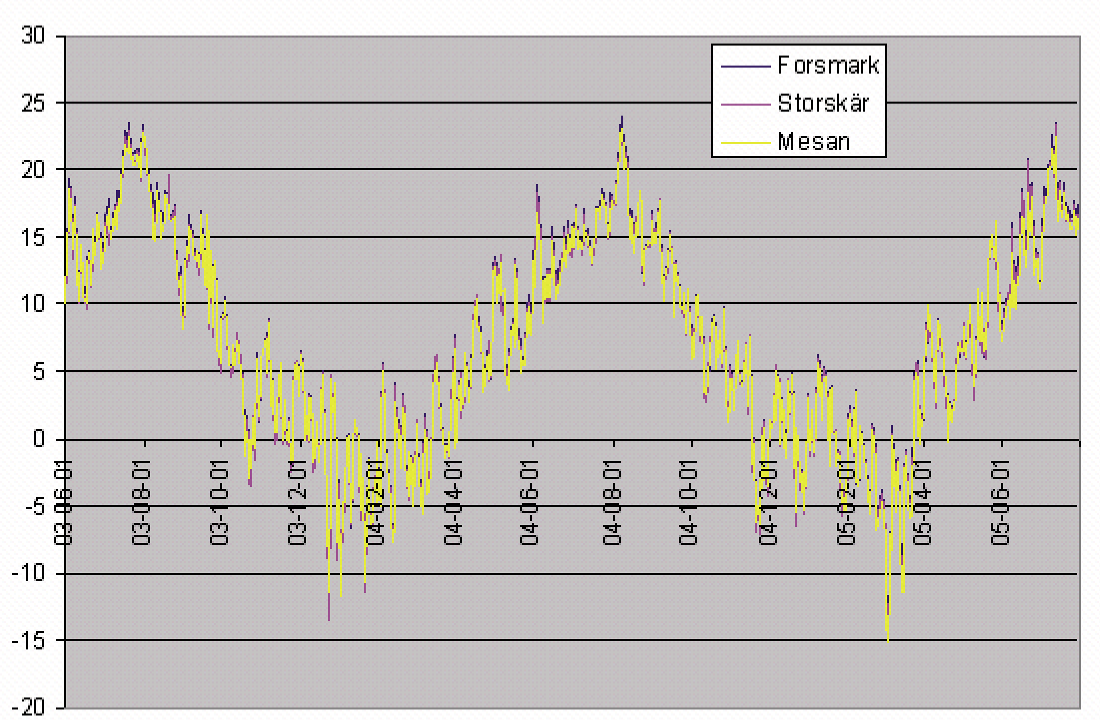


***Figure 1.*** *Temperature in °C, daily values. June 2003–July 2005.*

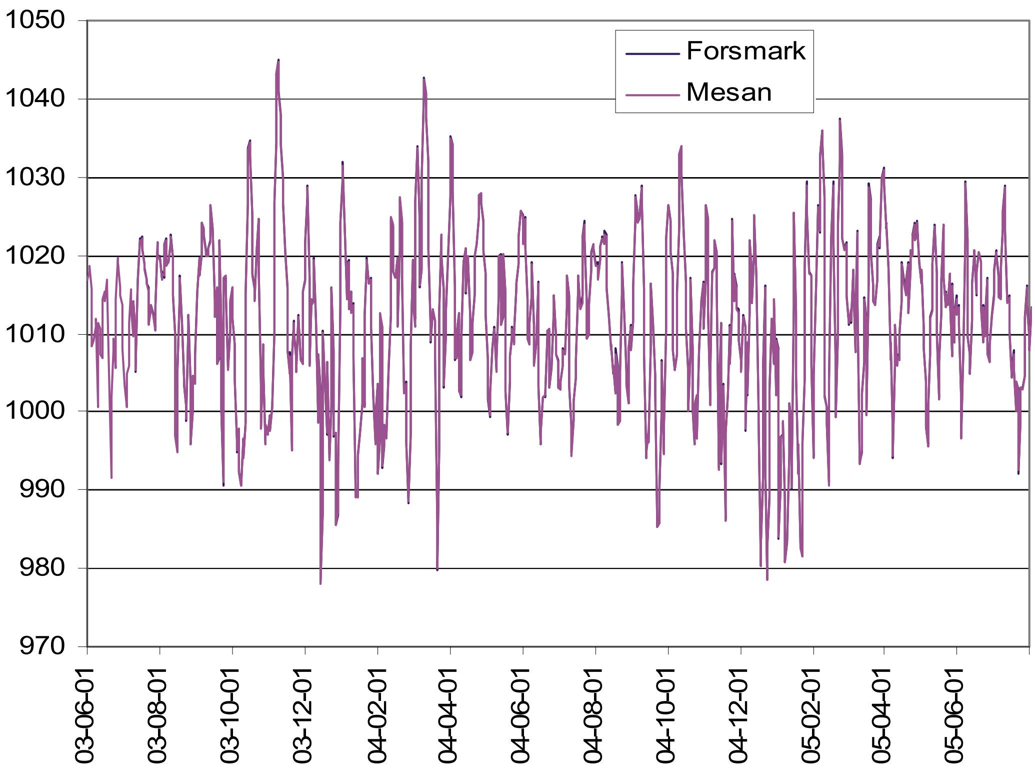


***Figure 2.*** *Barometric pressure in hPa, daily values. June 2003–July 2005.*

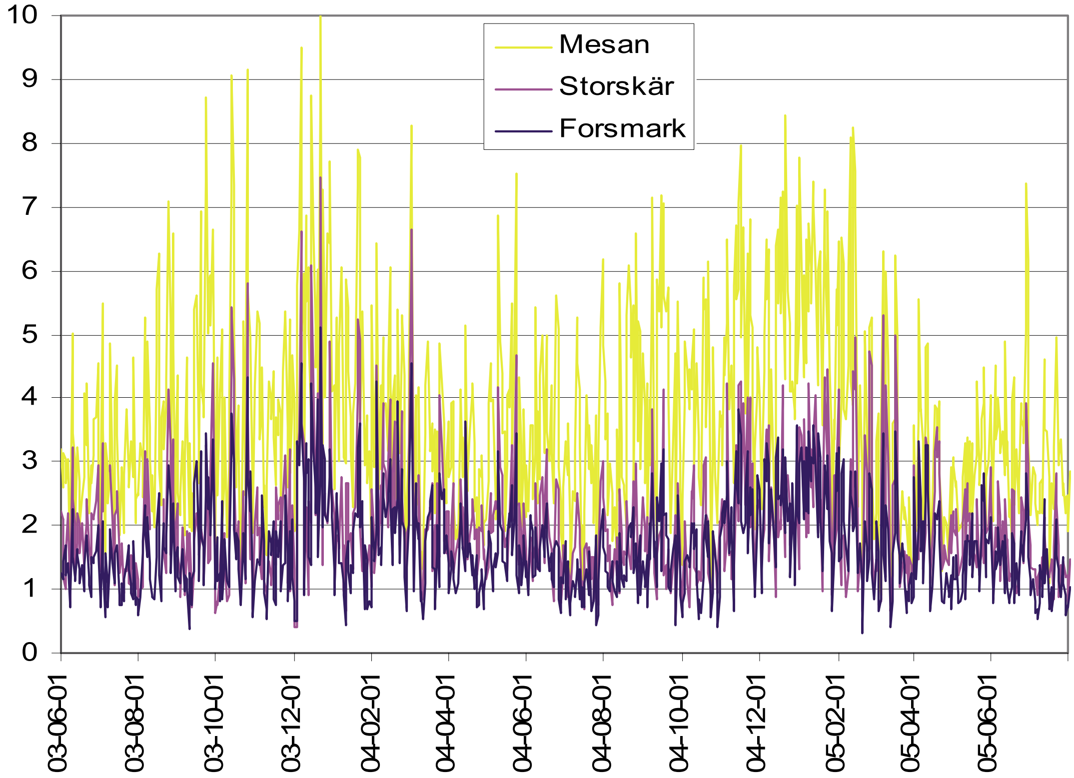


