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

A. Karion

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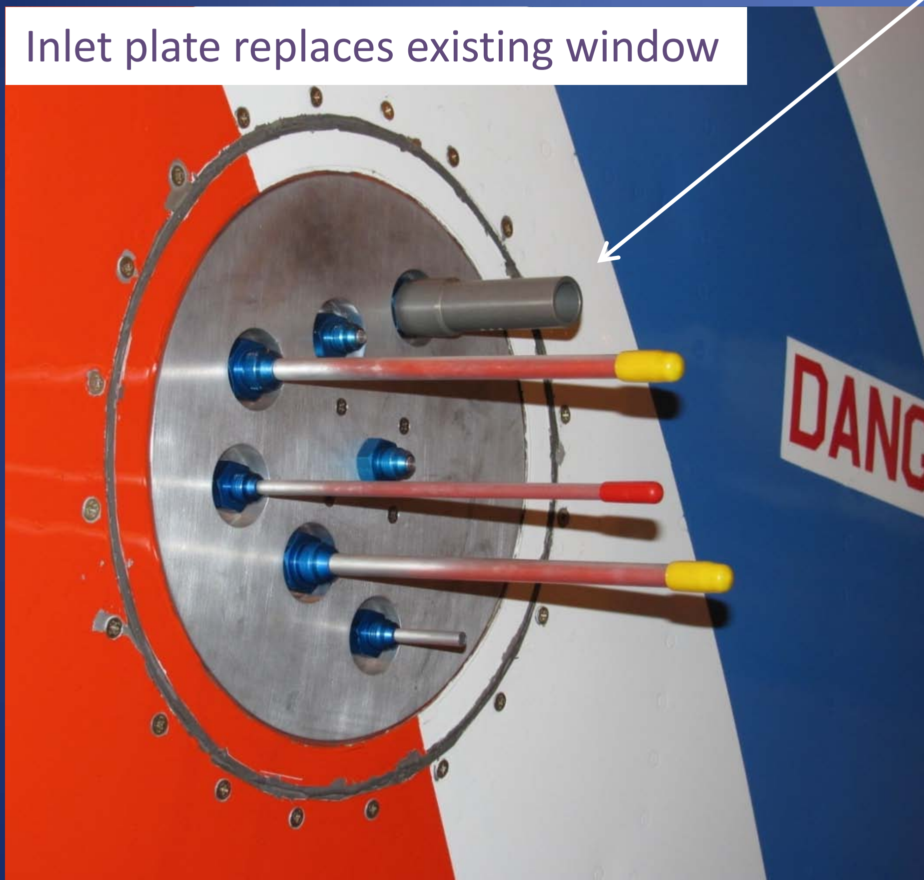
Outline

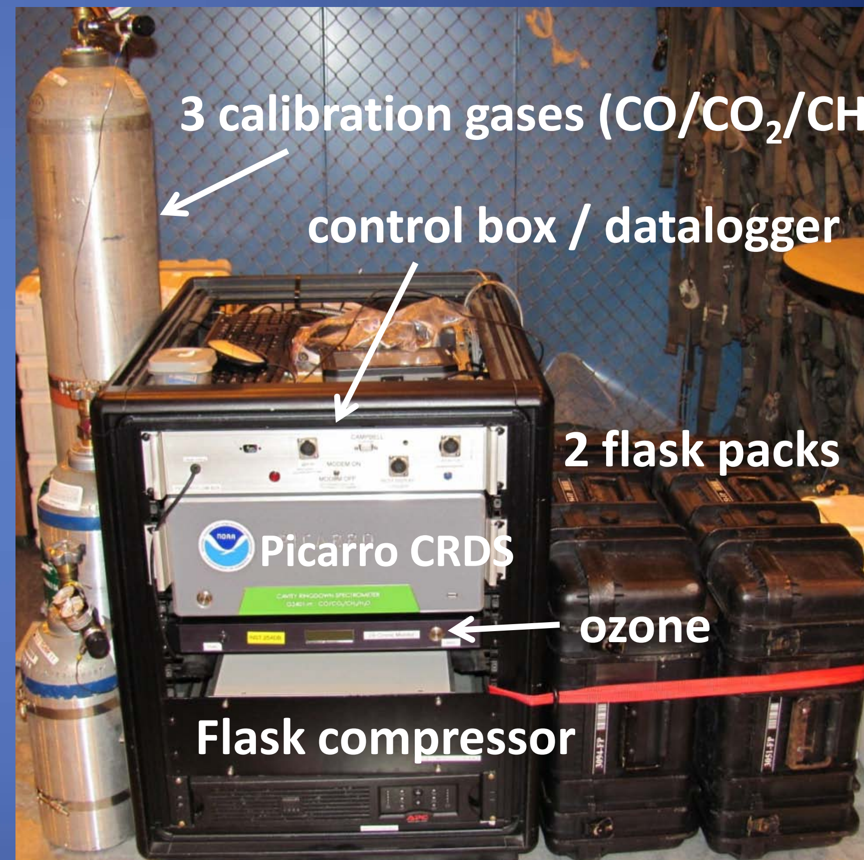
- Motivation
- Instrumentation and data quality
- Factors influencing seasonal variability
  - Boundary layer processes
  - Stratospheric exchange
  - Transport from low latitudes

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

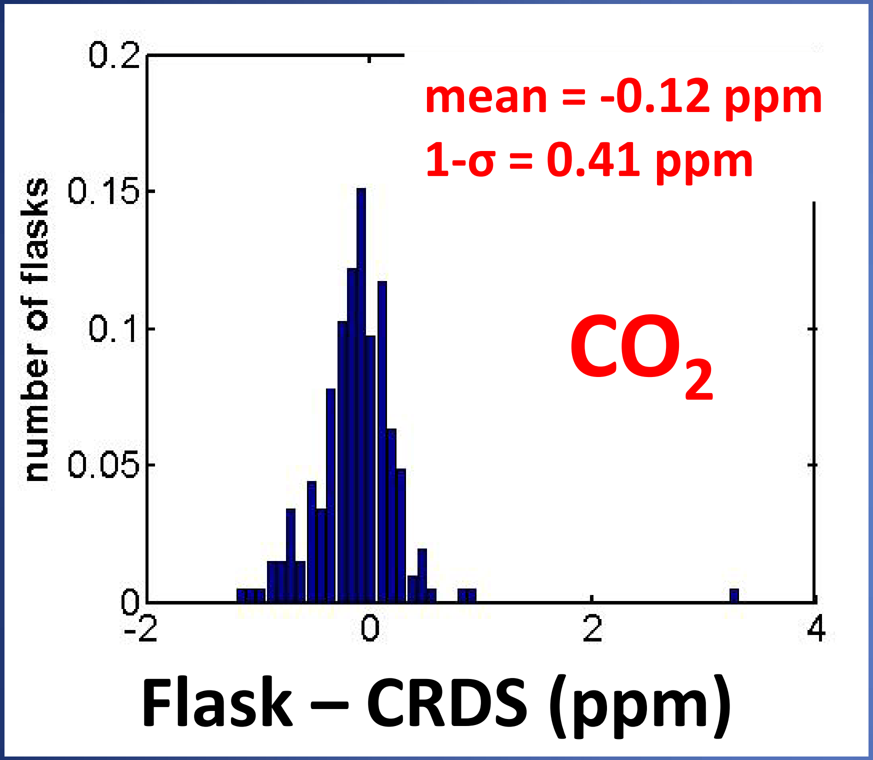




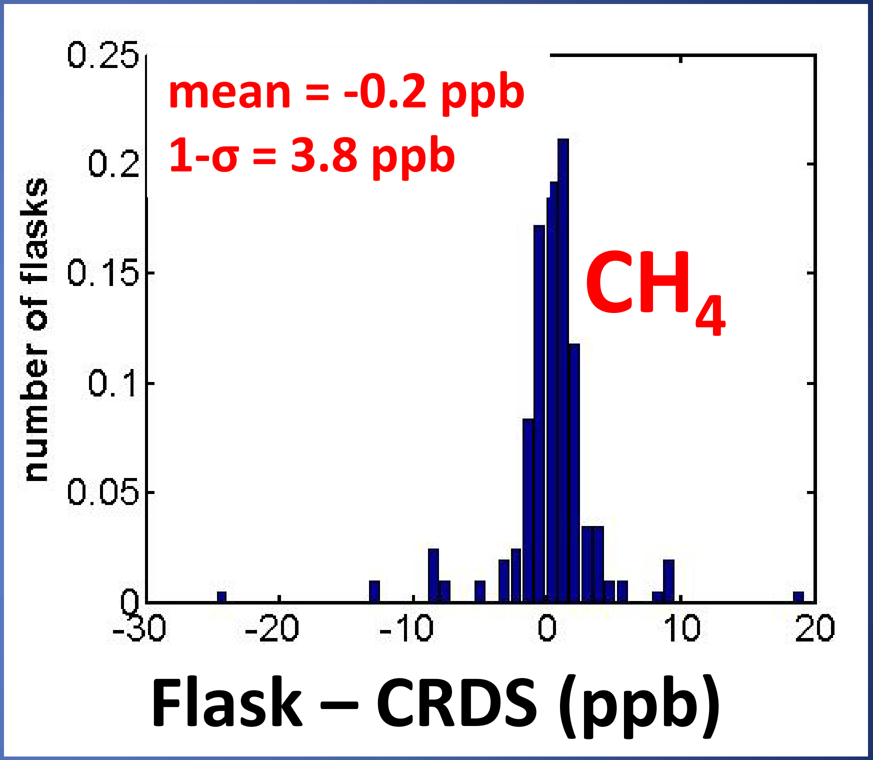
- continuous $CO_2/CH_4/CO$, O_3, T, RH, P
- 24 Flasks (PFP) with > 50 species

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

Flask Comparisons (2010 season)

