Harvard
School of Engineering
and Applied Sciences

Retrieval of BrO from SCIAMACHY Limb during ARCTAS, spring 2008

J. P. Parrella, K. Chance, T. Kurosu, and D. J. Jacob

Special thanks: C. Sioris, X. Liu, and C. Nowlan

SCIAMACHY

Importance of BrO_x Chemistry Research

Brief Highlights in Arctic Bromine

1981 - 1986 — 1st surface O_3 depletions observed in Arctic

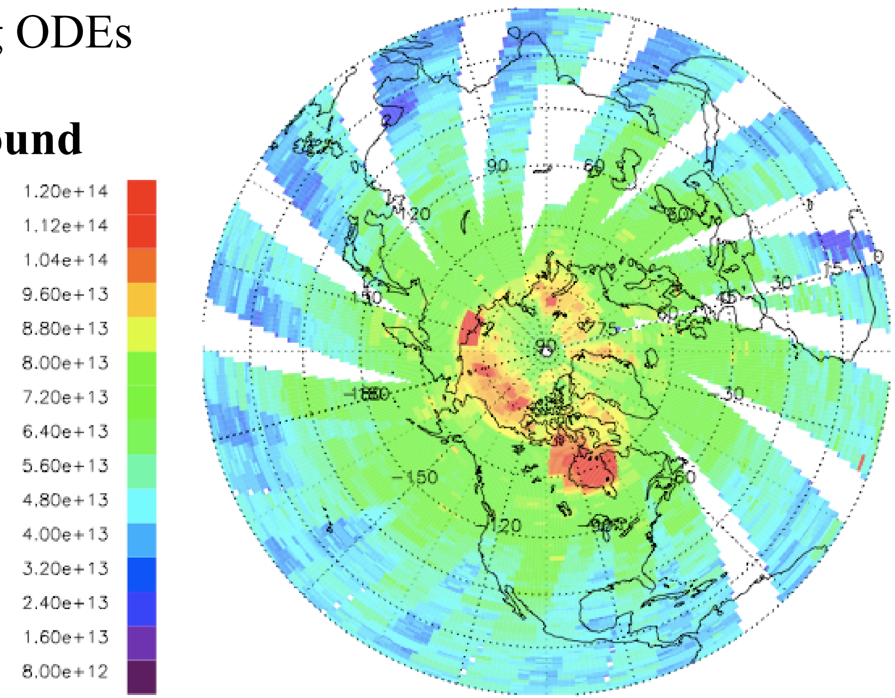
1988 — Barrie et al. anti-correlate f-Br and O_3 during ODEs

1998 — First satellite BrO retrievals: **global background**

Chance 1998; Wagner and Platt 1998

2003 — WMO 2002 highlights importance of VSL halogen sources

Large uncertainty in how much stratospheric Br_y coming from VSLs (1 - 10 ppt possibly)



Chance, 1998

April, 2008 — **Why in-situ BrO during ARCTAS?** (1[st] tropospheric in-situ flight measurements)

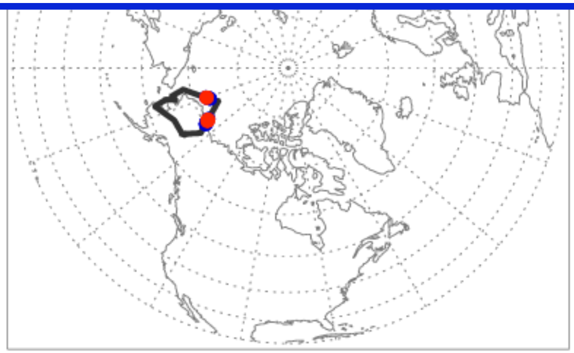
1. Trigger for “bromine explosions” still unknown
2. Emissions poorly constrained (inorg. and organic)
3. Opportunity to validate nadir satellite BrO.
   - Vertical structure in troposphere? How deep?

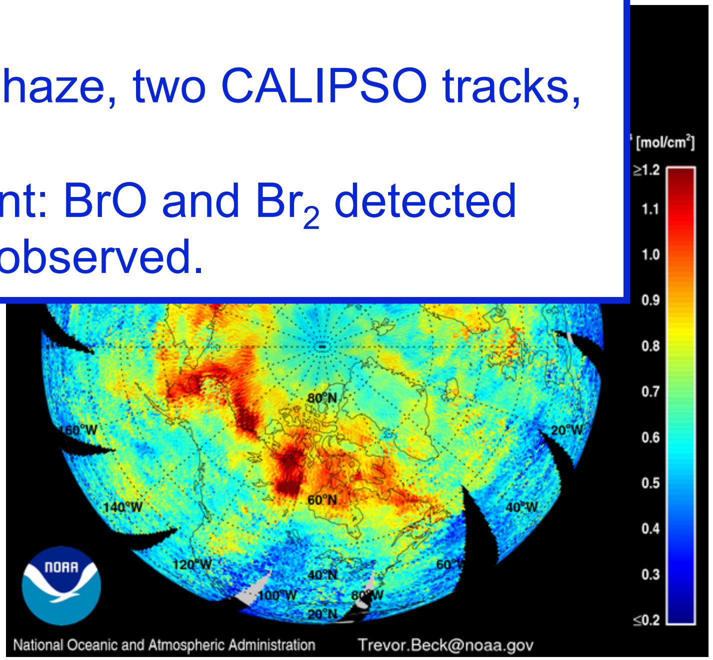
Flight 9: 080416 (Fairbanks to Thule to Iqaluit)

Flight Report:

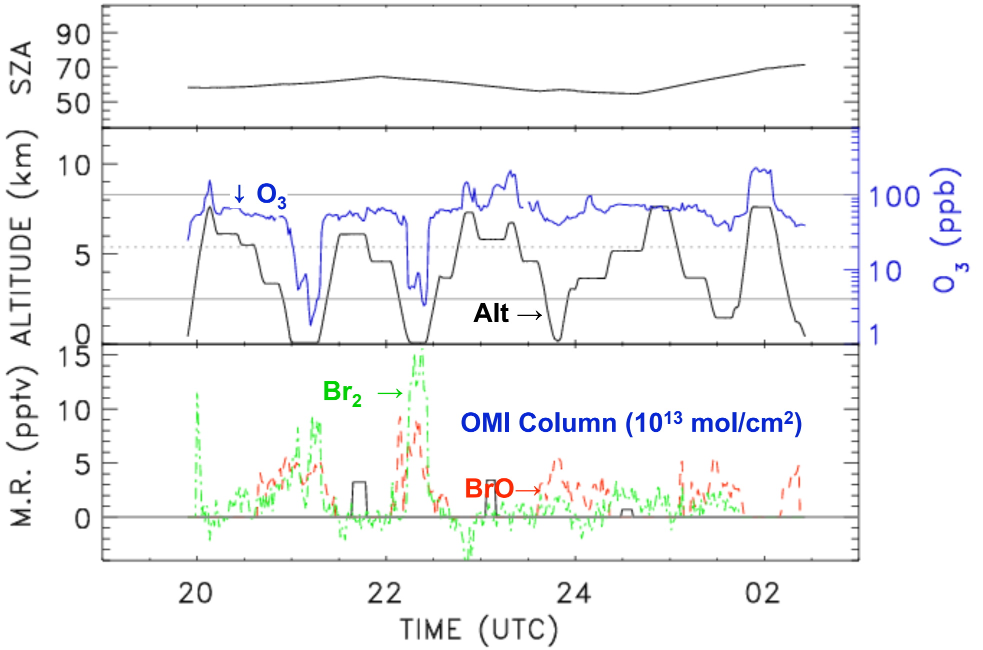
Objectives: Asian biomass burning and Arctic haze, two CALIPSO tracks, and ozone depletion in BL.

