A NEW VISION ON THE MARTIAN ATMOSPHERE AND SURFACE THROUGH MESOSCALE MODELING. A. Spiga[1], F. Forget[1], J.-B. Madeleine[1], I. Smith[1], E. Millour[1], T. Bertrand[1], L. Montabone[1], A. Pottier[1], T. Navarro[1], A. Määttänen[2], J. Holt[3]. [1] Laboratoire de Météorologie Dynamique, Université Pierre et Marie Curie, Centre Nationale de la Recherche Scientifique, Paris, France (aymeric.spiga@upmc.fr) [2] LATMOS, Paris, France [3] UTIG, University of Texas, USA.

Introduction: Mesoscale modeling aims at resolving the vast and diverse population of phenomena of smaller extent than a few hundreds of kilometers – in other words, the smorgasbord of atmospheric phenomena left unresolved by Global Climate Models. In this abstract, we discuss several examples studied with the LMD Mars Mesoscale Model in which mesoscale modeling for the Martian atmosphere 1. unveils new possible interpretations of regional and local phenomena observed on Mars and 2. opens perspectives and discussions that go much further than the interest for mesoscale meteorology, (and the impact thereof on Martian robotic and human exploration) and has implications on climatology, geology, glaciology, chemistry, …

Surface energy budget: Infrared measurements show that the nighttime surface temperature in several regions characterized by uneven topography is up to 20K warmer on slopes than on surrounding plains. It has been thought that this is caused by contrasts in thermal inertia. We discovered by conducting mesoscale modeling for those regions with an horizontal resolution of a few kilometers that those warm surface departures in the night, correlated with slope steepness, could just as well be accounted for by mesoscale atmospheric winds only, notably powerful katabatic winds which form over Martian sloping terrains all night long in various seasons [1]. This behavior is caused by atmospheric heating by adiabatic compression, combined with an enhanced sensible heat flux that becomes comparable to radiative contributions. Part of the surface temperature signal thus conveys information about mesoscale slope winds, that needs to be taken into account e.g. in thermal inertia measurements. These predictions will be confirmed (or not) by the Curiosity rover soon.

Polar regions: Several observations (radar observations, frost streaks, spectral analysis of ices, …) concur to show that aeolian processes play a key role in glacial processes in Martian polar regions. A spectacular manifestation of this resides in elongated clouds that forms in polar troughs. The interest of those clouds is not obvious at first glance. Notwithstanding this, with mesoscale modeling in polar regions using 5 nested domains operating a model downscaling from horizontal resolutions of about twenty kilometers to 200 meters, we were able 1. to predict the near-surface wind structure over the whole Martian polar caps, with interactions between katabatic acceleration, Coriolis deflection, transient phenomena, and thermally-forced circulations by the ice / bare soil contrast and 2. to show that katabatic jumps (also named Loewe phenomena) form at the bottom of polar troughs with an horizontal morphology similar to trough clouds, vertical velocity (up to +1.5 m/s) and temperature perturbations propitious to cloud formation. Mesoscale modeling suggests here that trough clouds are present manifestation of the ice migration that yielded the internal cap structure discovered by radar observations, as part of a "cyclic step" process [2]. This has important implications for the stability and possible migration over geological timescales of water ice surface reservoirs.

Dust storms: Dust storms are often considered as indicative of regional and global winds, and having an impact on global circulation. Mesoscale modeling could draw a slightly different picture. Our simulations with a dust transport scheme showed that deep convective motions, implying a fast and efficient upward transport of dust particles, occur in Martian local and regional dust storms, a phenomena we named "rocket dust storms" [3]. The supply of convective energy is provided by the absorption of incoming sunlight by dust particles, rather than by latent heating as in moist convection on Earth and other environments. A potentially strong implication is the formation of detached layers of aerosols, which needs to be parameterized in Global Climate Models [4]. This new view on local dust storms might also help to understand how a large regional storms becomes a planet-encircling dust storm.

Perspectives: Mesoscale modeling will undoubtedly play a key role in future Martian studies : interpretation of Curiosity measurements, understanding of InSight pressure signal, … An interesting perspective is offered by "global" mesoscale modeling (i.e. high resolution Global Climate Modeling) which will permit an analysis for instance of interactions between atmospheric phenomena at different spatial scales.

References: [1] A. Spiga et al. Icarus 2011 [2] I. Smith et al. JGR 2013 (+ this issue) [3] A. Spiga et al. JGR 2013 [4] T. Bertrand et al. This issue

Acknowledgments: We acknowledge support from ESA and CNES.

