ANEXO IX: DOCUMENTO DE VERIFICACIÓN DEL MODELO DE SIMULACIÓN

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NLR-CR-2017-443 | April 2018

Doc29 noise computations for Barcelona–El Prat Airport

CUSTOMER: AENA SME S.A.

NLR – Netherlands Aerospace Centre

Netherlands Aerospace Centre

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EXECUTIVE SUMMARY

UNCLASSIFIED

Doc29 noise computations for Barcelona–El Prat Airport

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Problem area

On request of AENA SME S.A. the Netherlands Aerospace Centre (NLR) validated their AENAs noise computations for Barcelona-El Prat Airport and provided noise contours using the Integrated Noise Model (INM). As described in the technical manual of INM, this model is compliant with the third version of the ECAC Doc.29 method, which is considered to be the best practice method for aircraft noise computations.

Description of work

The following steps were taken to provide the requested results:

- Input data for the year 2016 was provided to NLR by AENA.
- NLR verified the input data and where necessary the input data were modified.
- NLR modelled a departure route from runway 25L including dispersion.
- NLR used INM to perform the noise computations.
- The results of the computations were processed to provide figures with noise contours.

Results and conclusions

NLR performed noise computations for the year 2016 and provided noise contours for the L_{den}, L_{day}, $L_{evening}$ and L_{night} metrics.

NLR considers the improved input data reliable and representative to provide a good assessment of the noise exposure around Barcelona-El Prat Airport.

Applicability

The results of this study can be used to gain insight into the noise exposure around Barcelona-El Prat Airport in 2016. The methodology that was used to generate these results can also be followed to validate other noise studies and to perform noise computations at other airports.

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NLR - Netherlands Aerospace Centre

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Abbreviations

ACRONYM	DESCRIPTION
AENA SME S.A	Aeropuertos Españoles y Navegación Aéra Sociedad Mercantil Estatal, Sociedad Anónima
AIP	Aeronautical Information Publication
ANP	Aircraft Noise and Performance
dBA	A-weighted decibel
CDA	Continuous Descent Approach
DTHR	Displaced threshold
ECAC	European Civil Aviation Conference
FAA	Federal Aviation Administration
L_{day}	Day noise exposure
L_{den}	Day-Evening-Night noise exposure
$L_{evening}$	Evening noise exposure
L_{night}	Night noise exposure
NLR	Netherlands Aerospace Centre
NPD	Noise-Power-Distance

1 Introduction

On request of AENA SME S.A. the Netherlands Aerospace Centre (NLR) validated their noise computations for Barcelona-El Prat Airport and provided noise contours using the Integrated Noise Model (INM). This report describes the approach and results of these computations and contains the following sections:

- Chapter 2 describes the methodology of the study.
- Chapter 3 provides the results of the computations.
- Chapter 4 describes the conclusions of the study.

2 Methodology

2.1 Noise model

For the purpose of this study, the Integrated Noise Model (INM) version 7.0d is used (see Ref. 1). INM is a widely used software tool developed by the US Federal Aviation Administration (FAA). As described in the technical manual of INM (ref. 2), INM is compliant with the third version of the ECAC Doc.29 method (see Ref. 3). The use of this version of ECAC Doc.29 is prescribed by regulation (EU) no 598/2014 (ref. 4) on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Union airports. ECAC Doc.29 is considered to be the best practice method for aircraft noise computations in Europe and the United States and it is developed on the request of the European Union (EU) to perform noise mapping studies for European airports.

2.2 Input data

This section gives a global overview of input data that is required for a noise computation. In order to perform noise computations, the following types of input data are required:

- Scenario input data.
- Airport input data.
- Model database.

The scenario input data or flight schedule provides the following information for each flight movement:

- Aircraft type, since aircraft performance and associated noise are different for different aircraft types.
- Arrival or departure time (e.g., time when a flight takes place, such as day, evening or night).
- Runway-end used for departure or landing.
- Flight route. For this study modelled flight routes are used. This means that flight movements are distributed over assumed routes. These routes are based on radar tracks and/or procedural descriptions, and for departures so-called sub-routes are used to include the effect of route dispersion.
- Departure or arrival as well as procedure used (e.g., take-off or landing).

For this study, helicopter and military traffic is not considered. This is in line with regulation (EU) no 598/2014 (ref. 4), which only applies to fixed-wing aircraft (thus excluding helicopters) and excludes military aircraft.

The airport input data provides information about the airport and consists of the following parameters:

- Coordinates of the runway ends; defining the location of the runways.
- Elevation of the runway ends; defining how high above sea level the runway ends are located.
- If applicable, information about displaced thresholds (DTHR) is required. For noise calculations, it should be known how far the DTHR is located from each runway end. If a DTHR is used, this means that aircraft do not land shortly after the beginning of the runway, but further down the runway. This has an effect on the altitude of the aircraft during the flight, which in turn influences the noise levels on the ground.
- Analysis area or calculation area; this is the area around the airport for which noise computations are performed.

The model database is a database that contains information about aircraft performance for a large number of aircraft types. Furthermore, it contains noise-power-distance (NPD) tables. These tables specify how much noise is produced by different types of engines and thus by different types of aircraft. The tables define noise levels as a function of thrust setting and distance to the observer. For the noise computations in this study, the database from INM is used.

ECAC Doc.29 recommends the use of the Aircraft Noise and Performance (ANP) database. The INM database is in general identical to the ANP database, but slightly more extensive. This means that in some cases, an aircraft type is available in the INM database but not included in the ANP database. If this occurs, the aircraft type is modelled using a different aircraft type that is selected from the ANP database. This only concerns a very low number of flight movements, so that the effect on the results is negligible.

Appendix A provides information about the noise model settings and input data that were used for the INM study.

2.3 Computation process

The following steps were taken to perform the noise computations:

- Input data for the year 2016 was provided to NLR by AENA.
- NLR verified the input data and made some modifications to the input data.
- NLR modelled a departure route from runway 25L including dispersion.
- NLR used INM to perform the noise computations.
- The results of the computations were processed to provide figures with noise contours.

All required INM input data was provided by AENA. NLR studied the provided data to verify the correctness of the input data. This was done by cross-checking the data to a number of data sources such as:

- Radar data that provides the basis to generate the nominal route and track dispersion of departure routes from runway 25L.
- The Aeronautical Information Publication (AIP), which contains information about flight routes and procedures. The procedures and routes from the AIP were compared to the modelled procedures and routes in INM for all runways except for the radar track-based departure routes from runway 25L. The INM routes do not need to be exactly equal to the AIP routes, since they are based on actual radar tracks.
- Information provided by AENA regarding the distribution of flight movements over different routes and runways.
- Traffic data provided by AENA regarding the number of aircraft movements with different aircraft types. This data was compared to the provided INM data to verify whether it corresponded to the number of aircraft movements in the INM study.
- The current flight schedule. Some departure and arrival times for 2016 are compared to the current flight schedule (November 2017). In most cases the flight times remain the same, so therefore this information can be used to verify the provided arrival and departure times at Barcelona-El Prat Airport.
- Publicly available traffic data (ref. 5). This information source was used to verify whether the total number of movements were in line with the INM input data.
- Publicly available information regarding terrain data from Google Earth. The data was compared to the terrain model in INM.
- Publicly available meteo data (ref. 6 and ref. 7). This was compared to the assumed weather conditions in the INM study.

