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ANALYSIS OF SHORT TERM PRECIPITATION IN NORWAY 1967-2010

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Abstract

Short-term rainfall intensity is studied by use of pluviometer data and by precipitation estimates derived from re-analysis datasets. The met.no pluviometer datasets include rainfall intensities from tipping bucket and weight-based gauges. Rainfall rate maps are established for intensities exceeded for 0001%, 0.001%, 0.1% and 0.5% of the time. The rainfall maps are compared to ITU-R P.837-5 rain intensity data, and for 0.01% values the latter map in general indicate higher values than the pluviometer based maps over Norway, and particularly in western coastal areas. For 20 stations with long series, there is a tendency of positive trends at more than half of the stations, but also some series with negative trends were identified. Based on 6-hourly data from ERA-Interim and empirical adjustment methodologies recommended by ITU, maps of estimated rainfall intensities were derived for values exceeded for 0.001% and 0.01% of the time. Comparison with the pluviometer based maps indicates substantial differences.

Keywords

Rainfall rate, observations, reanalysis, climate maps

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Contents

1 Introduction

In telecommunication heavy precipitation can lead to outage. [1], [4]. Met.no is therefore asked to analyze short term precipitation in Norway, down to one minute's time resolution.

1.1 Observation of short term precipitation in Norway

At traditional weather and precipitation stations, precipitation has been measured twice and once a day, respectively. However, for many purposes, more frequent observations are necessary, and met.no therefore established several tipping bucket rain gauge stations, with time resolution 1 minute, at the end of the 1960s. At the beginning of the 1990s, met.no established a network of weight pluviometer stations with time resolution one hour.

Most of the tipping bucket stations were operating only from April to October. During the last 5-10 years some stations have been upgraded to work all-year-round.

A more thorough treatment on short term precipitation in Norway is given in [3]. Here regional values for maximum precipitation from 1 minute to 24 hours are given, and also return periods for 1 hour and 24 hours precipitation.

1.2 Types of stations

1.2.1 Tipping bucket rain gauge stations

A tipping bucket rain gauge consists of a funnel, two small buckets and a magnet. The rain goes down the funnel and drips into one of the two buckets, balanced on a pivot. The top bucket is held in place by a magnet until it has filled to the calibrated amount (usually 0.1 or 0.2 mm of rain). When the bucket has filled to this amount, the magnet will release its hold, causing the bucket to tip. The water then empties down a drainage hole and raises the other to sit underneath the funnel. When the bucket tips, it triggers a reed switch (or sensor), sending a message to the display or weather station. The display counts the number of times the switch is triggered. By counting the number of buckets tips, the rain intensity within a given time interval (e.g. 1 minute) may be calculated.

In Norway the first tipping bucket stations were established in the spring of 1967. Se table 22 in the appendix for details about the stations.

1.2.2 Weight pluviometer stations

A weighing-type precipitation gauge consists of a storage bin, which is weighed to record the mass. Certain models measure the mass using a pen on a rotating drum, or by using a vibrating wire attached to a data logger. The advantages of this type of gauge over tipping buckets are that it does not underestimate intense rain, and it can measure other forms of precipitation, including rain, hail and snow. These gauges are, however, more expensive and require more maintenance than tipping bucket gauges.

In Norway, the Geonor precipitation gauge is prevailing. A bucket is suspended by three cylinders, each housing a vibrating wire. The vibrating wires are driven by a spectrum of frequencies and vibrate at their resonance frequencies. The resonance frequency of each wire depends upon the tension in the wire, which is directly related to the amount of weight in the bucket. Information is processed by three signal conditioning boxes and sent to a data logger where average accumulations are stored.

The first station was established in December 1991. See table 23 in the appendix for details about the stations.

2 Rainfall rate statistics from tipping bucket rain gauge data

At first, only stations with more than 10 years of operation were included. Geographical considerations saw the need for some stations with only 8 years of operation. The total number of stations are therefore 77. See table 22 in the appendix for details about the stations. The following stations have been in operation all-year-round: 3810, 17980, 18020, 18210, 18320, 18420, 18701, 18815, 18920, 19020, 26999, 27020, 27564, 39150, 44190, 44580, 44620, 44640, 44660, 44730, 47240, 50480, 50490, 64300, 68230, 68863. These stations are marked with an A in the first column of table 22.

2.1 Maximum recorded 1 minute values

The analysis includes almost 5 000 000 observations of rainfall intensities. Table 1 gives the highest 1-minute rainfall intensities (parameter RR_01) registered at Norwegian pluviometer stations. Only three times the intensity has exceeded 4 mm/minute. In the period 1967-2010 a total of 35 observations exceeded 3 mm/minute. The table also shows that very heavy precipitation is not restricted to the Southeastern part of Norway, but can occur in Western Norway and Northern Norway as well.

STNR	NAME	MUNICIPALITY	COUNTY	RR_01	DATE AND TIME (UTC)
4781	GARDERMOEN SØR	Ullensaker	Akershus	4.3	08.07.1973 09:32
62290	MOLDE - NØISOMHED	Molde	Møre og Romsdal	4.3	01.08.1986 17:12
18701	OSLO - BLINDERN PLU	Oslo	Oslo	4.1	17.06.1980 14:38
32100	GVARV	Sauherad	Telemark	3.8	16.07.1982 01:30
62290	MOLDE - NØISOMHED	Molde	Møre og Romsdal	3.8	01.08.1986 17:11
62290	MOLDE - NØISOMHED	Molde	Møre og Romsdal	3.8	01.08.1986 17:13
82090	FAUSKE	Fauske	Nordland	3.6	19.07.1988 18:21
17980	OSLO - LJABRUVEIEN	Oslo	Oslo	3.6	12.07.2010 22:20
18020	OSLO - LAMBERTSETER	Oslo	Oslo	3.6	12.07.2010 22:24
18269	OSLO - HAUGENSTUA	Oslo	Oslo	3.5	12.07.2010 22:31

Table 1: Maximum l rainfall intensities. Unit: mm/minute

Figure 1 shows all 1-minute rainfall intensity observations from 18701 Oslo - Blindern in the period 1968-2010. Intensities over 4 mm/minute has occured only once, 3 mm/minute has been exceeded 5 times and 2 mm/minute 12 times. We also notice the change of instrument in 2004, when the volume of the tipping bucket was reduced from 0.2 mm to 0.1 mm, giving more accurate observations.

Table 2 to 5 gives maximum annual 1 minute intensities for all stations. As can be seen, both from this table and figure 1, the maximum intensity varies a lot from year to year. Intensities over 2 mm/minute do not occur often. However, the average of the highest intensity each year for the whole period is as high as 2.8 mm/minute, indicating that very heavy showers occur almost on an annual basis.

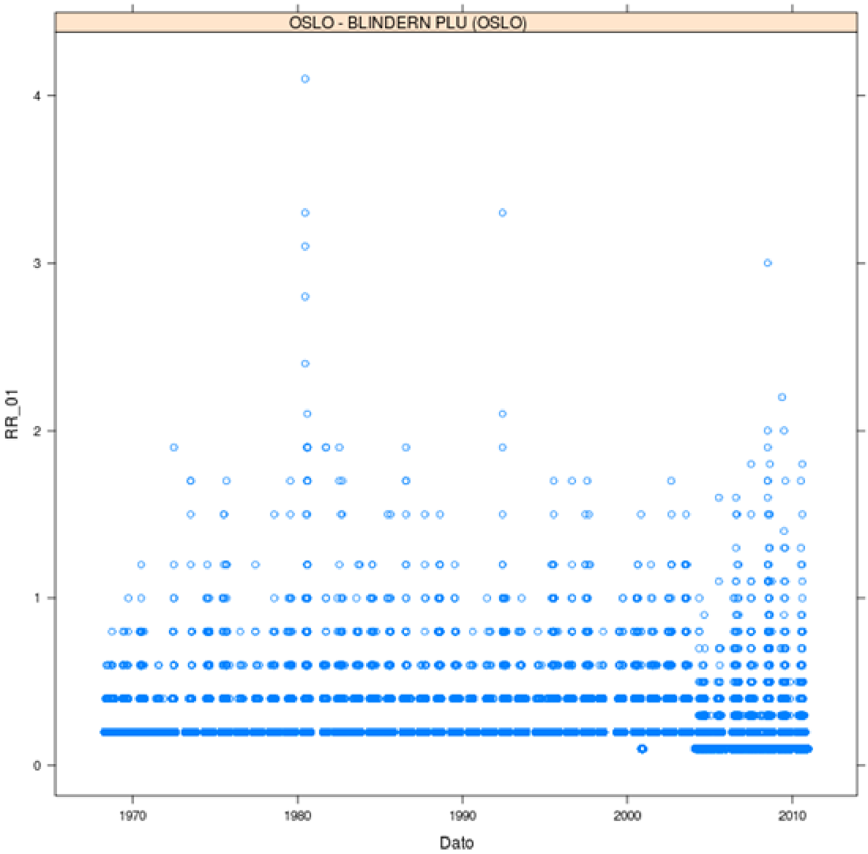

Figure 1: One minute rainfall intensities recorded at 18701 Oslo - Blindern 1968-2010

YEAR/STNR	200	1220	2840	3030	3810	4220	4781	11620	12290	12670	15720	17260	17870	17980	18020	18210	18270	18320	18420	18640
1967	1.9						1.0													
1968	1.0				1.2		1.5		1.9		0.2									
1969	0.4				1.0		1.0		1.7	0.6	0.6									
1970	0.6			3.1	2.4		1.0		2.4	1.7	0.4									
1971	0.6			1.9	0.6					0.8	0.4									
1972	2.6		2.1	1.2	1.2		1.9		1.9	1.0	0.4									
1973	0.8		1.9	1.9	1.9		4.3		2.6	1.9	0.2	0.4								
1974	1.0	1.0	1.0	0.8	1.2		1.0	0.8	0.8	0.6	0.4	3.1	1.7				1.5			1.2
1975		1.5	1.5	1.5	1.7	2.1	1.9	1.2	0.8	0.8	0.2	1.2	0.8				2.4			2.1
1976		0.8	1.5	0.6	0.6	1.5	1.9	1.7	1.9	0.8	0.2	0.6	0.8				0.8			1.2
1977		1.0	1.5	1.0	0.8	1.0	1.5	1.5	1.2	1.0	0.4	1.0	1.5				1.9			0.8
1978		1.7	0.8	1.9	1.2	1.5	1.2	1.0	1.0	1.2	0.6	1.0	0.8				1.0			1.7
1979		1.5	1.7	1.9	1.5	1.2	1.9	1.5	1.5	1.2	0.4	1.2	1.9				2.1			1.0
1980		1.2	1.9	2.1	0.8	2.6	1.0	1.2	1.0	1.2	1.0	2.4	1.5				1.2			1.7
1981		0.8	2.8	1.0	1.0	1.0	1.7	1.2	1.0	0.6		1.5	1.2				3.1			2.4
1982		1.0	2.4	1.0	1.0	1.7	0.8	0.6	1.0	1.2	0.6	1.9	1.2				1.2			1.9
1983			1.7	0.4	1.0	1.2	2.6			0.2	0.4	0.8	1.7				1.2			1.0
1984		1.0	1.7	1.5	2.8	1.2	0.8	0.6	0.6	1.7	0.4	1.5	2.8				1.5	1.2		2.4
1985		1.9	2.8	1.2	2.6	0.8	2.6	1.9	1.5	1.7	0.6	1.9	2.1		1.3		1.9	0.4		0.4
1986		1.7	1.9	2.1	0.6	1.0	1.5	1.0	1.2	1.7	0.4	1.9	1.7		0.4		1.5	2.4		1.5
1987		1.2	0.8	0.8	0.6		0.8	1.7	0.8	0.6	0.4		1.0		0.9			1.2		1.5
1988				1.9	1.9		1.7	1.0	0.8	1.2		1.9	1.0		1.3			1.4		1.5
1989		2.6		1.2	1.9		2.1	1.7	0.2	1.0		1.5	1.5		0.3			1.3		
1990				0.8	1.7	0.2	0.8	1.9	0.2	0.6		1.2	0.8		1.3			0.2		
1991		1.0		1.7	1.2	1.5	1.7	0.8	1.7	0.6		1.0			1.6			1.4		
1992		1.2		0.4	1.5	1.2	1.7	1.0	1.5						1.1			1.6		
1993					1.9		1.2					1.7	0.8		0.9			0.5		
1994		0.8		0.8	1.7		1.2	0.8	0.4			0.8	0.4		1.3			0.8		
1995		1.0		1.2	1.2		1.9	1.0	2.1				2.8		1.4		1.0	1.2		
1996							1.2	1.0	1.0				1.2		2.0		0.4	2.1		
1997							1.9						2.0		0.9		1.8	0.8		
1998							1.0		0.8				1.6		0.6	0.6	0.6	0.6	0.6	
1999					0.9		1.0		1.5				2.0		1.6	1.1	0.4		1.2	
2000					0.7		1.7		2.1				2.0	1.6	0.8	1.2	1.8	1.0	2.1	
2001					1.3		2.8		1.2				1.2	1.3	0.6	2.2	1.8	2.6	1.3	
2002					3.2		2.8		1.7				2.2	3.2	1.4	2.2	2.2	1.9	2.7	
2003					1.4		2.1		0.2				1.4	2.3	1.8		1.8	2.1	1.6	
2004					1.4		2.0		0.2				2.8	1.1	1.4	1.2	1.6	0.8	1.4	
2005							1.5						0.8	1.1	2.6	1.4	1.0	0.8	1.4	
2006							2.1		1.9				1.8	1.7	1.7	2.0	1.6	1.4	1.5	
2007					0.6		1.0		1.5					1.9	1.1	2.2	1.8	1.3	1.4	
2008					2.0		1.0		0.2					0.9	1.9	1.5	2.2	2.2	2.0	
2009					1.6		1.2		0.7					2.2	1.3	0.8	2	2.2	2.0	
2010					2.3		1.9		1.5					3.6	3.6	2.5		2.3	2.9	
Maks	2.6	2.6	2.8	3.1	3.2	2.6	4.3	1.9	2.6	1.9	1.0	3.1	2.8	3.6	3.6	2.5	3.1	2.6	2.9	2.4

Table 2: Maximum annual rainfall intensities for station numbers 200 to 18640. Unit: mm/minute

YEAR/STNR	18701	18815	19020	19490	19510	19710	20300	24880	26890	26999	27270	27470	27564	27580	30270	30310	32100	36060	38130	39150
1967					1.2			1.0									1.2	1.2		
1968	0.8				1.2			0.4	1.2							1.5	1.9	2.8		
1969	1.0				0.8		1.0	0.6	0.8									0.4		
1970	1.2			1.9	1.5		1.2	0.8	1.2							0.8	1.0	1.2		
1971	0.6			1.0	0.8		1.2	0.4	1.0							1.2	1.5	1.0		
1972	1.9			1.2	1.9		1.9	1.7	1.7			1.9				0.4	2.1	2.1		
1973	1.7			2.1	1.2		2.4	1.2	1.5			1.9		0.4	0.4	1.5	1.0	1.7		
1974	1.2			1.5	1.5		0.4	0.6	1.7			1.0		1.5	1.7	1.7	1.5	1.0	0.6	0.4
1975	1.7			1.0	1.2		0.8	1.5	1.2			1.5		1.9	1.9	1.5	1.0	1.9	1.5	1.5
1976	0.8			2.6	1.5		0.6	0.8	1.2			1.0		1.5	0.4	0.8	2.1	1.0	1.2	2.1
1977	1.2			1.0	1.5		0.8	0.6	2.1			1.2		0.8	2.4	1.0	1.5	1.7	0.8	1.2
1978	1.5			1.7	1.5		0.8	0.6	1.9			3.3		1.0	1.5	1.5	1.2	1.0	2.6	1.0
1979	1.7			1.0	1.2		1.5	1.5	0.8			1.0		0.6	1.5	1.7	1.5	1.2	1.2	1.0
1980	4.1			1.5	1.5		1.0	1.0	1.9			1.7		1.0	1.0	1.2	1.0	1.9	1.7	1.9
1981	1.9			1.0	1.9		1.0	0.8	0.6			1.2		1.2	1.0	1.5	1.7	1.2	1.9	1.2
1982	1.9				1.5		1.7	0.8	1.0			1.0			1.5	1.5	3.8	1.0	1.2	
1983	1.2			0.6		1.5	0.6	0.6	0.8			0.8		1.5	1.5	1.0	1.0	1.0	1.0	0.4
1984	1.2			1.2	1.9	1.2	1.2	1.5	2.1			0.8			1.7	1.9	1.7	0.8	1.0	1.5
1985	1.5		1.5	1.9	1.5	1.5	0.8	0.8	1.5			2.1		1.2	1.9	1.9	1.2	1.2	1.0	0.6
1986	1.9		1.2	1.7	2.8		1.9	0.8	1.5			2.8		1.2	1.7	0.8	1.5	1.0	2.1	1.5
1987	1.5		0.8	1.2	0.8	1.0	0.6		0.8			0.6		1.0	1.0	0.6	0.8	1.7	0.8	0.8
1988	1.5		0.9	1.2	1.2	1.2	0.8		2.4					1.2	1.5	1.2		1.0	0.4	
1989	1.2		1.2		1.2	1.2	0.8		0.8					1.0	2.4	1.0		0.6	3.1	
1990	0.8		0.5	0.4	1.2	1.5	1.0		1.5					1.2	0.8	1.2		1.2	1.0	1.9
1991	1.0		0.7	1.0	1.2	2.6	0.6							1.0	1.2	1.2		1.0	0.6	0.4
1992	3.3		0.3	2.1	1.2	1.7	0.8		1.2					1.5	1.2	1.0		1.2	1.7	2.0
1993	1.0		1.4			1.0	1.7		1.0					2.8					2.1	0.6
1994	0.8		1.6			0.8	0.4		1.0					0.8					2.8	1.4
1995	1.7		1.9	1.5	0.8	1.7			1.5										1.2	0.8
1996	1.7		1.8	1.2	1.5	1.7								1.7				1.0	1.5	1.6
1997	1.7		0.9			2.1										2.8			1.2	2.0
1998	0.8					1.5							0.2			1.5				1.4
1999	1.0					1.7				1.2			1.7			1.7				1.2
2000	1.5					1.9				1.2	1.8		1.6			1.5				1.6
2001	1.2					1.7				1.3	1.9		2.1							1.4
2002	1.7	0.6				1.7				1.6	1.5		1.8							1.4
2003	1.5	1.8				1.2				0.8	1.3		0.4							2.6
2004	1.0	0.6				2.6				1.3	1.1		2.2							2.0
2005	1.6	1.3				0.8				0.8	0.9		2.5							1.4
2006	1.6	1.9		1.3	1.4	2.1				1.3	1.4		1.7							2.4
2007	1.8	1.2		2.2	1.3	1.7				0.5	1.5		0.7							1.8
2008	3.0	2.1		1.3	1.1	2.4					1.0									2.2
2009	2.2	1.2		1.1	1.1	1.9					1.1									
2010	1.8	2.8		0.7	2.7	1.5					2.4									
Maks	4.1	2.8	1.9	2.6	2.8	2.6	2.4	1.7	2.4	1.6	2.4	3.3	2.5	2.8	2.4	2.8	3.8	2.8	3.1	2.6

