NOAA/ESRL Greenhouse Gas and Ozone Measurements from Aircraft in Alaska

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CIRES
Cooperative Institute for Research in Environmental Sciences

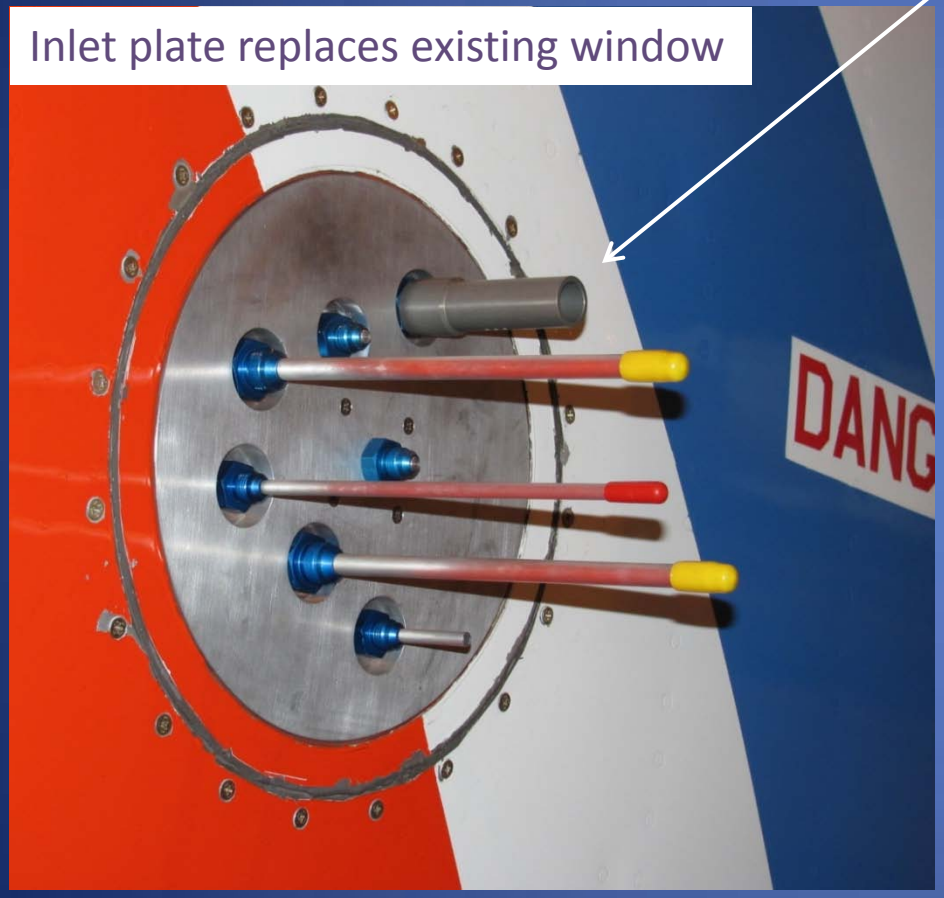
Outline

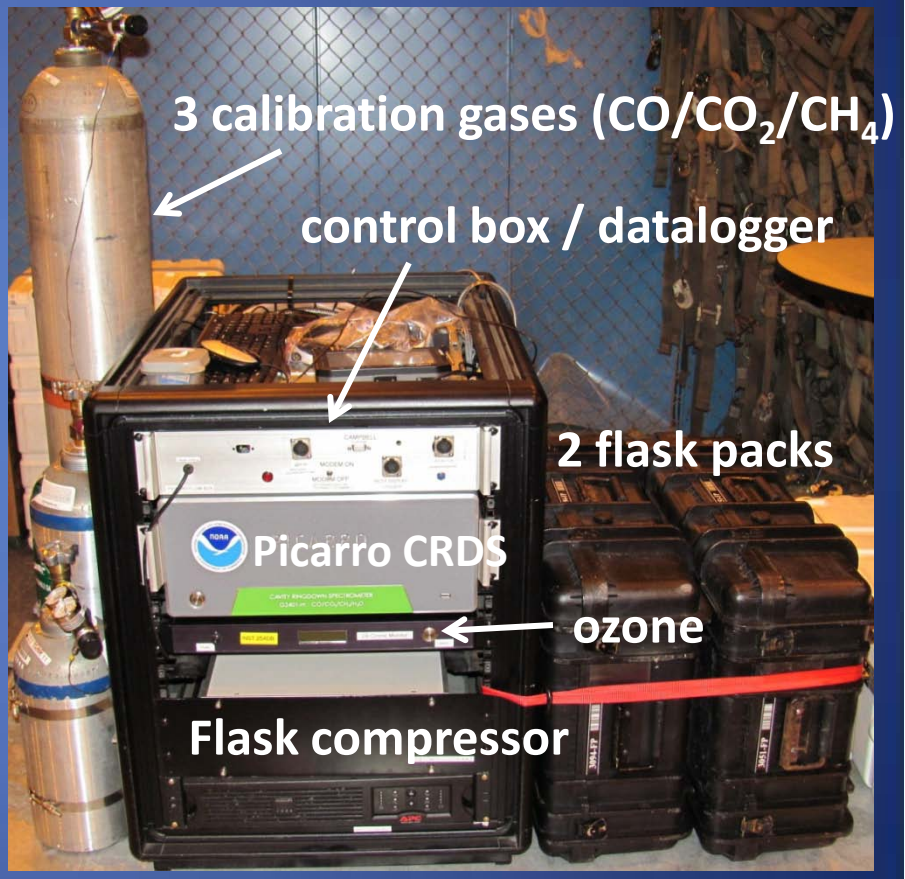
- Motivation
- Instrumentation and data quality
- Factors influencing seasonal variability
  - Boundary layer processes
  - Stratospheric exchange
  - Transport from low latitudes

Alaska Coast Guard (ACG) Aircraft Site

- U.S. Coast Guard conducts regular flights across Alaska for **Arctic Domain Awareness (ADA)**; for search and rescue operations as sea ice melts.
- NOAA/USCG collaboration – flights of opportunity
- Test bed for instrumentation for commercial aircraft
- Unprecedented scientific opportunity
  - monitoring Arctic response to warming and sea ice melting
  - establish baseline and monitor inter-annual variability
  - stratospheric/tropospheric exchange

Alaska Coast Guard (ACG) Aircraft Site

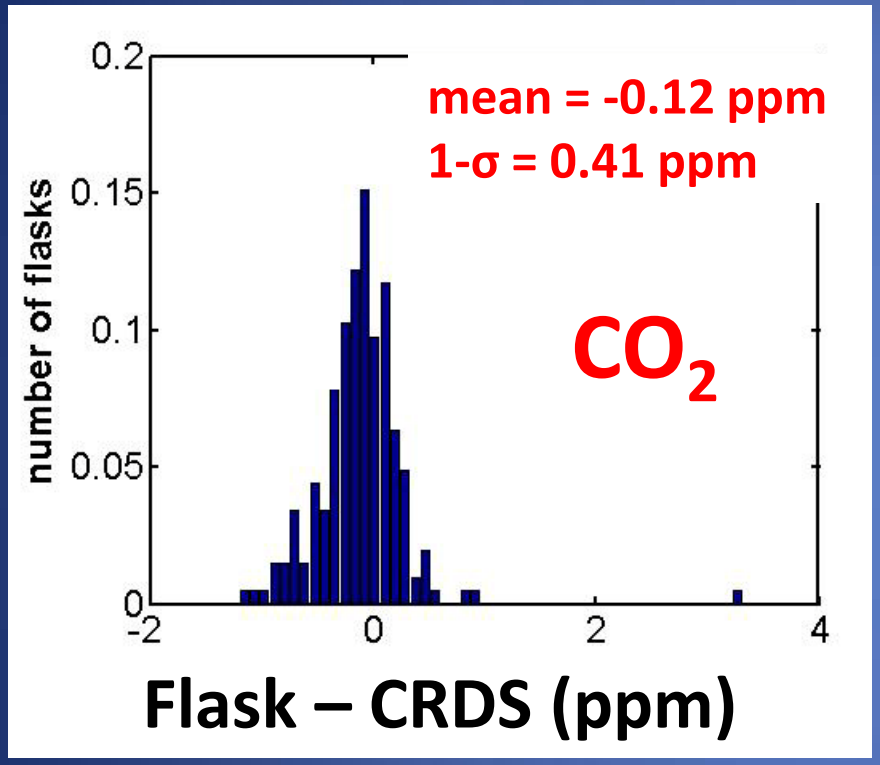




- continuous CO_2/CH_4/CO, O_3, T, RH, P
- 24 Flasks (PFP) with > 50 species

*Thanks to Duane Kitzis, Pat Lang, Paul Novelli for tanks and flask analysis.

Flask Comparisons (2010 season)



