Tropospheric Ozone Retrievals from OMI Measurements

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Outline

- **Introduction**
- **OMI/MLS TOR with trajectory mapping: method, results, and validation**
- **OMI ozone profile retrievals: method, results, and validation**
- **Summary**

Introduction

- **Tropospheric Ozone Residual (TOR) [*Fishman and Larsen*, 1987]: Trop. O_3 Column (TOC) = Total O_3 Column – Strat. O_3 Column (SOC)**
  - **Most methods prior to the Aura derive monthly mean TOC in the tropics**
  - **Poor spatiotemporal sampling (e.g., low vertical resolution of nadir sensors and poor horizontal sampling of limb sensors) or large uncertainty in SOC**
- **With OMI/MLS on AURA and techniques (e.g., Trajectory/PV mapping, assimilation), possible to derive daily TOC globally [*Ziemke et al.*, 2006; *Schoeberl et al.*, 2007; *Yang et al.*, 2007, *Stajner et al.*, 2007]**
- **Direct ozone profile & trop. O_3 retrievals from backscattered hyperspectral UV instruments (e.g., GOME, OMI) [e.g., *Chance et al.*, 1997, *Munro et al.*,1998, *Liu et al.*, 2005] and infrared instruments (e.g., TES, and IASI)**
  - **UV: Strong wavelength dependence of ozone absorption in the Hartley and Huggins bands and temperature dependence in the Huggins bands**

Introduction

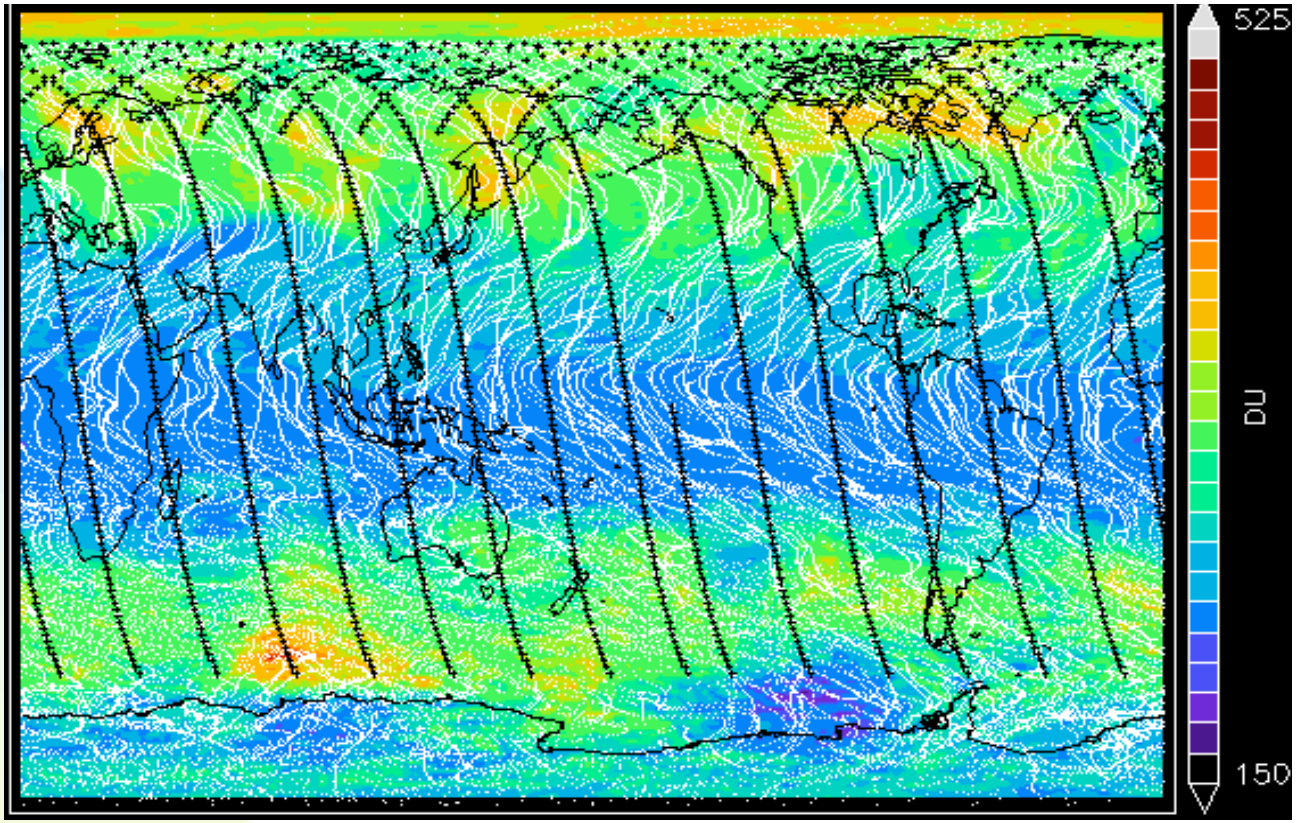
- **Present two methods of tropospheric O_3 retrievals and their characterization (e.g., information, accuracy) from OMI:**
  - **OMI/MLS TOR with trajectory mapping [*Schoeberl et al.*, 2007]**
  - **OMI ozone profile retrievals [*Liu et al.*, 2005]**

- **OMI [*Levelt et al.*, 2006]:**
  - **Nadir-viewing push-broom UV/Visible instrument (270-500 nm)**
  - **Spatial resolution at nadir: 13 × 24 km^2 for UV2 (310-365 nm) and Visible (350-500 nm) and 13 × 48 km^2 for UV1 (270-310 nm)**
  - **2600-km swath, daily global coverage**

