Sounding and Imaging of Ice Sheets Over Chinese Kunlun Station and Grove Mountains From East Antarctica as a Part of Chinese National Antarctic Research Expedition

Shinan Lang[1], Xiaojun Liu[2], Bo Zhao[2], Guangyou Fang[2], and Qiang Wu[1]

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1. Radar System

3. Along-track Signal Processing

2. Field Deployment

4. Results

Navigation

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[Radar System]

- The High-resolution Ice-sounding Radar (HRISR) is developed by the Key Laboratory of Electromagnetic Radiation and Sensing Technology of Institute of Electronics, Chinese Academy of Sciences (IECAS) , the newest version has been used in CHINARE 29 and 30
- The system mainly consists of three subsystems including the digital unit, the transmitter and the receiver.
- Basic parameters:

Radar System Figures

CHINARE29/30 IPR	Parameters	
Central Unit	Peak power	500 W
	Center frequency	150 MHz
	Pulse repetition frequency（PRF）	8000 Hz
	Sampling time window	50 μs
	Sampling rate	500 MHz
	Digitizer resolution	12 bits
	Maximum penetrating depth in ice	> 3500m
	Combined dynamic range	> 110 dB
	Signal presuming in slow time	128 times

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Transects' Figures

[Field Deployment]

- To date, the HRISR system has been operated over one main transect from Chinese Zhongshan Station to Kunlun Station along with transects over Chinese Kunlun Station during CHINARE 29
- The HRISR system has been operated over Grove Mountains during CHINARE 30
- In order to achieve the best measurement results, the selection of the chirped-pulse duration, the power amplifier value, the variable attenuators values and the coherent integration number are listed in the parameter configurations given in Table:

Detection Depth (km)	Chirped-pulse Duration (μs)	Power Amplifier (W)	Variable Attenuators (dB)	Coherent Integration Number
<0.5	2	400	5-0	32
0.5-1	2	400	5-0	64
1-1.5	2	400	5-0	64
1.5-2	2	450-500	0	128
2-2.5	4	450-500	0	128
2.5-3	8	450-500	0	128
>3	8	450-500	0	128

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[Along-track Signal Processing]

- We chose the additional focused synthetic aperture radar (SAR) processing because of the clutter reduction and the significant improvement in azimuth resolution
- Two kinds of focused SAR imaging techniques are used: the modified range migration algorithm using curvelets, and the modified nonlinear Chirp Scaling (CS) algorithm
- The modified range migration algorithm using curvelets is a wave-euqation-based ice sounding imaging method using curvelets as building blocks of ice-sounding data, which could reduce the speckle noise during the imaging processing without degrading the ability in along-track clutter reduction
- The modified nonlinear Chirp Scaling (CS) algorithm was proposed to deal with the massive amount of ice-sounding data imaging problem. The algorithm needs only complex multiplication and Fourier transform instead of interpolation, which improves the computational efficiency greatly

Flowchart of the modified range migration algorithm using curvelets for ice sounding

Flowchart of the modified nonlinear CS algorithm for ice sounding

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[Results]

- Six sample results collected along the traverse near Kunlun Station during CHINARE 29
- One sample result collected along the traverse of Wilson Ridge during CHINARE 30
- One sample result collected along the traverse of Mason Peaks during CHINARE 30