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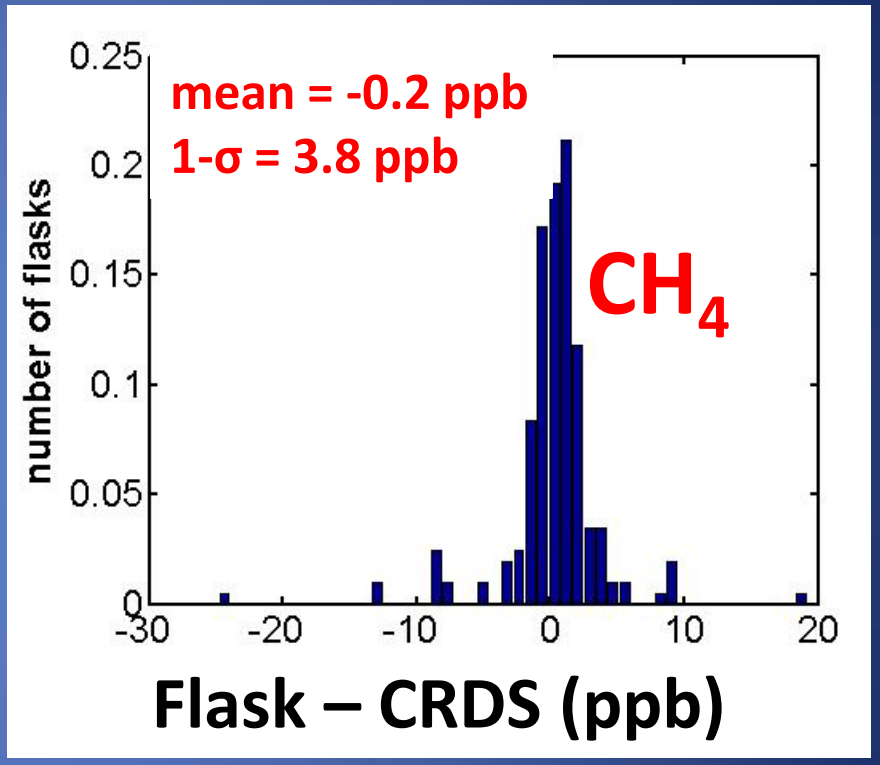
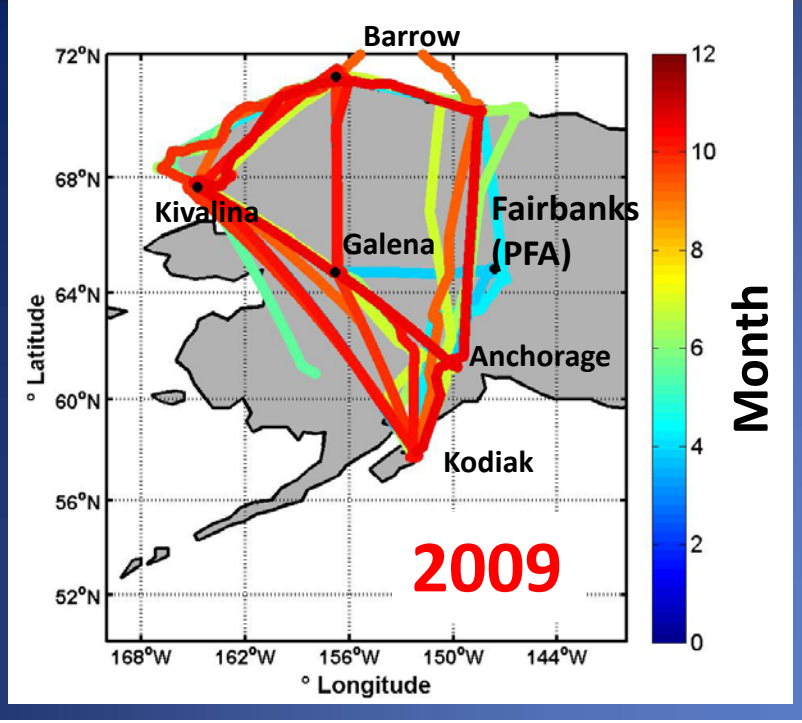
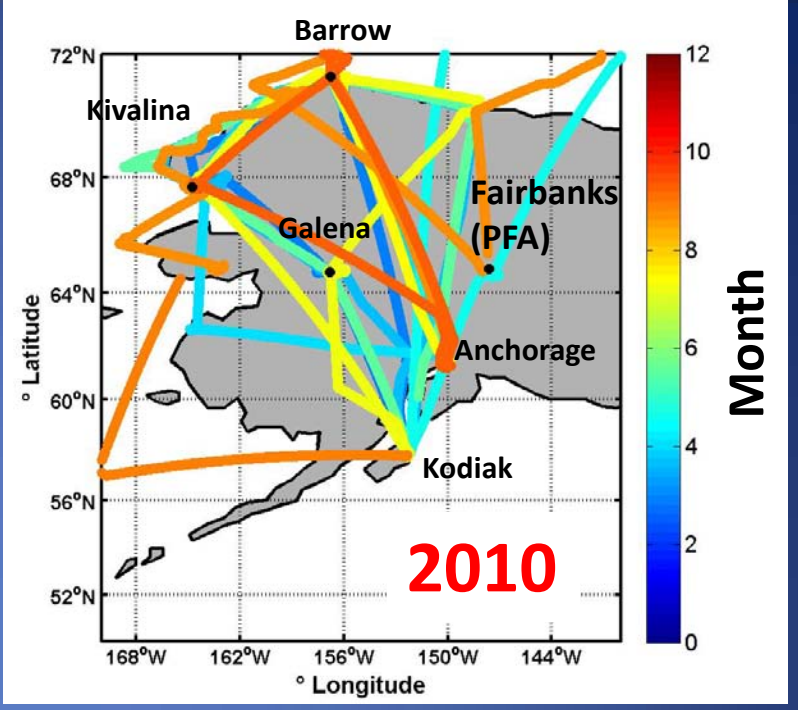
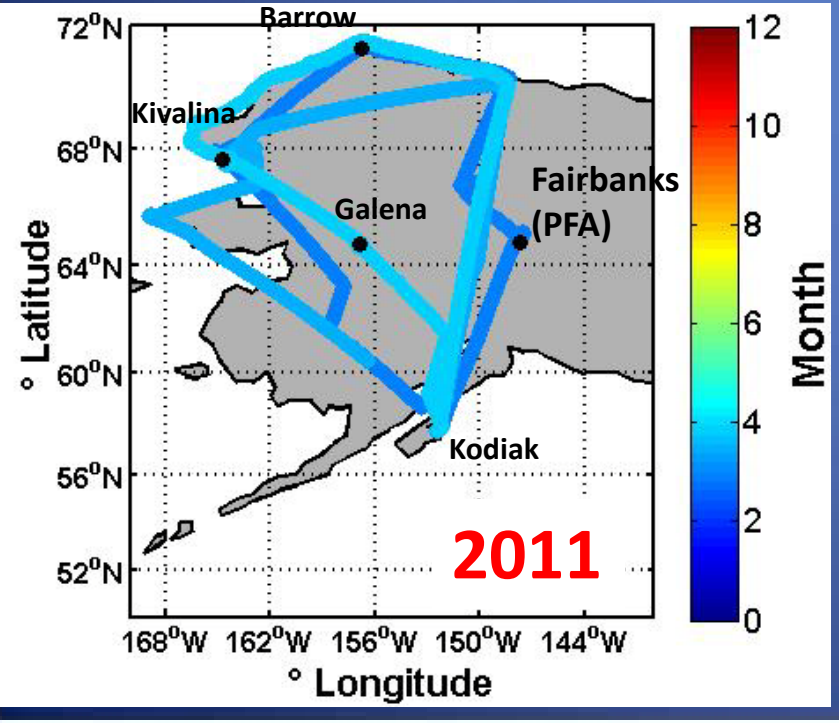


N=203

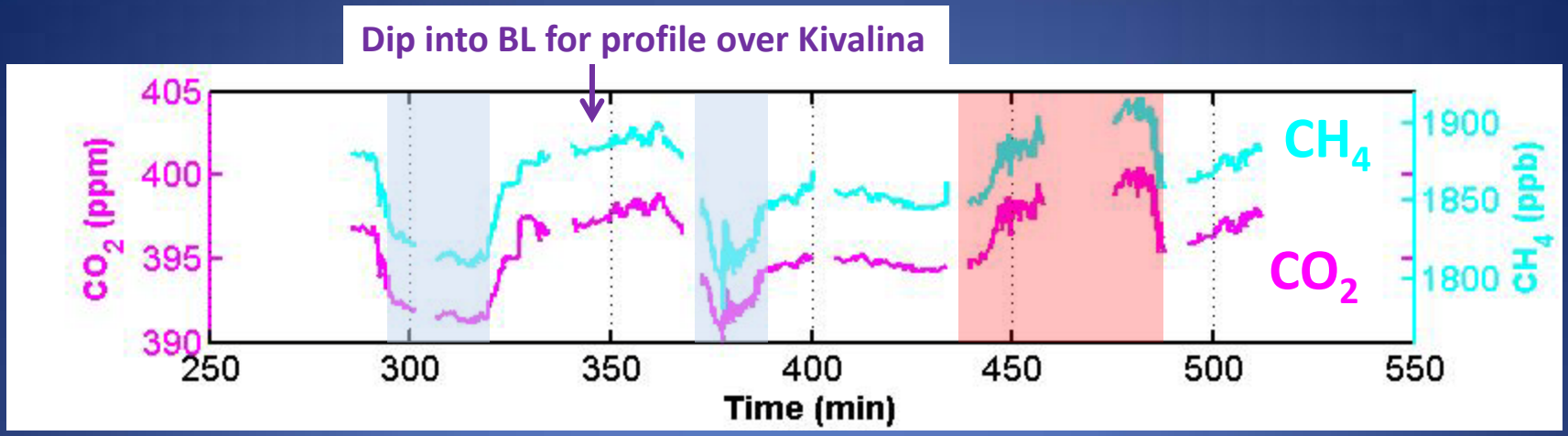
*only 2 flights with CO
so far: -3 ppb ± 4 ppb



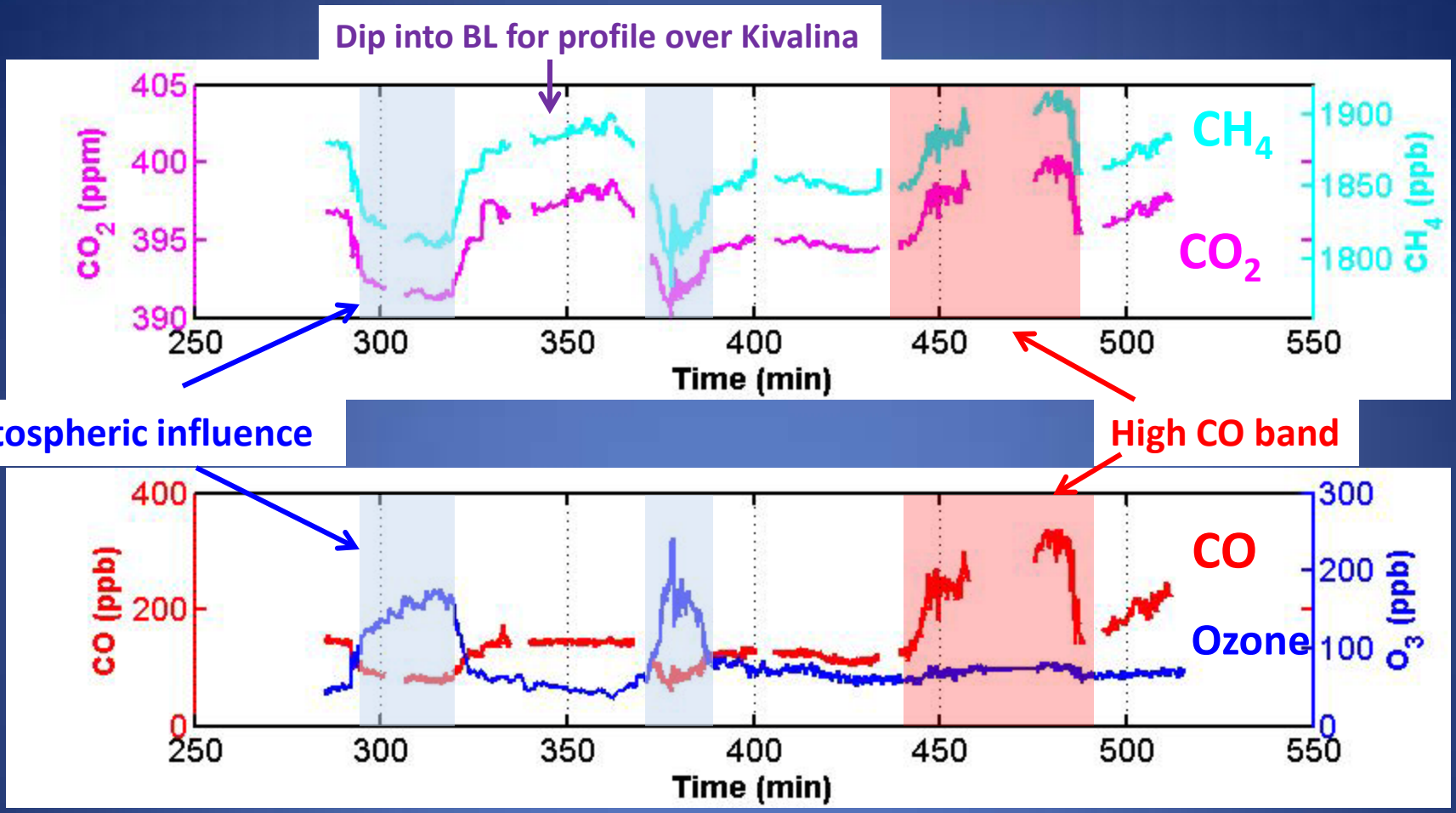




- Bi-weekly 8-hour flights on C-130
- March – November
- **16** flights per season
- large spatial extent (> 3000 km & 3 profiles per flight)
- much of the sampling occurs at high altitude (~8000 m)

