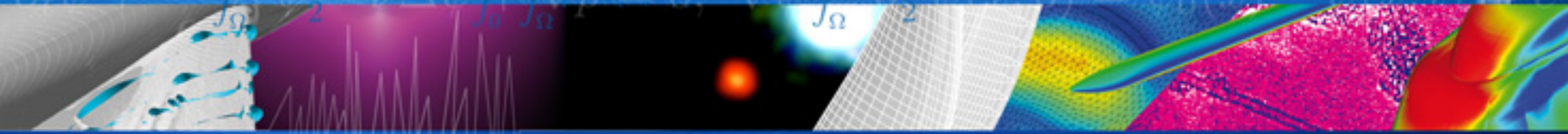

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ONERA contribution to the SBPW2 Propagation

Gérald Carrier, ONERA, Applied Aerodynamics Dept. , Meudon, France

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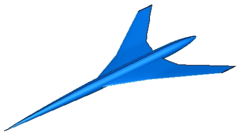
Outline

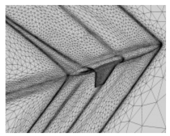
- Introduction
- Prediction codes
  - Short description
  - Specific parameters/options
- Summary of analysed cases
- Results for Case 1 (Axisymetrical body)
- Results for Case 2 (LM1021)
- Highlights
- Conclusions

Introduction:
Background

PhD ONERA/INRIA

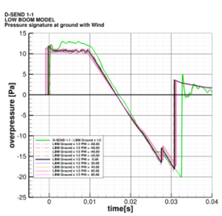
Aerodynamics /sonic boom optimization (A. Minelli, 2010-2013):
- Collaboration with INRIA (both OPALE and GAMMA2 teams)
- Advanced sonic boom prediction methods: CFD, mesh adaptation, multipole matching
- Advanced multicriteria optimization techniques :
  Nash Games, Multiple Gradient Descent Algorithm (J.A. Désidéri)





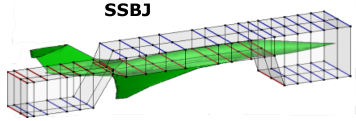
ONERA/JAXA

- **Analysis of DSEND#1 experiments :**



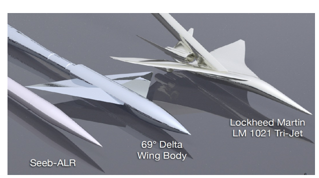
- **QSST DESIGN by inverse design method**

Parametrisation of JAXA SSBJ



ONERA/AIAA

AIAA Sonic Boom Prediction Workshop:
- Participation to the first AIAA SBP workshop in collaboration with **Dassault Aviation** and **INRIA**
- Validation of CFD-based prediction capabilities



Propagation code

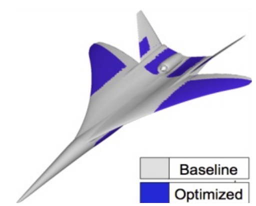
Long term collaboration with F. Coulouvrat (UPMC) since 2000:
- French national projects (COS, DGAC)
- EU projects (HISAC, ATLLAS, ATLLASII)

Use of the Airbus/UPMC code BANGV

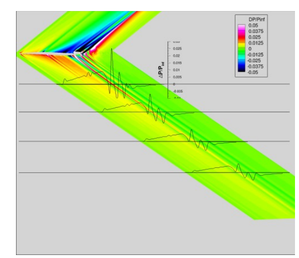
ONERA/STANFORD

Use of Stanford SU² code for sonic boom/aero optimizations

Application of ONERA sonic boom prediction tools on configuration Lockheed-Martin



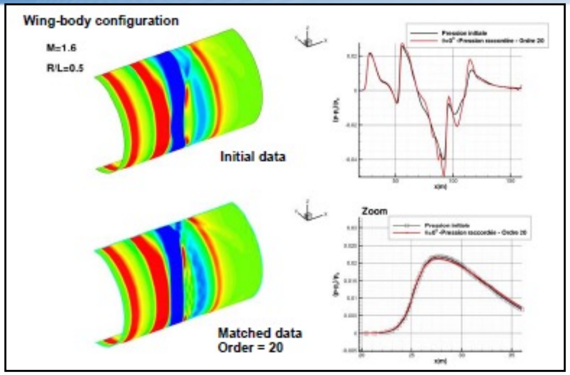
Adjoint based optimization of sonic boom (SU²)

