Joint Analysis of Cloud and Wind Structure from APR-2 and Nearby DAWN Wind Profiles During CPEX

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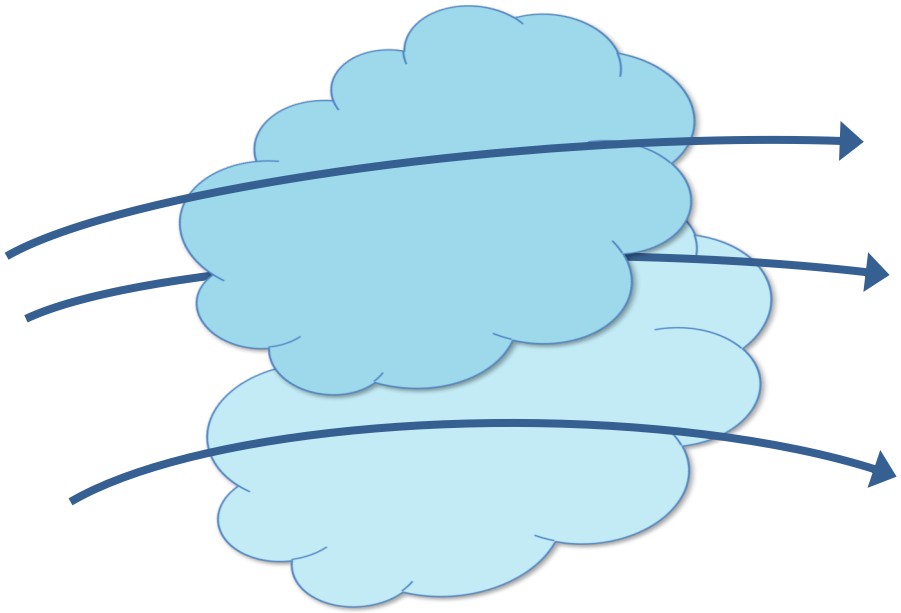
Air Motion Near and in Convective Clouds

These are two quantities that are so closely intertwined but rarely, if ever, measured in close proximity

In general, forecast models have limited information on 3-D air motion (close to areas where clouds form) at model state update cycles

NASA's Convective Processes Experiment (CPEX) in May-June 2017, (based out of Ft Lauderdale), 100 DC-8 flight hours

Capture developing oceanic convection with JPL Ku/Ka-band APR-2 radar, and nearby "clear air" to capture 3-D wind structure from a Doppler wind lidar (DAWN)



ARMSTRONG FLIGHT RESEARCH CENTER

TEST
UNIVERSAL
DIM
30.3 NM
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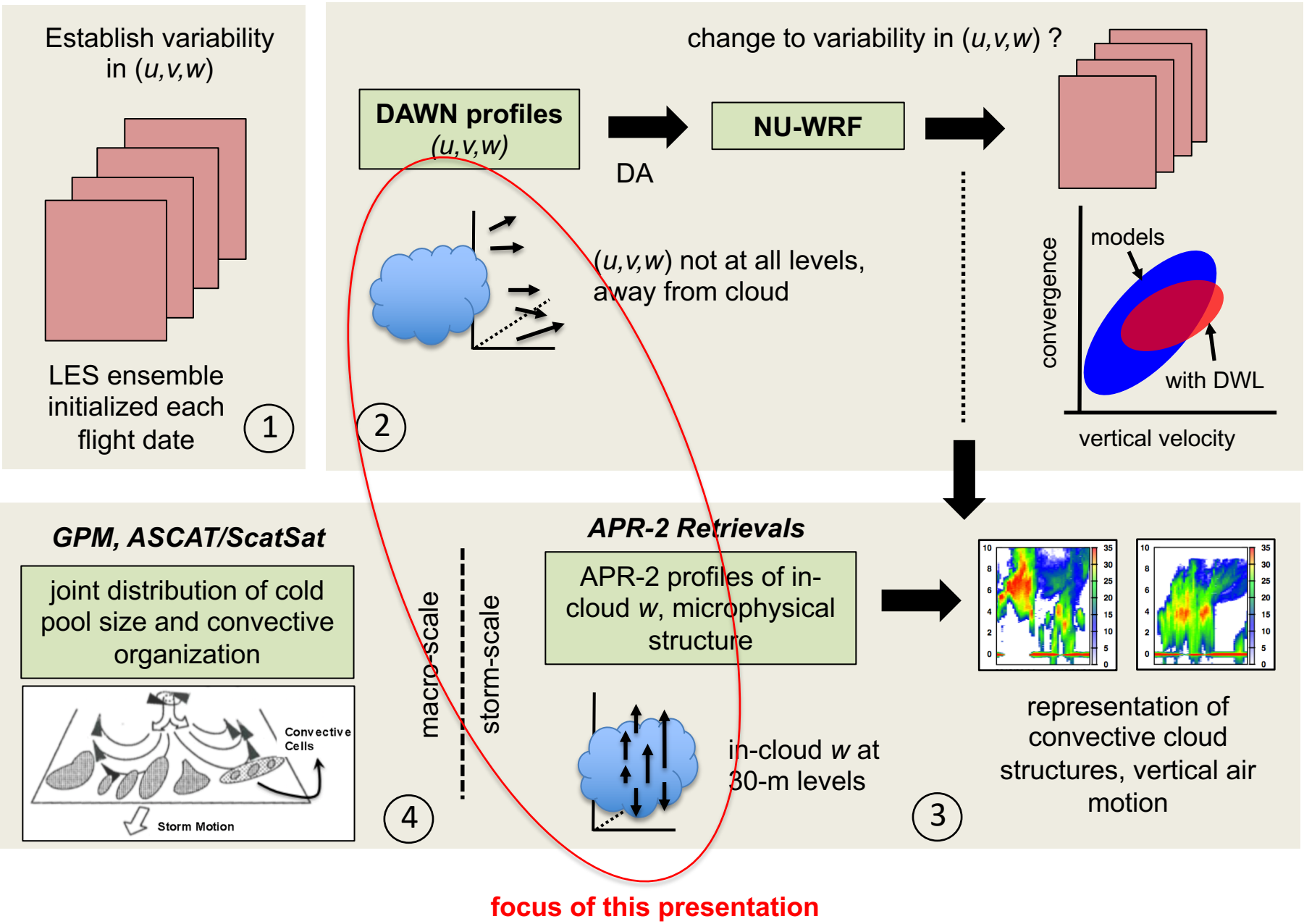
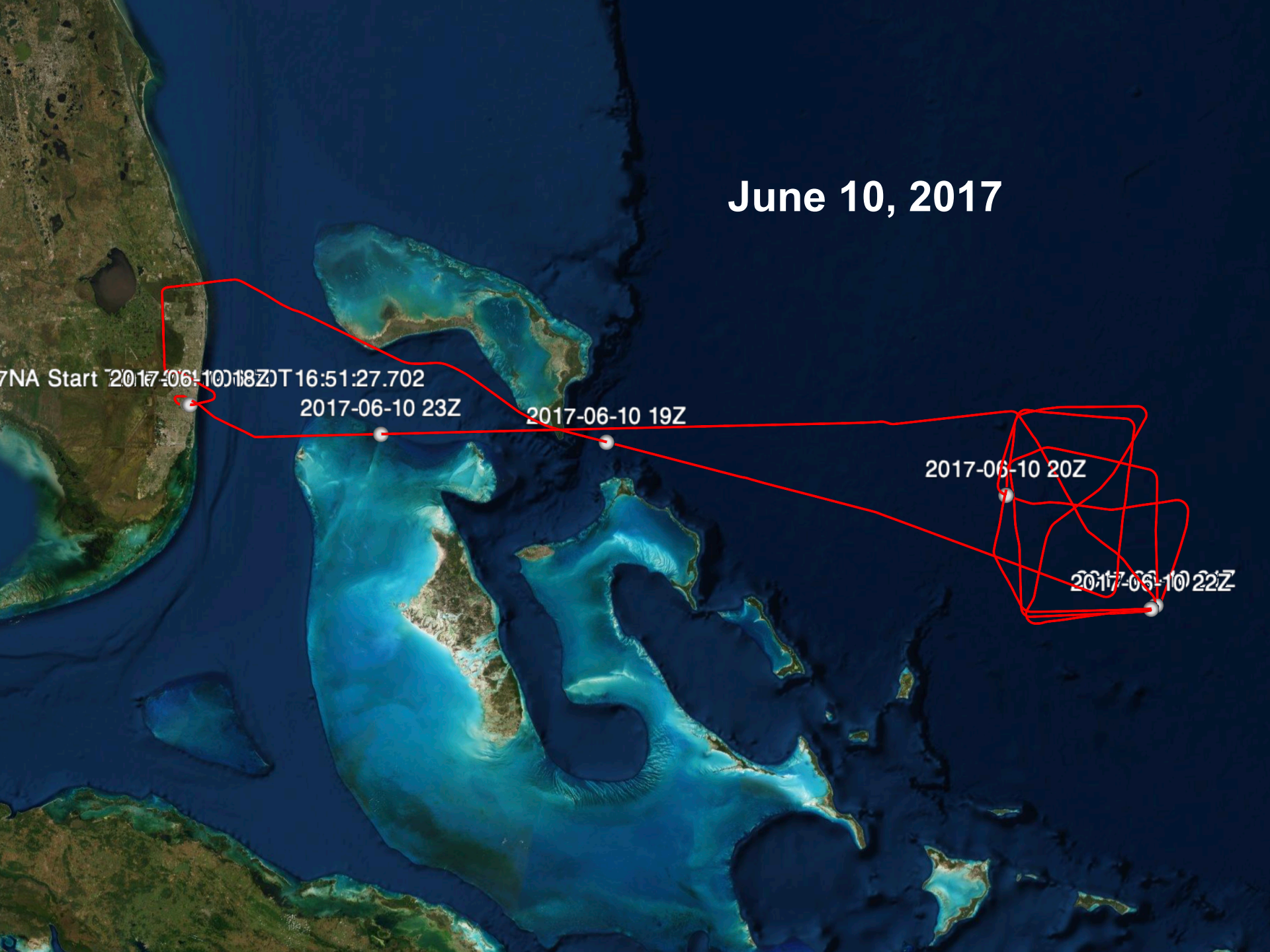
AB/BL
FL
FMS1
MSL 240
EXT W/S
WX
TCAS
NAV
406 KTS

Investigation Design




June 10, 2017
7NA Start 2017-06-10 18Z
T16:51:27.702
2017-06-10 23Z
2017-06-10 19Z
2017-06-10 20Z
2017-06-10 22Z

June 10 Study

The purpose of this study is to provide observational context for assessment of Sara Zhang's NU-WRF forecast impact study (following presentation- does DA of DAWN winds develop the convection in the times and places where APR-2 observed it?)

On this flight date, the DC-8 entered the area of investigation (AOI) from the west near 1815 UTC, and exited the AOI near 2230 UTC.

Four 1-hour analysis periods are selected: 1830-1930, 1930-2030, 2030-2130, 2130-2230. These correspond to the data assimilation windows.

During the 1900-1930 period, the DC-8 collected data just outside of the periphery (west side) of the AOI.

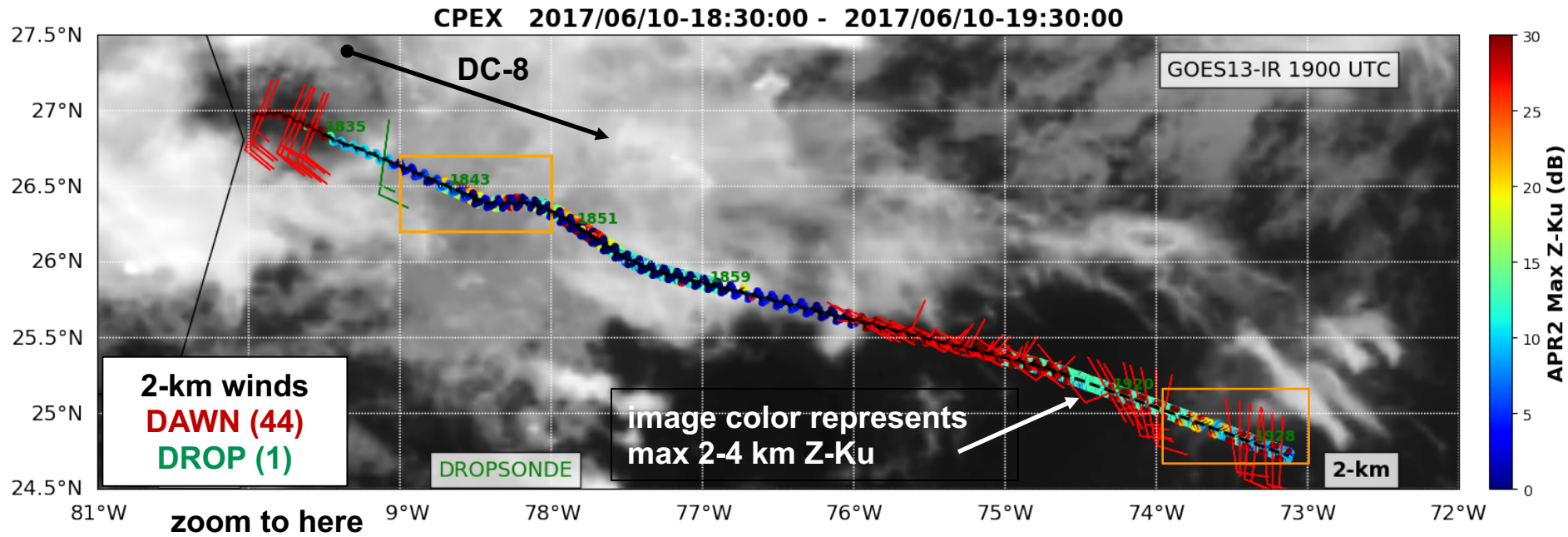
APR-2 scans across track (23 positions) every 1.8 seconds, providing an ≈ 8-km swath on the surface from 10-km flight altitude. DAWN stares (2-5 looks at multiple azimuth angles) for several seconds, as the DC-8 moves forward (200 m/s).

