

Status of Processing P3 W-band Nadir Radar Observations in support of CalWater 2015

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30-August-2016

Outline

This document highlights processing that was performed to prepare the P3 W-band radar observations for scientific interpretation.

Specifically, the following steps were performed:

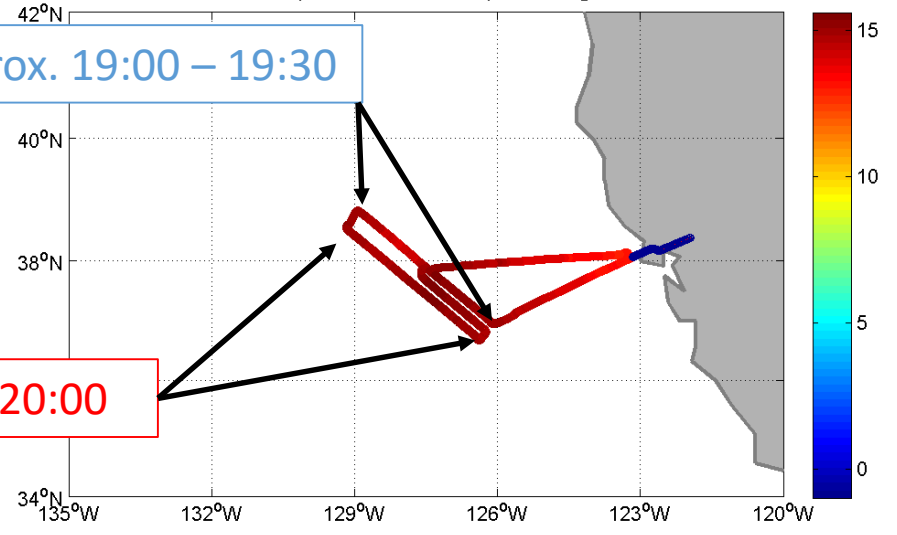
1. Converted from downward range gate to Earth relative height (ASL)
2. Removed aircraft vertical motion from radial velocities
3. Removed aircraft horizontal motion due to off-nadir beam pointing from radial velocities

W-band spectra are ready for boundary layer turbulence and raindrop size distribution retrieval studies.

05-February-2015

Leg 1 – approx. 19:00 – 19:30

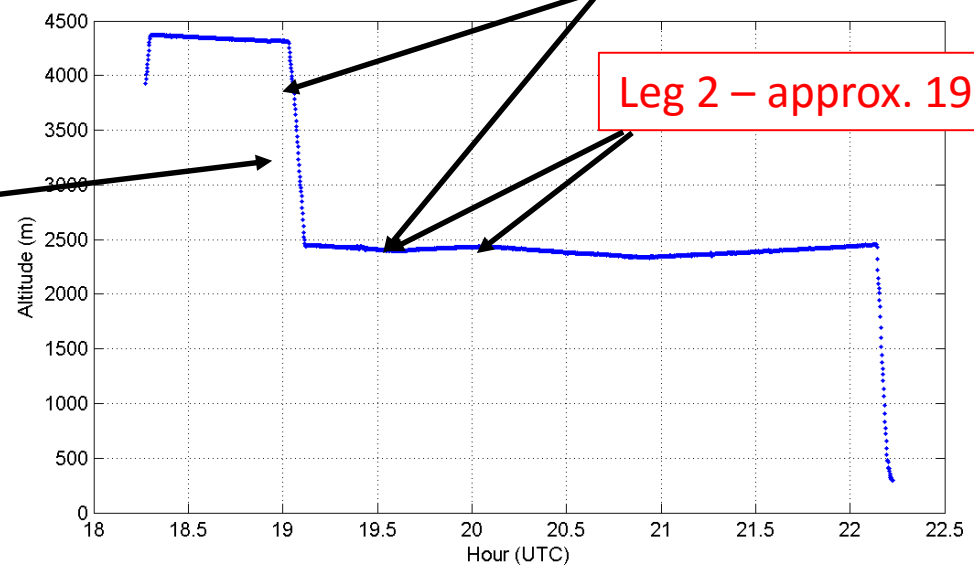
Leg 2 – approx. 19:30 – 20:00



Leg 1 – approx. 19:00 – 19:30

Leg 2 – approx. 19:30 – 20:00

Aircraft drops in altitude

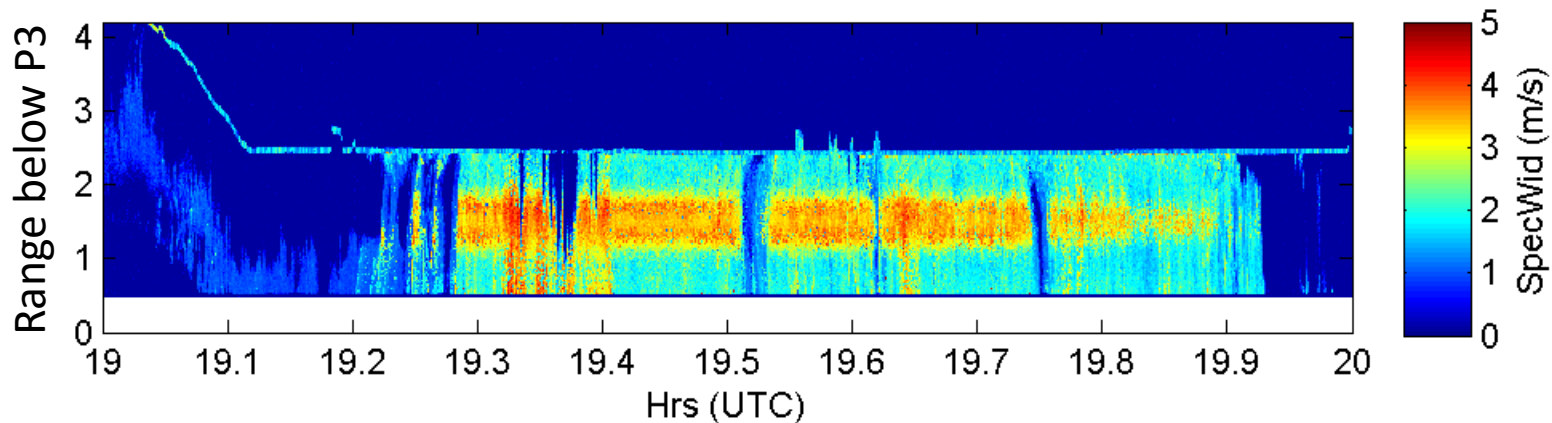
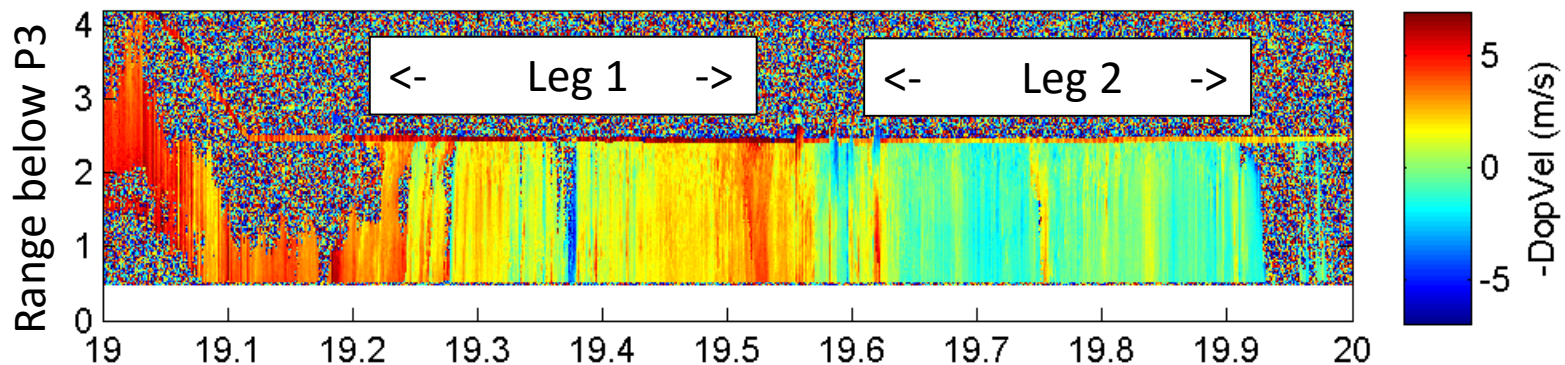
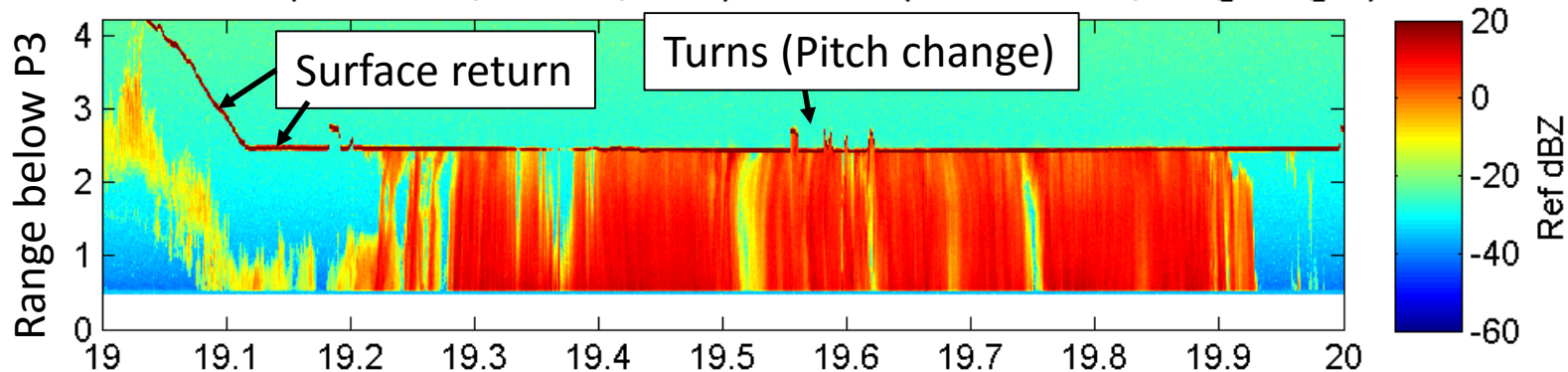


- Original Radar Observations
- Hour 19 UTC
- Range below aircraft

CALWATER2 (2015-02-05, DOY036, Hr-19). W-Band (motionread=1, Kongsberg=0)

Hour 19 UTC

Aircraft is at 0



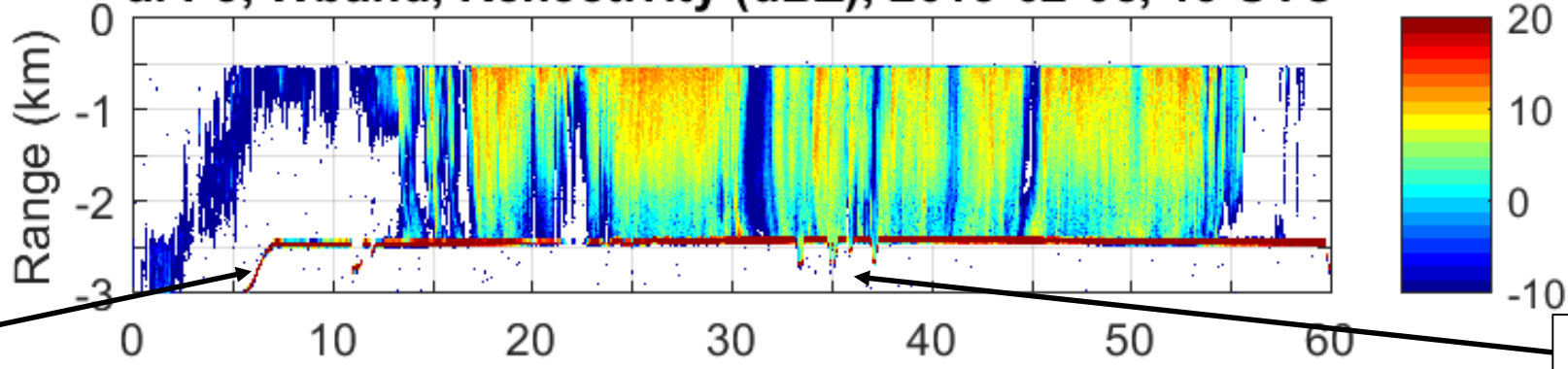
Aircraft is at 0

Nadir pointing radar

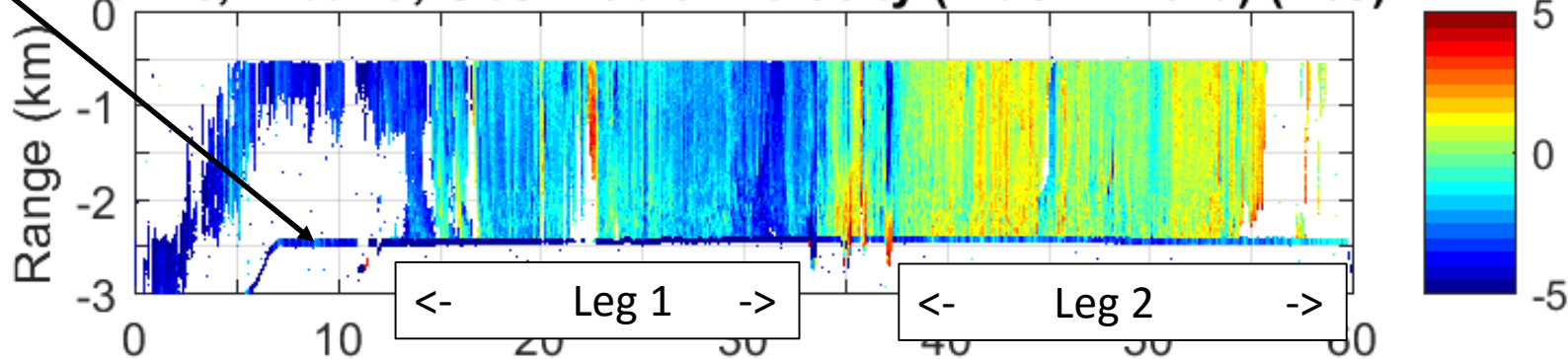
Surface return

Turns (Pitch change)

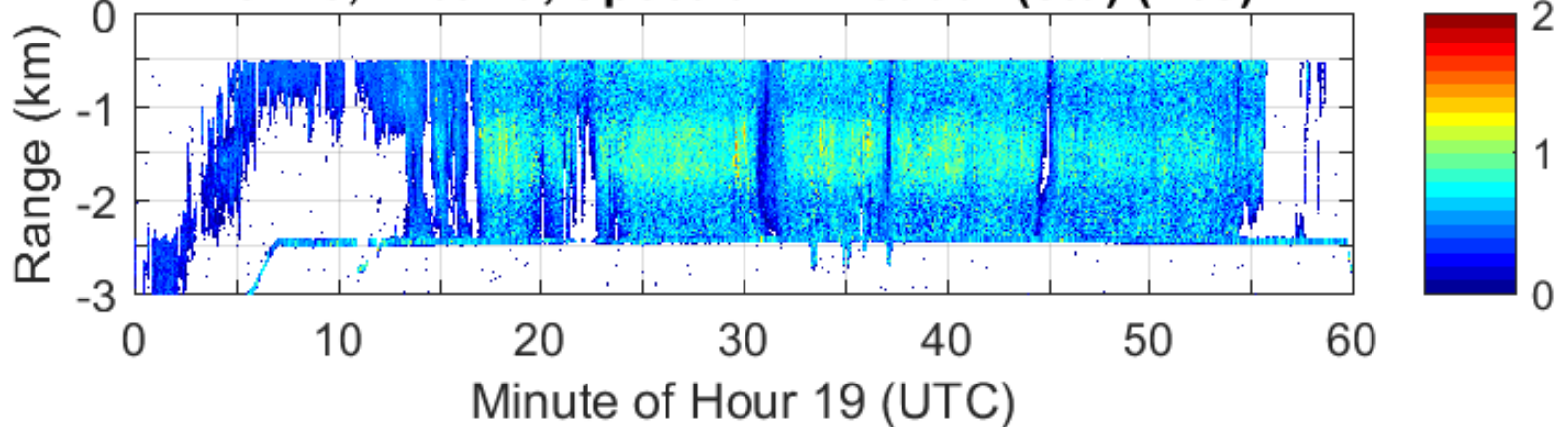
a. P3, Wband, Reflectivity (dBZ), 2015-02-05, 19 UTC



b. P3, Wband, Obs. Radial Velocity (+ downward) (m/s)

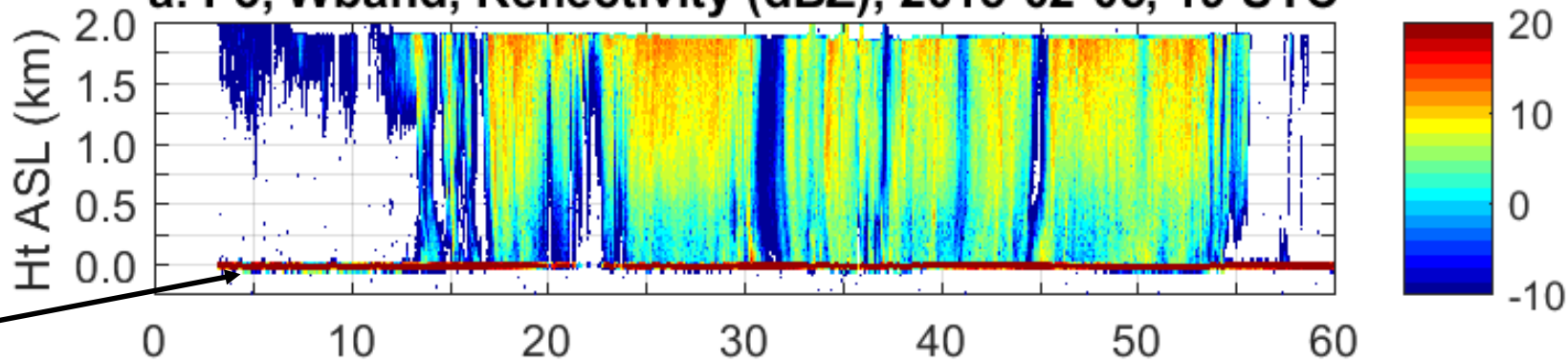


c. P3, Wband, Spectrum Breadth (std) (m/s)



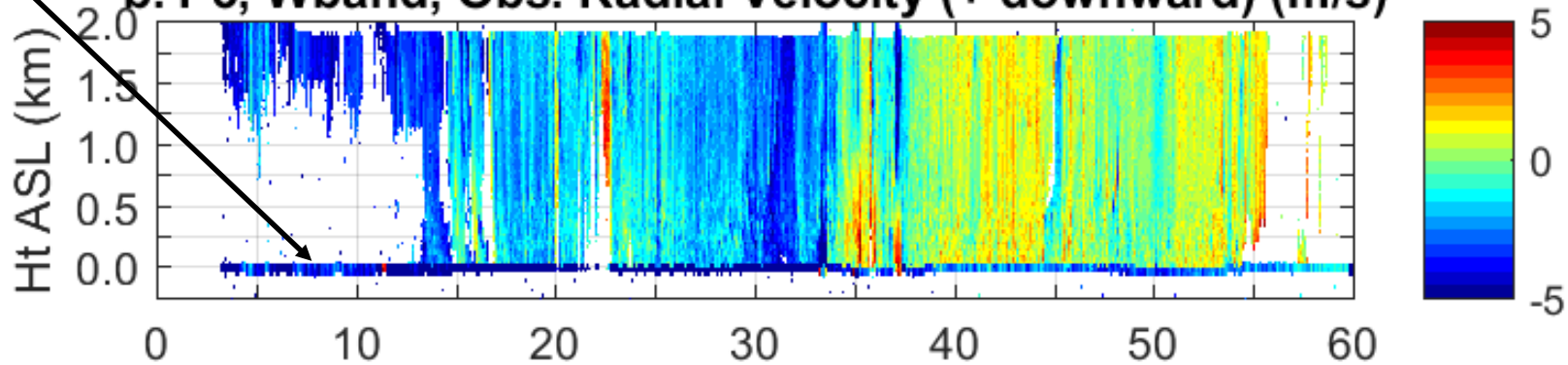
- Original Radar Observations
- Surface Detection
- Plot Height Above Sea Level (ASL)
- Hour 19 UTC

a. P3, Wband, Reflectivity (dBZ), 2015-02-05, 19 UTC

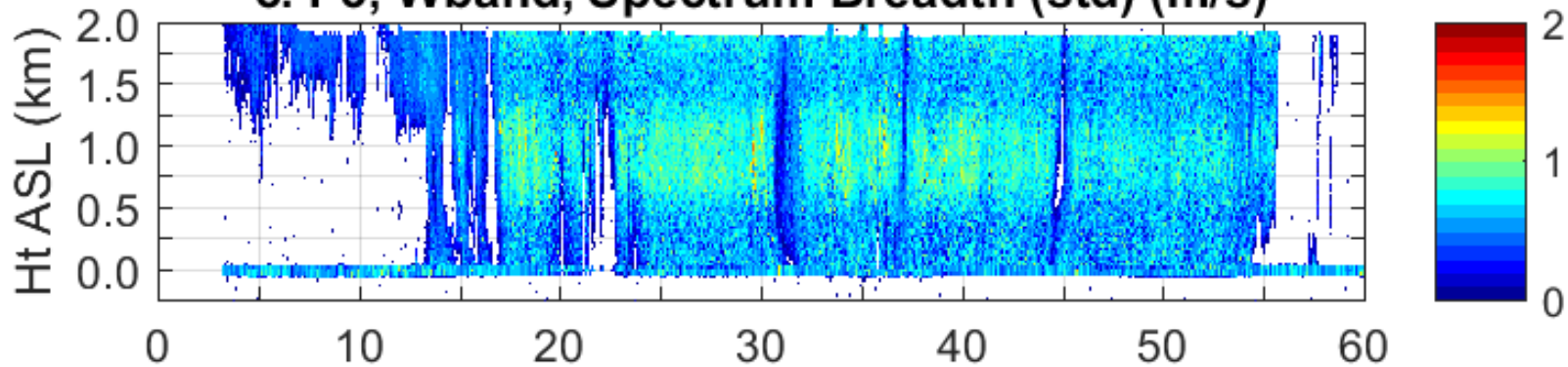


Surface return

b. P3, Wband, Obs. Radial Velocity (+ downward) (m/s)

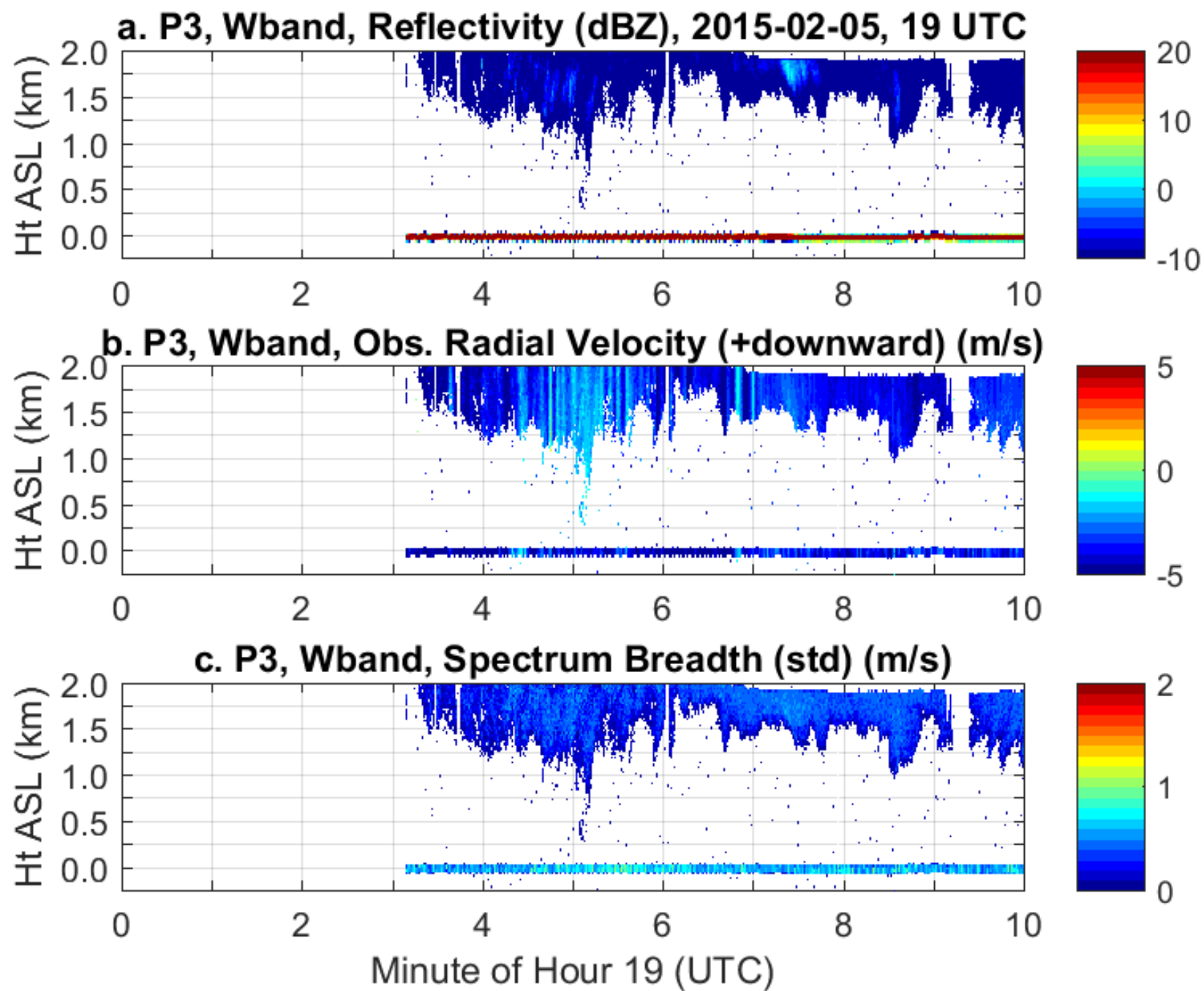


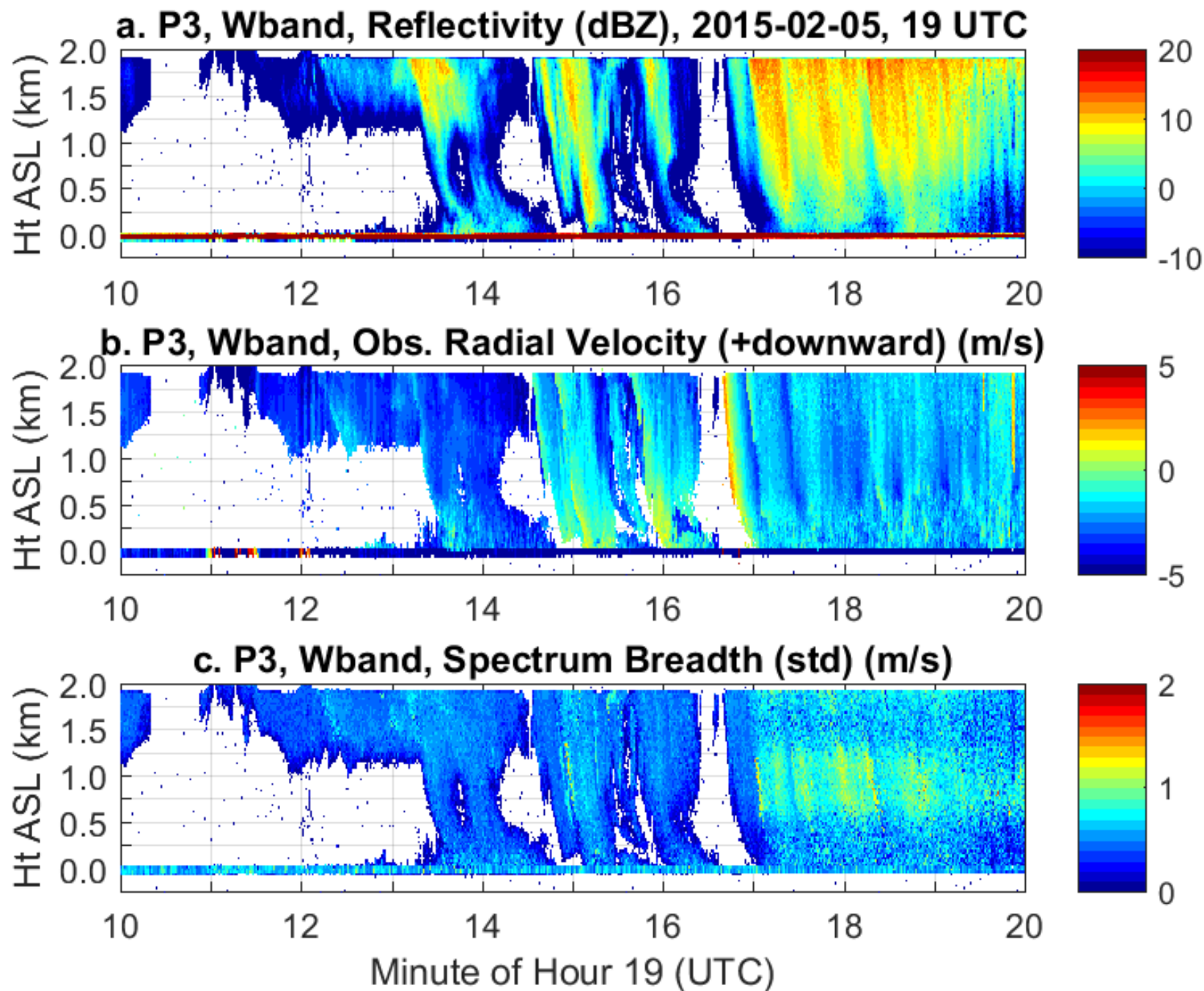
c. P3, Wband, Spectrum Breadth (std) (m/s)