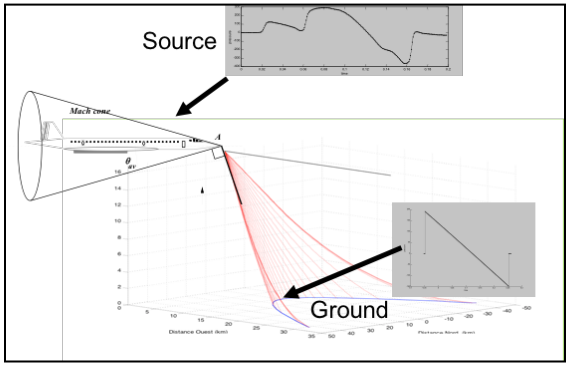


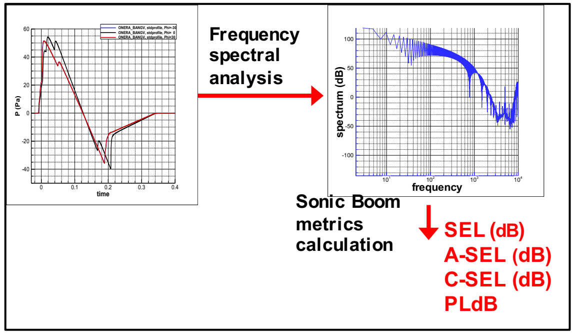
Sonic boom evaluation of LMCO configuration

Prediction codes
Available codes at ONERA for SB

- Multipole matching code
  - In-house code based on Plotkin and Page, 2002 [1]
- Propagation codes:
  - In-house code based on TRAPS [2] code (non viscous)
  - BANGV : developped at UPMC/CNRS (Université Pierre et Marie Curie, Paris) by F. Coulouvrat et al., Airbus property
- Loudness calculation:
  - pyBoomMetrics: in-house Python code for dB, PLdB, A-SEL, C-SEL metrics calculation
  - Internal BANGV loudness routines



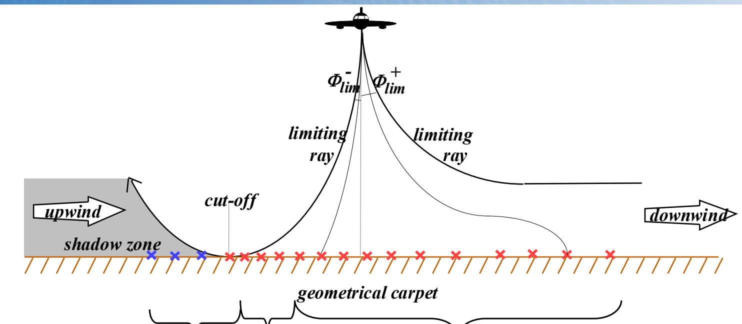




[1] I. Salah El Din et al., « Impact Of Multipole Matching Resolution On Supersonic Aircraft Sonic Boom Assessment », Progress in Flight Physics 5 (2013) 601-620

[2] A. D. Taylor, « The Traps Sonic Boom Program », NOAA Technical Memorandum ERL ARL-87, July 1980 Air Resources Laboratories, Silver Spring, Maryland

Prediction codes:
BANGV – v4



BANGV – v4:

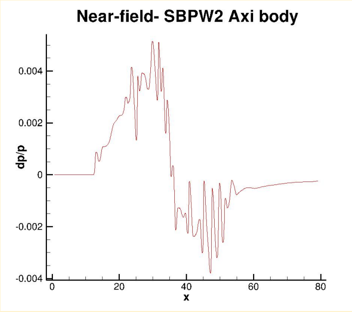
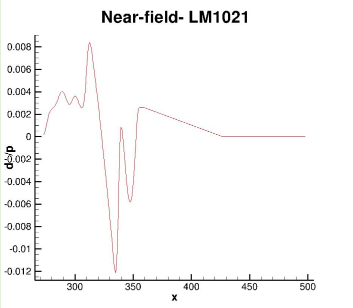
- Assumptions:
  - Stratified atmosphere, no turbulence
  - Flat, absorbing ground
- Methods:
  - Ray tracing: integrating a system of 13 ODEs in dZ, specific param. near ground)
  - Along rays: solves Burgers equation (with dissipation due to thermoviscous effects + molecular relaxation)
  - Ground reflection : mult. factor (1,9)
  - Diffraction at the limit of carpet by Fock integral
  - Shadow zone at and after cutoff: creeping wave

- Capable of calculating more complex physics such as caustics (Tricomi equ.)
- Inputs:
  - SB Source: Whitham F function or pressure at a distance of the A/C
  - Trajectory, atmospherical data (T, rho, RH, wind) interpolated by cubic spline
- Perfos: typical runtime few tens of CPUs for 1 ray on one single 2GHz PC processor