***Figure 3.*** *Wind speed in m/s, daily values. June 2003–July 2005.*

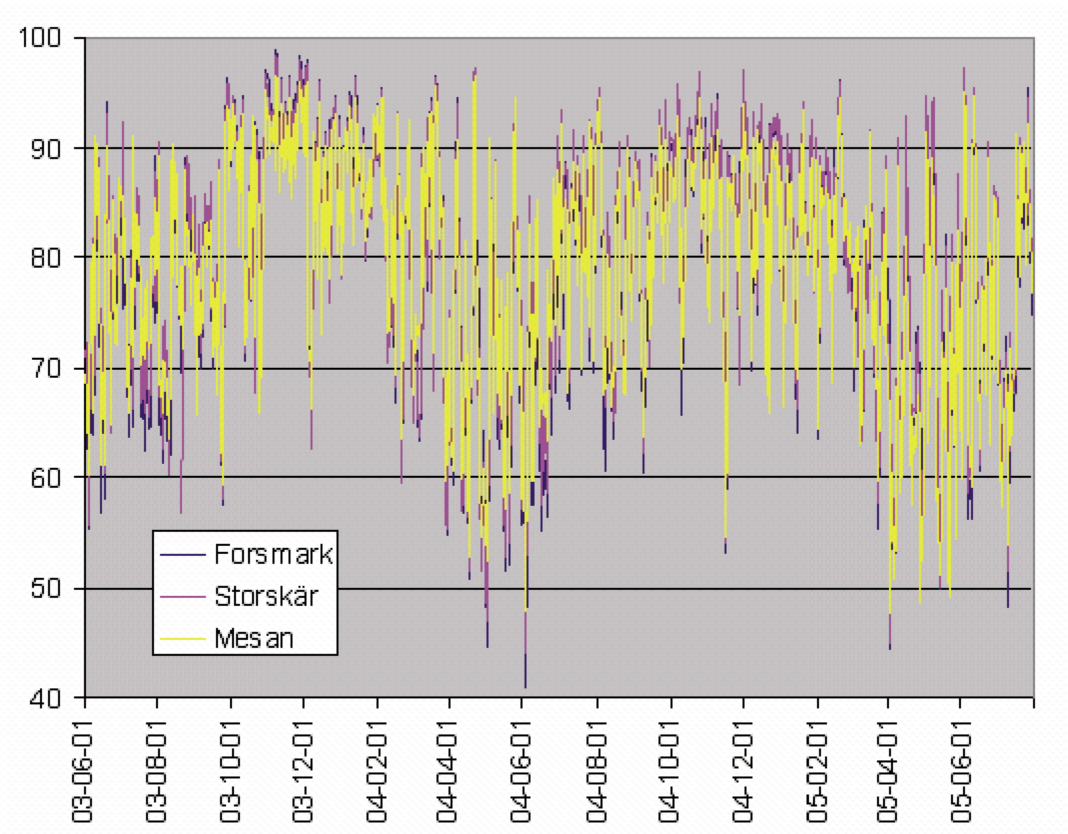


***Figure 4.*** *Relative humidity in percent, daily values. June 2003–July 2005.*

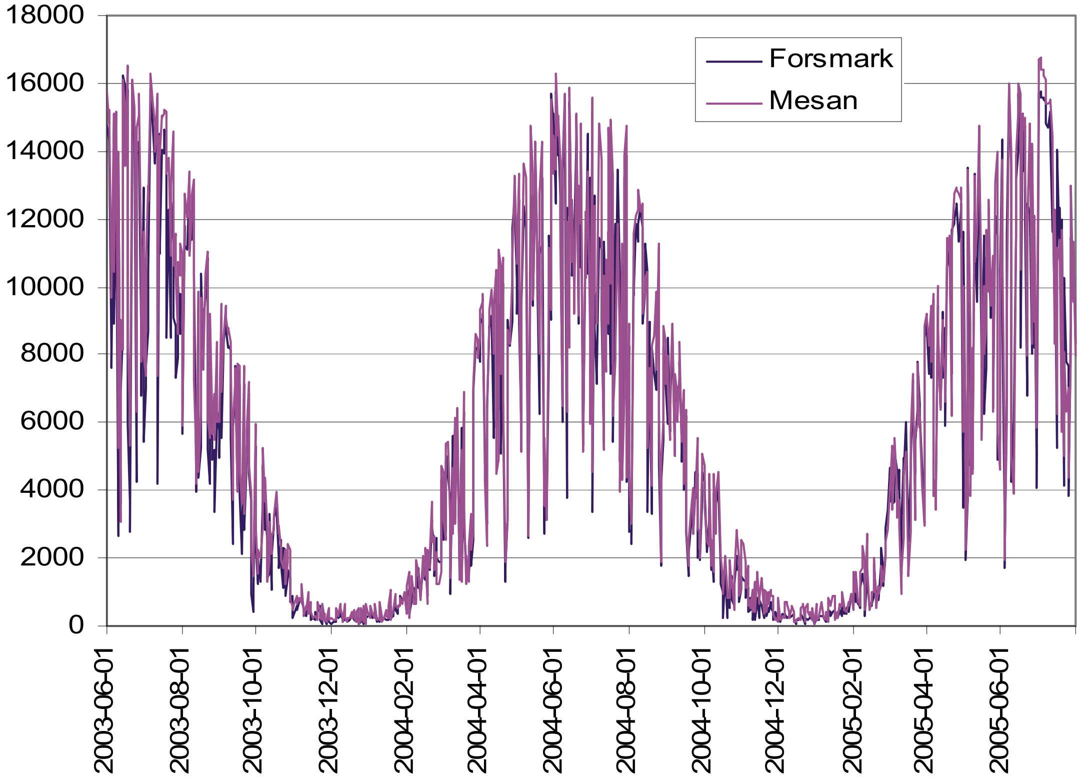


***Figure 5.*** *Global radiation in Wh/m², daily sum. June 2003–July 2005.*

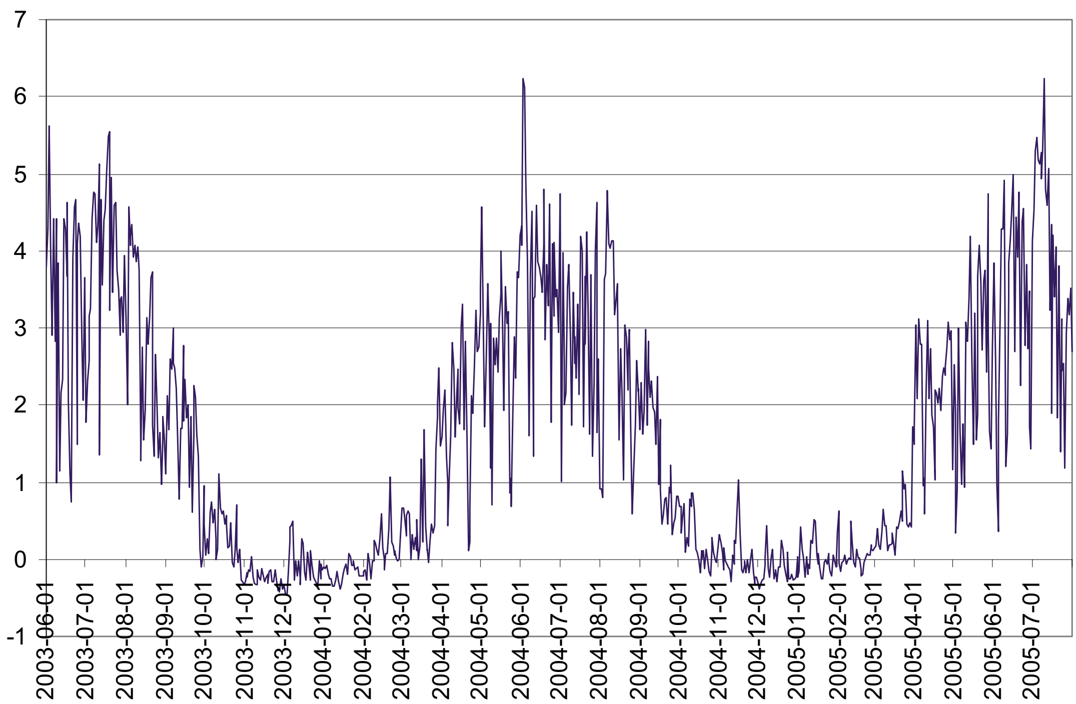