Table 3: Maximum annual rainfall intensities for stations numbers 18701 to 39150. Unit: mm/minute

YEAR/STNR	40140	40500	44190	44580	44620	44640	44660	44730	47240	47890	50480	50490	52290	52300	54730	58700	60940	62290	63420	63500
1967																				
1968									1.7	0.8			0.8	0.8	1.2	0.4				0.4
1969									1.0	2.1			0.8	0.8	0.2	0.4				0.2
1970									2.4	1.9			0.8	0.8	0.6	0.4	0.8			0.6
1971	0.6								0.8	0.8			0.8	0.8	0.4	0.4	0.8			0.2
1972	1.9								1.5	2.1			1.5	1.5	0.6	1.0	1.0			0.2
1973	1.9								1.0	1.7			0.8	0.8	0.8	0.4	1.0			0.4
1974	1.0							1.2	1.5	1.9			1.5	1.5	0.6	0.8	0.8	0.6		0.4
1975	0.8	1.0						1.7	1.2	1.0			0.8	0.8	0.6	0.2	1.5	0.6		1.0
1976	0.4							1.0	0.8	1.2			0.6	0.6	0.4	0.6	0.4	0.6		1.0
1977	0.6	0.4						0.8	1.2	1.5			1.0	1.0		2.4	0.6	0.4		0.8
1978	1.5	0.4							1.2	1.0			0.8	0.8		0.8	0.8		0.6	
1979	1.0	0.8							1.2	1.9			0.8	0.8		0.4	0.6	0.4	0.6	
1980	1.2	1.9						2.4	1.5	1.7			1.2			0.4	1.2	0.8	1.5	
1981	1.2	0.6	1.5					1.0	1.2	1.2			0.8			0.4	0.6	1.0	0.4	
1982		0.8					0.8		1.5	1.7		1.7	1.0			0.4	0.6	0.6	0.4	
1983		0.4		1.0			1.0		1.5	1.2		1.2	0.6			0.4	0.8	0.6	0.8	
1984		1.0		0.6			0.8	1.0	1.0	1.7	1.1	1.0	0.8			0.4	0.4	0.8	0.6	
1985				1.9			1.7	1.5	1.5	1.0	1.6	1.7	1.2			1.5	1.0	0.8	0.8	
1986			1.5	0.6			1.0	1.0		0.8	1.5		0.2			0.4	0.4	4.3	0.6	
1987			0.6	1.2			0.8	1.0		1.2	1.3		0.6			0.4	0.8		0.6	
1988			2.4	1.9			1.7		1.2		0.4						0.8			
1989			1.9	0.6			0.6	1.0	1.7		1.3						0.4			
1990				1.5			0.8	1.5	1.0		2.0						0.8			
1991			1.5	1.0			1.0	1.7	1.0		1.5						1.7			
1992			1.4				1.0	1.4	1.7		0.7						0.6			
1993			1.2	0.6				1.2	0.8		0.8									
1994			1.0					1.0	1.0		0.7						0.8			
1995			1.6					0.8	0.6								0.2			
1996			3.2					1.8	2.6		1.2									
1997			1.6					1.4	1.9			1.4								
1998			1.0					1.0	1.0			1.2								
1999			1.0	0.9	0.5	1.3	0.8	1.0	2.4			1.2								
2000			1.2	1.0	1.2	0.7	1.3	1.0	1.9			0.6								
2001			1.4					1.4	0.8		0.3	1.2								
2002			1.4					3.3	1.2		2.5									
2003			1.0	2.6	1.6	1.5	0.8	3.3	0.4		1.4									
2004			1.2	1.5	1.3	0.7	0.6													
2005			0.8	2.0	1.1	1.5	1.3				1.2									
2006			1.0	2.1	1.4	1.7	1.3													
2007			1.0	1.1	0.8	1.8	0.9				1.7									
2008			0.4	2.2	1.0	1.1	2.0	3.1												
2009				1.4	1.3	1.2	1.3													
2010						0.9														
Maks	1.9	1.9	3.2	2.6	1.6	1.8	2.0	3.3	2.6	2.1	2.5	1.7	1.5	1.5	1.2.0	2.4	1.7	4.3.0	1.5	1.0

Table 4: Maximum annual rainfall intensities for station numbers 40140 to 63500. Unit: mm/minute

YEAR/STNR	64300	66830	68170	68190	68230	68863	71000	72850	73490	80200	81620	84710	89350	97250	99370
1967			0.6					1.9	1.9		0.6				
1968		0.2	0.6					0.8	0.2		0.2			0.8	0.2
1969		0.4	1.2					0.6	0.4		0.2		0.4	0.4	0.6
1970		1.0	0.6					1.2			1.0		1.5	1.2	0.8
1971		0.6	0.8					1.0	0.6		0.8		0.4	1.0	1.2
1972		0.8	1.7					2.1	1.2		1.2			1.2	1.7
1973	0.4	1.5	1.0					1.2	1.2		1.0		1.5	0.6	0.4
1974	0.6		1.0	1.0				1.5	1.2		0.6		0.4	1.2	1.9
1975	0.4	0.8	1.0	0.6				1.0	2.4		0.4		0.4	0.8	0.4
1976	0.8	0.8	0.8	0.4				0.4	0.8		0.2		0.6	0.8	
1977	0.4	0.6	0.4	0.4				0.6	0.4		0.6		0.8	1.0	1.0
1978	1.7	1.2	0.6	0.8				0.6	0.8		1.0		0.4	0.4	0.4
1979	0.8	1.5	1.5					0.6	2.1		0.8		1.0	1.0	
1980		0.8	2.1	2.6				2.8	1.0		0.6		0.6	0.8	1.0
1981			0.2	1.5							0.4		1.0	2.1	0.8
1982		0.8	1.7						0.4				0.4	1.2	0.4
1983		1.2	0.4	0.6								0.4	0.6	0.6	0.4
1984	1.9	1.0		1.7			0.4					0.6	0.6	1.9	0.4
1985	1.0			1.2			1.2					0.6	1.0	0.8	1.7
1986	0.4		0.4		0.2							0.4	0.4	0.6	
1987	0.6		1.2		0.7		0.8					0.6	0.2	0.6	0.4
1988	1.0		0.4		2.2		0.4					0.4			
1989	1.2		0.4		2.1		1.2								
1990	0.8		0.8		0.8		0.6								
1991	0.8		1.0		1.5		0.6			0.4					
1992	1.2		0.4		1.4		3.2								
1993	1.0		1.5		1.1					0.6		0.4			
1994	0.8				0.7					0.6		0.6			
1995	0.8				0.5					1.2					
1996	0.8				0.5							0.8			
1997	0.8				0.6					0.8					
1998	1.2				0.2					0.6					
1999	1.4				0.8					0.8					
2000	1.0				0.4										
2001	0.4				0.9										
2002	0.6				1.7	0.9									
2003	1.0				1.6	1.0									
2004	1.0				1.4	0.9									
2005	0.8				1.1	0.4									
2006	1.3				1.4	1.2									
2007	0.8				3.3	2.2									
2008					1.5	0.7									
2009					1.0	0.8									
2010						1.2									
Maks	1.9	1.5	2.1	2.6	3.3	2.2	3.2	2.8	2.4	1.2	1.2	0.8	1.5	2.1	1.9

Table 5: Maximum annual rainfall intensities for station numbers 64300 to 99370. Unit: mm/minute

2.2 Seasonal variations

Table 6 and 7 gives monthly values of maximum 1 minute intensities for each station. As can be seen, the highest intensities mainly occur during summer, but for some stations the most heavy precipitation has been in May (19490, 27580, 44730, 60940, 85430) or September (3810, 44640), and even October (44660, 64300). Intensities over 2 mm/minute has also occured in May (station number 3810, 18270, 18701, 19490, 27580, 39150, 44730) and as late as November (station number 44730 and 68230).

STNR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAX	MONTH
200				0.4	0.6	1.7	2.6	1.2	0.8	0.4			2.6	JUL
1220			0.2	1.5	1.0	1.7	1.9	2.6	1.0	1.0	0.8	0.2	2.6	AUG
2840				2.4	1.7	2.4	2.8	1.9	1.7	1.0	0.8		2.8	JUL
3030				0.4	1.5	3.1	2.1	1.9	1.5	0.8	0.6		3.1	JUN
3810	0.3	0.2	0.4	0.8	2.5	2.1	2.8	1.7	3.2	1.2	0.6	0.3	3.2	SEP
4220				0.2	1.5	2.1	2.1	2.6	1.2	1.0	0.4	0.2	2.6	AUG
4781				0.2	1.9	2.6	4.3	2.8	2.6	1.7	0.4	0.2	4.3	JUL
11620				0.2	1.2	1.5	1.9	1.5	1.7	0.4	0.2		1.9	JUL
12290	0.1	0.1	0.1	0.2	1.3	1.9	2.4	2.6	1.9	1.0	0.2	0.2	2.6	AUG
12670				0.2	0.8	1.9	1.7	1.5	1.2	0.8	0.2		1.9	JUN
15720		0.2			0.4	0.4	1.0	0.6	0.4	0.4			1.0	JUL
17260				0.4	0.8	3.1	1.9	2.4	1.2	1.0	1.0	0.4	3.1	JUN
17870	0.2	0.2	0.2	0.4	1.2	2.8	2.8	2.8	2.0	1.6	1.7	0.4	2.8	AUG
17980	0.3	0.3	0.7	0.5	1.0	1.9	3.6	2.9	1.5	3.2	1.1	0.3	3.6	JUL
18020	0.2	0.3	0.6	0.6	1.3	1.9	3.6	2.6	1.6	0.9	0.7	0.6	3.6	JUL
18210	0.4	0.2	0.4	0.8	1.2	2.2	2.5	2.2	1.2	0.7	0.6	0.3	2.5	JUL
18270	0.4	0.4	0.4	0.6	3.1	2.2	3.1	2.1	1.8	1.0	0.8	0.2	3.1	JUL
18320	1.1	0.3	0.5	0.5	1.2	2.1	2.4	2.6	1.9	0.9	0.9	1.0	2.6	AUG
18420	1.0	0.4	0.2	0.4	1.8	1.8	2.9	2.1	2.7	1.4	0.6	0.2	2.9	JUL
18640			0.2	0.4	1.0	1.7	2.4	2.4	2.1	0.8	0.4	0.2	2.4	JUL/AUG
18701	0.3	0.4	0.4	0.7	2.2	4.1	3.0	2.1	1.9	1.5	0.8	0.2	4.1	JUN
18815	0.3	1.8	0.7	0.8	0.9	1.4	2.8	2.1	0.8	0.8	0.4	0.3	2.8	JUL
18980	0.2	0.3	0.3	0.9	0.6	1.1	2.7	1.4	1.3	1.0	0.5	0.3	2.7	JUL
19020	0.9	0.9	0.8	0.4	0.7	1.8	1.9	1.8	0.7	0.8	0.4	0.3	1.9	JUL
19490	0.1	0.1	0.7	0.8	2.6	2.2	2.1	1.9	1.3	0.6	0.7	0.4	2.6	MAY
19510	0.2	0.1	0.3	0.4	1.7	1.9	2.7	2.8	1.5	1.0	0.4	0.3	2.8	AUG
19710				0.2	1.9	1.9	2.6	1.9	2.1	0.8	0.6	0.4	2.6	JUL
20300				0.2	0.8	1.7	1.9	2.4	0.8	0.8	0.6	0.2	2.4	AUG
24880				0.2	1.5	1.7	1.5	1.0	0.6	0.4	0.2		1.7	JUN
26890				0.6	1.2	2.1	2.4	2.1	1.0	1.0	0.4		2.4	JUL
26999	0.5	0.1	0.2	0.9	1.3	1.0	1.3	1.6	1.1	0.9	0.6	0.3	1.6	AUG
27270	0.4	0.2	0.2	0.7	0.9	1.1	2.4	2.8	1.4	1.9	1.8	0.7	2.8	AUG
27470				0.4	0.6	3.3	1.9	2.8	1.0	0.8	0.6	0.2	3.3	JUN
27564	0.7	0.4	0.3	0.8	0.8	1.6	2.1	2.5	1.3	1.6	0.8	0.6	2.5	AUG
27580	0.4			0.4	2.8	1.2	1.5	1.9	1.5	1.2	0.6	0.4	2.8	MAY
30270				0.4	1.2	1.7	1.7	2.4	1.9	1.0	0.4	0.2	2.4	AUG
30310				0.4	1.7	1.9	2.8	1.9	1.7	1.5	0.8	0.2	2.8	JUL
32100				0.2	1.0	1.7	3.8	1.7	1.9	1.0	0.4		3.8	JUL
36060				0.8	1.2	2.8	2.1	1.7	1.9	1.2	1.0	0.2	2.8	JUN
38130			0.2	0.4	0.8	3.1	2.6	2.1	1.5	1.0	0.6		3,1	JUN

Table 6: Maximum monthly rainfall intensities. Station numbers 200 to 38130. Unit: mm/minute

Figure 2 shows how the one minute rainfall intensities at 18701 Oslo - Blindern are distributed throughout the year. 01 is January, 02 February et cetera.

STNR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAX	MONTH
39150	0.4	0.6	0.4	1.4	2.0	1.9	2.6	2.4	2.1	1.6	1.2	1.3	2.6	JUL
40140				0.2	1.0	1.9	1.9	1.0	1.0	0.8	0.2		1.9	JUN/JUL
40500					0.6	1.0	1.9	1.0	0.8	0.8	0.2		1.9	JUL
44190	0.6	0.6	0.4	0.8	0.8	3.2	1.6	1.5	2.4	1.4	0.8	1.0	3.2	JUN
44580	1.1	0.6	0.5	0.4	1.5	1.5	1.9	2.6	1.9	1.3	0.9	0.9	2.6	AUG
44620	1.0	0.4	0.5	0.6	1.1	0.6	1.3	1.6	1.1	1.4	1.4	0.9	1.6	AUG
44640	0.9	0.6	0.4	1.0	0.7	1.1	1.2	1.6	1.8	1.3	1.7	0.7	1.8	SEP
44660	0.6	0.5	0.6	0.8	0.8	1.7	1.7	1.3	1.5	2.0	0.8	0.8	2.0	OCT
44730	1.2	0.8	0.6	0.6	3.3	3.3	3.2	1.8	2.0	1.4	3.1	1.0	3.3	MAY/JUN
47240	0.6	0.6	0.4	1.2	1.9	1.2	2.4	2.6	1.7	1.2	0.8	0.8	2.6	AUG
47890				0.6	1.2	1.9	2.1	2.1	1.5	1.7	1.0	0.6	2.1	JUL/AUG
50480	0.9	0.6	1.4	0.7	1.3	1.0	1.6	2.5	1.7	1.2	1.2	0.9	2.5	AUG
50490	0.6	0.6	0.4	0.2	0.6	1.2	1.4	1.7	1.7	1.0	1.0	0.4	1.7	AUG/SEP
52290				0.4	0.8	1.2	0.8	1.5	1.5	0.8	0.6		1.5	AUG/SEP
52300				0.4	0.8	0.8	0.8	1.5	1.5	0.8	0.6		1.5	AUG/SEP
54730						0.6	0.8	0.4	1.2	0.2			1.2	SEP
58700				0.4	0.4	1.0	1.5	0.6	2.4	0.4	0.4		2.4	SEP
60940				0.4	1.7	0.8	1.0	1.2	1.0	1.5	0.8		1.7	MAY
62290				0.2	0.6	0.8	1.0	4.3	1.0	0.8	0.8	0.6	4.3	AUG
63420				0.2	0.4	0.8	1.5	0.8	0.4	0.4	0.2		1.5	JUL
63500					0.2	1.0	1.0	0.6	0.2	0.4	0.2		1.0	JUN/JUL
64300	0.7	0.6	0.8	0.8	1.0	1.4	1.0	1.7	1.3	1.9	1.0	1.0	1.9	OCT
66830					0.4	1.2	1.5	0.8	0.8	0.4			1.5	JUL
68170	1.0	0.4	0.2	0.4	0.8	0.8	1.7	2.1	1.5	0.4	0.4	0.6	2.1	AUG
68190				0.2	0.2	0.8	1.7	2.6	0.8	0.8	0.6	0.2	2.6	AUG
68230	0.9	0.4	0.4	0.9	0.7	1.7	1.4	3.3	2.1	1.2	2.2	1.9	3.3	AUG
68863	0.4	0.3	0.3	0.4	0.7	1.0	1.2	2.2	0.9	0.9	0.4	0.5	2.2	AUG
71000	0.4	0.4	0.4	0.2	0.6	3.2	0.4	1.2	0.6	0.4	0.4	0.2	3.2	JUN
72850					0.4	0.6	2.8	1.2	1.0	0.6	0.2		2.8	JUL
73490					0.2	1.2	2.4	2.1	0.6	0.2			2.4	JUL
80200					0.4	0.4	0.6	1.2	0.8	0.6			1.2	AUG
81620					0.2	1.0	1.2	0.8	1.0	0.6	0.2		1.2	JUL
82310	0.6	0.4	0.4	0.4	0.4	1.8	1.4	1.0	1.6	0.6	0.6	0.6	1.8	JUN
84710					0.4	0.4	0.6	0.8	0.4	0.6	0.6		0.8	AUG
85430					1.0	0.2	0.2	0.6	0.8	0.6			1.0	MAY
89350					0.6	0.6	1.5	1.5	0.6	0.2			1.5	JUL/AUG
97250					0.4	1.0	2.1	1.9	1.2	0.2			2.1	JUL
99370					0.2	1.0	1.9	1.7	0.4	0.2			1.9	JUL

Table 7: Maximum monthly rainfall intensities. Station numbers 39150 to 99370. Unit: mm/minute

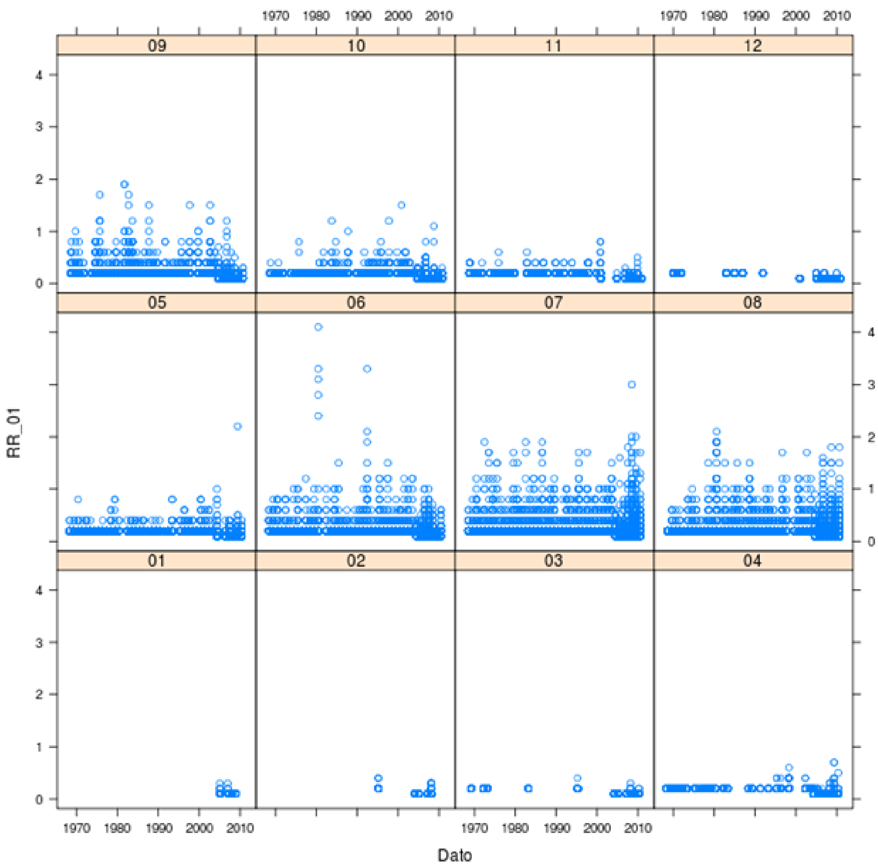

Figure 2: Monthly distribution of one minute rainfall intensities (mm/minute) recorded at 18701 Oslo - Blindern 1968-2010

3 Rainfall rate statistics from weight pluviometer data

These stations measure 1 full hour precipitation, RR_1, by subtracting the parameter RA, Total precipitation, at time (t-1) from RA at time t, thus RR_1(t)= RA(t)-RA(t-1).

