DAWN Contributions to Investigating Arctic Atmospheric Dynamics and Numerical Model Validation

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NASA LaRC

Working Group Meeting on Space-based Lidar Winds

Newport News, VA

March 21 2017

NASA's PolarWinds

- NASA funded two airborne Doppler Wind Lidar campaigns:
  - Campaign 1 Oct-Nov 2014 on NASA UC-12B King Air based Kangerlussuaq, Greenland
  - Campaign 2 May 2015 on NASA DC-8 based Keflavik, Iceland
- Over 80 hours of research flights in the Arctic region near Greenland and Iceland
- Purpose was to conduct basic polar science investigations and demonstrate DWL technology readiness for ADM Cal/Val
- Included Co-flights (six) with high-altitude DLR Falcon with DWL

PolarWinds Science Objectives

- Validate numerical model forecasts (WRF, P-WRF) and reanalysis (ASR, ERA) characterizations of airflow in the lower atmosphere over the open oceans, land, ice sheets and transition zones
- Conduct detailed investigations into dynamic features such as Arctic low level jets (Tip Jet), barrier winds and OLEs.
- Characterize and study the wind regime of the lower atmosphere over marginal ice zones in the Arctic
- Provide wind/aerosol observations to validate or compare with existing remote sensing platforms
    - CALIPSO aerosol measurements
    - MODIS Atmospheric Motion Vectors
    - ASCAT Ocean Vector Winds

Instruments and Models

- DAWN (Doppler Aerosol WiNd **lidar**)
    - Coherent detection lidar (aerosol)
    - Downward pointing scanner
    - 2-12 Scanning angles (mostly 2 and 5)
- Yankee Environment (YES) Dropsondes
    - Campaign 2 – almost 90 dropsondes
- OSU Polar WRF run operationally twice daily
- University of Colorado WRF for research

DAWN on board the NASA King Air 12-C (11/2014) and NASA DC-8 (May 2015)

DAWN

Attribute	Value
Airplanes Flown	DC-8 and UC-12B
Solid-State Laser Crystal and Wavelength	Ho:Tm:LuLiF, 2.053472 Microns
Laser Pulse Energy E, Rate f, FWHM Duration t	250 mJ, 10 Hz, 180 ns
Pointing Knowledge Technique	Dedicated INS/GPS on Lidar
LOS Wind Measurement Precision	< 1 m/s
u, v, w Measurement Precision	< 1 m/s
Horizontal Resolution of Full Vertical Profile	2-7 km
Vertical Resolution of Full Vertical Profile	75 – 150m

DAWN Performance and Data

- While DAWN performed less than ideally due to misalignments and sensitivity issues (see Emmitt and Henderson talks), the DAWN profiles demonstrated close agreement with Dropsondes
- Post processing for optimum data set removed ground and aircraft effects
- Final DAWN data have provided quality data for numerical model (e.g. Polar WRF) validation and for the scientic study of atmospheric circulations such as LLJs and Upper Jets.

Polar Winds DAWN-Dropsonde Comparison – 5 Days (35 Drops)

Height Layer	Number	Δz (m)	DWL – Drop (m/sec) Mean ΔWS	DWL – Drop (m/sec) Mean ABS(ΔWS)	DWL – Drop (deg) Mean ΔWD	DWL – Drop (deg) Mean ABS(ΔWD)	RMSE DWL-Drop ΔWS
ALL	1669	2.37	-0.08	1.30	1.90	8.66	3.15
>5000m	1009	2.64	-0.27	1.34	1.31	4.88	3.30
< 5000 m	660	1.95	0.21	1.23	2.78	14.43	2.91
< 2000m	265	1.98	-.02	1.29	3.62	9.44	3.22

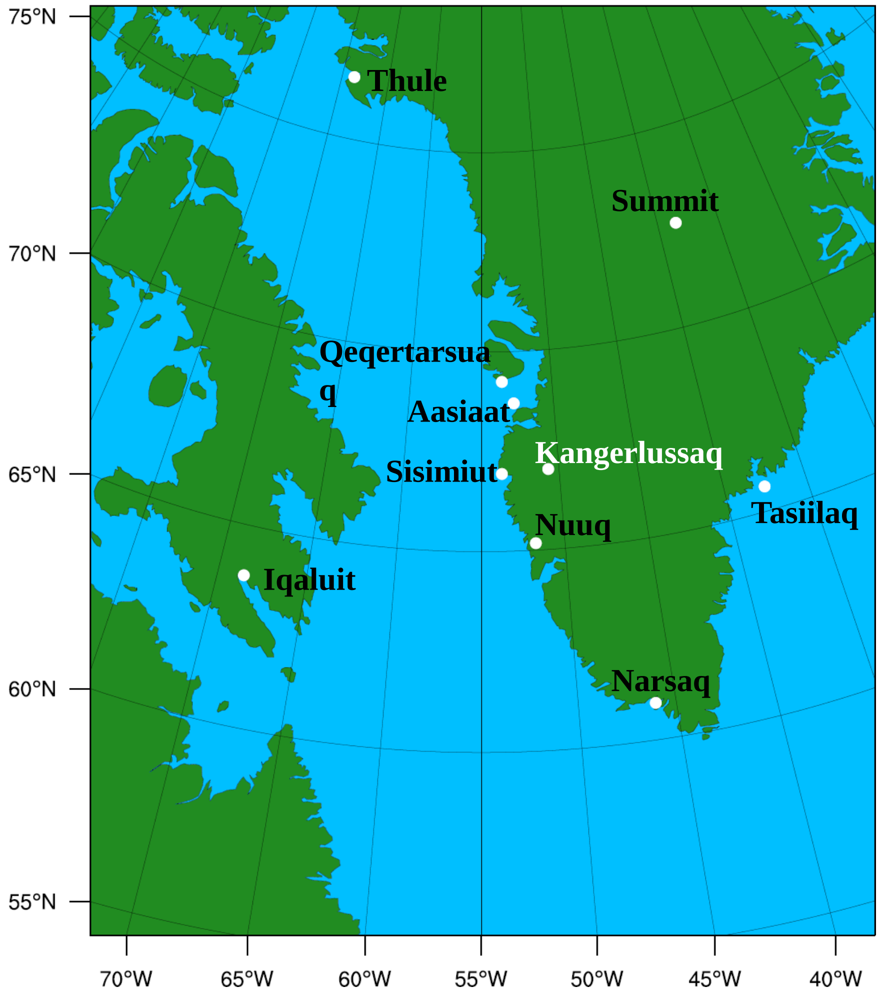
DAWN-Dropsonde Comparison for May 21, 2015 mission including 8 dropsondes

Height Layer	Number of Comparisons	Δz (m)	DAWN – Drop (m/sec) Mean ΔWS	DAWN – Drop (m/sec) Mean ABS(ΔWS)	DAWN – Drop (deg) Mean ΔWD	DAWN – Drop (deg) Mean ABS(ΔWD)	RMSE DAWN - Drop ΔWS
ALL	468	1.97	-0.004	1.15	-1.75	9.11	2.28
5200 – 4000 m	87	2.28	0.13	1.06	-7.80	13.81	1.87
4-3000 m	92	2.21	0.26	1.28	0.8	13.28	2.94
3-2000 m	92	1.92	-0.005	0.92	-1.95	11.33	1.32
2-1000 m	133	1.74	0.108	1.14	-0.27	4.70	2.03
1000m – sfc	64	1.73	-0.815	1.52	0.084	2.67	3.81

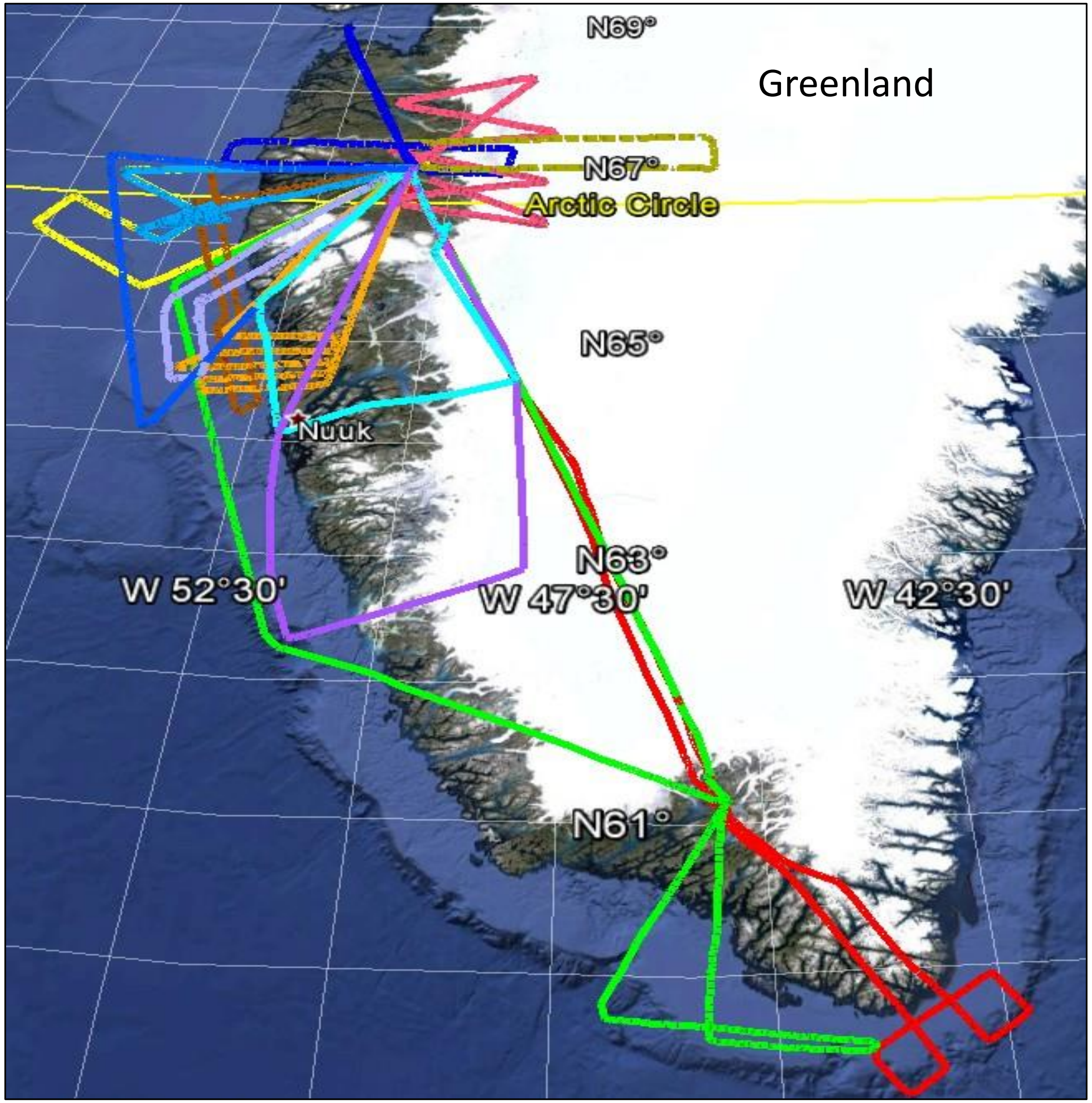
Polar Winds Model Specifications WRF 3.6.1 with OSU BPCRC polar optimizations (Polar WRF)

- 274 x 324 one-domain grid with 8 km spacing
- 48 layers: Lowest levels at 7 and 14 m; 8 layers at lowest 500 m;
- 60-sec time step; run with 20 tasks; 48-hr runs; output every 3 hr
- Morrison 2-moment microphysics
- RRTMG longwave and shortwave radiation
- MYJ Planetary boundary layer and surface boundary layer
- Noah Land surface model
- Fractional sea ice 1.5 m thick; albedo 0.82; 5 cm snow on sea ice
- Run TWICE a day with 00 & 12 UTC as its initial times
- IC and BC interpolated from the daily (00, 12Z) NCEP GFS

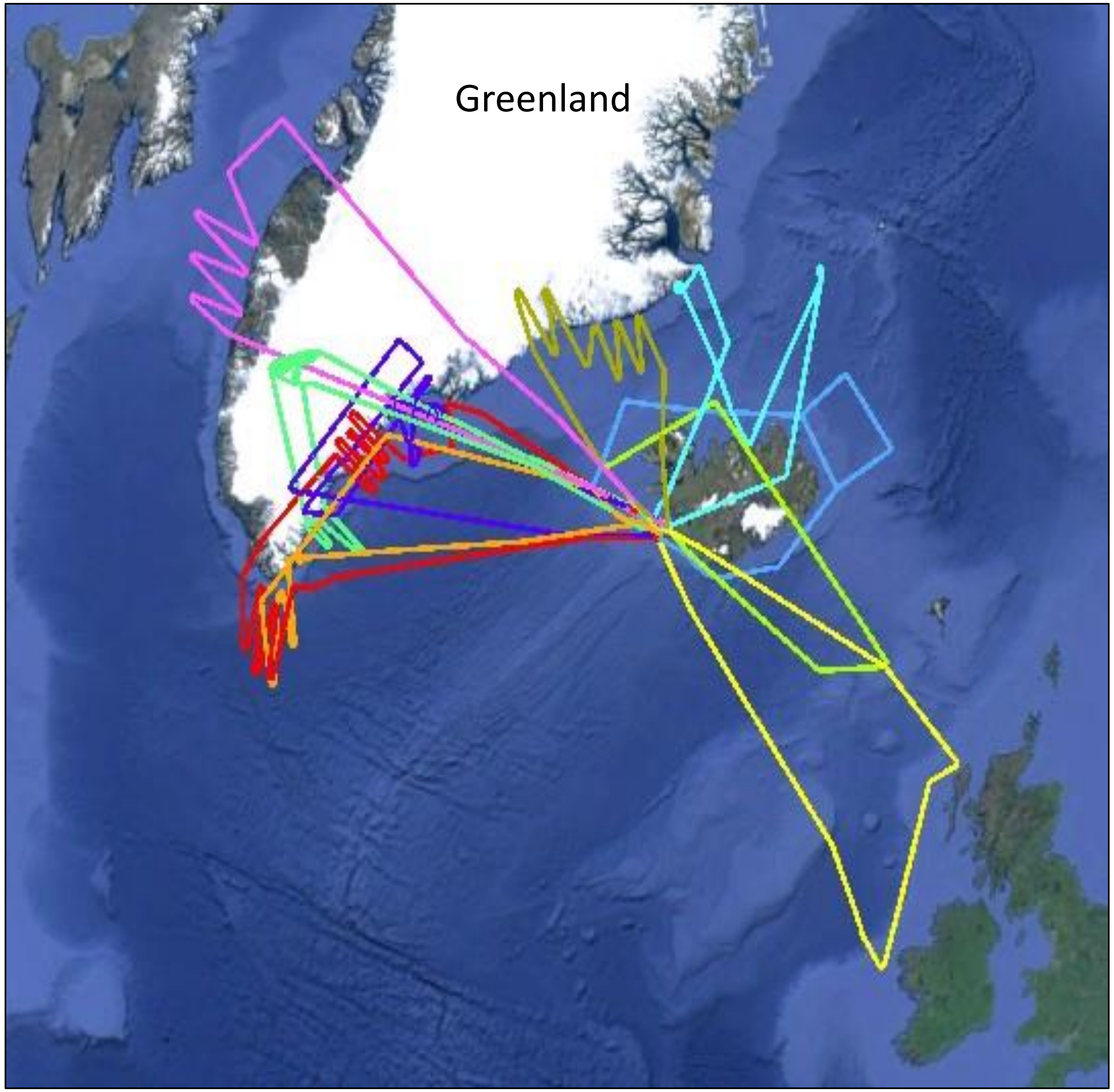
Polar Winds North Atlantic/Greenland Grid



Polar WRF 3.6.1   274 x 324 Points   Δx = 8 km



PolarWinds Campaign I Flight Tracks

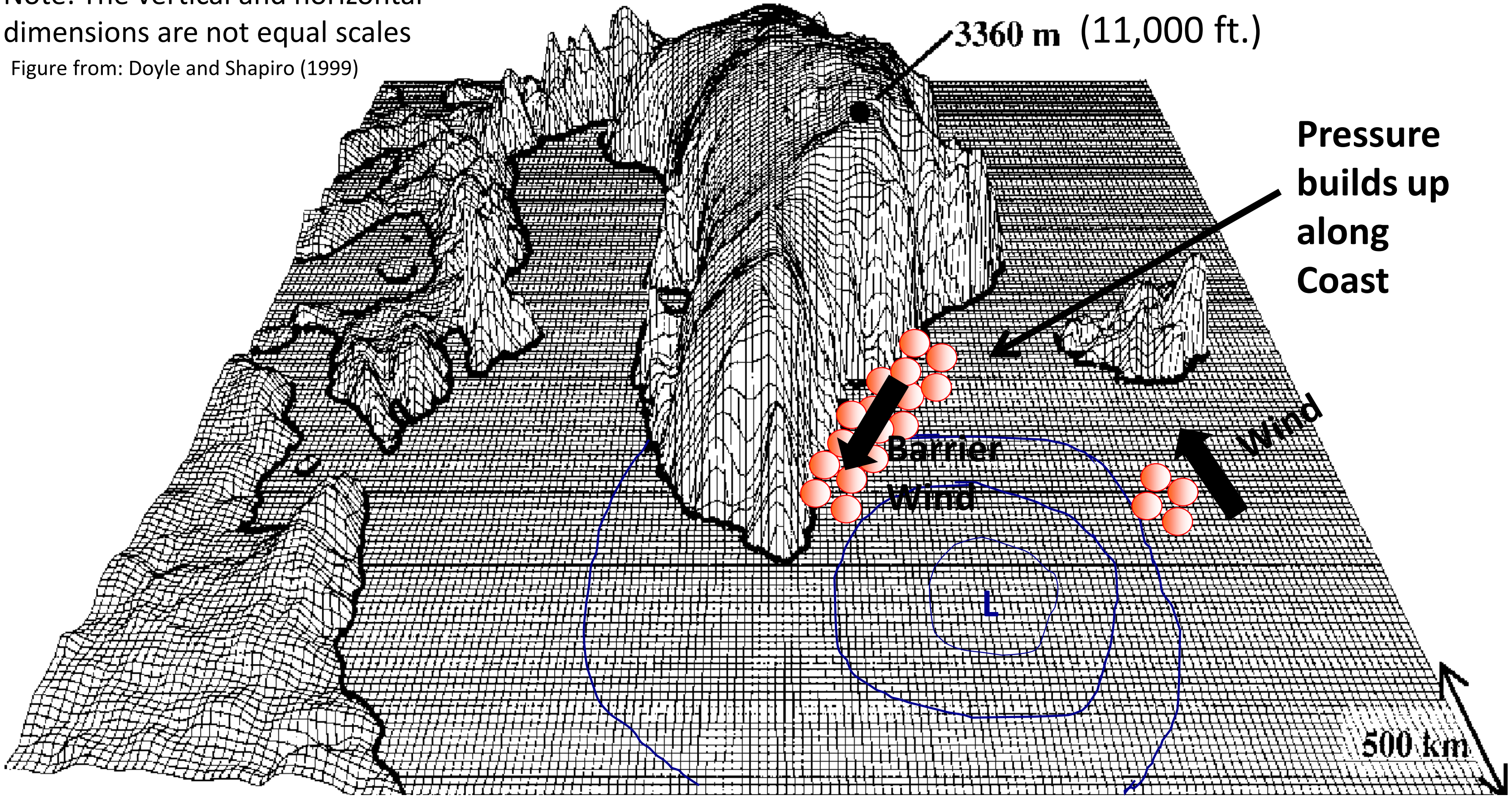


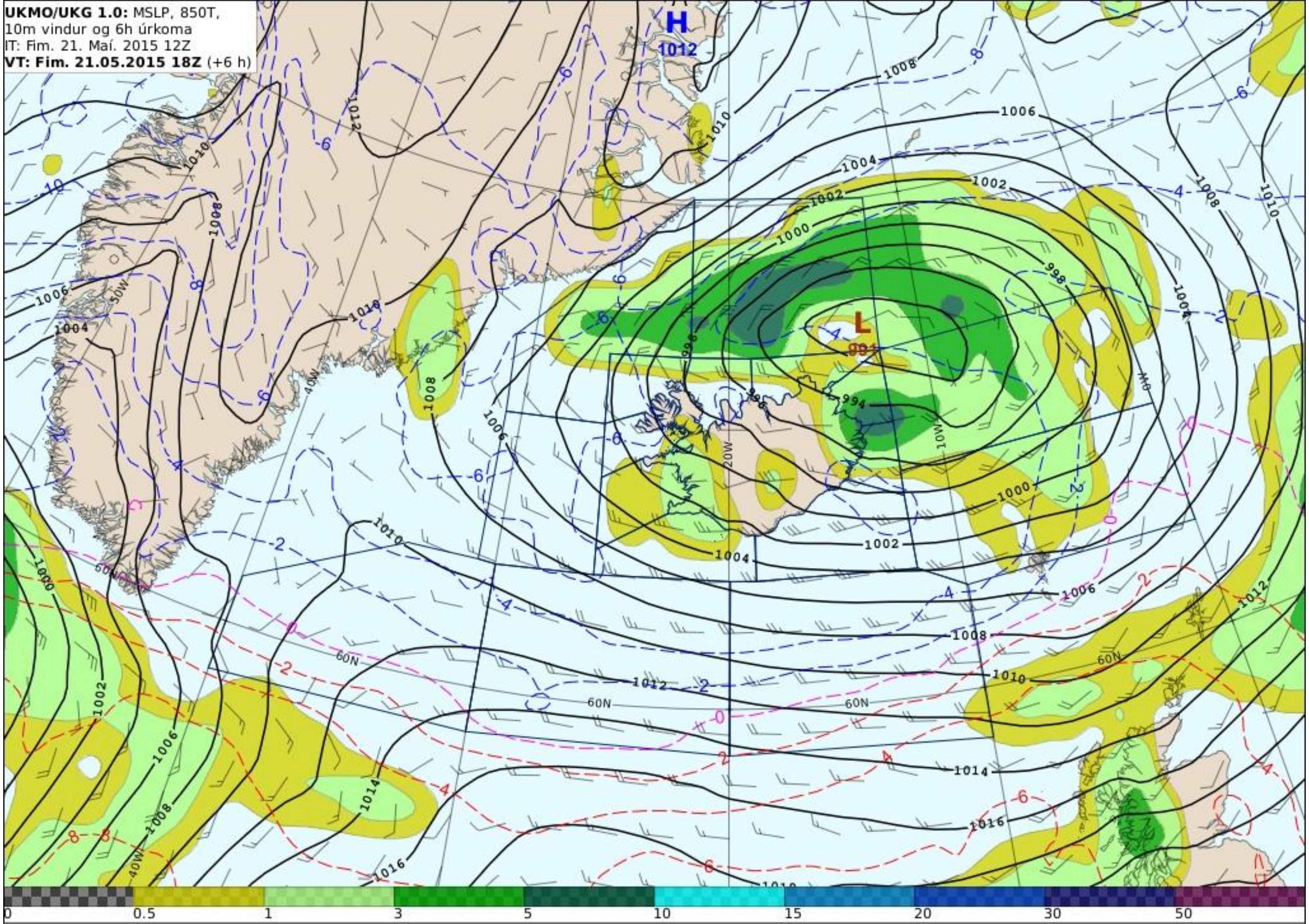
PolarWinds Campaign II Flight Tracks

May 21, 2015 – Barrier Wind Study
Intercomparison of DAWN, Dropsondes and WRF

Note: The vertical and horizontal dimensions are not equal scales

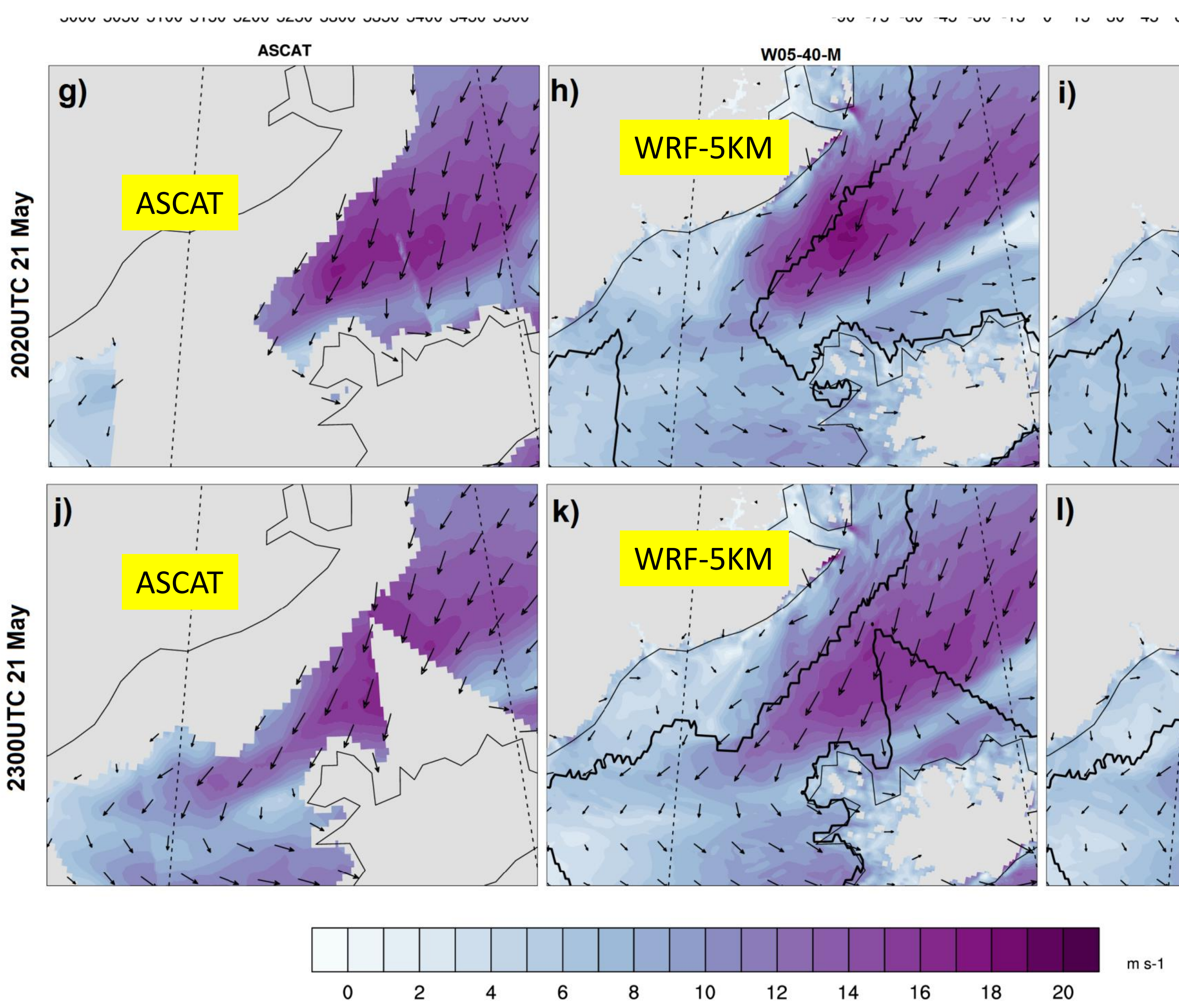
Figure from: Doyle and Shapiro (1999)




