Analysis of daily precipitation thresholds in Meteoalarm

(Andrew Stepek, Ine Wijnant, Gerard van der Schrier)

Abstract:

The main aim of this work is to propose new precipitation thresholds for Meteoalarm which are based on local climate. At the moment each participating country individually decides what threshold to use for the different levels of warning (yellow, orange and red). There is a Meteoalarm guideline for the frequency of issuing warnings, but it gives very unrealistic guidelines for many countries and not all countries choose their thresholds accordingly. Unrealistic differences in the frequency and severity of the warnings between neighbouring countries are the result of this. Thresholds based on return values will make the warning system more uniform and will give a better idea of how extreme the weather related event is compared to local climate. We expect these new thresholds to give a more realistic warning of the possible danger of the weather-related event or its impact on society.

We calculated return values for the annual highest daily precipitation amounts with the precipitation data available in the European Climate Assessment & Dataset (ECA&D). One of the conclusions is that the current code yellow thresholds for daily precipitation amounts should on average be lower to get them in accordance with Meteoalarm guidelines. The new code orange thresholds we suggest are based on 2 year return values. Quite a few countries see strong regional differences and could differentiate their thresholds accordingly. Current thresholds above 60 mm/24h are unrealistically high. We suggest that new thresholds for code red warnings should be based on 5 year return values. This means that the current code red warnings are on average too high: currently an average code red warning does not happen once in 5 years, but once in 50 years or even less often. Because of climate change thresholds based on return values slowly change in time. It may also be useful to consider the seasonal dependence of return values.

Content:

1. Meteoalarm guidelines

In Meteoalarm there are 10 awareness types for dangerous weather-related events. For each awareness type the current Meteoalarm guideline is to issue lowest level warnings (yellow) more than 30 times a year, orange warnings 1-30 times a year and highest level warnings (red) less than once a year. These return periods are initially the same for all countries but are then normalised to a standard country size of 300.000 km^2. The reason for applying this size weighting to the return period is that intuitively you would expect large countries to issue warnings more often than small countries because the chance that dangerous weather will hit large countries is greater. However, this normalisation for country size results in very unrealistic guidelines for many countries (appendix 1) and this implies that the above reasoning which seems intuitively right is in fact fundamentally flawed.

The intuitive reasoning that bigger countries should issue more warnings than smaller ones is true if one assumes that the warning thresholds and the climate are the same for all countries but that is obviously not true. For example: Germany is about 3 times bigger than Iceland, but despite this you would expect Iceland to warn more often for high winds because the Icelandic climate is windier. On the other hand, if Germany uses a low threshold, then it may issue just as many or even more warnings than Iceland.

Thresholds should not be the same for all countries because what is extreme for the one country, might be very normal for the other and how extreme the event is compared to the local climate will, to a large extent, determine the possible danger or social impact of the event (and therefore the level of the warning). Thresholds based on return values do reflect the local climate and they also take into account the size of the country because they are based on measurements made throughout the whole country.

The aim of this report is to present new Meteoalarm return period guidelines which are similar to the current guidelines for most of the member countries but then with warning thresholds which are based on the corresponding return values calculated using measurements of the local climate of each country.

2. Return values in ECA&D

Return values give a good indication of how extreme the event is in comparison with local climate. A return value of 2 years for example refers to an event that happens on average once in 2 years. There is a standard tool available in the European Climate Assessment & Dataset (ECA&D) to calculate thresholds that match with return values of 2, 5, 10 and 20 years (eca.knmi.nl). Fig 1 shows that for the Netherlands the 2 year return value for the highest daily precipitation amount is 25-45 mm. This means that on average the Netherlands should expect a maximum daily precipitation amount between 25 and 45 mm once every 2 years. The 1 year return value of the annual highest daily precipitation amount in a given period is the same as the highest daily precipitation amount that on average occurs once a year in that period and that is equal to the average of all the annual highest daily precipitation amounts in the period.

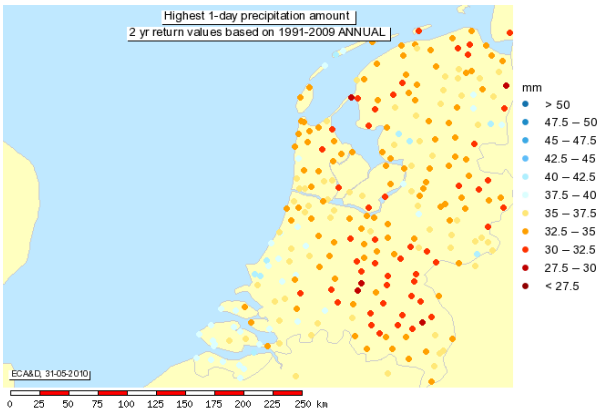

Fig 1: 2 year return values of daily precipitation amount for the Netherlands based on 1991-2009: all values 25-45 mm

Before return values can be calculated the raw data have to be checked (quality control and homogeneity tests) and only data that meet stringent completeness requirements will be used to calculate indices (such as the annual maximum of the daily precipitation amount or the number of days in a year with precipitation amount ≥ 20 mm). Additional completeness requirements and testing are necessary to decide whether return values can be calculated based on these indices.

The quality control requirements are:

- Daily precipitation amount should be ≥ 0 mm and ≤ 299.8 mm
- The number of days with the same precipitation amount should not be more than 9 (for amounts > 1 mm)
- The number of days with the same precipitation amount should not be more than 4 (for amounts > 5 mm)

Homogeneity tests are required if you want to reliably calculate return values or say something about climate change (trends). You need to exclude "breaks" (caused by relocation of stations or changes in surroundings, but also by changes in measuring equipment or methods) in order to make sure that the trend you see is a real one caused by climate change and not by changes in where and how you did your measurements. If you measure larger precipitation amounts due to relocation, this will have an impact on return values.