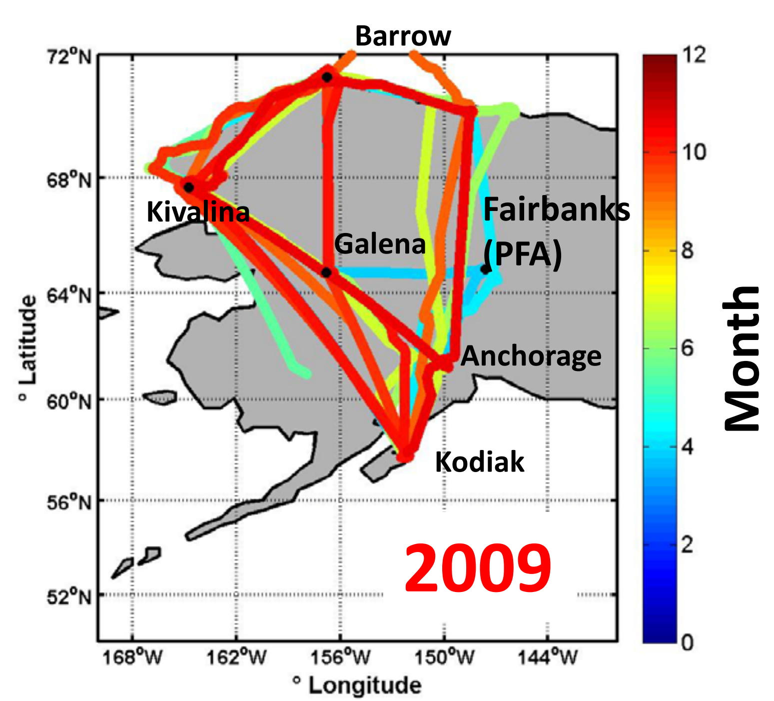


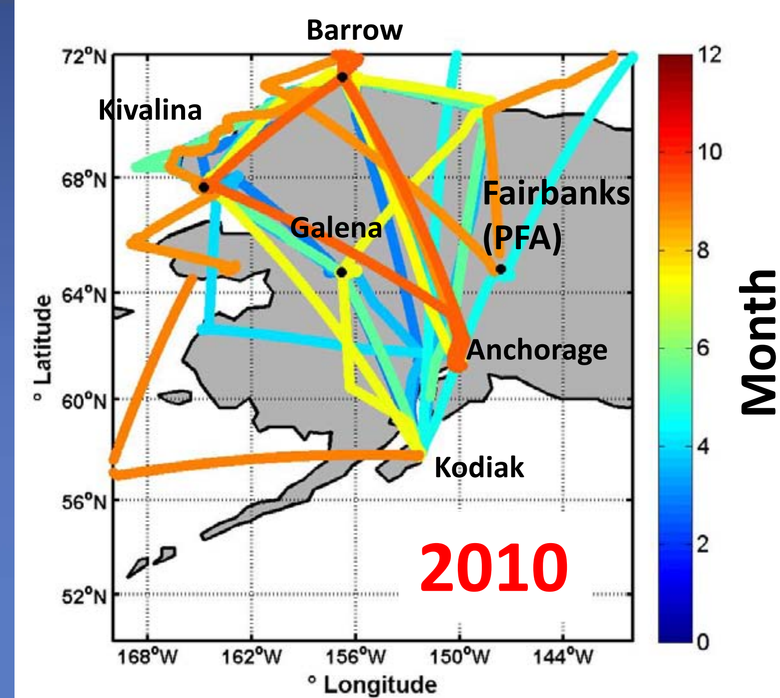
N=205

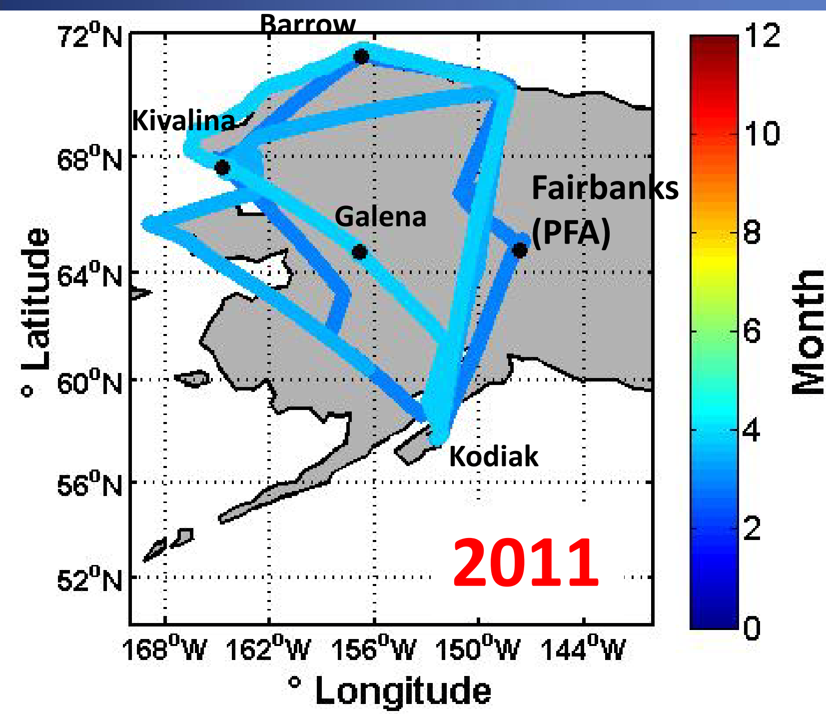


N=203

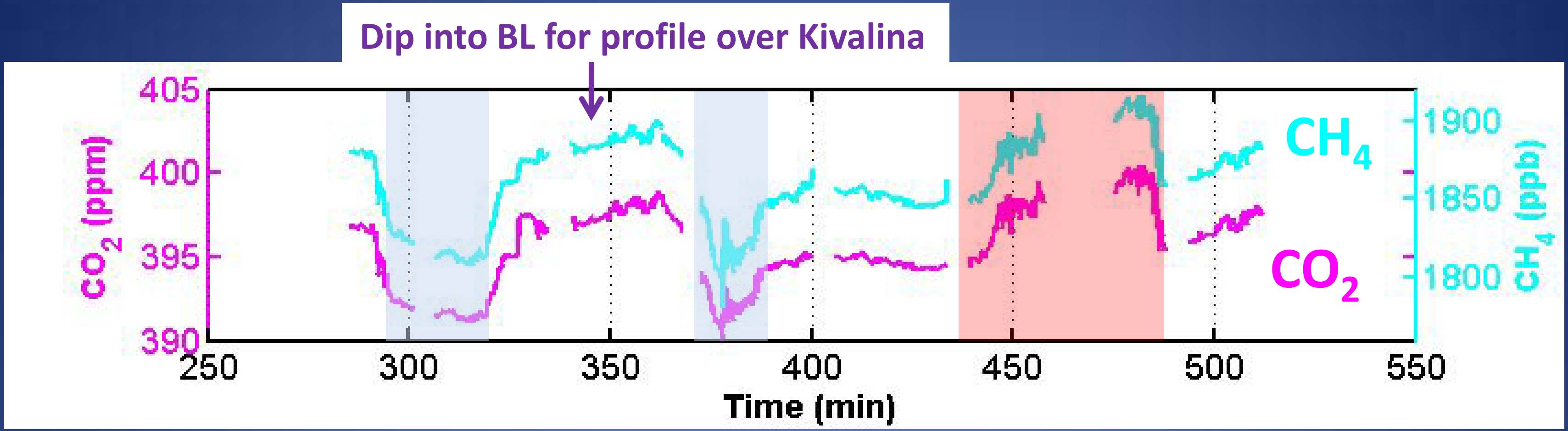
*only 2 flights with CO
so far: -3 ppb ± 4 ppb



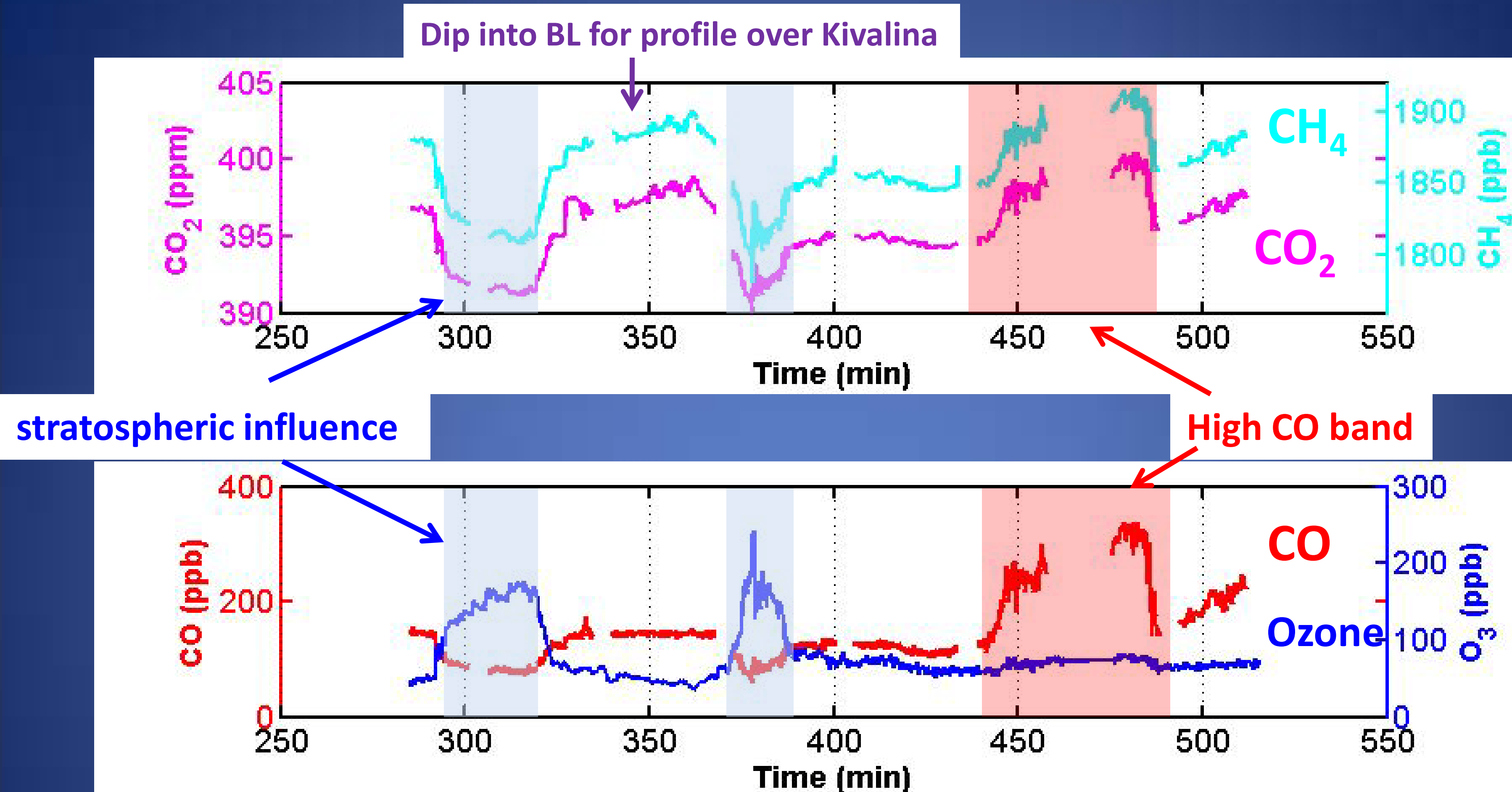




- Bi-weekly 8-hour flights on C-130
- March – November
- **16** flights per season
- large spatial extent (> 3000 km & 3 profiles per flight)
- much of the sampling occurs at high altitude (~8000 m)