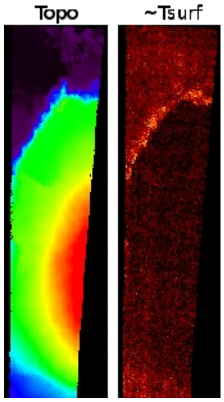
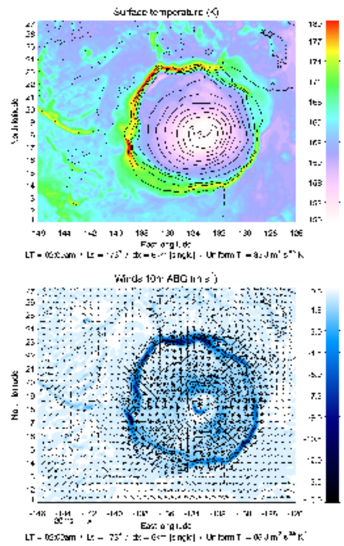
<table>
<tr>
<td>Warmer surface over slopes at night


Figure courtesy of B. Gondet, OMEGA team</td>
<td>« Classic » interpretation :
A contrast of thermal inertia

New interpretation by mesoscale modeling :
Warm katabatic ring

Perspectives :
Thermal inertia measurements, surface energy budget</td>
<td>

Surface temperature (K, top) and winds 10 m above local surface (m s1, bottom) predicted in the Olympus Mons/Lycus Sulci area by a mesoscale simulation Season is northern fall, local time 02:00. Topography is contoured (contour interval is 2 km). In the bottom plot, vectors (plotted for every 5th grid point) indicate wind direction with vector length being proportional to horizontal wind speed; vertical wind velocity is shaded (it is positive for upward atmospheric circulations). Figure from Spiga et al. Icarus 2011</td>
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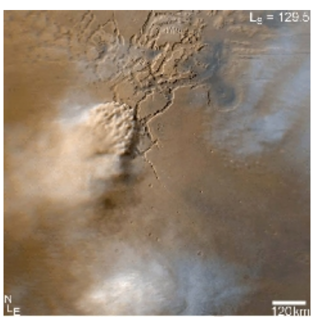
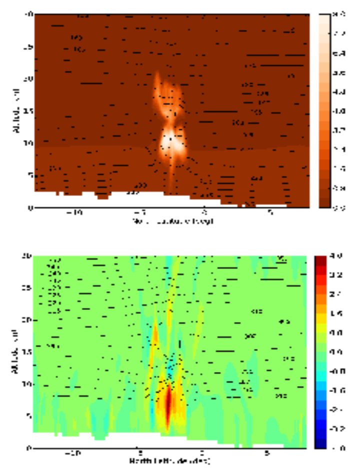
<tr>
<td>Local dust storms


Figure from
Malin et al. Icarus 2008</td>
<td>« Classic » interpretation :
Lifted dust organized by regional winds

New interpretation by mesoscale modeling :
Rocket dust storm

Perspectives :
Detached layers of dust, tracer transport, global dust storms</td>
<td>
Mesoscale simulations of the dust storm witnessed by OMEGA and described in Määttänen et al. 2009. Latitude-altitude sections obtained at local time 1500. MCS-like density-scaled optical depth in 10^3 m^2 kg^{-1} (top plot, shaded). Temperature in K (top plot, contours). Vertical wind in m s1 (bottom plot, shaded). Potential temperature in K (bottom plot, contours). Figure from Spiga et al. JGR 2013</td>
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<tr>
<td>Clouds in polar troughs

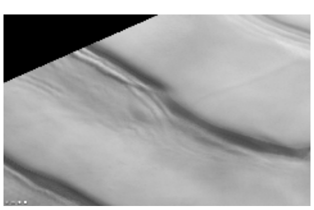
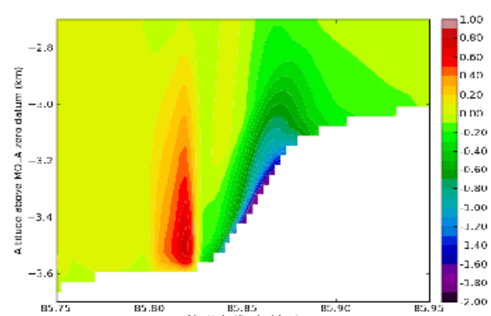



Figure from
Smith et al. JGR 2013</td>
<td>« Classic » interpretation :
Just another nice cloud

New interpretation by mesoscale modeling :
Katabatic jumps

Perspectives : ice deposition, ice migration, cap history over geologic ages</td>
<td>

Result of a nested 3D mesoscale simulations which can reproduce the katabatic jumps occurring in polar troughs, and putatively giving rise to trough clouds; vertical velocity field is shown at longitude -43E in nest 5</td>
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