

# Measurements of trace gas emissions from biomass burning events detected at PEARL, Eureka, Nunavut, Canada, from 2007 to 2011



IRWG/TCCON 2012 meeting  
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# Outline

- **Introduction : scientific context**
- **Observations of Biomass Burning (BB) species and Aerosol Optical Depth (AOD) at Eureka**
- **Comparison of Fourier Transform InfraRed (FTIR) CO and HCN with GEOS-Chem**
- **Detection of BB plumes over Eureka : case study**
- **Correlation of AOD and trace gas columns in BB plumes**
- **Conclusions and perspectives**

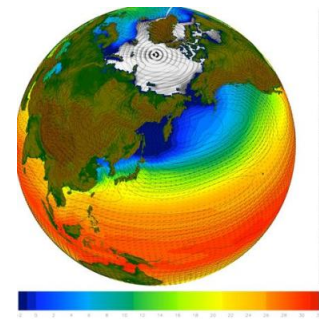
# Introduction



**Fires**, from natural causes and human activities, can be sporadic, but release considerable amounts of radiatively and photochemically active trace gases and aerosols [IPCC, 2007].



Because the **Arctic** is a major receptor for mid-latitude pollution [Shaw, 1995; Quinn et al., 2007; Shindell et al., 2008], **BB** can affect atmospheric chemistry, degrade air quality and affect radiative transfer in this region [Lavoué et al., 2000; Stohl et al., 2006, 2007; Paris et al., 2009; Warneke et al., 2009, 2010] that can lead to regional and global warming [Koch and Hansen, 2005; Shindell et al., 2006a; McConnell et al., 2007; Quinn et al., 2008; Shindell and Faluvegi, 2009].



But, **modeling** of the Arctic climate system is difficult due to complex and sensitive feedbacks [Serreze and Francis, 2006] and despite 50 years of **observations** of Arctic pollution, there remains considerable uncertainty concerning the sources [Fisher et al., 2010].

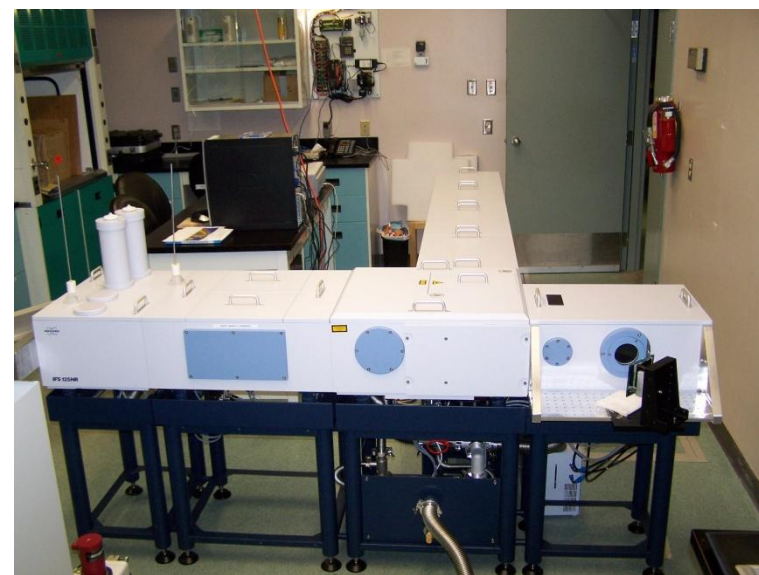
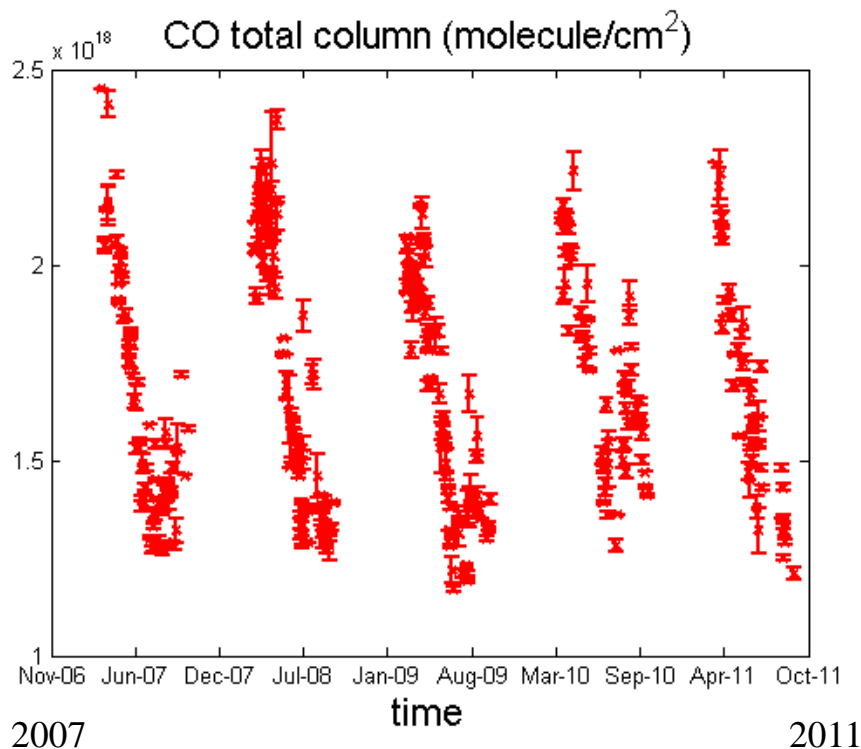
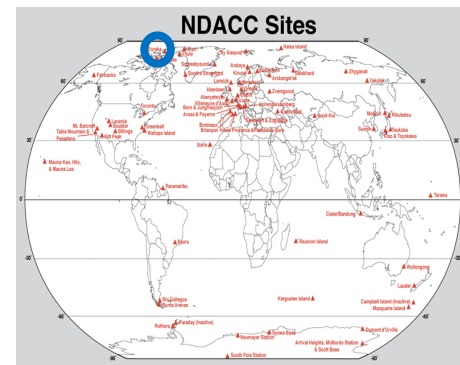


**Therefore, it is important to estimate the sources and establish reliable means of estimating the emissions from biomass burning for use in atmospheric chemical transport models**

[Andreae and Merlet, 2001; Paton-Walsh et al., 2010].

# Observations of BB species

## Polar Environment Atmospheric Research Laboratory (PEARL)



High-resolution (0.0035cm<sup>-1</sup>) Bruker IFS 125 FTIR

# Observations of BB species

Simultaneous measurements of various species released by BB events

SFIT2

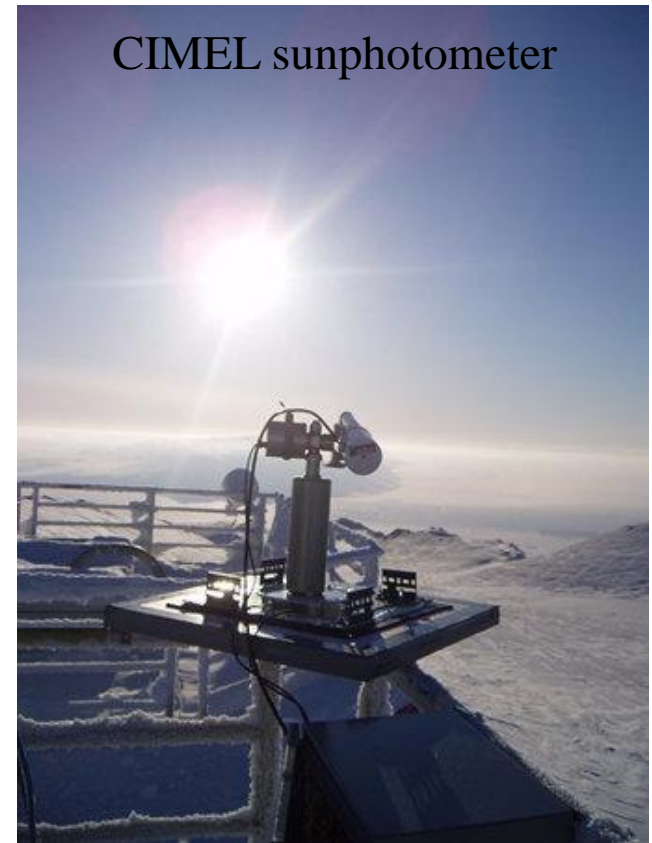
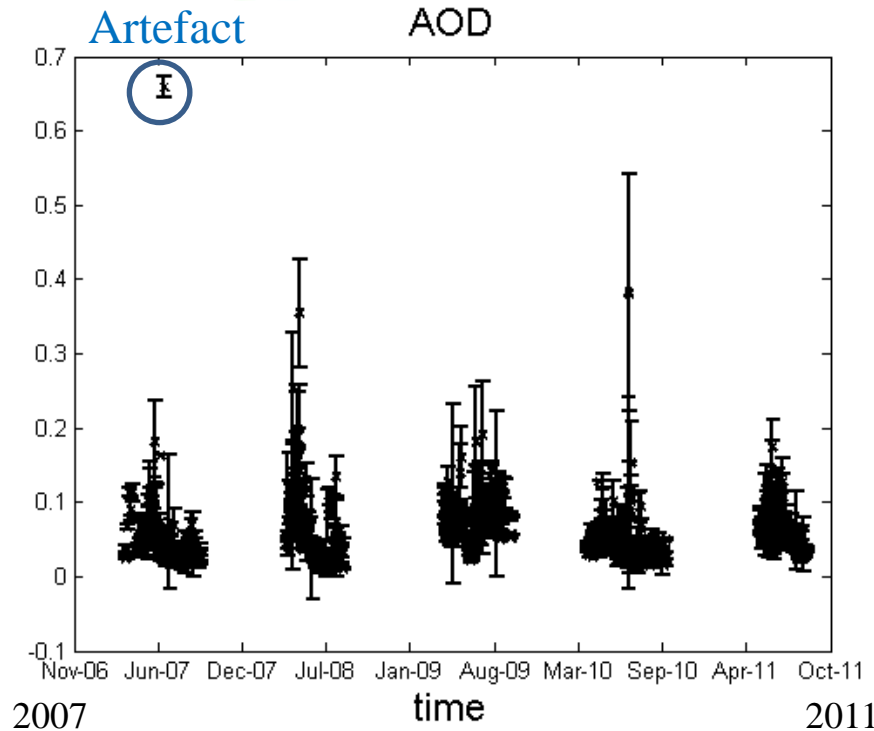
Target species	MW		error (%)			Degrees Of Freedom (DOFs)			Sources	Lifetimes
	spectral range	interfering species	0.6-10 km	10 - 50 km	0.6-120 km	0.6-10 km	10 - 50 km	0.6-120 km		
<b>CO</b>	2057.684-2058.0	O <sub>3</sub> CO <sub>2</sub> OCS	2.5	8.4	2.6	2.2	1.7	3.9	BB, volcano, transport, steel industry, methane oxidation	2 months
	2069.56-2069.76	O <sub>3</sub> CO <sub>2</sub> OCS								
	2157.507-2159.144	O <sub>3</sub> N <sub>2</sub> O H <sub>2</sub> O OCS								
<b>C<sub>2</sub>H<sub>6</sub></b>	2976.66-2976.95	H <sub>2</sub> O O <sub>3</sub>	3.1	27.6	3.3	1.7	0.5	1.9	BB, biofuel use	2 months
	2983.20-2983.55	H <sub>2</sub> O O <sub>3</sub>								
	2986.5-2986.95	H <sub>2</sub> O O <sub>3</sub>								
<b>HCN</b>	3268.0-3268.38	H <sub>2</sub> O	11.1	8.9	0.7	1.5	BB, industry	2-6 months		
	3287.0-3287.48	H <sub>2</sub> O								
<b>CH<sub>4</sub></b>	2613.7-2615.4	HDO NO <sub>2</sub> CO <sub>2</sub> H <sub>2</sub> O	8.1	14.6	8.7	1.5	1.5	2.8	BB, wetland, livestock, coalmining, rice cultivation,...	8-12 years
	2650.6-2651.3	HDO NO <sub>2</sub> CO <sub>2</sub> H <sub>2</sub> O								
	2835.5-2835.8	HDO NO <sub>2</sub> CO <sub>2</sub> H <sub>2</sub> O								
	2903.6-2904.03	HDO NO <sub>2</sub> CO <sub>2</sub> H <sub>2</sub> O								
	2921.0-2921.6	HDO NO <sub>2</sub> CO <sub>2</sub> H <sub>2</sub> O								
<b>HCOOH</b>	1102.75-1106.40	HDO H <sub>2</sub> O O <sub>3</sub>	5.6			1.0			Pyrogenic and biogenic emission	4 days
<b>H<sub>2</sub>CO</b>	2778.12-2778.80	CH <sub>4</sub> CO <sub>2</sub> O <sub>3</sub>	28.8	29.1	1.0	1.2	Pyrolysis emission product	< 2 days		
	2780.60-2781.17	CH <sub>4</sub> CO <sub>2</sub> O <sub>3</sub>								

More details about those retrievals during the poster session ...

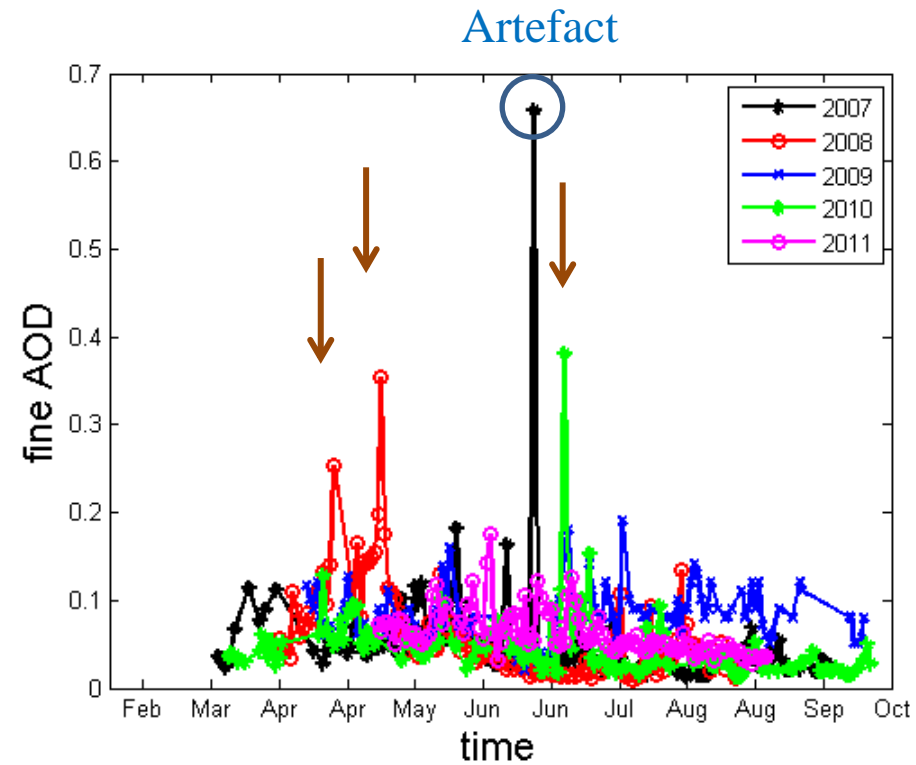
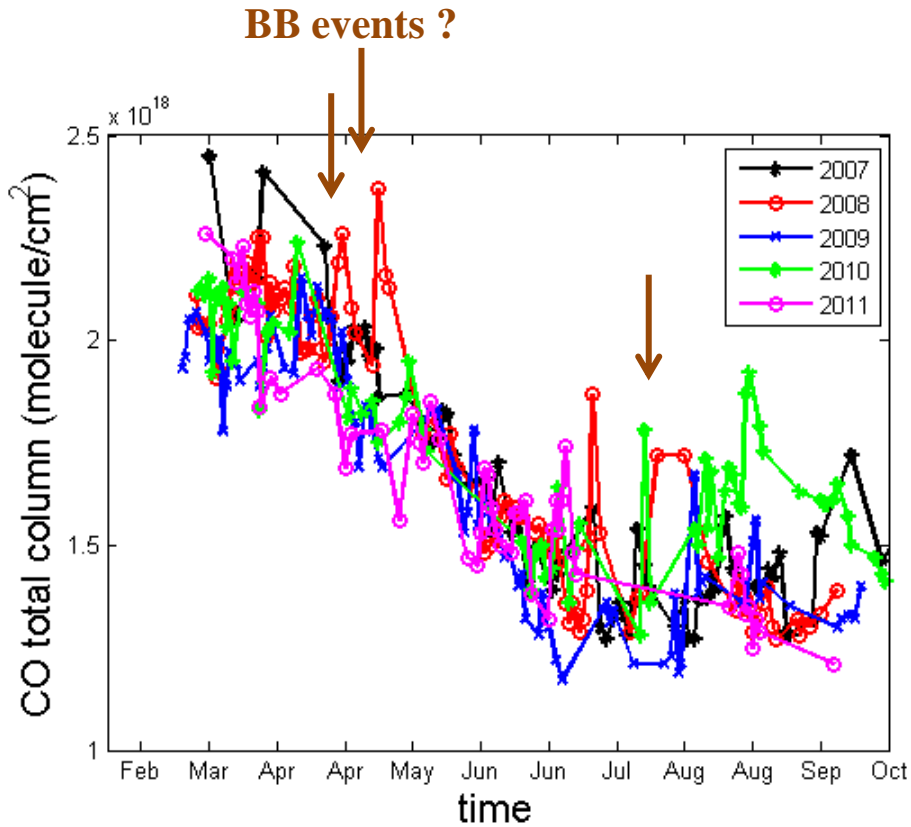
# Observations of AOD



