Analysis of weak low-level echo by EarthCARE/CPR

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EarthCARE validation and science workshop 2025@Tokyo

Purpose and approach

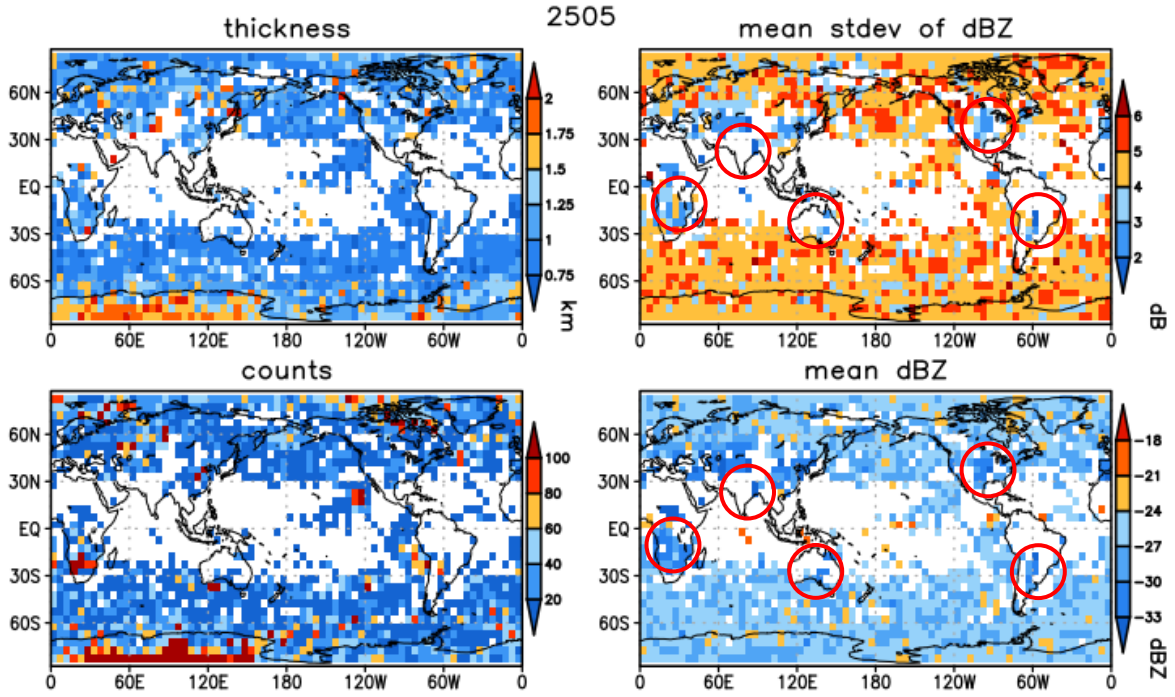
- Assessment of the possibility of observing weak echoes which was not detected by CloudSat
- weak low-level echoes are targeted.

- Analysis
  - Global distribution of weak low-level echo
    - $Z < -25$ dBZ, echo top height < 3 km, horizontal extent > 50 km
    - Calculate the occurrence frequency, mean thickness, and mean and standard deviation of Z within a 5-degree latitude and longitude range
  - Case study
    - Comparison of Echo characteristics and particle type from CPR and ATLID, and cloud type from MSI

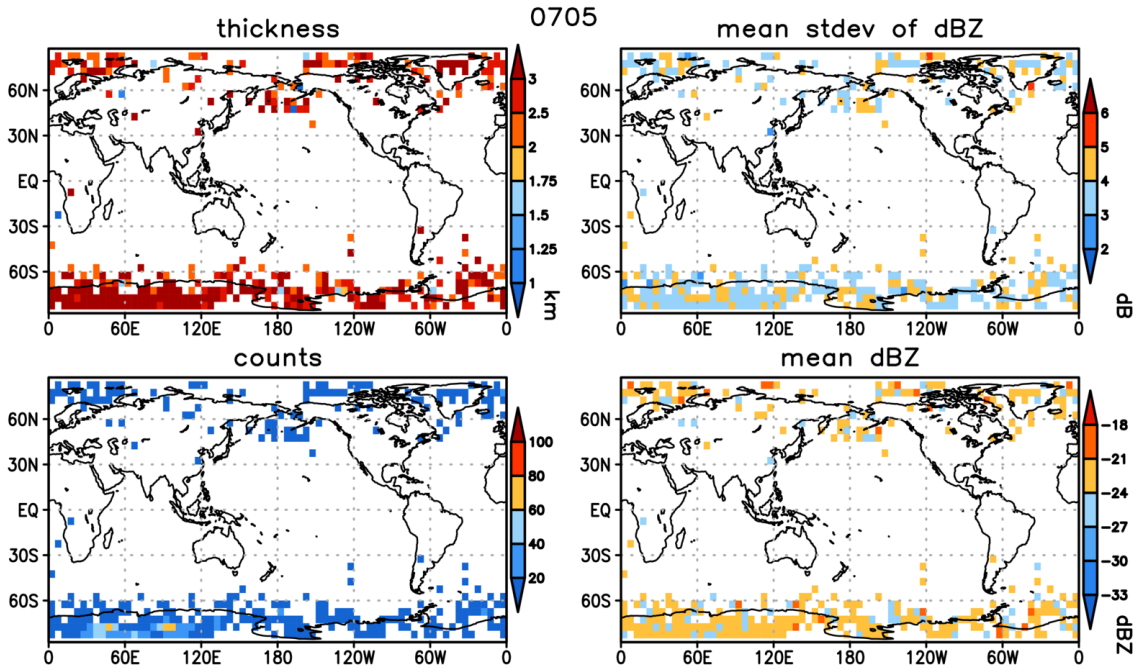
✓ Data
- EarthCARE CPR L1, CPR-ATLID L 2 CLP (JAXA); ATLID L1, L2 AER (ESA); MSI L1, L2 CM (ESA) Aug. 2024-May 2025
- CloudSat L2 GEOPROF 2007

Global Distribution

EarthCARE May 2025



CloudSat May 2007



Clear difference between EarthCARE and CloudSat

- weak shallow echoes are only detected **polar region** by CloudSat
- weak shallow echoes are detected over **mid latitude** by EarthCARE

Characteristic thin weak echo regions are identified (encircled region)

Case study (examples in encircled region)

- Currently, three types are classified.

Type 1: liquid water cloud
  - ATLID shows high backscattering at the top of the CPR echo.

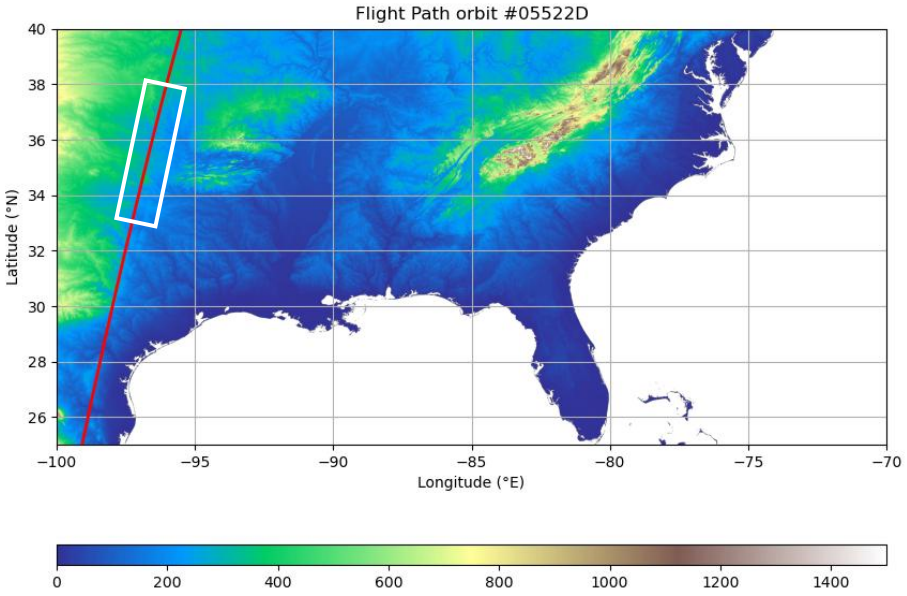
Type 2: dust and liquid cloud mixture (?)
  - overlapping CPR echo region and ATLID echo region

Type 3: unknown
  - noisy ATLID echo but warm water cloud from CPR

Type 1a. nimbostratus

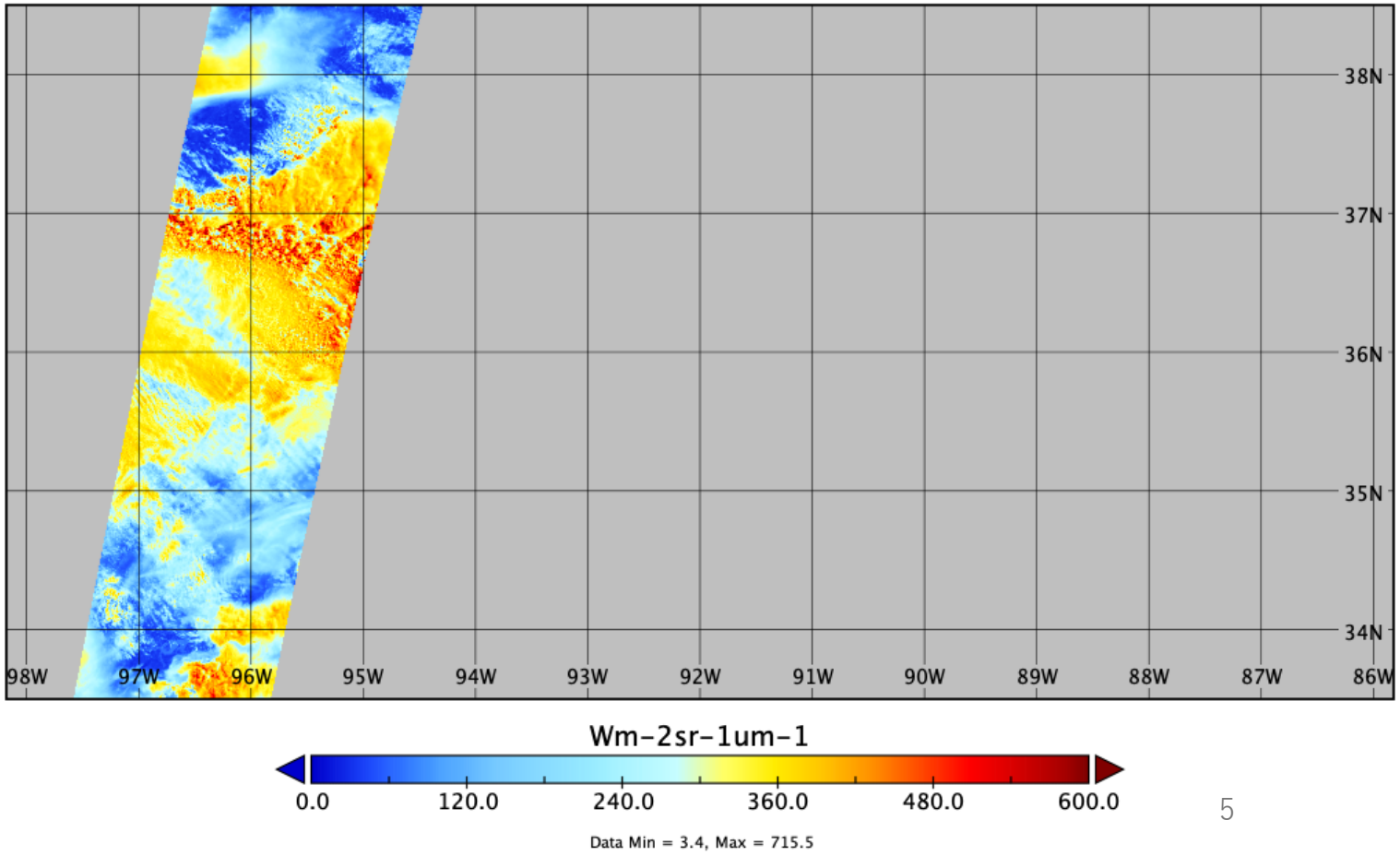
CASE: 18 May 2025 orbit #05522D over North America

EarthCARE trajectory



MSI CH-1 (VIS)

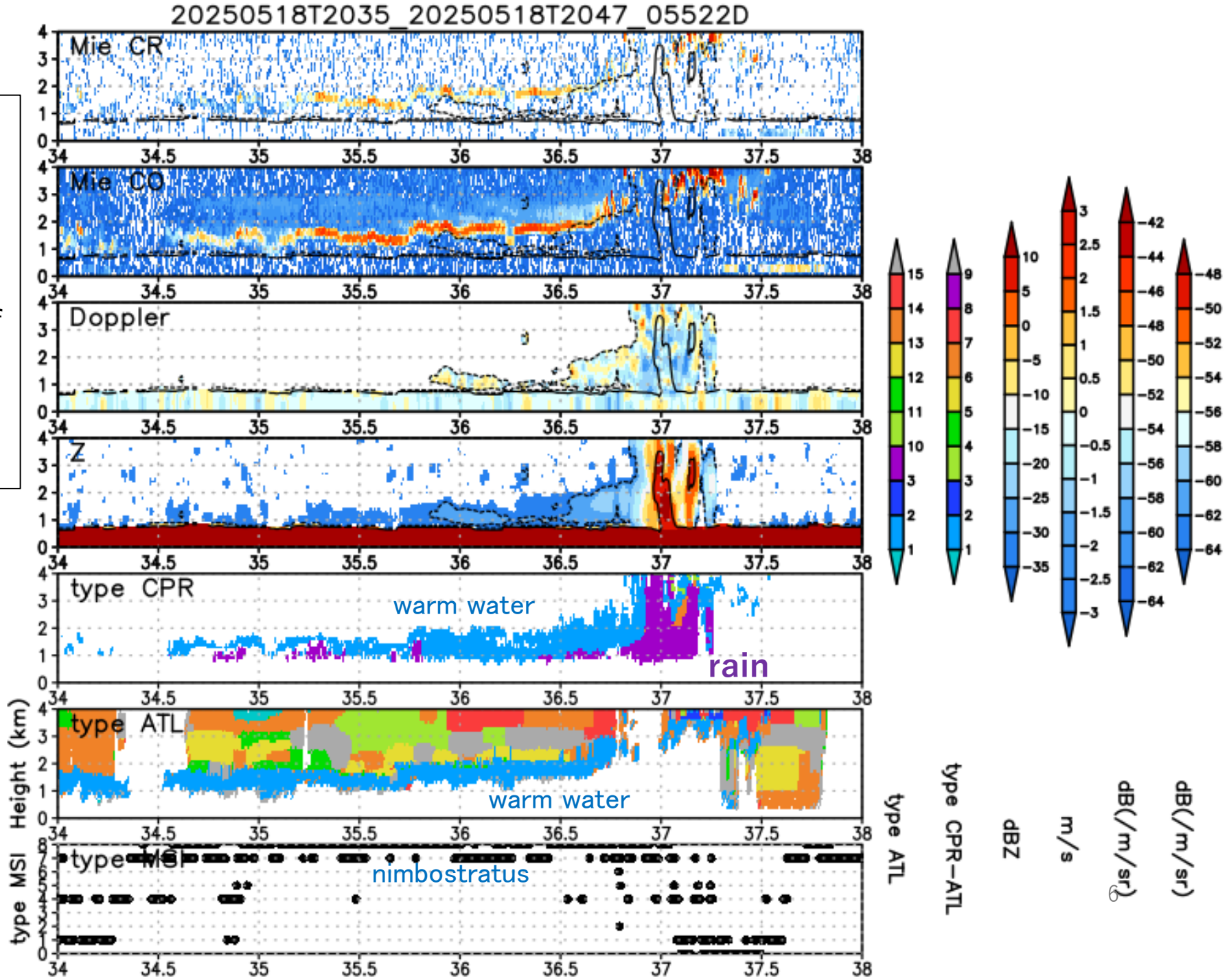
Radiance (VNS bands) CH1 20250518 05522D



Type 1a

- warm water cloud
  - warm water cloud (CPR-ATLID)
  - water signature at the top of the cloud (ATLID)
- Nimbostratus (MSI)

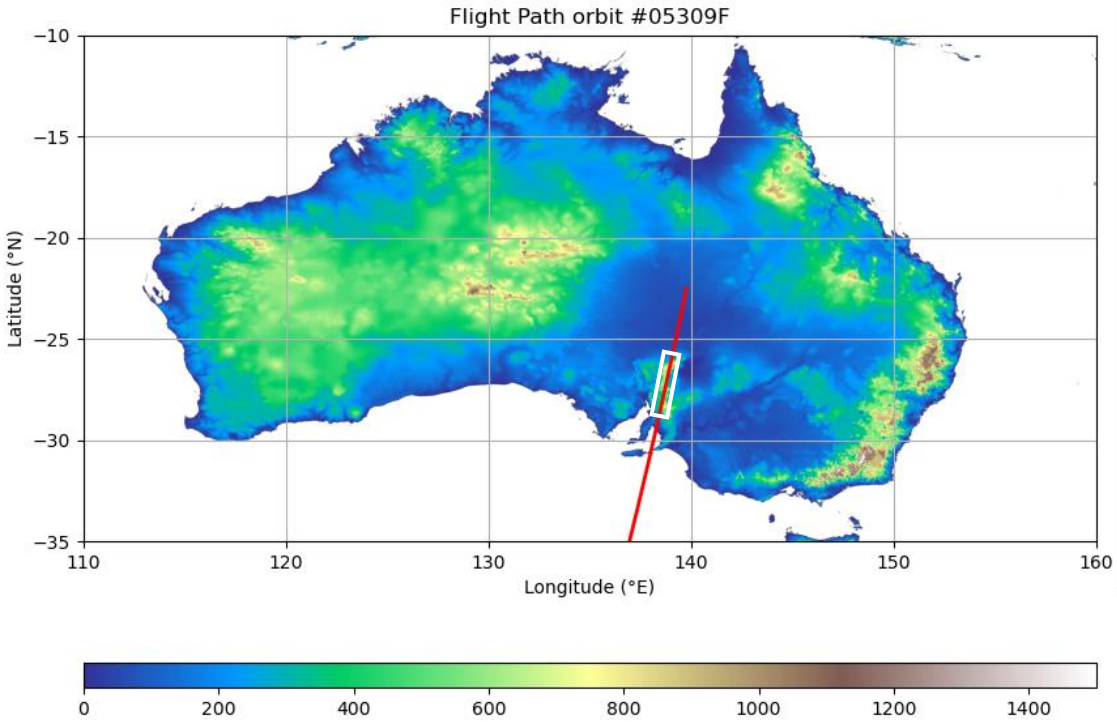
ATLID:
1: warm water 10: dust
12: Continental Pollution
13:smoke 14:dusty smoke
15: dusty mix
MSI:
1:cumulus,2:altocumulus,
3:cirrus, 4:stratocumulus,
5:altostratus, 6:cirrostratus,
7:stratus, **8:nimbostratus**



Type 1b. Cumulus

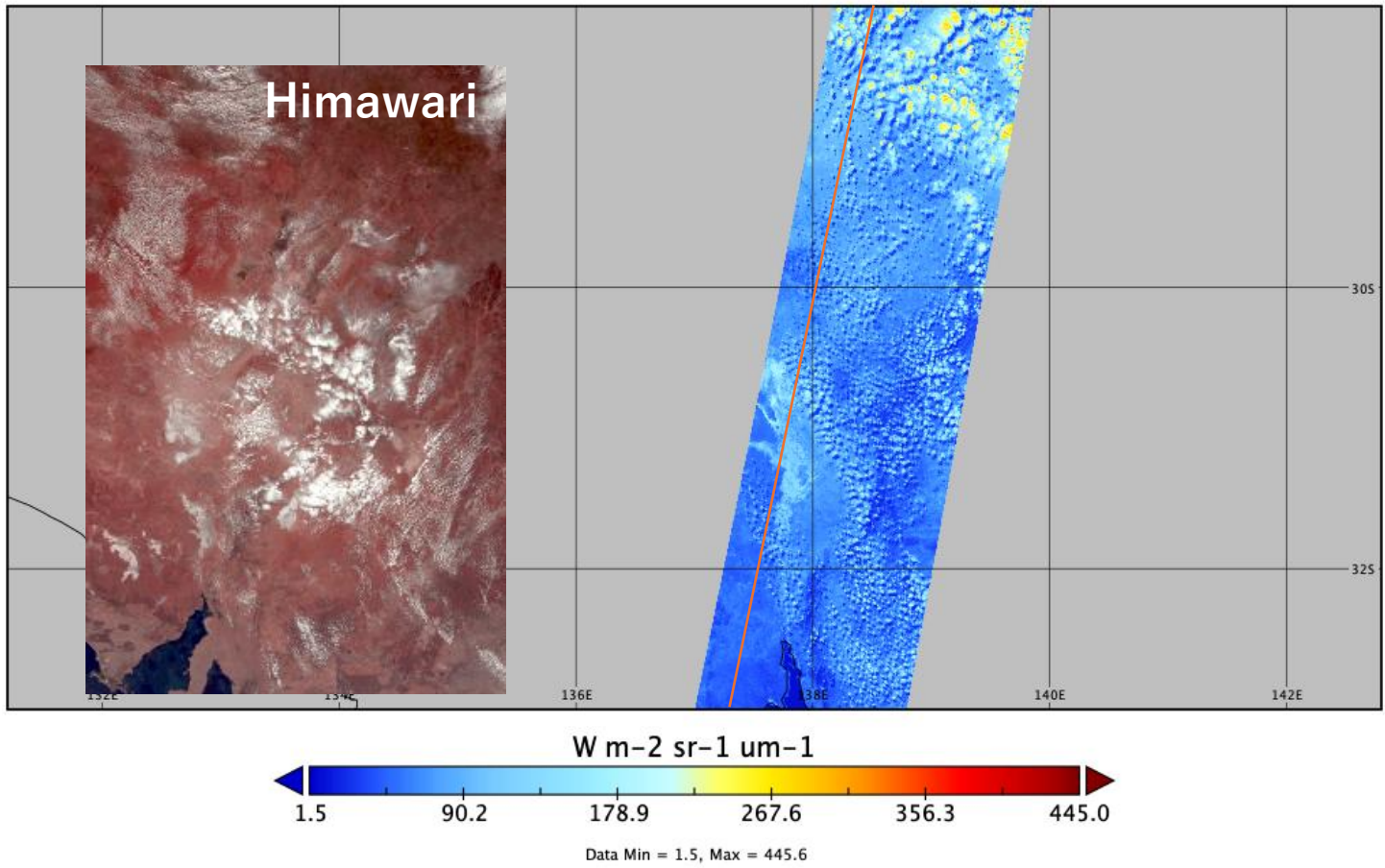
CASE: 5 May 2025 orbit #05309F over Australia

EarthCARE trajectory



MSI CH-1 (VIS)

Radiance (VIS) 20250505 05309F

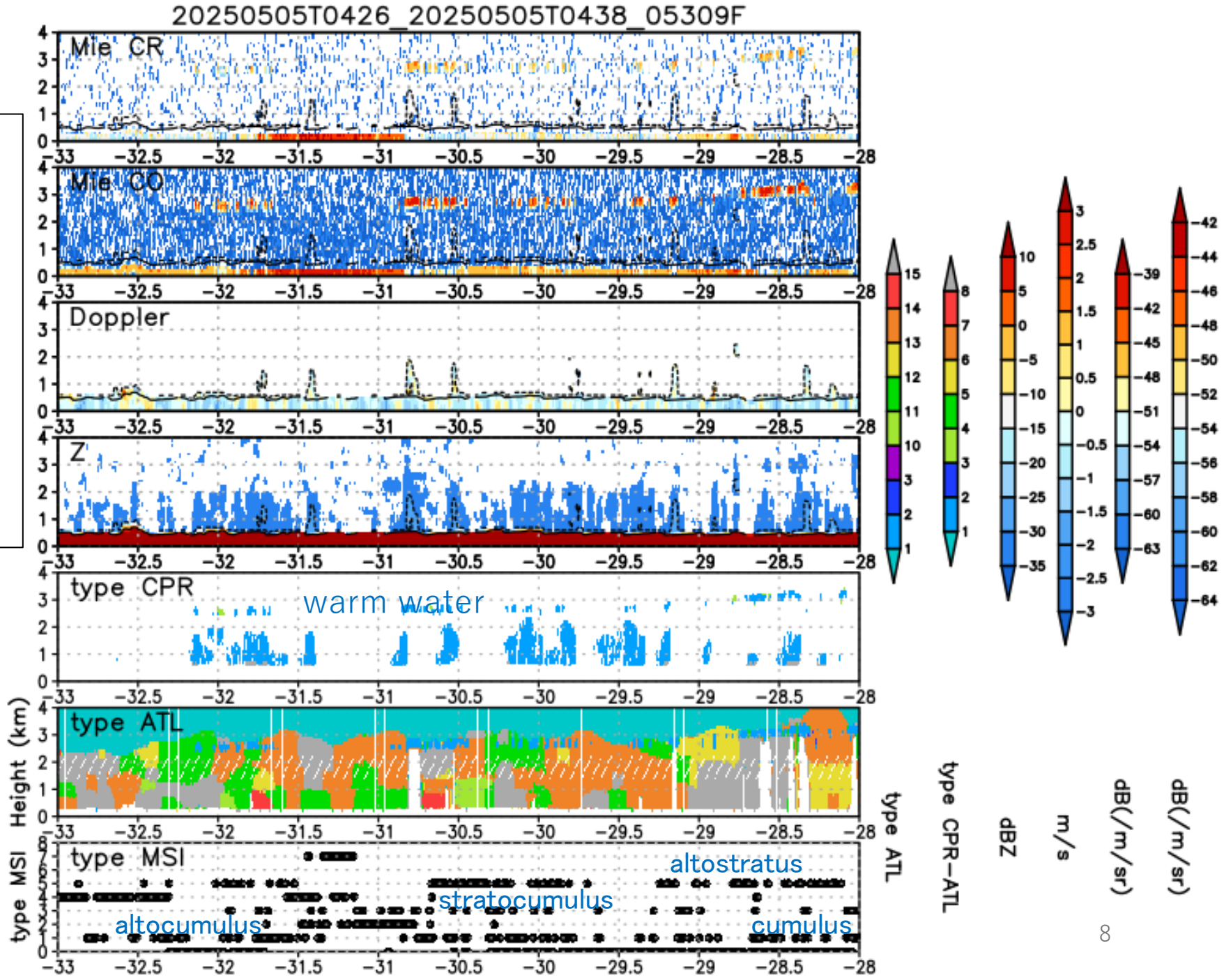


Type 1b

- Shallow cumulus clouds
  - warm water (CPR-ATLID)
  - water signature at the top of the cloud, but smoke, dusts below the cloud top (ATLID)
- Mixture of cumulus, altocumulus and stratocumulus (MSI)

ATLID:
1: warm water 11: sea salt
12: Continental Pollution
13:smoke 14:dusty smoke
15: dusty mix

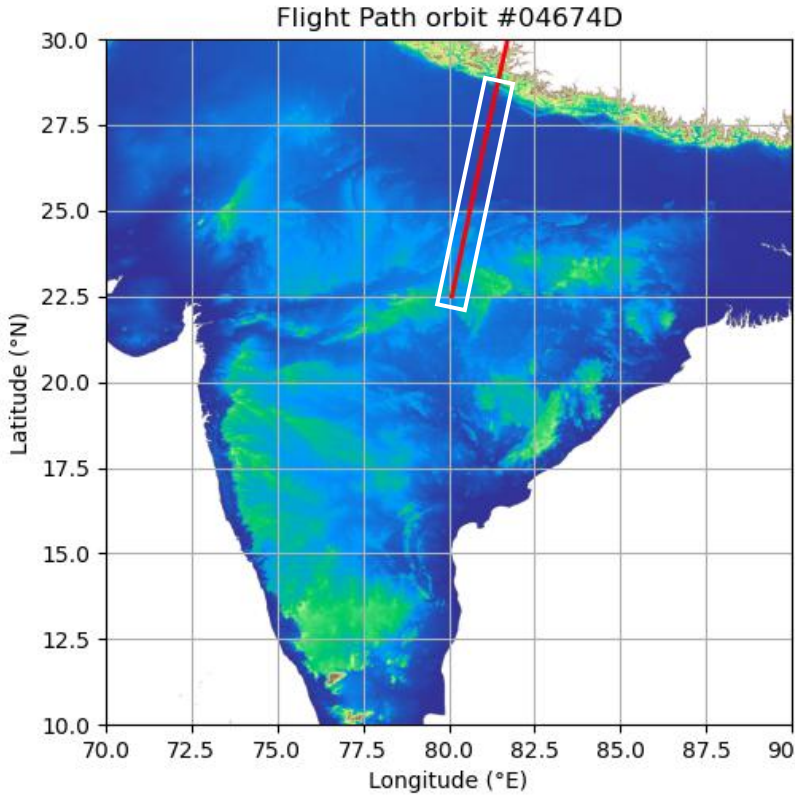
MSI:
1:cumulus,**2:altocumulus**,
3:cirrus, **4:stratocumulus**,
5:altostratus, 6:cirrostratus,
7:stratus, 8:nimbostratus,

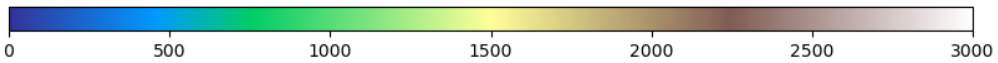


Type 2. dust & cloud mixture?

CASE: 25 March 2025 orbit #04674D over India

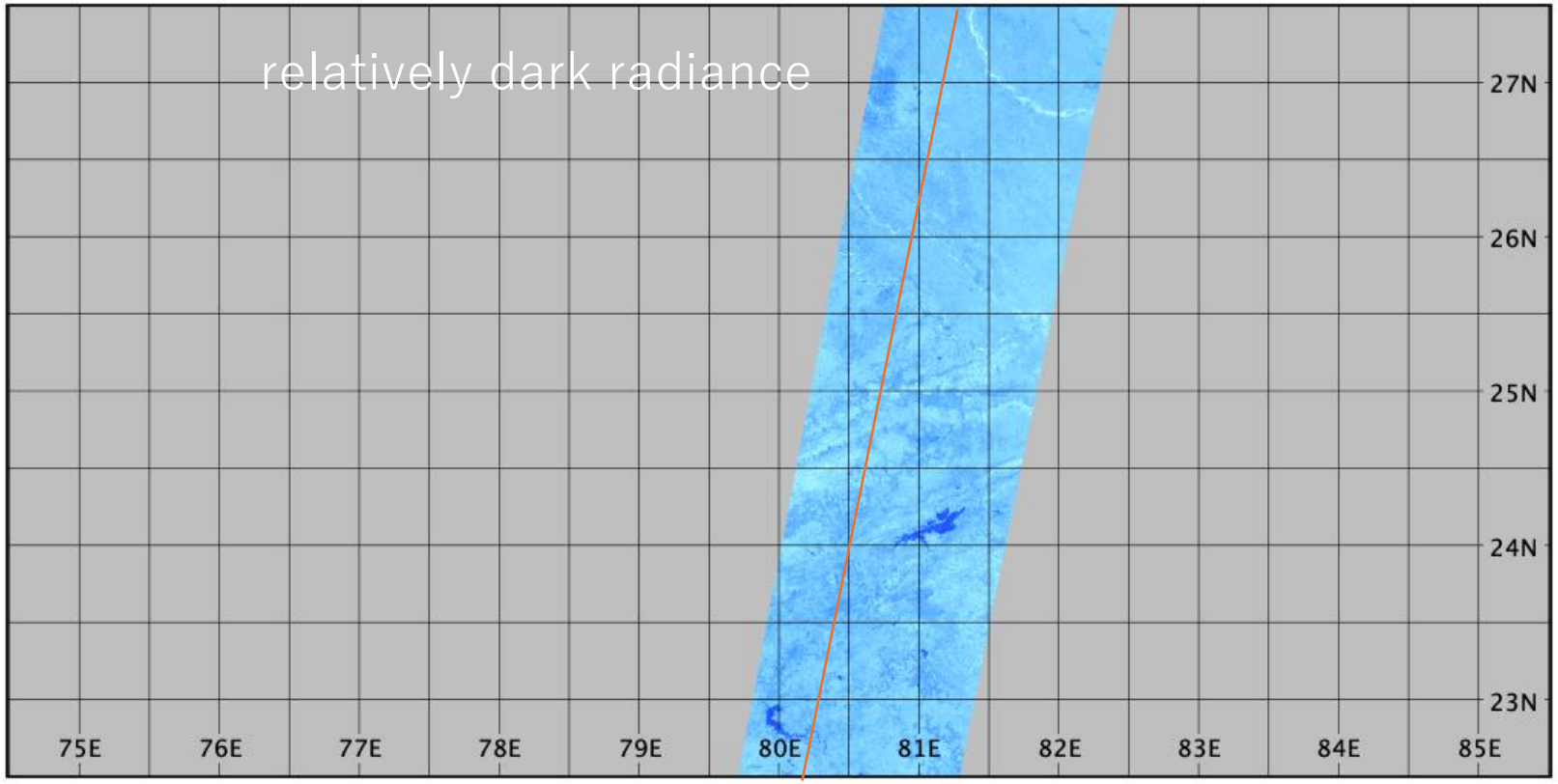
EarthCARE trajectory

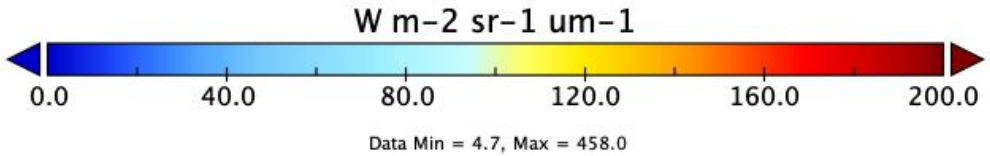




MSI CH-1 (VIS)

