Bury, Yannick and Chide, Baptiste and Murdoch, Naomi and Cadu, Alexandre and Mimoun, David and Maurice, Sylvestre Wake-induced pressure fluctuations on the Mars2020/SuperCam microphone inform on Martian wind properties. (2019) In: EPSC-DPS Joint Meeting 2019, 15 September 2019 - 20 September 2019 (Geneva, Switzerland). (Unpublished)

Wake-induced pressure fluctuations on the Mars2020/SuperCam microphone inform on Martian wind properties

Studying the Martian Winds using the Influence of the SuperCam Wake Flow Regimes on the Mars2020 Microphone

Y. Bury[1], B. Chide[1,2], N. Murdoch[1]*, A. Cadu[1], D. Mimoun[1], S. Maurice[2]

**Naomi.Murdoch@isae-supaero.fr*

#1589-1

Background

Mars Microphone:

- Add-on to SuperCam [1]
- Records from 100 Hz to 10 kHz
- Three operating modes: microphone only, laser continuous and laser synchronized

Sound Propagation:

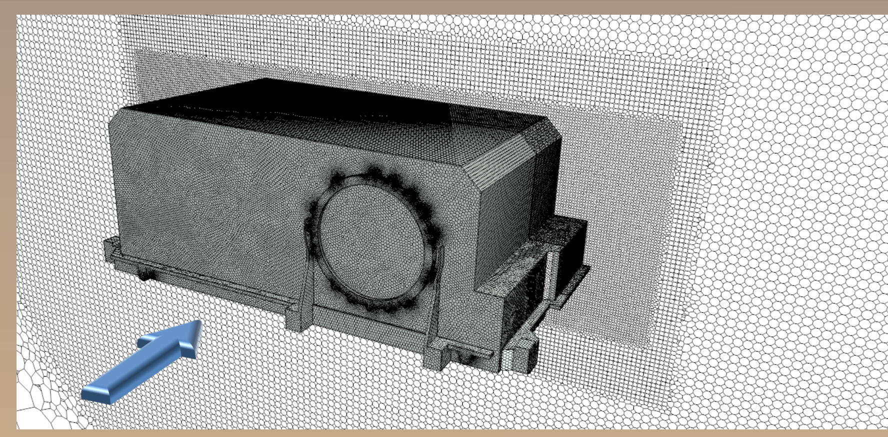
- ~240 m/s
- High frequency sounds are absorbed by the CO_2

Objectives

- Support the Laser-Induced Breakdown Spectroscopy (LIBS) investigation by determining rock physical properties and laser induced crater depth [2]
- Contribute to basic atmospheric science by recording the noise of the wind flowing past the instrument
- Listening to the rover mechanical noise

[1]Institut Supérieur de l'Aéronautique et de l'Espace (ISAE-SUPAERO), Toulouse France
[2]Institut de Recherche en Astrophysique et Planétologie (IRAP-CNRS), Toulouse France.

