# Airborne Measurements in Support of the NASA Atmospheric Carbon and Transport – America (ACT-America) Mission

A23B-0291

Byron Meadows[1], Ken Davis[2], John Barrick[3], Edward Browell[3], Gao Chen[1], Jeremy Dobler[4], Alan Fried[5], Thomas Lauvaux[2], Bing Lin[1], Matt McGill[6], Natasha Miles[2], Amin Nehrir[1], Michael Obland[1], Chris O'Dell[7], Colm Sweeney[8], and Melissa Yang[1]

[1]NASA Langley Research Center, Hampton, VA 23681; [2]The Pennsylvania State University, University Park PA 16802; [3]STARSS II Affiliate, NASA Langley Research Center, VA 23681; [4] Harris Corp., Ft. Wayne, IN 46801; [5]University of Colorado, Boulder, CO 80309; [6] NASA Goddard Space Flight Center, Greenbelt, MD 20771; [7]Colorado State University, Fort Collins, CO 80523; [8]National Oceanographic and Atmospheric Administration, Boulder, CO 80304

## Abstract

NASA announced the research opportunity Earth Venture Suborbital - 2 (EVS-2) mission in support of the NASA's science strategic goals and objectives in 2013. Penn State University, NASA Langley Research Center (LaRC), and other academic institutions, government agencies, and industrial companies together formulated and proposed the Atmospheric Carbon and Transport – America (ACT – America) suborbital mission, which was subsequently selected for implementation. The airborne measurements that are part of ACT-America will provide a unique set of remote and *in-situ* measurements of $CO_2$ over North America at spatial and temporal scales not previously available to the science community and this will greatly enhance our understanding of the carbon cycle.

ACT - America will consist of five airborne campaigns, covering all four seasons, to measure regional atmospheric carbon distributions and to evaluate the accuracy of atmospheric transport models used to assess carbon sinks and sources under fair and stormy weather conditions. This coordinated mission will measure atmospheric carbon in the three most important regions of the continental US carbon balance: Northeast, Midwest, and South. Data will be collected using 2 airborne platforms (NASA Wallops' C-130 and NASA Langley's B-200) with both *in-situ* and lidar instruments, along with instrumented ground towers and under flights of the Orbiting Carbon Observatory (OCO-2) satellite. This presentation provides an overview of the ACT-America instruments, with particular emphasis on the airborne $CO_2$ and backscatter lidars, and the rationale, approach, and anticipated results from this mission.

