DANISH MINISTRY OF THE ENVIRONMENT

Environmental Protection Agency

Noise mapping by use of Nord2000

Reduction of number of meteo-classes from nine to four

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Contents

Resume og konklusioner

Den reviderede fælles nordiske beregningsmetode Nord2000 baserer sig på, at årsmiddelværdien af parametrene L_{den} og L_{night} beregnes for 25 forskellige typer af vejrsituationer og dertil hørende lydudbredelsesforhold, vejrklasserne. Der er fastlagt et format til bestemmelse af den hyppighed, hvor de forskellige vejrklasser optræder indenfor hver af de tre perioder dag, aften og nat. Formatet tillader desuden, at der benyttes data for lufttemperatur og relativ fugtighed for hver af vejrklasserne.

I Danmark har det vist sig, at der i praksis kun forekommer 9 vejrklasser. De nødvendige data for disse klasser indgår som bilag i bekendtgørelse om kortlægning af ekstern støj og udarbejdelse af støjhandlingsplaner (nr. 717 af 13. juni 2006).

Det har efterfølgende vist sig, at der i forbindelse med støjkortlægning af større områder opstår uhensigtsmæssigt lange regnetider, når støjniveauet skal beregnes for 9 vejrklasser. Idet regnetiden er direkte proportional med antallet af vejrklasser, er det undersøgt om en reduktion af antallet af vejrklasser kan benyttes ved støjkortlægning uden at der opstår fejl herved.

I projektet, som denne rapport omhandler, anbefales det at reducere antallet af vejrklasser til fire i forbindelse med støjkortlægning og andre beregningsopgaver, hvor regnetiden har stor betydning. I andre tilfælde, hvor regnetiden er mindre væsentlig, eller når kravene til nøjagtighed er større, anbefales det at benytte de oprindelige ni vejrklasser i bekendtgørelsen.

Ved støjkortlægning i tætte byområder anbefales det at benytte én vejrklasse, hvor der ses bort fra meteorologiens indflydelse på lydudbredelsen. På grund af de generelt kortere afstande og mange refleksioner har vejrforholdene generelt mindre betydning i tætte byområder. I de situationer, hvor meteorologien kan have indflydelse, er det imidlertid tvivlsomt om de lokale vejrforhold i bygaderne svarer til de generelle forhold i landet som helhed.

Summary and conclusions

In a joint Nordic work for calculation of noise from road traffic it was proposed that calculation of the yearly average of L_{den} and L_{night} should be based on 25 meteorological classes. A format was defined for the probability of occurrence of each meteo-class together with the average air temperature and relative humidity in the meteo-class for the day, evening and night period, respectively. The method has been accepted by the Danish Environmental Protection Agency, and the necessary statistics have been provided. The statistics included nine significant meteo-classes while the other classes contained no significant occurrences.

For strategic noise mapping the use of nine meteo-classes has subsequently been found too calculation time consuming. As the calculation time is proportional to the number of meteo-classes, it has been found necessary to reduce the number of classes.

As the result of the present work, a reduction to four meteo-classes is recommended for strategic noise mapping or other cases where the calculation time plays an important role. In cases where the calculation time issue is less important, it is recommended to use the original statistics with nine significant meteo-classes.

For a city environment it is recommended to use only one meteo-class (ignoring weather effects). Due to shorter distances and many reflections, the weather will be of less importance in many cases, and in cases where weather effects are significant, it is doubtful that weather conditions defined by the statistics are of relevance to the local conditions in the city streets.

1 Background

In a joint Nordic work for calculation of noise from road traffic it was proposed that calculation of the yearly average of L_{den} and L_{night} should be based on 25 meteorological classes as described in [1] and [2]. In the work a format was defined for the probability of occurrence of each meteo-class together with the average air temperature and relative humidity in the meteo-class for the day, evening and night period, respectively. The meteo-class statistics vary with the direction of propagation, and it was decided that values should be available in the range 0-360° with a spacing of 10°.

In the work each participating country calculated the statistics according to this format. In the Danish statistics (as well as in the statistics of the other Nordic countries) a large number of the meteo-classes contained no occurrences, and a few classes contained so few occurrences that they could be moved to neighbouring classes. After this reduction the resulting statistics for Denmark included nine significant classes as described in [3].

For strategic noise mapping the use of nine meteo-classes has subsequently been found too calculation time consuming. As the calculation time is proportional to the number of meteo-classes, it has been found necessary to reduce the number of classes further.

In the European Harmonoise/IMAGINE workgroup accurate calculation of L_{den} and L_{night} is also based on the format with 25 classes but the number of noise classes has been reduced to four for strategic noise mapping in general and to one for city streets (ignoring meteorological effects).

On this basis, the aim is to reduce the number of meteo-classes for strategic noise mapping to the same magnitude as used in the European method. In the European method the four classes have been based on a parameter D/R where D is the propagation distance and R is the ray curvature. However, the parameter D/R is not an input parameter in Nord2000. Therefore, when using Nord2000, the format containing the 25 classes has to be kept, but the number of classes containing occurrences can be reduced by combining two or more classes into one. Another reason for using this approach is that new statistics can be derived from available statistics. The experience from the European work can support the process of reducing the number of meteo-classes.

2 Method

The reduction of the number of meteo-classes is based on the quantity D/R where D is the propagation distance and R is the ray curvature. The procedure for calculating R is described in [4] ([5] contains slightly modified equations). [5] contains four propagation classes M1-M4 which will serve as a guideline for the reduction of meteo-classes.