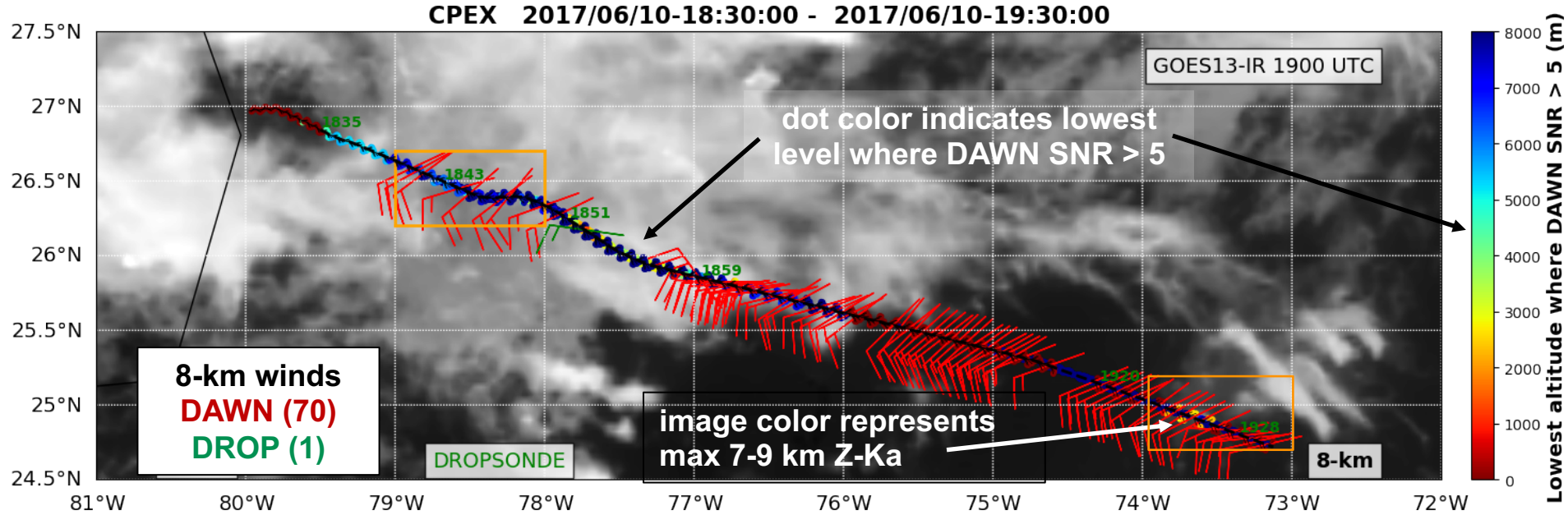
June 10, 2017

Flight Segment 1

1830-1930 UTC

Segment 1: 10 June 2017 1830-1930 UTC





Line segments indicate ray path for each DAWN LOS profile

1835-1855 UTC

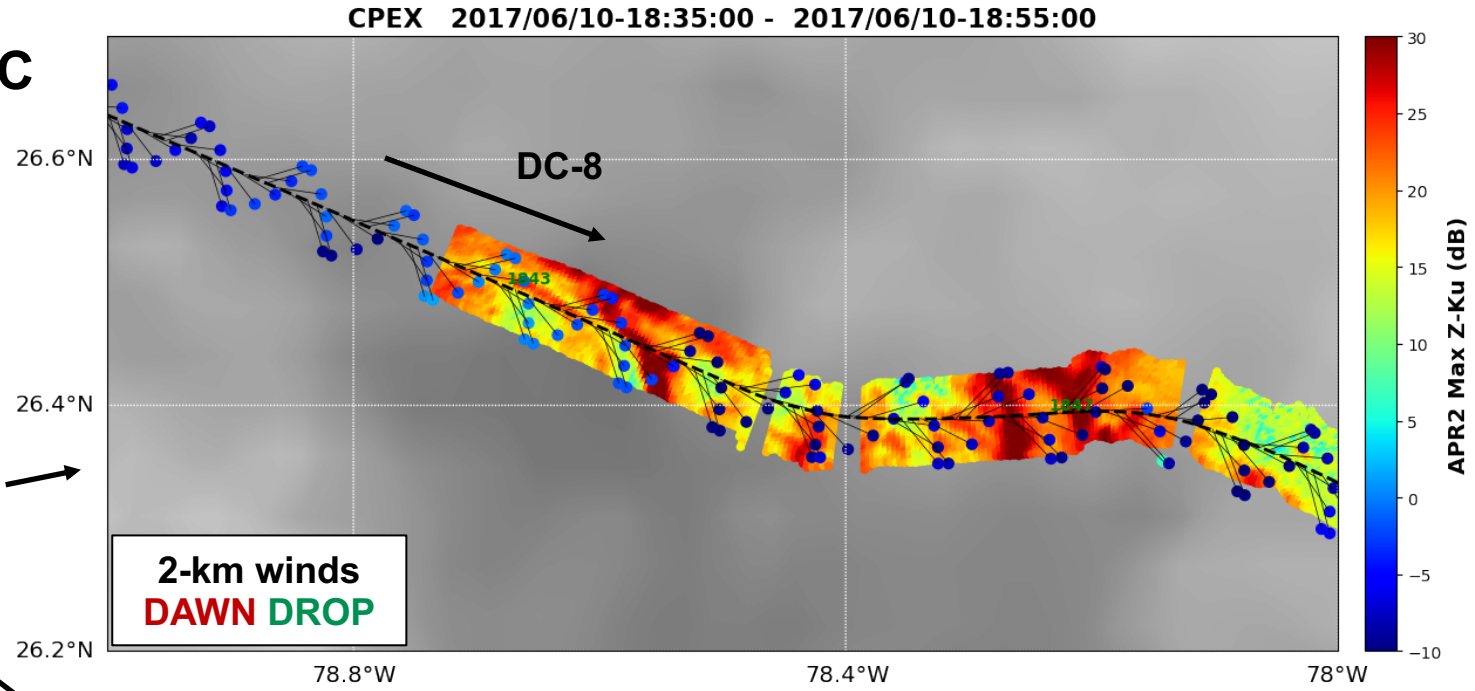
Image color represents:

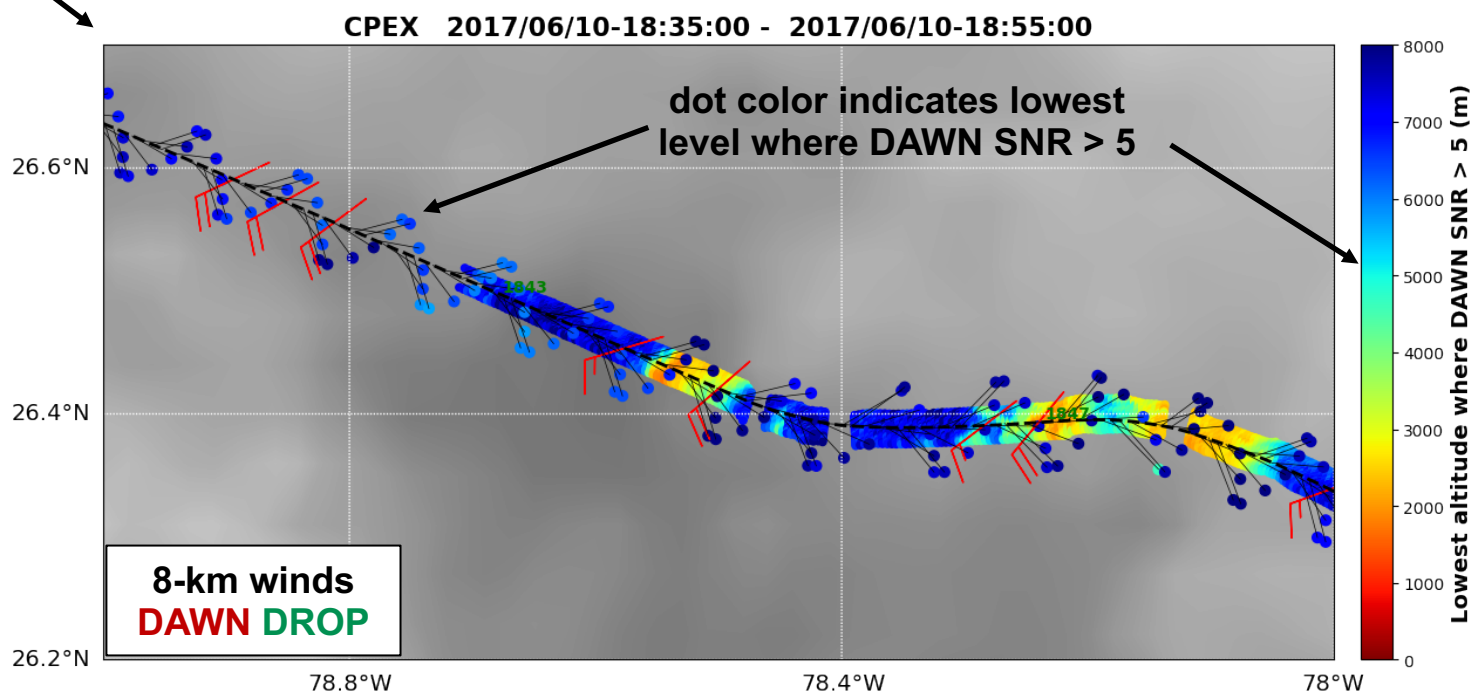
Top:
Max 2-4 km Z-Ku

Bottom:
Max 7-9 km Z-Ka

Line segments indicate ray path for each DAWN LOS profile

Dot color at the end of each line indicates lowest level where DAWN SNR > 5





1924-1930 UTC

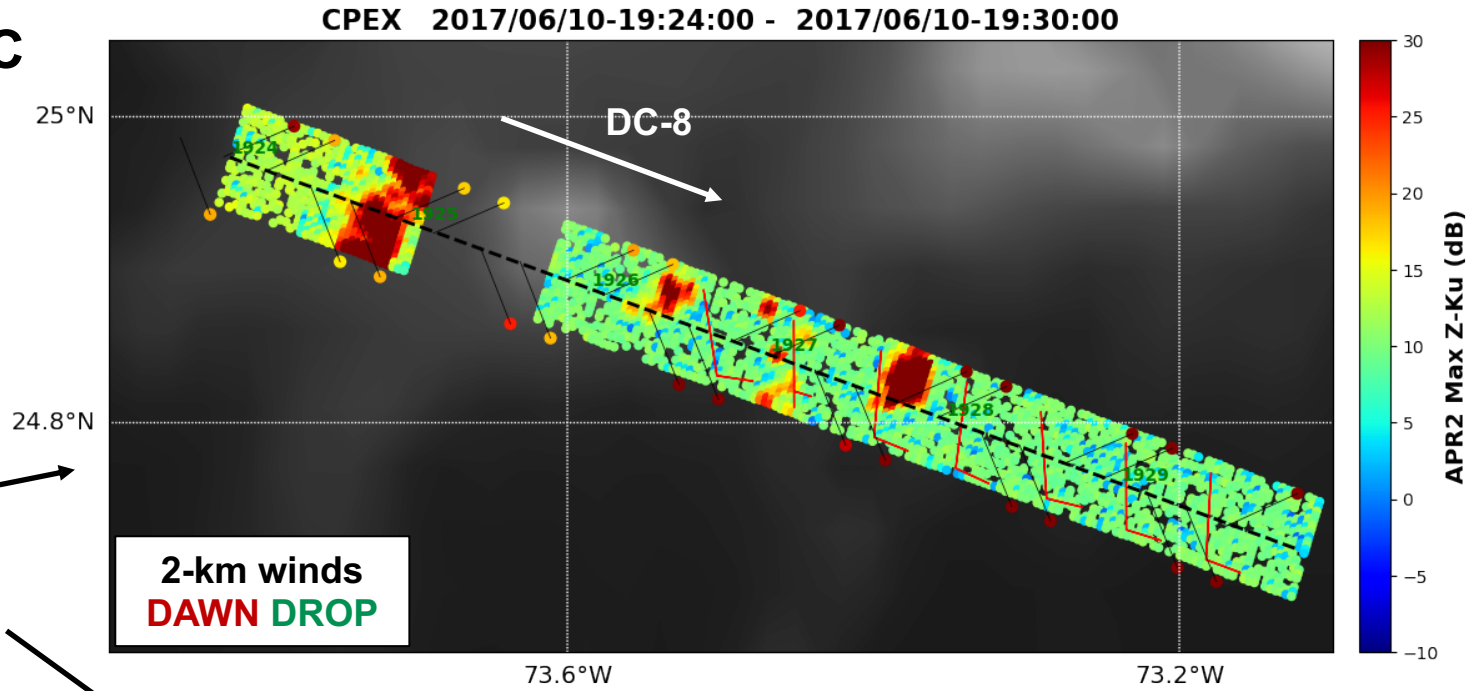
Image color represents:

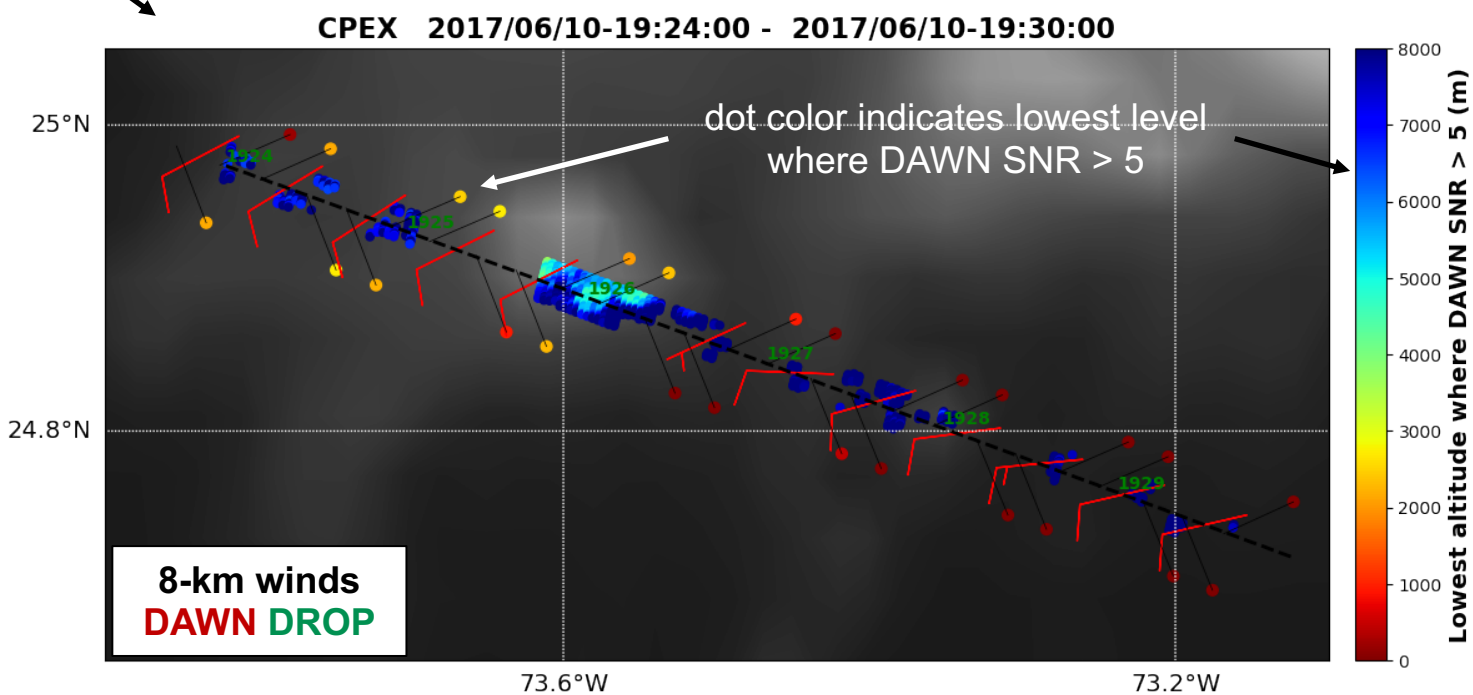
Top:
Max 2-4 km Z-Ku

Bottom:
Max 7-9 km Z-Ka

Line segments indicate ray path for each DAWN LOS profile

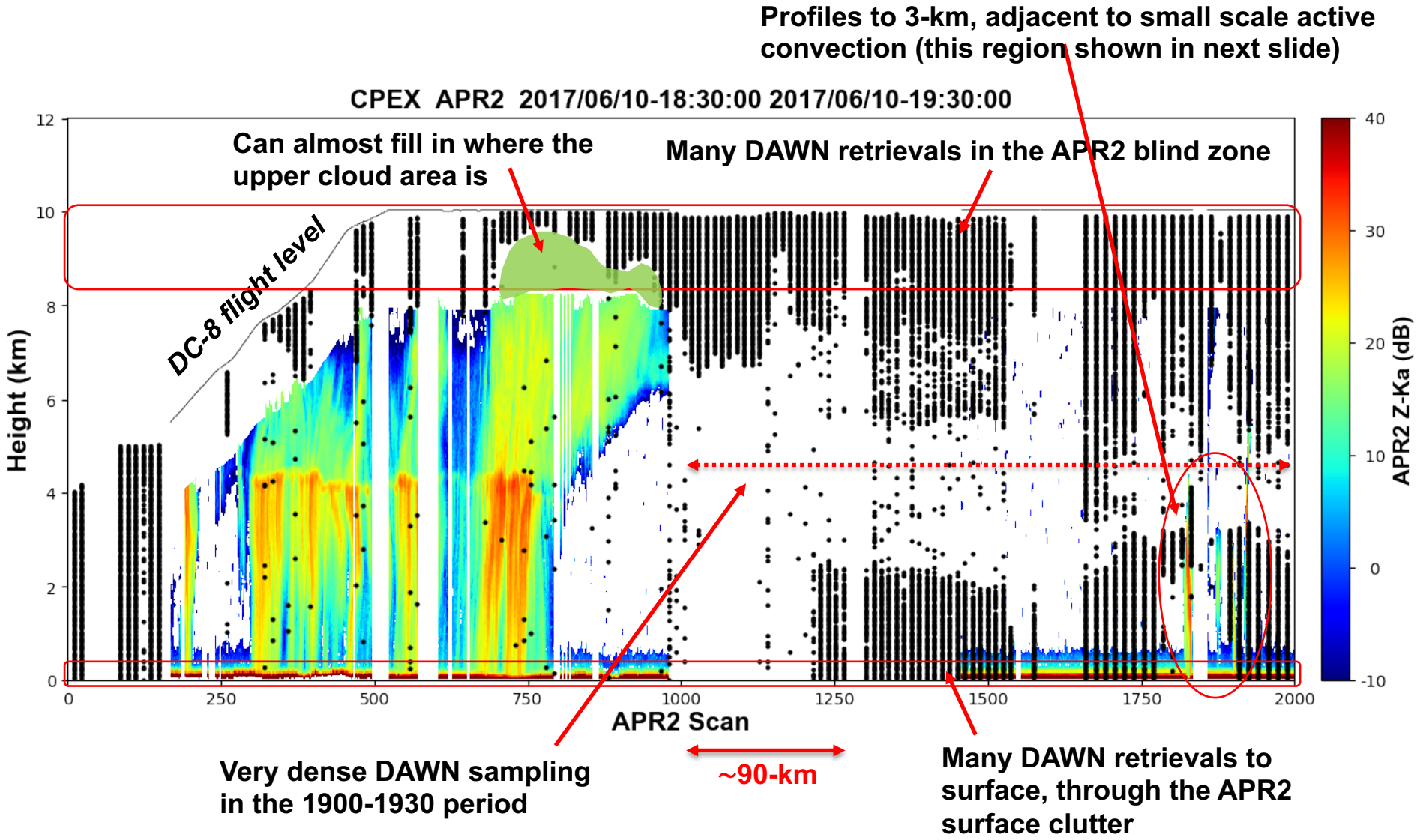
Dot color at the end of each line indicates lowest level where DAWN SNR > 5





Segment 1: 10 June 2017 1830-1930 UTC

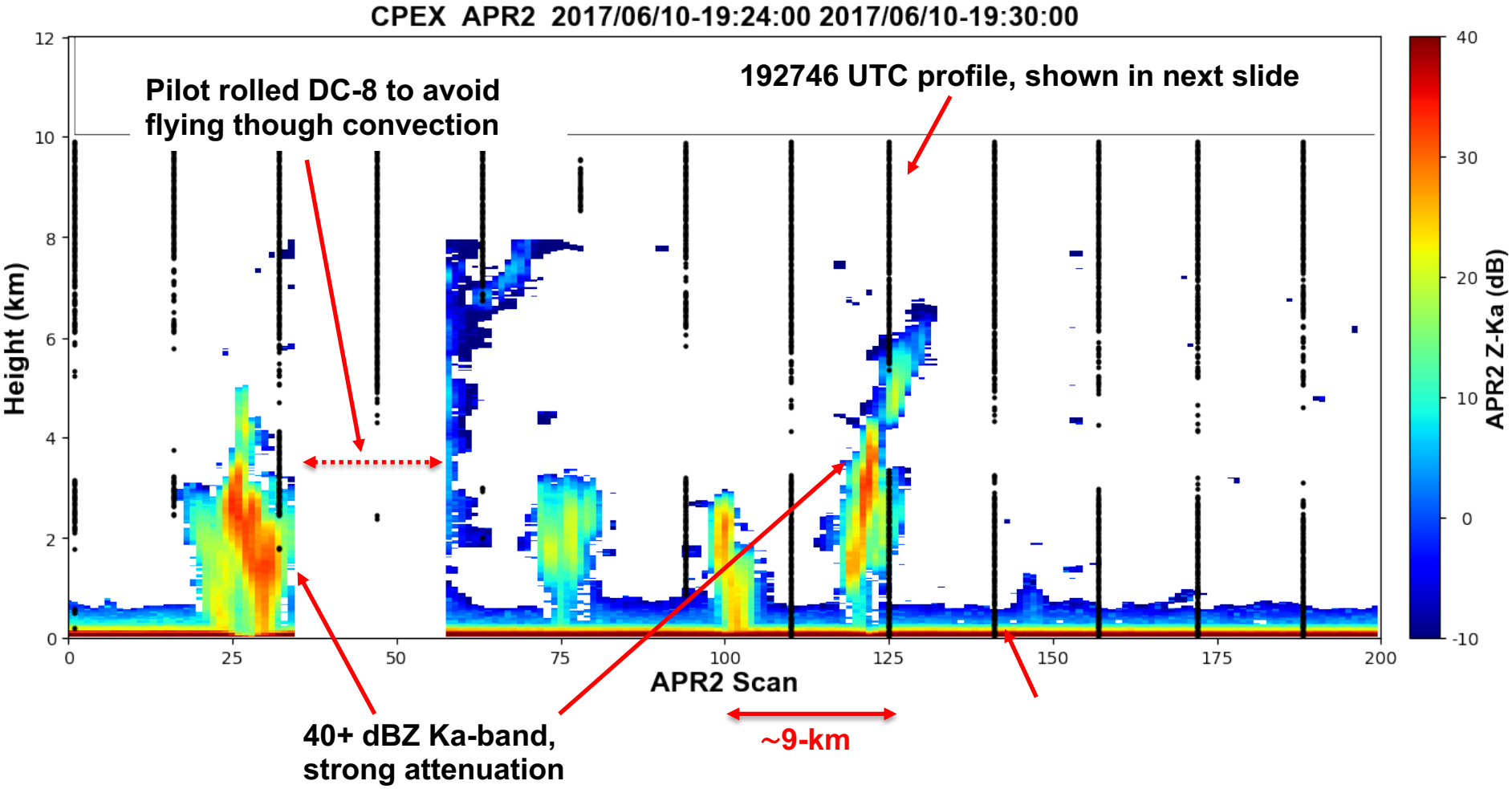
dots indicate levels where DAWN provided a valid (*u,v*) wind product



Segment 1: 1924-1930 UTC Zoom-in

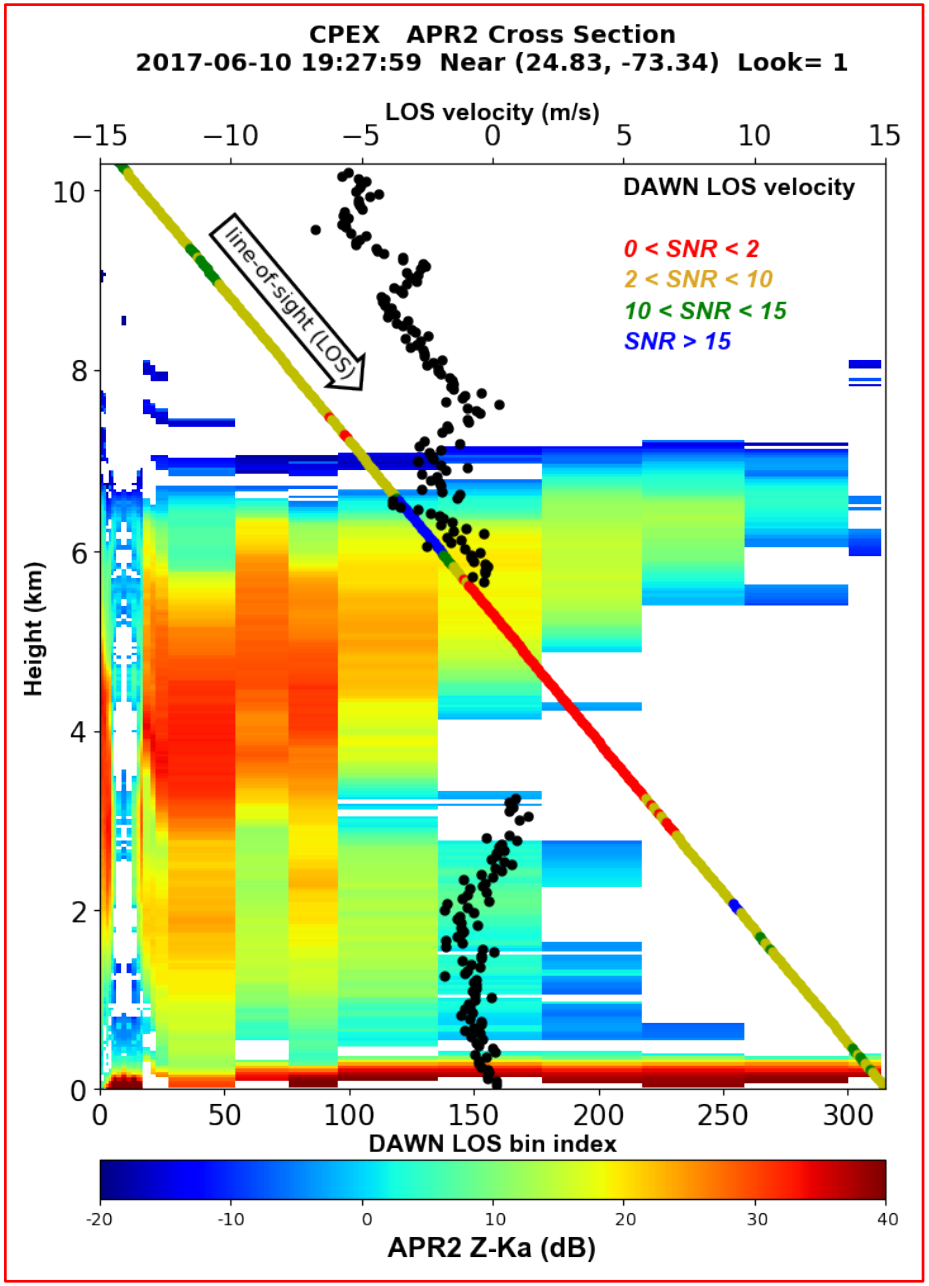
Small scale (2-3 km) active growing convection

