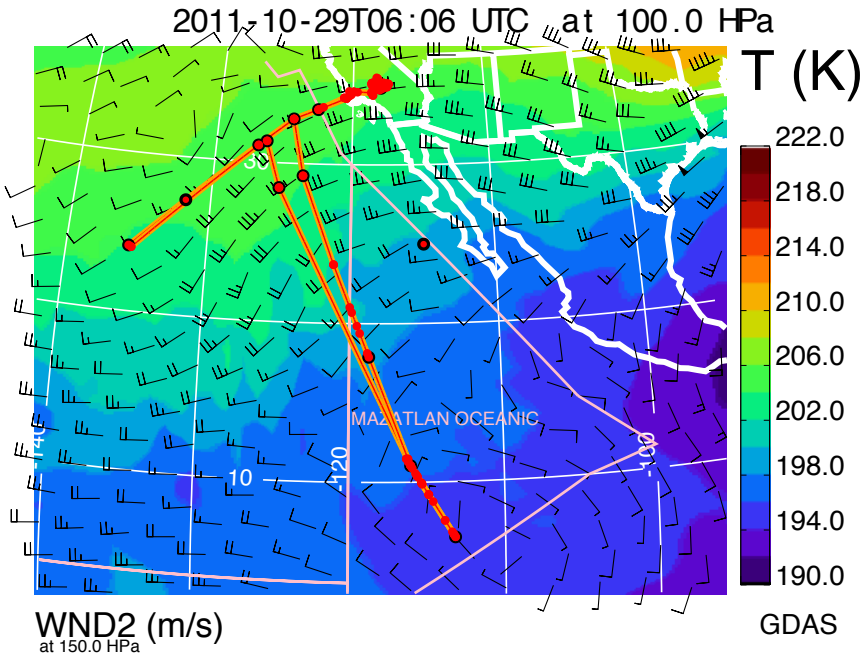
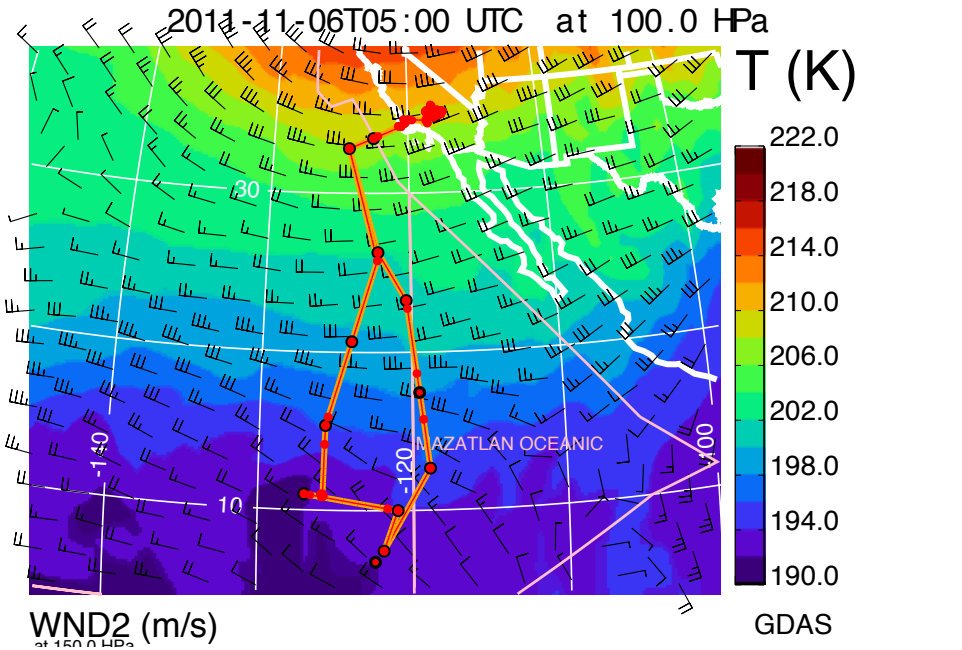
Evidence for Two Distinct Types of TTL Cirrus Indicated by ATTREX Measurements

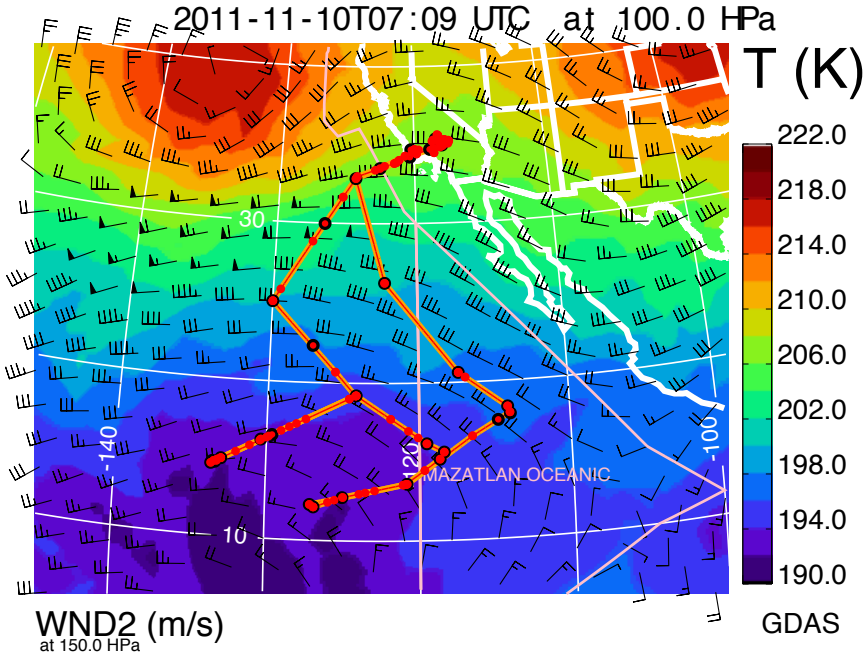
- DLH (G. Diskin)
- FCDP (P. Lawson)
- MMS (P. Bui)
- CPL (M. McGill, D. Hlavka)
- NOAA O_3 (R.-S. Gao)