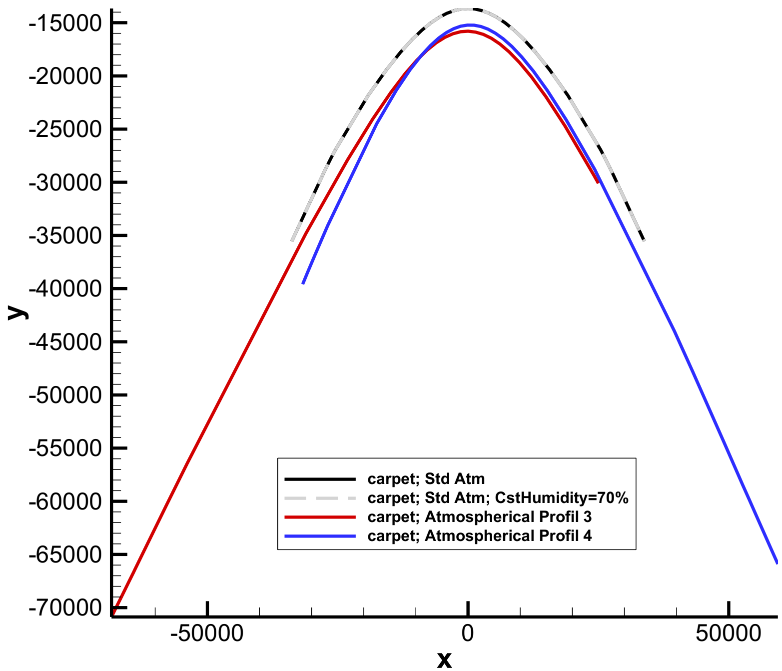
Specific parameters/options

- Data pre/post-processing:
  - Direct matching (no use of multipole matching)
  - Change axis for A/C trajectory (X-> -Y, Y->X)
  - Altitude shift of atm. data to have ground at alt. zero
  - Apply factor 1.9/2.0 on ground pressures on BANGV results
- Propagation:
  - Discretization:
    - Pressure input signal re-sampled every ~0.01 m with 32,768 points
    - Rays integration : 200 steps (for dissipative effects)
    - Altitude: 500,000 points (for identification of carpet limits rays)
- Loudness metrics calc.:
  - Resampling at 46 kHz
  - Max. freq for spectrum integration: 10 kHz

Summary of analysed cases

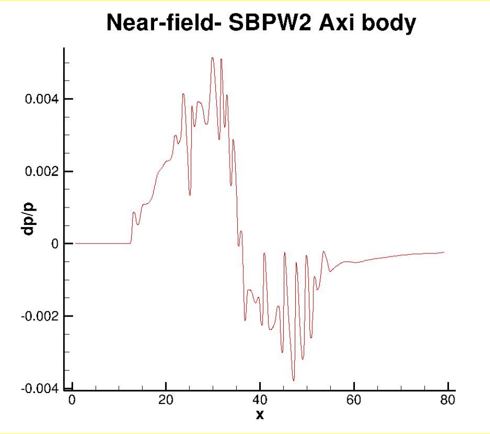
			Ground pressure	Lateral cut-off rays	Loudness
	Case 1 Axi body	Std. Atm.	-45°,0°,45° (BANGV + TRAPS)	BANGV, TRAPS	pyBoomMetrics
		Std. Atm. + 70% RH	-45°,0°, 45° (BANGV)	BANGV	pyBoomMetrics
		Atm. Profile 3	-45°,0°, 45° (BANGV)	BANGV	pyBoomMetrics
		Atm. Profile 4	-45°,0°, 45° (BANGV)	BANGV	pyBoomMetrics
	Case 2 LM1021	Std. Atm.	-30°,0°, 30° (BANGV)	BANGV	pyBoomMetrics
		Std. Atm. + 70% RH	-30°,0°, 30° (BANGV)	BANGV	pyBoomMetrics
		Atm. Profile 1	-30°,0°, 30° (BANGV)	BANGV	pyBoomMetrics
		Atm. Profile 2	-30°,0°, 30° (BANGV)	BANGV	pyBoomMetrics

