Mapping Tropospheric Ozone Profiles from An Airborne UV/Visible Spectrometer

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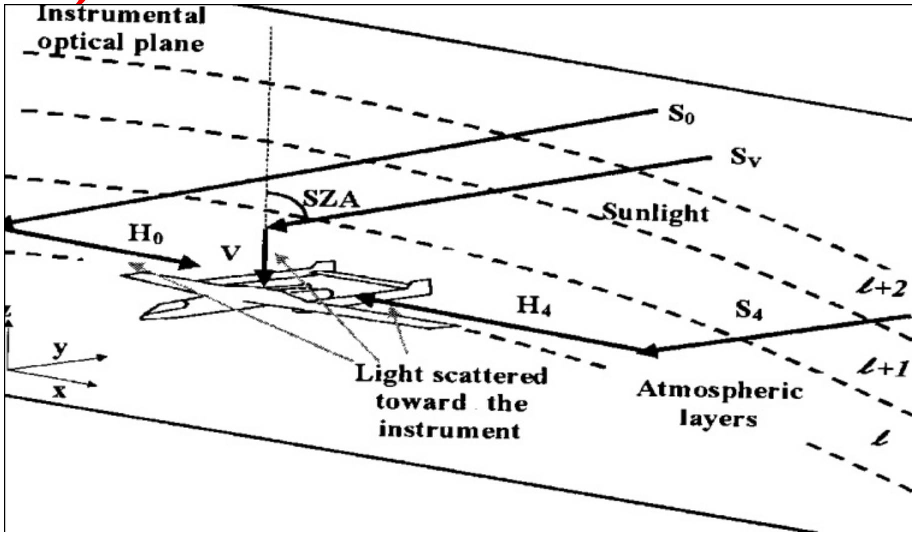
Outline

- **Introduction**
- **Technique to Measure Tropospheric Ozone Profiles from an Airborne Platform**
- **Application to ACAM (Airborne Compact Atmospheric Mapper) Measurements**

Introduction

- **Airborne UV/Visible DOAS in the 1990s: zenith-sky spectra, stratospheric column abundances of trace gases such as O_3, NO_2, OClO, BrO (e.g., Wahner et al., 1990).**



- **Airborne UV/Visible off-axis measurements of O_3 in 1999 (Petritoli et al., 2002): O_3 near aircraft**

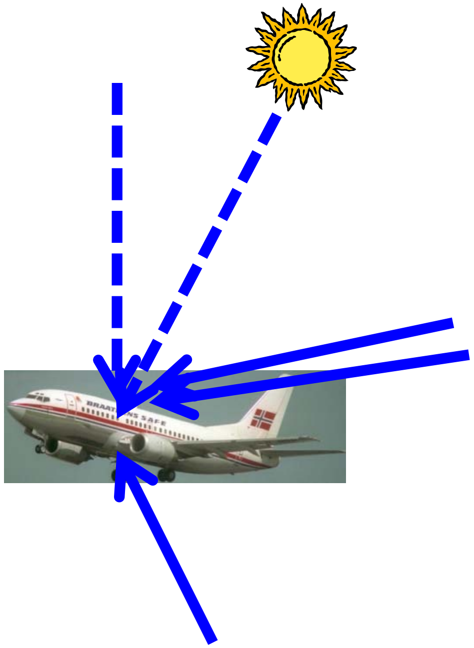
- **AMAX-DOAS (Airborne Multi-Axis DOAS, Wagner et al., 2001): stratospheric and tropospheric columns, vertical profiling (Bruns et al., 2004)**

Introduction

- **ACAM (Airborne Compact Atmospheric Mapper, developed at NASA GSFC by Dr. Scott Janz): UV/Vis., tropospheric and boundary columns, mapping**
- **Chance et al. (2005) proposed the TROPSPEC instrument for the NSF HIAPER program: UV/Vis. Spectrometer 300-700 nm) plus 16 filter channels (0.47-1.64 μm) , across-track scanning (2 km×2 km)**
- **Developed a measurement technique: tropospheric ozone profiles with a vertical resolution of 2-6 km below aircraft at high spatial resolution (Liu et al., 2005, Applied Optics)**
- **Describe the measurement technique and its application to ACAM measurements**

