3rd AIAA Sonic Boom Prediction Workshop

Dassault Aviation results and perspectives

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769896.

Pierre-Elie Normand (Dassault Aviation)

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Dassault Aviation and the supersonic : International collaboration on SB activities

- Participation to WG1 activities within ICAO/CAEP
- Participation to NASA SonicBAT flight test campaign analysis
- Participation to the AIAA Sonic Boom Workshop (2nd & 3rd)
- Participation in EU/RU RUMBLE project
  (RegUlation and norM for low sonic Boom LEvels)
  - Dedicated Work Package on Sonic Boom prediction capabilities
    - Validation of Near field modeling
    - Validation of Far field modeling

RUMBLE project description

WP1 – Recommendations for Regulation on Low Sonic Boom

Requirements, coordination of RUMBLE achievements with ICAO workplan, recommandations for a Sonic Boom Standard

WP2 – Sonic Boom prediction capabilities

Near field sonic boom prediction, modeling of atmosphere effects on far field , indoor sonic boom effects models, Low boom aerodynamic shapes definition,recommandations for prediction tools chain progress

WP3 – Human response to Sonic Boom

Outdoor and indoor human response to low sonic boom, outdoor low boom simulator tests, indoor low boom simulator tests, assessment of metrics, recommendations for low boom demonstrator community surveys

WP4 – Flight Procedures and Instrumentation Specifications

Relevant flight procedures and instrumentation for the substantiation of sonic boom levels, innovative way to characterize the atmosphere, recommendations for the flight procedures and instrumentation

WP5 – Flight Tests

flight tests using a legacy aircraft to validate the flight procedures, instrumentation and post processing of the test data, experimental database to validate sonic boom prediction

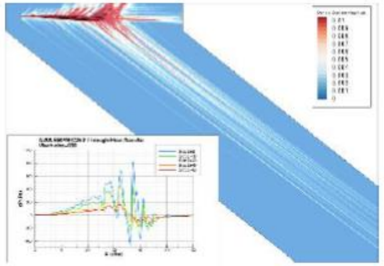
WP6 – Concept for a Low boom flying demonstrator

High level technical requirements toward a Low boom Flying Ddemonstrator, recommendations for a low boom flying demonstrator design

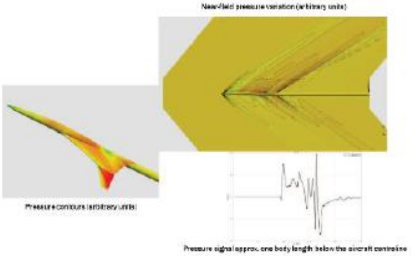
WP7 – Dissemination and Exploitation

WP8 – Management

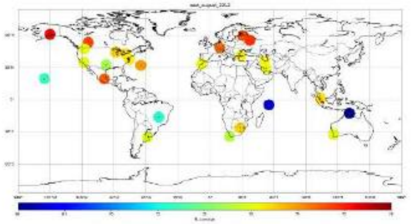
RUMBLE project description: Illustration of the work performed by partners



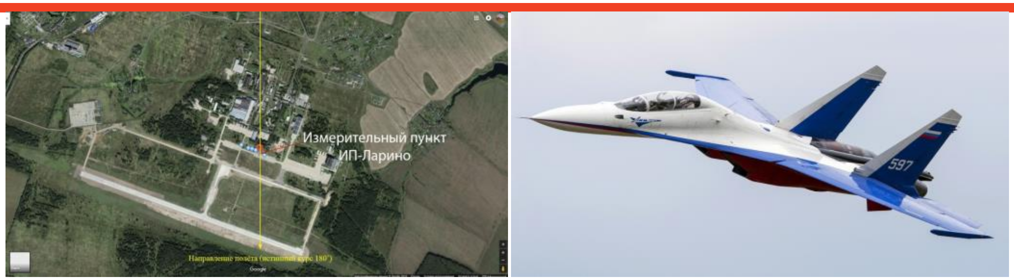
ONERA (near-field CFD)



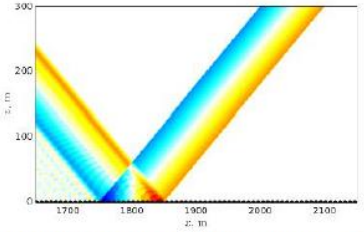
Airbus (near-field CFD)



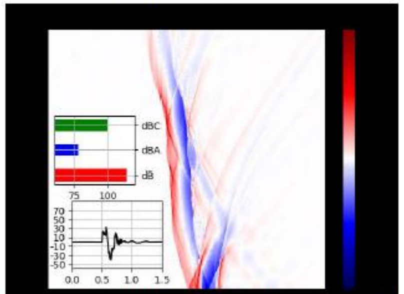
Dassault Aviation (meteo variability)



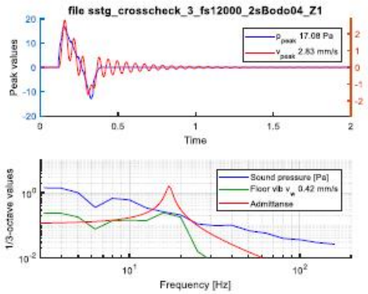
Flight test campaign performed by Gromov Flight Research Institute (Russia) in July 2018 and August 2019



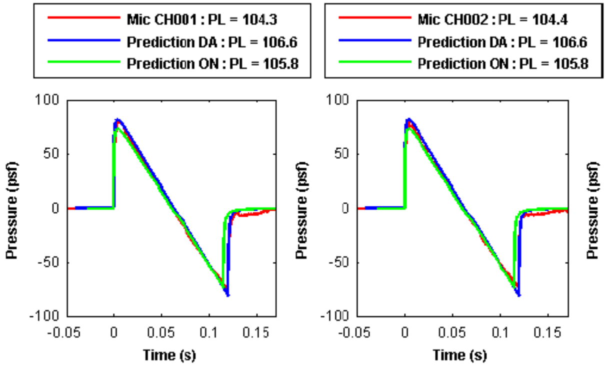
ECL/LMFA (ground waviness effect)



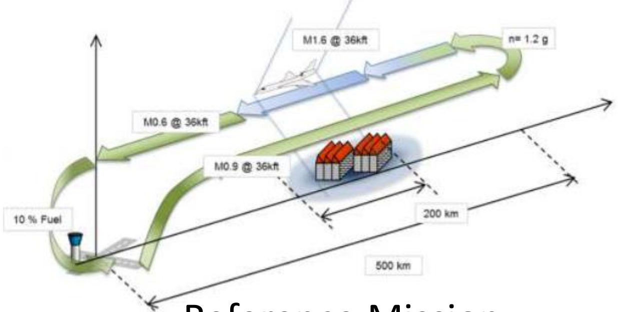
Sorbonne/UPMC (turbulence effect)



