High Altitude Airborne Formaldehyde

ESTOFEST
Wednesday, 15-June, 2015

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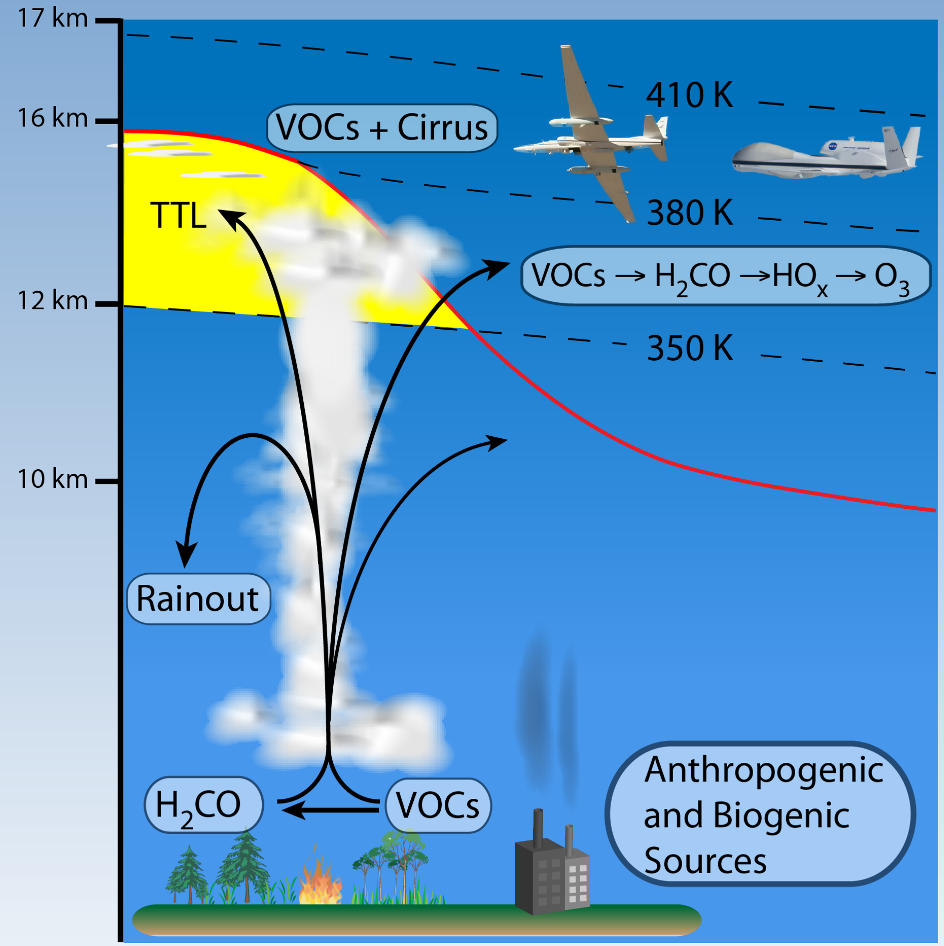
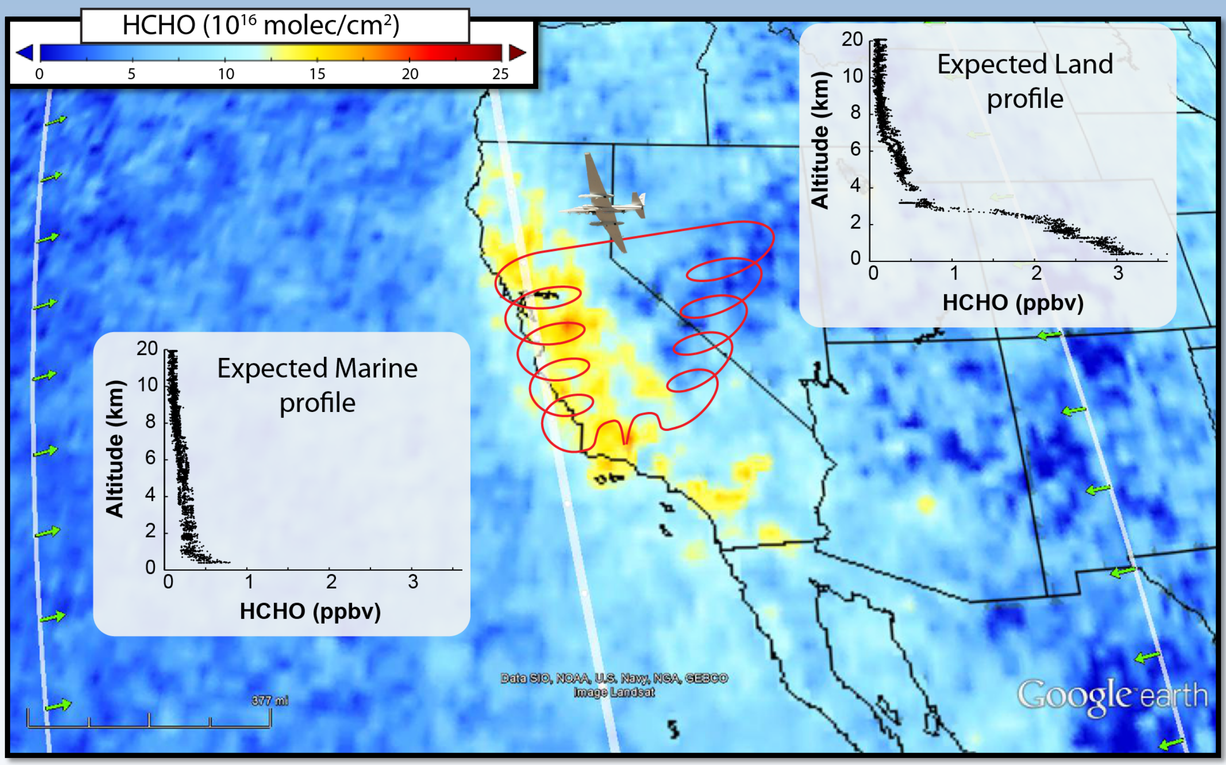
Motivation

- Measurements of formaldehyde can be used to help quantify:
  - Convective transport
  - The abundance of volatile organic compounds (VOCs)
  - Pollution effects on cirrus formation
  - HOx and Ozone production
- Validation of space-based measurements:
  - OMI (2005 -)
  - OMPS (2011 -)
  - Trop-OMI (2016)
  - TEMPO (2019?)
- A high altitude *in situ* HCHO instrument does not exist



Motivations (cont.)

- Support satellite based observations of HCHO with in situ cal/val.
  - Existing : Aura – OMI, JPSS – OMPS
  - Planned: EV1 TEMPO (2019), Trop-OMI (2016)
- Support directed and Venture aircraft campaigns



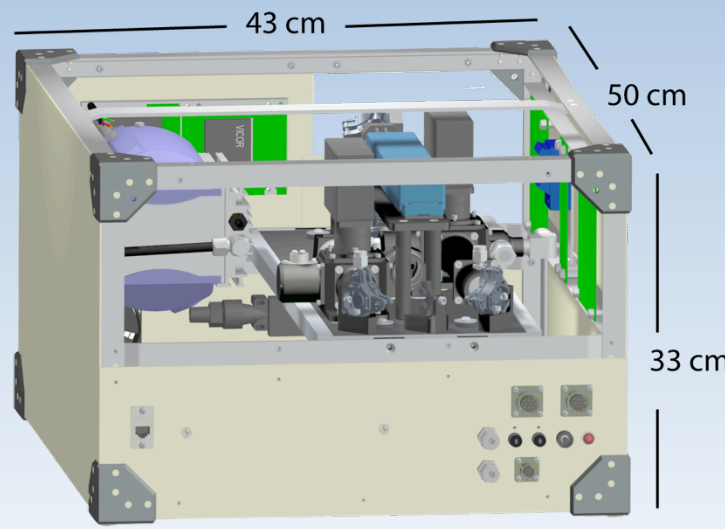
High Altitude Airborne Formaldehyde

Objectives

Airborne Instrument Technology Transfer (AITT): Develop an instrument for the in-situ measurement of HCHO on high altitude NASA aircraft.

- Small, lightweight, and low power
- Autonomous
- High reliability for 24 hr duration flights in remote locations

Instrument Performance Objectives	
Size	0.07 m^3
Weight	30 kg
Power	600 W
Time Response	0.1 s
Sensitivity	20 ppt
Accuracy	+/- 10%



Technology: Laser Induced Fluorescence

Our state of the art:

- Resonant with rotational state of HCHO electronic transisition (sub-pm linewidth).
- Use **selective excitation** of HCHO

Advantages:

- Super sensitive, accurate, small, low power.
- Proven technique

Disadvantage:

- Research grade tunable fiber laser
- Complicated $$$

AITT:

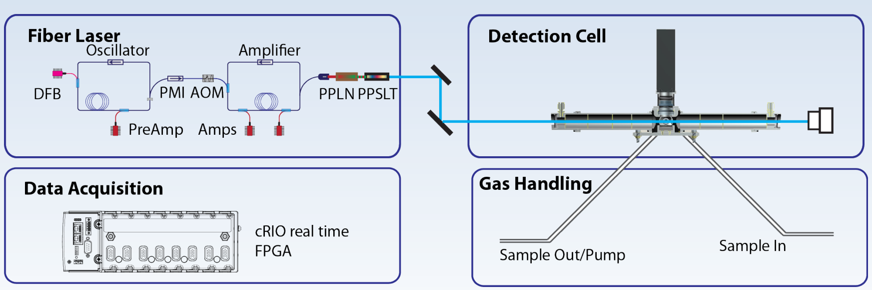
- Non-resonant with rotational state of HCHO electronic transisition (nm linewidth).
- Use **selective detection** of HCHO.

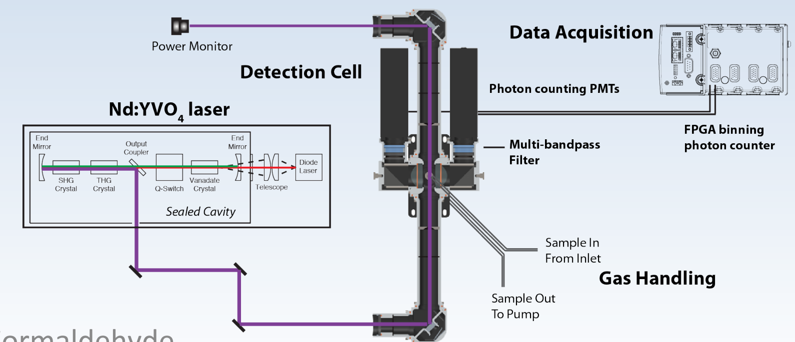
Advantages:

- Very sensitive, accurate, small, low power.
- Industrial COTS laser $
- Turnkey

Disadvantage:

- Less sensitive than TFL (factor of 2 – 3)
- New technique



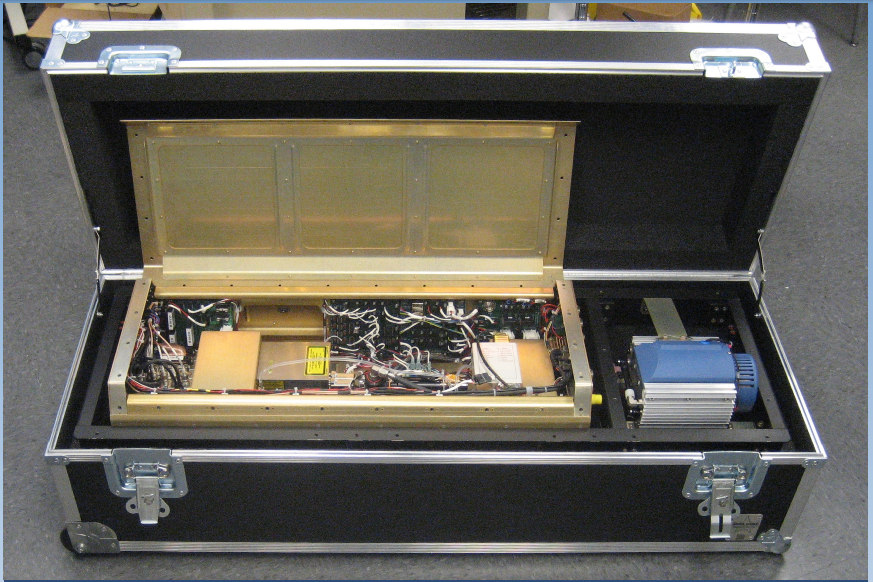


High Altitude Airborne Formaldehyde

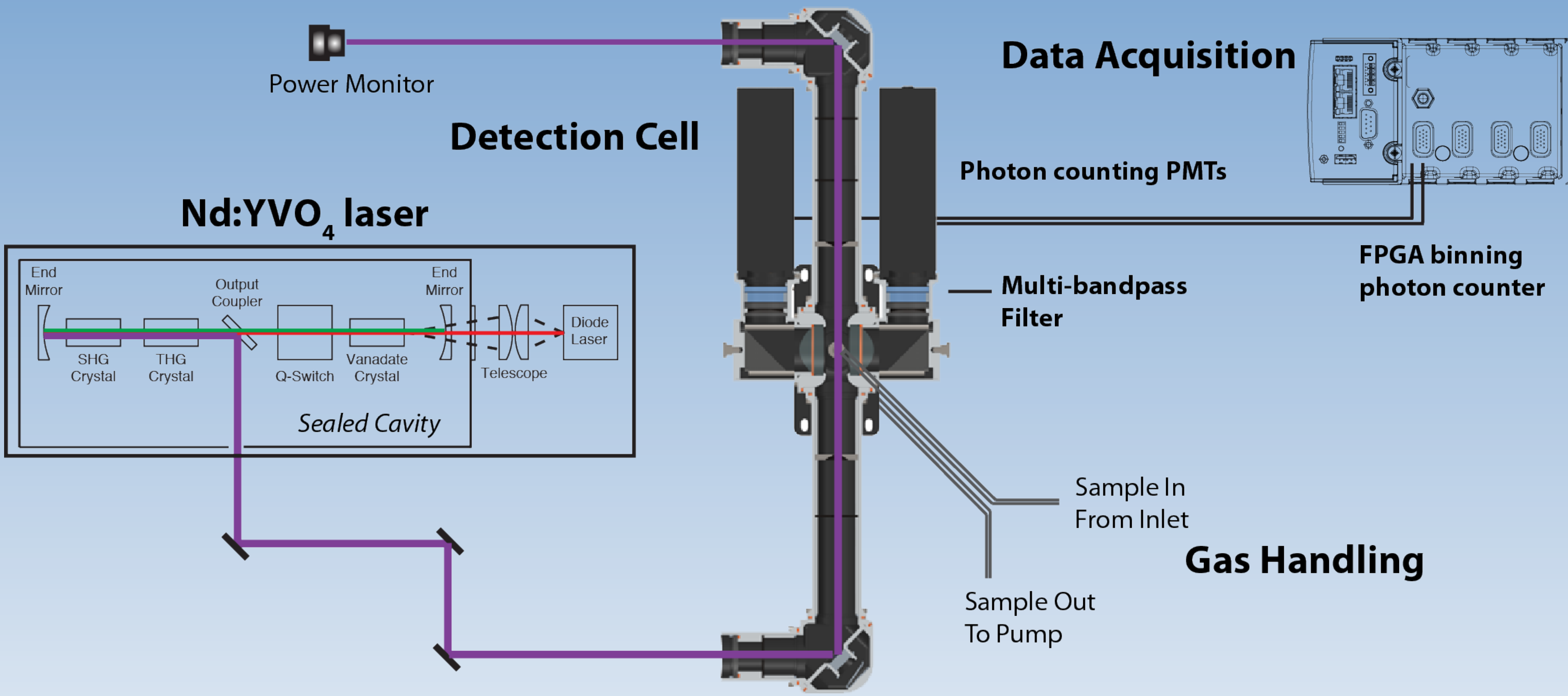
NR-LIF Prototype

Non-Resonant LIF prototype

- Developed HCHO selective detection using multi-band optical filters.
- Developed new time binning for fluorescence detection for added selectivity.
- Better fit for high-altitude long duration flights.
- Modest drop in sensitivity compensated by high reliability, lower cost, and smaller size.
- Turnkey