OMI/MLS TOR with Trajectory Mapping

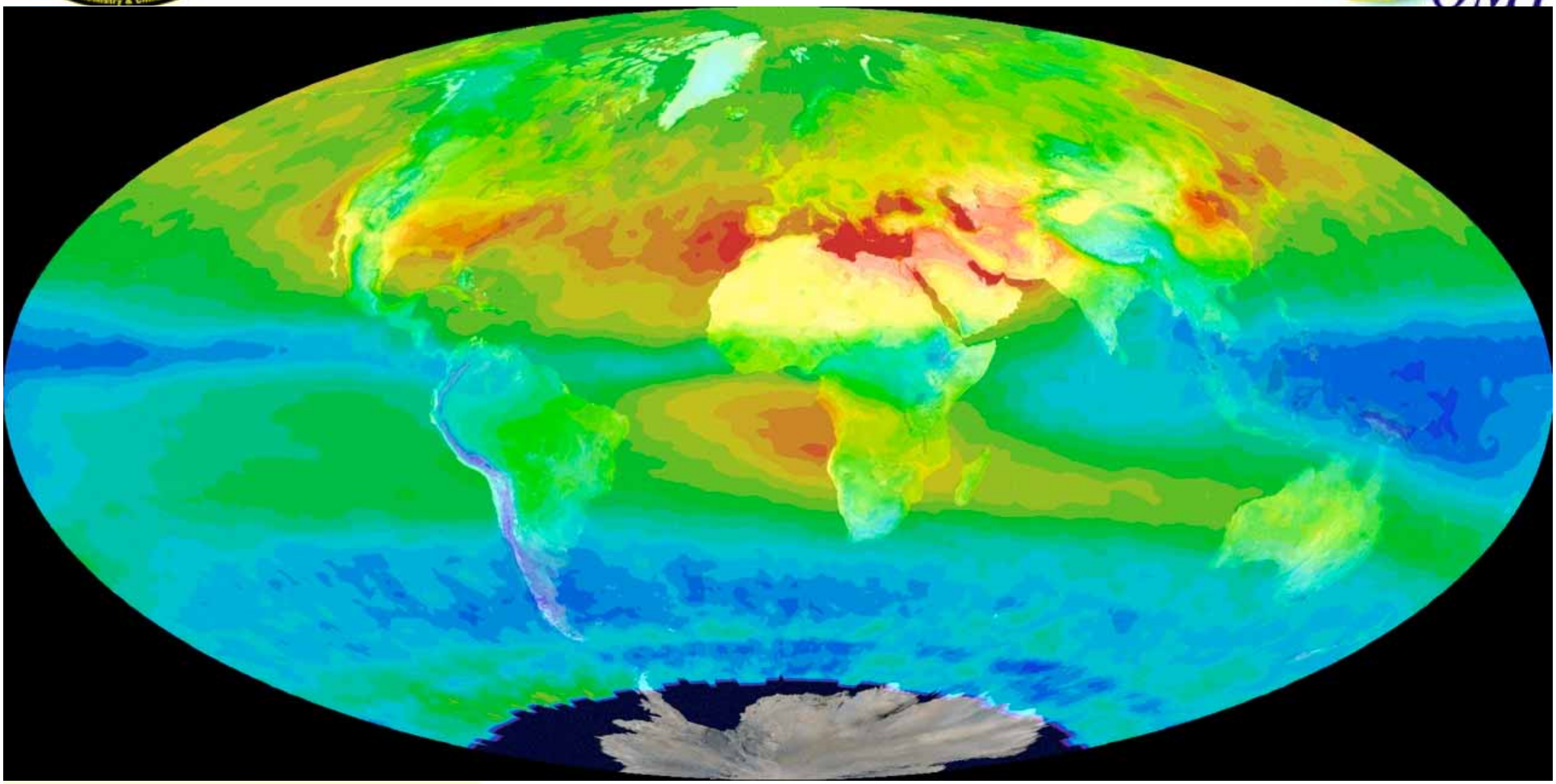
- Use OMTO3 total O_3 column (Level 2G): 1.25° × 1°
- Use MLS for SOC:
  - Profiles good down to ~215 hPa
  - Profiles along orbit track (200 × 6 km^2), ~25° longitude apart
- TOR issues:
  - Tropopause: derive surface-200 hPa TOC
  - Relative accuracy between OMI/MLS
  - Time synchronization: total O_3 column and SOC must be near simultaneous in the extra-tropics due to rapid tropopause undulations
  - Need SOC with comparable horizontal resolution with total O_3 column

OMI/MLS with Trajectory Mapping



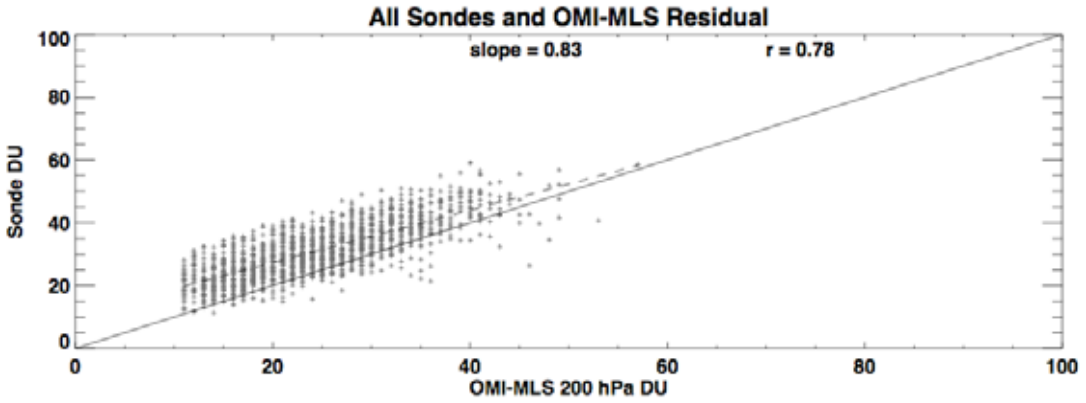
- Gather measurements from multiple days (forward and backward) to generate many more points for interpolation
- Theoretical improvement: 6 days (3 backward and 3 forward) of trajectory mapping gives ~ 2-3º horizontal resolution.