NGI (building vibrations simulations)



Scheme Exercice (SonicBAT)



Reference Mission

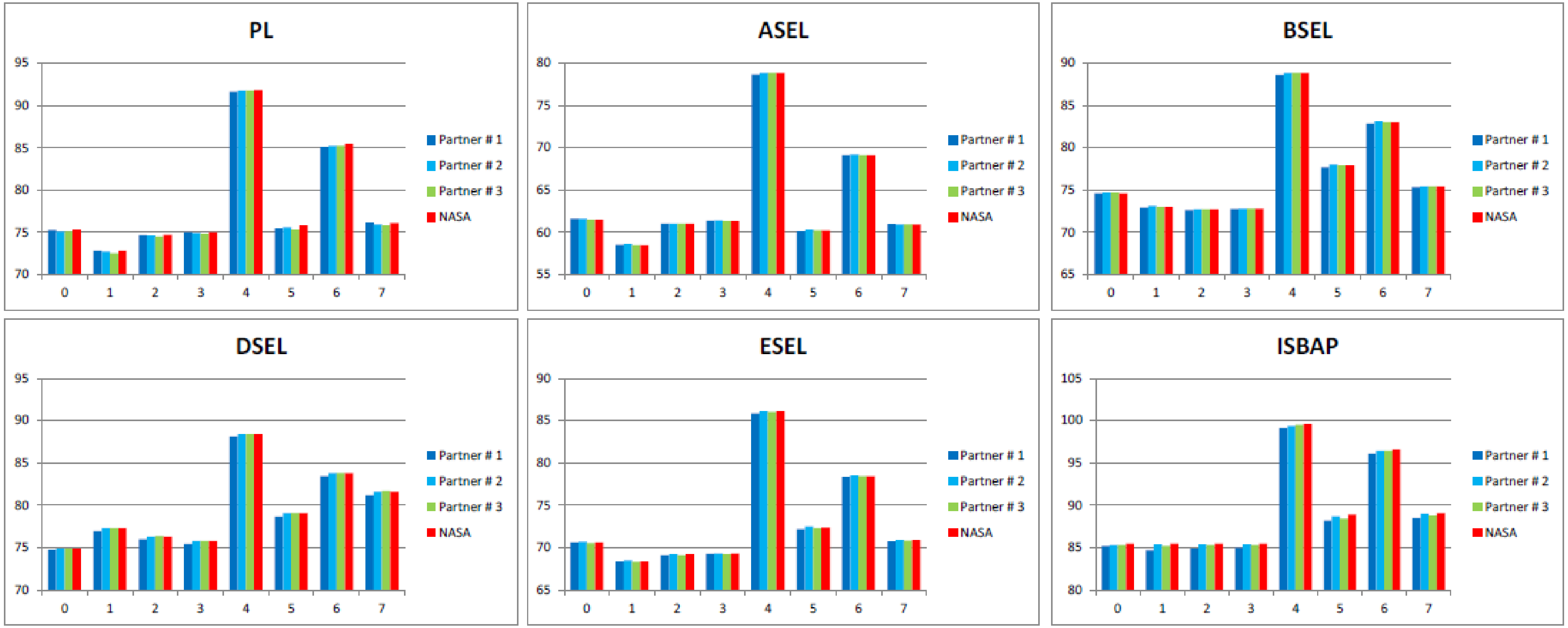
UPMC Sonic Boom Demonstrator at St-Cyr. 19th June 2019 ICAO/CAEP/WG1 visit.

Comparison between RUMBLE Partners

- Comparison of metrics between NASA and RUMBLE partners

The results show an overall good comparison (< 0.3 to 0.5 dB difference)

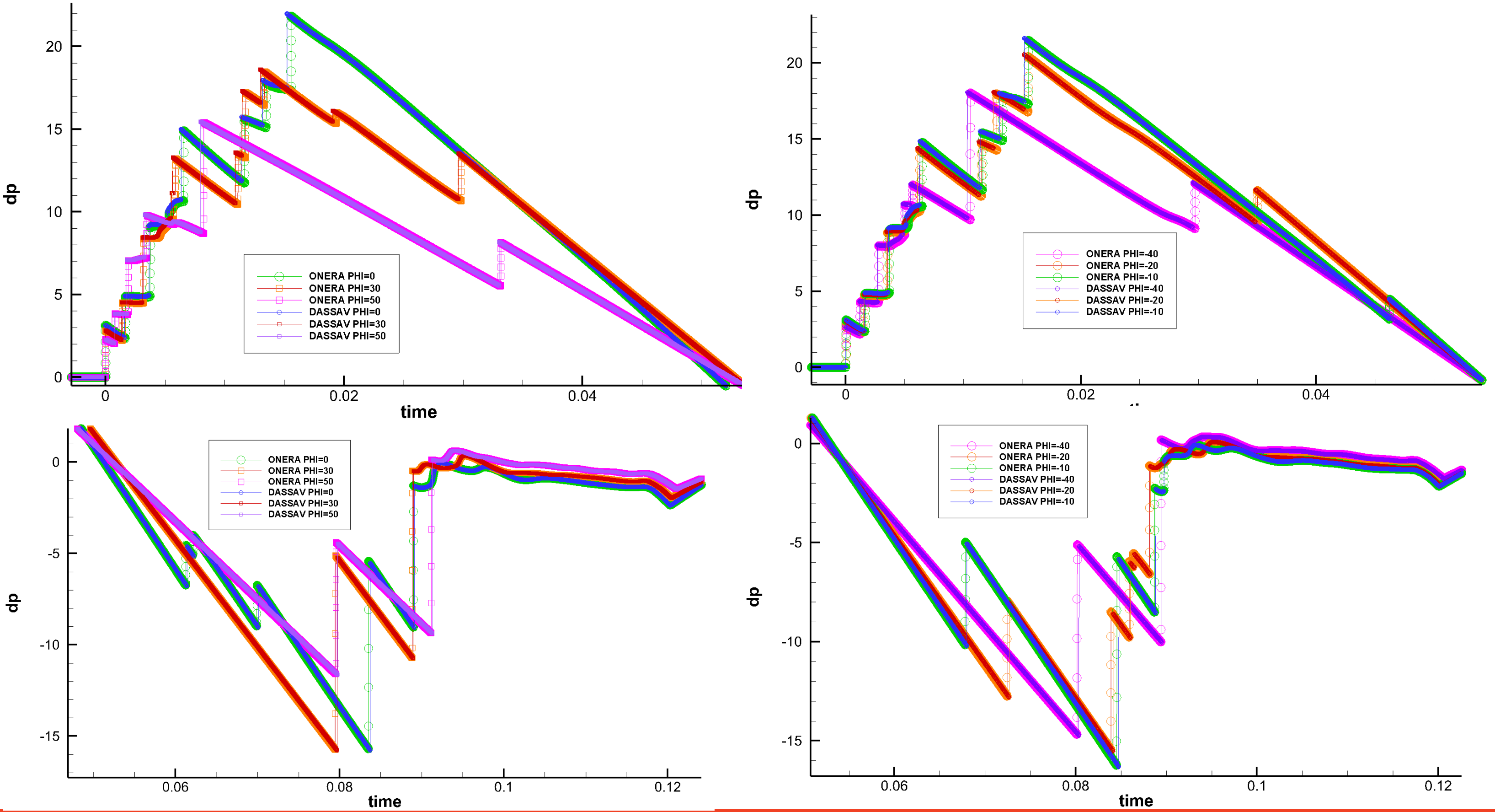
A Python package was delivered to the partners to share a common tool to compute sound metrics.



