Following Intense Forest Fire Activity.

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Abstract

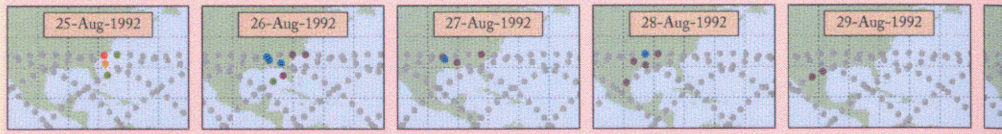
On 24 August 1992, the Microwave Limb Sounder (MLS) on the Upper Atmosphere Research Satellite observed a significant enhancement in the abundance of lower stratospheric methyl cyanide (CH_3CN) at ~100–68 hPa (16–19 km altitude) in a small region off the coast of Florida. Concentrations of order 1400 parts per trillion by volume (pptv) were observed, compared to a typical stratospheric background level of 30 pptv. Observations of additional atmospheric constituents, together with trajectory calculations, provide strong evidence that this enhancement arose from the stratospheric injection, by severe thunderstorms, of air with high CH_3CN concentrations originating in regions of extensive forest fire activity in Idaho (not observed by MLS in this period because of orbital geometry). After being lofted into the lower stratosphere, this air was advected towards the regions observed by MLS, and subsequently dispersed over ~5 days. No other events of comparable magnitude have been seen in the ~8 year MLS dataset.

Introduction: Methyl cyanide and MLS.

- Methyl Cyanide (CH_3CN, also known as Acetonitrile) is a product of Biomass burning [Arijs and Brasseur, 1986; Hamm and Warneck, 1990].
  - Estimated production is 0.8 Tg/year.
  - For comparison: 1990 CFC-12 emissions were estimated at ~400 Tg/y
- The Microwave Limb Sounder (MLS) [Waters et al., 1999] on the Upper Atmosphere Research Satellite (UARS) has provided the first global CH_3CN dataset [Livesey et al., 2000].

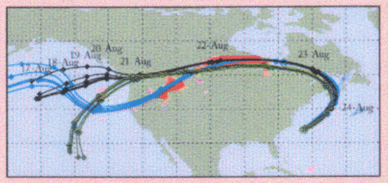
  - UARS was launched in September 1991 on shuttle *Discovery*.
  - UARS/MLS observes from 34° in one hemisphere to 80° in the other, alternating 'majority viewing' hemisphere every ~36 days.
  - In normal atmospheric conditions, MLS CH_3CN data is scientifically useful from 68 to 1 hPa (20–50 km.)
- Stratospheric CH_3CN concentrations are typically ~10–40 pptv.
- MLS data show a persistent stratospheric 'peak' in CH_3CN concentration around 22 hPa in tropics.
  - This is evidence for a previously unknown tropical stratospheric CH_3CN source.
  - However there have been no *in-situ* tropical observations to corroborate this finding as yet.

A dramatic enhancement in observed CH_3CN



- MLS Observes significant enhancement in 100 and 68 hPa CH_3CN on 25 Aug. 1992.
  - Note that while the 100 hPa data is unreliable under normal stratospheric loading, enhancements of this magnitude can be easily seen.
  - The resolution and response of the instrument at these levels make it hard to asses the true height of the enhancement, it could be as low as 150 hPa.
- Nothing is seen earlier, or above these altitudes.
- The motion of the enhancement is consistent with trajectory calculations.
- While some (~3) similar events are seen in the ~9 year dataset, none are of this horizontal extent or duration.

Back trajectory calculations



This figure shows trajectories launched from one enhanced MLS CH_3CN profile (#425) on 25 August 1992. Cyan: 379 K (potential temperature), black: 399 K (~100 hPa), green: 419 K. The filled contours show TOMS Aerosol Index [Krotov et al., 1997; Torres et al., 1998]. Magenta, red, blue shadings correspond to 21, 22, 23 August 1992 respectively.

- Back trajectories have been c… hanced profiles.
  - The calculations are as de… [1994].
  - Code uses UKMO horizo… temperatures, with a radia… abatic descent rates
- Trajectories launched from … show similar patterns.
- All the trajectories cross or … hanced aerosol as seen by TO… denly on 22nd August.

