

On the monitoring of the vibratory environment of DCMIX4 campaign.

Preliminary results.

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Abstract

This work presents the preliminary characterization of the vibrational environment of the DCMIX4 thermodiffusion experiment conducted onboard the ISS from December 2018 to February 2019. Given the long duration of each one of the 49 runs of the campaign and to ensure a correct interpretation of the results, an accurate analysis of acceleration levels all along the experiment is advisable. Digital signals coming from the nearest sensor, es09006, located in the Microgravity Science Glovebox (Destiny module) were downloaded from the PIMS NASA website. The techniques used to identify the main disturbances during the experiments were defined both in time and frequency domains. It is expected that the results obtained can help the experimentalist to have an overview of the possible sources of disturbances that may affect their experiments. To visualize the possible impact of the accelerometric environment on the experiment a numerical simulation has been performed. Four signals have been chosen, one considering the ideal case $g = 0$, one coming from the OSS raw sensor (outside the Microgravity Science Glovebox) and the other two, coming from the es09006 sensor that needed to be mathematical manipulated for considering only the low frequency range. Independent of the location of the sensor, numerical simulations do not detect, in any case, appreciable flow disturbances if quiescent periods are considered. Therefore, in case the reference sensor is not available one can use other sensors placed in the same module.

Introduction

In the framework of the European Space Agency, all campaigns of the program called “Diffusion and Thermodiffusion Coefficients Measurements in Ternary Mixtures (DCMIX)” aim to accurately measure pure diffusion, thermodiffusion and Soret coefficients of different, but technologically relevant, ternary liquid systems (Mialdun et al 2015, Ryzhkov et al 2009, Rahman et al 2014, Shevtsova et al 2014, Triller et al 2018) inside the International Space Station (ISS). The first campaign called DSC-DCMIX1 (November 2011 - January 2012) focused on 1,2,3,4-tetrahydronaphthalene, isobutylbenzene and n-dodecane as working mixture with the aim of having a better understanding of the thermodynamic behaviour in oil reservoirs. The second campaign DCMIX2 (December 2013 - January 2014) focused on the toluene-methanol-cyclohexane system mainly because of the presence of a broad miscibility gap within the mixture and because, depending of the composition, this system was convectively unstable on Earth laboratories. The third set of runs, DCMIX3 (September - November 2016), was centered on the aqueous mixture water-ethanol-triethylene glycol, with a variable Soret coefficient sign (positive and negative) that has already been detected for certain binary subsystems of this ternary one. Finally, the fourth DCMIX4 campaign (December 2018 - February 2019) was oriented to complete the characterizations of DCMIX2 mixtures and also to introduce the ternary polymer system, polystyrene-toluene-hexane, and the ternary nanofluids tetralin-toluene-fullerene with applications ranging from photovoltaics to biotechnology. This set of runs were performed in five different cells with different mixtures and component concentrations. The first three cells ran with the same DCMIX2 mixture but at different concentrations while cells 4 and 5 ran with tetralin-toluene-fullerene and polystyrene-toluene-hexane, respectively (see Table 1). The campaign consisted of 58 runs lasting between 12 and 48 hours. Remark that, during the first runs of each cell the acceleration data were unavailable, due to sensor malfunctions. In addition, all the runs had a missing period data when passing from one day to another. In other words, the signal’s recording was always stopped during 10 minutes after midnight. Moreover, there are signals that were not fully completed (See more details in Table 1).

Due to the own nature of the physical processes implied, molecular diffusion and thermodiffusion experiments take a long time, therefore a preliminary planning is needed with the aim of making sufficient quiescent intervals compatible with the mandatory crew daily activities. However, compatibility is sometimes difficult to achieve in the dynamic ISS environment: reboostings for orbital adjustments or to avoid collisions with orbital debris, dockings/berthings to bring astronauts/equipment, undockings to return the crew to the Earth, flight attitude changes to reorient the ISS to the Sun for power supply reasons, extra vehicular activities for maintenance purposes, and so on. A careful monitoring of the vibrational environment is, thus, of capital importance to prevent spurious results potentially related to detectable disturbances occurred during the runs. Previous works clearly demonstrated that, in case of strong disturbances, the surveillance of the acceleration environment is improved if the nearest sensor to the run, the reference

one, is selected (Ollé et al 2017, Dubert et al 2018). In addition, numerical simulations based on real signals demonstrate that high acceleration levels associated to the reboosting maneuvers can influence the fluid-dynamic field and the accuracy of the Soret coefficient determination (Jurado et al. 2017, Jurado et al. 2019). Therefore, the experiment schedule must be previously optimized to plan most of the runs during quiescent periods in order to avoid unwanted external disturbances.

Under this scenario, it is interesting to also evaluate if the residual accelerations (low acceleration levels characteristics to the quiescent period) could have an impact on these DCMIX runs. The literature reports different approaches to solve this problem. Some authors used pure sinusoidal signals with different amplitudes and frequencies to infer general consequences about the impact of vibrations on thermodiffusion experiments [Shevtsova et al 2010, Shevtsova et al 2011, Shevtsova et al 2015]. Others used real signals coming from the FOTON platform or manipulated acceleration signals (Fourier series with coefficients derived from real acceleration measurements) coming from the ISS, though no general conclusion was drawn. In other words, some works established that the thermodiffusion experiments onboard the ISS can achieve a relatively good accuracy [Chacha et al 2005, Yan et al 2007a, Yan et al 2007b, Srinivasan et al 2010], meanwhile others reported a noticeable impact on the component separation [Srinivasan et al 2011, Ahadi et al 2012, Ahadi et al 2013, Khoshnevis et al 2014]. These discrepancies make the problem still interesting to be considered here.

Therefore, the present work focuses on two main objectives. The first one deals with the preliminary characterization of the DCMIX4 accelerometric environment taking into account the signals coming from the es09006 sensor, nearest to the experiment. The raw accelerometric signals, with a sampling rate of 142 Hz and a cut-off frequency of 6 Hz, were freely downloaded from PIMS NASA website (PIMS website: PIMS 2019). Moreover, the signal characterization is centered on the low frequency range which is known to be the most harmful for the thermodiffusion experiments (Shevtsova et al. 2015). The second objective try to consider the possible impact of the vibratory environment associated to quiescent periods on the fluid behaviour, introducing real acceleration signals into a 3D numerical simulation of the flow.

2. Accelerometric characterization of DCMIX4 runs

2.1 Methodology

Digital signal processing techniques were systematically applied minute by minute to all the signals, covering both the time and frequency analyses: Root Mean Square (RMS), Power Spectral Density (PSD), and warning maps based on the RMS values evaluated over one-third octave frequency bands (Ollé et al 2017, Dubert et al 2018). The experimental run 2r07 has been selected, as an example, to fix the applied techniques in a particular case.

RMS in time

The one-minute RMS interval is estimated for each acceleration component following the equation (1):

$$\text{RMSa}_{jk} = \sqrt{\frac{1}{M} \sum_{i=1}^M a_j^2} \quad (1)$$

where M is the number of the points in the segment k , k represents the one-minute interval, and a_j describes one of the acceleration components (a_x , a_y or a_z).