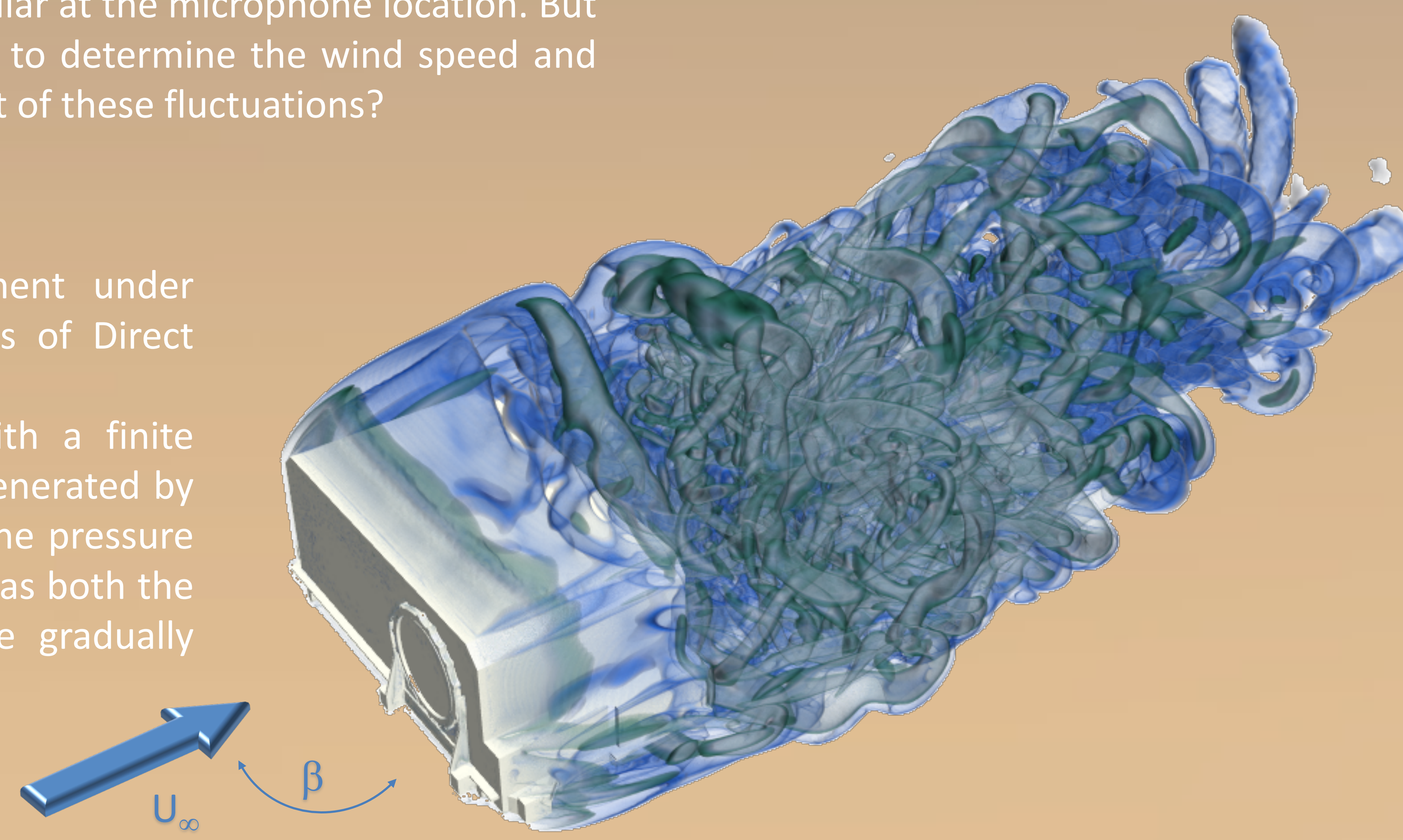
Numerical approach



When the Martian wind flows around the SuperCam instrument, it will generate a wind-dependent wake, made of varieties of vortices. These vortices will promote local pressure fluctuations, in particular at the microphone location. But can we use the SuperCam Mars Microphone to determine the wind speed and direction on Mars, based on the measurement of these fluctuations?

We analyze the flow around the instrument under Martian environmental conditions by means of Direct Numerical Simulations (DNS).

The Navier-Stokes equations are solved with a finite volume approach [3]. Flow Instabilities are generated by the SuperCam instrument. Their impact on the pressure field exerted on the microphone is evaluated as both the direction and the velocity of the wind are gradually varied.



Wake structure and pressure fluctuations

The numerical results reveal the occurrence of complex instability modes in the close wake of SuperCam, depending on the direction of the wind. Fig.1 depicts the vortical structures in the wake of SuperCam for a 5 m/s Martian wind. The wake features very different shapes and different spreading of the size of the vortices as the instrument is progressively rotated 360°.

The analysis of the time histories of the pressure signal measured at the location of the Mars Microphone (Fig.2) highlights different trends as a function of the direction of the wind. These trends are confirmed whatever the velocity of the wind.

The direction of the wind impacts both the mean and fluctuating values of the pressure signal at the location of the microphone: from maximum when the Mars microphone is facing the wind (β = 0°), the mean value reaches a minimum when the flow is facing either the lateral left face (β = 270°) or the back face (β = 180°) of SuperCam, since the microphone is immersed in a massively separated region of the flow. Interestingly enough, the *r.m.s.* value provides more detailed information on both the wind direction and speed. It is minimum when β = 0°, but reaches a maximum value when β = 90°. For this direction of the wind, and to a lesser extent for β = 270°, the PSD of pressure fluctuations (Fig.3) is fueled on a larger band and depicts a peak, related to the wind speed. This peak highlights the vortex shedding process promoted by the SuperCam instrument.

The identification of both the minimum and maximum values of the pressure fluctuations and of the vortex shedding frequency peak as the SuperCam is rotated is thus the solution to determine *in situ* the Martian wind speed and direction.