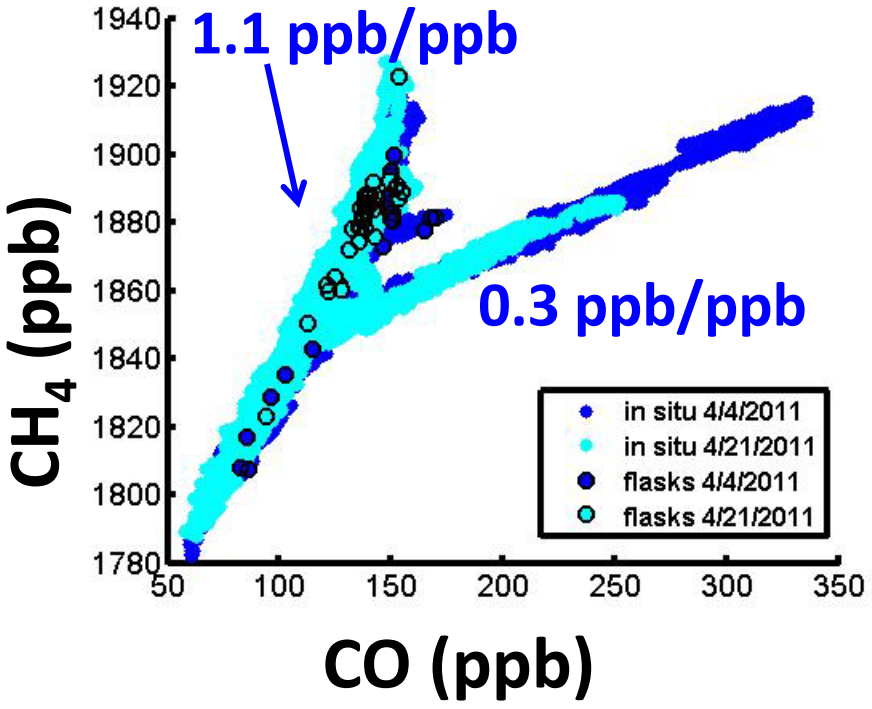

Dip into BL for profile over Kivalina
405
400
395
390
CO2 (ppm)
250
300
350
400
450
500
550
Time (min)
CH4
CO2
1900
1850
1800
CH4 (ppb)

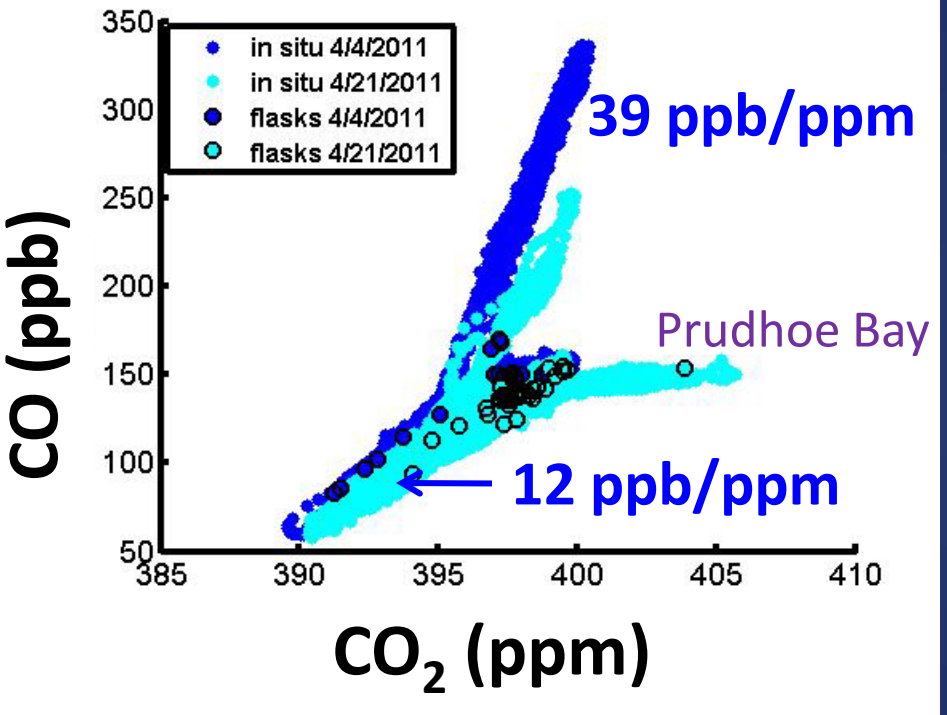
4 April 2011


Dip into BL for profile over Kivalina
stratospheric influence
High CO band
CH4
CO2
CO
Ozone
CO2 (ppm)
CH4 (ppb)
CO (ppb)
O3 (ppb)
Time (min)
Time (min)

4 April 2011

2011 ACG flights: high CO layers

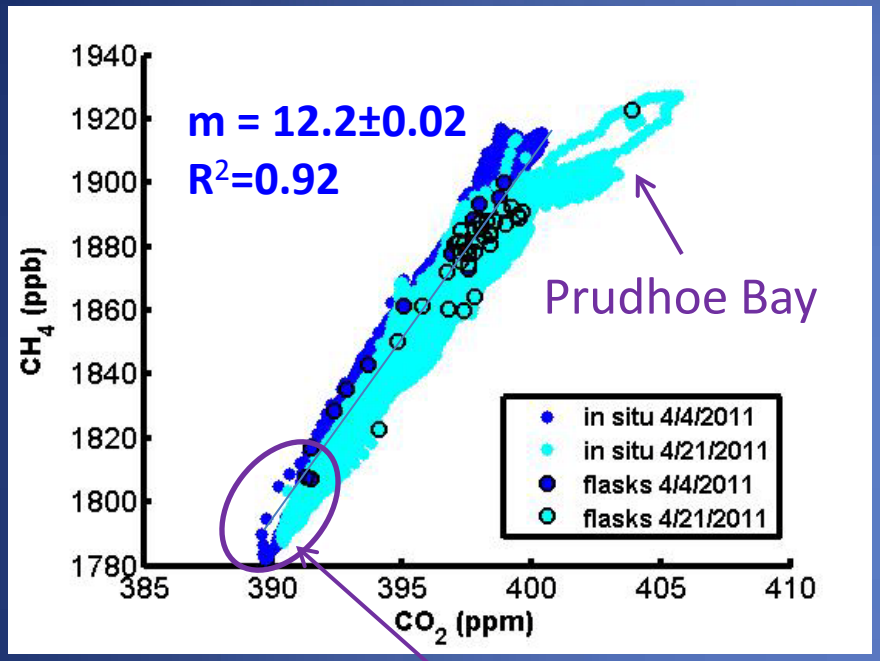




High-altitude pollution band (~7.8 km)

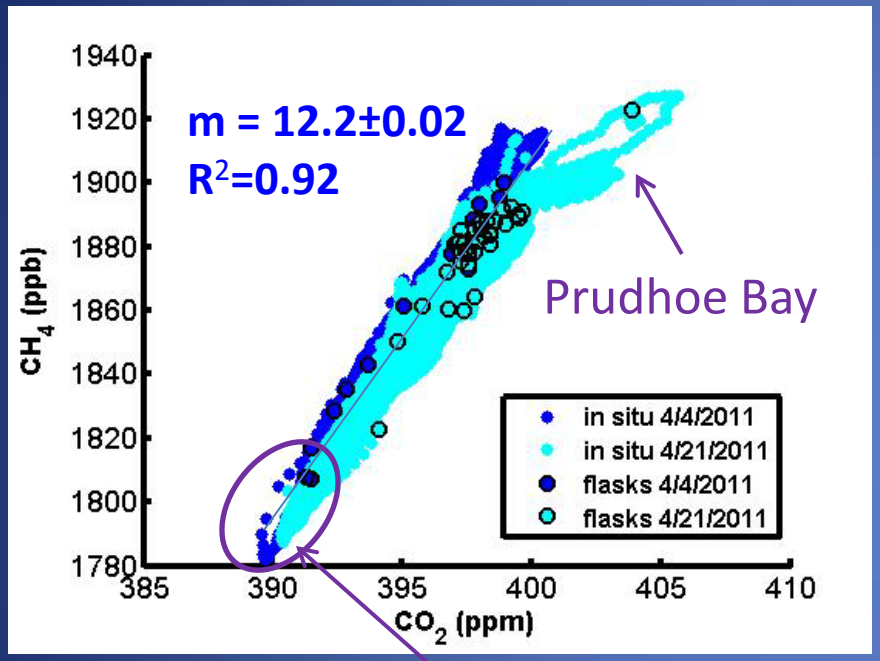
Similar bands of high-altitude CO observed in recent campaigns (ARCTAS [Singh et al. 2010, Warneke et al. 2009], and HIPPO [Wofsy et al. 2011])