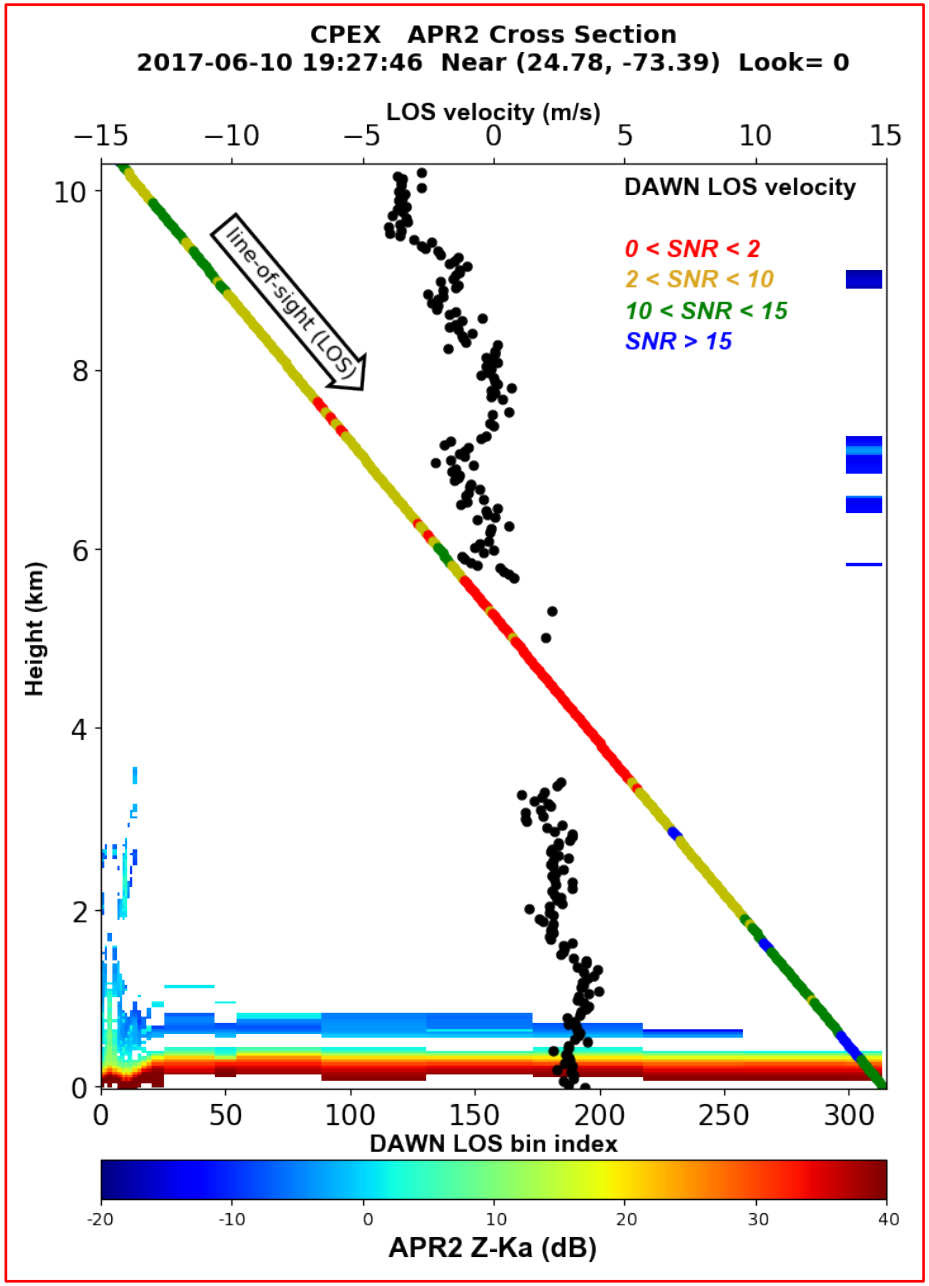
DAWN data collected nearby to 4 small convective cells



Segment 1: 192746 UTC LOS Profiles showing APR-2 Ka-band "ray slice"

Lidar penetrated through 20 dB region near upper-level outflow, to surface



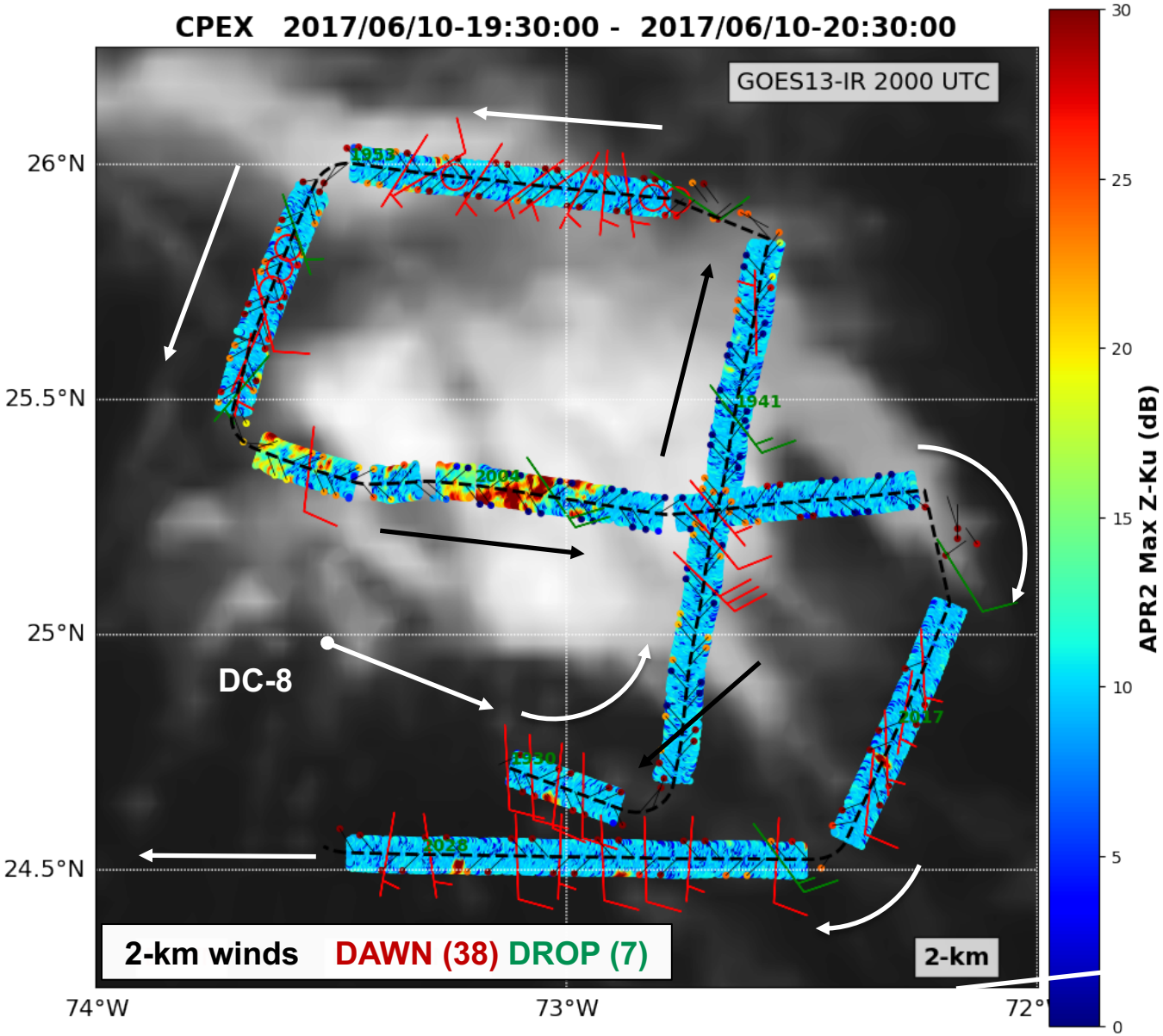


June 10, 2017

Flight Segment 2

1930-2030 UTC

Segment 2: 10 June 2017 1930-2030 UTC (2-km)

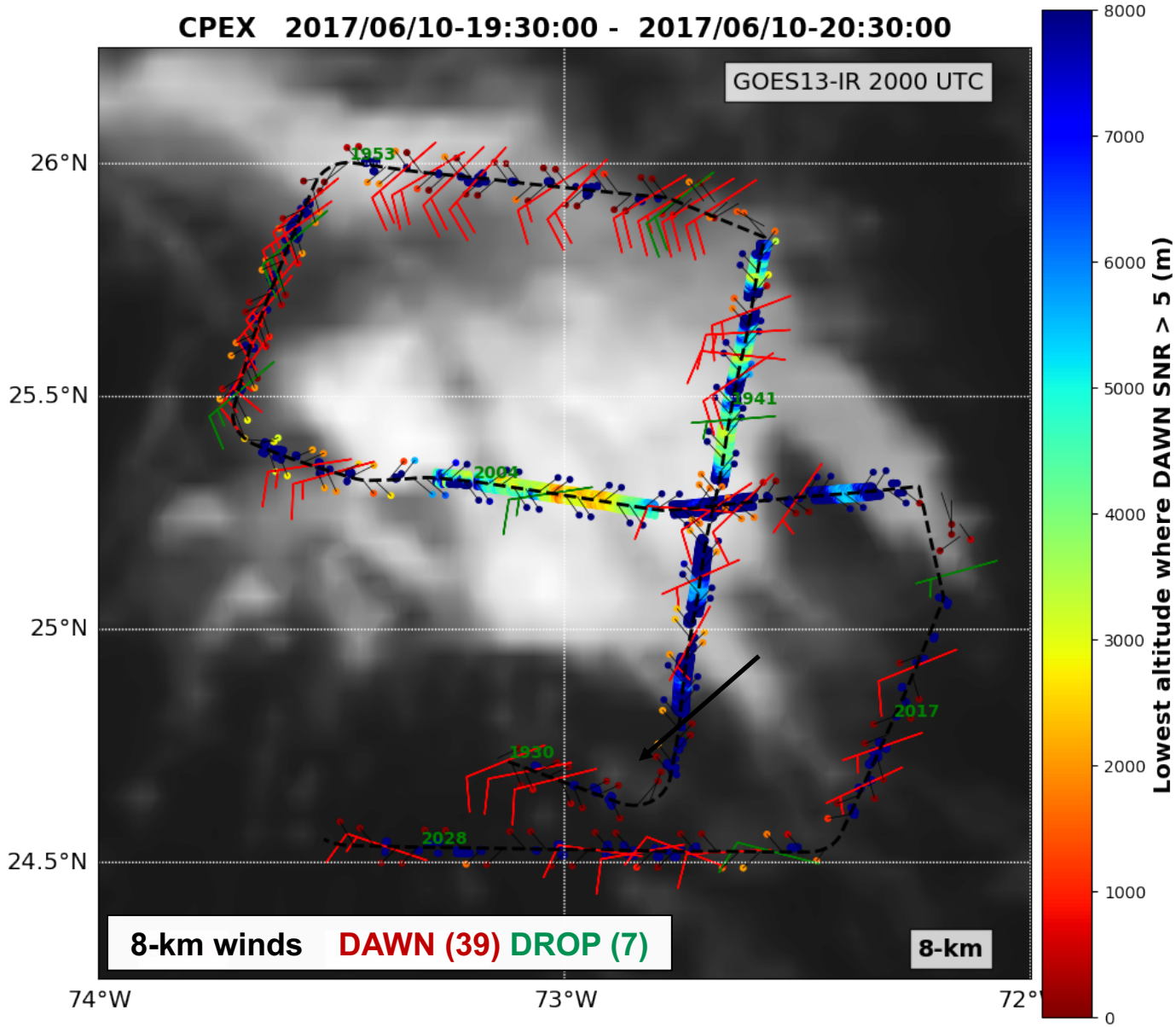


Good 2-km sampling S of the AOI on the return segment, between 2020-2030

Also N of the AOI between 1945-1955

Line segments indicate ray path for each DAWN LOS profile

Segment 2: 10 June 2017 1930-2030 UTC (8-km)