- Data from Aerosol Robotic Network (AERONET) [Holben et al., 1998]
- AOD using Spectral Deconvolution Algorithm of O'Neill et al. [2003] from Level 1.0 (non-cloud-screened)
- Use fine mode for characterizing BB [Dubovik et al., 2002; O'Neill et al., 2008; Eck et al., 2009]



# Observations of BB species and AOD



We have data from 2007 to 2011 but here focus on 2007-2008.



# Comparison of FTIR and GEOS-Chem data

**GEOS-Chem** is a global 3-D Chemical Transport Model [Bey et al., 2001]

We use V8-02-01 released 26 May 2009

- Assimilated meteorological data from Goddard Earth Observing System v5 (GEOS-5) at 6h res.
- Horizontal resolution of  $2^{\circ} \times 2.5^{\circ}$  for HCN and  $4^{\circ} \times 5^{\circ}$  for CO.
- 47 levels including 10 levels in the stratosphere and 37 in the troposphere.
- Monthly mean emissions are from the EDGAR 3.2 [Olivier and Berdowski, 2001] for anthropogenic CO and from the Global Fire Emission Database v2 (GFED-2) for BB emission of HCN using an emission ratio of 0.27 % [Van der Werf et al., 2006].

Validations of GEOS-Chem model : HCN data with FTIR [Li et al., 2009] and CO with aircraft and satellite data [Fisher et al., 2010].

For more information please see :

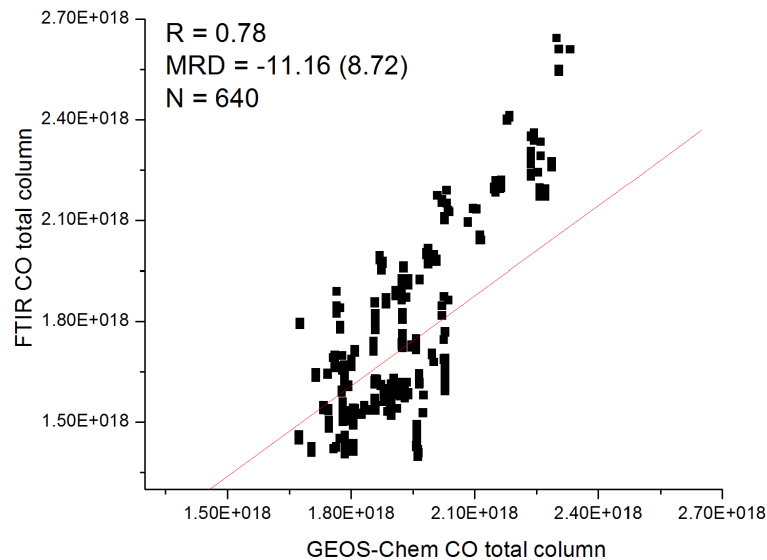
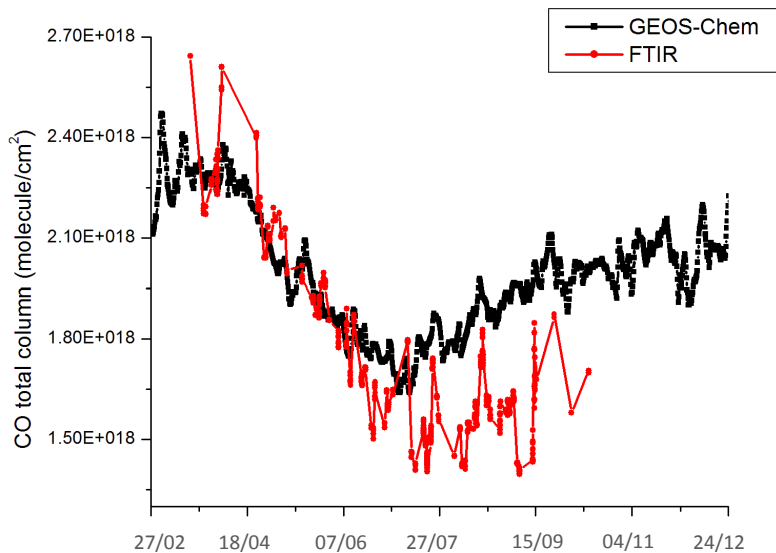
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[http://wiki.seas.harvard.edu/geos-chem/index.php/GEOS-Chem\\_versions\\_under\\_development](http://wiki.seas.harvard.edu/geos-chem/index.php/GEOS-Chem_versions_under_development)

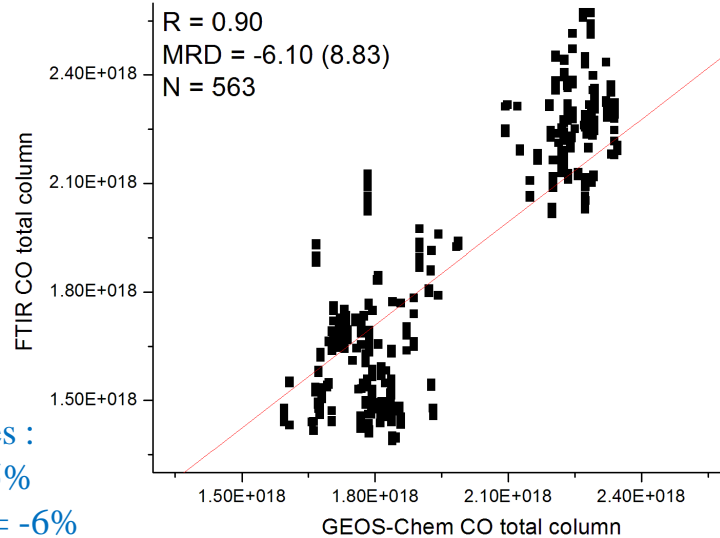
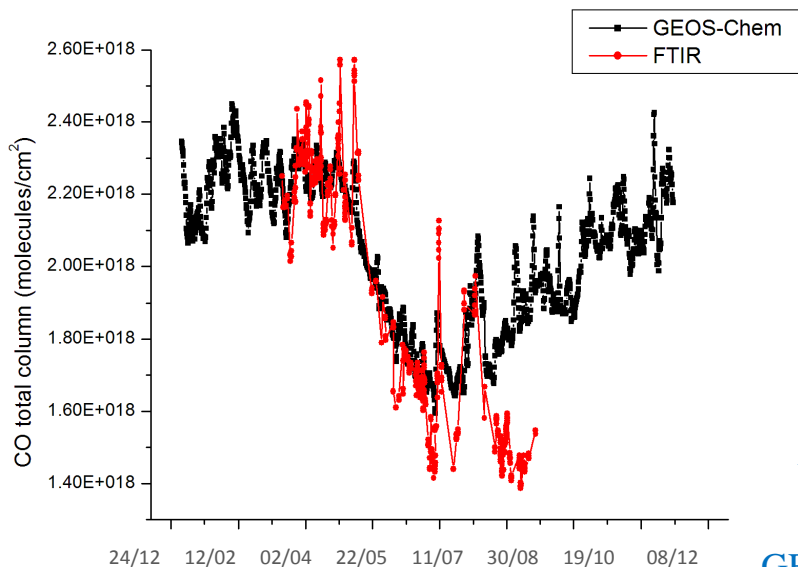
# Comparison of CO with GEOS-Chem

Mean Relative Difference = MDR =  $[(\text{obs}-\text{model})/\text{model}]*100$

2007



2008

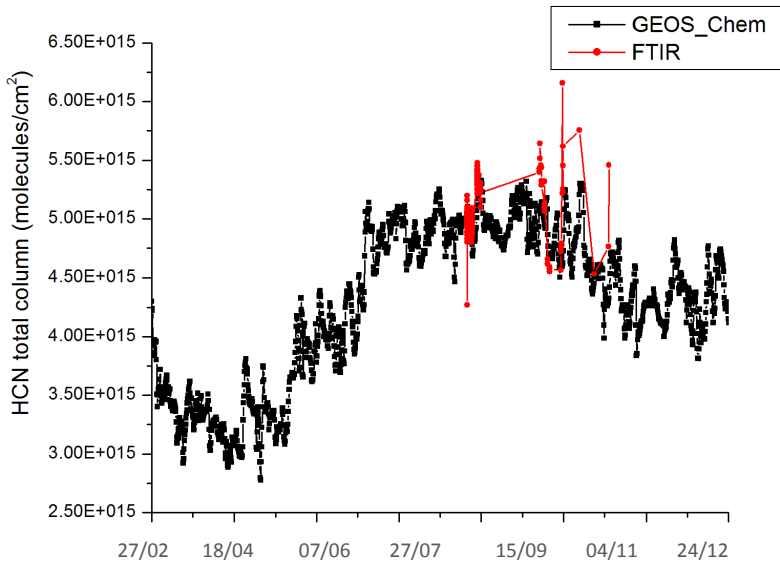


Uncertainties :  
FTIR = 2.5%  
GEOS-Chem = -6%

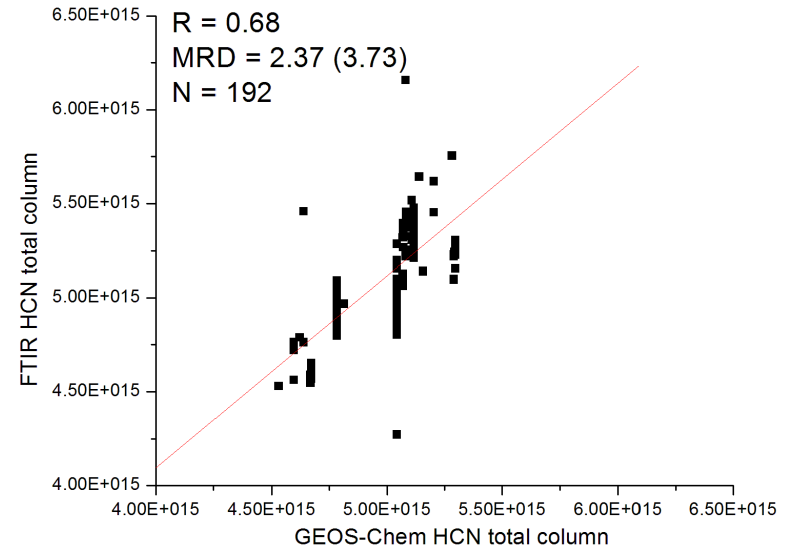


# Comparison of HCN with GEOS-chem

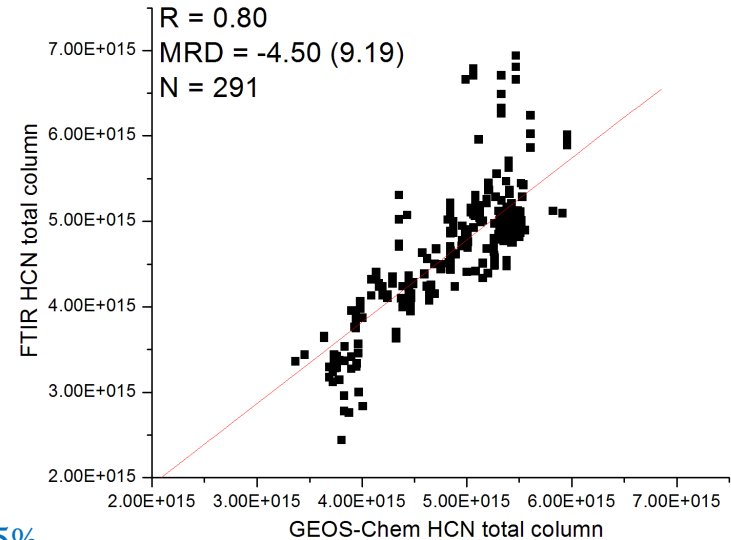
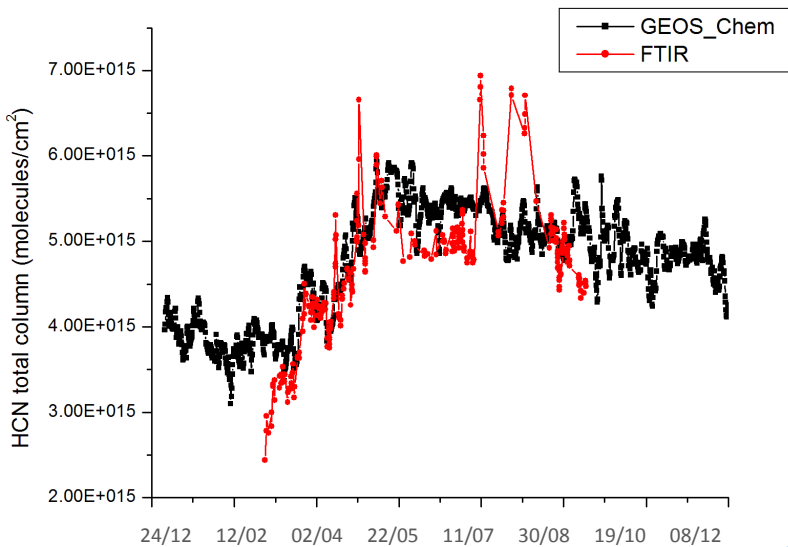
2007



