Recent Efforts to use Small Unmanned Aircraft in Studying the Arctic Atmosphere: An Overview of COALA and ERASMUS

Gijs de Boer[1,2]

with substantial contributions from (alphabetical):

Brian Argrow[1], Al Bendure[3], Geoff Bland[4], Nathan Curry[1], Phillip D'Amore[1], Jack Elston[5], Will Finamore[1], Ru-Shan Gao[2], Terry Hock[6], Mark Ivey[3], Dale Lawrence[1], Gabe LoDolce[1], Chuck Long[1,2], James Mack[1], Tevis Nichols[1], Scott Palo[1], Beat Schmid[7], Hagen Telg[1,2], Doug Weibel[1]

(1) University of Colorado Boulder

(2) NOAA

(3) Sandia National Laboratories

(4) NASA

(5) BlackSwift Technologies

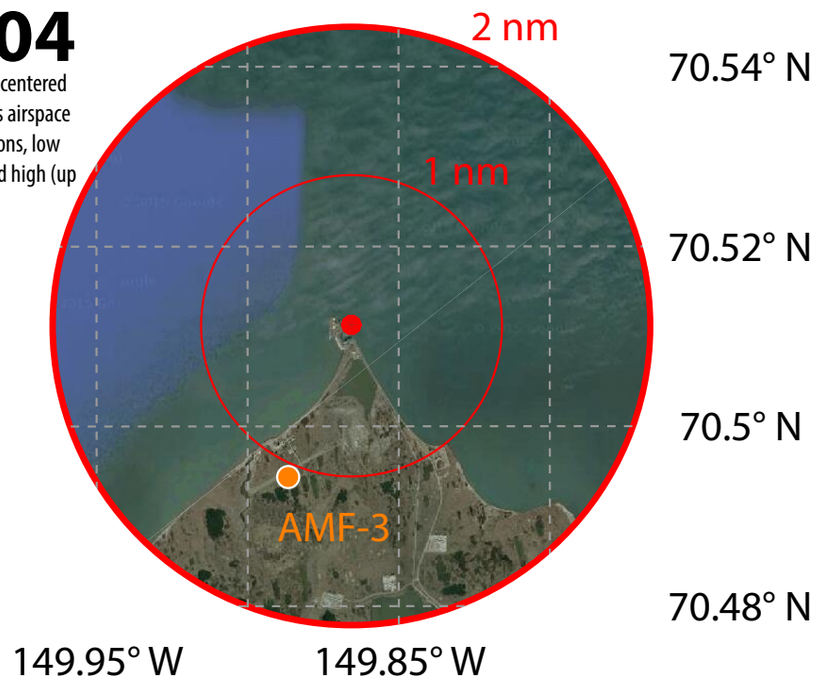
(6) NCAR

(7) Pacific Northwest National Laboratory

Access to Airspace

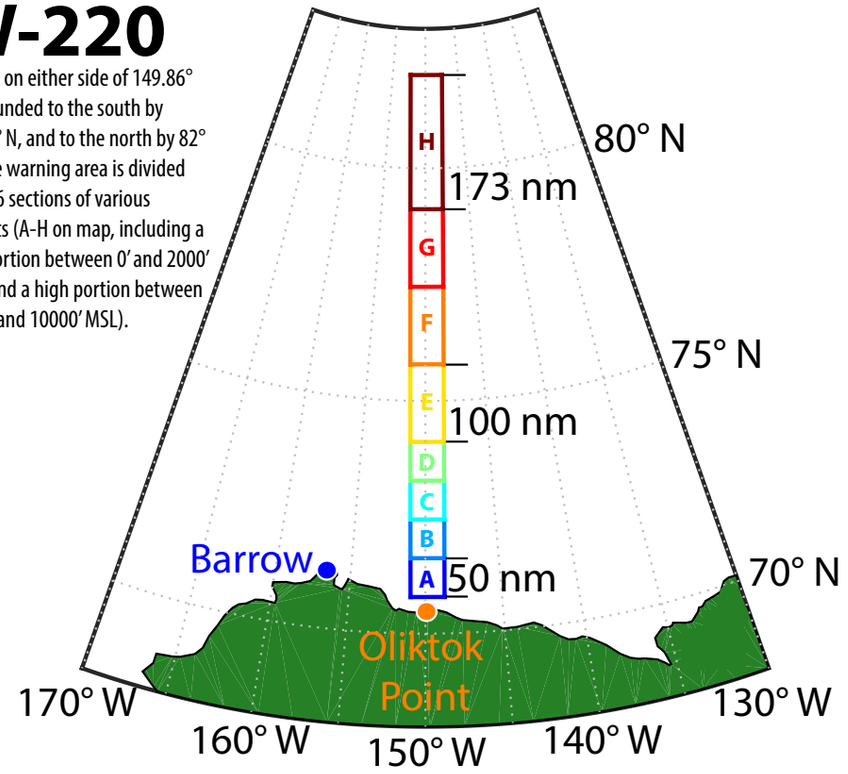
R-2204

4 nm diameter circle centered on Oliktok Point. This airspace is split into two sections, low (up to 1500′ MSL) and high (up to 7000′ MSL).



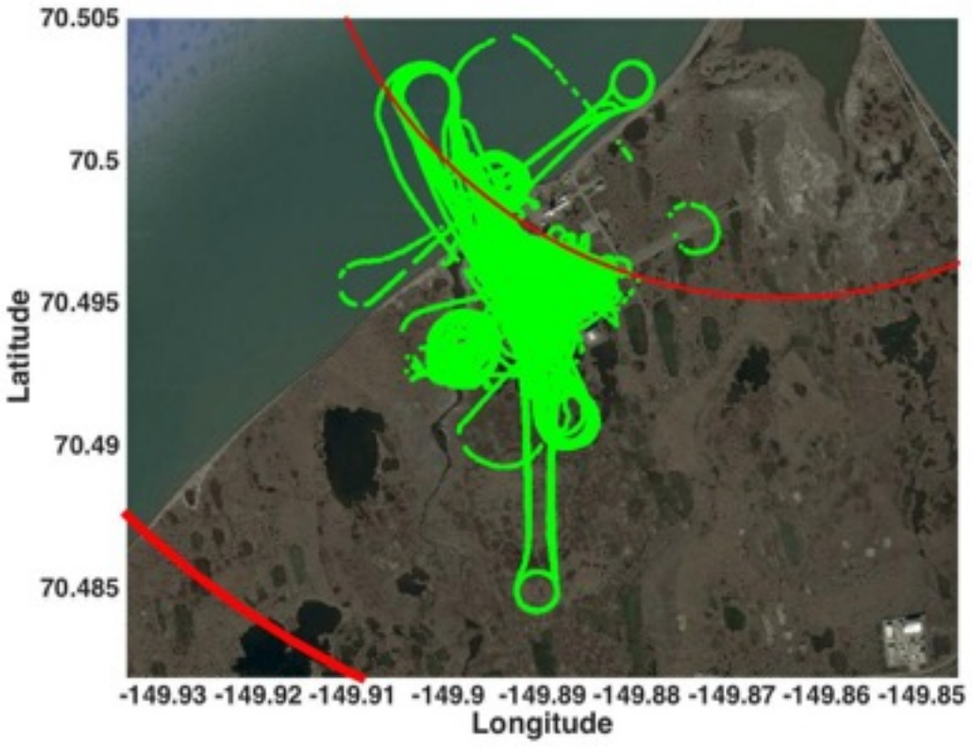
W-220

20 nm on either side of 149.86° W, bounded to the south by 70.78° N, and to the north by 82° N. The warning area is divided into 16 sections of various lenghts (A-H on map, including a low portion between 0′ and 2000′ MSL and a high portion between 2000′ and 10000′ MSL).