2011 ACG flights: Winter

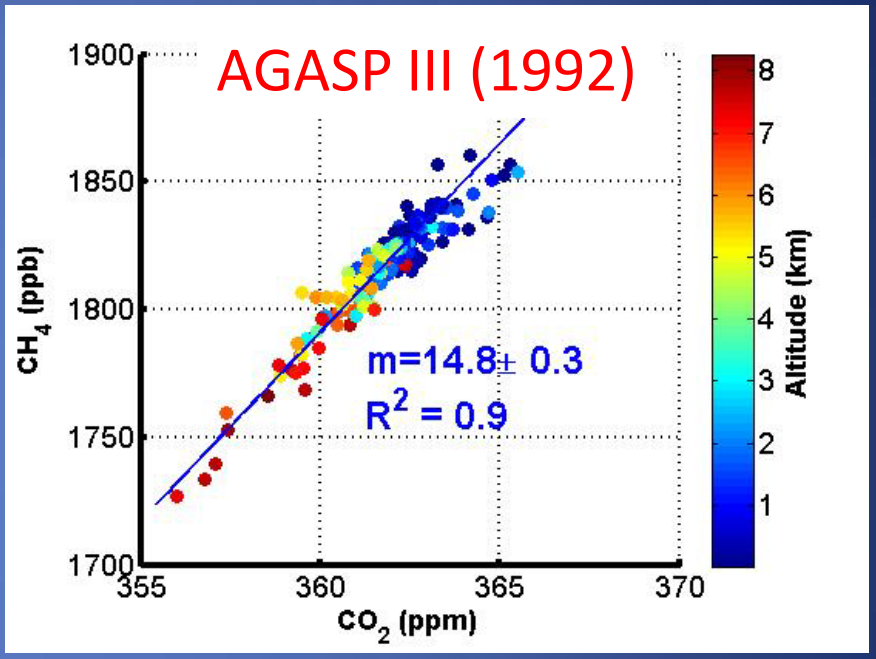


Stratospheric influence

2011 ACG flights: Winter

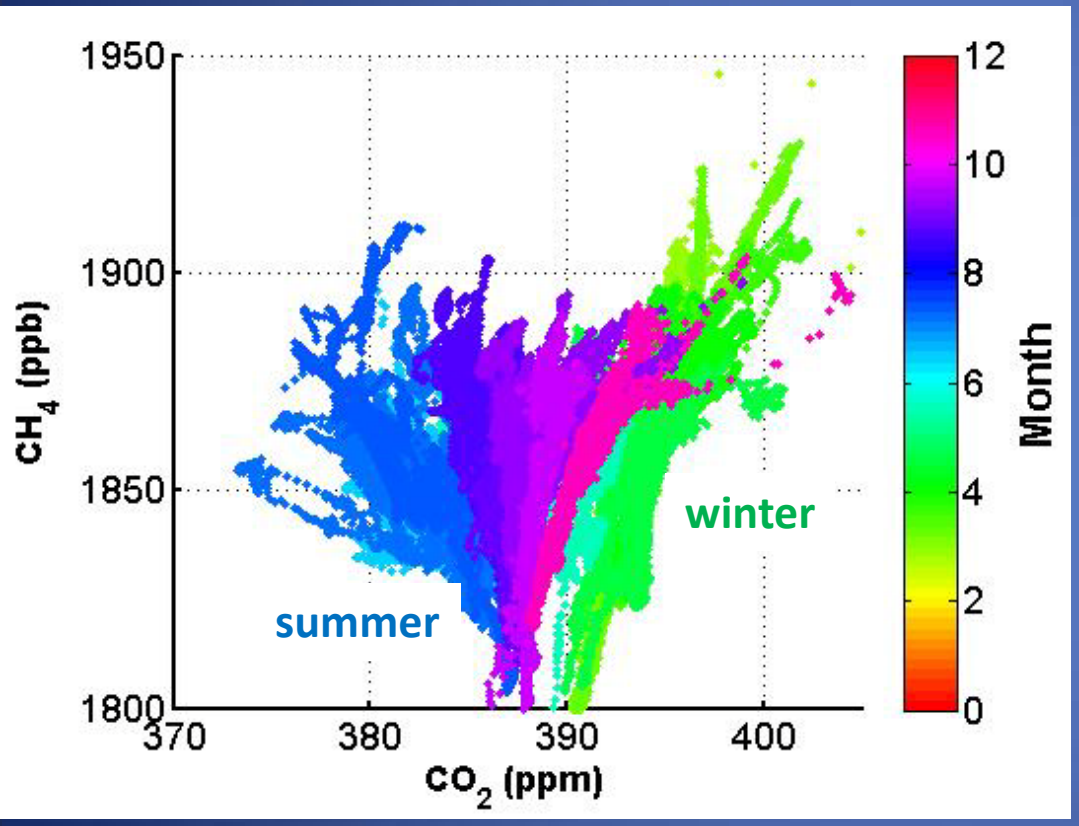


Stratospheric influence

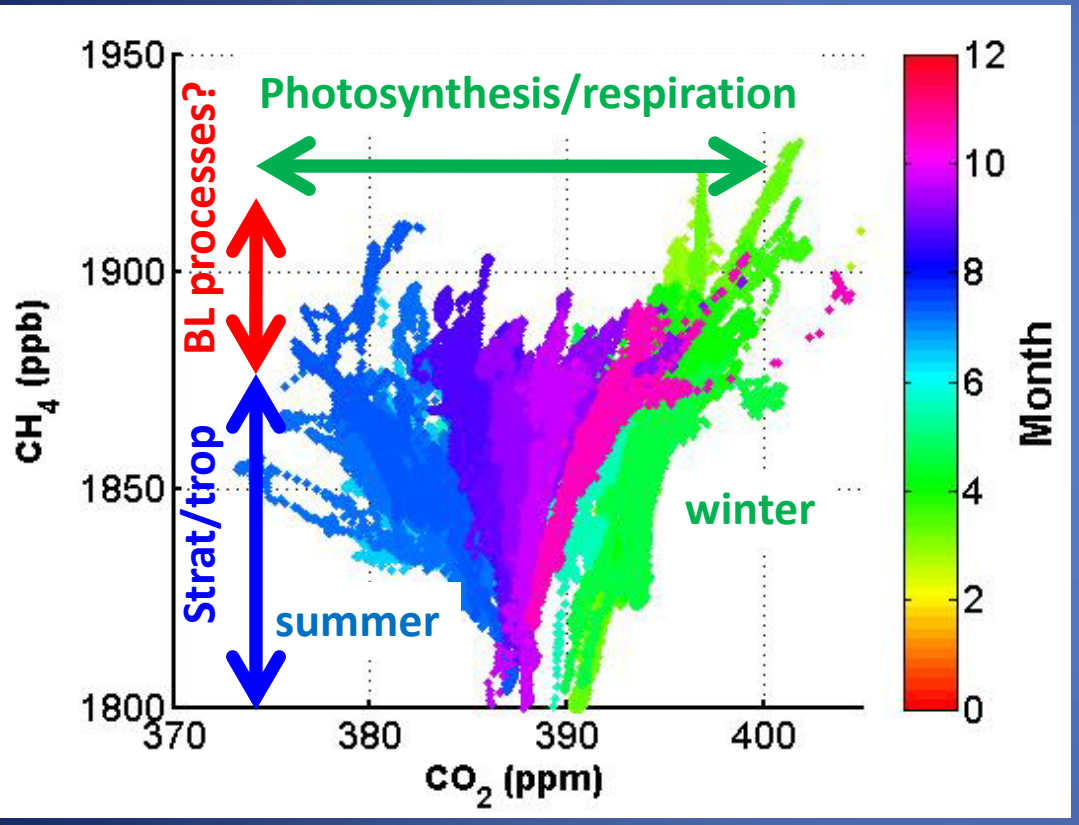


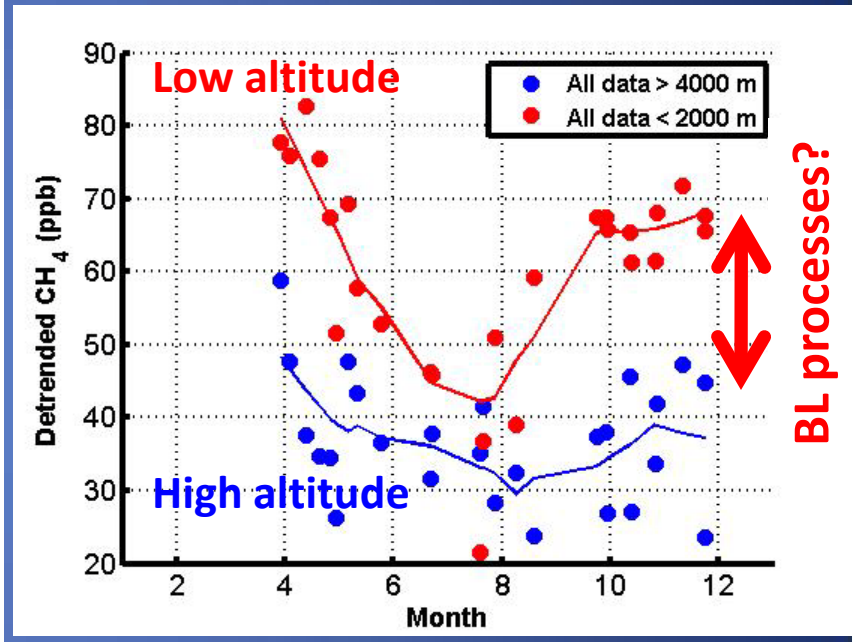
*Conway et al., 1993

Seasonal Cycle in CO_2 and CH_4



Seasonal Cycle in CO_2 and CH_4

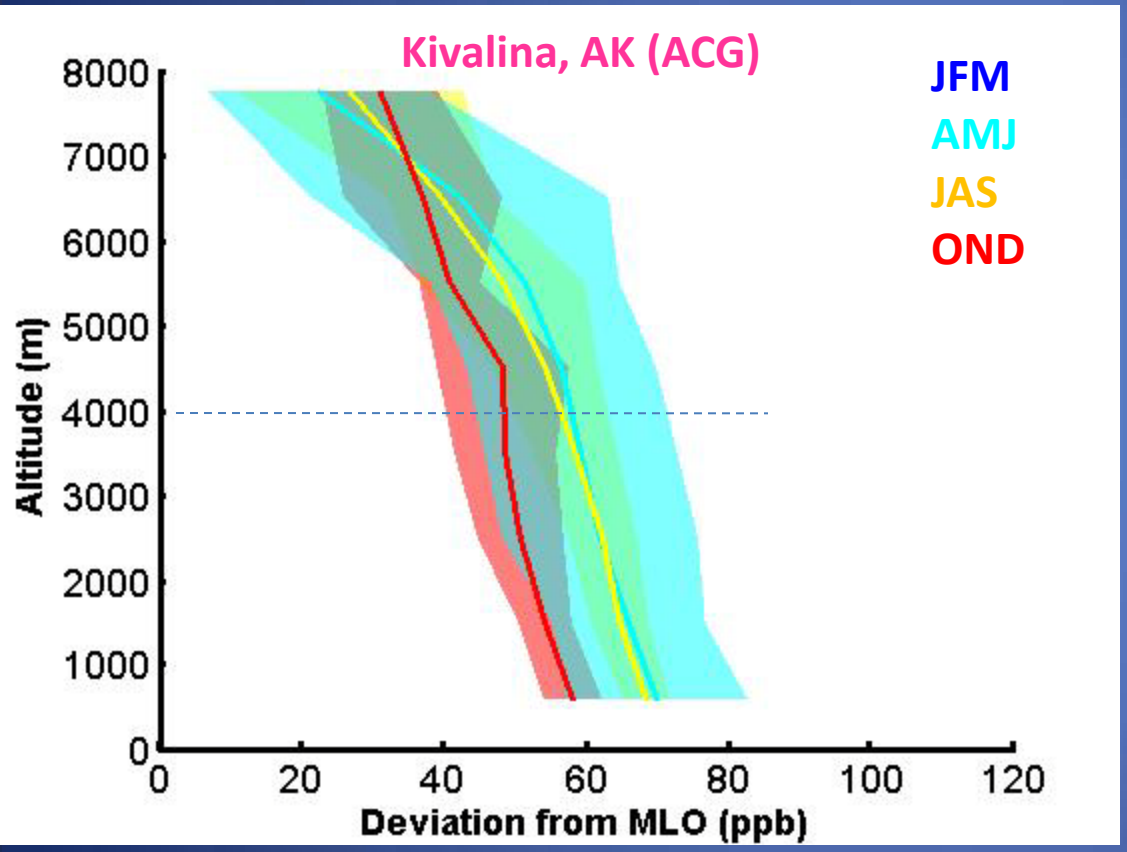


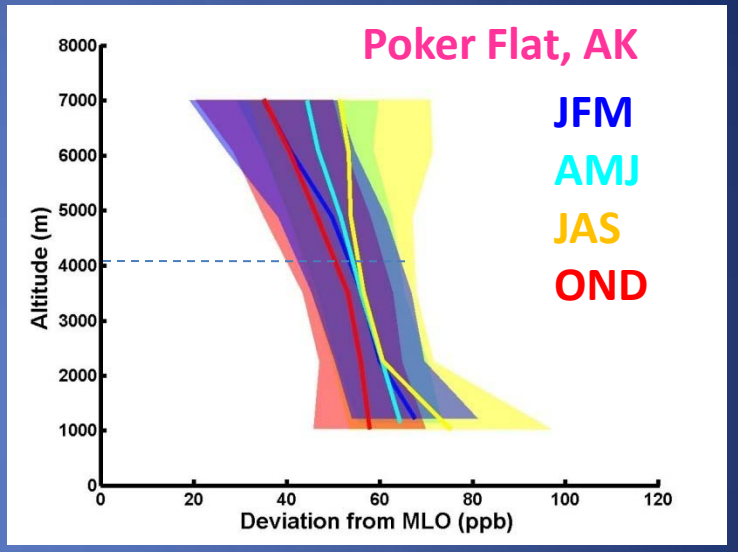


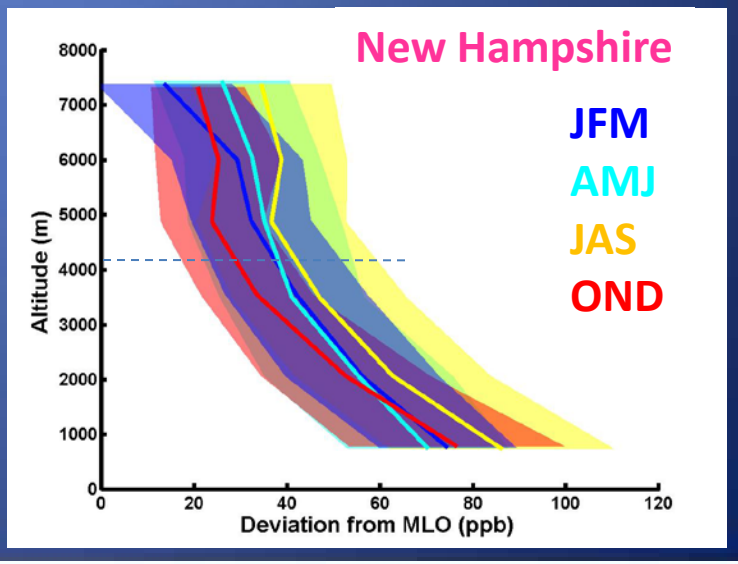
CH_4 by month

Altitude (in-)dependence of Seasonal Cycle (CH_4)

→ Much of the variability is transported from lower latitudes







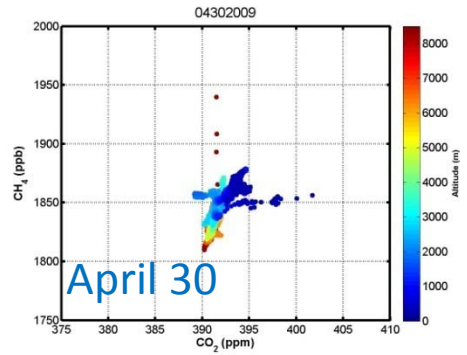
Small gradient despite surface influence of interior Alaska

