Assessment of a Simplified Environmental Model for Aircraft Noise Prediction

Ilkka Karasalo (KTH) and Ulf Tengzelius (CIT)

Purpose

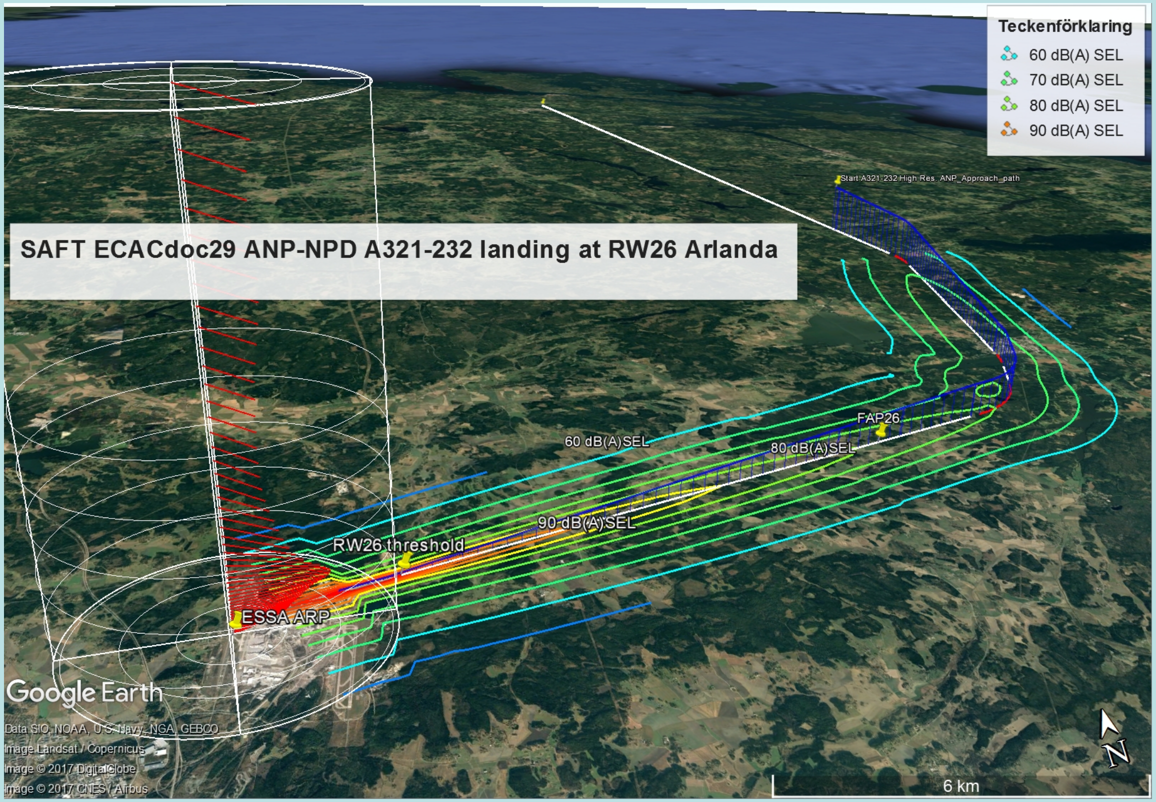
- Noise on the ground from passing aircraft depends strongly of environmental influences on the sound propagation

- The SAFT* simulation code predicts noise levels on the ground using simplified models of the medium and the sound propagation

- We assess the accuracy of SAFT's noise predictions by comparing the acoustic transfer function to the ground modelled by SAFT to that by XRAY, a code employing more elaborate - and more time-consuming - modeling

*Tengzelius, et.al.: "SAFT - Simulation of atmosphere and Air traffic For a quieter environment", CEAS-ASC 2018, Netherlands Aerospace Centre – Amsterdam, 2018.

Noise level at approach to runway 26 at Arlanda predicted by SAFT



Computational study

- The acoustic transfer function to the ground was computed for four aircraft locations on a linear flight path with 3^{o} elevation from runway 26