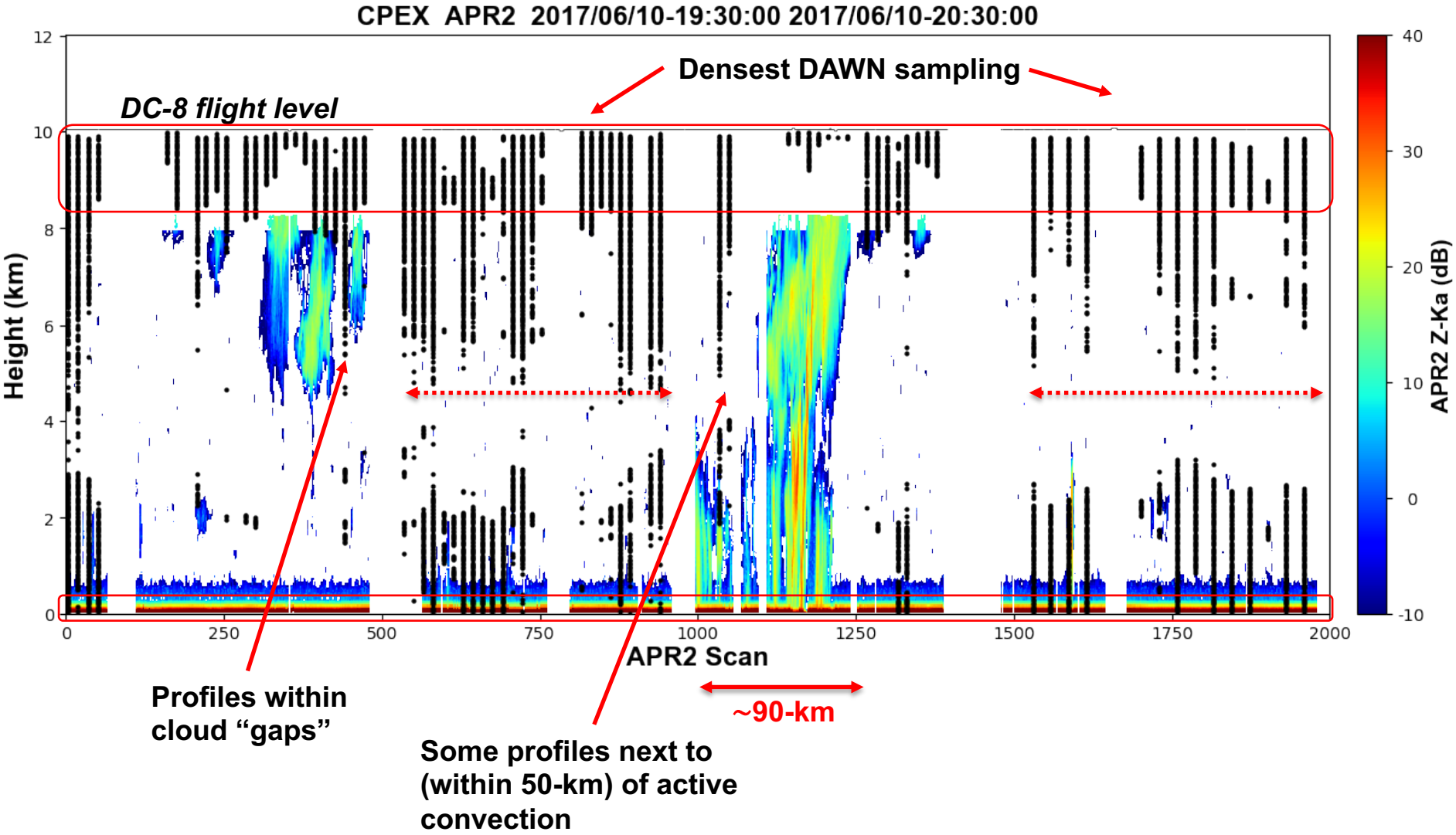


Good 8-km sampling NW of the AOI midway thorough this segment, between 1945-1955

Line segments indicate ray path for each DAWN LOS profile

Segment 2: 10 June 2017 1930-2030 UTC

dots indicate levels where DAWN provided a valid (*u,v*) wind product

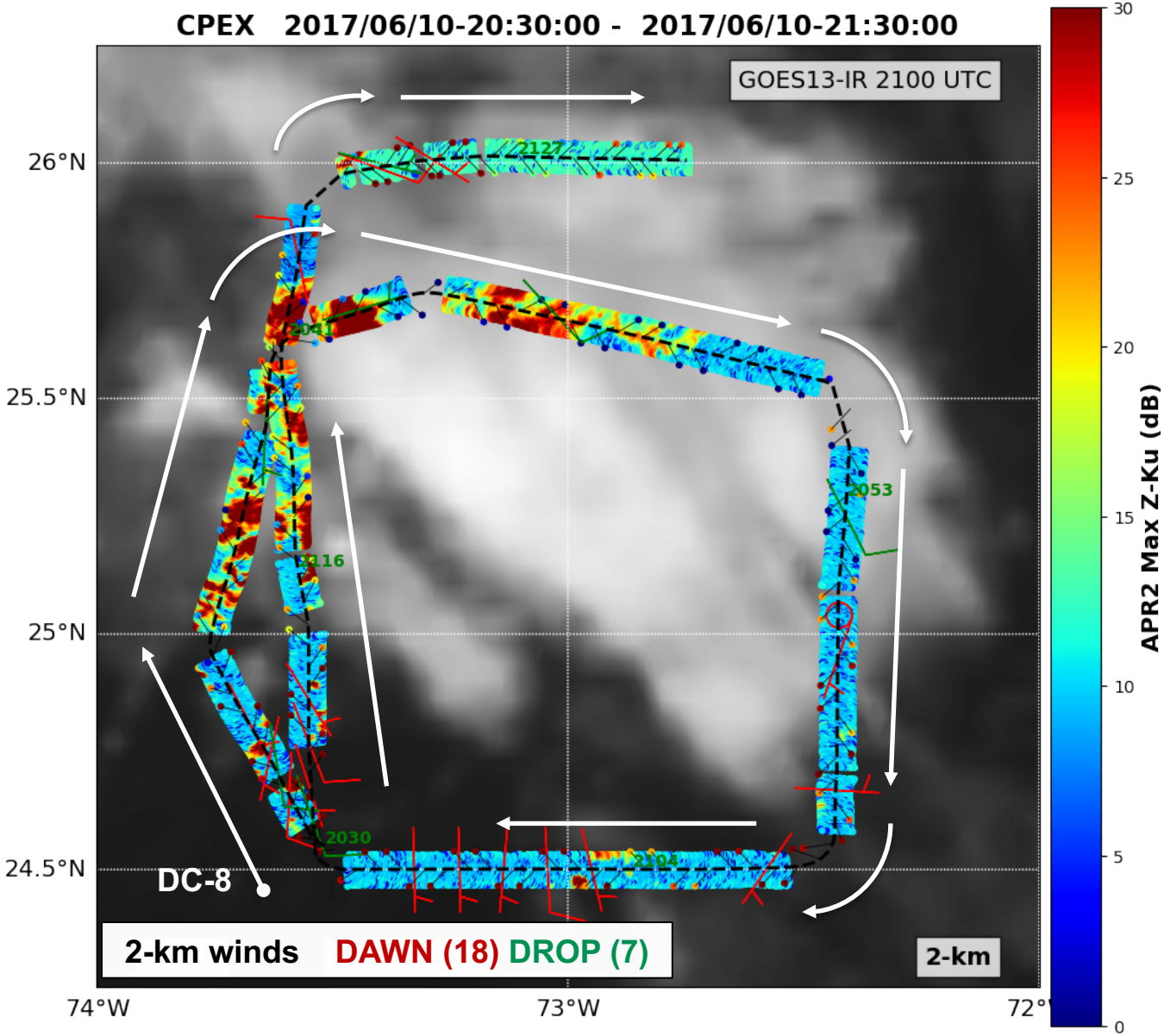


June 10, 2017

Flight Segment 3

2030-2130 UTC

Segment 3: 10 June 2017 2030-2130 UTC (2-km)

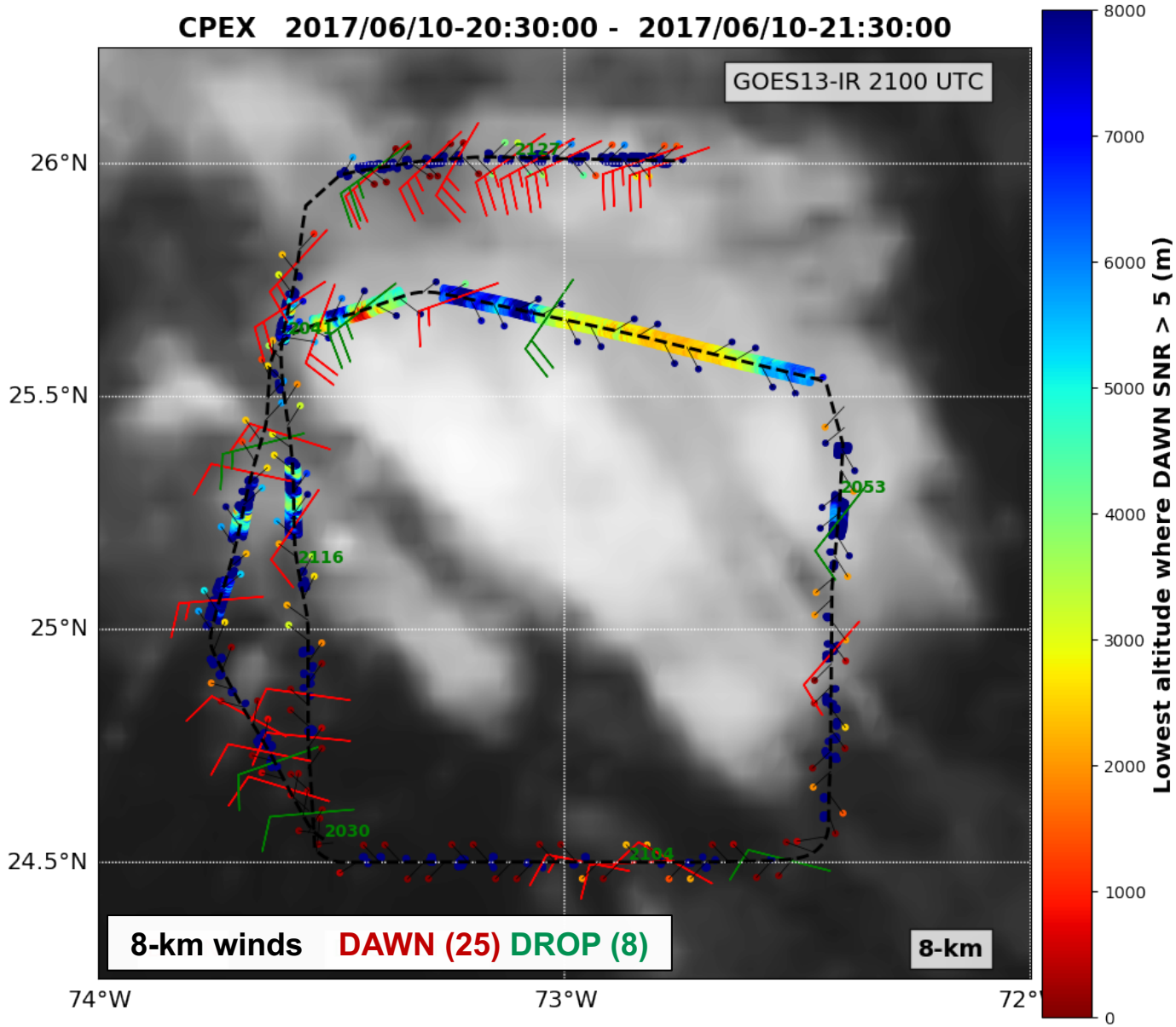


Still fairly high sampling at 2-km S of the AOI

image color represents max 1-3 km Z-Ku

Line segments indicate ray path for each DAWN LOS profile

Segment 3: 10 June 2017 2030-2130 UTC (8-km)



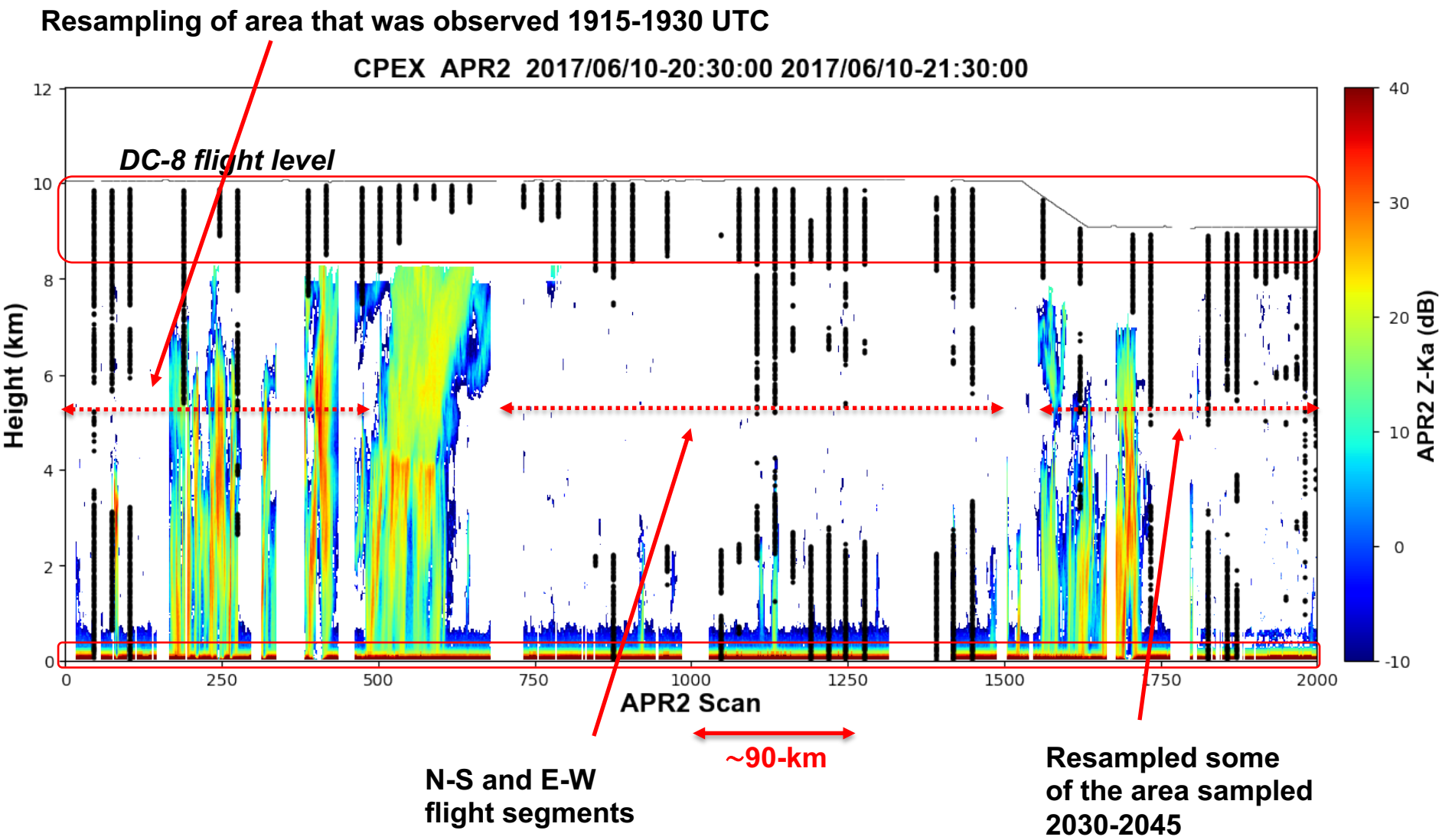
Still fairly high sampling at 2-km S of the AOI

