SAFT

Simulation of atmosphere and Air traffic For a quieter environmenT

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To be presented:

1. Intro SAFT - CSA
2. Aircraft noise mapping - Integrated vs Simulation methods
3. SAFT features
4. SAFT run examples
5. Future SAFT development and studies

1. Intro SAFT – CSA

CSA
Centre for Sustainable Aviation

- SAFT – a 3 year project funded through CSA, Centre for Sustainable Aviation
- CSA – centre financed during 10 years (5MEuro) by the Swedish Transport Administration (Trafikverket) with the aim to:

  ”Coordinate Swedish research on the environmental impact of aviation, in particular noise” (https://www.kth.se/en/sci/centra/hallbarluftfart)

- The centre, and research investments, were partly a result of a settlement between communities and neighbour organisations on one side and on the other Swedavia who operates and owns Arlanda, the biggest airport in Sweden
- As of today, 4 projects are running under CSA, whereof SAFT is one

The ongoing CSA-projects:

- **SAFT** - establish an **aircraft noise simulation tool** capable to produce **noise histories and contour lines on groun**d for **existing and future aircraft**, given aircraft/engine performance along general trajectories

- **Brantare** - ("Steeper") potentially reduced noise on ground for **descent angels > 3 degrees**, linked to **operational behaviour by pilots**, changes of timing of flap/slat/landing gear extension, use of speed brake, speed selection and engine thrust

- **ULLA** - **noise measurements** around airports

- **INFRA** – identifying possibilities and obstacles for implementation of "noise-optimised" procedures at Arlanda airport on a organisational level

2. Aircraft noise mapping - Integrated vs Simulation methods

- **Integrated methods** like ECAC doc.29, INM and AEDT combining sound sources and sound propagation into total sound levels on ground, dependent on aircraft distance and trust setting only

- The aim with the integrated methods is primarily to study yearly noise patterns around airports

- These methods are guiding in the legal processes (rather than measurements)

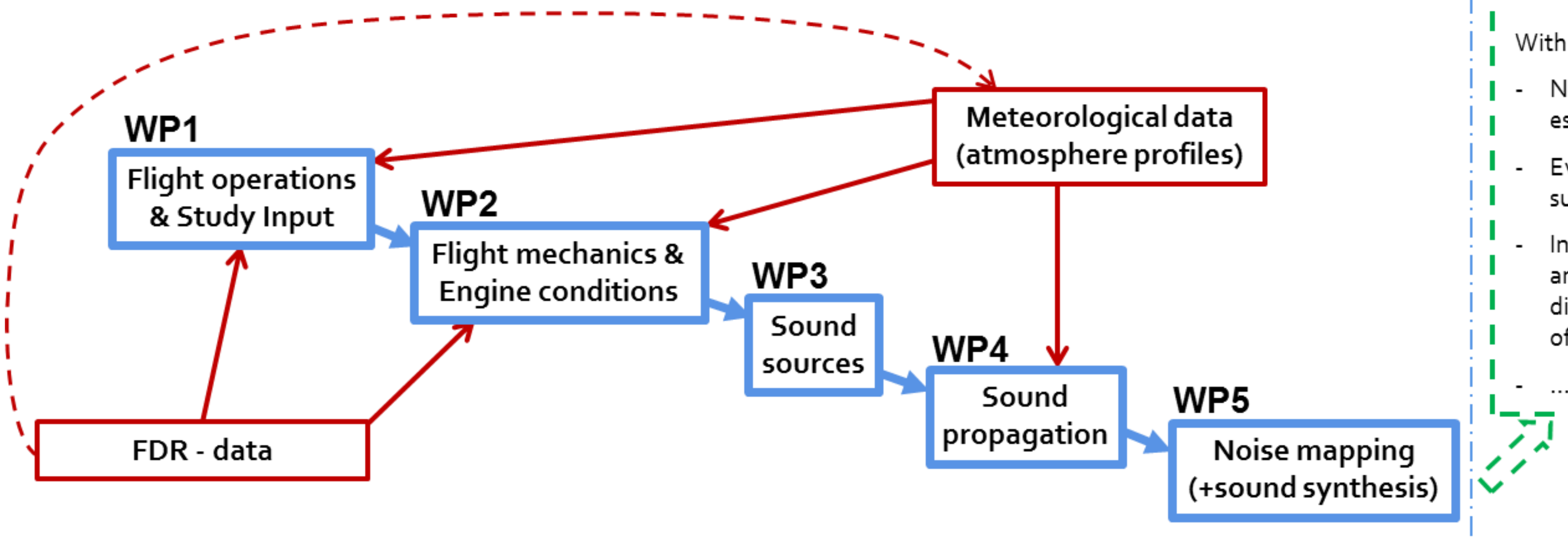
- **Simulation methods**: time + frequency dependent directive moving source, possible to account for a "real" atmosphere and individual noise events on ground

… cont. 2. Noise mapping - Integrated vs Simulation methods

	Simulation tools	Integrated tools
Typical application	Single event operations	Combined fleet, yearly mean
Sound source	Separated from propagation Semi-empirical, physics-based Frequency and space resolved	Merged with propagation Measured Frequency and directivity info missing
Source data availability	Limited open data available	Good OASPL data found in the open ANP*-database
Sound propagation	Yes - separated from sound source	No - not separated from source
Studies of noise abatement flight procedures	Yes - Possible to simulate	No - or very limited possibilities
Time history for noise events	Yes - Possible to simulate (as well as listening tests based on these)	No – not possible to extract
Atmosphere impact	Yes - Possible to include	No - not included (ANP/NPD data established under certain "standard atm. conditions")
New technology studies	Yes – possible to simulate new aircraft or engine concepts	No – not possible to include
Computational time	Computationally more "heavy"	Computationally fast

3. SAFT features

Main outline:



Future use in studies of:

- Operations
- New engines
- …

With:

- Noise effects estimation
- Evaluations support
- Information and dissemination of knowledge
- …

WP0 = Support programs, data and systems
WP6 = System architecture/interfaces, in- and output data, testing of complete chain
WP7 = Project management work and time plan

SAFT implemented main computational paths:

Integrated method (immision model)

- ECAC Doc.29 immission-/integrated model
  - extended with "real atmosphere" data for absorption and various atm.abs.models

Emission/Simulation models:

- NPD-data based reversed engineering sound sources, SEL+spectral class or user defined spectra + source directivity

- "Full simulation" of individual sound sources (separate sources, fan fwd., jet, ..., landing gear, airframe – like in ANOP)

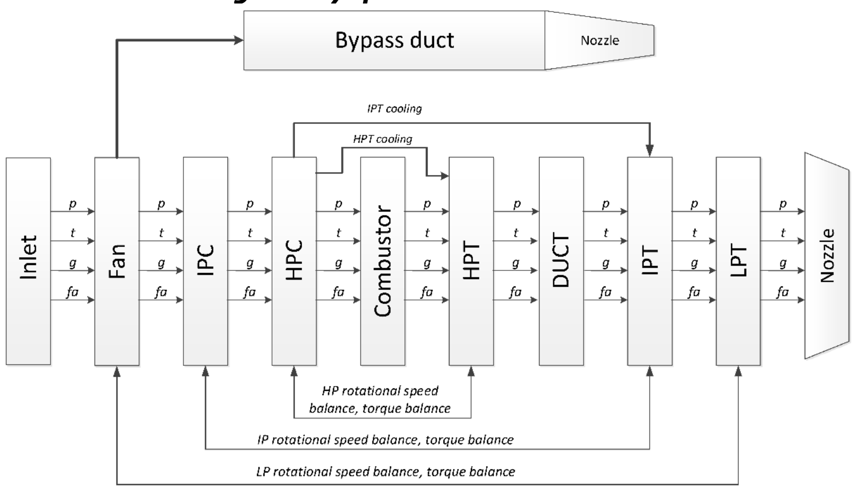
Both with the possibility to compute sound propagation with ray-tracing (refractive atmosphere)

... cont. 3. SAFT features

Flight operations & Study Input | **Flight mechanics & Engine conditions** | **Sound sources**

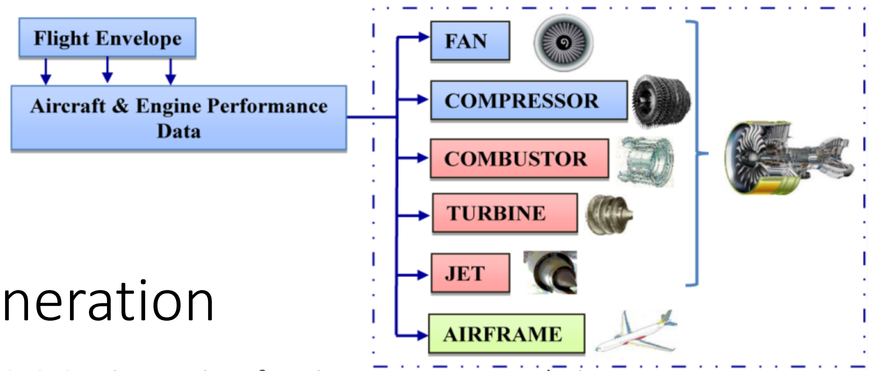
Different ways to generate flight paths for a given aircraft type:

- ”Standard Procedures” from the ANP-database
- Flight simulation programs
- FDR-data



Engine conditions + other sound source input:

- Chalmers Engine performance program GESTPAN

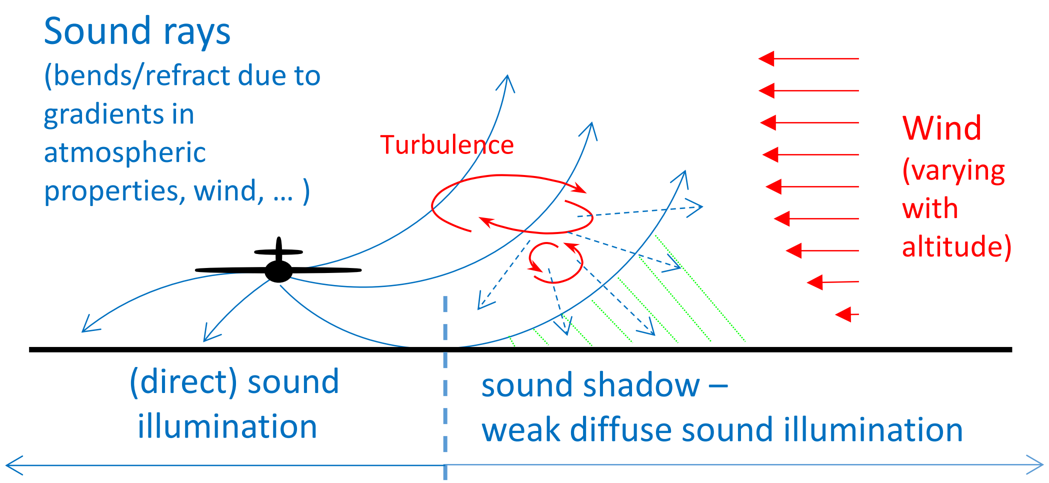


Sound sources:

- CHOICE – Chalmers code for semi-empirical source generation

... cont. 3. SAFT features

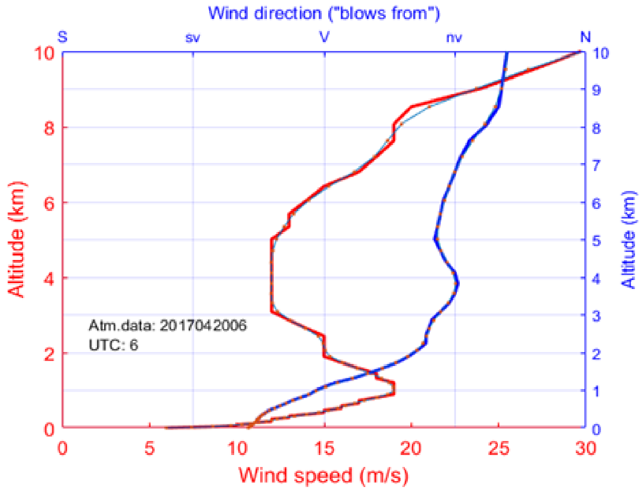
Sound propagation | **Noise mapping**



3 alternative atmosphere models:

1. ISA atmosphere + wind
2. Typical atmospheres wrt cloud cover, stability, temp + wind as of IMAGINE project
3. Forecast data (AROME- “Scandinavia”)

Atmospheric data



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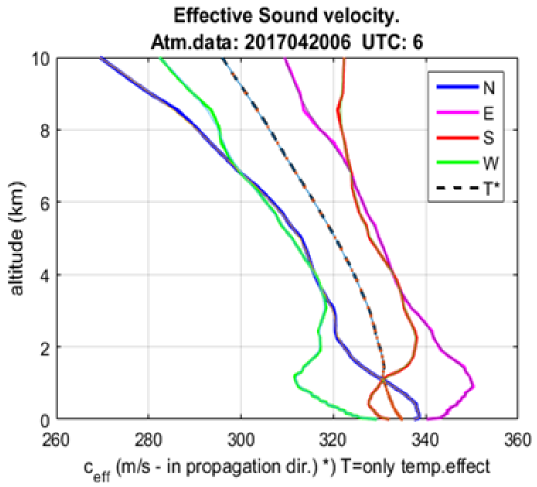
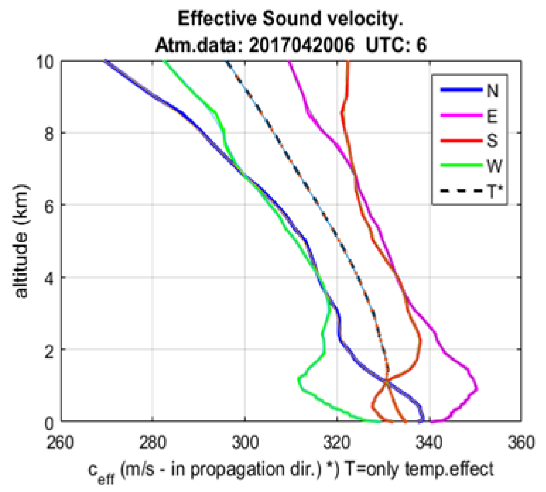
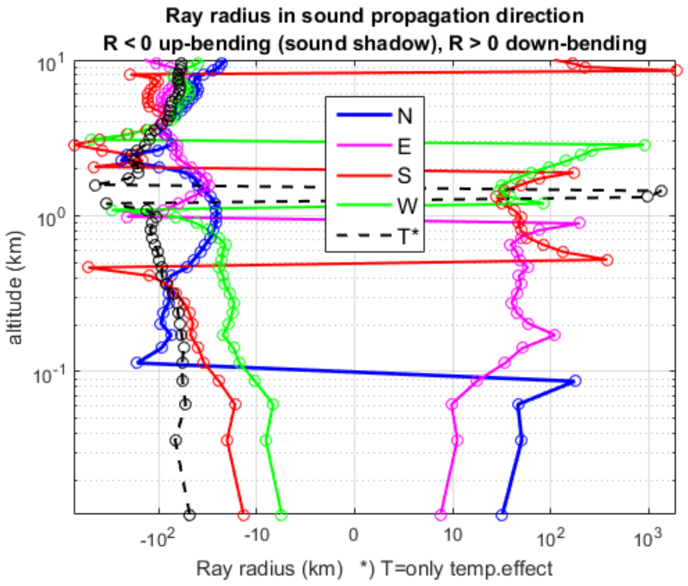


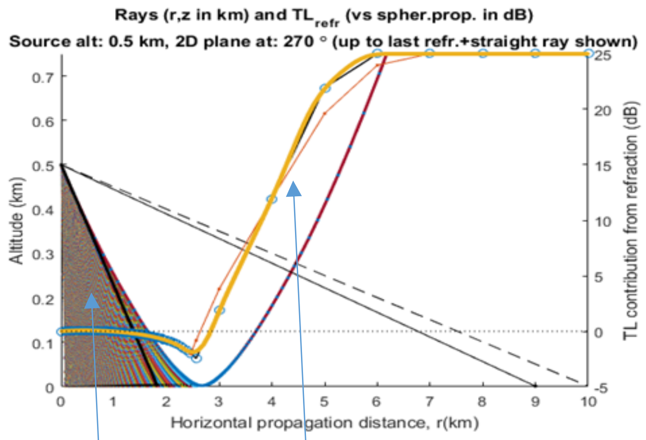
Effective sound velocity

... cont. 3. SAFT features **Sound propagation**





Sound rays and computed Transmission Loss (TL) due to refraction – i.e. relative spherical propagation



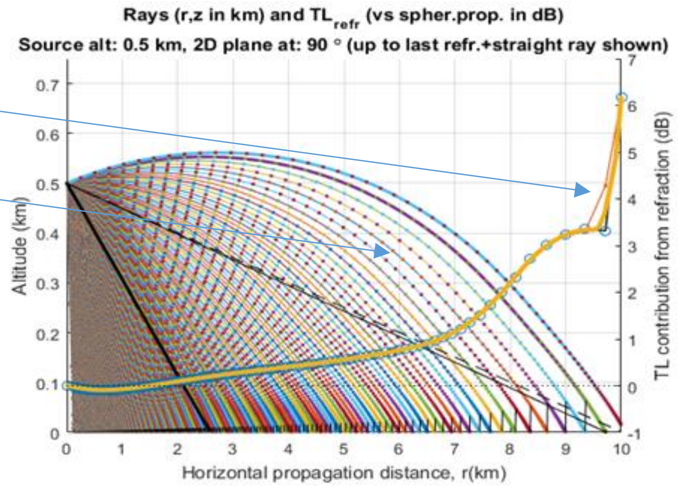
Ex. Source at alt. 500 m sound propagation to west ("headwind")

Yellow curve =$TL_{refraction}(r)$

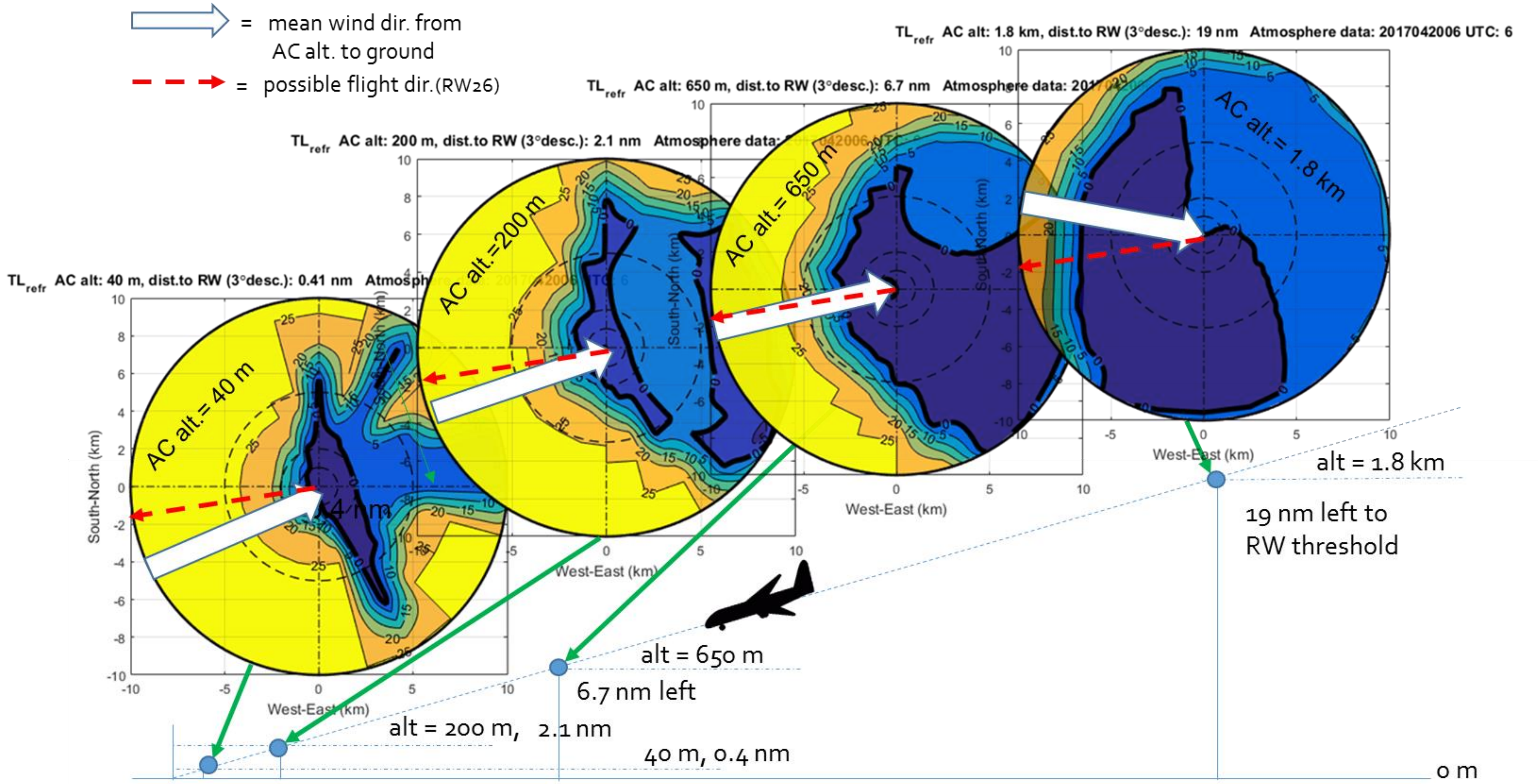
$TL_{refraction}$

Sound rays

Ex. Source at alt. 500 m sound propagation to east ("tailwind")