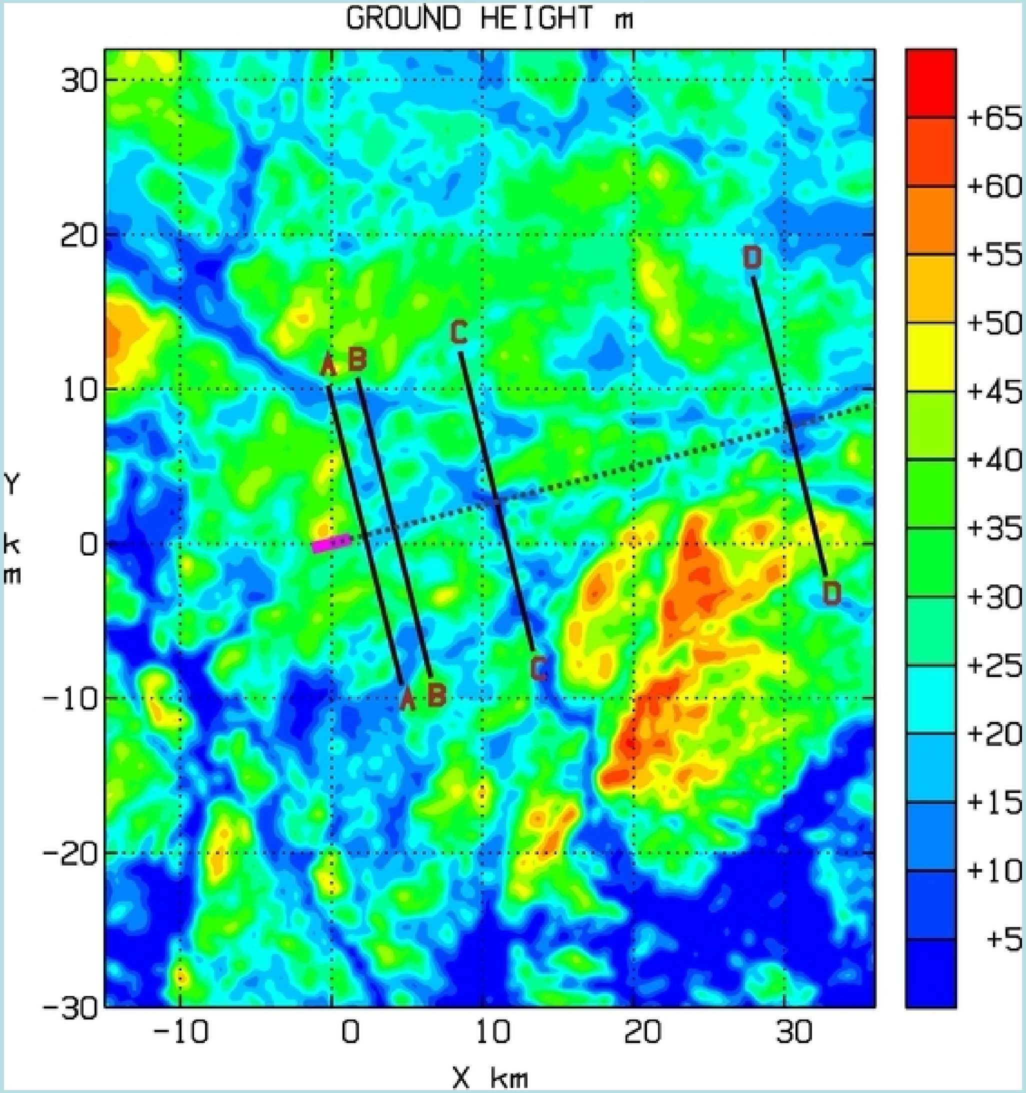
- Snapshots of the atmospheric field at two-hour intervals throughout the year 2017 were used

- Atmospheric data from the AROME prognosis model were provided by the Norwegian Meteorological Institute*

*http://thredds.met.no/thredds/catalog/meps25epsarchive/2017/catalog.html, Norwegian Meteorological Institute, Norway.

Arlanda, approach to runway 26

Ground height*, flight path, receivers



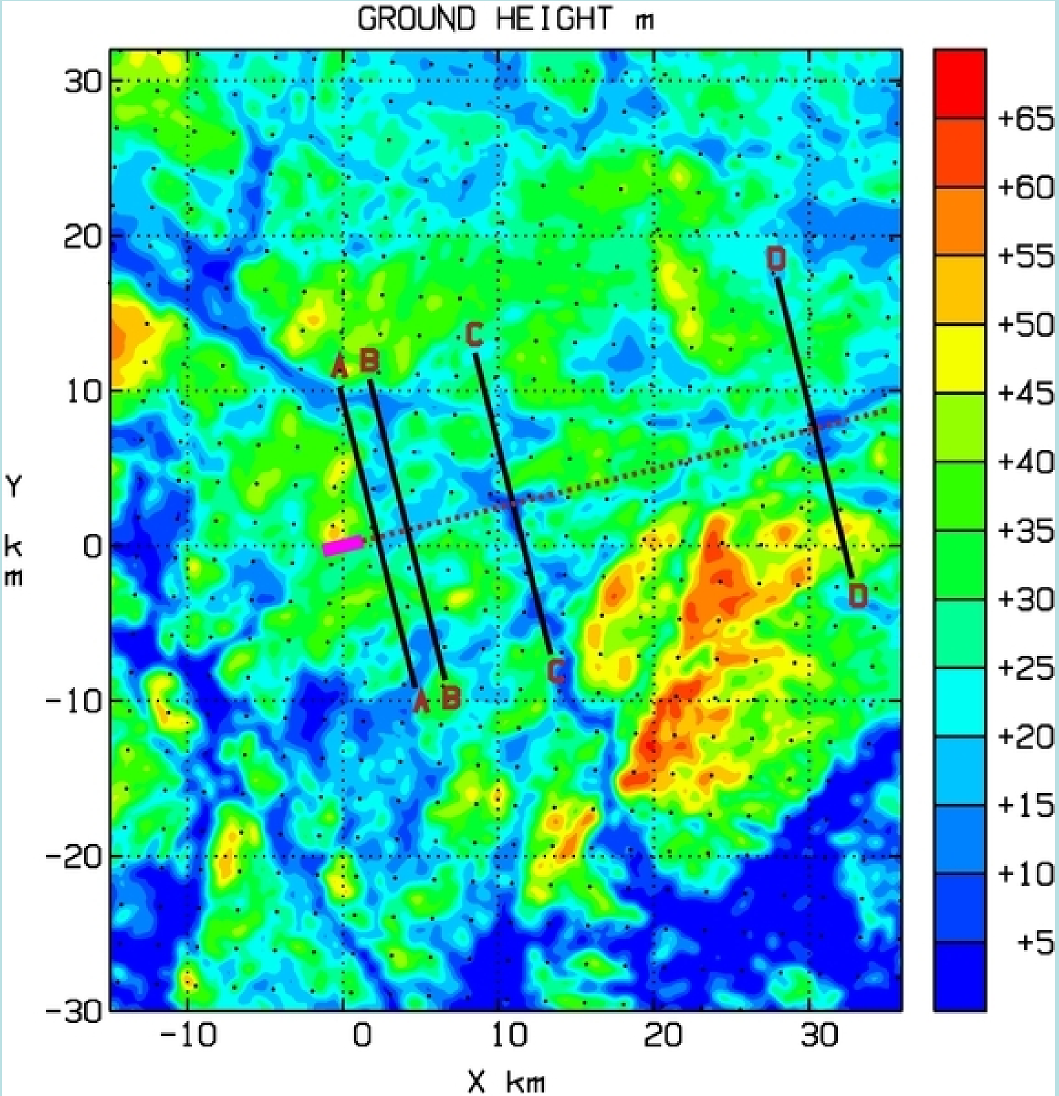
Four aircraft positions:
1, 3, 10, 30 km from runway