$$\text{MRD} = [(\text{obs}-\text{model})/\text{model}]*100$$



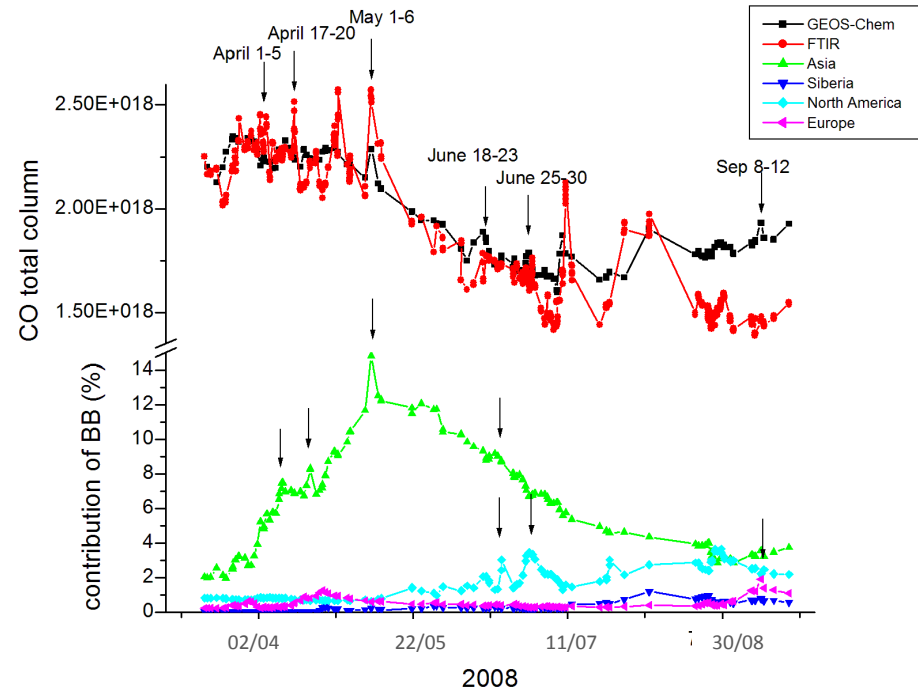
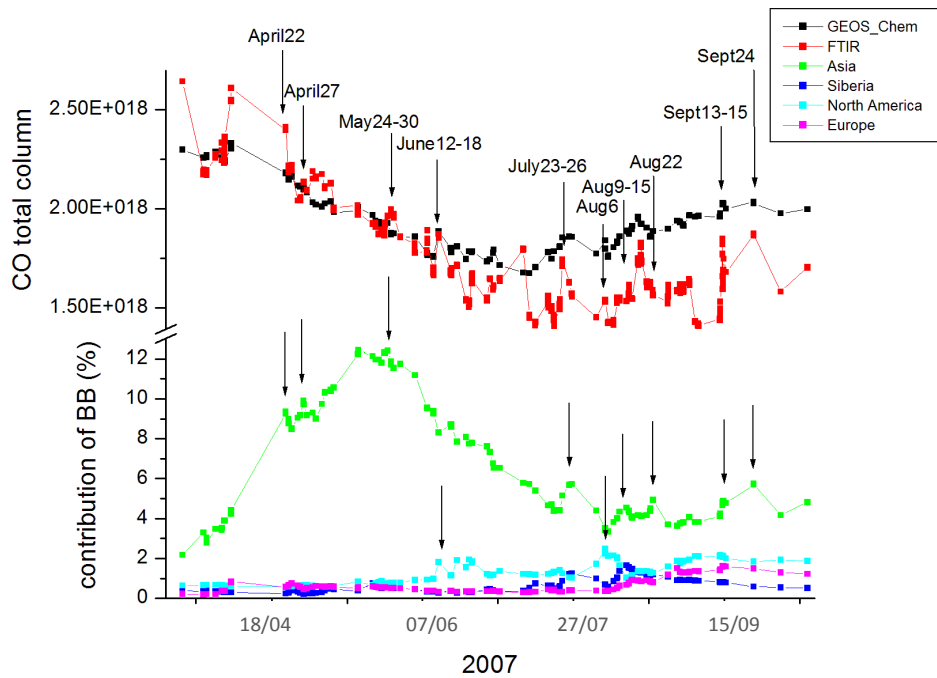
2008



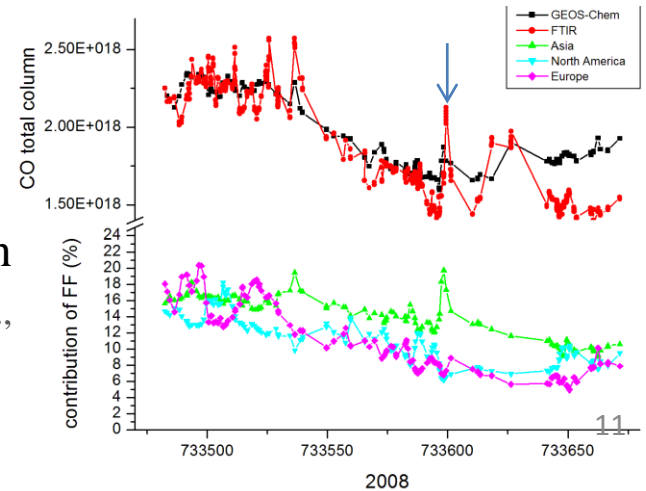
Uncertainties :  
 FTIR = 8.9%  
 GEOS-Chem = 5%

# Detection of BB plumes over Eureka

## Identification of BB events over Eureka with GEOS-Chem

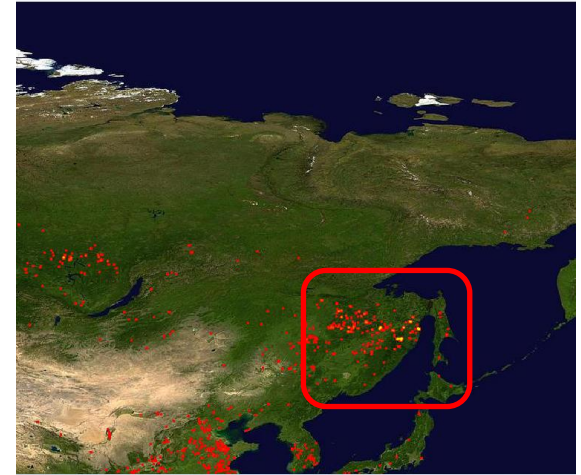
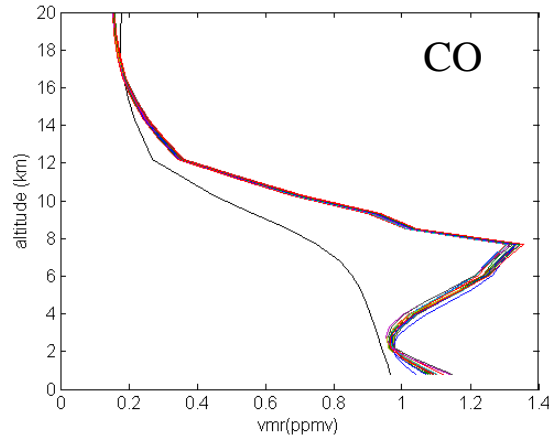
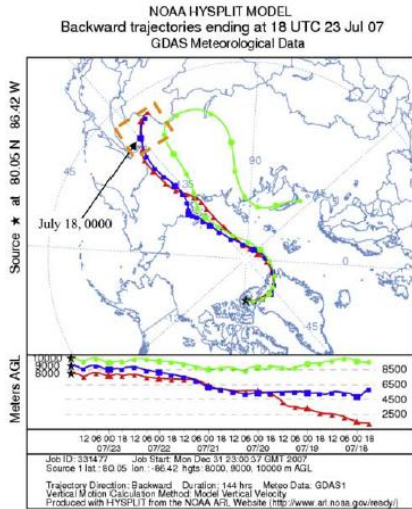


- Other spikes can be due to pollution transport (Fossil Fuel)
- The major BB contribution of CO over the Arctic region comes from Asia [consistent with Koch and Hansen, 2005; Fisher et al., 2010] and North America [consistent with Sharma et al., 2006]

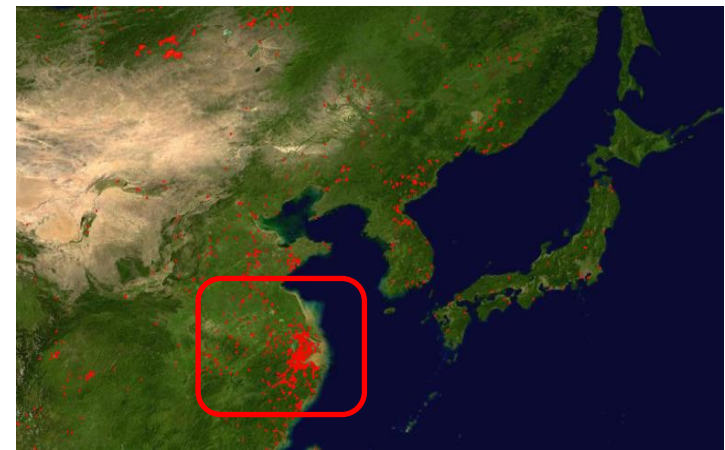
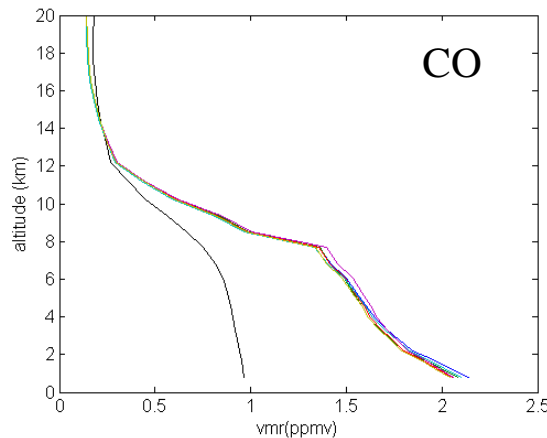
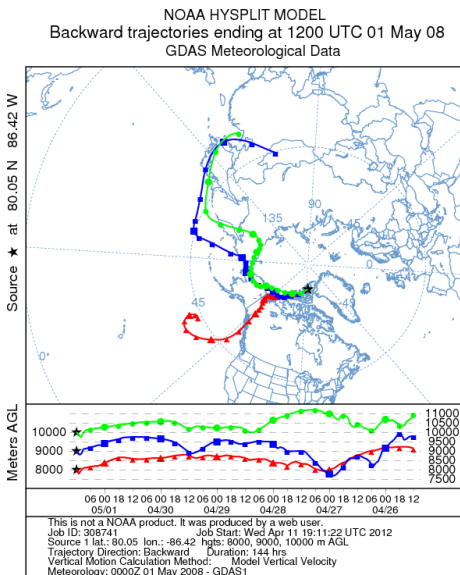


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July 23<sup>rd</sup> 2007 : Fire in Russia (North of Khabarovsk) [O'Neill et al., 2008]



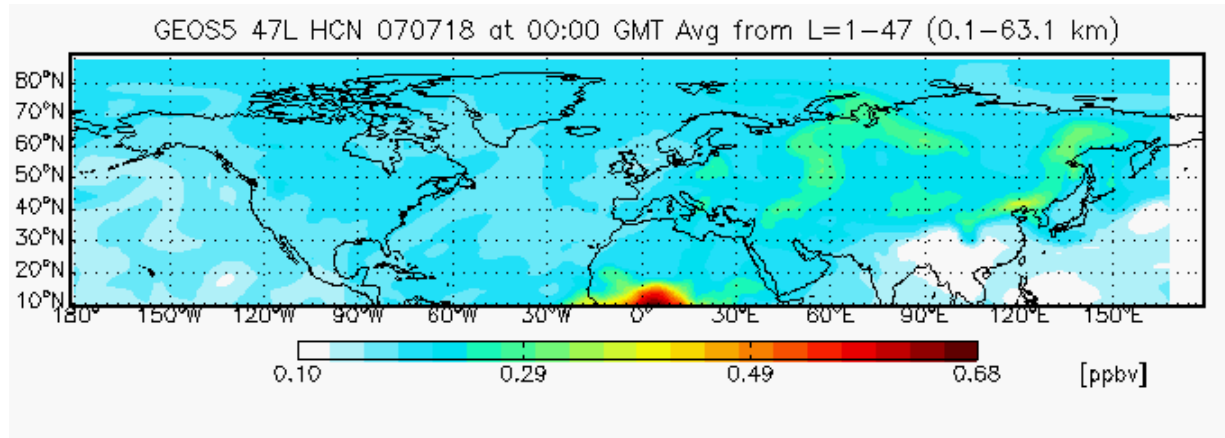
May 1<sup>st</sup> 2008 : Fire in China (agriculture in Shanghai area during harvest) [Li et al., 2010]