de Boer et al., 2016a

Recent Activities: COALA

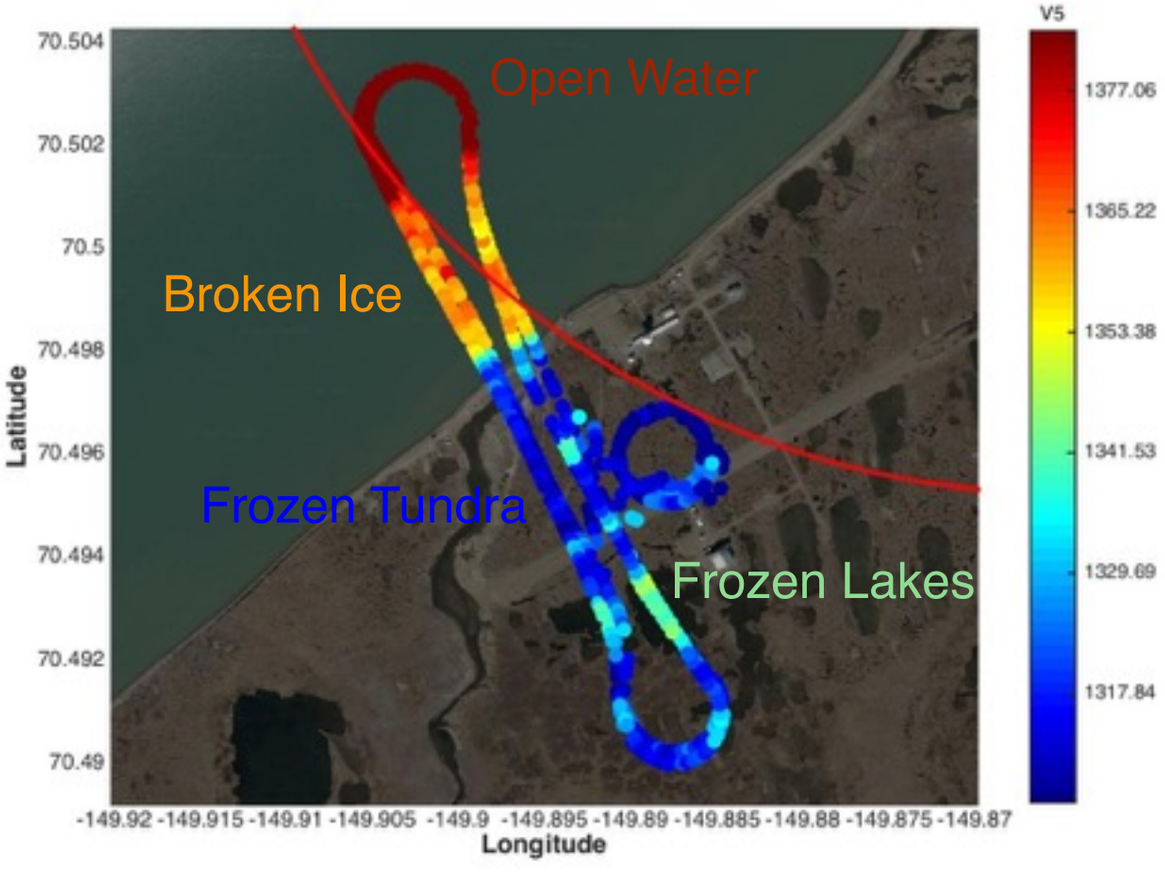


Recent Activities: COALA

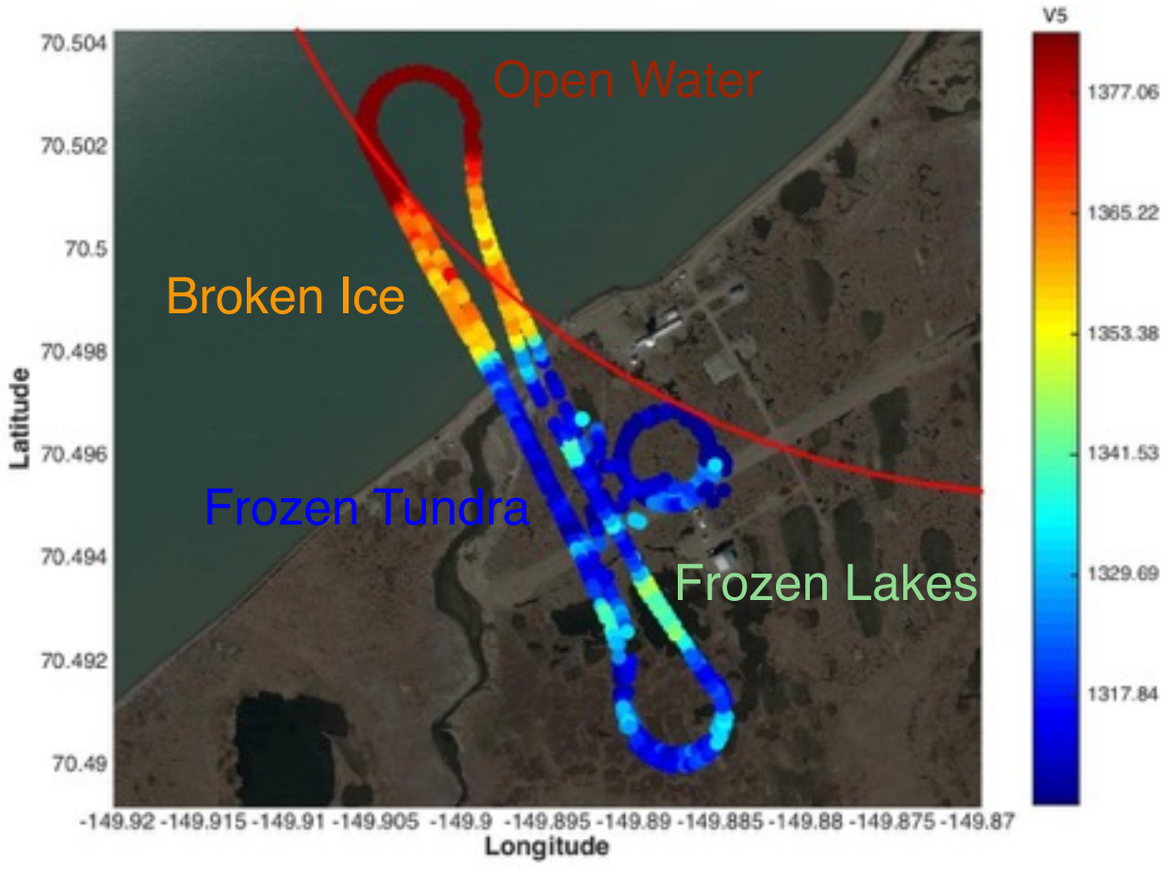
Recent Activities: COALA

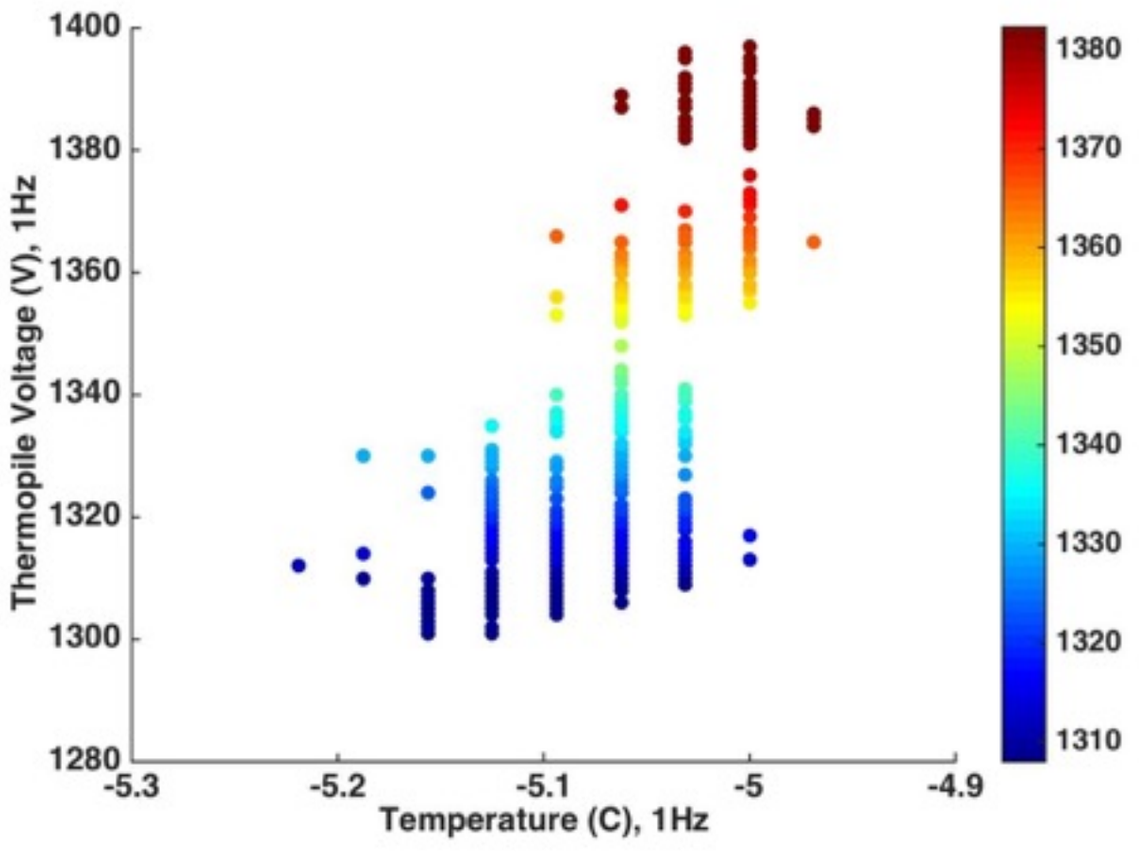
Recent Activities: COALA

Recent Activities: COALA

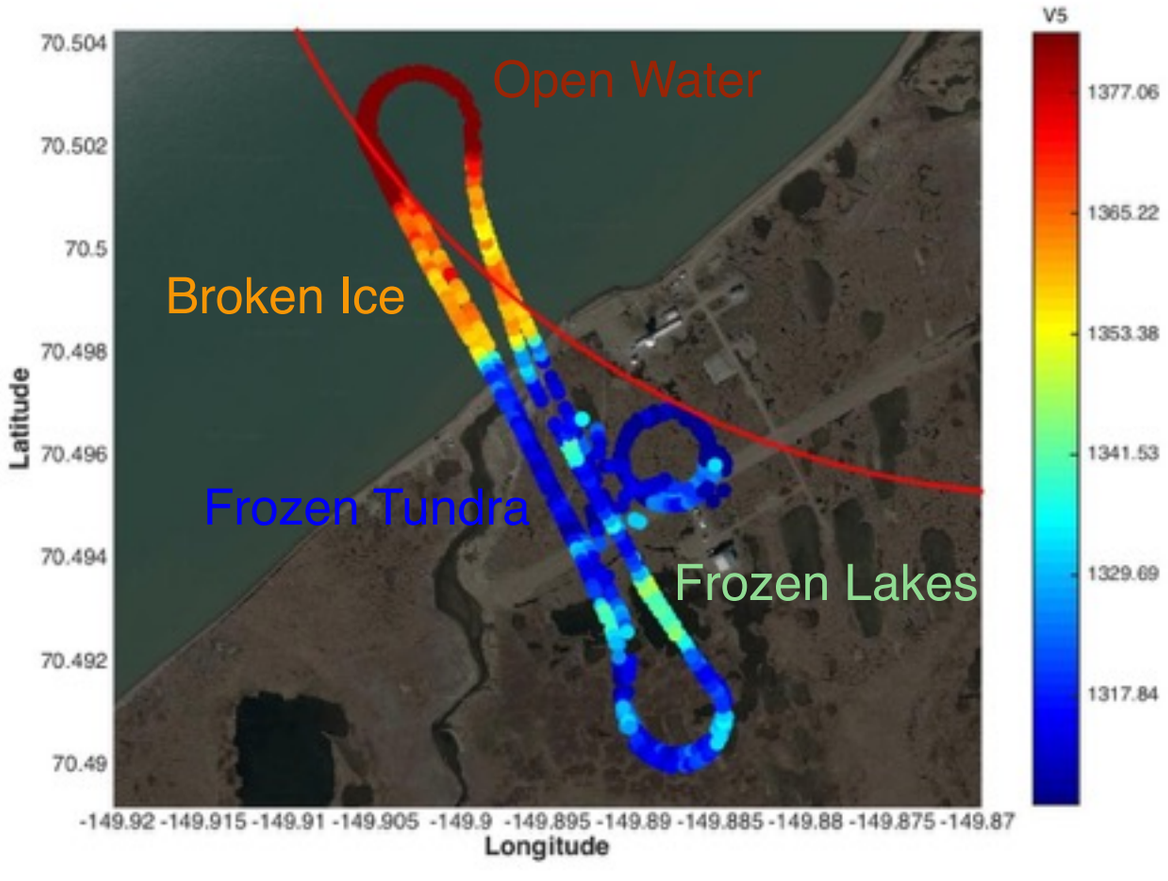


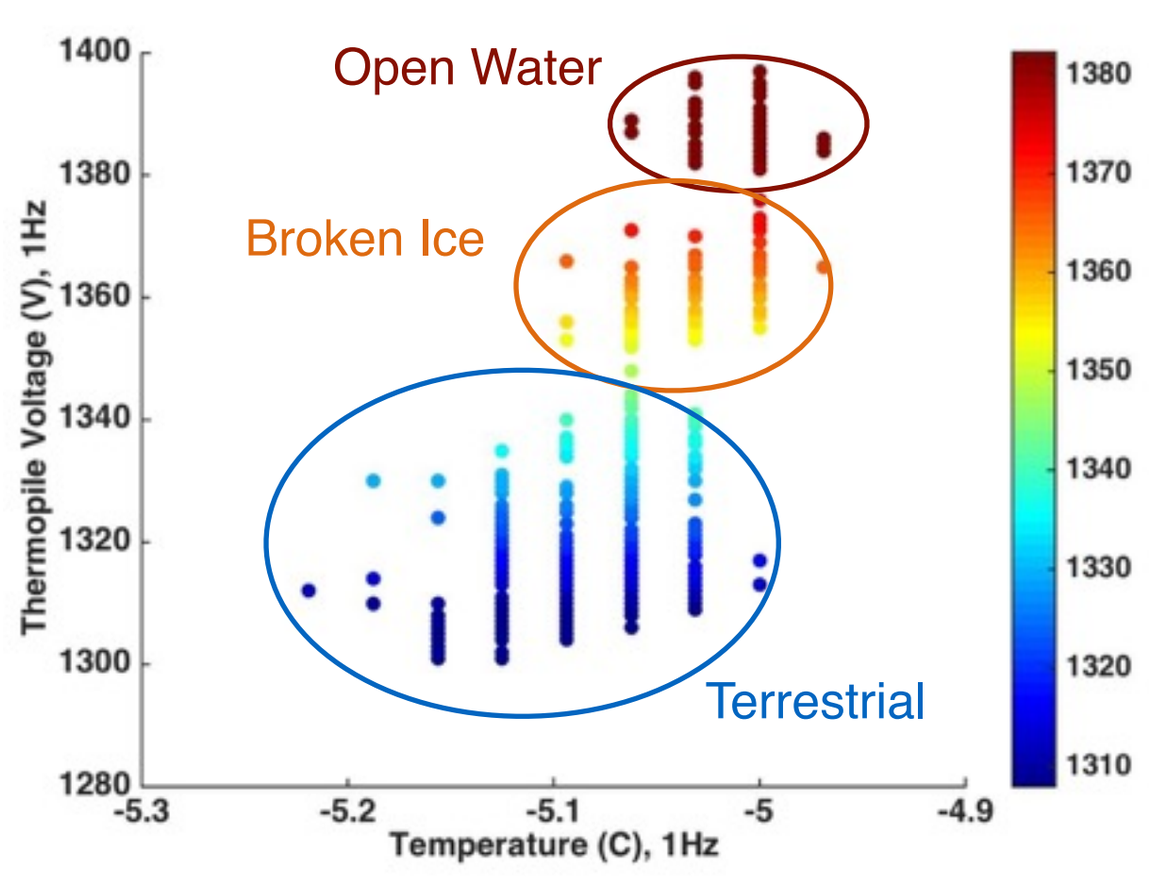
Recent Activities: COALA



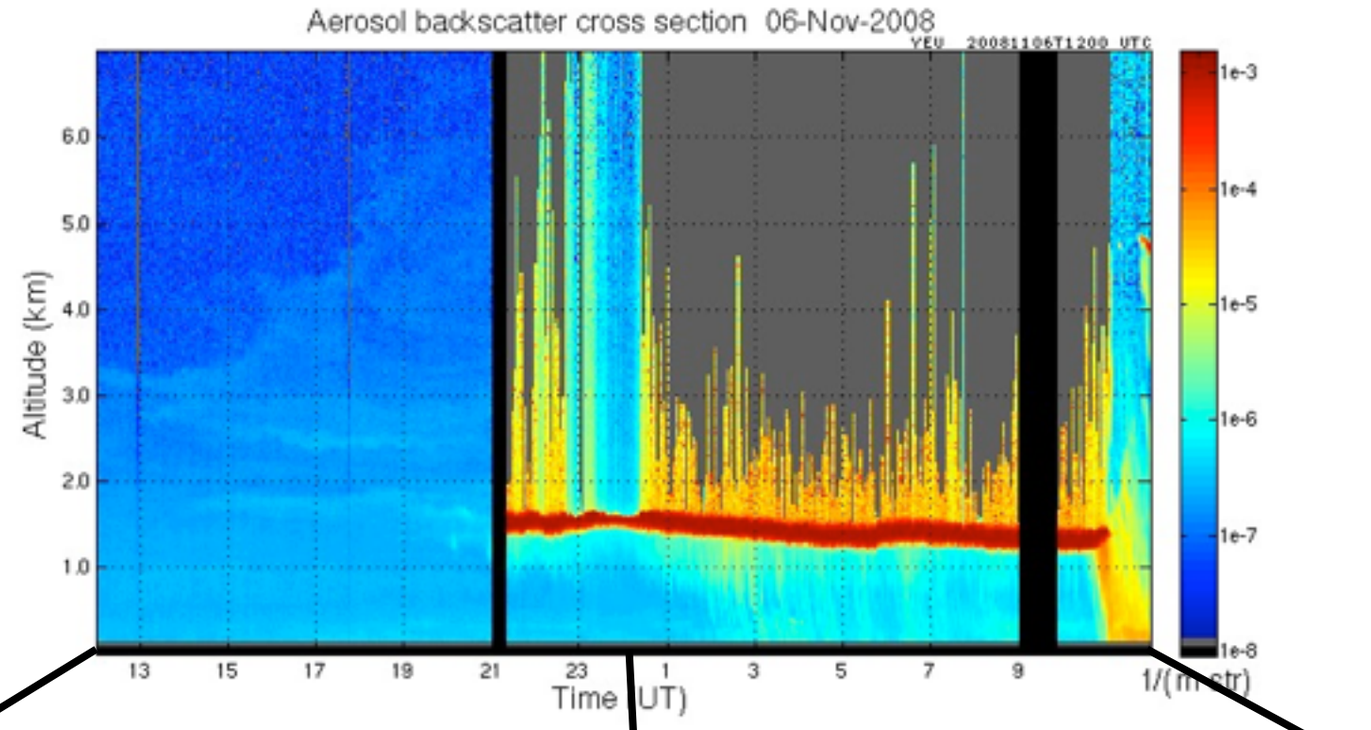