Kunlun Station Results

Wilson Ridge Results

Mason Peaks Results

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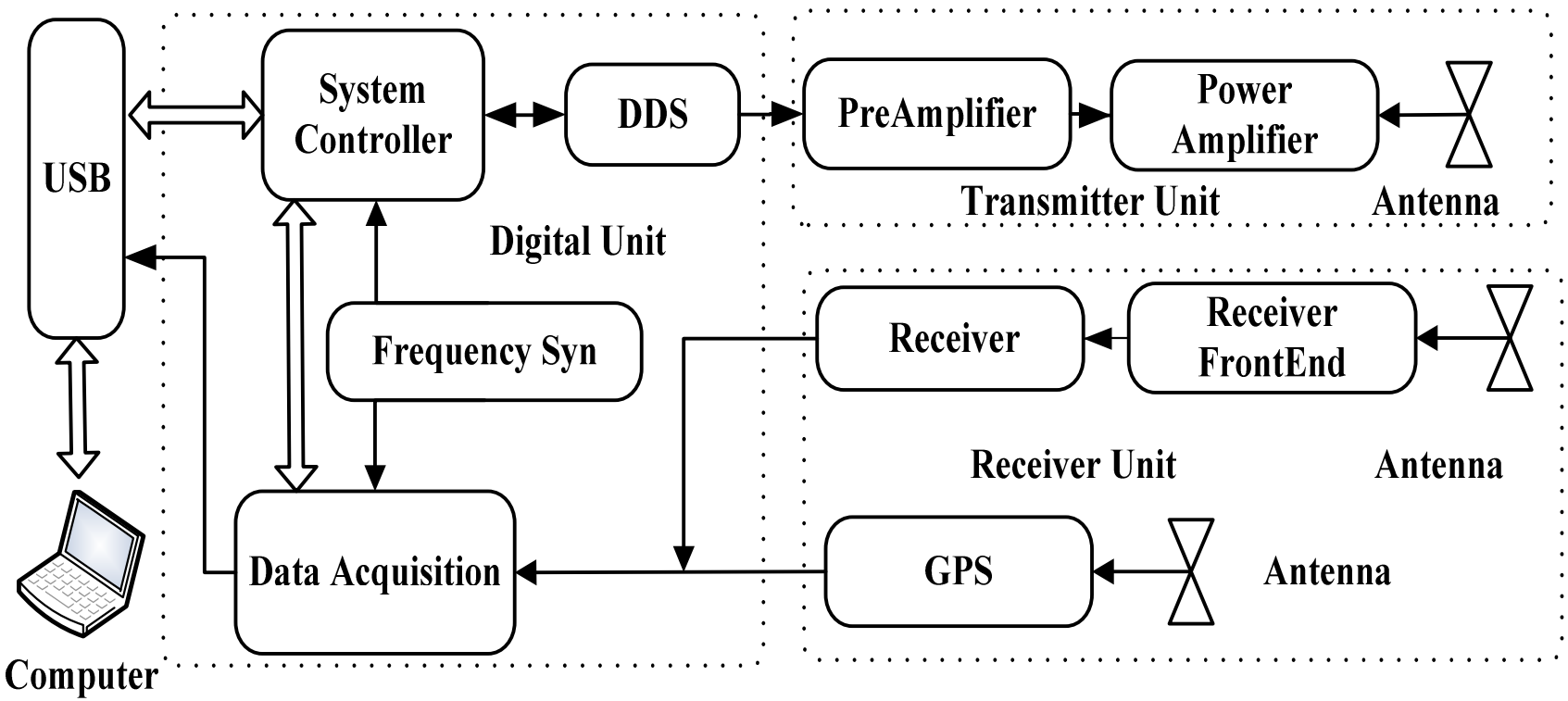
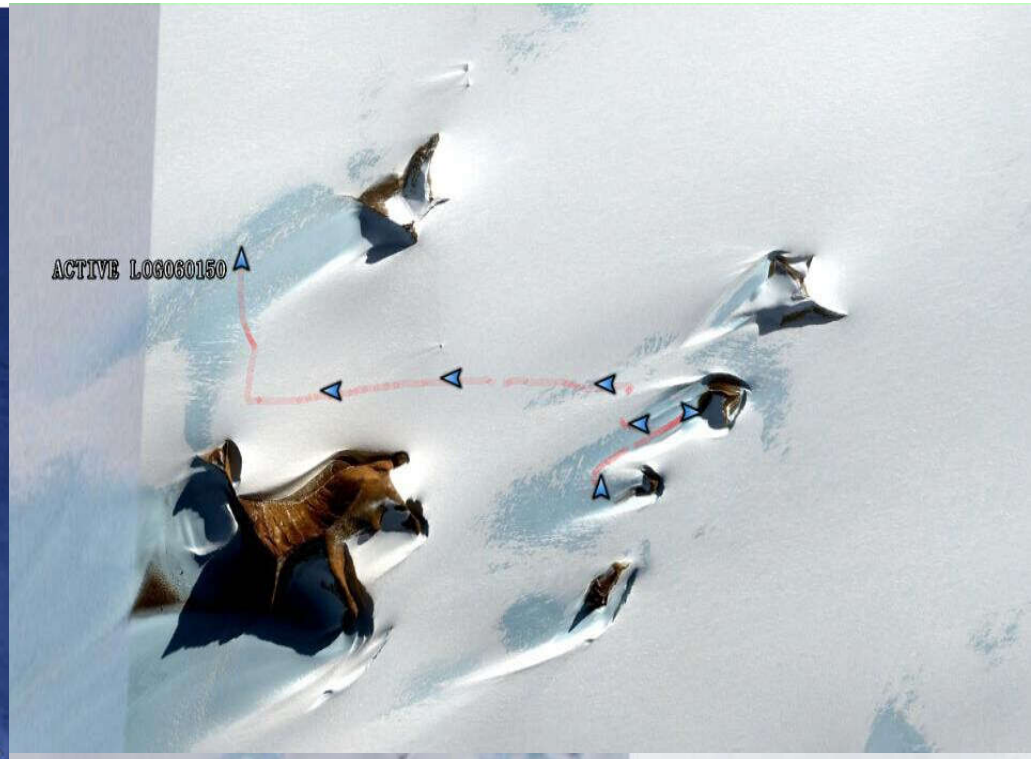

