Examining the oxidative capacity of the troposphere in the remote tropical Western Pacific

Julie Nicely

23 October 2014

University of Maryland

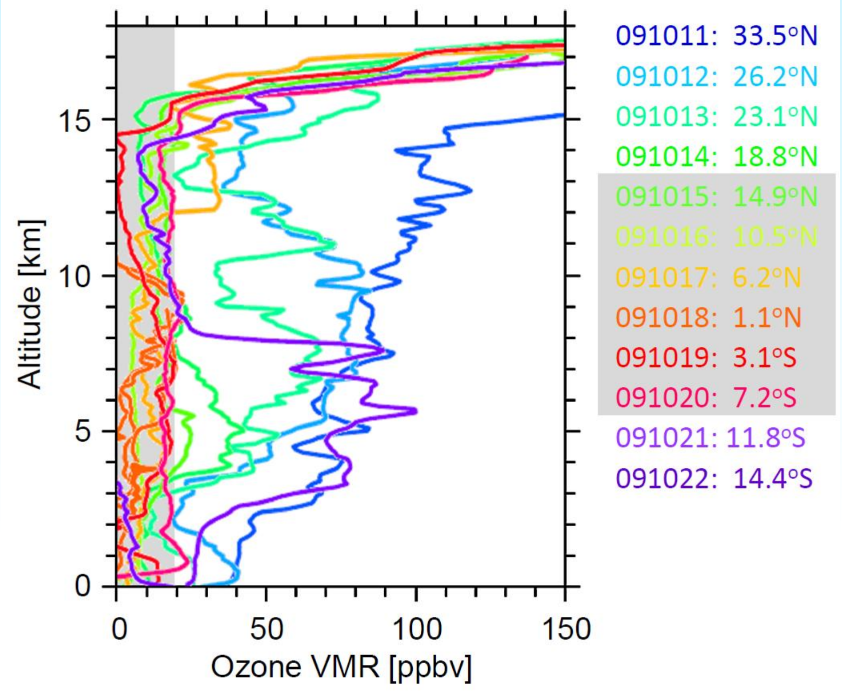
Ross Salawitch, Tim Canty, Dan Anderson, Doug Kinnison, Teresa Campos, Cameron Homeyer, Dan Riemer, Andy Weinheimer, et al.

Outline

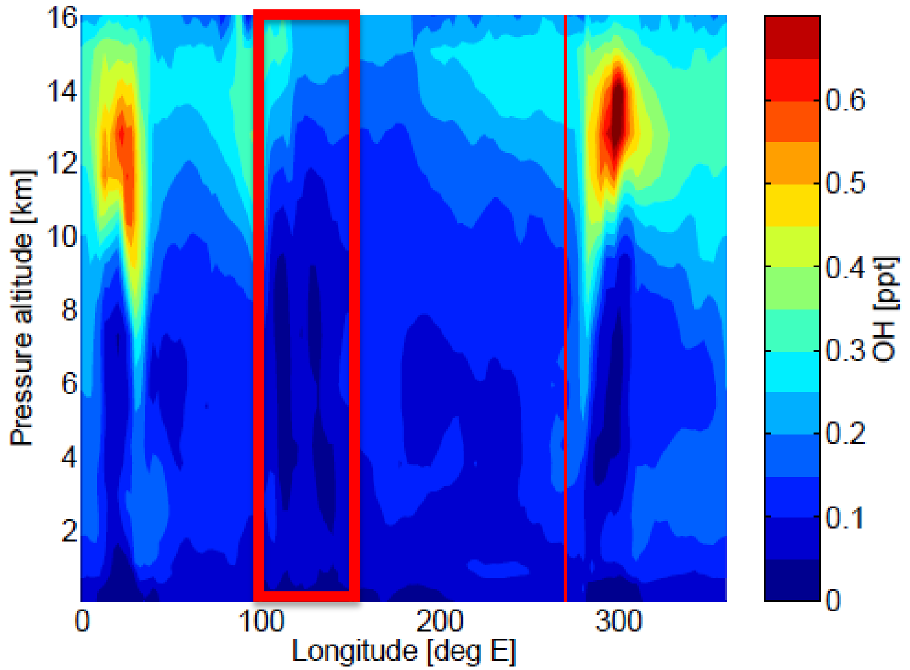
- Why OH in the tropical western Pacific is of particular interest
- Box modeling method
- Early results:
  - OH box modeled from CONTRAST data
  - OH box modeled from CAMChem output
  - Impact of high O_3/low H_2O filaments on OH
- Future work

“OH Hole” predicted by Rex et al. in tropical western Pacific

Sondes, Oct 2009



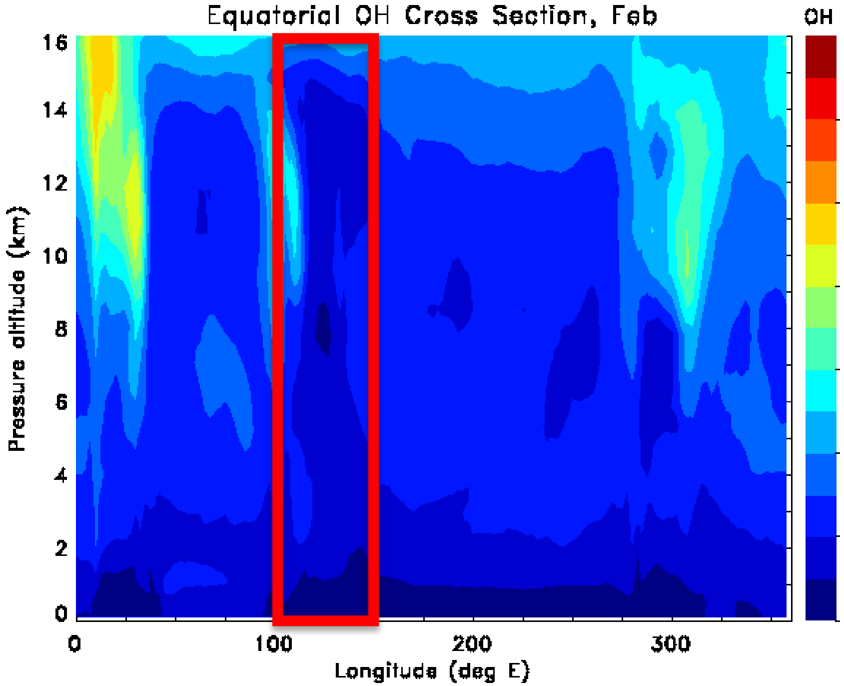
24 Hr Avg OH,
GEOS-Chem
first half Oct 2009



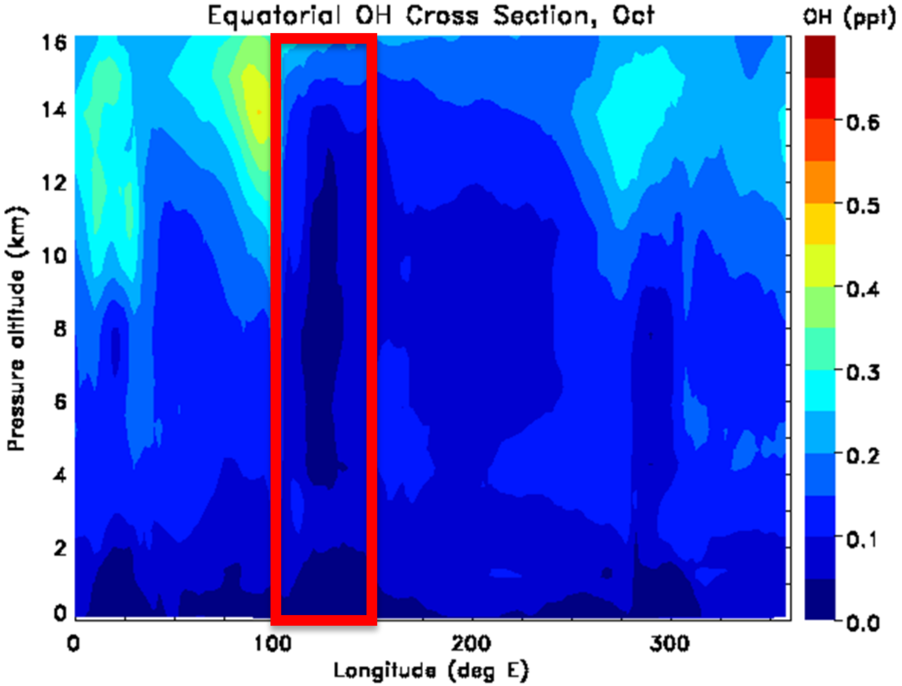
Rex *et al.*, *ACP*, 2014

“OH Hole” predicted by Rex et al. in tropical western Pacific

24 Hr Avg OH,
CAM-Chem
Feb 2008

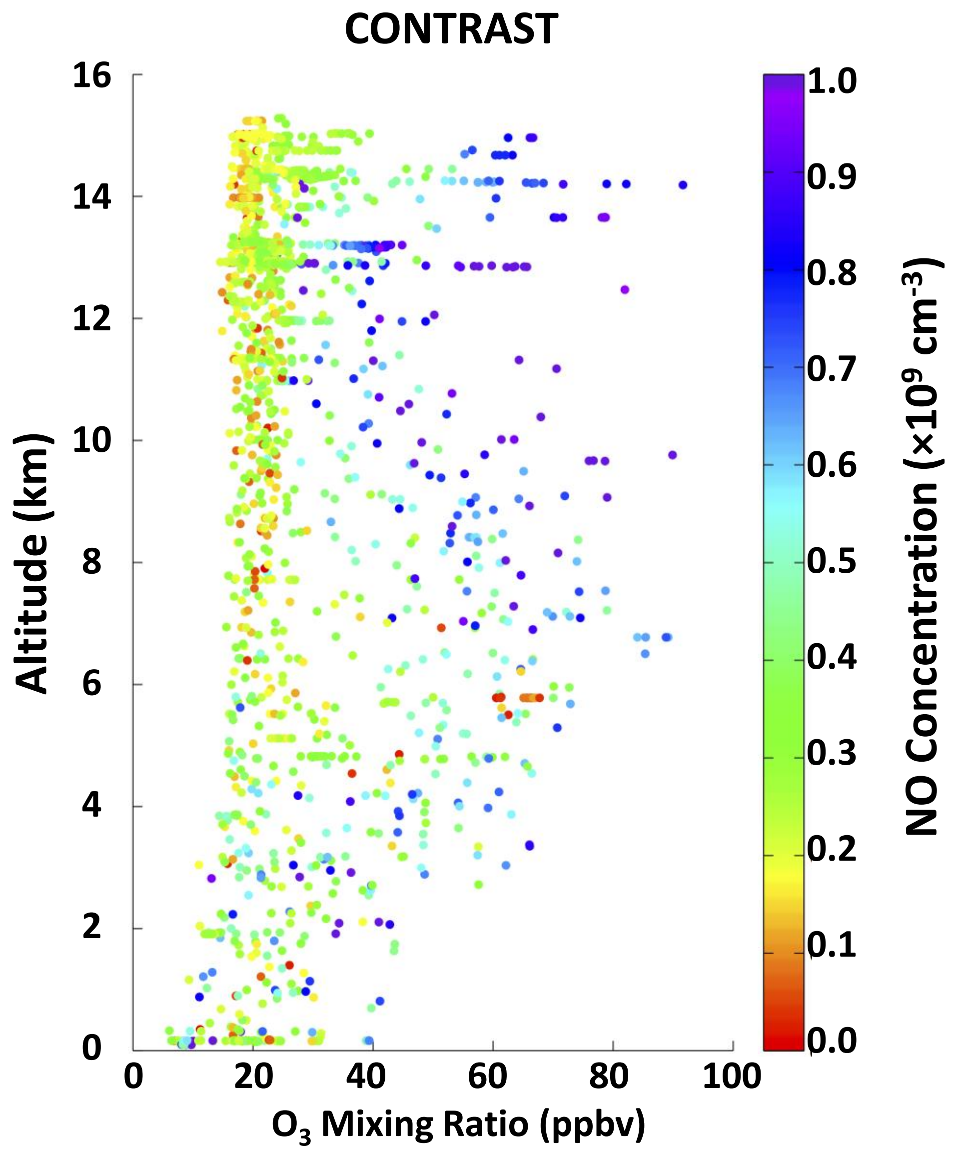


24 Hr Avg OH,
CAM-Chem
Oct 2008



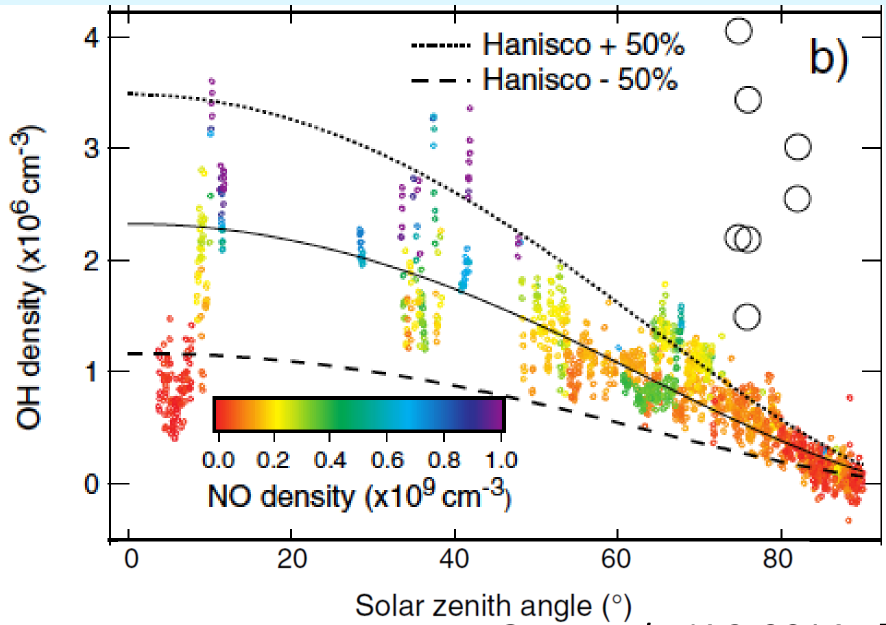
Analysis of POLMIP CTM model archive

“OH Hole” predicted by Rex et al. in tropical western Pacific ...but did NO get low enough?



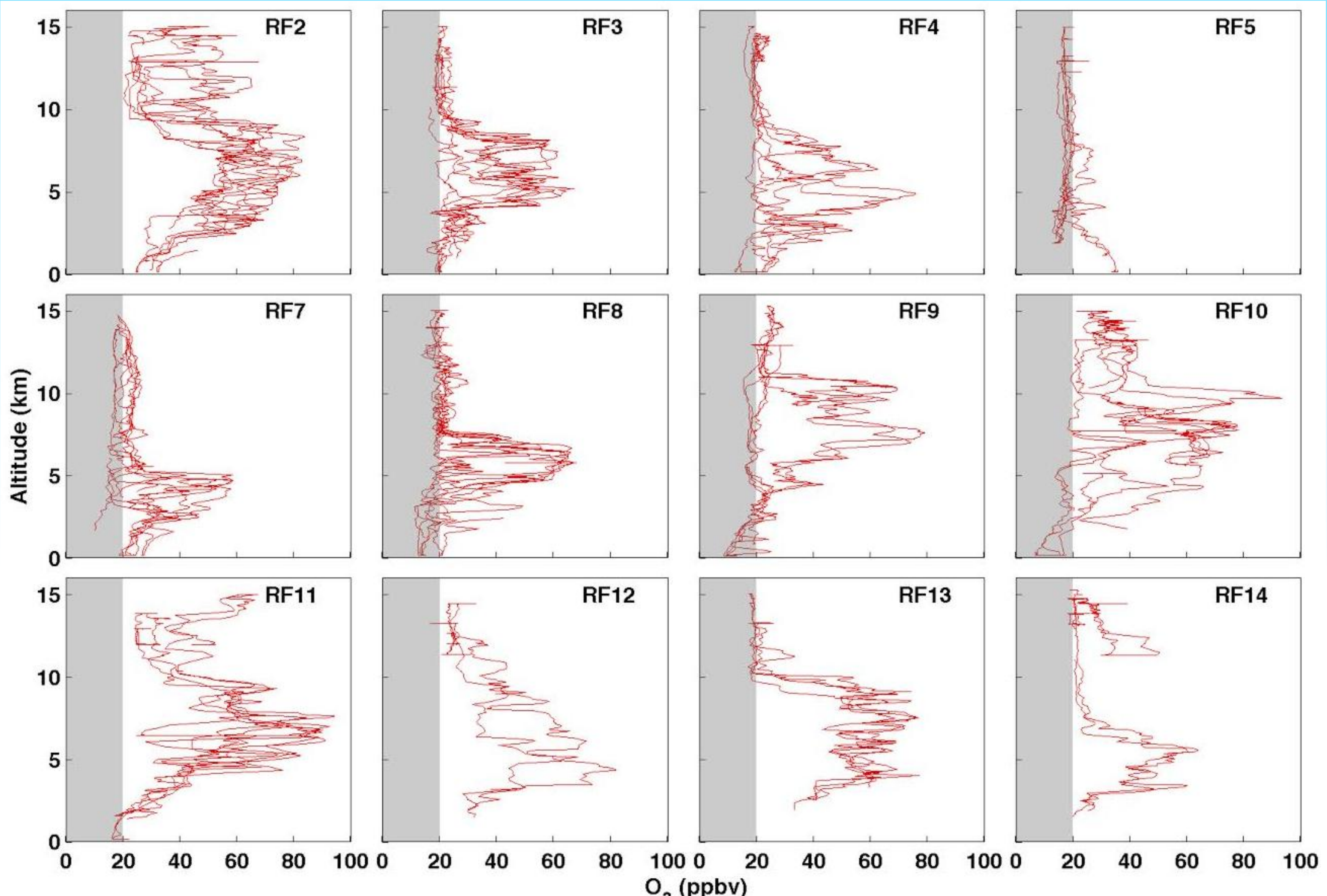
Gao et al. (2014) &
Rex et al. (2014) associate
NO < 1×10^8 cm^{-3}
with this “tropical OH hole”

[NO] this low was rarely seen
during CONTRAST

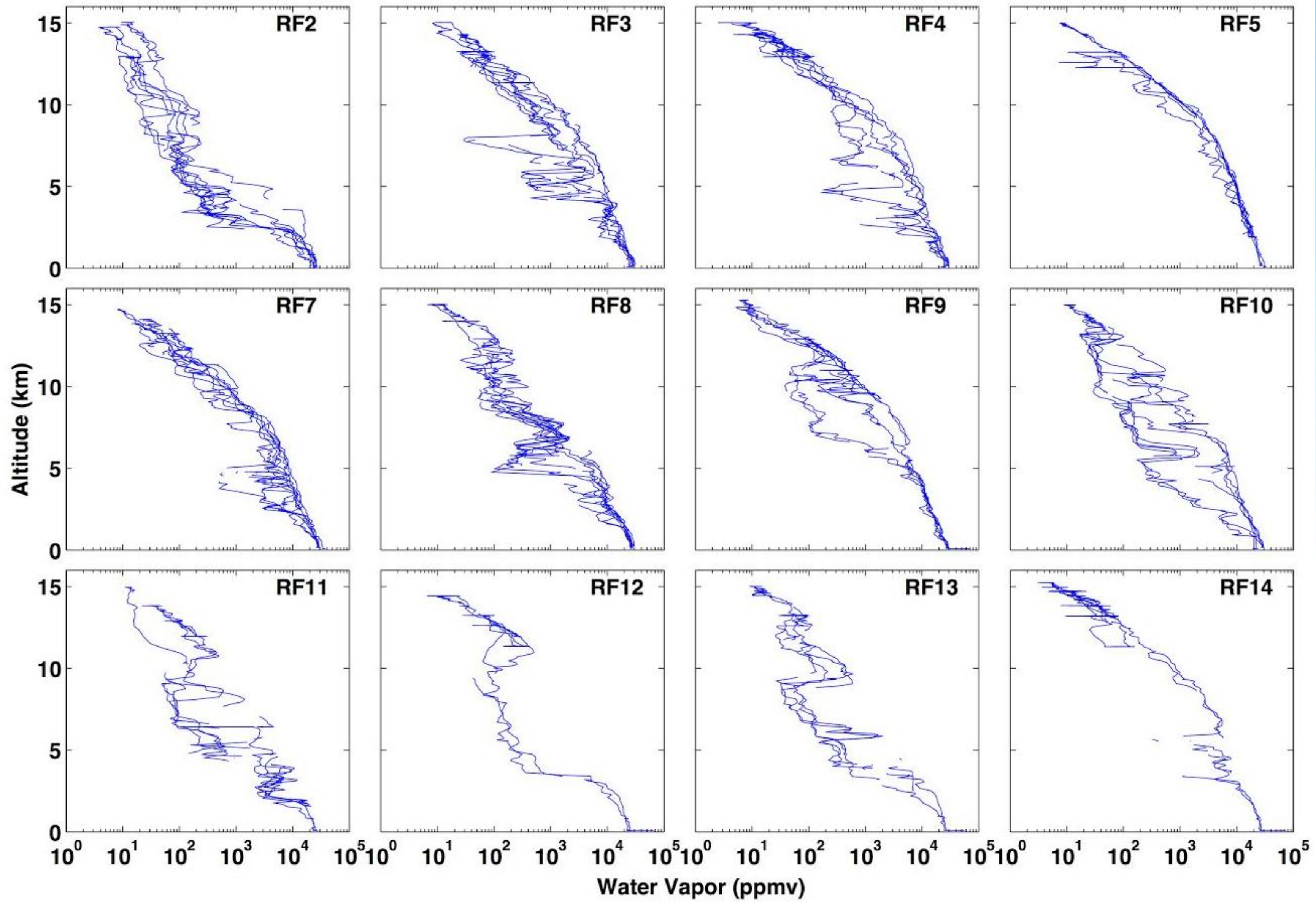


Gao *et al.*, *JAC*, 2014

Also want to investigate impact of high O_3/low H_2O on OH



Also want to investigate impact of high O_3/low H_2O on OH



Box Model

DSMACC: Dynamically Simple Model for Atmospheric Chemical Complexity
tropospheric chemistry box model that can interface to various chemical mechanisms

-Emmerson and Evans, ACP, 2009

Makes use of the:

KPP (Kinetics PreProcessor)

Damian et al., Computers and Chemical Engineering, 2002.

