Cold Lands Imaging Using Airborne Microwave Radiometer

CLPX02-03

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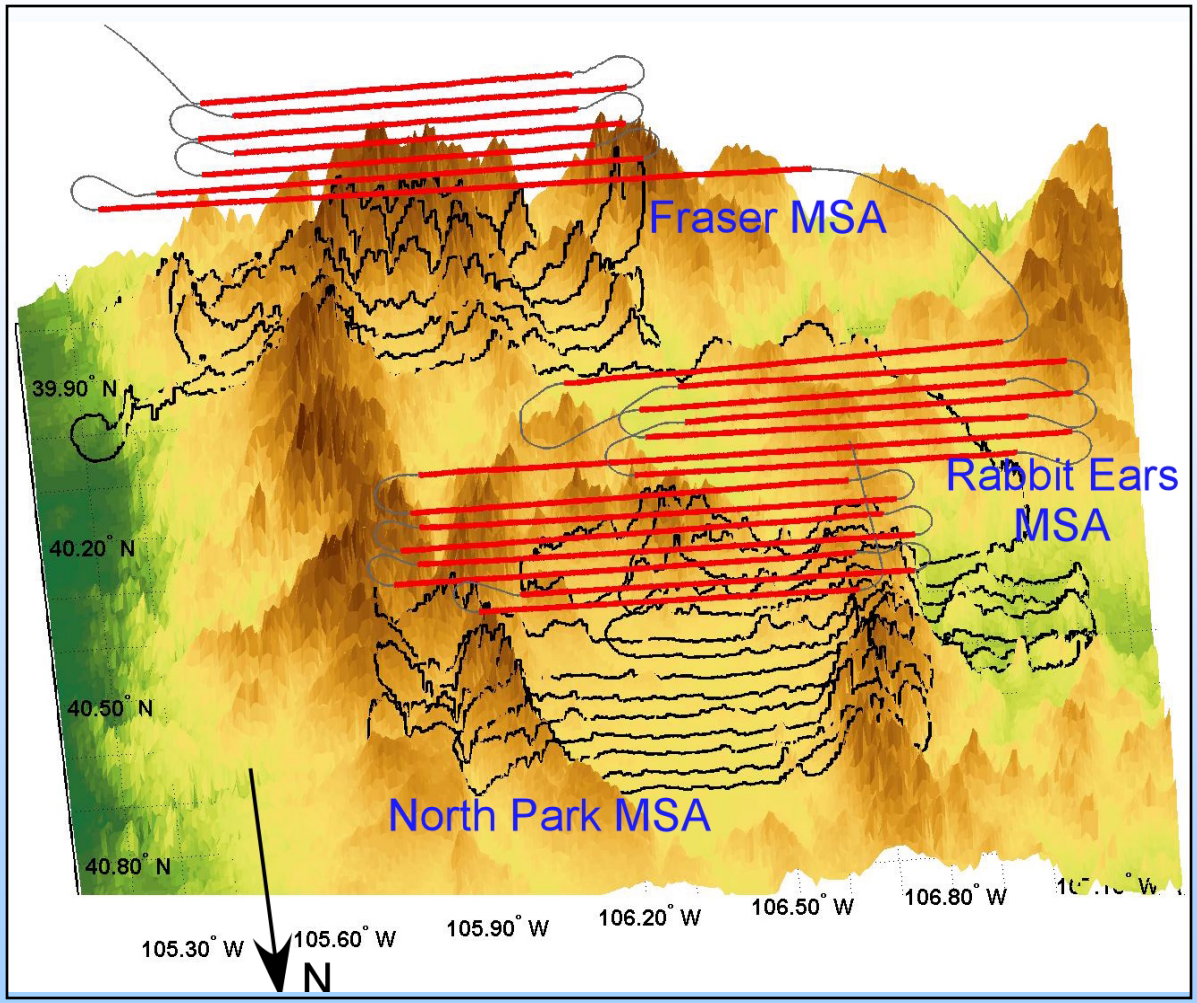
Introduction

During the three Cold Land Processes Experiments (CLPX) in February 2002, February 2003, and March 2003, multispectral polarimetric microwave brightness temperature maps of snowpack in the Colorado Rocky Mountains were obtained using the NOAA Polarimetric Scanning Radiometer (PSR). These data are being used for several purposes including:

- calibration and validation of the AMSR-E sensor,
- snowpack and snowmelt hydrology,
- cryospheric satellite sensor design,
- wideband snow emissivity modeling, and
- snowpack change detection.

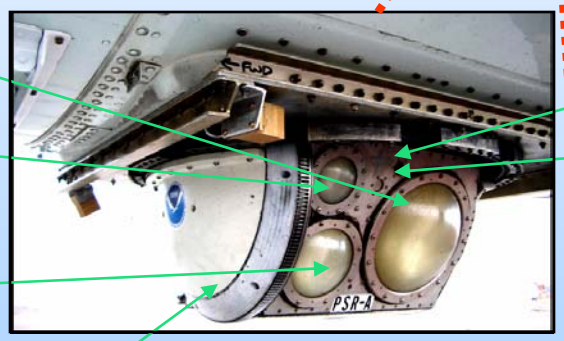
PSR/A Experimental Area



3D view of the CLPX Mesoscale Study Areas (MSA) that were sampled during February 2002, February 2003 and March 2003. Flight lines (red), flight lines projection onto the ground (black)

PSR Configuration for CLPX

	CLPX02	CLPX03A	CLPX03B
Aircraft	DC8	P-3	P-3
Scanhead	PSR/A	PSR/A	PSR/A PSR/CX



10.7 GHz
37.0 GHz

89.0 GHz

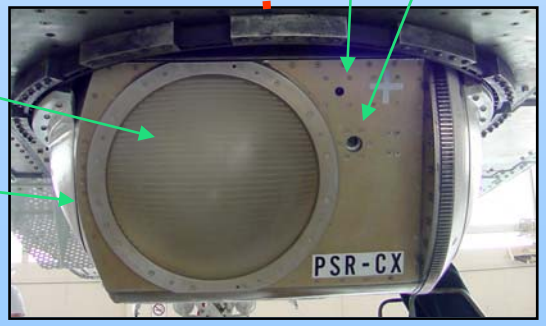
18.7 GHz
21.5 GHz

Video

10 μm IR

6.7 GHz
10.7 GHz

Aerodynamic Fence



PSR Radiometer System Parameters

- PSR is the first airborne multi-band conical-scanned imaging radiometer system.
- The PSR was designed for a variety of high-resolution environmental remote sensing purposes and it is uniquely suited for CLPX studies.
- The most recent PSR hardware improvement permits simultaneous use of multiple PSR scanheads on a single aircraft to provide imagery at all of the AMSR-E bands.

Frequency (GHz)	Scanhead	Polarization	Beamwidth[1] (°)	ΔT_{rms}[2] (K)
5.8-7.5	PSR/CX[3]	v,h,U,V	10	0.2
10.6-10.8	PSR/CX[3] PSR/A	v,h,U,V	7 8	0.4 0.6
18.6-18.8	PSR/A	v,h,U,V	8	0.3
21.4-21.7 (H_2O)	PSR/A	v,h	8	0.4
36-38	PSR/A	v,h	2.3	0.5
86-92	PSR/A	v,h,U	2.3	0.6
10 mm (IR)	PSR/A	unpolarized	7	0.2

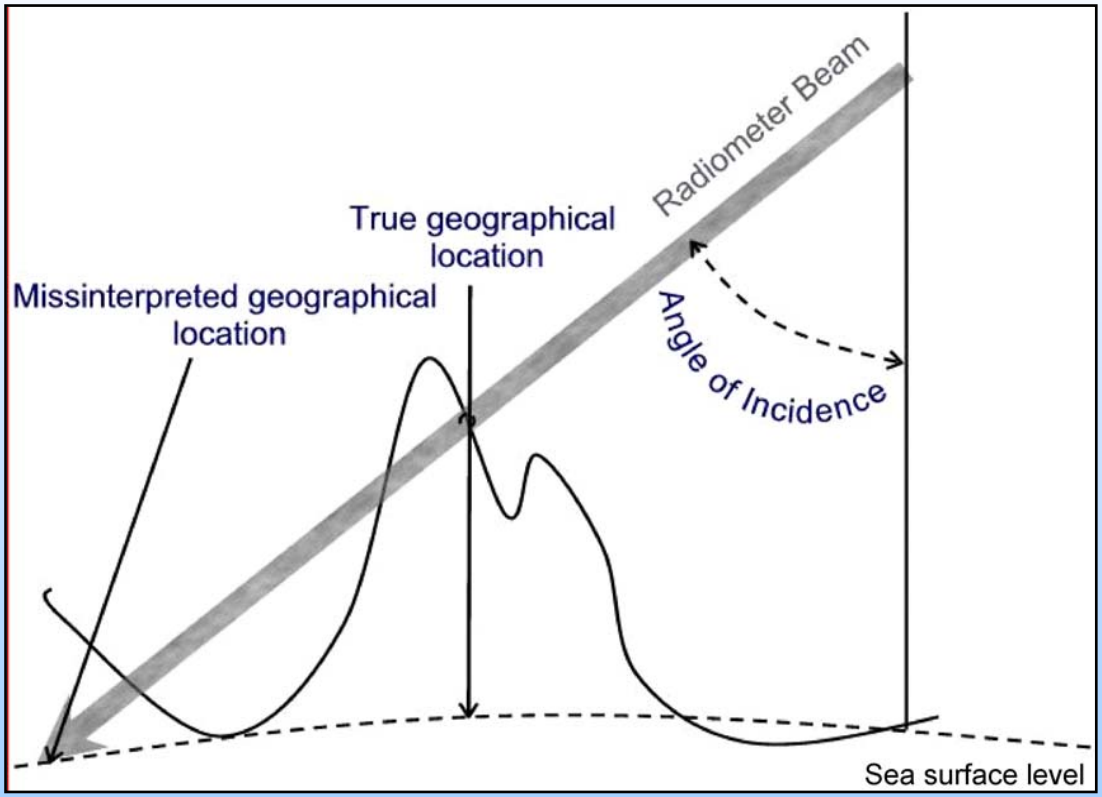
[1] Half-power beamwidth; [2] 18 msec equivalent integration time, v & h; [3] Multiple Sub-bands for interference mitigation

CLPX02-03 PSR Data Summary and Flight Characteristics

Exp. Name	MSA	Date	Obs. Times (UTC)	Tot. # of Flt. Lines	Flt. Alt. (km AGL)	3 dB Resolution Range (m) @ 37, 89 / 10, 18, 21 GHz	T_{surf} Max/min (°F)	TPW (cm)	Cloud/ Precipitation (T=trace)
CLPX02	RE	2/19/02	21:18-22:35	7	2.34	88 / 308 – 209/728	54 / 29	0.47	Clear / 0.06”
	FM	2/21/02	16:45-18:49	7	2.10	55 / 191 – 234/812	52 / 23	0.48	Clear / T
	NP	2/23/02	16:57-18:34	7	2.10	54/ 184 – 203/708	64 / 38	0.42	Clear / --
CLPX03A	NP	2/22/03	18:35-20:35	7	3.93	184 / 642 – 334/1161	50 / 23	0.52	Cloudy / T
	NP, RE, FM	2/23/03	17:35-21:37	21	2.18	65 / 229 – 215/749	47 / 6	0.37	Cloudy / 0.02”
	NP, RE	2/24/03	20:30-23:05	14	2.22	71 / 246 – 206/718	15 / -3	0.39	Cloudy / 0.05”
	NP, RE, FM	2/25/03	17:30-21:00	21	2.18	65 / 229 – 215/749	12 / 0	0.64	Cloudy / 0.02”
CLPX03B	NP, RE, FM	3/25/03	17:50-22:05	21	2.18	65 / 229 – 215/749	40 / 30	1.15	Cloudy / 0.09”
	NP, RE, FM	3/30/03	18:10-22:30	21	2.18	65 / 229 – 215/749	37 / 26	0.70	Clear / T
	NP, RE, FM	3/31/03	17:50-21:50	21	2.18	65 / 229 – 215/749	58 / 38	0.90	Clear / --

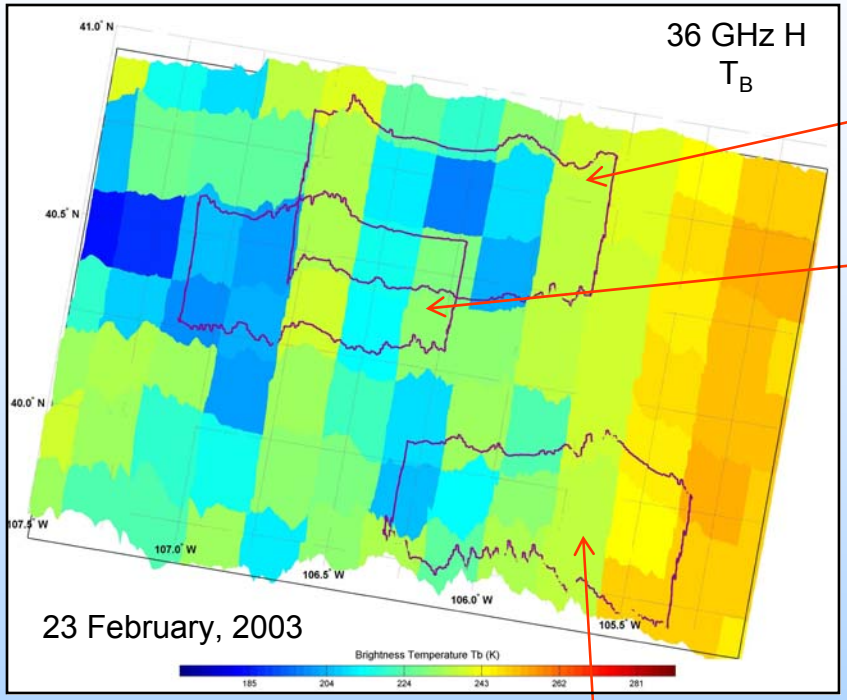
NP = North Park, RE = Rabbit Ears, FM = Fraser Meadows

CLPX Spot Geolocation



- Because the MSAs are located in mountainous areas a ray-tracing geolocation procedure was necessary.
- The procedure used USGS 30-m resolution terrain data to locate points where PSR beams intersected the surface.

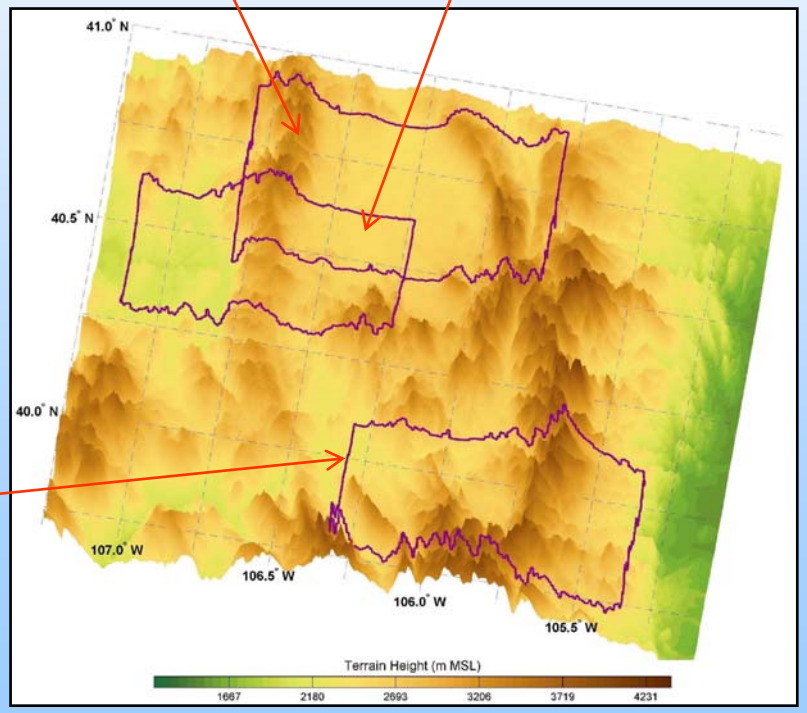
AMSR-E 36 GHz Horizontal Polarization



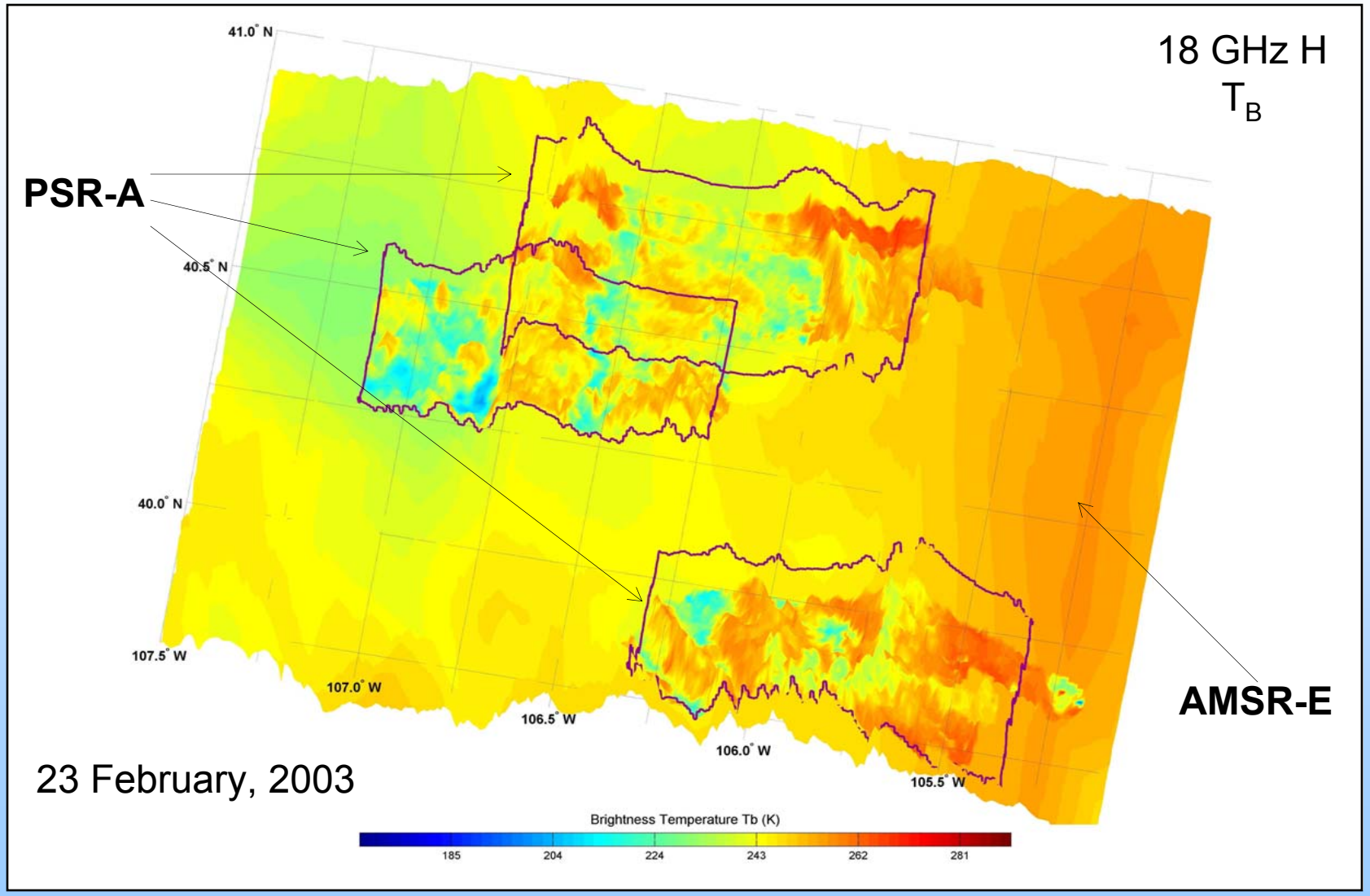
North Park

Rabbit Ears

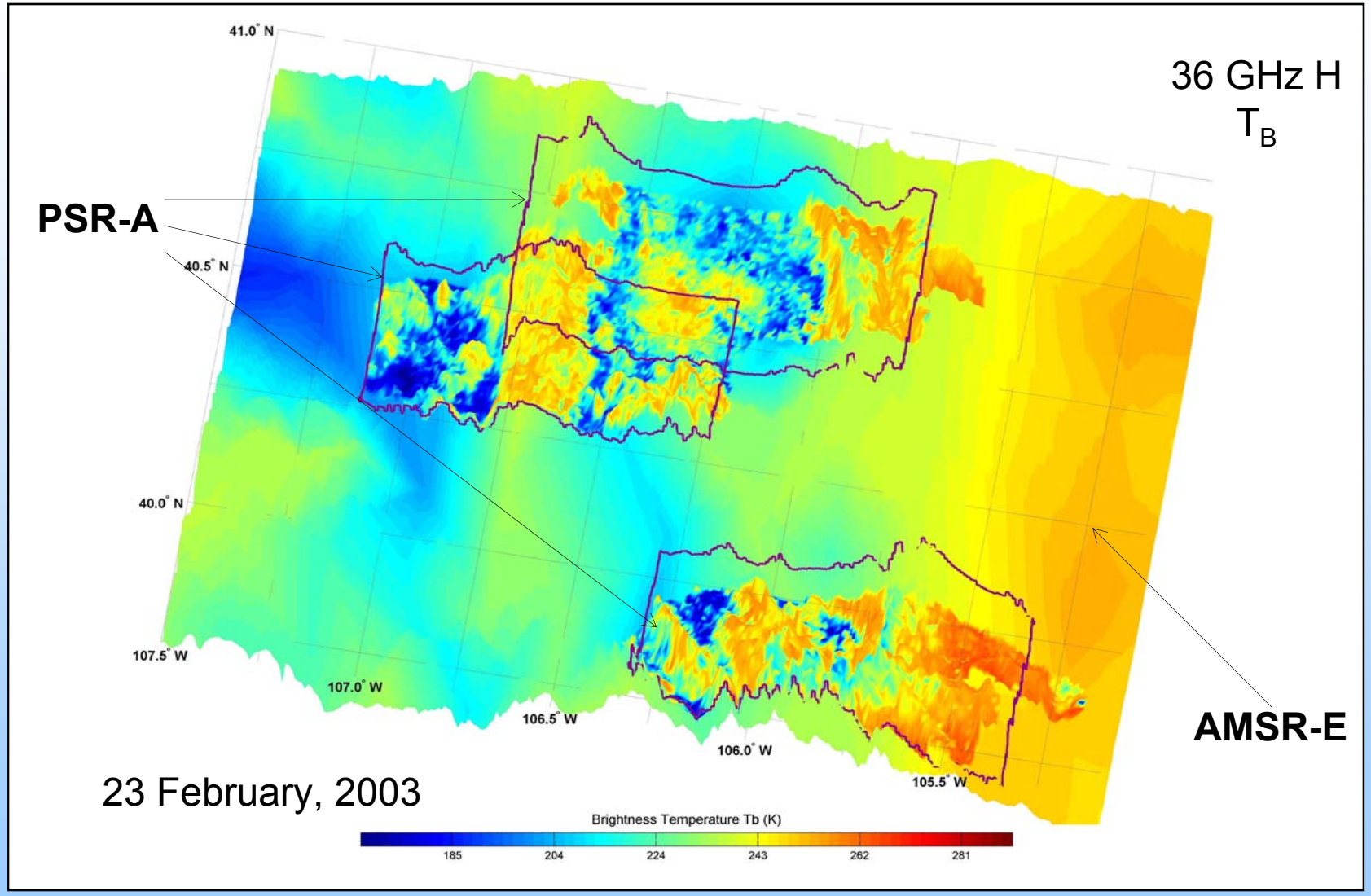
Fraser Meadows



AMSR-E to PSR-A Intercomparison



AMSR-E to PSR-A Intercomparison



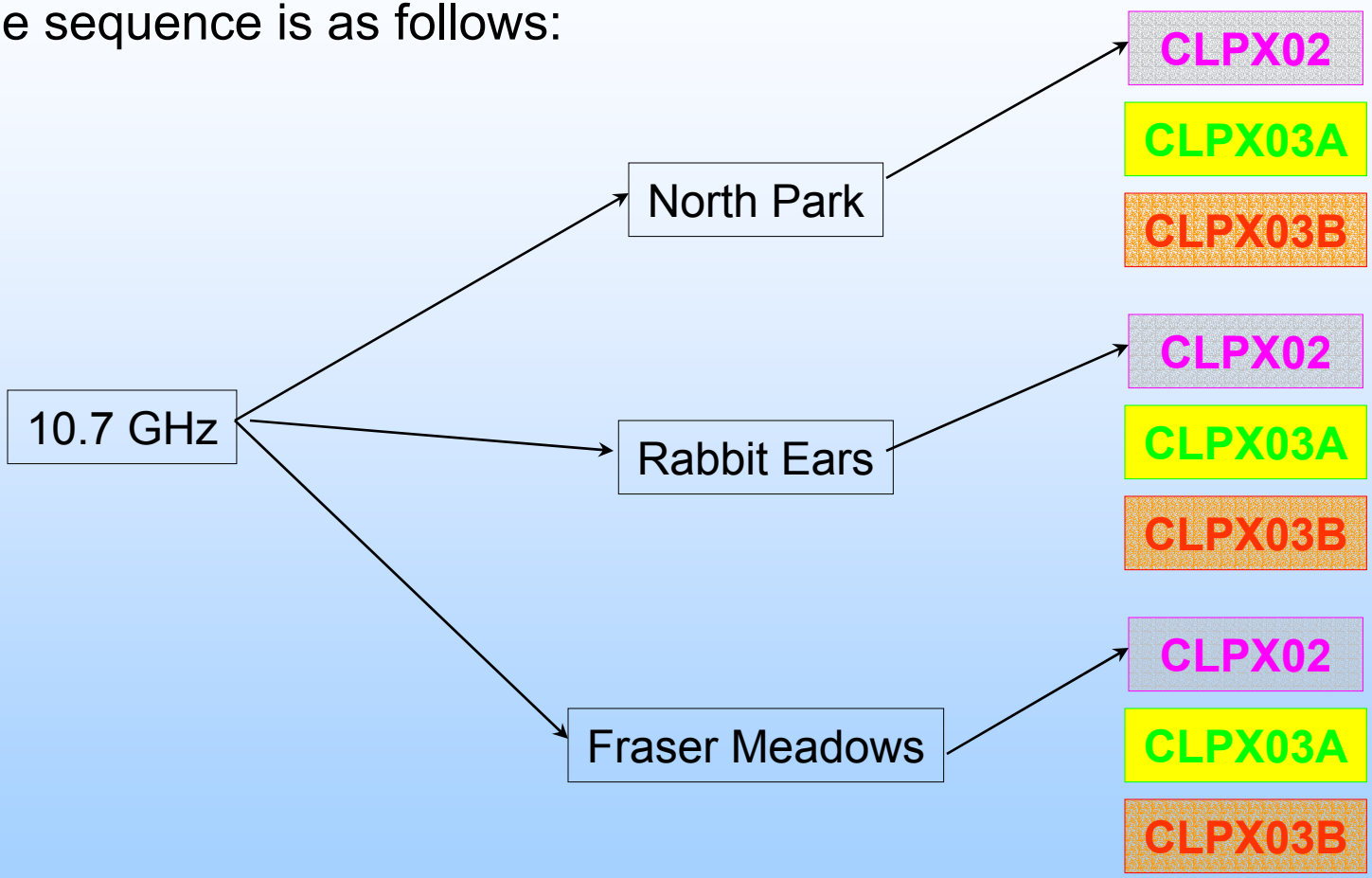
CLPX02-03 PSR/A Snowpack Images

The following animated images of the observed brightness temperature fields show:

- A general radiometric cooling from CLPX02 to CLPX03A at North Park, Rabbit Ears, and Fraser Meadows in all channels suggesting more widespread snow coverage in 2003 than 2002.
- The onset of snowmelt is clearly seen in the opposite brightness trends between CLPX03A and CLPX03B.
- Snowmelt signatures are less visible in the 89 GHz data since the emissivity varies significantly over diurnal freeze/thaw cycles.

CLPX02-03 PSR/A Snowpack Images

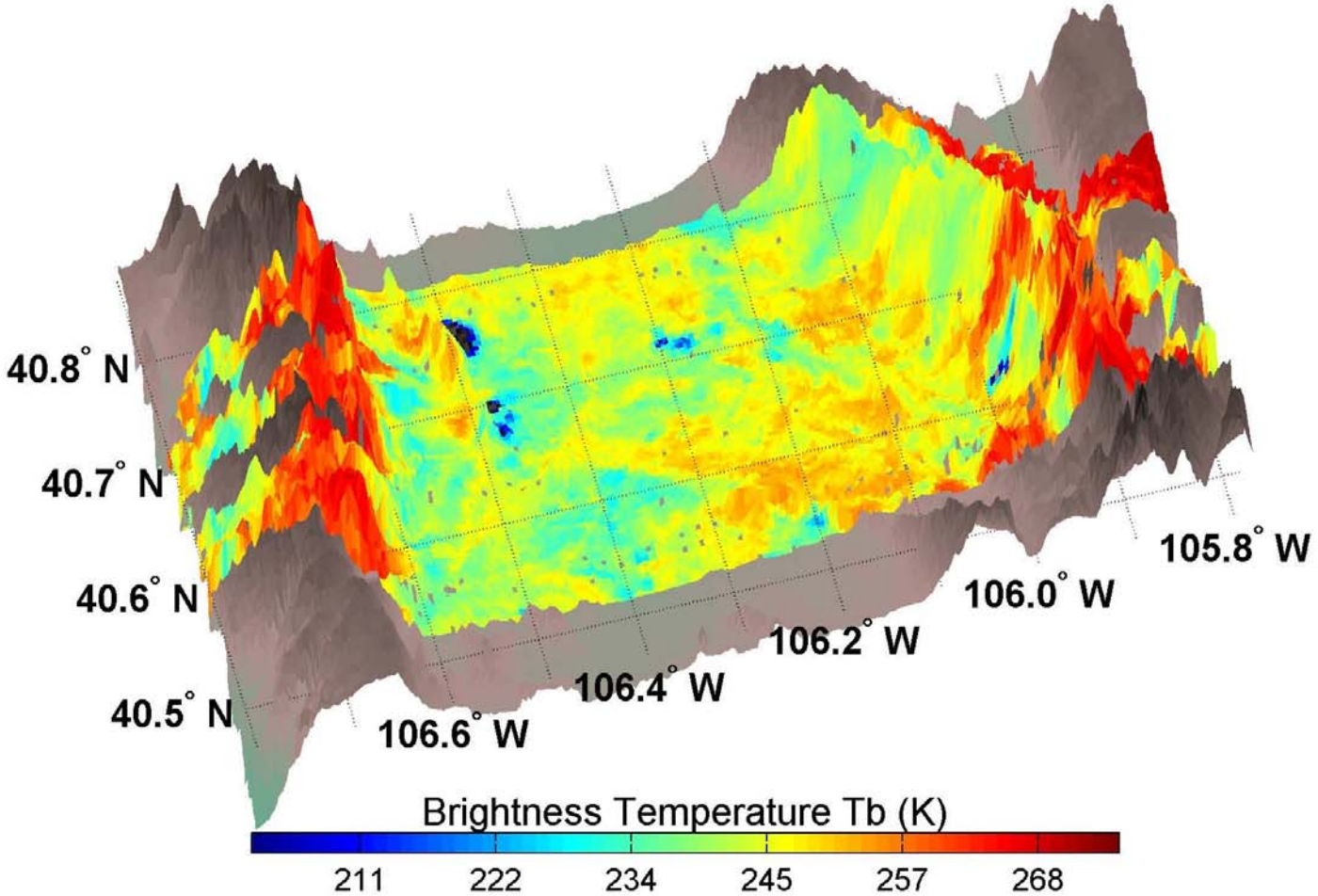
Image sequence is as follows:



This structure repeats for each horizontal polarization frequency.

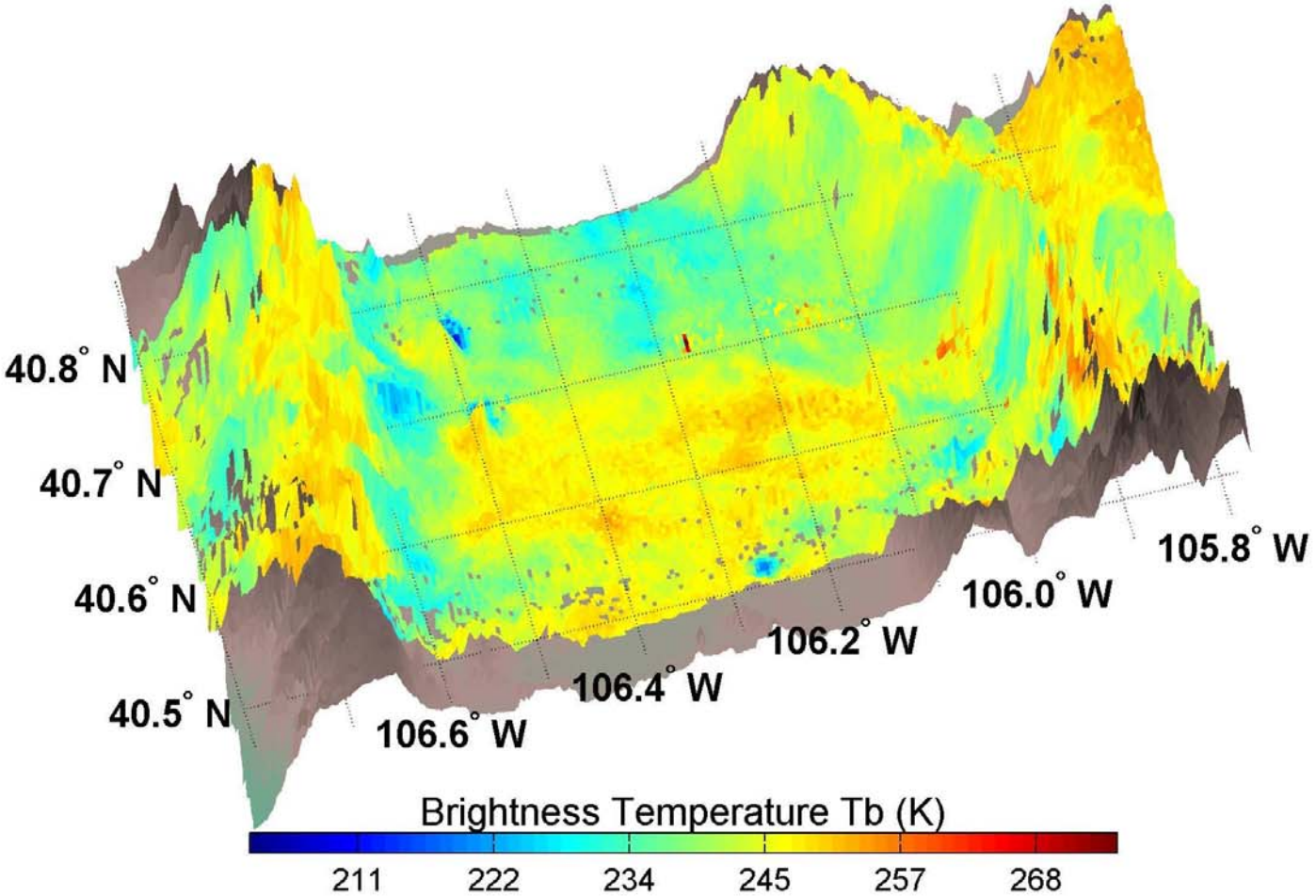
CLPX02

NorthPark: CLPX02 02/23/2002 10.7 GHz Th

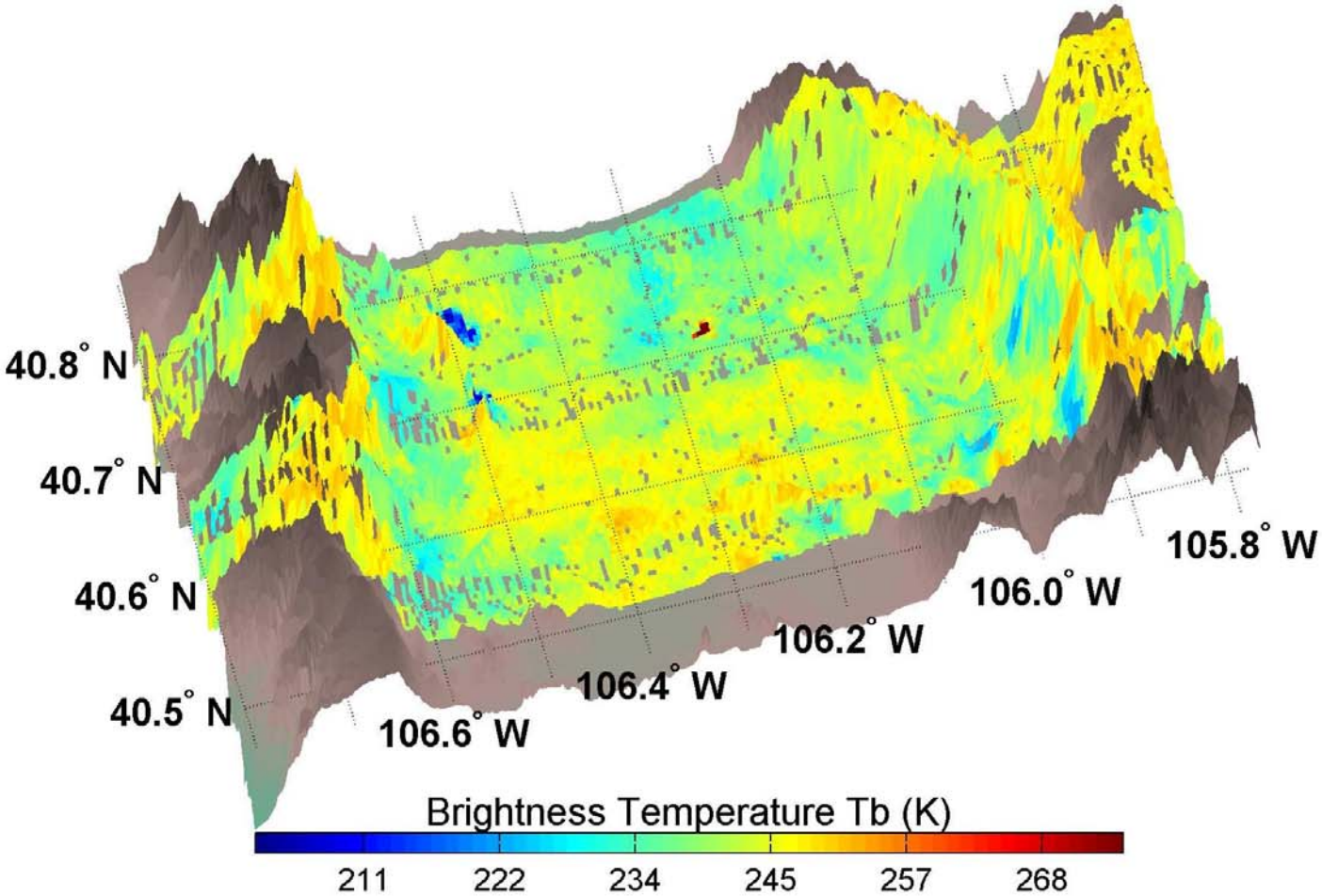


CLPX03A

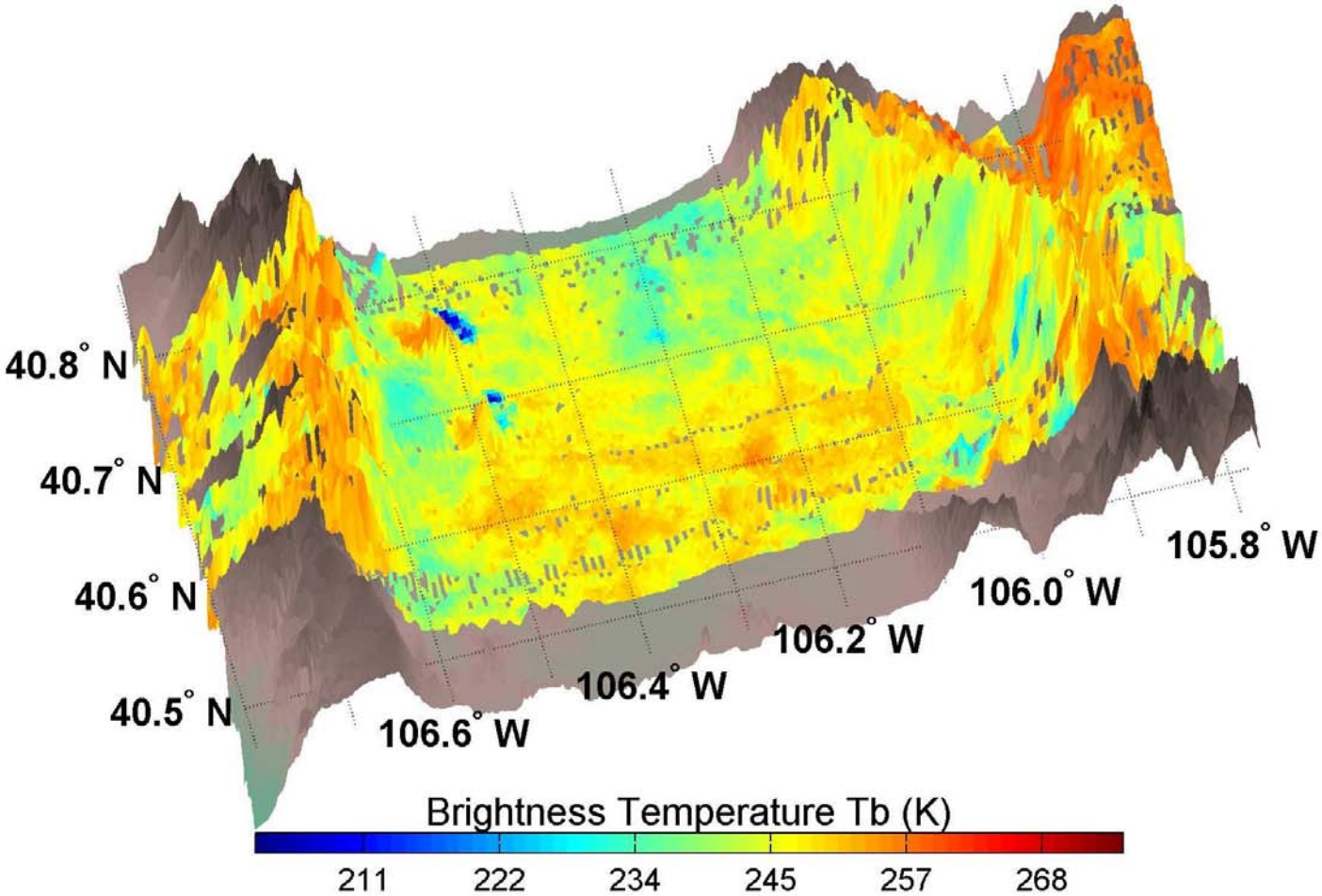
NorthPark: CLPX03A 02/22/2003 10.7 GHz Th



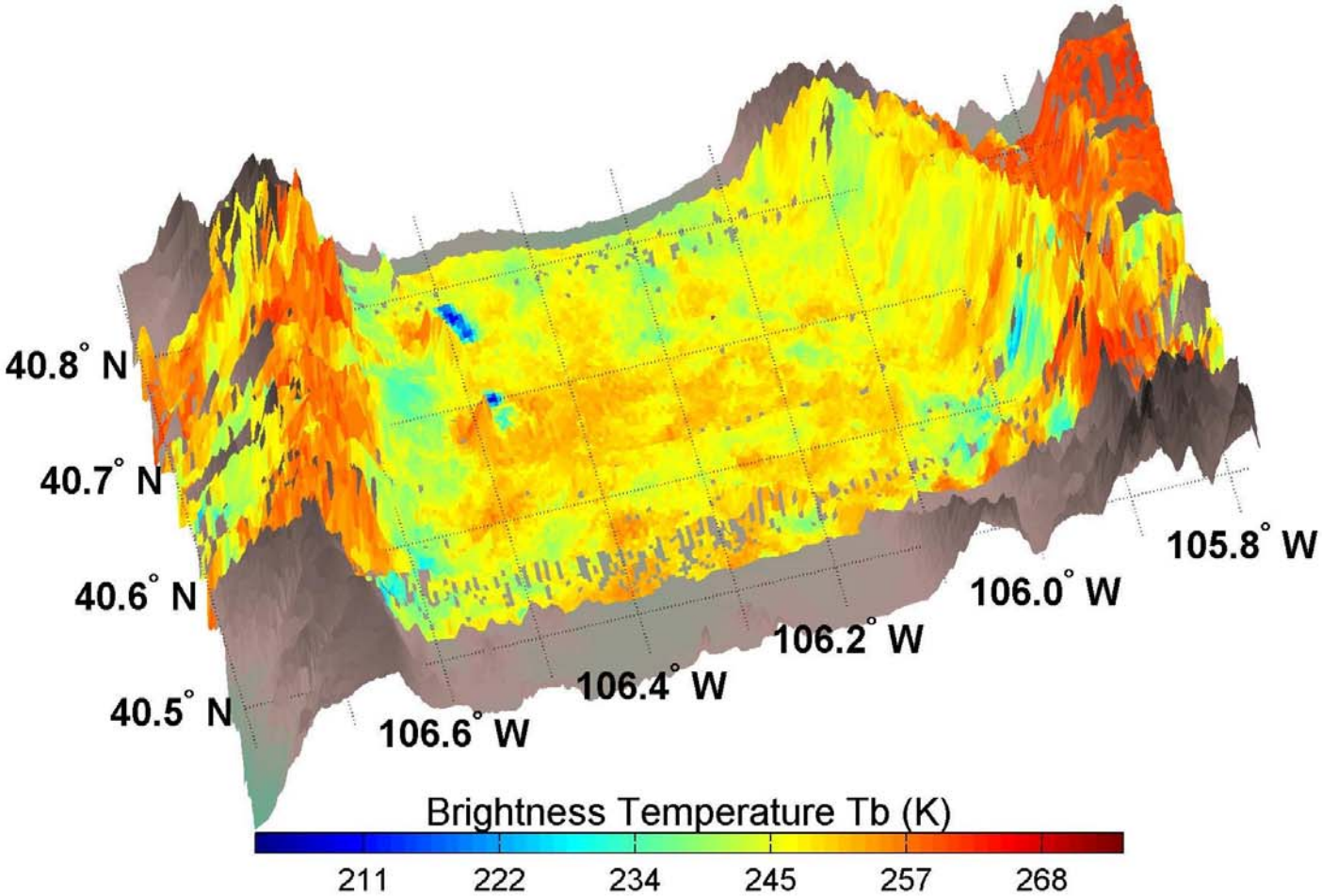
NorthPark: CLPX03A 02/23/2003 10.7 GHz Th



NorthPark: CLPX03A 02/24/2003 10.7 GHz Th

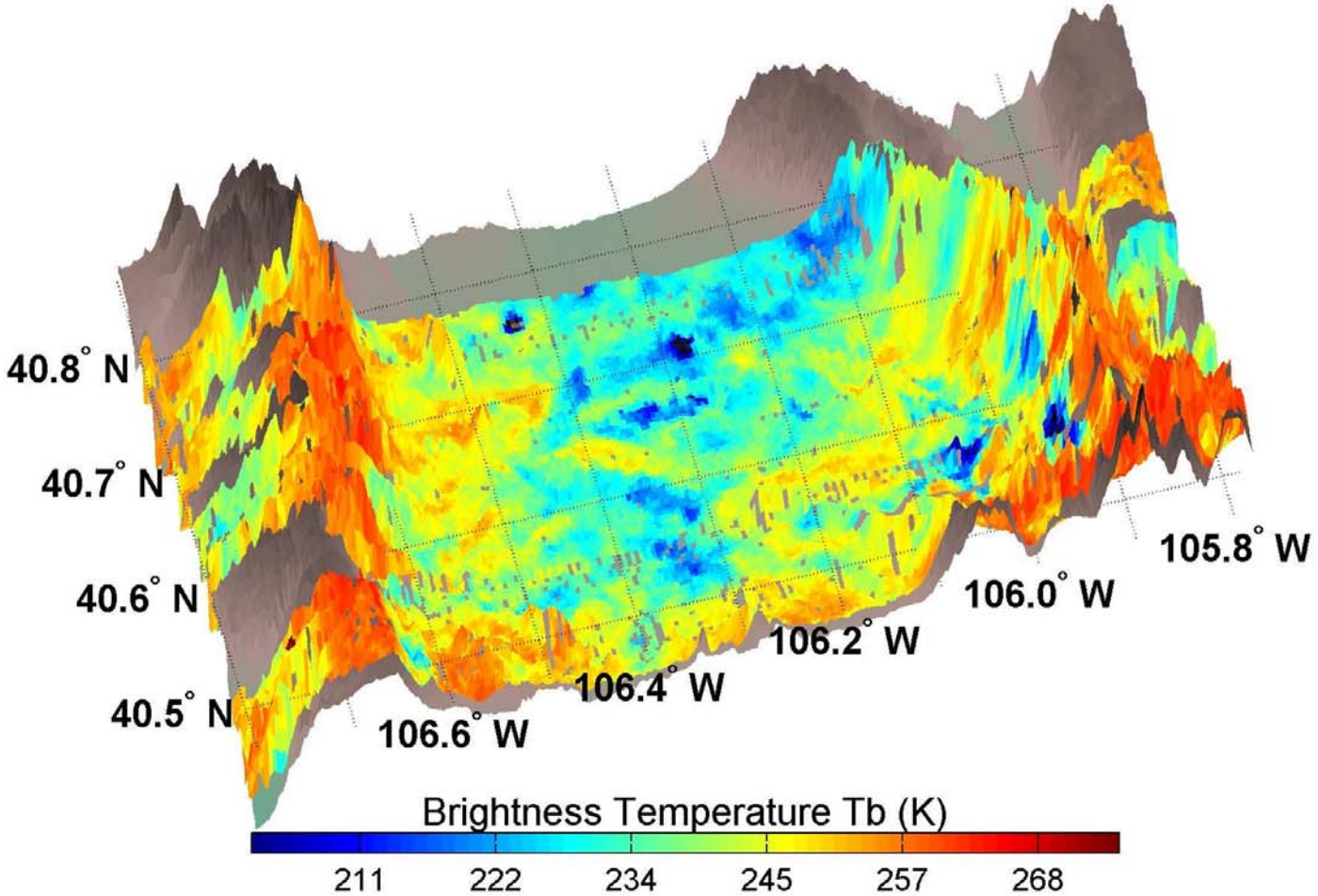


NorthPark: CLPX03A 02/25/2003 10.7 GHz Th

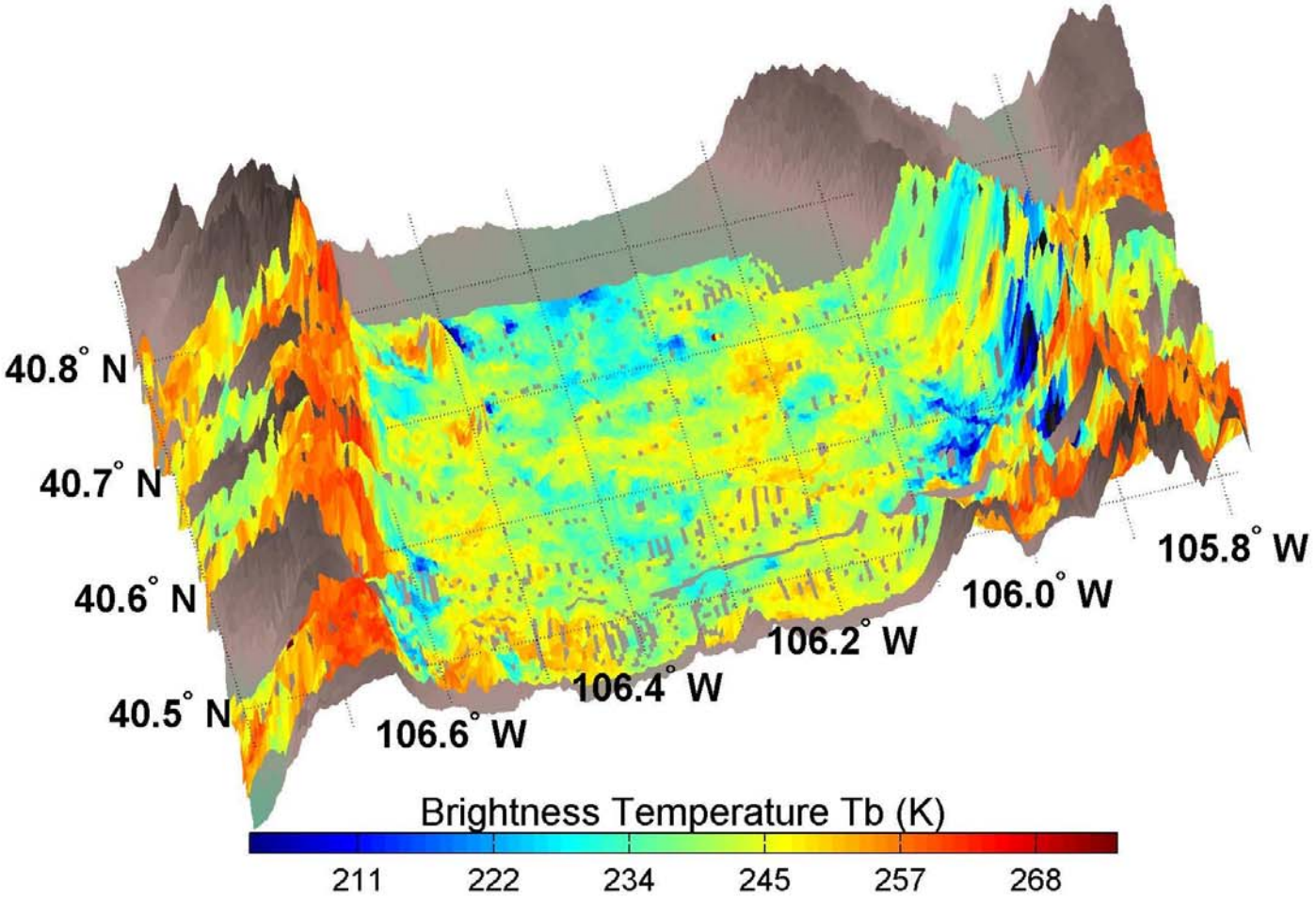


CLPX03B

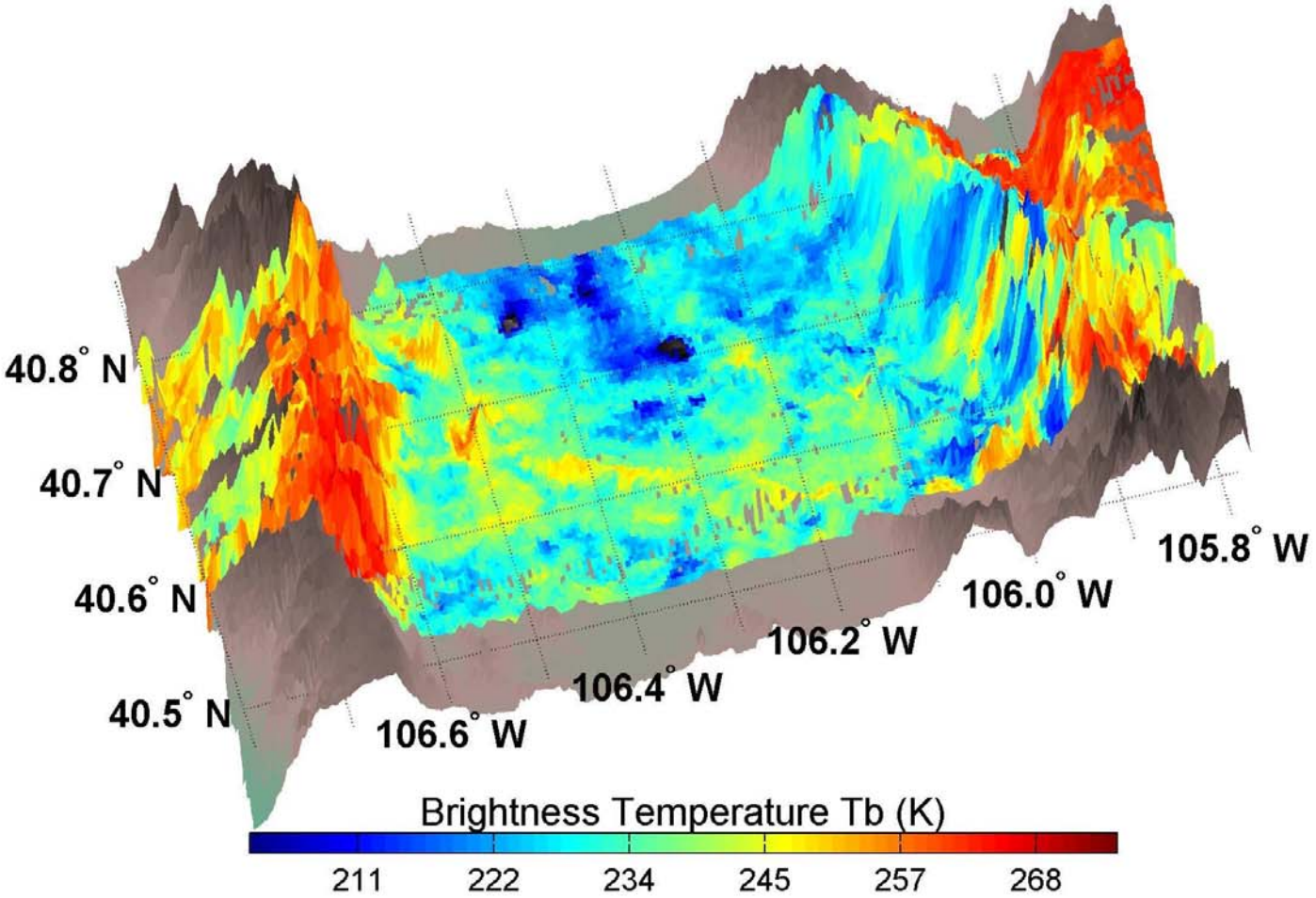
NorthPark: CLPX03B 03/25/2003 10.7 GHz Th