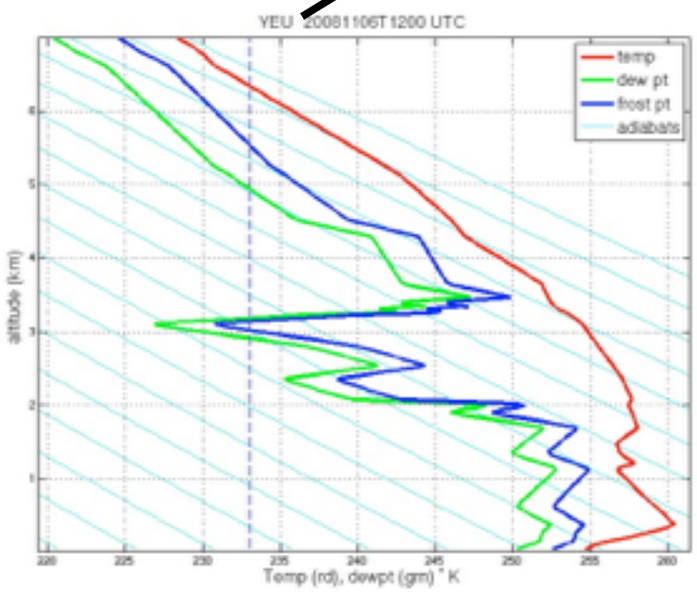
Recent Activities: COALA

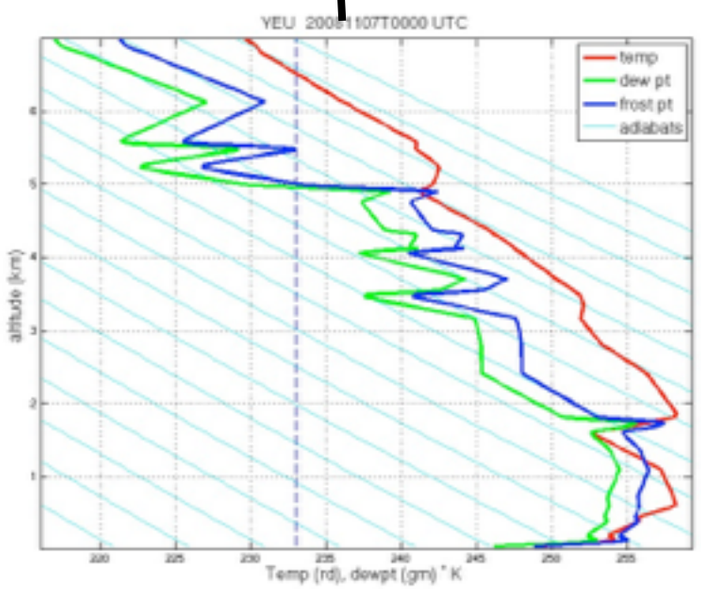


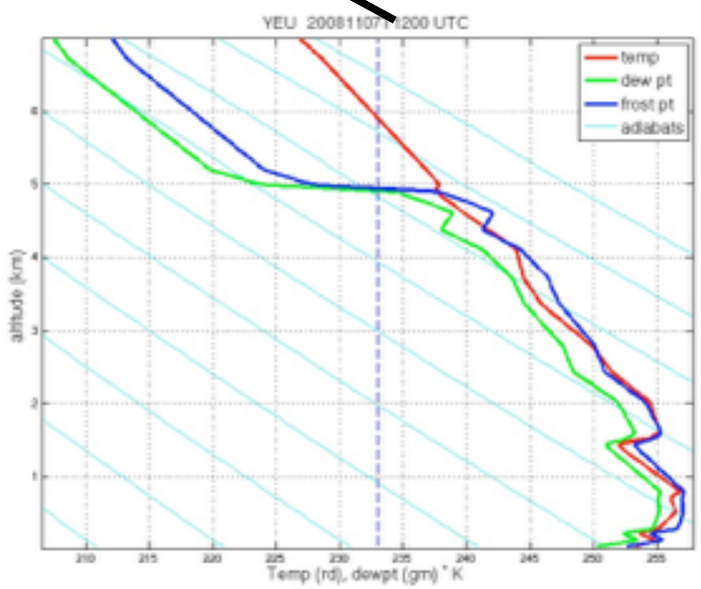


ERASMUS I

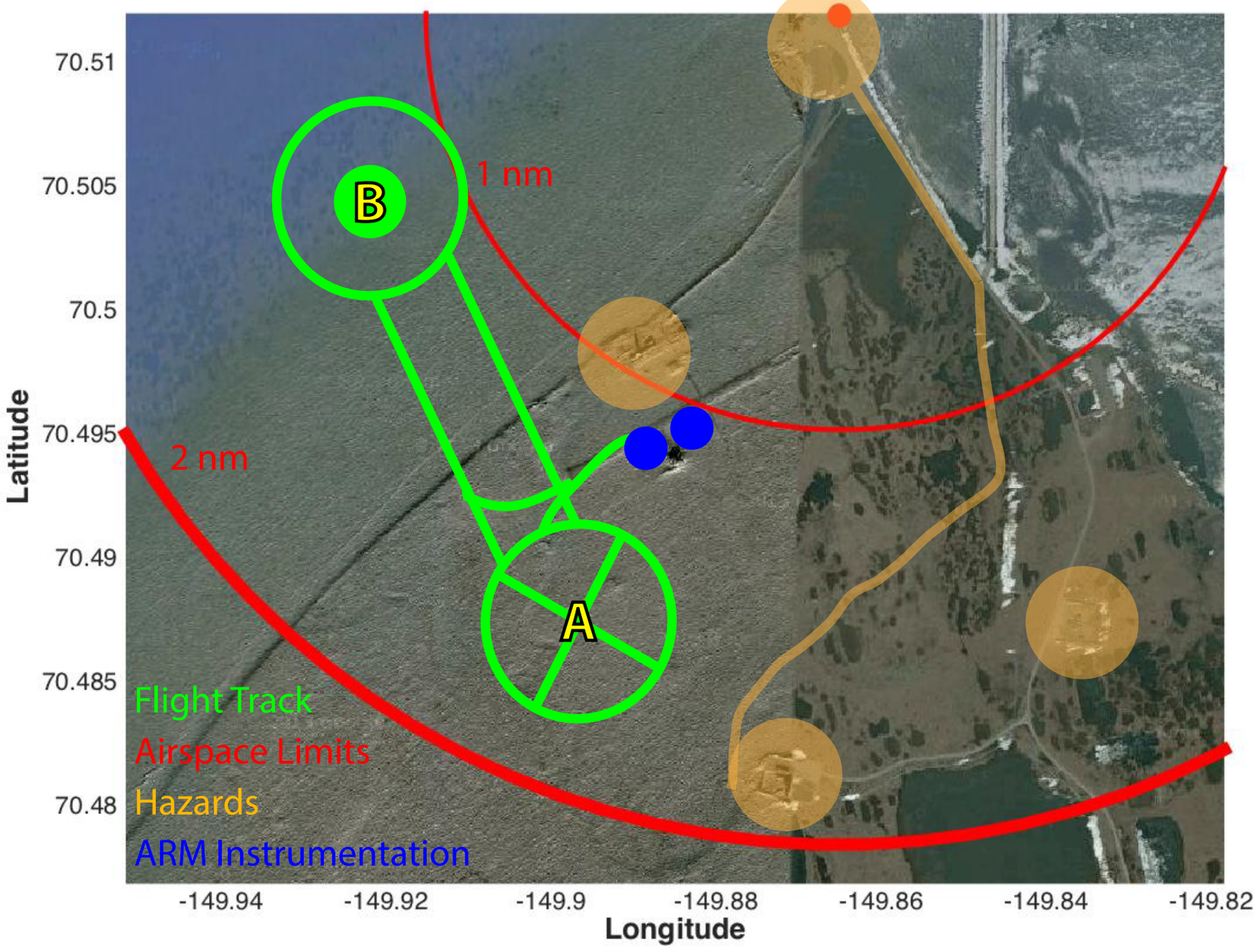

Aerosol backscatter cross section 06-Nov-2008
YEU 20081106T1200 UTC
Altitude (km)
6.0
5.0
4.0
3.0
2.0
1.0
13
15
17
19
21
23
1
3
5
7
9
Time (UT)
1e-3
1e-4
1e-5
1e-6
1e-7
1e-8
1/(m str)