Results for Case 1 (Axisymetrical body)
Lateral carpet extent / cut-off angles

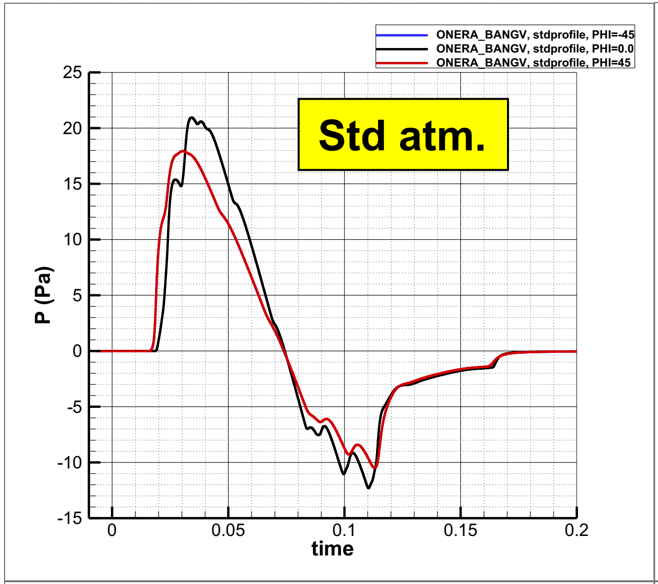


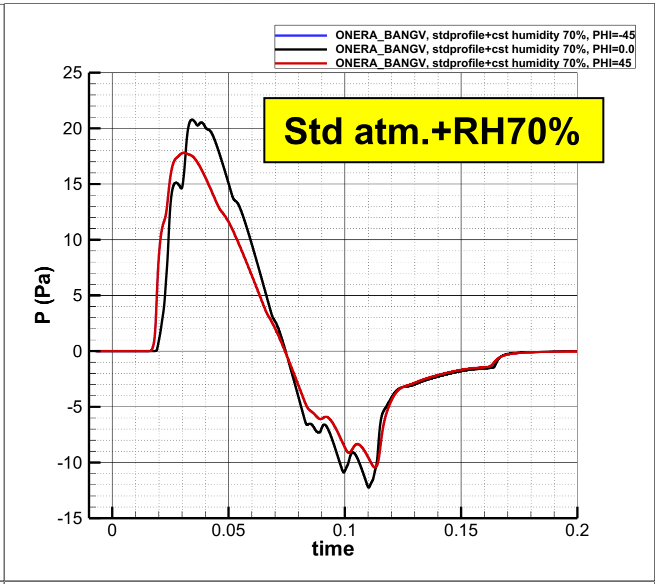
	Φmin (deg)	Φmax (deg)	Ymin (m)	Ymax (m)
Stand. Atm.	-49.6	49.6	-28006	28006
Stand. Atm. + 70% RH	-49.6	49.6	-28006	28006
Atm. Profile 3	-53.7	47.5	-64160	25186
Atm. Profile 4	-44.0	46.5	-35340	52615

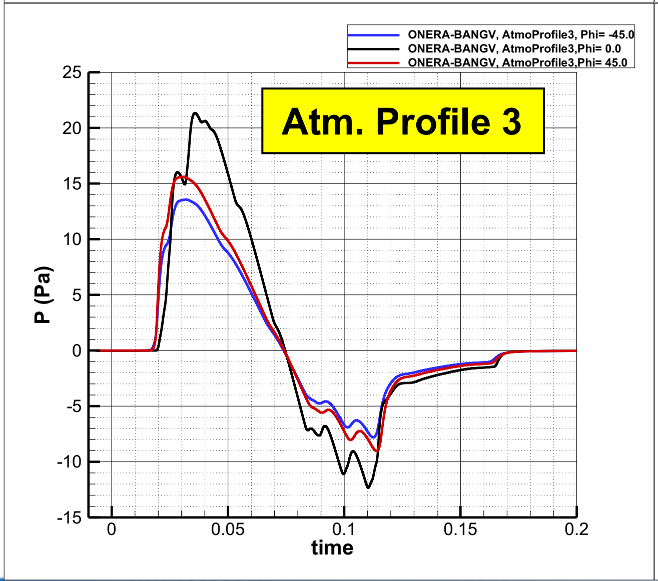
Results for Case 1 (Axisymetrical body)
Ground propagated signals (ϕ=-45˚, 0˚, 45˚)