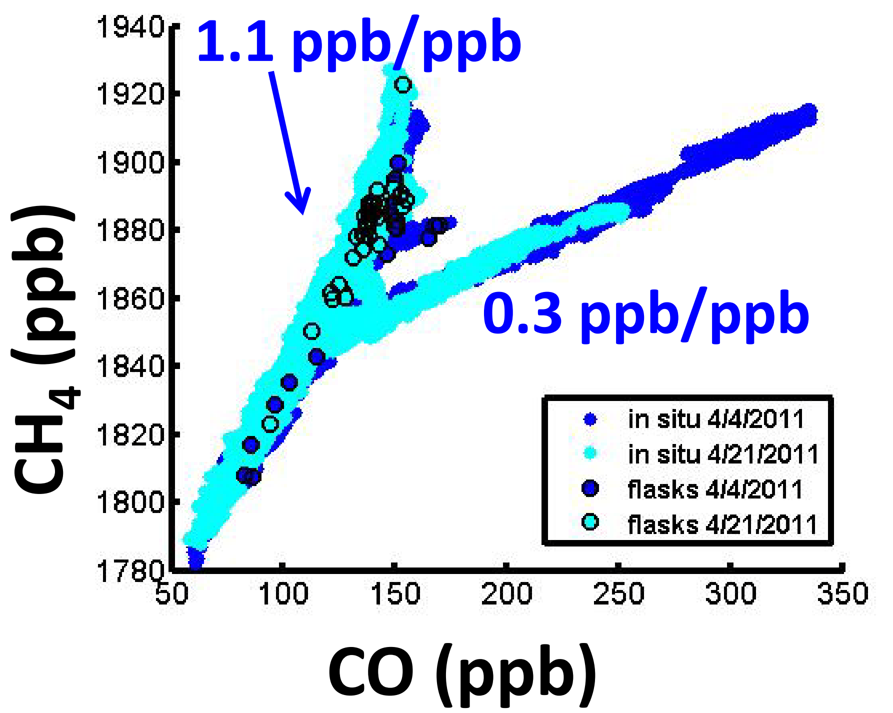

Dip into BL for profile over Kivalina
CH4
CO2
405
400
395
390
CO2 (ppm)
1900
1850
1800
CH4 (ppb)
250
300
350
400
450
500
550
Time (min)

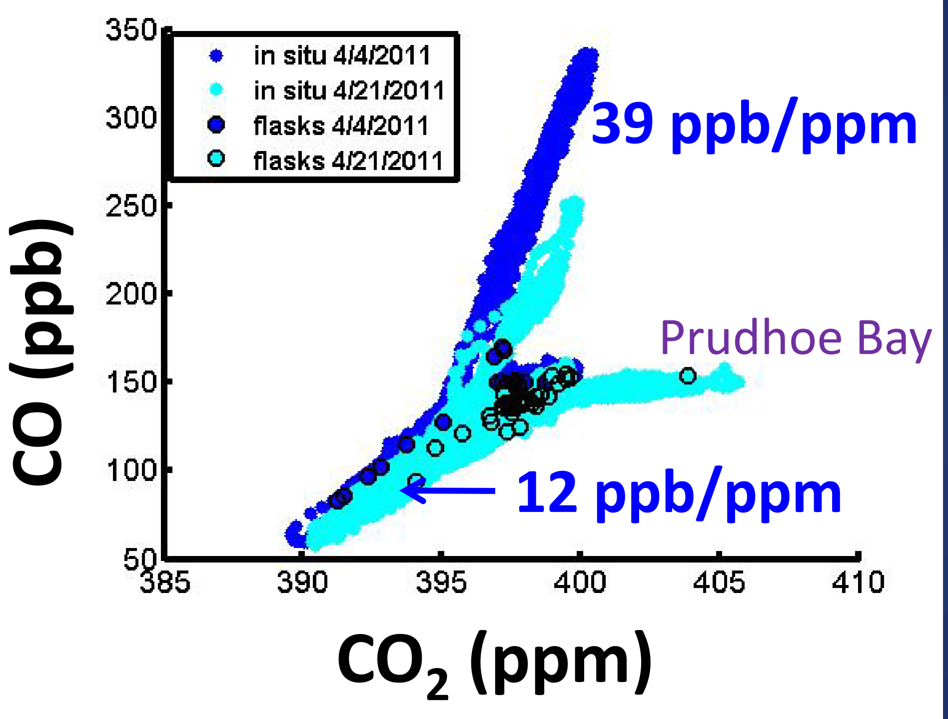
4 April 2011


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

4 April 2011

2011 ACG flights: high CO layers

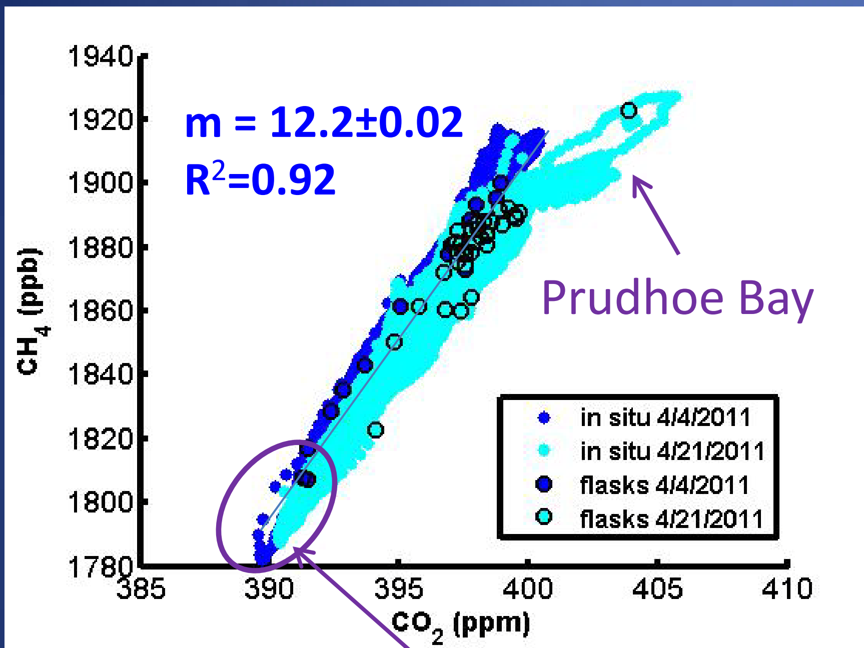




High-altitude pollution band (~7.8 km)

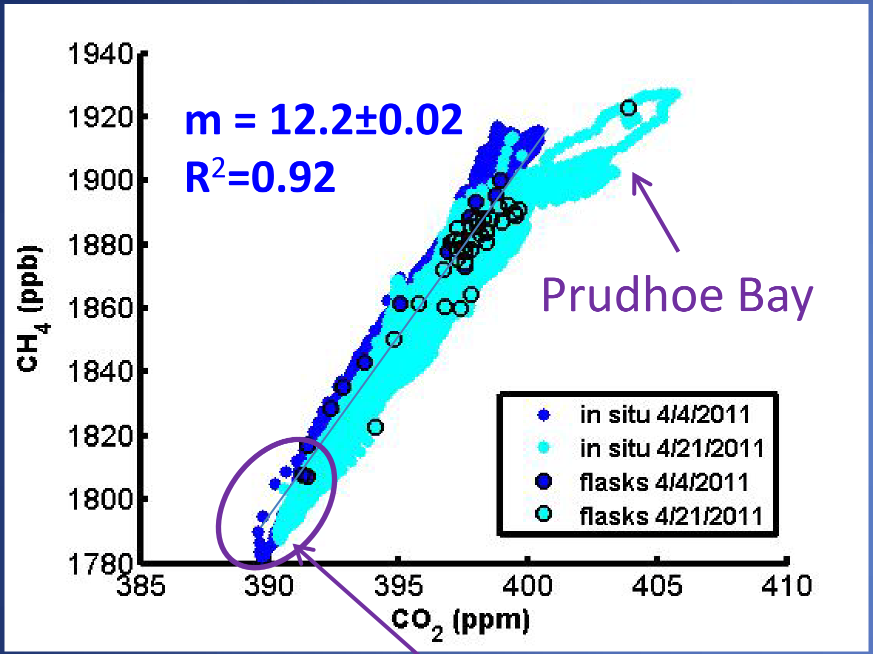
Similar bands of high-altitude CO observed in recent campaigns (ARCTAS [Singh et al. 2010, Warneke et al. 2009], and HIPPO [Wofsy et al. 2011])