USB
System Controller
DDS
PreAmplifier
Power Amplifier
Transmitter Unit
Antenna
Digital Unit
Frequency Syn
Receiver
Receiver FrontEnd
Receiver Unit
Antenna
Data Acquisition
GPS
Antenna
Computer

[close]

Kunlun Station
80°25′01″S,
77°06′58″E
Zhongshan Station
69°22′24″S
76°22′40″E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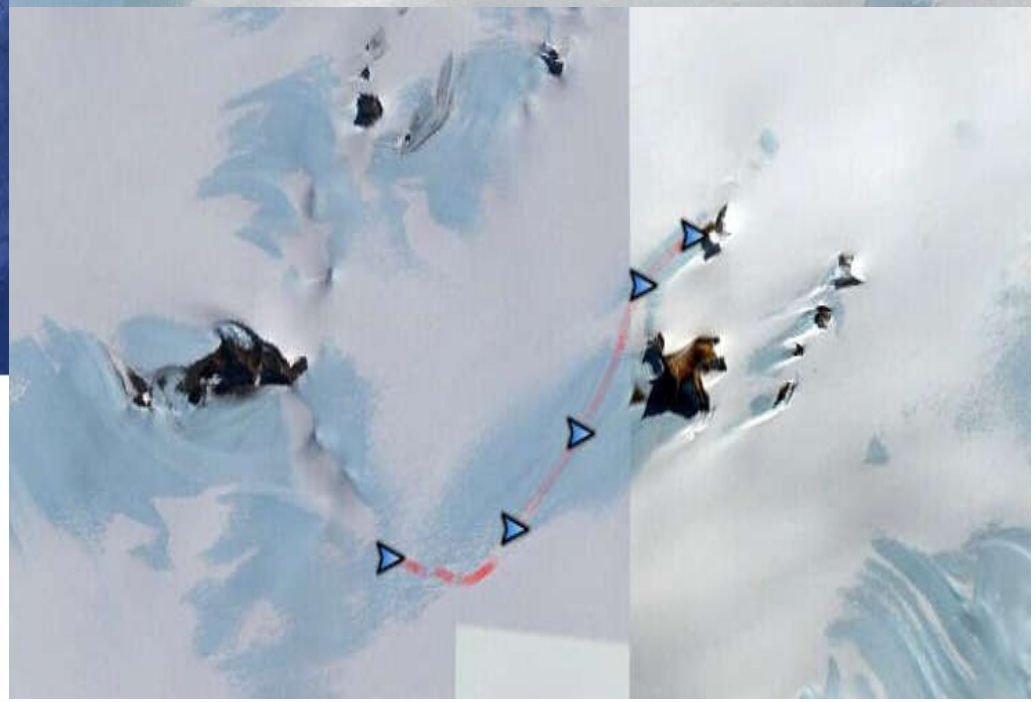

