Variability of OH in the middle and upper stratosphere

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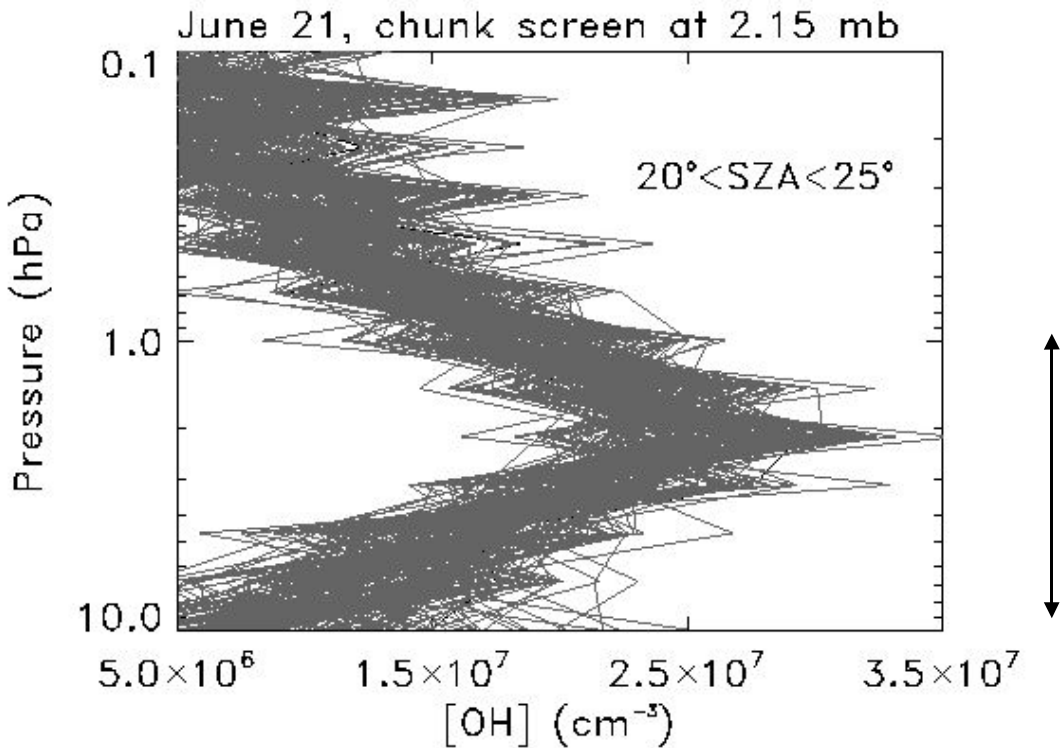
Brief Description: MLS observations of OH, O_3, and H_2O are used to test our understanding of the daytime HO_x budget of the middle and upper stratosphere.

Sample OH profiles from version1.51 retrievals



10 to 1.0 hPa,
near region of maximum
in OH concentration

Key MLS measurements and conditions:
OH, H_2O, O_3, SZA (solar zenith angle)

Time frame: June - July 2005. Months with smallest SZA, typically 15-30°.

One Scenario for OH Variability:

Production of HO_x is primarily through $O^1(D) + H_2O$

Loss is primarily through $OH + HO_2$ (leads to square root)

$$[OH] \propto \{ [O^1(D)][H_2O] \}^{1/2}$$

Also, the amount of O1(D) is proportional to

$$[O^1(D)] \propto J_{O3}[O_3] \propto \exp\{-\sigma_{O3} N_{O3} sec(\theta)\}[O_3]$$

where σ_{O3} = mean ozone cross section

N_{O3} = overhead column of ozone

θ = sza

Then

$$\delta[OH]/[OH] = \tfrac{1}{2} \Big\{ \delta[H_2O]/[H_2O] + \delta[O_3]/[O_3] - \tau_{O3}\delta N_{O3}/N_{O3} - \tau_{O3}\delta sec(\theta)/sec(\theta) \Big\}$$

This simple analysis suggests...

fractional changes in OH should be one-half as large as fractional changes in H_2O and O_3 (with the same sign),

and

fractional changes in OH should be one-half as large as fractional changes in the O_3 column and $sec(\theta)$ (with opposite sign).