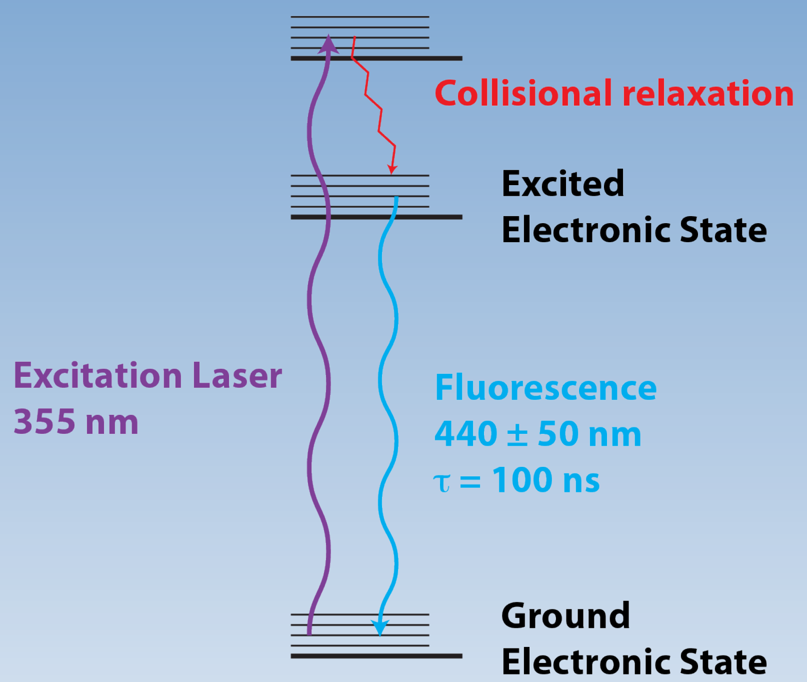


NR-LIF Detection Schematic



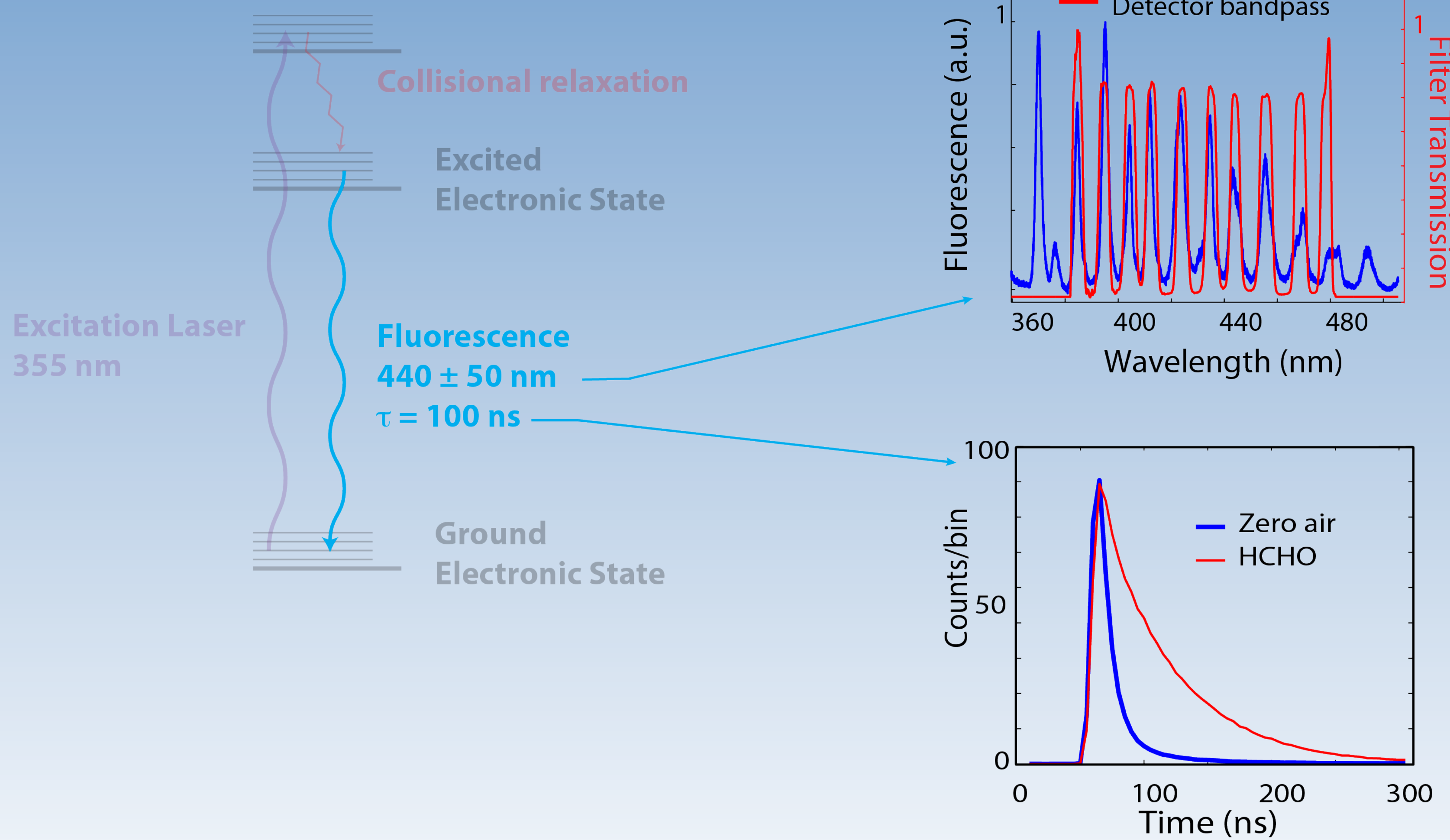
Laser Induced Fluorescence

HCHO Laser Induced Fluorescence

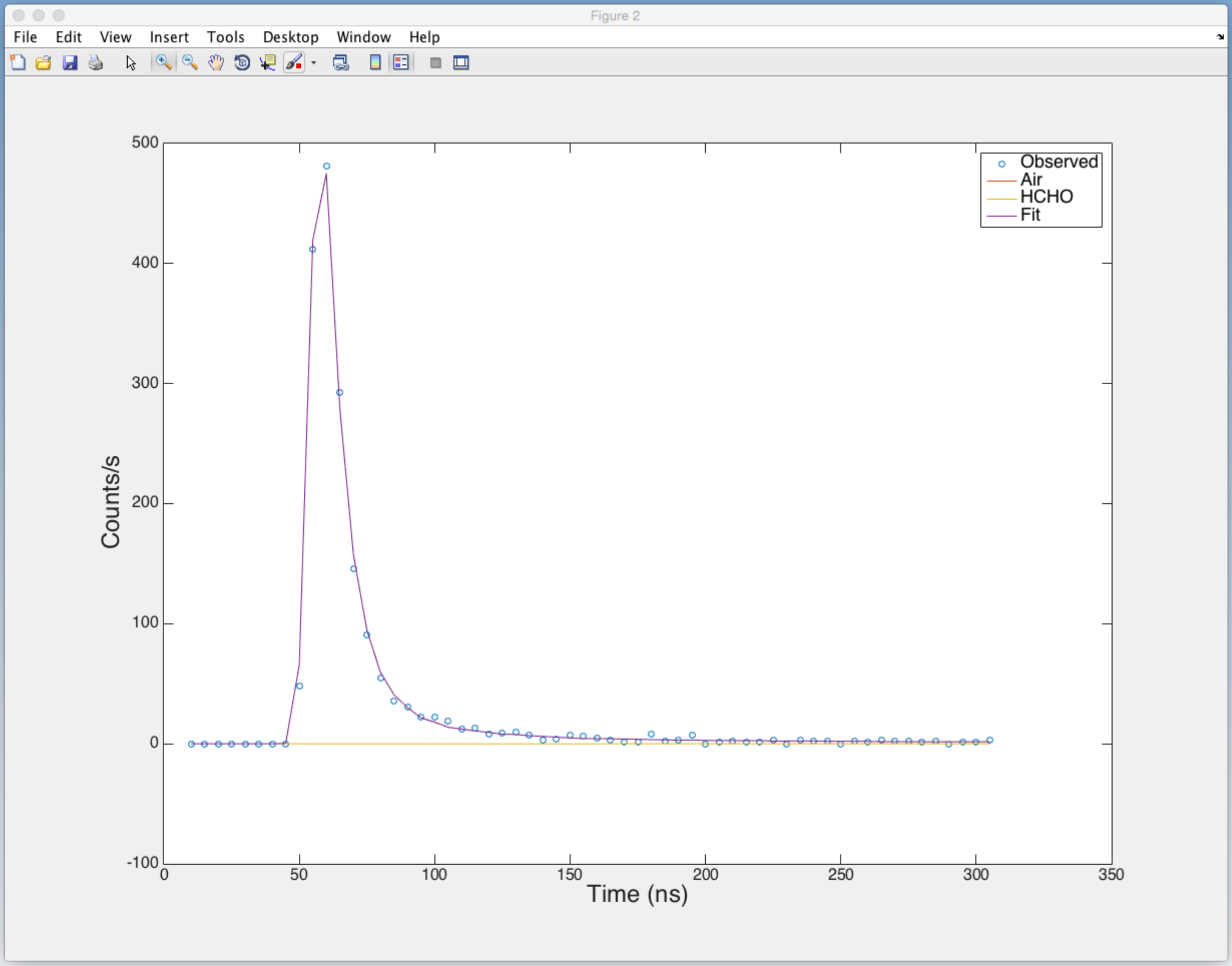


Non Resonant LIF

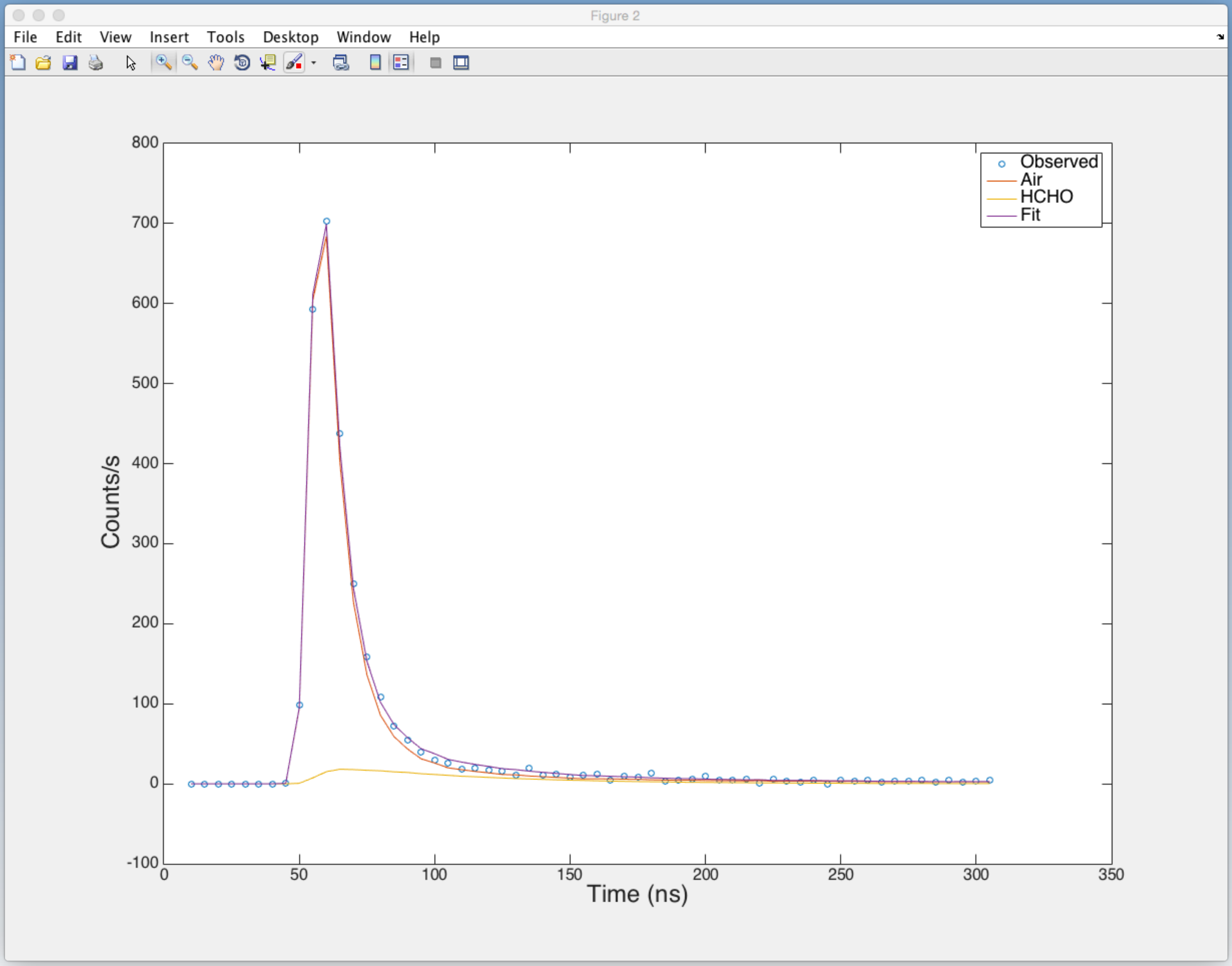
HCHO Laser Induced Fluorescence



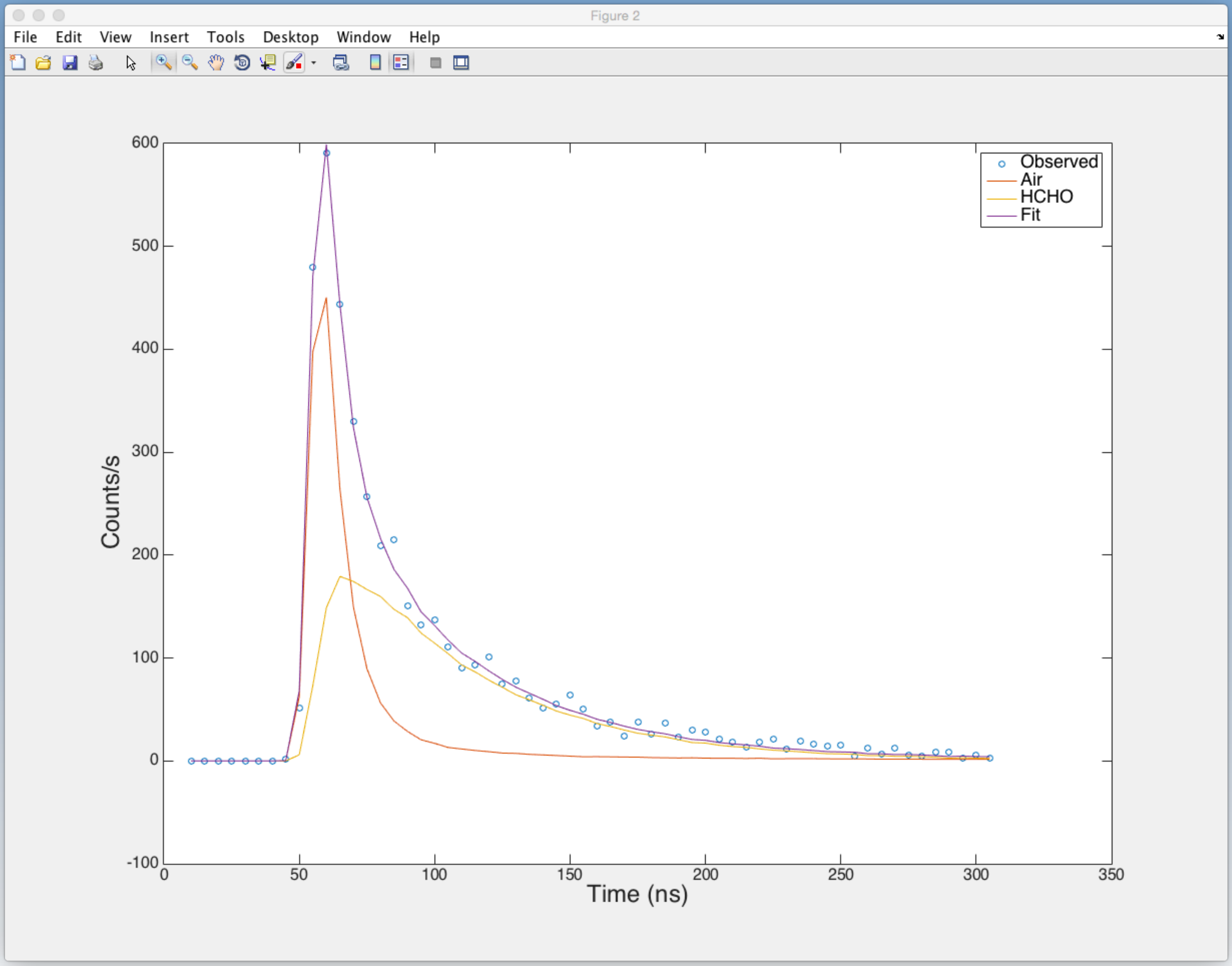
NR-LIF time binning



NR-LIF time binning

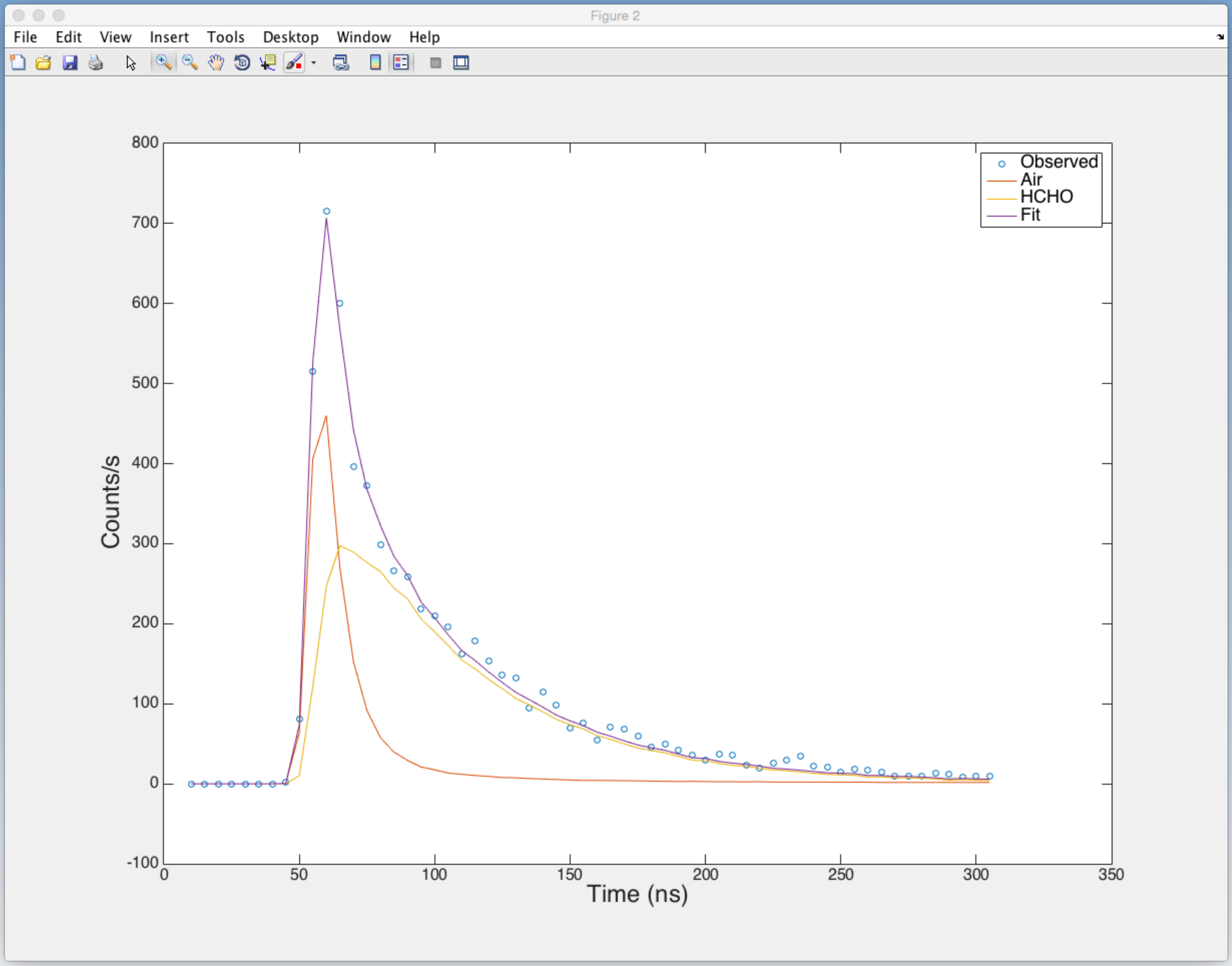


NR-LIF time binning