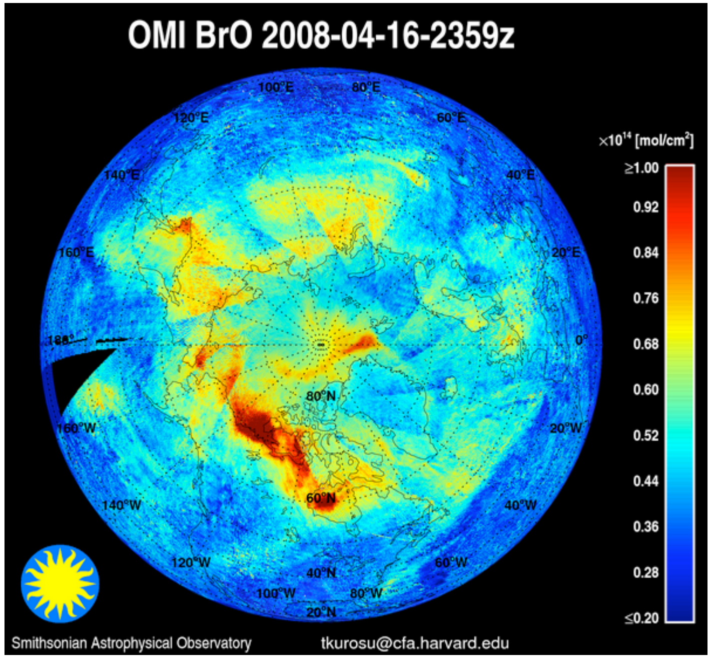
Both ozone depletion and Br chemistry evident: BrO and Br_2 detected at ~2 ppt levels and soluble bromide also observed.





T. Kurosu, K. Chance, T. Beck, G. Huey, A. Weinheimer





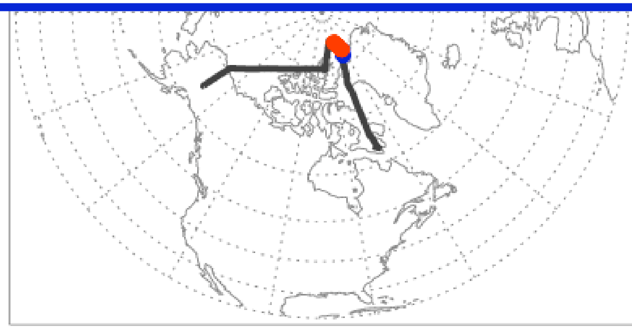
R. Salawitch

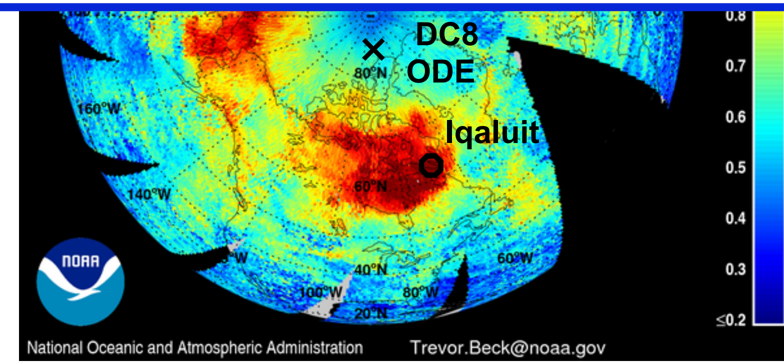
Flight 6: 080408 (Fairbanks to Thule to Iqaluit)

Flight Report:

Exploratory BL run north of Alert found O_3 < 0.5 ppb (Major ODE) with significant levels of soluble Br^- and Br_2, but very low levels of BrO.

Flew length of Frobisher Bay in the BL, just prior to landing, in a satellite BrO "hotspot". Not clear if O_3 was depleted, but no BrO was detected.