Based on the verification results, a different aircraft type from the INM database is used for a small number of flight movements, which leads to small changes in the noise exposure. In addition, NLR modelled a departure route from runway 25L based on an analysis of radar data.

In one case AENA and NLR decided to not further improve the input data. This concerns the modelling of departure procedures, where a conservative approach is applied, so that the modelling results in an overestimation of the noise exposure. This conservative approach is used to determine the so-called *stage length* of a departure.

In noise modelling a stage length is assumed for a departure, which increases if the distance to the destination increases. If this distance increases, the aircraft will have more fuel on board, which in turn makes the aircraft heavier. A heavier aircraft will climb slower and therefore will stay closer to the ground compared to a lighter aircraft. The lower altitude results in higher noise levels below the flight path. Since AENA always assumes the highest stage length possible for all departures, the total noise exposure at almost all locations around the airport will be overestimated, which will have a clear effect on the size of the noise contours.

More information regarding the verification of the input data is provided in Appendix B.

After the validation of the input data, the noise computations were performed. In total 4 noise metrics are considered:

- L_{den}: this is a measure for the amount of noise produced by all flight movements during a year. It considers all flight movement during the whole day and a 5 and 10 dBA penalty is applied for respectively movements during the evening and night periods.
- L_{day}: this is a measure for the amount of noise produced by all flight movements during daytime (a 12 hour period from 7:00 until 19:00). It does not apply any penalties for flights at specific times.
- $L_{evening}$: this is a measure for the amount of noise produced by all flight movements during the evening (a 4 hour period from 19:00 until 23:00). It does not apply any penalties for flights at specific times.
- L_{night}: this is a measure for the amount of noise produced by all flight movements during night time (an 8 hour period from 23:00 until 07:00). It does not apply any penalties for flights at specific times.

L_{den}, L_{day}, $L_{evening}$ and L_{night} computations are performed on a grid, so that the noise exposure in each metric is known at each grid point. Based on this result, noise contours can be derived.

3 Results

Using the INM noise model (see section 2.1) and available input data (see section 2.2) noise computations were performed (see section 2.3) to obtain noise contours for the L_{den}, L_{day}, $L_{evening}$ and L_{night} metrics, which are shown in Figure 1 to Figure 4.