Refractive part of Transmission Loss



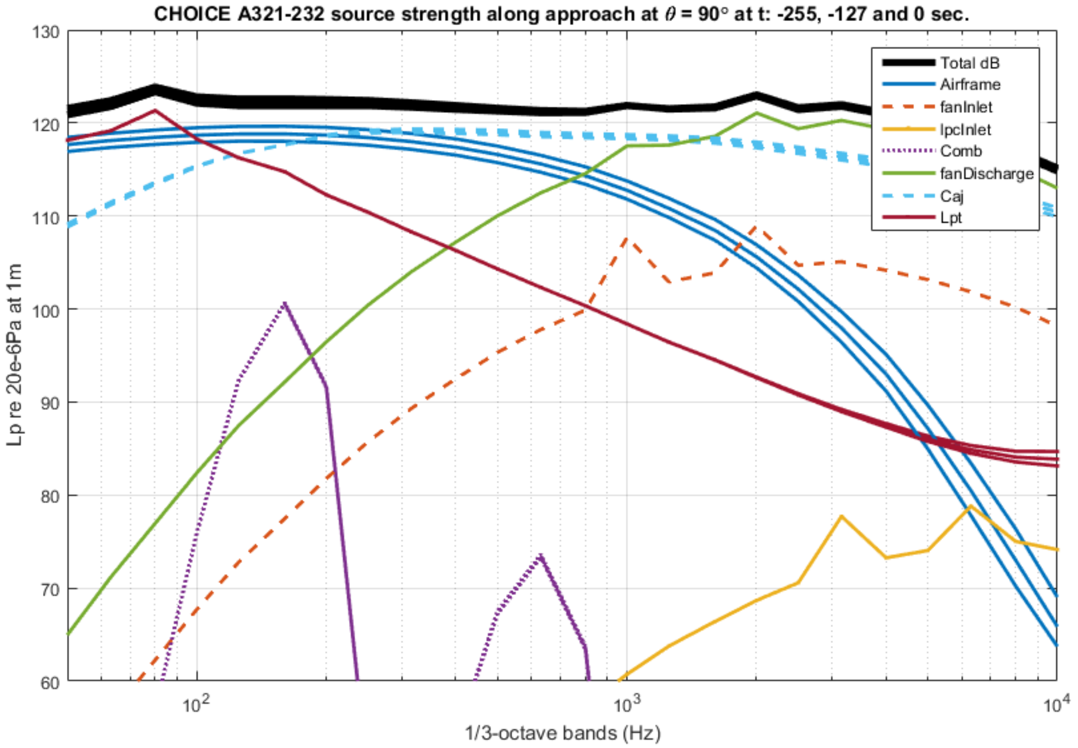
Special SAFT features with regard to sound propagation:

- **Fast: TL-interpolant matrix approach** – time and lat, long invariant TL matrix used for all trajectory grid points (fcn of source alt, horizontal distance and propagation heading, 0-360°, also emission- and incident angles are interpolated in the same way)
- Simple selection or generation of new **ground tracks**
- “Automatic” **effective gridding** around any ground track
- **Time event analyses possible in any grid point**, including sub-division in separate TL contributions based on the physics behind
- **Direct grid comparisons possible** – contours of “ΔdB”, e.g. between different propagation models, different weather data, different aircraft, procedures,...
- **“Real” weather prognoses** – allow for **forecasting noise patterns** including different forecasts with various probability

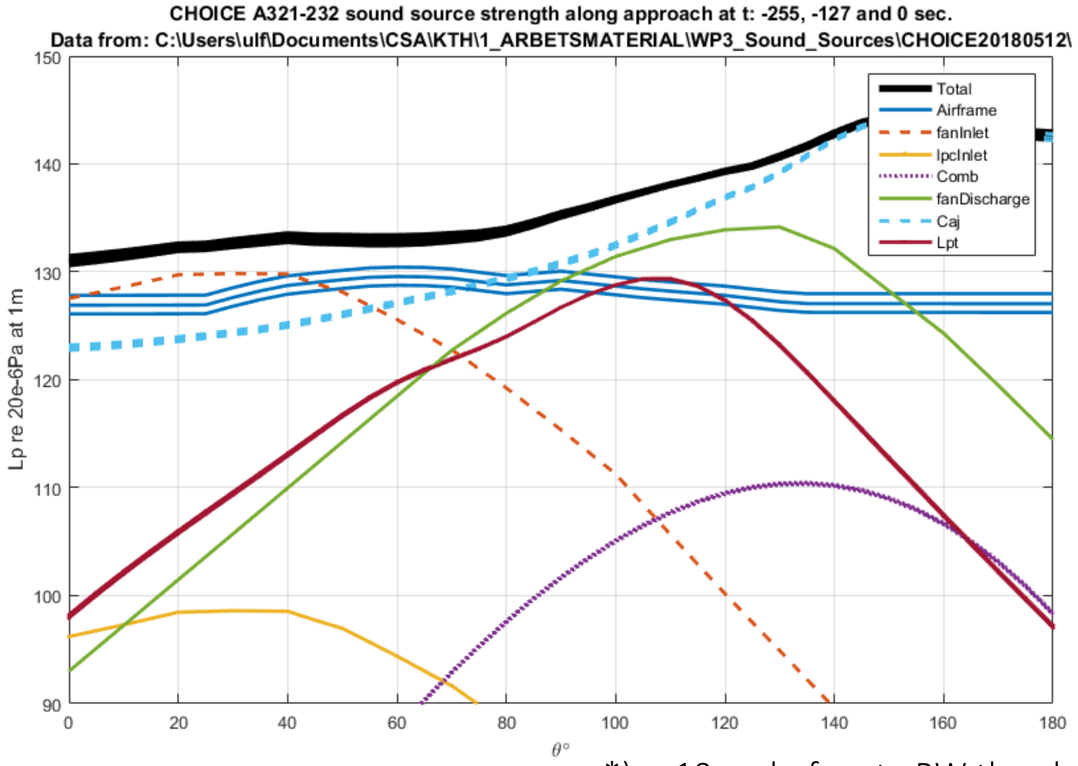
4. SAFT run examples

a) First test run of GESTPAN +CHOICE for A321-232 sound sources along approach* NOTE: *to be further trimmed and validated!!!*

Spectrum at $\theta = 90°$

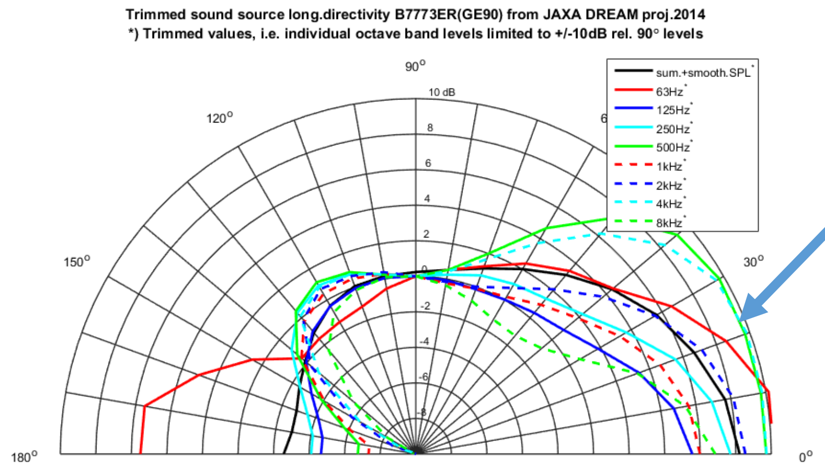


Total level as function of longitudinal directivity, θ



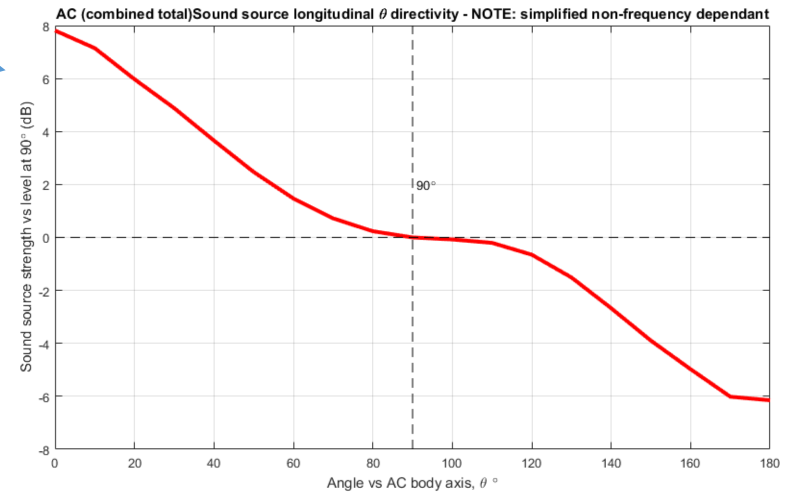
*)ca 10nm before to RW threshold

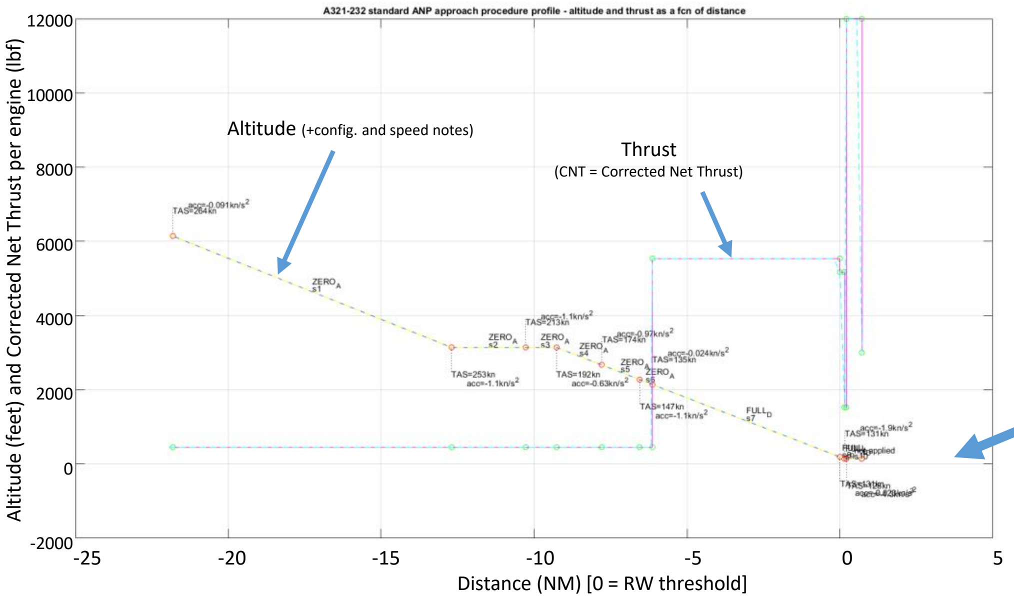
b) SAFT reversed engineering A321-232 sound source from NPD-SEL case 1.



