

# Mapping the Oxidizing Capacity of the Global Remote Troposphere

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# Systematic Biases in Global Hydroxyl

Chemical proxies (e.g. methyl chloroform) tell us that models get OH wrong...

## Methane Lifetime

Observations:  $11.2 \pm 1.3$  y

Global models:  $9.7 \pm 1.5$  y

## N/S Hemisphere Ratio

Observations: 0.85 - 0.98

Global models:  $1.28 \pm 0.10$

*Naik et al. (2013); Prather et al. (2012);  
Montzka et al. (2000); Patra et al. (2014)*

# Wanted: New OH Constraints

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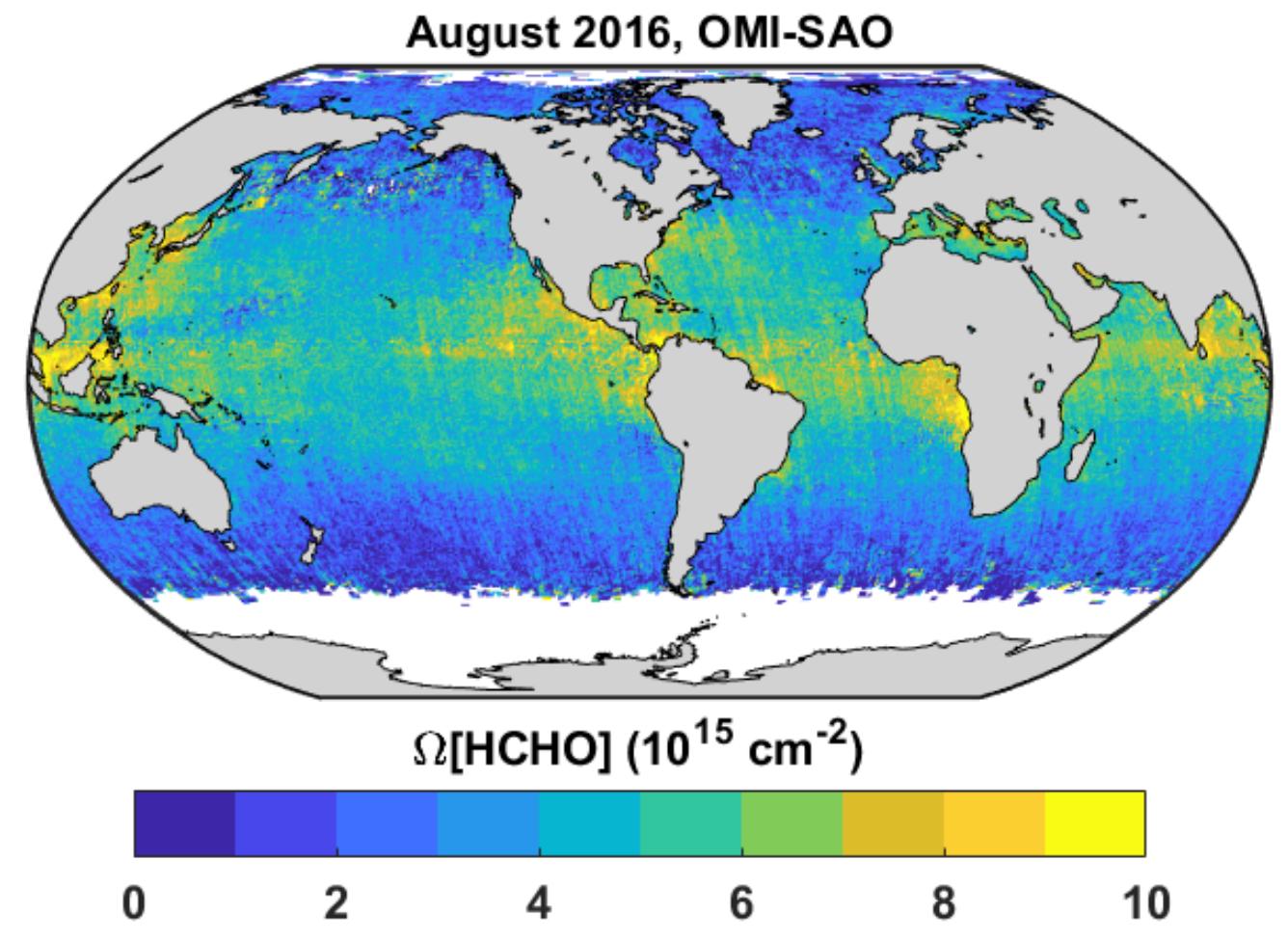
...but such constraints are annual and global/hemispheric at best.

- Seasonal cycles?
- Anthropogenic perturbations?
- Lightning? Wildfires? El Niño?

To build process-level understanding, we need to know how OH varies in space and time.

# Formaldehyde (HCHO)

- Product of OH + CH<sub>4</sub> (and every other hydrocarbon)
- Atmospheric lifetime ~hours (lost via photolysis and OH)
- Observable via UV/Vis solar scatter (total column)