High Altitude Airborne Formaldehyde

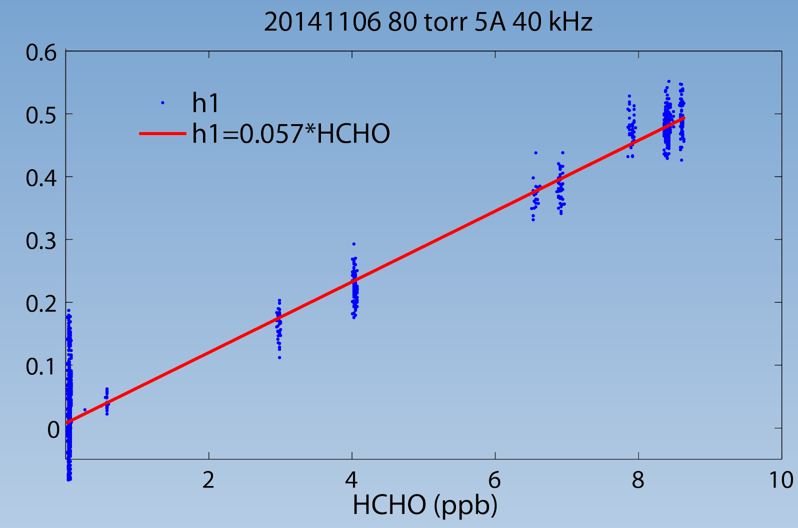
NR-LIF time binning

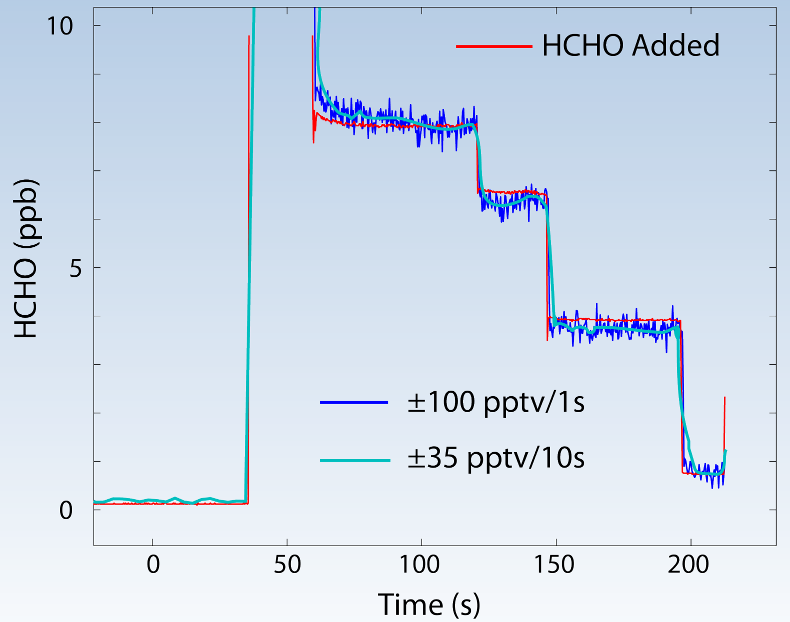


High Altitude Airborne Formaldehyde

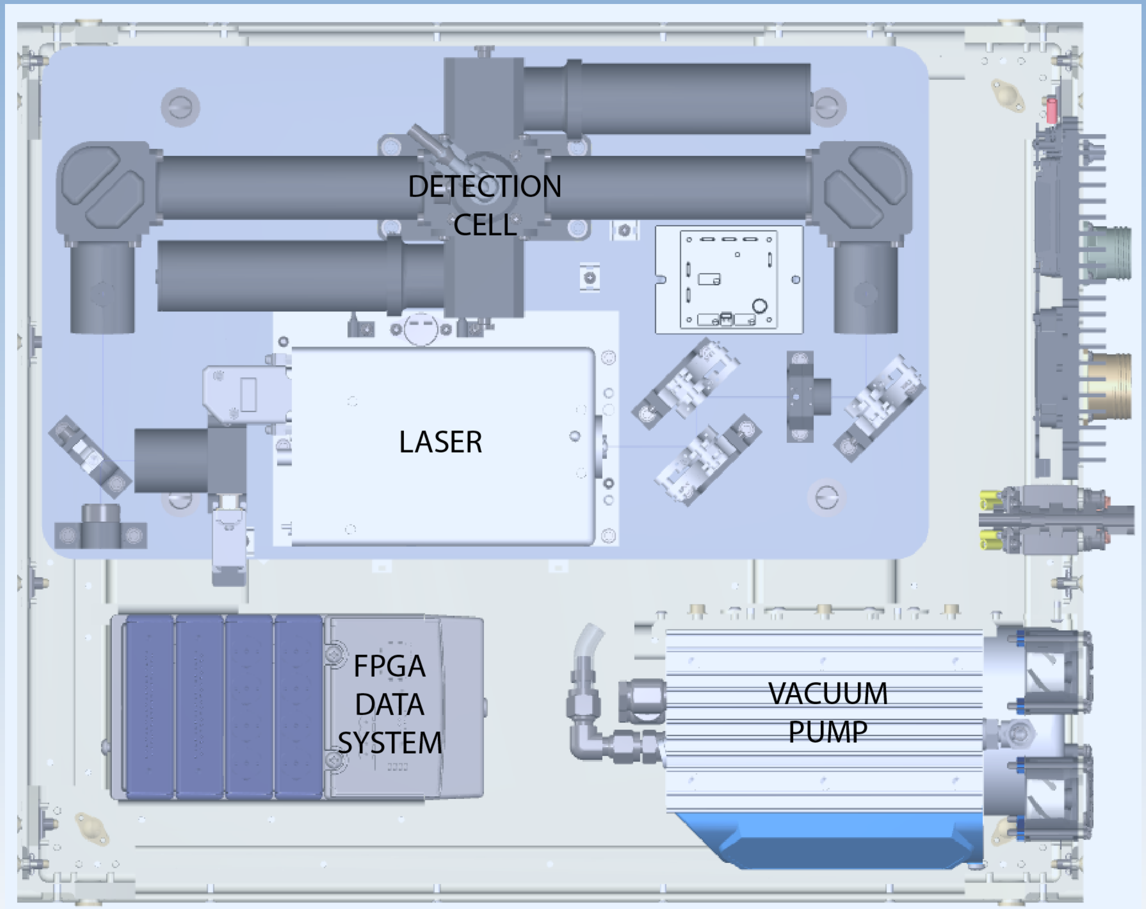
Calibrations

- Calibration is performed by standard addition using a gas addition system.
- A known quantity of HCHO from a calibrated standard (560 ppbv) is diluted with air.
- Concentrations are determined from measurements of the mass flow of air and HCHO.