Heights above runway:
52, 157, 524, 1572 m

Receivers:
1.5 m above ground along four lines marked A, B, C, D

*http://www.lantmateriet.se/sv/Kartor-och-geografisk-information/Hojddata/GSD-Hojddata-grid-50-/ , Lantmäteriet, Sweden.

Atmospheric data



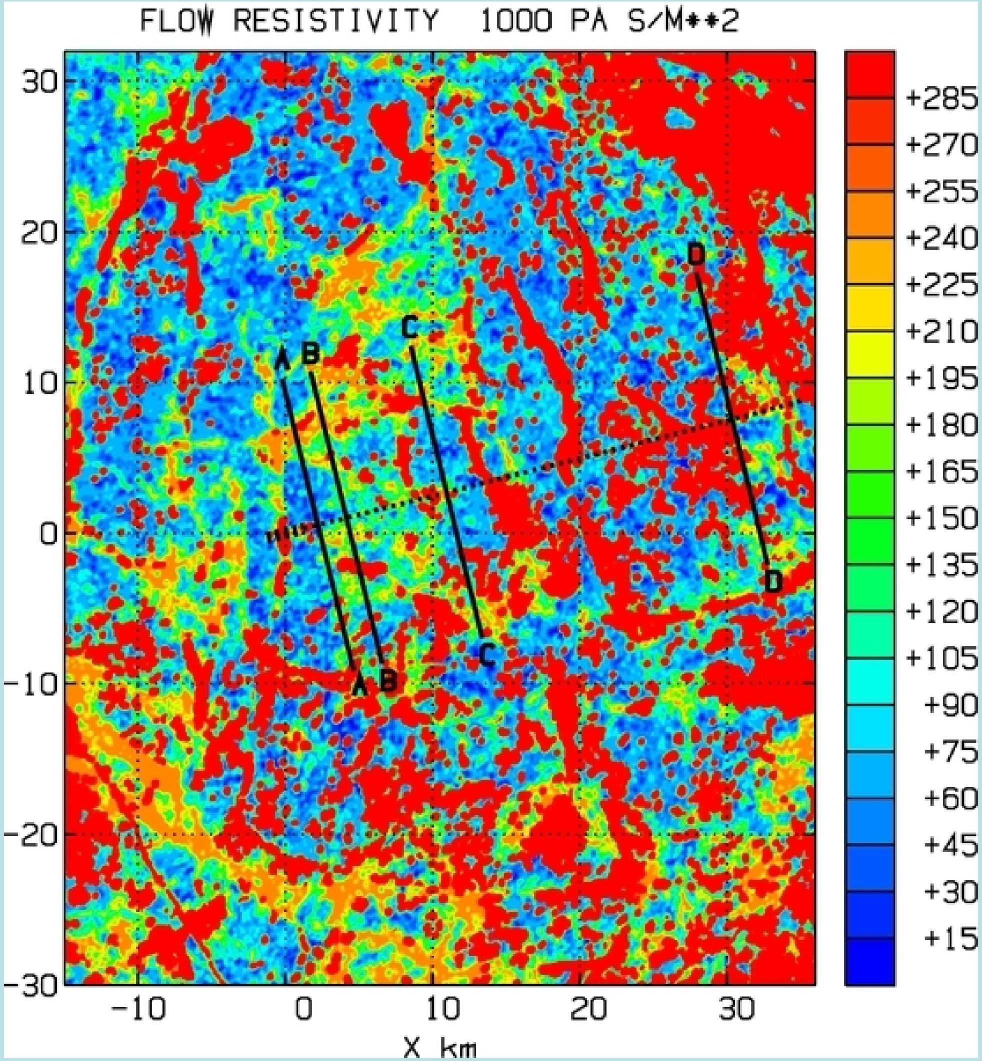
AROME* prognosis model
65 vertical levels, 2.5x2.5 km horizontal resolution