ATTREX fall 2011Tropical Flights



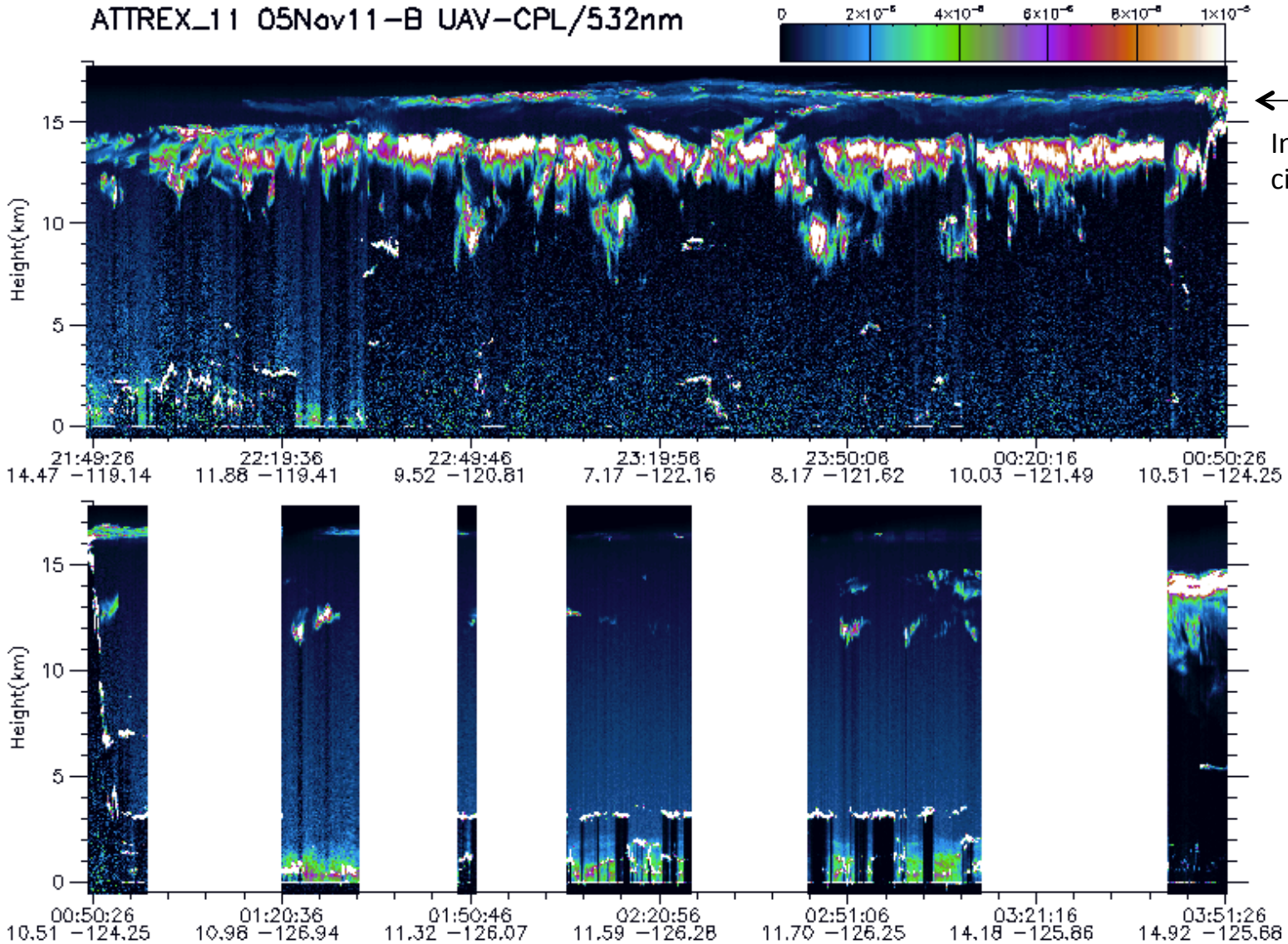


GLOBALHAWK AV6: repro 2011-11-05 v. 0

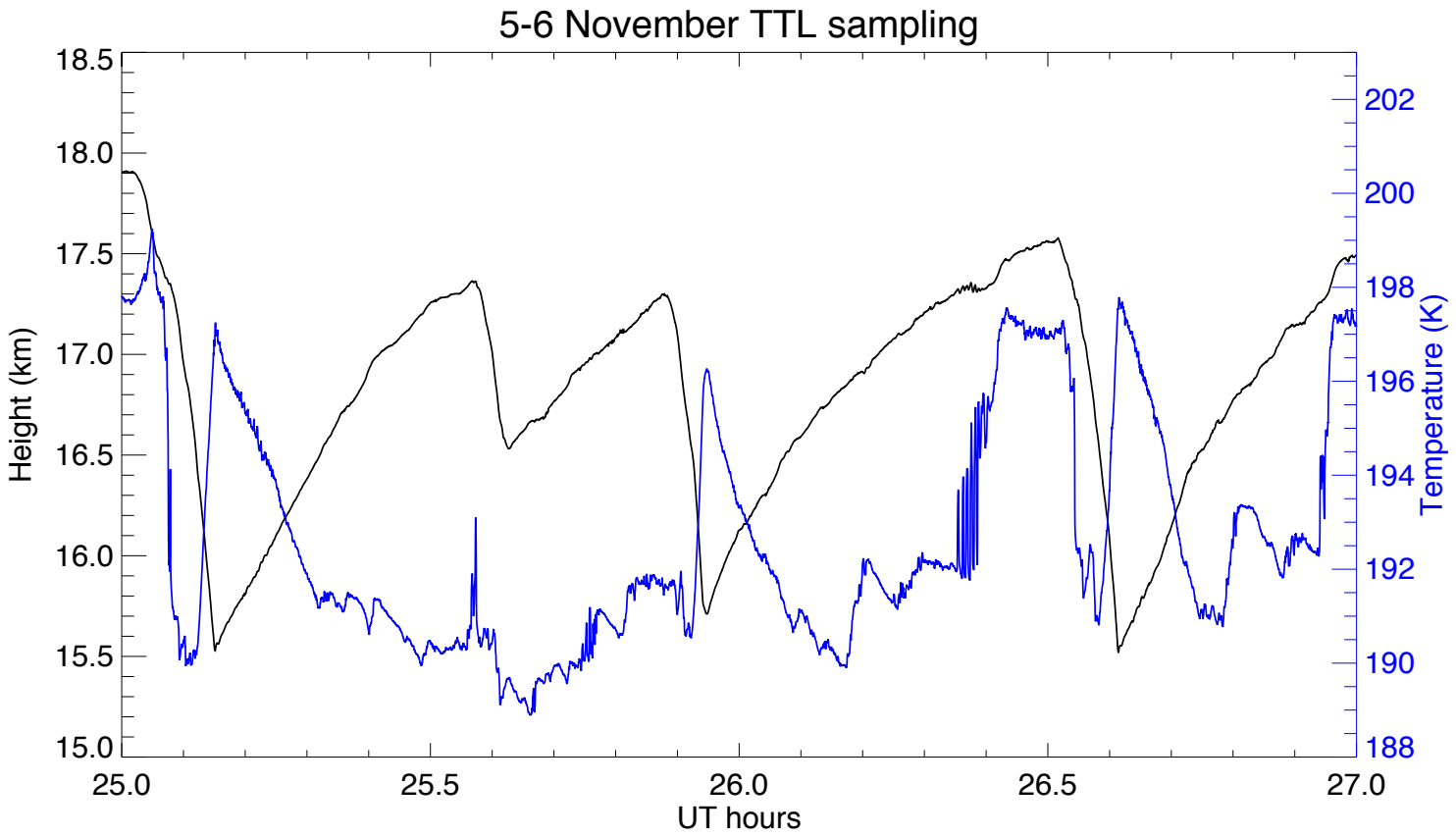


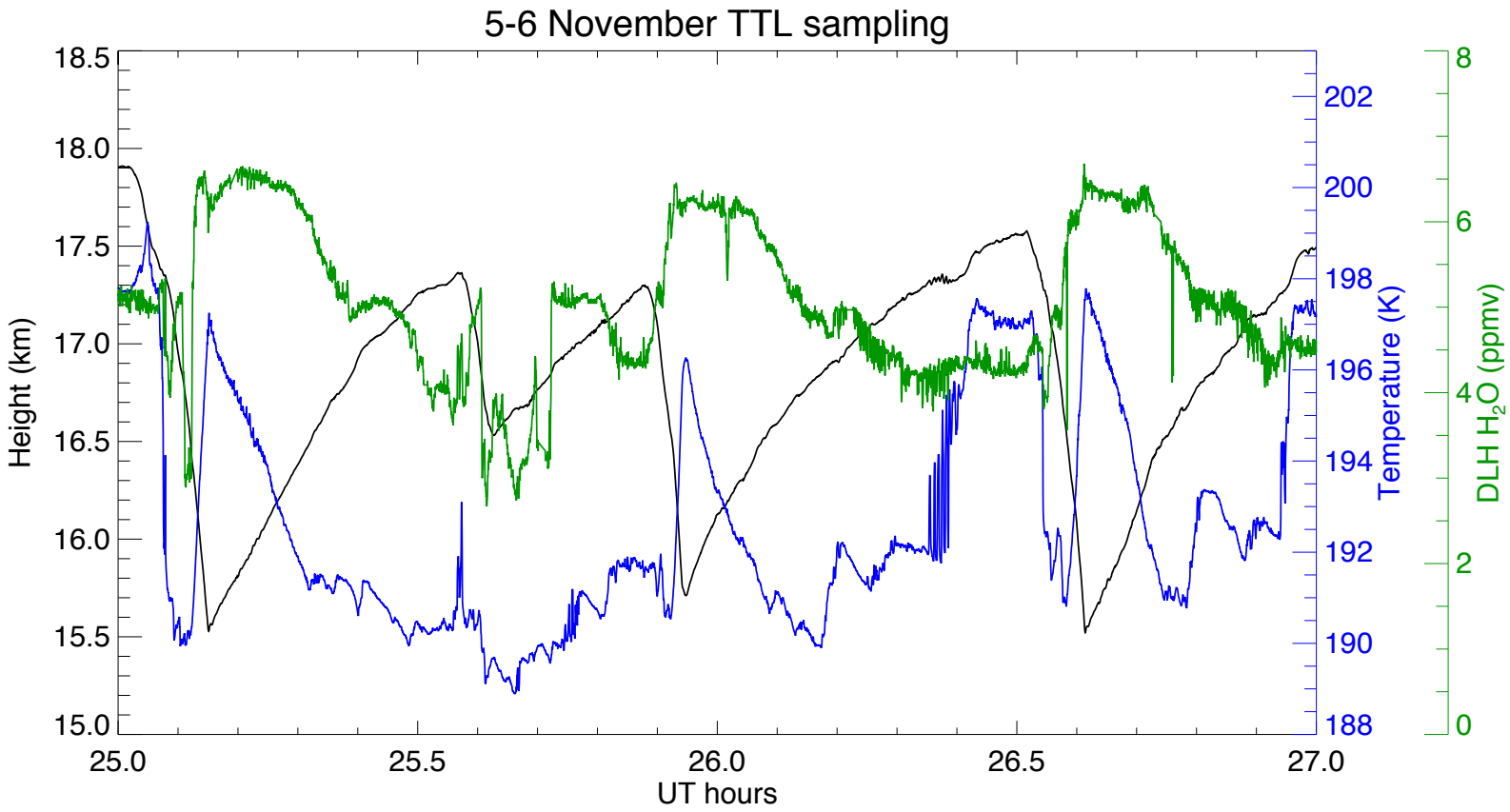
GLOBALHAWK AV6: repro 2011-11-09 v. 3

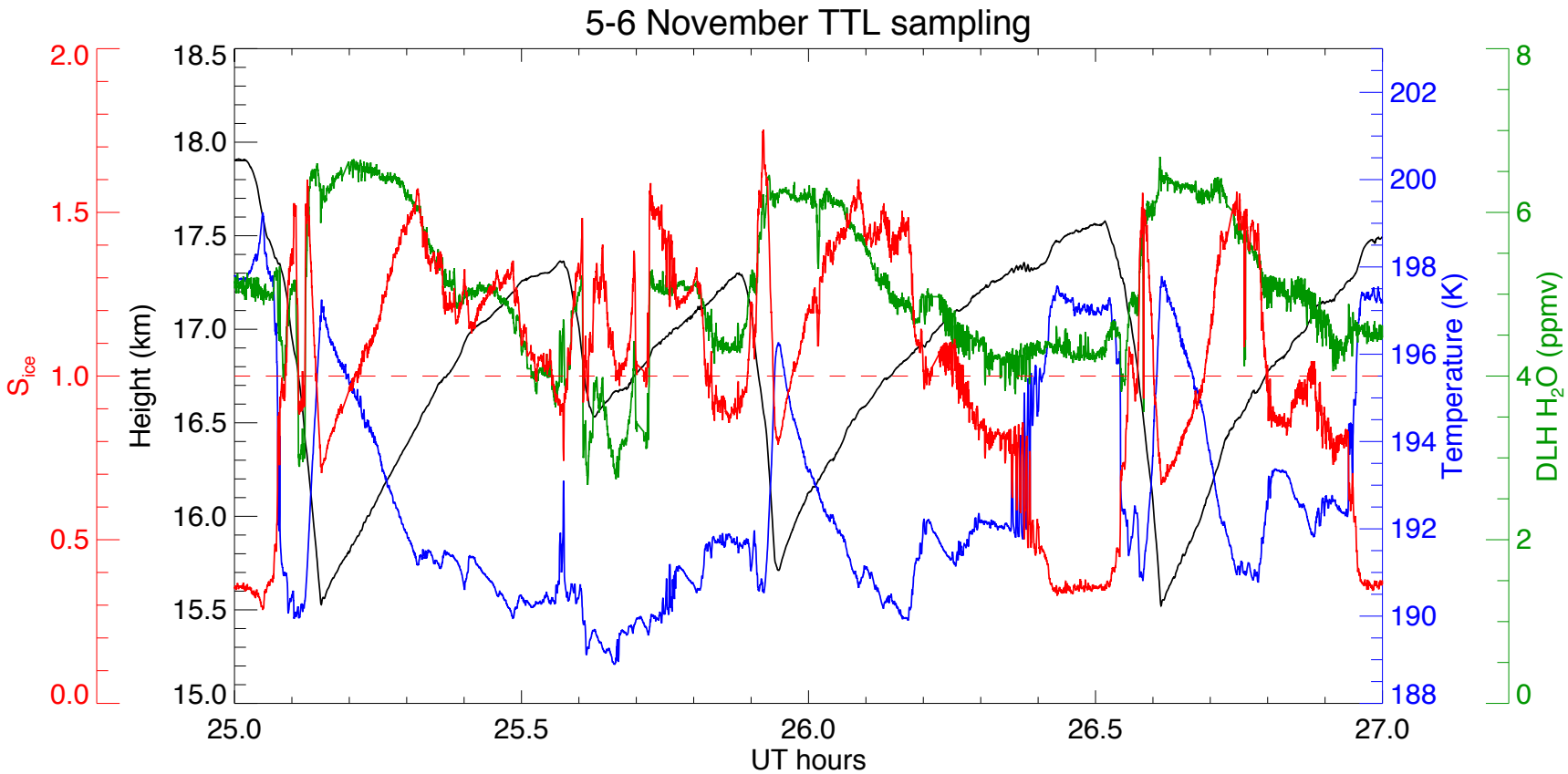
November 5-6 TTL profiling