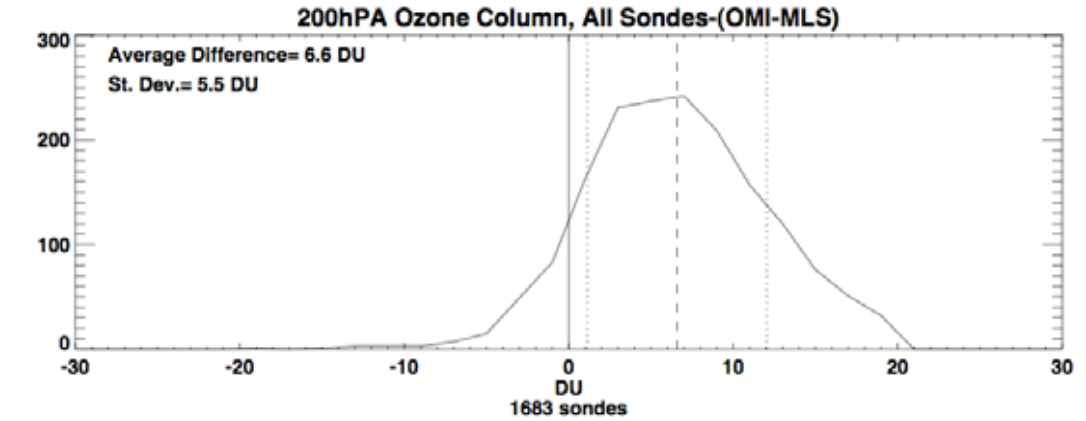
OMI/MLS TOR during Summer 2006



- High O_3 over the South Atlantic (biomass burning, lighting, dynamics) and low ozone in the Pacific Ocean
- Enhanced O_3 over regions of pollution outflow in North Mid. Latitudes

Validation of Current OMI/MLS TOR





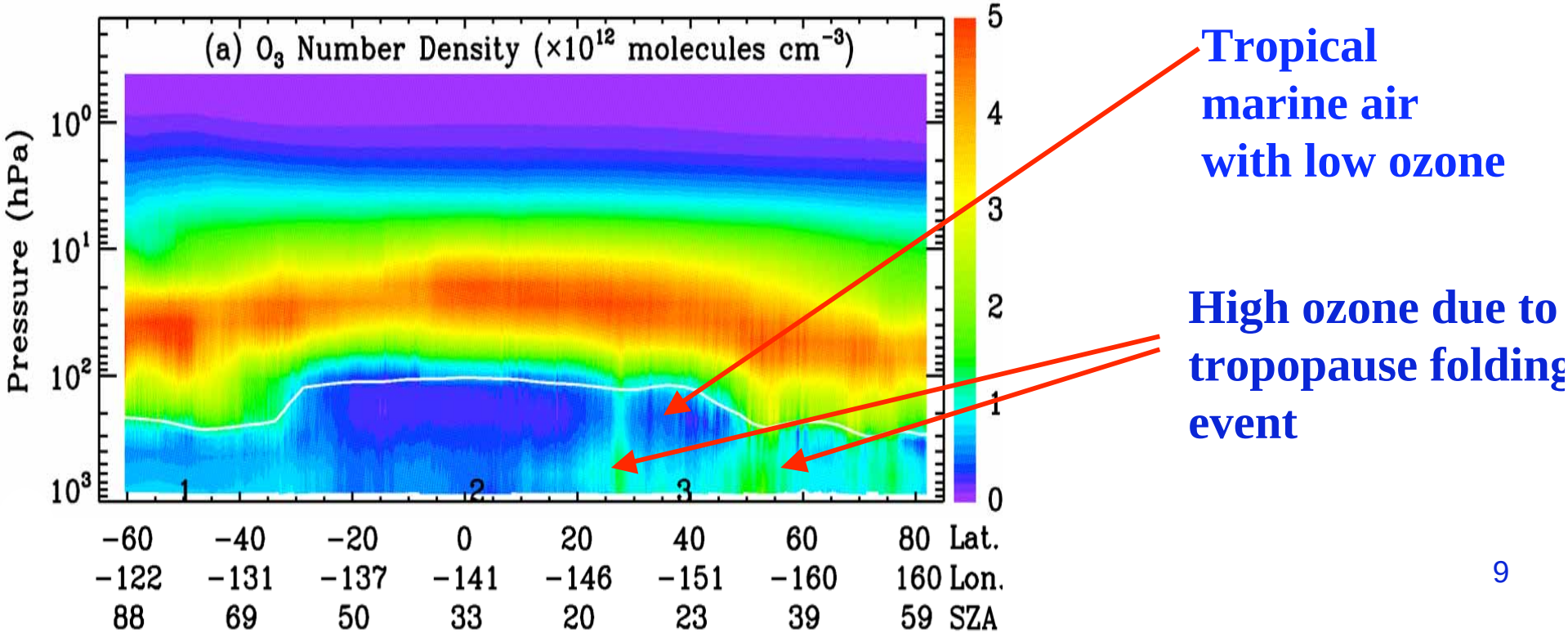
- **Averaging kernels: total O_3 column averaging kernels in the troposphere**
- **The accuracy of OMI/MLS TOR results from the sum of 3 errors in:**
  - **Total O_3 (~1%, 2-4 DU)**
  - **SOC (~2%, 4-7 DU): reduced using traj. mapping**
  - **Interpolation errors**

- **Validation against ozonesonde measurements:**
  - **6.6 ± 5.5 DU, R=0.78, Slope=0.83**
  - **Systematic biases due to relative accuracy between OMI total ozone (~-3 DU) and MLS SOC (~+3 DU)**