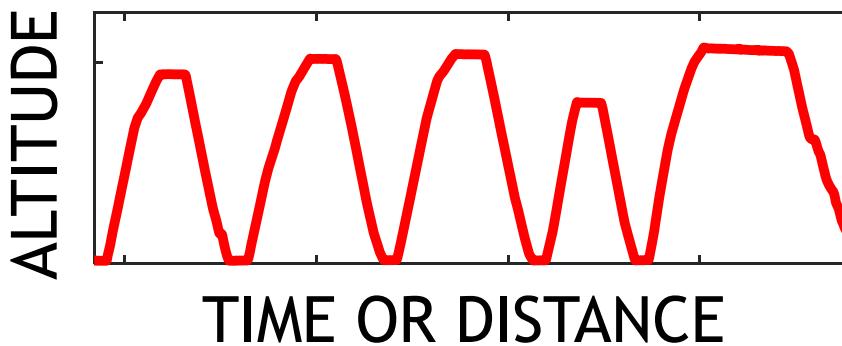
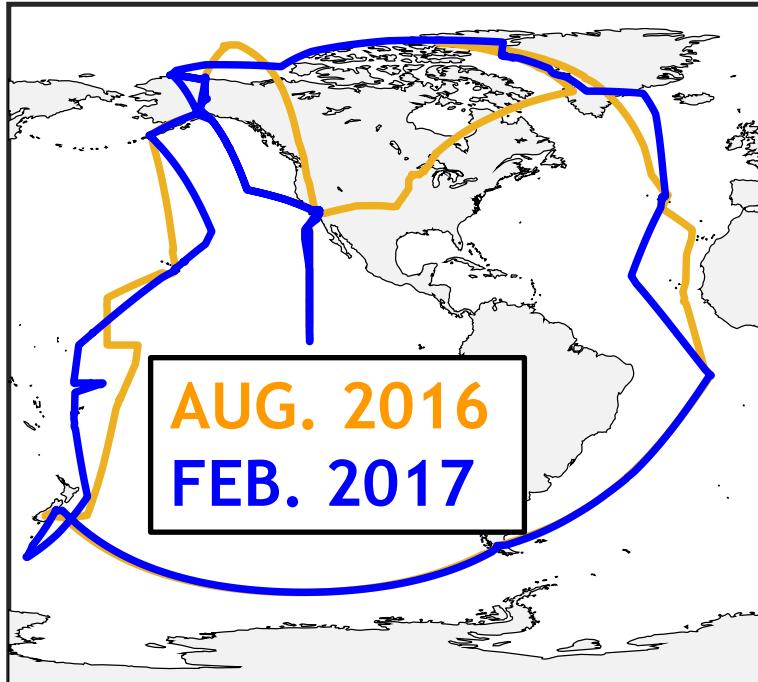
# Recipe for Constraining Near-Global OH

What is the link between  
 $\Omega[\text{HCHO}]$  and  $\Omega[\text{OH}]$ ?

Is OMI  $\Omega[\text{HCHO}]$  valid in  
remote regions?

Map of remote  
tropospheric  
column OH

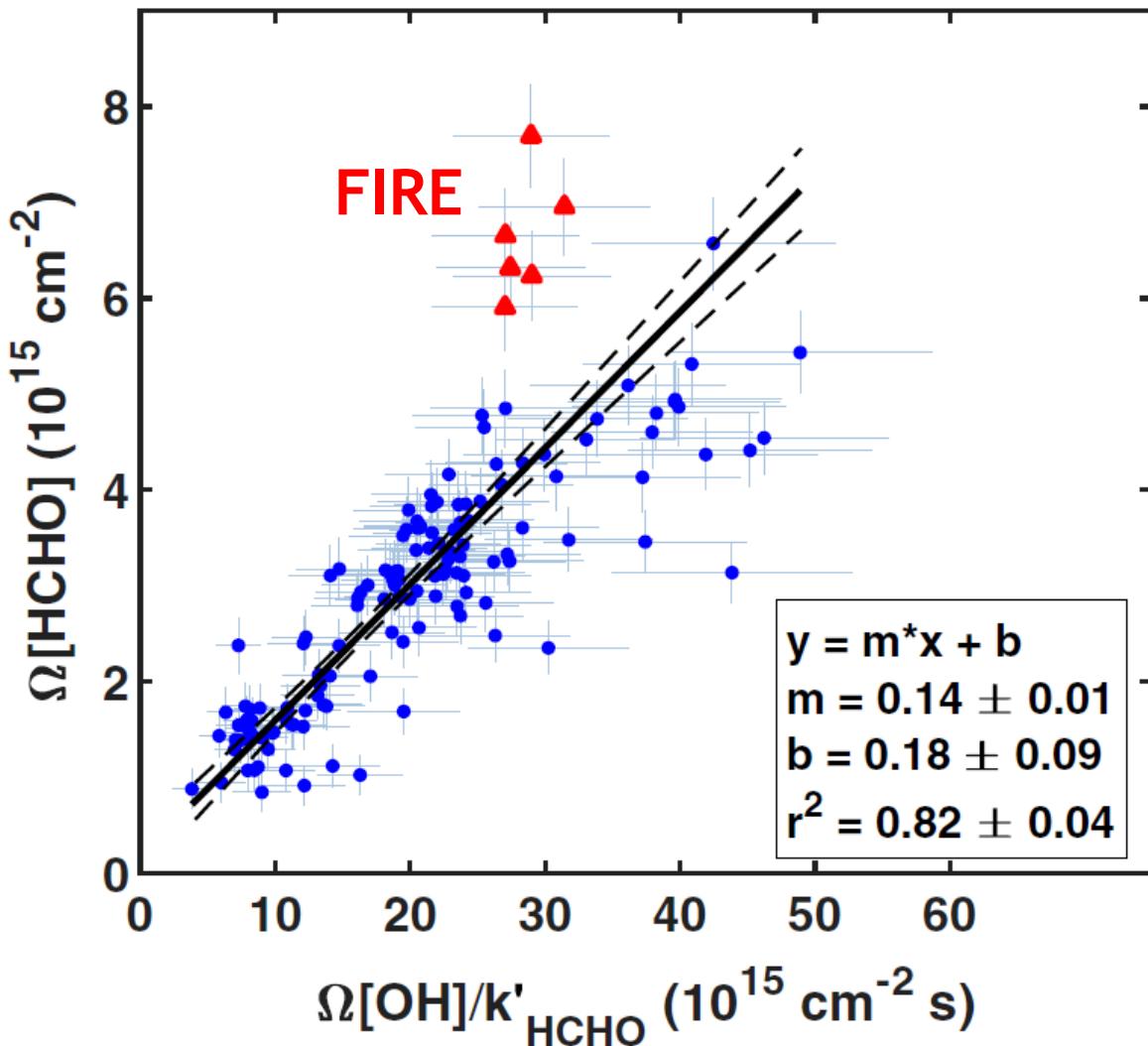
# The Atmospheric Tomography Mission (ATom)



