

Modified AirCore for non-CO₂ trace gases on NOAA SkyWisp Unmanned Aircraft Systems (UAS)

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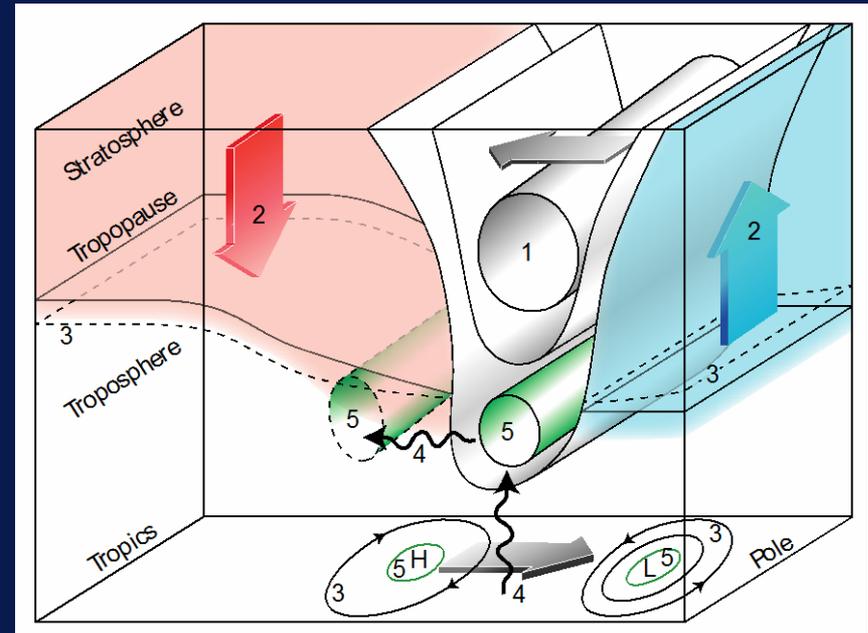
AirCore and Balloon Assisted Glider UAS

Goals of Work and Scientific Question

- NOAA Goal: To understand and predict changes in climate.
- Is there a less expensive way than aircraft or satellites to make observations to get useful vertical profile and transport information?
- Climate Models requires vertical profiles of trace gases to evaluate transport effects. Is transport changing with time?

Motivation: Stratospheric Circulation

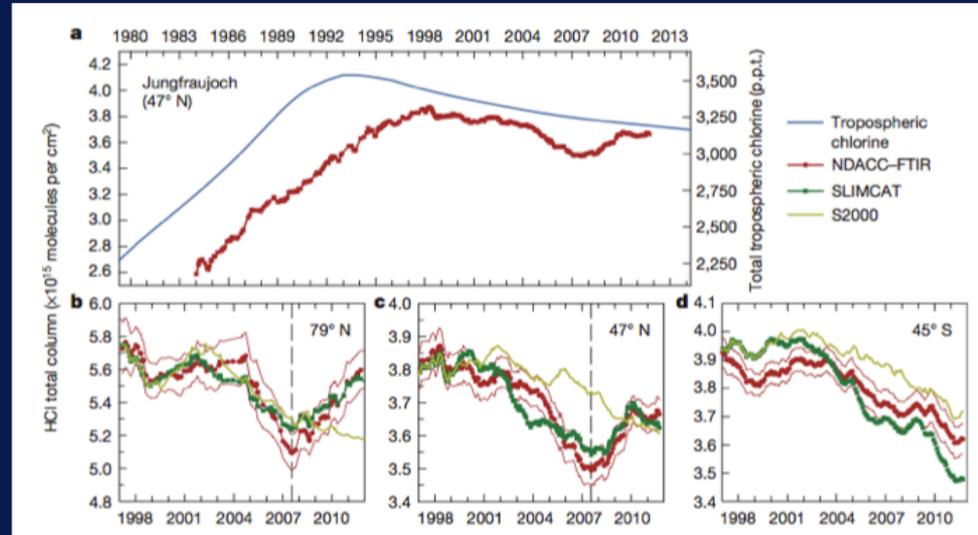
- A powerful influence on the weather that we experience on the ground can be exerted by the stratosphere.
- “Following a weakening of the stratospheric jet (1), impacts on the surface weather include a higher likelihood of extremely low temperature over northern Europe and the eastern USA. The tropospheric jet (5) moves poleward, along with storm tracks, producing colder temperatures (blue). Eddy feedbacks (4) in the troposphere amplify the surface impacts, but the mechanisms underlying these dynamics are not fully understood.”
- Stratospheric circulation can affect the tropospheric jet streams, storms, and surface weather over days to a whole season.