Normally RA should only be increasesing, but for some stations the RA values in periods have moved up and down by as much as 10-20 mm, indicating erroneous recordings. In the analysis these periods of suspicious observations have been tried to be excluded.

The total number of weight pluviometer stations are 65, however, only 20 controlled stations were used in the analysis. See table 23 in the appendix for details about the stations.

3.1 Maximum recorded 1 hour values

Table 8 gives maximum annual 1-hr precipitation from selected controlled stations. We notice that most values are between 5 and 20 mm/h, and that values above 30 mm/h do not occur often. Notice the high intensities at 63420 in 2006 (31.4 mm/h) and also 90400 in 2010 (21.7).

STNR/YEAR	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	MAX
180		14.2	17	13.2	6.9	10.8	16.0	4.1		8.2	17.6	16.0	10.8	12.5	8.9	10.4	7.8	17.6
9580/10000	5.6	6.0	3.8	5.0	7.2	6.3		4.2	6.4	7.5	9.4	8.9	8.3	7.7	6.3	7.0	21.2	21.2
11500	5.8	11.6	11.0	10.9	5.6	11.1	5.9	8.5	9.9	19.8	16.2	10.0	16.7	9.8	6.1	10.3	18.2	19.8
12550	9.5	10.5	19.9	9.7	5.9	6.4	8.6	10.8	4.8	8.7	18.8	8.1	17.1	13.9	17.3	10.8	17.4	19.9
12680		7.8	10.6	18.5	9.2	13.6	14.7	6.3	15.2		9.5	8.0	11.0	8.2	7.5	11.5	18.2	18.5
17000	4.7	8.7	6.4	10.4	11.8	6.6			26.0	35.5	24.0	18.9	17.6	16.3	28.7	13.5	9.3	35.5
18700	16.0	19.5	14.5	14.7	10.6				14.3	16.5	10.0	4.9	14.1	14.8			15.7	19.5
18701	7.6	18.1	13.5	12.7	8.2	11.8	14.8	10.6	13.4	17.1	10.1	8.4	9.8	16.5	24.1	18.7	16.8	24.1
23500	8.7	15.9	9.2	10.5	6.5	8.6	11.5	10.4	8.6	4.1	6.0	5.1	5.2	5.0	13.8	9.1	12.2	15.9
27450						16.0	7.6		9.6	15.4	17.3	25.5	16.8	17.2	22.5	11.2	29.3	29.3
39040		5.9	6.3	17.7	9.6	11.6	17.1	10.8	17.3	9.4	17.6	8.8	36.1	12.2	17.8	14.3	17.7	36.1
40880		10.5	5.3	20.9	9.3	9.4	8.7	5.4	12.8	19.3	12.0	6.4	9.8	6.9	7.7	13.9	7.1	20.9
44080	12.0	12.7	25.5	11.6	12.7		5.3	13.1				14.0	19.1	14.6	11.5	13.2	10.9	25.5
44300	14.5	8.2	8.3	17.5	33.2	10.1	12.3	23.7	31.7	14.6	8.5	12.5	15.1	13.2	12.5	14.5	9.0	33.2
53101	10.7		4.5		3.5	7.3	7.4	8.3	7.7	5.8	8.0	6.1	7.0	6.6	5.4	7.3	9.0	10.7
56420	8.9	8.9	10.1	13.6	11.1	9.5	10.7	11.6	11.8	15.4	9.5	11.5	12.8	11.6	9.2	11.4	16.4	16.4
58900	4.2	12.4	6.8	12.3	6.8	18.4	19.9	10.0	9.5	20.1	8.0	14.8	13.0	7.7	8.2	9.0	23.0	23.0
63420											6.8	6.5	31.4	11.1	8.9	5.5	7.5	31.4
68860			4.5	5.5	5.9	10.8	5.2	14.9	5.7	12.8	6.4	9.5	9.6	11.0	12.7	6.6	9.7	14.9
69150	4.7	7.6	5.9	9.8	5.6	8.3	4.4	7.2	6.9	14.5	6.3	5.6	6.1	8.3	7.2	9.1	10.0	14.5
82260	7.3	8.8	10.2	6.3	6.1	8.7	5.8	6.9	8.3	10.1	8.8	7.9	8.9	10.5	9.8	8.6	10.0	10.5
90400	3.9	4.6	4.4	7.3	4.9	8.6	6.8	5.6	6.0	9.9	6.9	6.7	4.8	7.9	5.6	7.5	21.7	21.7

Table 8: Maximum annual 1 hour precipitation. Unit: mm/hour

For the tipping bucket stations we also have 1 full hour precipitation back to 1967. Notably values from these registrations are 43.4 mm, registered in 19710 Asker in July 1991 (55 mm in the most intense 60 minutes period), and 41.5 mm at 18701 Oslo - Blindern in June 1980.

In [2] there is a long list of heavy showers for the period 1895-1943. Some of the most intense ca 1 hour precipitation includes 64.9 mm in 55 minutes at 38800 Tovdal at July 22nd 1943 and 59.5 mm in 60 minutes at 46050 Ulla June 14th 1933. Worth mentioning is also 100 mm in 90 minutes at 9100 Foldal June 27th 1935.

Figure 3 shows all 1 hour values for 90400 Tromsø - Holt. Only once in the period 2000-2010 the 1 hour intensity has exceeded 20 mm/h.

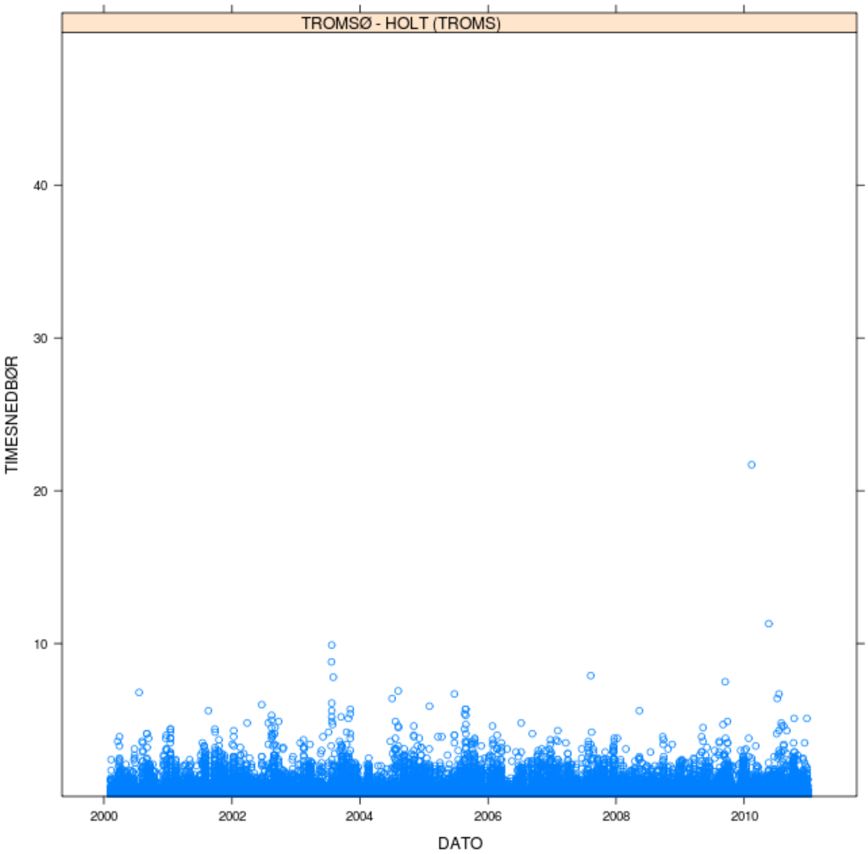

Figure 3: 1 hr rainfall from 90400 Tromsø - Holt. Unit: mm/h

3.2 Seasonal variations

Table 9 gives maximum monthly 1-hr precipitation from some selected tipping bucket stations.

In summer, typical values from 12-15 to 20-30 mm/h can be found at both Østlandet and southern part of Vestlandet. In rare occasions values above 40 mm/h are registered. In Trøndelag the highest values are typically 15-20 mm/h, and in Northern Norway 10-15 mm/h, but remember the registration of 21.7 mm/h at 90400 Tromsø - Holt in 2010.

Typical values in winter are 3-5 mm/h at Øslandet, and 5-8 to 10-14 mm/h at Vestlandet and Trøndelag.

STNR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAX
200				1.6	7.0	18.3	15.2	10.8	8.4	7.4			18.3
1220			0.6	3.9	11.8	15.4	19.7	15.4	9.4	7.4	6.2	3.6	19.7
2840				3.4	8.2	13.0	23.6	18.7	8.4	7.4	8.8		23.6
3030				4.8	10.8	21.5	24.2	17.2	9.6	8.6	9.0		24.2
3190			0.4	2.6	6.2	12.7	19.6	13.8	5.8	10.2	5.0		19.6
3810	3.7	3.8	3.0	4.1	10.4	31.9	21.9	14.2	31.1	9.0	7.2	4.5	31.9
4220				4.8	11.6	9.8	18.4	12.2	7.6	7.4	3.6	0.2	18.4
4781				1.8	11.8	11.8	23.5	20.1	20.2	11.4	5.4	1.0	23.5
11620				4.0	7.2	12.4	19.6	16.3	10.2	5.6	6.0		19.6
12290	1.6	2.2	1.2	3.8	7.0	14.5	18.9	14.4	10.4	7.2	3.1	2.9	18.9
12670				2.6	10.6	11.2	14.4	8.4	11.4	7.0	2.6		14.4
15720					3.6	7.0	10.4	6.8	4.4	3.6			10.4
17260				4.2	11.0	13.8	17.5	34.1	9.2	12.2	5.8	3.6	34.1
17870	6.0	3.8	3.6	3.6	9.2	22.4	31.2	17.0	20.6	10.6	7.4	5.2	31.2
17980	4.4	3.4	6.3	4.2	9.1	15.5	21.1	21.7	18.2	7.7	8.4	4.4	21.7
18020	4.3	5.5	6.5	4.8	15.0	16.1	33.3	24.9	16.7	11.7	6.2	5.9	33.3
18210	4.1	3.1	4.9	4.8	10.0	39.6	17.9	25.2	16.9	7.9	6.8	7.0	39.6
18270	3.6	4.0	3.0	5.2	17.5	8.6	16.4	14.6	19.2	9.4	5.8	2.6	19.2
18320	4.5	3.5	3.9	7.4	15.0	20.0	21.1	27.2	13.6	14.1	7.4	4.5	27.2
18640			0.8	4.4	9.0	7.8	17.0	28.3	15.7	7.4	4.2	3.0	28.3
18701	3.5	4.3	3.6	7.6	9.0	30.8	18.7	41.5	16.3	9.1	6.0	4.0	41.5
19020	6.7	5.6	10.9	4.1	8.2	12.8	20.7	19.4	8.8	11.4	5.9	6.0	20.7
19490	1.3	2.2	3.3	5.2	14.7	33.4	35.2	16.1	13.3	7.6	6.8	5.8	35.2
19510	3.4	2.8	2.1	4.3	11.5	21.4	20.8	18.0	13.9	10.4	7.4	4.6	21.4
19710				1.0	12.2	15.4	43.4	14.8	12.6	12.8	8.0	3.4	43.4
20300				3.2	6.2	9.0	18.8	15.1	8.4	4.2	3.8		18.8
24880					5.1	12.4	10.4	6.4	5.8	4.2	2.2		12.4
26890				7.4	7.8	20.2	18.5	12.2	14.2	6.4	5.4		20.2
26999	5.0	3.1	3.6	4.6	6.1	10.4	12.3	19.4	13.4	12.3	6.9	6.5	19.4
27270	5.6	4.4	5.8	5.3	13.1	12.9	32.1	16.1	17.1	15.2	11.7	8.3	32.1
27470				.5	9.8	18.1	20.8	14.2	14.4	8.4	11.2	6.2	20.8
27564	5.9	4.1	4.6	5.9	6.5	14.6	19.2	18.8	15.0	11.5	5.3	6.6	19.2
27580	3.2			3.6	22.5	20.8	12.4	17.1	13.4	13.2	10.0	7.8	22.5
30270				3.2	17.6	12.1	18	33.1	14.5	5.8	5.6	7.0	33.1
30310				6.0	21.3	16.7	13.7	26.9	15.8	15.7	8.8	4.2	26.9
32100				1.0	10.4	12.6	30.2	19.4	18.0	6.0	2.6		30.2
36060				6.0	13.4	2.5	27.8	14.8	20.8	22.0	11.0	3.0	27.8
38130			1.4	4.8	9.4	14.1	40.6	24.5	13.8	11.0	5.2		40.6
39150	10.4	6.2	3.6	8.4	8.0	30.7	19.8	32.6	14.7	20.2	7.8	14.0	32.6
40140				1.2	10.8	8.8	17.4	12.8	9.8	10.4	1.8		17.4
40500					4.4	7.6	19.5	11.4	7.0	9.8	9.6		19.5
44190	7.2	6.4	6.2	6.0	6.8	41.9	17.0	13.6	13.2	11.2	9.2	5.8	41.9
44580	4.4	8.4	5.0	3.6	4.6	6.2	15.9	10.4	15.3	6.0	9.0	7.8	15.9
44640	7.8	5.5	4.1	5.1	6.3	9.8	10.6	8.6	8.2	12.1	8.7	7.1	12.1
44660	5.2	4.2	5.2	4.8	5.4	5.6	19.5	16.2	16.4	12.6	7.4	6.4	19.5
44730	6.8	5.0	5.6	5.2	13.8	19.3	17.2	23.0	12.2	9.4	7.2	8.0	23.0
47240	6.2	7.2	6.8	6.4	12.5	9.4	18.6	25.0	15.1	10.6	11.2	9.6	20.5
47890				11.2	9.4	12.4	18.8	25.7	20.6	17.2	17.6	12.4	25.7
50480	7.0	7.0	6.7	7.2	6.2	8.4	17.5	16.0	14.0	8.7	8.6	7.8	17.5
50490	8.8	8.6	5.8	5.4	5.8	9.8	12.6	10.6	12.6	9.8	10.6	6.0	12.6
52290				7.8	10.2	10.0	11.6	20.1	13.0	12.0	11.4		20.1
54730						6.8	10.4	7.2	7.2	3.0			10.4
58700				6.6	5.8	6.0	10.9	5.6	6.4	7.0	7.0		10.9
60940				4.6	5.2	8.0	6.6	11.6	11.0	7.2	8.8		11.6
62290				4.0	5.2	5.6	7.0	28.9	8.2	7.8	9.6	5.4	28.9
63500					3.4	4.8	10.2	5.0	4.4	7.6	1.8		10.2
64300	8.5	8.6	6.2	6.4	4.3	9.8	11.0	21.8	14.6	9.6	8.2	8.6	21.8
66830					5.6	8.0	23.2	9.8	6.0	5.0			23.2
68170	7.2	4.8	3.4	4.2	6.8	5.6	10.4	10.4	14.6	7.4	6.6	7.0	14.6
68190				3.2	3.8	4.8	10.4	12.2	6.0	8.4	5.0	3.0	12.2
68230	8.9	5.7	8.8	4.1	8.0	11.5	10.6	9.3	12.4	18.7	6.8	9.8	18.7
68863.0	4.3	4.1	3.9	4.7	4.1	6.9	10.6	11.6	5.7	9.4	4.0	2.6	11.6
72850					4.4	7.8	15.9	6.8	6.0	7.0	1.8		15.9
73490					3.8	10.8	9.9	17.2	4.0	2.0			17.2
80200					4.6	11.2	9.4	10.6	14.6	9.2			14.6
81620					2.6	6.2	9.2	11.8	5.6	7.0	4.6		11.8
84710					4.4	3.4	10.8	7.6	7.6	5.4	9.2		10.8
89350					2.8	5.0	12.6	10.8	5.8	3.2			12.6
97250					5.2	8.0	16.4	15.8	7.2	2.0			16.4
99370					3.8	6.2	13.7	18.0	5.0	3.0			18.0

Table 9: Maximum monthly 1 hour precipitation. Unit: mm/hour

3.3 Conversion method from 1 hour to 1 minute precipitation

In section 5.2 we take a look at return periods for 1 minute and 60 minutes precipitation. The ratio between 10 years return periods for these two durations is shown i table 10. These factors can then be used to convert 1 hour precipitation to 1 minute values.

STNR.	RATIO	STNR	RATIO
200	8.4	40140	9.9
1220	8.2	40500	8.1
2840	8.4	44190	10.7
3030	9.6	44580	9.0
3190	8.2	44620	8.9
3810	8.4	44640	10.8
4220	7.8	44660	8.7
4781	7.5	44730	10.1
11620	9.3	47240	8.2
12290	6.9	47890	9.4
12670	7.9	50480	10.6
15720	12.0	52290	9.5
17260	8.8	52300	12.4
17870	8.8	54730	14.7
17980	7.6	58700	13.8
18020	10.1	60940	11.3
18270	8.3	62290	9.6
18320	9.3	63420	10.6
18420	10.8	63500	11.1
18640	9.7	64300	11.7
18701	10.3	66830	9.4
19020	10.2	68170	11.6
19490	10.4	68190	8.6
19510	9.9	68230	7.9
19710	9.7	71000	7.6
20300	8.3	72850	7.5
24880	8.6	73490	8.5
26890	9.1	80200	7.3
26999	10.2	81620	7.4
27270	10.1	84710	6.8
27470	9.8	89350	15.5
27564	8.6	97250	10.0
27580	9.8	99370	7.0
30270	10.1		
30310	10.0		
32100	9.1		
36060	11.2		
38130	9.9		
39150	10.3		
39260	10.2		

Table 10: Ratio of 10 year return period for 1 minute and 60 minutes precipitation

4 Rainfall rate maps

In the analysis, there is a special interest in finding the rainfall intensity exceeded 0.001 %, 0.01 %, 0.1 % and 0.5 % of the time of a year.