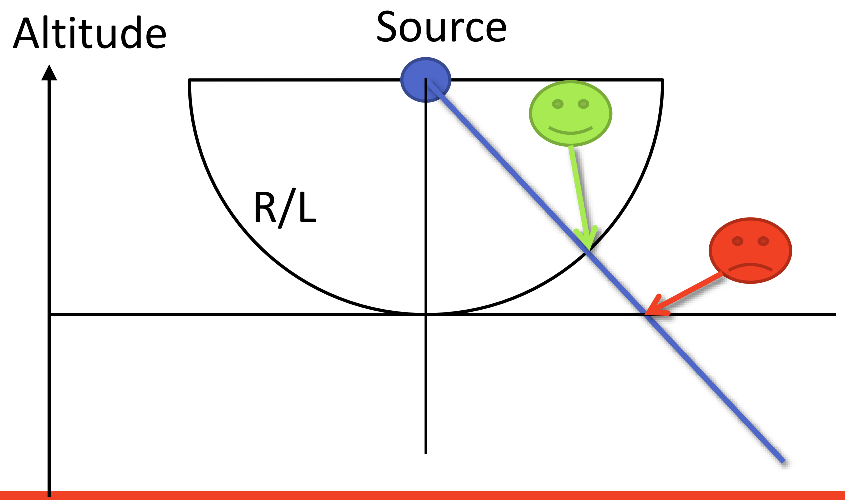
Comparison between RUMBLE Partners

•Far field prediction comparison: ONERA - DASSAULT

Using the workshop test cases : Case 1 with no dissipation



The comparison is excellent in this specific test case with no absorption



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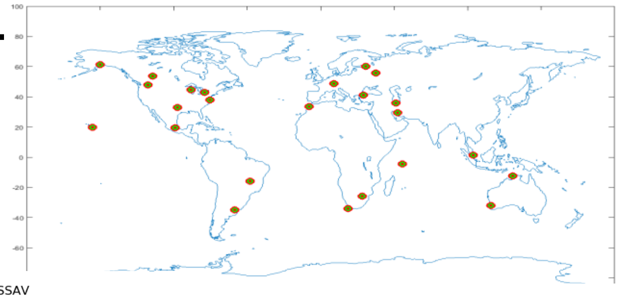
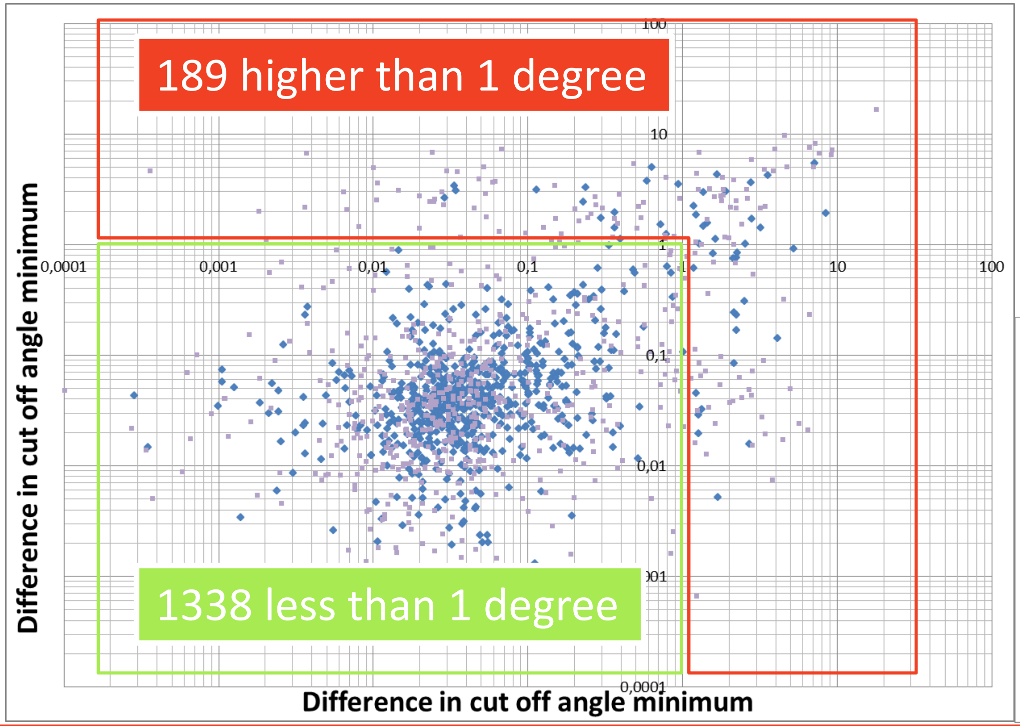
Comparison between RUMBLE Partners

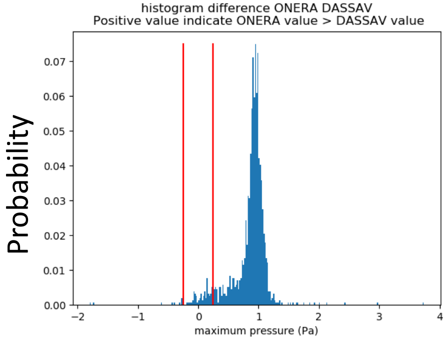
- Far field prediction comparaison: ONERA - DASSAULT

