CEPT ECC
Electronic Communications Committee

PTD (#5)

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Subject: **Comparison between flat-terrain and real terrain path propagation**

Group membership required to read? (Y/N) N

Summary:

For many compatibility studies involving RAS stations, for example under WRC-23 Agenda Item 1.5, analyses are based on flat-terrain aggregation studies, to provide generic information, independent on specific sites. Sometimes concerns are raised that for real RAS observatories, the actual topography would provide natural shielding by means of diffraction losses and thus the overall path propagation losses would be significantly higher than for the case of flat terrain. Here, we provide a comparison of both cases by looking at typical attenuation values as a function of distance, calculated according to ITU-R P.452. In one case we take all topographical information into account, and in the other case we assume a flat surface of the Earth. For the exemplary frequencies 610 MHz and 6.65 GHz we find that the difference between simplified and topographically correct attenuation is between 0 dB and about 30 dB. In fact there are several European and international RAS stations, which are located in relatively flat terrain. Therefore, for generic (i.e., general-purpose) analyses that are usually performed at ITU-R or regional level there are good reasons to base compatibility studies on flat-terrain topography.

Of course, where appropriate, national administrations can and should take into account terrain features during the process of national coordination and/or frequency assignments. This contribution provides some hints towards this aim, but further work is usually necessary when analyzing site-specific cases.

Proposal:

invites Group to take note of the information provided in this document for future discussions of compatibility studies involving passive services.

Background:

(RAS) compatibility studies for frequencies in the range of 0.1 to 50 GHz making use of Recommendation ITU-R P.452 occasionally neglect topographical information and calculate path propagation under the assumption of a flat surface of the Earth. The validity of this approach has not been studied in detail.

1 INTRODUCTION

The appropriate level of accuracy is critical in compatibility studies. Approximations in corresponding calculations are being made for a number of reasons, e.g., to save computing power- and time, or to make dominating physical processes more transparent. This is desirable as long as the impact of the approximation on the result of the study can be estimated. In the case of (RAS) compatibility studies of active and passive services operating between 0.1 GHz and 50 GHz the approximation of a flat Earth's surface is occasionally made. In this contribution we compare simulations to calculate the typical attenuation of a radio signal as a function of distance from a passive radio service station according to ITU recommendation ITU-R P.452. For a number of exemplary RAS stations, we calculate the 5%, the 50% (median), and the 95% percentiles of the attenuation (in dB), once fully taking into account the topographical structure of the surroundings, and once making the simplification of a flat surface of the Earth. We then calculate and tabulate the average difference for radii beyond 10 km. We first describe the method (Sect. 2) to then present the results (Sect. 3). We finally discuss the validity of neglecting the topography in RAS compatibility studies in Sect. 4.

2 METHOD

We make use of the pycraf[1] software package, which provides an implementation of the path propagation model recommended in ITU-R P.452. The topographical information enters into the model through Space Shuttle Radar Topography Mission (SRTM)[2] height maps (in Digital Terrain Elevation Data format), which have a resolution of 3 arcsec (about 90 m).

For each of the exemplary European RAS sites (Effelsberg, Westerbork, Sardinia, Yebes, Jordrell Bank, Onsala, Nançay, see Table 1), a topographical map with a size of 7° × 7° and a pixel size of 6" × 6" was generated (see an example in Fig. 1).

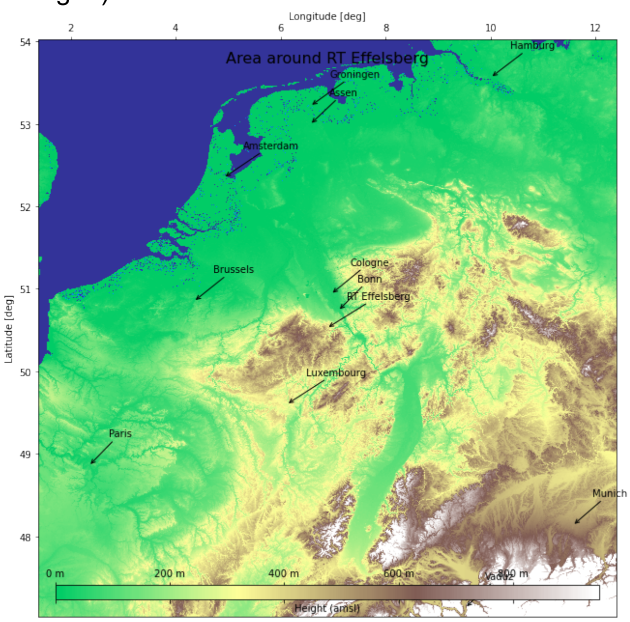

Fig. 1: SRTM Topographical map around RT Effelsberg with a size of 7° × 7° and a pixel size of 6"× 6".

This map was then used to calculate the path attenuation between the RAS station at the centre of the map and each pixel of the map according to recommendation ITU-R P.452. For these calculations, a temperature of 290 K, a pressure of 1013 hPa, and a time percentage of 2 percent was used (i.e., for 2% of the time the attenuation is expected to be lower than the given value for each pixel), and they were carried out for 610 MHz and 6.65 GHz. 2% is the statistically allowable loss in time percentage for RAS due to interferences from a single service in shared or adjacent bands (ITU-R RA.1513-2). The heights above ground of the Rx stations are listed in Table 1. We varied the heights above ground for the Tx stations: 30 m and 1.5 m for 610 MHz,

[1] https://bwinkel.github.io/pycraf/

[2] T. G. Farr, P. A. Rosen, E. Caro, R. Crippen, R. Duren, S. Hensley, M. Kobrick, M. Paller, E. Rodriguez, L. Roth, D. Seal, S. Shaffer, J. Shimada, J. Umland, M. Werner, M. Oskin, D. Burbank and D. Alsdorf, "The Shuttle Radar Topography Mission:" Reviews of Geophysics, vol. 45, 2007"

20 m and 1.5 m for 6.65 GHz, representing for example typical heights of IMT base stations and handsets. Examples are given in Fig. 2.