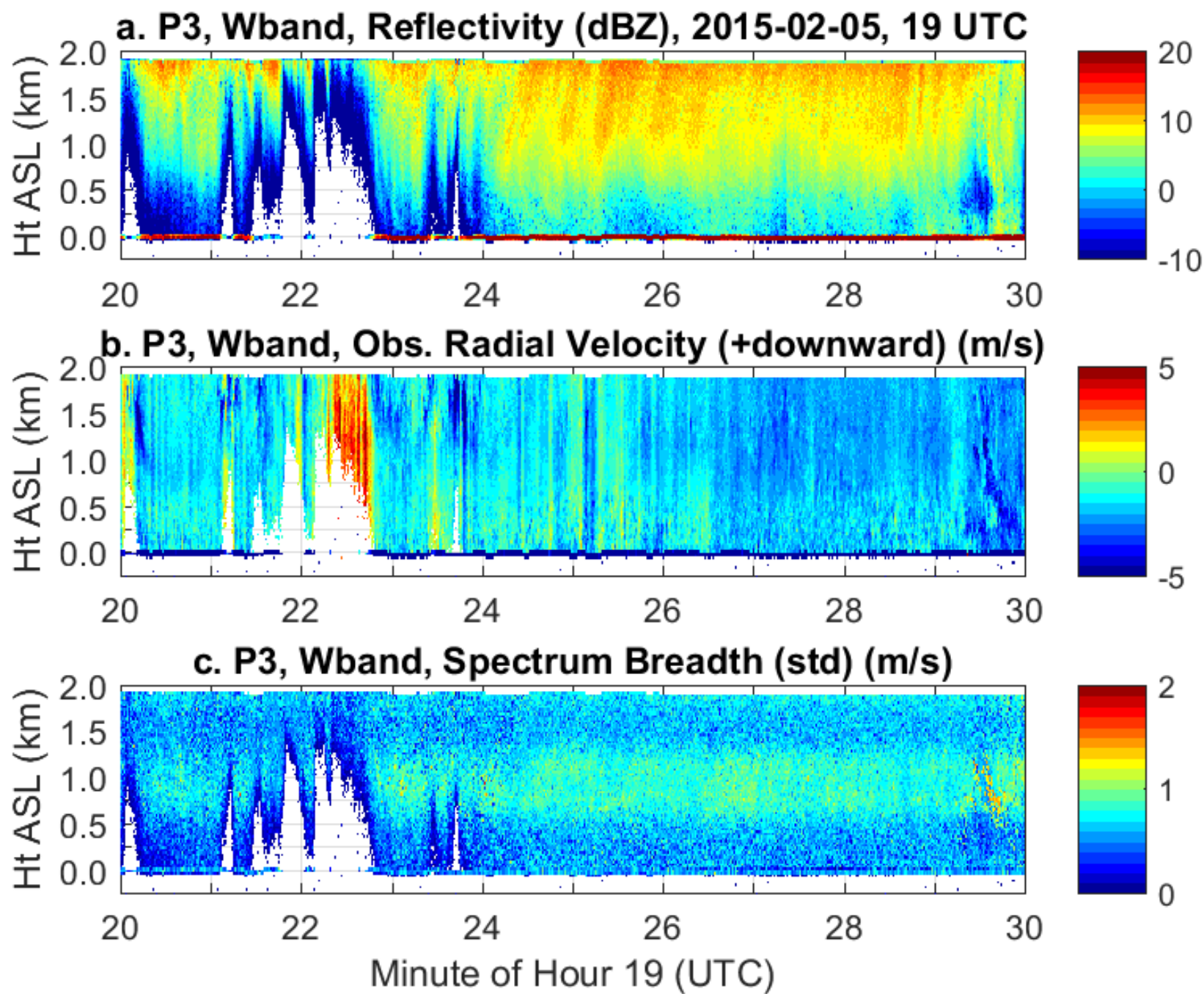


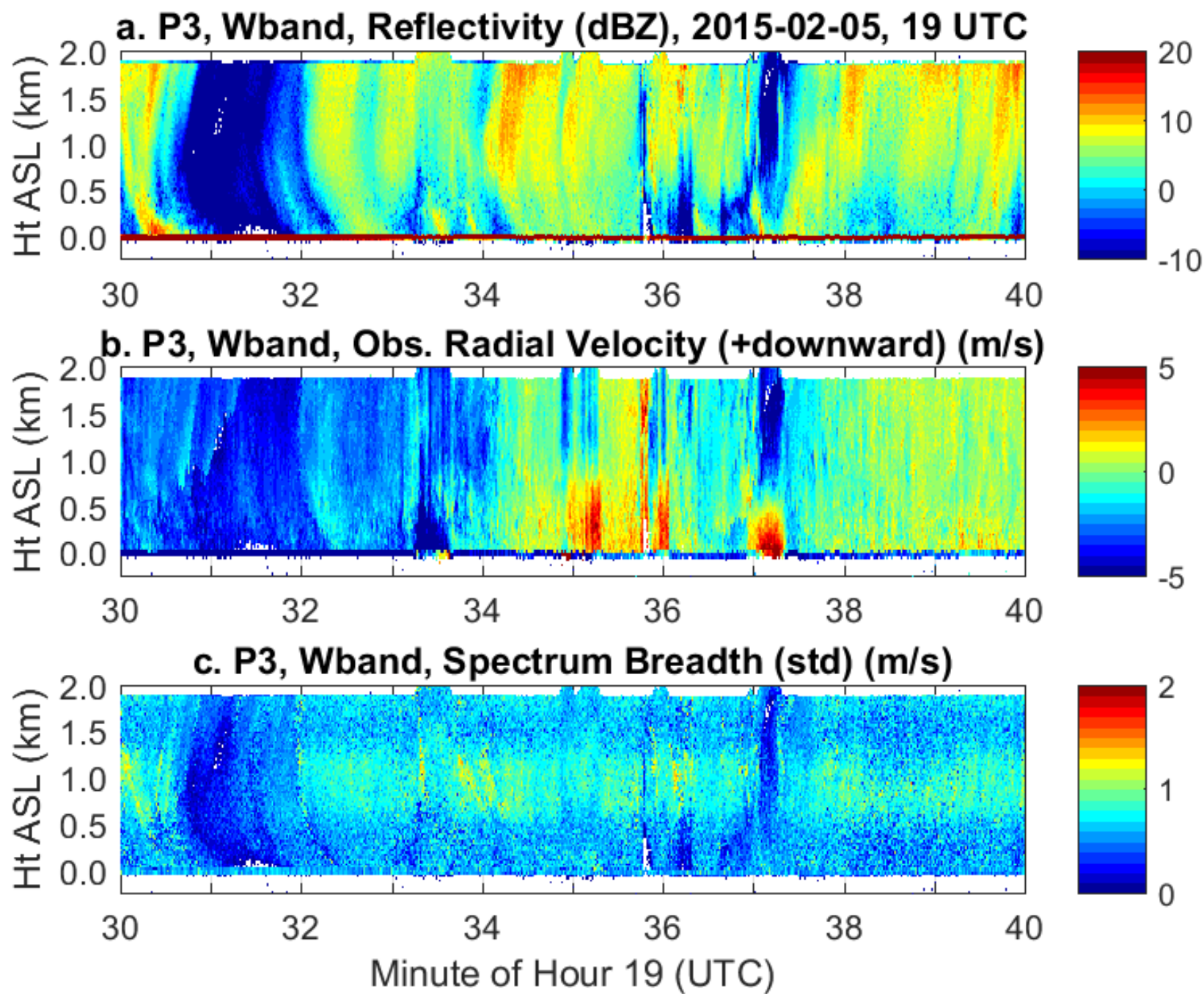
Minute of Hour 19 (UTC)

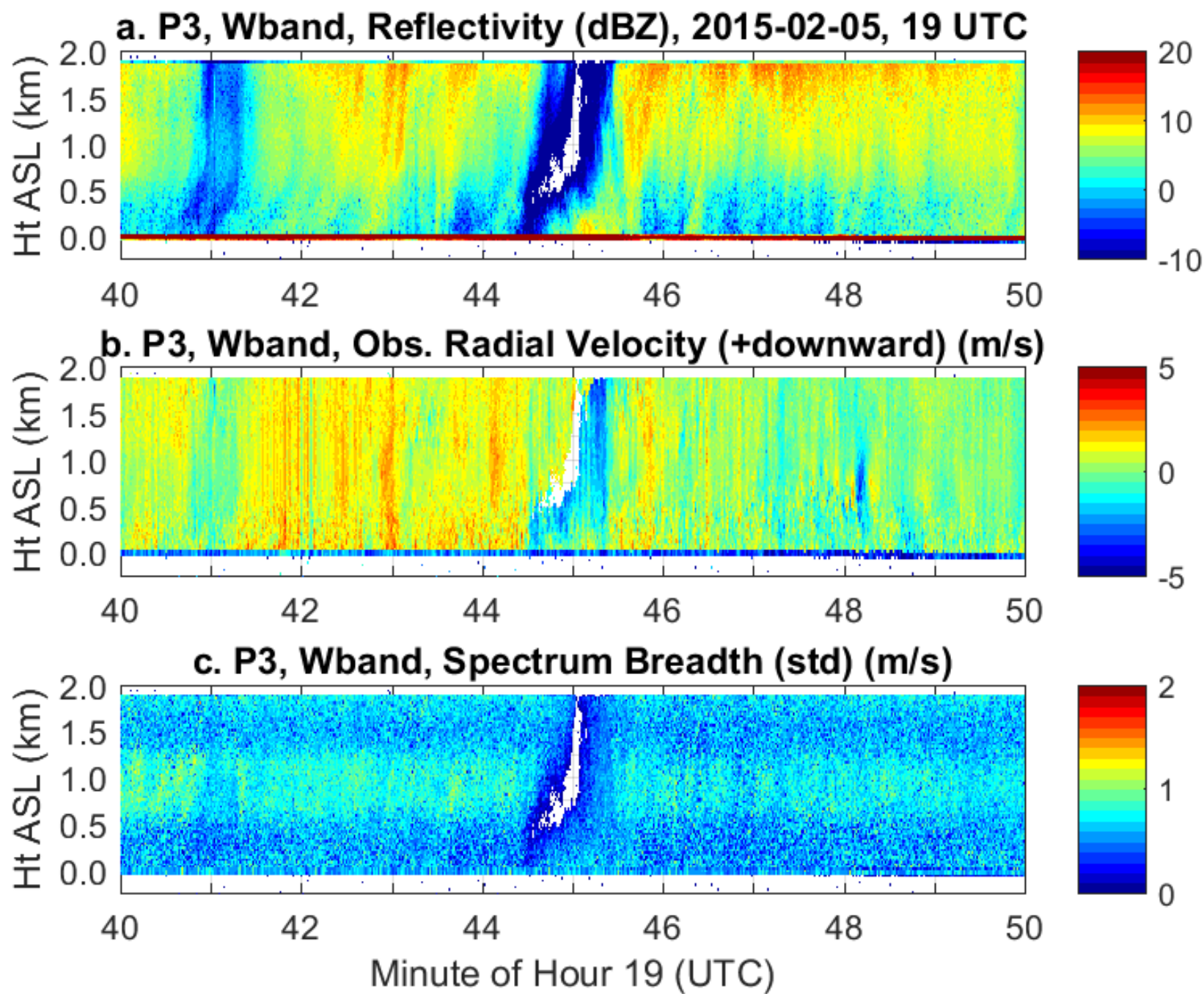
- Original Radar Observations
- Plot Height Above Sea Level (ASL)
- 10 minute sections of Hour 19

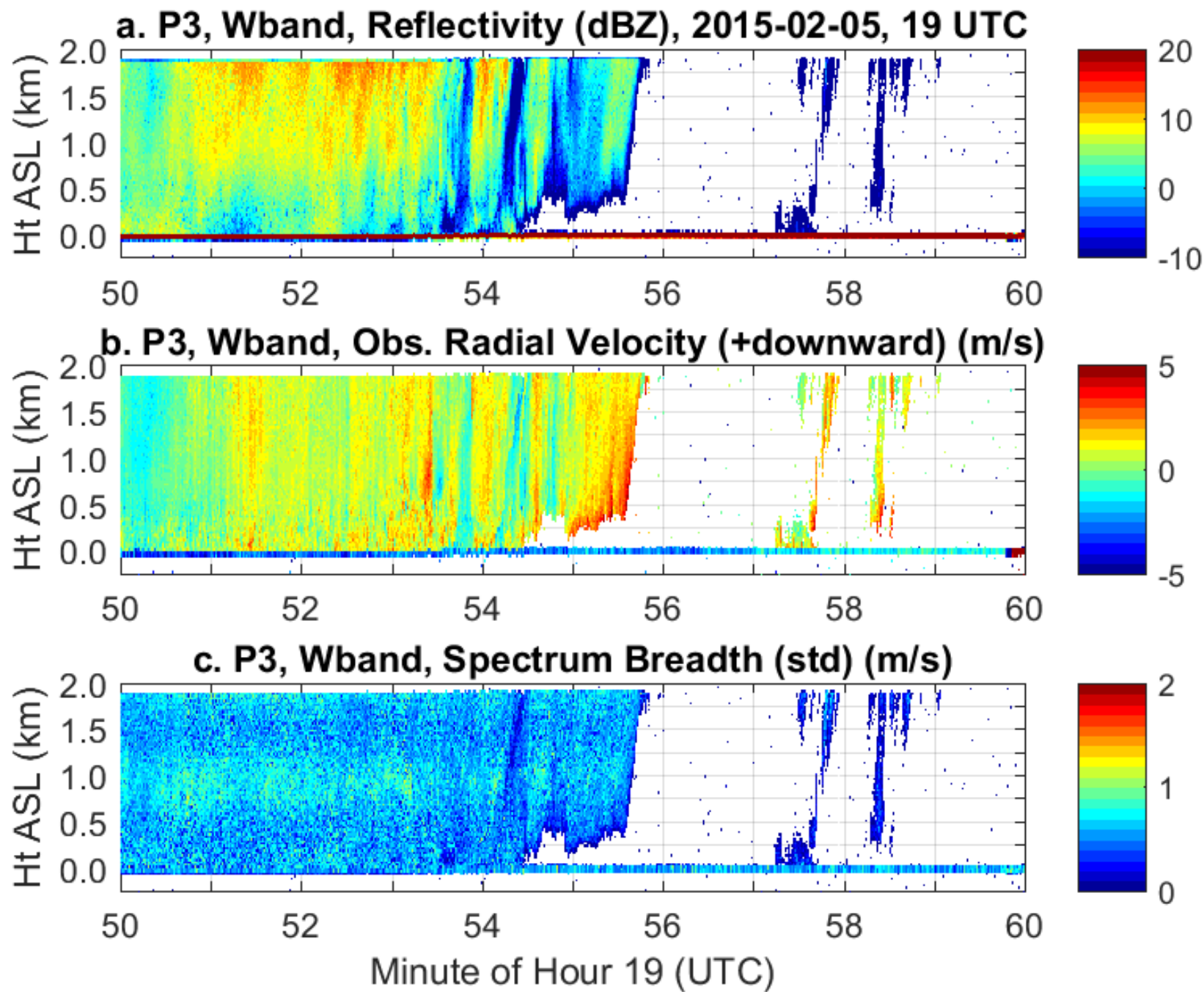












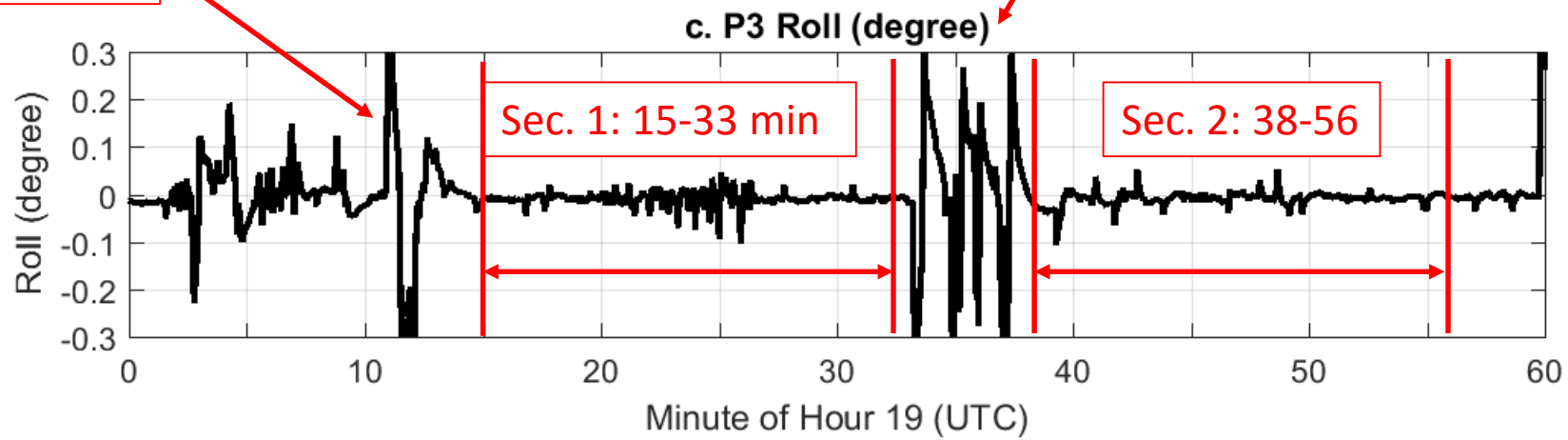
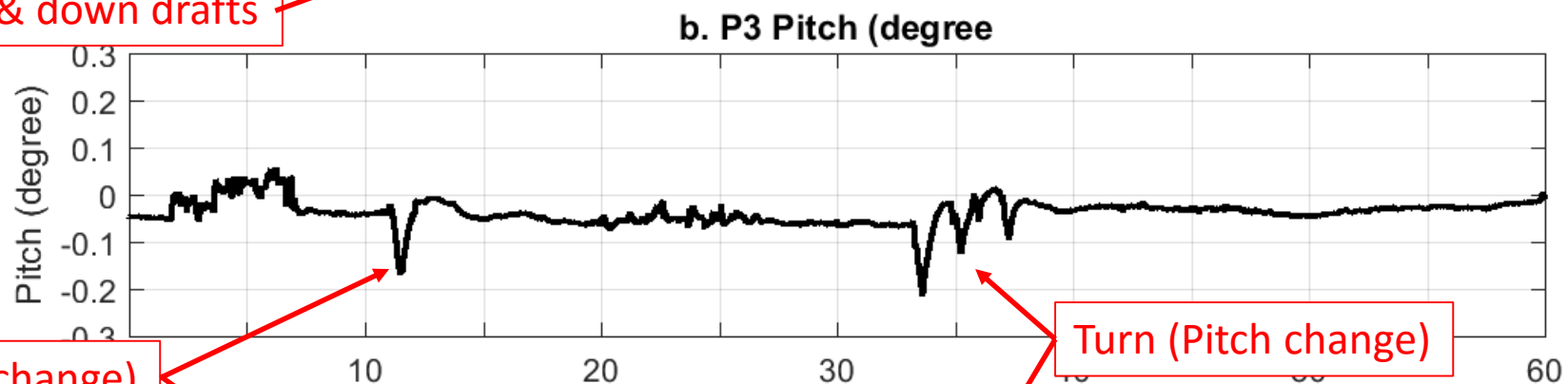
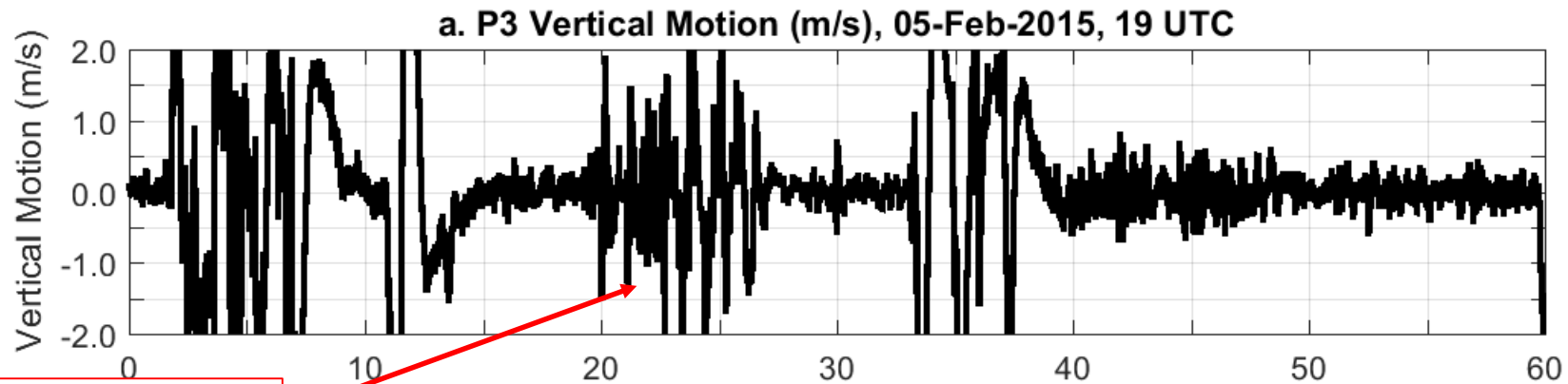
- Kongsberg Sensor

- Vertical Motion, Pitch, and Roll

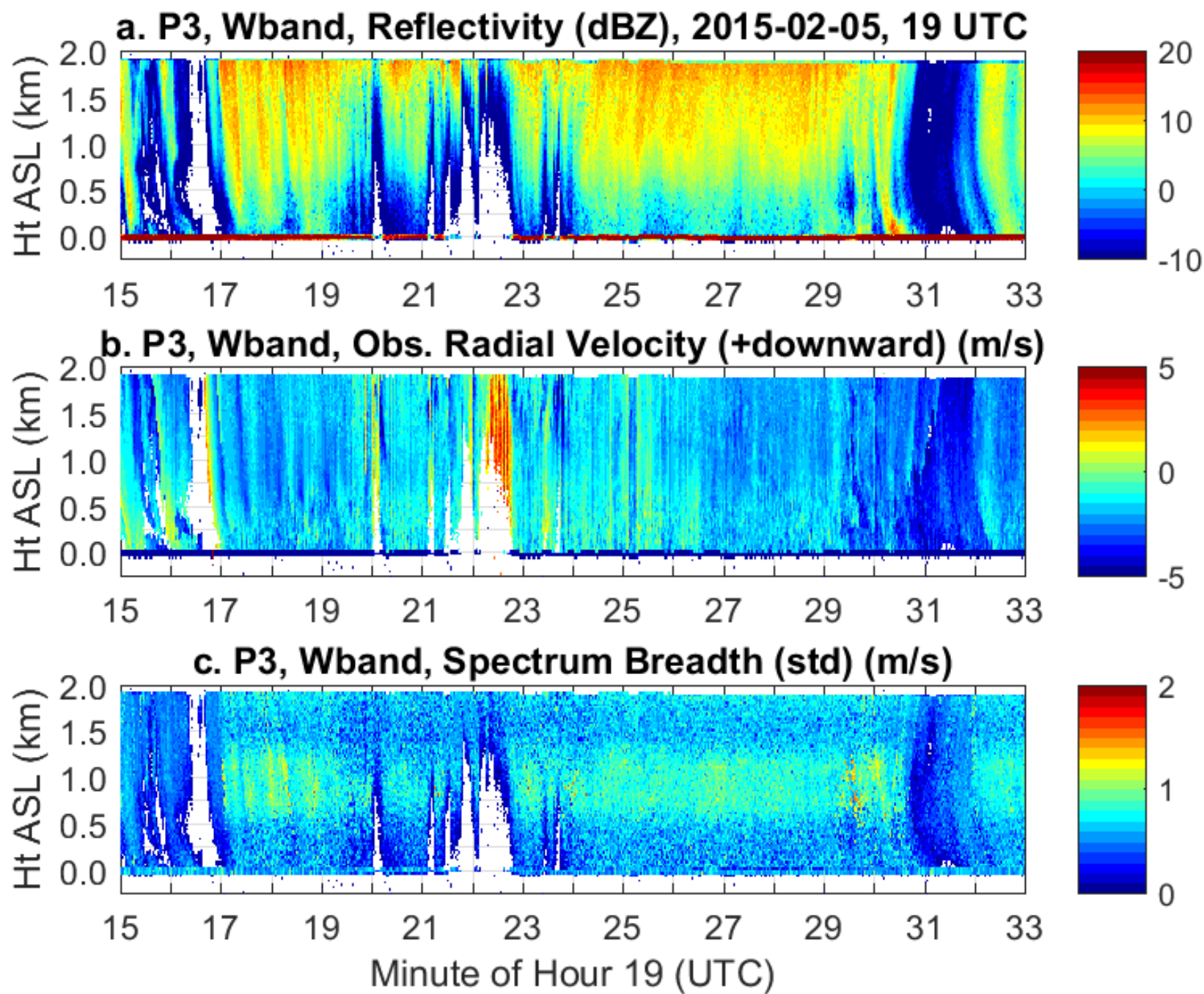
Define Steady Flight Segments

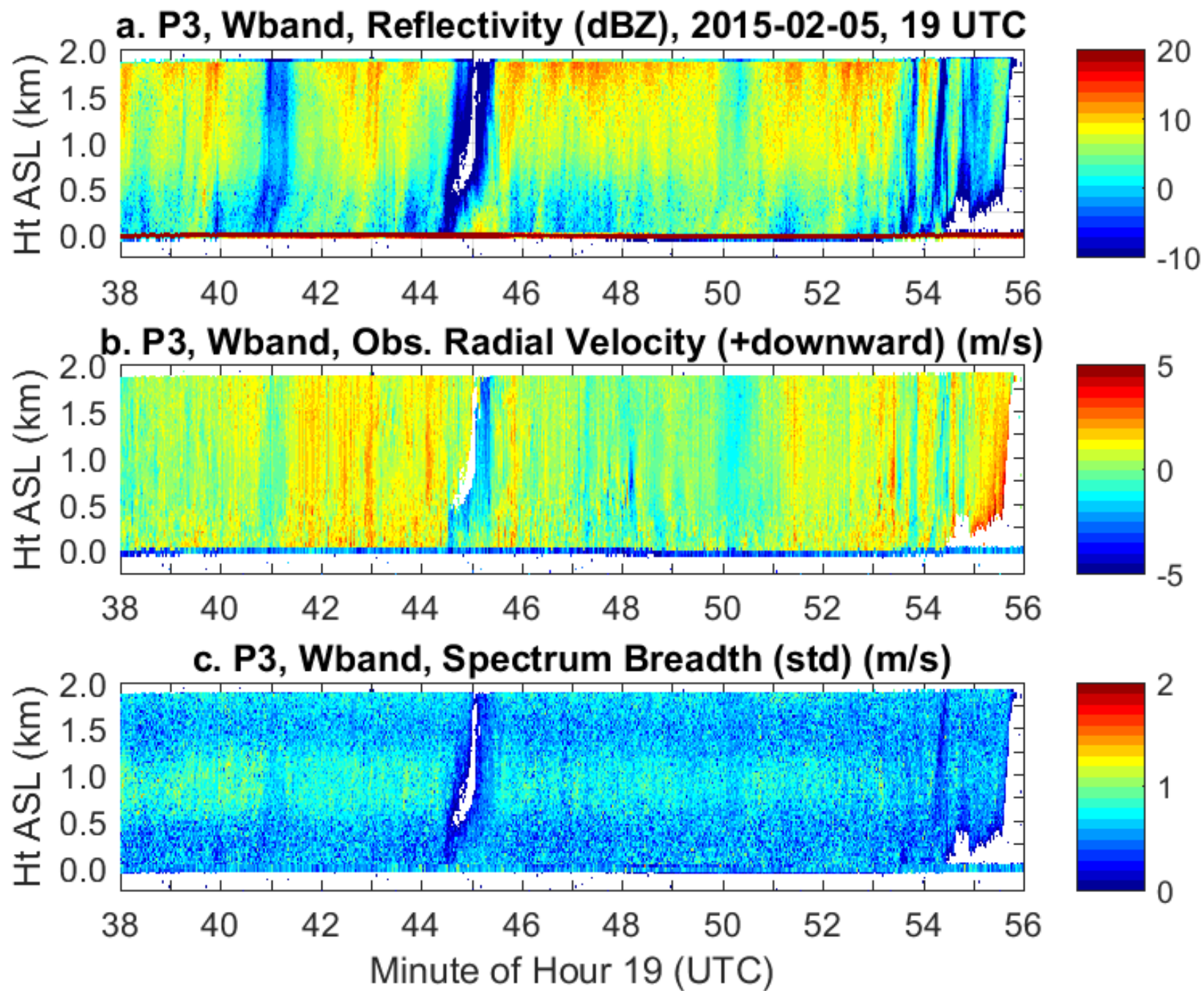
- minutes 15-to-33 (18 min duration)

- minutes 38-to-56 (18 min duration)



- Original Observations
- Steady Flight Segments
 - minutes 15-to-33 (18 min duration)
 - minutes 38-to-56 (18 min duration)





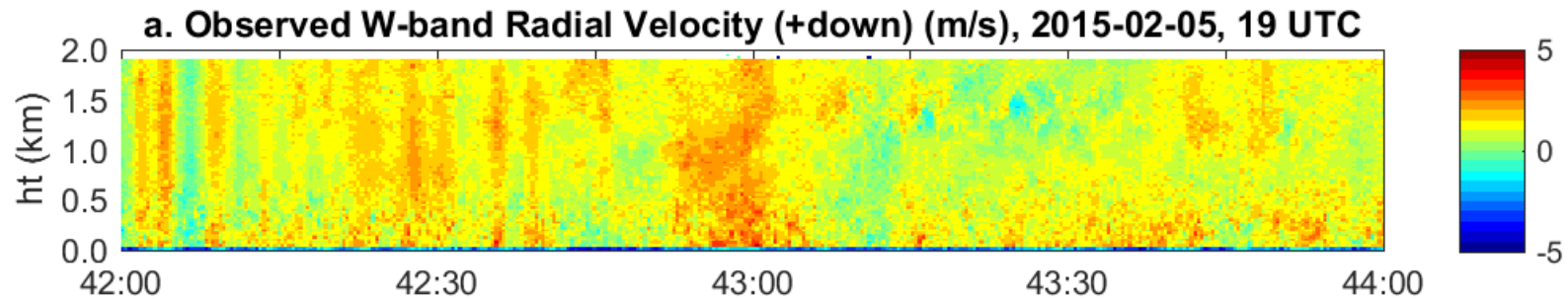
-Removing aircraft motion in velocity
Kongsberg vertical motion

vs.

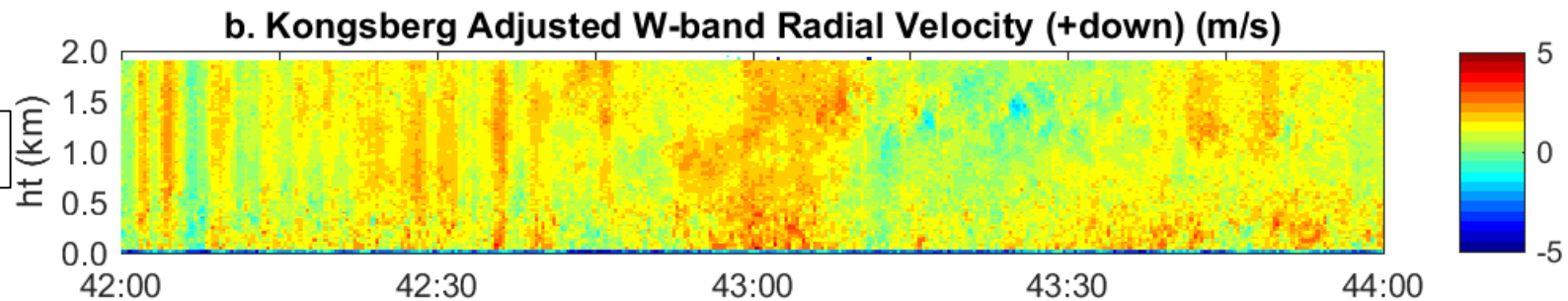
High Pass Column Mean (HPCM)
velocity (16 second period cutoff)

It is better to use the High Pass Column Mean to estimate aircraft motion than using the Kongsberg vertical motion estimates.