Leeds Master Chemical Mechanism

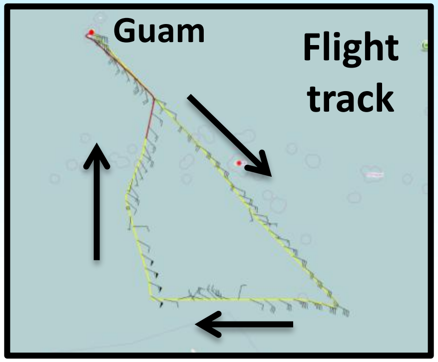
Jenkin et al., Atmos. Environ., 1997; Saunders et al., ACP, 2003

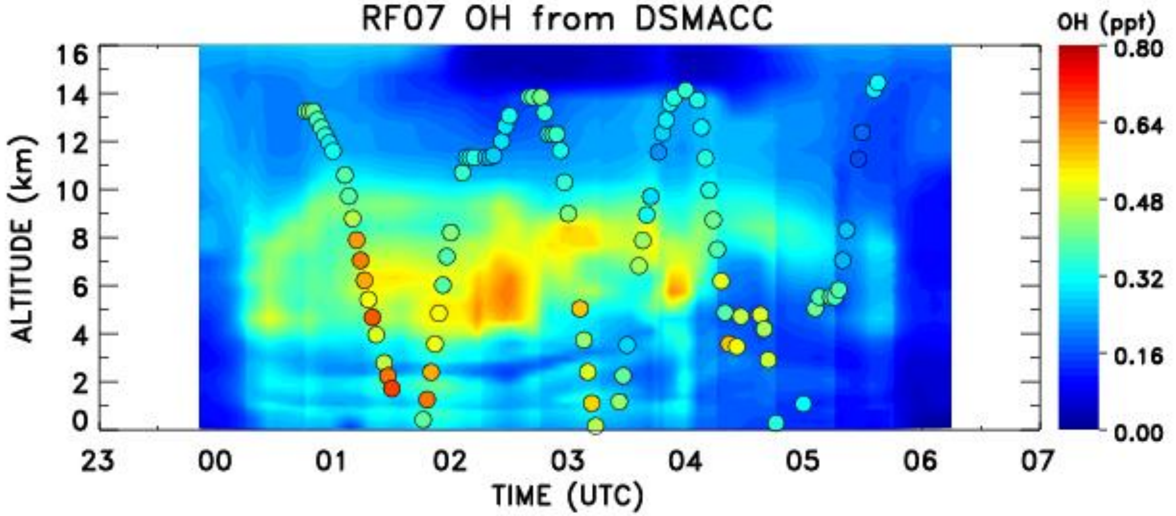
Box model can be run with inputs from observations, from a global model, or a combination of both

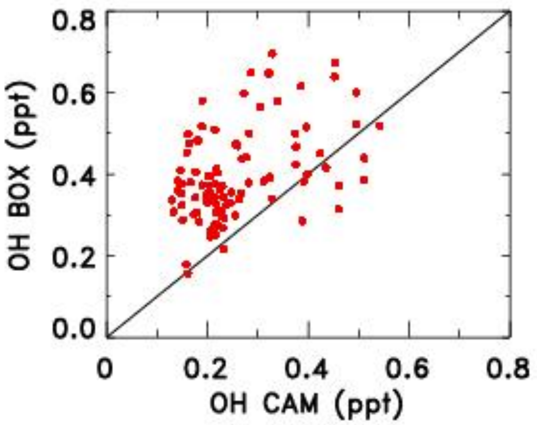
Box model inputs: all measured on GV
p
T
H_2O
O_3
CO
CO_2
NO
NO_2
CH_4
Acetone
C_3H_8
Isoprene
MVK
MACR
CH_3OH
CH_3CHO
HCHO
$J(O^1D)$
$J(NO_2)$

Box Modeling with Data

OH
RF07

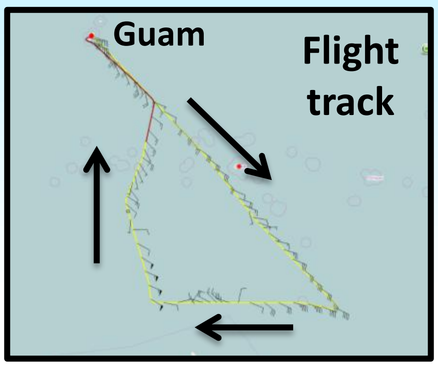


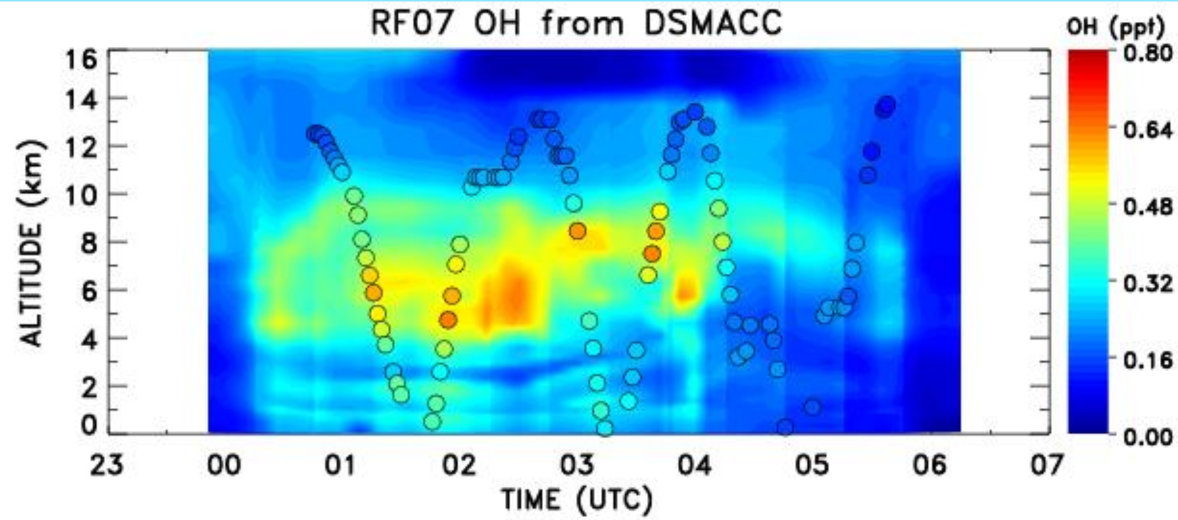




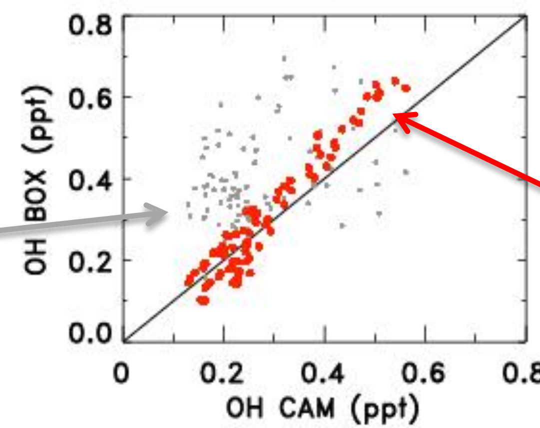
Box Modeling with CAM-Chem

OH
RF07





Box model results with observed inputs

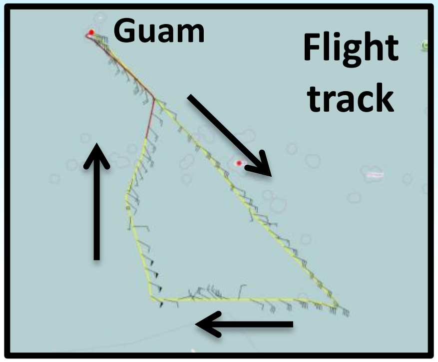


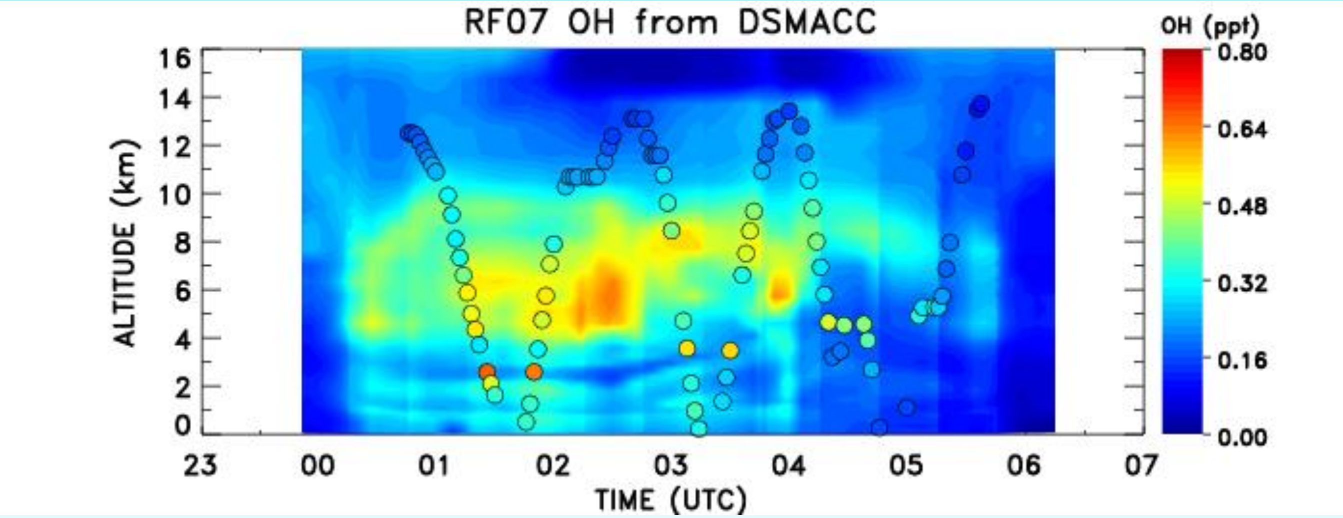
Box model results with CAM-Chem inputs:

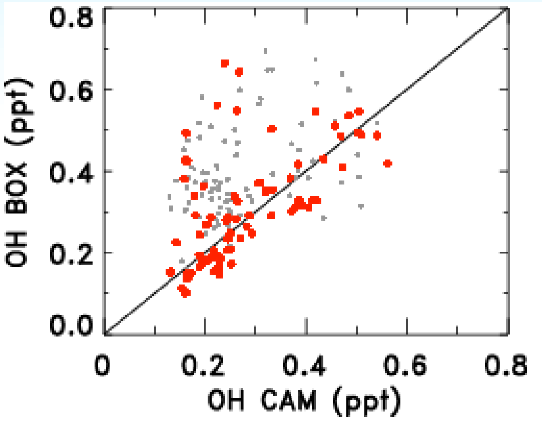
__Box model is good approximation of CAM-Chem chem mechanism__