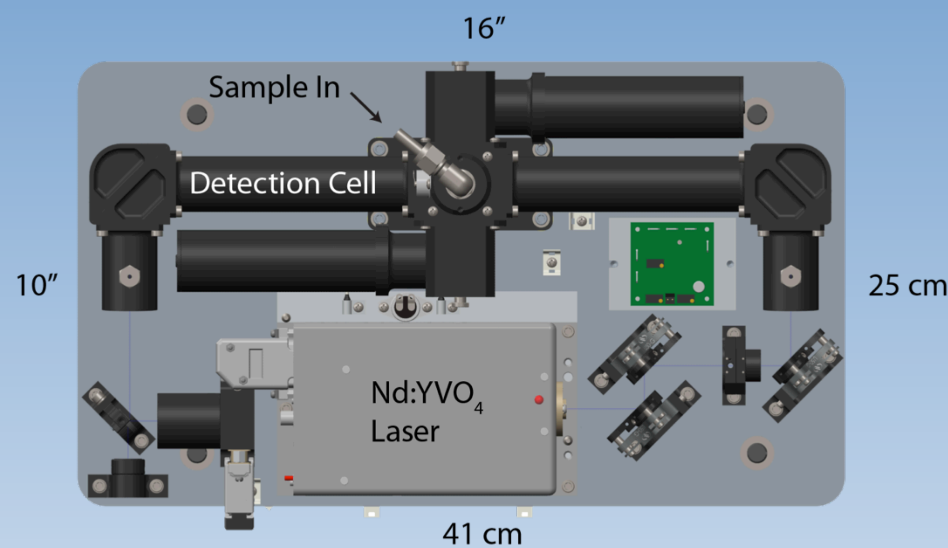




Enclosure layout



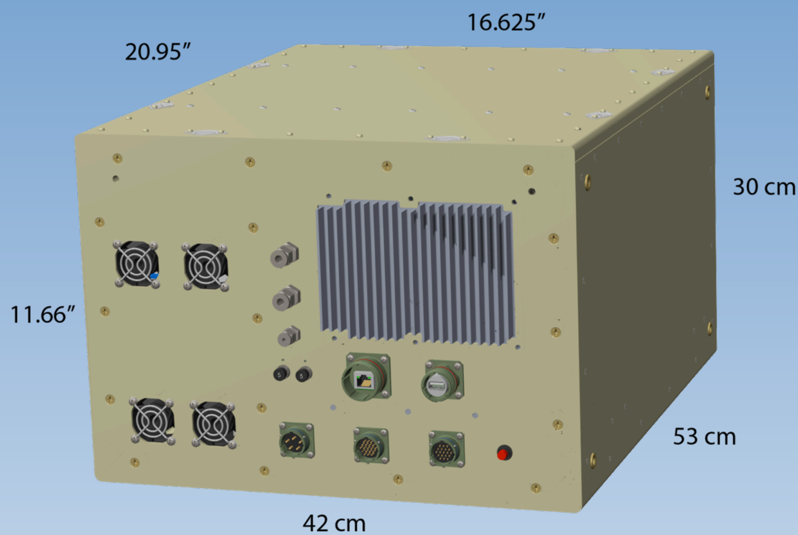
Optical Plate



Top View

Side View

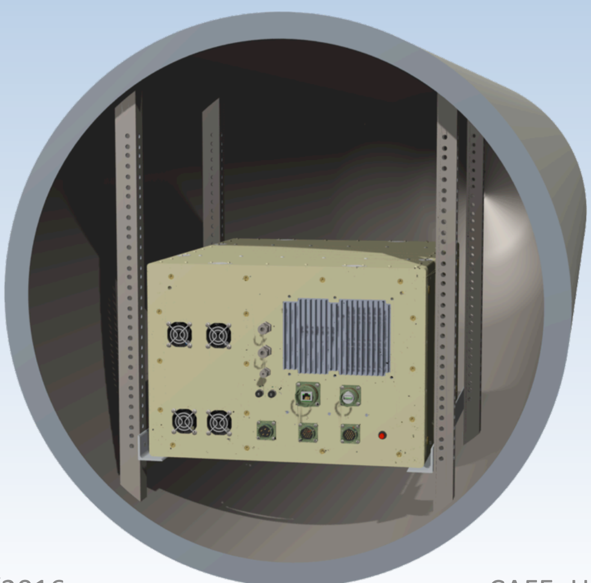
ER-2 CAFE Integration



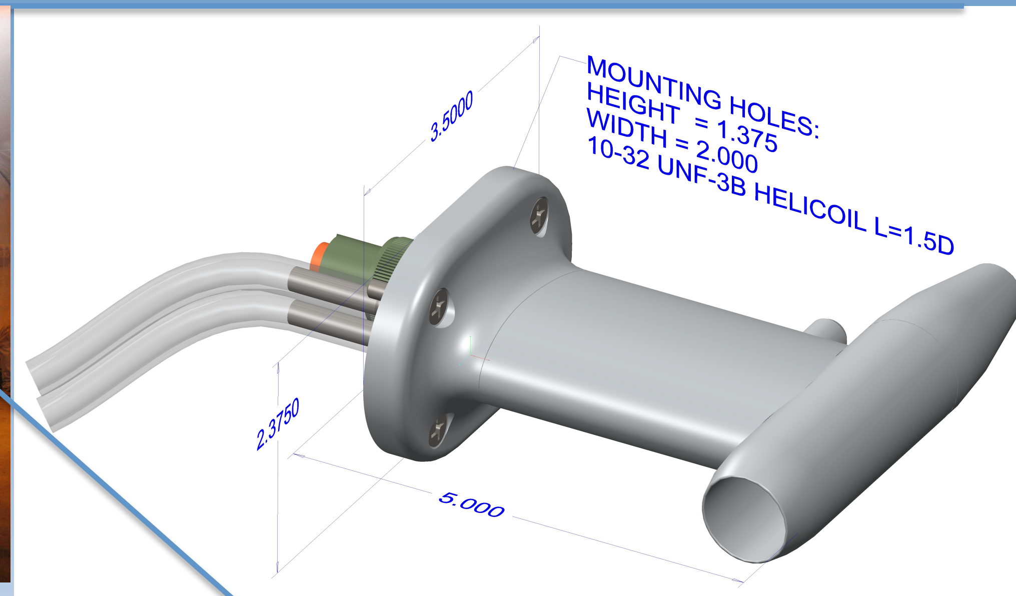
CAFE will mount in the fixed forward mid-body of ER-2 superpod.

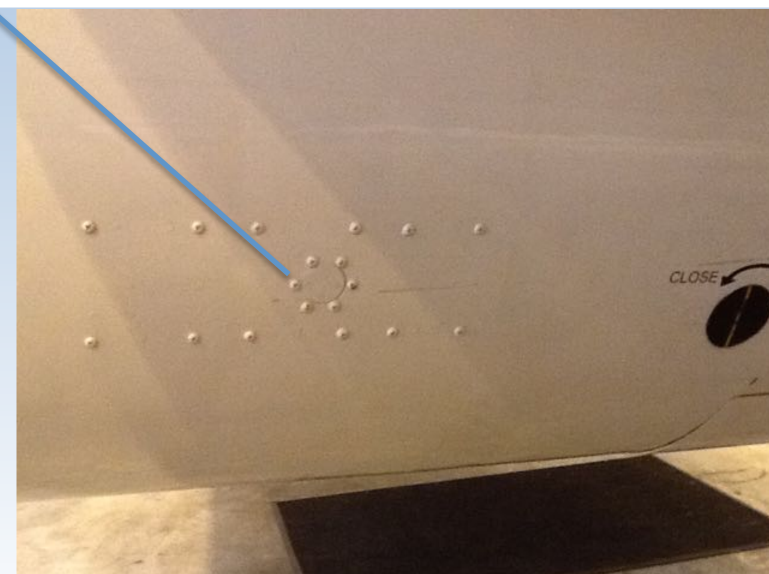
7 U of vertical height in a 19” rack.

CAFE will use standard angles for support.



Inlet

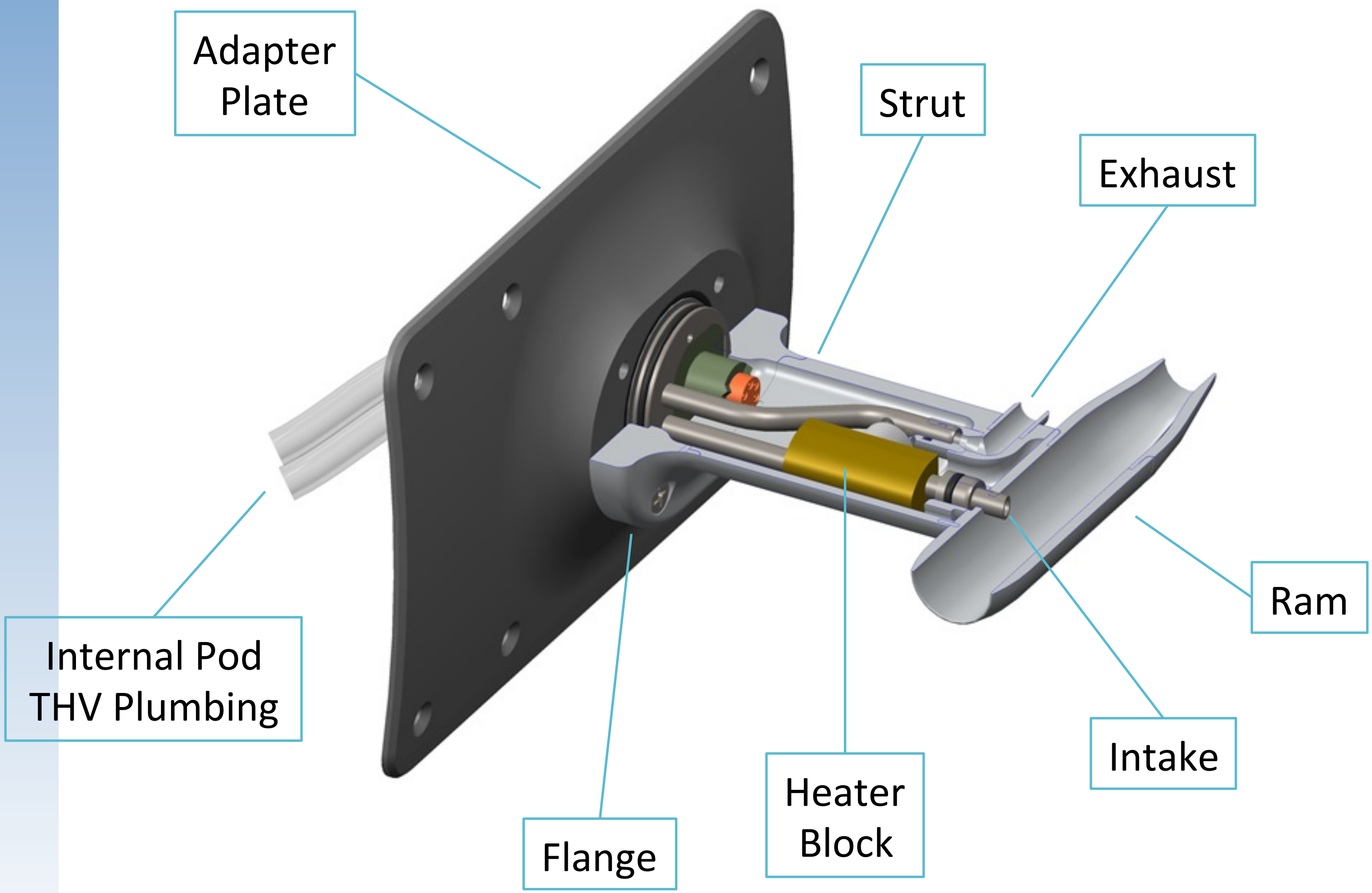




In situ sampling requires an inlet in the free stream

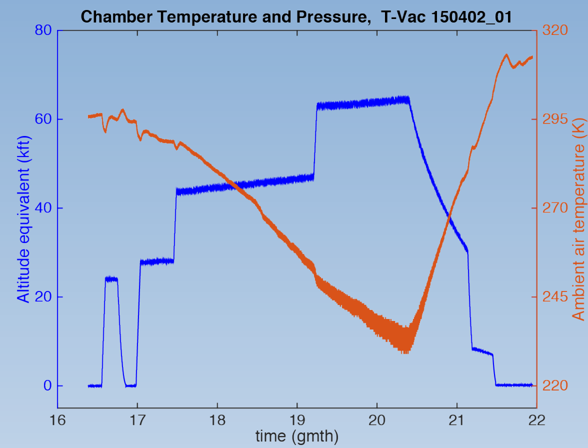
Mount external on the ER-2 pod at the MASP hardpoint