Based on equation (1), the global RMS related to the module of the acceleration is calculated as follows:

$$\text{RMS}(|a|)_k = \sqrt{\text{RMSa}_{xk}^2 + \text{RMSa}_{yk}^2 + \text{RMSa}_{zk}^2} \quad (2)$$

RMS in frequency domain: Warning maps

The RMS level associated to any acceleration signal, a , integrated over each one of the one-third octave bands, is calculated by using (Rogers et al. 1997)

$$\text{RMSa}_j = \sqrt{\sum_{i=\text{flow}_j}^{i=\text{fhigh}_j} (\text{PSDa}(i)) \cdot \Delta f} \quad (3)$$

where Δf is the frequency resolution in the evaluation of the PSD magnitude and flow_j , fhigh_j are the minimum and maximum frequency values in the j frequency band calculated by the expressions:

$$\text{flow}_j = 0.1 \cdot 2^{\frac{j-1}{3}} \cdot 2^{-\frac{1}{6}} \quad (4)$$

$$\text{fhigh}_j = 0.1 \cdot 2^{\frac{j-1}{3}} \cdot 2^{\frac{1}{6}} \quad (5)$$

By using the eq. (3) applied for the three acceleration components (a_x , a_y , a_z), the overall RMS acceleration as a function of frequency can be computed as:

$$\text{RMSa} = \sqrt{(\text{RMSa}_x)^2 + (\text{RMSa}_y)^2 + (\text{RMSa}_z)^2} \quad (6)$$

NASA's International Space Station vibratory limit requirements are defined by (DeLombard et al. 2005)

$$\begin{aligned} 0.01 \leq f \leq 0.1 \text{ Hz, } \text{RMS} &\leq 1.8 \text{ } (\mu\text{g}) \\ 0.1 \leq f \leq 100 \text{ Hz, } \text{RMS} &\leq 18 \cdot f \text{ } (\mu\text{g}) \\ 100 \leq f \leq 300 \text{ Hz, } \text{RMS} &\leq 1800 \text{ } (\mu\text{g}) \end{aligned} \quad (7)$$

Assuming that the values of the RMS in any band is lower than the above-mentioned three thresholds, 1.8 μg , 18f μg and 1800 μg , the microgravity environment can be considered of sufficiently good quality.

RMS warning map technique is a quick visual way to display if the vibratory limits have been surpassed or not, along the experiment. The map plots the frequency bands on the X axis and the experiment's duration on Y axis. Symbols in the RMS warning map represent each of the ISS vibratory limits that were exceeded.

Despite warning maps are qualitative, because they do not include the amount of excess respect to the vibratory requirement limits, they enable an easy identification of the problematic frequency bands that outdo the ISS limit requirements. In addition, it has been possible to optimize this map by adding a color bar which shows the difference between the calculated RMS and the corresponding ISS limit. The authors quantified this difference as warning intensity (WI, dB) of each bin (f) comparing the RMS of each spectral component, $\text{RMSa}(t, f)$ with the ISS limit ($\text{ISSL}(f)$) as follows:

$$\text{WI}(t, f) = 10 \times \log\left(\frac{\text{RMSa}(t, f)}{\text{ISSL}(f)}\right) \quad (8)$$

where t is the one-minute step used to calculate the warning intensity.

2.2 Results and discussion

Fig. 1 plots the calculated global RMS values along the whole experiment for the selected run (2r07). During the 16 hours of the experiment, two noticeable spikes can be observed. A spike can be considered a warning if its RMS value exceeds the 20% of the mean of all RMS values of the signal (Ollé et al. 2017). Therefore, the above peaks could be treated as time domain warnings and the experimentalists should take them into account when interpreting the experimental results. More details of the spikes found during all the runs are presented in Table 2.

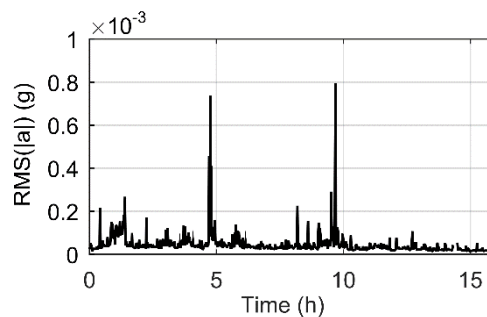


Fig.1 Global RMS of run 2r07

Figure 2 summarizes the RMS statistics of the 2r07 acceleration signal. To illustrate the warnings in the frequency domain, Fig. 2.a displays the acceleration module's warning

map together with the WI along all the experiment. It has been detected three time periods with large vibrations, at the beginning of the record, after 5 hours and after 10 hours. Note that, low frequencies (below 0.4 Hz) concentrates the larger amount of warning alerts that could be associated to the structural frequencies, while at frequencies above 5 Hz no warnings are detected since the signal's cut-off frequency is 6 Hz. This fact is confirmed by visualizing the high accumulation of this warnings at low frequencies as a projection of the mapped data (Fig. 2.a) into the frequency-axis in logarithmic scale (see Fig. 2.b) by summing the number of warnings occurring for each octave. In addition, mean RMS (red line) and the mean RMS that outdo the ISS limit (empty circle markers) are compared to the ISS requirements (blue line) and plotted in Fig. 2.c. Similarly, Figs. 2.d and 2.e show the number of warning and the mean RMS of the whole signal for the period analysed. Clearly, it can be noticed the presence of the three periods of high vibration detected by applying warning map tool (Fig. 2.a). Another way to quantify the warnings is presented in Fig. 2.f as histogram of WI calculated by eq. (8) and considering the whole RMS values (both that outdo the ISS limit and that are below it). Red line (WI = 0) indicates when the RMS values coincide with the ISS limit requirements. The negative values indicate that RMS values accomplish the ISS limit and implicitly no warning alerts to be taken into account by the experimentalists. Values exceeding the limits imposed by NASA, WI above 0, corresponds to less than 6 % of the total data, and only 0.1 % exceeds 5 dB.

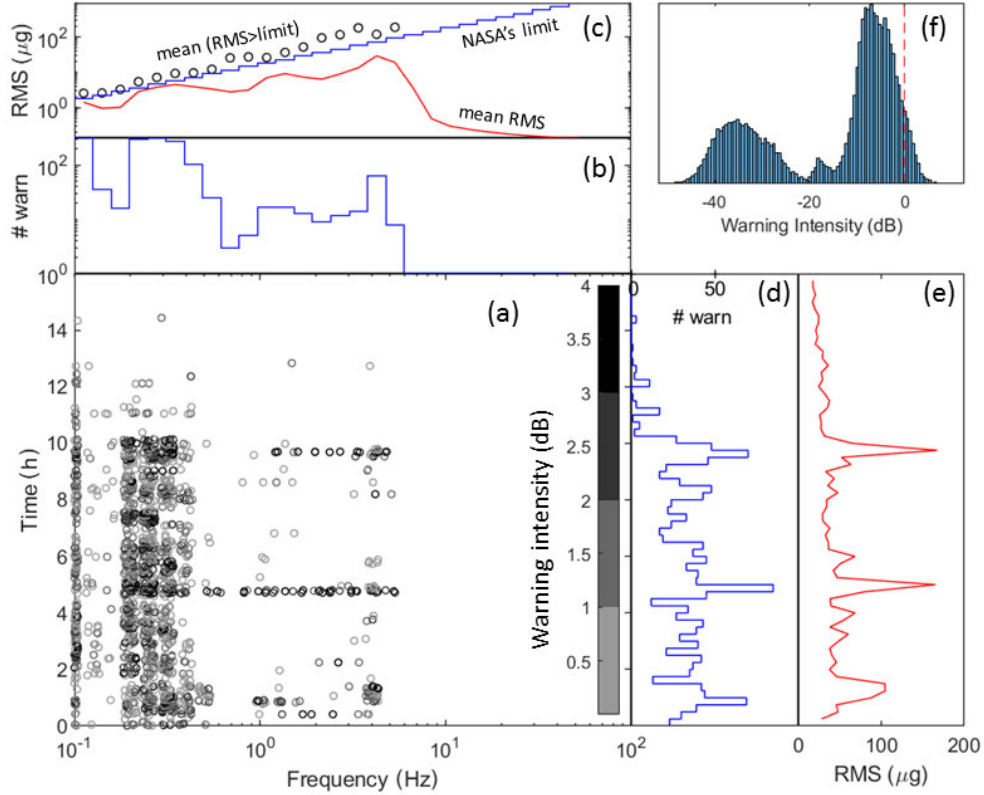


Fig. 2. Warning map and statistics of the run 2r07

3. Numerical simulations of DCMIX experiments

3.1 Details of the Soret cell

The experimental setup used in all ISS SODI DCMIX experiments is a parallelepipedic cell (Soret cell) with dimensions of $10 \times 10 \times 5$ mm (Shetsova et al. 2014, Mialdum et al. 2015) (see Fig. 3). During a typical experiment, two different temperatures are imposed and maintained constant on two opposite walls, while the rest of the walls are intended to be adiabatic. This temperature gradient causes a concentration gradient produced by the Soret effect. The concentration difference (CD) of each component of the mixture is defined as the concentration difference between the hot and cold walls. The cell is orientated in accordance to the absolute ISS coordinates (X_A , Y_A , Z_A).

