



# New evidence of ice particle shattering by OAP-2DC



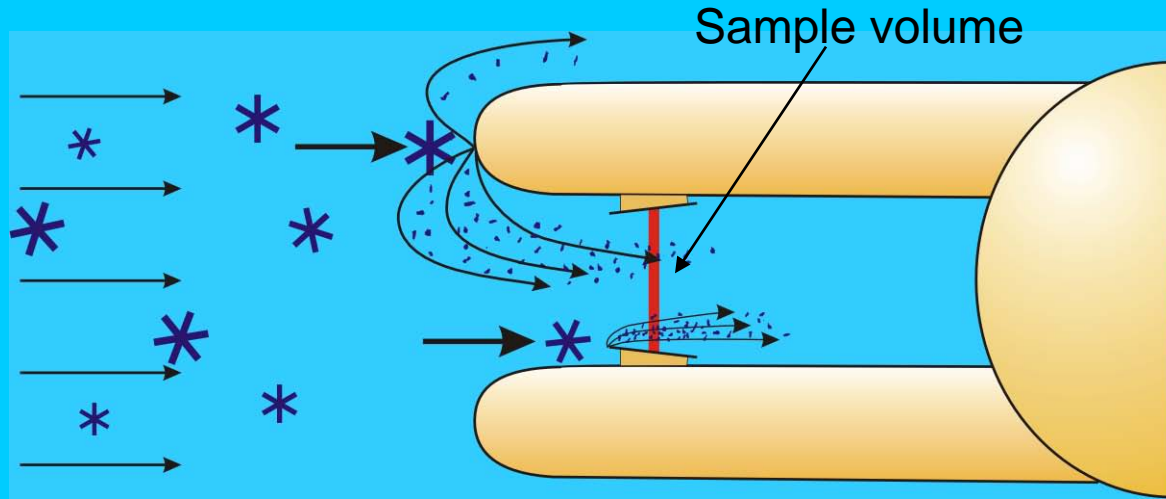
**Alexei Korolev, Walter Strapp**  
*Environment Canada, Toronto, Ontario, Canada*

**Ed Emery**  
*NASA, Cleveland, OH, USA*

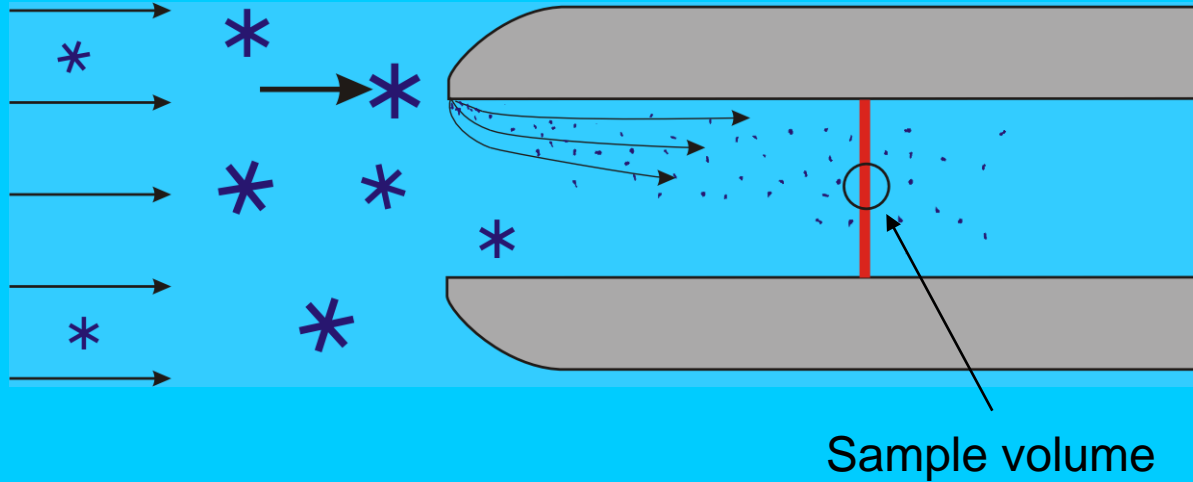
## **Objective:**

To estimate the effect of airborne probe inlets on the accuracy of ice particle measurements

**OAP-2DC, OAP-2DP, HVPS, CIP**



**FSSP, CPI, CAPS, SID**

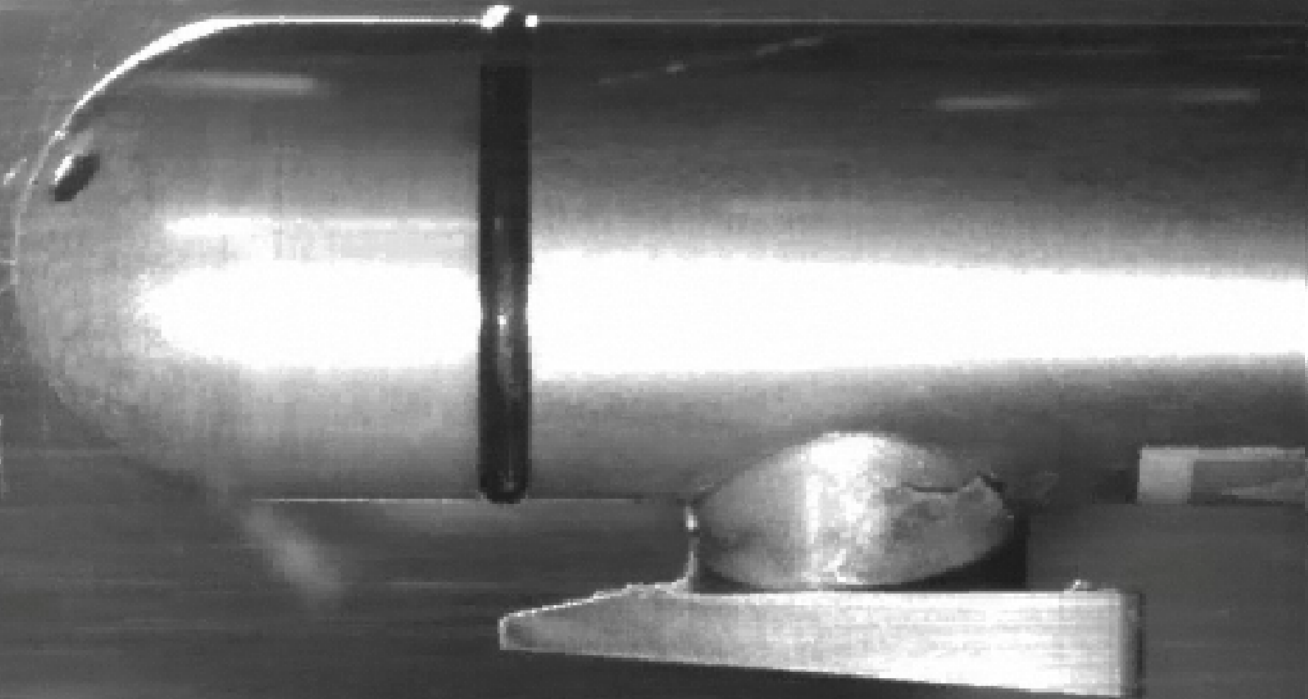


## Cox Wind Tunnel

OAP-2DC arm

D ~ 2.5cm

TAS ~ 70m/s



**How can shattering events be identified from measurements?**

# OAP-2DP (200 $\mu\text{m}$ pixel resolution)

OAP-2DP; MSC 6 February 2003; 20:44:11.32



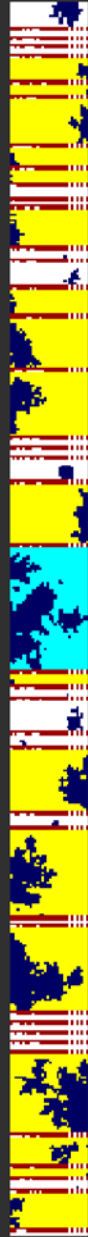
OAP-2DP; MSC 6 February 2003; 20:45:03.05



OAP-2DP; MSC 6 February 2003; 20:45:07.11



OAP-2DP; MSC 6 February 2003; 20:44:29.60



OAP-2DP; MSC 6 February 2003; 20:44:21.32



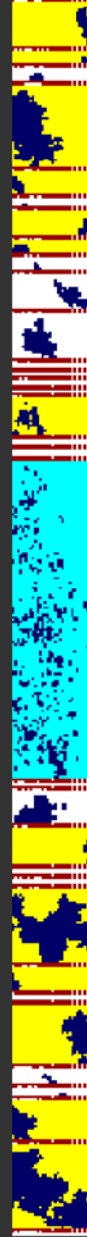
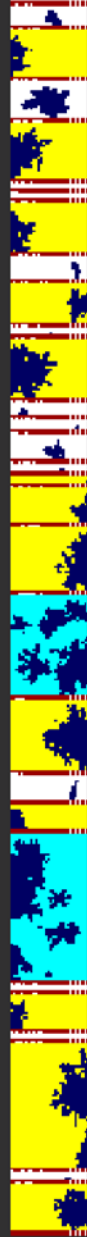
OAP-2DP; MSC 6 February 2003; 20:45:21.28



OAP-2DP; MSC 6 February 2003; 20:43:38.05

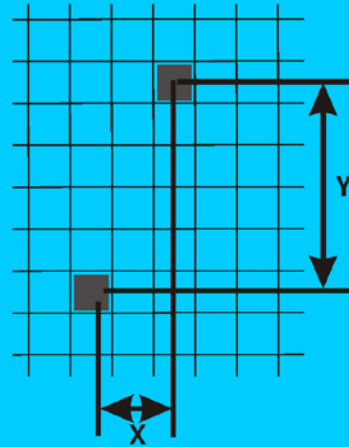
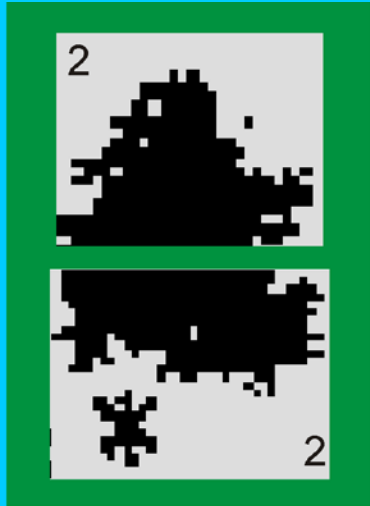


