

Airborne Measurements in Support of the NASA Atmospheric Carbon and Transport – America (ACT-America) Mission A23B-0291

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Abstract

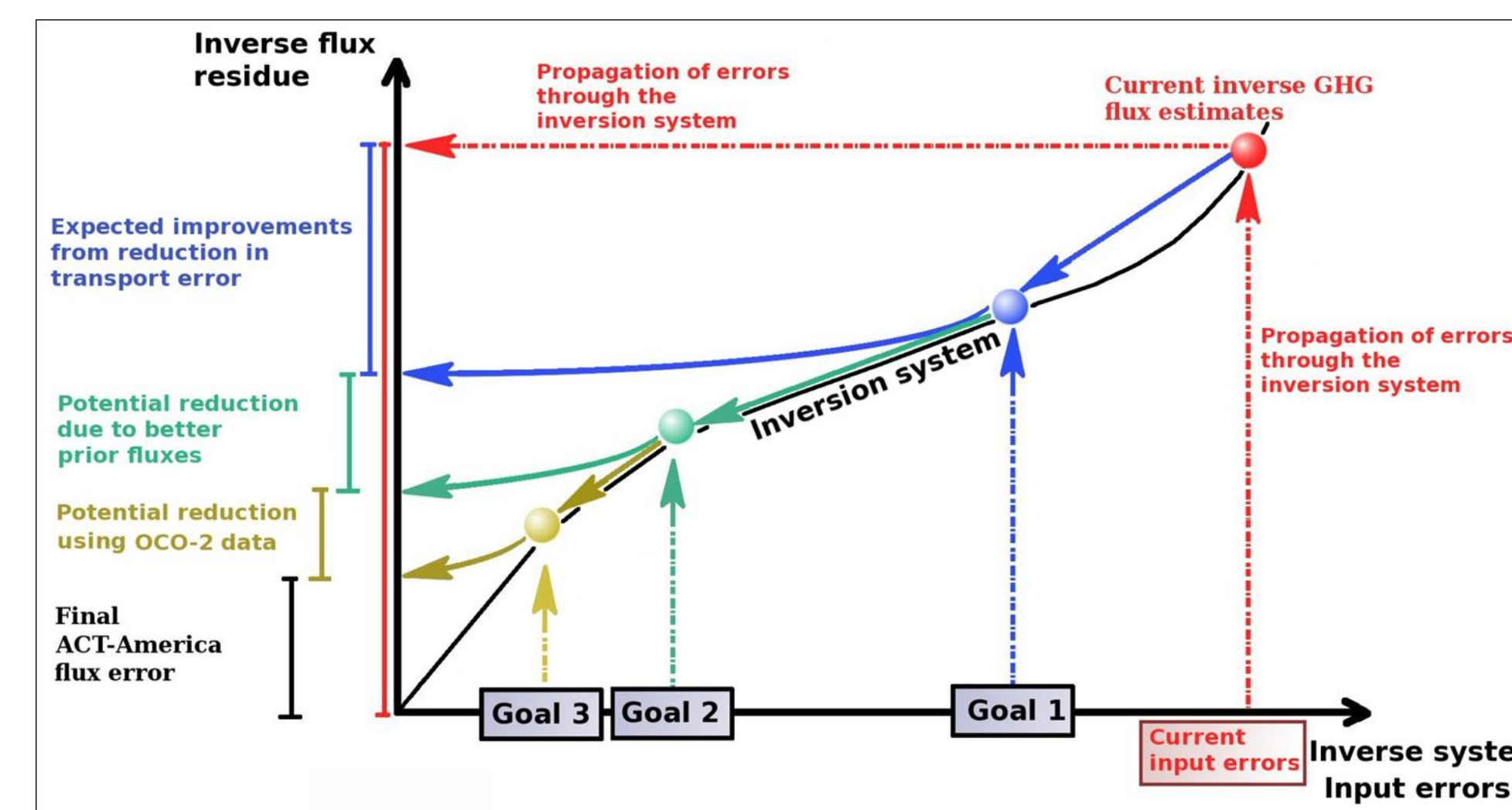
NASA announced the research opportunity Earth Venture Suborbital - 2 (EVS-2) mission in support of the NASA's science strategic goals and objectives in 2013. Penn State University, NASA Langley Research Center (LaRC), and other academic institutions, government agencies, and industrial companies together 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 CO₂ 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 CO₂ and backscatter lidars, and the rationale, approach, and anticipated results from this mission.



