Quasi-Lagrangian measurements of polar stratospheric cloud particle development from long-duration balloon platforms OPP proposal

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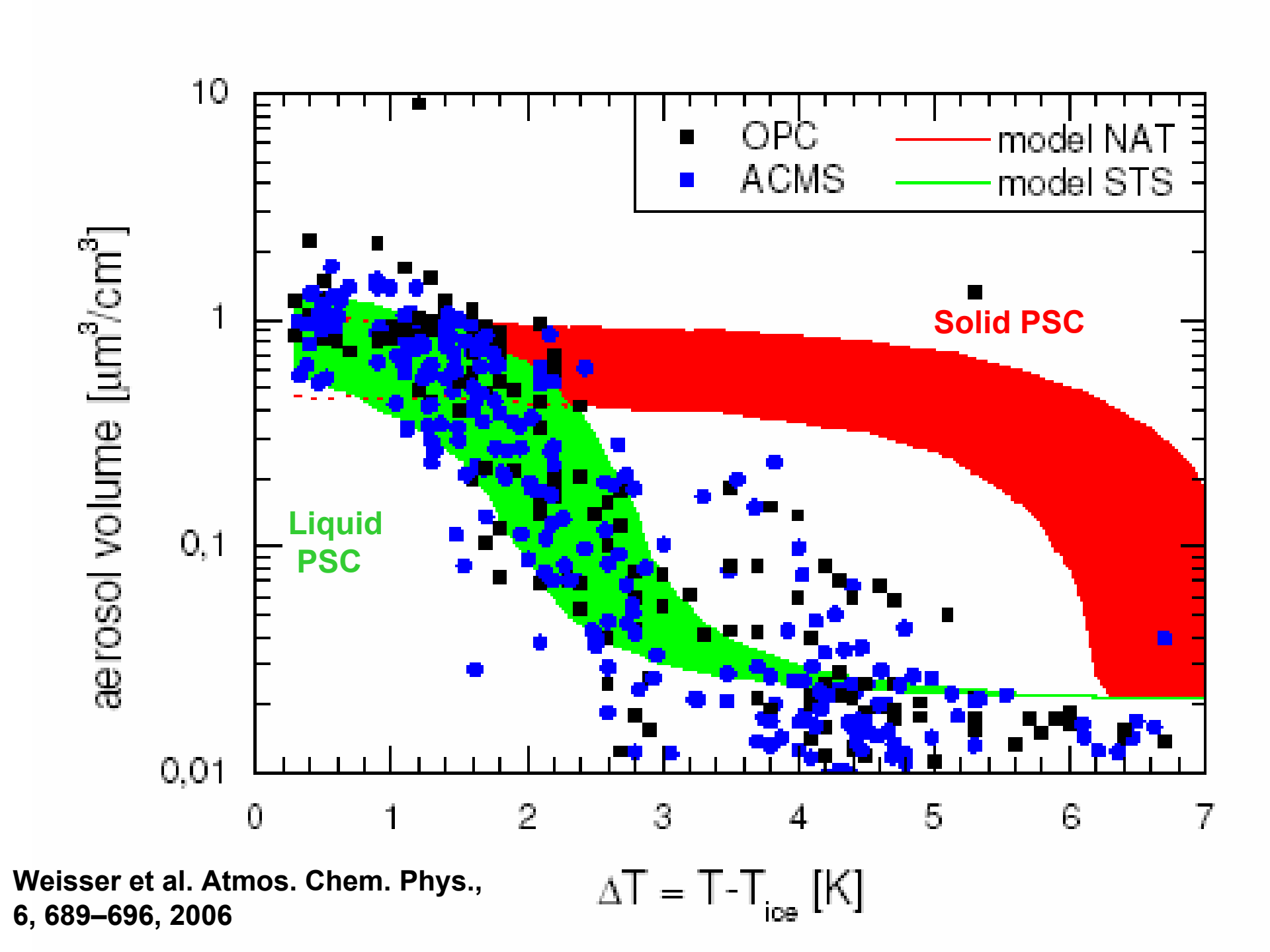
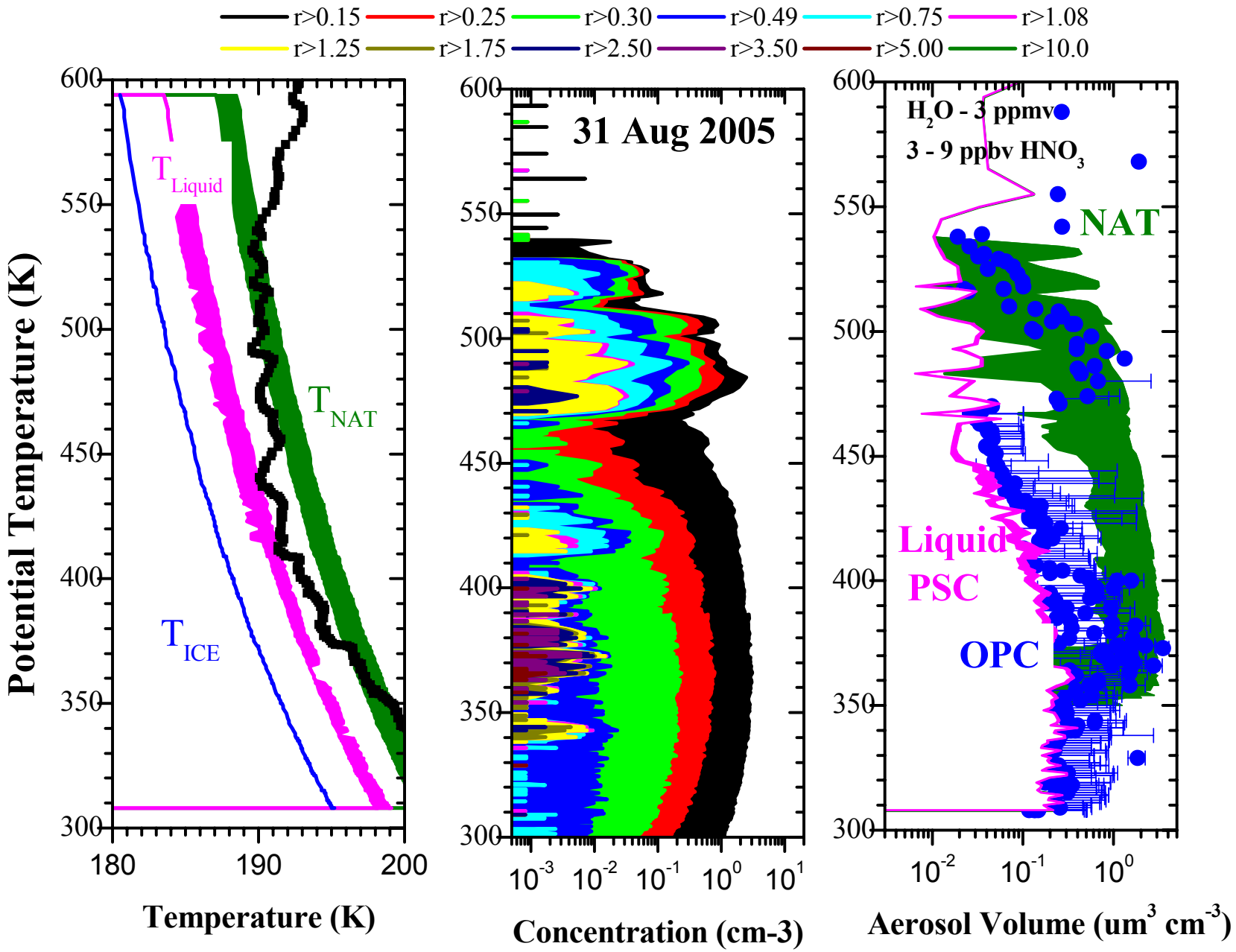
- Goals
  - Capture the processes of particle growth during formation and dissolution of polar stratospheric clouds (PSCs) as instruments pass into and out of temperature regimes favorable for PSC development.
  - Particle and Temperature measurements provide observations of threshold temperatures for PSC particle condensation forming:
    - liquid cloud particles, including some estimates of their growth rate
    - solid nitric acid trihydrate (NAT) particles, including estimates of their nucleation threshold.
  - The question of solid PSC (NAT) nucleation is one of the major unanswered questions concerning PSC particle development.