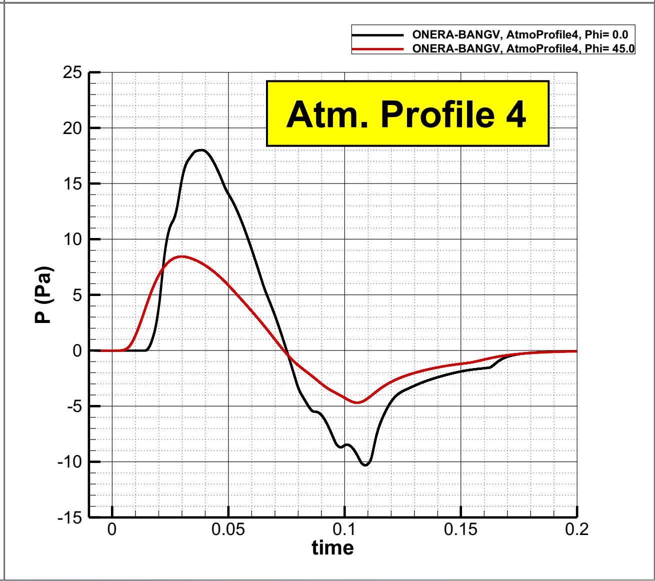


Near Field



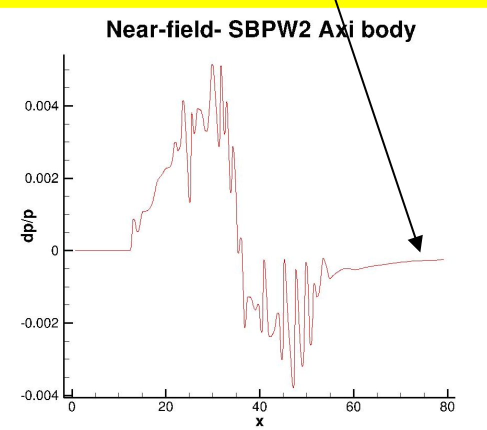




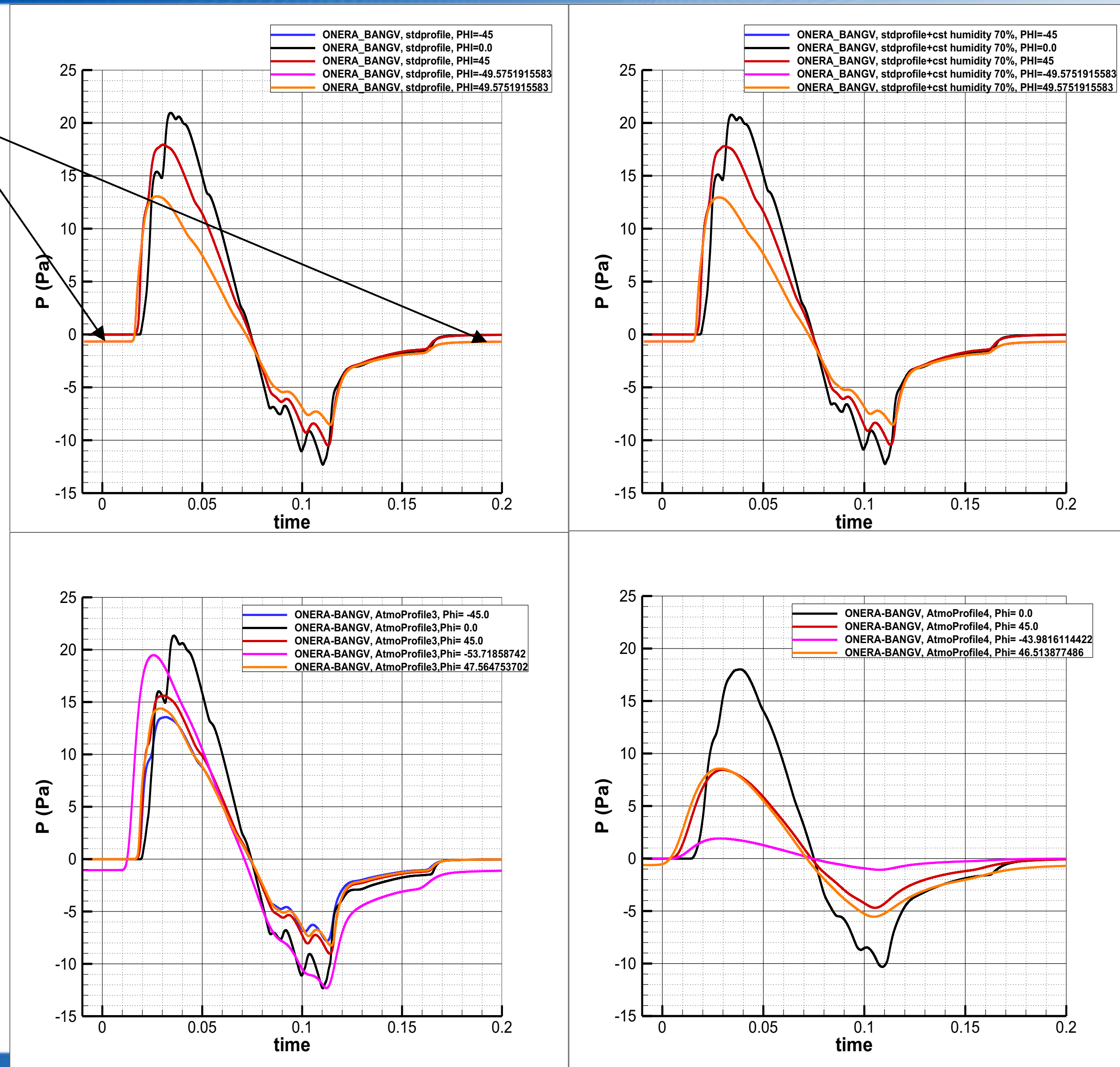


Results for Case 1 (Axisymetrical body)
Ground propagated signals (lateral cut-off)