47x54 = 2538 horizontal gridpoints

4319 snapshots of
Pressure p
Temperature T
Rel humidity µ
Wind velocity east u
Wind velocity north v
at two-hour intervals throughout year 2017

*Muller, et.al, ‘AROME-MetCoOp: A Nordic Convective-Scale Operational Weather Prediction Model’, https://doi.org/10.1175/WAF-D-16-0099.1

Flow resistivity of the ground



The ground is modelled as an impedance boundary of the acoustic field

Ground coverage type by Naturvårsdverket***

Flow resistivity as function of ground type by Embleton*

Acoustic impedance as function of flow resistivity and frequency by Delany-Bazley**

*T.F.W.Embleton, et.al:"Effective flow resistivity of ground surfaces determined by acoustical measurements'', JASA 1983.
**M.E. Delany, E.N.Bazley:"Acoustical properties of fibrous absorbent materials", Applied Acoustics (3) 1970, p.105-116.
***Naturvårdsverket: https://www.naturvardsverket.se/Sa-mar-miljon/Kartor/Nationella-Marktackedata-NMD

Modelling

	Simple model (SAFT)	Detailed model (XRAY)
Ground height h(x,y)	Independent of (x,y), given by ground height at runway	2D B-spline expansion* fitted to all ground height data
Atmospheric fields f(x,y,z)	Independent of (x,y), given by a single AROME profile at the runway	3D B-spline expansions fitted to data in entire AROME grid
Flow resistivity	Constant	2D B-spline expansion fitted to all flow resistivity data
Ray launch angles	Fixed launch angles	Adaptive to keep range between ground hits small
Ray paths	Fixed step, rays traced to first ground hit only	Variable step, error control, multiple ground reflections
Ray tube area	Numerical derivatives w.r.t. launch angle	Auxiliary ODEs for partial derivatives w.r.t. launch angle

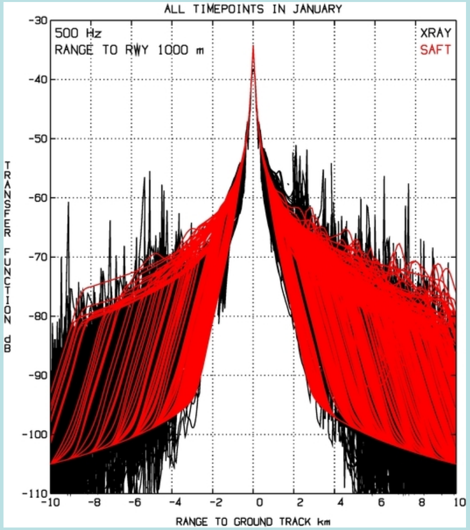
*C. de Boor: “A Practical Guide to Splines”, Springer, 1985.