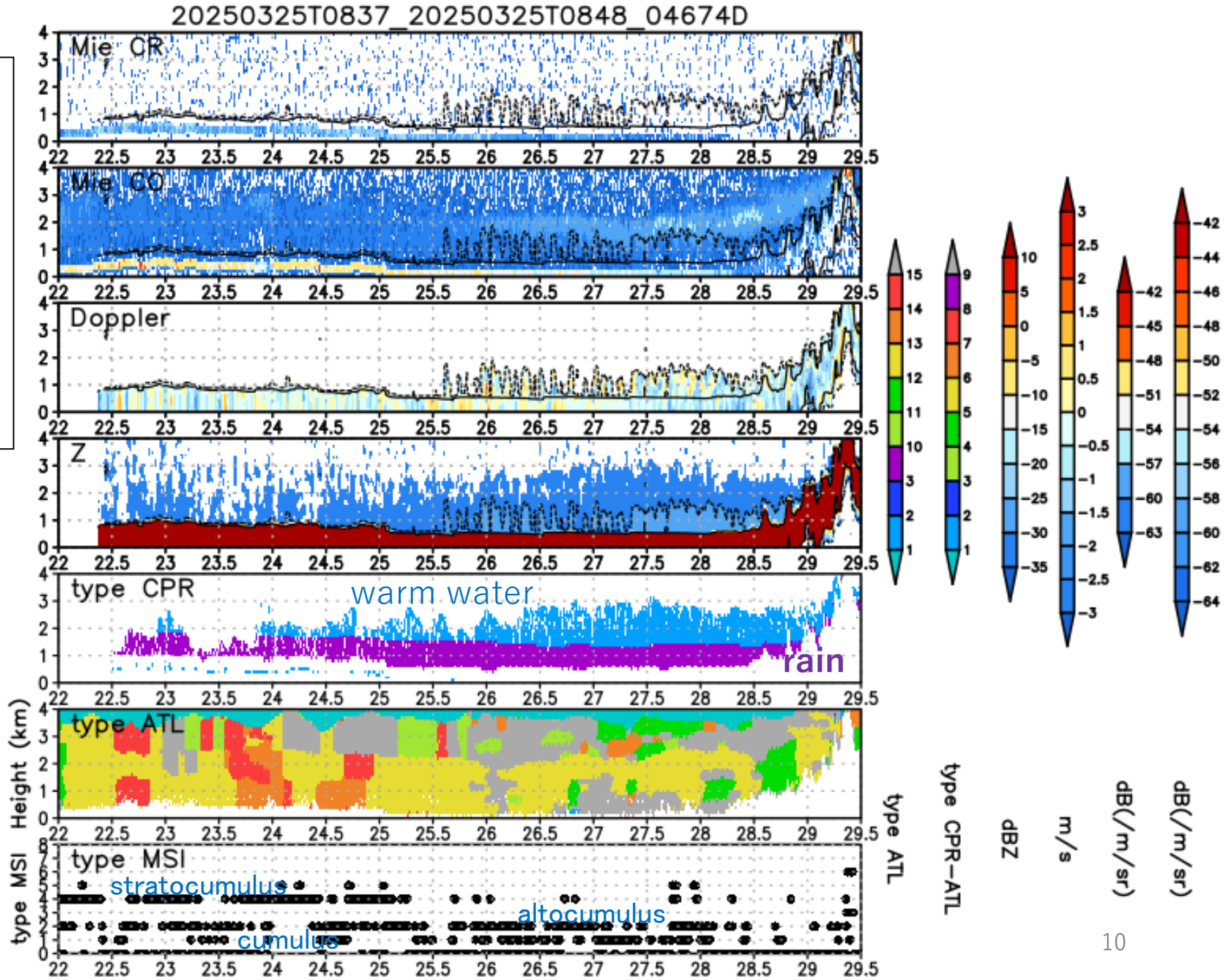
CH1 25 Mar. 2025 #04674D





Type 2

- Shallow cumulus clouds?
  - warm water + ? (CPR-ATLID)
  - no water signature, but continental pollution (ATLID)
- Mixture of cumulus, altocumulus and stratocumulus (MSI)



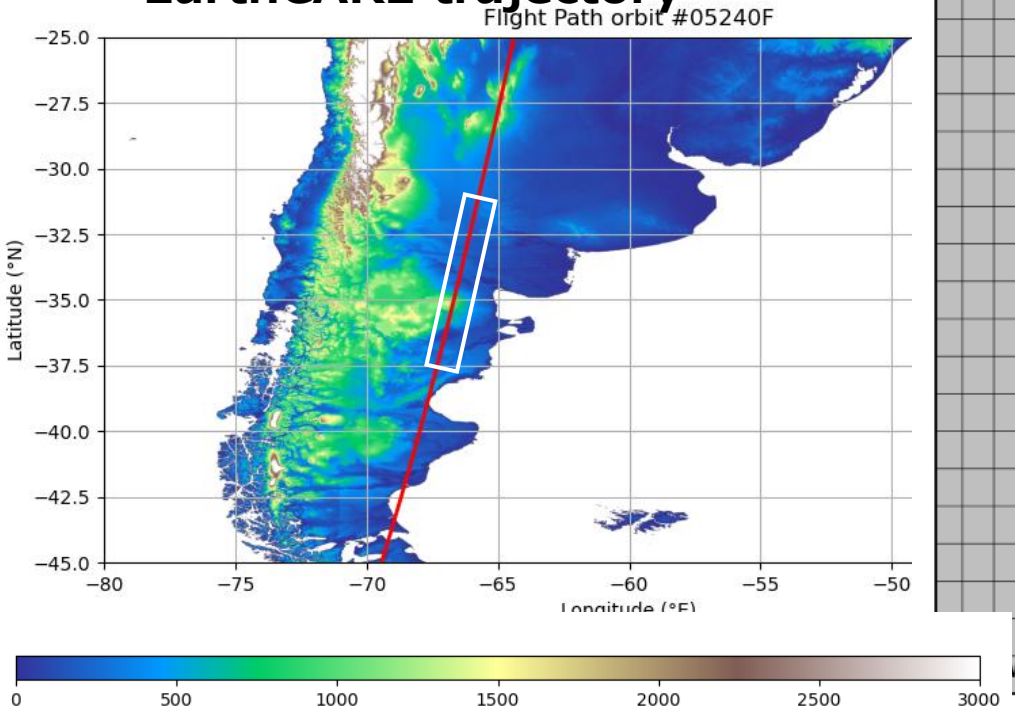
ATLID:
1: warm water 11: sea salt
12: Continental Pollution
13:smoke **14:dusty smoke**
15: dusty mix

MSI:
1:cumulus,**2:altocumulus**,
3:cirrus, **4:stratocumulus**,
5:altostratus, 6:cirrostratus,
7:stratus, 8:nimbostratus,

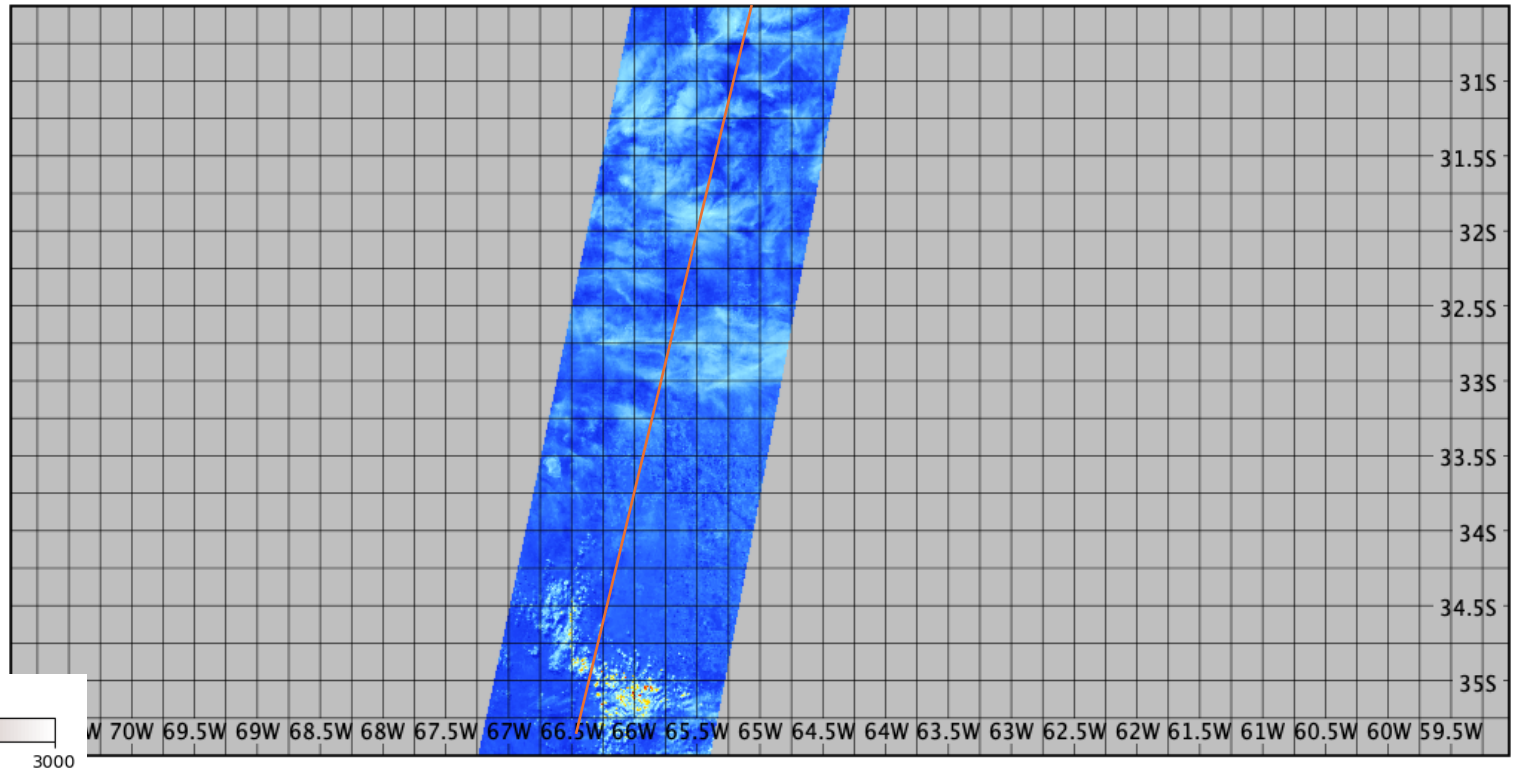
Type 3. unknown

CASE: 30 April 2025 orbit #05240F over South America

EarthCARE trajectory



MSI CH-1 (VIS)



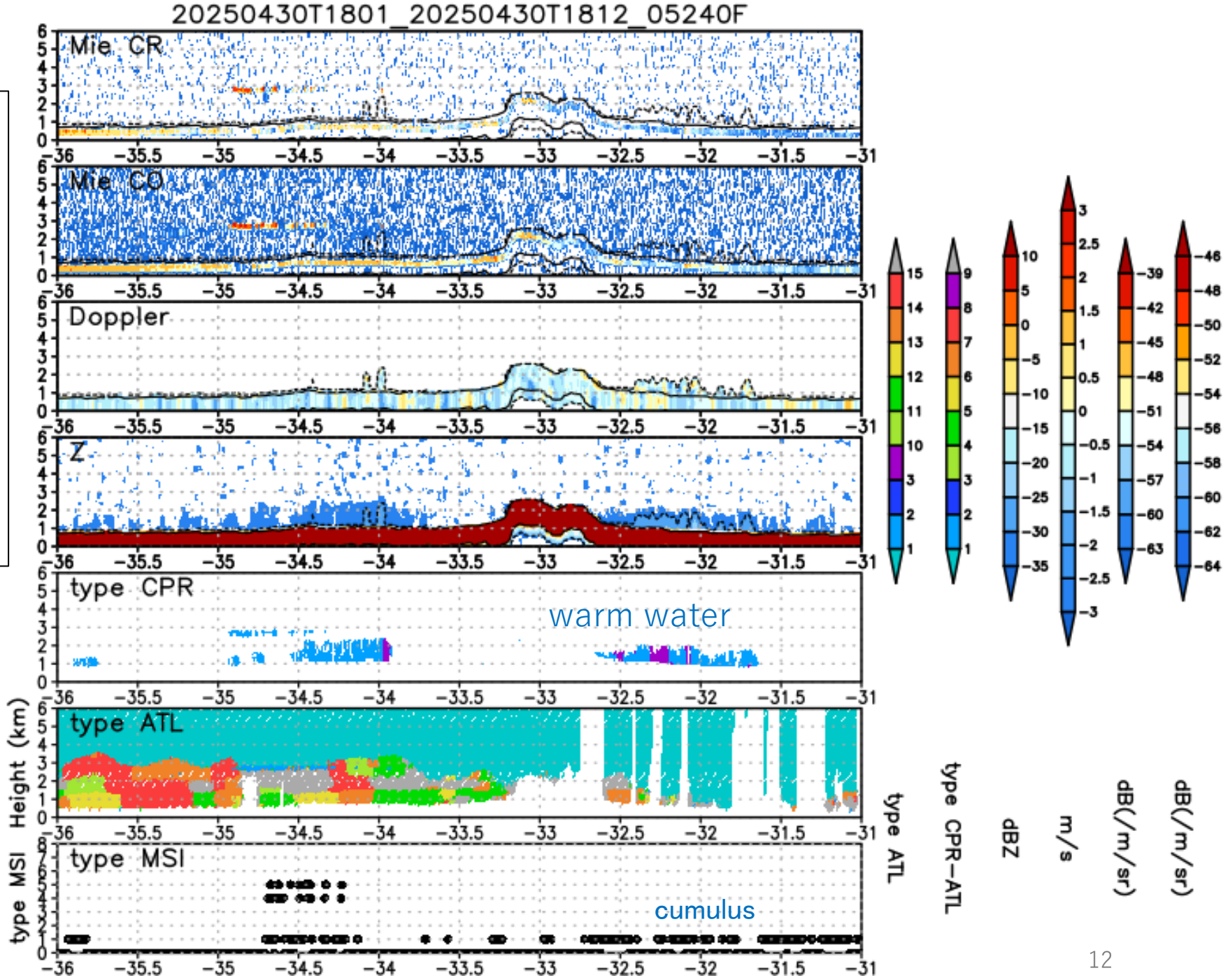
Type 3

- Shallow cumulus cloud
  - warm water (CPR-ATLID)
  - no water signature, dusty or clear (ATLID)
- Cumulus cloud (MSI)

- Weak echo (max < -30 dBZ) from CPR and noisy echo from ATLID

ATLID:
1: warm water 11: sea salt
12: Continental Pollution
13:smoke **14:dusty smoke**
15: dusty mix

MSI:
1:cumulus,2:altocumulus,
3:cirrus, 4:stratocumulus,
5:altostratus, 6:cirrostratus,
7:stratus, 8:nimbostratus,



Summary

- EarthCARE/CPR demonstrated significantly higher sensitivity than CloudSat/CPR in detecting weak echoes in the lower layers.
- Weak low-level echoes are categorized so far into three types by the ATLID observation:
  - ATLID echo exists only top of the echo
  - ATLID echo overlaps with CPR echo
  - Noisy ATLID echo over CPR echo
- MSI visible observation showed these clouds are nimbostratus, cumulus, stratocumulus etc.
- Further investigation is needed with ground based observations.

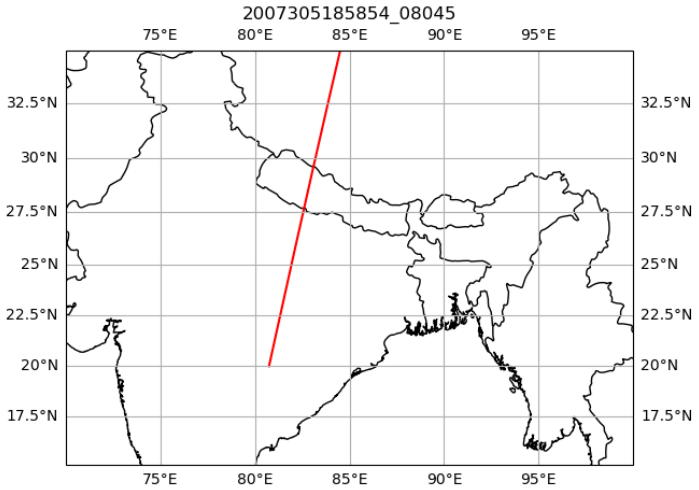
CloudSat observation

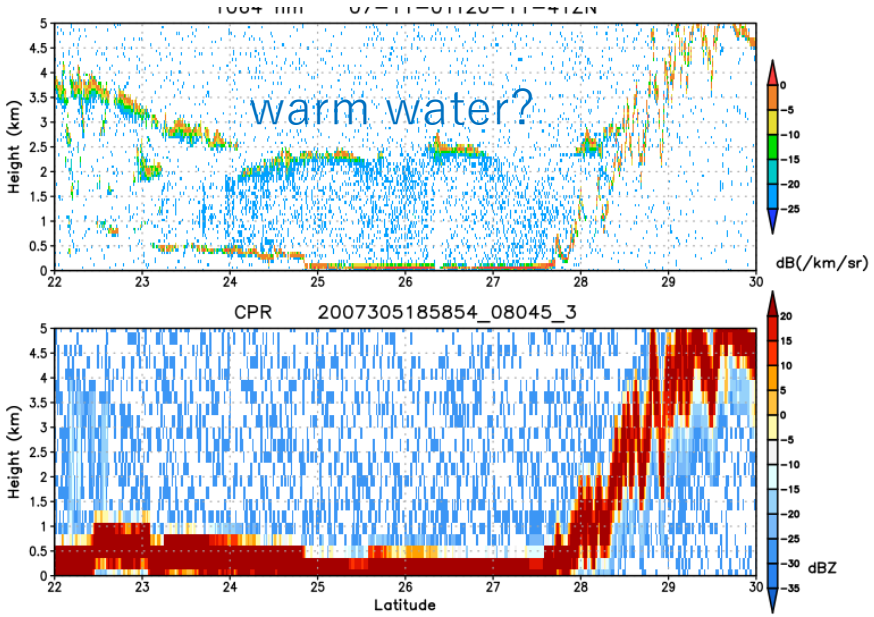
1 Nov. 2007

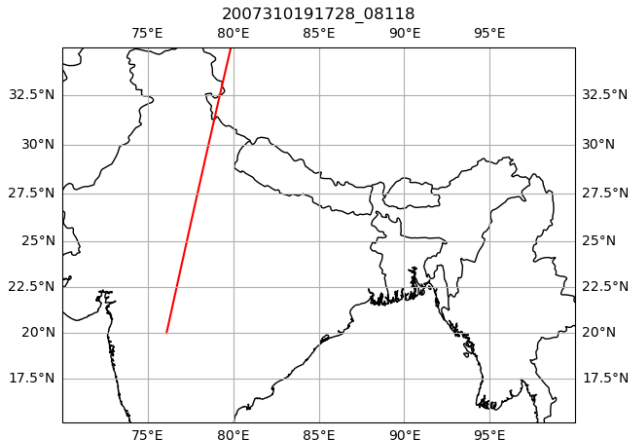
6 Nov. 2007

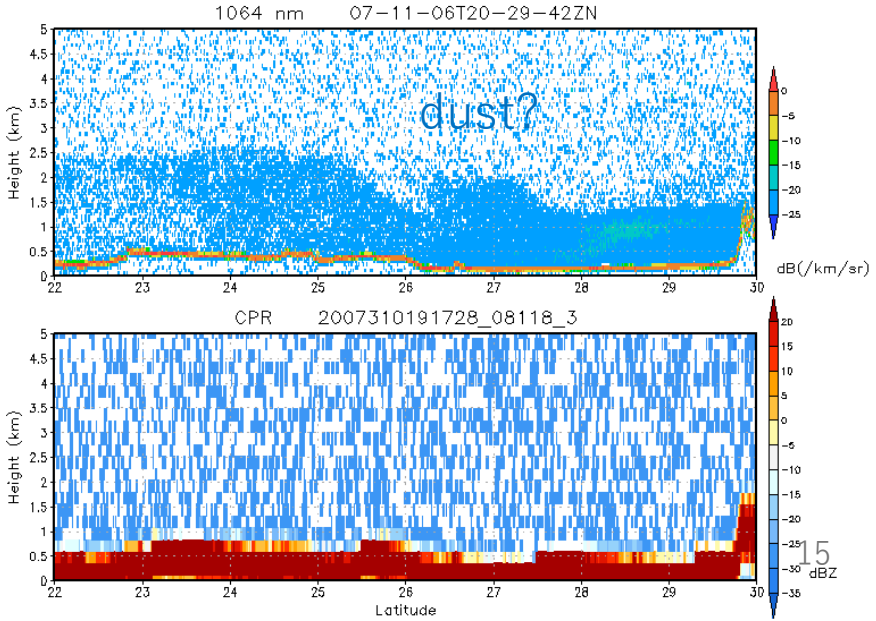
CALIOP

CloudSat/CPR









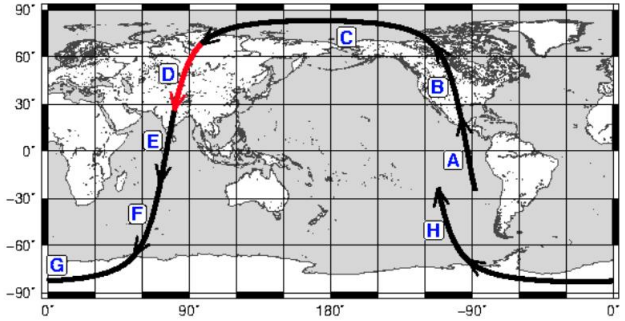
04674D

EarthCARE Quick Look

English

データ利用　プロダクト情報

Overlay　最新情報



Observation Date:

Start: 2025/03/25 08:37
End: 2025/03/25 08:48

Search Menu

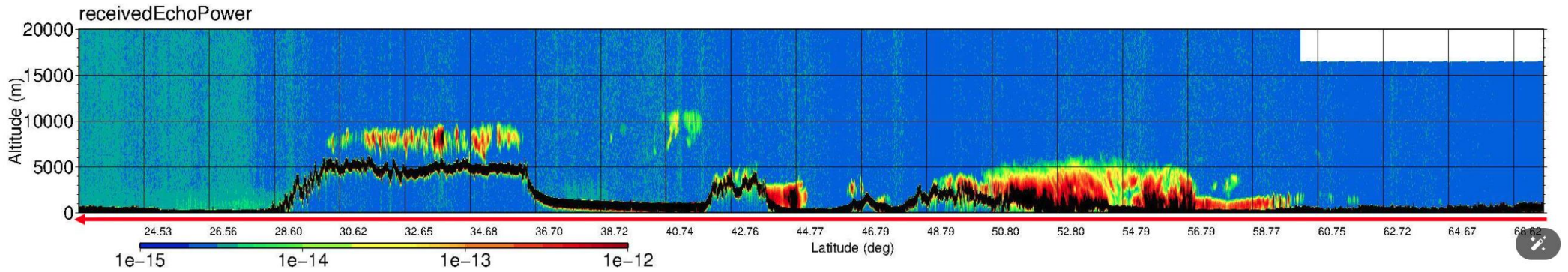
Obs. Date	2025 / 3 / 25
Orbit No. (Day)	04674
Frame No.	Frame D: (N67.5-N22.5 Descending Track)
Skip Span	○Day ○Orbit ◉Frame

Prev. | Search | Latest | Next

全て | CPR L1B (CPR_CLP) | CPR Echo (CPR_ECO) | CPR Cloud (CPR_CLP) | ATLID L1B (ATL_NOM) | ATLID L2a (ATL_CLA) | MSI L1c (MSI_RGR) | MSI L2a (MSI_CLP) | BBR L1B (BBR_NOM) | CPR-ATLID (AC__CLP)

CPR L1b プロダクト (CPR_NOM)

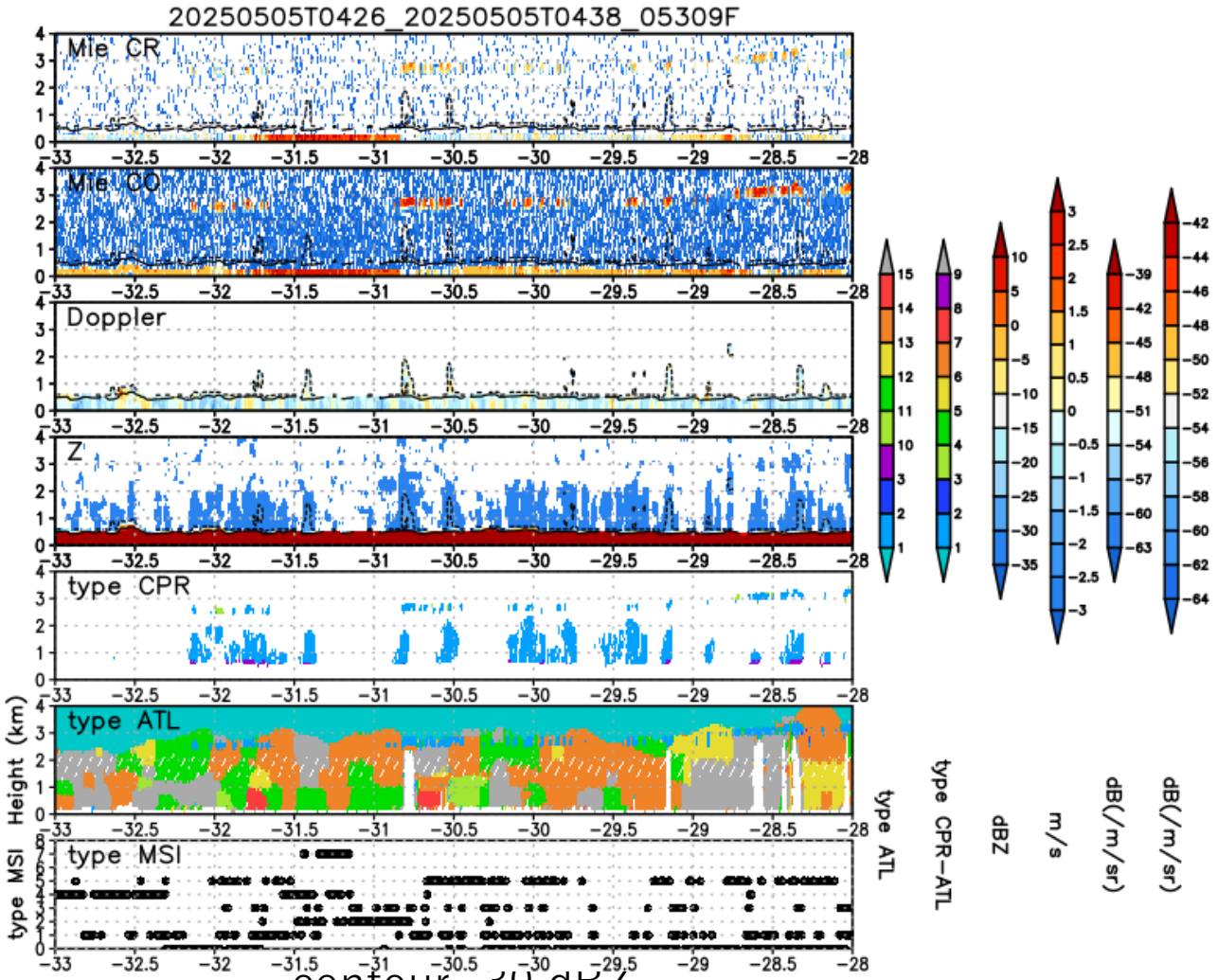
◉ receivedEchoPower　○ dopplerVelocity

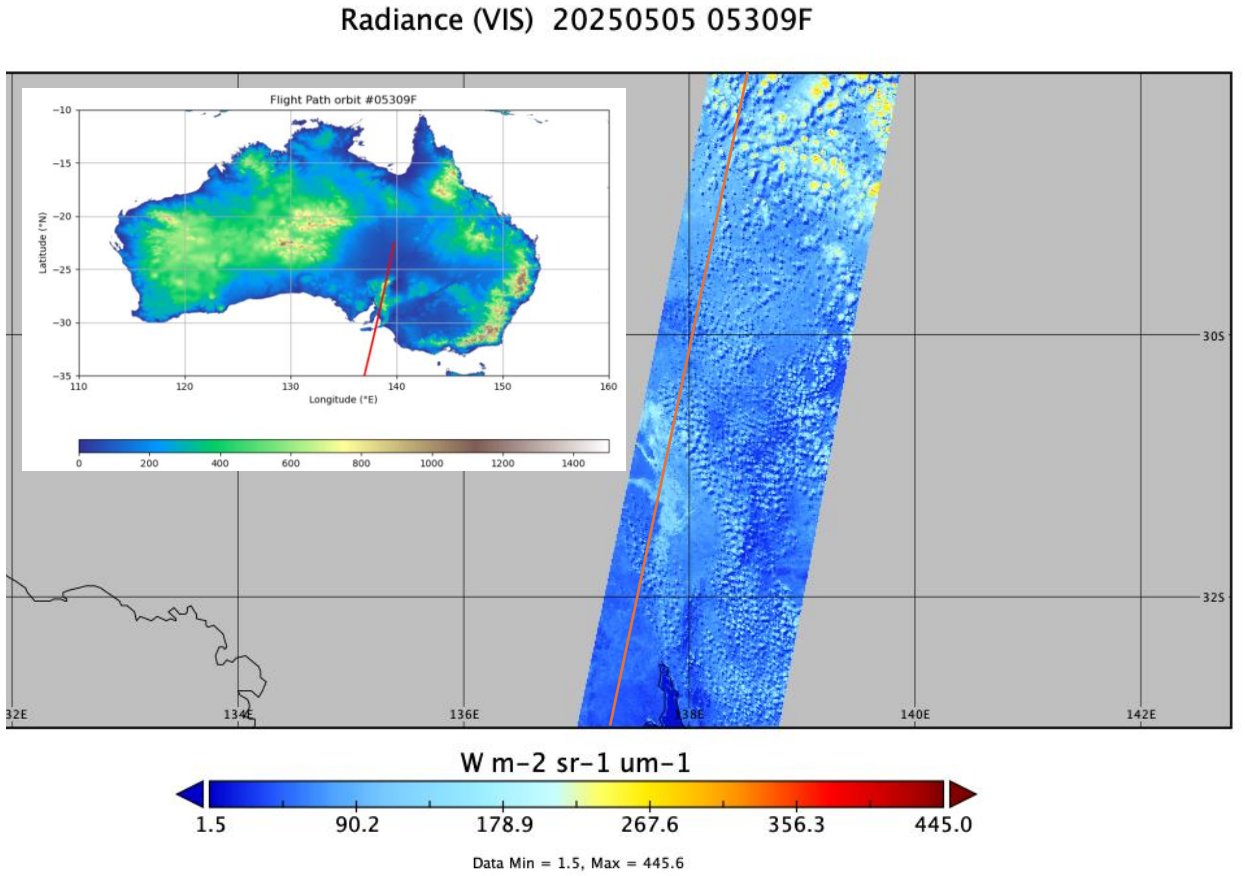


Type 1b. Cumulus

- MSI: 1:cumulus,2:altocumulus, 4:stratocumulus, 5:altostratus
- CPR: weak echo (max > -30 dBZ)
- ATLID: weak co-pol. and cross-pol. echo @2.5 km around cloud top

Australia



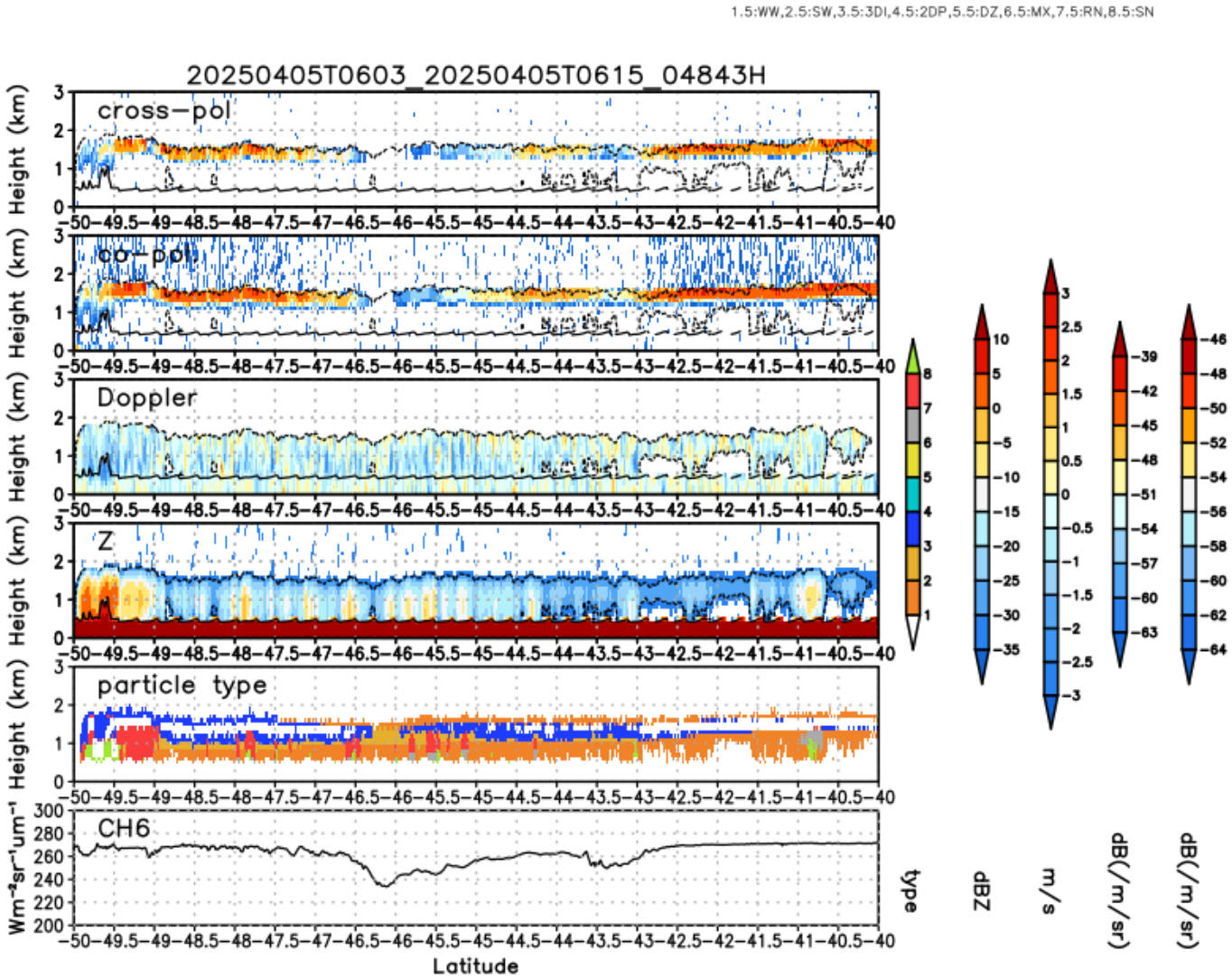


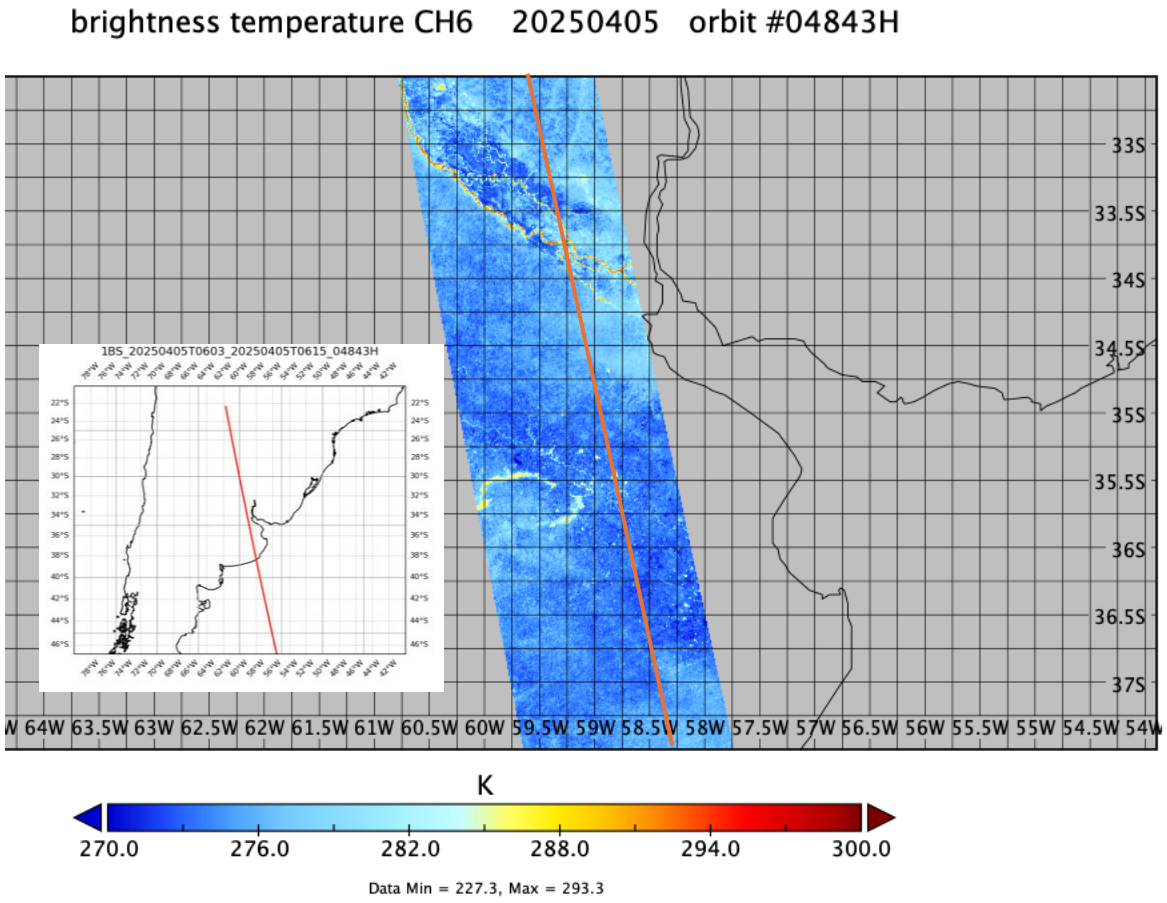
contour -30 dBZ

Type 1b.