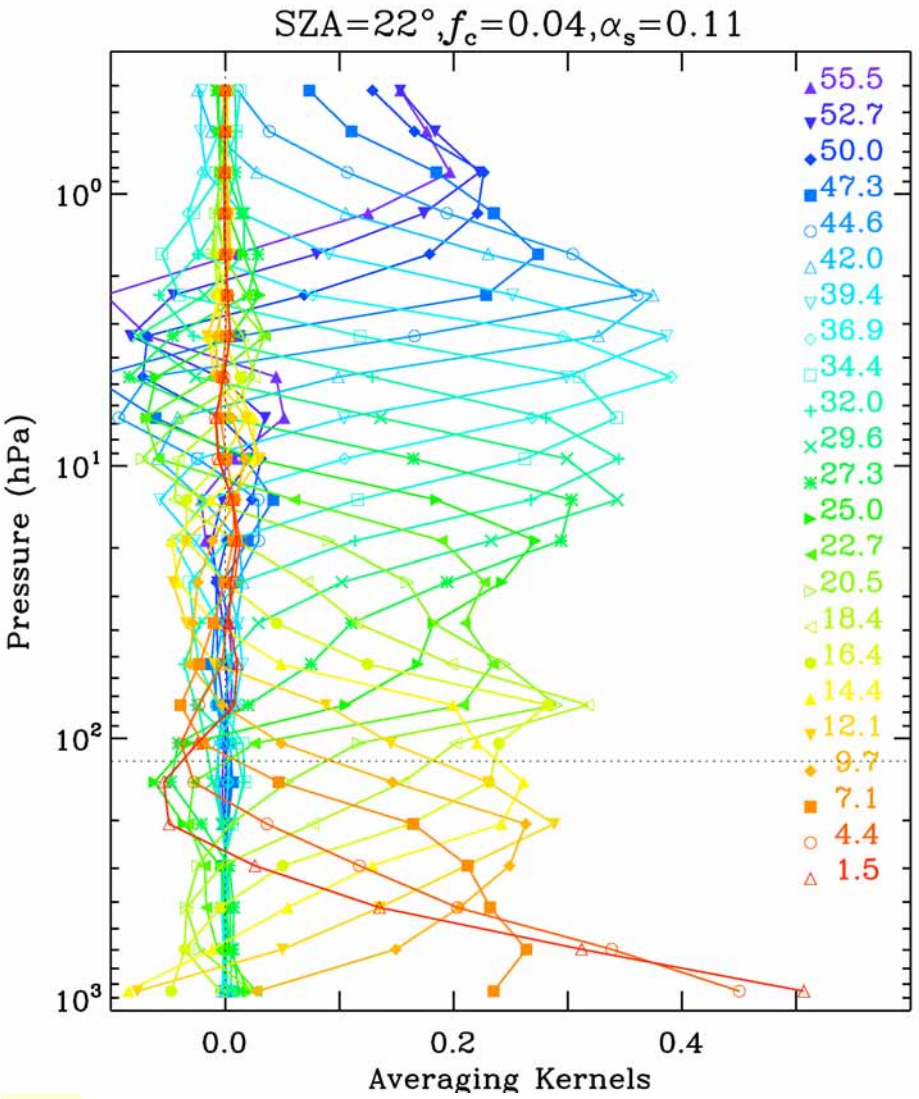
OMI Ozone Profile Retrievals

- **OMI ozone profile retrieval**
  - **Spectral fitting (270-330 nm) + VLIDORT + optimal estimation**
  - **Retrieve ozone at 24 layers from surface to ~60 km**
  - **Constrained by O_3 profile climatology [*Mcpeters et al.*, 2007]**