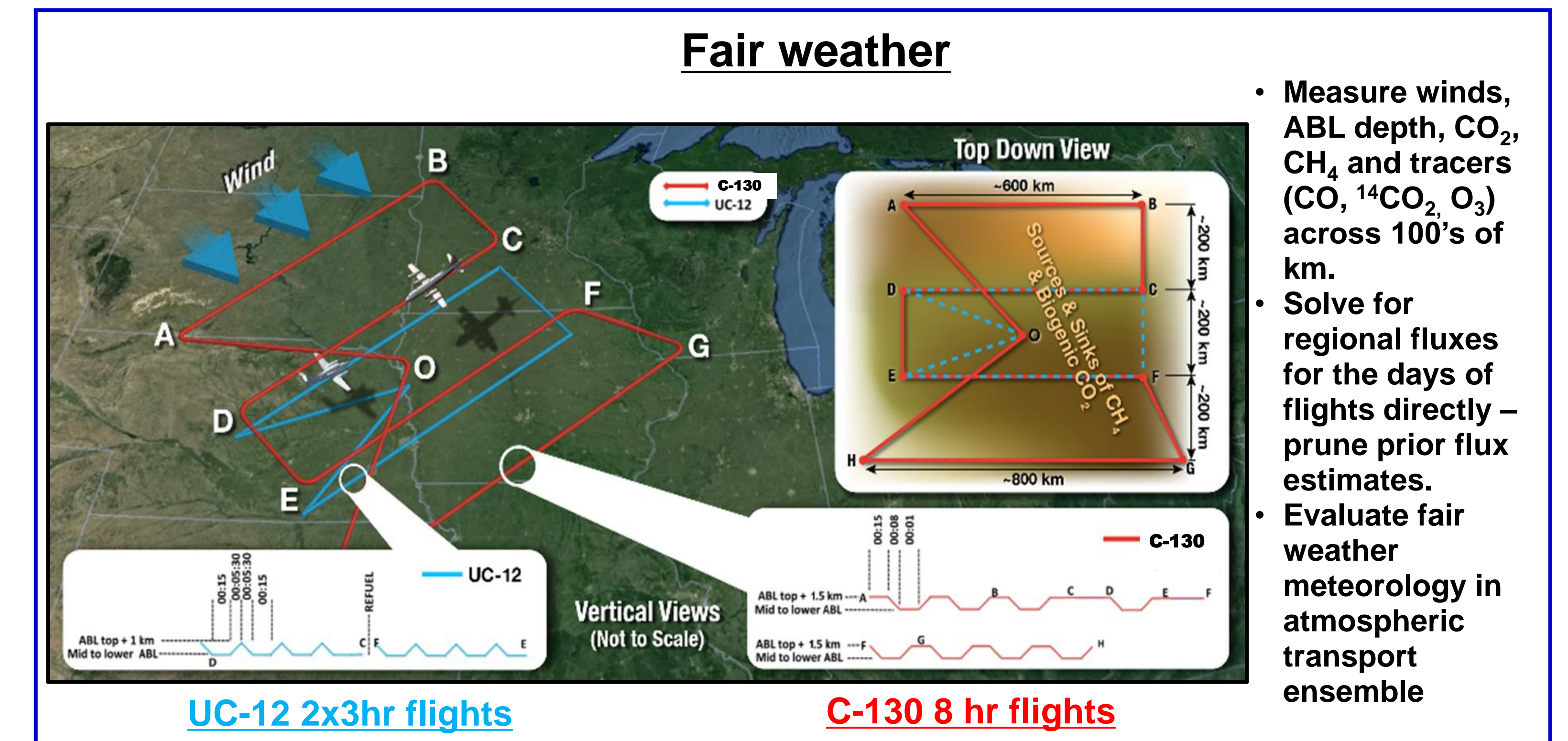
- The overarching goal of the Atmospheric Carbon and Transport-America (ACT-America) mission is to improve regional to continental scale diagnoses of carbon dioxide (CO₂) and methane (CH₄) sources and sinks.
- The mission will enable and demonstrate a new generation of atmospheric inversion systems for quantifying atmospheric CO₂ and CH₄ 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.