NASA DC-8 with *in situ* chemistry payload,  
including HCHO, OH, and friends

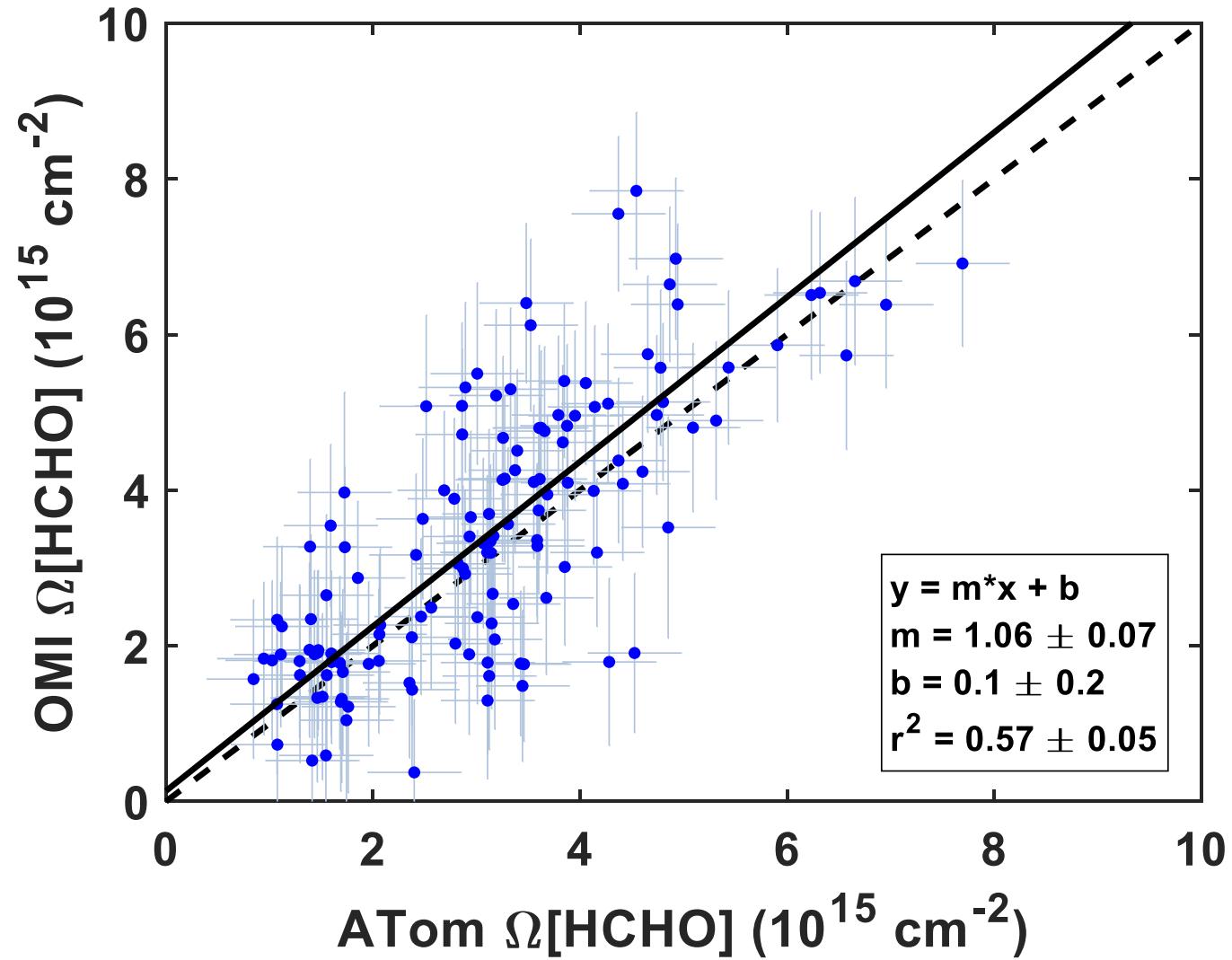


# $\Omega[\text{OH}]$ and $\Omega[\text{HCHO}]$ Production/Loss Correlate

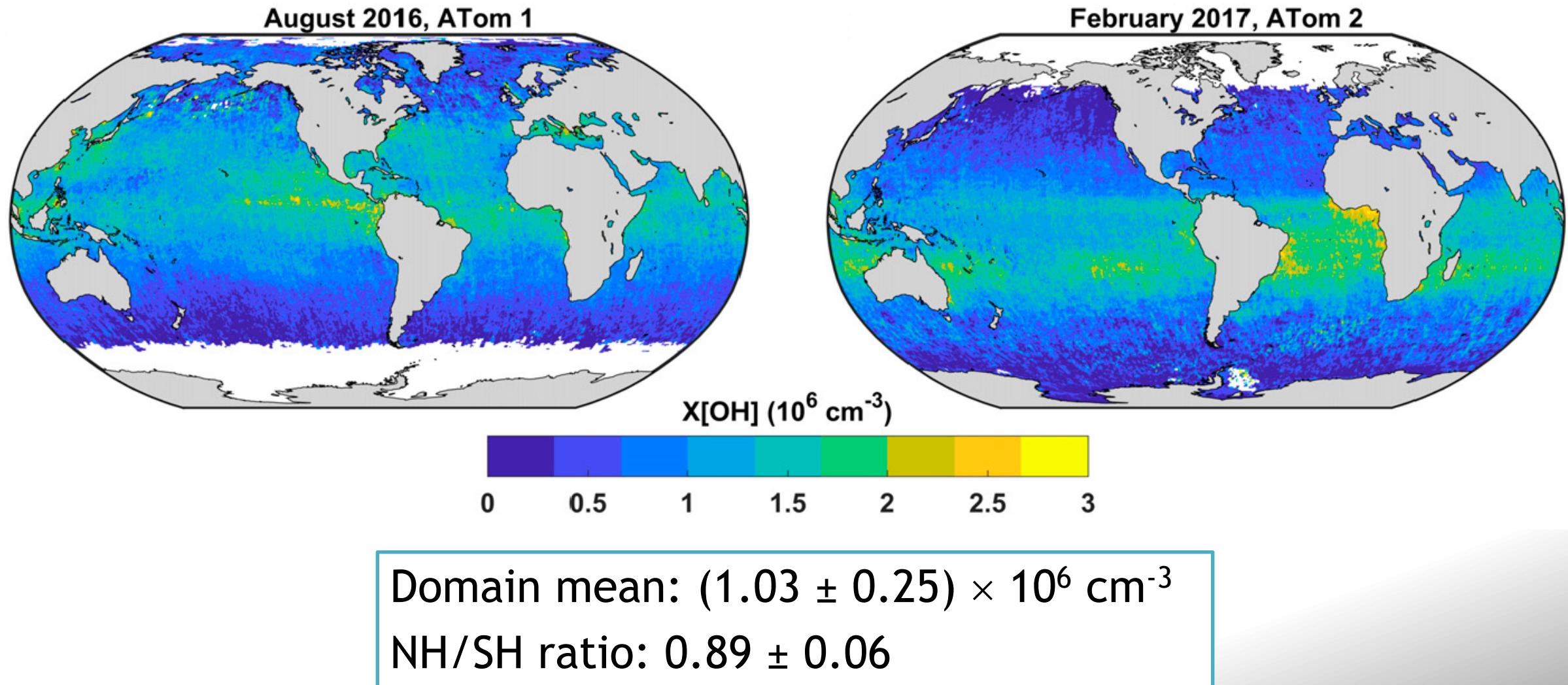