***Figure 6****.* *Potential evapotranspiration in mm, daily sum at Forsmark. June 2003–July 2005.*

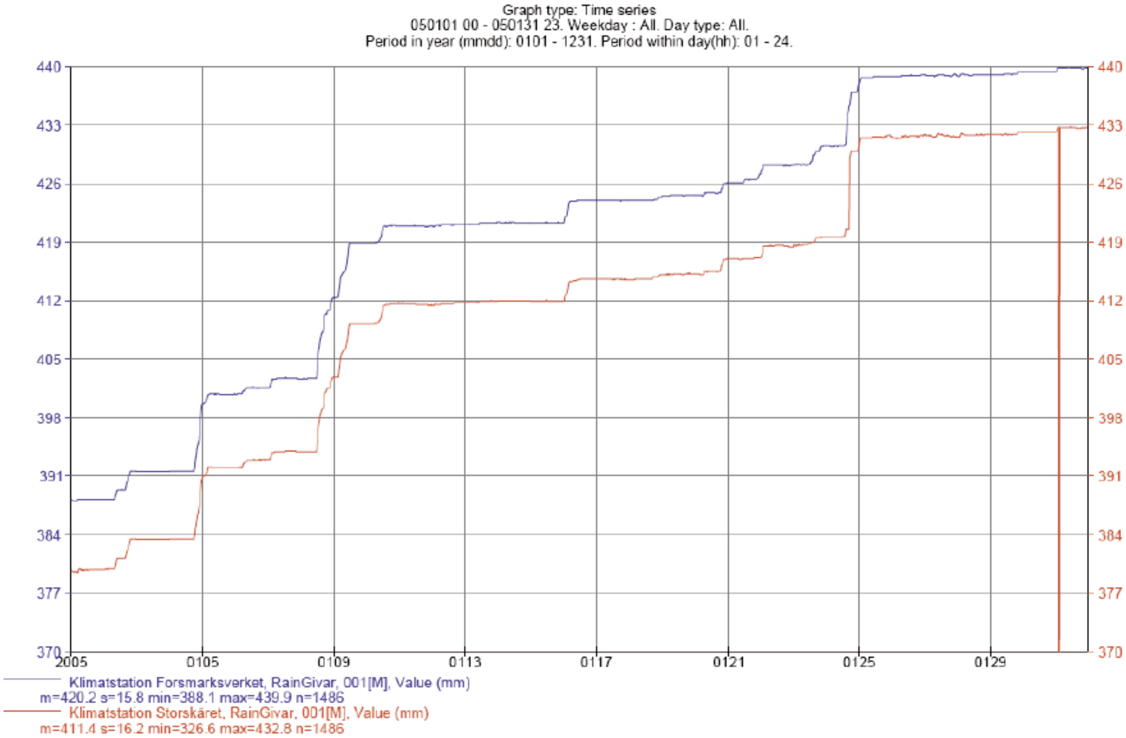


***Figure 7.*** *Precipitation in mm, 30-minutes values. January 2005.*

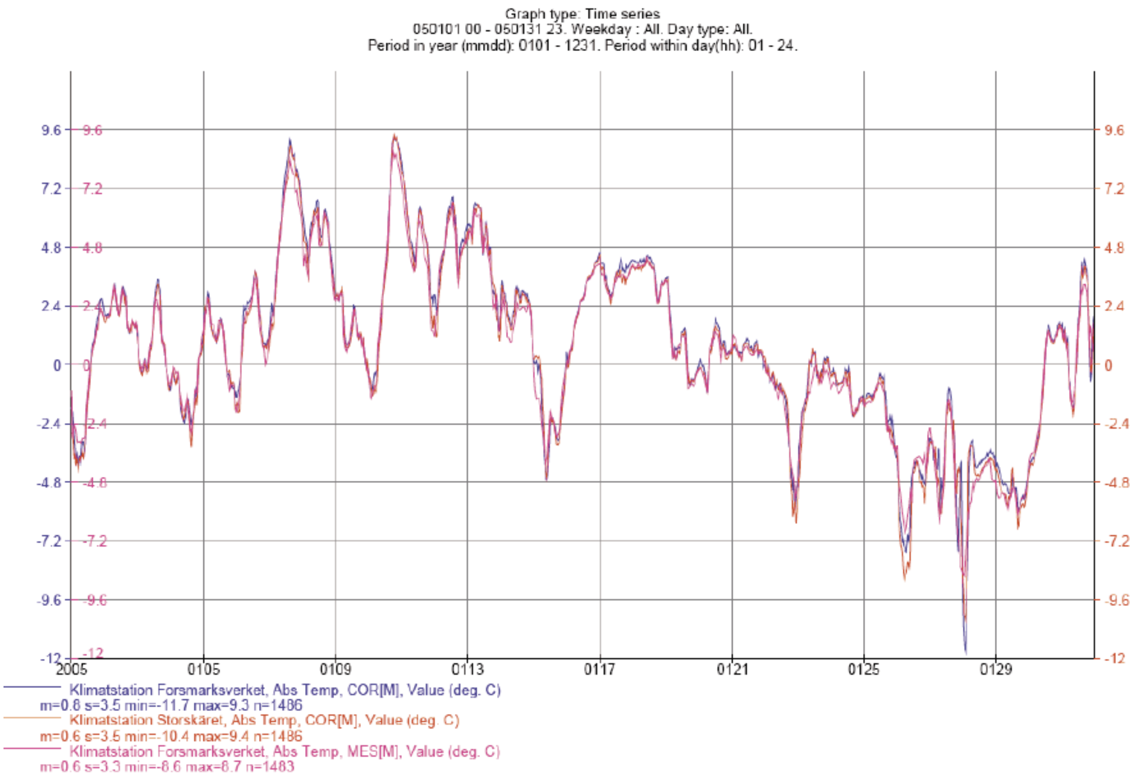


***Figure 8****. Temperature in °C, 30-minutes values. January 2005.