## Aircraft and Instrument Suites

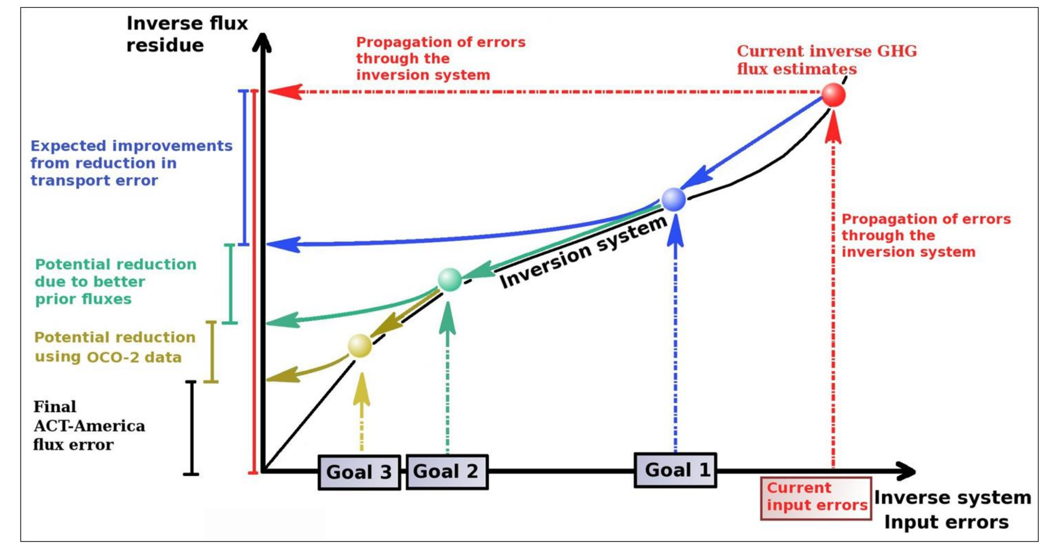
**Wallops C-130**

**Langley B-200**

| Instrument | Platform | Technique | Species/ Parameter | Instrument Precision (Averaging Time) | Variables Measured | Sampling Frequency | Data Latency (Archiving) | Purpose of measurement |
|---|---|---|---|---|---|---|---|---|
| **Lidars** | | | | | | | | |
| MFLL | C-130 | LAS[1] | $CO_2$ Column Density[4] | ≤0.08% (10 sec) ≤0.25% (1 sec) | Column $CO_2$ number density, altimetry, surface reflectance | 10 Hz | 1 day (≤6 months) | Core GHG $CO_2$ measurement & ranging capability |
| | | Pseudorandom Number Altimetry | Range to ground | < 1m (0.1 sec) | | | | |
| CPL | C-130 | Pulsed Lidar | ABL Height[5] | ≤ 100 m (10 sec) | ABL height, aerosol distribution | 2 Hz, 30m vertical resolution | 1 day (≤4 months) | Transport model constraint, OCO-2 validation |
| ACES | C-130 | | | | | | | |
| **In-situ Instruments** | | | | | | | | |
| Picarro G2401-m | C-130, B-200 | CRDS[2] | $CO_2$ | ≤ 0.15 ppm (5 sec) | $CO_2$, $CH_4$, CO, $H_2O$ mole fraction | 1 Hz | 1 day (≤4 months) | Core GHG measurements, combustion & airmass tracer |
| | | | $CH_4$ | ≤ 1 ppb (5 sec) | | | | |
| | | | CO | ≤ 30 ppb (5 sec) | | | | |
| | | | $H_2O$ | ≤ 0.12 g/kg (5 sec) | | | | |
| 2B Tech Model 205 | C-130, B-200 | Laser Spectrometer | $O_3$ | 1 ppb (10 sec) | $O_3$ mole fraction | 1 Hz | 1 day (≤4months) | Airmass tracer |
| Picarro G2301 | Tower | CRDS[2] | $CO_2$ | ≤ 0.07 ppm (5 sec) | $CO_2$, $CH_4$, $H_2O$ mole fraction | 1 Hz | 1 day (≤6 months) | Core GHG measurements. |
| | | | $CH_4$ | ≤ 0.5 ppb (5 sec) | | | | |
| Flasks | C-130, B-200 | GC/ MS[3] | $CO_2$, $CH_4$, CO, $^{14}CO_2$, COS | 0.2 ppm $CO_2$;1 ppb $CH_4$; 2 per mil $^{14}CO_2$;2 ppt COS; (all 10 sec) | Multiple trace gases. See table 3-2 | 12 flasks / aircraft / flight | 1 month (≤6 months) | Core GHG measurements, GHG source tracers. |
| CAMS | | | | | | | | |
| Environmental Parameters Suite | C-130 | INS[3] | Wind Speed and Direction | 1 m/s; +/- 5 degrees (0.1 sec) | GPS Lat.-Lon, Wind speed, direction, Pressure, Temp. | 1 Hz or higher | 1 day (≤6 months) | Evaluate atmospheric transport models |
| | C-130 | Various | Pressure | 0.25 mbar (0.015 sec) | | | | |
| | B-200 | | Temperature | 0.2 deg C (0.15 sec) | GPS Lat. and Lon., Pressure, Temperature | 1 Hz or higher | 1 day (≤6 months) | Evaluate atmospheric transport models |