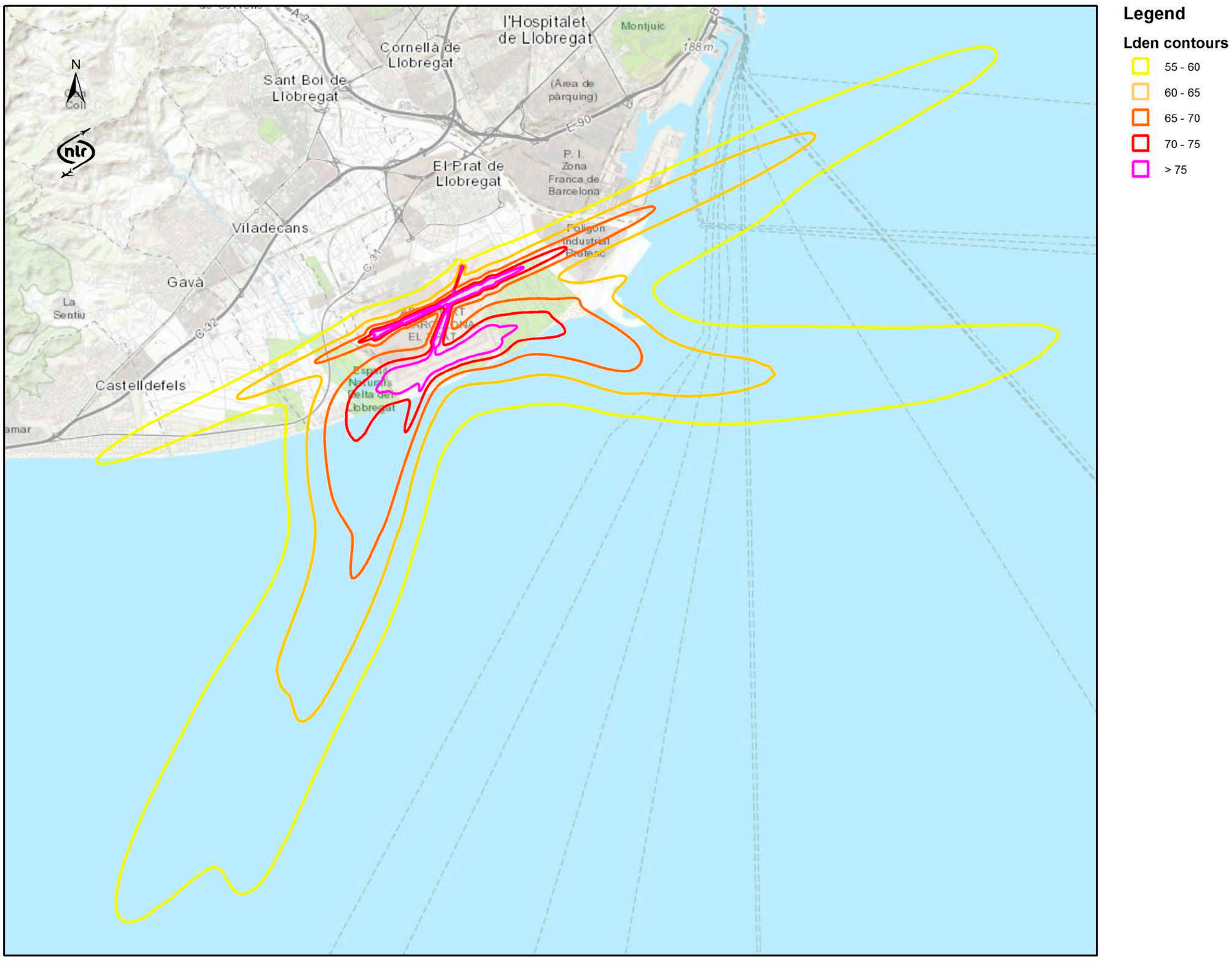

Figure 1: L_{den} contours

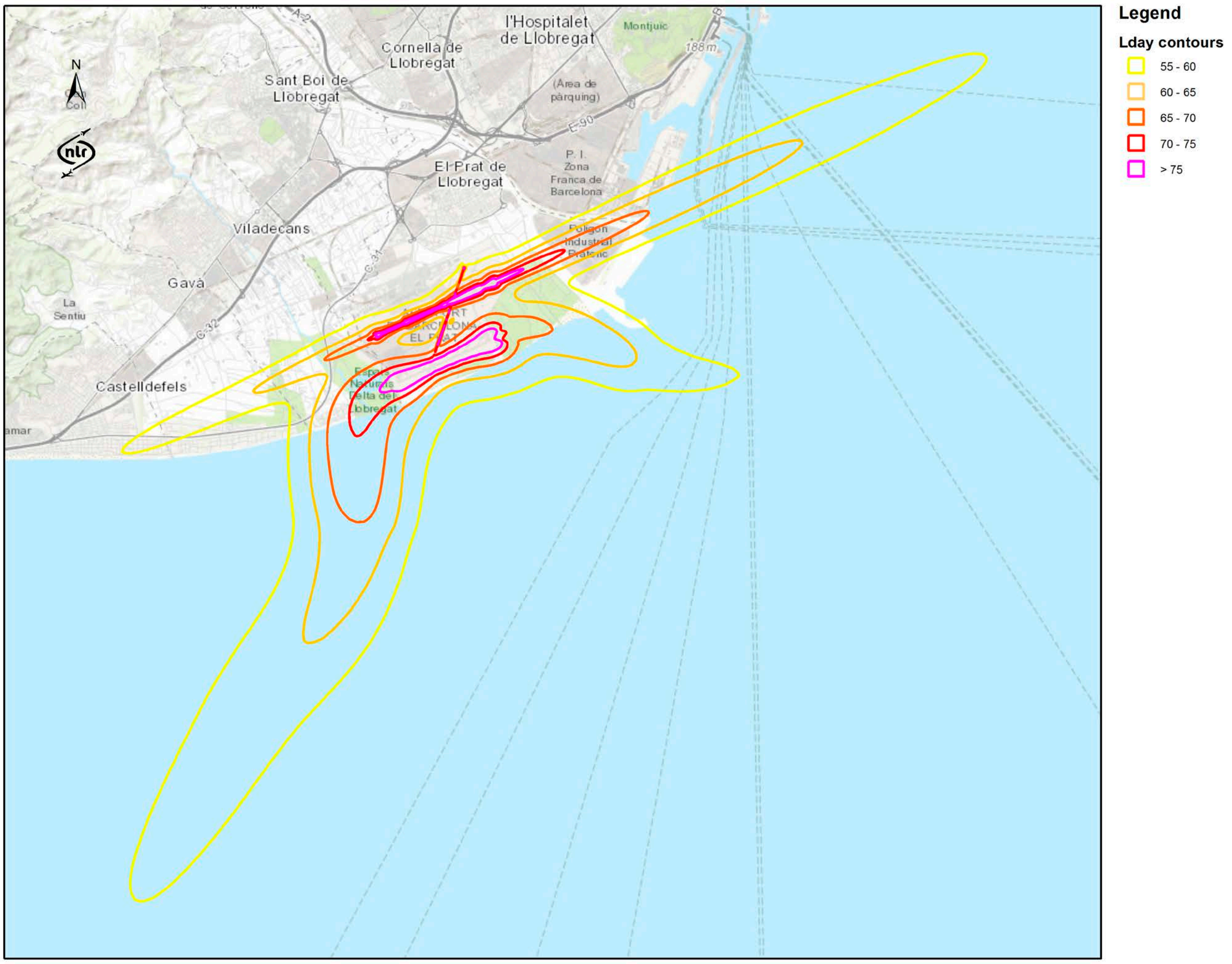

Figure 2: L_{day} contours

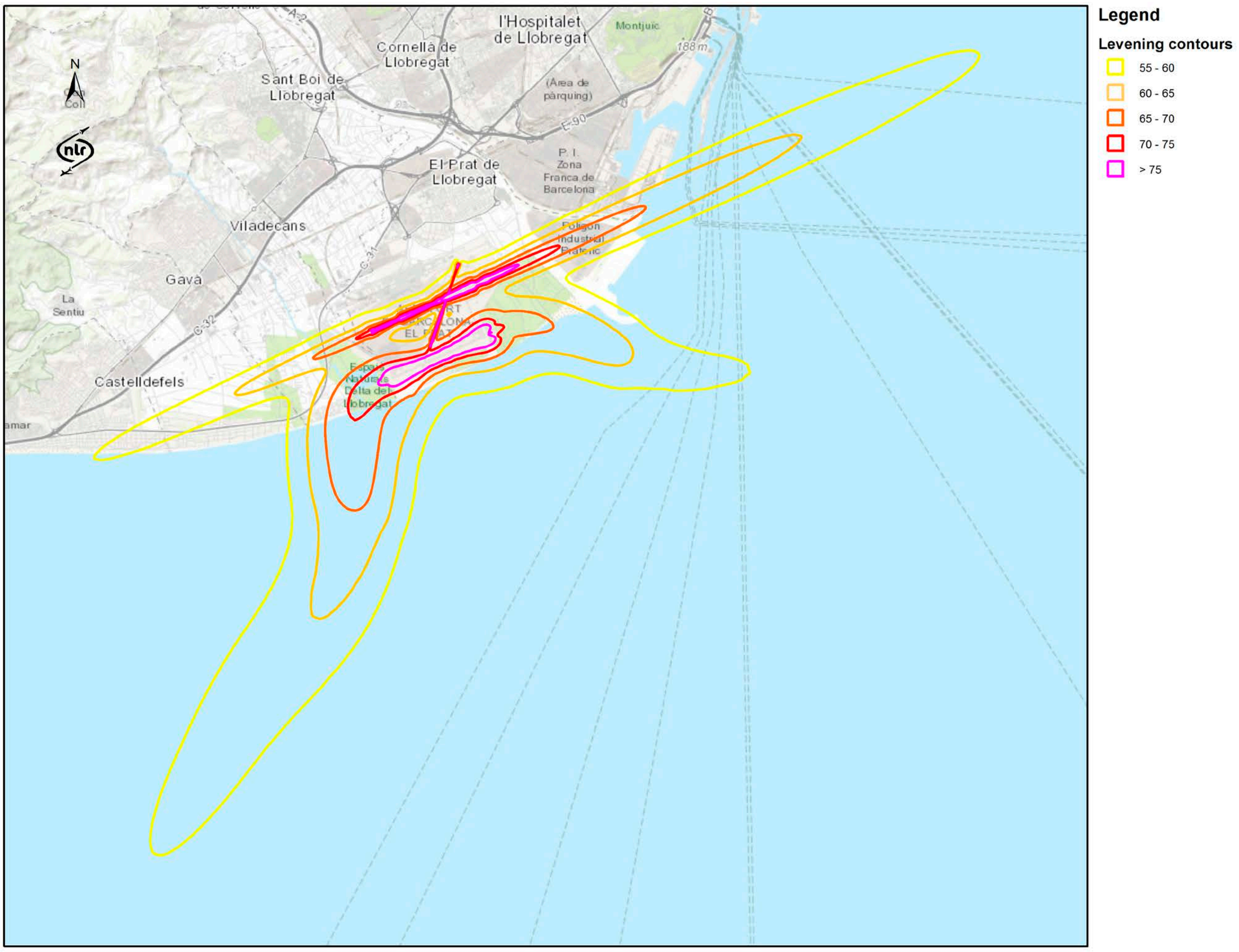

Figure 3: $L_{evening}$ contours

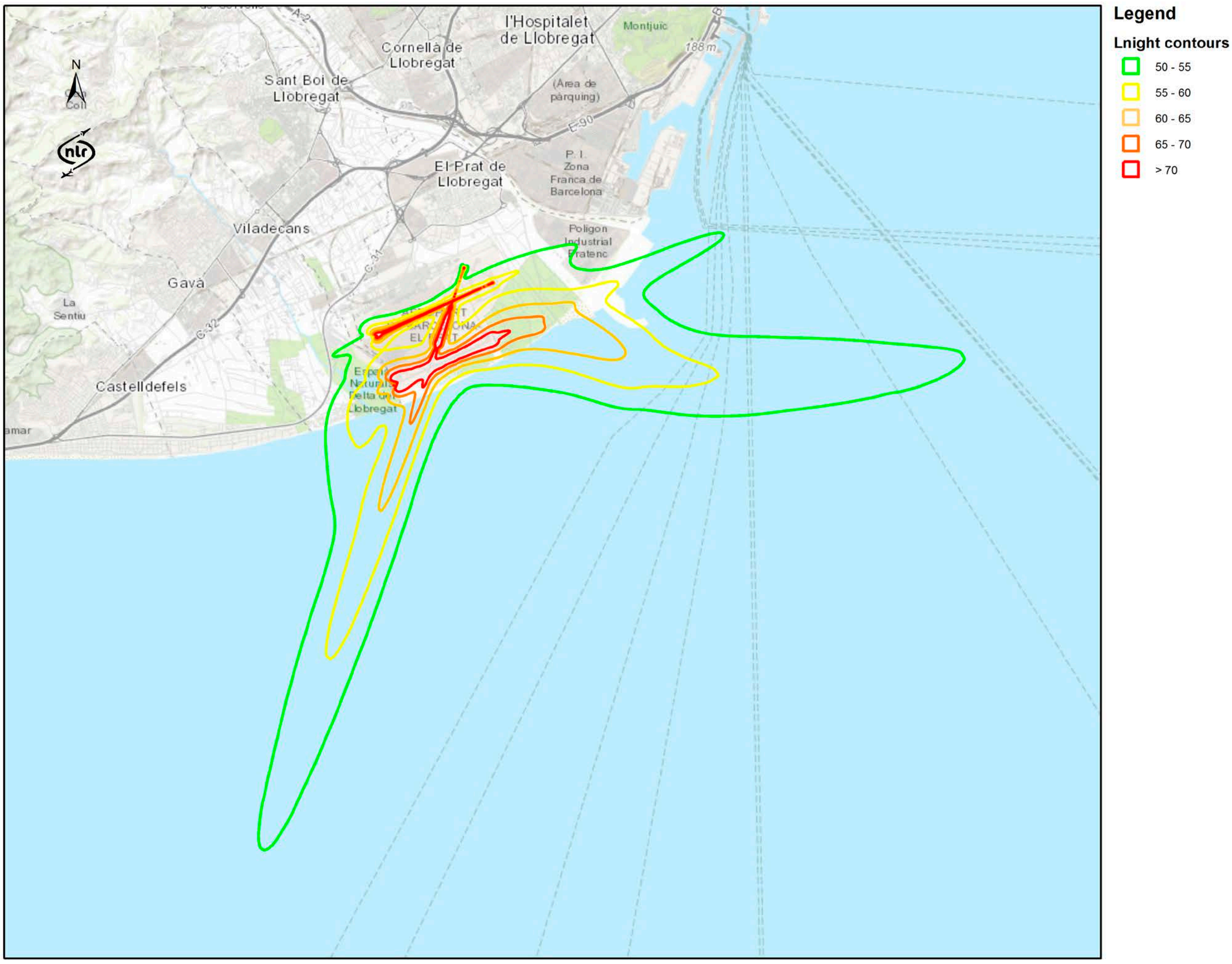

Figure 4: L_{night} contours

4 Conclusions

On request of AENA, the Netherlands Aerospace Centre (NLR) validated their noise computations for Barcelona–El Prat Airport and provided noise contours using the Integrated Noise Model (INM).

In order to do this the following steps were taken:

- Input data for the year 2016 was provided to NLR by AENA.
- NLR verified the input data and where necessary the input data were modified.
- NLR modelled a departure route from runway 25L including dispersion.
- NLR used INM to perform noise computations.
- The results of the computations were processed to provide figures with noise contours.

After the validation of the input data, some improvements were made to the input data. NLR considers the improved input data reliable and representative to provide a good assessment of the noise exposure around Barcelona–El Prat Airport.

Using the improved input data, NLR performed noise computations and provided noise contours for the L_{den}, L_{day}, $L_{evening}$ and L_{night} metrics.

5 References

1. INM website: www.faa.gov/about/office_org/headquarters_offices/apl/research/models/inm_model/, cited on 28th of August 2017.

2. FAA, office of environment and energy, *INM technical manual*, January 2008.

3. Report on Standard Method of Computing Noise Contours around Civil Airports, ECAC.CEAC Doc 29, 3rd Edition, Volume 2: Technical Guide, December 2005.

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5. http://www.aena.es/csee/ccurl/660/807/Estadisticas2016.pdf, cited on 22nd of November 2017.

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7. https://www.worldweatheronline.com/barcelona-weather-averages/catalonia/es.aspx, cited on 22nd of November 2017.

8. http://www.latlong.net/, cited on 22nd of November 2017.

9. AENA, Evaluación acústica escenario 2016. memoria técnica, Aeropuerto de Barcelona - El Prat, October 2017.

Appendix A Noise model and settings

This appendix provides an overview of the INM settings and input data for the Barcelona-El Prat Airport study.