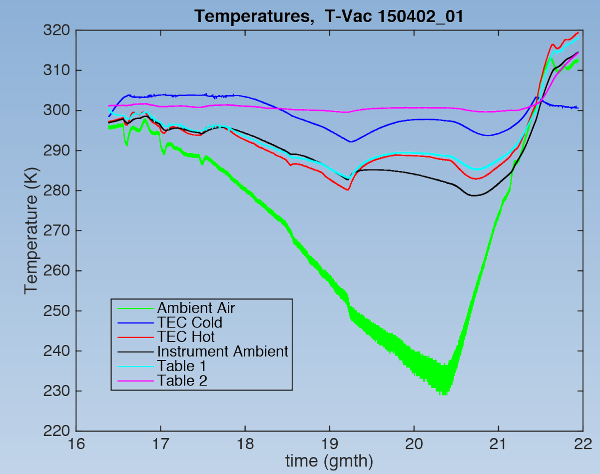
Inlet Details

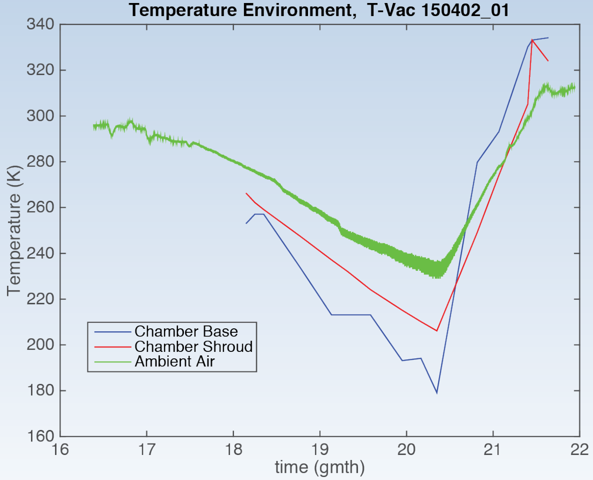


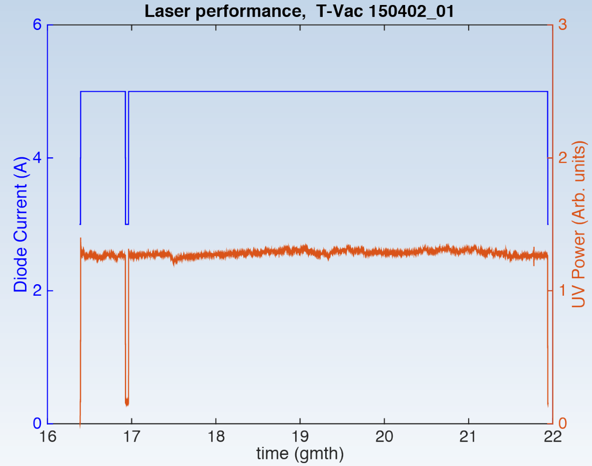
Thermal Vacuum Test

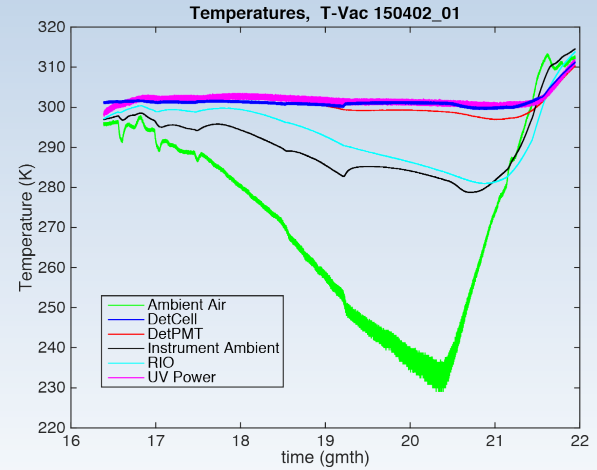
Successful thermal vac test with instrument prototype. All components pass.









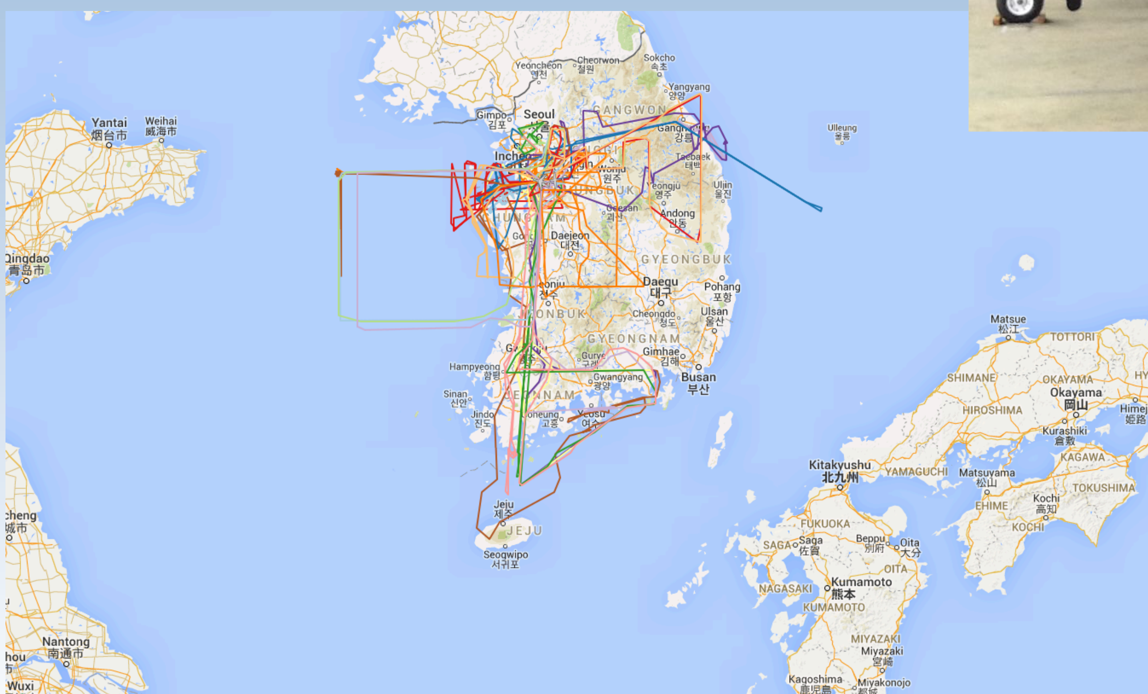


First flights KORUS-AQ

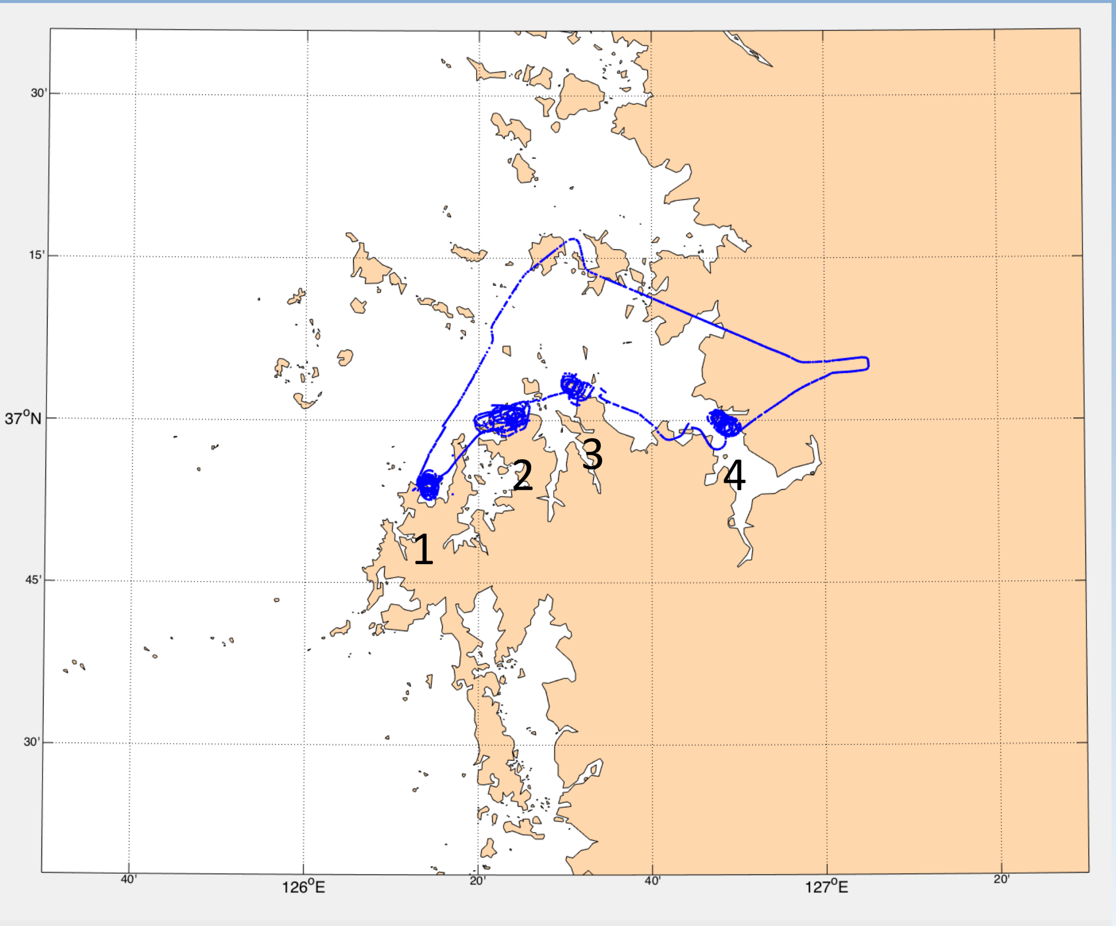
Successful first flight on Hanseo University KingAir in Taean, South Korea.

KORUS-AQ field campaign studying air quality in South Korea: 40 flights in May/ June, 2016

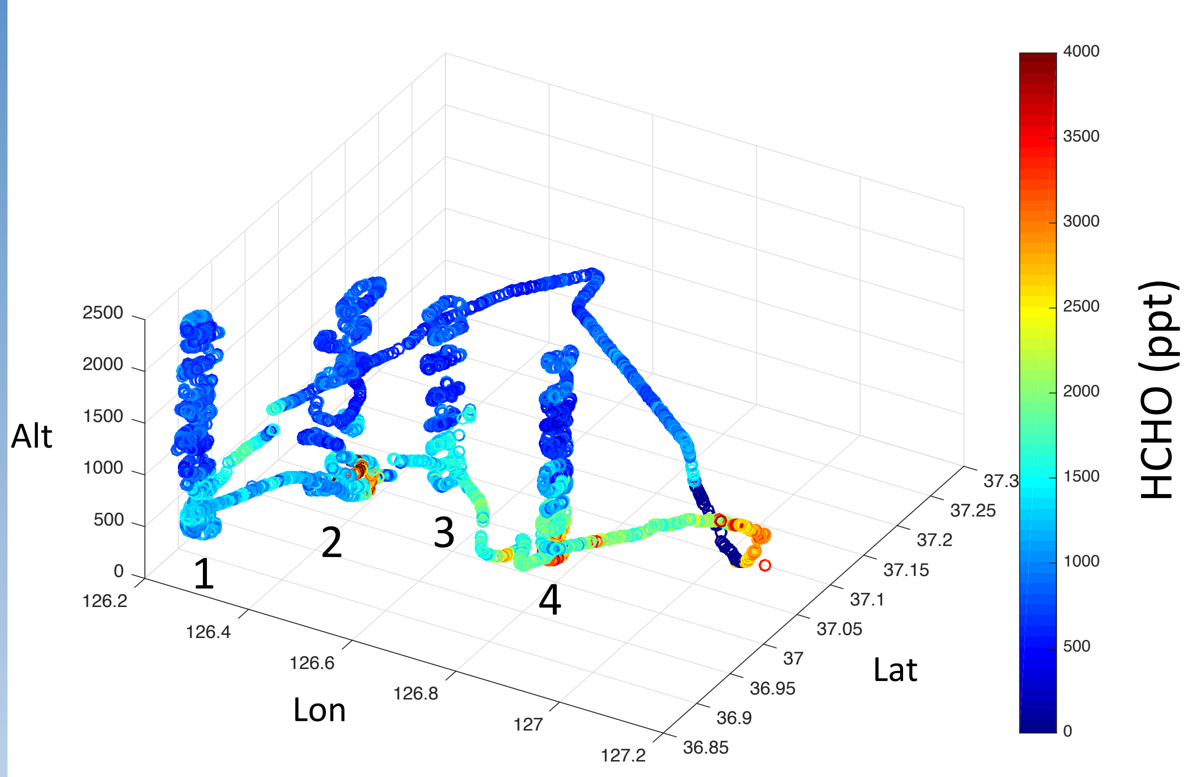
VOCs ➔ HCHO ➔ Ozone (Smog)