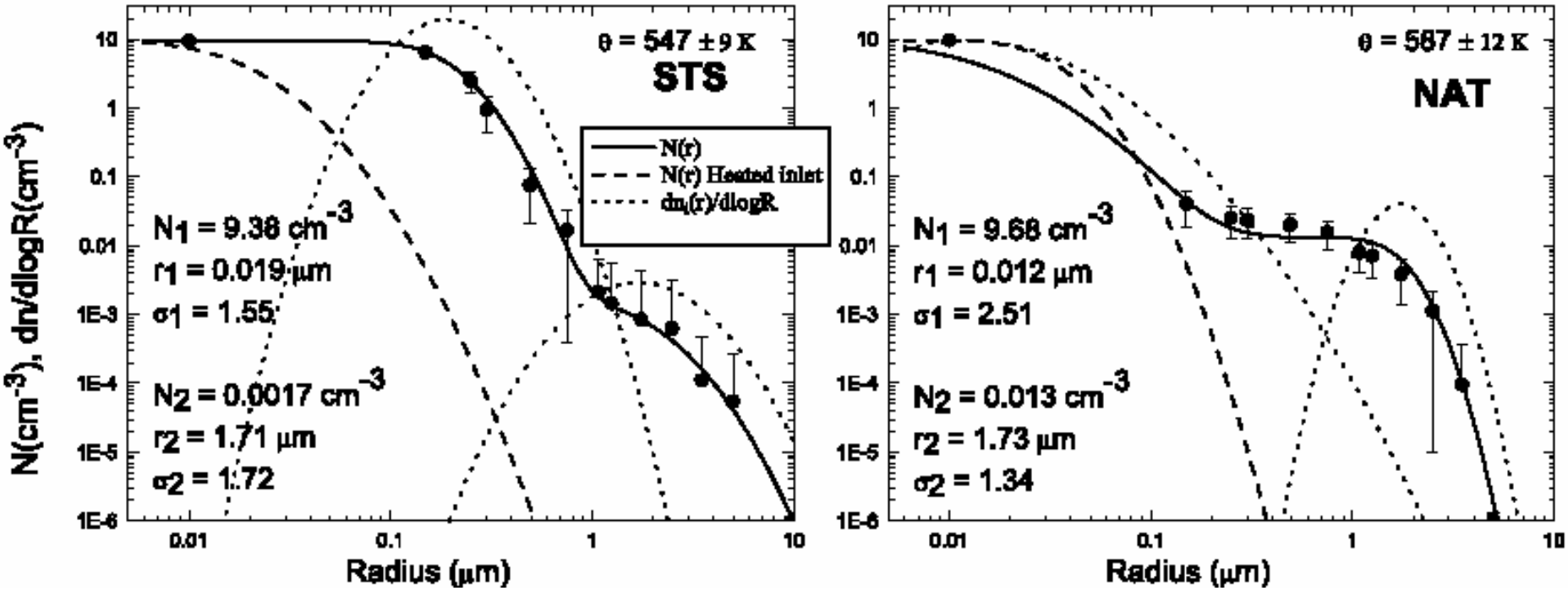
Weisser et al. Atmos. Chem. Phys., 6, 689–696, 2006