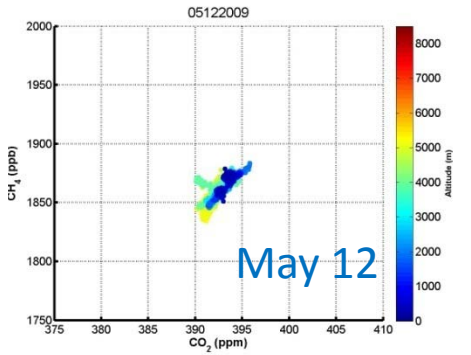
(MLO Seasonal Cycle AND Trend subtracted)

Summary

- Regular flights on a C-130 collect continuous data autonomously
- Test bed for future measurements on commercial or cargo aircraft
- Reveal interesting science
  - regular flights throughout the season
  - over multiple years
- Variability in CO_2 and CH_4 largely transported from lower latitudes
- Addition of continuous CO valuable for pinpointing high-altitude pollution

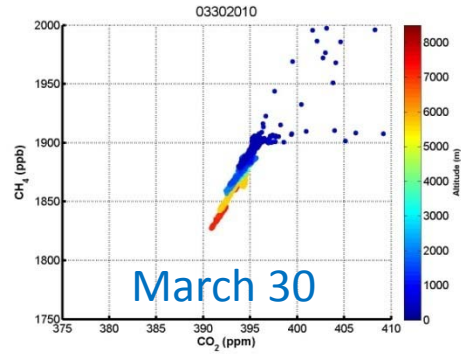
Spring

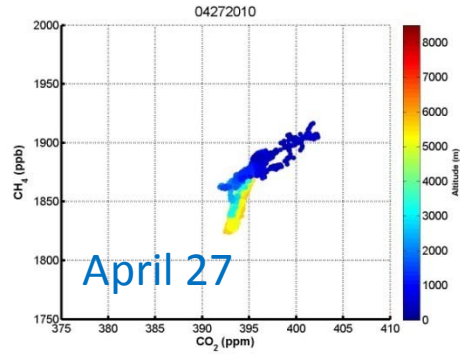


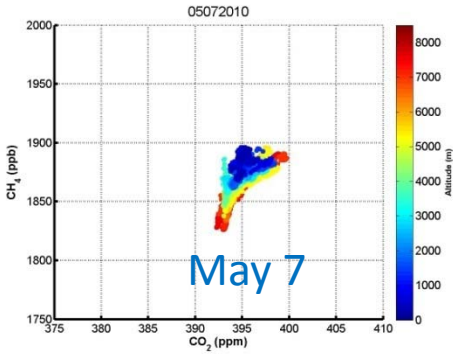


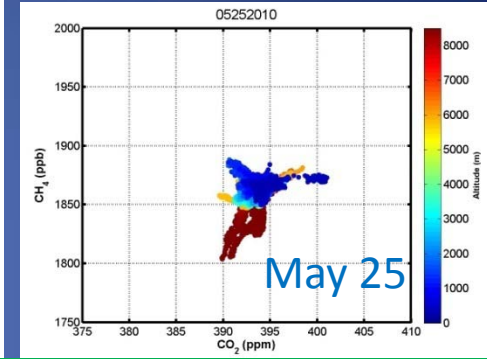
← 2009

2010 →





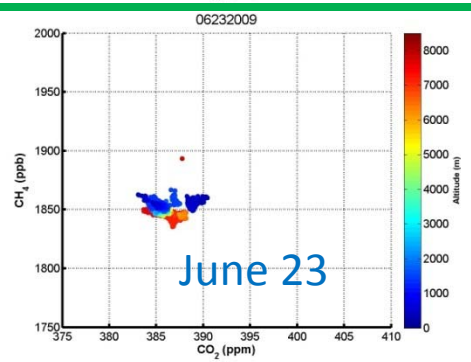


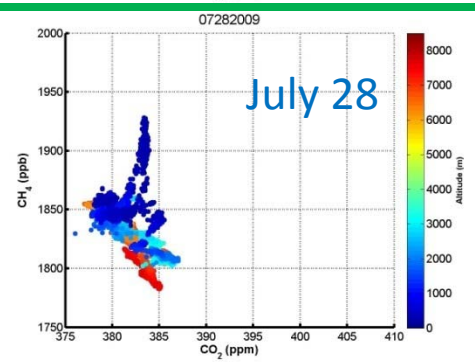


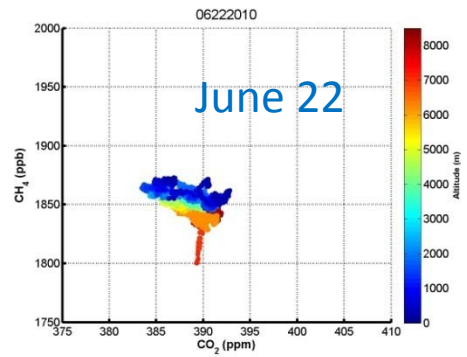
Summer

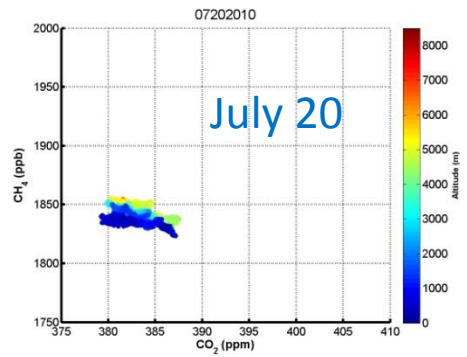
← 2009

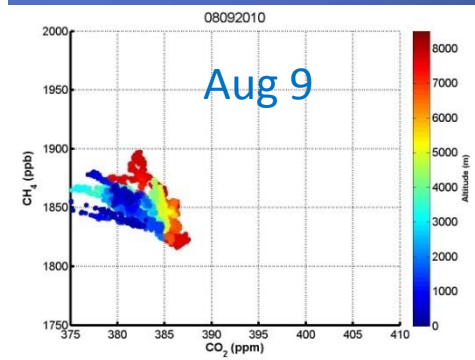
2010 →

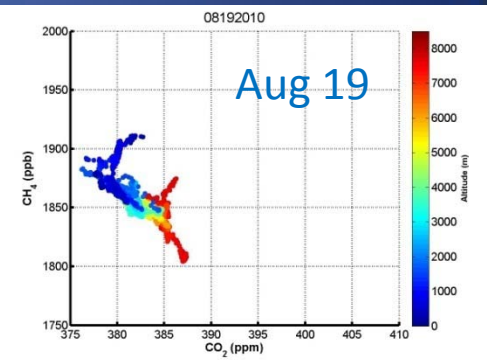








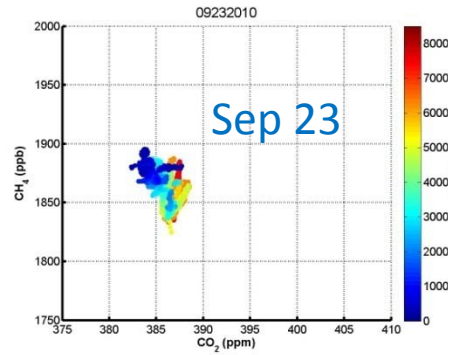


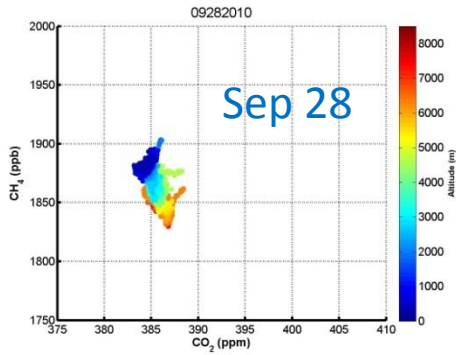


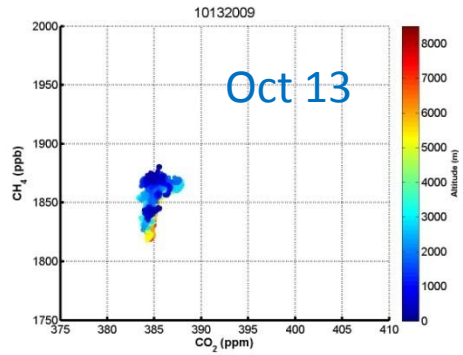