!!! Something wrong in pressure at lateral cut-offs



Near Field



Results for Case 1 (Axisymetrical body) Loudness

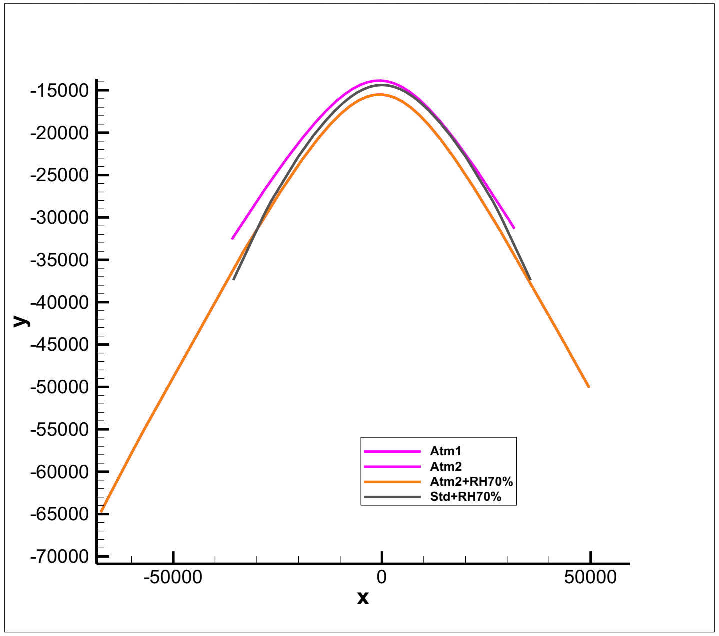
Stand. Atm.	PLdB	CSEL	ASEL
Φ= - 45°	79.11	90.93	64.42
Φ= 0°	80.60	91.92	65.61
Φ= 45°	79.11	90.93	64.42
~~Φmin~~	~~79.05~~	~~88.82~~	~~61.41~~
~~Φmax~~	~~79.05~~	~~88.82~~	~~61.41~~

Stand. Atm. + 70% RH	PLdB	CSEL	ASEL
Φ= - 45°	78.55	90.75	63.86
Φ= 0°	80.27	91.78	65.32
Φ= 45°	78.55	90.75	63.86
~~Φmin~~	~~78.78~~	~~88.67~~	~~61.08~~
~~Φmax~~	~~78.78~~	~~88.67~~	~~61.08~~

Atm. Profile 3	PLdB	CSEL	ASEL
Φ= - 45°	75.39	88.39	60.99
Φ= 0°	81.07	91.98	65.74
Φ= 45°	78.25	89.89	63.61
~~Φmin~~	~~80.17~~	~~91.67~~	~~61.80~~
~~Φmax~~	~~77.08~~	~~89.25~~	~~62.18~~

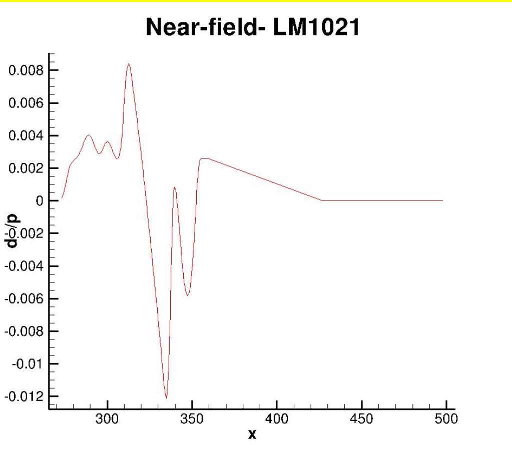
Atm. Profile 4	PLdB	CSEL	ASEL
Φ= - 45°	-	-	-
Φ= 0°	71.48	89.45	56.68
Φ= 45°	50.66	81.84	41.19
~~Φmin~~	~~18.44~~	~~69.08~~	~~28.99~~
~~Φmax~~	~~71.47~~	~~82.15~~	~~54.36~~

