Modelling the Martian Surface Thermal Environment with ESATAN and ESARAD

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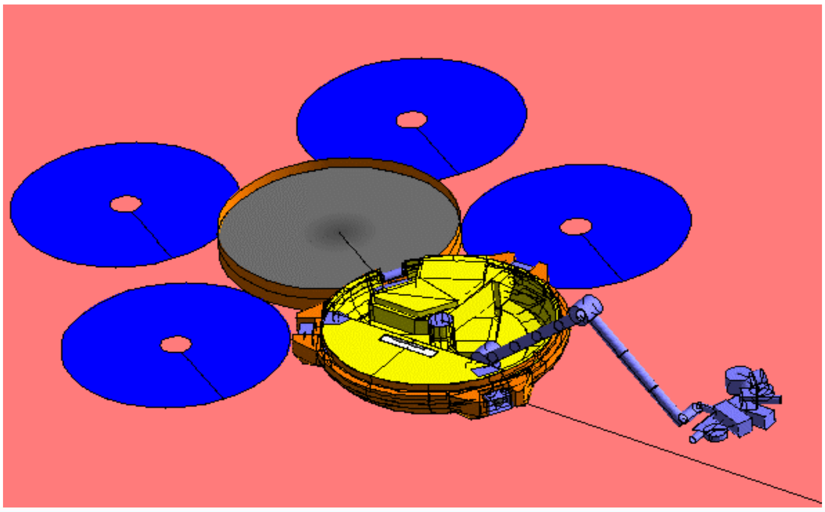
Contents

- Environmental overview.
- Environmental modelling approach.
- Suggested improvements to ESATAN and ESARAD.



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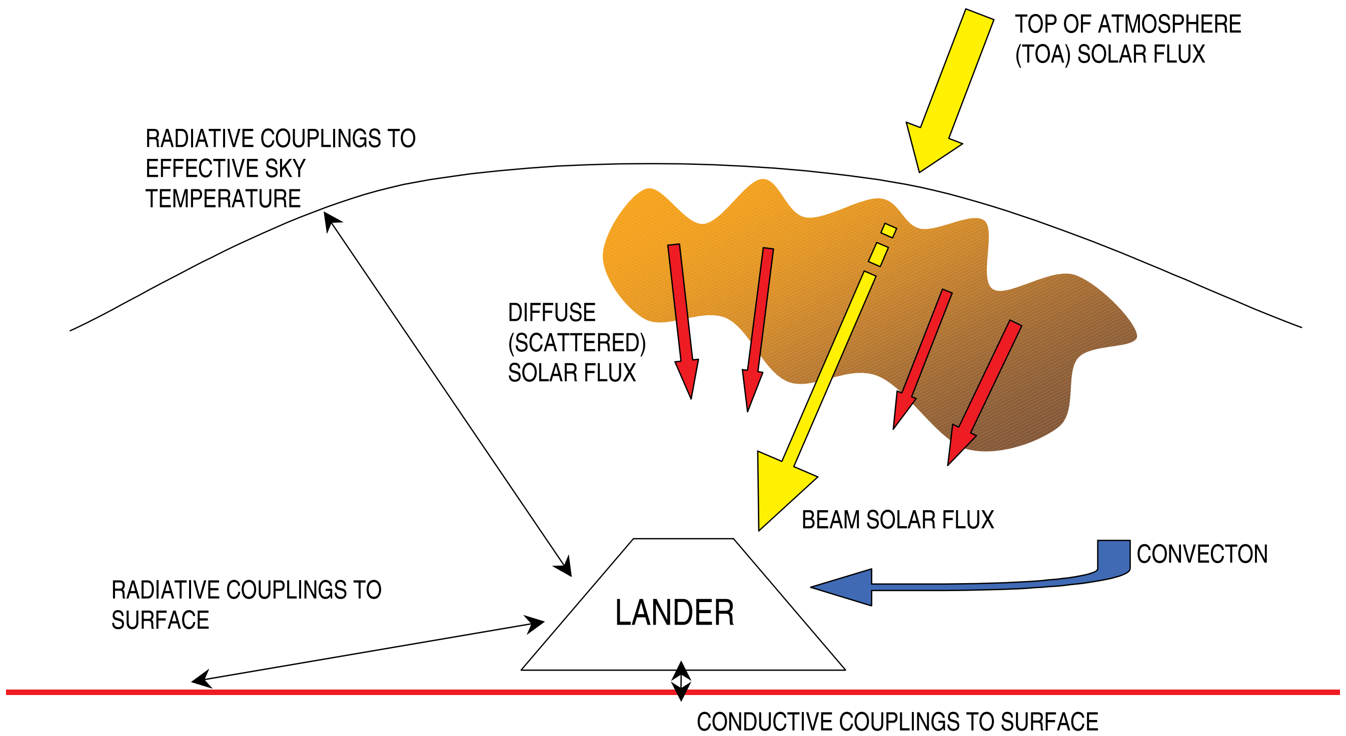
Lander Environmental Boundary Conditions