NorthPark: CLPX03B 03/30/2003 10.7 GHz Th

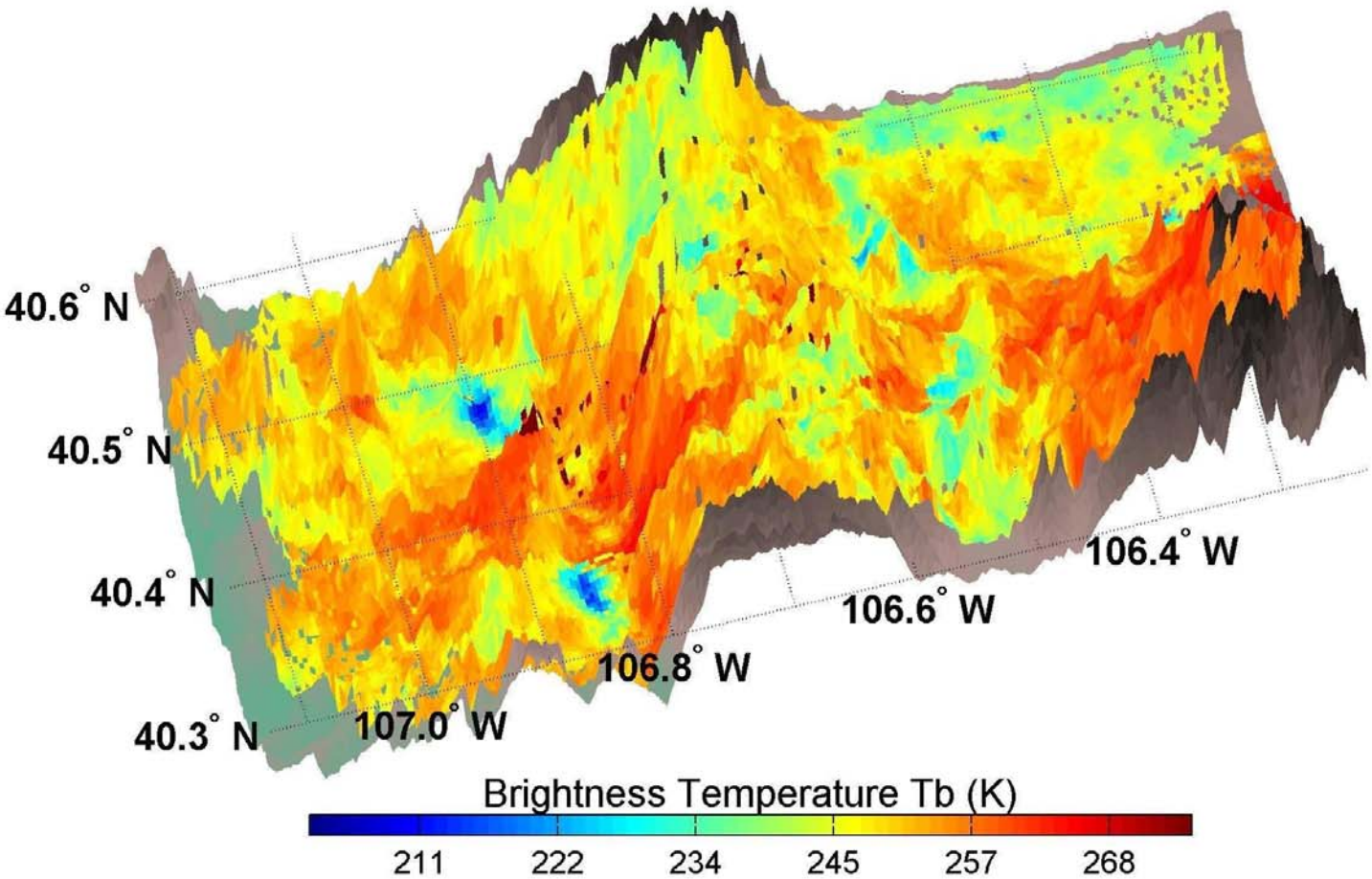


NorthPark: CLPX03B 03/31/2003 10.7 GHz Th



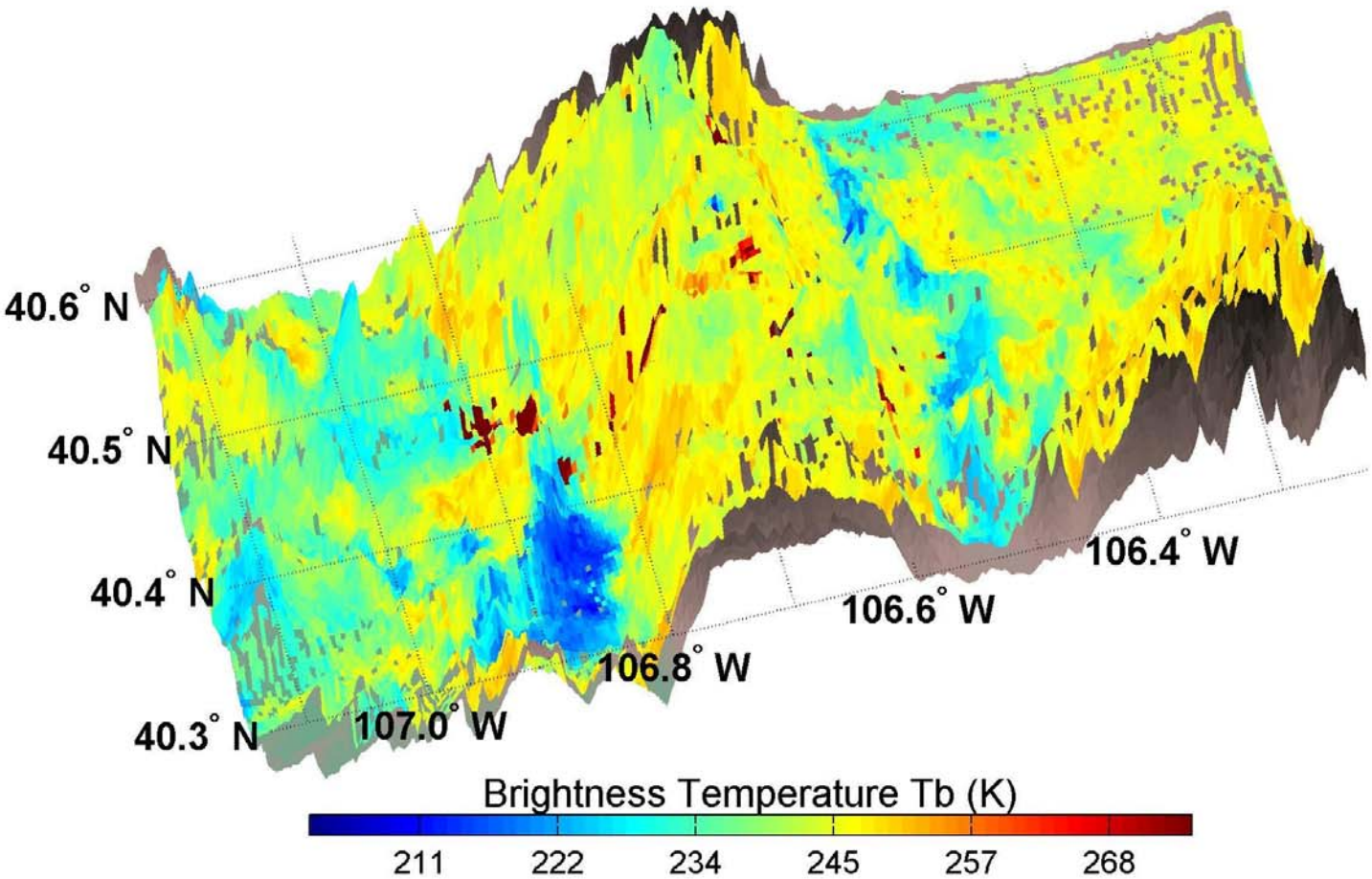
CLPX02

RabbitEars: CLPX02 02/19/2002 10.7 GHz Th



CLPX03A

RabbitEars: CLPX03A 02/23/2003 10.7 GHz Th



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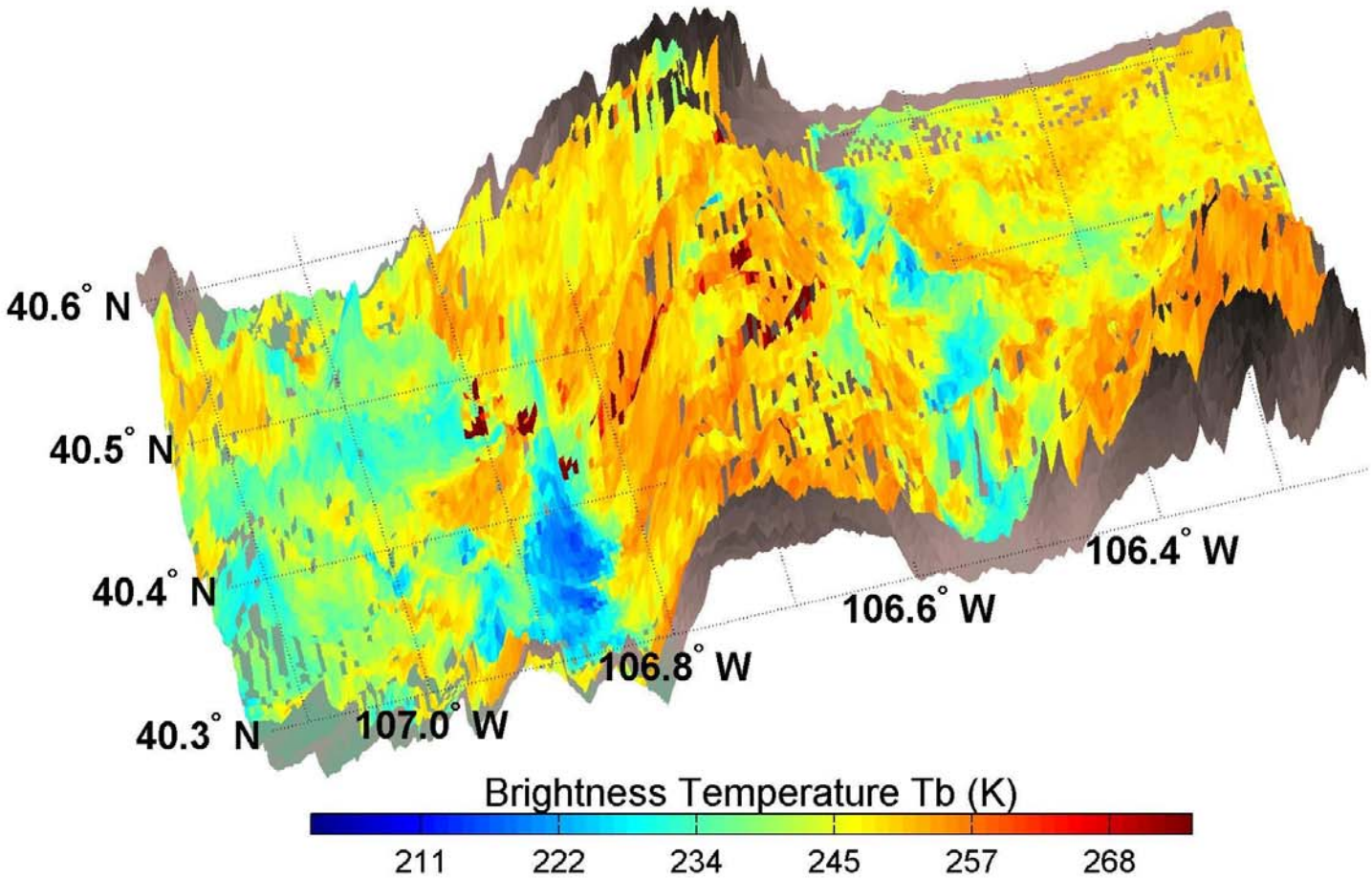
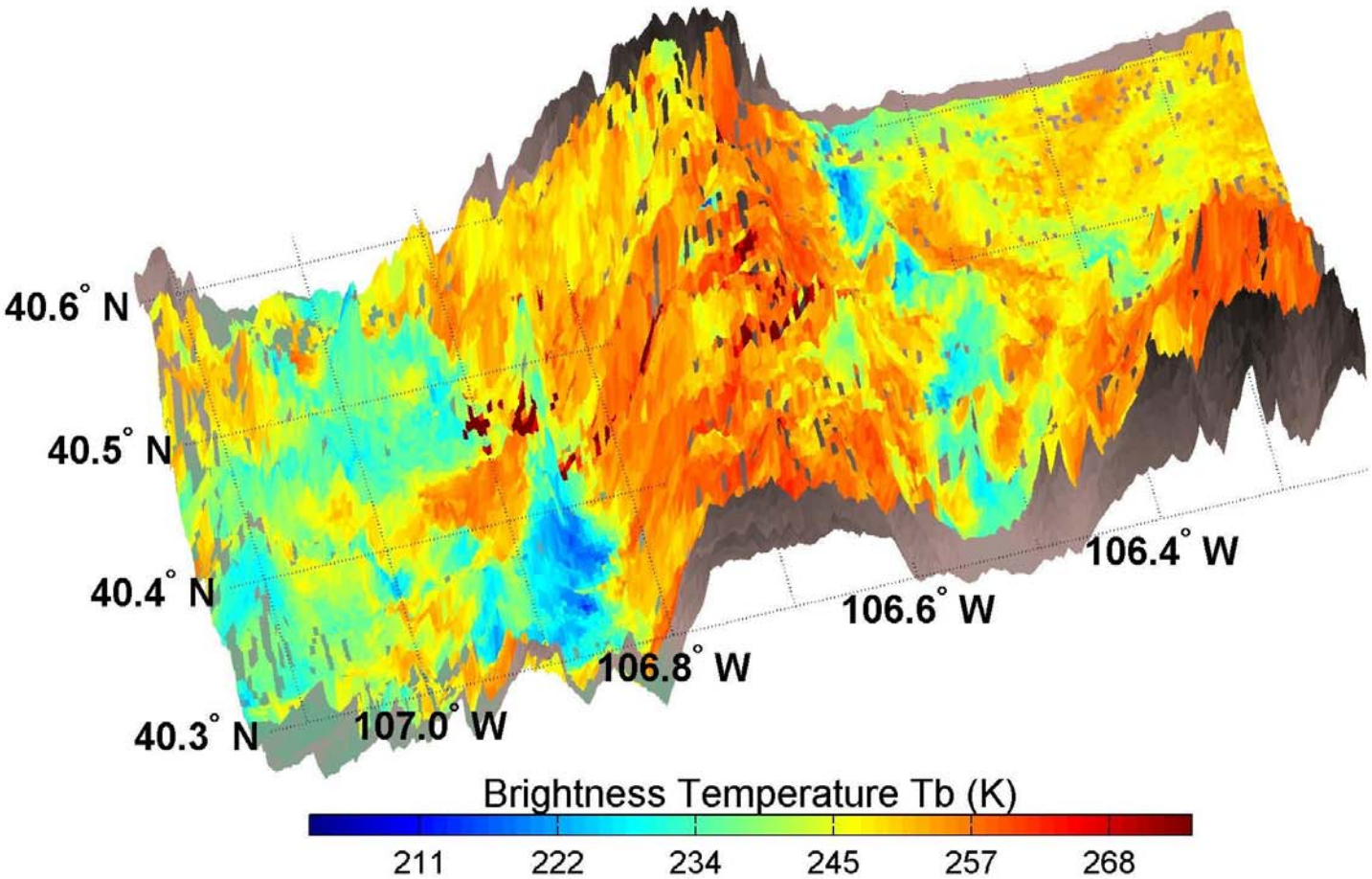
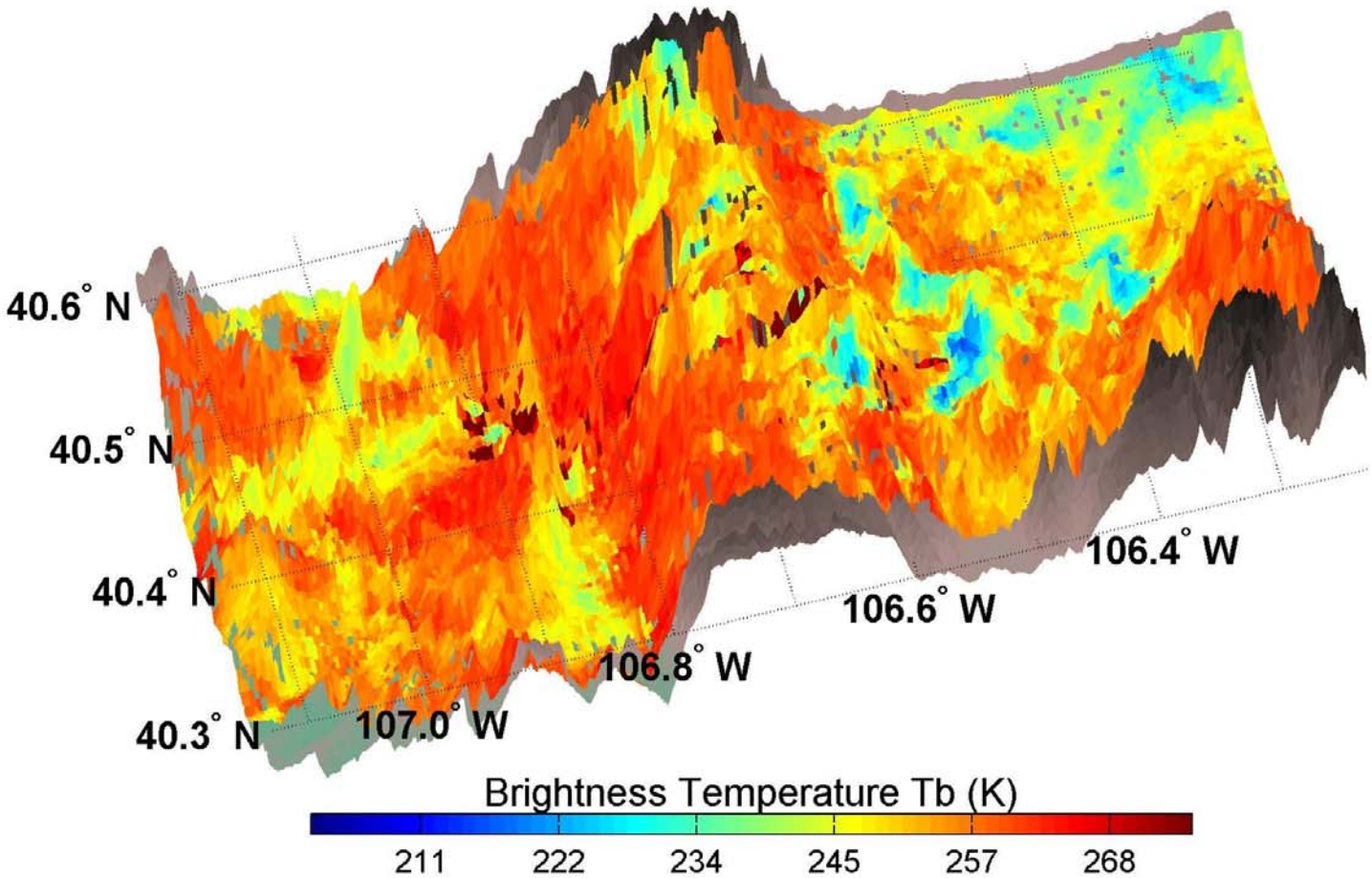


RabbitEars: CLPX03A 02/25/2003 10.7 GHz Th

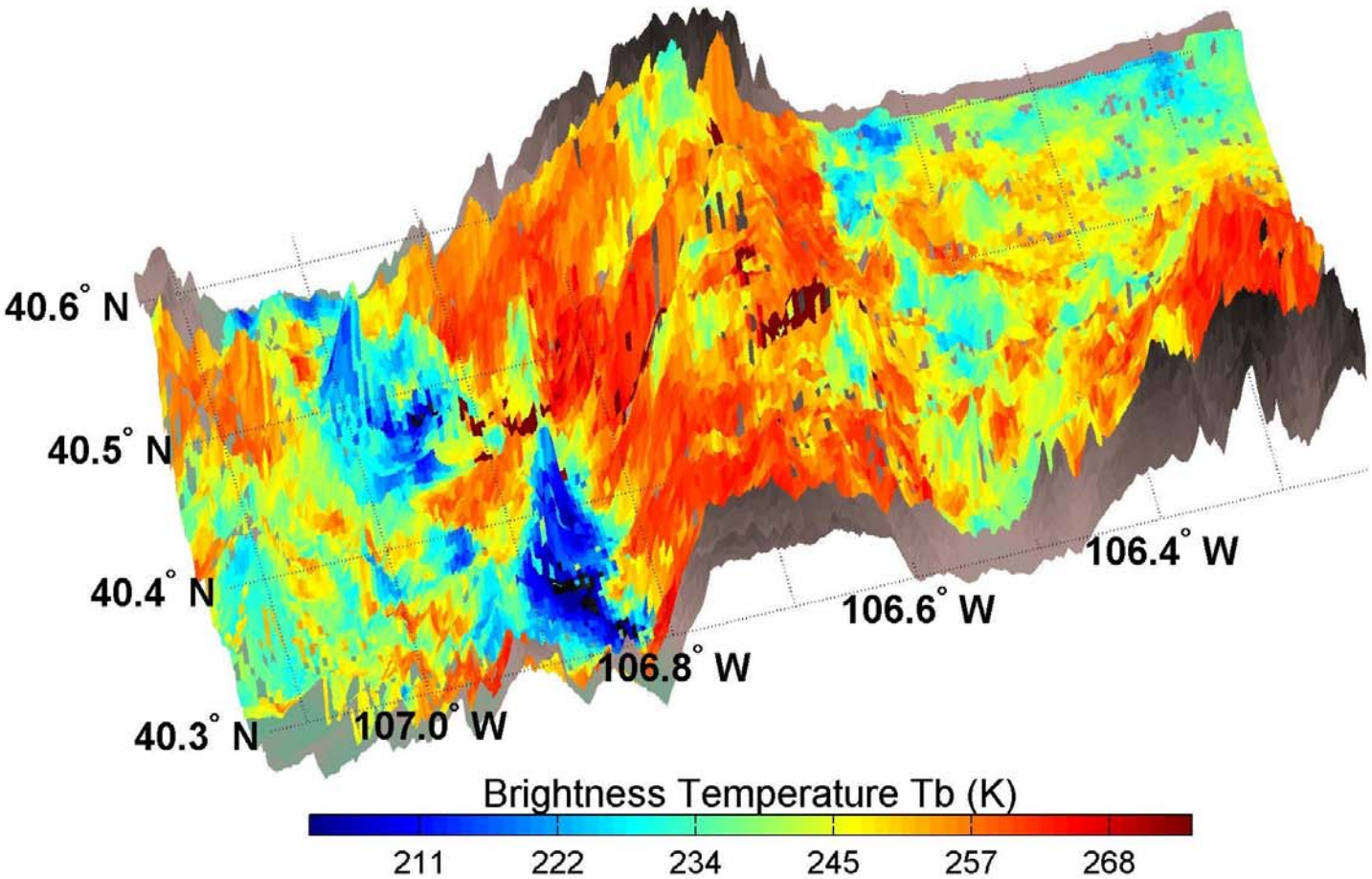


CLPX03B

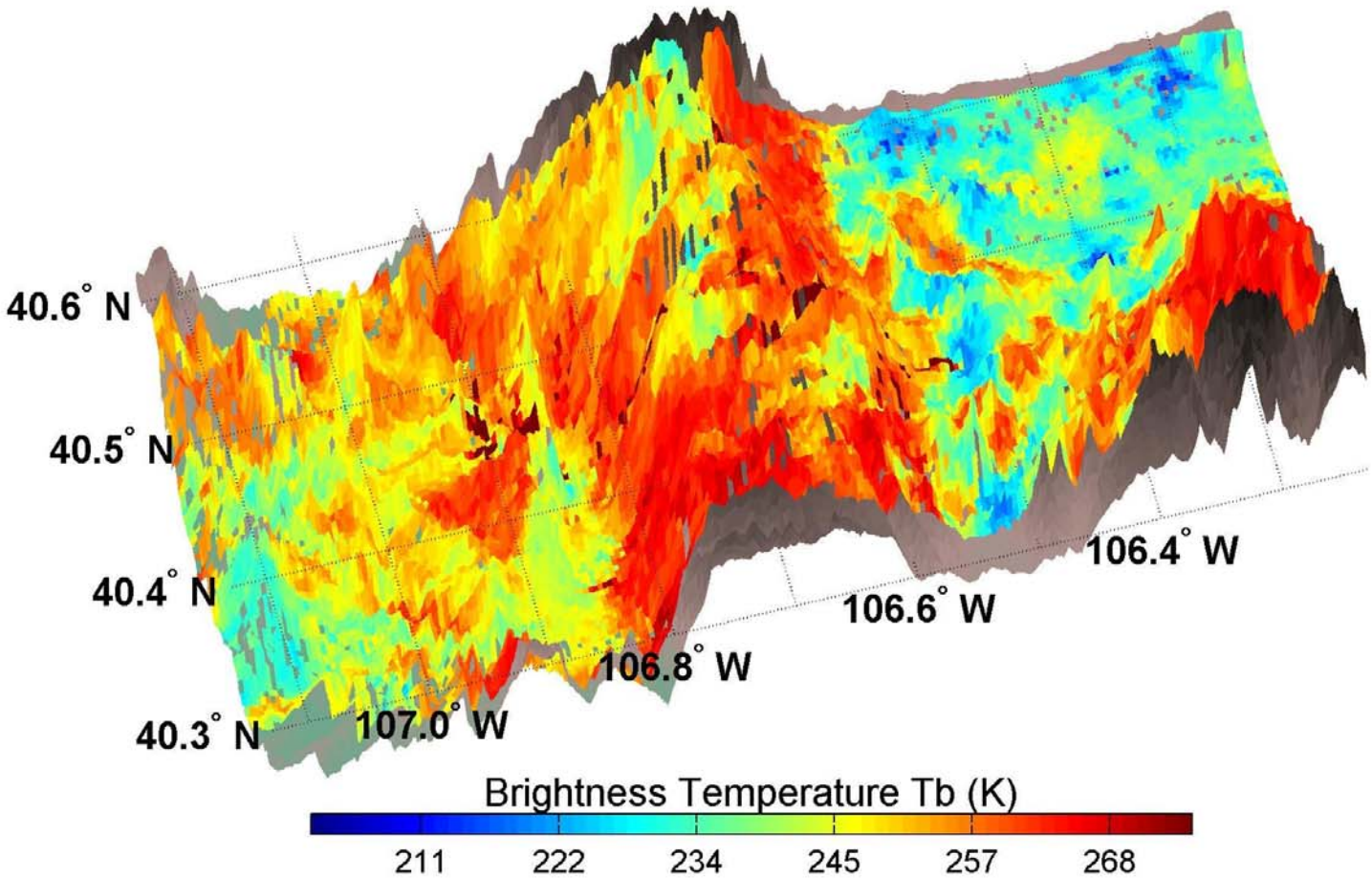
RabbitEars: CLPX03B 03/25/2003 10.7 GHz Th



RabbitEars: CLPX03B 03/30/2003 10.7 GHz Th

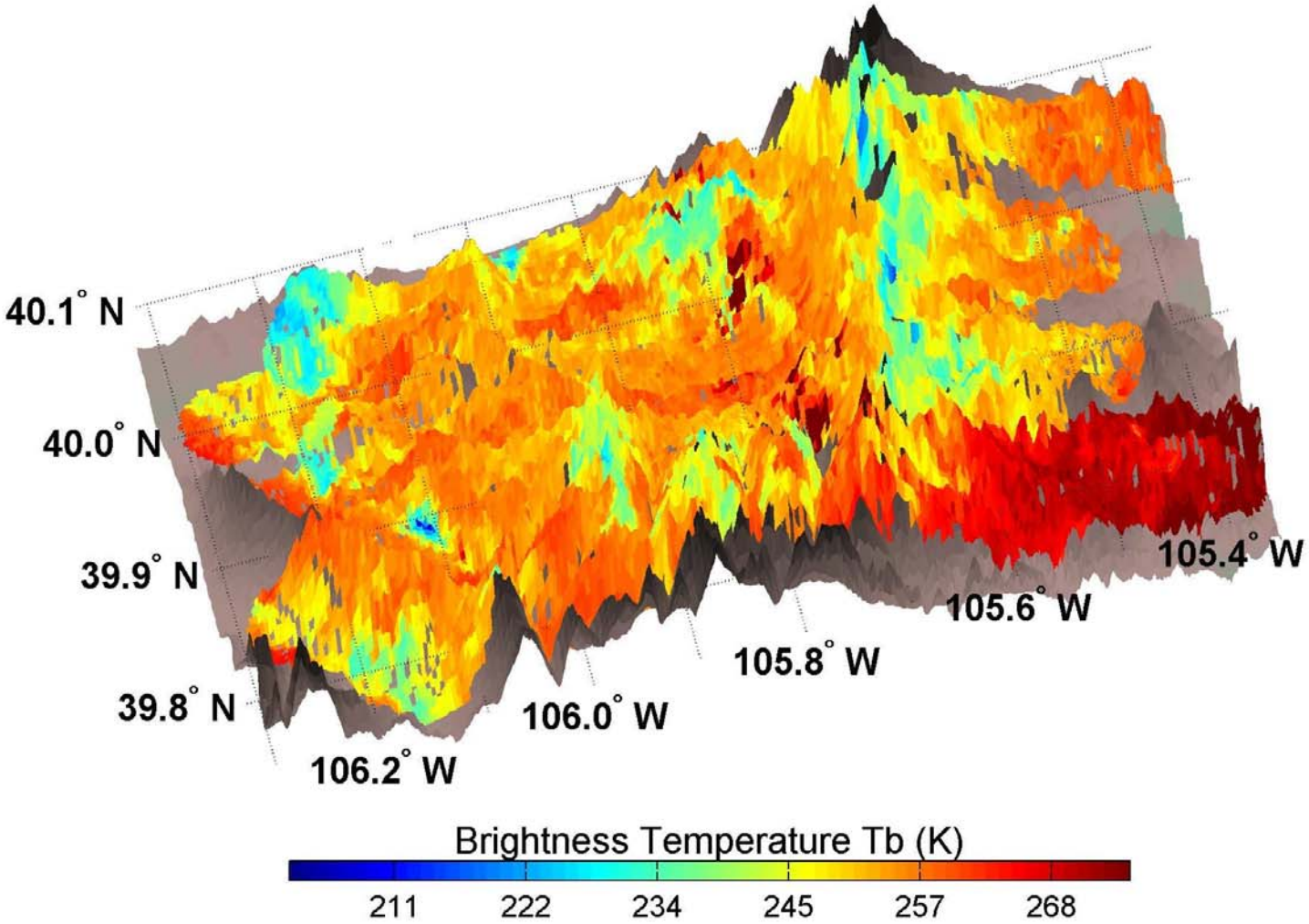


RabbitEars: CLPX03B 03/31/2003 10.7 GHz Th



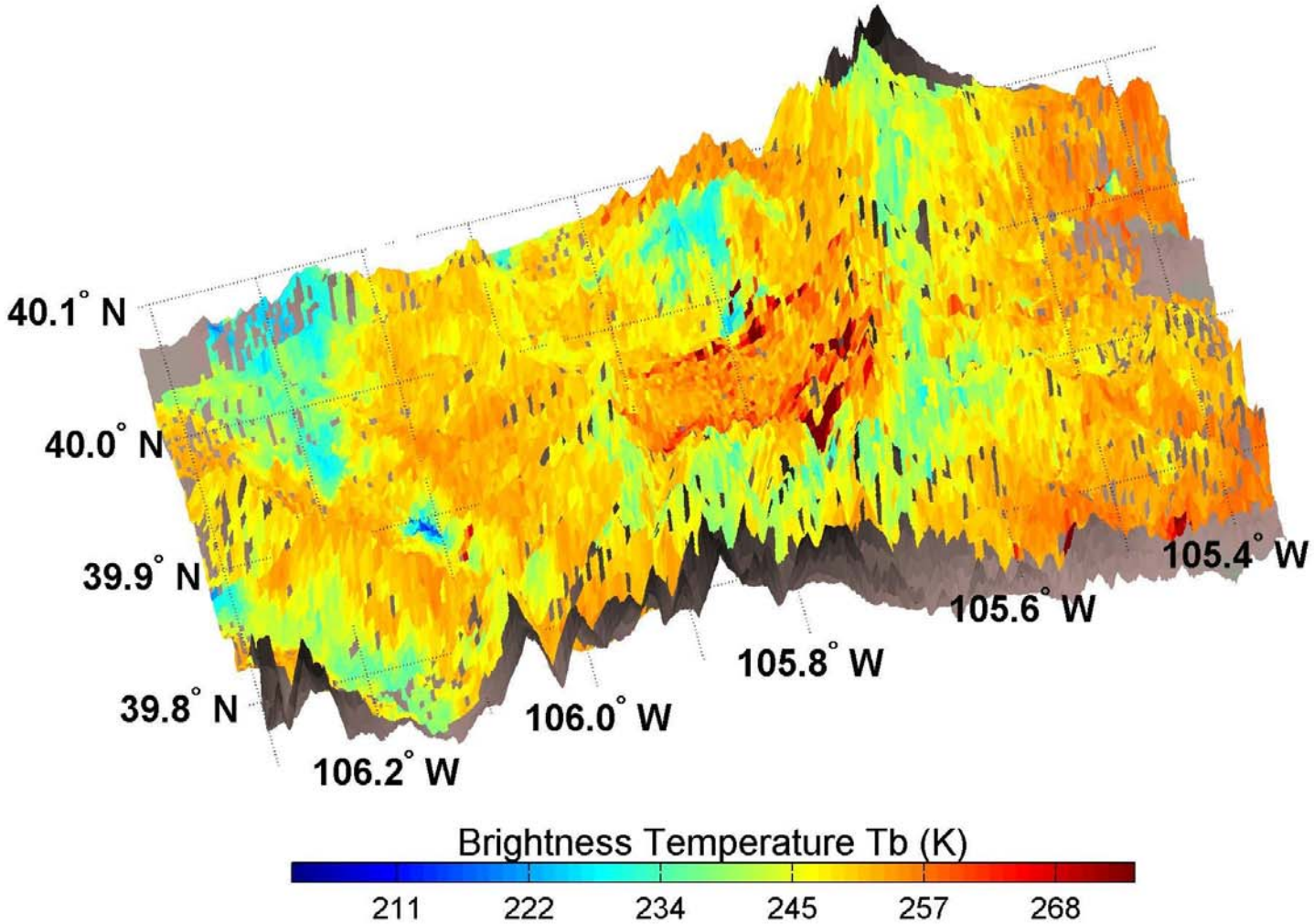
CLPX02

Fraser: CLPX02 02/21/2002 10.7 GHz Th

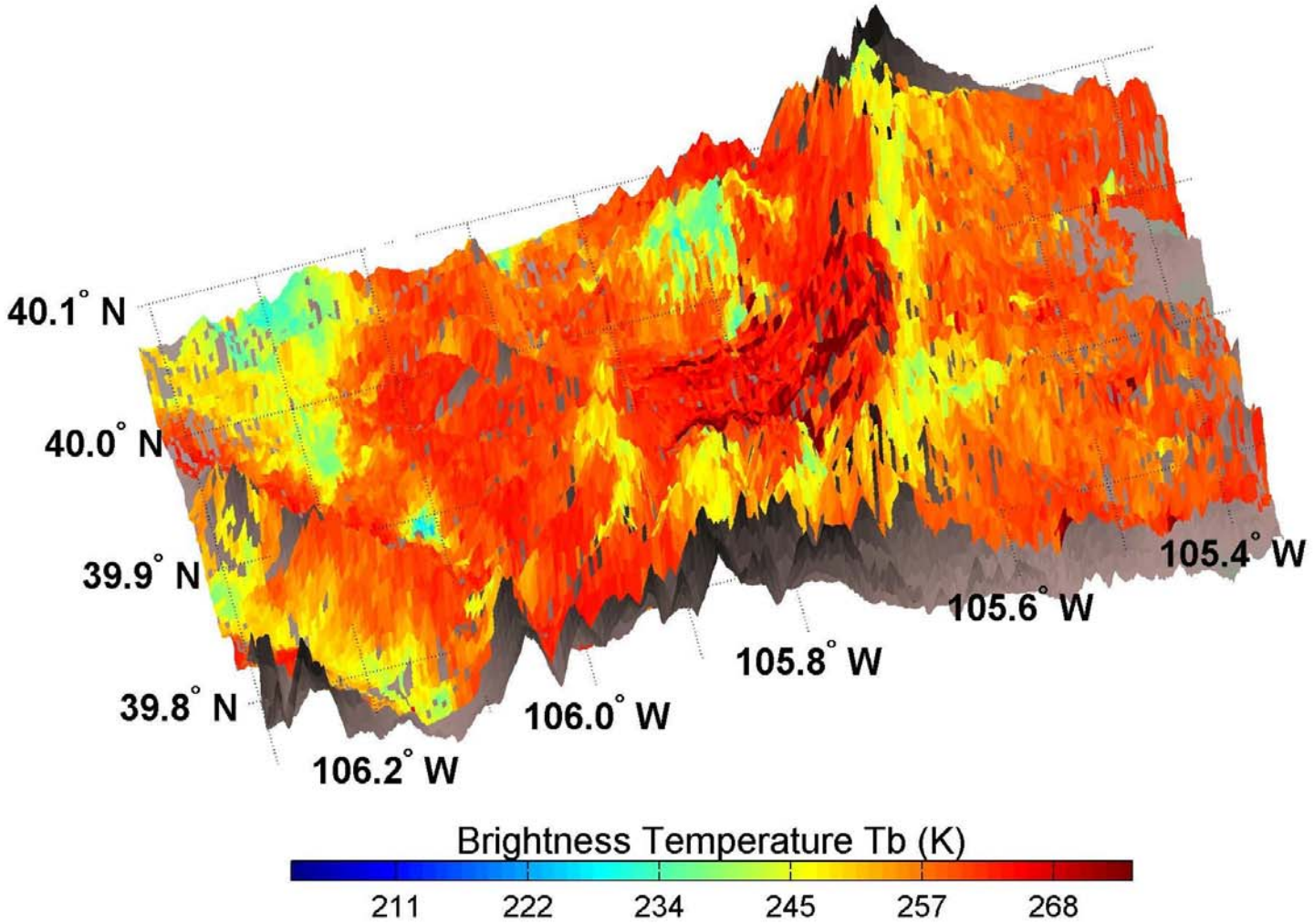


CLPX03A

Fraser: CLPX03A 02/23/2003 10.7 GHz Th

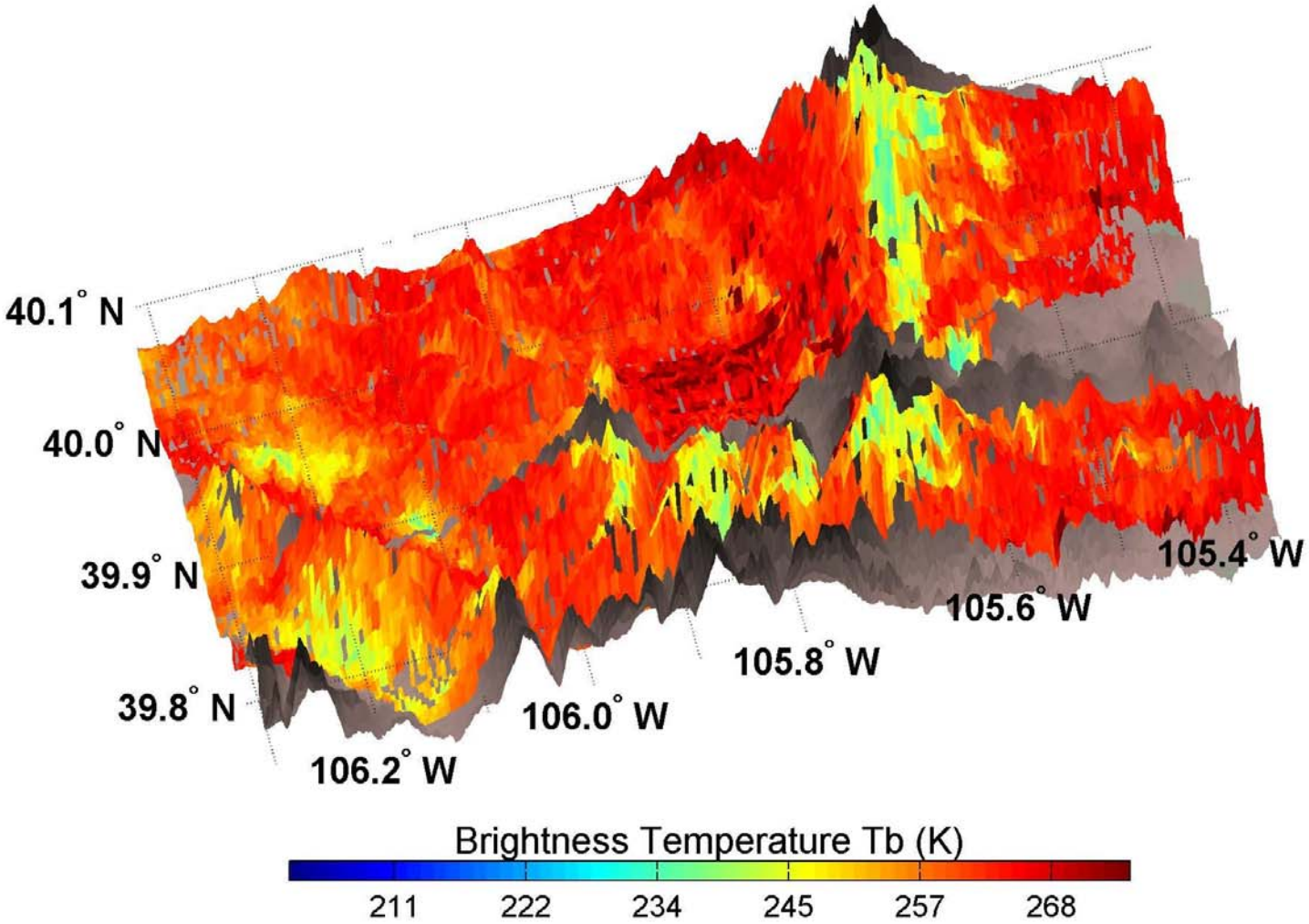


Fraser: CLPX03A 02/25/2003 10.7 GHz Th

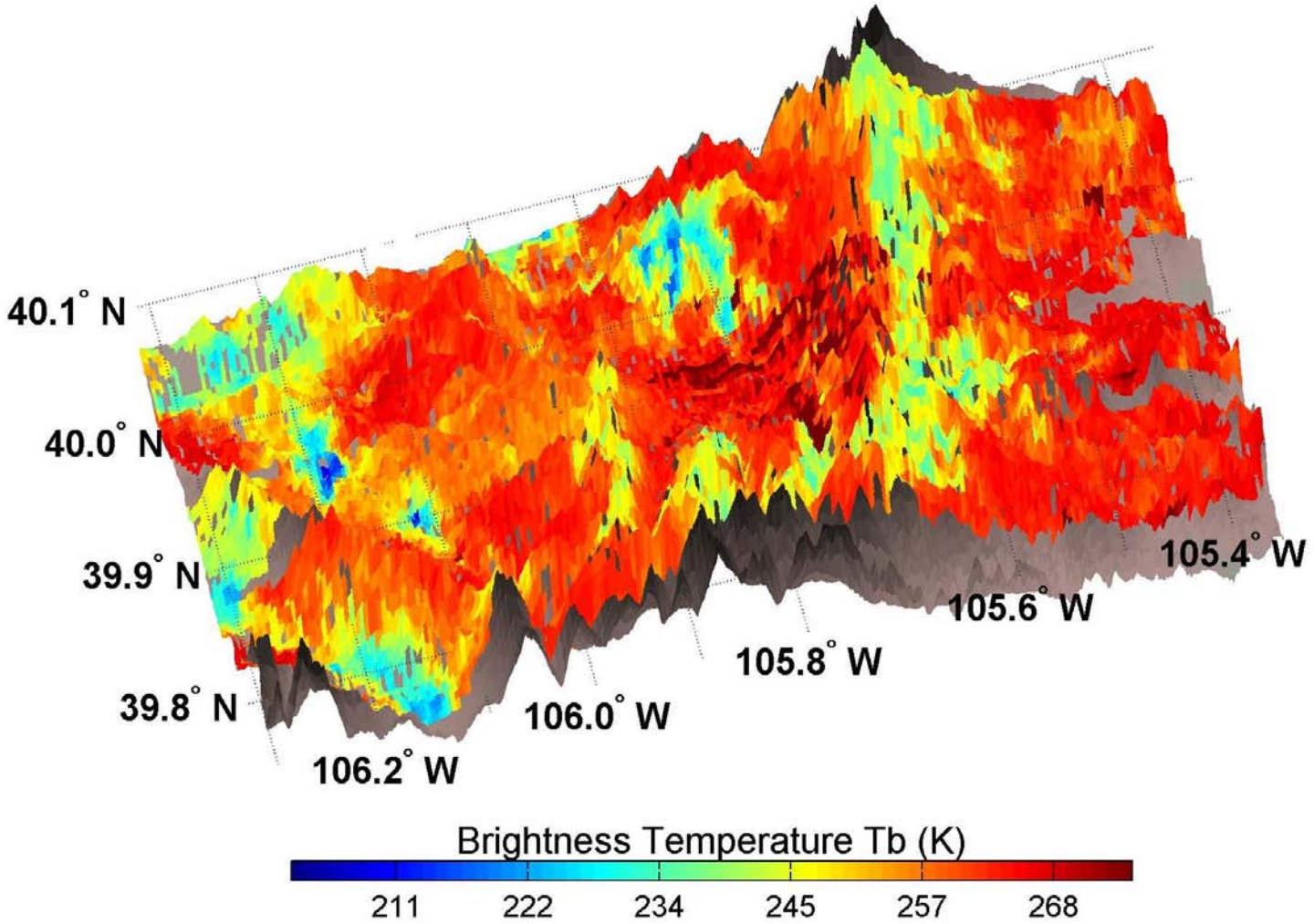


CLPX03B

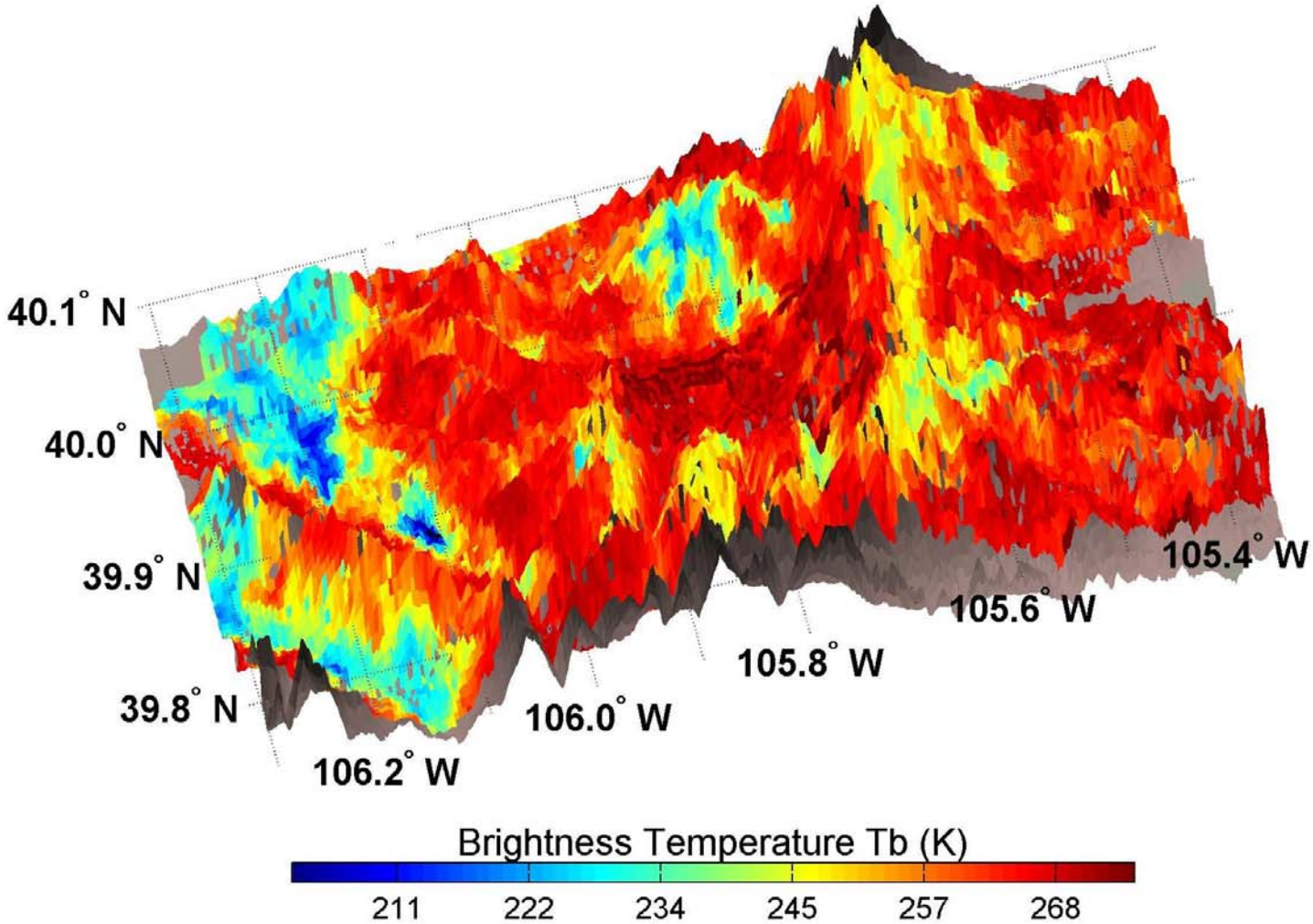
Fraser: CLPX03B 03/25/2003 10.7 GHz Th



Fraser: CLPX03B 03/30/2003 10.7 GHz Th

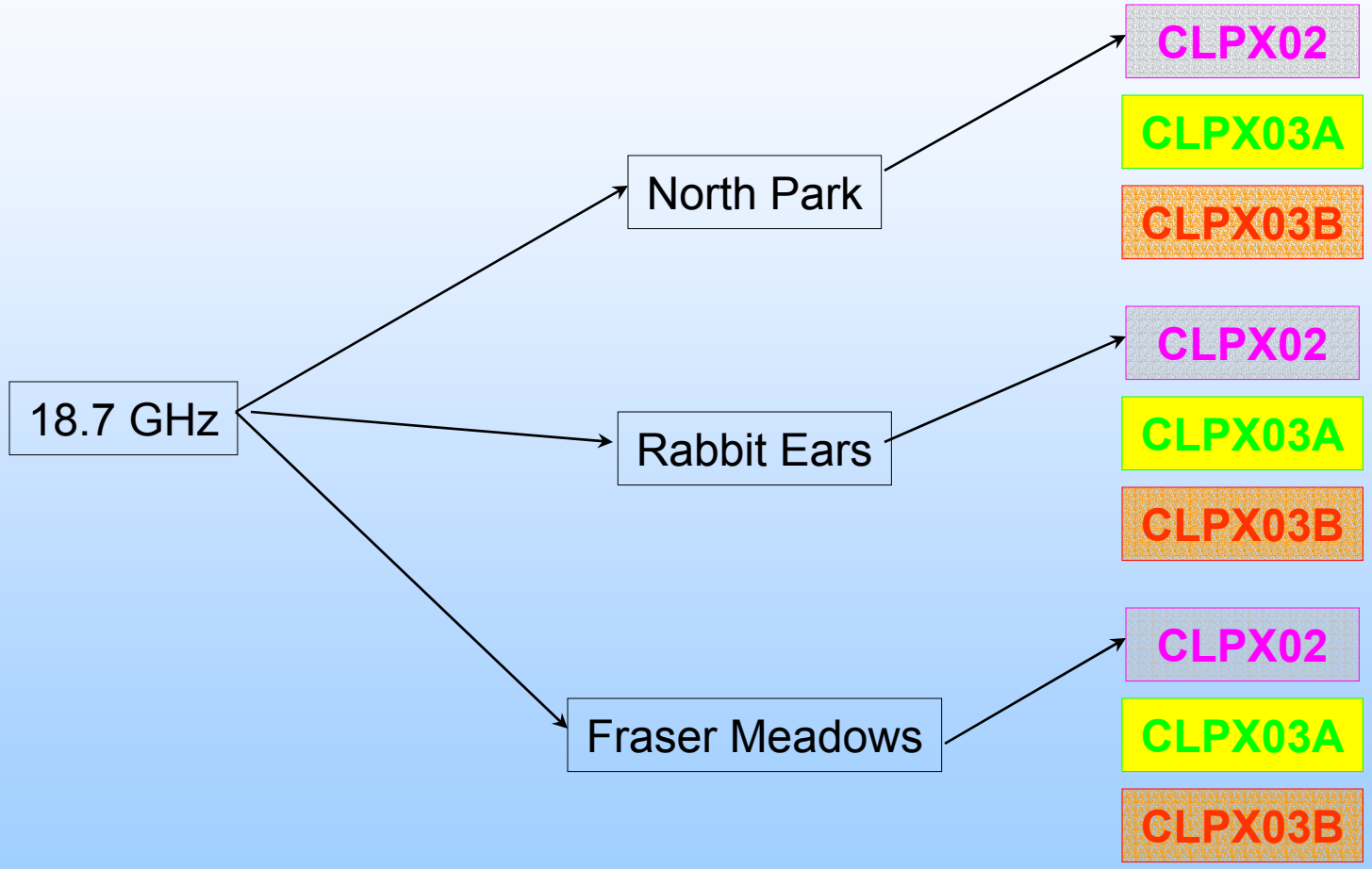


Fraser: CLPX03B 03/31/2003 10.7 GHz Th



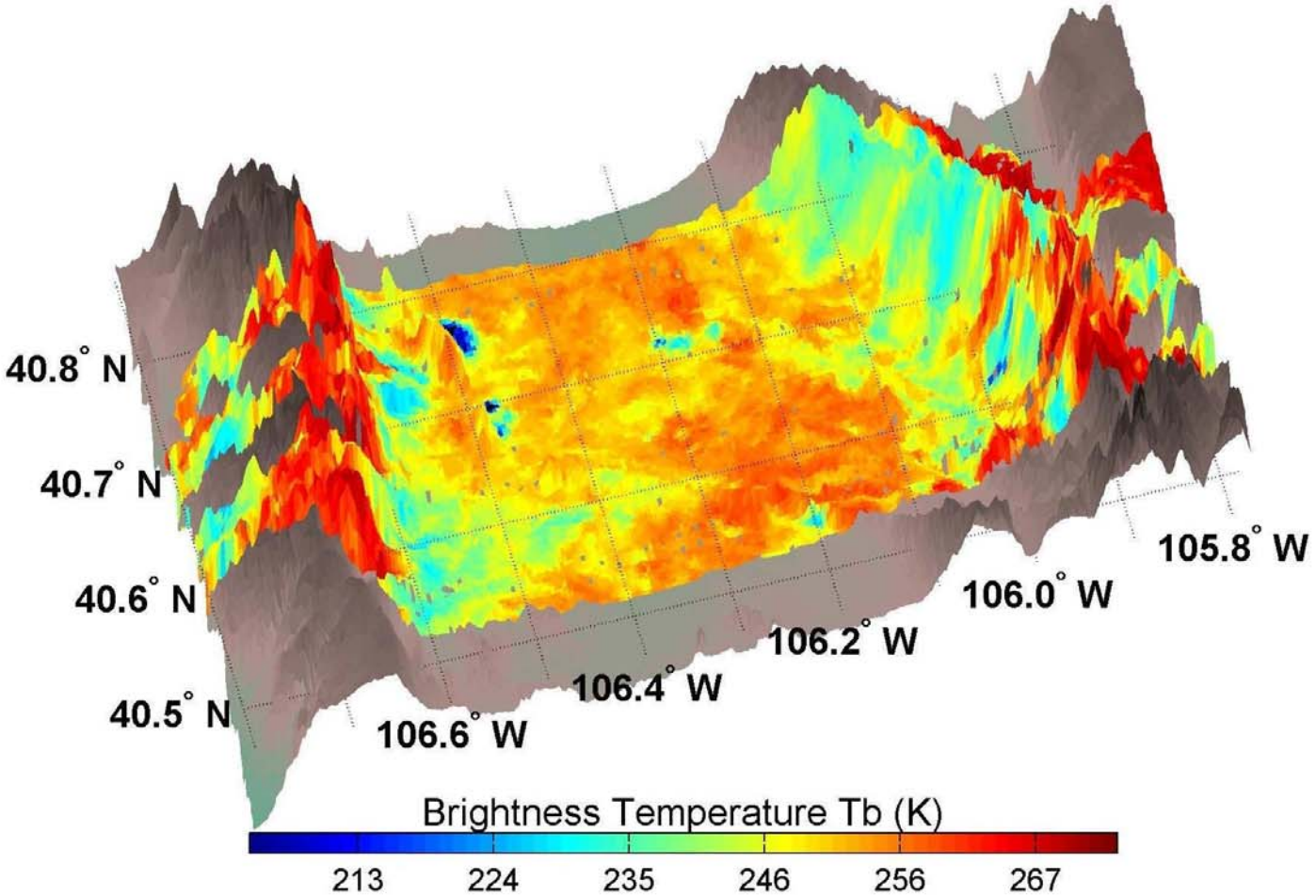
CLPX02-03 PSR/A Snowpack Images

Image sequence is as follows:



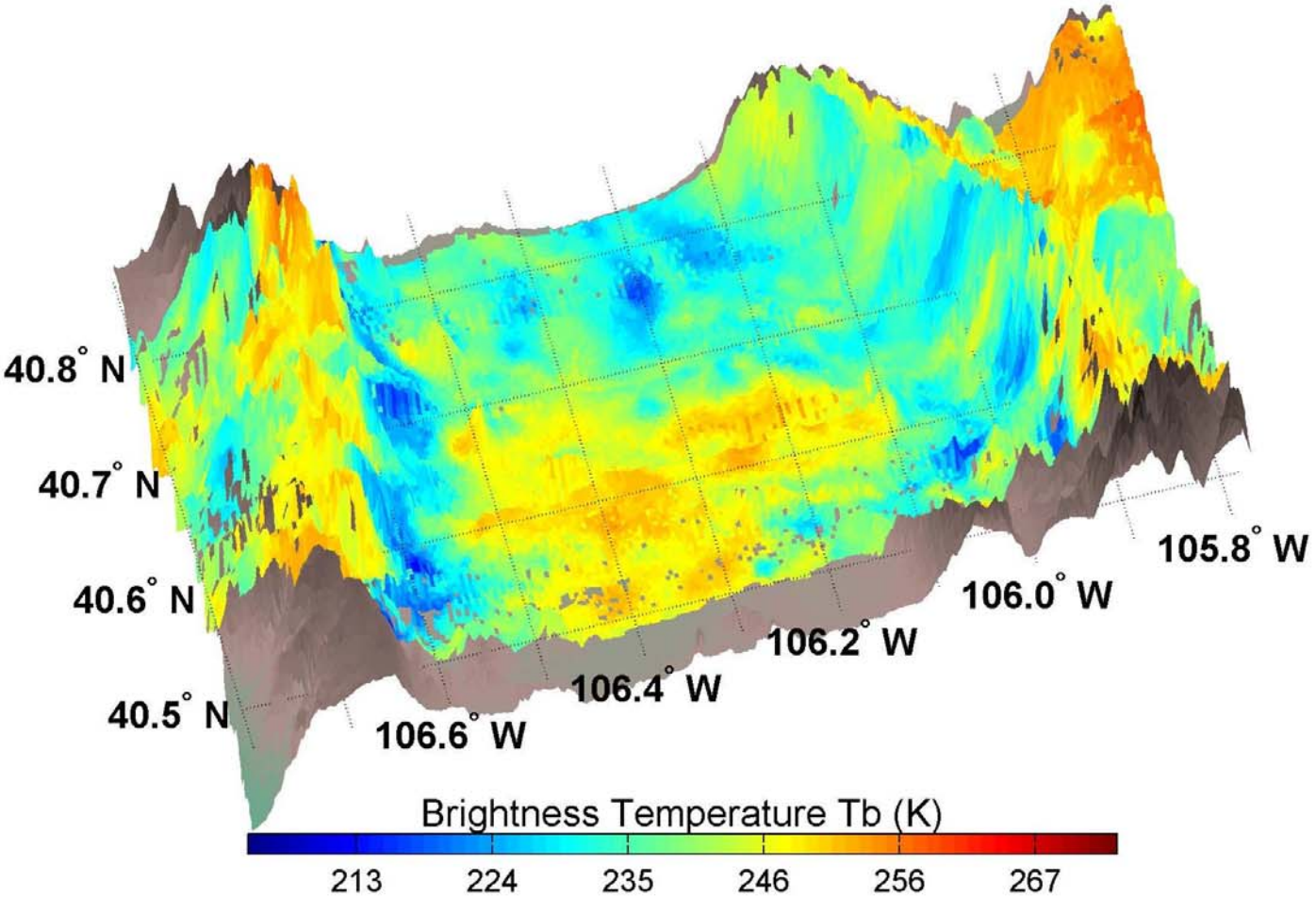
CLPX02

NorthPark: CLPX02 02/23/2002 18.7 GHz Th

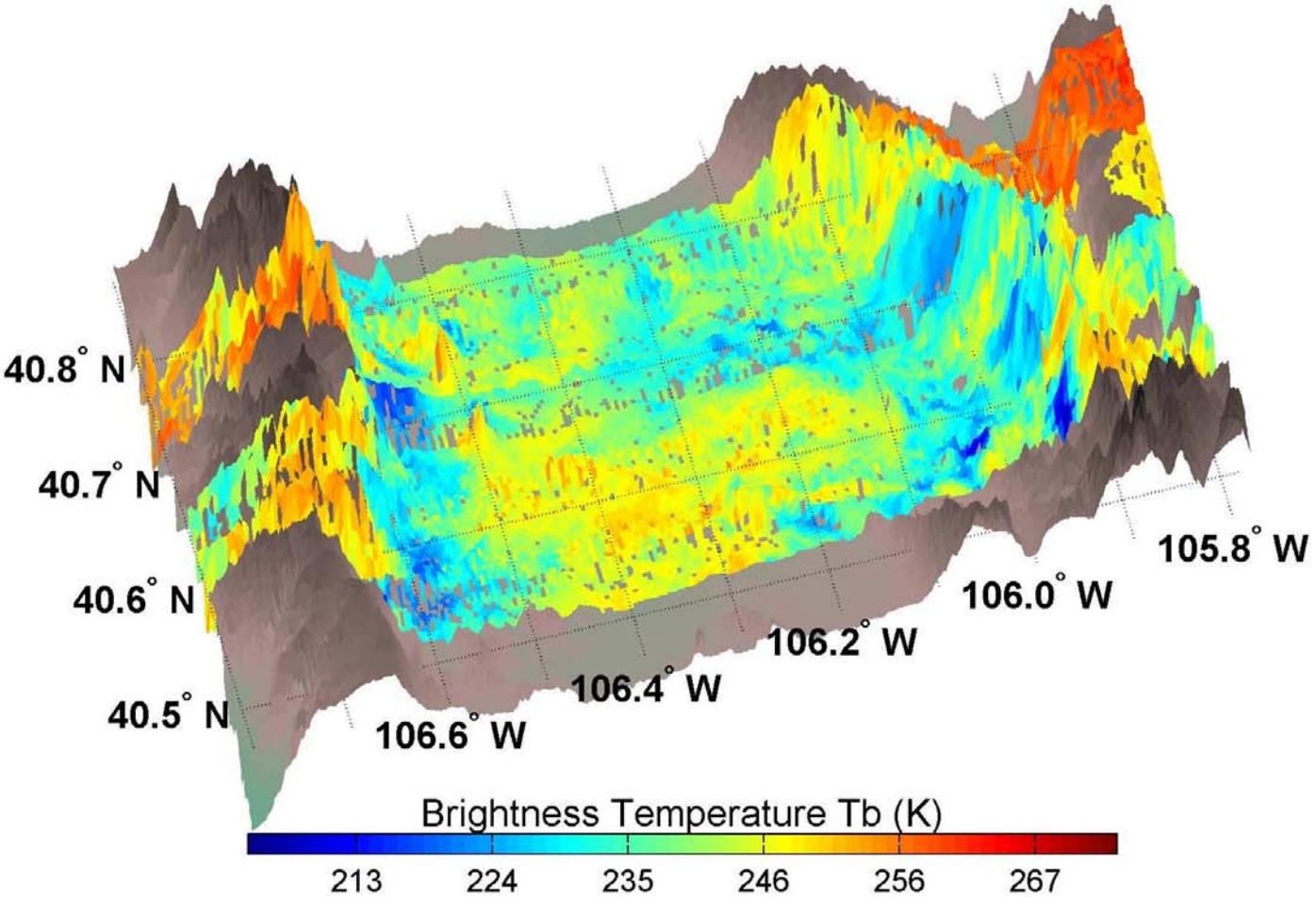


CLPX03A

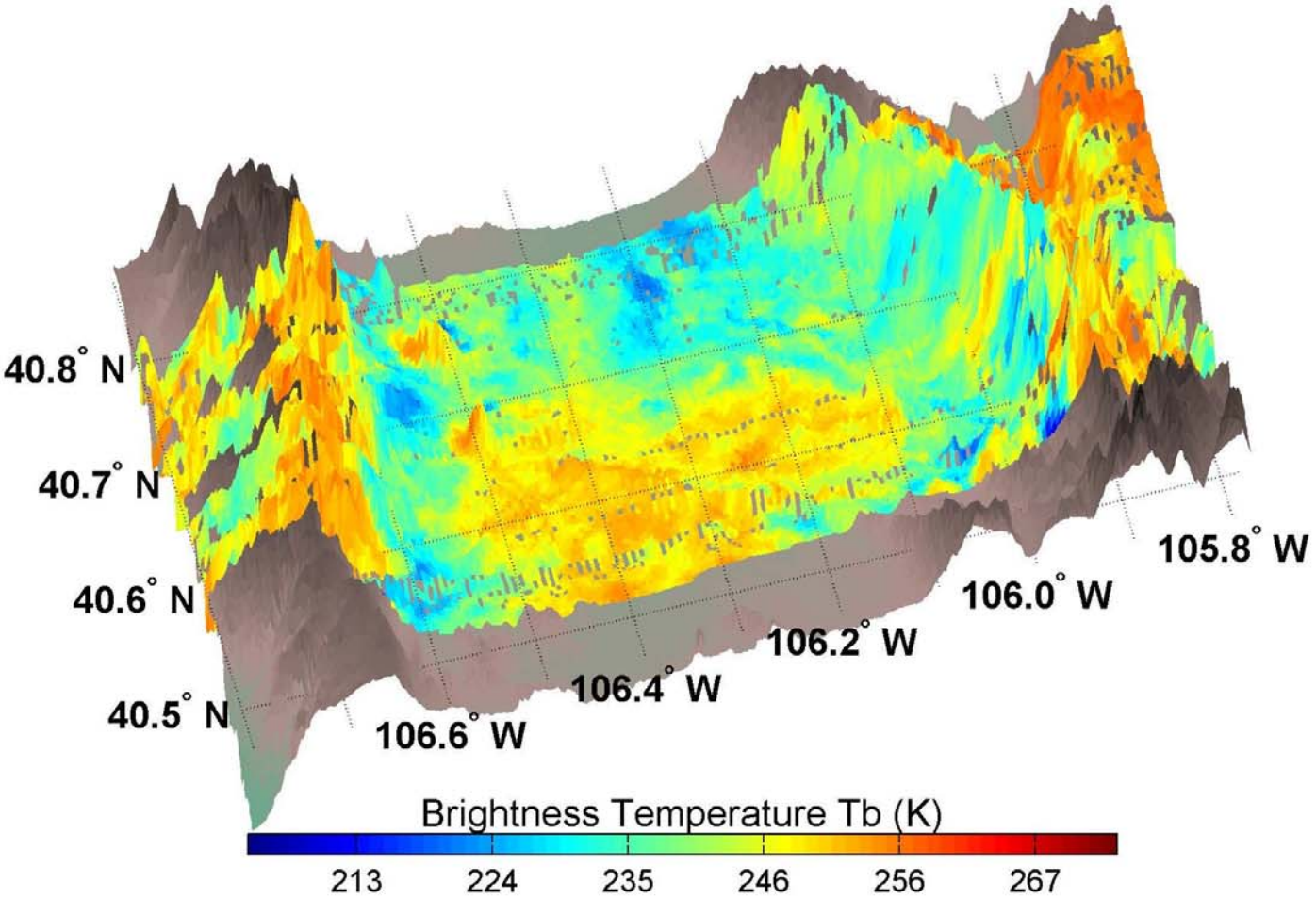
NorthPark: CLPX03A 02/22/2003 18.7 GHz Th



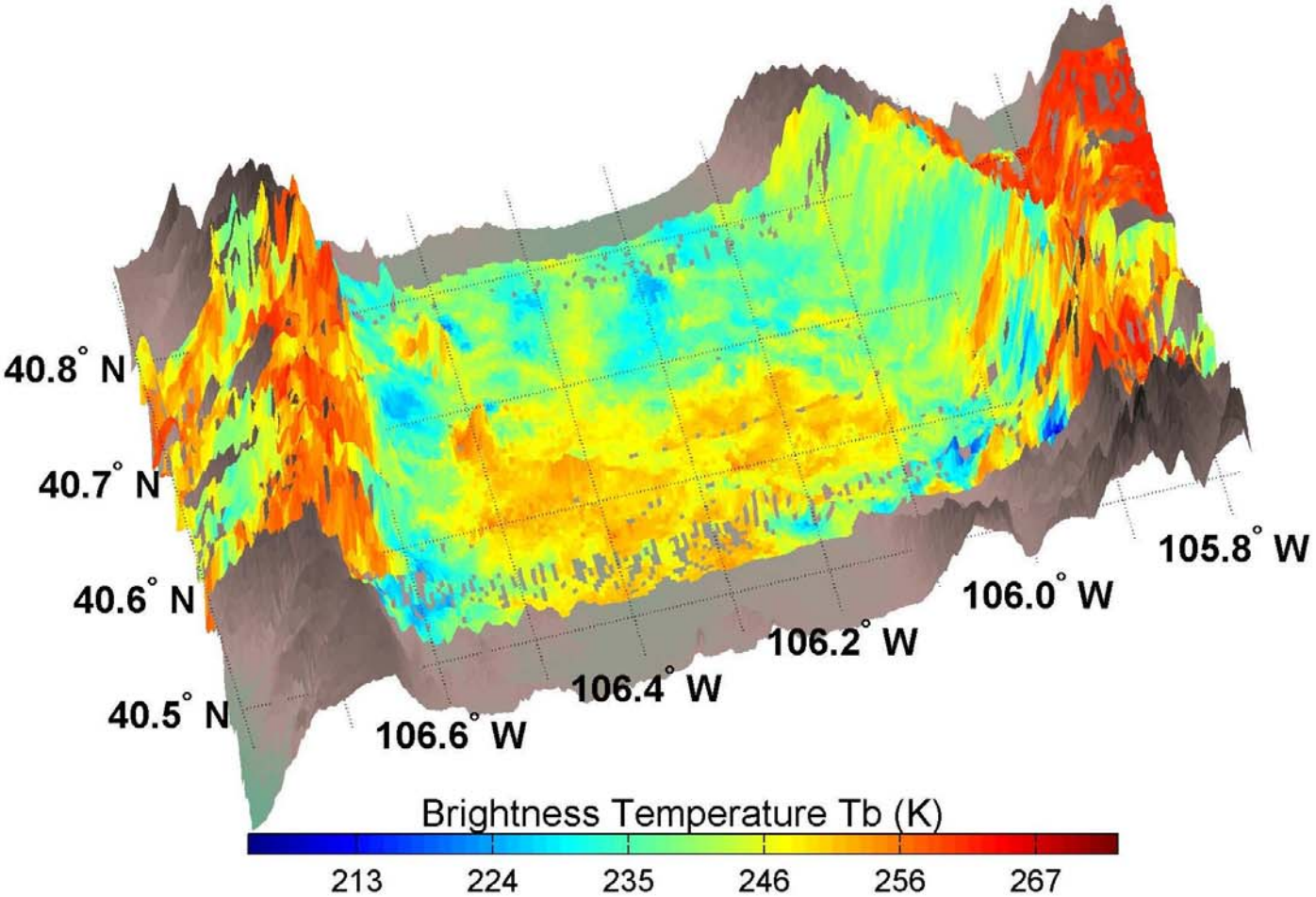
NorthPark: CLPX03A 02/23/2003 18.7 GHz Th



NorthPark: CLPX03A 02/24/2003 18.7 GHz Th

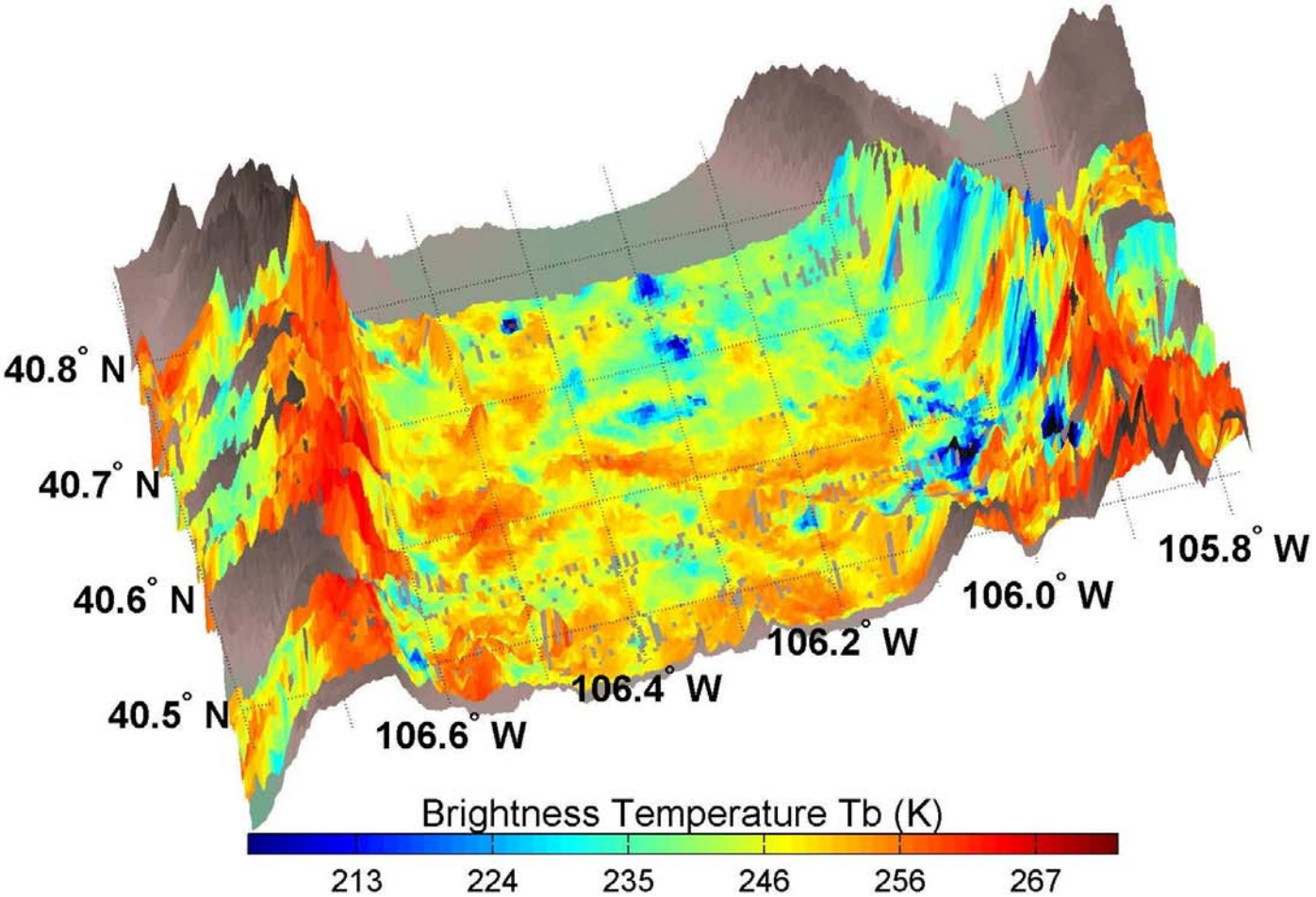


NorthPark: CLPX03A 02/25/2003 18.7 GHz Th

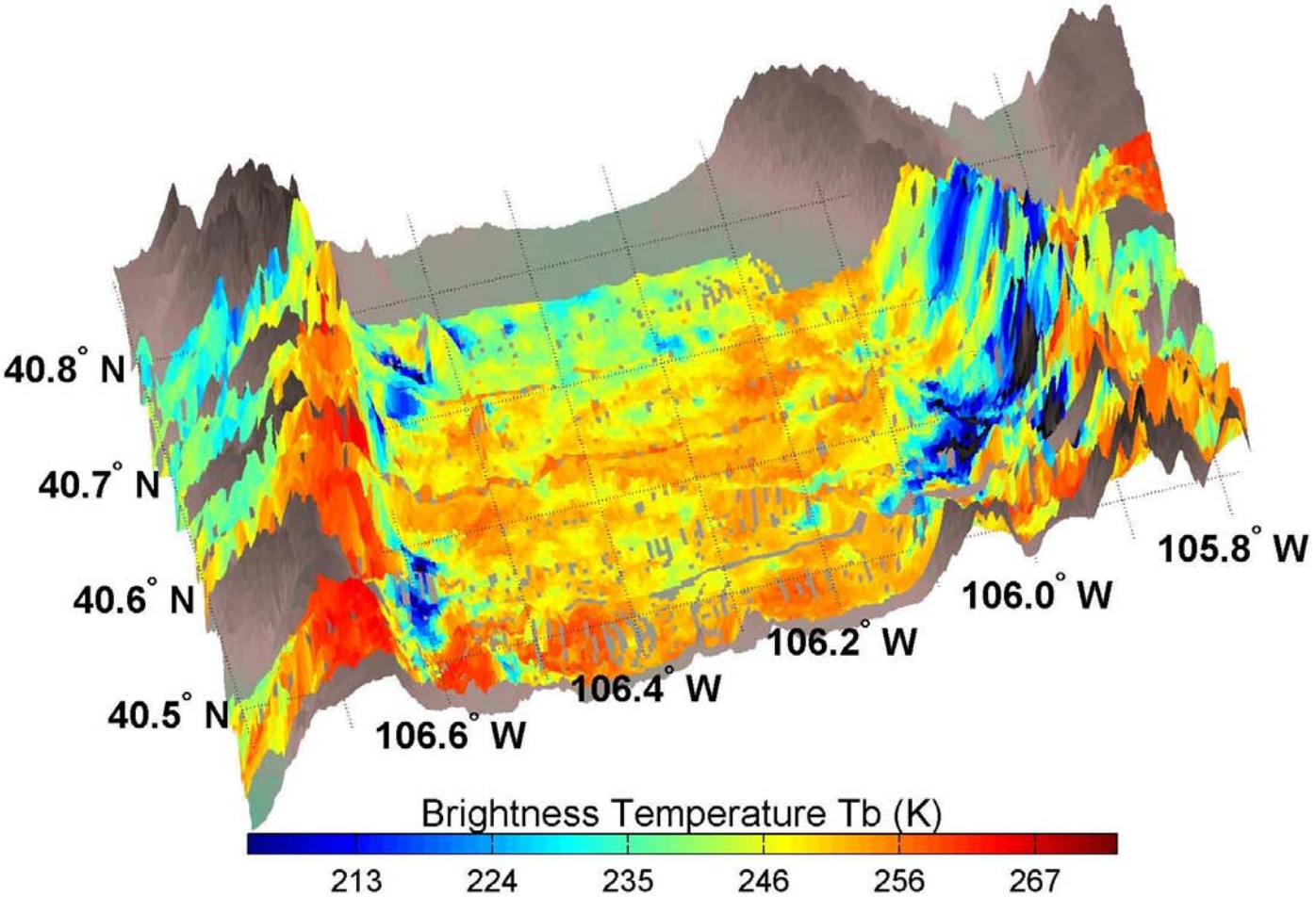


CLPX03B

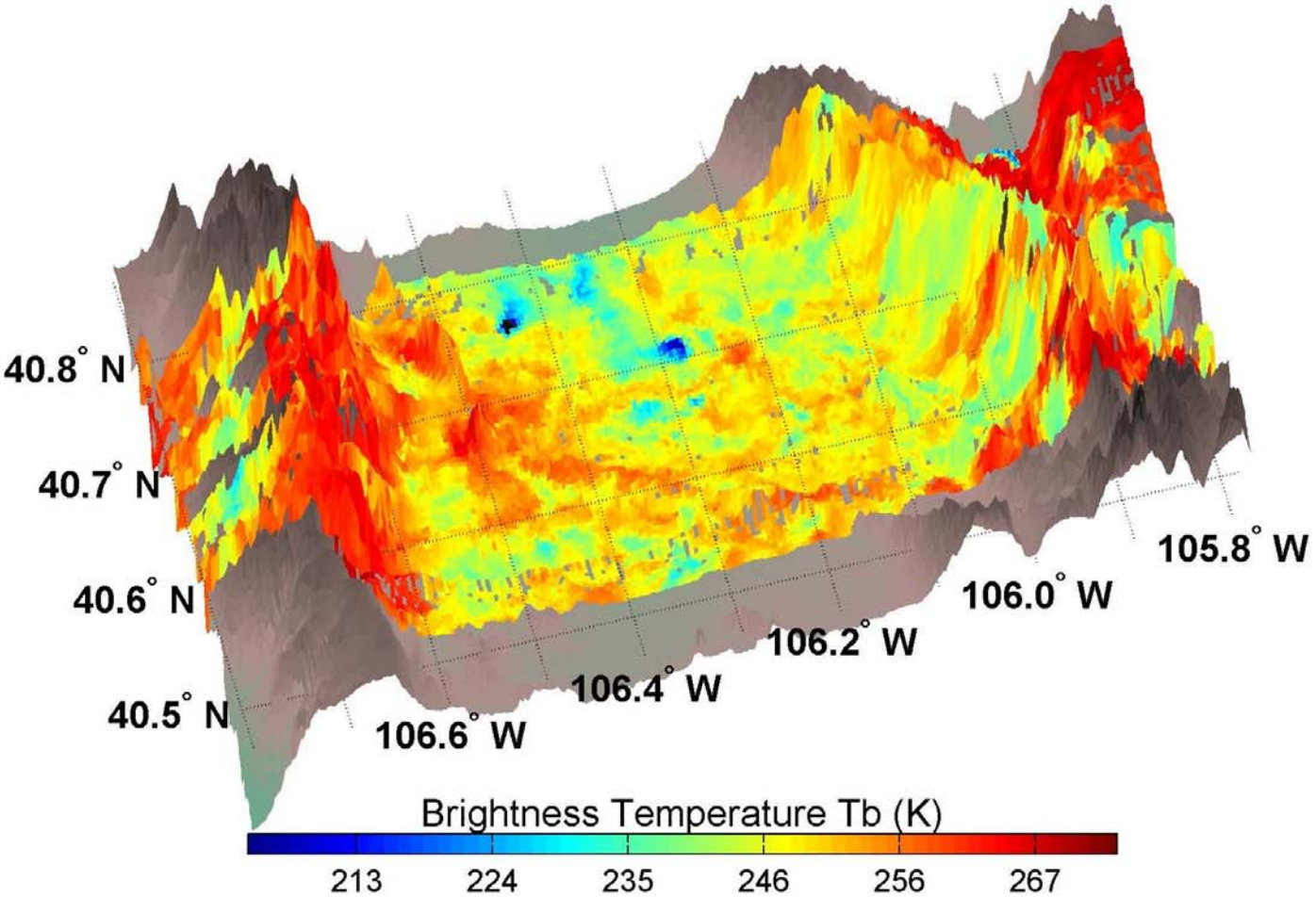
NorthPark: CLPX03B 03/25/2003 18.7 GHz Th



NorthPark: CLPX03B 03/30/2003 18.7 GHz Th

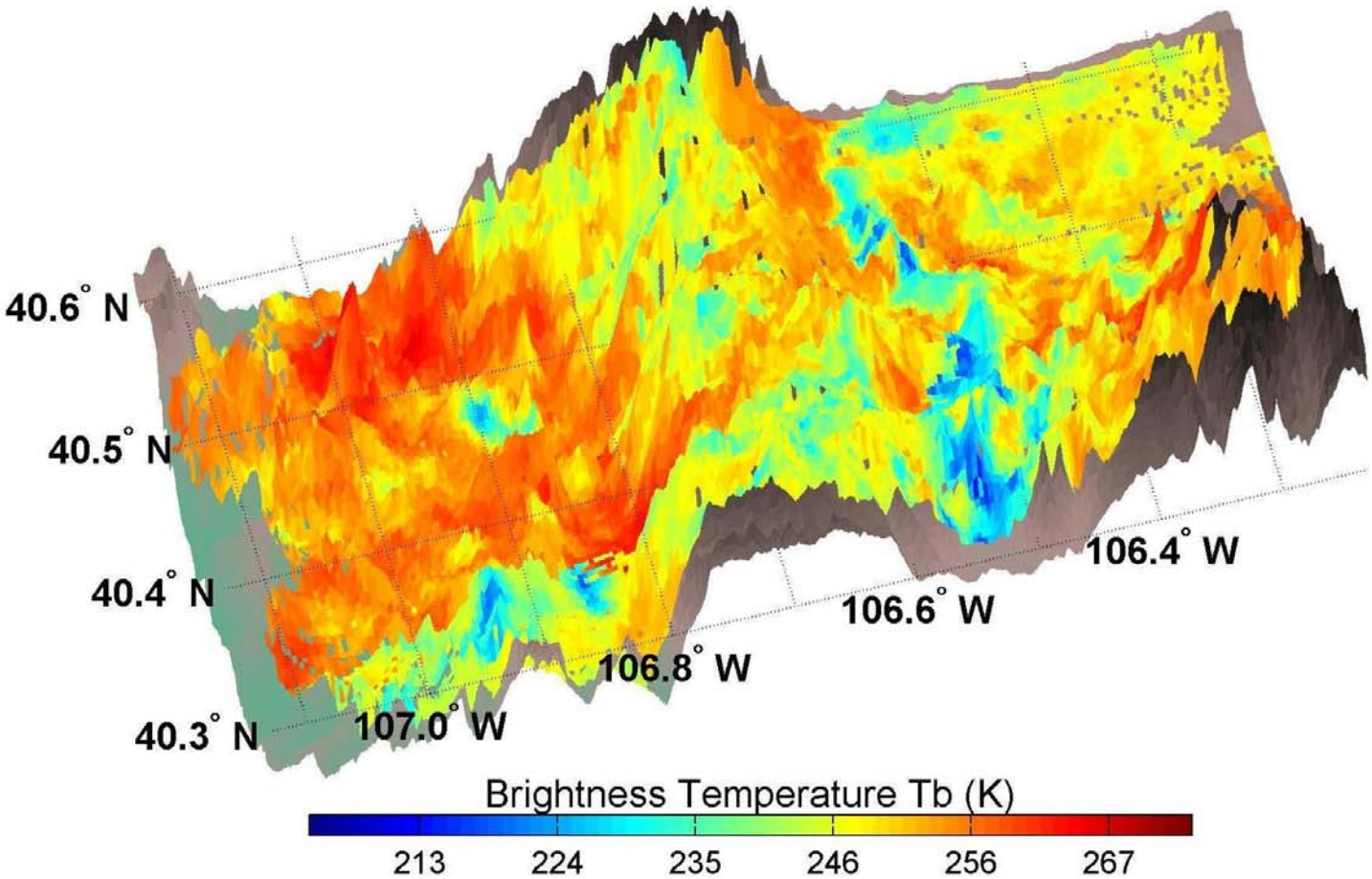


NorthPark: CLPX03B 03/31/2003 18.7 GHz Th



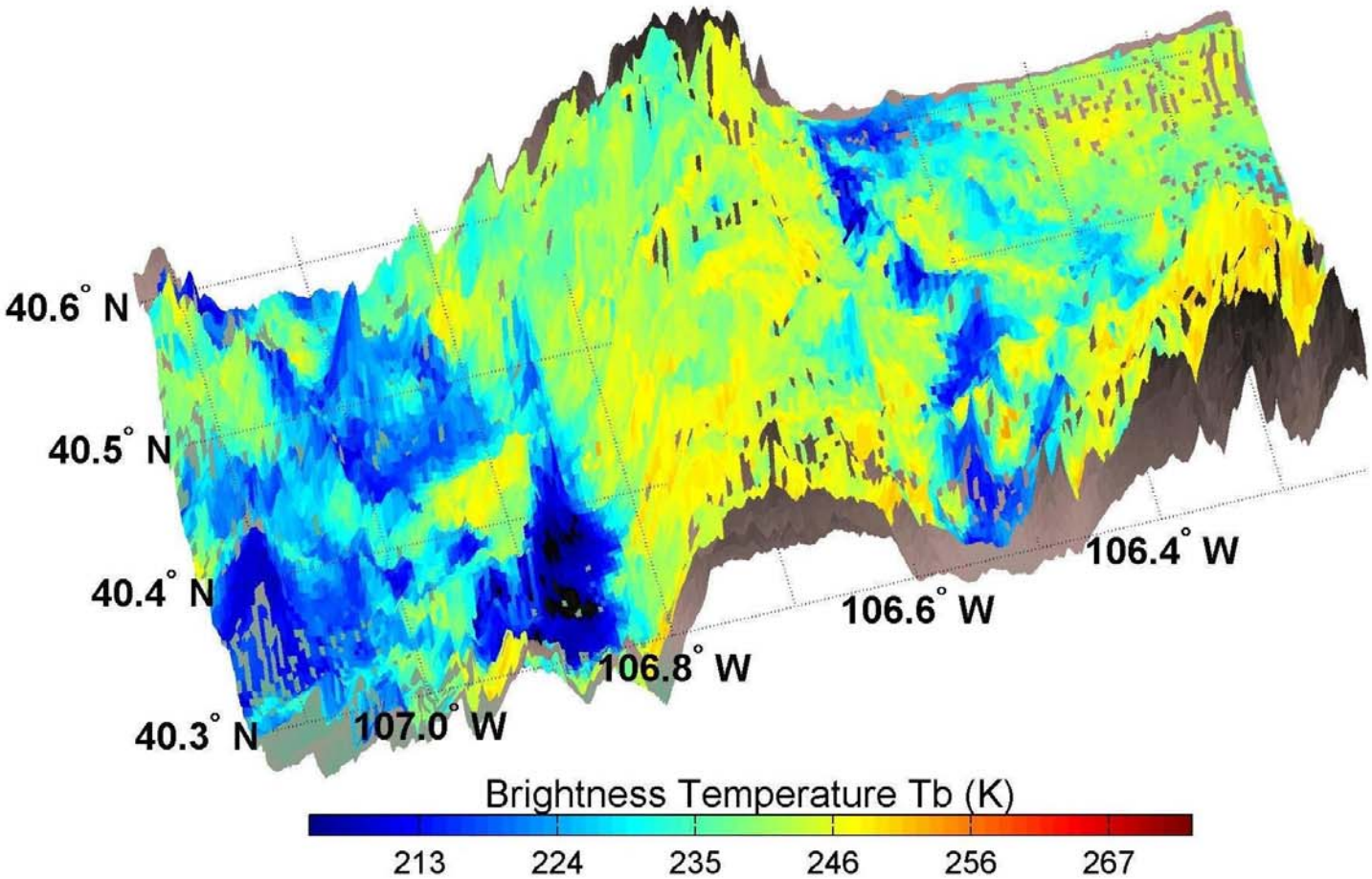
CLPX02

RabbitEars: CLPX02 02/19/2002 18.7 GHz Th

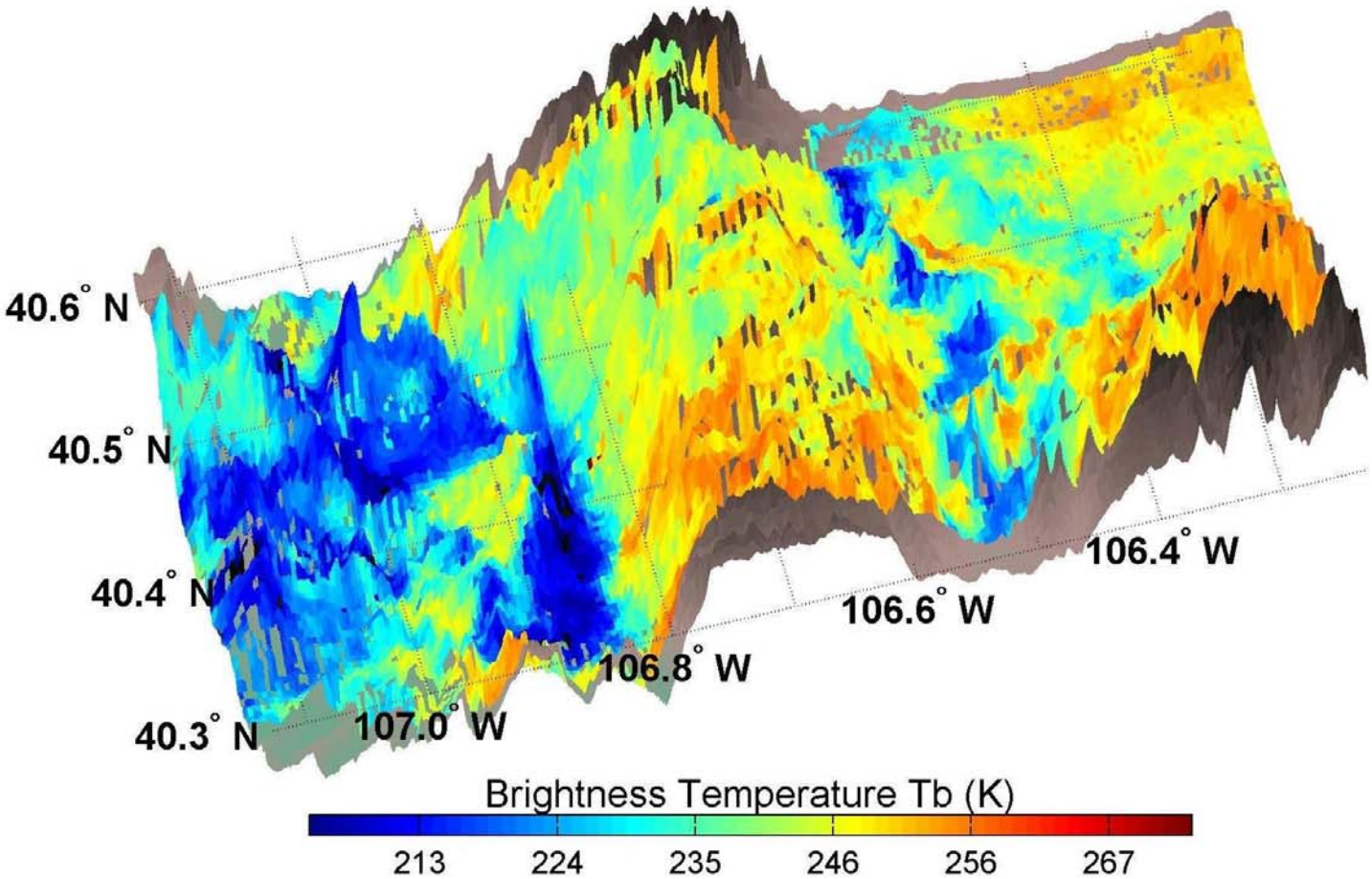


CLPX03A

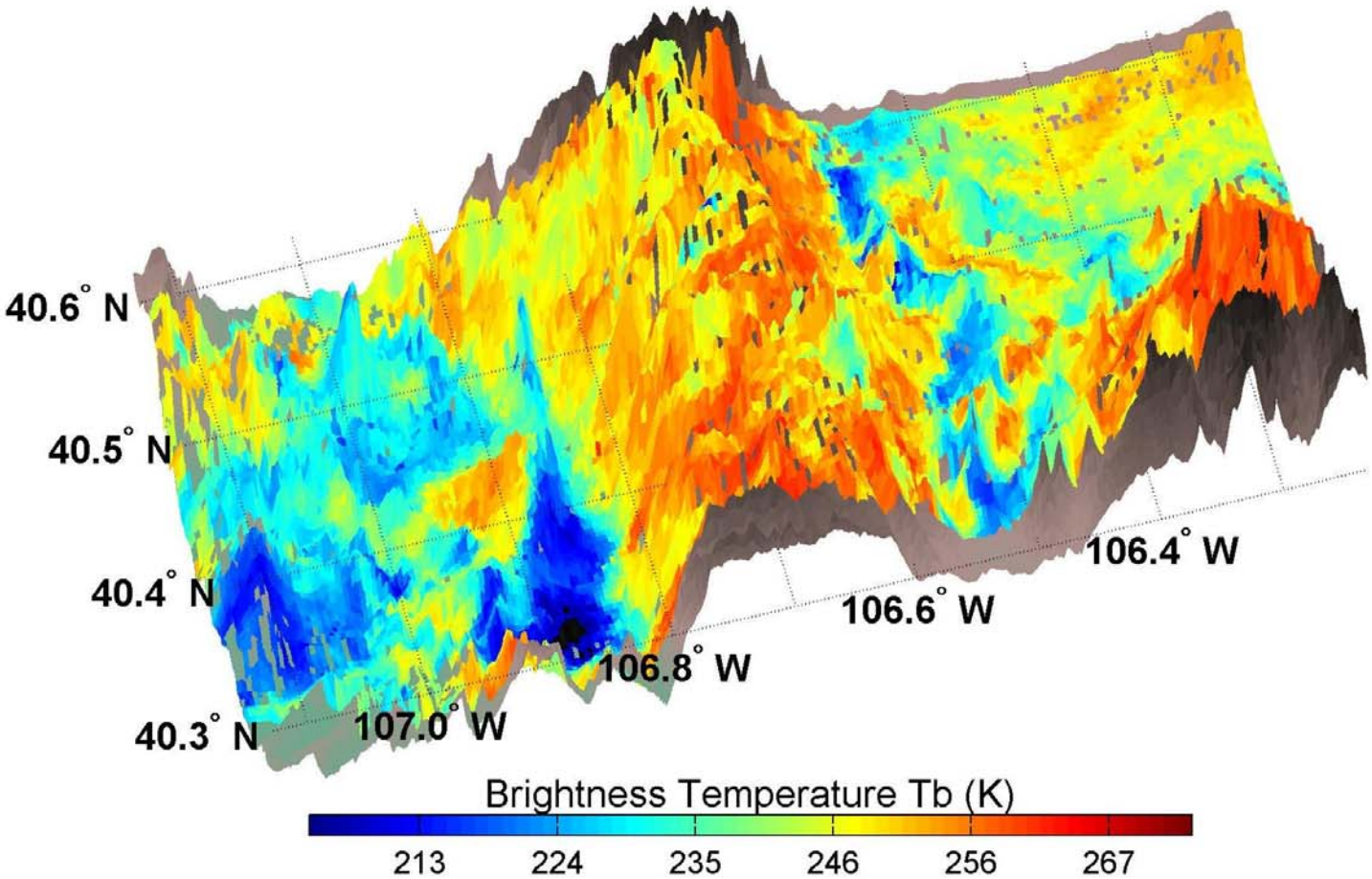
RabbitEars: CLPX03A 02/23/2003 18.7 GHz Th



RabbitEars: CLPX03A 02/24/2003 18.7 GHz Th

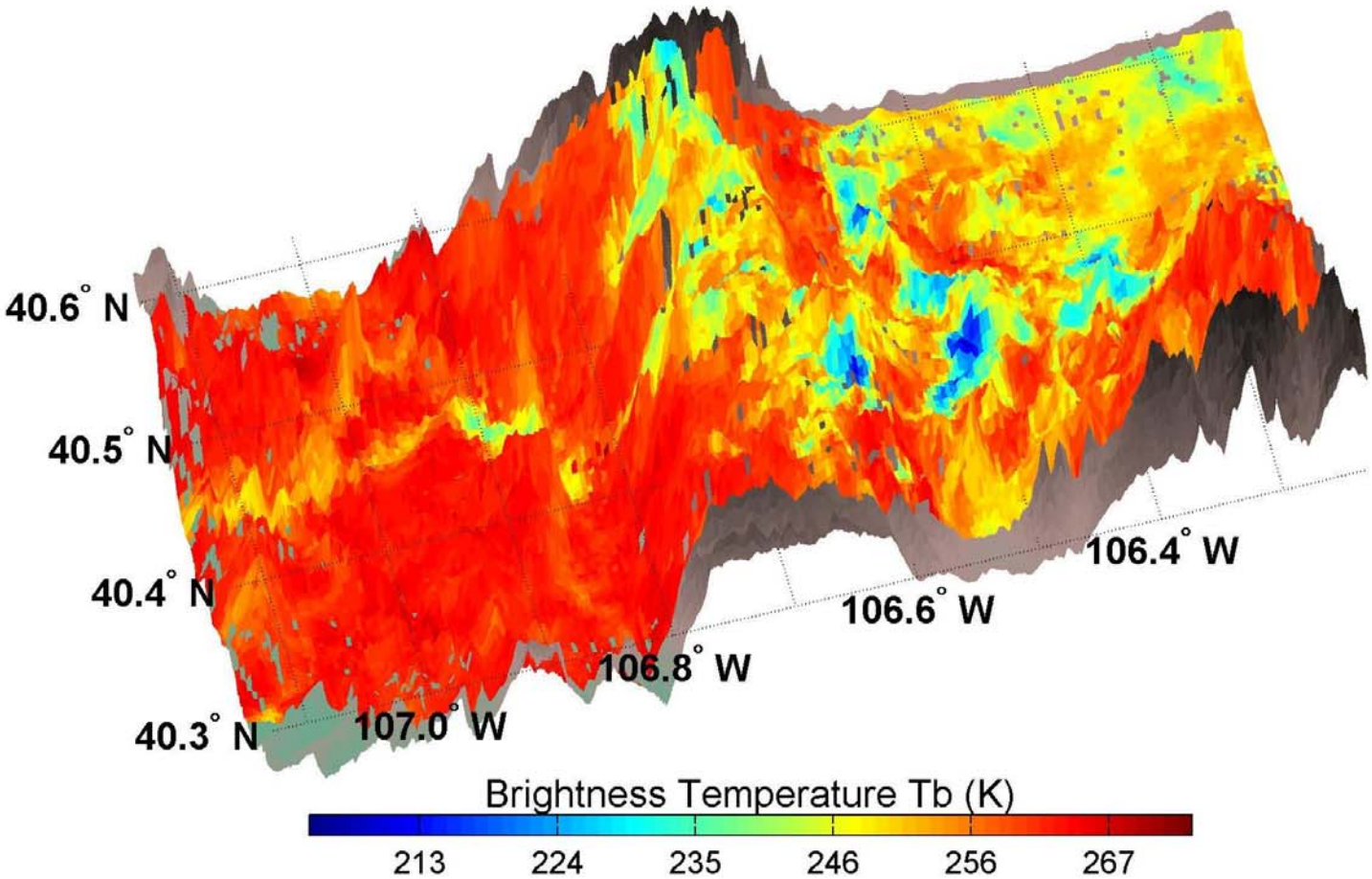


RabbitEars: CLPX03A 02/25/2003 18.7 GHz Th

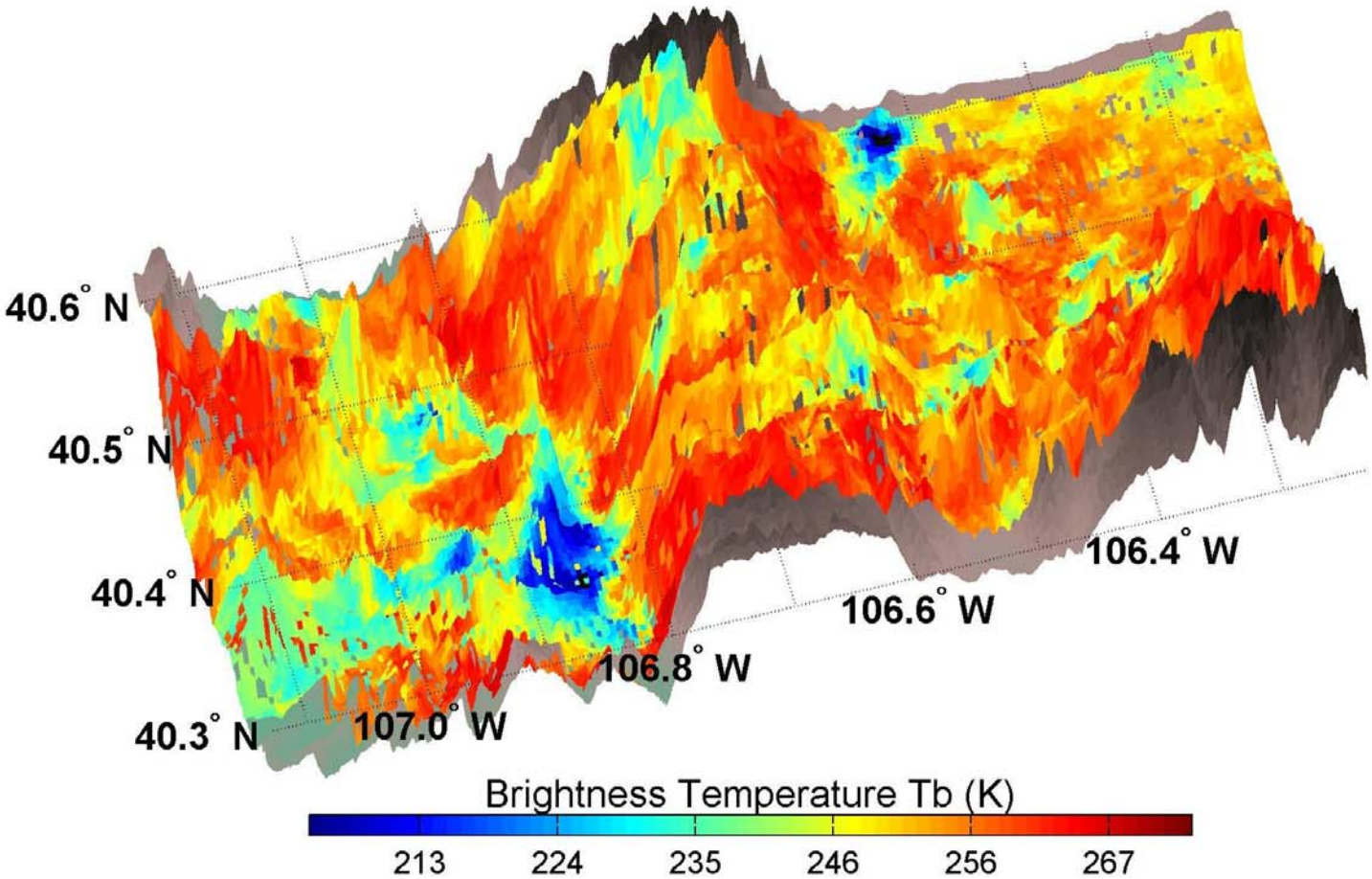


CLPX03B

RabbitEars: CLPX03B 03/25/2003 18.7 GHz Th



RabbitEars: CLPX03B 03/30/2003 18.7 GHz Th



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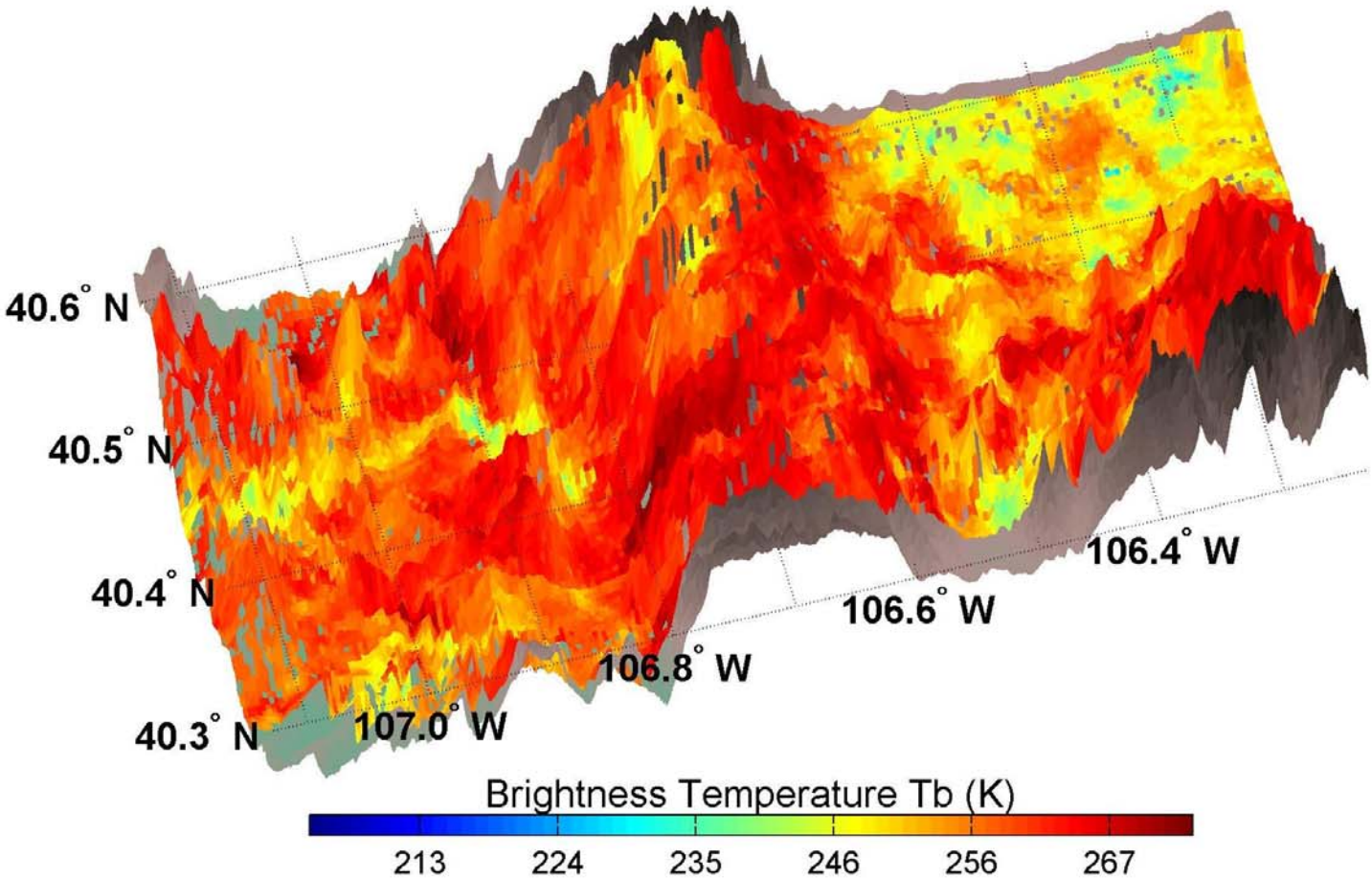
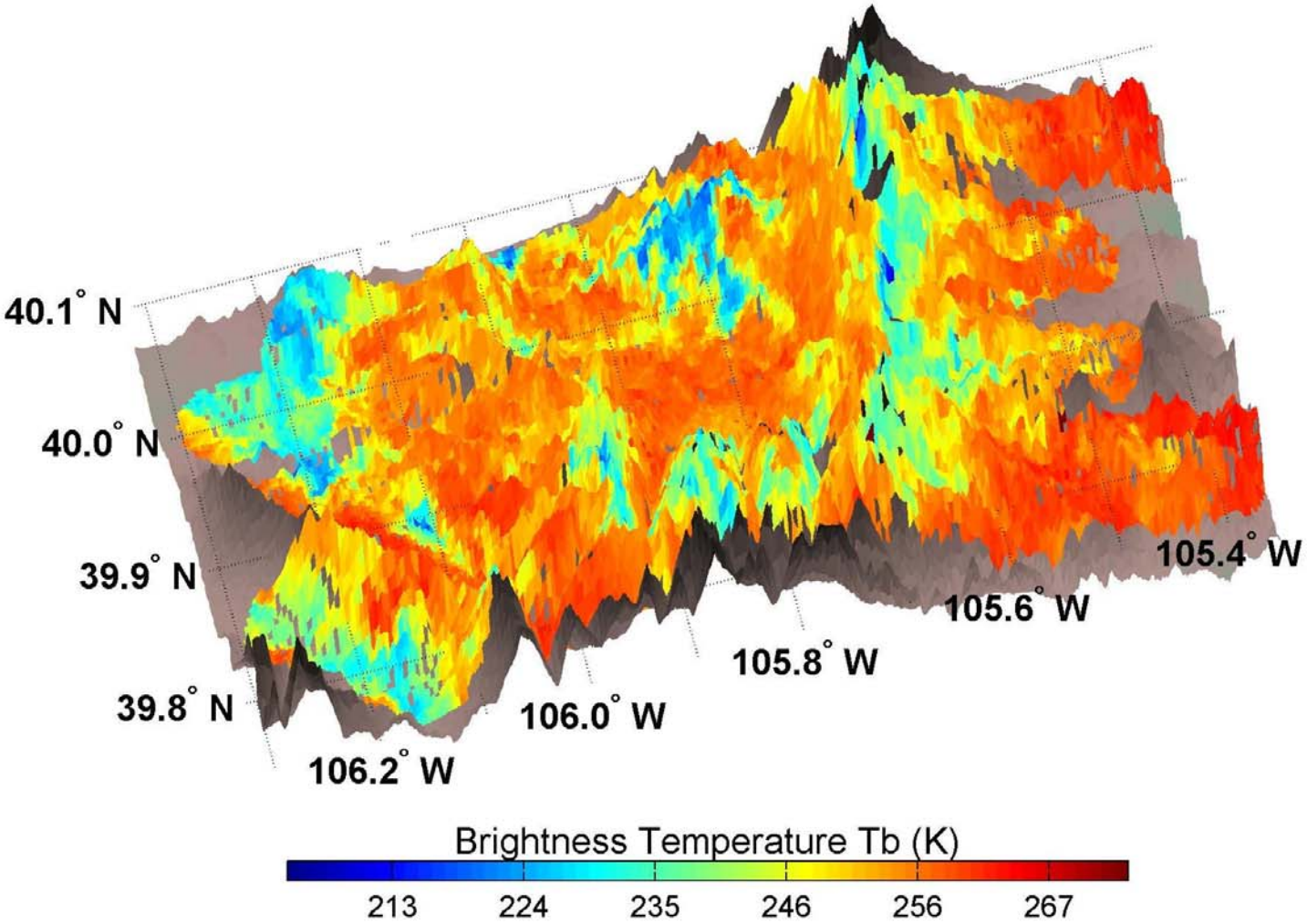