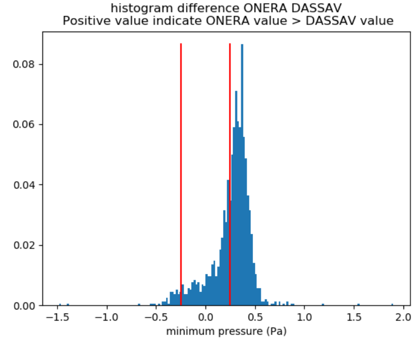
August 2012 IGRA Atmospheric profiles:

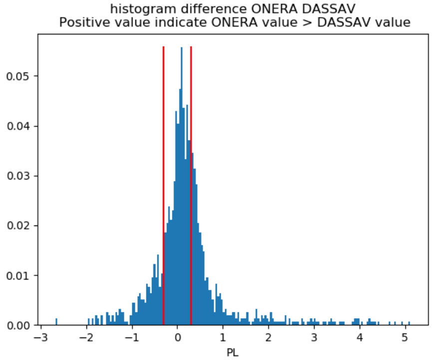
Data from August 2012 from a subset of 24 locations in the world have been firstly assembled by NASA.
Around 1100 atmospheres propagations have been run and the propagations compared.



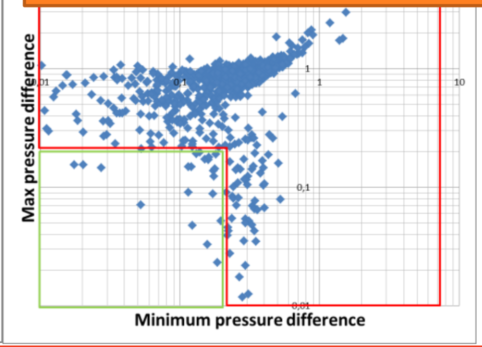


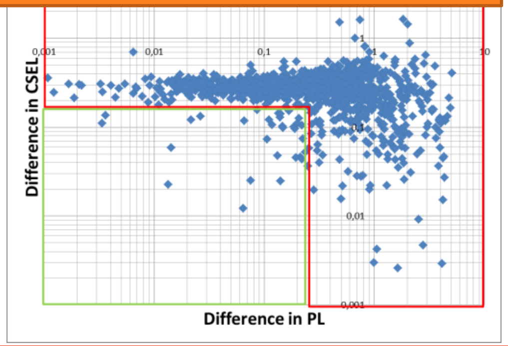


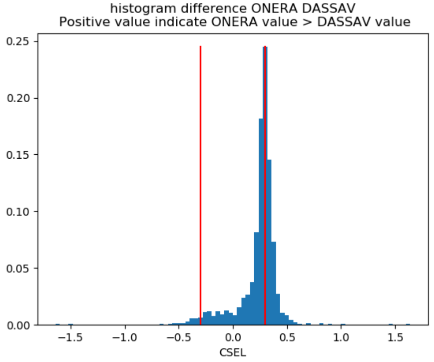




The differences may be in the absorption model



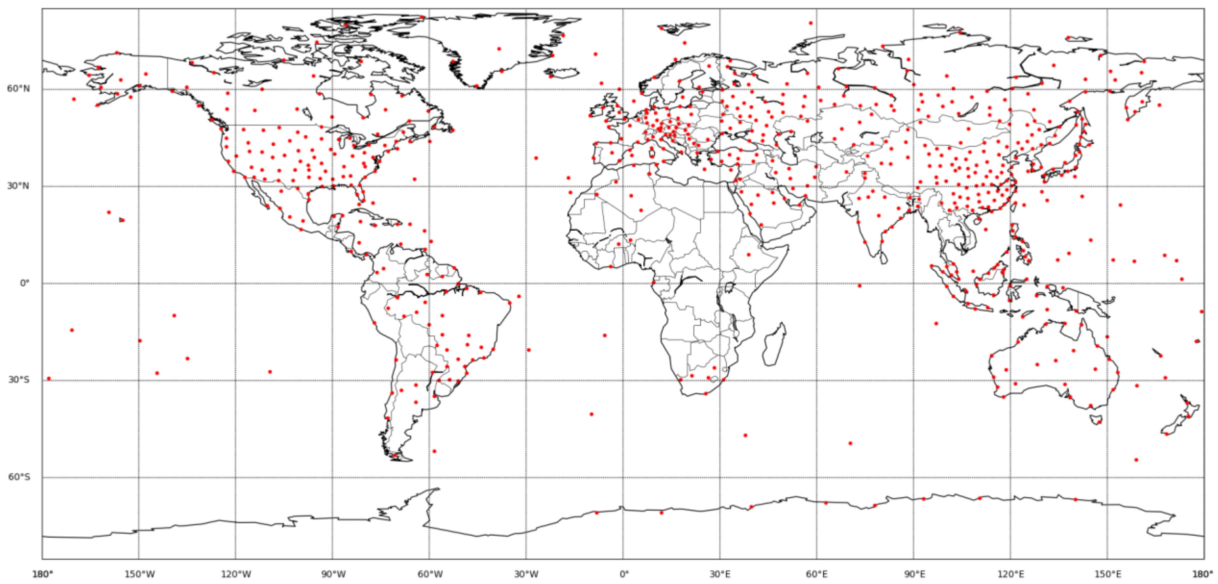




Far field propagation applications

- Using atmosphere database (IGRA, radiosonde and ERA5 Reanalysis)
- Sensitivity evaluation of propagation through different atmospheres :
    - Ground signal amplitude
    - Mach cut-off
    - Focusing zones