Early hypotheses for the origin of the enhancement

Atlas I rocket launch and destruction

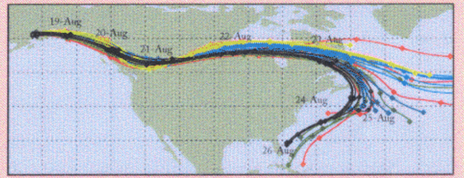
- An Atlas I rocket carrying a communications satellite was launched from Cape Kennedy on August 22.
- The payload included an Apogee 'kick' motor.
- A self destruct command was sent when the rocket was at 160 km altitude, as one of the two engines in the upper stage failed to ignite.
- It is likely that the payload itself remained intact during the fall until ~20 km [S. Kent, A. McRonald, personal communications 2000].
- Back trajectories are inconsistent with this hypothesis.
- Also, the CH_3CN mass loading (>~2000 kg) make this hypothesis unlikely.

The eruption of Mt. Spurr in Alaska

- The 18 August eruption of Mt. Spurr in Alaska was also considered.
- Some back trajectories fall close to its location.
- CH_3CN is not a known direct product of eruptions.
  - Indirect mechanisms such as increased biomass burning are possible, however.

- Although SO_2 (usually produced by volcanos) and CH_3CN are spectrally correlated, the enhancement is clearly CH_3CN.

Trajectory studies rule out Mt. Spurr hypothesis



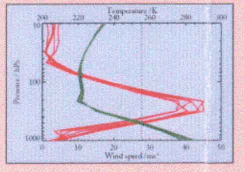
Trajectories launched from the location of Mt. Spurr at the time of eruption (August 18, 16:41 ADT, 22:41 UT). Trajectories are launched at 390 K (red), 400 K (green), 410 K (black) 420 K (blue) 430 K (cyan) and 440 K (yellow)

- The forward trajectory calculations from Mt. Spurr indicate.
  - Some of the trajectories end in the enhanced region.
  - However, not in time for the first observations of enhanced CH_3CN.
  - The majority of the trajectories end up much further East.
  - No enhanced CH_3CN is observed in this more Easterly region.

Strongest hypothesis for origin of enhanced CH_3CN

- From 19th August to 4th September 1992 a major wildfire raged near Boise, Idaho.
  - "… largest fire since 1910." *(Idaho Sentinel.)*
- Fire burned 226,040 acres.
  - For comparison the largest 1998 fire burned 111,130 acres.
  - 1988 fire in Yellowstone – 1,585,000 acres.
- This would have led to significant tropospheric CH_3CN enhancement.
  - Concentrations as high as ~1 ppmv have been seen in wildfires.
- Also, a series of major thunder storms occurred near the fires on ~22nd August.
- We suggest:
  1. One or more of these storms lofted CH_3CN enriched air into the lower stratosphere.
  2. The observed aerosol is a result of the fire and was present in the lower stratosphere.
  3. The CH_3CN enriched stratospheric air was advected into the region observed by MLS.
- Fromm et al. [2000] show evidence for similar events as seen by POAM II and SAGE II.

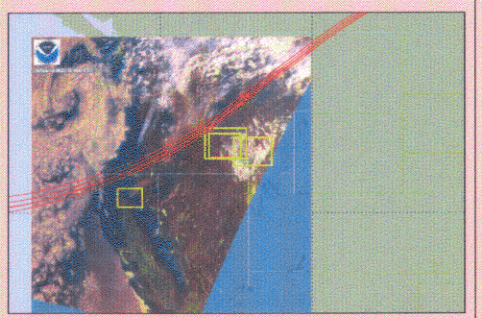
Spread of the TOMS aerosol enhancement



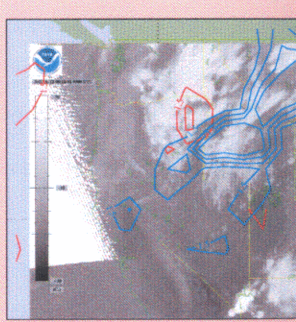
Selected profiles of UKMO wind speed (red, bottom axis) and temperature (green, top axis) within the region of TOMS Aerosol Index enhancement. The dotted line shows the approximate speed that would be required to account for the spread of the enhancement region over 24 hours.