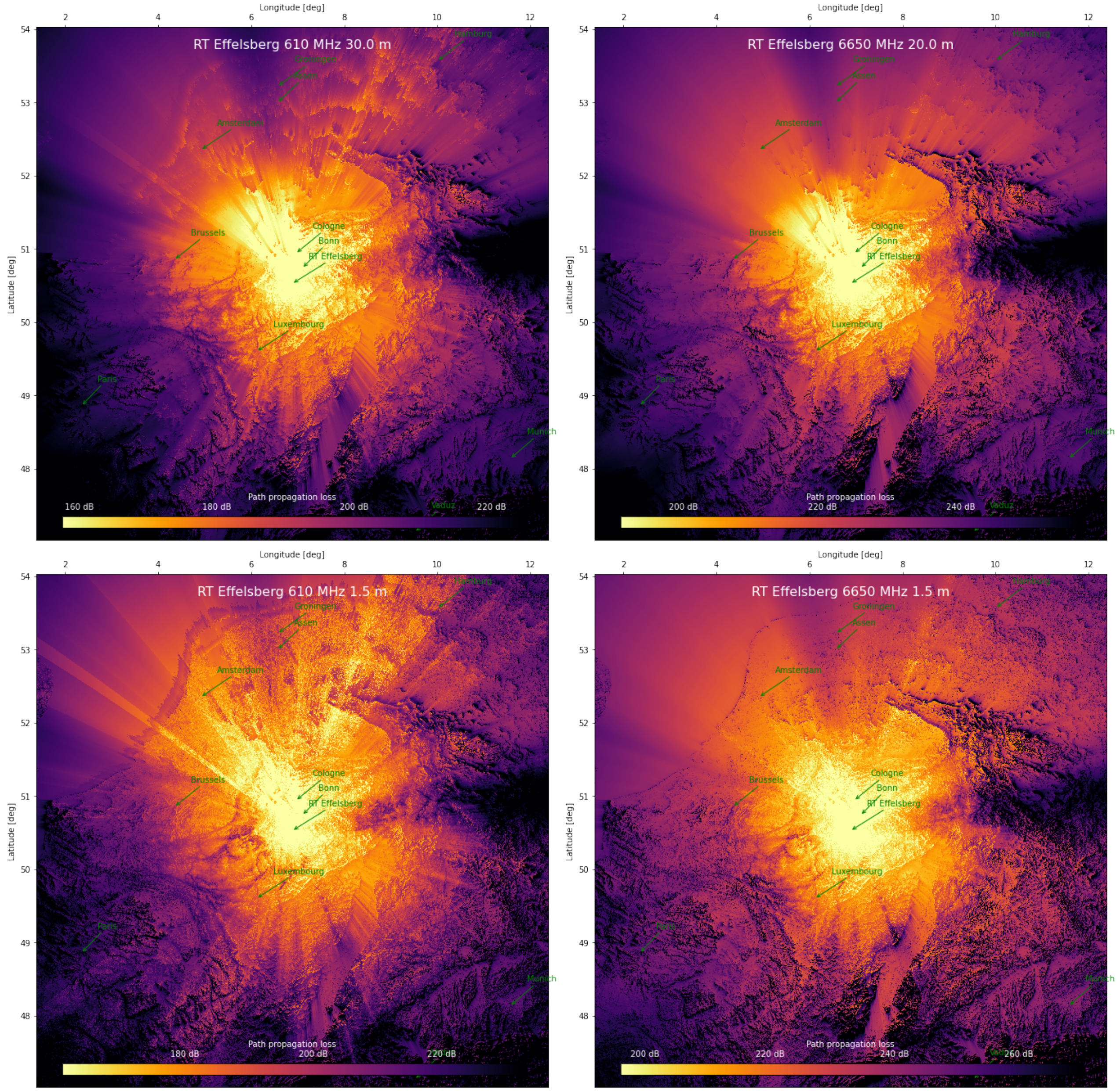

Fig. 2: Attenuation maps around RT Effelsberg with a size of 7° × 7° and a pixel size of 6”× 6“. Each pixel reflects the attenuation under standard condition and a time percentage of 2% towards the map centre (RT Effelsberg). Left: 610 MHz. Right: 6.650 MHz. Top left: Tx 30 m above ground. Top right: Tx 20m above ground. Bottom left and right: 1.5 m above ground.

Then, in radial bins of 1 km, the maximum, the 95% percentile, the median, the 5% percentile, and the minimum were calculated for each bin. The calculations were repeated under the assumption of a flat surface, i.e., a topography with an elevation of 0 m above the geoid at each pixel. Given that along any circle around the position of the passive station the attenuation is the same if a constant elevation of 0 m is assumed, the spread in attenuation is close to 0, and its scatter is due to resolution effects. We hence only considered the median value for the attenuation in the flat-surface approximation.

As expected, the attenuation in the flat-surface approximation is lower than when taking topological effects into account. We subtracted the flat-surface attenuation curve from the 95%, 50%, and 5% percentiles in the full simulation and, to get a single figure-of-merit for an estimate, calculated an average difference between flat-surface curve and the median curve for the full simulation the in the range 10 km – 500 km. Figure 3 shows an example.

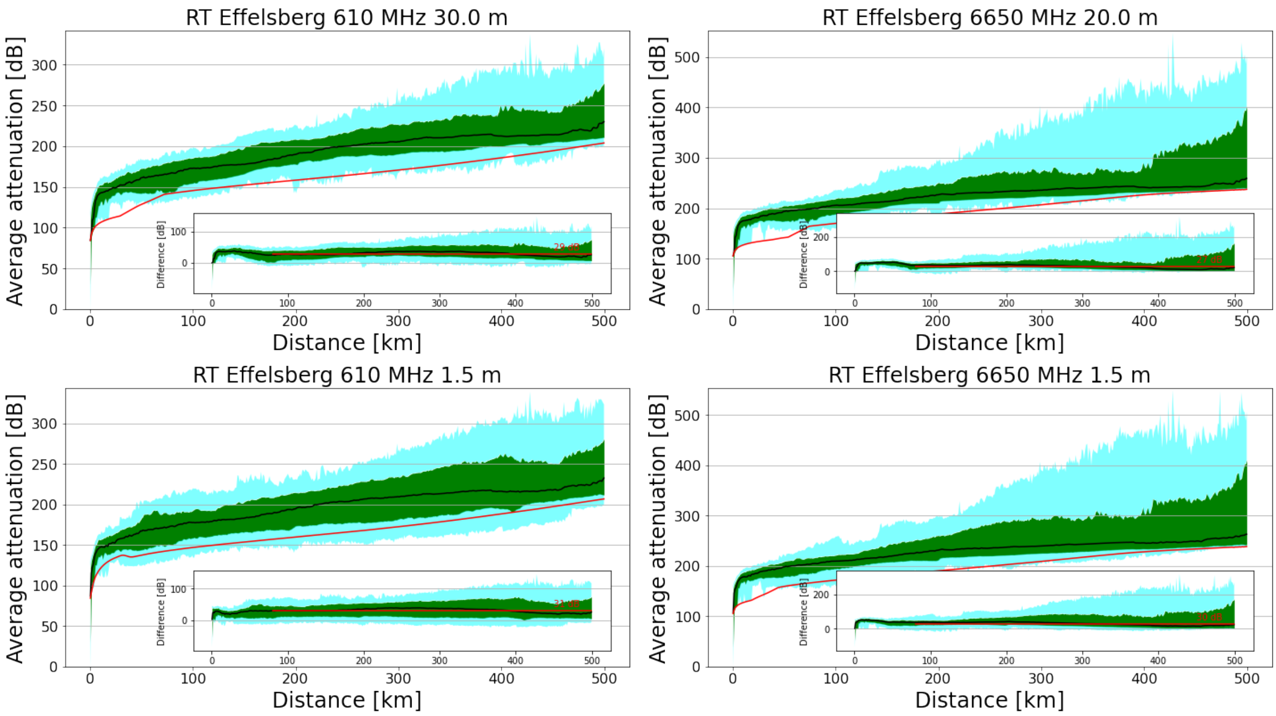

Fig. 3: Attenuation as a function of distance from RAS station Effelsberg under standard conditions and for a time percentage of 2% following ITU-R P.452. Main panel: black line: median. The envelopes of the green area are the 5% and the 95% percentiles, the envelopes of the cyan area are the minimum and the maximum value. The red line is the median attenuation when assuming a flat surface. Inlay: Same quantities as main panel minus the flat-surface (red) line in the main panel. Red line: average of the difference between the medians (red and black line in main panel) between a distance of 10 km and 500 km. Left: 610 MHz. Right: 6.65 GHz. Top left: Tx 30 m above ground. Top right: Tx 20 m above ground. Bottom left and right: Tx 1.5 m above ground.

3 RESULTS AND DISCUSSION

We show the results of our calculations for the single radio stations in Figs. 1-8 in the previous section and the Annex, while Table 1 shows again the averaged differences between a flat-earth calculation and the full simulations between 10 km and 500 km distance between the RAS station and the potential transmitter.