Different homogeneity tests have been developed to detect "breaks" in data-sets and the standard tests in ECA&D are Standard Normal Homogeneity Test, Buishand, Pettitt and Von Neumann. These tests were run on the annual number of days with precipitation amount > 1 mm because many stations have a lot of dry days and dry days are insensitive to the way the precipitation is measured. Homogeneity tests are done for periods starting in 1901, 1946, 1961, 1976 or 1979 and ending last year and 2 years earlier. In the period considered the daily precipitation amount should be available for 80% of the time.

The completeness requirements are as follows. For a particular year, indices (such as the annual maximum gust) will only be calculated if there is sufficient data (at least 362 days per year with valid daily data). Only sufficiently long series (at least 10 years) are stored in the database and can be used for calculating return values.

The Gumbel fit requirements are as follows. It is only possible to calculate a return value for a certain period if there is an index for 80% of the years in that period. In order to get a return value, an Extreme Value Distribution (Gumbel in this case) is fitted to the index (very heavy precipitation days with amount ≥ 20 mm) and an Anderson-Darling test with a 5% significance level is used to determine whether this fit is good enough.

3. New code yellow thresholds for daily precipitation amounts

Fig 2 shows that the median of the daily precipitation amount thresholds currently used in Meteoalarm countries for code yellow (25 mm) corresponds in a large part of Europe with return values of less than once a year (in other words: a maximum daily precipitation amount of 25 mm happens less frequently than once a year). According to Meteoalarm guidelines however, most countries (with the exception of Malta and Luxembourg) should issue code yellow warnings more than once a year (appendix 1) which means that the thresholds currently used for code yellow warnings (appendix 2) are on average a bit too high.

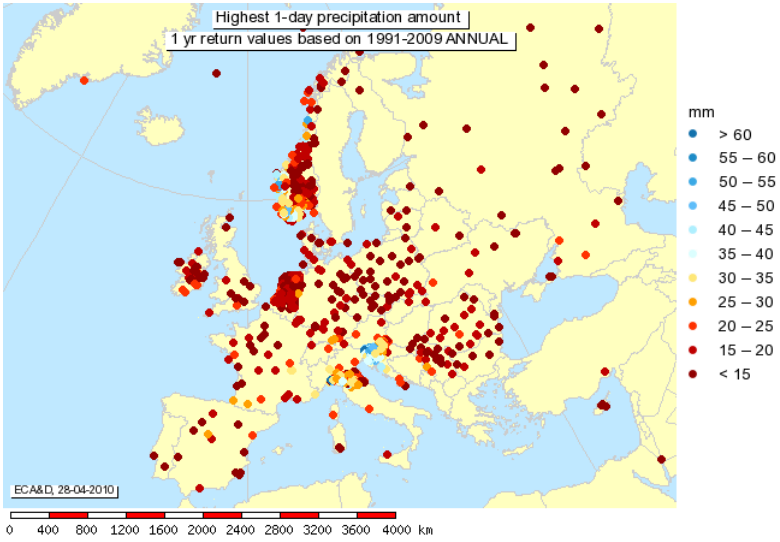

Fig 2: 1 year return values of annual maximum 1 day precipitation amount [mm] based on 1991-2009 period

Currently there is index in ECA&D of the number of days in a year where the precipitation amount ≥ 25 mm, but there is an index of the average number of days where the precipitation amount ≥ 20 mm. For most of Europe precipitation amounts of ≥ 20 mm occur less than 3 days a year and only in parts of Norway, Slovenia and Italy are there locally more than 10 days a year with precipitation amounts of ≥ 20 mm (fig 3).

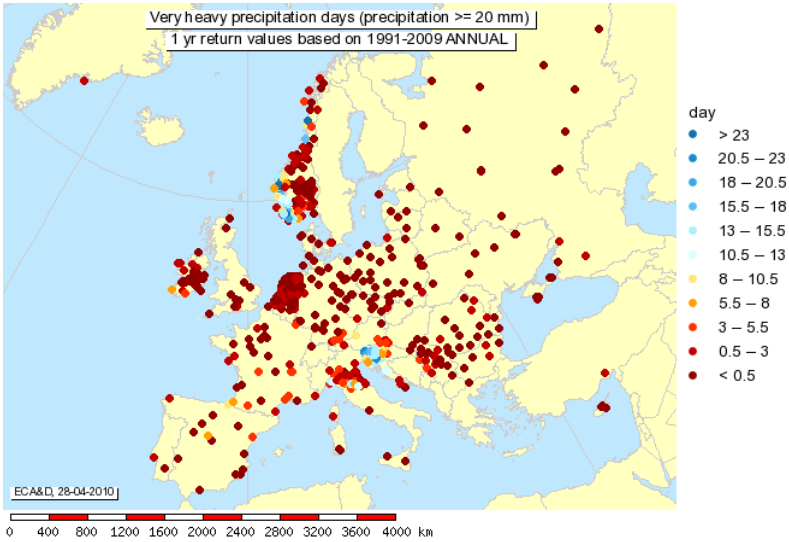

Fig 3: 1 year return values of very heavy precipitation days with ≥ 20 mm [days] based on 1991-2009 period