July 11, 2006



Retrieval Vertical Information

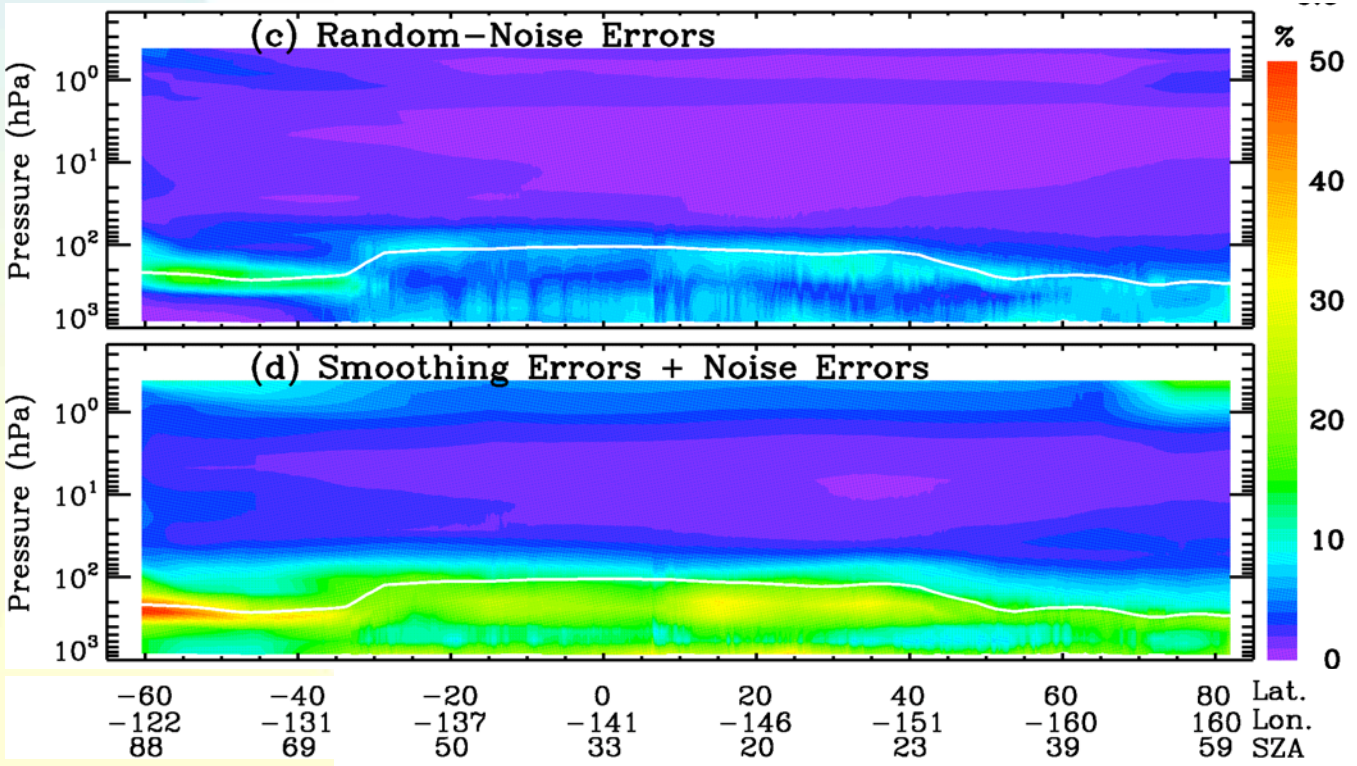


Retrieval Without Interference

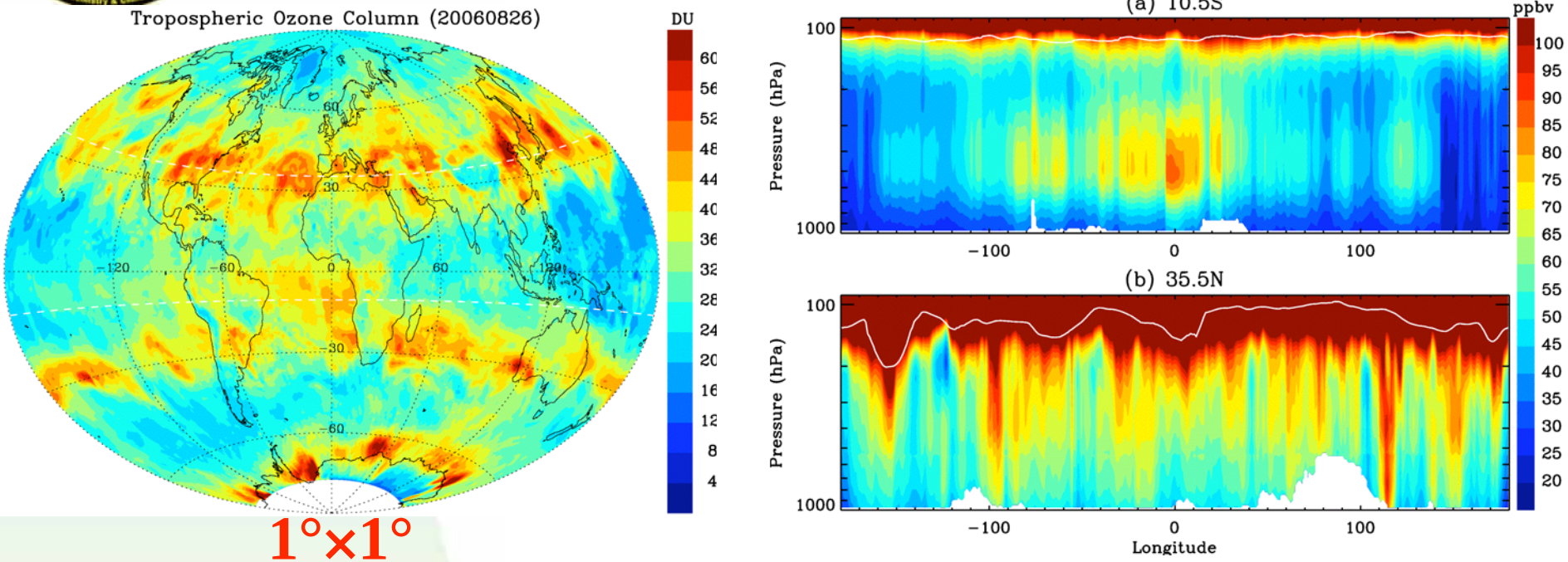
- **DFS: 6-7 with up to 1.5 in the trop.**
- **~6-9 km FWHM in the strat. and ~9-14 km in the troposphere**
- **For tropical and mid-latitude summer, DFS in the trop. generally peaks in the 500-700 hpa layer, retrievals are effectively sensitive to O_3 down to 850-880 hPa.**
- **Currently, retrievals especially in the lower troposphere are subject to interferences from other auxiliary parameters (used to partly account for inadequate instrumental calibration and forward modeling).**

Random (N) and Smoothing (S) Errors

- Random errors (N): 0.5-2% above ~20 km and within ~10% below
- Smoothing+Random-noise errors: within 0.8-3% between 20-40 km, increase to 10% above 40 km, and to 6-35% in the troposphere.
- Errors in O_3 columns (SZA < 80º)
  - Total O_3 column: 0.2-2 DU (N), 0.2-4 DU (S+N)
  - Stratospheric O_3 column: 0.5-2 DU (N), 1.5-5 DU (S+N)
  - Tropospheric O_3 column: 1-3 DU (N), 2.0-6 DU (S+N)



Examples of Tropospheric O_3 (2006m0826)