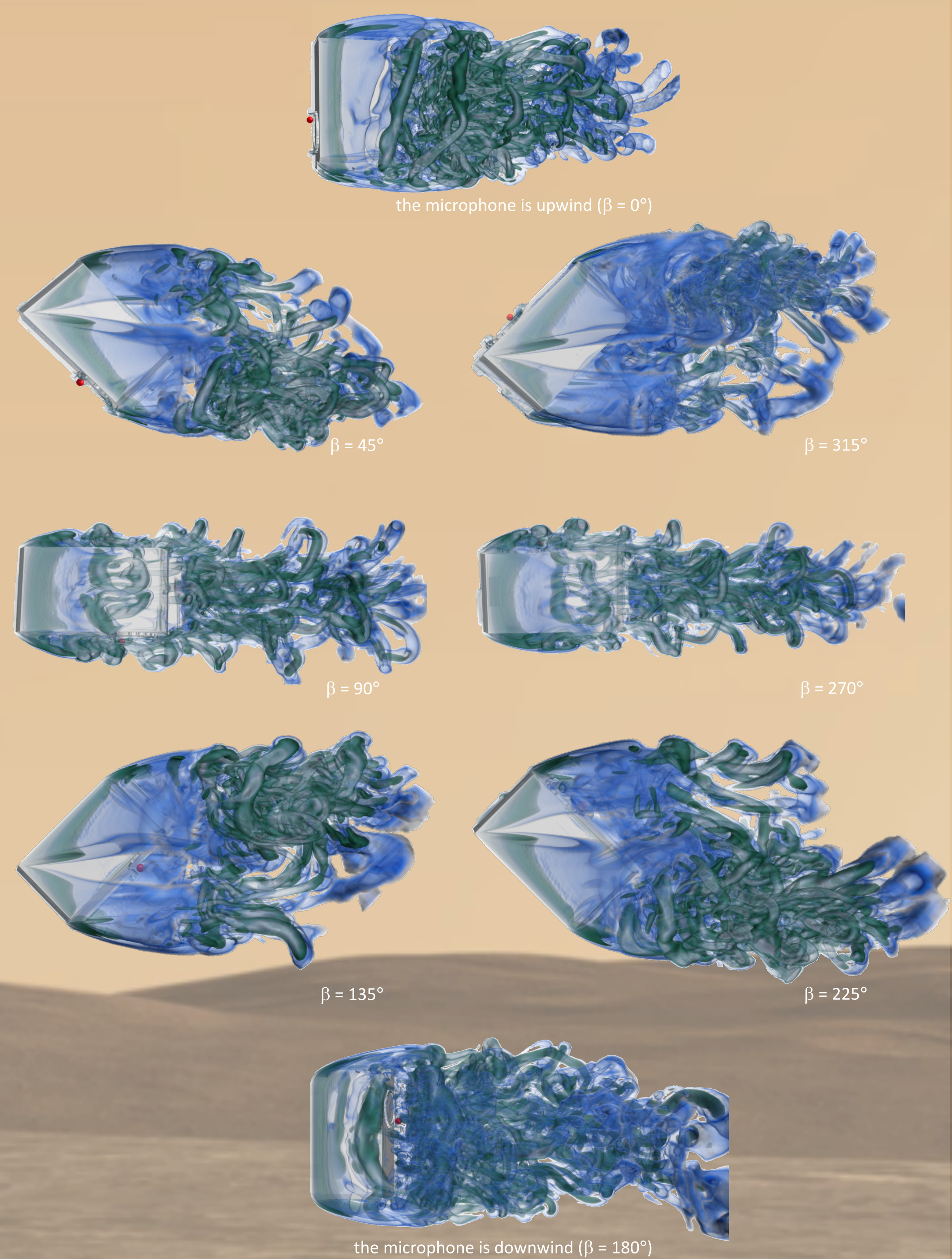


Fig.1: Iso-surfaces of Q-criterion [3], revealing the vortical structures in the wake of the SuperCam instrument (upper view), for a 5m/s wind (96 % CO2, density 0.02 kg/m3, pressure 600 Pa, temperature 210 K) flowing from left to right, as the SuperCam is rotated 360°. The different colors correspond to more or less (dark green to light blue) intense vortices. The red dot illustrates the Mars Microphone location.