- *Annual number of very heavy precipitation days is the number of days in that year where the daily precipitation amount is ≥ 20 mm*
- *If the 1 year return value of very heavy precipitation days is 10, then the annual average number of days with ≥ 20 mm is 10 days*

4. New code orange thresholds for daily precipitation amounts

According to current Meteoalarm guidelines France (with 643.427 km² the biggest of the Meteoalarm countries) should issue a code orange warning between 2 and 65 times a year and Malta (with 316 km² the smallest of the Meteoalarm countries) at most once in 33 years. For the median of the sizes of the countries these values are between 8-9 times a year and once in 3-4 years. Which return value should be linked to code orange warnings is up to the Meteoalarm Expert Team, but as a first estimate we looked at 2 year return values because this is appropriate for a median sized country according to the current guidelines:

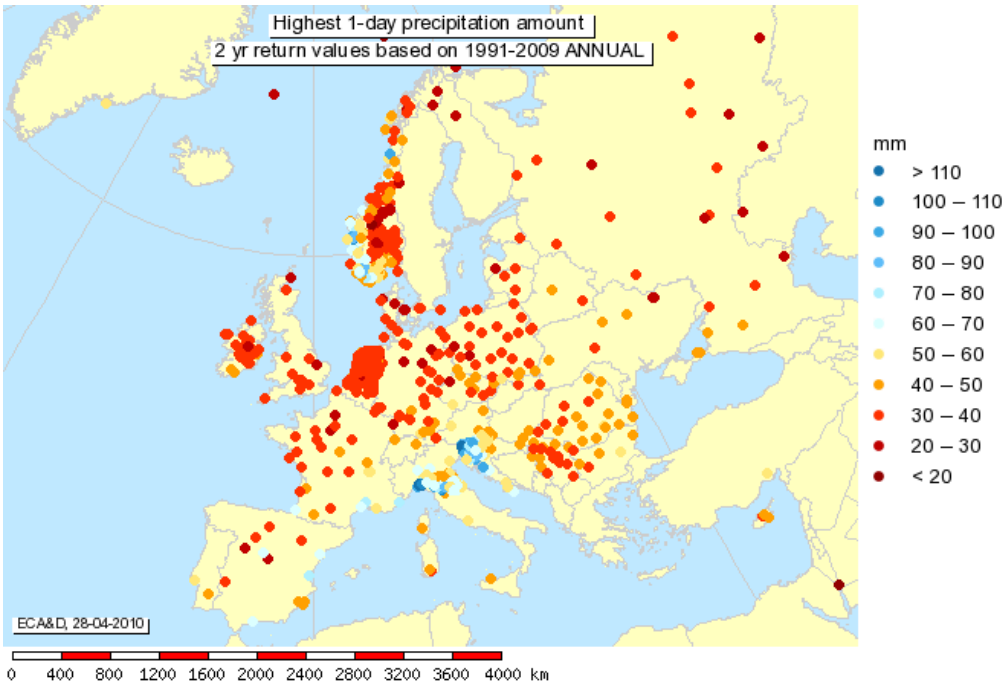

Fig 4: 2 *year return values of annual maximum 1 day precipitation amount [mm] based on 1991-2009 period*

- *Annual highest 1 day precipitation amount [mm] is the maximum daily precipitation amount measured in a particular year.*
- *There are no values for Iceland, Greece, Hungary, Slovakia and Sweden in the figure because the data failed to meet the stringent quality control and completeness requirements used in ECA&D*

For Switzerland, Finland and Sweden the most recent period (1991-2009) did not provide enough return values due to data gaps in the recent part of the records, so we calculated the 2 year return values for another period (1981-2000) (fig 5). These return values may be less accurate because we expect return values to change due to climate change (see section 6: Trends).

Based on these 2 year return values we can draw the following conclusions for code orange thresholds:

- Regional differences within a country can be very large, for example in:
  - Norway: on the coast locally 65-105 mm, elsewhere 20-60 mm
  - Italy: in the northwest 80-160 mm, elsewhere 40-80 mm (not a lot of data in central and south Italy)
  - Slovenia: in the east 90-170 mm, elsewhere 40-90 mm
  - Switzerland: 40-60 mm, in the south 90-140 mm

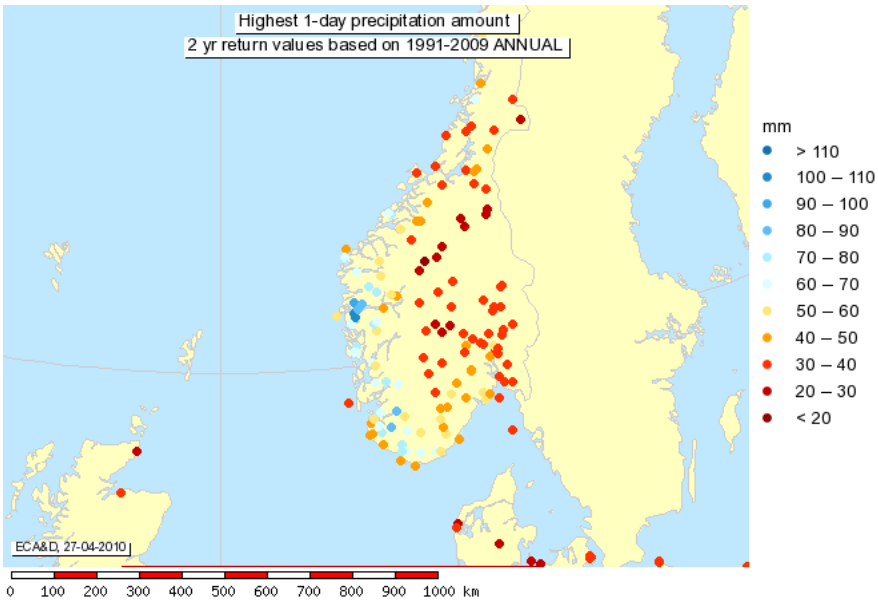

Fig 5: 2 *year return values of annual maximum 1-day precipitation amount [mm] based on 1991-2009 period: values in Norway vary from 20 mm inland to 105 mm (station Takle ECA&D sta_id 1049) locally on the SW coast*