- Steady-state theory predicts a pseudo-linear relationship between OH concentrations and HCHO production/loss rates
- Slope depends mainly on OH sink distribution (CO, CH<sub>4</sub>, other VOC)

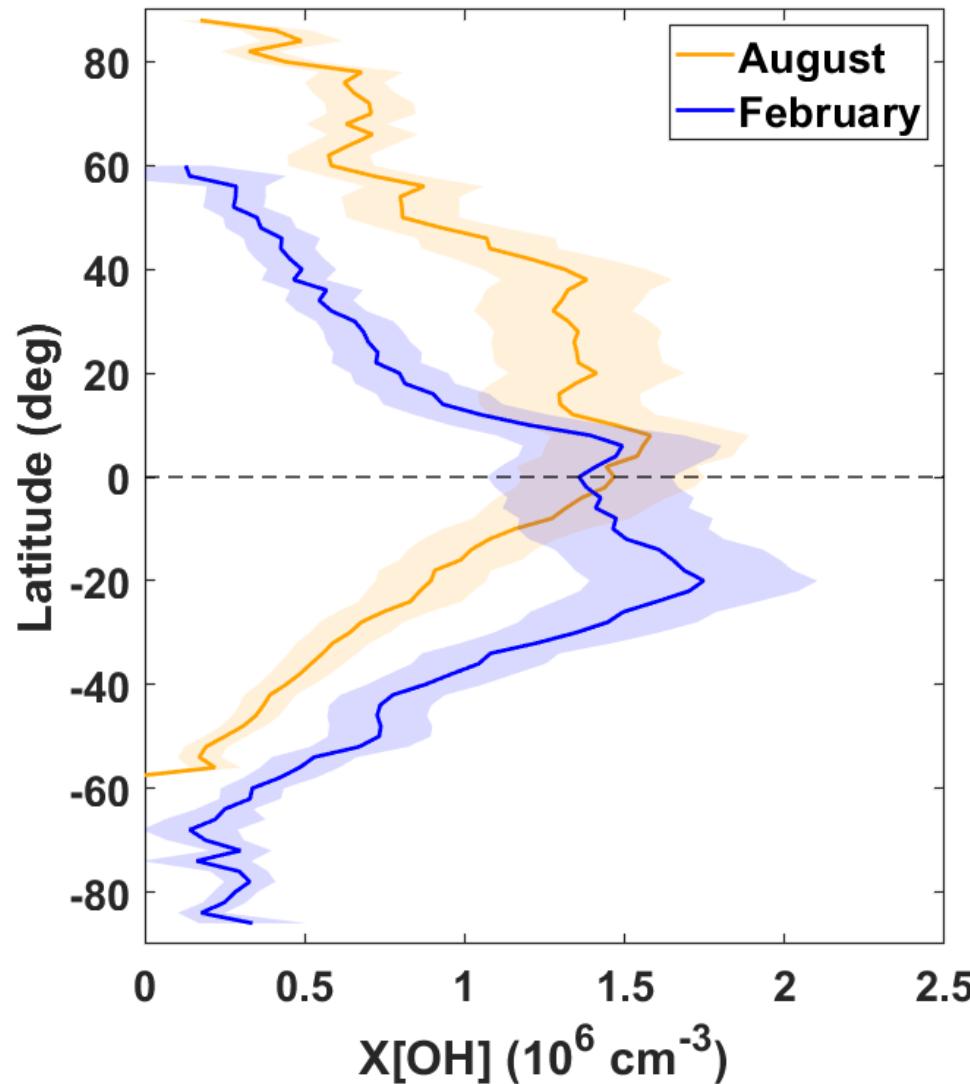
# OMI-SAO $\Omega[\text{HCHO}]$ is Valid in Remote Regions