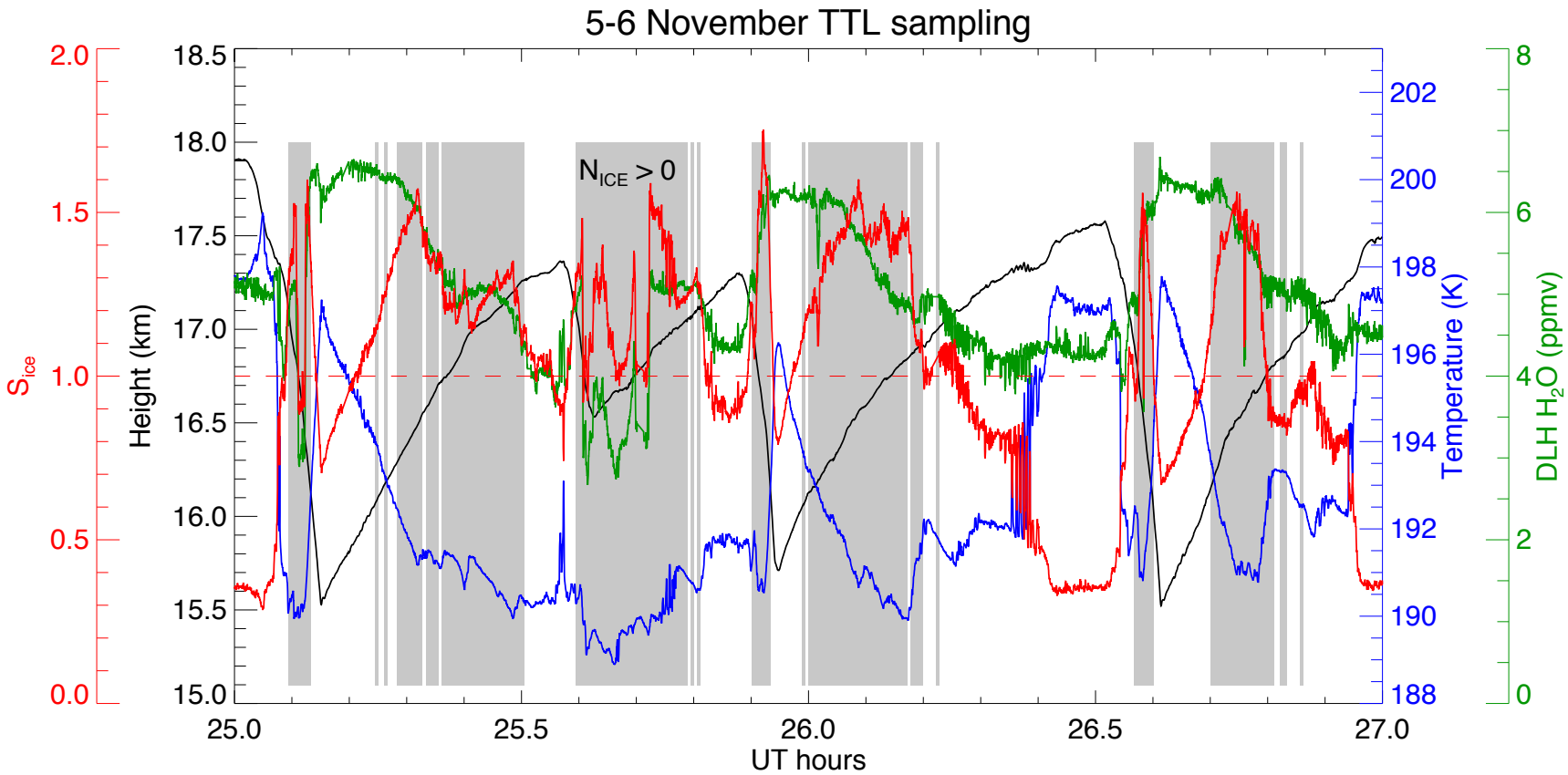


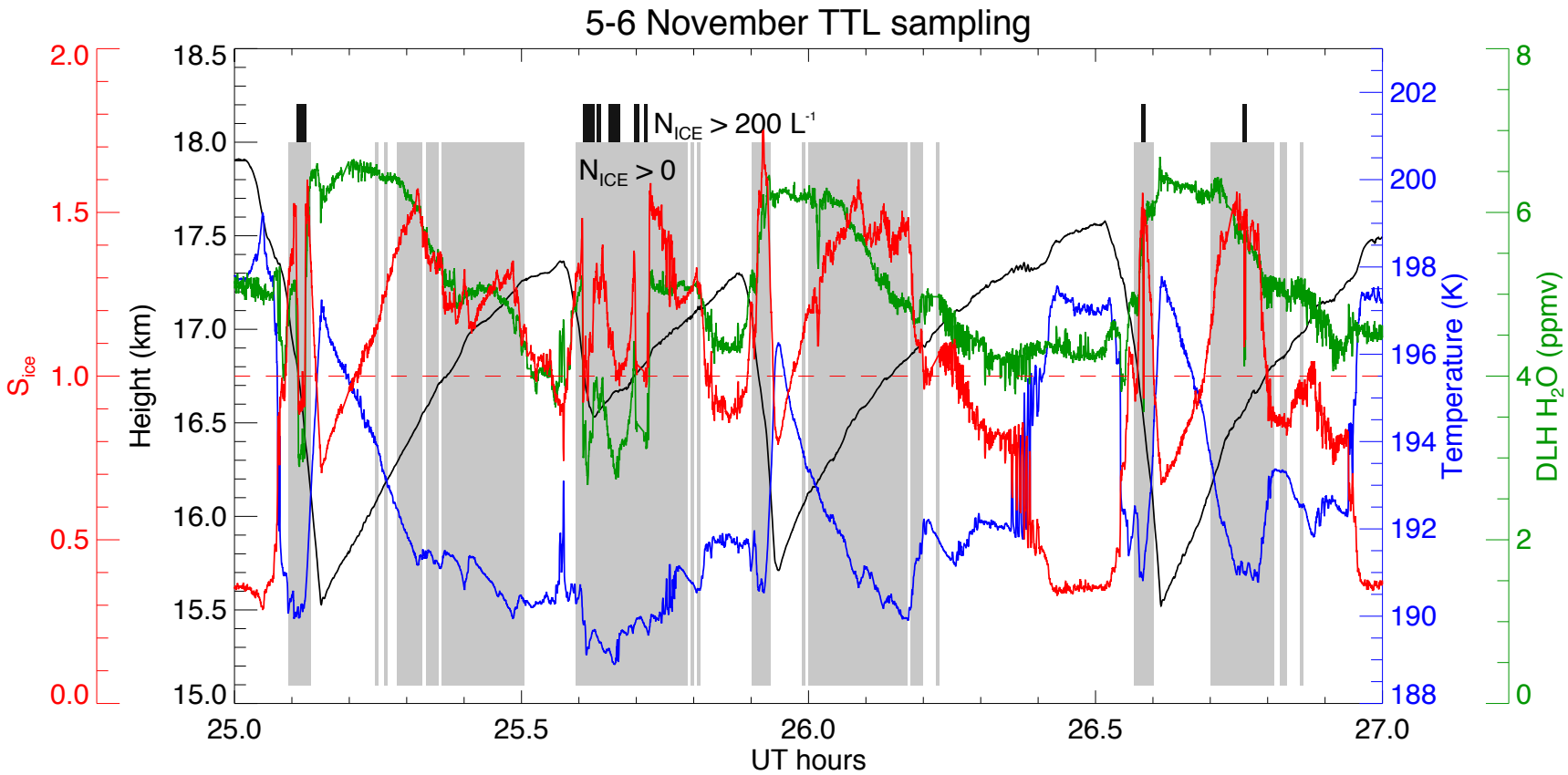
In situ cirrus layer

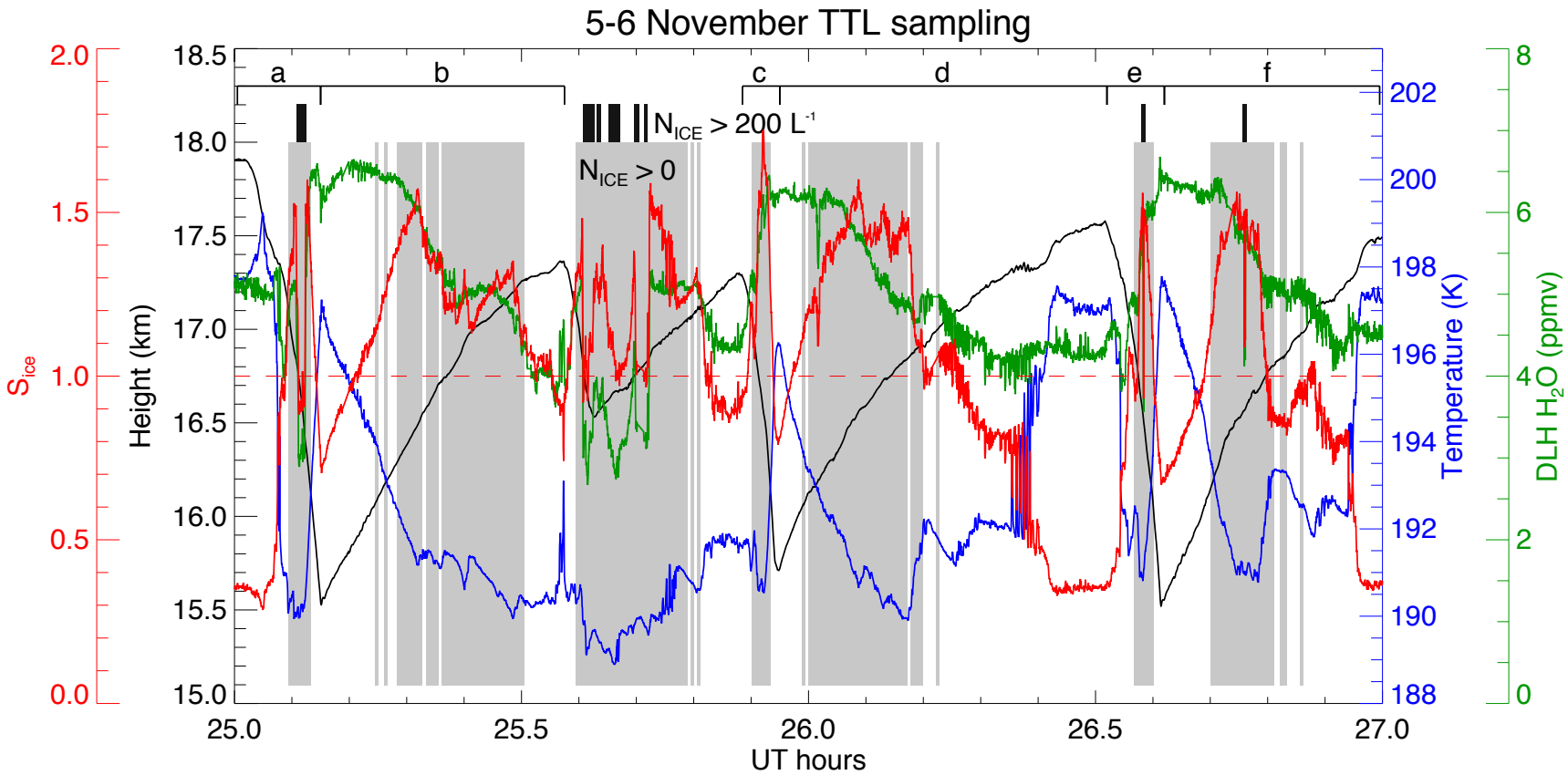

5-6 November TTL sampling
Height (km)
18.5
18.0
17.5
17.0
16.5
16.0
15.5
15.0
Temperature (K)
202
200
198
196
194
192
190
188
25.0
25.5
26.0
26.5
27.0
UT hours