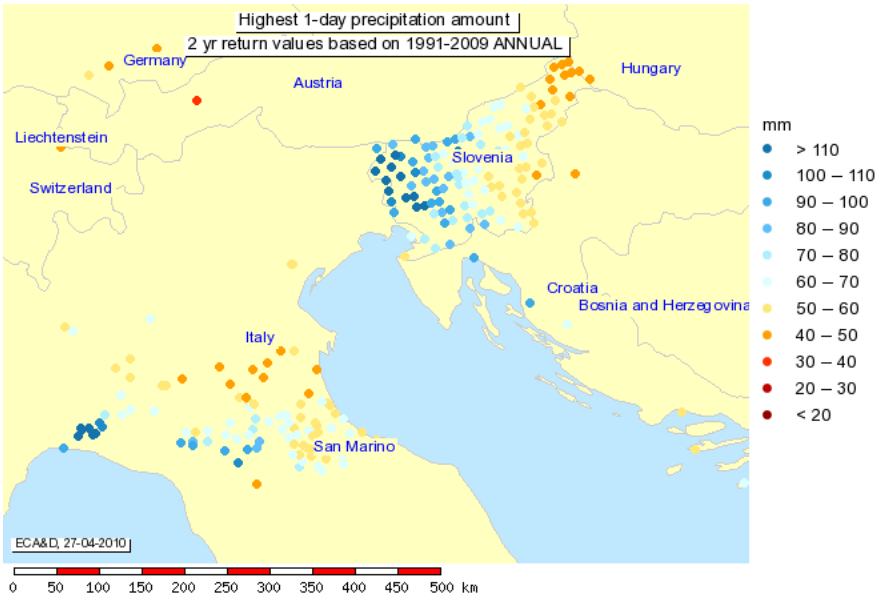

Fig 6: 2 *year return values of annual maximum 1-day precipitation amount [mm] based on 1991-2009 period: values in N-Italy vary from 50 mm in the east to 159 mm (Parazzuolo ECA&D sta_id 2859) in the west; values in Slovenia vary from 40 mm in the east to 172 mm (Zaga ECA&D sta_id 3391) in the west*

- If we aim for 2 year return values of the annual maximum of the daily precipitation amount, the thresholds currently used at the high end of the threshold spectrum, above 60 mm (appendix 2), are in general unrealistically high (except in parts of Norway, Slovenia, Switzerland and Italy and very locally in France or Spain, where we suggest regional thresholds):
  - Based on the 1991-2009 period:
    - ✓ Cyprus: 30-50 mm (current code orange threshold is 85 mm)
    - ✓ Netherlands: 25-40 mm and locally 40-50 mm (threshold is 75 mm)
    - ✓ Norway: see regional thresholds (threshold is 65 mm)
  - Based on the 1981-2000 period:
    - ✓ Switzerland: see regional thresholds (current code orange threshold is 75 mm)
    - ✓ Finland: 20-40 mm (threshold is 70 mm)
    - ✓ Sweden: 20-40 mm (threshold is 70 mm)

- On the low end of the threshold spectrum, Serbia seems to have a realistic threshold for daily precipitation amount i.e. the current threshold is comparable to the 2 year return value, but there are not enough good stations to provide return values to suggest a threshold for Greece:
    - ✓ Serbia: 30-50 mm (current code orange threshold is 40 mm)
    - ✓ Greece: no return values for 1991-2009 and only two in the south for 1981-2000: 45 and 54 mm (current threshold is 40 mm)
- There are quite a few Meteoalarm countries where there is currently no (code orange) warning for daily precipitation amounts (Spain and Hungary only issue a warning for a 12 hour precipitation amount, Latvia, Estonia and Lithuania for a 14 hour amount and Portugal for a 6 hour amount; Poland does issue a 24 hour warning, but only a code yellow one). If the aim is to issue a code orange warning for daily precipitation amounts with a 2 year return value, the thresholds should be something like this:
    - ✓ Denmark: 20-40 mm
    - ✓ Spain: 20-40 mm, in the southeast 40-70 mm
    - ✓ Hungary: not enough return values available (nothing for 1991-2009 and only one for 1981-2000, Budapest 37 mm)
    - ✓ Iceland: no return values for 1991-2009 and only four for 1981-2000 (two in the east 60-80 mm and two in the west 30-35 mm): we cannot explain why the west should get less rain than the east so for the time being we suggest 30-50 mm, locally 60-80 mm
    - ✓ Poland: 20-40 mm, in extreme south 30-50 mm
    - ✓ Portugal: 40-60 mm
    - ✓ Latvia: 20-30 mm
    - ✓ Estonia: 30-40 mm
    - ✓ Lithuania: 30-40 mm
- For Malta and Slovakia the thresholds currently used are unknown (appendix 2):
    - ✓ Malta: no return values available (precipitation data is available for one station, Luqa)
    - ✓ Slovakia: not enough return values (only one for 1991-2009, Poprad/Tatry 37 mm)
- The remaining Meteoalarm countries issue a code orange warning for daily precipitation amounts between 45 and 60 mm, fairly close to the current median of 50 mm. If the aim is a 2 year return value, the threshold should be something like this:
    - ✓ Austria: 40-60 mm
    - ✓ Czech Republic: 30-50 mm, in the west locally 50-60 mm
    - ✓ Belgium: 30-40 mm
    - ✓ Germany: 20-40 mm, in extreme south 30-50 mm
    - ✓ France: 20-40 mm, in the south 30-70 mm
    - ✓ Ireland: 20-40 mm, in the southwest 40-50 mm
    - ✓ Italy: 40-80 mm (not a lot of return values in central and south Italy), in the northwest 80-160 mm
    - ✓ Luxembourg: 30-40 mm
    - ✓ Romania: 30-50 mm
    - ✓ Slovenia: 40-90 mm, in the east 90-170 mm
    - ✓ UK: 30-40 mm (should probably be higher in Scotland and Wales: not a lot of return values in Scotland and Wales and in Scotland there is only data available on the east coast where precipitation amounts are significantly lower than on the west coast)