Table 1: Propagation classes defined in [5].

Propagation class	*D/R Range*	*D/R Representative value*	*Verbal description*
M1	< -0.04	-0.08	Unfavourable
M2	-0.04 ... 0.04	0.00	Neutral
M3	0.04 ... 0.12	0.08	Favourable
M4	> 0.12	0.16	Very favourable

In Nord2000 ([6], [7]) as well as in the Harmonoise/IMAGINE method ([4], [5]) the vertical effective sound speed profile is assumed to be a log-lin profile as shown in Eq. (1). The procedure for calculating the yearly average of the noise levels is based on log-lin profiles, and the meteo-classes are defined by A and B (as defined in [2]). In the IMAGINE method the definition of A and B has been interchanged.

$$c(z) = A \ln\left(\frac{z}{z_0} + 1\right) + Bz + C \qquad (1)$$

An overview of the meteorological statistics in [3] is given in Figure 1 where the percentage of occurrence in each meteo-class is the average of all propagation directions 0-360°. The figure shows that the nine significant meteo-classes are 3, 7, 8, 13, 18, 19, 20, 23, and 24. The five classes 3, 8, 13, 18, and 23 are the purely logarithmic sound speed profiles (B = 0) with increasing favourable propagation conditions ranging from strong upward propagation (class 3) over neutral propagation (class 13) to strong downward propagation (class 23). The other four classes have an additional linear component which increases the refraction effect relative to the purely logarithmic profile (A and B have the same sign which implies that the refraction effect is enhanced by B, e.g. class 7 is more unfavourable than 8, and 24 is more favourable than 23) . The nine classes are defined by A and B in Table 2.

Figure 1: Percentage of occurrences in 25 meteo-classes averaged for propagation directions 0-360°.

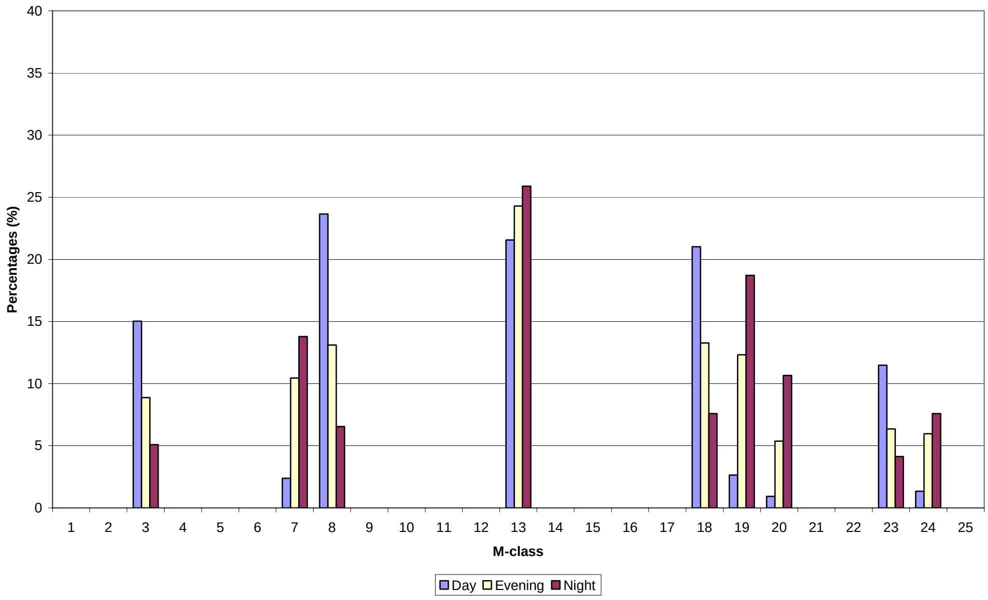


Table 2: The nine meteo-classes in the Danish statistics in [3] and the corresponding values of A and B.

Meteo-class	*A*	*B*
3	-1.0	0
7	-0.4	-0.04
8	-0.4	0
13	0	0
18	0.4	0
19	0.4	0.04
20	0.4	0.12
23	1	0
24	1	0.04

For the nine classes in Table 2 the parameter D/R is calculated using the equations in [4]. For the logarithmic profiles the value of D/R will be independent of the distance while the numerical value of D/R will increase with the distance if the profile has a linear component. The result of the calculations is shown in Annex A. If the nine meteo-classes are reduced to four based on D/R solely, the outcome will be Proposal 1 in Table 3. On the basis of the results shown in Annex A, meteo-classes 8, 13, 18, and 24 has been selected to represent the four classes M1-M4 defined in Table 1.

Table 3: Two proposals for reducing the number of meteo-classes.

Propa-gation class	*Meteo-class*	*Original classes to include in the combined meteo-classes*	
		Proposal 1	*Proposal 2*
"M1"	8	3, 7, 8	3, 7, 8
"M2"	13	13	13
"M3"	18	18	18, 19
"M4"	24	19, 20, 23, 24	20, 23, 24

For propagation class "M4" combining 19, 20, 23, and 24, one of the classes with a moderate linear component seems to be the natural choice. However, it must be expected that the use of class 19 will underestimate the noise levels whereas class 24 may lead to an overestimation in the lower range of distances. Therefore, it was decided also to investigate a Proposal 2 where class 19 has been moved to the "M3" which is represented by class 18. In addition, a Proposal 3 has been defined where the four groups for combing the meteo-classes are the same as in Proposal 2, but where class 19 is used to represent "M3" instead of class 18.