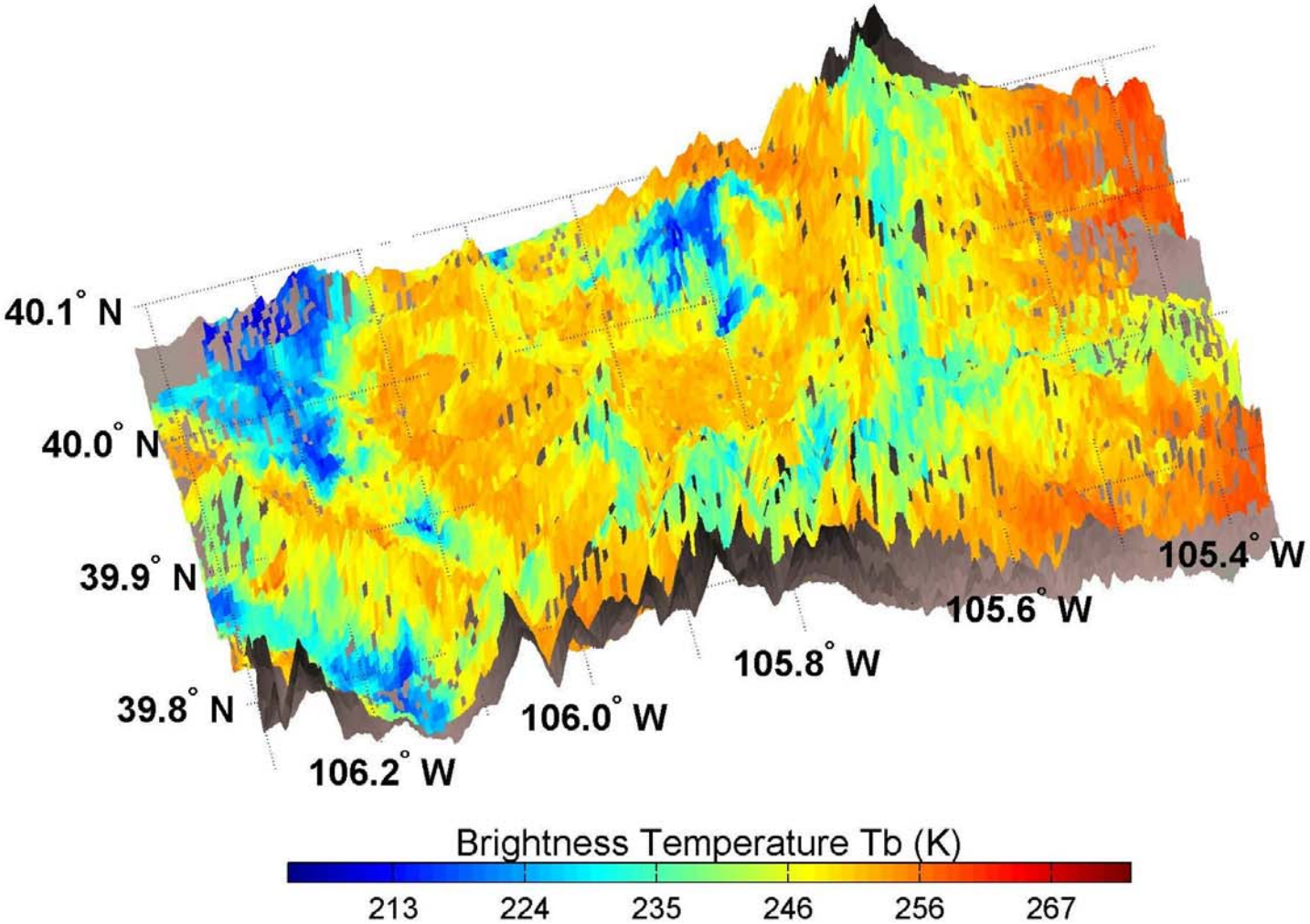
CLPX02

Fraser: CLPX02 02/21/2002 18.7 GHz Th



CLPX03A

Fraser: CLPX03A 02/23/2003 18.7 GHz Th



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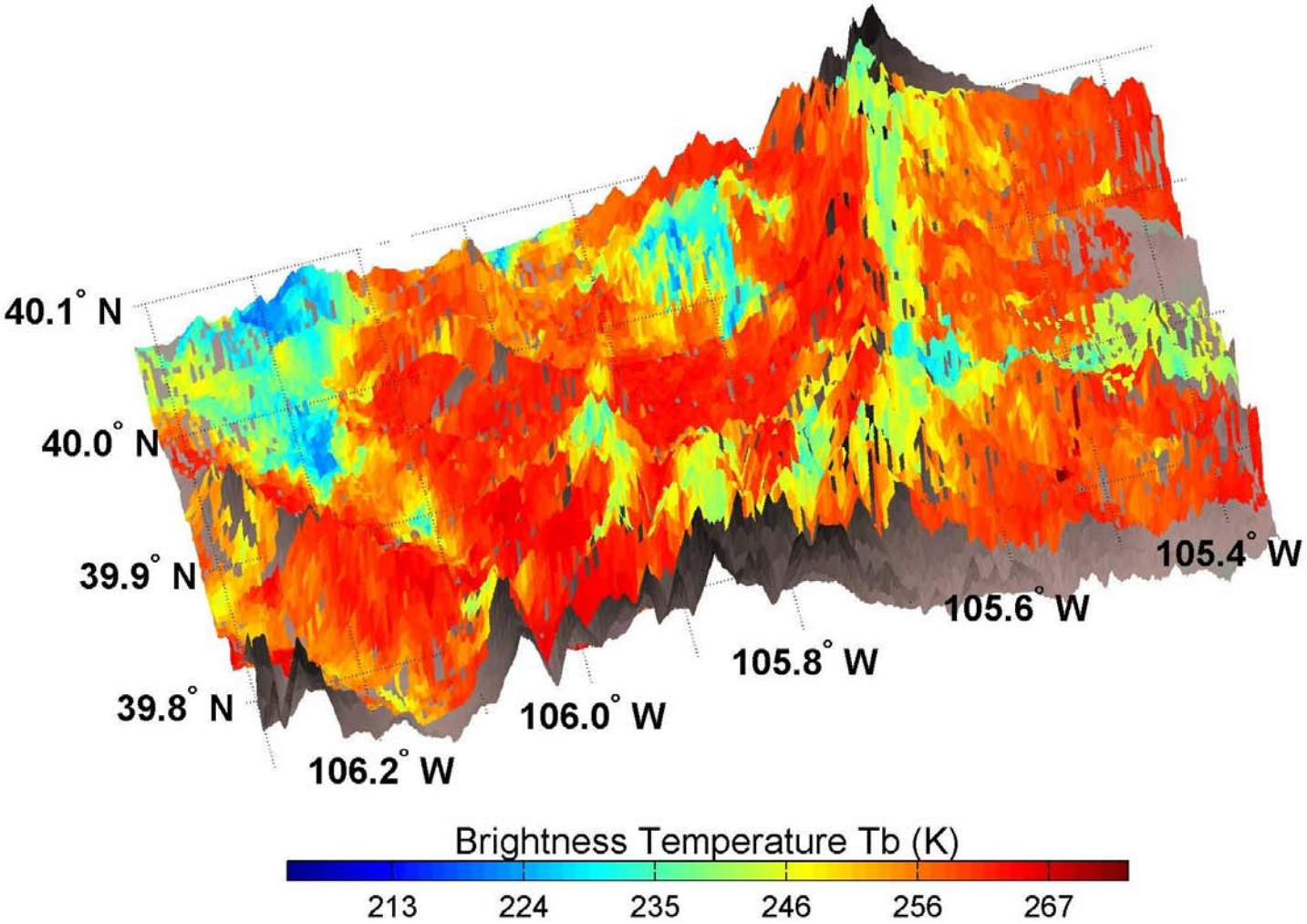

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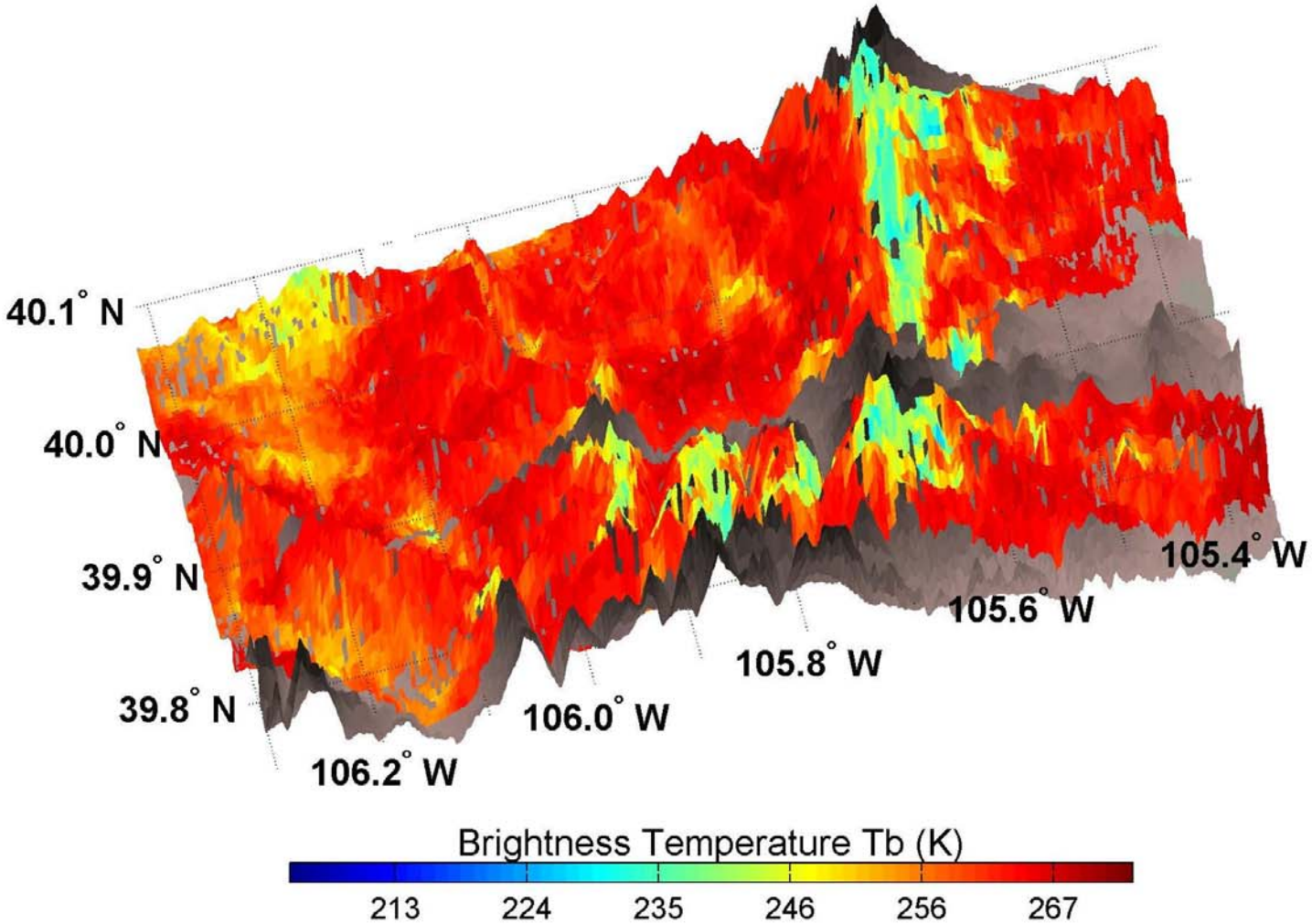

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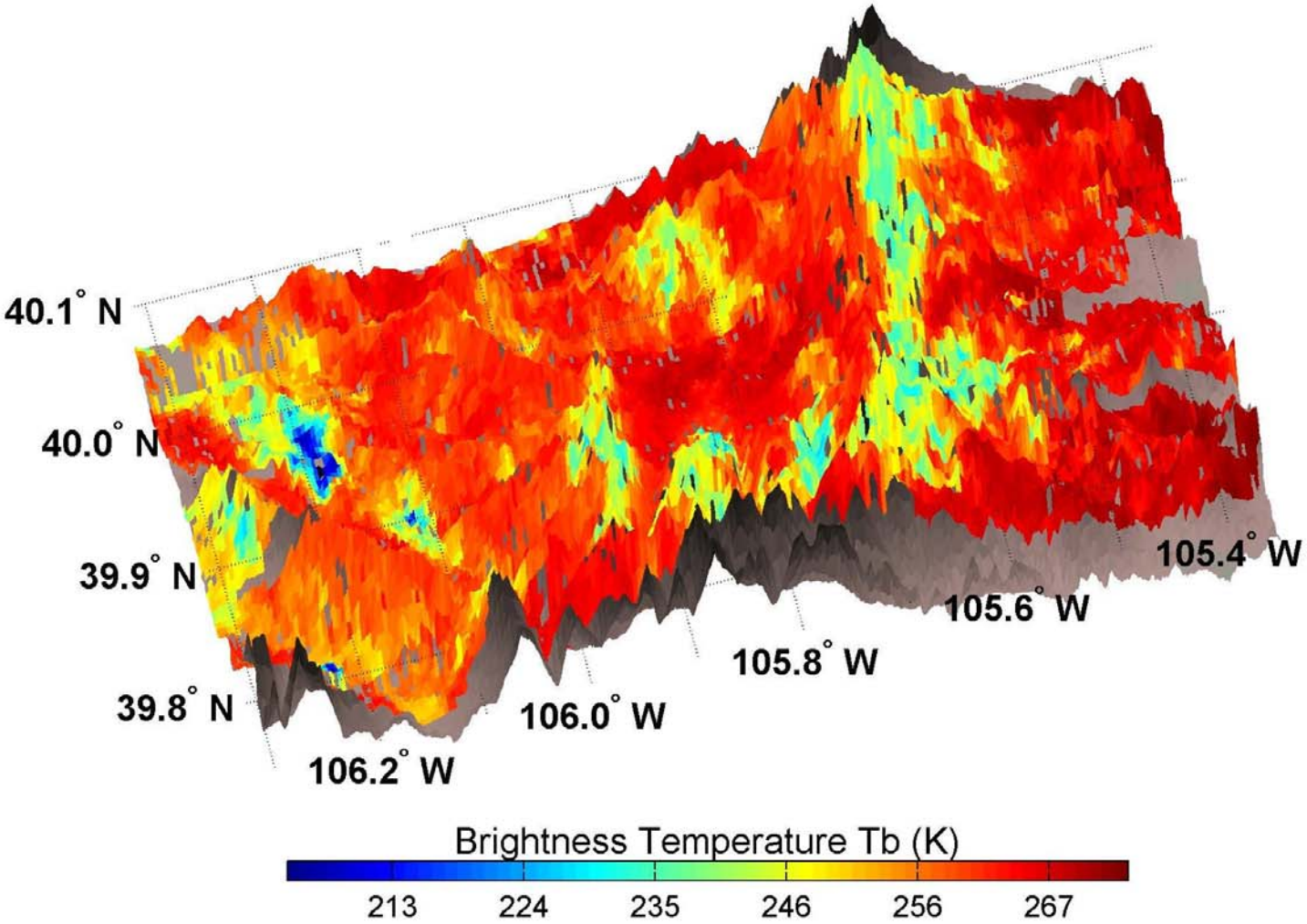

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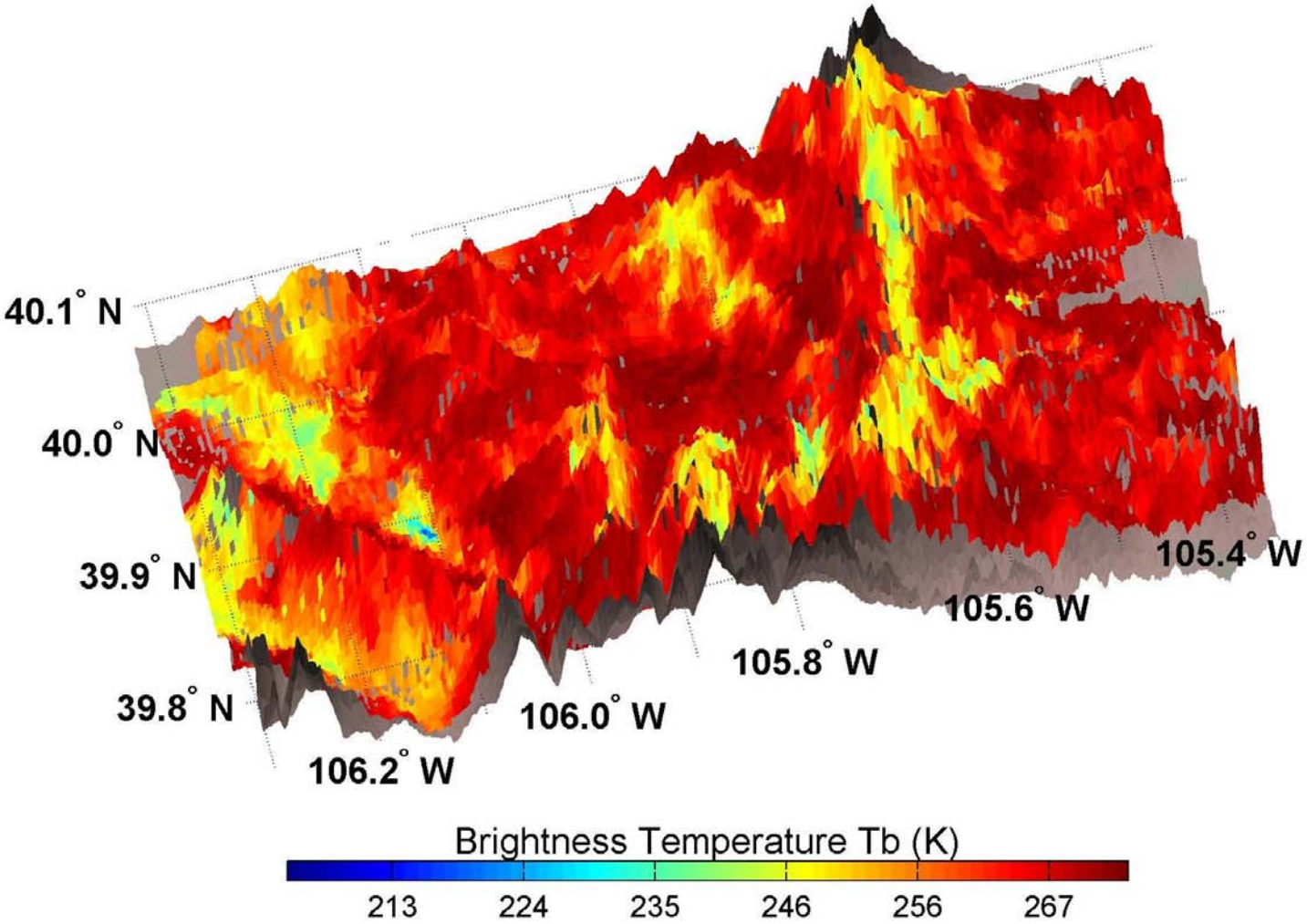

CLPX02-03 PSR/A Snowpack Images

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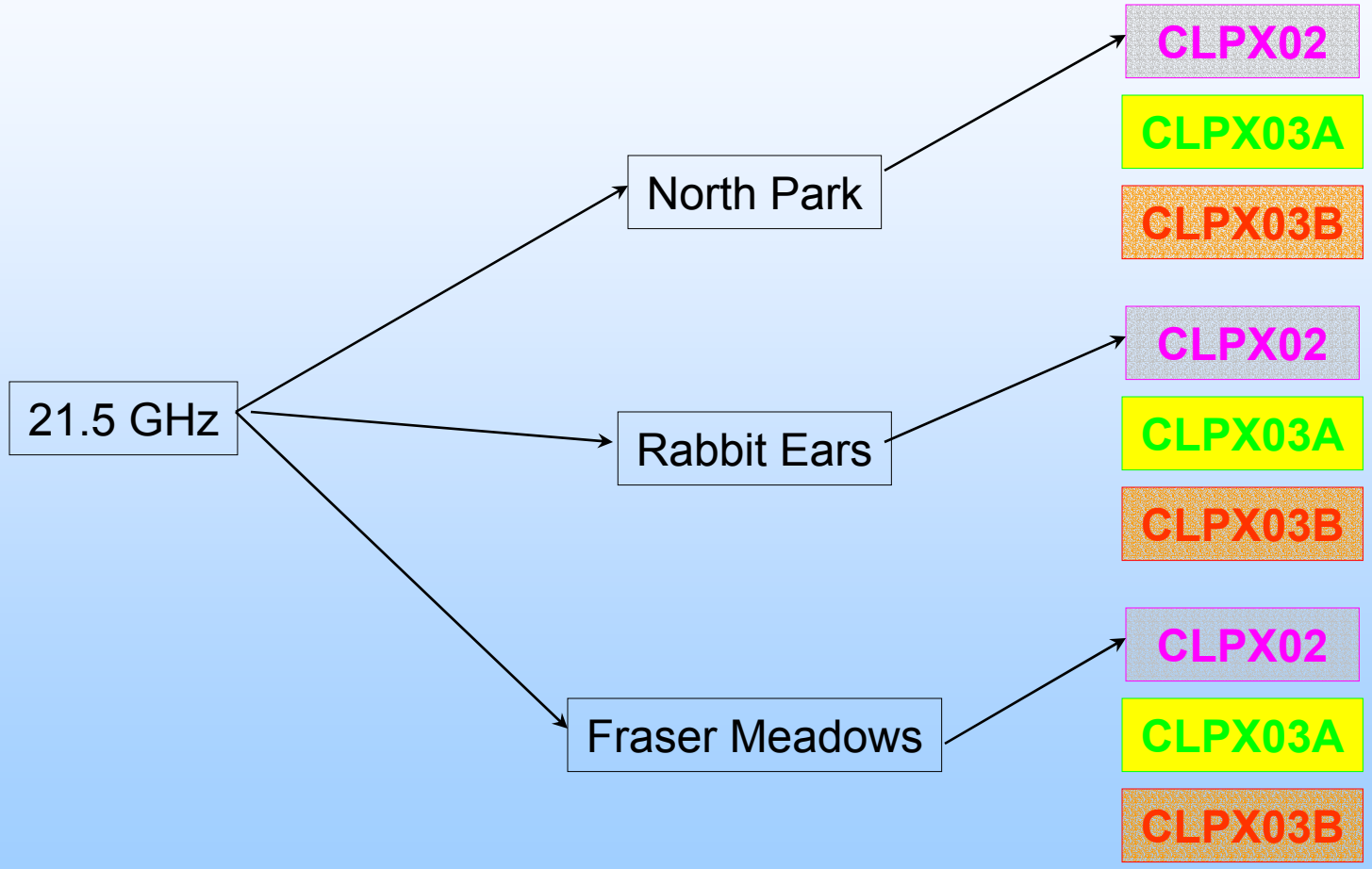
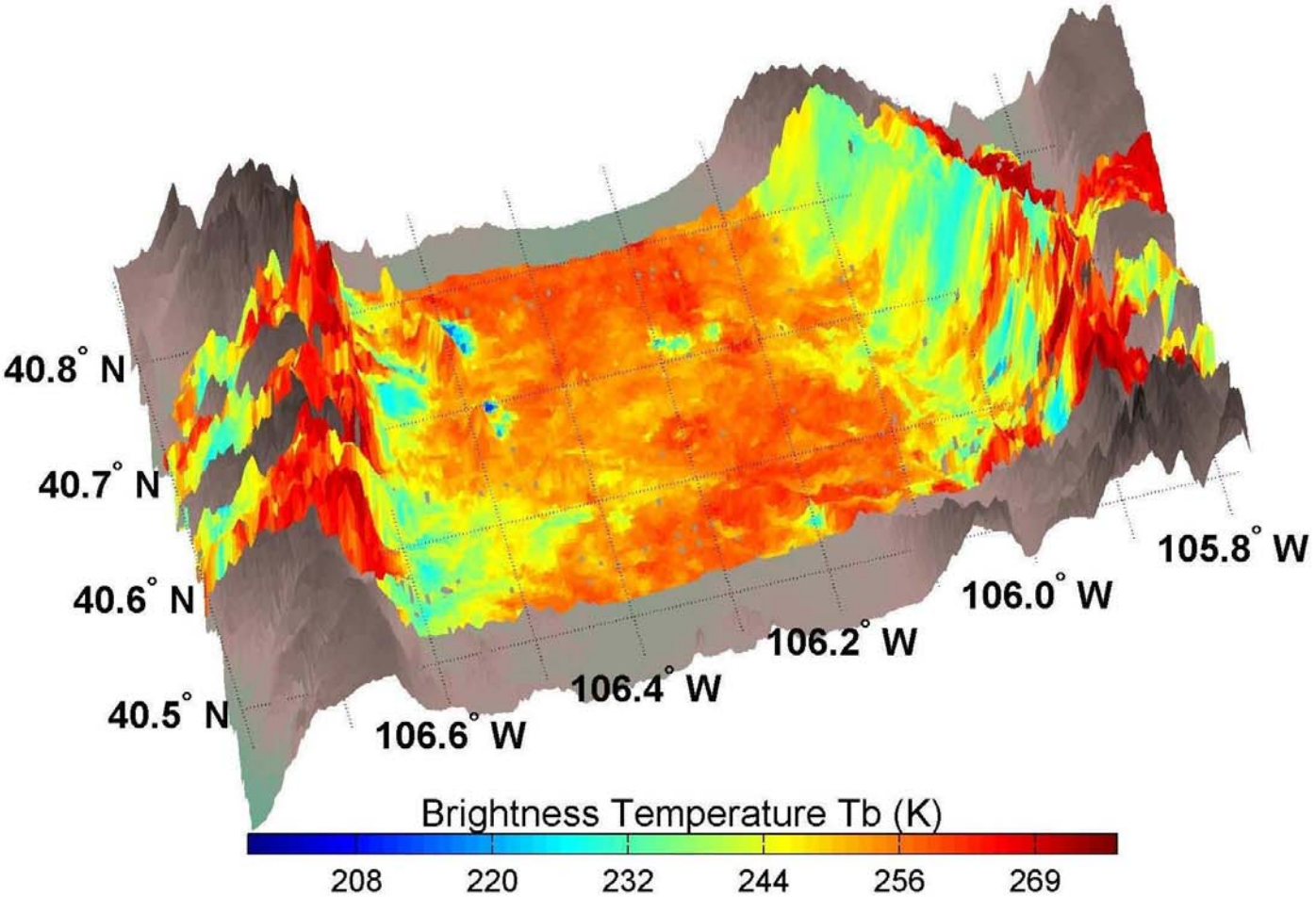


CLPX02

NorthPark: CLPX02 02/23/2002 21.5 GHz Th



CLPX03A

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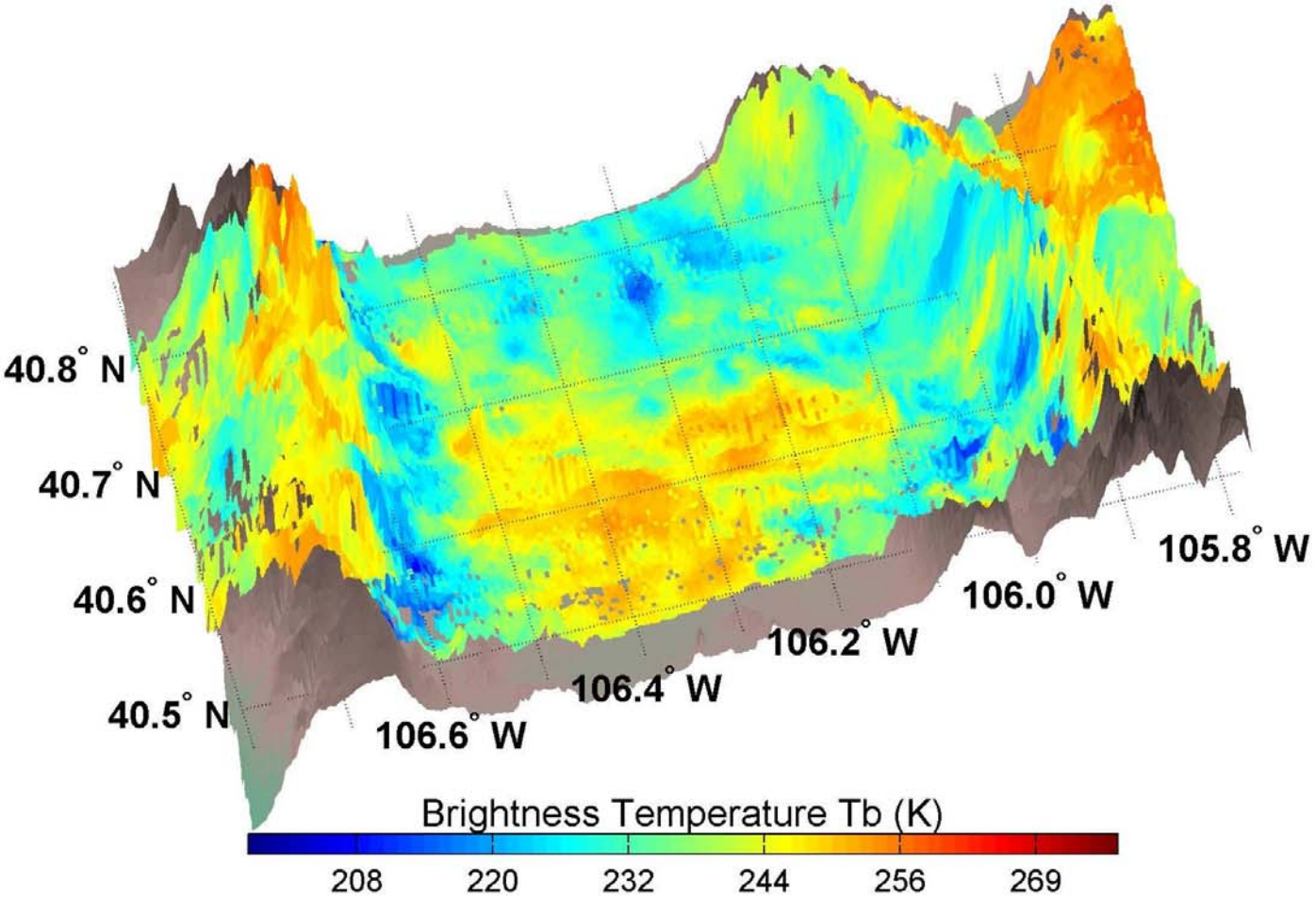

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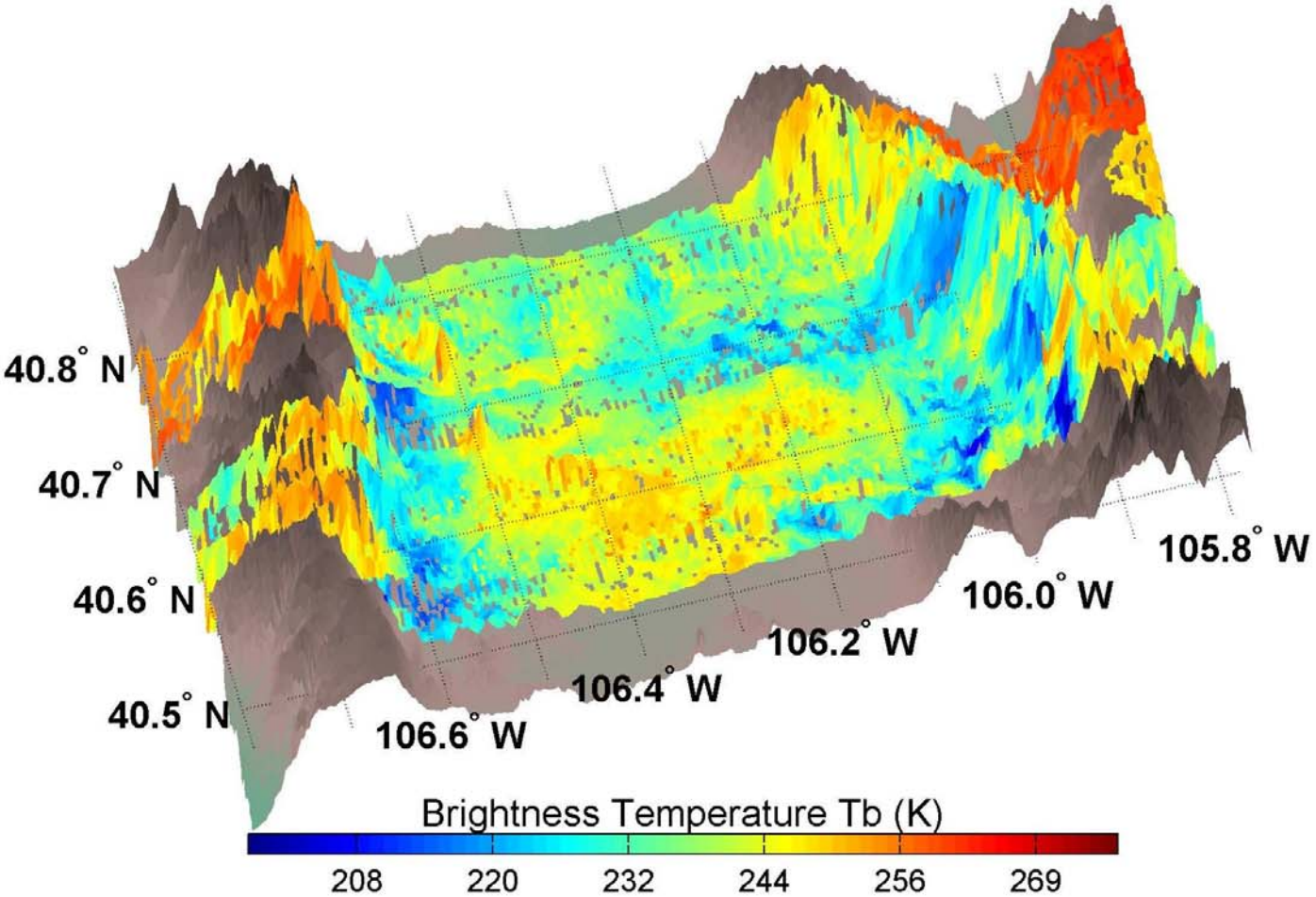

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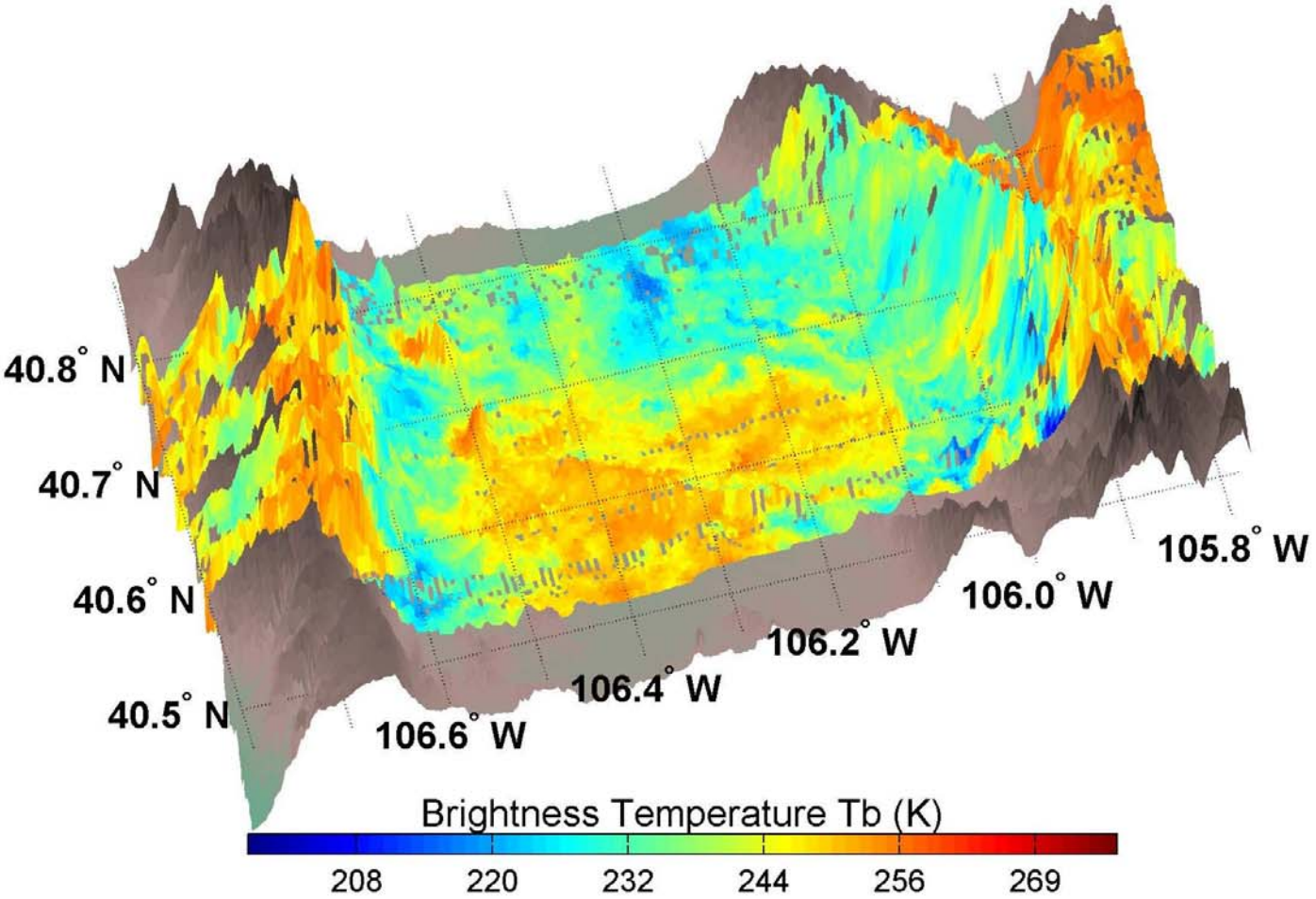

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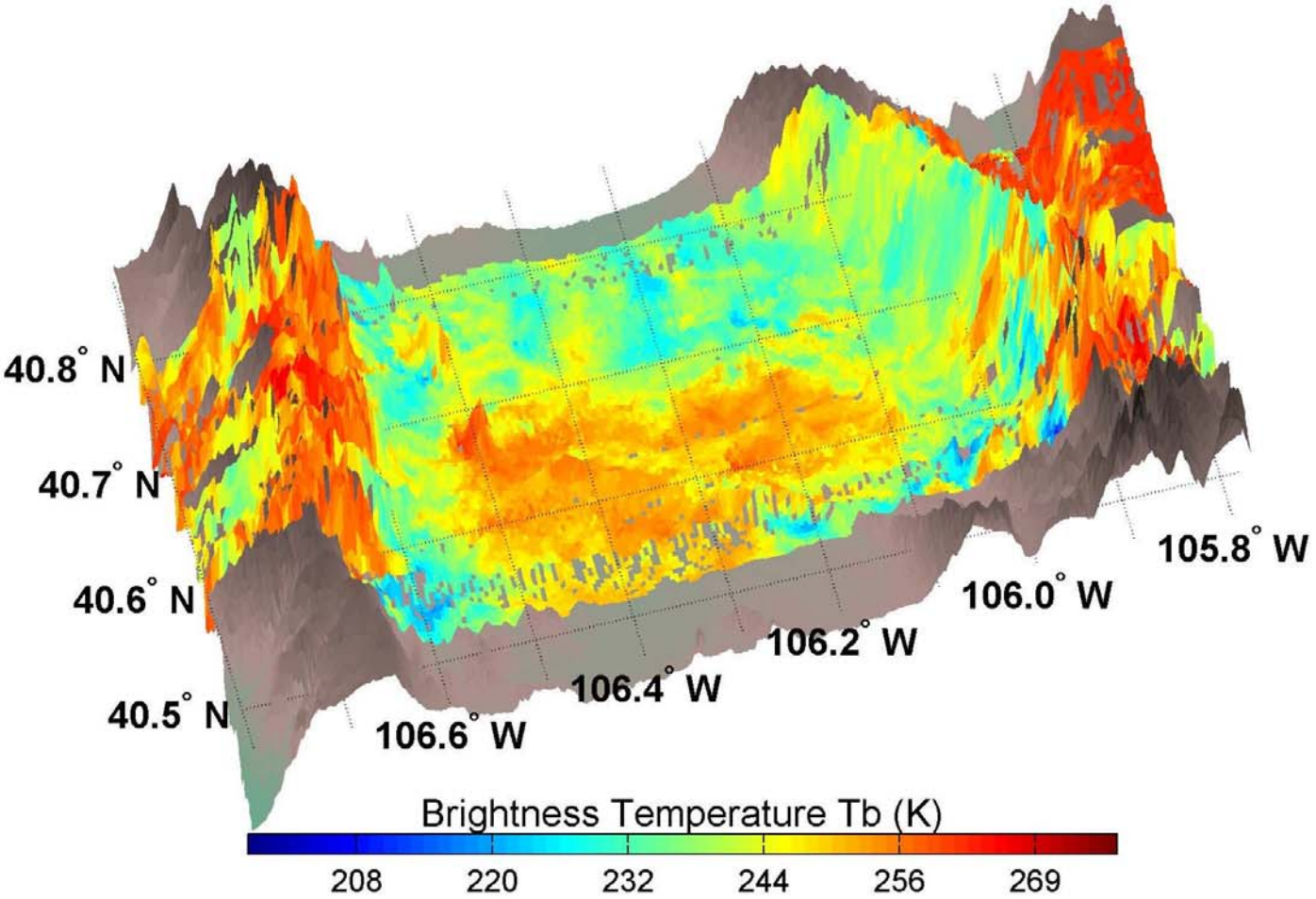

CLPX03B

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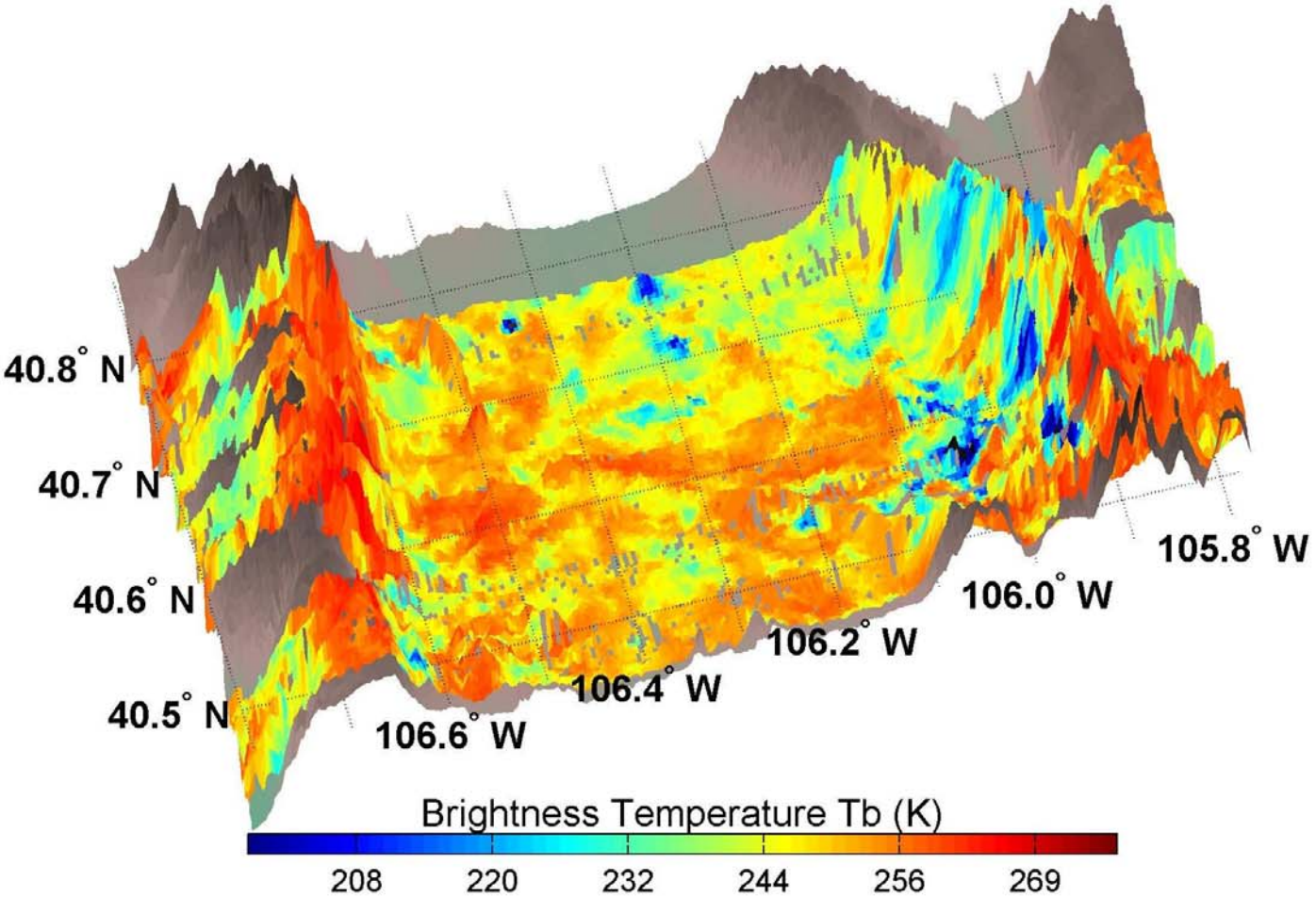

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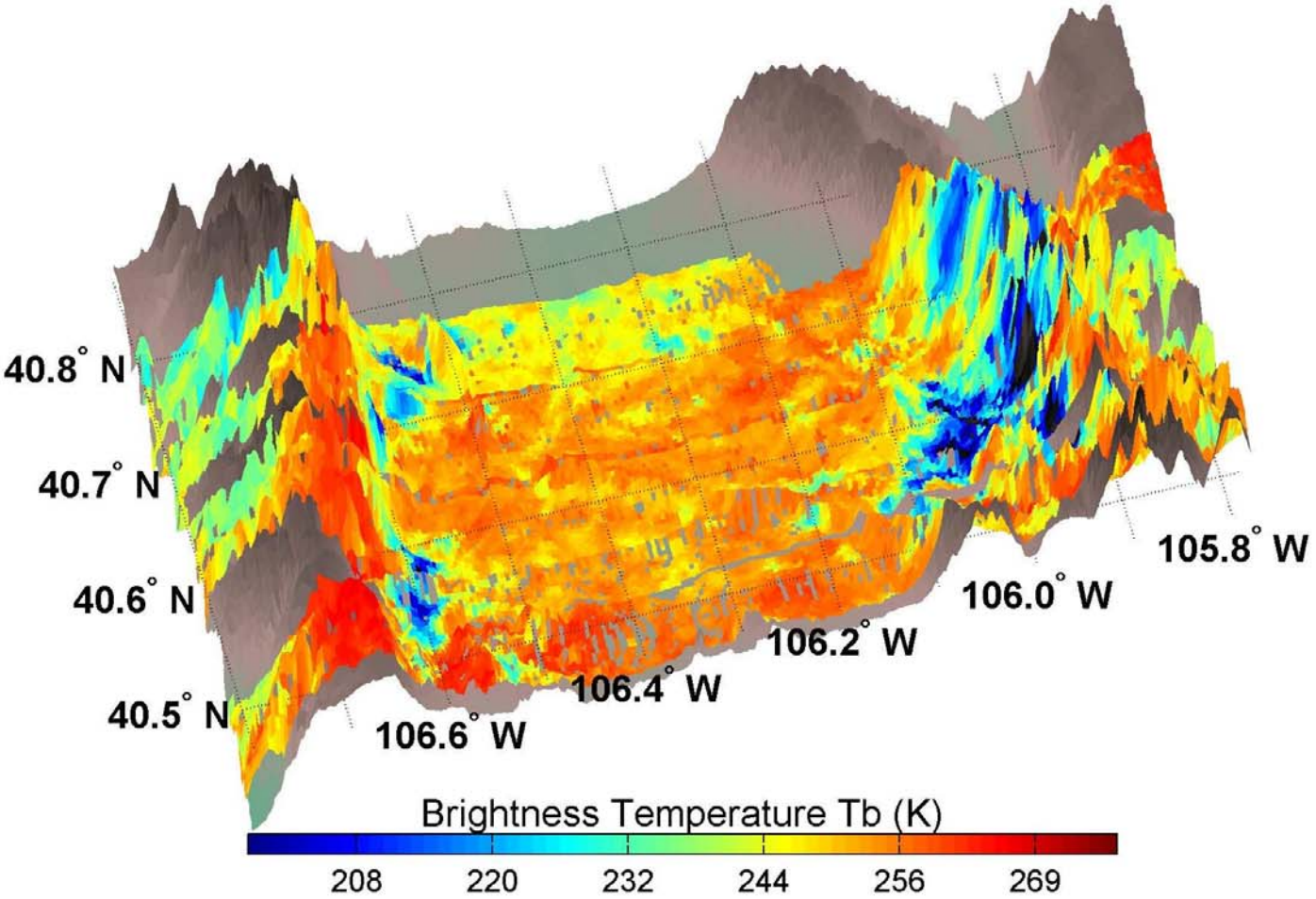

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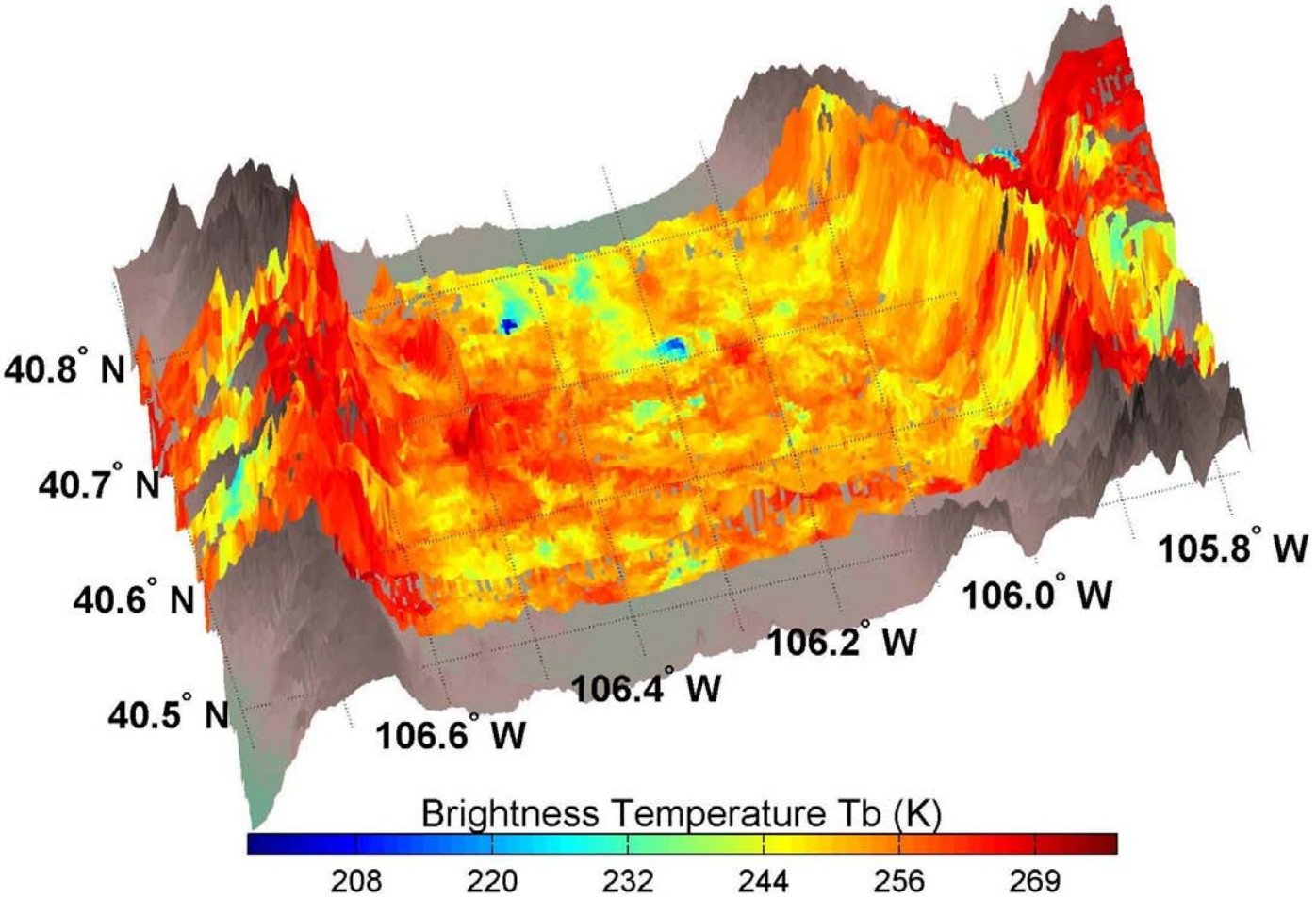
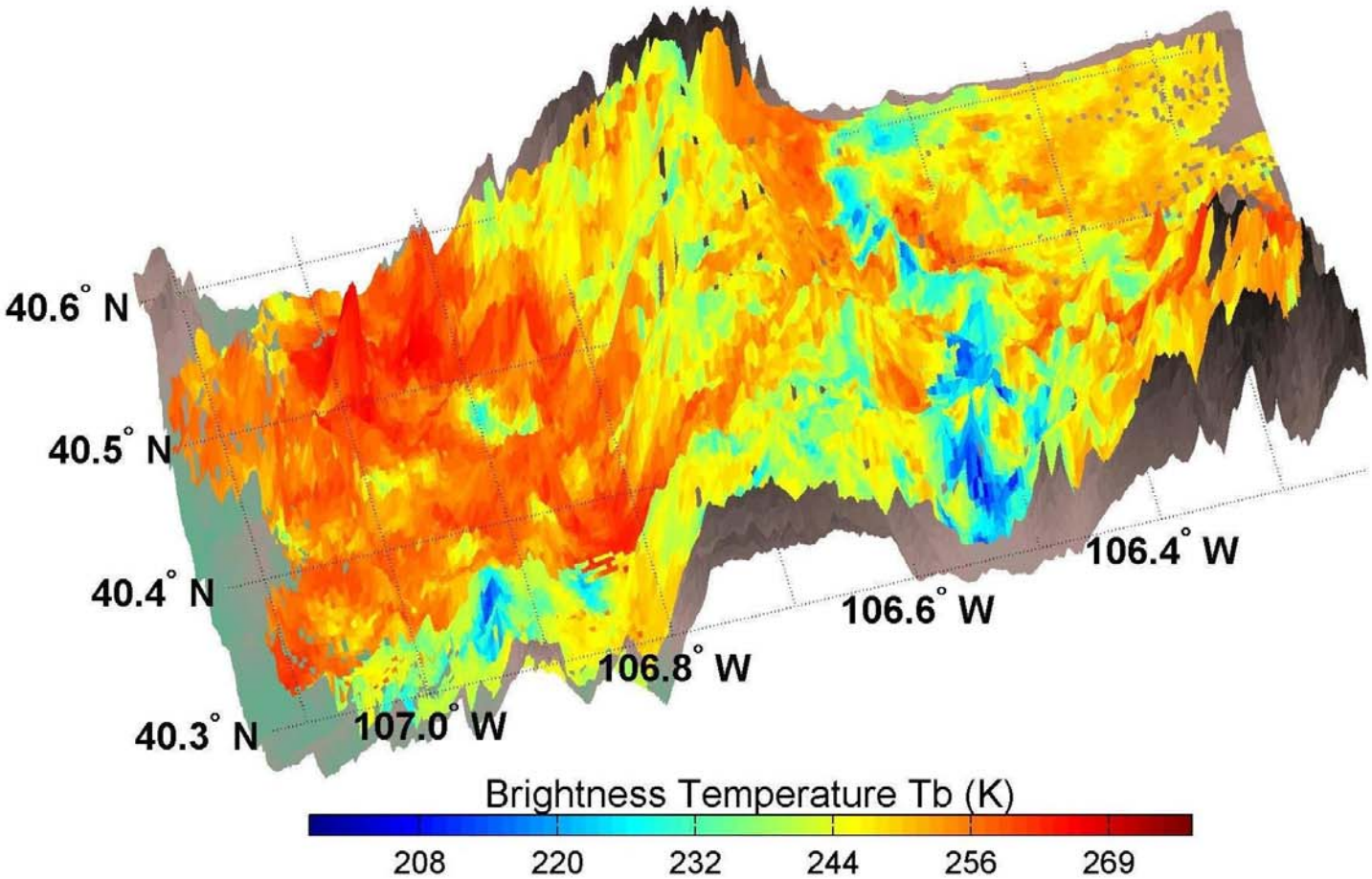