Table 1: Geographical position (latitude and longitude) and height above ground of exemplary radio stations and average difference in attenuation between full simulations following ITU-R P.452 and under the assumption of a flat surface of the earth for transmitters Tx 30 m, 20 m, and 1.5 m above the ground.

RAS station	Latitude (deg)	Longitude (deg)	Height above ground (m)	Average difference in attenuation 610 MHz 30 m/1.5 m (dB)	Average difference in attenuation 6.65 GHz 20 m/1.5 m (dB)
Effelsberg	50.52483	6.88361	50	29/31	27/30

RAS station	Latitude (deg)	Longitude (deg)	Height above ground (m)	Average difference in attenuation 610 MHz 30 m/1.5 m (dB)	Average difference in attenuation 6.65 GHz 20 m/1.5 m (dB)
RT Westerbork	52.91474	6.60334	22.5	0/1	0/2
RT Sardinia	39.49278	9.24500	32	32/31	34/33
Yebes	40.52467	-3.08694	20	25/26	25/26
Jordrell Bank	53.23611	-2.30722	38	20/19	18/18
Onsala	57.39306	11.91778	12.8	10/12	9/11
Nançay	47.37333	2.197222	2.0	20/21	23/26

From Table 1 it can be concluded that the *difference* in attenuation does not vary much between 610 MHz and 6.65 GHz, despite the fact that the absolute attenuation is significantly larger in the higher frequency range. In total, the difference between attenuations calculated using a flat-surface approximation and a full estimate including topographical information ranges between 0 dB and about 30 dB. As expected, the largest differences emerge if the surroundings of the RAS stations deviate significantly from a flat surface, i.e., when the RAS stations are sited in a mountain area. This is the case for the stations Effelsberg and Sardinia. On the contrary, for RAS station Westerbork in The Netherlands, no practical difference between the two approaches can be seen.

4 SUMMARY

We hence show that radio stations exist, for which the approximation of a flat surface is accurate. This implies that for the general case of a compatibility study aiming at the protection of all radio stations in Europe or world-wide, including the most unprotected ones, the assumption of a flat surface is justified and can (or even should) be used for compatibility studies.
Of course, where appropriate, national administrations can and should take into account terrain features during the process of national coordination and/or frequency assignments. This contribution provides some hints towards this aim, but further work is usually necessary when analyzing site-specific cases.

Since the most vulnerable RAS stations have to be included in a general compatibility study, the assumption of a flat Earth's surface is accurate for generic compatibility studies involving RAS stations (within Europe).

ANNEX 1:

We present the calculated maps and profiles for the single exemplary RAS stations in this work. The following descriptions are valid for all Figs. In this annex:
Figures a, Top panel: Topological map around RAS station.
Middle panels: Attenuation maps around the RAS station with a size of 7° x 7° and a pixel size of 6´´x 6´´. Each pixel reflects the attenuation under standard condition and a time percentage of 2% towards the map centre (RAS station). Left: 610 MHz. Right: 6.650 MHz. Top left: Tx 30 m above ground. Top right: Tx 20m above ground. Bottom left and right: 1.5 m above ground.
Figures b: Attenuation as a function of distance from the RAS station under standard conditions and for a time percentage of 2% following ITU-R P.452. Main viewgraph: Black line: median. The envelopes of the green area are the 5% and the 95% percentiles, the envelopes of the cyan area are the minimum and the maximum value as a function of radius. The red line is the median attenuation when assuming a flat earth's surface. Inlay: Flat-surface (red) line in the main panel subtracted from corresponding quantities shown in the main panel (maximum, 95% percentile, median, 5% percentile, minimum). Red line in inlay: average of the difference between the medians (red and black line in main panel) for distances between 10 km and 500 km.
Left: 610 MHz. Right: 6.650 MHz. Top left: Tx 30 m above ground. Top right: Tx 20m above ground. Bottom left and right: 1.5 m above ground.

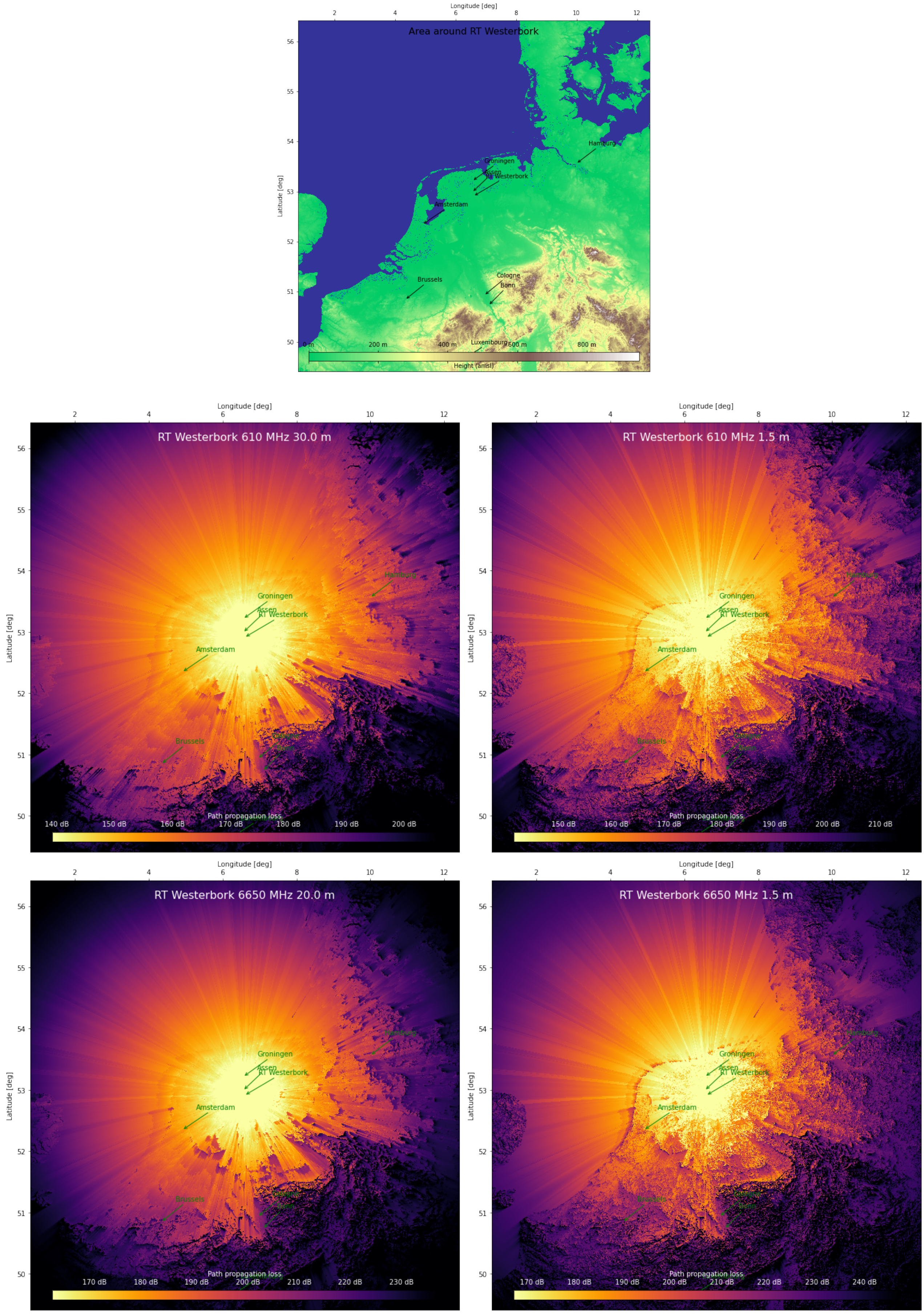

Fig. 4a: RAS station Westerbork Synthesis Radio Telescope (WSRT)