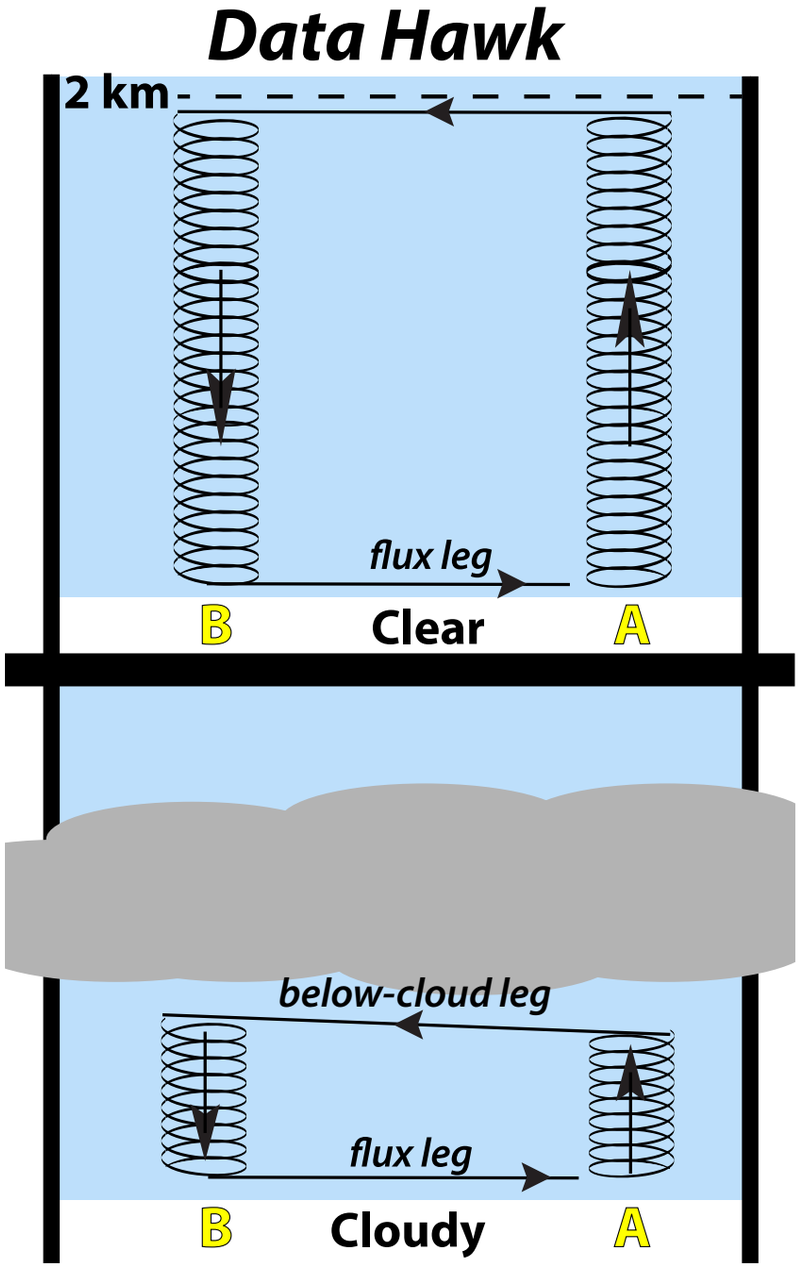

YEU 20081106T1200 UTC
temp
dew pt
frost pt
adiabats
altitude (km)
Temp (rd), dewpt (grn) ° K


YEU 20081107T0000 UTC
temp
dew pt
frost pt
adiabats
altitude (km)
Temp (rd), dewpt (grn) ° K


YEU 20081107T1200 UTC
temp
dew pt
frost pt
adiabats
altitude (km)
Temp (rd), dewpt (grn) ° K

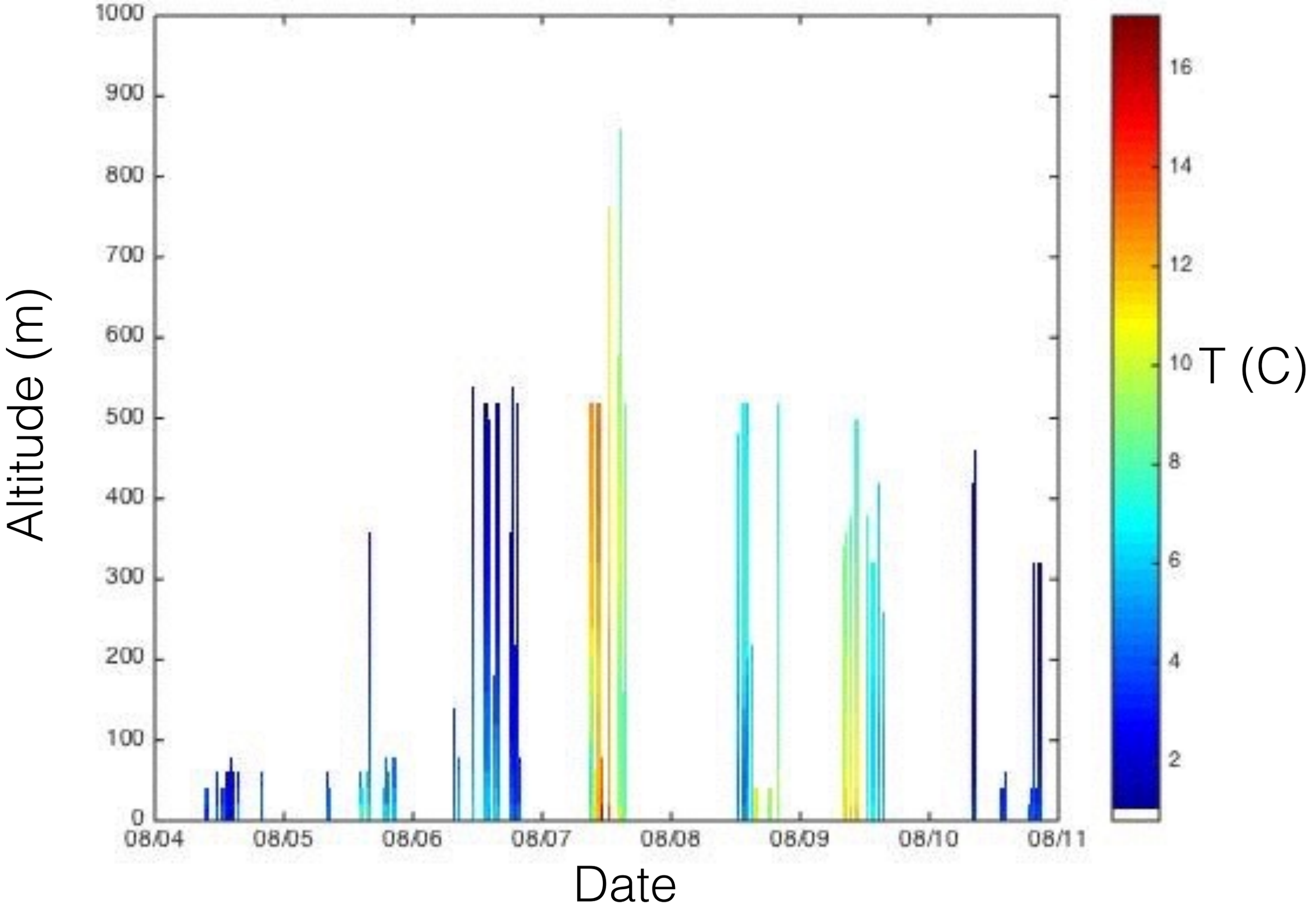
ERASMUS I


70.51
70.505
70.5
70.495
70.49
70.485
70.48
Latitude
-149.94
-149.92
-149.9
-149.88
-149.86
-149.84
-149.82
Longitude
B
A
1 nm
2 nm
Flight Track
Airspace Limits
Hazards
ARM Instrumentation

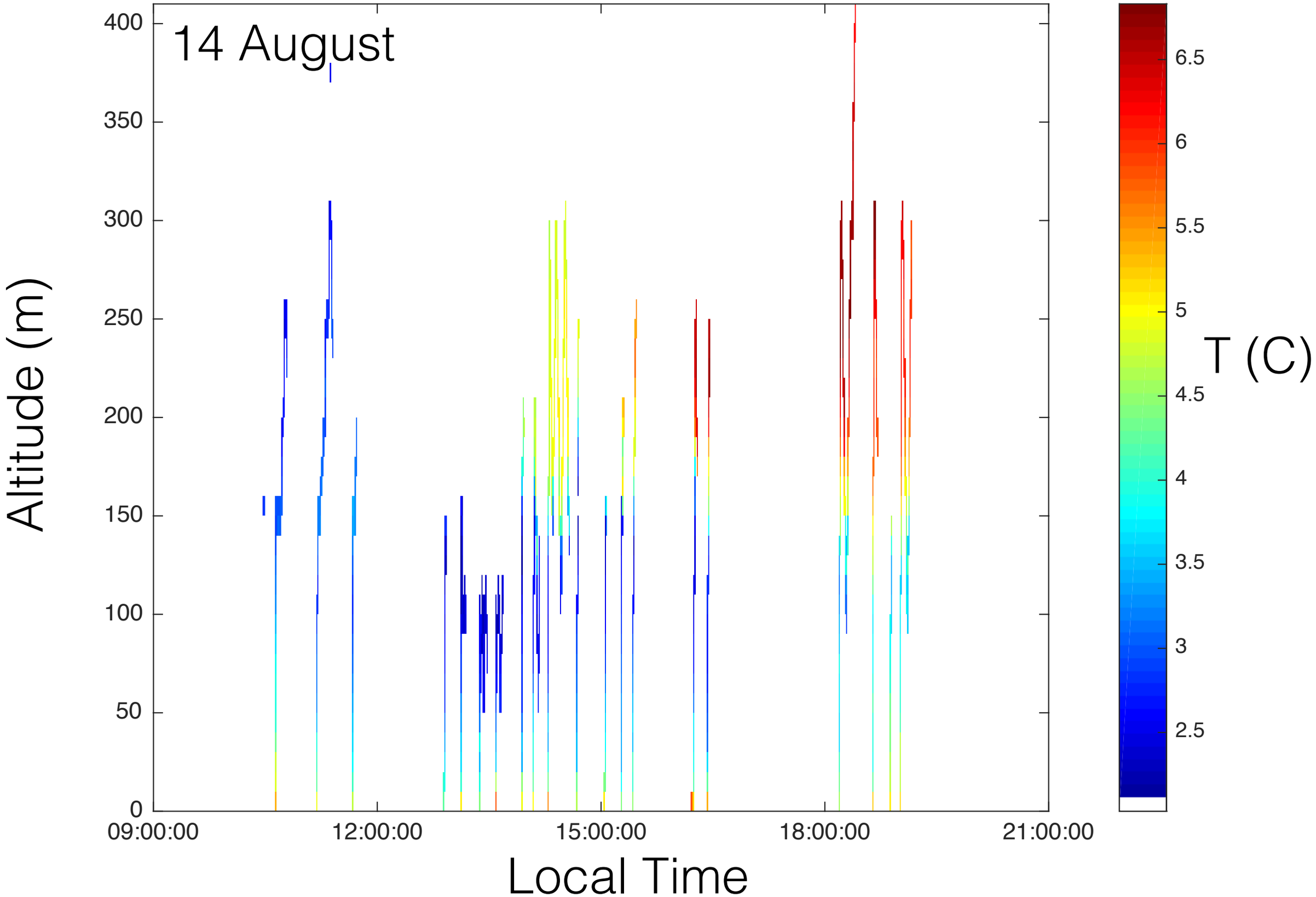

Data Hawk
2 km
flux leg
B
Clear
A
below-cloud leg
flux leg
B
Cloudy
A

ERASMUS I

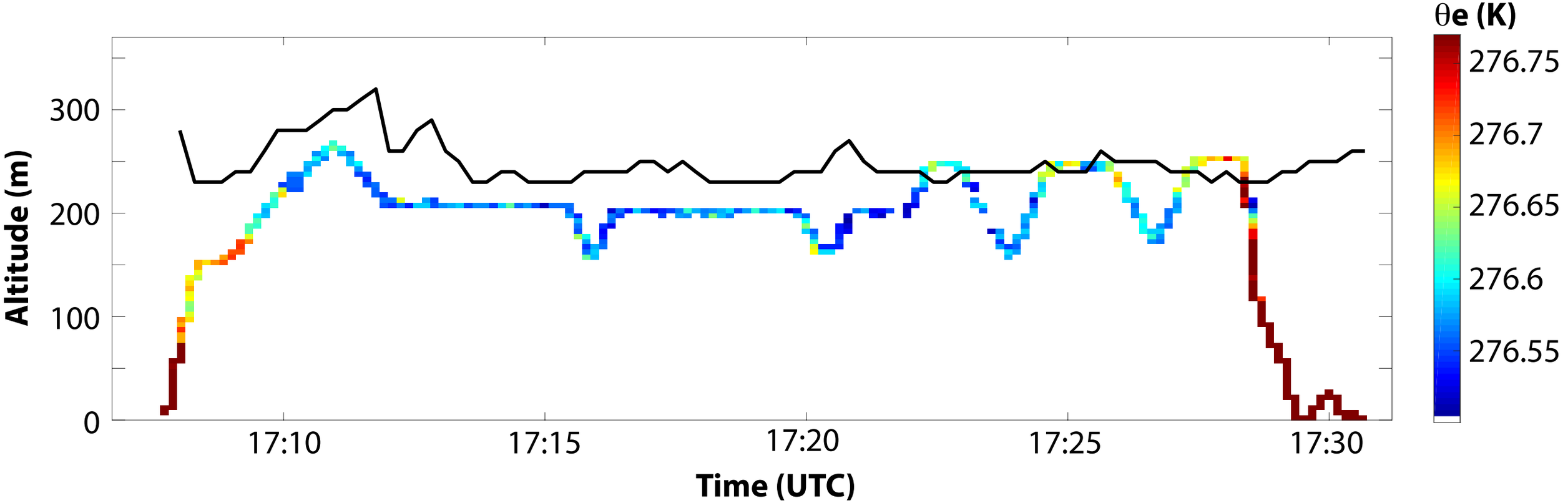
ERASMUS I


Altitude (m)
1000
900
800
700
600
500
400
300
200
100
0
08/04
08/05
08/06
08/07
08/08
08/09
08/10
08/11
Date
16
14
12
10
8
6
4
2
T (C)