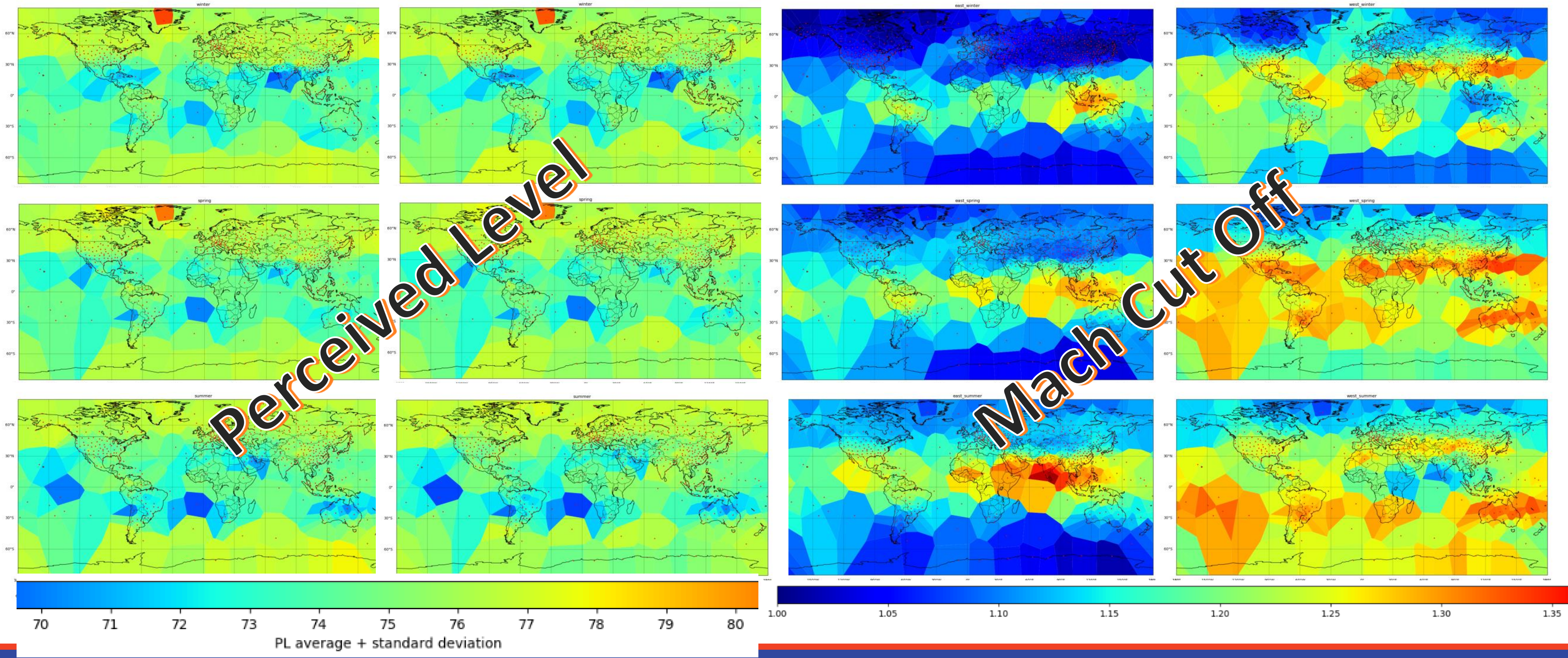
- Design



Number of atmospheres	December to February	March to May	June to August	September to November	Total
IGRA	90830	97990	98465	96030	383315
ERA5	239760	245088	245088	242424	972360

RUMBLE

Atmospheric sensitivity



Governing equations (DAbang)

$$\begin{cases} \frac{dx_{ray}}{d\psi} = u_{0x}(z) + c_0(z).\frac{s_x}{s} \\ \frac{dy_{ray}}{d\psi} = u_{0y}(z) + c_0(z).\frac{s_y}{s} \\ \frac{dz_{ray}}{d\psi} = c_0(z).\frac{s_z}{s} \\ \frac{ds_x}{d\psi} = 0 \\ \frac{ds_y}{d\psi} = 0 \\ \frac{ds_z}{d\psi} = -s\frac{dc_0}{dz} - s_x\frac{du_{0x}}{dz} - s_y\frac{du_{0y}}{dz} \end{cases}$$

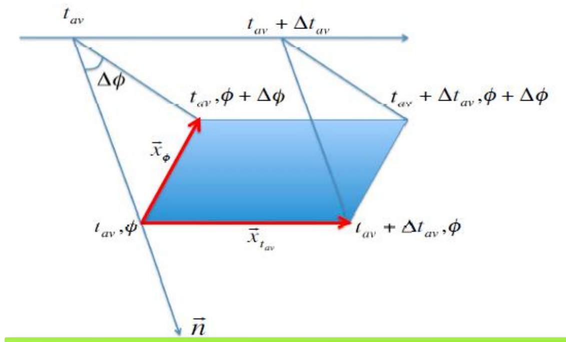
Ray : 6 equations

$$\mathbf{s} = (\mathbf{s}.\mathbf{n})\mathbf{n} = s\mathbf{n} = \frac{\mathbf{n}}{c_0 + \mathbf{n}.\mathbf{u_0}}$$

$$p_a(\mathbf{x}(t_{av}, \Phi, \psi)) = p_a(\mathbf{x}(t_{av} - \psi, \Phi, \psi_{av}))\left(\frac{B(t_{av}, \Phi, \psi_{av})}{B(t_{av}, \Phi, \psi)}\right)^{\frac{1}{2}}$$

Blokhintsev invariant : $B(t_{av}, \Phi, \psi)$

$$\hat{p}_a^2 \left\| \frac{c_0\mathbf{n} + \mathbf{u_0}}{\rho_0 c_0^2 \Omega} \right\| \delta A = cte$$



Tube area: 12 equations

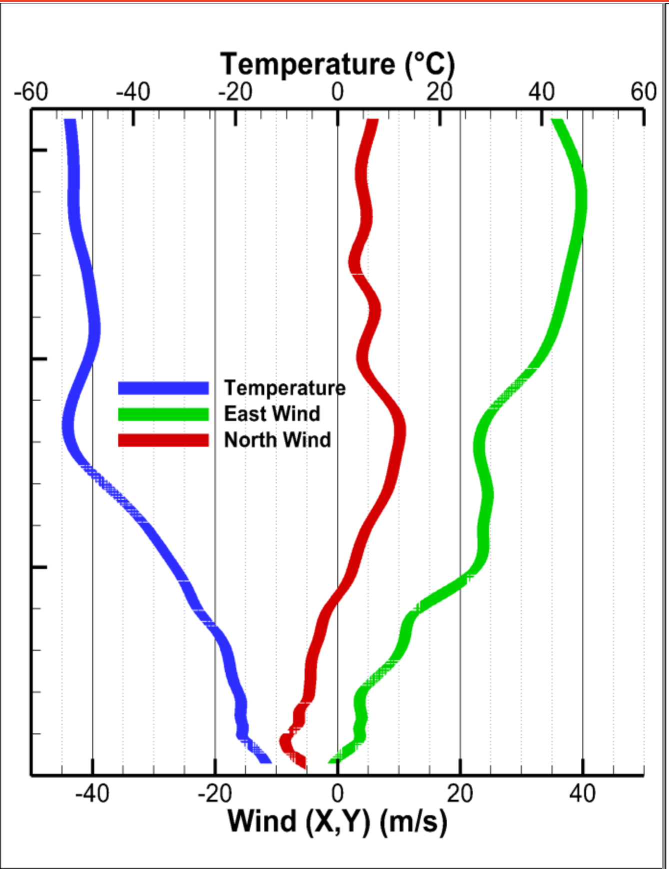
$$\hat{p}_a(\tau, l) = \hat{q}(\tau, l)/\sqrt{||\mathbf{a_0}||\delta A} \qquad \frac{\partial \hat{q}}{\partial l} = \frac{\beta}{\hat{\rho}_0^2 c_0^4 ||\mathbf{a_0}||^{3/2}(\delta A)^{1/2}} \hat{q}\frac{\partial \hat{q}}{\partial \tau}$$