OAP-2DP; MSC 22 February 2003; 22:43:08.13

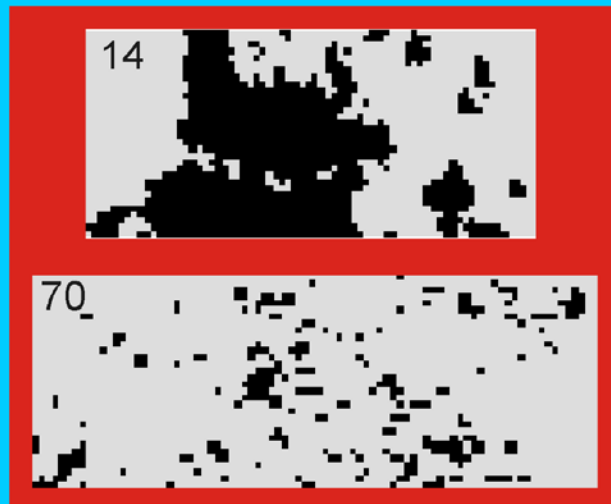
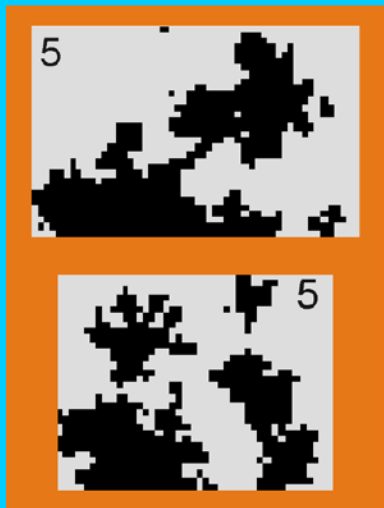


6.4mm

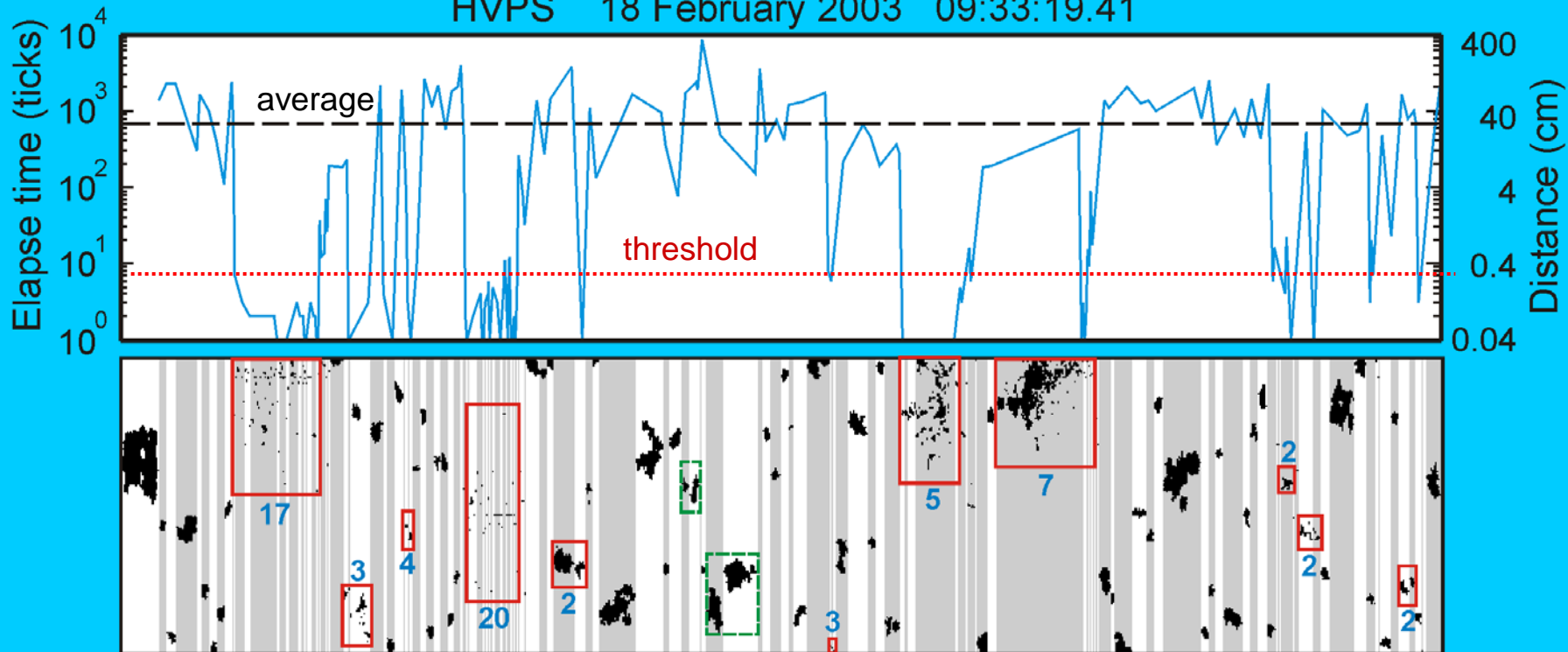
# Set of criteria for identifying images of shattered particles



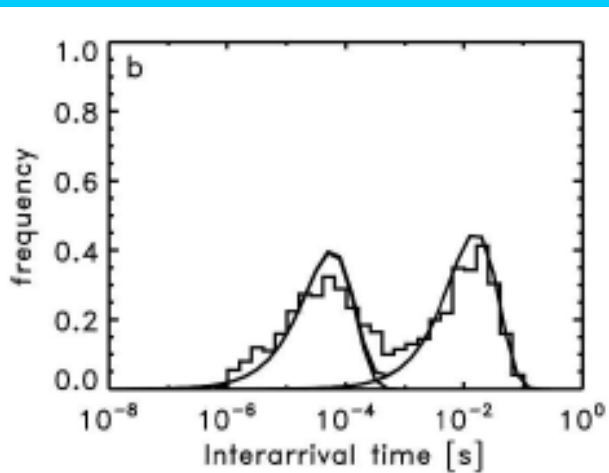
1. Number of fragments
2. Relative size of fragments
3. Gaps in X and Y directions
4. Area density



HVPS 18 February 2003 09:33:19.41



### Bimodal distribution of interarrival time



Field et al. 2006



# Shattering events can be identified based on:

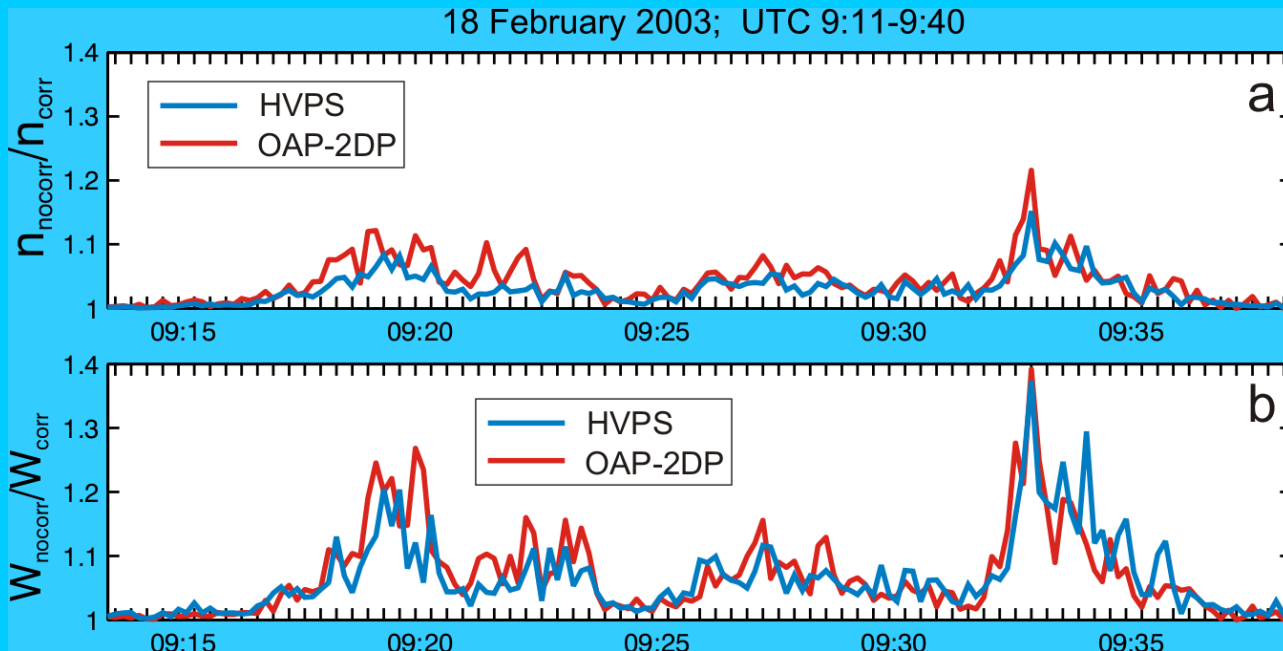
## 2D (imaging) probes:

the combination of rules for interarrival time, size of fragments and number of fragments in the image  
(Korolev and Isaac, 2005, Field et al. 2006, Baker et al. 2008)

## 1D probes:

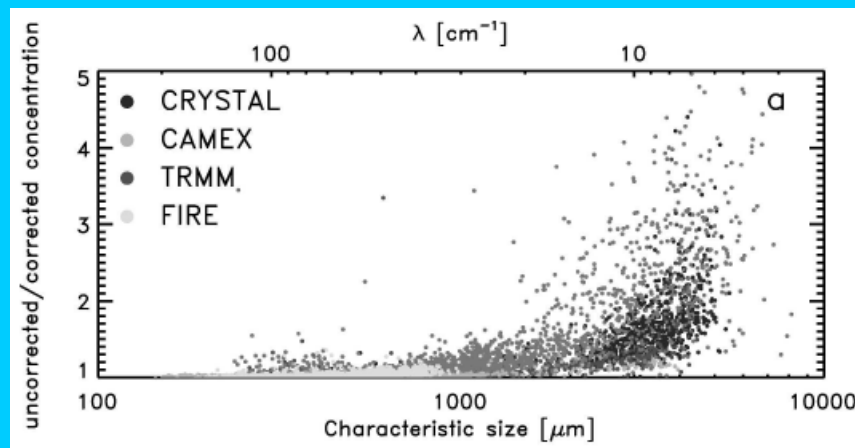
interarrival time  
(Field et al. 2003)