Table A - 1: Noise model information

Software version	INM 7.0d
Bank angle effects	Enabled
Terrain	Enabled
Atmospheric absorption correction	Enabled
Lateral attenuation model[1]	All-soft-ground
Grid type	Recursive (tolerance = 0.25, refinement = 12)
Metrics	L_{day} (07h-19h), $L_{evening}$ (19h-23h), L_{night} (23h-07h) & L_{den} (24h)

Table A - 2: Meteorological conditions

Temperature	16.7°C
Pressure	1016 mbar
Relative Humidity	69%
Headwind component[2]	14.8 km/h

Table A - 3: Traffic summary with total number of movements in 2016

Runway	Arrivals	Departures
02	15,656	0
20	2	68
07L	25,303	811
07R	20	37,374
25L	3,118	114,146
25R	109,771	1,595

[1] ECAC Doc.29 does not support other lateral attenuation models
[2] ECAC Doc.29 default

Appendix B Verification procedure

This appendix provides more details on the verification of the input data that was provided by AENA as a basis of the INM noise computations. After the validation of the input data, some improvements were made to the input data. NLR considers the improved input data reliable and representative to provide a good assessment of the noise exposure around Barcelona–El Prat Airport.

The verification of the following types of data will be discussed:

- Computation grid (see Appendix B.1).
- Airport data (see Appendix B.2):
    - Runway locations.
    - Terrain data.
    - Meteorological information.
- Flight routes (see Appendix B.3).
- Flight procedures (see Appendix B.4).
- Aircraft data (see Appendix B.5).
- Flight schedule (see Appendix B.6).

Appendix B.1 Computation grid

NLR verified that the grid that was used for the noise computations was suited for this purpose.
A so-called recursive grid is used, which is an efficient method that is suited to compute noise contours in this type of noise studies. To use this method, values for the tolerance and refinement are defined. Both have values that are suited for this type of study.

Appendix B.2 Airport data

Appendix B.2.1 Runway locations

In INM the following information is provided for each runway:

- The location of both runway ends.
- The elevation of both runway ends.
- The displacement of the threshold. This can be defined for approaches and departures individually.

The INM studies use a local Cartesian coordinates system, with the origin at the one of the runway ends. All other relevant locations are defined by their offset of this origin in the UTM coordinate system.

The threshold locations were calculated from the AIP (with an additional visual cross check using Ref. 8). For runways with a displaced threshold, the displacement was taken from the AIP and the locations of the runway end locations were calculated, either directly from the locations provided in the AIP, or from the threshold locations in combination with the displacement. All required runway end elevations were available directly from the AIP.

The calculated runway end locations, and the obtained runway end elevations and threshold displacements were compared to the data modelled in the INM study. This showed that the modelling was correct.

Appendix B.2.1 Terrain data

The INM study contains a so-called terrain model. This model is used to include the effect of differences in elevation in the area around Barcelona-El Prat Airport. The terrain directly around the airport is flat, but further away from the airport, some changes in elevation occur.

The terrain model was compared to elevation information in Google Earth. This was done for the runways and for two locations around the airport. This showed that the elevation in the INM terrain model was comparable with the information from Google Earth.

Appendix B.2.2 Meteorological information

For noise computations, assumptions are made regarding meteorological information, such as the temperature, air pressure and relative humidity. AENA provided historical data and using this data, NLR verified the average levels for temperature and pressure for 2016. For pressure, a very small difference was found, with a negligible effect. Therefore, the value of the pressure was not changed. For temperature, exactly the same value was found as in the INM study. Furthermore, NLR compared climatic data (Ref. 6 and Ref. 7) with the values used in the INM study. This showed that the temperature, pressure and relative humidity are realistic.

Appendix B.3 Flight routes

Since Barcelona-El Prat Airport is located close to the sea, most of the flight routes are mainly located above the water. When an aircraft flies over the sea, not too close to the land, no people will be affected by the noise and therefore, the accuracy of flight routes at such locations is less relevant. Therefore, the flight procedure modelling further away from the coast has not been verified in detail, especially when the effect on the noise contours is expected to be small.

From each runway, one or more arrival and departure routes can be defined. For each route two aspects are modelled:

- The nominal flight route, that models the average location of the flight route.
- The route dispersion for departure routes. The dispersion models the deviations from the nominal flight route that occur in practice since not every aircraft on a specific flight route will follow exactly the same flight path.

For runway 25L and 25R two approach routes are available, but with minor differences, further away from the airport and above the sea. The other runways only use a single straight-in route. Considering the extent of the noise contours and the AIP, this modelling is considered to be correct for all relevant areas.

In the INM study, the route dispersion of departure routes is based on radar tracks (ref. 9). For departure routes from runway 25L, NLR analysed radar tracks and modelled a flight route including dispersion based on this analysis. All other departure routes were provided by AENA and NLR compared these routes with the AIP. This comparison shows that these routes are modelled in a realistic manner in all relevant areas (populated areas above land and inside or near the noise contours). The modelled routes do not need to be exactly equal to the AIP routes, since they are based on actual radar tracks.

In order to model a departure route from runway 25L including dispersion, radar tracks were analysed by NLR. This was done by analysing the locations of actual flight tracks at several gates along the route using the following steps:

- Collect intersection locations for five predefined gates for all radar tracks of departures from runway 25L for a period of three months.
- Perform statistical analyses of the intersection data at all gates.
- Define points for a nominal route and sub-tracks at all gates.
- Define additional points based on interpolation between the points at the gate locations.
- Define additional points based on extrapolation after the last gate.

Suggestions from the Doc29 methodology were taken into account in the modelling of the departure route from runway 25L.

Appendix B.4 Flight procedures

For all arrivals a continuous descending (CDA) flight path is assumed in the INM study. This means that aircraft do not level off at intermediate altitudes during the approach, at least not at relatively low altitudes. Before verifying the flight procedure modelling, NLR first determined whether the modelling of flight procedures is expected to have an effect on the noise contours. If this is not the case, further verification is not deemed necessary.

For this purpose, arrivals to each runway were considered separately:

- Arrivals runway 02: the AIP describes an arrival procedure with a horizontal segment at 2000 feet for this runway. Since arrival routes to this runway are almost completely above the sea, using a CDA profile is sufficient to provide good modelling of the noise above land.
- Arrivals runway 07L: the AIP describes an arrival procedure with a horizontal segment at 3000 feet for this runway. If this procedure should be used instead of a CDA, this might have impact on the shore region north of flight the path. NLR still thinks that using a CDA profile is acceptable since this is outside all considered noise contours and since a visual inspection of the area using Google Earth shows that this area is sparsely populated.
- Arrivals runway 07R: this runway is not regularly used for approaches and therefore arrival procedures to this runway do not require further verification.
- Arrivals runway 20: this runway is almost never used for arrivals and therefore arrival procedures to this runway do not require further verification.