Mission Overview & Goals



- Quantify and reduce atmospheric transport uncertainties
 - Improve regional-scale, seasonal prior estimates of CO₂ and CH₄ fluxes
 - Evaluate the sensitivity of Orbiting Carbon Observatory-2 (OCO-2) column CO₂ measurements to regional variability in tropospheric CO₂
- These goals address the three primary sources of uncertainty in atmospheric inversions – transport error, prior flux uncertainty and limited data density

Flight Profiles



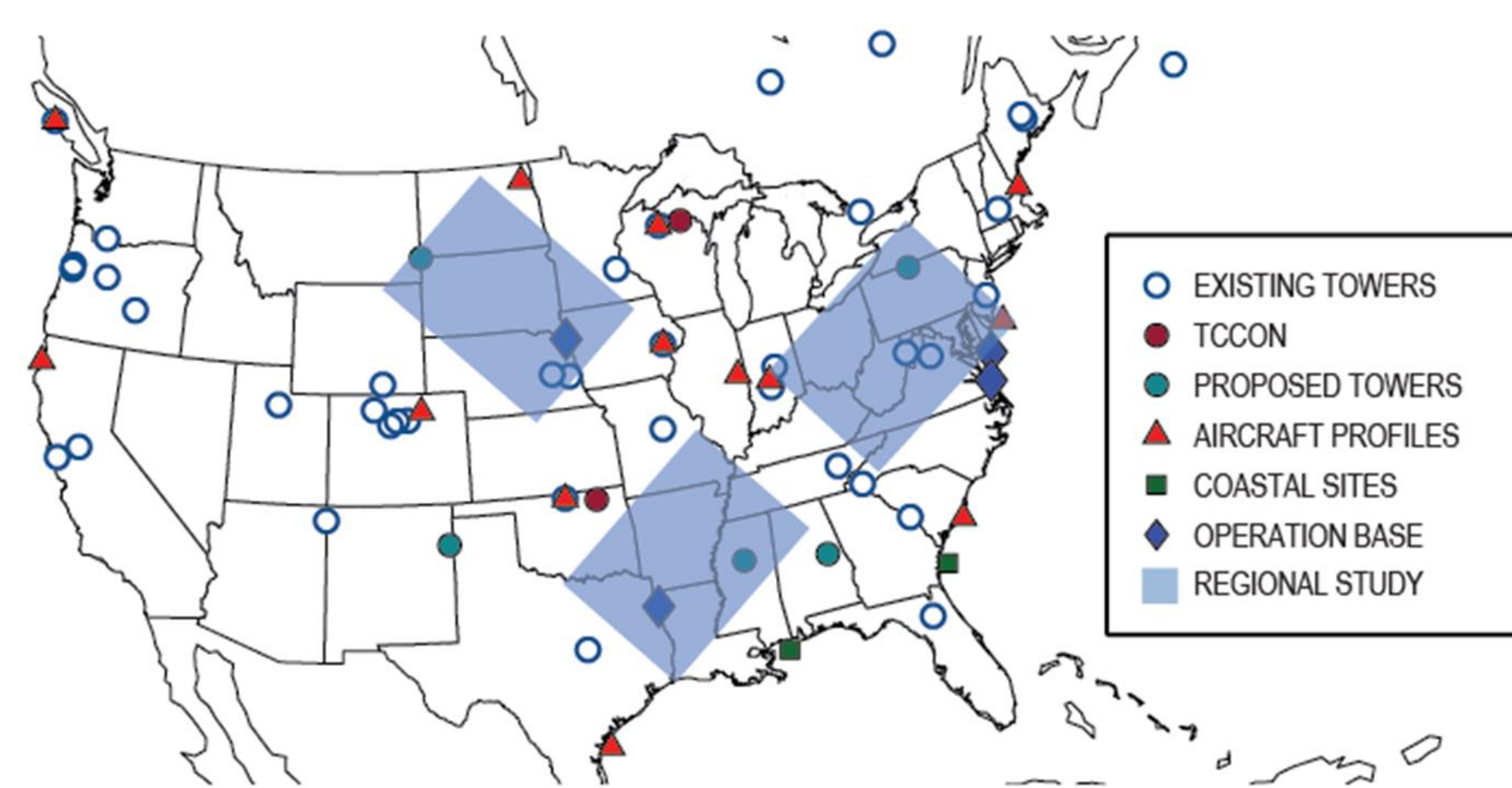
- Measure winds, ABL depth, CO₂, CH₄ and tracers (CO, ¹⁴CO₂, O₃) across 100's of km.
- Solve for regional fluxes for the days of flights directly – prune prior flux estimates.
- Evaluate fair weather meteorology in atmospheric transport ensemble

