MLSM

Mars Lidar Simulation Model

Simpson Weather Associates, Inc.
Date/Time

- LS: 0 deg · Spring
- LS: 90 deg · Summer
- LS: 180 deg · Fall
- LS: 270 deg · Winter

Start Hour: 00
Simulation Time: 01 hours

Buttons: OK, Cancel, Help
The Shot Coverage Model is running.

MLSM version 1.0
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The Lidar Simulation Model is running.
MLSM

Mars DWL Simulation

Simpson Weather Associates, Inc.
DWL Single Profile Bracketing Performances

Background Dust
- Extreme Dust

PLATFORM INPUTS
- Starting altitude of the satellite (km): 400.00
- Starting orbit inclination angle (deg): 98.00

LASER SYSTEM INPUTS
- Energy per pulse (joules) for DWL lidar: 0.25
- Laser wavelength (µm) for DWL lidar: 2.053472
- Pulse duration (µsec): 2.00
- Prf of the scanner (Hz): 10.00

TELESCOPE/SCANNER INPUTS
- Scanner shot manager type: step-stare
- Diameter of the primary telescope mirror (m): 0.50
- Number of discrete azimuths: 4
- Nadir scan angle for each azimuth (deg): 45.00
- Time for a fixed beam to fire shots (s): 25.00
- Fixed/step-stare discrete azimuth (deg): 45.00
- Fixed/step-stare discrete azimuth (deg): 135.00
- Fixed/step-stare discrete azimuth (deg): 225.00
- Fixed/step-stare discrete azimuth (deg): 315.00
- Duty cycle of the scan pattern (%): 100.00

LIDAR SIGNAL PROCESSING INPUTS
- Signal processing bandwidth (m/s): 15.00
- Gross error probability threshold: 0.50
- DWL shot processing: accumulation shot processing
- Altitude Boundary Level for DWL (km): 3.00
  - vertical bin > ABL to accumulate over (km): 1.00
  - vertical bin <= ABL to accumulate over (km): 1.00

ATMOSPHERIC INPUTS
- Atm. Library: MCD Mars Global Surveyor
- Subgrid Scale Variance Option: 3 point
- Aerosol Backscatter Option: median
- Backscatter Mixing Ratio Option: Constant
- Aerosol Concentration: 0.5E+07
- Mode Radius (µm) Background: 0.30
- Elevated Backscatter Mode: user defined
- Mode Radius (µm) Elevated: 0.00
- Elevated Backscatter Mode: Extreme Dust Storm
MLSM

Mars DIAL Simulation

Simpson Weather Associates, Inc.
\[
\frac{\rho_{\text{CO}_m}^2}{\rho_{\text{CO}_S}^2} = \ln \left[ \frac{\bar{P}_{\text{on}_m} \times \bar{P}_{\text{off}_m}}{\bar{P}_{\text{on}_B} \times \bar{P}_{\text{off}_B}} \right]_m \quad \ln \left[ \frac{\bar{P}_{\text{on}_s} \times \bar{P}_{\text{off}_s}}{\bar{P}_{\text{on}_T} \times \bar{P}_{\text{off}_T}} \right]_S
\]

Accumulated DIAL Products

\[
\bar{P}_{\text{on}_m} = \frac{\sum_t P_{\text{on}_m}}{N} \quad \bar{P}_{\text{on}_s} = \frac{\sum_t P_{\text{on}_s}}{N}
\]

\[
\bar{P}_{\text{off}_m} = \frac{\sum_t P_{\text{off}_m}}{N} \quad \bar{P}_{\text{off}_s} = \frac{\sum_t P_{\text{off}_s}}{N}
\]

where

- \(\bar{P}_{\text{on}_m}\): accumulated measured signal product for the on channel
- \(\bar{P}_{\text{on}_s}\): accumulated signal product for the on channel
- \(\bar{P}_{\text{off}_m}\): accumulated standard atm. signal product for the on channel
- \(\bar{P}_{\text{off}_s}\): accumulated standard atm. signal product for the off channel
- \(N\): number of samples in the grid volume
- \(T\) and \(B\): top and bottom of the accumulation layer, respectively
- \(\rho_{\text{CO}_m}\): density measurement product of CO2
- \(\rho_{\text{CO}_S}\): density standard atm. product of CO2
Differential Absorption Lidar
Concentration Percent Error

RUN: MCD Ls=0 deg 2001Z (2 hr sim.) Global
ALTITUDE: 400 Km ORBIT INC: 98 deg
TARGET ATM.: median Backscatter, R= 0.30, constant Q
ELEVATED DUST: user defined R = 0.00 um

DETECTION: DIAL SCAN: 1 pt. Step/Stare
WAVELENGTH: ON: 2.0531997 um OFF: 2.053472 um
ENERGY: ON: 0.25 J OFF: 0.25 J APERTURE: 0.5 m
PRF: 10 Hz ACCUM. TIME: 60 s NADIR: .01 deg
\( \phi \) is the average number of coherently detected photoelectrons per estimate (Frehlich)

\( \phi_{\text{thr}} \) is the user input threshold for \( \phi \)