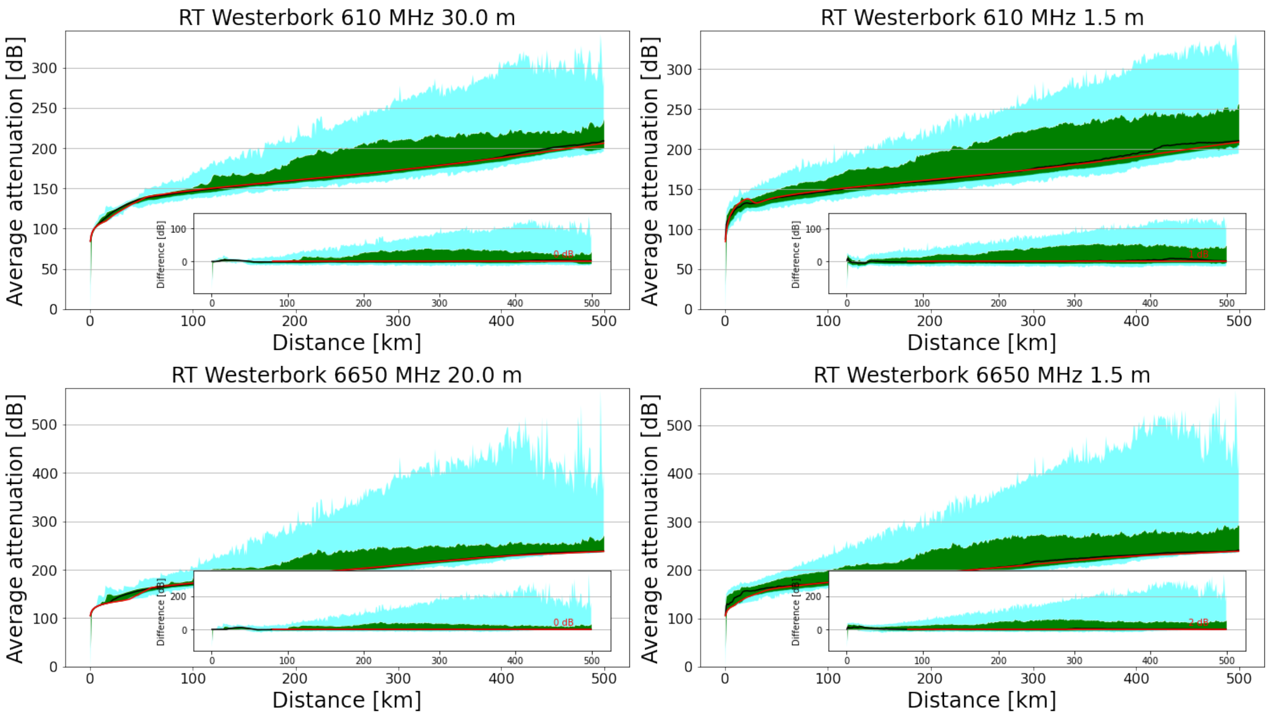

Fig. 4b: RAS station Westerbork Synthesis Radio Telescope (WSRT)