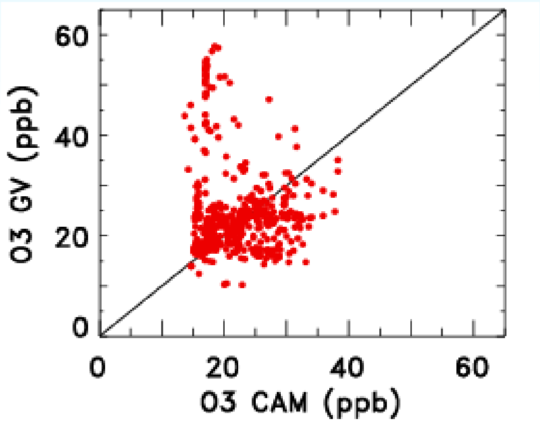
Box Modeling with CAM-Chem + GV O_3

OH
RF07



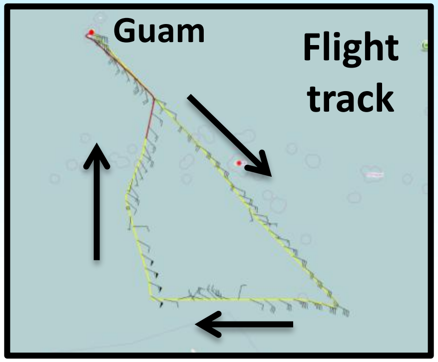


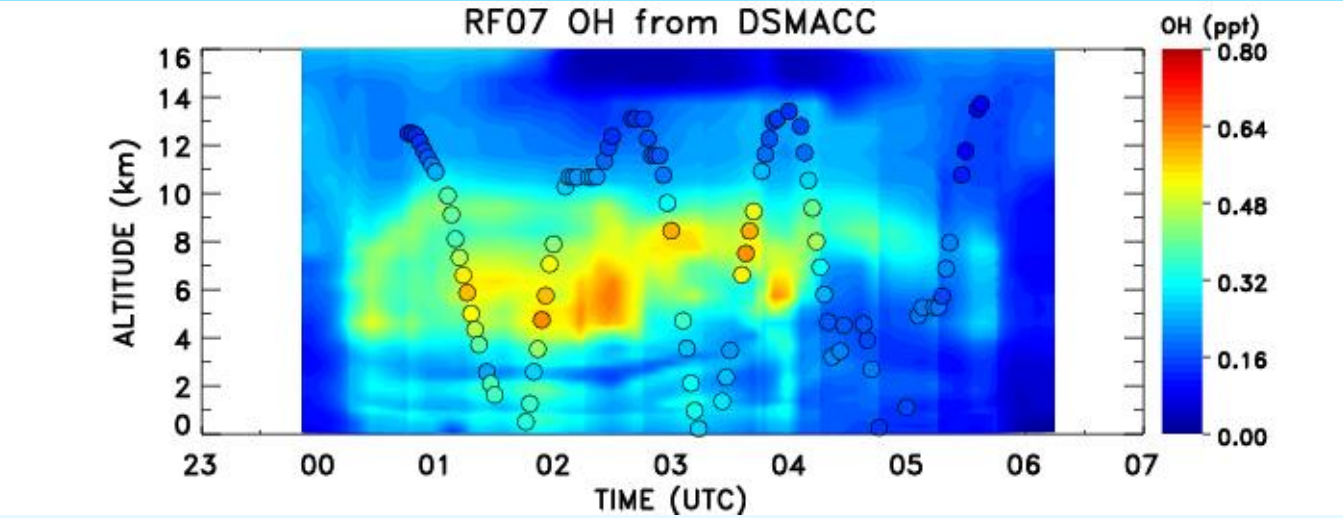


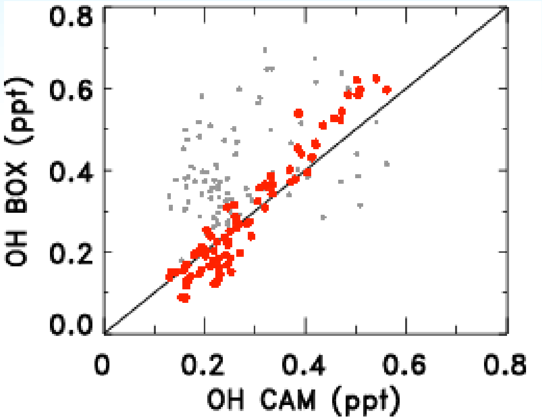


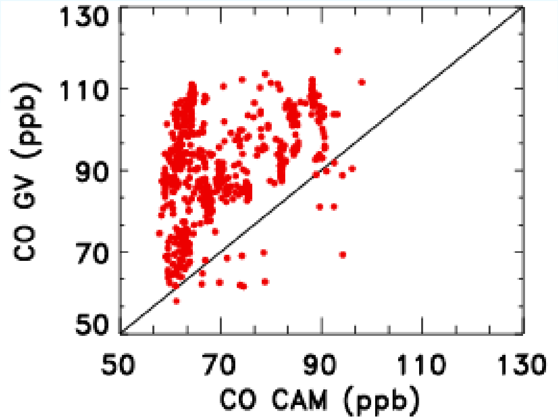
Box Modeling with CAM-Chem + GV CO

OH
RF07



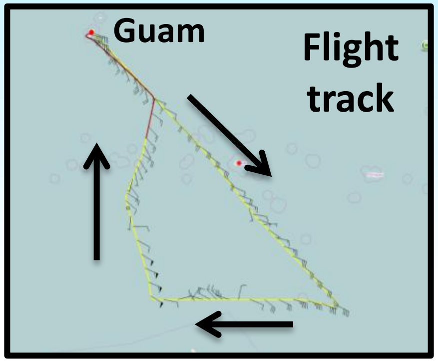


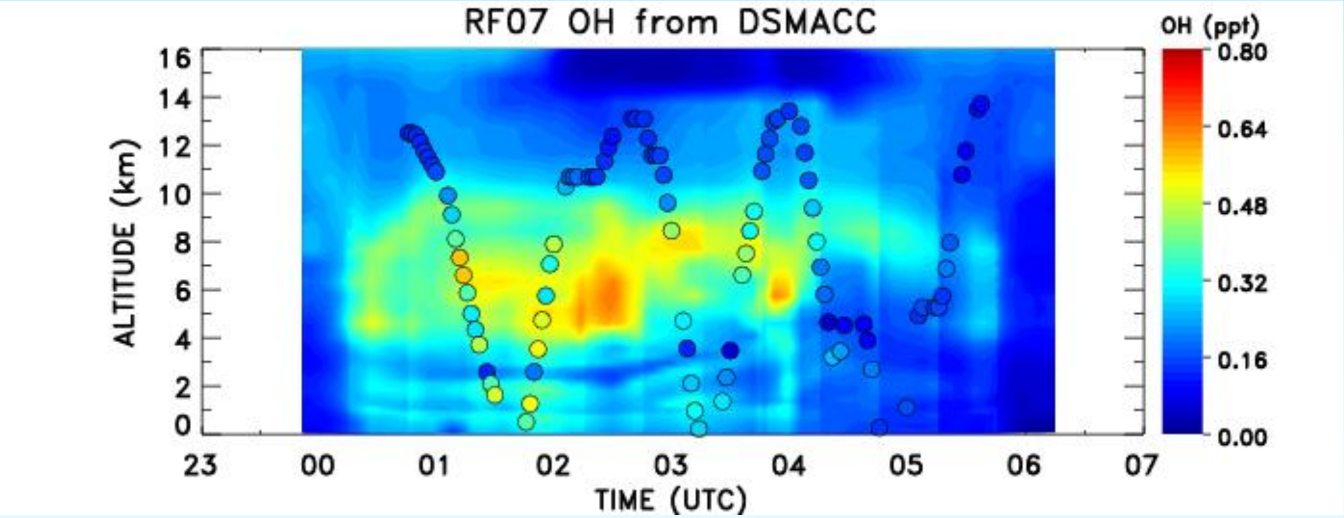


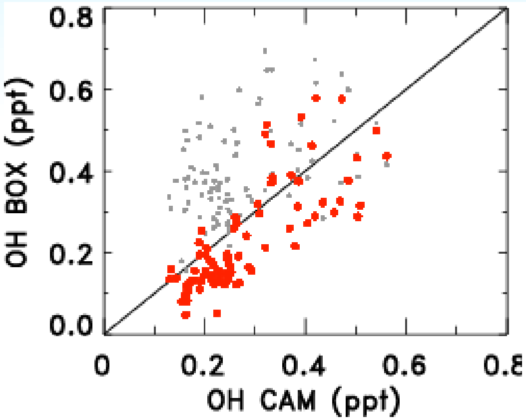


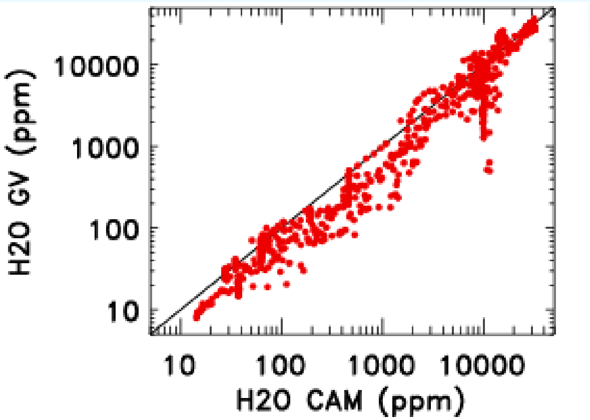
Box Modeling with CAM-Chem + GV H_2O

OH
RF07



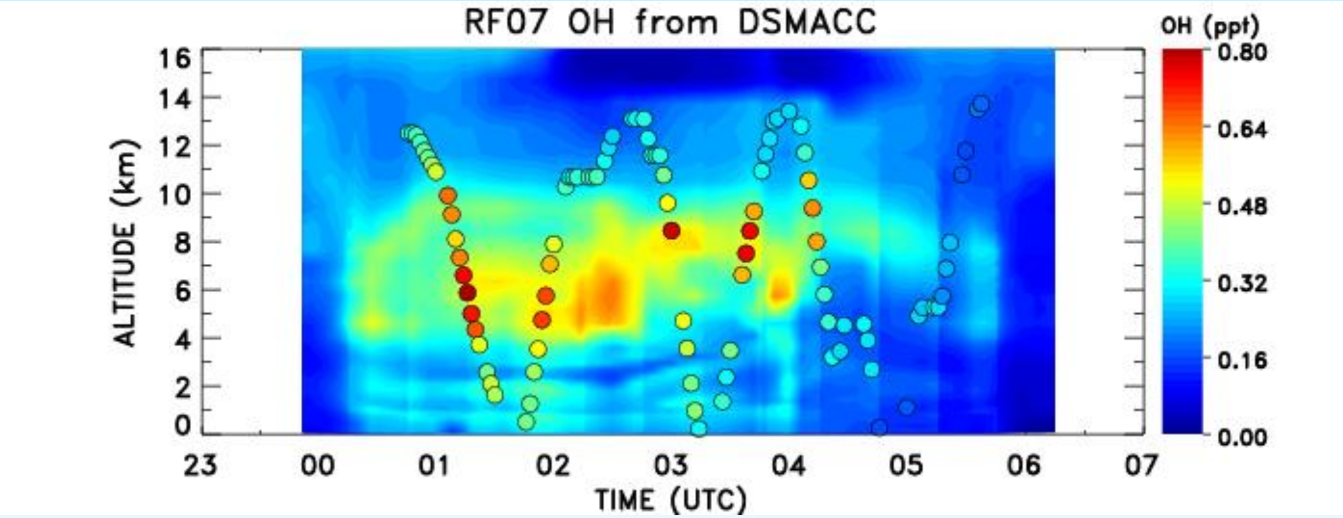


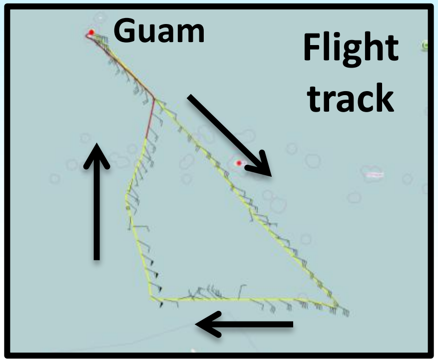


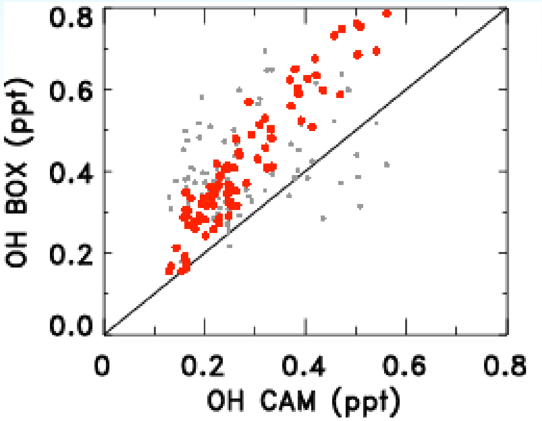


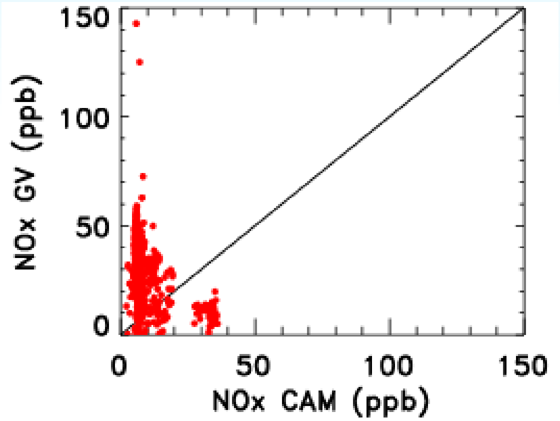
Box Modeling with CAM-Chem + GV NO_x

OH
RF07



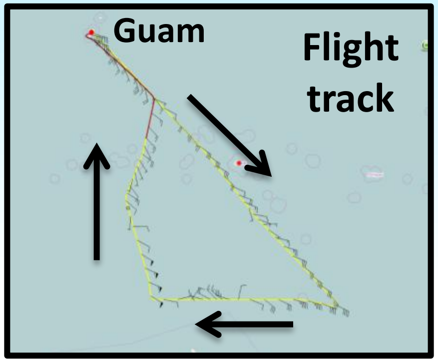


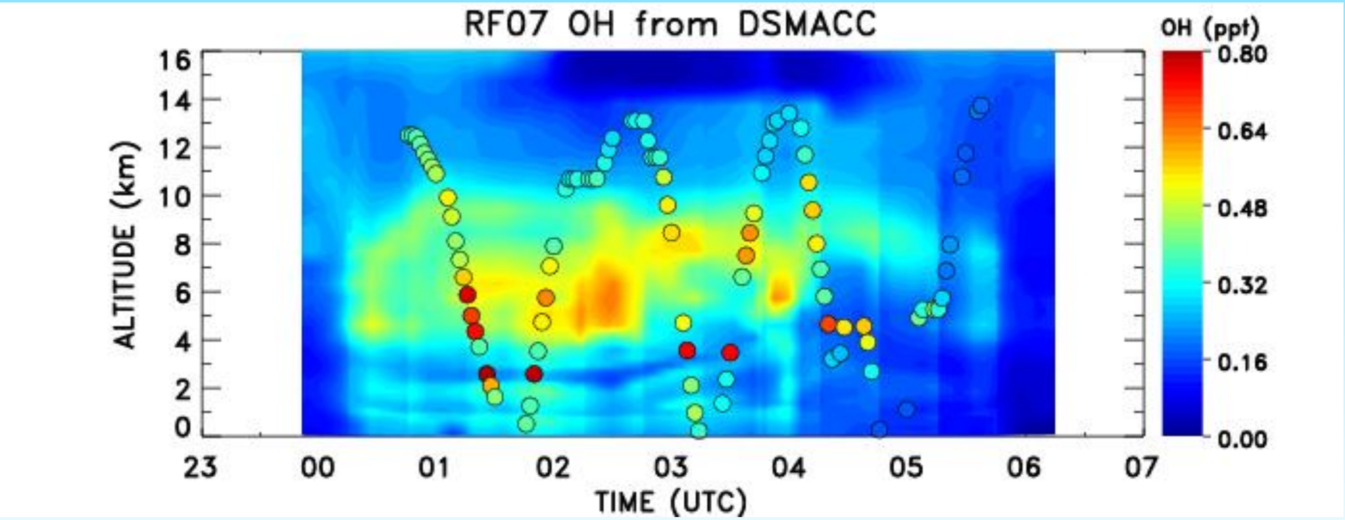


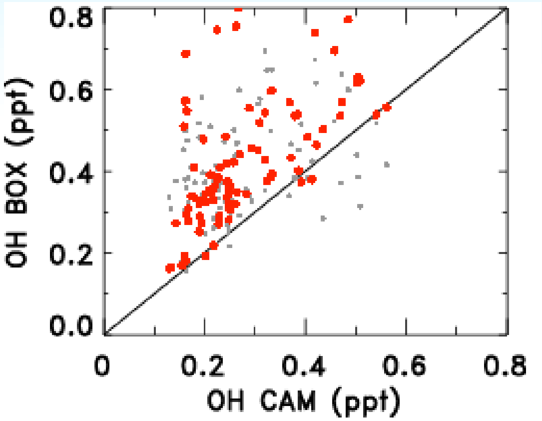


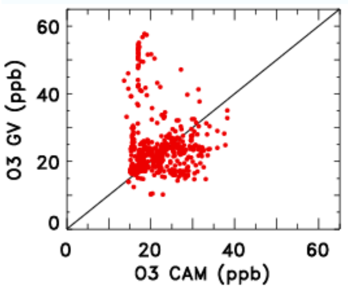
Box Modeling with CAM-Chem + GV O_3+NO_x