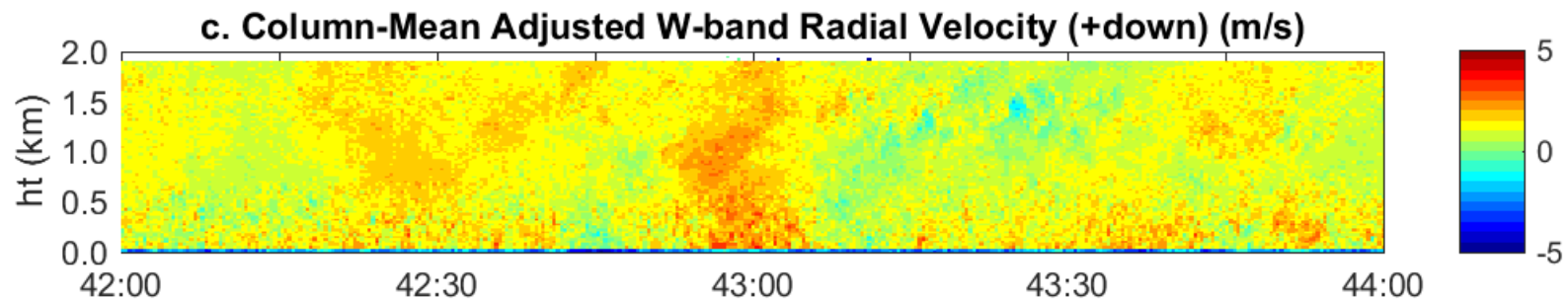
Original Velocity



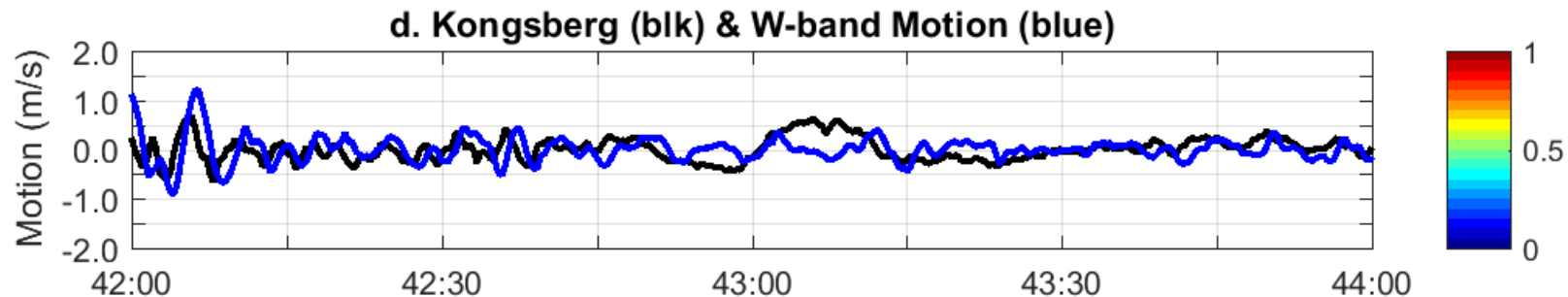
Kongsberg adjusted



HPCM adjusted



Kongsberg motion & HPCM motion



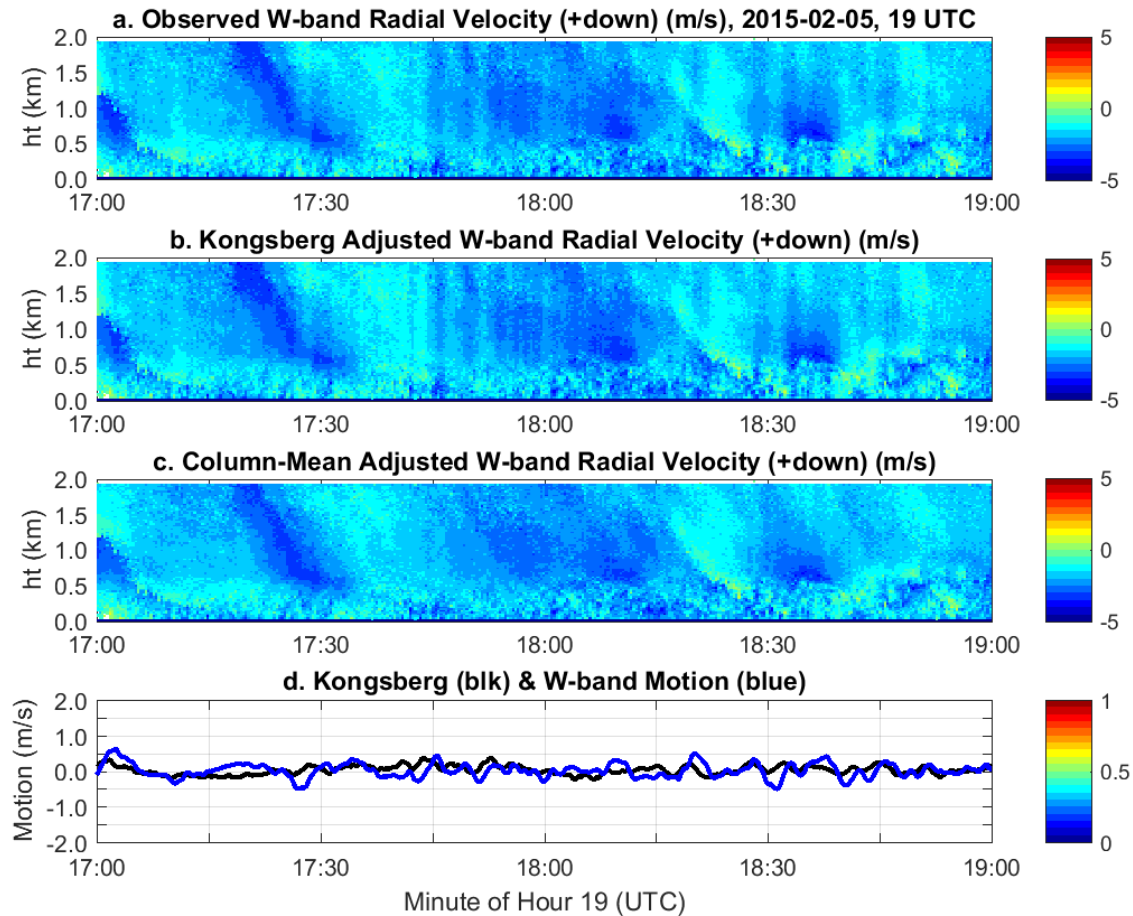
HPCM = High Pass Column Mean

Minute of Hour 19 (UTC)

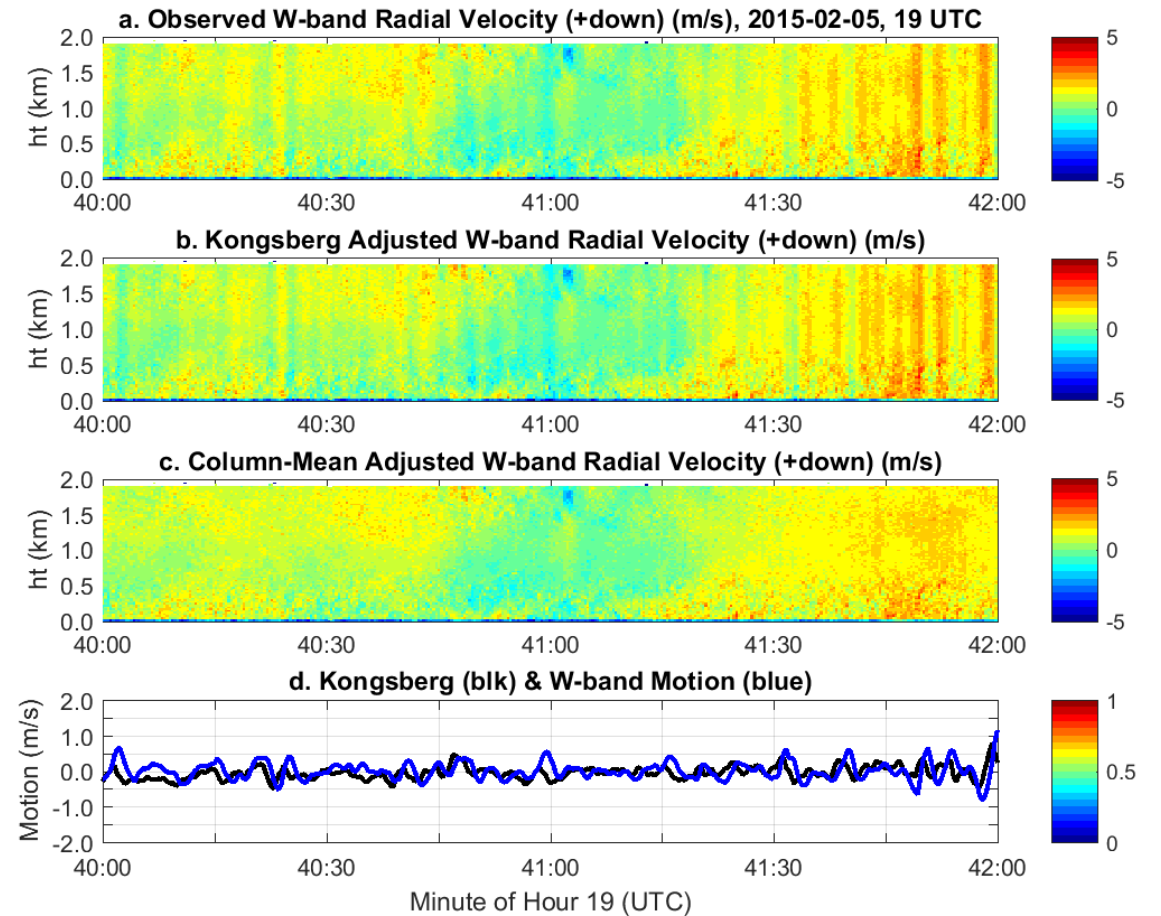
- Mean Radial Velocities are shifted for Leg 1 and Leg 2
- I believe this is because the radar beam is not pointing straight down such that aircraft motion is being projected into radial velocities

Example of radial velocities for Leg 1 and Leg 2

Section 1 – Minutes 17 & 18.
Radial velocities are **upward**

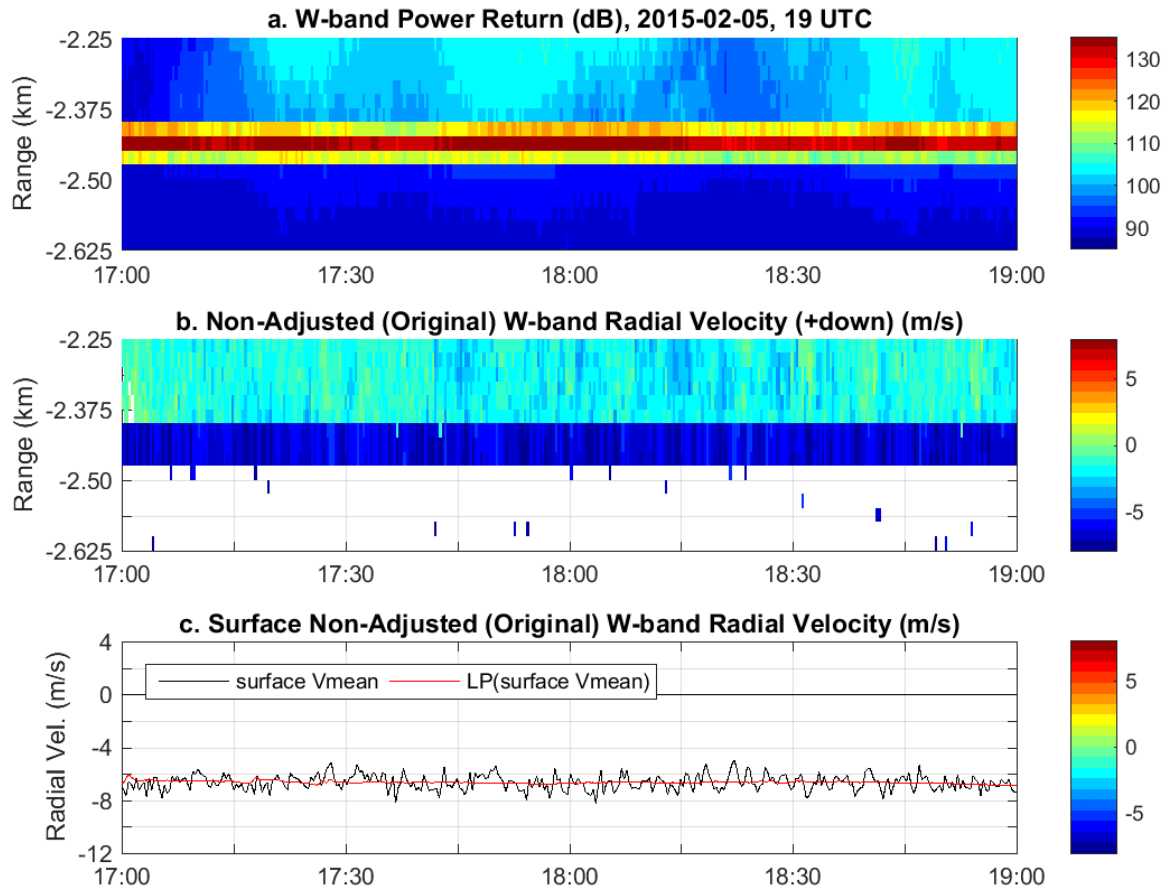


Section 2 – Minutes 40 & 41.
Radial velocities are **downward**

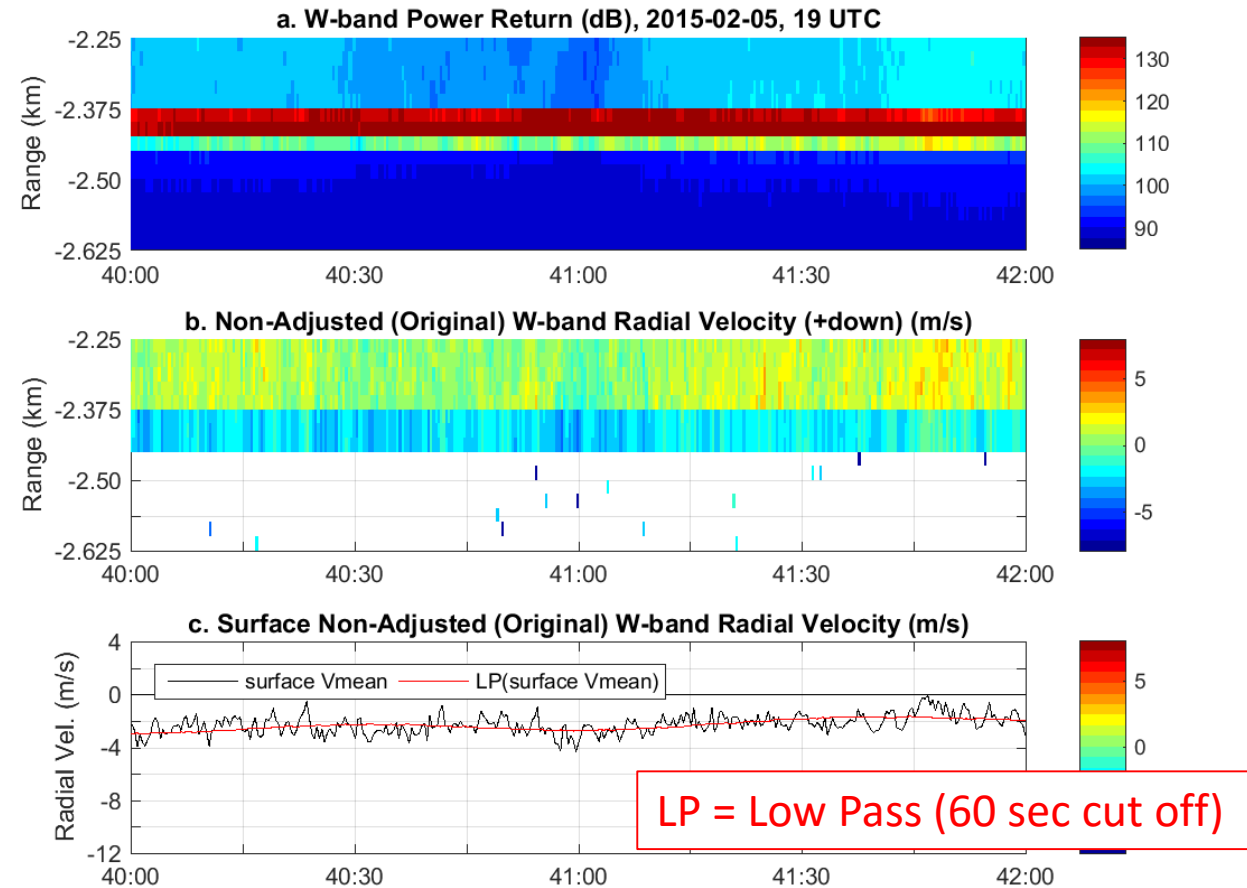


Surface return mean radial velocities are different for Leg 1 and Leg 2

Section 1 – Minutes 17 & 18.
Surface Return Power and Radial Velocities



Section 2 – Minutes 40 & 41.
Surface Return Power and Radial Velocities



Note that surface radial velocities are different for Section 1 and 2 (which correspond to Leg 1 and Leg 2)

-Surface Radial Velocity contains 3 components:

- Aircraft motion
- Nadir beam pointing error
- Surface wave structure

$$V_{\text{surface}} = V(\text{aircraft}) + V(\text{Nadir beam pointing error}) + V(\text{surface waves}) + V(\text{other})$$

Can the surface motion be used to account for aircraft vertical motion?

-Compare Aircraft vertical Motions:

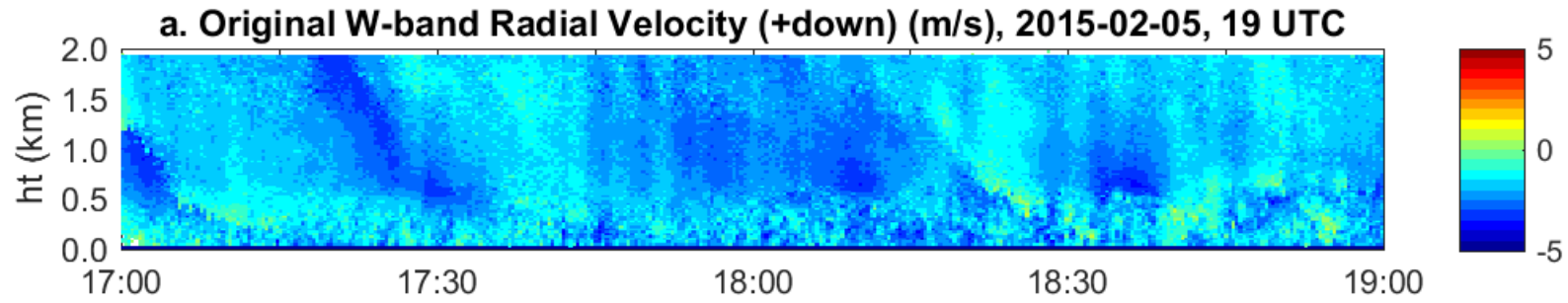
-High Pass Column Mean Velocity

VS.

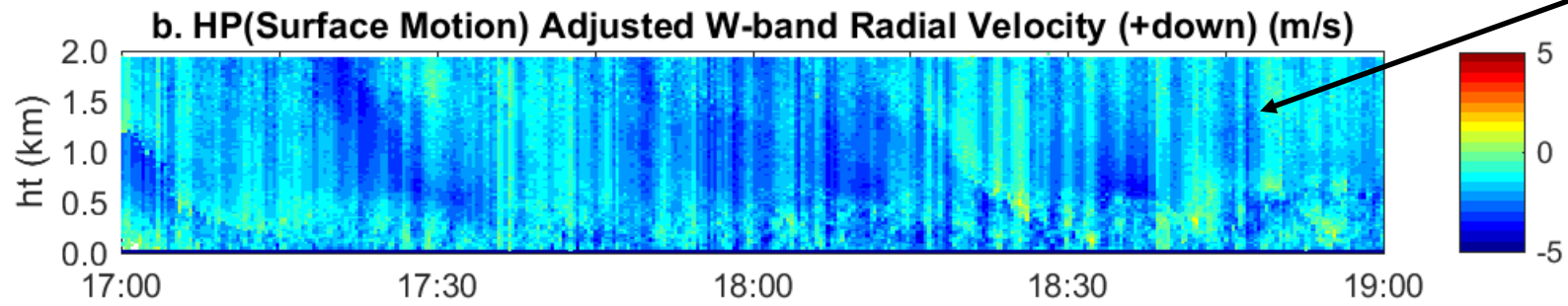
-High Pass Surface Velocity

No. The surface velocity contains high frequency variations that are not due to aircraft motion. **Therefore, use High Pass Column Mean Velocity to account for aircraft motion.**

Original Velocity

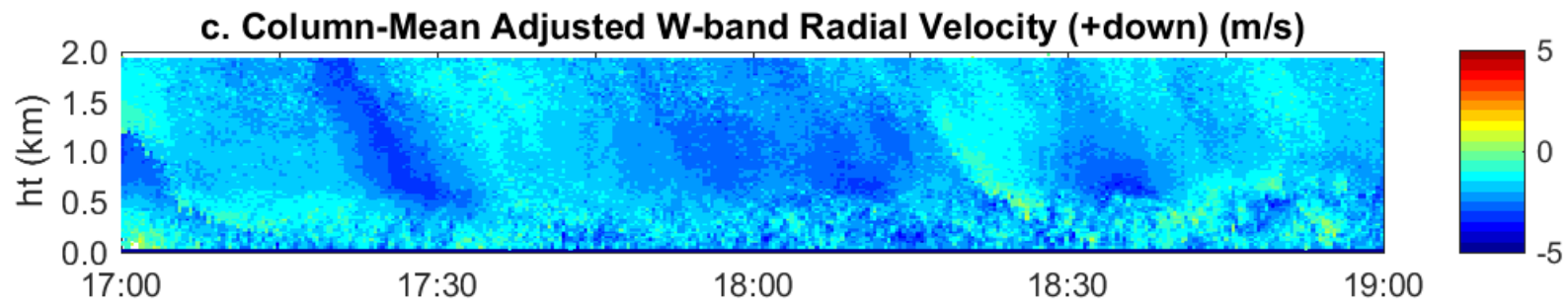


HP Surface velocity adjusted

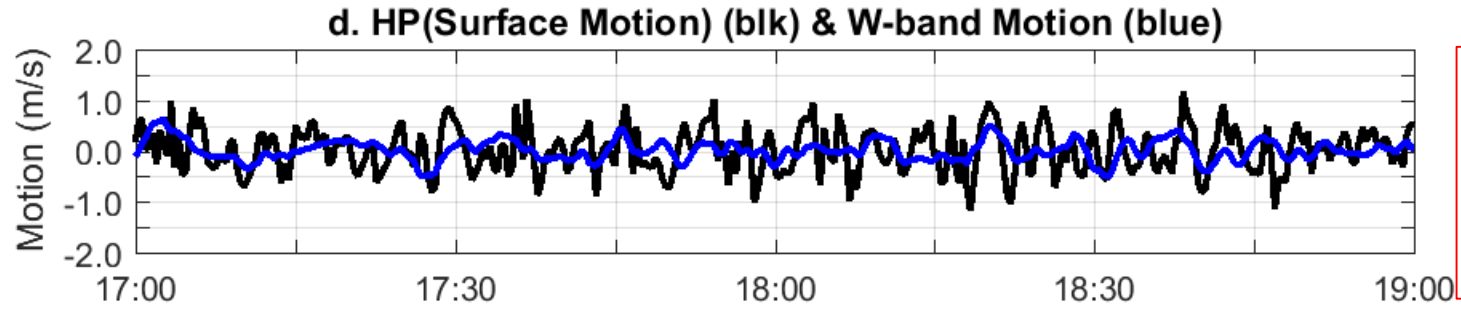


Adjusting radial velocity with HP Surface Motion projects surface wave variations into radial velocities.

HP Column Mean Velocity adjusted



HP Surface motion & HPCM motion



Variations in HP Surface Motion are due to surface wave structure

HP = High Pass with 16 second period cutoff

Minute of Hour 19 (UTC)

Can the surface motion be used to account for off-Nadir Beam Pointing Error?

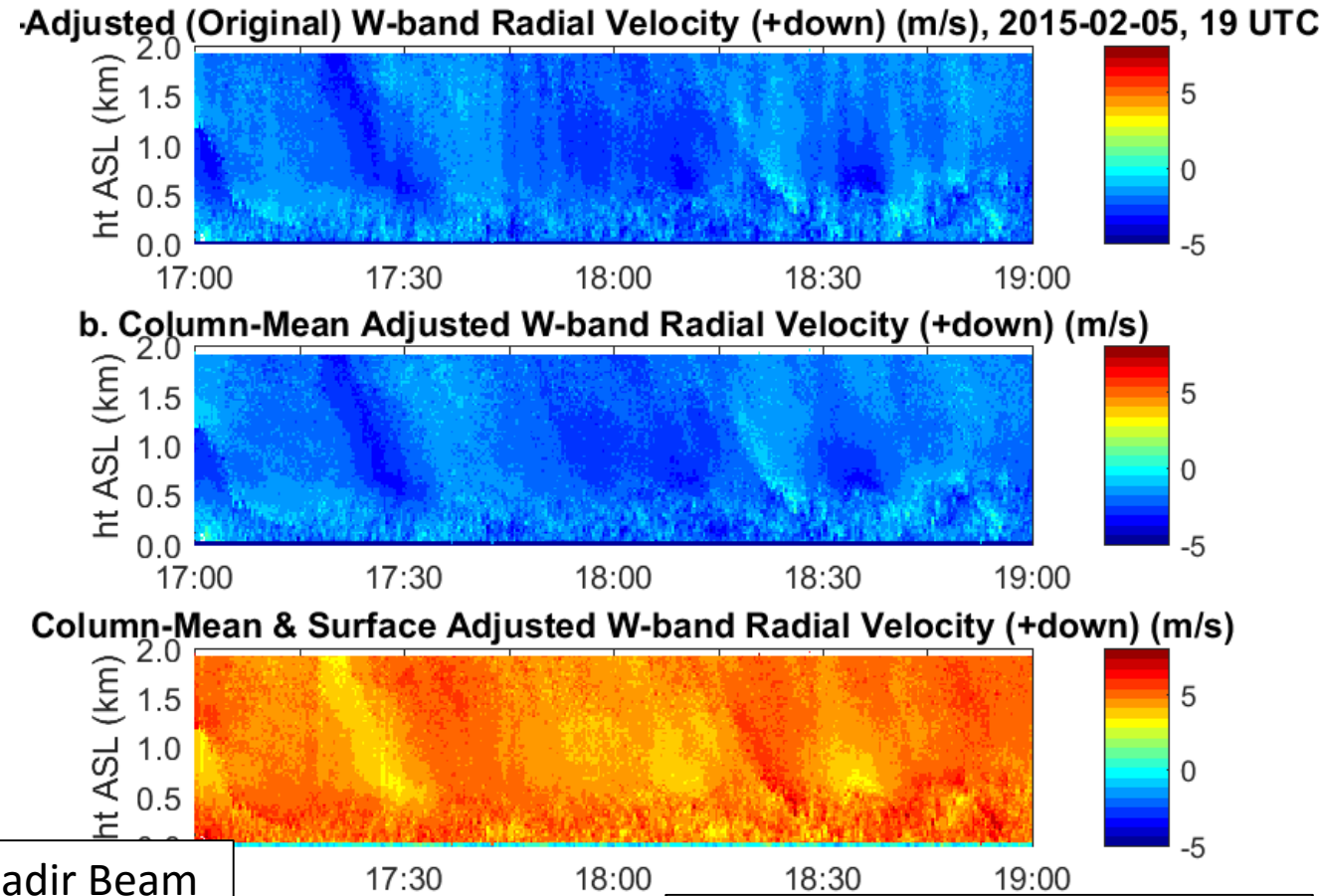
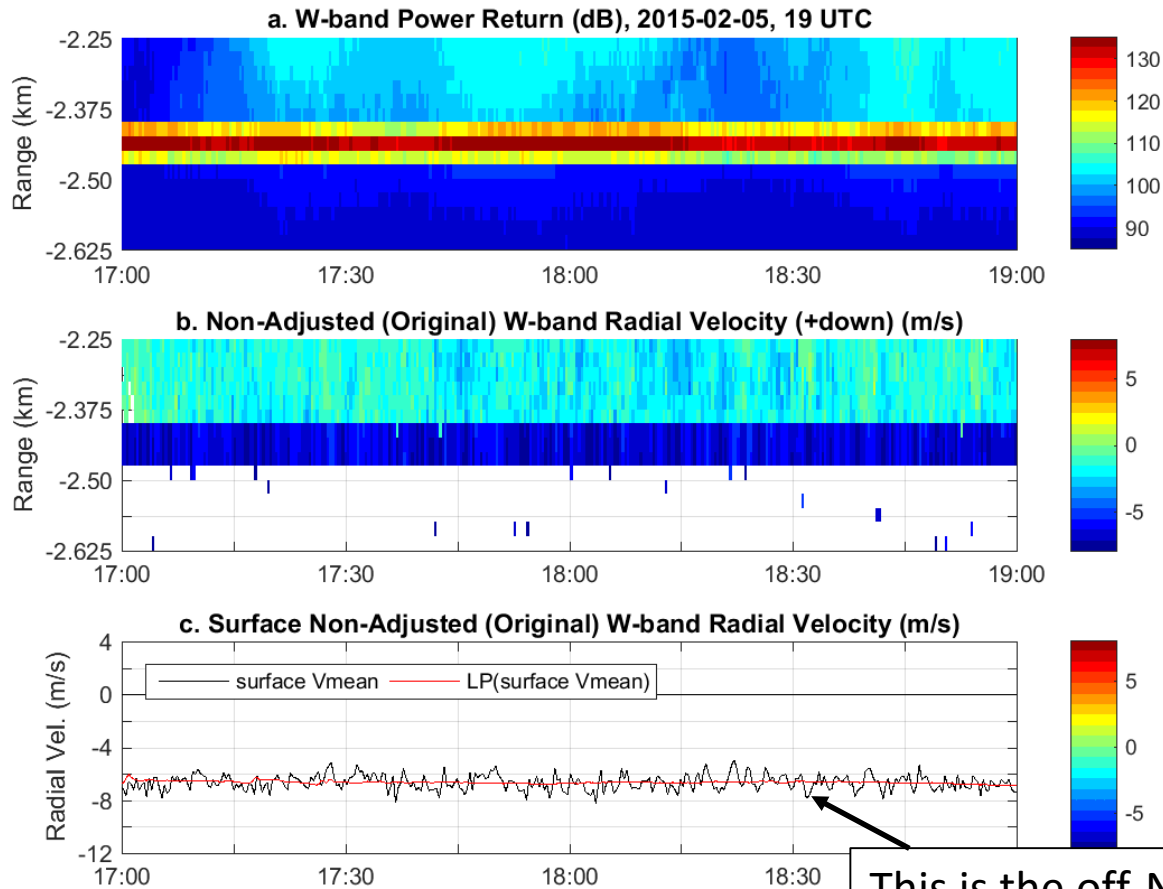
(Aircraft horizontal motion is projected into radial velocities for off-Nadir beams.)