- Arrivals runway 25L: the AIP describes an arrival procedure with a horizontal segment at 1800 feet approach for this runway. The point where aircraft reach this altitude is far from the shore. Therefore, using a CDA profile is sufficient to provide good modelling of the noise above land.
- Arrivals runway 25R: the AIP describes an arrival procedure with a horizontal segment at 2300 feet for this runway. The point where aircraft reach this altitude is far from the shore. Therefore, using a CDA profile is sufficient to provide good modelling of the noise above land.
- For some runways, the AIP indicates that a so-called VOR procedure is available, which might have a horizontal segment at a lower altitude. These procedures are not modelled in INM, but NLR expects that these procedures are not regularly used and that even for these procedures, a CDA provides an acceptable modelling in all populated areas within the noise contours. Therefore, NLR agrees with the fact that these procedures are not separately modelled in INM.

In summary, this means that NLR agrees with the modelling of all arrival procedures to each runway.

For departures, as indicated in section 2.3, the modelling is done in a conservative way, which leads to an overestimation of the noise exposure.

Appendix B.5 Aircraft data

For noise computations two types of aircraft data are required:

1. Performance data that defines the speed, thrust and altitude of an aircraft along its flight path.
2. Noise data that defines the noise levels of an aircraft for different thrust settings and different distances between the aircraft and the ground.

Both are provided by the aircraft database of INM. However, ECAC Doc.29 recommends the use of the Aircraft Noise and Performance (ANP) database. The INM database is in general identical to the ANP database, but slightly more extensive. This means that in some cases, an aircraft type is available in the INM database but not included in the ANP database. Therefore, NLR investigated what aircraft types from the INM database are not available in the ANP database and replaced these types in the study by similar types that are available in the ANP database. The overall effect on the results is expected to be negligible, as it concerns relatively small and quiet aircraft with less than 10 movements.

Furthermore, NLR also checked the mapping between the registered aircraft types (ICAO aircraft type code) and the selected representative INM/ANP aircraft type. The ANP database provides guidance for this mapping, based on the so-called ANP recommended substitution list. NLR performed a detailed check of the applied mapping for the types that together generate at least 97.5% of the flight movements and a visual inspection for the remaining types. The detailed check included an analysis of the engine models used by the different airlines that visit the airport, at least for the cases where the ANP recommended substitution list indicates that this is relevant for the mapping.

Based on these checks, the modelling is considered to be correct. In order to make sure that the modelling is in line with the ANP database, NLR changed the mapping of 4 aircraft types.

Appendix B.6 Flight schedule

The flight schedule as used in the INM study for 2016 was verified. The flight schedule contains information on the following aspects:

- The total number of flight movements
- Flight times
- Aircraft type used
- Runway used
- Flight route used
- Flight procedure used.

Number of flight movements

Reference 5 contains information about the total number of movements. The number of movements in this document corresponds to the number of movements in the INM study.

Flight times

The source data for the flight schedule as provided by AENA contains the departure and arrival times for all 2016 flight movements. NLR compared several departure and arrival times in this data with the current (November 2017) scheduled times for these flights. While scheduled times of particular flights may have changed since last year, it is expected that for most flights the times should remain the same. For the investigated cases, this indeed turned out to be the case. This check also confirmed that the recorded times are indeed in UTC, not in local time.

Based on the departure and arrival times of the flights, NLR calculated the local time for each flight and determined whether it should be treated as a day, evening or night flight. The results were compared to flight schedule data as used in the calculation. This showed that the division of flights of day, evening and night was done correctly.

Aircraft type used

The source data for the flight schedule as provided by AENA contains the ICAO aircraft type for all flight movements. Apart from the mapping (see Appendix B.5), NLR verified that the distribution of the flights over the different aircraft types corresponded to the distribution as used in the INM study.

Runway used

The source data for the flight schedule as provided by AENA (PALESTRA data) does contain the runway used. NLR had no means of verifying the source data, but could confirm that the runway assignment in the source data corresponds to the runway use as modelled in the INM study. This means that the source date was correctly used to generate the input data for INM.

Flight route used

In most cases, the assignment of departure routes is trivial since for all runways, except for runway 20, only one departure route is available (this means that it is not possible to assign the wrong flight route to a flight movement from such a runway). For runway 20, the PALESTRA data, AIP and INM study have been compared. This showed that the correct departure routes were assigned for the departures from runway 20.

For runways 25L and 25R, two arrival routes are available, but these routes only vary above the sea relatively far away from the land. Therefore, there is no need to validate the route assignment to these routes.

Flight procedure used

In the INM study, only one departure and one arrival procedure is used. This means that it is not possible that the wrong procedure is assigned to a departure or arrival (if more than one arrival and/or departure procedure would have been available, this could have been the case). Therefore, there is no need to verify the procedure assignment in detail.

Appendix C Contour figures in larger format

This appendix contains larger versions of Figure 1 to Figure 4.