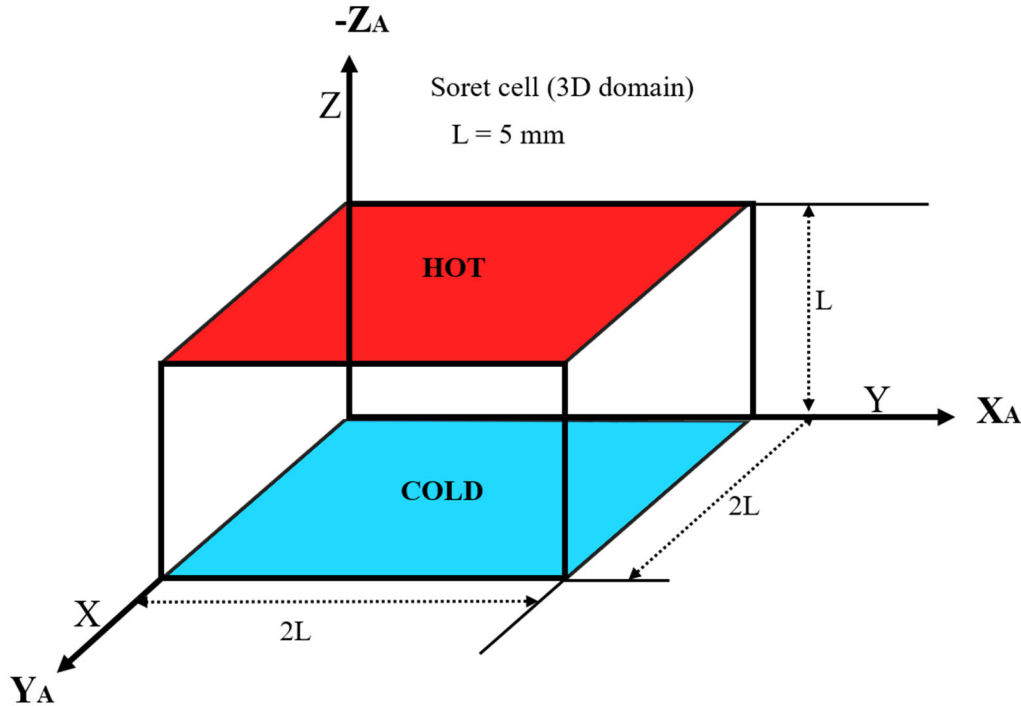


Fig. 3 Sketch of the Soret Cell

3.2 Mathematical approach to the thermodiffusive phenomenon

In case of ternary mixtures, the dimensionless continuity, momentum, mass transfer and energy equations under the Boussinesq approximation can be written as:

$$\frac{\partial u_i^*}{\partial x_i^*} = 0 \quad (9)$$

$$\frac{\partial u_i^*}{\partial t^*} + \frac{\partial u_j^* u_i^*}{\partial x_j^*} = -\frac{\partial p^*}{\partial x_i^*} + Sc \frac{\partial^2 u_i^*}{\partial x_j^{*2}} + [Gr_1(w_1 - w_{01}) + Gr_2(w_2 - w_{02}) - Gr_T(T^* - T_0^*)] \quad (10)$$

$$\frac{\partial T^*}{\partial t^*} + \frac{\partial u_j^* T^*}{\partial x_j^*} = \frac{1}{Pr} \frac{\partial^2 T^*}{\partial x_j^{*2}}. \quad (11)$$

$$\frac{\partial w_1}{\partial t^*} + \frac{\partial u_j^* w_1}{\partial x_j^*} = \frac{\partial^2 w_1}{\partial x_j^{*2}} + D_{12}^* \frac{\partial^2 w_2}{\partial x_j^{*2}} + D_{T1}^* \frac{\partial^2 T^*}{\partial x_j^{*2}} \quad (12)$$

$$\frac{\partial w_2}{\partial t^*} + \frac{\partial u_j^* w_2}{\partial x_j^*} = D_{21}^* \frac{\partial^2 w_1}{\partial x_j^{*2}} + D_{22}^* \frac{\partial^2 w_2}{\partial x_j^{*2}} + D_{T2}^* \frac{\partial^2 T^*}{\partial x_j^{*2}} \quad (13)$$

with $t^* = \frac{t D_{11}}{H^2}$, $x_i^* = \frac{x_i}{H}$, $u^* = \frac{u H}{D_{11}}$, $T^* = \frac{T - T_{cold}}{\Delta T}$, $\Delta T = T_{hot} - T_{cold}$. In Equation (10), $Sc = \nu/D_{11}$ is the Schmidt number and $Gr_1 = \beta_1 L^3 \vec{g}(t)/\nu^2$, $Gr_2 = \beta_2 L^3 \vec{g}(t)/\nu^2$ and $Gr_T = \beta_T L^3 \vec{g}(t)/\nu^2$ are the two solutal and thermal Grashof number respectively. The values β_1 , β_2 and β_T involved in the buoyancy term, are the solutal and thermal expansion factors related with the variation in concentration and temperature respectively, ν is the kinematic viscosity and $\vec{g}(t) = (g_x(t), g_y(t), g_z(t))$ is the acceleration field acting on the cell as a function of time. The non-dimensional diffusion matrix elements D_{ij}^* and the thermodiffusion coefficient, defined as $D_{ij}^* = D_{ij}/D_{11}$ and $D_{T'i}^* = D_{T'i}/D_{11}$, are also normalized by D_{11} . Finally, in Equation (11), $Pr = \nu/\alpha$ is the Prandtl number, where α is the thermal diffusivity.

The computational domain is a parallelepiped cavity with the same dimensions of the real Soret cell used in all SODI DCMIX runs (height, H , 5 mm; width and length equal to 10 mm). No-slip impermeable boundary conditions for velocity are imposed at all the six walls of the parallelepiped domain. Constant temperature values have also been imposed in the top, $T_{top}^* = 1$, and bottom, $T_{bot}^* = 0$ walls while the rest of lateral ones have been considered adiabatic. Zero mass flux conditions have also been considered in all the walls for the two main species of the ternary mixture. In particular, this zero flux is fixed for top and bottom walls:

$$\frac{\partial w_1}{\partial x_3^*} = -\left(\frac{D_{12}}{D_{11}} \cdot \frac{\partial w_2}{\partial x_3^*} + \frac{D_{T'1}}{D_{11}} \cdot \frac{\partial T^*}{\partial x_3^*}\right); \quad \frac{\partial w_2}{\partial x_3^*} = -\left(\frac{D_{21}}{D_{22}} \cdot \frac{\partial w_1}{\partial x_3^*} + \frac{D_{T'2}}{D_{22}} \cdot \frac{\partial T^*}{\partial x_3^*}\right) \quad (14)$$

Initial conditions are: fluid at rest, constant homogenous average temperature $T_{av} = (T_{top} + T_{bot})/2$ and constant concentration values w_{01}, w_{02}, w_{03} .