- Low Pass filter Surface Velocity
(60 second period cutoff)

Yes. The Low Pass filtered surface velocity can account for off-nadir beam pointing error.

Section 1 – Minutes 17 & 18.
Surface Return Power and Radial Velocities

Adjust Observed Radial Velocities:
- Aircraft motion (HP Column Mean)
- Off-Nadir Beam Pointing error (LP surface motion)



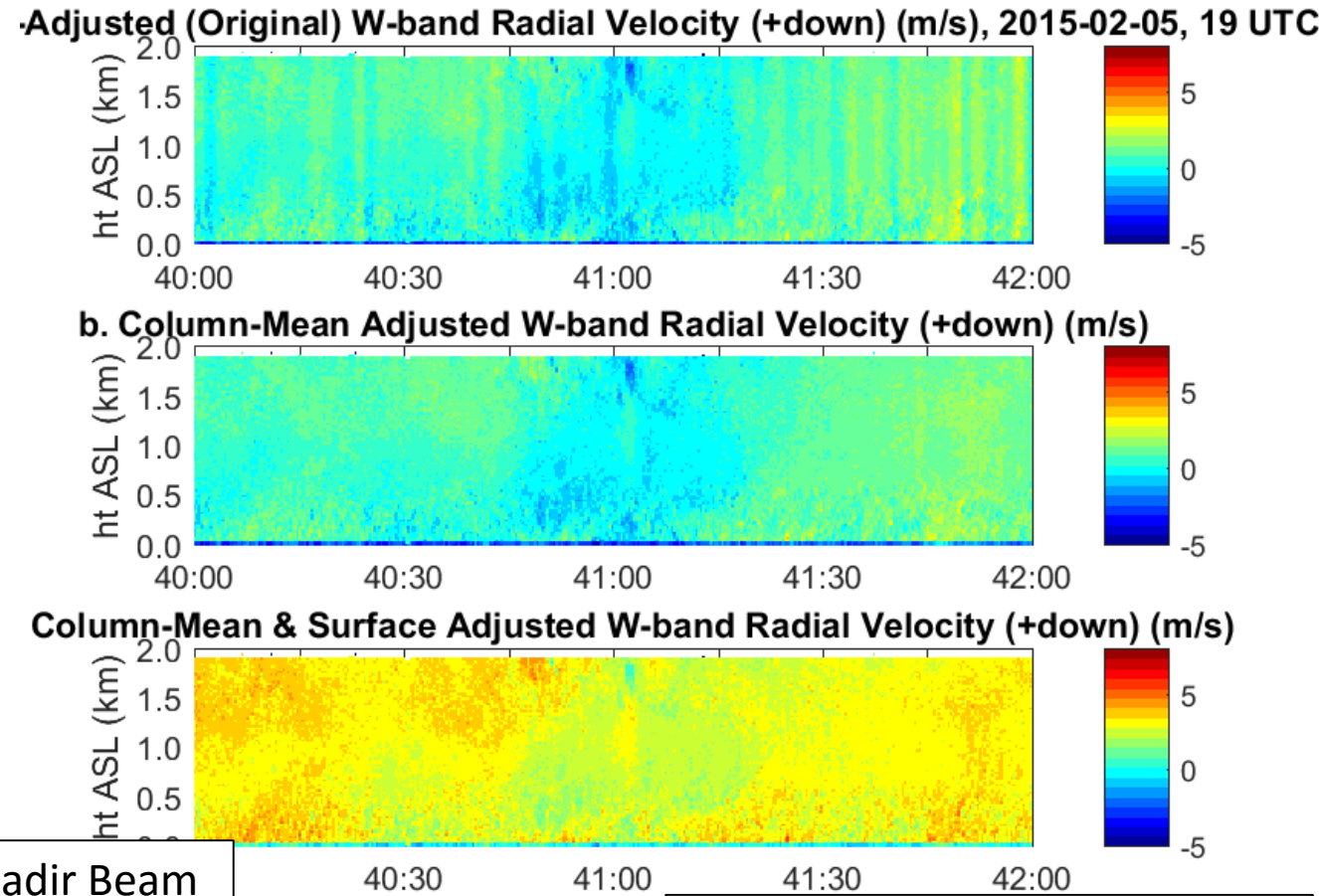
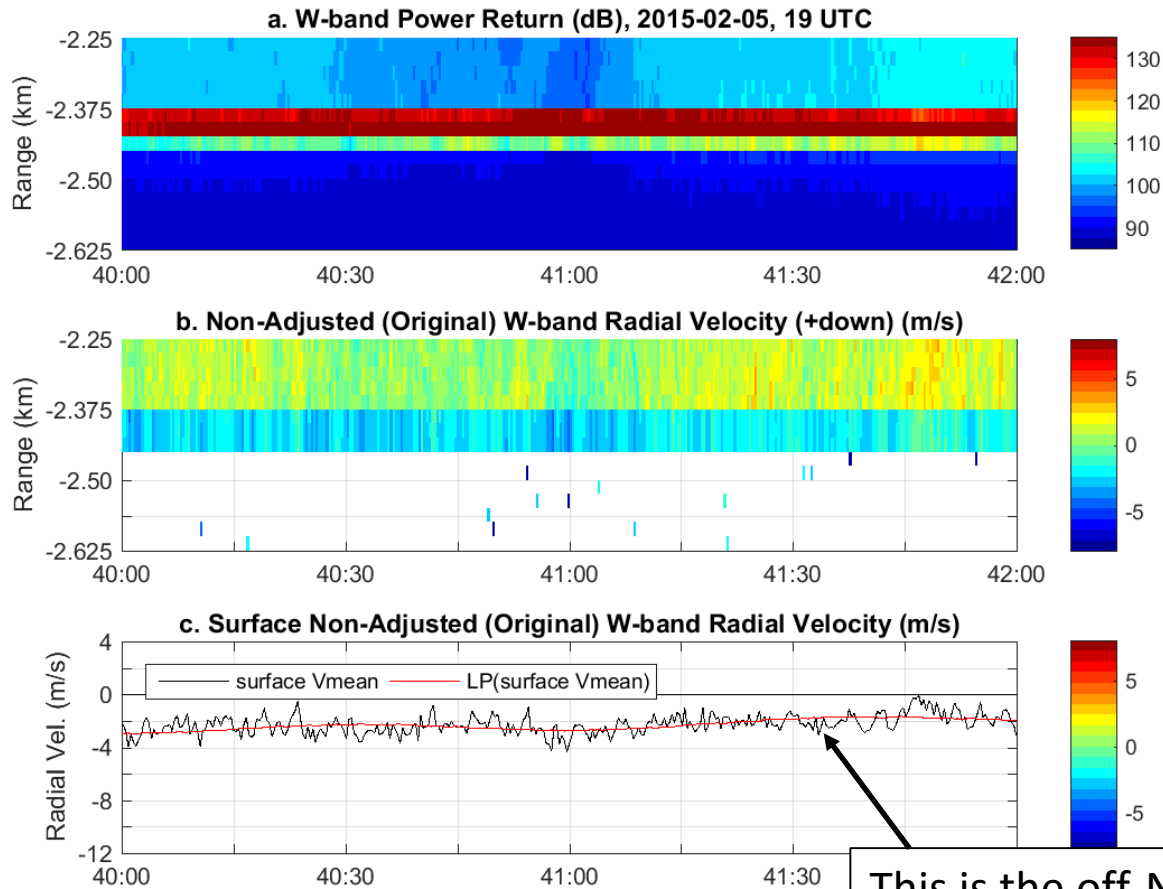
LP = Low Pass (60 sec cut off)

This is the off-Nadir Beam Pointing adjustment

Radial velocities are downward

Section 2 – Minutes 40 & 41.
Surface Return Power and Radial Velocities

Adjust Observed Radial Velocities:
- Aircraft motion (HP Column Mean)
- Off-Nadir Beam Pointing error (LP surface motion)



LP = Low Pass (60 sec cut off)

This is the off-Nadir Beam Pointing adjustment

Radial velocities are downward

Now that aircraft vertical motion and horizontal motion have been removed from radial velocity, plot:

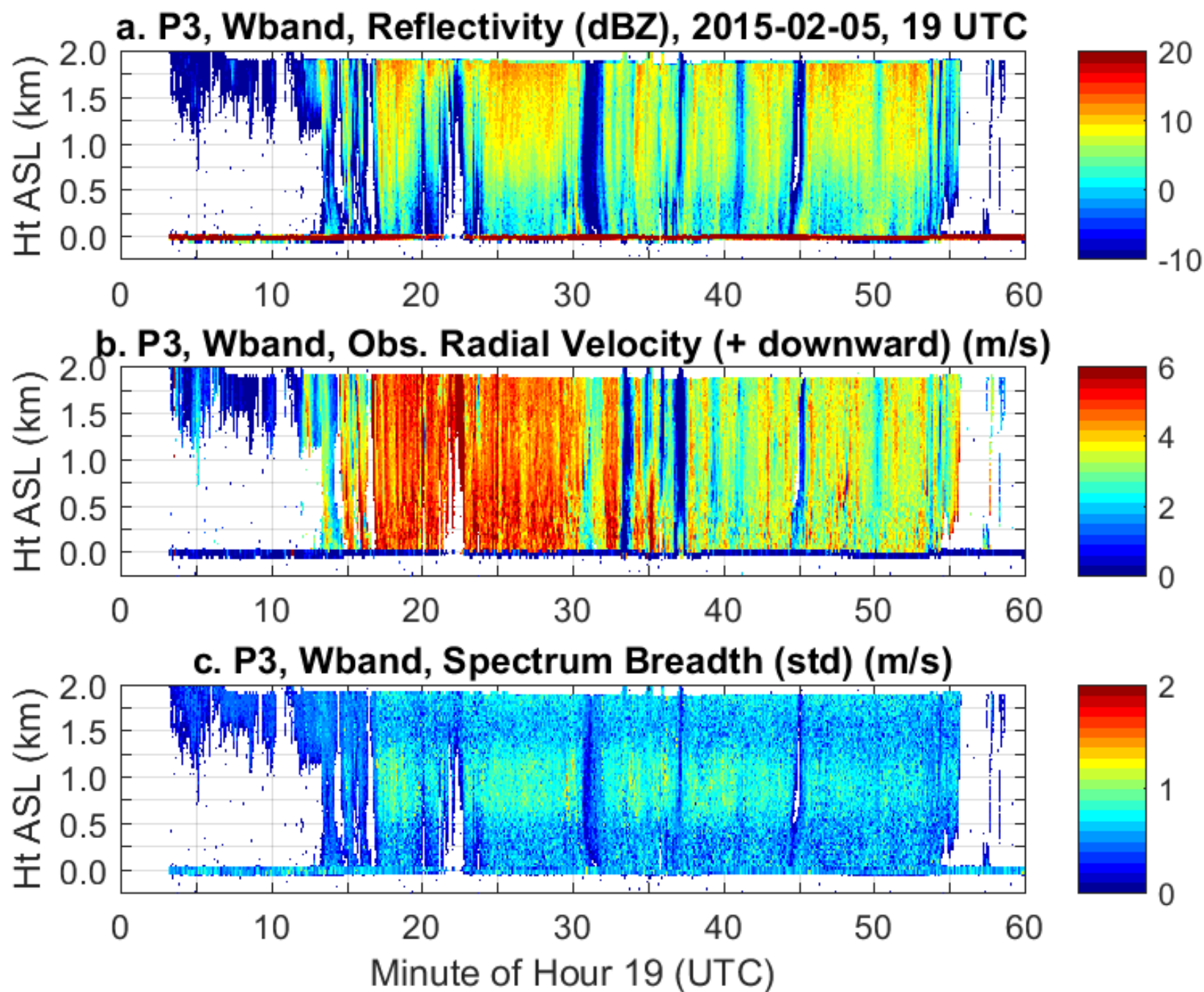
- Reflectivity
- Adjusted Radial Velocity, and
- Spectrum Breadth (spectrum std)

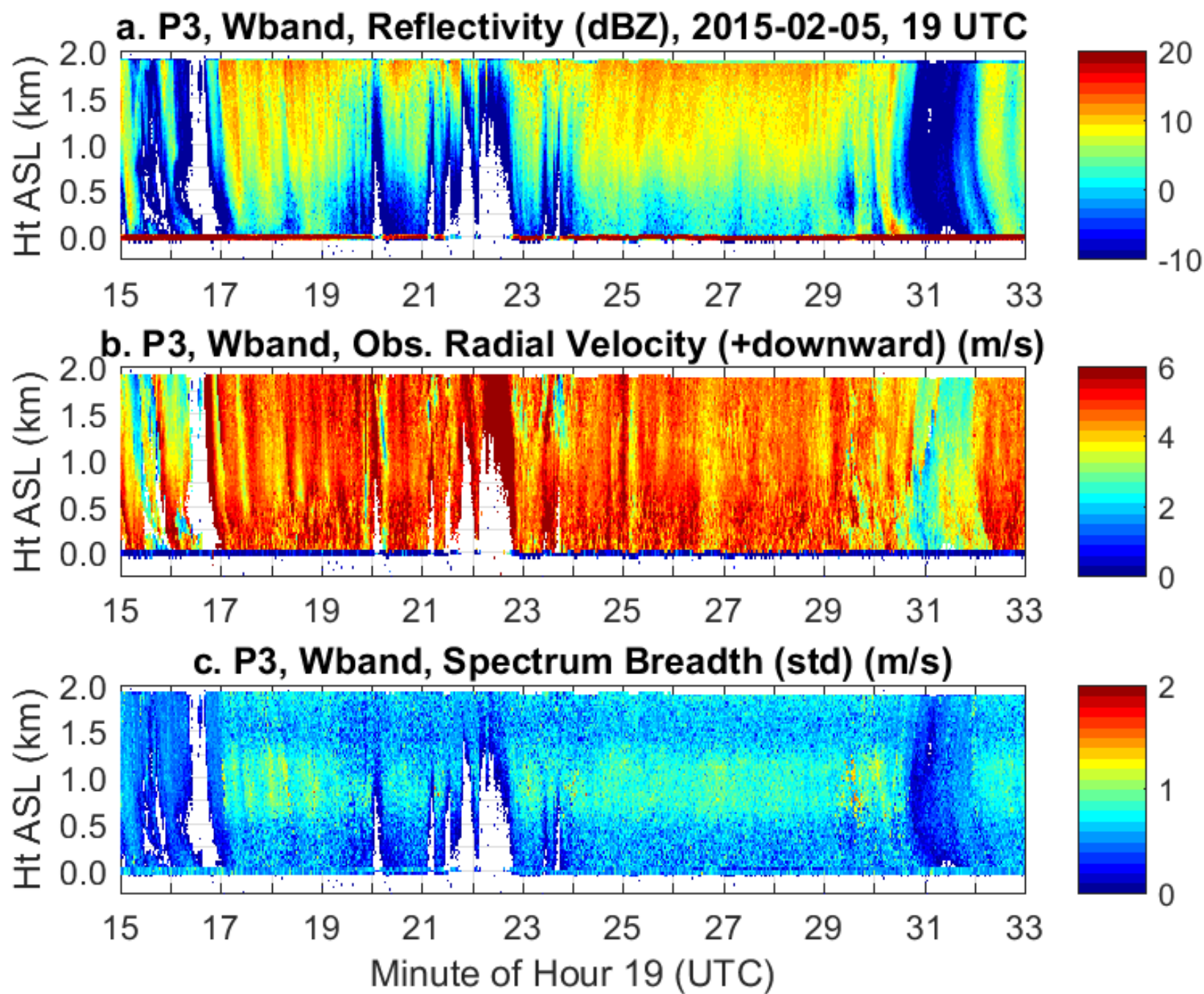
Plots are:

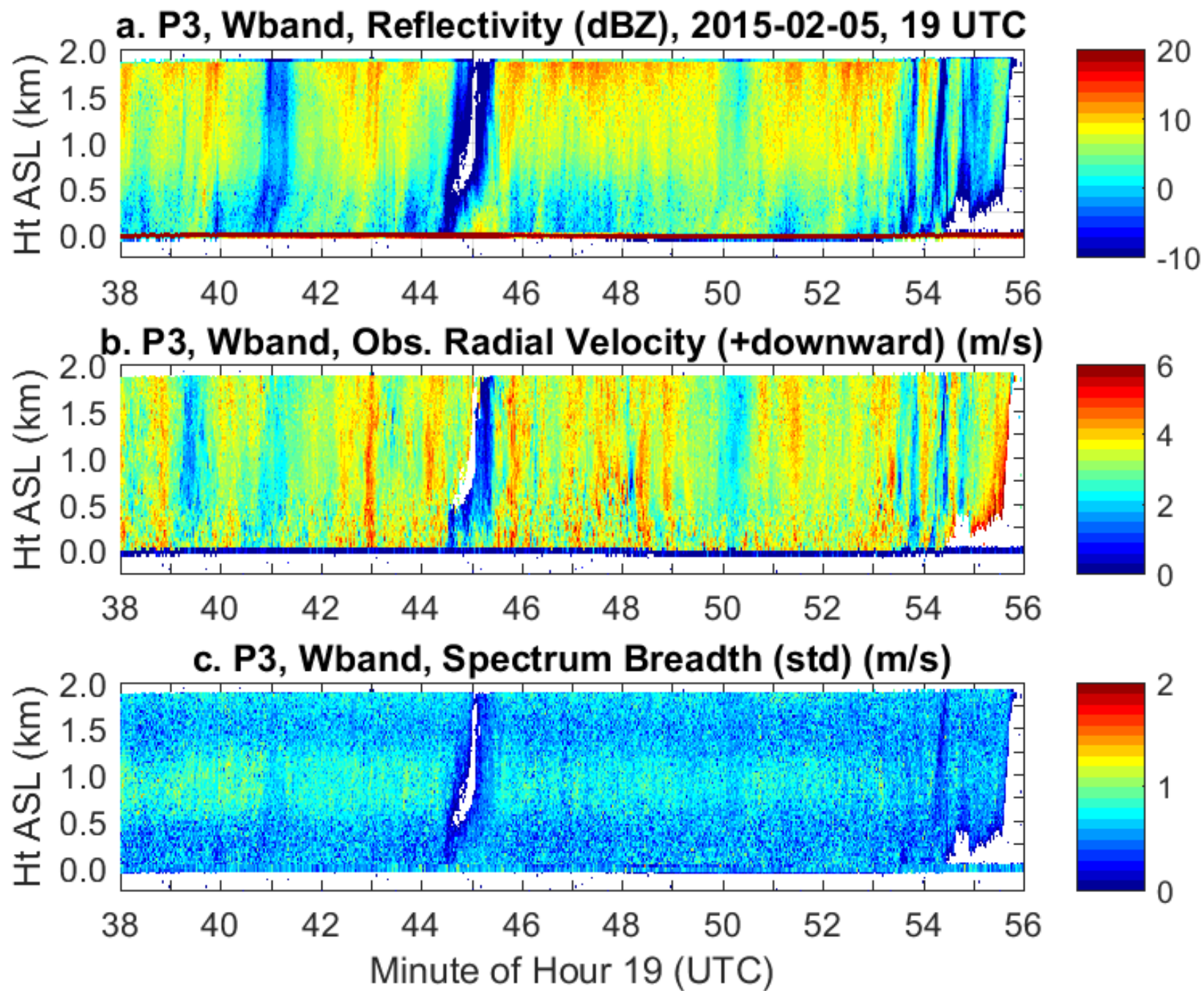
60 minutes of hour 19

minutes 15-33 (section 1)

minutes 38-56 (section 2)







Science Applications

- Boundary Layer Turbulence
- DSD Retrievals

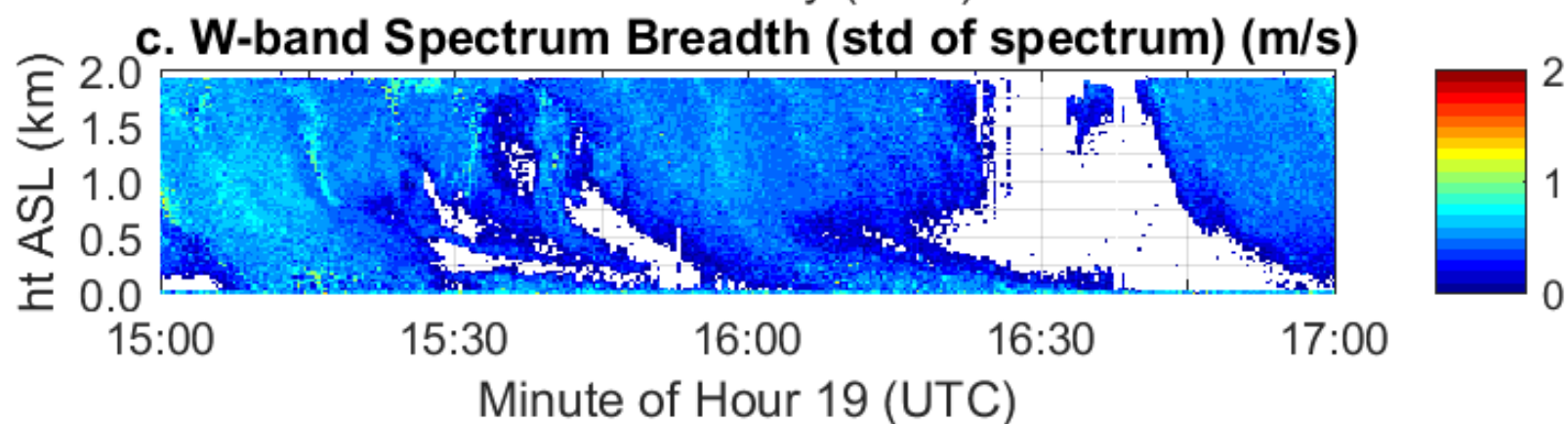
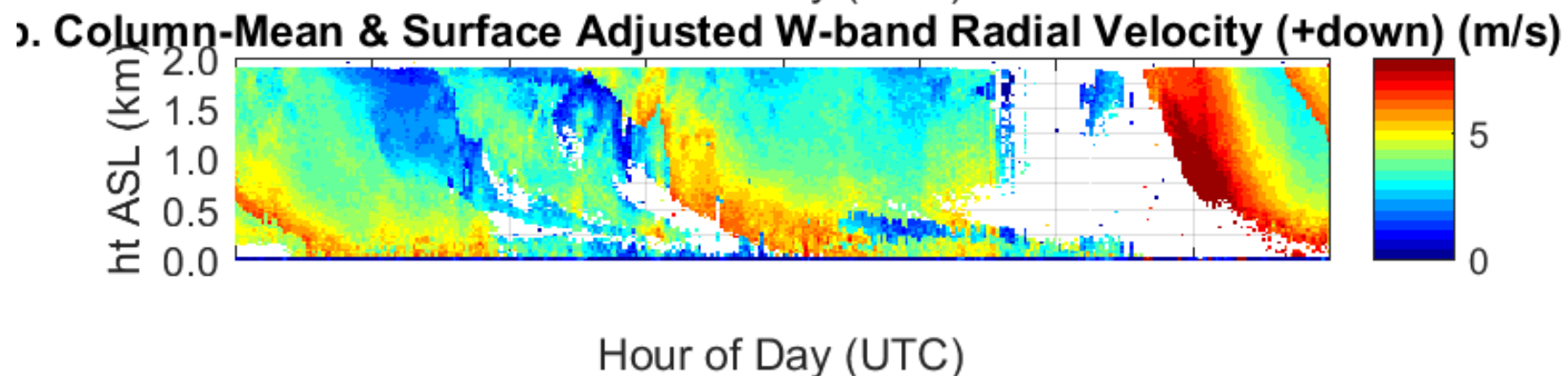
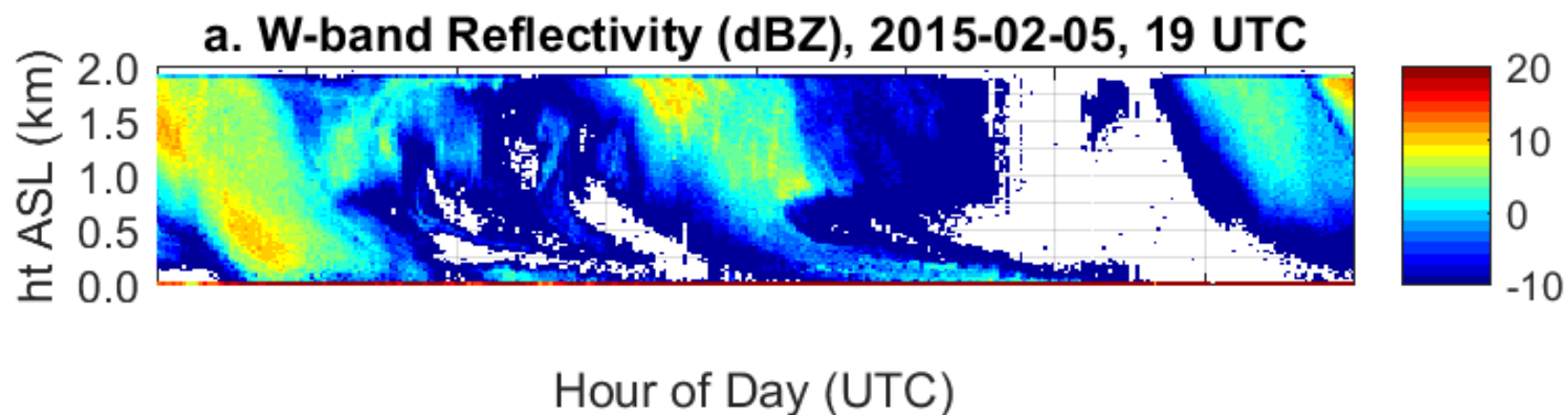
Science Applications

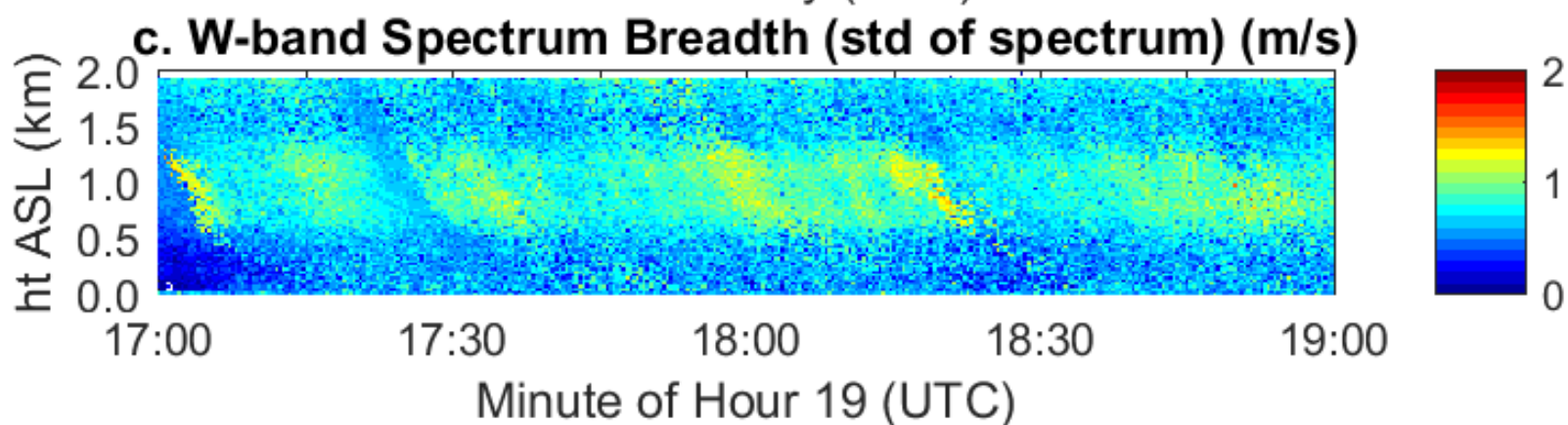
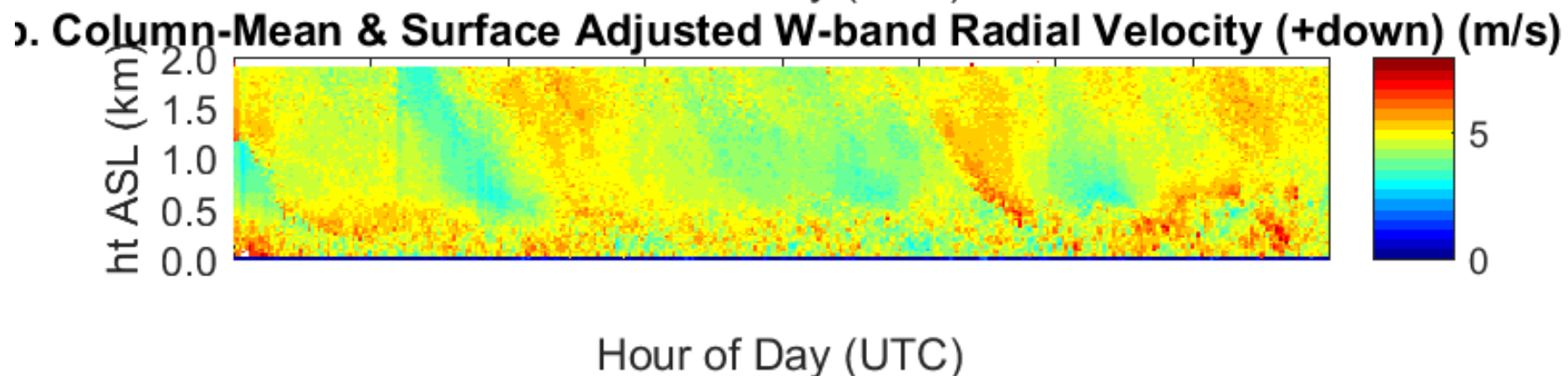
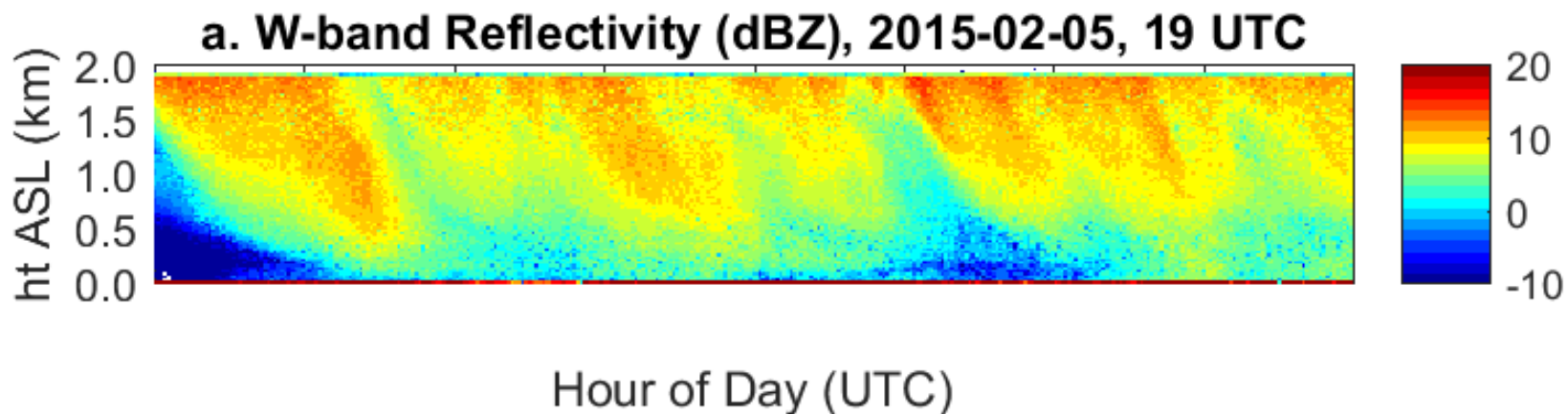
- Boundary Layer Turbulence