- CPR particle type: low level=warm water, cloud top=3D Ice or warm water?
- CPR: stronger echo (max > -10 dBZ)
- ATLID: clear co-pol. and cross-pol. echo @2.5 km

around cloud top

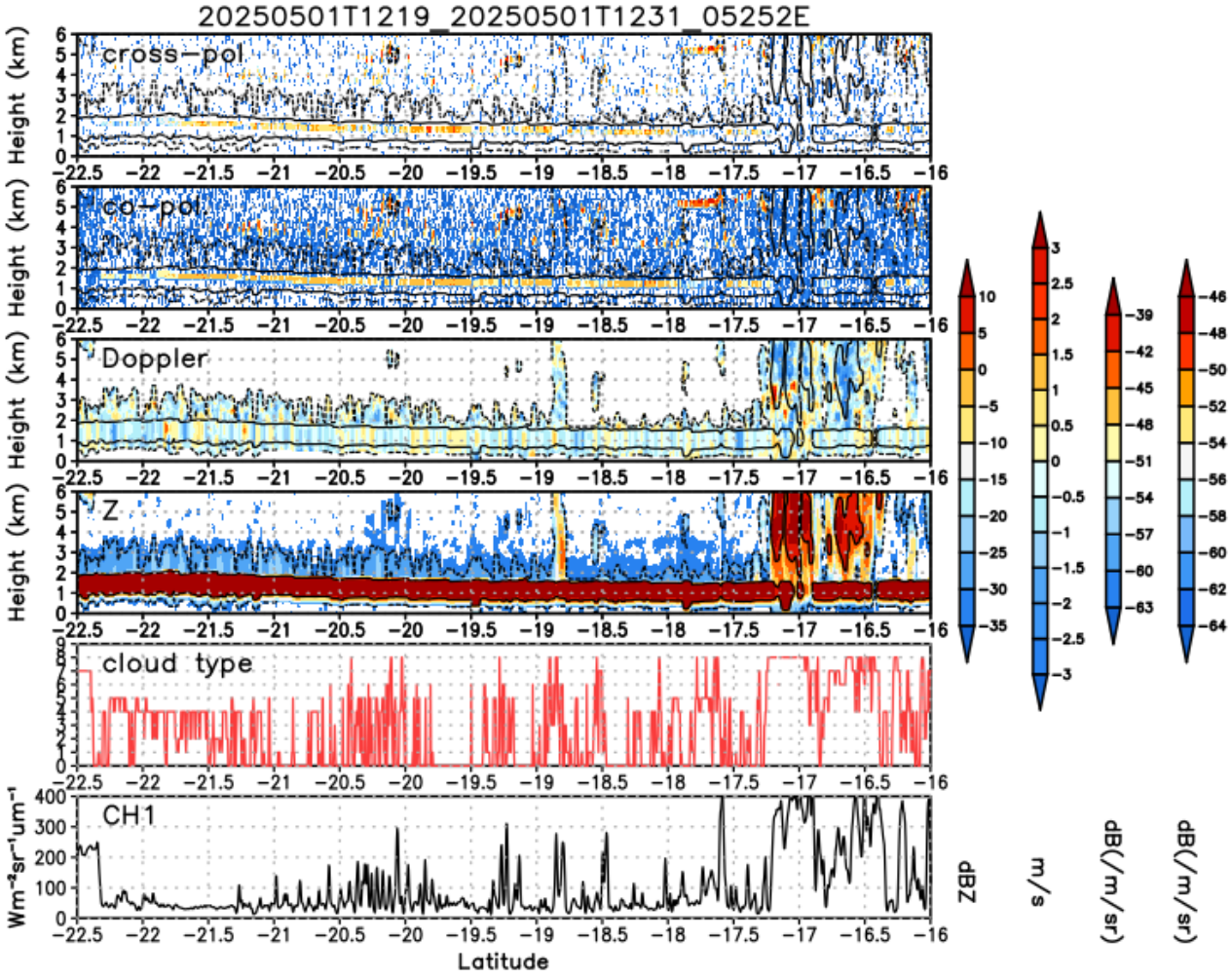


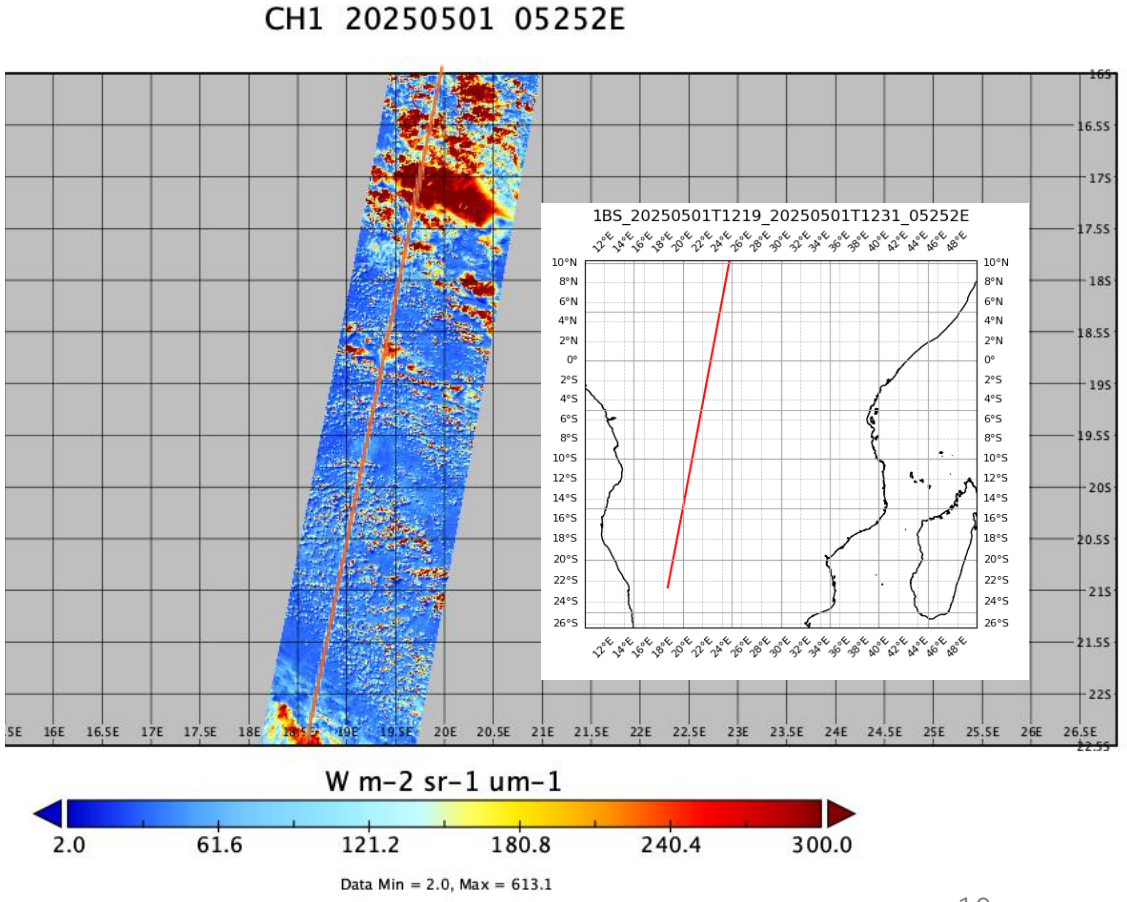


Type 4a.

- MSI: 4:stratcumulus, 5:altstratus, 6:cirrostratus
- CPR: weak echo (max < -25 dBZ)
- ATLID: almost no echo

Africa

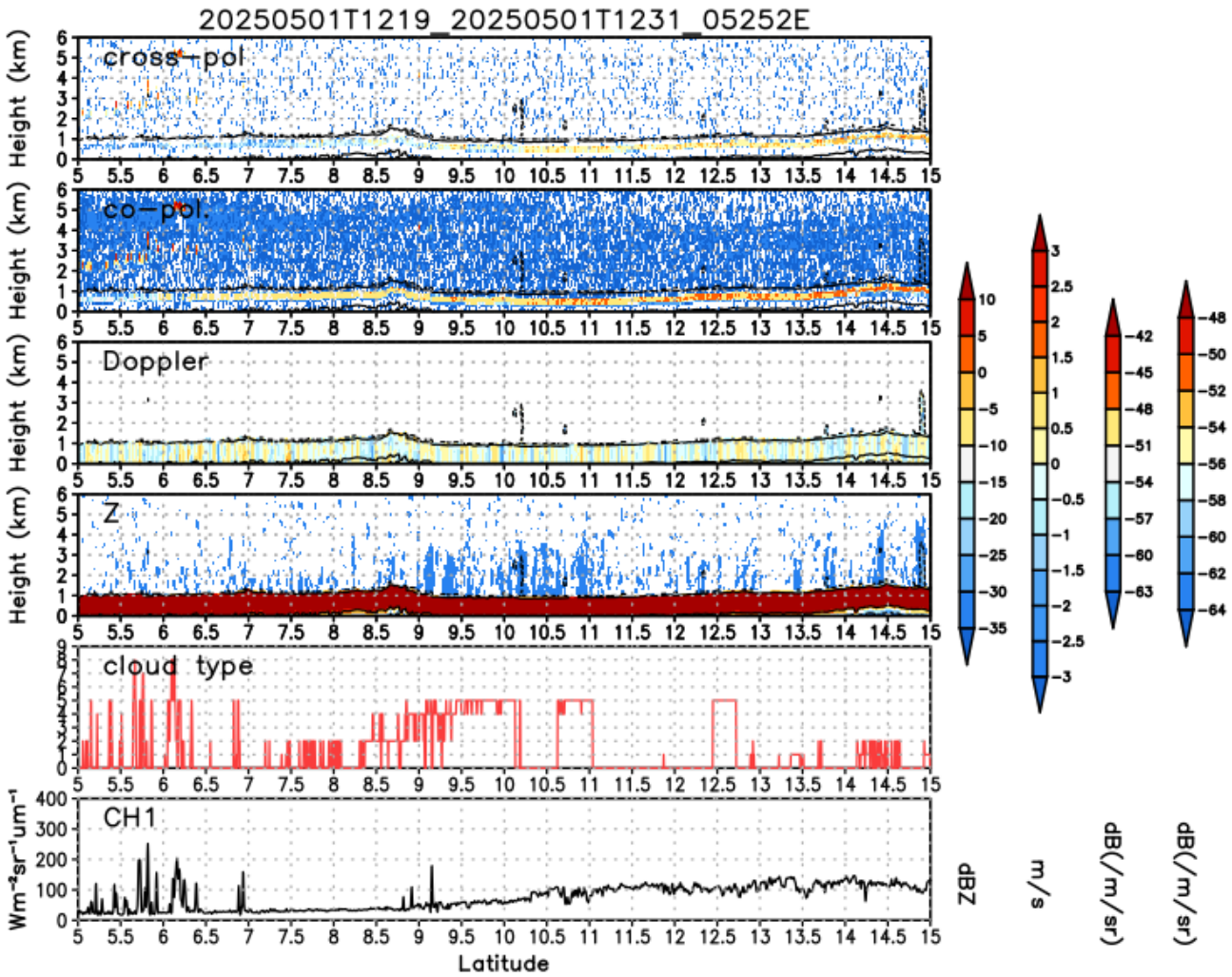


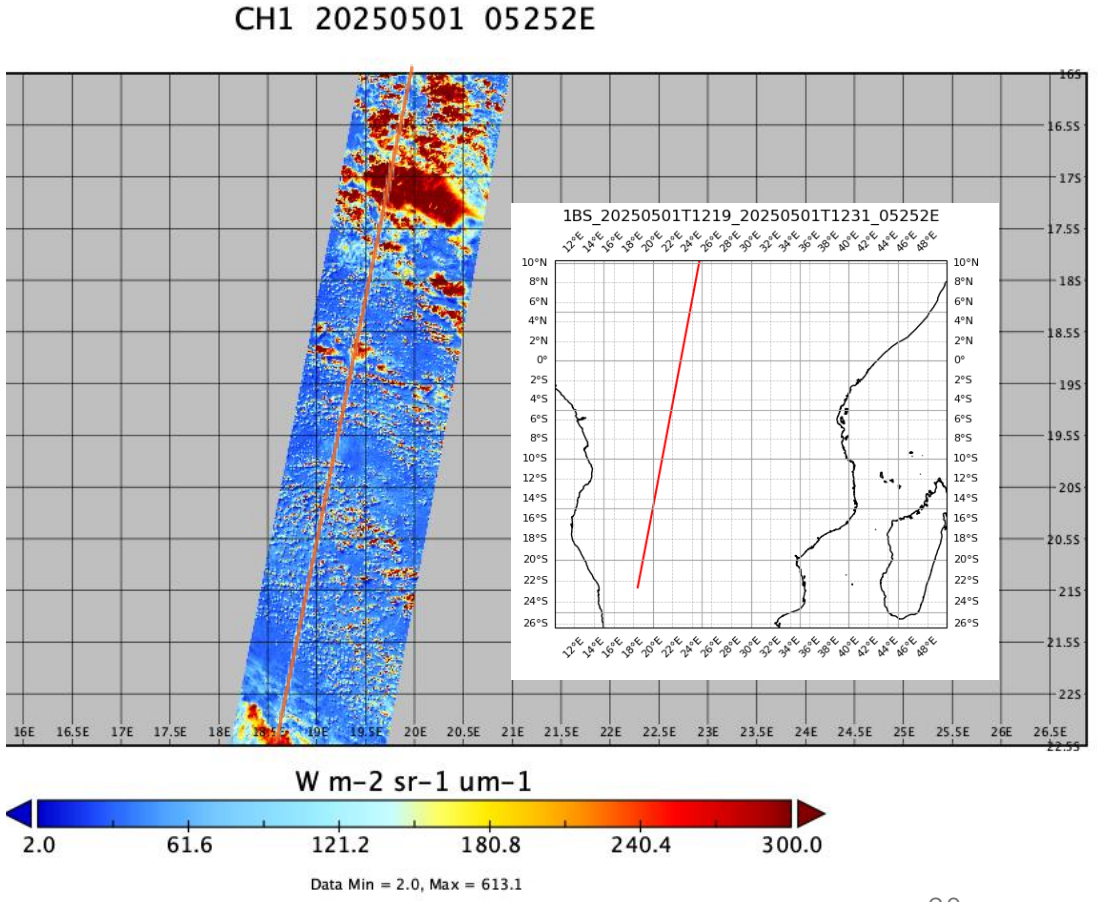


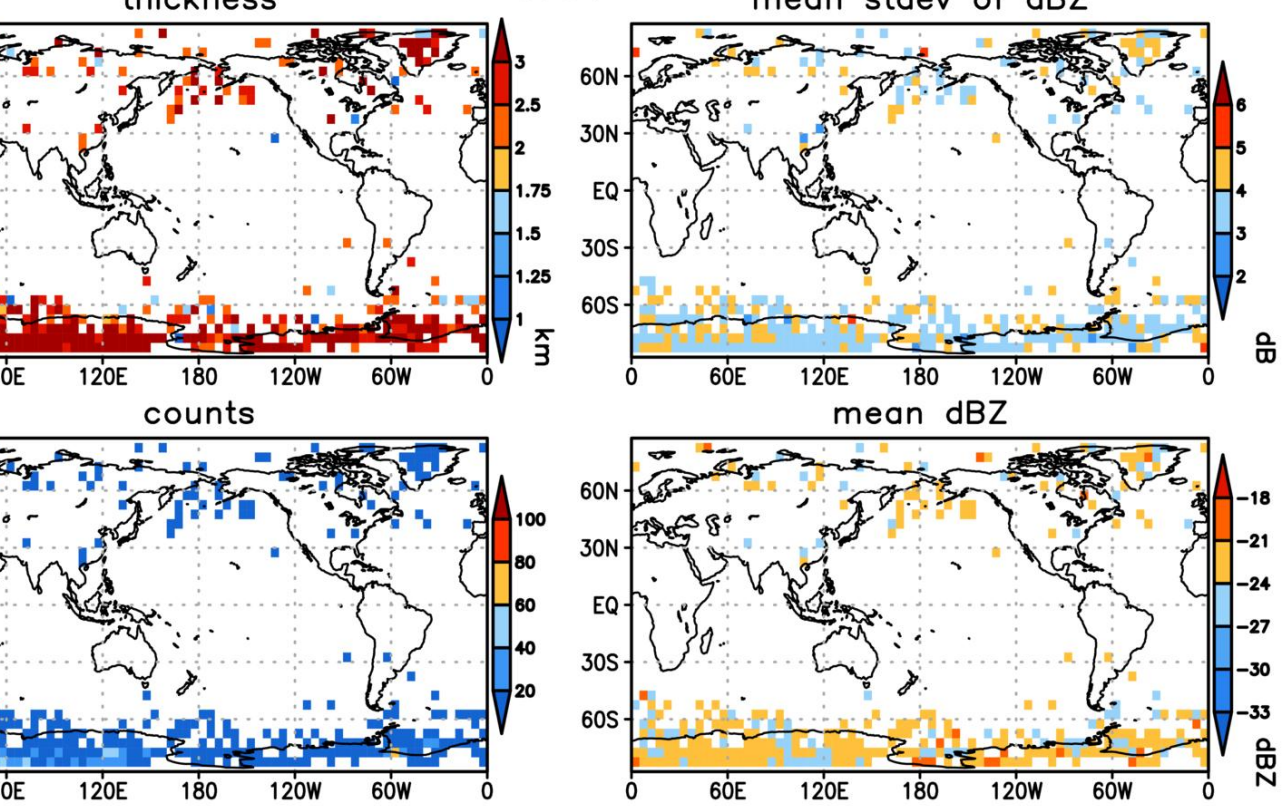
Type 4b.

- MSI: 4:stratcumulus, 5:altstratus
- CPR: weak echo (max < -30 dBZ)
- ATLID: very weak spreading echo

Africa



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mean stdev of dBZ
counts
mean dBZ
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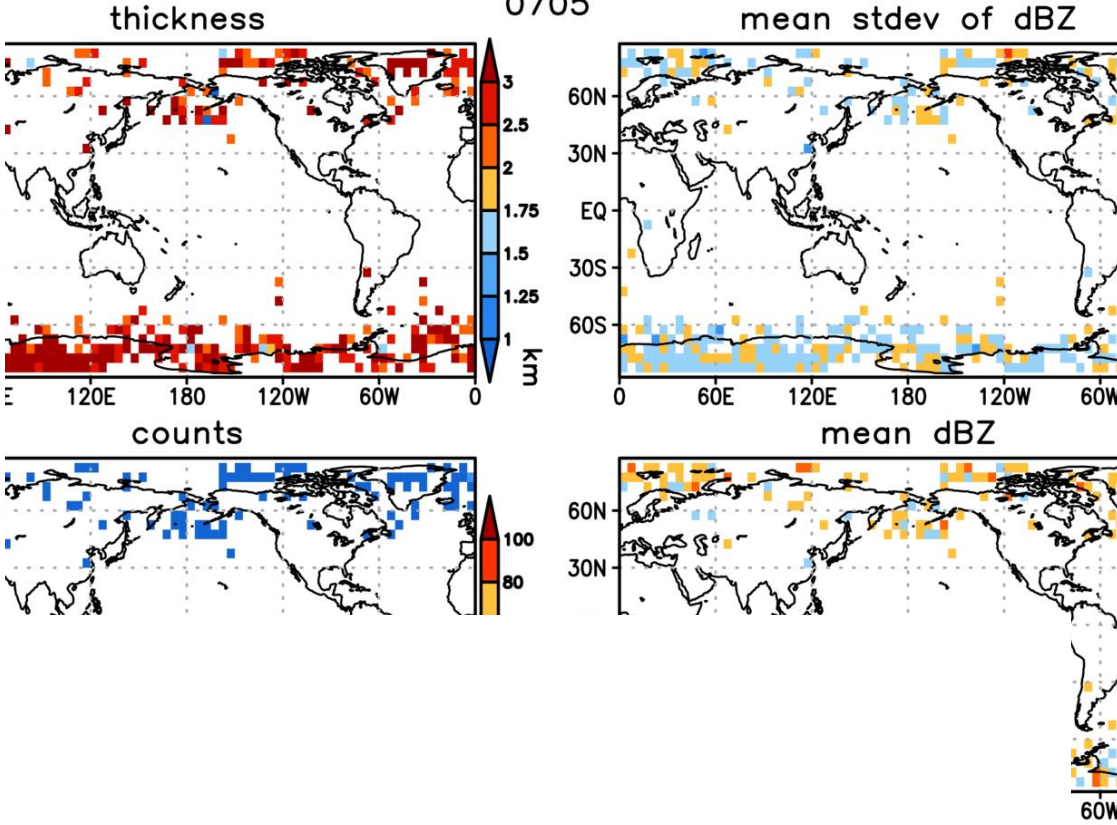
dB
dBZ
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W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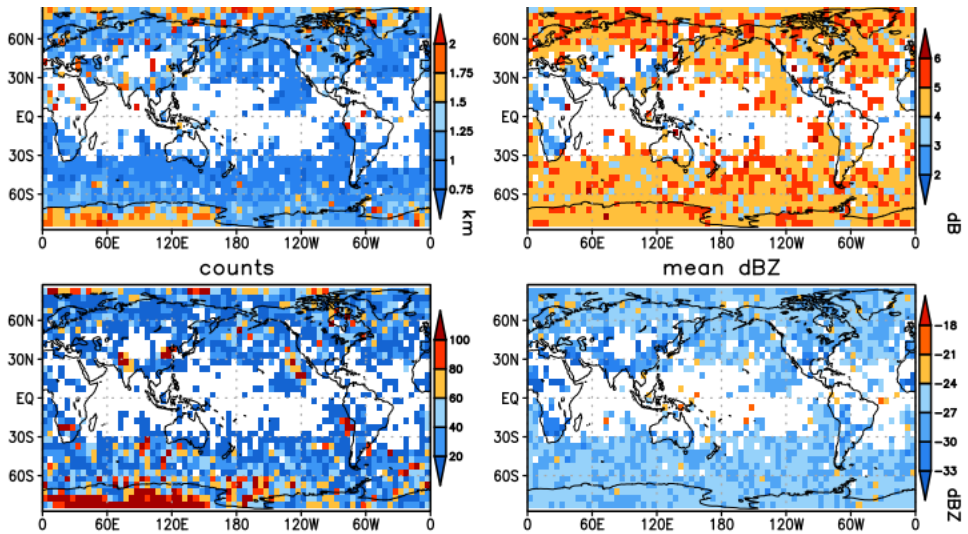
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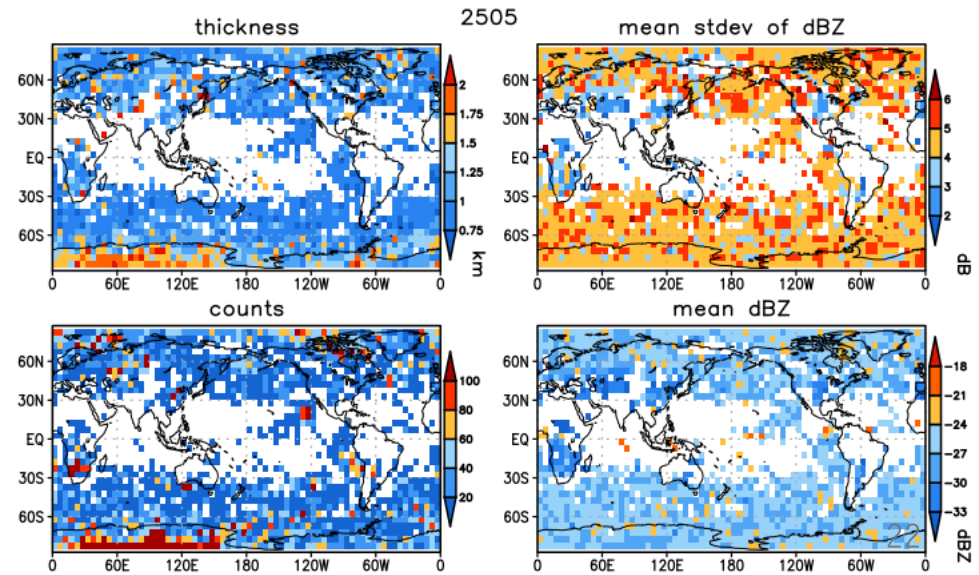
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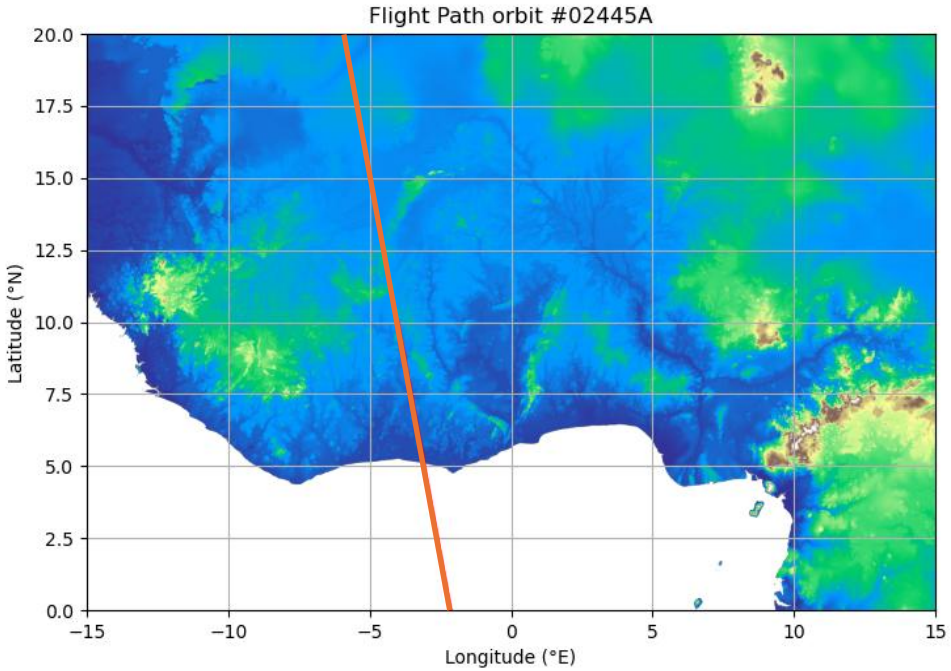
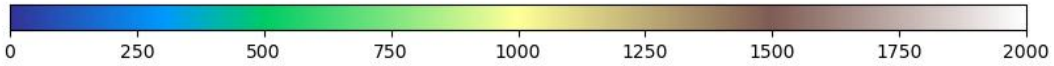
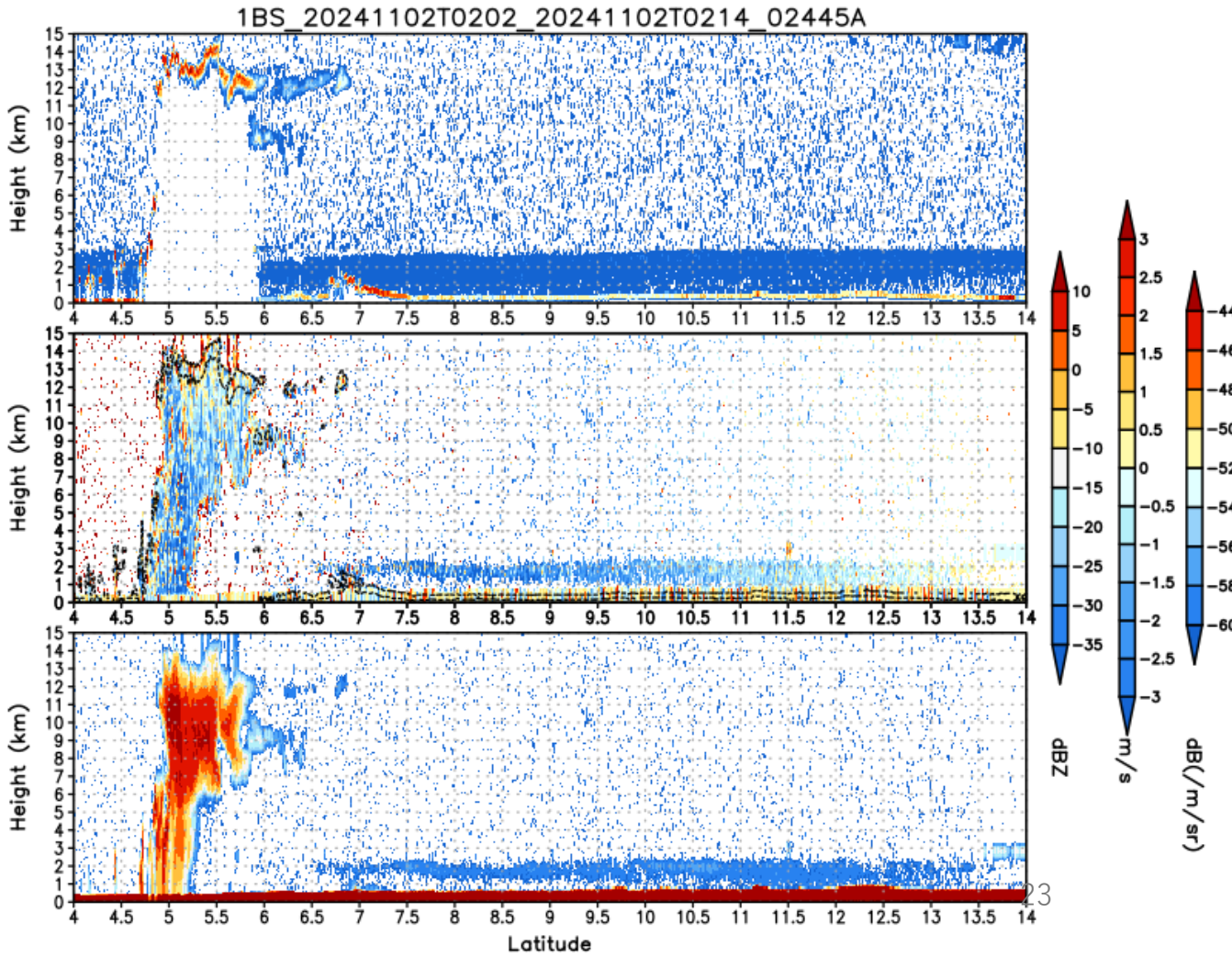
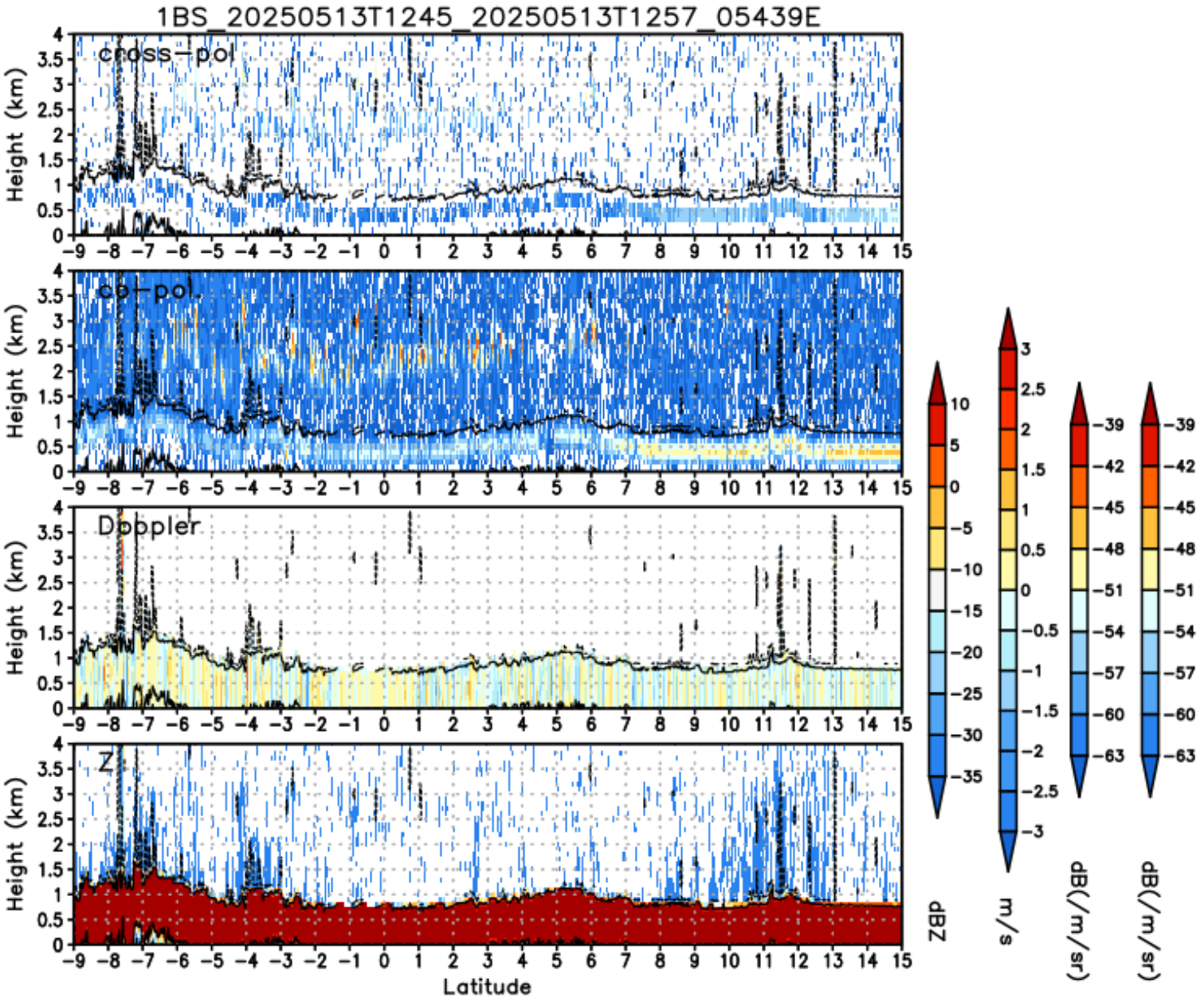
2024年11月02日 0202UTC