## Mission Overview & Goals

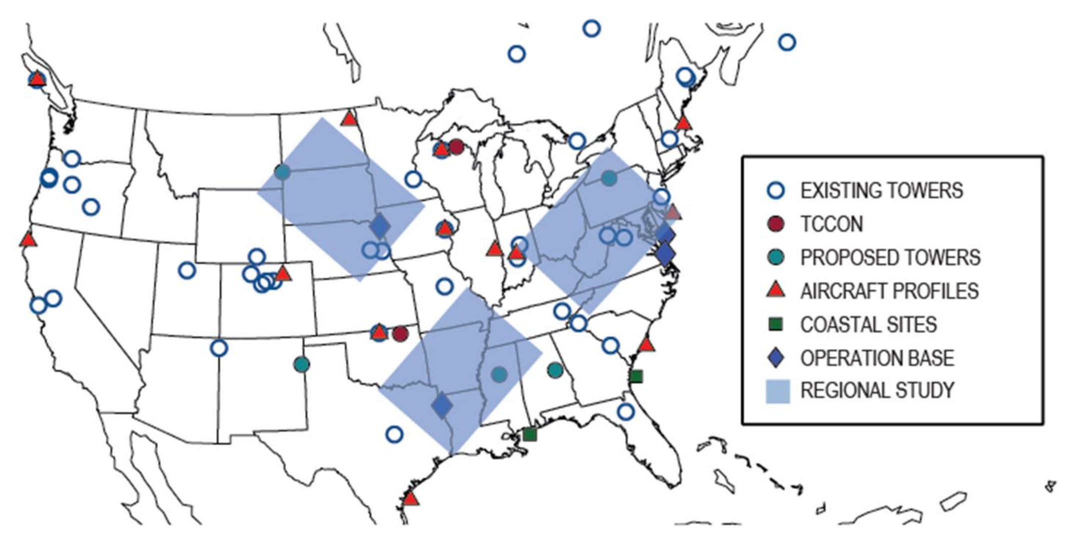
- The overarching goal of the Atmospheric Carbon and Transport-America (ACT-America) mission is to improve regional to continental scale diagnoses of carbon dioxide ($CO_2$) and methane ($CH_4$) sources and sinks.
- The mission will enable and demonstrate a new generation of atmospheric inversion systems for quantifying atmospheric $CO_2$ and $CH_4$ fluxes.
- These inversion flux estimates will be able to:
  - Evaluate and improve terrestrial carbon cycle models, and
  - Monitor carbon fluxes to support climate-change mitigation efforts.




1. Quantify and reduce atmospheric transport uncertainties
2. Improve regional-scale, seasonal prior estimates of $CO_2$ and $CH_4$ fluxes
3. Evaluate the sensitivity of Orbiting Carbon Observatory-2 (OCO-2) column $CO_2$ measurements to regional variability in tropospheric $CO_2$

These goals address the three primary sources of uncertainty in atmospheric inversions – transport error, prior flux uncertainty and limited data density

## Mission Schedule/ Locations




| Season Fiscal Year | Fall 2015 | Winter 2016 | Spring 2016 | Sum 2016 | Fall 2016 | Winter 2017 | Spring 2017 | Sum 2017 | Fall 2017 | Winter 2018 | Spring 2018 | Sum 2018 - Sum 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Campaign | Aircraft & Instrument Prep | | | 1 | | 2 | | 3 | 4 | | 5 | Analysis & Model Dev. |

6 week campaign (2 weeks in each region).

- Northeast: 2 weeks (Wallops Flight Fac./Langley Research Ctr.
- Midwest:2 weeks Lincoln, NE
- Southeast: 2 weeks Shreveport, LA

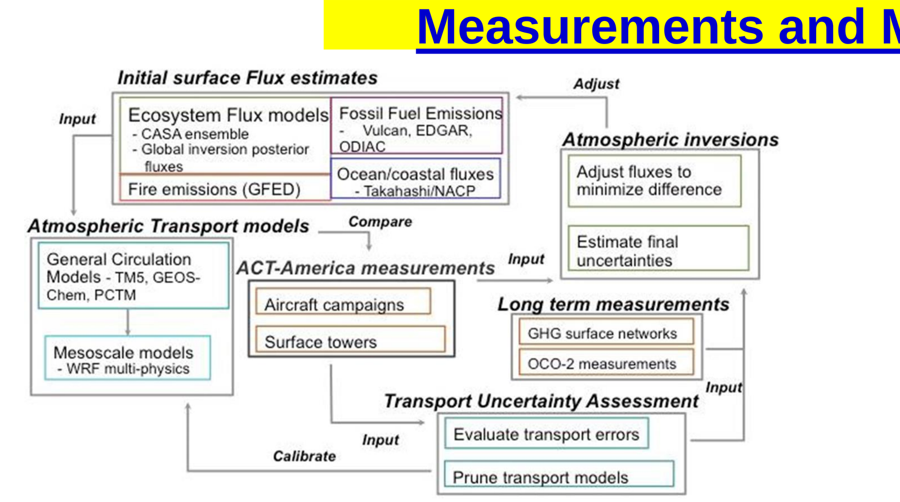
14 flights per campaign (two aircraft)