2011 ACG flights: Winter

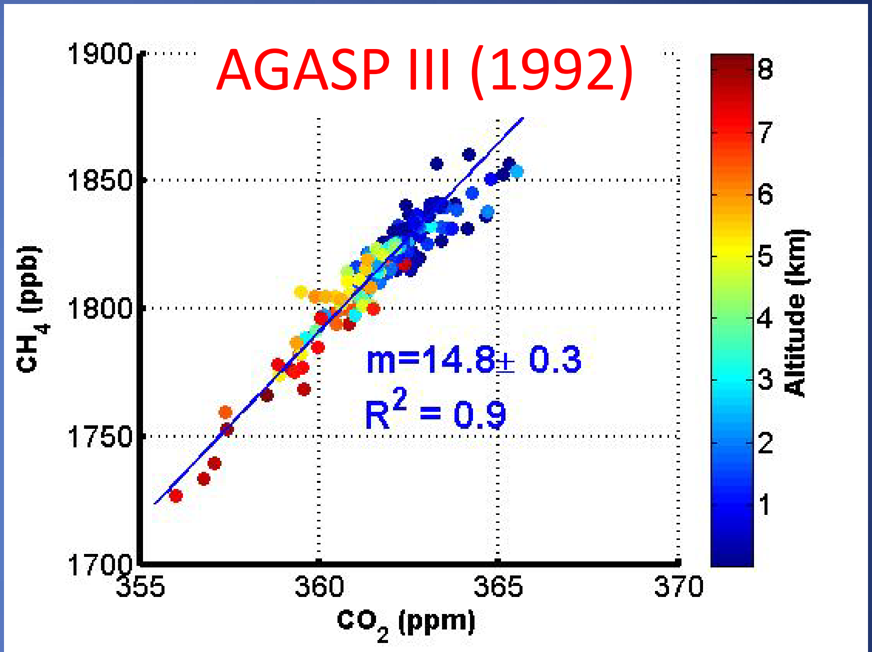


Stratospheric influence

2011 ACG flights: Winter

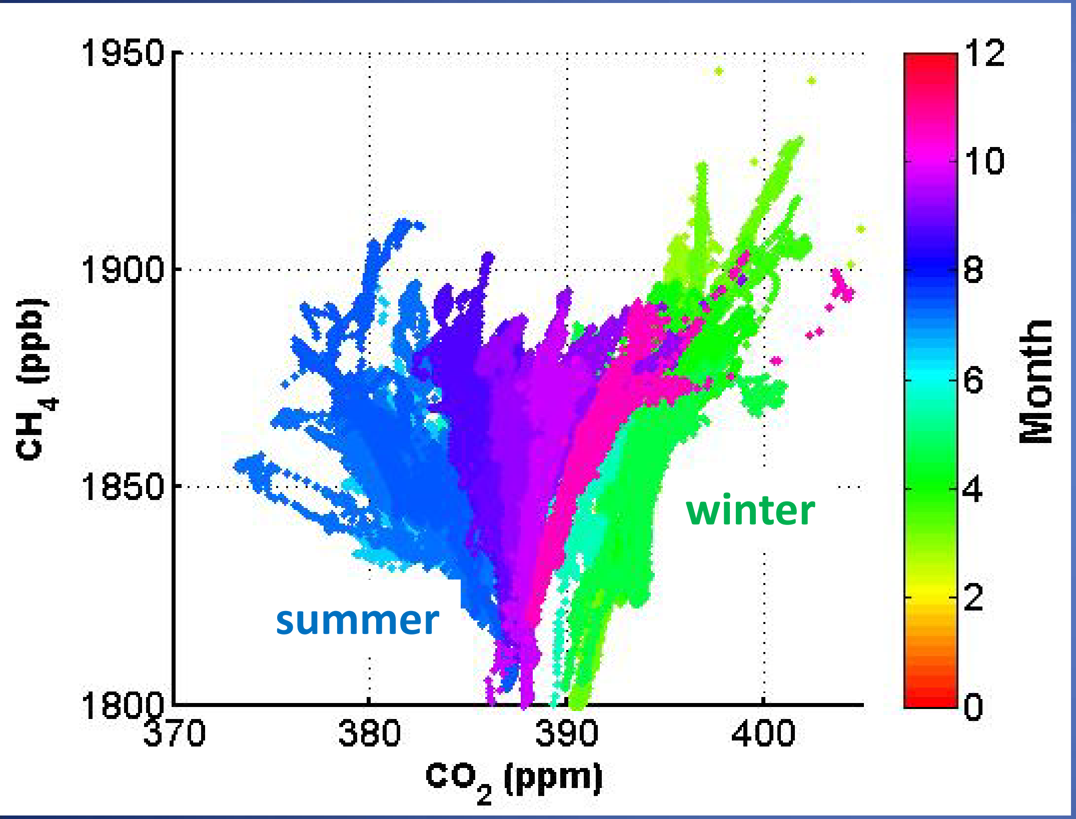


Stratospheric influence

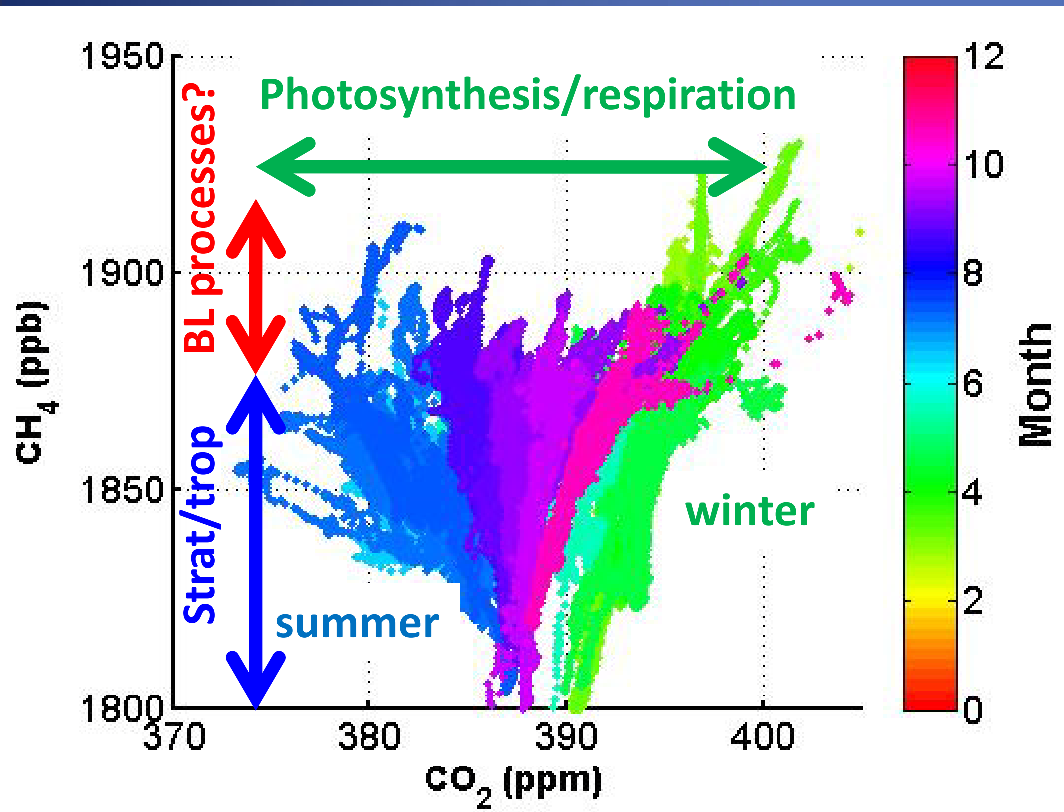


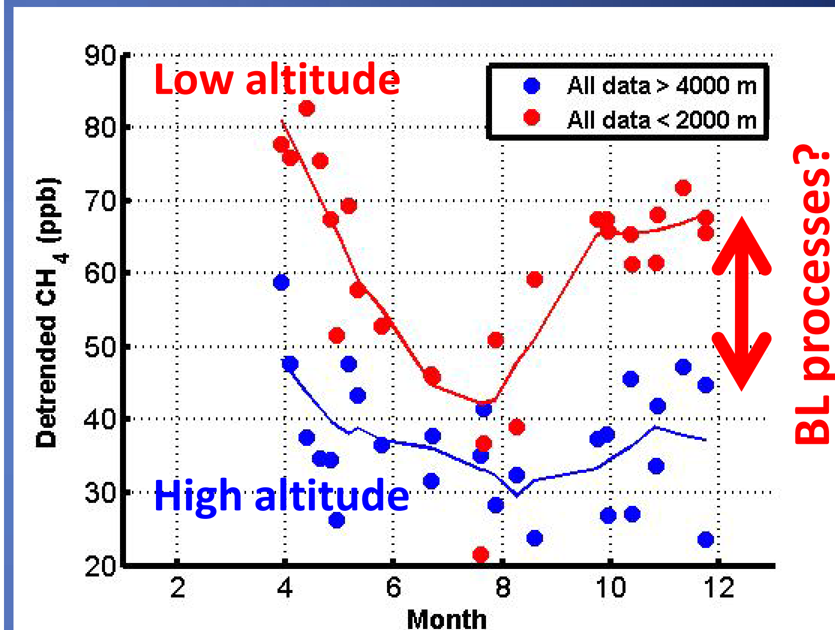
*Conway et al., 1993

Seasonal Cycle in CO_2 and CH_4



Seasonal Cycle in CO_2 and CH_4

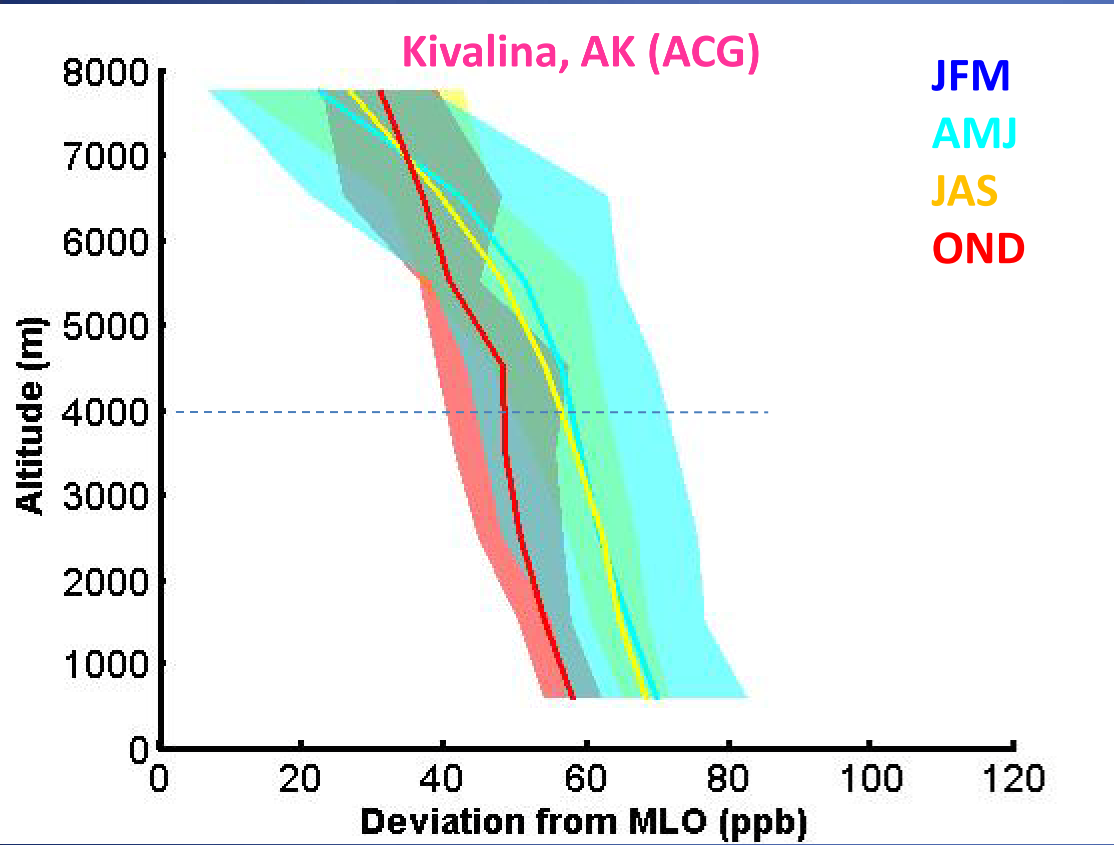


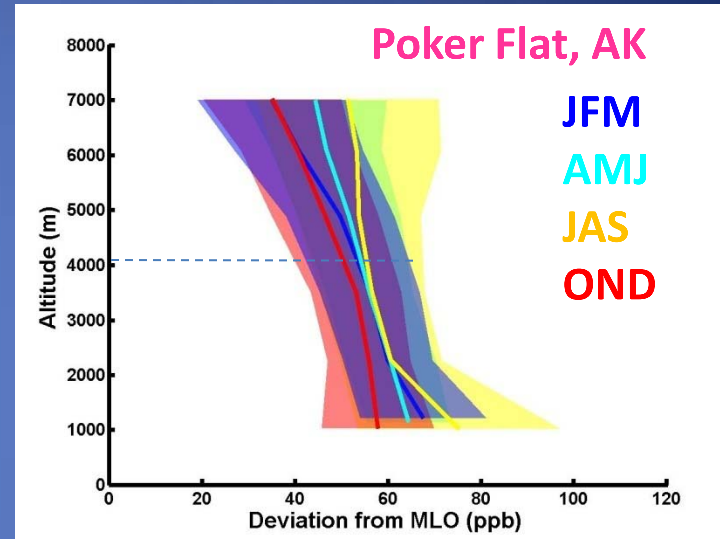


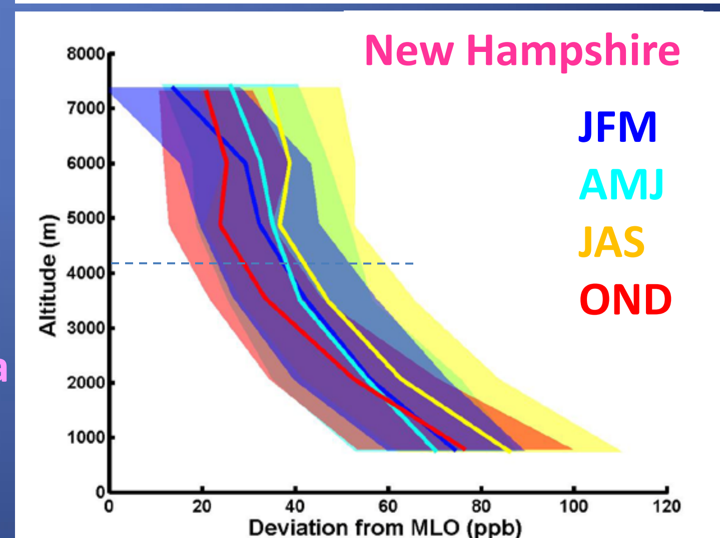
CH_4 by month

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

→ Much of the variability is transported from lower latitudes