Assumed directivity

original frequency dependent data taken from B7773ER measurements, and trimmed to give an approximate "total" directivity representative for modern high bypass turbofans characterised by increased forward sound source strength at lower thrust settings during approach

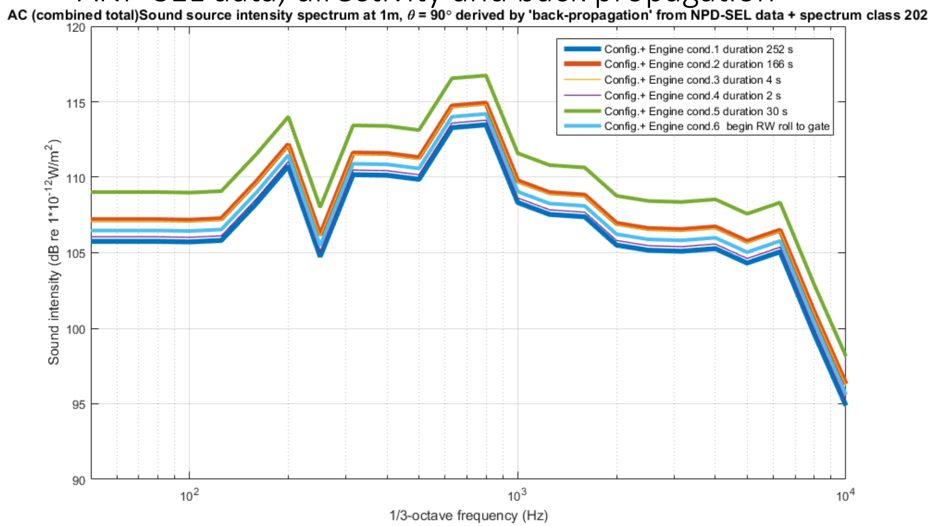




Simplified ANP data standard approach for A321-232

Assumed total source strength, sound intensity level

Based on ANP spectrum class, thrust setting along approach, ANP-SEL data, directivity and back propagation



... cont 4. SAFT run examples b) SAFT reversed engineering A321-232 sound source from NPD-SEL, grid and noise contours case 1. Landing in head wind

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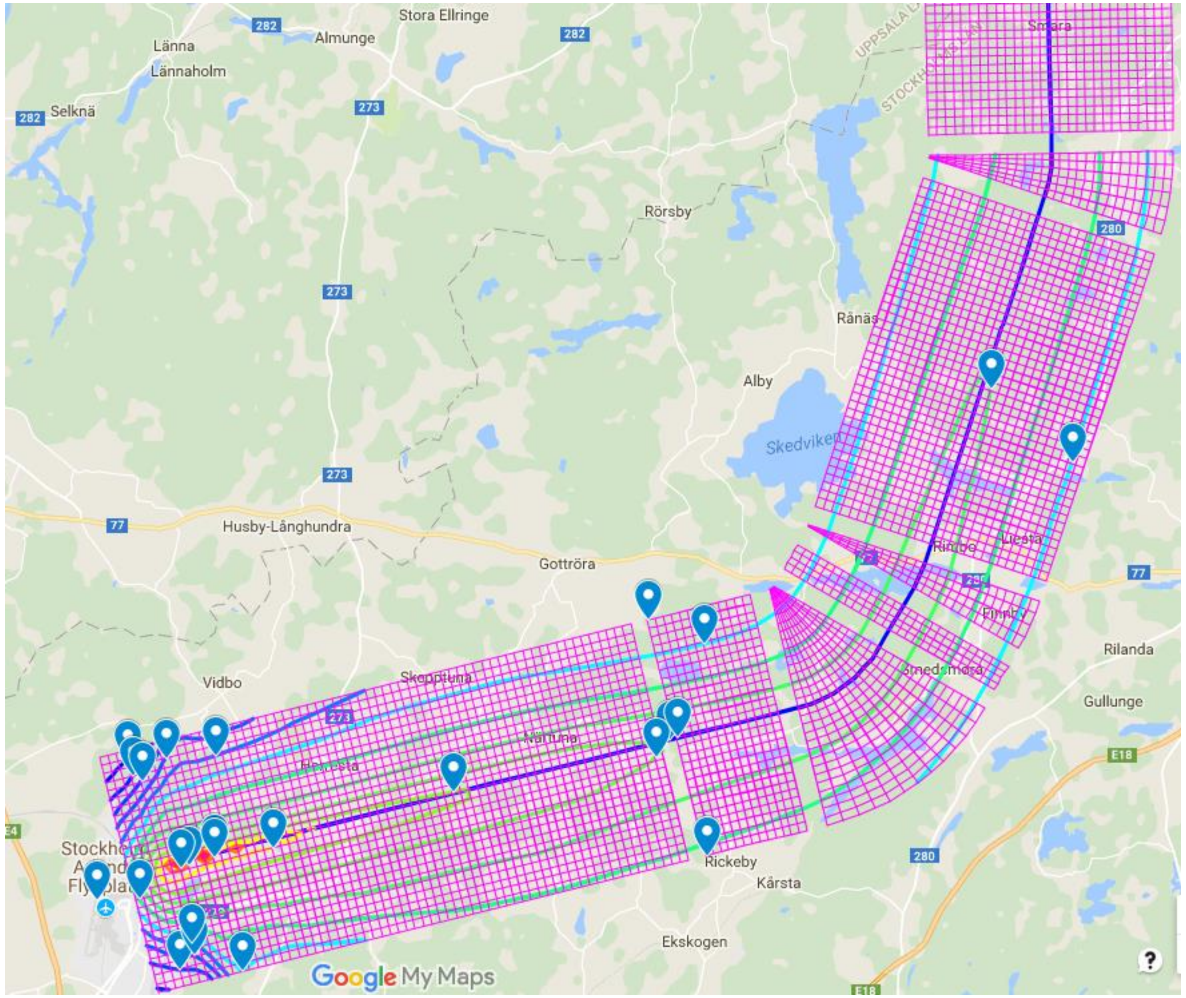
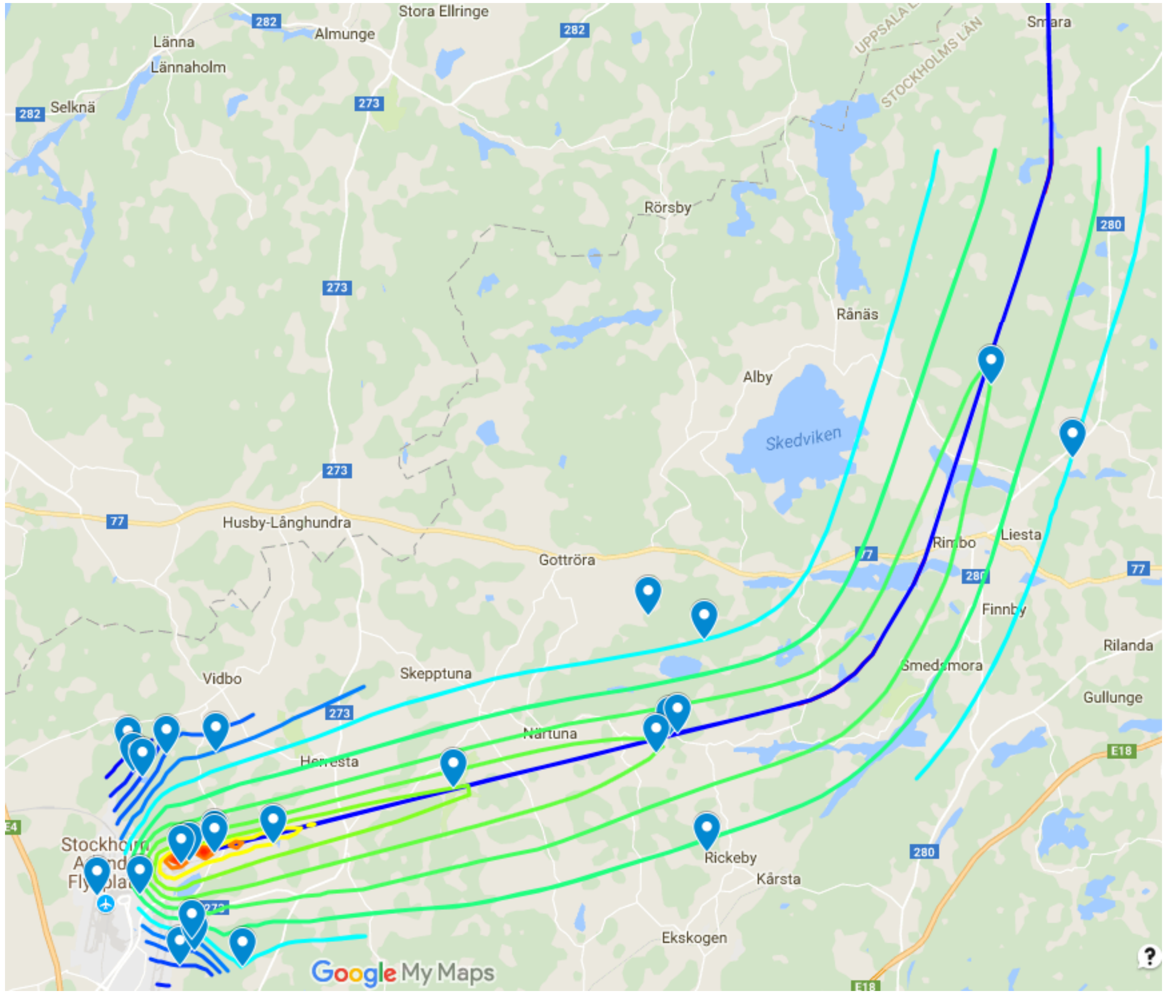
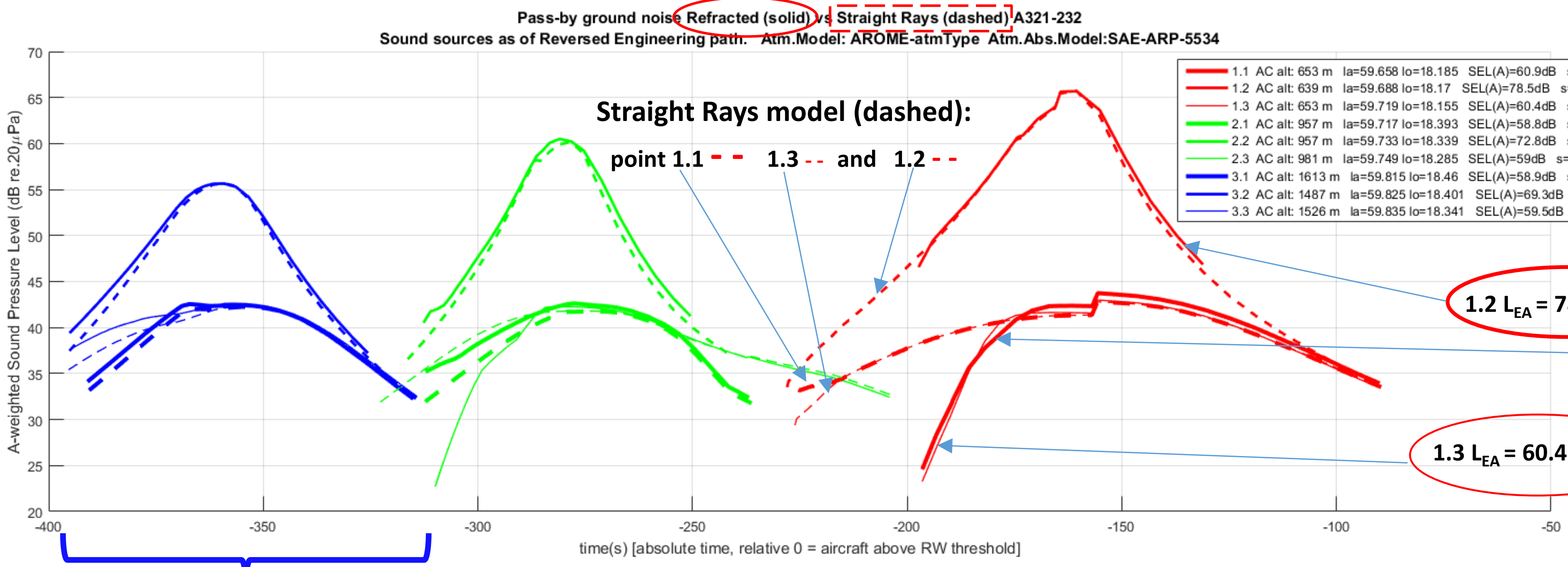
Grid, ground track and resulting SEL-contours ...