- アフリカ ガーナ付近で弱いエコーを観測
  - ドップラー速度は、IQ信号のバイアスの除去が不完全
  - よく





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Doppler
Z
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Latitude
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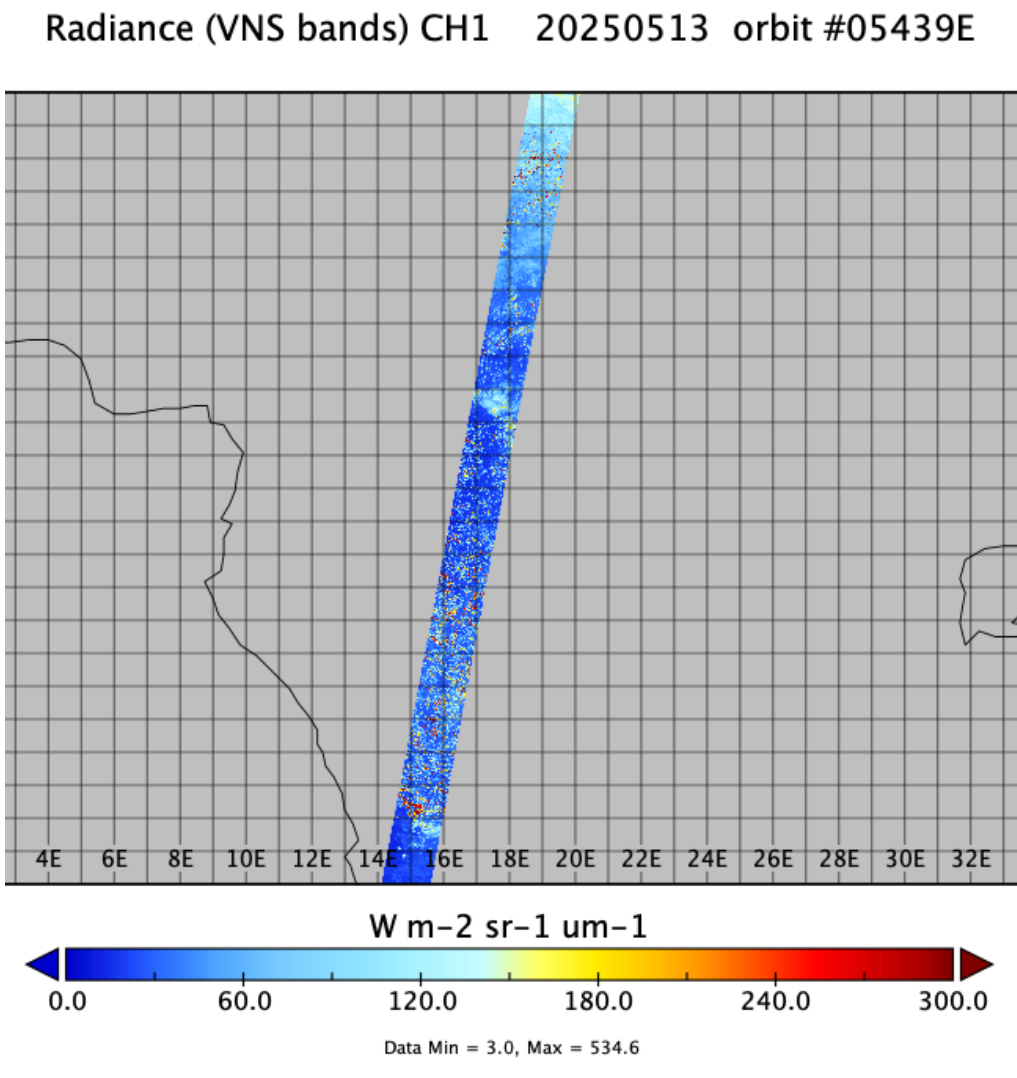
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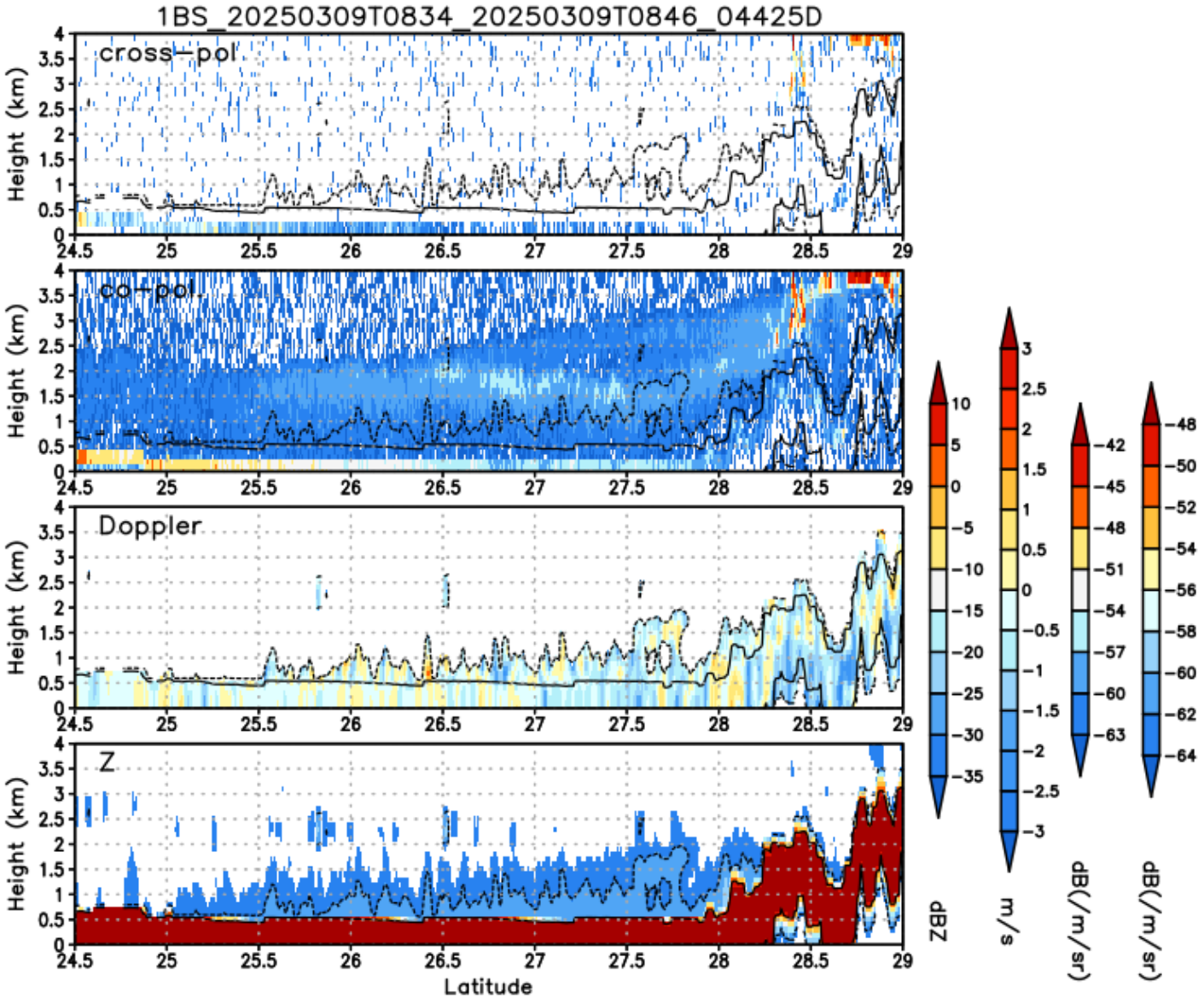
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Height (km)
Latitude
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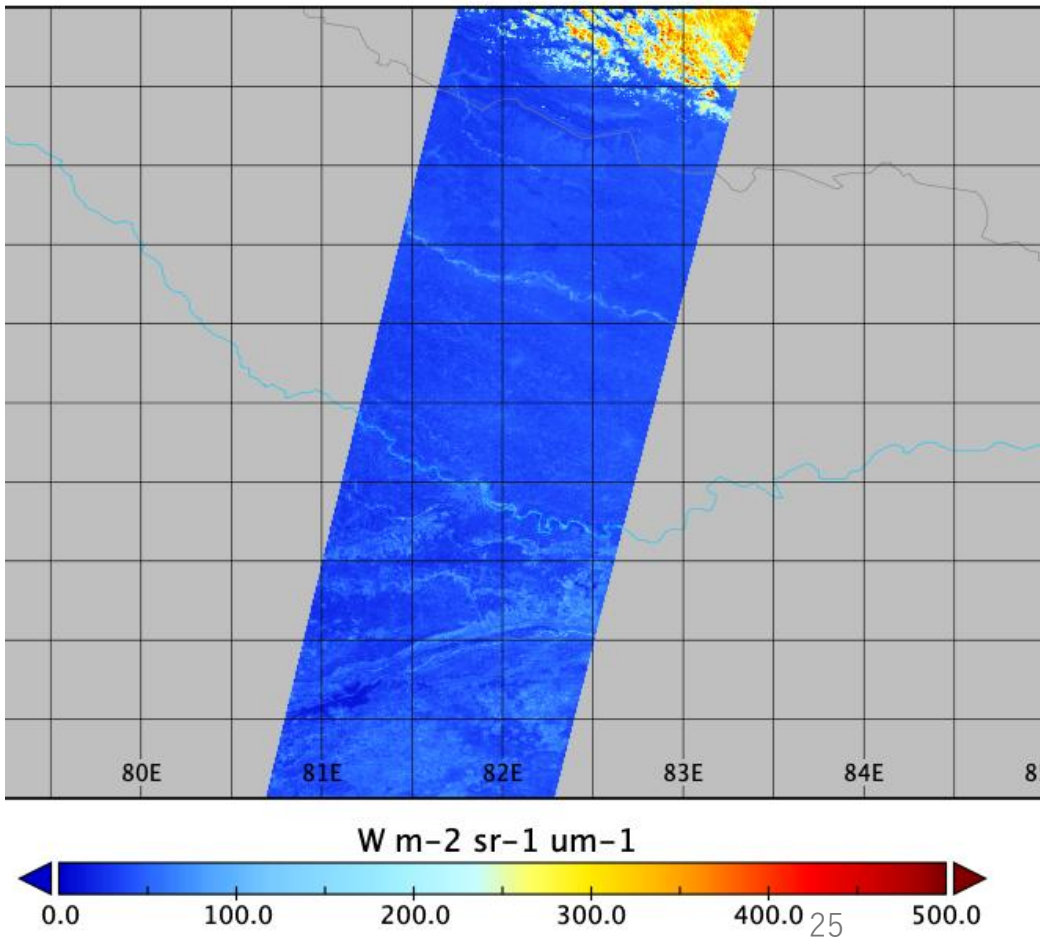
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81E
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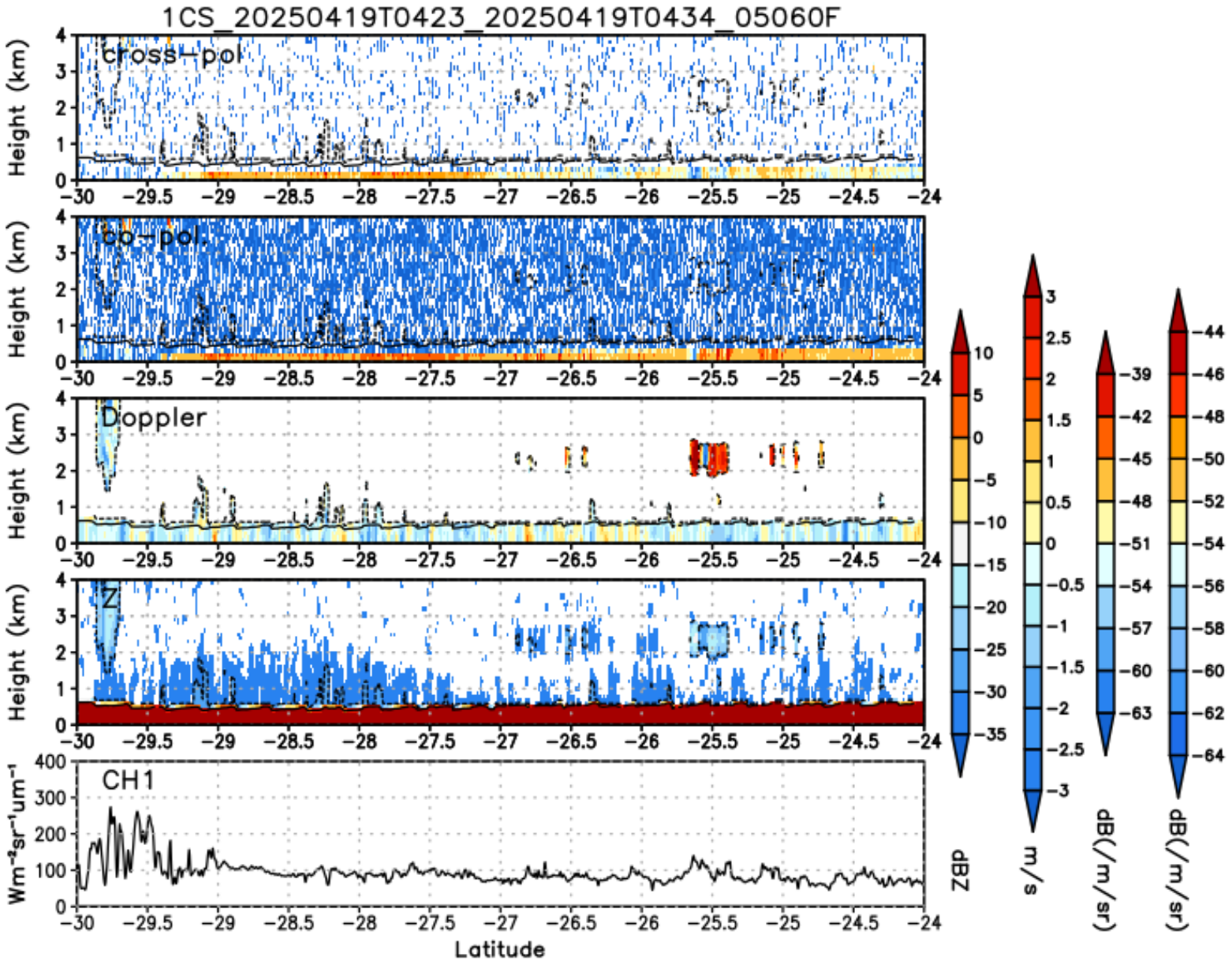
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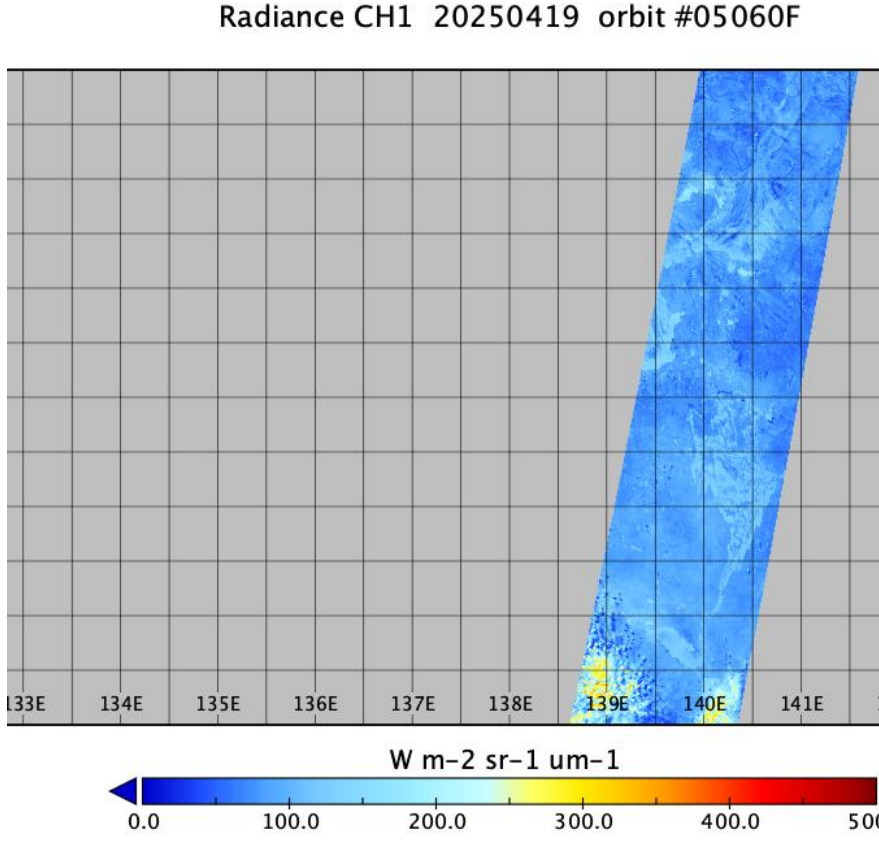
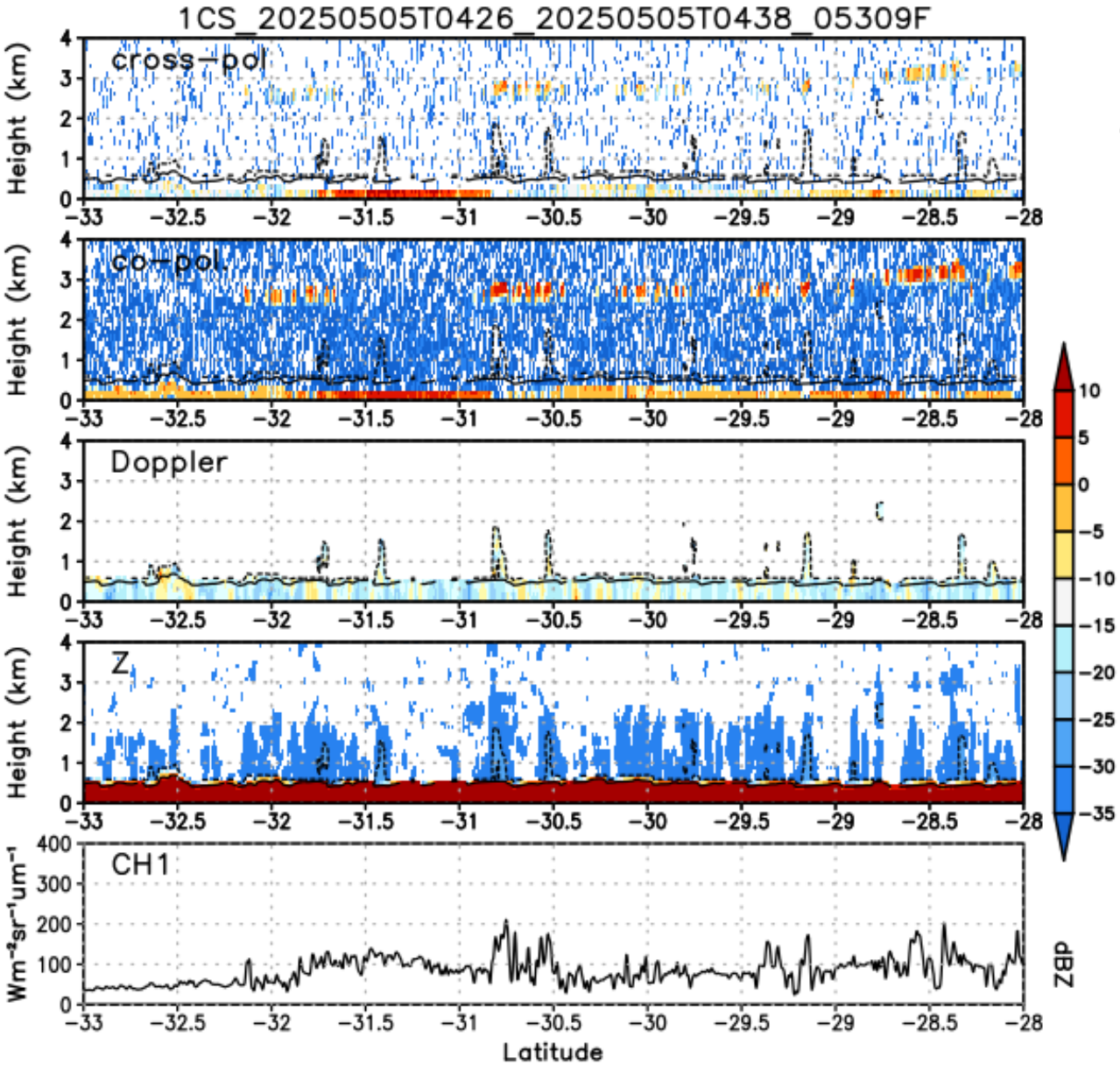
m/s
dB(/m/sr)
dB(/m/sr)