*

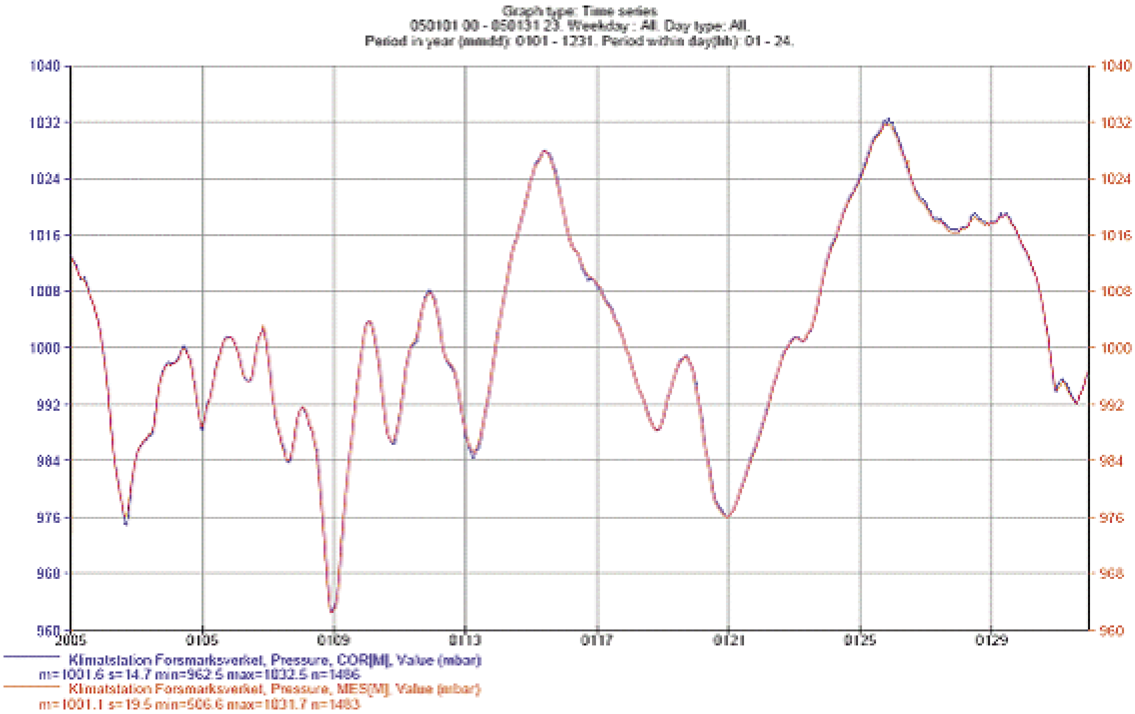


***Figure 9.*** *Barometric pressure in hPa, 30-minutes values. January 2005.*

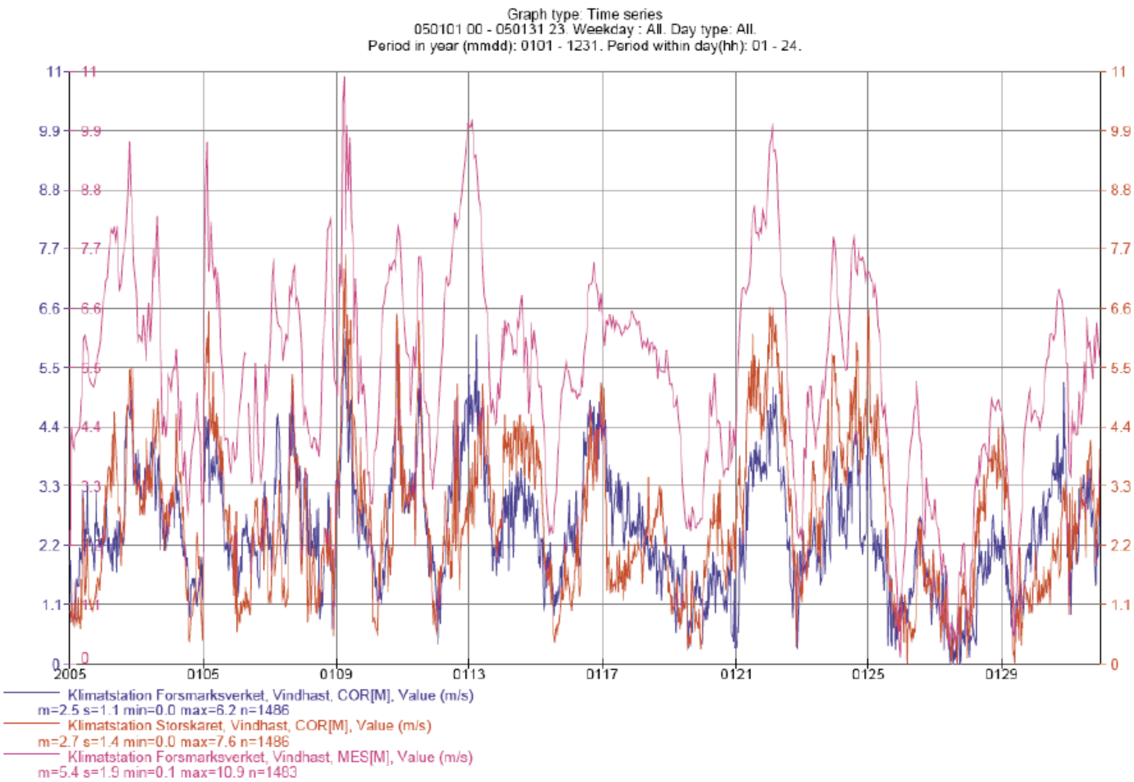


***Figure 10.*** *Wind speed in m/s, 30-minutes values. January 2005.*

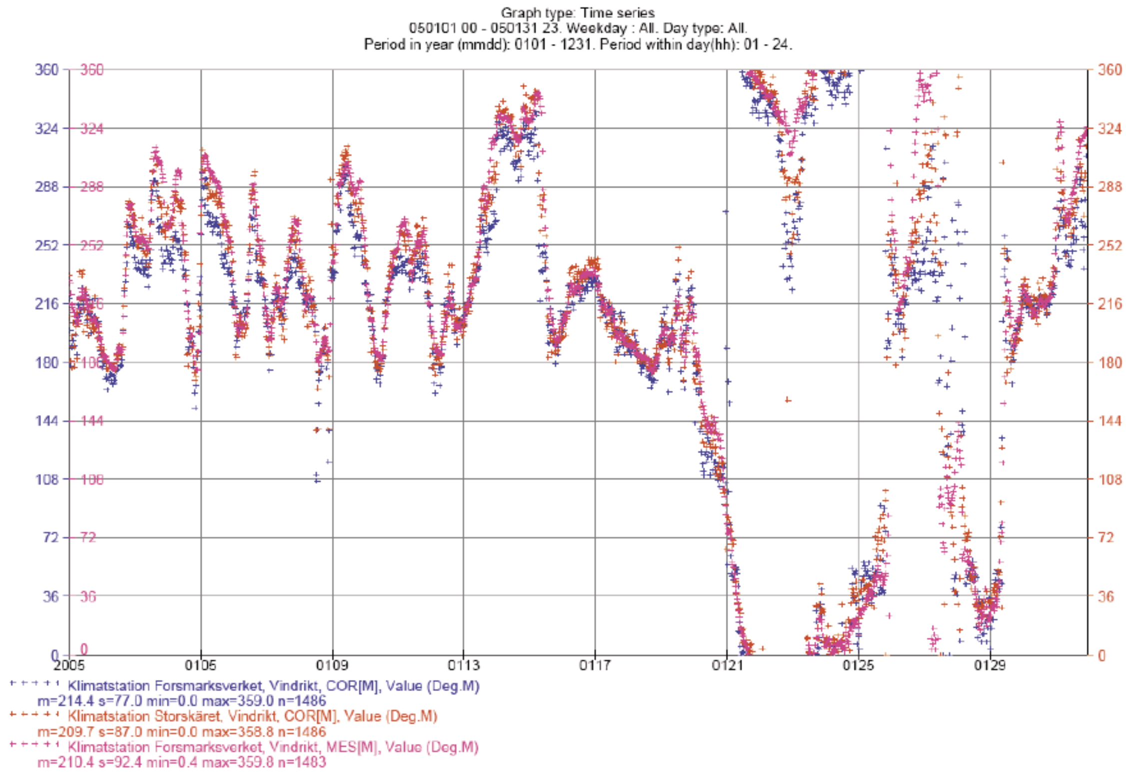