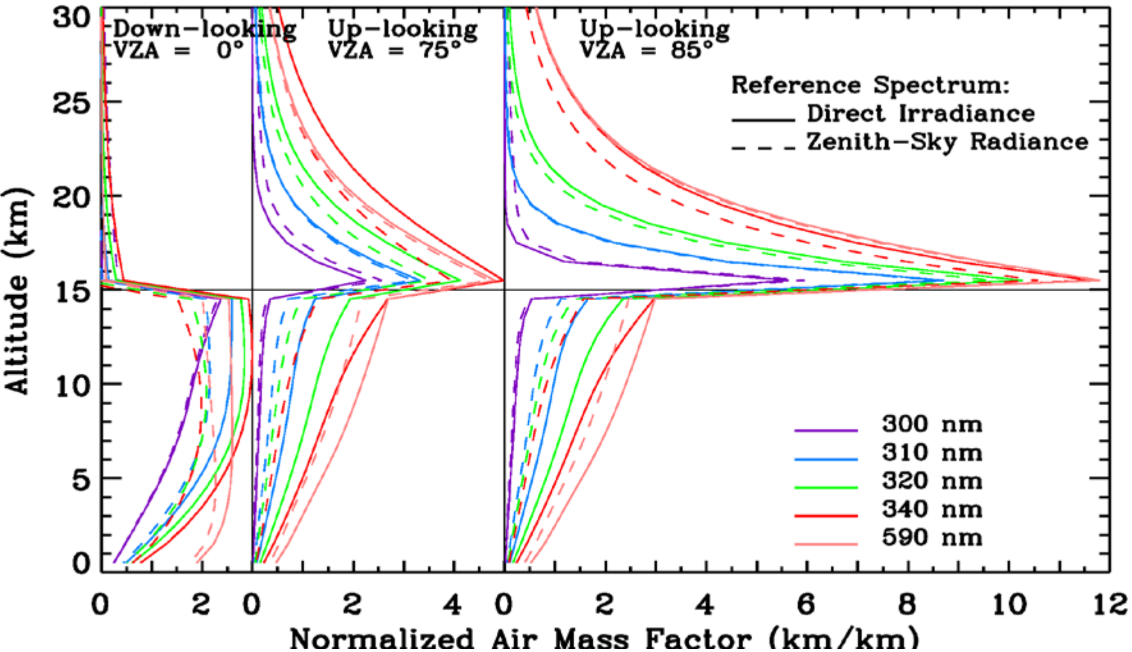
Measurement Technique

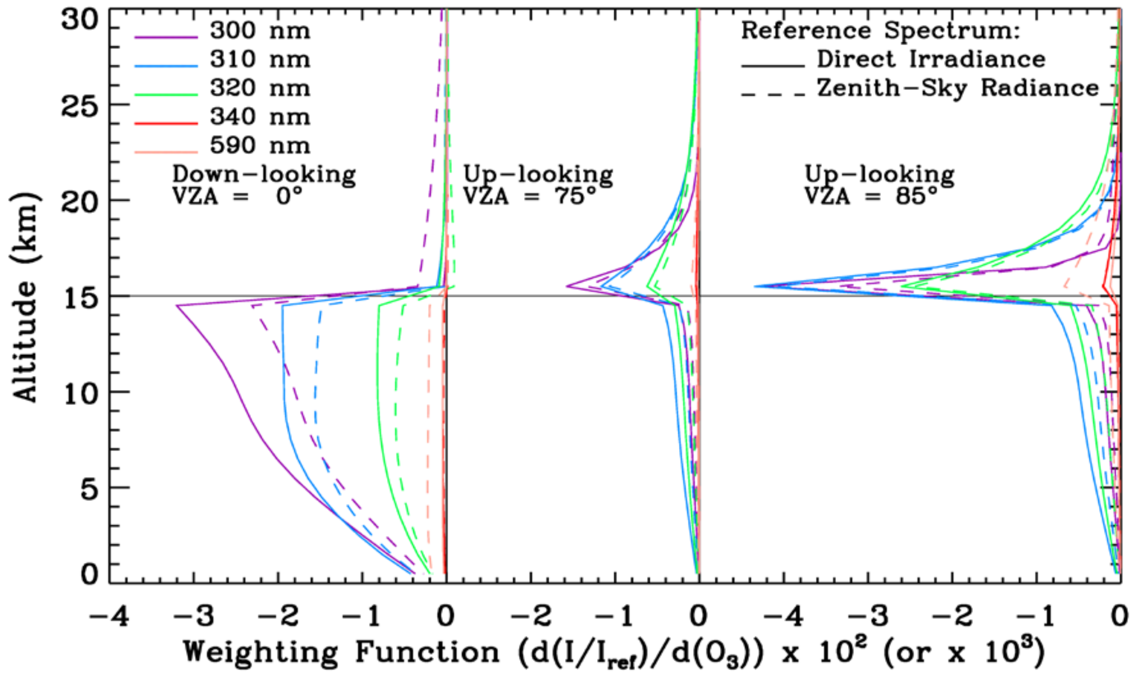
- **TROPSPEC: UV (300-400 nm, 0.2 nm FWHM) and visible (400-700 nm, 0.6 nm FWHM)**
  - **Uplooking: several zenith angles (calibration, stratospheric)**
  - **Downlooking: 160 km swath (±80°) and 2 km×2 km at nadir (e.g., flight altitude of 15 km), tropospheric/boundary**
  - **SNR based on GOME: 3000 at 340 nm, 2000 at 600 nm**
- **Configuration for trop. O_3:**
  - **Two uplooking angles: 75° and 85°**
  - **Any one downlooking**
  - **Direct irradiance or zenith-sky for calibration**
  - **Spectral regions: Huggins (300-340 nm), Chappuis (530-650 nm)**



- **Base case: US standard atmosphere with background aerosols (LOWTRAN)**
  - **SZA=45°, Surface albedo is 0.10, clear-sky**
  - **15 km flight altitude**
  - **Direct irradiance reference**