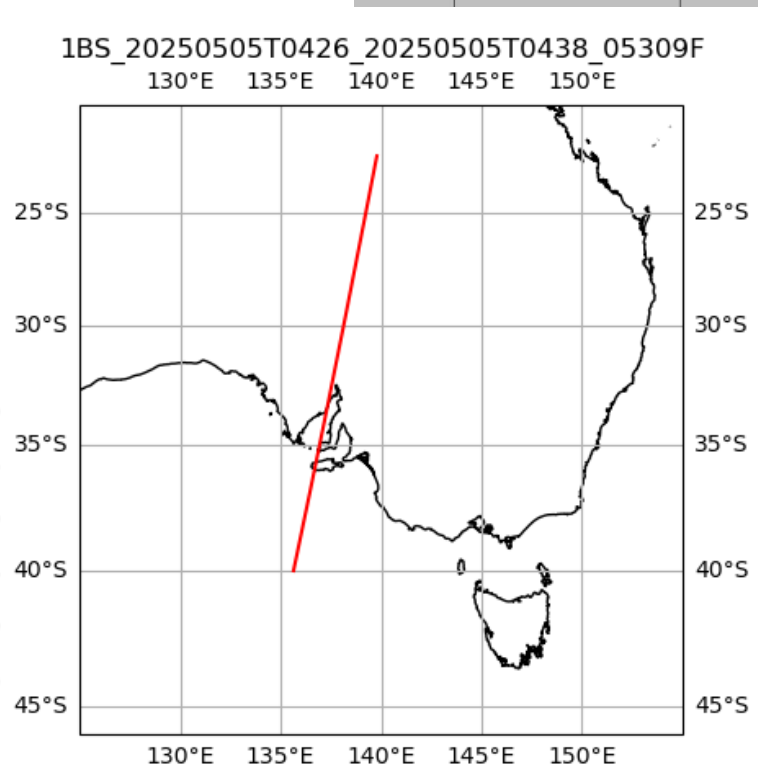

Radiance CH1 20250419 orbit #05060F
W m-2 sr-1 um-1

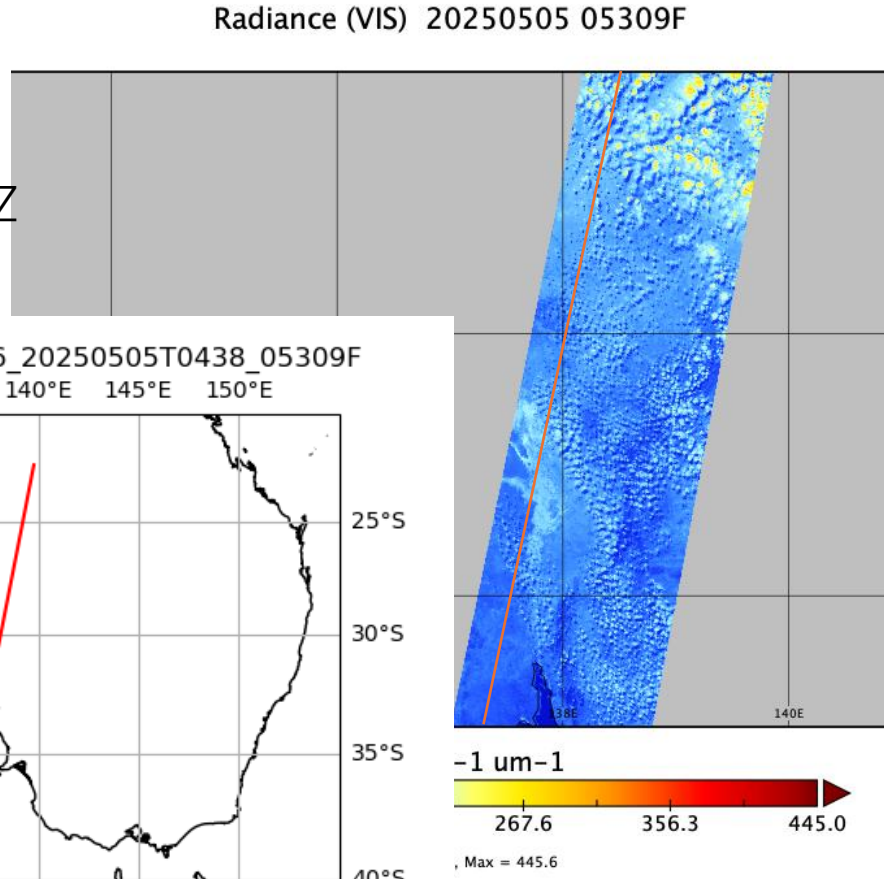
Australia

- weak echo that corresponds to shallow clouds



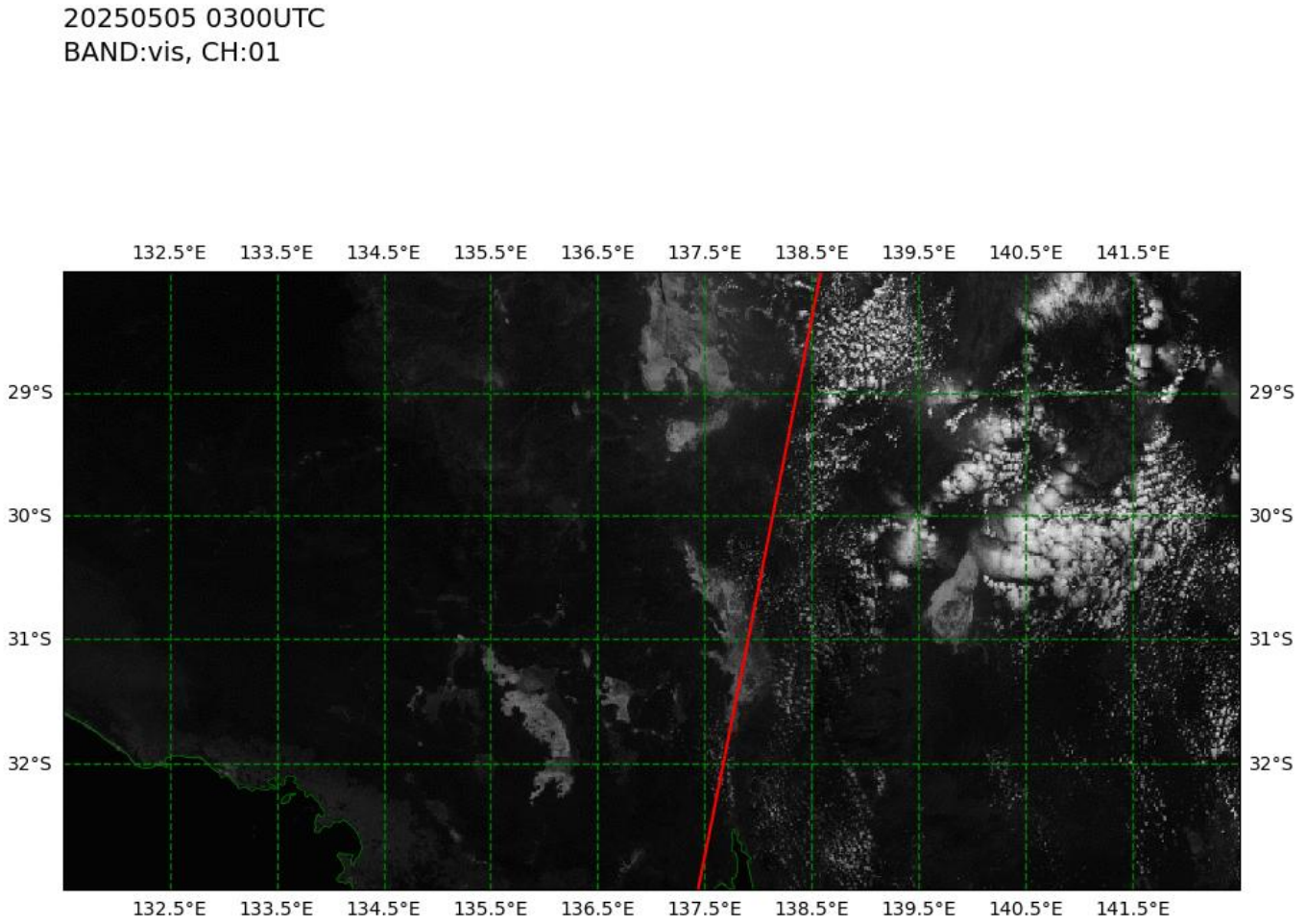
contour -30 dBZ



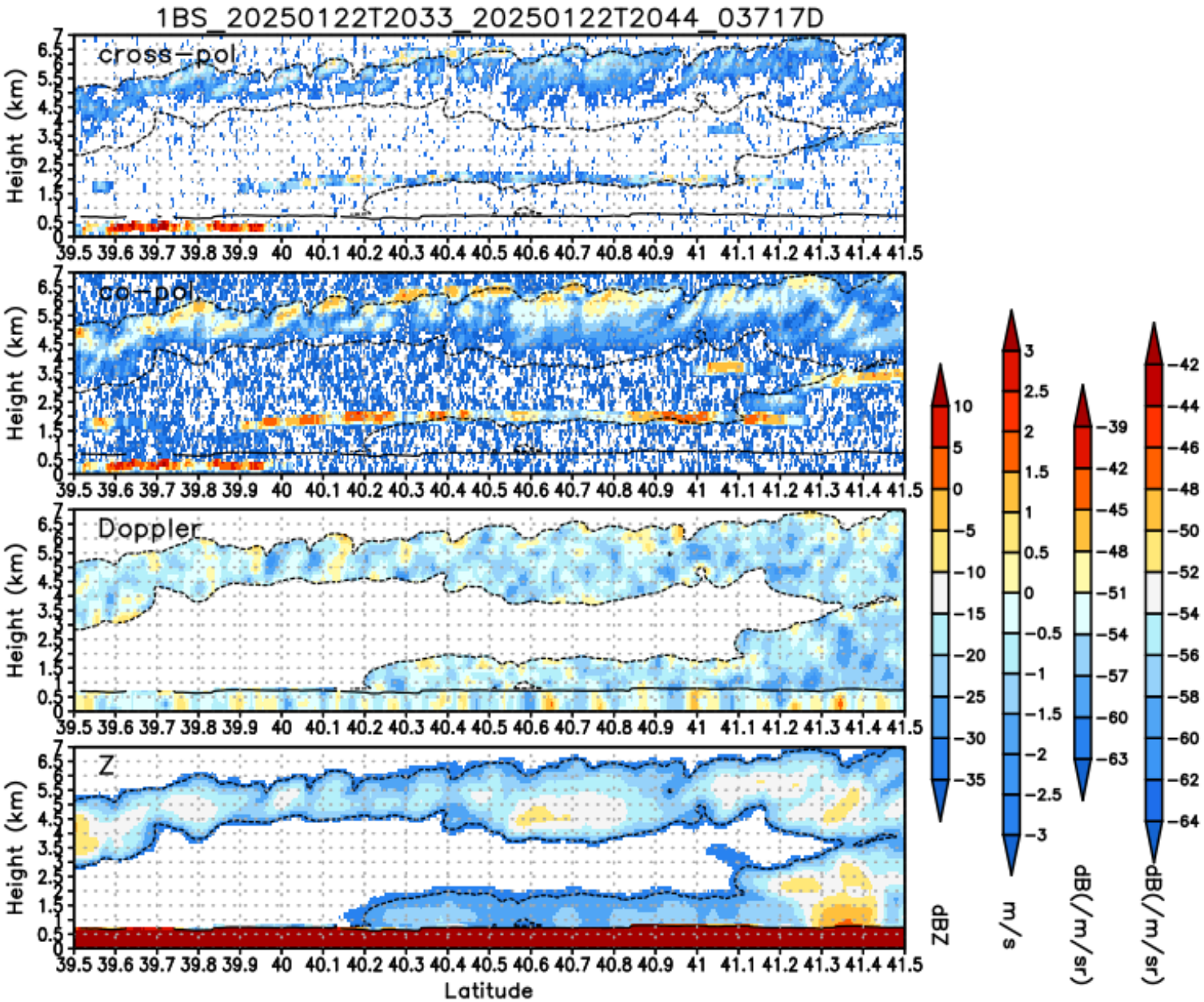


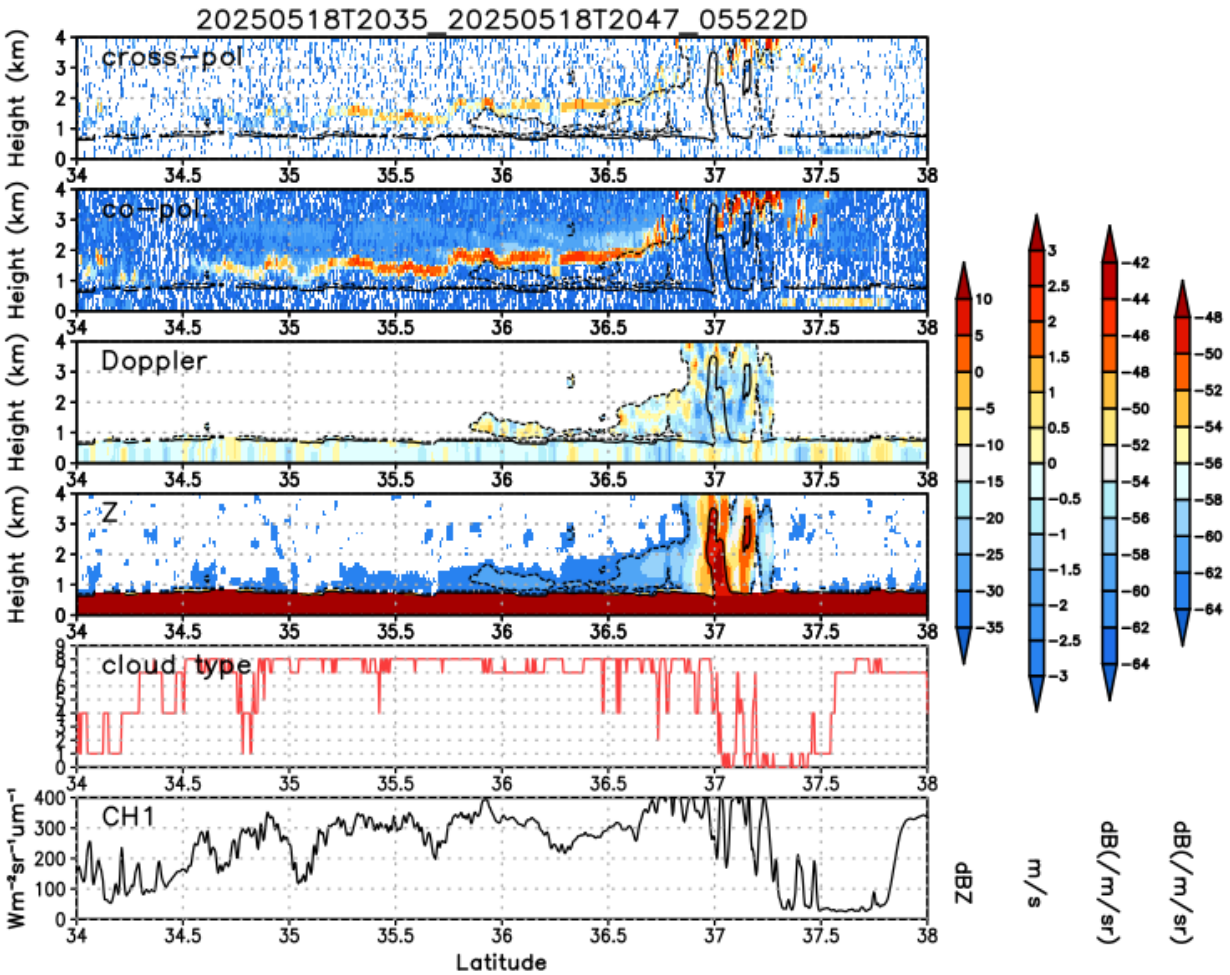
Himawari

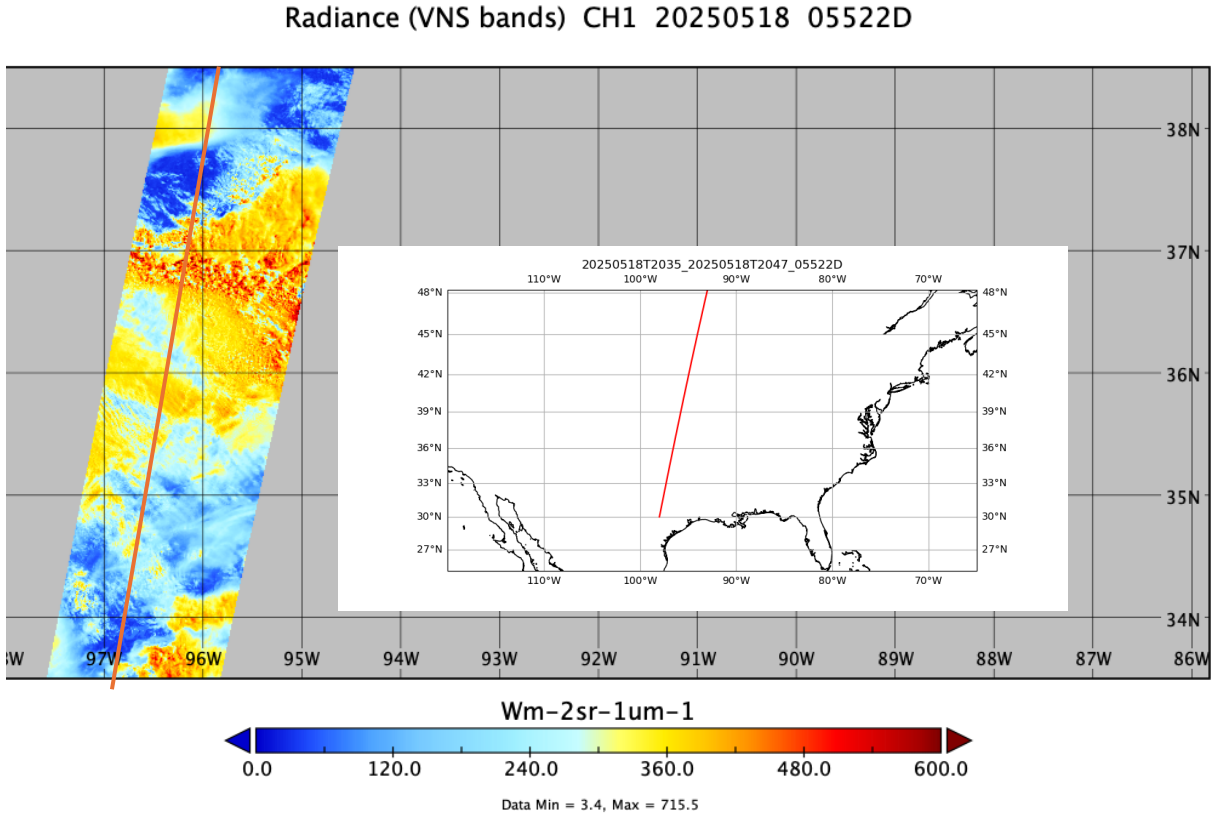
- 0300-0550UTC

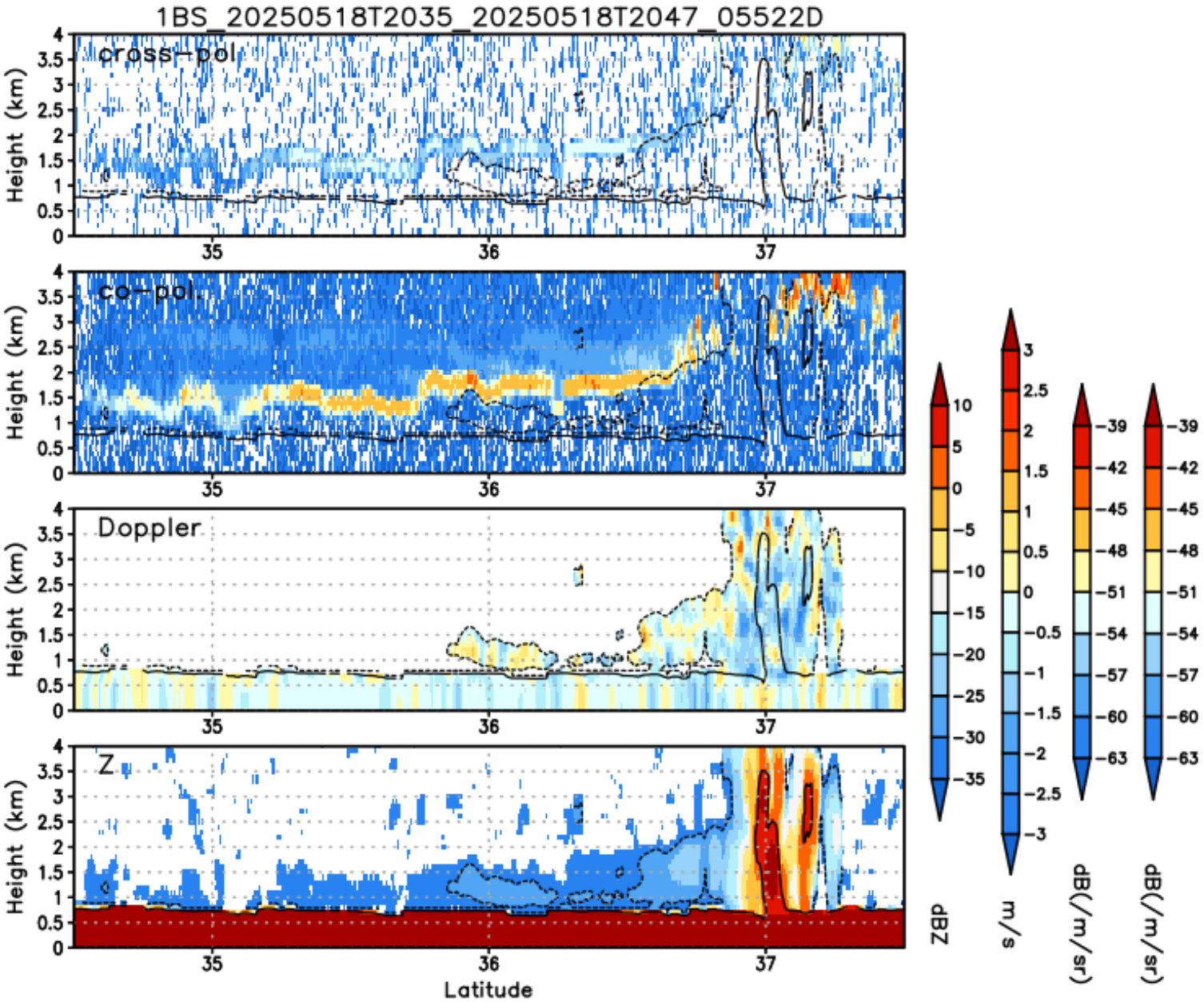


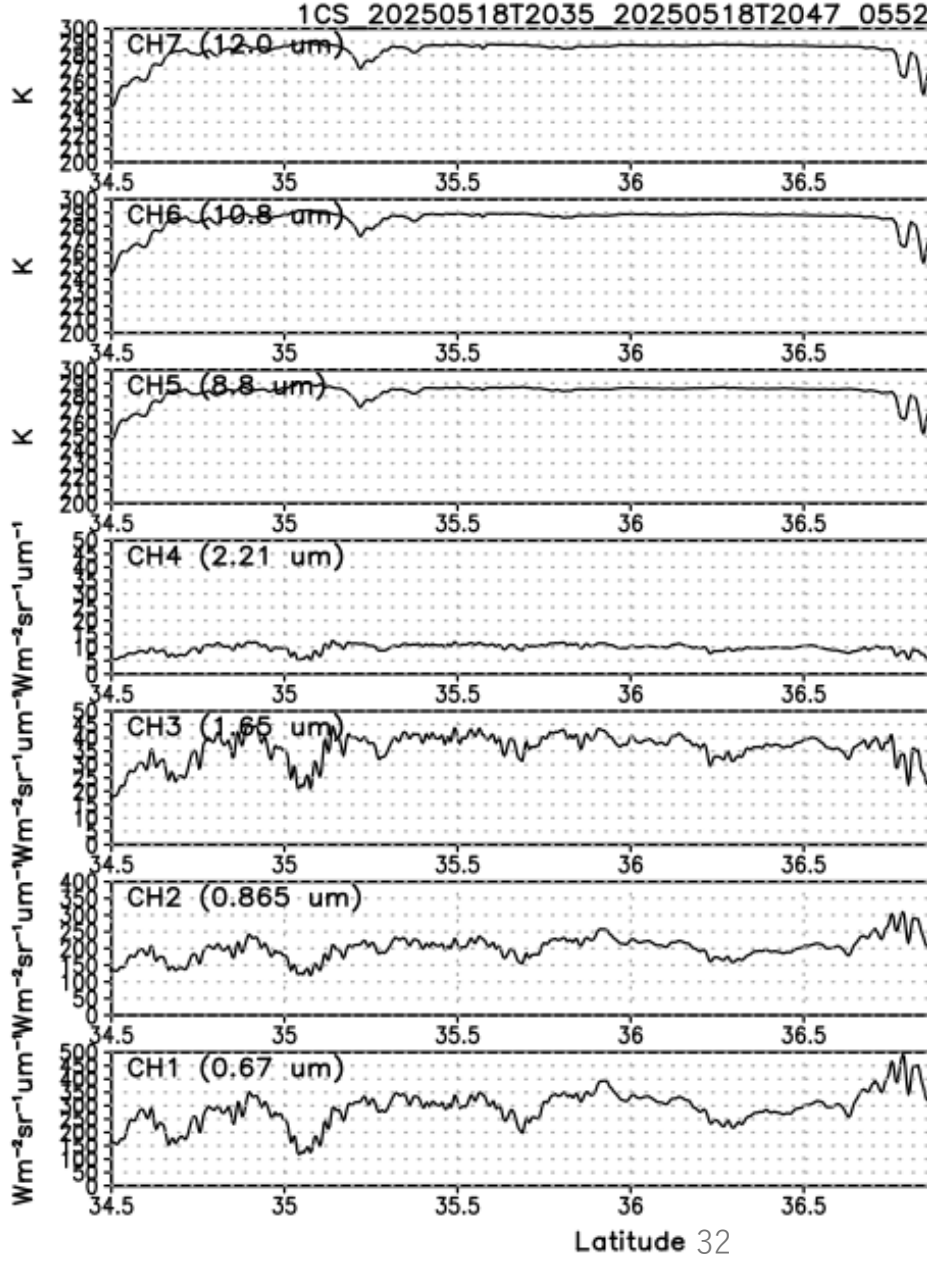
北米

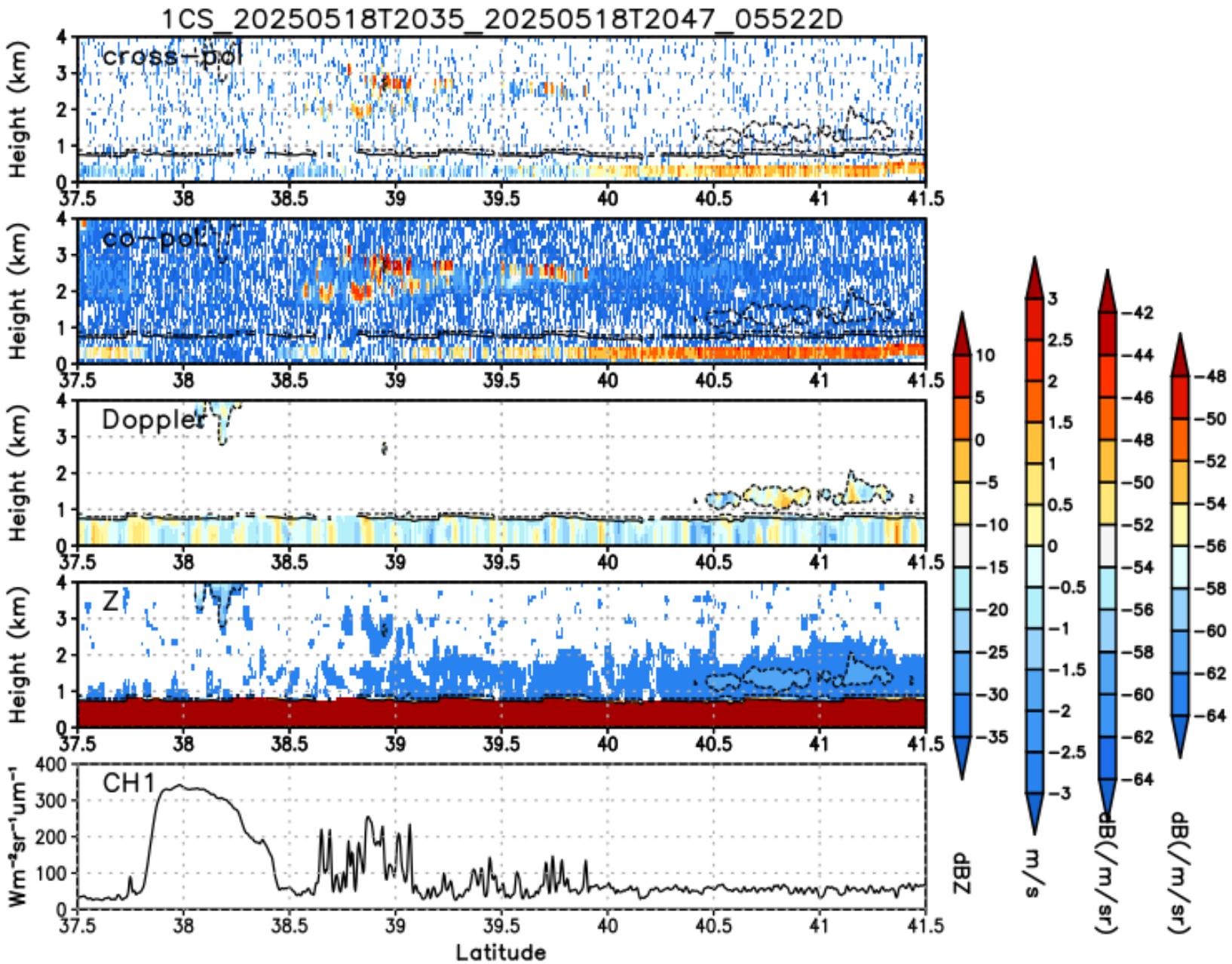

1BS_20250122T2033_20250122T2044_03717D
cross-pol
co-pol
Doppler
Z
Height (km)
Latitude
39.5 39.6 39.7 39.8 39.9 40 40.1 40.2 40.3 40.4 40.5 40.6 40.7 40.8 40.9 41 41.1 41.2 41.3 41.4 41.5
dBZ
m/s
dB(/m/sr)
dB(/m/sr)

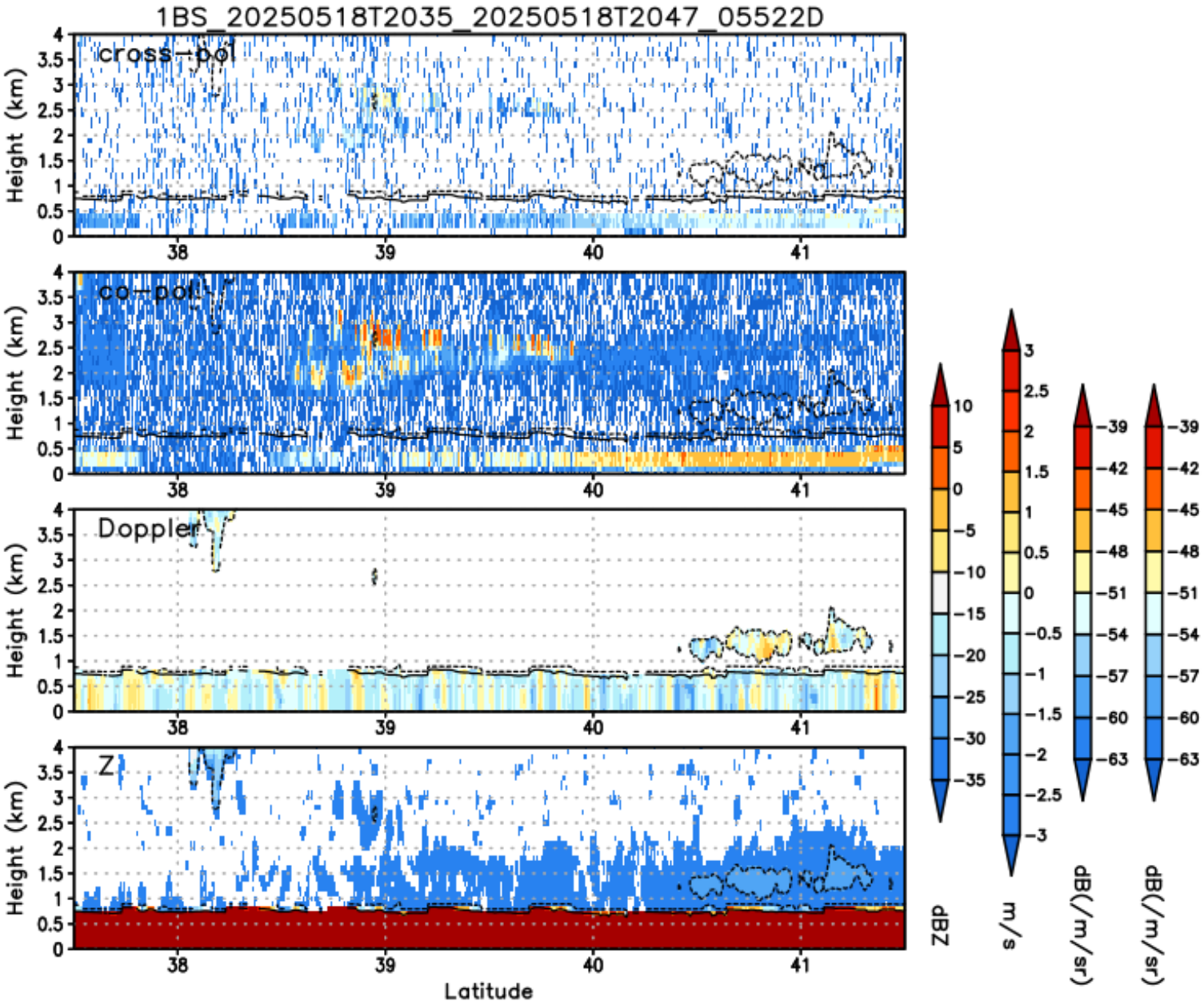

20250518T2035_20250518T2047_05522D
cross-pol
co-pol
Doppler
Z
cloud type
CH1
Height (km)
Wm-2sr-1um-1
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)

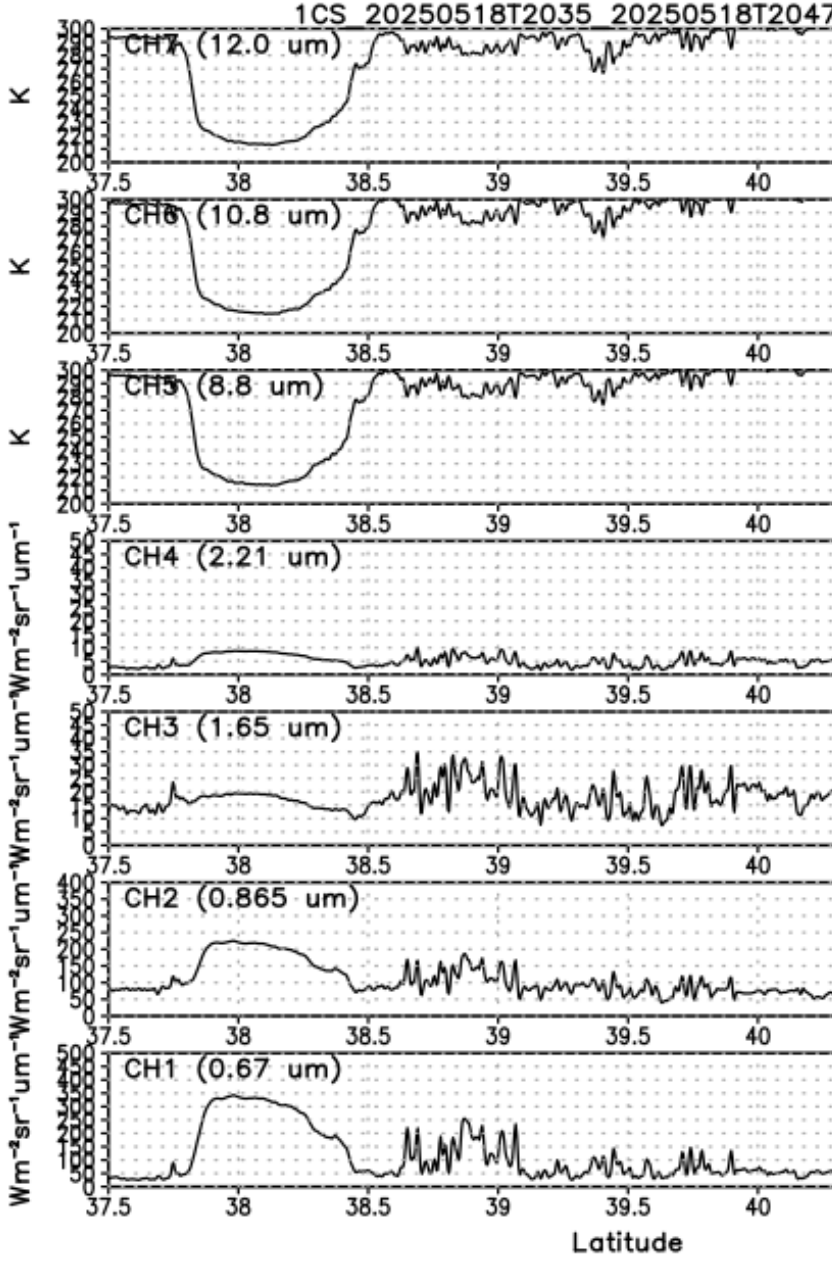

Radiance (VNS bands) CH1 20250518 05522D
20250518T2035_20250518T2047_05522D
Wm-2sr-1um-1
0.0
120.0
240.0
360.0
480.0
600.0
Data Min = 3.4, Max = 715.5


1BS_20250518T2035_20250518T2047_05522D
cross-pol
co-pol
Doppler
Z
Height (km)
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)

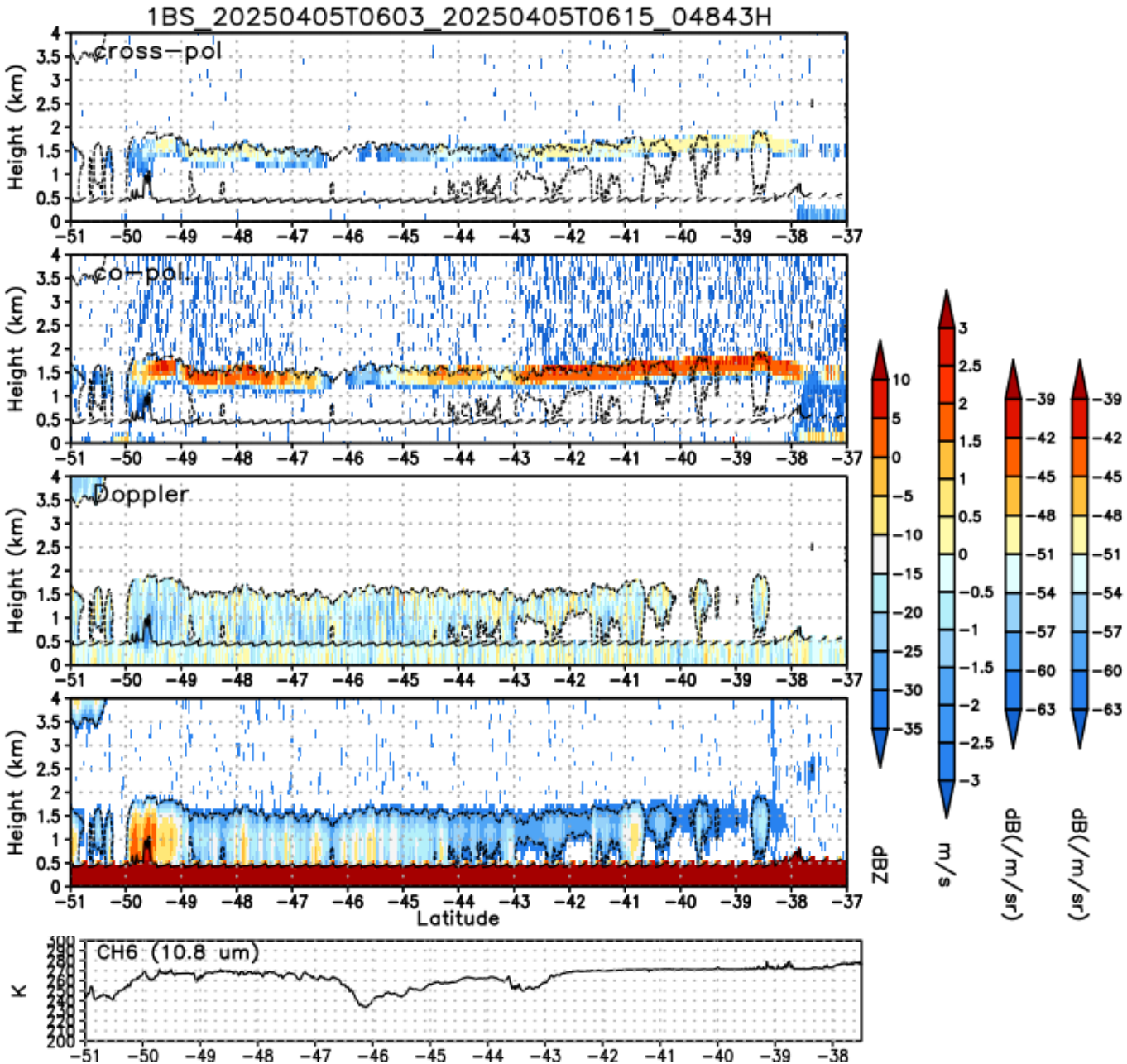

1CS_20250518T2035_20250518T2047_0552
CH7 (12.0 um)
CH6 (10.8 um)
CH5 (8.8 um)
CH4 (2.21 um)
CH3 (1.65 um)
CH2 (0.865 um)
CH1 (0.67 um)
K
Wm⁻²sr⁻¹um⁻¹
Latitude

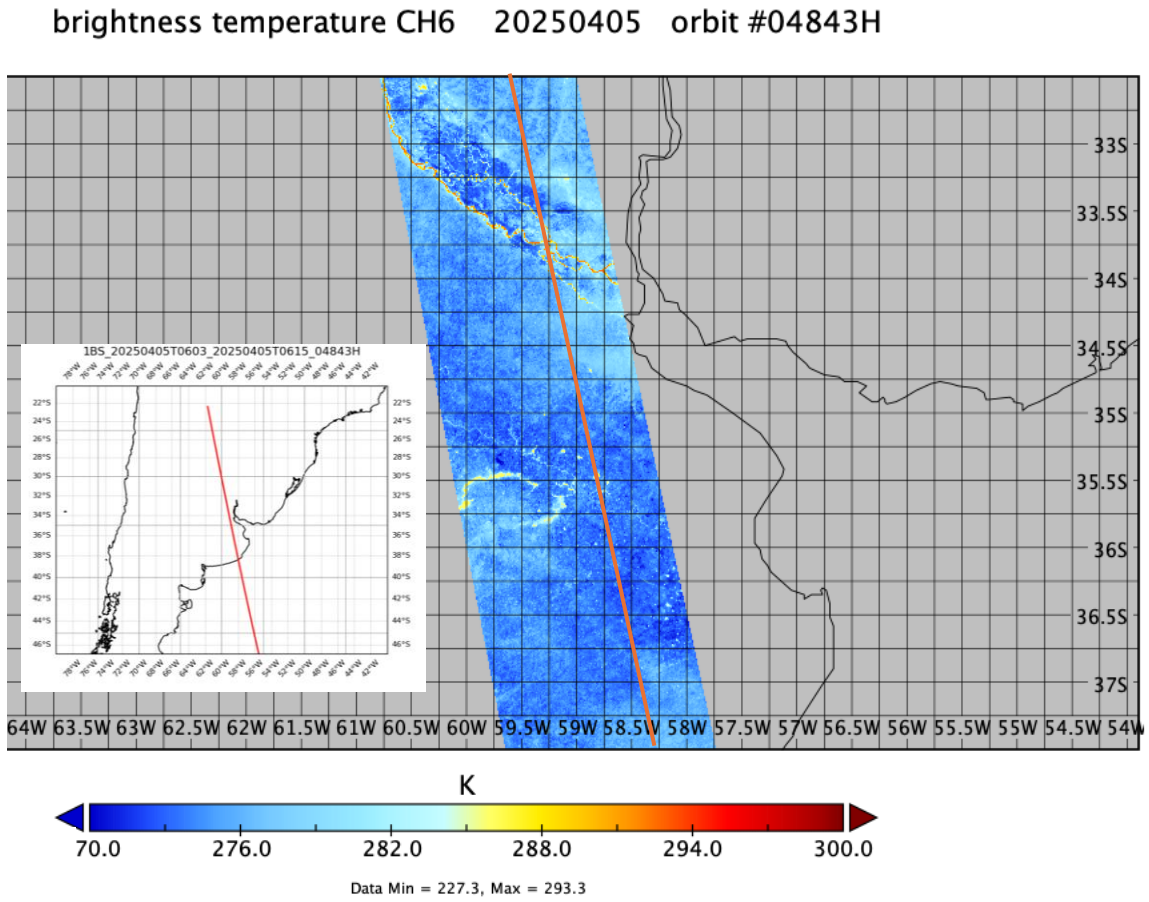

1CS_20250518T2035_20250518T2047_05522D
cross-pol
co-pol
Doppler
Z
CH1
Height (km)
Wm⁻²sr⁻¹um⁻¹
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)

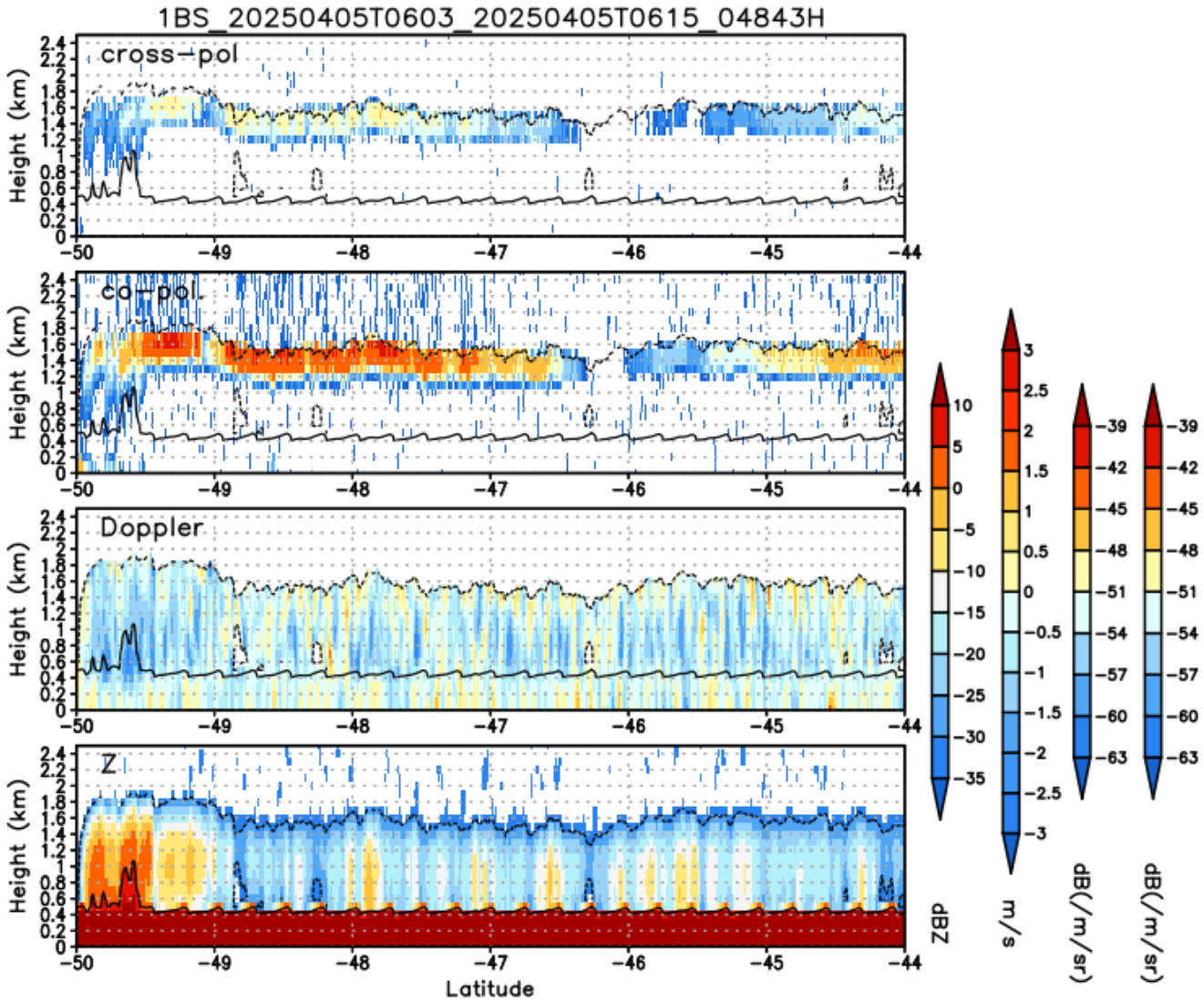

1BS_20250518T2035_20250518T2047_05522D
cross-pol
co-pol
Doppler
Z
Height (km)
Latitude
dBZ
m/s
dB/(m/sr)
dB/(m/sr)