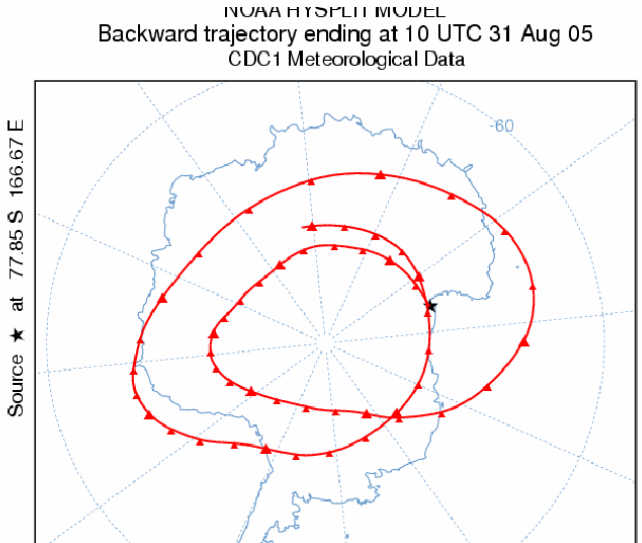
Importance

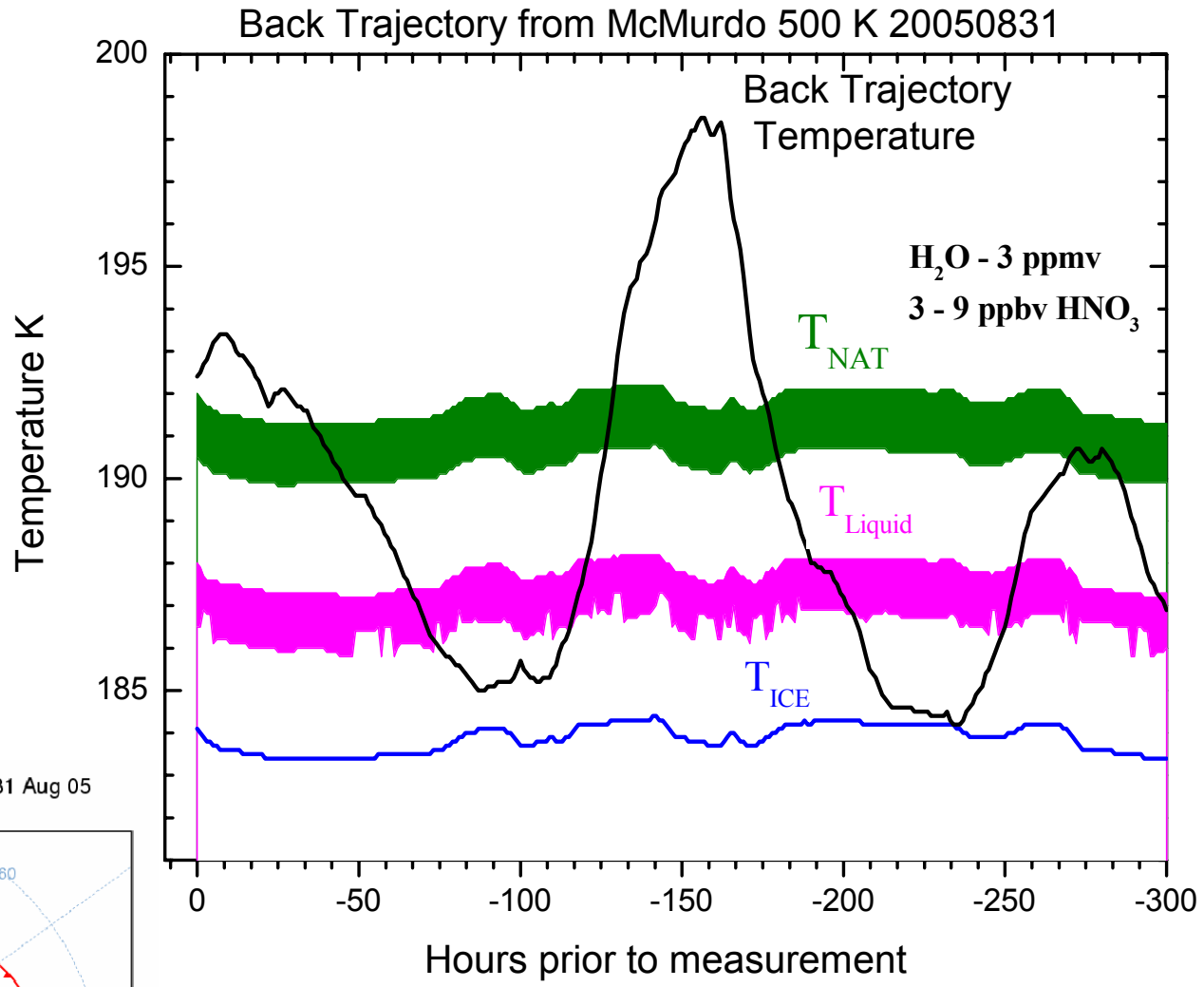
- Nucleation thresholds for solid PSC hydrates are necessary for incorporation of more realistic PSC models into current ozone loss models. At what temperature should models form PSCs?
  - T (PSC_{solid}) ~ T (PSC_{liquid}) + 3 K ~ T (PSC_{ice}) + 7 K
- Laboratory nucleation thresholds (~T_{ice}-2K) appear too cold based on limited field observations.
- New (2006) JPL laboratory measurements of the photolysis cross section of ClOOCl are a factor 6 below previous values
  - Previous agreement of models and ozone loss measurements will be called into question
  - Resolution will require among other things better estimates of ClOx, BrOx concentrations
  - These concentrations depend on the surface area and persistence of PSCs.
  - Denitrification is also controlled by the nucleation of solid PSCs