Appendix 3 gives a summary of thresholds based on 2 year return periods.

5. New code red thresholds for daily precipitation amounts

Fig 7 shows that the median of the daily precipitation thresholds currently used in Meteoalarm countries for code red (90 mm) corresponds in a large part of Europe with return periods of 50 years or more (in other words: a maximum daily precipitation amount of 90 mm happens once in 50 years or even less frequently than that).

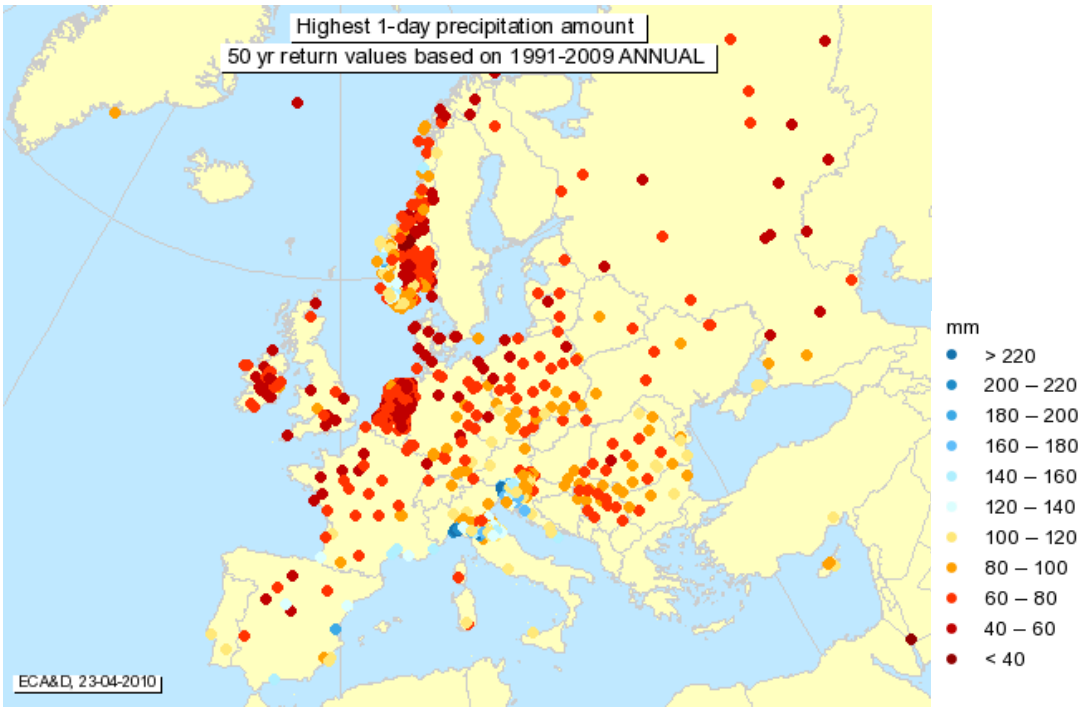

Fig 7: 50 year return values of annual maximum 1-day precipitation amount [mm] based on 1991-2009 period.

The result of country size weighting of the code red criterium (as is done in the current Meteoalarm guideline) is that France has to issue a code red warning less than 2 times a year but Malta less than once in 950 years (appendix 1). A medium sized country such as Ireland (70273 km²) has to issue a code red warning less often than once every 4 years. Which return value should be linked to code red warnings is up to the Meteoalarm Expert Team, but as a first estimate we looked at 5 year return values. Based on the return values we calculated, the code red threshold for Ireland should be between 30 and 60 mm (current threshold is 80 mm).