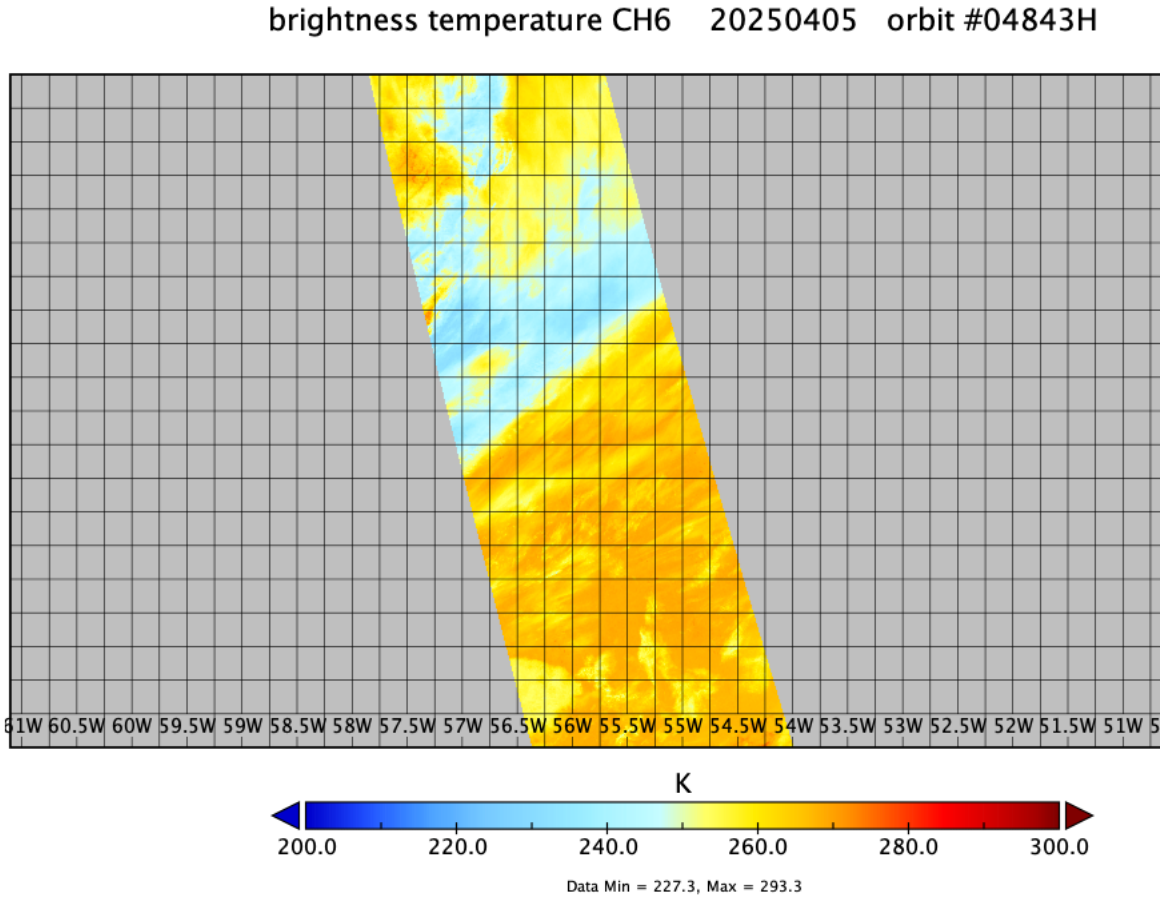

1CS_20250518T2035_20250518T2047
CH7 (12.0 um)
CH6 (10.8 um)
CH5 (8.8 um)
CH4 (2.21 um)
CH3 (1.65 um)
CH2 (0.865 um)
CH1 (0.67 um)
K
Wm⁻²sr⁻¹um⁻¹
Latitude

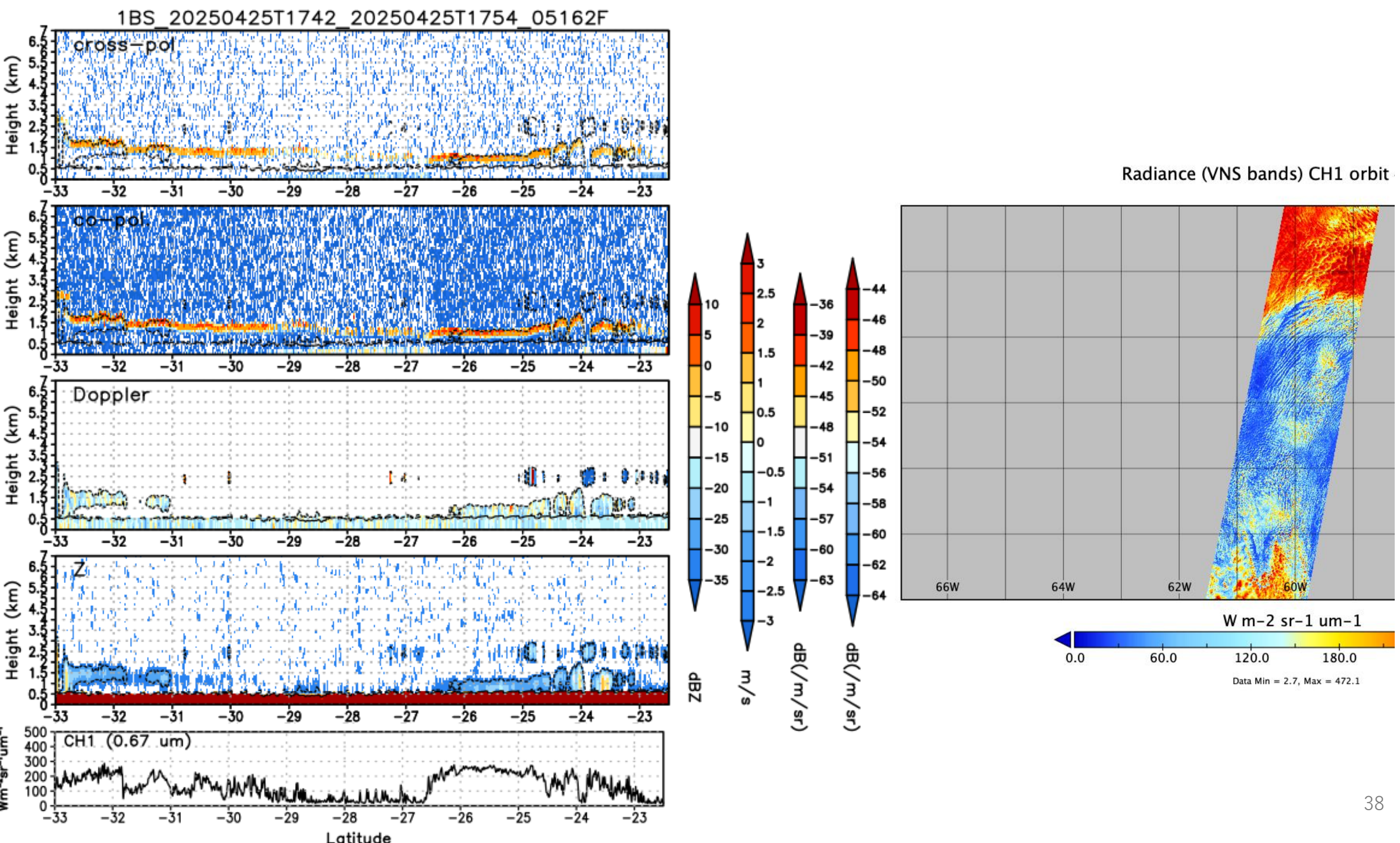
南米

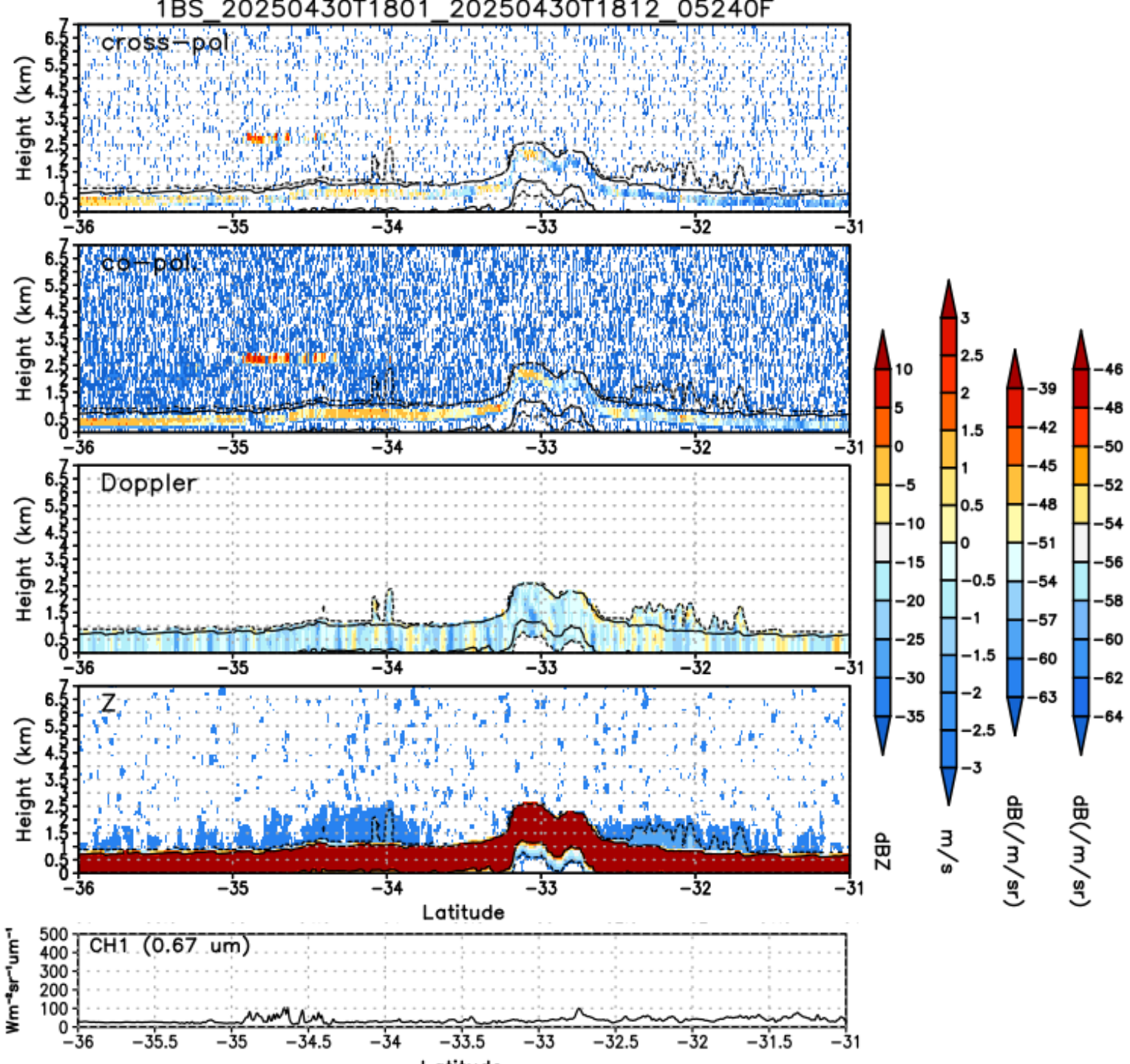

1BS_20250405T0603_20250405T0615_04843H
cross-pol
co-pol
Doppler
Height (km)
Latitude
CH6 (10.8 um)
K
dBZ
m/s
dB(/m/sr)
dB(/m/sr)

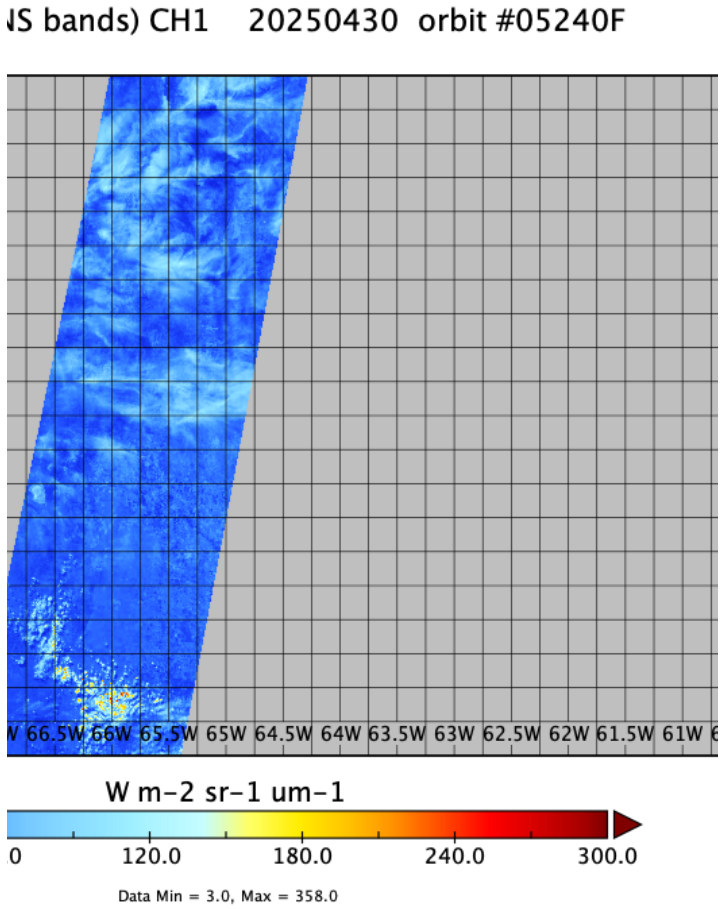

brightness temperature CH6 20250405 orbit #04843H
1BS_20250405T0603_20250405T0615_04843H
K
70.0
276.0
282.0
288.0
294.0
300.0
Data Min = 227.3, Max = 293.3

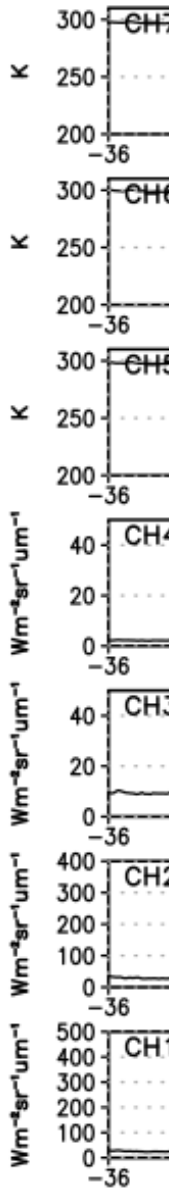

1BS_20250405T0603_20250405T0615_04843H
cross-pol
co-pol
Doppler
Z
Height (km)
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)


brightness temperature CH6 20250405 orbit #04843H
K
200.0
220.0
240.0
260.0
280.0
300.0
Data Min = 227.3, Max = 293.3

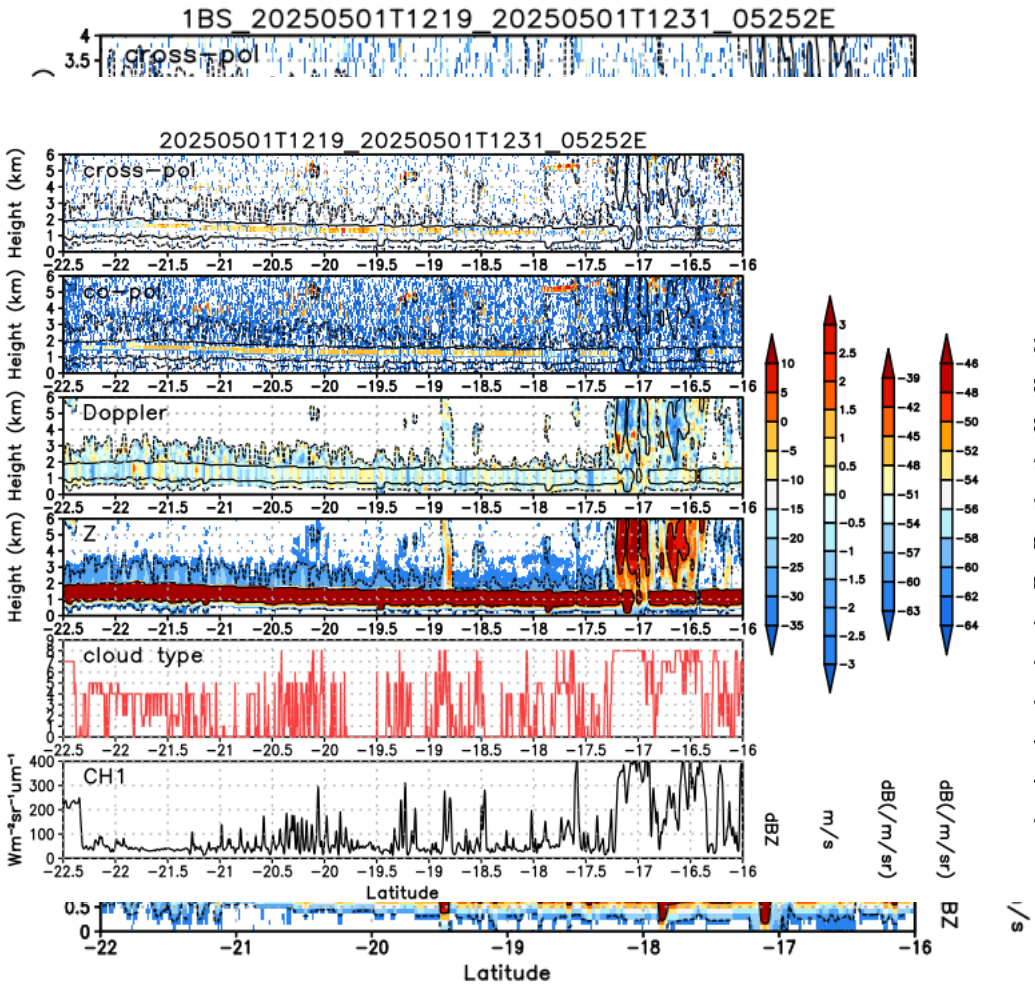

1BS_20250425T1742_20250425T1754_05162F
cross-pol
co-pol
Doppler
Z
CH1 (0.67 um)
Height (km)
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)
Radiance (VNS bands) CH1 orbit
66W
64W
62W
60W
W m-2 sr-1 um-1
0.0
60.0
120.0
180.0
Data Min = 2.7, Max = 472.1
K
Wm-2sr-1um-1

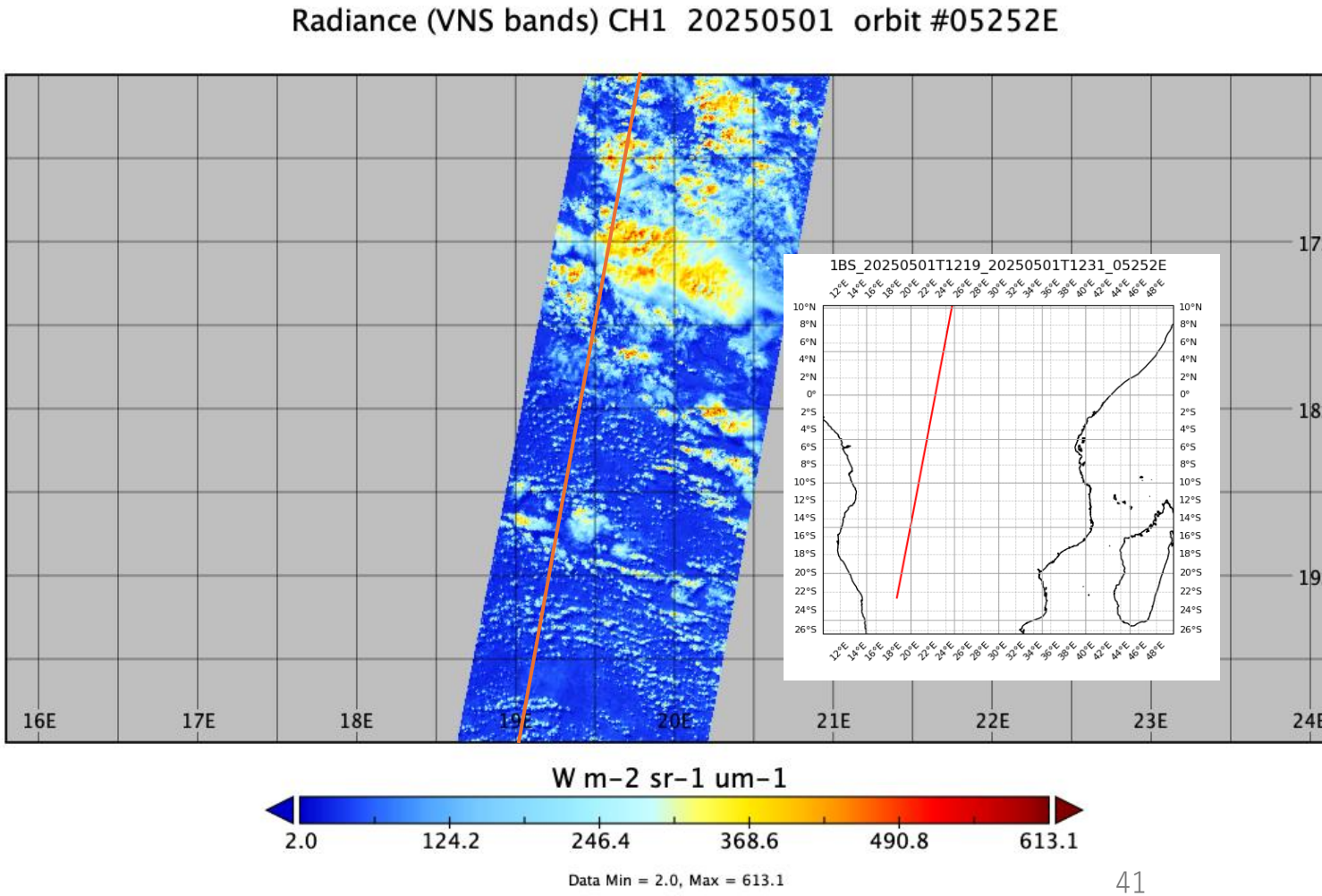

1BS_20250430T1801_20250430T1812_05240F
cross-pol
co-pol
Doppler
Z
Height (km)
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)
CH1 (0.67 um)
Wm-2sr-1um-1

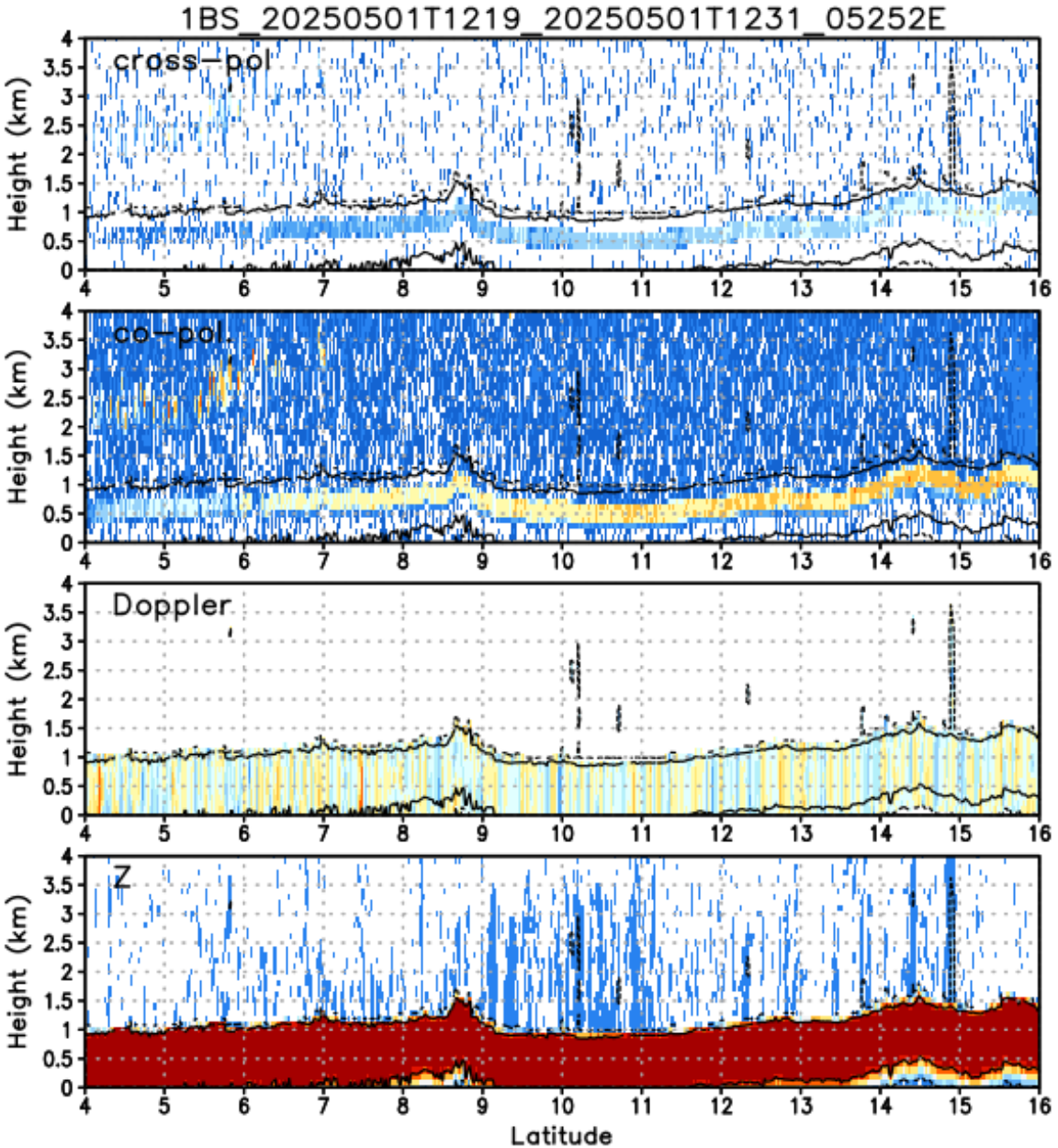

JS bands) CH1 20250430 orbit #05240F
W m-2 sr-1 um-1
0
120.0
180.0
240.0
300.0
Data Min = 3.0, Max = 358.0

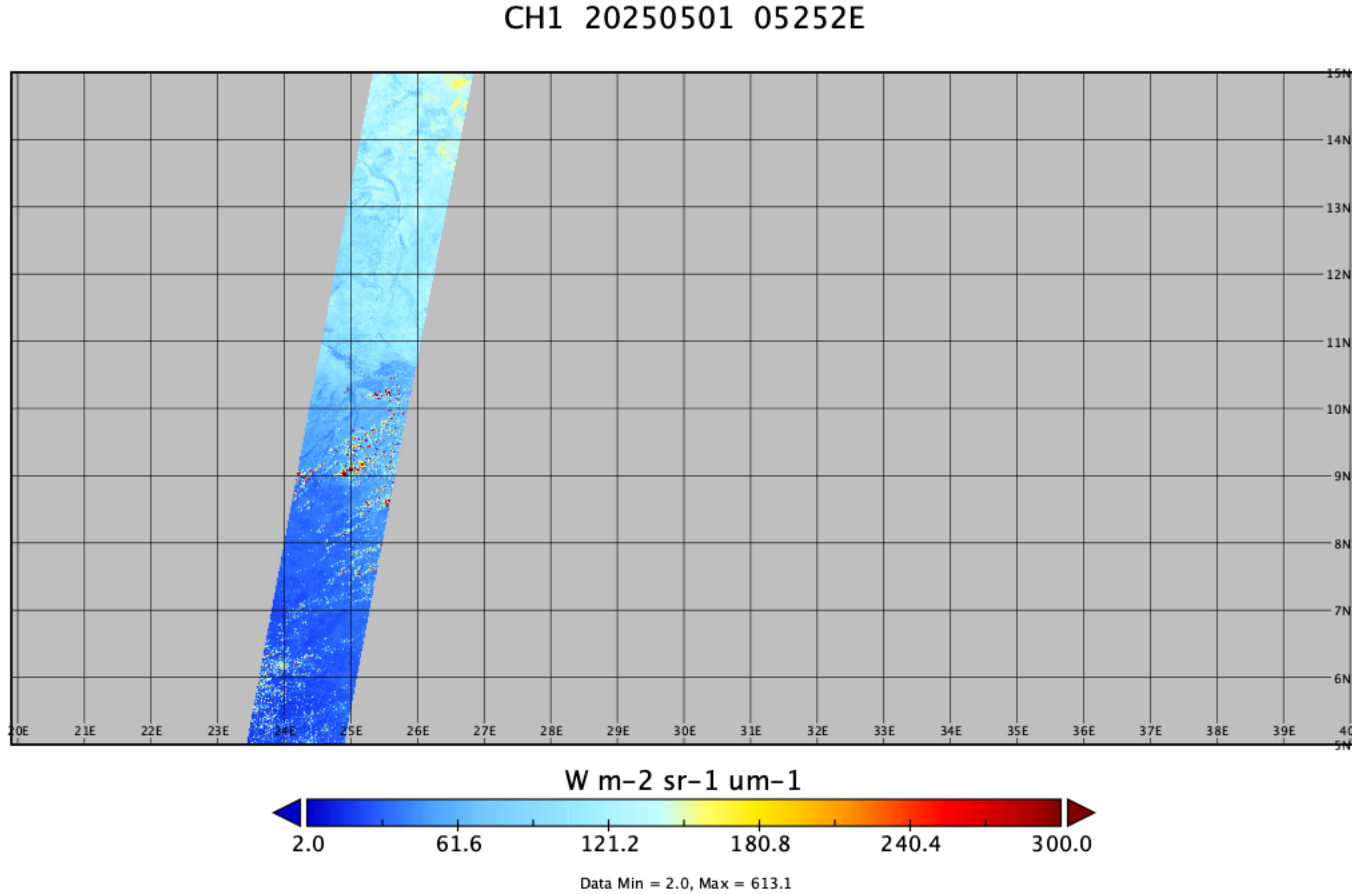

K
Wm-2sr-1um-1

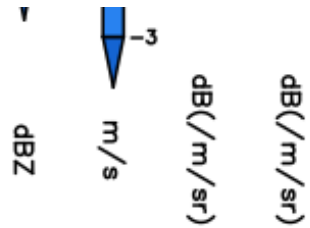
アフリカ

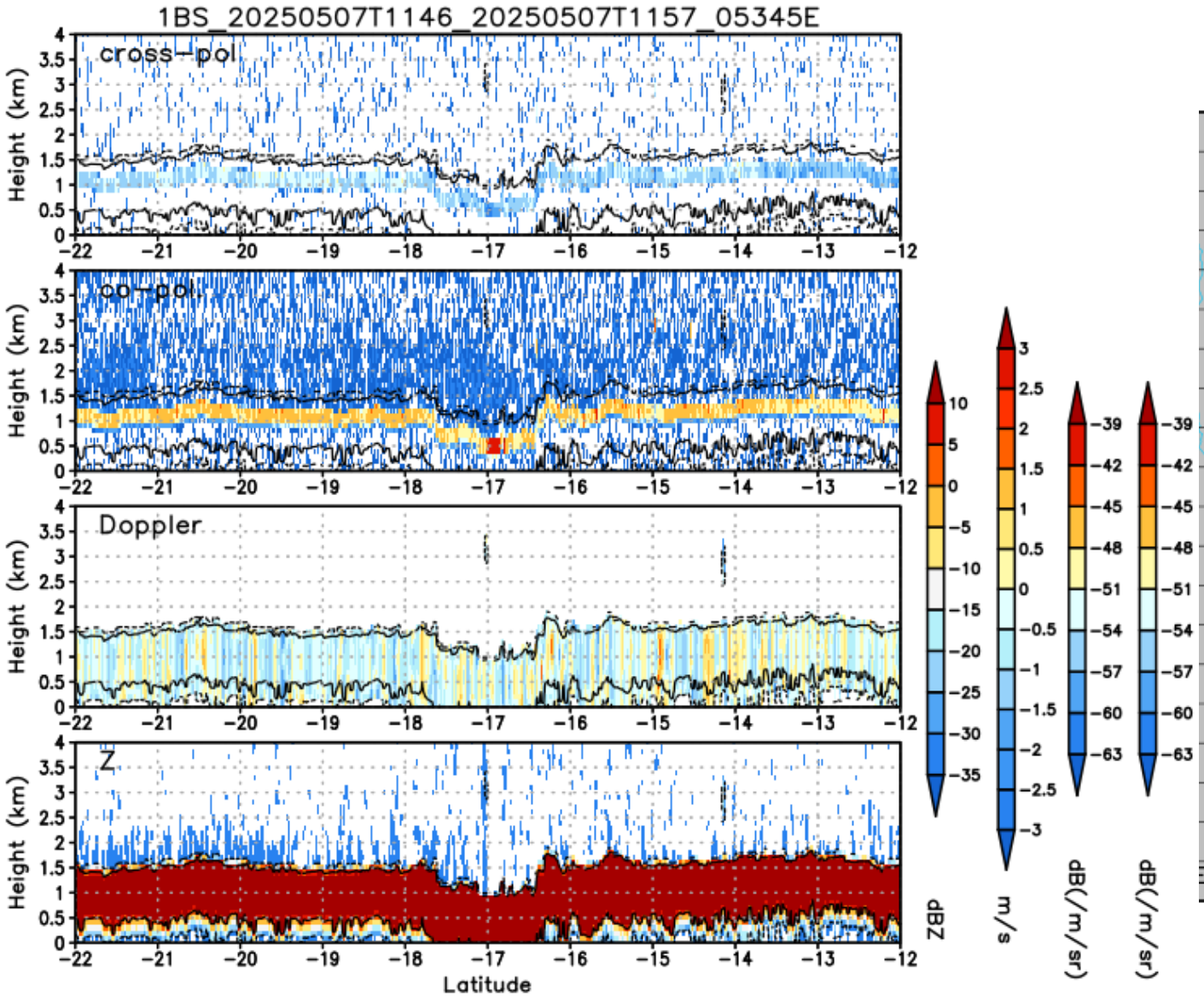

1BS_20250501T1219_20250501T1231_05252E
cross-pol
20250501T1219_20250501T1231_05252E
cross-pol
co-pol
Doppler
Z
cloud type
CH1
Height (km)
Wm⁻²sr⁻¹um⁻¹
ZBZ
m/s
dB(/m/sr)
dB(/m/sr)
BZ
Latitude
Latitude