# $X[OH]$ : Monthly Tropospheric Mean Concentration



# Hemispheric Seasonality & Global Buffering



Individual hemispheres exhibit  
strong seasonality

*but*

“Global” average  $X[OH]$  is  
identical in both seasons

# Take Away

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- HCHO and OH are tightly coupled throughout the troposphere
- We can, and will, do better in the future
  - Satellite HCHO retrieval differences
  - Scaling factor dependence on CO, hydrocarbons, etc.
  - Expansion across the OMI record (2004 - now)

X[OH] offers spatial and temporal variability!

*For the full story, see [Wolfe et al., PNAS \(2019\)](#)*

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# EXTRA

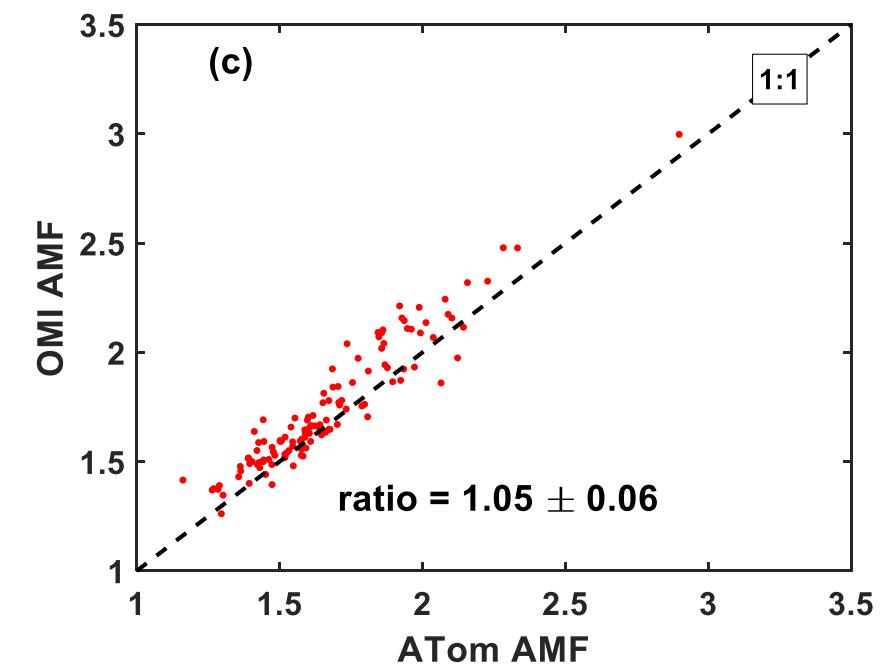
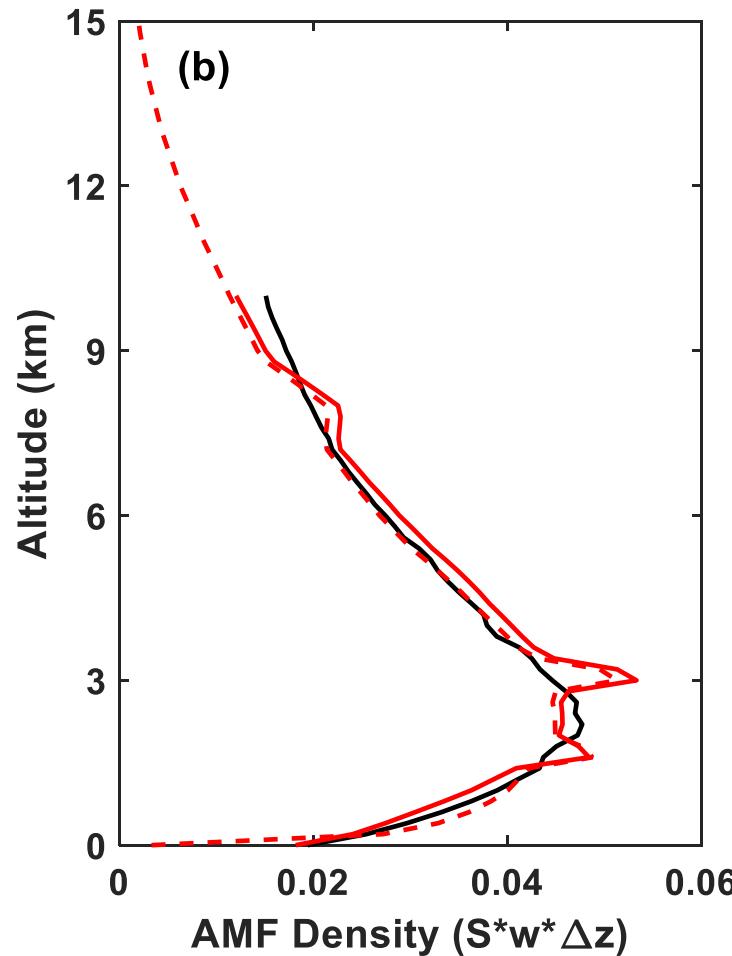
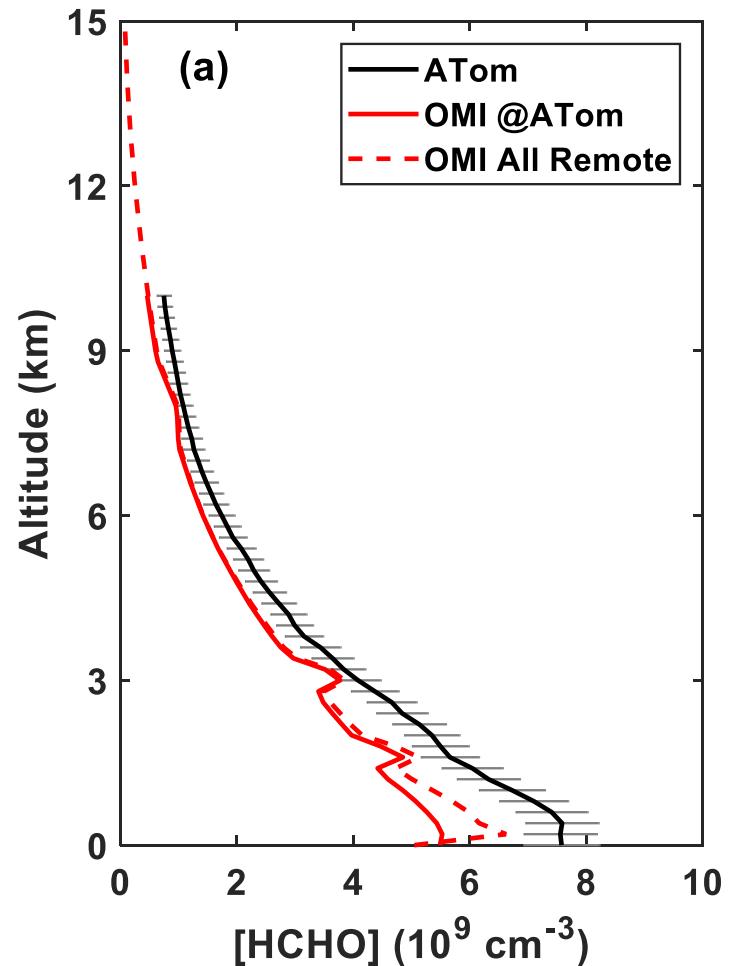
# Column Pseudo-Linear Model