***Figure 11**. Wind direction in degrees, 30-minutes values. January 2005.*

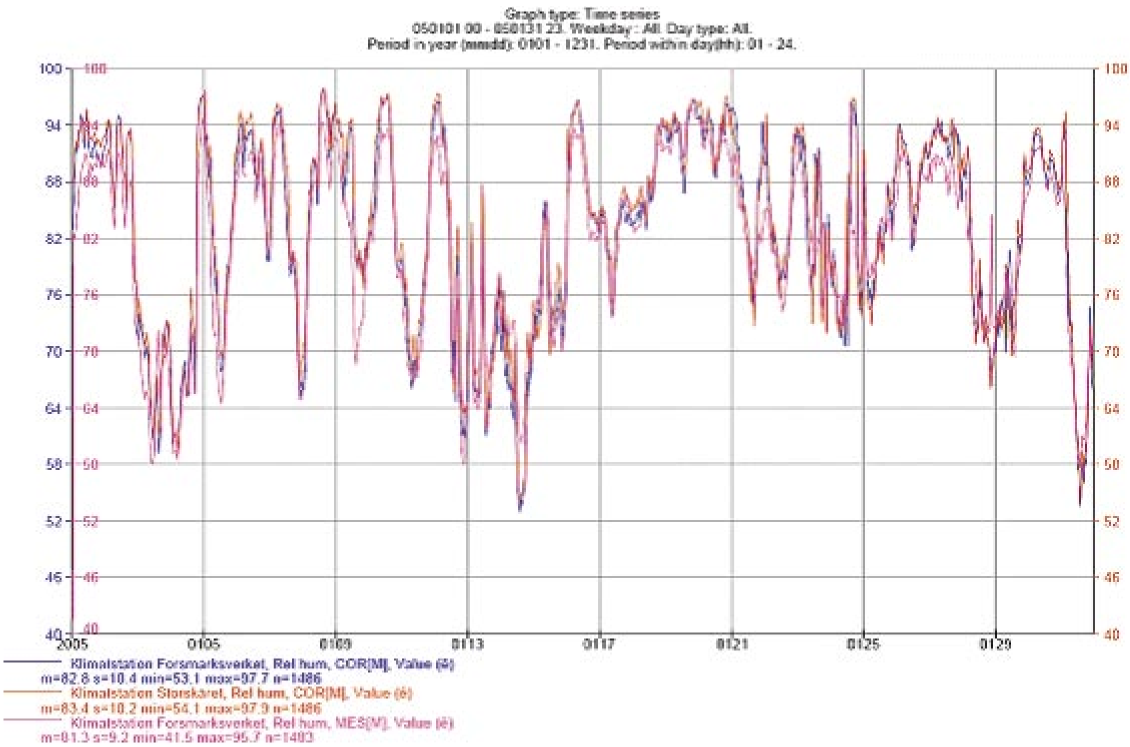


***Figure 12.** Relative humidity in percent, 30-minutes values. January 2005.*

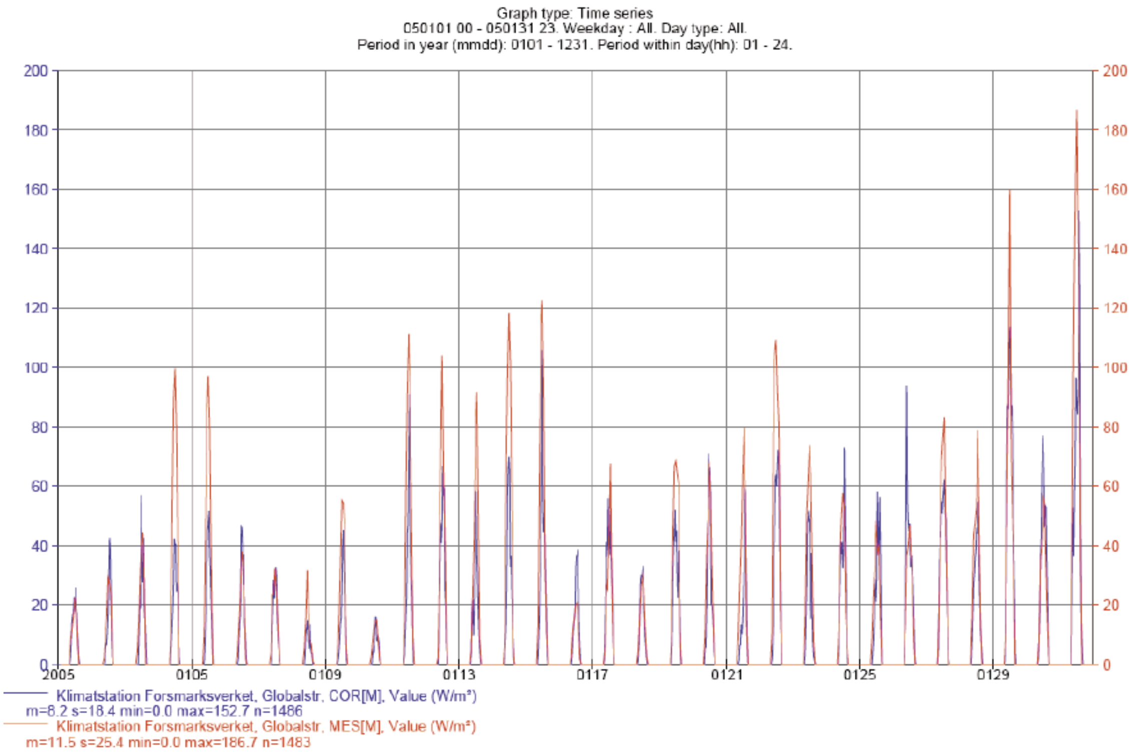


***Figure 13.*** *Global radiation in W/m², 30-minutes values. January 2005.*

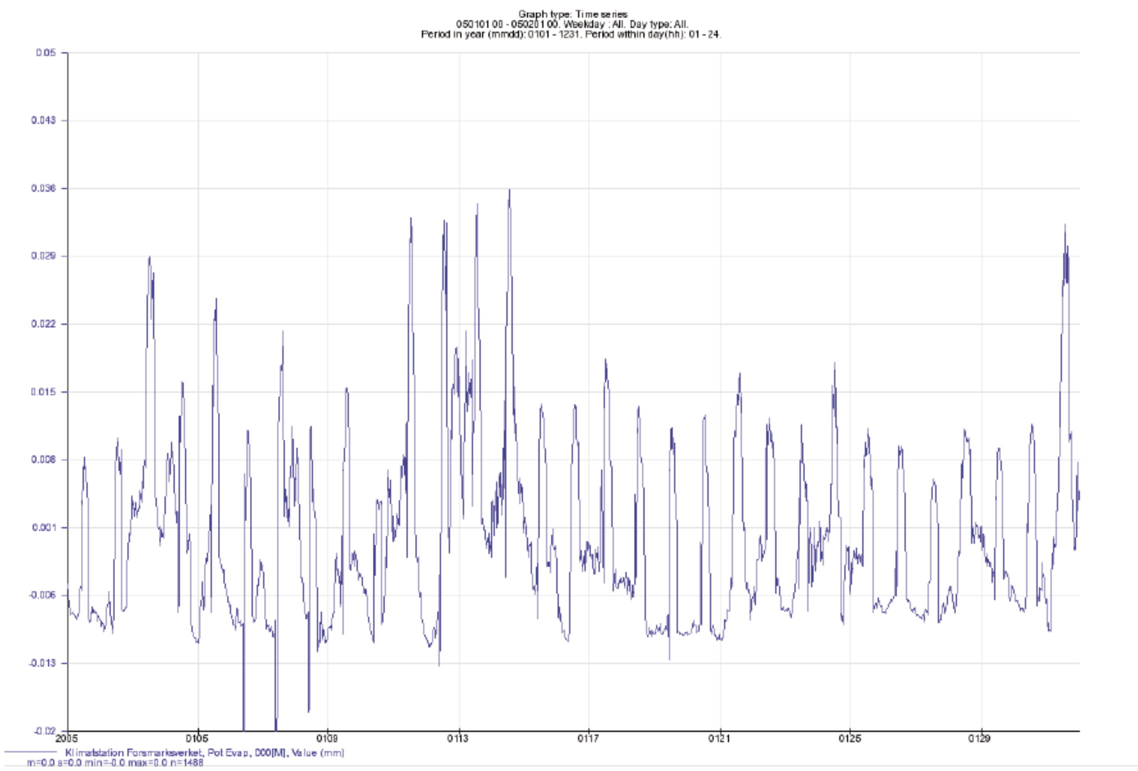


***Figure 14**. Potential evapotranspiration in mm, 30-minutes values. January 2005.*

# Appendix 2

## Enkel bedömning av nederbördsmätförluster på fyra automatstationer

Av Hans Alexandersson

För fyra stationer med GEONOR-nederbördsmätare, två nära Forsmark och två nära Simpevarp, har en bedömning av mätförluster gjorts enligt samma kriterier som i /Alexandersson 2003/. För bedömningen användes främst ett antal foton samt kartor med det exakta läget. Efter att stationerna klassats med avseende på vindutsatthet las denna information in i samma program som tidigare körts för SMHI:s stationsnät.