# Relative errors in the concentration and mass calculations caused by ice particles shattering in OAP-2DP and HVPS



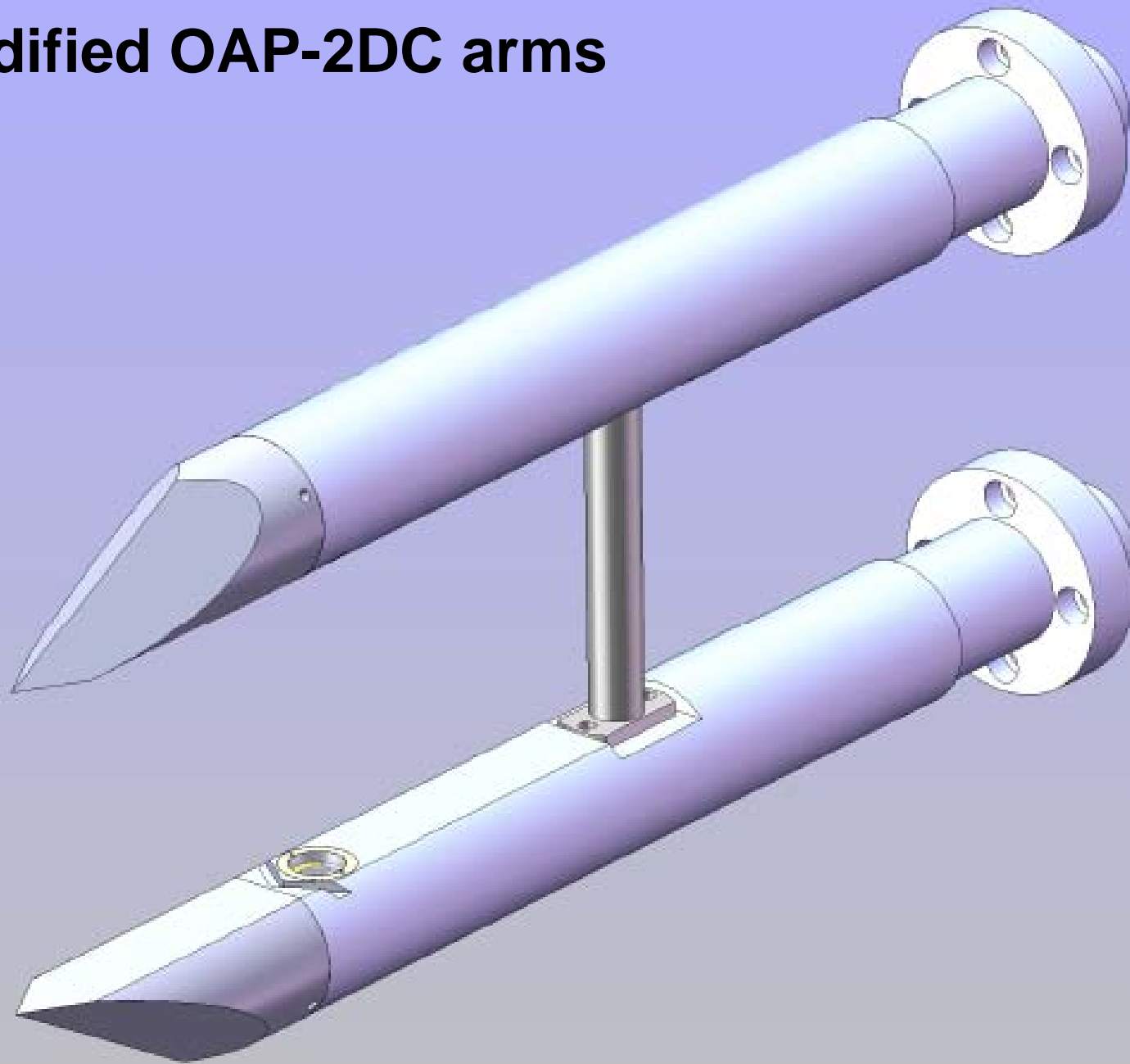
UTC (hh:mm)

Korolev and Isaac, 2005



Field et al. 2006

# Modified OAP-2DC arms





10° angle of attack



Cox Wind Tunnel; Mar-2008

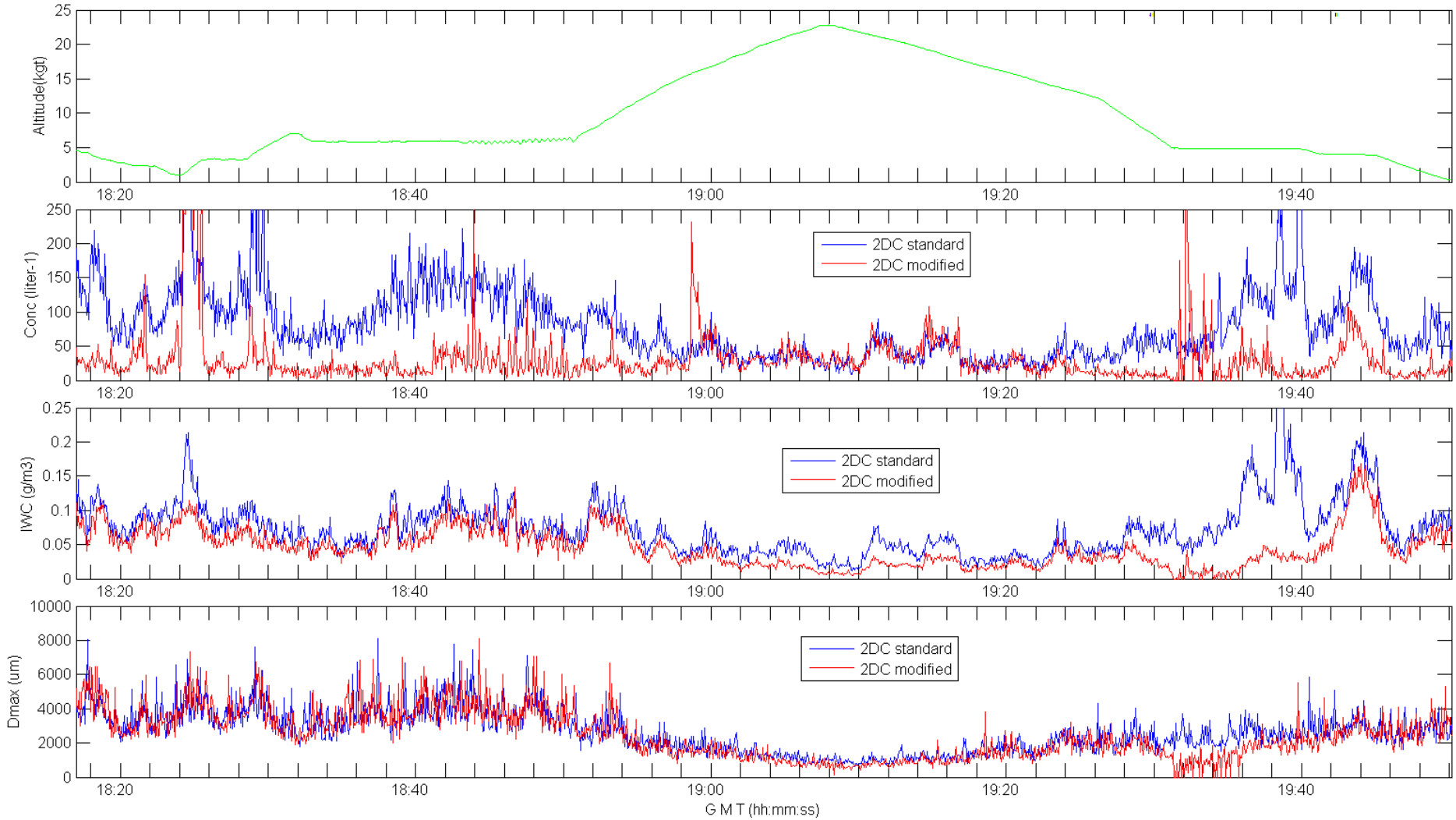


**30 April 2008, NRC Convair 580, ISDAC, Fairbanks**



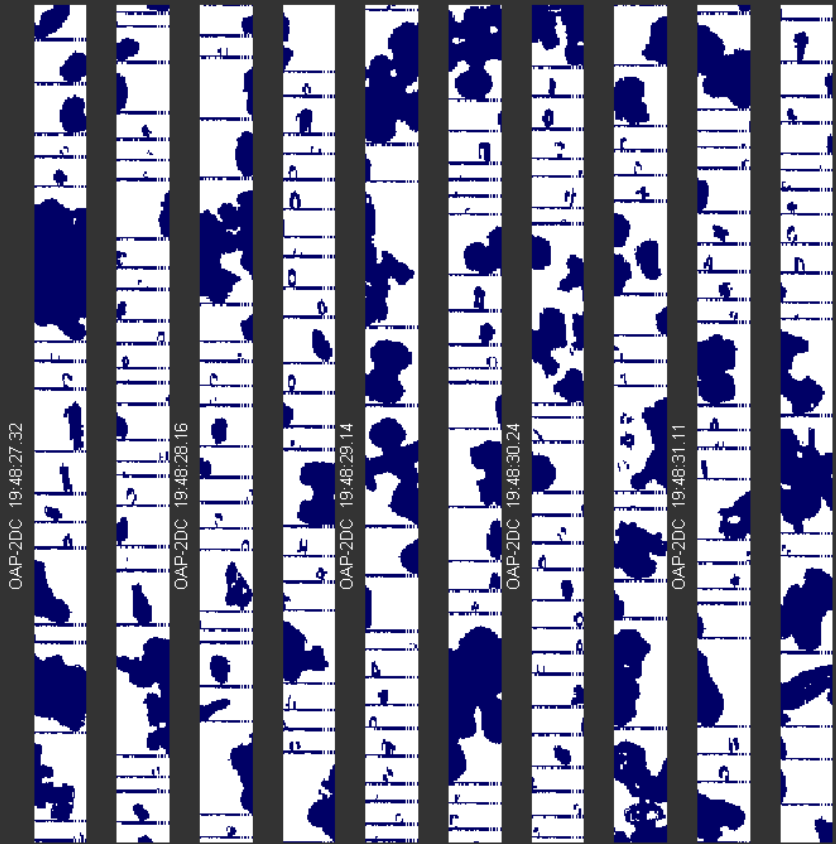
# Comparison of OAP-2DC with modified and standard arms