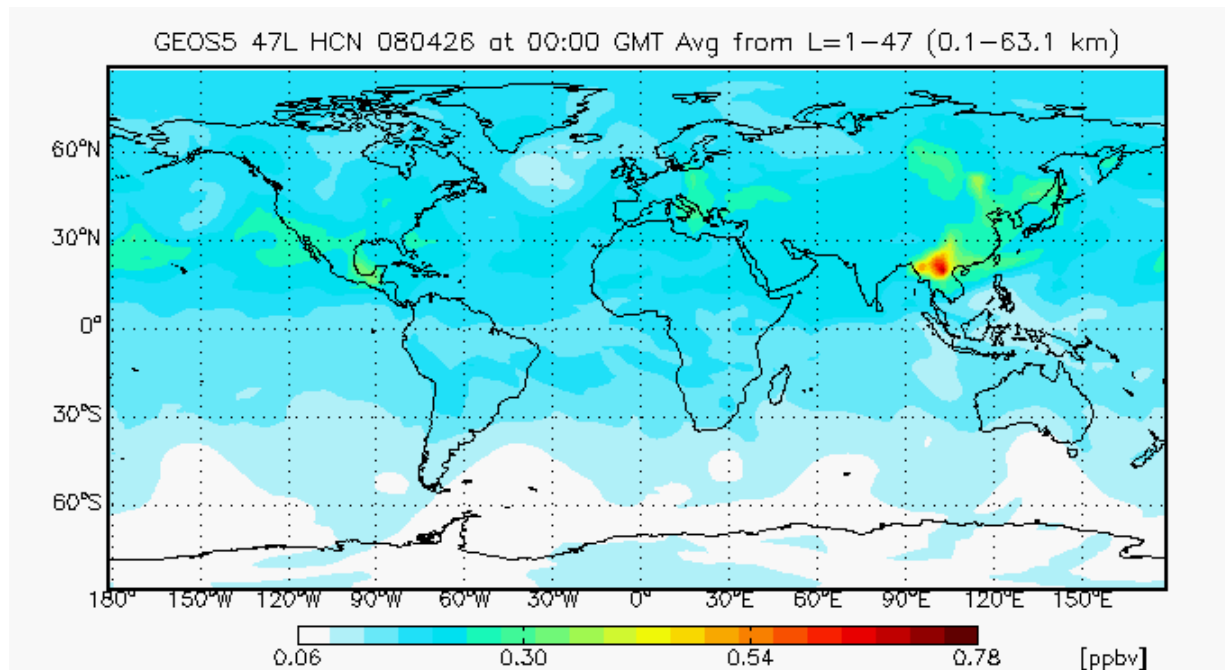


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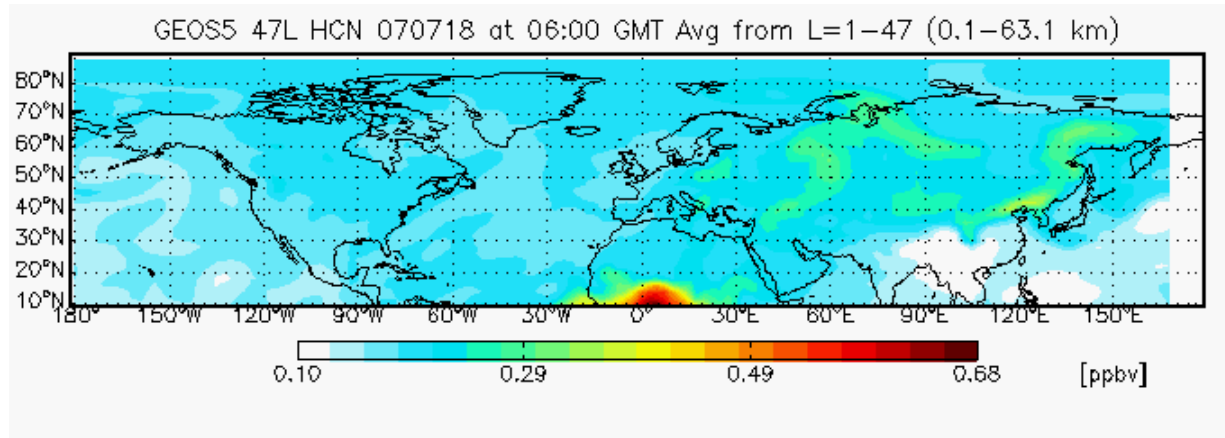
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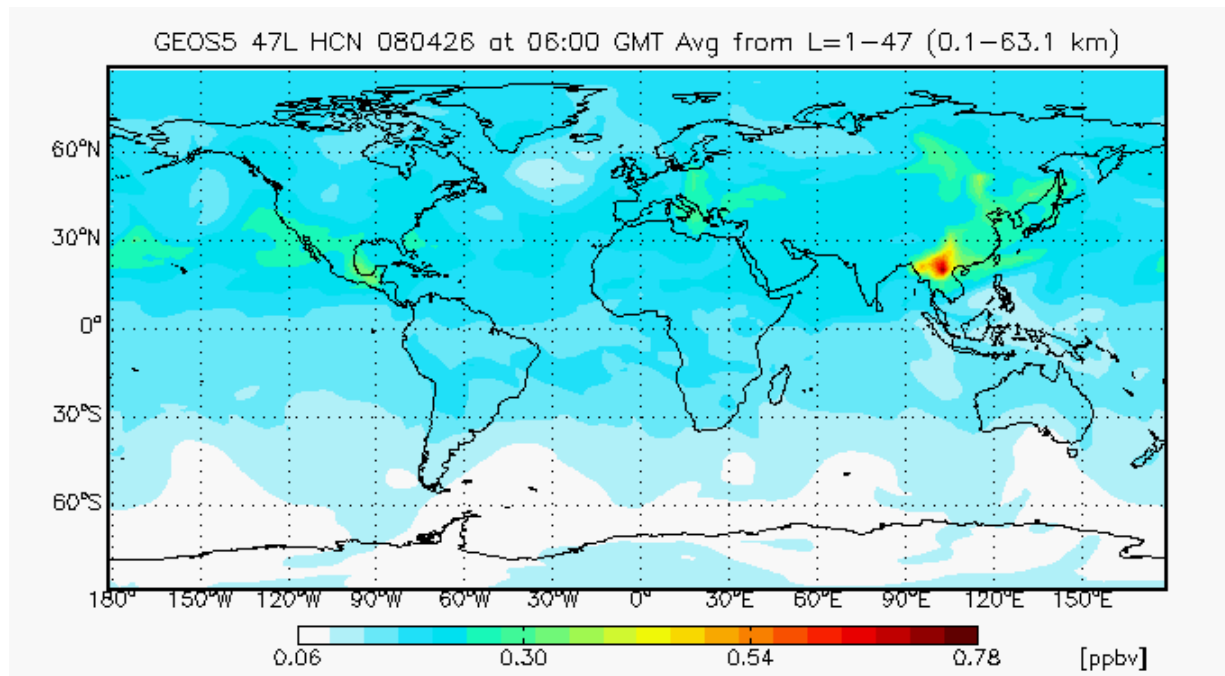


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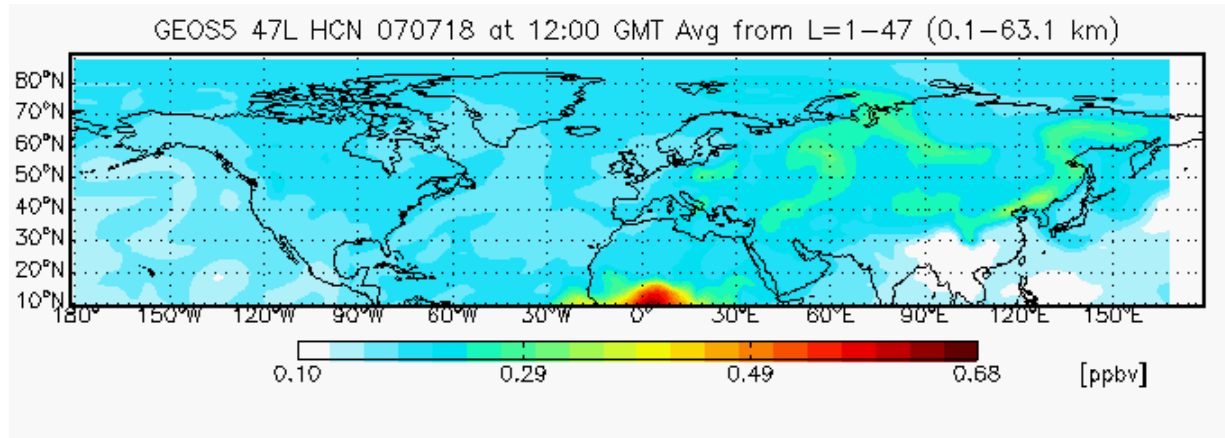
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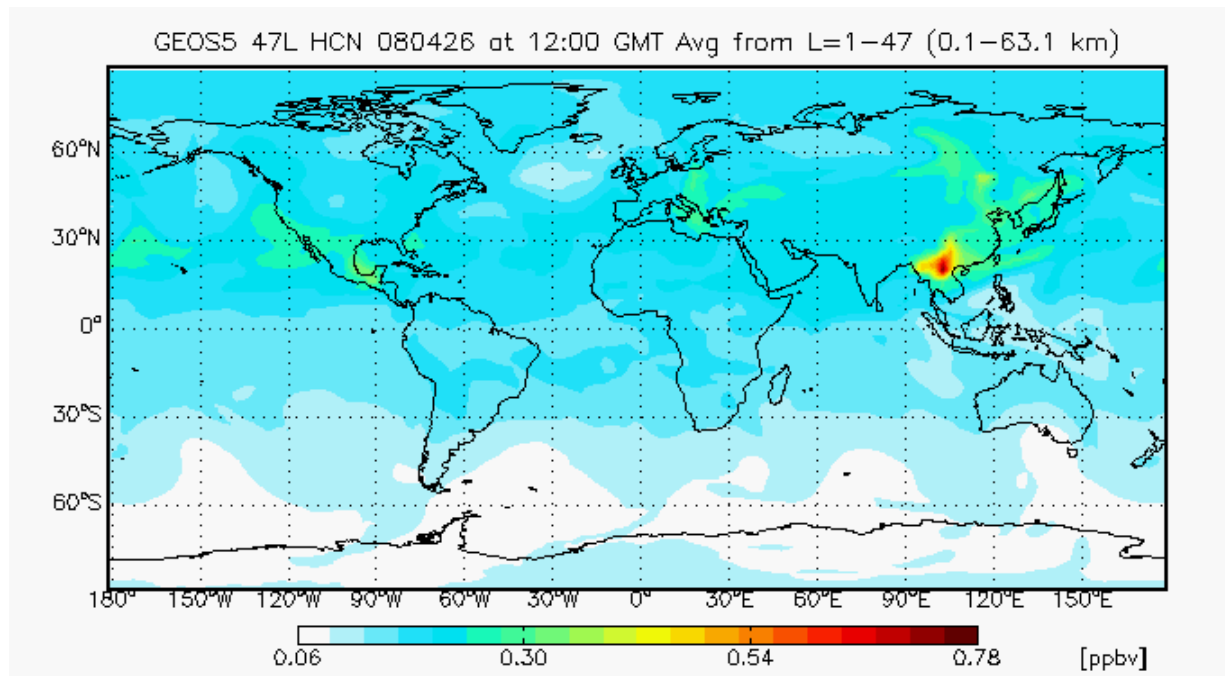


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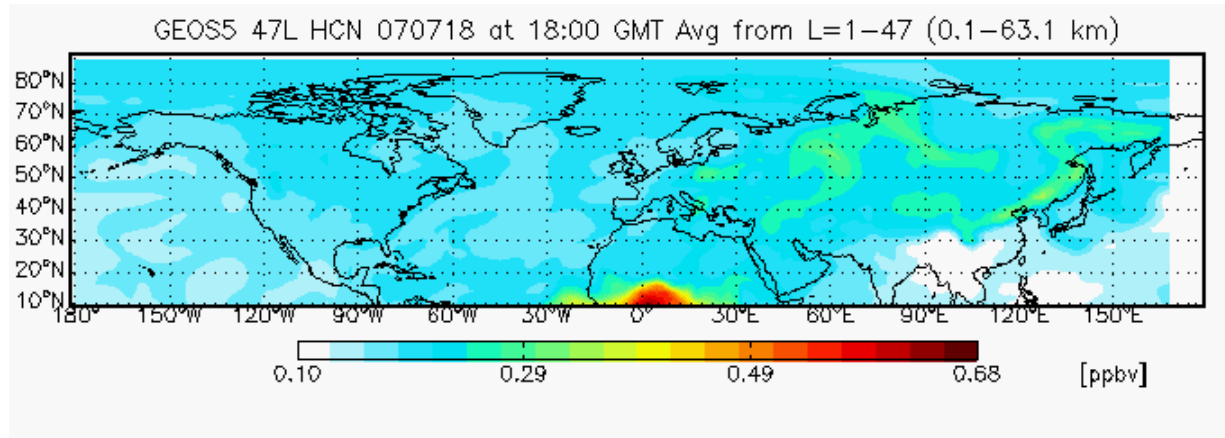
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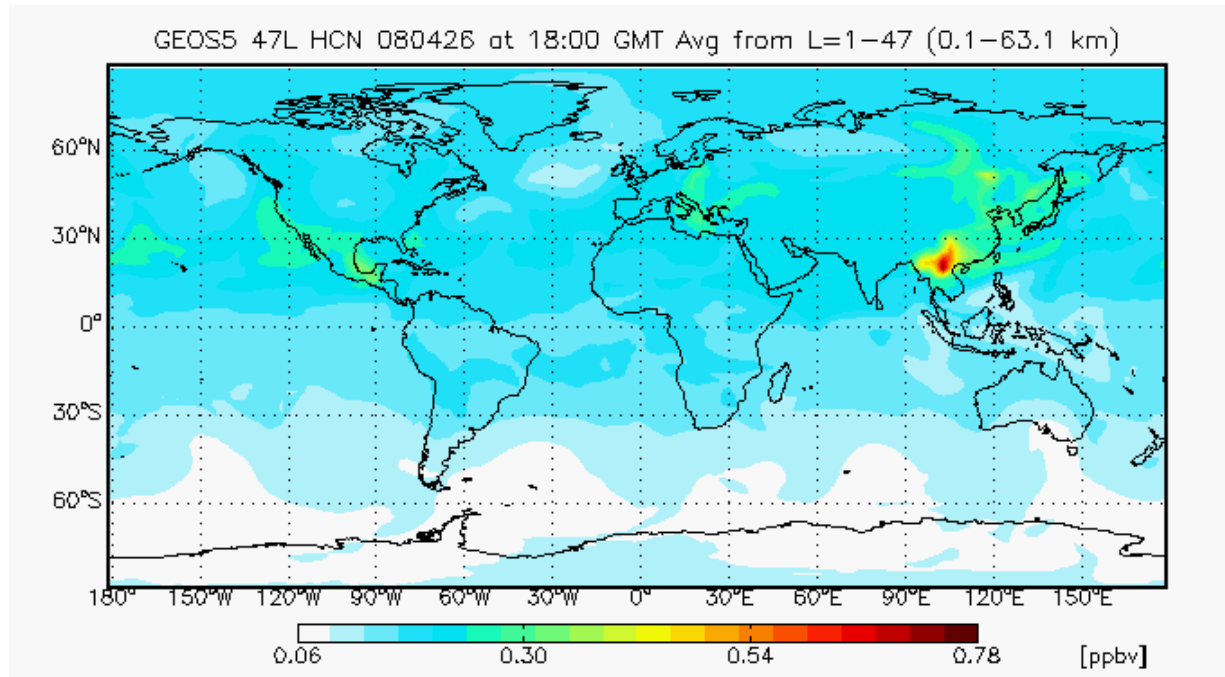