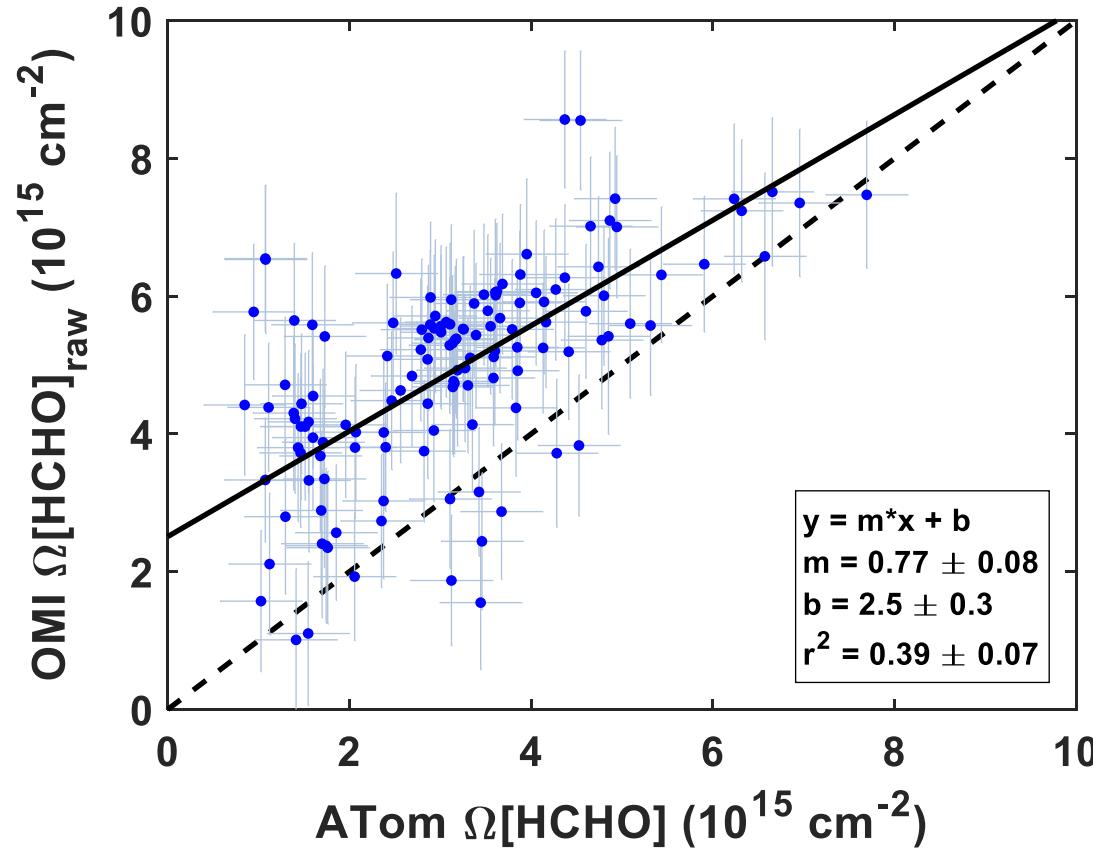
$$\Omega[\text{HCHO}] = s_{\text{OH}} \left( \frac{\Omega[\text{OH}]}{k'_{\text{HCHO}}} \right) + \Omega[\text{HCHO}]_0$$

- Slope ( $s_{\text{OH}}$ ) depends on OH sink distribution (CO, CH<sub>4</sub>, other VOC) and should not vary much in remote regions
- $k'_{\text{HCHO}}$  depends weakly on OH, but photolysis is dominant HCHO sink