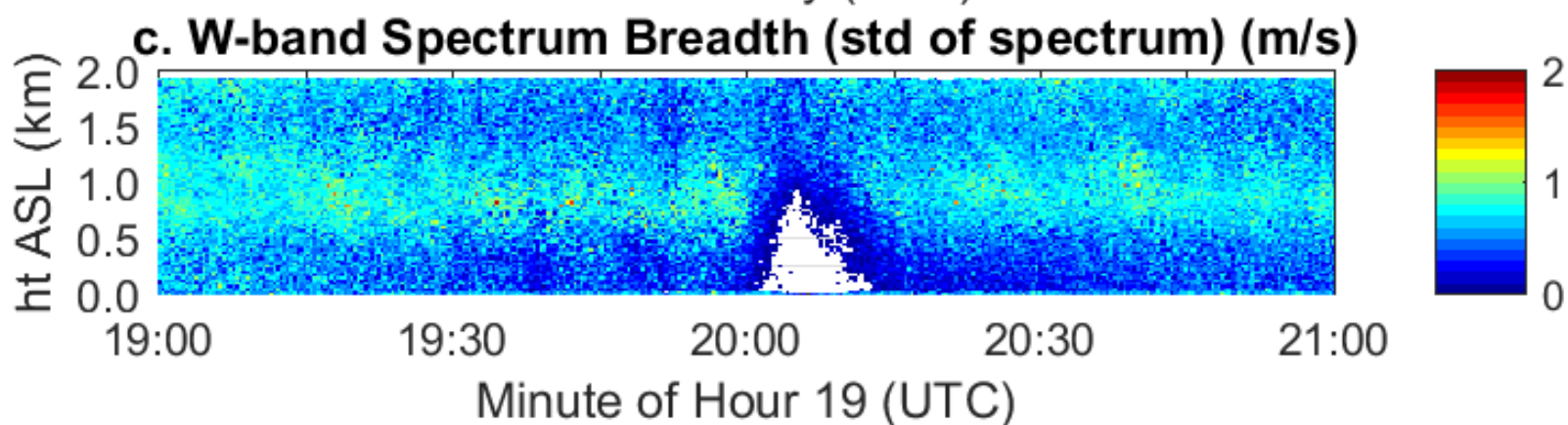
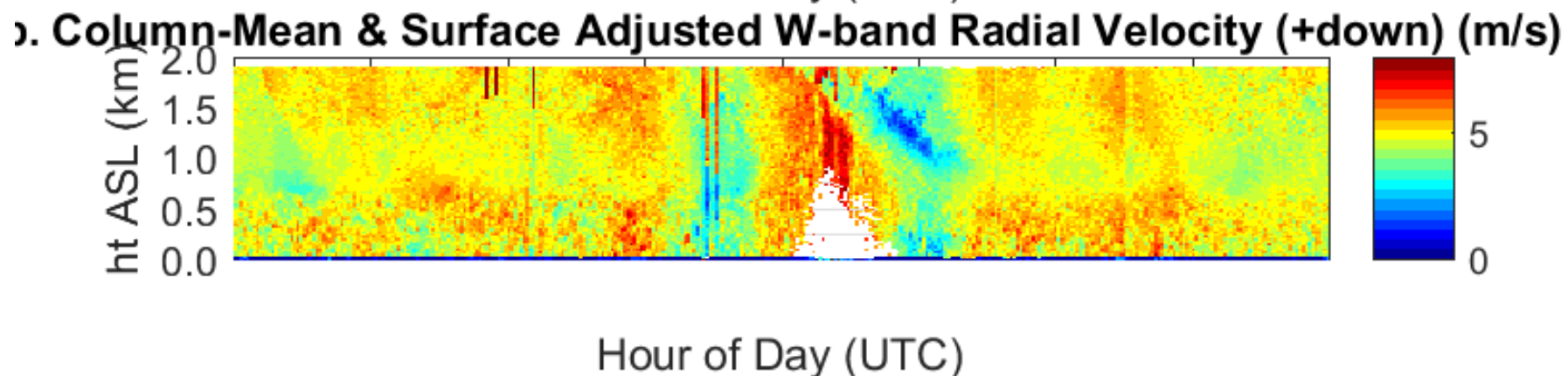
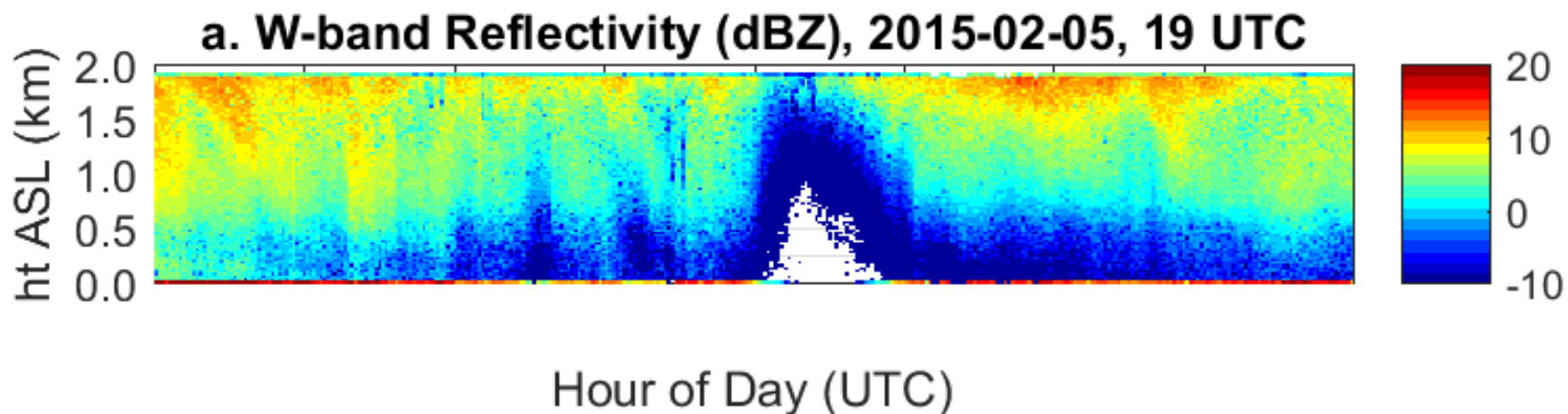
- DSD Retrievals

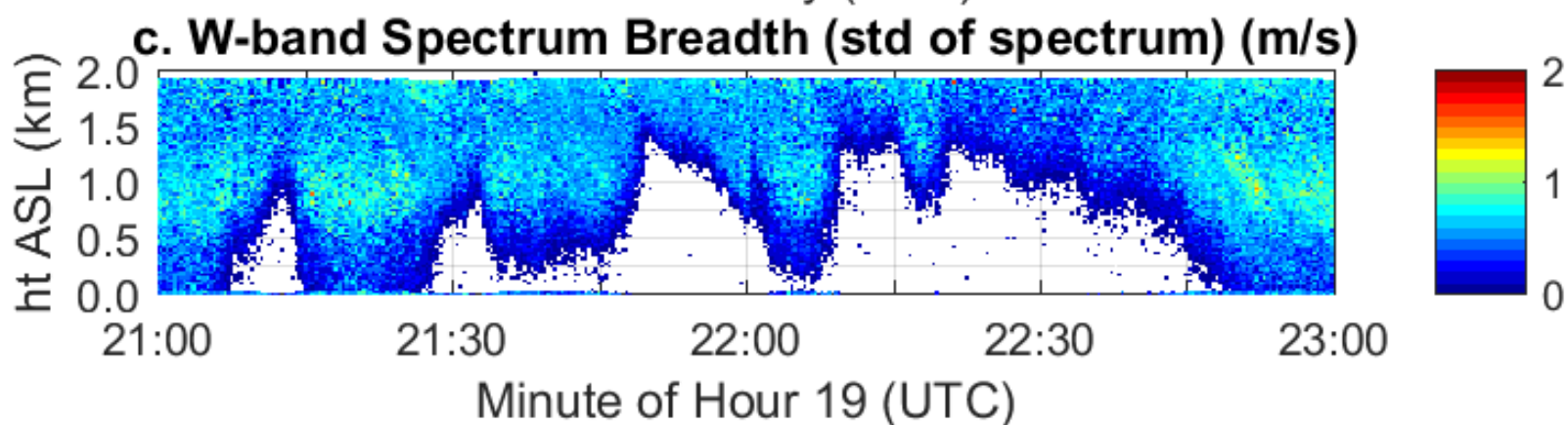
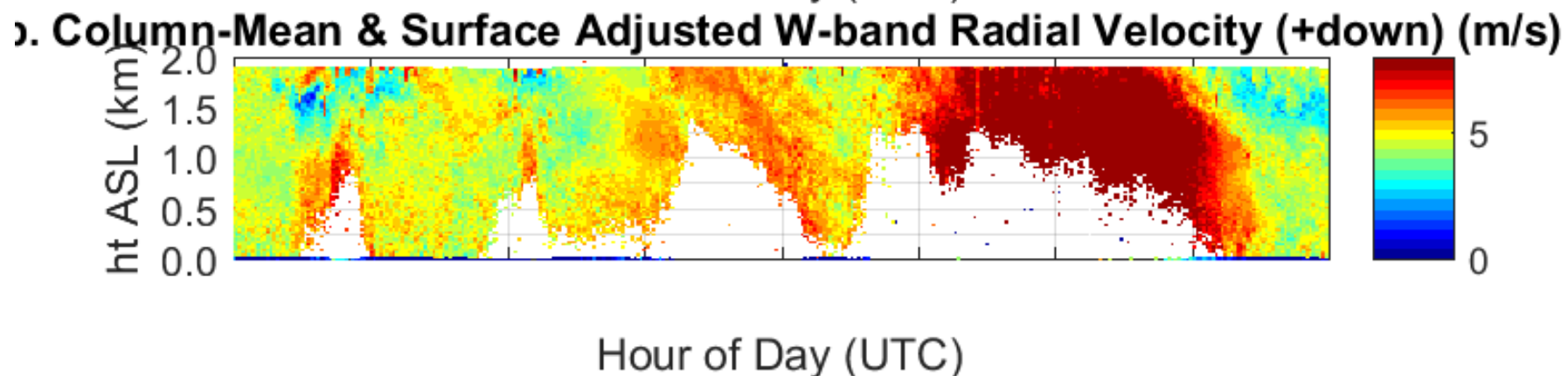
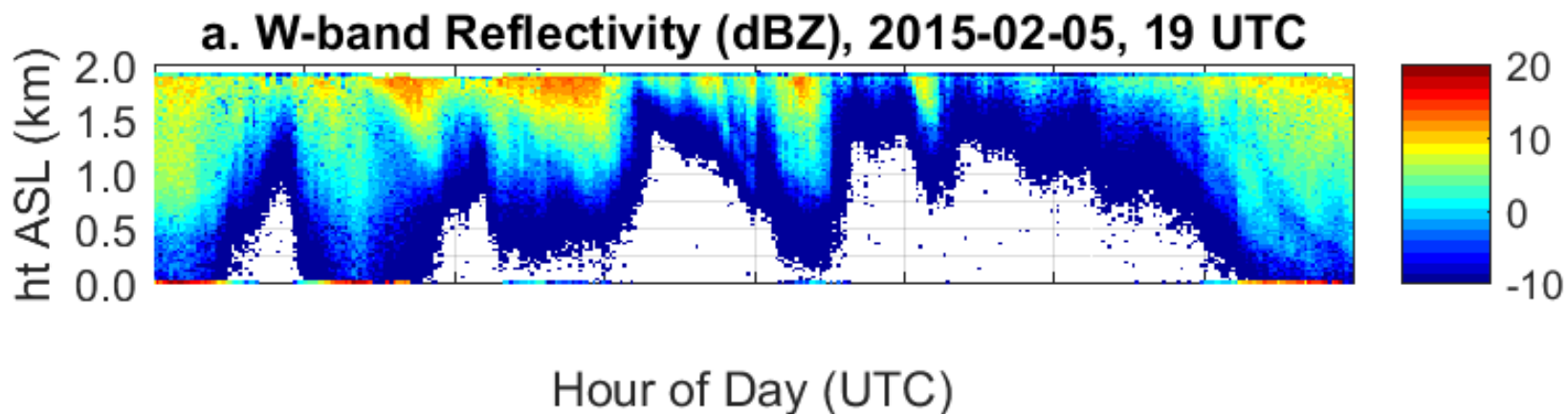
The following 18 slides show 2
minute time-height cross-sections of
 Z , V_{mean} , and V_{sig}

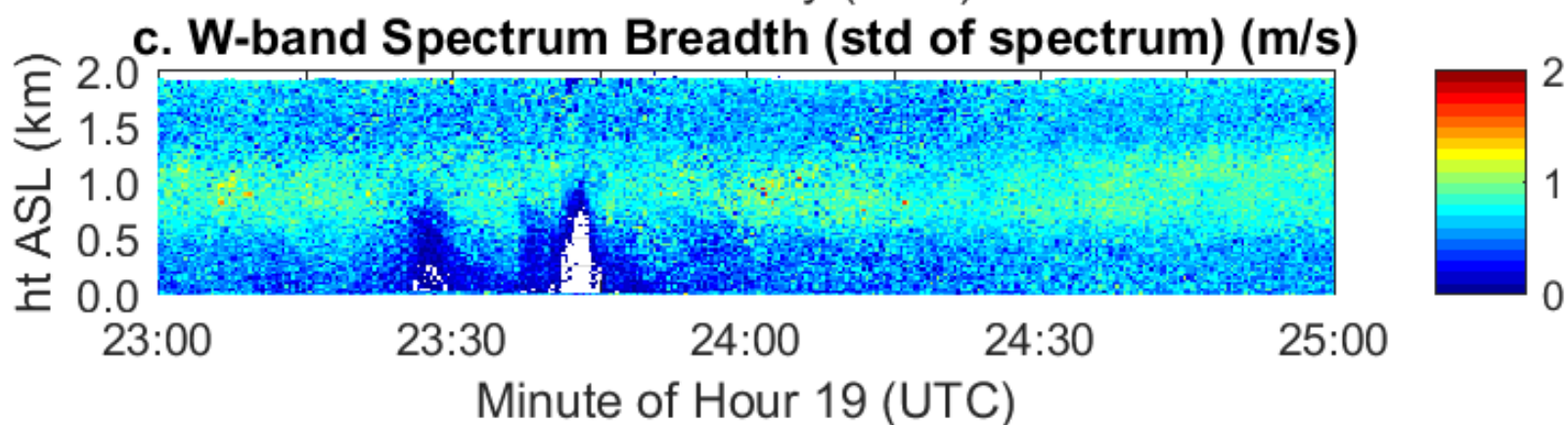
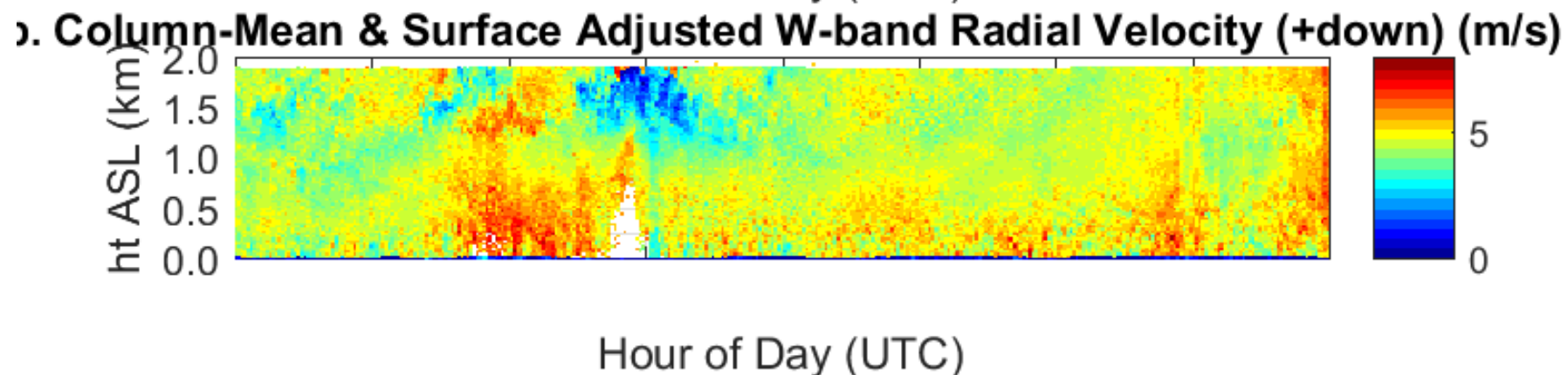
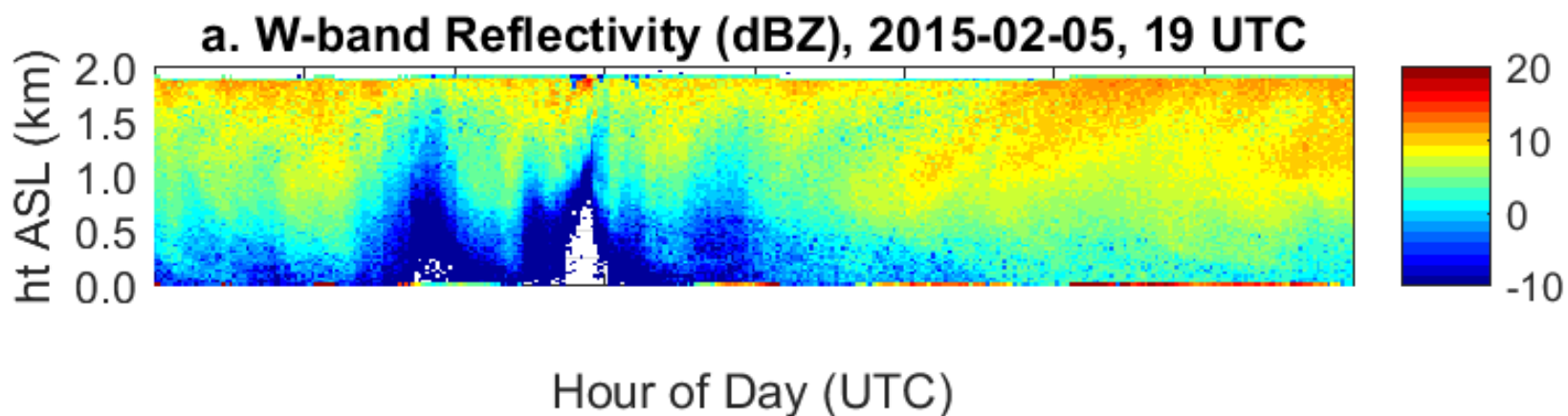
-Is there enhanced turbulence in
lowest 500 m?

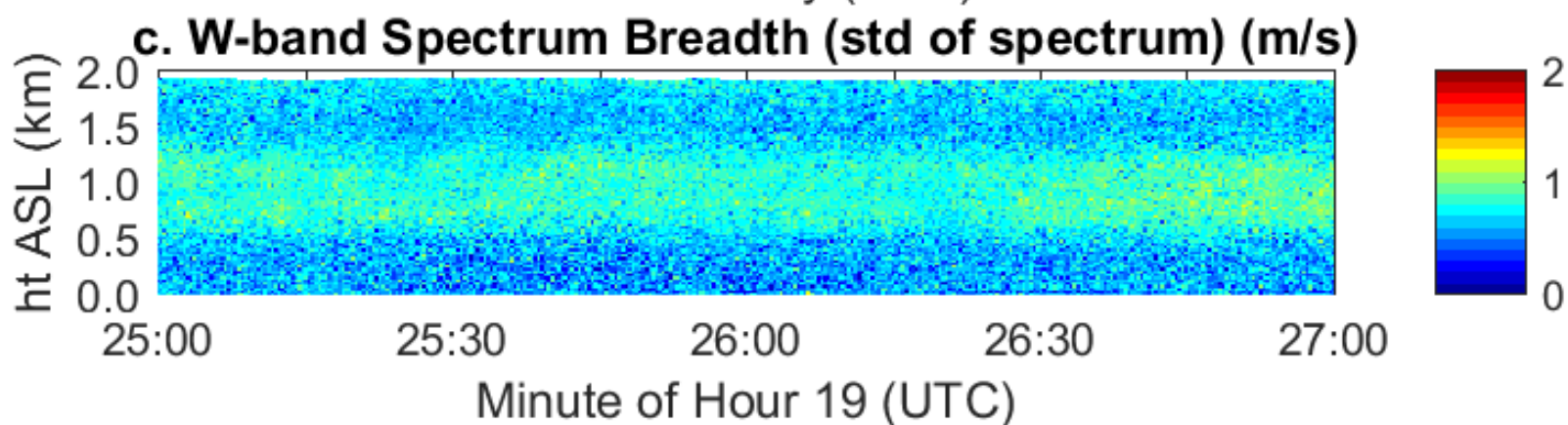
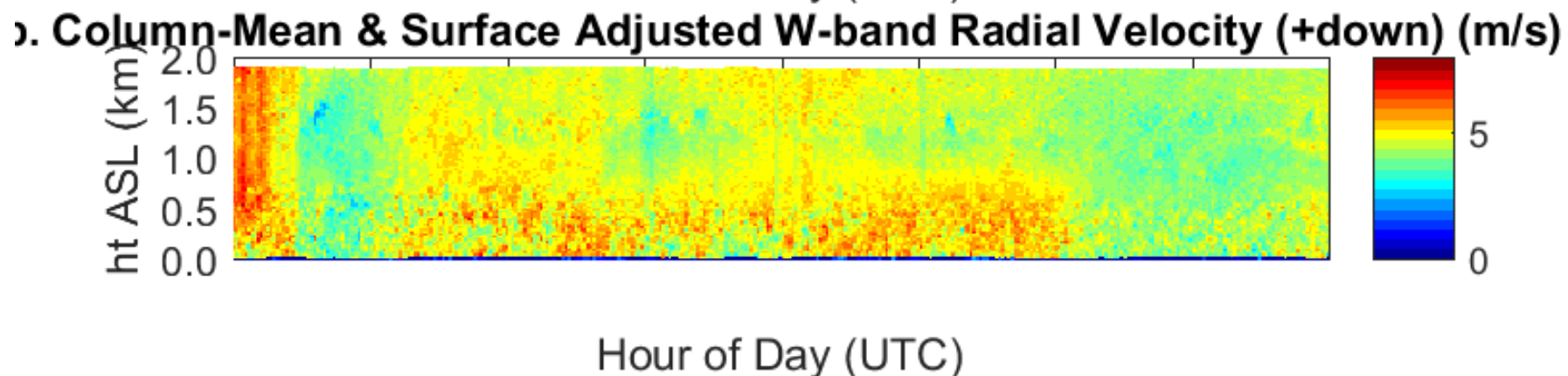
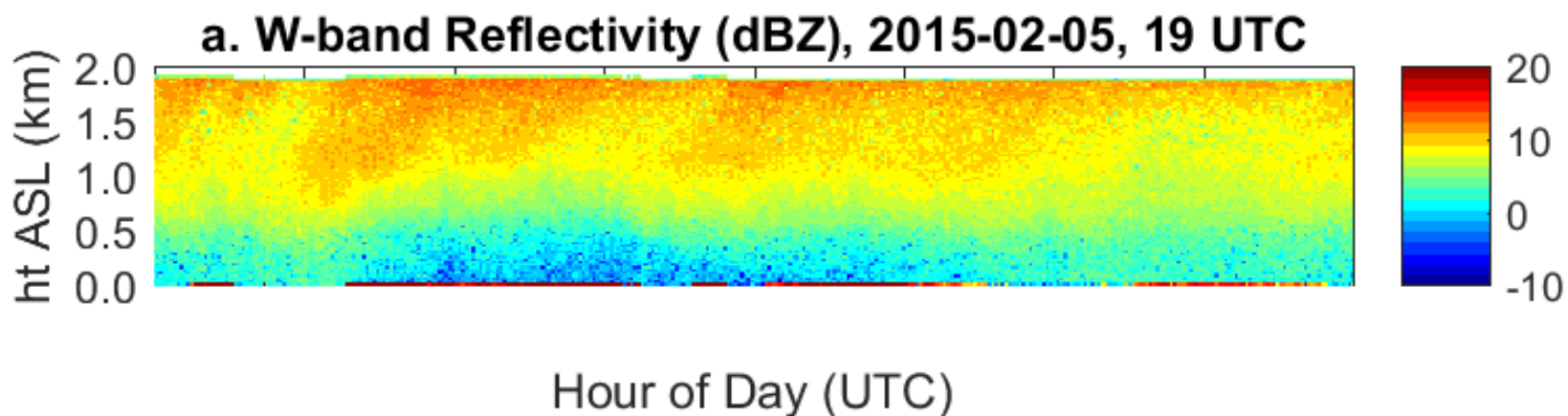


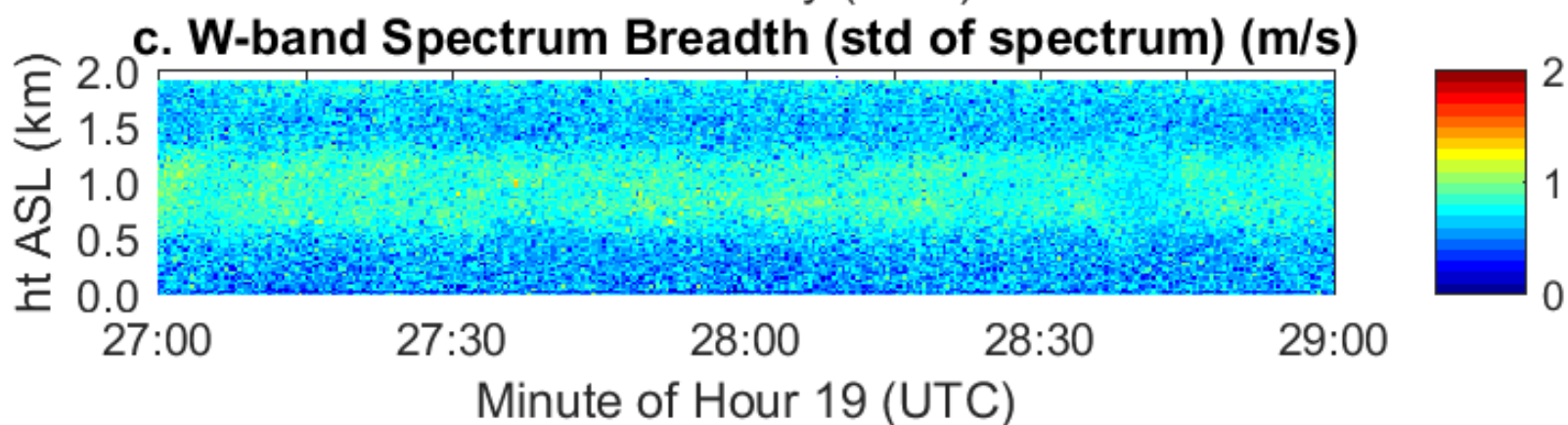
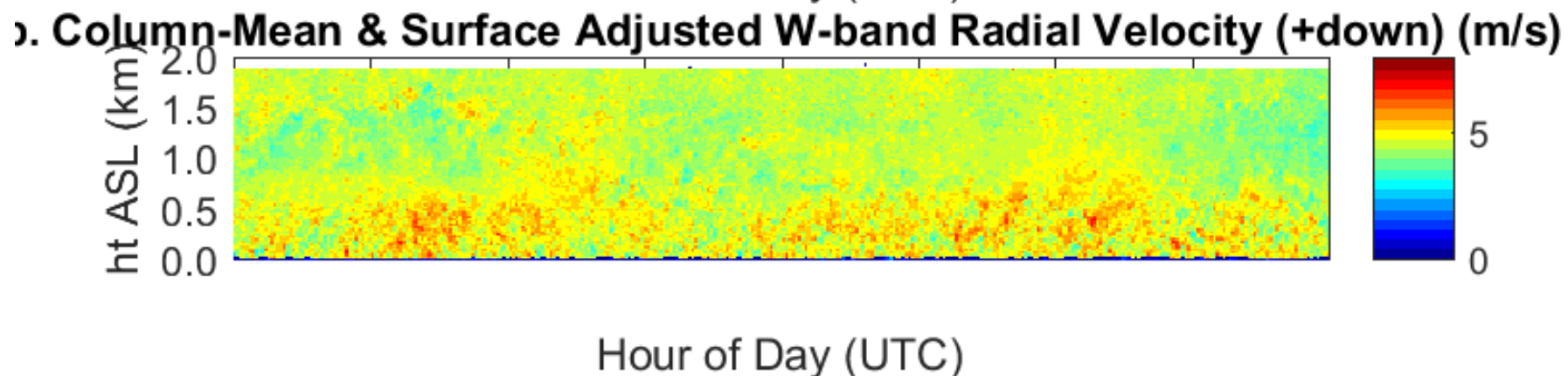
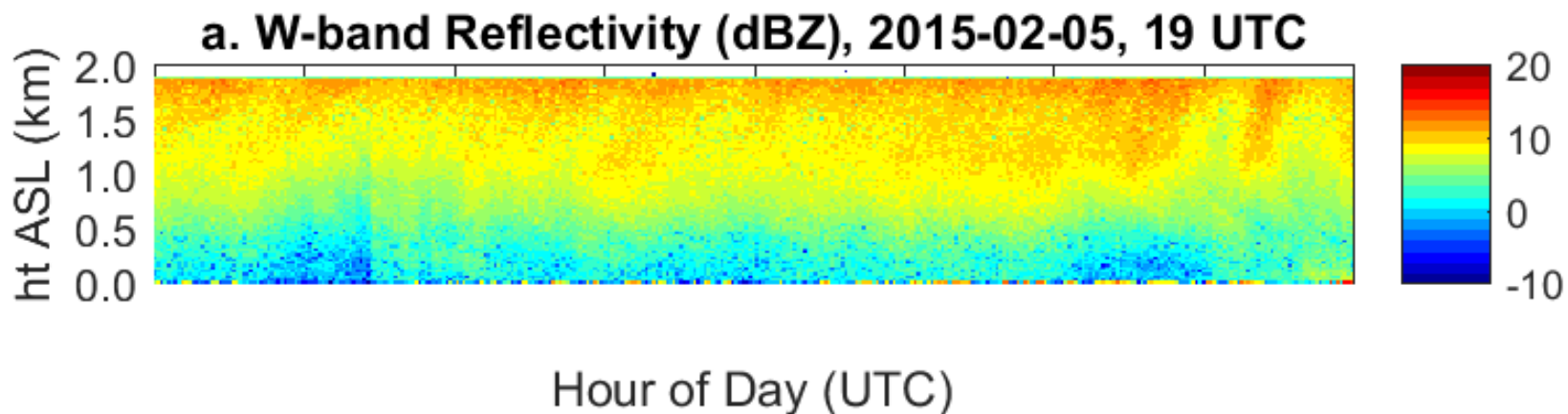