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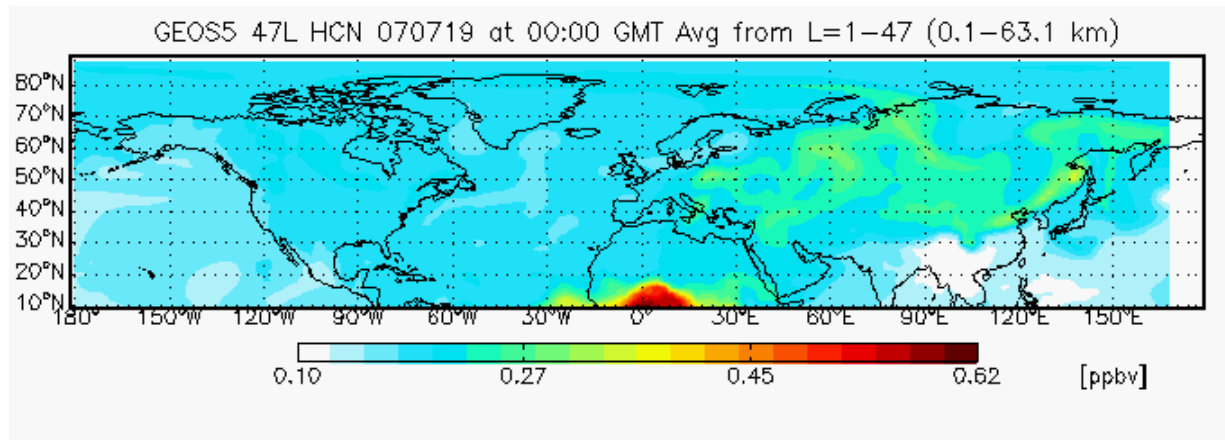
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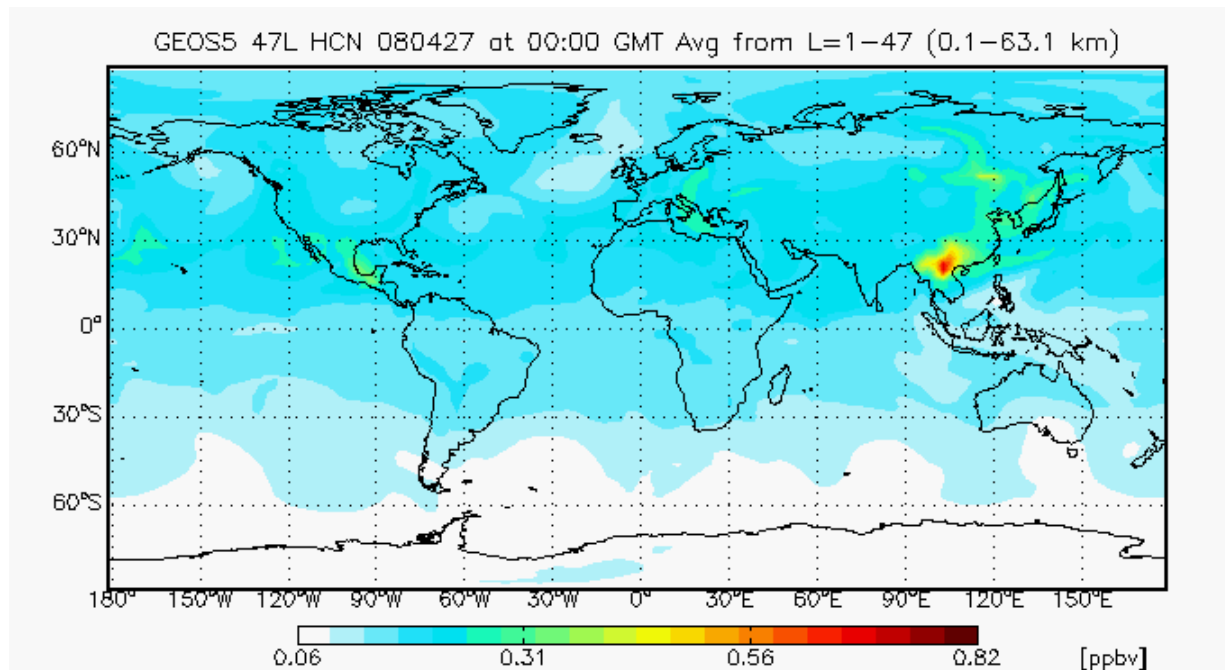


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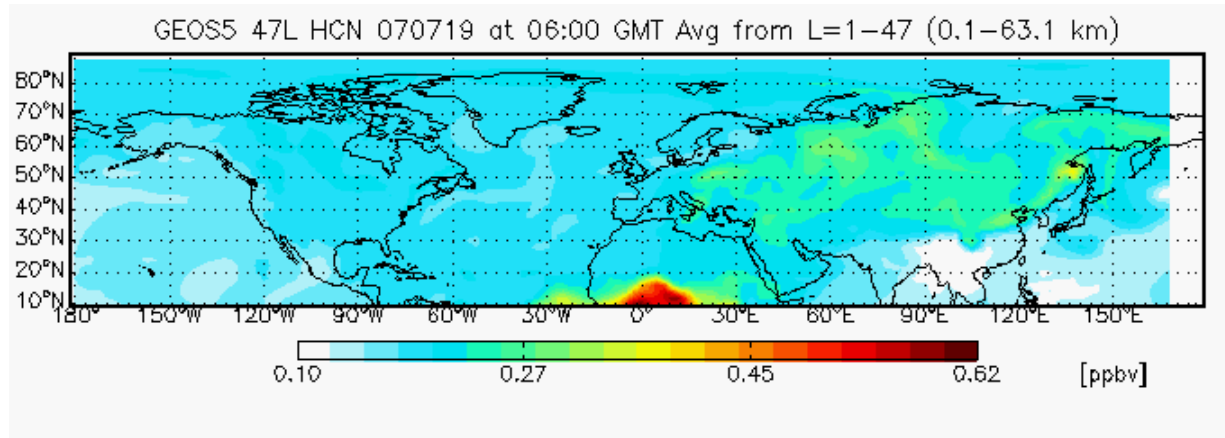
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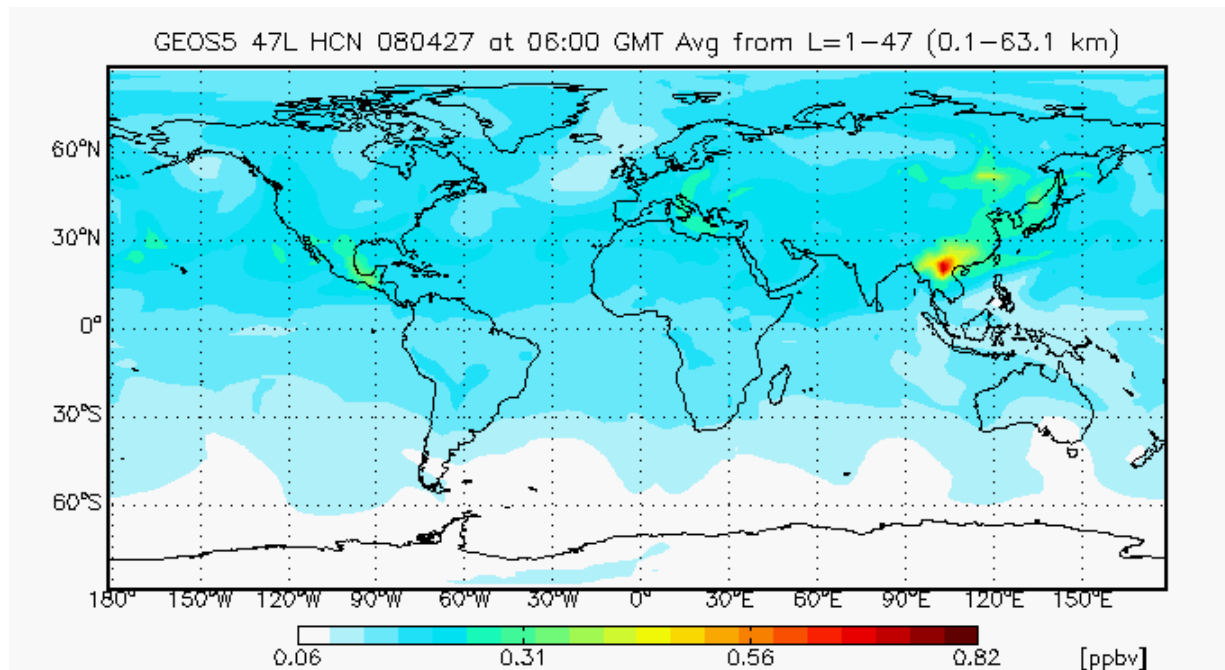


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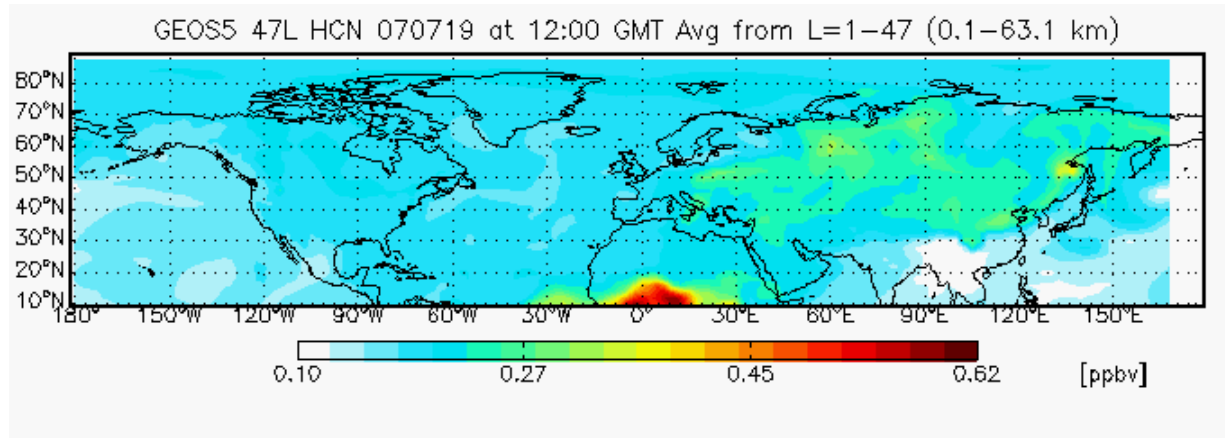
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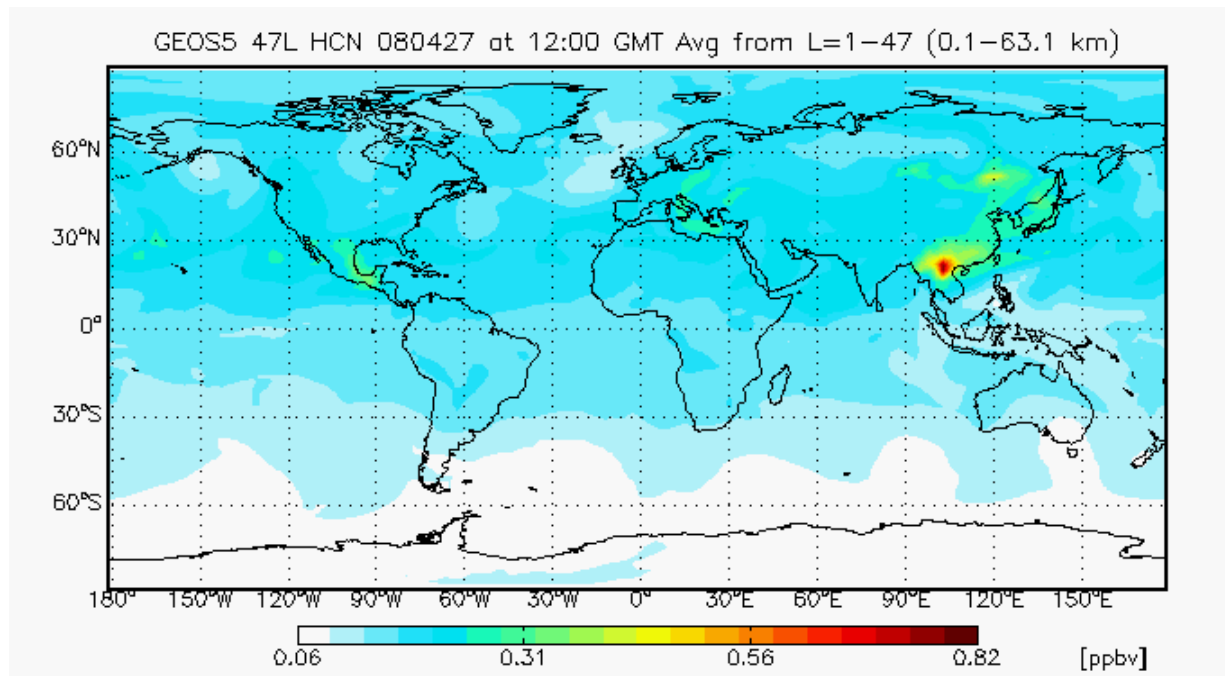


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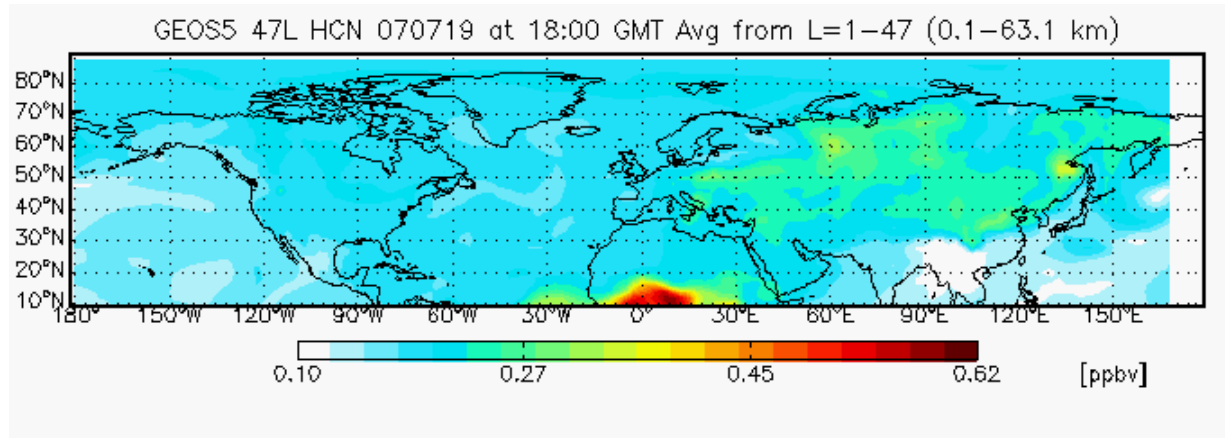
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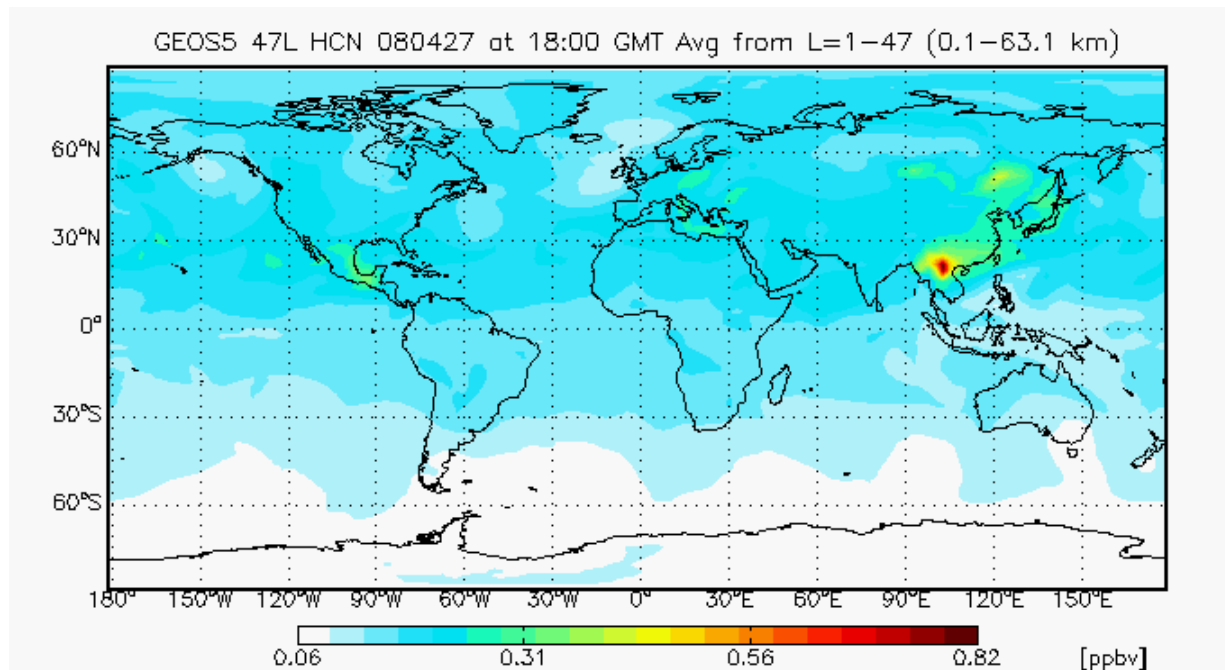


