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Properties of Martian winds as determined from trajectory modelling of jettisoned spacecraft hardware

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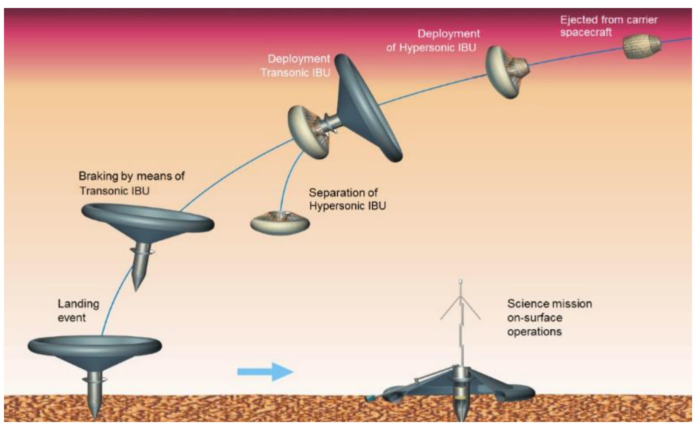
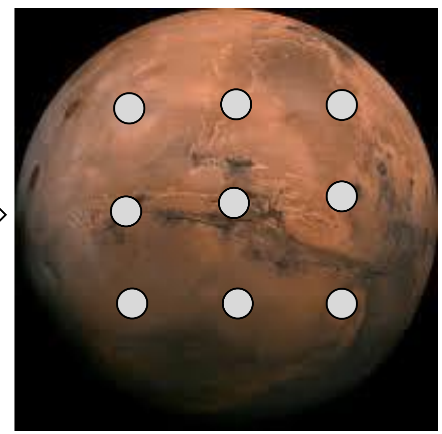
Motivations

- **Atmospheric model validation (column, mesoscale, GCM)**
  - FMI / Uni. Helsinki PBL column model, Mars Local Area Model
- **Independent verification of wind measurements**
- **Support scientific investigations**
- **Entry, Descent and Landing investigations**
- **MetNet**



A.-M. Harri et al, **The MetNet vehicle: A lander to deploy environmental stations for local and global investigations of Mars**, Geoscientific Instrumentation, Methods and Data Systems Discussions, 6, 103-124 (2017)



Support atmospheric model verification efforts (as well as science)

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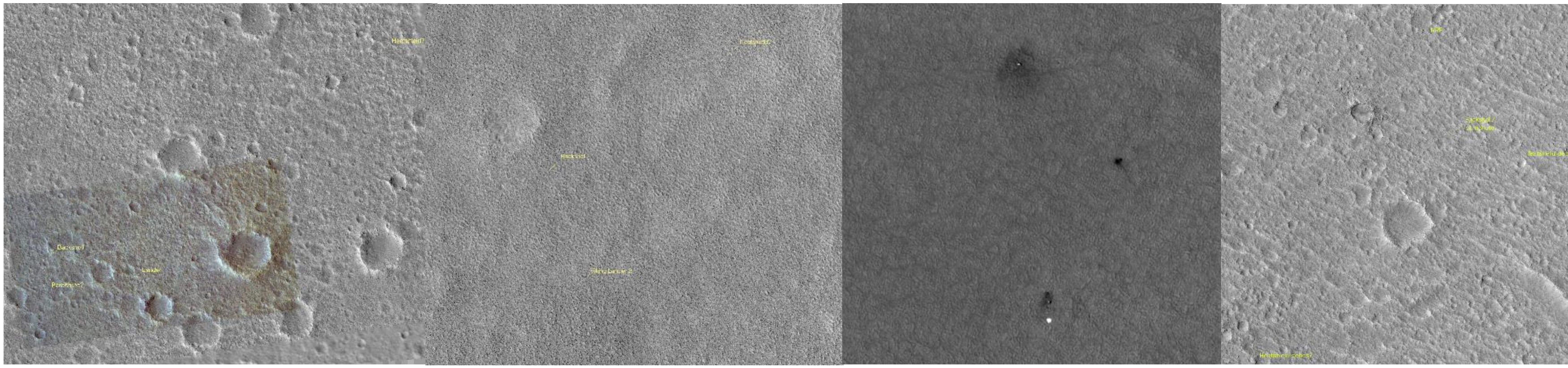
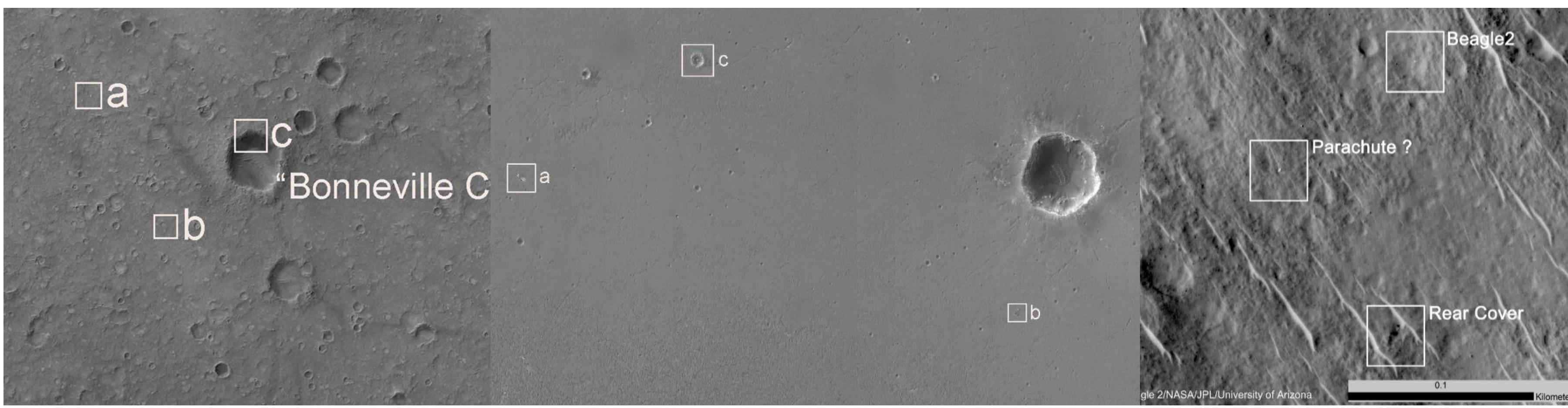
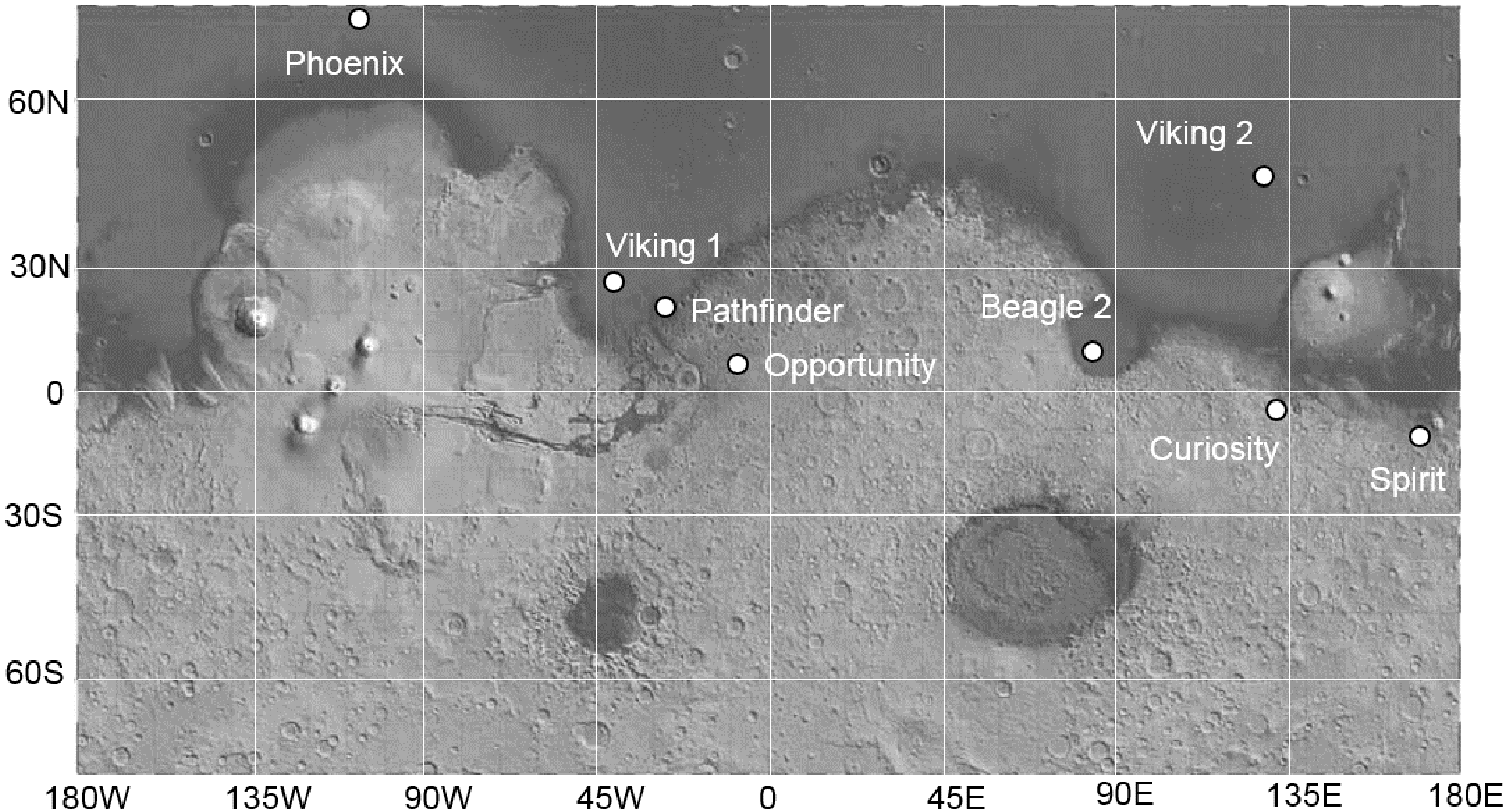
HiRISE images of spacecraft hardware