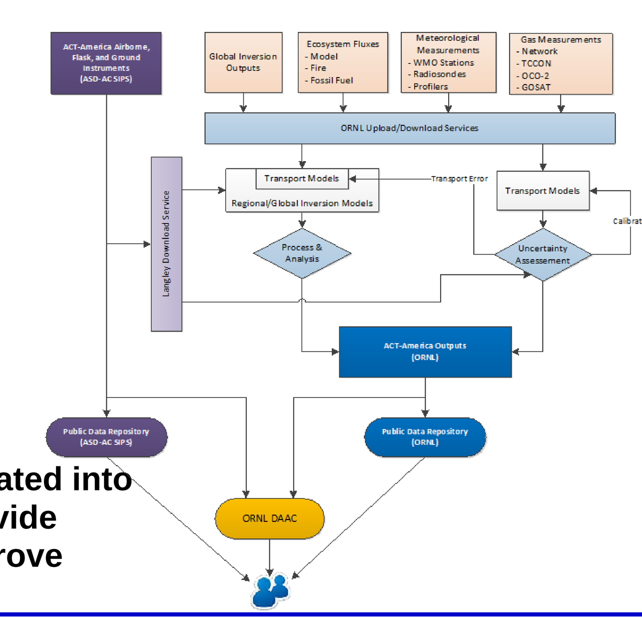
Plan: 4 flights per region + 2 OCO under flights

- Minimum: one fair and stormy weather flight in each region, for each campaign.

**Interested in collaborating or data sets? Contact Ken Davis (kjd10@psu.edu) or go to http://act-america.larc.nasa.gov/**