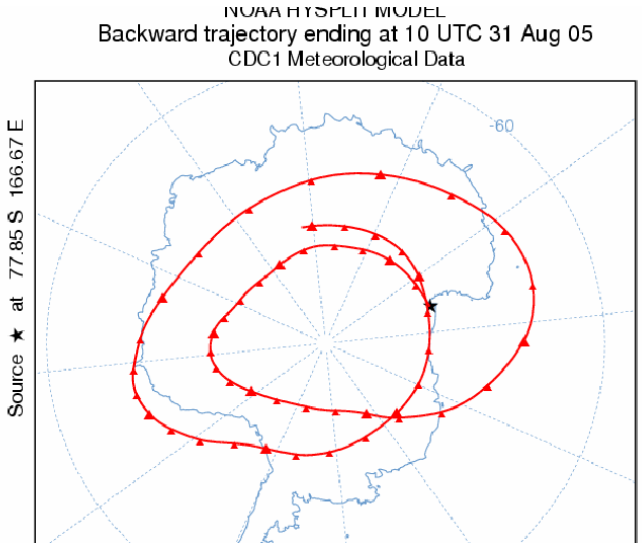

r>0.15
r>0.25
r>0.30
r>0.49
r>0.75
r>1.08
r>1.25
r>1.75
r>2.50
r>3.50
r>5.00
r>10.0
Potential Temperature (K)
600
550
500
450
400
350
300
180
190
200
Temperature (K)
T Liquid
T NAT
T ICE
31 Aug 2005
10-3
10-2
10-1
100
101
Concentration (cm-3)
H2O - 3 ppmv
3 - 9 ppbv HNO3
NAT
Liquid
PSC
OPC
10-2
10-1
100
Aerosol Volume (um3 cm-3)

J. Geophys. Res., 2003




NOAA HYSPLIT MODEL
Backward trajectory ending at 10 UTC 31 Aug 05
CDC1 Meteorological Data
Source ★ at 77.85 S 166.67 E
-60


Back Trajectory from McMurdo 500 K 20050831
Back Trajectory
Temperature
H2O - 3 ppmv
3 - 9 ppbv HNO3
T NAT
T Liquid
T ICE
Temperature K
200
195
190
185
0
-50
-100
-150
-200
-250
-300
Hours prior to measurement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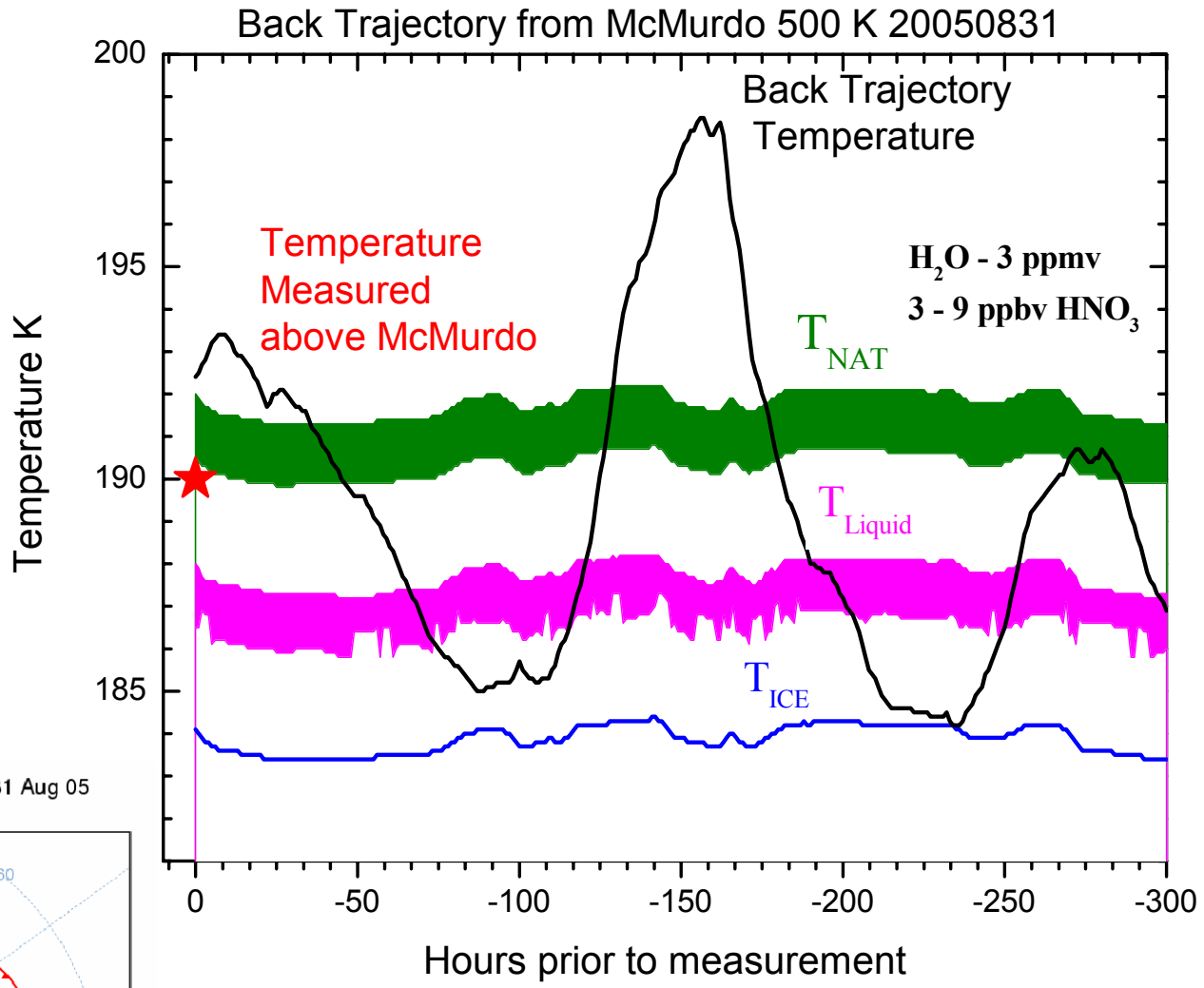
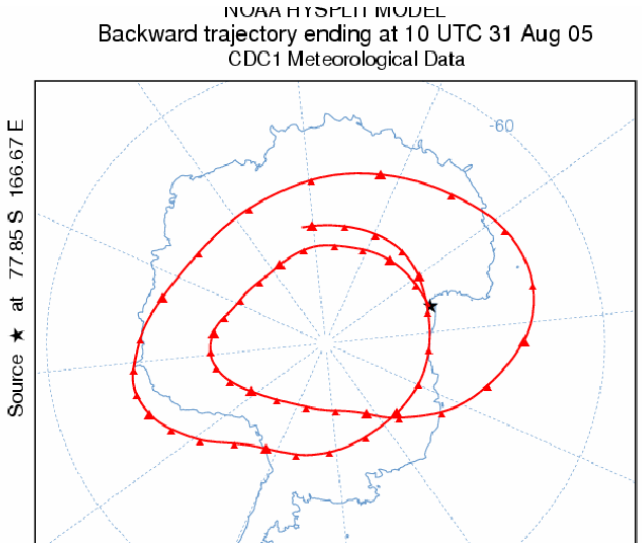