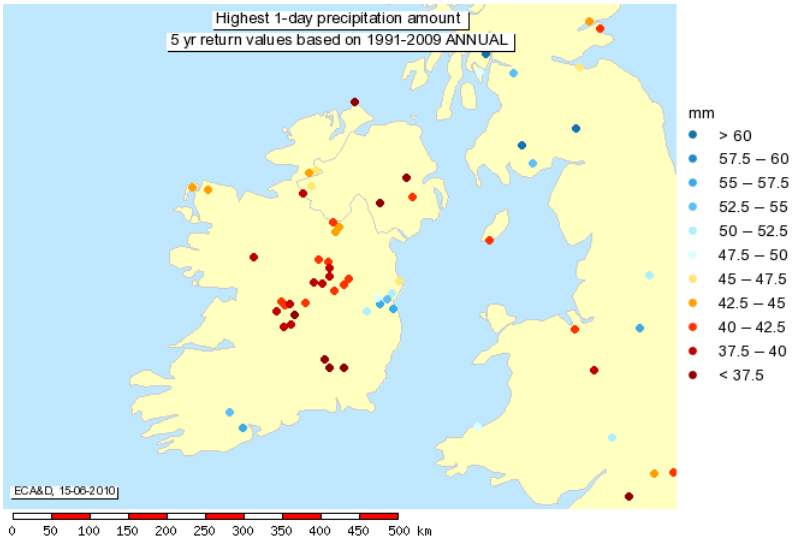

Fig 8: 5 year return values of annual maximum 1-day precipitation amount [mm] based on 1991-2009 period.

The current Meteoalarm guideline suggests that Slovenia should issue a code red warning less than once in 15 years (appendix 1). The calculated 10 and 50 year return values indicate that regional thresholds are required (fig 9 and 10). Although the threshold currently used (100 mm) is not too bad as a country average (fig 9), 100 mm corresponds with a return value of about 50 years for eastern parts of the country (fig 10).

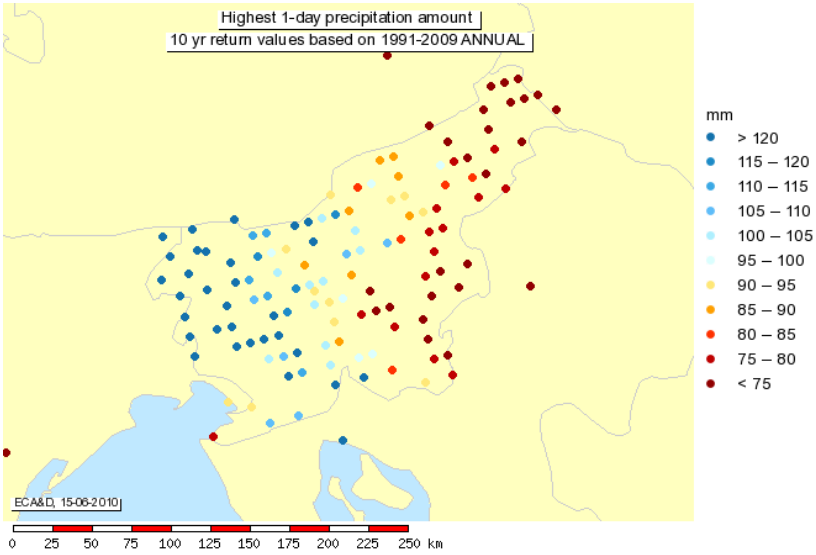

Fig 9: 10 year return values of annual maximum 1-day precipitation amount [mm] based on 1991-2009 period; Values vary from 60 mm in the east to 160 mm in the west

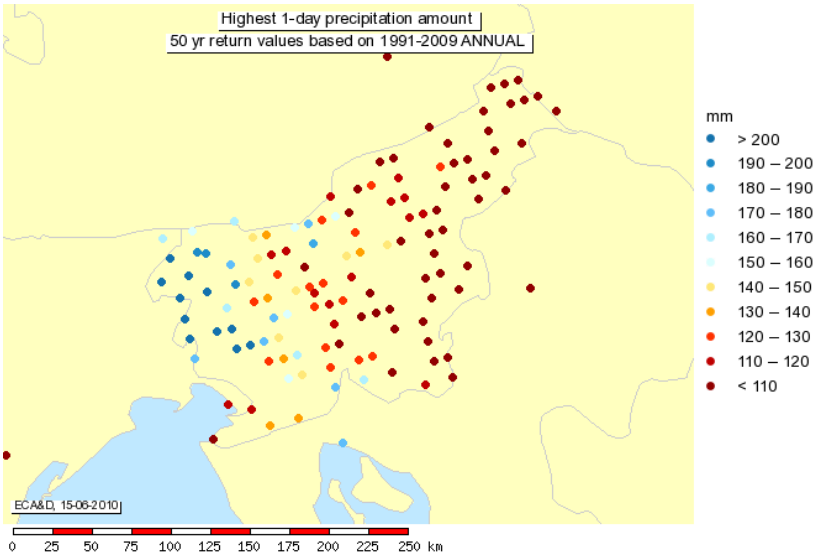

Fig 10: 50 year return values of annual maximum 1-day precipitation amount [mm] based on 1991-2009 period; Values vary from 75 mm in the east to 305 mm in the west

6. Trends

Because of climate change, return values will probably change slowly in time and therefore thresholds based on return values should be regularly updated. Comparing fig 11 (based on the 1941-1960 period) and fig 12 (based on the 1991-2009 period) shows that The Netherlands gets on average higher daily precipitation extremes than 50 years ago (return values have increased). The change is most significant for coastal areas (return values increase from 25-35 to 35-45 mm).