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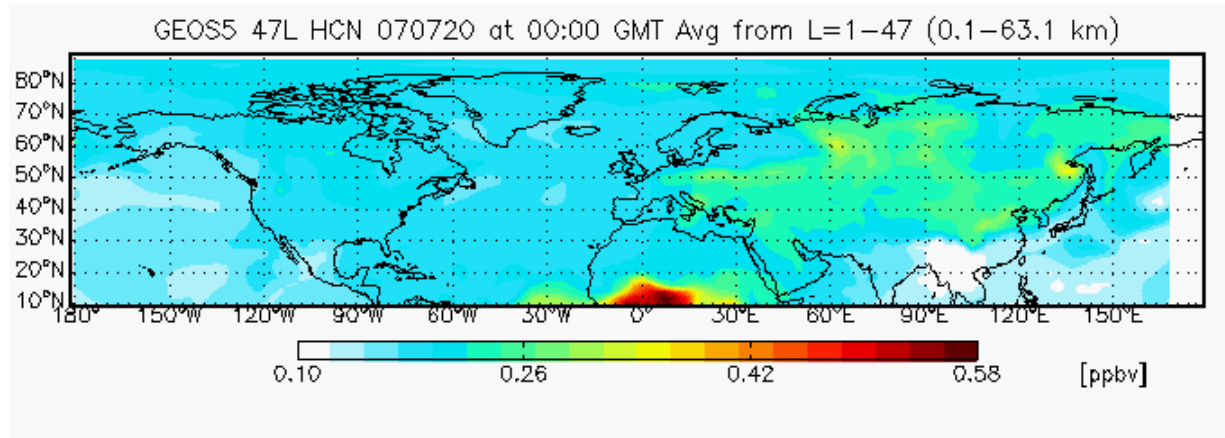
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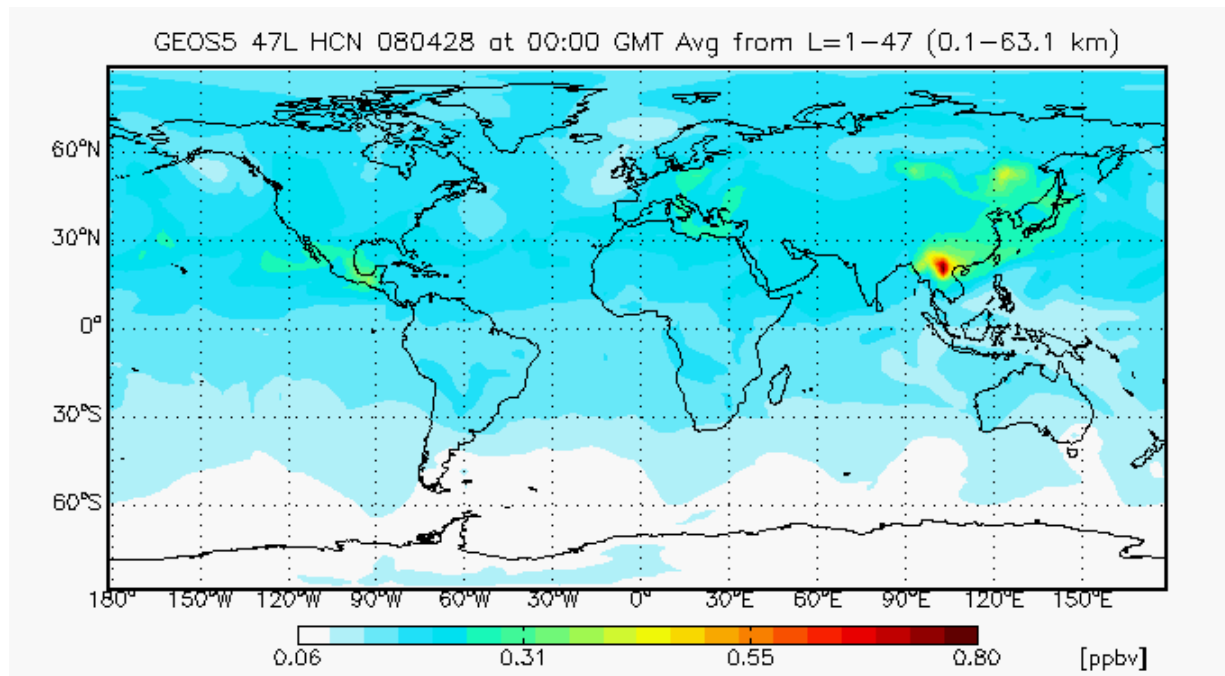


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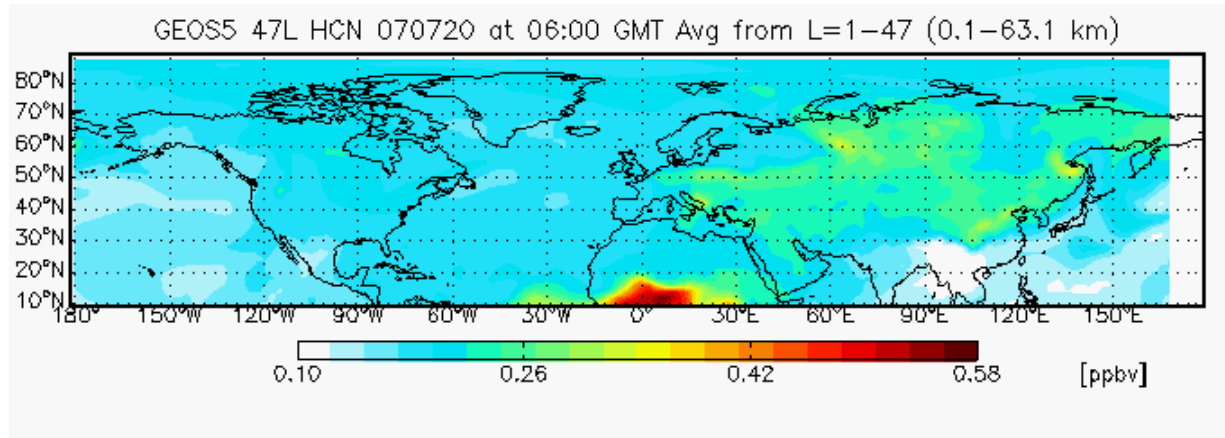
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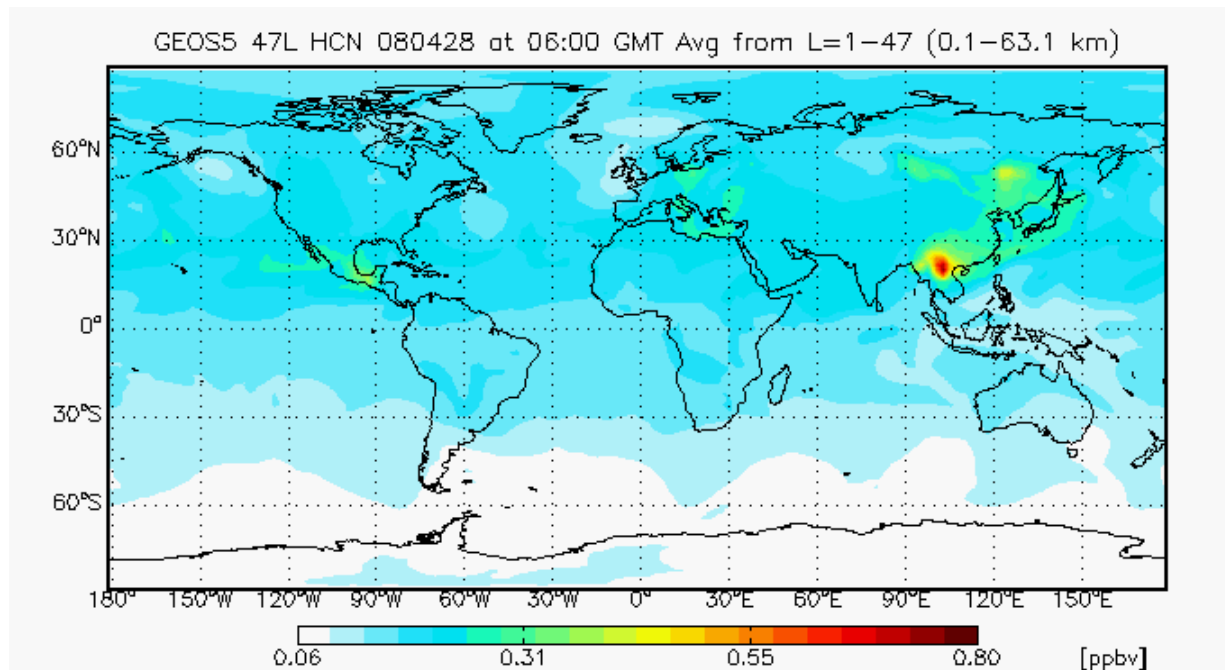


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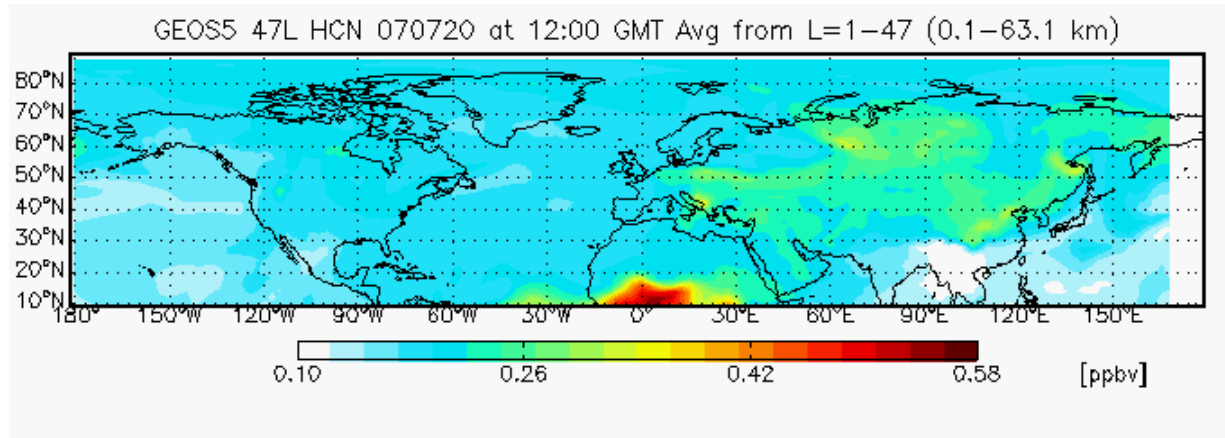
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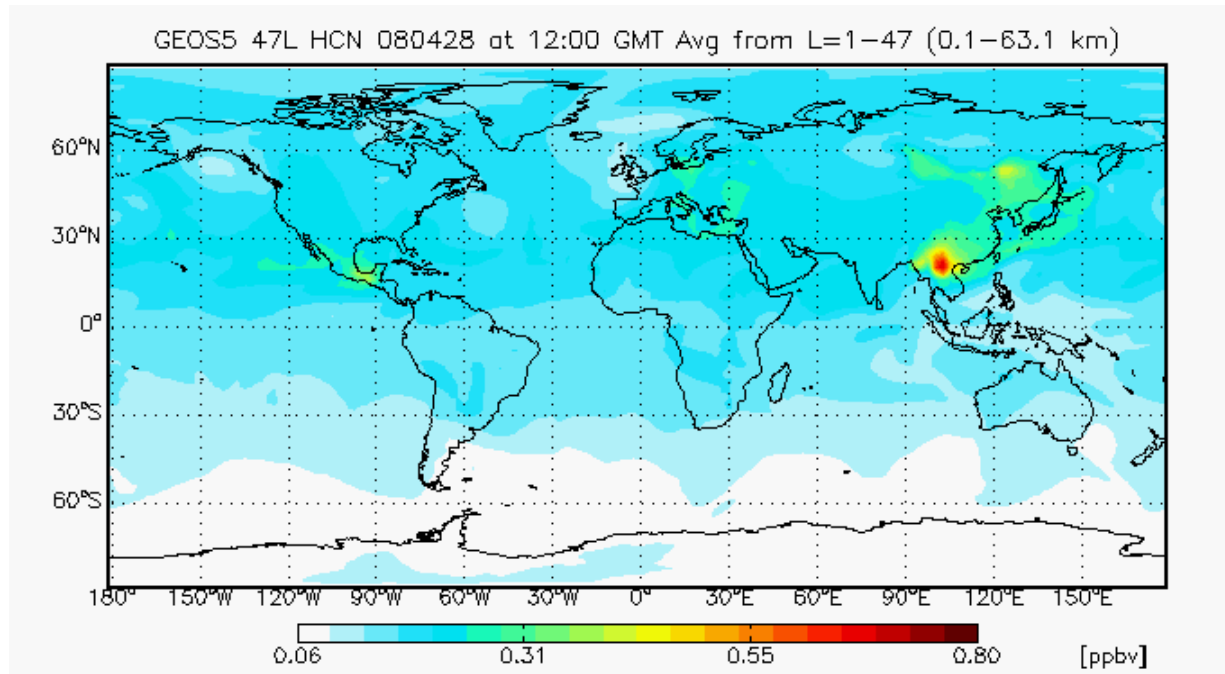