The governing equations (9-13), together with the corresponding initial and boundary conditions, have been solved numerically with the open source package OpenFOAM. Second order schemes in space and in time have been used to numerically integrate the system. The pressure-velocity coupling has been solved by using the PIMPLE method, a combination of PISO (**P**ressure **I**mplicit with **S**plitting of **O**perators) and SIMPLE (**S**emi-**I**mplicit **M**ethod for **P**ressure **L**inked **E**quations) algorithms. The momentum and the mass transfer equations are integrated in time by applying the Crank-Nicolson scheme.

This combination of numerical discretization has already been applied to the simulation of the solute's natural convective flows in ternary mixtures [Jurado et al 2017 , Jurado et al 2019]. The mesh used was, 40 x 40 x 20, which means that the centre cells are separated by a distance of 0.25 mm in the three X, Y and Z directions. A detailed test about mesh accuracy indicated that the above-mentioned mesh offers a good compromise between spatial accuracy and computing cost, an important parameter to be taken into account herein due to the elevated time which is needed to compute the thermodiffusive phenomena [Jurado et al 2019].

3.3 Pre-simulation considerations

In order to carry out the numerical simulation, one needs to know the physical parameters of the DCMIX4 mixtures. But due to the recent completion of the experiment, these physical properties are not available in the literature yet. Since the first three cells of DCMIX4 reproduce the DCMIX2 mixtures but at different concentrations, a possible solution for the simulation to be carried out is to select the above mixtures as preliminary study because their physical properties are well known. The selected DCMIX2 mixture's concentration and its physical properties are summarized in Table 3. Therefore, to be consistent, the real acceleration signal selected for the present study also corresponds to the DCMIX2 run6 (Desember 7th 2013) and comes from the es03 sensor, nearest to the experiment (inside the Glovebox). The signal's sample rate is 250 Hz and the cut-off frequency 101 Hz. Forasmuch as DCMIX4 focuses on the thermodiffusion process, only the first 10 hours of the es03 signal have been selected for the simulation as they correspond to the thermodiffusion step (DCMIX2 runs included both thermodiffusion and diffusion steps).

On the other hand, the literature reports that for the selected 40x40x20 mesh a time step of 0.1s (10 Hz) is the best compromise in terms of computational efficiency [Jurado et al 2017]. To fix this value two possible strategies are presented and compared herein. The first one is to select a signal coming from a sensor which acquires the data at a sample rate of 10 Hz and a cut-off frequency of 1Hz, such as the OSS Raw sensor located in the Destiny module but outside the Glovebox. In this way no manipulation should be made with the signal and it can be used readily as input in the simulations. The second strategy deals with the mathematical manipulation of the es03 signal based on two procedures: resampling from 250 Hz to 10 Hz and then denoising. In the last procedure, the Symlet 8 was used as mother wavelet function with two decomposition levels fixed at two and three, implying that the signal was filtered at frequencies roughly lower than 1.5 Hz and 0.8 Hz, respectively [more details in Jurado et al. 2016] to approximate its frequency content to the one of the OSS Raw signal.

Figs. 4 and 5 present the RMS and PSD values for the three signals: OSS Raw, es03 resampled and denoised at 1.5 Hz -thereafter lev 2- and es03 resampled and denoised at 0.8 Hz -thereafter lev 3-. Note that, all three signals show suitable microgravity levels for the three directions. No significant differences between the RMS and PSD values for all

three acceleration components have been detected. To sum up, Lev2 and Lev3, practically, present small discrepancies in temporal and frequency-based characteristics. To assure that these differences does not produce appreciable distortions in the concentration field, the authors decided to carry out numerical simulations for all the signals. In addition, the ideal case with gravity zero ($g = 0$) is included in order to compare the influence of the real residual acceleration in the temporal evolution of concentration field.

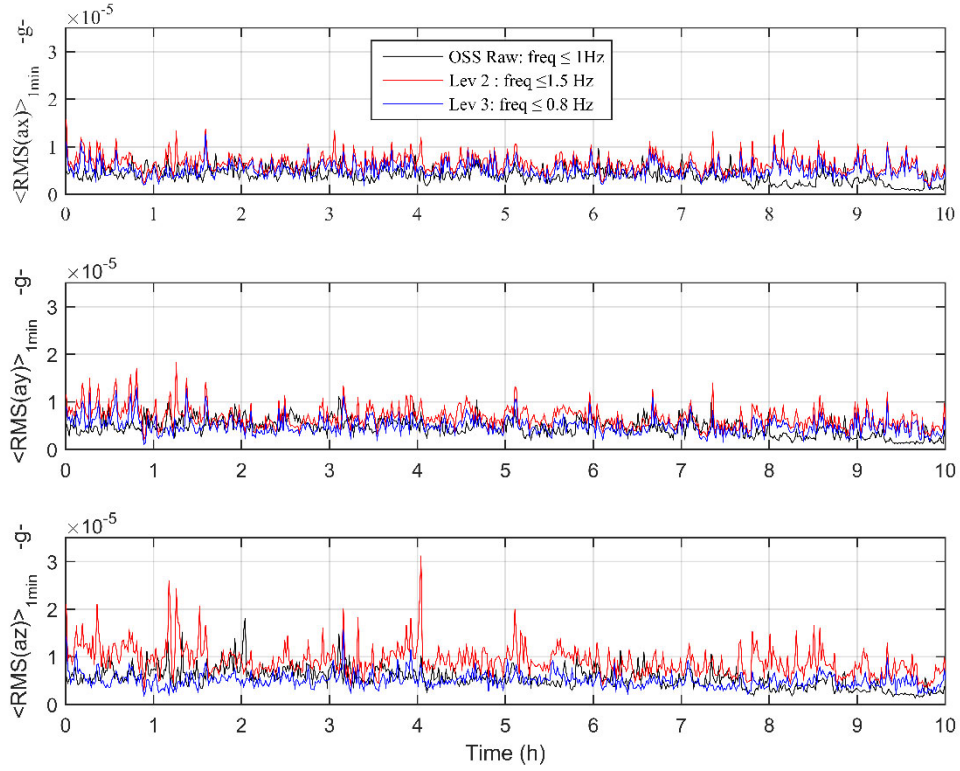


Fig. 4 RMS values calculated for the three signals considered: OSS Raw, Lev2 and Lev3

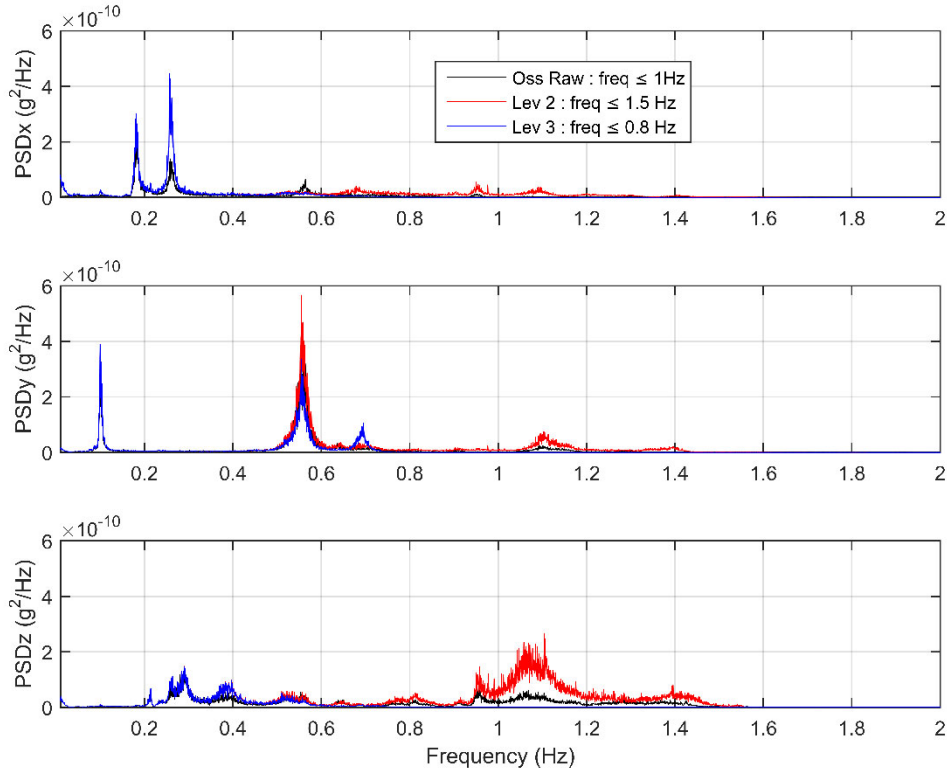


Fig. 5 PSD for the three OSS Raw, Lev2 and Lev3 signals.