Results for Case 2 (LM 1021)
Lateral carpet extent / cut-off angles

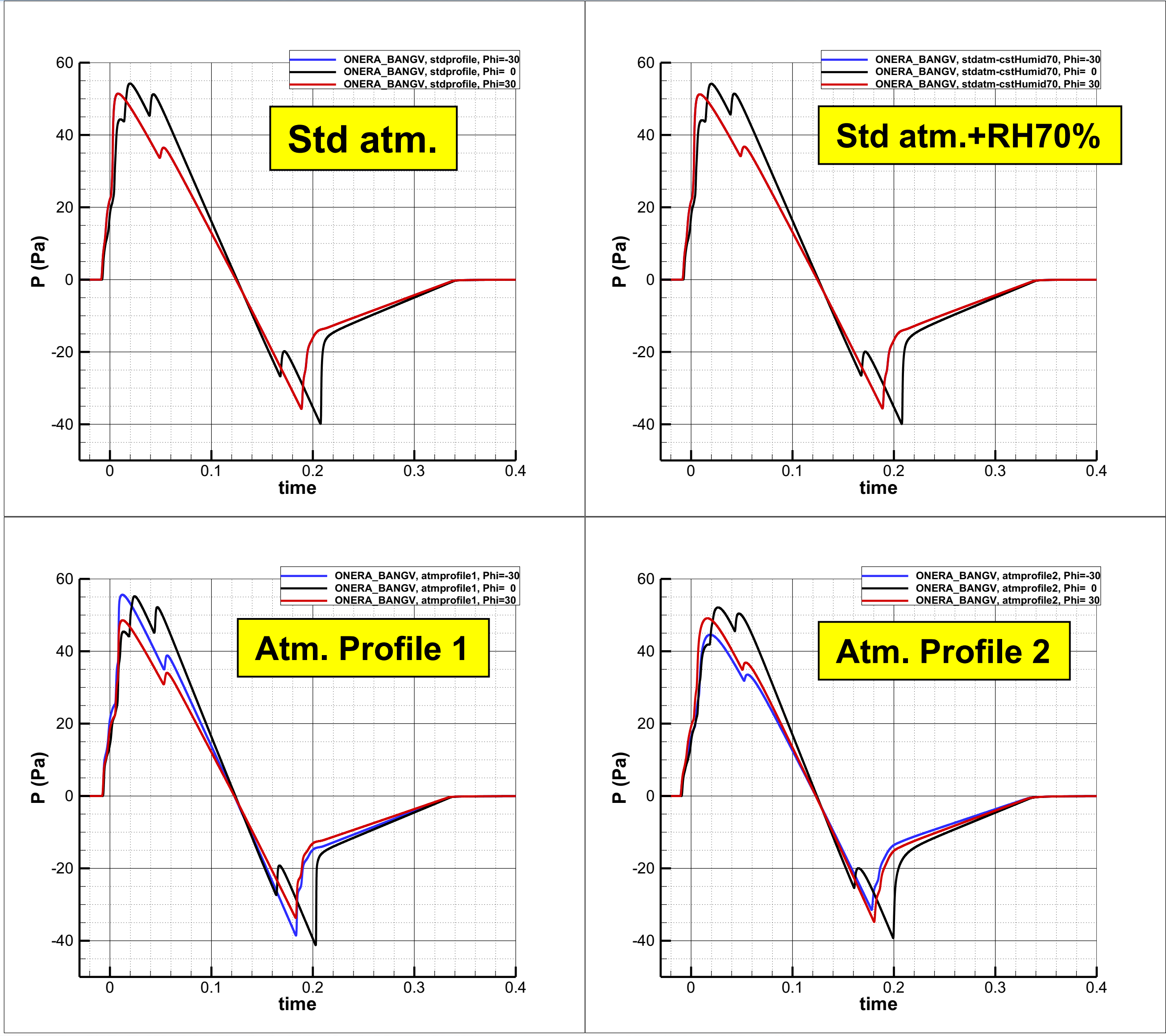


	Φmin (deg)	Φmax (deg)	Ymin (m)	Ymax (m)
Stand. Atm.	-49.7	49.7	-29109	29109
Stand. Atm. + 70% RH	-49.7	49.7	-29109	29109
Atm. Profile 1	-69.8	53.8	-64160	25186
Atm. Profile 2	-59.3	65.2	-73253	46776

Results for Case 2 (LM 1021)
Ground propagated signals (ϕ= -30˚, 0˚, 30˚)



Near Field



Results for Case 2 (LM 1021) Loudness metrics

Stand. Atm.	PLdB	CSEL	ASEL
Φ= - 30°	89.27	98.14	74.06
Φ= 0°	91.13	97.84	76.13
Φ= 30°	89.27	98.14	74.06

Stand. Atm. + 70% RH	PLdB	CSEL	ASEL
Φ= - 30°	89.01	98.04	73.77
Φ= 0°	90.75	97.72	75.79
Φ= 30°	89.01	98.04	73.77

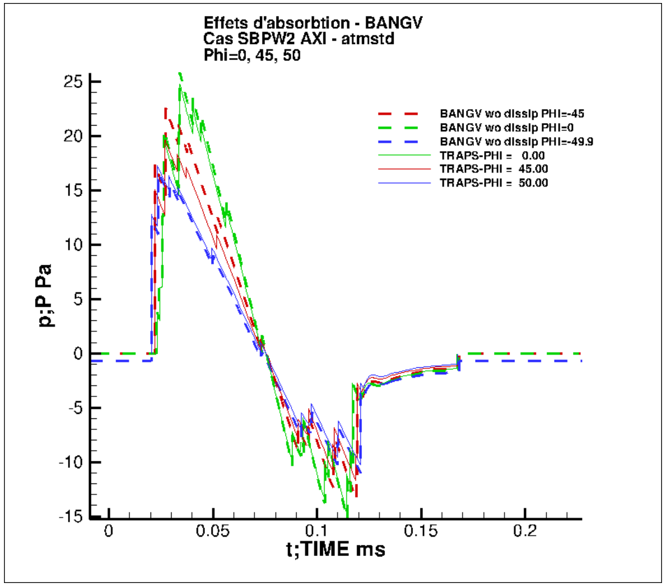
Atm. Profile 1	PLdB	CSEL	ASEL
Φ= - 30°	90.70	98.07	76.64
Φ= 0°	93.48	98.02	79.38
Φ= 30°	88.58	96.82	74.21