\( N \) is the number of estimates in a grid volume

\( S \) is the average signal in a layer

\( \varepsilon \) is the percent error in calculating CO\(_2\) concentration due to the uncertainty in the absorption line due to temperature, pressure and wavelength uncertainties

For \( \phi_{\text{on}} > 1 \) and \( \phi_{\text{off}} > 1 \)

\[
S_I = \frac{\sum \text{snr}_I}{N_I}
\]

\[
S_{II} = \frac{\sum \text{snr}_{II}}{N_{II}}
\]

if \( \phi_{\text{on}} > \phi_{\text{thr}} \), then \( \omega = 1 \)

if \( 1 < \phi_{\text{on}} < \phi_{\text{thr}} \), then \( \omega = (\phi_{\text{thr}} + 1) - \phi_{\text{on}} \)

\[
\omega \left( \frac{1}{N_{I\text{on}}} + \frac{1}{N_{I\text{off}}} + \frac{1}{N_{II\text{on}}} + \frac{1}{N_{II\text{off}}} \right)^{1/2}
\]

\[
\text{Error} = \varepsilon^2 \cdot \frac{\ln \left( \frac{S_{I\text{on}}}{S_{I\text{off}}} \cdot \frac{S_{II\text{off}}}{S_{II\text{on}}} \right)^2}{\left[ \ln \left( \frac{S_{I\text{on}}}{S_{I\text{off}}} \cdot \frac{S_{II\text{off}}}{S_{II\text{on}}} \right) \right]^2}
\]
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Mars Atmosphere Discussions

Simpson Weather Associates, Inc.
Mars Climate Database - Mean Density (kg/m³) for Ls: 0 deg, 2001

Sigma Level: 65 km
Mars Climate Database - Mean Density (kg/m³) for Ls: 0 deg, 2001
MARS Aerosol Backscatter for Varying Size Distributions

Aerosol Properties
Wavelength: 2.2 um (Bell et al., 1997)
Extinction Efficiency: 3.25 (Bell et al., 1997)
Asymmetry Parameter: 0.63 (Bell et al., 1997)
Haze L - A: 5e6 (Deirmendjian, 1969)
Alpha: 2.0 (Toon et al, 1977)
Gamma: 0.5 (Toon et al, 1977)
Maximum TAU
Year 1 Ls - 2.25 deg
Year 2 Ls - 2.25 deg
Year 1 Ls - 197.5 deg
Year 2 Ls - 197.5 deg

<table>
<thead>
<tr>
<th>$R_{\text{eff}}$</th>
<th>$R_{m}$</th>
<th>Tau (0.6 um)</th>
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</thead>
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<tr>
<td>0.5</td>
<td>0.1</td>
<td>0.00046792</td>
</tr>
<tr>
<td>1</td>
<td>0.2</td>
<td>0.01497296</td>
</tr>
<tr>
<td>1.5</td>
<td>0.3</td>
<td>0.11361707</td>
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<tr>
<td>2.0</td>
<td>0.4</td>
<td>0.476751</td>
</tr>
<tr>
<td>2.5</td>
<td>0.5</td>
<td>1.43834388</td>
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<tr>
<td>3.0</td>
<td>0.6</td>
<td>3.50475407</td>
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<tr>
<td>3.5</td>
<td>0.7</td>
<td>7.34437513</td>
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<tr>
<td>4.0</td>
<td>0.8</td>
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<td>4.5</td>
<td>0.9</td>
<td>23.62610817</td>
</tr>
<tr>
<td>5.0</td>
<td>1.0</td>
<td>37.88884354</td>
</tr>
</tbody>
</table>

Tes Minimum: 0.059
0.1 low dust: 0.1
2.0 moderate: 2.0
5.0 Severe dust: 5.0
Wavelength spread of CO2 Molecular Attenuation Coefficient (km⁻¹) as a function of Altitude

Two Way Nadir attenuation effects on Backscatter

<table>
<thead>
<tr>
<th>Z(km)</th>
<th>αβ (λ₉₈)</th>
<th>αβ (λ₉₇)</th>
<th>β₉₈ (m⁻¹ sr⁻¹)</th>
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<tbody>
<tr>
<td>40.0</td>
<td>7.0020192E⁻³⁰</td>
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<td>50.0</td>
<td>2.2386592E⁻³⁰</td>
<td>1.1591713E⁻⁸</td>
<td>1.1606788E⁻⁸</td>
</tr>
<tr>
<td>60.0</td>
<td>1.3556114E⁻²⁰</td>
<td>3.2198180E⁻⁹</td>
<td>3.2209477E⁻⁹</td>
</tr>
<tr>
<td>70.0</td>
<td>4.9105889E⁻¹²</td>
<td>8.6672497E⁻¹⁰</td>
<td>8.6680274E⁻¹⁰</td>
</tr>
</tbody>
</table>

Absorption line (2.053204 μ)

Absorption line (2.05320 μ)
Mars CO² Attenuation Coefficients per Km

Red - line
Green - left of line
Blue - right on line

EARTH CIRRUS CLOUD ALPHA

2.053204 μ

Solid Line: Based on Maximum T&P
Dashed Line: Based on Minimum T&P

2.053472 μ
Conclusion

• Equation modifications
• Trade Studies
• MLSM wrap-up