Back Trajectory from McMurdo 500 K 20050831
Back Trajectory
Temperature
Temperature
Measured
above McMurdo
H2O - 3 ppmv
3 - 9 ppbv HNO3
T NAT
T Liquid
T ICE
Temperature K
Hours prior to measurement
200
195
190
185
0
-50
-100
-150
-200
-250
-300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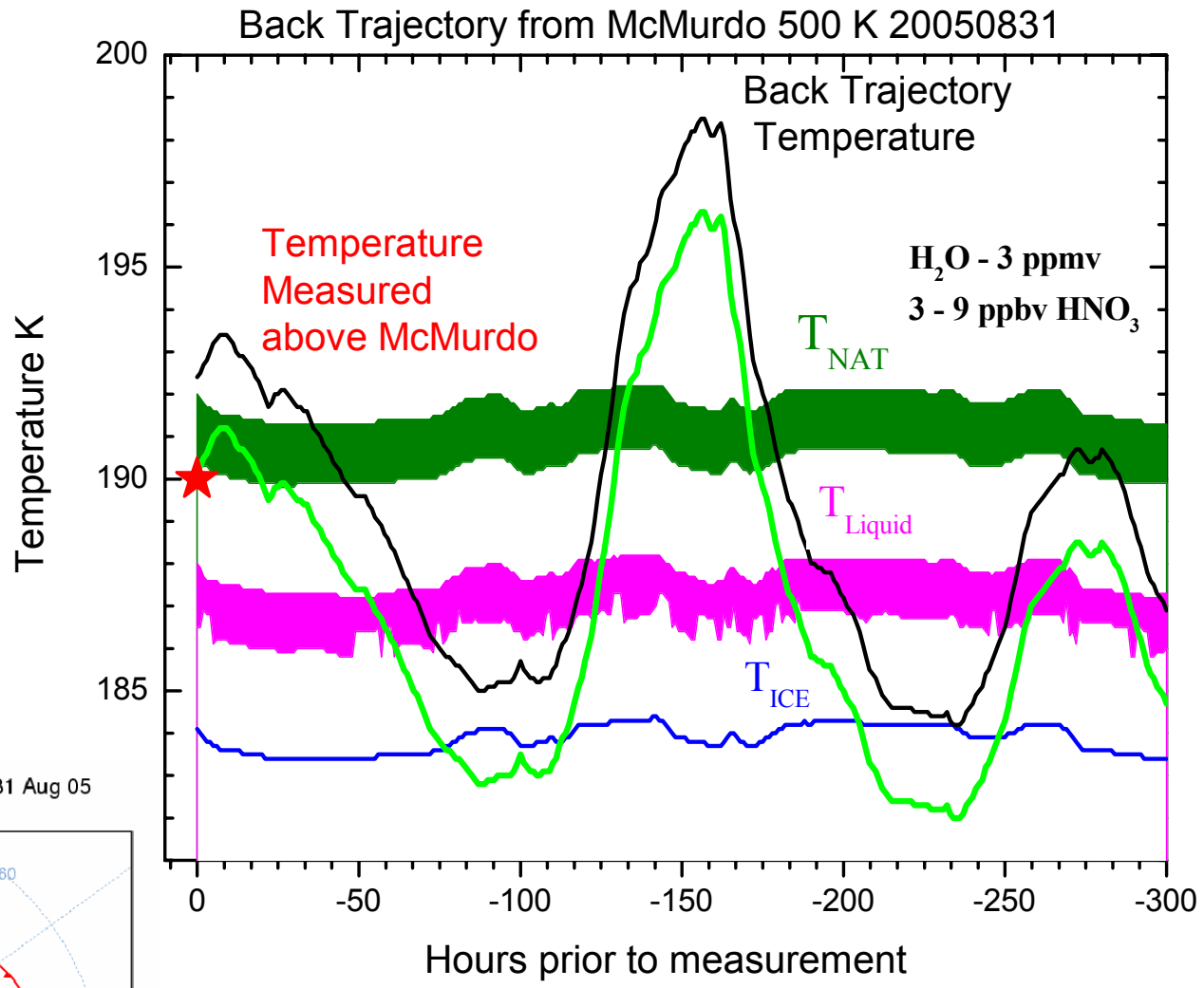
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200
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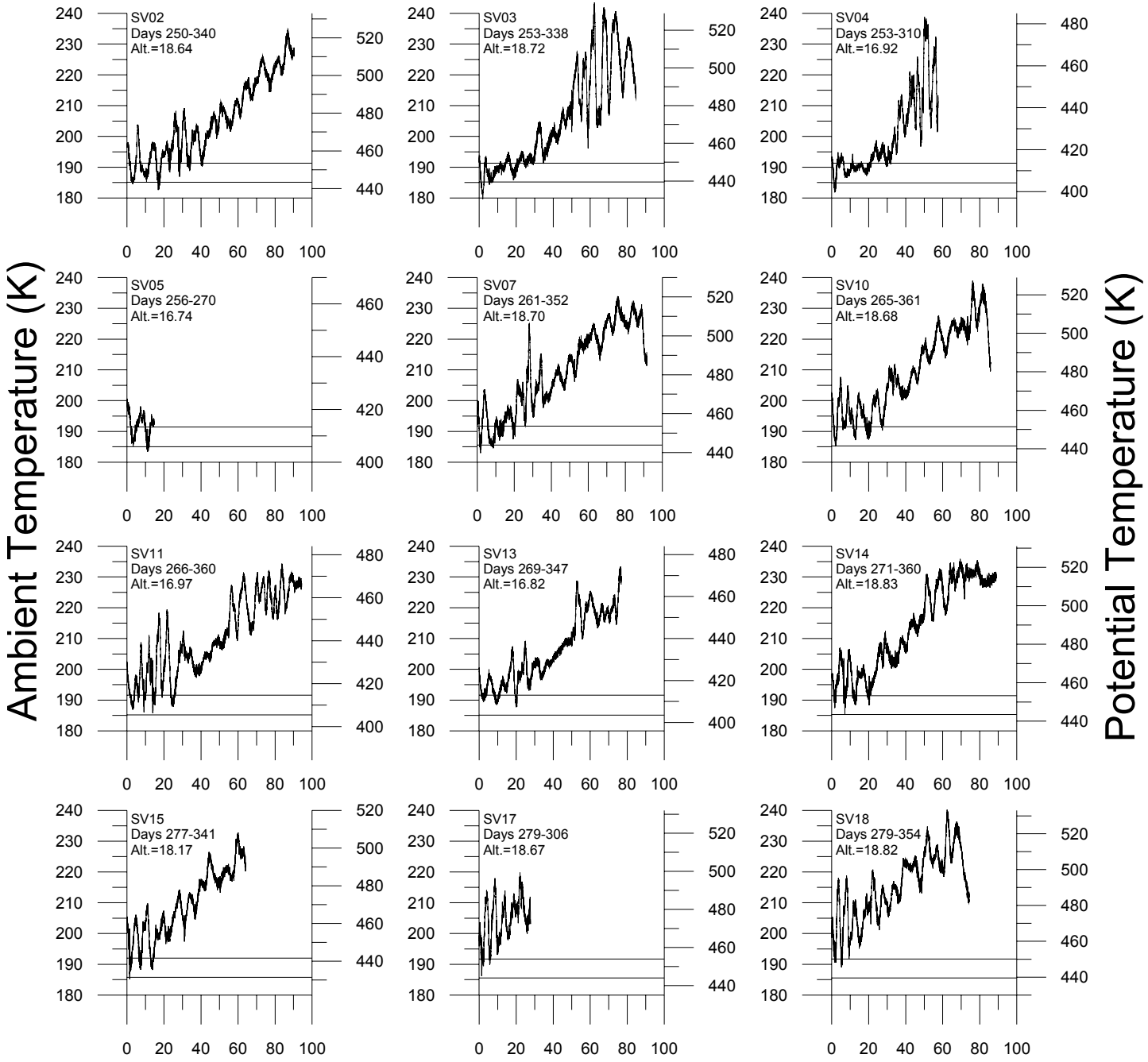
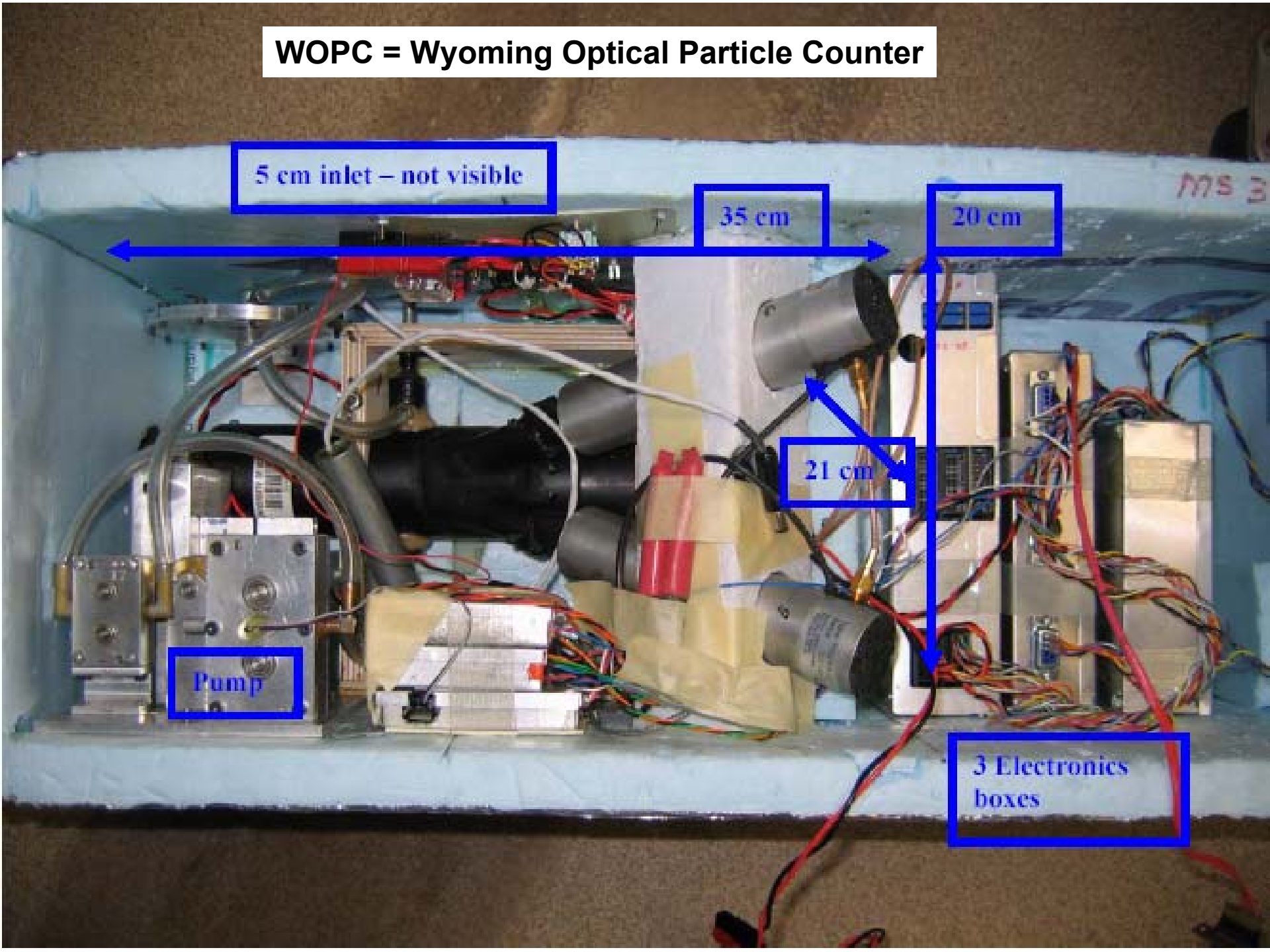
-250
-300
Hours prior to measurement