For each of the three proposals new meteo-statistics have been determined using the 25-class format defined in [2]. Temperature and humidity in the new classes are obtained by calculating the weighted average (weighted by the percentages) of the values in the classes which are combined.

To test the effect of reducing the number of meteo-classes, calculation of the yearly average L_{den} has been carried out for a few cases based on the test cases described in [8]. Test case 1 and 2 among the test case group "Test Cases for the Yearly Average" in [8] have been selected for this purpose. Test case 1 and 2 cover propagation from a road placed north-south over flat terrain to a receiver east or west of the road, respectively, 100 m from the road. Calculations are carried out for these cases and for additional distances of 25, 50, 200, and 500 m. The calculations are repeated for a terrain corresponding to terrain group 7 (thin hard screen on flat ground) in test case group "Test Cases for a Straight Road" in [8]. The two groups are denoted "Flat" and "Screen", respectively.

3 Results

New weather statistics have been created where the number of weather classes is reduced to four. This has been done for each of the three proposals for combining the original meteo-classes described in Section 2.

For the three proposals the effect of reducing the number of meteo-classes for 20 propagation cases has been determined as described in Section 2. The results are shown in Table 4.

Table 4: Calculated changes in L_{den} when reducing the number of meteo-classes from nine to four according to Proposal 1-3.

Terrain	*Receiver position*	*Distance (m)*	*L_{den} (dB)*	*Changes in L_{den} (dB)*		
				Proposal 1	*Proposal 2*	*Proposal 3*
Flat	East	25	64.4	0.9	0.3	0.4
Flat	West	25	63.8	0.9	0.3	0.4
Flat	East	50	60.8	1.1	0.4	0.5
Flat	West	50	59.9	1.2	0.4	0.5
Flat	East	100	58.4	1.0	0.3	0.4
Flat	West	100	57.3	1.1	0.3	0.4
Flat	East	200	55.6	0.4	0.1	0.2
Flat	West	200	54.4	0.4	0.1	0.2
Flat	East	500	50.0	0.0	0.0	0.0
Flat	West	500	48.7	0.0	0.0	0.0
Screen	East	25	60.3	2.2	0.8	0.9
Screen	West	25	59.5	2.4	0.8	1.0
Screen	East	50	57.2	1.9	0.6	0.9
Screen	West	50	56.4	2.0	0.6	0.9
Screen	East	100	52.8	1.4	0.2	0.8
Screen	West	100	52.1	1.5	0.2	0.8
Screen	East	200	49.0	1.4	0.0	0.8
Screen	West	200	48.1	1.4	-0.1	0.8
Screen	East	500	43.7	1.4	-0.1	0.9
Screen	West	500	42.7	1.4	-0.4	0.9
Average deviation				1.2	0.2	0.6

Table 4 shows that Proposal 1 where the combination of the meteo-classes is solely based on the parameter D/R as used by IMAGINE leads to a general overestimation of L_{den} as already suggested in Section 2. The average deviation of the calculated cases is 1.2 dB with a maximum deviation of 1.2 dB for flat terrain and 2.4 dB for screens.

Moving meteo-class 19 from propagation class “M4” to “M3” in Proposal 2 clearly improves the agreement between the calculation where all nine classes were used and the four-class approach. The average deviation of the calculated cases is 0.2 dB with a maximum deviation of 0.4 dB for flat terrain and 0.8 dB for screens.

The use of meteo-class 19 in Proposal 3 to represent propagation class “M3” instead of meteo-class 18 in Proposal 2 will only increase the L_{den} slighly for flat terrain. However, for screens L_{den} will be overestimated by approx. 1 dB.

4 Conclusions and Recommendations

The calculation results in Section 3 show that a reduction of the number of meteo-classes in the weather statistics which is based directly on the parameter D/R used in the IMAGINE work will lead to a significant overestimation of the yearly average of L_{den}.

A more neutral estimate is obtained in the investigated propagation cases by Proposal 2 which is recommended.

If a more conservative estimate is desirable, it can be recommended to use Proposal 3 where L_{den} shows only slightly higher values than Proposal 2 for flat terrain, but where the calculated values in screen cases are overestimated by approx. 1 dB. Still, from an acoustical point of view a neutral simplification is provided by Proposal 2.

Due to the financial limitations in the present project the effects of reducing the number of meteo-classes have only been investigated for a limited number of terrain cases. However, it is expected that the magnitude of deviations between calculations using the nine meteo-classes and the recommended proposal will be acceptable in other terrain cases.

The statistics reduced to four meteo-classes shall only be applied when the calculation time plays an important role such as in the case of strategic noise mapping. In other cases it is recommended to use the nine meteo-classes to obtain the best accuracy.

For a city environment where L_{den} is dominated by shorter distances to the noise vehicles and by a considerable number of reflections is recommended to use only one meteo-class. This is also in accordance with the recommendation of IMAGINE (mentioned at the final conference in Budapest, October 2006). Due to shorter distances the weather will be of less importance in many cases, and in cases where weather effects are expected to be significant it is doubtful that weather conditions defined by the weather statistics are of relevance to the local weather conditions in the city streets. It is recommended to use meteo-class 13 for city environments corresponding to a homogeneous atmosphere.