Aircraft and Instrument Suites



	Instrument	Platform	Technique	Species/Parameter	Instrument Precision (Averaging Time)	Variables Measured	Sampling Frequency	Data Latency (Archiving)	Purpose of measurement	
Lidars	MFL	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	B-200	CRDS ²	CO ₂ , CH ₄ , CO, H ₂ O	CO ₂ : ≤ 0.15 ppm (5 sec) CH ₄ : ≤ 1 ppb (5 sec) CO: ≤ 30 ppb (5 sec) H ₂ O: ≤ 0.12 g/kg (5 sec)	CO ₂ , CH ₄ , CO, H ₂ O mole fraction	1 Hz	1 day (≤4 months)	Core GHG measurements, combustion & air mass tracer	
	2B Tech Model 205	C-130, B-200	Laser Spectrometer	O ₃	1 ppb (10 sec)	O ₃ mole fraction	1 Hz	1 day (≤4 months)	Airmass tracer	
	Picarro G2301	Tower	CRDS ²	CO ₂ , CH ₄	CO ₂ : ≤ 0.07 ppm (5 sec) CH ₄ : ≤ 0.5 ppb (5 sec)	CO ₂ , CH ₄ , H ₂ O mole fraction	1 Hz	1 day (≤6 months)	Core GHG measurements	
	Flasks	C-130, B-200	GC/MS ³	CO ₂ , CH ₄ , CO, ¹³ C, COS	0.2 ppm CO ₂ ; 1 ppb CH ₄ ; 2 per mil ¹³ C; 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	C-130	INS ⁴	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	
	Environmental Parameters Suite	C-130, B-200	Various	Pressure, Temperature	0.25 mbar (0.015 sec) 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 Schedule/ Locations