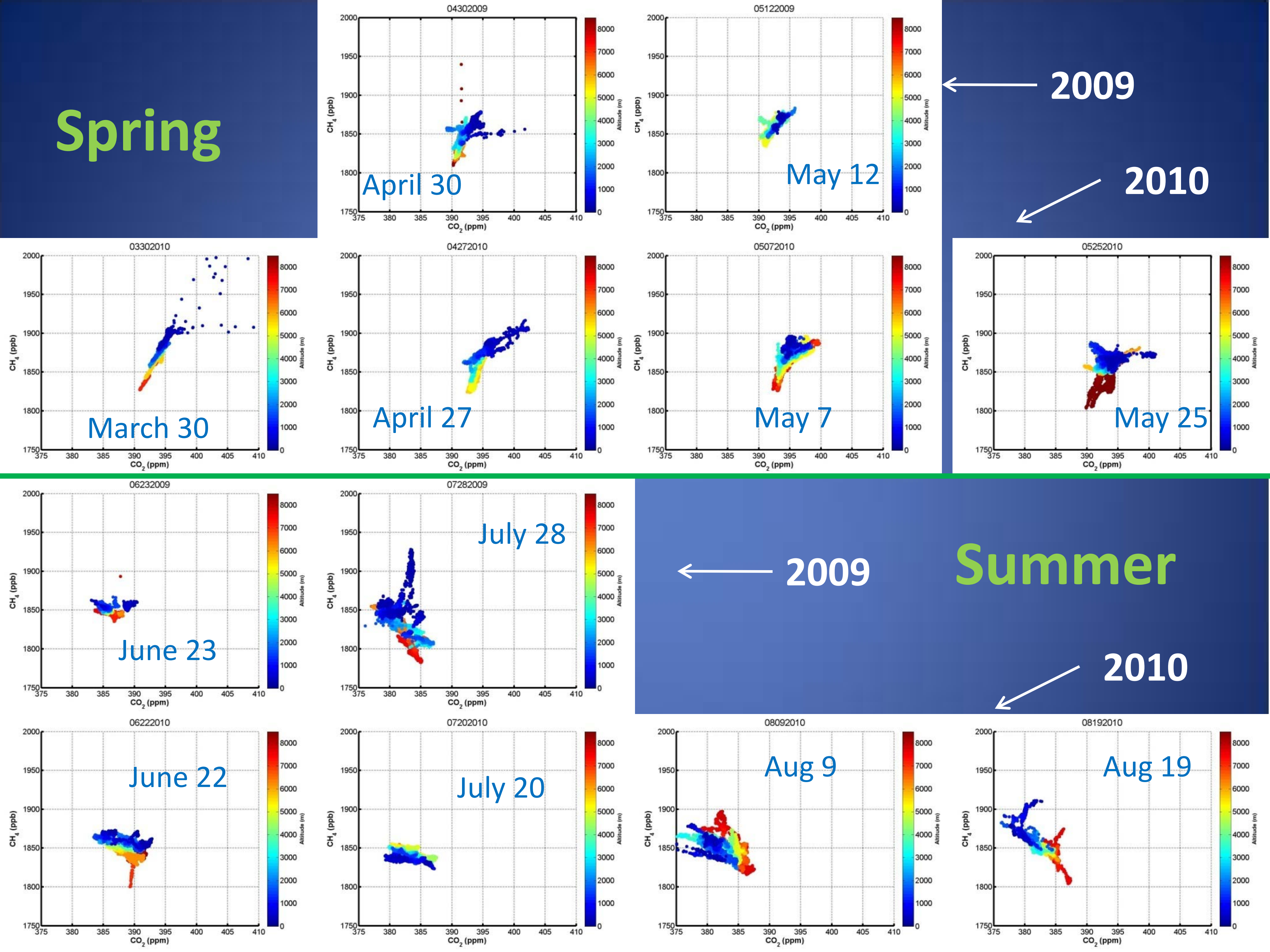


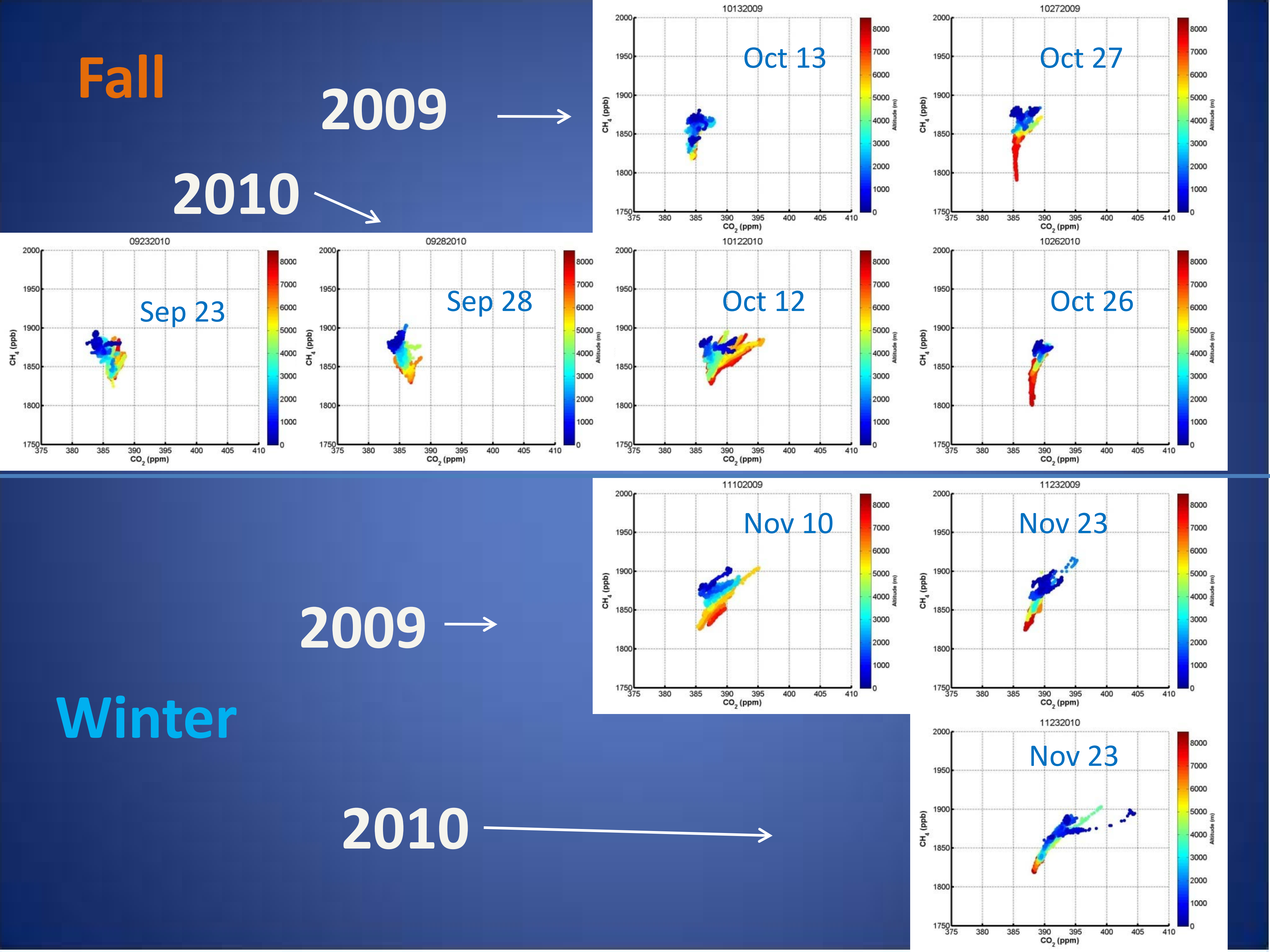
Small gradient despite surface influence of interior Alaska

(MLO Seasonal Cycle AND Trend subtracted)

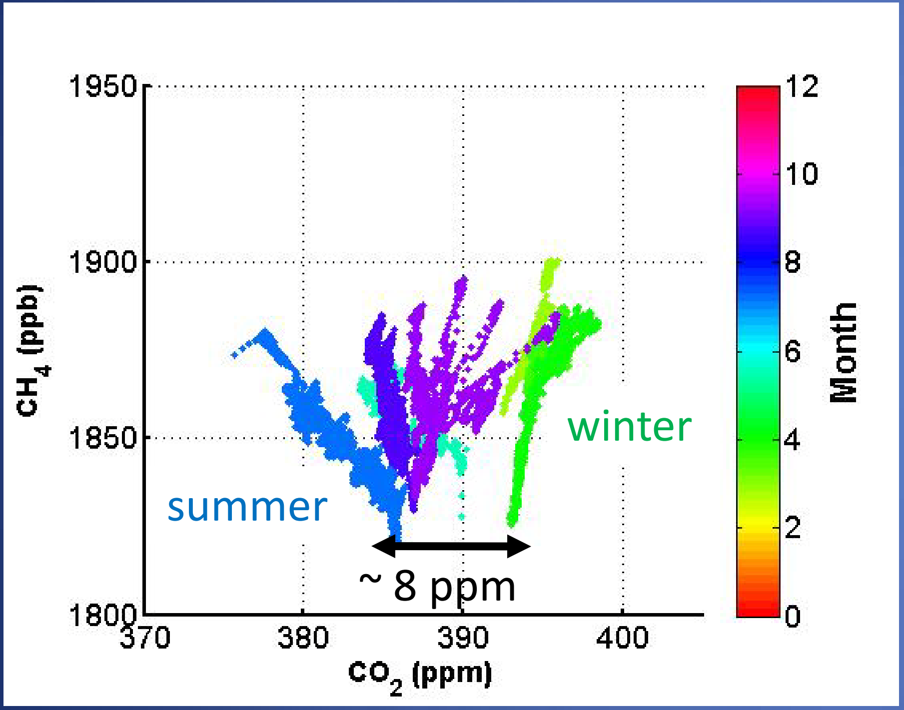
Summary

- 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

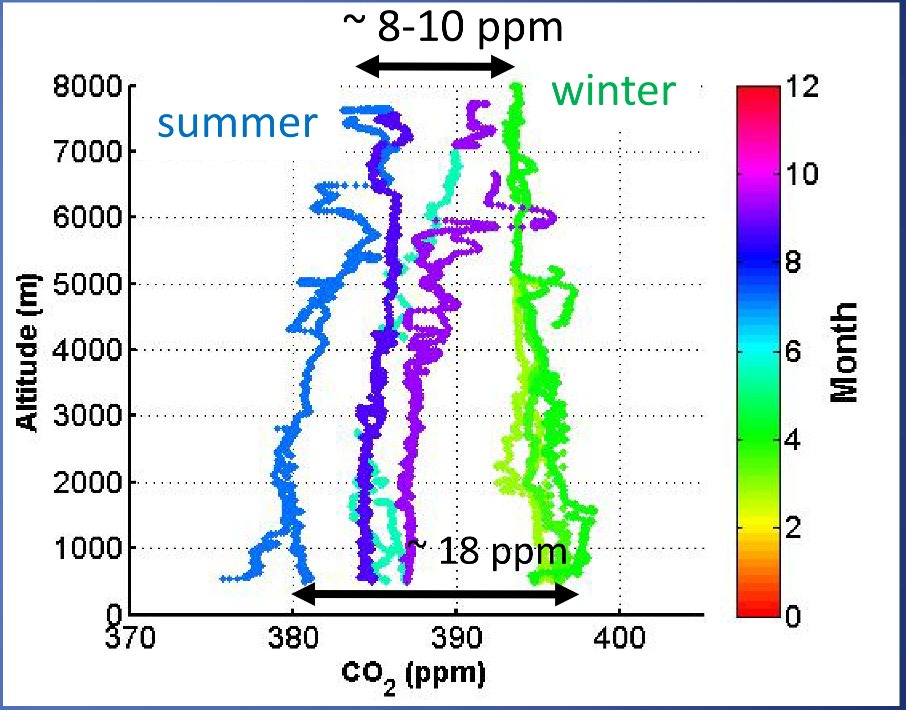

Spring
2009
2010
04302009
April 30
05122009
May 12
03302010
March 30
04272010
April 27
05072010
May 7
05252010
May 25
Summer
2009
2010
06232009
June 23
07282009
July 28
06222010
June 22
07202010
July 20
08092010
Aug 9
08192010
Aug 19
CH4 (ppb)
CO2 (ppm)
Altitude (m)