UKMO/UKG 1.0: MSLP, 850T,
10m vindur og 6h úrkoma
IT: Fim. 21. Maí. 2015 12Z
VT: Fim. 21.05.2015 18Z (+6 h)
H
1012
L
991
0
0.5
1
3
5
10
15
20
30
50

Colorado WRF V3.7.1 – Summary of Model Runs

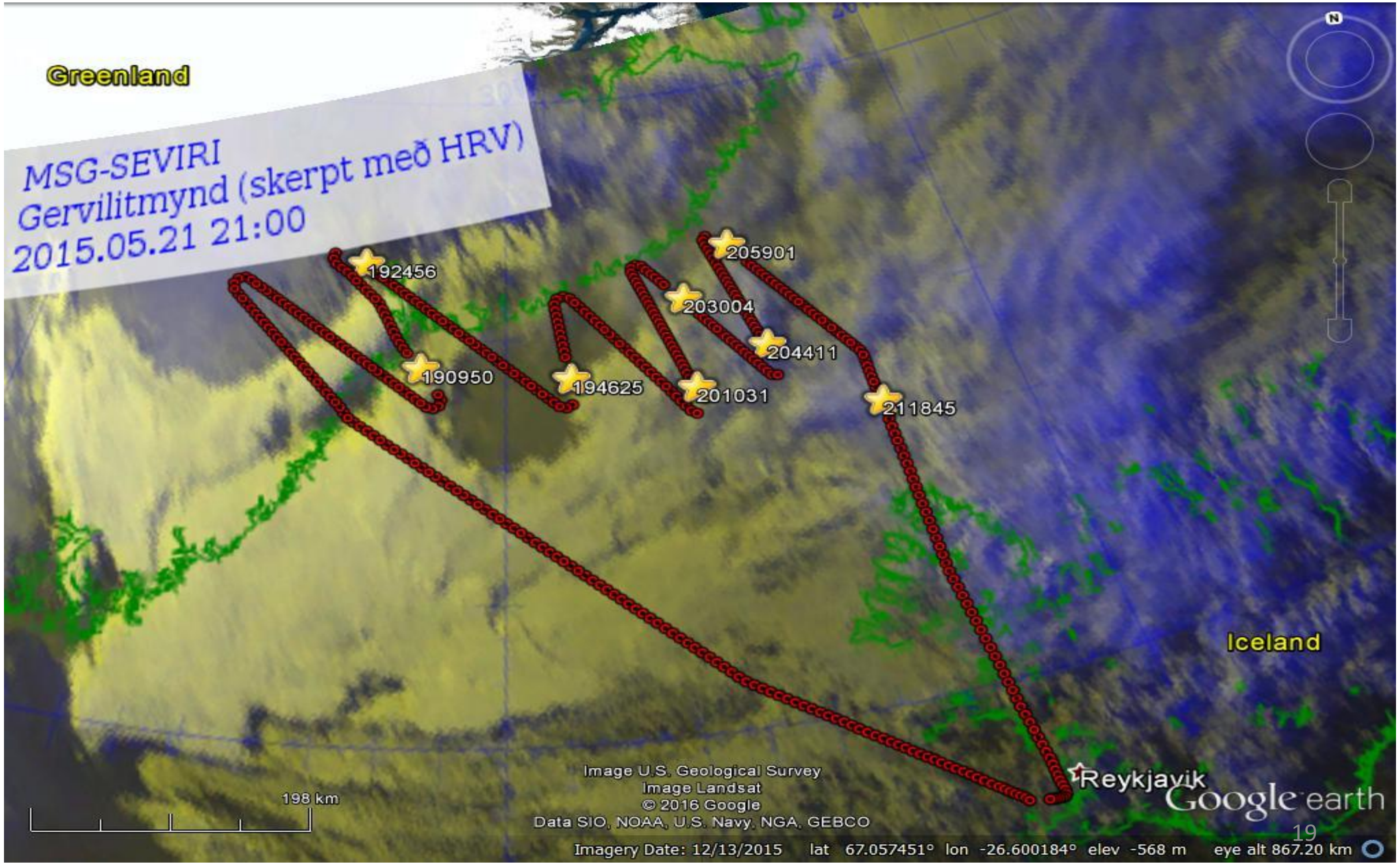
- 50, 25, 10, 5 km grid spacing (no nesting) over same domain
- 40 and 60 vertical Levels
- MYNN2.5 and UW Boundary Layer Schemes
- Sea ice thickness = 0.5m
- RRTMG shortwave and longwave radiation
- Kain-Fritsch cumulus
- Morrison microphysics
- Revised MM5 surface layer

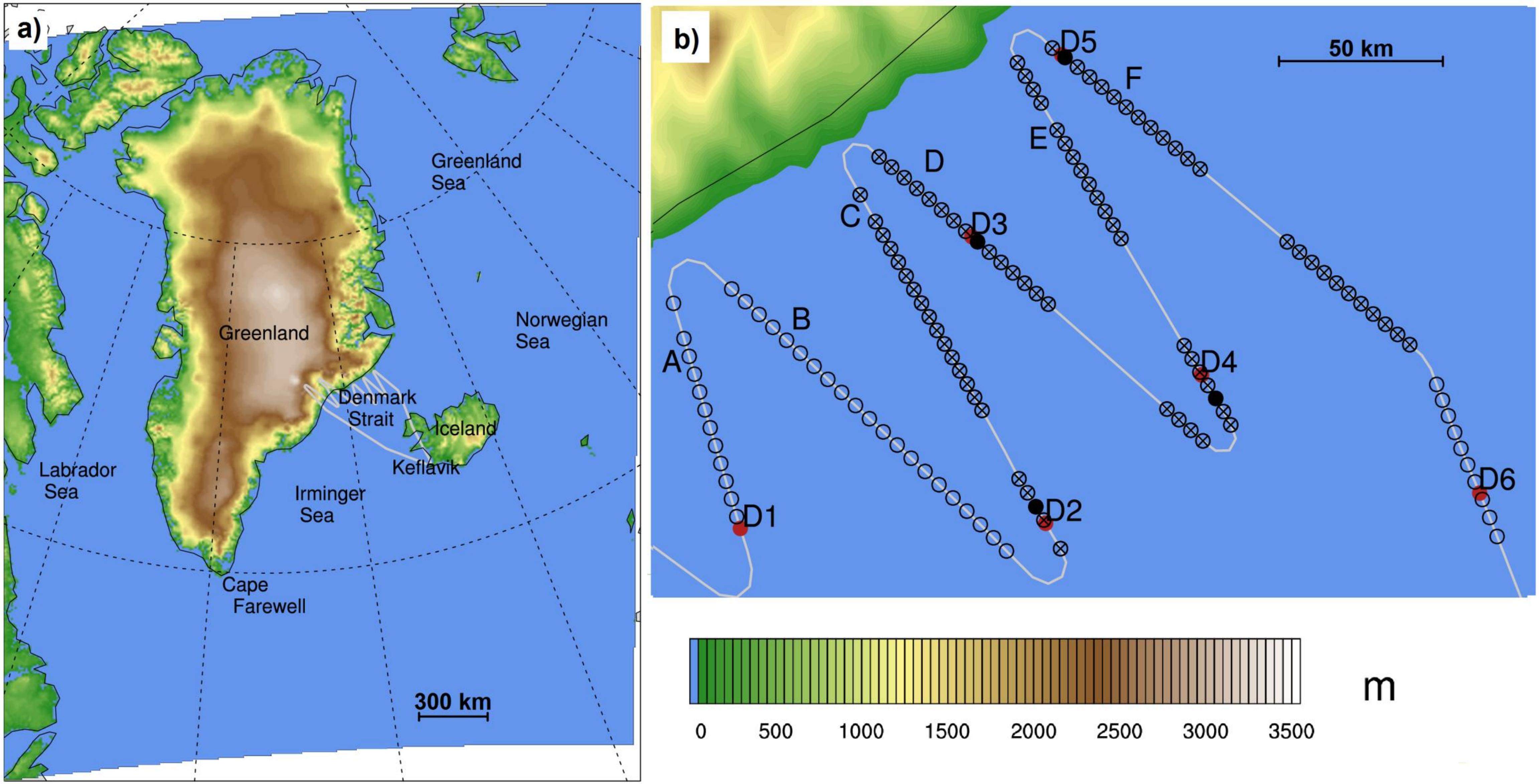

ASCAT
W05-40-M
W05-nonudge
2020UTC 21 May
g)
ASCAT
h)
WRF-5KM
i)
2300UTC 21 May
j)
ASCAT
k)
WRF-5KM
l)
0
2
4
6
8
10
12
14
16
18
20
m s-1

DAWN/dropsonde comparisons in highly varying coastal region: **Greenland East Coast Barrier Wind Case**

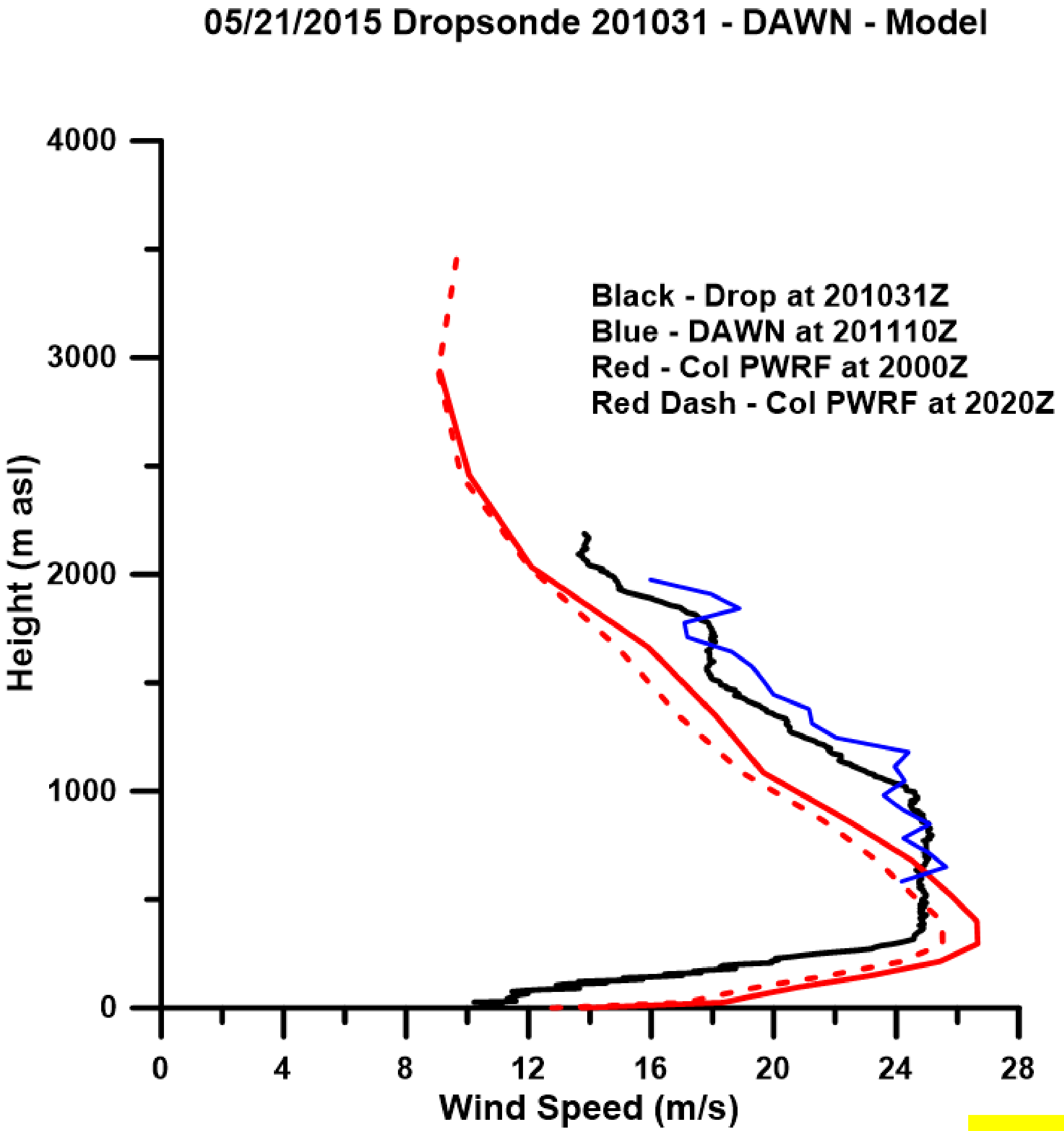
Red circles:
DAWN profiles

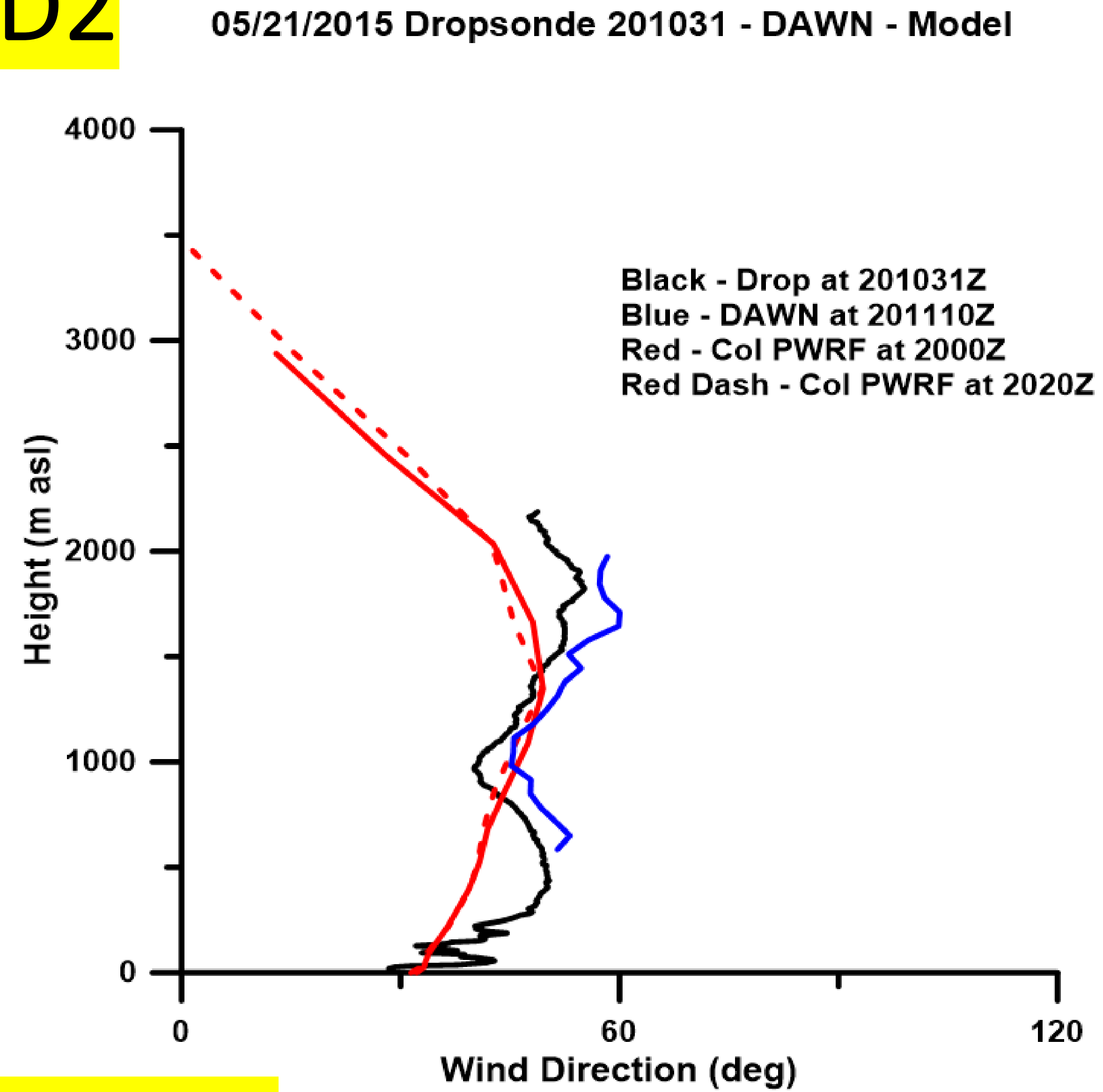
Yellow stars:
Dropsondes




a)
Greenland Sea
Norwegian Sea
Greenland
Denmark Strait
Iceland
Keflavik
Labrador Sea
Irminger Sea
Cape Farewell
300 km
b)
50 km
D5
F
E
D
D3
C
B
A
D4
D2
D1
D6
0
500
1000
1500
2000
2500
3000
3500
m

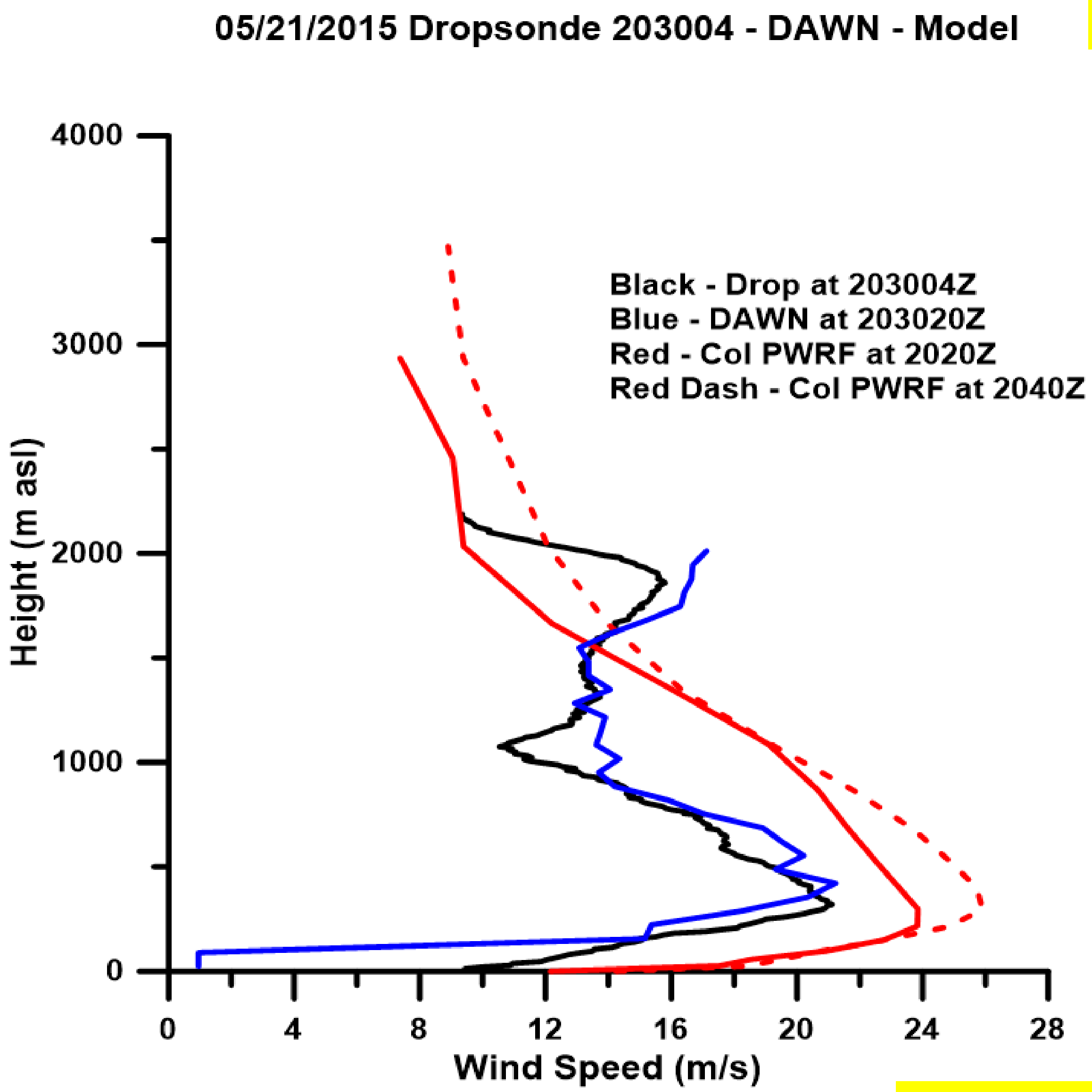
D2

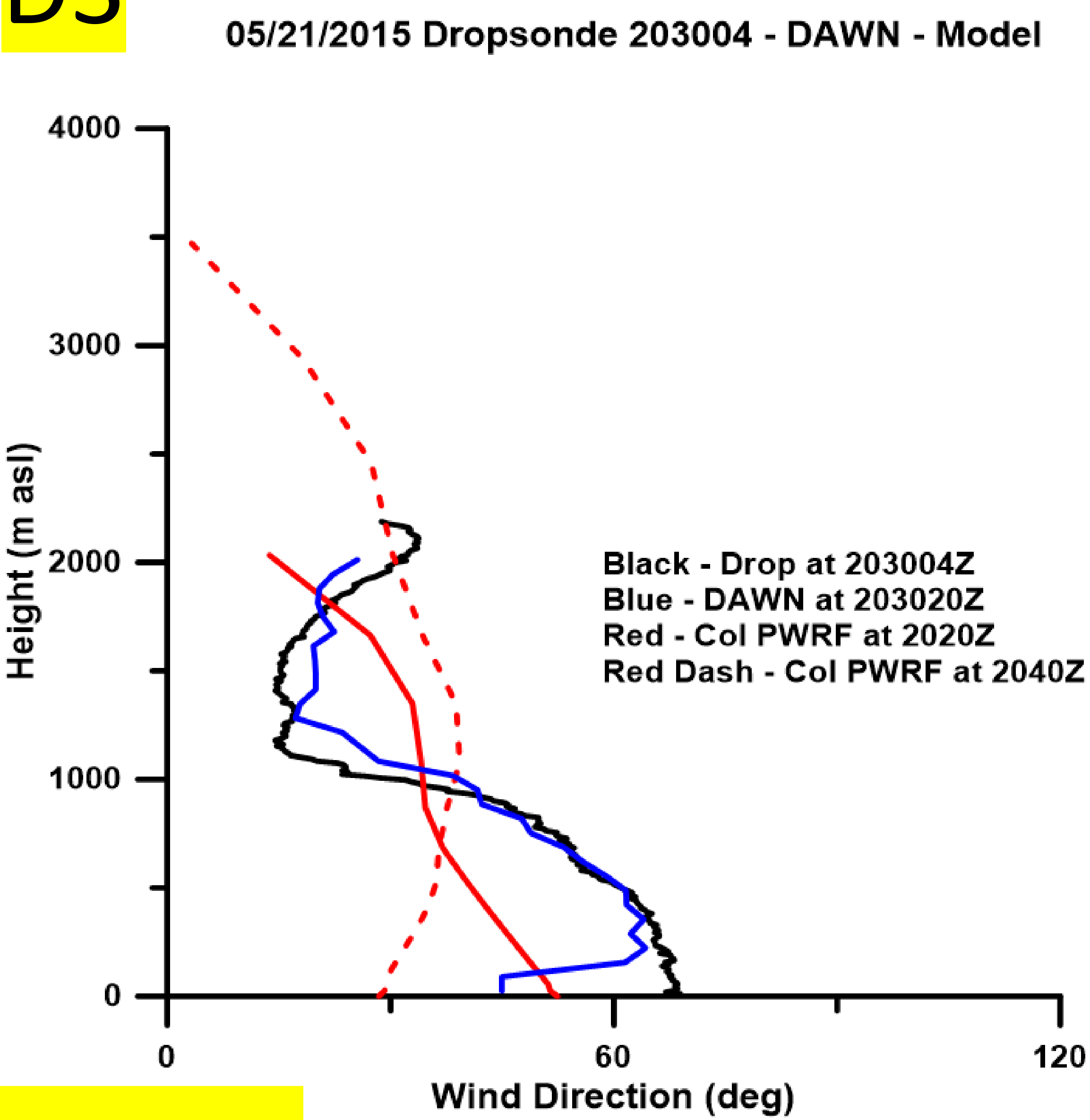

05/21/2015 Dropsonde 201031 - DAWN - Model
Black - Drop at 201031Z
Blue - DAWN at 201110Z
Red - Col PWRF at 2000Z
Red Dash - Col PWRF at 2020Z
Height (m asl)
0
1000
2000
3000
4000
0
4
8
12
16
20
24
28
Wind Speed (m/s)


05/21/2015 Dropsonde 201031 - DAWN - Model
Black - Drop at 201031Z
Blue - DAWN at 201110Z
Red - Col PWRF at 2000Z
Red Dash - Col PWRF at 2020Z
Height (m asl)
0
1000
2000
3000
4000
0
60
120
Wind Direction (deg)

