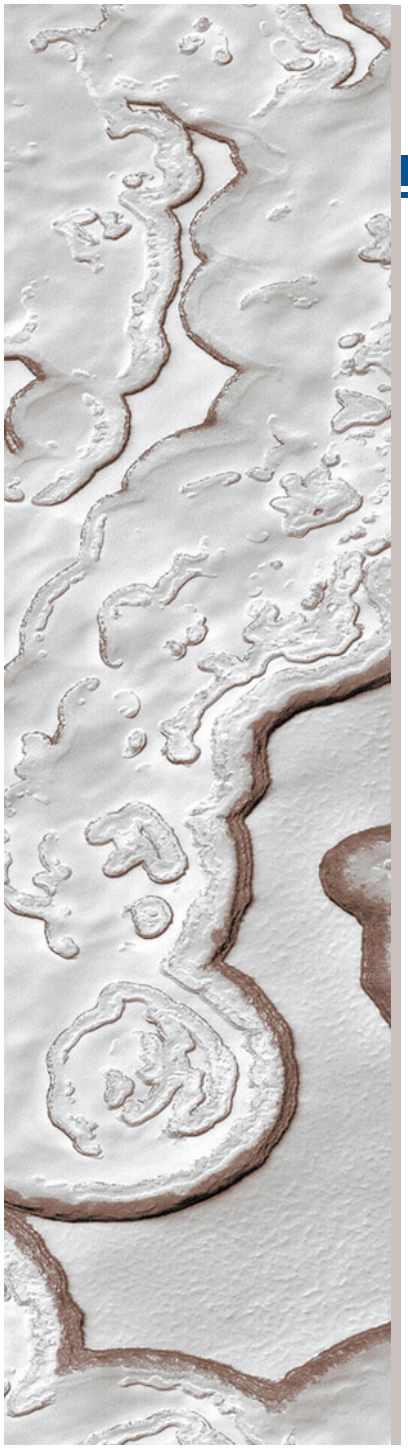


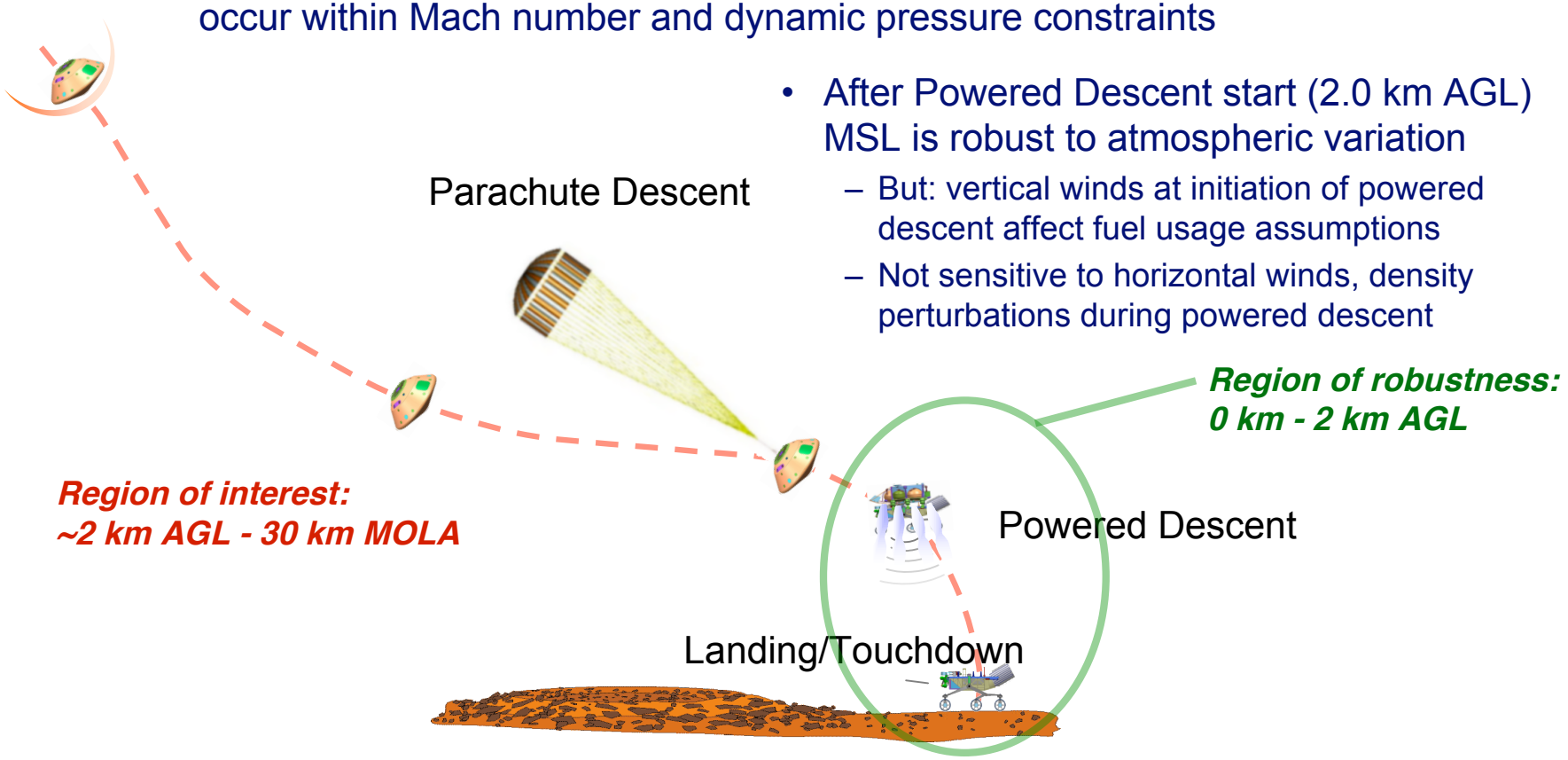
Potential Atmospheric Hazards

EDL “Council of Atmospheres”

October 23, 2007

EDL System Sensitivities

- Closed-loop, guided entry based on inertial measurements
- Below 30 km MOLA, variations in density/wind/speed of sound from predicted values may cause the internally computed velocity and acceleration with respect to Mars to diverge from the true values
- Both parachute deploy and heatshield separation are critical events that must occur within Mach number and dynamic pressure constraints



- After Powered Descent start (2.0 km AGL) MSL is robust to atmospheric variation
  - But: vertical winds at initiation of powered descent affect fuel usage assumptions
  - Not sensitive to horizontal winds, density perturbations during powered descent

Engineering Safety Constraints

(Within 100 km of the Site)

Thresholds for landing elevations > -1 km MOLA

	Entry	*Parachute Trigger*	*Heatshield Separation*	
density	**<15%** unc. from **20** km MOLA to **30** km MOLA	**< 10%** unc. from **6.5** km MOLA to **20** km MOLA		**All Landing Altitudes**
u,v		**< 25 m/s** unc. from **6.5** km MOLA to **20** km MOLA	**< 20 m/s** unc. from **3** km MOLA to **6.5** km MOLA	*Sky Crane* **max. < 30 m/s** From **0** to **10** m AGL
w			**< 20 m/s** unc. from **3** km MOLA to **6.5** km MOLA	**max. < 20 m/s** From **1** to **5** km AGL
c_{sound}		**< 7%** unc. from **6.5** km MOLA to **15** km MOLA	**< 7%** unc. From **3** km MOLA to **6.5** km MOLA	*Backshell*