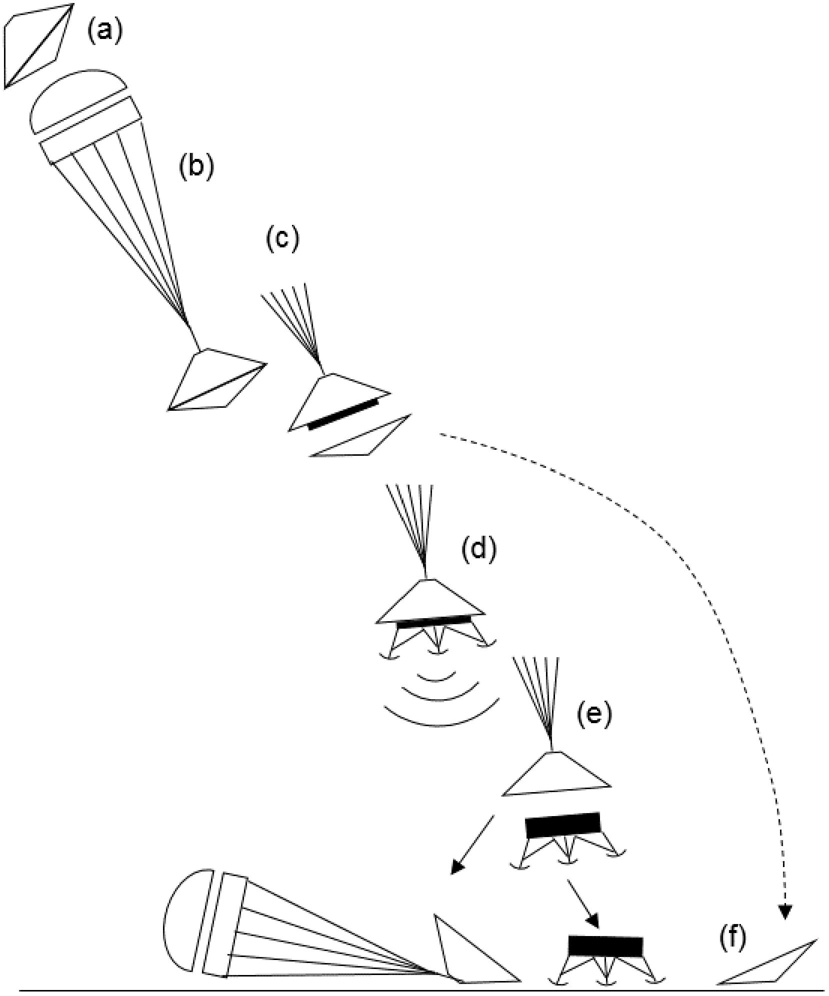




Can start by verifying wind properties derived from HiRISE images with output from Mars Climate Database



Background



Distribution of EDLS hardware with no winds

EDL profile

(a) Entry
(b) Parachute deployment
(c) Jettison heat shield
(d) Activate radar and deploy legs
(e) Jettison parachute
(f) Touchdown

The heat shield has a relatively high ballistic coefficient impacting the surface further down range than the lander when there are no winds.