CLPX02

RabbitEars: CLPX02 02/19/2002 21.5 GHz Th



CLPX03A

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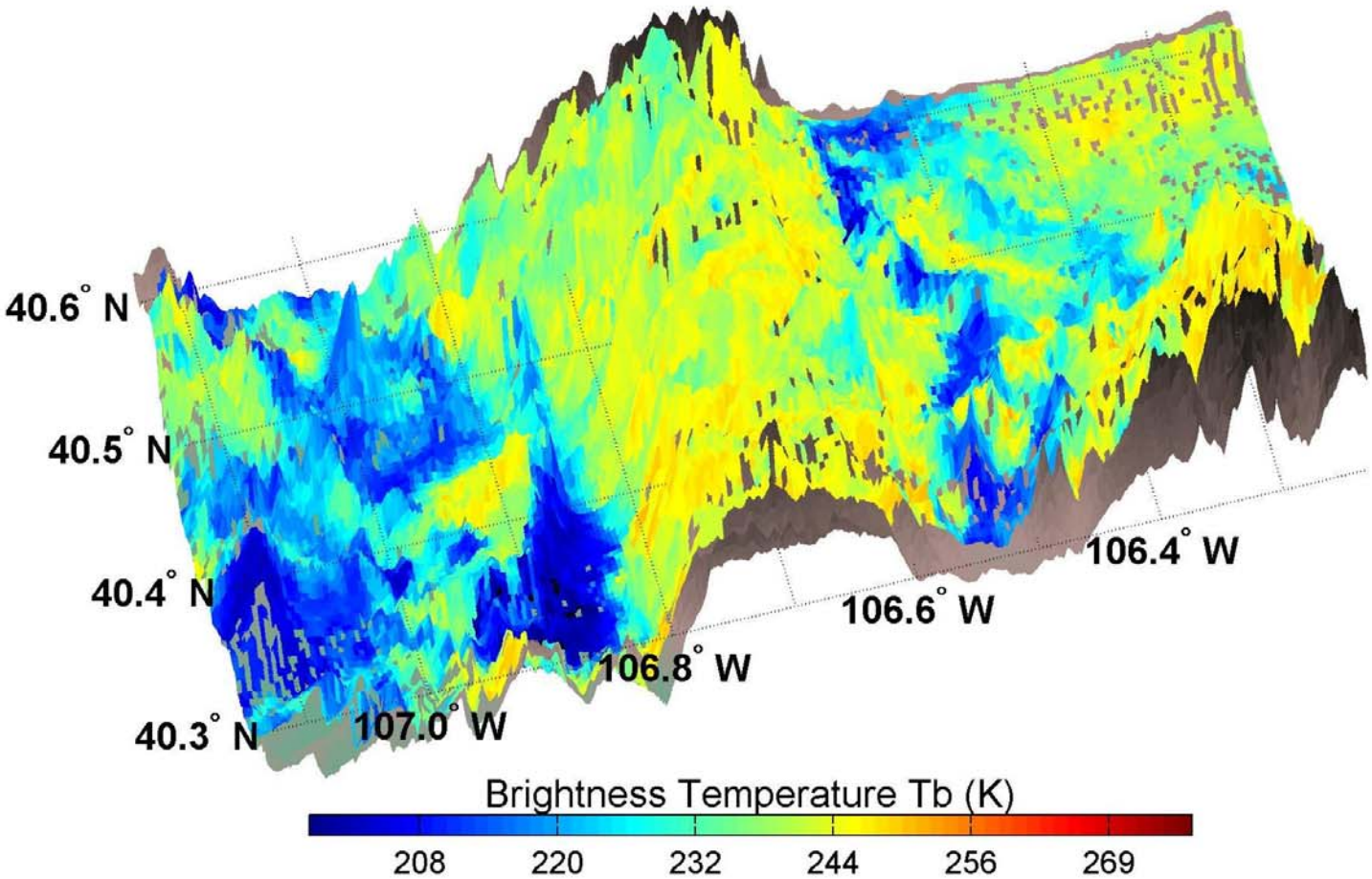

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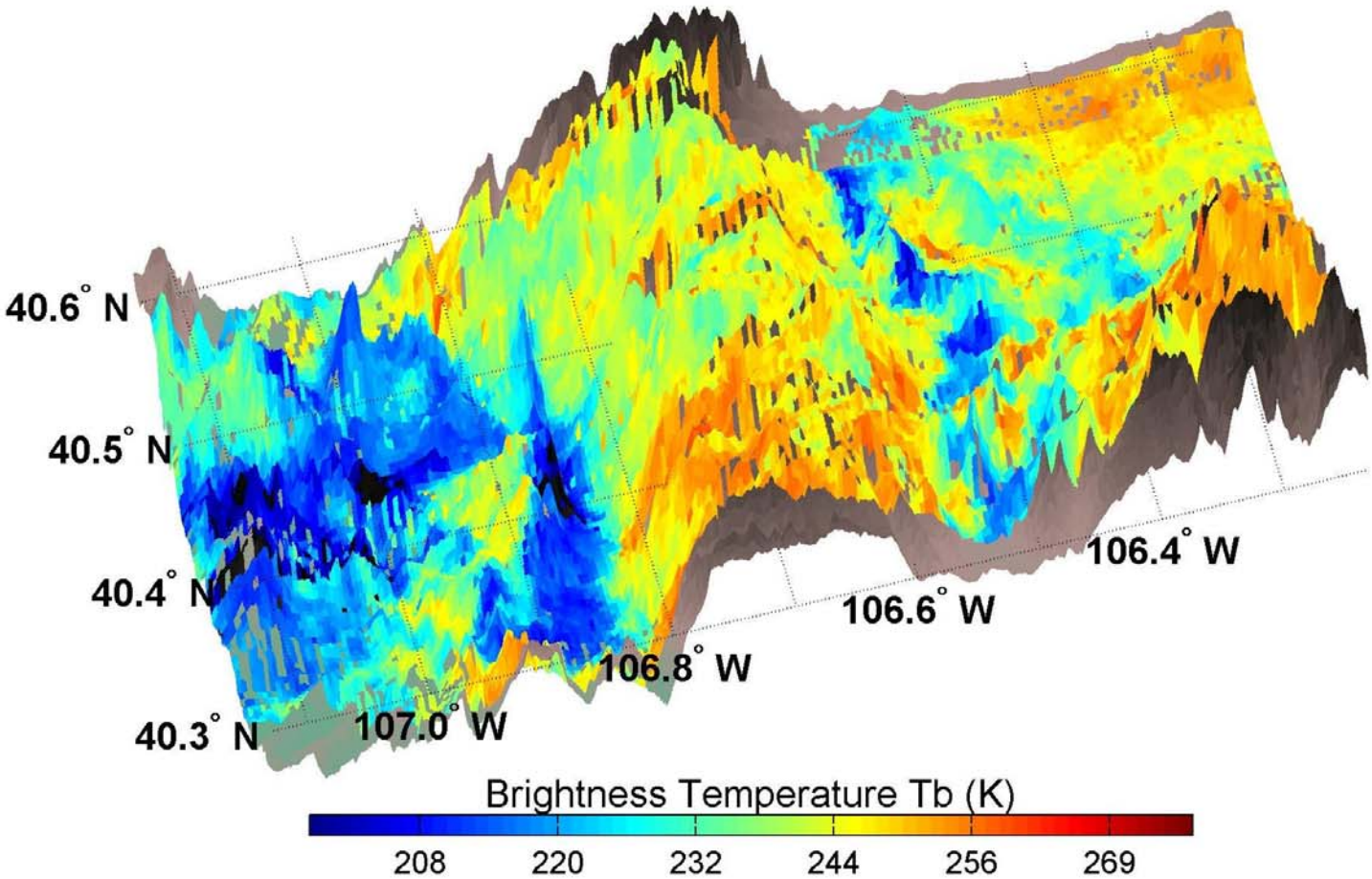

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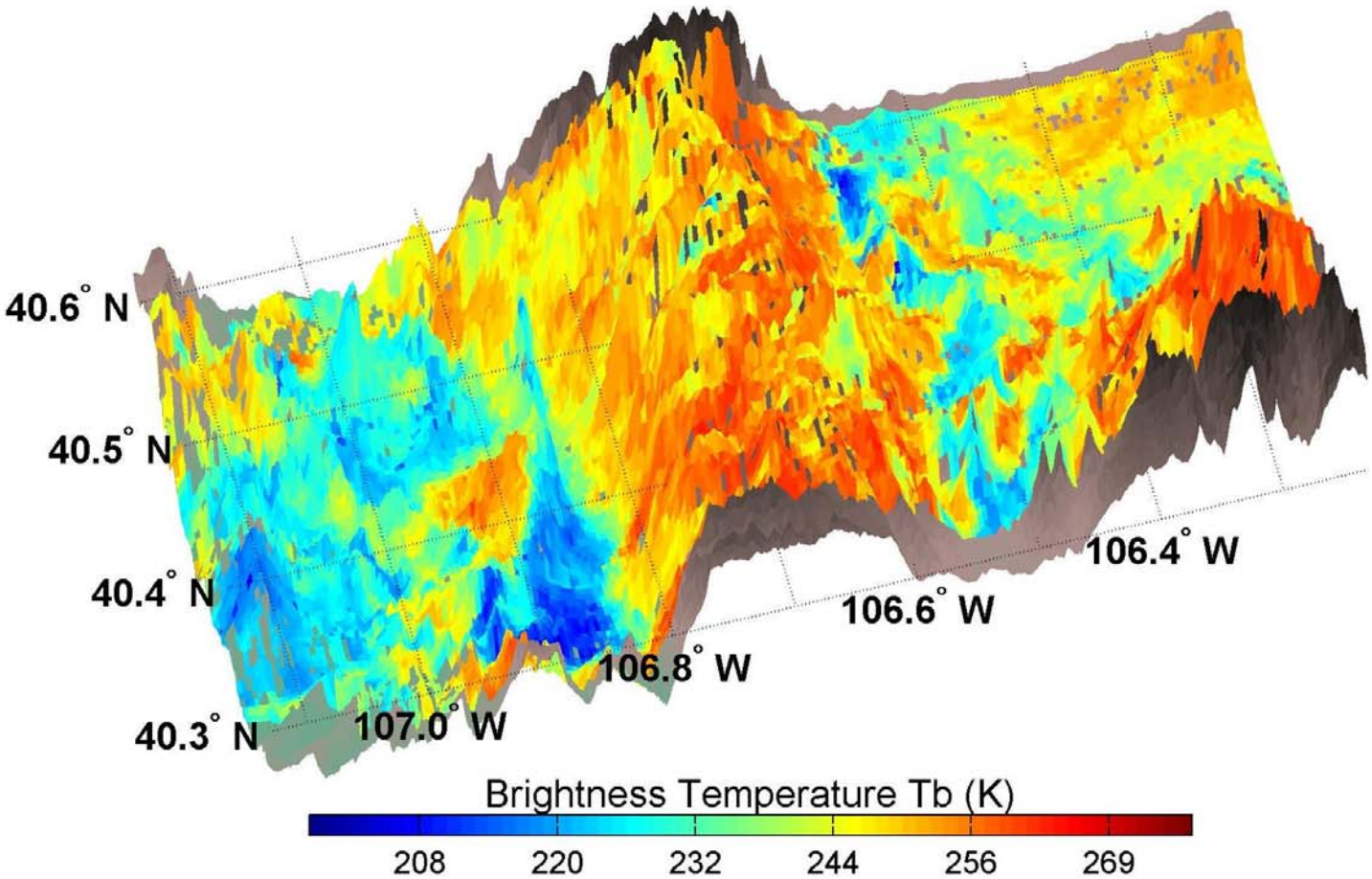

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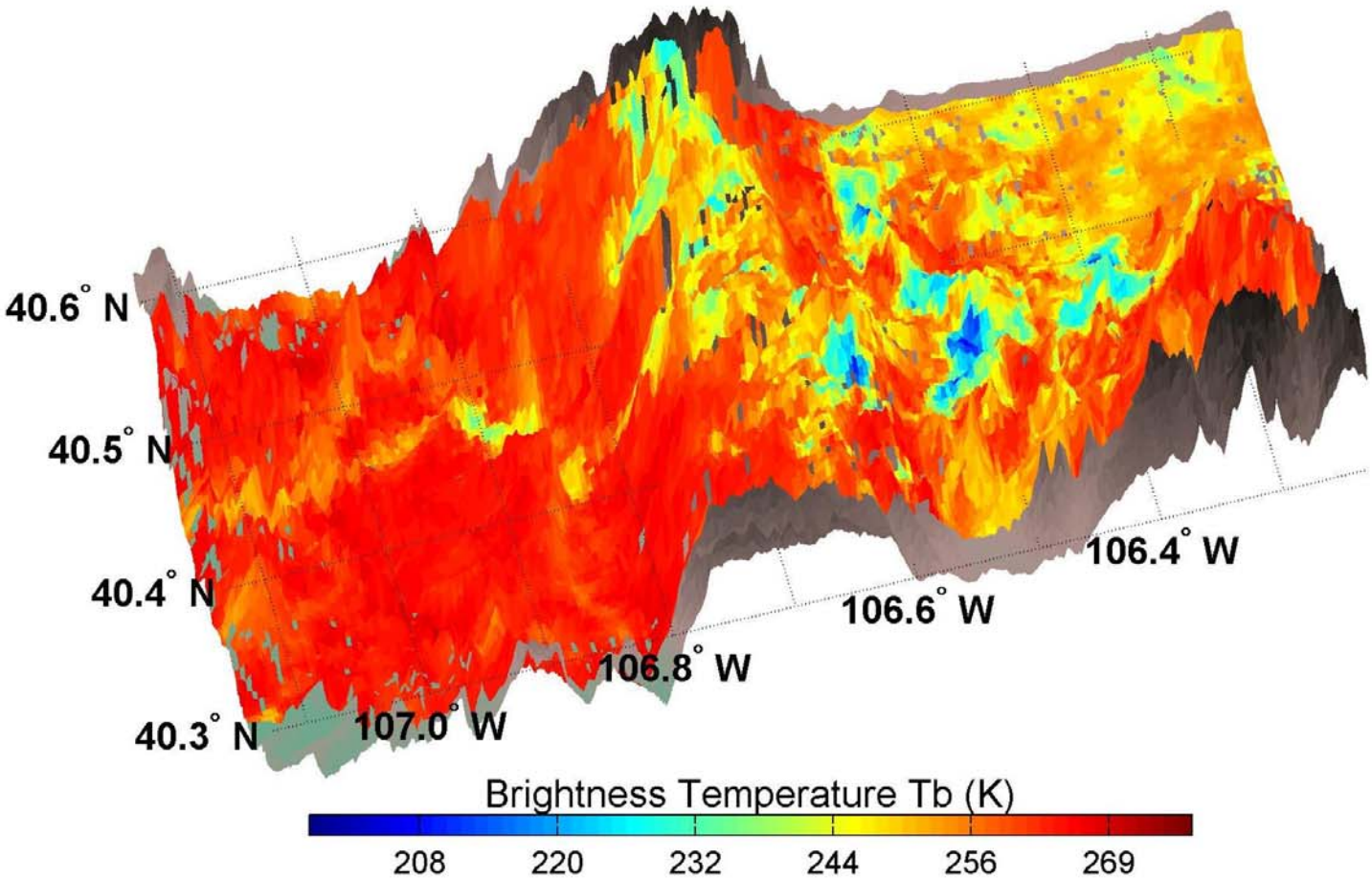

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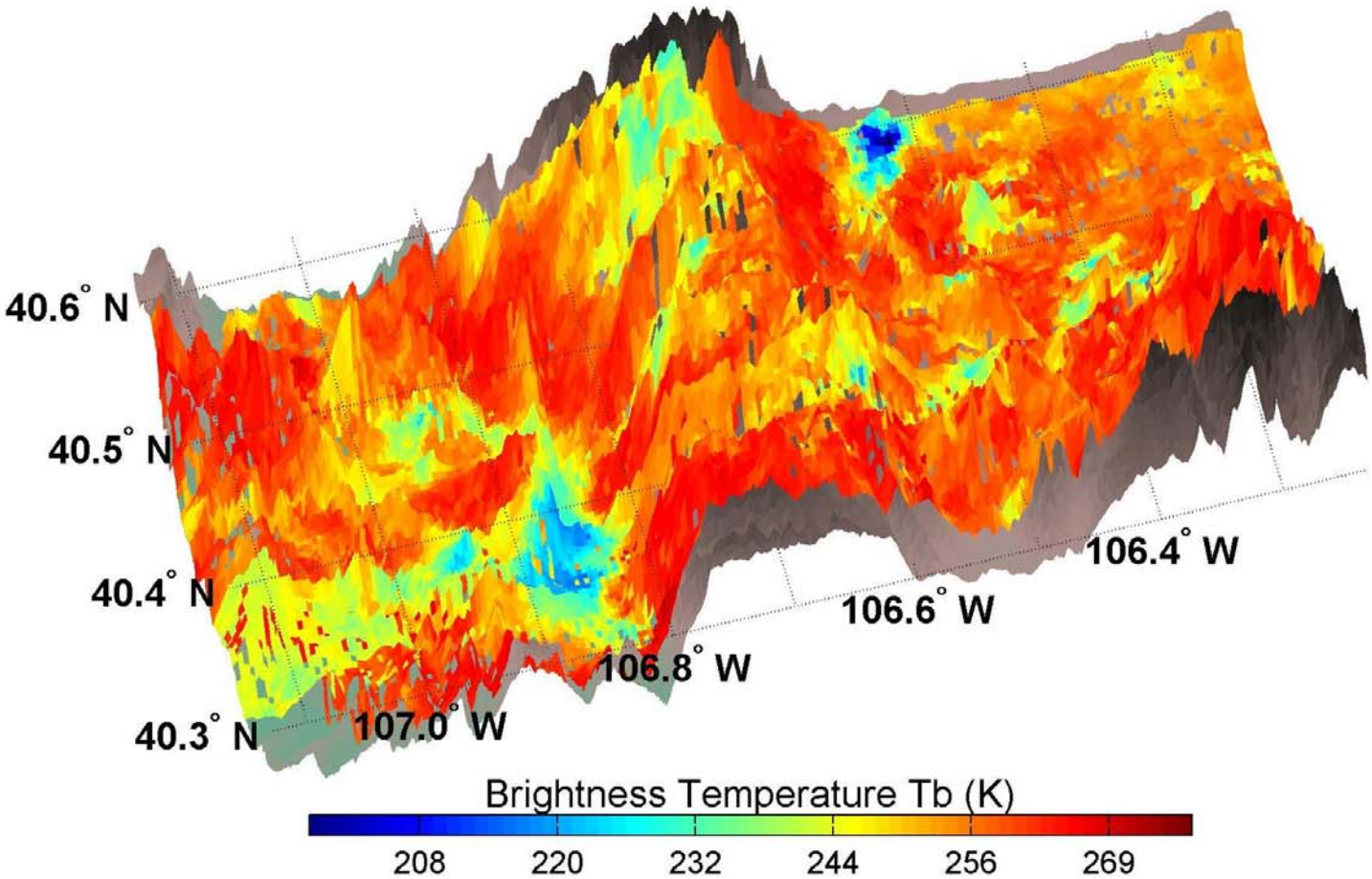

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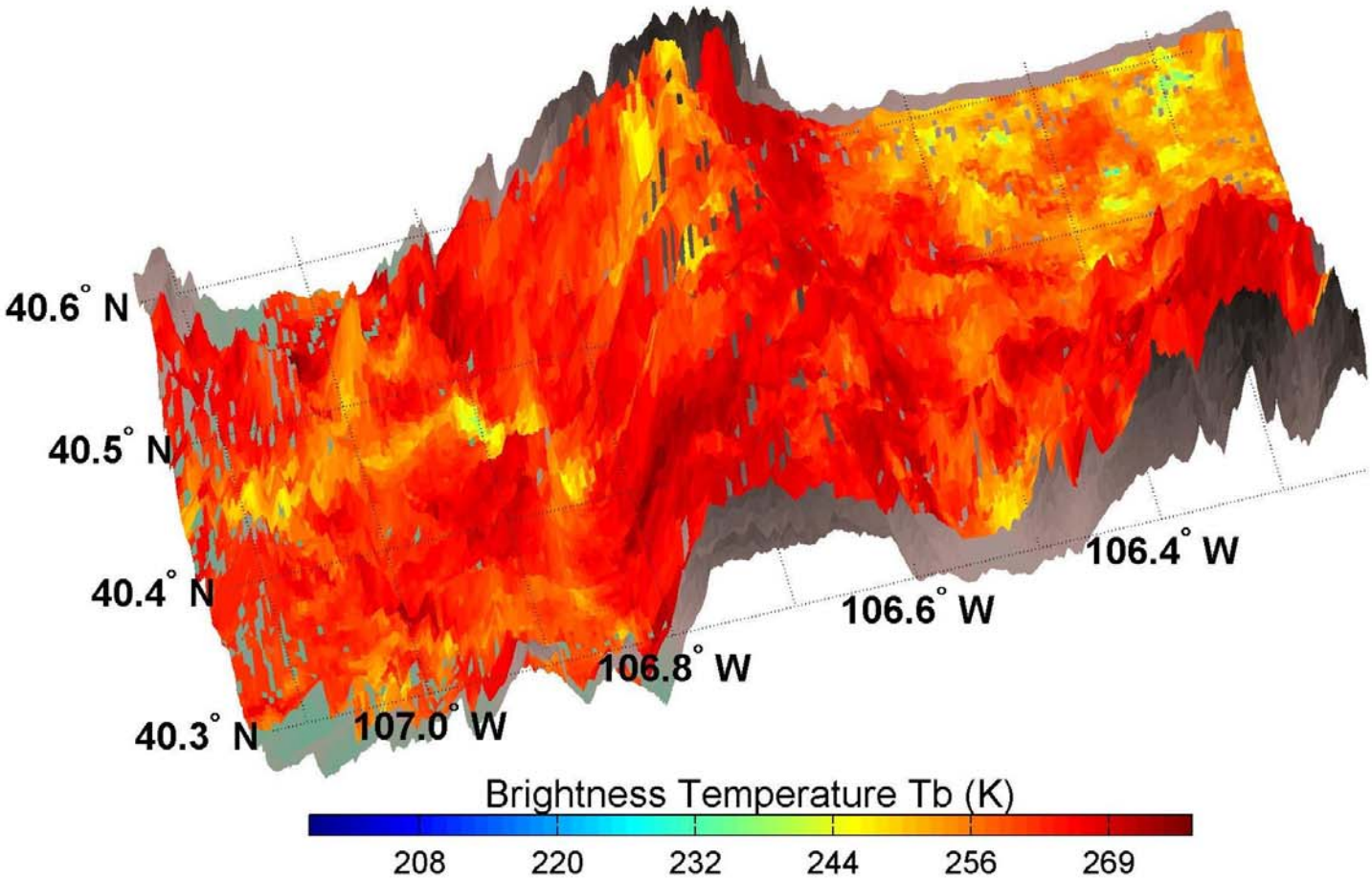

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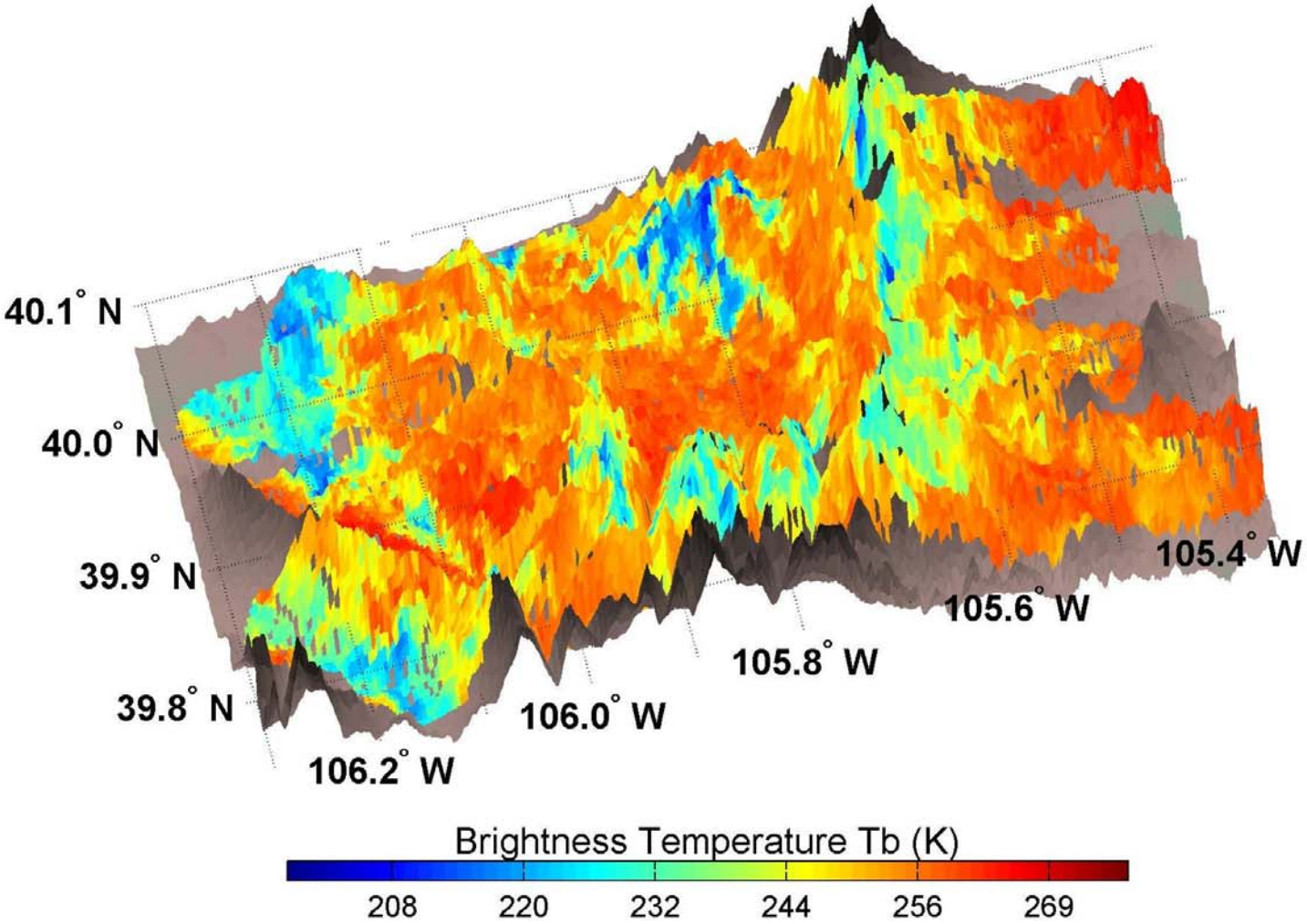
Fraser: CLPX02 02/21/2002 21.5 GHz Th



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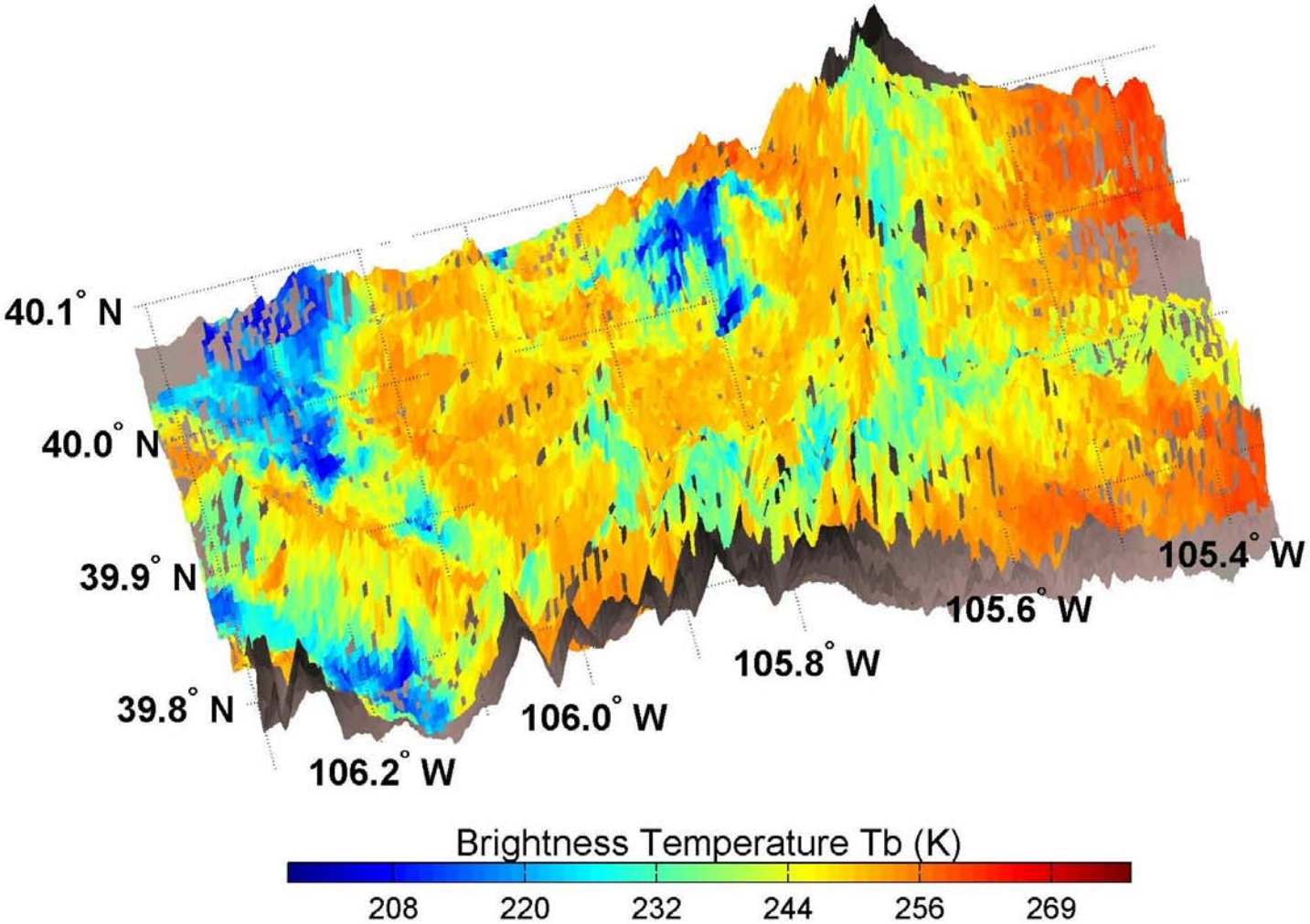

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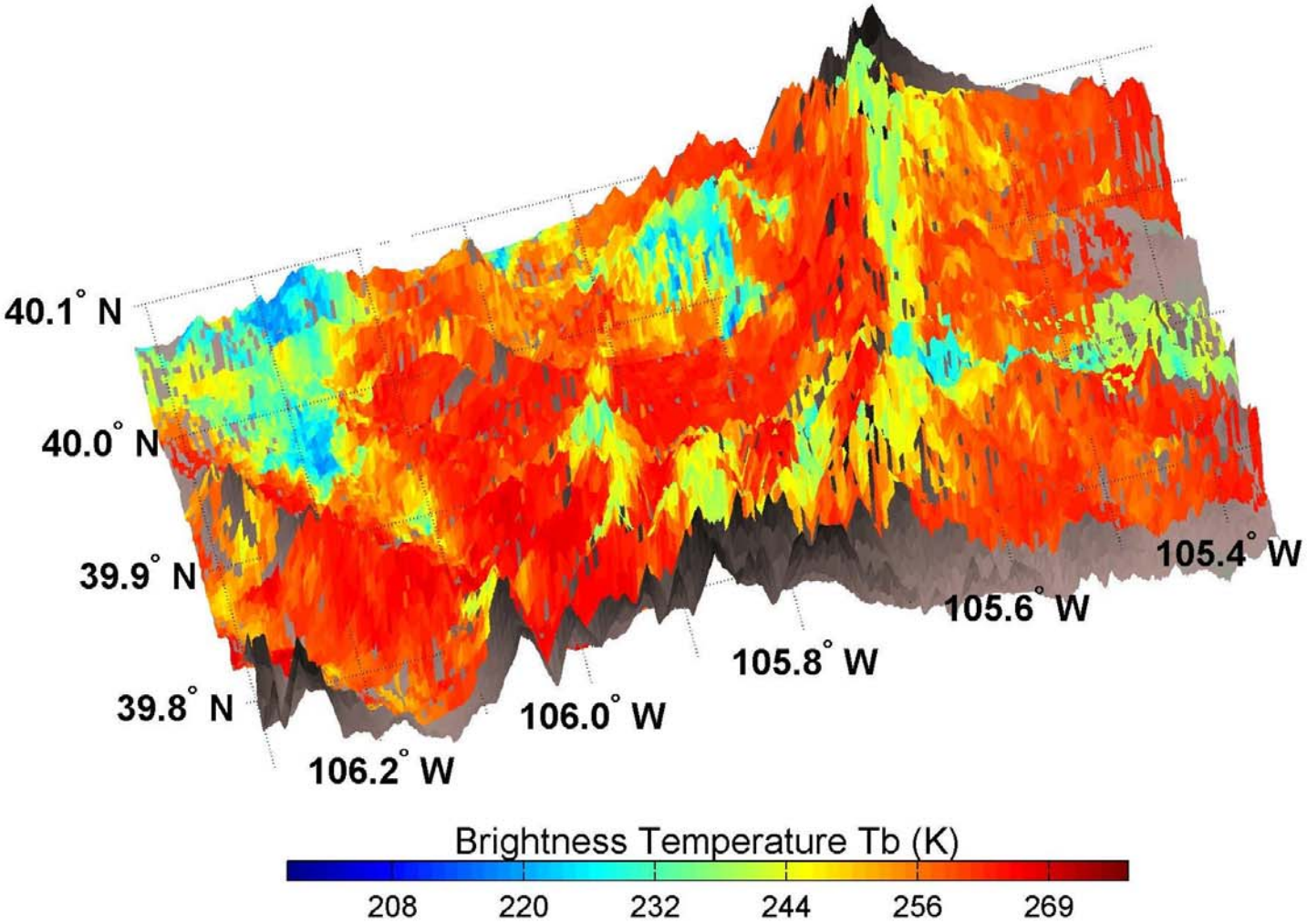

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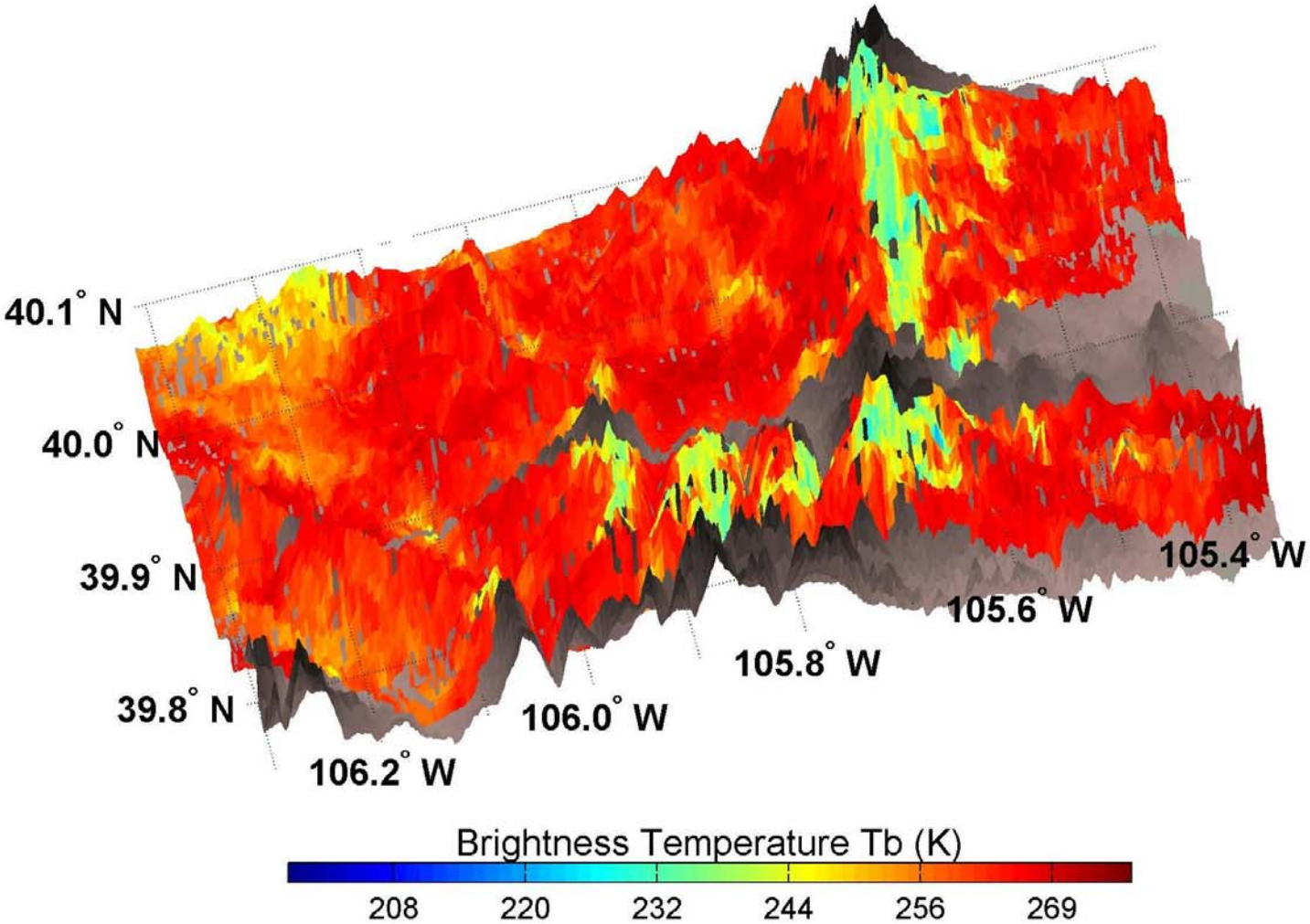

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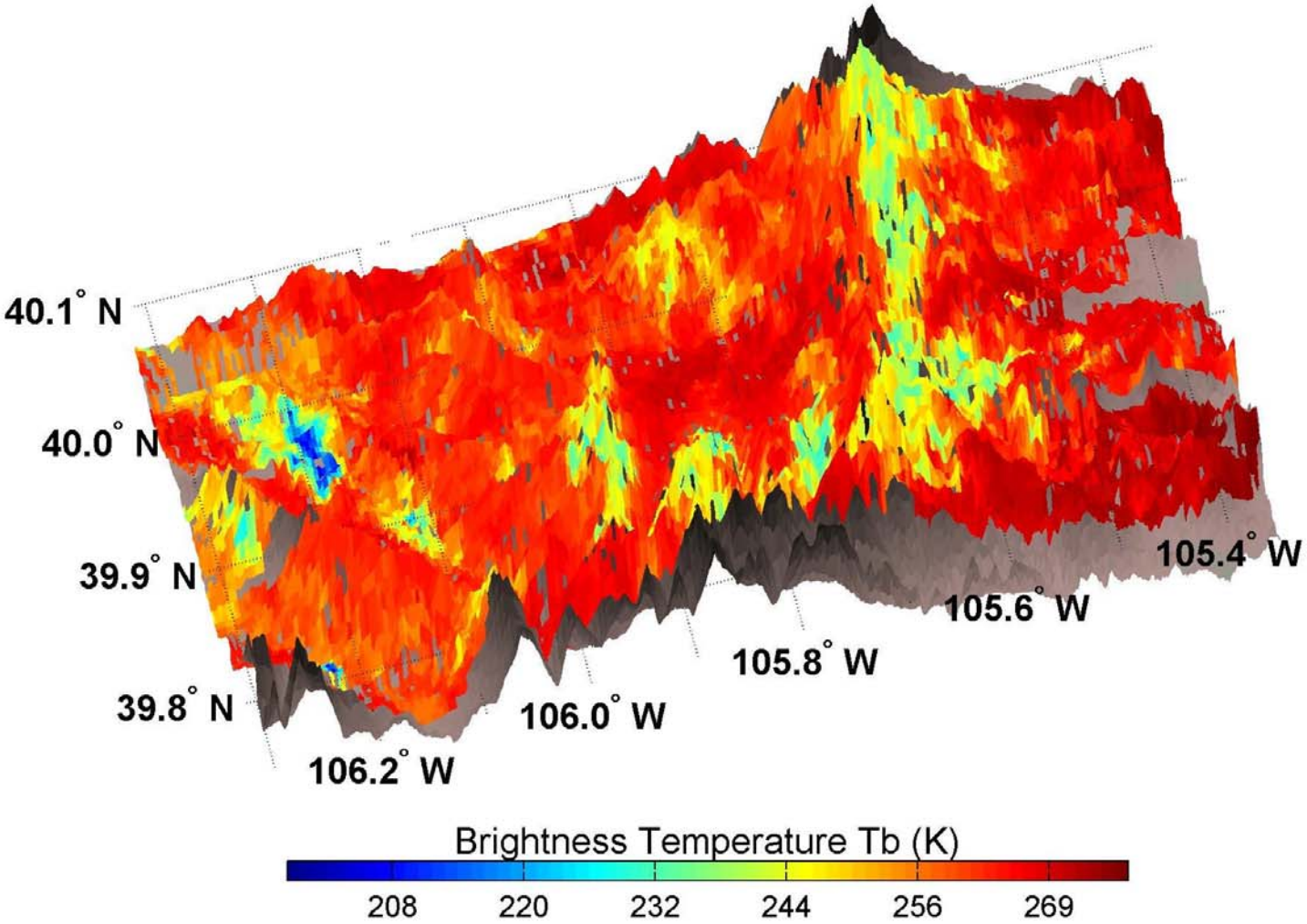

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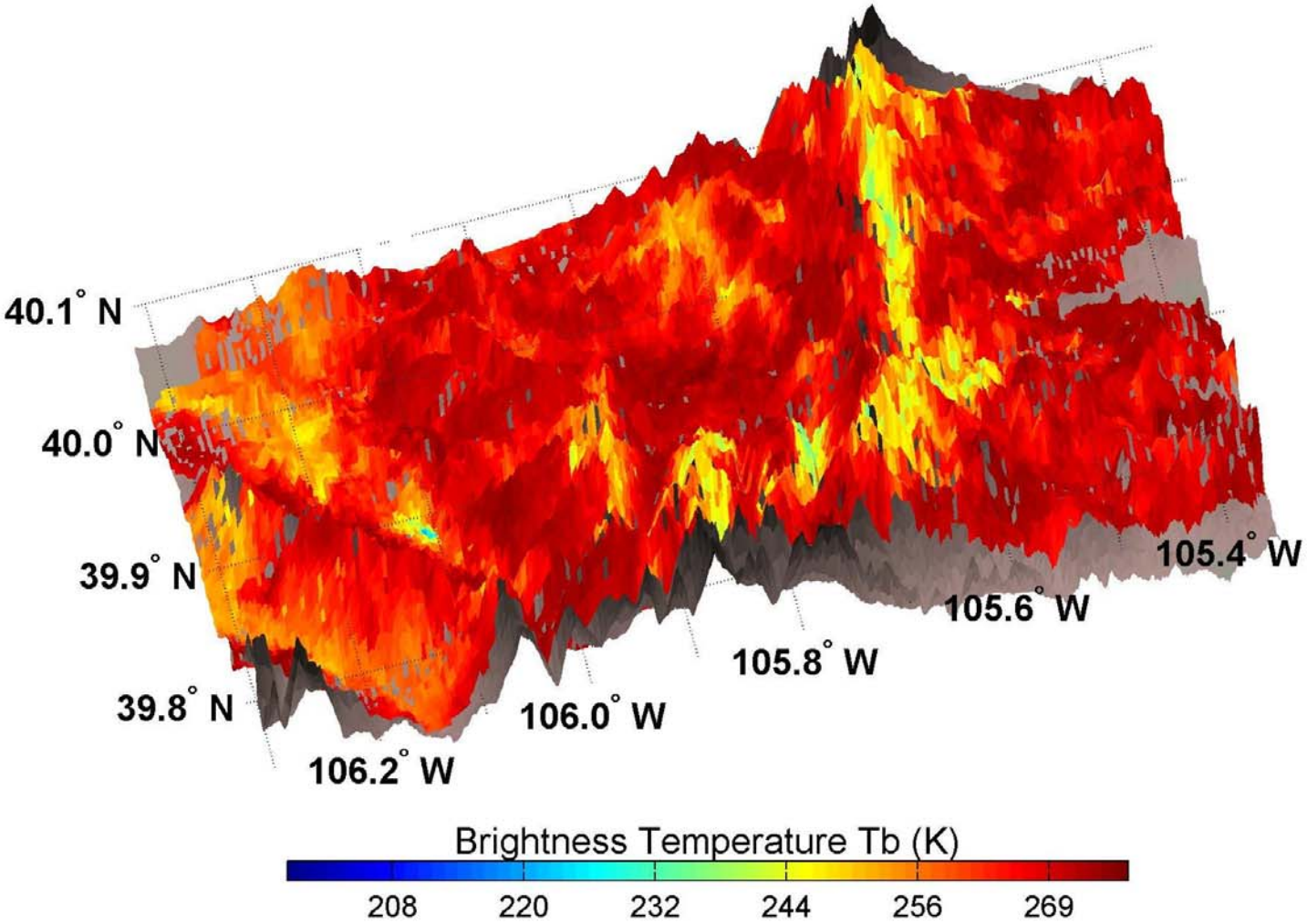

CLPX02-03 PSR/A Snowpack Images

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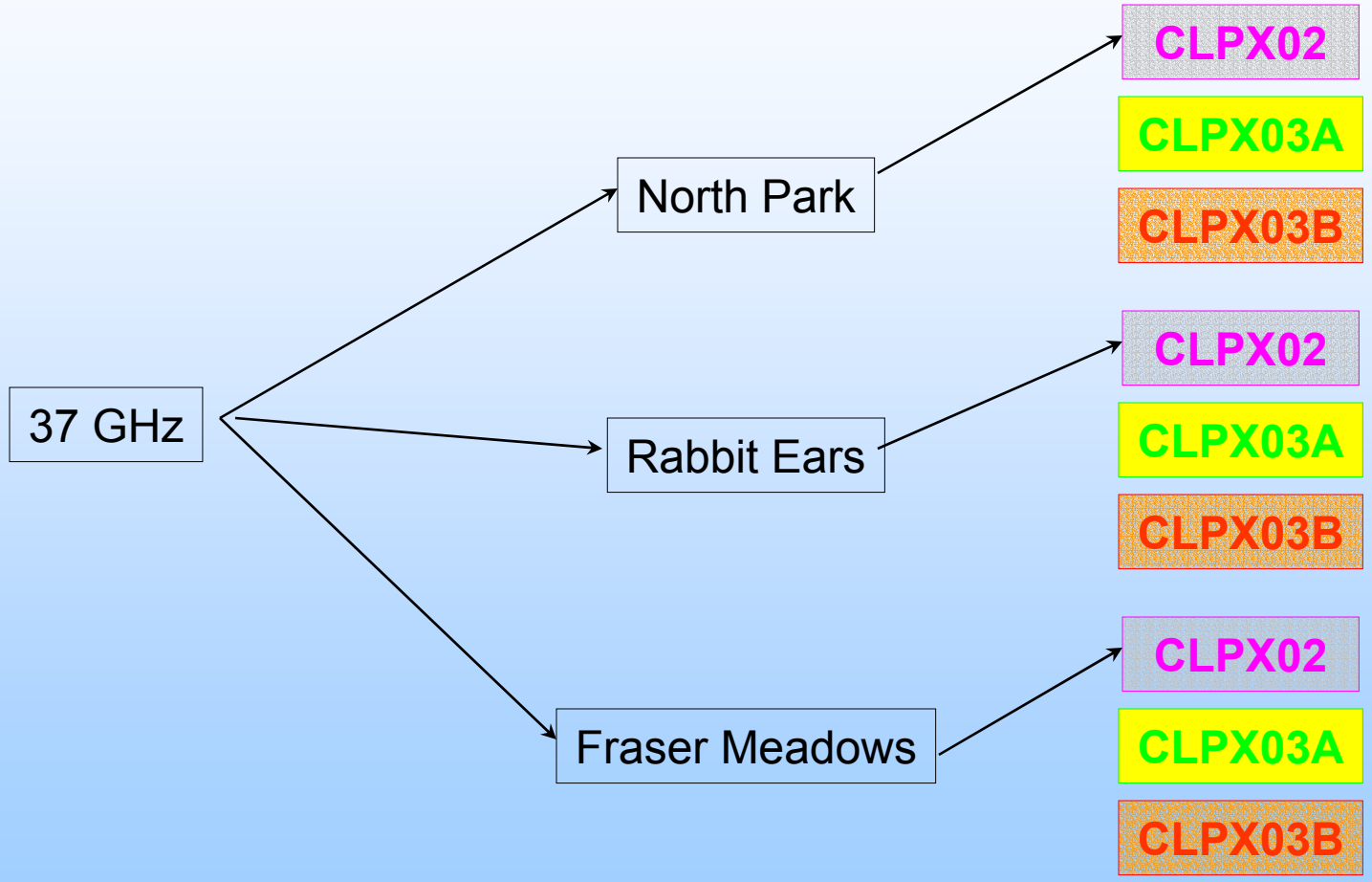
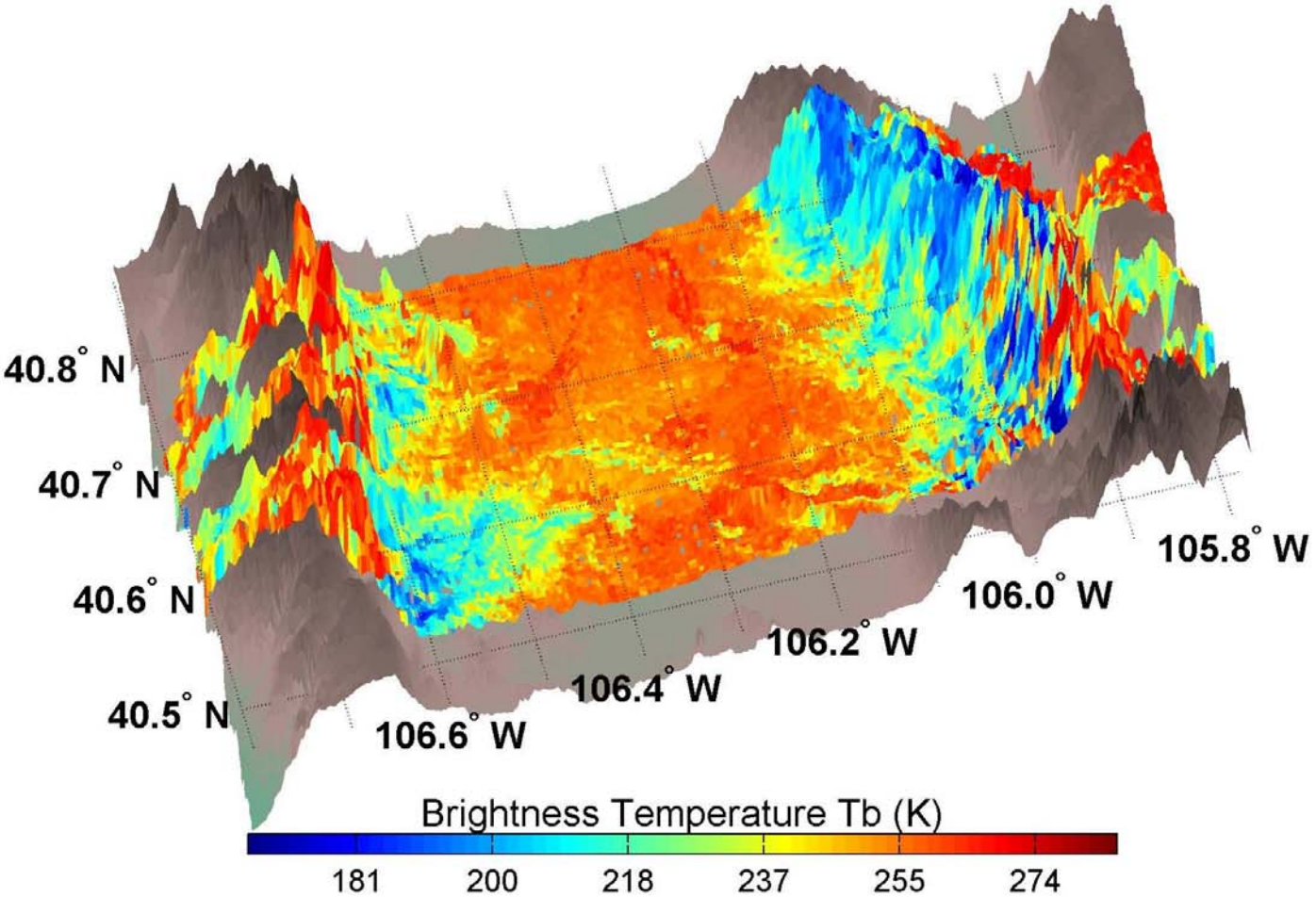