Kidston et al, (2015) Nature Geoscience, DOI: 10.1038/NGEO2424

Motivation: Observations are Important.

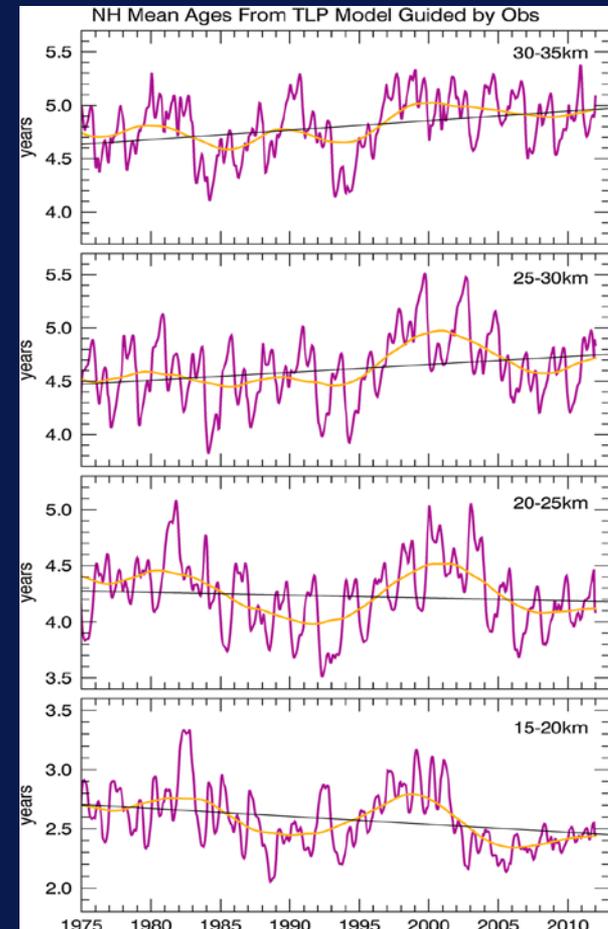
- Total column values of HCl formed from banned CFCs showed an abrupt increase. Had the Montreal Protocol failed or was flawed?
- A slowdown in the Northern Hemisphere atmospheric circulation, occurring over several consecutive years, transporting more aged air to the lower stratosphere, and characterized by a larger relative conversion of source gases to HCl.
- A good example of stratospheric circulation change on a several year time scale affecting trace gas distributions, in this case over the column(5 yrs).



Mahieu et al., (2014)doi:10.1038/nature13857

Motivation: Long term transport changes in the stratosphere

- Mean age appears to be decreasing below 25 km according to balloon observations of SF₆ and CO₂ and model results.
- We want to measure photolytic species with various lifetimes in the stratosphere using inexpensive balloon flights and active control of landing.

