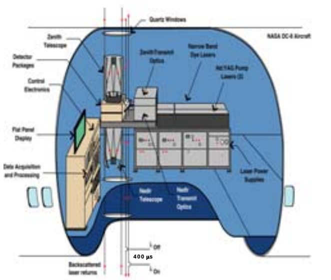
Aerosol Characteristics Measured by DIAL During INTEX-NA

Carolyn Butler, [1,2] Edward Browell, [1] John Hair, [1] Marta Fenn, [1,2] Anthony Notari, [1,2] Susan Kooi, [1,2] Syed Ismail, [1] and Vince Brackett[1,2]

(1)Atmospheric Sciences Research, NASA Langley Research Center, MS 401A, Hampton, Virginia, 23681,USA
(2) Science Application International Corporation, Hampton, NASA Langley Research Center, MS 927, VA 23666 USA

All back-trajectory images are from the NOAA Aeronomy Lab /ICARTT analysis using the FLEXPART mode

Airborne DIAL System Configuration



Nadir and Zenith

- **Ozone Differential Absorption Lidar (DIAL) Profiles (λ_{ON} = 288 nm & λ_{OFF} = 299 nm)**
- **Aerosol Scattering Ratio Profiles (1064, 588, 299 nm)**
- **Aerosol Depolarization Ratio Profiles (588 nm)**

DIAL Aerosol Products

Asian Outflow
- *enhanced aerosol scattering*
- *1.5 - 2.5 wavelength dependence*
- *5 – 15% depolarization (some dust layers?)*
- *70 – 150 ppbv O_3*

California Outflow
- *enhanced aerosol scattering*
- *wavelength dependence < 1 (large particles)*
- *5 – 15% depolarization (some smoke and/or dust)*
- *50 – 90 ppbv O_3*

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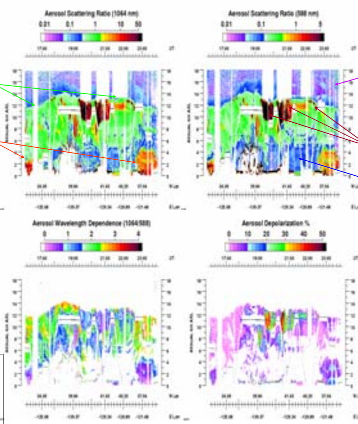

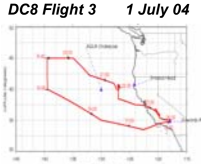

Aerosol wavelength dependence (α) is calculated only when ASR_{IR}>0.3 and ASR_{VS}>0.13. The value of α can range from 0 to 4 where 0 are large particles (> 1 μ) and 4 are very small particles. Values of α are biased low in regions of aerosol attenuation and biased high in regions where normalizations were performed in attenuated regions.

Stratospheric Aerosols
- *low scattering: ASR_{IR}<0.5, ASR_{VS}<0.15*
- *>2.0 wavelength dependence*
- *no depolarization*

Cirrus
- *large aerosol scattering*
- *low wavelength dependence*
- *high depolarization*

Clean Marine Air
- *low aerosol scattering*
- *>1.5 wavelength dependence*
- *no depolarization*

Aerosol depolarization is calculated only when ASR_{VS} > 0.17. Most depolarizing aerosols are found in a mix of air masses and so the values reported here as "dust" or "smoke" may be somewhat diluted by the presence of other non-depolarizing aerosols.

Some Lidar Fundamentals

The Lidar equation is expressed as the received power (P) as a function of range (r):

$$P(r)=\frac{C_0}{r^2}\beta(r)T^2(r)=\frac{C_0}{r^2}(\beta_a(r)+\beta_m(r))T_a^2(r)T_m^2(r)$$

where β_a and β_m are the aerosol and molecular scattering cross-sections and T_a and T_m are the aerosol and molecular extinction terms. The range-corrected signal is then:

$$X(r)=r^2P(r)=C_0(\beta_a(r)+\beta_m(r))T_a^2(r)T_m^2(r)$$

The signal is corrected for molecular extinction, divided by a molecular density profile (from the AGFL standard atmosphere tables) and normalized to 1 in an aerosol-free region of the profile. The resulting atmospheric scattering ratio (**not corrected for aerosol attenuation**) is then:

$$R(r) = C_0(\beta_a(r)+\beta_m(r))T_a^2(r) / \beta_m(r) = C_0 T_a^2(r) (\beta_a(r)/\beta_m(r)+1)$$

The total depolarization is the ratio of the perpendicular polarized signal to the parallel polarized signal:

$$D_T(r) = P_{\perp}(r) / P_{\parallel}(r)$$

and the aerosol depolarization ratio is defined by the total D_T and the molecular D_M:

$$D_A(r) = (R(r) D_T(r) - D_M)/ (R(r) - 1)$$

The Aerosol Scattering Ratio (shown in the images) is

$ASR(r) = R(r) - 1$ 1064 nm
$ASR(r) = [R(r)(1 + D_T(r)) / (1 + D_M)] - 1$ 588 nm

The aerosol wavelength dependence (of the backscatter) is:

$$\alpha(r) = 4.0 - [\ln(ASR_{IR}(r)/ASR_{VS}(r)) / \ln(\lambda_{IR}/\lambda_{VS})]$$