Off Coast

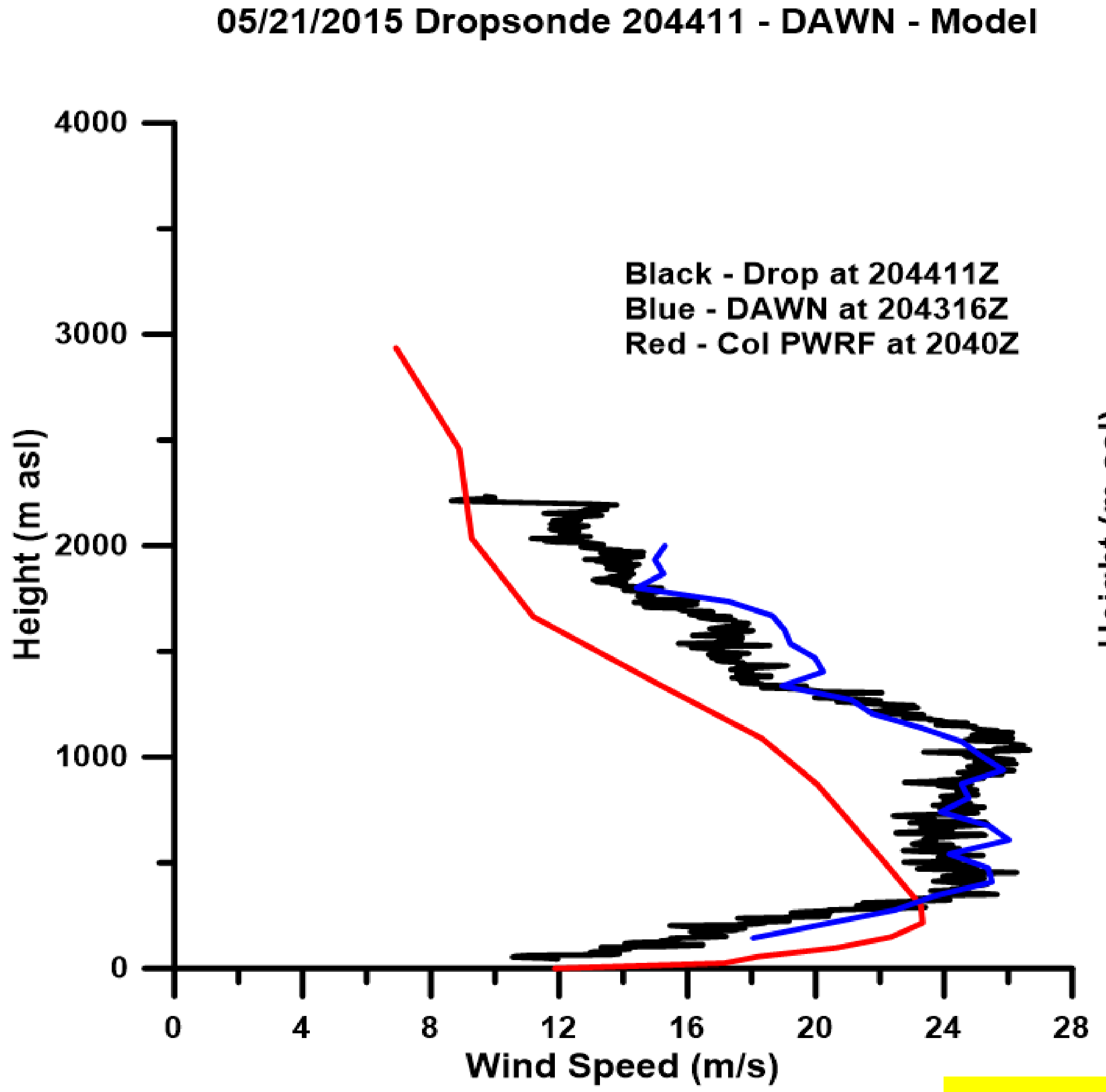
D3

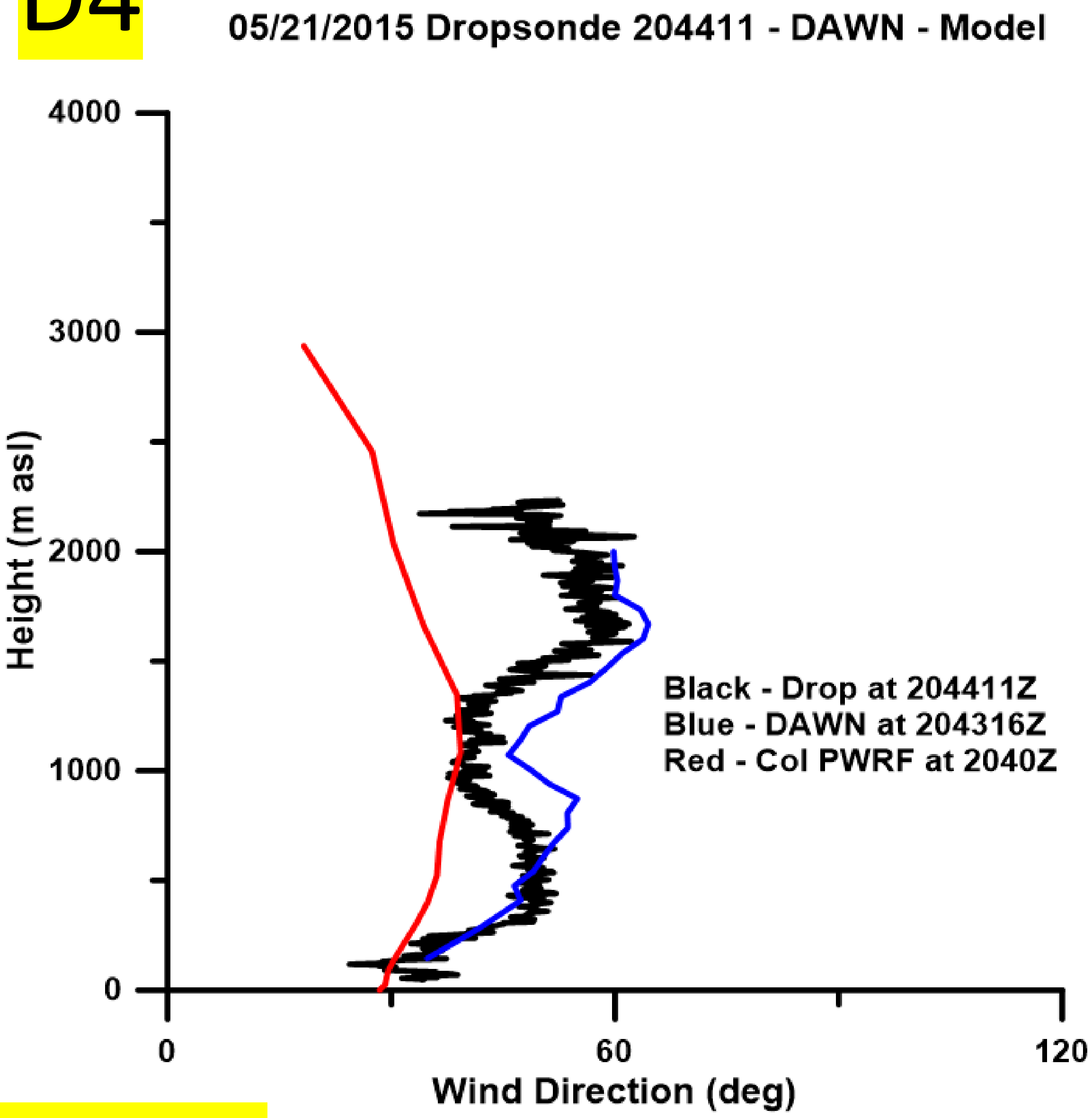




Near Coast

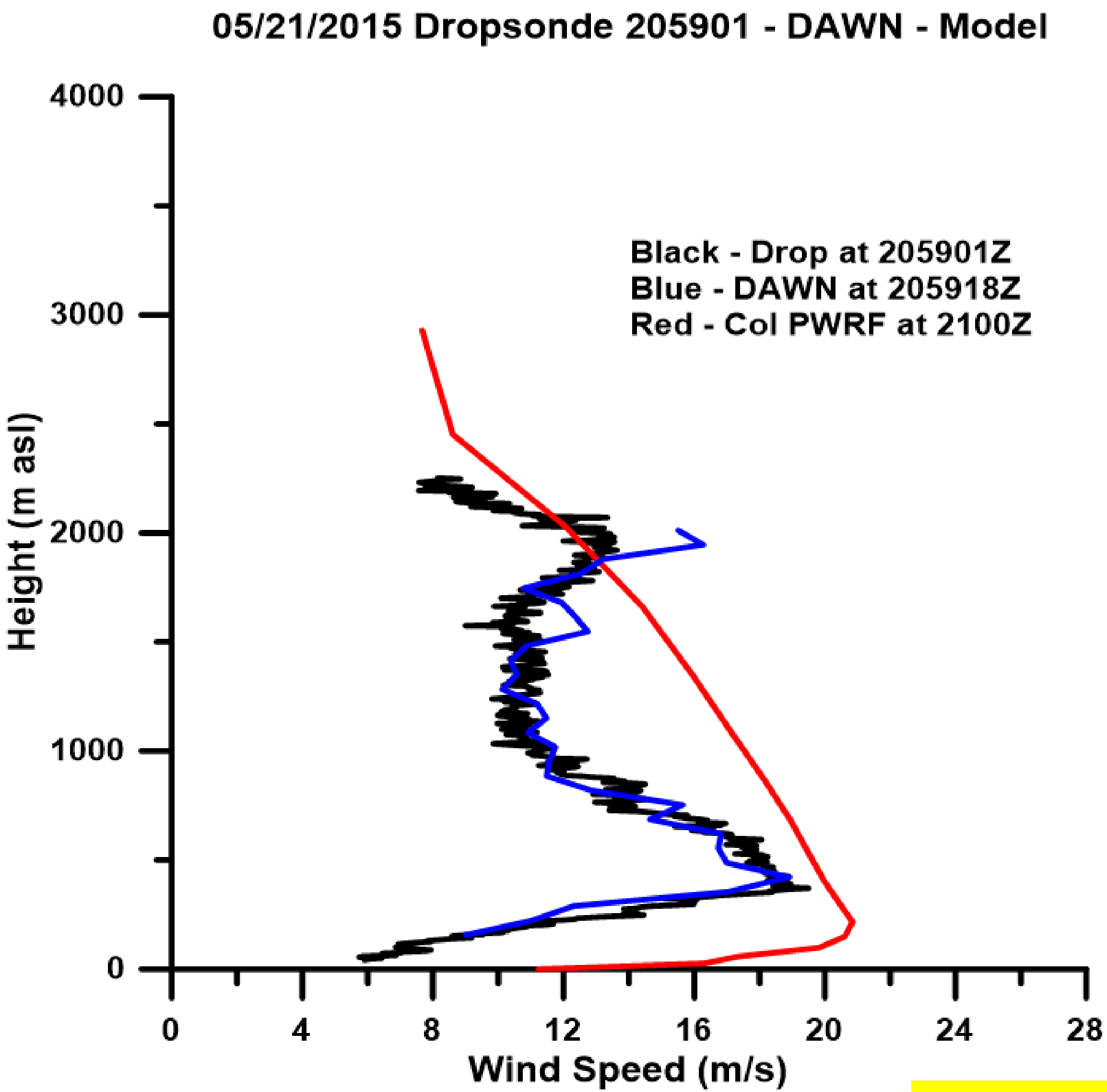
D4

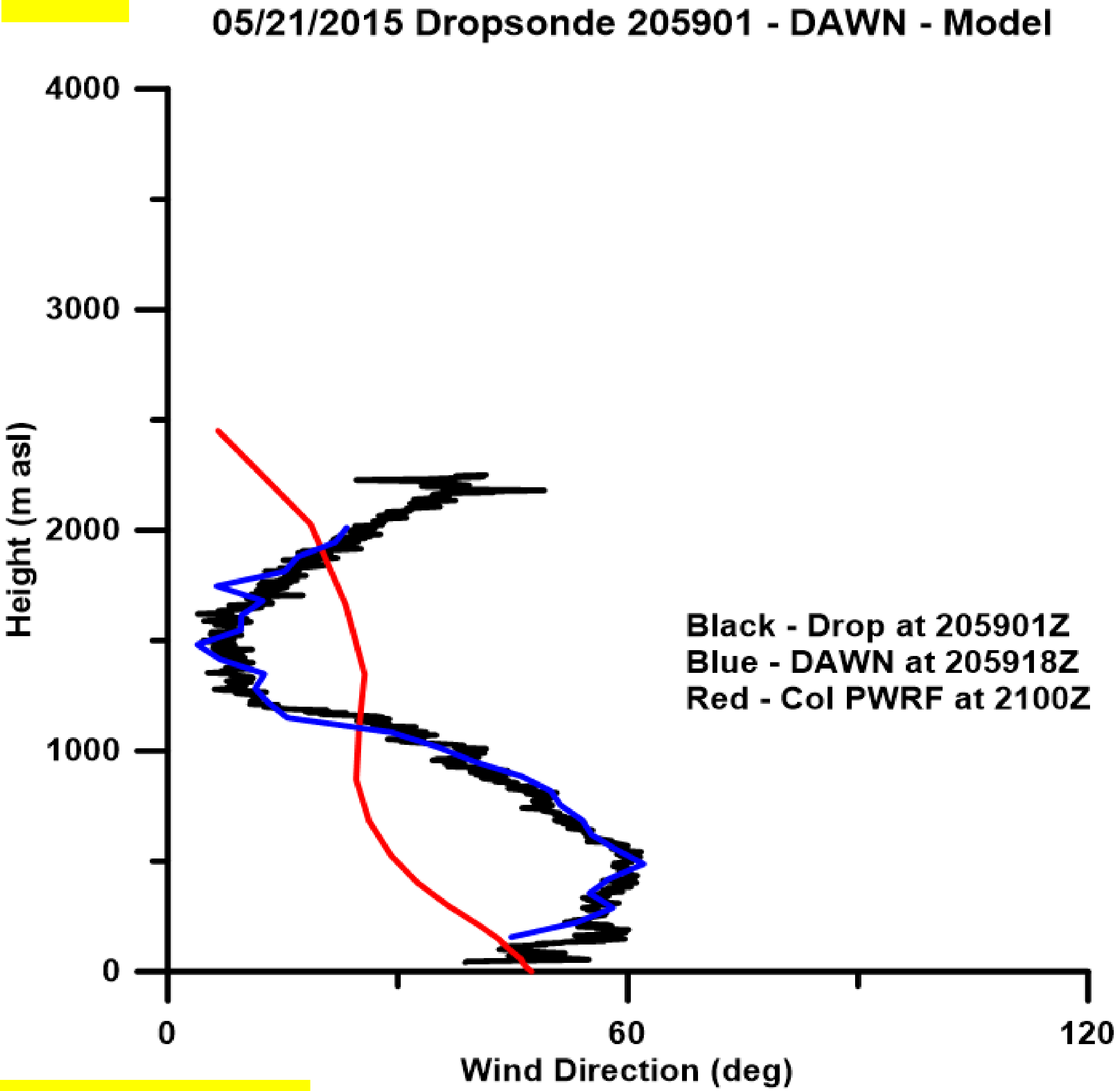

05/21/2015 Dropsonde 204411 - DAWN - Model
Black - Drop at 204411Z
Blue - DAWN at 204316Z
Red - Col PWRF at 2040Z
Height (m asl)
0
1000
2000
3000
4000
0
4
8
12
16
20
24
28
Wind Speed (m/s)


05/21/2015 Dropsonde 204411 - DAWN - Model
Black - Drop at 204411Z
Blue - DAWN at 204316Z
Red - Col PWRF at 2040Z
Height (m asl)
0
1000
2000
3000
4000
0
60
120
Wind Direction (deg)

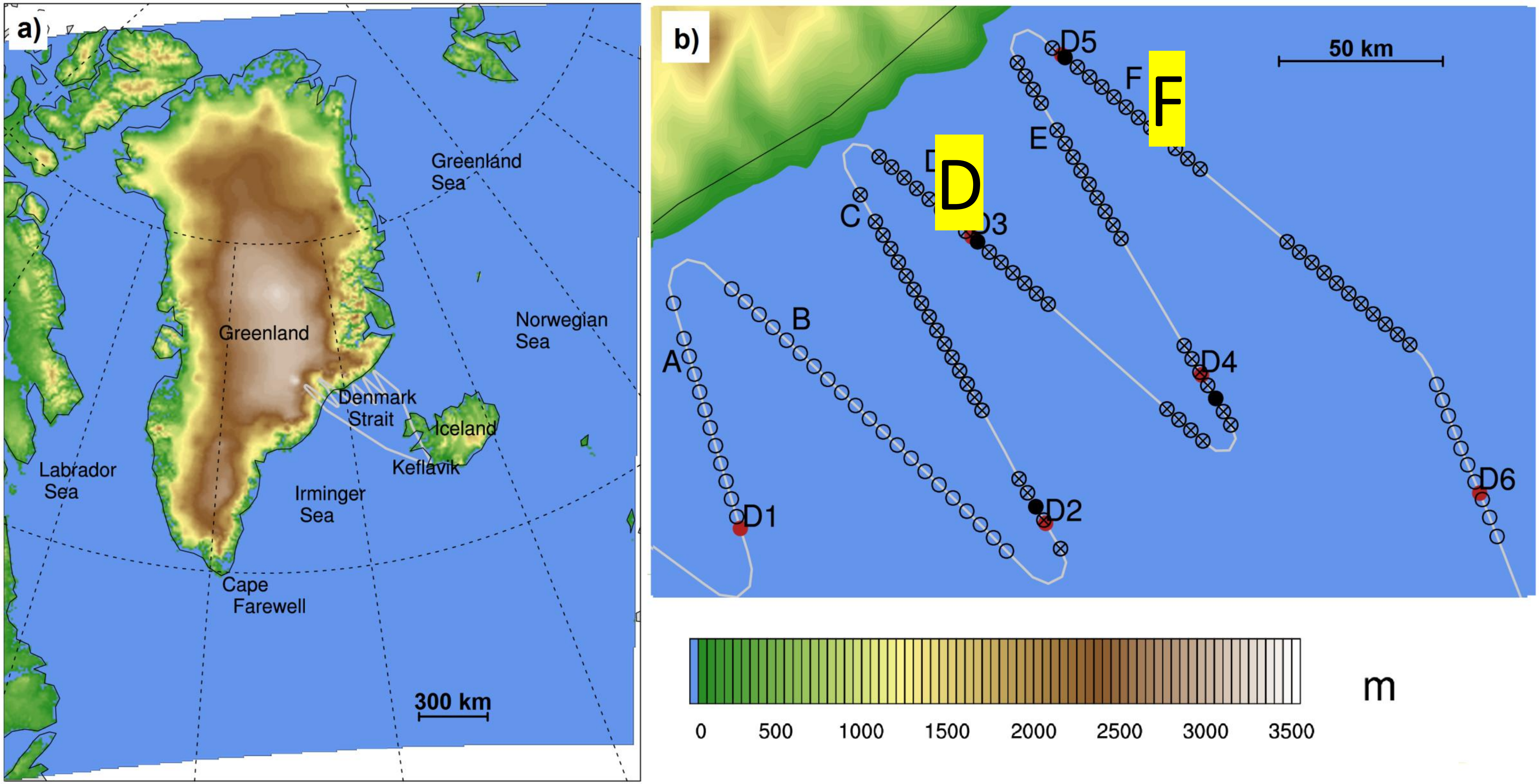
Off Coast

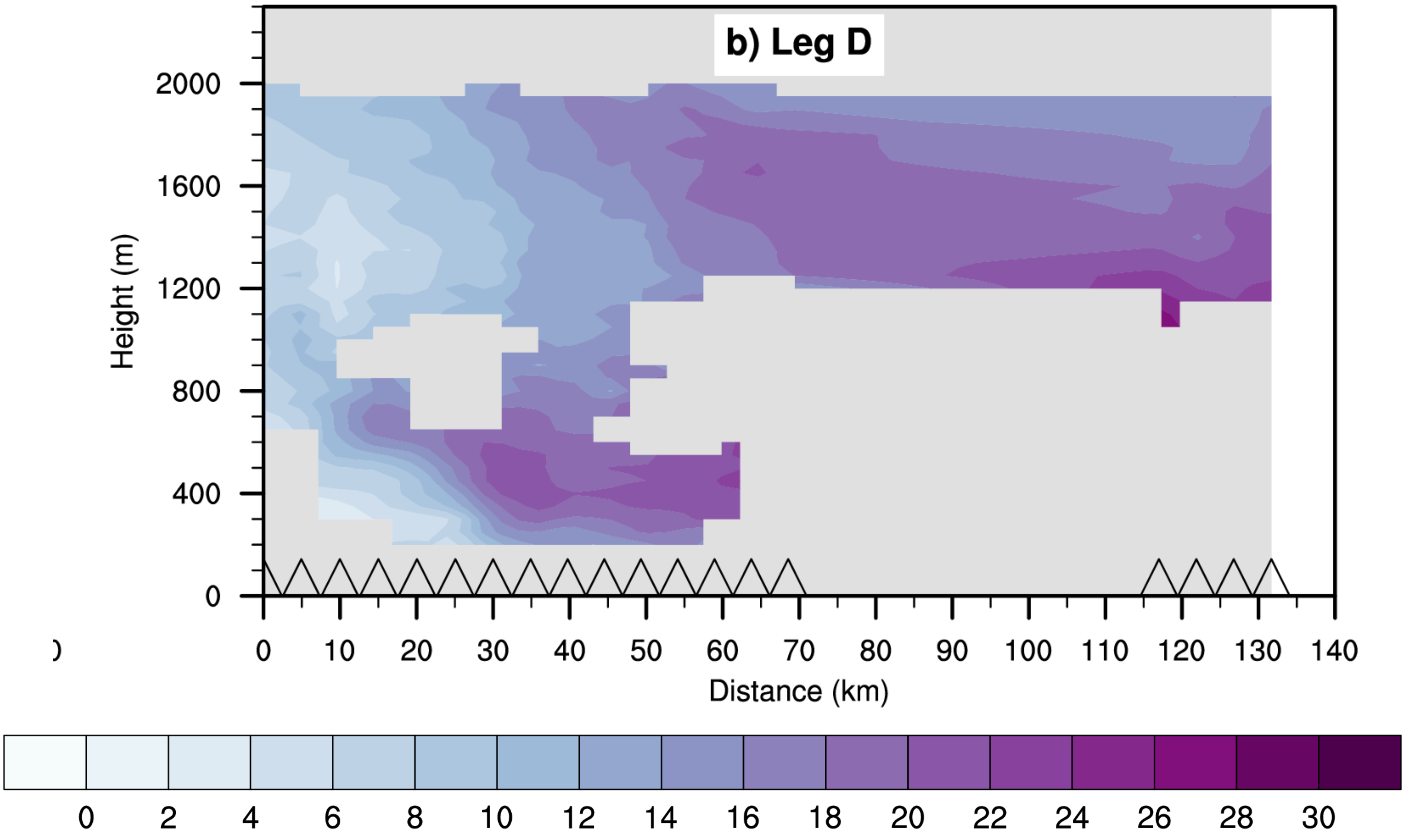
D5



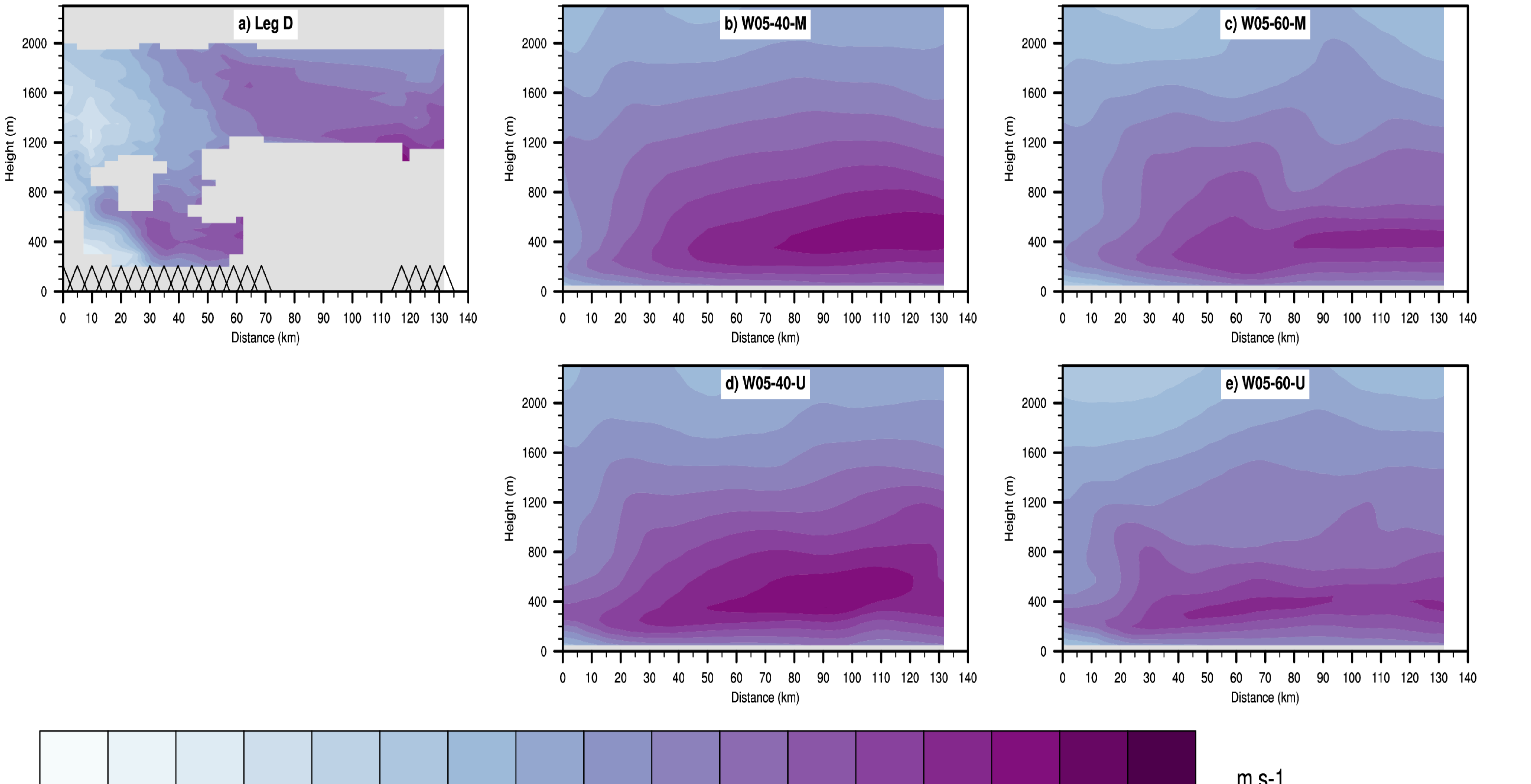


Near Coast

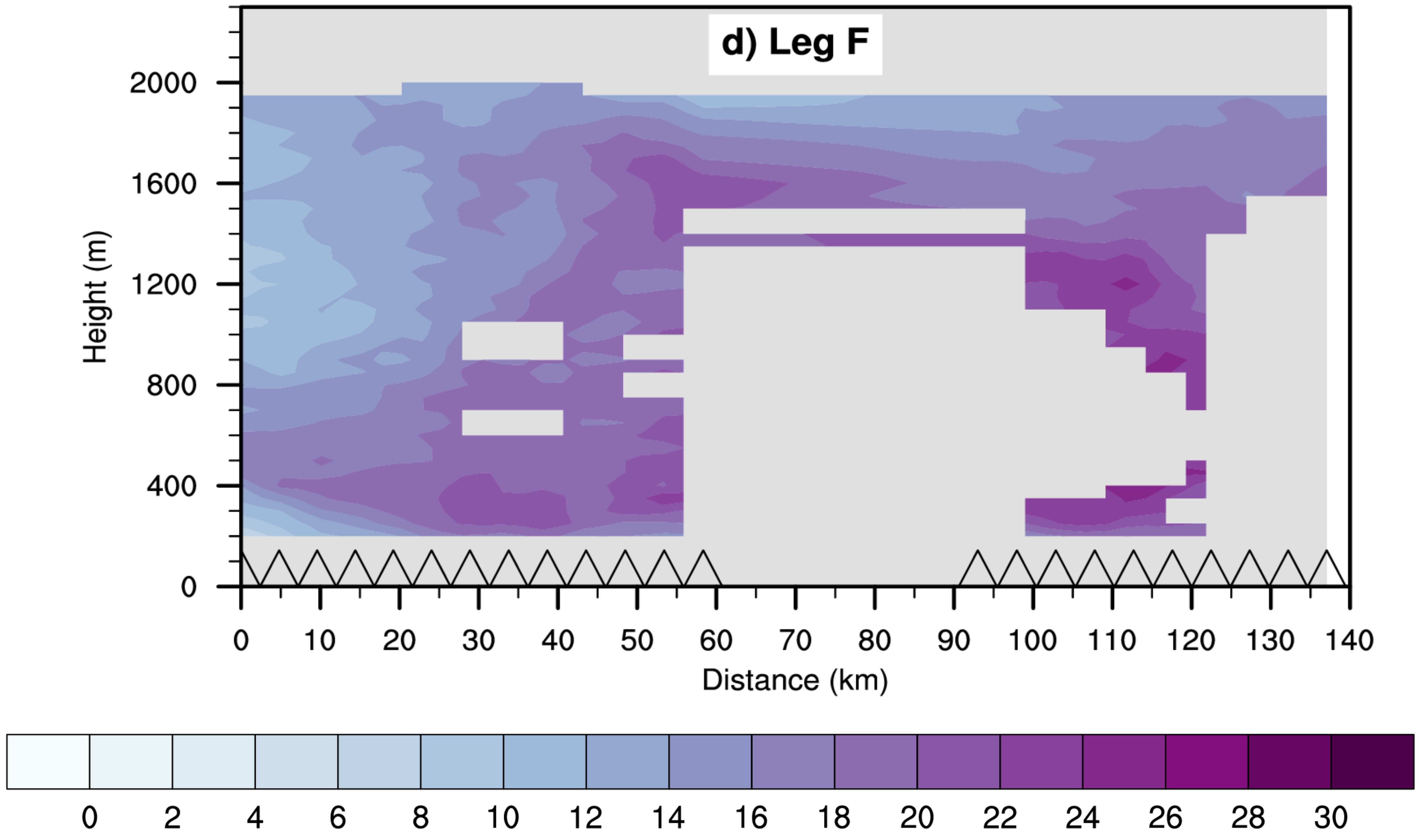

a)
Greenland Sea
Norwegian Sea
Greenland
Denmark Strait
Iceland
Keflavik
Labrador Sea
Irminger Sea
Cape Farewell
300 km
b)
50 km
D5
F
F
E
D
D
D3
C
B
A
D4
D6
D2
D1
0
500
1000
1500
2000
2500
3000
3500
m