Fall
2009
2010
10132009
Oct 13
10272009
Oct 27
09232010
Sep 23
09282010
Sep 28
10122010
Oct 12
10262010
Oct 26
Winter
2009
2010
11102009
Nov 10
11232009
Nov 23
11232010
Nov 23
CH_4 (ppb)
CO_2 (ppm)
Altitude (m)

2010 Seasonal Cycle: Kivalina

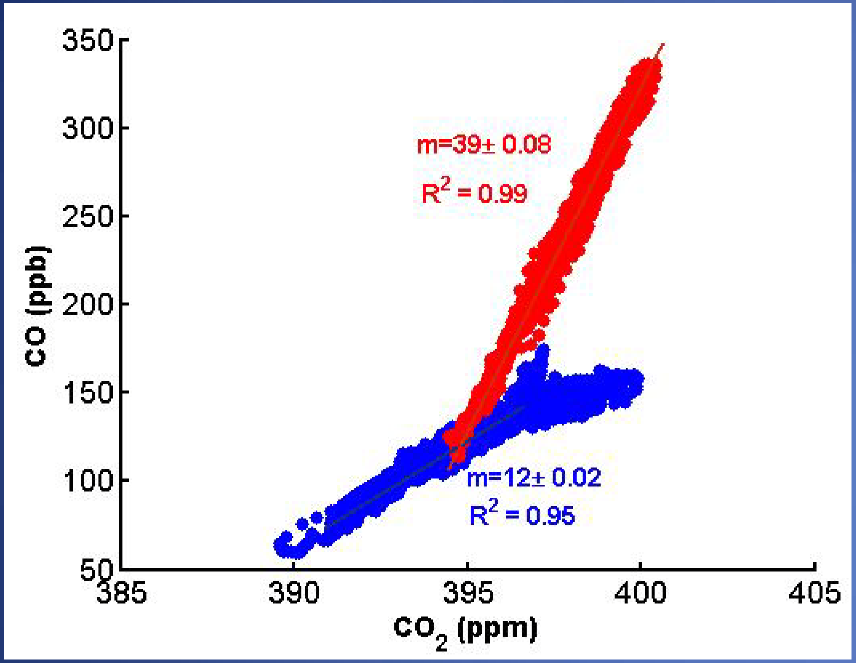


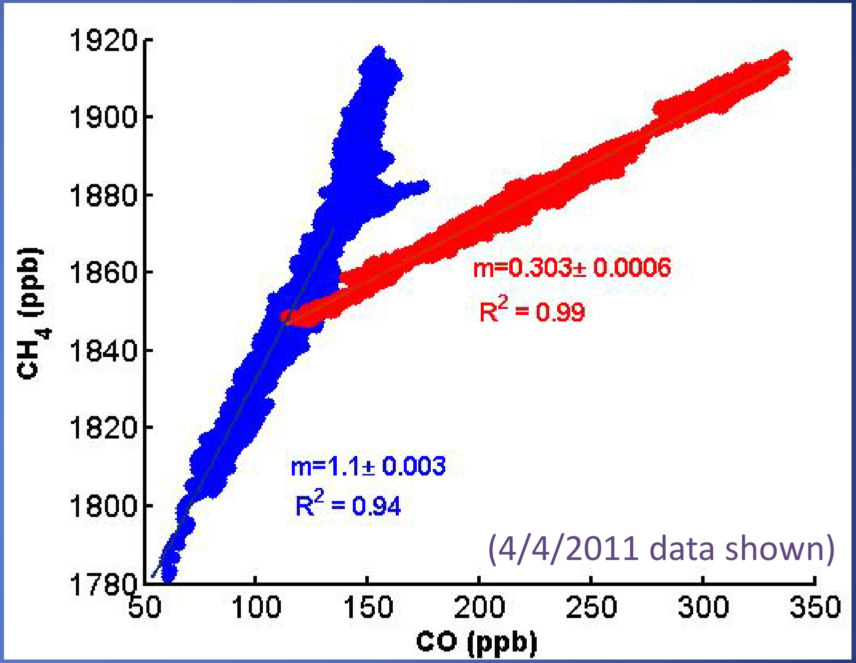
CO_2 and CH_4 over Kivalina



CO_2 altitude profile over Kivalina

2011 flights: high CO layers

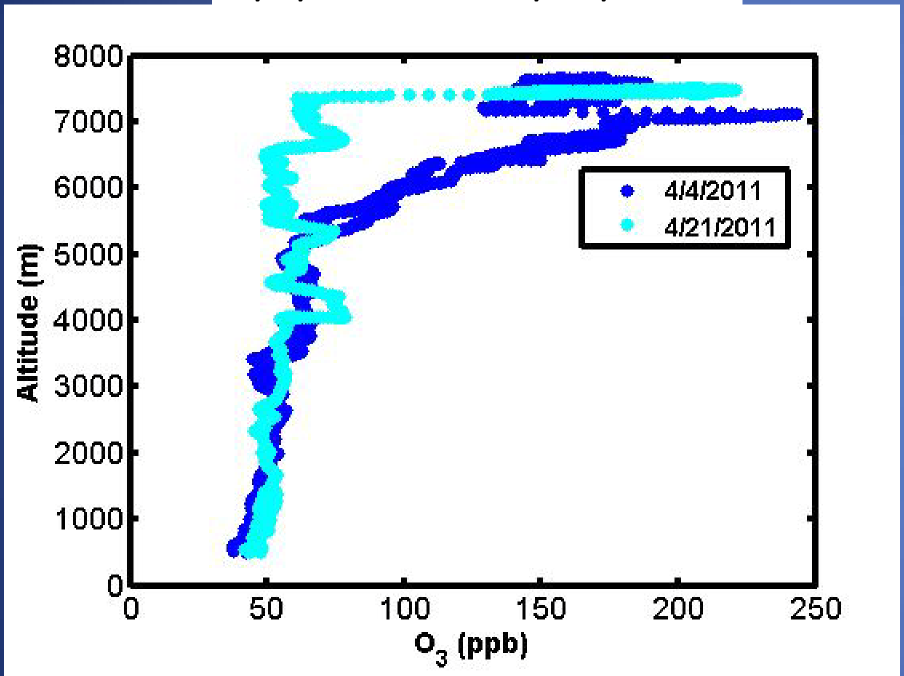




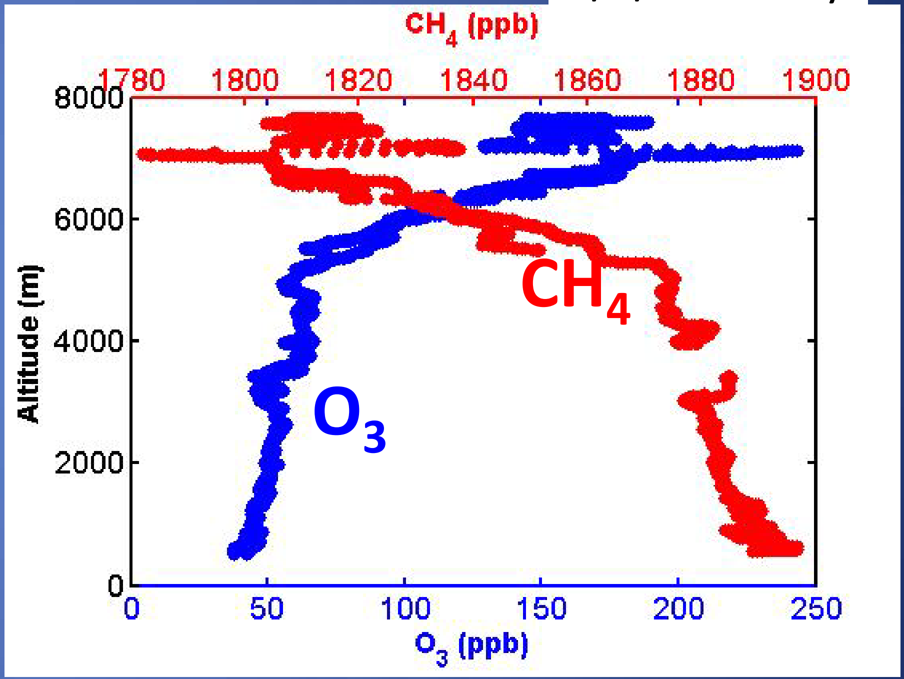
- ARCTAS campaign observed similar plumes (Warneke 2009; Singh 2010) attributed to biomass burning in Asia in 2008.
- Singh et al report 0.25 ppb CH_4 / ppb CO and 65 ppb CO/ ppm CO_2 in “aged” BB / urban plumes at 6.9 km over Alaska.
- Pollution bands also observed on HIPPO-2 (Nov 2009) at 6-8 km over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