Physical Principle

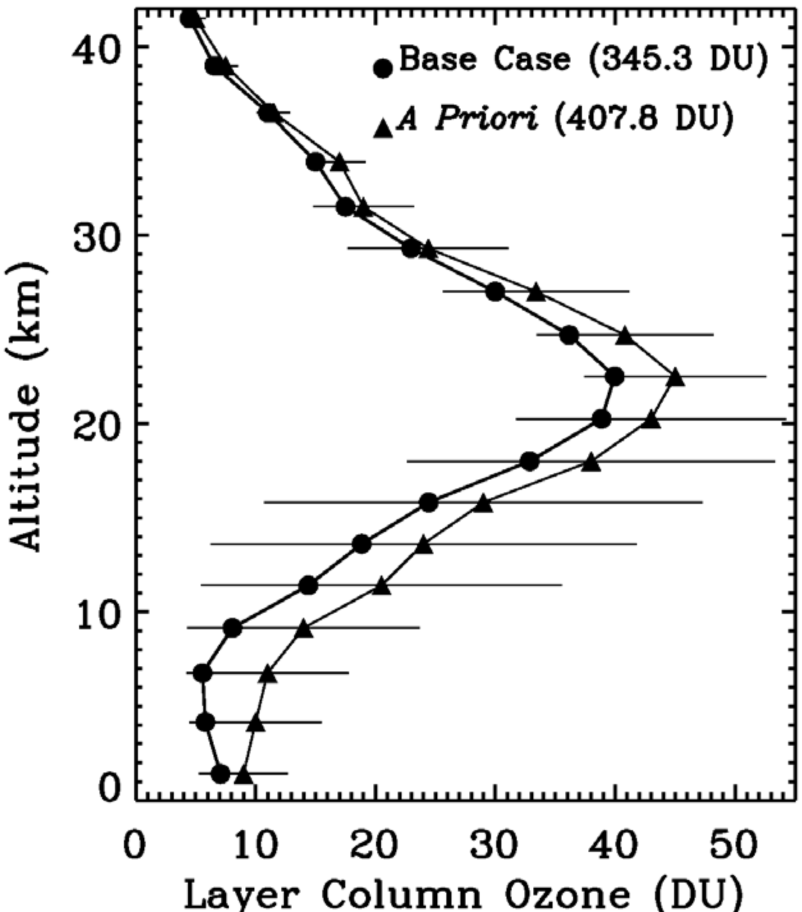


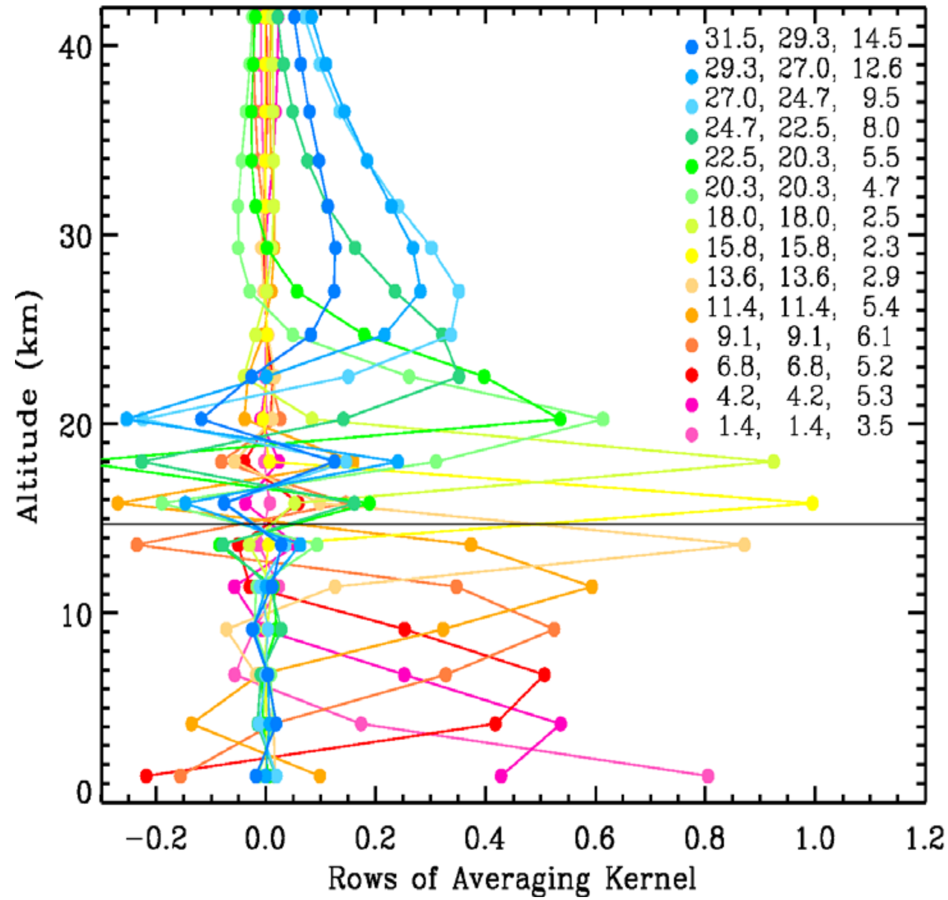


- **Air mass factor M and weighting functions ($M \times \alpha_{O_3}$)**
- **Downlooking: mainly sensitive to O_3 below, photons penetrate deeper into the surface at longer wavelengths**
- **Uplooking: mainly near air-craft but with significant sensitivity to O_3 above &below, longer wavelengths sensitive to broader altitude ranges.**
- **Direct irradiance reference slightly better than zenith-sky reference**

