

UNIVERSITÀ DEGLI STUDI DI PADOVA

Micro-Physics and Modelling of Martian Dust Storms

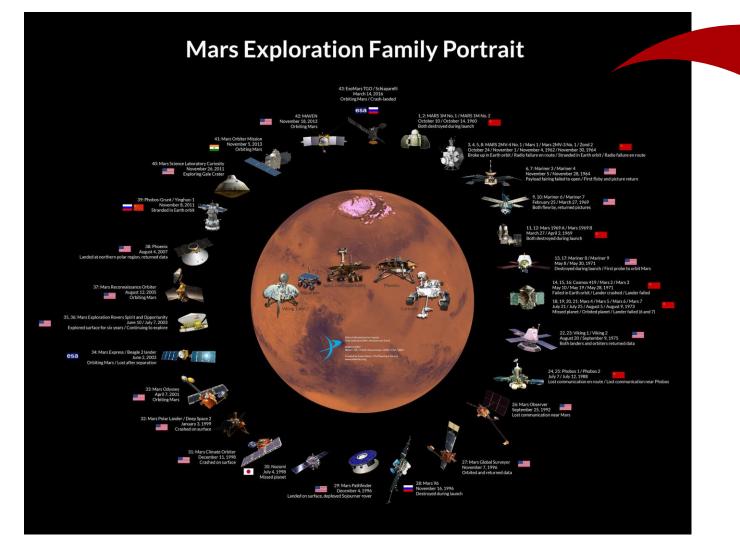
Lorenzo Martinuzzo - 40th Cycle

Supervisor: Dr. Federico Dalla Barba Admission to the first year - 13/11/2024



Project Motivations





Toward manned missions on Mars





Project Motivations



Dust storms could have a significative impact on both manned and unmanned missions on Mars:

- Huge amount of dust lifts in the atmosphere;
- Wide extent of dust storms.



NASA, Mars Global Surveyor, 2001

These storms lead to several limitations for Mars exploration, e.g.:

- Telecommunication attenuation;
- Solar radiation reduction on solar photovoltaic power systems.



NASA, Opportunity rover



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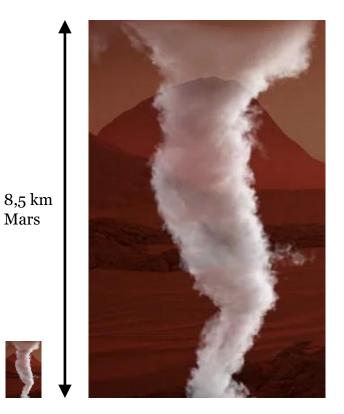
Project Motivations



Lift, suspension and sedimentation mechanisms need a deep study of the micro-physics from a computational point of view since wide in situ measurements campaign are not available.

Martian atmosphere has some peculiar characteristics that distinguish it form the Earth atmosphere:

- Larger density ration between rock particles and the atmosphere;
- Bigger temperature gradients;
- Strong influence of the sublimation/frosting cycle of CO₂ ices on the atmospheric pressure.



Dust Devils maximum observed height comparison between Earth and Mars

1 km

Eart



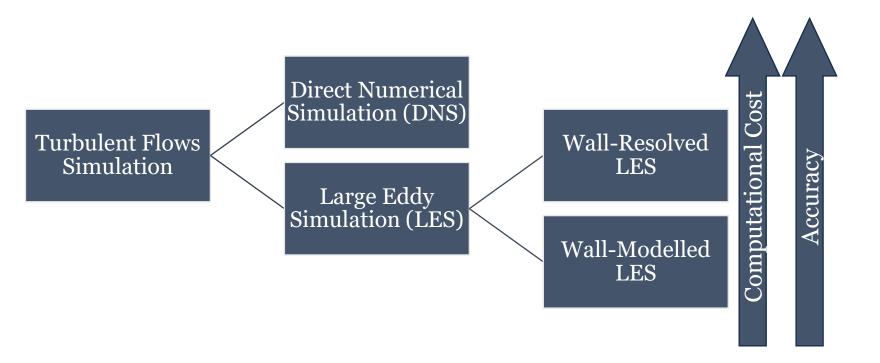
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State of Art in Multiphase CFD



Particles laden flows require to simulate both fluid dynamics and the particles dynamics.

DNS and LES are the state of art for turbulent flow simulations.



DNS: direct solution of Navier-Stokes equations for all scales.

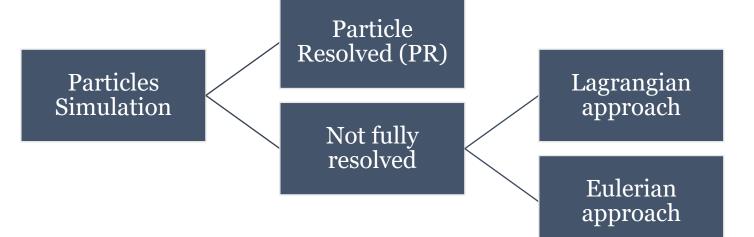
WR-LES: small scale are modelled, large scale are solved.

WM-LES: the near wall region is modelled.