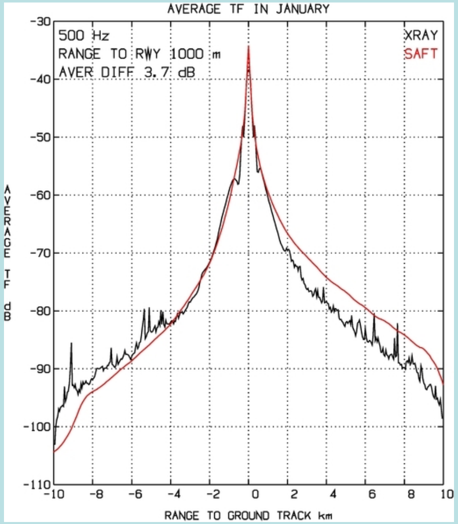
TF(r) January

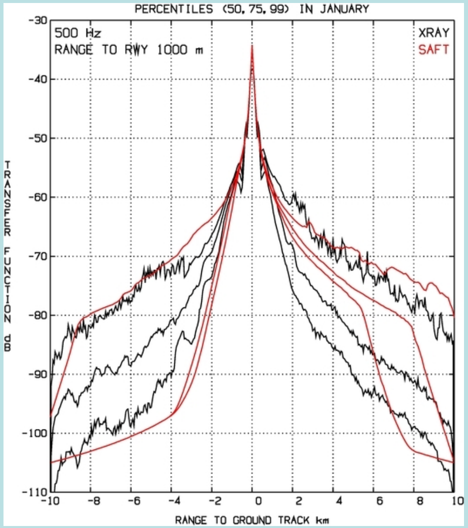
Range to rwy & hgt

Ensemble | Average | Percentiles 50%, 75%, 99%

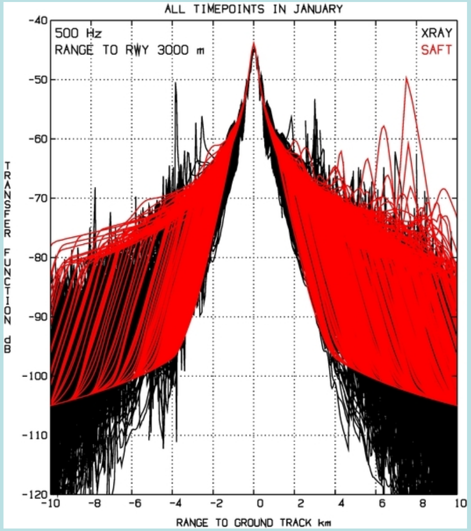
1 km
52 m

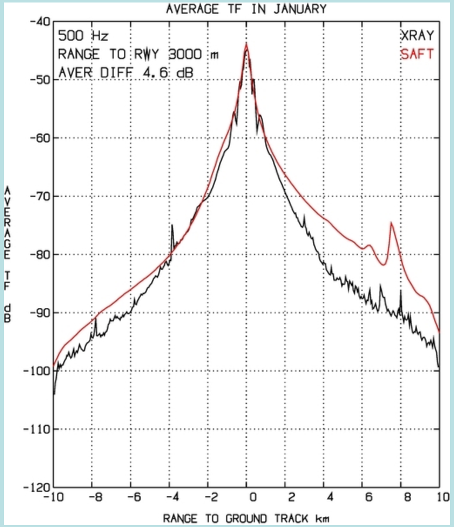


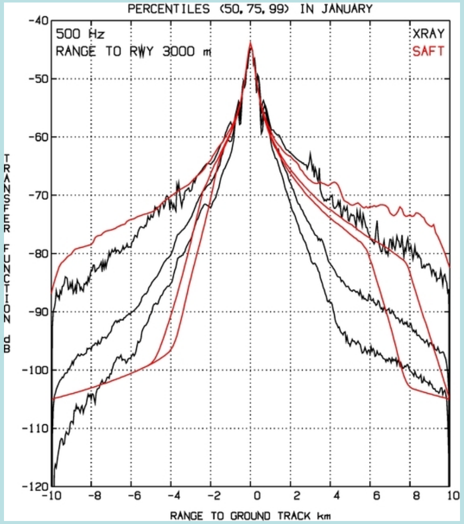




3 km
157 m







TF(r) January

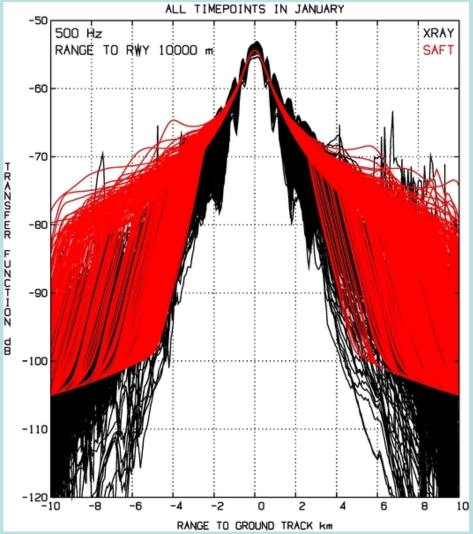
Range to rwy & hgt

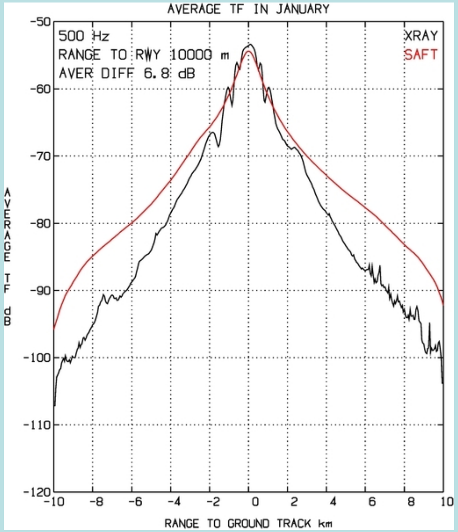