Fall

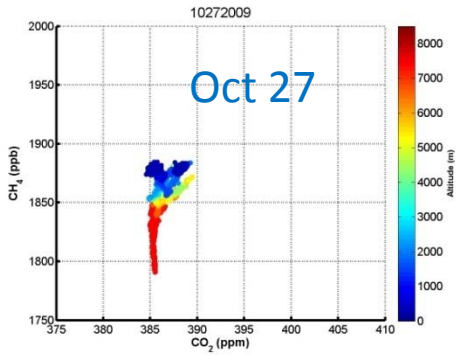
2009 →

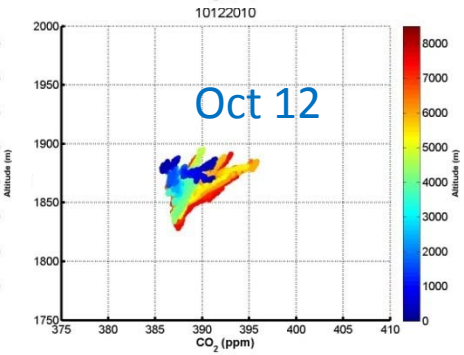
2010 →

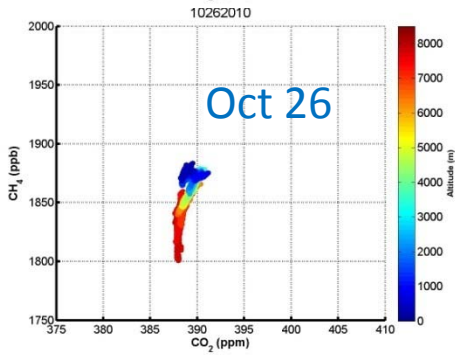








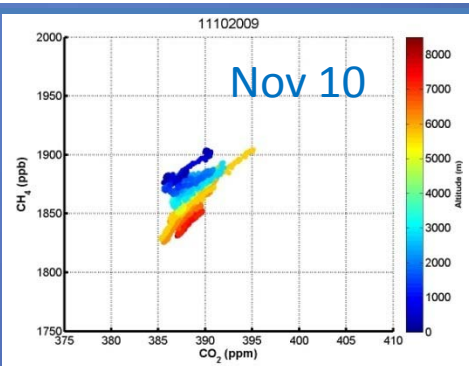


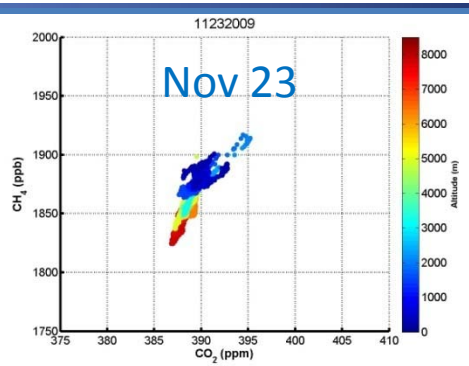


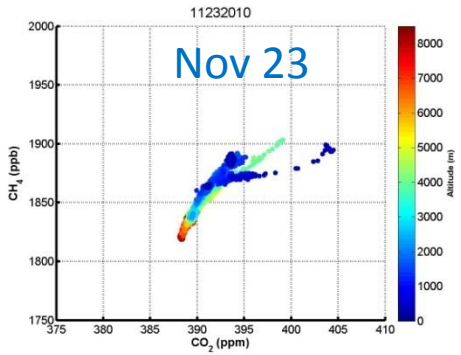
Winter

2009 →

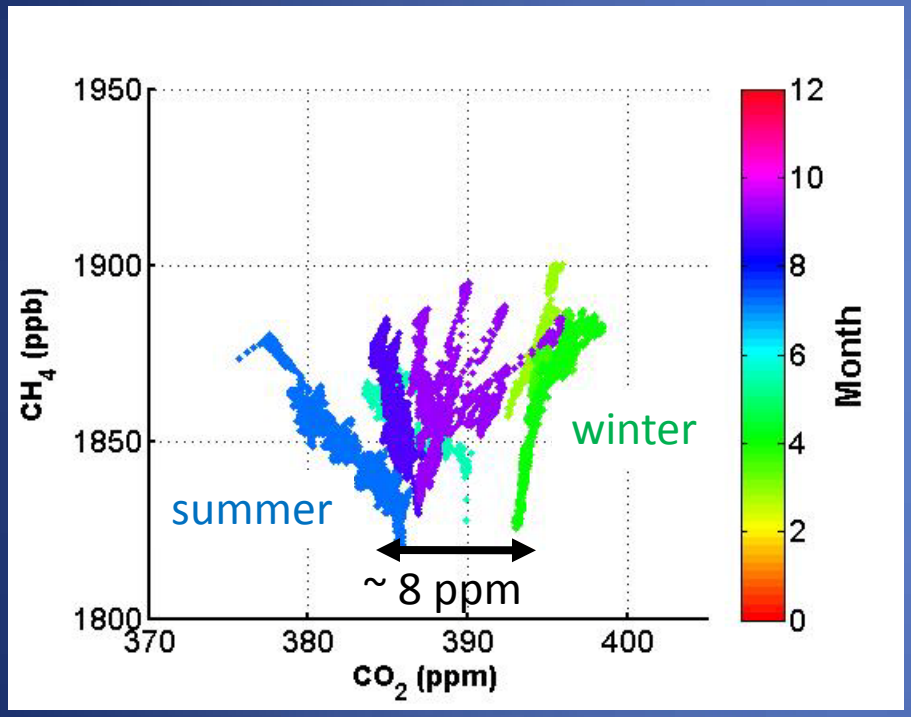
2010 →



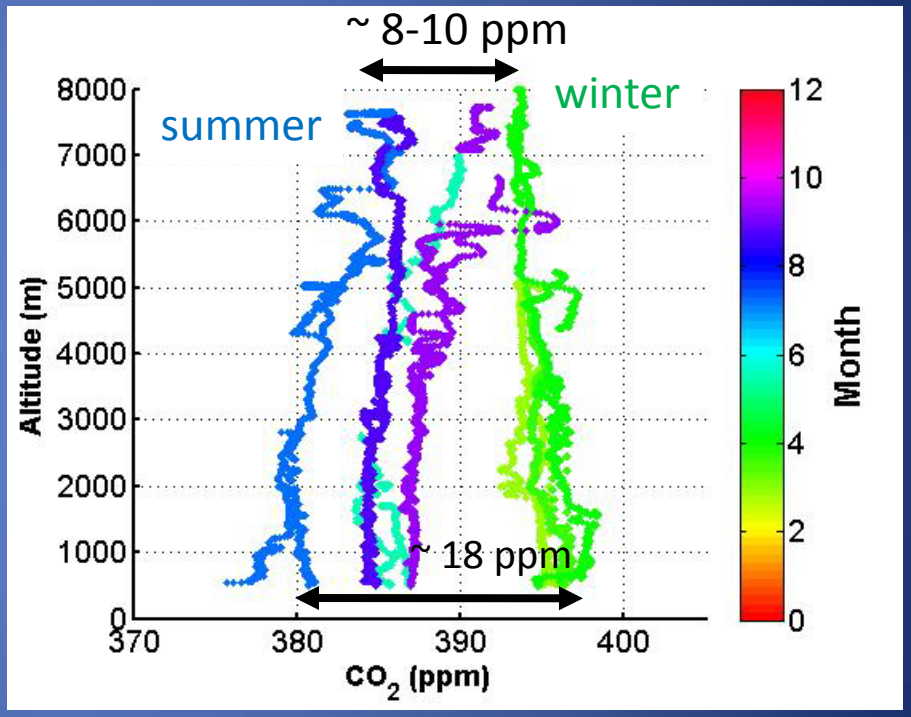




2010 Seasonal Cycle: Kivalina

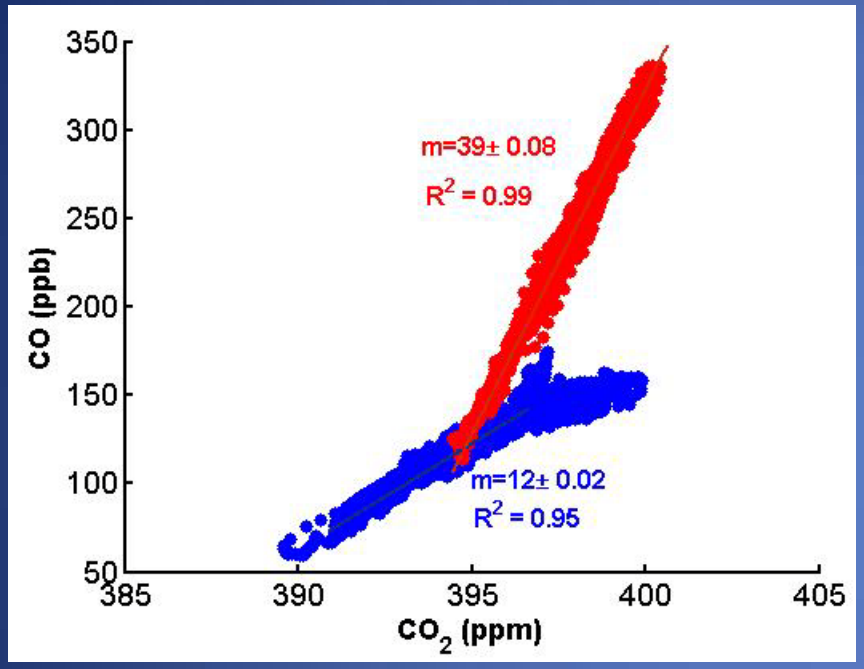


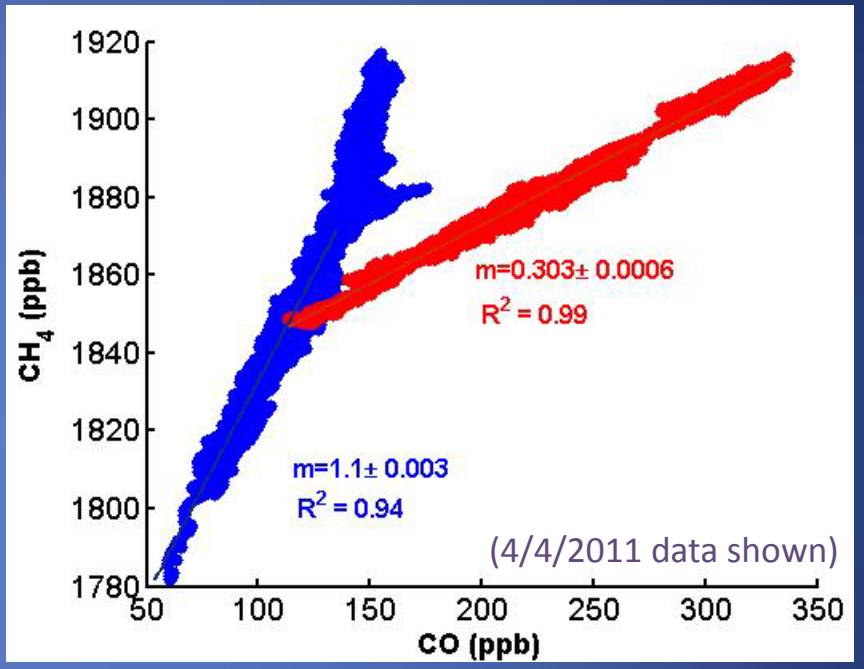
CO_2 and CH_4 over Kivalina



CO_2 altitude profile over Kivalina

2011 flights: high CO layers

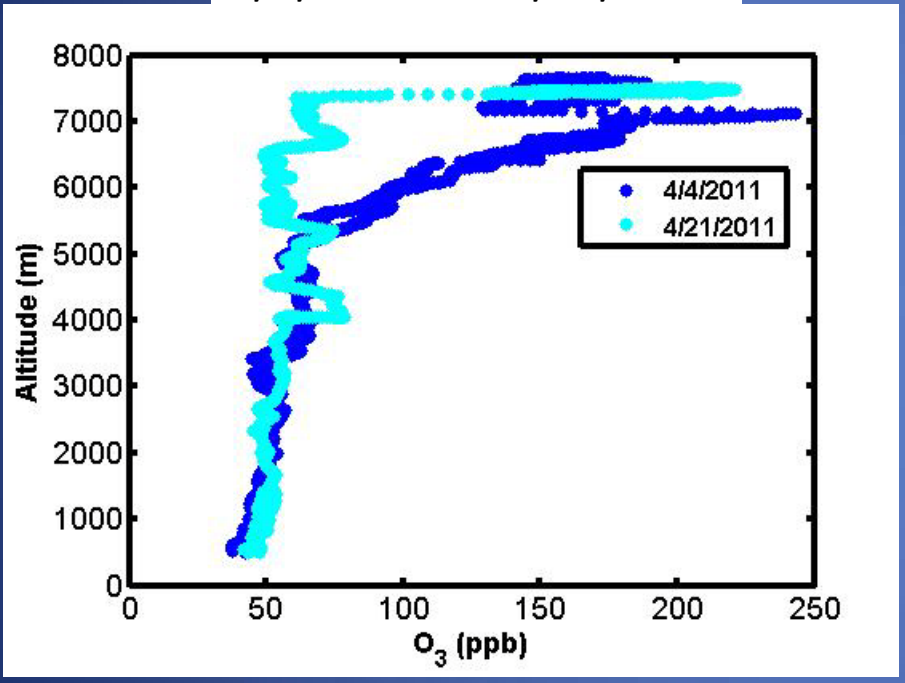




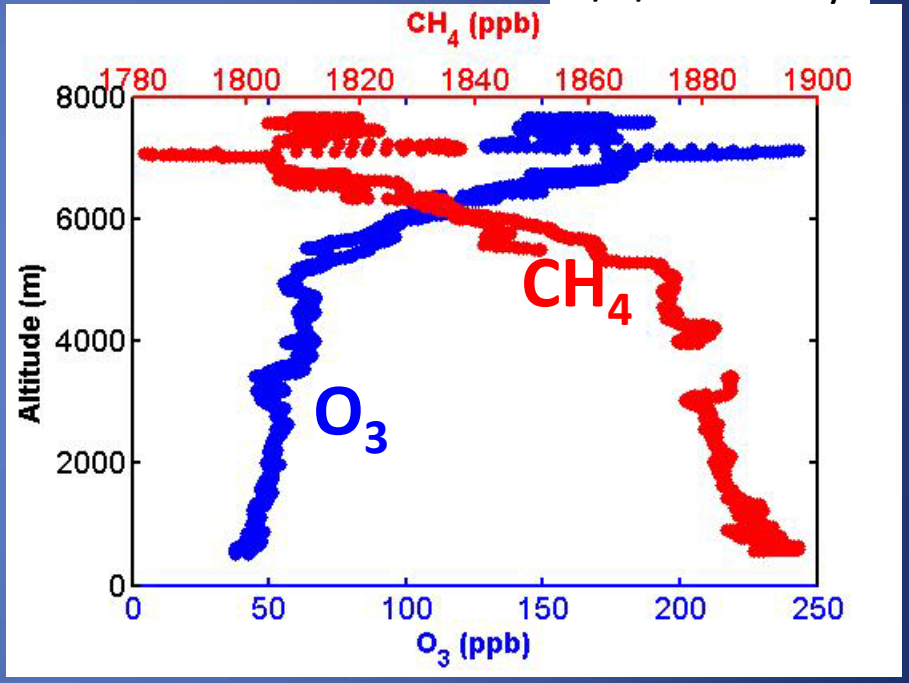
- ARCTAS campaign observed similar plumes (Warneke 2009; Singh 2010) attributed to biomass burning in Asia in 2008.
- Singh et al report 0.25 ppb CH_4 / ppb CO and 65 ppb CO/ ppm CO_2 in “aged” BB / urban plumes at 6.9 km over Alaska.
- Pollution bands also observed on HIPPO-2 (Nov 2009) at 6-8 km over Arctic (Wofsy et al, 2011), with CO up to 250 ppb.