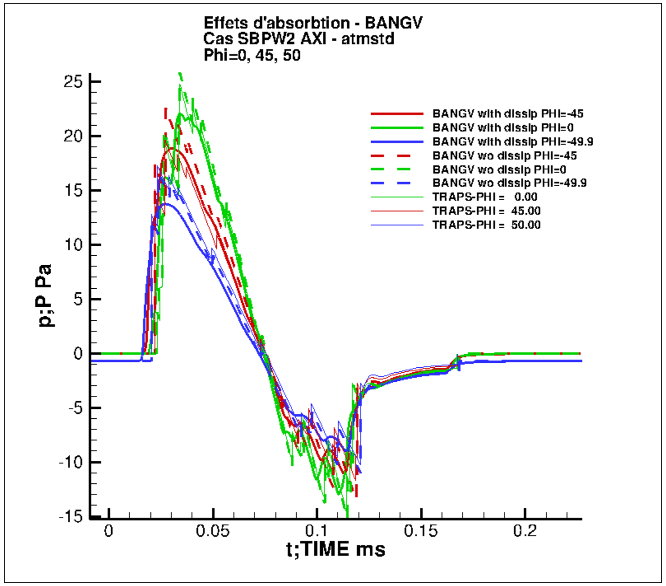
Atm. Profile 2	PLdB	CSEL	ASEL
Φ= - 30°	81.74	94.56	67.31
Φ= 0°	87.34	95.98	72.22
Φ= 30°	83.93	95.96	68.82

Highlights

- Impact of tail pressure relaxation in the near-field
- Detected an issue in ONERA ground pressure (therefore loudness) results at cut-off

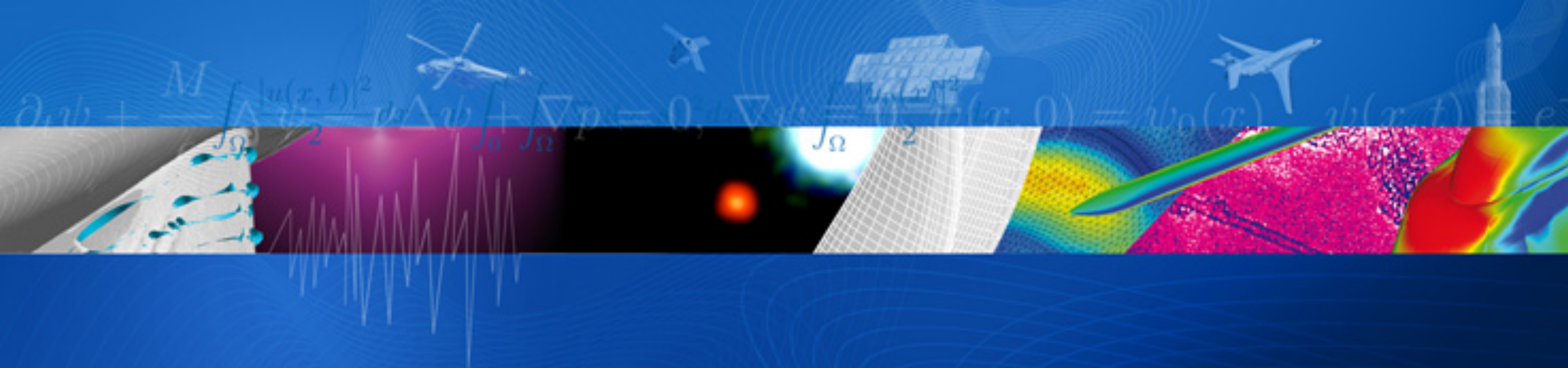
- Comparison between TRAPS and BANGV propagation codes :





Conclusions

- Both AXIsymetrical Body and LM1021 test cases computed for all atmosphere profiles
- BANGV-v4 code used for propagation and loudness metrics calculated with in-house code
- Perspectives :
  - Investigate and fix the prblm detected on lateral cut-off signals
  - More extensive convergence studies (propagation code parameters, loudness calculation)
- Suggestions for future SBPW :
  - Validation of interim ray tracing results (comparison of 3D ray paths, ray area)
  - Spectrum comparison
  - Validation of loudness calculation code on common ground propagated signal(s)
  - Focalisation cases



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