Ensemble

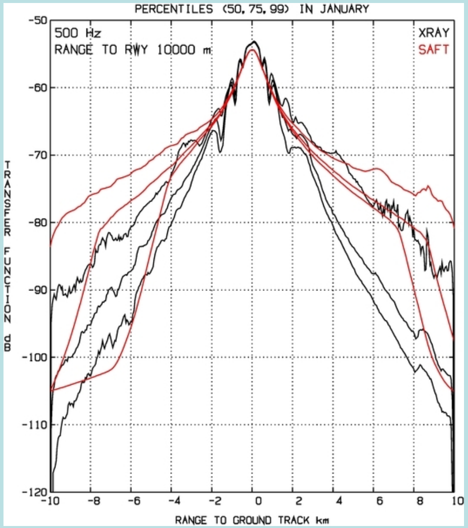
Average

Percentiles 50%, 75%, 99%

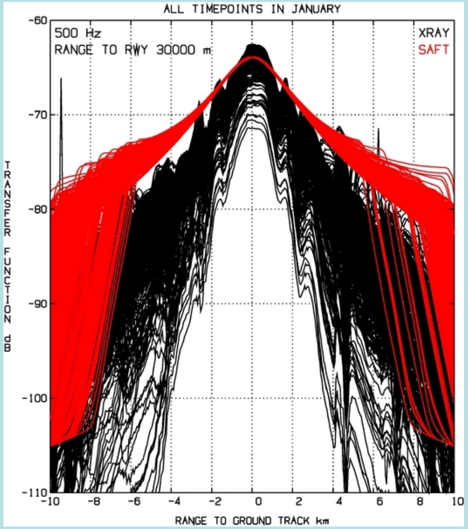
10 km
524 m

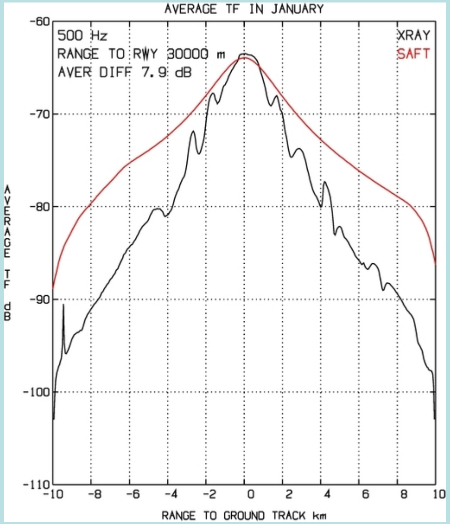


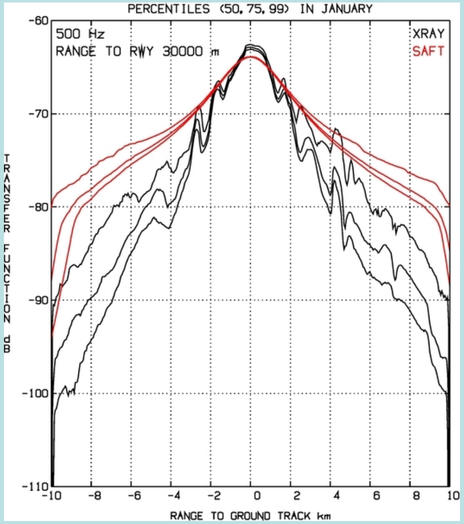




30 km
1572 m





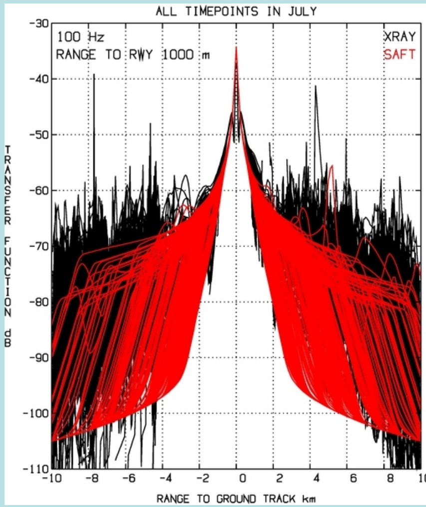


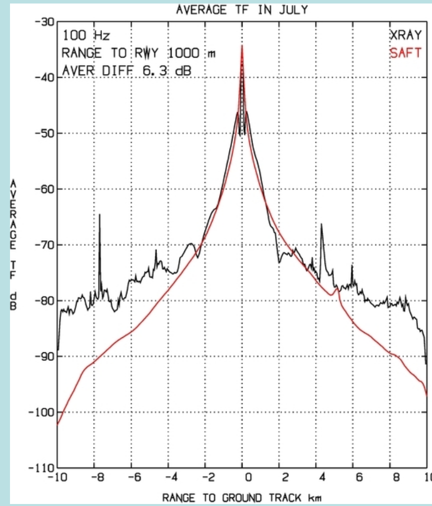
Transfer function to ground, July 2017

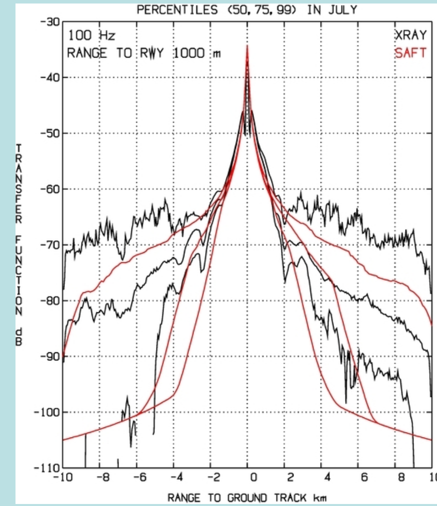
Range to rwy & hgt