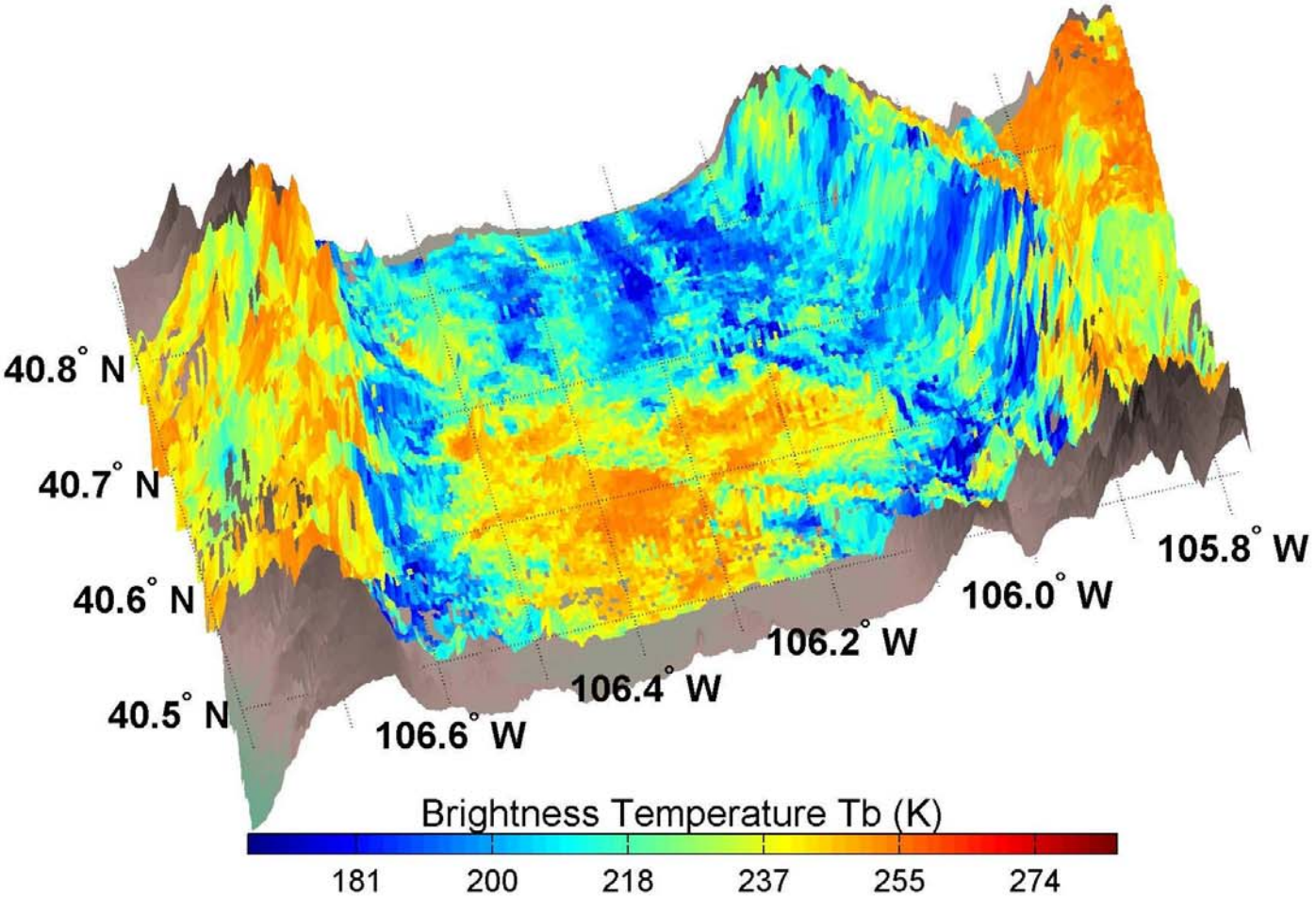
CLPX02

NorthPark: CLPX02 02/23/2002 37.0 GHz Th



CLPX03A

NorthPark: CLPX03A 02/22/2003 37.0 GHz Th



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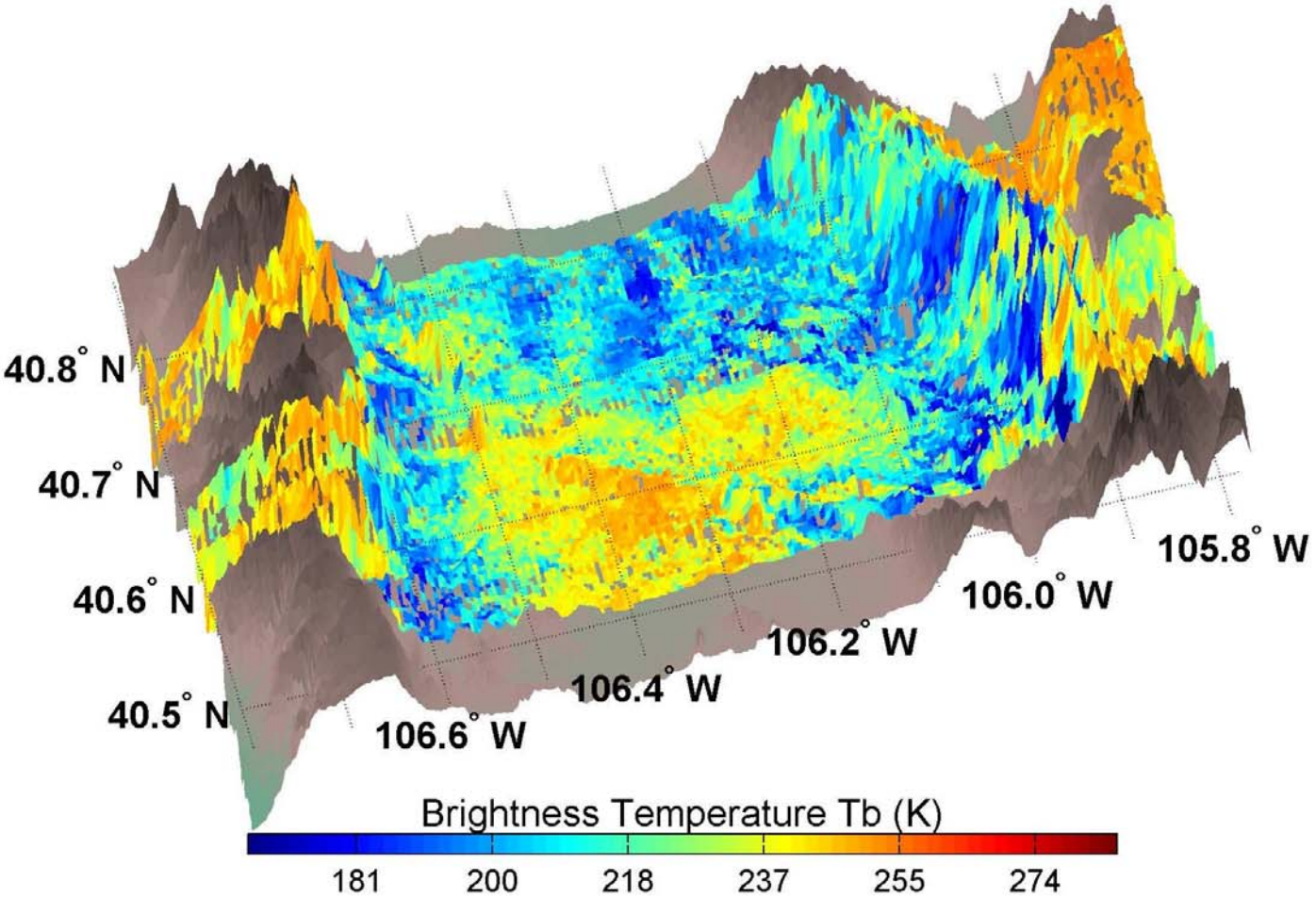

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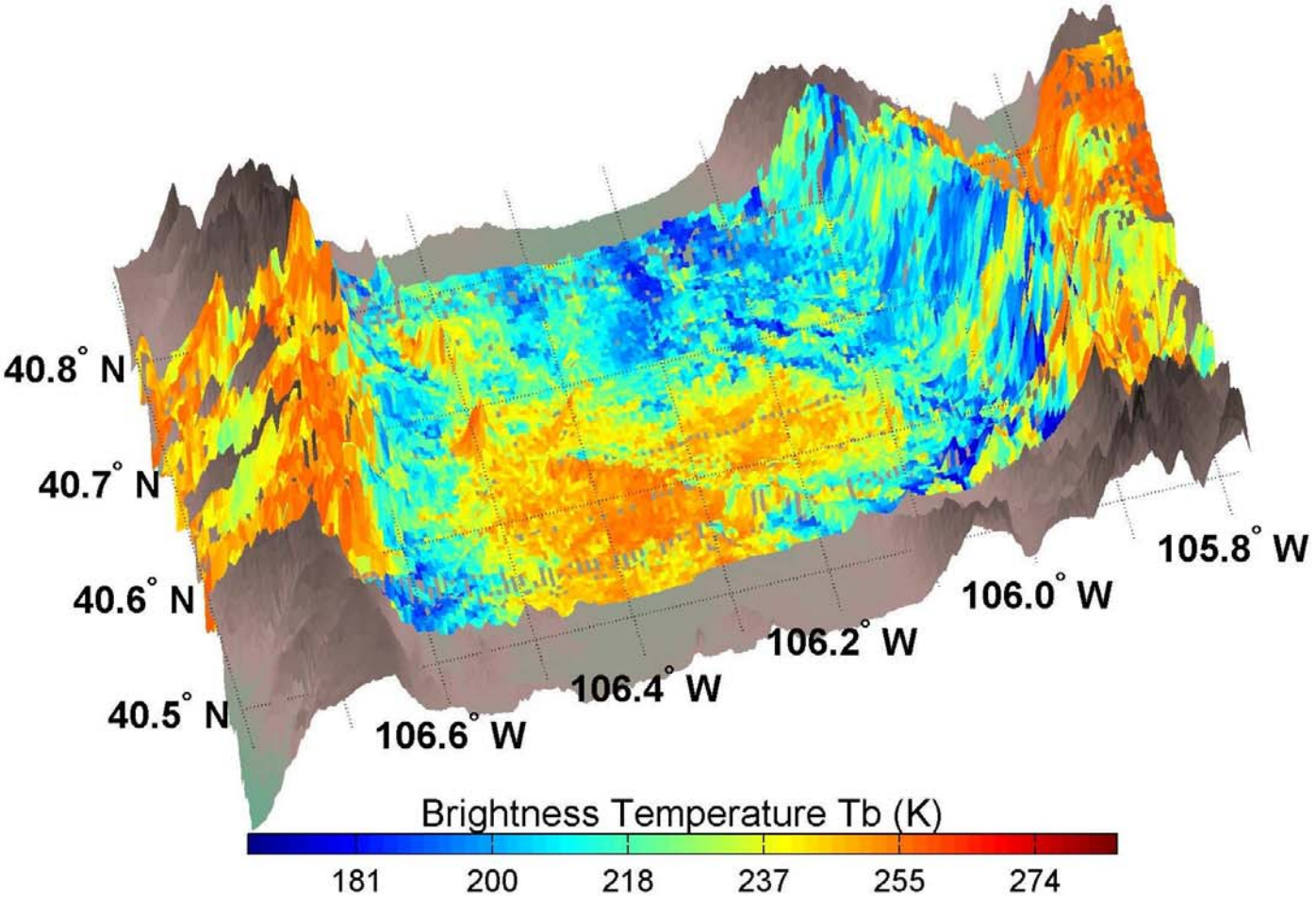

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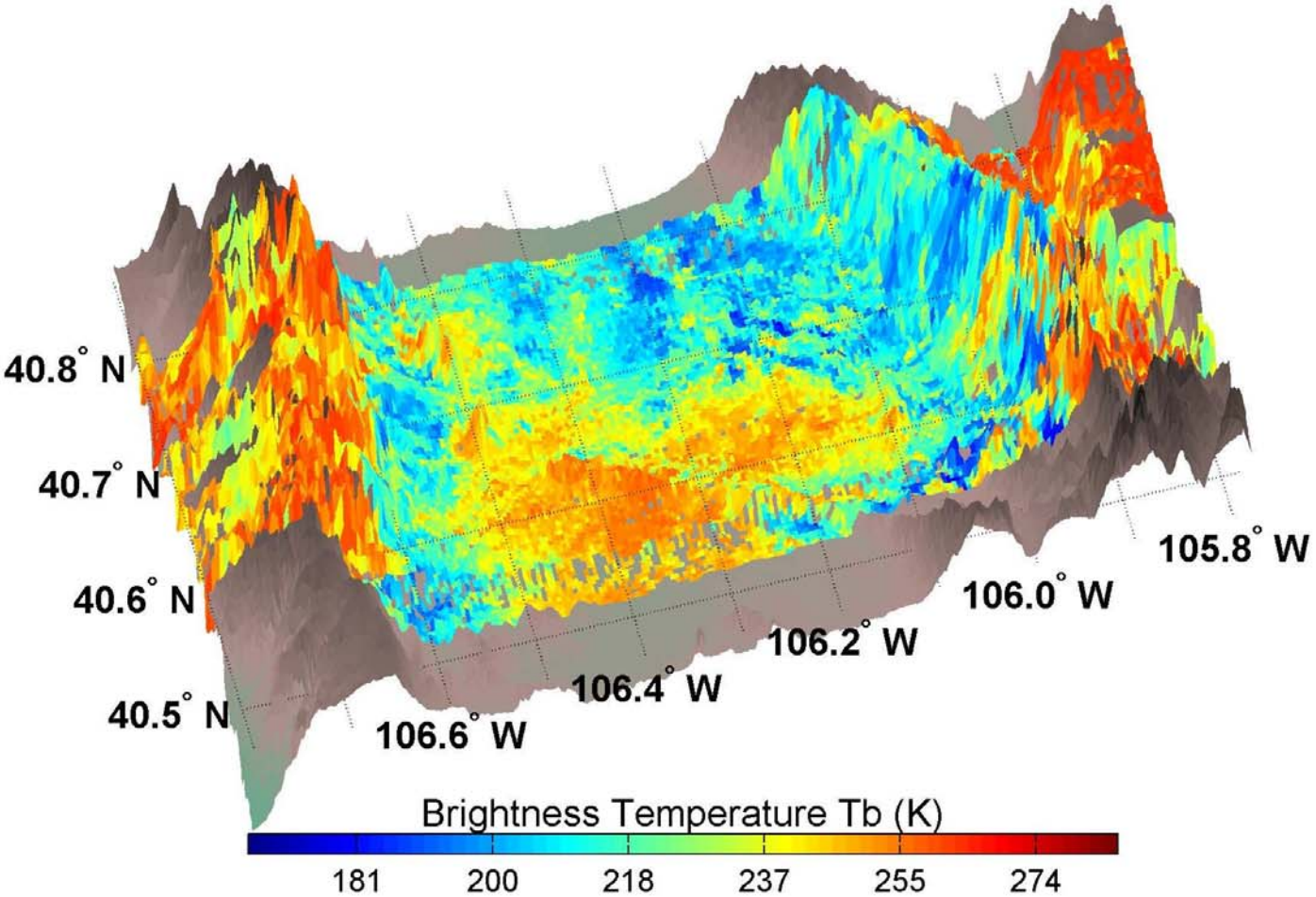

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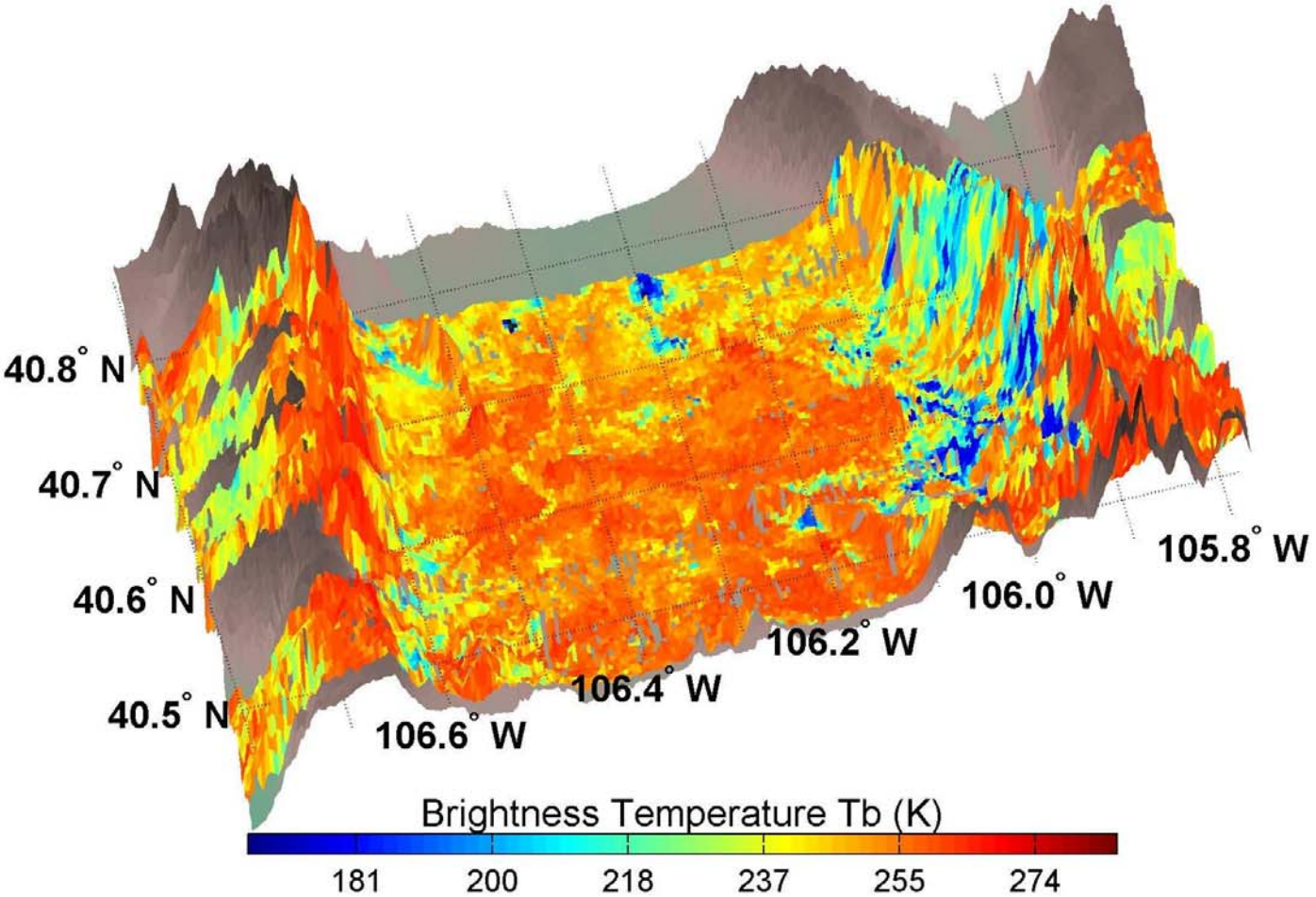
NorthPark: CLPX03B 03/25/2003 37.0 GHz Th



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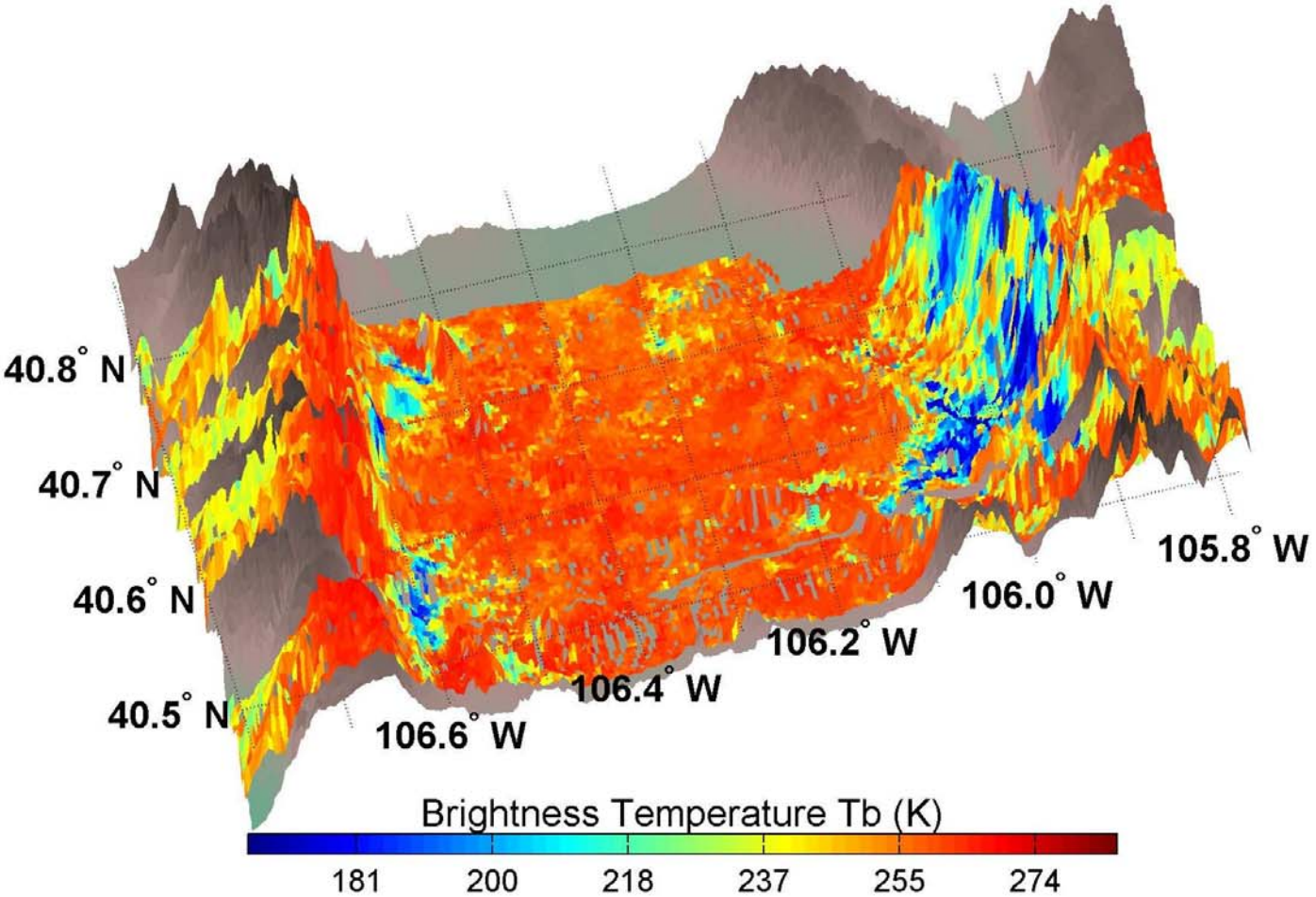

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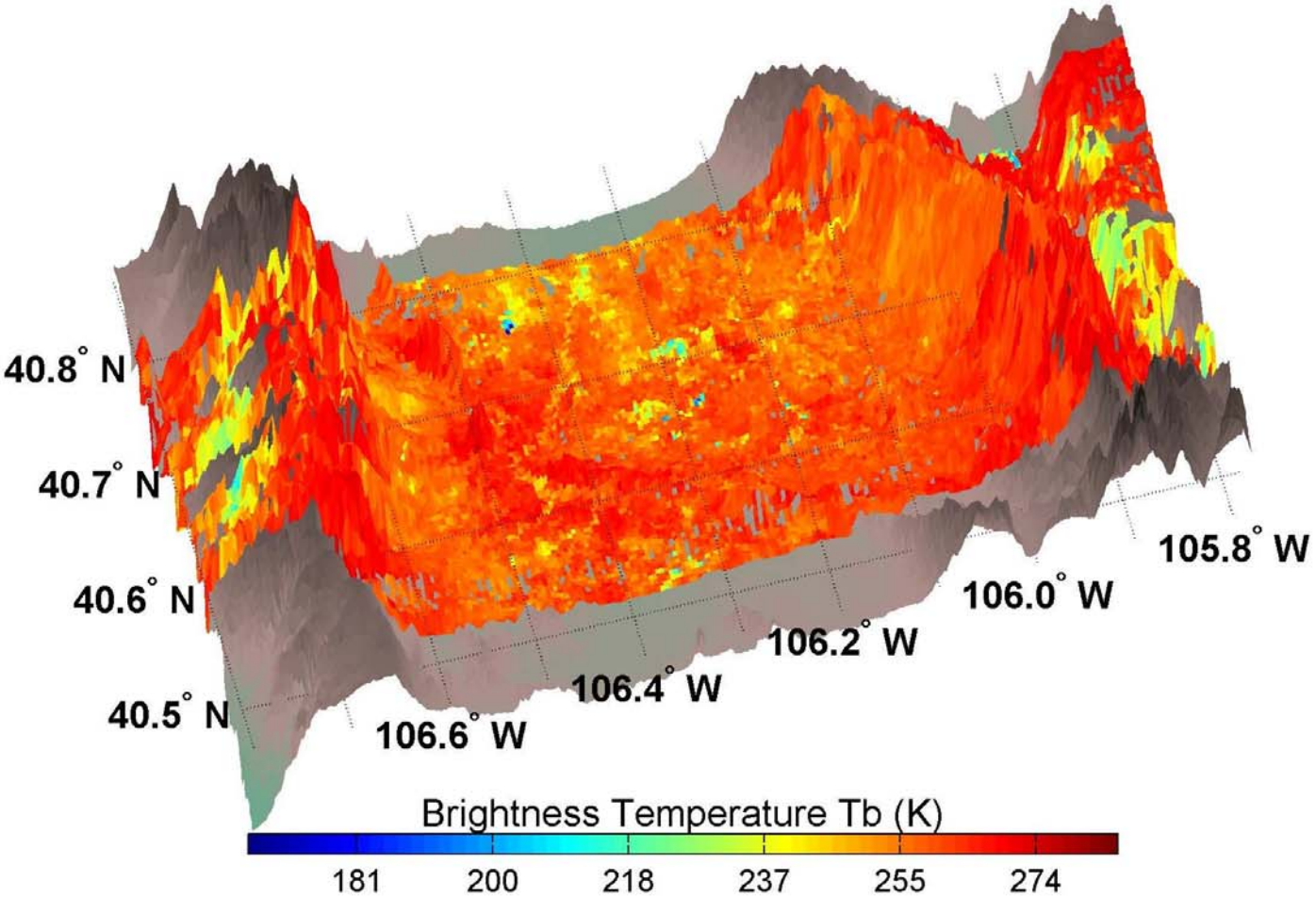
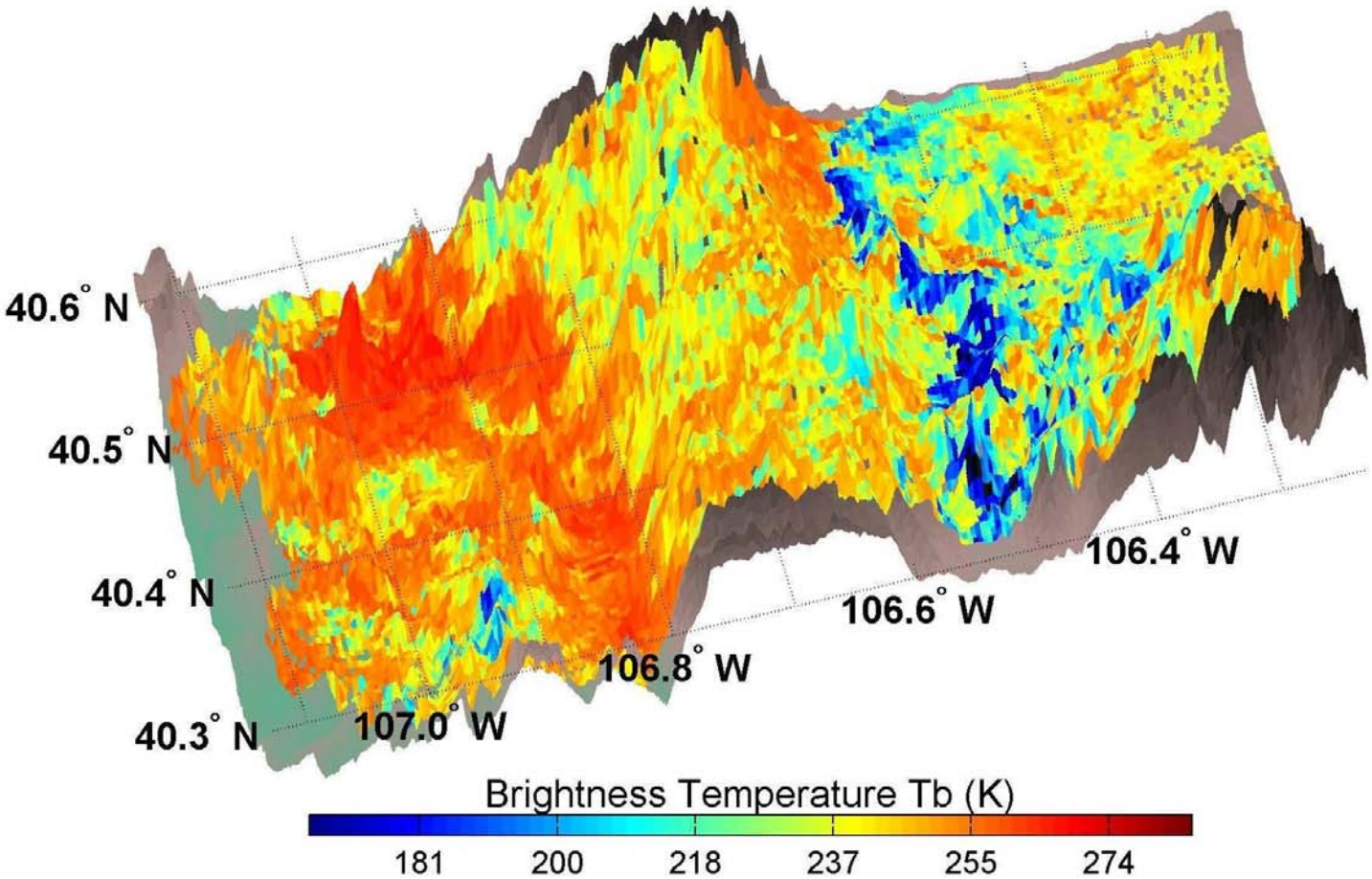


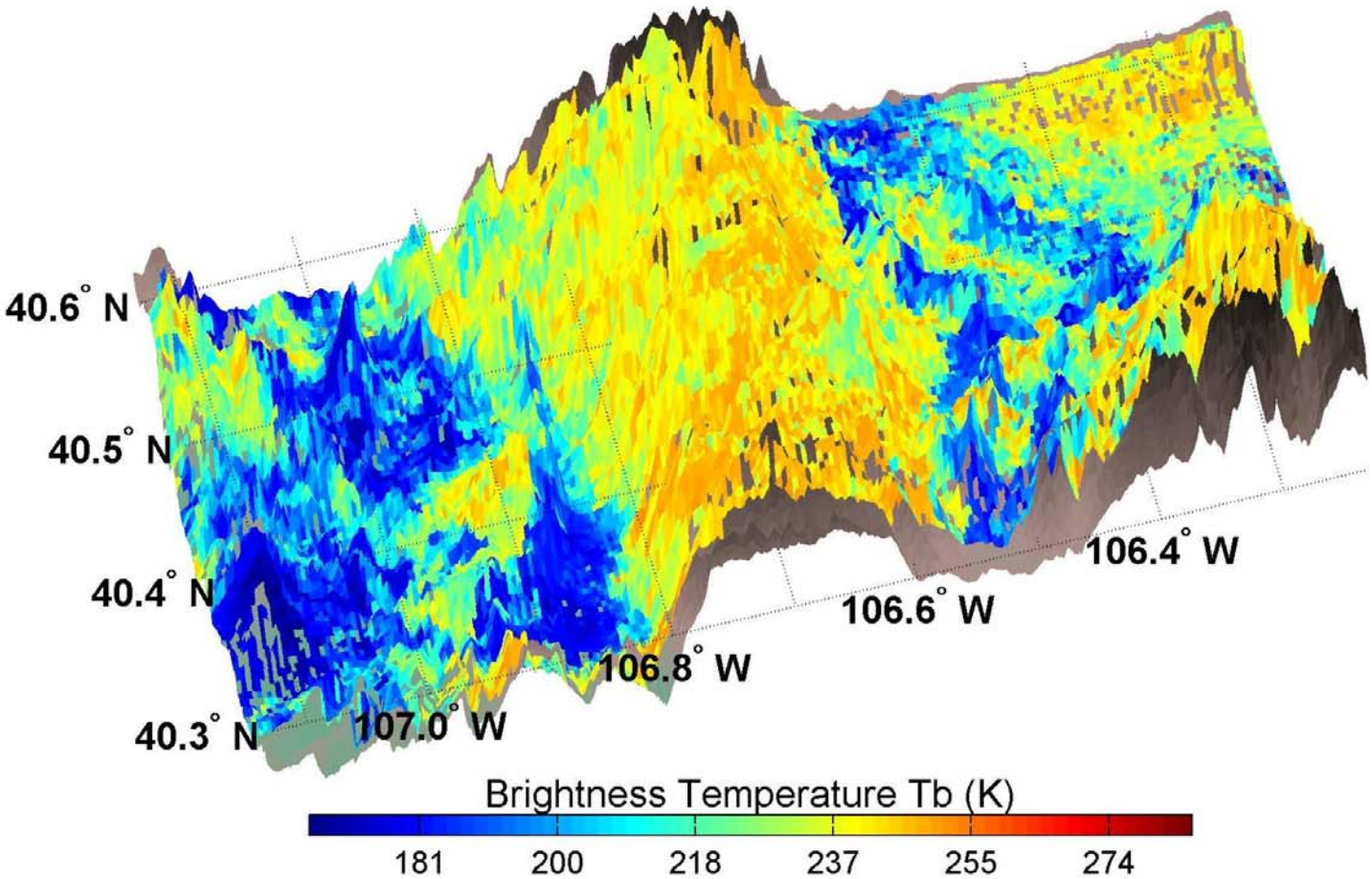
CLPX02

RabbitEars: CLPX02 02/19/2002 37.0 GHz Th



CLPX03A

RabbitEars: CLPX03A 02/23/2003 37.0 GHz Th



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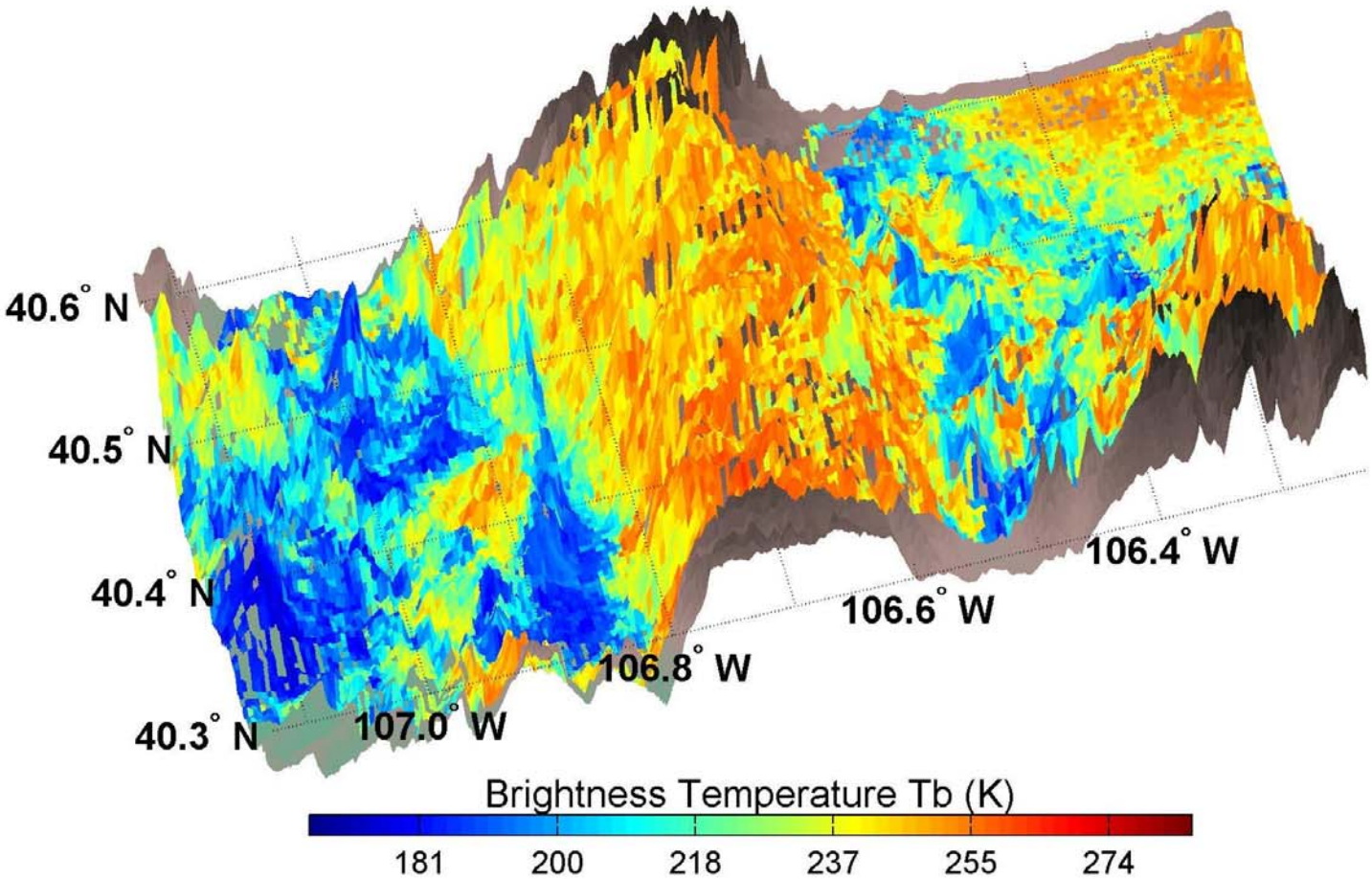

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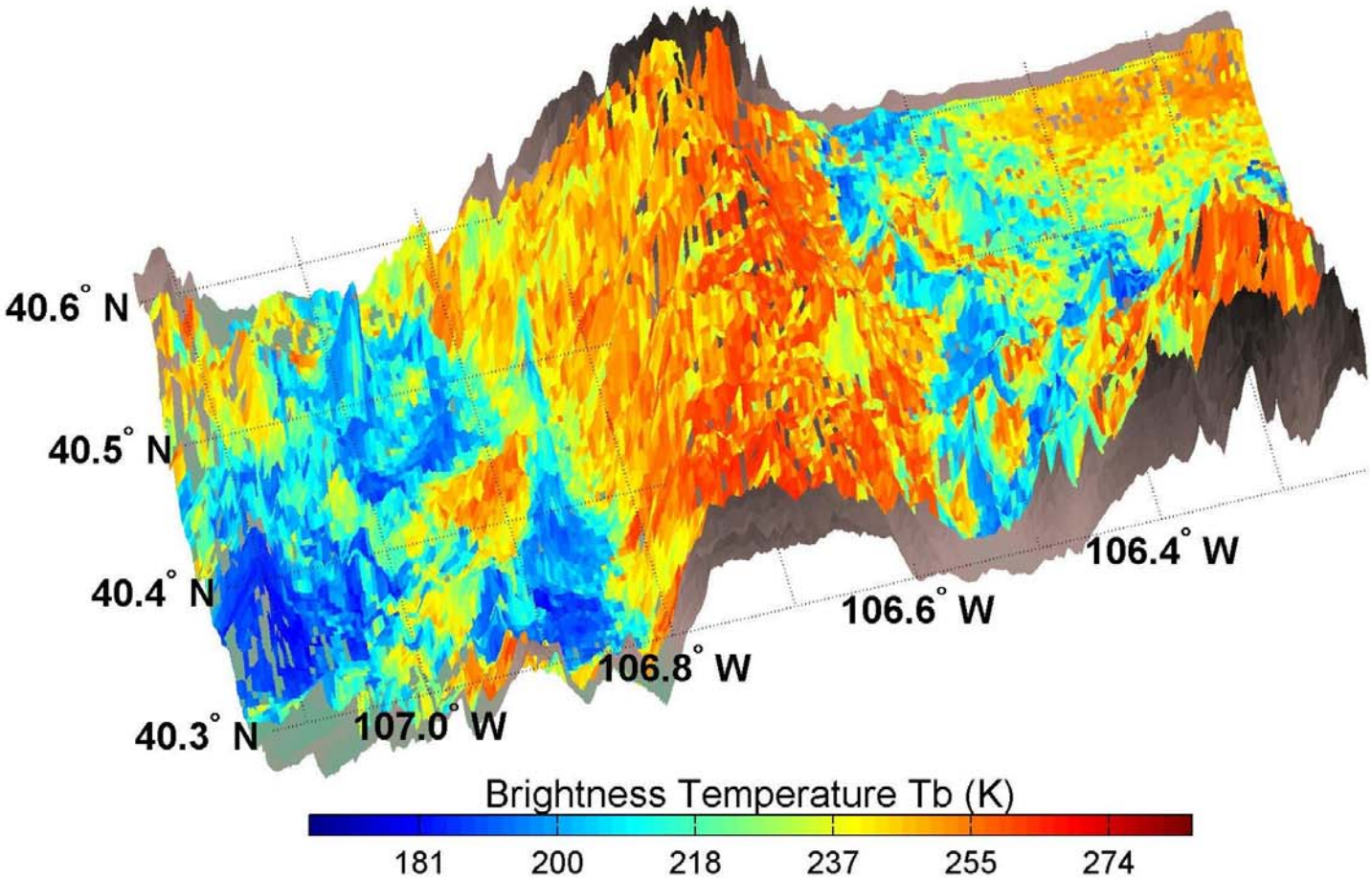
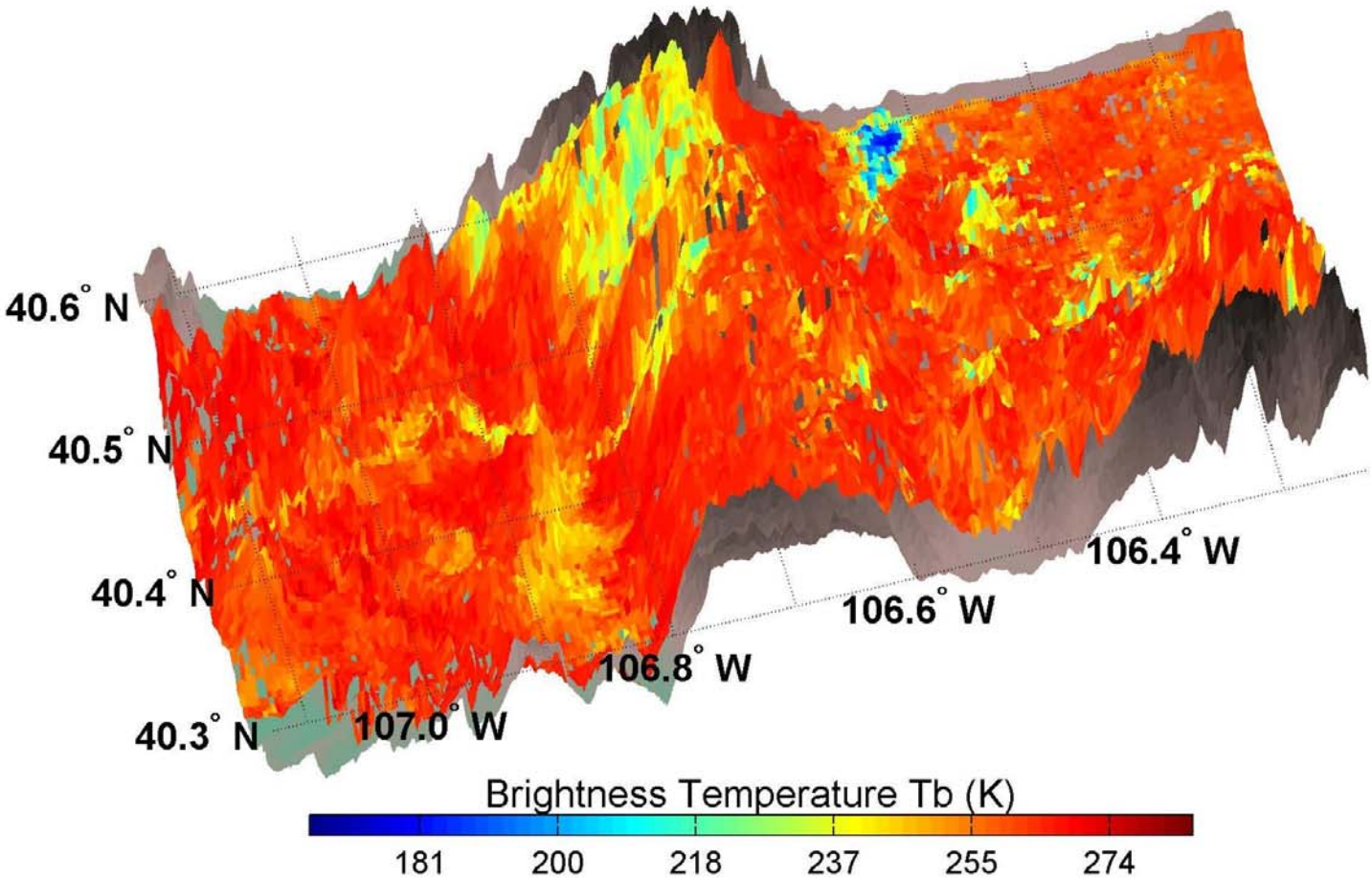


CLPX03B

RabbitEars: CLPX03B 03/30/2003 37.0 GHz Th



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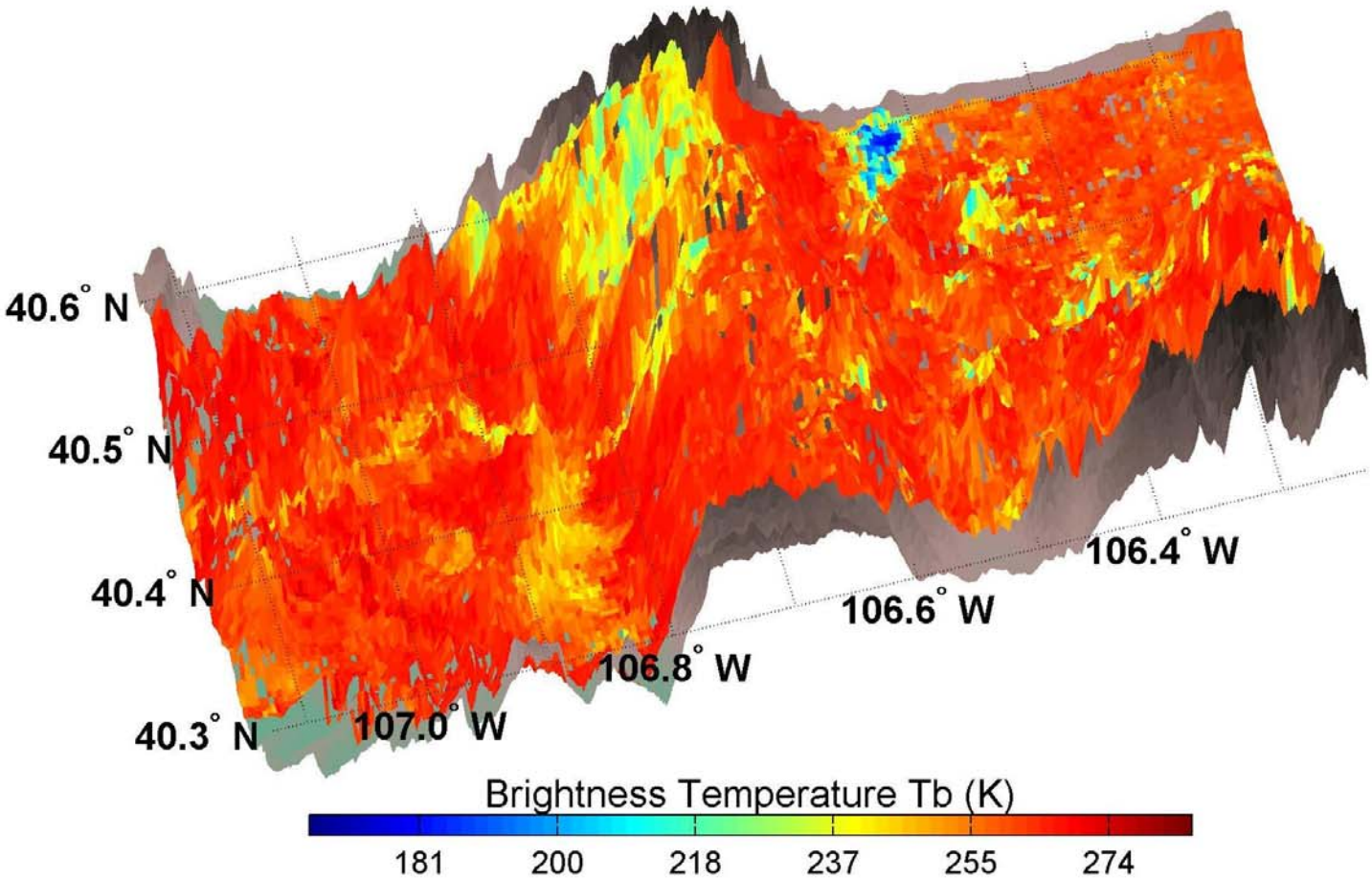

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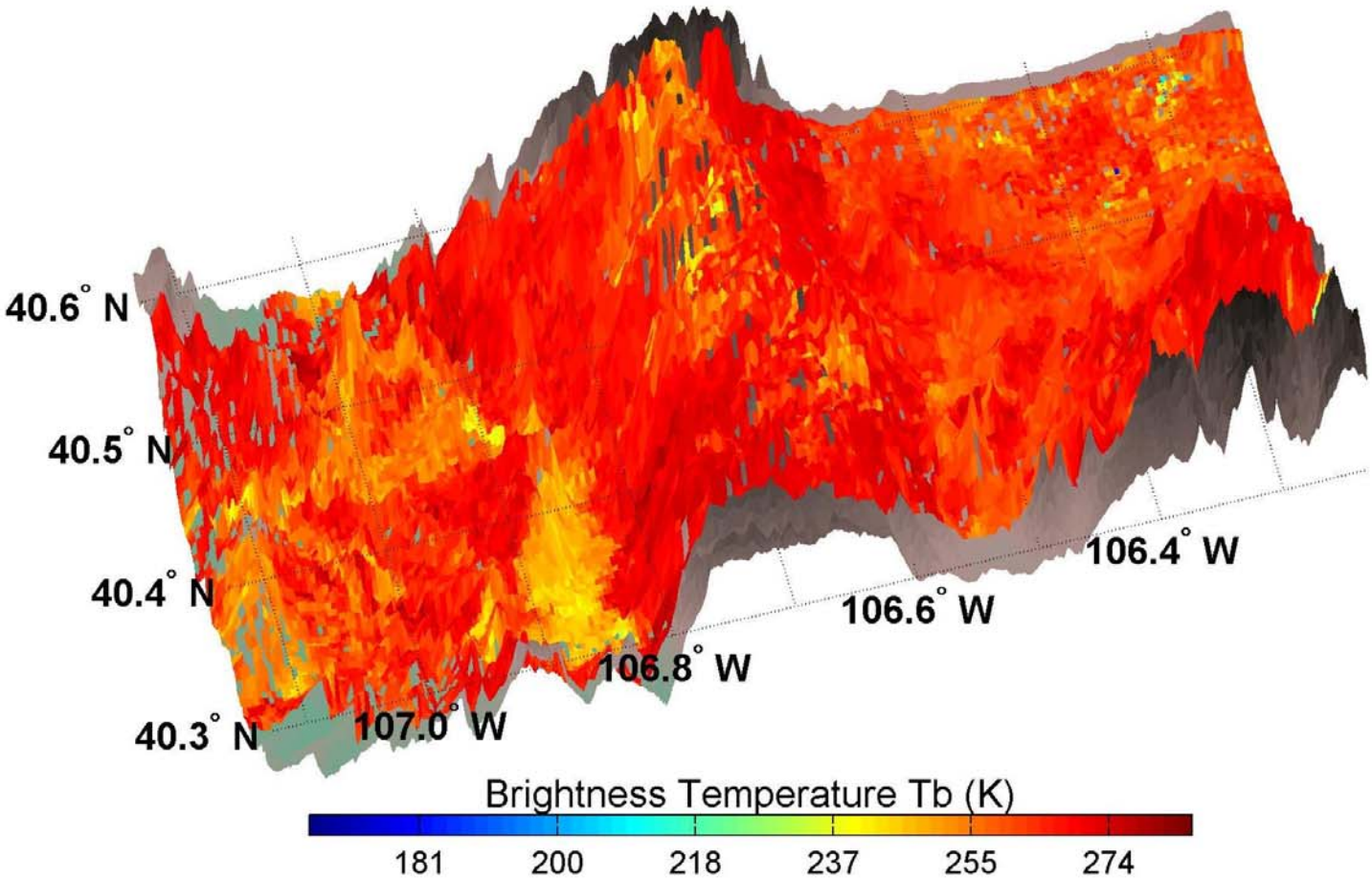

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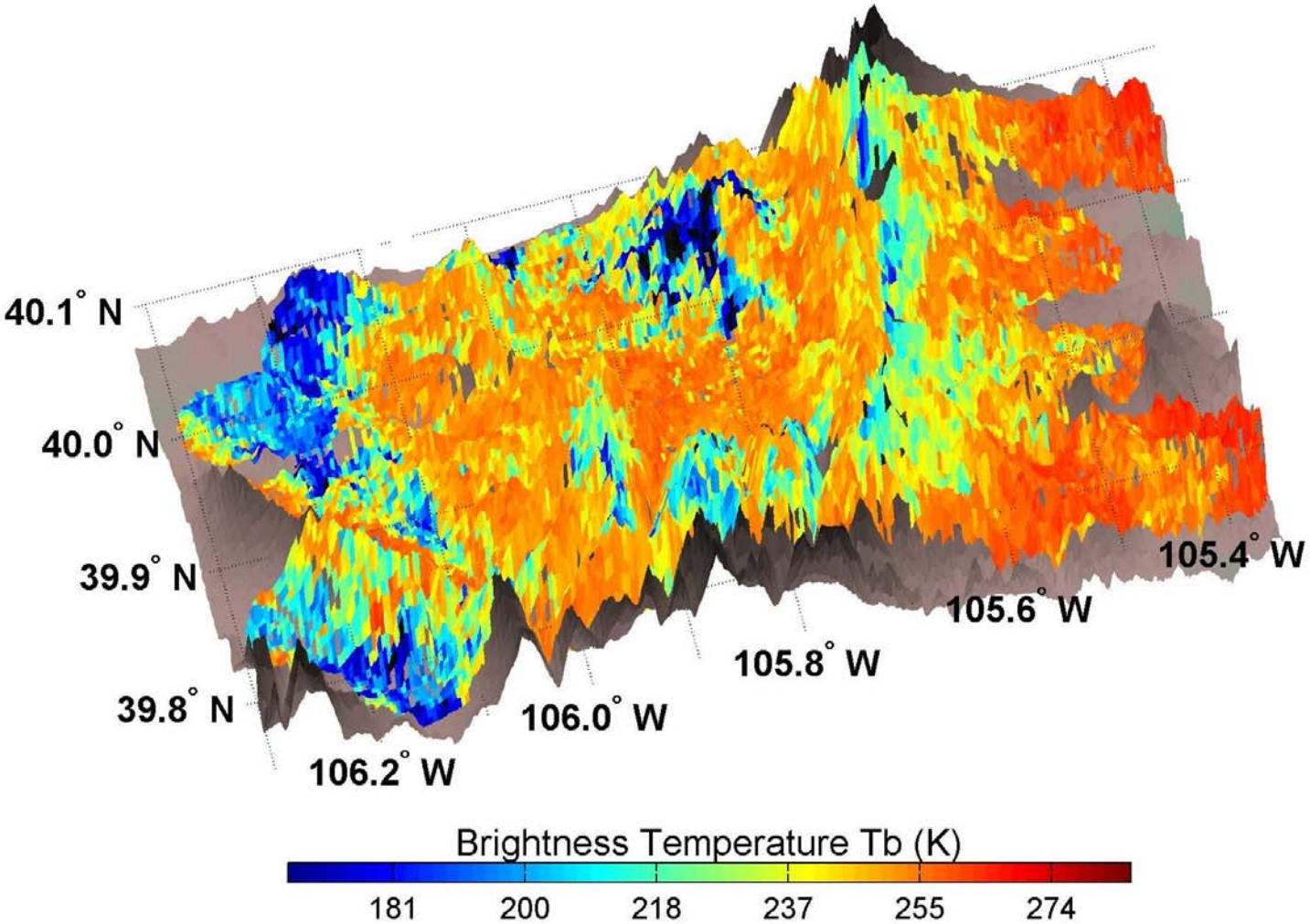
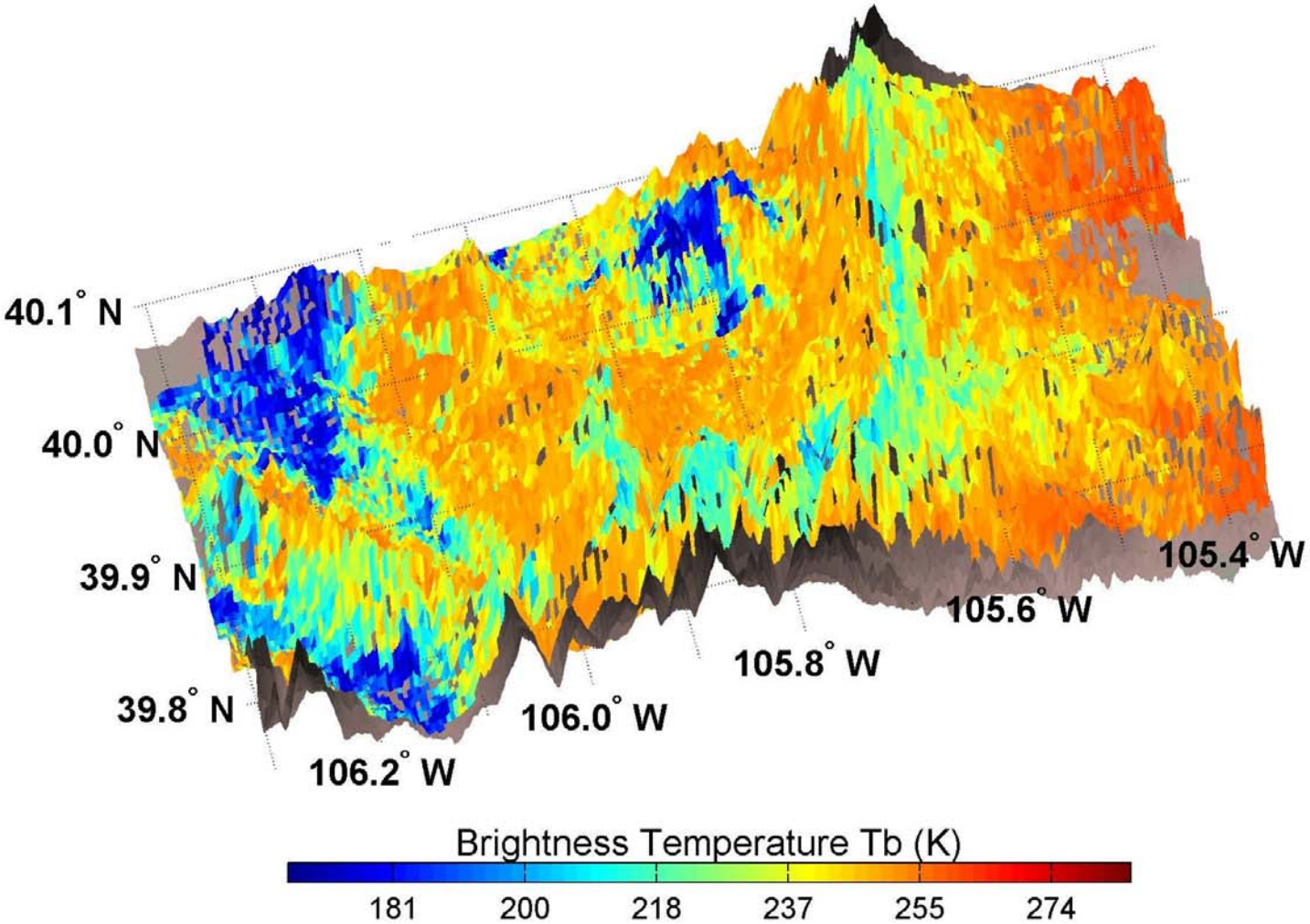