... only ground track and resulting SEL-contours



... cont 4. SAFT run examples b) SAFT reversed engineering A321-232 sound source from NPD-SEL, noise events case 1. Landing in headwind



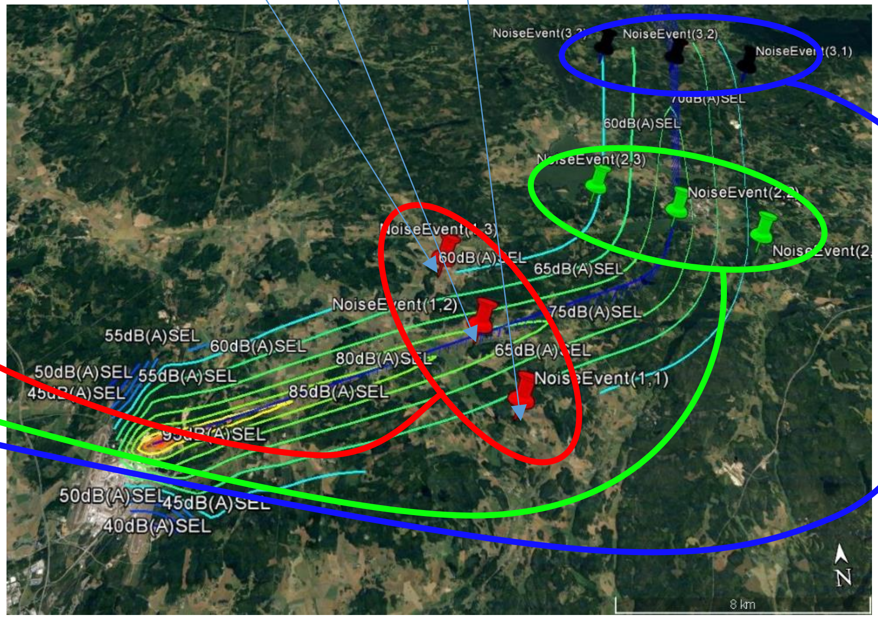
Refracted rays model (solid):

1.2 L_{EA} = 78.5 dB(A)

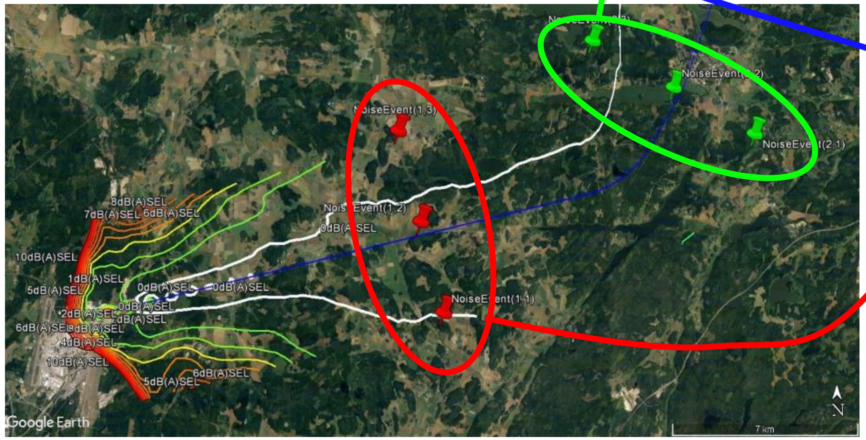
1.1 L_{EA} = 60.9dB(A)

1.3 L_{EA} = 60.4dB(A)

<u>SEL contours (refracted rays)</u>



<u>Difference SEL refracted vs straight rays contours</u>



Head wind approach ⇒ small differences refracted vs straight rays model, mostly a duration impact

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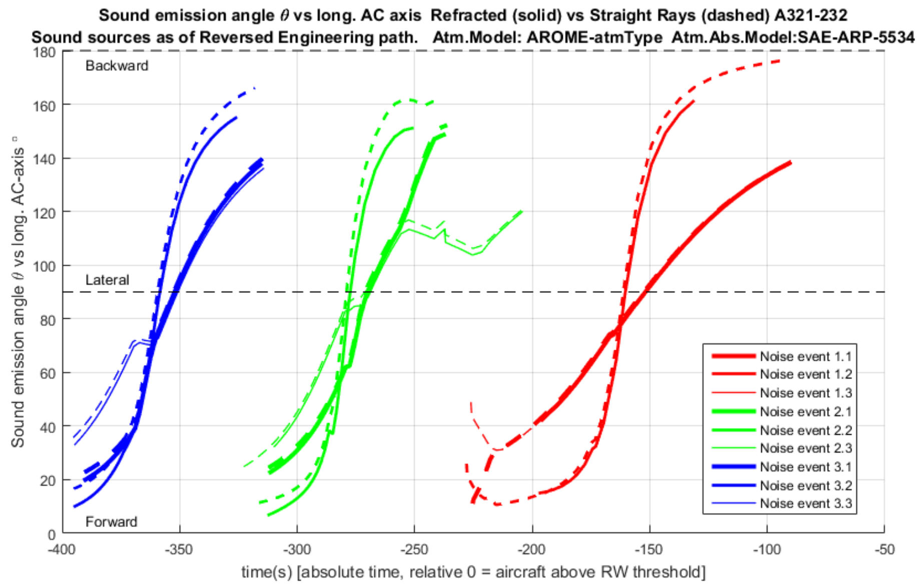
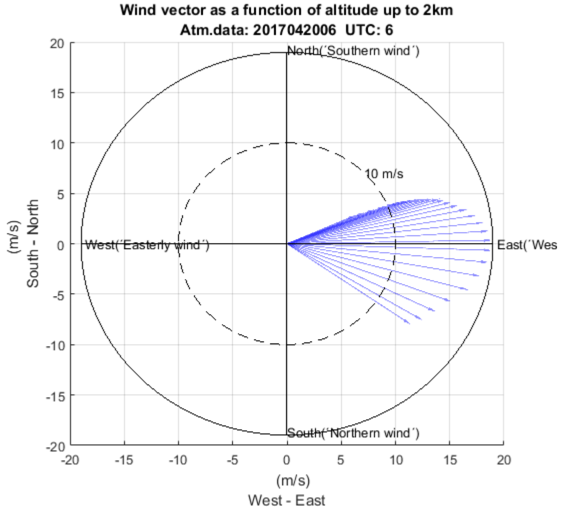
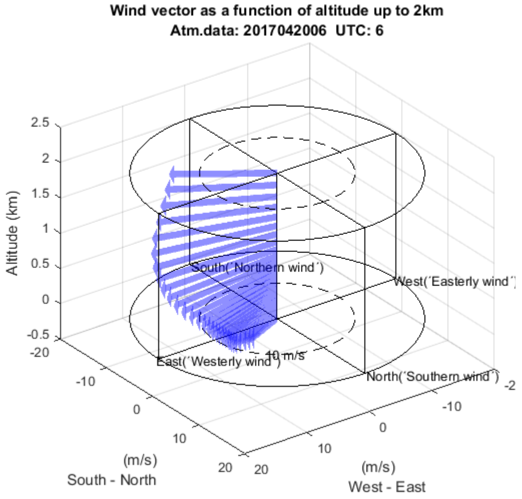
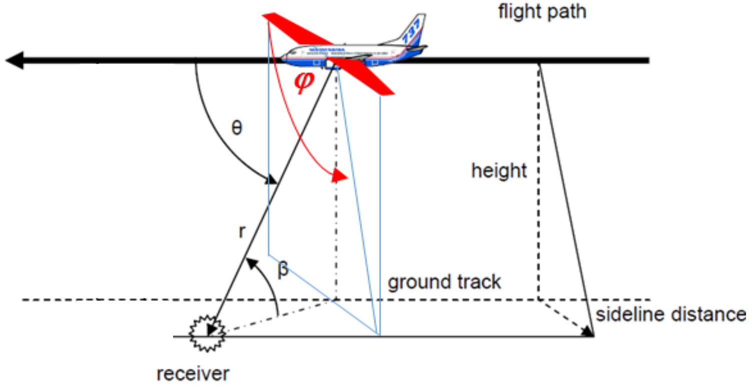
... cont 4. SAFT run examples b) SAFT reversed engineering A321-232 sound source from NPD-SEL, noise events emission and propagation angles case 1.