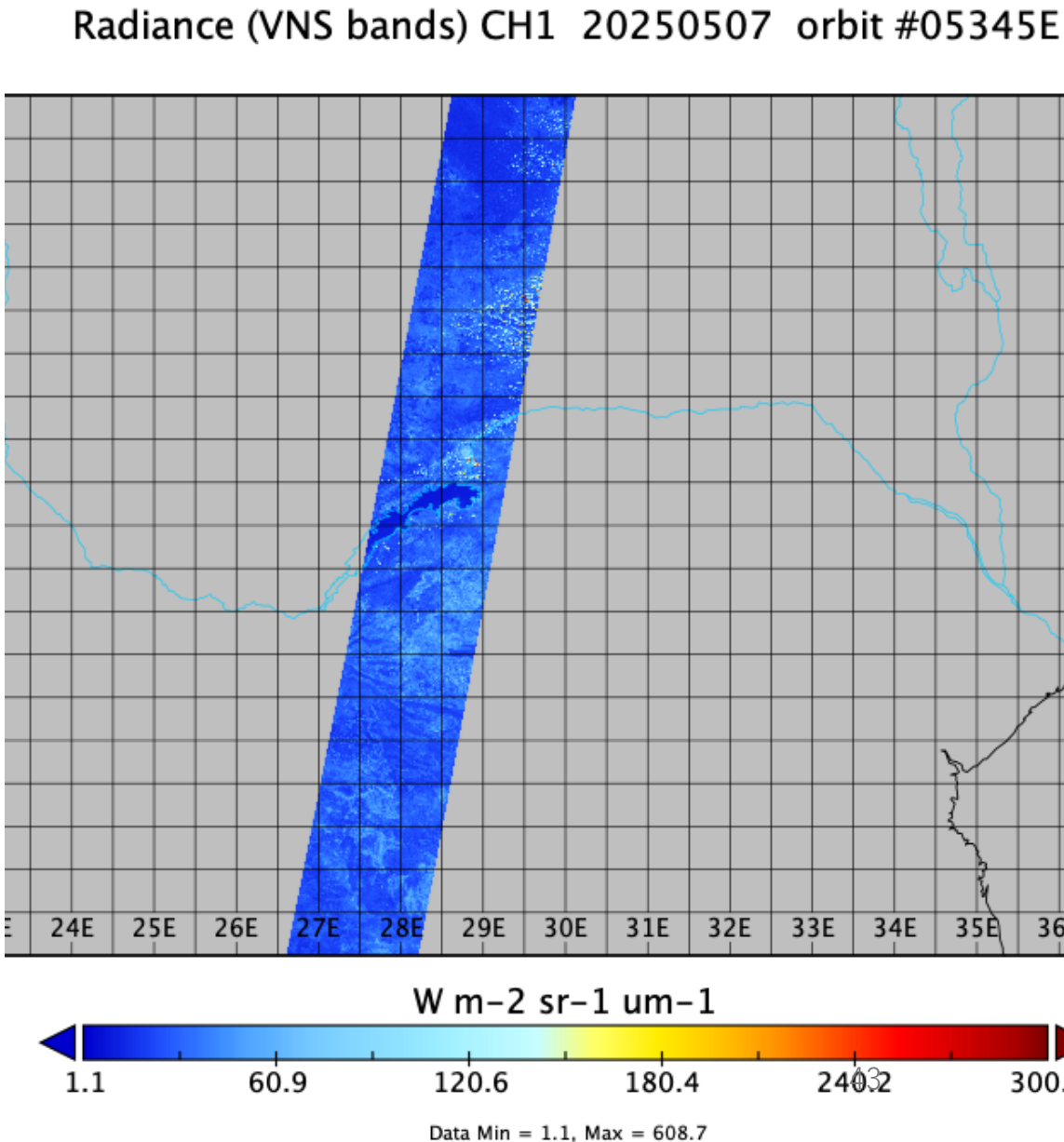

Radiance (VNS bands) CH1 20250501 orbit #05252E
1BS_20250501T1219_20250501T1231_05252E
16E
17E
18E
19E
20E
21E
22E
23E
W m-2 sr-1 um-1
2.0
124.2
246.4
368.6
490.8
613.1
Data Min = 2.0, Max = 613.1

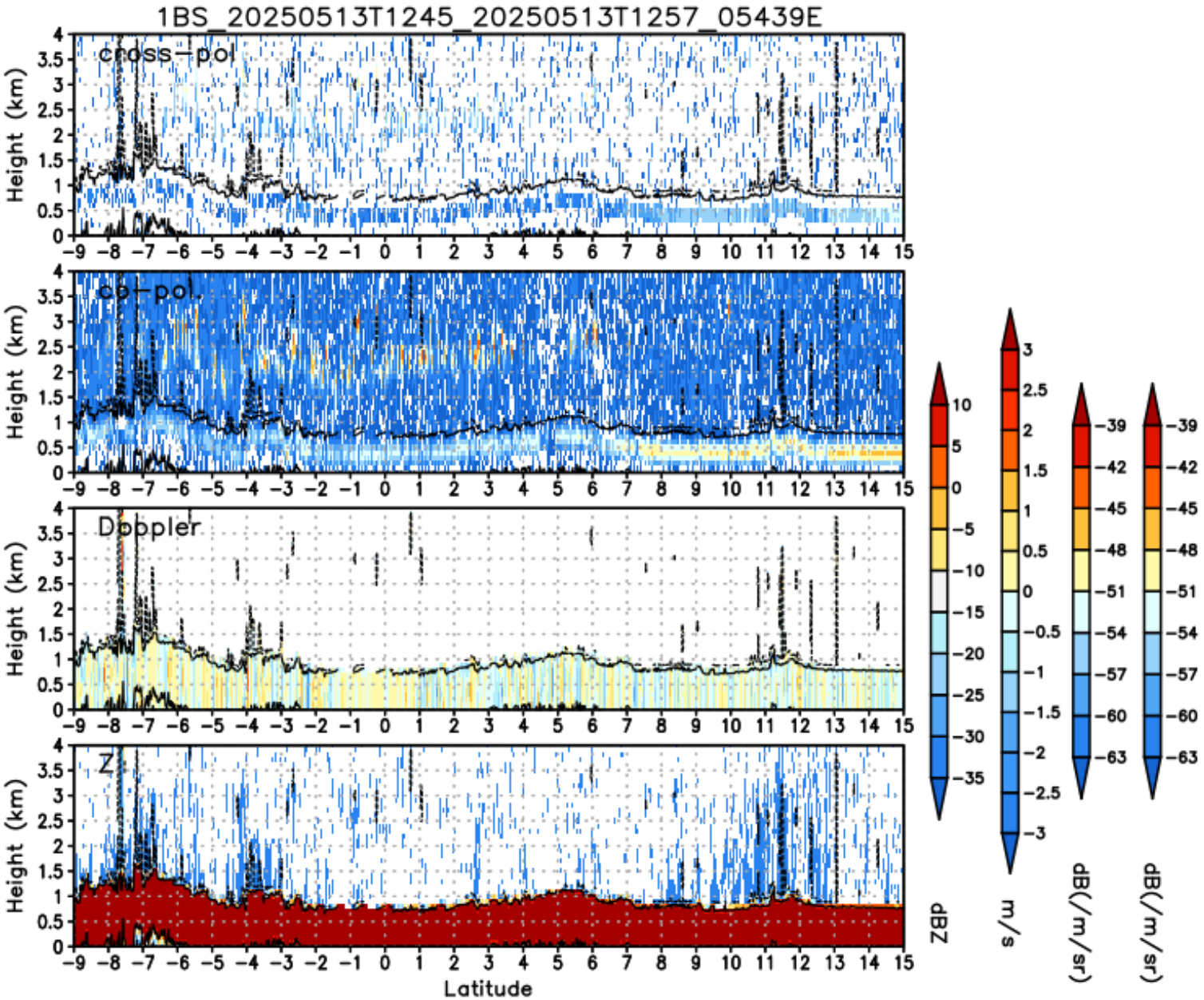

1BS_20250501T1219_20250501T1231_05252E
cross-pol
co-pol
Doppler
Z
Height (km)
Latitude

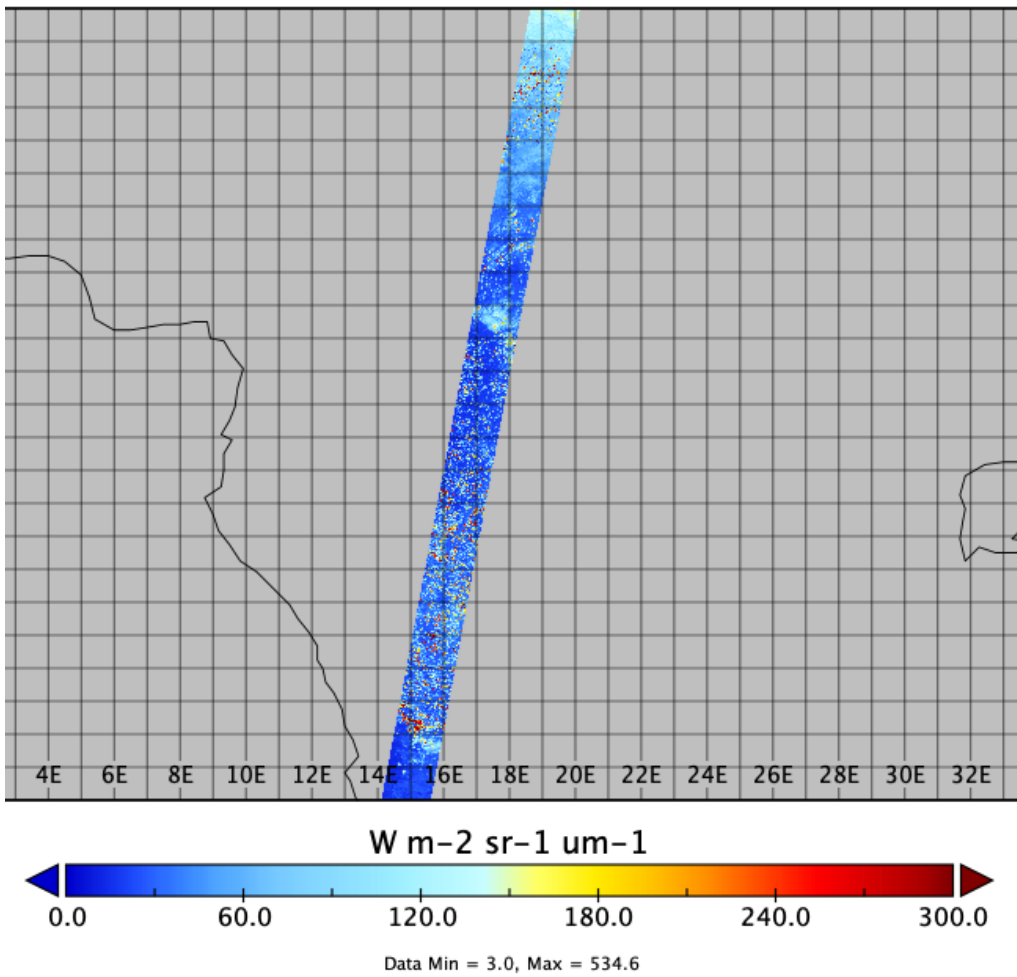

CH1 20250501 05252E
W m-2 sr-1 um-1
2.0
61.6
121.2
180.8
240.4
300.0
Data Min = 2.0, Max = 613.1

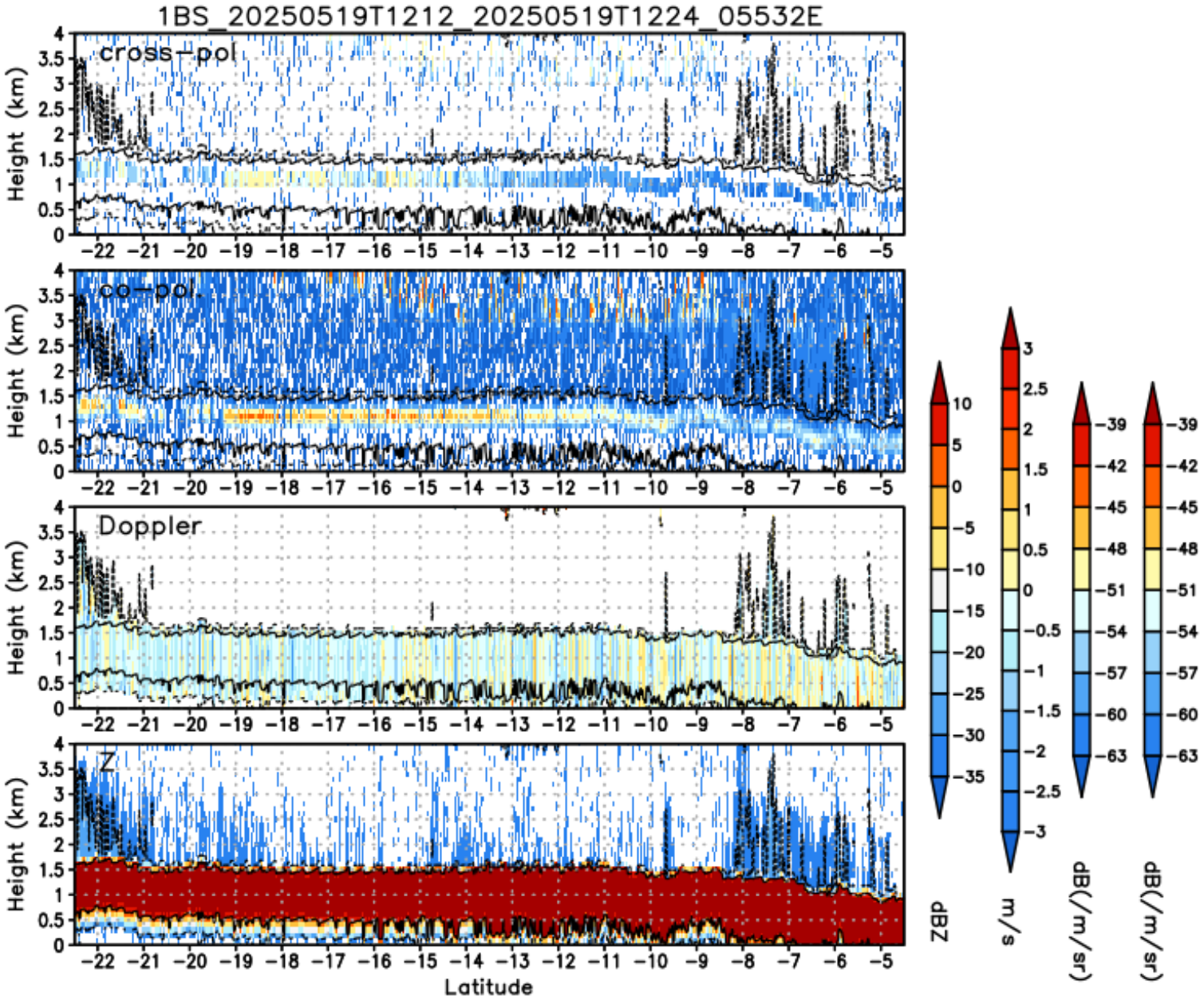

ZDR
m/s
dB(/m/sr)
dB(/m/sr)
-3

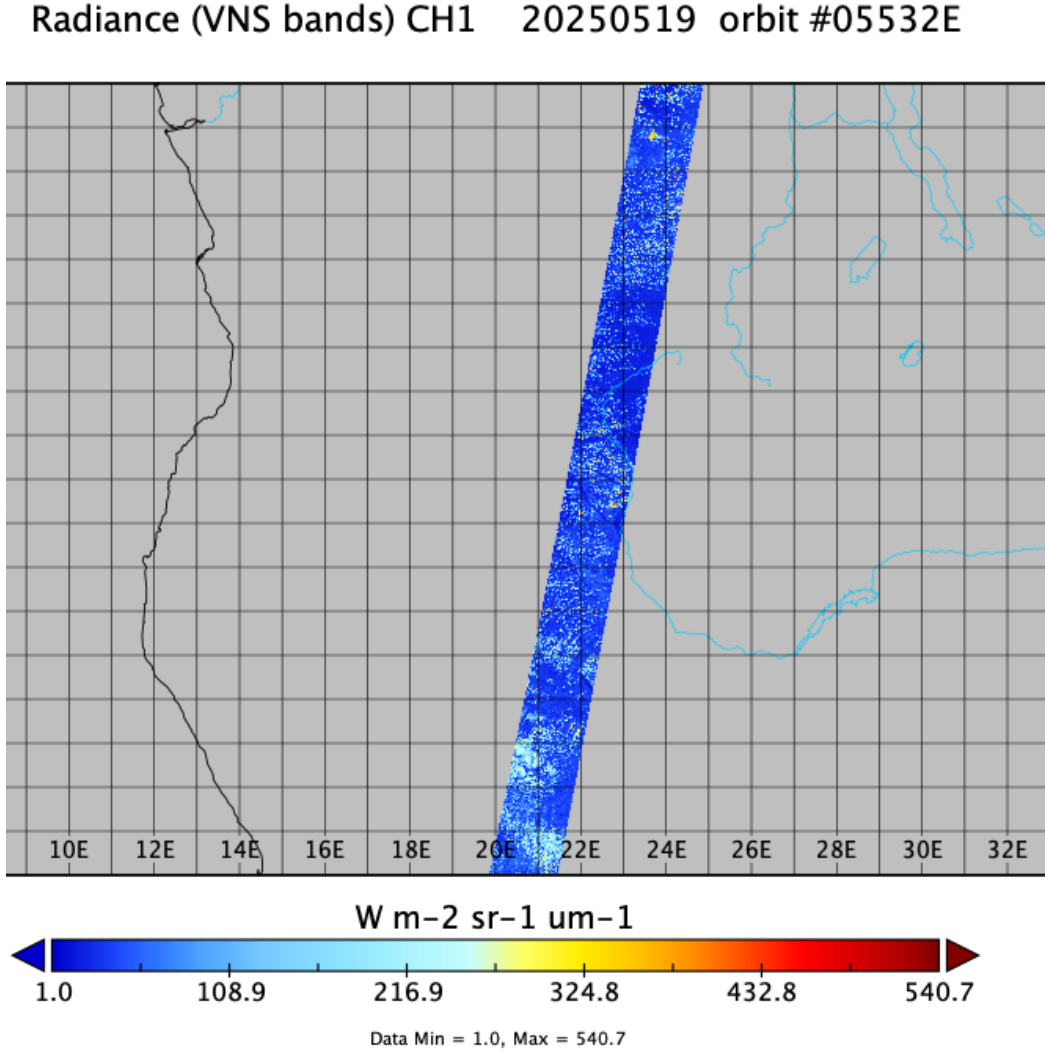

1BS_20250507T1146_20250507T1157_05345E
cross-pol
co-pol
Doppler
Z
Height (km)
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)


Radiance (VNS bands) CH1 20250507 orbit #05345E
W m-2 sr-1 um-1
Data Min = 1.1, Max = 608.7

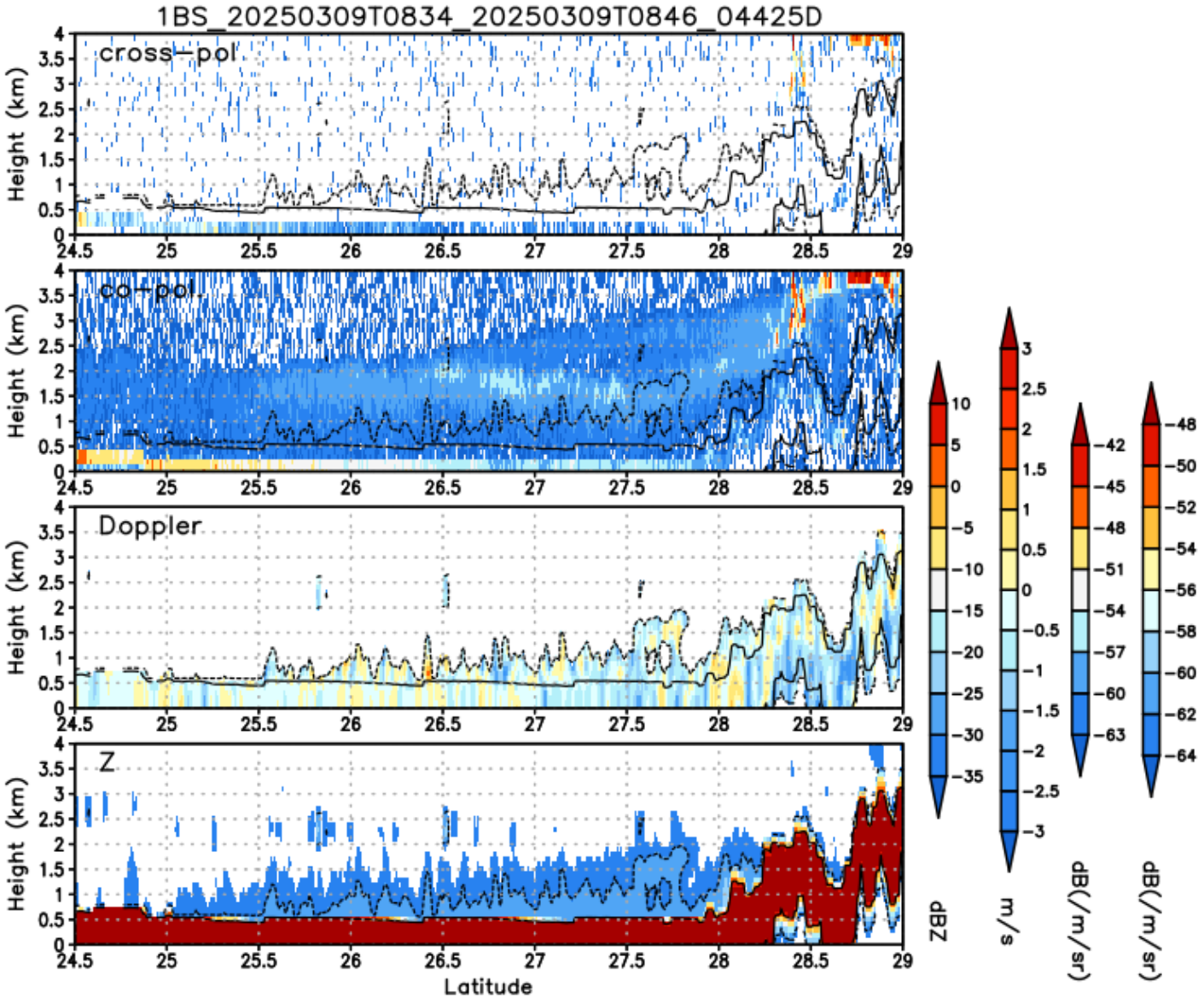

1BS_20250513T1245_20250513T1257_05439E
cross-pol
co-pol
Doppler
Z
Height (km)
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)

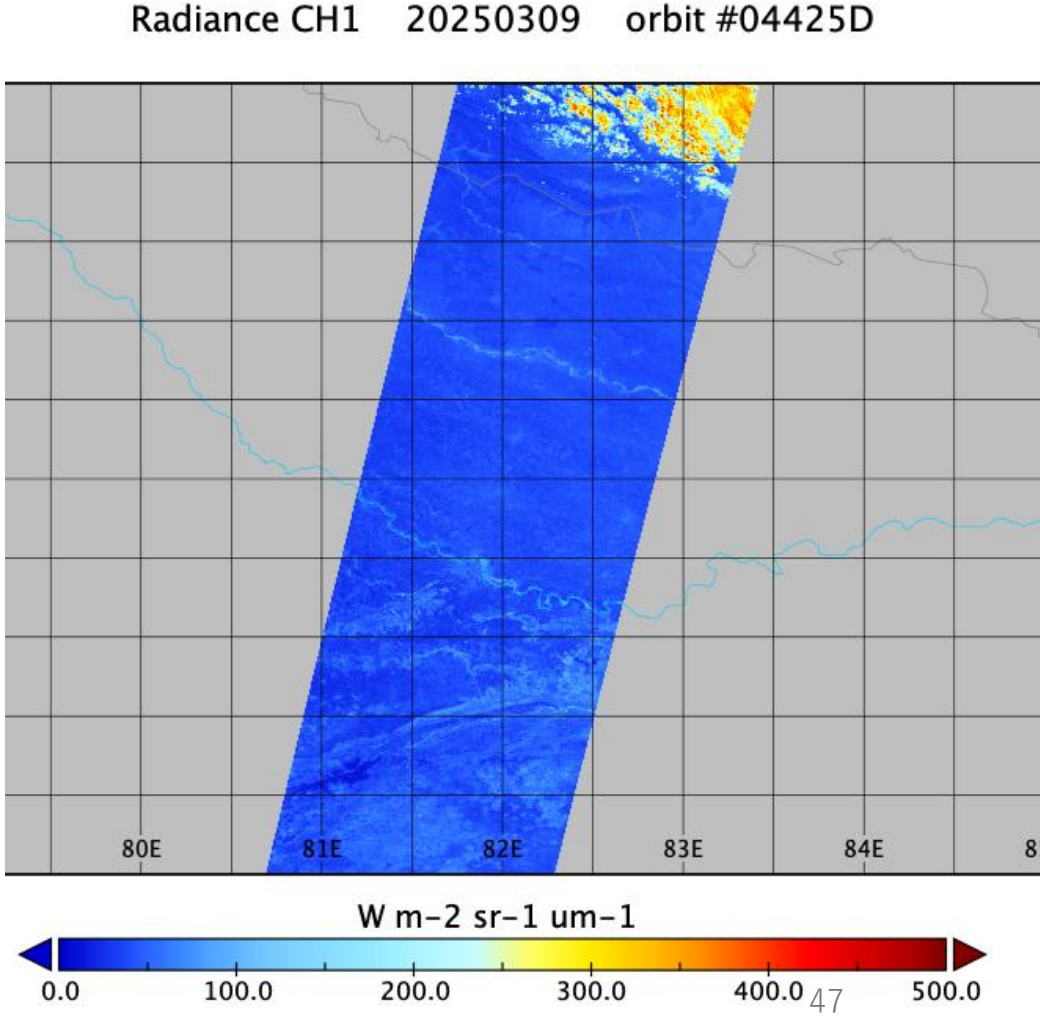

Radiance (VNS bands) CH1 20250513 orbit #05439E
W m-2 sr-1 um-1
Data Min = 3.0, Max = 534.6

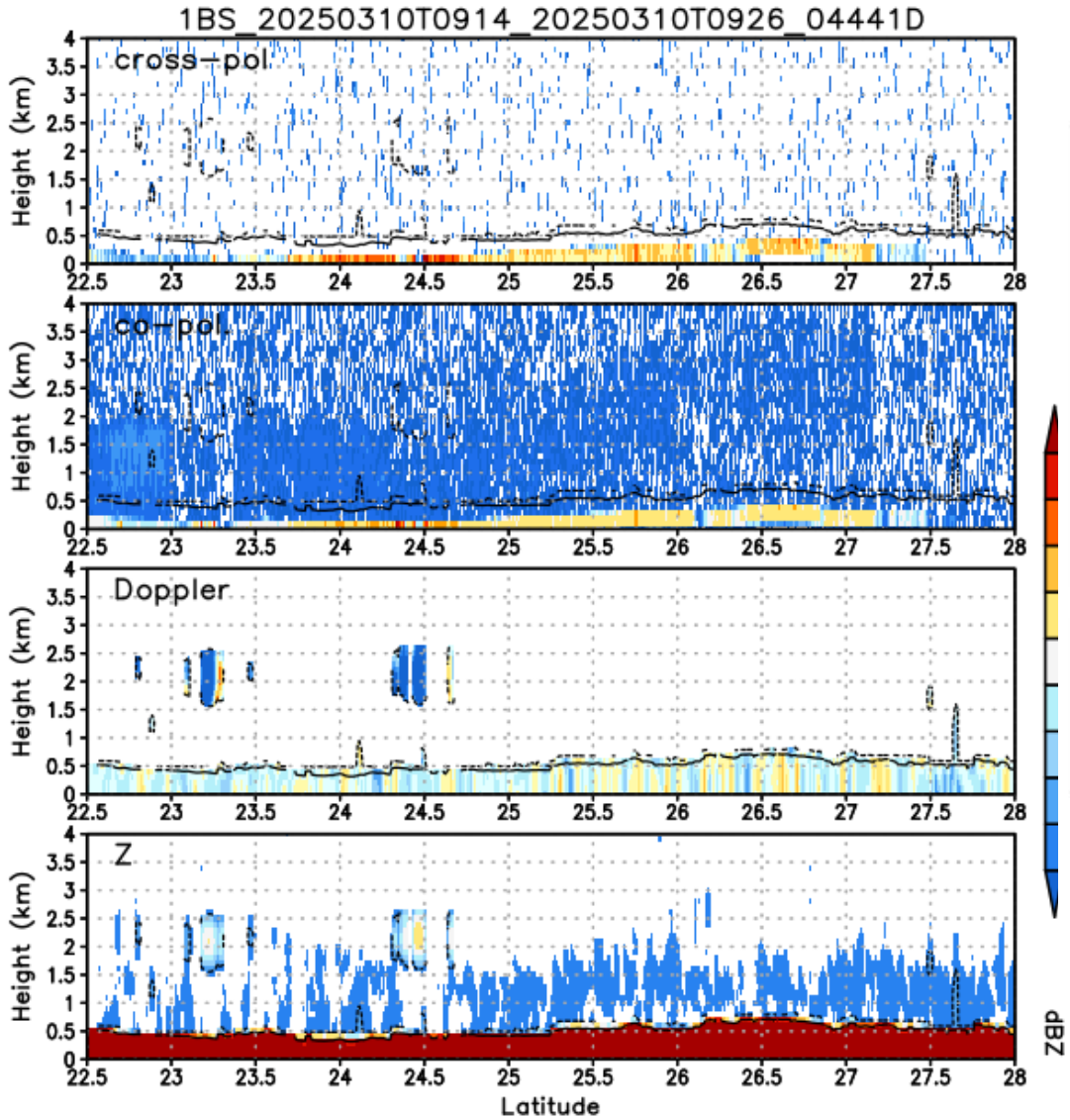

1BS_20250519T1212_20250519T1224_05532E
cross-pol
co-pol
Doppler
Z
Height (km)
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)

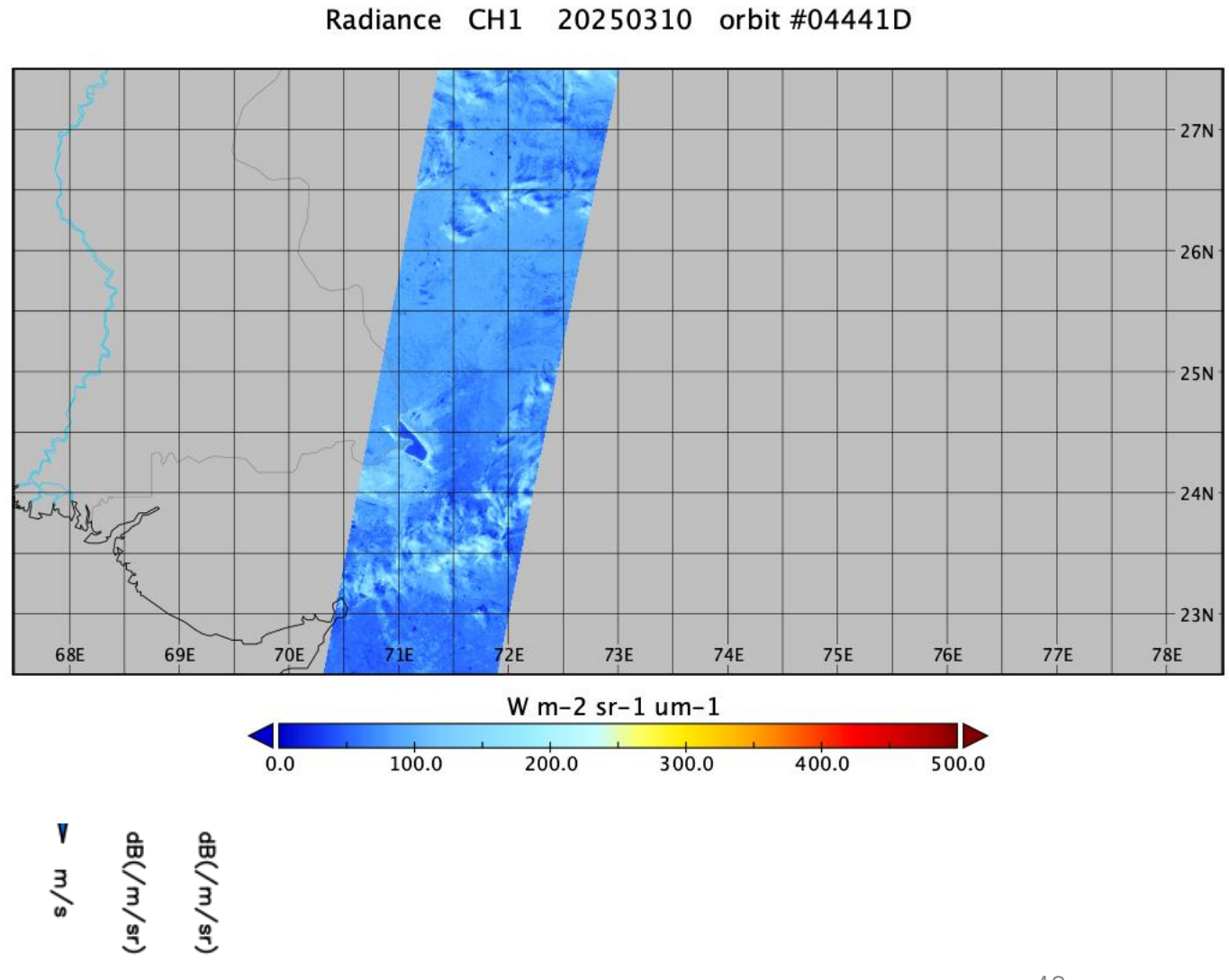

Radiance (VNS bands) CH1 20250519 orbit #05532E
10E
12E
14E
16E
18E
20E
22E
24E
26E
28E
30E
32E
W m-2 sr-1 um-1
1.0
108.9
216.9
324.8
432.8
540.7
Data Min = 1.0, Max = 540.7