Typical variations for MLS measurements in upper stratosphere, based on June daytime data (~40,000 profiles):

- $sec(\theta)$: ranges from 1 to ∞ (largest impact on OH)
- O_3: ~50% variation (~25% effect on OH)
- NO_3: ~40% variation (~20% effect on OH)
- H_2O: ~18% variation (~9% effect on OH)

Data processing details:

All data:

- Positive precision
- Even status

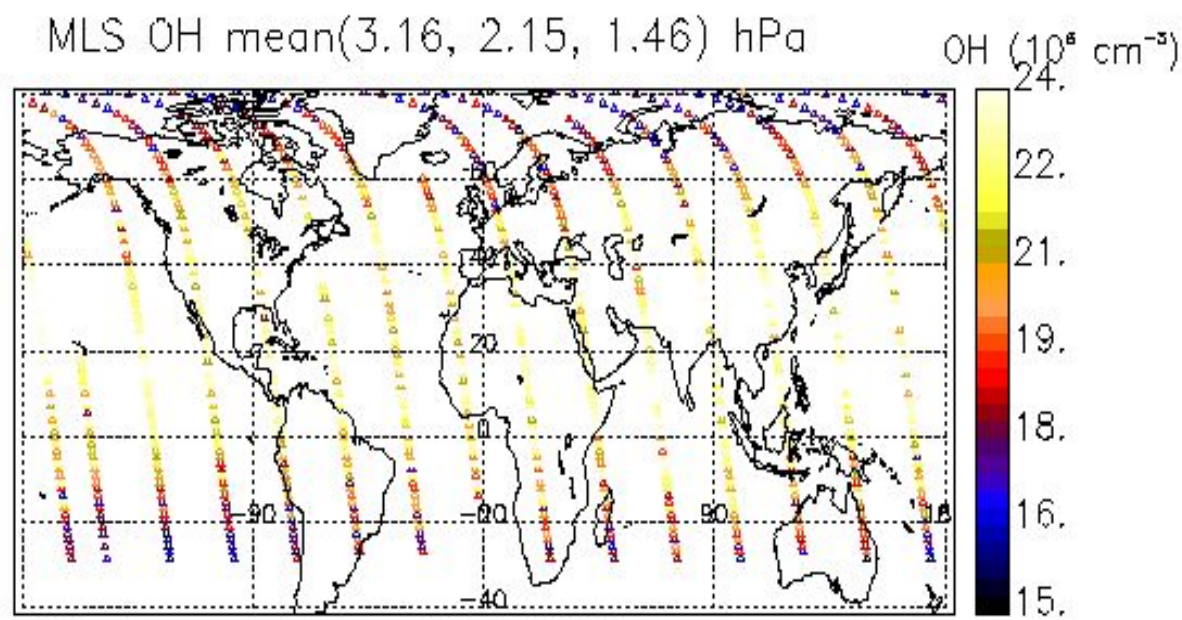
OH:

- Chunk convergence
- Quality ≥ 0.5

O_3: Quality ≥ 0.1

H_2O: Quality ≥ 0.02

Temperature: Quality ≥ 1.0



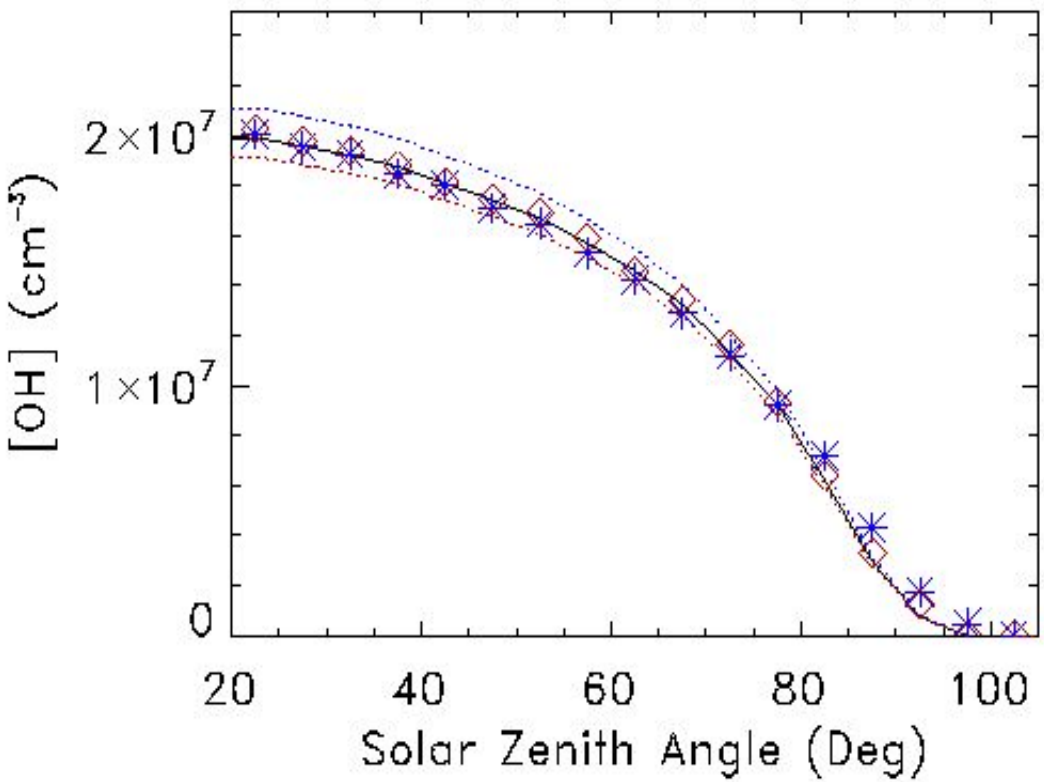
Average dependence on SZA, P=2.15 hPa

Solid curve: mean OH for data where H_2O is within 0.5σ of mean H_2O

Blue stars: mean OH for H_2O greater than 0.5σ above mean H_2O

Red triangles: mean OH for H_2O less than 0.5σ below mean H_2O

Blue and Red dotted curves: Predicted variation from solid curve based on changes in H_2O



Variation with respect to SZA is consistent with expected for ozone optical depth ~ 1 (see next page)

Expect about 10% P-to-P amplitude about mean due to changes in H_2O, but generally not observed

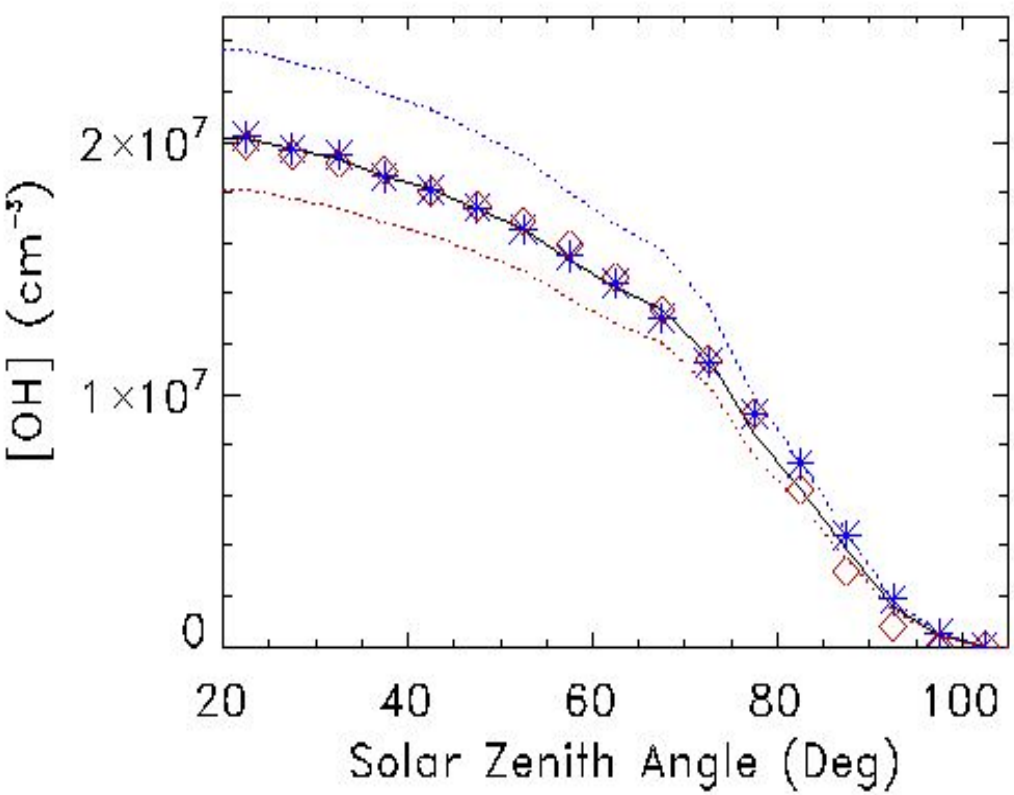
Dependence on SZA, part 2

Solid curve: mean OH for data where O_3 is within 0.5σ of mean O_3

Blue stars: mean OH for O_3 greater than 0.5σ above mean O_3

Red triangles: mean OH for O_3 less than 0.5σ below mean O_3

Blue and Red dotted curves: Predicted variation from solid curve based on changes in O_3. Amplitude is larger than in previous page because $\delta O_3/O3$ is about twice as large compared with H_2O.