CLPX03A

Fraser: CLPX03A 02/23/2003 37.0 GHz Th



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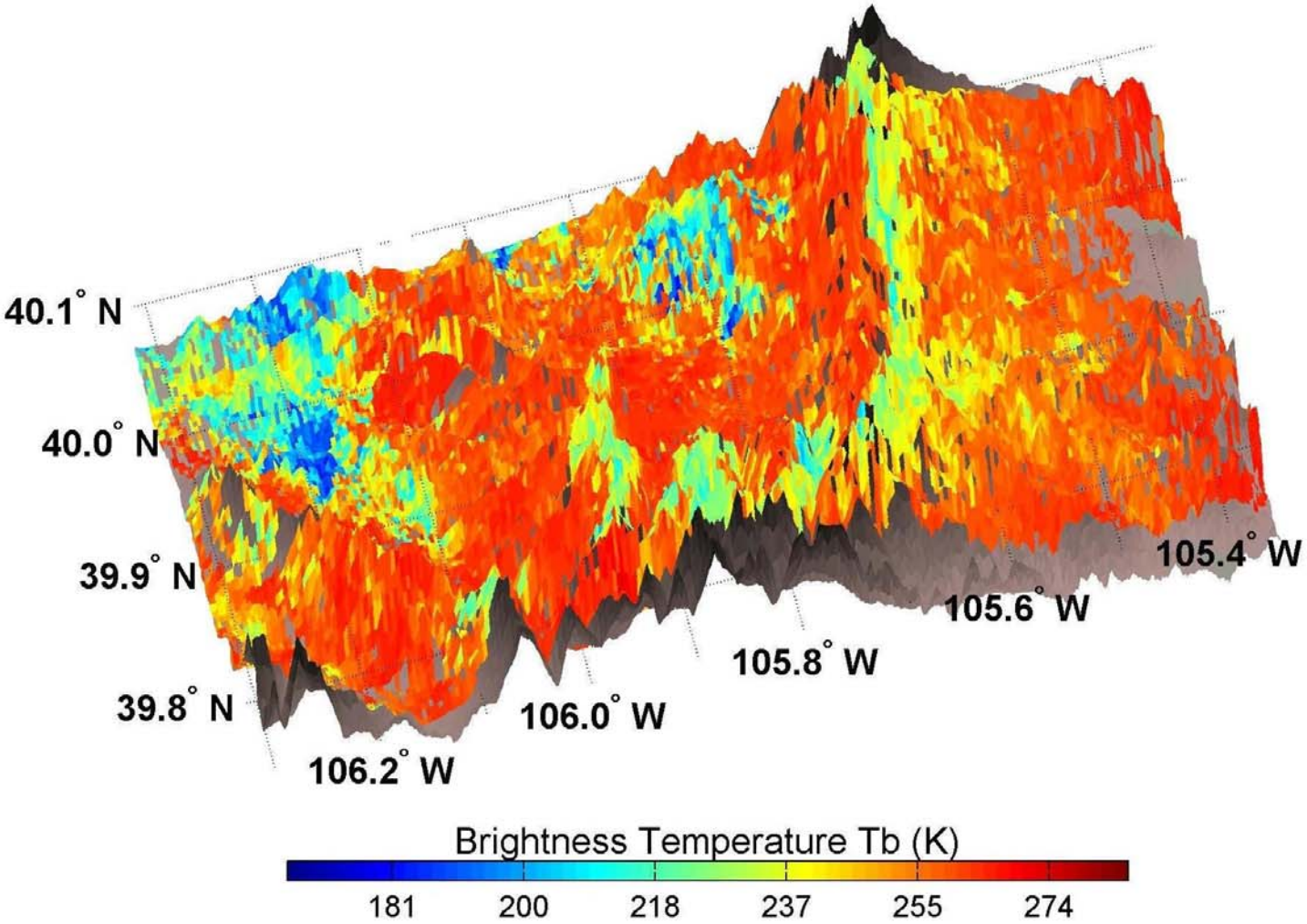

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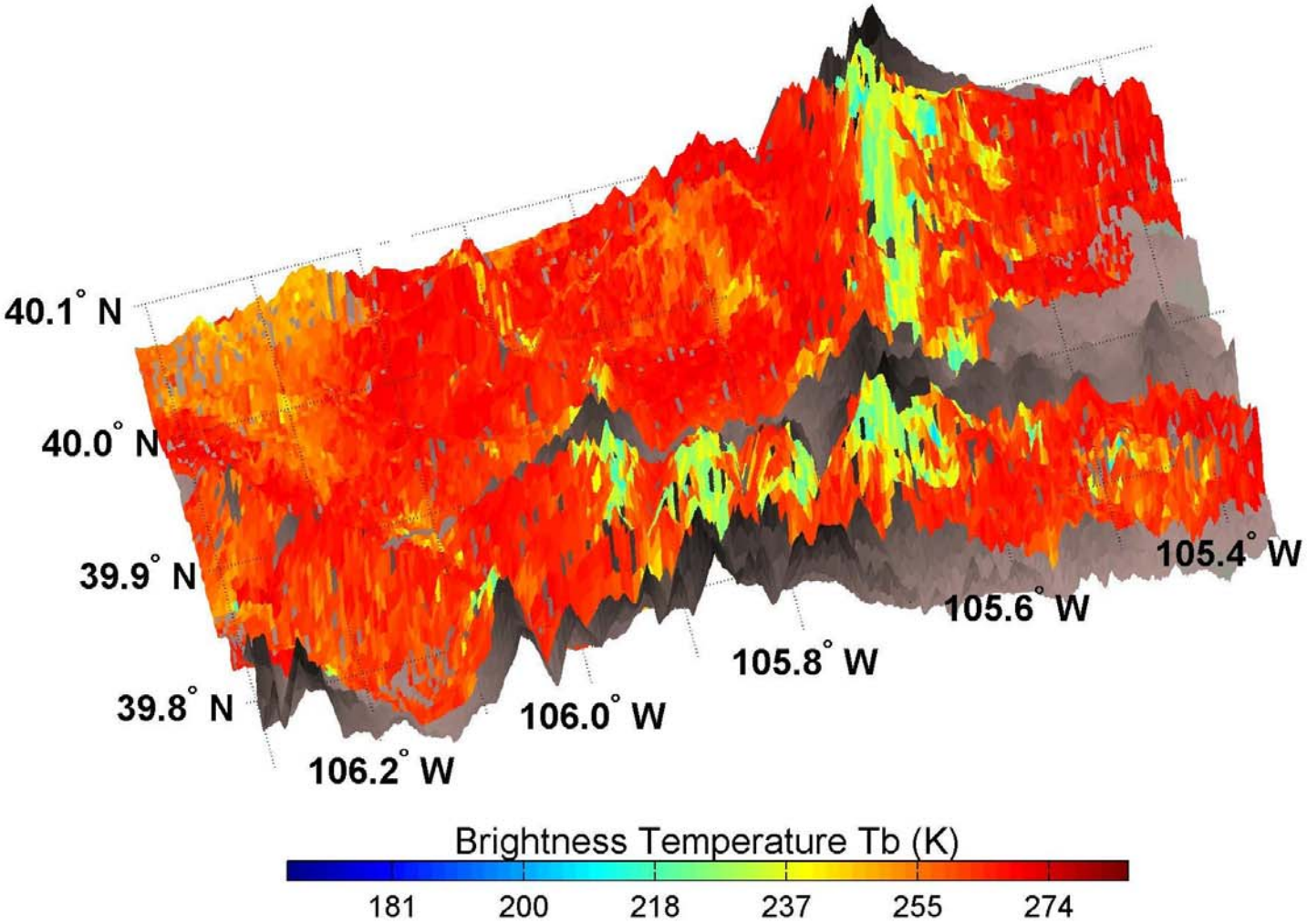

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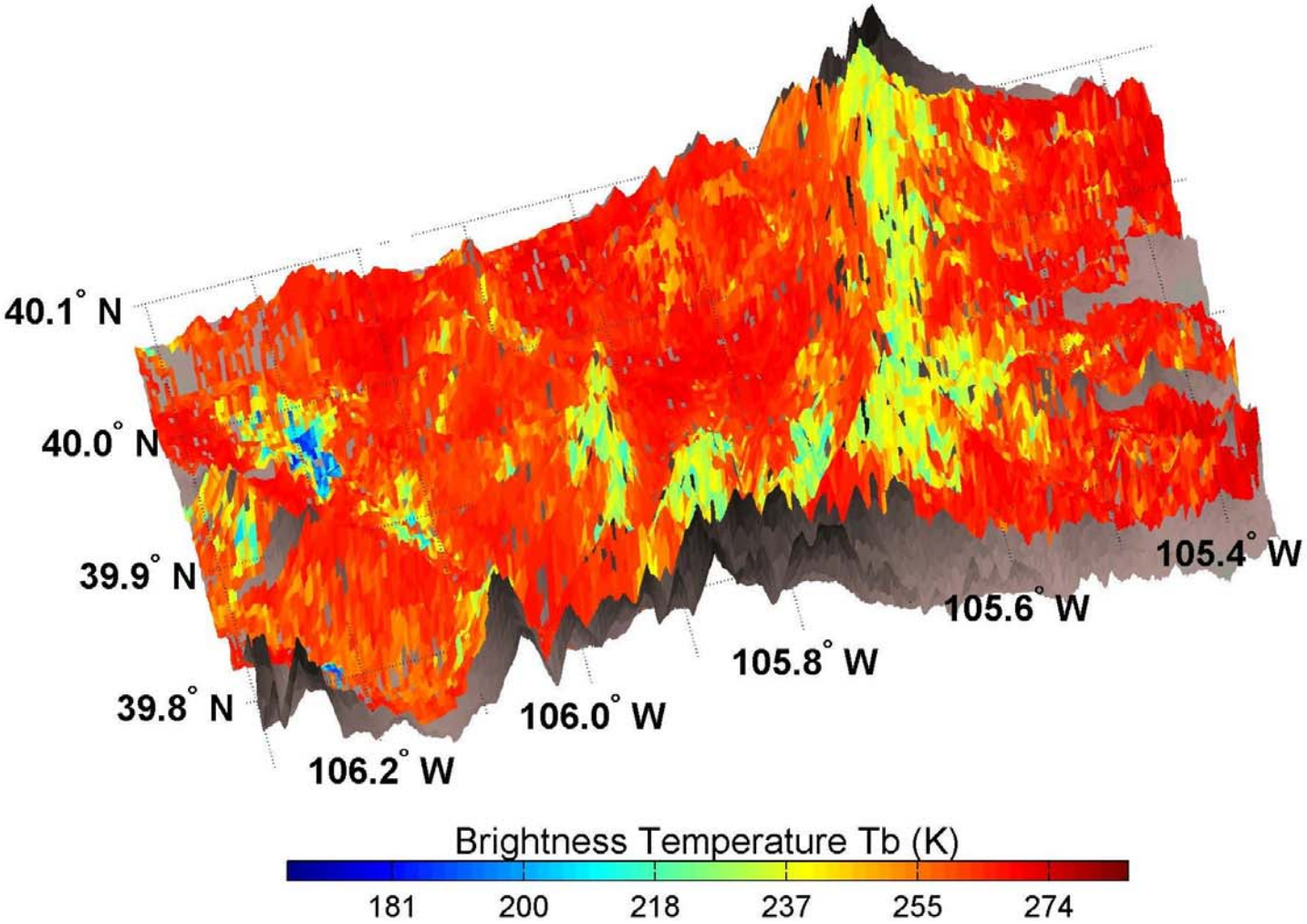

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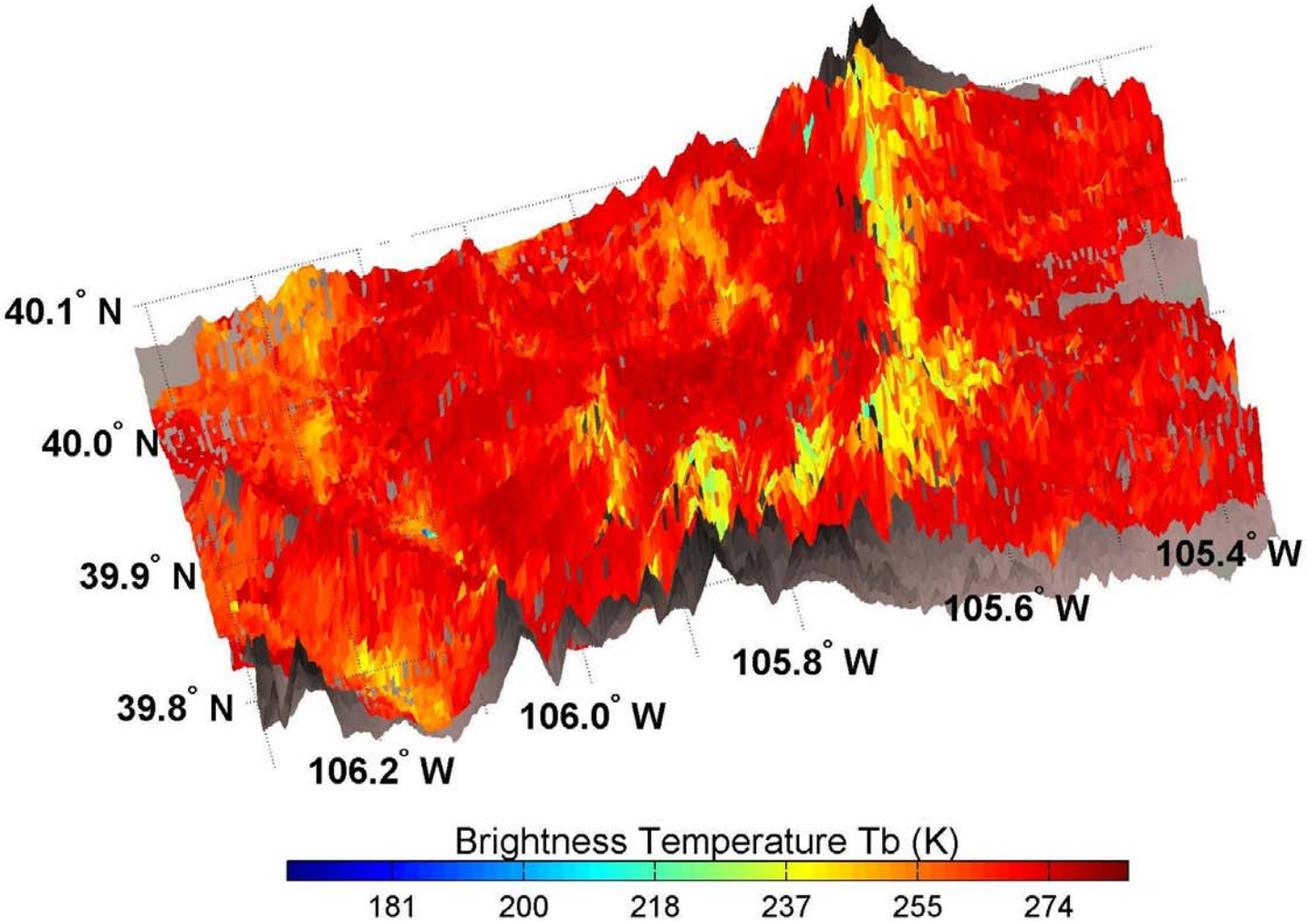
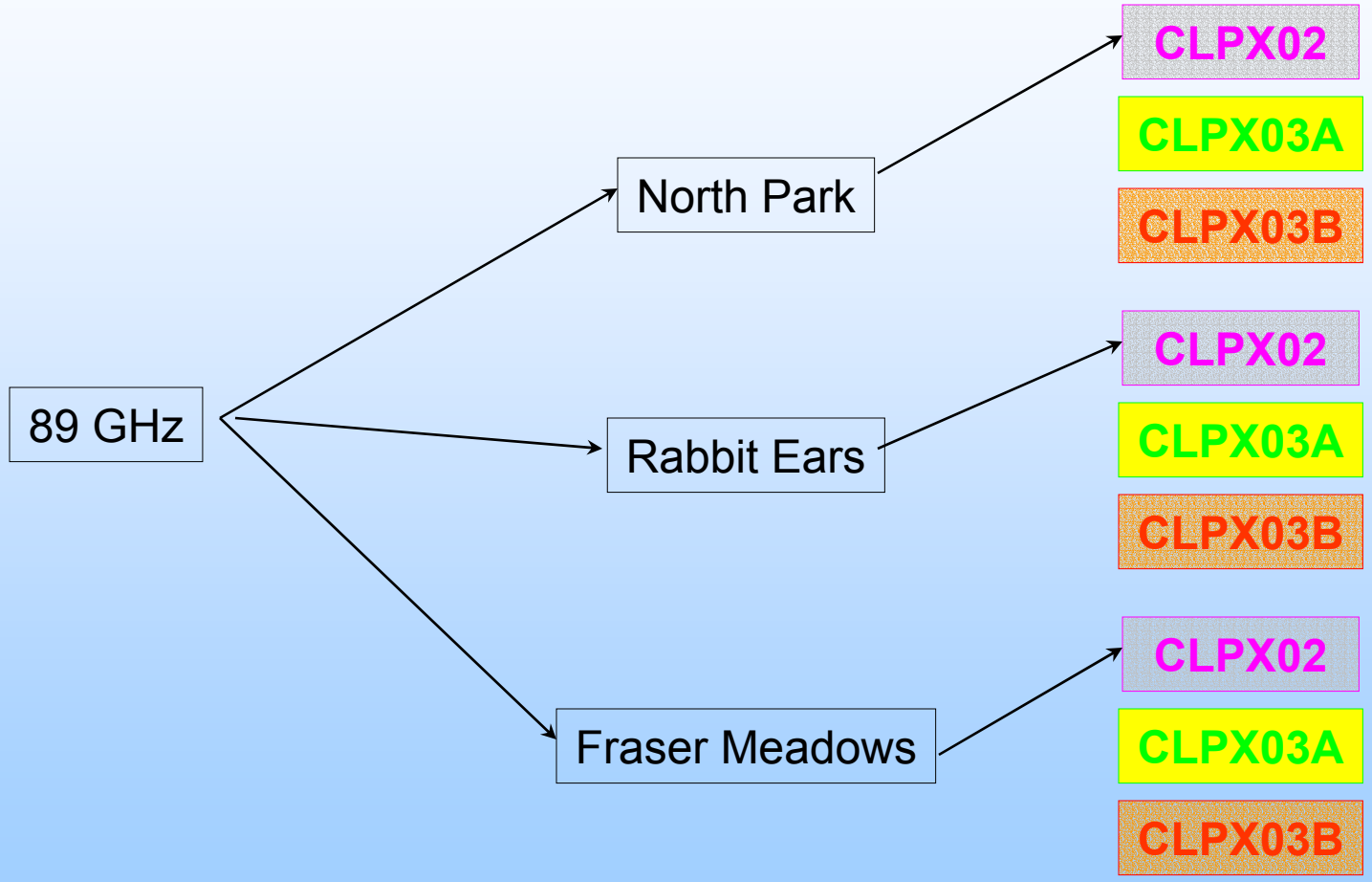


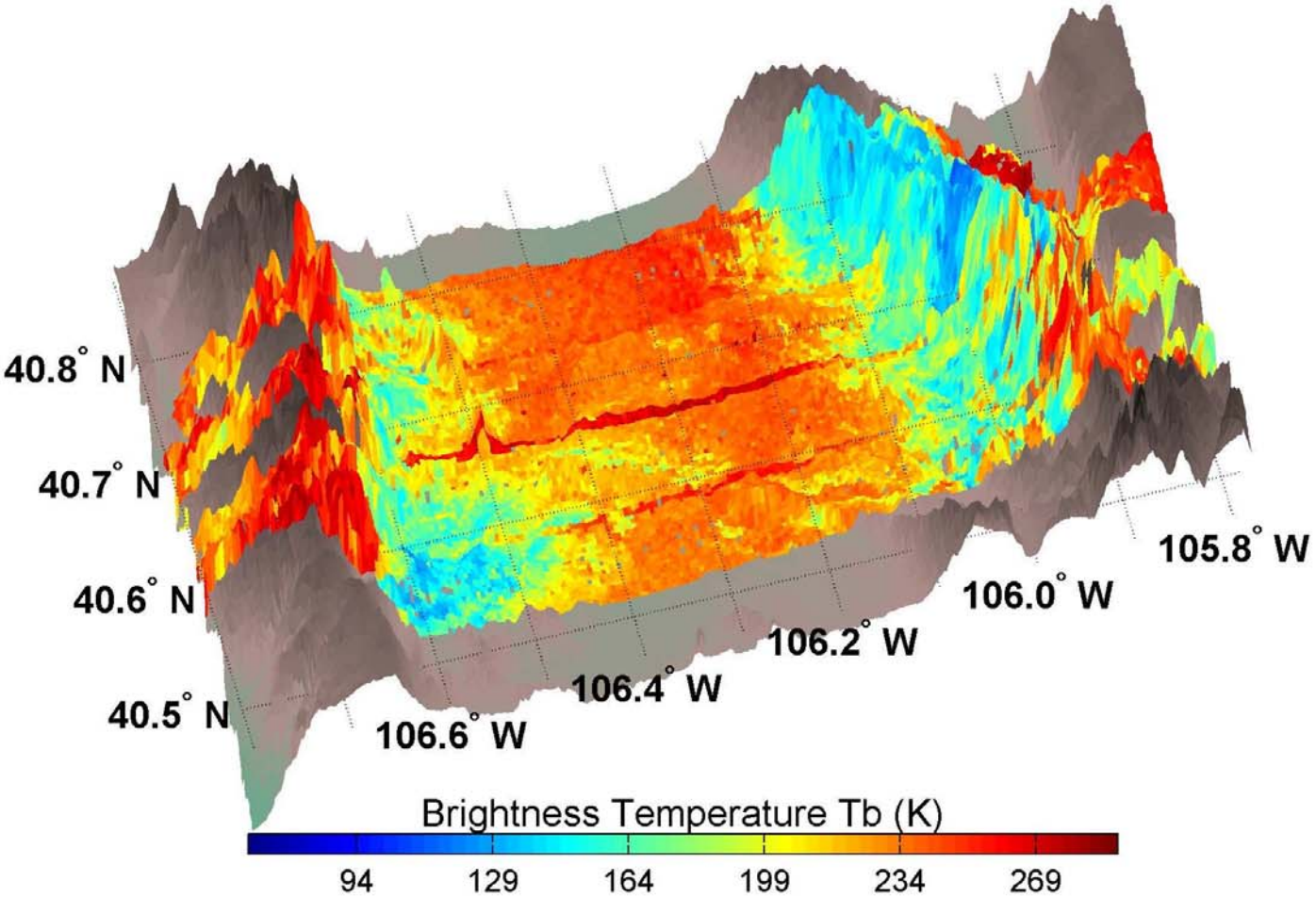
CLPX02-03 PSR/A Snowpack Images

Image sequence is as follows:



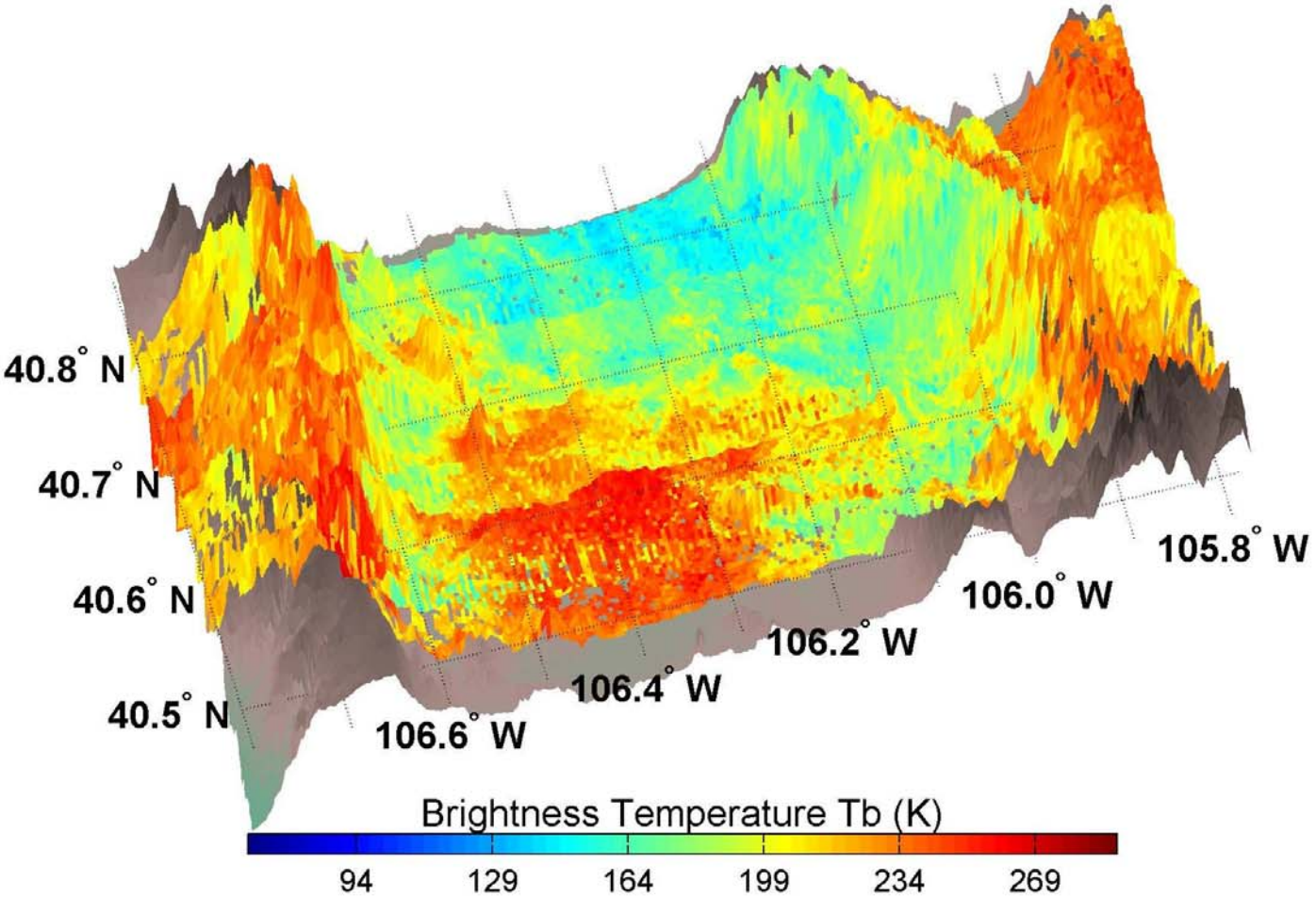
CLPX02

NorthPark: CLPX02 02/23/2002 89.0 GHz Th

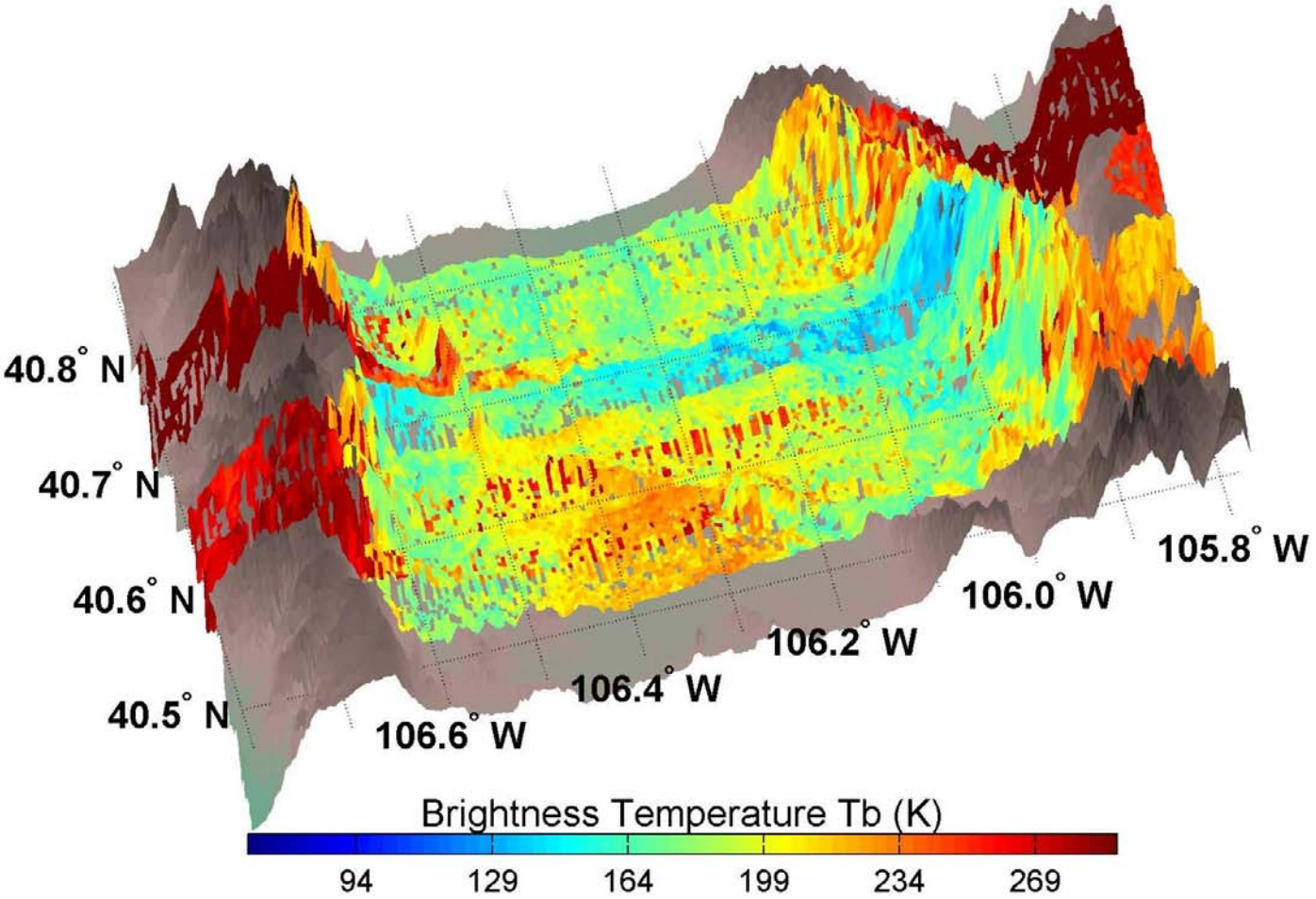


CLPX03A

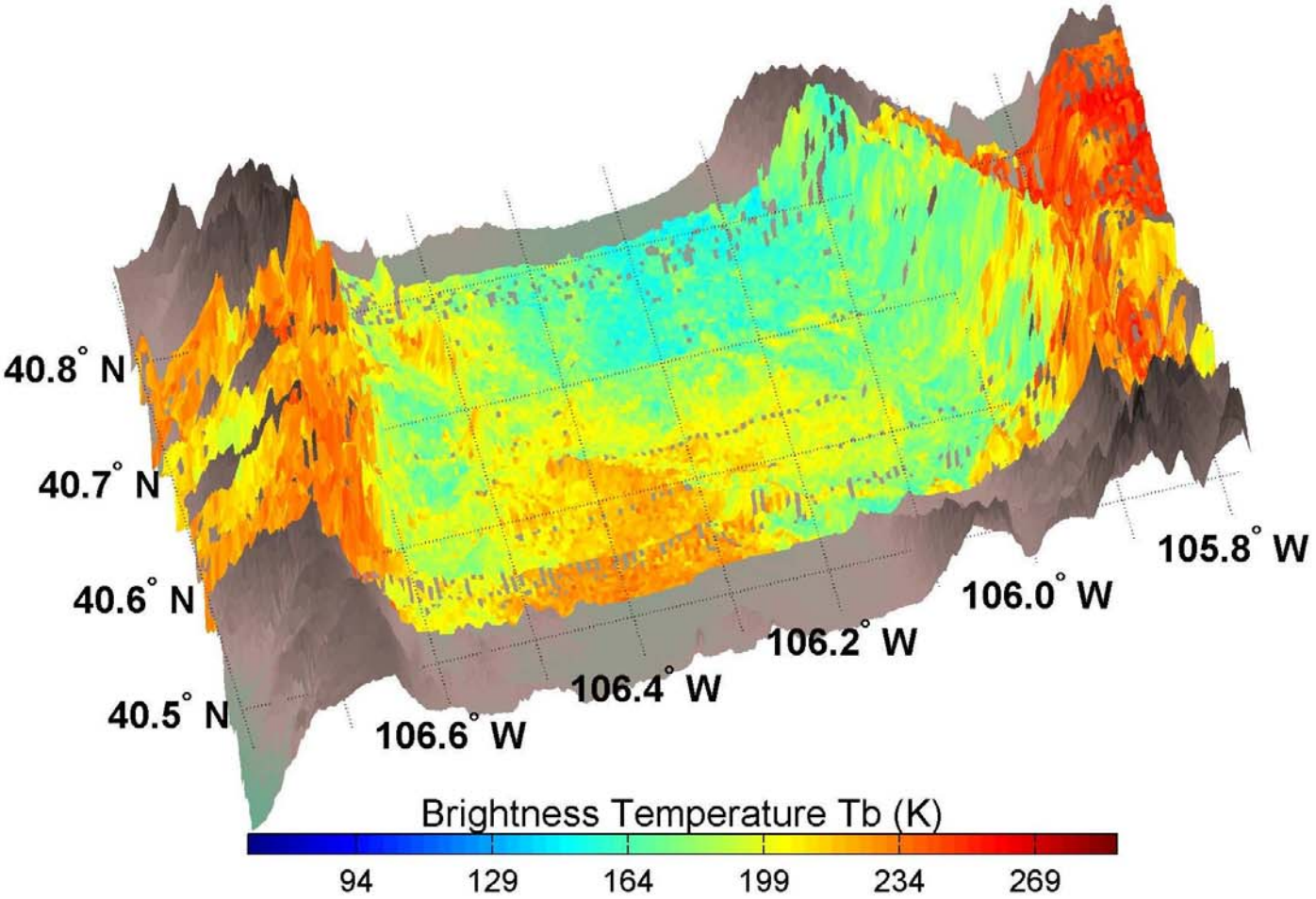
NorthPark: CLPX03A 02/22/2003 89.0 GHz Th



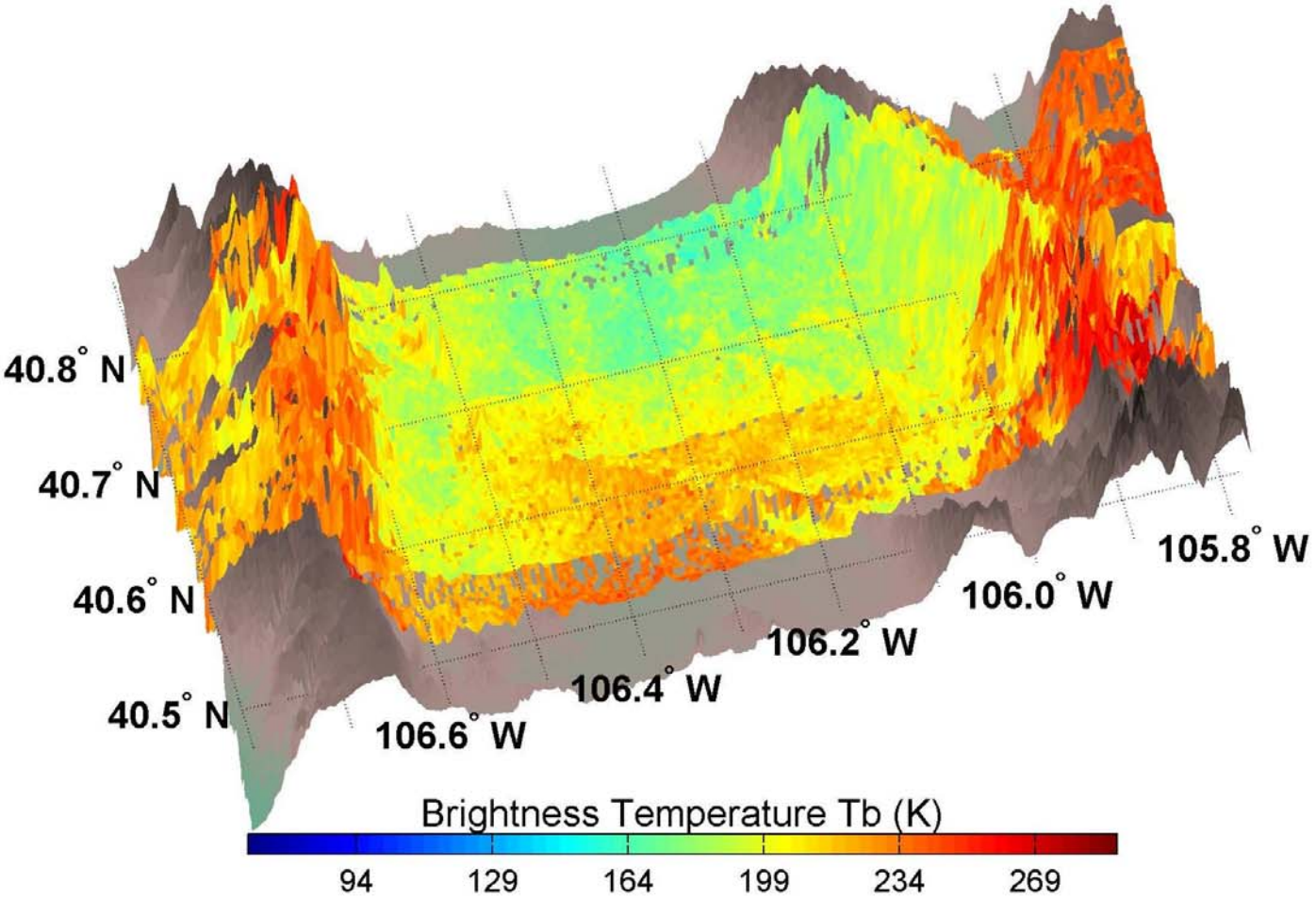
NorthPark: CLPX03A 02/23/2003 89.0 GHz Th



NorthPark: CLPX03A 02/24/2003 89.0 GHz Th

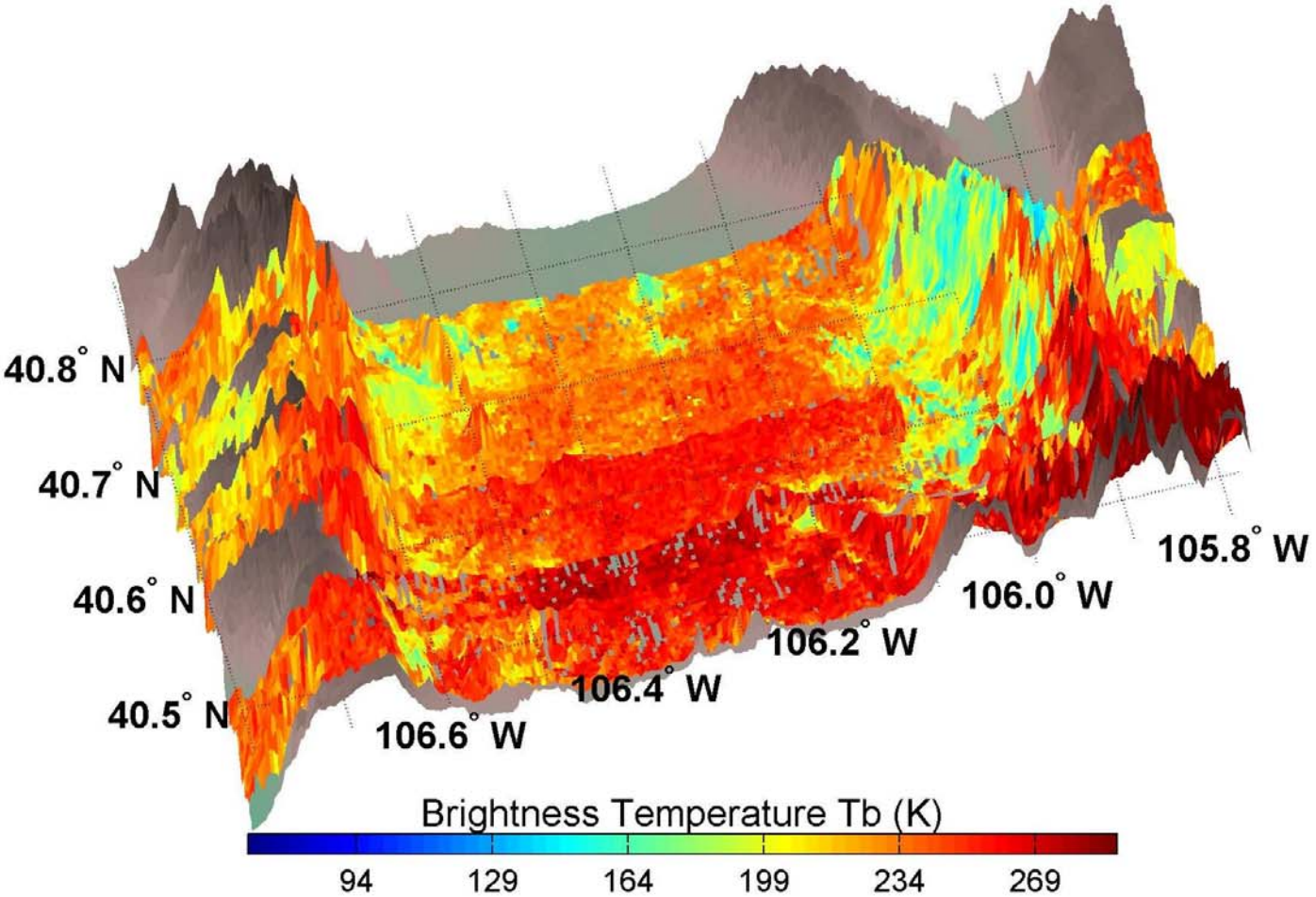


NorthPark: CLPX03A 02/25/2003 89.0 GHz Th

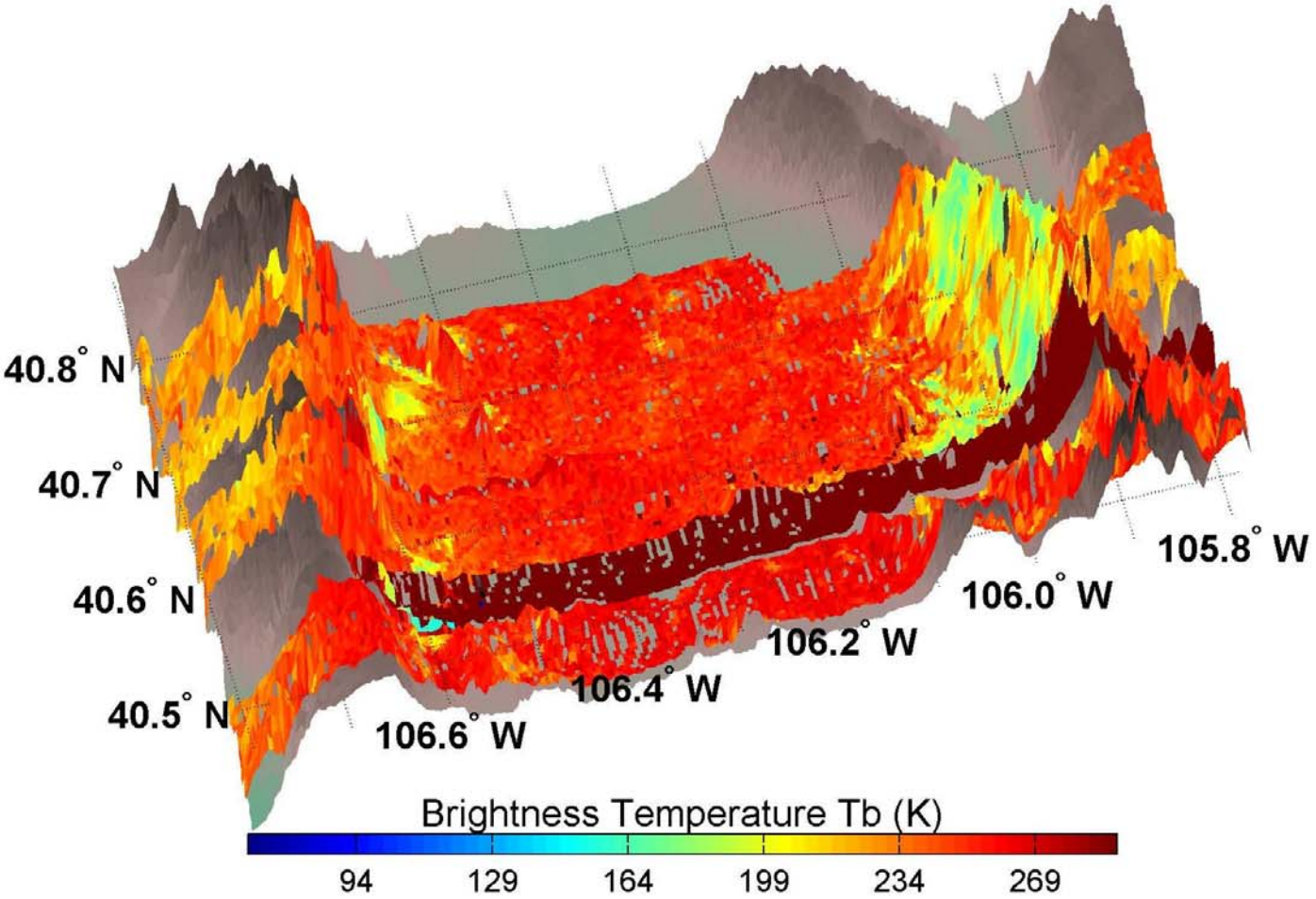


CLPX03B

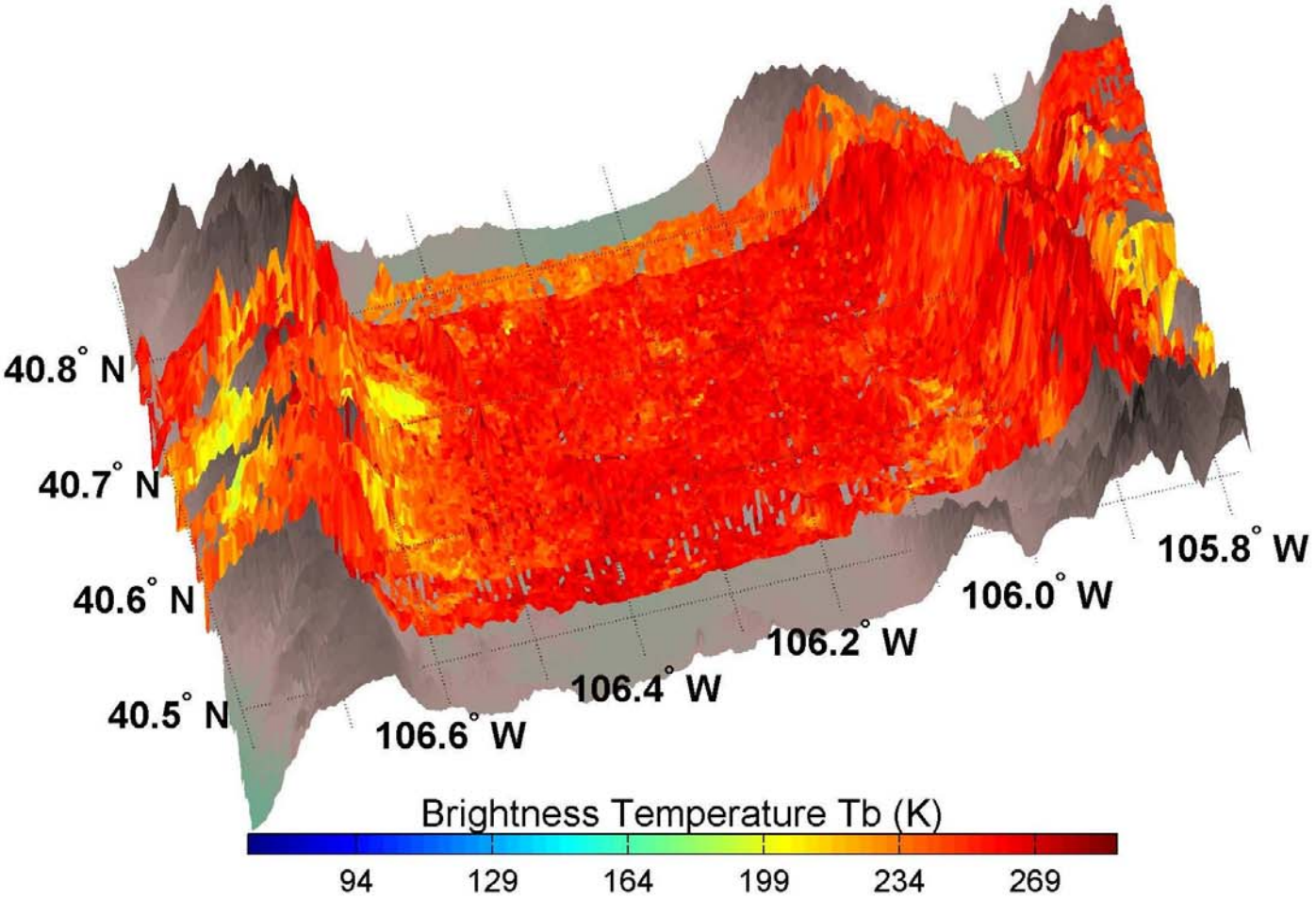
NorthPark: CLPX03B 03/25/2003 89.0 GHz Th