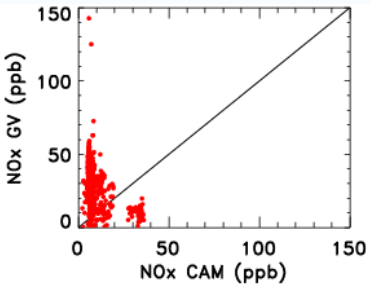
OH
RF07





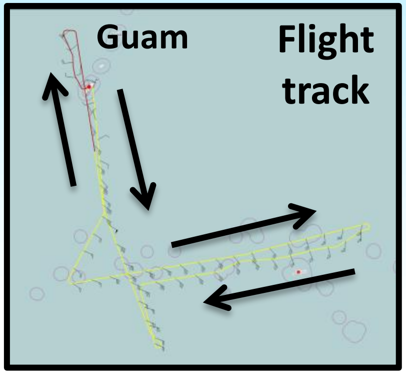


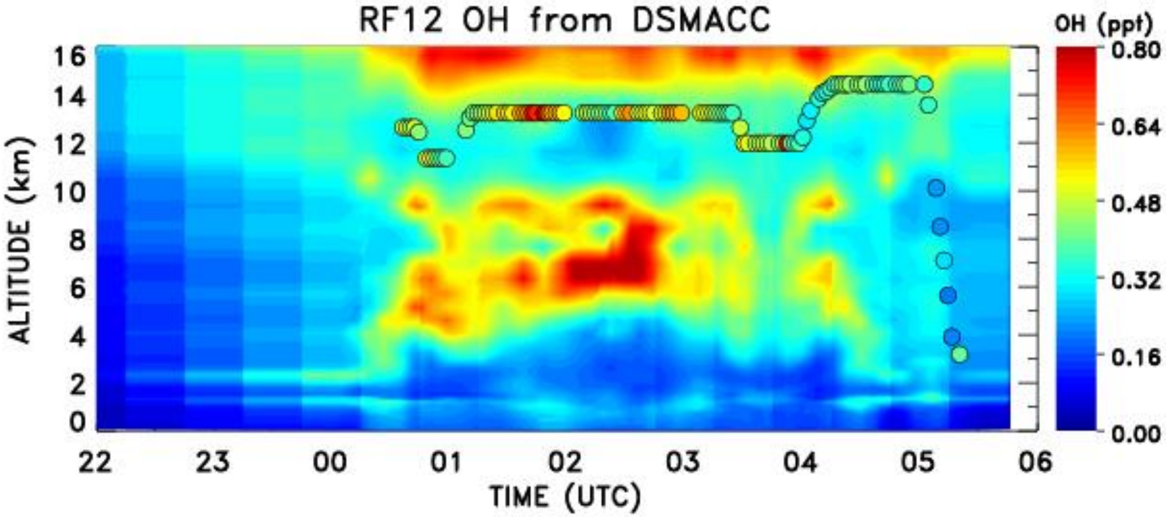


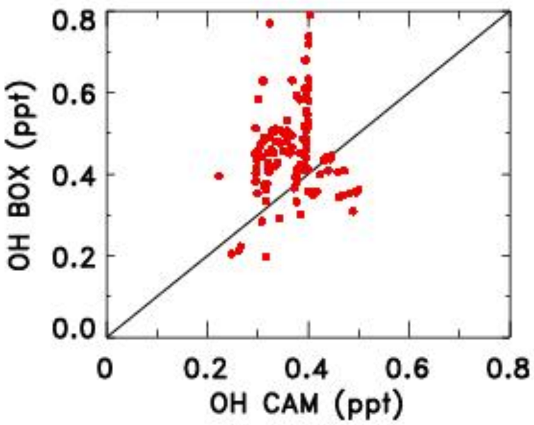


Box Modeling with Data

OH
RF12

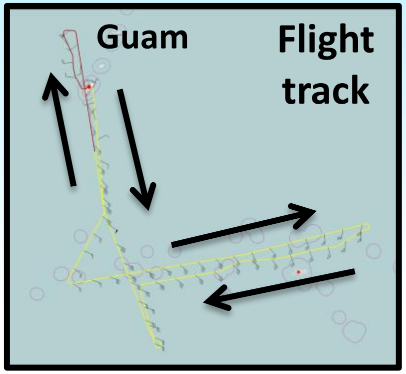


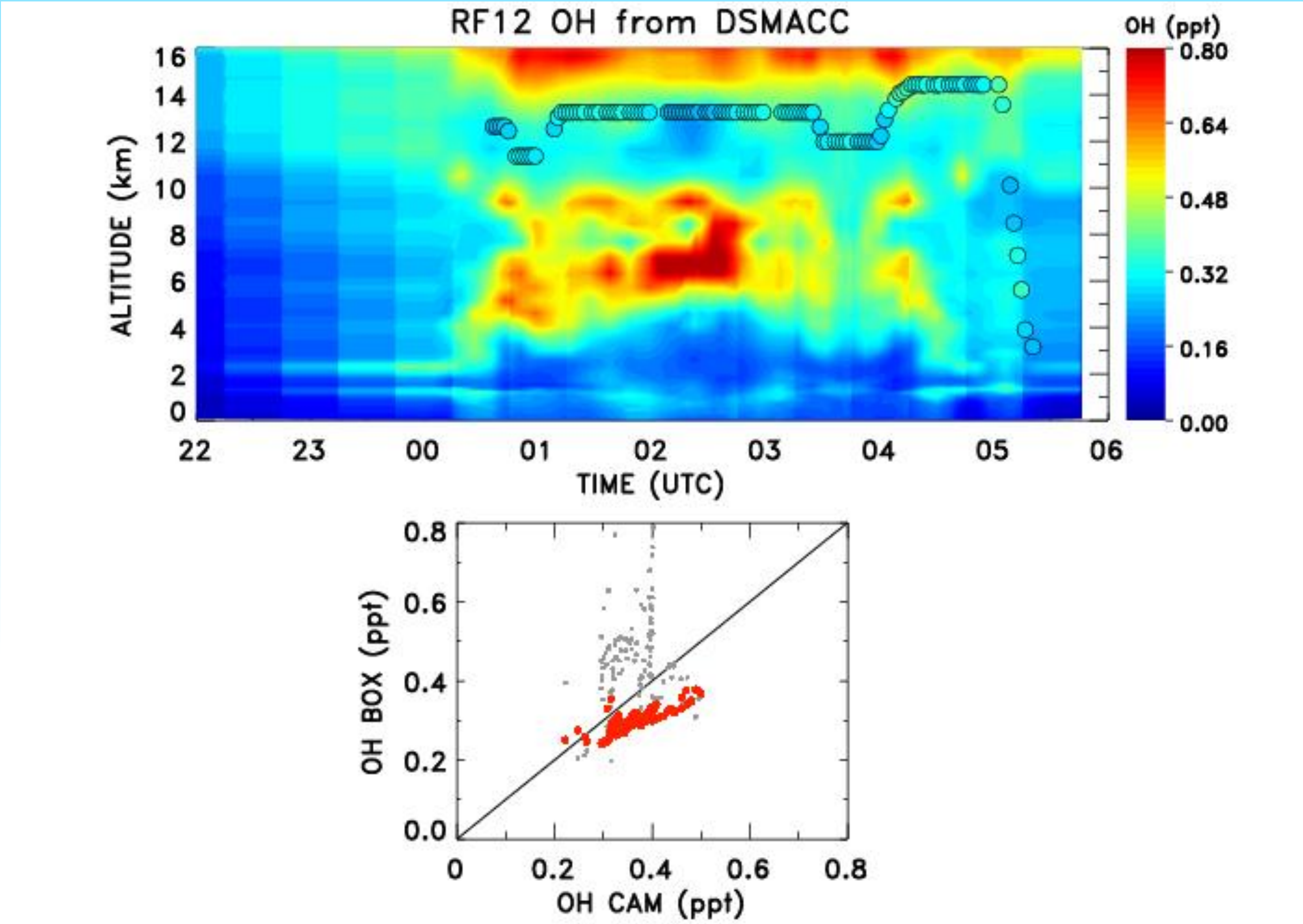




Box Modeling with CAM-Chem

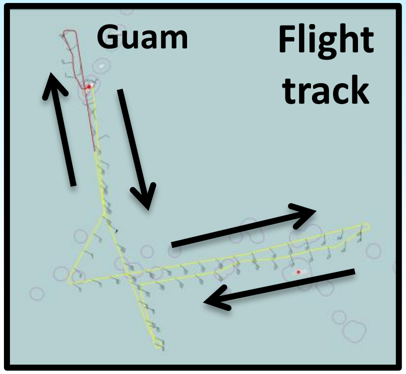
OH
RF12

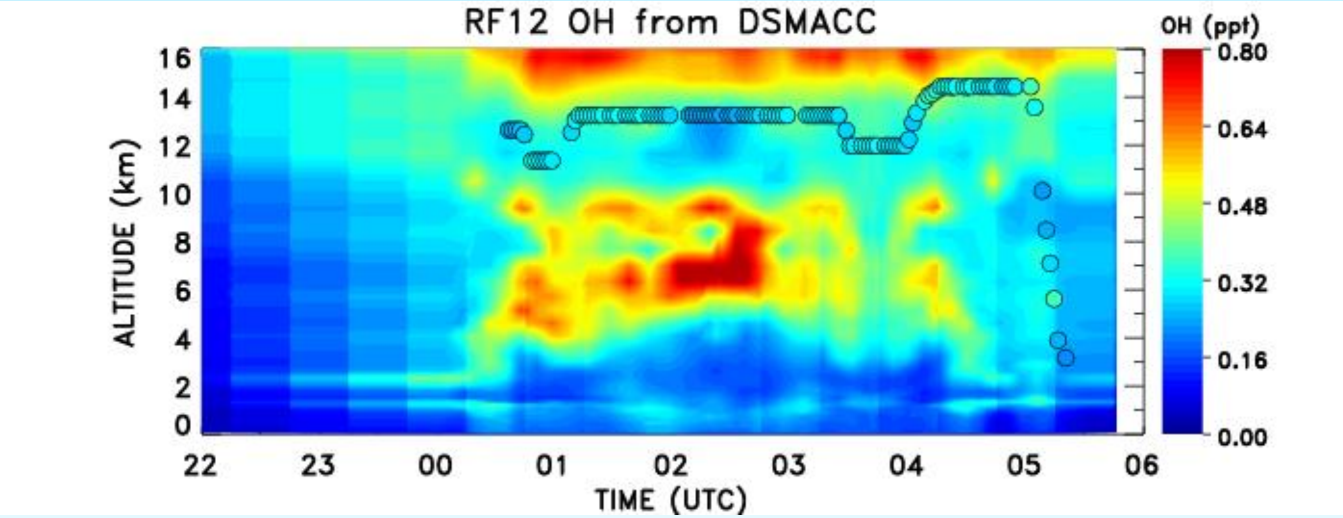


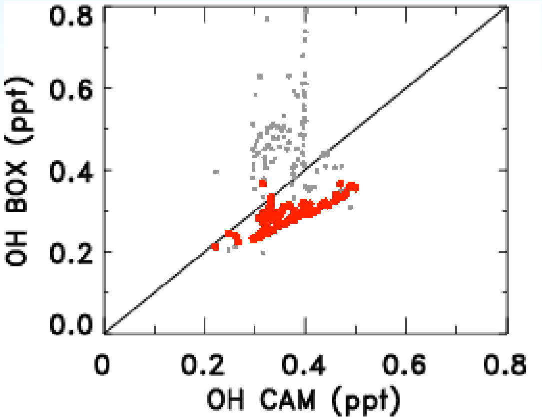


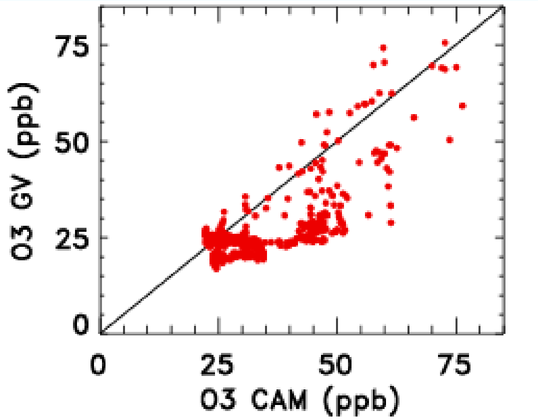
Box Modeling with CAM-Chem + GV O_3

OH
RF12



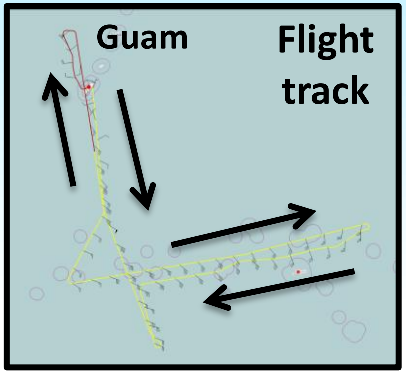


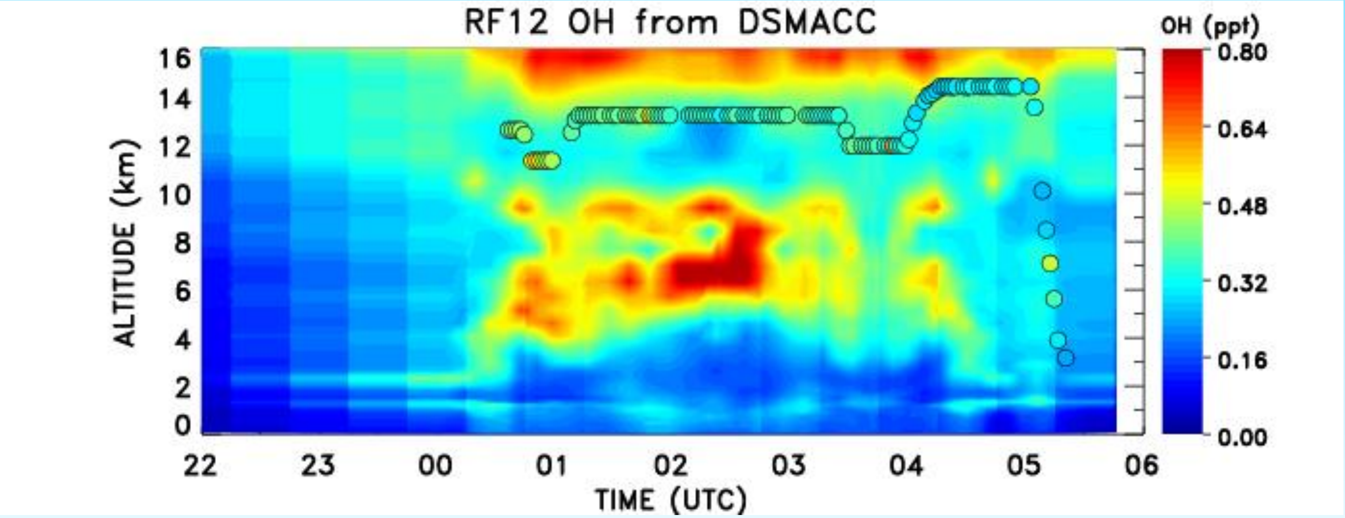


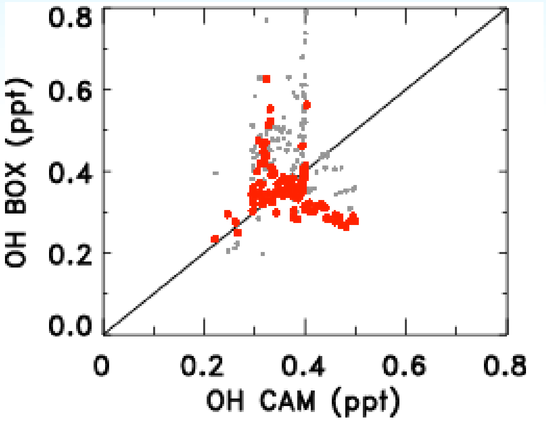


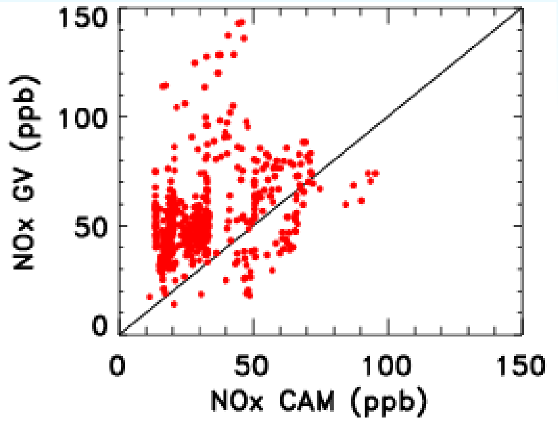
Box Modeling with CAM-Chem + GV NO_x

OH
RF12



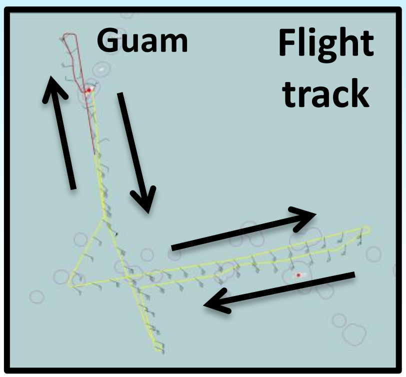


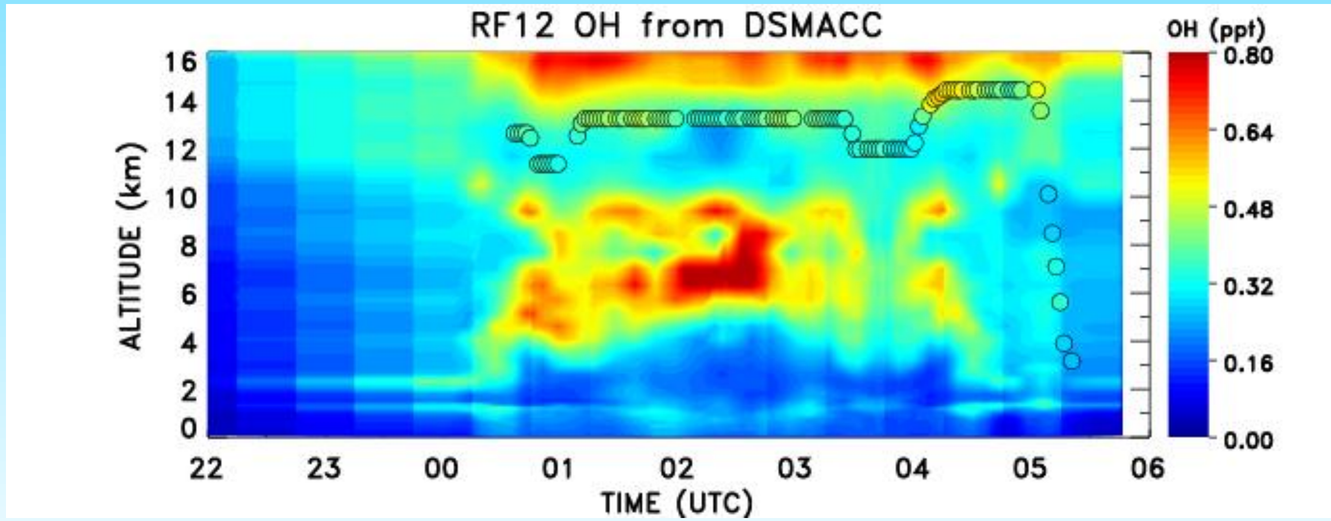


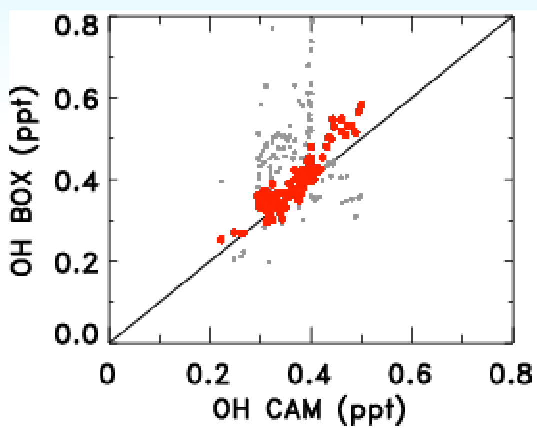


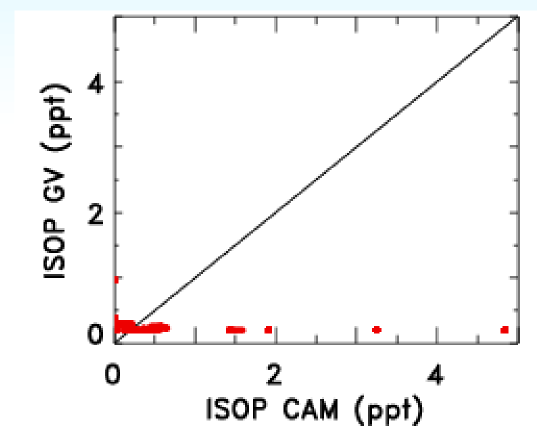
Box Modeling with CAM-Chem + GV VOCs

OH
RF12





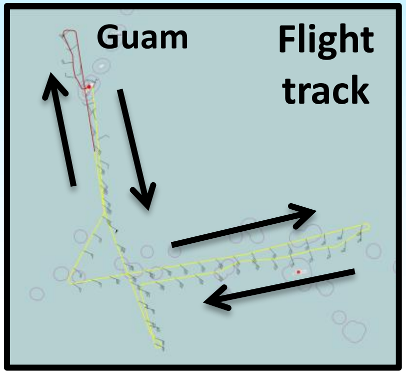


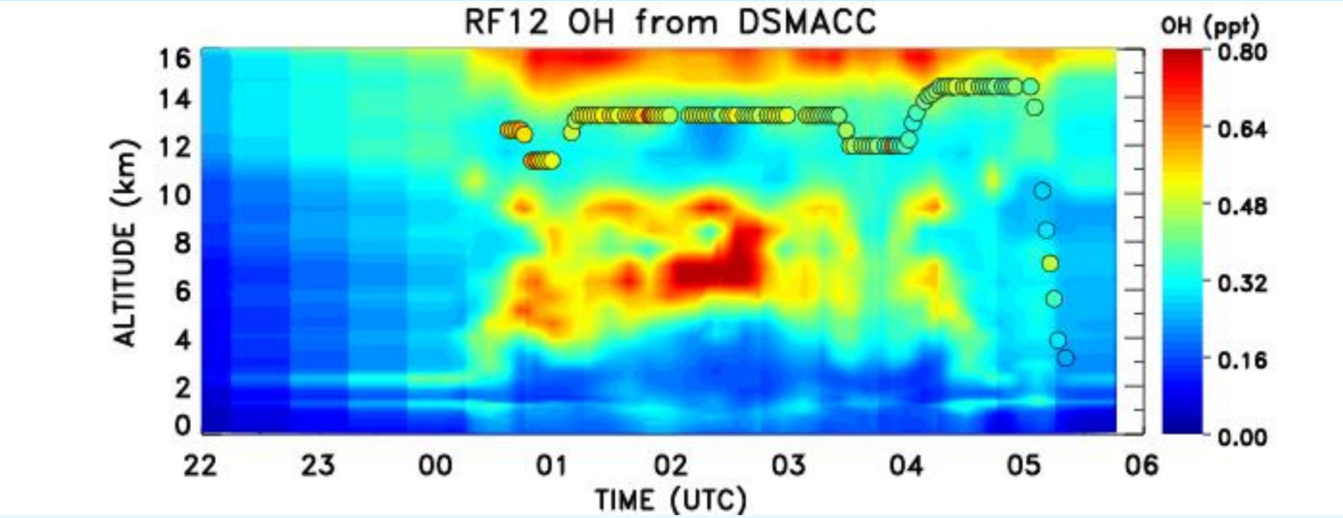


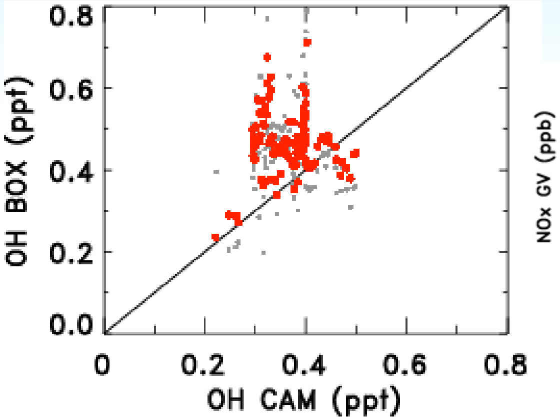
VOCs = ISOP + C_3H_8 + CH_3COCH_3 + MVK + MACR + CH_3OH + CH_3CHO + HCHO

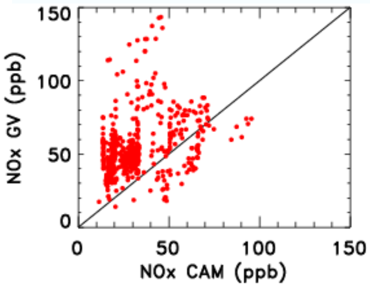
Box Modeling with CAM-Chem + GV NO_x+VOCs