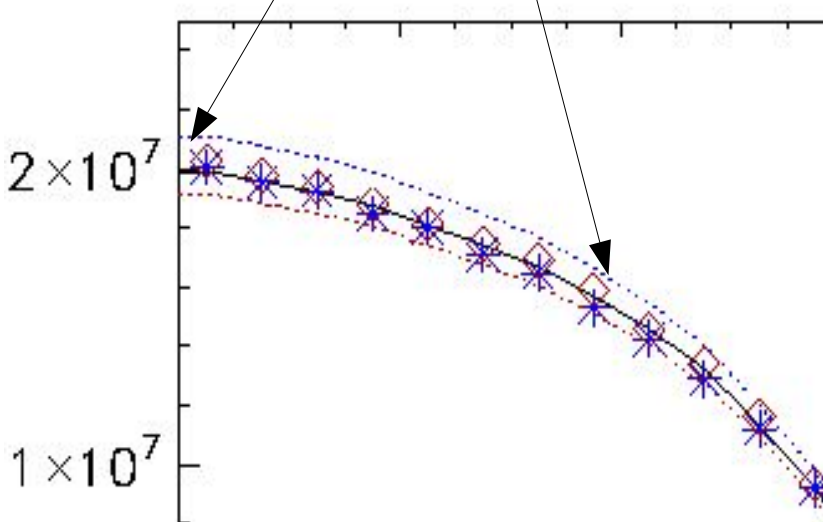


Expect about 20% P-to-P amplitude based on ozone changes, not seen here.

Likely cancellation effect from correlation between local O3 and overhead column O3

Decrease in OH from SZA=20º to SZA=60º is about 28%.

The corresponding increase in sec(SZA) is 62%.



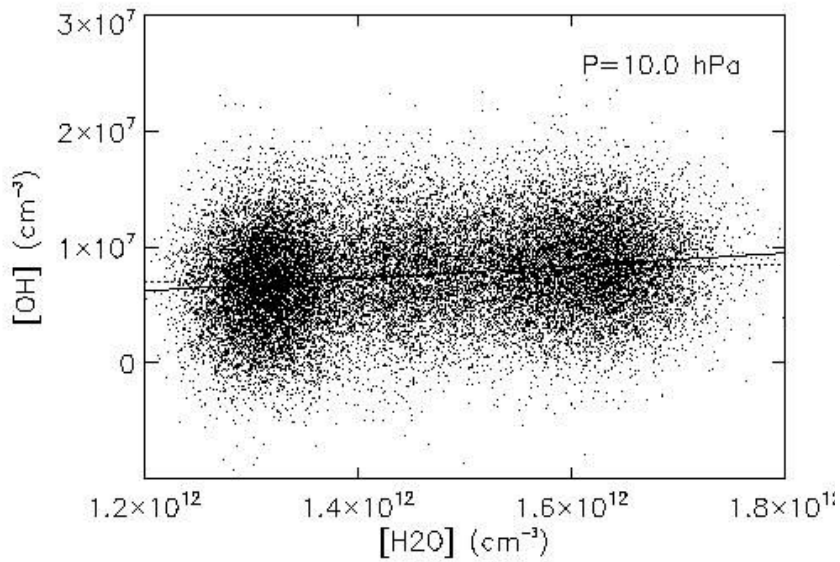
Simple radiative transfer suggests that most of the ozone photolysis occurs around conditions where $\tau_{O3} \sim 1$.

Based on

$$\delta[OH]/[OH] = \tfrac{1}{2}\left\{-\tau_{O3}\,\delta sec(\theta)/sec(\theta)\right\},$$

we find that the data are consistent with this relation if τ_{O3} is about 0.9 (or close to one!)