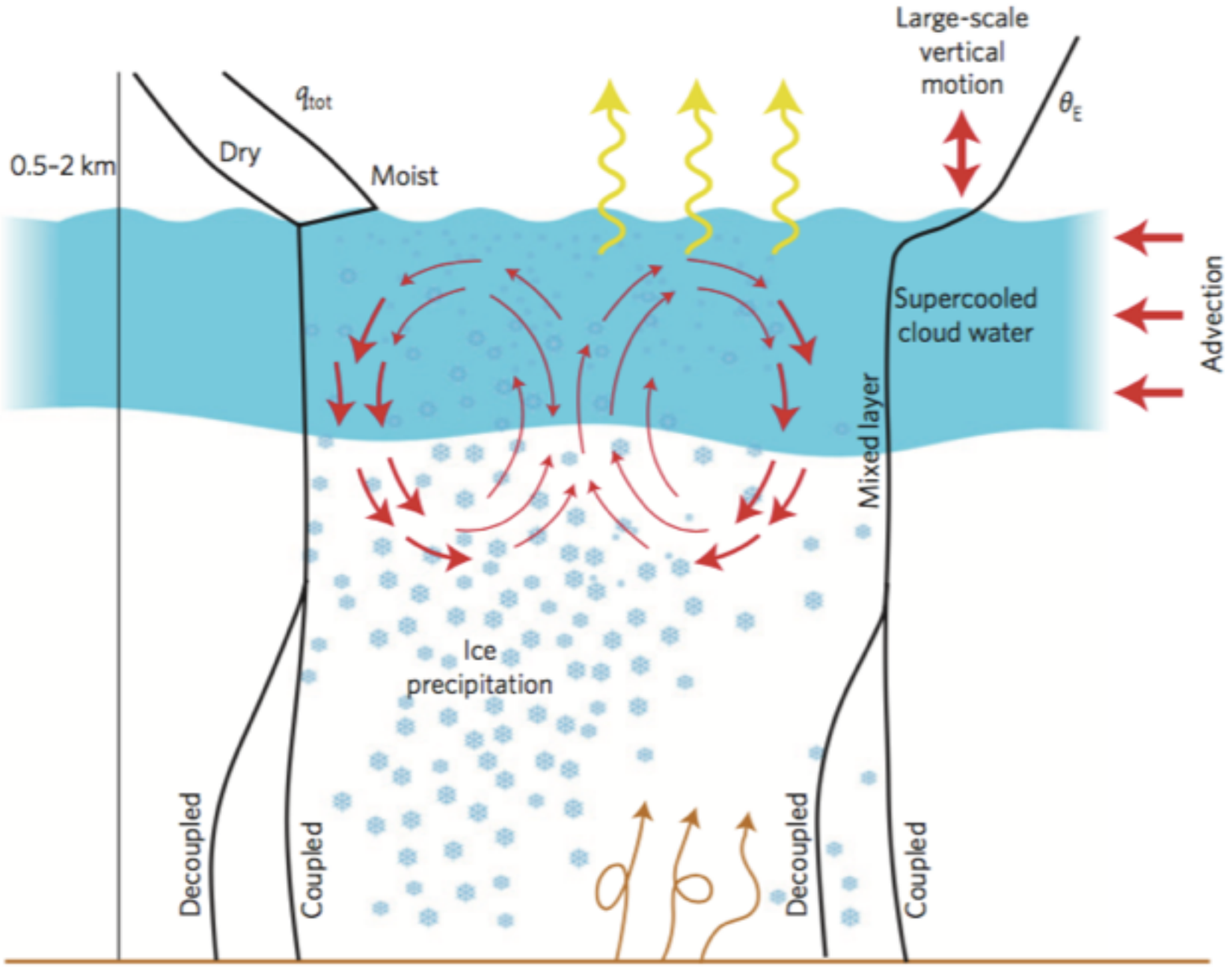
ERASMUS I


14 August
Altitude (m)
400
350
300
250
200
150
100
50
0
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
Local Time
T (C)
6.5
6
5.5
5
4.5
4
3.5
3
2.5

ERASMUS I


θe (K)
276.75
276.7
276.65
276.6
276.55
Altitude (m)
300
200
100
0
17:10
17:15
17:20
17:25
17:30
Time (UTC)

ERASMUS II



Radiative Cooling
- Drives buoyant production of turbulence
- Forces direct condensation within inversion layer
- Requires minimum amount of cloud liquid water

Microphysics
- Liquid forms in updrafts and sometimes within the inversion layer
- Ice nucleates in cloud
- Rapid ice growth promotes sedimentation from cloud

Dynamics
- Cloud-forced turbulent mixed layer with strong narrow downdrafts, weak broad updrafts, and q_{tot} and θ_E nearly constant with height
- Small-scale, weak turbulence in cloudy inversion layer
- Large-scale advection of water vapour important

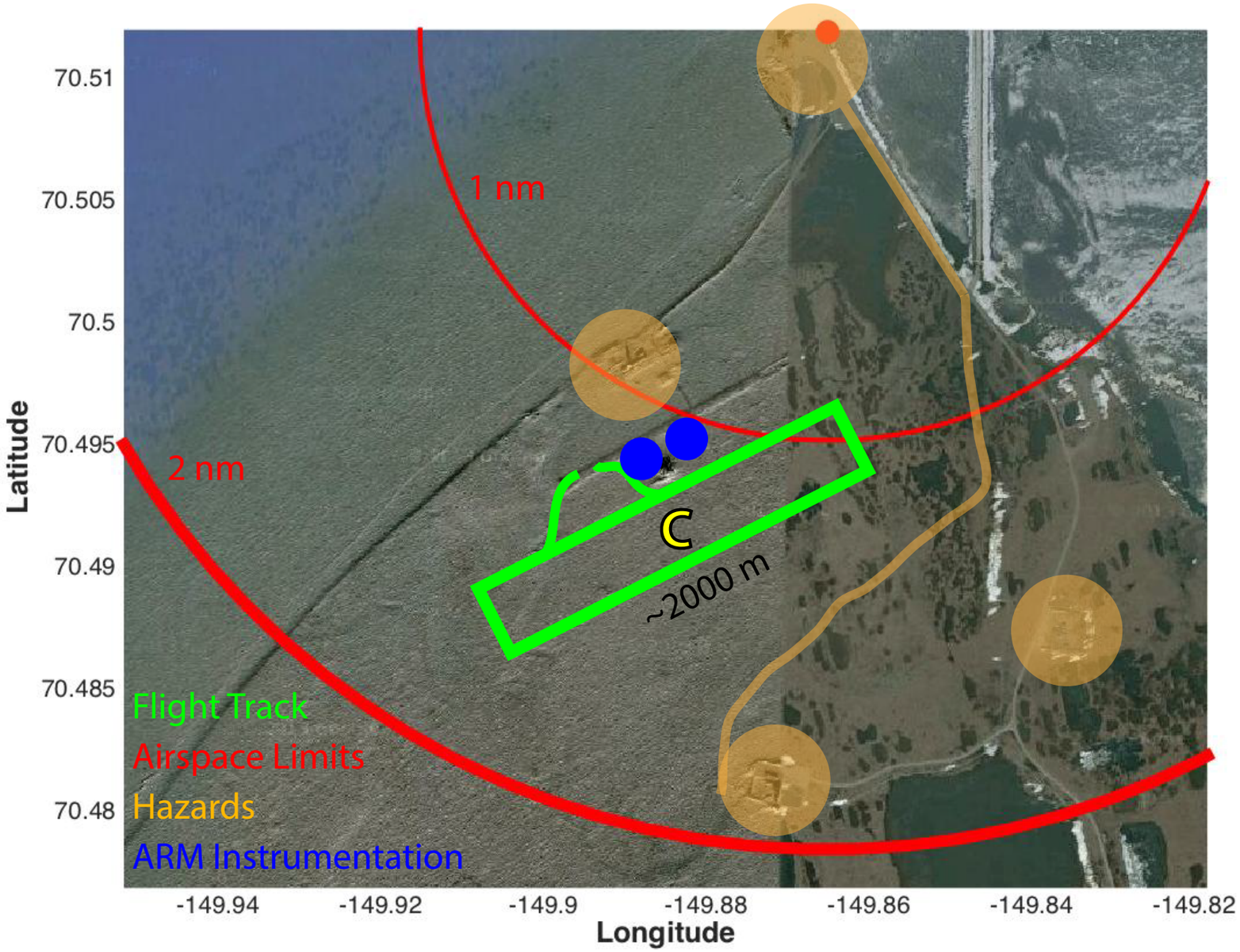
Surface Layer
- Turbulence and q contributions can be weak or strong
- Sink of atmospheric moisture due to ice precipitation
- Surface type (ocean, ice, land) influences interaction with cloud