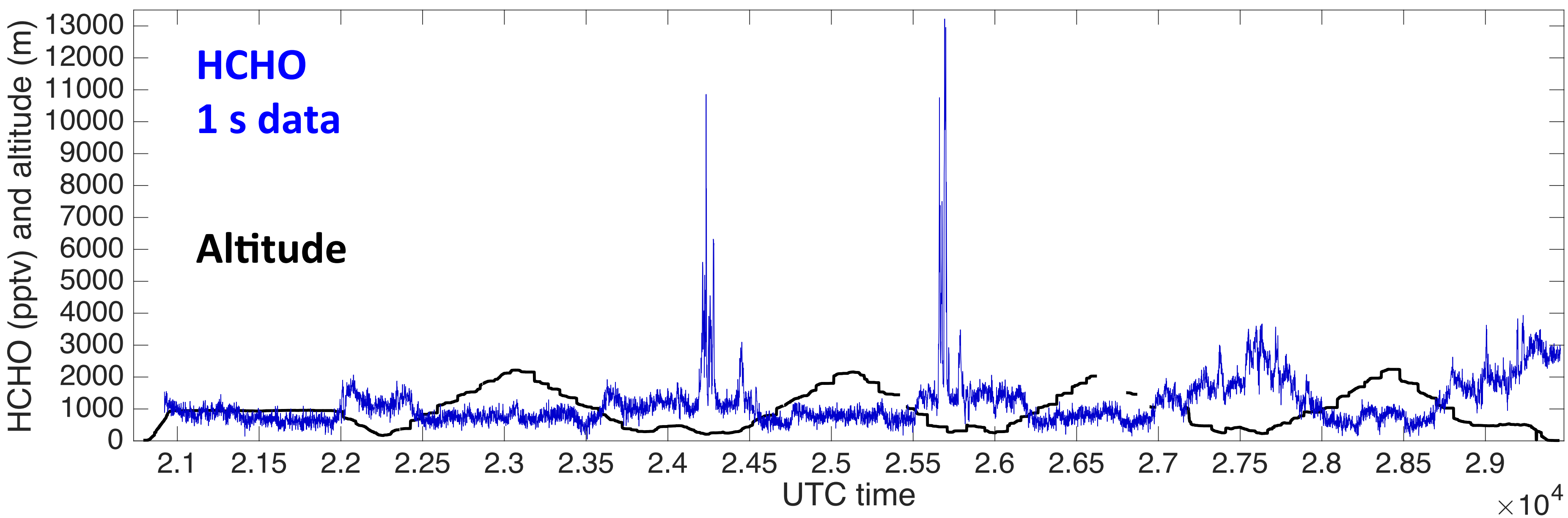
May 31 , 2016 2nd Flight :
Western coastal industrial facilities



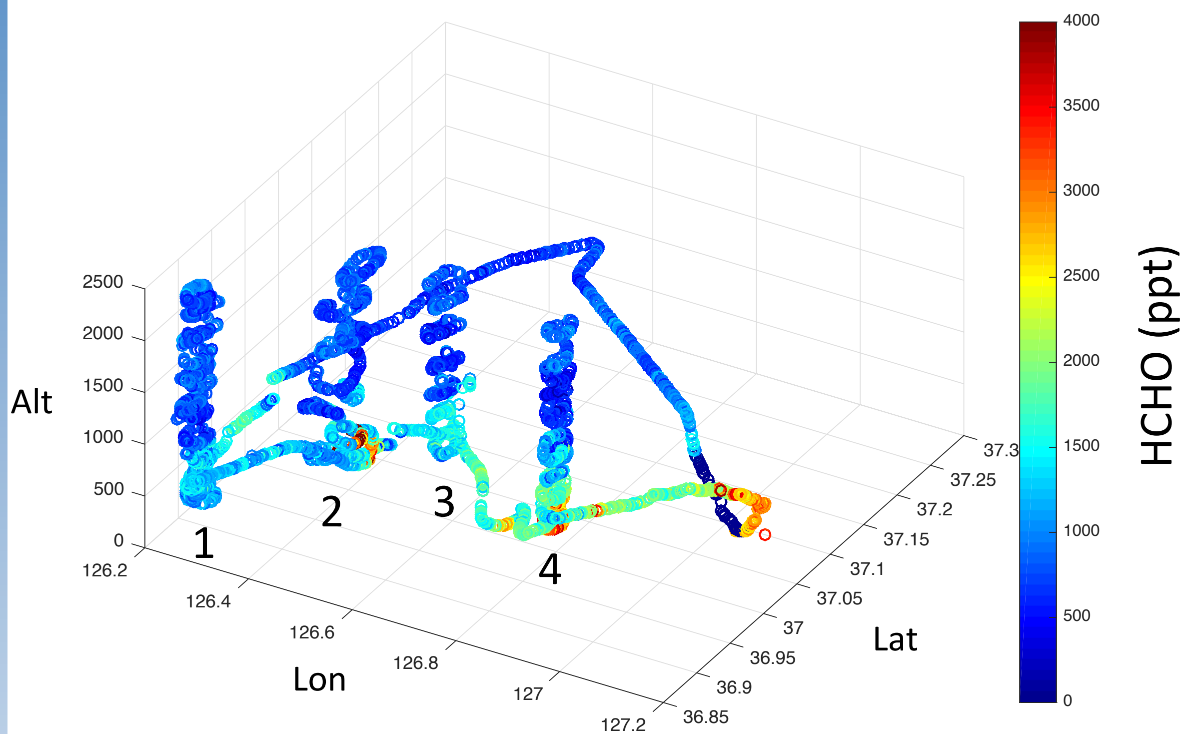
1. Power plant
2. Petroleum facilities
3. Power plant
4. Steel facilities



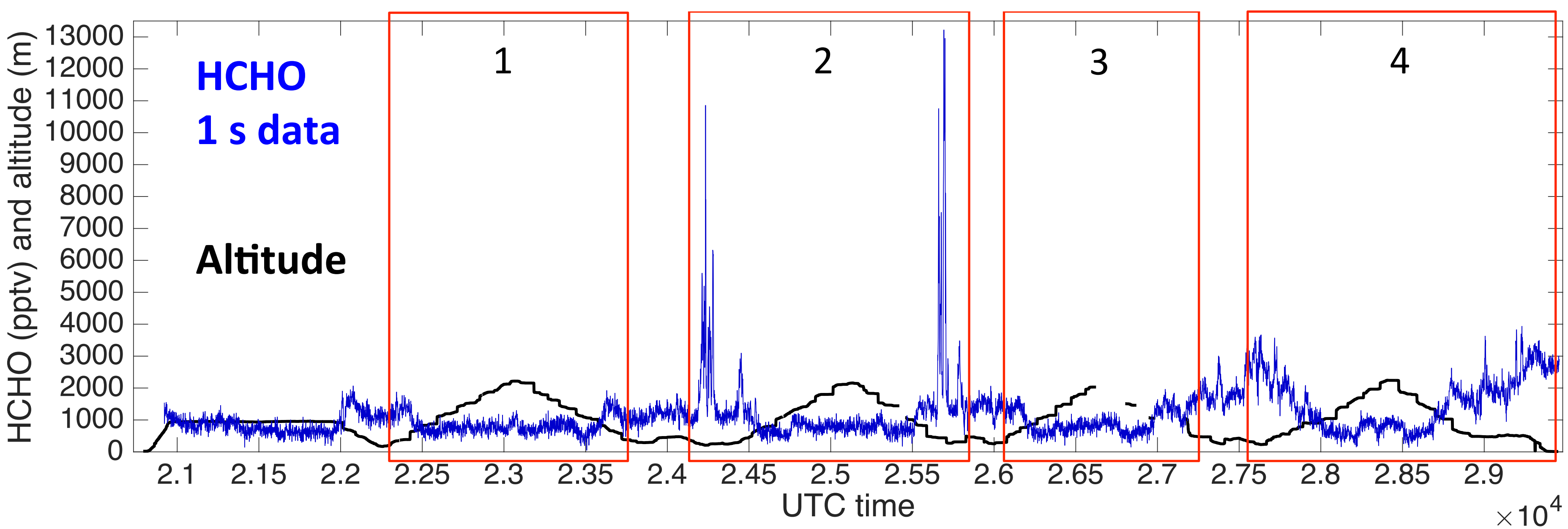
HCHO (ppt)
4000
3500
3000
2500
2000
1500
1000
500
0
Alt
2500
2000
1500
1000
500
0
Lon
126.2
126.4
126.6
126.8
127
127.2
Lat
36.85
36.9
36.95
37
37.05
37.1
37.15
37.2
37.25
37.3
1
2
3
4



HCHO
1 s data
Altitude
HCHO (pptv) and altitude (m)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2.1
2.15
2.2
2.25
2.3
2.35
2.4
2.45
2.5
2.55
2.6
2.65
2.7
2.75
2.8
2.85
2.9
UTC time
×10^4