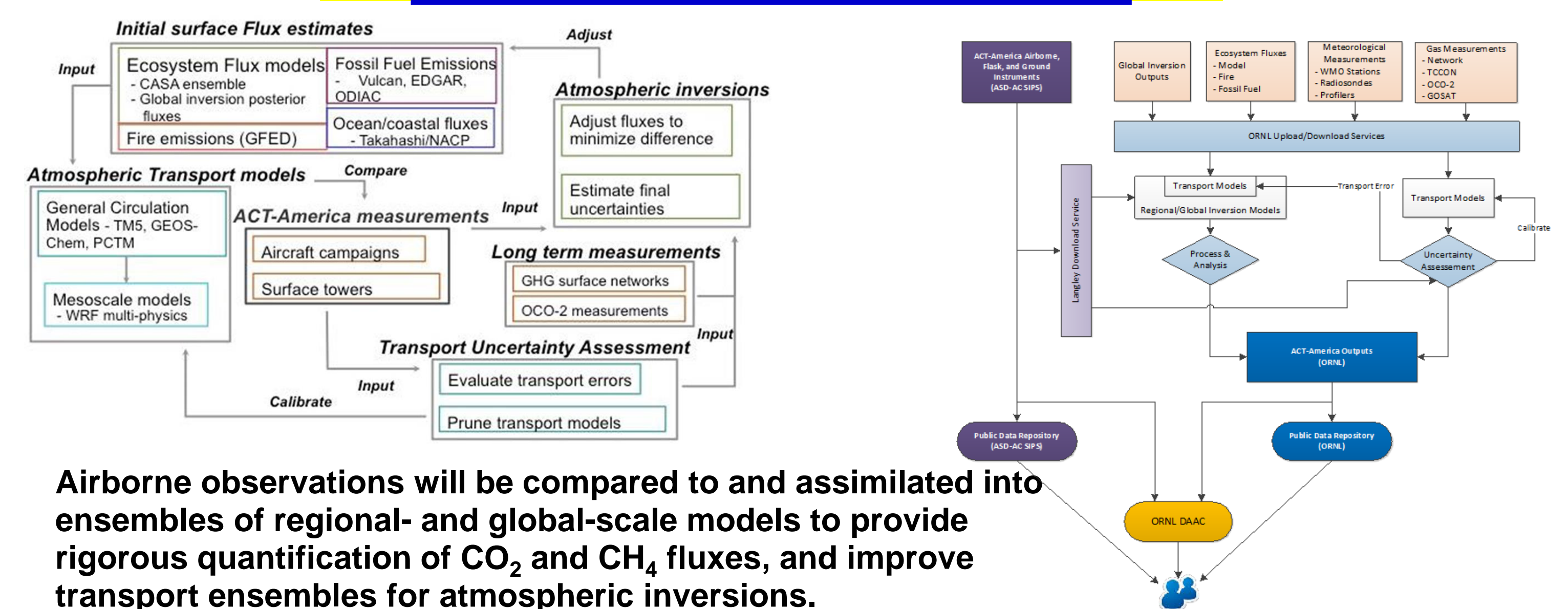


- 6 week campaign (2 weeks in each region).
- Northeast: 2 weeks (Wallops Flight Fac./Langley Research Ctr.)
 - Midwest: 2 weeks Lincoln, NE
 - Southeast: 2 weeks Shreveport, LA
- 14 flights per campaign (two aircraft)
Plan: 4 flights per region + 2 OCO under flights