Ensemble | Average | Percentiles 50, 75, 99

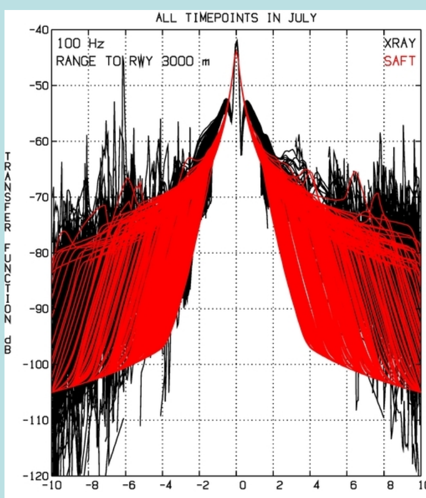
1 km
52 m

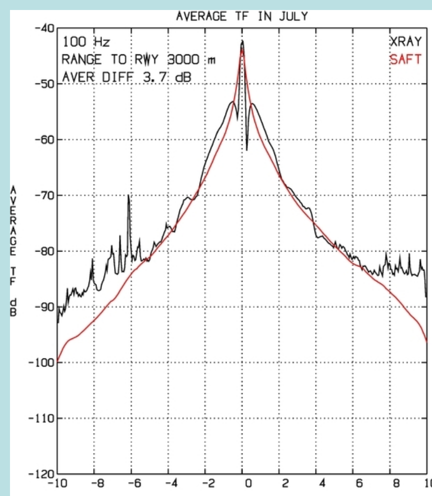


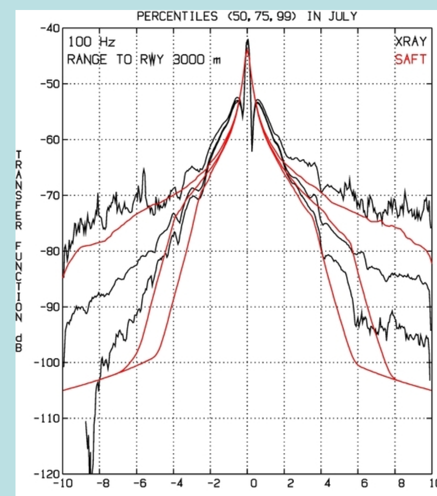




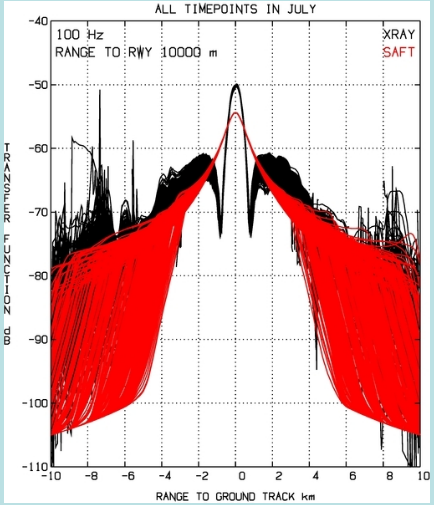
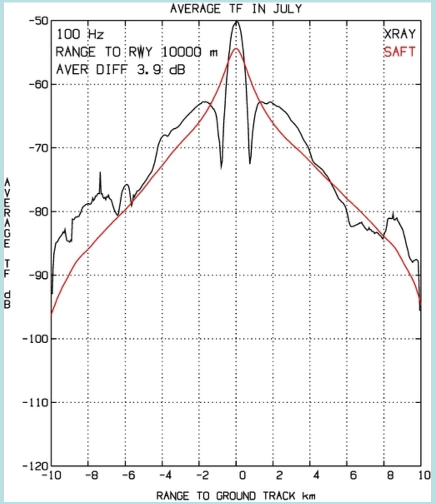
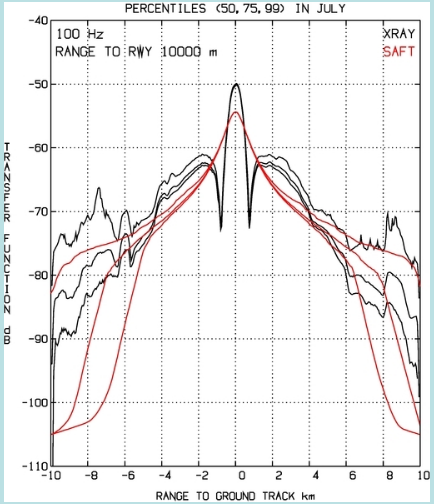
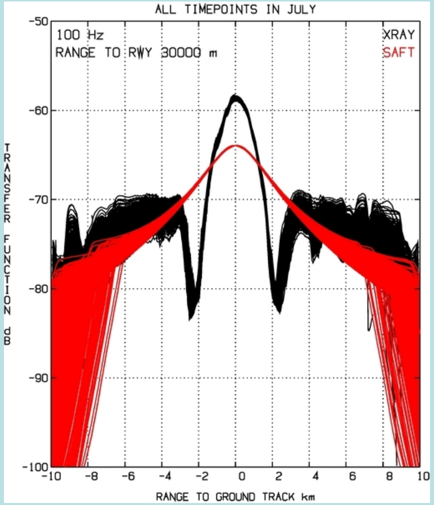
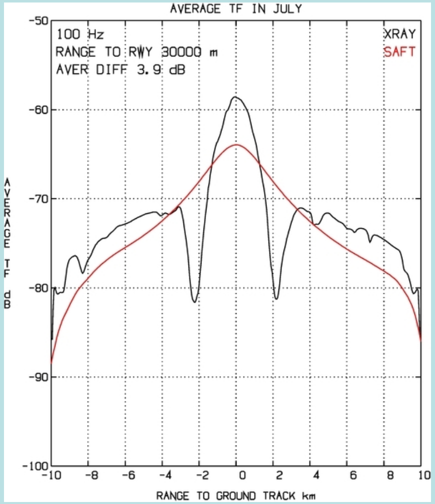
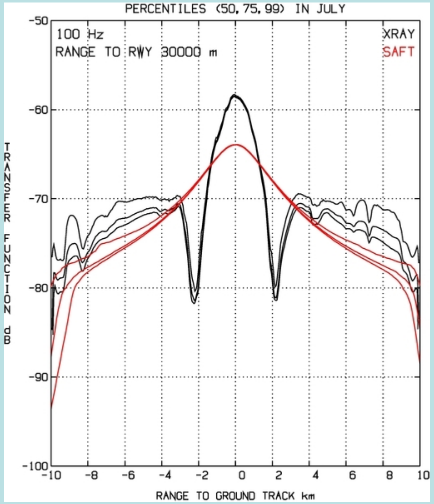
3 km
157 m