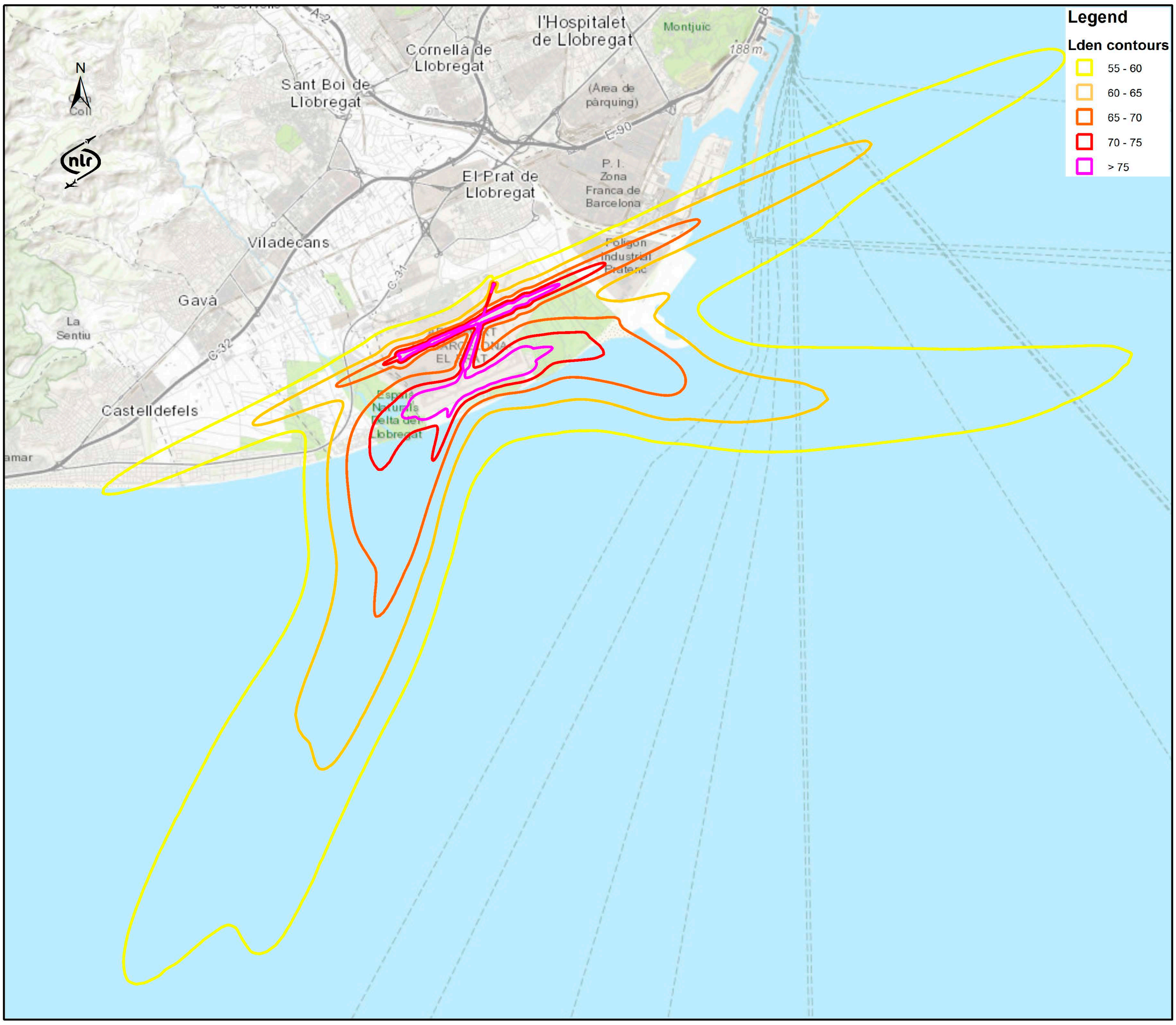

Figure C - 1: L_{den} contours

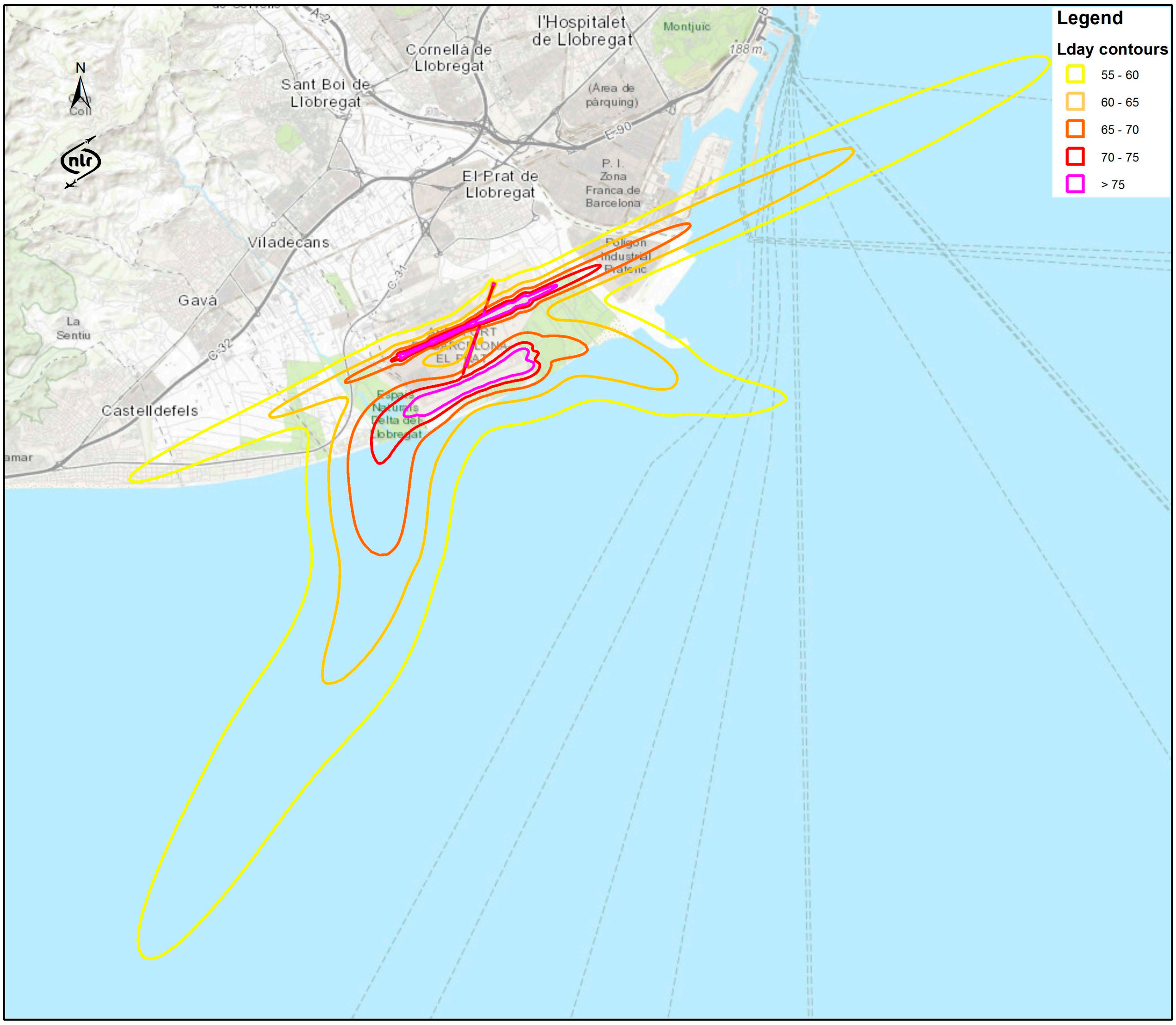

Figure C - 2: L_{day} contours

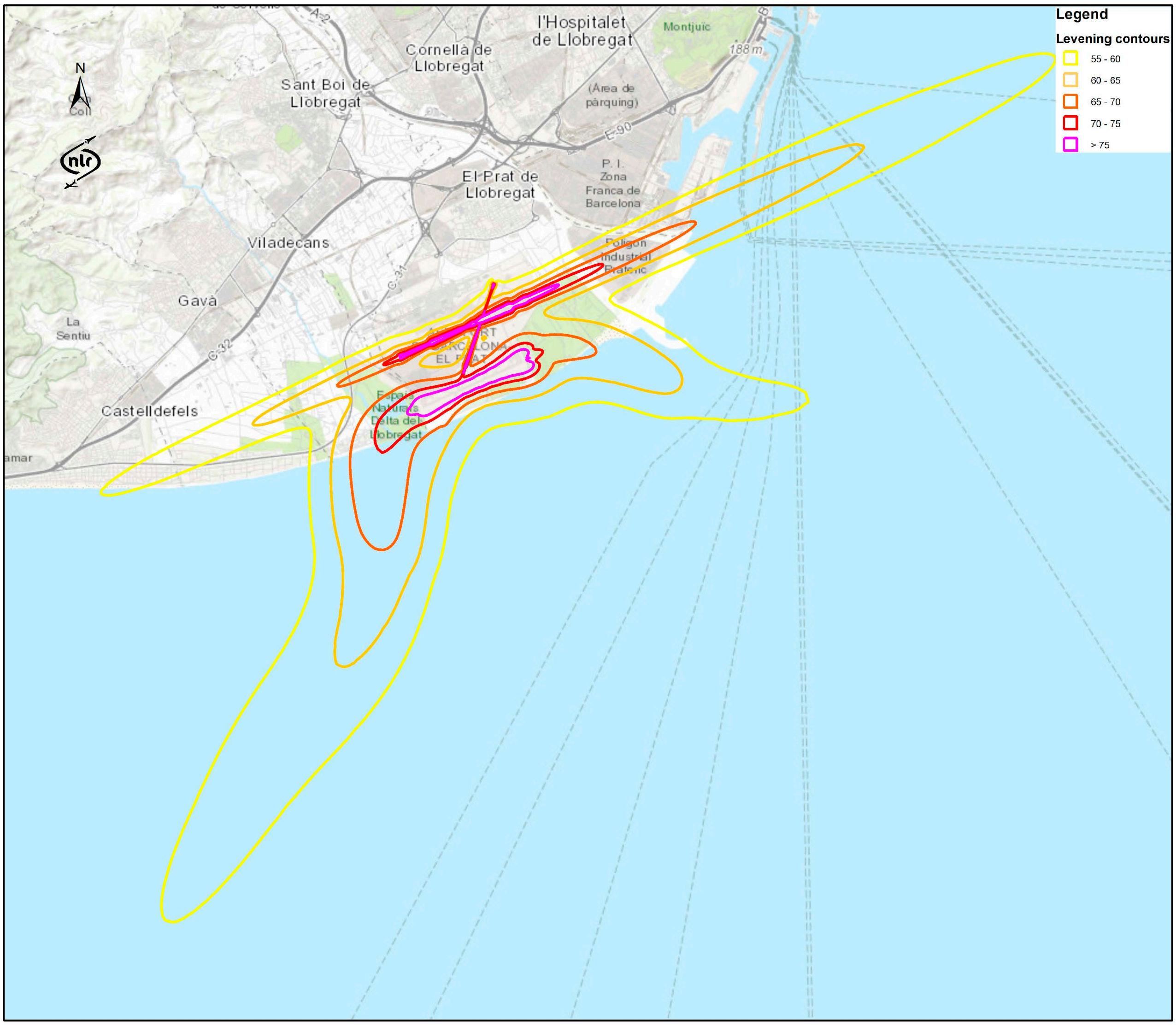