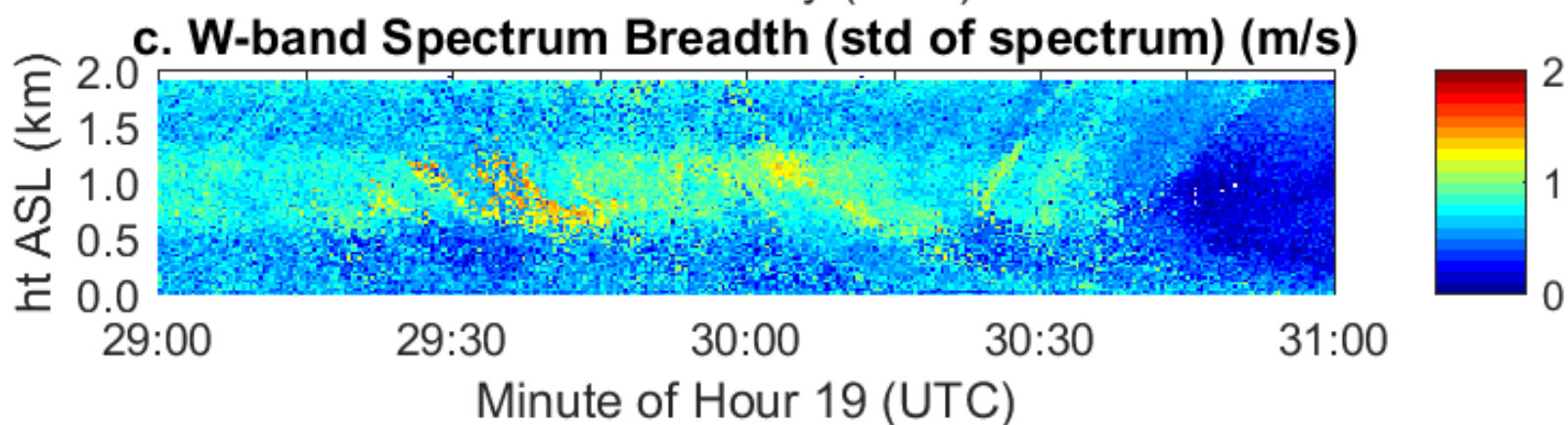
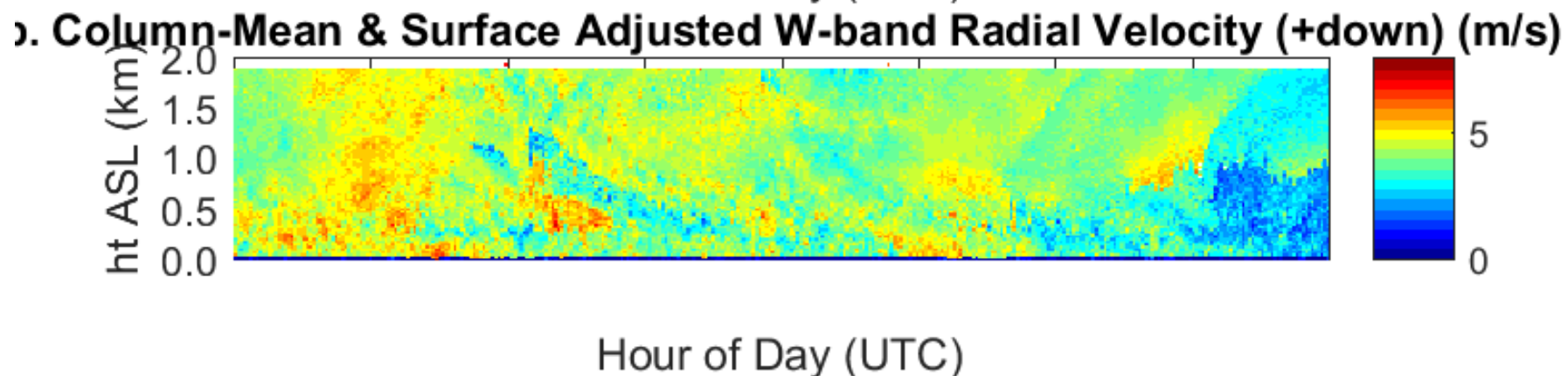
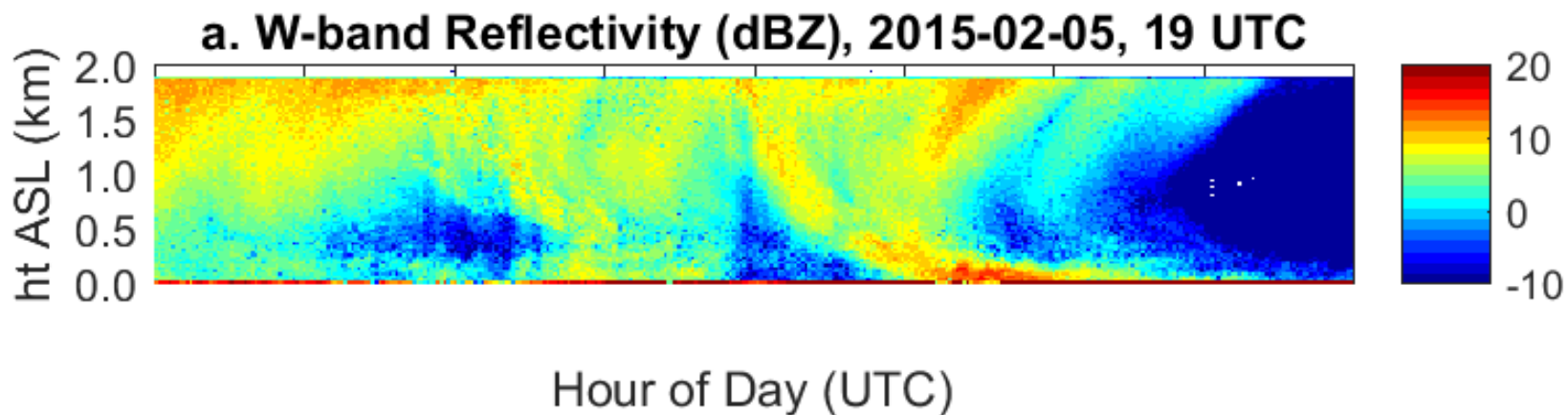


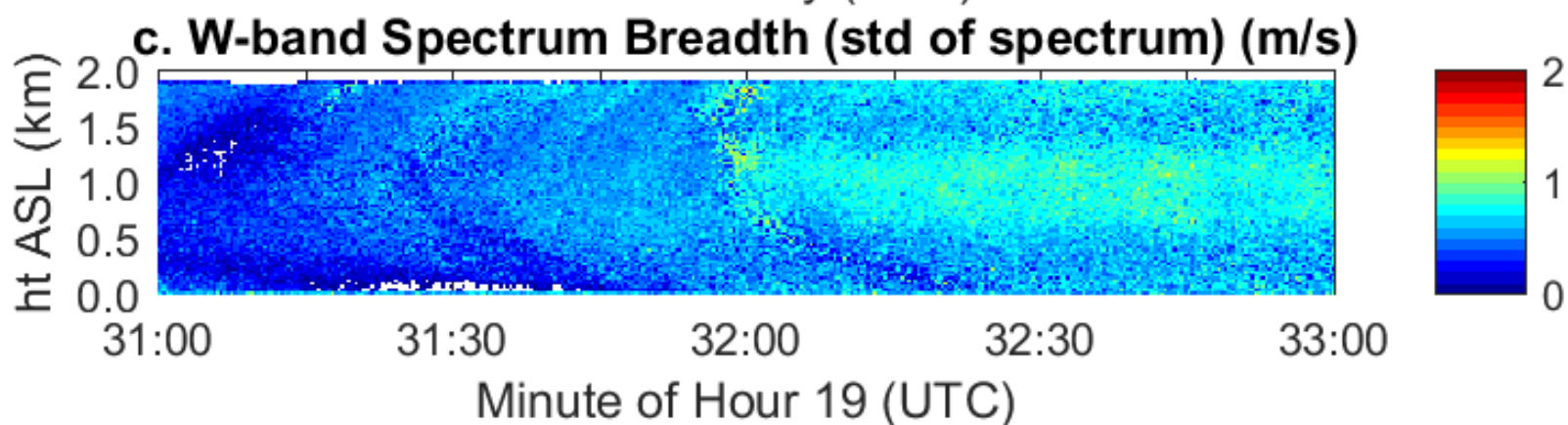
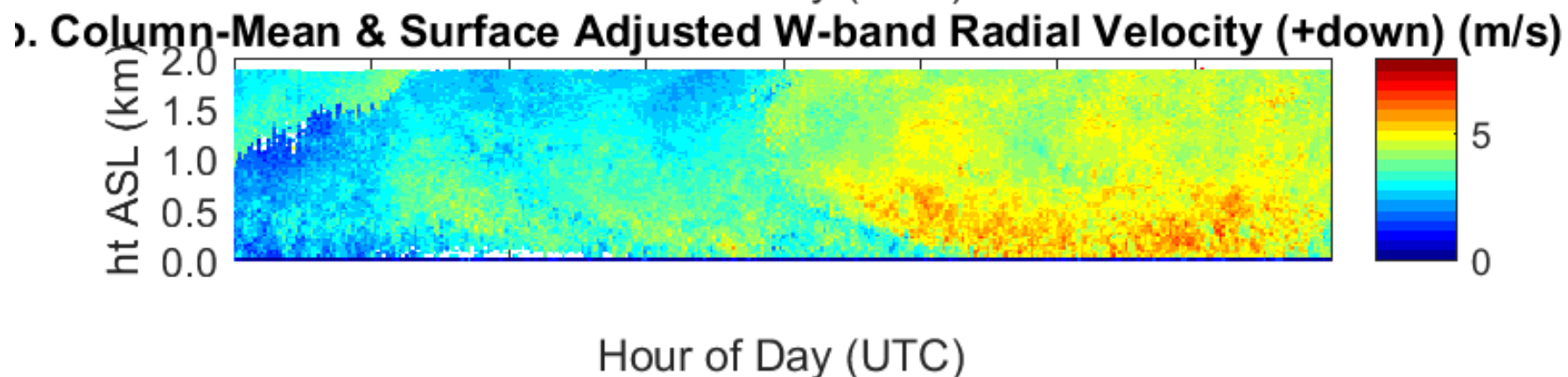
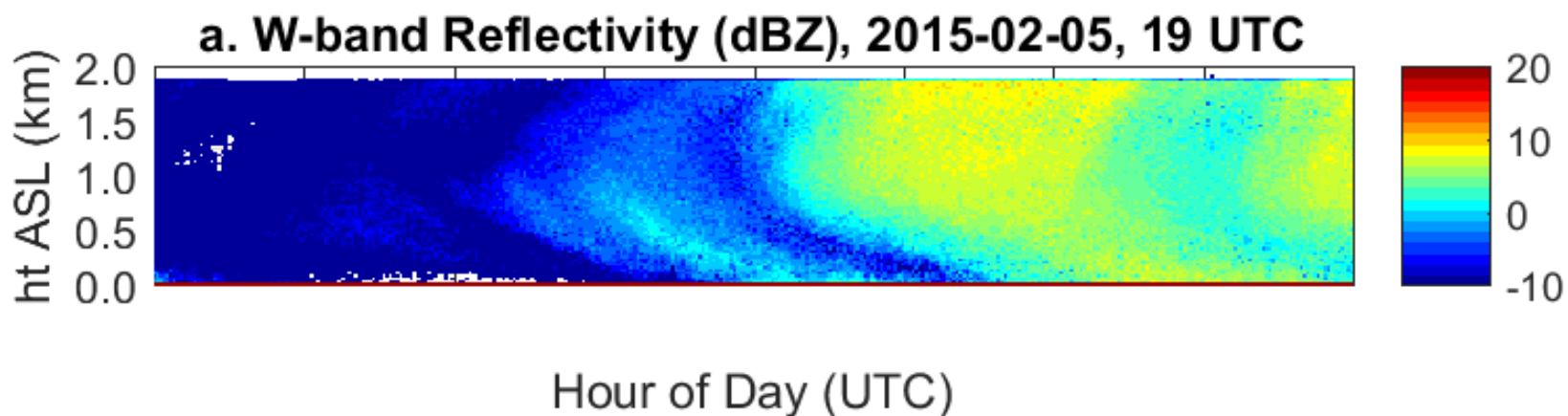


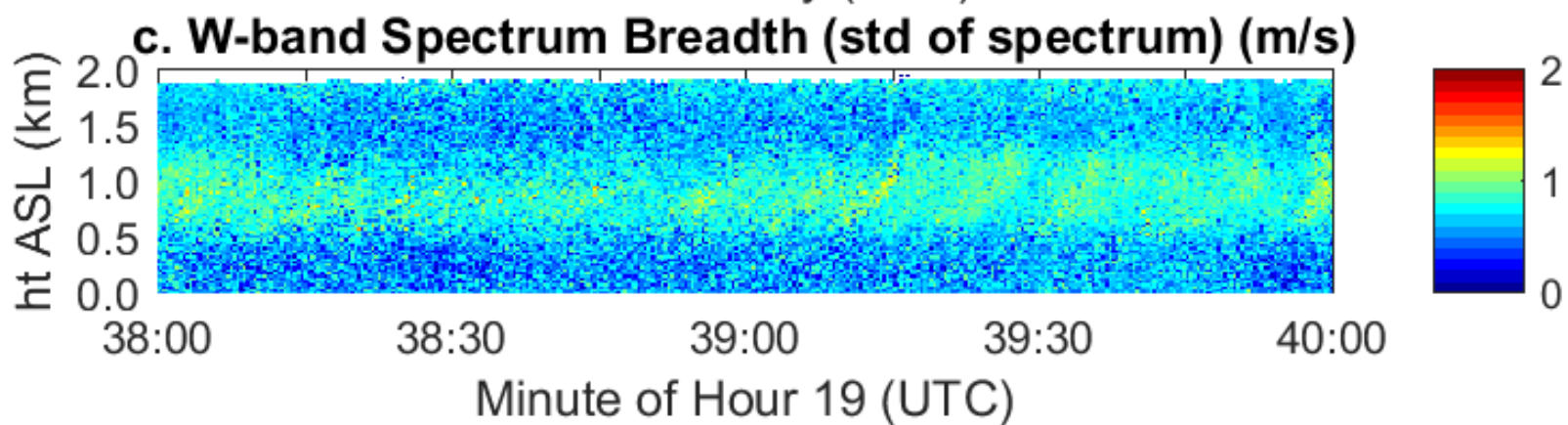
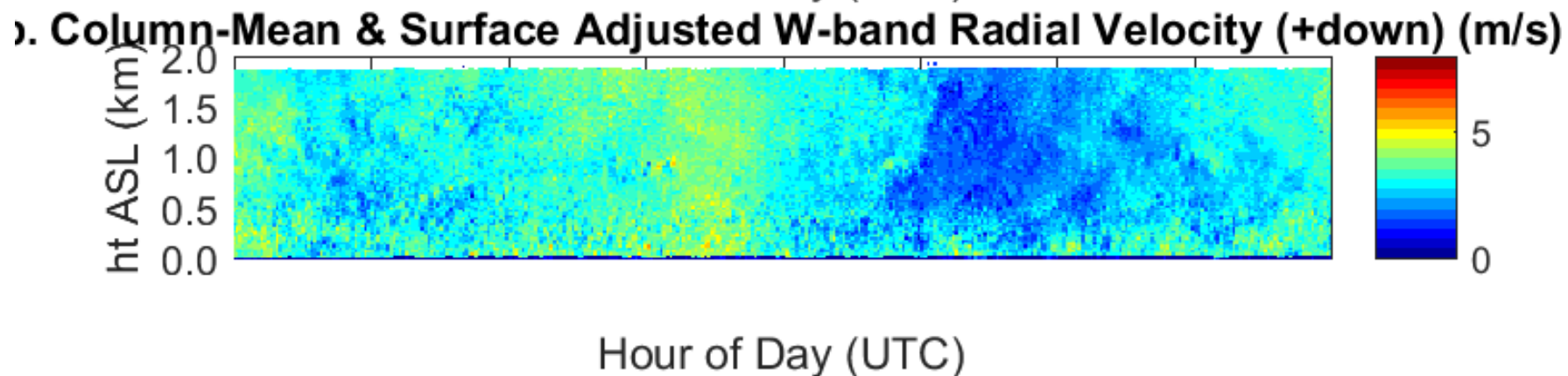
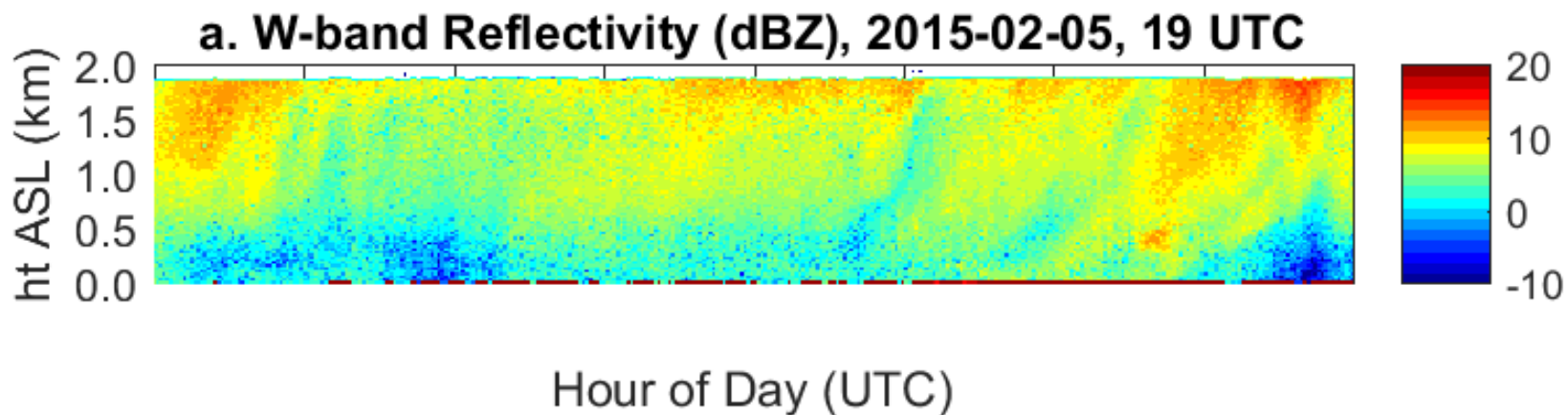


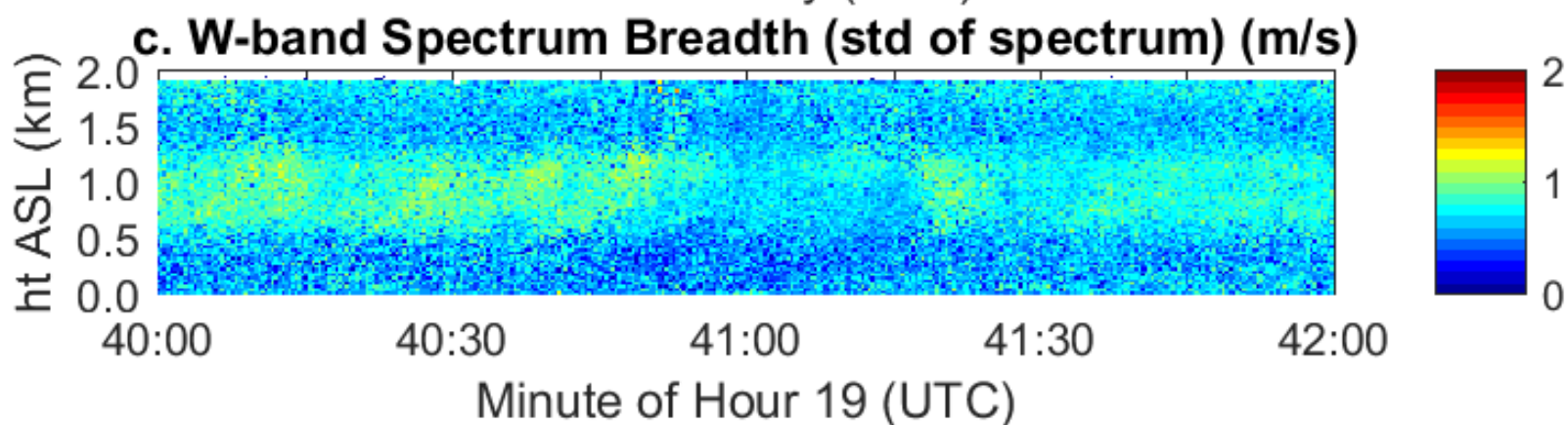
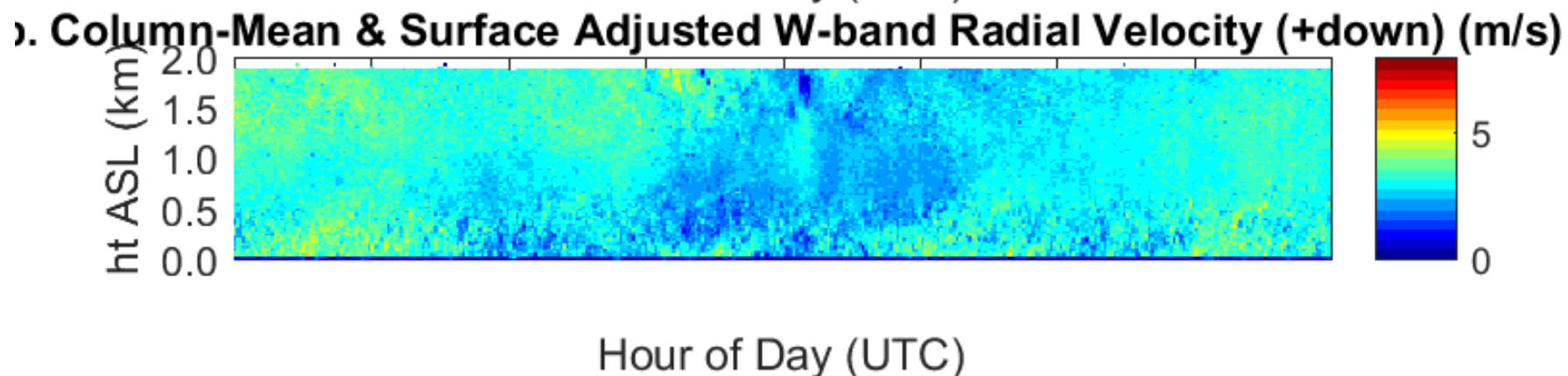
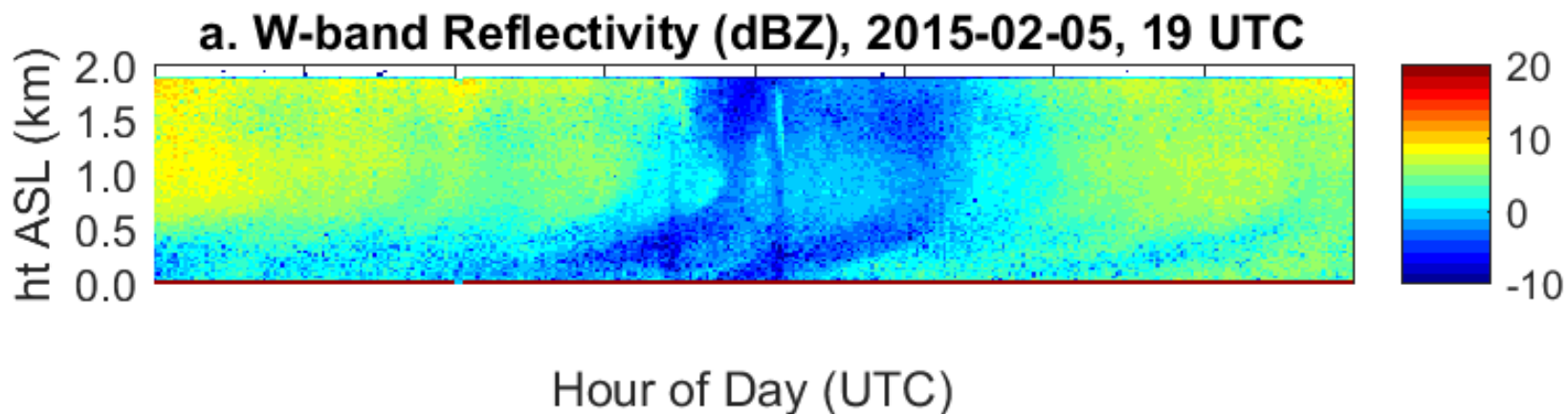


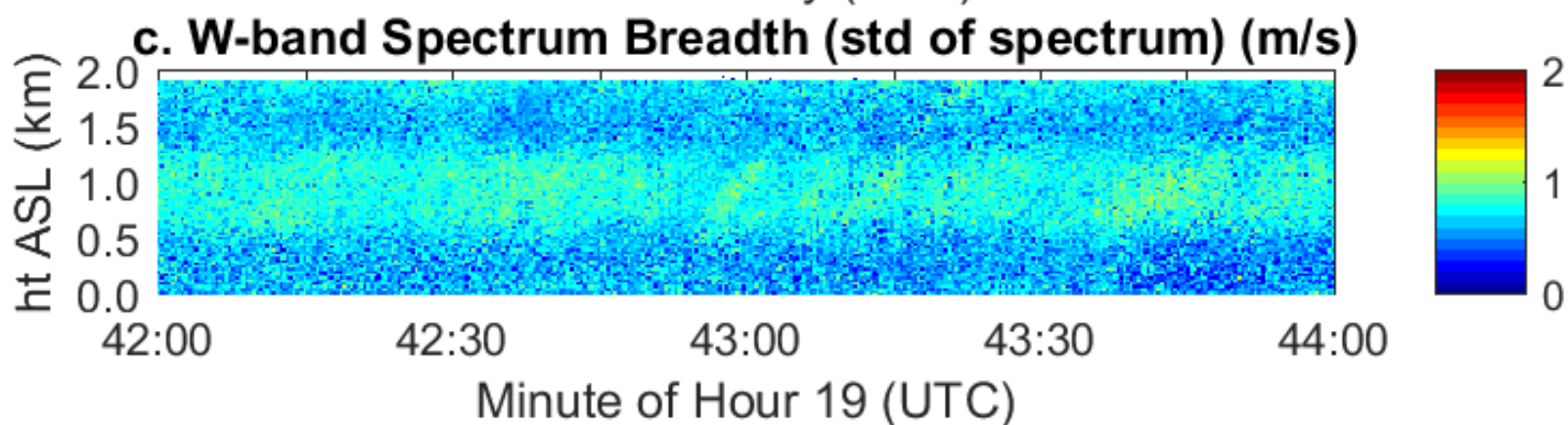
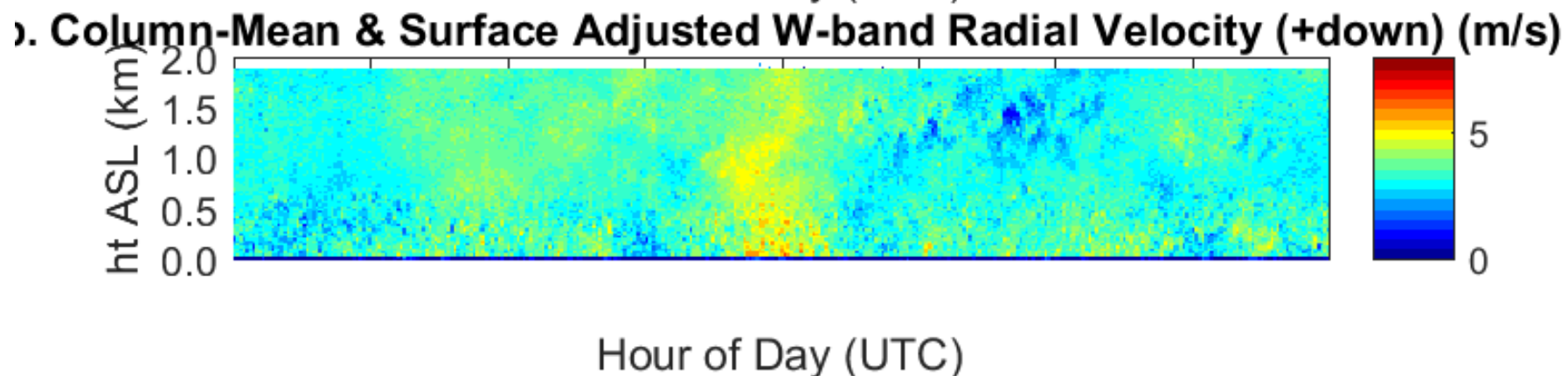
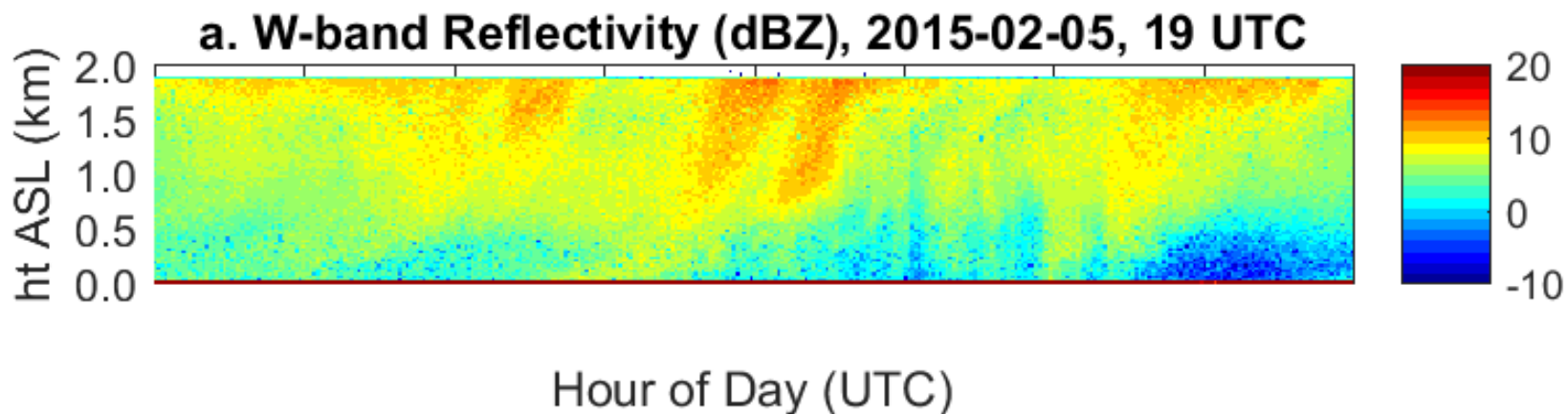