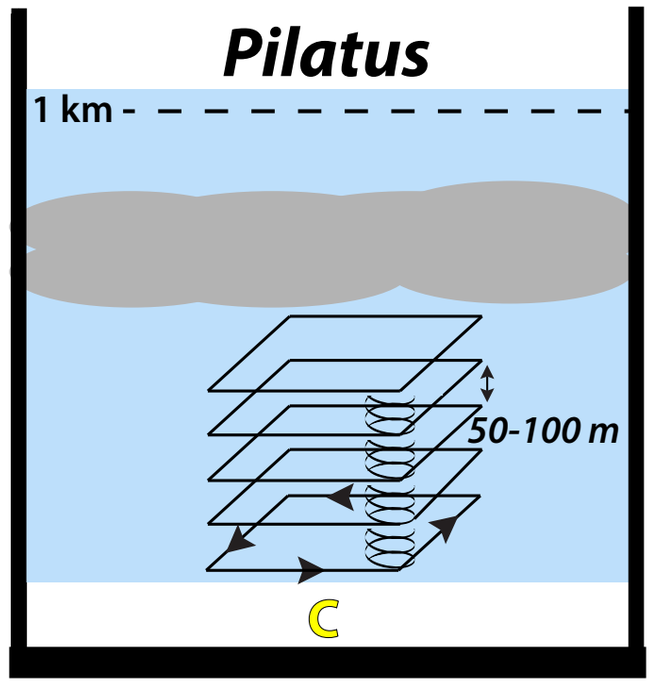
Morrison et al., 2012

CU Pilatus

de Boer et al., 2016b

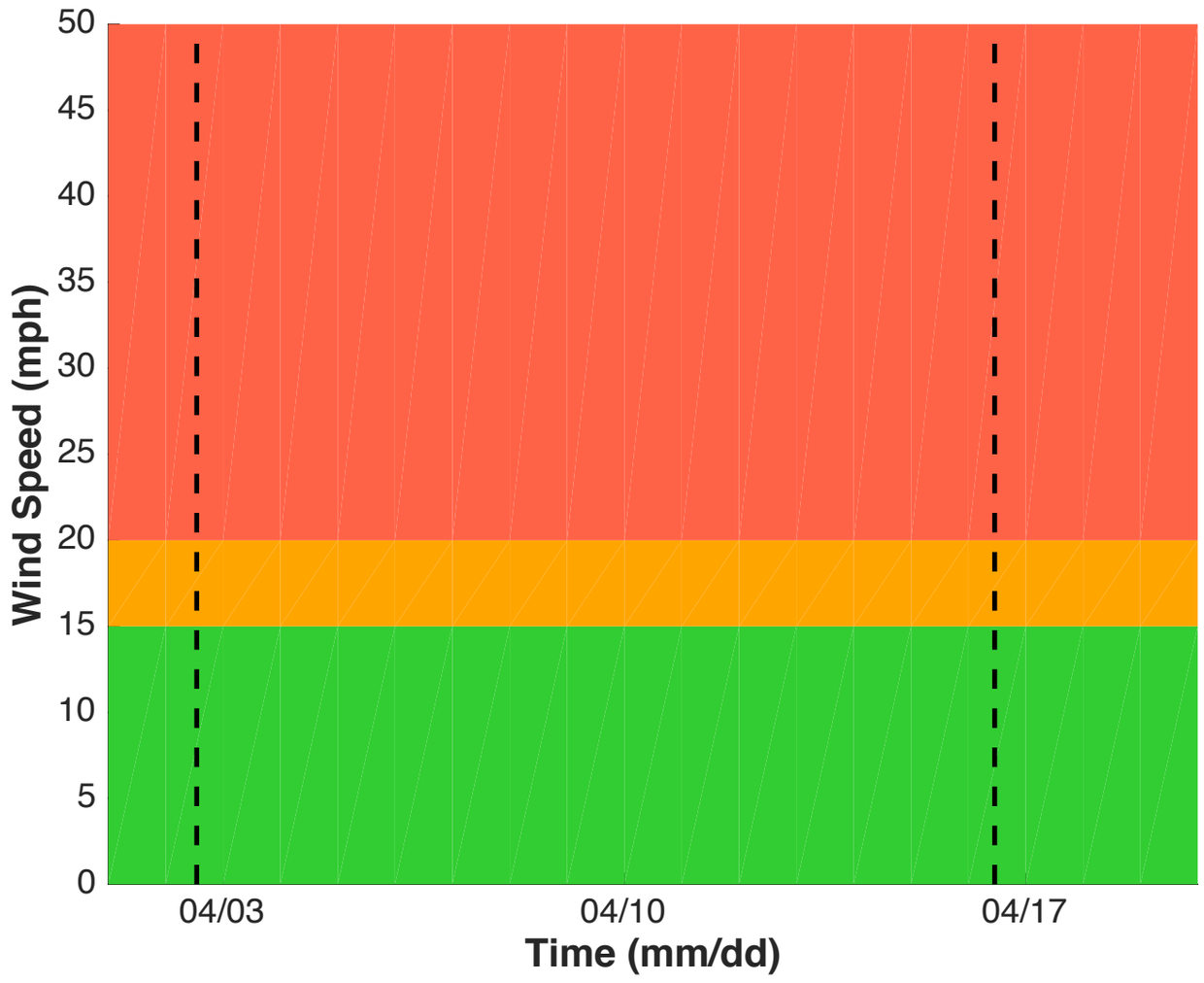
ERASMUS II


70.51
70.505
70.5
70.495
70.49
70.485
70.48
Latitude
1 nm
2 nm
C
~2000 m
Flight Track
Airspace Limits
Hazards
ARM Instrumentation
-149.94
-149.92
-149.9
-149.88
-149.86
-149.84
-149.82
Longitude

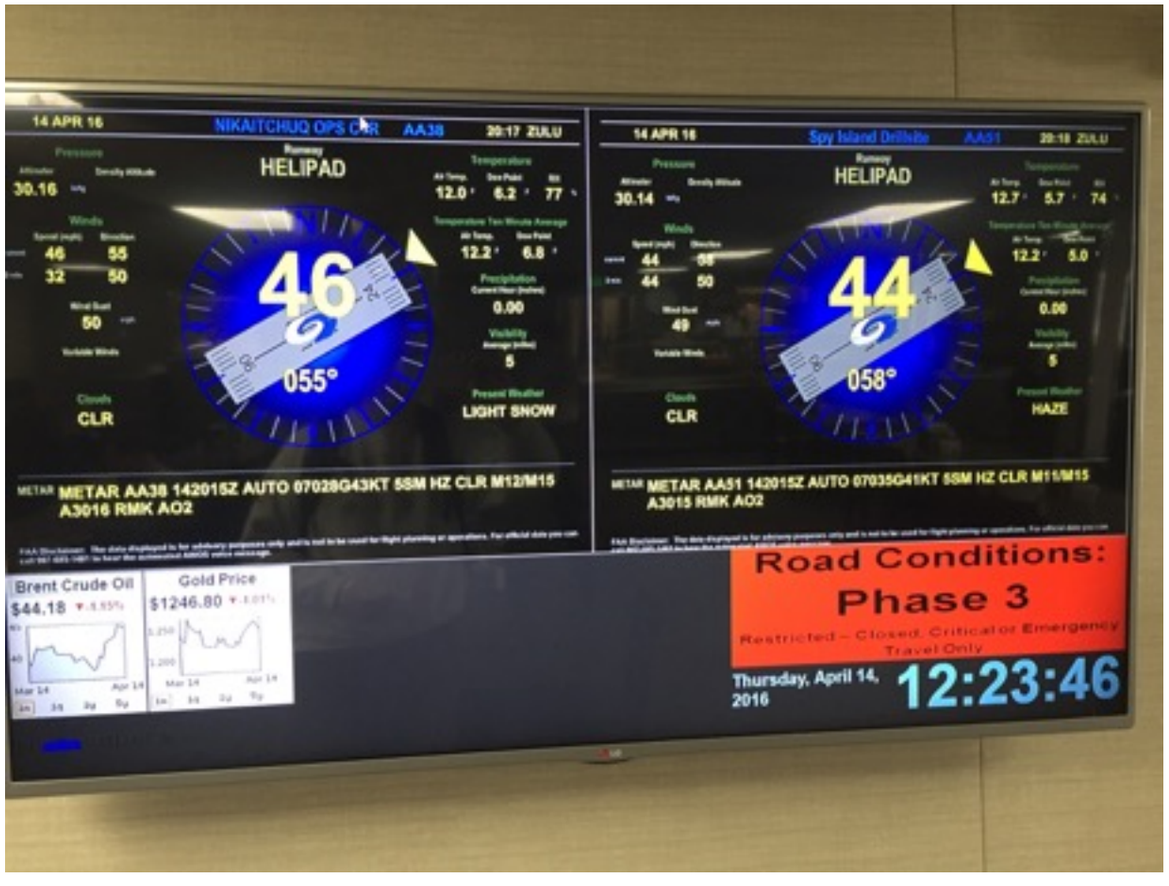

Pilatus
1 km
50-100 m
C

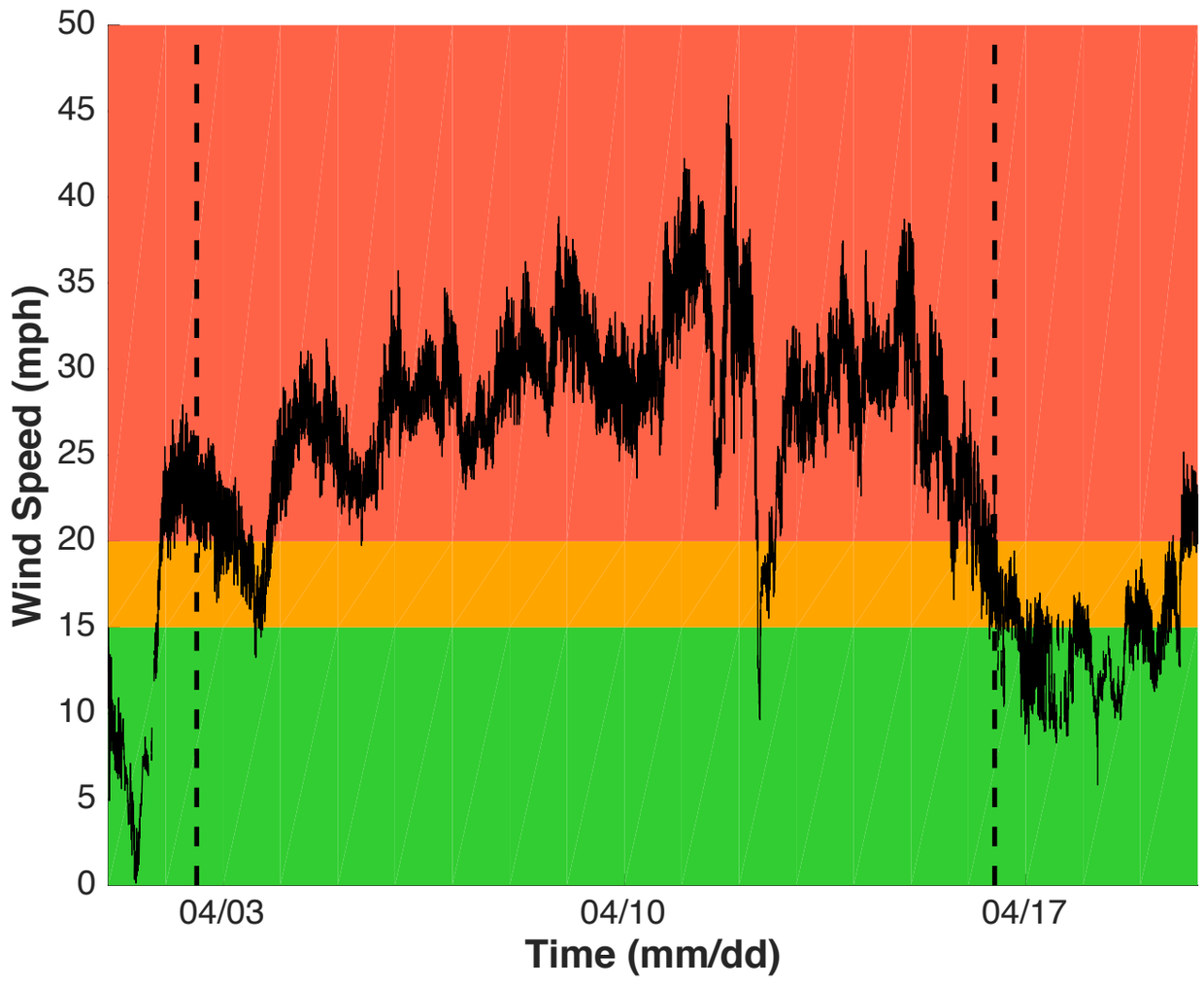
ERASMUS II


14 APR 16
NIKAITCHUQ OPS CTR
AA38
20:17 ZULU
HELIPAD
30.16
46
055°
CLR
LIGHT SNOW
METAR AA38 142015Z AUTO 07028G43KT 5SM HZ CLR M12/M15 A3016 RMK AO2
14 APR 16
Spy Island Drillsite
AA51
20:18 ZULU
HELIPAD
30.14
44
058°
CLR
HAZE
METAR AA51 142015Z AUTO 07035G41KT 5SM HZ CLR M11/M15 A3015 RMK AO2
Brent Crude Oil
$44.18
Gold Price
$1246.80
Road Conditions:
Phase 3
Restricted – Closed, Critical or Emergency Travel Only
Thursday, April 14, 2016
12:23:46

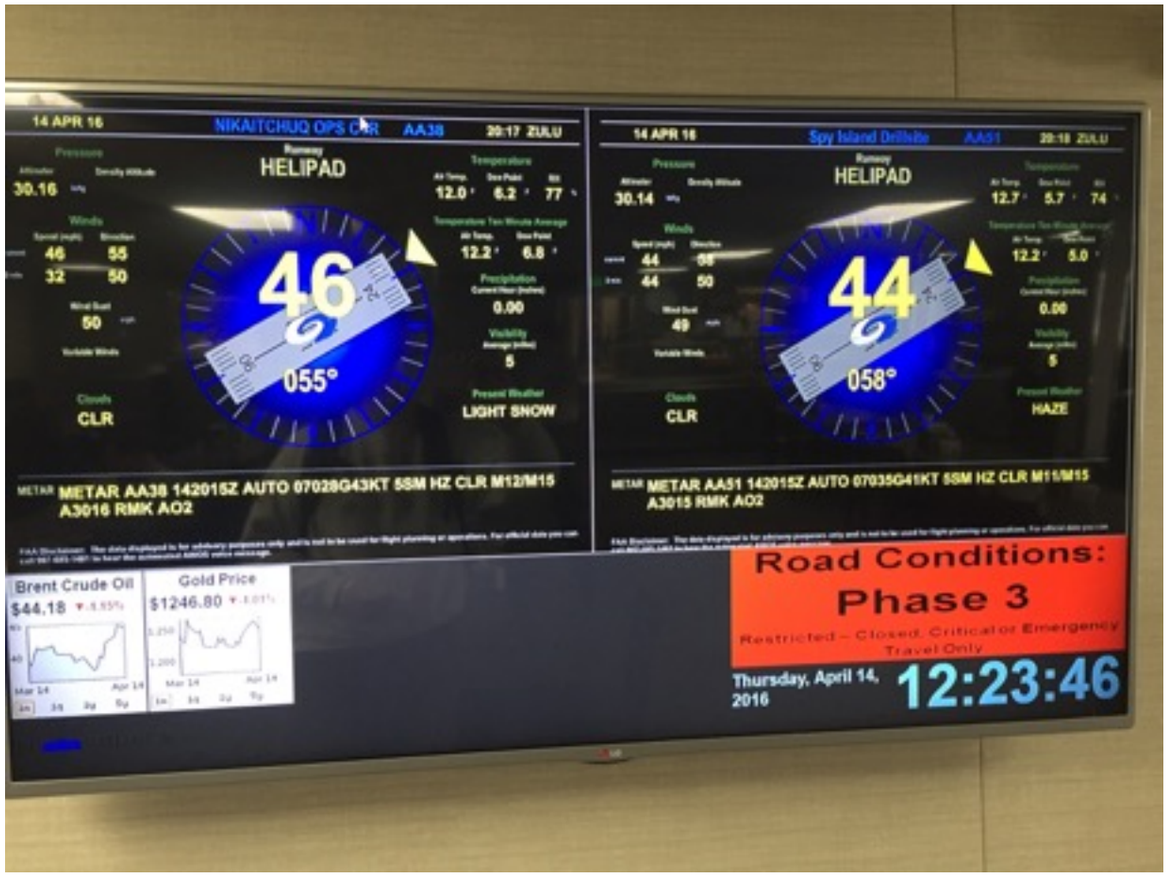

Wind Speed (mph)
50
45
40
35
30
25
20
15
10
5
0
04/03
04/10
04/17
Time (mm/dd)