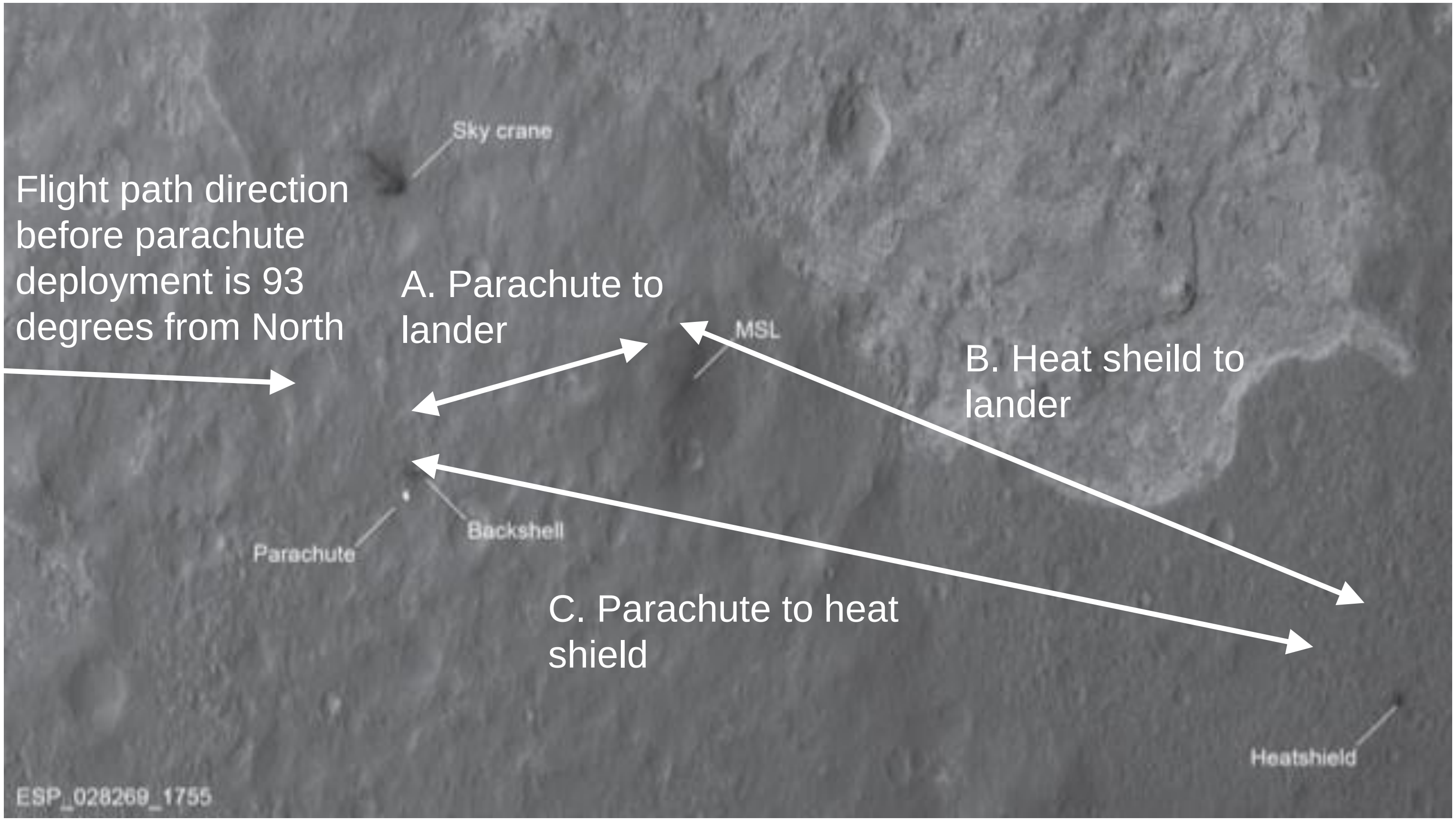
The parachute has a low ballistic coefficient tending to follow the lander down to the surface and landing very close when there are no winds.

Definition of distances in HiRISE images for the Monte Carlo analysis

A. Location of parachute minus location of lander

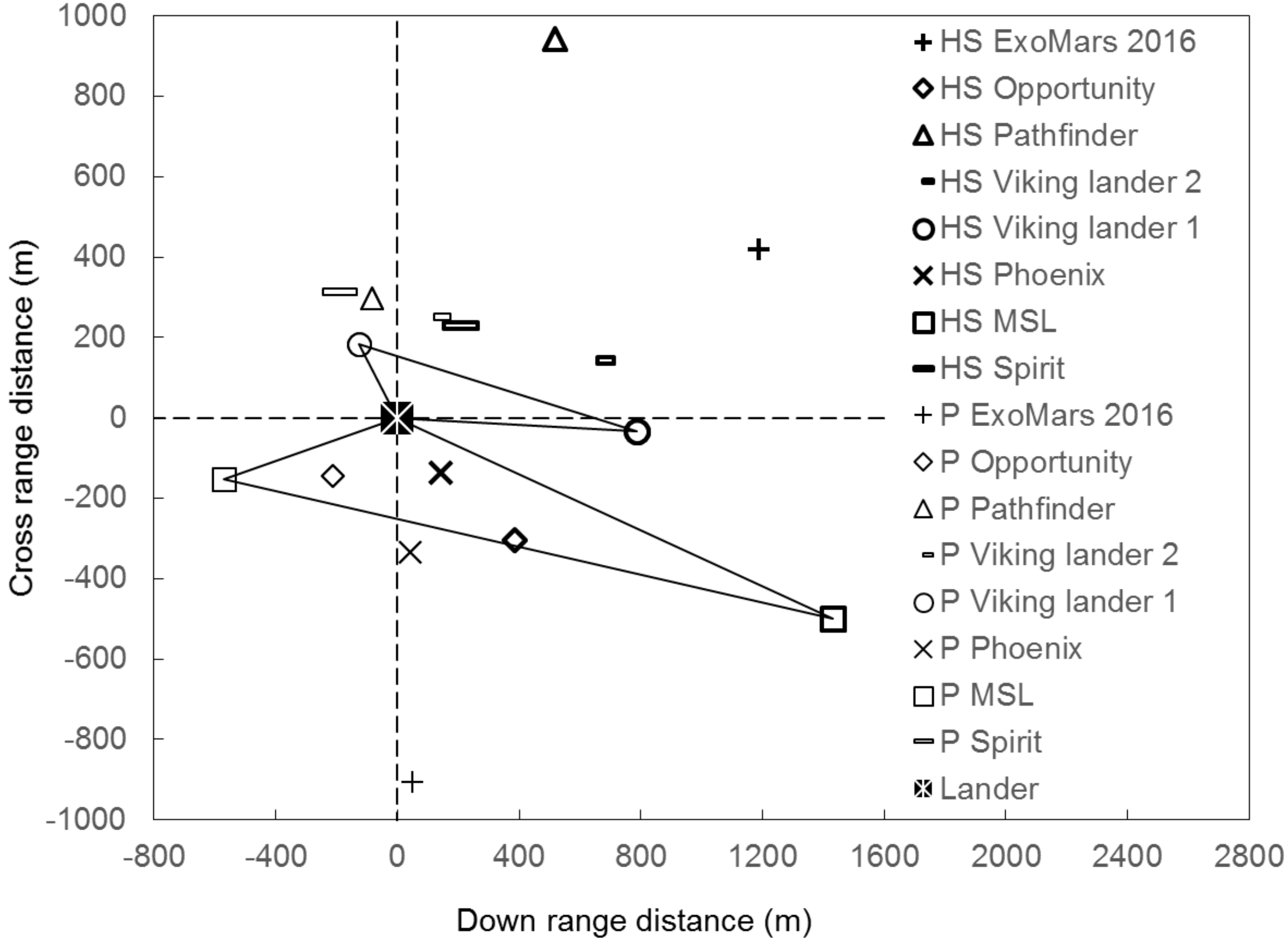
B. Location of heat shield minus location of lander