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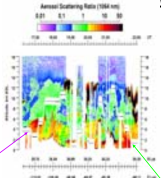
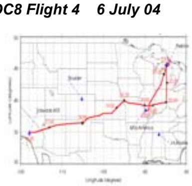
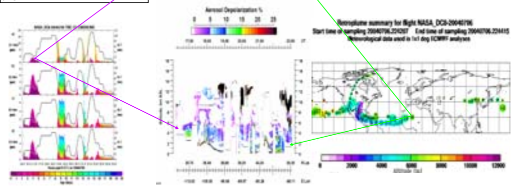
Arizona smoke
ASR_{IR} ~ 8, ASR_{VS} ~ 0.7
D_A ~3 - 12%, α ~ 0.5

Dust
ASR_{IR} ~ 10, ASR_{VS} ~ 1.5
D_A ~5 - 12%, α < 0.3

Very fresh smoke plumes as the DC8 passed over Arizona had very similar aerosol characteristics to the dust observed at the end of the flight.







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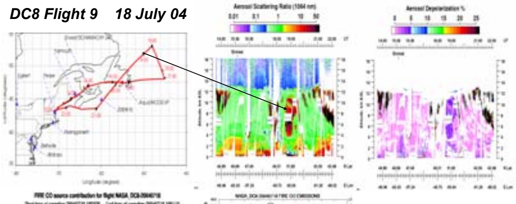

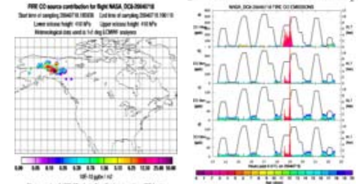

Alaskan Smoke Plume
3 to 5 days old
ASR_{IR} ~ 25, ASR_{VS} ~3,
D_A ~3.5%, α < 1

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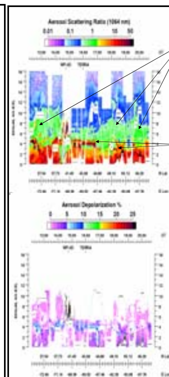
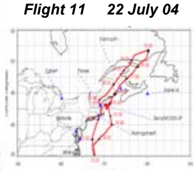
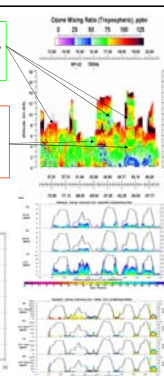
Asian Pollution + Stratospheric Air
ASR_{IR} ~ 0.5 to 1, ASR_{VS} ~0.2 to 0.5,
D_A < 1%, α ~ 1 to 2
O_3 ~ 60 to 180 ppbv

Smoke Plumes with Elevated O_3
~ 7 days old
ASR_{IR} ~ 10, ASR_{VS} ~5,
D_A ~5 to 10%, α < 0.5
O_3 ~60 to 130 ppbv







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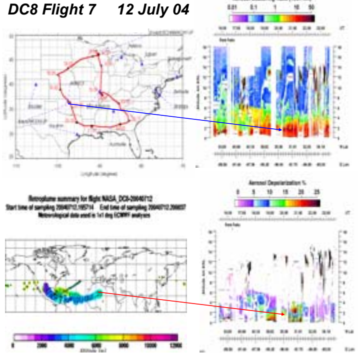
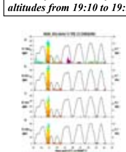
Dust (from Sahara)
ASR_{IR} ~ 8, ASR_{VS} ~ 0.7
D_A ~10 - 20%, α < 0.5

High concentrations of dust were observed (in situ) in the boundary layer from Nebraska southward. Back trajectories provided by NOAA Aeronomy Lab using the FLEXPART model suggest possible origins in Africa. The model also indicates recent exposure to Arizona fires at aircraft altitudes from 19:10 to 19:50.





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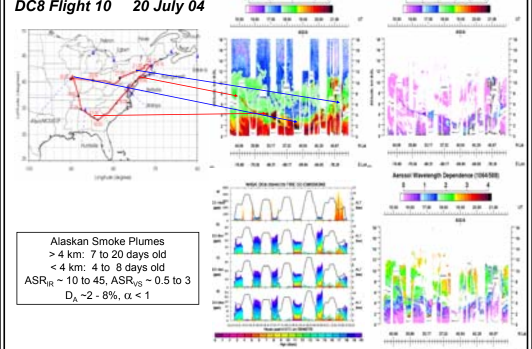

Alaskan Smoke Plumes
> 4 km: 7 to 20 days old
< 4 km: 4 to 8 days old
ASR_{IR} ~ 10 to 45, ASR_{VS} ~ 0.5 to 3
D_A ~2 - 8%, α < 1

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Cirrus
(just below tropopause)
ASR_{IR} >80, ASR_{VS} >10,
D_A~50%, α <0.5

Continental Outflow
ASR_{IR} ~0.5 to 5, ASR_{VS} ~0.2 to1,
D_A < 1%, α ~ 1 to 2
O_3 ~70 to 170 ppbv

Clean Marine Boundary Air
ASR_{IR} ~9, ASR_{VS} ~1,
D_A < 1% , α < 0.5
O_3 < 20 ppbv

High Depolarization from Cirrus

Multiple scattering from clouds