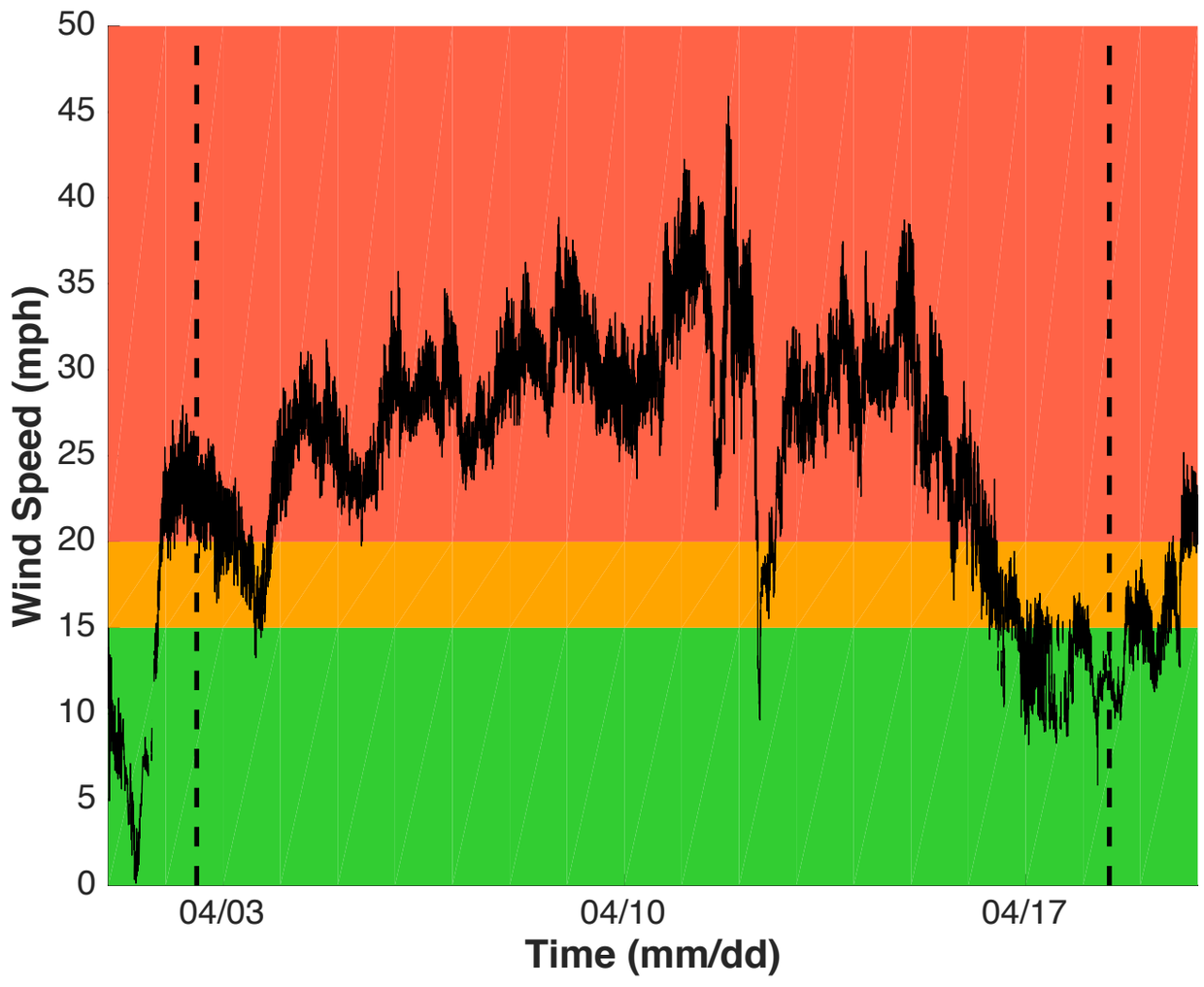
ERASMUS II


14 APR 16
NIKAITCHUQ OPS CTR
AA38
20:17 ZULU
HELIPAD
30.16
46
055°
CLR
LIGHT SNOW
METAR AA38 142015Z AUTO 07028G43KT 5SM HZ CLR M12/M15 A3016 RMK AO2
14 APR 16
Spy Island Drillsite
AA51
20:18 ZULU
HELIPAD
30.14
44
058°
CLR
HAZE
METAR AA51 142015Z AUTO 07035G45KT 5SM HZ CLR M11/M15 A3015 RMK AO2
Brent Crude Oil
$44.18
Gold Price
$1246.80
Road Conditions:
Phase 3
Restricted – Closed, Critical or Emergency Travel Only
Thursday, April 14, 2016
12:23:46


Wind Speed (mph)
50
45
40
35
30
25
20
15
10
5
0
04/03
04/10
04/17
Time (mm/dd)

ERASMUS II

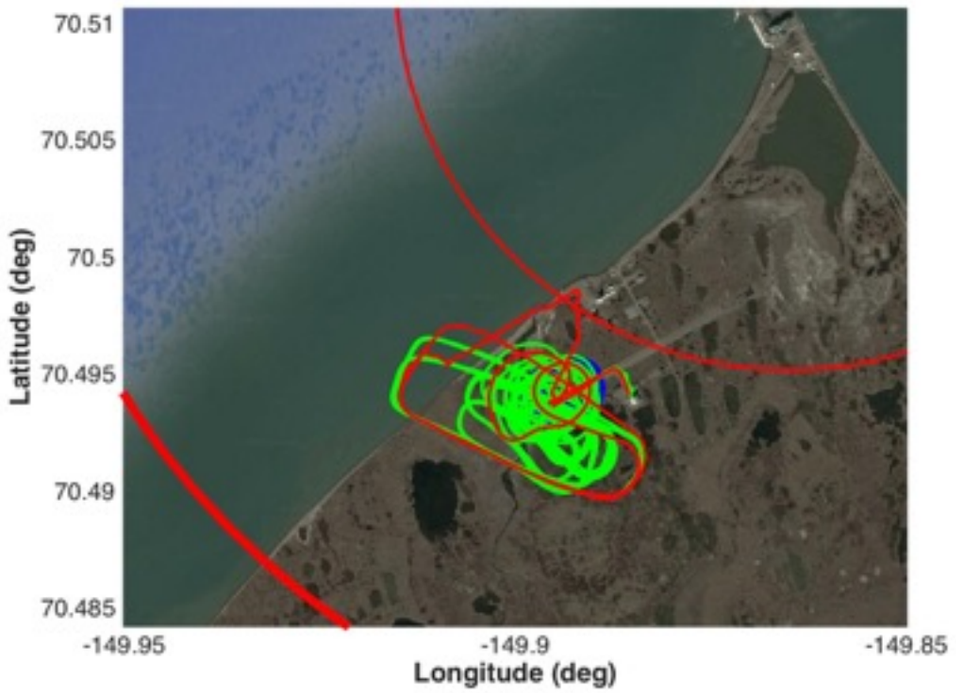

14 APR 16
NIKAITCHUQ OPS CTR
AA38
20:17 ZULU
HELIPAD
30.16
46
55
32
50
50
055°
CLR
LIGHT SNOW
METAR METAR AA38 142015Z AUTO 07028G43KT 5SM HZ CLR M12/M15 A3016 RMK AO2
14 APR 16
Spy Island Drillsite
AA51
20:18 ZULU
HELIPAD
30.14
44
58
44
50
49
058°
CLR
HAZE
METAR METAR AA51 142015Z AUTO 07035G45KT 5SM HZ CLR M11/M15 A3015 RMK AO2
Brent Crude Oil
$44.18
Gold Price
$1246.80
Road Conditions:
Phase 3
Restricted – Closed, Critical or Emergency Travel Only
Thursday, April 14, 2016
12:23:46

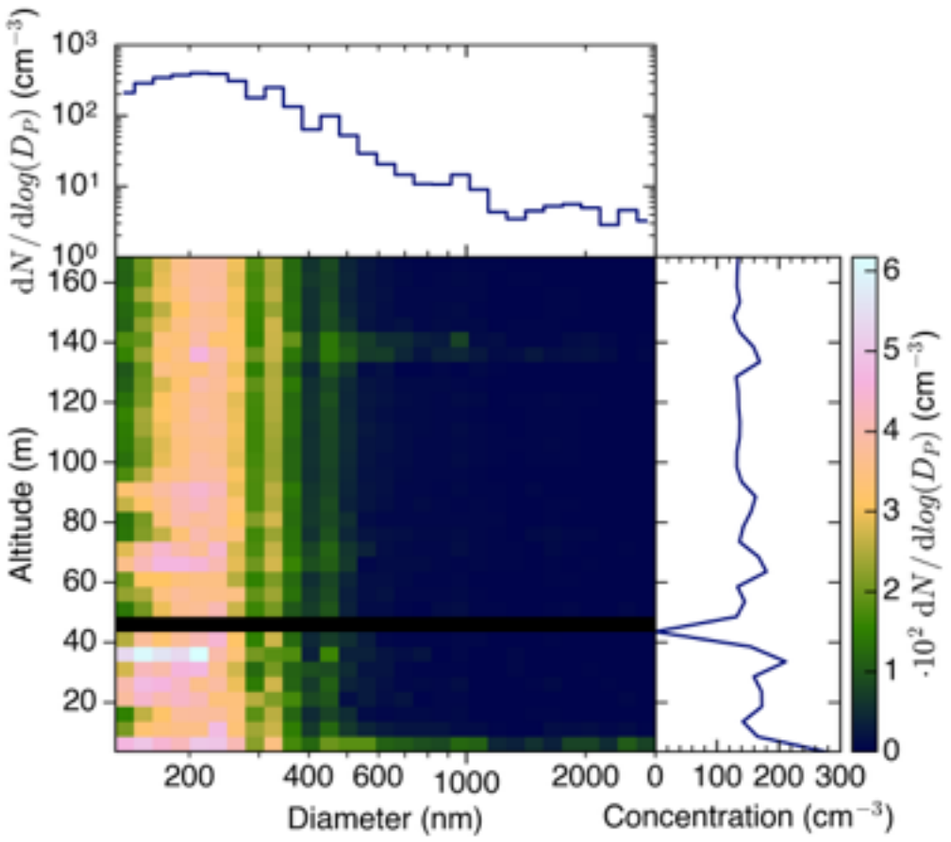

Wind Speed (mph)
50
45
40
35
30
25
20
15
10
5
0
04/03
04/10
04/17
Time (mm/dd)