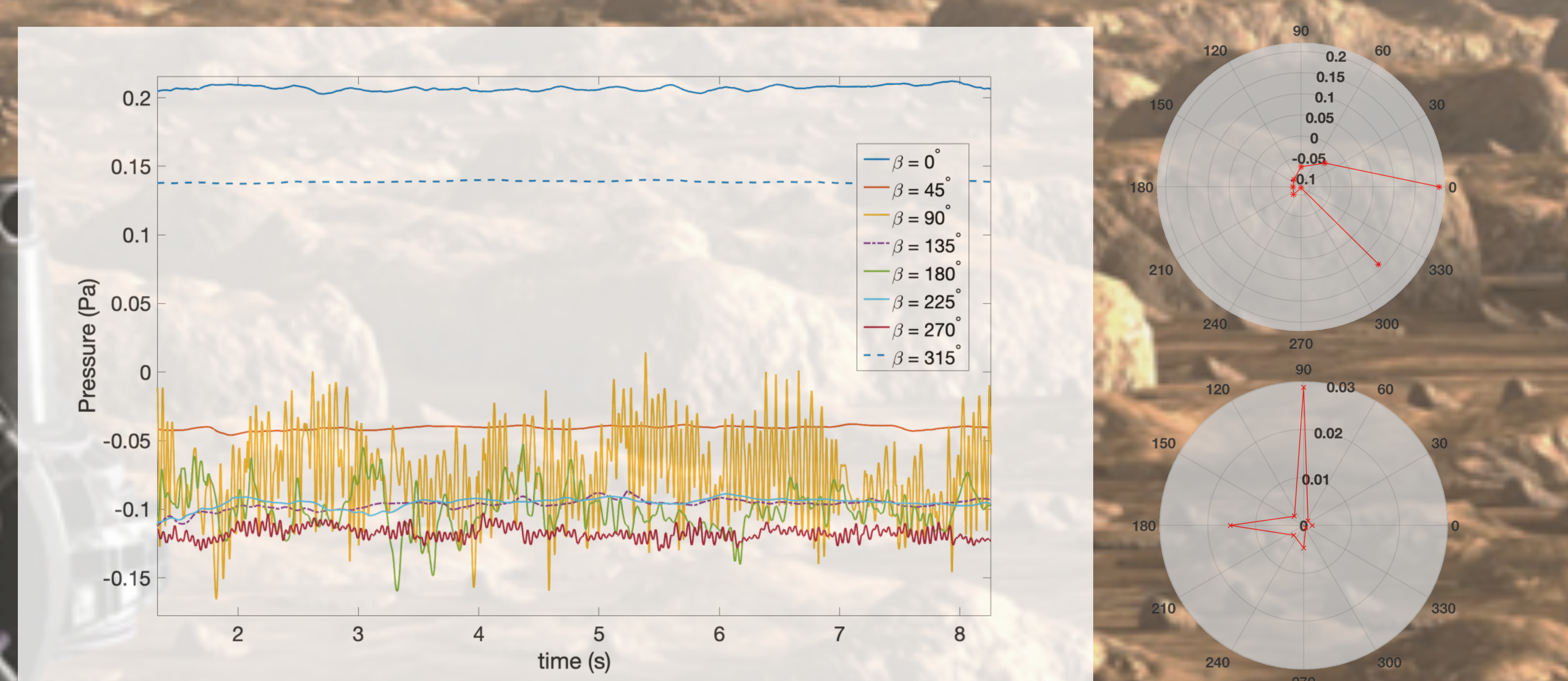


Fig.2: (left) Time histories of the pressure signals (relative to ambient pressure) and (right) polar plots of the time-averaged (upper) and *r.m.s.* (lower) pressure at the location of the microphone, for a 5 m/s wind velocity coming from various directions.