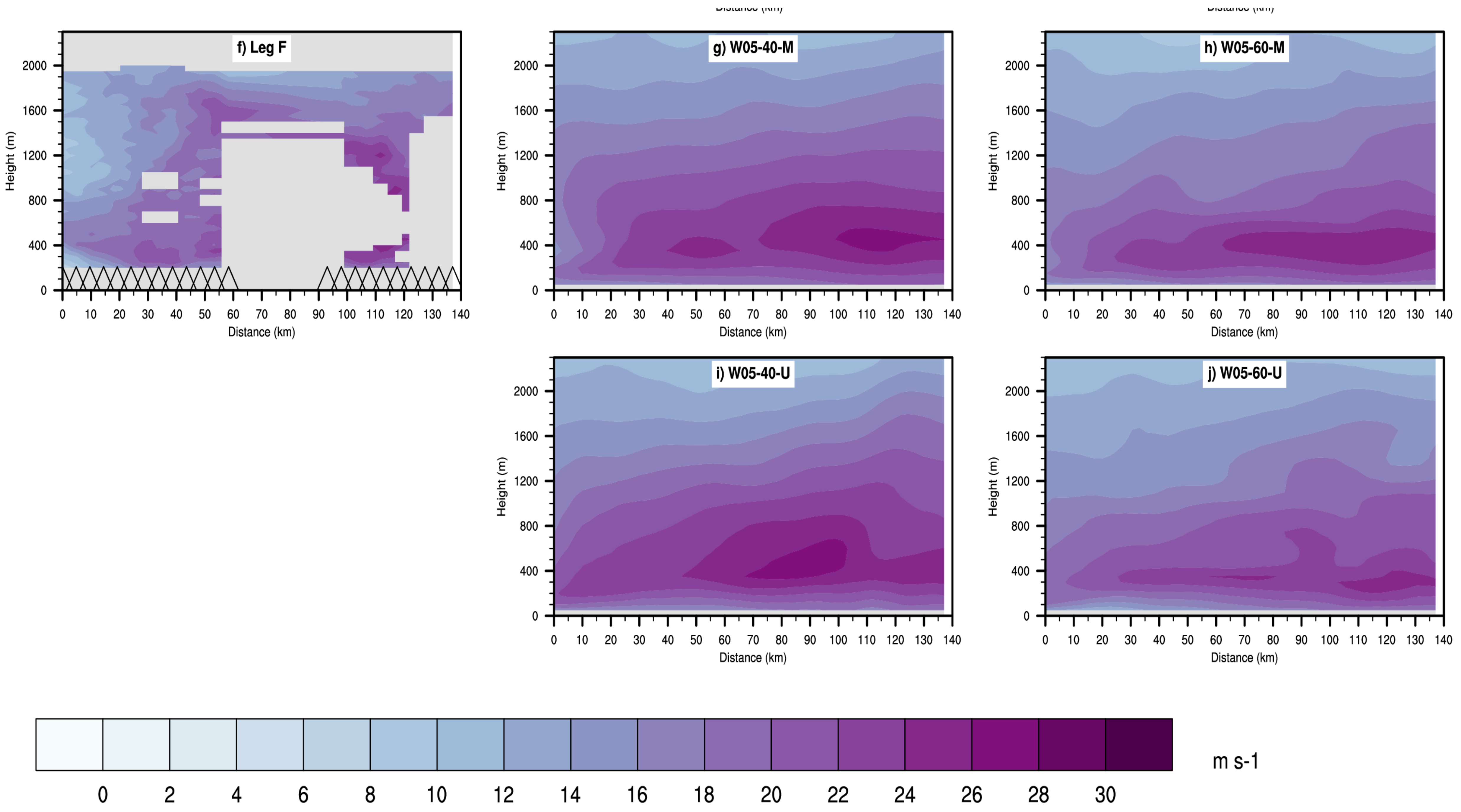


b) Leg D
Height (m)
2000
1600
1200
800
400
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Distance (km)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30



a) Leg D
b) W05-40-M
c) W05-60-M
d) W05-40-U
e) W05-60-U
Height (m)
Distance (km)
m s-1


d) Leg F
Height (m)
2000
1600
1200
800
400
0
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
Distance (km)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30

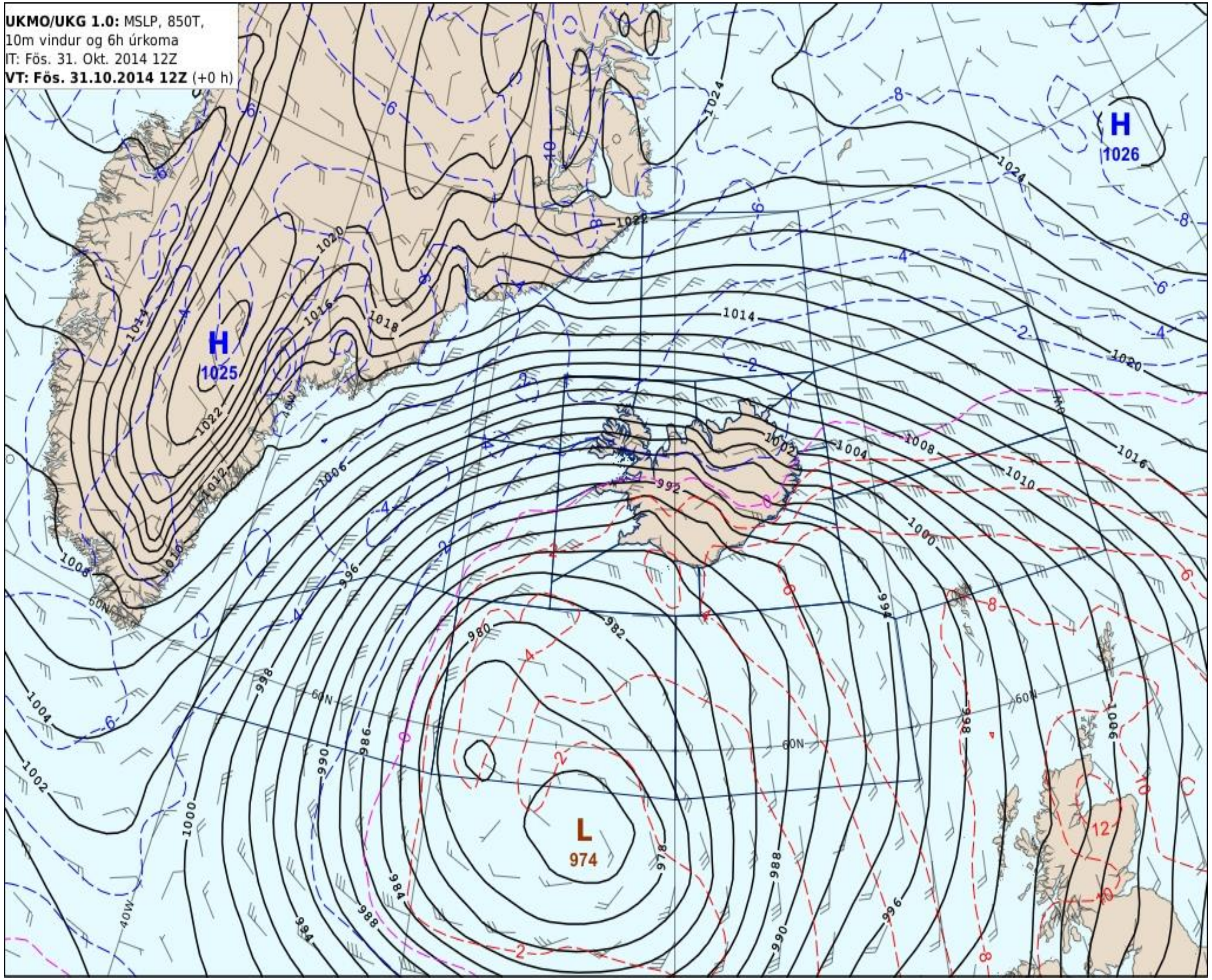


f) Leg F
g) W05-40-M
h) W05-60-M
i) W05-40-U
j) W05-60-U
Height (m)
Distance (km)
0
400
800
1200
1600
2000
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
m s-1

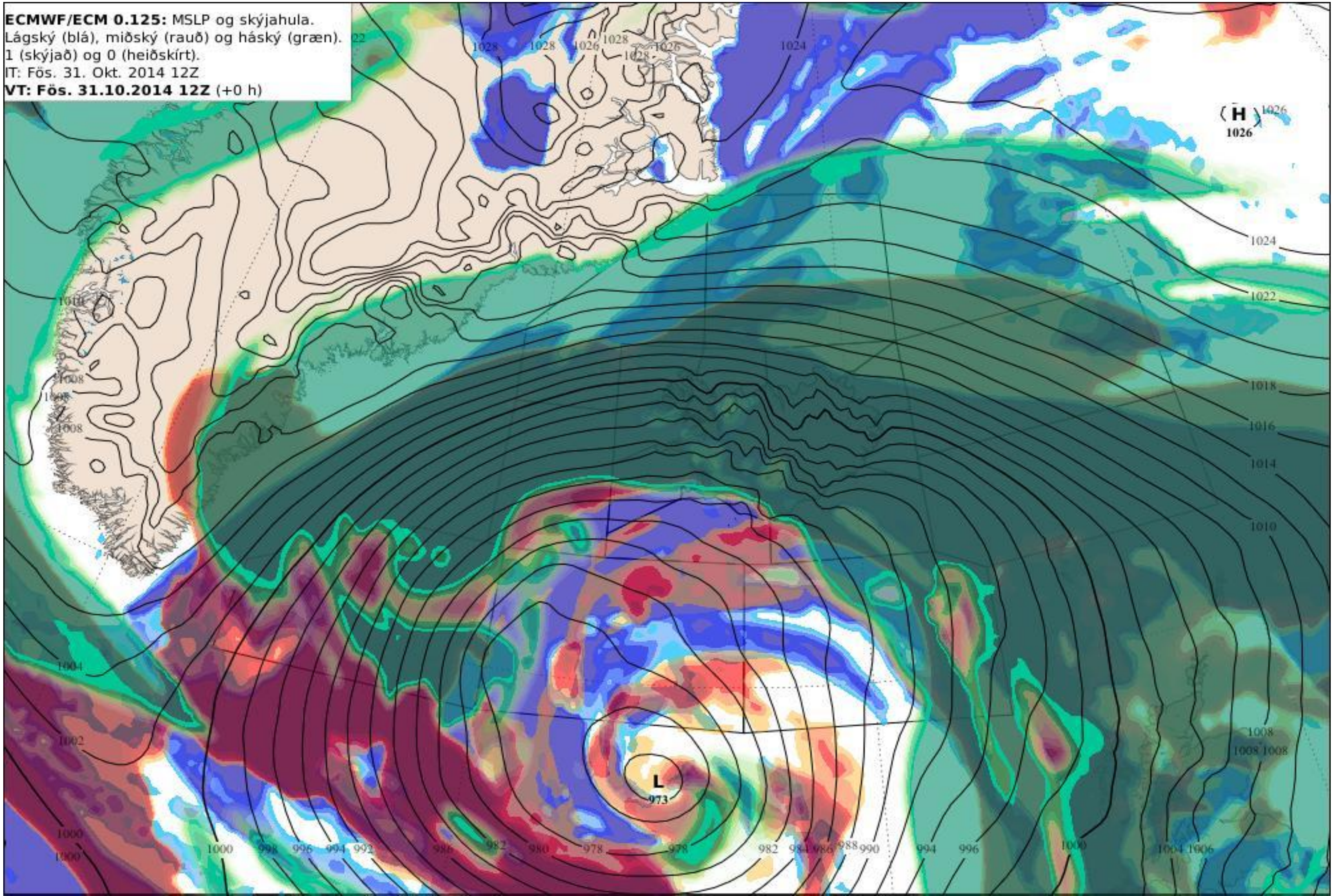
Barrier Winds Summary

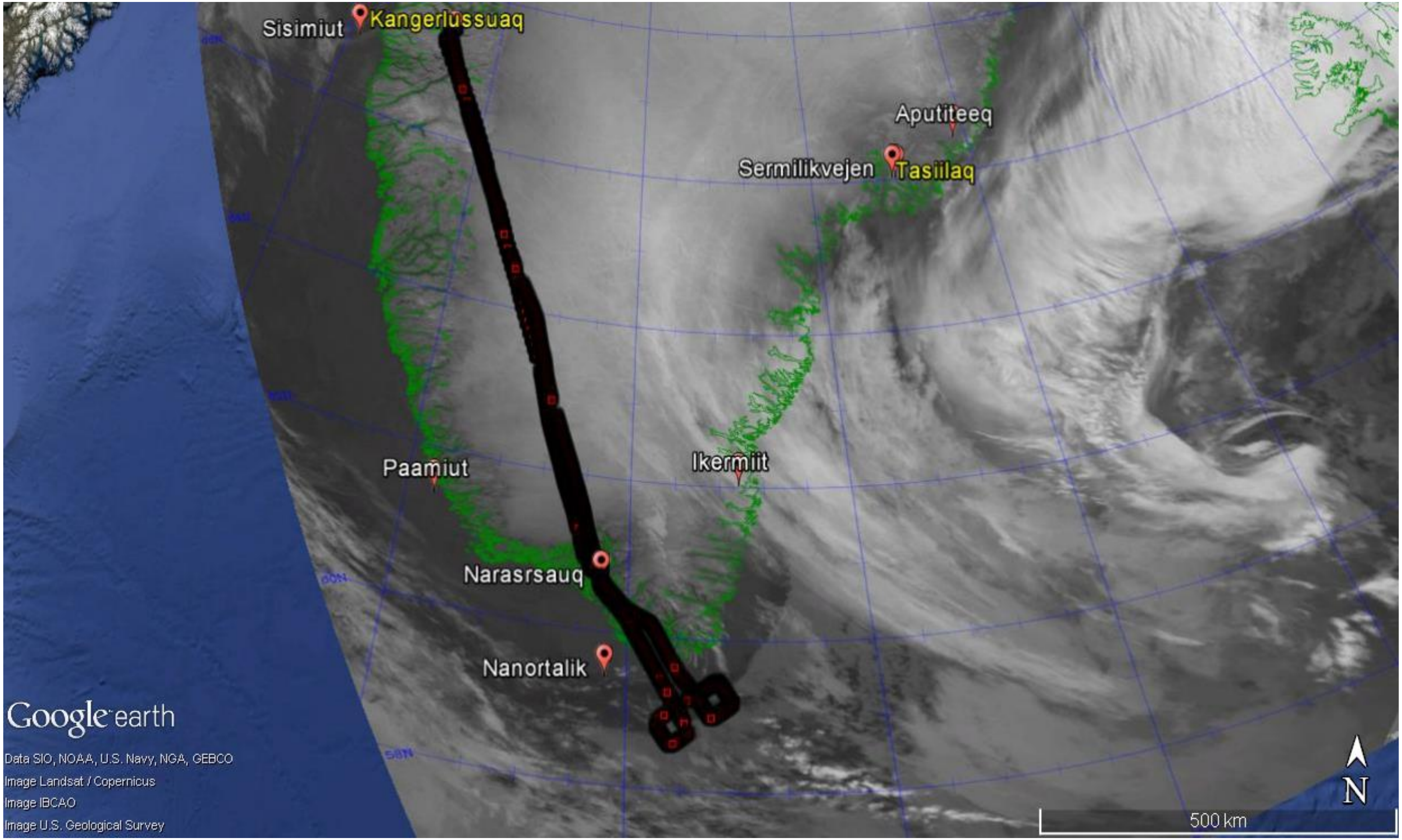
- DAWN wind profiles closely match dropsondes
- DAWN and dropsondes show stronger narrower jet near the coast but a broader/deeper and slightly weaker wind max further off the coast
- Higher horizontal and vertical resolution model runs better capture jet winds
- Higher vertical resolution run is needed to capture DAWN observed jet structure but WRF still misses speed gradients and variability
- Choice of BL scheme made little difference
- DuVivier et al., (2017) – complete model study ACCEPTED for publication in MWR

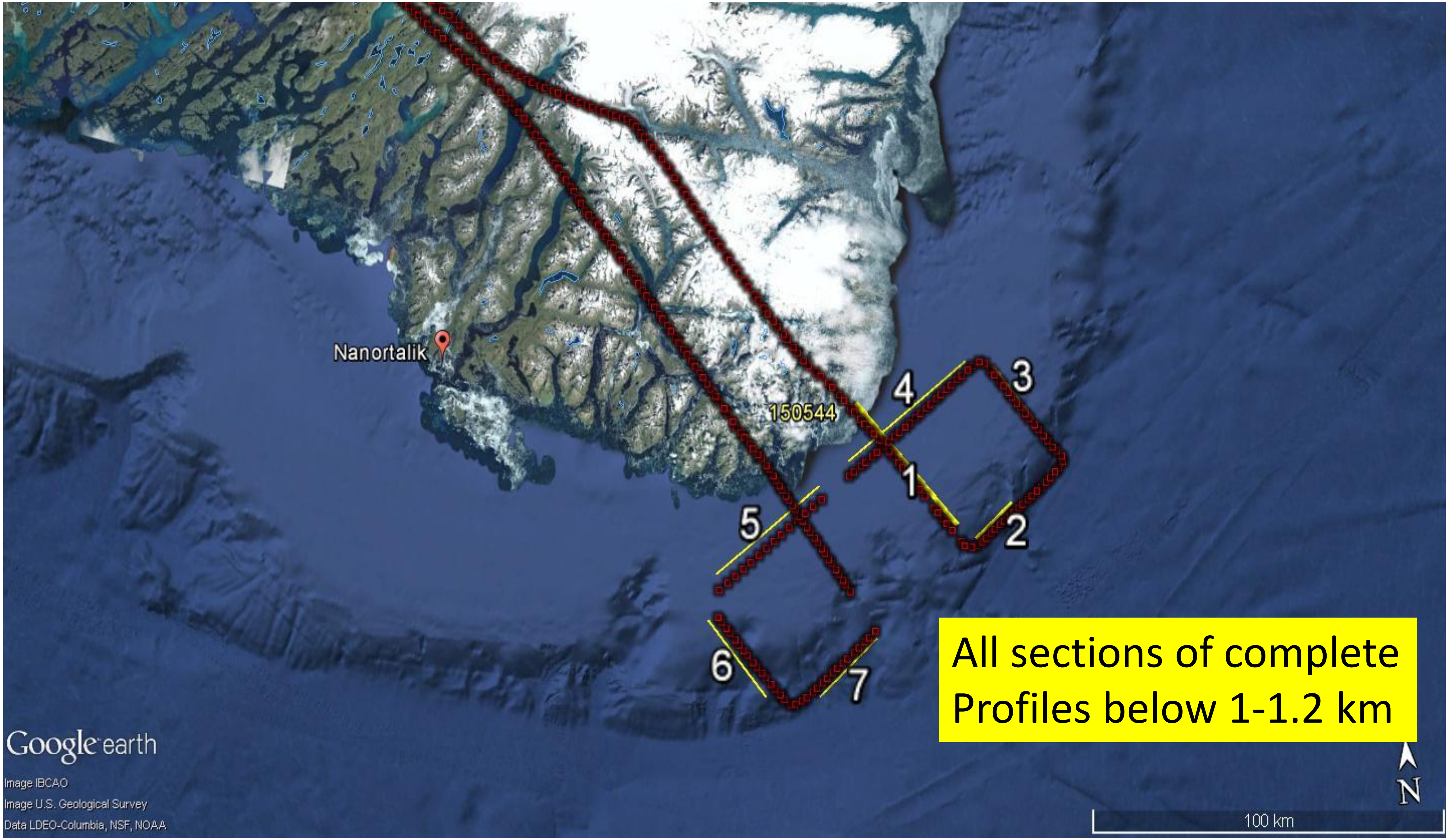
October 31, 2014– Tip Jet Study
Intercomparison of DAWN and OSU Polar WRF



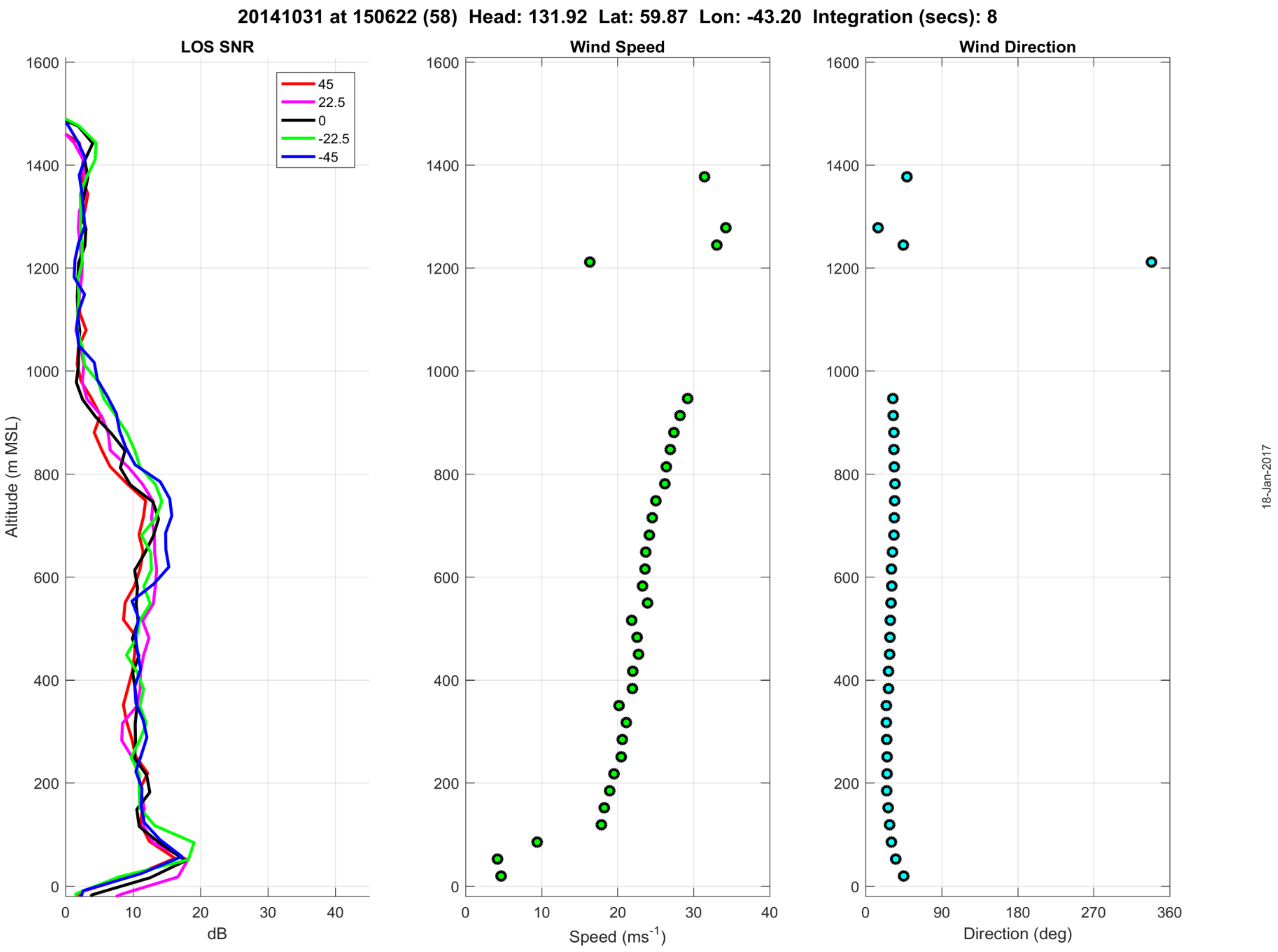
Very similar to the easterly tip jet studied by Renfrew et al., 2009 (QJRMS)


ECMWF/ECM 0.125: MSLP og skýjahula.
Lágský (blá), miðský (rauð) og háský (græn).
1 (skýjað) og 0 (heiðskírt).
IT: Fös. 31. Okt. 2014 12Z
VT: Fös. 31.10.2014 12Z (+0 h)
H
1026
L
973

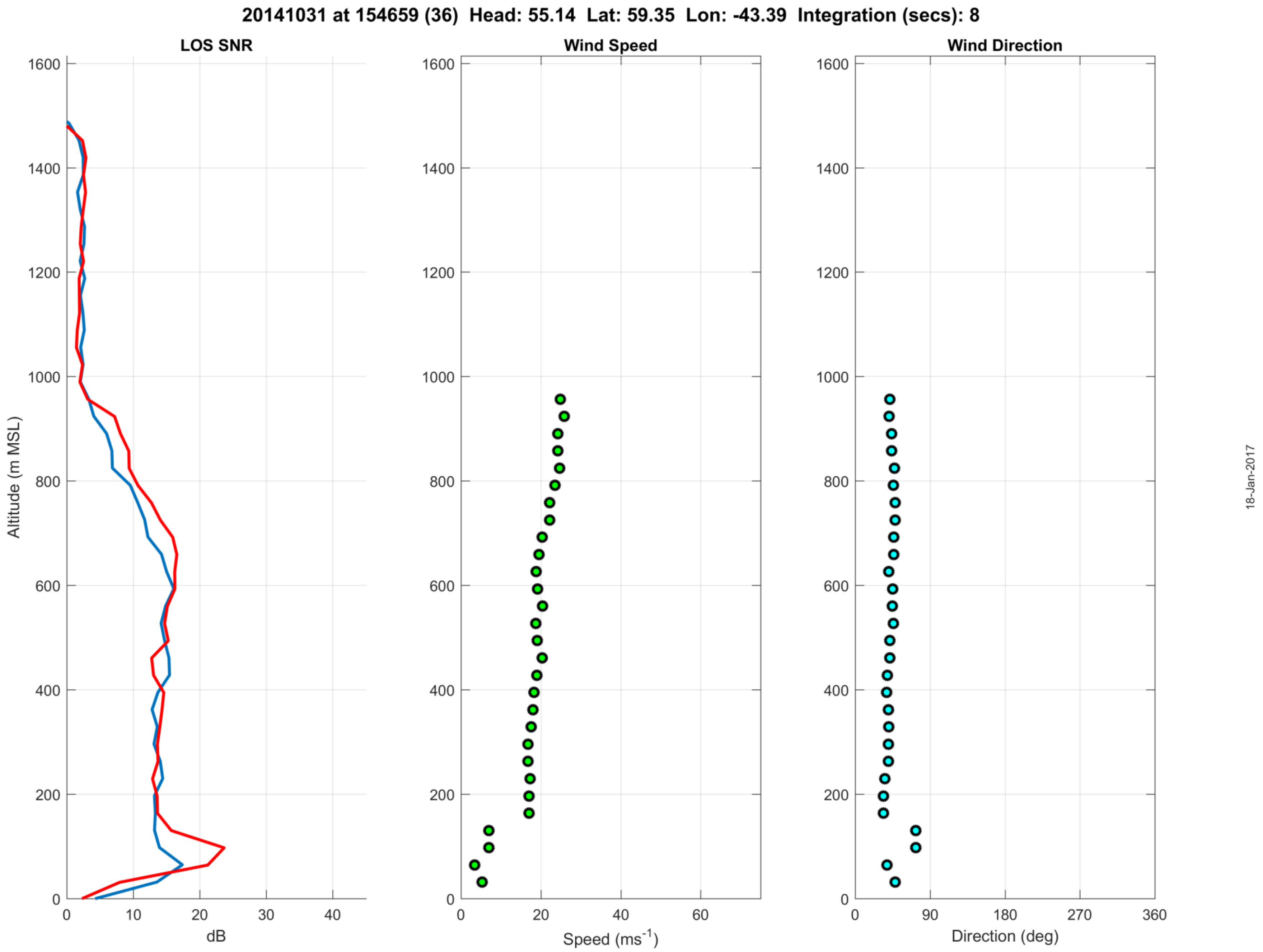

Sisimiut
Kangerlussuaq
Aputiteeq
Sermilikvejen
Tasiilaq
Paamiut
Ikermiit
Narasrsauq
Nanortalik
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Image IBCAO
Image U.S. Geological Survey
N
500 km