Minimum: one fair and stormy weather flight in each region, for each campaign.

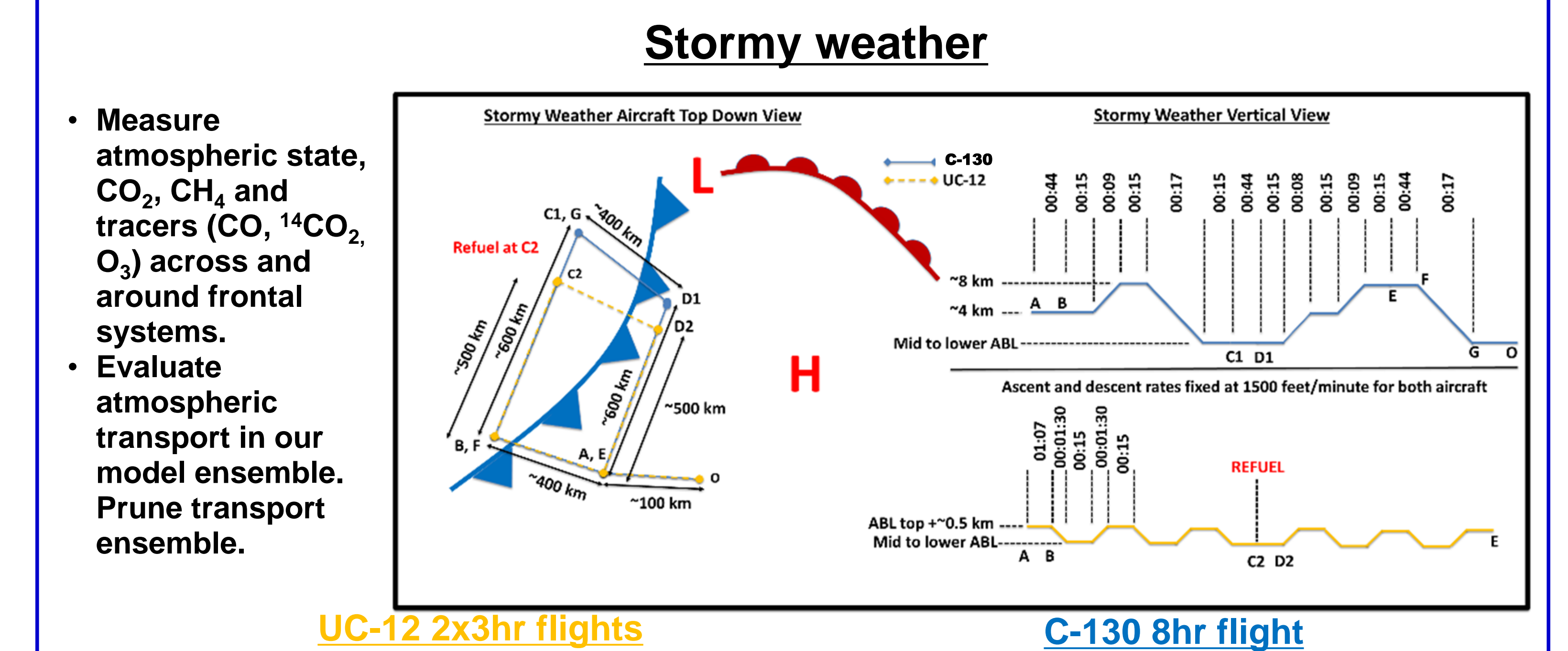
Season Fiscal Year	Fall 2015	Winter 2016	Spring 2016	Summer 2016	Fall 2016	Winter 2017	Spring 2017	Summer 2017	Fall 2017	Winter 2018	Spring 2018	Summer 2018	Summer 2018 - Summer 2019
Campaign	Aircraft & Instrument Prep	1	2	3	4	5	Analysis & Model Dev.						