30 April 2008, ISDAC, Fairbanks



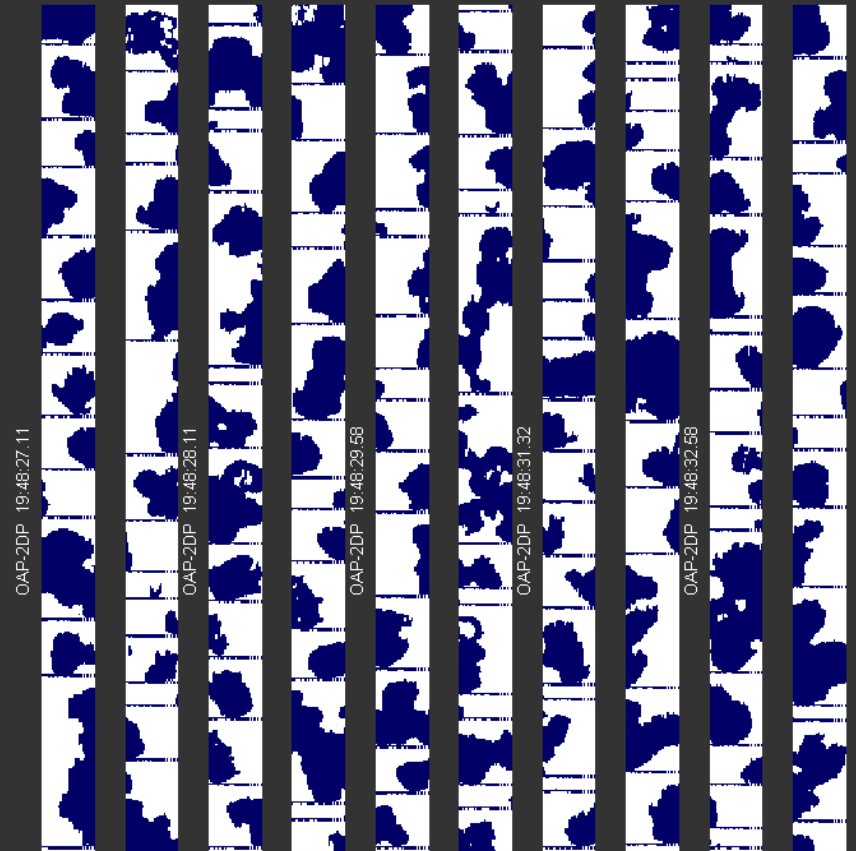
# Standard OAD-2DC arms

30 April 2008



# Modified OAD-2DC arms

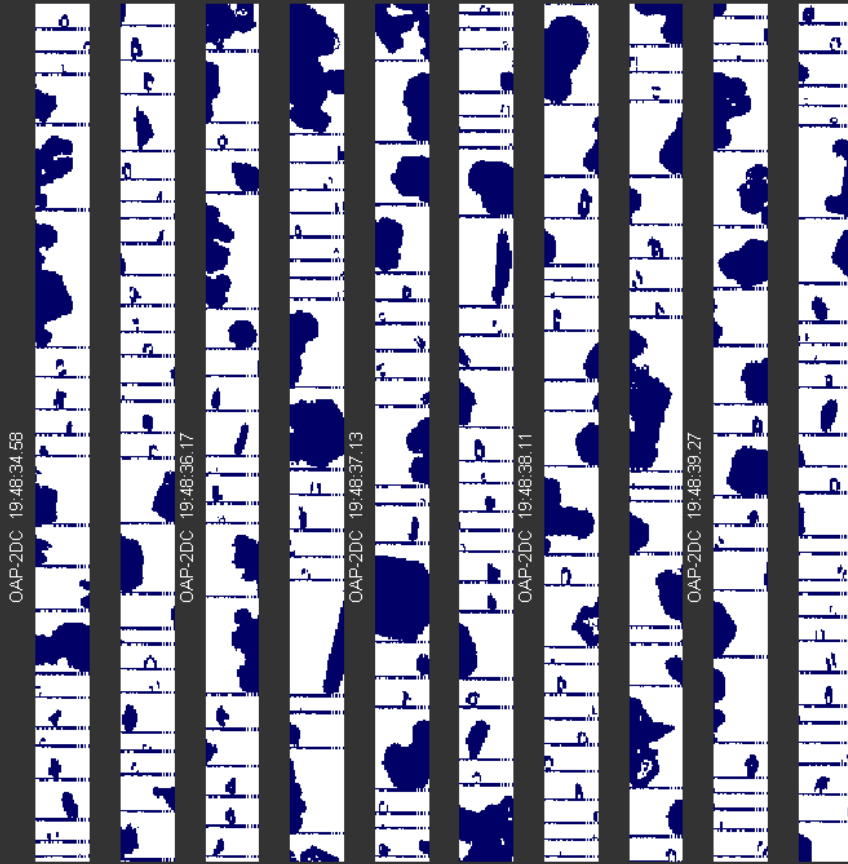
30 April 2008





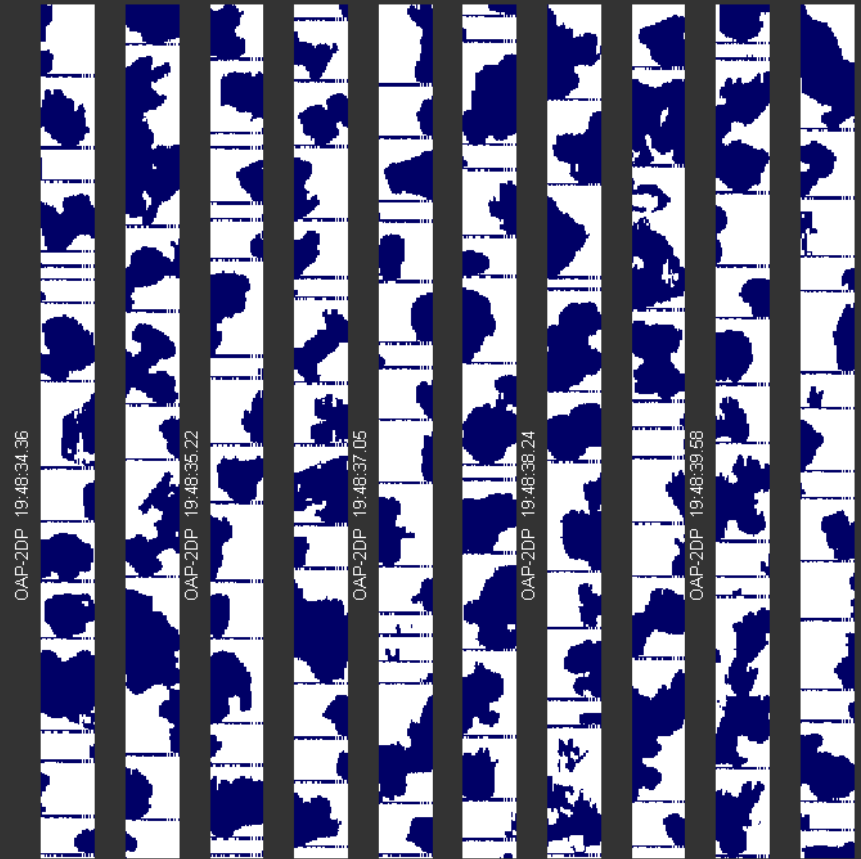
# Standard OAD-2DC arms

30 April 2008

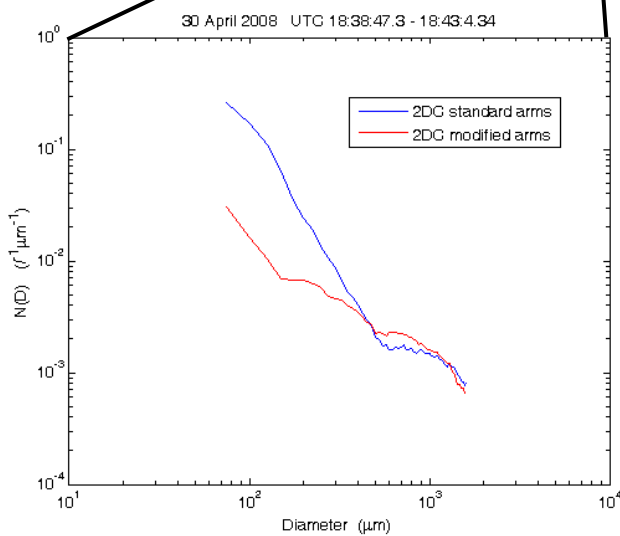
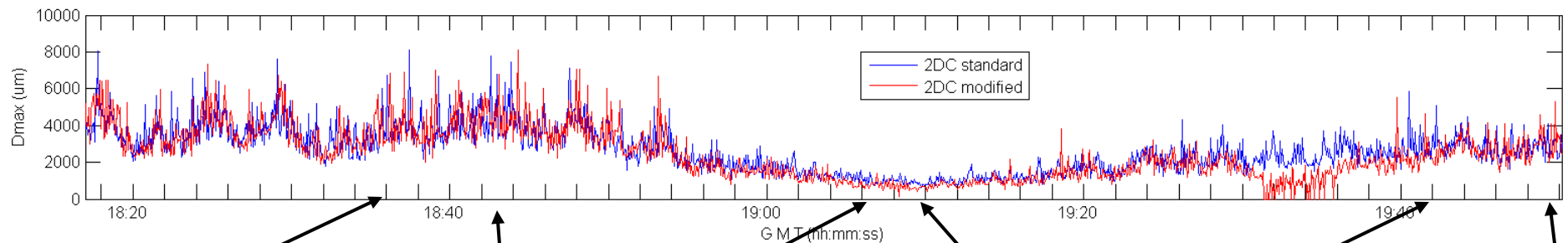
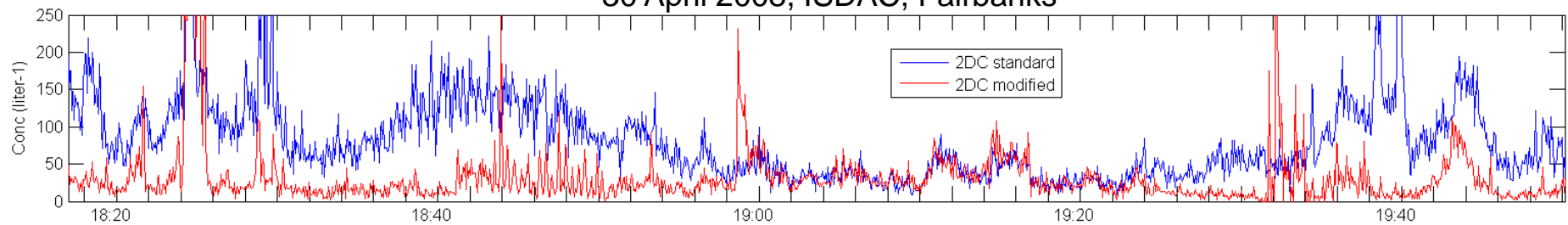