Dependence on O_3, H_2O, N_{O3} --- 10 hPa pressure level

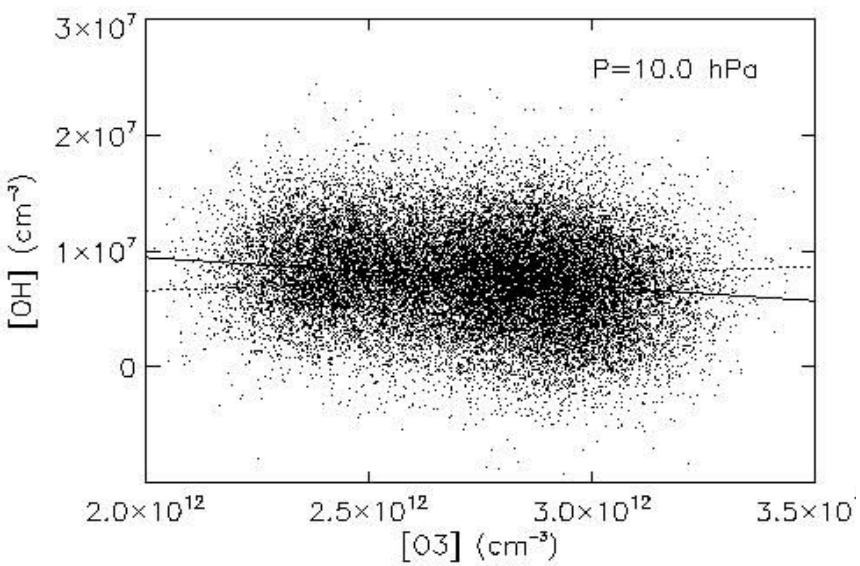


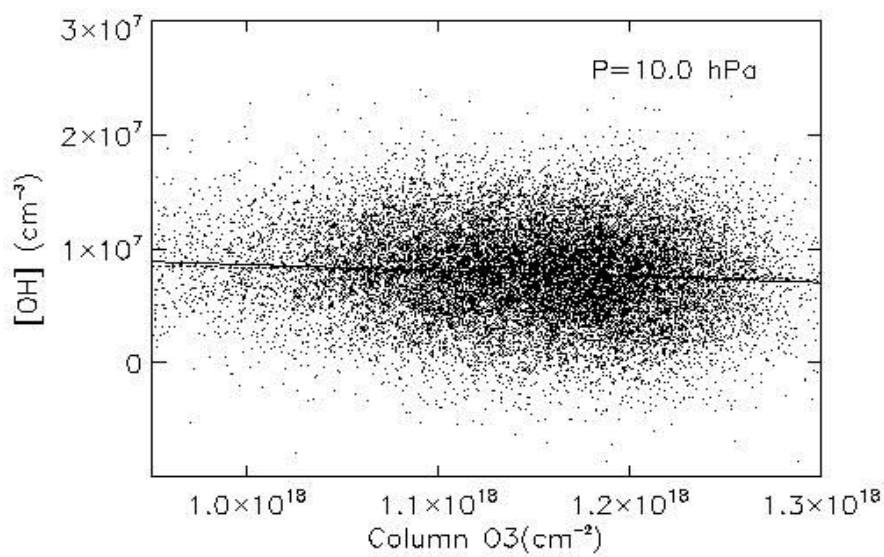
- Data pts from individual profiles where SZA<40°
- Solid lines are linear regressions
- Dotted lines are predicted correlations

Water vapor: positive correlation (r = 0.19, N~24,000), close to expected slope

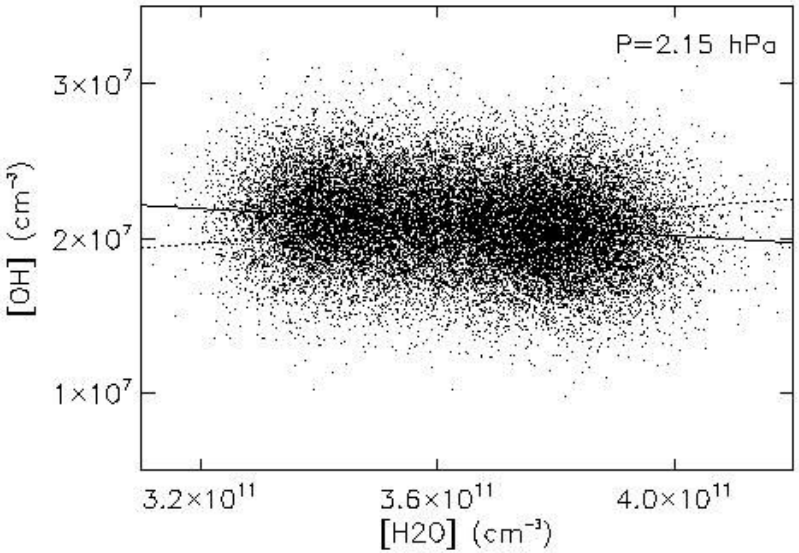
Ozone: *negative* correlation (r=-0.16)

Column ozone: negative correlation (r=-0.09), slope is very close to expected.