[close]

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Raw data
$s(x, z=0, t)$

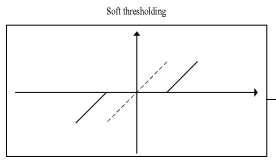
Range FFT

Azimuth NUFFT:
$S(k_x, z=0, \omega)$

Migration to air-ice interface:
$S(k_x, z=h, \omega)$

Multiplied by the scaled windows $U_j(\xi)$:
curvelet coefficients $\hat{C}_\mu$

Two-dimensional IFFT:
curvelet coefficients C_μ



Two-dimensional FFT:
$\hat{c}_\mu(k_x, z=h, \omega)$

Stolt interpolation

Two-dimensional IFFT:
$s_\mu(x, z, t=0)$

Last curvelet basis according to nonzero coefficients ?

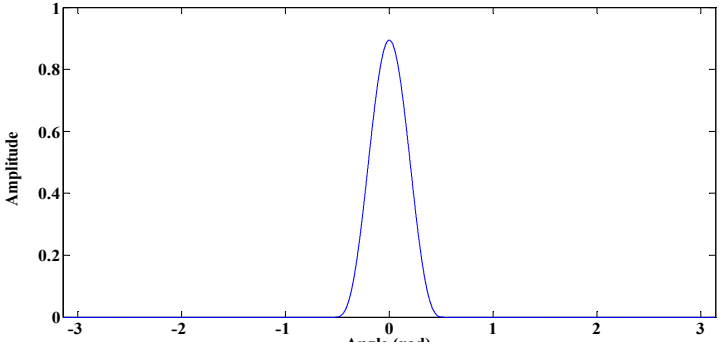
No

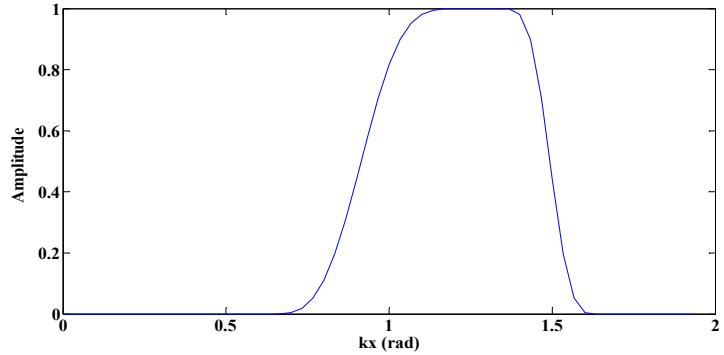
Yes

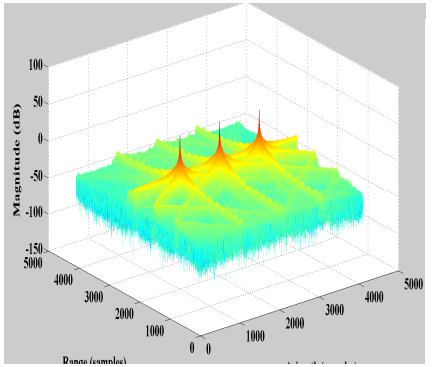
Total image:
$s(x, z, t=0)$

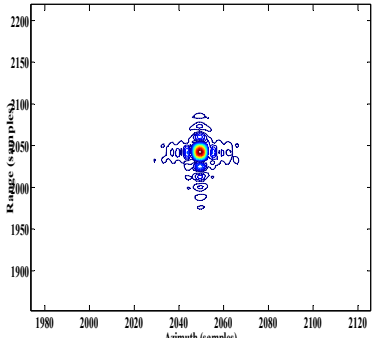
End

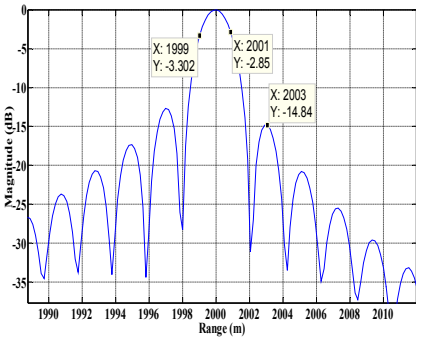
[close]

