The micrometeor flux in the MLT

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Santa Fe, NM June 24-28, 2007

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Meteors and the CEDAR Community
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Several decades of measuring winds by detecting meteor trails
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Kelley, Gardner, Chu, et al.
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2001: Diego Janches got the CEDAR Postdoc award for meteor related research.
Why meteors are important at CEDAR?
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- Meteor Plasma physics
- Space hazard
Atmospheric Chemistry and Dynamics
How much is the total amount of mass coming in?
How much is the total amount of mass coming in?
Where is it coming from and what are its characteristics?
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Where is it coming from and what are its characteristics?
How do we observe it?
Uniform flux no good to explain:
1) Seasonal and global behavior of metal layers. In particularly the seasonal asymmetry of the metals (maximum in late autumn/early winter in the NH)
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2) Lack of Atmospheric Ca and high Ca+/Ca
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1) Seasonal and global behavior of metal layers. In particular, the seasonal asymmetry of the metals (maximum in late autumn/early winter in the NH)

2) Lack of Atmospheric Ca and high Ca+/Ca

Ca depletion by a factor of 120-360 (depending in season)!!
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3) Global distribution of meteoric smoke if it exists; smoke particle size distribution
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2) Lack of Atmospheric Ca and high Ca+/Ca

3) Global distribution of meteoric smoke if it exists; smoke particle size distribution

4) Meteoric smokes may have influenced paleoclimates
Meteor Showers

Sporadic meteors
Day Number
Number of meteor per hour
Janches et al., GRL, 2004
Lau et al, JGR, 2006

Janches et al., GRL, 2004
Lau et al, JGR, 2006
Sources of radar signal scattering from a meteor event

Direction of motion

Meteoroid
$R \sim \text{microns to mm}$
$V \sim 10 \text{ to } 70 \text{ km/sec}$
Sources of radar signal scattering from a meteor event

Direction of motion

Meteoroid
R ~ microns to mm
V ~ 10 to 70 km/sec

Air Molecules
Sources of radar signal scattering from a meteor event

Direction of motion

Meteoroid
$R \sim$ microns to mm
$V \sim$ 10 to 70 km/sec

Air Molecules

Meteor Head echo
Cloud of electron traveling at the speed of the meteoroid
$R \sim$ cm to m
Sources of radar signal scattering from a meteor event

- Trail of ions left behind the meteoroid path
- Sources of radar signal scattering from a meteor event
- Direction of motion
- Meteoroid $R \sim$ microns to mm, $V \sim$ 10 to 70 km/sec
- Air Molecules
- Meteor Head echo
- Cloud of electron traveling at the speed of the meteoroid $R \sim$ cm to m

Trail of ions left behind the meteoroid path
Specular Meteor Radar Observing Geometry

Meteor Trail (perpendicular to the radar beam)

Radar Beam

Meteor Radar
Specular Meteor Radar Observing Geometry
HPLA Radar Meteor Observing Geometry

- Radar Beam
- Meteor Head Echo
- Direction of Motion
- Meteor Radar
HPLA Radar Meteor Observing Geometry

Close, Dyrud, Oppenheim, et al.

Non-specular trail

Head Echo

Altitude (km)

Power (dB)

Time (sec)
Meteor Detection at Arecibo

AO 430 MHz Meteor Experiment

Meteor Detection Example

Signal received from a moving target (or meteor head echo)

Real component meteor signal returned

Imaginary component meteor signal returned

SNR

Acceleration = \(-10.6 \text{ km/sec}^2\)

Janches et al., JGR, 2003
**Meteor Motion/State Equations**

**Deceleration**

\[ M \frac{dV}{dt} = -\Gamma S \rho_{air} V^2 + g M \left( \frac{R_{Earth}}{R_{Earth} + z} \right)^2 \cos(\theta) \]

**Energy Transfer**

\[ \frac{1}{2} C_h \rho_{air} V^3 = \sigma_{sb} R E \left( T_{Melt}^4 - T_{Air}^4 \right) + \frac{4}{3} R_{Met} \rho_{Met} C_{sh} \frac{dT_{Met}}{dt} \]

**Vertical Velocity**

\[ \frac{dz}{dt} = -V \cos(\theta) \]

**Electron line Density**

\[ q_{line}(z) = \frac{\tau_{ion} \rho_{Air}(z) A \sigma(z) \Gamma}{2\eta} \left( \frac{M(z)}{\rho_{Met}} \right)^{2/3} V^4(z) \]