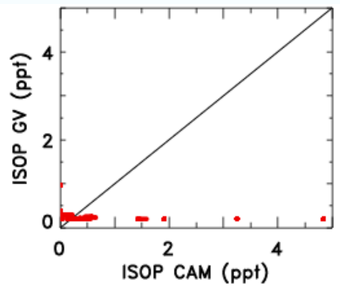
OH
RF12



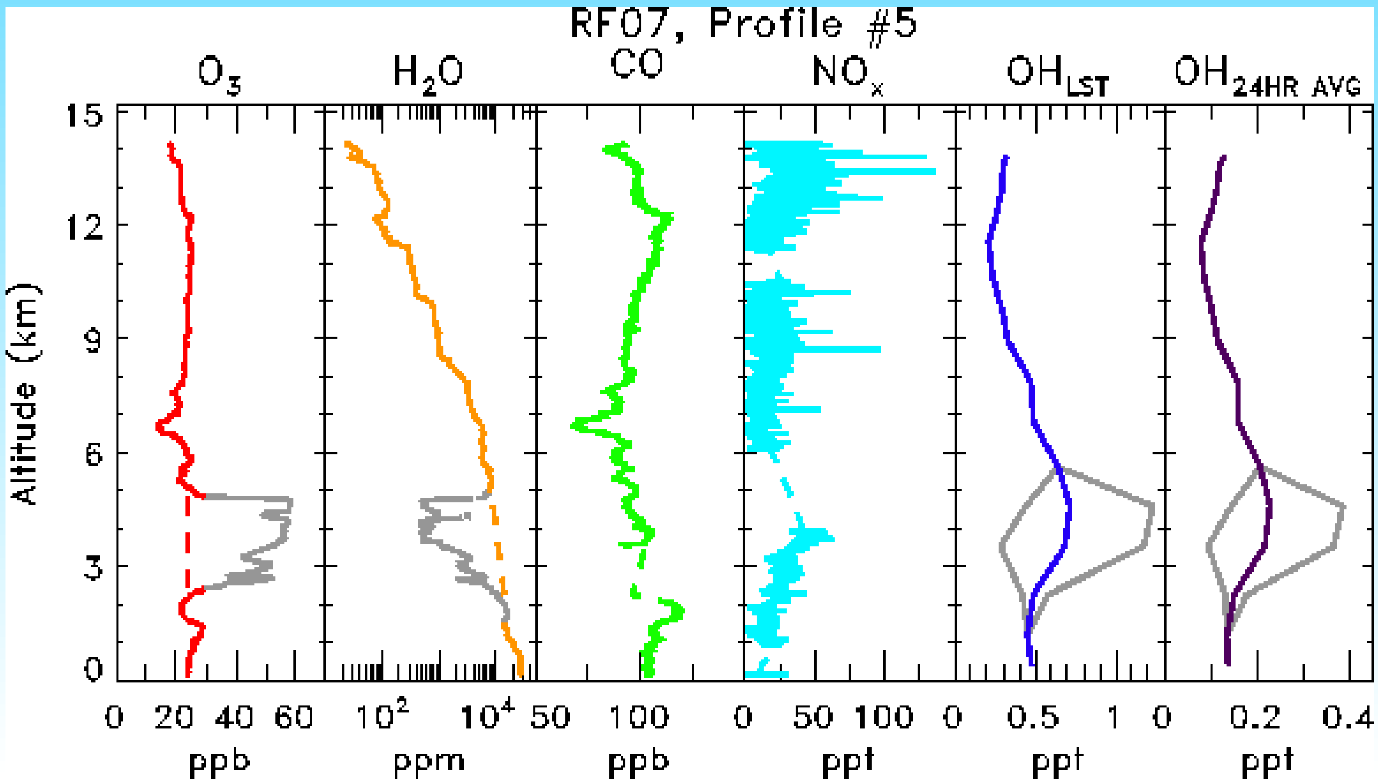






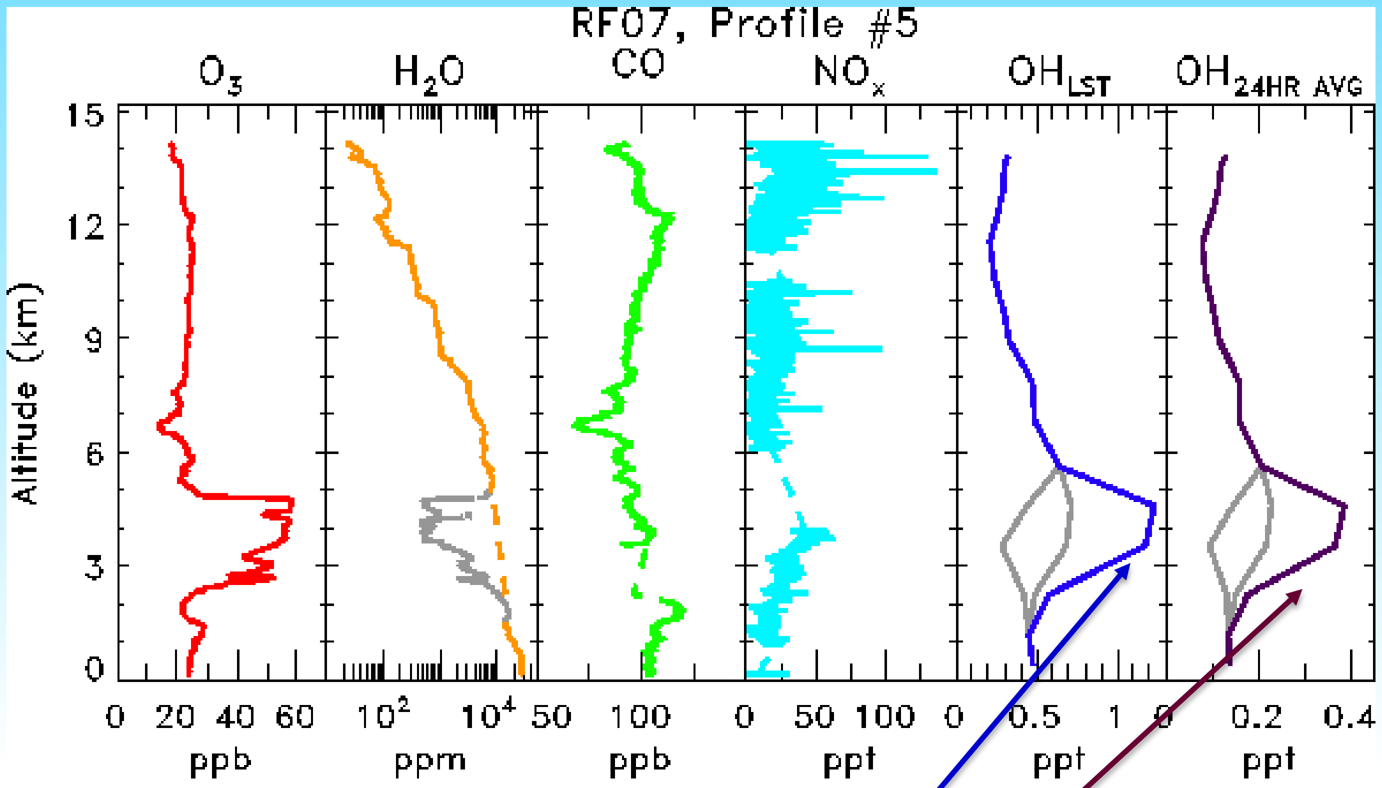


First Look: Effect of O_3 filaments



1.) Box model run *__as if filament doesn't exist__*

First Look: Effect of O_3 filaments

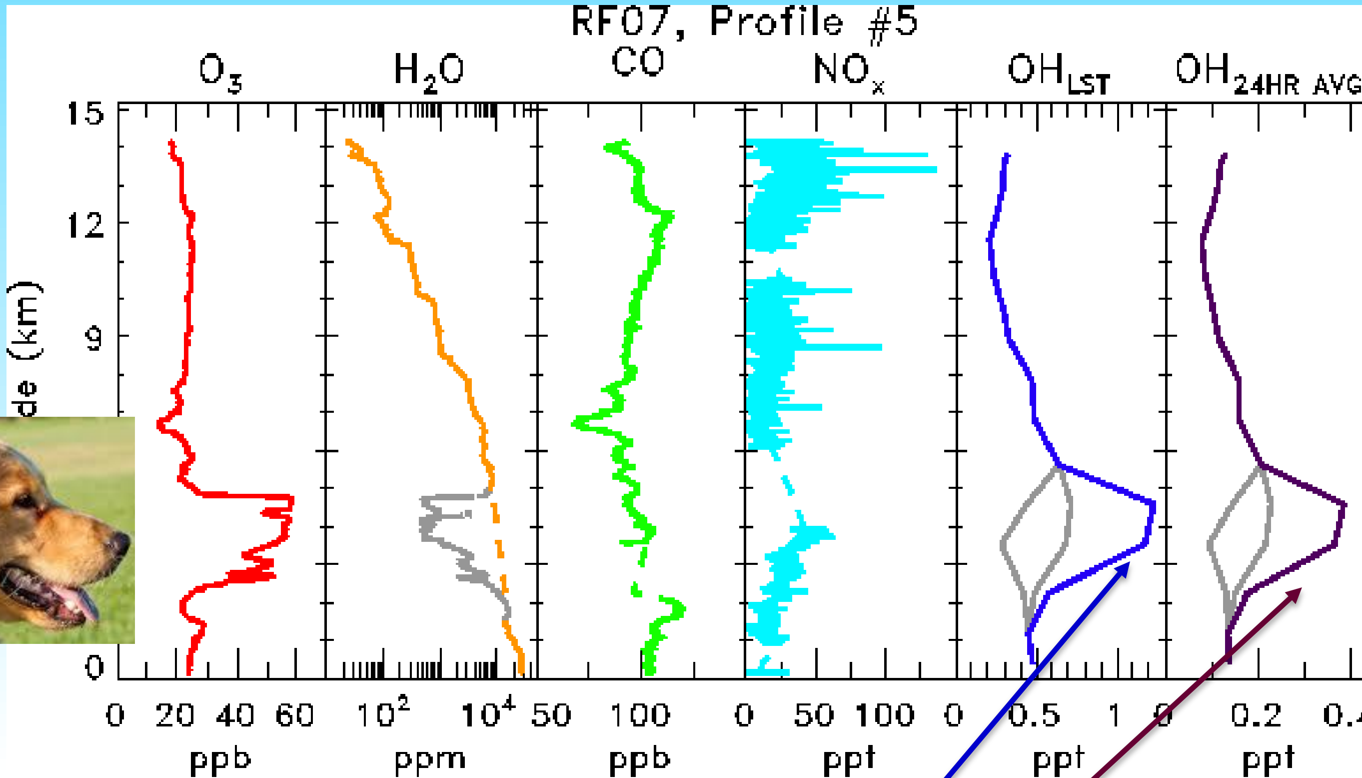


Elevated O_3 causes modeled OH to rise

1.) Box model run *as if filament doesn't exist*

2.) Run with elevated O_3, but *not* low H_2O

First Look: Effect of O_3 filaments



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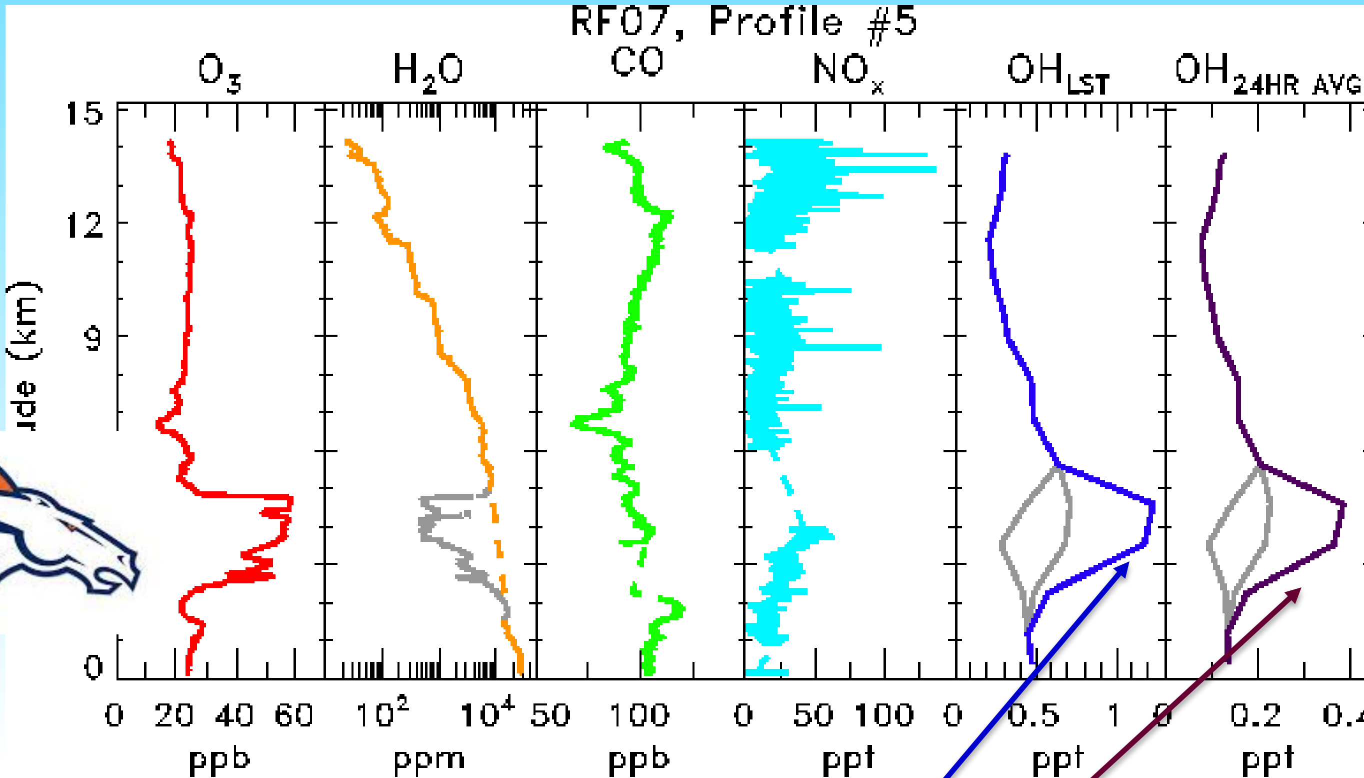
First Look: Effect of O_3 filaments



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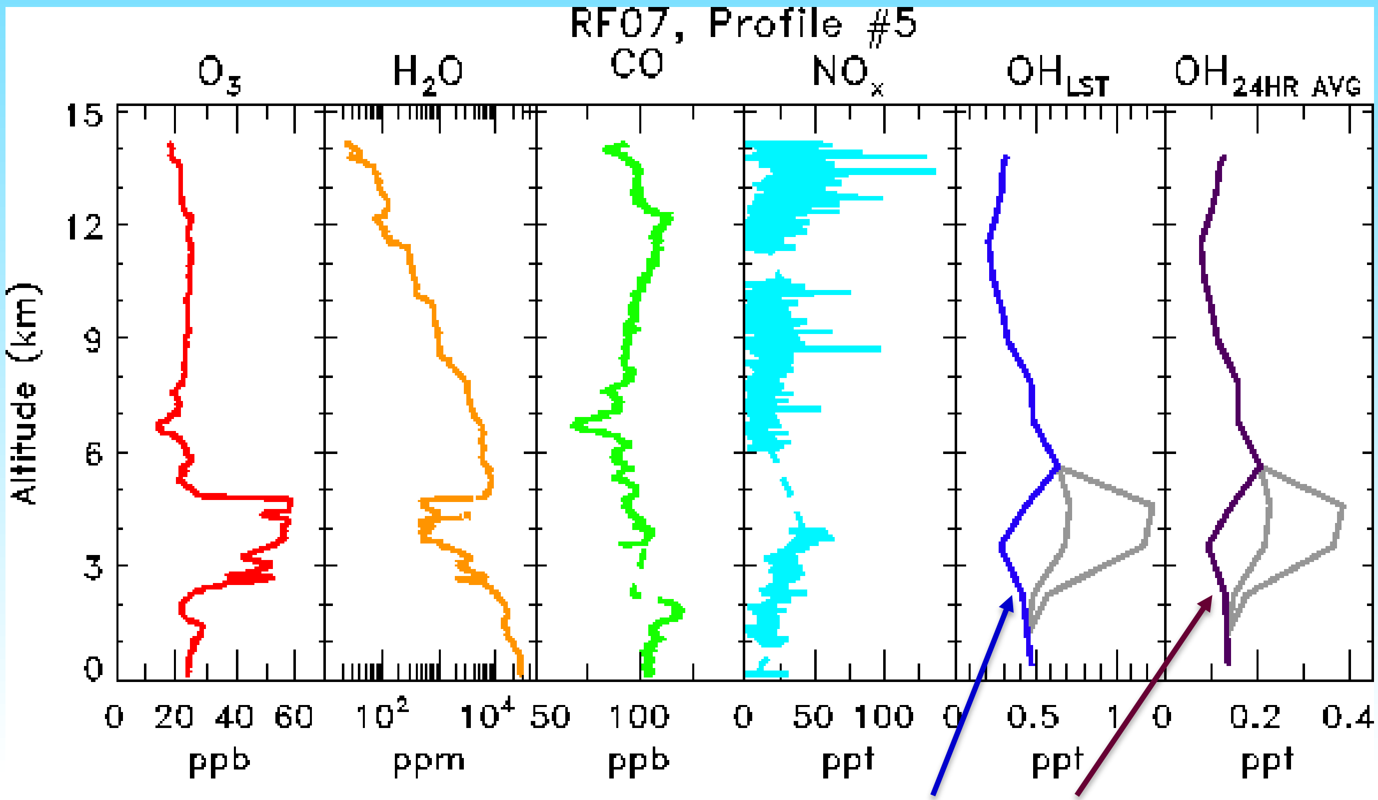
First Look: Effect of O_3 filaments



Depressed H_2O causes modeled OH to fall by more than the O_3 induced rise

1.) Box model run *as if filament doesn't exist*

2.) Run with elevated O_3, but *not* low H_2O

3.) Run with elevated O_3 *and* low H_2O

Conclusions

- Inferred OH doesn't reach values nearly as low as predicted by Rex et al.
  *Analysis is contingent on accuracy of NO_x measurements; NO_x used here is in-field, preliminary data
- Effect of low H_2O > effect of high O_3 on OH in filaments
- CAM-Chem is underestimating OH due to combination of O_3, NO_x, & VOCs

Future Work

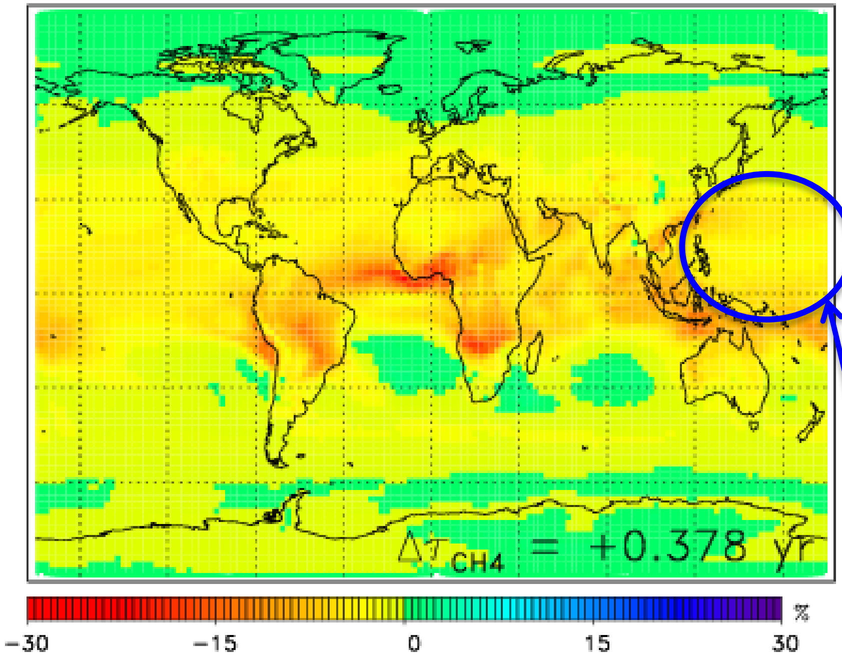
- Continue box modeling OH for more flights/as data are revised and comparing to CAM-Chem
- Continue O_3 filament examination: effect on OH & τ's
- Compare model vs observations in similar air masses
  - Use tracer-tracer relationships
  - Independent of whether model predicts filament location

Backup

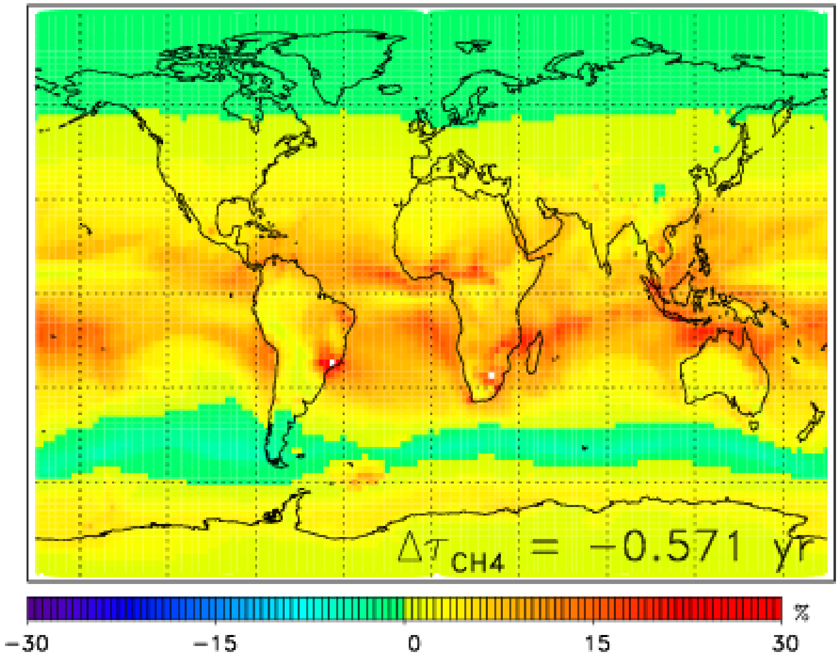
Δ(OH Column) as a result of swapping fields of CO between CAM-Chem and GMI