C. Location of heat shield minus location of parachute



Locations of parachutes, heat shields relative to the various landers

Direction of approach for all landers normalised to 90°

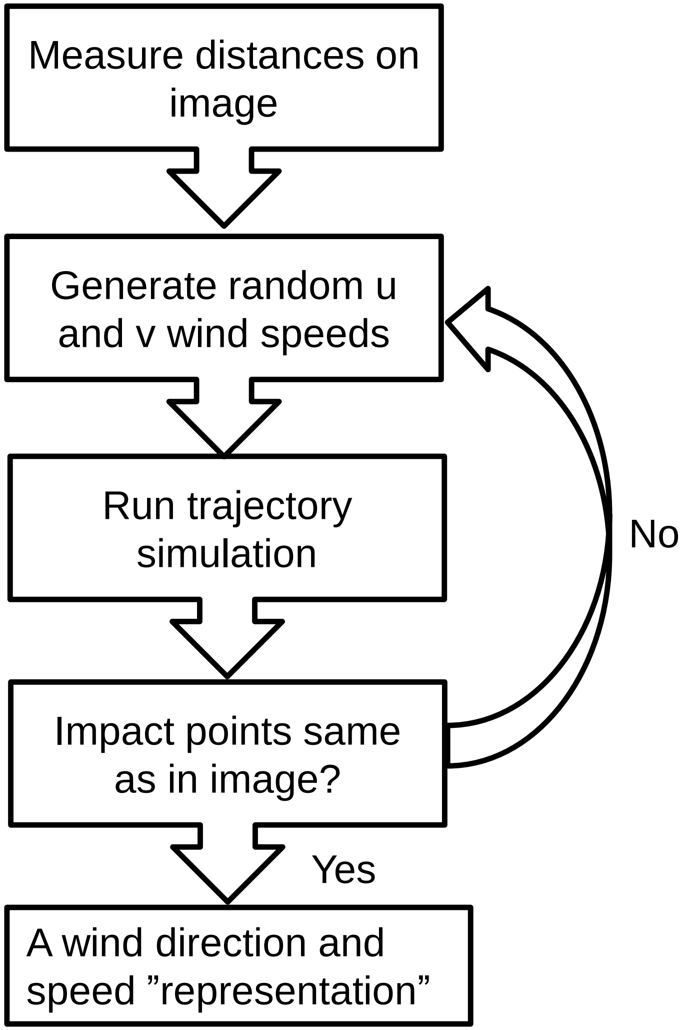


Method

Trajectory modelling

- Point mass, single body, 3 DoF global trajectory model
- Wind model verified against parachute descent data
- Trajectory simulations validated against spacecraft navigation data, i.e. altitude, position, velocity, acceleration etc

Approach

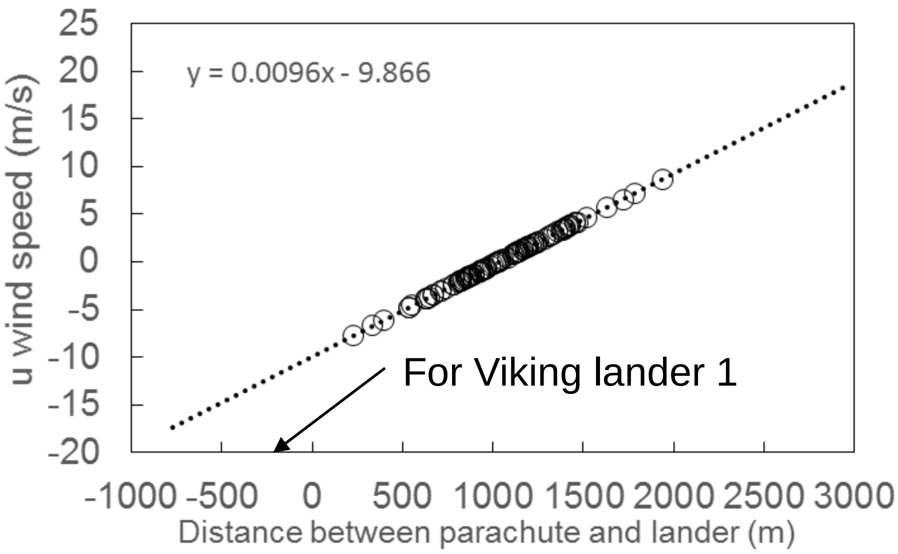

Measure distances on image
Generate random u and v wind speeds
Run trajectory simulation
Impact points same as in image?
No
Yes
A wind direction and speed ”representation”