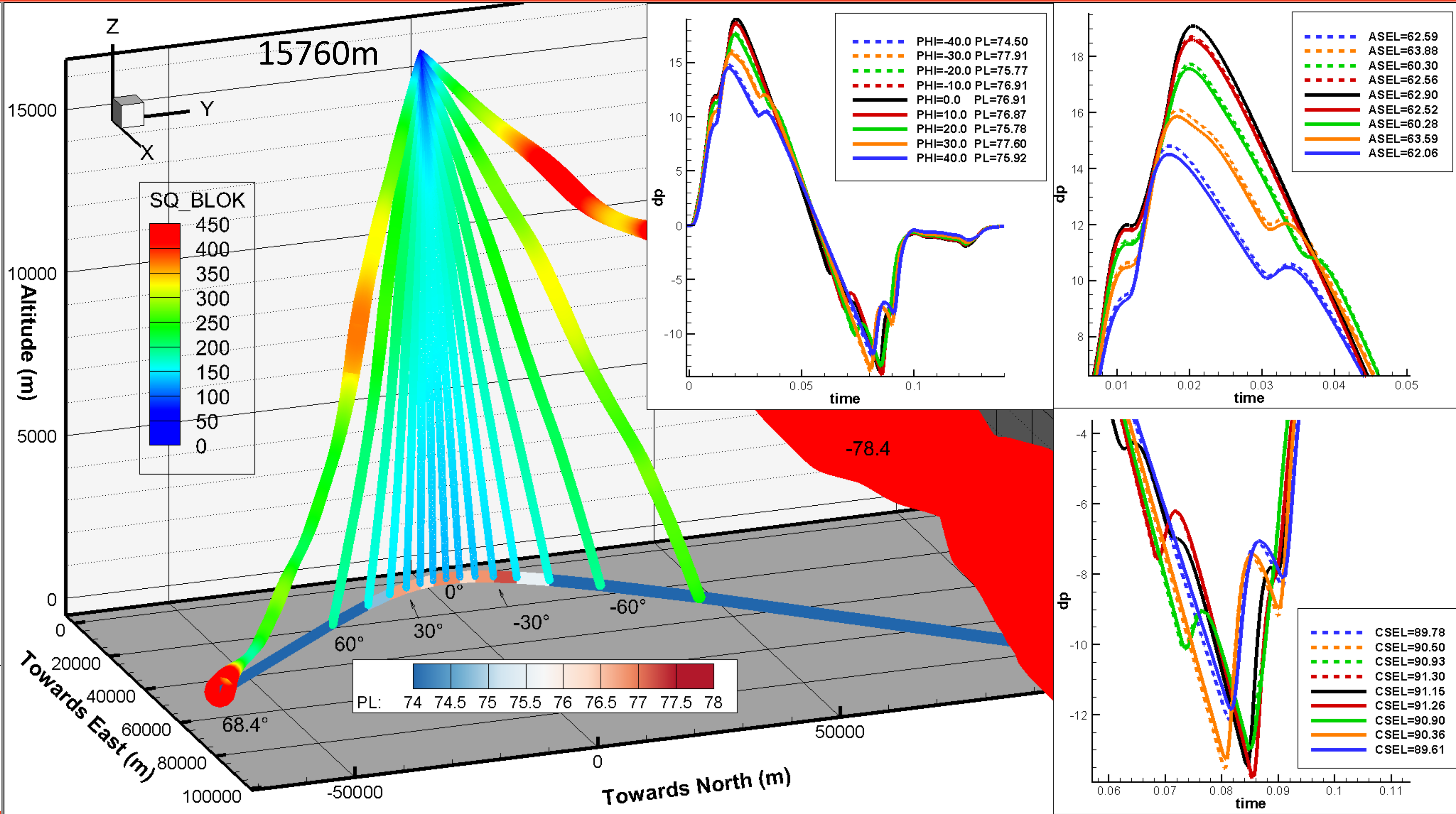
Age variable: 1 equation

$$\sigma = \int_0^l \frac{\beta}{\rho_0^2 c_0^4 ||\mathbf{a_0}||^{3/2} \delta A^{1/2}} dl \qquad \frac{\partial \hat{q}}{\partial \sigma} = \hat{q}\frac{\partial \hat{q}}{\partial \tau}$$

ODE solved with a Runge Kutta order 5 algorithm

Sonic Boom Prediction Workshop Results
Test Case 1



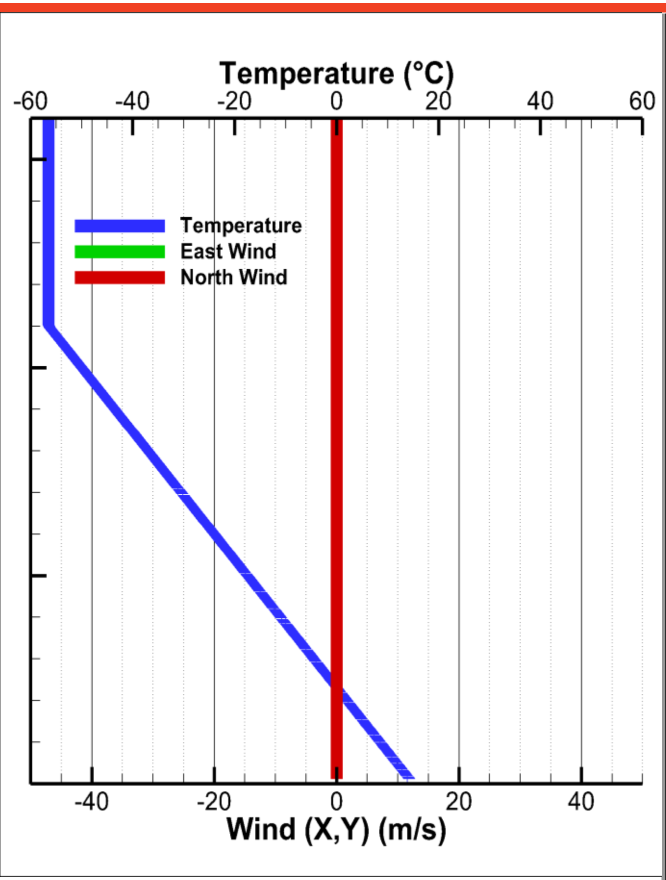


Meteo:

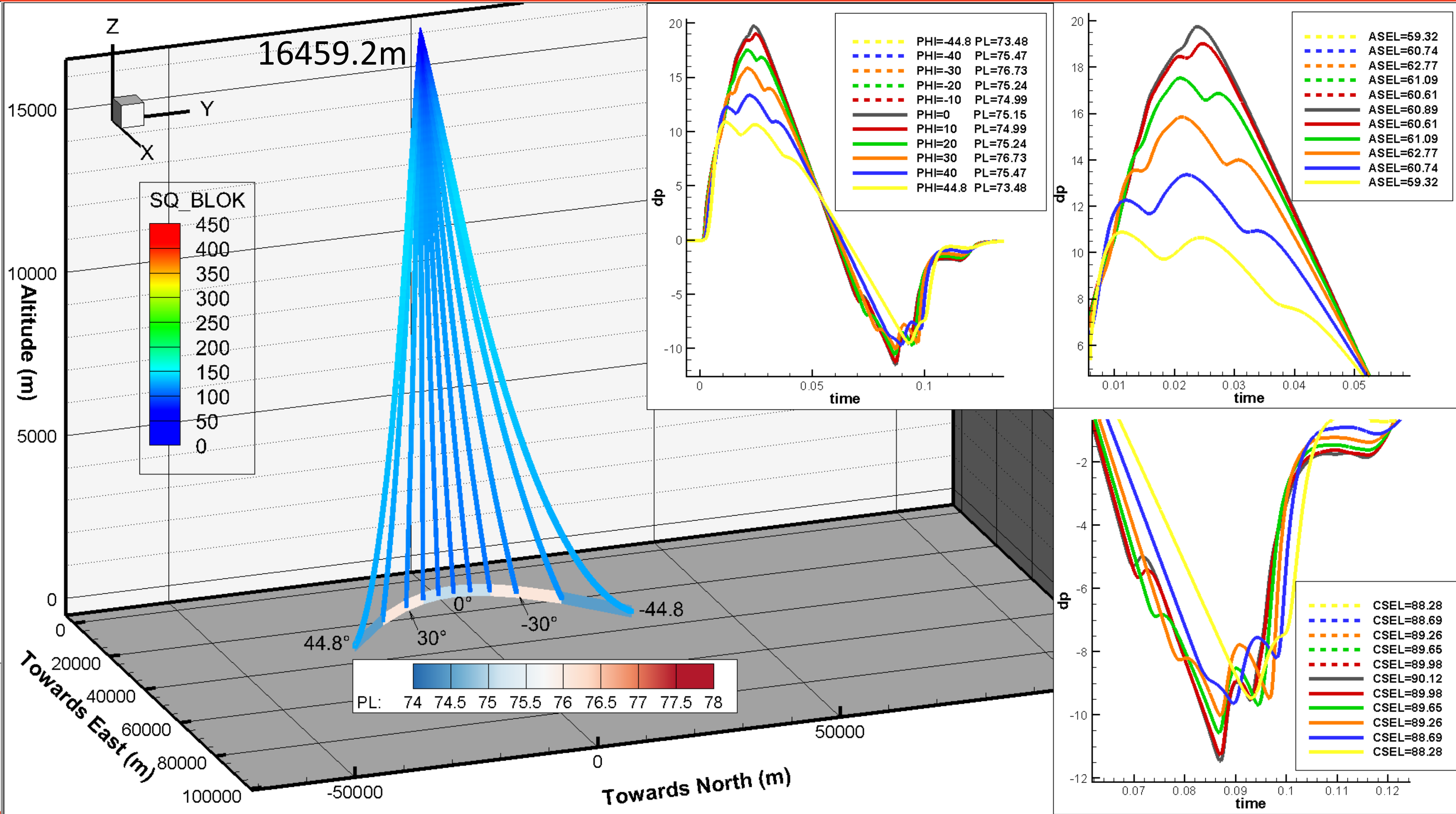
-Major North and strong East wind

-Temperature inversion near tropopause

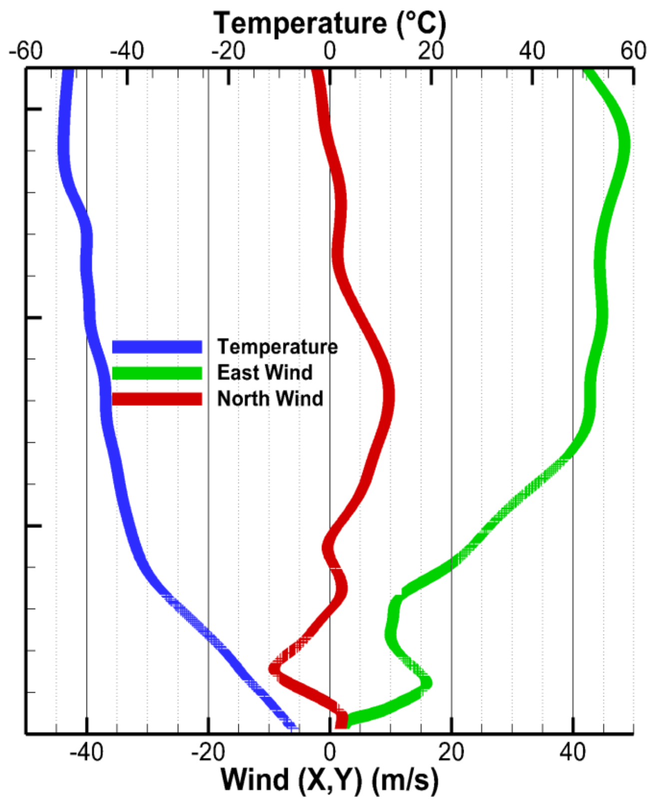
Sonic Boom Prediction Workshop Results
Test Case 2 : Standard Atmosphere