As a year has 8760 hours, or 525600 minutes, 0.001 % of this amounts to 5.256 minutes, 0.01 % amounts to 52.56 minutes, 0.1 % to 8.76 hours and 0.5 % to 43.8 hours. See table 11.

Percent	Hours	Minutes
0.001 %	0.0876	5.256
0.01 %	0.876	52.56
0.1 %	8.76	525.6
0.5 %	43.8	2628

Table 11: Percent of time in hours and minutes

4.1 Rainfall intensity exceeded 0.001 % of the time

In the database, the tipping bucket observations are stored chronologically, as in table 12. The first record is the time for start-up, where RR_01 is given the value -6. At shut-down, a value of -5 is given. The value of RR_01 at any time has been registered in the time interval between two consecutive datings, e.g. 0.2 mm has been recorded between April 17th at 04:24 and 04:28, giving an intensity of 0.2 mm/4 minutes= 3.0 mm/hour.

STNR	TIME	RR_01
18701	16.04.1968 00:00:00	-6
18701	17.04.1968 21:19:00	0.2
18701	18.04.1968 04:24:00	0.2
18701	18.04.1968 04:28:00	0.2
18701	18.04.1968 22:08:00	0.2
18701	18.04.1968 22:27:00	0.2
18701	18.04.1968 23:36:00	0.2
18701	19.04.1968 00:04:00	0.2
18701	19.04.1968 00:23:00	0.2
18701	19.04.1968 00:41:00	0.2
18701	19.04.1968 01:00:00	0.2
18701	19.04.1968 01:37:00	0.2
18701	19.04.1968 01:54:00	0.2

Table 12: The structure of the database

For all stations the intensities in mm/hour has been calculated this way. Finally the data were sorted by station and descending intensities for each year.

STNR	TIME	RR_01	TIME DIFFERENCE	INTENSITY (MM/HOUR)
18701	16.04.1968 00:00:00	-6	0	NA
18701	17.04.1968 21:19:00	0.2	2719	0.00
18701	18.04.1968 04:24:00	0.2	425	0.03
18701	18.04.1968 04:28:00	0.2	4	3.00
18701	18.04.1968 22:08:00	0.2	1060	0.01
18701	18.04.1968 22:27:00	0.2	19	0.63
18701	18.04.1968 23:36:00	0.2	69	0.17
18701	19.04.1968 00:04:00	0.2	28	0.43
18701	19.04.1968 00:23:00	0.2	19	0.63
18701	19.04.1968 00:41:00	0.2	18	0.67
18701	19.04.1968 01:00:00	0.2	19	0.63
18701	19.04.1968 01:37:00	0.2	37	0.32
18701	19.04.1968 01:54:00	0.2	17	0.71

Table 13: Calculation of time difference and intensity

STNR	TIME	RR_01	TIME DIFFERENCE	INTENSITY (MM/HOUR)	ACCUMULATED TIME
18701	17.06.1980 14:38:00	4.1	1	246	1
18701	17.06.1980 14:37:00	3.3	1	198	2
18701	17.06.1980 14:39:00	3.1	1	186	3
18701	17.06.1980 14:36:00	2.8	1	168	4
18701	17.06.1980 14:40:00	2.4	1	144	5
18701	06.08.1980 01:41:00	2.1	1	126	6
18701	06.08.1980 01:34:00	1.9	1	114	7
18701	06.08.1980 01:36:00	1.9	1	114	8
18701	06.08.1980 01:39:00	1.9	1	114	9
18701	06.08.1980 01:42:00	1.9	1	114	10

Table 14: The final table sorted in descending order for intensity

In these tables the fifth position each year gives the rain rate exceeded for five clock minutes of that year, close to 0.001% of the time. Similarly, the 52nd position gives the value exceeded for 0.01% of the time of a year, i.e 52 minutes.

When two intensities are equal, the fifth position, row number five, still contains the desired intensity, even if the rank only is the fourth highest value. See table 15 which shows an fictive example.

Row_number	Rank	Intensity (mm/hour)
1	1	186
2	2	168
3	3	144
4	4	126
5	**4**	**126**
6	6	114

Table 15: With intensities sorted in descending order, row number five contains the intensity exceeded only five minutes a year

For each station, and each year, the intensity in row number five was found. Then, the average of all the yearly values was computed. Values for all stations are presented in table 16. The highest values occur in the Oslo/Akershus area, with 70 mm/h. The lowest values are found in the inner, northern districts of Southern Norway with 16-20 mm/h. Be aware that these results include stations with different years of observation and also different types of instrumentation.

On the basis of these observations, a digital map has been constructed. See figure 4.

Generally, the gridded maps presented in figures 4, 5, 7 and 8 are derived by using a thin-plate spline method implemented in ArcGIS. Along the western coast the station coverage is sparse, and the maps resulting from this automatic routine deviate from manual analysis. To compensate for this, a few stations with “fictive” values and isolines are used to derive the maps in figures 4 and 5. Real stations are marked with a circle, while a square indicates fictive stations.

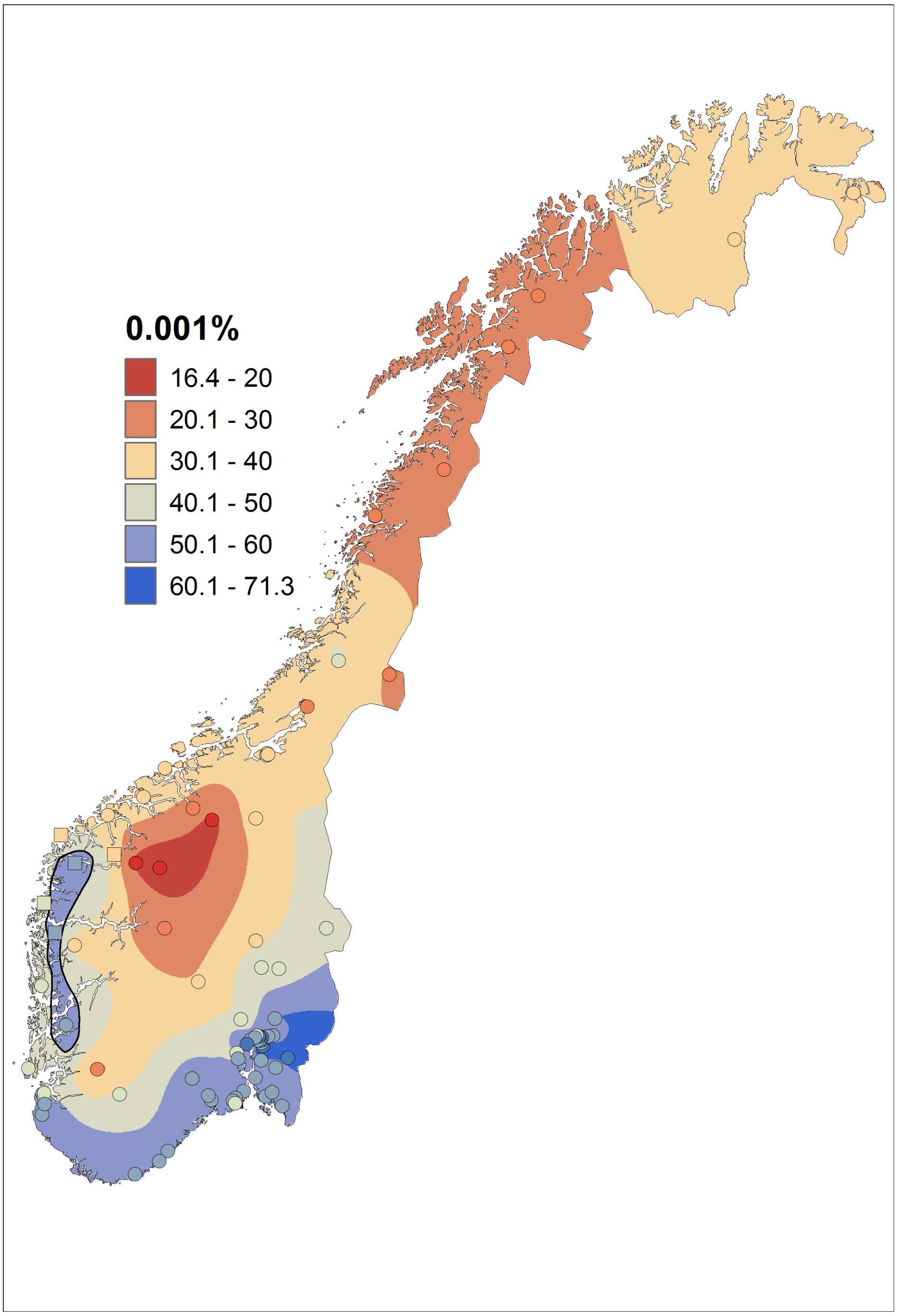

Figure 4: Rainfall intensity exceeded 0.001 % of the time. Unit: mm/h. The map is based on data from a limited number of stations, and must be considered less accurate in areas with few stations. Real stations are marked with a circle, while a square indicates fictive stations

STNR	0.001 % VALUE	STNR	0.001 % VALUE	STNR	0.001 % VALUE	STNR	0.001 % VALUE
200	45.8	18701	57.3	40140	41.5	64300	36.0
1220	50.7	18815	54.7	40500	29.3	66830	35.2
2840	64.1	19020	47.1	44190	55.6	68170	30.2
3030	52.8	19490	54.4	44580	52.4	68190	39.0
3810	54.6	19510	56.1	44620	52.0	68230	40.0
4220	53.2	19710	63.3	44640	51.0	68863	40.7
4781	59.6	20300	41.1	44660	47.1	71000	30.0
11620	45.1	24880	31.2	44730	58.2	72850	40.3
12290	43.7	26890	49.8	47240	49.9	73490	29.1
12670	38.6	26999	50.7	47890	53.7	80200	25.7
15720	16.4	27270	61.6	50480	46.6	81620	25.6
17260	52.5	27470	55.1	50490	48.7	84710	24.0
17870	58.6	27564	57.0	52290	34.2	89350	24.0
17980	66.5	27580	49.4	52300	36.0	97250	34.8
18020	56.8	30270	52.5	54730	25.3	99370	30.4
18210	69.5	30310	56.8	58700	18.6		
18270	58.5	32100	56.1	60940	33.1		
18320	53.5	36060	54.0	62290	38.0		
18420	68.3	38130	53.8	63420	26.4		
18640	59.6	39150	59.3	63500	19.2		

Table 16: Rainfall intensity exceeded 0.001 % of the time. Unit: mm/h

4.2 Rainfall intensity exceeded 0.01 % of the time

0.01 % of a year are nearly 52 minutes. For finding the value exceeded only 0.01 % of the time of a year, the average of the values in the 52. position each year for each station were calculated. These figures are found in table 17, Method 1, and serves as a basis for the digital map in figure 5. The highest values, above 25, are found in the Oslo/Akershus area, and also along a "coastal" zone from Hordaland to Østfold. The lowest values are located in Northern Norway and the inner districts of Southern Norway with 12-15 mm/h. Also these results include stations with different years of observation and different instrumentation.

To check the validity of these values, another method, Method 2 in table 17, was also used. As 52 minutes are almost 1 hour, we calculated the average of the highest annual 1 full hour rainfall from the tipping bucket stations. The values were corrected for 1 full hour versus an arbitrary 60 minutes period (factor 1.13) and also for the time difference between 52 minutes and 60 minutes, 0.867, giving a total correction factor of 0.98. Both set of values are found in table 17. Method 1 are larger by a factor of roughly 2.

STNR	METHOD 1	METHOD 2	STNR	METHOD 1	METHOD 2	STNR	METHOD 1	METHOD 2	STNR	METHOD 1	METHOD 2
200	15.0	9.	18640	21.6	12.	38130	21.5	13.	63500	12.0	6.
1220	22.7	10.	18701	23.5	13.	39150	26.4	13.	64300	16.5	8.
2840	23.3	12.	18815	22.8	15.	40140	17.5	10.	66830	14.4	10.
3030	21.6	11.	18920	26.7	14.	40500	14.7	9.	68170	13.0	8.
3190	25.5	11.	19020	21.7	13.	44190	24.5	13.	68190	13.2	8.
3810	21.5	11.	19490	23.1	13.	44580	24.6	9.	68230	15.0	9.
4220	21.6	10.	19510	22.7	13.	44620	27.3		68863	17.4	7.
4781	22.9	12.	19710	24.9	13.	44640	24.0		71000	13.5	
11620	16.0	10.	20300	14.8	8.	44660	23.4	10.	72850	12.9	8.
12290	16.2	9.	24880	13.2	7.	44730	25.6	11.	73490	12.0	7.
12670	15.7	9.	26890	20.9	10.	47240	23.6	11.	80200	18.9	10.
15720	12.0	5.	26999	19.3	12.	47890	27.0	15.	81620	12.0	6.
17260	21.0	12.	27270	25.5	14.	50480	23.6	9.	84710	12.0	7.
17870	23.6	13.	27470	22.5	13.	50490	24.0	10.	89350	12.0	6.
17980	24.5	12.	27564	26.4	12.	52290	20.4	10.	97250	13.8	8.
18020	21.8	12.	27580	22.9	11.	54730	12.0	7.	99370	12.7	7.
18210	25.4	16.	30270	22.2	12.	58700	12.0	6.			
18270	23.1	10.	30310	23.6	11.	60940	14.9	7.			
18320	22.2	13.	32100	21.0	13.	62290	14.0	9.			
18420	27.9	15.	36060	24.0	13.	63420	12.0	6.			

Table 17: Rainfall intensity exceeded 0.01 % of the time

Figure 5 shows a digital map with the average values for method 1 for rainfall intensity exceeded 0.01 % of the time.

Figure 6 is supplied by Telenor, and is based on the ITU-R P.837-5 rain data. It shows rainfall rate exceeded 0.01 % of a year and is therefore comparable to figure 5. The Telenor map shows generally higher values, especially at the Western part of Norway. The highest values are found over the adjacent sea areas, which is not realistic. Generally, extreme short-term (i.e. minutes) rainfall intensty is higher over land areas than over adjacent ocean areas. The enhanced convective rainfall intensity over land is due to increased vertical instability because of higher daytime warming of the land surface and the lower troposhere. Also the topography may increase the vertical velocity of the airmasses, and thus intensify the condensation process.

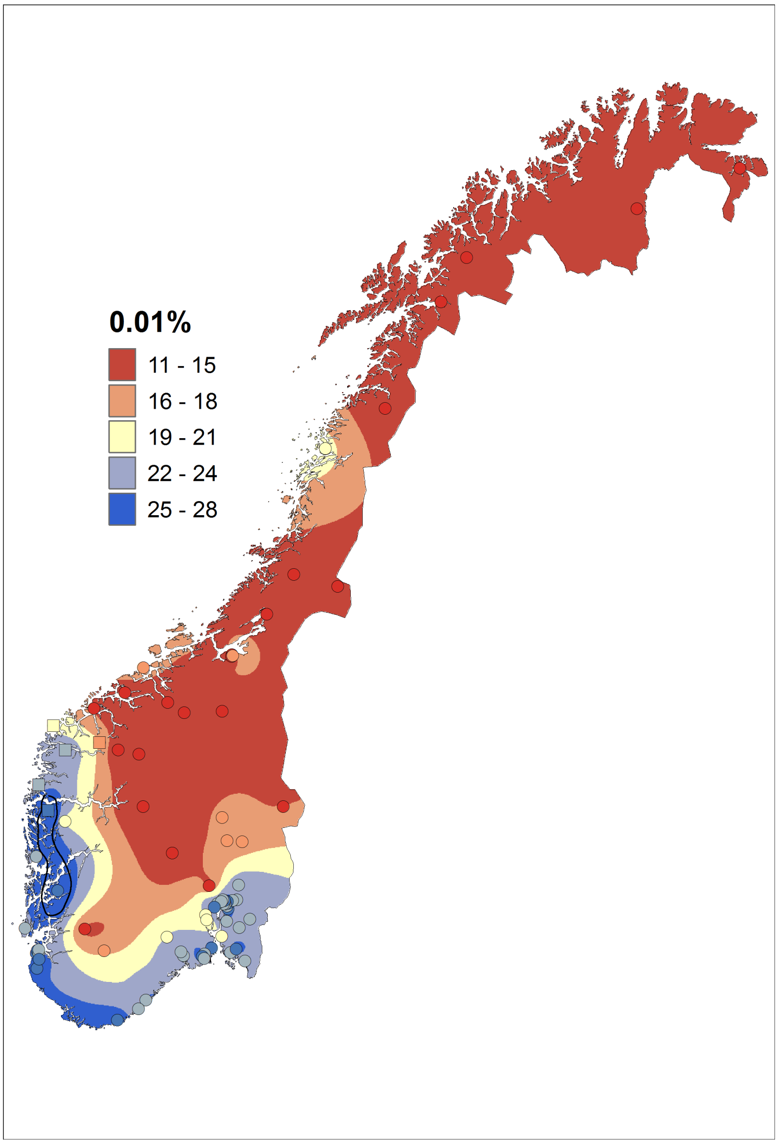

Figure 5: Rainfall intensity exceeded 0.01 % of the time. Unit: mm/h. The map is based on data from a limited number of stations, and must be considered less accurate in areas with few stations. Real stations are marked with a circle, while a square indicates fictive stations

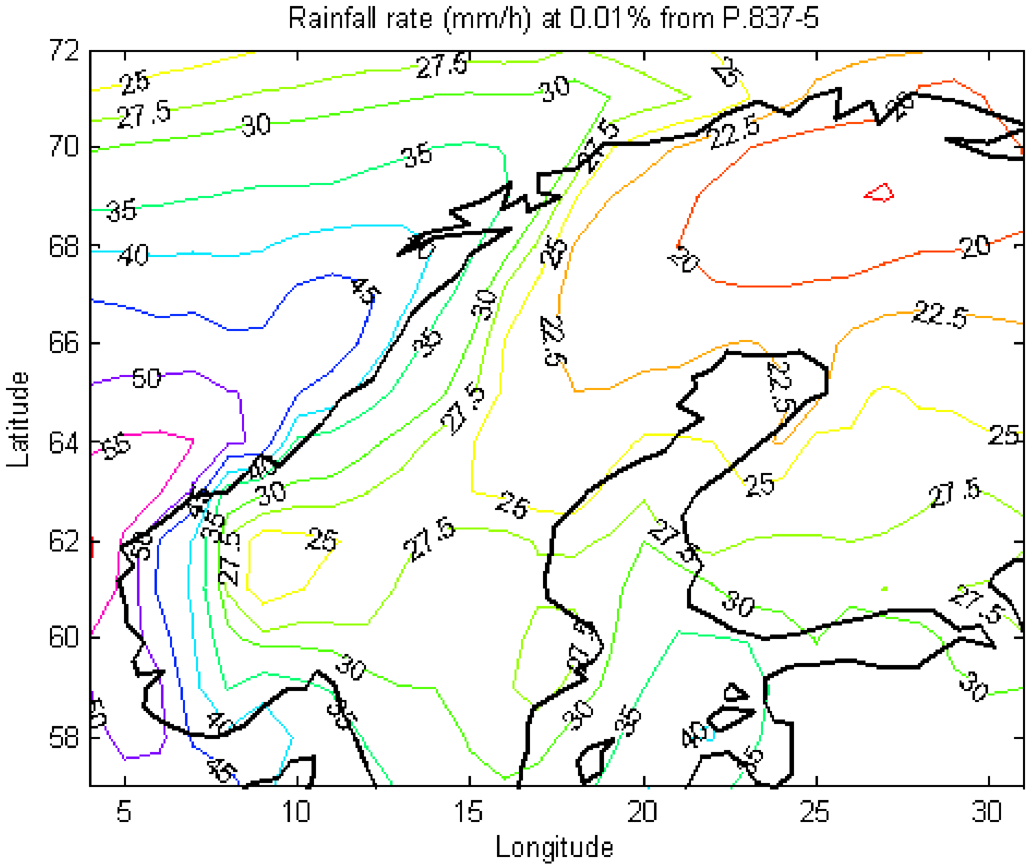

Figure 6: Rainfall intensity exceeded 0.01 % of the time. From P.837-5. Unit: mm/h

4.2.1 Monthly values

One month equals about 40 000 minutes, so 0.01 % is 4 minutes. By analogy to section 4.1, these values were computed by finding the 4th highest value for each station for each month and each year. The average values can be found in table 18.