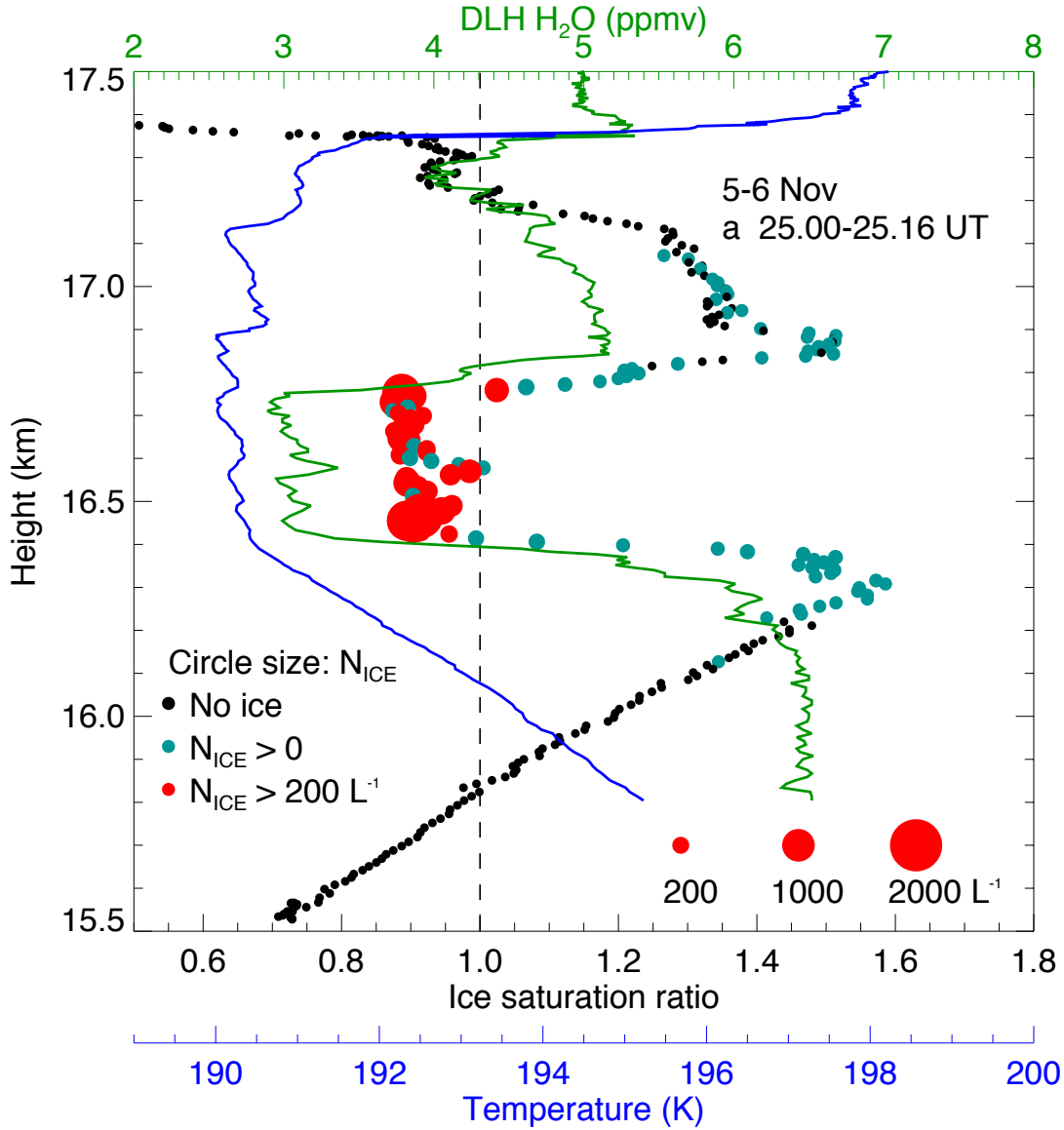

5-6 November TTL sampling
Height (km)
18.5
18.0
17.5
17.0
16.5
16.0
15.5
15.0
25.0
25.5
26.0
26.5
27.0
UT hours
Temperature (K)
202
200
198
196
194
192
190
188
DLH H_2O (ppmv)
8
6
4
2
0

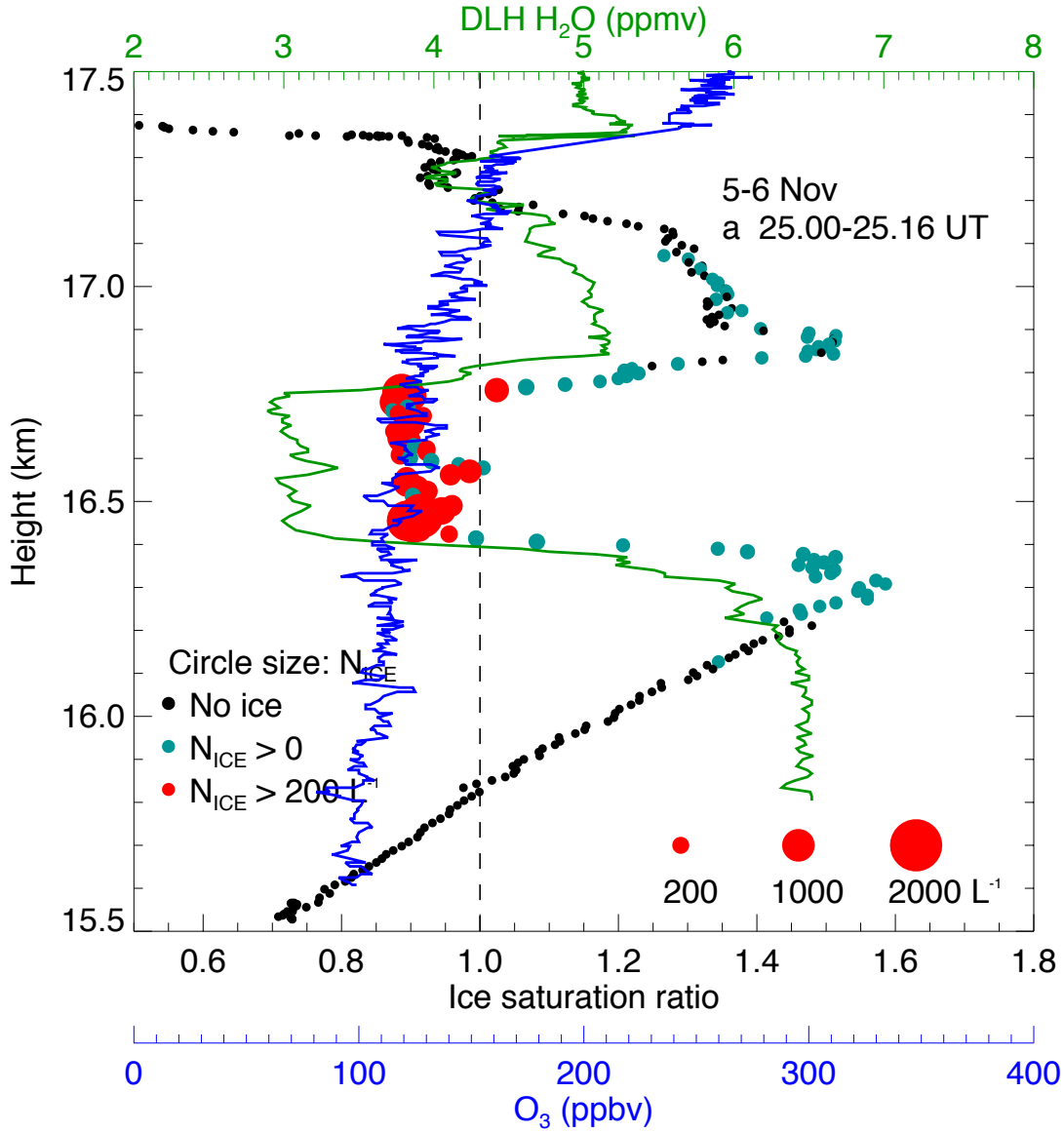

5-6 November TTL sampling
S_{ice}
2.0
1.5
1.0
0.5
0.0
Height (km)
18.5
18.0
17.5
17.0
16.5
16.0
15.5
15.0
Temperature (K)
202
200
198
196
194
192
190
188
DLH H_2O (ppmv)
8
6
4
2
0
25.0
25.5
26.0
26.5
27.0
UT hours

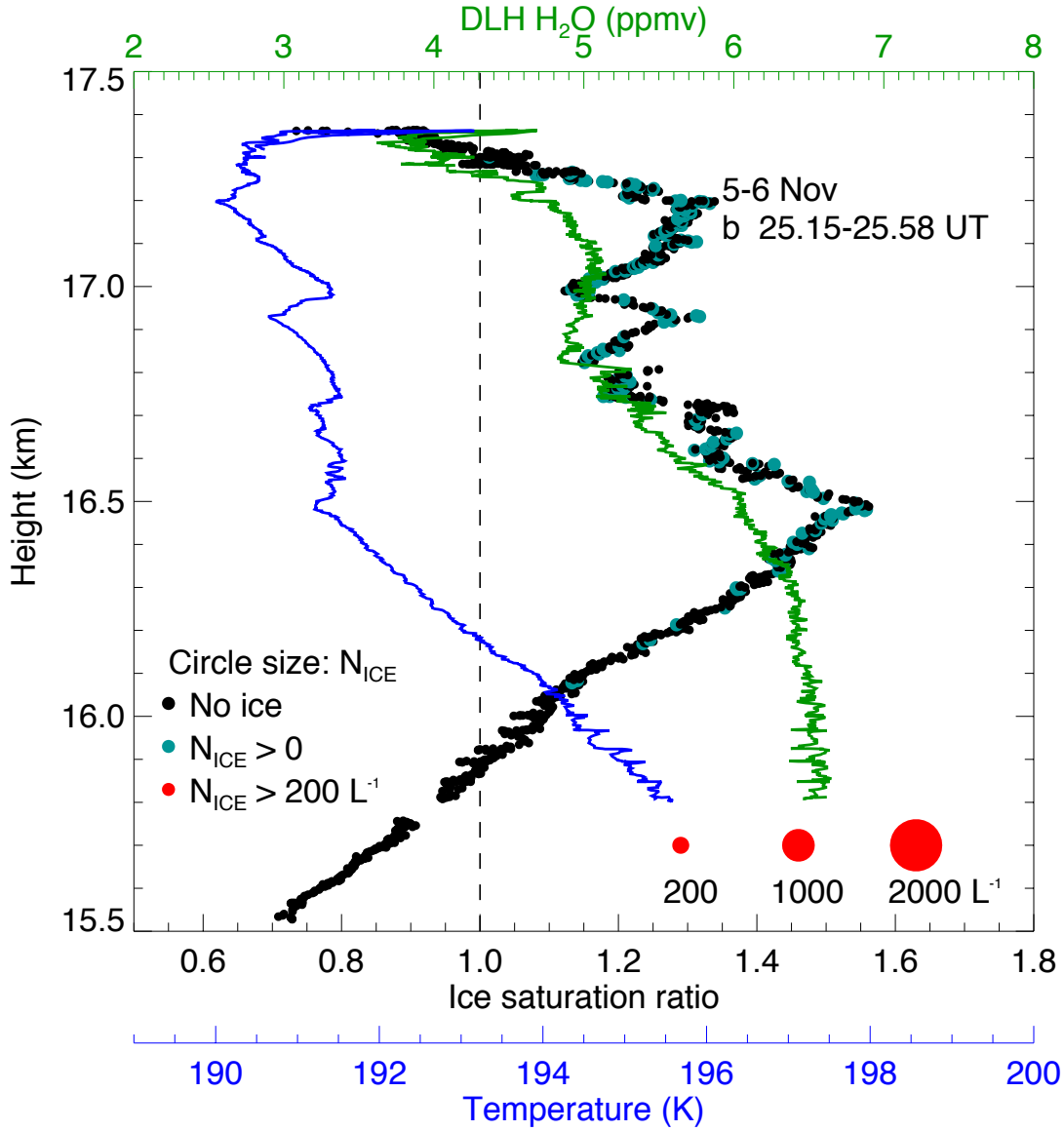

5-6 November TTL sampling
$N_{ICE} > 0$
S_{ice}
Height (km)
Temperature (K)
DLH H_2O (ppmv)
UT hours
2.0
1.5
1.0
0.5
0.0
18.5
18.0
17.5
17.0
16.5
16.0
15.5
15.0
202
200
198
196
194
192
190
188
8
6
4
2
0
25.0
25.5
26.0
26.5
27.0