5 Referencer

[1] J. Kragh et al., ***User's Guide Nord2000 Road***, Report AV 1171/06, Hørsholm 2006

[2] R. Eurasto, ***Nord2000 for road traffic noise prediction. Weather classes and statistics***, VTT Research Report No. VTT-R-02530-06, Esbo 2006

[3] BEK nr. 717, ***Bekendtgørelse om kortlægning af ekstern støj og udarbejdelse af støjhandlingsplaner*** (in Danish), 13 June 2006

[4] R. Notaz, R. Barelds, D. Van Maercke, ***Harmonoise WP3 Engineering method for road traffic and railway noise after validation and fine-tuning***, Harmonoise Technical Report Deliverable 18, HAR 32TR-040922-DGMR20, January 2005

[5] D. Van Maercke, ***Processing meteorological data and determination of long term averaged indicators L_{den} and L_{night}***, IMAGINE Report IMA03TR-060610-CSTB01 (Draft), July 2006

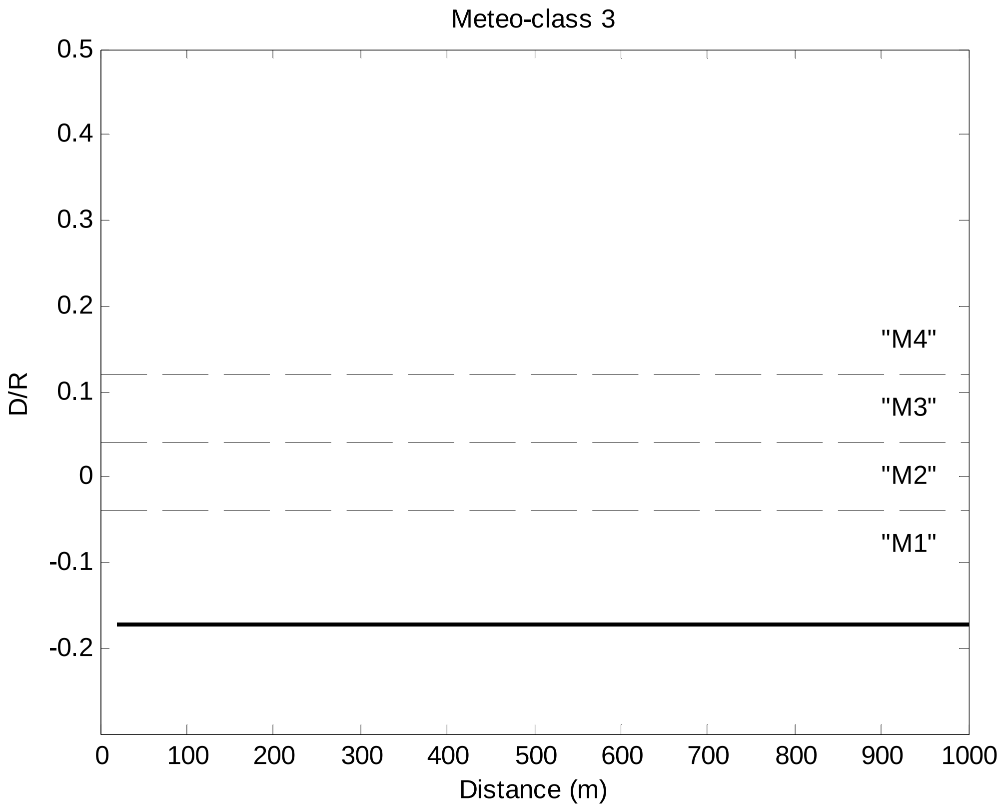
[6] B. Plovsing and J. Kragh, ***Nord2000. Comprehensive Outdoor Sound Propagation Model. Part 1: Propagation in an Atmosphere without Significant Refraction***, DELTA Acoustics & Vibration, Revised Report AV 1849/00, Hørsholm 2006

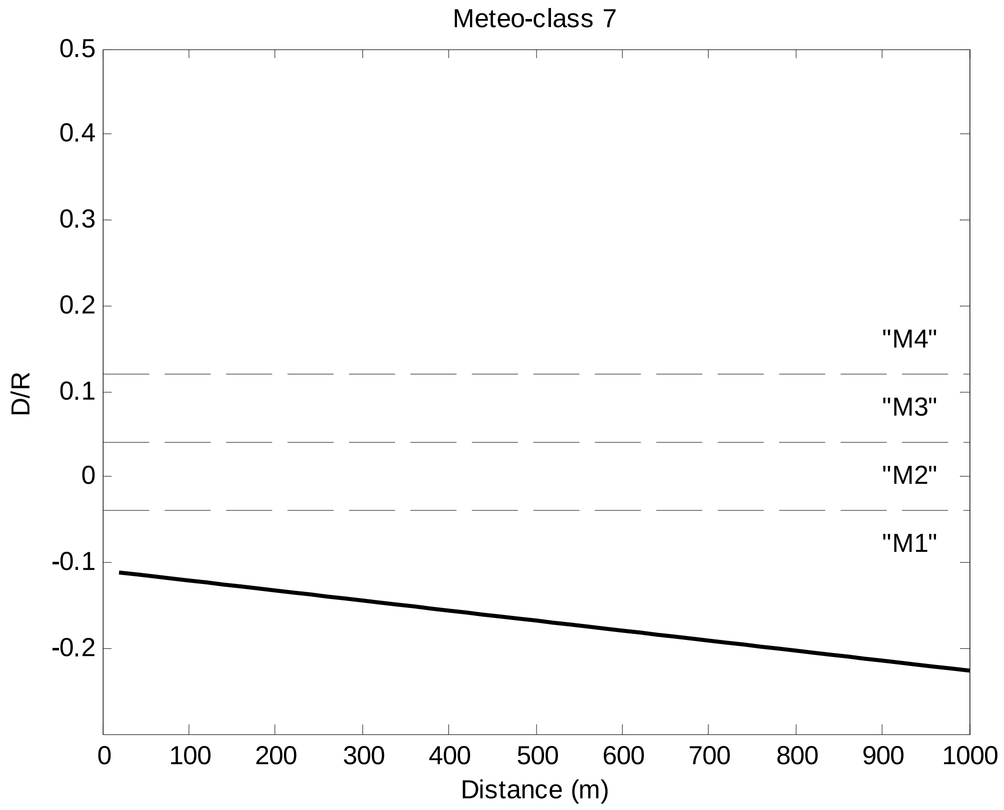
[7] B. Plovsing and J. Kragh, ***Nord2000. Comprehensive Outdoor Sound Propagation Model. Part 2: Propagation in an Atmosphere with Refraction***, DELTA Acoustics & Vibration, Revised Report AV 1851/00, Hørsholm 2006