Interested in collaborating or data sets? Contact Ken Davis (kj10@psu.edu) or go to <http://act-america.larc.nasa.gov/>

Measurements and Model Data

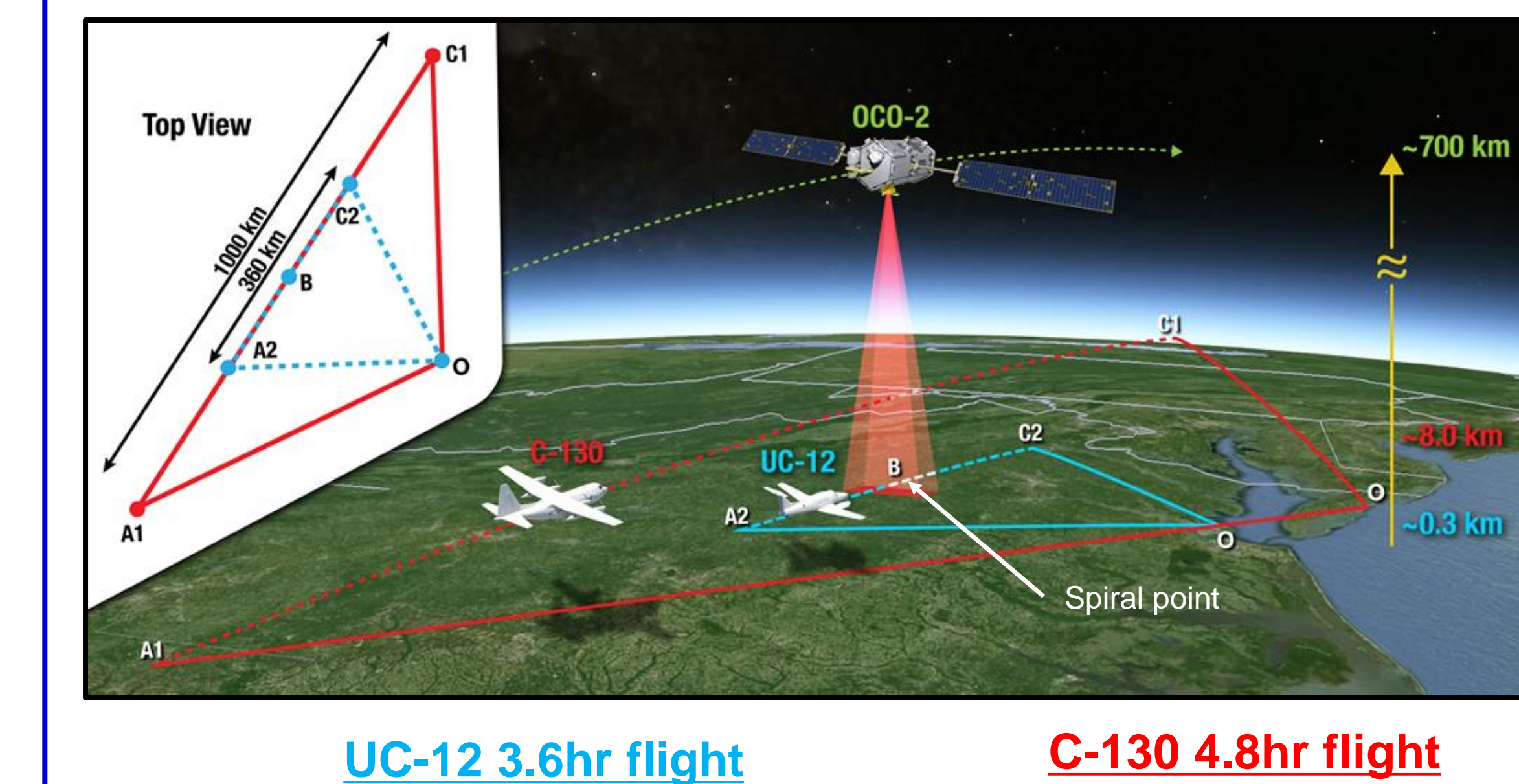


Airborne observations will be compared to and assimilated into ensembles of regional- and global-scale models to provide rigorous quantification of CO₂ and CH₄ fluxes, and improve transport ensembles for atmospheric inversions.



- Measure atmospheric state, CO₂, CH₄ and tracers (CO, ¹⁴CO₂, O₃) across and around frontal systems.
- Evaluate atmospheric transport in our model ensemble. Prune transport ensemble.

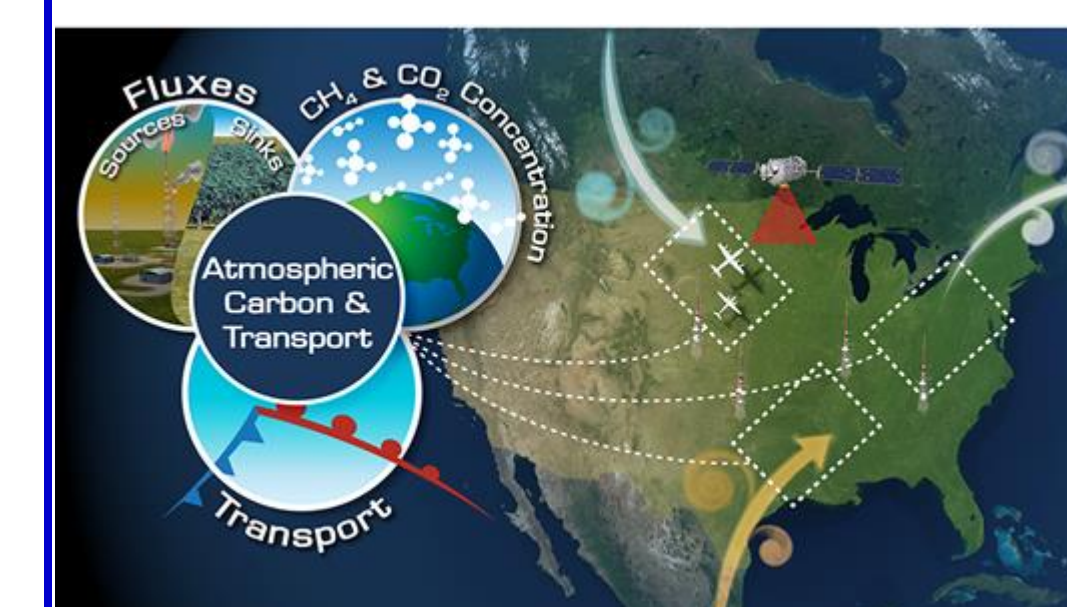
OCO-2 Under flights



- 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 ability to capture tropospheric CO₂ variability along-track.

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