4.3 Rainfall intensity exceeded 0.1 % of the time

0.1 % of a year is 8.76 hours or 525.6 minutes. Also for finding the intensity exceeded 0.1 % of a year, two methods were used. First, the average of the 525th highest intensity for each station, were calculated. Second, the average of the 9th highest annual 1 hour rainfall from the tipping bucket stations were calculated. Both set of values are found in table 19. Data from the weight pluviometer stations were not used because of occasional poor data quality, making it difficult to calculate reliable averages of the 9th highest annual values.

The first method is considered to give the most accurate values, but for stations not operating all-year-round the results are based on the premise that precipitation in summer is most intense.

Method 1 gives values from 1-3 mm/h in the dry, inner parts of Southern Norway to 8-11 at the most wet parts of Western and Northern Norway. The second method gives less variation, from 2-3 mm/h to 6-9 mm/h, respectively.

A digital map based on the highest results of method 1 and 2 is provided in figure 7.

STNR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MAX
200				12.0	16.0	29.1	39.8	28.0	18.9	12.0			39.8
1220			12.0	13.3	18.4	33.8	37.7	38.3	21.9	18.8	16.0	12.0	38.3
2840				12.0	18.8	33.4	51.8	36.4	26.3	16.0	14.0		51.8
3030				12.0	17.0	31.4	40.0	33.4	25.8	19.8	14.8		40.0
3190				12.0	15.4	39.4	53.1	42.0	24.0	36.0	12.0		53.1
3810	8.4	6.0	8.4	10.8	18.2	31.8	45.9	38.1	27.3	18.4	11.7	8.3	45.9
4220				12.0	20.0	36.4	44.6	36.0	19.4	16.4	13.5		44.6
4781				12.0	19.4	32.2	41.6	41.1	25.1	15.2	13.3	12.0	41.6
11620				12.0	12.8	25.3	38.1	28.6	17.7	12.6	12.0		38.1
12290	6.0	6.0	6.0	12.0	15.3	24.6	36.2	30.9	18.2	13.6	9.8	6.0	36.2
12670				12.0	16.2	28.6	34.4	22.8	17.7	12.6	12.0		34.4
15720					12.0	12.7	13.9	15.3	12.0	12.0			15.3
17260				12.0	17.6	35.3	37.6	43.8	24.0	19.8	14.7	12.0	43.8
17870	12.0	12.0	12.0	12.0	17.8	35.0	41.0	40.3	26.1	21.0	13.8	12.0	41.0
17980	8.4	6.7	9.6	9.6	23.4	34.7	56.7	58.2	31.6	19.1	11.5	7.8	58.2
18020	6.5	7.8	7.1	10.7	15.5	30.5	46.8	37.9	26.3	16.0	11.2	8.6	46.8
18210	6.9	6.0	6.8	9.0	21.0	38.2	56.4	56.2	27.8	16.4	9.8	7.8	56.4
18270	18.0	18.0	14.4	12.6	25.1	30.2	47.8	38.4	23.5	18.5	13.2	12.0	47.8
18320	7.7	7.4	7.9	10.0	14.8	26.5	48.0	42.8	22.0	15.5	11.4	7.7	48.0
18420	9.8	7.1	7.5	9.5	23.5	35.1	59.1	43.8	28.6	18.9	10.6	7.0	59.1
18640			12.0	12.0	20.0	29.6	42.0	43.4	32.4	15.4	12.0	12.0	43.4
18701	9.0	9.6	9.3	12.4	17.9	35.0	45.3	37.7	26.6	17.3	13.6	9.6	45.3
18815	7.2	8.4	6.0	11.3	16.5	33.4	54.8	38.3	22.3	19.0	10.0	9.0	54.8
18920	8.0	12.0	9.0	19.0	18.9	36.0	73.7	46.5	21.4	18.0	15.8	7.7	73.7
19020	15.3	12.0	13.8	12.0	16.4	27.5	34.9	43.2	19.8	20.2	12.0	12.7	43.2
19490	6.0	6.0	8.4	12.4	22.3	33.8	43.2	37.3	20.3	15.1	12.4	8.4	43.2
19510	8.0	6.0	7.2	11.4	16.7	25.7	48.0	40.3	22.9	14.1	11.6	8.0	48.0
19710				12.0	22.9	29.1	52.6	42.5	28.2	19.7	14.4	12.0	52.6
20300				12.0	14.2	21.4	32.0	28.8	15.5	13.6	12.0	12.0	32.0
24880					15.0	22.7	29.3	15.8	13.9	12.0	12.0		29.3
26890				12.8	15.0	29.8	36.9	33.8	23.1	13.9	13.3		36.9
26999	9.0	6.0	7.7	10.3	16.7	25.3	36.0	46.5	20.3	17.1	13.0	8.4	46.5
27270	10.0	7.8	7.6	12.0	24.5	22.4	51.3	45.3	36.7	23.5	21.3	13.3	51.3
27470				12.0	16.5	28.1	41.3	38.6	25.6	17.5	16.5	12.0	41.3
27564	11.1	6.9	8.6	12.8	21.0	26.3	58.3	55.7	41.1	30.0	19.0	16.3	58.3
27580	12.0			12.0	22.7	25.6	32.3	36.7	26.3	22.8	16.6	12.0	36.7
30270				12.0	18.4	24.6	37.9	41.0	30.0	15.4	12.0	12.0	41.0
30310				12.0	21.6	29.1	38.1	39.7	31.8	20.0	15.3	12.0	39.7
32100				12.0	16.7	30.4	45.2	33.0	27.7	15.3	12.0		45.2
36060				12.0	19.1	27.1	37.9	37.3	33.8	25.1	17.3	12.0	37.9
38130			12.0	12.0	16.2	29.4	37.7	41.1	29.2	19.5	14.0		41.1
39150	15.4	13.3	13.6	14.3	22.6	32.6	41.4	43.6	36.2	28.4	22.0	16.5	43.6
40140				12.0	16.0	25.3	37.1	27.6	15.6	16.8	12.0		37.1
40500					12.0	18.0	22.3	22.0	20.6	16.0	12.0		22.3
44190	14.4	12.8	13.5	12.0	14.5	34.5	33.6	41.4	36.0	27.6	21.5	16.2	41.4
44580	21.3	14.0	12.0	12.5	19.7	22.4	31.2	46.7	43.3	33.4	22.5	18.9	46.7
44620	22.3	13.0	13.7	12.9	19.7	18.9	36.8	47.3	34.5	37.5	27.3	21.3	47.3
44640	21.8	11.0	10.5	15.4	14.3	21.4	29.3	44.0	32.7	35.3	26.4	18.7	44.0
44660	18.0	12.6	15.8	12.4	16.8	25.8	31.9	35.3	36.8	26.8	27.4	20.6	36.8
44730	15.8	12.7	12.7	13.1	19.8	36.0	34.3	39.4	33.0	27.2	19.3	15.8	39.4
47240	14.7	13.3	12	12.9	19.4	22.0	31.0	39.8	34.1	25.5	21.4	18.0	39.8
47890				13.1	16.9	31.1	37.0	42.0	36.6	27.3	23.3	22.3	42.0
50480	18.5	14.2	16.4	12.5	16.9	21.8	39.0	49.0	44.5	29.5	31.1	21.5	49.0
50490	19.2	19.2	14.4	12.0	14.0	22.0	27.4	41.3	34.7	26.7	24.0	14.0	41.3
52290				12.8	14.8	22.0	24.7	28.9	28.0	23.3	20.3		28.9
54730						15.0	24.0	15.4	15.0	12.0			24.0
58700				12.0	12.0	13.3	15.6	13.2	13.2	12.6	12.0		15.6
60940				12.0	12.6	15.7	18.3	24.5	24.0	21.9	16.0		24.5
62290				12.0	14.7	17.3	20.0	39.3	22.0	16.8	16.0	12.0	39.3
63420				12.0	12.0	19.2	20.4	16.8	14.4	12.0	12.0		20.4
63500					12.0	15.4	21.3	13.5	12.0	13.3	12.0		21.3
64300	17.5	16.9	15.2	14.1	13.8	19.8	22.4	27.0	25.4	21.9	17.1	17.4	27.0
66830					12.0	18.9	32.0	20.6	16.0	12.0			32.0
68170	20.0	12.0	12.0	12.0	14.7	14.4	25.2	22.4	18.5	13.6	13.8	13.5	25.2
68190				12.0	12.0	16.0	24.0	30.6	14.7	14.7	14.4	12.0	30.6
68230	12.3	10.3	9.3	10.2	11.7	18.5	27.3	24.9	23.7	14.5	14.3	17.7	27.3
68863	9.0	7.2	8.3	8.7	12.7	22.5	32.3	27.8	22.0	17.3	10.7	10.5	32.3
71000	12.0	12.0	12.0	12.0	12.0	22.3	17.1	26.0	12.0	16.0	12.0	12.0	26.0
72850					13.2	18.0	41.1	20.7	20.7	13.8	12.0		41.1
73490					12.0	17.0	25.8	28.4	14.0	12.0			28.4
80200					12.0	16.0	22.3	26.0	24.0	19.2			26.0
81620					12.0	15.4	20.6	19.0	13.8	13.0	12.0		20.6
84710					12.0	12.0	18.0	18.0	13.3	13.3	16.0		18.0
89350					12.0	12.8	19.8	20.0	12.0	12.0			20.0
97250					13.0	17.6	31.1	22.8	14.0	12.0			31.1
99370					12.0	16.8	20.5	21.2	13.4	12.0			21.2

Table 18: Monthly values of rainfall intensity exceeded 0.01 % of the time

STNR	METHOD 1	METHOD 2	STNR	METHOD 1	METHOD 2	STNR	METHOD 1	METHOD 2	STNR	METHOD 1	METHOD 2
200	4.1	4.2	18640	3.7	4.4	38130	6.5	5.5	66830	2.4	3.1
1220	4.2	4.3	18701	4.9	5.0	39150	8.8	5.9	68170	3.2	3.5
2840	4.6	4.5	18815	5.6	5.6	40140	4.7	4.5	68190	2.9	3.4
3030	4.3	4.5	18920	10.5	6.2	40500	4.4	4.1	68230	5.7	4.2
3190	6.2	5.2	19020	6.7	5.4	44190	7.5	5.4	68863	6.0	3.1
3810	4.7	4.6	19490	4.8	4.9	44580	8.7	4.0	72850	3.4	3.4
4220	3.8	4.3	19510	4.6	4.9	44660	8.3	5.0	73490	1.8	2.5
4781	4.5	4.6	19710	6.7	6.1	44730	7.7	5.2	80200	11.0	6.4
11620	3.4	4.0	20300	2.3	3.2	47240	8.6	5.5	81620	2.1	2.8
12290	2.8	3.6	24880	2.2	2.9	47890	11.4	9.1	84710	2.4	3.0
12670	3.1	3.7	26890	4.9	4.8	50480	10.4	5.5	89350	1.0	2.0
15720	1.0	2.3	26999	6.0	5.3	50490	8.2	5.8	97250	1.1	2.7
17260	4.7	4.6	27270	9.8	6.1	52290	10.2	6.3	99370	1.4	2.5
17870	5.0	4.8	27470	5.4	5.3	54730	1.2	2.5			
17980	6.0	5.9	27564	9.0	4.8	58700	3.0	3.6			
18020	6.0	5.0	27580	5.5	5.1	60940	5.1	4.1			
18210	5.8	5.7	30270	4.7	4.6	62290	5.7	4.4			
18270	4.8	4.7	30310	6.1	5.4	63420	3.0	3.5			
18320	6.0	4.7	32100	4.4	4.8	63500	1.8	2.9			
18420	7.4	6.2	36060	7.0	5.6	64300	5.1	3.9			

Table 19: Rainfall intensity exceeded 0.1 % of the time. Unit: mm/h

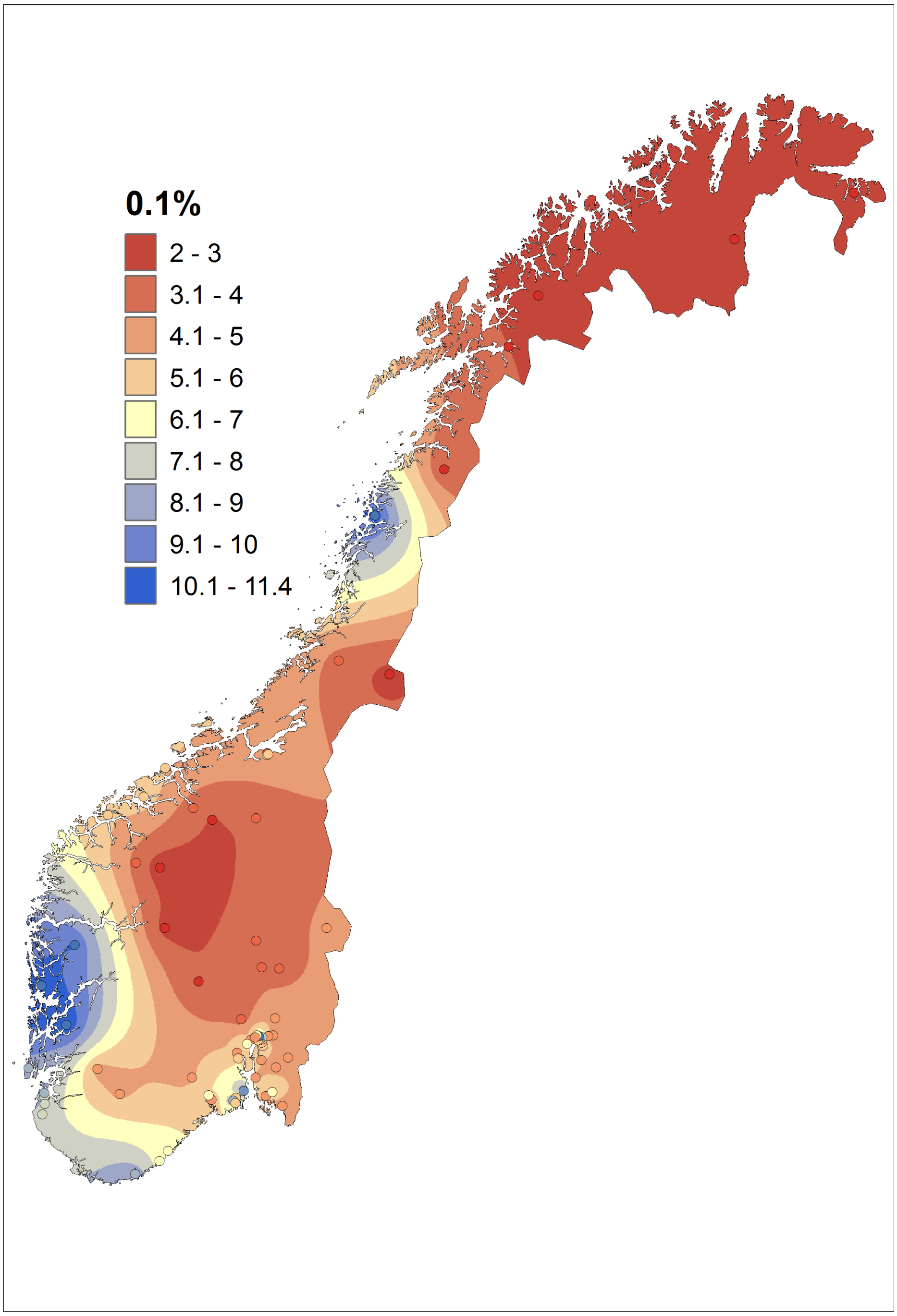

Figure 7: Rainfall intensity exceeded 0.1 % of the time. Unit: mm/h. The map is based on data from a limited number of stations, and must be considered less accurate in areas with few stations. Real stations are marked with a circle

4.4 Rainfall intensity exceeded 0.5 % of the time

0.5 % of a year equals 2628 minutes or 43.8 hours.

Only intensities for stations with long data series were calculated by the most accurate method: by finding the annual values for each station in the position where the accumulated time difference, see table 14, is 2628.

This method, method 1 in table 20, was compared to another method where averages of the 44th highest 1 hour precipiation were calculated from data for the tipping bucket stations. Again, data from the weight pluviometer stations were not used, because of occasional poor data quality, making it difficult to calculate reliable averages.

The results are presented in table 20. The values are very similar for all parts of the country, except for a few stations. The intensities vary from 1 mm/h in Northern Norway to 4-5 mm/h at the most rainy parts of Western Norway.

STNR	METHOD 1	METHOD 2	STNR	METHOD 1	METHOD 2	STNR	METHOD 1	METHOD 2	STNR	METHOD 1	METHOD 2
200		2.1	18640		2.0	38130		2.4	63500		1.3
1220		2.1	18701	2.4	2.4	39150	3.7	2.9	64300	3.2	2.3
2840		2.1	18815		2.8	40140		2.3	66830		1.4
3030		1.9	18920		3.0	40500		2.1	68170		1.8
3190		2.3	19020	3.3	3.0	44190		3.1	68190		1.8
3810	2.2	2.2	19490		2.2	44580		2.1	68230	3.0	2.5
4220		2.0	19510		2.1	44640	4.5	3.5	68863		1.9
4781		2.2	19710		3.0	44660		2.9	72850		1.8
11620		1.8	20300		1.4	44730		3.0	73490		1.1
12290	1.4	1.5	24880		1.5	47240	3.5	3.1	80200		3.0
12670		1.7	26890		2.3	47890	5.4	5.1	81620		1.4
15720		1.0	26999		2.6	50480	4.8	3.4	84710		1.5
17260		2.1	27270		3.4	50490		3.3	89350	1.0	1.0
17870	2.4	2.2	27470		2.7	52290		3.7	97250	1.0	1.0
17980	3.0	2.8	27564	3.3	2.7	52300		3.9	99370		1.1
18020	2.4	2.4	27580		2.5	54730		1.0			
18210	2.8	2.8	30270		2.0	58700		2.0			
18270	2.5	2.2	30310		2.5	60940		2.3			
18320		2.0	32100		2.2	62290		2.6			
18420		3.1	36060		2.8	63420		1.9			

Table 20: Rainfall intensity exceeded 0.5 % of the time. Unit: mm/h

Figure 8 shows a map for rainfall intensity exceeded 0.5 % of the time of a year and is based on the highest value of method 1 and 2 in table 20.