# OMI AMF Evaluation

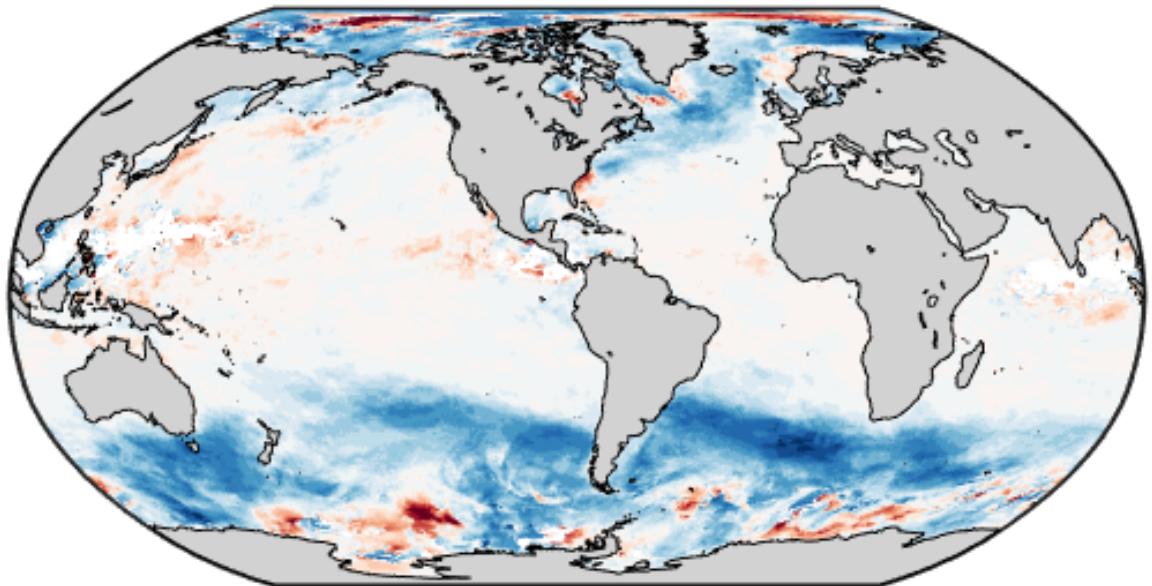


# OMI Reference Sector Correction Evaluation

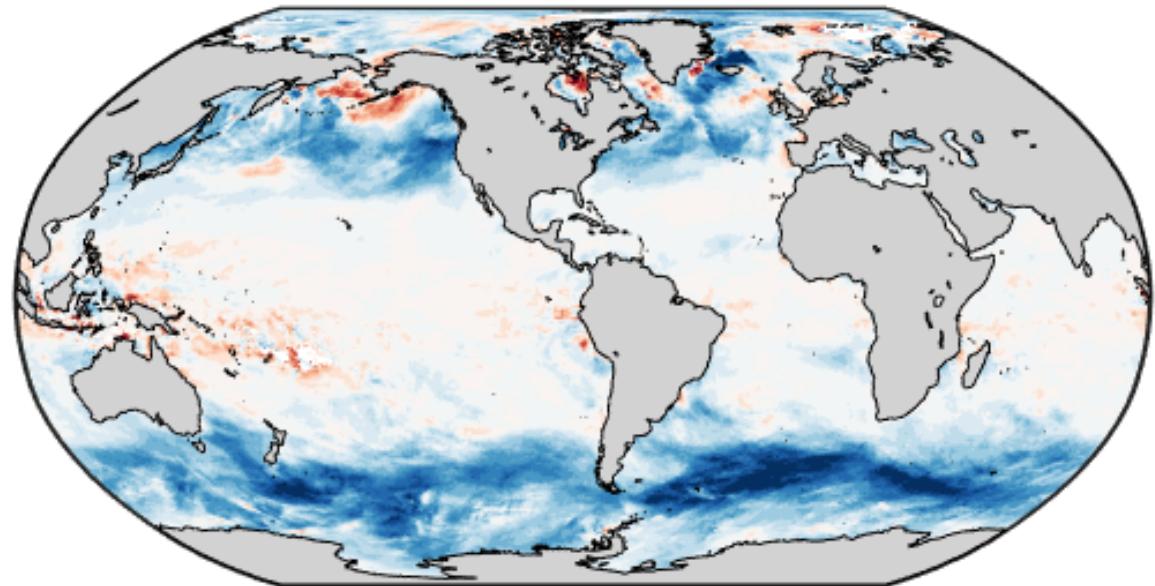


# OMI HCHO Bias from Cloud Filtering

(a) August 2016, ATom 1



(b) February 2017, ATom 2

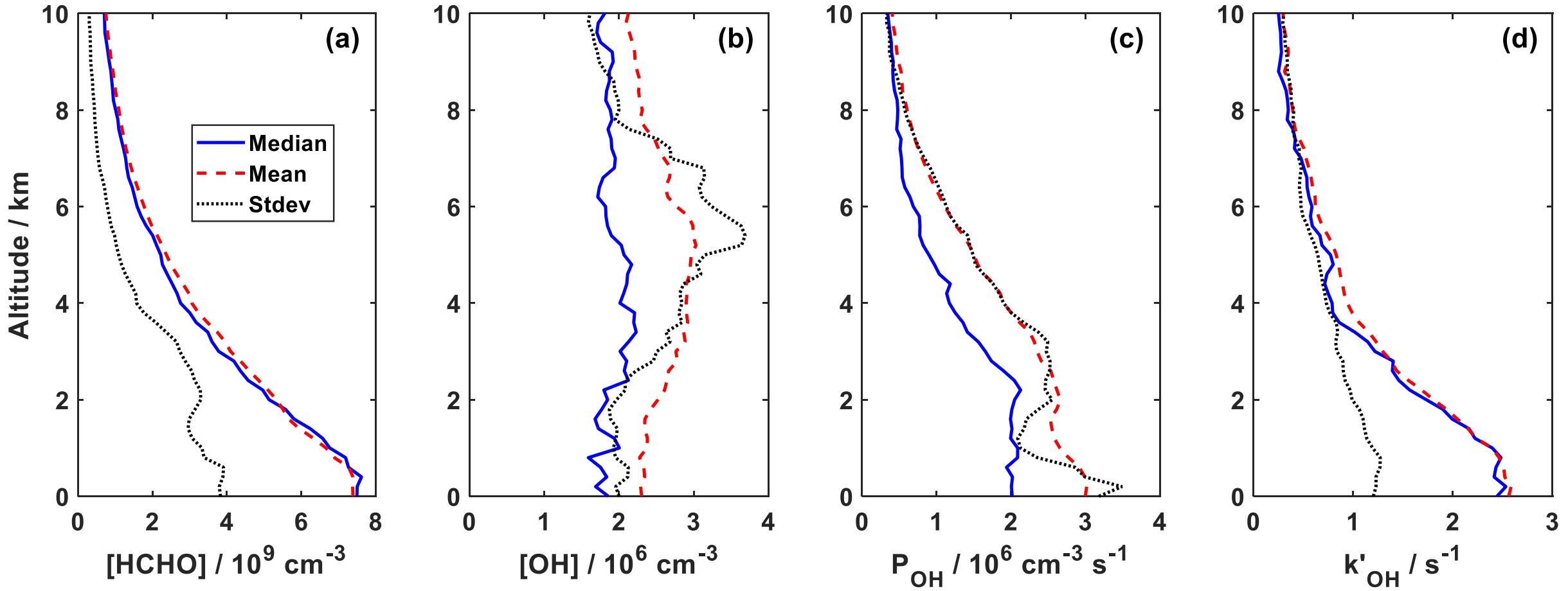


$$\Omega[\text{HCHO}]_{\text{cld} < 0.3} / \Omega[\text{HCHO}]_{\text{all}} - 1$$



-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5