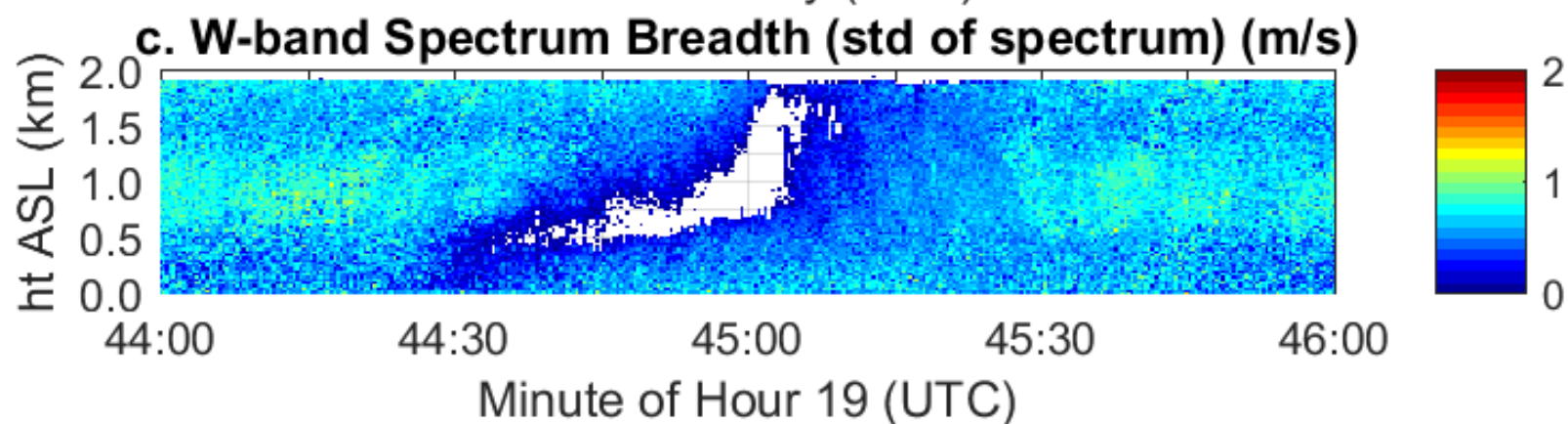
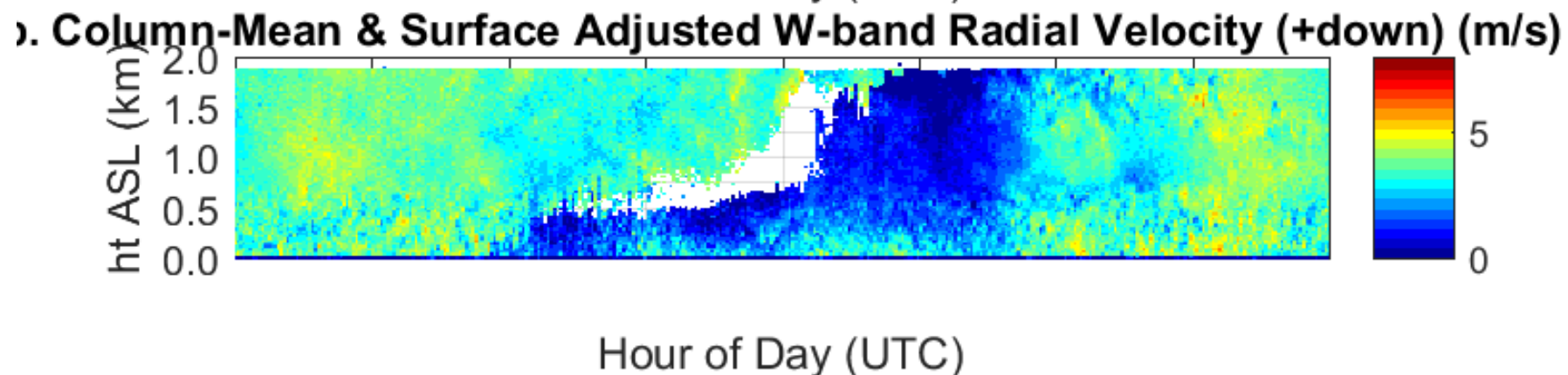
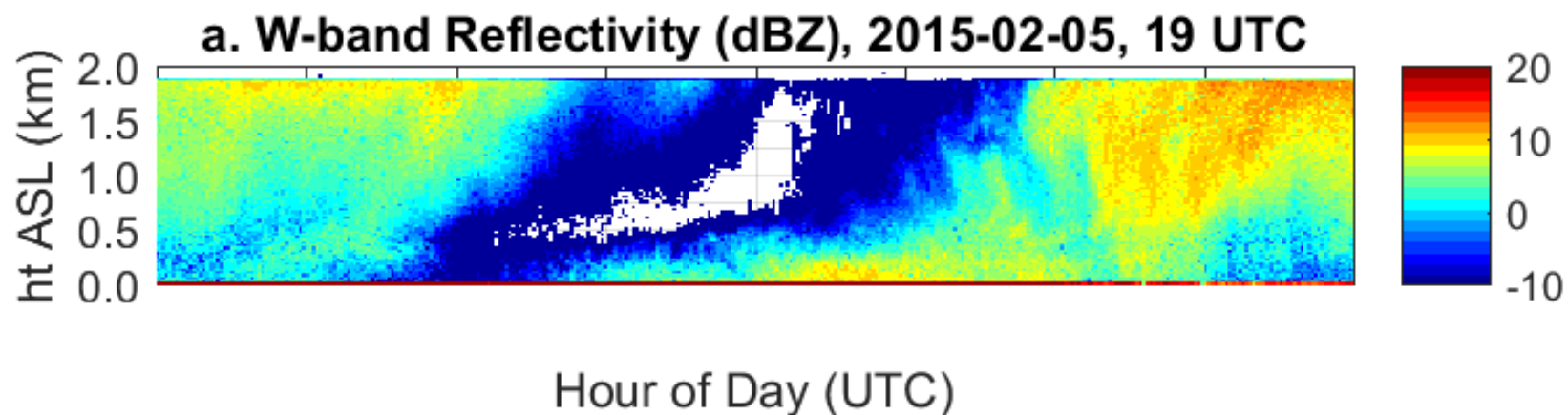


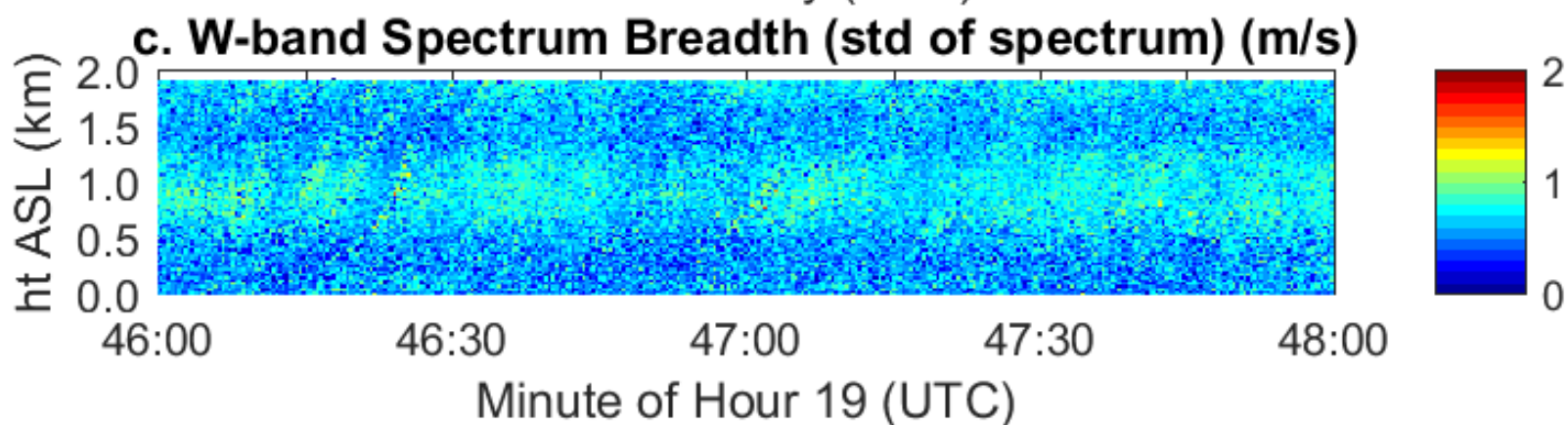
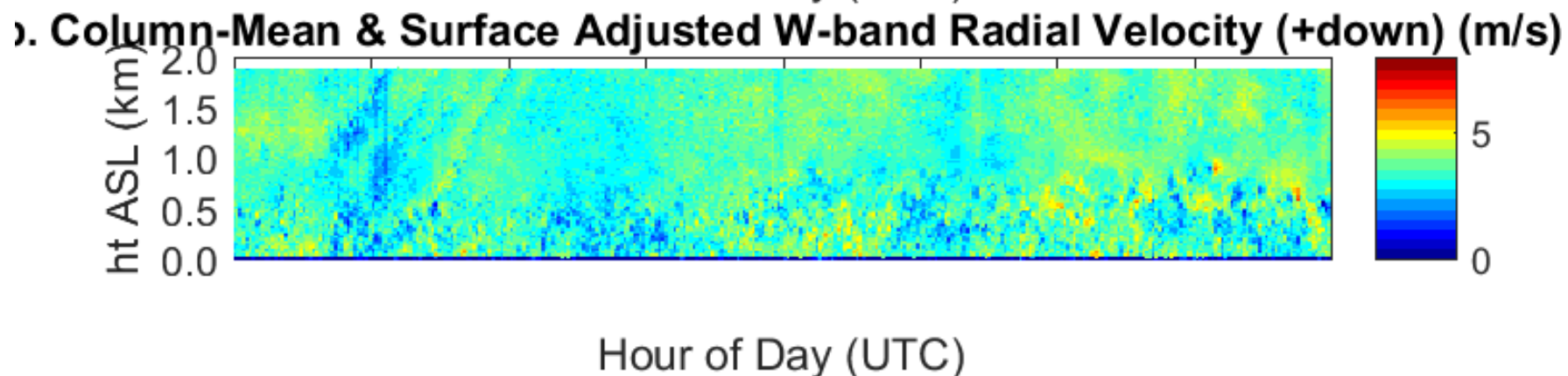
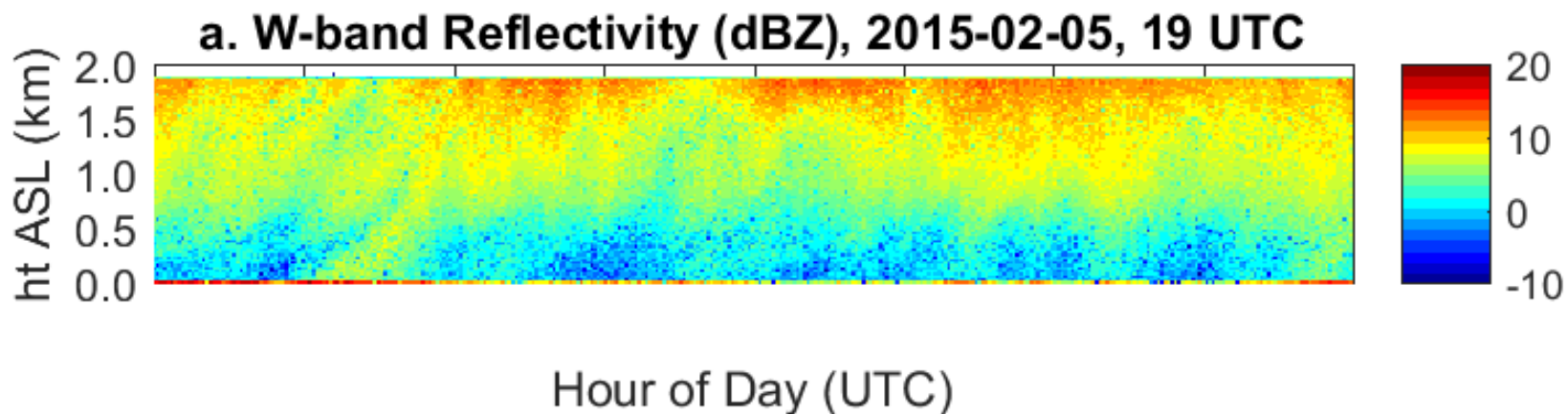


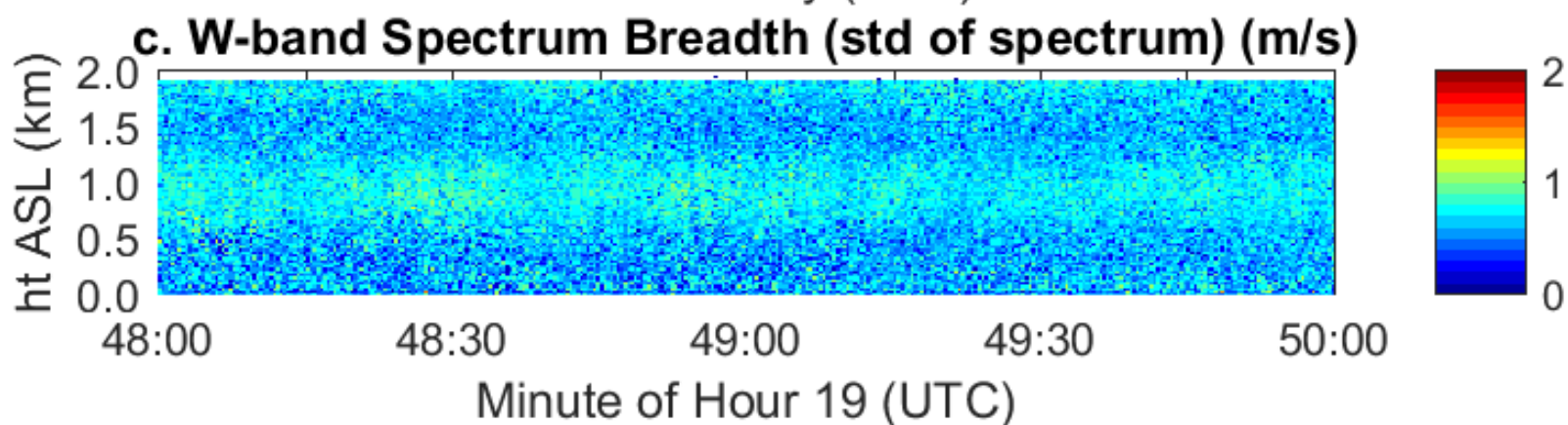
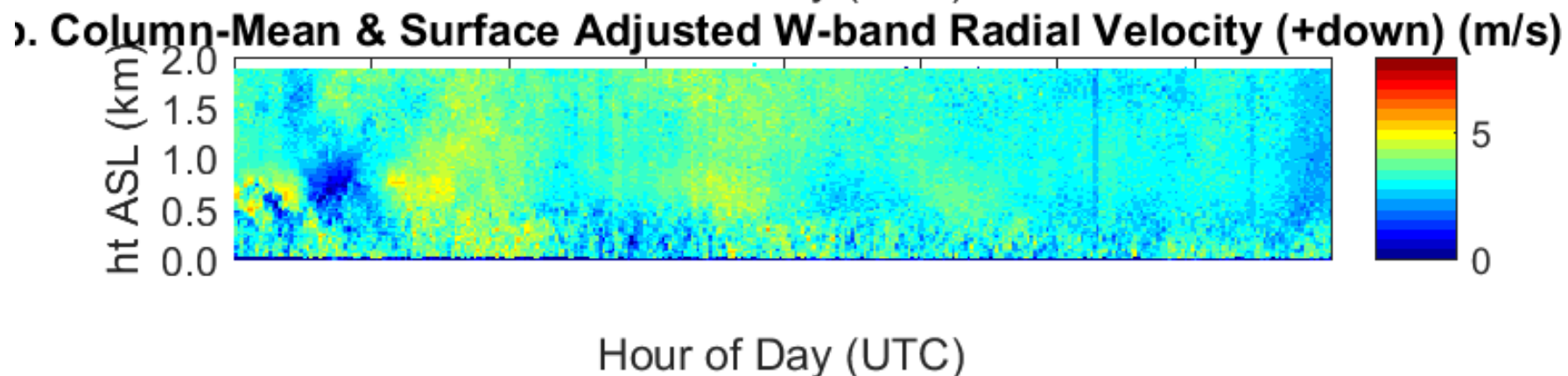
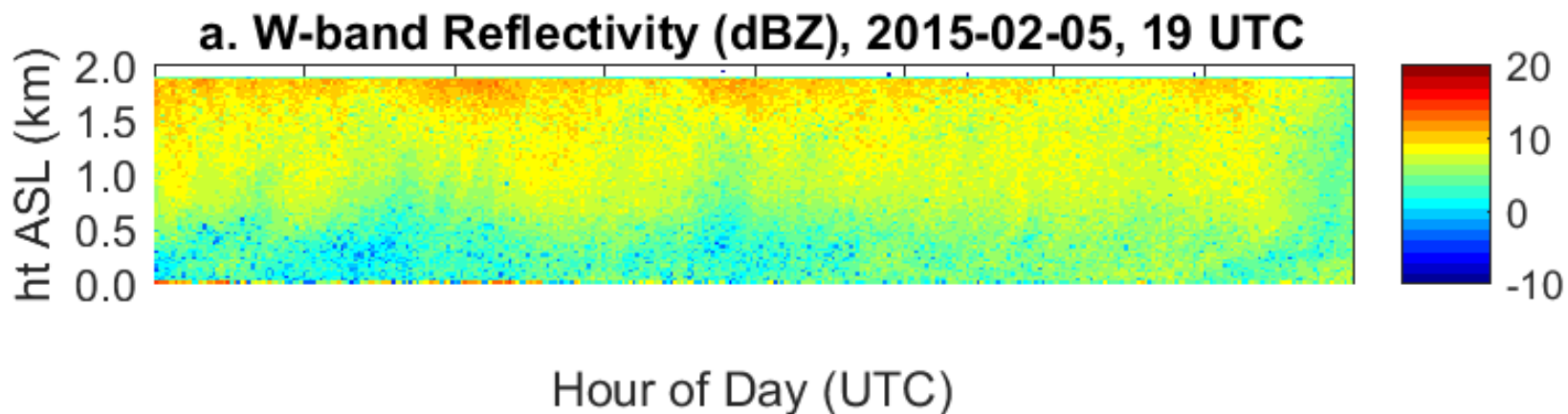


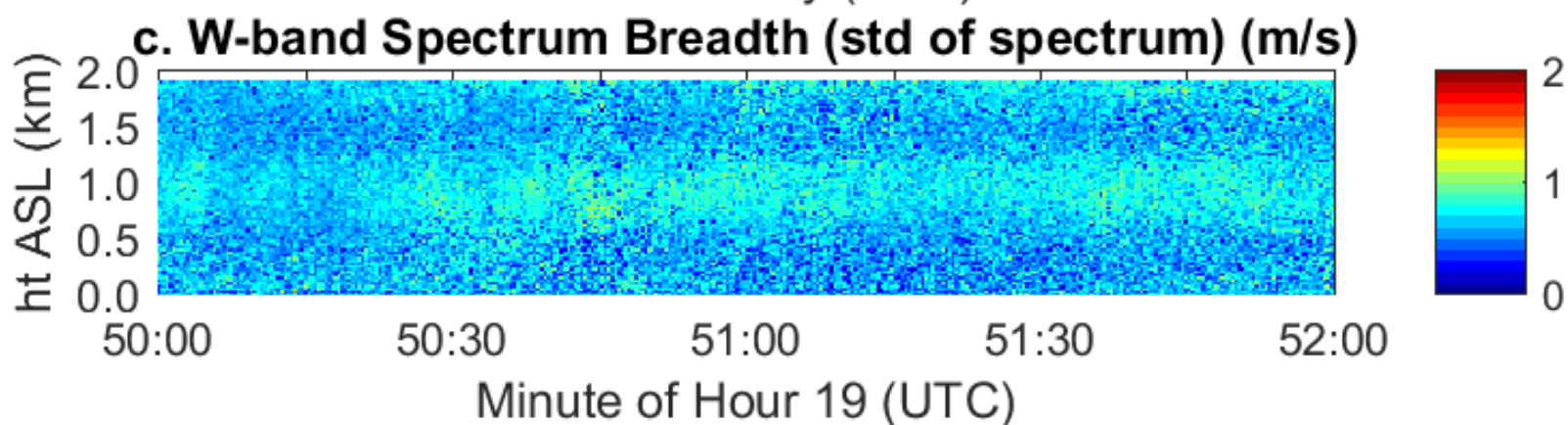
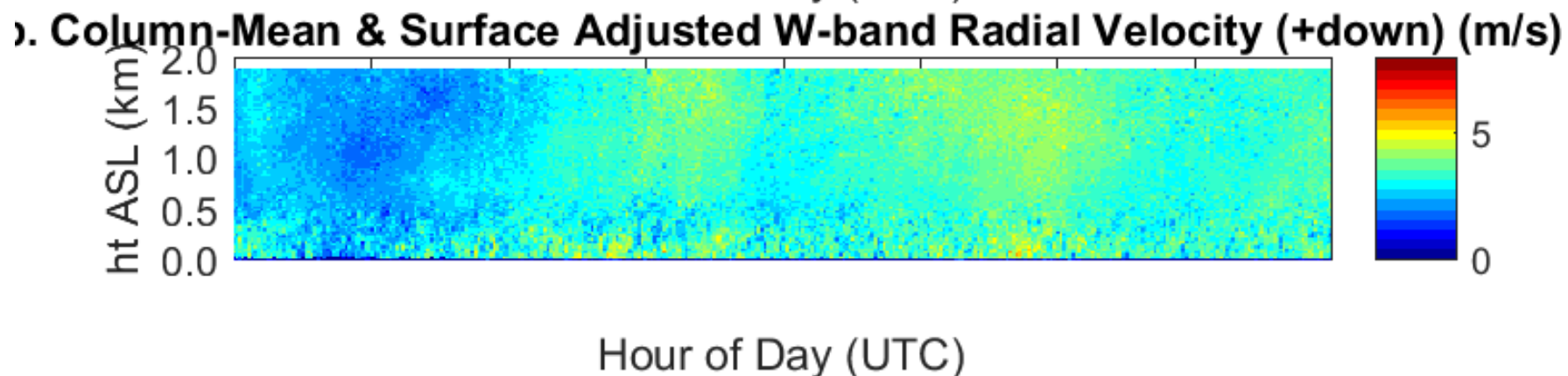
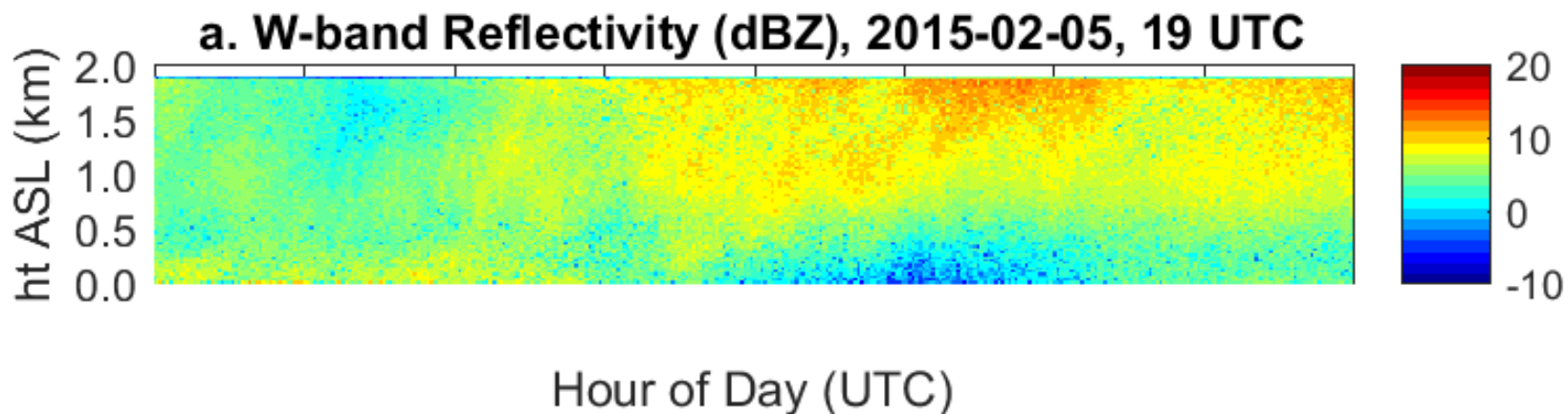


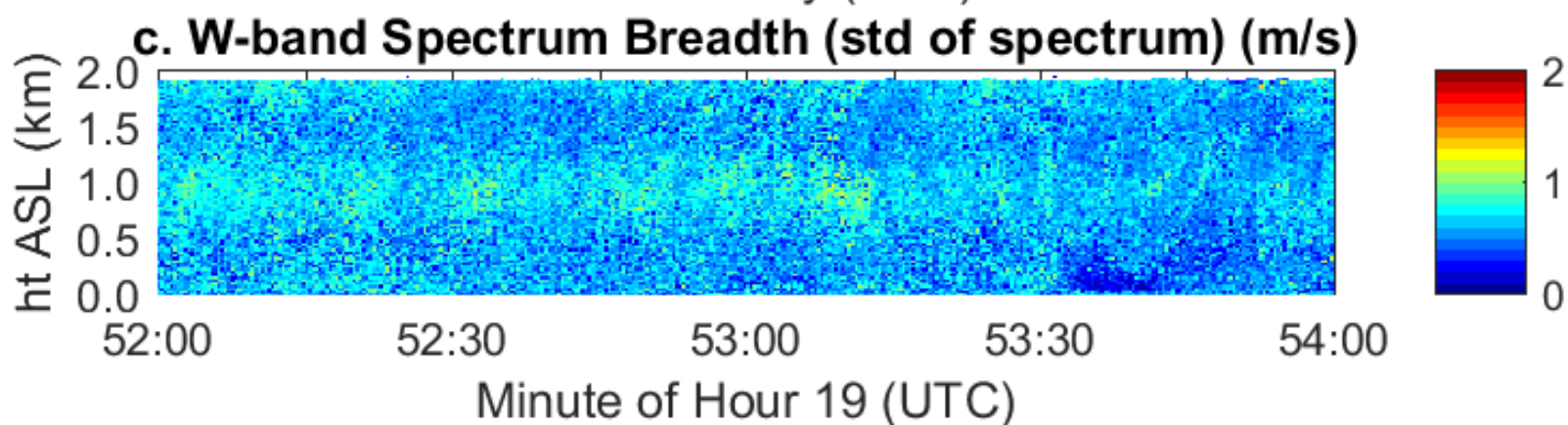
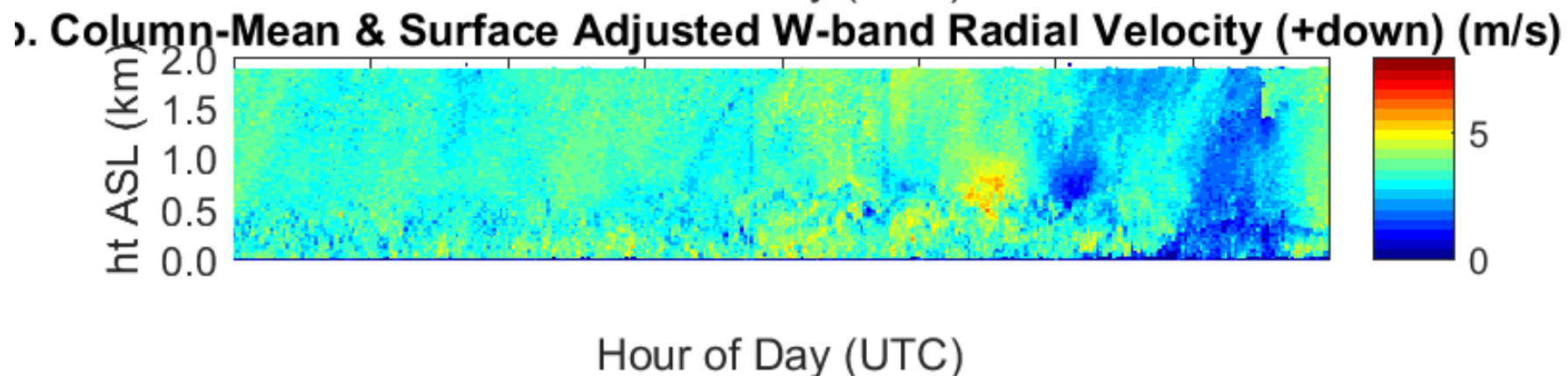
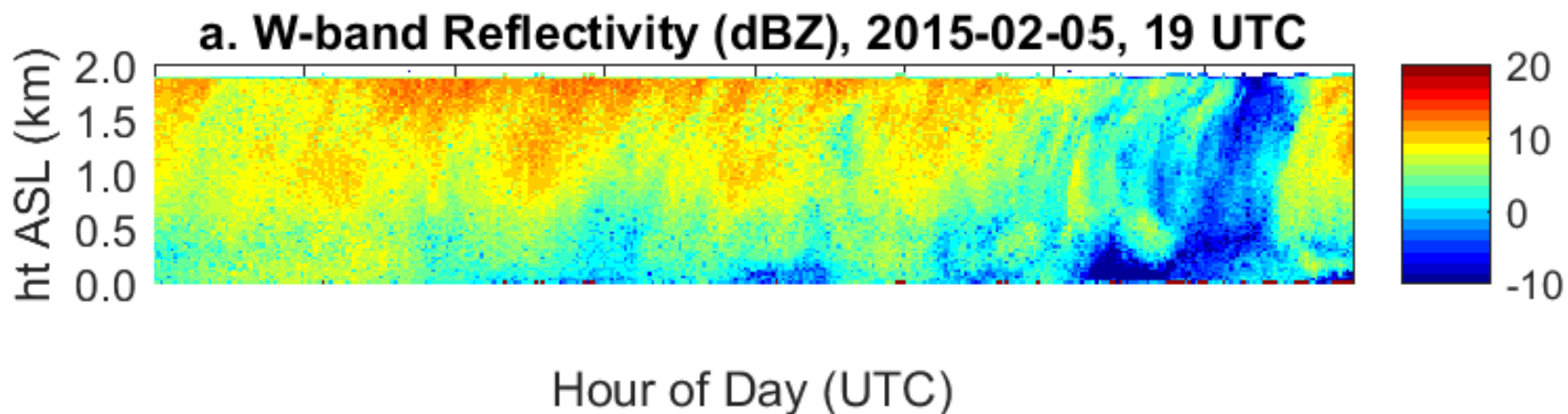