2011 flights: Stratospheric Influence

4/4/2011 and 4/21/2011

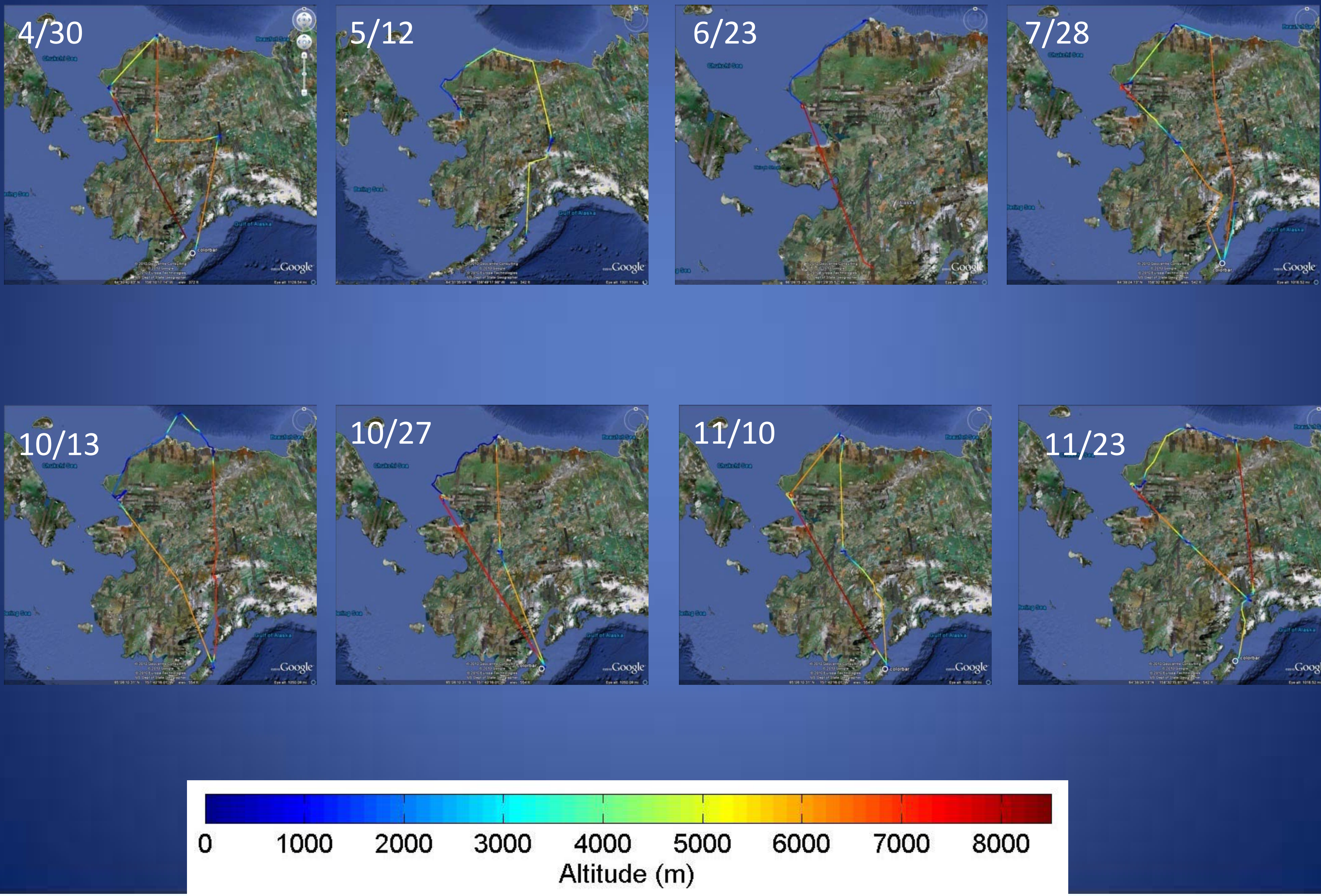


4/4/2011 only

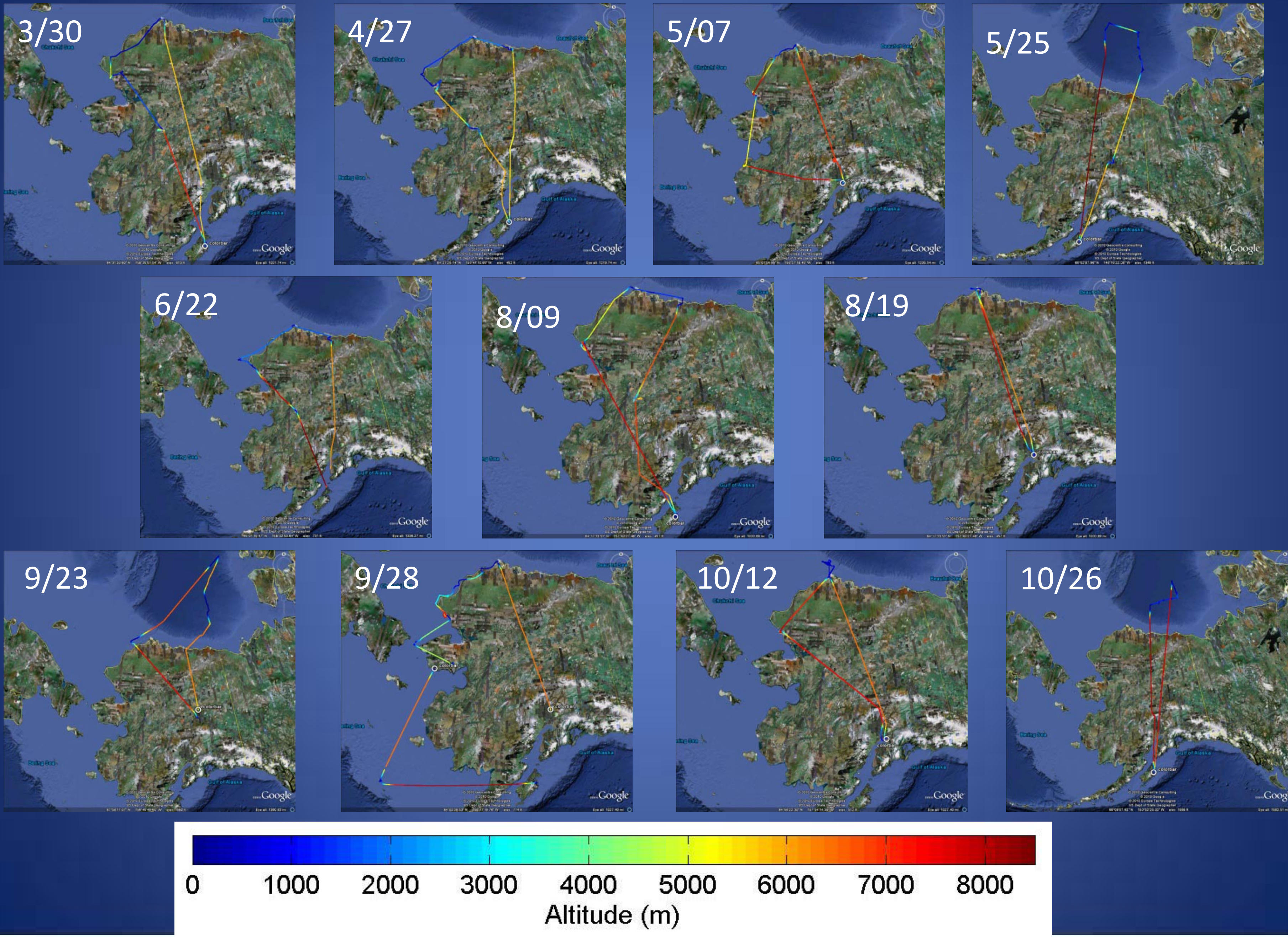


Ozone profiles over Kivalina on two different days show significant stratospheric influence.