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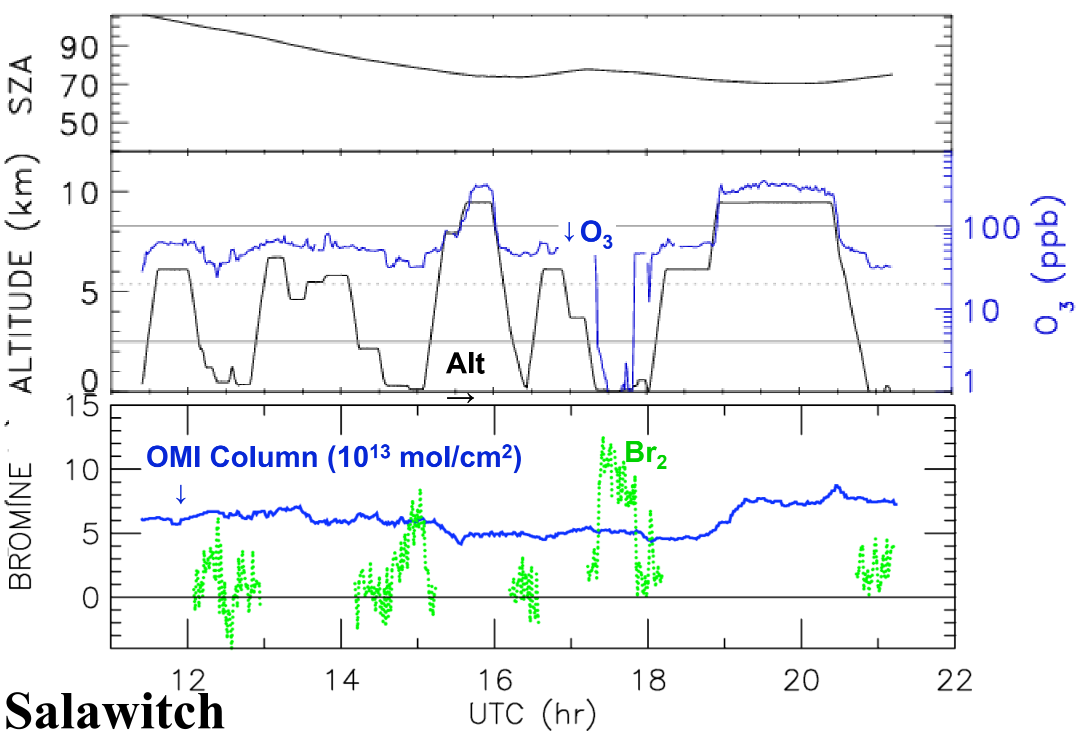
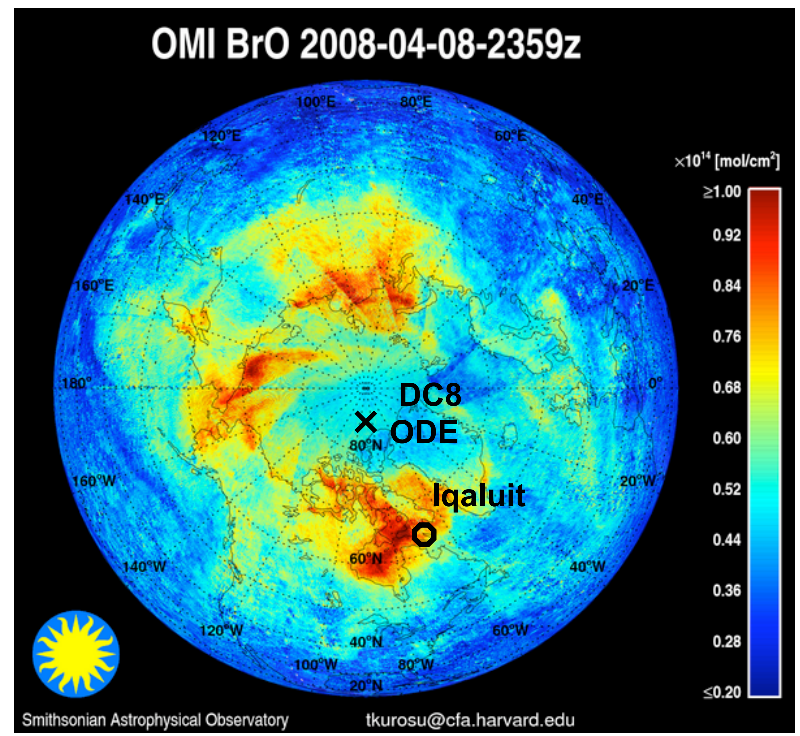
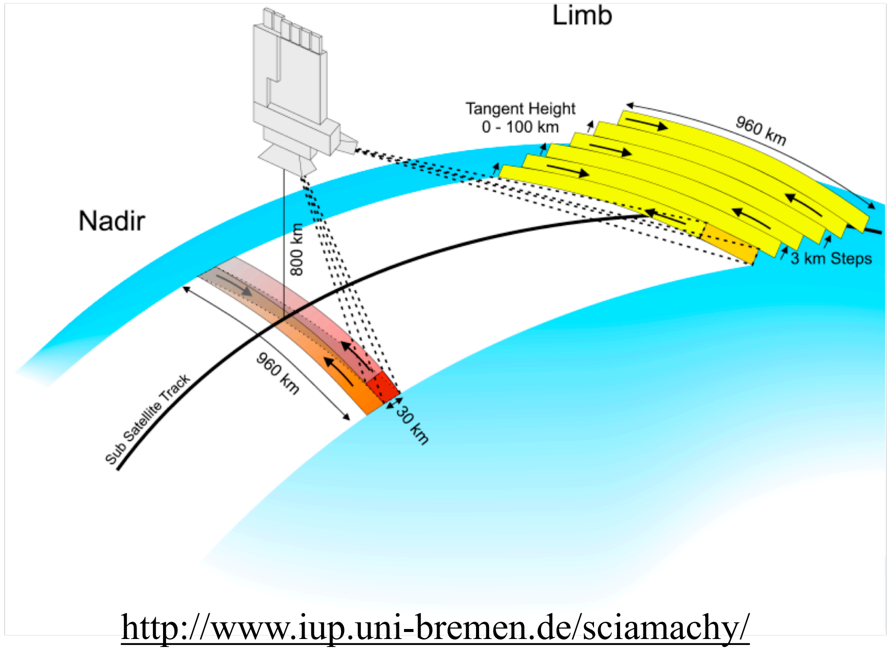