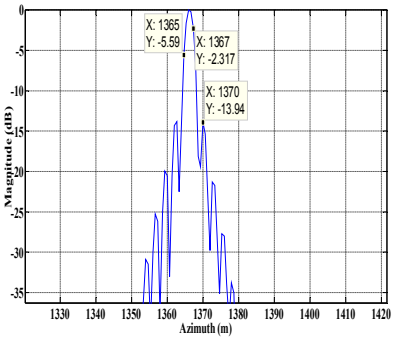












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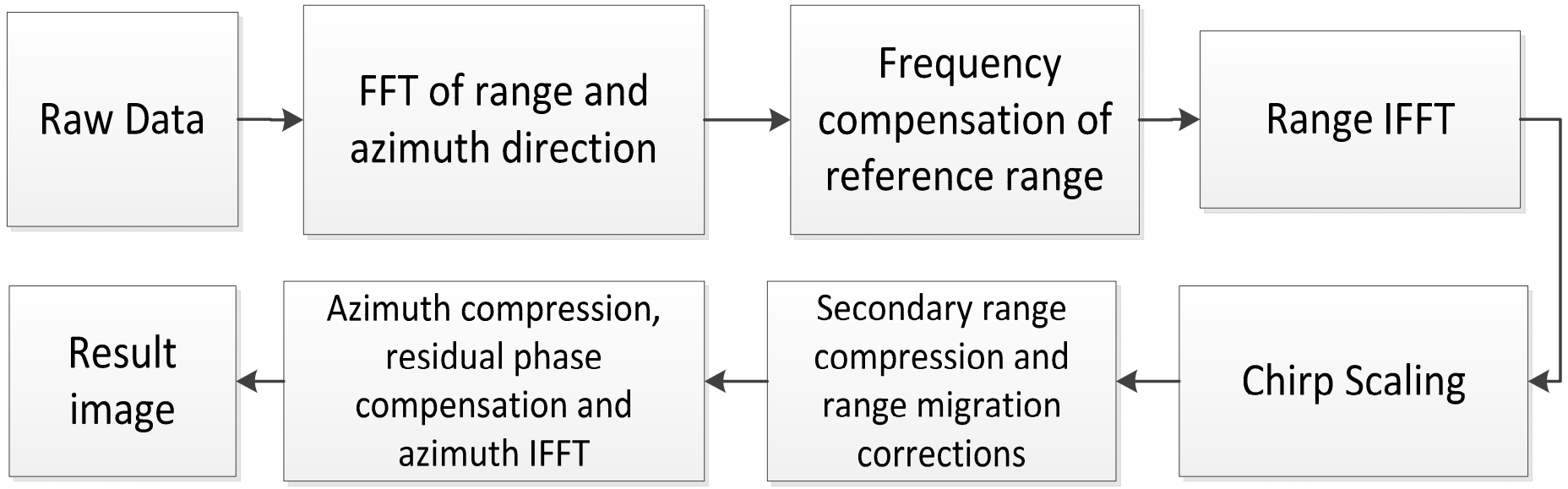
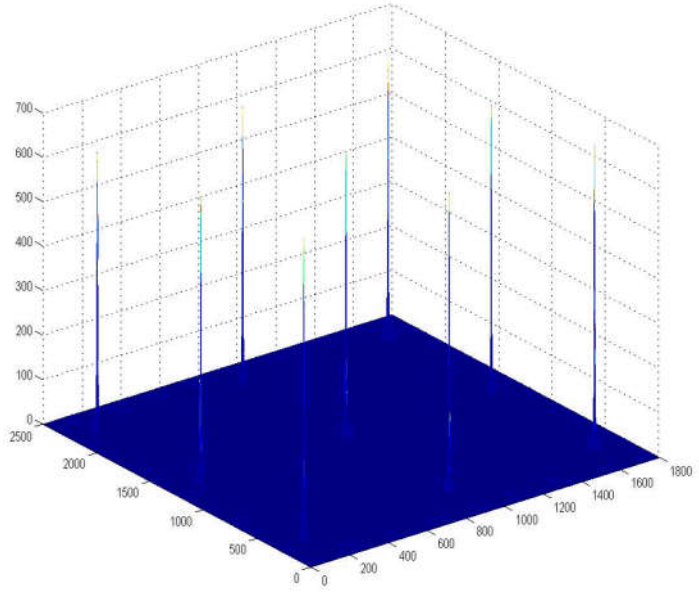
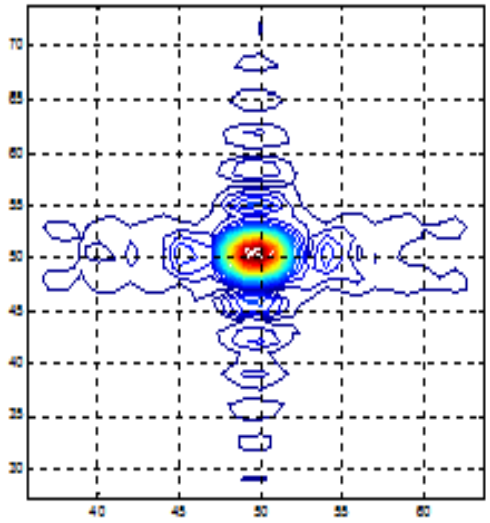
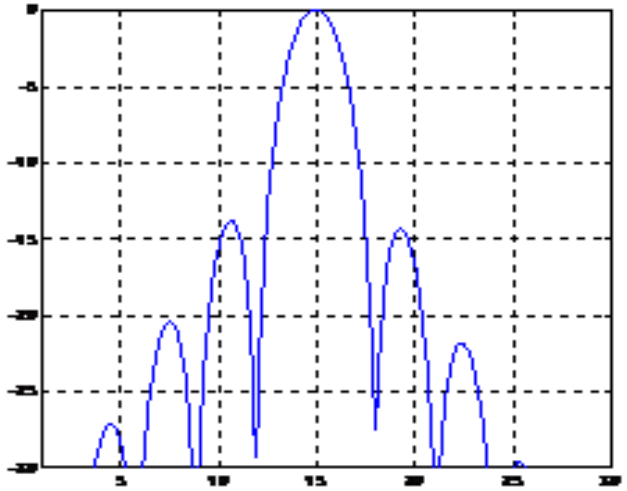