# ATom Vertical Profiles

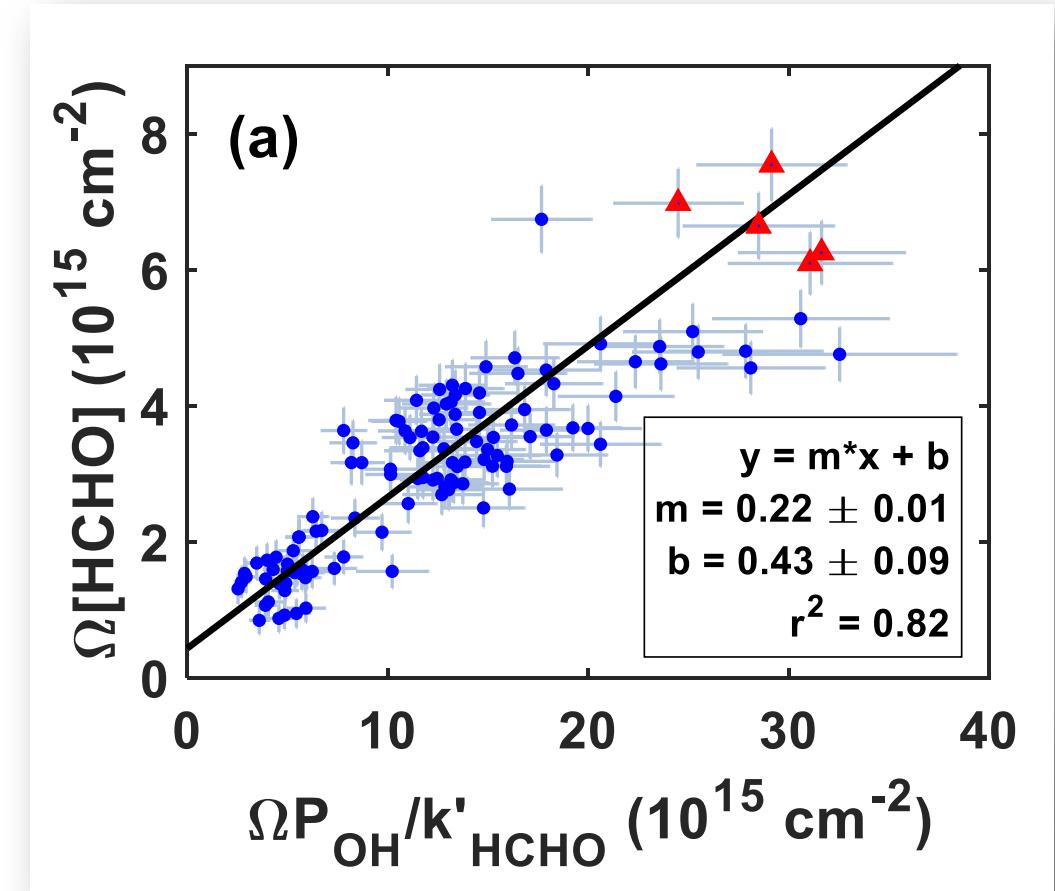


# ATom OH Production and HCHO

$$\Omega[HCHO] = \alpha \frac{\Omega P_{OH}}{k'_{HCHO}} + \Omega[HCHO]_0$$

## OH Production

$O_3 + h\nu + H_2O \rightarrow 2OH + O_2$	(38%)
$HO_2 + NO \rightarrow OH + NO_2$	(35%)
$HO_2 + O_3 \rightarrow OH + 2O_2$	(15%)
$H_2O_2 + h\nu \rightarrow 2OH$	(6%)
Other reactions	(6%)



# Global Model Comparison