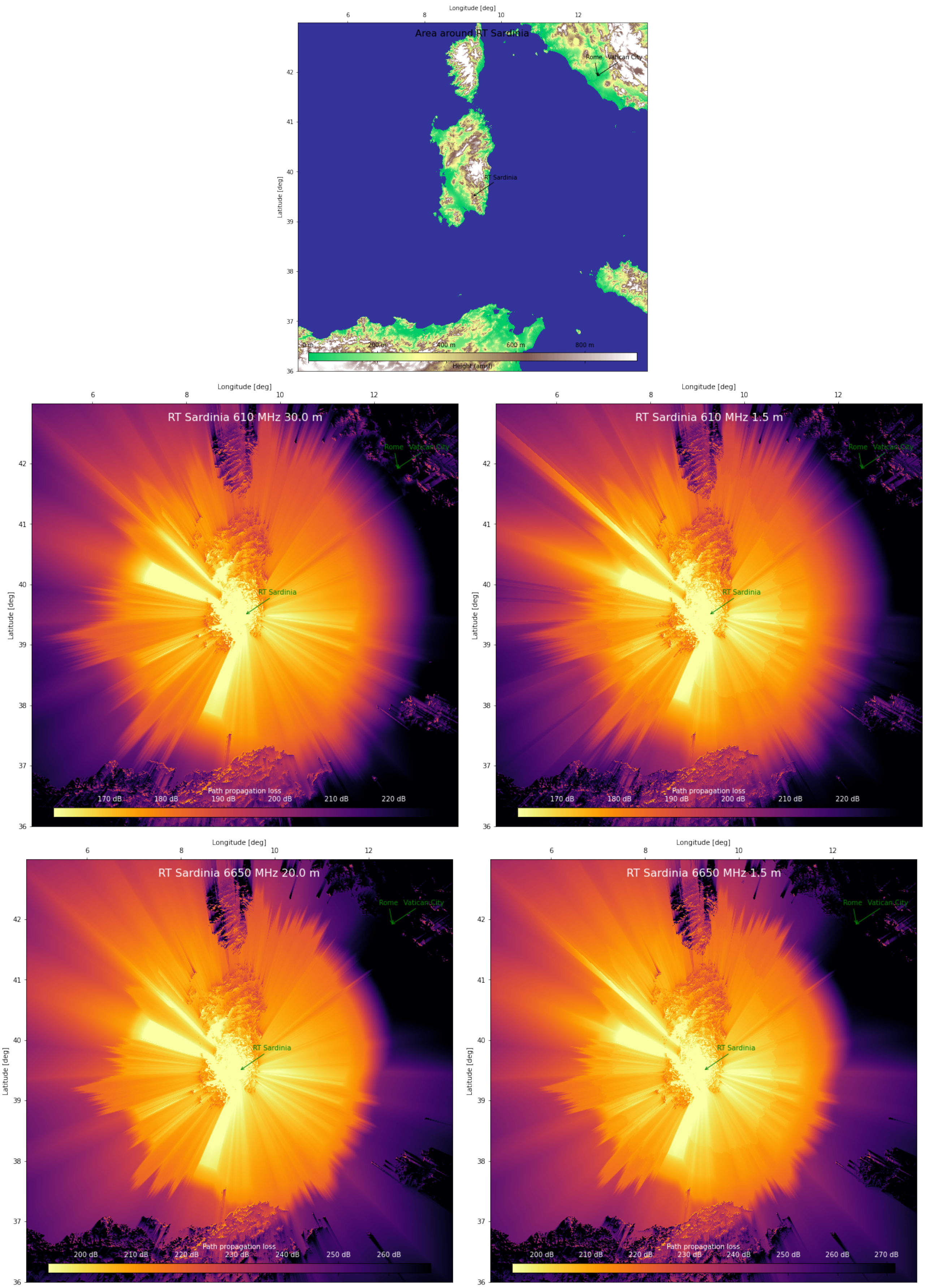

Fig. 5a: RAS station Sardinia Radio Telescope

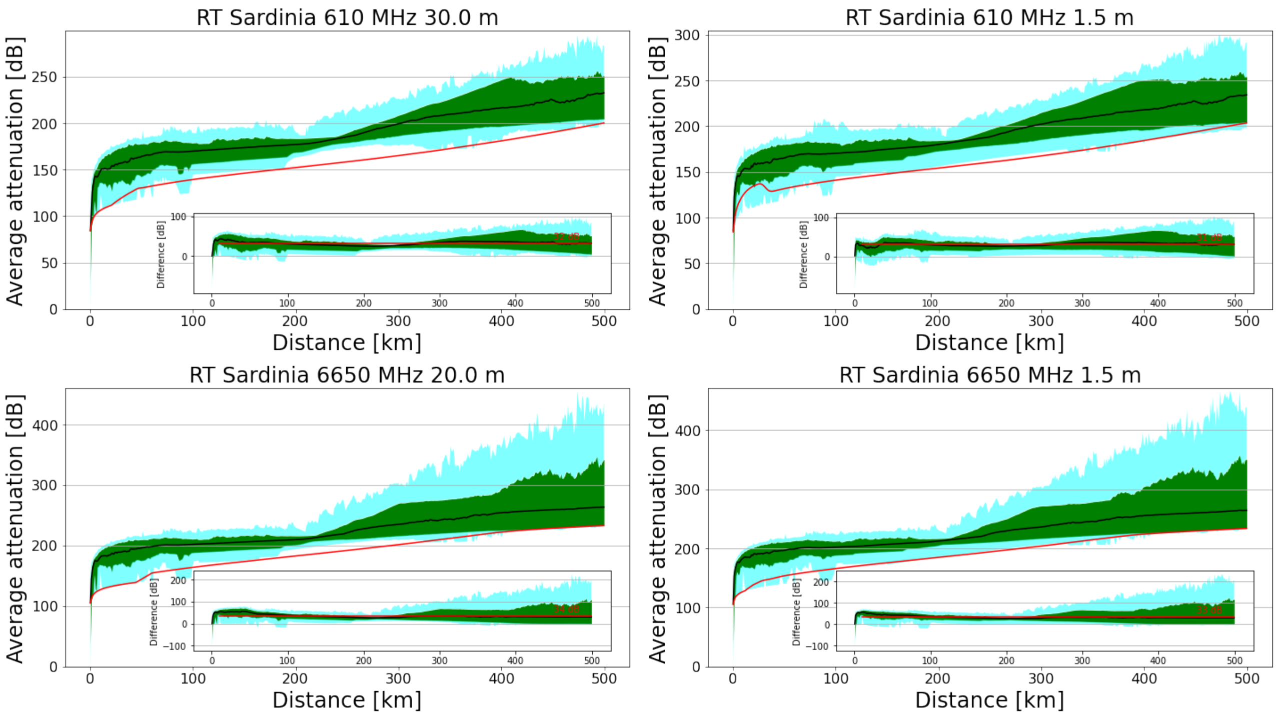

Fig. 5b: RAS station Sardinia Radio Telescope