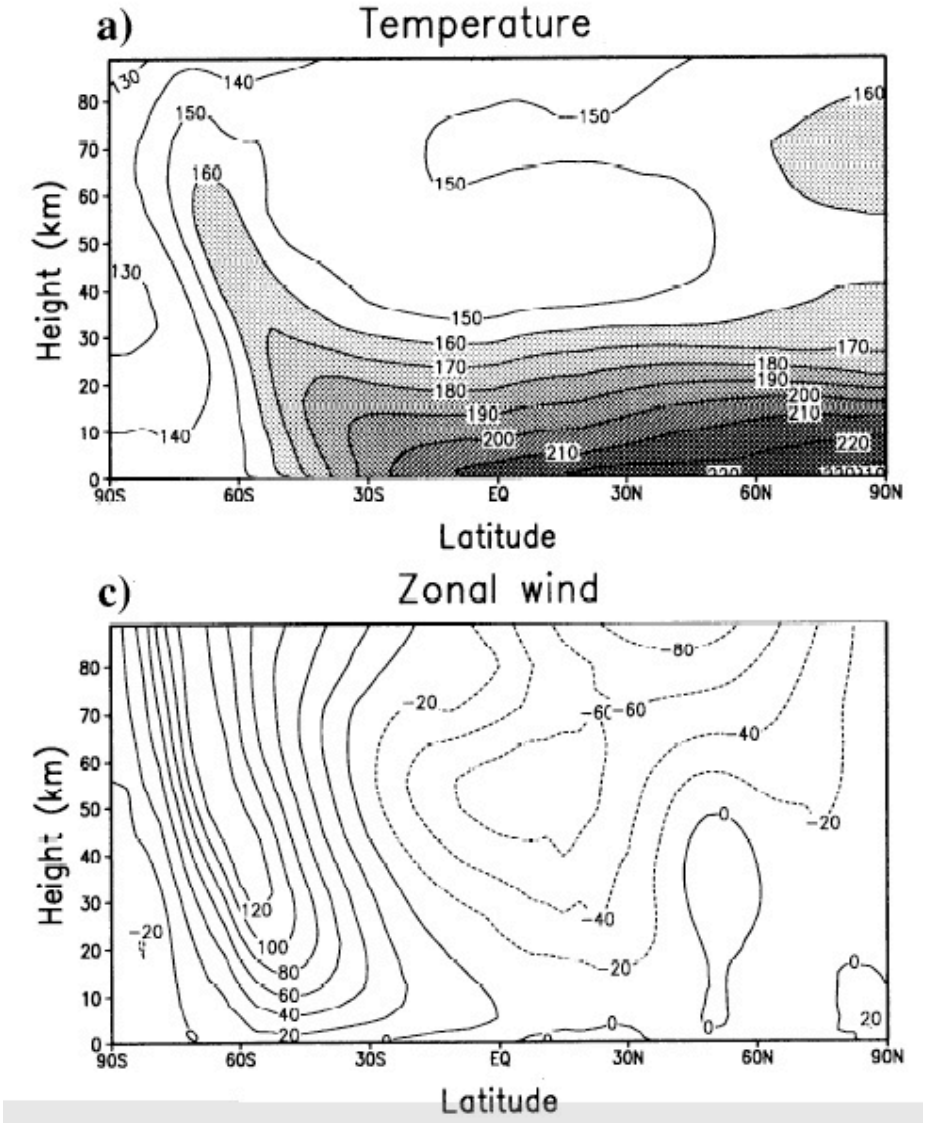
Atmospheric Working Group

- Held workshops in 2005 and 2006 to bring the EDL team and atmospheric scientists together; reviewed EDL simulations and scientific models; discussed approaches of MER and PHX.
- In October 2006 we formed a “Council of Atmospheres” to perform analyses and advise the project:
  - MSL Project: EDL team, Mission Manager, Project Science
  - External scientists: Scot Rafkin (SwRI), Jeff Barnes and Dan Tyler (OSU)
  - MarsGRAM and EDL Simulations: Jere Justus, Hilary Justh, Alicia Cianciolo, David Way
  - Additional help from Rich Zurek, Michael Mischna, David Kass, Bruce Cantor
- Goals:
  - Identify potential hazards (regions, phenomena, etc.)
  - Generate simulations, analysis tools, and interfaces
  - Certify safety of candidate sites

Atmospheric Working Group

- Two major workshops and biweekly telecons
- Identified “challenge sites” based on candidate landing sites and a survey of the entire MSL-accessible region.
- Simulated nominal conditions at these sites using MarsGRAM database and state-of-the-art GCM, mesoscale, and LES models.
  - Terby, Melas Chasma, Meridiani, Nili Fossae Trough, Gale
- Extracted relevant results and statistics and assessed them against EDL engineering safety constraints.
- Successfully demonstrated an end-to-end simulation of the MSL spacecraft flying through a model-generated atmosphere.