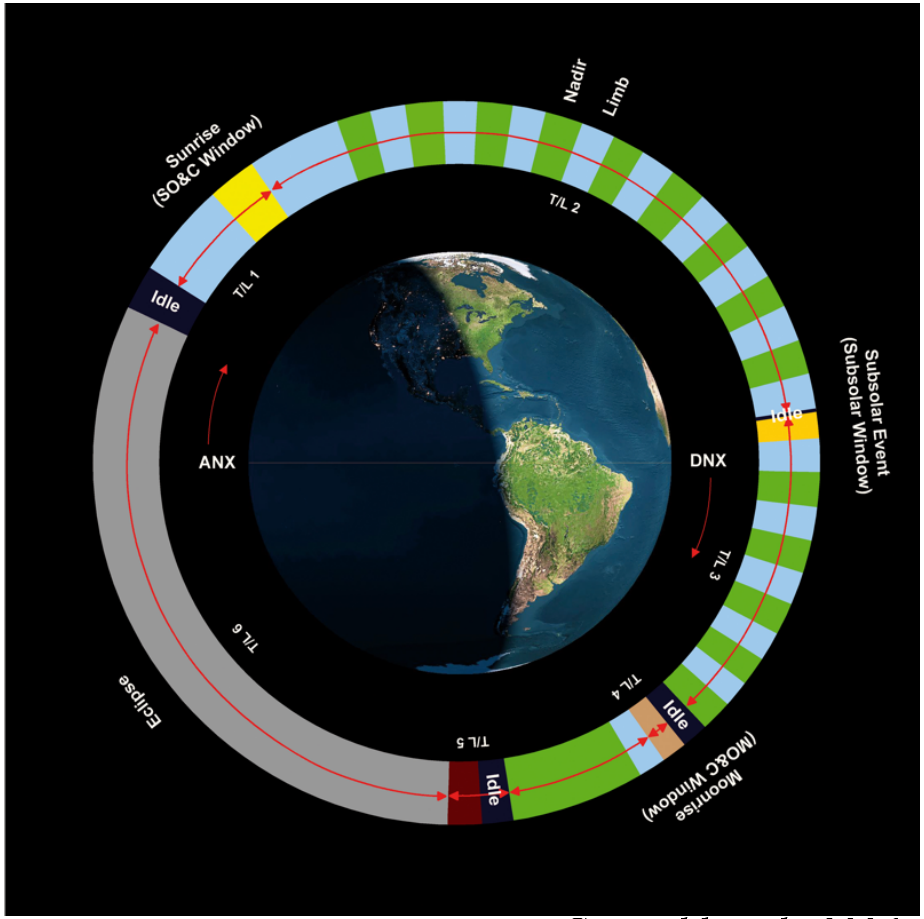


R. Salawitch

Questions from ARCTAS



http://www.iup.uni-bremen.de/sciamachy/

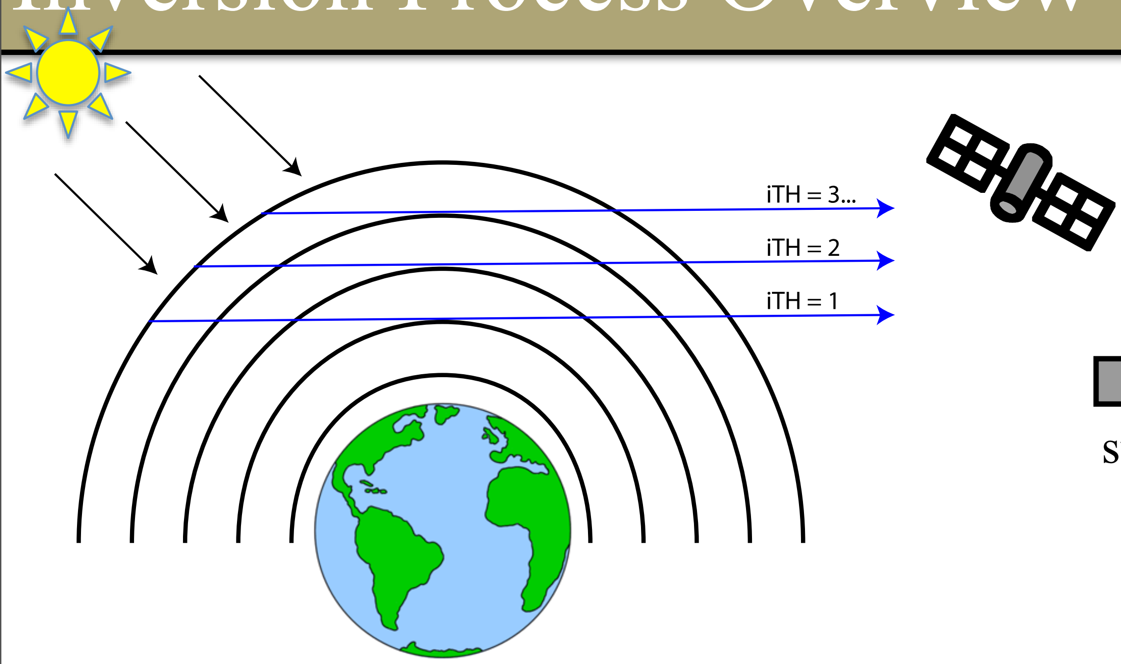


Gottwald et al., 2006

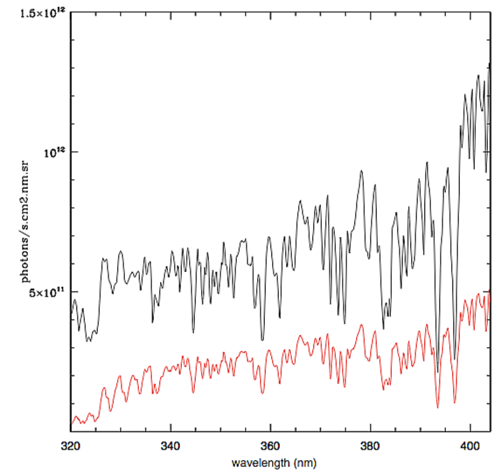
1. Can we see enhanced stratospheric BrO with SCIAMACHY limb?
   - Depressed tropopause events?
   - What do strat. BrO profiles look like during OMI nadir / in-situ measurement discrepancies?

2. How much of the nadir observations is tropospheric?

Inversion Process Overview



steps 1 & 2



steps 3 & 4

1. Calibrate the spectra

a. SCIA standard calibrations (-cal 0, 1, 2, 3, 4, 5)

b. Fit Radiance Reference spectrum (coadd 33 - 50 km):

get: (1) λ-shift, and (2) fit a gaussian slit function

2. Fit spectra: (each TH separately)

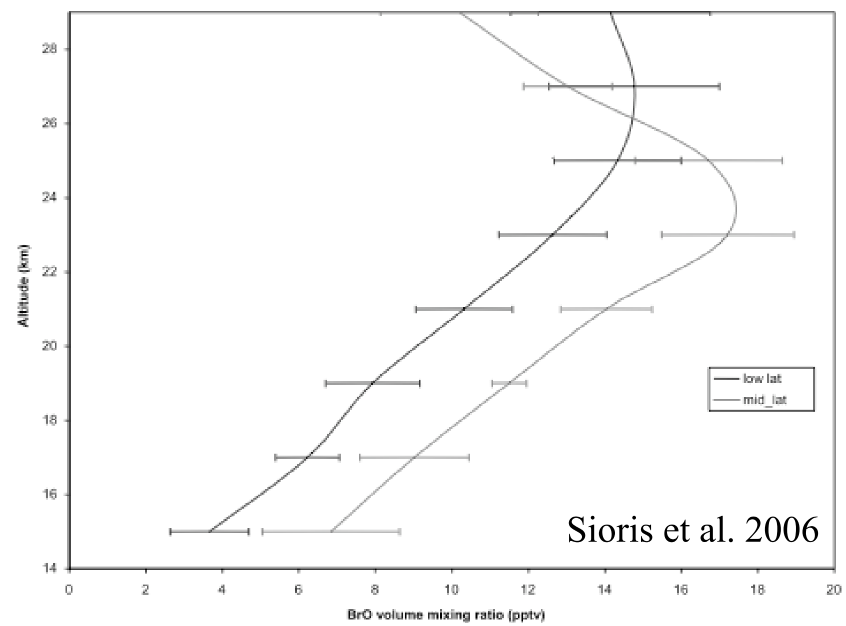
- Fitted **columns** fill the OE **y**, the variances fill diag. of $\mathbf{S}_y$

3. Get Jacobian:

- finite differencing using McLinden Limb RTM

4. Gauss-Newton Optimal Estimation:

- Applying a smoothing constraint to S_a to suppress oscillations (*Rozanov et al., in prep.*). 100% σ in a apriori.
- iterate till convergence (small $\Delta\chi^2$)



Sioris et al. 2006

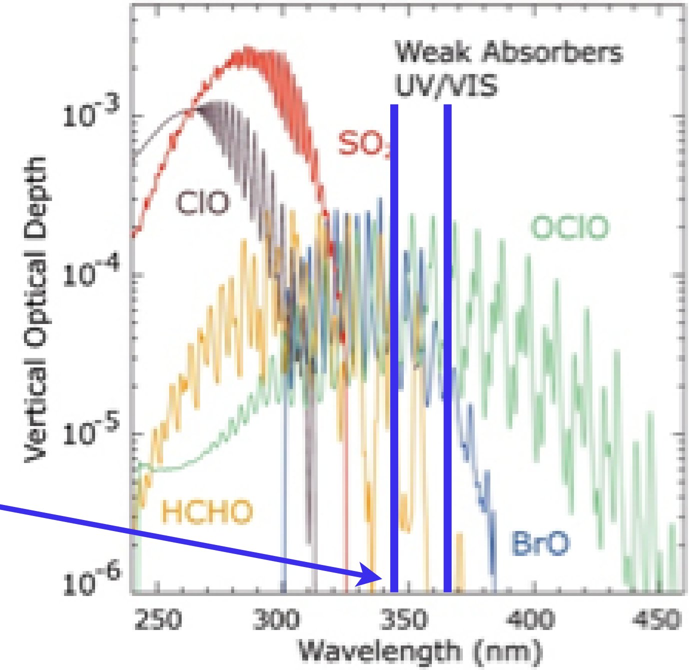
Algorithm: Spectral Fits

Step 1:

- Radiance Reference spectrum: 30 km - 50 km THs coadded
- fit against Kitt Peak synthetic Solar Reference:
  - calculate wavelength shift and instrument slit function (gaussian)

* Set up the basis functions based on *actual* λ-grid and resolution

K. Chance

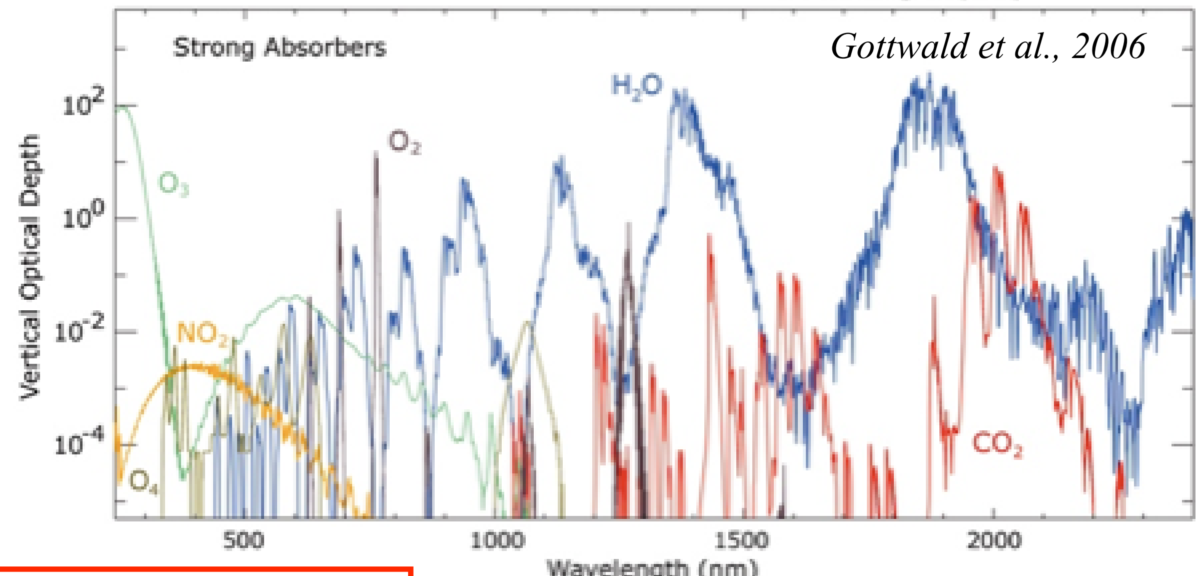


Our fitting window:
344 - 365 nm

Step 2:

Each TH using OMI operational code

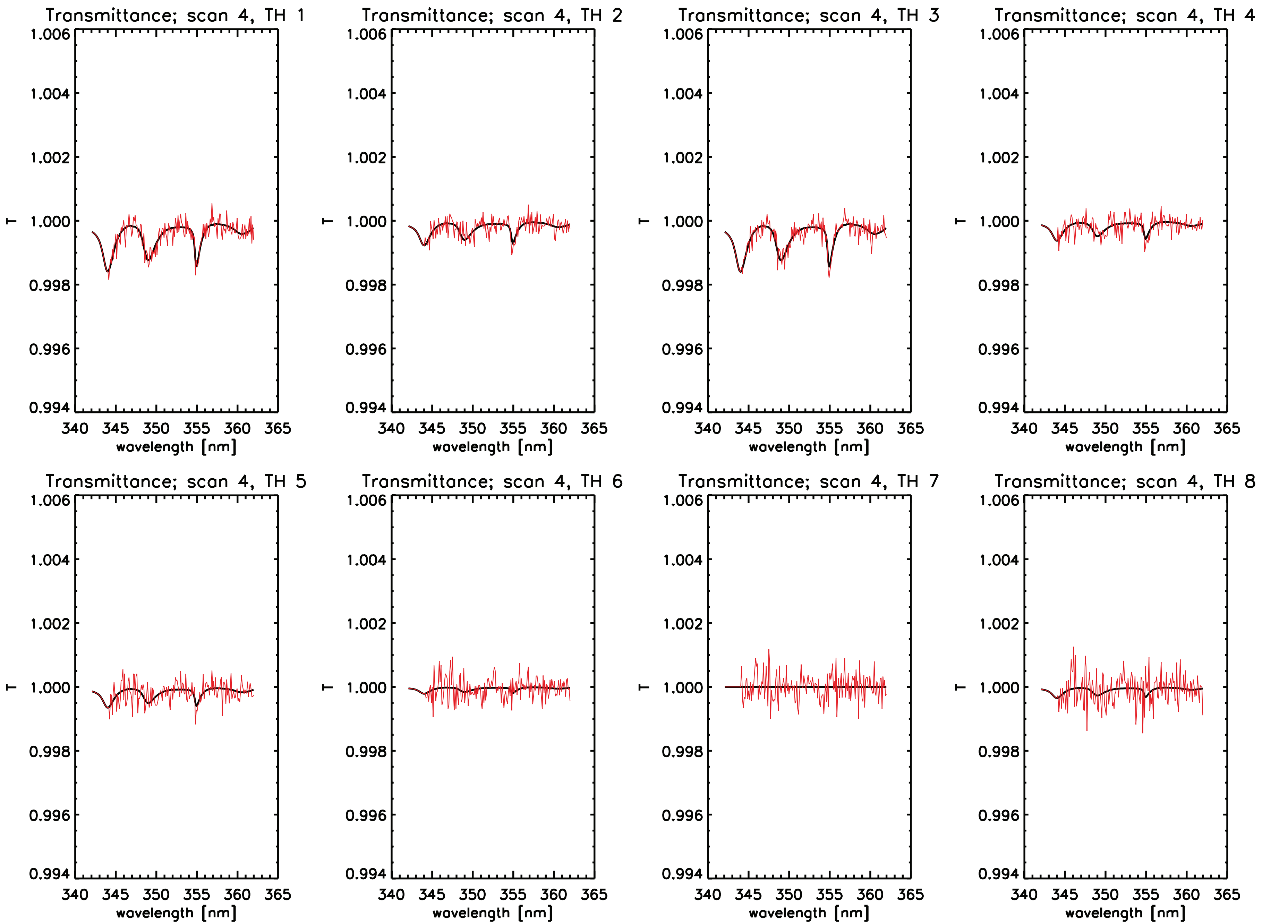
Nonlinear Least Squares Fit for SCD(TH)
BrO (Wilmouth, 228K)
O_3 (Brion, 218K)
NO2 (IASB, 220K)
O_4 (BISA, 294K)
Undersampling Basis Fn's
Rayleigh & Mie Scattering
Ring Effect
Common Mode



output → Column amounts and error

Example spectral fits:

Using Low TH Common Mode:



Algorithm: Calculating Jacobians

Finite differencing model output $$K(TH_t, BrO_{z_i}) \approx \frac{\Delta column_{TH_t}}{\Delta[BrO]_{z_i}}$$

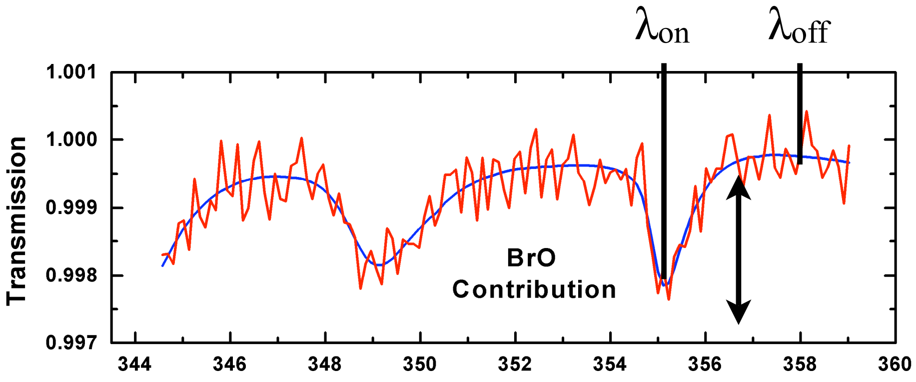
Radiative Transfer Model: VECTOR (*McLinden et al. 2002; 2006*)

- 3 orders of scattering
- if SZA > 75°, treat diurnal effect (*McLinden et al. 2006*)
- ** no polarization or aerosols treated in this version of data
- Pressure and Temp. from GEOS-5 assimilated data (4°x5° res.)
- O_3 from McPeters et al. Climatology
  - We can retrieve O_3 well in this window too. Future work will include this in online BrO retrieval

Simulate radiance for two wavelengths ⟶ approximate column Jacobian (*Haley et al. 2004*)

$$c(h_t) \approx \frac{\ln\left[\frac{I_0(\lambda_{off})}{I(\lambda_{off},h_t)}\right] - \ln\left[\frac{I_0(\lambda_{on})}{I(\lambda_{on},h_t)}\right]}{\sigma(\lambda_{off}) - \sigma(\lambda_{on})}$$

Haley et al. (2004)



plot from K. Chance

Computational Advantage:
* you run RTM n + 1 times for K.
Each of these times, calc. for 2 λ's instead of ~300.