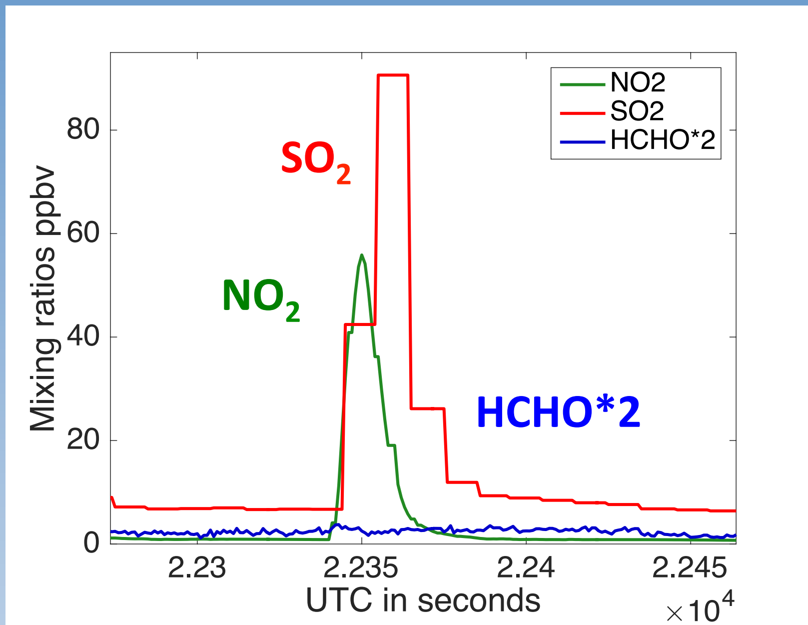


Alt
Lon
Lat
HCHO (ppt)
1
2
3
4

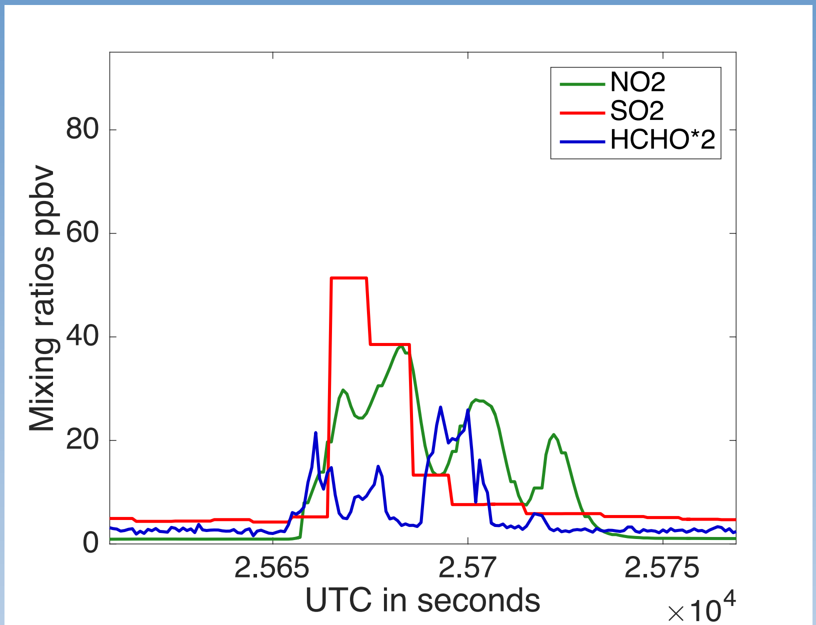


HCHO
1 s data
Altitude
HCHO (pptv) and altitude (m)
UTC time
×10^4
1
2
3
4

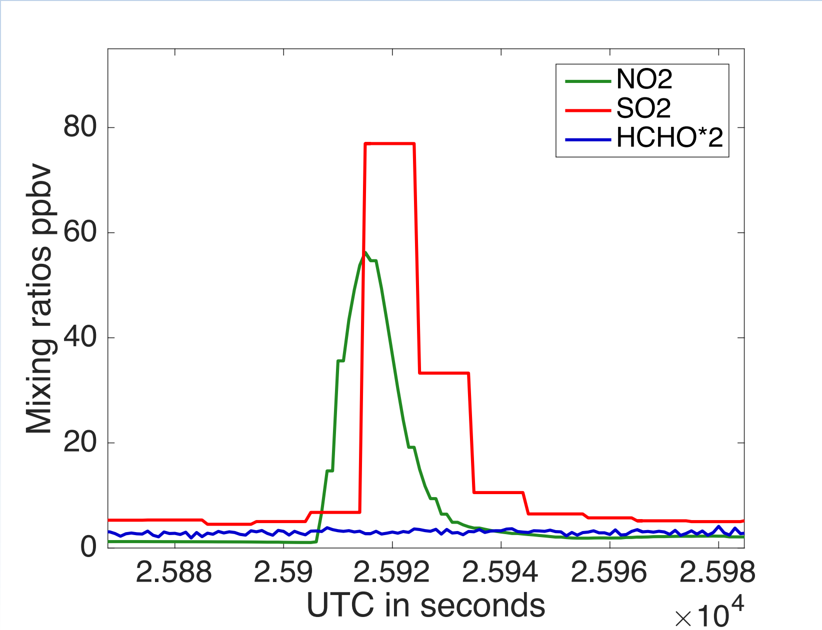
Spiral 1 (power plant)



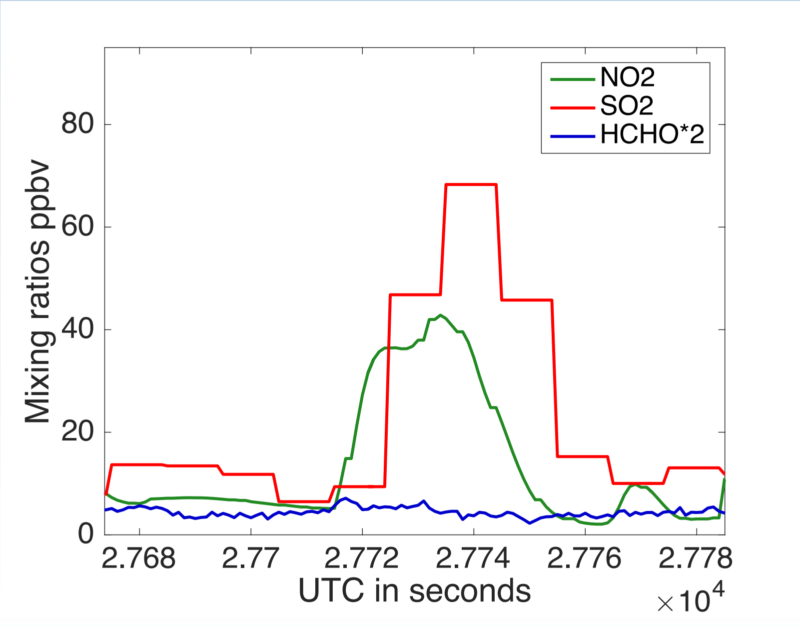
Spiral 2 (petroleum facilities)



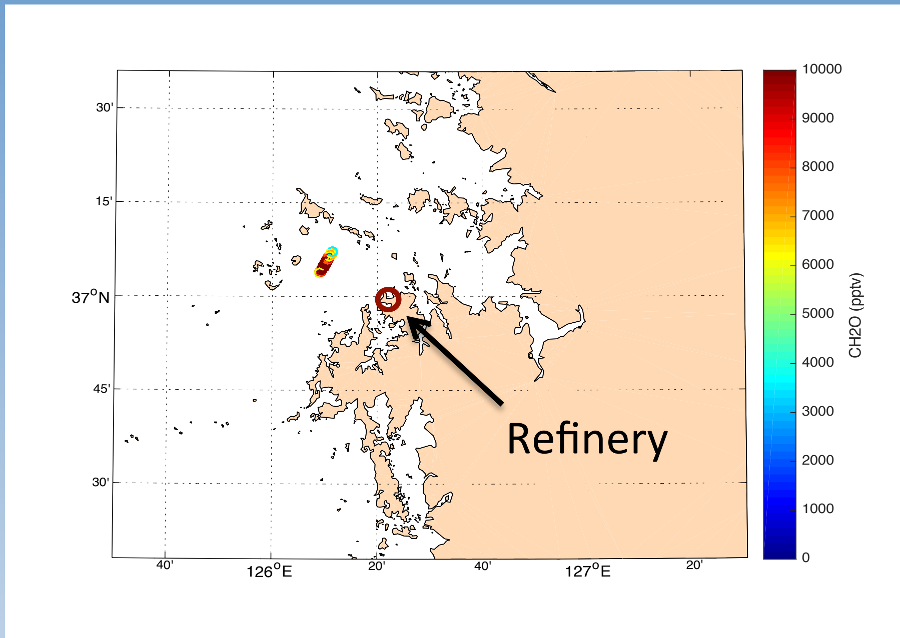
Spiral 3 (power plant)

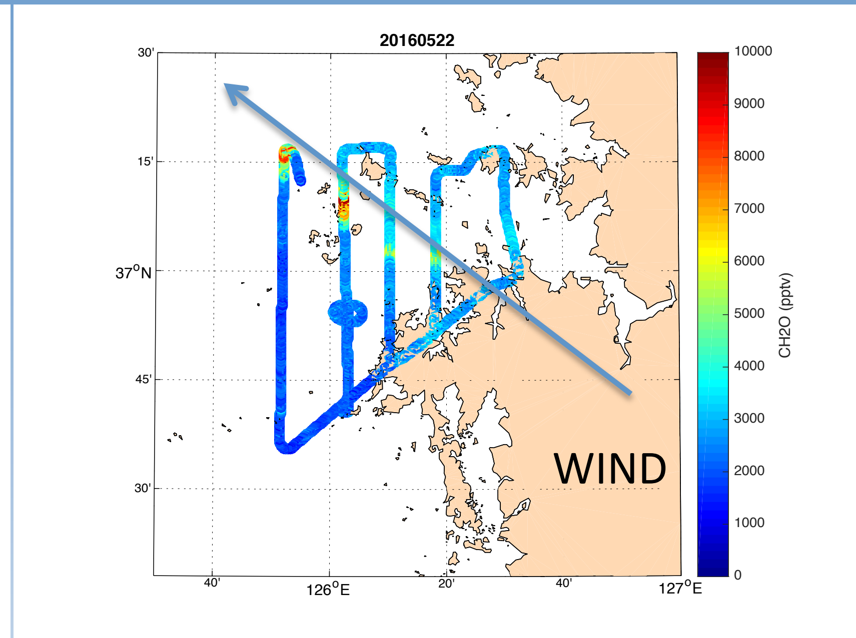


Spiral 4 (steel facilities)

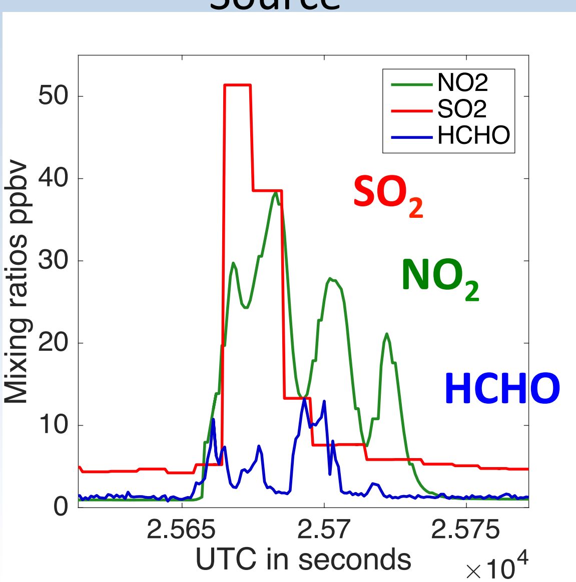


Petroleum facilities source and downwind (May 22nd)





Source

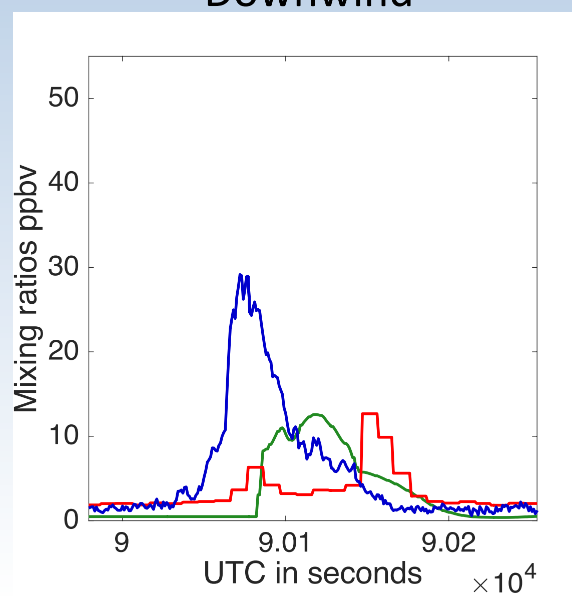


Formation of HCHO From VOCs

→

Dilution of SO_2 NO_2

Downwind



Technology comparison to the state of the art

	DFGAS Univ CO	ISAF GSFC	CAFE GSFC AITT
Sensitivity (pptv)	50	10	30
Accuracy (%)	13	10	10
Time response (s)	2	0.1	0.1
Weight (kg)	260	45	25
Volume (m^3)	0.66	0.13	0.07

Near term plans (3 - 6 mos.)

- Test flight on ER-2
  - Integration June 27
  - Test flight July 5, 8, 9
- Potential science flights on ER-2 or WB-57 in Fall 2016