**Mass Loss**

\[ \frac{dM}{dt} = -C_h S \rho_{air} V^3 \]

**Electron Volume Density**

\[ q_{vol}(z) = \frac{q_{line}(z)}{\pi r_{mfp}^2} \]

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MIF Modeling Equation Integration

Initial Conditions

1 Microgram
20 km/sec
0 Entry Angle
$T_{int} = 300$ K
$Alt_{int} = 200$ km

Fentzke and Janches, JGR, Submitted 2007
Electron Density (el/m³)

Electron Threshold: $1 \times 10^8$
Electron Threshold: $5 \times 10^8$

Electron Threshold: $1 \times 10^9$
Electron Threshold: $5 \times 10^9$

Electron Threshold: $1 \times 10^{10}$
Electron Threshold: $5 \times 10^{10}$

Electron Threshold: $1 \times 10^{11}$
Electron Threshold: $5 \times 10^{11}$

Fentzke and Janches, JGR, Submitted 2007
Altitude distributions

![Graph showing altitude distributions with data points for Arecibo, Jicamarca, Sondrestrom, and ALTAIR-VHF.](image-url)
Differential Ablation of Meteoroids

5 μg 20 km s⁻¹

<table>
<thead>
<tr>
<th>Ablated At %</th>
<th>Centroid km</th>
<th>FWHM km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>100</td>
<td>84.7</td>
</tr>
<tr>
<td>Mg</td>
<td>100</td>
<td>84.0</td>
</tr>
<tr>
<td>Fe</td>
<td>100</td>
<td>84.5</td>
</tr>
<tr>
<td>Ca</td>
<td>61</td>
<td>(83.2)</td>
</tr>
<tr>
<td>Na</td>
<td>100</td>
<td>100.5</td>
</tr>
<tr>
<td>K</td>
<td>100</td>
<td>96.5</td>
</tr>
<tr>
<td>O</td>
<td>96</td>
<td>84.2</td>
</tr>
</tbody>
</table>

Ca/Na = .62
Model of the meteor head-echo

Courtesy of Lars Dyrud
Simulation of head-echo RCS

Radar Cross Section (dB)

Radar Frequency (MHz)

θ = 0 degree
θ = 30 degree
θ = 60 degree
θ = 90 degree

Courtesy of Lars Dyrud
Global Mass Input-Ceplecha

6 Rad. Sources and Velocity Dist.

Minimum Electron Threshold
Some promising results

Fentzke and Janches, JGR, Submitted 2007
More promising results

Fentzke and Janches, JGR, Submitted 2007

April 17, 2002
May 16, 2002
June 25, 2002
January 21, 2002
February 14, 2002
March 25, 2002
Total and Local Modeled Mass Input

Log[Dm/(kg/ΔT/d(LogM)/Area)] vs Log[M (micrograms)]

- Love and Brownlee (1993)
- L&B modified with AO velocities
- January 2002 AO Observations
- June 2002 AO Observations
- Our Model
- Mathews et al. (2001)
  1997 AO Observations
- ~1 μm
- ~200 μm
Total and Local Modeled Mass Input

Adopted global flux as input to the model

Love and Brownlee (1993)

L&B modified with AO velocities

January 2002 AO Observations

June 2002 AO Observations

Coplecha et al. (1998)

Modeled local flux over Arecibo

~1 μm

~200 μm
Seasonal Variability of MIF over Arecibo

Relative number of meteors

Arecibo Puerto Rico
Latitude ~ 18 N
Longitude ~ 66 W

Janches et al., JGR, 2006
Diurnal Variability of MIF over Jicamarca

Number of Meteor per Minute

Janches et al., JGR, 2006
Seasonal Variability of MIF over Jicamarca

Jicamarca, Peru
Latitude ~ 12 S
Longitude ~ 77 W

Janches et al., JGR, 2006
Dirunal Variability of MIF over Sondrestrom

Janches et al., JGR, 2006
Seasonal Variability of MIF over Sondr

Relative number of meteors

Sondrestrom, Greenland
Latitude ~ 67 N
Longitude ~ 51 W

Janches et al., JGR, 2006
Global, Seasonal and Diurnal Variability

Janches et al., JGR, 2006
Conclusions and Final Remarks
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In the last decade we have made crucial progress towards the understanding of the meteoric mass flux in the upper atmosphere.
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We are very close to accurately understand how much, when and where meteoric mass is deposited in the MLT.