# Modified OAD-2DC arms

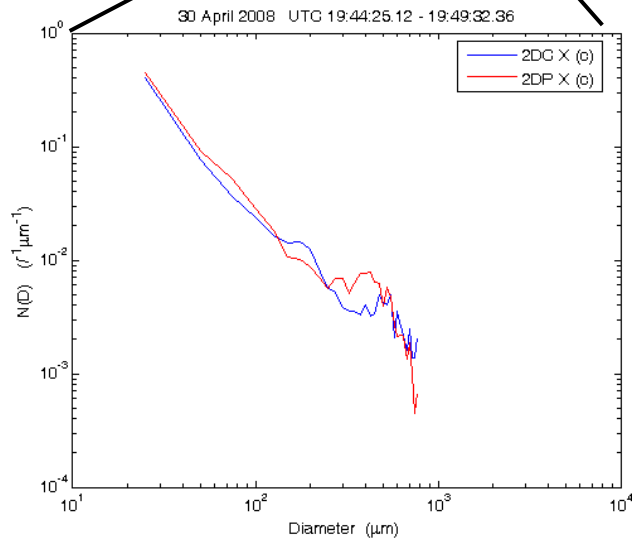
30 April 2008



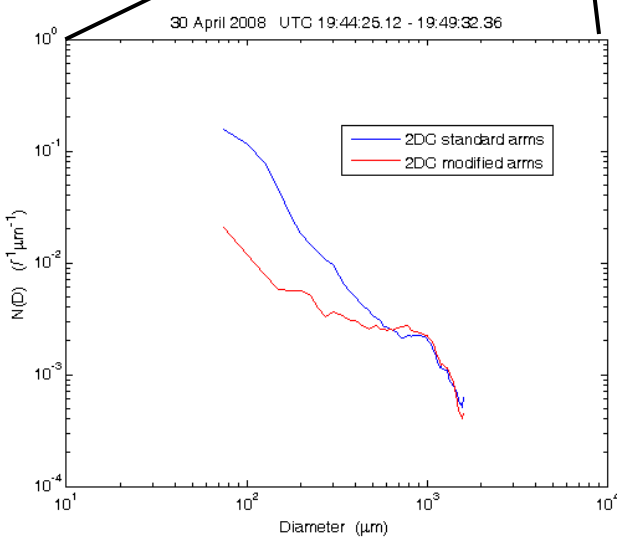
# 30 April 2008, ISDAC, Fairbanks



Large particles:  $D_{\text{max}} \sim 4\text{-}6\text{mm}$

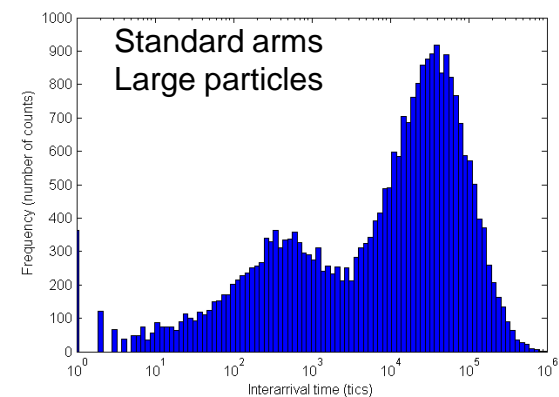
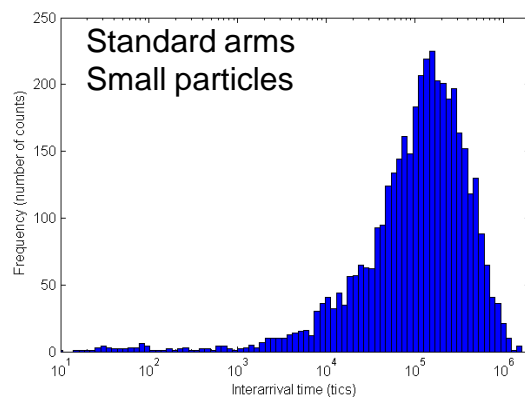
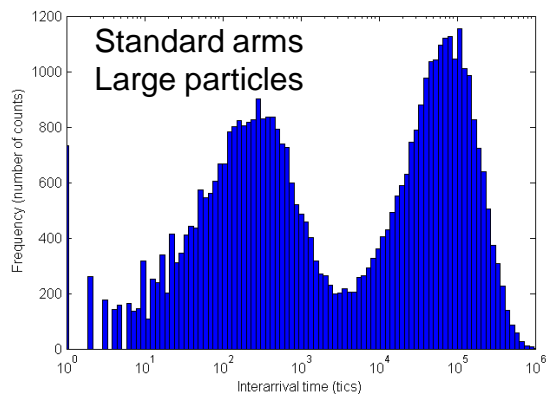
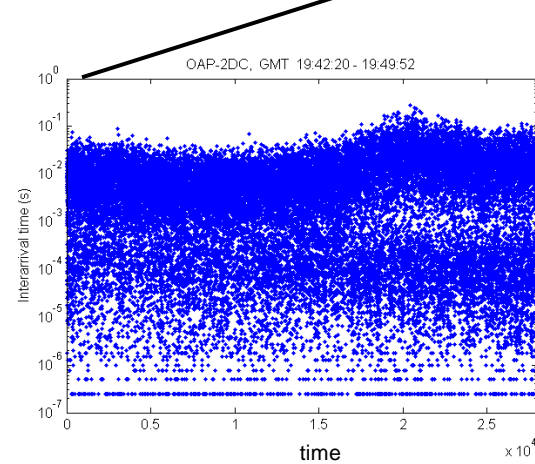
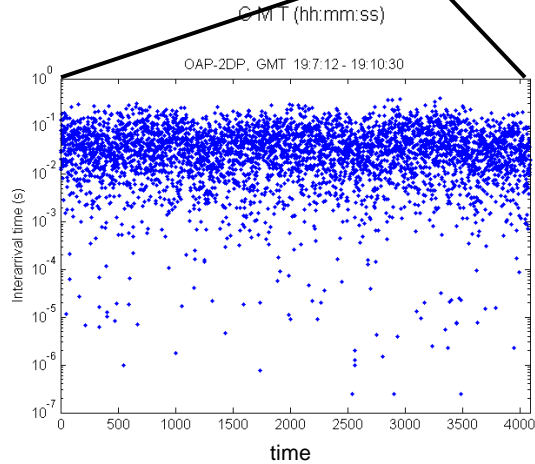
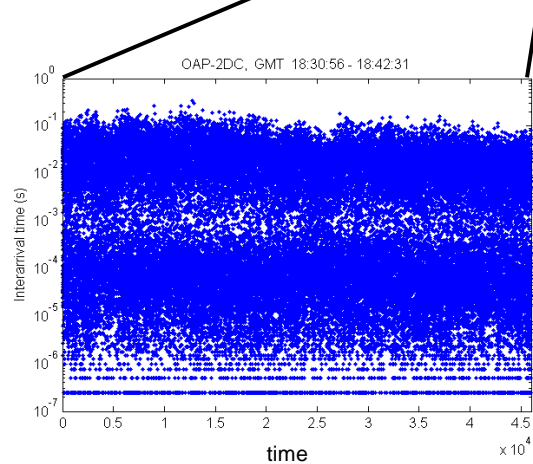
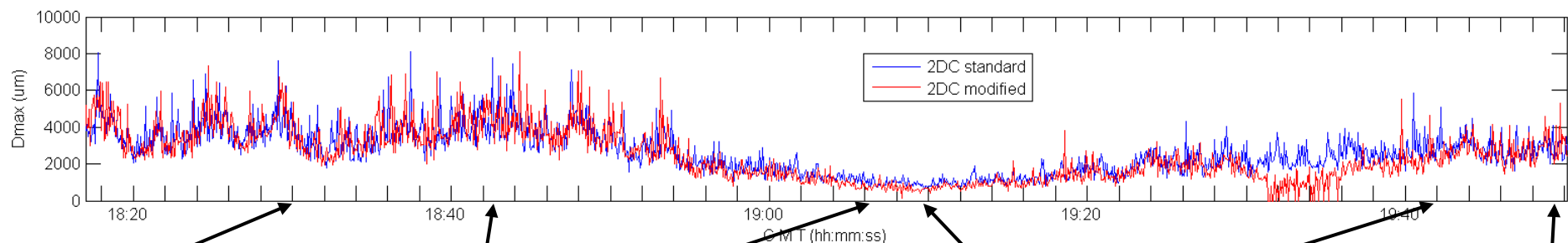
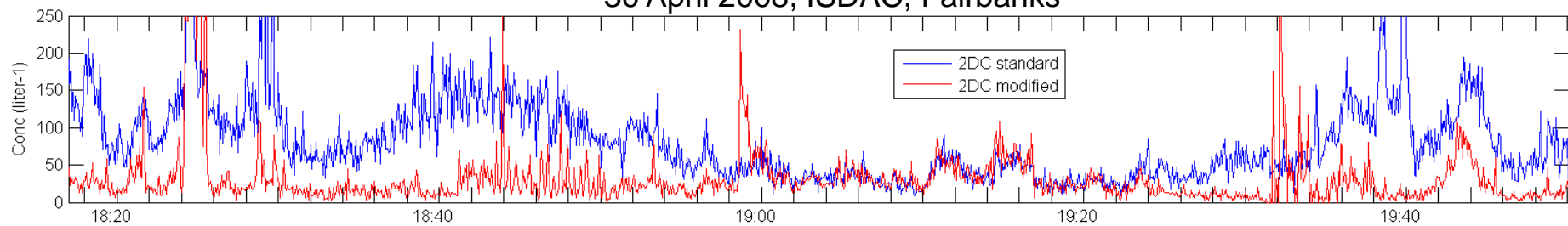