3.4 Results and discussion

Fig. 6 depicts the temporal evolution of the concentration difference of toluene, Δw_1 , and methanol, Δw_2 , along the thermodiffusion period for all four signals considered. The concentration difference has been calculated as the difference between the average concentration values of the XY plane's bottom and top, chosen at $z = 0.3$ mm and $z = 4.7$ mm to avoid the boundary effects.

The time evolution of the concentration difference of the toluene is positive, toluene tends to concentrate at the bottom part of the cell, except in the first time steps, when the difference is negative. This is due to the constant balance between thermodiffusion and diffusion phenomena. At the beginning the concentration field is uniform and the predominant mechanism is the thermodiffusion. According to the eq. (12) the temperature gradient term $D_{T1}^* \frac{\partial^2 T^*}{\partial x_j^2}$, with $D_{T1}^* = \frac{DT1}{D_{11}}$ gains over the diffusion terms. Due to the fact that the thermodiffusion coefficient is negative, the concentration gradient opposes the temperature gradient. For this reason, the toluene concentrates, at the beginning of the experiment, at the top. Afterwards, this initial behaviour reverses as the diffusive terms gain relevance. Whereas, both diffusion coefficients are positive, see Table 3, the toluene tends to concentrate at the bottom. On the other hand, the time evolution of the concentration difference of methanol is always negative, therefore it accumulates at the

top of the cell. As the thermodiffusion coefficient of the methanol is negative, in the initial time steps its behaviour is very similar to the toluene one (see equation (13)). When the diffusion phenomenon takes over, the methanol keeps concentrating at the top of the cell due to the different sign of the diffusion coefficients, $D_{22} > 0$ and $D_{21} < 0$, (see Table 3).

Fig. 6 also indicates that the evolution of the concentration differences of toluene and methanol considering the OSS Raw, es03 Lev2 and Lev3 signals is roughly the same and always coincide with the ideal zero-g case. The maximum concentration difference between the real and ideal signals is, in any case, less than 0.1 %. This means that to evaluate the flow impact of the accelerometric environment in quiescent periods there is no difference between the information gathered from sensors located outside or inside the Microgravity Science Glovebox.

The above-mentioned behaviour is confirmed by the concentration fields in the plane YZ at $X = 5$ mm and their middle vertical profiles for different time steps and for the two species. As an example, Figs. 7 and 8 show the iso-concentration lines and their vertical profiles for the Lev 3 signal and for w1 and w2 respectively. At the beginning ($t = 200$ s) it can be perfectly seen that toluene and methanol diffuse towards the top while at the end of the experiment ($t = 10$ h) the toluene migrates to the bottom of the cell. This change has been noticed passing $t = 2500$ s, see Fig. 7.b. Remark that, methanol's behaviour is kept the same, concentrating more and more at the top. Finally, Figs. 9 and 10 present the velocity fields, u_x , u_y , u_z , calculated at $t = 200$ s and $t = 10$ h respectively. These fields correspond to the XY ($z = 2.5$ mm) and ZY ($x = 5$ mm) middle planes. Negligible velocities magnitudes ($\approx 10^{-8}$ m/s) have been detected in all cases which were maintained during the whole thermodiffusion period.

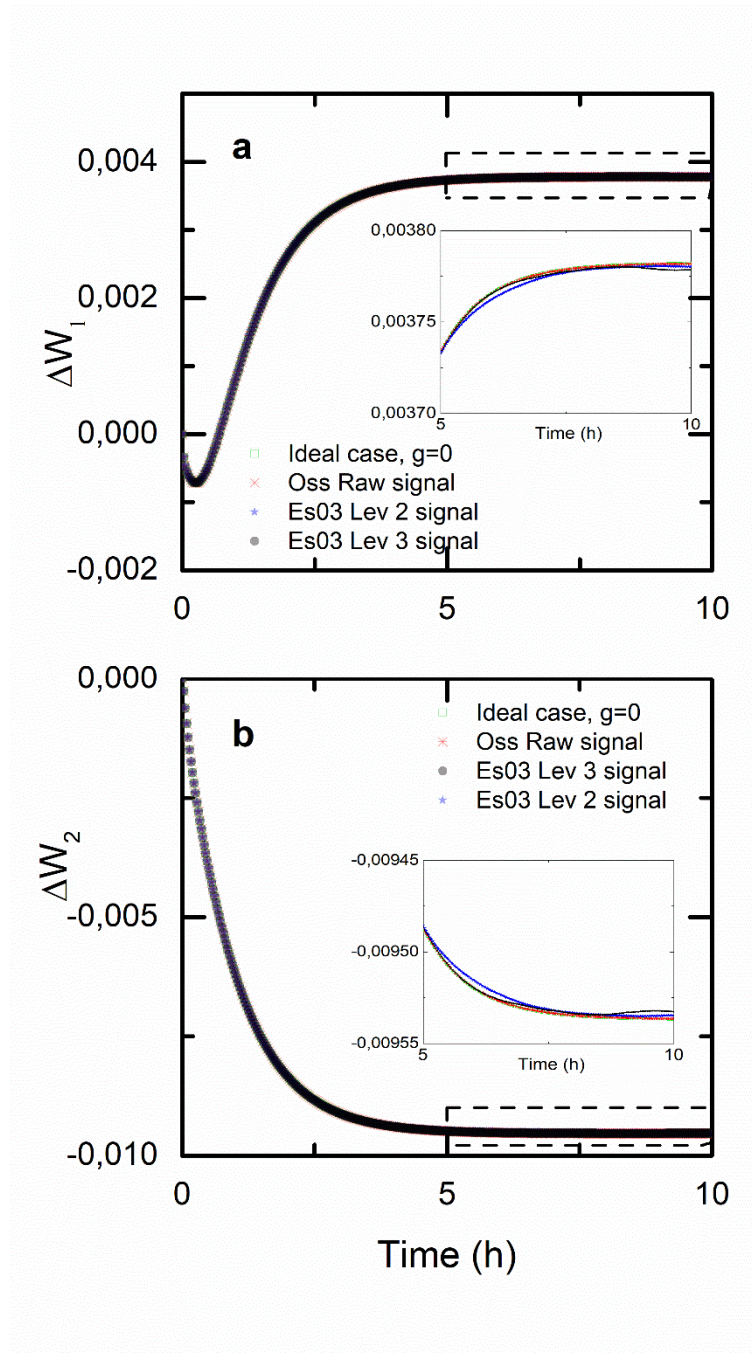


Fig. 6 Temporal variation of the concentration difference for a) toluene (Δw_1) and b) methanol (Δw_2). The insets show a zoom of the marked regions (dashed rectangle)..