Results from neural network analysis of POLMIP CTMs

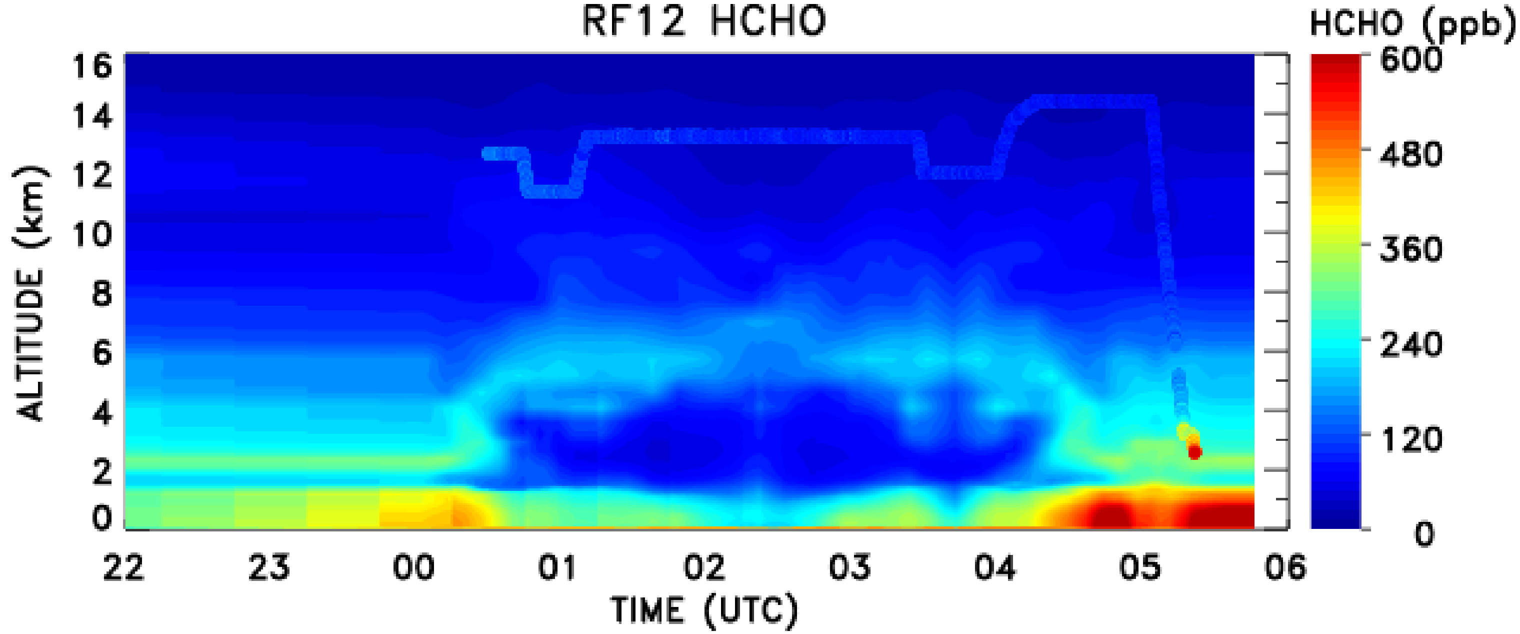
CAM-Chem + (GMI CO)

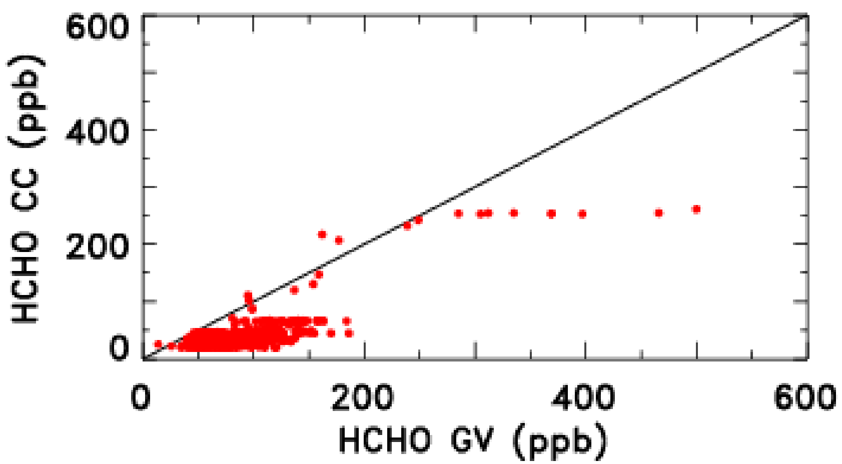


GMI + (CAM-Chem CO)



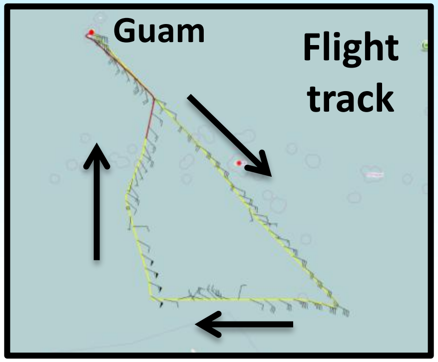
Relatively small effect on OH, τ_{CH4} in TWP region

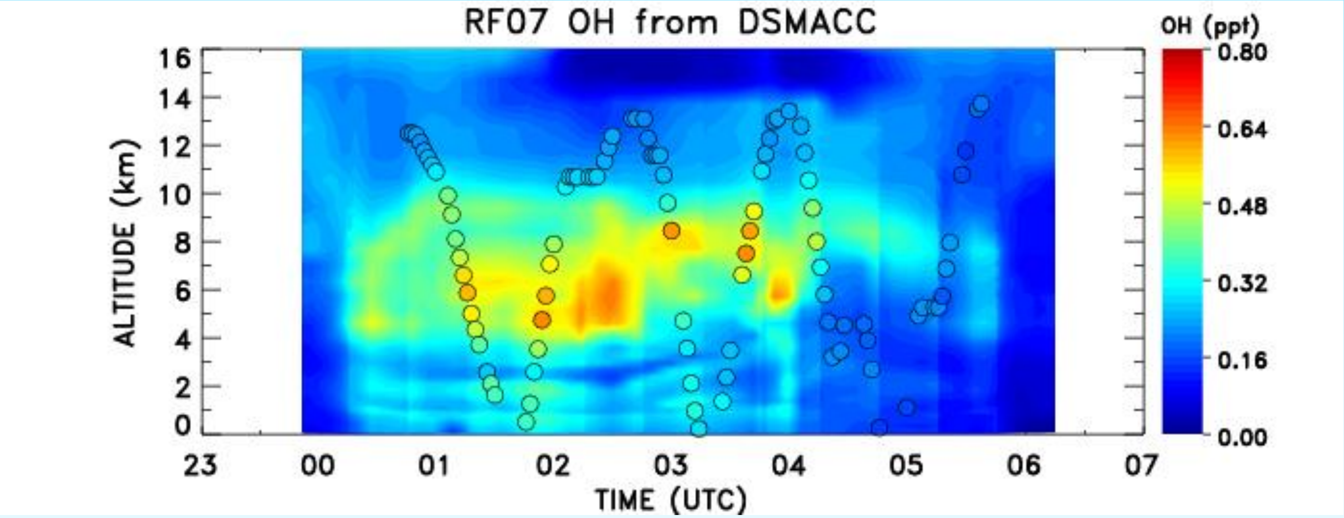

RF12 HCHO
HCHO (ppb)
600
480
360
240
120
0
16
14
12
10
8
6
4
2
0
ALTITUDE (km)
22
23
00
01
02
03
04
05
06
TIME (UTC)

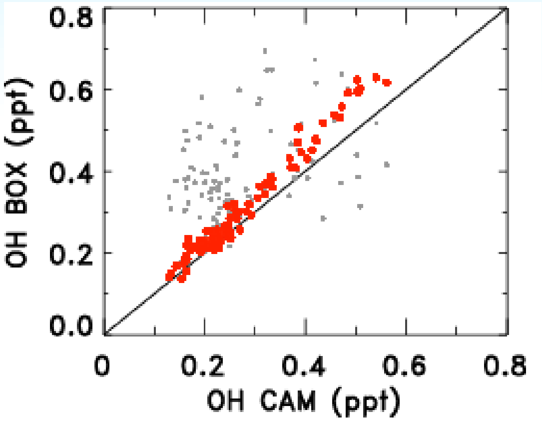

600
400
200
0
HCHO CC (ppb)
0
200
400
600
HCHO GV (ppb)