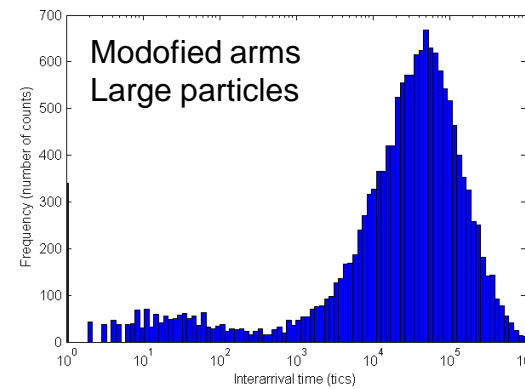
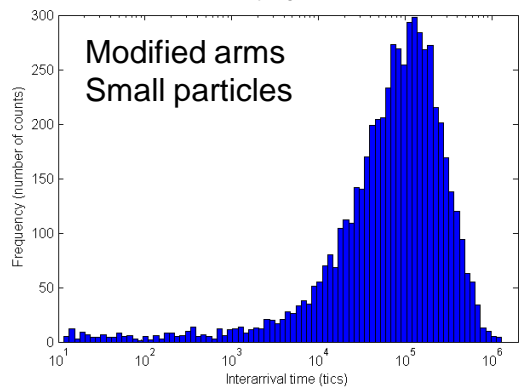
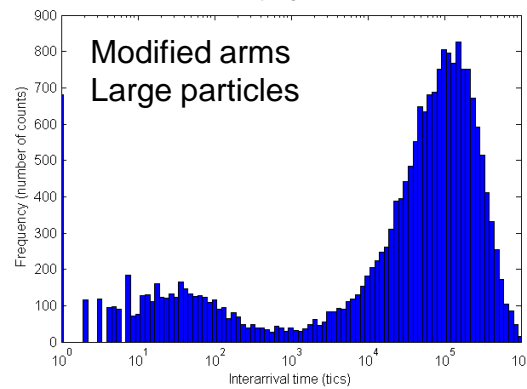
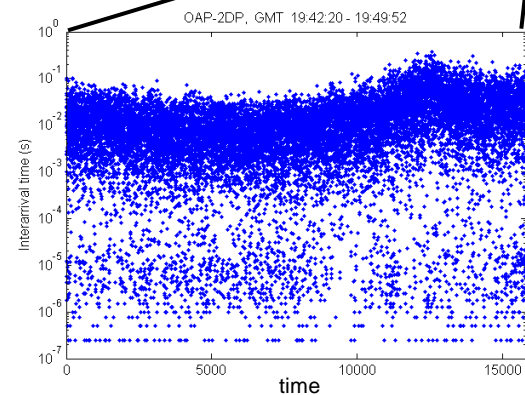
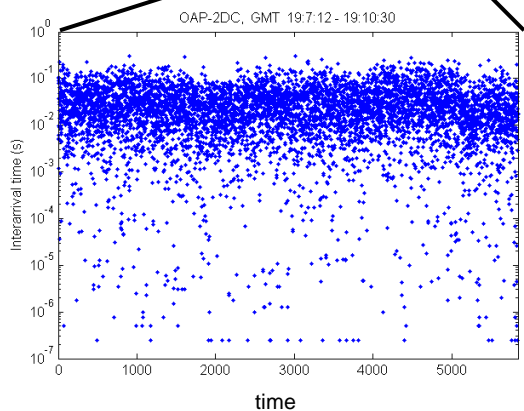
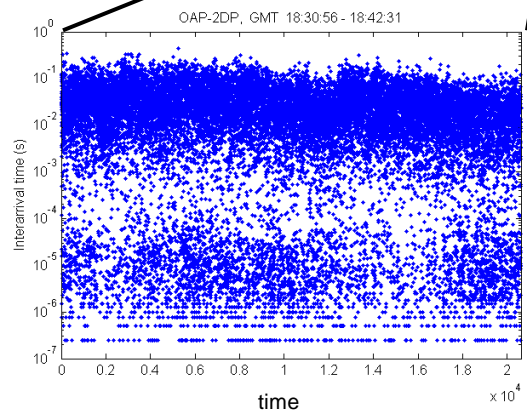
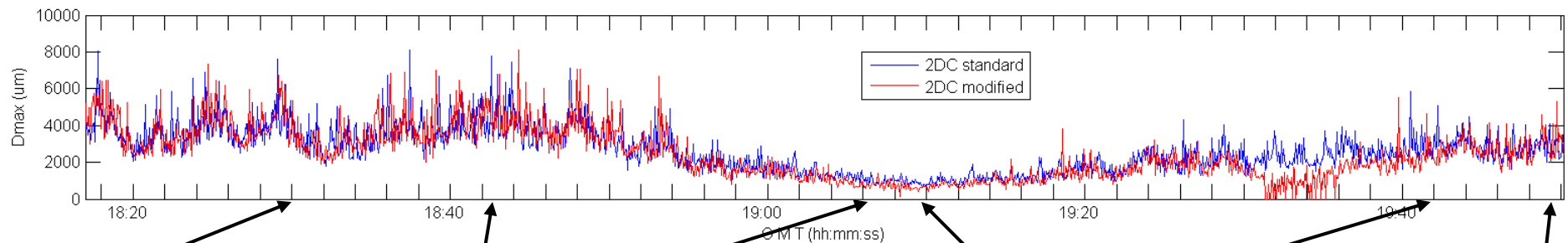
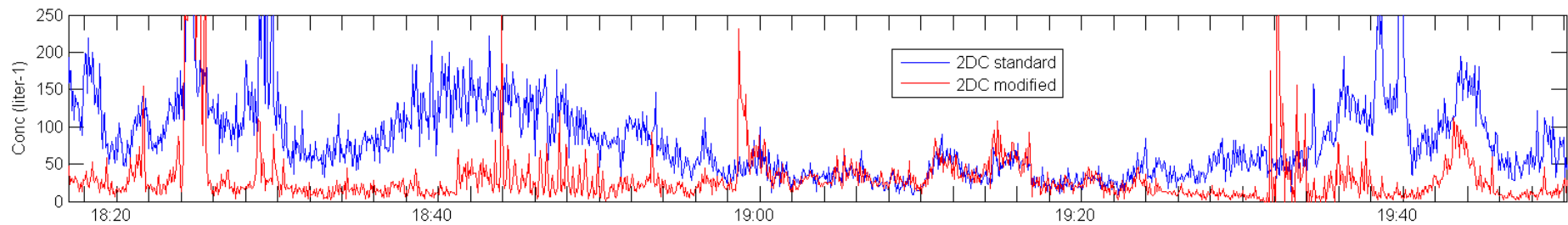
Small particles:  $D_{\text{max}} \sim 1\text{mm}$



Large particles:  $D_{\text{max}} \sim 2\text{-}4\text{mm}$

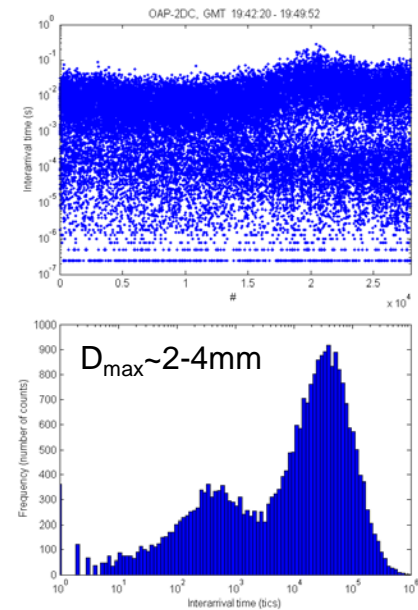
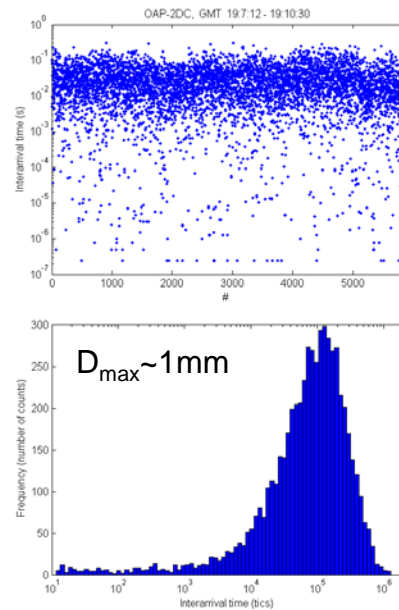
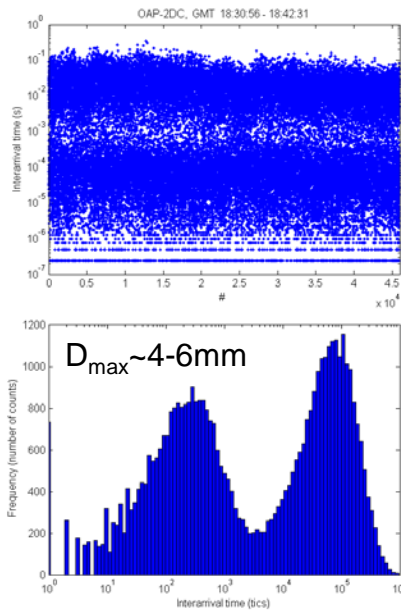
# 30 April 2008, ISDAC, Fairbanks