No-Noise Test Retrieval

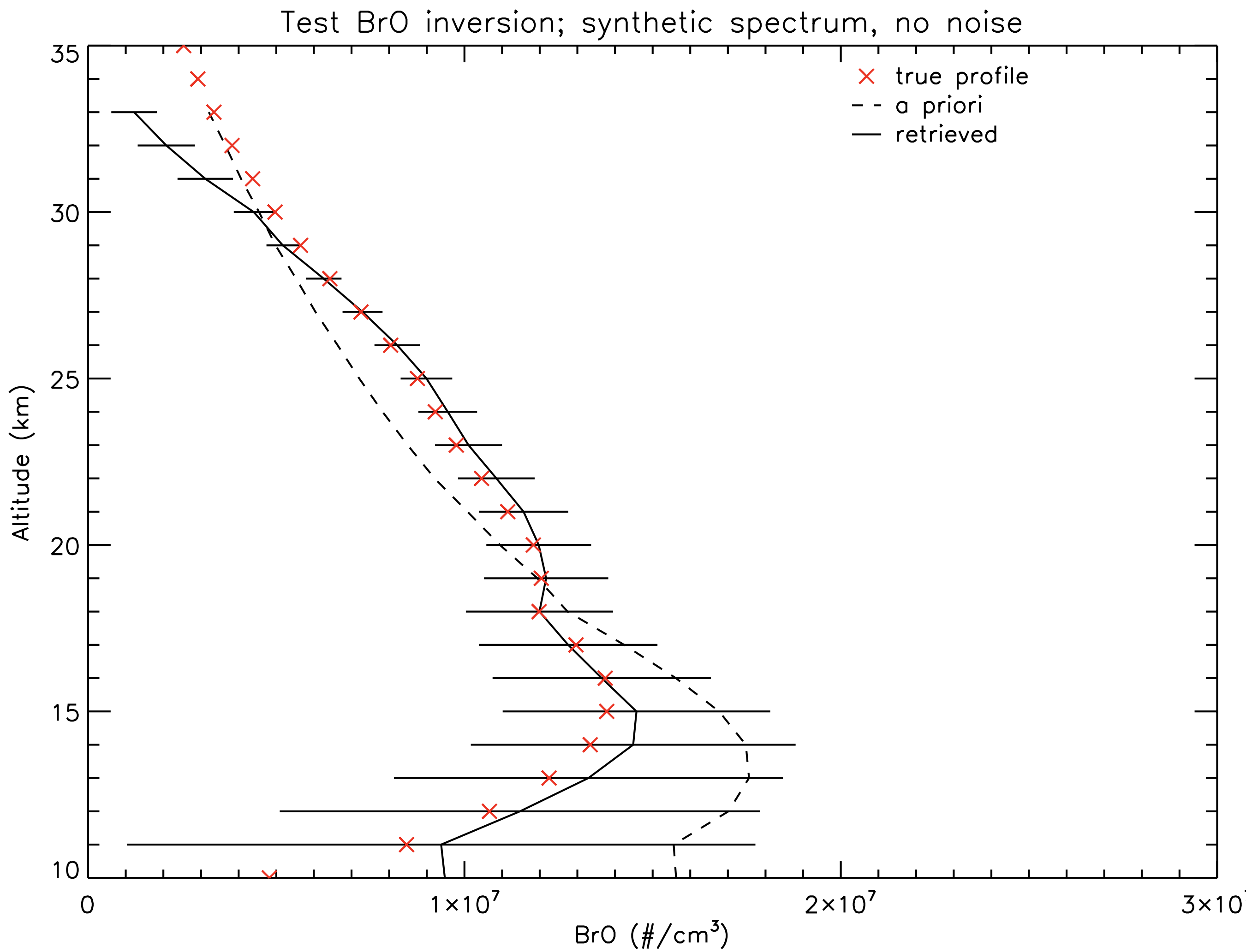
McLinden RTM

↓ Radiances w/ true profile

Spectral Fitting with ELSUNC

↓ Fitted slant columns

OE iteration with Jacobians from McLinden RTM



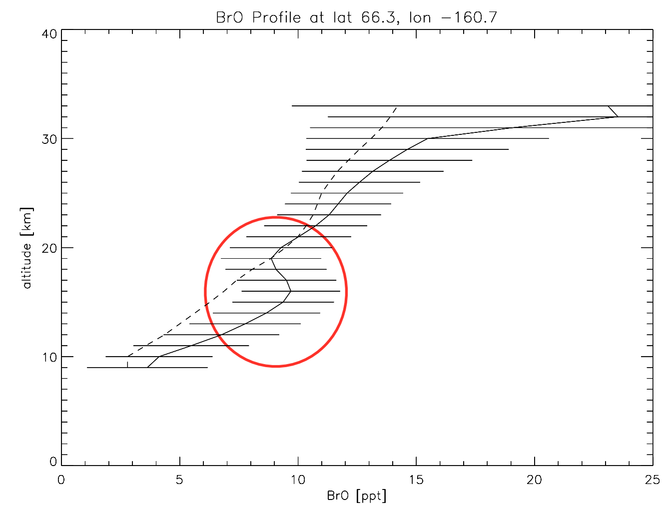
Treatment of the Actual Retrievals

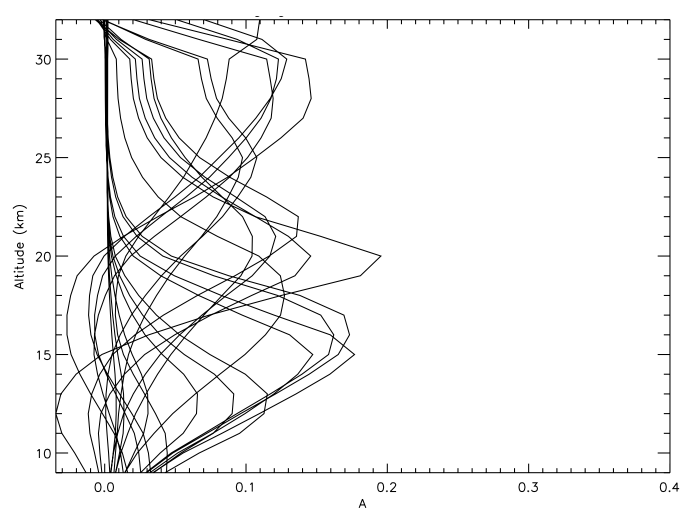
Q: Data Quality. How Best to filter bad spectra/data

<u>Currently:</u> (we need more!)
- South Atlantic Anomaly
- Ascending portion of orbit
- All measurement TH's between 8 and 33 km go into retrieval.

<u>Planned:</u>
- RMS of spectral fits?
- Cloud filtering
  - PSC "color" threshold (*von Savigny et al., 2005*)
  - Large convective clouds
- Other?

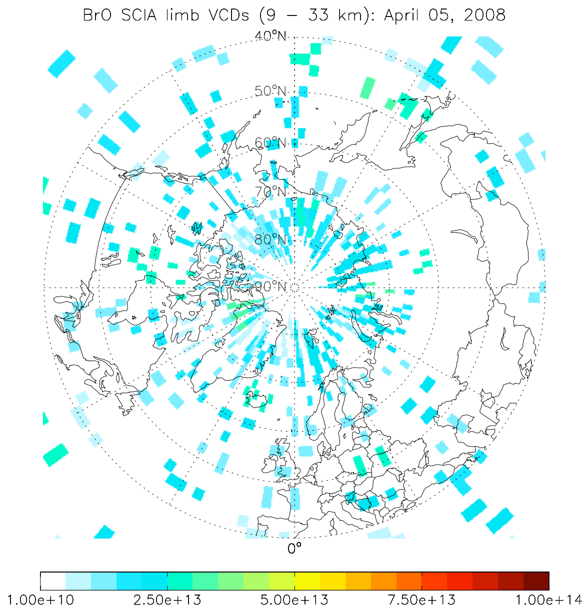
Q: Can we see lower stratospheric BrO enhancements from SCIA limb?



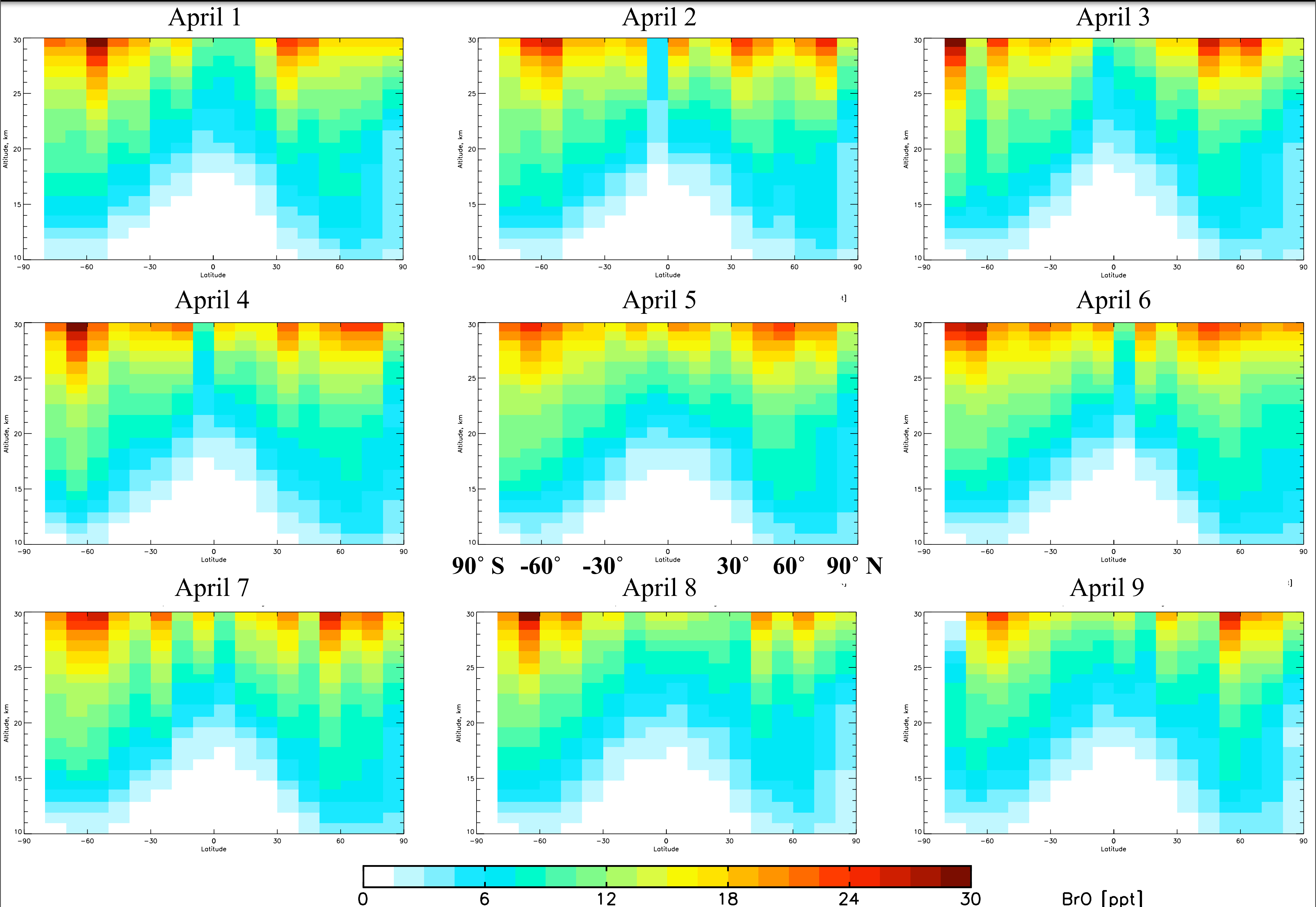


Q: How much of the nadir measurements are in the troposphere?