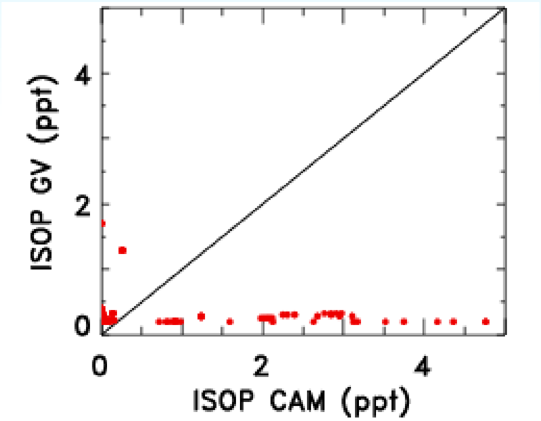
Box Modeling with CAM-Chem + GV VOCs

OH
RF07



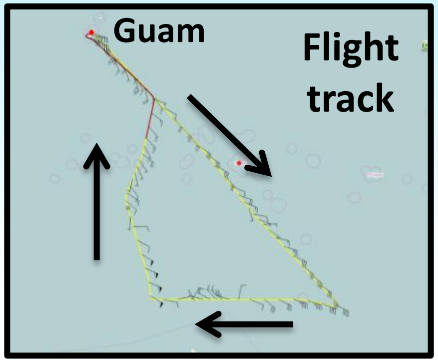


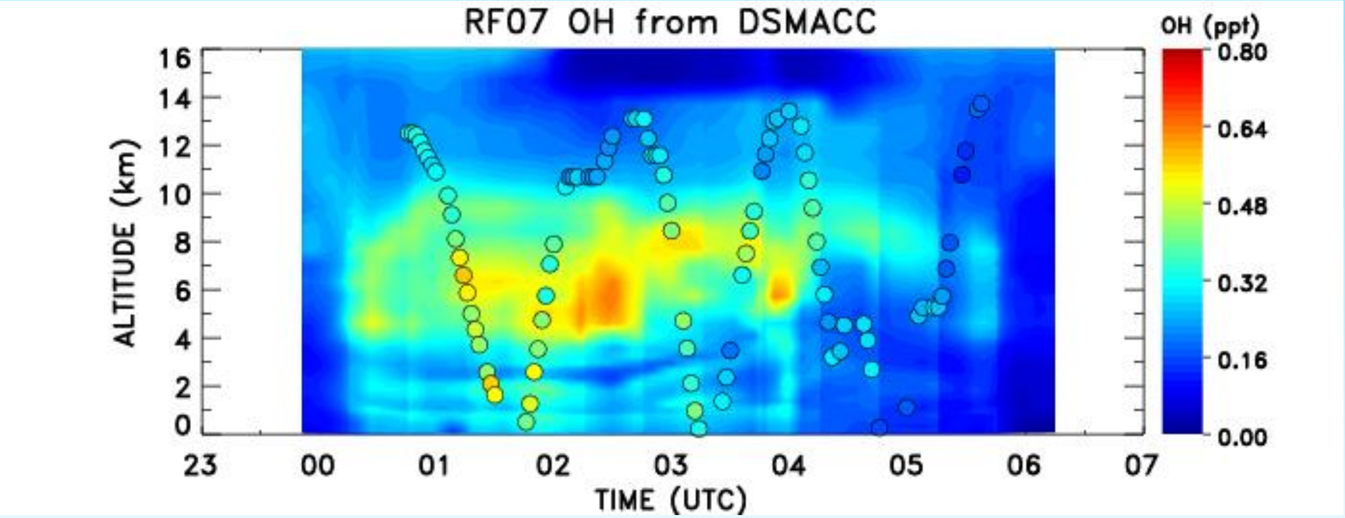


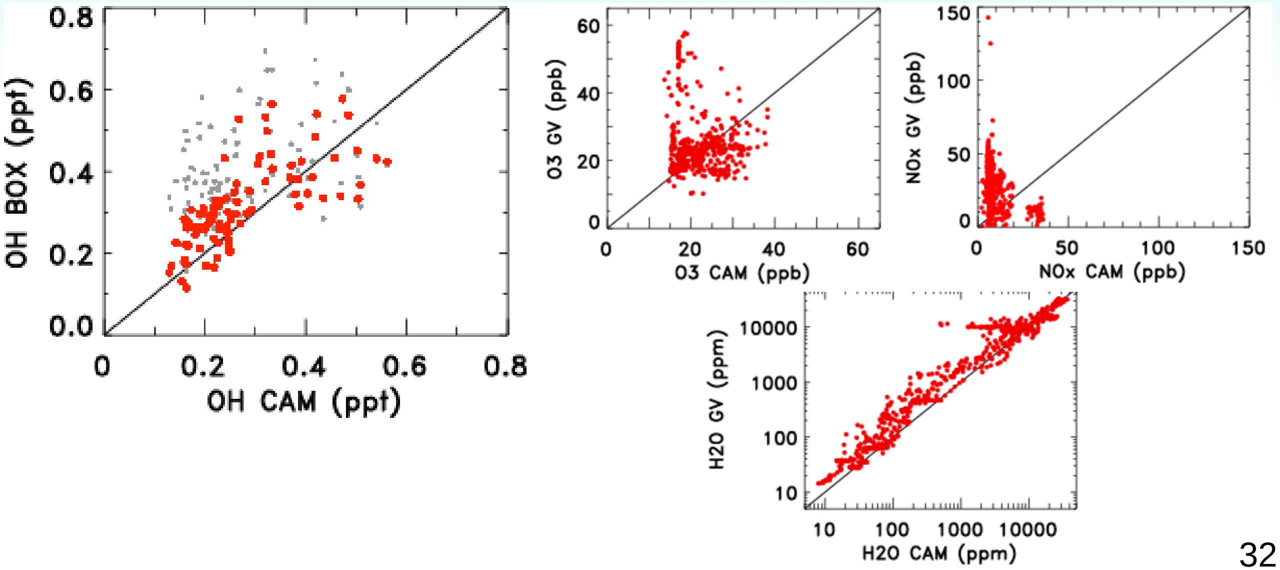


Box Modeling with CAM-Chem + GV O_3+NO_x+H_2O

OH
RF07

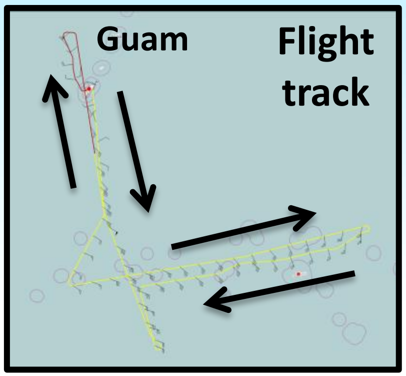


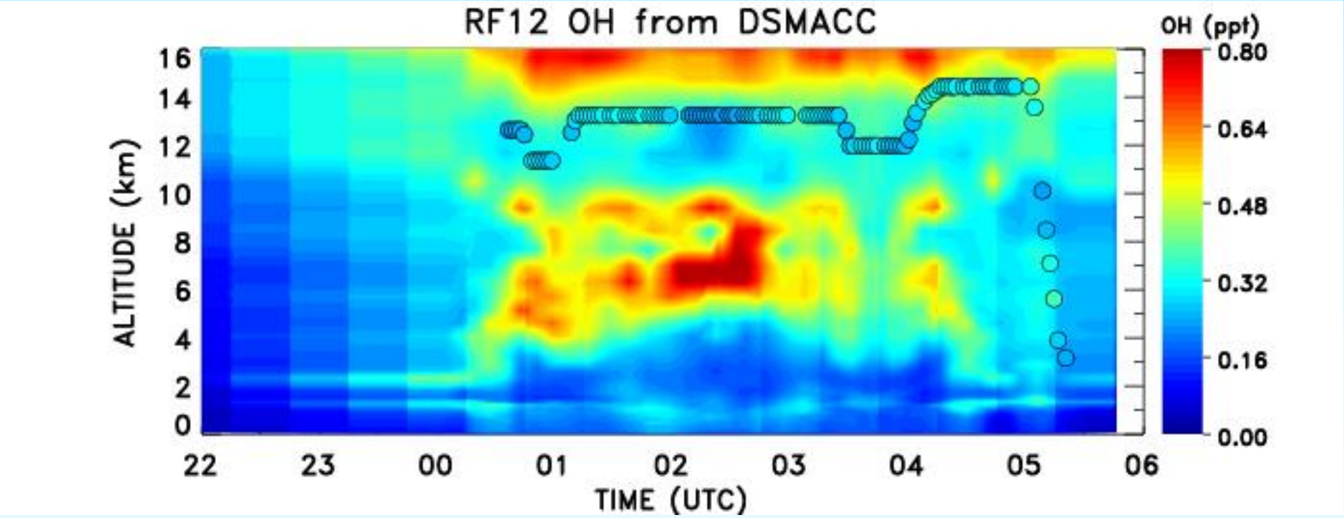


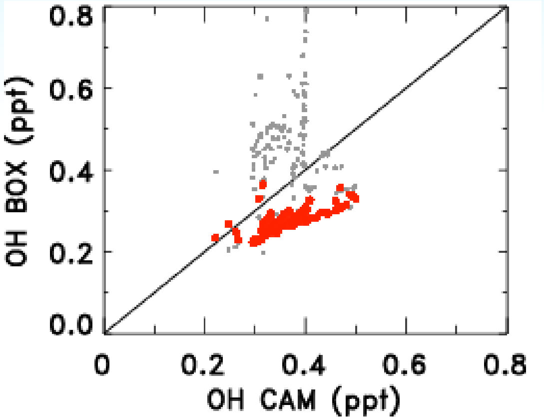


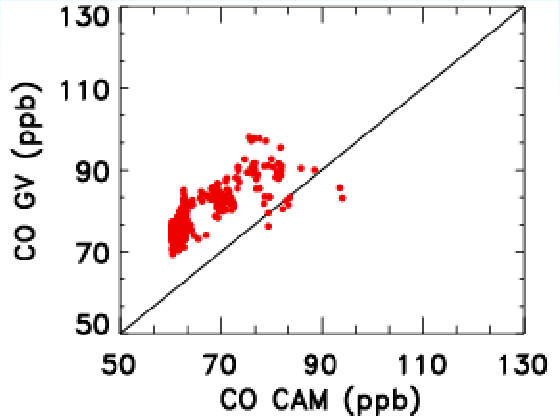
Box Modeling with CAM-Chem + GV CO

OH
RF12



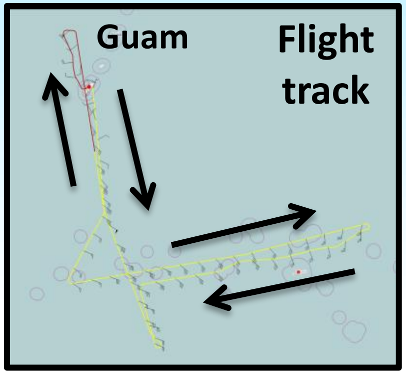


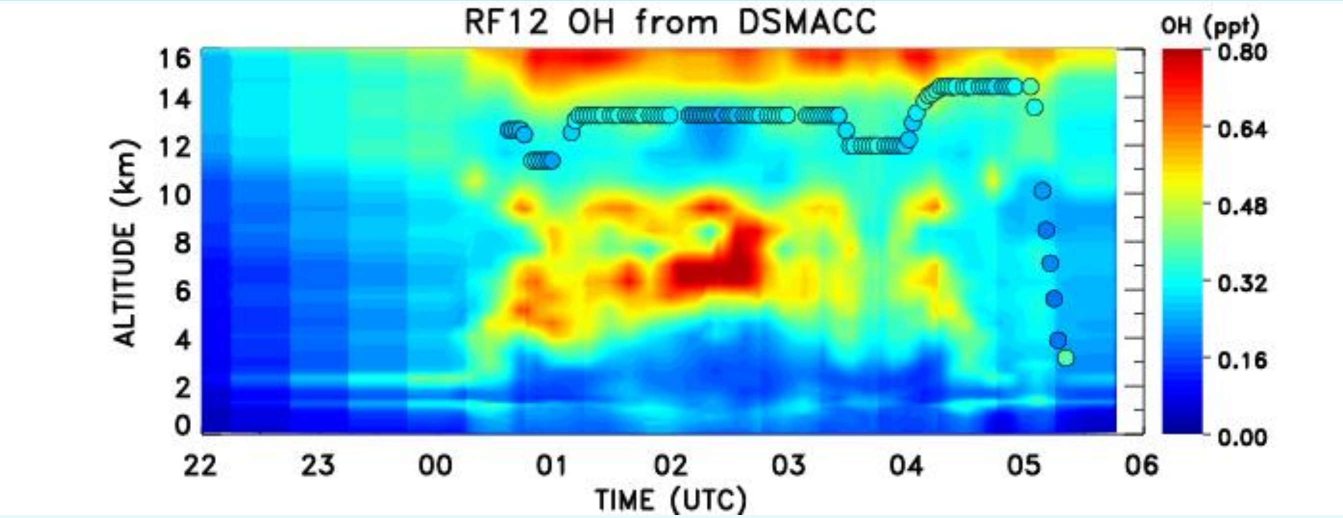


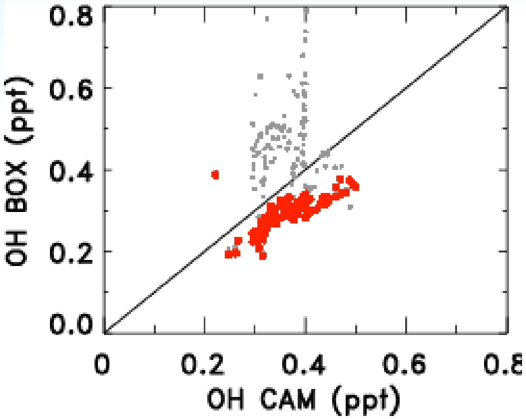


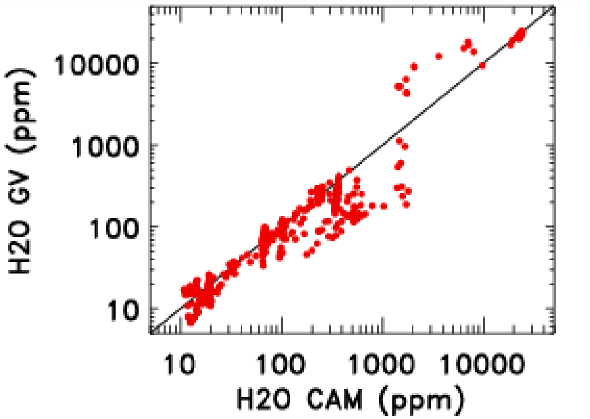
Box Modeling with CAM-Chem + GV H_2O

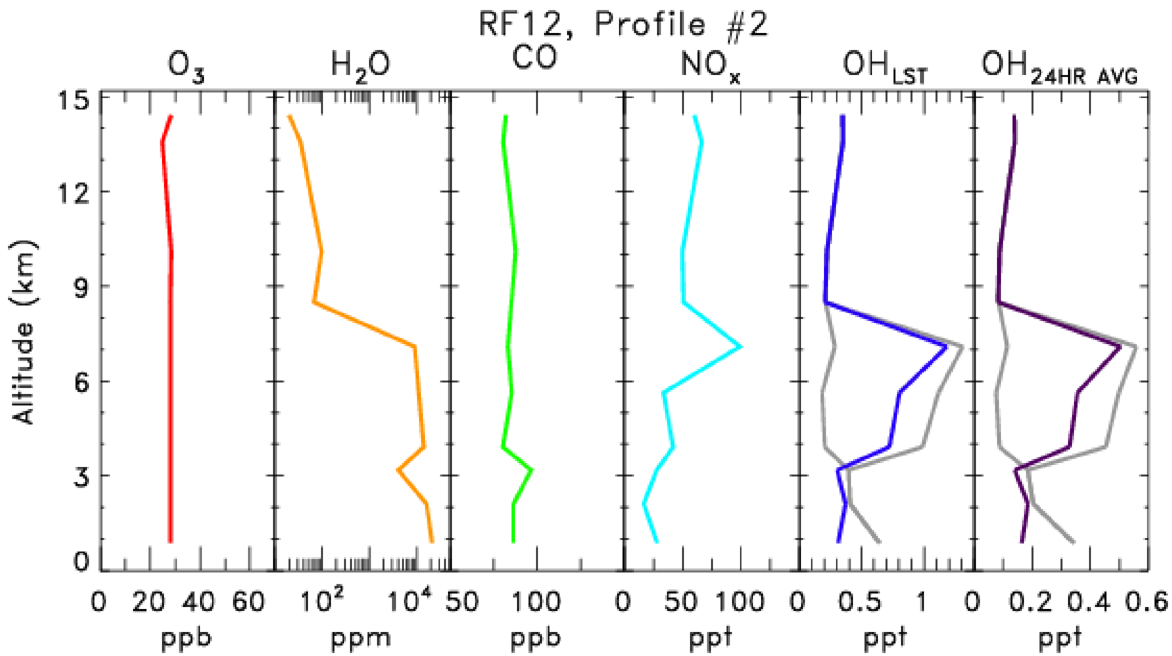
OH
RF12



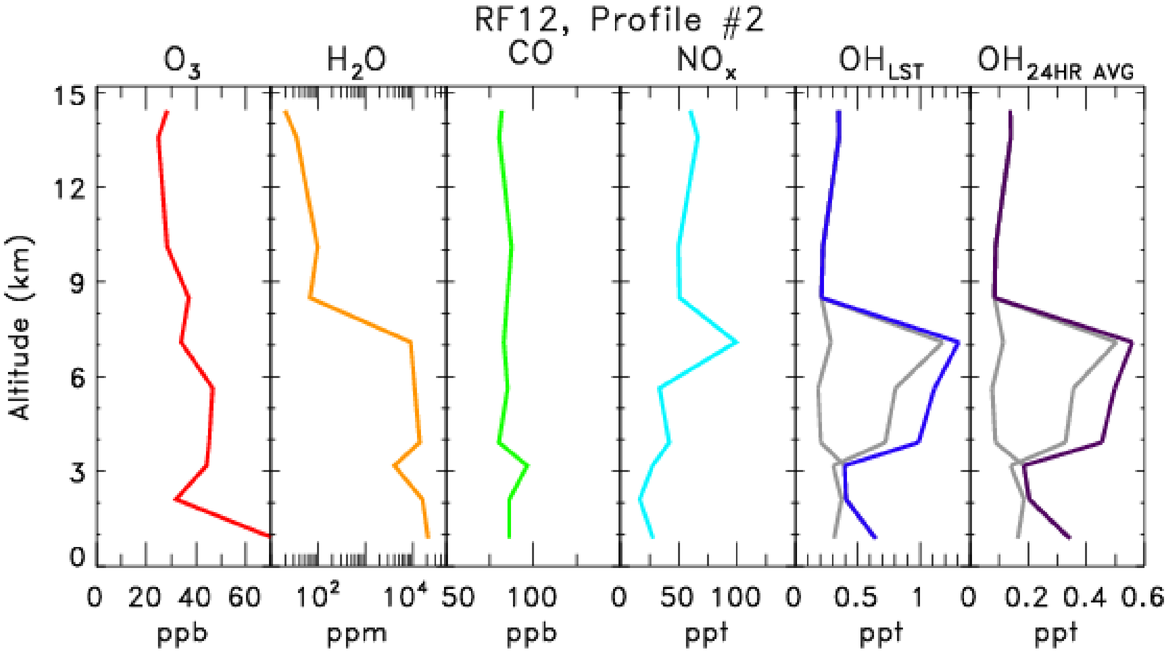


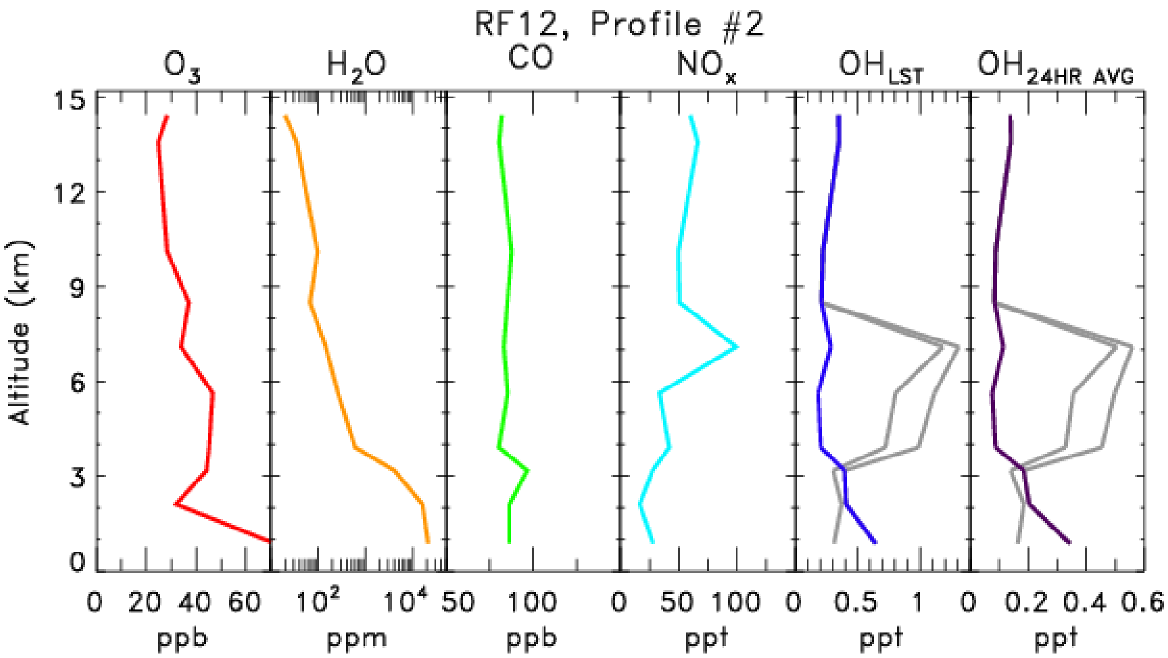






RF12, Profile #2
O3
H2O
CO
NOx
OHLST
OH24HR AVG
Altitude (km)
15
12
9
6
3
0
0 20 40 60
ppb
10^2 10^4
ppm
50 100
ppb
0 50 100
ppt
0 0.5 1
ppt
0 0.2 0.4 0.6
ppt

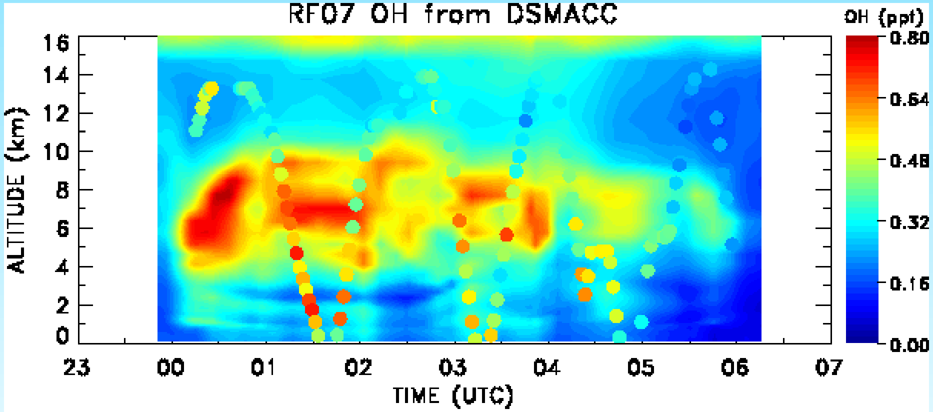

RF12, Profile #2
O3
H2O
CO
NOx
OHLST
OH24HR AVG
Altitude (km)
0
3
6
9
12
15
0 20 40 60
ppb
10^2 10^4
ppm
50 100
ppb
0 50 100
ppt
0 0.5 1
ppt
0 0.2 0.4 0.6
ppt

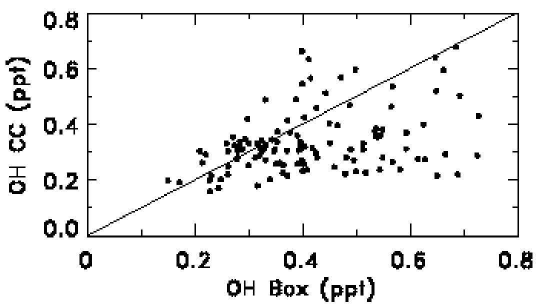

RF12, Profile #2
O_3
H_2O
CO
NO_x
OH_{LST}
$OH_{24HR\ AVG}$
Altitude (km)
0 3 6 9 12 15
0 20 40 60
ppb
10^2 10^4
ppm
50 100
ppb
0 50 100
ppt
0 0.5 1
ppt
0 0.2 0.4 0.6
ppt

Older analysis

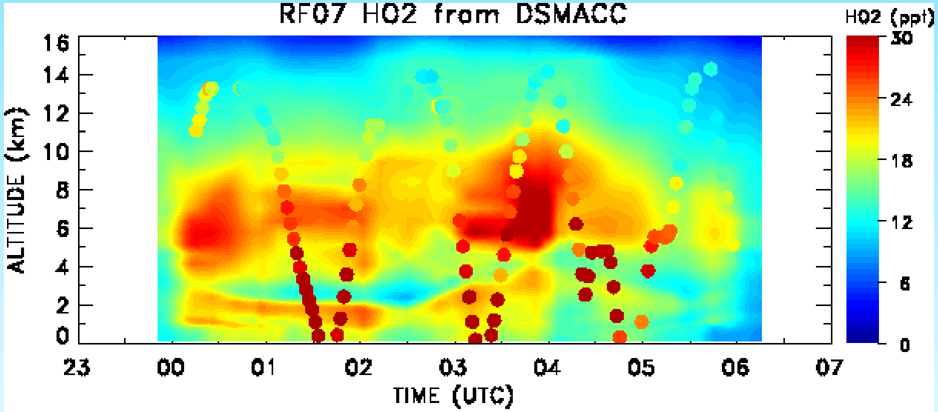
Box Modeling with Data
Preliminary TOGA
RF07

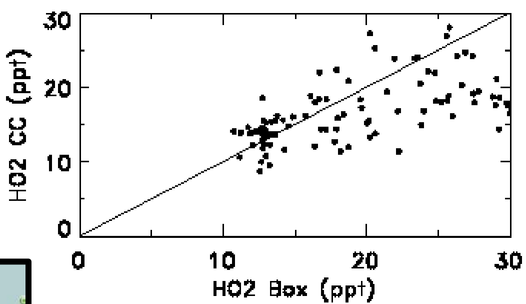
OH

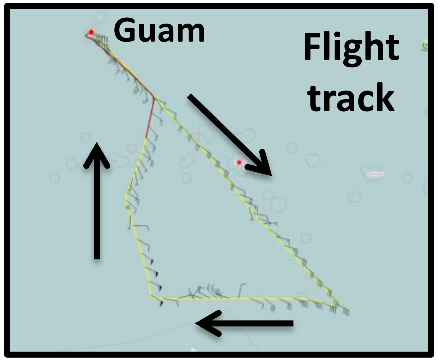




HO_2

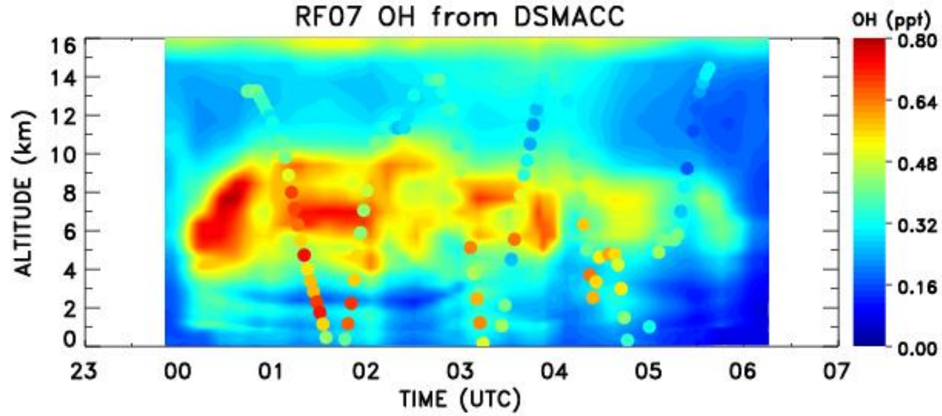


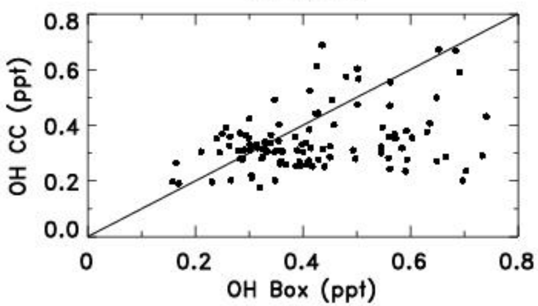


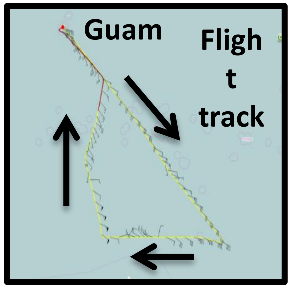


Box Modeling with Both Data + CAMChem CH_4 RF07

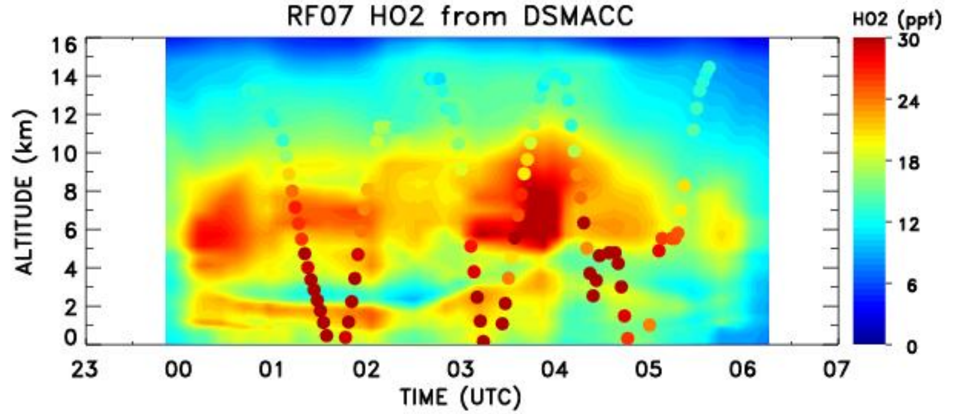
OH

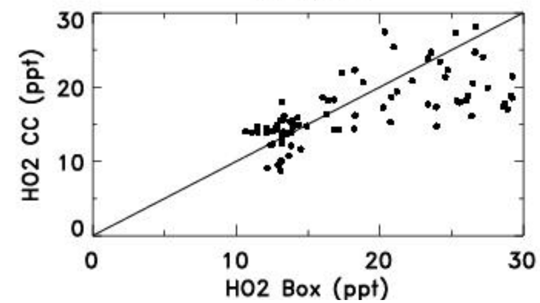


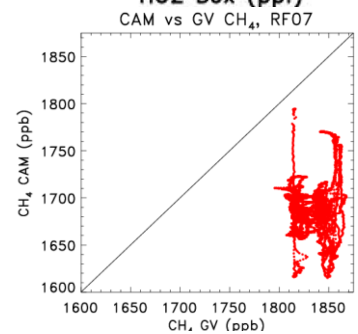




HO_2



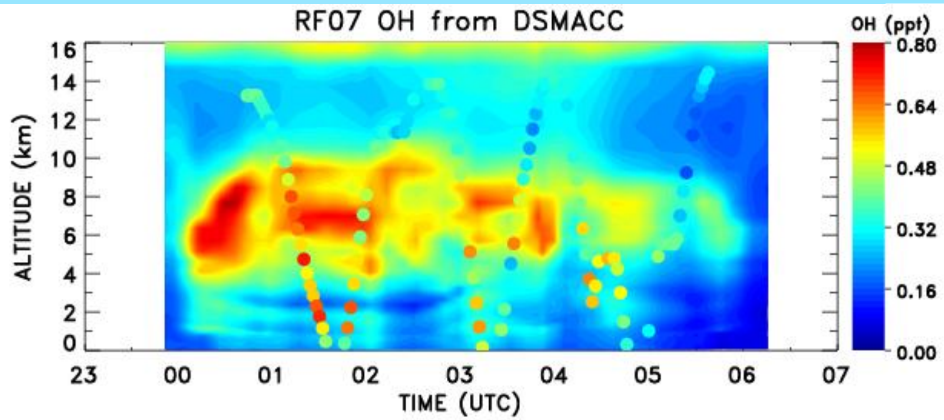


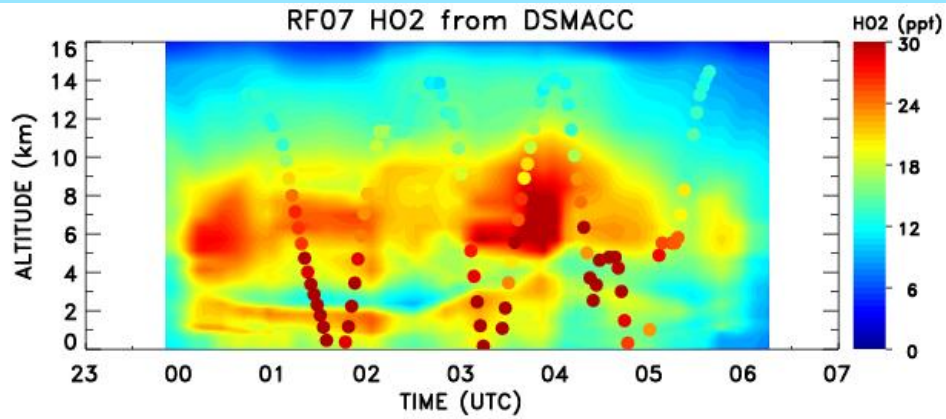


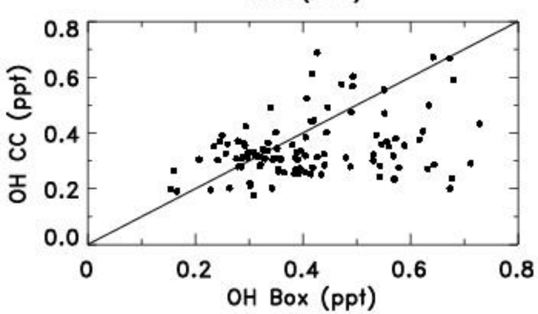
Box Modeling with Data
Finalized TOGA/preliminary everything else
RF07