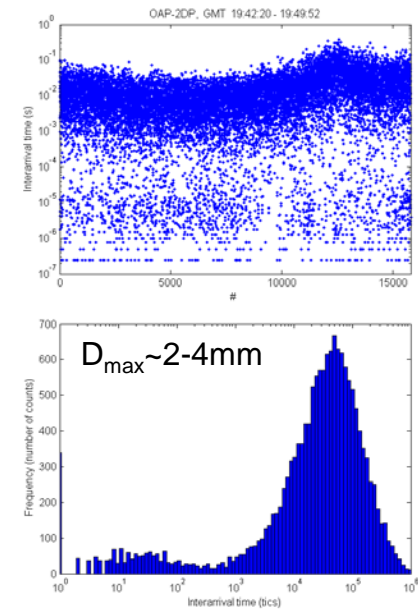
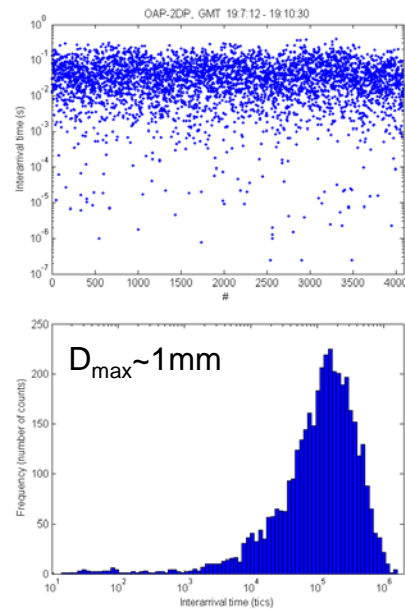
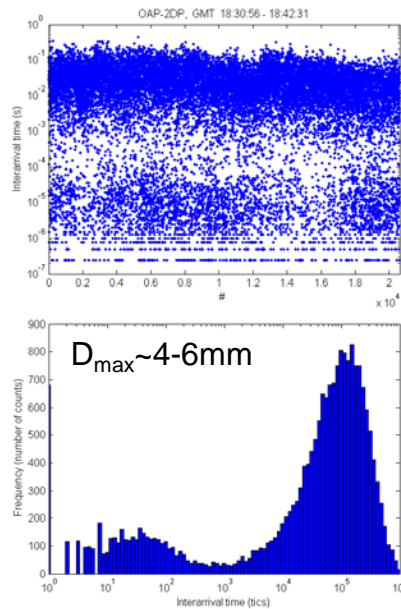


# Statistics of OAP-2DC interarrival time

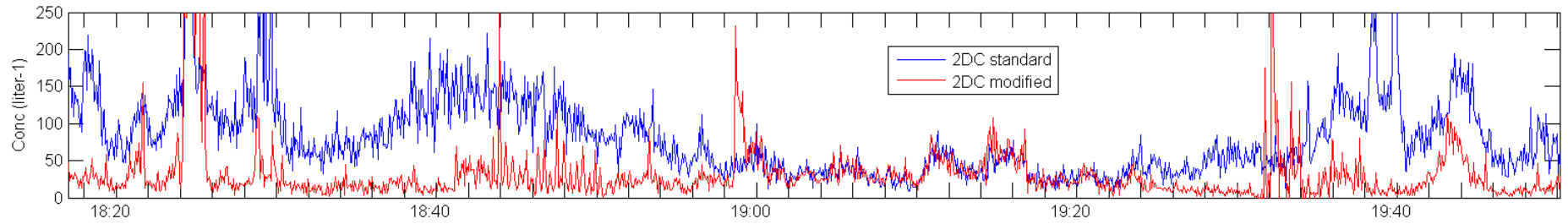
Standard arms



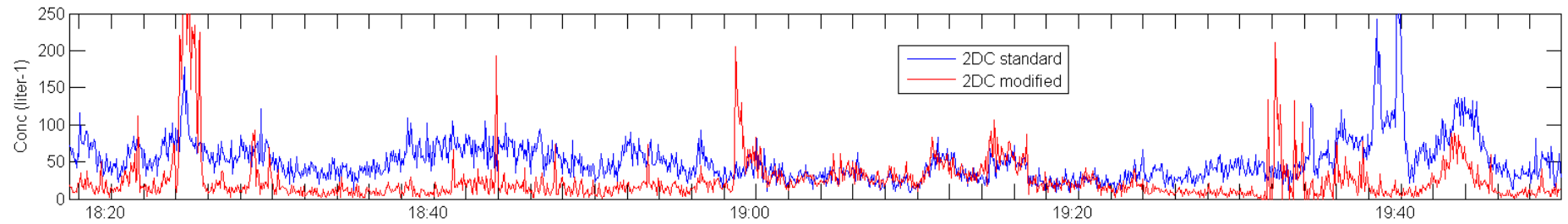
Modified arms



## No corrections on shattering



## After corrections



# Rejected and accepted OAP-2DC images

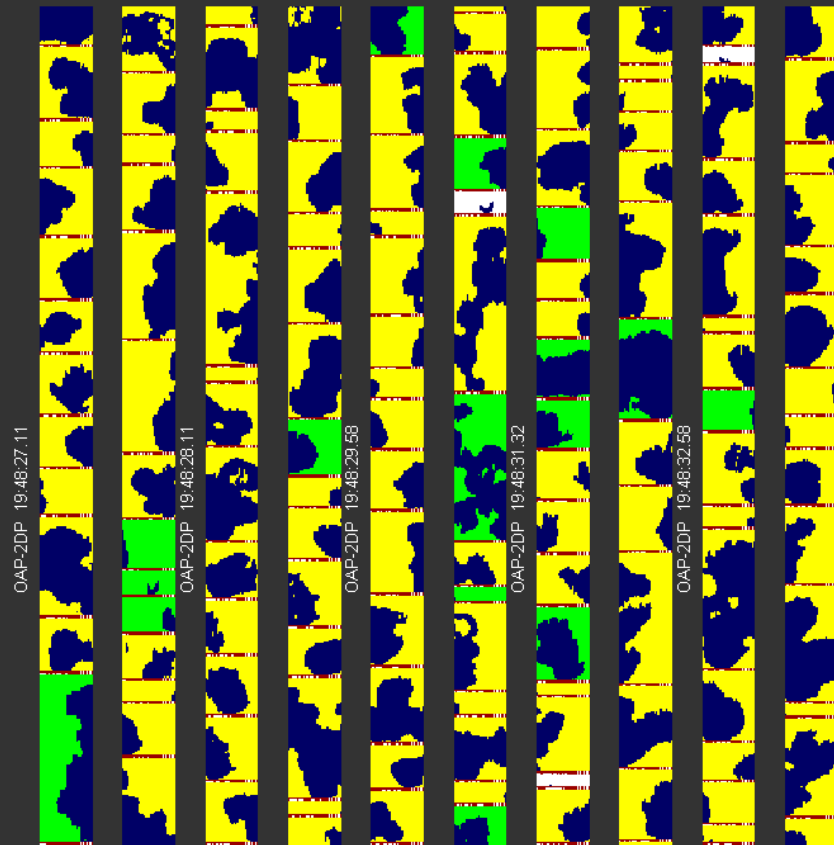
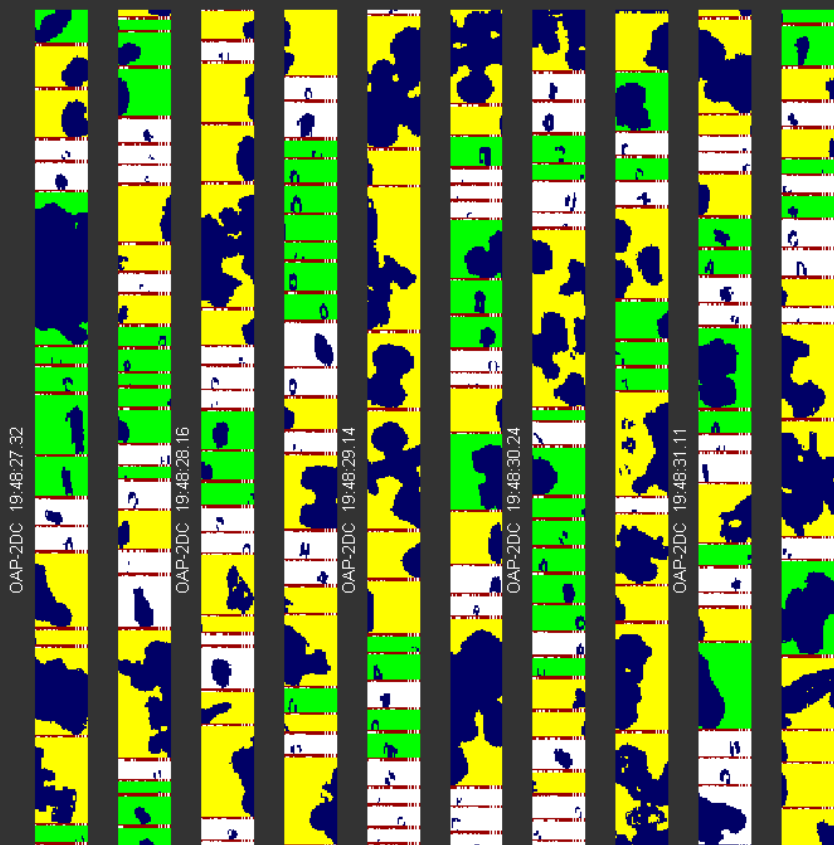
$$\tau_{\text{rej}}=1000 \text{ tics} \Leftrightarrow \Delta X=2.5\text{cm}$$