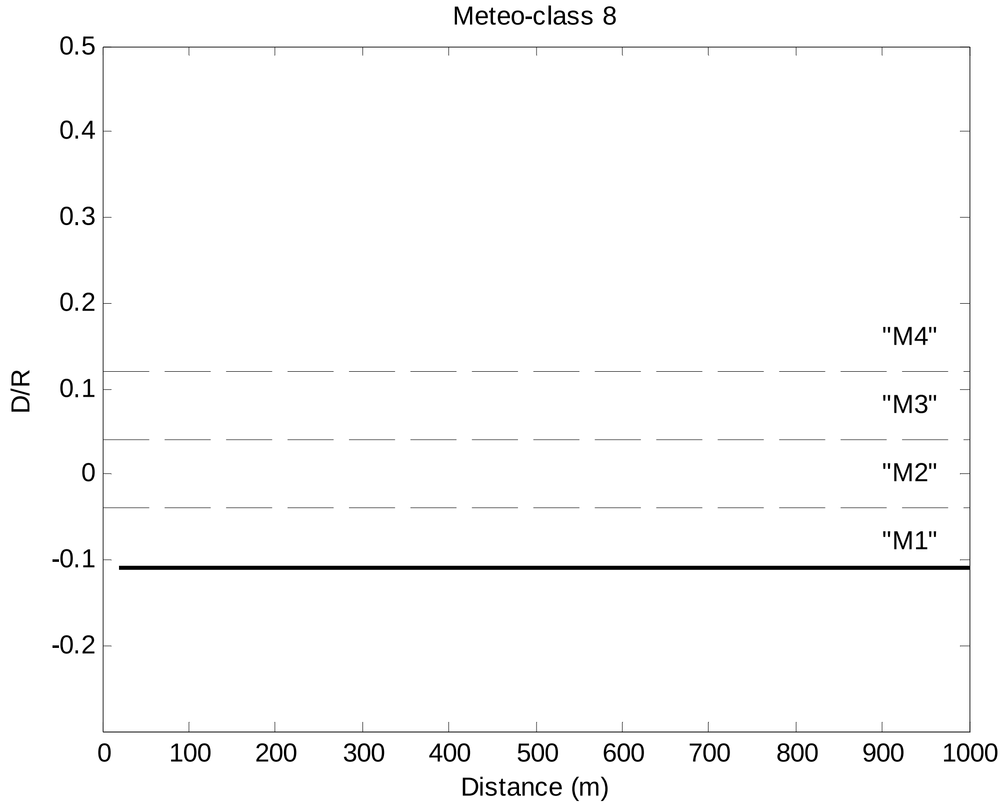
[8] ***Test cases for control of Nord2000***, Danish Environmental Protection Agency, Environmental Project No. 1111, 2006