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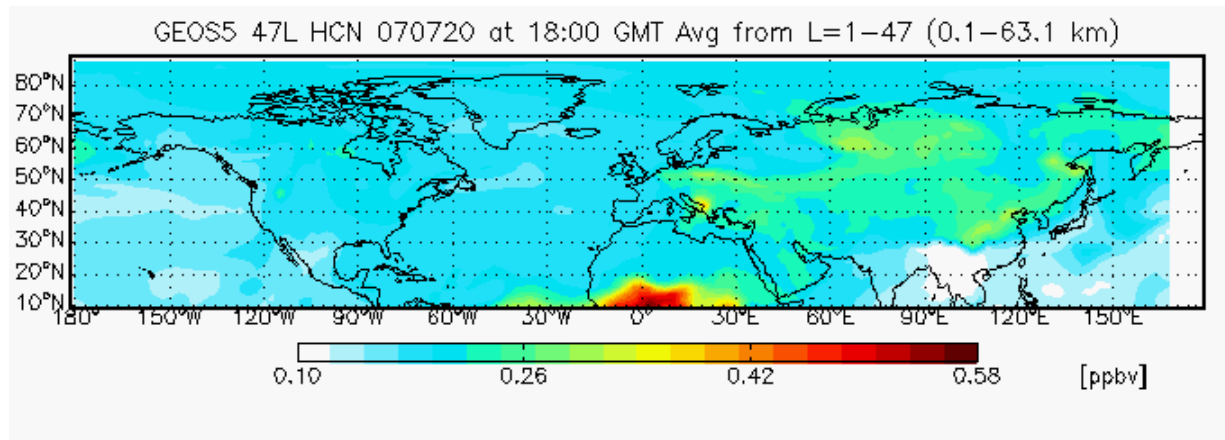
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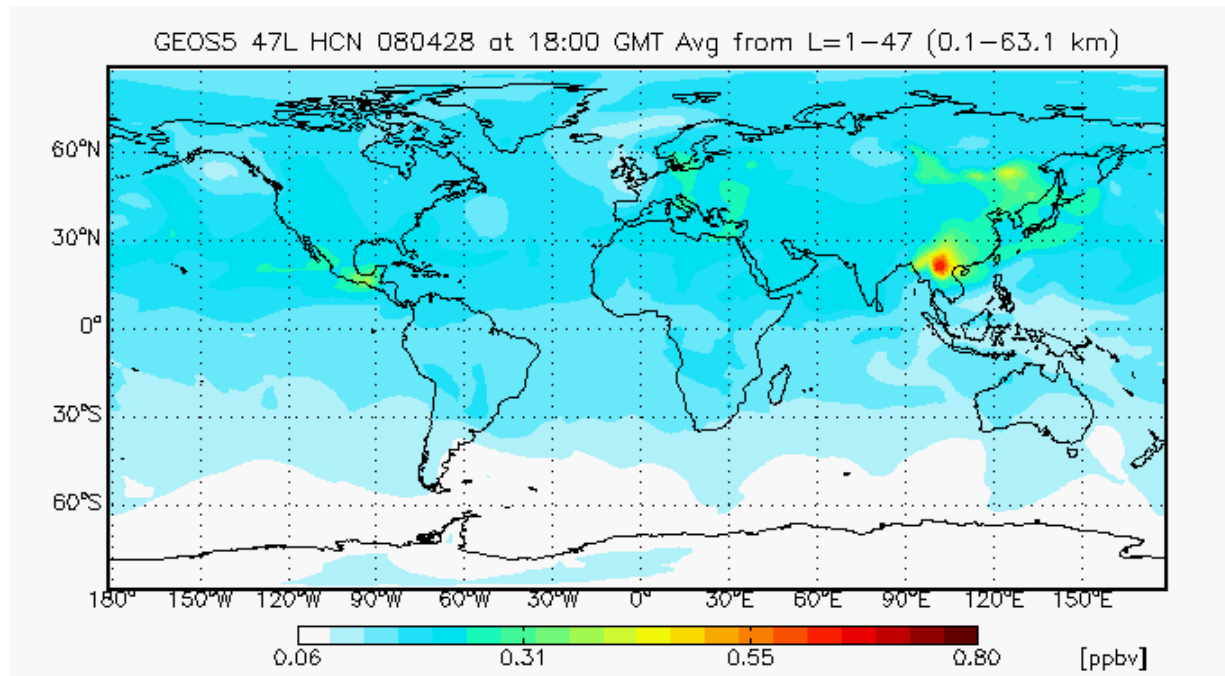


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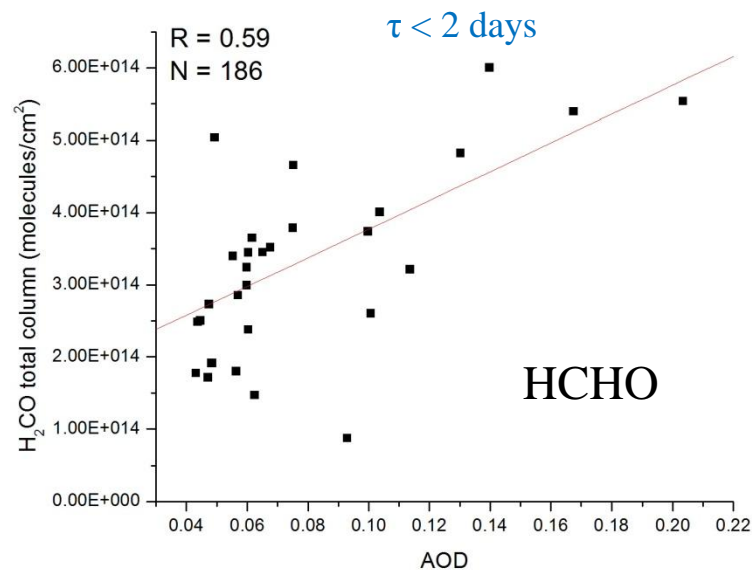
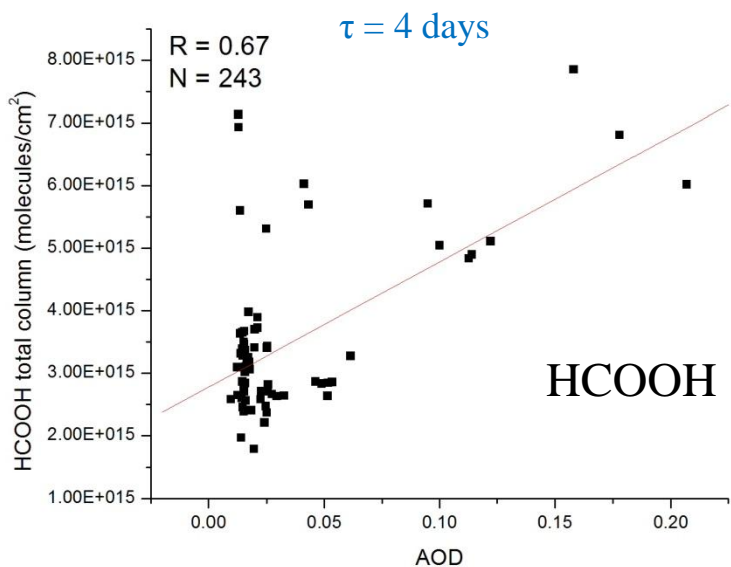
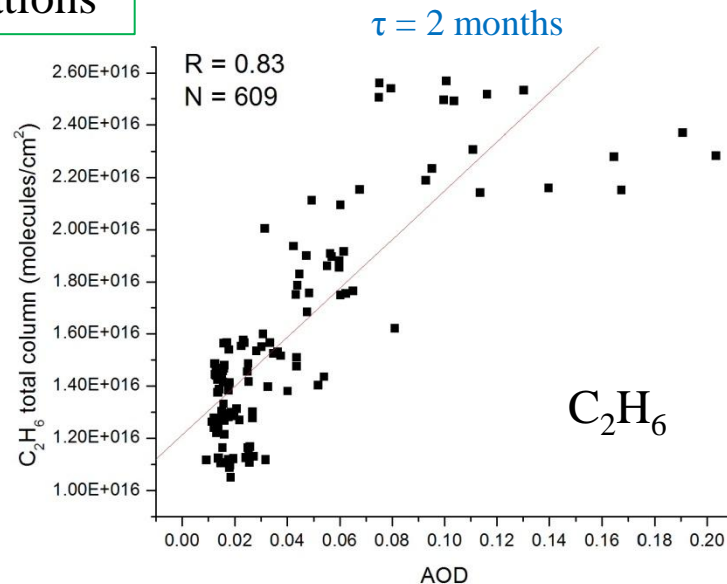
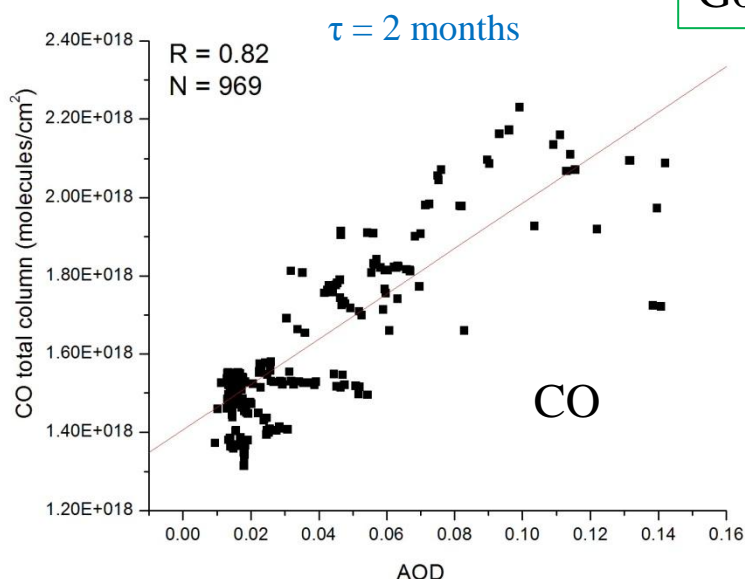


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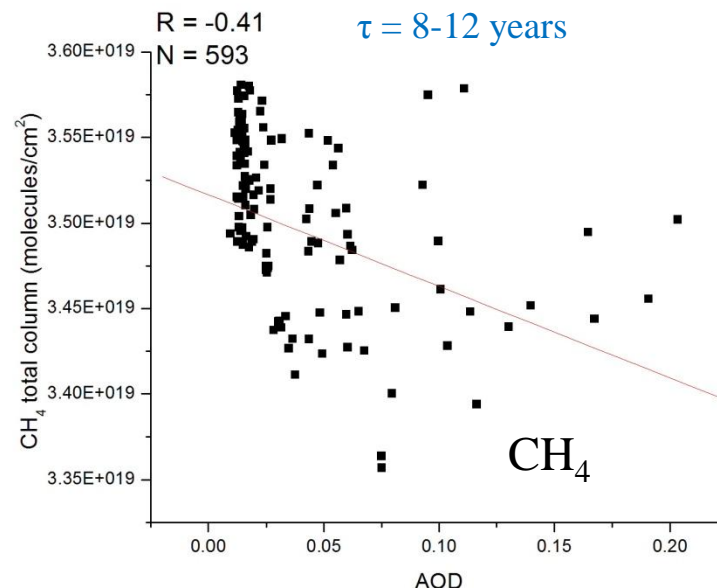
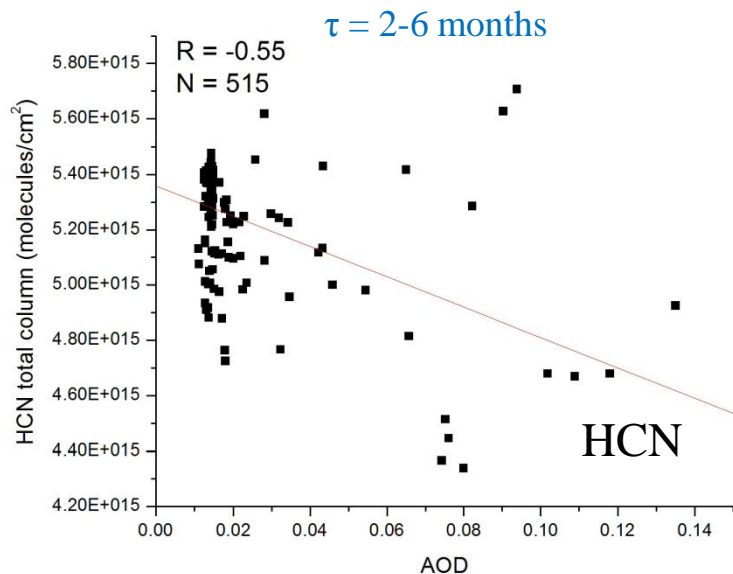
# Trace gas and AOD correlations in BB plumes

Good correlations



# Trace gas and AOD correlations in BB plumes

No correlations ...



- 1) Lifetime of methane is long.
- 2) HCN it is a BB tracer. But ocean uptake is the major sink [Li et al., 2009].  $R = 0.57$  for 2008 and  $R = -0.34$  for 2007 and this year was found to be the lower summer sea ice extend [NSIDC, National Snow and Ice Data Center].



# Conclusions and perspectives

## Conclusions

- There is **evidence** that **BB events affect the Arctic** (around 15 events observed at Eureka in 2007 and 2008).
- **FTIR measurements** (of CO and HCN) **agree** well with data from **GEOS-Chem**.
- The **synergy between FTIR and AOD** measurements provide **tools to quantify emission** of various species released by fires. Good correlation were found for CO, C<sub>2</sub>H<sub>6</sub>, and weaker correlation for the others gas, HCOOH and H<sub>2</sub>CO due to their different lifetimes or retrieval methods.

## Future work

- Extend this study to include 2009-2010-2011.
- Compare with the latest version of GEOS-Chem (old version V8.02.01 to new one V9.01.02).
- Refine retrievals of new species and better understand HCN results.
- Estimate emission ratio relative to CO or to AOD as a CO proxy for boreal forest
- Examine other sources of pollution besides BB, such as Fossil Fuel emissions ...

## Acknowledgements

### **PEARL/CANDAC:**

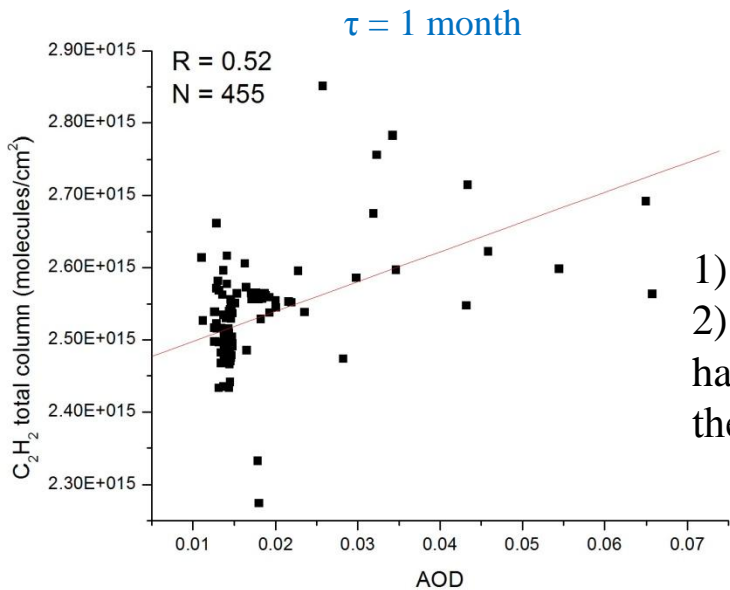
**ARIF, AIF/NSRIT, CFCAS, CFI, CSA, EC, GOC-IPY, INAC, NSERC, NSTP, OIT, ORF, PCSP, SEARCH**

**Canadian Arctic ACE Validation Campaigns: CSA, EC, NSERC, NSTP, Project PI Kaley A. Walker**

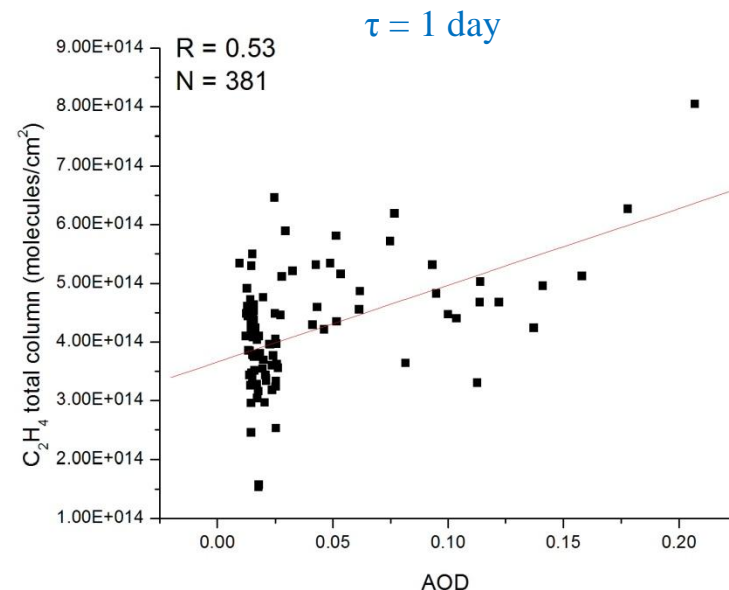
**Logistical and operational support at Eureka: The wonderful team at the EC Weather Station, CANDAC/PEARL PI James R Drummond, PEARL site manager Pierre Fogal, The CANDAC operators, CANDAC Data Manager Yan Tsehtik**