## Standard OAD-2DC arms

## Modified OAD-2DC arms

30 April 2008

30 April 2008



 interarrival time     aspect ratio     partial images     complete images

# Rejected and accepted OAP-2DC images

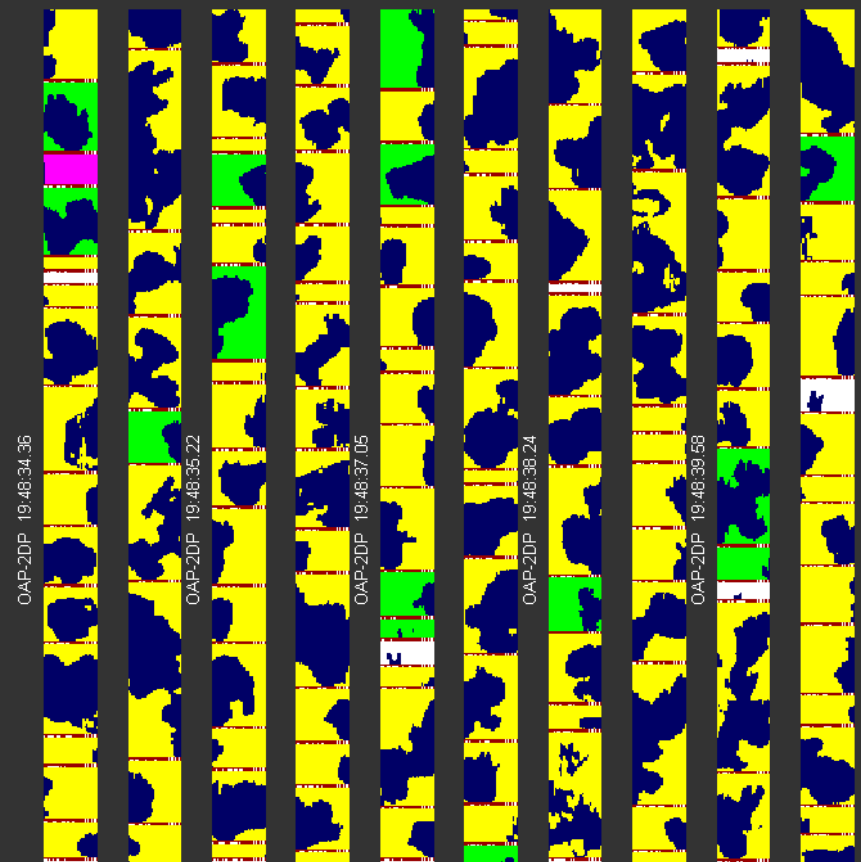
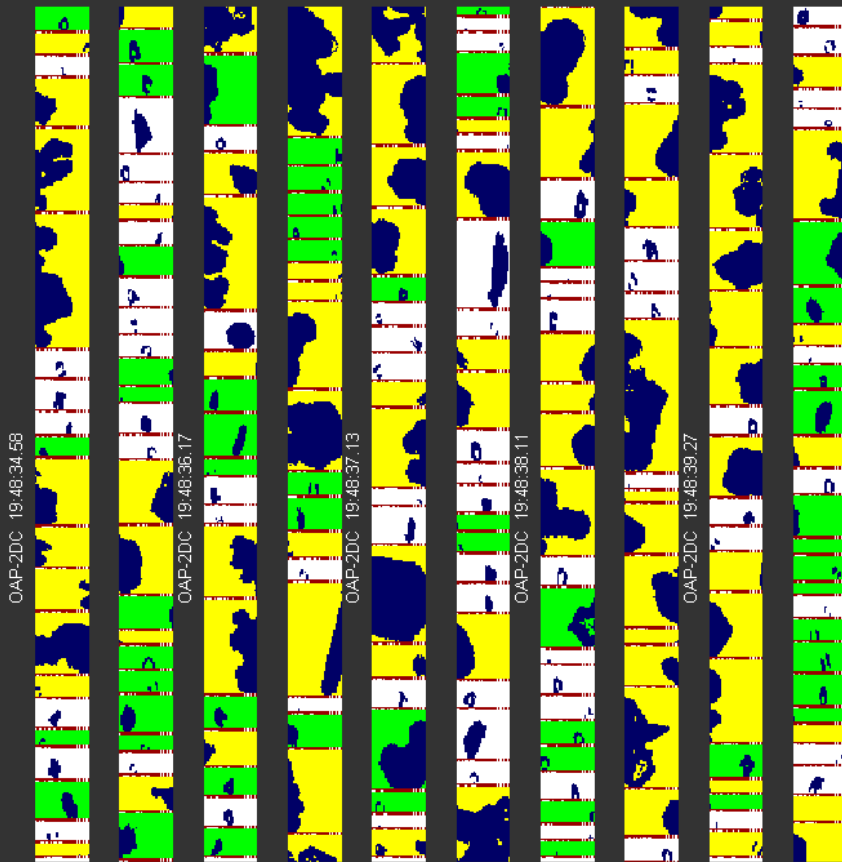
$$\tau_{\text{rej}}=1000 \text{ tics} \Leftrightarrow \Delta X=2.5\text{cm}$$

## Standard OAD-2DC arms

## Modified OAD-2DC arms

30 April 2008

30 April 2008

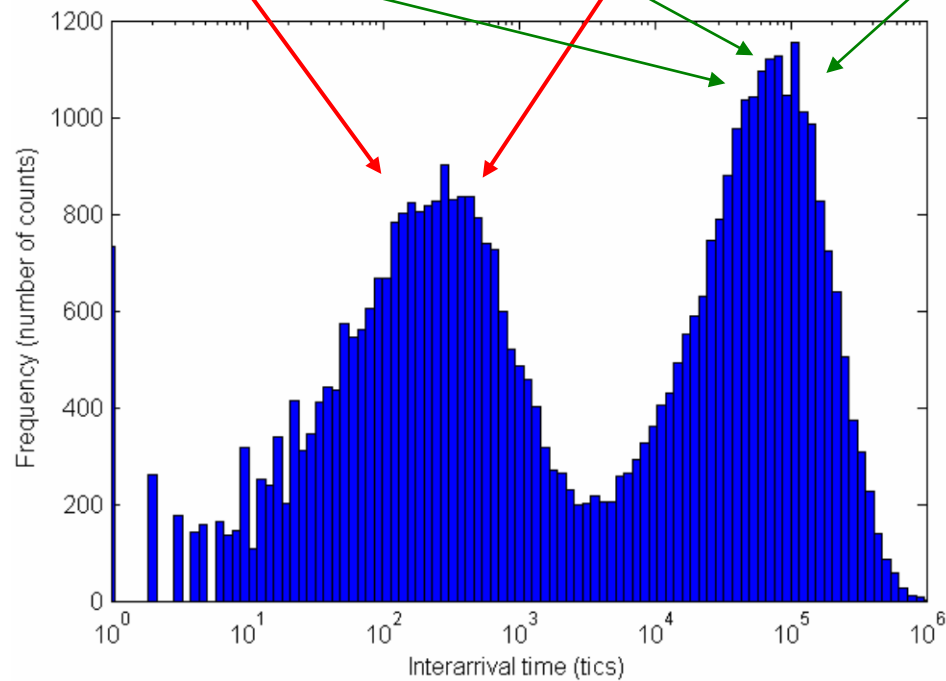
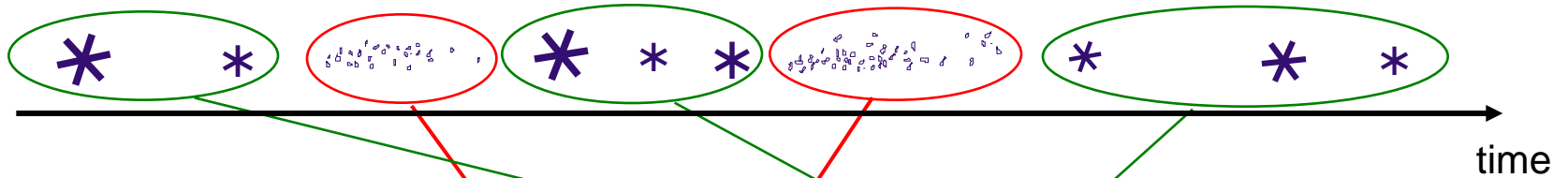


 interarrival time     aspect ratio     partial images     complete images



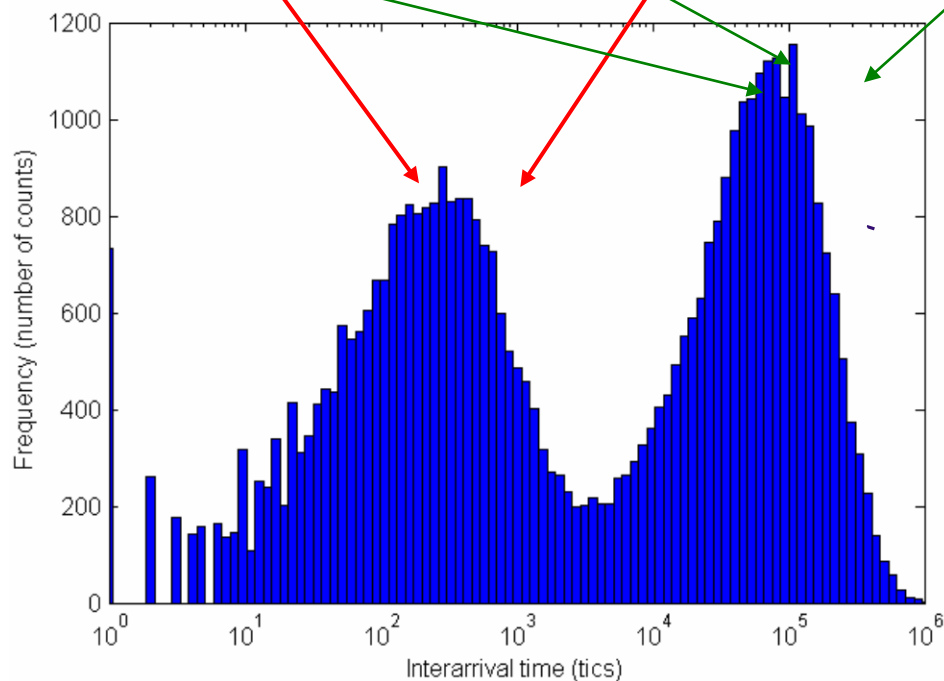
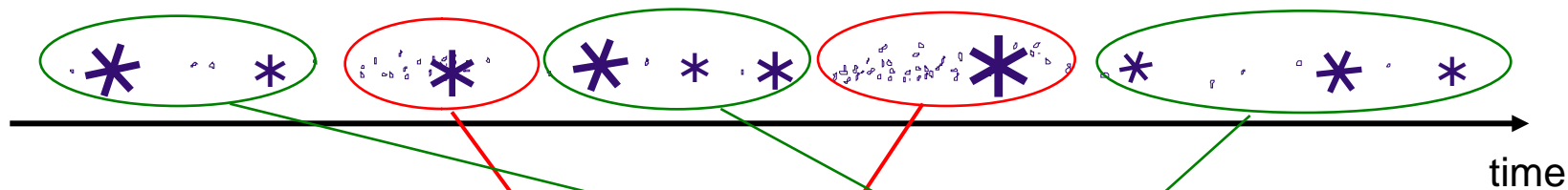
# Idealized concept of filtering out shattering events based on interarrival time

Sequence of particles measured by a probe



# ACTUAL filtering of shattering events based on interarrival time

Sequence of particles measured by a probe



## **Conclusions**

1. Ice particle shattering with the standard OAP-2DC arms may result in the overestimation of the measured concentration ten fold or more.
2. Existing algorithms are incapable of filtering out all shattering events.
3. Modification of probes inlets seems to be the only solution for the shattering problem.