Synthetic Retrievals wit Measurement Noise

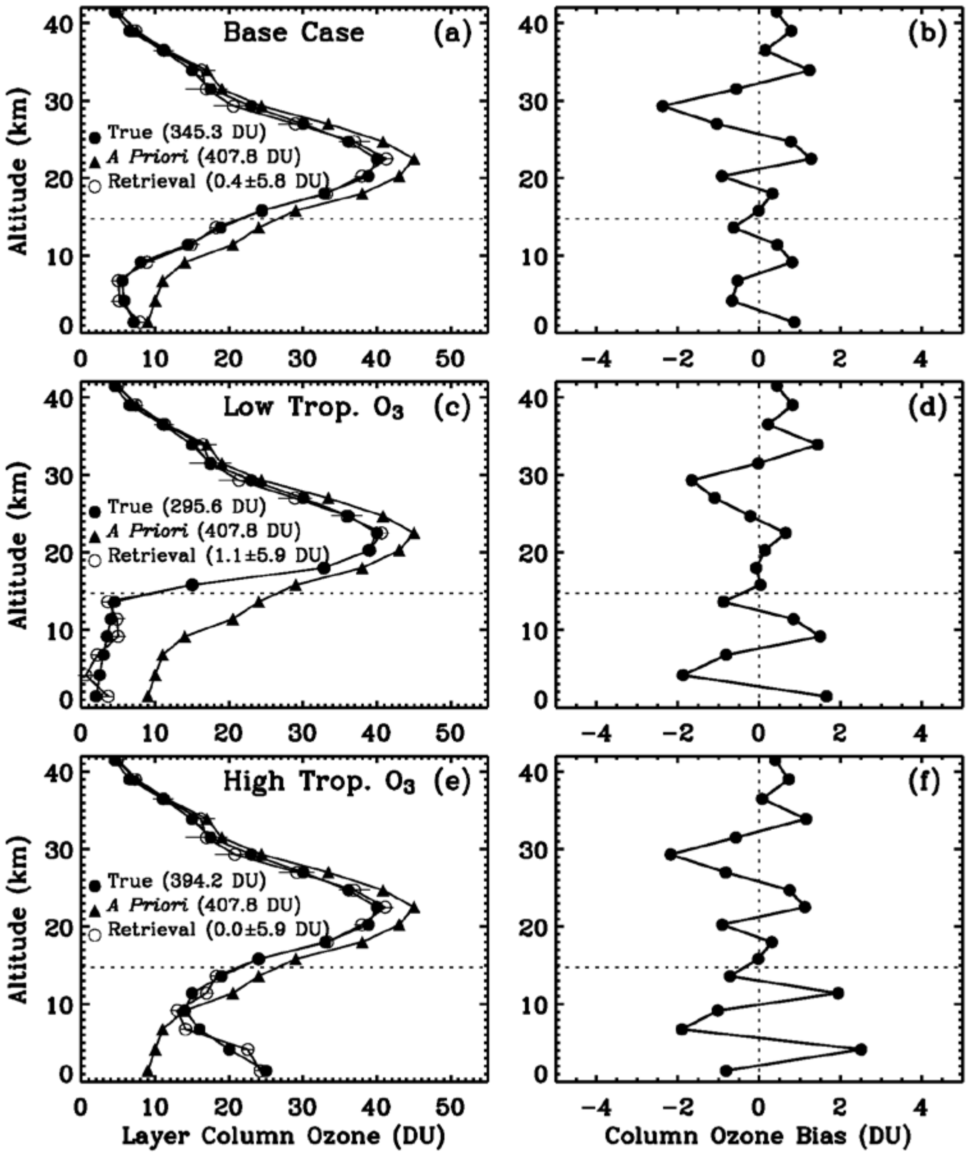
- Perform synthetic retrievals with measurement noise
- Optimal estimation with modified a priori
- Vertical resolution: **2-6 km between surface-23 km (2-3 km at ~15 km), 3.5 DFS below 15 km**.