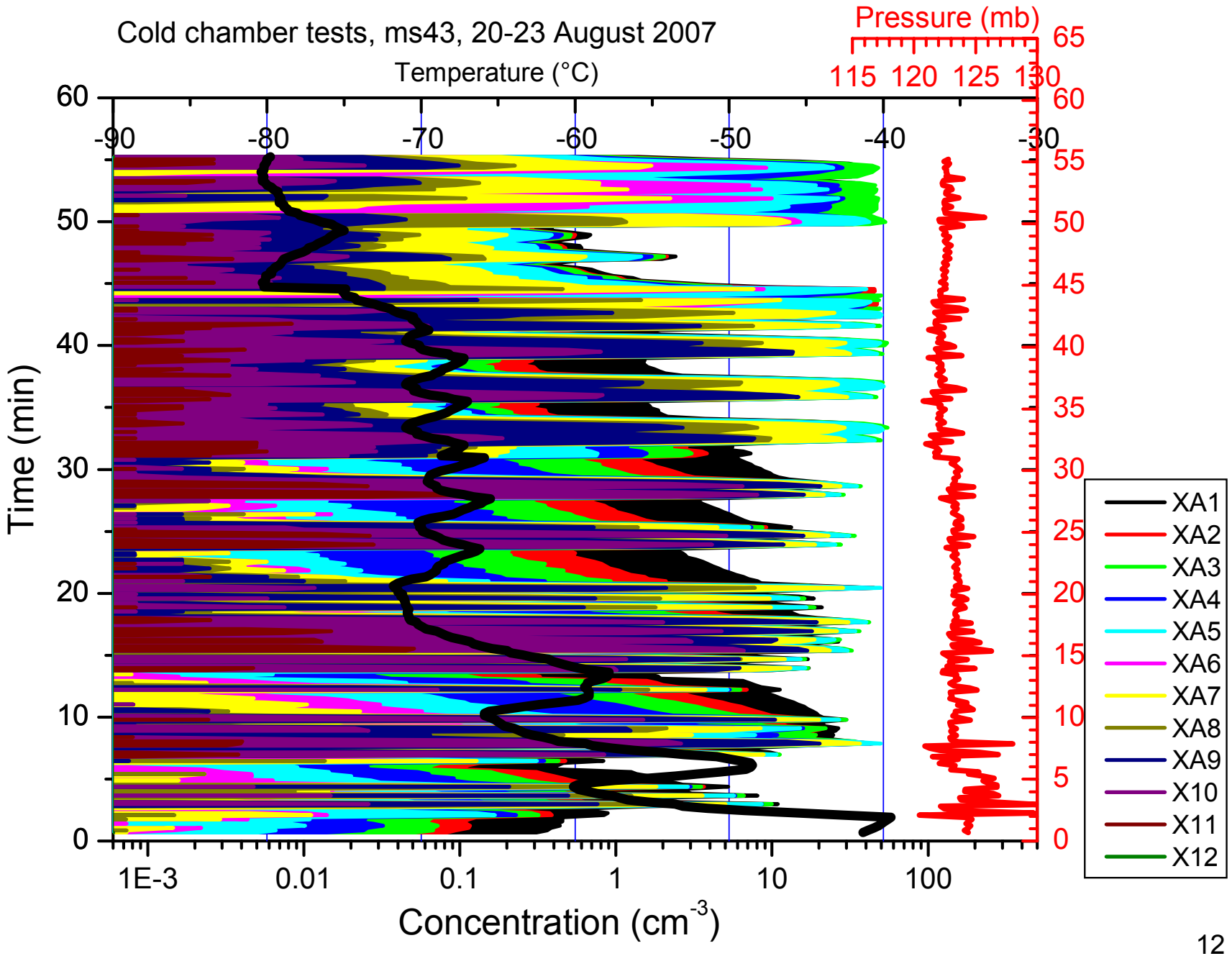
Conclusions

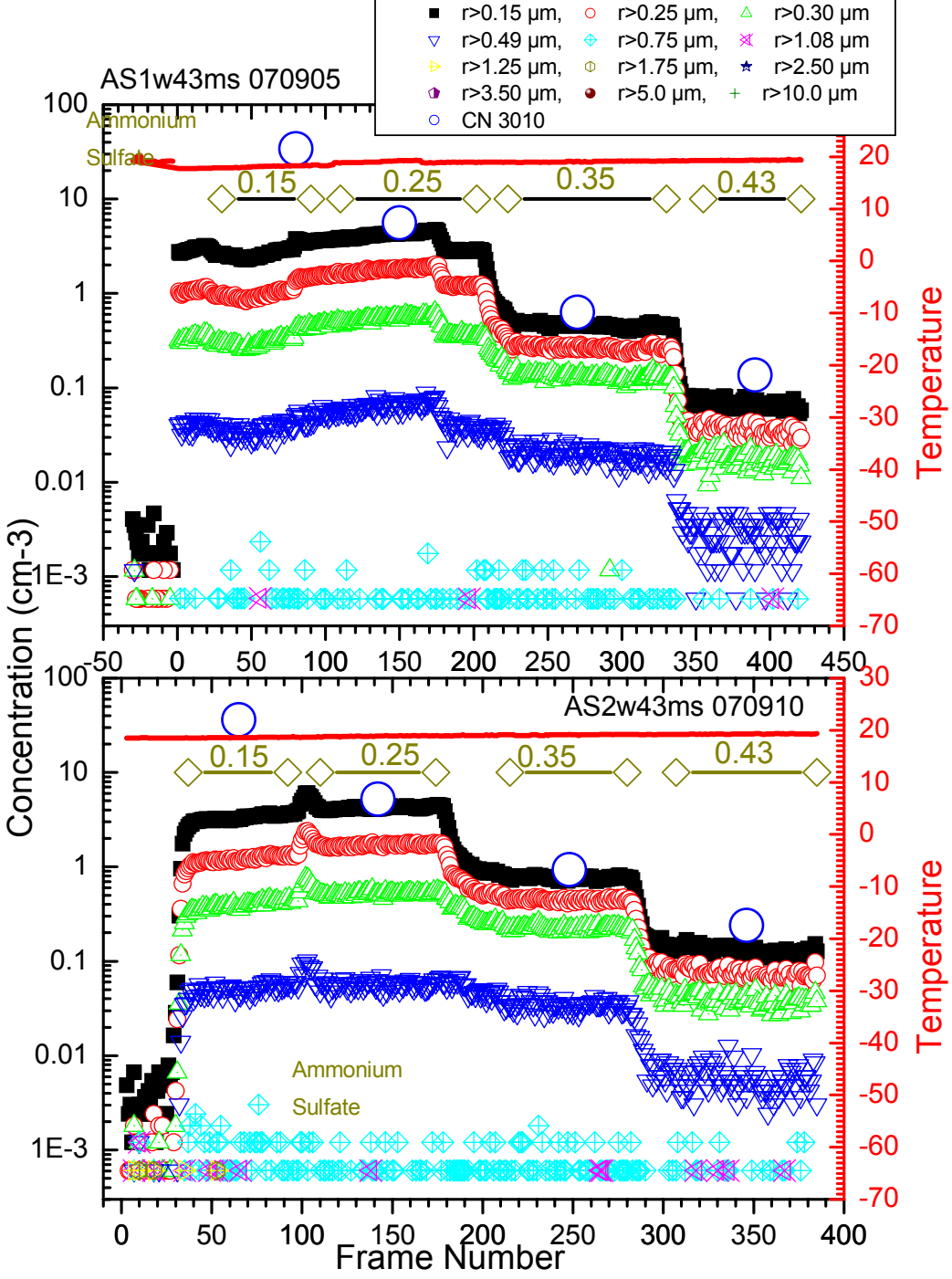
- Profile PSC measurements coupled with back trajectory models suggest that nucleation temperatures for NAT are warmer than laboratory estimates.
- Field estimates, however, are not definitive. There are:
  - uncertainties in the back trajectory temperature histories
  - in the accuracy of model temperatures
  - no estimates of particle growth rate along air parcel tracks.
- Lagrangian in situ microphysical and profile measurements would help resolve this question by reducing uncertainties in:
  - air parcel history
  - temperature accuracy
  - particle type and growth