Figure C - 3: $L_{evening}$ contours

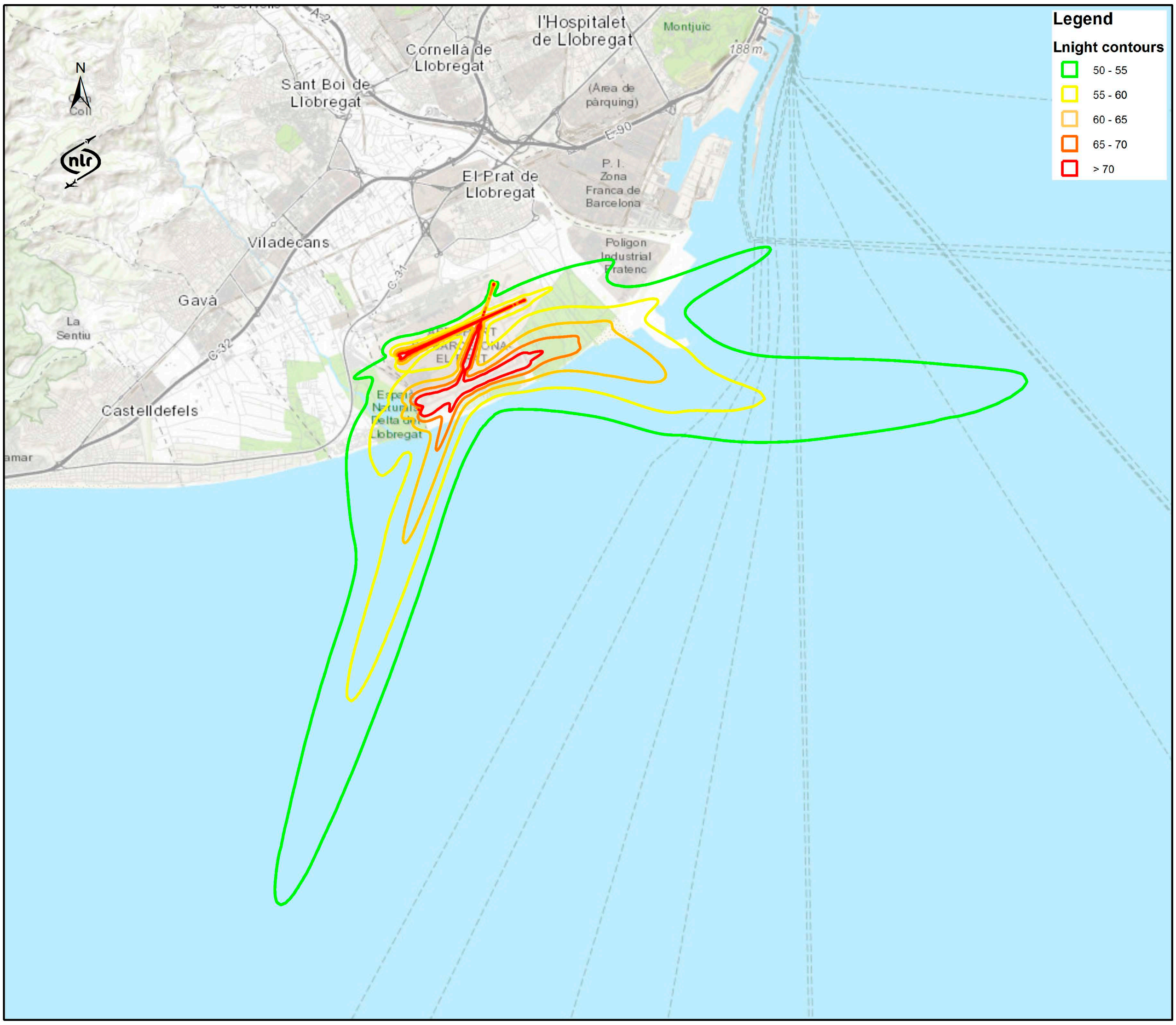

Figure C - 4: L_{night} contours

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