Sound source (= AC) emission angles ***wrt AC long. axis***

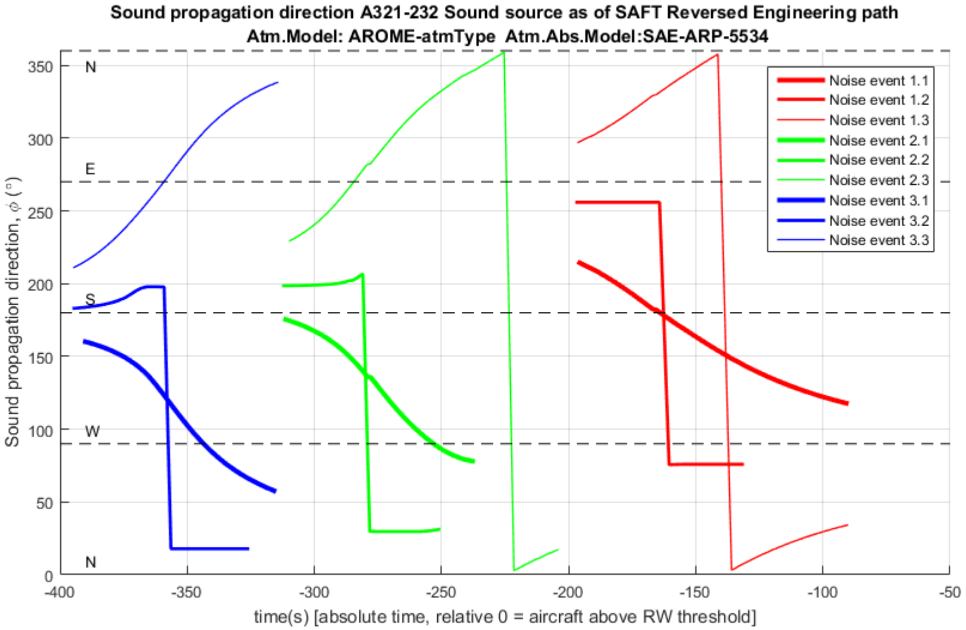








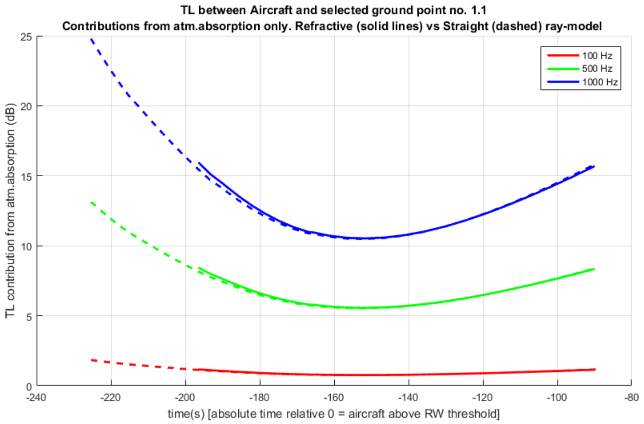
Sound source (= AC) emission angles ***wrt compass direction****

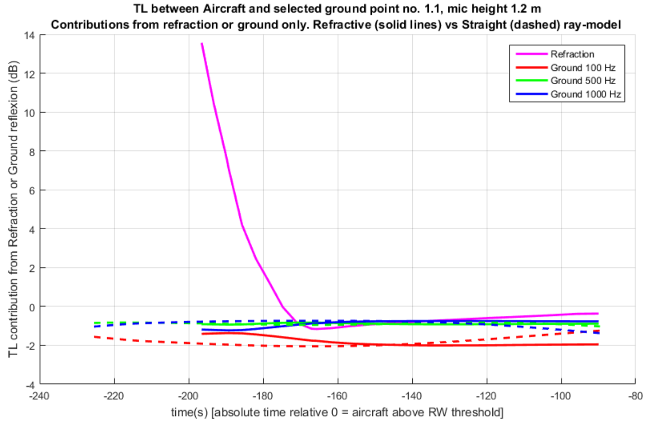


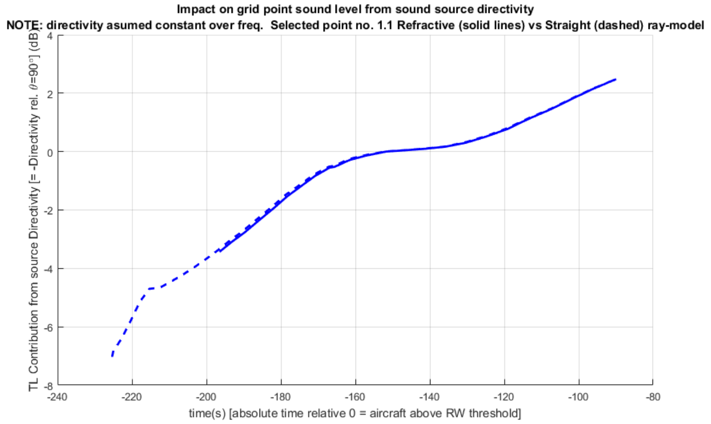
***)** assumed to be the same for refractive and straight rays in the applied 2D-ray tracing approach where rays are not allowed to leave individual vertical planes

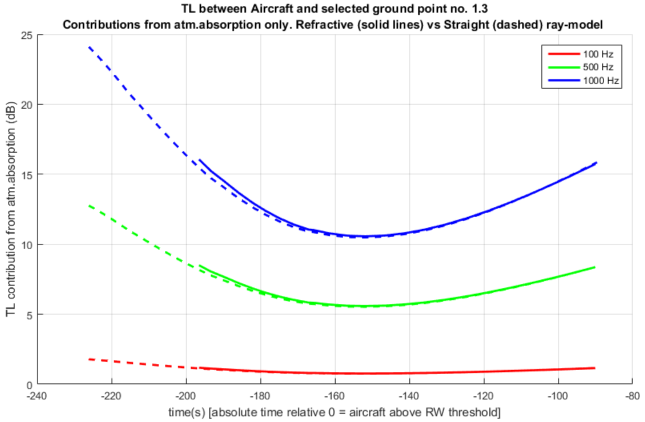
TL contributions in receiving points 1.1 and 1.3 from ...

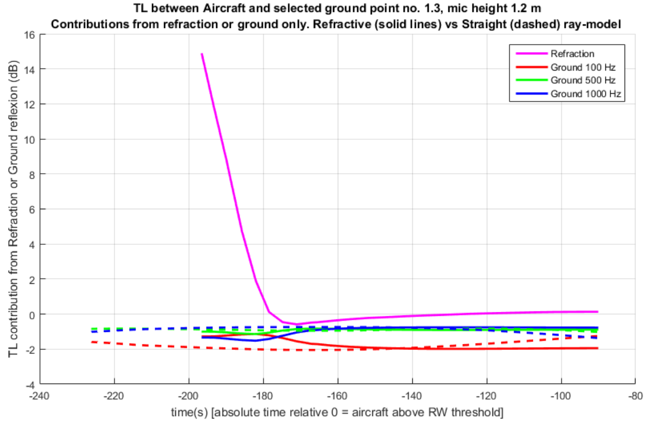
... absorption ... refraction(-) and ground reflexions ... source directivity

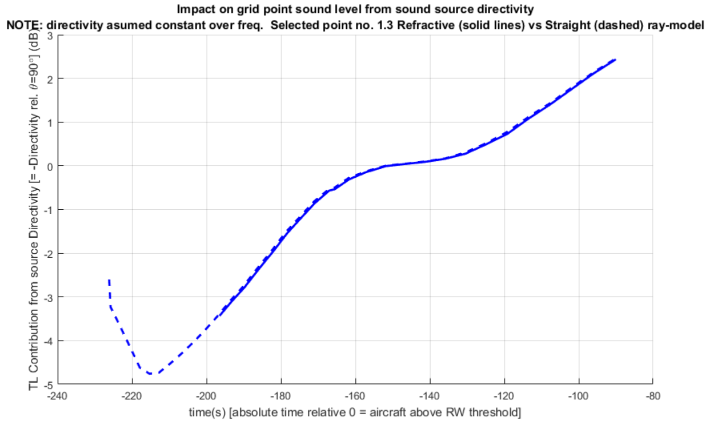












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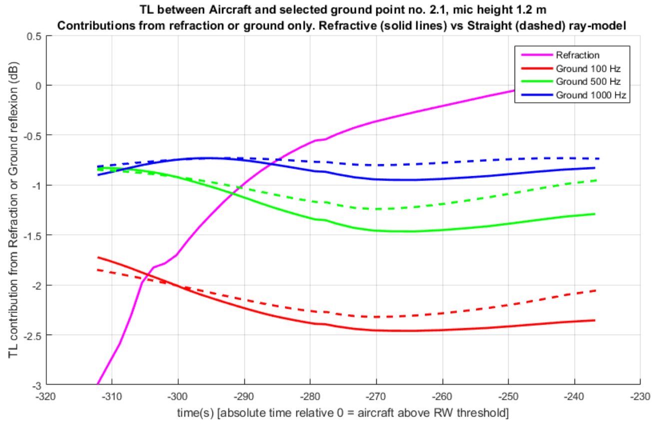
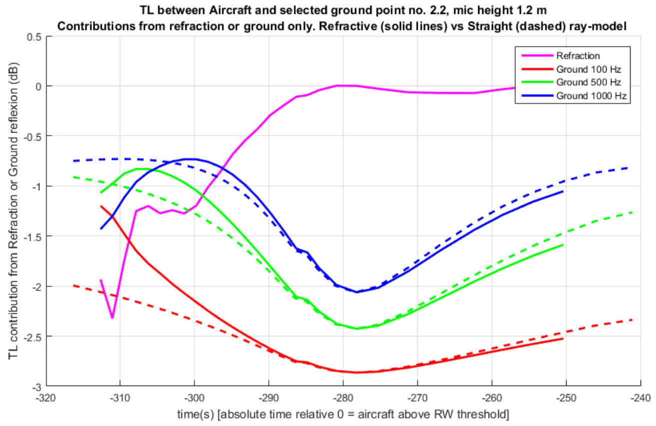
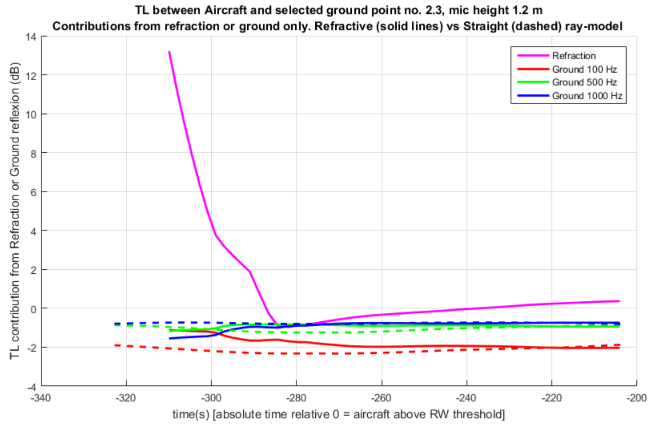
... cont 4. SAFT run examples b) SAFT reversed engineering A321-232 sound source from NPD-SEL, noise events individual TL contributions + spectrum(t) case 1.