Vindförlusterna är under i övrigt lika betingelser större för GEONOR-mätaren än för den traditionella manuella mätaren (SMHI-kannan) som används i Sverige. Därför läggs det på lite extra korrektion för GEONOR-mätaren inom respektive vindklass. För GEONOR-mätaren kombineras adhesions- och avdunstningförluster.

Följande vindklasser (1 perfekt, 7 ytterst olämplig) och temperaturstationer användes:

| | | |
|---|---|---|
| Högmasten | 2 | Singö |
| Storskäret | 2 | Singö |
| Äspö | 4 | Oskarshamn |
| Plittorp | 2 | Oskarshamn |

Alla stationer utom i viss mån Äspö sitter alltså väldigt bra placerade. Klass 2 är en så gott som ideal placering, 4 är däremot en placering som ger lite större förluster. I stort sett sitter tre av mätarna så bra det är möjligt i en kustzon med ofta relativt höga vindhastigheter i samband med nederbörd. Mätaren på Äspö sitter dock på en något välvd kulle med berg i dagen, men egentligen med tämligen bra skydd av träd för att vara en ö. Trädridåer finns på 20–30 meters håll i alla riktningar utom i någon smal glipa ungefär mot ostnordost. Tillhörande temperaturstationer användes för att ge ett mått på den genomsnittliga andelen snönederbörd.

Programmet som körts ger primärt uppmätta och korrigerade normalvärden. För dessa stationer har (fiktiva) uppmätta normalvärden tagits från nämnda grannstationer. Sedan har korrektioner i procent beräknats för varje månad utifrån dessa uppmätta respektive korrigerade värden. Det är mest praktiskt att använda faktorer och det ger inget nämnvärt fel (mot att t ex ge adhesionsfelet som ett absolutbelopp vid ett visst ”nederbördstillfälle”) sett över lite längre perioder.

Följande tabell med korrektioner i procent erhölls:

| Plats | Jan | Feb | Mar | Apr | Maj | Jun | Jul | Aug | Sep | Okt | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Högmasten | 13 | 14 | 13 | 11 | 10 | 10 | 10 | 10 | 10 | 10 | 11 | 12 |
| Storskäret | 13 | 14 | 13 | 11 | 10 | 10 | 10 | 10 | 10 | 10 | 11 | 12 |
| Äspö | 21 | 21 | 19 | 16 | 14 | 14 | 14 | 14 | 14 | 16 | 17 | 20 |
| Plittorp | 12 | 13 | 12 | 10 | 10 | 9 | 9 | 10 | 10 | 10 | 10 | 12 |

För Högmasten och Storskäret, som fått identiska korrektioner i denna bedömning, ska sålunda nederbörden i januari multipliceras med 1,13. Korrektionen kan, då det bara är en faktor, tillämpas på timvärden men man får behålla några decimaler så att summor över längre tid – beräknade som summor av timvärden – blir korrigerade enligt samma faktor som vid en direkt korrektion av t ex en dygnssumma.

Vid en efterkontroll jämfördes korrigerade värden med motsvarande korrigerade manuella mätningar i närheten. Dessa jämförelser baserades dock bara på cirka två års mätningar. Manuella jämförelsestationer var främst Östhammar för Forsmarksmätarna och Kråkemåla för Simpevarpsmätarna. Även de yttäckande analyserna i Väder och Vatten utnyttjades. De först antagna vindförlustklasserna behövde därvid *ej* omprövas då de korrigerade mängderna föll in tillräckligt väl i mönstret. Vid jämförelsen var den mest slående olikheten att Östhammar hade närmare dubbel nederbörd jämfört med Högmasten och Storskäret under höstmånaderna 2004. Vid en kontroll av hur analyserna såg ut för dessa månader var det dock slående hur stark gradienten var i detta område. Nederbörden avtog nämligen snabbt åt norr och nordväst längs denna del av Upplandskusten. För övrigt var det nästan motsatta förhållanden hösten 2003, medan det som helhet var mycket likartade och mycket starkt korrelerade månadsvärden.

Förslag på individuella korrektioner för varje mättillfälle och som funktion av vindhastighet vid mätarens öppning samt rådande temperatur finns publicerade /Førland et al. 1996/. Dessa samband är dock ganska komplicerade att tillämpa, bl a då vind ej mäts vid själva nederbördsmätarens öppning. En sådan metod kan heller inte ta hänsyn till närmiljöns inflytande på vindfältet inklusive vertikalvindarna, ett inflytande som kan vara stort i komplicerade miljöer. Här har vi i stället valt att satsa på en enklare korrektion vars huvudsyfte är att ge något sånär sann nederbörd sett över en lite längre tid.

Slutligen kan sägas att röjning av buskar och kanske vid något tillfälle träd bör ske så ofta att inga buskar eller träd når mer än cirka 45° över horisonten sett från mätarens öppning. Röjning bör då troligen behöva utföras med några års mellanrum i de fall det inte är mest berg i dagen nära mätaren.