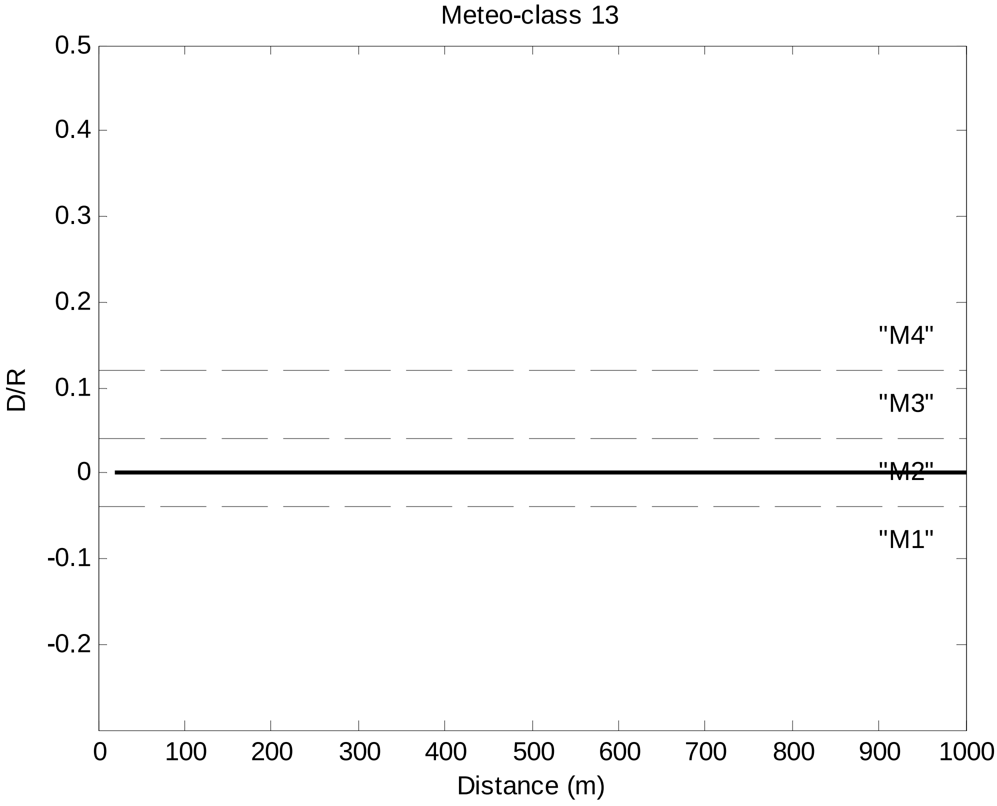
Annex A. Illustration of D/R

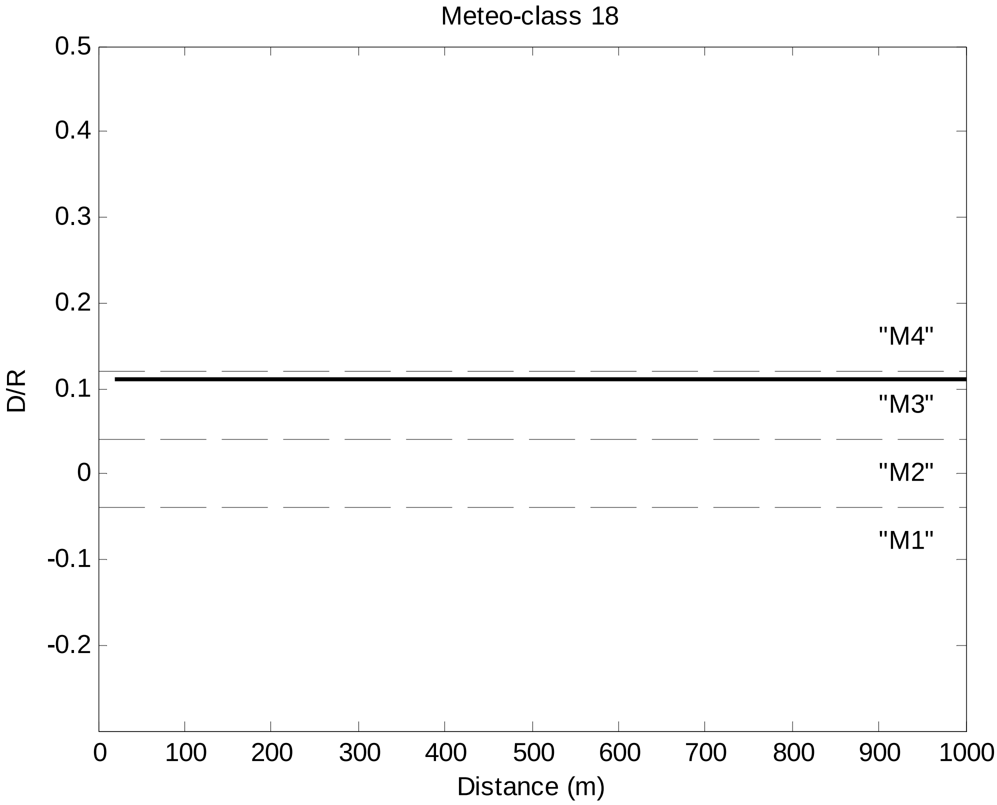
The parameter D/R has been calculated as a function of propagation distance D in the range 20 to 1000 m for the nine significant meteo-classes in the Danish statistics. For each meteo-class the result is shown below. Each figure shows with a solid thick line D/R calculated for the actual meteo-class while the lower and upper range of the four propagation classes M1-M4 defined in Table 1 are indicated by dashed lines.