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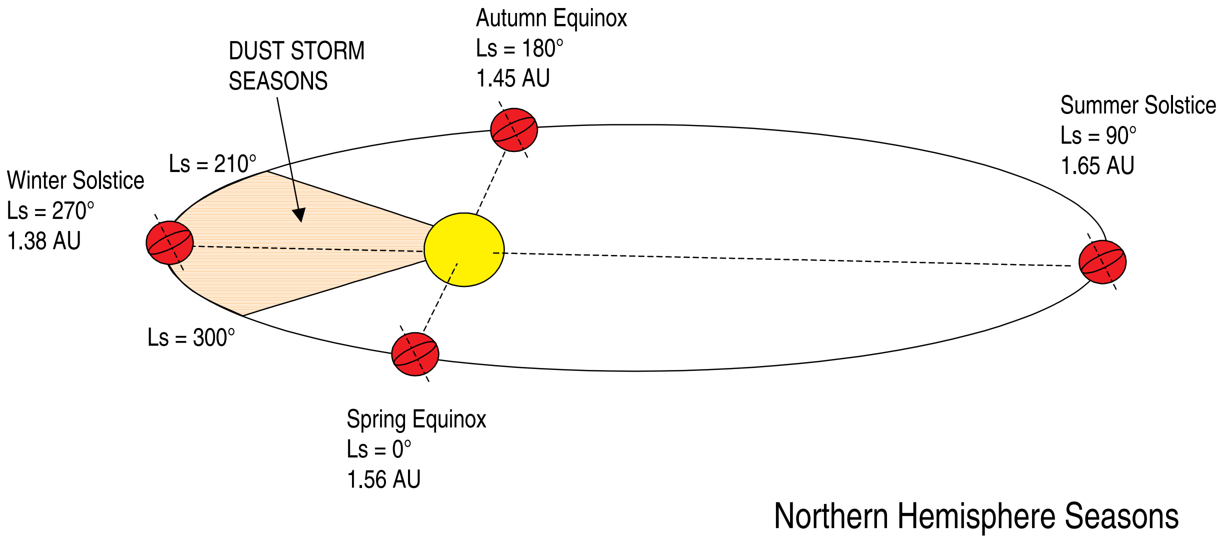
Orbit and Seasons of Mars



Environmental Overview

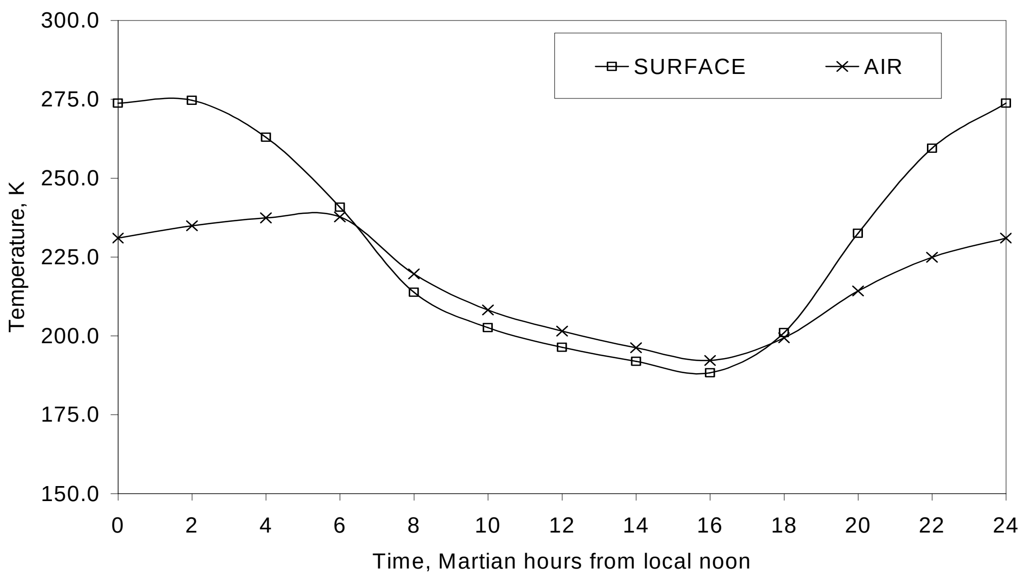
Lander boundary conditions are a strong function of optical depth:

- Attenuation and scattering of TOA flux.
- Effective sky temperature.
- Surface and air temperatures.
- Dust settling / contamination of surface finishes.
  - 0.3% area coverage per Sol recorded by Sojourner MAE experiment.

Optical depth varies with Season:

- Optical depths up to ~ 3.0 recorded by Viking Landers during dust storms.
- Optical depth can exceed 5.0 (the Sun would hardly be visible from the surface).
- Optical depth decreases to < 0.5 outside of dust storm seasons.