- Given the sudden appearance of the TOMS aerosol enhancement, we can estimate its height by considering the speed of its spread.
- The figure above indicates that the enhancement spread is consistant with wind speeds either around 500 hPa or 150 hPa.
- The AVHRR data (below) show thick cloud in the upper troposphere in this region.
- TOMS would not be able to see aerosol at 500 hPa through such cloud.
- Therefore it is more likely that the observed aerosol is at 150 hPa.

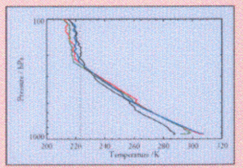
AVHRR images of smoke and cloud



AVHRR visible image taken at 16:30 UT on 21 August 1992. Smoke is seen over Northern California, Eastern Oregon and Idaho. The red lines indicate the trajectories at 379 K shown before. Yellow boxes indicate locations of significant fires in August (>20,000 acres) The area of the box shown is 100× area of fire.



AVHRR infrared image, taken at 03:00 UT on 22 A… seen over NE Oregon, SE Washington and Idaho. … index, as shown before. Red contours are for 21 Au… gust 1992.



Radioso… times fr… gust 199… August … midnigh… (black). … −50°C … AVHRR…

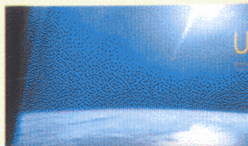
- The coldest region of the infrared image w… enhancement is around −50°C (223 K).
- Radiosonde profiles from Boise Idaho in… around 220 hPa, close to the tropopause.
- Such a strong storm could lead to tropop…
- These would transport CH_3CN enriched … stratosphere.

Conclusions and further work

- MLS has provided the first global dataset of stratospheric CH_3CN.
- A dramatic enhancement in lower stratospheric CH_3CN is seen off the Florida coast in August 1992.

… the local tropospheric air.

- A series of thunderstorms lofted this air into the stratosphere.
- The CH_3CN enriched air was advected over the next few days into the regions observed by MLS.



References

E. Arijs and G. Brasseur. Acetonitrile in the stratosphere and implications for positive ion composition. *Journal of Geophysical Research*, 91(D3):4,003–4,016, 1986.

M. Fromm, J. Alfred, J. Hoppel, J. Hornstein, R. Bevilacqua, E. Shettle, R. Servranckx, Z. Li, and B. Stocks. Observations of boreal forest fire smoke in the stratosphere by POAM II, SAGE II, and lidar in 1998. *Geophysical Research Letters*, 27(9):1,407–1,410, 2000.

S. Hamm and P. Warneck. The interhemispheric distribution and the budget of acetonitrile in the troposphere. *Journal of Geophysical Research*, 95(D12):20,593–20,606, 1990.

N.A. Krotov, A.J. Krueger, and P.K. Bhartia. Ultraviolet optical model of volcanic clouds for remote sensing of ash and sul-

UARS Microwave Limb Sounder. *Geophysical Research Letters*, 2000. Accepted, available on the MLS web site `http://mls.jpl.nasa.gov`.

G.L. Manney, R.W. Zurek, A. O'Neill, and R. Swinbank. On the motion of air through the stratospheric polar vortex. *Journal of Atmospheric Science*, 51,2:973–2,994, 1994.

O. Torres, P.K. Bhartia, J.R. Herman, Z. Ahmad, and J. Gleason. Derivation of aerosol properties from satellite measurements of backscattered ultraviolet radiation: Theoretical basis. *Journal of Geophysical Research*, 103:17,099–17,110, 1998.

J.W. Waters, W.G. Read, L. Froidevaux, R.F. Jarnot, R.E. Cofield, D.A. Flower, G.K. Lau, H.M. Pickett, M.L. Santee, D.L. Wu, M.A. Boyles, J.R. Burke, R.R. Lay, M.S. Loo, N.J. Livesey, T.A. Lungu, G.L. Manney, L.L. Nakamura, V.S. Perun, B.P. Ridenoure, Z. Shippony, P.H. Siegel, and R.P. Thurstans. The UARS