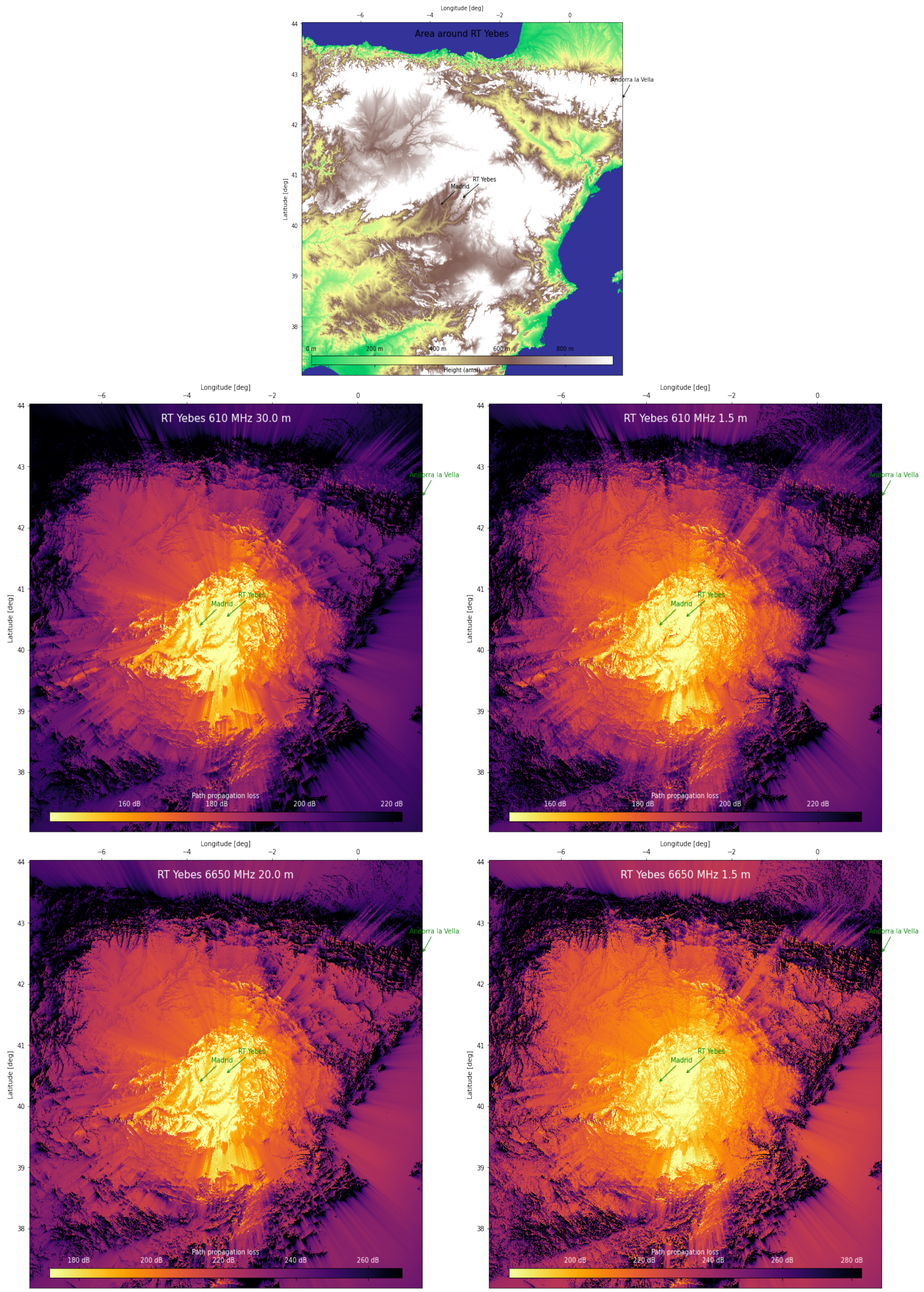

Fig. 6a: RAS station Yebes

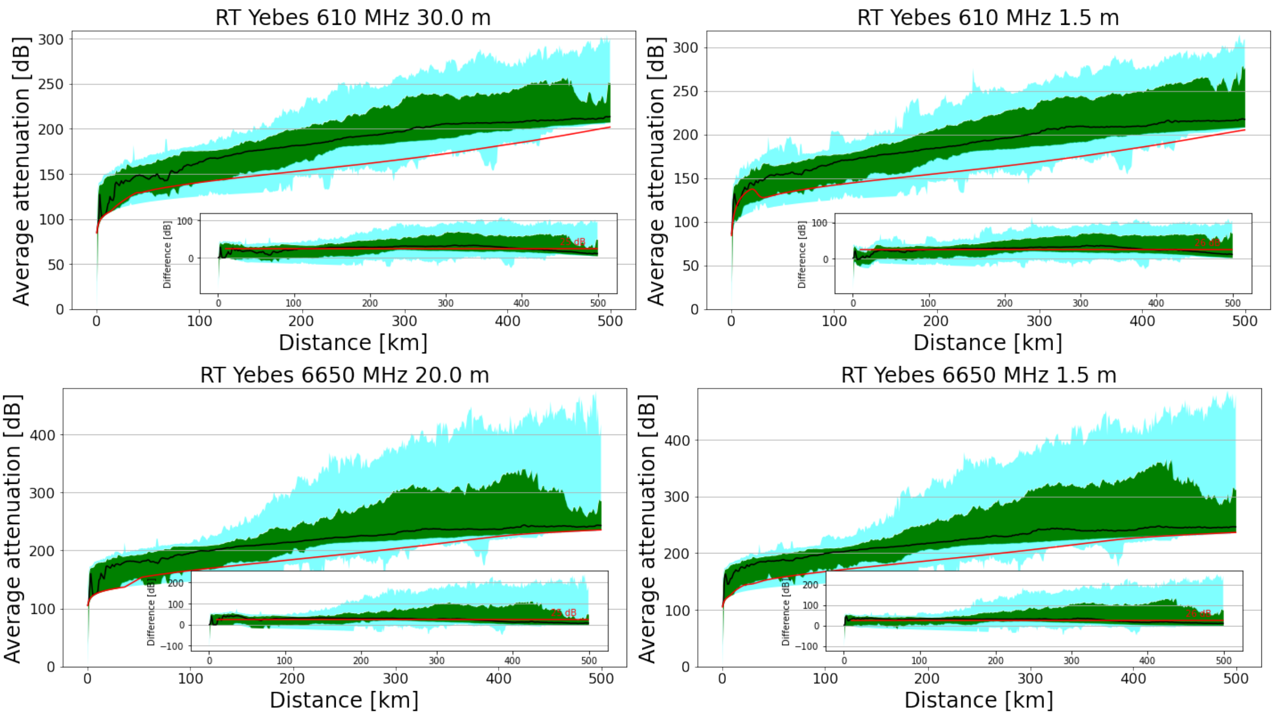

Fig. 6b: RAS station Yebes

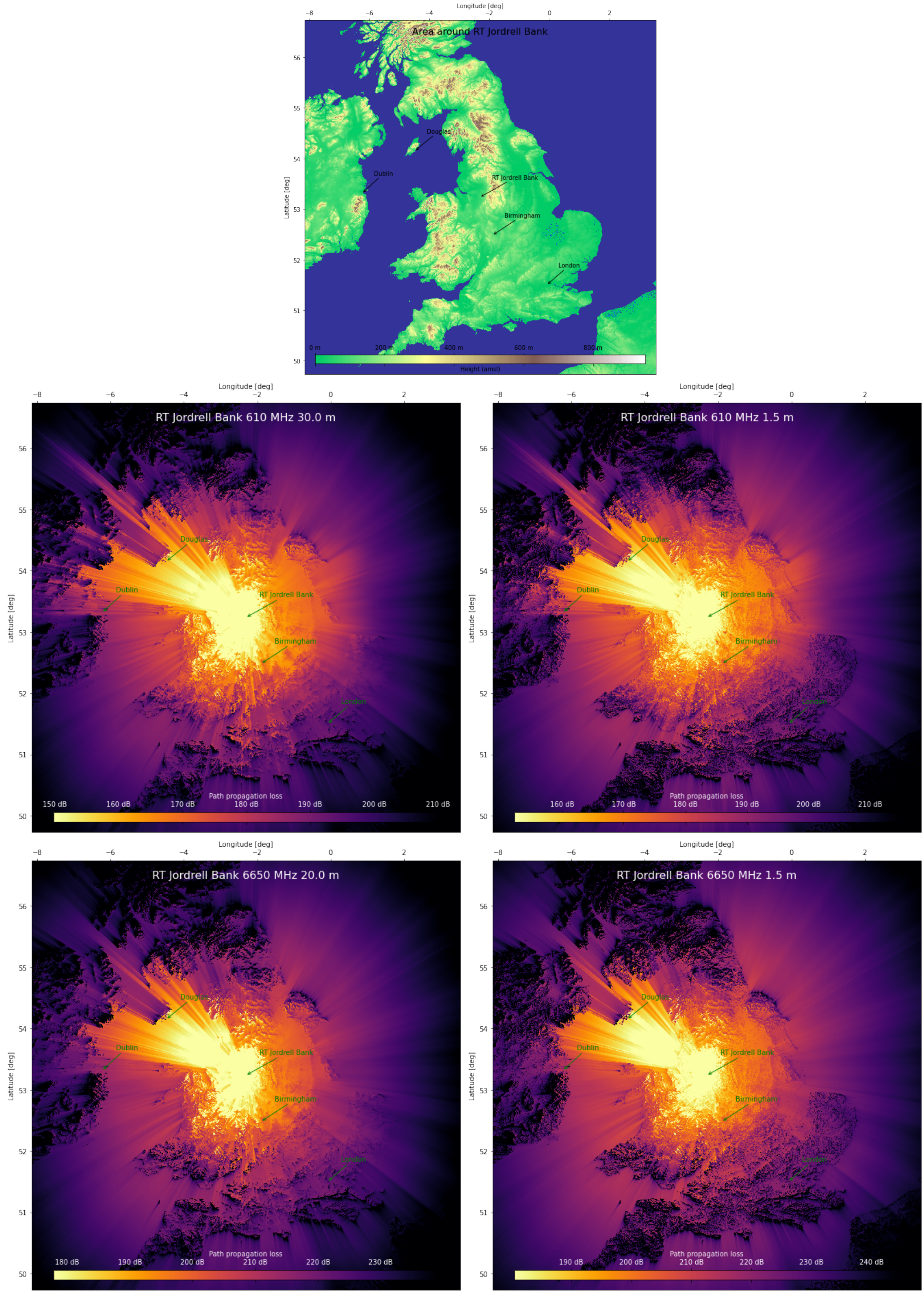