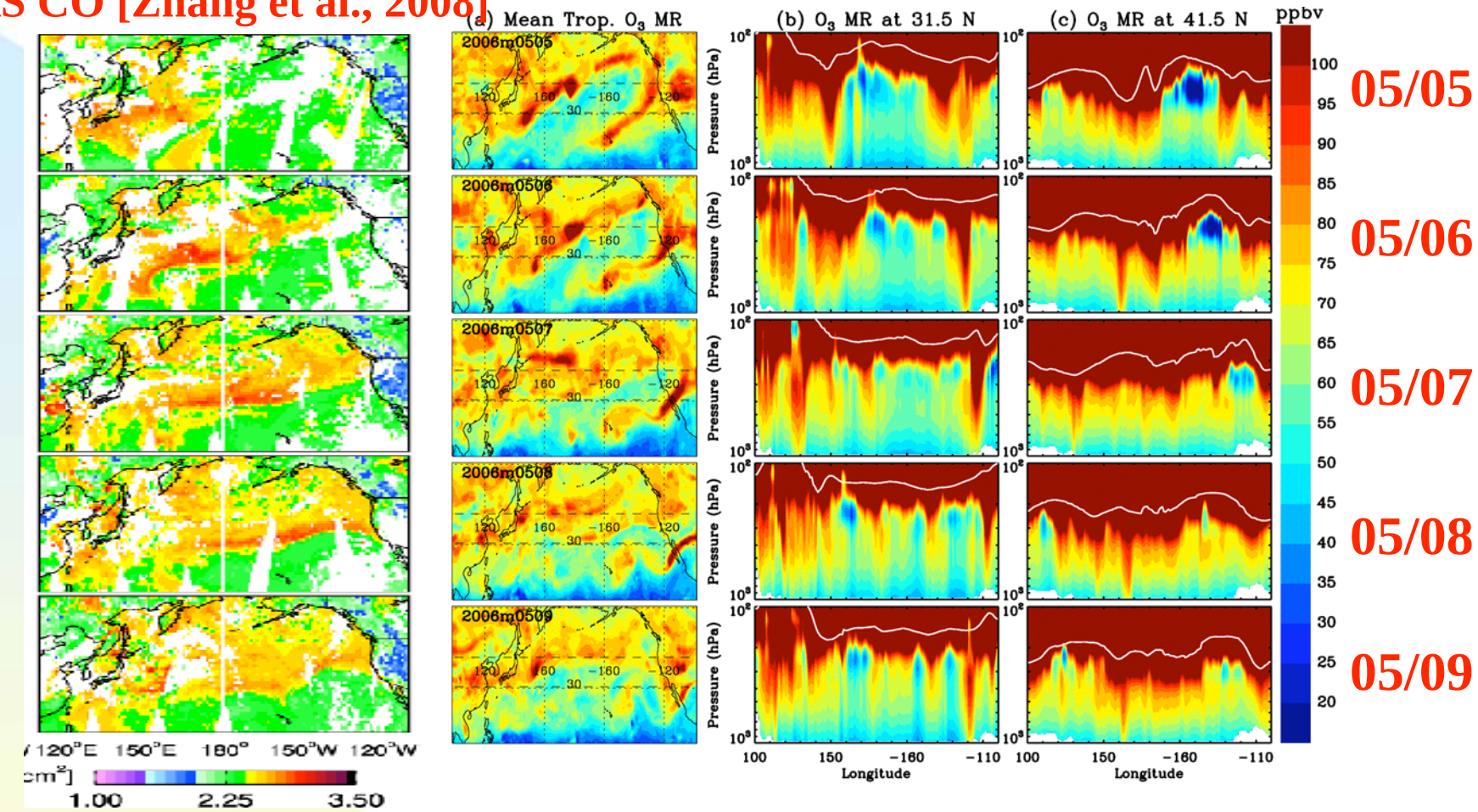


1°×1°

- Enhanced ozone (60-90 ppbv) in the mid. & upper troposphere of the South Atlantic and Indonesia, and low ozone of 20-40 ppbv over the Pacific Ocean
- Large longitudinal variability in the mid-latitudes: pollution, stratospheric intrusion, low ozone tropical air

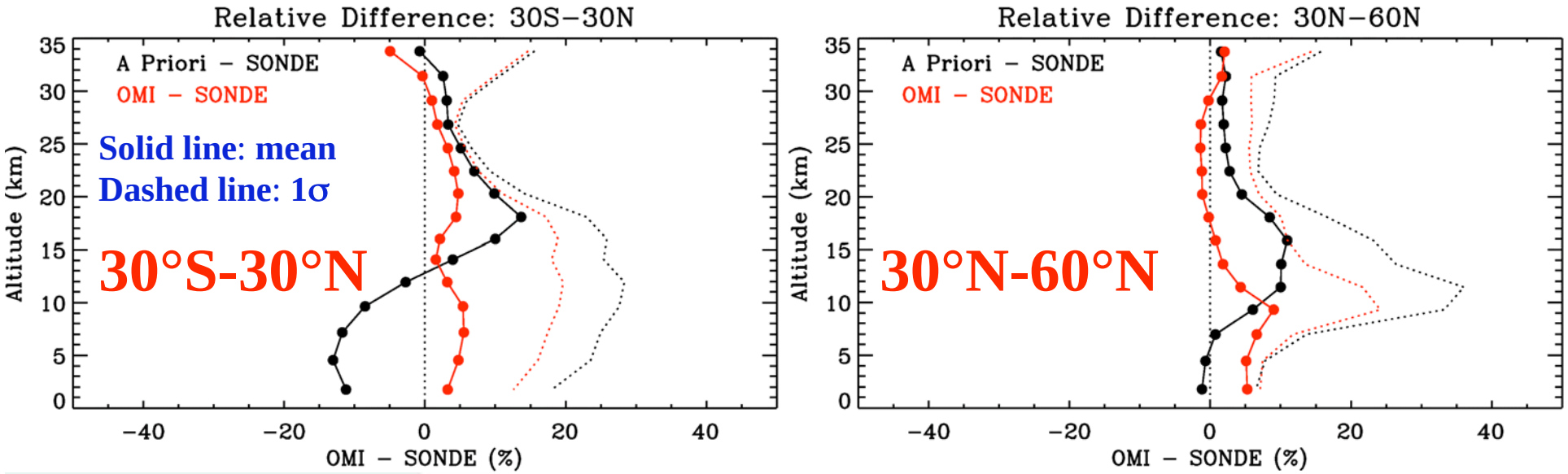
An Event of Ozone Pollution Transport (May 05-09, 2006)

AIRS CO [Zhang et al., 2008]



- An event of transpacific transport of ozone pollution *[Zhang et al., 2008]*
- OMI ozone tracks AIRS CO very well except for the stratospheric folding event near west coast of US (low CO, high O_3)
- Stratospheric intrusions mix with Asian pollution plumes