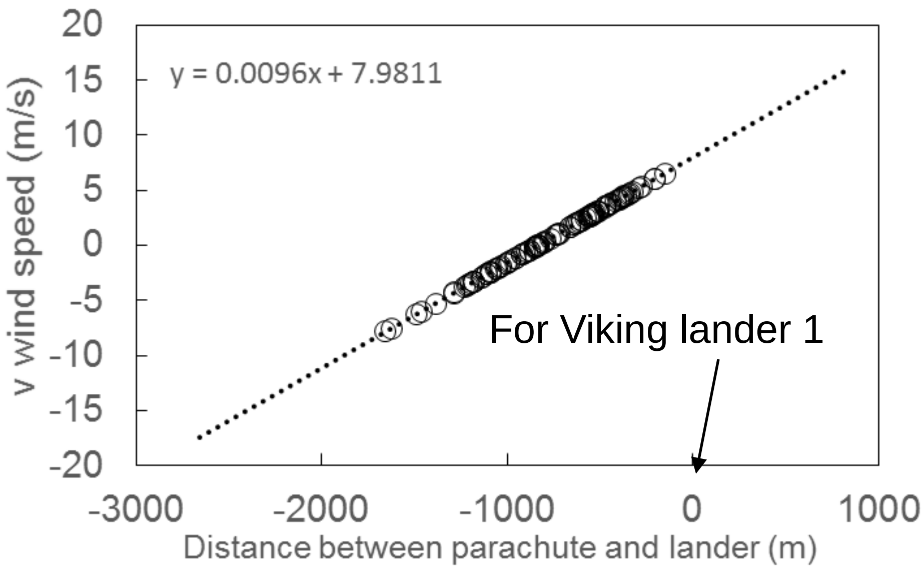
Case specific approaches used

Spacecraft	*Hardware used for analysis*	*Method used*
VL-1 < 1.5 km	Parachute and lander	Single layer, continuous profile
VL-2 < 1.5 km	Parachute and lander	Single layer, continuous profile
Pathfinder	-	
Beagle 2	First and second parachutes	Single layer
Spirit	-	
Opportunity	-	
Phoenix	Parachute, lander and heat shield	Double layer
Curiosity	Parachute, lander and heat shield	Double layer
Schiaparelli	Parachute and heat shield	Single layer

Monte Carlo analysis (simple example)

The example below shows the case for VL-1 below an altitude of 1.5 km.





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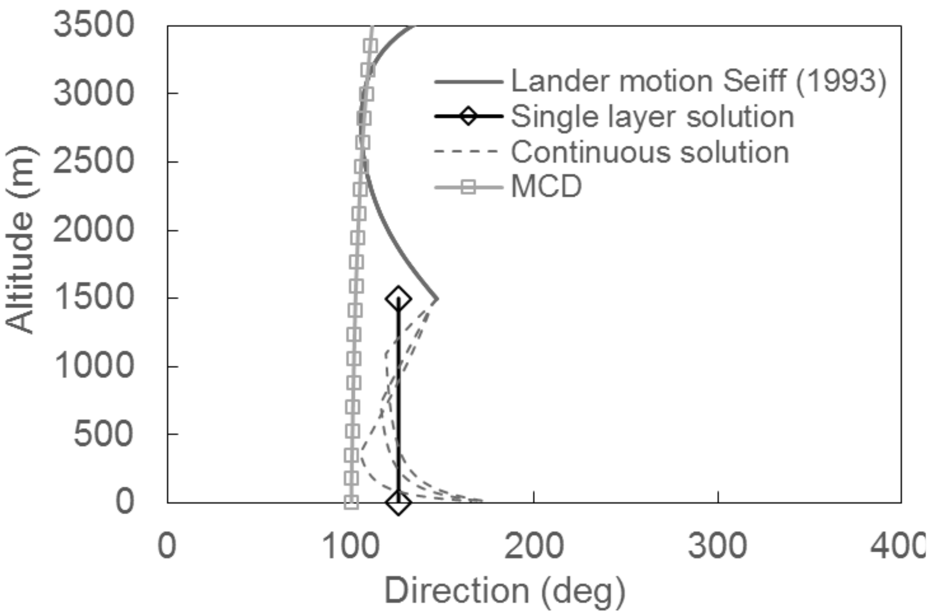
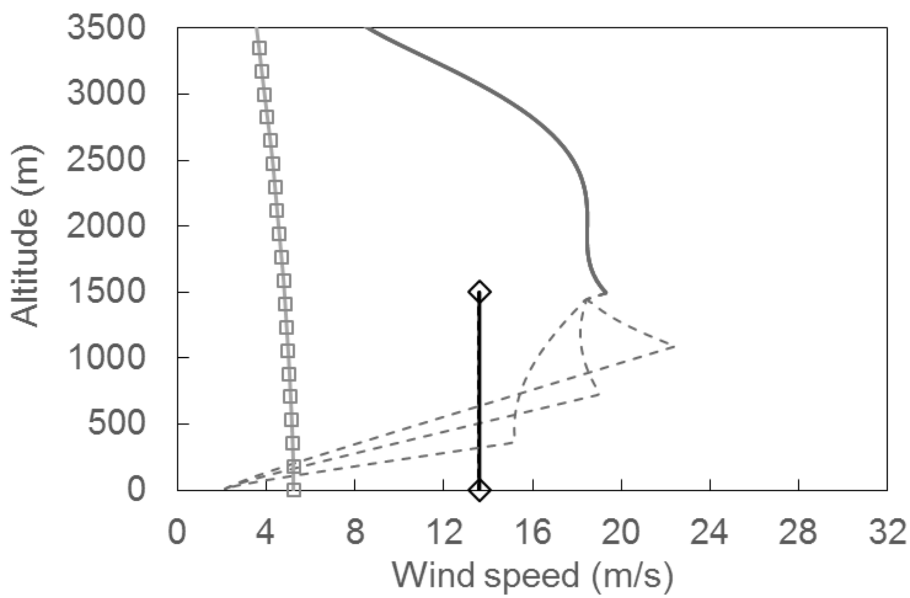
Results