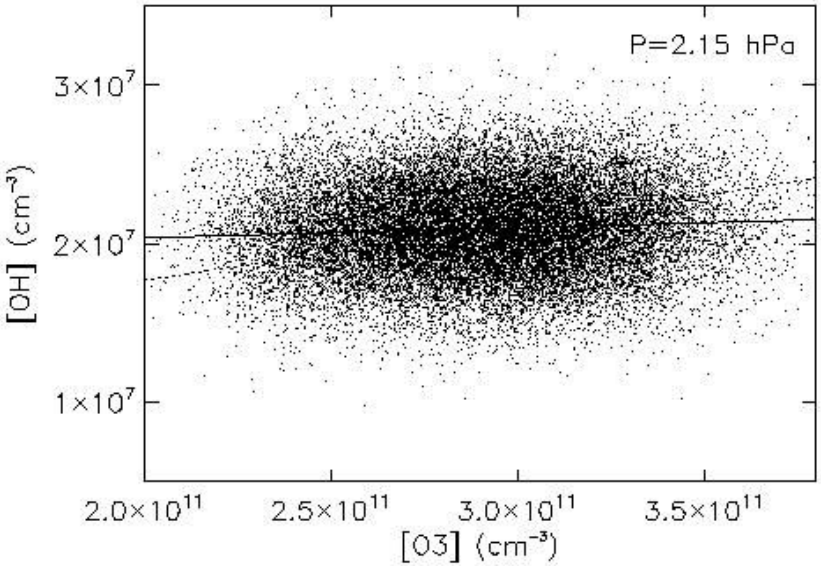
Dependence on O_3, H_2O, N_{O3} --- 2 hPa pressure level



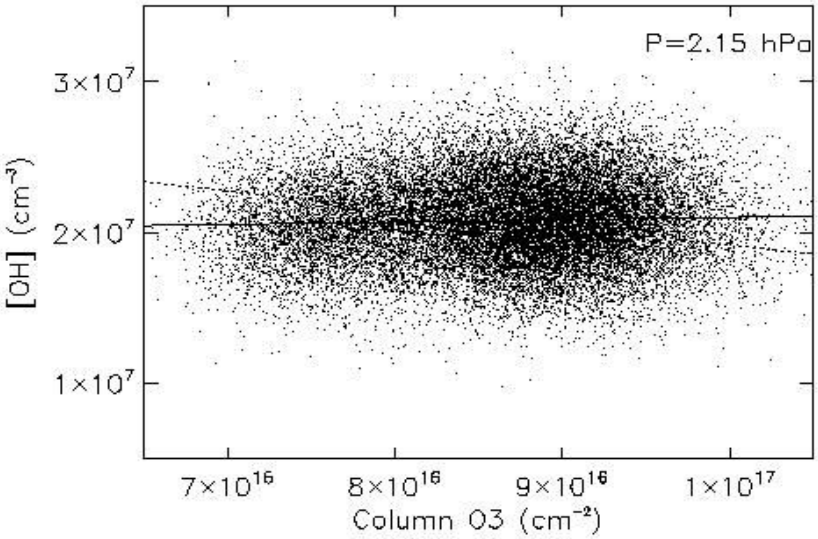
- Data pts from individual profiles where SZA<40°
- Solid lines are linear regressions
- Dotted lines are predicted correlations

Water vapor: *negative* correlation (r = 0.15, N~24,000)

Ozone: weak positive correlation (r=0.07) but slope is much smaller than expected



Column ozone: no significant correlation



Preliminary Conclusions

- OH behaves very much as expected with respect to solar zenith angle.
- Variation of OH with H_2O and column O_3 is in good agreement with photochemical prediction at 10 hPa.
- Appears to be some cancellation between effect of local ozone and overhead column ozone at 10 hPa.
- Variations at 2 hPa appear to conflict with predictions.

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