NEW TOOLS AND METHODS TO FULLY CHARACTERIZE THE ATMOSPHERIC ENVIRONMENT FOR A MARTIAN EDL. APPLICATION TO THE 2016 EXOMARS DESCENT MODULE.

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Because of the presence of a relatively thin and highly variable atmosphere, the Entry Descent and Landing of Martian probes is a difficult task which requires the best possible characterization of the Martian atmosphere, from the upper atmosphere to the boundary layer. Ideally, one want to predict as accurately as possible density, temperature, pressure and winds (including their variability and perturbations) as well as possible updraft and downdraft in the boundary layer (for the parachute phase) and the aerosols mixing ratio (in particular for the heatshield erosion), etc.

We will review the various tools that are now available to address these questions (with a focus on tetools and data that have been made available in the last couple of years). This includes:

- **Spacecraft observations,** which have been the reference source of information to prepare an IDL. A climatology of the Martian atmosphere has been collected since 1999 (begginning of mapping mission of Mars Global Surveyor) by various instruments. In particular, data from the Mars Climate Sounder on MRO which monitor the atmosphere from the surface to above 70 km are now available. Altogether, we have now detailed climatologies on the Martian weather for 7 years, wich allows us for the first time to derive reliable statistics on the year-to-year variability. At some seasons, it seems that the Martian atmosphere is very repeatable from year to year. This can give a lot of confindence in the prediction.
- **Global Climate Model (GCM) and derived tools.** GCMS have been extensively used to provide reliable climatologies of the Martian climate. They are constantly improving and are now able to predict the Martian weather anywhere and at anyseason with a astriking accuracy. GCM simulations can be used directly or through tools that exploit the GCM outputs to provide engineering tools like Mars Gram or the Mars Climate database suitable to combine outputs from the GCM with variability models suitable for Monte-Carlo EDL simulations. The MCD is for instance designed to simulate a variety of possible entry profile for various dust loading and meteorological conditions. It also include a tool designed to predict surface pressure with the highest possible accuracy by combining 1) reference pressure measure of Viking lander 1 site at a given seasonal date, 2) large scale spatial variation due to meteorology (including thermal tides at a given local time) from the GCM and 3) small scale variations due to topography, using 1/32 degree MOLA data (~2km horizontal resolution). Overall this tool is thought to predict pressure with an error of less than a couple of percent.
- **Data assimilation** are obtained by optimally combining observations (obtained at various locations and time) with the a-priori knowledge from a GCM. State of the art techniques that are used on the Earth to construct reference climatologies ("re-analysis") are now available on Mars from various group using the MGS TES and MRO MCS data.
- **Meso-scale models** with a resolution of a few kilometers are also necessary to complement the GCMS, in particular to predict the local winds resulting from the topography below 10 km and the landing conditions.
- **Large Eddy Simulation models (LES)** are new kind of tools with a resolution of a few tens of-meters which are able to simulate the convective boundary layer environment (during daytime) at a landing site, and in particular the strong convective updraft and downdraft which may be dangerous for a probe under a parachute.
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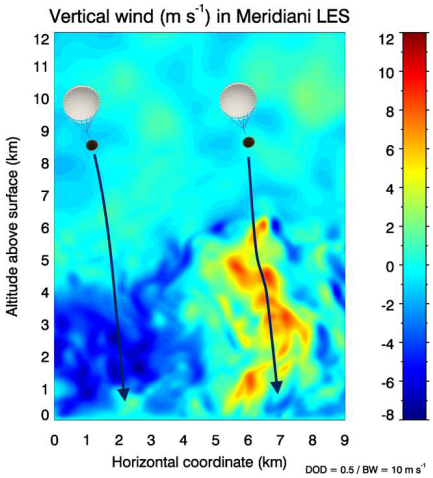

Figure: an example of "Large Eddy simulations" of the convective boundary layer used to model the parachute descent of a probe.

In our presentation, we will review all the tools available, and illustrate the kind of results that can be obtained with the cas of the ESA Exomars Descent module schedule to land on Mars in October 2016