# Design of a novel aircraft open path cavity ringdown spectrometer

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## Background

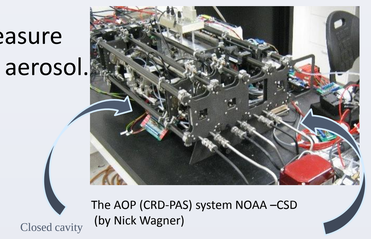
**Aerosols and their effect on the radiative properties of clouds contribute one of the largest sources of uncertainty to the Earth's energy budget.**

### Current measurements of aerosol optical properties

Typically, measured by drawing an aerosol sample into a cabin based instrument through long lengths of tubing.

However, these methods does not measure the actual **ambient conditions** of the aerosol.

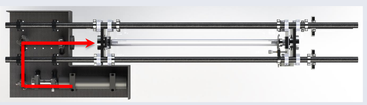
- Loss of large particles
- Changes in the hydration state
- Loss of volatile compounds



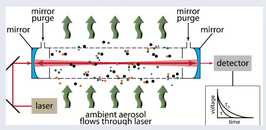

The AOP (CRD-PAS) system NOAA –CSD (by Nick Wagner)

### Deployment of a NOAA ground based open path extinction measurement

The NOAA CRD open oath cavity ring down was developed to avoid these sampling issues (described in Gordon et al 2015[1])

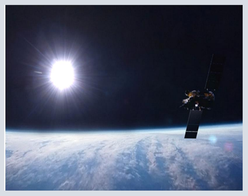


The NOAA-CSD Open path cavity ring down



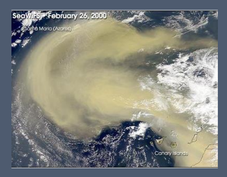

### Mounting an open path extinction measurement externally to the aircraft cabin

Validate remote sensing measurements



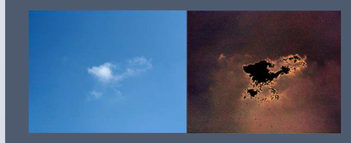
NASA image by Ryan Zuber, GSFC Scientific Visualization Studio

Enable us to study course mode aerosols (dust and sea salt)




Satellite picture from SeaWIFS showing dust transported from the Sahara; NASA

Study aerosols under a range of RH conditions (in the vicinity of clouds)



From Koren at al 2007 [2], An image of a cloud and the "twilight zone" taken from the ground using a digital camera

Developing a self consistency for large multi-instrument field studies

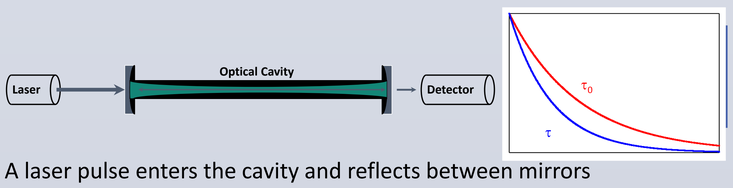
CRD-PAS

Aerosol mass spectrometer(AMS)

PALMS

PALMS

## Aerosol measurements using Cavity ring down (CRD)



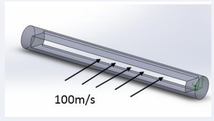

- A laser pulse enters the cavity and reflects between mirrors
- With each reflection a fraction of light is transmitted through one mirror to a detector.
- When the pulse is absorbed or scattered by particles the transmitted light decreases.
- The extinction coefficient $\alpha_{extinction}$ is a function of the decay rate with and without particles ($\tau$ and $\tau_0$, respectively) in the cavity

where c is the speed of light, L is the cavity length, and d is the sample length.

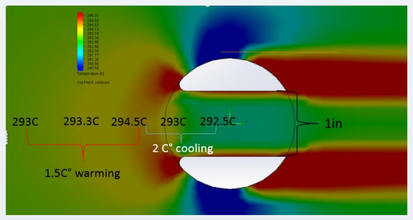
- The precision and accuracy of this method are very high
- However, the system needs to be zeroed frequently

## Flow simulation results for the temperature profile

### Open/close tube design

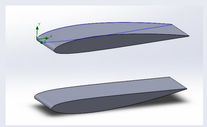


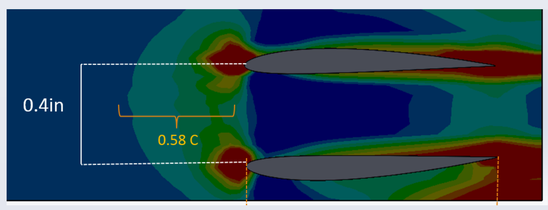

Residence time ~ 0.5 ms




**The flow simulation shows that a close/open tube design could not maintain ambient conditions due to heating the stagnation points**

### Airfoil profile design



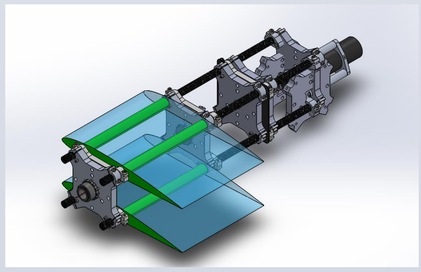



## Zeroing the cavity

Since it is very difficult to design an open/closed cavity for repeated zeroing during flight:

- An open CRD will be mounted outside the aircraft
- An additional closed CRD will be constantly zeroing inside the aircraft
- A camera and a PMT will be placed together to detect changes in the alignment during the flight
- Zero box will be designed for use before takeoff
- The alignment will be tested in clean aerosol conditions (high altitudes)

## Main design challenges



Drawing of the current open path cavity ring down design for an aircraft

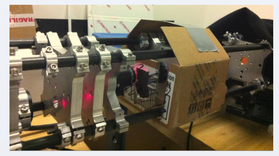
**1) Maintain ambient sampling conditions**

- The aerosols sampled in the cavity should be measured at the ambient temperature RH
- The flow regime inside the cavity needs to well characterized

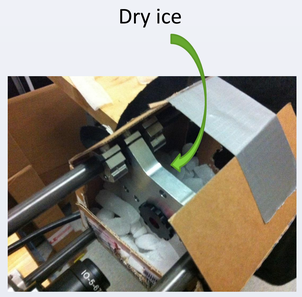
**2) The cavity need to maintain high stability in flight conditions**

- The system needs to be easily aligned and rigid at the same time
- The alignment needs to be resistant to external vibration and temperature gradient

## Laboratory test for temperature gradient



The instrument show no significant change in the alignment even in a steep temperature gradient (room temp vs dry ice)




## Future instrument testing and implementation

The instrument will be mounted on the window of the NOAA van
This experiment will be testing :

- The changes in the alignment due to vibration
- Changes in the alignment due to temperature gradient
- Some indication for the effect of the flow regime on the result ( i.e. with and without airfoils, different air velocity)

**FIREX NOAA :**
Fire Influence on Regional and Global Environments Experiment


## Acknowledgments

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Thanks to Richard McLaughlin, Rebecca Washenfelder and Bill Dube

## References

1) T. D. Gordon, N. L. Wagner, M. S. Richardson, D. C. Law, D. Wolfe, E. W. Eloranta, C. A. Brock, F. Erdesz & D. M. Murphy (2015) Design of a Novel Open-Path Aerosol Extinction Cavity Ringdown Spectrometer, Aerosol Science and Technology, 49:9, 717-726, DOI: 10.1080/02786826.2015.1066753

2) I. Koren, L.A. Remer, Y.J. Kaufman, Y. Rudich, J.V. Martins
On the twilight zone between clouds and aerosol. Geophys Res Lett, 34 (2007), p. 8805