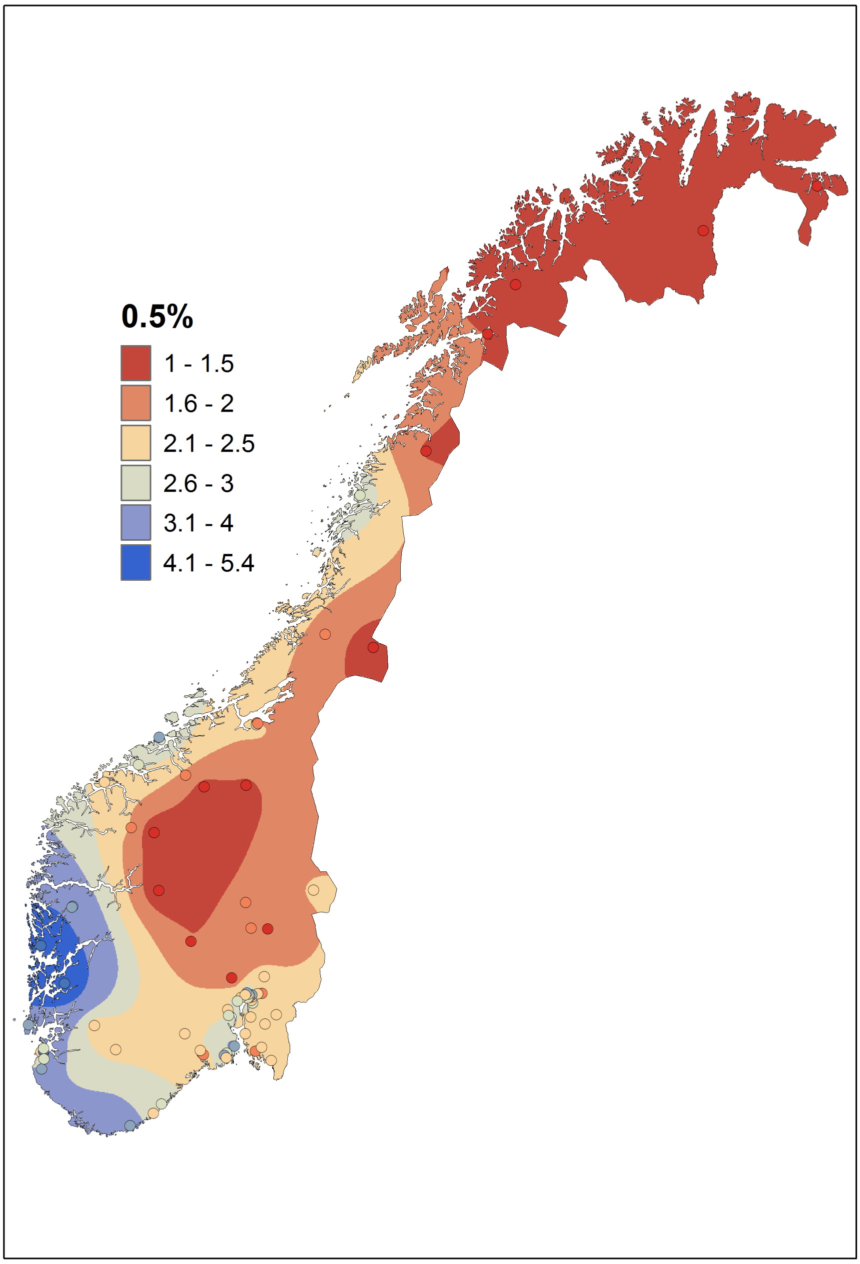

Figure 8: Rainfall intensity exceeded 0.5 % of the time. Unit: mm/h. The map is based on data from a limited number of stations, and must be considered less accurate in areas with few stations. Real stations are marked with a circle

5 Rainfall rate trends from tipping bucket data and return periods

5.1 Rainfall rate trends

For trend analysis long series of observations are necessary. A rule of thumb is that the longest return period to be calculated is four times the length of the observations series. Thus, one needs at least 25 years of observations to calculate a return period of 100 years.

5.1.1 Trends of maximum annual 1-minute intensity

Figure 9 shows highest annual one minute rainfall with a linear trend line for each station with long series. Unfortunately stations north of Trondheim are not available.

Stations with a definitive positive trend are 3810, 4781, 17870, 18701, 19710, 39150, 44580, 64300 and 68230. A large negative trend is found for station 44190. Stations with an almost horizontal trend line are 12290, 18270, 19490, 19510, 30310, 36060, 44660, 44730, 47240 and 50480.

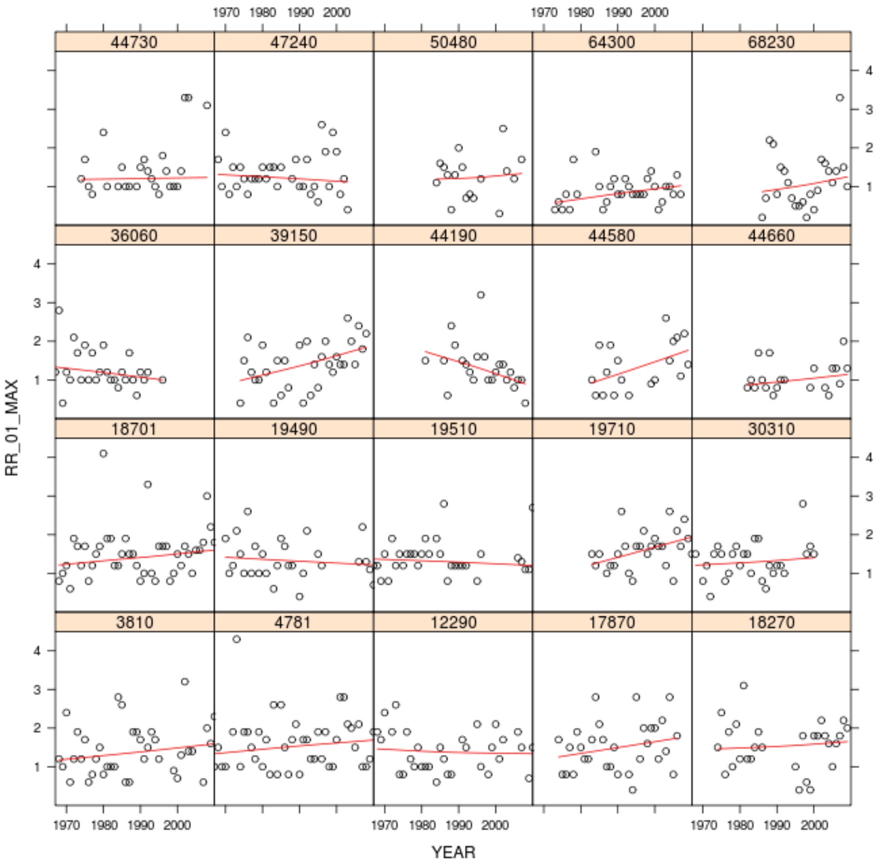

Figure 9: Highest annual 1-minute rainfall with linear trend lines

5.1.2 Trends of intensity exceeded 0.01 % of the time

For the same stations as in the previous section, trends for intensity exceeded 0.01 % of the time were calculated. The results are shown in figure 10.

Stations with a definitive positive trend are 3810, 17870, 18701, 39150, 44580, 50480, 64300, 68230. A large negative trend is found for station 44190. Stations with an almost horizontal trend line are 4781, 12290, 18270, 19490, 19510, 19710, 30310, 36060, 44190, 44660, 44730, 47240.

For some stations in the south of England, [4] found an increasing trend in rain rates associated with outages.

5.2 Return periods

Table 21 shows 2, 5, 10 and 25 years return periods for 1 minute and 60 minutes precipitation for the tipping bucket stations. The column “Ratio” is the 10 year value for 60 minutes precipitation divided by the value for 1 minute. This ratio could be used to convert 1 hr precipition values from the weight pluviometer stations to 1 minute values.

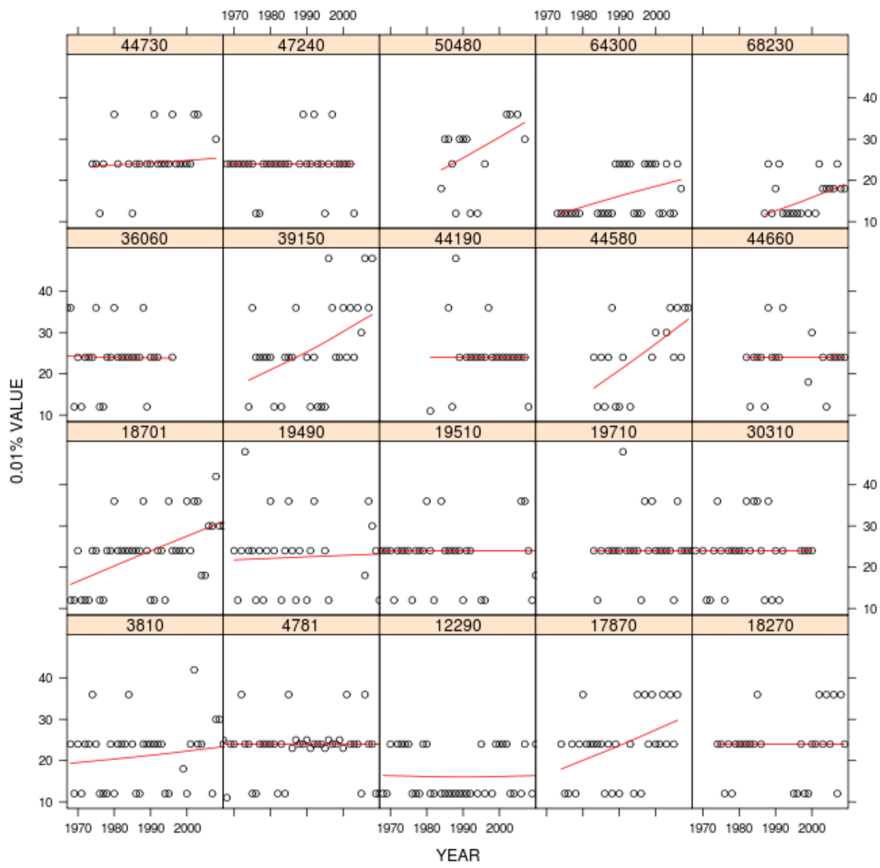

Figure 10: Annual values of rainfall intensity exceeded 0.01 % of the time with linear trend lines

	1 minute				60 minutes				Ratio
STNR/RET. PER	2	5	10	25	2	5	10	25	
200	1.4	2.1	2.6	3.1	11.8	18.3	22.6	28.0	8.4
1220	1.5	1.9	2.1	2.5	12.3	17.2	20.5	24.6	8.2
2840	1.9	2.4	2.7	3.1	15.9	23.1	27.9	34.0	8.4
3030	1.6	2.0	2.3	2.7	15.3	21.7	26.0	31.4	9.6
3190	1.8	2.3	2.7	3.1	14.8	19.2	22.2	26.0	8.2
3810	1.6	2.1	2.4	2.9	13.5	19.2	23.0	27.8	8.4
4220	1.5	2.0	2.3	2.6	11.7	14.8	16.9	19.5	7.8
4781	1.8	2.3	2.7	3.2	13.5	17.1	19.5	22.5	7.5
11620	1.3	1.6	1.8	2.1	12.1	16.5	19.3	23.0	9.3
12290	1.5	1.9	2.2	2.5	10.4	13.5	15.7	18.3	6.9
12670	1.3	1.5	1.7	2.0	10.3	12.6	14.1	16.0	7.9
15720	0.5	0.7	0.8	1.0	6.0	8.5	10.1	12.2	12.0
17260	1.6	2.1	2.5	2.9	14.0	20.4	24.6	30.0	8.8
17870	1.7	2.2	2.5	2.8	14.9	21.1	25.2	30.4	8.8
17980	2.1	2.8	3.2	3.7	16.0	21.2	24.7	29.0	7.6
18020	1.5	1.9	2.1	2.3	15.2	19.4	22.2	25.8	10.1
18270	1.8	2.3	2.7	3.1	15.0	20.2	23.7	28.0	8.3
18320	1.5	1.9	2.2	2.6	14.0	17.0	19.0	21.4	9.3
18420	1.8	2.4	2.8	3.3	19.5	24.3	27.5	31.5	10.8
18640	1.6	2.1	2.4	2.7	15.5	21.5	25.5	30.6	9.7
18701	1.6	2.2	2.5	3.0	16.5	23.1	27.4	32.9	10.3
19020	1.4	1.8	2.0	2.2	14.3	17.6	19.7	22.4	10.2
19490	3.1	3.8	4.3	5.0	32.3	51.1	63.6	79.3	10.4
19510	1.6	1.9	2.2	2.5	15.8	20.8	24.2	28.4	9.9
19710	1.7	2.1	2.3	2.5	16.5	25.4	31.4	38.8	9.7
20300	1.2	1.6	1.8	2.2	9.9	12.5	14.2	16.4	8.3
24880	1.0	1.3	1.5	1.7	8.6	12.1	14.3	17.2	8.6
26890	1.4	1.8	2.0	2.3	12.7	15.5	17.4	19.7	9.1
26999	1.2	1.4	1.5	1.7	12.2	16.3	19.1	22.6	10.2
27270	1.5	1.8	1.9	2.1	15.1	18.0	19.8	22.2	10.1
27470	1.6	2.3	2.8	3.4	15.6	20.3	23.4	27.4	9.8
27564	1.7	2.0	2.2	2.4	14.7	20.2	23.8	28.4	8.6
27580	1.5	2.0	2.4	2.8	14.7	18.8	21.6	25.1	9.8
30270	1.5	1.9	2.1	2.4	15.2	21.1	24.9	29.9	10.1
30310	1.5	1.8	2.0	2.3	15.0	20.1	23.4	27.6	10.0
32100	1.6	2.2	2.6	3.1	14.5	20.0	23.6	28.2	9.1
36060	1.3	1.6	1.8	2.0	14.5	16.5	17.9	19.6	11.2
38130	1.6	2.1	2.5	3.0	15.9	23.6	28.7	35.1	9.9
39150	1.8	2.1	2.3	2.6	18.6	24.3	28.0	32.8	10.3
39260	1.5	1.7	1.9	2.1	15.3	19.3	21.9	25.1	10.2

	1 minute				60 minutes				Ratio
STNR/RET. PER	2	5	10	25	2	5	10	25	
40140	1.3	1.7	2.0	2.3	12.9	15.6	17.5	19.8	9.9
40500	1.0	1.4	1.7	2.0	10.7	15.4	18.5	22.4	8.1
44190	1.6	2.1	2.4	2.9	14.4	22.4	27.6	34.2	10.7
44580	1.5	2.0	2.2	2.6	13.4	16.6	18.8	21.5	9.0
44620	1.3	1.5	1.6	1.7	14.1	19.4	22.9	27.4	8.9
44640	1.4	1.7	1.9	2.1	12.2	14.8	16.6	18.8	10.8
44660	1.3	1.6	1.8	2.0	13.1	17.8	20.9	24.8	8.7
44730	1.6	2.2	2.5	3.0	13.1	17.0	19.5	22.6	10.1
47240	1.4	1.8	2.0	2.3	13.2	17.1	19.6	22.8	8.2
47890	1.6	1.9	2.1	2.4	17.0	20.1	22.0	24.6	9.4
50480	1.5	1.8	2.0	2.2	14.3	16.8	18.5	20.6	10.6
52290	1.0	1.2	1.4	1.6	12.4	16.2	18.7	21.9	9.5
52300	0.9	1.2	1.4	1.7	13.2	18.2	21.5	25.7	12.4
54730	0.6	0.9	1.1	1.4	8.3	10.2	11.4	12.9	14.7
58700	0.6	1.1	1.5	1.9	6.8	8.0	8.7	9.6	13.8
60940	0.9	1.2	1.3	1.5	8.6	10.1	11.1	12.3	11.3
62290	0.9	2.1	2.9	3.9	9.5	16.3	20.8	26.5	9.6
63420	0.7	1.0	1.2	1.5	7.8	9.3	10.2	11.4	10.6
63500	0.6	0.9	1.1	1.4	7.0	9.4	10.9	13.0	11.1
64300	1.1	1.4	1.6	1.8	10.3	13.4	15.6	18.2	11.7
66830	1.0	1.3	1.4	1.7	11.6	18.5	23.1	28.9	9.4
68170	1.0	1.4	1.7	2.0	8.6	11.3	13.0	15.2	11.6
68190	1.2	1.8	2.3	2.8	9.5	13.2	15.8	18.9	8.6
68230	1.4	2.0	2.3	2.8	10.6	13.4	15.3	17.7	7.9
71000	1.1	2.2	2.8	3.7	8.0	11.8	14.4	17.6	7.6
72850	1.3	1.9	2.3	2.9	9.6	12.6	14.7	17.2	7.5
73490	1.2	1.8	2.1	2.6	8.2	11.7	14.0	16.9	8.5
80200	0.8	1.1	1.3	1.5	12.4	14.0	15.1	16.4	7.3
81620	0.8	1.0	1.2	1.4	8.0	10.0	11.3	13.1	7.4
84710	0.6	0.7	0.8	1.0	8.2	10.3	11.7	13.4	6.8
89350	0.7	1.1	1.3	1.6	8.0	11.6	14.0	17.1	15.5
97250	1.0	1.4	1.7	2.0	9.9	13.4	15.7	18.6	10.0
99370	1.0	1.4	1.7	2.0	8.6	13.7	17.1	21.3	7.0

Table 21: 2, 5, 10 and 25 year return periods for 1 minute and 60 minutes precipitation

6 Methods used to derive rainfall intensity data from long term historical data set

The analysis was based on large-scale and convective 6hr precipitation data from ERA-Interim [5] (ERAINT), which were retrieved from ECMWF MARS-archive. ERAINT has improved resolution and better models for hydrological processes compared to ERA40, and it was therefore of interest to use this dataset to investigate reasons for increased ITU-R P.837-5 rainfall intensities at Norwegian coastal and oceanic areas. The data files contains data on a 480-by-241 spatial grid, one for each time of observation (every 6hr, corresponding to approximately 1500 per year). Since the amount of data is too much to process simultaneously, the data was stored as one data file for each year, each consisting of 6 and 12 hr accumulated precipitation amounts, and with forecasts starting at 00:00hr and 12:00. The layout of the data complicates the extraction of information, but an R-script was written to compute the 6-hr accumulated precipitation for the times 00:00, 06:00, 12:00, and 18:00. In order to keep track of the times, the code used the time stamp of the netCDf files containing the ERAINT data (hours since 1900-01-01 00:00:0.0), subtracting the values at times 12:00 and 00:00 with the previous 6hr interval (06:00 and 18:00 respectively). The wet-spell total was taken to be the number of 6hr intervals at each grid points with 6-hr amounts greater than 0.1 mm. The preprocessing computed the total accumulated large-scale and convective for the period 1989-2010, based on the 6hr precipitation data extracts. Furthermore, the number of wet 6hr intervals and total number of intervals were saved in the pre-procesing process. The annual mean total precipitation was taken to be M_t and annual mean convective precipitation to be M_c, and the difference M_s = M_t - M_c. The total precipitation cannot logically be less than the convective precipitation, but in areas where nearly all precipitation is of convective type, the data some times indicated $M_t < M_c$. This discrepancy was attributed to inaccuracies associated with round-off errors, and hence M_s was set ot zero when $M_s < 0$. The probability of precipitation during a 6hr interval (00:00, 06:00, 12:00, 18:00) was derived according to

$$Pr6h = 100 \times N_{wet}/N_{tot}.$$

The definition of a set of parameters were taken from Recommendation ITU-R P.837-4:

$$a = 1.11;$$

$$b = M_t/(22932 \times P0);$$

$$c = 31.5b$$

$$P0 = Pr6h(1 - exp(-0.0117 \times M_s/Pr6h));$$

The probability distribution function (pdf) was computed according to the expression:

$$p(X) = P0 \times exp[-a \times X \times (1 + b \times X)/(1 + c \times X)],$$

where X is the precipitation in mm. The definition of a pdf is that the area under the curve describing its shape is unity (=1).