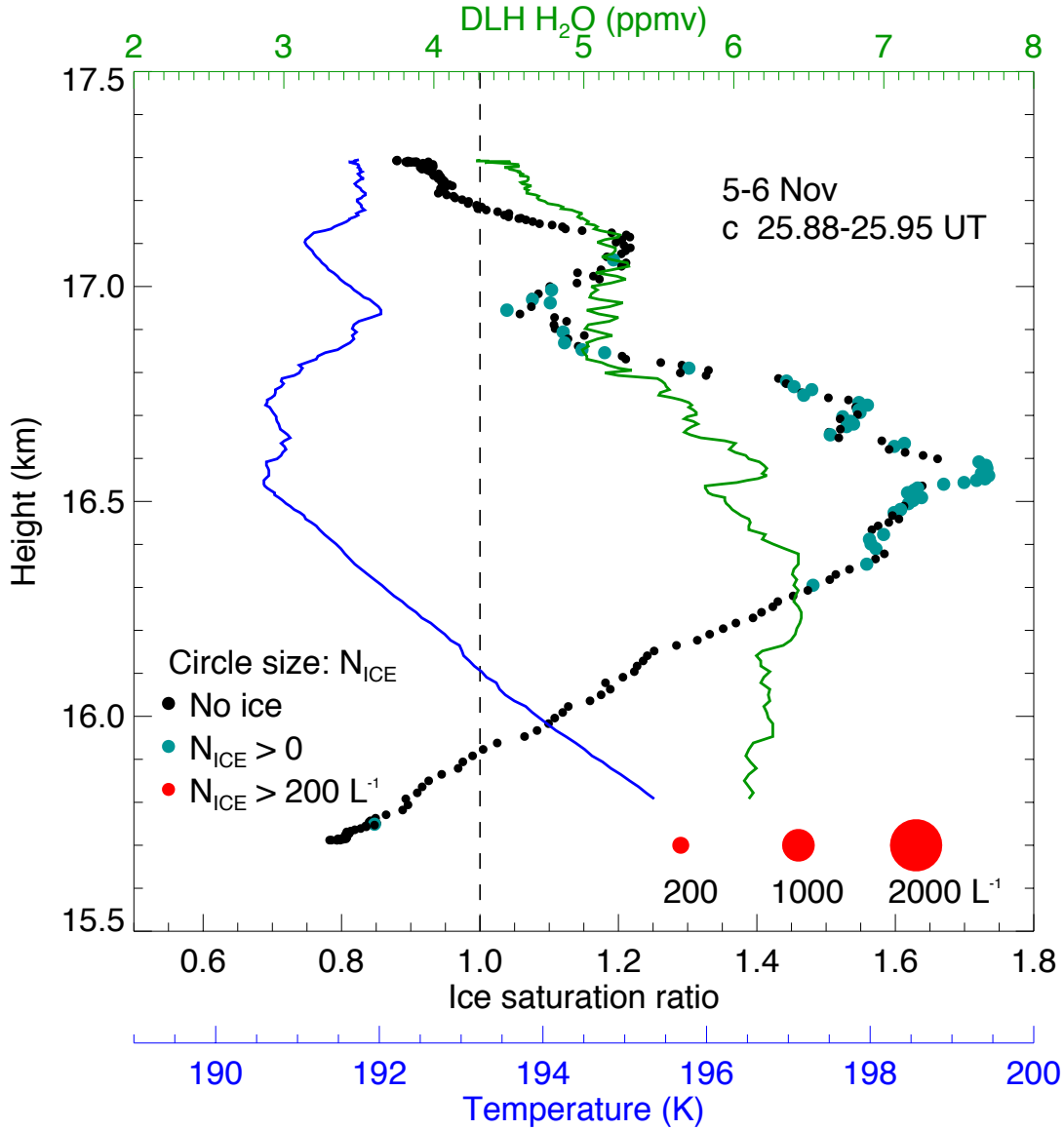

5-6 November TTL sampling
N_{ICE} > 200 L^{-1}
N_{ICE} > 0
S_{ice}
Height (km)
Temperature (K)
DLH H_2O (ppmv)
UT hours
2.0
1.5
1.0
0.5
0.0
18.5
18.0
17.5
17.0
16.5
16.0
15.5
15.0
202
200
198
196
194
192
190
188
8
6
4
2
0
25.0
25.5
26.0
26.5
27.0

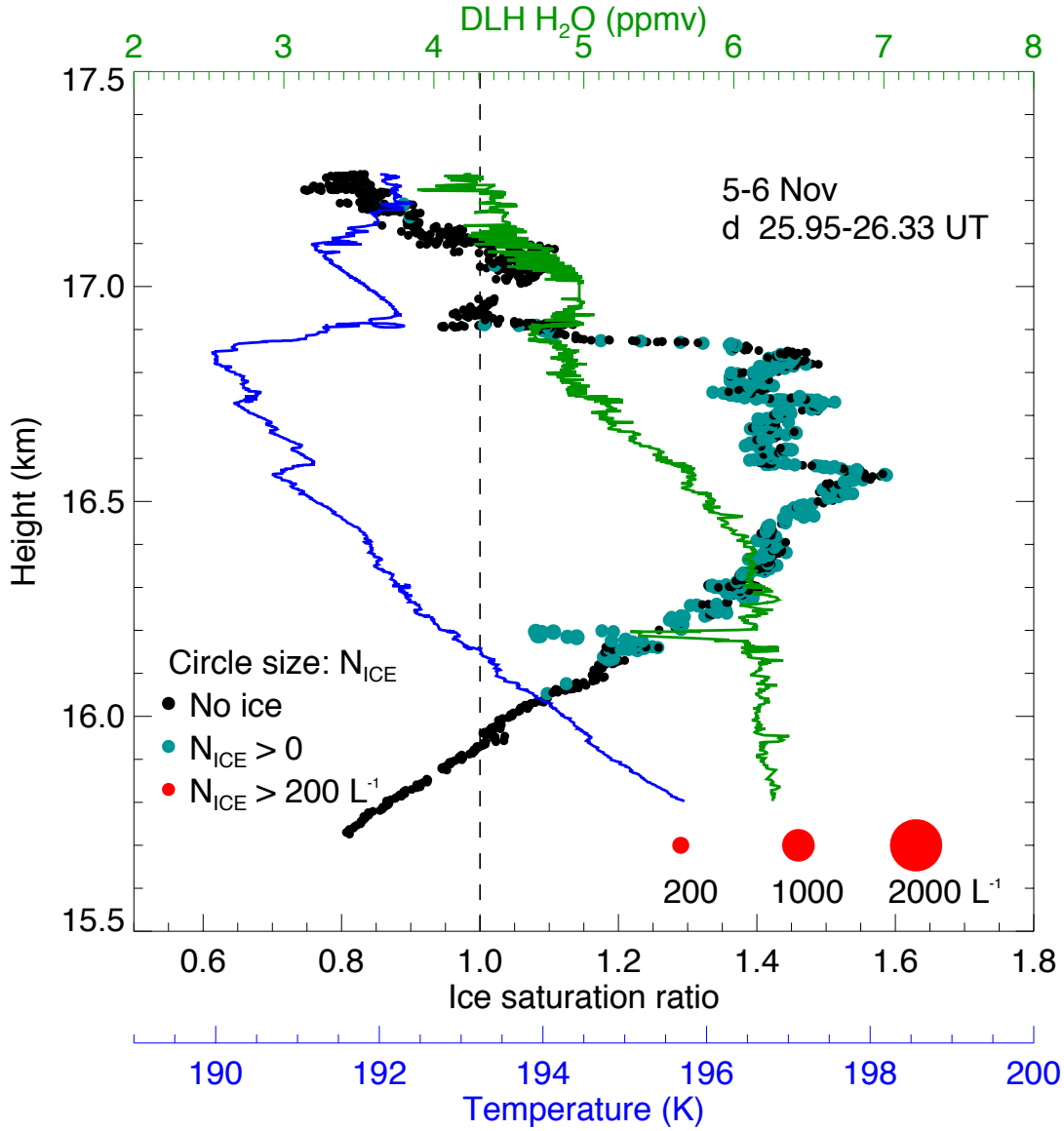

5-6 November TTL sampling
a
b
c
d
e
f
N_{ICE} > 200 L^{-1}
N_{ICE} > 0
S_{ice}
Height (km)
Temperature (K)
DLH H_2O (ppmv)
UT hours
2.0
1.5
1.0
0.5
0.0
18.5
18.0
17.5
17.0
16.5
16.0
15.5
15.0
202
200
198
196
194
192
190
188
8
6
4
2
0
25.0
25.5
26.0
26.5
27.0