image color represents max 7-9 km Z-Ka

Line segments indicate ray path for each DAWN LOS profile

Segment 3: 10 June 2017 2030-2130 UTC

dots indicate levels where DAWN provided a valid (*u,v*) wind product

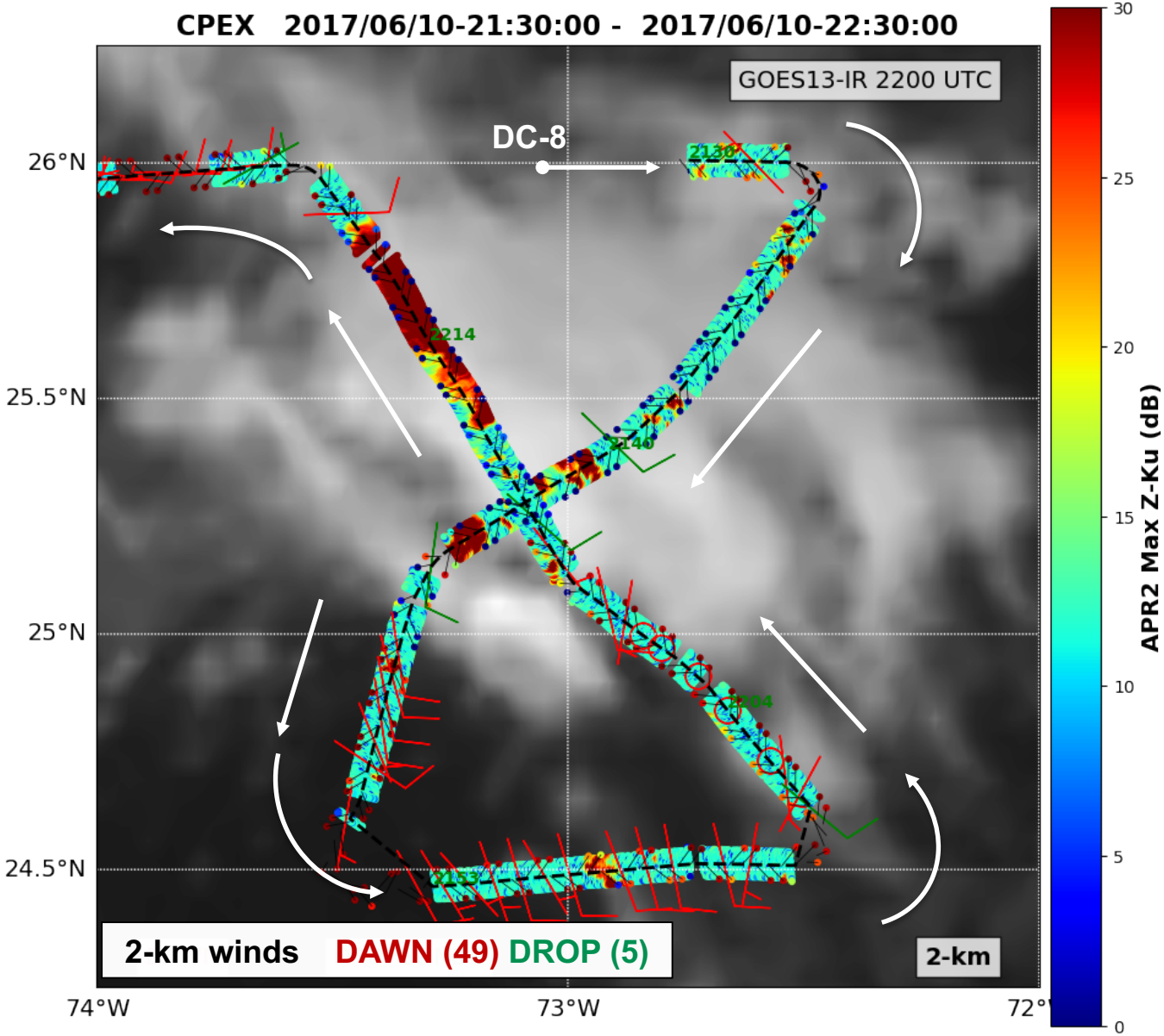


June 10, 2017

Flight Segment 4

2130-2230 UTC

Segment 4: 10 June 2017 2130-2230 UTC (2-km)

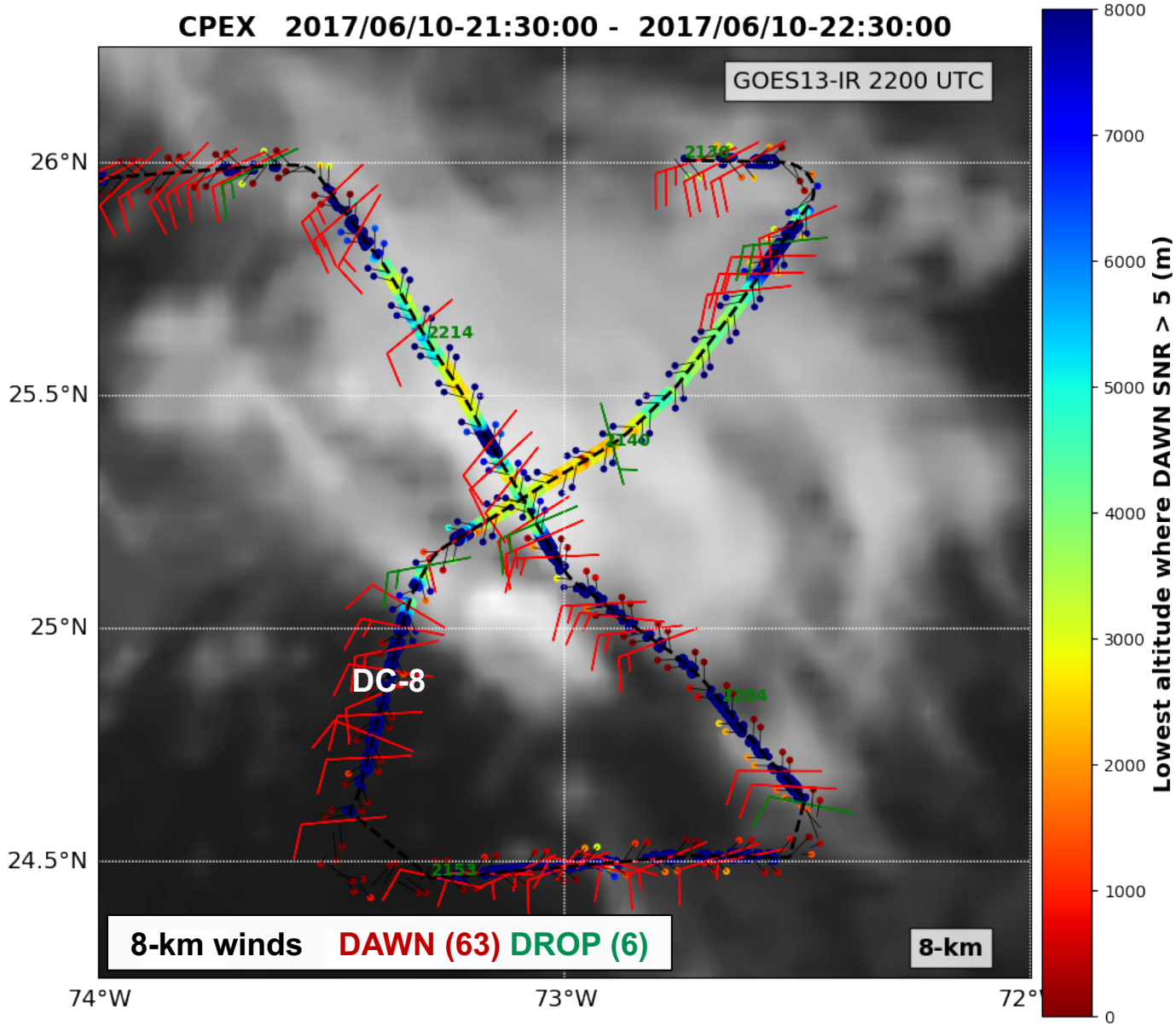


Still fairly high sampling at 2-km S of the AOI

image color represents max 1-3 km Z-Ku

Line segments indicate ray path for each DAWN LOS profile

Segment 4: 10 June 2017 2130-2230 UTC (8-km)



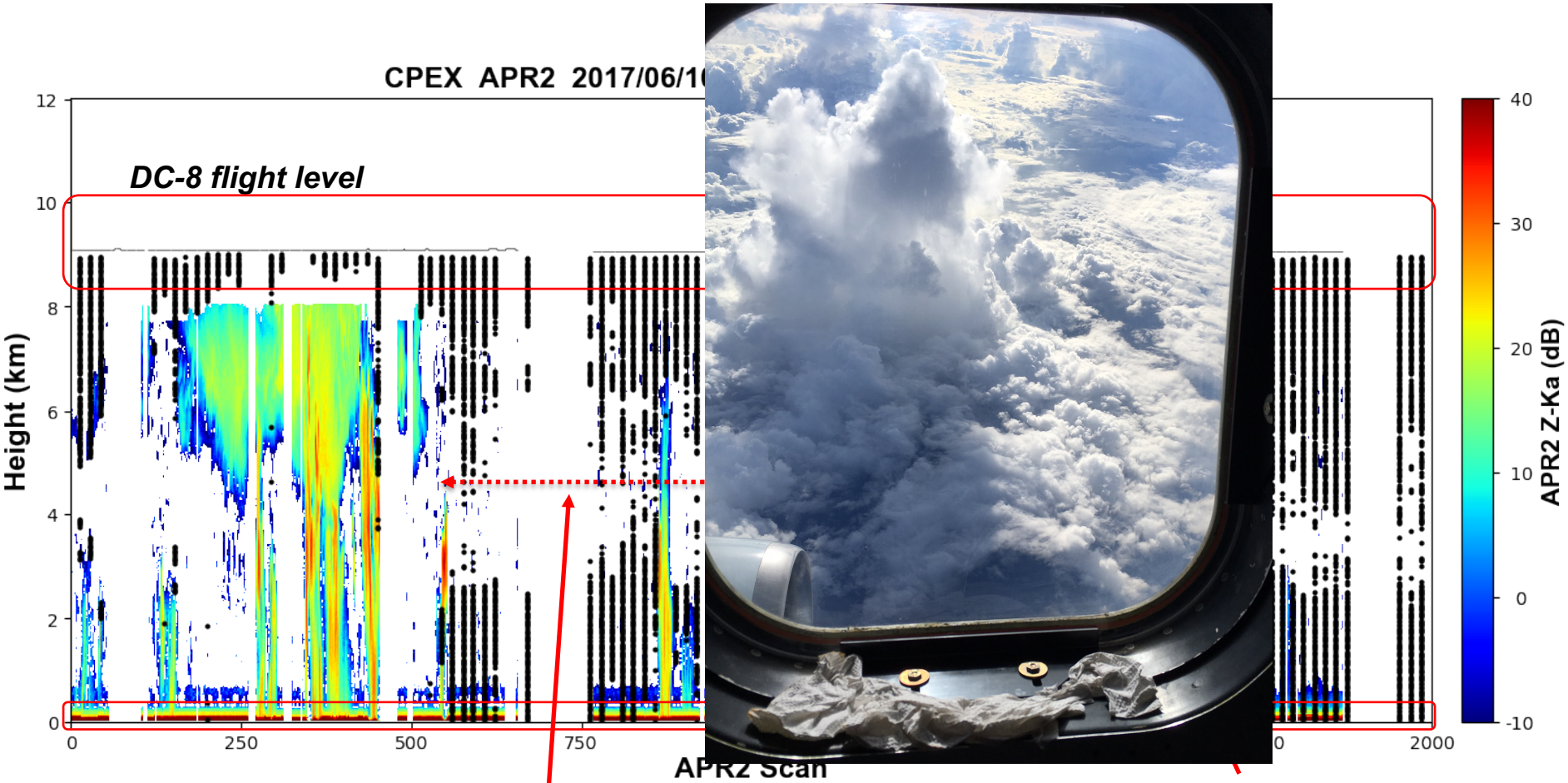
Still fairly high sampling at 2-km S of the AOI