The cumulative distribution function (cdf) was estimated numerically by taking the cumulative sum of the pdf:

$$P(X < x) = \sum_{x=0}^{X} p(X).$$

The extracted data and set of parameters were saved in a seperate netCDF file. The following figures below were generated using a visualisation tool called Ferret, and show the quantities for some of the parameters defined above.

ERAINT should be one of the best global data sets, but to make reliable maps, one has to look at both methods and calibration.

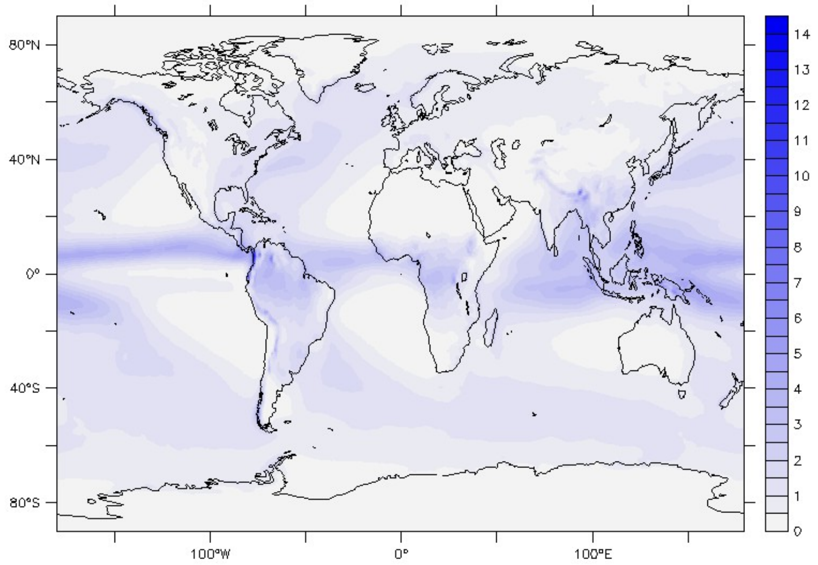

Figure 11: Total precipitation (annual mean in m)

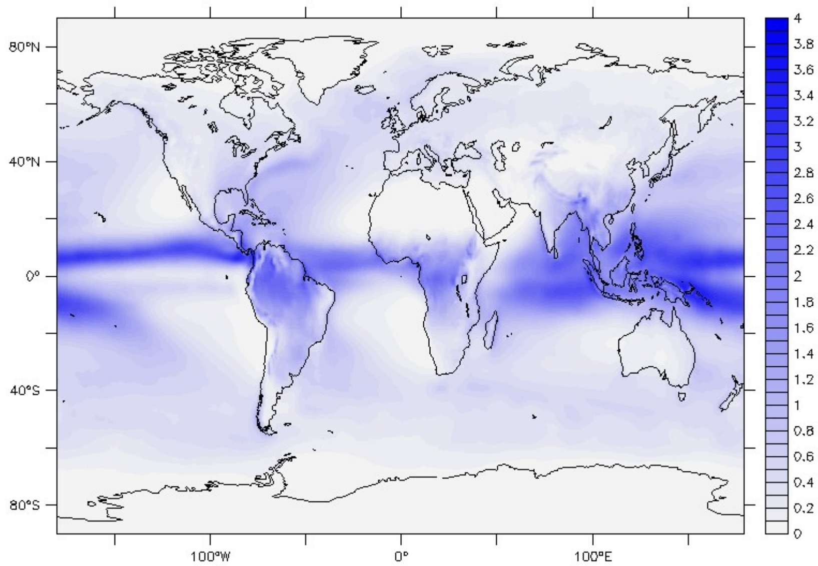

Figure 12: Convective precipitation (annual mean i m)

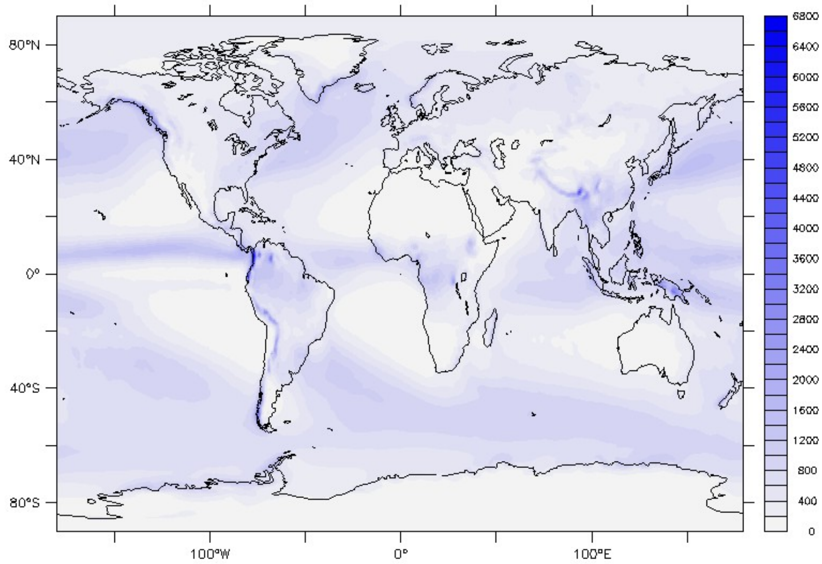

Figure 13: P0

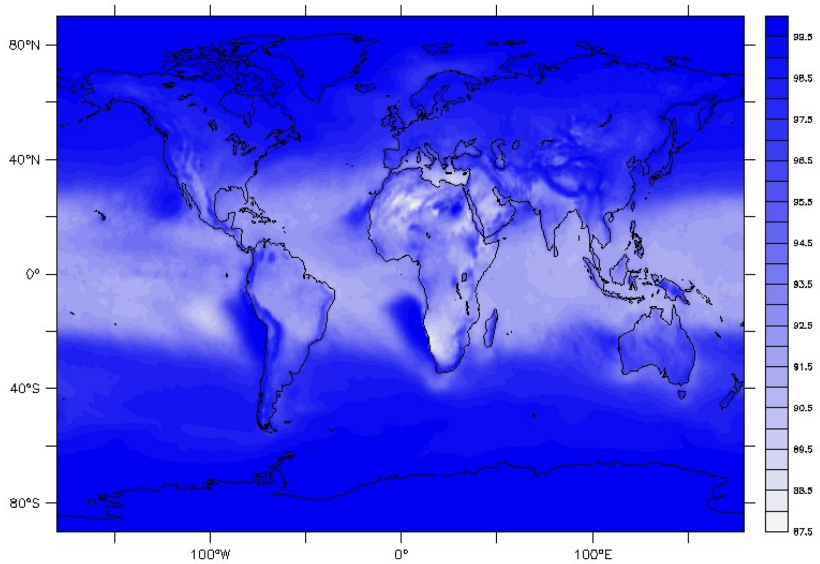

Figure 14: Probability for amounts less than 50mm

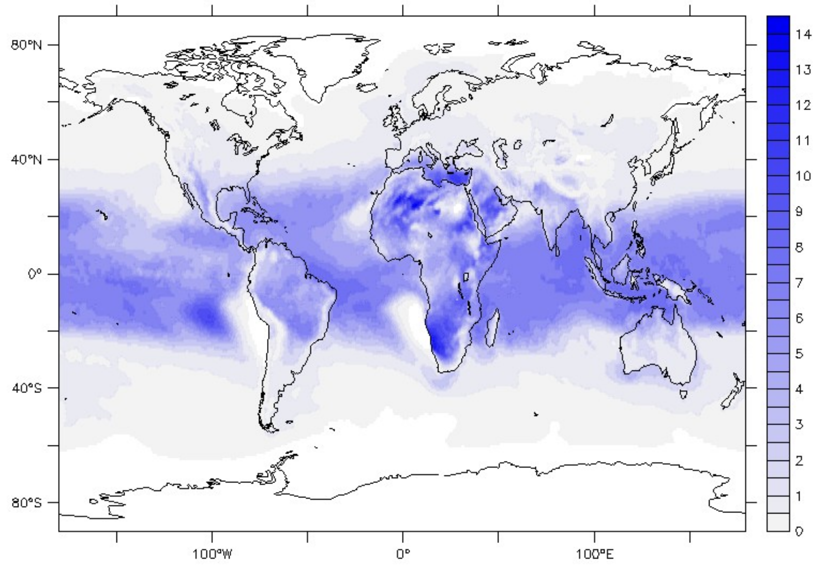

Figure 15: 50th percentile (mm)

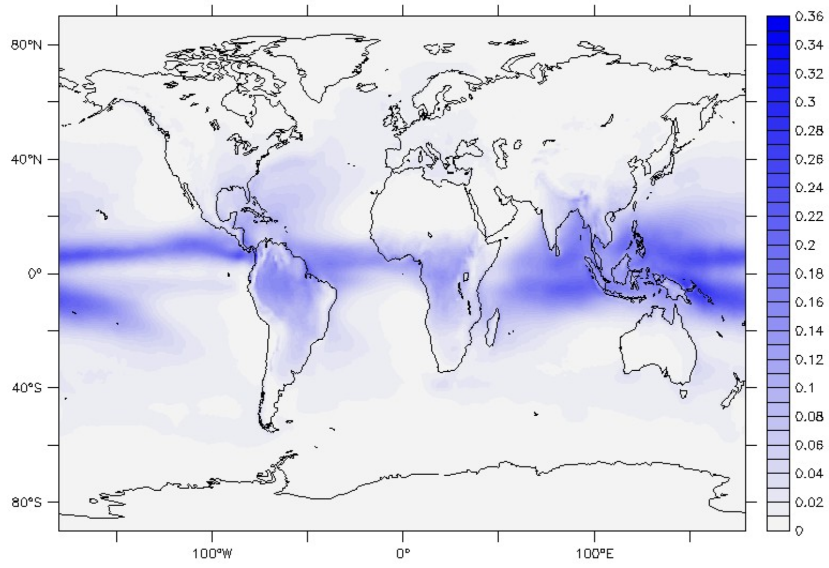

Figure 16: The pdf - p(50mm)

In sections 4.1 and 4.2 the rainfall intensities exceeded for 0.001% and 0.01% of the time, corresponding to approx. 5 min and 52 min duration of the year, were presented in figure 4 and 5, respectively. Similar maps were presented globally in ITU-R P.837-5 based on calibrated ERA40 precipitation data using set of calibration constants. While the calibration data in the ITU-R recommendation is based on globally available data, separately analysed for the ocean and land areas, we have used met.no gridded precipitation data for the Norwegian land areas as a first attempt, primarily due to higher spatial resolution. The rainfall intensities from calibrated ERAINT data for Norway were computed using the formulas and previous constants listed in ITU-R P.837-4, the formulas in P.837-5 gave similar results. The first results remain however, quite different from previous maps (figure 4 and 5); (1) The intensities are generally higher than in the ITU-R recommendation and in sections 4.1 and 4.2, (2) The geographical picture reflects the total precipitation data themselves with the highest values somewhat inland at the western coast. This is in contrast to figures 4 and 5, which show high values in the lowland parts southeast in Norway as well. Only total precipitation is available as a observed parameter, while the formulas contains additional parameters, large-scale and convective precipitation (M_s and M_c) and probability of rainy 6-hour intervals (Pr6hr), which still have to be estimated from the ERAINT data. In addition the constants used are based on ERA40, and they probability need to be re-estimated for the ERAINT data.

One way to try to improve the ITU-R P.837-4 and P.837-5 set of equations could be to convert the empirical constants to functions of latitude and longitude:

$$a = a(lat, lon)$$

The comparison between the estimates derived from the ITU formulae applied to the ERAINT data and the maps based on Norwegian rain gauge data suggested quite significant differences. These results suggest that the equations applied to the ERAINT need to be re-calibrated, however, another issue is whether a small selection of stations at lower latitudes provide good estimates for Norway.

One suggestion for re-calibration is to identify appropriate probability density functions (pdfs) for minute/hourly precipitation for locations with available data and corresponding pdfs for 24-hr precipitation for all met.no stations. Two different types of pdfs can describe precipitation: (a) one for wet-event episodes, and (b) one describing the timing between each event (wet-event frequency). A Bayesian framework can be used to describe the pdf for both wet and dry conditions. It is not yet known what type of pdf that is most appropriate for the different cases, however, the extreme value distribution is one possible candidate for the rainfall intensity and a Poisson distribution may possibly be more appropriate for the time between/duration of each event.

It is plausible that a regression analysis may be able to identify relations between the parameters describing the pdfs associated with different time scales (for both types of pdfs). A systematic relation between pdfs for precipitation of different time scales may potentially provide an improved basis for generating digital maps. Similarly, a relationship between pdfs for 6-hr and precipitation of shorter duration may be used to guide a re-calibration of the ERAINT.

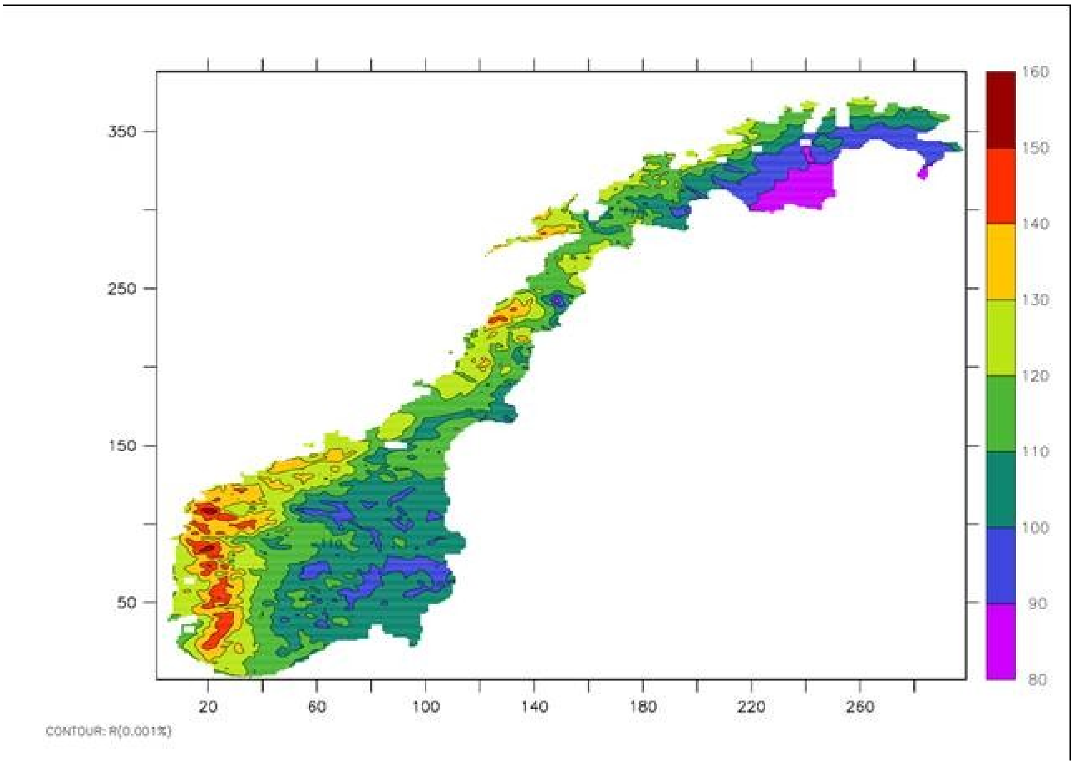

Figure 17: Estimated rainfall rate (mm/h) exceeded for 0.001% (approx. 5 min.) of the average year, based on calibrated mean annual rainfall (gridded met.no observations) and the constants given in ITU-R P.837-4 Ch. 5.1

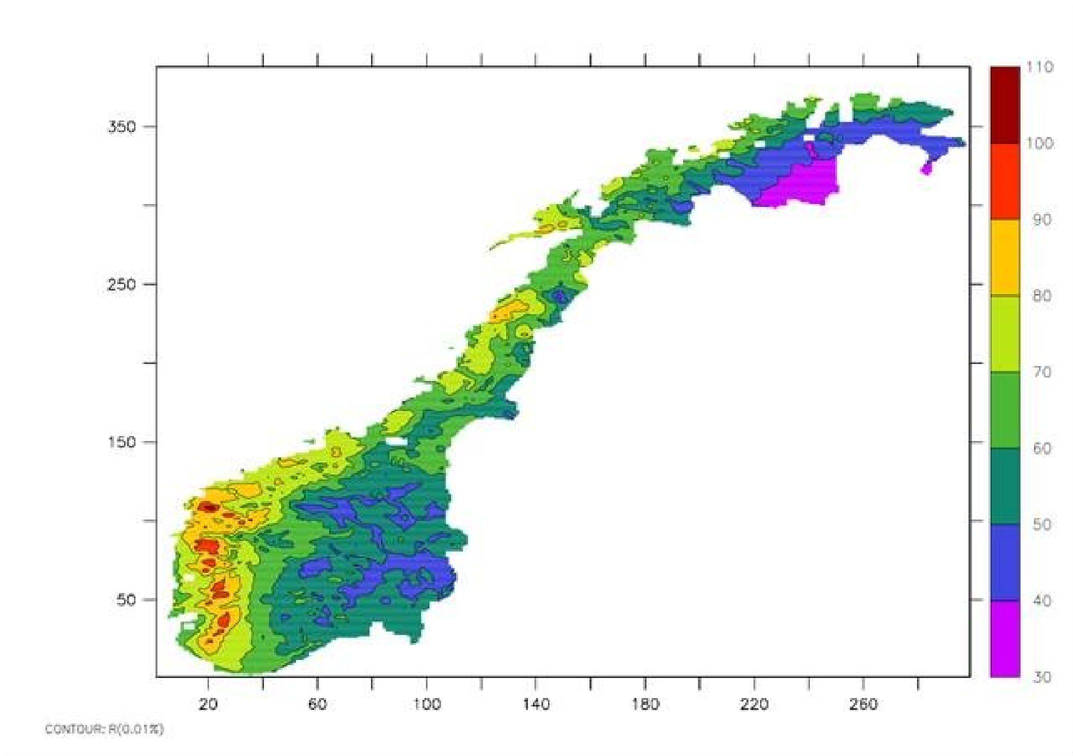

Figure 18: Estimated rainfall rate (mm/h) exceeded for 0.01% (approx. 52 min.) of the average year, based on calibrated mean annual rainfall (gridded met.no observations) and the constants given in ITU-R P.837-4 Ch. 5.1