2011 flights: Stratospheric Influence

4/4/2011 and 4/21/2011

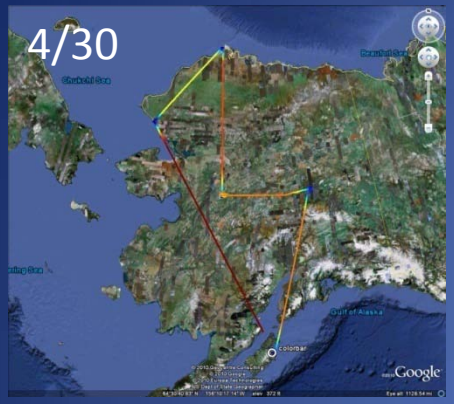


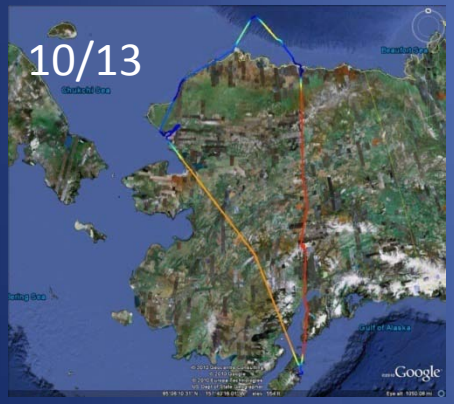
4/4/2011 only

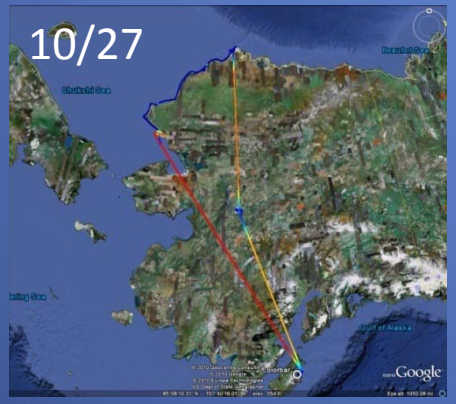


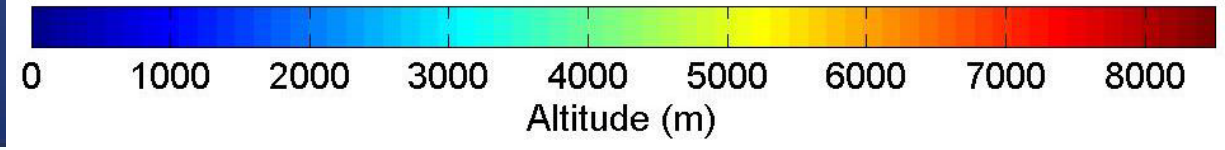
Ozone profiles over Kivalina on two different days show significant stratospheric influence.