Fig. 7a: RAS station Jordrell Bank

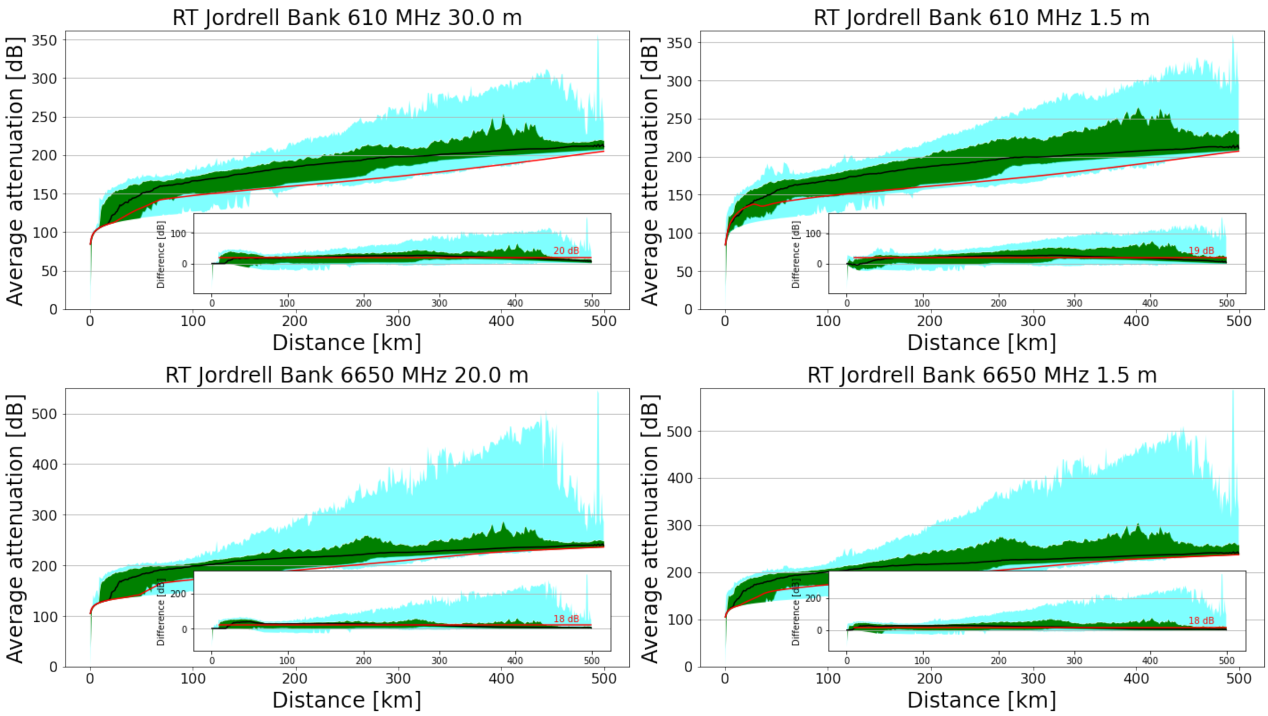

Fig. 7b: RAS station Jordrell Bank

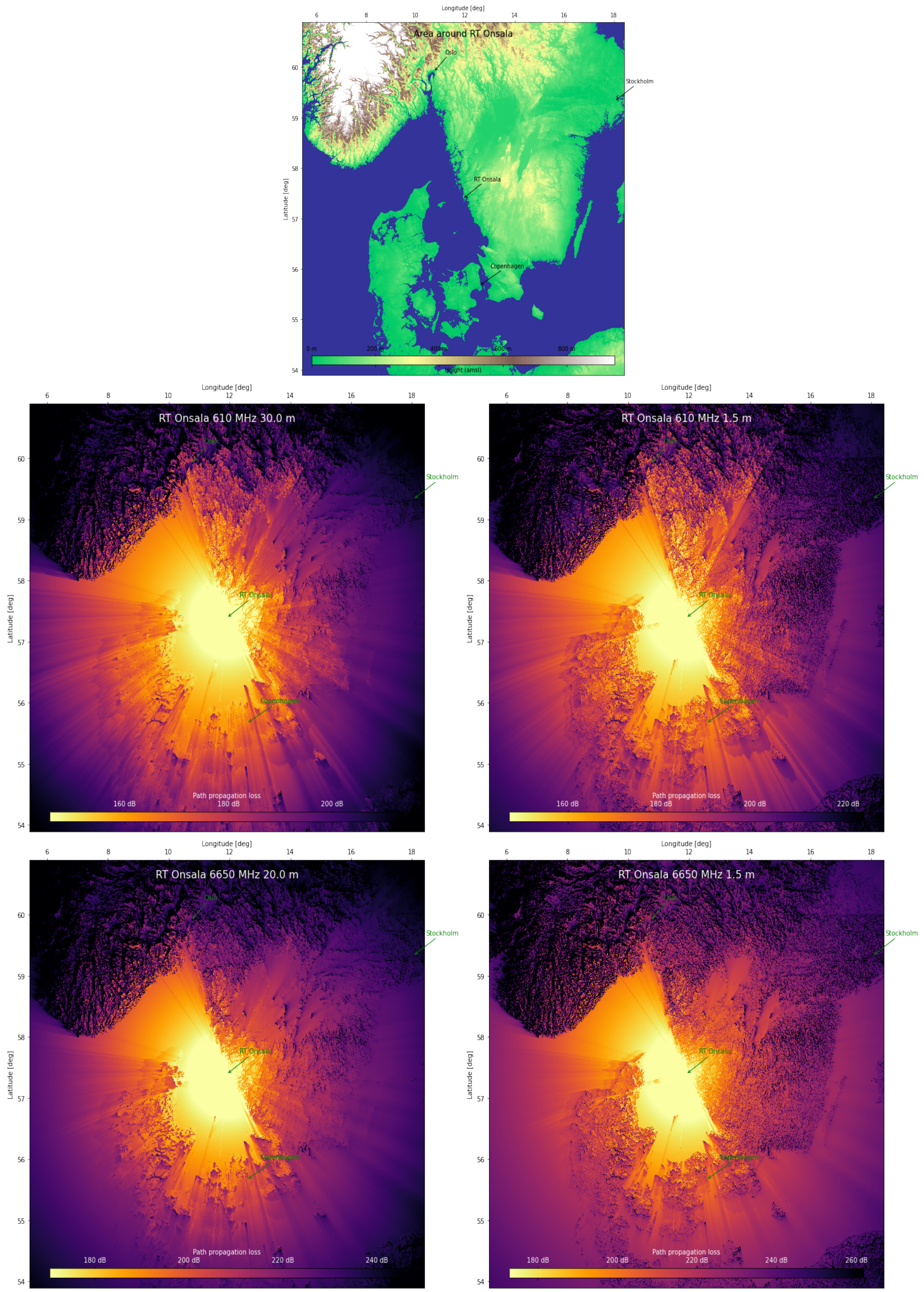

Fig. 8a: RAS station Onsala

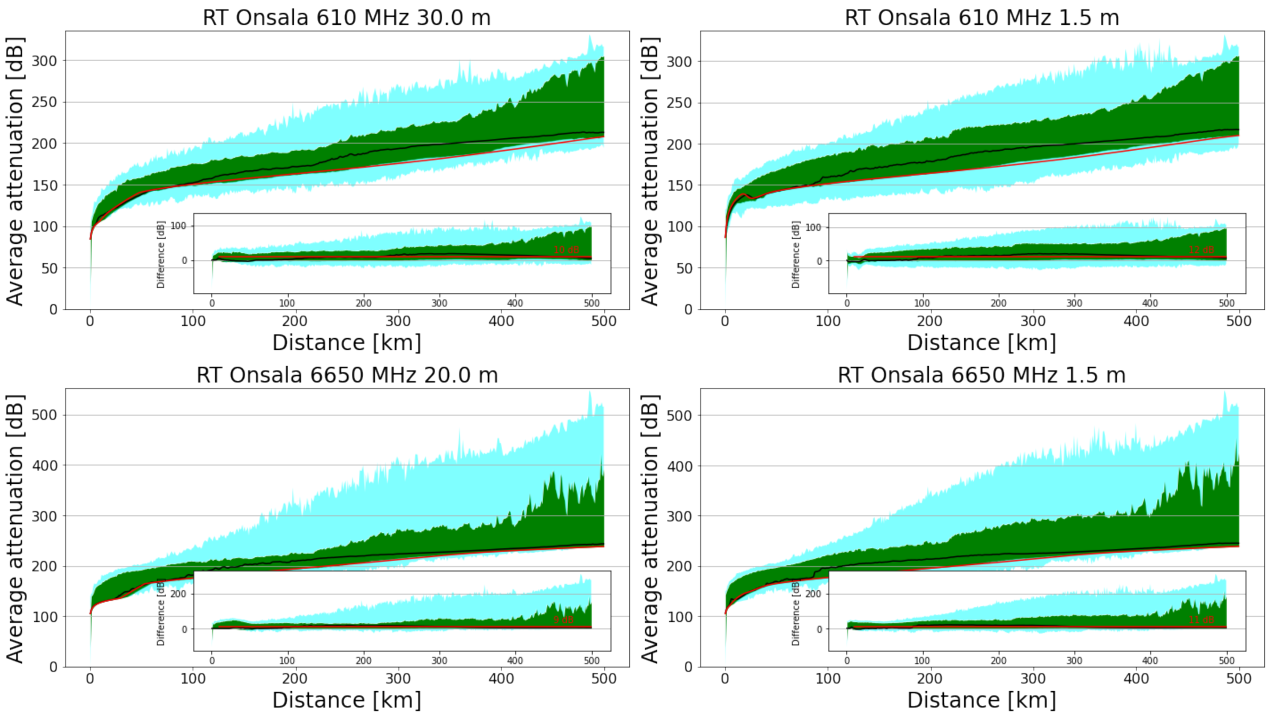