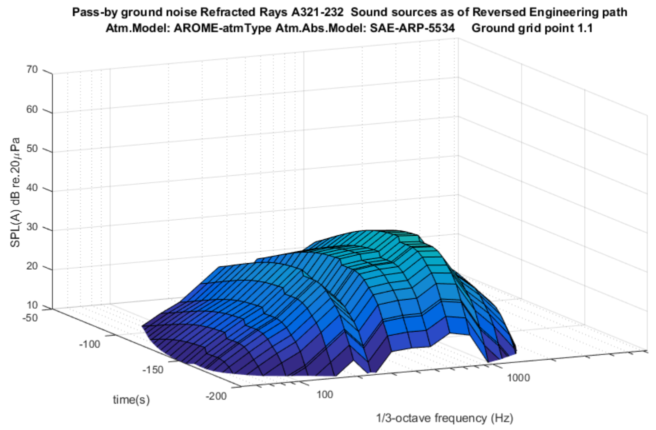
TL contributions in receiving points 2.1 to 2.3 from refraction(-) and ground reflexions

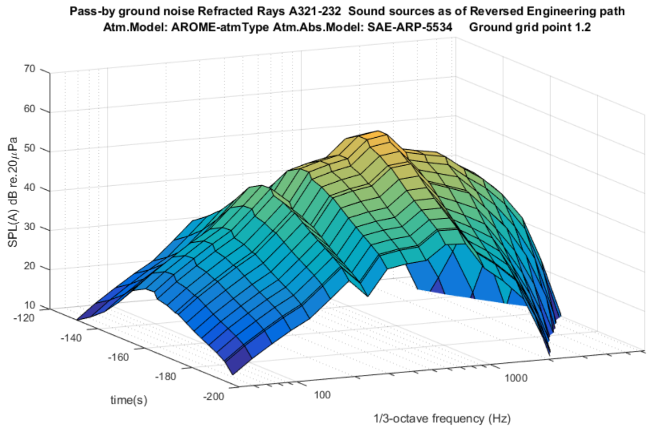


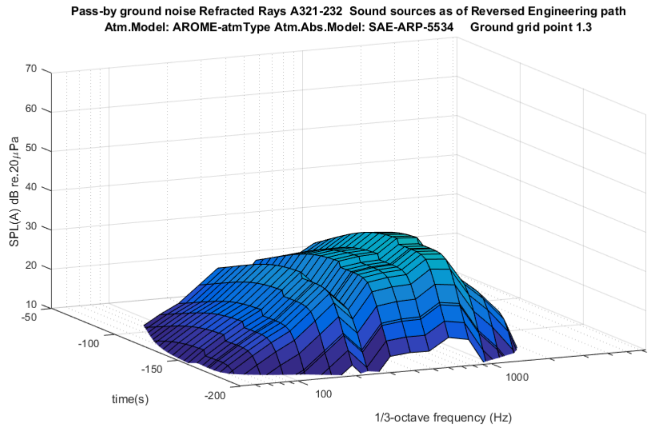




Sample sound spectrum(t) in receiving points 1.1 to 1.3







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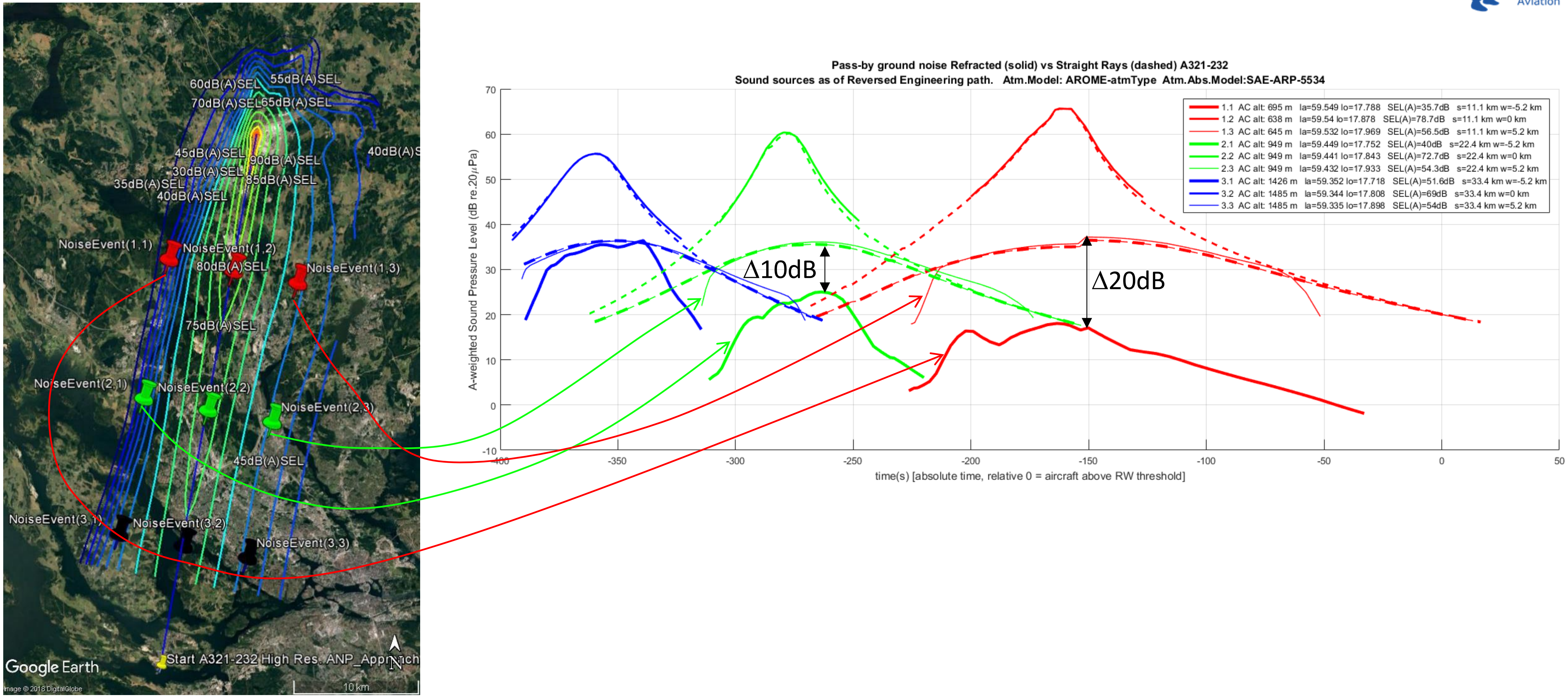
Example 2. Landing in side wind ⇒ *significant asymmetry for lateral ground positions*



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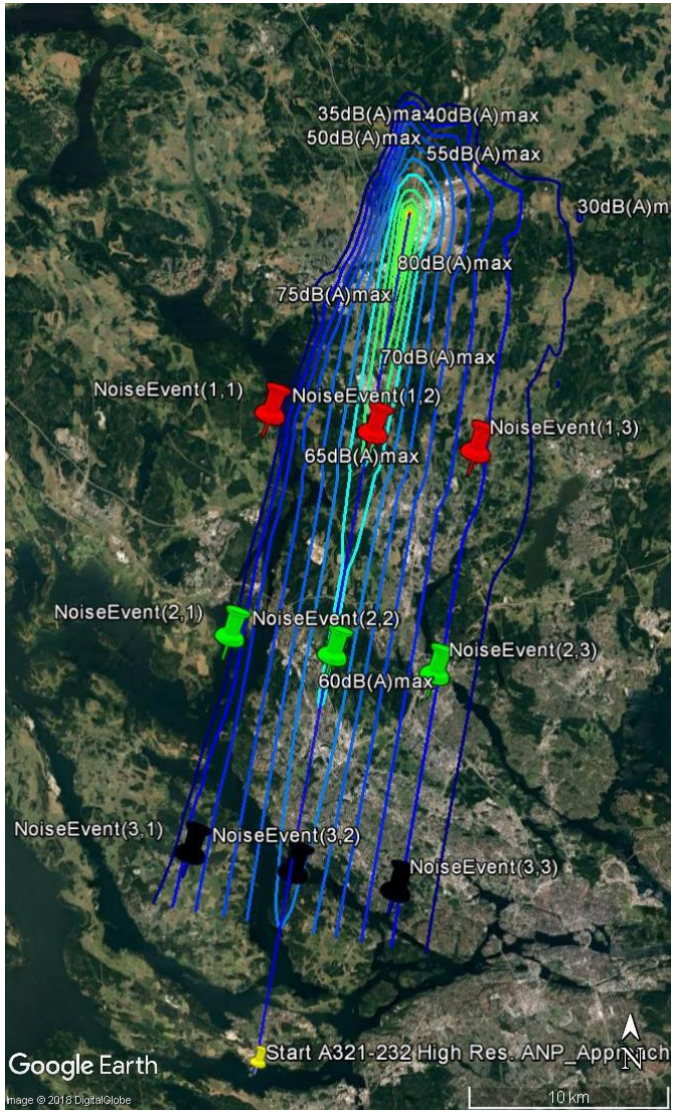
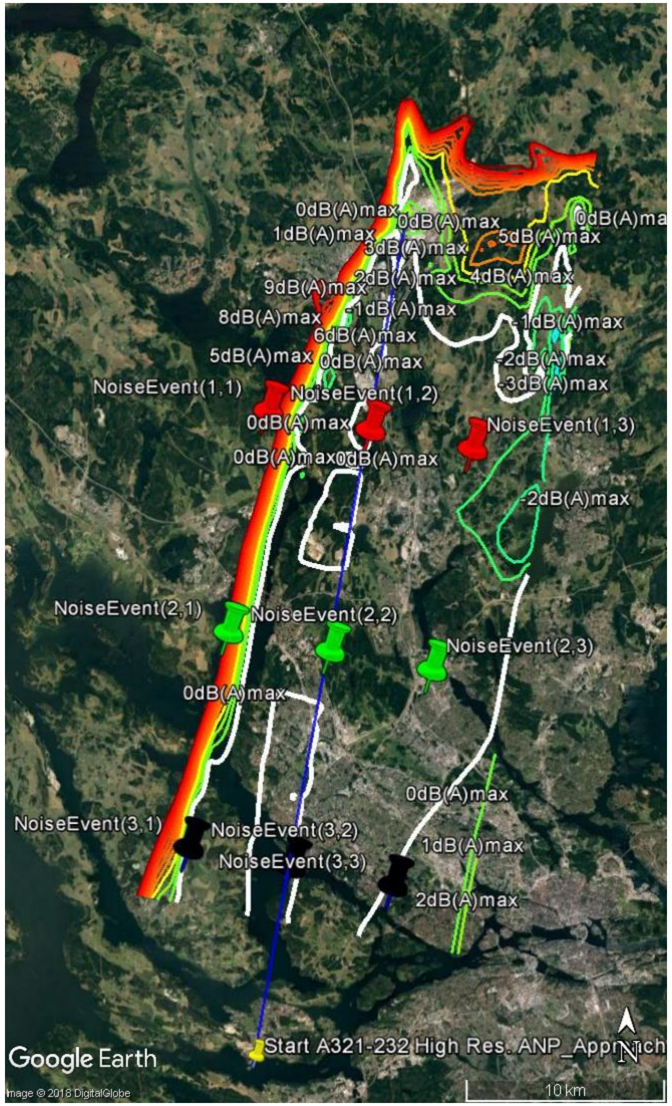
$L_{pmax(A)}$ contours (refr.rays)