Environmental Overview



Typical surface and air temperature profiles

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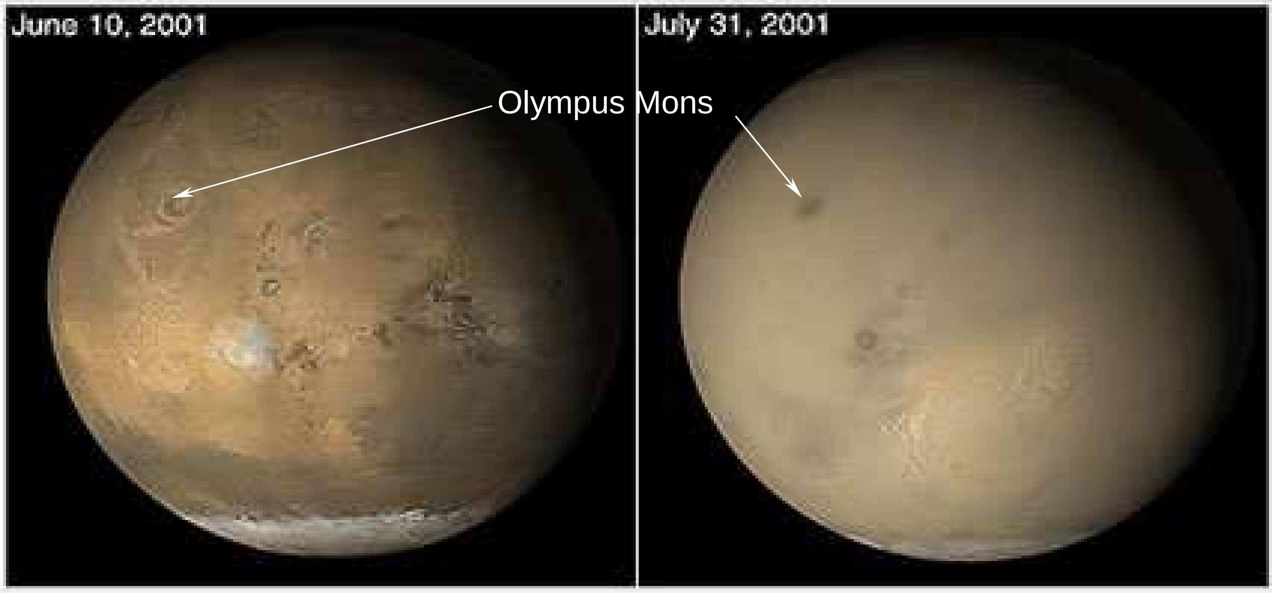
Dust Storms – Mars Global Surveyor Images



NASA/JPL/Malin Space Science Systems

End of Martian winter to early spring

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Modelling Boundary Conditions

TOA Flux: function of Mars orbital parameters.

Beam Flux: function of TOA flux, optical depth, and zenith angle.

$$S_b = S \exp\left(\frac{-\tau}{\cos(\theta_z)}\right)$$

Diffuse Flux: from atmospheric modelling. Array interpolation as function of optical depth and zenith angle.

Surface and air temperatures: from atmospheric modelling (Mars Climate Database). Array interpolation as function of time.

Effective sky temperature: from atmospheric modelling. Array interpolation as function of optical depth and time.

Other Thermal Modelling Considerations

Convection: heat transfer coefficients can be estimated from standard correlations (need to account for gravity and atmospheric density/pressure)

Gas conduction: gas nodes may be required. Shape factors required for gas conduction between surfaces and gas nodes.

Time: conversion between Mars and Earth time systems.

Implementation in ESARAD

Beam solar loads calculated, as a function of time, to nodes for a nominal TOA flux and no attenuation. A kernel has been written to do this as a function of landing site location and orbital characteristics.

Radiative couplings in solar wavelengths from all nodes to the sky (for calculation of diffuse solar loads).

Radiative couplings in thermal infrared wavelengths.

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Implementation in ESATAN

Determines local solar times, zenith angles, and sunset/sunrise events as function of landing site location and Ls.

Calculates the actual beam solar loads by scaling ESARAD calculated loads (as function of TOA flux, zenith angle, and optical depth).

Calculates the actual diffuse solar loads by scaling the TOA flux with the nominal diffuse flux datasets and the ESARAD calculated solar wavelength radiative couplings.

Interpolates surface, air, and sky temperatures datasets.

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Suggested Improvements

ESARAD:

- Include radiative/analysis case for planet surface calculations.
- Allow solar-wavelength radiative couplings to be readily exported (at present having to use ‘report’ and manually edit file).
- Generation of surface to surface shape factors for gas conduction links.
- Management of surface properties for various cases (e.g., BOL, EOL). Prefer not to have separate geometry files for each case.
- Allow output file of ALP (and other) parameters and values (to be used as input files for solar load calculations).

Suggested Improvements

ESATAN:

- Include routines to convert between Universal Coordinated Time (UTC) and Mars Local True Solar Time (mission planning, correlation with on-surface measurements)