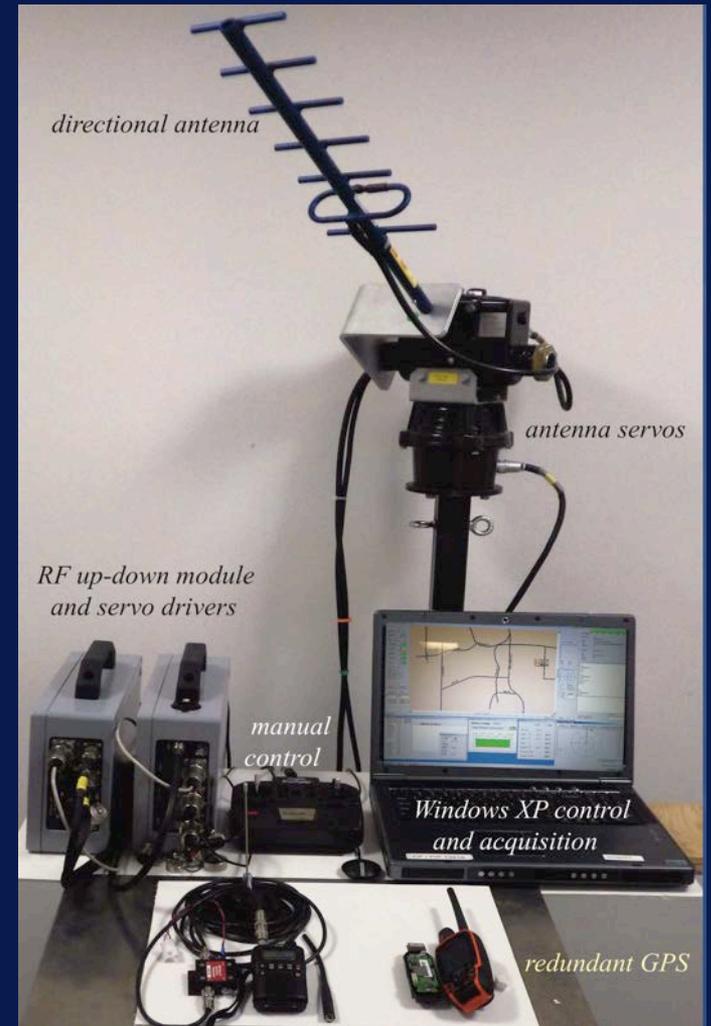


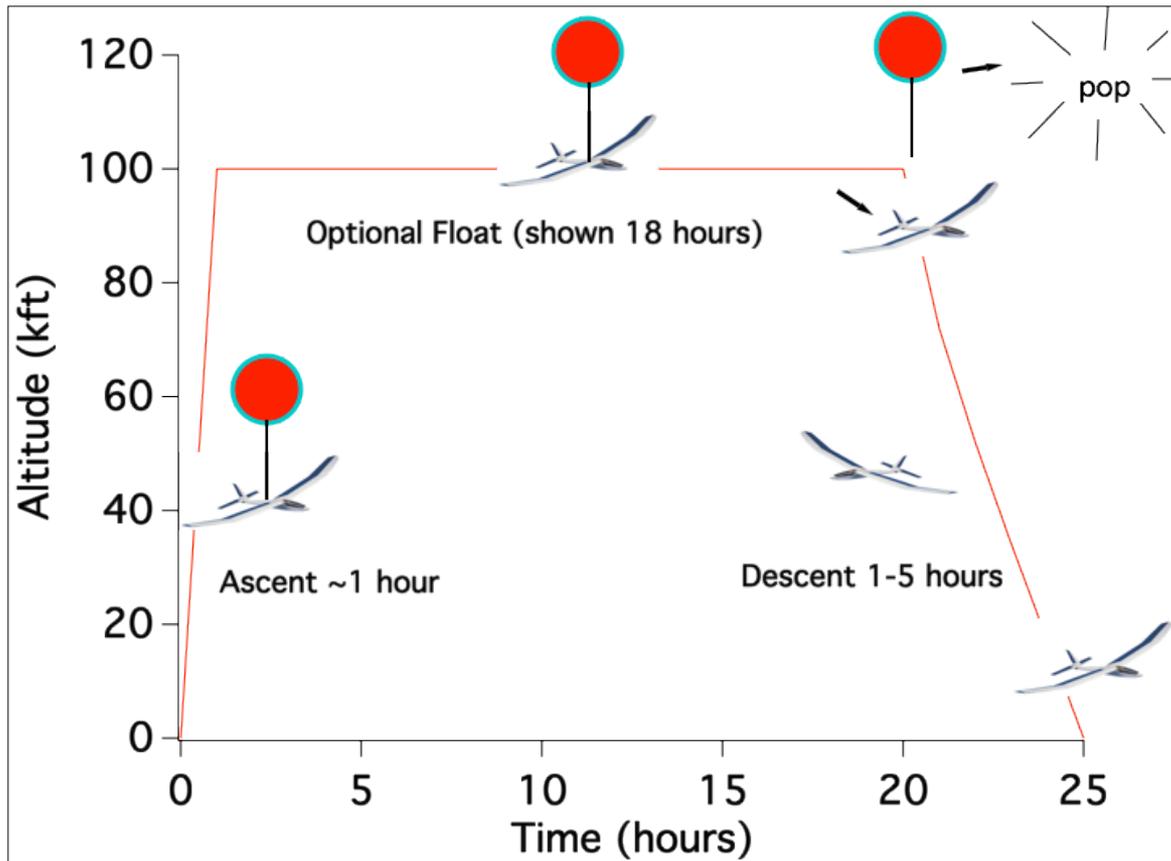
Ray, E. A., et al. (2014), J. Geophys. Res. Atmos., 119, 14,110–14,128, doi:[10.1002/2014JD021802](https://doi.org/10.1002/2014JD021802).