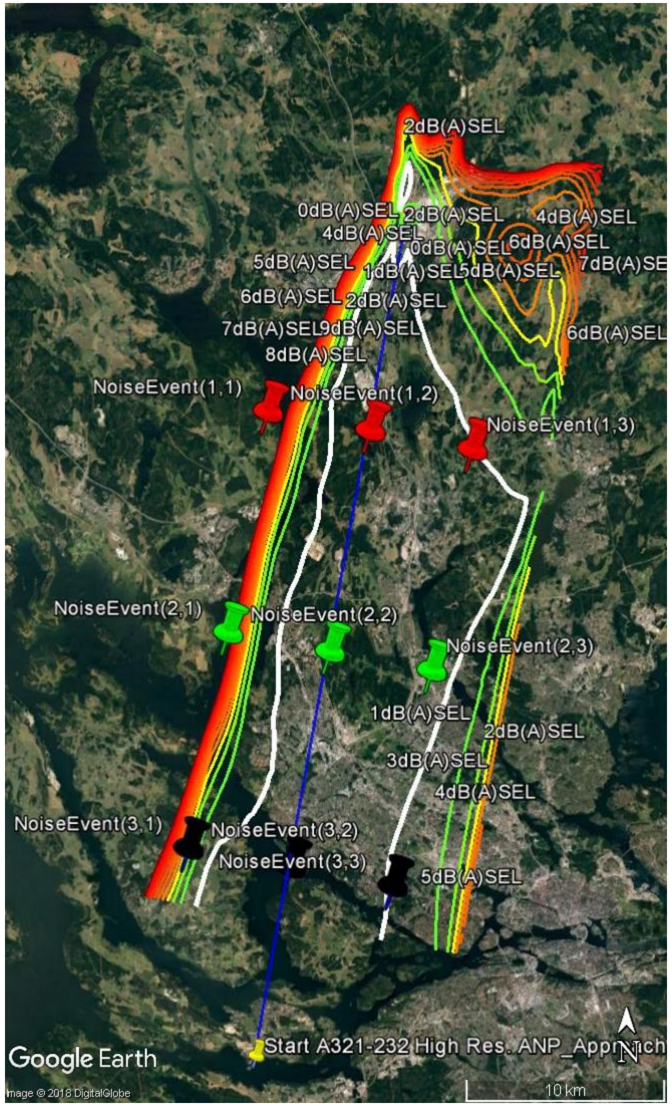


Difference (dB) Straight vs Refracted rays model

$\Delta dB_{Str.-Refr.}$ $L_{pmax(A)}$



$\Delta dB_{Str.-Refr.}$ SEL(A)



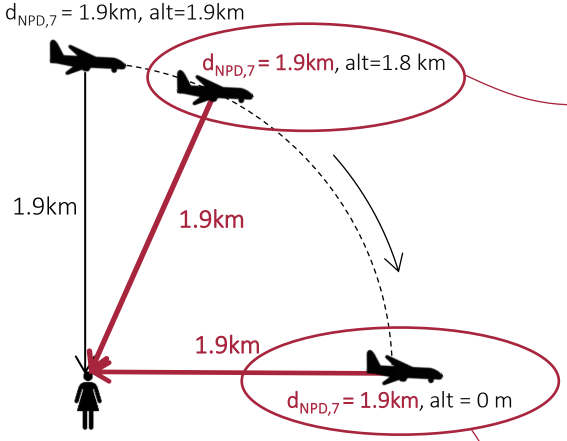
Example c) Absorption model impact – difference SAE-ARP-866A – “new model” along NPD distances (d_{NPD1}, d_{NPD2}, ...) in dB

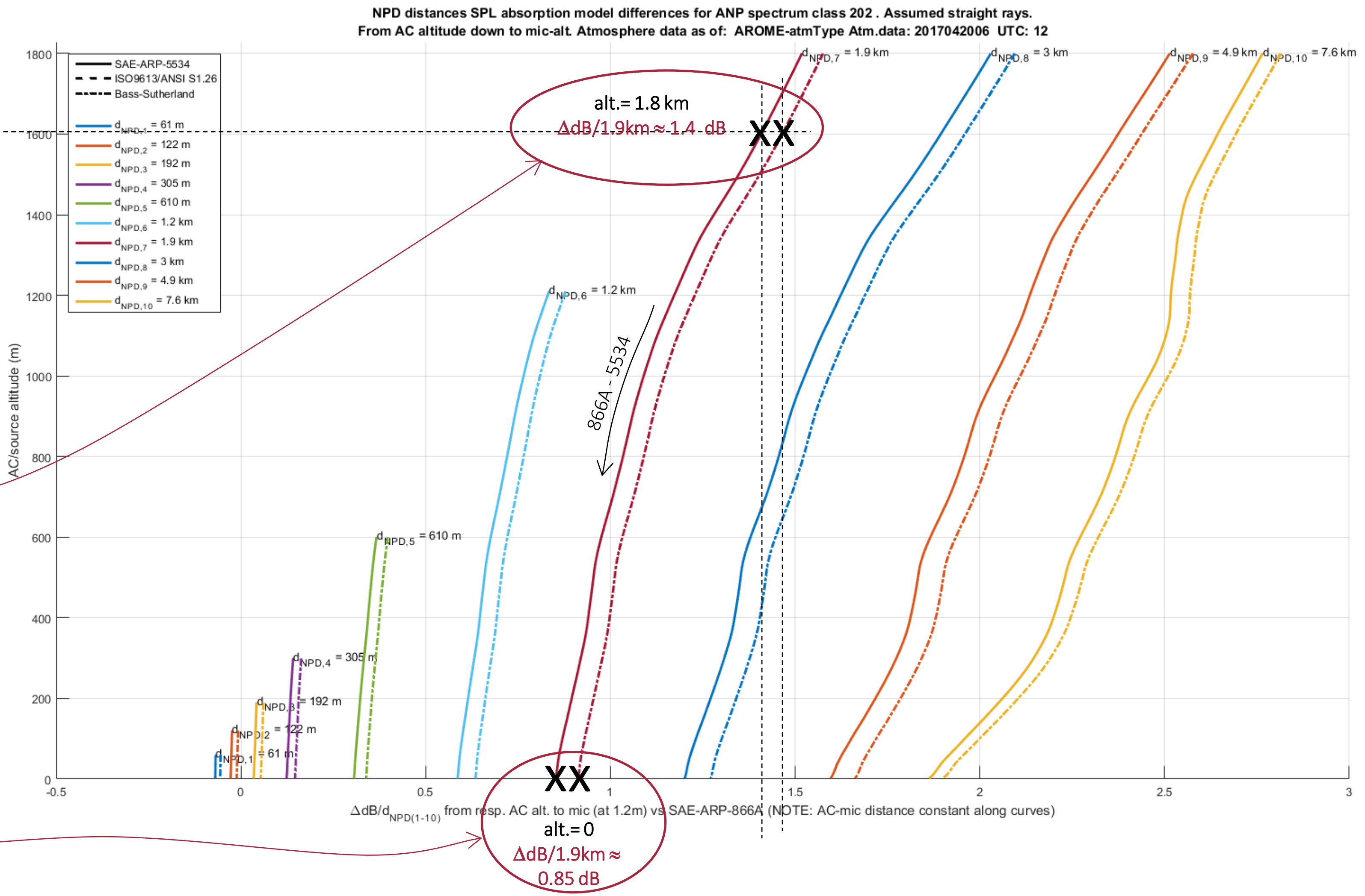
Parametric curves of: difference in total absorption given for fixed (NPD-) distances with varying Aircraft altitude for a sample atmosphere. (+ sign indicates: “new model” gives lower absorption/higher noise levels)

Remarks:

1. ISO9613 and Bass-Sutherland gives the same results here
2. ANSI 1.26 = ISO9613 (the same model)
3. SAE-ARP-5534 based on ANSI 1.26 + assuming a specific 1/3-octave spectra

Example: $d_{NPD,7}$ = 1.9 km		
AC alt.	ΔdB, SAE-ARP-866A – “new”	
	“new”= SAE-ARP-5534	“new”= ISO9613 or Bass- Sutherland
1.8 km	1.4 dB	1.45 dB
0 m	0.8 dB	0.85 dB





4. Future SAFT development and studies

Further developments:

- Validate SAFT A321-232 with support of measurements (CSA sibling project ULLA)
- Add tonal noise
- Implement batch-running mode (now: only interactive runs possible)
- Add other aircraft types (+drones/UAV's or helicopters if asked for) to SAFT library
- Alternative AC performance modelling tools linked with SAFT – in-house and commercial alternatives
- Implementation of Take-off scenarios

... cont 4. Future SAFT development and studies

Studies:

- Comparison TL-interpolation method vs “exact high-fidelity”
- Optimal approach routes geographic and procedural design with regard to population distribution, weather (current or typical, time of day/year)
- Studies of new and non existing aircraft
- Support of aircraft and engine design with regard to simulated ground noise from individual sources
- Support to runway-use patterns and approach route design, existing or to be built new runways
- Protected areas overflight impact
- Support aircraft noise measurements and data analysis
- ...

Thank you!