image color represents max 7-9 km Z-Ka

Line segments indicate ray path for each DAWN LOS profile

Segment 4: 10 June 2017 2130-2230 UTC

dots indicate levels where DAWN provided a valid (*u,v*) wind product



Some of the same area (south of AOPI) captured midway through segment 3

Caught the most developed clouds on the exit, mainly stratiform signature

June 10 Study: Summary

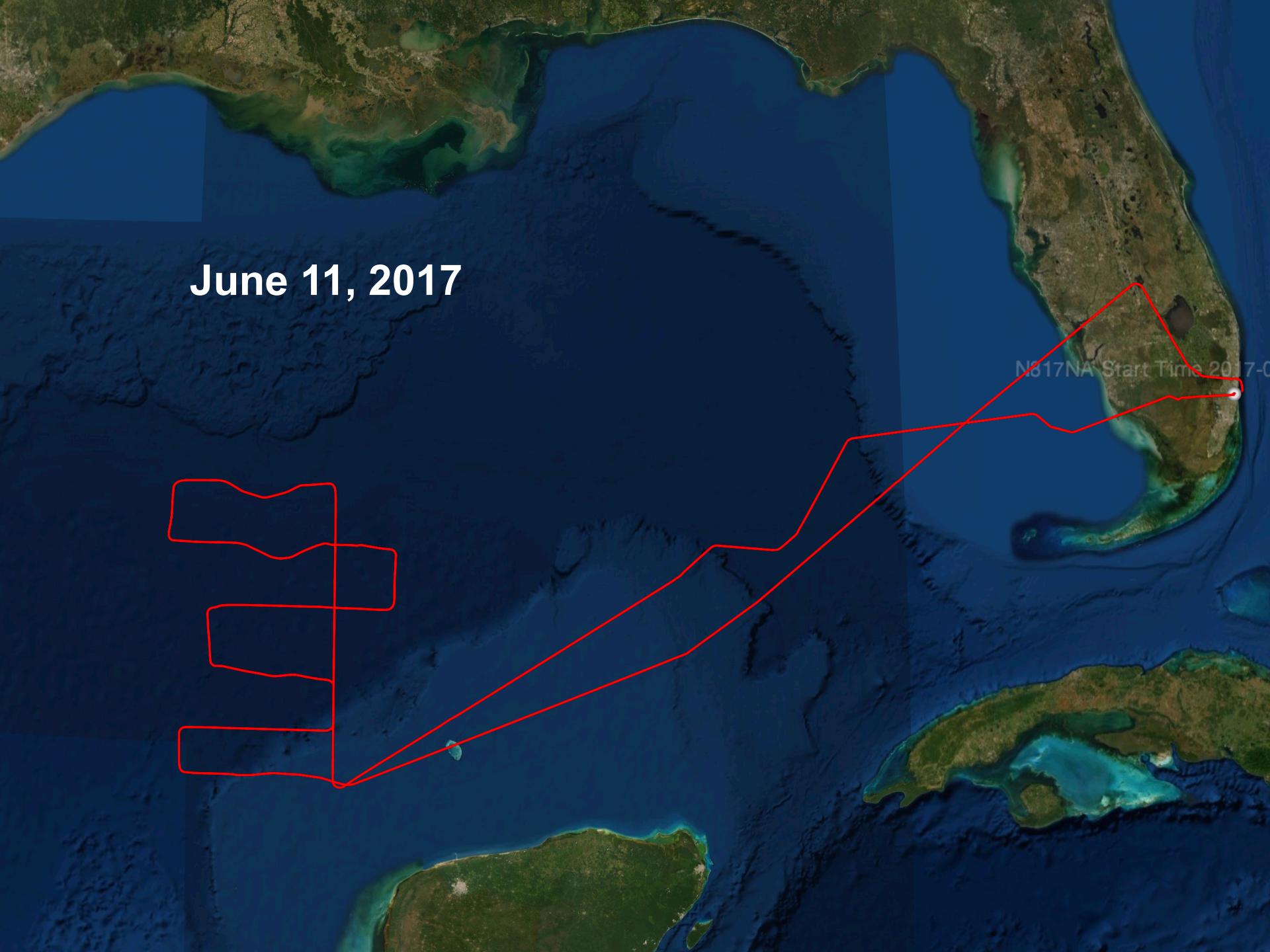
The region west of where the main convection was fairly free of clouds and well-sampled by DAWN at lower and upper levels during a 400-km flight line between 1900-1930.

SW winds at 8-km, more SE at 2-km.

Growing clouds were mainly to the W of the AOI at this stage, radar tops near 4-6 km, narrow 3-km width cells with (in some cases) rather high precipitation-sized liquid water contents (strong attenuation at Ka-band, signal attenuated before surface).

Some of the region that was sampled from 1915-1930 was re-sampled from 2030-2045.

Generally much less 2-km wind sampling during flight segments 2 and 3. By 2130, much of the other convection sampled by APR-3 was already developed (DC-8 flew through a lot of upper level clouds).

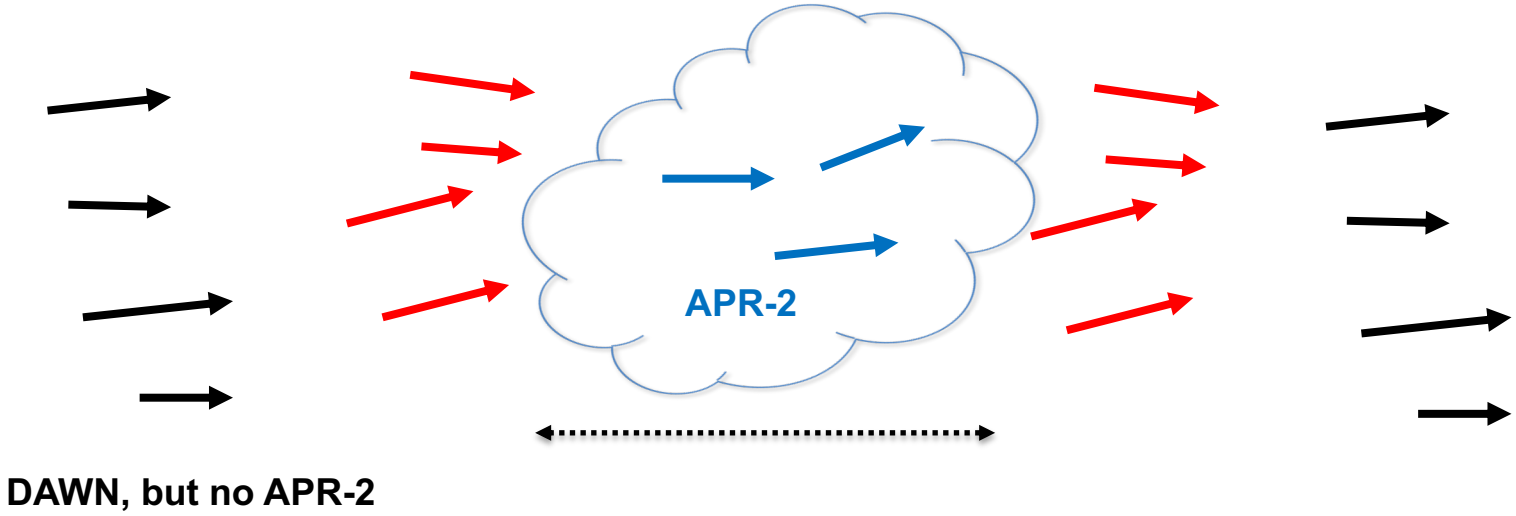

June 11, 2017
N817NA Start Time 2017-0

In-Cloud Air Motion

During CPEX, DAWN provided abundant profiles away from clouds but progressively fewer nearer the clouds.

Conversely, APR-2 provides along-beam Doppler wind profiles in the cloud (mostly vertical component, but some across-scan component).

Since convection involves air being exchanged and transported in/out of clouds, can these two different measurements be joined together?



(example plan view, not to scale)

June 11 Study

On this flight date, the DC-8 flew convergence boxes along predominantly cardinal directions (0, 90, 180, 270 flight bearings).

This enables an estimate of *w* and either the *u* or *v* wind from the APR-2 Doppler wind profiles.

How to they compare to nearby DAWN (*u,v*)? (Note that in general such comparisons could be done for arbitrary flight directions).

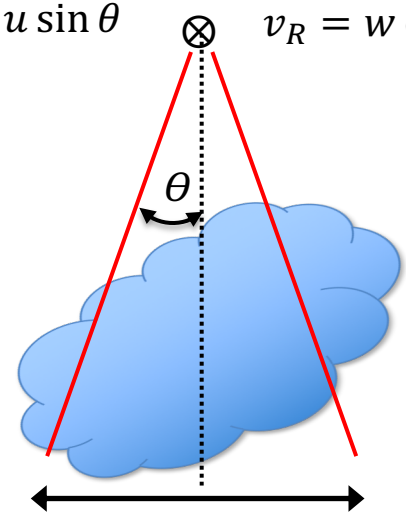
left (L) side

$$v_L = w\cos\theta - u\sin\theta$$

right (R) side

$$v_R = w\cos\theta + u\sin\theta$$

DC-8 flying into paper along a 0-deg bearing



APR-2 swath width

Sum and difference provide:

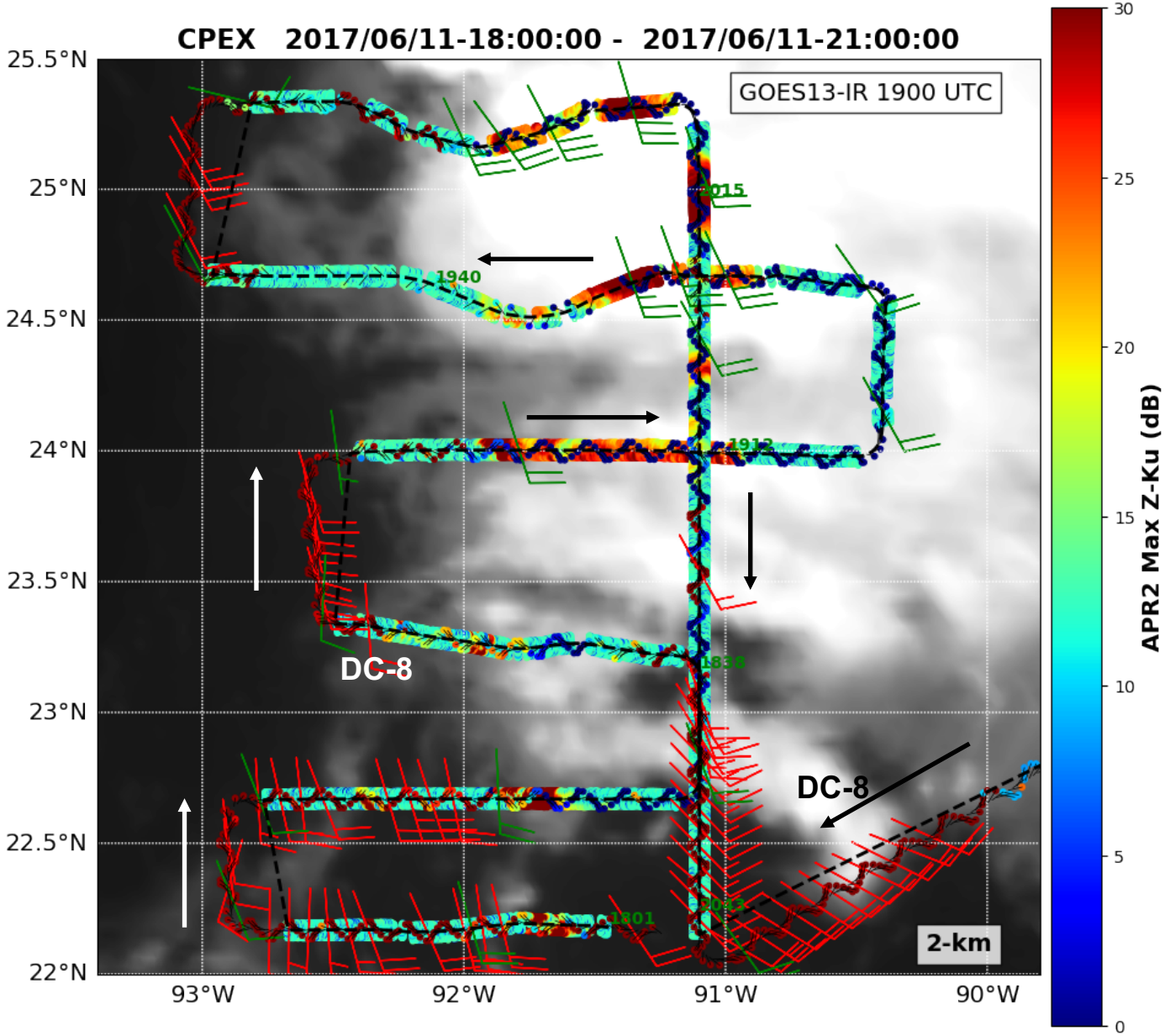
$$w = (v_L + v_R)/2\cos\theta$$

$$u = (v_L - v_R)/2\sin\theta$$

Along a 90-deg bearing:

$$v = (v_L - v_R)/2\sin\theta$$

11 June 2017 1800-2100 UTC (2-km)



2-km winds
DAWN (59)
DROP (22)

Image color represents:

Max 2-4 km Z-Ku

Line segments indicate ray path for each DAWN LOS profile

Dot color at the end of each line indicates lowest level where DAWN SNR > 5

Line segments indicate ray path for each DAWN LOS profile

11 June 2017 1800-2100 UTC (8-km)

8-km winds
DAWN (114)
DROP (21)

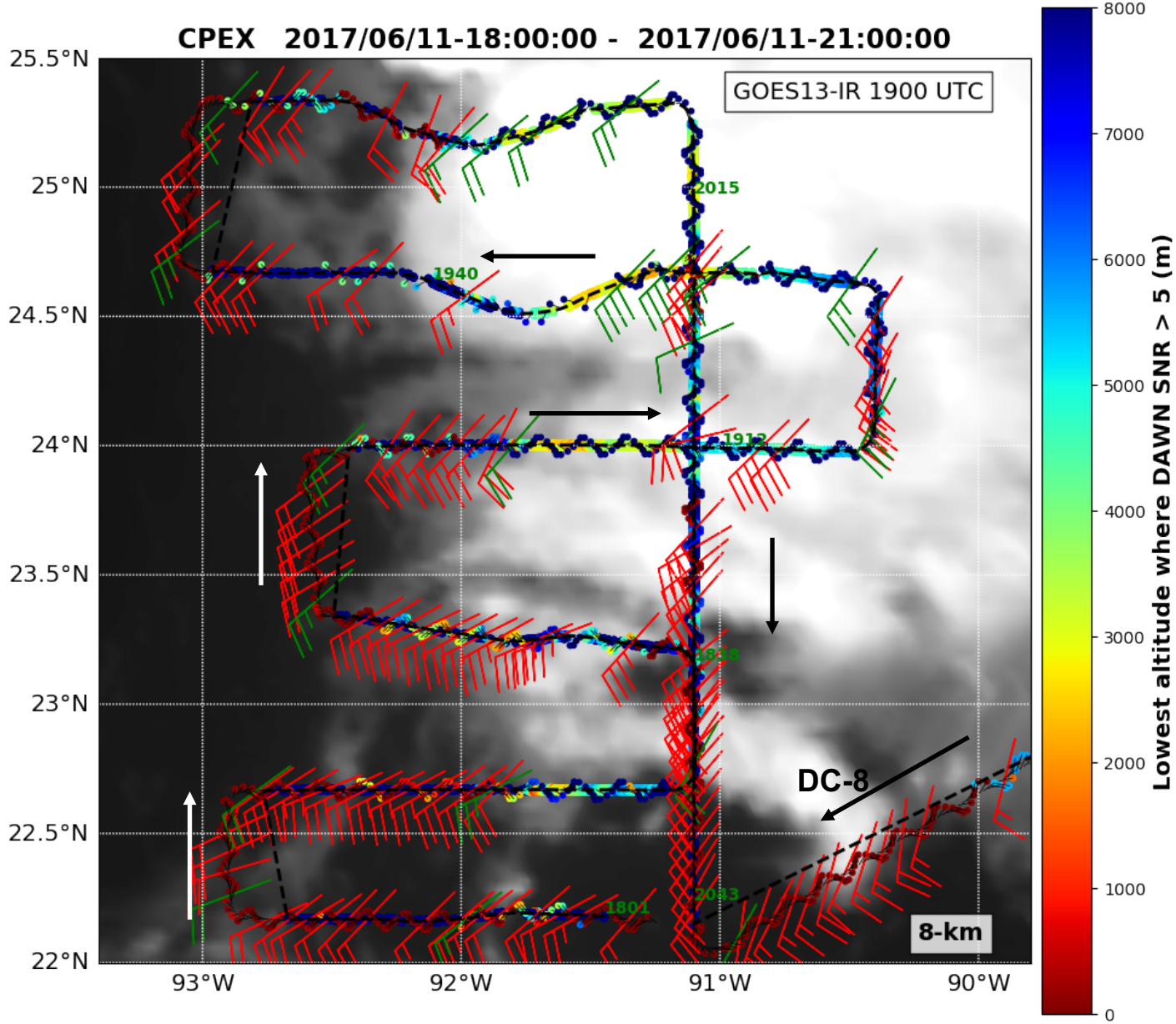


Image color represents:

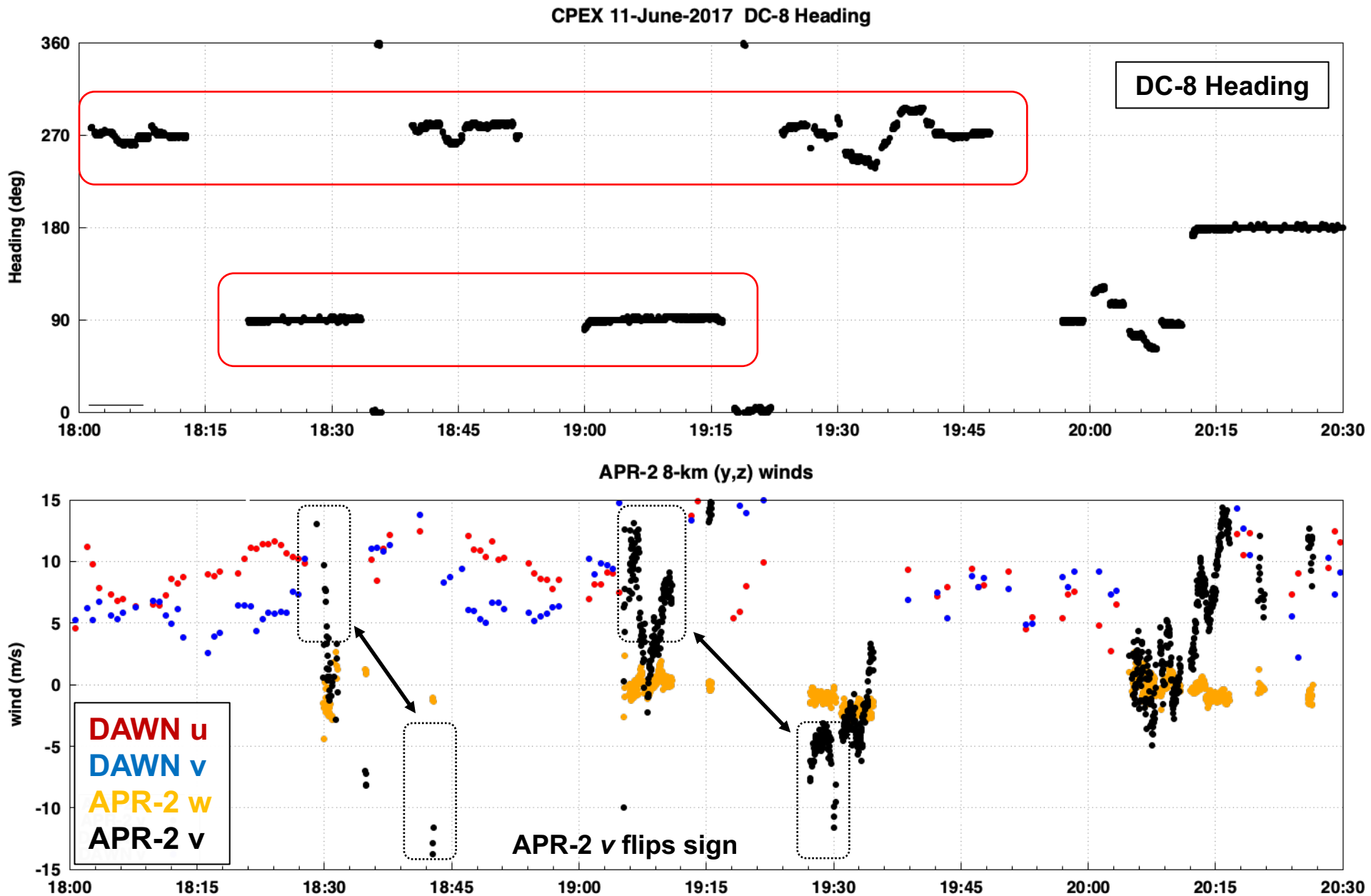
Max 7-9 km Z-Ka

DC-8 entered area along NE-SW direction

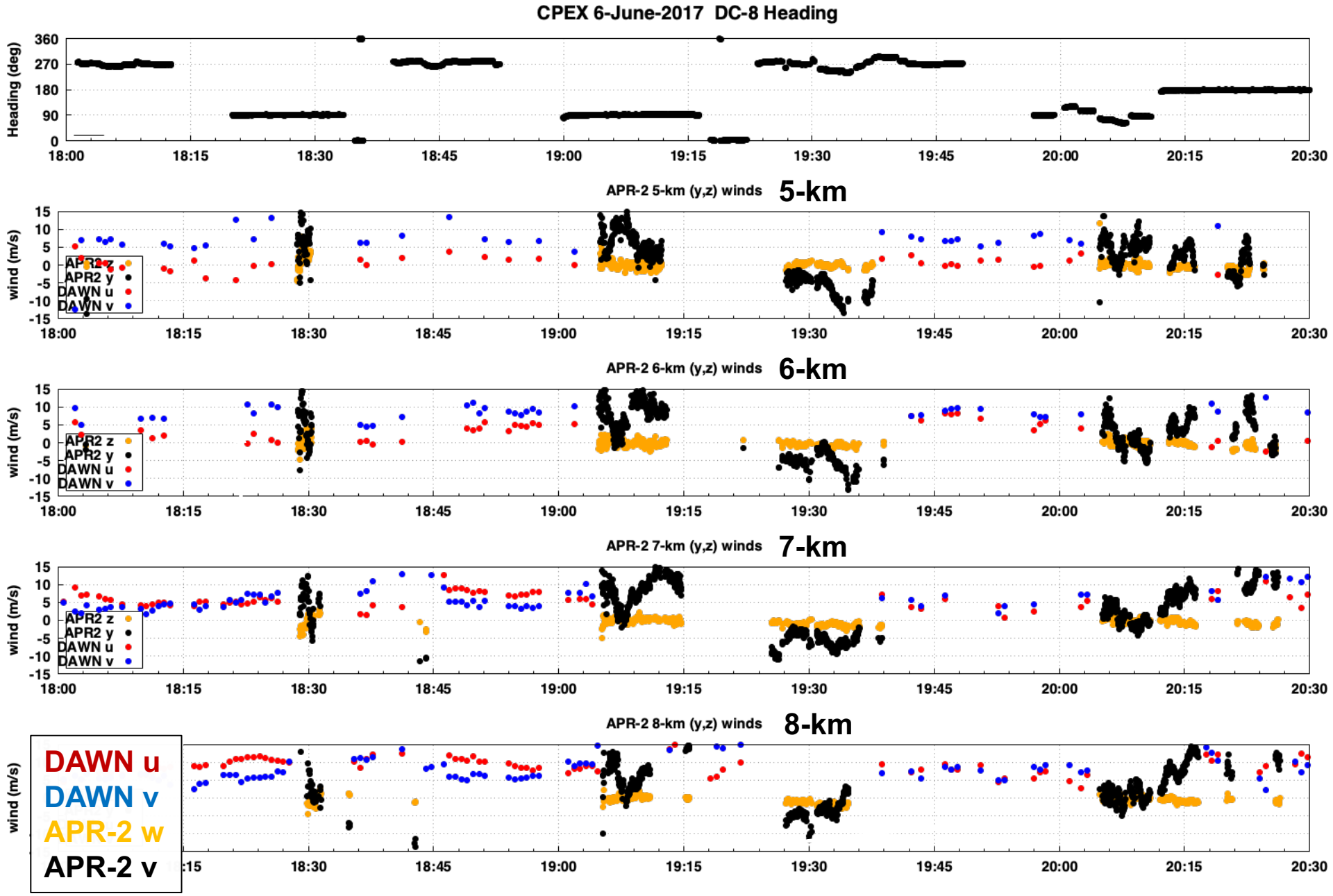
8-km wind direction mainly SW-to-NE across the entire area

Line segments indicate ray path for each DAWN LOS profile

11 June 2017 1800-2030 UTC (8-km)



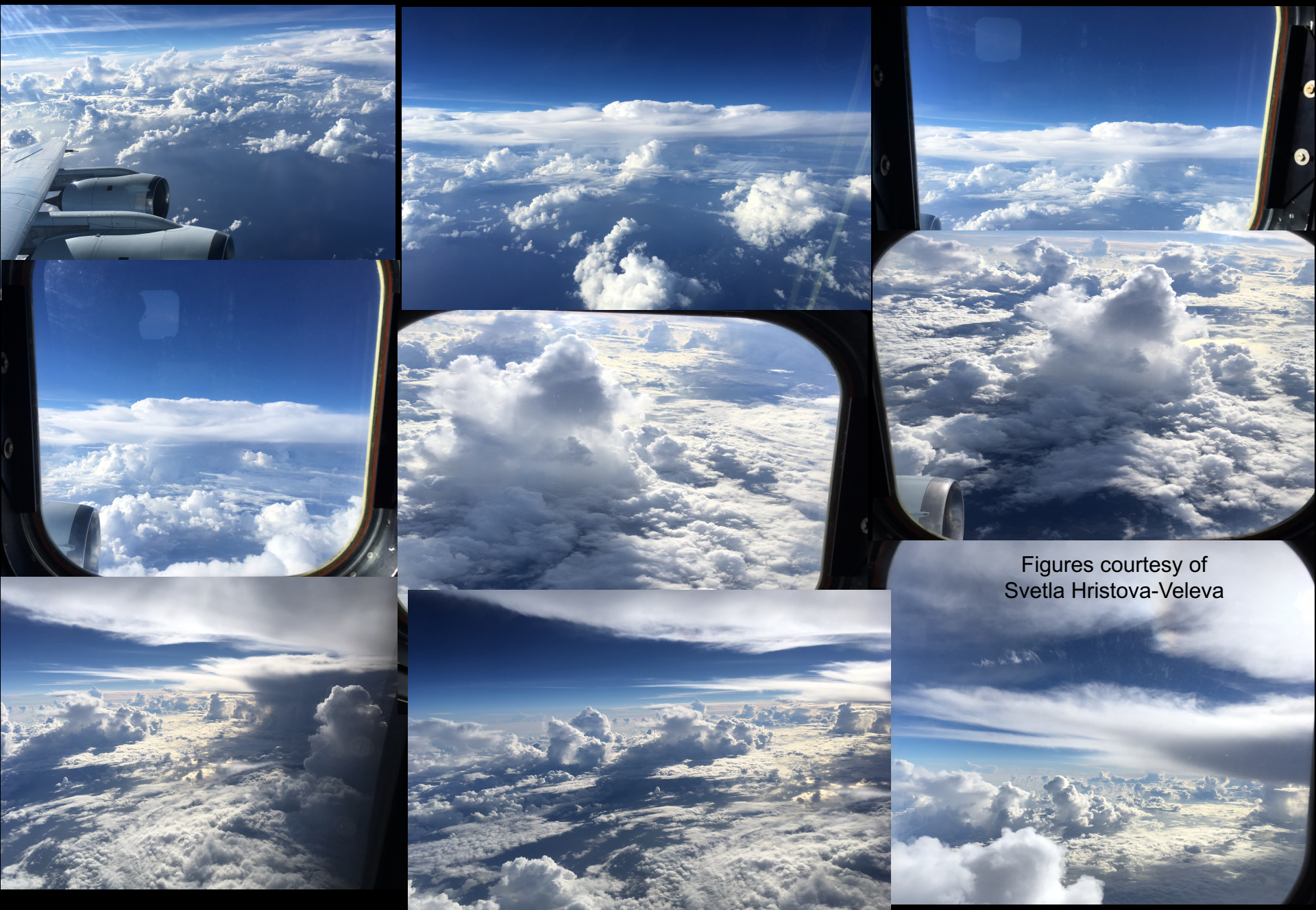
11 June 2017 1800-2030 UTC (8-km)



Summary

Joint operation of APR-2 and DAWN from a common aircraft demonstrated that in many instances useful airborne lidar wind profiles can be obtained fairly close (within 50-km) of growing convection.

Potential implications for wind vector DA when observations are gathered at times and locations of sensitive areas. Sara Zhang's presentation (following) to examine this assumption further.

Under certain conditions some additional information on the *z*, and *u* or *v* wind components within clouds and cloud edges may be possible to extract from a airborne scanning Doppler radar (more comprehensive evaluation required).

Visual Appearance from the window 10 June 2017, between 2145-2205 UTC