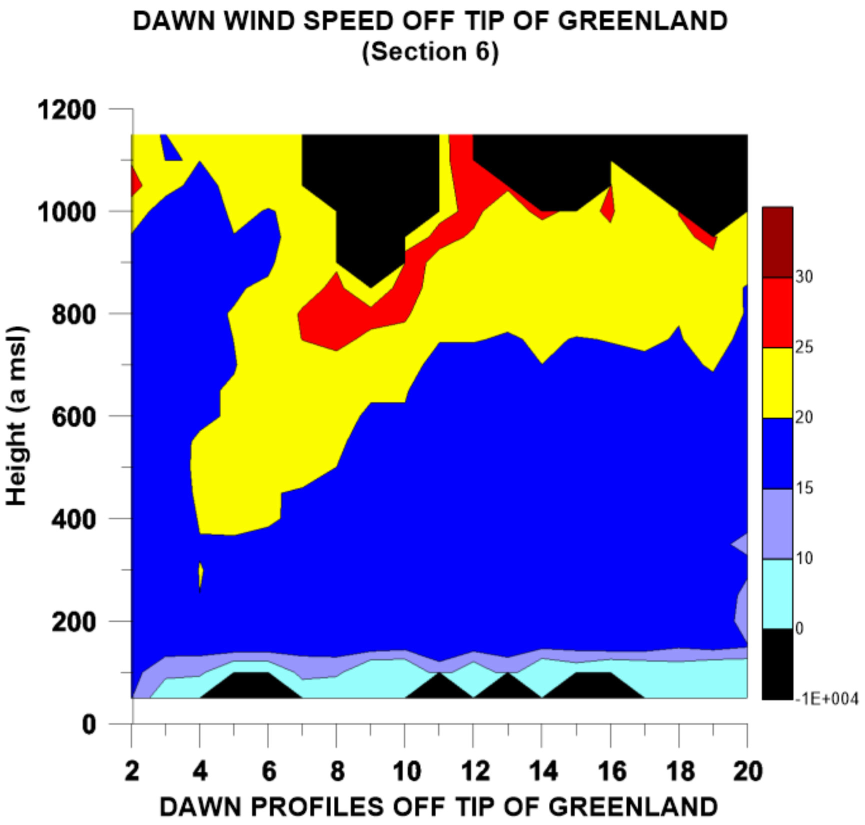

Nanortalik
150544
1
2
3
4
5
6
7
All sections of complete Profiles below 1-1.2 km
Google earth
Image IBCAO
Image U.S. Geological Survey
Data LDEO-Columbia, NSF, NOAA
N
100 km

Stronger winds Near Tip Section 1



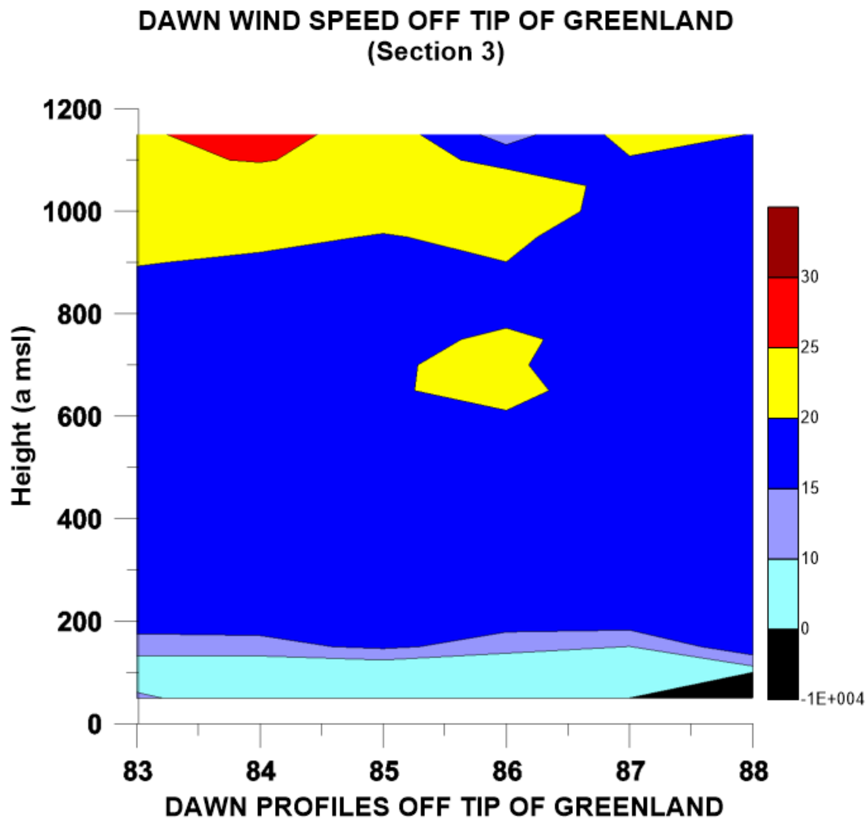
Weaker winds SW of TIP



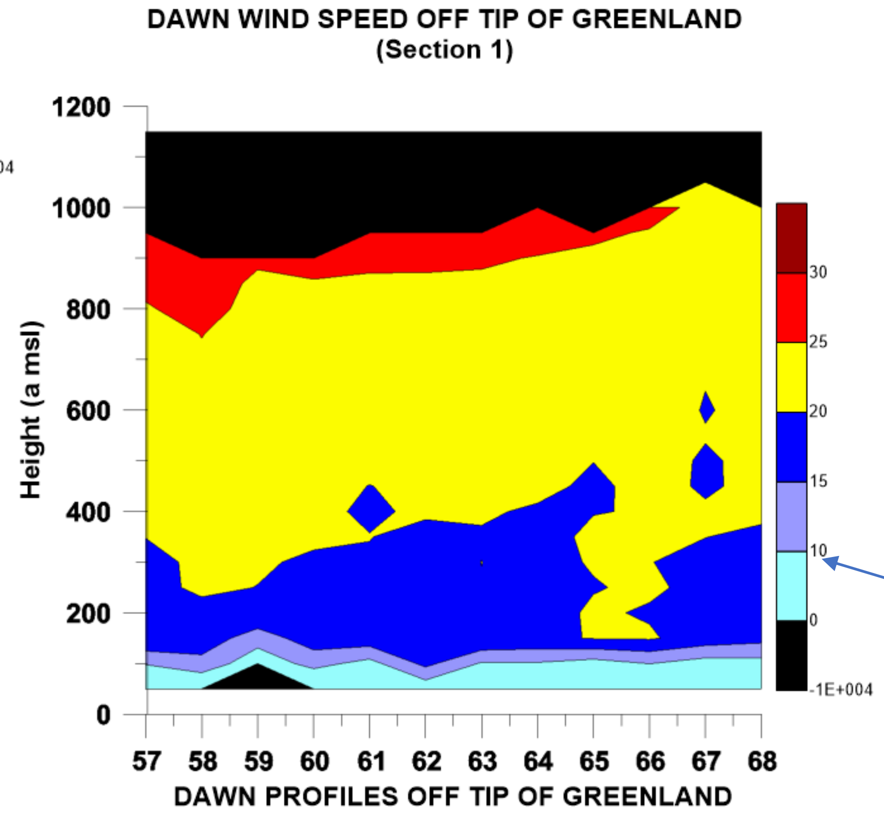


6

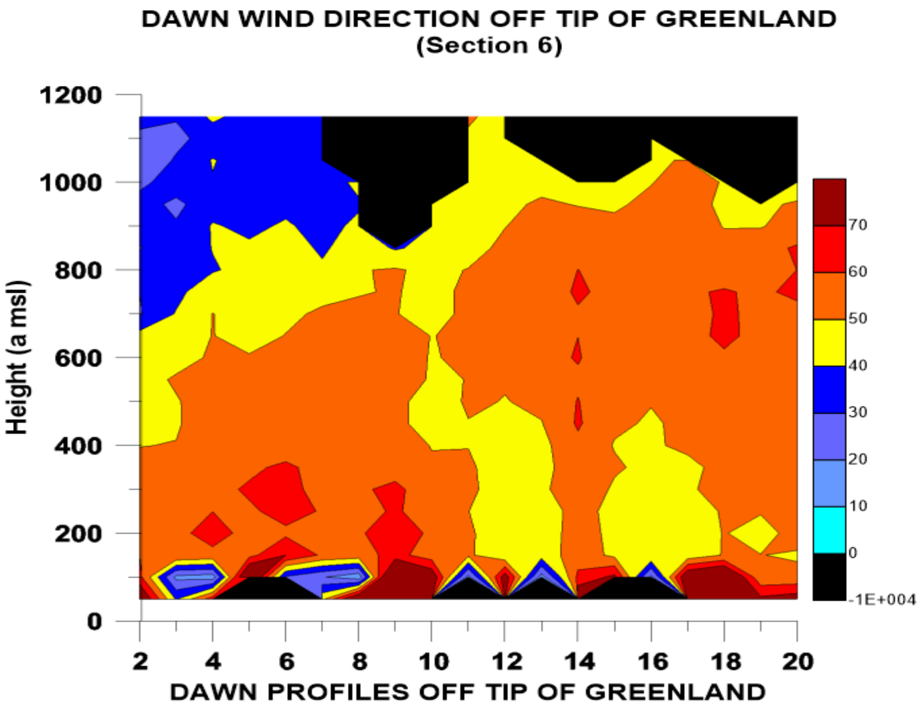
3



1

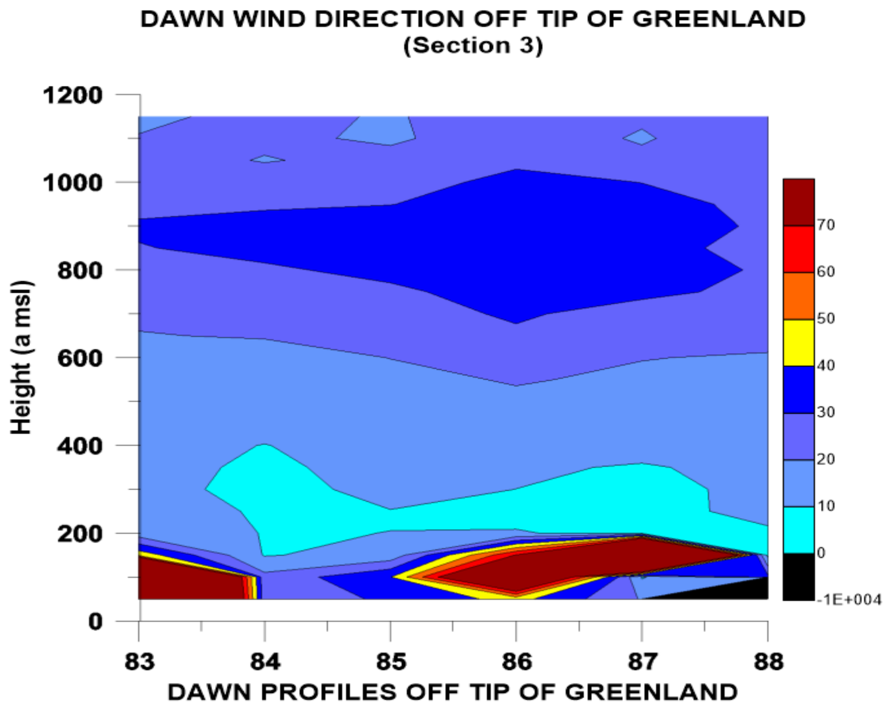


Acceleration near tip



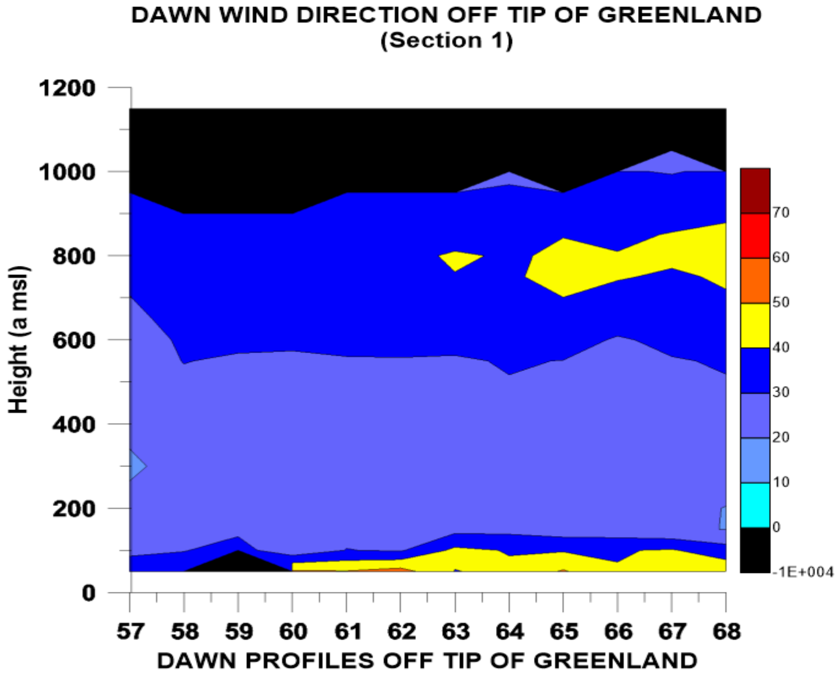
6

3

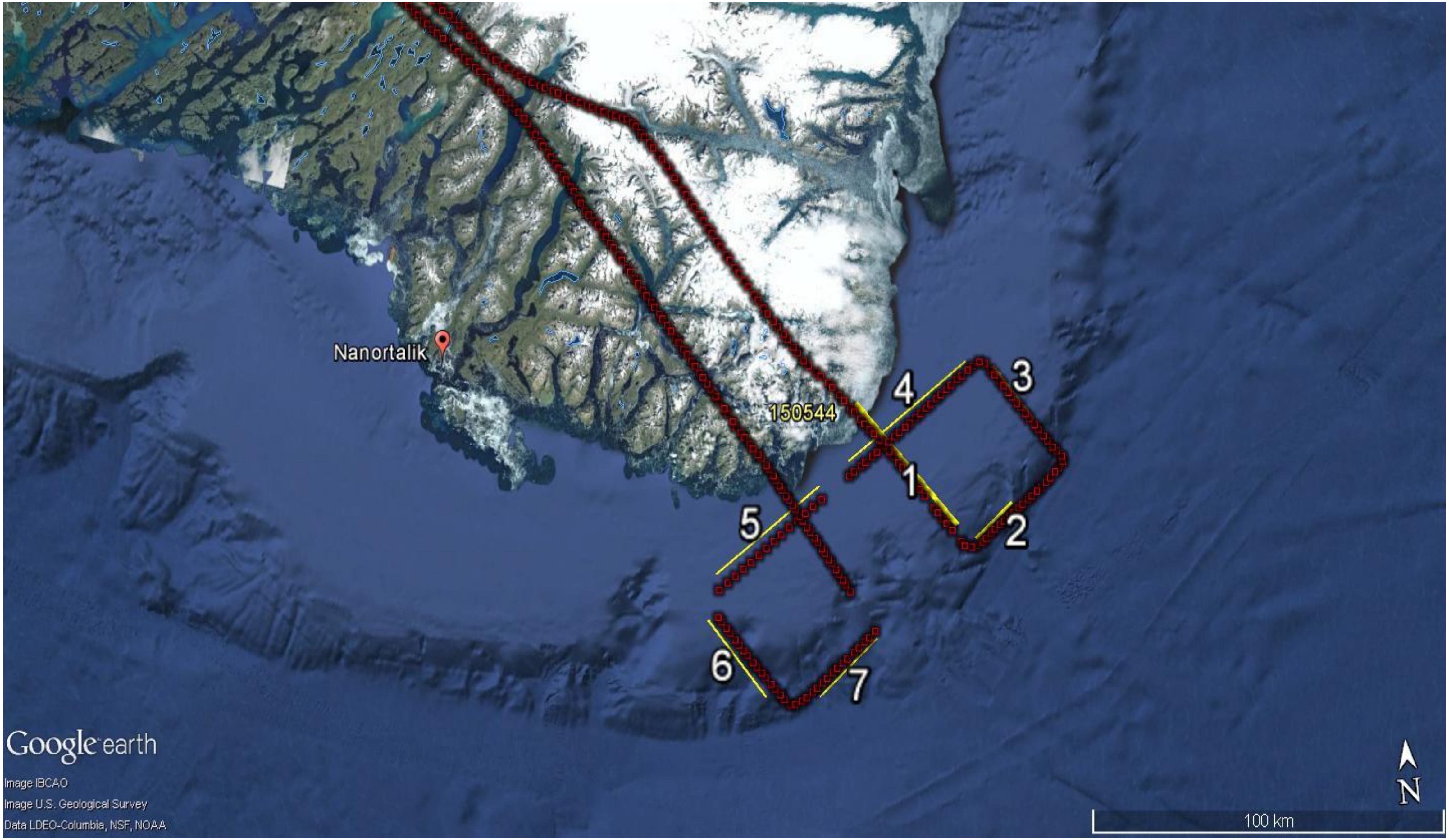


Veering around tip

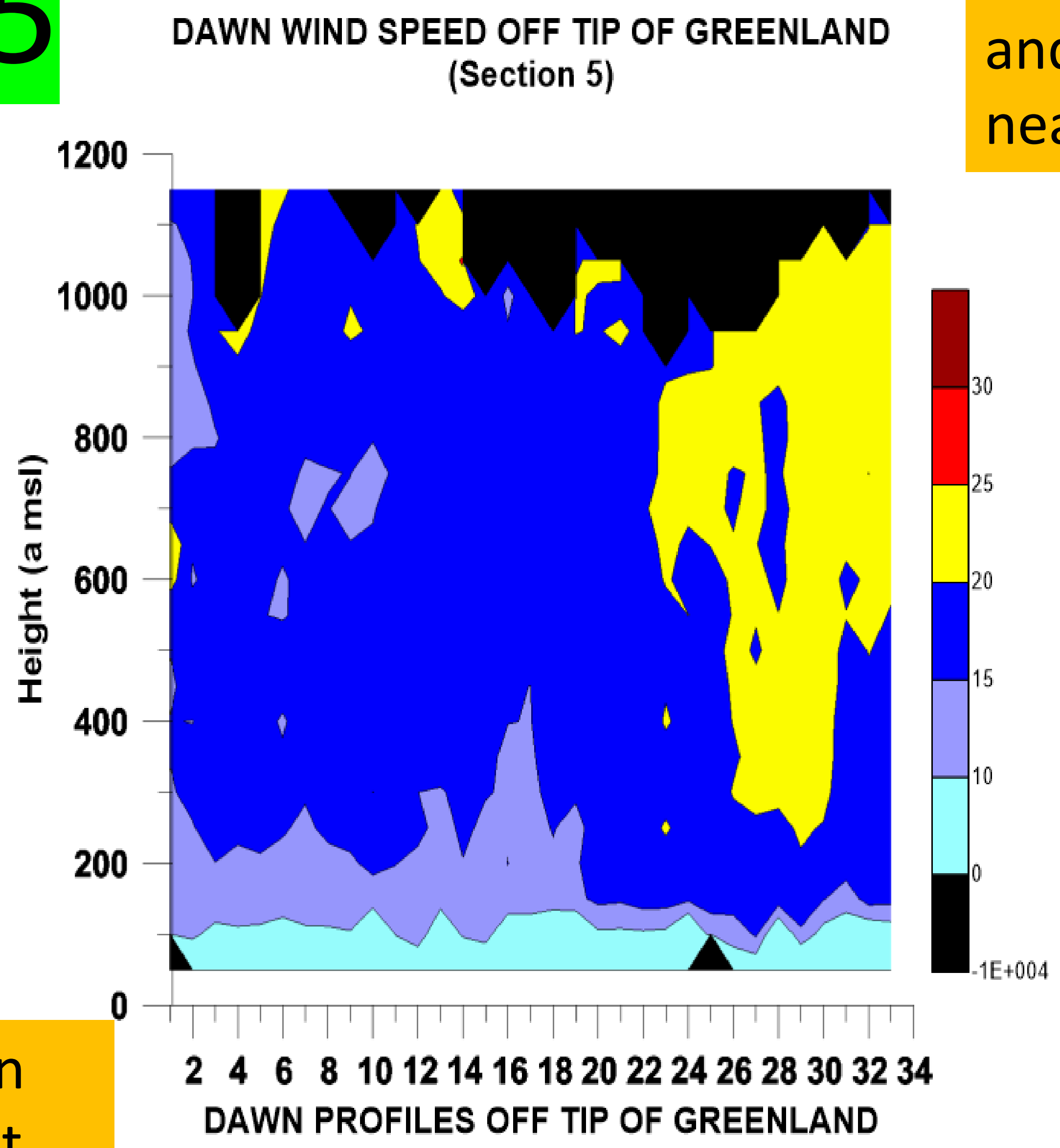
1



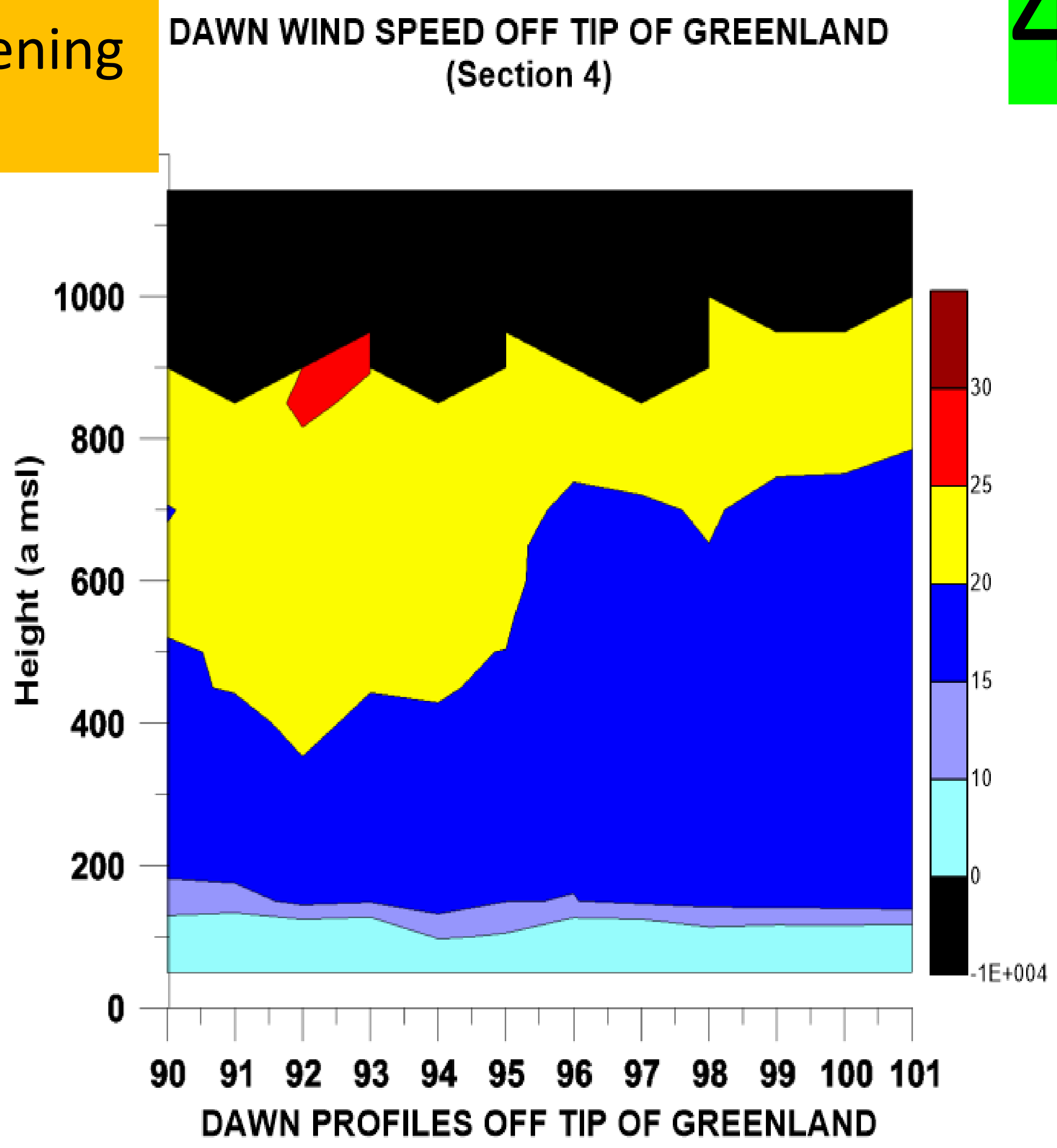
Separation of flow layers


Nanortalik
150544
1
2
3
4
5
6
7
Google earth
Image IBCAO
Image U.S. Geological Survey
Data LDEO-Columbia, NSF, NOAA
N
100 km