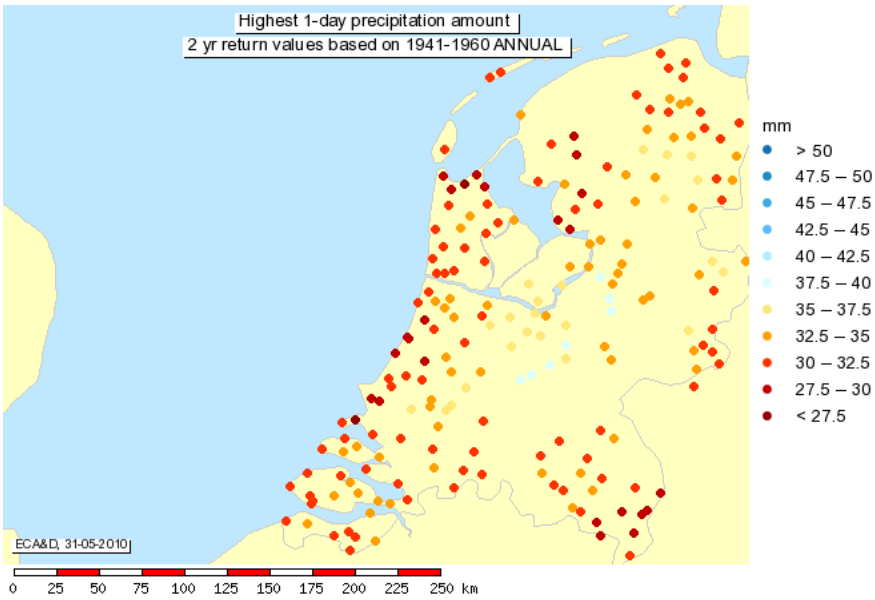

Fig 11: 2 year return values of annual maximum 1-day precipitation amount [mm] for The Netherlands based on 1941-1960 period: no values > 40 mm

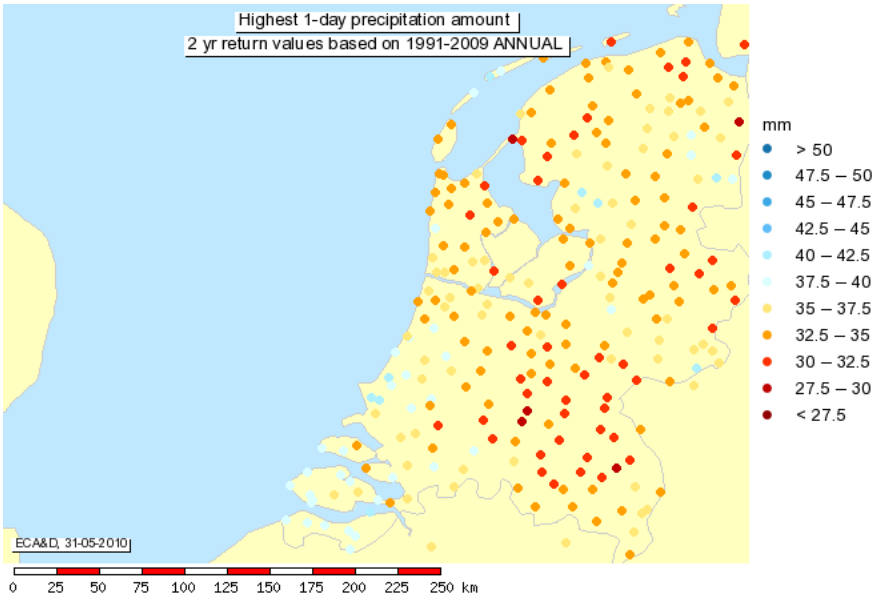

Fig 12: 2 year return values of annual maximum 1-day precipitation amount [mm] for The Netherlands based on 1991-2009 period: values locally 40-45 mm

An ECA&D trend map (fig 13) shows climate change even more clearly. In coastal areas the highest daily precipitation amount has increased significantly.

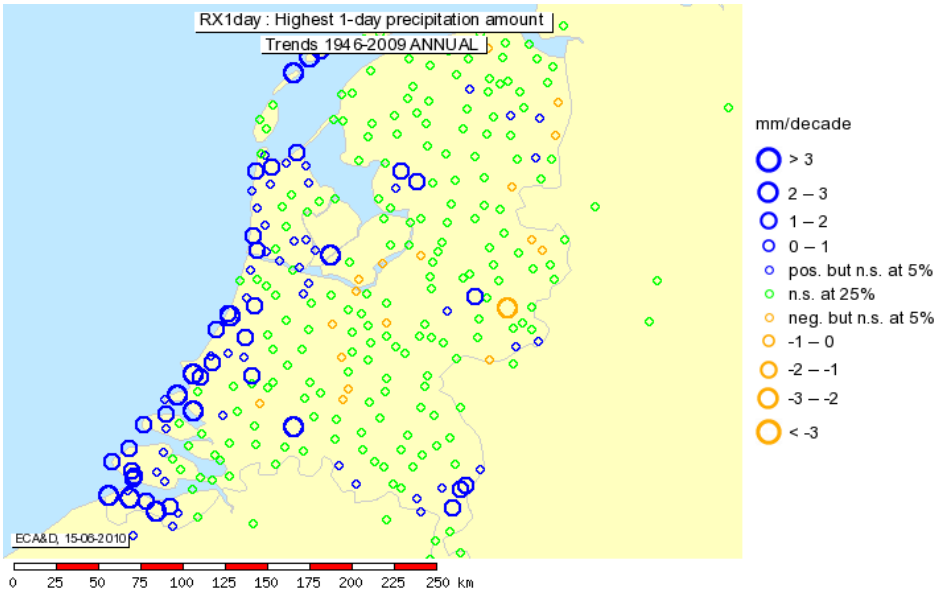

Fig 13: Trend map 1946-2009 for annual highest 1-day precipitation amount [mm/decade]

7. Seasonal dependency

Return values do not only change in time, but their value also depends on what period the calculations are based on. So far we have only looked at annual return values, but in ECA&D you can also calculate return values based on one specific month, one specific season (winter dec-feb, summer jun-aug, spring mar-may, autumn sep-nov) or a winter or a summer half year (oct-mar or april-sept).