Synthetic Retrievals wit Measurement Noise

- Good agreement for both low and high ozone conditions



Retrieval Sensitivity to Different Parameters

Cases	Column O_3 Bias (DU)			DFS
	Total	Below	Above	
Base case	0.4±7.7	0.3±0.3	0.1±4.3	7.4/3.5
1.0-nm FWHM	4.6±9.0	-0.2±0.3	4.8±5.4	6.9/3.3
Zenith reference	0.8±8.5	0.5±0.5	0.3±5.0	7.0/3.2
Solar reference	0.2±4.8	0.2±0.2	-0.0±0.1	8.5/3.5
No Chappuis	0.1±8.0	0.3±0.8	-0.2±4.4	7.0/3.0
No up-looking	13.1±3.6	0.3±0.3	12.8±17.7	4.7/3.3
No up-looking 75°	-1.8±8.2	0.0±0.3	-1.8±4.8	7.3/3.4
SZA 0°	-0.7±7.3	0.3±0.2	-1.0±4.1	7.7/4.0
SZA 75°	0.9±7.5	0.3±0.4	0.3±2.2	7.0/3.0
*VZA 75°	0.7±7.1	0.4±0.7	0.6±4.3	7.5/3.6
Surface albedo 0.6	-0.0±7.4	0.0±0.1	-0.1±4.2	7.7/3.8
0.2 times S/N noise	1.2±1.9	0.9±1.0	0.3±7.6	5.9/2.7
Polluted	0.0±7.6	0.0±0.3	0.0±4.3	7.6/3.7
Remote	1.1±7.5	0.4±0.3	0.7±4.3	7.5/3.6
Aircraft at 10 km	-2.0±2.4	0.3±0.3	-2.5±8.0	7.0/2.8
Aircraft at 5 km	2.4±6.9	0.3±0.2	2.1±11.2	6.4/1.8

* Down-looking direction

- **Doesn't require high spec. reso.**
- **Zenith/solar ref.**
- **No Chappuis bands mainly affect boundary layer retrievals.**
- **No uplooking angles barely affects retrievals below aircraft.**
- **High SNR is not critical.**

Application to ACAM Data and Plans

- **ACAM: UV/visible spectrometers with cloud camera**
  - **304-520 nm (0.8 nm FWHM), 460-900 nm (1.5 nm FWHM)**
  - **Zenith-sky reference (2º)**
  - **Scan across-track, +18º to -21º**
  - **Spatial resolution: 800 m×800 m (UV) and 375×800 m (Visible)**
- **The airborne tropospheric ozone technique can be applied to ACAM data assuming good radiometric/wavelength calibrations**
  - **Cross-correlate to high-resolution solar irradiance to derive slit functions and perform wavelength calibration**
  - **Use collocated satellite/ozonesonde ozone profiles to check the instrument calibration**
  - **Use external solar irradiance (high-resolution solar irradiance convolved with instrument slit function)**

Applicability to ACAM Data and Plans

- **Modify our GOME/OMI O_3 profile retrieval algorithms for ACAM data (Liu et al., 2005, 2010)**
  - **Optimal estimation + VLIDORT calculations**
  - **Initially focus on clear-sky conditions and UV-only**
  - **Check radiometric/wavelength calibrations**
  - **Test the inclusions of Chappuis bands**
  - **Clouds: OMI-like algorithms (i.e., rotational Raman scattering or O_4/O_2-A absorption bands, non-absorbing wavelengths)**
  - **Aerosols: important to account for absorbing aerosols for boundary layer retrievals**
    - **Use aerosol information in-situ/LIDAR measurements**
    - **Simultaneous retrievals of aerosols (aerosol height and optical thickness)**
  - **Surface albedo (especially in Chappuis bands): fit surface albedo polynomials, use available surface albedo models**
  - **Initially apply the algorithm to Global-Hawk data during April 2010**

Summary

- An technique is developed to retrieve tropospheric ozone profiles from airborne UV/Visible measurements
- Two uplooking angles (75º, 85º) and any one downlooking angle, direct-sun/zenith sky reference for self-calibration
- Especially sensitive to ozone below the aircraft and ozone ~ 8 km above the aircraft with vertical resolution of 2-6 km
- High spatial resolution, suitable for regional and air quality studies
- Can be applied to ACAM data and we plan to adapt our OMI retrieval algorithm initially to Global-Hawk data

Acknowledgements

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