5



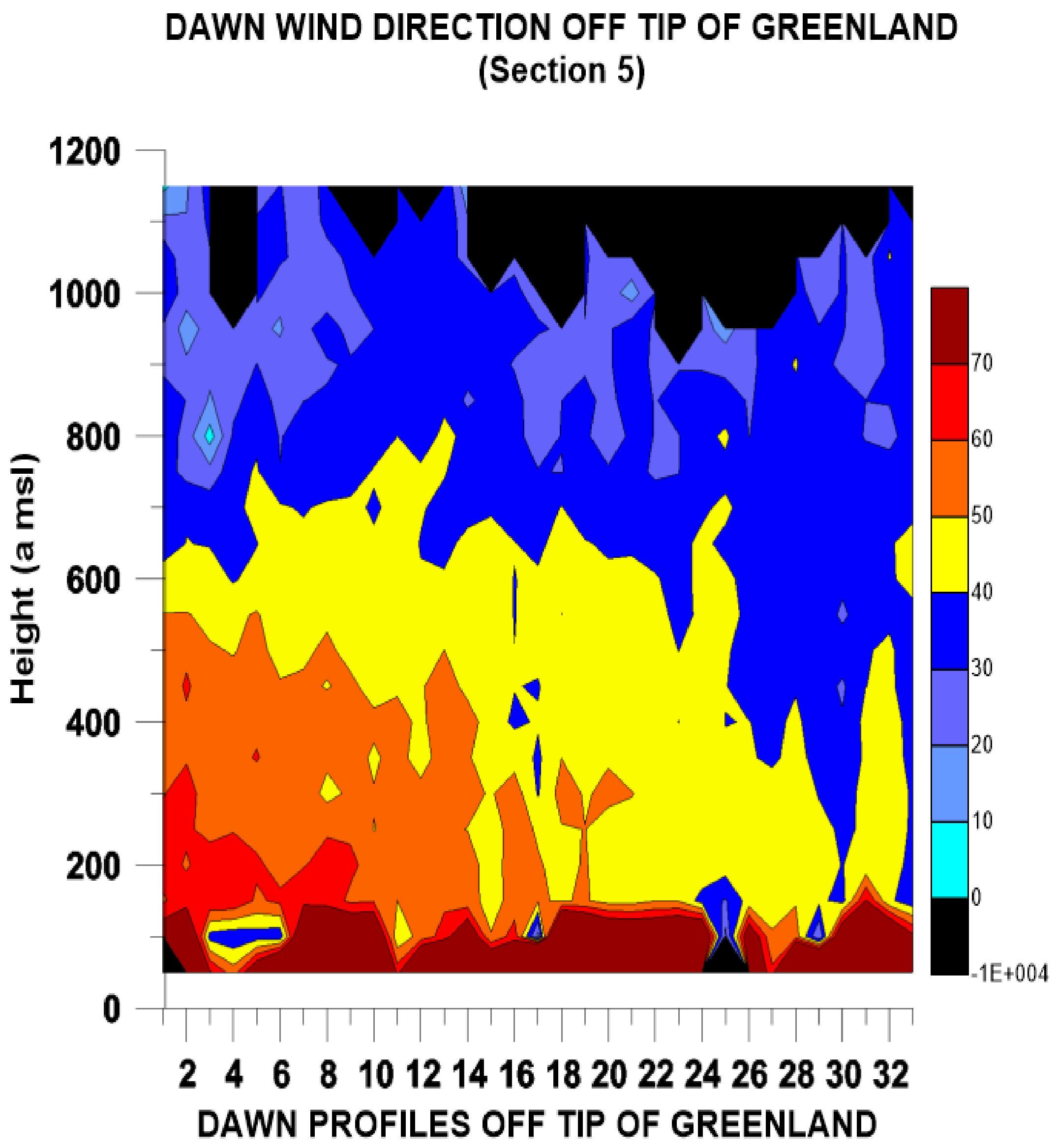
Acceleration and deepening near tip



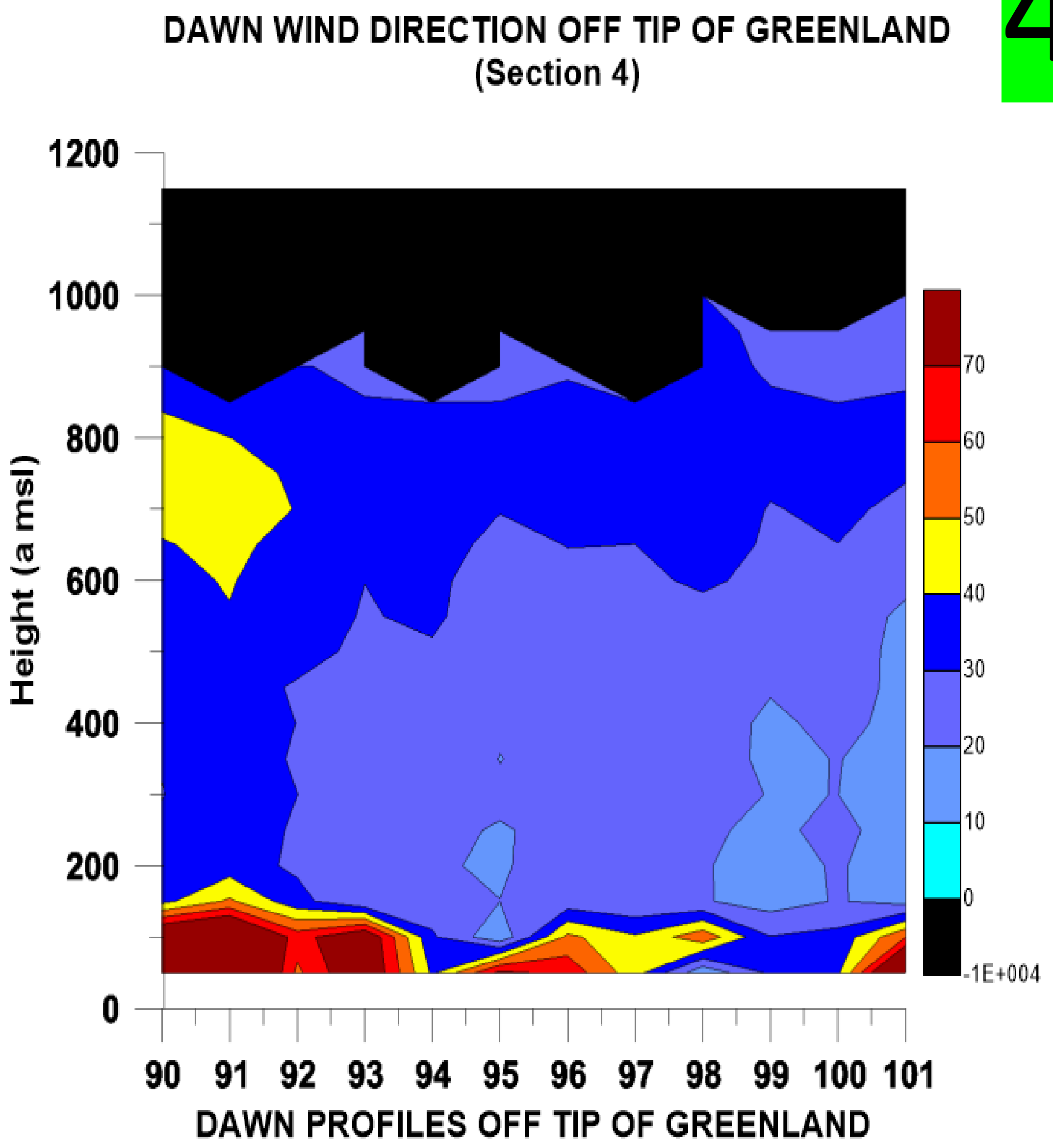
4

ation
west

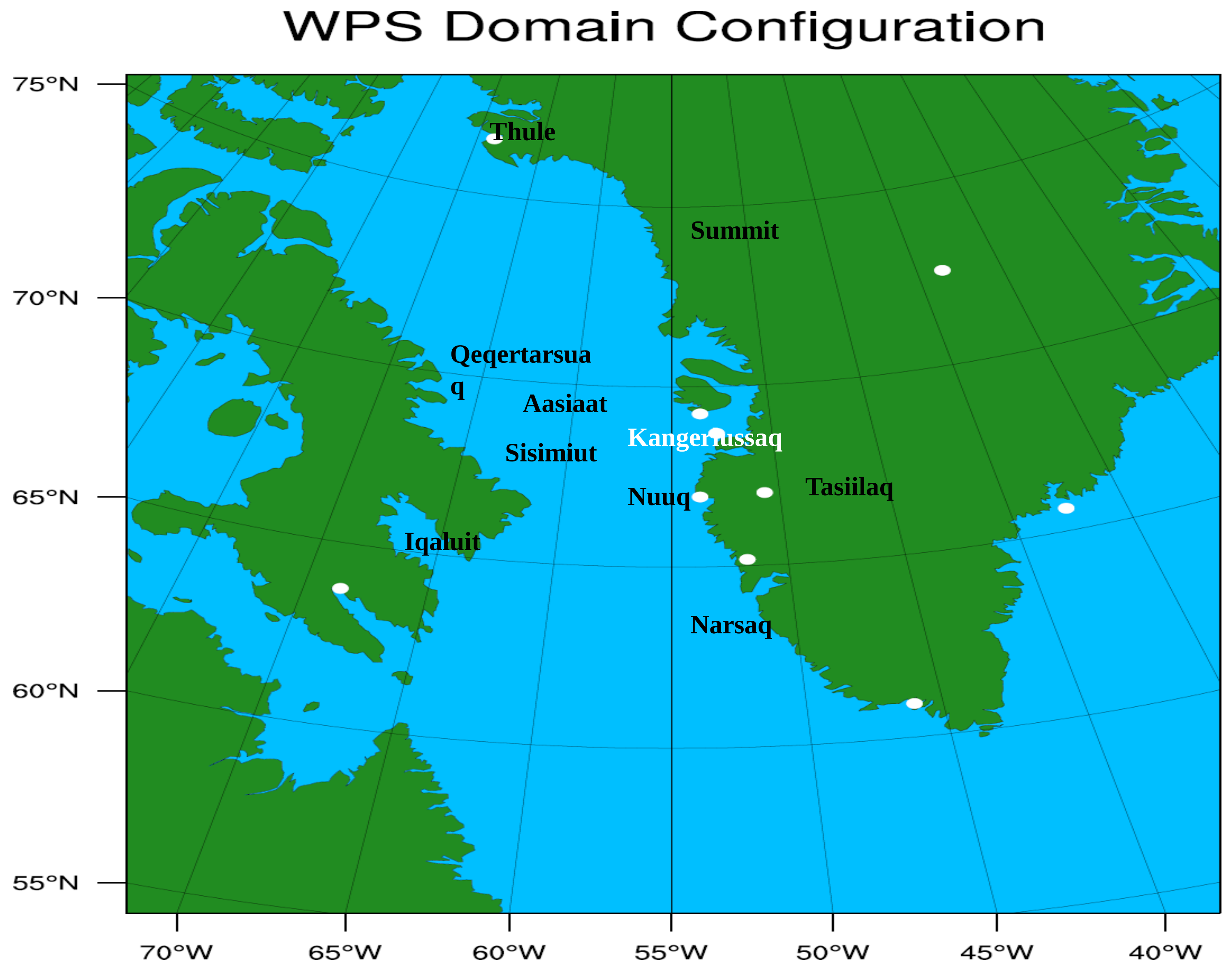
5


DAWN WIND DIRECTION OFF TIP OF GREENLAND
(Section 5)
Height (a msl)
1200
1000
800
600
400
200
0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
DAWN PROFILES OFF TIP OF GREENLAND
70
60
50
40
30
20
10
0
-1E+004

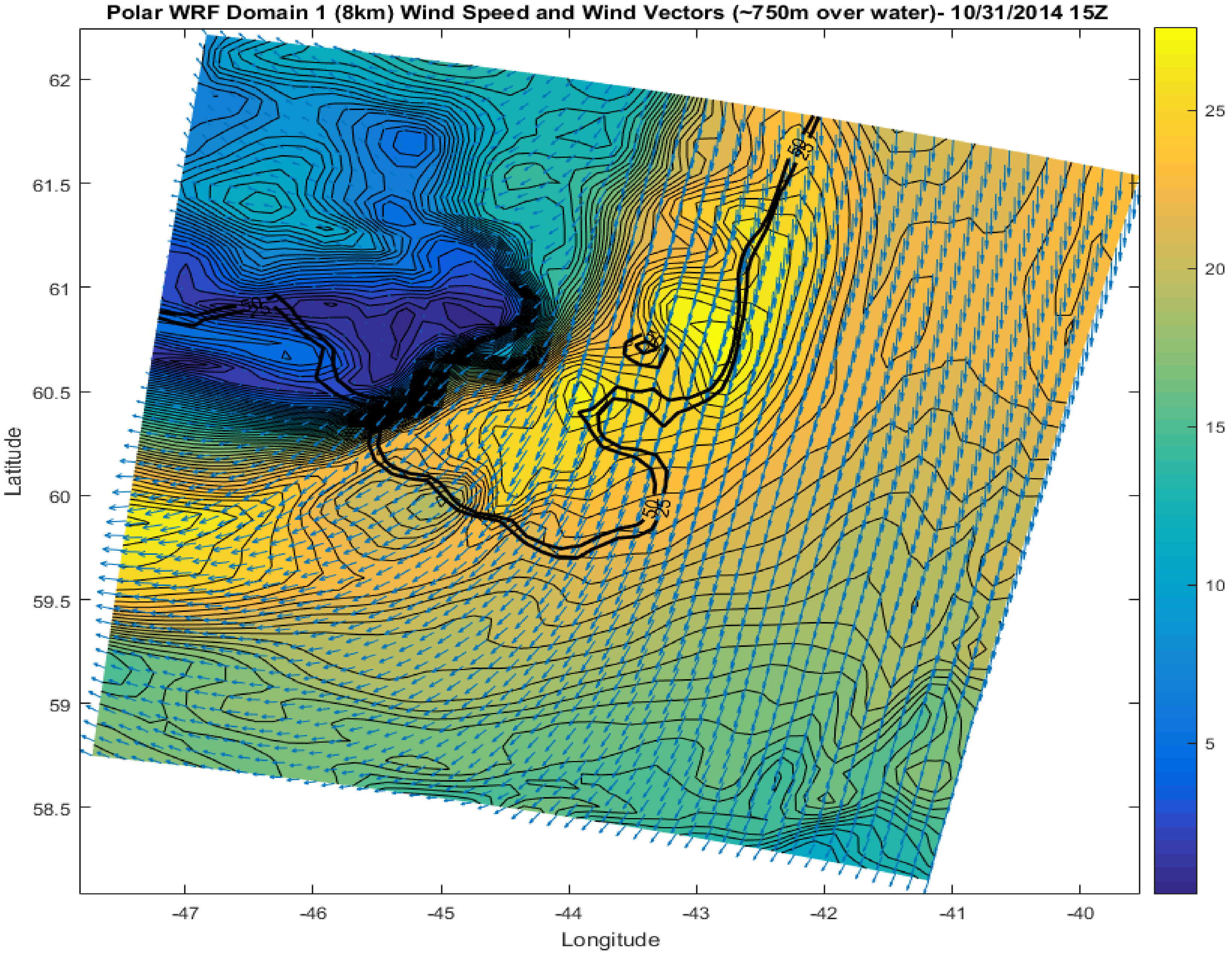
4


DAWN WIND DIRECTION OFF TIP OF GREENLAND
(Section 4)
Height (a msl)
1200
1000
800
600
400
200
0
90 91 92 93 94 95 96 97 98 99 100 101
DAWN PROFILES OFF TIP OF GREENLAND
70
60
50
40
30
20
10
0
-1E+004

Polar WRF

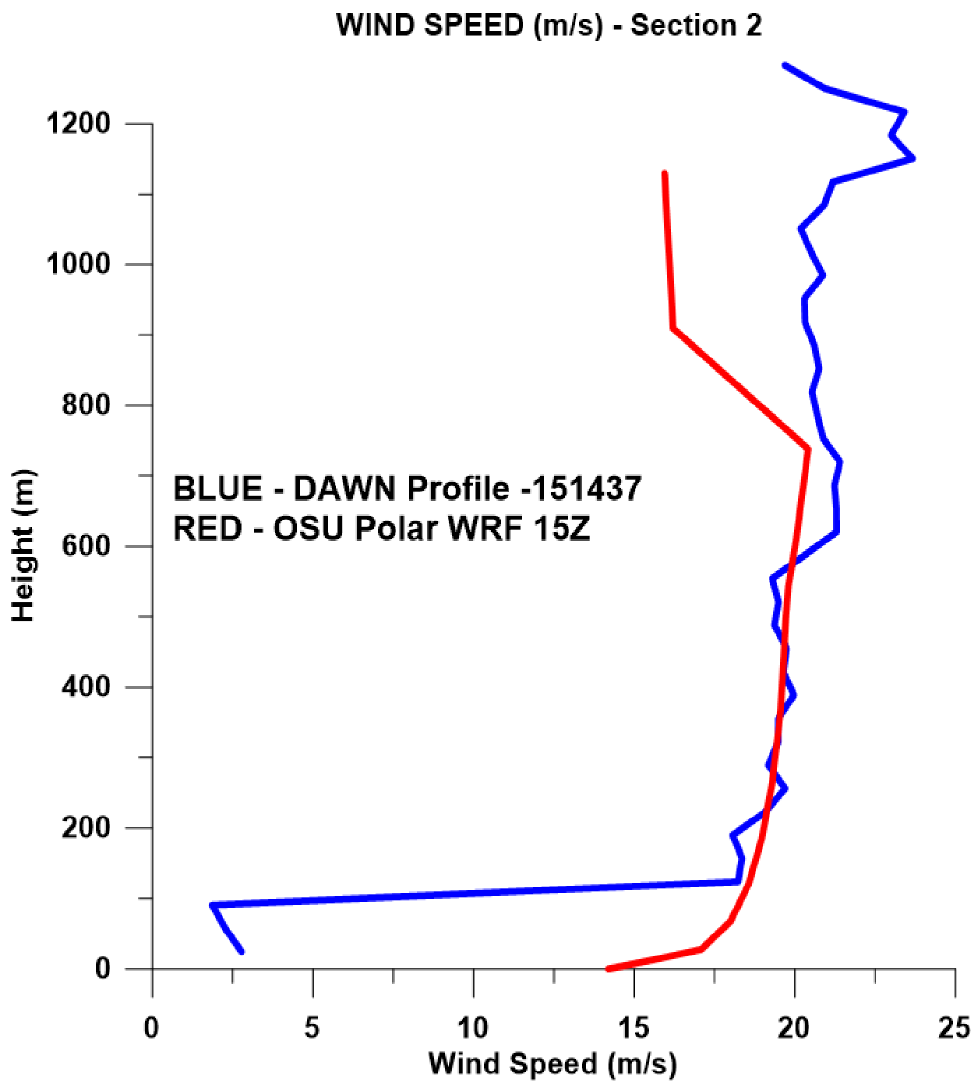


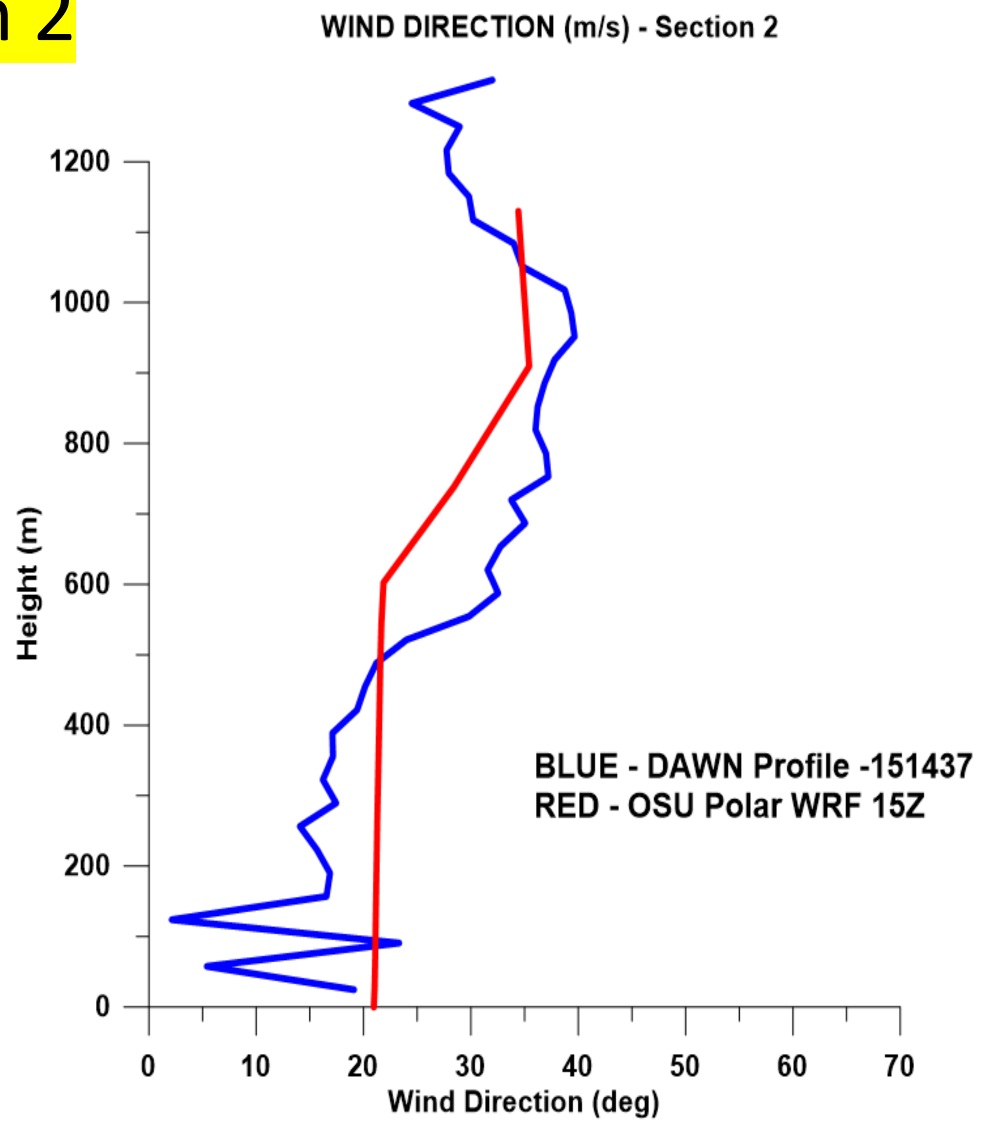
Polar WRF 3.6.1   274 x 324 Points   Δx = 8 km



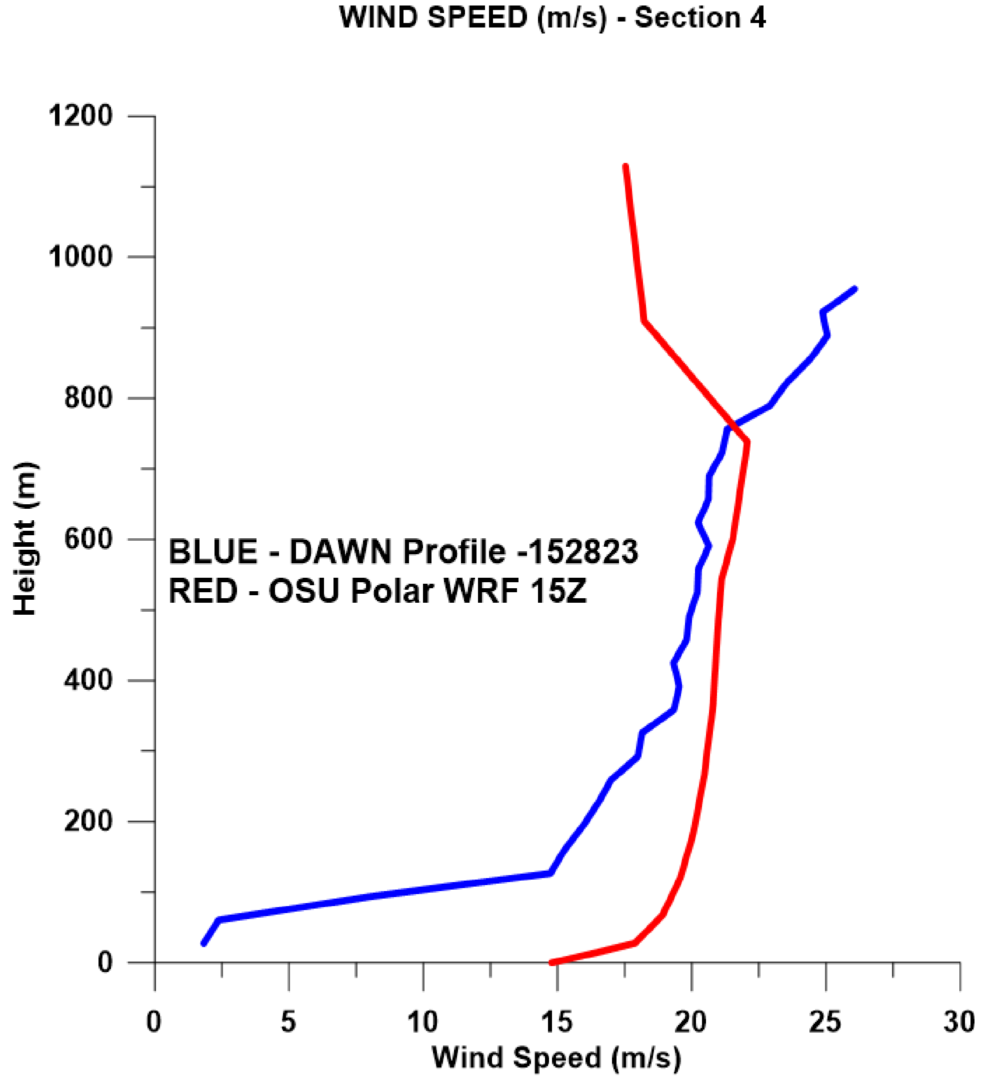
Polar WRF Domain 1 (8km) Wind Speed and Wind Vectors (~750m over water)- 10/31/2014 15Z
Latitude
Longitude
62
61.5
61
60.5
60
59.5
59
58.5
-47
-46
-45
-44
-43
-42
-41
-40
25
20
15
10
5

Section 2

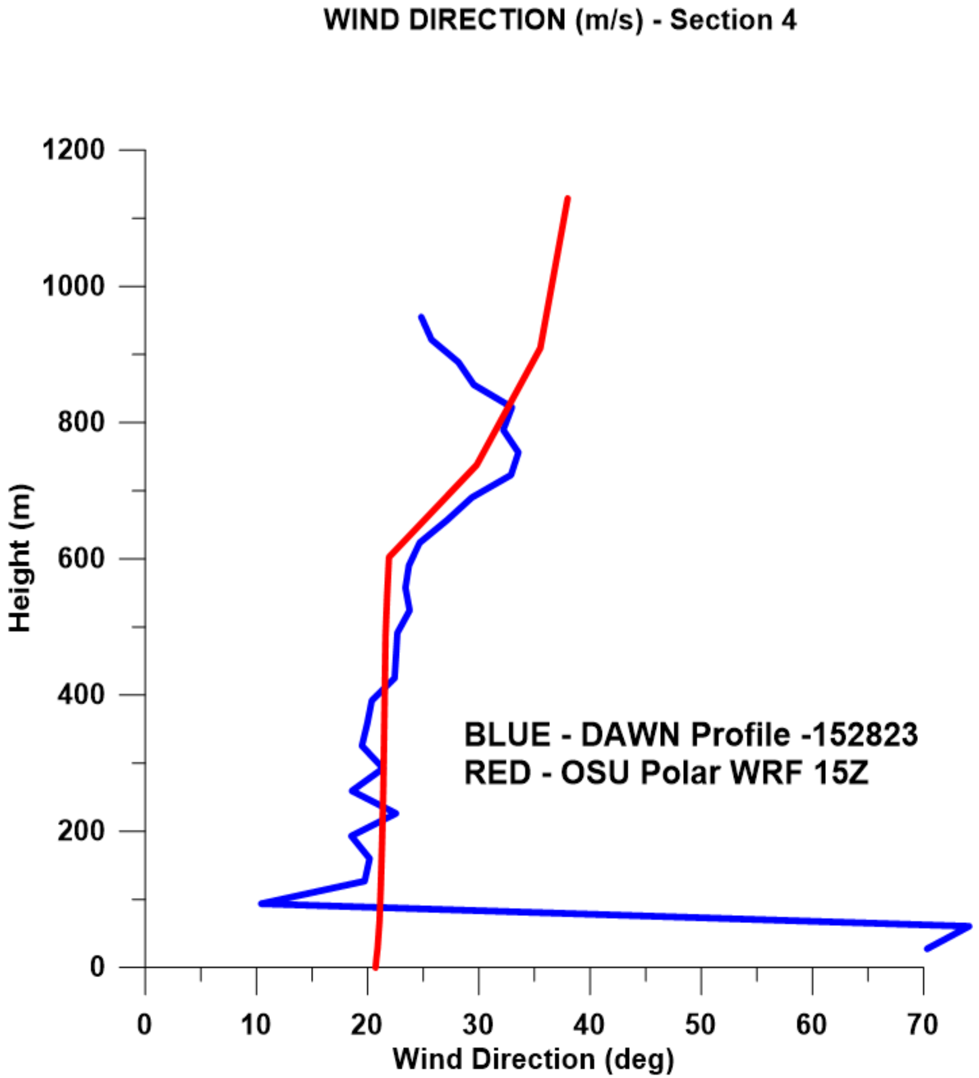

WIND SPEED (m/s) - Section 2
BLUE - DAWN Profile -151437
RED - OSU Polar WRF 15Z
Height (m)
0
200
400
600
800
1000
1200
0
5
10
15
20
25
Wind Speed (m/s)