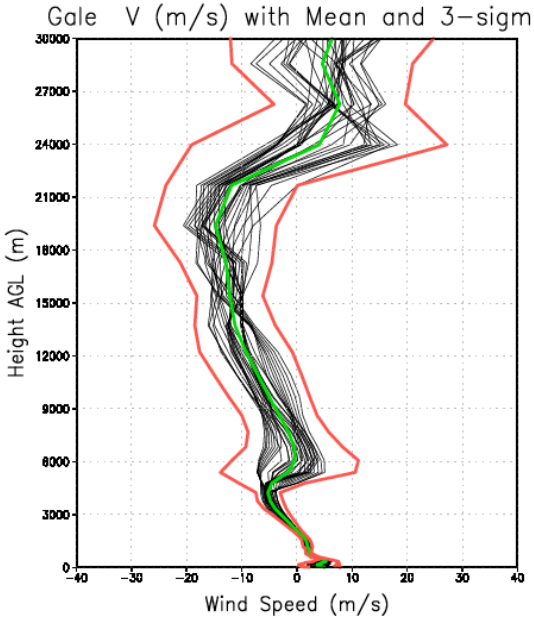
Atmospheric Hazards

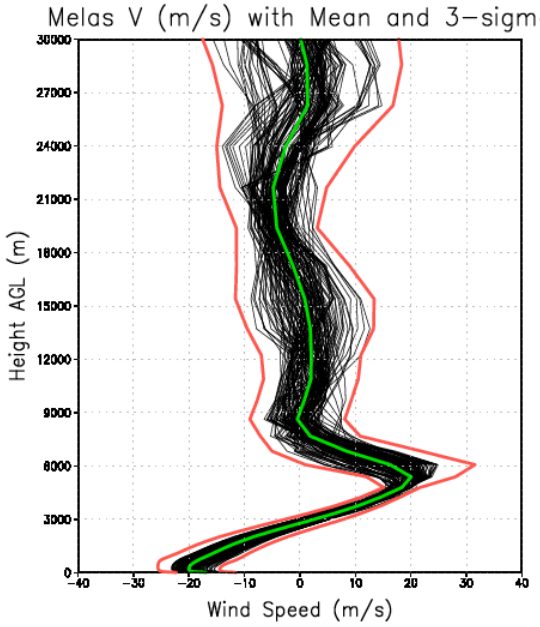


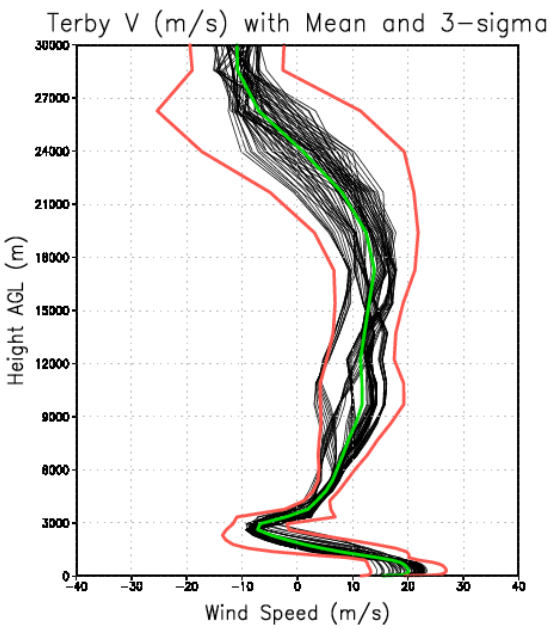
- Season is near the maximum extent of the southern CO_2 cap; deep southern winter
- Descent through SH jet stream is a challenge unique to MSL
- Jet stream has variability in latitude, magnitude
- Also associated with cyclonic winter storms (like Earth)
- Other hazards include vertical winds due to large-scale convergences, orographic and slope winds, planetary boundary layer convection (amplified in NH summer)

Atmospheric Hazards

Multiple profiles of horizontal wind (v) and variability envelopes for three challenge sites from MRAMS:

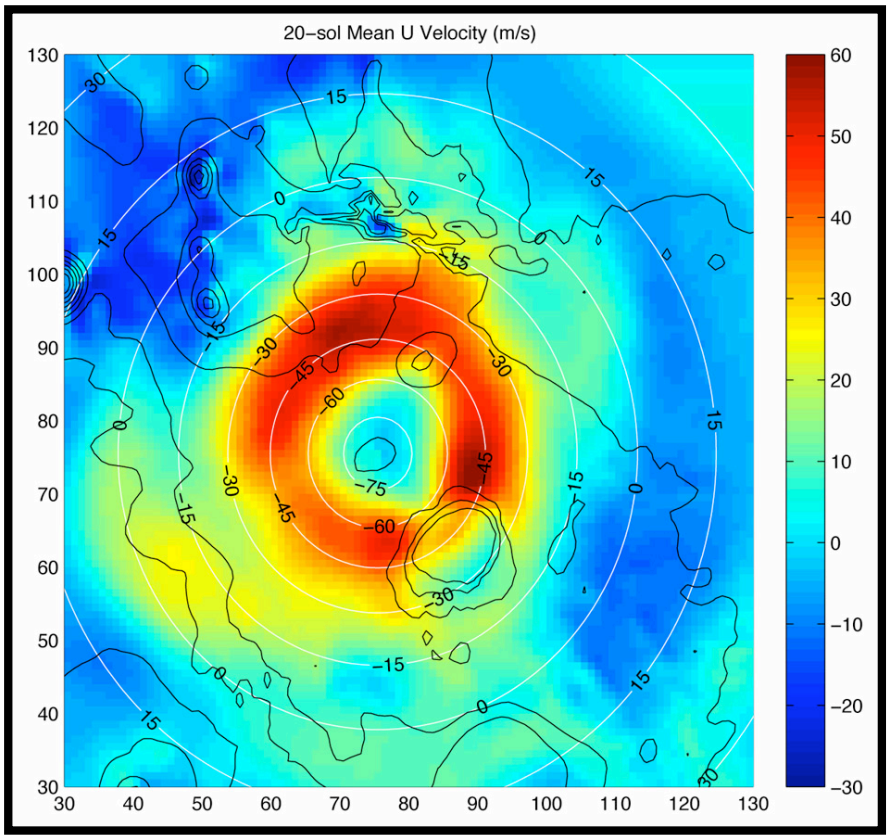


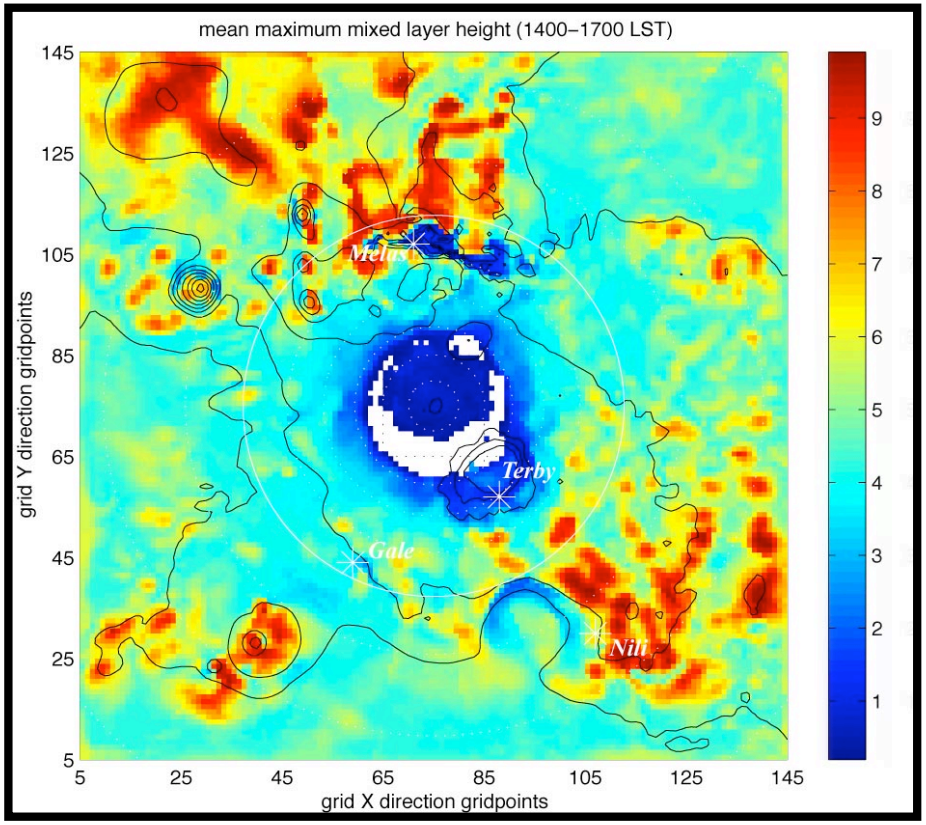




Atmospheric Hazards

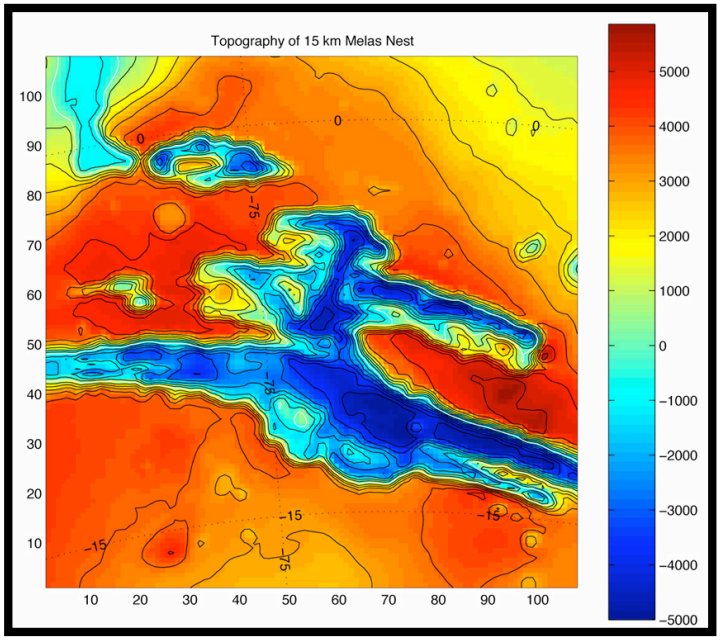
SH jet stream mean velocity and afternoon mixed layer depth from OSU Mars-MM5:

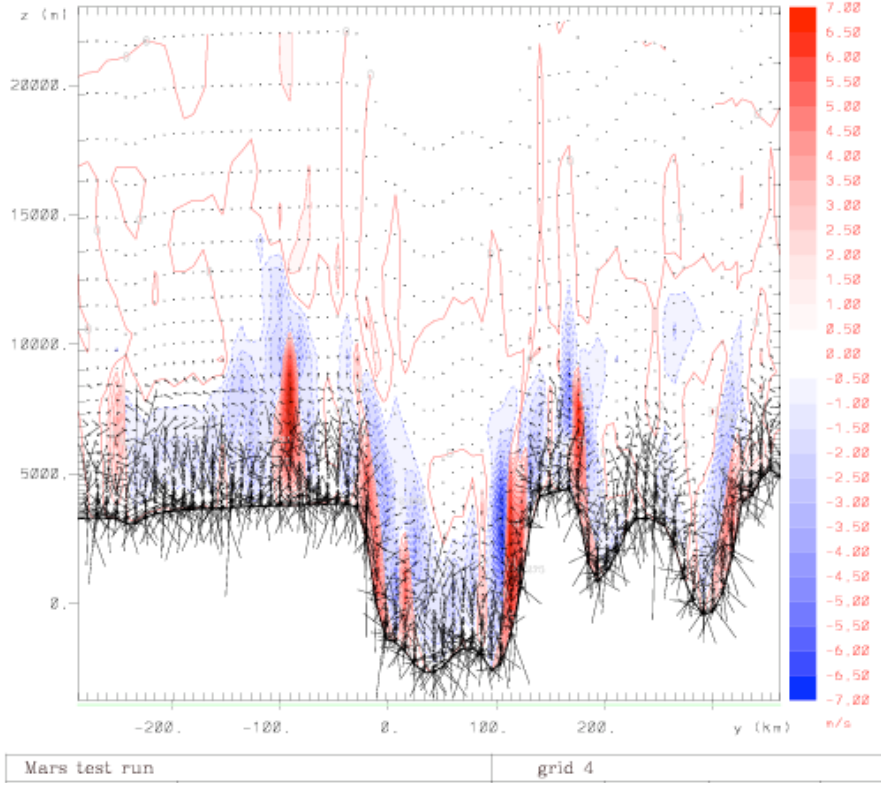




Atmospheric Hazards

Example of mesoscale model topography and vertical winds in Melas Chasma:





Atmospheric Assessment

- For this workshop, our team has provided a “stoplight” ranking of each candidate site based on what we’ve learned through the prelimenary assessment of our challenge sites.
  - Proximity to regional topographic or albedo/TI gradients; active PBL
  - Local topography that may induce orographic or slope-driven winds
- After the workshop, we will perform a detalied and comprehensive assessment of each candidate site against the engineering constraints as part of the final selection & certification process.
  - Planetary and regional circulations
  - Topographic and convectively driven winds at the highest spatial resolution possible
  - Sub-grid turbulence; waves
  - Validation against observations
  - Non-nominal conditions including local / regional dust storms