# Thanks for your attention !

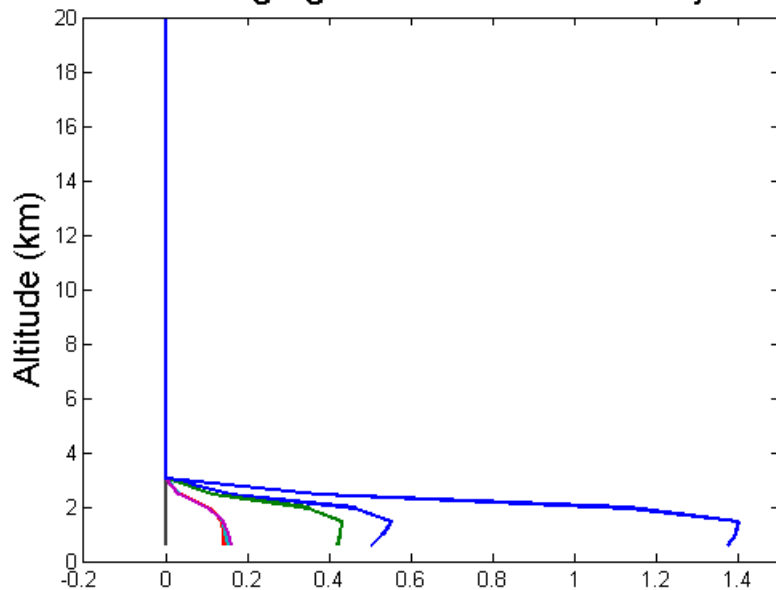
# Less good correlations



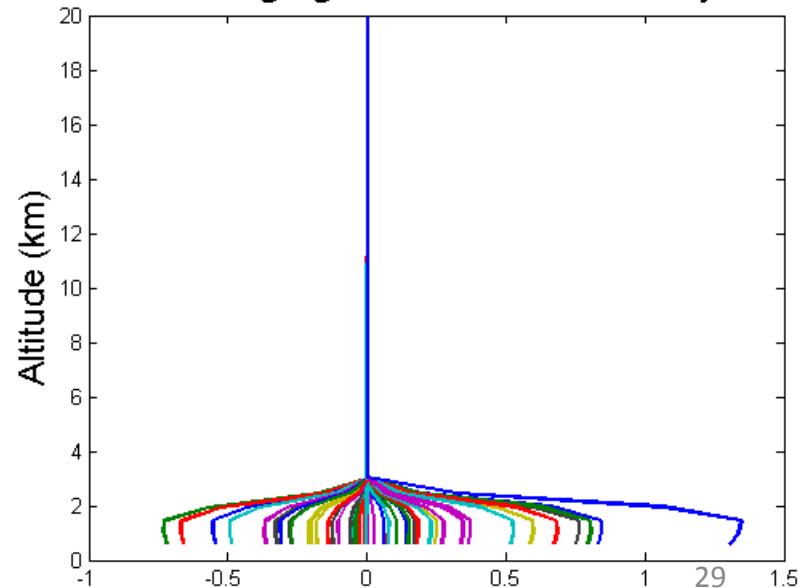
- 1) Lifetimes are smaller
- 2) Retrieval methods have to be improved for these two species ...



### Averaging Kernel and Sensitivity

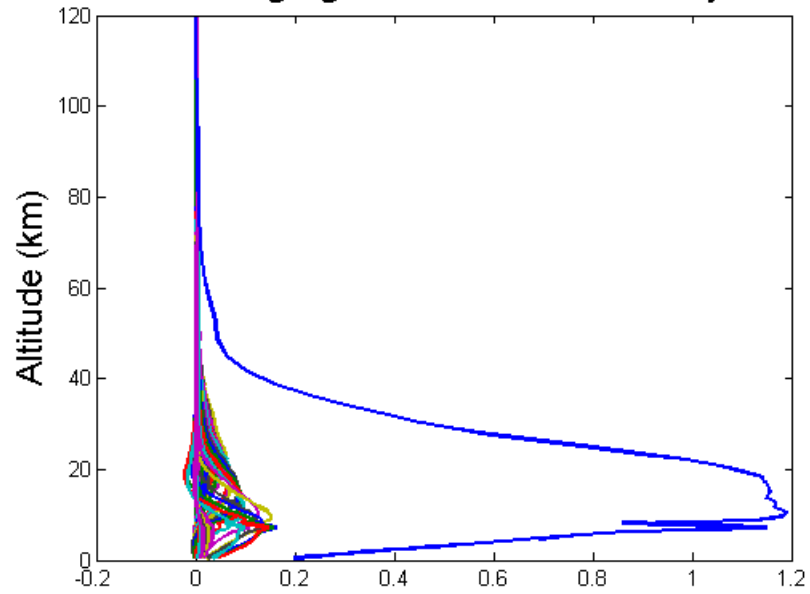


### Averaging Kernel and Sensitivity



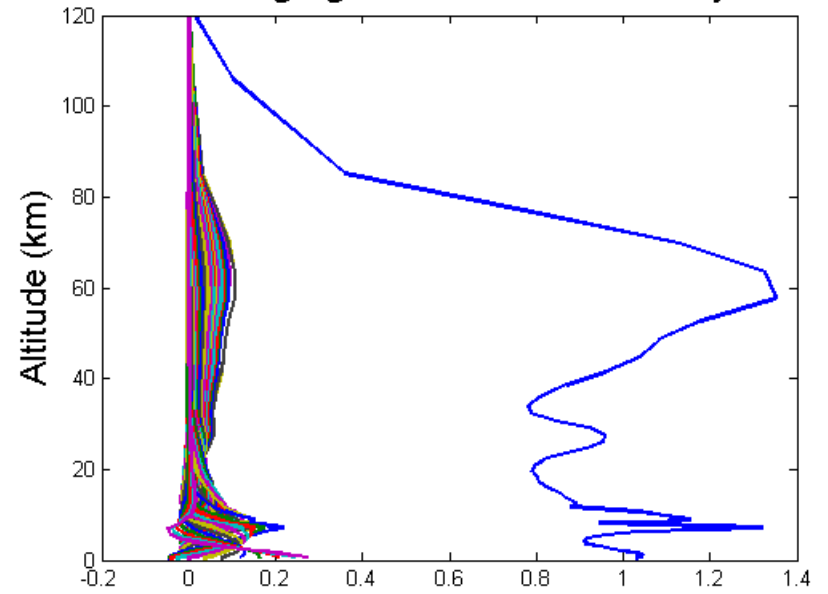
# HCN

## Averaging Kernel and Sensitivity



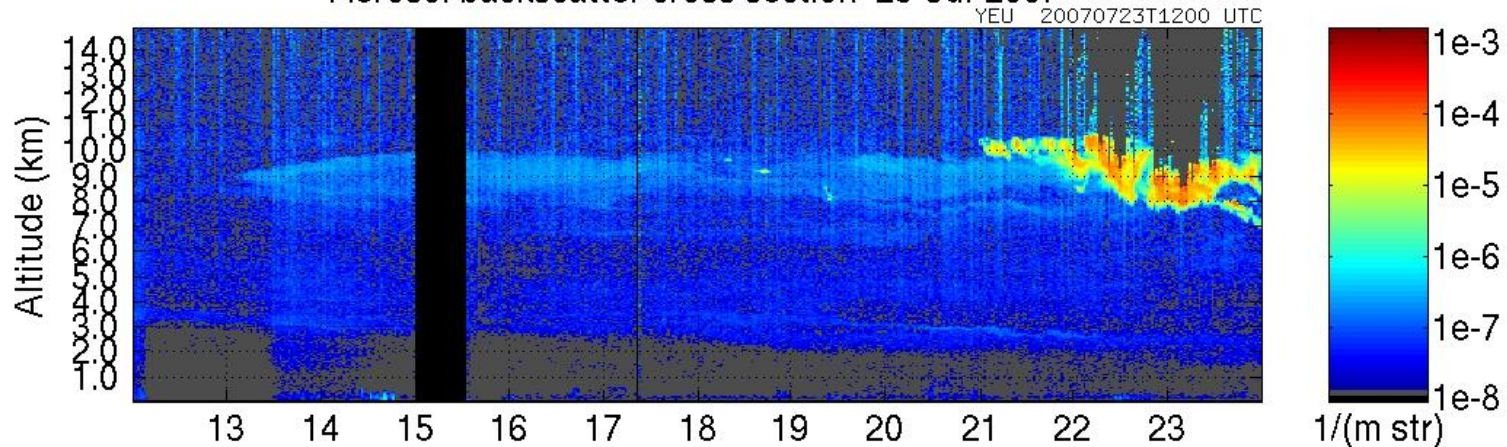
# CO

## Averaging Kernel and Sensitivity

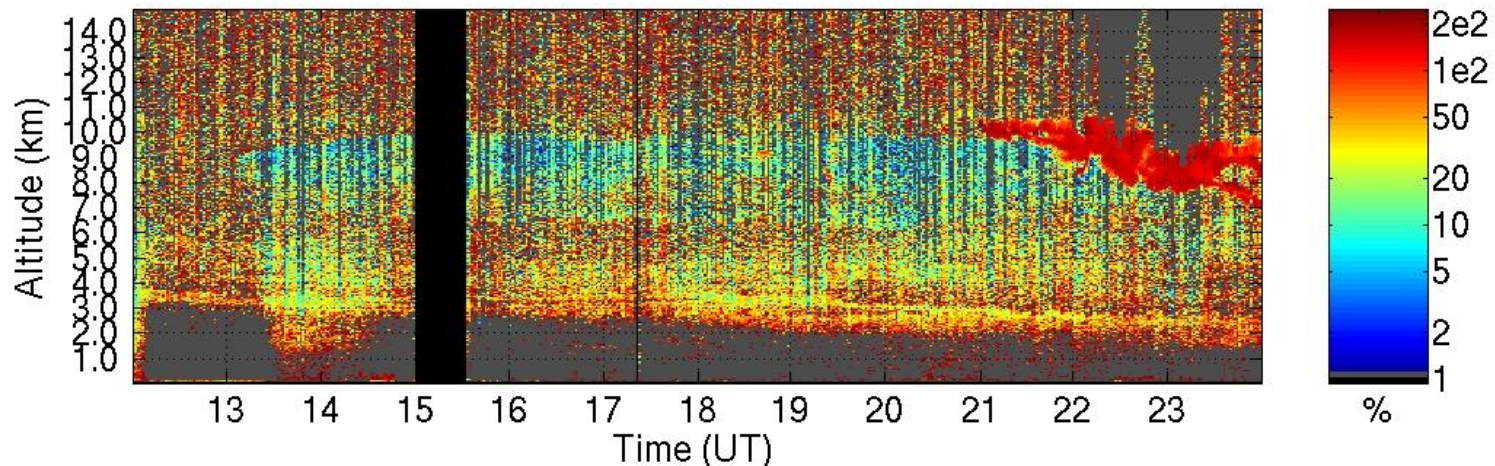


# 23 July 2007 AHSL lidar.ssec.wisc.edu

Aerosol backscatter cross section 23-Jul-2007

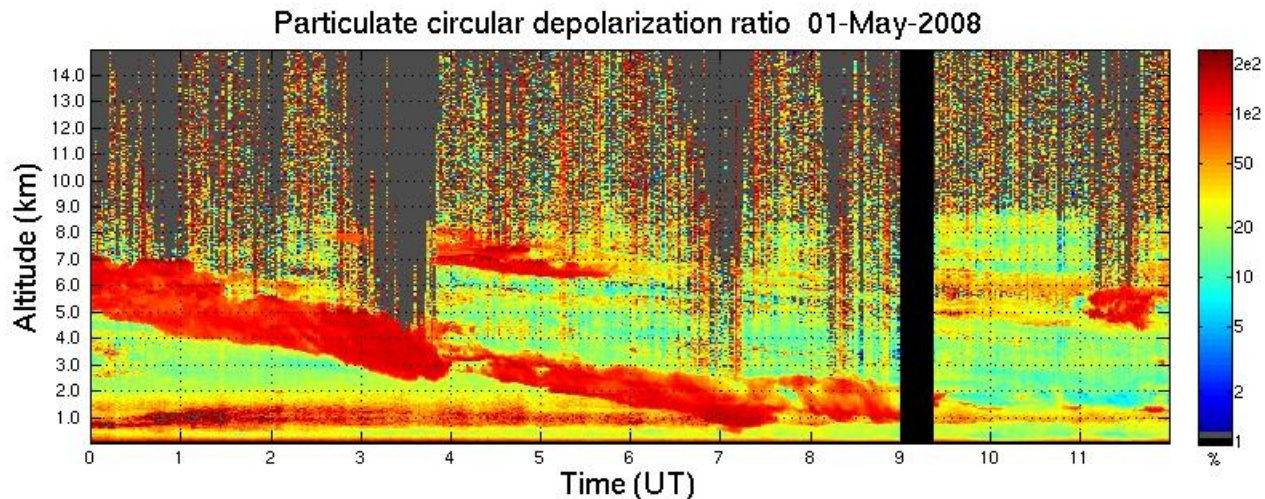
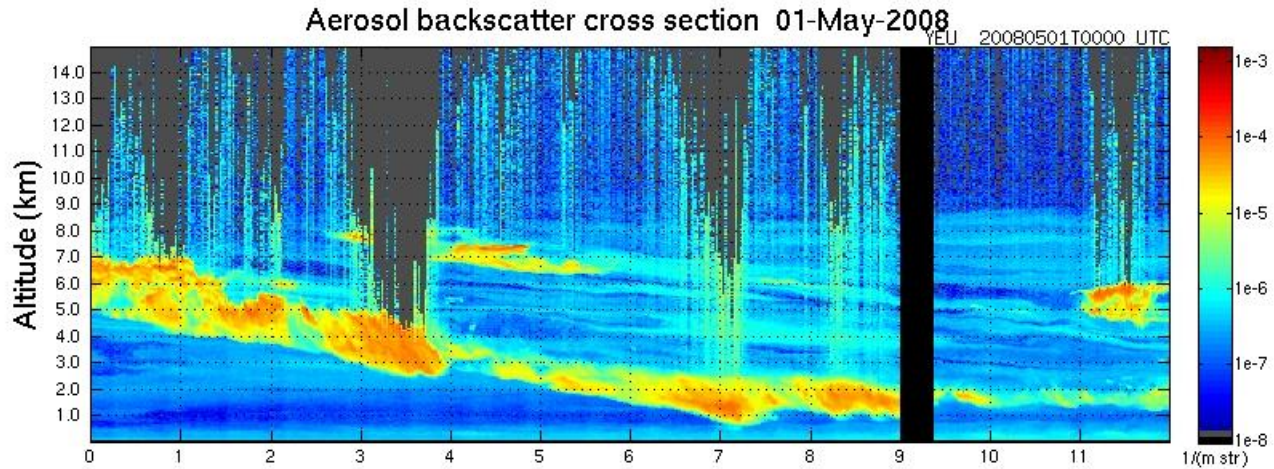


Particulate circular depolarization ratio 23-Jul-2007



BB particles = spherical shape = low depolarization / Ice crystal = irregular shape = high depolarization

# 1 May 2008 AHSL [lidar.ssec.wisc.edu](http://lidar.ssec.wisc.edu)



BB particles = spherical shape = low depolarization / Ice crystal = irregular shape = high depolarization

50 years of observations of the Arctic, referring primarily to satellite sea ice observation