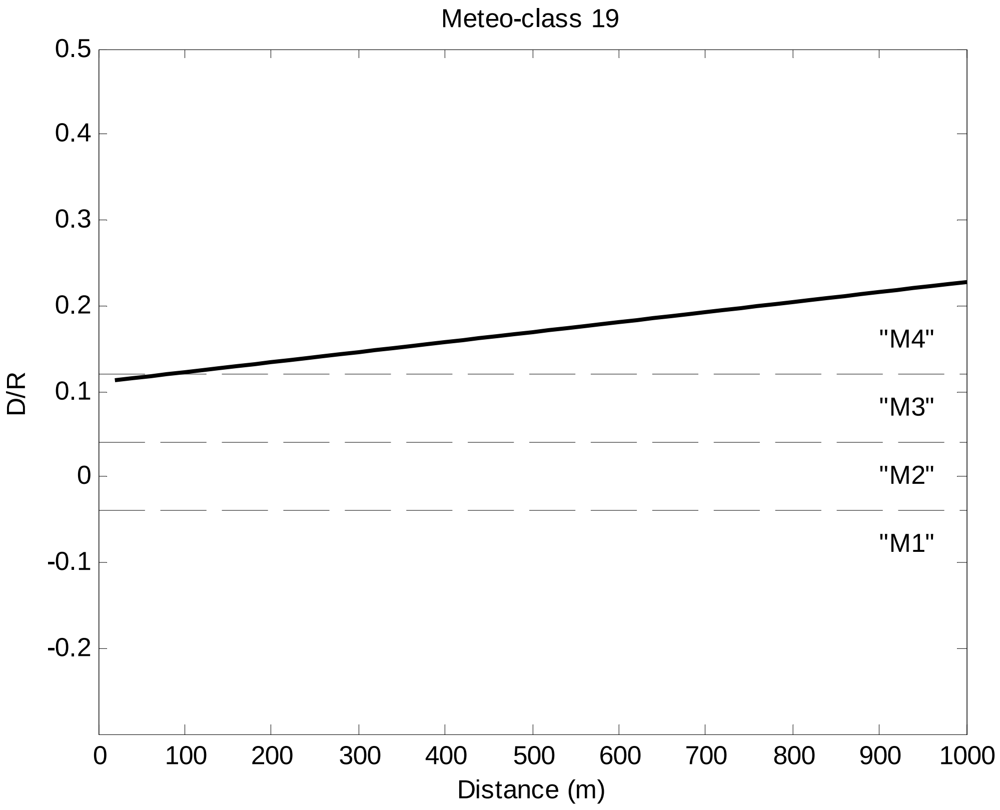


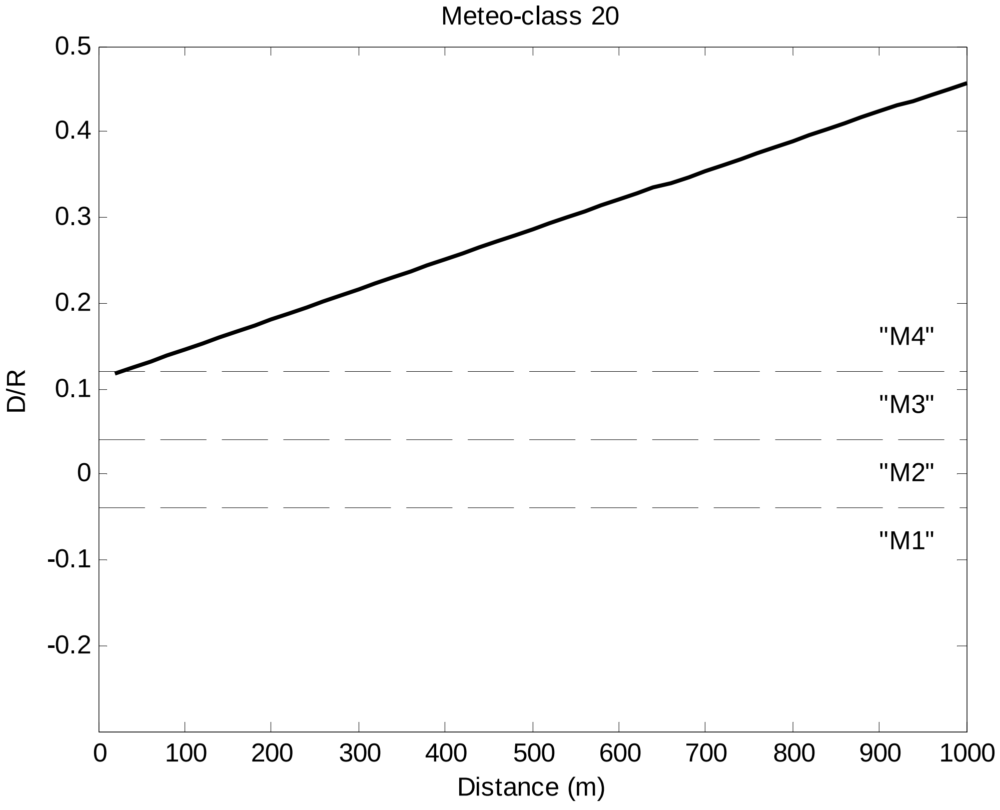

Meteo-class 7
D/R
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
"M4"
"M3"
"M2"
"M1"
0
100
200
300
400
500
600
700
800
900
1000
Distance (m)