NorthPark: CLPX03B 03/30/2003 89.0 GHz Th

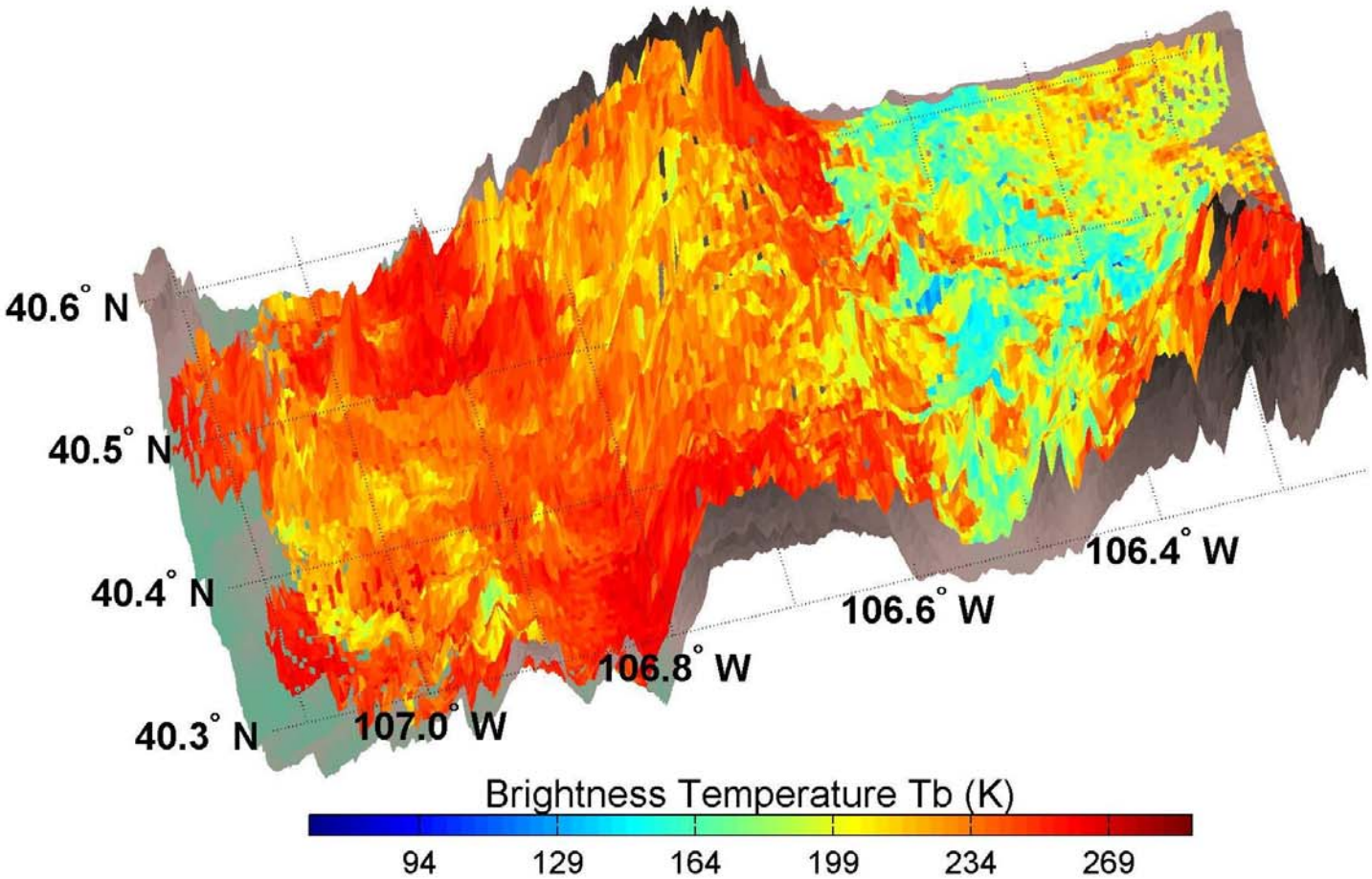


NorthPark: CLPX03B 03/31/2003 89.0 GHz Th



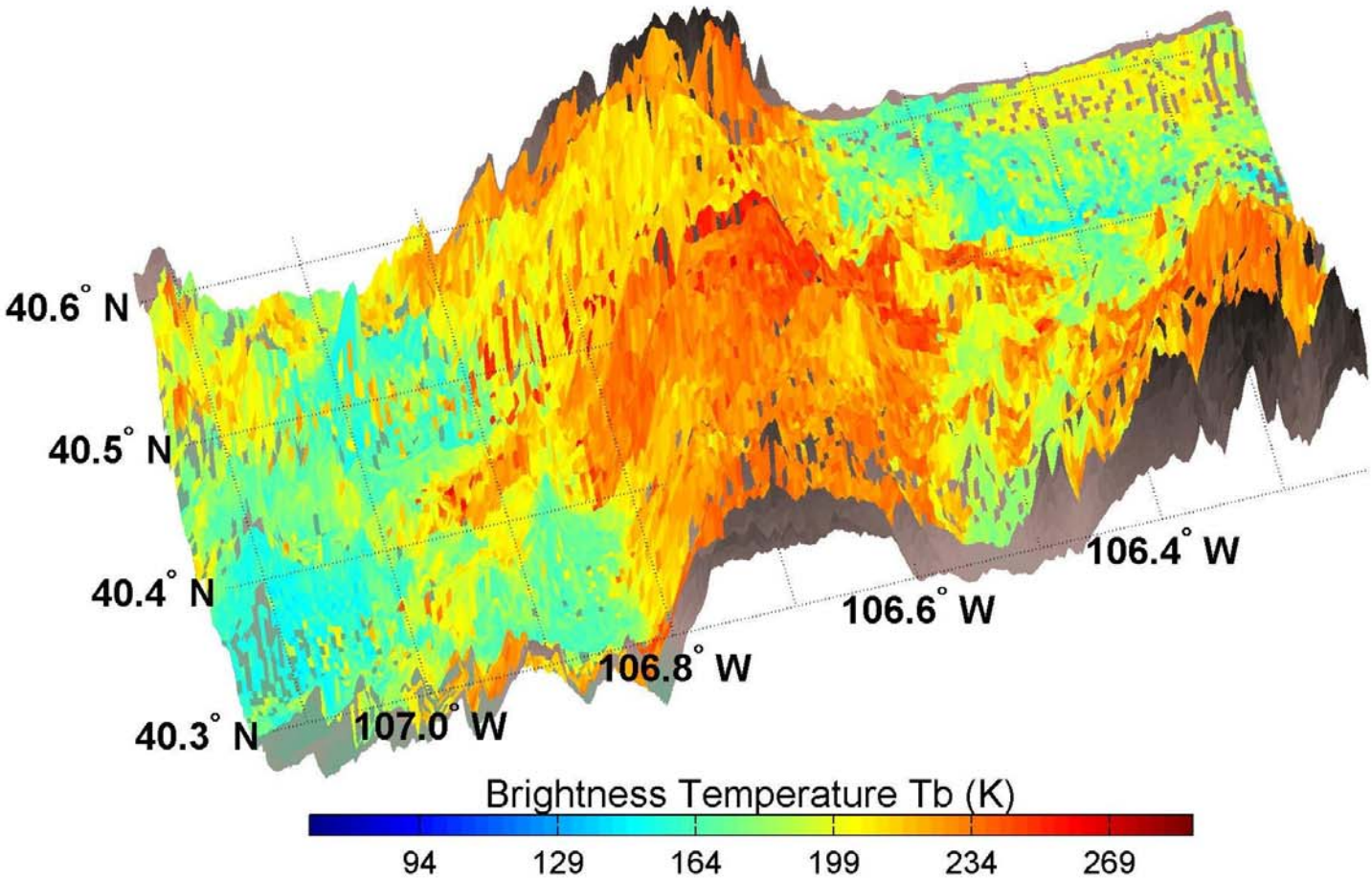
CLPX02

RabbitEars: CLPX02 02/19/2002 89.0 GHz Th

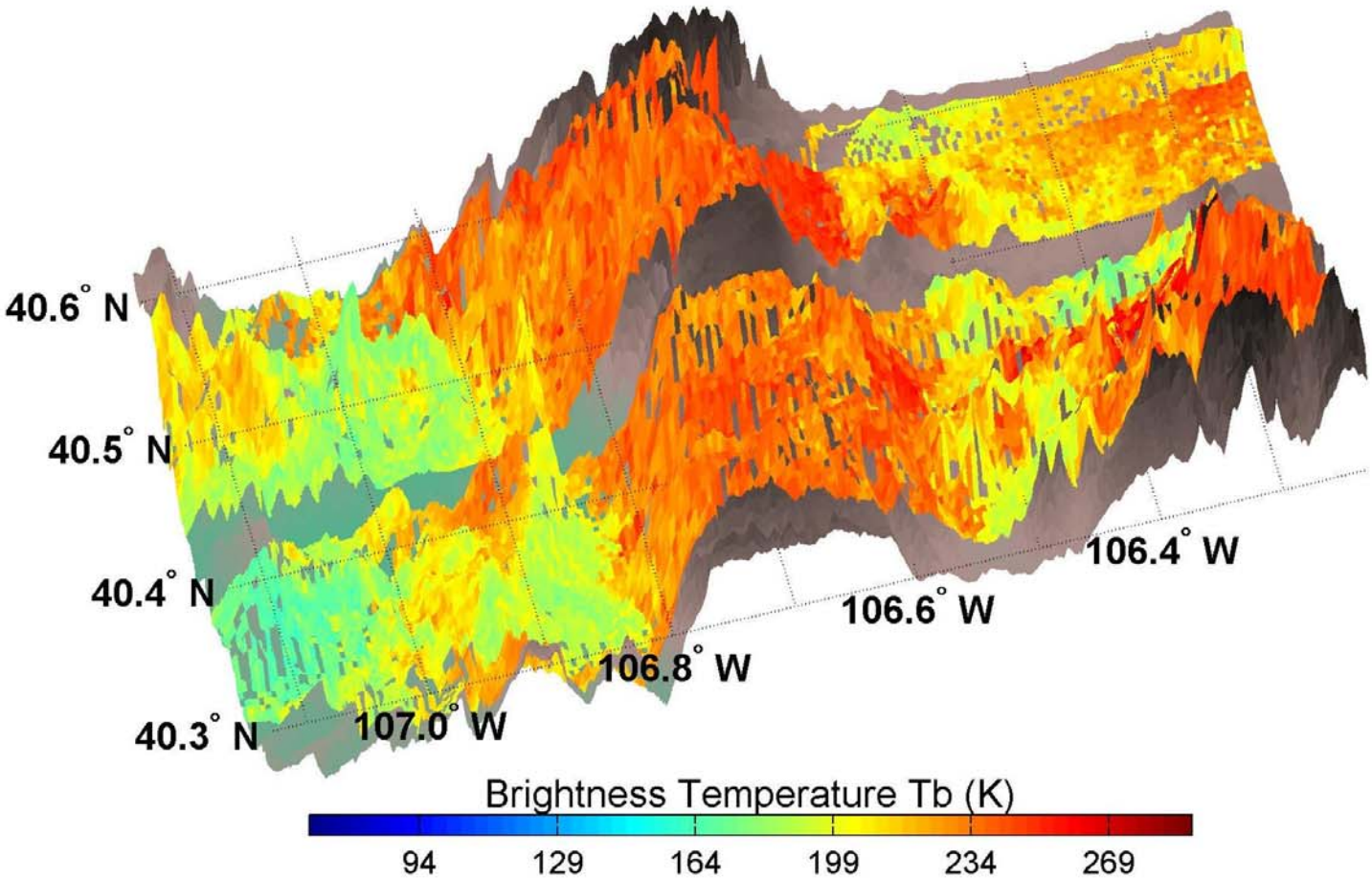


CLPX03A

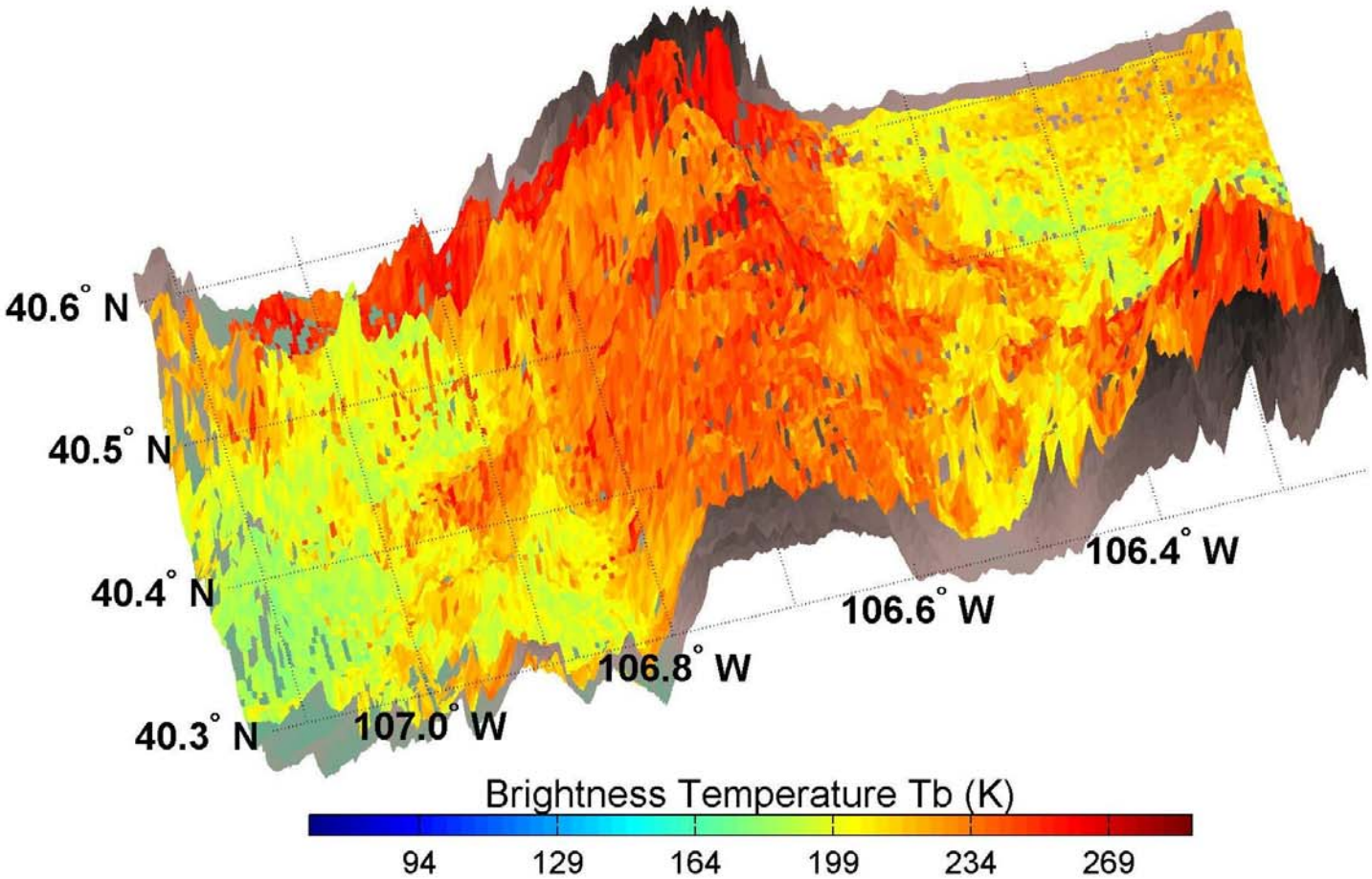
RabbitEars: CLPX03A 02/23/2003 89.0 GHz Th



RabbitEars: CLPX03A 02/24/2003 89.0 GHz Th

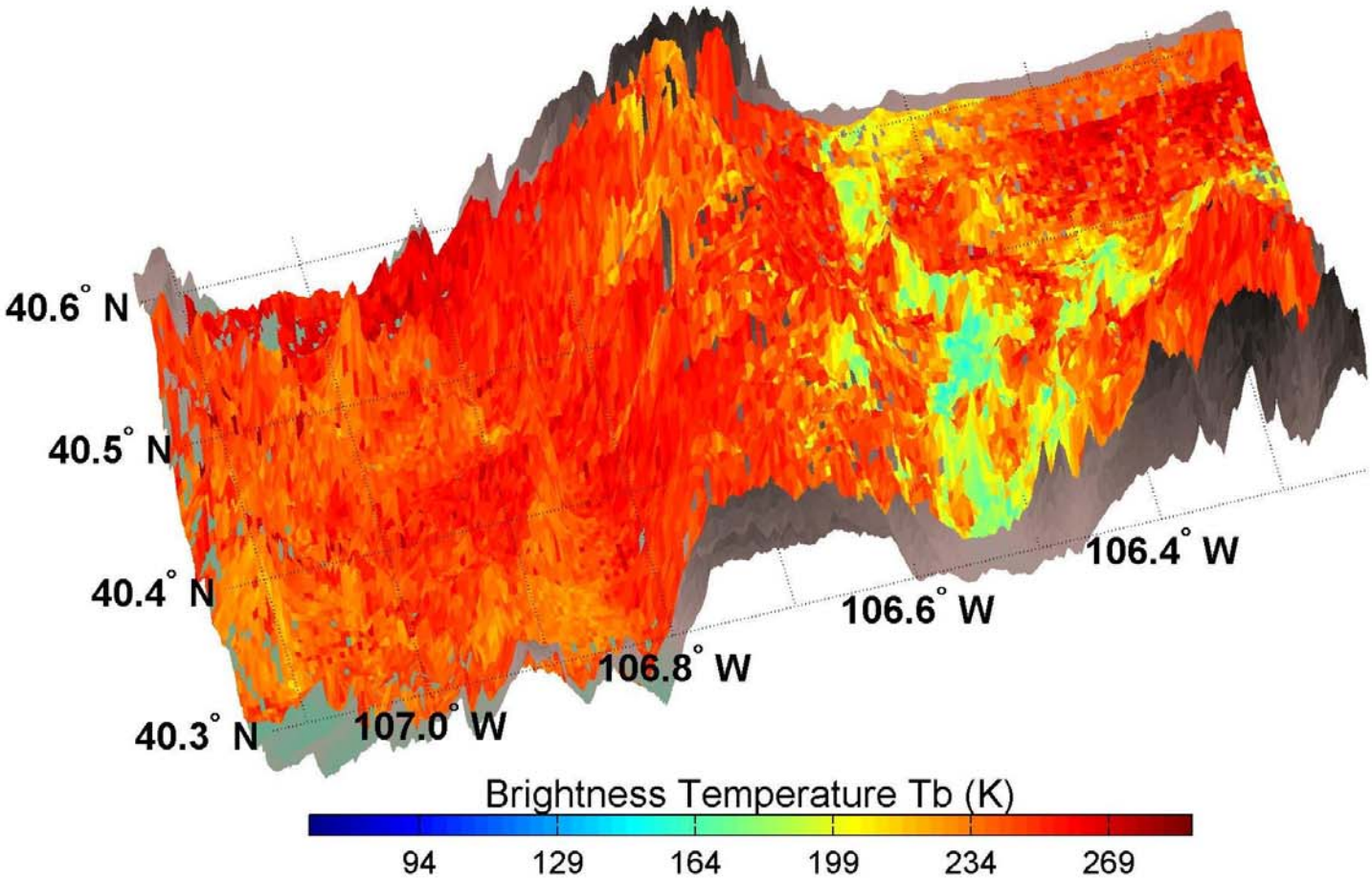


RabbitEars: CLPX03A 02/25/2003 89.0 GHz Th

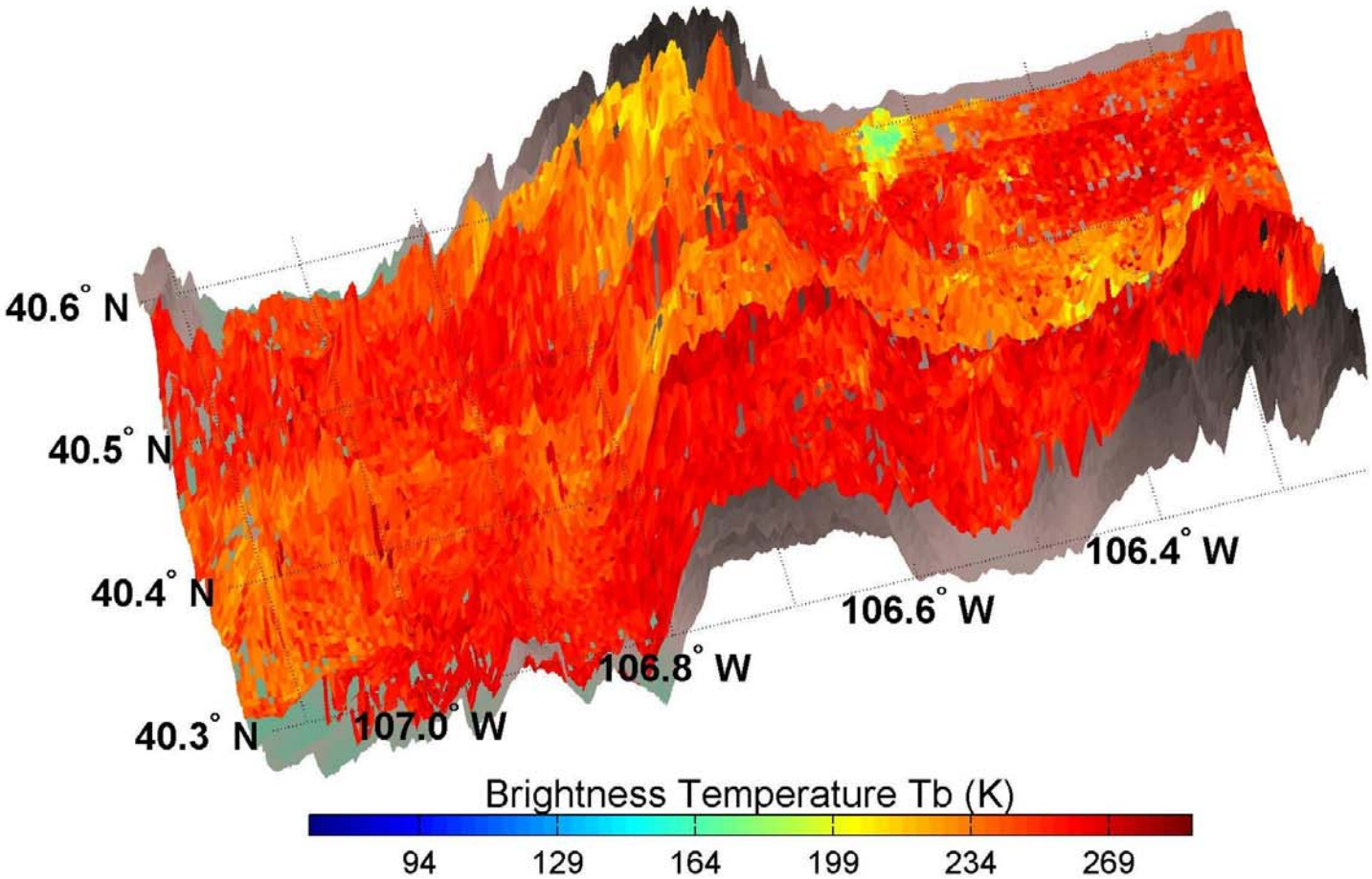


CLPX03B

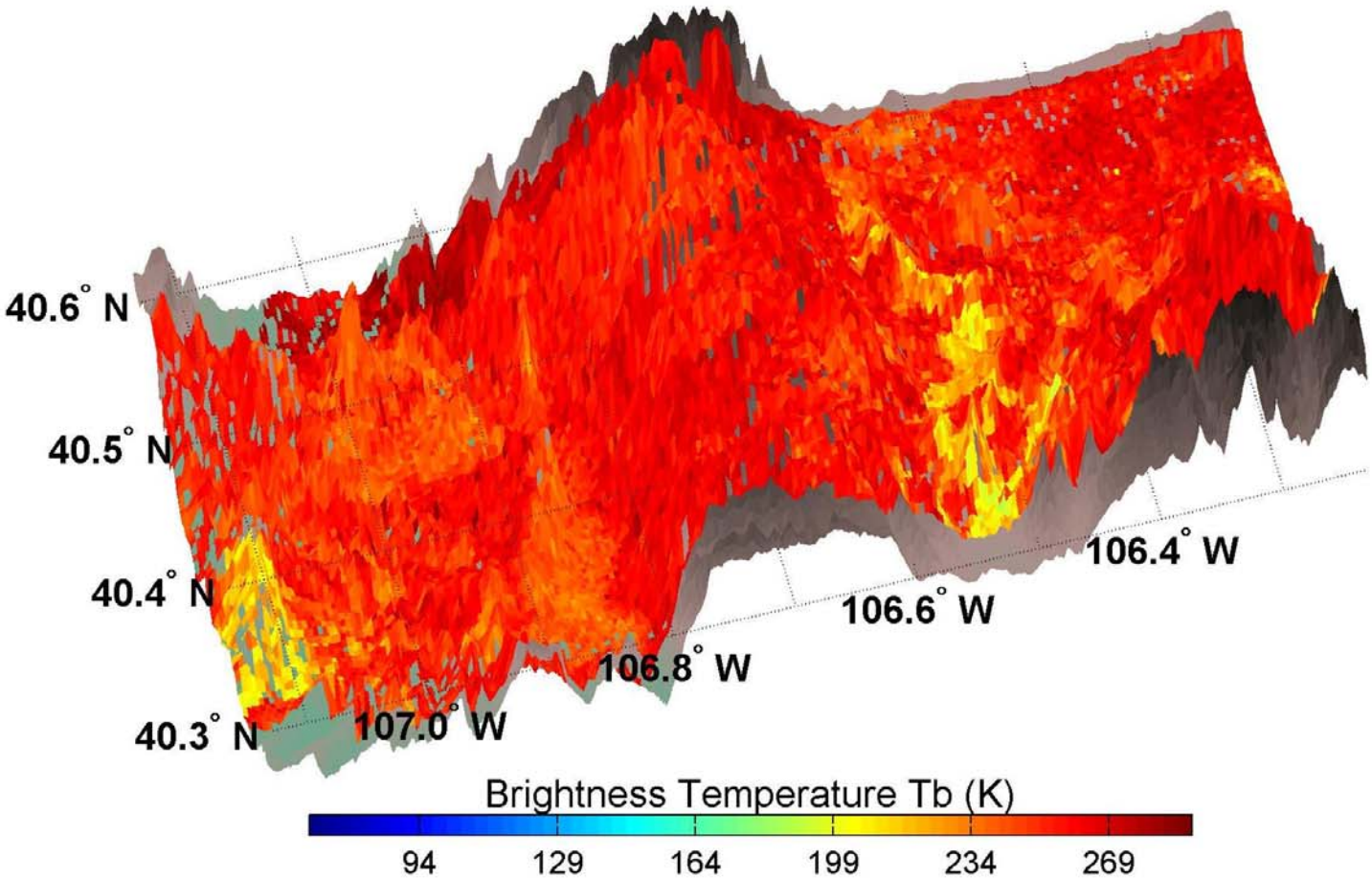
RabbitEars: CLPX03B 03/25/2003 89.0 GHz Th



RabbitEars: CLPX03B 03/30/2003 89.0 GHz Th

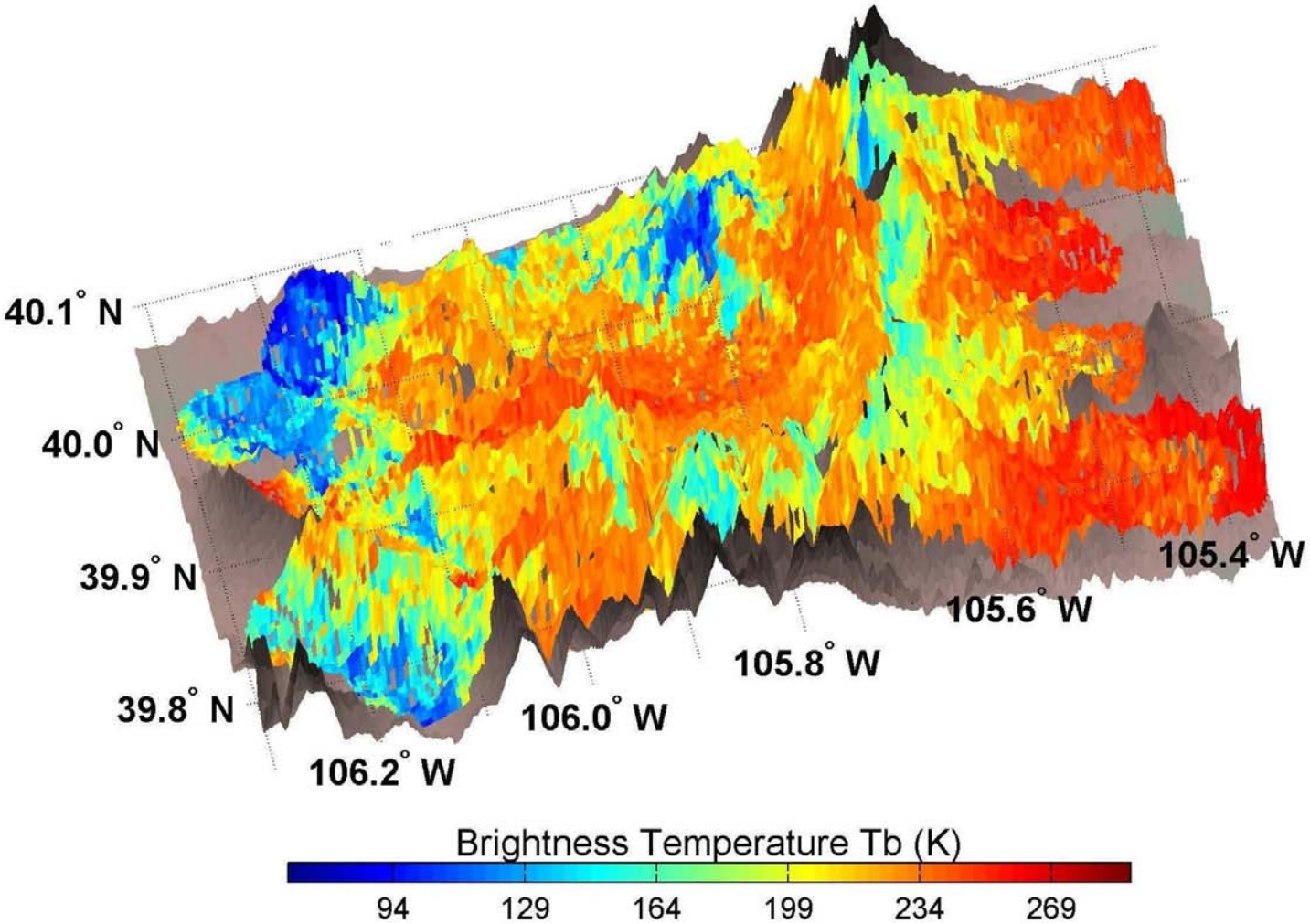


RabbitEars: CLPX03B 03/31/2003 89.0 GHz Th



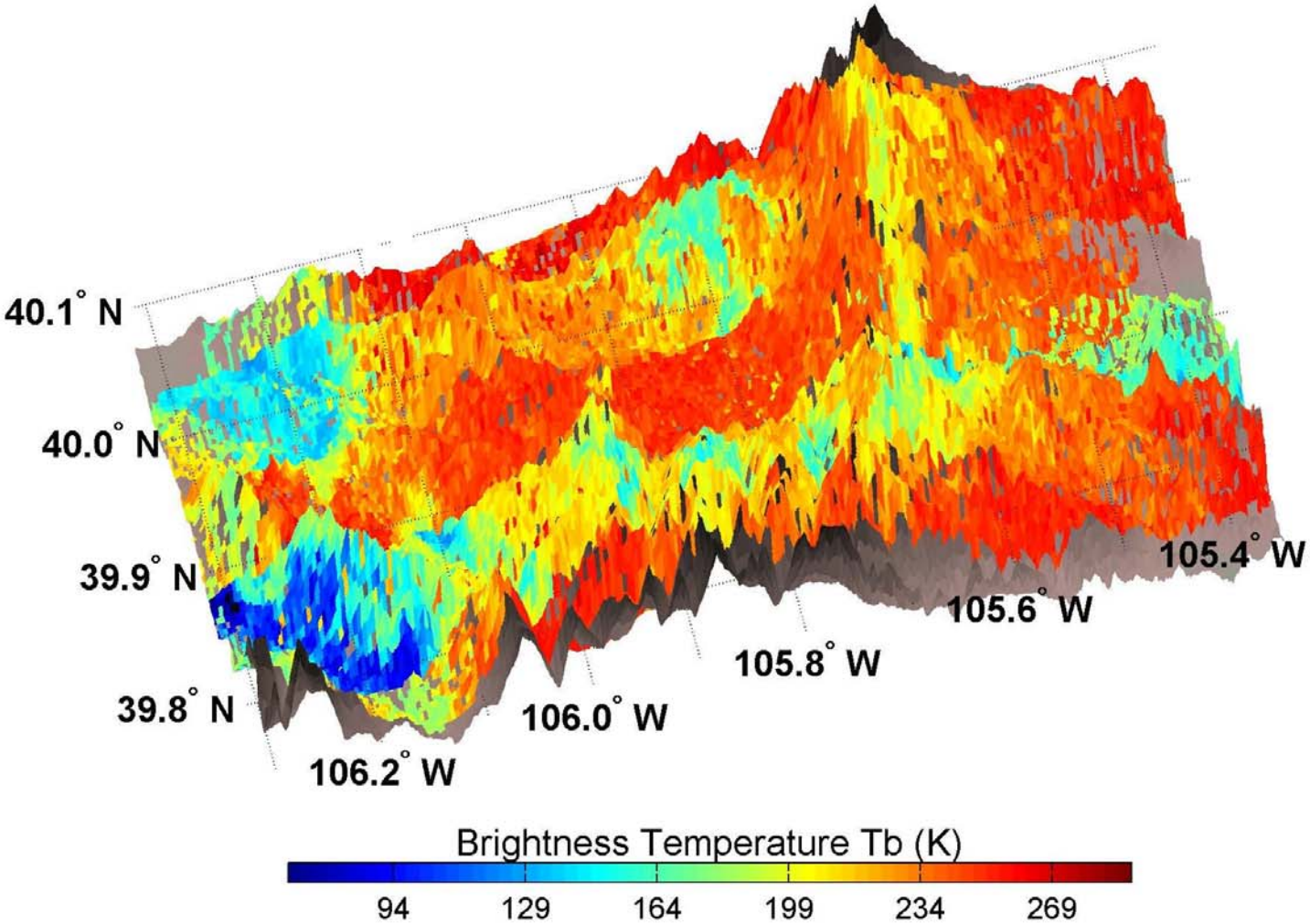
CLPX02

Fraser: CLPX02 02/21/2002 89.0 GHz Th

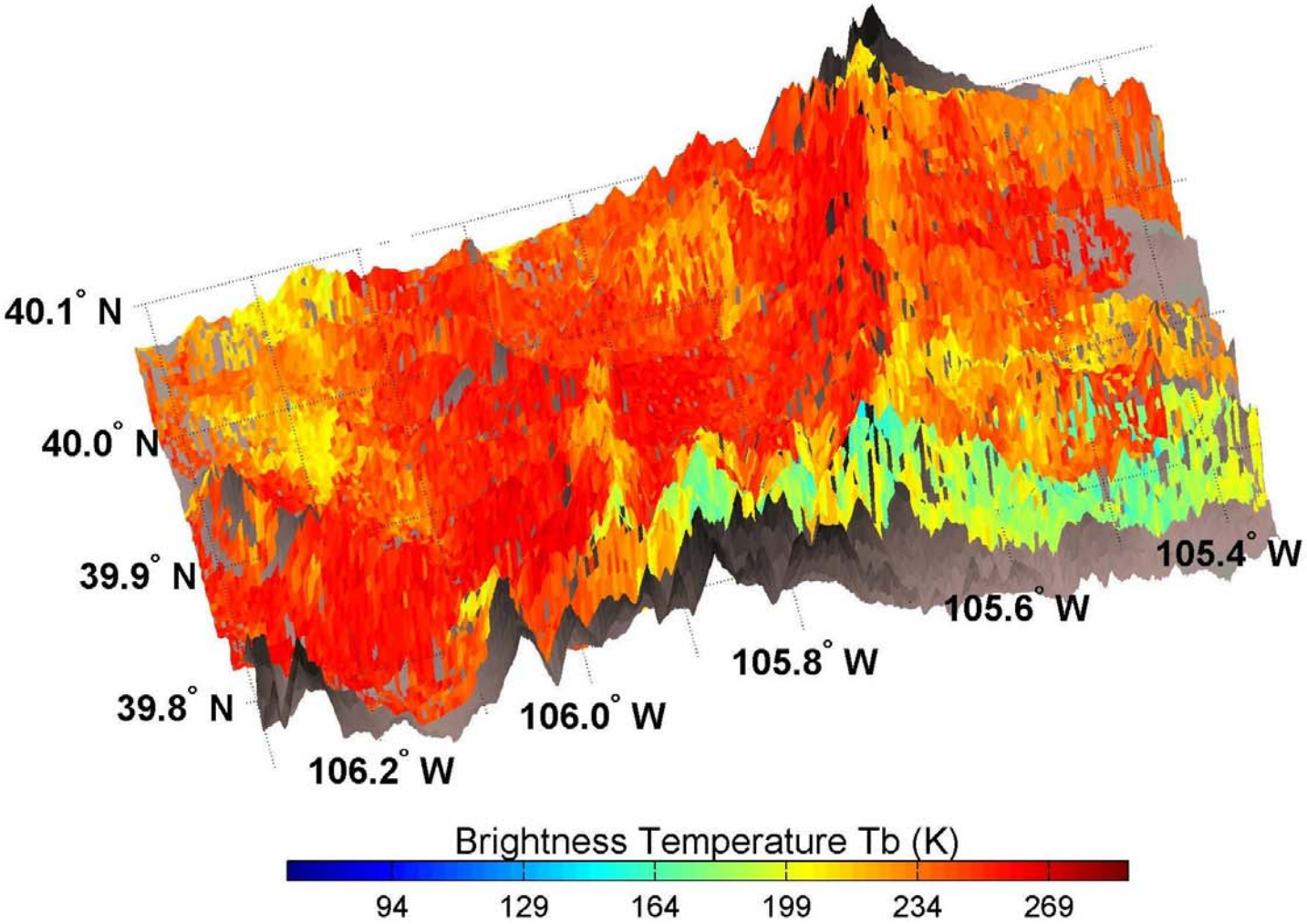


CLPX03A

Fraser: CLPX03A 02/23/2003 89.0 GHz Th

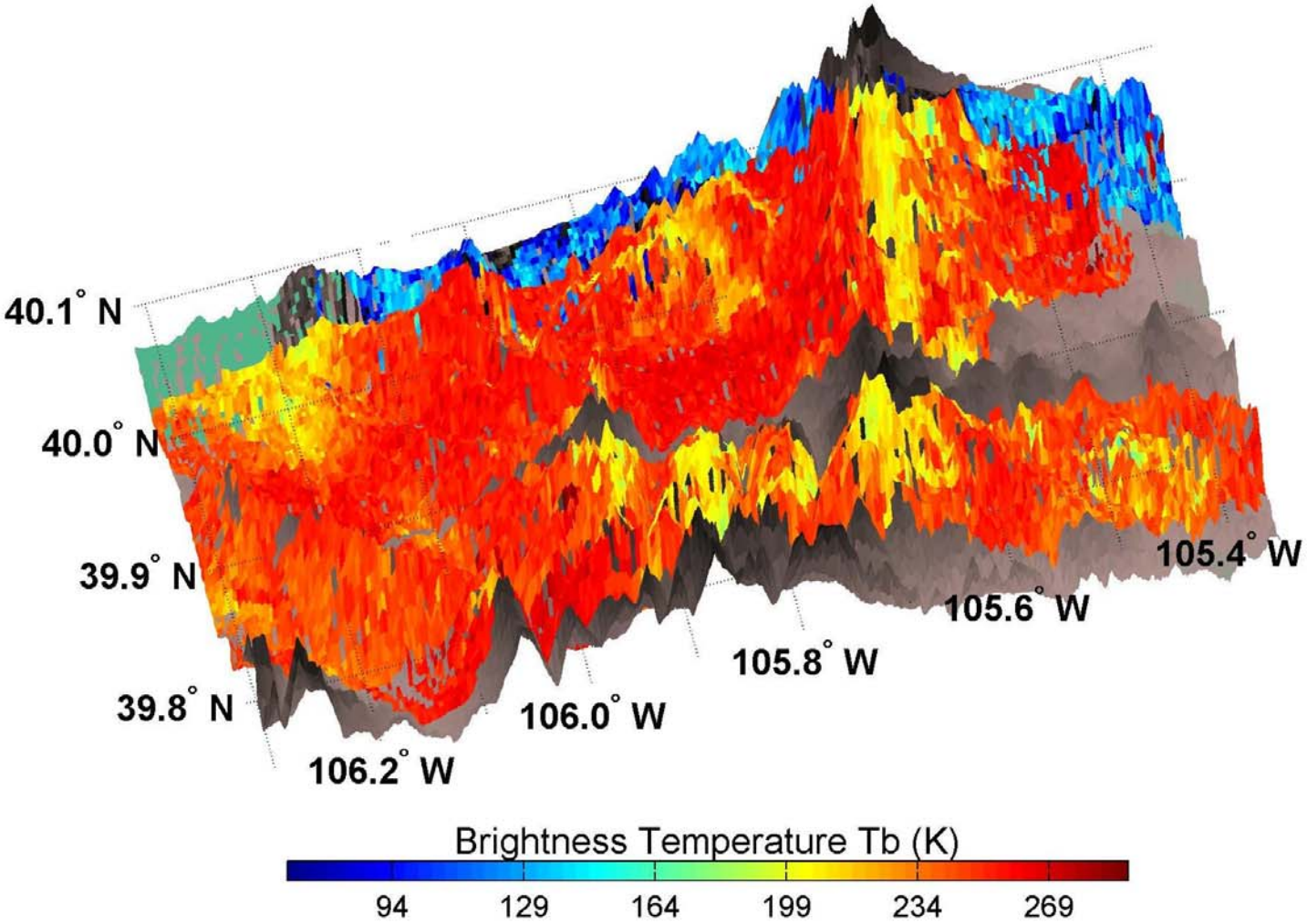


Fraser: CLPX03A 02/25/2003 89.0 GHz Th

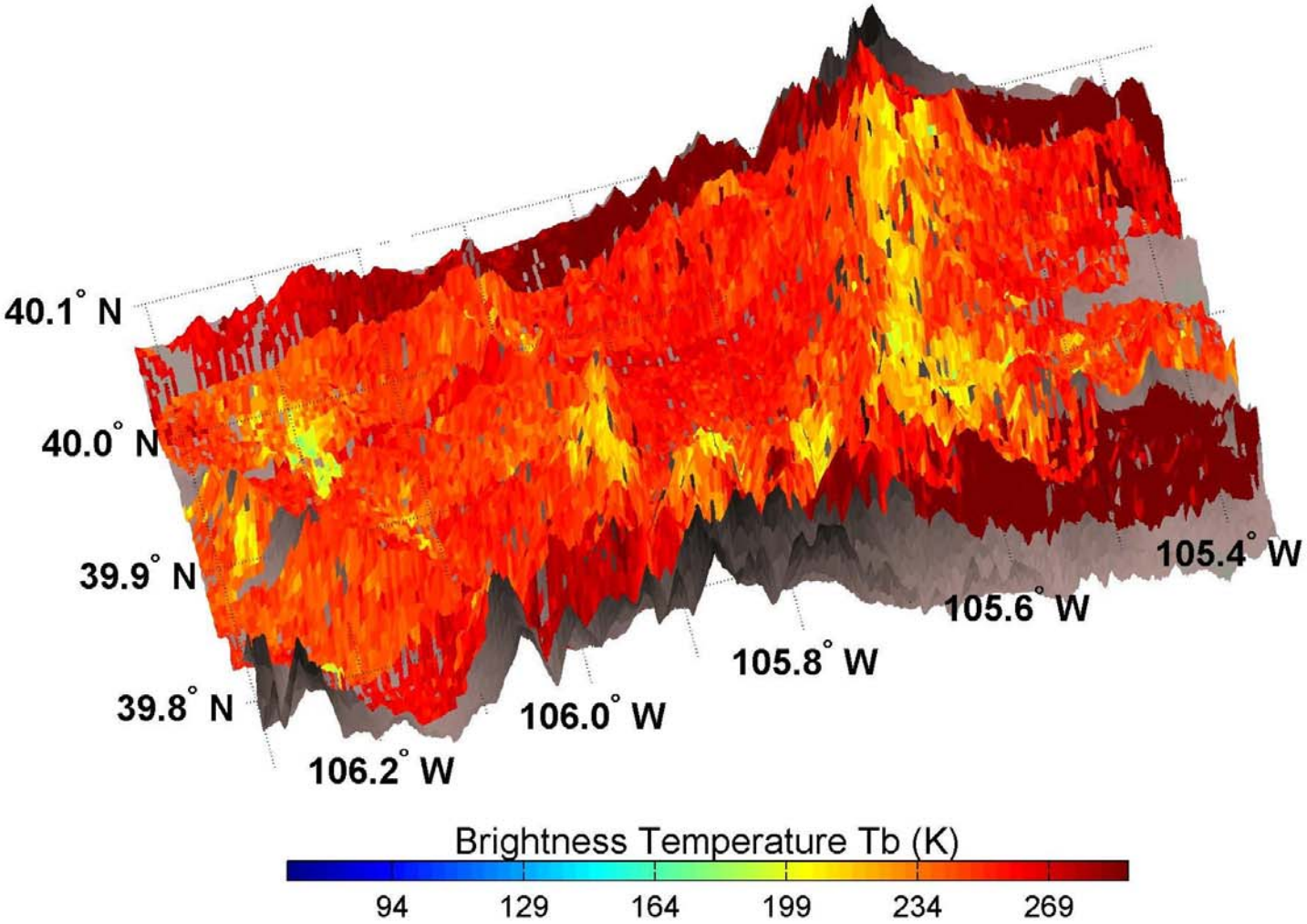


CLPX03B

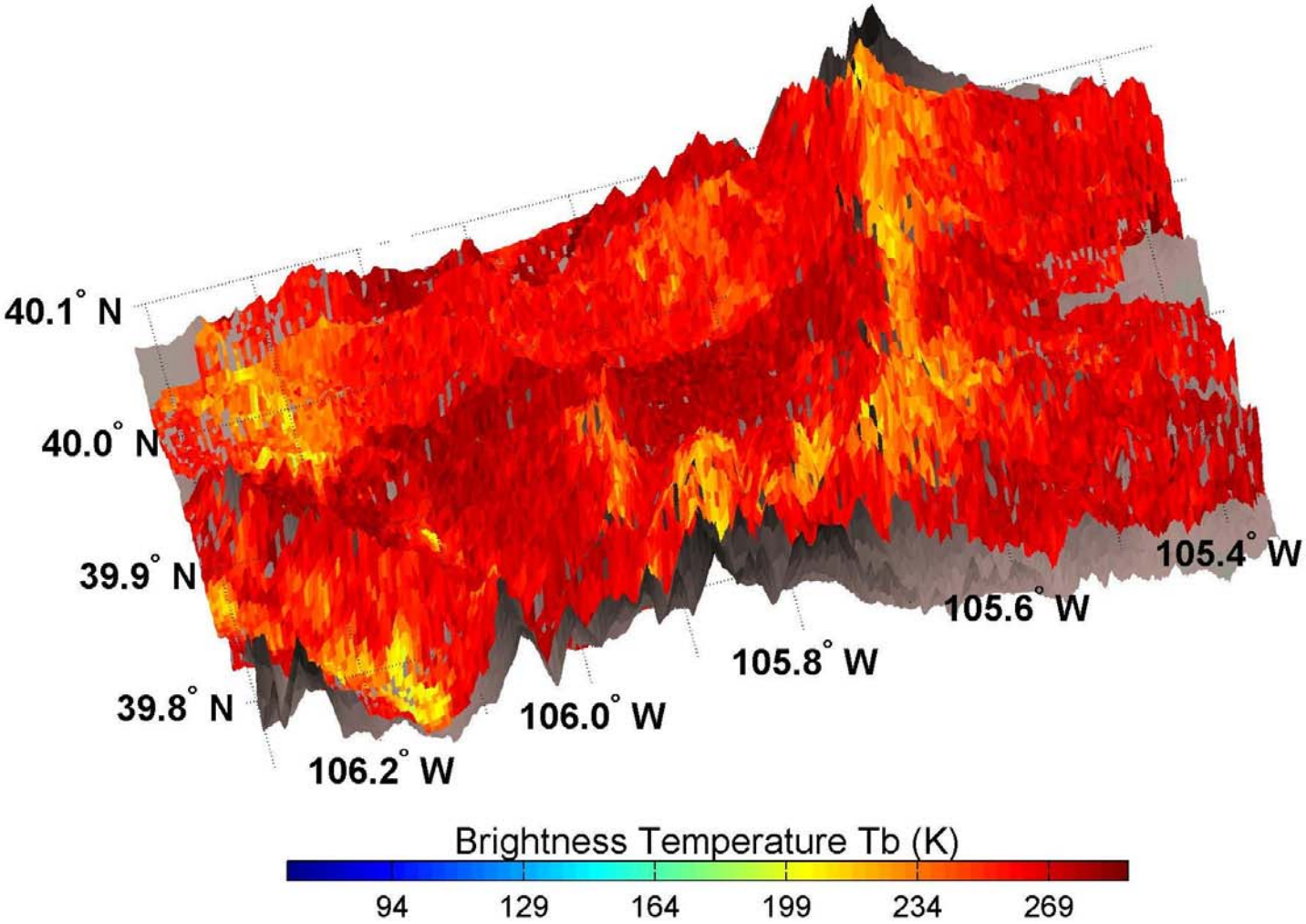
Fraser: CLPX03B 03/25/2003 89.0 GHz Th



Fraser: CLPX03B 03/30/2003 89.0 GHz Th



Fraser: CLPX03B 03/31/2003 89.0 GHz Th

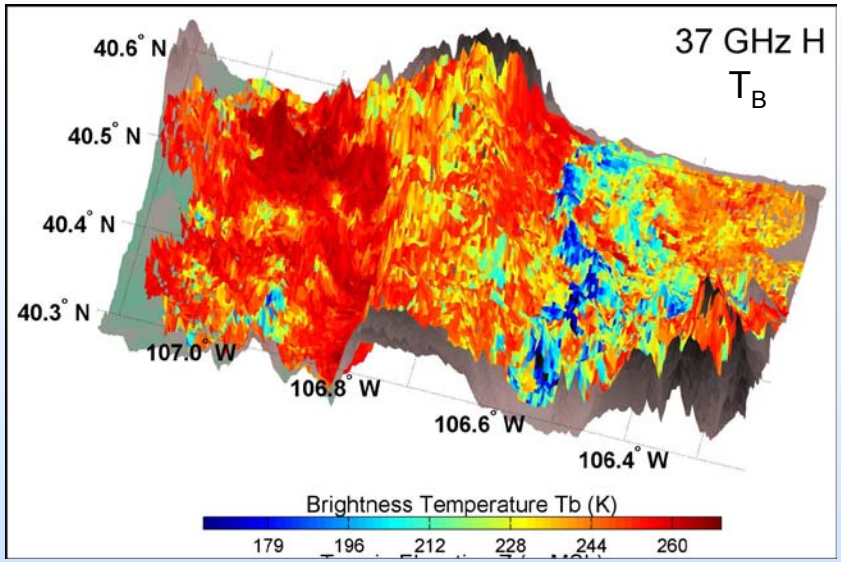


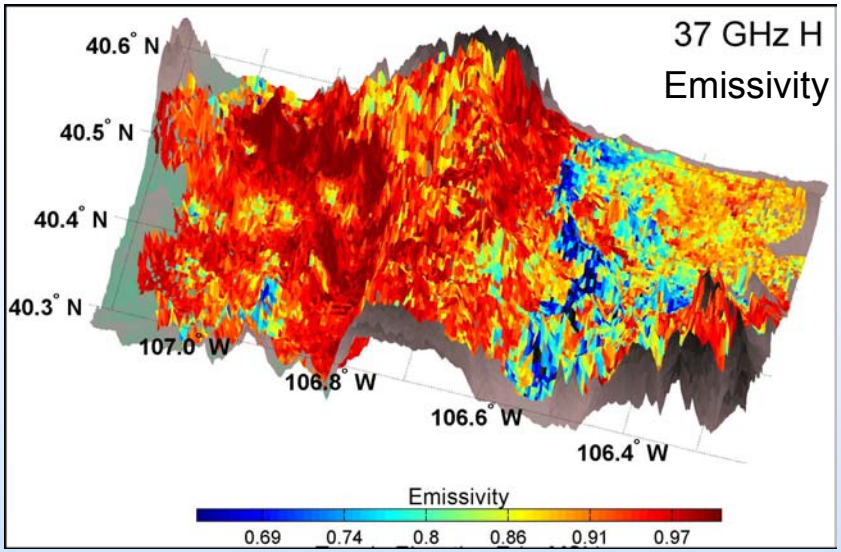
Snow Emissivity

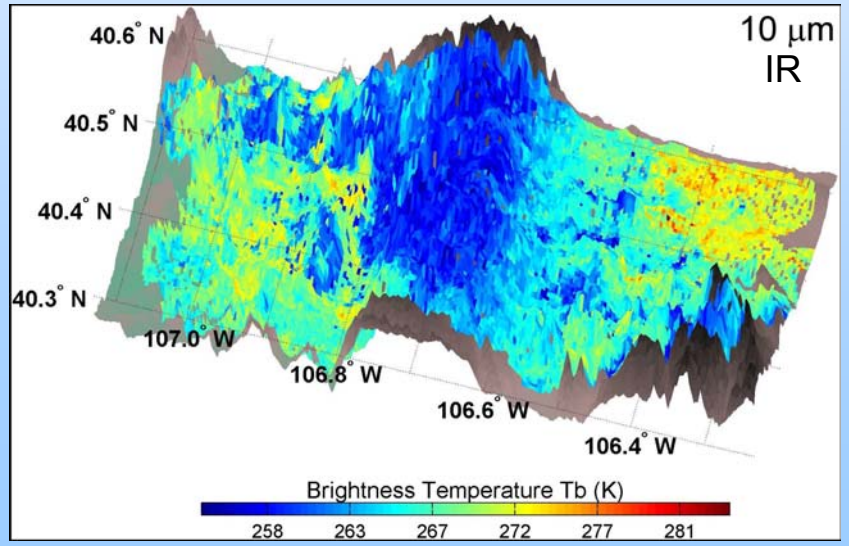
Maps of the microwave surface emissivity for the clear air cases during CLPX02 were computed using 10 μm IR surface temperatures and radiosonde-based atmospheric profiles in the following way:

- The emissivity is given approximately by the ratio of measured brightness temperature (T_B) to the surface temperature (T_s), i.e. $\varepsilon \sim T_B/T_s$.
- To estimate the atmospheric contribution to the observed T_B a nearby NWS radiosonde temperature and water vapor profiles and the Microwave Radiative Transfer (MRT) model were used.
- The MRT corrections included the angle of incidence of specular rays consistent with the local terrain slope.

Snow Emissivity Example







The derived emissivity differs from the 37 GHz T_B measurements at the Rabbit Ears ridge where cooler surface temperatures and reduced atmospheric radiance contributions were present.

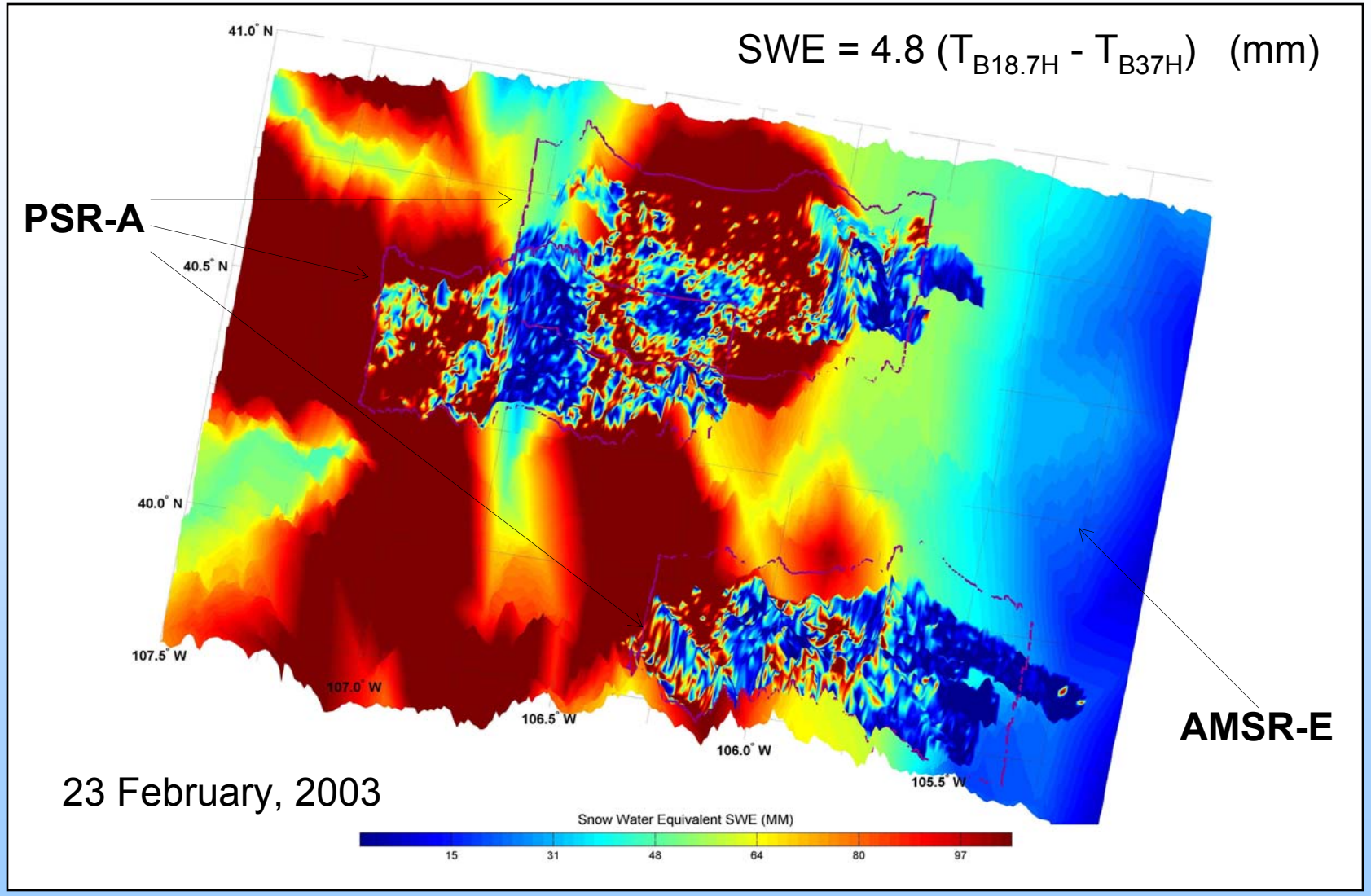
Snow Water Equivalent

Scattering of high frequency microwaves from ice particles reduces high frequency T_B measurements relative to the lower frequency T_B measurements. This concept has been historically used to estimate the snow water equivalent (SWE):

$$SWE = 4.8\,(T_{B18.7H} - T_{B37H}) \quad (mm)$$

Chang, A.T. C., J.L. Foster and D.K. Hall, “Nimbus-7 derived global snow cover parameters,” Annals of Glaciology, vol. 9, pp. 39-44. 1987.

AMSR-E to PSR-A Intercomparison



CLPX PSR Status

- PSR/A was operated successfully during CLPX02, CLPX03A and CLPX03B. All 147 flight lines yielded accurate and useful data.
- PSR/A CLPX02 geolocated, 2nd version data were delivered to NSIDC in December 2002. 3rd version expected in ~September 2003.
- PSR/A CLPX03A and CLPX03B quicklook images were published at the NOAA/ETL web site within 5 days after each flight.
- PSR/A CLPX03A and CLPX03B 2nd version data will be available in ~ October 2003.
- PSR/A CLPX03A and CLPX03B 3rd version data will be delivered to NSIDC in ~ December 2003.
- PSR/CX data will be analyzed by ~ October 2003. This data will be important for the interference mitigation (pioneered at NOAA/ETL).

Conclusions

- The first high-resolution observations and retrievals of snow pack properties using the PSR multi-channel conically-scanned airborne microwave radiometer during CLPX have been presented.
- The results show promise for improved observation, understanding, and prediction of snow properties