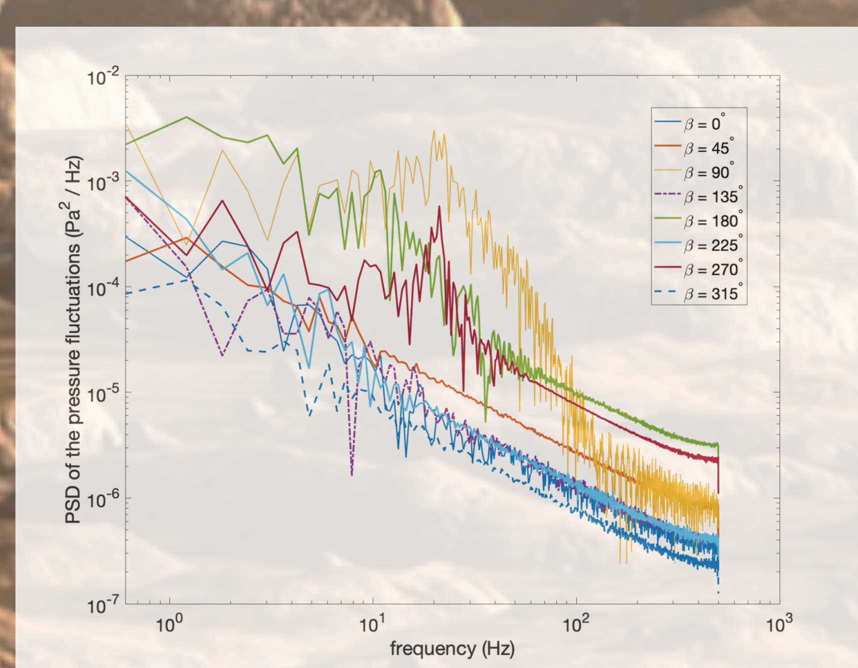


Fig.3: PSD of the pressure fluctuations at the location of the microphone, for a 5 m/s wind velocity coming from various directions.

[1] R.C. Wiens, S. Maurice, F.R. Perez, The SuperCam remote sensing instrument suite for the mars 2020 rover mission: a preview, Spectroscopy 32 (2017),), [2] Chide B. et al. (2019) Spectro. Chem. Acta B., [3] Bury Y. and Jardin T., Transitions to chaos in the wake of an axisymmetric bluff body. Phys. Lett. A.

EPSC Abstracts
Vol. 13, EPSC-DPS2019-**PREVIEW**, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Studying the Martian Winds using the Influence of the Supercam Wake Flow Regimes on the Mars2020 Microphone

Yannick Bury (1), Baptiste Chide (1,2), Naomi Murdoch (1), Alexandre Cadu (1), David Mimoun (1), Sylvestre Maurice (2)
(1) Institut Supérieur de l'Aéronautique et de l'Espace (ISAE-SUPAERO), Université de Toulouse, France, (2) Institut de Recherche en Astrophysique et Planétologie (IRAP-CNRS), Toulouse, France (yannick.bury@isae.fr)

Abstract

The SuperCam Mars 2020 Microphone, a collaboration between ISAE-SUPAERO, IRAP in Toulouse and the Los Alamos National Laboratory (LANL), will record sounds from the surface of Mars in the audible range. It will support SuperCam Laser-Induced Breakdown Spectroscopy (LIBS) investigation by recording LIBS shock waves but it will also record aeroacoustic noise generated by wind flowing past the microphone. Here we use Computational Fluid Dynamics to study the interaction between the wind and SuperCam, by means of Direct Numerical Simulations. The goal is to understand how the microphone signal can be used to determine the wind speed and direction on Mars.

1. Introduction

The SuperCam instrument suite selected for the NASA Mars 2020 rover will include as an add-on, the Mars Microphone developed by ISAE-SUPAERO in partnership with IRAP and LANL, which is designed and tested to record Martian sounds from 100 Hz up to 10 kHz [1]. It will help to document SuperCam LIBS targets by inferring hardness and laser pit depth [2]. It will also contribute to basic atmospheric studies as the Martian environment is subject to variable wind speeds [3]. This suggests complex interactions between the flow imposed by the wind and SuperCam. Vortices or turbulent structures generated in the wake and around the instrument can impact acoustic measurements, depending on the positioning of SuperCam relative to the wind, by imposing fluctuations of the pressure field in the vicinity of the instrument. A comprehensive understanding of the interaction between wind and the instrument could also help us to determine wind speed and wind direction, which are of great interest to atmospheric sciences.

2. Objectives and Challenges

We propose to study the incompressible unsteady, low Reynolds number flow generated in the close environment of SuperCam under the influence of the Martian wind. The specificity of the environmental conditions representative of the Martian surface - atmosphere composed of 96 $\%$ CO2, average density of $0.02\ kg/m^3$, pressure of about $600\ Pa$ and temperature of $210\ K$, variable wind speeds, raises many questions about the flow regimes induced past the SuperCam instrument.

Their prediction is, however, important for a full understanding of the acoustic measurements performed *in situ* by the microphone. It also paves the way for the definition of a potential experimental protocole able to provide information about the wind speed and direction as a function of the signal acquired.

3. Methods

In this context, we analyse the flow around the instrument under Martian environmental conditions by means of Direct Numerical Simulations.