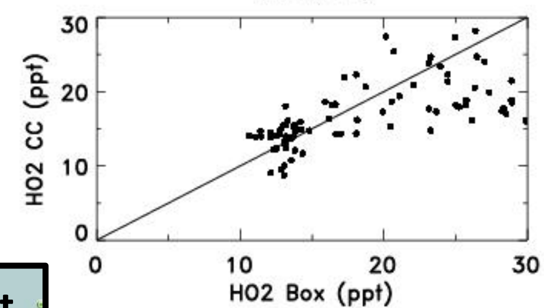
OH

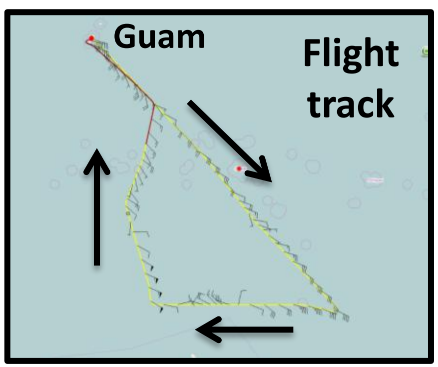
HO_2







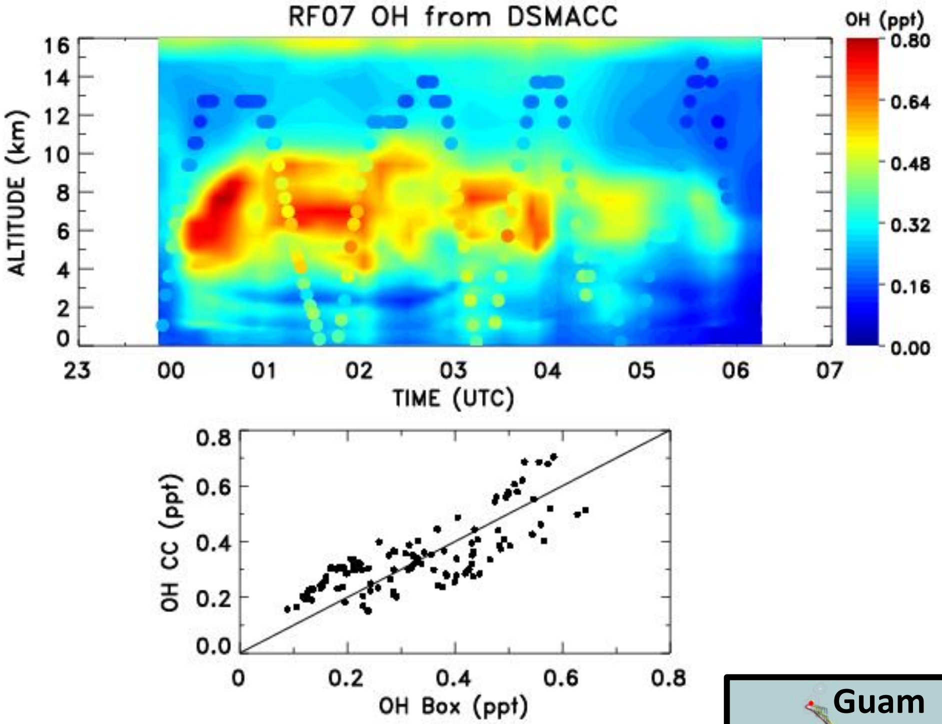


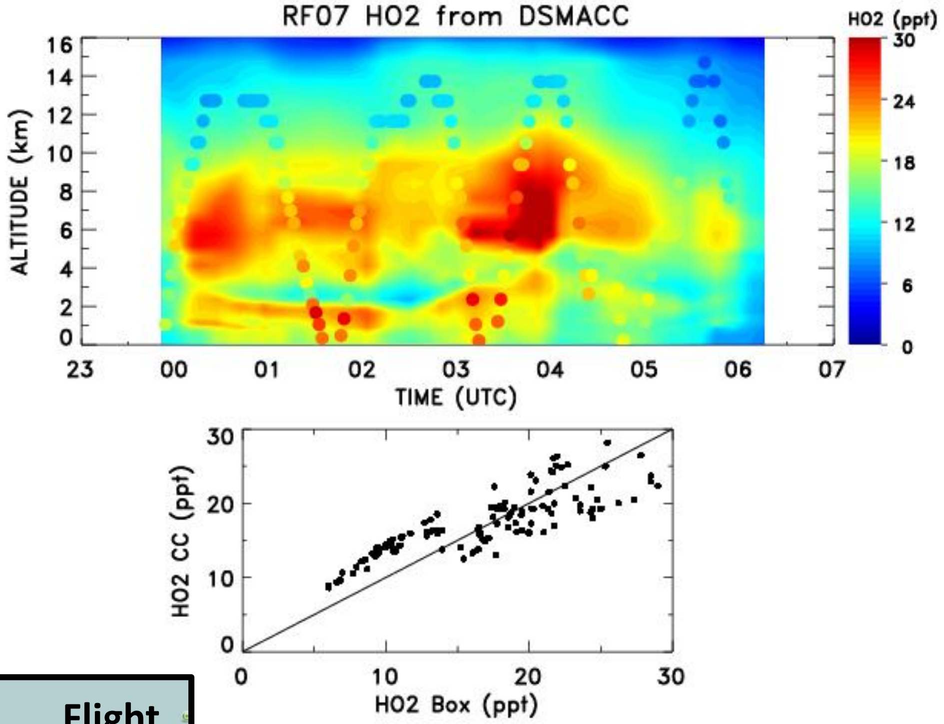


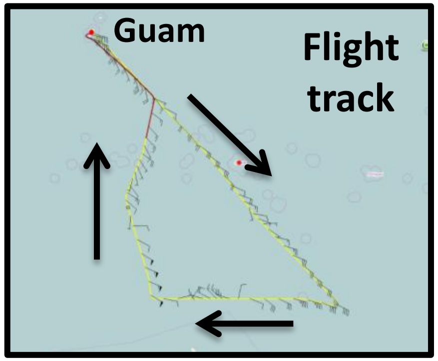
Box Modeling with CAMChem
RF07

OH

HO_2

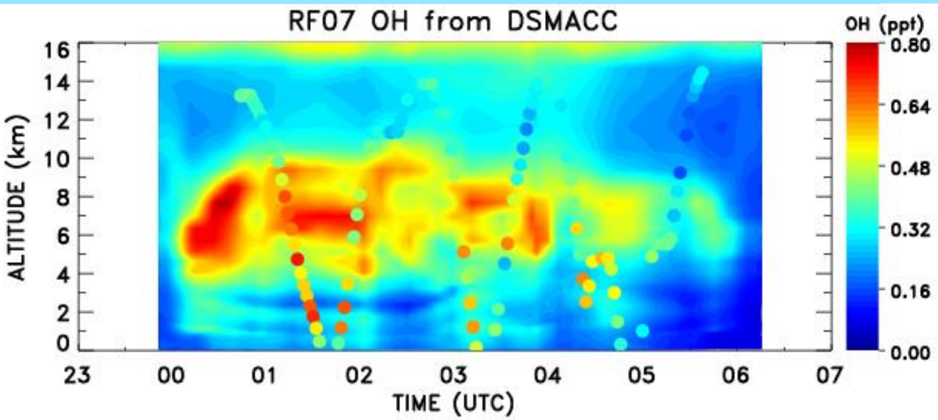


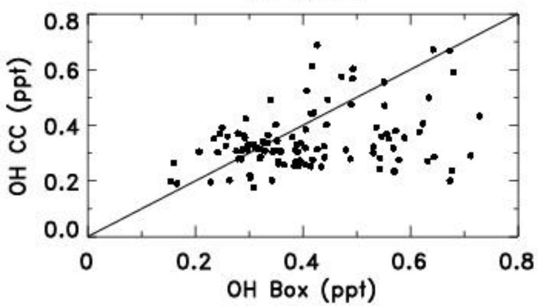




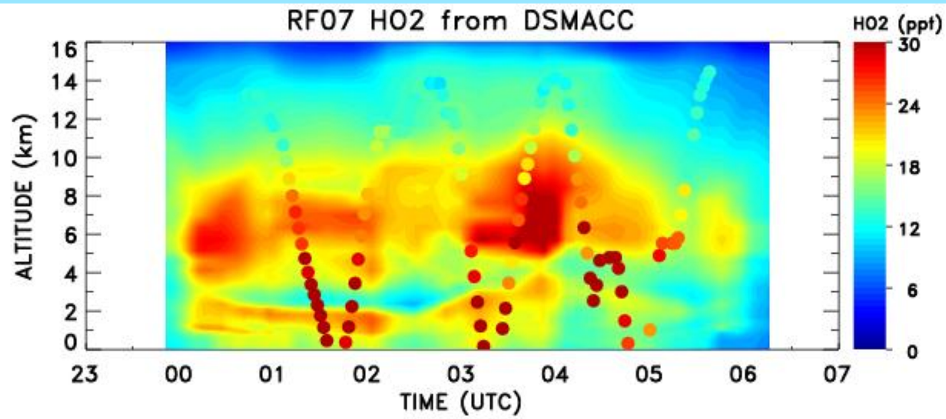
Box Modeling with Data
Finalized TOGA/preliminary everything else
RF07

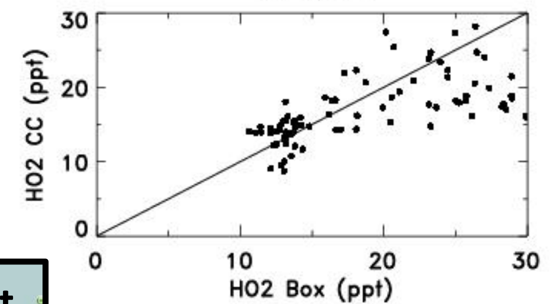
OH

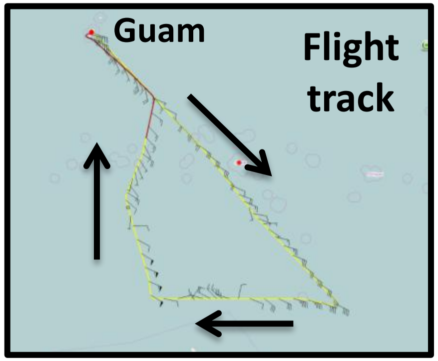




HO_2



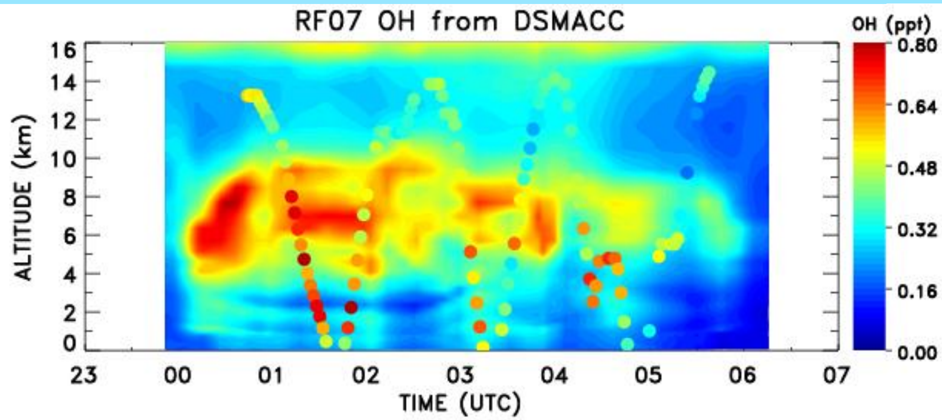


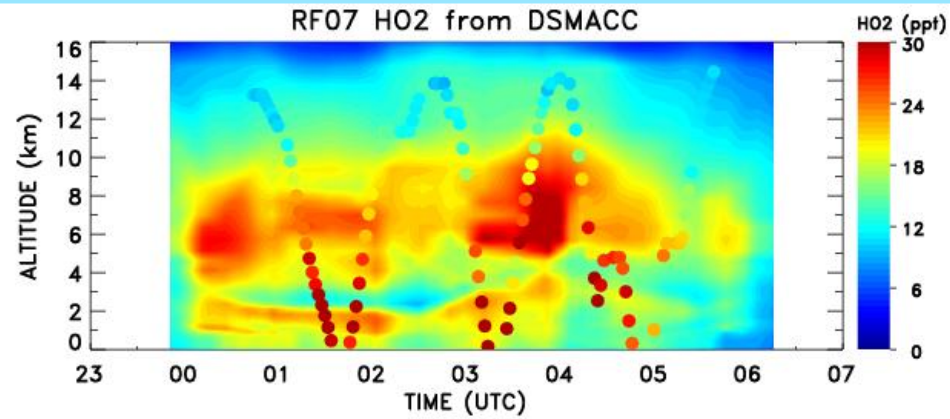


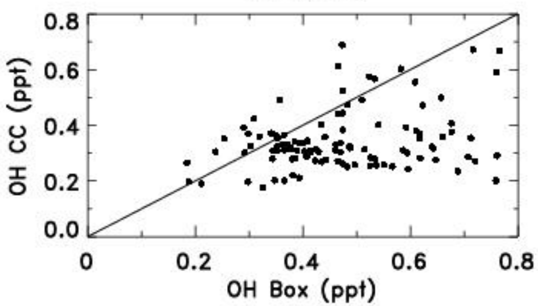
Box Modeling with Both Data + CAMChem CO RF07

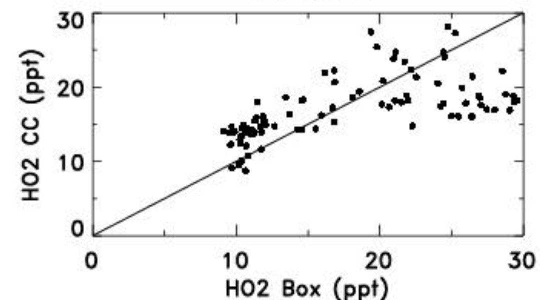
OH

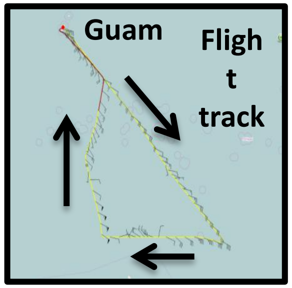
HO_2

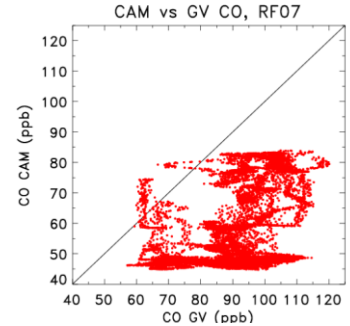






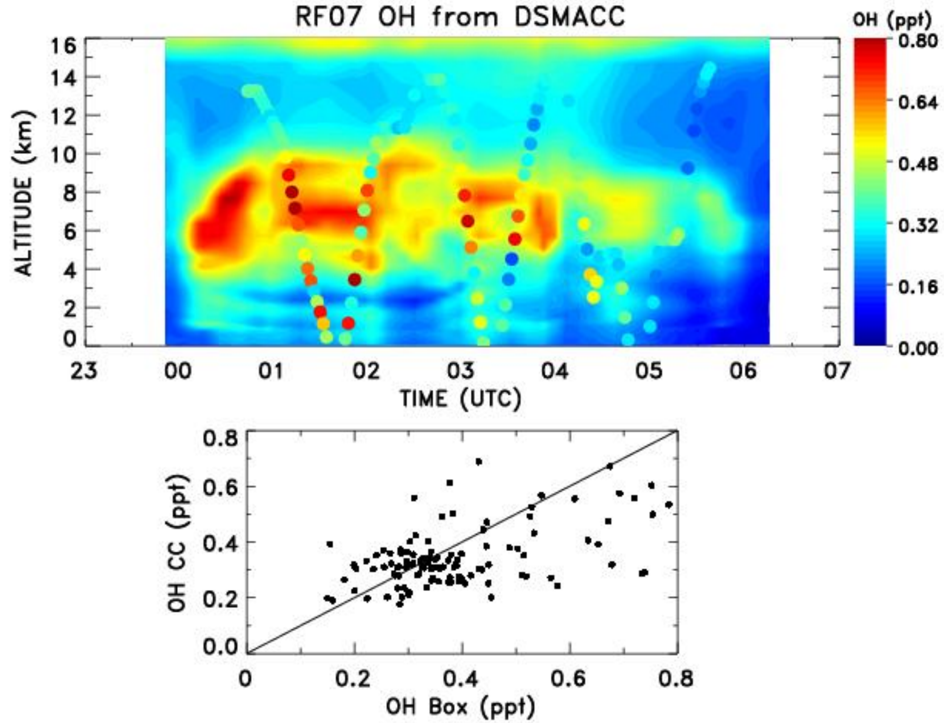


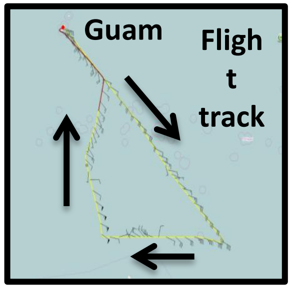




Box Modeling with Both Data + CAMChem O_3 RF07

OH





HO_2