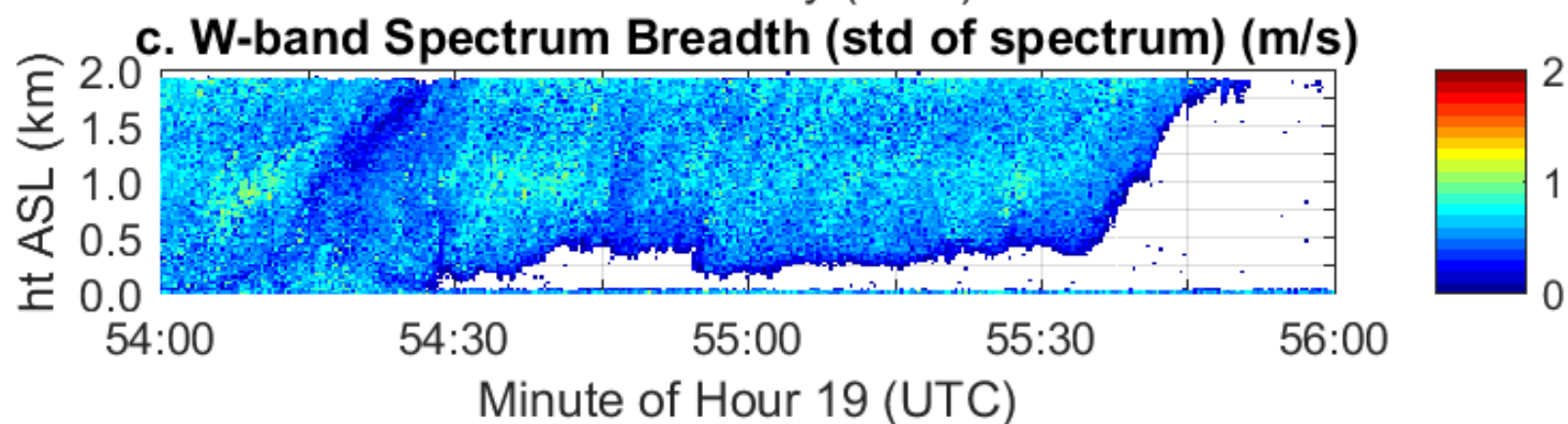
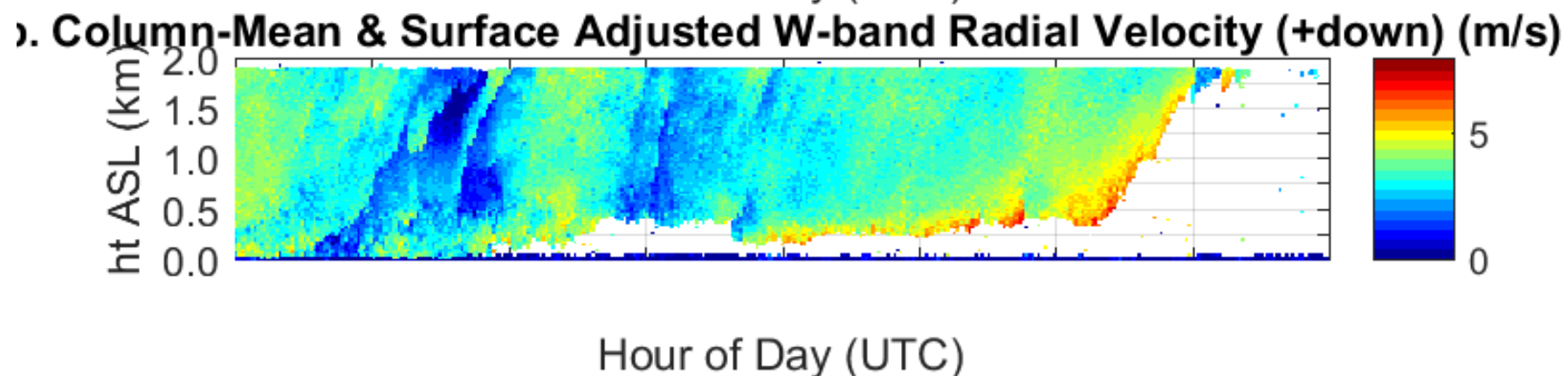
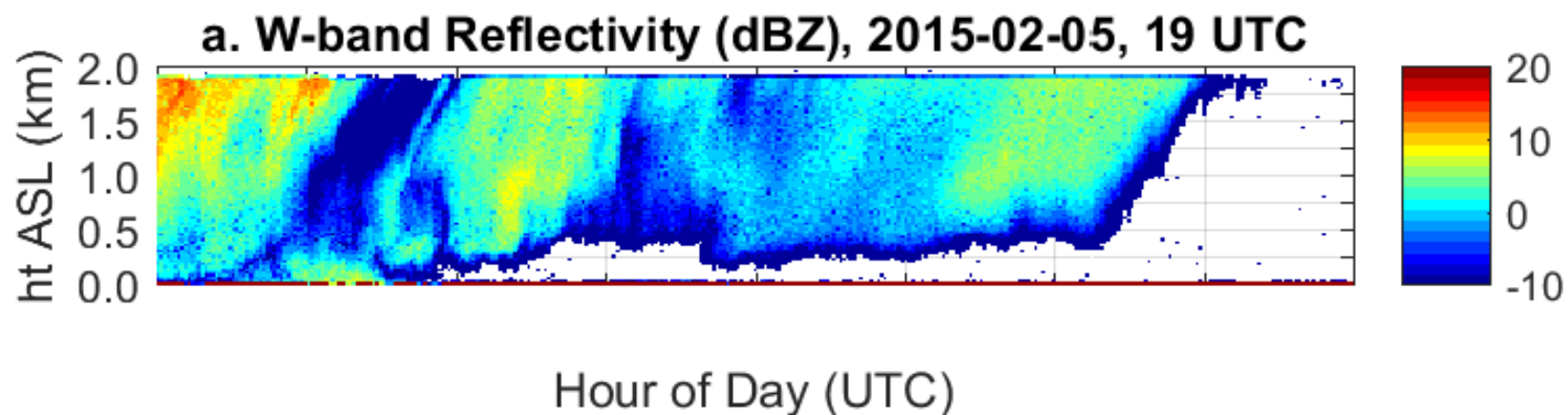












Science Applications

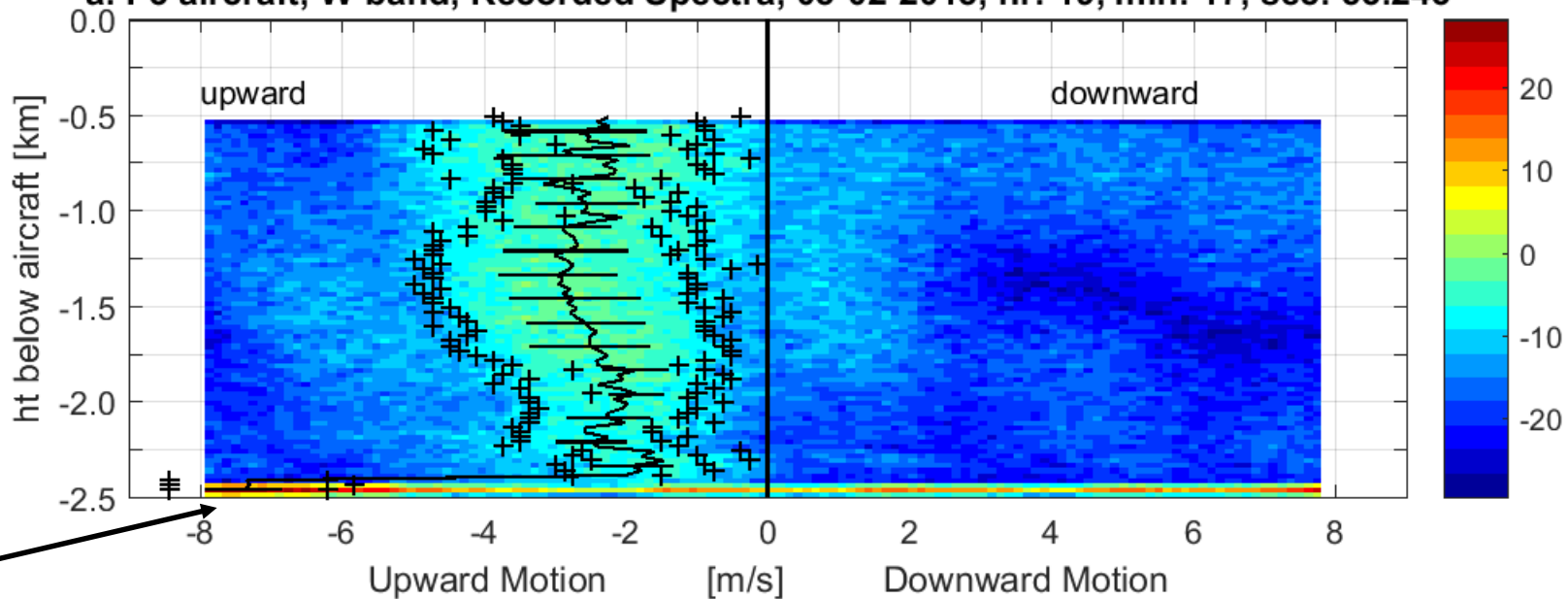
- Boundary Layer Turbulence

- DSD Retrievals

- To avoid harmonics in raw spectra, spectral moments were estimated from dominate single peak
- Next two slides show spectra and moments from pre- and post-aircraft motion correction

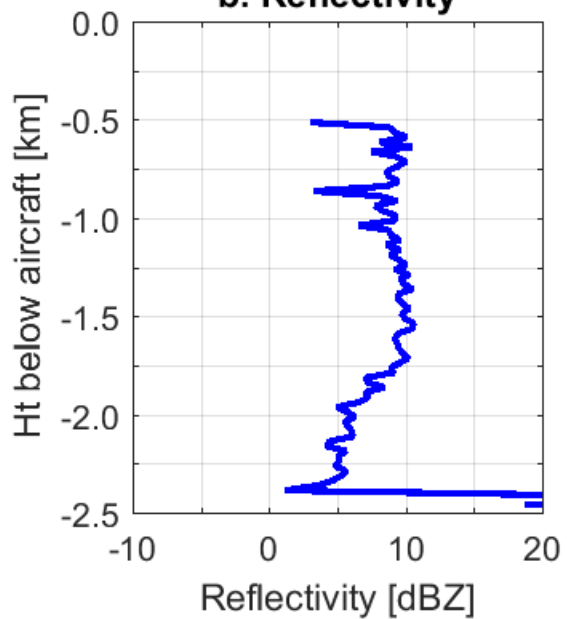
a. P3 aircraft, W-band, Recorded Spectra, 05-02-2015, hr: 19, min: 17, sec: 53.243

Raw Observations
(range below aircraft)

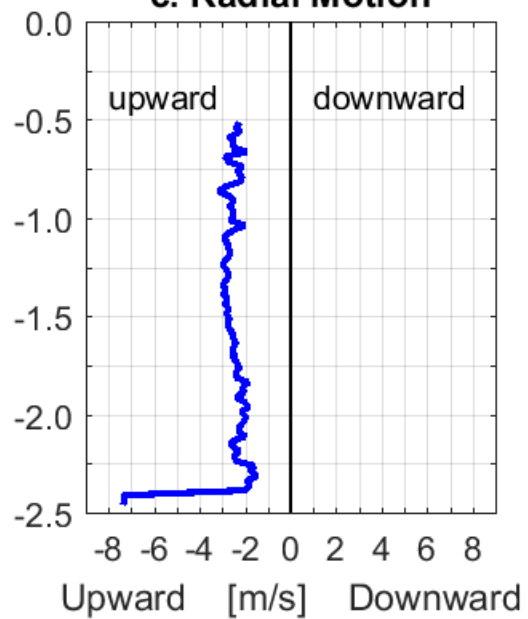


Surface return

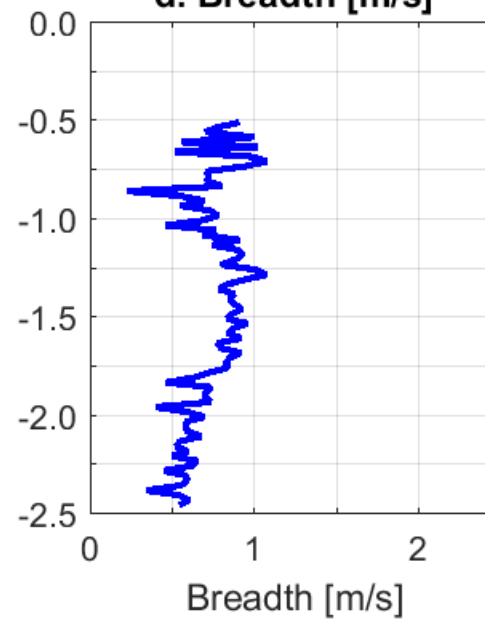
b. Reflectivity



c. Radial Motion

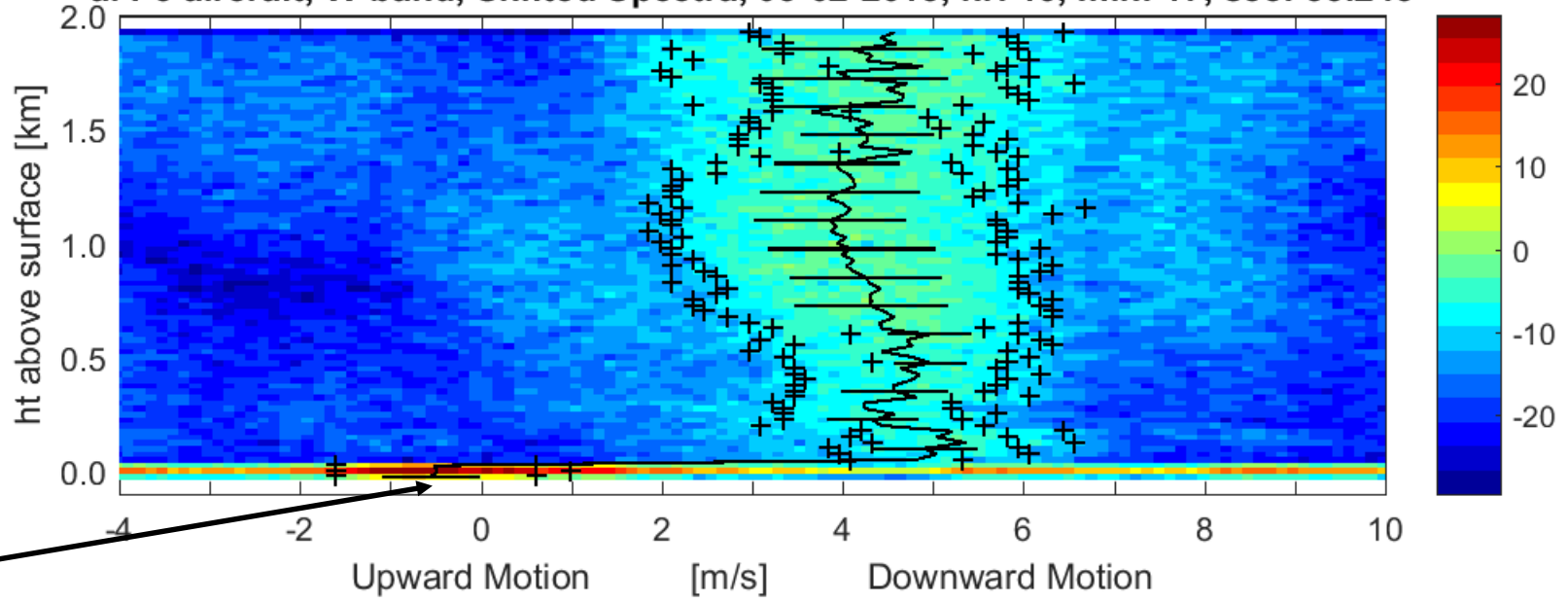


d. Breadth [m/s]

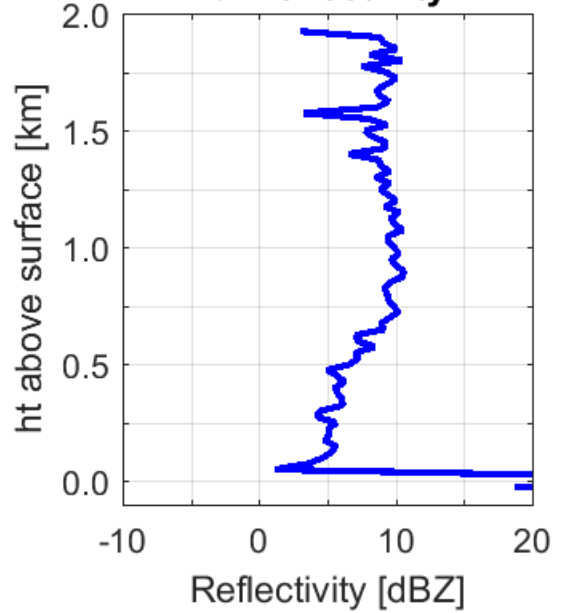


a. P3 aircraft, W-band, Shifted Spectra, 05-02-2015, hr: 19, min: 17, sec: 53.243

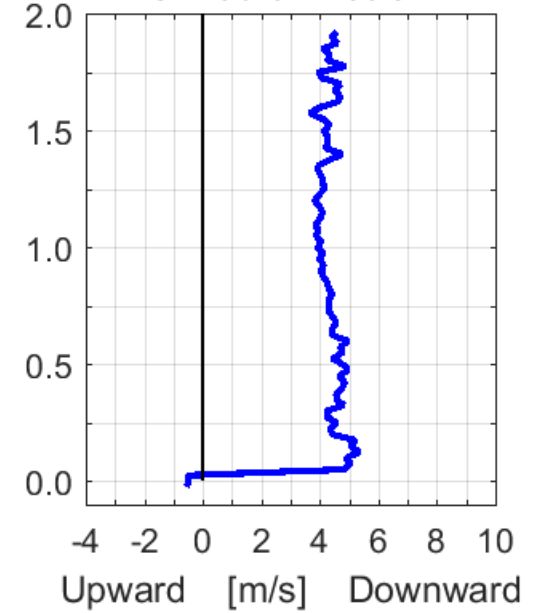
Aircraft adjusted
Observations
(ht above sea level)



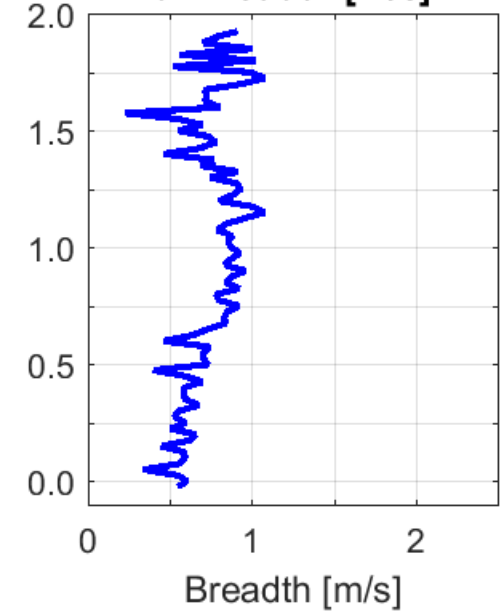
b. Reflectivity



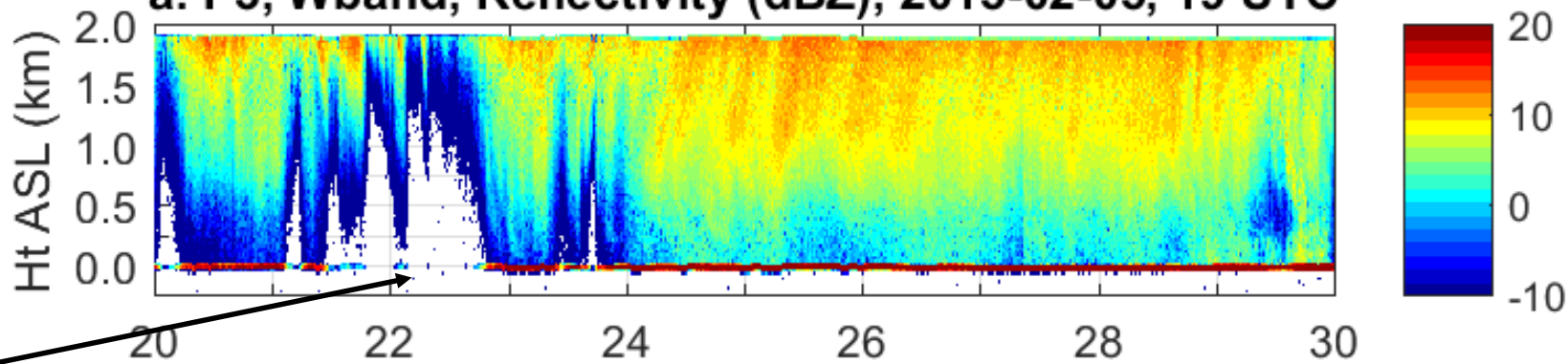
c. Radial Motion



d. Breadth [m/s]

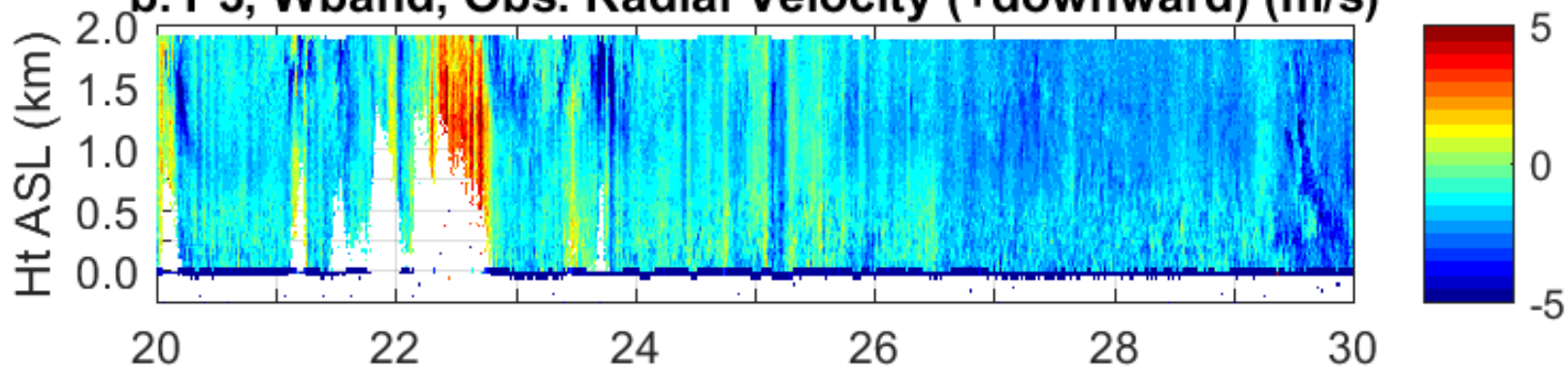


a. P3, Wband, Reflectivity (dBZ), 2015-02-05, 19 UTC

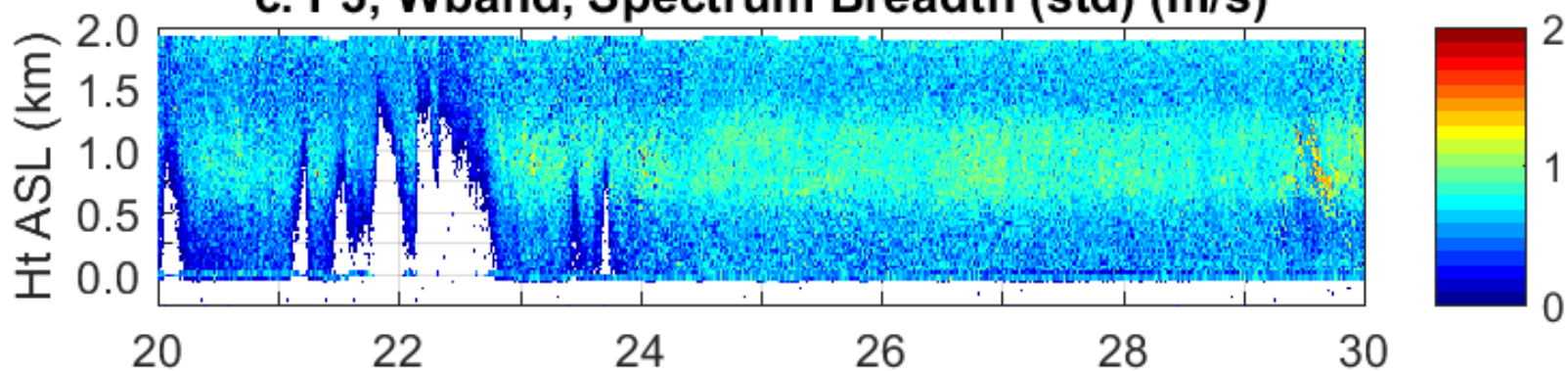


Missing surface return indicates extinguished signal

b. P3, Wband, Obs. Radial Velocity (+downward) (m/s)

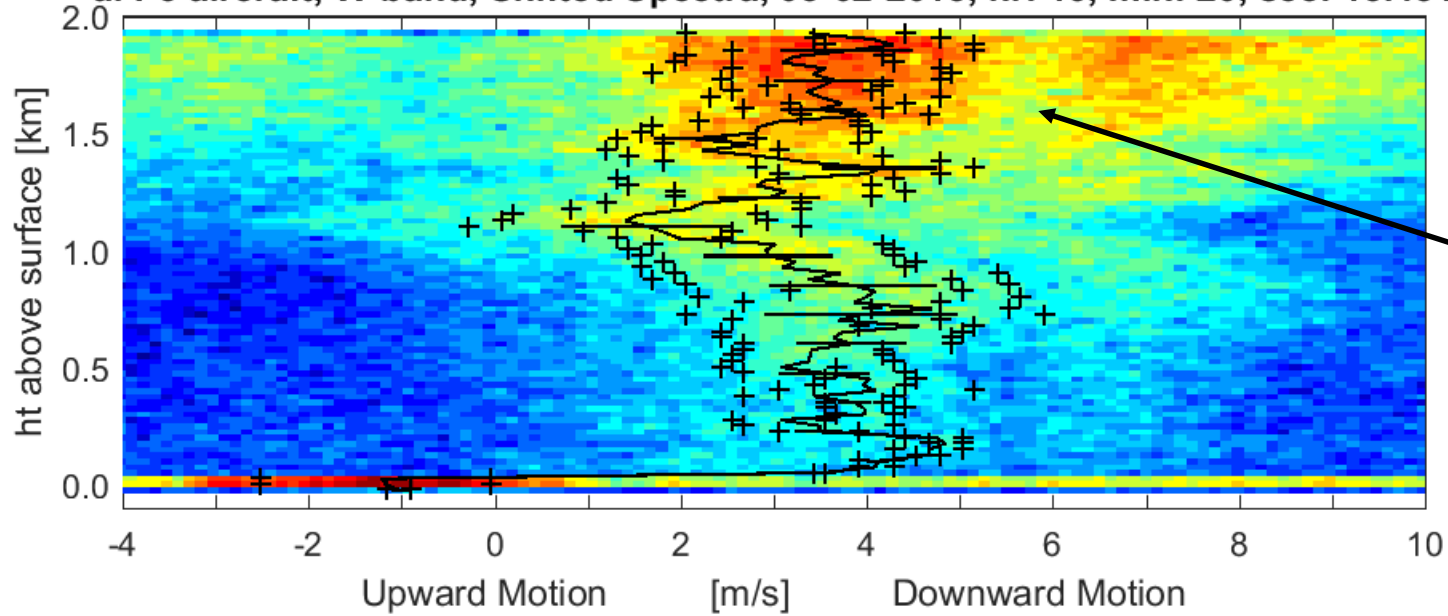


c. P3, Wband, Spectrum Breadth (std) (m/s)



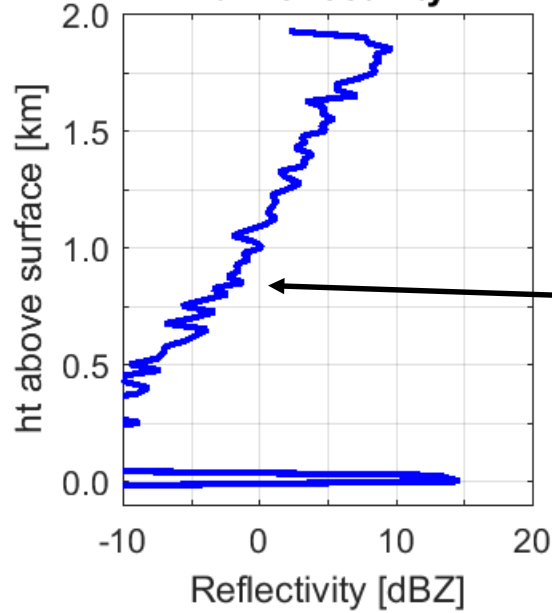
Minute of Hour 19 (UTC)

a. P3 aircraft, W-band, Shifted Spectra, 05-02-2015, hr: 19, min: 20, sec: 15.431

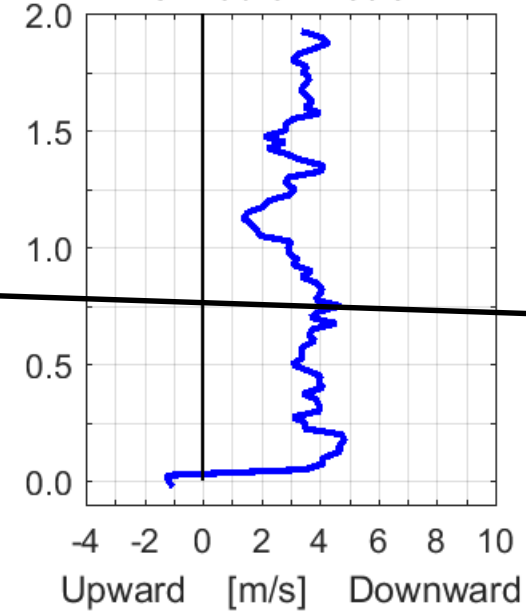


Mie minimum occurs during stronger precip.
(code only identified single peak. DSD retrieval will include Mie minimum)

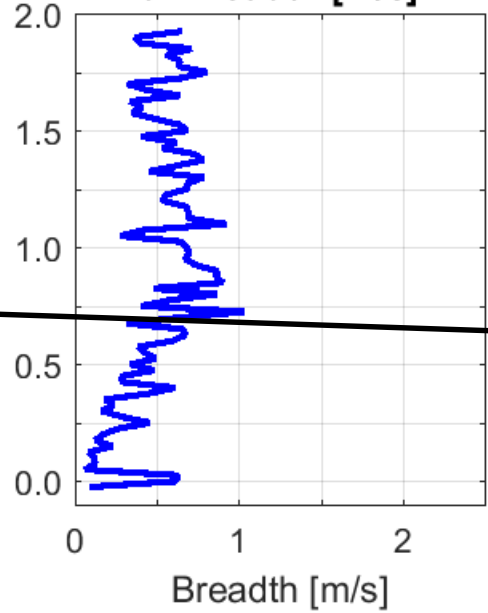
b. Reflectivity



c. Radial Motion



d. Breadth [m/s]



Measured reflectivity includes attenuation ($Z_m = Z_e - \text{atten}$).
DSD retrieval will account for attenuation.