## Measurements and Model Data

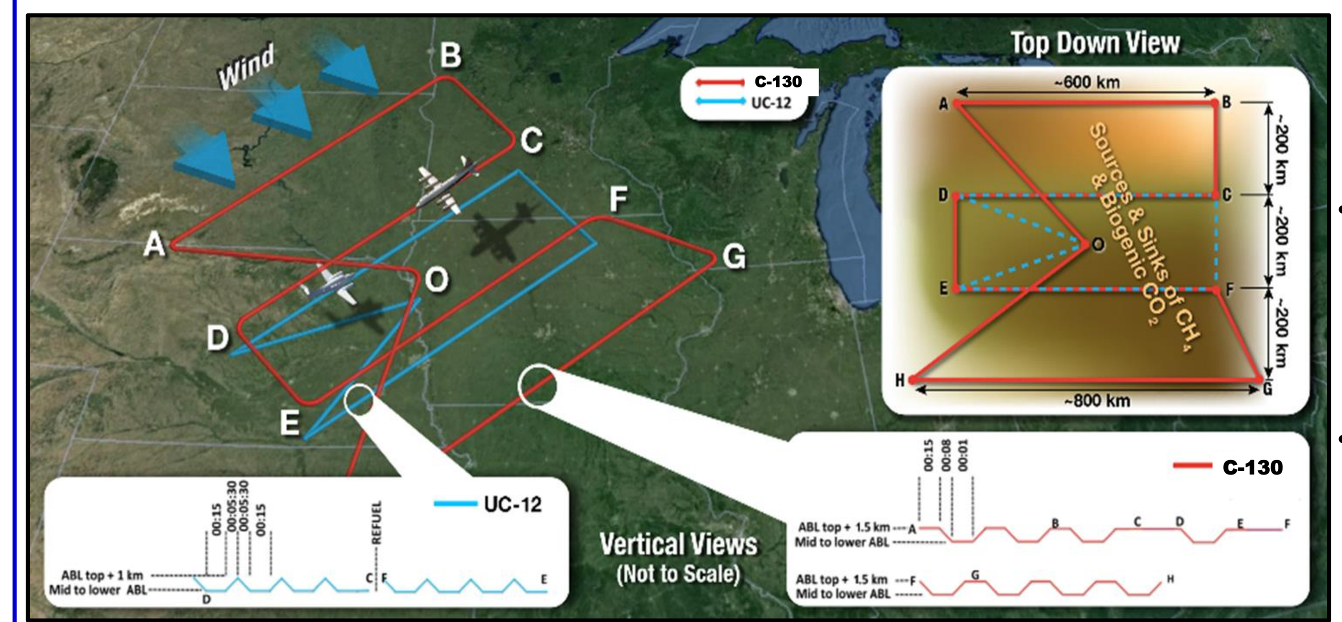


Airborne observations will be compared to and assimilated into ensembles of regional- and global-scale models to provide rigorous quantification of $CO_2$ and $CH_4$ fluxes, and improve transport ensembles for atmospheric inversions.

## Flight Profiles

### Fair weather



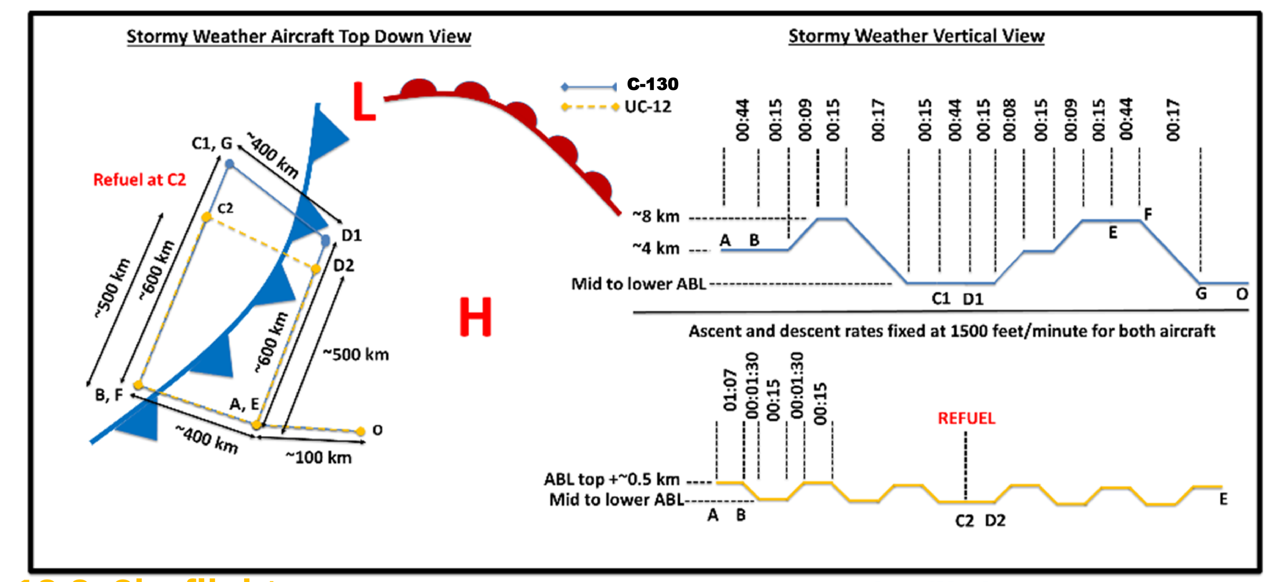

UC-12 2x3hr flights

C-130 8 hr flights

- Measure winds, ABL depth, $CO_2$, $CH_4$ and tracers (CO, $^{14}CO_2$, $O_3$) across 100's of km.
- Solve for regional fluxes for the days of flights directly – prune prior flux estimates.
- Evaluate fair weather meteorology in atmospheric transport ensemble