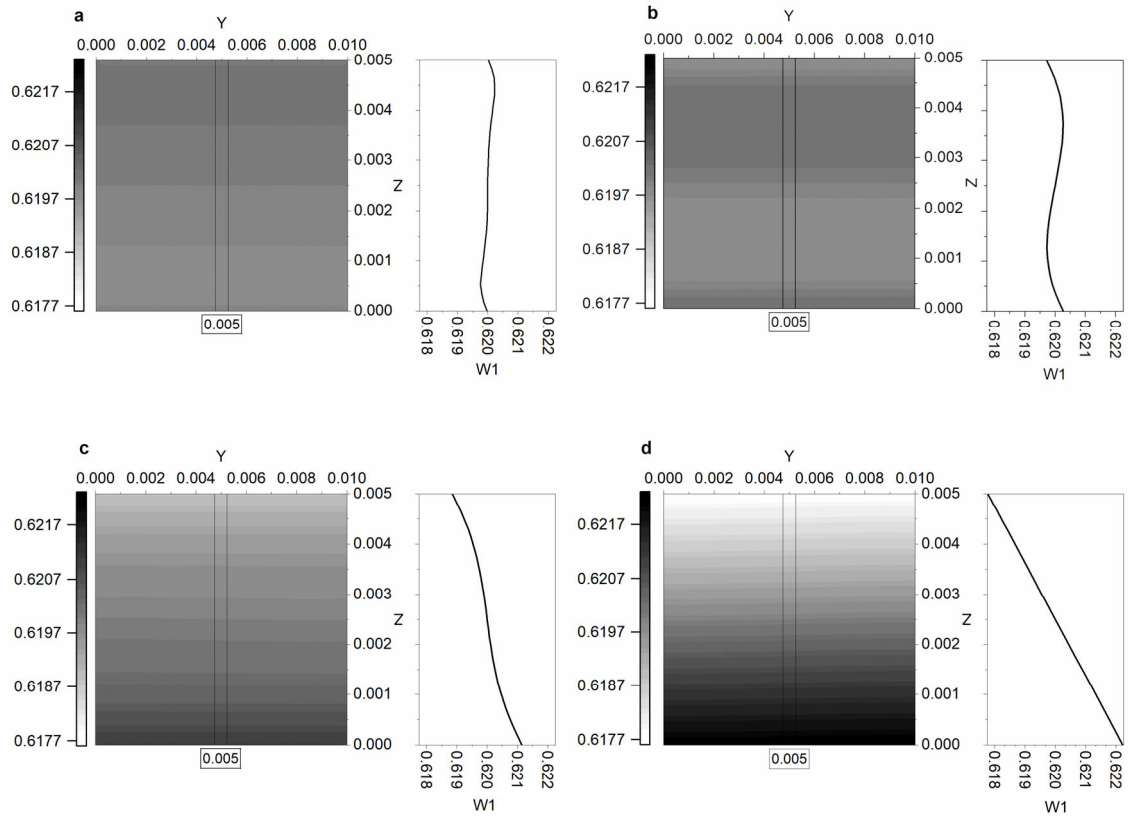


Fig. 7 Toluene iso-concentration lines and their vertical profiles for the Lev3 signal at different time steps: a) $t_1 = 200$ s, b) $t_2 = 2500$ s, c) $t_3 = 5000$ s and d) $t_4 = 36000$ s. Note That, Y and Z axes are in meters.

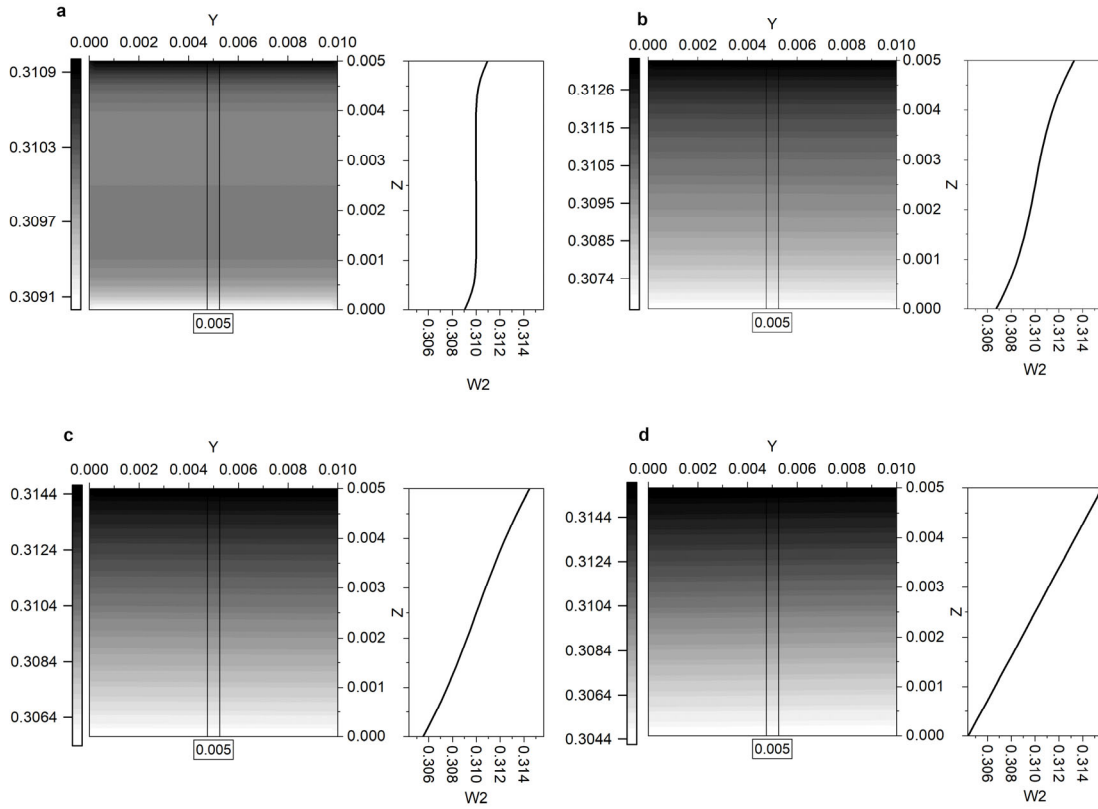


Fig. 8 Methanol iso-concentration lines and their vertical profiles for the Lev3 signal at different time steps: a) $t_1 = 200$ s, b) $t_2 = 2500$ s, c) $t_3 = 5000$ s and d) $t_4 = 36000$ s. Note That, Y and Z axes are in meters.