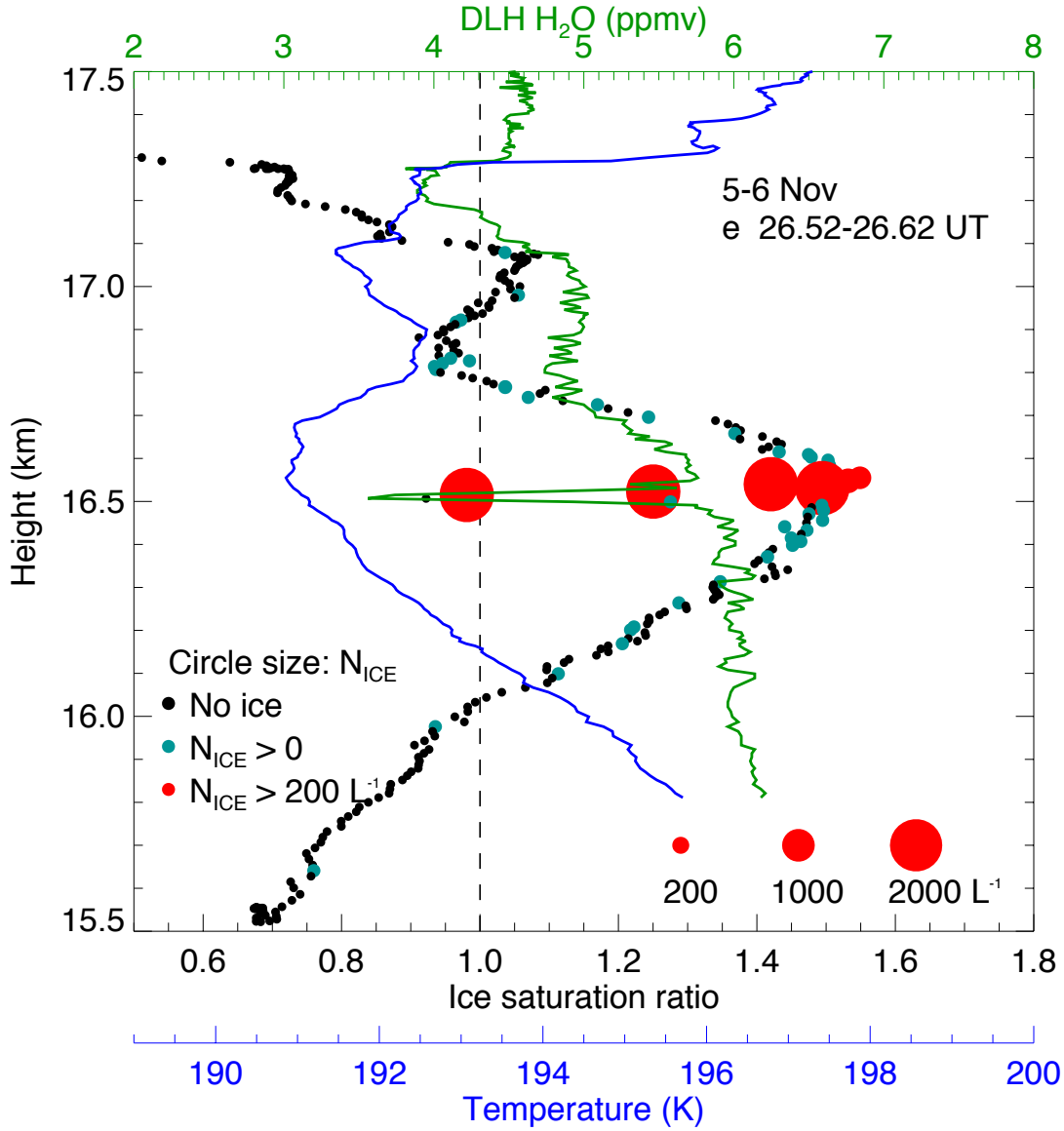

DLH H_2O (ppmv)
2
3
4
5
6
7
8
17.5
17.0
16.5
16.0
15.5
Height (km)
5-6 Nov
a 25.00-25.16 UT
Circle size: N_{ICE}
No ice
$N_{ICE} > 0$
$N_{ICE} > 200\ L^{-1}$
200
1000
2000 L^{-1}
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Ice saturation ratio
190
192
194
196
198
200
Temperature (K)

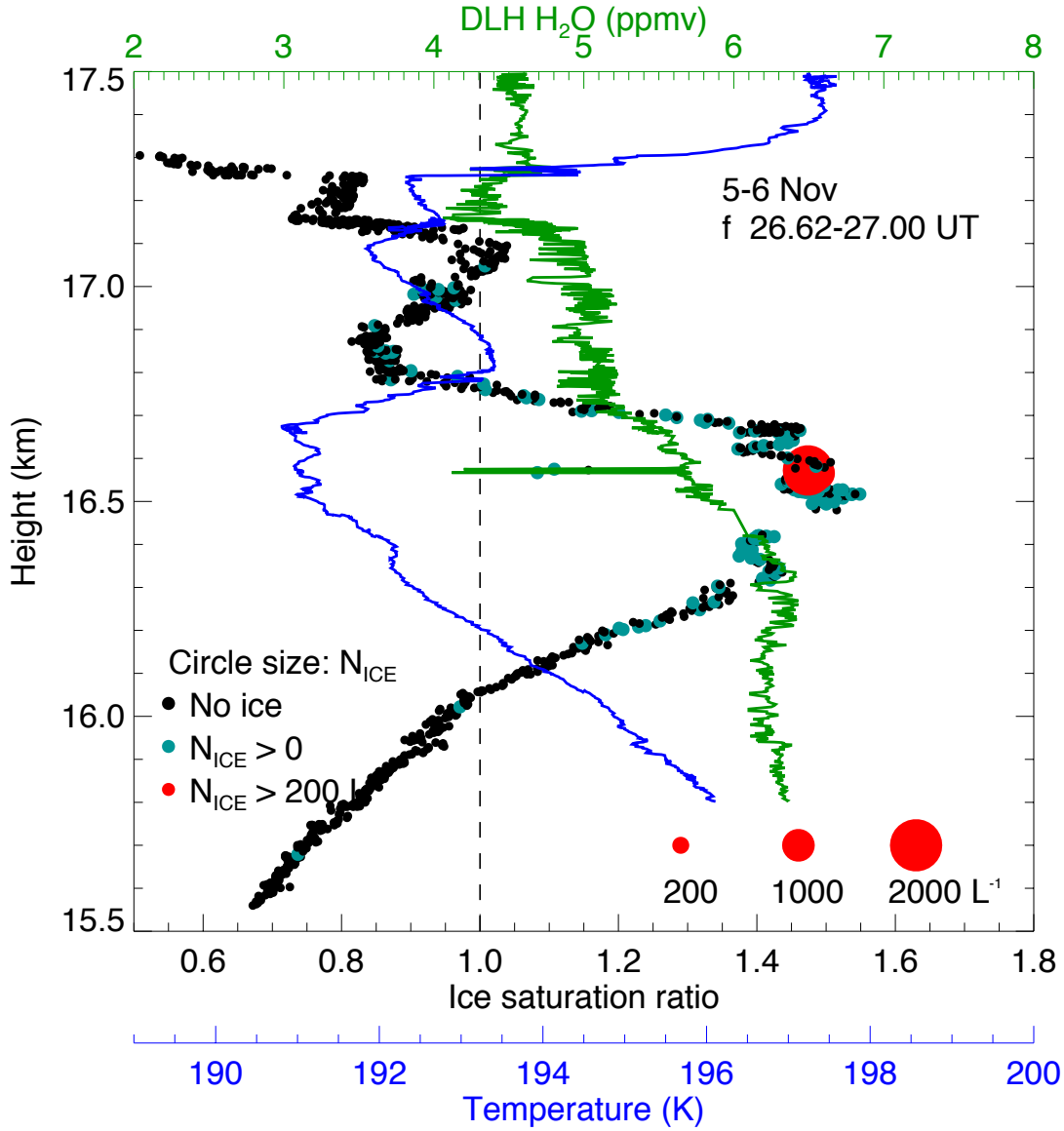

DLH H_2O (ppmv)
2
3
4
5
6
7
8
17.5
17.0
16.5
16.0
15.5
Height (km)
5-6 Nov
a 25.00-25.16 UT
Circle size: N_{ICE}
No ice
$N_{ICE} > 0$
$N_{ICE} > 200\ L^{-1}$
200
1000
2000 L^{-1}
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Ice saturation ratio
0
100
200
300
400
O_3 (ppbv)

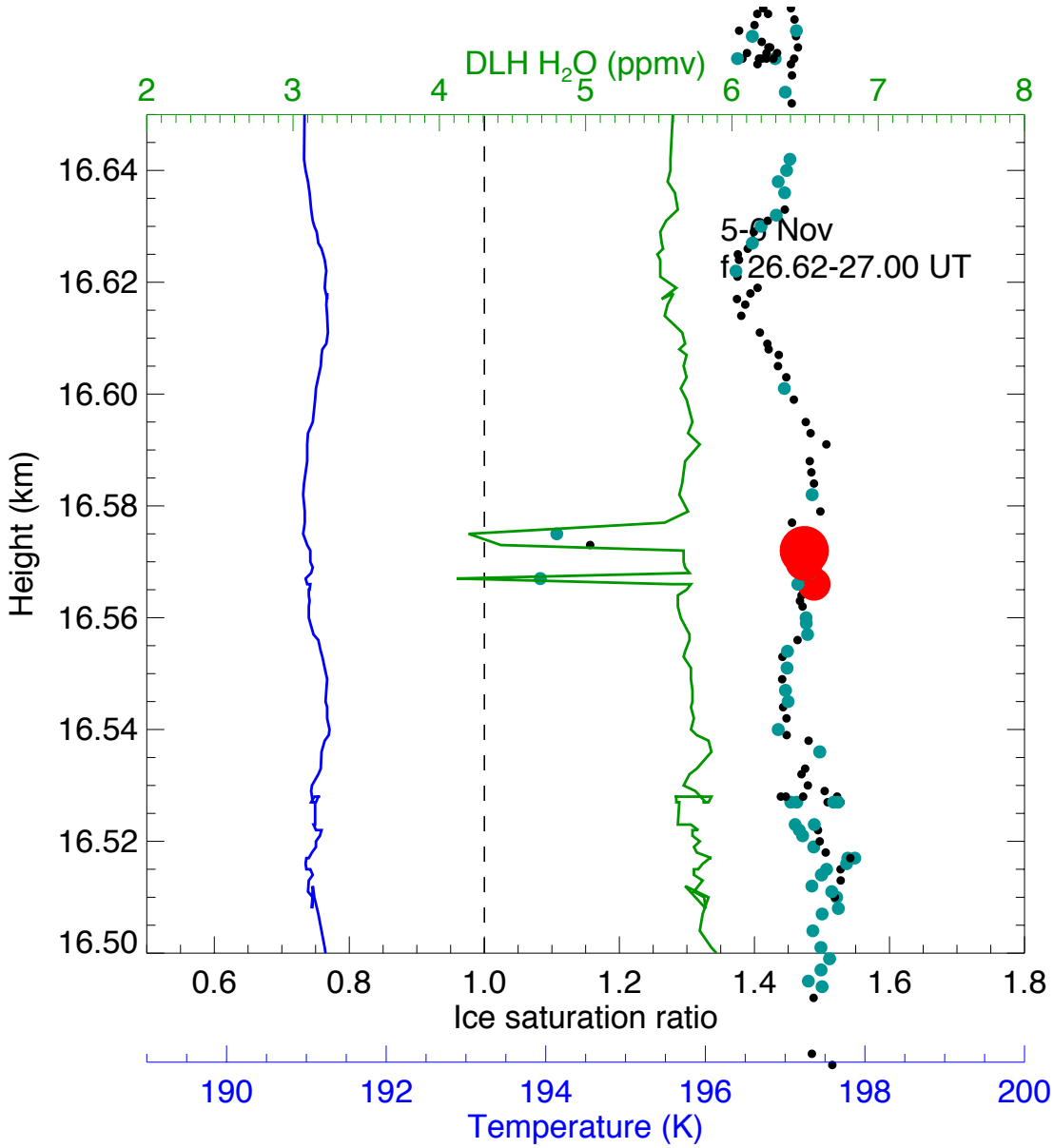

DLH H_2O (ppmv)
2
3
4
5
6
7
8
17.5
17.0
16.5
16.0
15.5
Height (km)
5-6 Nov
b 25.15-25.58 UT
Circle size: N_{ICE}
No ice
$N_{ICE} > 0$
$N_{ICE} > 200\ L^{-1}$
200
1000
2000 L^{-1}
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Ice saturation ratio
190
192
194
196
198
200
Temperature (K)