### Stormy weather

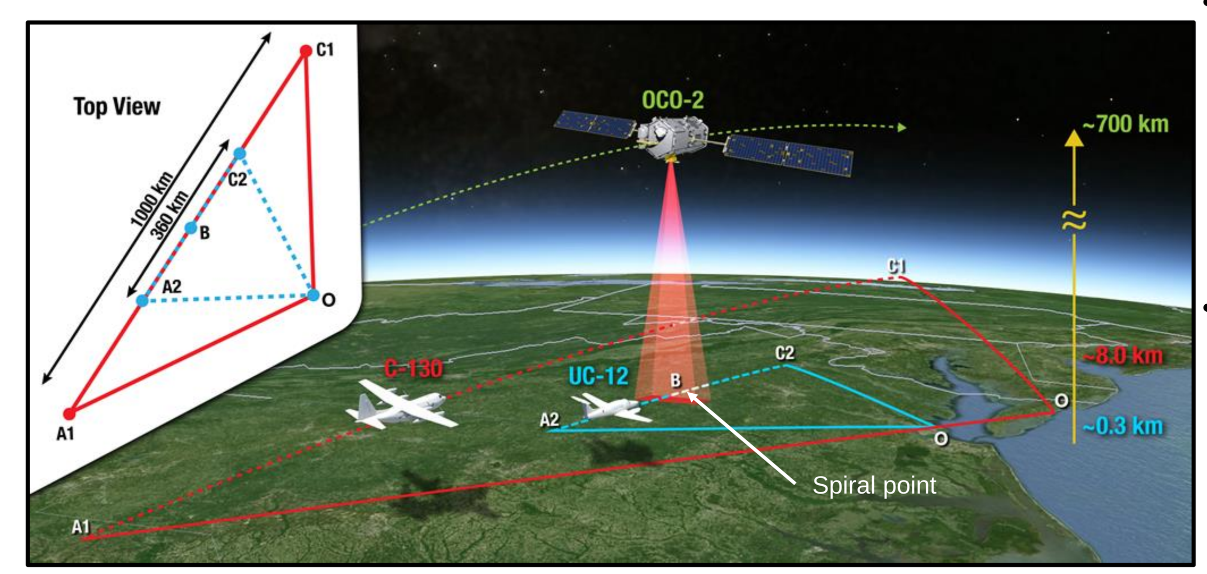
- Measure atmospheric state, $CO_2$, $CH_4$ and tracers (CO, $^{14}CO_2$, $O_3$) across and around frontal systems.
- Evaluate atmospheric transport in our model ensemble. Prune transport ensemble.




UC-12 2x3hr flights

C-130 8hr flight

### OCO-2 Under flights



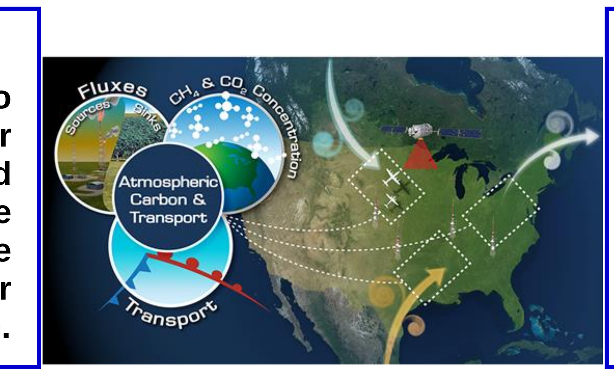

UC-12 3.6hr flight

C-130 4.8hr flight

- Measure much of the atmospheric CO2 column at < 20km horizontal resolution across 100's of km below OCO-2. Also measure aerosols, clouds with lidar.
- Compare spatial variability in airborne CO2 to OCO-2 CO2. Evaluate OCO-2 ability to capture tropospheric CO2 variability along-track.

### Acknowledgements

The authors would like to acknowledge NASA HQ for selecting this proposal and NASA Wallops and the Research Services Directorate at NASA Langley for their support in planning the mission.




### Contact Information:

Byron Meadows
NASA Langley Research Ctr.
MS468
Hampton, VA 23681

Byron.L.Meadows@nasa.gov