Integrate SCIA limb retrievals for stratospheric columns. Compare to nadir (OMI for now)



1. Prelim. Data: zonal averages, April 2008



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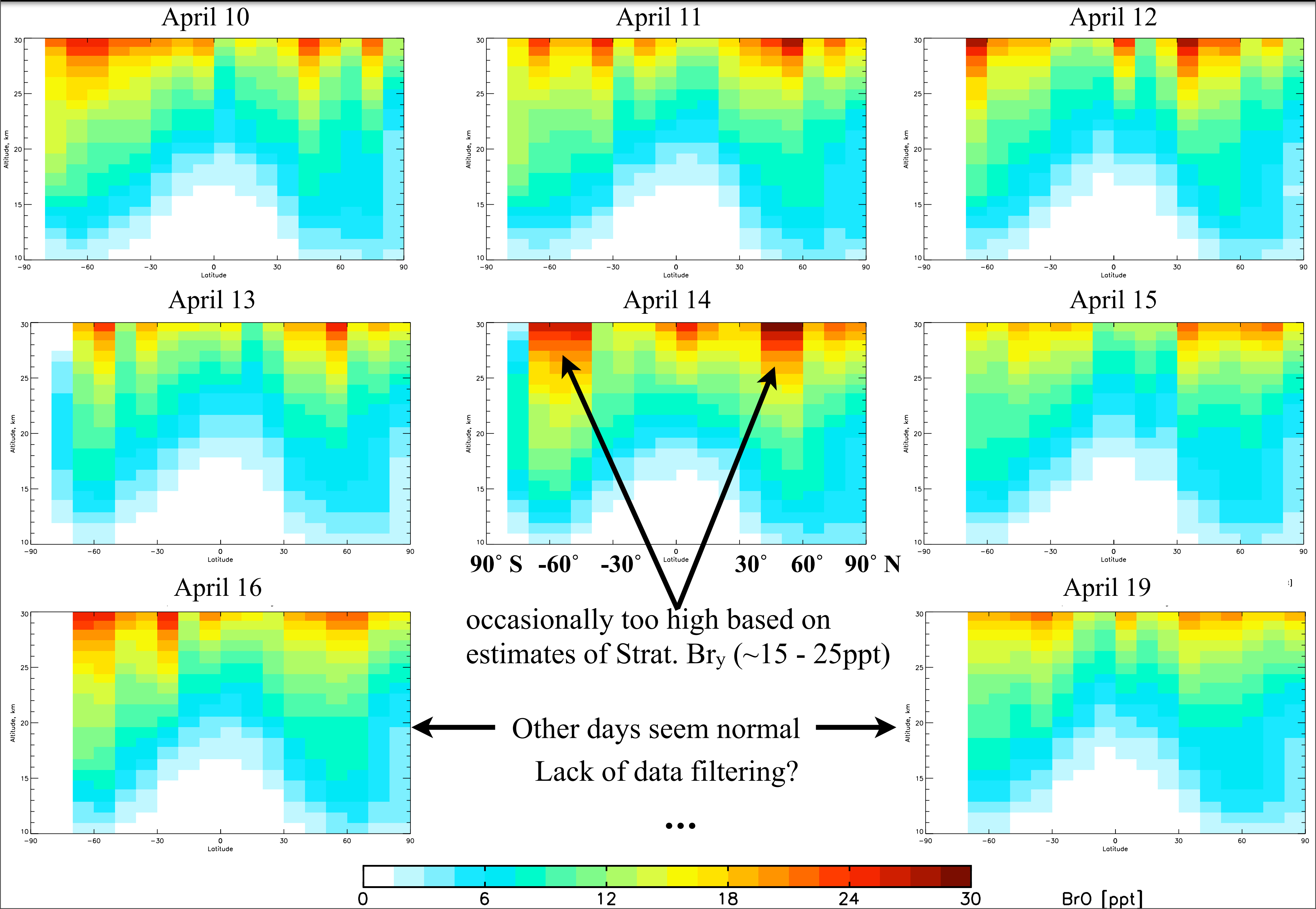


Soon to come: Comparing OMI and SCIAMACHY

Challenges:

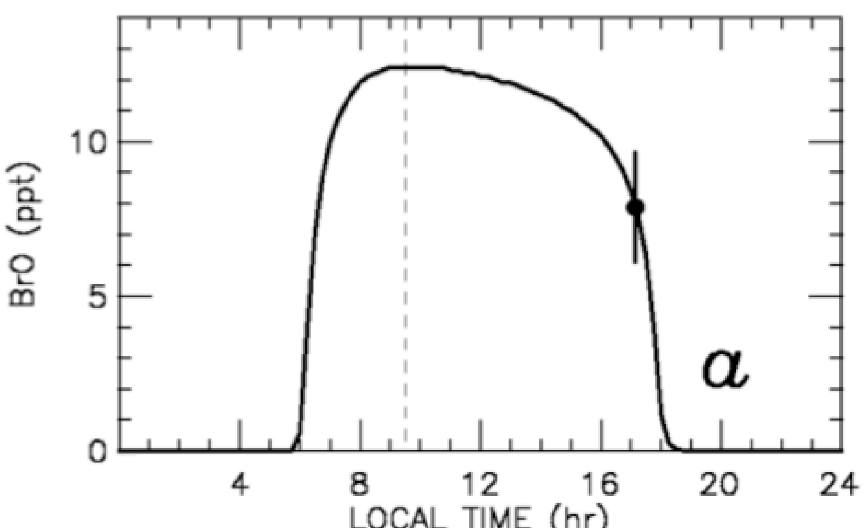
1. OMI and SCIA have different overpass times
2. BrO strong diurnal variation

Plan A:

1. Adjust the SCIA data to OMI's 1:30 overpass (~3hr difference)

Plan B:

1. Start at pixel level & scale to a dummy SZA.
2. Bin processed SCIA and OMI data to common grid using Tessellation routine.



C. Sioris et al., 2006

T. Kurosu, pers. comm.