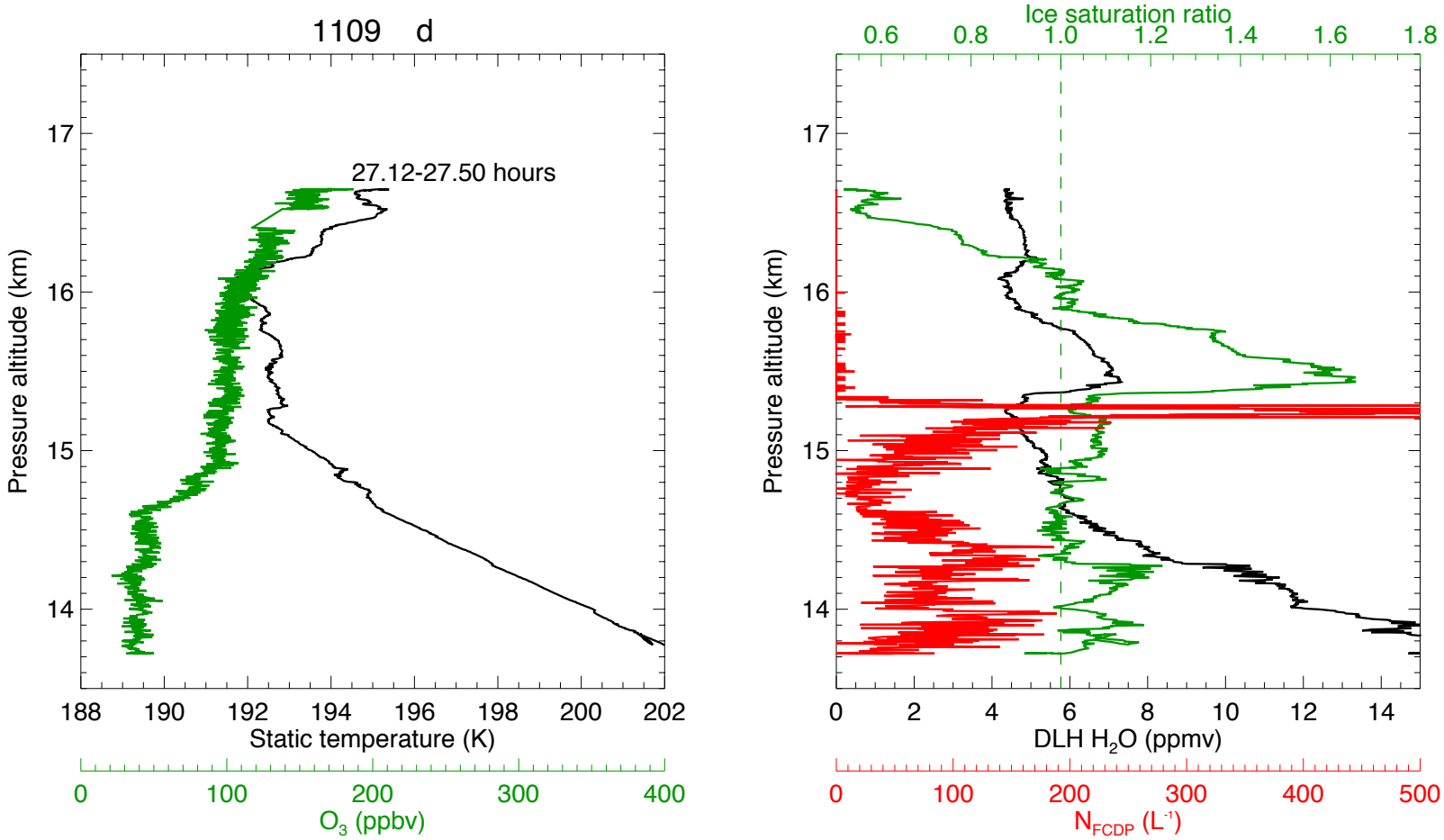

DLH H_2O (ppmv)
2
3
4
5
6
7
8
17.5
17.0
16.5
16.0
15.5
Height (km)
5-6 Nov
c 25.88-25.95 UT
Circle size: N_{ICE}
No ice
$N_{ICE} > 0$
$N_{ICE} > 200\ L^{-1}$
200
1000
2000 L^{-1}
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Ice saturation ratio
190
192
194
196
198
200
Temperature (K)

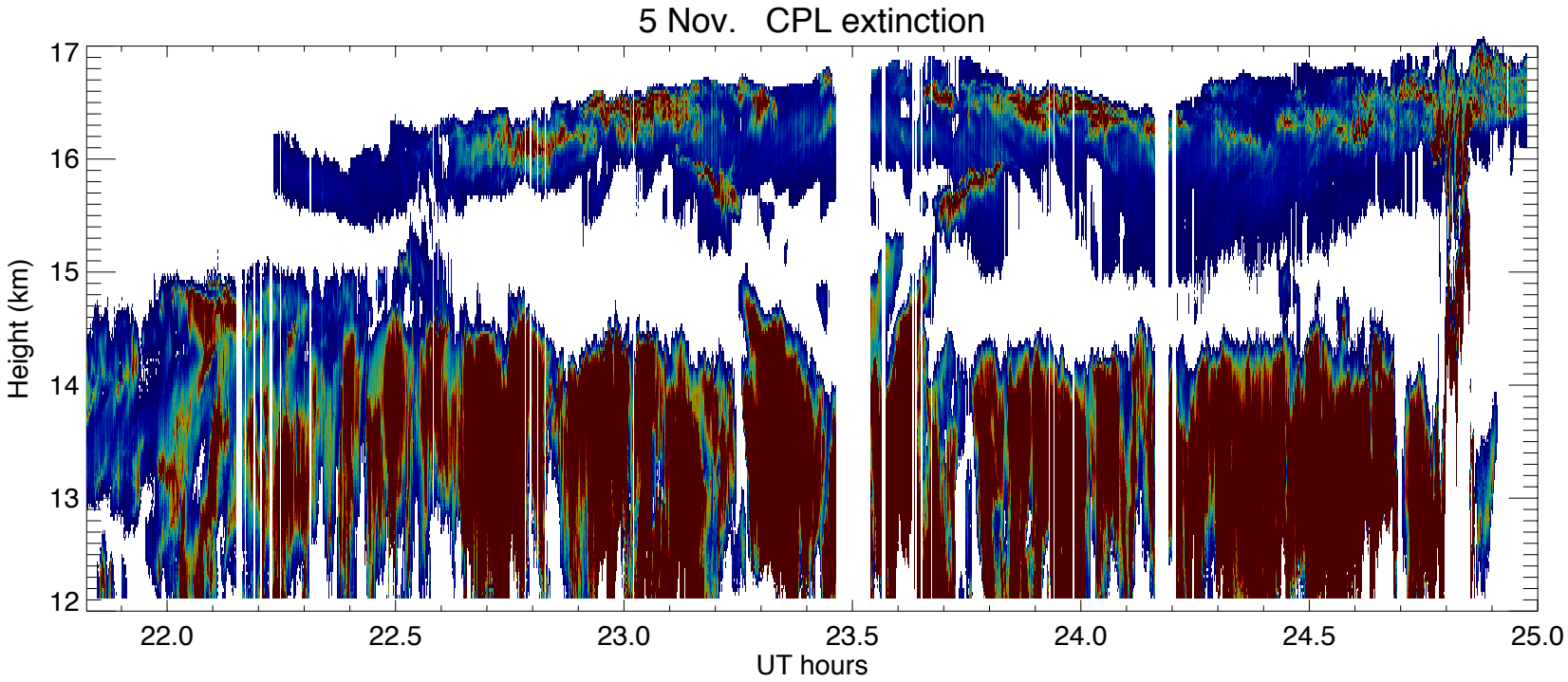

DLH H_2O (ppmv)
2
3
4
5
6
7
8
17.5
17.0
16.5
16.0
15.5
Height (km)
5-6 Nov
d 25.95-26.33 UT
Circle size: N_{ICE}
No ice
$N_{ICE} > 0$
$N_{ICE} > 200\ L^{-1}$
200
1000
2000 L^{-1}
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Ice saturation ratio
190
192
194
196
198
200
Temperature (K)

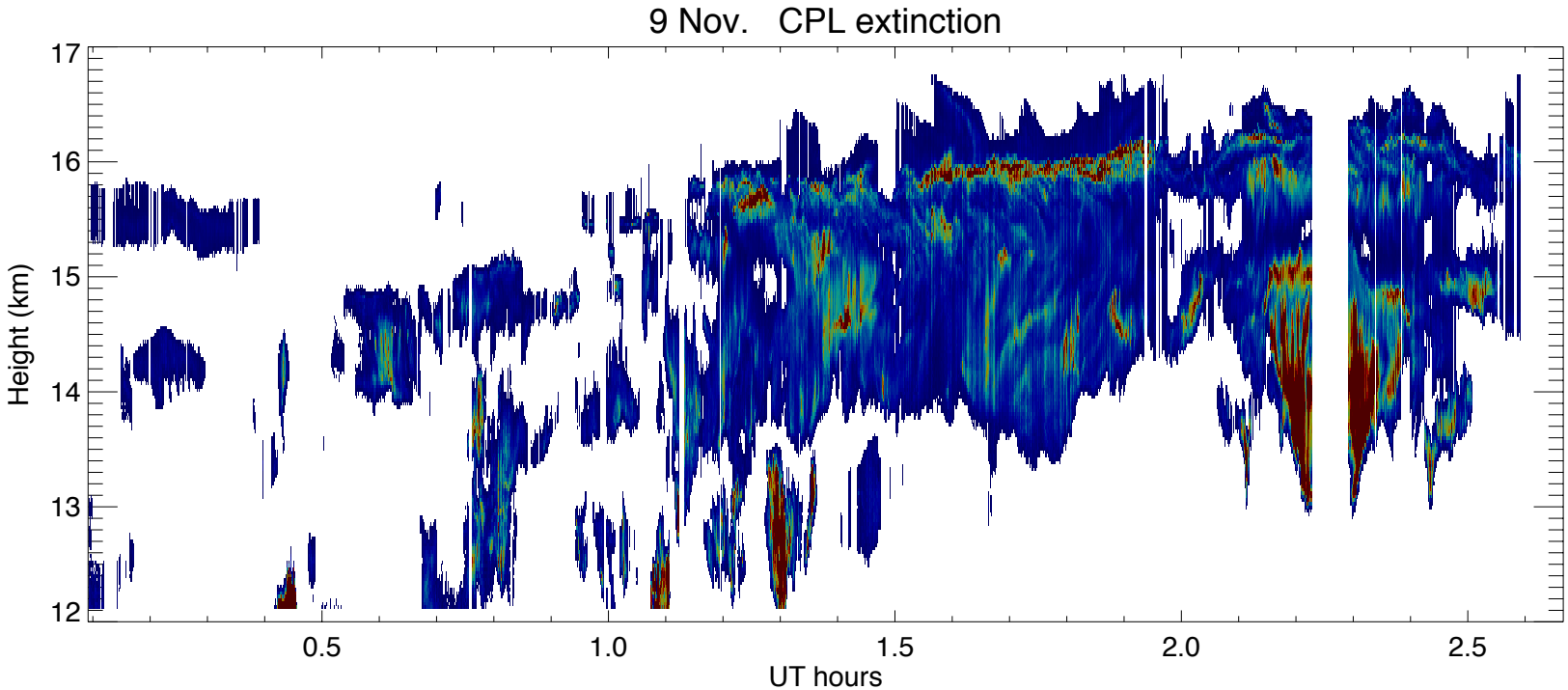

DLH H_2O (ppmv)
2
3
4
5
6
7
8
17.5
17.0
16.5
16.0
15.5
Height (km)
5-6 Nov
e 26.52-26.62 UT
Circle size: N_{ICE}
No ice
$N_{ICE} > 0$
$N_{ICE} > 200\ L^{-1}$
200
1000
2000 L^{-1}
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Ice saturation ratio
190
192
194
196
198
200
Temperature (K)