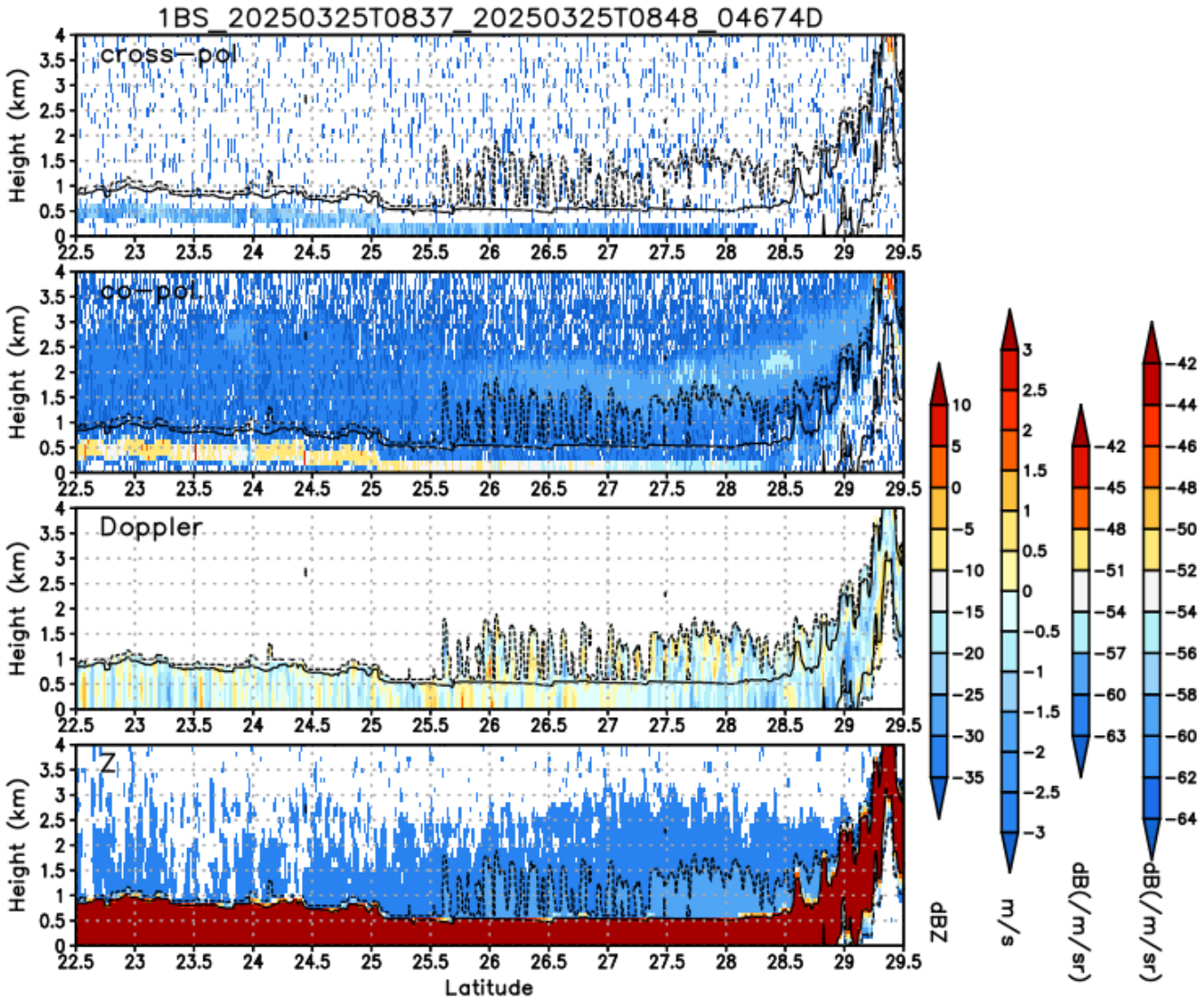
インド

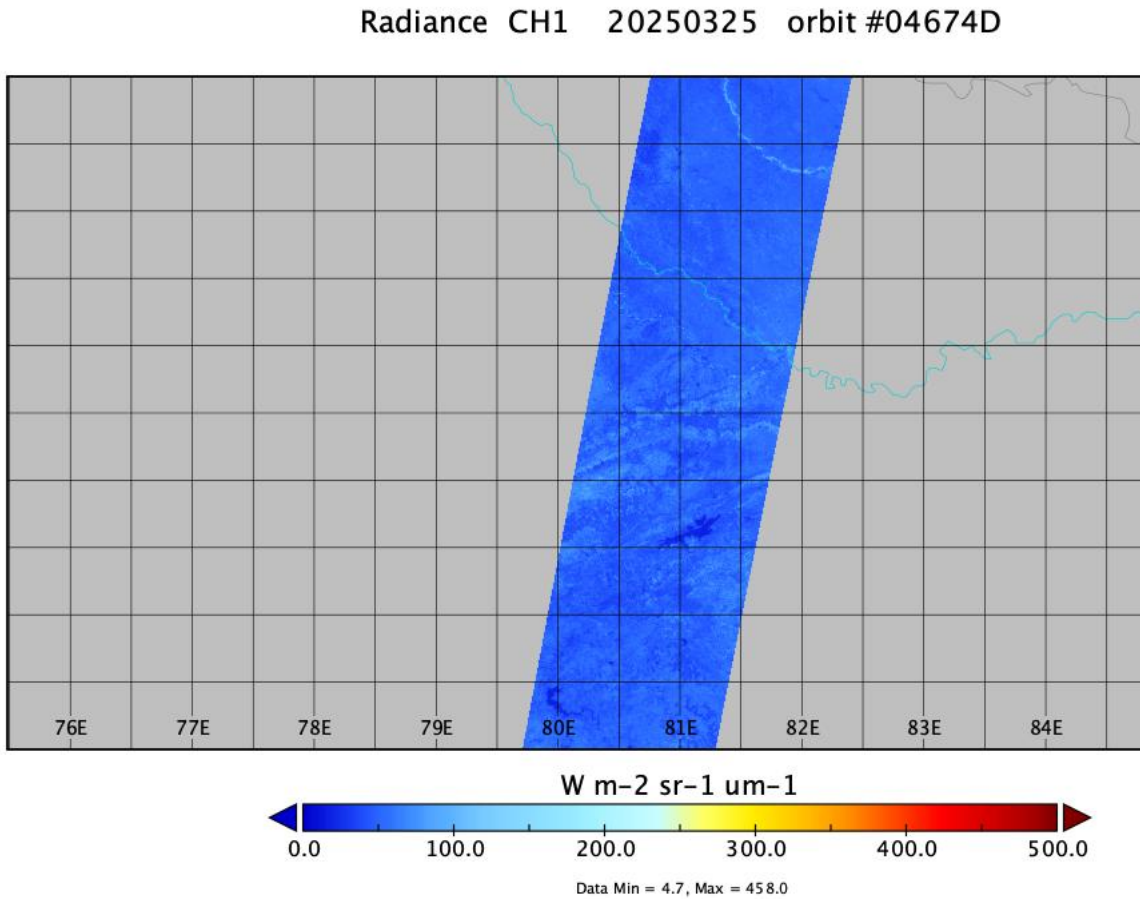

1BS_20250309T0834_20250309T0846_04425D
cross-pol
co-pol
Doppler
Z
Height (km)
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)

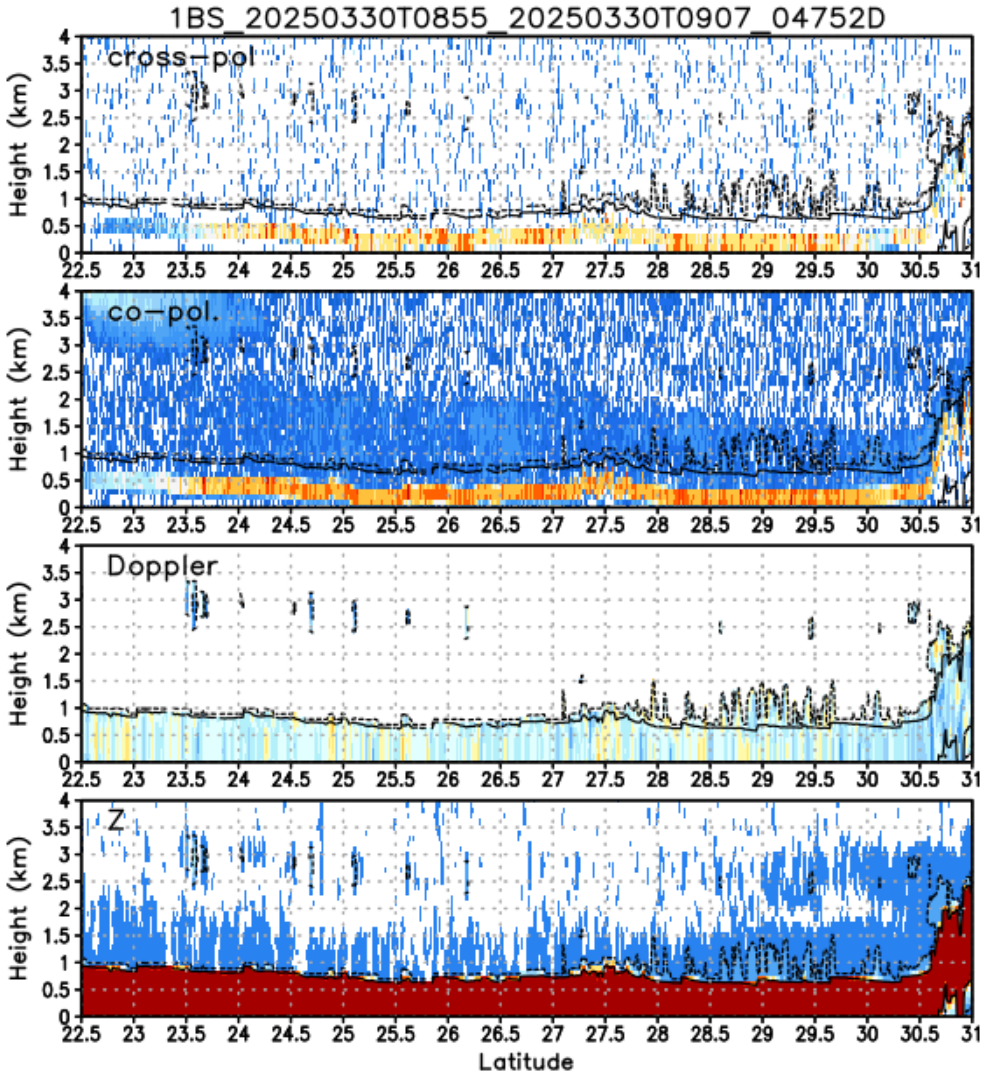

Radiance CH1 20250309 orbit #04425D
80E
81E
82E
83E
84E
W m-2 sr-1 um-1
0.0
100.0
200.0
300.0
400.0
500.0

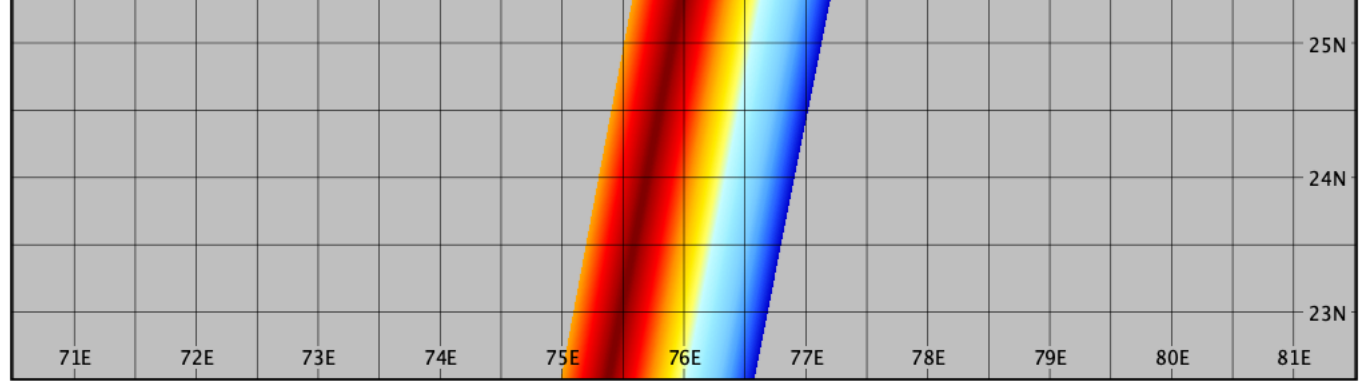

1BS_20250310T0914_20250310T0926_04441D
cross-pol
co-pol
Doppler
Z
Height (km)
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)

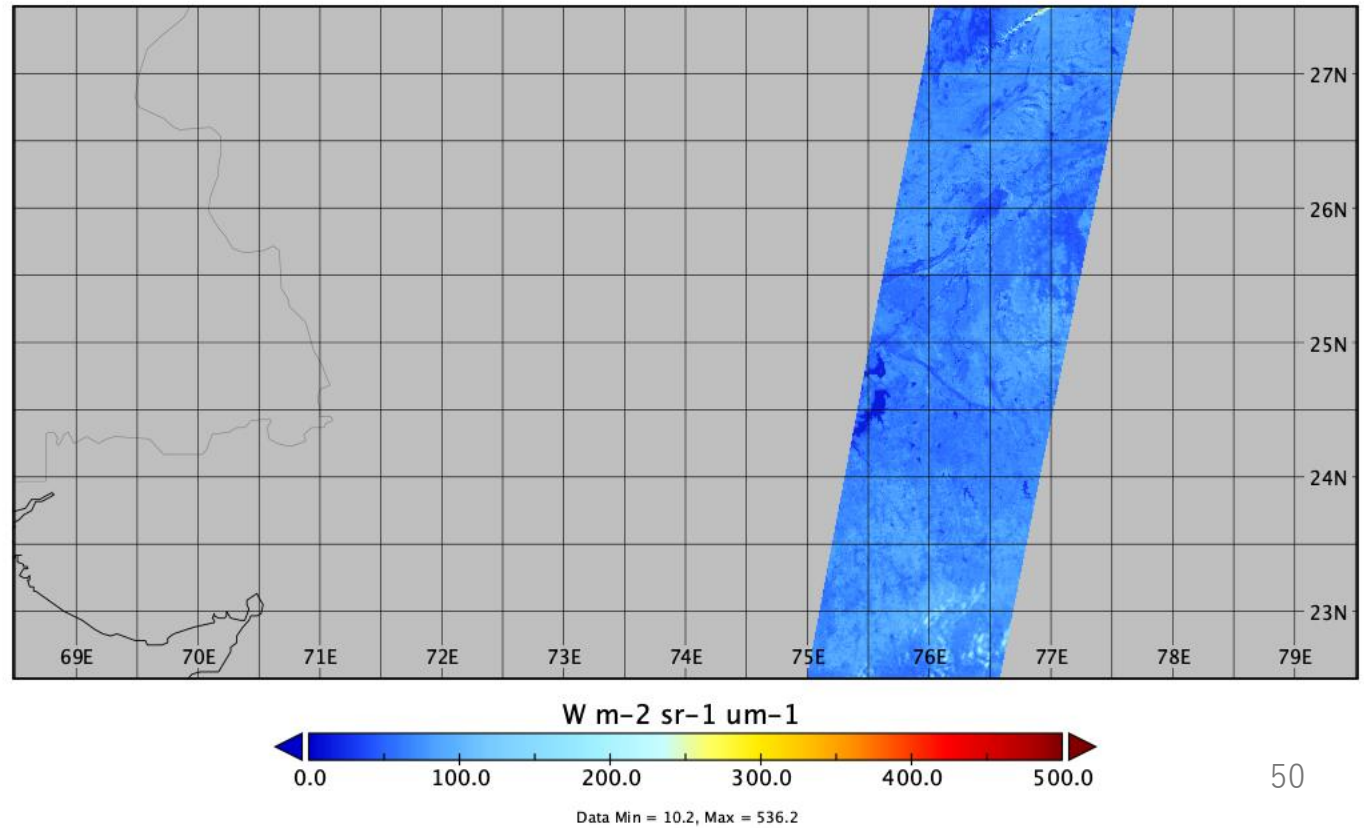

Radiance CH1 20250310 orbit #04441D
27N
26N
25N
24N
23N
68E
69E
70E
71E
72E
73E
74E
75E
76E
77E
78E
W m-2 sr-1 um-1
0.0
100.0
200.0
300.0
400.0
500.0

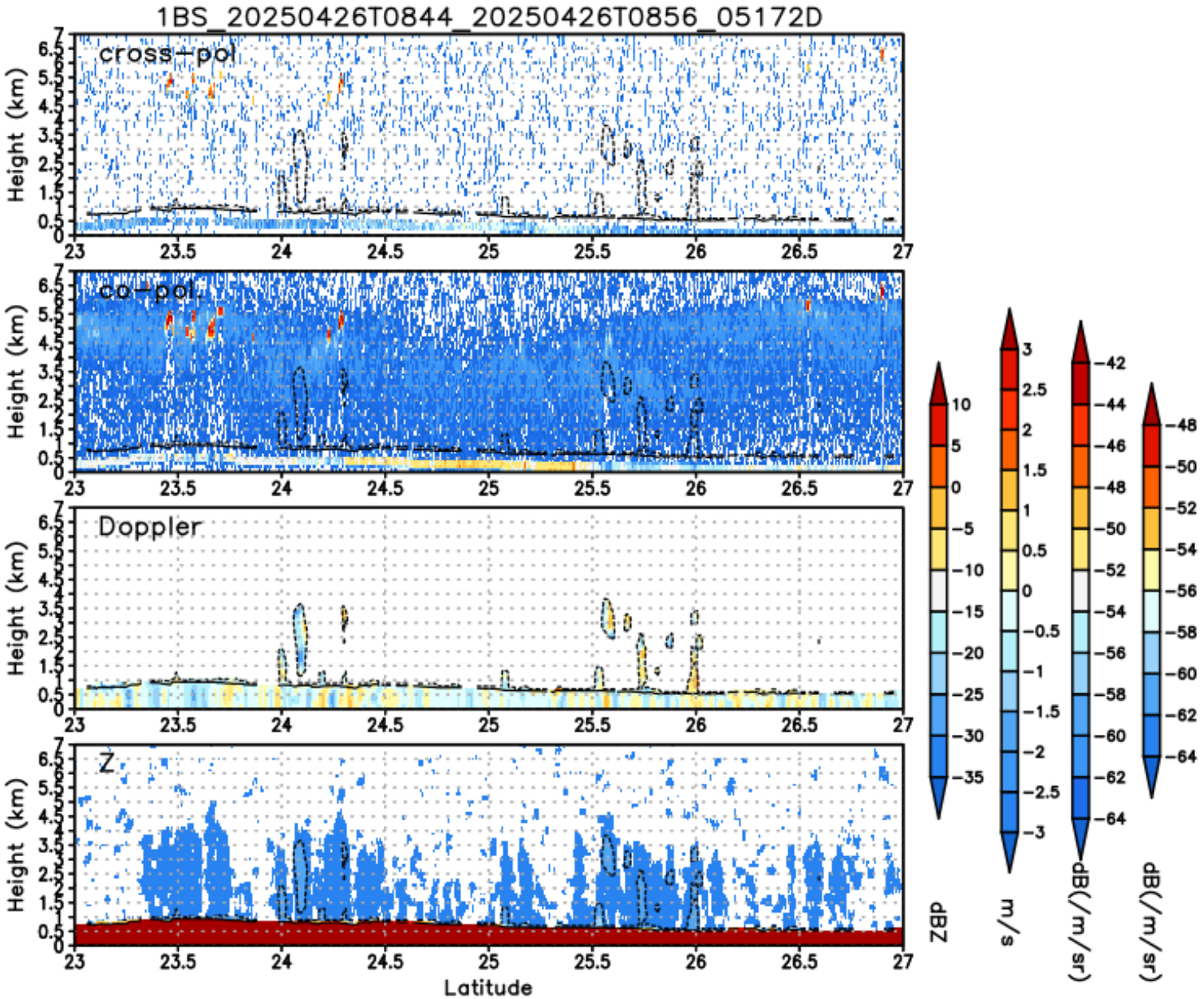

1BS_20250325T0837_20250325T0848_04674D
cross−pol
co−pol
Doppler
Z
Height (km)
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)

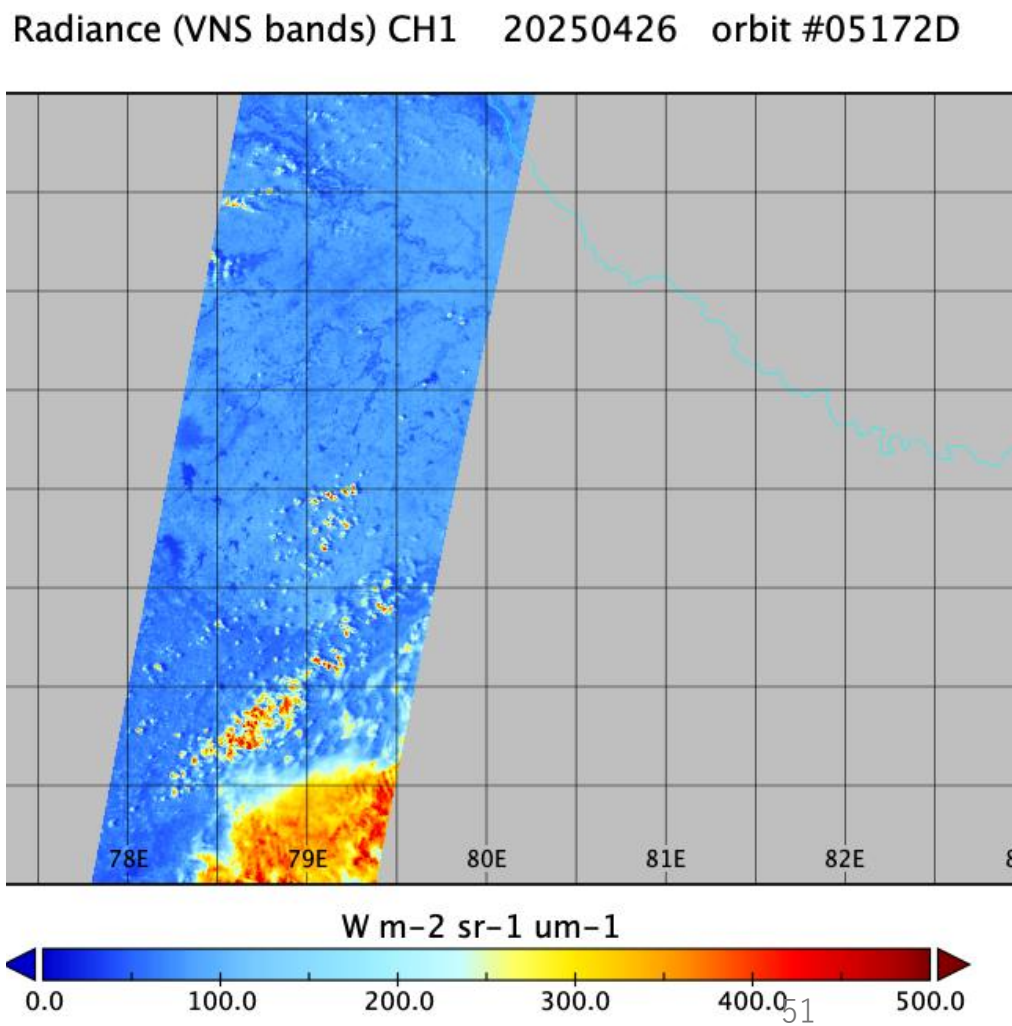

Radiance CH1 20250325 orbit #04674D
76E
77E
78E
79E
80E
81E
82E
83E
84E
W m−2 sr−1 um−1
0.0
100.0
200.0
300.0
400.0
500.0
Data Min = 4.7, Max = 458.0

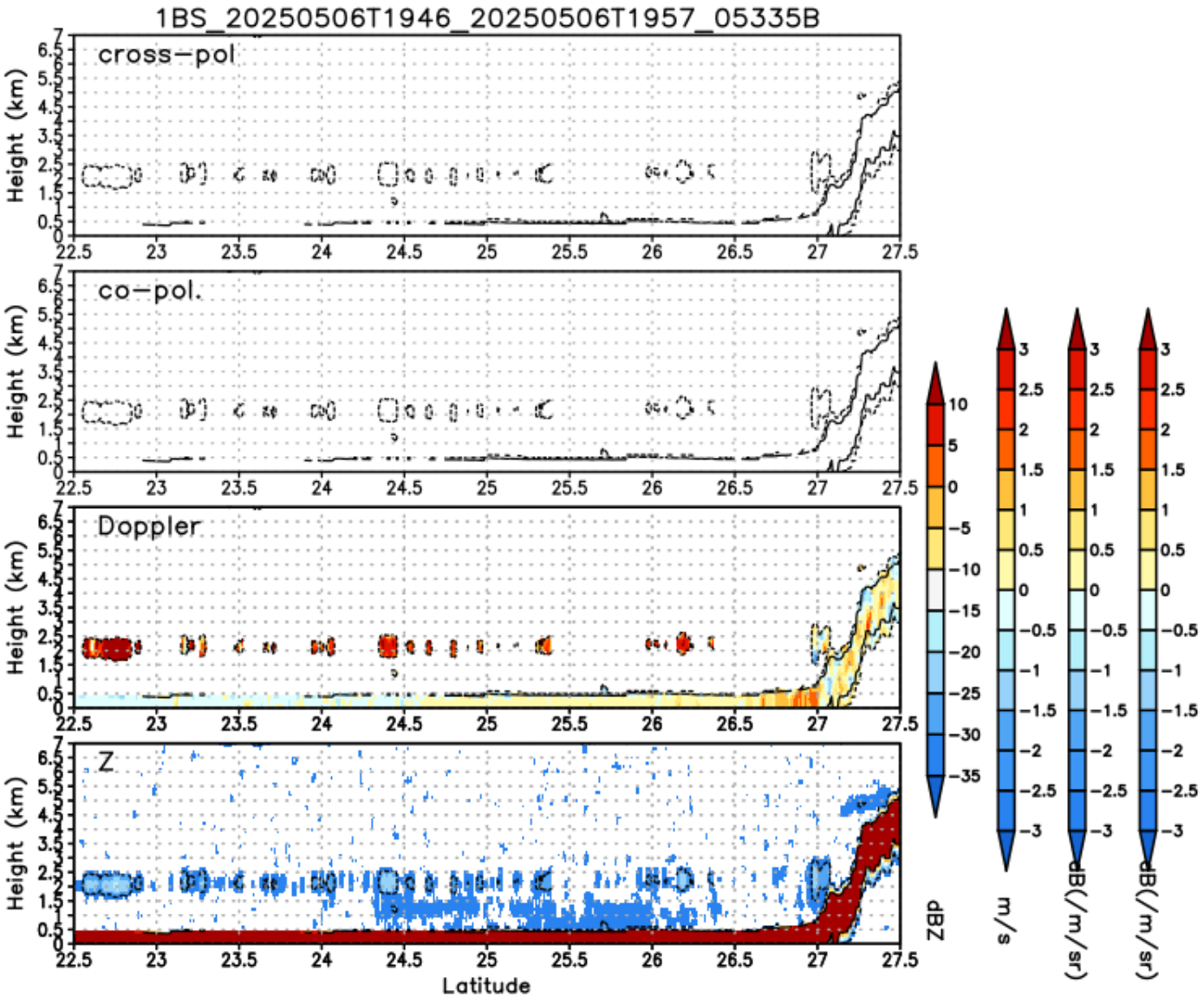

1BS_20250330T0855_20250330T0907_04752D
cross-pol
co-pol.
Doppler
Z
Height (km)
Latitude

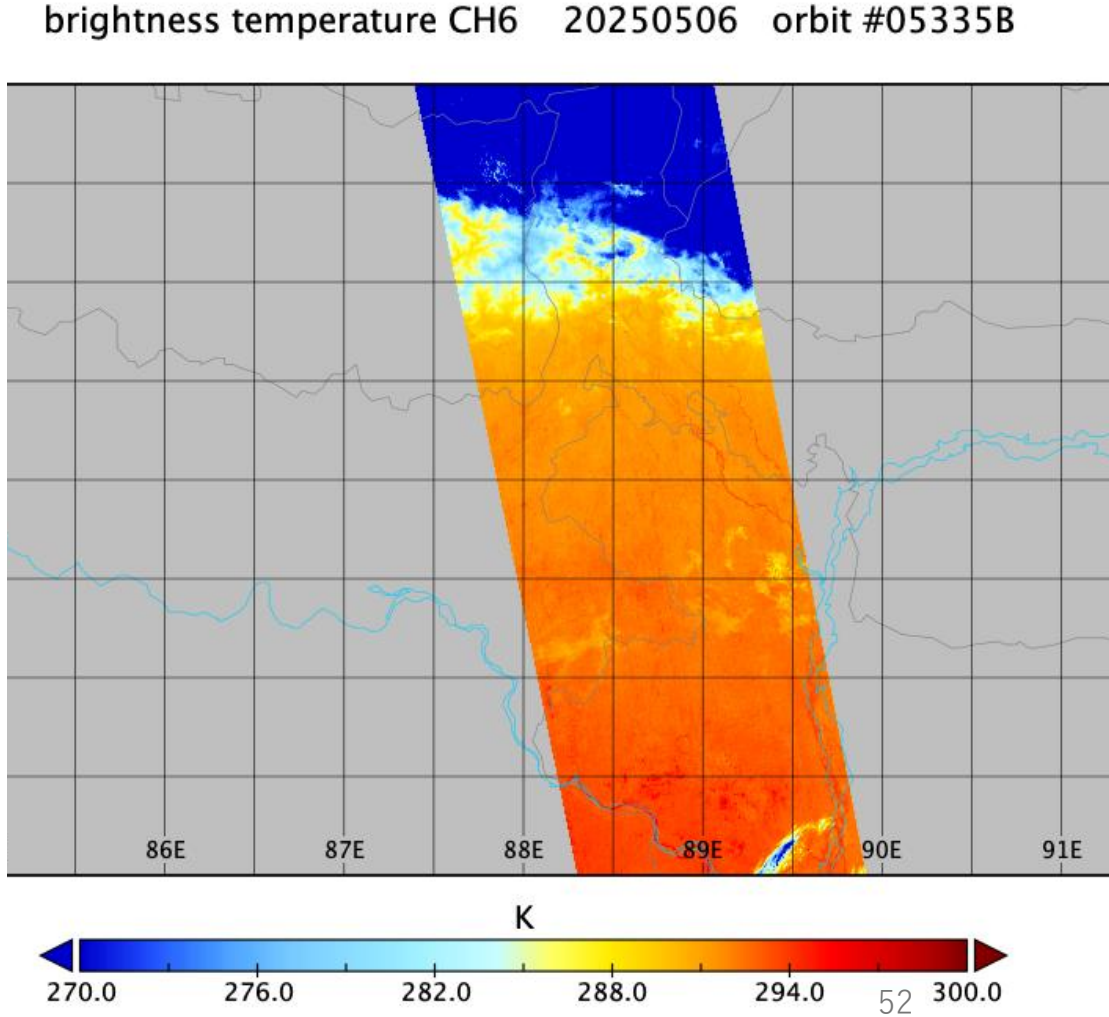

71E
72E
73E
74E
75E
76E
77E
78E
79E
80E
81E
25N
24N
23N
Sensor elevation angle (degree)
72.0
75.5
78.9
82.4
85.9
89.3
Data Min = 72.0, Max = 89.3

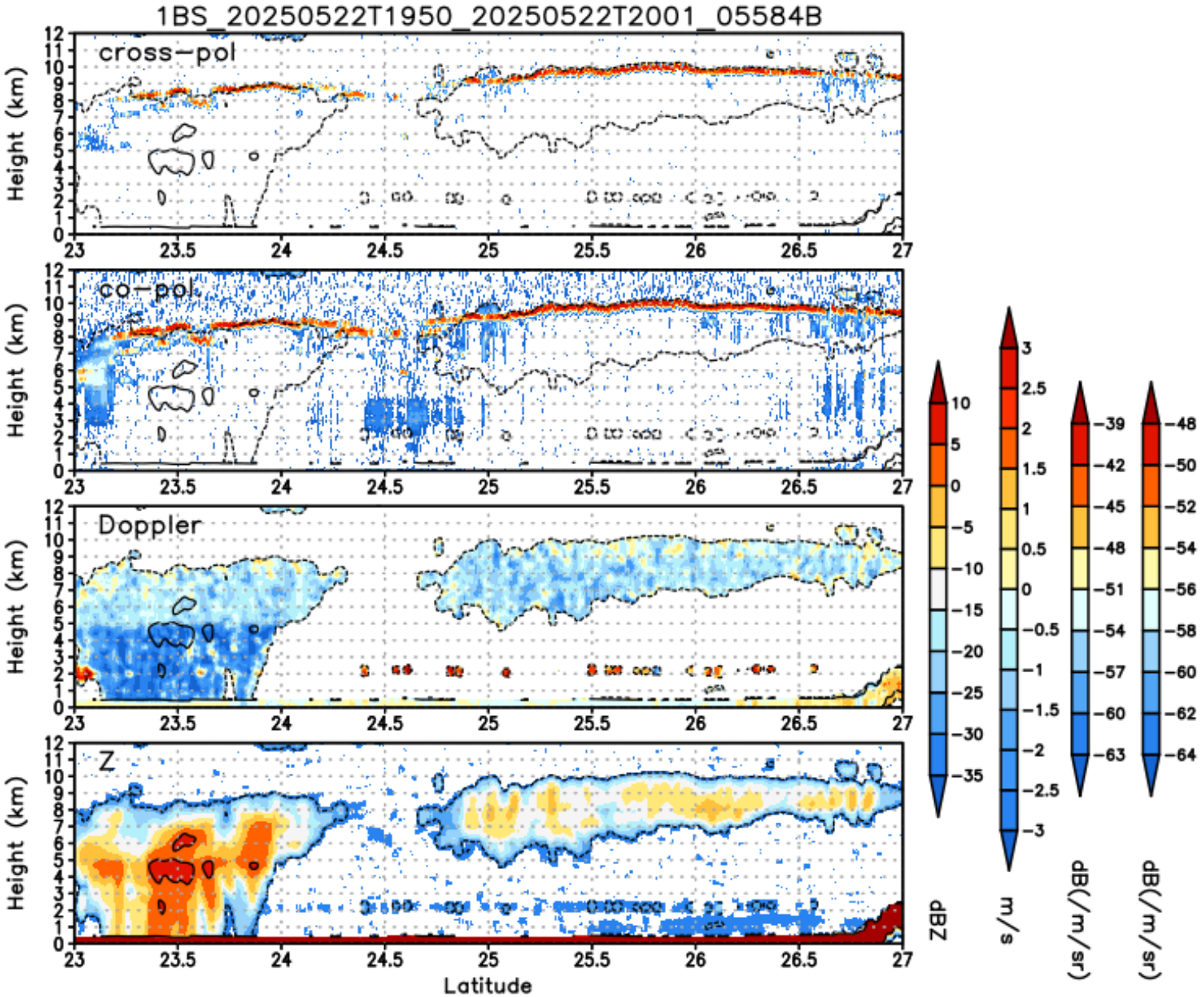

69E
70E
71E
72E
73E
74E
75E
76E
77E
78E
79E
27N
26N
25N
24N
23N
W m-2 sr-1 um-1
0.0
100.0
200.0
300.0
400.0
500.0
Data Min = 10.2, Max = 536.2

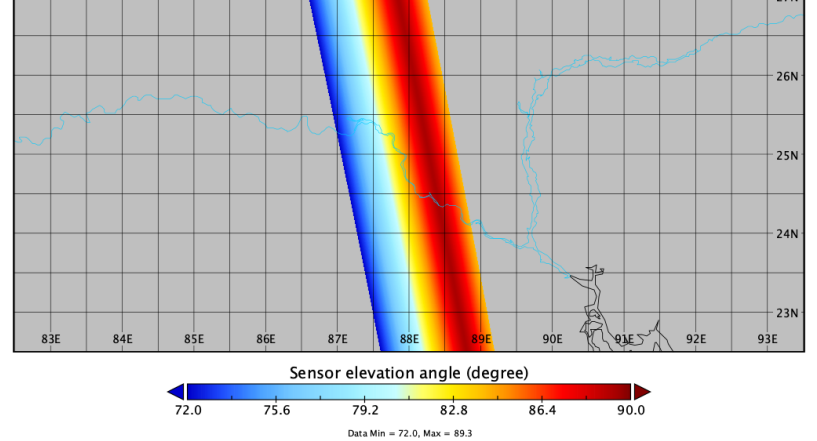

1BS_20250426T0844_20250426T0856_05172D
cross-pol
co-pol
Doppler
Z
Height (km)
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)


Radiance (VNS bands) CH1 20250426 orbit #05172D
78E
79E
80E
81E
82E
W m-2 sr-1 um-1
0.0
100.0
200.0
300.0
400.0
500.0


1BS_20250506T1946_20250506T1957_05335B
cross−pol
co−pol.
Doppler
Z
Height (km)
Latitude
dBZ
m/s
dB(/m/sr)
dB(/m/sr)


brightness temperature CH6 20250506 orbit #05335B
86E
87E
88E
89E
90E
91E
K
270.0
276.0
282.0
288.0
294.0
300.0





brightness temperature (TIR bands) CH6 20250522 orbit #0