Balloon Assisted Glider UAS

Fred Moore, Co-I, with SwRI SkyWisp at the NOAA David Skaggs Research Center in Boulder CO.





Typical SwRI SkyWisp NOAA Flight Profile

Use a standard weather balloon to assist Glider UAS to altitude then release from balloon and glide it to wave points on the ground for package pickup and delivery to lab to analyze samples.

Approach

OBJECTIVE: Use lightweight version of modified Aircore on a SKYWISP Glider to acquire stratospheric concentration data for purpose of detecting change in transport and climate. Reduce the cost comparable to radio-, ozone- and water-sonde measurement.

METHOD:

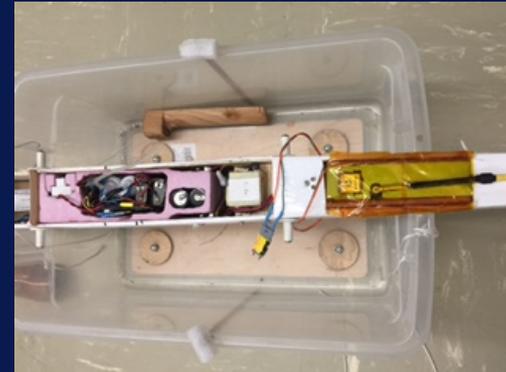
- Target long-lived gases, SF₆, N₂O, CFC-12, CFC-13, CFC-11 and halon-1211 from upper troposphere to 30 km in upper stratosphere.
- Land a balloon atmospheric sensor payload with Aircore™ and/or sonde at prescribed site for recovery.

TEAM: Jim Elkins NOAA/GMD, Fred Moore/CIRES/GMD, Pieter Tans NOAA/GMD.

Sensor and Platform Progress



iMet Radiosonde (white) redesign



Redesign ECC Ozone-sonde (pink) & spare GPS (left)