SV02
Days 250-340
Alt.=18.64
SV03
Days 253-338
Alt.=18.72
SV04
Days 253-310
Alt.=16.92
SV05
Days 256-270
Alt.=16.74
SV07
Days 261-352
Alt.=18.70
SV10
Days 265-361
Alt.=18.68
SV11
Days 266-360
Alt.=16.97
SV13
Days 269-347
Alt.=16.82
SV14
Days 271-360
Alt.=18.83
SV15
Days 277-341
Alt.=18.17
SV17
Days 279-306
Alt.=18.67
SV18
Days 279-354
Alt.=18.82
Ambient Temperature (K)
Potential Temperature (K)
Elapsed Time (Days)

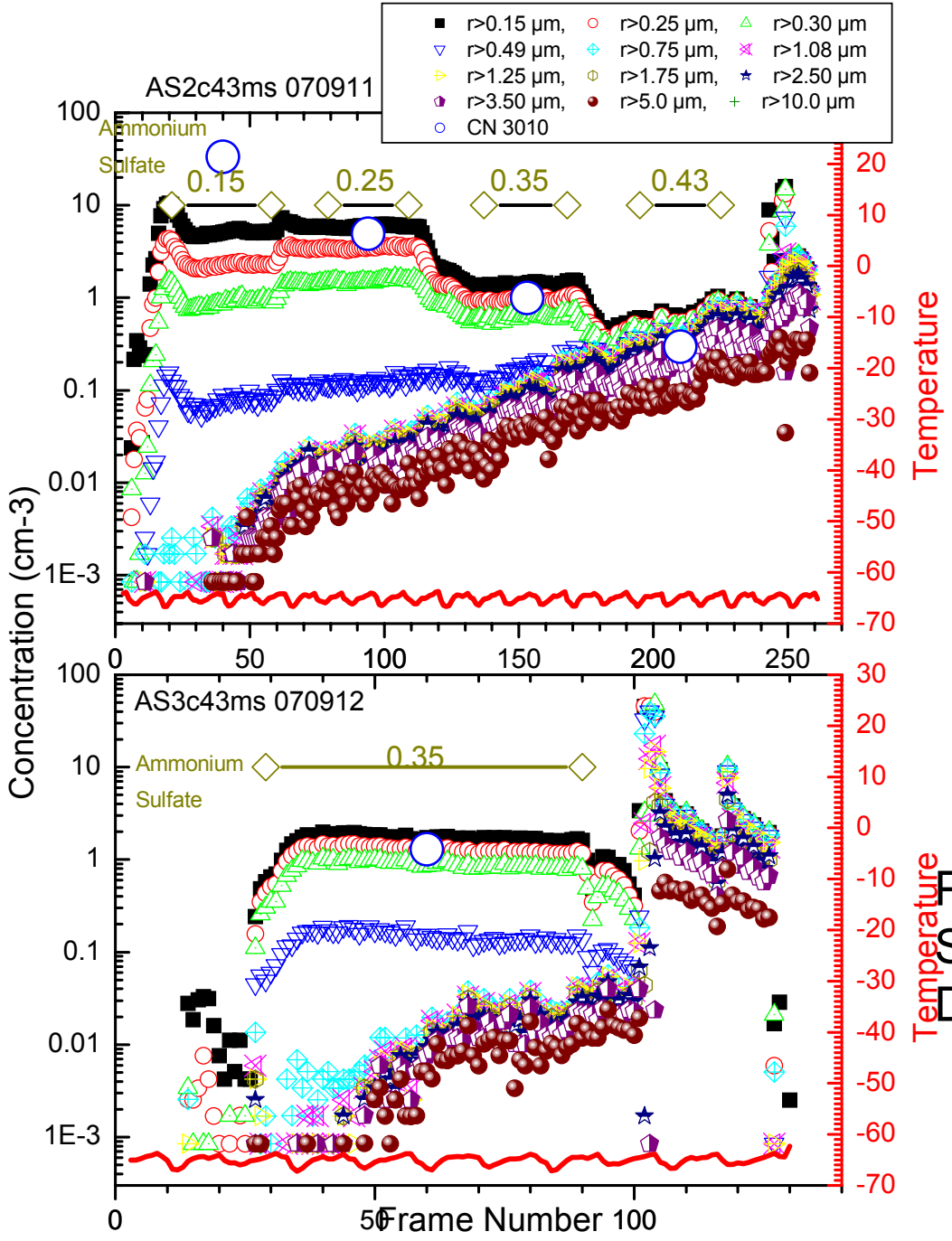
WOPC = Wyoming Optical Particle Counter




Cold chamber tests, ms43, 20-23 August 2007
Temperature (°C)
Pressure (mb)
115 120 125 130
65
60
55
50
45
40
35
30
25
20
15
10
5
0
-90 -80 -70 -60 -50 -40 -30
60
50
40
30
20
10
0
Time (min)
1E-3 0.01 0.1 1 10 100
Concentration (cm-3)
XA1
XA2
XA3
XA4
XA5
XA6
XA7
XA8
XA9
X10
X11
X12



