Upper-tropospheric clouds and pollution over Asia: New insights from MLS on Aura

D. L. Wu\(^1\), J. H. Jiang\(^1\), M. J. Filipiak\(^2\), W. G. Read\(^1\), Q. B. Li\(^1\), N. J. Livesey\(^1\), J. W. Waters\(^1\), Y. Zhang\(^3\), and B. Wang\(^3\)

\(^1\) Jet Propulsion Laboratory, California Institute of Technology
Pasadena, California, USA
\(^2\) Institute of Atmospheric and Environmental Science, School of GeoSciences
University of Edinburgh, Edinburgh EH9 3JZ, Scotland, UK
\(^3\) International Pacific Research Center, University of Hawaii at Manoa
Honolulu, Hawaii, USA

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Outline:

1. Pollution problems over Asia
2. Observations from Microwave Limb Sounder (MLS) on Aura
3. Enhancements during Asian summer monsoon
4. Implications to climate change
Clouds over India on 2004.12.17

China Haze on 2 Jan. 2002 (credit: NASA SeaWiFS)

China CO Emission 1-20 Jan. 2003 (credit: NCAR MOPITT)

Aerosol optical depth over Bihar, India

Photo credit: NASA MODIS team

Image credit: NASA MODIS team
Global CH₄ Distribution from SCIAMACHY
(August-November 2003)

Credits: University of Heidelberg/KNMI

Global Aerosol Optical Depth from MISR

Credits: NASA MISR team
- Are these changes due to anthropogenic aerosol emissions?
- Does climate respond linearly to the forcing?
- Where will these trends lead us to?

China Precipitation Trend (1961-2000)

China Dustfall Trend (1960-2000)

China Aerosol OD (Luo et al. 2001)
The EOS MLS on NASA Aura satellite

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Pol</th>
<th>Vertical (km)</th>
<th>Horizontal (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1A (115-122)</td>
<td>V</td>
<td>6.5</td>
<td>13</td>
</tr>
<tr>
<td>R1B (115-122)</td>
<td>H</td>
<td>6.5</td>
<td>13</td>
</tr>
<tr>
<td>R2 (178-184, 200-207)</td>
<td>V</td>
<td>4.5</td>
<td>9</td>
</tr>
<tr>
<td>R3 (230-237, 243-250)</td>
<td>H</td>
<td>3.5</td>
<td>7</td>
</tr>
<tr>
<td>R4 (625-637, 649-661)</td>
<td>H</td>
<td>1.5</td>
<td>3</td>
</tr>
<tr>
<td>R5H (2501-2515, 2531-2544)</td>
<td>~H</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>R5V (2501-2515, 2531-2544)</td>
<td>~V</td>
<td>2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Advantages with MLS:
- Better vertical resolution
- Less contamination from surface and low clouds
- Better sensitivity to low density clouds
- Simultaneous measurements of CO, H$_2$O, O$_3$, and T.

Trade-offs:
Poor horizontal resolution

(launched in July 2004)
MLS Limb Radiance Spectra

R1
$f_{LO} = 126.8 \text{ GHz}$

R2
$f_{LO} = 191.9 \text{ GHz}$

R3
$f_{LO} = 239.7 \text{ GHz}$

R4
$f_{LO} = 642.9 \text{ GHz}$

R5V and R5H
$f_{LO} = 2522.8 \text{ GHz}$

2005d003
Clear (Blue)
Cloudy (Red)

Cloudy Clear
MAFs: 373, 370.
Lats: -5.9, -10.3.
MLS Cloud-Induced Radiance (Tcir) Measurements

- Tcir is the excessive radiance beyond clear-sky variability
- Tcir is proportional to cloud ice mass (e.g., IWC, IWP)
- The ratio of Tcir at 240 and 640 GHz provides particle size information.

30 August 2004; Ht =~15 km
Clouds and pollution over India and southern China (15 Aug - 14 Sep 2004)

- Collocated cloud and CO enhancements
- Strong Influences by monsoon and typhoon dynamics
- Aerosol and high cloud interactions?

GEOS-CHEM: Aerosol and CO both enhanced and trapped in the region

(Li et al., 2005)
MLS Obs on 29 Aug – 3 Sep 2004

**CO**
Large enhancements at 147 and 100 hPa over India and southern China

**Temperature**
Cold regions at 100 hPa over South Asia and Indonesia

**H₂O**
Enhancements at 147 hPa in the regions similar to CO but not at 100 hPa

**O₃**
Low values at 100 hPa in the regions similar to Temperature
• Slow buildup but sharp dropoff in clouds
• CO and O3 anti-correlation at 100mb
• CO lag H2O/Cloud peaks
• Rainfall/Low cloud lag high cloud peaks

• Same rates in cloud buildup and dropoff
• CO and O3 anti-correlation at 100mb
• Weak CO and H2O/Cloud correlation
• Rainfall/Low cloud correlated with high clouds
Cloud variations over Asia (18 Aug-18 Sep 2004)

Accumulating dense cirrus

Rainout & Fall

15 km, 2004d231–234

15 km, 2004d235–238

15 km, 2004d239–242

15 km, 2004d243–246

15 km, 2004d247–250

15 km, 2004d251–254

15 km, 2004d255–258

15 km, 2004d259–262

15 km

T_{cir} (K)

640 GHz

0.0 1.4 2.7 4.1 5.5 6.8 8.2 9.5 10.9

4 km

T_{cir} (K)

240 GHz

0.0 3.6 7.3 10.9 14.5 18.2 21.8 25.5 29.1
Aerosol-Cloud Interactions: Chemistry and Dynamics

H$_2$O

strong solar radiation

SUMMER

Low pressure

Hot land surface

Elevation (m)

[Diagram showing aerosol-cloud interactions and processes such as cloud processing, aerosol-cloud interactions, and elevation changes.]
- Aerosol-cloud interactions? sources, sinks, transport, properties
- Radiative effects? heating vs. cooling
- Hydrological effect? drought vs. flooding
- Regional climate change? health, warming

Credit: NASA Earth Observatory
Summary

- MLS on Aura provides detailed observations on interactions between high clouds and pollution over Asia.

- Polluted air is likely to hold more water and delay rainfall over southern China by modifying cloud properties in both the lower and upper troposphere.

- Aerosol-cloud interactions are complex and influenced strongly by monsoon and typhoon dynamics.

- Interplays among aerosols, clouds and rainfalls are key elements to the regional climate, but remain unclear at present.