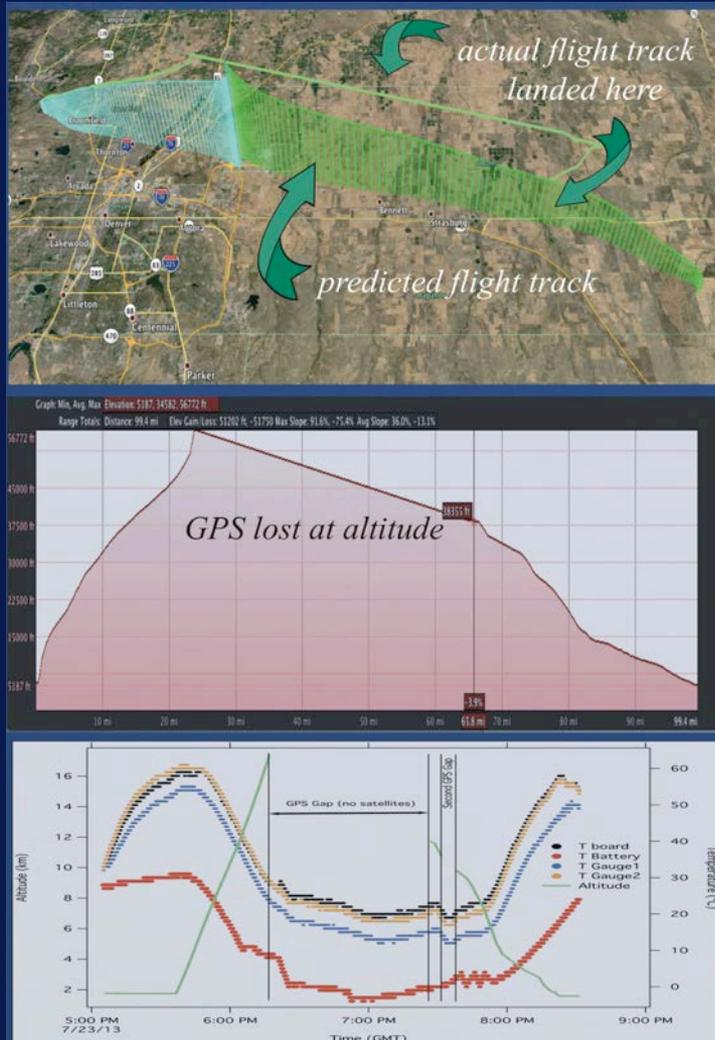


MSR Meteorological Sensor



SkyWisp on Balloon

High Altitude Long Range Flight



- NOAA operated flight with SwRI observer
- Altitude > 60,000 ft
- Range > 100 miles
- Successful flight, tracking, change of flight plane in route.
- Problem: Lost GPS due to cold temperature, but recovered GPS at 38kft.
- High surface winds made recovery difficult, NOAA pilot caused body damage.
- Autopilot could have landed SkyWisp.

Key Project Milestones

1. Build Analyzer for Aircore samples. (Completed mid-2013)
 2. AirCore has been put together and tested in the lab to give 5 mbar resolution at 1% accuracy. In progress is the the electronics for the P, T measurements that are necessary to register those 5 mbar measurements to the atmosphere.
 3. Acquire and analyze several samples of stratospheric air to recover the Aircore™ from two balloon flights. (in Progress)
 4. Get COA to operate SKYWISP in NAS. (Completed 01/13)
 5. Test fly SKYWISP with ozone and/or radiosonde package. Include training for OMOA pilots. (Completed 07-08/13)
 6. Conduct test flights with reduced volume Aircore™ on SKYWISP. Three flights during two different seasons. (in Progress)
 7. Flown open source Aero powered glider with great success (Summer 2014-2016)
 8. Demonstrate quality of data set through tracer-tracer analysis with comparison to previous and concurrent data sets (in Progress)
- Current TRL:5 Test and demonstrate in relevant environment
Final Goal TRL:9.

Accomplishments and Issues

PERFORMANCE PERIOD: 05/12 - 08/16

ACCOMPLISHMENTS:

Designed Radio- and Ozone- sonde instrument for SkyWisp 07/12

Lab test of SkyWisp works /Demonstration of SkyWisp on roof 11/12

Received FAA ruling that SkyWisp doesn't require COA. 01/13

Flight Training conducted twice by SWRI 06-07/13

Flew HD camera on high altitude flight (~57 kft) over Front Range. Loss link due to previous crash with nearly invisible wire cut 07/13

Developed backup GPS system to track sUAS using "dog-collar" 02/15

Two publications from this research:

Gao, R. S., J. W. Elkins, G. J. Frost, A. C. McComiskey, F. L. Moore, D. M. Murphy, J. A. Ogren, I. Petropavlovskikh, and K.H. Rosenlof (2015) A Novel Approach to Atmospheric Measurements Using Gliding UASs. In: Ravela S., Sandu A. (eds) Dynamic Data-Driven Environmental Systems Science (DyDESS 2014) . Lecture Notes in Computer Science, vol 8964. Springer, ChamS. Ravela and A. Sandu (Eds.): LNCS 8964, pp. 10–15, 2015. DOI: 10.1007/978-3-319-25138-7_2

Moore, F. L., E. A. Ray, K. H. Rosenlof, J. W. Elkins, P. Tans, A. Karion and C. Sweeney, (2014), A Cost-Effective Trace Gas Measurement Program for Long-Term Monitoring of the Stratospheric Circulation, *Bulletin of the American Meteorological Society*, 95, 1,doi: 10.1175/BAMS-D-12-00153.1

Lessons Learned and Next Steps

- Project was modestly funded, plus we were able to get two Hollings Students.
- A DoD balsa wood glider with proprietary software and hardware is not the best way to go.
- We have had considerable success at low altitude with Styrofoam gliders and open source software is better and less expensive way to go forward. Aero glider (3DRobotics)
- Our FAA CoA exception is not longer valid, so we must work out a deal with DoD and using restricted air space (e.g. like NASA Armstrong/Edwards AFB, CA).
- There are many examples that atmospheric circulation has changed, most likely the result of global atmospheric climate change.

Questions?



Open Source Pixhawk and 3DRobotics Aero