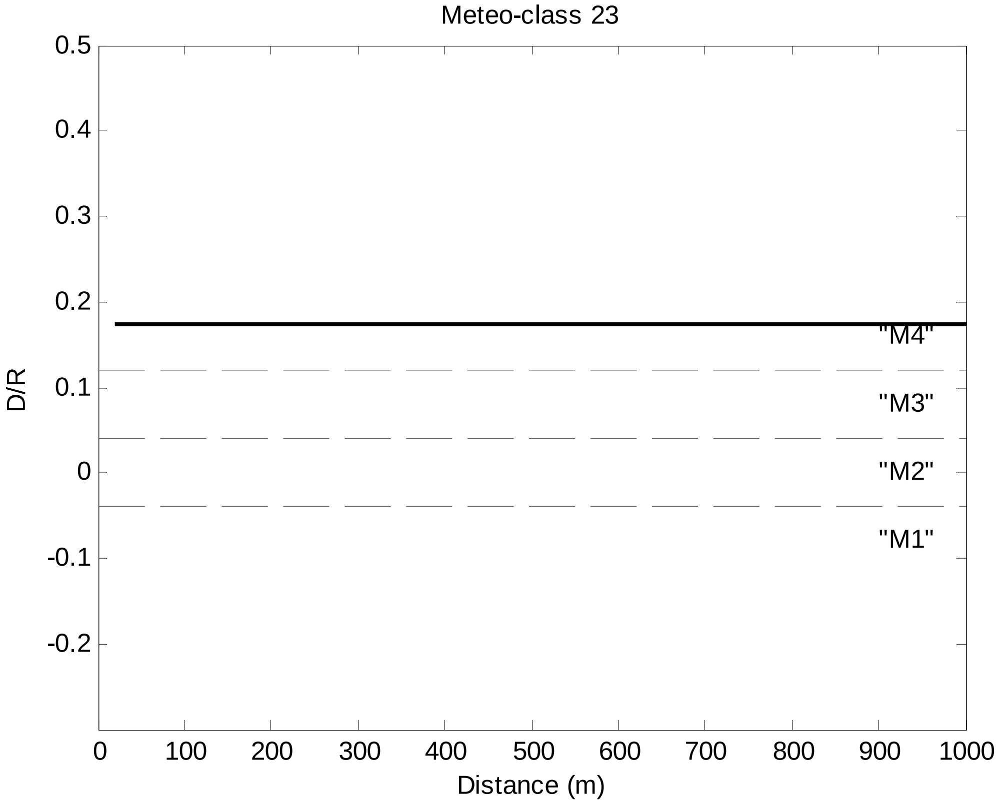

Meteo-class 8
D/R
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
"M4"
"M3"
"M2"
"M1"
0
100
200
300
400
500
600
700
800
900
1000
Distance (m)

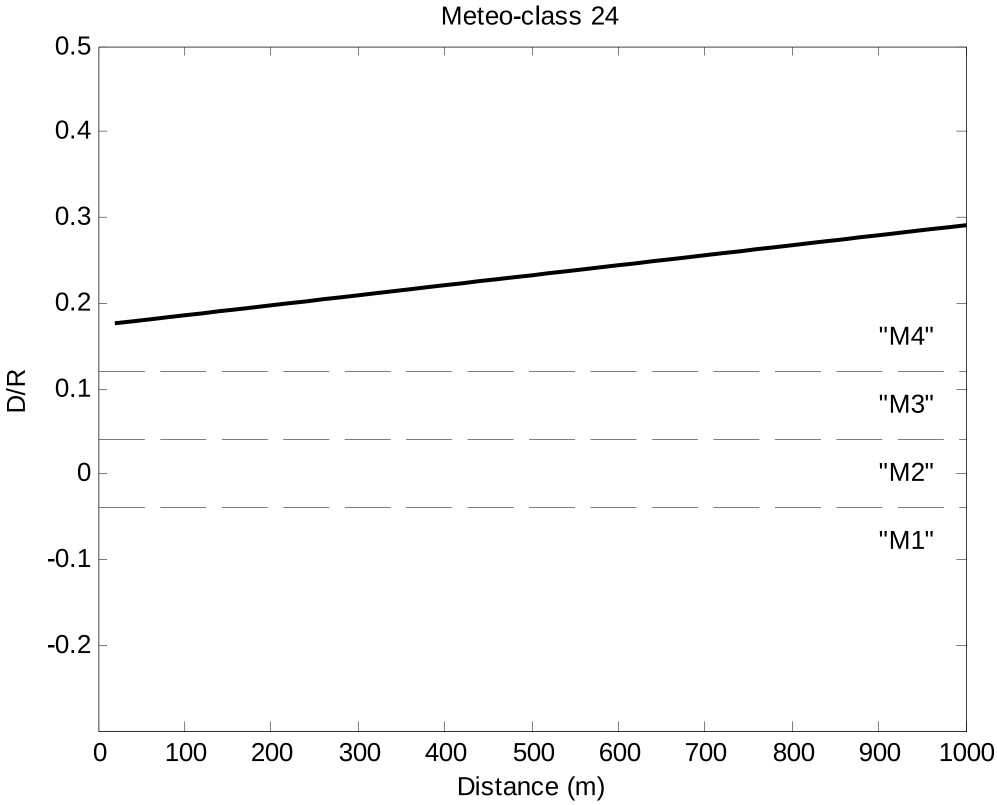

Meteo-class 13
D/R
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
"M4"
"M3"
"M2"
"M1"
0
100
200
300
400
500
600
700
800
900
1000
Distance (m)


Meteo-class 18
D/R
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
"M4"
"M3"
"M2"
"M1"
0
100
200
300
400
500
600
700
800
900
1000
Distance (m)


Meteo-class 19
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
D/R
"M4"
"M3"
"M2"
"M1"
0
100
200
300
400
500
600
700
800
900
1000
Distance (m)


Meteo-class 20
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
D/R
"M4"
"M3"
"M2"
"M1"
0
100
200
300
400
500
600
700
800
900
1000
Distance (m)


Meteo-class 23
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
D/R
"M4"
"M3"
"M2"
"M1"
0
100
200
300
400
500
600
700
800
900
1000
Distance (m)


Meteo-class 24
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
D/R
"M4"
"M3"
"M2"
"M1"
0
100
200
300
400
500
600
700
800
900
1000
Distance (m)