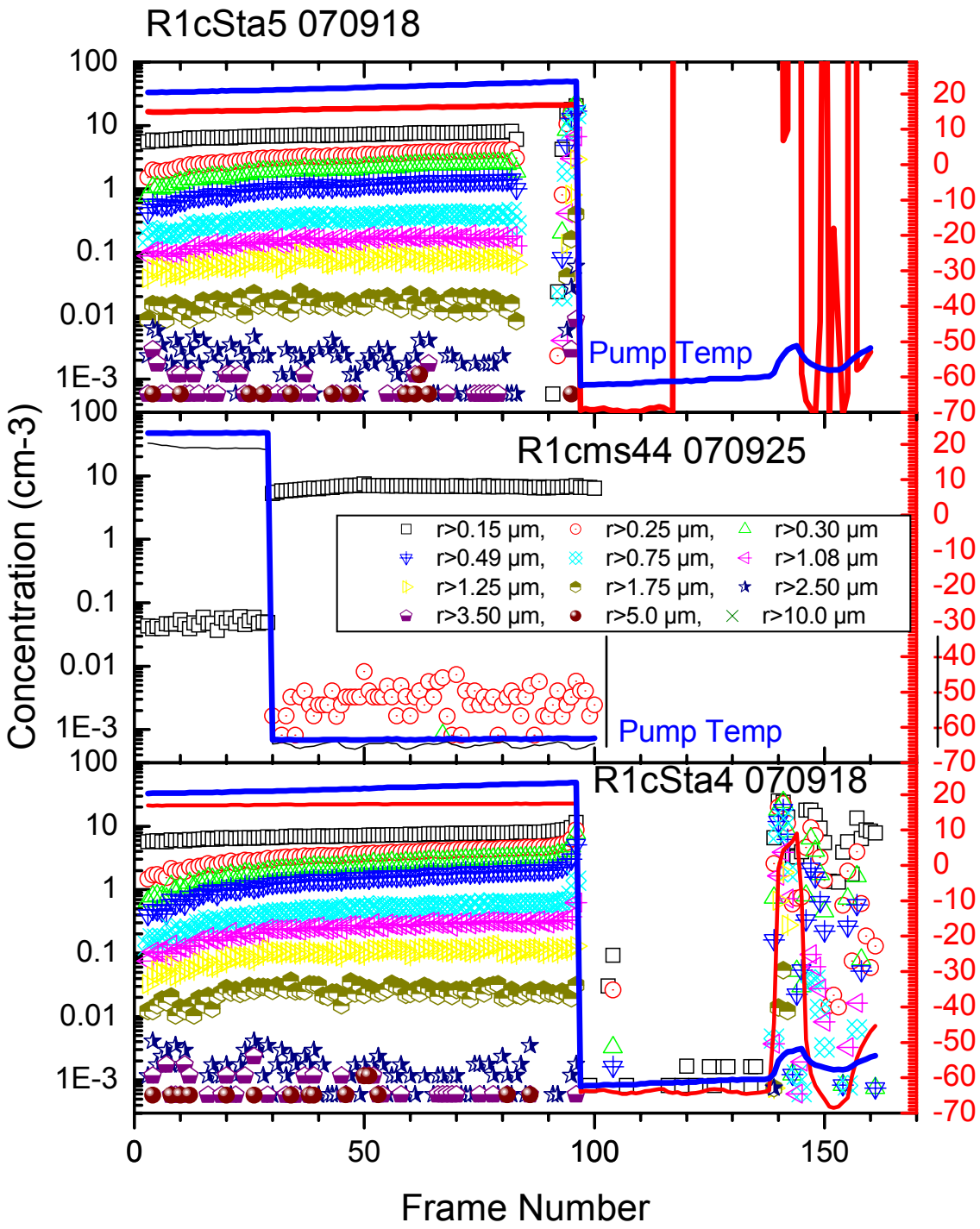
Tests at room temperature



Frost grows on particles In sample line. Multiple Radii tested

Single radius tested
Frost grows on particles

Post cold tests indicated Significant calibration Drift.



Pump would not start
Lamp and both
PMTs failed

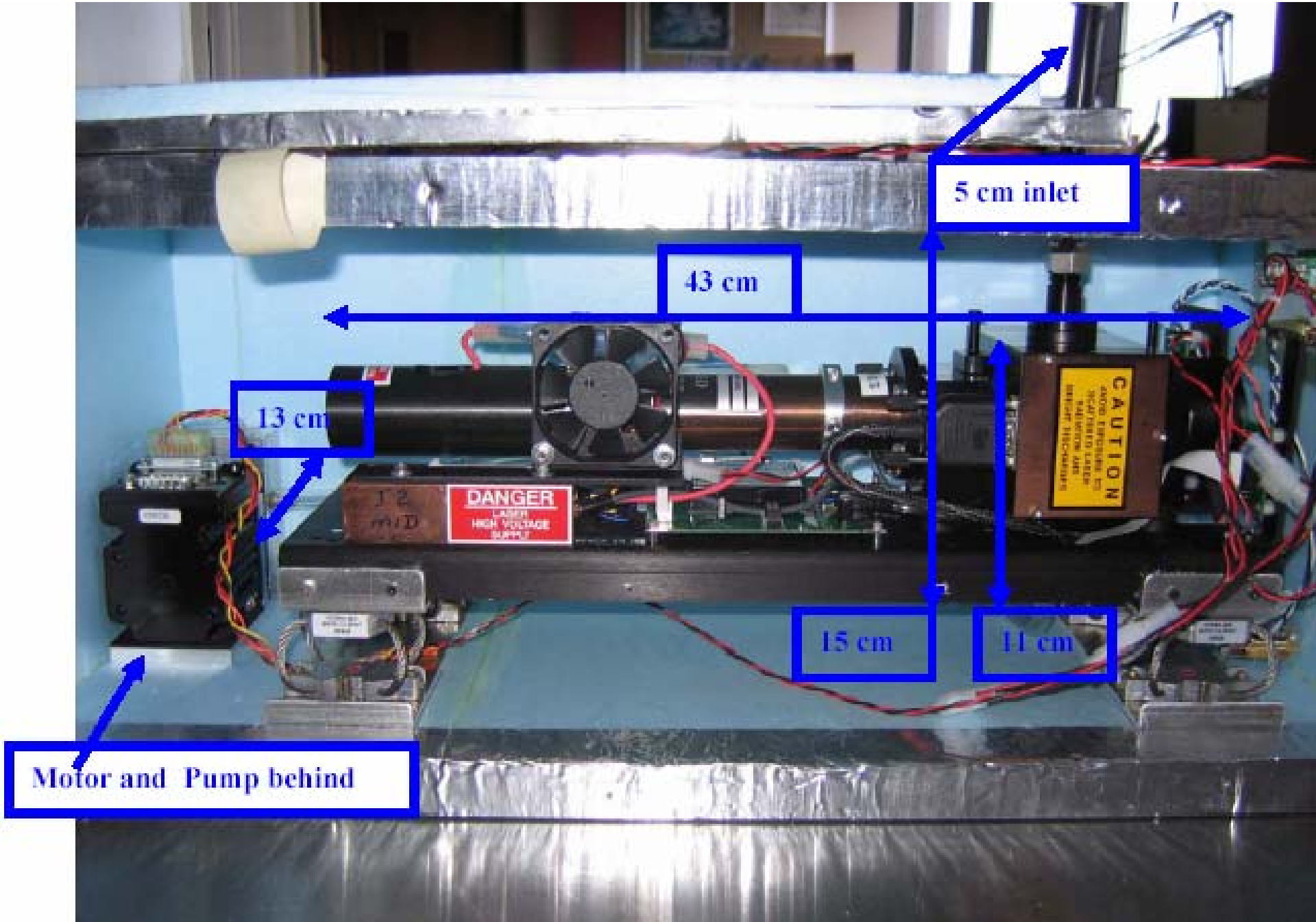
Air path blocked
By ice
CPU failure
Post cold test
Calibration drift

Pump started by
Hand, but then inlet
Iced up
Post cold test
Calibration drift

Conclusions on UWOPC

- Some success with one instrument, but three failures.
- The points of potential (and actual) failure due to temperature dependence are many:
  - Photomultiplier tubes
  - Pulse height analyzer board
  - Power supply
  - Microprocessor
- Parts and replacements electronics extremely limited and not available.
- The mechanical integration would be difficult.
- Not confidant that 4 working instruments could be built with existing parts.
- Engineering resources unavailable to develop more than one instrument for deployment.

LOPC = Laser Optical Particle Counter (Jupiter)



Results of cold temperature tests on Jupiter

- Problems
  - Extensive potting required to prevent arcing at low pressures.
  - From a warm start unit operates to -40 C.
  - Cold starts are limited to temperatures > -25C
  - Laser –
    - The metal used for the glass to metal weld on the laser tube was selected for expansion properties similar to glass during warming
    - The metal has different characteristics during cooling.
    - This is possibly the source of the laser failure of the instrument used for cold testing

Conclusions on Jupiter

- Advantages
  - Commercially available
  - Simpler design – mechanically and electronically
  - Chance of sampling lower density, larger PSC particles
- Issues
  - Mounting cannot be vertical due to possibility of debris from laser settling onto one of the lenses. Thus the angled mounting
  - Only preliminary cold testing completed
    - Focused on testing of temperature limits for operability
    - No systematic particle testing done
    - Tests of the survivability of the laser to a cold soak have yet to be completed
- Future
  - Four new instruments have been ordered from PMI. Delivery in January
  - PMI has supplied several lasers for cold soak tests as part of this order
  - Processors have been ordered to manage the communication between Jupiter and ISBA. The software for these will be in development soon.
  - Plan for manual operation of the instrument in flight to avoid building complicated software to manage instrument turn on. This requires:
    - Position
    - Temperature – exterior and interior
    - Battery capacity
  - Plan to initially be quite stringent on temperature limits for operation