Viking lander 1

Location> 312 E 22.5 N
Season (Ls)> 97°
Time of landing> 1613 LT

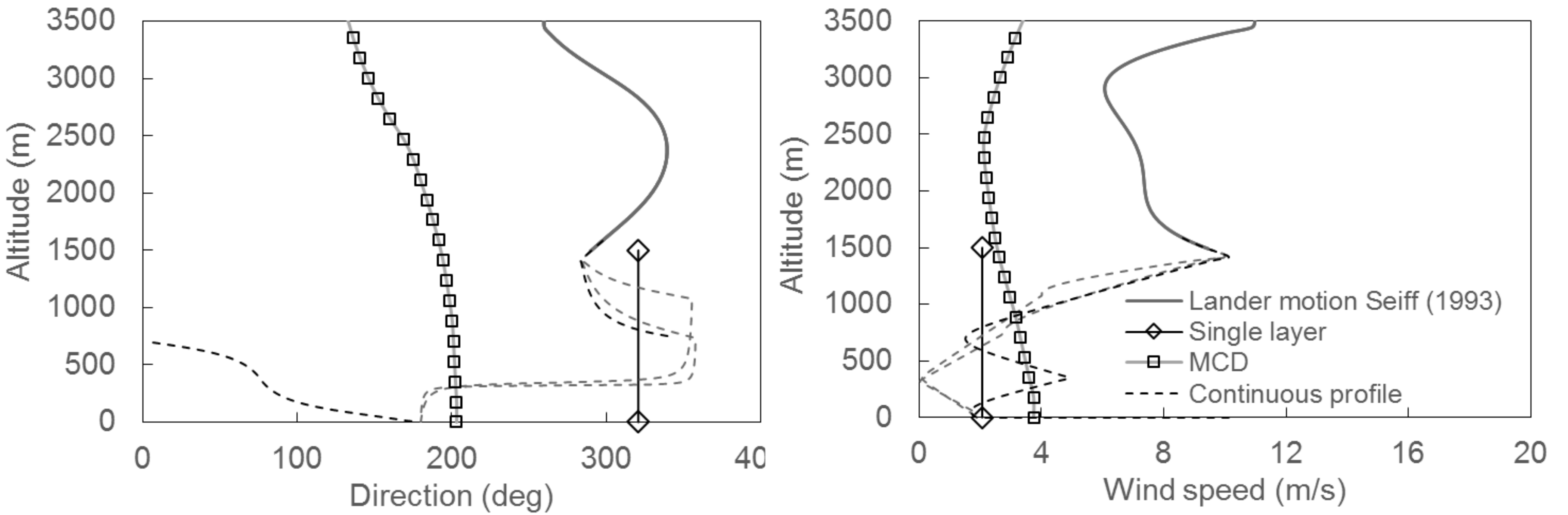




Comparison to Mars Climate Database (MCD) with default settings
http://www-mars.lmd.jussieu.fr/mcd_python/

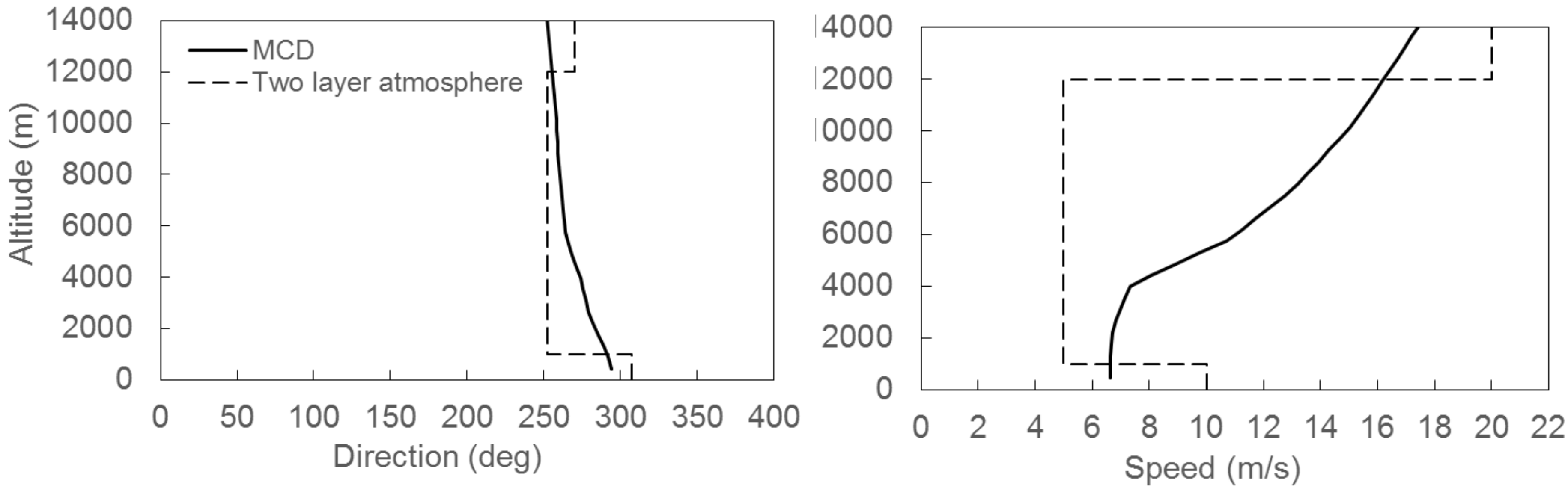
Viking lander 2

Location> 134 E 48 N
Season (Ls)> 121°
Time of landing> 0949 LT



Phoenix

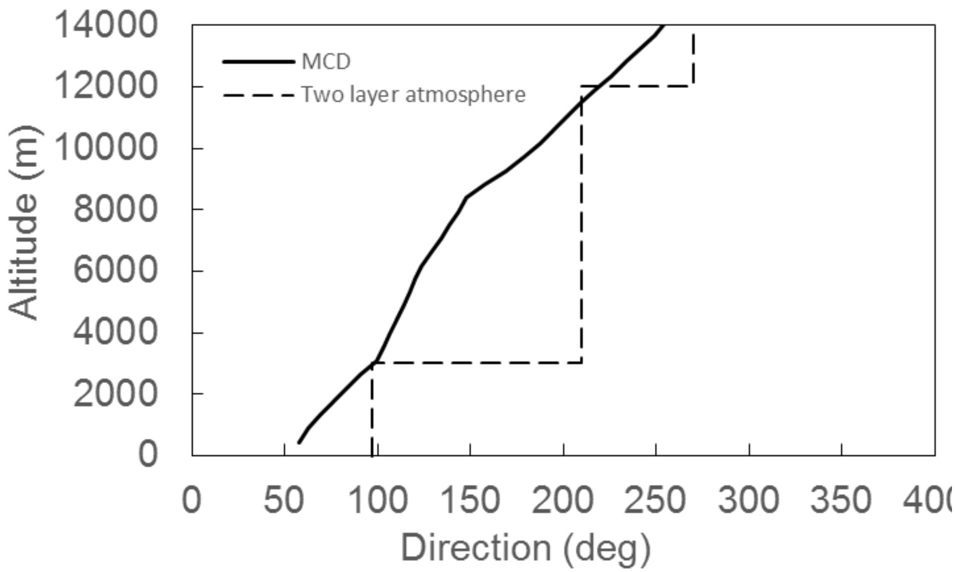
Location> 234 E 62 N
Season (Ls)> 77°
Time of landing> 1600 LT

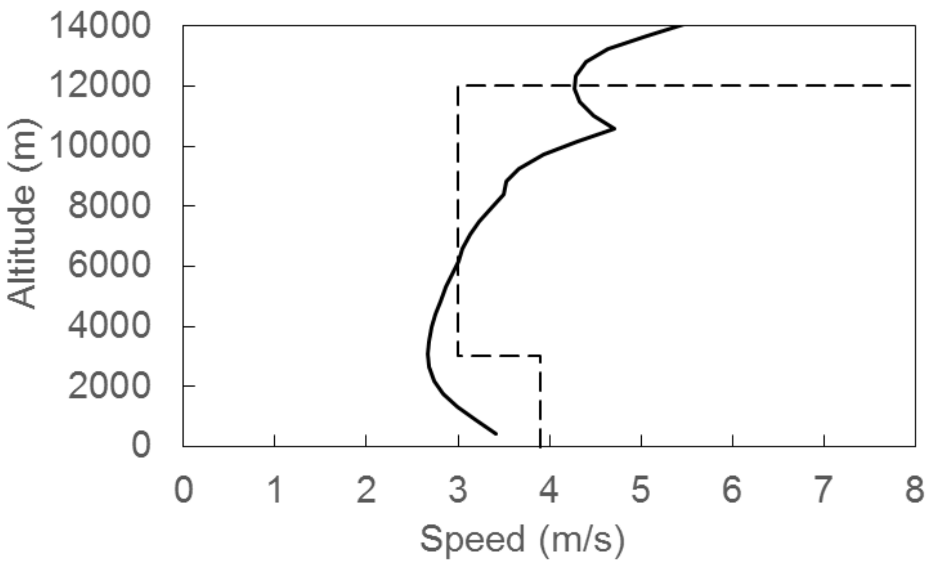


Seem to be consistent with winds aloft properties measured by Moores et al. (2010) for the Phoenix landing site