ERASMUS II

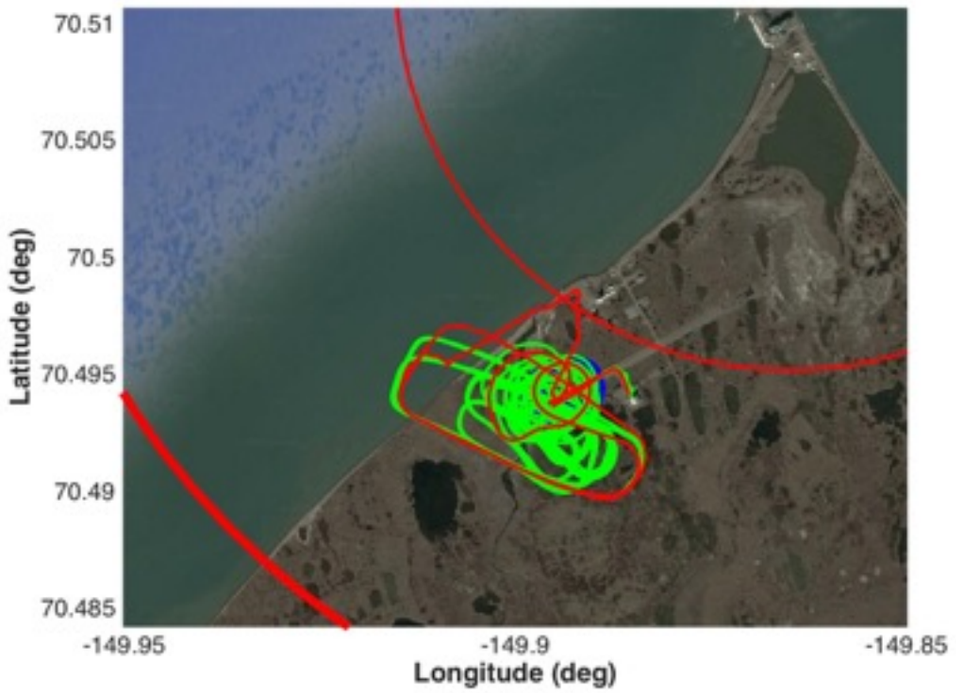
ERASMUS II

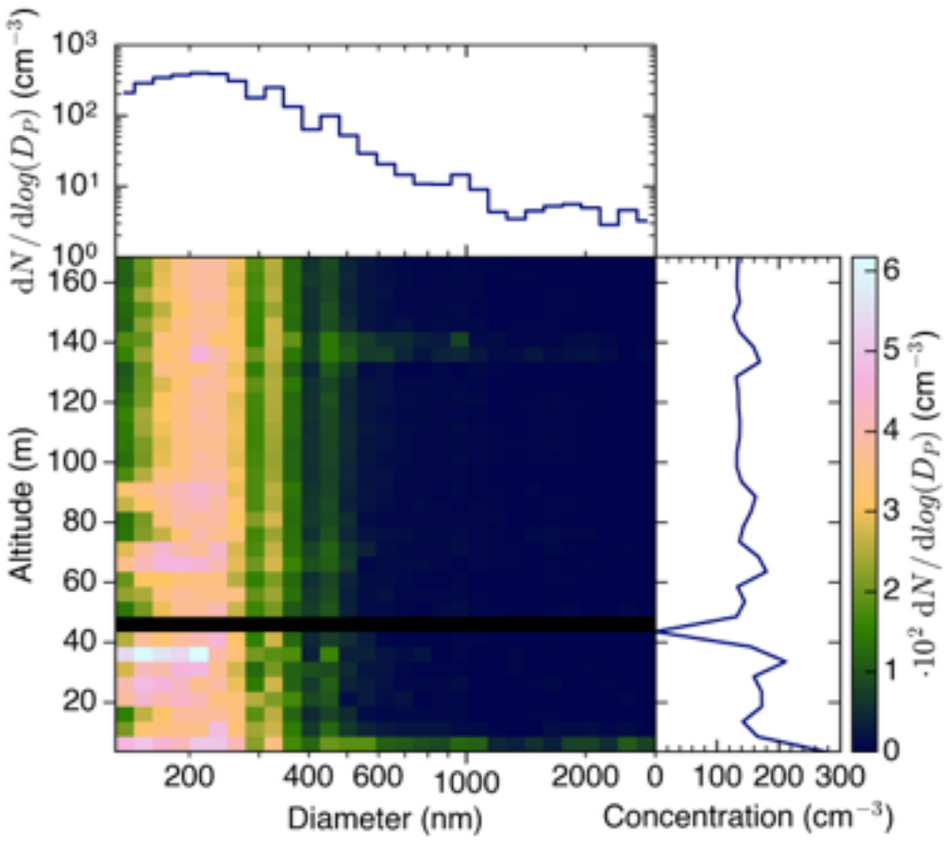
ERASMUS II


70.51
70.505
70.5
70.495
70.49
70.485
Latitude (deg)
-149.95
-149.9
-149.85
Longitude (deg)


$dN/d\log(D_P)$ (cm^{-3})
10^3
10^2
10^1
10^0
Altitude (m)
160
140
120
100
80
60
40
20
200
400
600
1000
2000
Diameter (nm)
0
100
200
300
Concentration (cm^{-3})
6
5
4
3
2
1
0
$\cdot 10^2$ $dN/d\log(D_P)$ (cm^{-3})

ERASMUS II


70.51
70.505
70.5
70.495
70.49
70.485
Latitude (deg)
-149.95
-149.9
-149.85
Longitude (deg)


$dN/d\log(D_P)$ (cm^{-3})
10^3
10^2
10^1
10^0
Altitude (m)
160
140
120
100
80
60
40
20
200
400
600
1000
2000
Diameter (nm)
0
100
200
300
Concentration (cm^{-3})
6
5
4
3
2
1
0
$\cdot 10^2$ $dN/d\log(D_P)$ (cm^{-3})

Acknowledgments and References

Funding/Support:

ASR Atmospheric System Research

ARM CLIMATE RESEARCH FACILITY

CIRES

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION U.S. DEPARTMENT OF COMMERCE

References:

de Boer, G., M. D. Ivey, B. Schmid, S. McFarlane, and R. Petty, 2016a: **Unmanned platforms monitor the Arctic atmosphere**, *Eos, 97.*

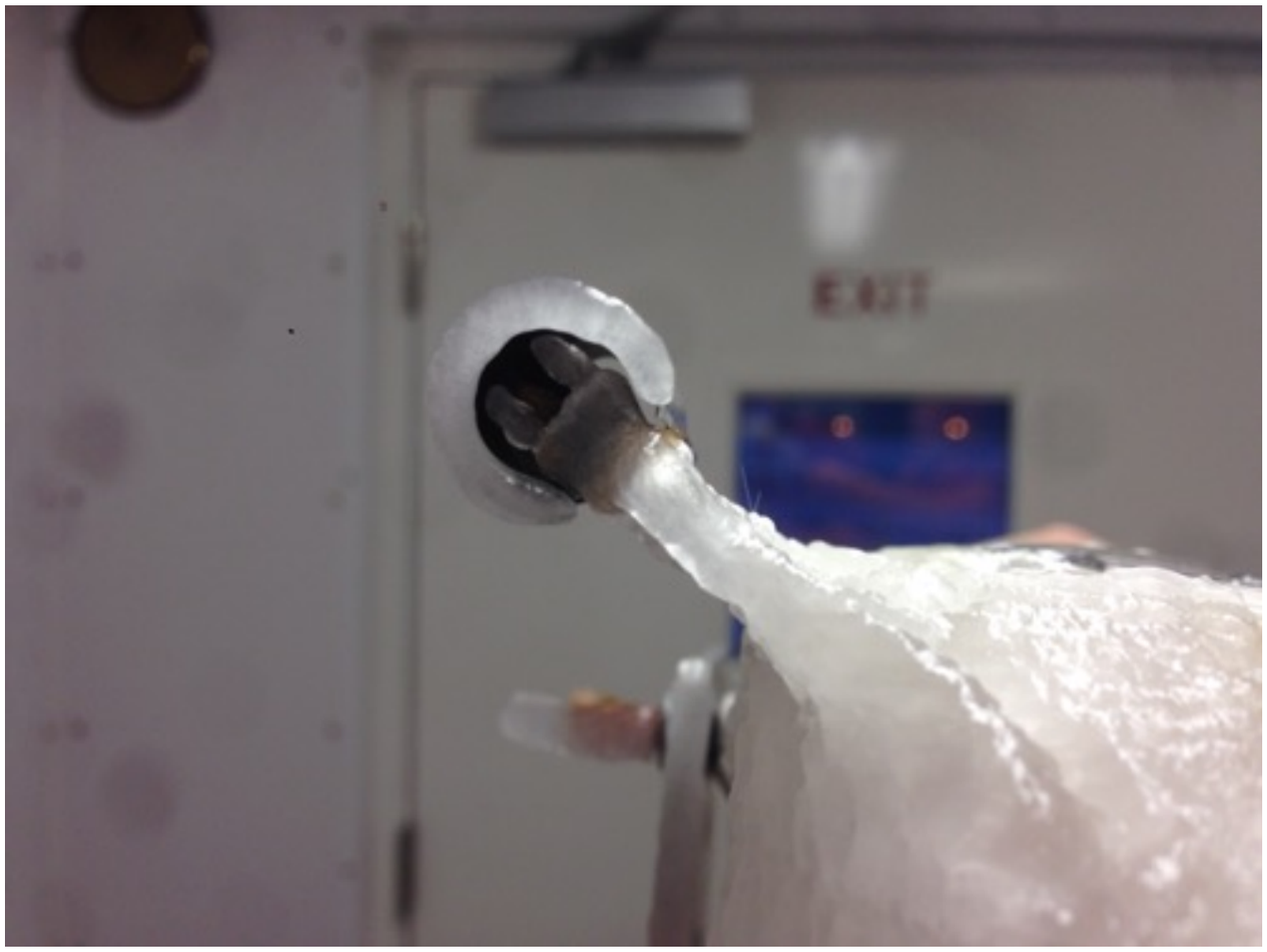
de Boer, G., S. Palo, B. Argrow, G. LoDolce, J. Mack, R.-S. Gao, H. Telg, C. Trussel, J. Fromm, C.N. Long, G. Bland, J. Maslanik, B. Schmid and T. Hock, 2016b: **The Pilatus Unmanned Aircraft System for Lower Atmospheric Research**, *Atmos. Meas. Tech.*, in review.

Gao, R.-S., Telg, H., McLaughlin, R., Ciciora, S., Watts, L., Richardson, M., Schwarz, J., Perring, A., Thornberry, T., Rollins, A., Markovic, M., Bates, T., Johnson, J., and Fahey, D., 2016: **A light-weight, high-sensitivity particle spectrometer for PM2.5 aerosol measurements**, *Aerosol Sci. Tech.*, 50, 88–99.

Long, C.N., A. Bucholtz, H. Jonsson, B. Schmid, A. Vogelmann and J. Wood, 2009: **A method for correcting for tilt from horizontal in downwelling shortwave irradiance measurements on moving platforms**, *Open. Atmos. Sci. J.*, **4**, 78-87.

Morrison, H., G. de Boer, G. Feingold, J.Y. Harrington, M.D. Shupe and K. Sulia (2012): **Resillience of Persistent Arctic Mixed-Phase Clouds**, *Nature Geosci.*, 5, 11-17.

COALA: Lessons Learned



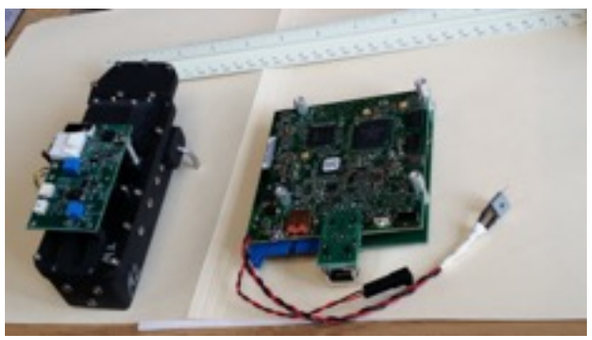
CU Pilatus

Delta-T SPN-1 (Broadband Shortwave)

- 0.4-2.700 μm
- < 200 ms response time
- 140 mm x 100 mm, 940 g
- Pilatus will fly with three SPN-1s — up and down unshielded, and upward looking with shielding pattern to separate between direct and diffuse radiation for aircraft attitude correction (See Long et al., 2009 for details on the correction)

Kipp and Zonen CGR4 (Broadband Longwave)

- 4.5-42 μm
- 18 s response time (95%)
- 79 mm x 72.5 mm, 600 g
- 180 degree FOV
- Pilatus will fly with two CGR4s — up and down looking



Printed Optical Particle Spectrometer (POPS)

- Developed by Ru-Shan Gao and colleagues (NOAA ESRL Chemical Sciences Division, Gao et al., 2016)
- Provides aerosol size distributions for particles between 140-3000 nm
- Inlet and tubing to be heated in order to provide dry size distributions and prevent icing
- Approximately 1 kg total weight, including battery (~800 g total), requires ~3 W of power
- Approximate dimensions: 15x10x7.6 cm (spectrometer), 13x10x2.5 (electronics)
- Weather balloon deployable