WIND DIRECTION (m/s) - Section 2
BLUE - DAWN Profile -151437
RED - OSU Polar WRF 15Z
Height (m)
0
200
400
600
800
1000
1200
0
10
20
30
40
50
60
70
Wind Direction (deg)

Section 4

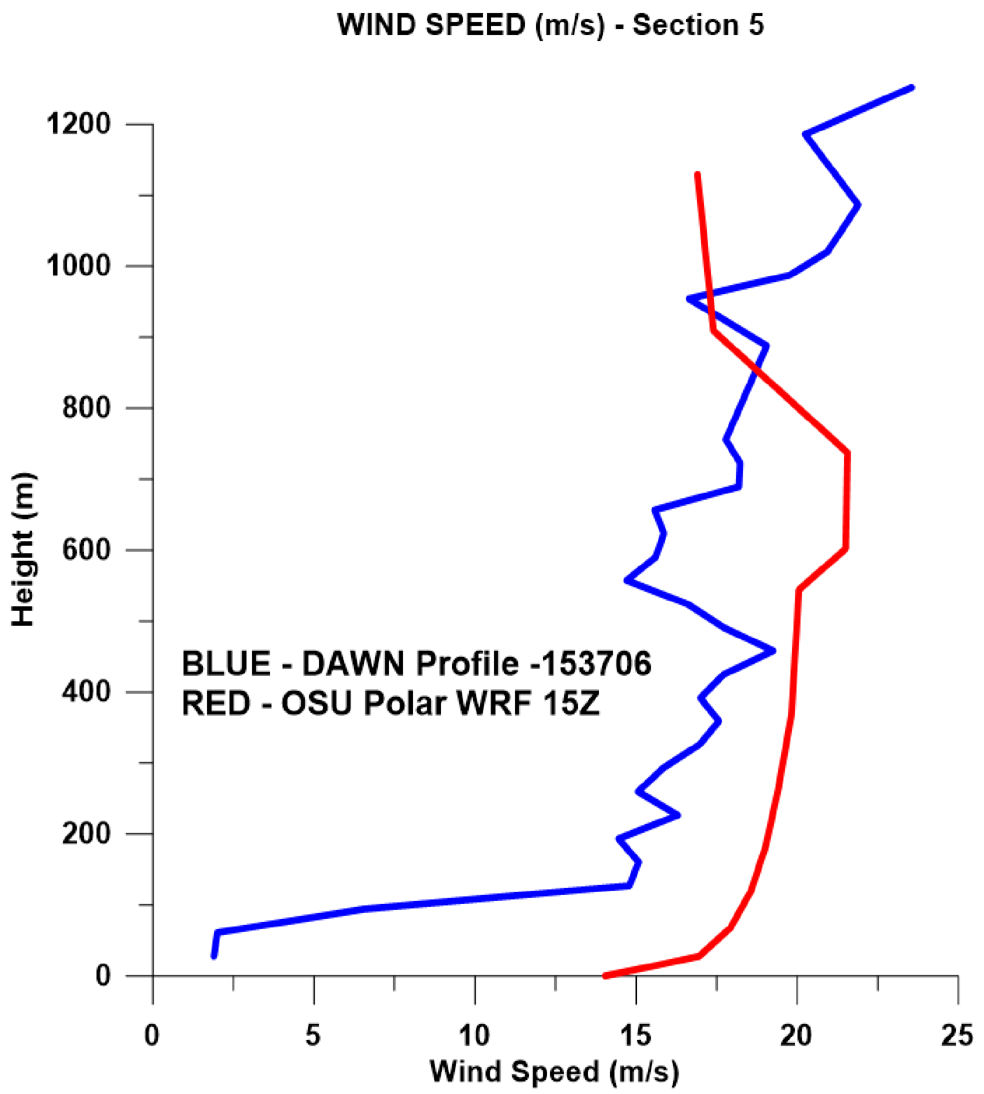


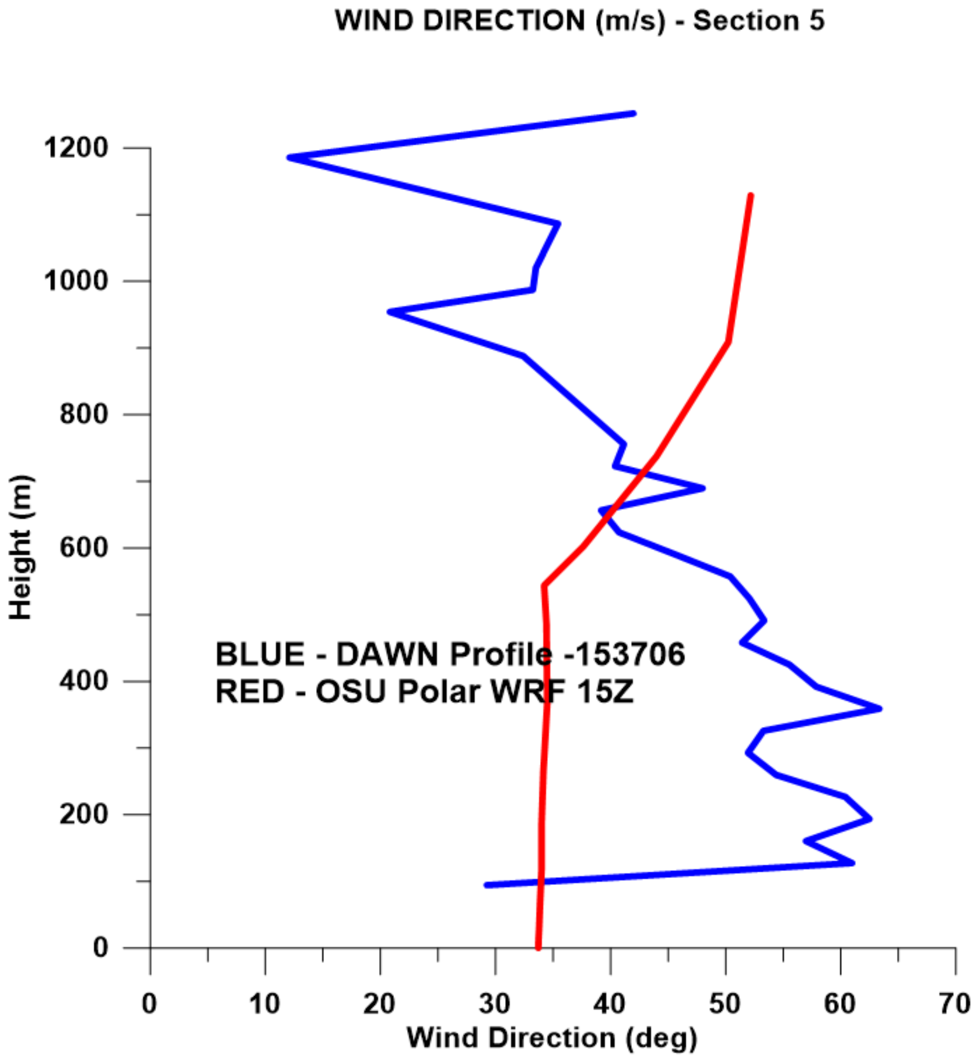
WIND SPEED (m/s) - Section 4
1200
1000
800
600
400
200
0
Height (m)
0
5
10
15
20
25
30
Wind Speed (m/s)
BLUE - DAWN Profile -152823
RED - OSU Polar WRF 15Z



WIND DIRECTION (m/s) - Section 4
1200
1000
800
600
400
200
0
Height (m)
0
10
20
30
40
50
60
70
Wind Direction (deg)
BLUE - DAWN Profile -152823
RED - OSU Polar WRF 15Z

Section 5


WIND SPEED (m/s) - Section 5
Height (m)
Wind Speed (m/s)
0
200
400
600
800
1000
1200
0
5
10
15
20
25
BLUE - DAWN Profile -153706
RED - OSU Polar WRF 15Z

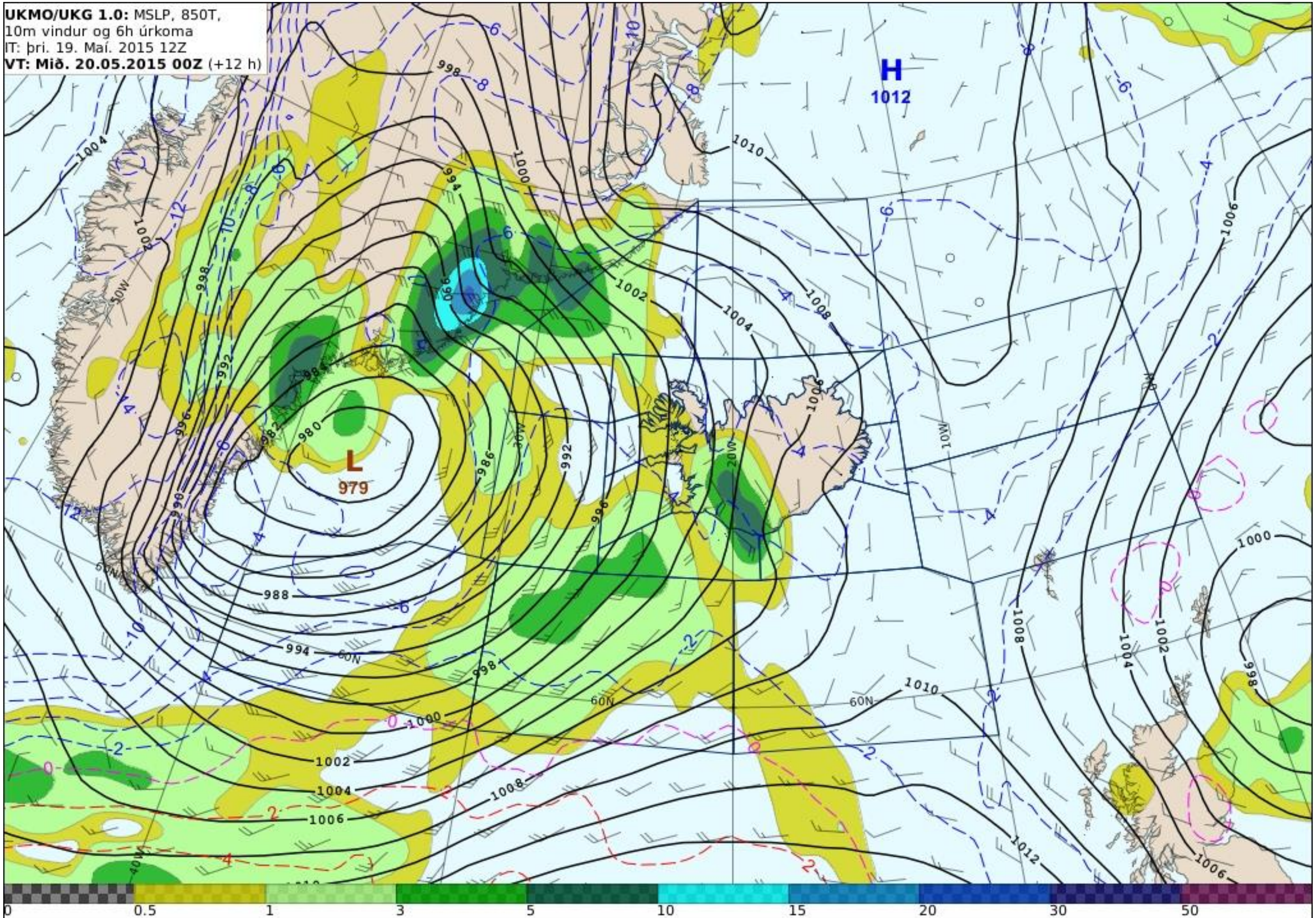

WIND DIRECTION (m/s) - Section 5
Height (m)
Wind Direction (deg)
0
200
400
600
800
1000
1200
0
10
20
30
40
50
60
70
BLUE - DAWN Profile -153706
RED - OSU Polar WRF 15Z

Tip Jet Summary

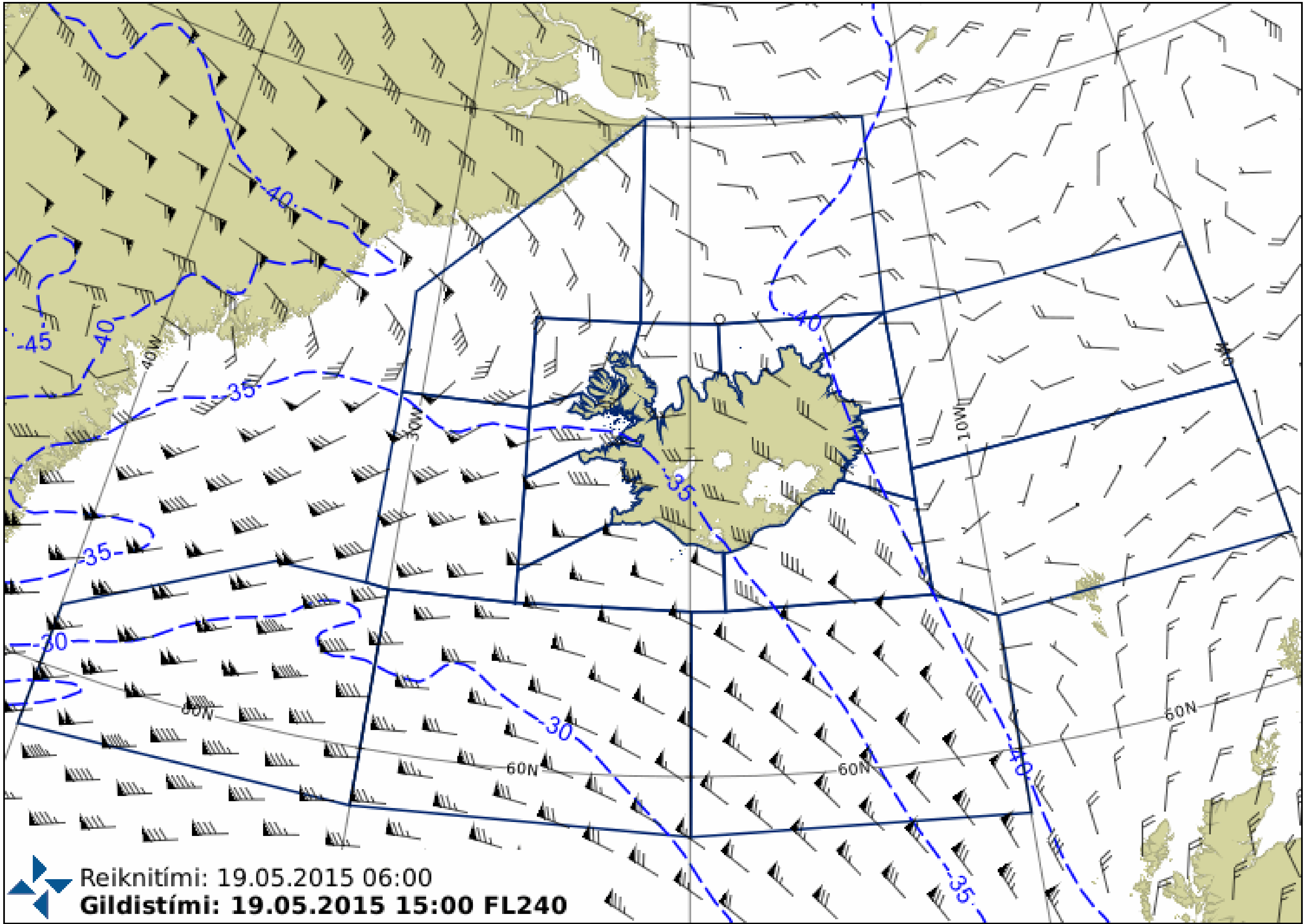
- OSU WRF does decent job in forecasting the wind speeds near the tip
- BL scheme chosen for PolarWRF results in very smooth and unchanging winds over significant layers and does not capture the variability in the DAWN profiles
- WRF does not seem to capture the veering of the wind “around” the tip
- Unfortunate that DAWN was unable to produce measurements above 1200-1300m

May 19, 2015– Upper Jet Study
Co-Flight with DLR Falcon
Intercomparison of DAWN and Dropsondes

SURFACE


UKMO/UKG 1.0: MSLP, 850T,
10m vindur og 6h úrkoma
IT: þri. 19. Maí. 2015 12Z
VT: Mið. 20.05.2015 00Z (+12 h)
H
1012
L
979
0
0.5
1
3
5
10
15
20
30
50

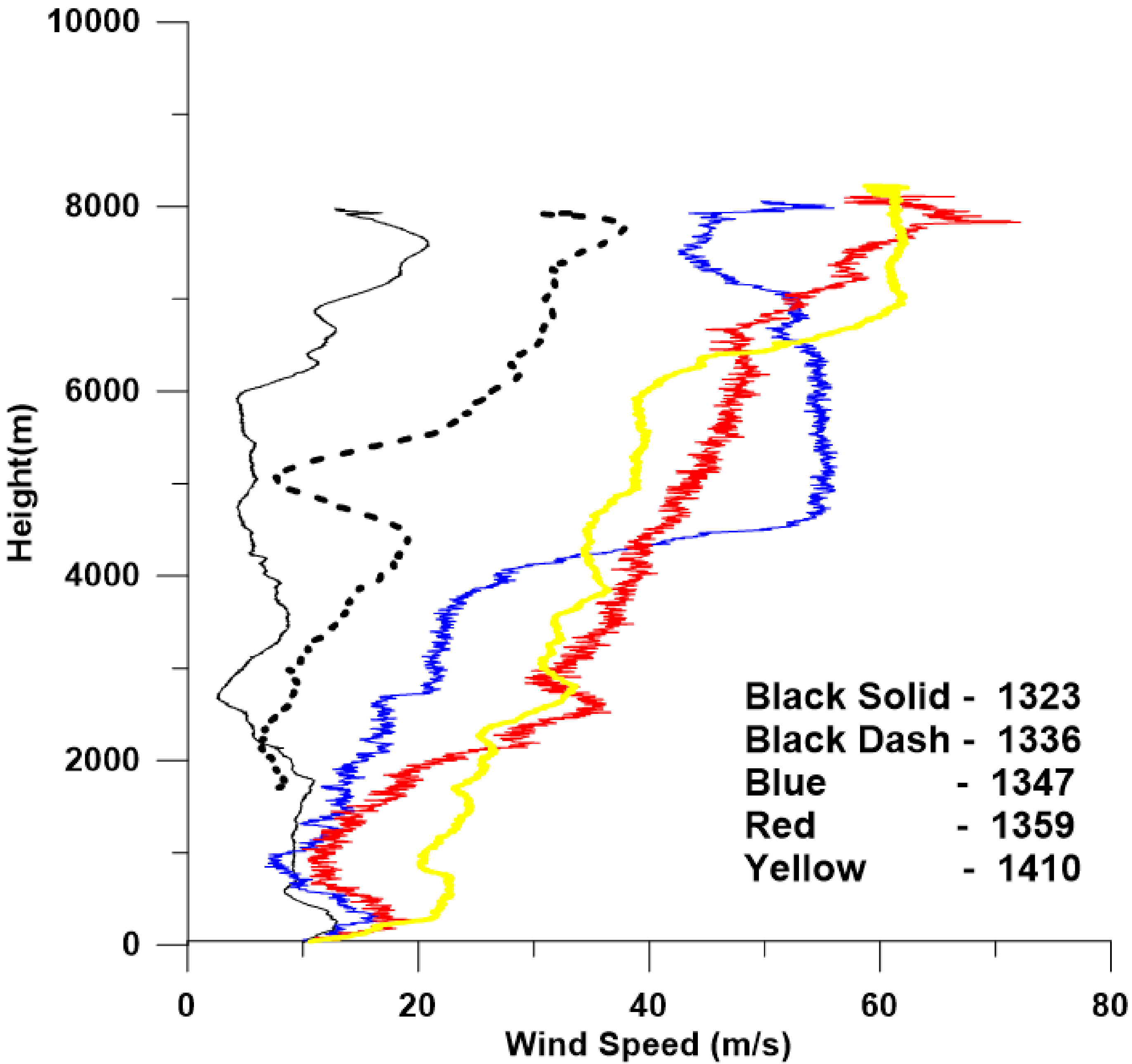
~ 8 km



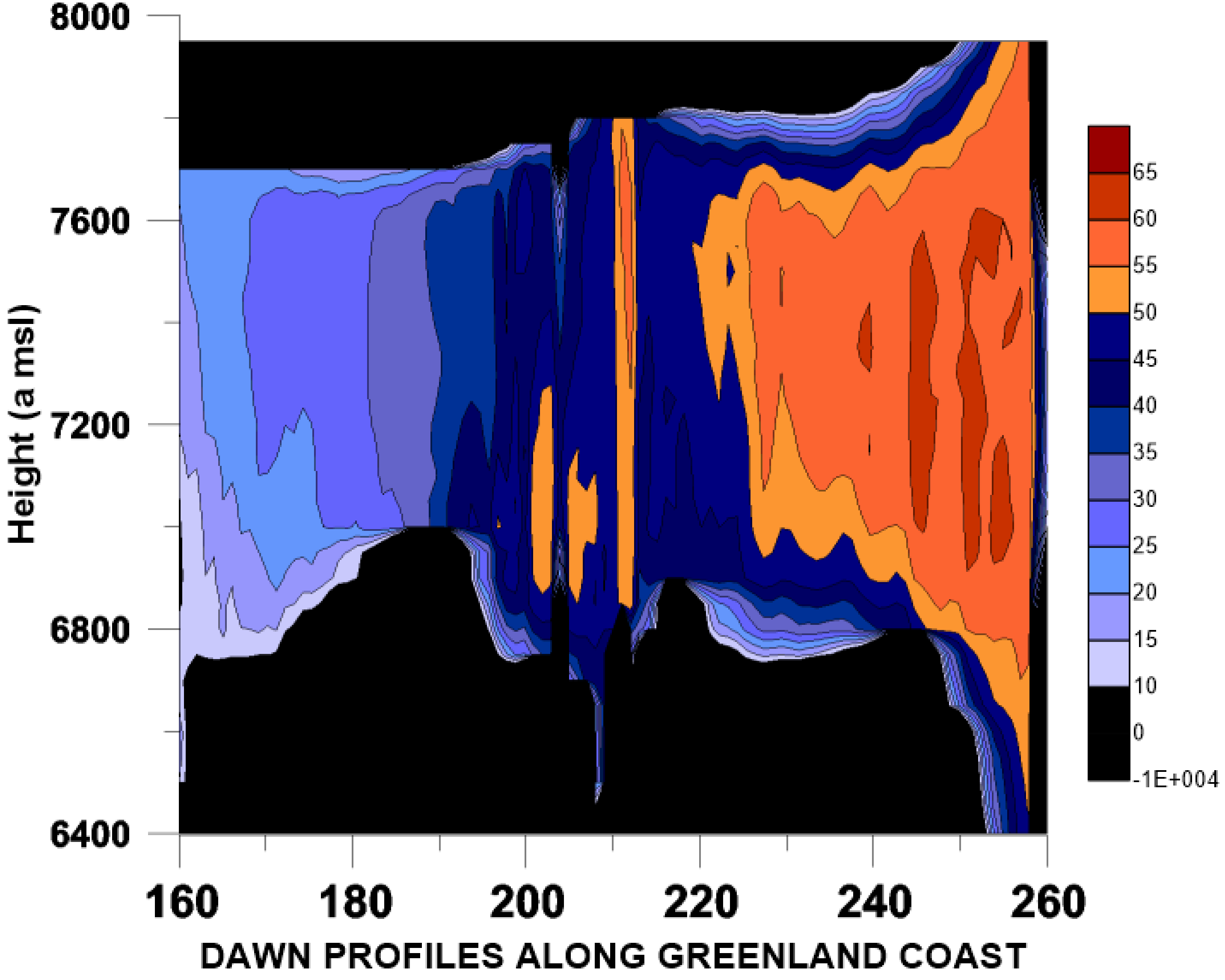
-45
-40
-35
-30
40W
30W
10W
60N
Reiknitími: 19.05.2015 06:00
Gildistími: 19.05.2015 15:00 FL240