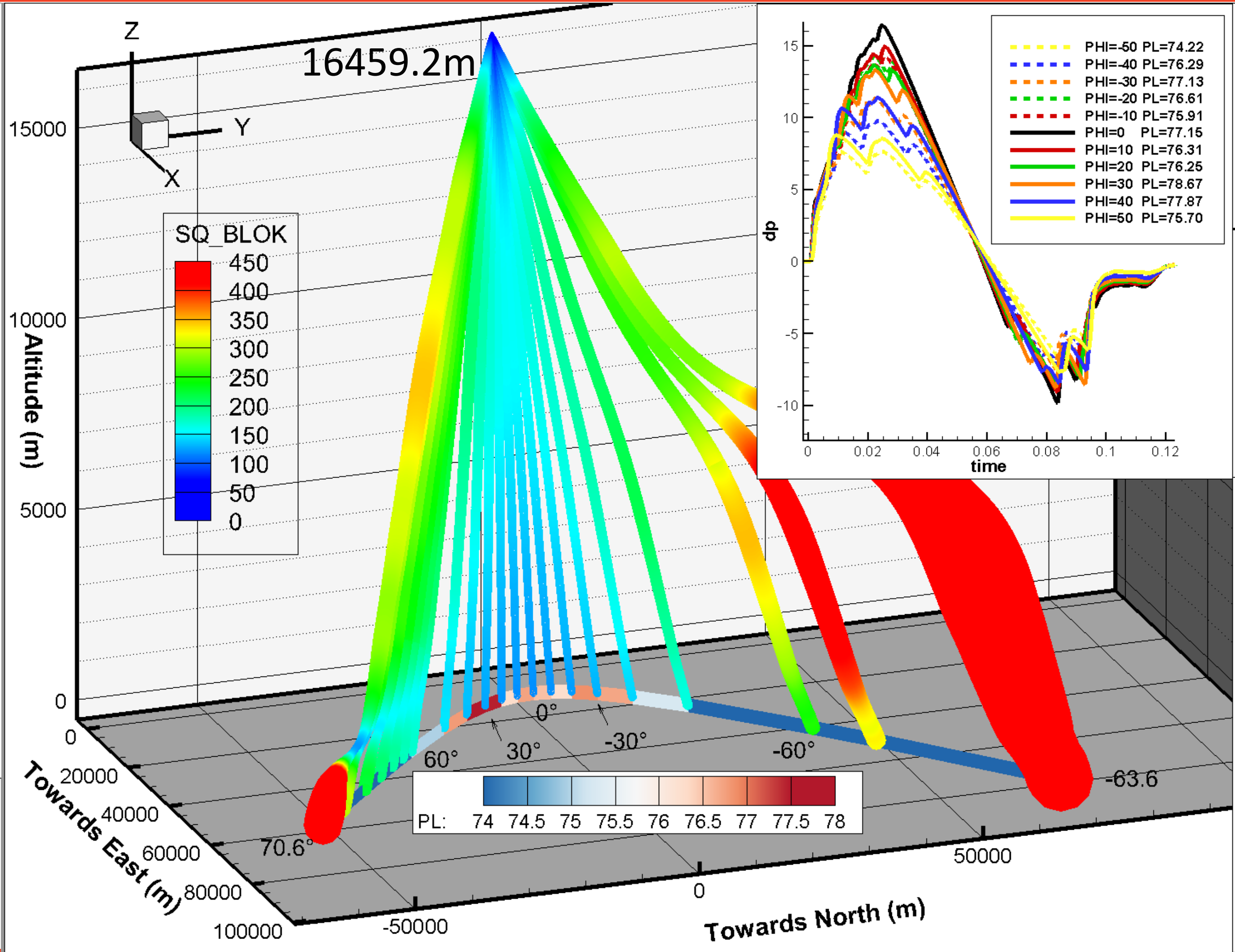
Meteo:
- No wind
- Strong temperature gradient

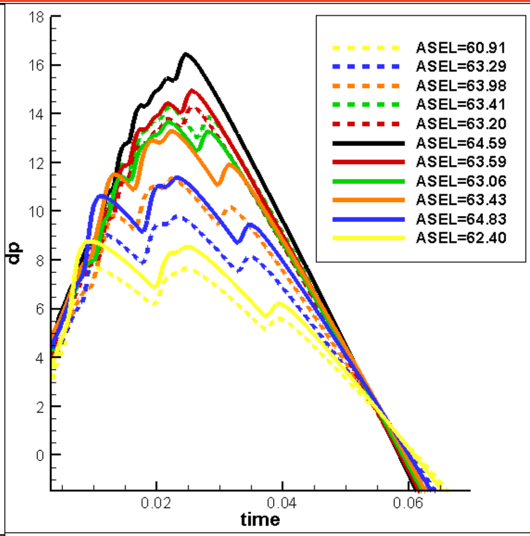


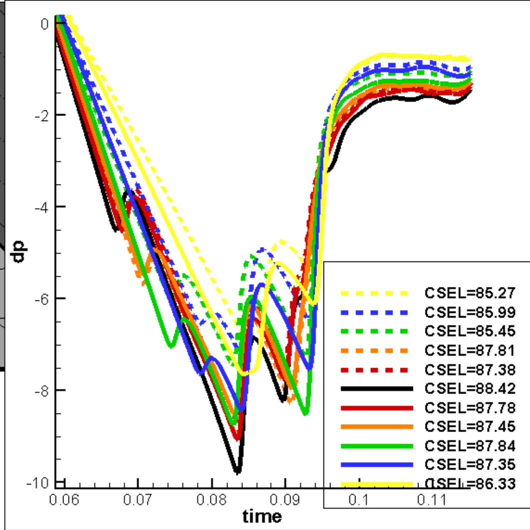
Sonic Boom Prediction Workshop Results
Test Case 2 : Balloon



Meteo:
- No North wind and strong East wind
- No temperature inversion







Summary & Perspectives

- Summary
  - Presented the RUMBLE activities
  - DAbang SB prediction code consists in solving a 19 ODE (6 for ray tracing, 12 for tube area, 1 for non linearities) by Runge Kutta order 5 algorithm.
  - Within RUMBLE we showed that with no absorption we have an excellent code-to-code comparison
  - Benched sound metrics computation
  - Applications : atmospheric sensitivity in terms of metrics and mach cut off
- Perspectives
  - Include cases without absorption effect (less physical but more discriminating)
  - Include in the comparison the value of the Blokhintsev invariant along the ray as well as the age variable
  - Share the implementation of the absorption model (damping ISO9613-B and dispersion terms)
  - Extend the comparison to a full database with a wide variety of atmospheres

Acknowledgments

•Many thanks to the Sonic Boom Prediction workshop committee for organizing, providing the test cases, accompanying the submittal and making the synthesis.

• Questions ?

Thank you!

The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769896.