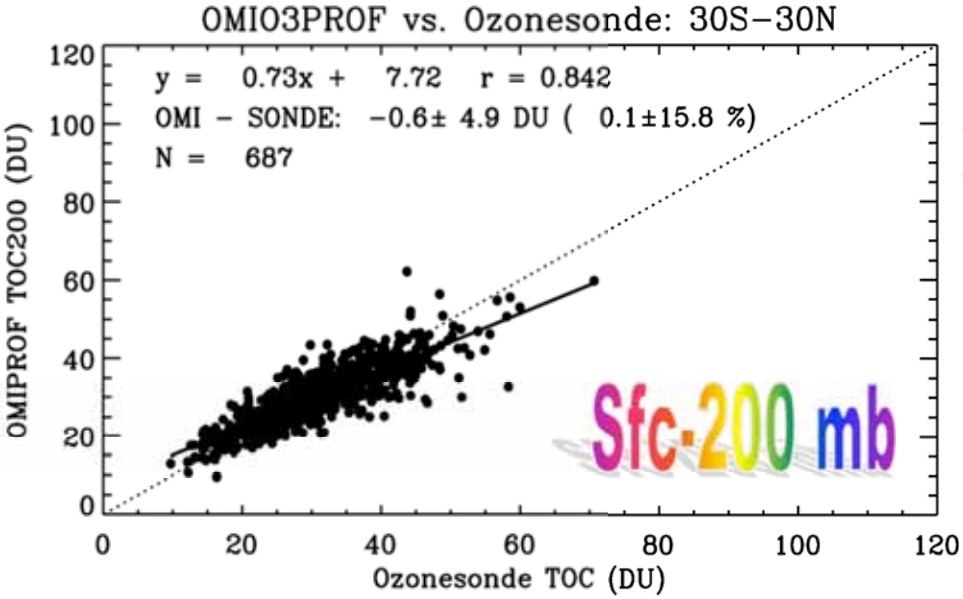
Comparison with Ozonesonde Observations

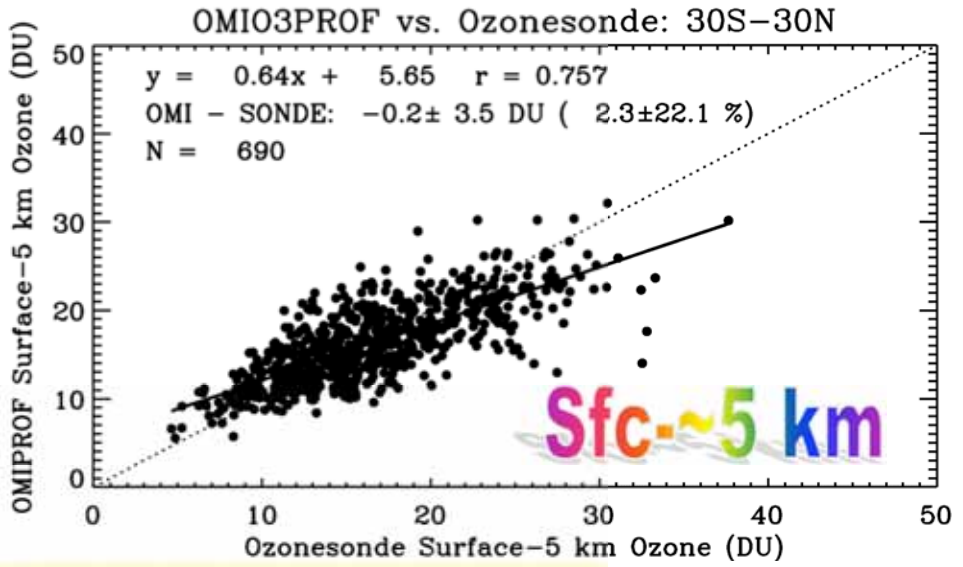


- Ozonesonde data during 2004-2007 (AURA AVDC)
- Coincidence criteria: ±6 hours, ± 1° lon./lat., cloud fraction <0.3
- In profile comparison, sondes are convolved with OMI AKs.
- Mean biases within 10% and 1σ within 20-25%.
- Our retrievals at middle latitudes show some seasonal-dependent biases possibly due to uncorrected straylight errors and radiative transfer approximations.