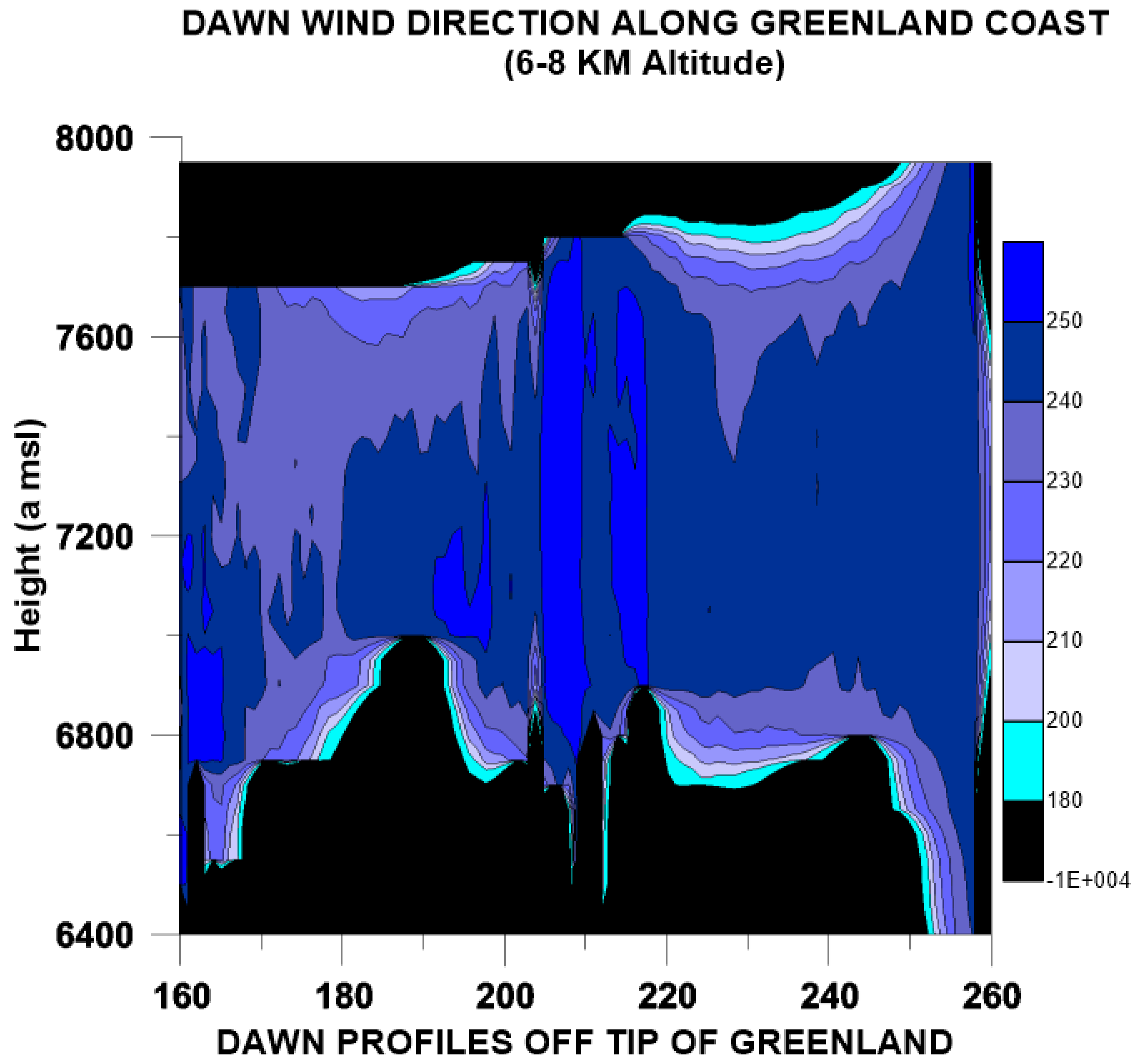
132354
170
133600
aamiut
Ikermiit
190
210
Narasrsauq
155801
135923
Nanortalik
230
250
141048
152209
Keflavik
Þri 19 Mai 14:54
-60
-55
-50
Google earth
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Image IBCAO
Image U.S. Geological Survey
N
300 km

May 19, 2015 Dropsondes

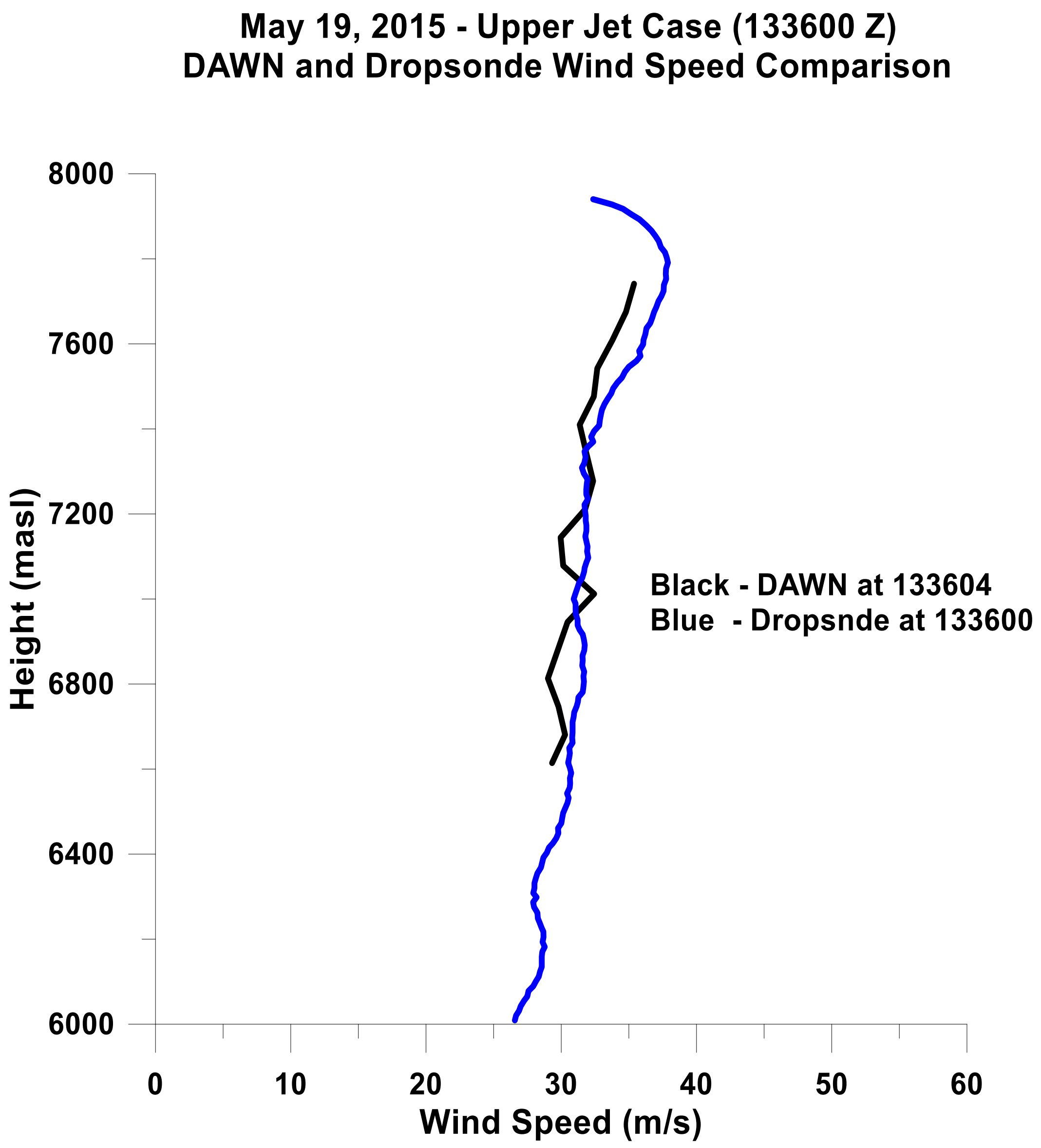


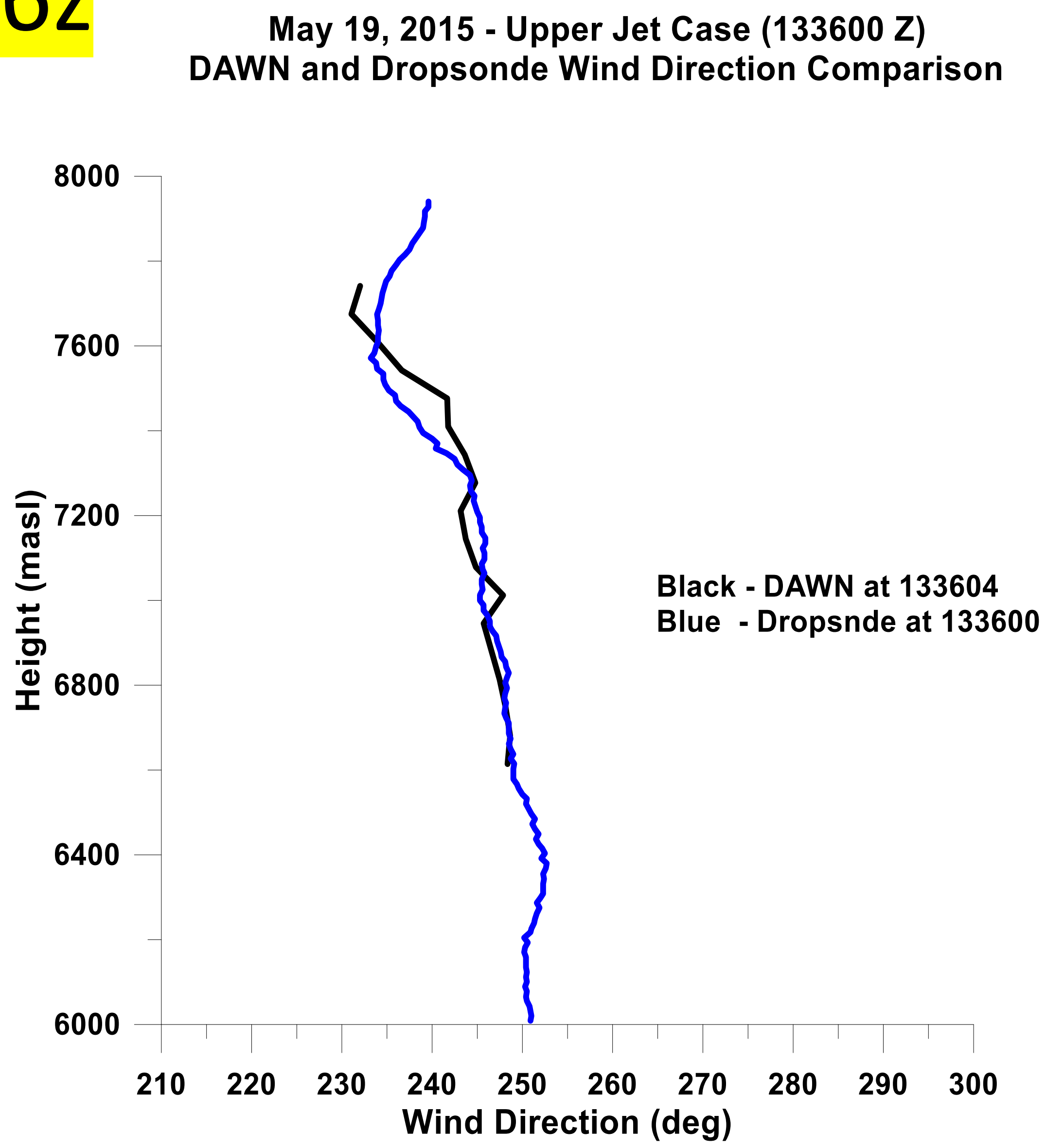
DAWN WIND SPEED ALONG GREENLAND COAST
(6-8 KM Altitude)



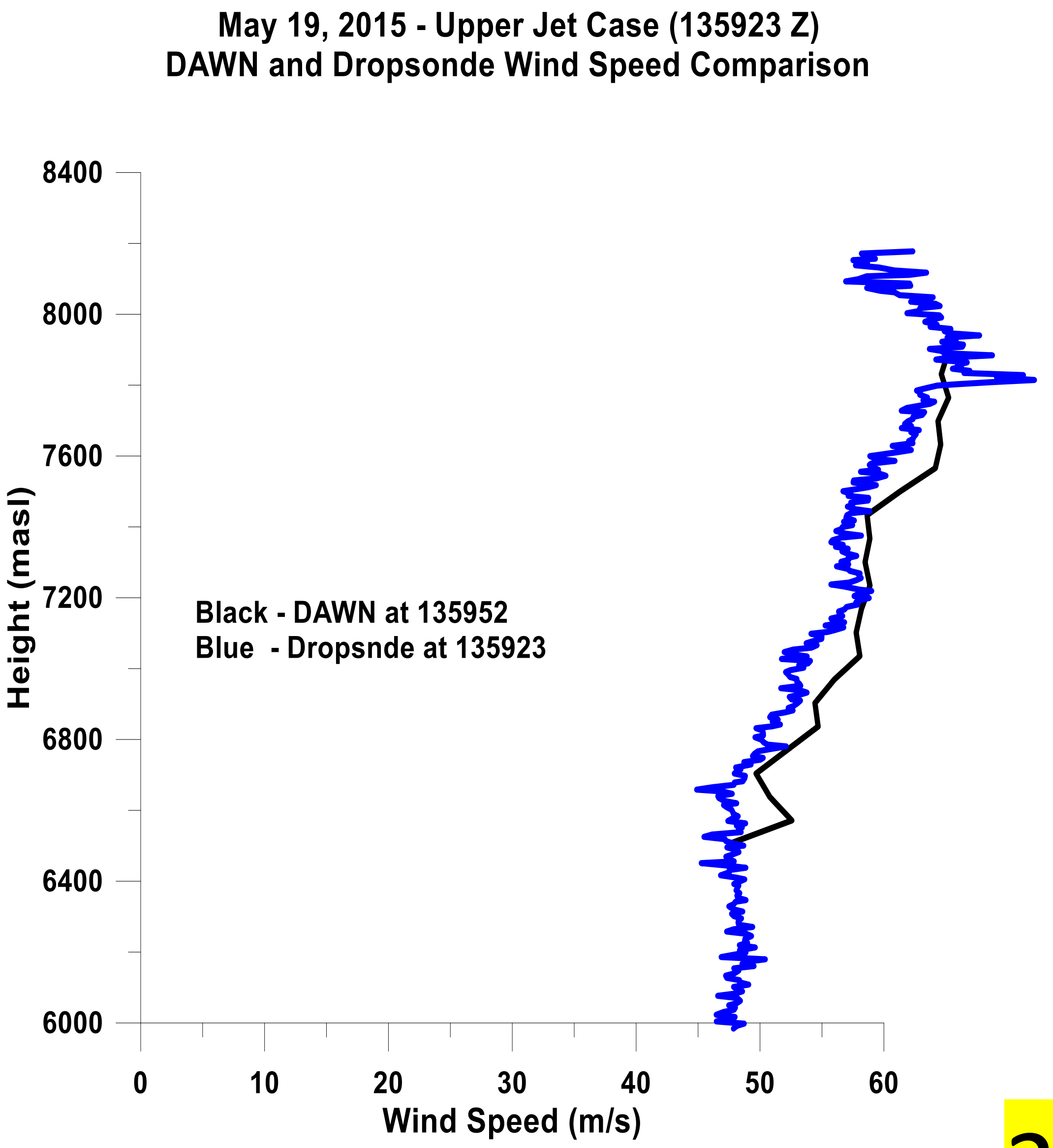

DAWN WIND DIRECTION ALONG GREENLAND COAST
(6-8 KM Altitude)
Height (a msl)
8000
7600
7200
6800
6400
160
180
200
220
240
260
DAWN PROFILES OFF TIP OF GREENLAND
250
240
230
220
210
200
180
-1E+004

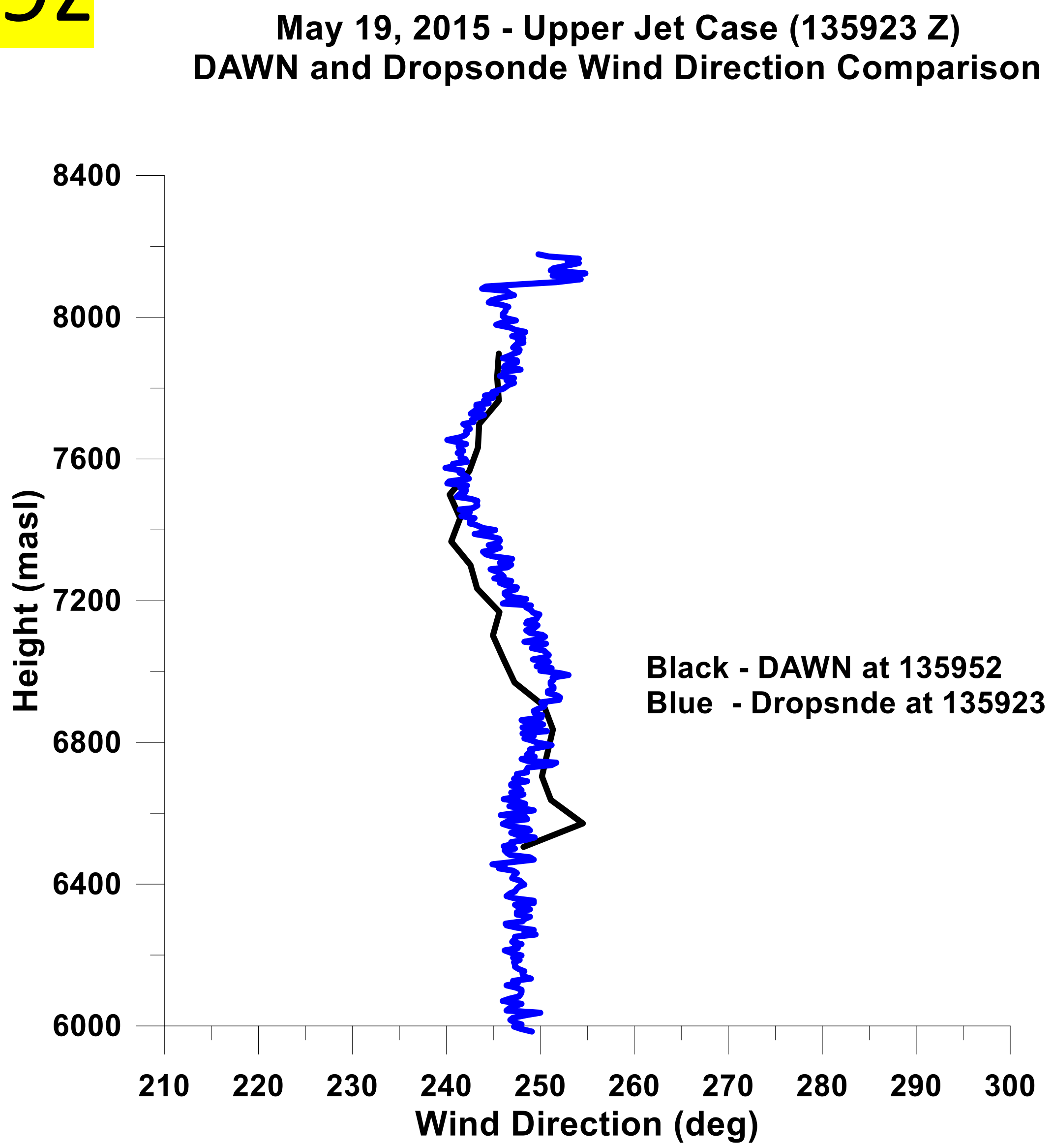
1336z


May 19, 2015 - Upper Jet Case (133600 Z)
DAWN and Dropsonde Wind Speed Comparison
8000
7600
7200
6800
6400
6000
Height (masl)
0
10
20
30
40
50
60
Wind Speed (m/s)
Black - DAWN at 133604
Blue - Dropsnde at 133600

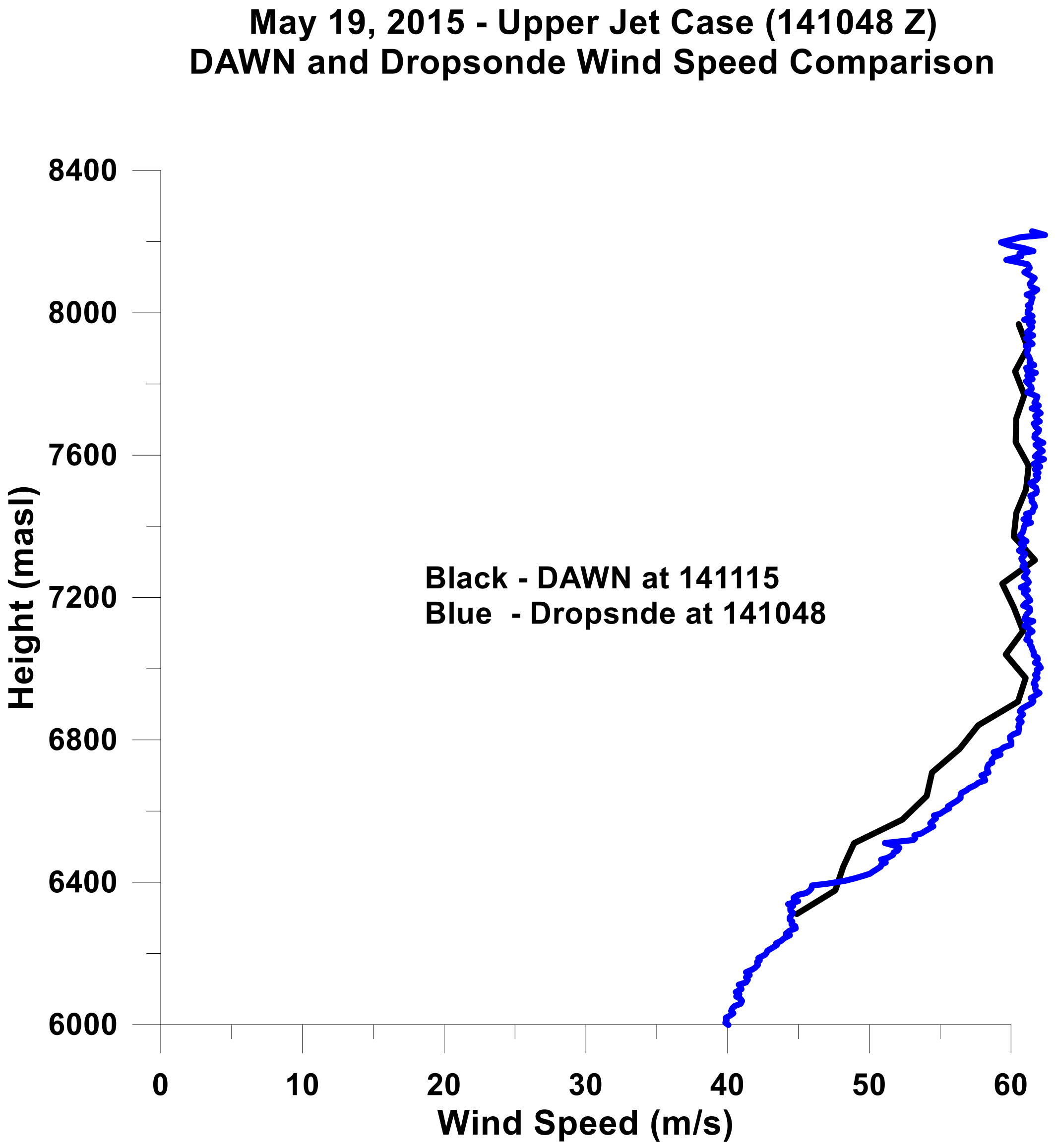

May 19, 2015 - Upper Jet Case (133600 Z)
DAWN and Dropsonde Wind Direction Comparison
8000
7600
7200
6800
6400
6000
Height (masl)
210
220
230
240
250
260
270
280
290
300
Wind Direction (deg)
Black - DAWN at 133604
Blue - Dropsnde at 133600

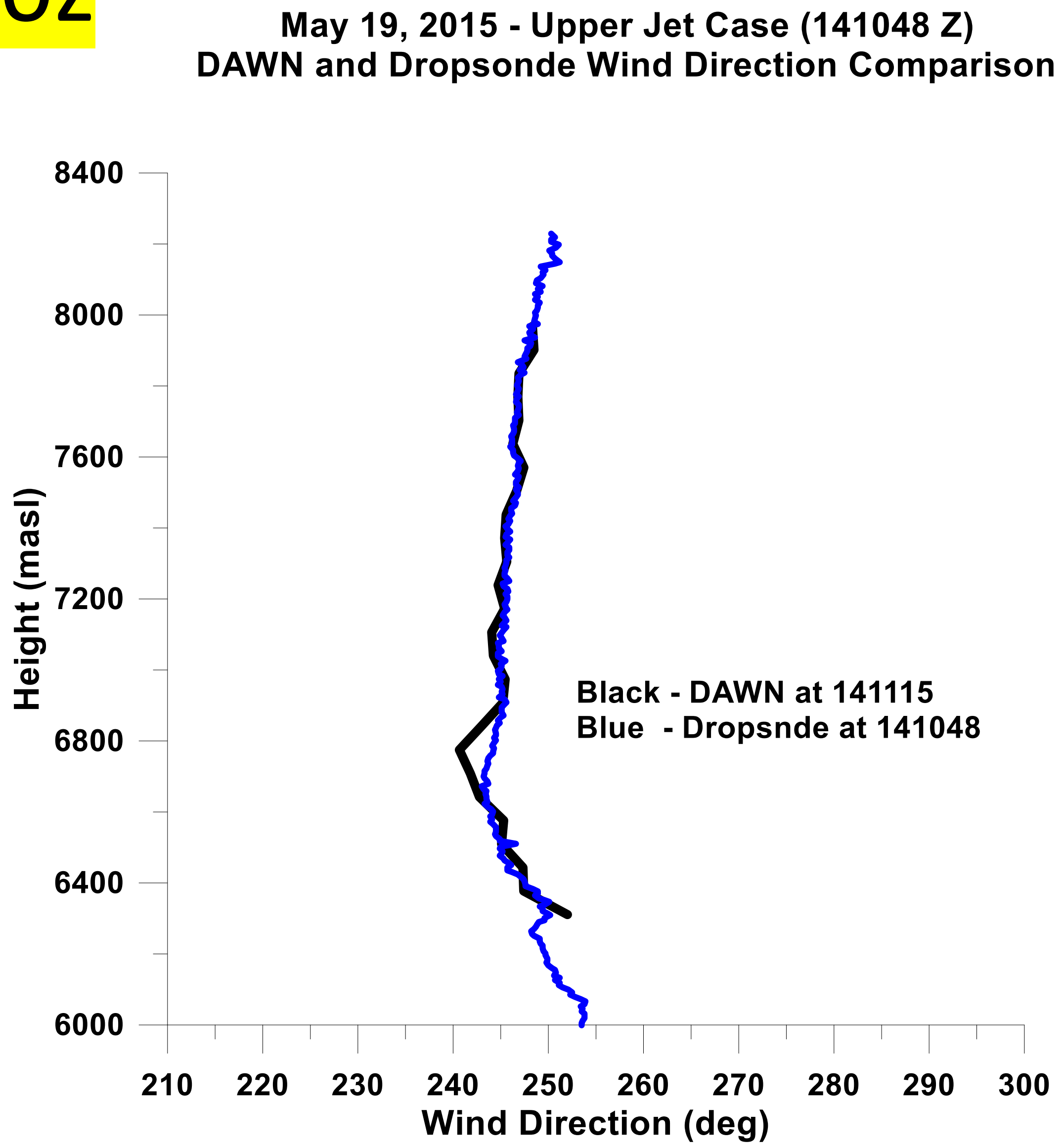
1359z


May 19, 2015 - Upper Jet Case (135923 Z)
DAWN and Dropsonde Wind Speed Comparison
Height (masl)
8400
8000
7600
7200
6800
6400
6000
Black - DAWN at 135952
Blue - Dropsnde at 135923
0
10
20
30
40
50
60
Wind Speed (m/s)


May 19, 2015 - Upper Jet Case (135923 Z)
DAWN and Dropsonde Wind Direction Comparison
Height (masl)
8400
8000
7600
7200
6800
6400
6000
Black - DAWN at 135952
Blue - Dropsnde at 135923
210
220
230
240
250
260
270
280
290
300
Wind Direction (deg)

1410z


May 19, 2015 - Upper Jet Case (141048 Z)
DAWN and Dropsonde Wind Speed Comparison
Height (masl)
8400
8000
7600
7200
6800
6400
6000
0
10
20
30
40
50
60
Wind Speed (m/s)
Black - DAWN at 141115
Blue - Dropsnde at 141048


May 19, 2015 - Upper Jet Case (141048 Z)
DAWN and Dropsonde Wind Direction Comparison
Height (masl)
8400
8000
7600
7200
6800
6400
6000
210
220
230
240
250
260
270
280
290
300
Wind Direction (deg)
Black - DAWN at 141115
Blue - Dropsnde at 141048

250

Current and Future Work

- Complete model validation for current and futures cases
- Complete DAWN-Dropsonde comparisons
- Processing and archival of all data
- Scientific investigations of:
    - Katabatic flows
    - OLEs
    - Low-level flow over Marginal Ice Zone