The Navier Stokes equations are solved with a finite volume approach [4]. The impact of the instability modes generated past SuperCam instrument on the pressure field exerting on the microphone is evaluated as both the direction and the velocity of the wind are gradually varied.

4. Results

The numerical results reveal the occurence of complex instability modes in the close wake of SuperCam, as the Reynolds number (*i.e.* the flow velocity) is progressively increased. Figure 1 depicts the vortical structures, identified as iso-contours of Q criterion [4], around and in the wake of SuperCam when it is facing a $5\ m/s$ wind.

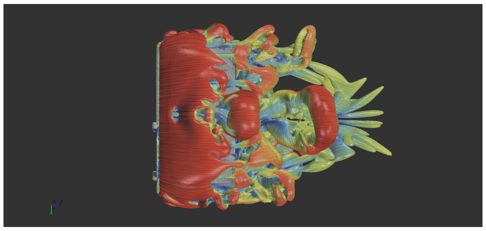


Figure 1: Upper view of the vortical structures, colored by velocity amplitude, past and in the wake of the SuperCam instrument, for a 5 m/s wind facing the front face of the instrument.

Interestingly enough, the analysis of the time histories of the pressure signal measured at the location of the microphone (Figure 2) highlights different trends as a function of the direction of the wind. These trends are confirmed whatever the velocity of the wind.

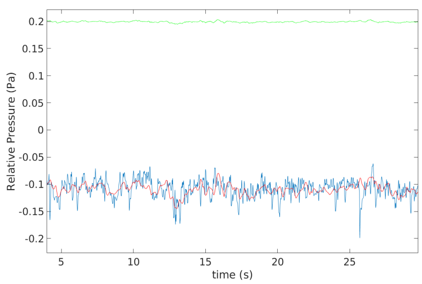


Figure 2: Time histories of the pressure variation signals (relative to ambient pressure) at the location of the microphone, for a 5 m/s wind velocity. Green, red and blue curves correspond to the wind facing the front, lateral (close to microphone) and back face of the instrument, respectively.

The direction of the wind impacts the mean value of the pressure signal at the location of the microphone. While the mean (resp. *r.m.s.*) pressure is obviously reaching a maximum (resp. minimum) value when the microphone is facing the wind (green curve on Figure 2), the mean (resp. *r.m.s.*) pressure measured at the location of the microphone tends to be minimum (resp. maximum) and almost equal, when the flow is facing either the lateral (red curve) or the back face (blue curve) of SuperCam, since the microphone is immersed in a massively separated region of the flow. Finally, while the temporal variations of the pressure signal are very low when the microphone faces the wind, the spectral content of the pressure fluctuations is enriched and spreads to lower scales as SuperCam is rotated and the microphone is moving downwind (red, then blue curve). This is driven by the inception of vortical structures of much more various scales in the separation zone located in the wake of SuperCam, in comparison with the ones promoted in the separation zones located on the lateral sides of the instrument.

5. Summary and Conclusions

In this paper, a numerical analysis of the flow regimes promoted around and in the close wake of the SuperCam instrument has been conducted. Different instability modes have been identified, depending on both the direction of the Martian wind and its speed. A protocol might then be been developed to use the signals acquired by the microphone to determine both the direction and the speed of the wind relative to the instrument, when SuperCam is rotated by 360^o. It should consist in identifying both the maximum variation of the mean pressure during the rotation, giving access to the amplitude of the speed, and in locating the angular positions of the Supercam when the spectral content of the fluctuating pressure is minimal, then maximal, giving access to the direction of the wind.

Acknowledgements

The authors gratefully acknowledge the computing center CALMIP for the computational resources provided under Grant P16034.

References

[1] Murdoch, N. et al., Laser-induced breakdown spectroscopy acoustic testing of the Mars 2020 microphone. Planetary and Space Sciences. doi: 10.1016/j.pss.2018.09.009, 2019

[2] Chide, B. et al.,: Listening to laser sparks: a link between Laser-Induced Breakdown Spectroscopy, acoustic measurements and crater morphology. Spectrochimica Acta B. doi: 10.1016/j.sab.2019.01.008, 2019.

[3] Murdoch, N. et al., Evaluating the Wind-Induced Mechanical Noise on the InSight Seismometers. Space. Sci. Rev. doi: 10.1007/s11214-016-0311-y, 2016

[4] Bury, Y. and Jardin, T.: Transitions to chaos in the wake of an axisymmetric bluff body. Phys. Lett. A. doi:10.1016/j.physleta.2012.09.011, 2012.