Curiosity

Location> 137 E -5 N
Season (Ls)> 151°
Time of landing> 1500 LT





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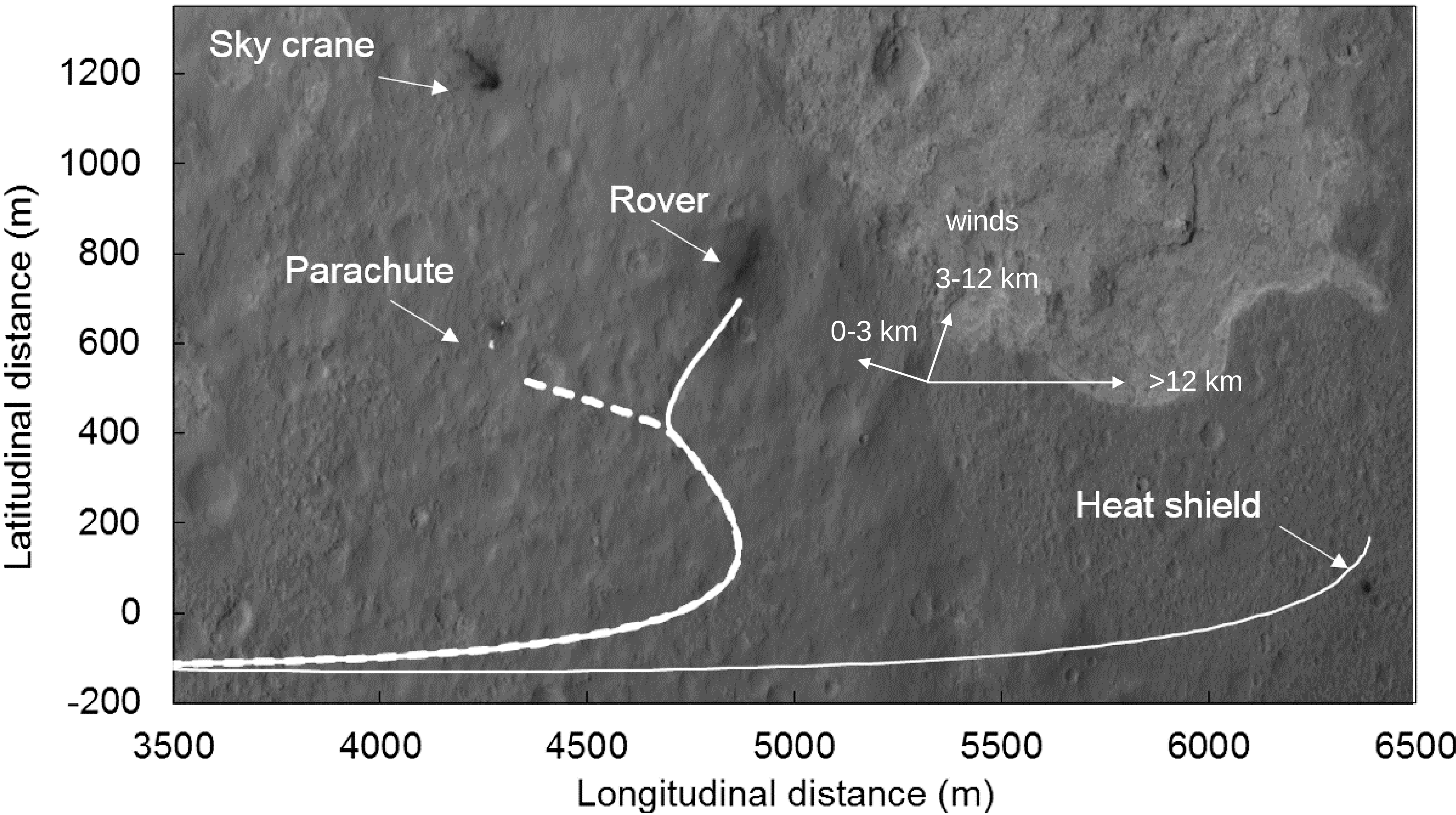
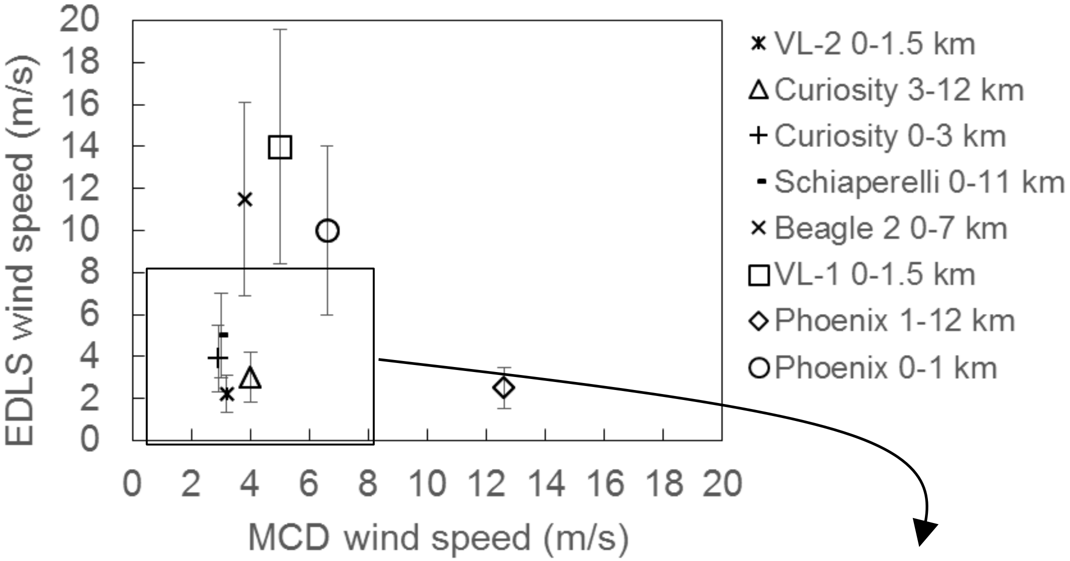
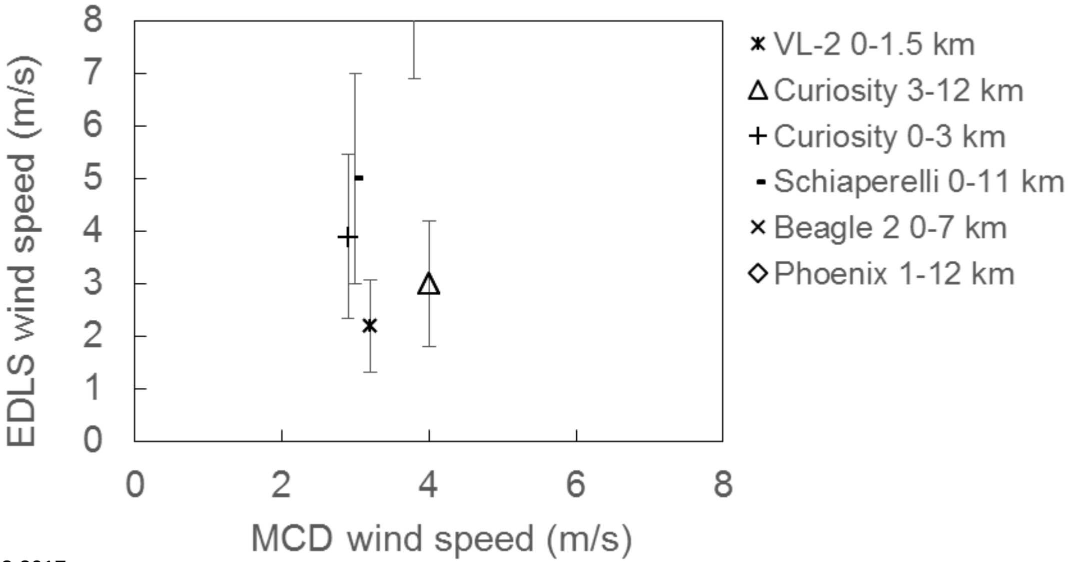
Curiosity ground track