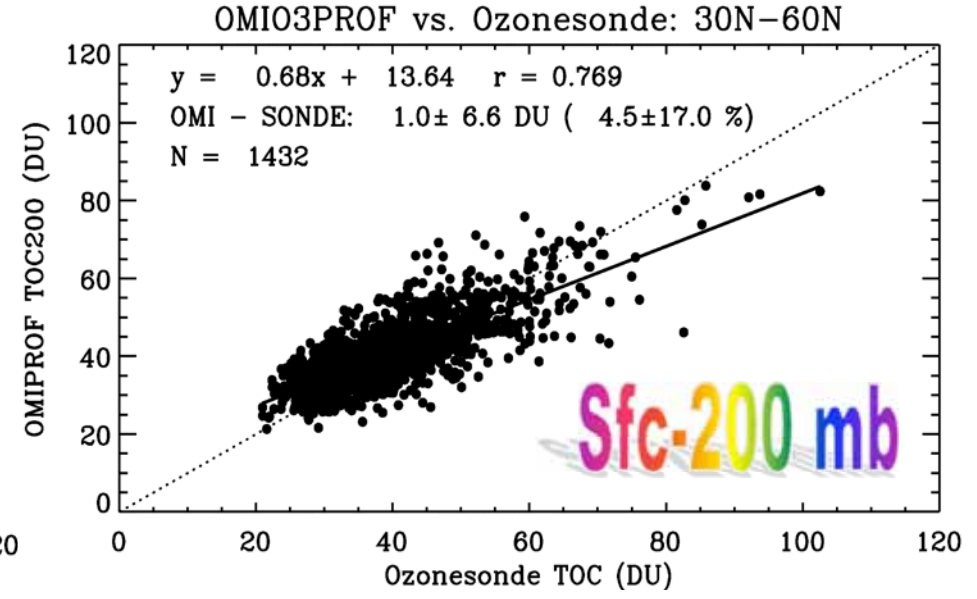
Comparison with Ozonesonde Observations

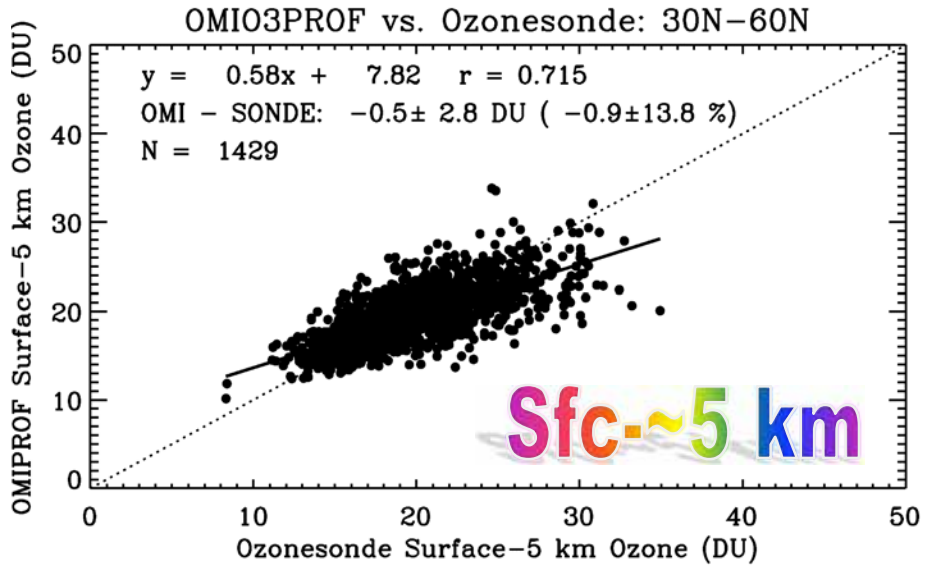
30°S-30°N





30°N-60°N

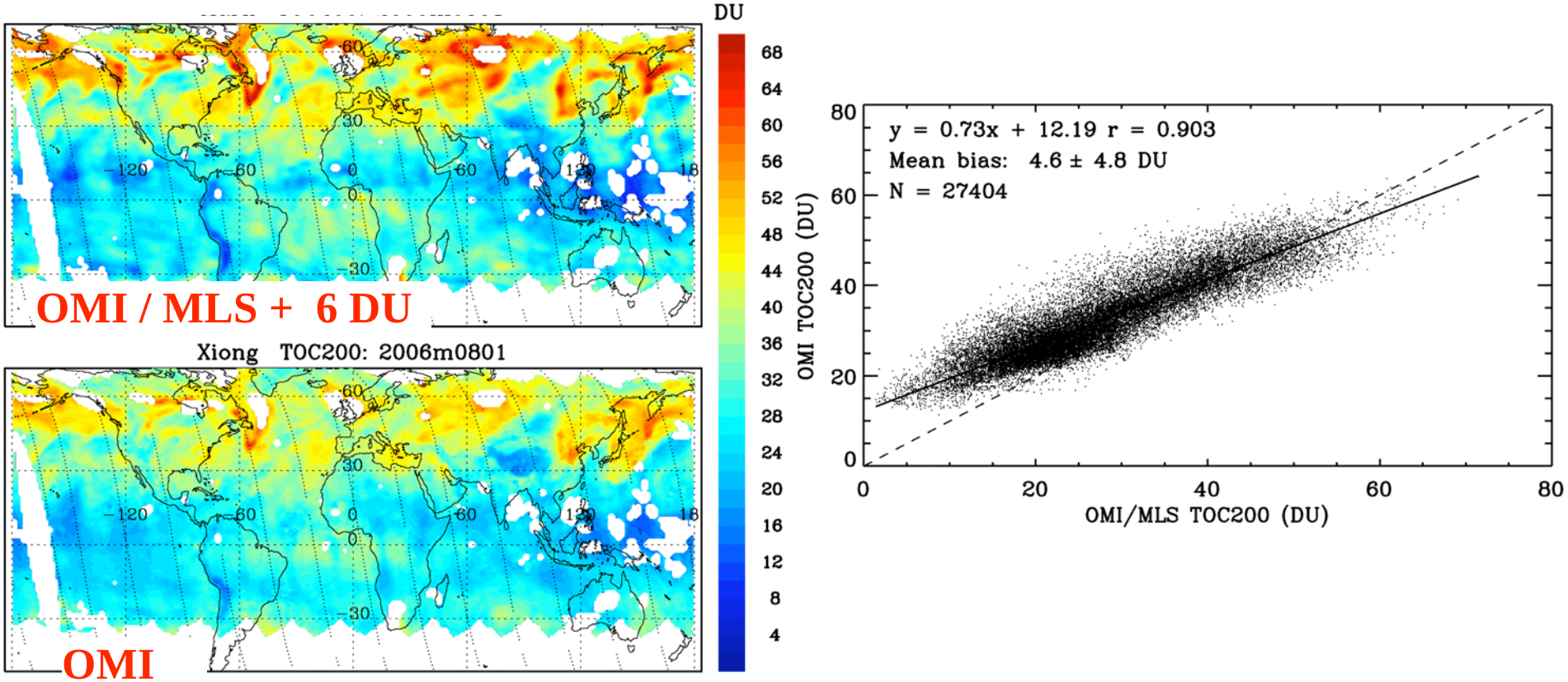




- Note that OMI averaging kernels are not applied here.

Comparison between OMI/MLS TOR and OMI Retrievals

2006m0801



- Surface-200 hPa TOC from these two methods agree quite well.
- Large differences occur in regions of large and small values.

Summary

- Two distinctly different methods to retrieve trop. O_3 from OMI:
  - OMI/MLS TOR with trajectory mapping
  - OMI ozone profile retrievals
- Both capture tropospheric ozone signals due to convection, biomass burning, pollution transport, and stratospheric influence.
- Both agree quite well with sondes except for a systematic bias in OMI/MLS TOR and season-dependent bias in direct retrievals.
- For direct retrievals in the troposphere:
  - 9-14 km FWHM vertical resolution, up to ~1.5 DFS
  - DFS peaks ~500-700 hPa, effectively sensitive to O_3 at 850-880 hPa
  - Errors due to precision and smoothing: 6-35%, 2-6 DU in TOC
  - Significant retrieval interference in the lower troposphere.

Acknowledgements

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