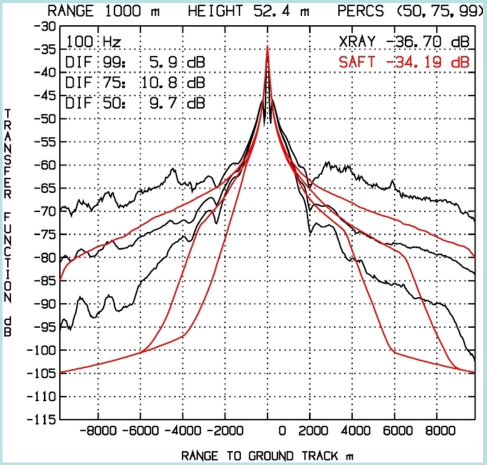


Transfer function to ground, July 2017

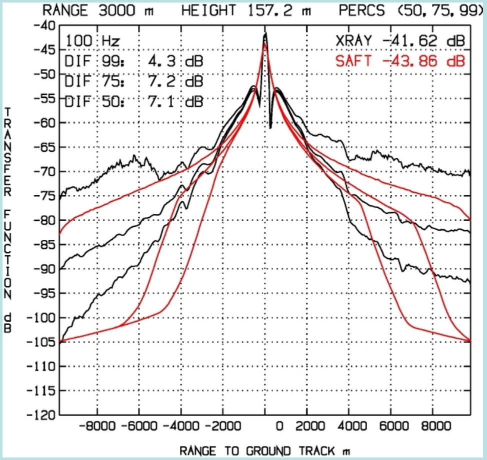
Range to rwy & hgt	Ensemble	Average	Percentiles 50, 75, 99
10 km 524 m			
30 km 1572 m			

Whole year 2017: Percentiles 50, 75, 99

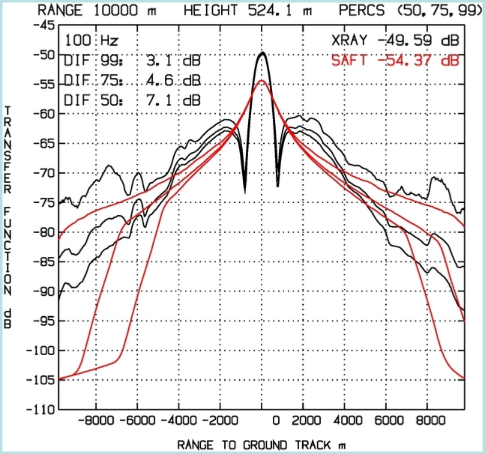
Range to rwy 1 km



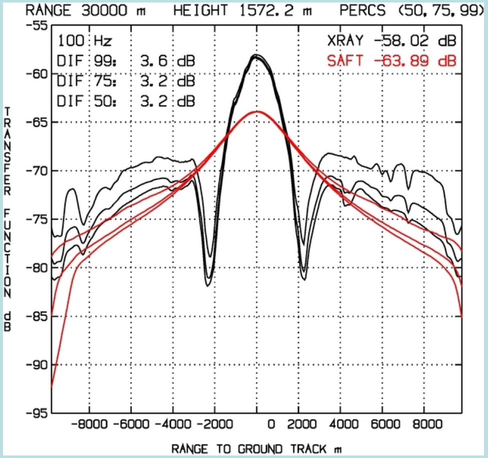
Range to rwy 3 km



Range to rwy 10 km



Range to rwy 30 km



Summary of results

TFs: Transfer function by SAFT, dB
TFx: Transfer function by XRAY, dB
r: Cross track range

The average of |Tfs – Tfx| is mostly < 10 dB

Coarse features of Tfx as function of r are captured by TFs(r)

Strong local variations in Tfx(r) with r, including the ground reflection effect in the nearfield, are not captured by TFs(r)

The difference between the maxima, |TFx(0) – TFs(0)|, increases with source height, due to different modelling of sound absorption.

For large r, the difference |TFx(r) – TFs(r)| increases with decreasing source height due to different modelling of sound propagating with shallow angles.