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7 Appendix - list of stations

ALL-YEAR	STNR	NAME	MUNICIPALITY	COUNTY	HEIGHT	UTM (EAST)	UTM (NORTH)	FIRST OBSERVATION	LAST OBSERVATION
	200	TRYSIL	Trysil	Hedmark	356	352818	6802244	20.05.1967	18.10.1974
	1220	HALDEN STADION	Halden	Østfold	10	292596	6559392	24.04.1974	05.12.1995
	2840	HØLAND - KOLLERUD	Aurskog Høland	Akershus	139	299878	6624918	30.05.1972	16.11.1987
	3030	FREDRIKSTAD	Fredrikstad	Østfold	30	269721	6572716	30.05.1970	10.11.1995
	3190	SARPSBORG	Sarpsborg	Østfold	57	278719	6578319	12.07.1984	22.08.1991
A	3810	ASKIM II	Askim	Østfold	141	283569	6611689	08.04.1968	26.12.2010
	4220	KJELLER TELENOR	Skedsmo	Akershus	114	279460	6655496	10.06.1975	28.08.1992
	4781	GARDERMOEN SØR	Ullensaker	Akershus	202	282365	6678855	11.05.1967	04.09.2010
	11620	GJØVIK - SOGSTAD	Gjøvik	Oppland	240	264085	6748310	02.08.1974	28.10.1996
	12290	HAMAR II	Hamar	Hedmark	132	287708	6746937	20.05.1968	09.12.2010
	12670	LILLEHAMMER	Lillehammer	Oppland	260	256284	6784678	07.07.1969	24.09.1991
	15720	BRÅTÅ	Skjåk	Oppland	712	125425	6884414	16.02.1968	15.10.1987
	17260	MOSS TROLLDALEN	Moss	Østfold	40	255652	6598006	29.08.1973	27.10.1994
	17870	ÅS - RUSTADSKOGEN	Ås	Akershus	120	263485	6621780	19.04.1974	31.12.2006
A	17980	OSLO - LJABRUVEIEN	Oslo	Oslo	92	266093	6641357	18.08.2000	22.12.2010
A	18020	OSLO - LAMBERTSETER	Oslo	Oslo	135	264179	6645365	15.05.1985	22.12.2010
A	18210	OSLO - HOVIN	Oslo	Oslo	100	265685	6650260	03.09.1998	25.11.2010
	18270	OSLO - VESTLI	Oslo	Oslo	200	273036	6654680	18.04.1974	30.11.2009
A	18320	OSLO - HAUSMANNSGT	Oslo	Oslo	12	262808	6651281	21.06.1984	19.12.2010
A	18420	OSLO - DISEN	Oslo	Oslo	130	264918	6652911	02.06.1998	18.12.2010
	18640	OSLO - VESTRE VIKA	Oslo	Oslo	10	261209	6649095	22.05.1974	03.10.1988
A	18701	OSLO - BLINDERN PLU	Oslo	Oslo	94	260972	6652714	16.04.1968	17.12.2010
A	18815	OSLO - BYGDØY	Oslo	Oslo	15	258620	6648705	01.01.2002	29.11.2010
A	18920	OSLO - BESSERUD	Oslo	Oslo	240	260164	6654412	27.05.2001	19.12.2010
A	19020	OSLO - VOKSENLIA	Oslo	Oslo	346	257732	6655766	14.05.1985	15.12.1997
	19490	GJETTUM	Bærum	Akershus	67	249325	6649469	03.07.1970	18.12.2010
	19510	ØVREVOLL	Bærum	Akershus	125	255499	6652819	19.05.1967	14.12.2010
	19710	ASKER	Asker	Akershus	163	244376	6644200	23.06.1983	29.12.2010
	20300	HØNEFOSS	Ringerike	Buskerud	140	236287	6677610	06.08.1969	14.11.1994
	24880	NESBYEN - SKOGLUND	Nes	Buskerud	167	178073	6729127	30.05.1967	01.11.1986
	26890	DRAMMEN - MARIENLYST	Drammen	Buskerud	3	230414	6631902	31.05.1968	19.11.1995
A	26999	SKOGER - JONSRUD	Sande	Vestfold	76	231900	6623928	01.03.1999	01.08.2007
A	27270	TØNSBERG - KILEN	Tønsberg	Vestfold	3	239763	6579935	28.01.2000	21.12.2010
	27470	TORP	Sandefjord	Vestfold	88	229013	6570241	13.04.1972	03.12.1987
A	27564	SANDEFJORD - MOSSERØD	Sandefjord	Vestfold	72	225728	6566677	12.12.1998	06.02.2007
	27580	SANDEFJORD - VARDEN	Sandefjord	Vestfold	70	228429	6563500	21.09.1973	12.11.1996
	30270	PORSGRUNN - SANNA	Porsgrunn	Telemark	10	195698	6567898	30.10.1973	14.10.1992
	30310	SKIEN - KLOSTERSKOGEN	Skien	Telemark	22	191593	6573765	27.06.1968	27.10.2000
	32100	GVARV	Sauherad	Telemark	26	169812	6597177	19.05.1967	05.10.1987
	36060	ARENDAL BRANNSTASJON	Arendal	Aust-Agder	44	136278	6497731	03.09.1967	13.10.1996
	38130	GRIMSTAD - HIA	Grimstad	Aust-Agder	15	124651	6484294	07.10.1974	05.11.1997
A	39150	KRISTIANSAND - SØMSKLEIVA	Kristiansand	Vest-Agder	12	91520	6466542	27.11.1974	29.12.2008
	40140	HYLESTAD - BROKKE	Valle	Aust-Agder	443	70940	6575336	01.07.1971	31.10.1981
	40500	TRETTHEDDERNUTEN	Bykle	Aust-Agder	1057	40417	6609590	12.07.1975	11.07.1984
A	44190	TIME - LYE	Time	Rogaland	135	-34980	6547733	13.08.1981	11.06.2008
A	44580	STAVANGER - MADLA	Stavanger	Rogaland	15	-35735	6571781	08.07.1983	29.12.2009
A	44620	STAVANGER - TASTA	Stavanger	Rogaland	30	-34266	6576009	16.11.1999	29.12.2009
A	44640	STAVANGER - VÅLAND	Stavanger	Rogaland	72	-32148	6572293	17.08.1999	19.12.2010
A	44660	STAVANGER - HUNDVÅG	Stavanger	Rogaland	5	-32116	6576971	03.09.1982	29.12.2009
A	44730	SANDNES - ROVIK	Sandnes	Rogaland	19	-31709	6561966	20.06.1974	30.12.2008
A	47240	KARMØY - BREKKEVANN	Karmøy	Rogaland	19	-53742	6610633	12.08.1968	26.03.2003
	47890	OPSTVEIT	Kvinnherad	Hordaland	38	-2184	6669759	08.09.1968	03.12.1987
A	50480	BERGEN - SANDSLI	Bergen	Hordaland	45	-36069	6723546	11.01.1984	10.11.2007
A	50490	BERGEN - SANDSLI	Bergen	Hordaland	45	-36069	6723546	17.08.1982	26.11.2001
	52290	MODALEN II	Modalen	Hordaland	114	9336	6779009	10.06.1968	16.11.1987
	52300	MODALEN	Modalen	Hordaland	104	8138	6778307	10.06.1968	06.11.1979
	54730	VARDEN - FILEFJELL	Vang	Oppland	1012	132105	6801902	12.06.1968	07.10.1976
	58700	OPPSTRYN	Stryn	Sogn og Fjordane	201	92666	6891186	05.07.1968	01.11.1987
	60940	ÅLESUND - SPJELKAVIK	Ålesund	Møre og Romsdal	55	54704	6955969	16.06.1970	20.06.1995
	62290	MOLDE - NØISOMHED	Molde	Møre og Romsdal	14	103398	6980852	02.04.1974	22.09.1986
	63420	SUNNDALSØRA III	Sunndal	Møre og Romsdal	6	170518	6965858	30.05.1978	14.09.1987
	63500	SUNNDAL	Sunndal	Møre og Romsdal	195	196868	6949321	16.05.1968	01.11.1977
A	64300	KRISTIANSUND - KARIHOLA	Kristiansund	Møre og Romsdal	39	132627	7020442	27.09.1973	31.12.2007
	66830	SÆTER I KVIKNE	Tynset	Hedmark	543	256412	6951857	22.05.1968	13.09.1984
	68170	TRONDHEIM - TYHOLT	Trondheim	Sør-Trøndelag	113	272030	7040801	07.06.1967	15.09.1993
	68190	TRONDHEIM - BLAKLI	Trondheim	Sør-Trøndelag	138	271595	7037870	30.05.1974	11.11.1985
A	68230	TRONDHEIM - RISVOLLAN	Trondheim	Sør-Trøndelag	100	271595	7037870	11.12.1986	31.12.2009
A	68863	TRONDHEIM - VOLL PLU	Trondheim	Sør-Trøndelag	127	273092	7039406	01.03.2002	30.12.2010
	71000	STEINKJER - SØNDRE EGGE	Steinkjer	Nord-Trøndelag	6	326609	7104351	05.05.1984	14.07.1992
	72850	HØYLANDET	Høylandet	Nord-Trøndelag	22	369214	7166695	26.06.1967	10.10.1980
	73490	NORDLI - BRATTVOLD	Lierne	Nord-Trøndelag	462	438246	7147784	10.06.1967	14.10.1982
	80200	LURØY	Lurøy	Nordland	115	418990	7364523	10.06.1991	15.10.1999
	81620	ØVRE SALTDAL	Saltdal	Nordland	26	513099	7427699	08.06.1967	25.09.1981
	84710	NARVIK - STASJONSVN.	Narvik	Nordland	50	601091	7595061	21.06.1983	30.10.1996
	89350	BARDUFOSS	Målselv	Troms	76	641141	7665015	13.08.1969	12.08.1987
	97250	KARASJOK	Karasjohka-Karasjok	Finnmark	129	909394	7741699	06.08.1968	27.10.1987
	99370	KIRKENES LUFTHAVN	Sør-Varanger	Finnmark	89	1071181	7805409	09.07.1968	01.11.1987

Table 22: Station list. Tipping bucket rain gauge stations. UTM-coordinates are zone 33

STNR	NAME	MUNICIPALITY	COUNTY	HEIGHT	UTM (EAST)	UTM (NORTH)	FIRST OBSERVATION	LAST OBSERVATION
180	TRYSIL VEGSTASJON	Trysil	Hedmark	360	353846	6798632	10.11.1993	31.12.2010
5590	KONGSVINGER	Kongsvinger	Hedmark	148	334039	6676368	01.07.2006	31.12.2010
6020	FLISA II	Åsnes	Hedmark	185	336500	6723521	21.11.2003	31.12.2010
9580	TYNSET - HANSMOEN	Tynset	Hedmark	482	278547	6911509	02.07.2001	31.12.2010
10000	TYNSET II	Tynset	Hedmark	482	282129	6912559	10.11.1993	02.12.1999
11500	ØSTRE TOTEN - APELSVOLL	Østre Toten	Oppland	264	274532	6736489	09.02.2000	31.12.2010
12320	HAMAR - STAVSBERG	Hamar	Hedmark	221	286294	6748919	21.10.2005	31.12.2010
12550	KISE PA HEDMARK	Ringsaker	Hedmark	128	271629	6744837	01.08.2003	31.12.2010
12680	LILLEHAMMER - SÆTHERENGEN	Lillehammer	Oppland	240	256243	6781518	22.11.1994	31.12.2010
16560	DOMBÅS - NORDIGARD	Dovre	Oppland	638	192861	6896174	31.08.2006	31.12.2010
17000	STRØMTANGEN FYR	Fredrikstad	Østfold	10	261507	6564358	09.05.1994	31.12.2010
18700	OSLO - BLINDERN	Oslo	Oslo	94	260970	6652718	07.11.1993	31.12.2010
18950	TRYVASSHØGDA	Oslo	Oslo	514	258447	6657618	16.09.1997	31.12.2010
20301	HØNEFOSS - HØYBY	Ringerike	Buskerud	140	236419	6679445	25.05.2005	31.12.2010
23500	LØKEN I VOLBU	Øystre Slidre	Oppland	521	180431	6790894	09.02.2000	31.12.2010
24890	NESBYEN - TODOKK	Nes	Buskerud	166	178700	6728926	17.11.2003	31.12.2010
25630	GEILO - OLDEBRÅTEN	Hol	Buskerud	772	126964	6729759	01.07.2006	31.12.2010
25830	FINSEVATN	Ulvik	Hordaland	1210	91443	6740648	15.11.1993	31.12.2010
26900	DRAMMEN - BERSKOG	Drammen	Buskerud	8	226155	6634058	24.09.2004	31.12.2010
27450	MELSOM	Stokke	Vestfold	26	234673	6574925	09.02.1999	31.12.2010
28922	VEGGLI II	Rollag	Buskerud	275	174236	6670691	05.07.2006	31.12.2010
31620	MØSSTRAND II	Vinje	Telemark	977	118161	6653245	11.10.2006	31.12.2010
32890	HØYDALSMO II	Tokke	Telemark	560	115363	6615099	23.08.2006	31.12.2010
33890	VÅGSLI	Vinje	Telemark	821	71781	6650079	01.11.1994	31.12.2007
34130	JOMFRULAND	Kragerø	Telemark	5	187214	6536763	11.10.1994	25.11.2010
36200	TORUNGEN FYR	Arendal	Aust-Agder	12	137302	6489879	08.06.2004	31.12.2010
38140	LANDVIK	Grimstad	Aust-Agder	6	121120	6484824	09.02.2000	31.12.2010
39040	KJEVIK	Kristiansand	Vest-Agder	12	93495	6471890	29.05.1995	31.12.2010
40880	HOVDEN - LUNDANE	Bykle	Aust-Agder	841	72100	6630829	06.11.1994	31.12.2010
42160	LISTA FYR	Farsund	Vest-Agder	14	3873	6471925	19.09.1994	31.12.2010
42550	SOLHOM I KVINESDAL	Kvinesdal	Vest-Agder	650	38936	6541609	31.12.1994	22.06.2004
42600	SIRDAL - ROSKREPP	Sirdal	Vest-Agder	840	46203	6569971	31.12.1994	24.06.2004
42921	SIRDAL - TJØRHOM II	Sirdal	Vest-Agder	500	30623	6556011	29.01.1998	23.06.2004
43000	SIRDAL - DUGE	Sirdal	Vest-Agder	760	36628	6581540	31.12.1994	23.06.2004
44080	OBRESTAD FYR	Hå	Rogaland	24	-46825	6540733	10.11.1993	31.12.2010
44300	SÆRHEIM	Klepp	Rogaland	87	-39759	6551167	09.02.2000	31.12.2010
44610	KVITSØY - NORDBØ	Kvitsøy	Rogaland	21	-48497	6587410	23.05.2006	31.12.2010
47300	UTSIRA FYR	Utsira	Rogaland	55	-75231	6618079	01.09.2003	31.12.2010
49800	FET I EIDFJORD	Eidfjord	Hordaland	735	75367	6721839	13.07.2005	11.12.2010
50070	KVAMSØY	Kvam	Hordaland	49	19548	6723146	16.11.2003	31.12.2010
50310	KVAMSKOGEN - JONSHØGDI	Kvam	Hordaland	455	2979	6728880	01.08.2006	31.12.2010
51530	VOSSEVANGEN	Voss	Hordaland	54	31735	6751635	29.01.2004	31.12.2010
53101	VANGSNES	Vik	Sogn og Fjordane	49	51509	6810572	12.12.1993	31.12.2010
55820	FJÆRLAND - BREMUSEET	Sogndal	Sogn og Fjordane	3	61324	6837695	01.12.2005	31.12.2010
56420	FURENESET	Fjaler	Sogn og Fjordane	7	-32044	6836094	09.02.2000	31.12.2010
58900	STRYN - KROKEN	Stryn	Sogn og Fjordane	208	57532	6893621	23.11.1993	31.12.2010
63420	SUNNDALSØRA III	Sunndal	Møre og Romsdal	6	170518	6965858	02.04.2004	31.12.2010
66150	ORKDAL - THAMSHAMN	Orkdal	Sør-Trøndelag	4	242139	7031085	10.08.2006	31.12.2010
68860	TRONDHEIM - VOLL	Trondheim	Sør-Trøndelag	127	273111	7039394	01.09.1996	31.12.2010
69150	KVITHAMAR	Stjørdal	Nord-Trøndelag	40	294886	7046589	09.02.2000	31.12.2010
69380	MERÅKER - VARDETUN	Meråker	Nord-Trøndelag	169	336640	7035612	07.05.2004	31.12.2010
71000	STEINKJER - SØNDRE EGGE	Steinkjer	Nord-Trøndelag	6	326609	7104351	06.12.1991	31.12.2010
71990	BUHOLMRÅSA FYR	Osen	Sør-Trøndelag	18	281033	7149582	16.10.1994	31.12.2010
74350	NAMSSKOGAN	Namsskogan	Nord-Trøndelag	140	397462	7181467	20.11.2006	31.12.2010
76530	TJØTTA	Alstahaug	Nordland	21	382648	7302916	09.02.2000	31.12.2010
80700	GLOMFJORD	Meløy	Nordland	39	455237	7410565	19.09.1997	28.11.2006
82260	BODØ - VÅGØNES	Bodø	Nordland	33	476365	7463301	09.02.2000	31.12.2010
85891	RØST III	Røst	Nordland	4	376493	7492793	16.05.2004	02.12.2008
86740	BØ I VESTERÅLEN III	Bø	Nordland	8	476931	7610615	14.06.2003	31.12.2010
87640	HARSTAD STADION	Harstad	Troms	45	562028	7633138	01.06.2003	31.12.2010
90400	TROMSØ - HOLT	Tromsø	Troms	20	651477	7731942	09.02.2000	31.12.2010
90450	TROMSØ	Tromsø	Troms	100	652672	7732176	20.02.2006	31.12.2010
91380	SKIBOTN II	Storfjord	Troms	5	706444	7706303	01.11.2004	31.12.2010
93301	SUOLOVUOPMI - LULIT	Guovdageaidnu-Kautokeino	Finnmark	381	831393	7742187	08.11.2004	31.12.2010
97251	KARASJOK - MARKANNJARGA	Karasjohka-Karasjok	Finnmark	131	909434	7741309	07.07.2004	31.12.2010

Table 23: Station list. Weight pluviograph rain gauge stations. UTM-coordinates are zone 33