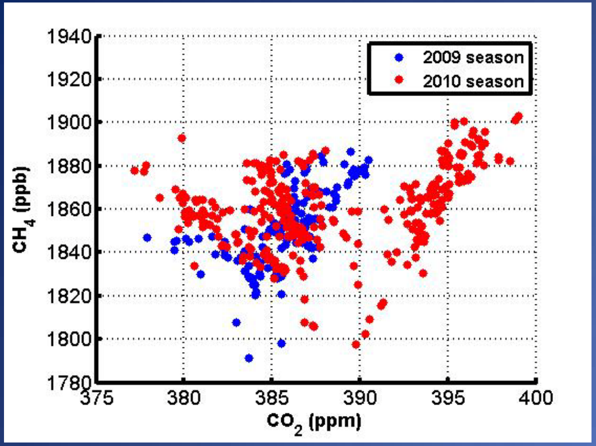
2009 Season Flight Paths

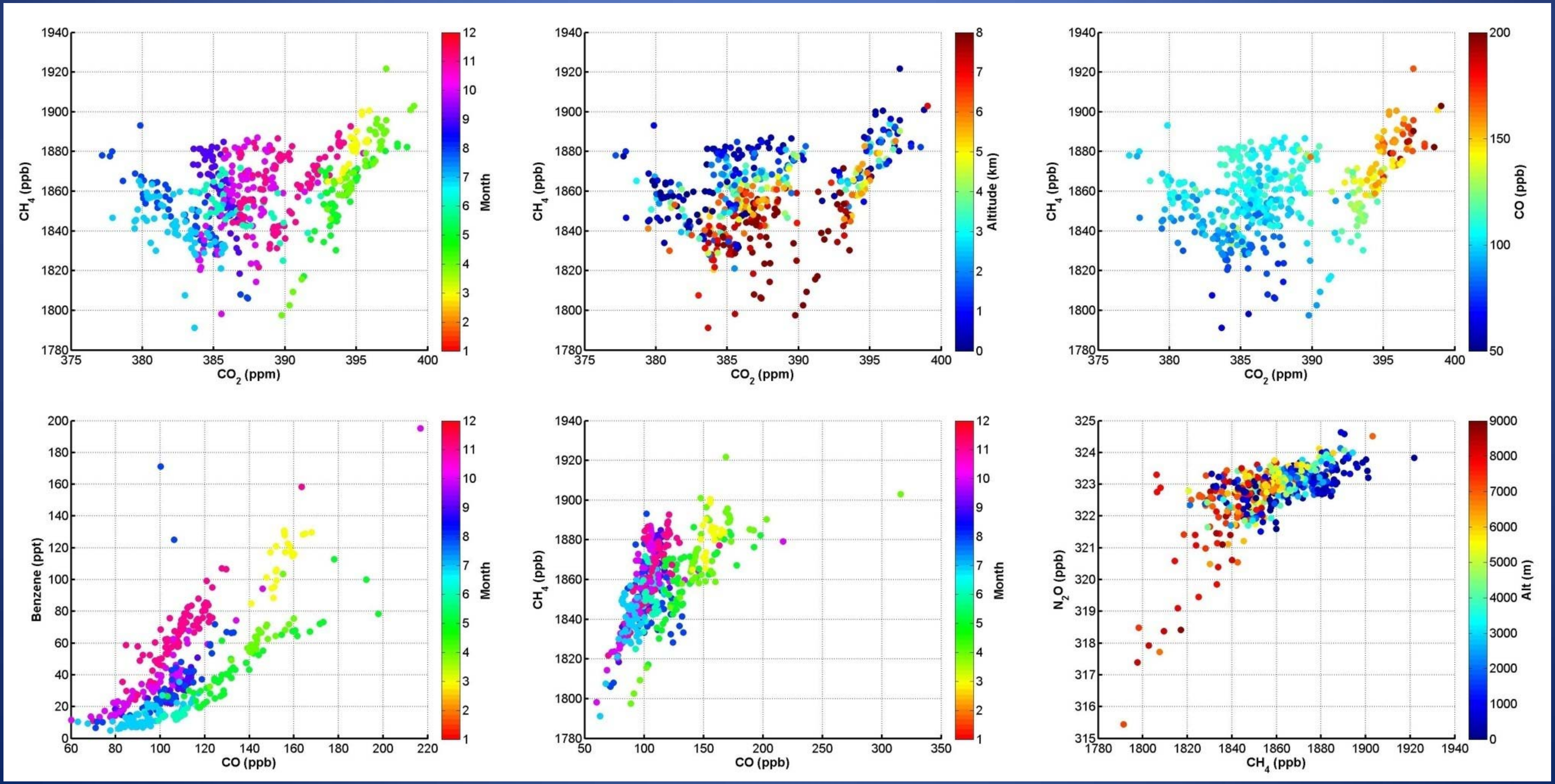


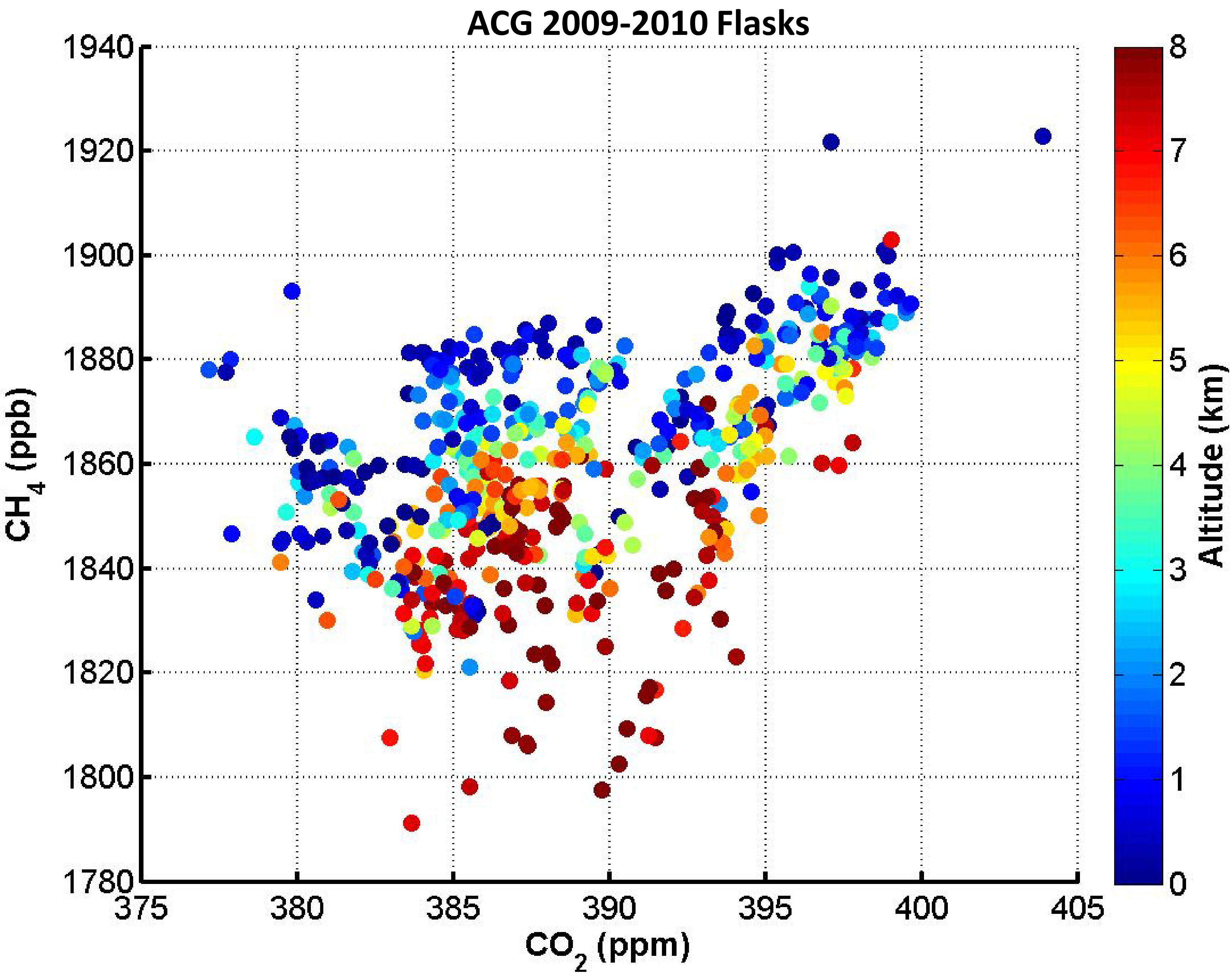
2010 Season Flight Paths



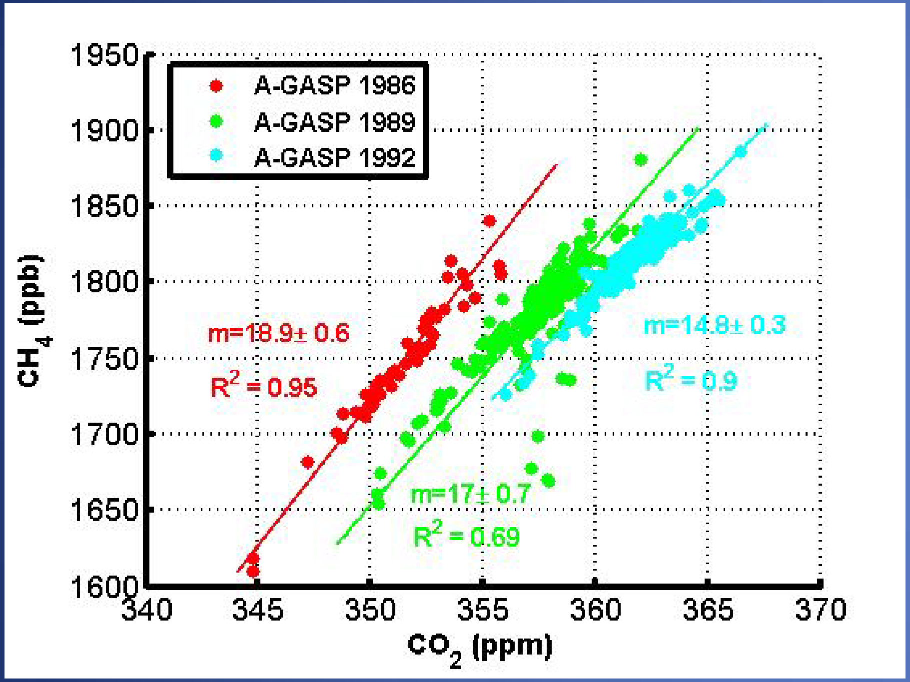
Flask Analysis (both seasons)

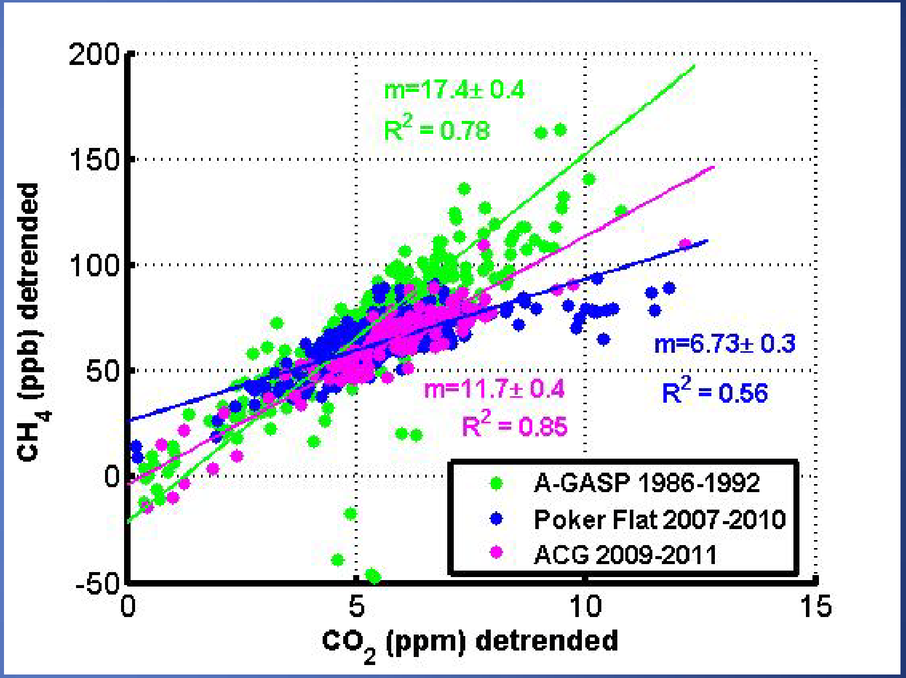





ACG 2009-2010 Flasks
1940
1920
1900
1880
1860
1840
1820
1800
1780
CH4 (ppb)
375
380
385
390
395
400
405
CO2 (ppm)
Altitude (km)
0
1
2
3
4
5
6
7
8

Comparison to other datasets: CO_2/CH_4

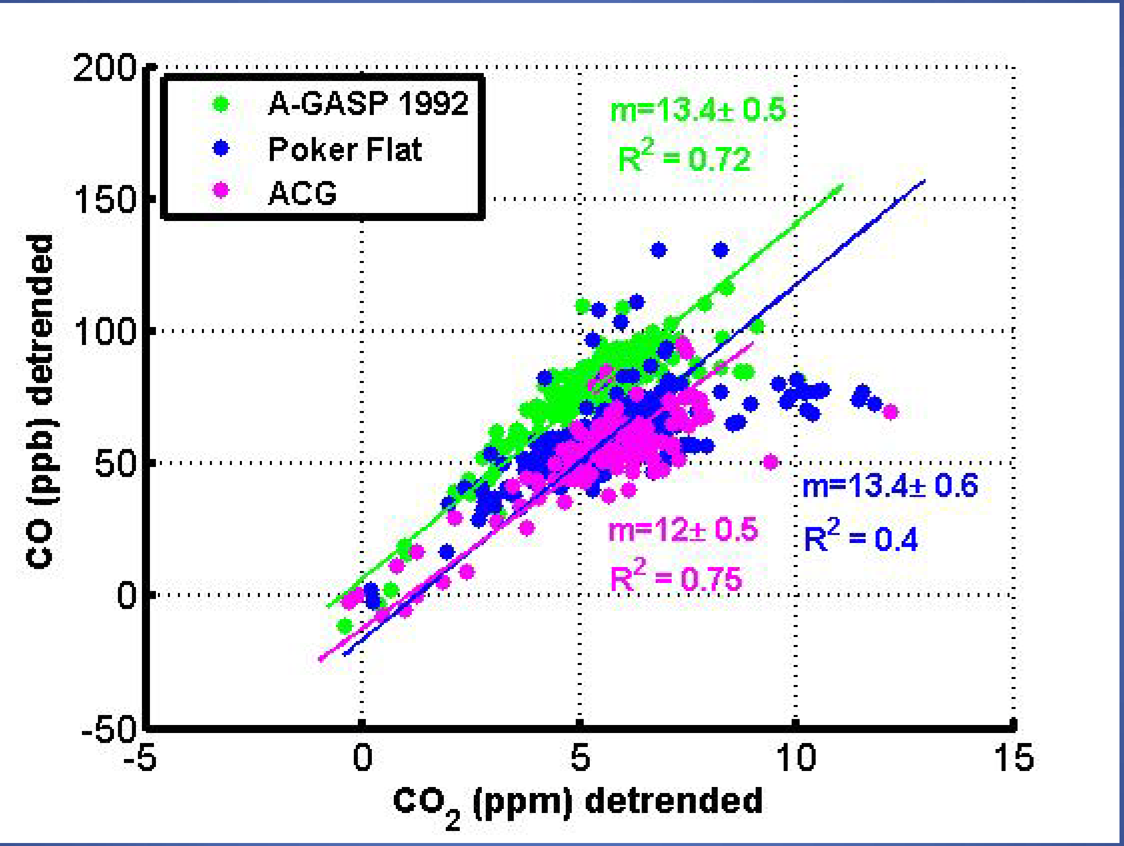




A-Gasp Missions (March & April)

- **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