2009 Season Flight Paths

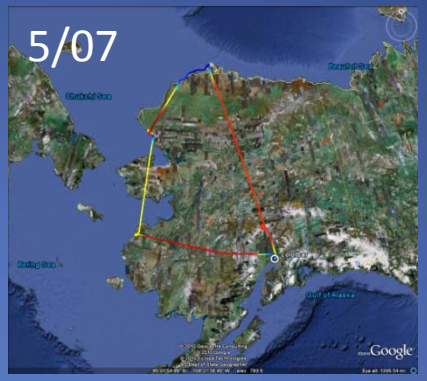


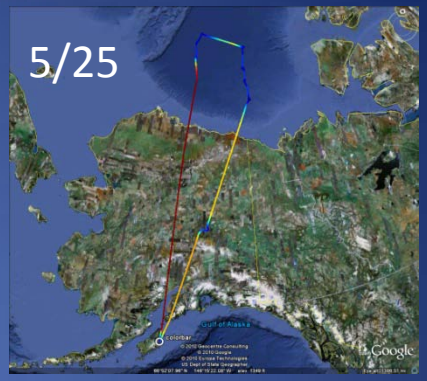


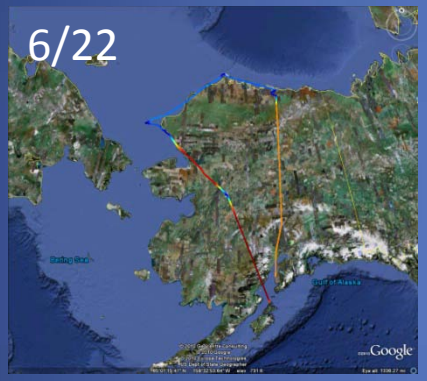


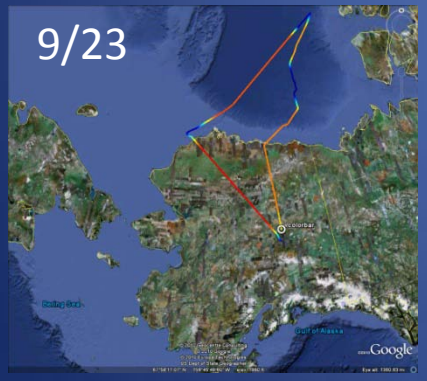


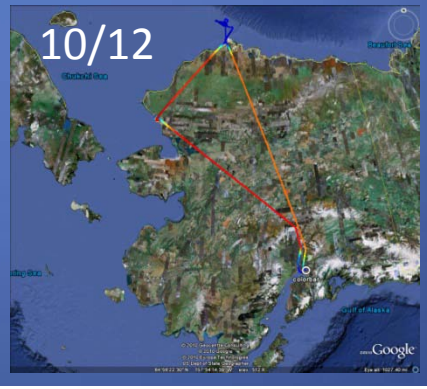
2010 Season Flight Paths

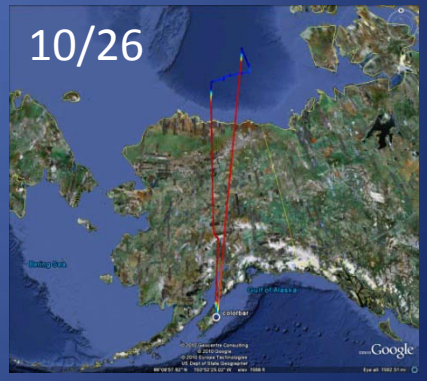


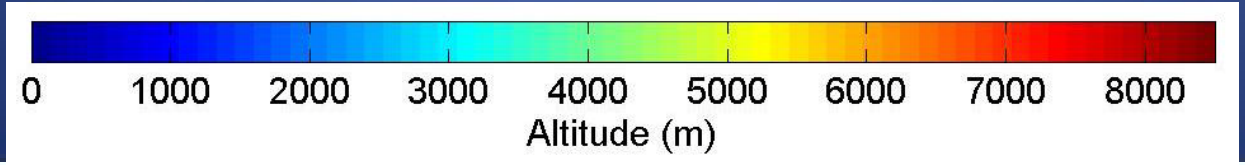




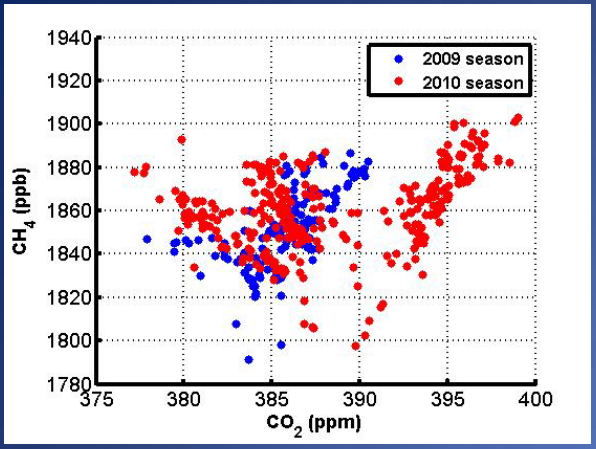


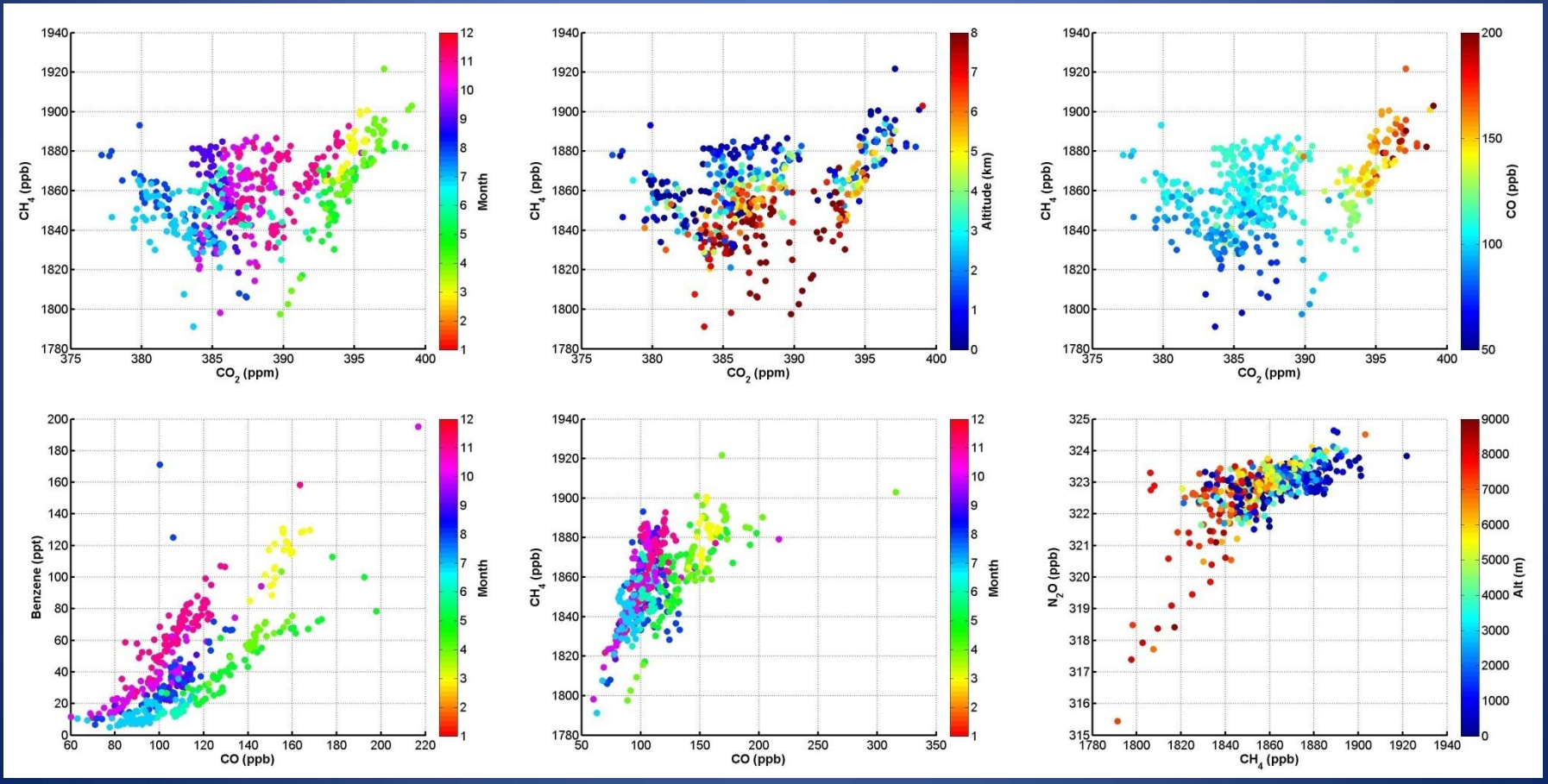


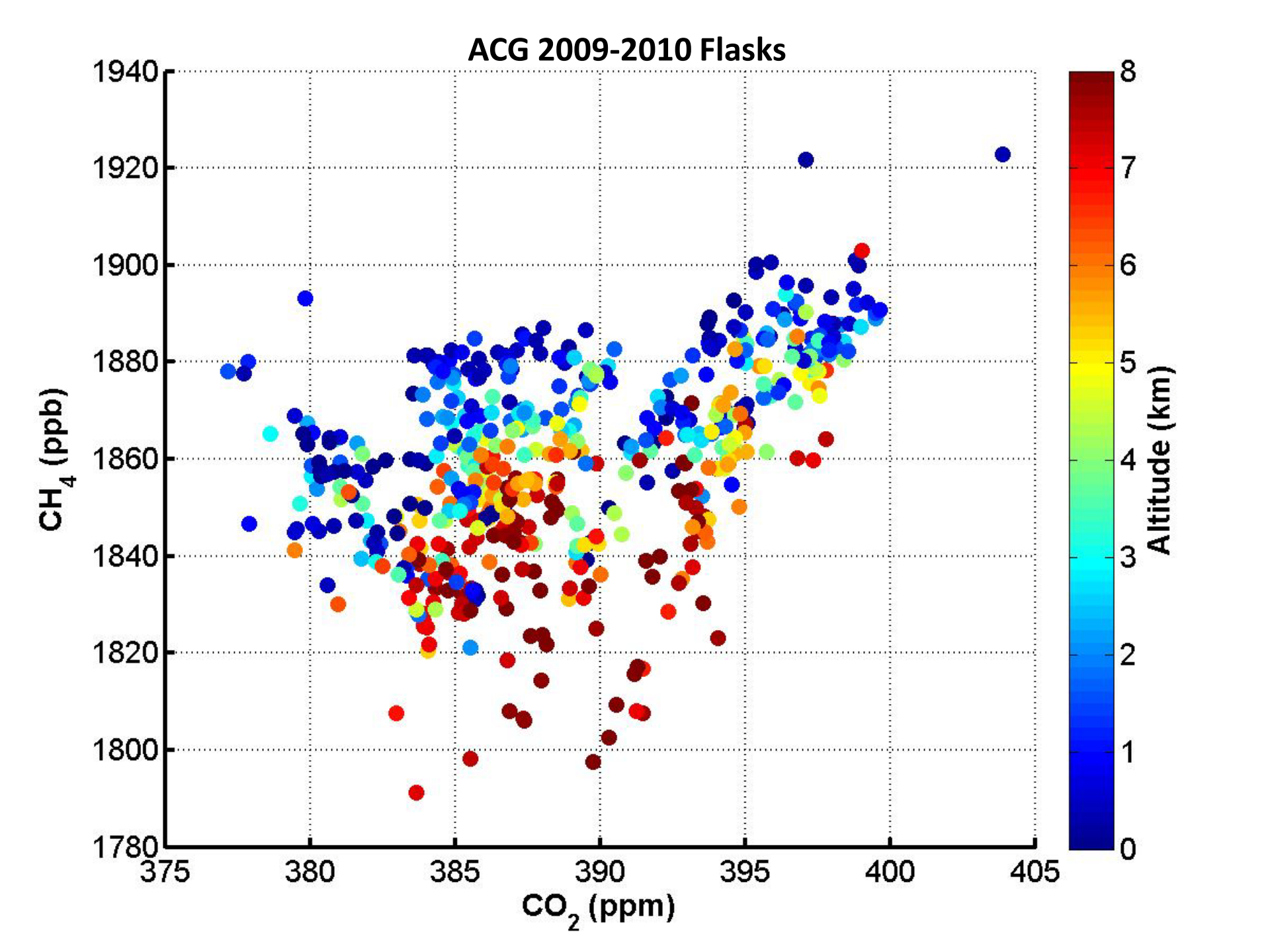




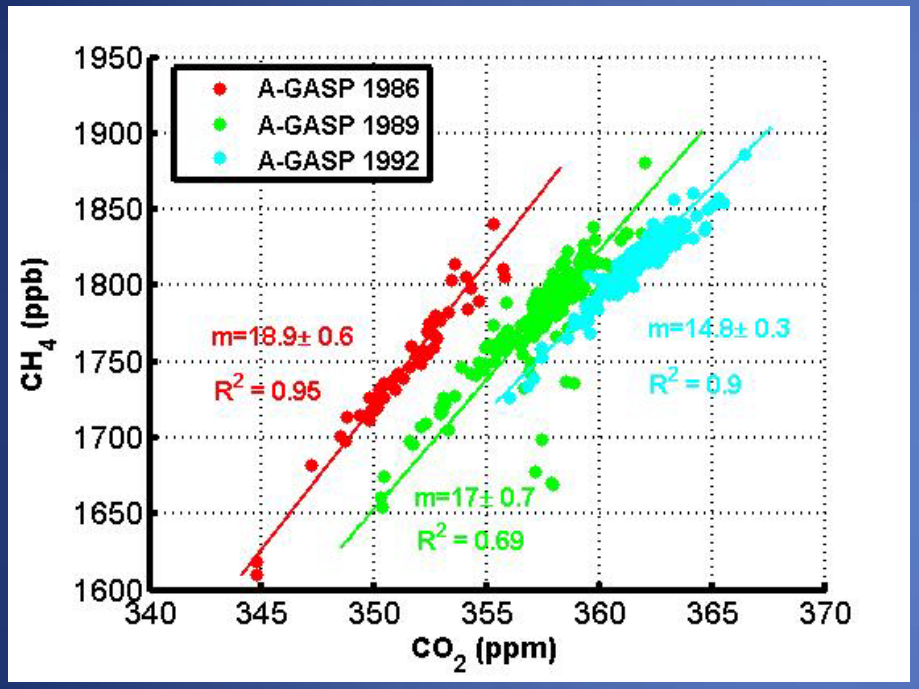
Flask Analysis (both seasons)

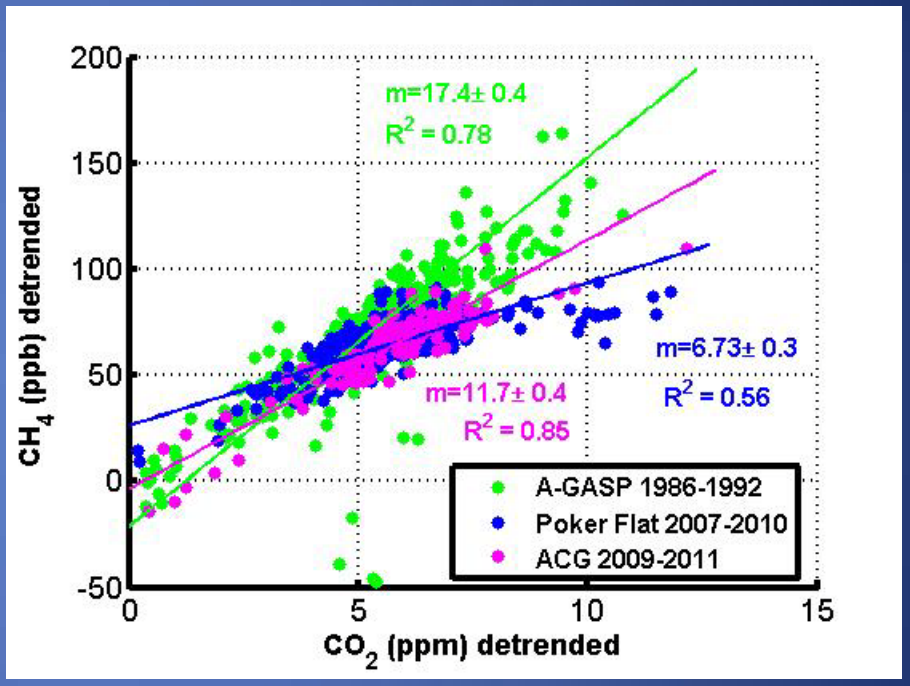





ACG 2009-2010 Flasks
1940
1920
1900
1880
1860
1840
1820
1800
1780
CH4 (ppb)
375
380
385
390
395
400
405
CO2 (ppm)
8
7
6
5
4
3
2
1
0
Altitude (km)

Comparison to other datasets: CO_2/CH_4

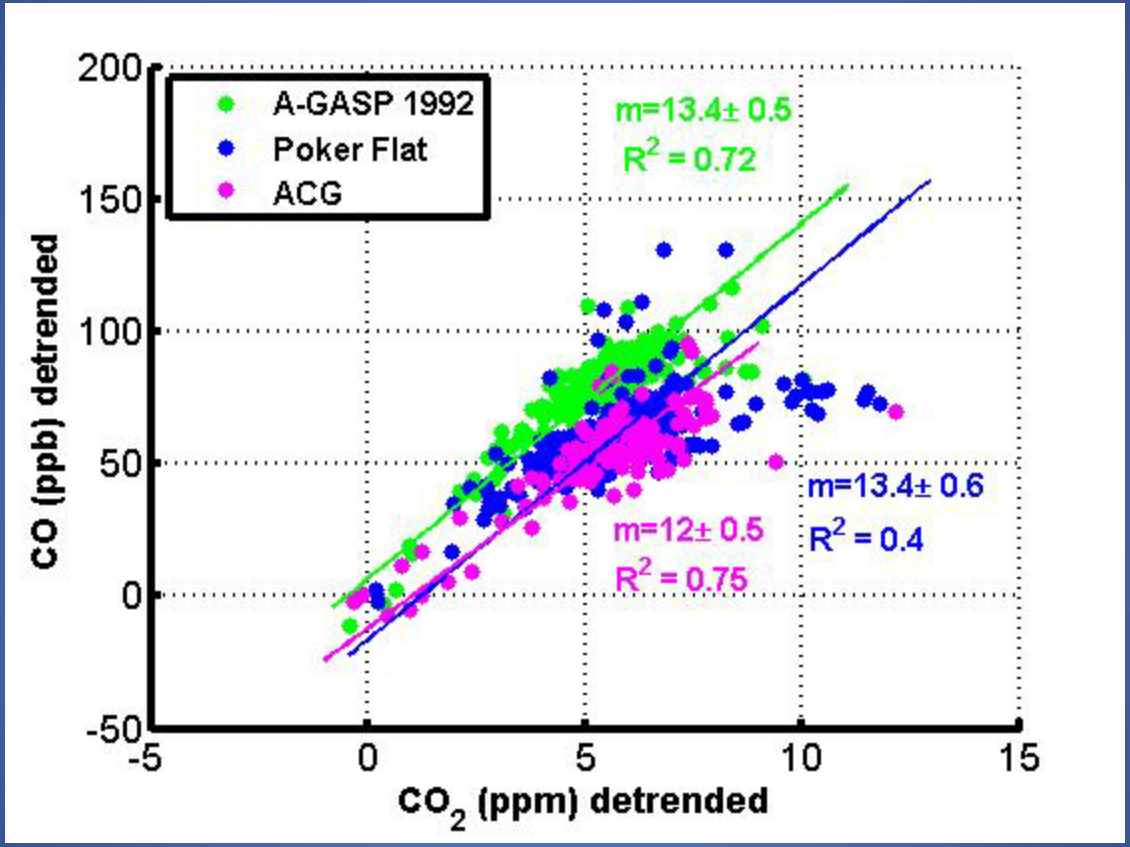




A-Gasp Missions (March & April)

- **subtract MLO trend**
- **include flights from Poker Flat, AK and ACG**
- **March/April only**
- **Flask data only**

Comparison to other datasets: CO_2/CO



- subtract MLO trend
- include flights from A-Gasp III, Poker Flat, AK and ACG
- March/April only
- enhancement ratios typical of urban air