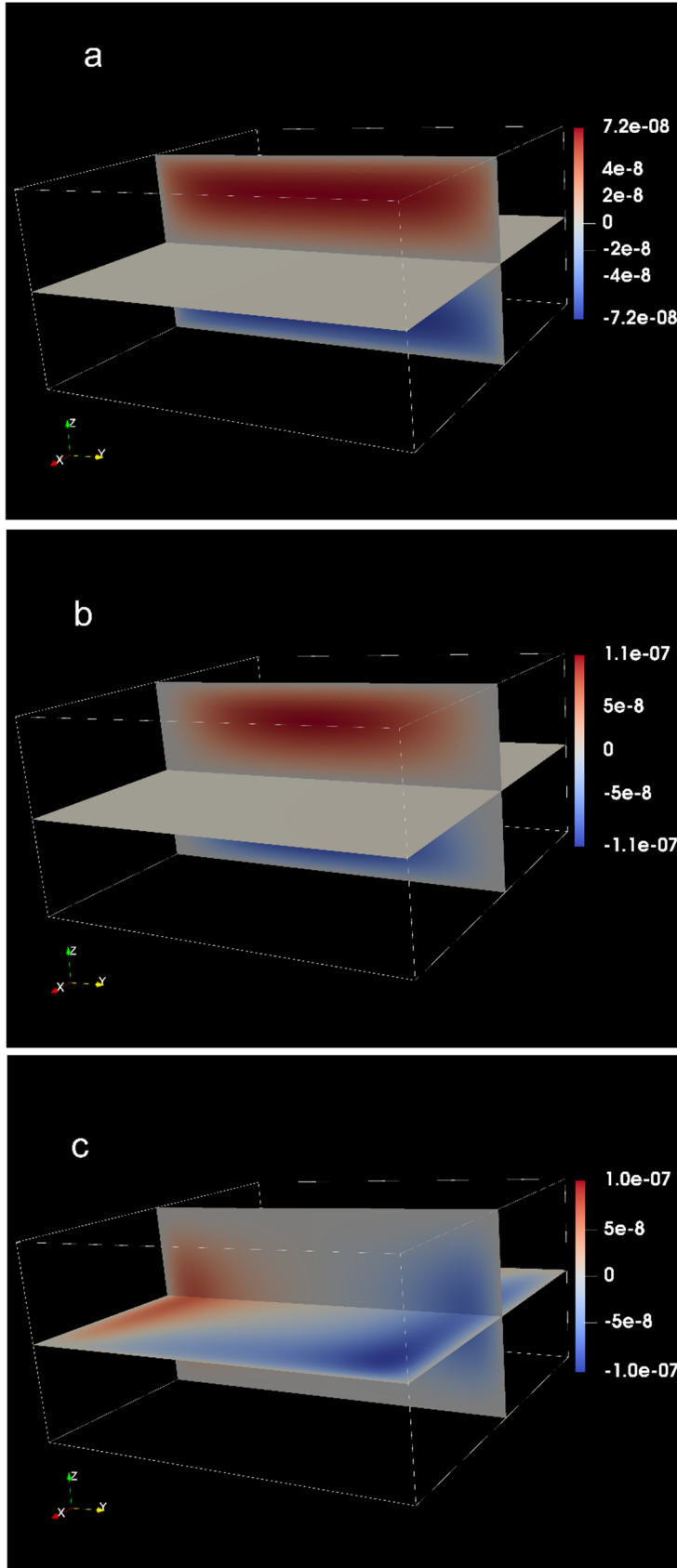


Fig. 9 Velocity fields, u_x , u_y , u_z , at $t = 200$ s correspond to the XY ($z = 2.5$ mm) and ZY ($x = 5$ mm) middle planes.

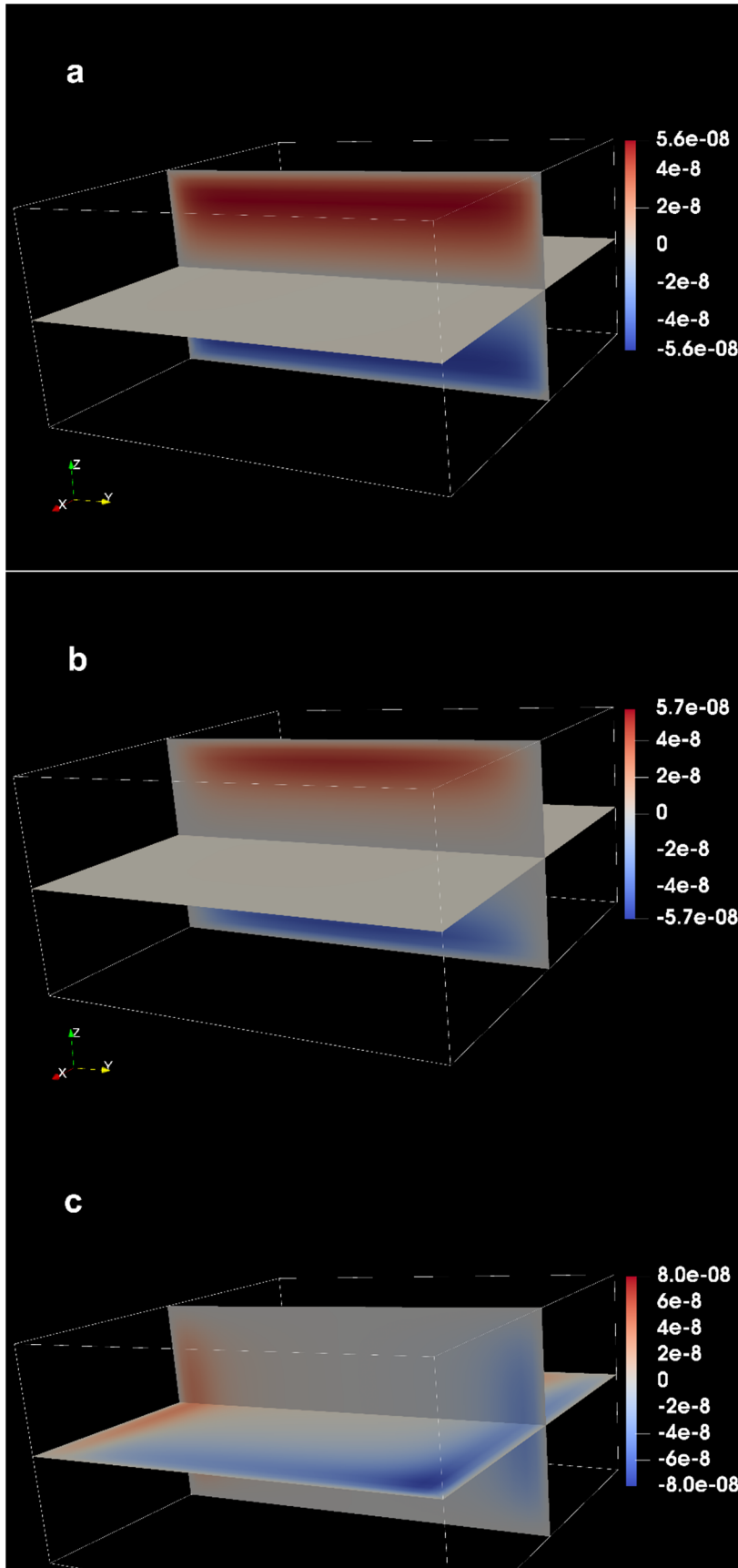


Fig. 10 Velocity fields, u_x , u_y , u_z , at $t = 10$ h correspond to the XY ($z = 2.5$ mm) and ZY ($x = 5$ mm) middle planes.

Conclusions

By using the above mathematical tools, a preliminary accelerometric characterization of the microgravity environment of DCMIX4 runs has been performed, enabling further evaluation of its potential impact on the experimental results. Note that all the low frequencies that surpass the ISS limits requirements may be correlated to the own ISS structural frequencies.

Numerical simulations, under quiescent conditions of acceleration, do not detect, appreciable flow disturbances independent of the location of the sensor used, outside (Oss Raw sensor) or inside (es009 sensor) the Glovebox. This means that during any ISS event (as reboosting) it is advisable to have a SAMS sensor nearby the experiment, but to evaluate the impact of a quiescent period it is equally suitable to select any sensor that are placed in the same module even though these signals to be properly mathematical manipulated.

Acknowledgements

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Table 1: Details of the DCMIX4 runs

Cell #1: Toluene–Methanol–Cyclohexane (0.20 – 0.25 – 0.55 wt%)				
Run	Start time (h:m)	End time (h:m)	Δt (h)	Remarks
1r01	18-12-18 (07:11)	19-12-18 (07:11)	24	No data
1r02	23-12-18 (02:08)	24-12-18 (02:08)	24	No data
1r03	25-12-18 (02:09)	26-12-18 (02:09)	24	No data
1r04	21-01-19 (07:21)	23-01-19 (07:21)	48	Complete*
1r05	24-01-19 (07:21)	25-01-19 (19:21)	36	Complete**
1r06	27-01-19 (21:35)	28-01-19 (21:35)	24	Complete***
1r07	21-02-19 (05:00)	23-02-19 (05:00)	48	
1r08	15-02-19 (22:00)	16-02-19 (22:00)	24	
1r08d	01-03-2019 (13:08)	02-03-19 (9:08)	20	
Cell #2: Toluene–Methanol–Cyclohexane (0.35 – 0.25 – 0.40 wt%)				
2r01	26-12-18 (02:09)	26-12-18 (18:09)	16	No data
2r02	27-12-18 (09:10)	28-12-18 (01:10)	16	No data
2r03	03-01-19 (06:45)	03-01-19 (22:45)	16	No data
2r04	09-01-19 (07:37)	09-01-19 (23:37)	16	No data
2r05	10-01-19 (11:40)	11-01-19 (03:40)	16	No data
2r06	29-01-19 (21:35)	30-01-19 (13:35)	16	
2r07	05-02-19 (09:34)	06-02-19 (01:34)	16	
2r08	06-02-19 (16:34)	07-02-18 (08:34)	16	
2r09	09-02-19 (14:00)	10-02-19 (06:00)	16	1h data missing at the end
2r10	10-02-19 (21:00)	11-02-19 (13:00)	16	3h data missing at the start
2r11	19-02-19 (14:00)	20-02-19 (06:00)	16	