Fig. 8b: RAS station Onsala

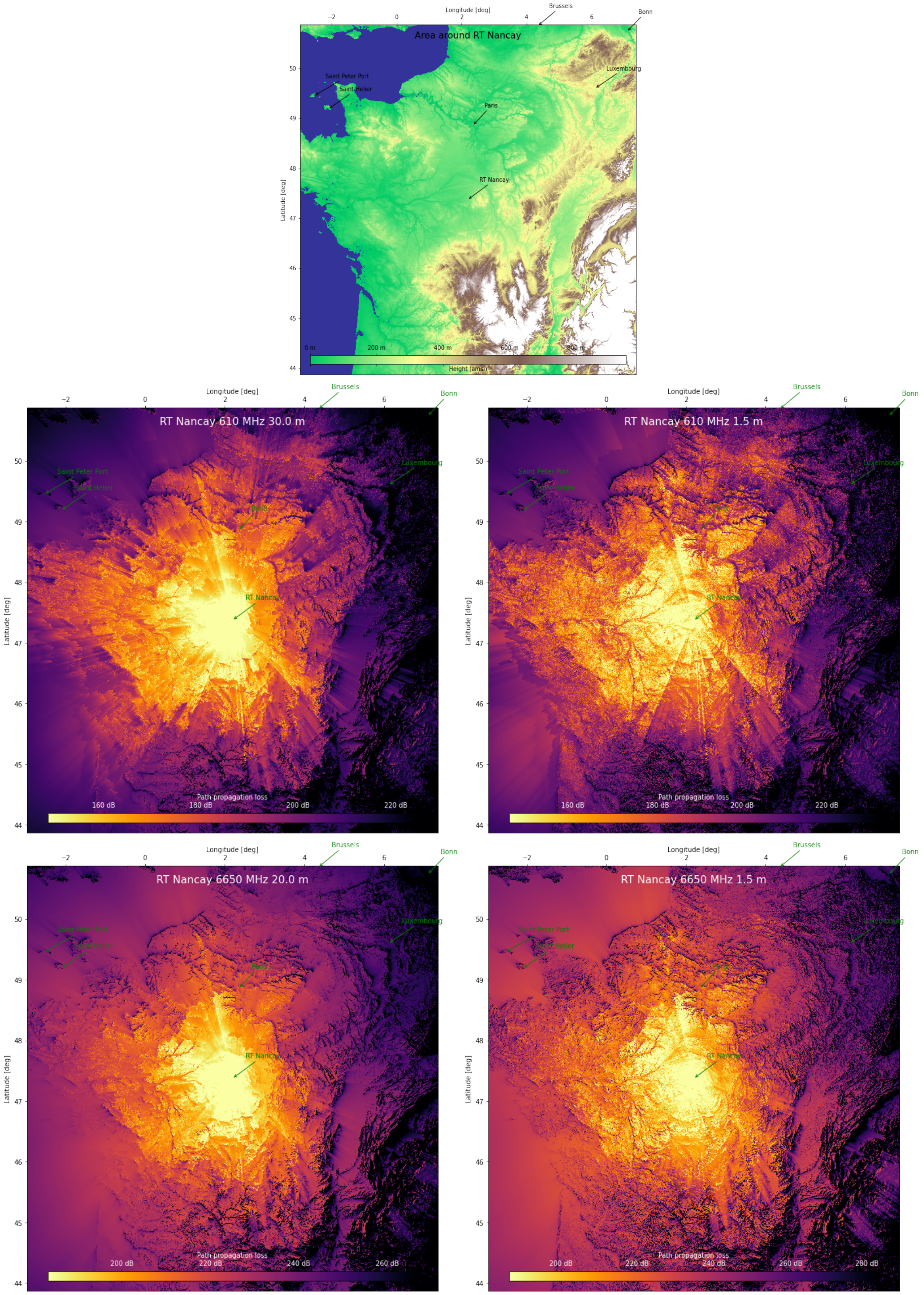

Fig. 9a: RAS station Nançay

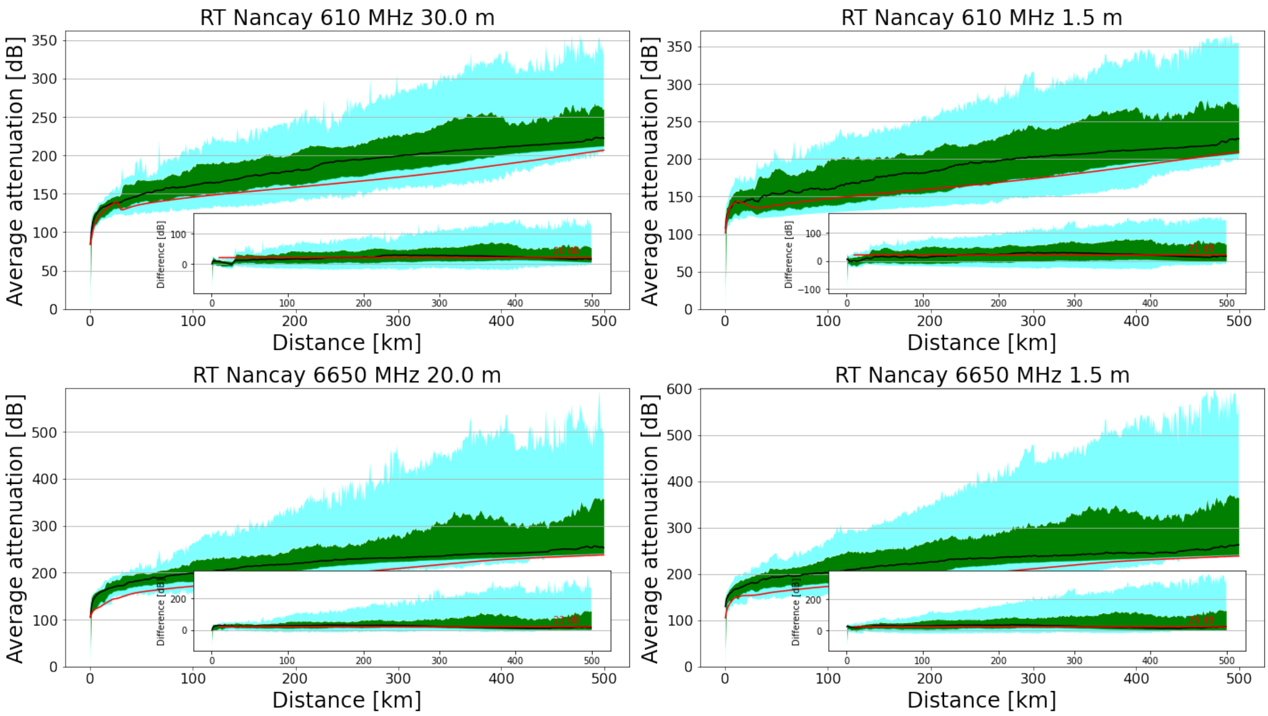

Fig. 9b: RAS station Nançay