DLH H_2O (ppmv)
2
3
4
5
6
7
8
17.5
17.0
16.5
16.0
15.5
Height (km)
5-6 Nov
f 26.62-27.00 UT
Circle size: N_{ICE}
No ice
$N_{ICE} > 0$
$N_{ICE} > 200$ L
200
1000
2000 L^{-1}
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Ice saturation ratio
190
192
194
196
198
200
Temperature (K)


DLH H_2O (ppmv)
2
3
4
5
6
7
8
5-6 Nov
f 26.62-27.00 UT
Height (km)
16.64
16.62
16.60
16.58
16.56
16.54
16.52
16.50
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Ice saturation ratio
190
192
194
196
198
200
Temperature (K)


1109 d
27.12-27.50 hours
Pressure altitude (km)
17
16
15
14
188
190
192
194
196
198
200
202
Static temperature (K)
0
100
200
300
400
O3 (ppbv)
Ice saturation ratio
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Pressure altitude (km)
17
16
15
14
0
2
4
6
8
10
12
14
DLH H2O (ppmv)
0
100
200
300
400
500
NFCDP (L-1)


5 Nov. CPL extinction
Height (km)
17
16
15
14
13
12
22.0
22.5
23.0
23.5
24.0
24.5
25.0
UT hours


9 Nov. CPL extinction
Height (km)
17
16
15
14
13
12
0.5
1.0
1.5
2.0
2.5
UT hours

Preliminary results from ATTREX

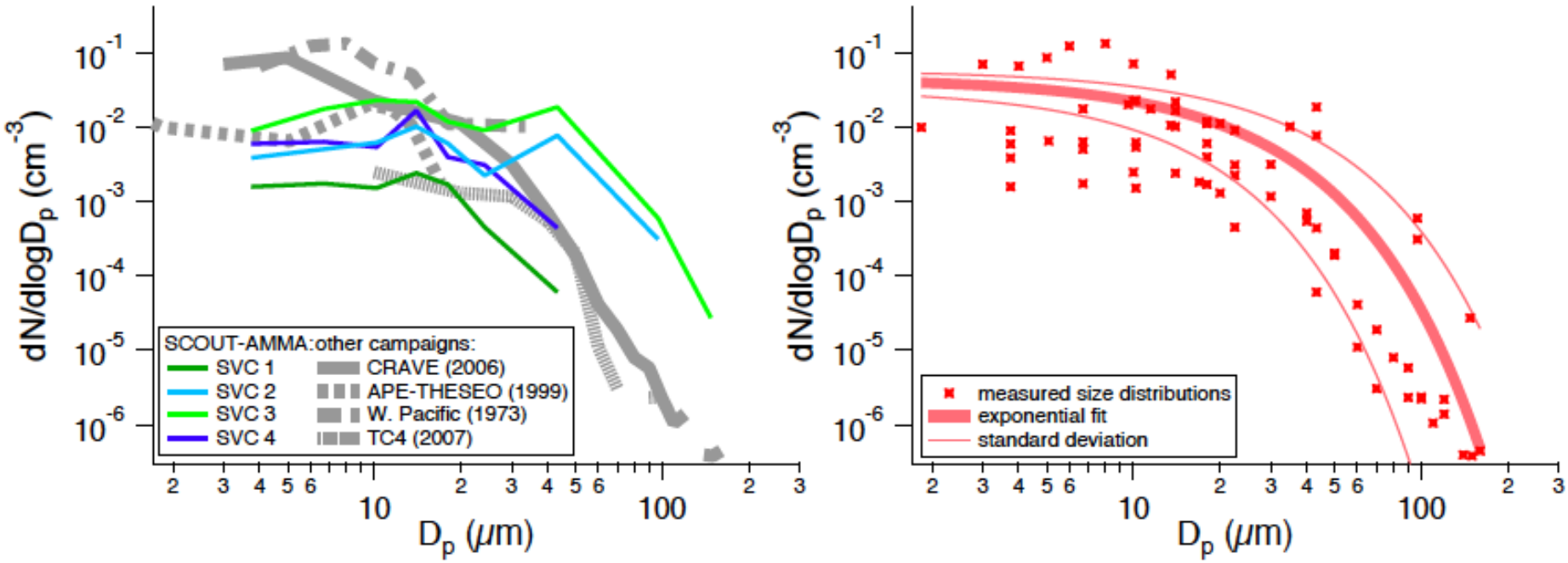
- Two distinct types of TTL cirrus:
  1. Low ice-concentration clouds that do not rapidly deplete vapor in excess of saturation (heterogeneous nucleation)
  2. High ice-concentration clouds that rapidly deplete vapor in excess of saturation (homogeneous freezing)

- High ice-concentration layers are narrow and embedded within broader low ice-concentration layers.

Contrast between CRAVE/TC4 and ATTREX TTL cirrus measurements

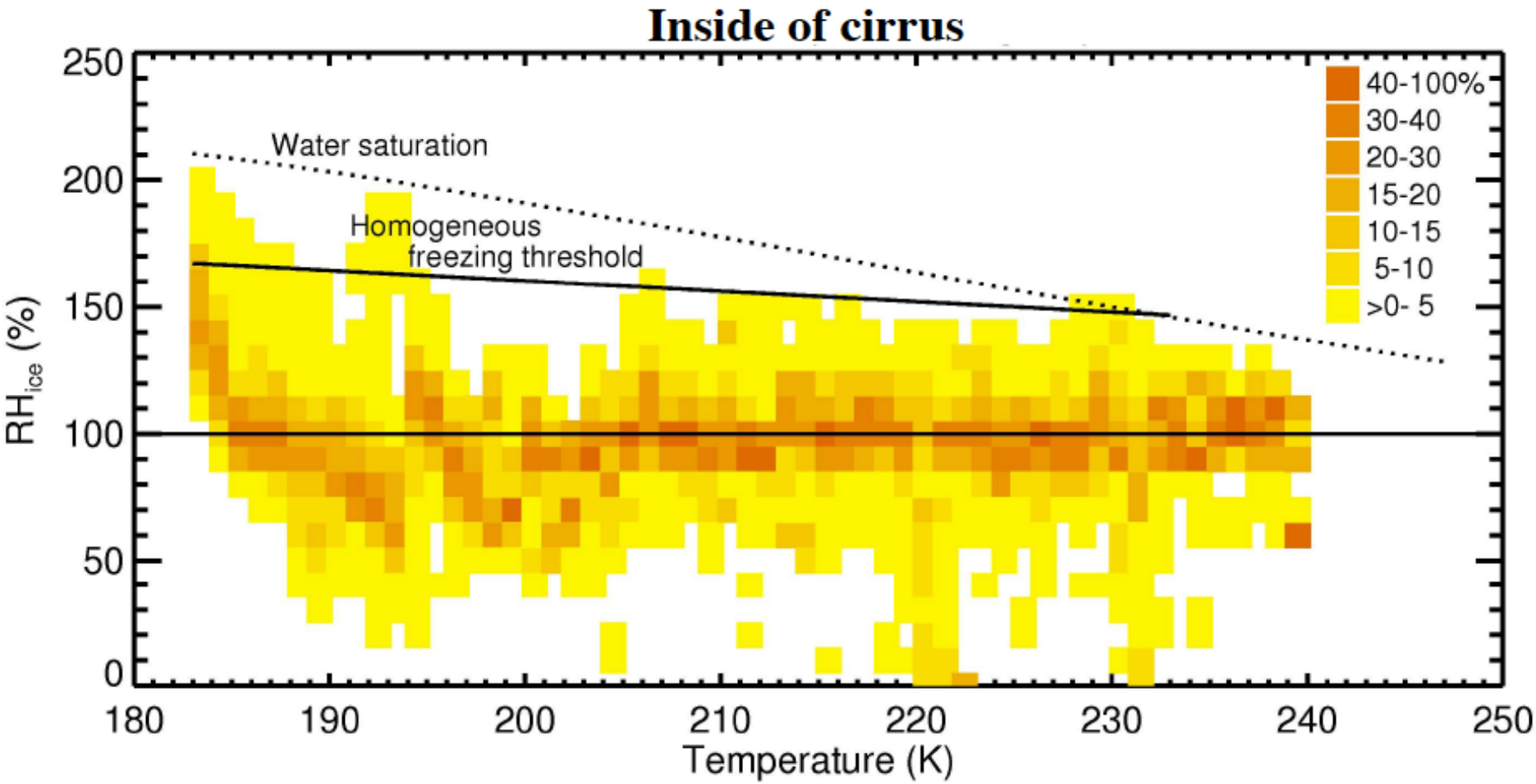
- Only low ice-concentration TTL cirrus were observed during CRAVE.
- ATTREX: $S_{ice} \approx 1$ in high-conc layers. No evidence of dehydration in CRAVE cirrus.
- Different microphysics (no evidence for homogeneous freezing in CRAVE clouds)?
  - Colder CRAVE clouds could mean glassy organic-containing aerosols (suppressed homogeneous freezing).
- Different stages of cloud lifecycle sampled?
  - We should attempt Lagrangian flights through TTL cirrus in future ATTREX deployments to sample full cloud lifecycle.
- How do TTL cirrus sampled by the Geophysica compare?

TTL cirrus size distributions (Frey et al., 2011)



Past measurements consistently indicate ice concentrations less than 100 L^{-1}.

Relative humidities in TTL cirrus (Krämer et al., 2009)



FISH H_2O measurements consistent with cold CRAVE measurements, but lower RHI at T > 186 K.

Future TTL cirrus measurements

- SEAC^{4}RS ER-2 measurements, Aug-Sept, 2012, SE Asia

- Future ATTREX deployments:
  - Jan-Feb, 2013, east-Pac
  - Jan-Feb, 2014, Guam
  - Jul-Aug, 2014, Darwin

  - Additional instrumentation: NOAA H_2O (vapor, total); Picarro CO_2, CO, CH_4; Hawkeye cloud microphysics

- Sampling of colder TTL cirrus
- Lagrangian flights
- Comparison of condensed-phase H_2O to apparent deficit in vapor