2r12	23-02-19 (14:00)	24-02-19 (06:00)	16	
2r13	24-02-19 (5:05)	25-02-19 (5:06)	24	
2r14	25-02-19 (21:05)	26-02-19 (13:05)	16	
2r15	27-02-19 (5:05)	27-02-2019 (21:05)	16	
2r16	28-02-19 (13:08)	01-03-19 (13:08)	48	
Cell #3: Toluene–Methanol-Cyclohexane (0.55 – 0.25 – 0.20 wt%)				
3r01	19-12-18 (19:17)	20-12-18 (07:17)	12	No data
3r02	26-12-18 (18:10)	27-12-18 (06:10)	12	No data
3r03	14-12-18 (02:31)	14-12-18 (14:31)	12	No data
3r04	28-12-18 (01:10)	28-12-18 (13:10)	12	No data
3r05	03-01-19 (22:46)	04-01-19 (10:46)	12	No data
3r06	12-01-19 (07:30)	12-01-19 (19:30)	12	No data
3r06r	26-01-19 (09:35)	26-01-19 (21:35)	12	No data
3r07	11-01-19 (03:40)	11-01-19 (15:40)	12	No data
3r08	31-01-19 (20:35)	01-02-19 (08:35)	12	
3r09	01-02-19 (11:34)	02-02-19 (10:34)	12	
3r10	02-02-19 (21:34)	03-02-19 (09:34)	12	
3r11	06-02-19 (01:34)	06-02-19 (13:34)	12	
3r12	07-02-19 (08:34)	07-02-19 (20:34)	12	
3r13	10-02-19 (06:00)	10-02-19 (18:00)	12	
3r14	11-02-19 (13:00)	12-02-19 (01:00)	12	
3r15	18-02-19 (10:00)	19-02-19 (22:00)	12	No data
3r16	20-02-19 (06:00)	20-02-19 (18:00)	12	No data
3r17	25-02-19 (5:05)	25-02-19 (21:07)	16	
3r18	26-02-19 (13:05)	27-02-19 (5:07)	16	
3r19	27-02-19 (21:05)	28-02-19 (9:05)	12	
Cell #4: Tetrahydronaphthalene–Toluene-Fullerene (0.60 -0.3993 – 0.0007 wt%)				
4r01	17-12-18 (07:11)	18-12-18 (07:11)	24	No data
4r02	20-12-18 (07:17)	21-12-18 (07:17)	24	No data
4r03	24-12-18 (02:09)	25-12-18 (02:09)	24	No data
4r04	23-01-19 (07:21)	24-01-19 (07:21)	24	
4r05	26-01-19 (21:35)	27-01-19 (21:35)	24	
4r06	28-01-19 (21:35)	29-01-19 (21:35)	24	
4r07	30-01-19 (20:35)	31-01-19 (20:35)	24	
4r08	12-02-19 (12:00)	13-02-19 (12:00)	24	
Cell #5: Polystyrene–Toluene-n-Hexane (0.02 – 0.49 – 0.49 wt%)				
5r01	01-01-19	03-01-19 (06:45)	48	No data

	(06:45)			
5r02	06-01-19 (22:45)	08-01-19 (22:45)	48	No data
5r03	03-12-19 (09:34)	05-02-19 (09:34)	48	
5r04	24-02-19 (23:00)	26-02-19 (23:00)	48	
5r02r	02-03-19 (9:10)	04-03-19 (9:10)	48	

Table 2: Vibrational observations

Run	Vibrational environmental observations	
	Time domain (time where there are RMS spikes, h)	Frequency domain (range that exceeds the ISS limits, Hz)
Cell #1: Toluene–Methanol–Cyclohexane (0.20 – 0.25 – 0.55 wt%)		
1r04	Small RMS peaks	0.2-0.3
1r05	27.05 h	0.2-0.3
1r06	Small RMS peaks	0.17-0.35
1r07	16.57h, 33.1h, 33.3h, 34.1h, 34.45 h	Correct
1r08	13.93 h, 16.74 h	0.22-0.28
1r08d	1.53 h	Correct
Cell #2: Toluene–Methanol–Cyclohexane (0.35 – 0.25 – 0.40 wt%)		
2r06	Correct	0.28-0.35
2r07	4.758 h, 9.692 h	0.17-0.35
2r08	Small RMS peaks	0.22-0.35
2r09	Correct	Correct
2r10	11.04 h, 12.19 h	Correct
2r11	Correct	0.22-0.28
2r12	5.542 h	Correct
2r13	9.89 h, 13.09 h, 14.03 h	Correct
2r14	11.05 h	0.17-0.22
2r15	1.6 h, 4.22 h, 14.04 h	0.17-0.35
2r16	2.46 h, 18.46 h, 18.69 h	Correct
Cell #3: Toluene–Methanol–Cyclohexane (0.55 – 0.25 – 0.20 wt%)		
3r08	Correct	0.22-0.28
3r09	0.525 h, 0.608h, 8.525h	0.17-0.35
3r10	Correct	Correct
3r11	Correct	Correct
3r12	Correct	0.22-0.28
3r14	0.125 h	0.22-0.28
3r17	4.21 h, 7.3 h, 7.76 h	0.17-0.22
3r18	1.25 h, 1.61 h, 2.73 h	Correct
3r19	Correct	Correct
Cell #4: Tetrahydronaphthalene–Toluene–Fullerene (0.60 -0.3993 – 0.0007 wt%)		
4r04	Correct	0.22-0.28
4r05	15.55 h	0.22-0.28
4r06	9.986 h	0.17-0.35
4r07	17.54 h, 19.92 h	0.17-0.35
4r08	1.508 h, 7.925 h, 20.69 h, 23.67 h	0.22-0.28
Cell #5: Polystyrene–Toluene–n-Hexane (0.02 – 0.49 – 0.49 wt%)		
5r03	6.408 h, 30.41 h, 31 h, 31.01 h,	0.17-0.35
5r04	13.84 h	0.17-0.35
5r02r	24.13 h, 26.7 h	0.17-0.35

Table 3. Physical properties of the DCMIX2 mixture

Run	T _{mean} (ΔT) K	ρ (Kg·m ⁻³)	10 ⁷ ·ν (m ² ·s ⁻¹)	10 ⁷ ·α (m ² ·s ⁻¹)	10 ³ ·β _T K ⁻¹	β _{w1}	β _{w2}	10 ⁹ ·D _{ij} m ² ·s ⁻¹				10 ¹³ ·D _{iT} m ² ·s ⁻¹ ·K ⁻¹		S _{Ti} x10 ³ K ⁻¹	
								D ₁₁	D ₁₂	D ₂₁	D ₂₂	D _{1T}	D _{2T}	S _{T1}	S _{T2}
DCMIX2 campaign [Toluene-Methanol-Cyclohexane (0.62-0.31-0.07)]															
6 (Cell#1)	298.15 (10)	829.99	6.7	0.94	1.16	0.14	0.045	2.30	1.52	-0.24	0.51	-6.82	-6.79	0.445	-1.122