Wind speed



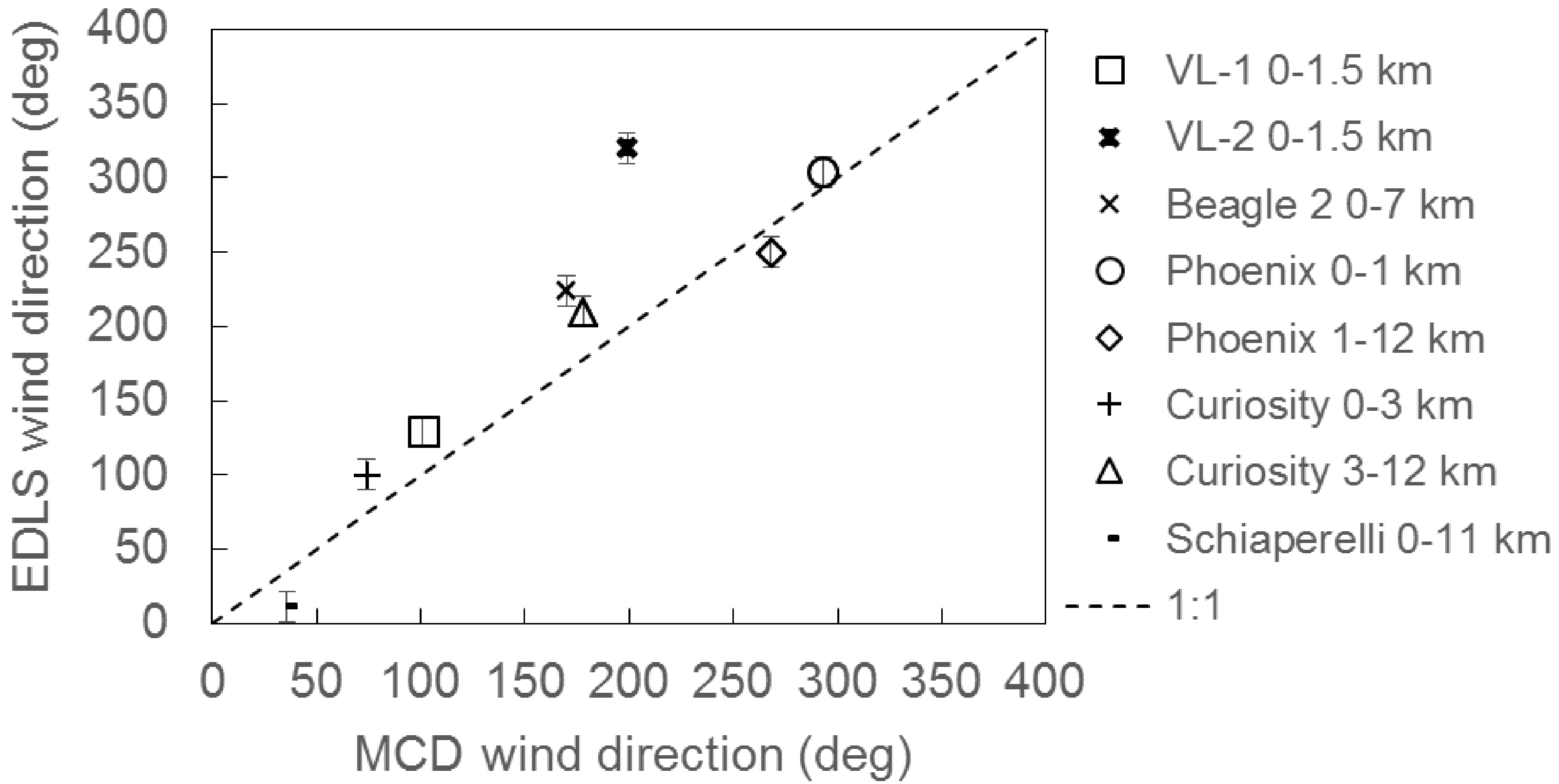
Derived wind speed compared to averaged wind speed from MCD



Large uncertainty on wind speed from the uncertainty on the aerodynamic properties of the EDLS hardware

Wind direction

Derived wind speed compared to averaged wind direction from MCD.



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Summary

- The wind speed does not match the MCD data very well.
- Wind direction matches the MCD reasonably well.
- The Beagle 2 HiRISE image is consistent with a wind speed of 11 m s^{-1} from the south-west. Similar wind speed as predicted in Rafkin et al. (2004) using MRAMS.
- Schiaparelli HiRISE image consistent with a wind of 5 m s^{-1} from north by east.