Appendix 1: Return values matching official Meteoalarm guidelines per country

Country Name	Country Size [km2]	Country size weighed Meteoalarm criterium (once a year)	Country size weighed Meteoalarm criterium (30 times a year)
Austria	83858	once in 3-4 years	8-9 times a year
Belgium	30528	once in 9-10 years	3-4 times a year
Swiss	41284	once in 7-8 years	4-5 times a year
Cyprus	9251	once in 32-33 years	about once a year
Czech rep	78866	once in 3-4 years	7-8 times a year
Germany	357022	1-2 times a year	35-36 times a year
Denmark	43094	once in 6-7 years	4-5 times a year
Spain	505992	about 2 times a year	50-51 times a year
Finland	338145	1-2 times a year	33-34 times a year
France	643427	about 2 times a year	64-65 times a year
Greece	131957	once in 2-3 years	13-14 times a year
Hungary	93032	once in 3-4 years	9-10 times a year
Iceland	103000	once in 2-3 years	10-11 times a year
Ireland	70273	once in 4-5 years	7-8 times a year
Italy	301318	about once a year	30-31 times a year
Luxembourg	2586	once in 116-117 years	about once in 4 years
Malta	316	once in 949-950 years	about once in 33 years
Netherlands	41528	once in 7-8 years	4-5 times a year
Norway	385155	1-2 times a year	38-39 times a year
Poland	312685	about once a year	31-32 times a year
Portugal	91982	once in 3-4 years	9-10 times a year
Romania	238391	about once a year	23-24 times a year
Sweden	449964	1-2 times a year	44-45 times a year
Slovenia	20256	once in 14-15 years	2-3 times a year
Slovakia	49033	once in 6-7 years	4-5 times a year
UK	242900	about once a year	24-25 times a year
Latvia	64600	once in 4-5 years	6-7 times a year
Estonia	45100	once in 6-7 years	4-5 times a year
Lithuania	65300	once in 4-5 years	6-7 times a year
Serbia	77474	once in 3-4 years	7-8 times a year
Median	81362	once in 3-4 years	8-9 times a year

In green the biggest and the smallest Meteoalarm countries France and Malta.

Appendix 2: Current Meteoalarm thresholds for extreme precipitation amounts.

Overview of current thresholds for precipitation (from a presentation by Ludo van Auwera to the Meteoalarm Expert Meeting in Geneve on 22-23 juni 2009):

		6h	6h	6h	12h	12h	12h	24h	24h	24h
1	Austria	15	35	75	20	45	100	25	55	125
2	Belgium	20	30					25	50	
3	Swiss	25	35	45	35	45	55	50	75	100
4	Cyprus	50	70	95				55	85	115
5	Czech R	30			35	50	70	40	60	90
6	Germany	20	35		25	40	70	30	50	80
7	Denmark	24								
8	Spain				40	80	120			
9	Finland							50	70	120
10	France	20	30					25	50	
11	Greece				10	30	60	15	40	75
12	Hungary				20	30	50			
13	Iceland				30					
14	Ireland		30	60		40	70	25	50	80
15	Italy		20	30				20	50	100
16	Luxemb	15	30	45				30	45	60
17	Malta	?	?	?	?	?	?	?	?	?
18	Netherl								75	
19	Norway							45	65	90
20	Poland							30		
21	Portugal	30	40	60						
22	Romania							25	50	90
23	Sweden				35				70	
24	Slovenia							25	50	100
25	Slovakia	?	?	?	?	?	?	?	?	?
26	UK							25	50	100
27	Latvia				15	50				
28	Estonia				15	50				
29	Lithuania				15	50	80			
30	Serbia				10	20	30	20	40	50

From these thresholds we calculated the median of the thresholds for the 24 hour amounts:

- Yellow: 25 mm
- Orange: 50 mm
- Red: 90 mm

Appendix 3:

Country	Orange threshold 24h (average)	Orange threshold 24h (min value)	Orange threshold 24h (max value)
Austria	50	40	60
Belgium	35	30	40
Cyprus	40	30	50
Czech R	40	30	50
Czech R (locally in West)	55	50	60
Denmark	30	20	40
Germany	30	20	40
Germany (extreme South)	40	30	50
Estonia	35	30	40
Finland	30	20	40
France	30	20	40
France (SE)	50	30	70
Greece			
Hungary			
Iceland	40	30	50
Iceland (locally)	70	60	80
Ireland	30	20	40
Ireland (SW)	45	40	50
Italy	60	40	80
Italy (NW)	120	80	160
Latvia	25	20	30
Lithuania	35	30	40
Luxembourg	35	30	40
Malta			
Netherlands	35	25	45
Netherlands (locally)	45	40	50
Norway	40	20	60
Norway (locally SW coast)	85	65	105
Poland	30	20	40
Poland (extreme South)	40	30	50
Portugal	50	40	60
Romania	40	30	50
Serbia	40	30	50
Slovakia			
Slovenia (E)	65	40	90
Slovenia (W)	130	90	170
Spain	30	20	40
Spain (SE)	55	40	70
Sweden	30	20	40
Swiss	50	40	60
Swiss (S)	115	90	140
UK (England)	35	30	40
UK (Scotland/Wales)			

Based on ECA&D dataset of 1981-2000 Unreliable due to too few return values

If the differences within a country are large, we suggest using regional thresholds.