- Particles simulation can be handled with different methodologies: •
- **PR:** fluid-particle boundary conditions are fully resolved;
- Lagrangian: Lagrangian equation of motion for particles, fluid interaction is modelled;
 - Eulerian: fluid and particles are treated as a continuum, models are required.





Activity 1: PR-DNS



Purposes:

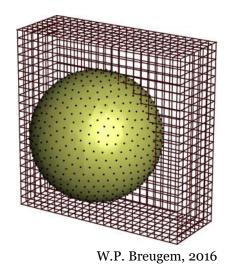
- Understand the physics of particles lift, suspension and sedimentation;
- Create a wide dataset of different flowparticles configurations.

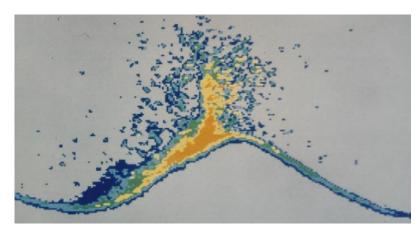
Adopted methodologies:

• Particle-Resolved DNS with IBM.

Activities:

- Integrating an already available numerical code + GPU acceleration;
- Validation of the code and simulations.





M. Mazzuoli et al., 2024



Activity 2: PP-DNS Models



Purposes:

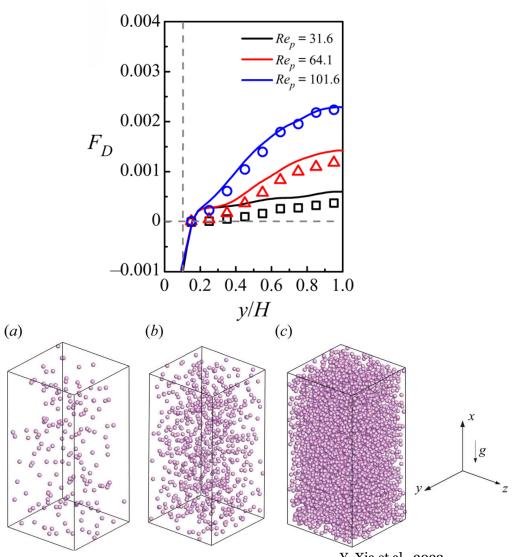
- Identification of fluid-particles interaction models;
- First reduction of computational cost.

Adopted methodologies:

• Point-Particle DNS.

Activities:

- Dataset analysis and model extraction;
- Validation of the models and simulation.





Activity 3: LES Models



Purposes:

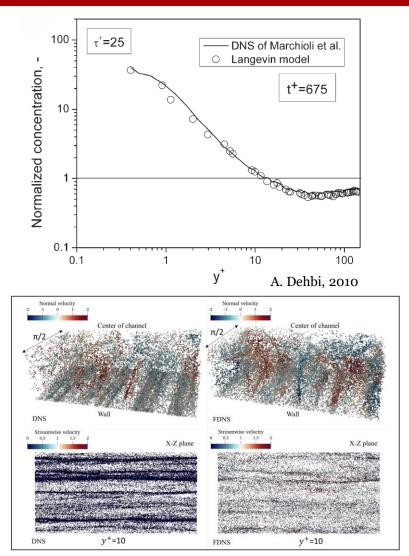
- Verify models for LES;
- Simulate more complex configurations for dust clouds.

Adopted methodologies:

- WR-LES;
- WM-LES.

Activities:

- Apply models to LES and validation;
- Simulation of Martian dust clouds at meso-scale.





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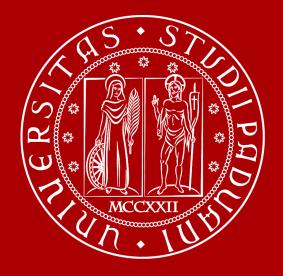
degli Studi di Padova

GANTT chart of the activities



	R TASK TITLE		FIRST YEAR									SECOND YEAR									THIRD YEAR									
WBS		% OF TASK		T1		T2		T3		Т	T4		T1		T 2	Т	T3		T4			T1		T2		Т3		Т	T4	
NUMBER		COMPLETE		DJ	F	М	AM	J	J	A	s o	Ν	D.	JF	М	AN	N J	J	Α	s o	N	D	J	F	MA	М	J	J	A S	; O
1	Particle-Resolved DNS and dataset creation																													
1.1	Analysis of the state of art	0%																												
1.2	Numerical method integration with GPU acceleration and optimization	0%																												
1.3	Test and validation of the numerical method	0%																												
1.4	DNS simulations to obtain a wide dataset	0%																												
2	Dataset analysis and Point-Particle modelling																													
2.1	Analysis of the state of art	0%																												
2.2	Dataset analysis	0%																												
2.3	Fluid-Particle interaction models identification from the dataset	0%																												
2.4	Point-Particle DNS simulation and model validation	0%																												
3	LES/WMLES simulation and a posteriori models																													
3.1	Analysis of the state of art	0%																												
3.2	LES/WMLES simulation with a posteriori models test and validation	0%																												
3.3	LES/WMLES to simulate Mars dust clouds conditions	0%																												
4	Writing thesis and reports																													
4.1	Report for the admission to the next year and conferences	0%																												
4.2	Writing thesis	0%																												

Thanks for the attention



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