Raw Data
FFT of range and azimuth direction
Frequency compensation of reference range
Range IFFT
Chirp Scaling
Secondary range compression and range migration corrections
Azimuth compression, residual phase compensation and azimuth IFFT
Result image







[close]

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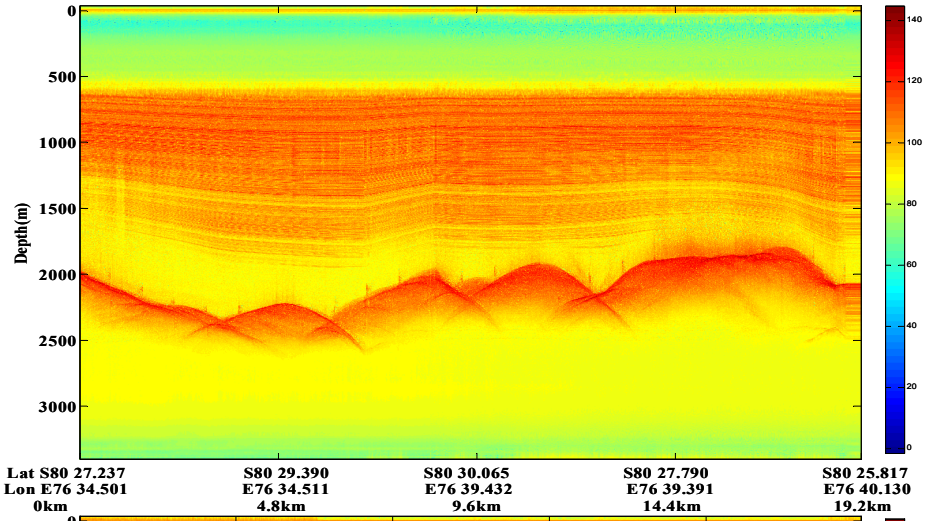
Depth(m)
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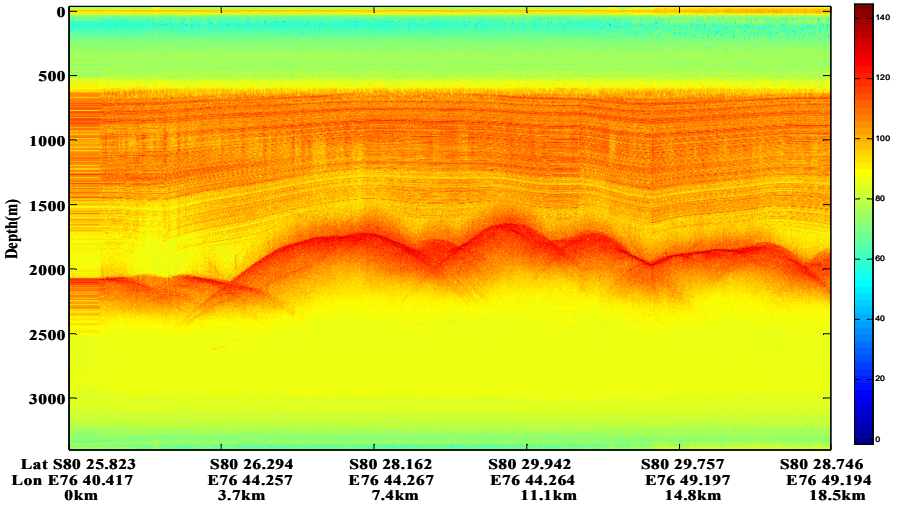
1000
1500
2000
2500
3000
140
120
100
80
60
40
20
0
Lat S80 27.237
Lon E76 34.501
0km
S80 29.390
E76 34.511
4.8km
S80 30.065
E76 39.432
9.6km
S80 27.790
E76 39.391
14.4km
S80 25.817
E76 40.130
19.2km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20
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Lon E76 40.417
0km
S80 26.294
E76 44.257
3.7km
S80 28.162
E76 44.267
7.4km
S80 29.942
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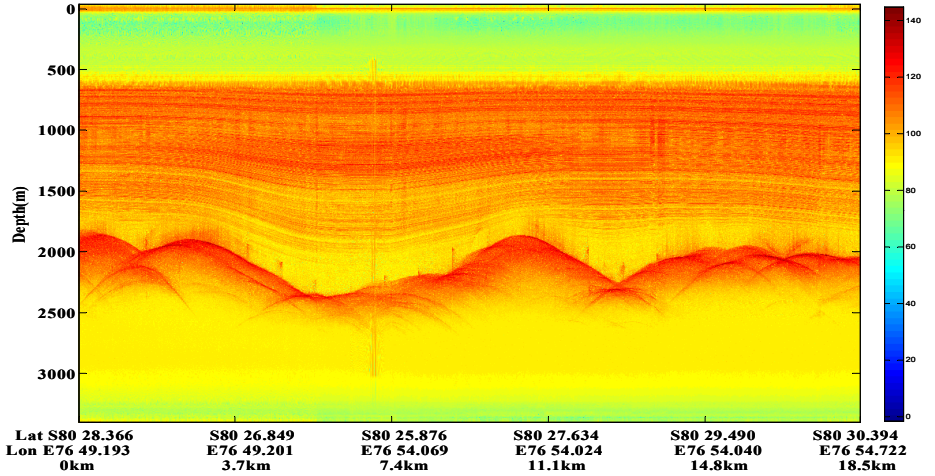
11.1km
S80 29.757
E76 49.197
14.8km
S80 28.746
E76 49.194
18.5km


Depth(m)
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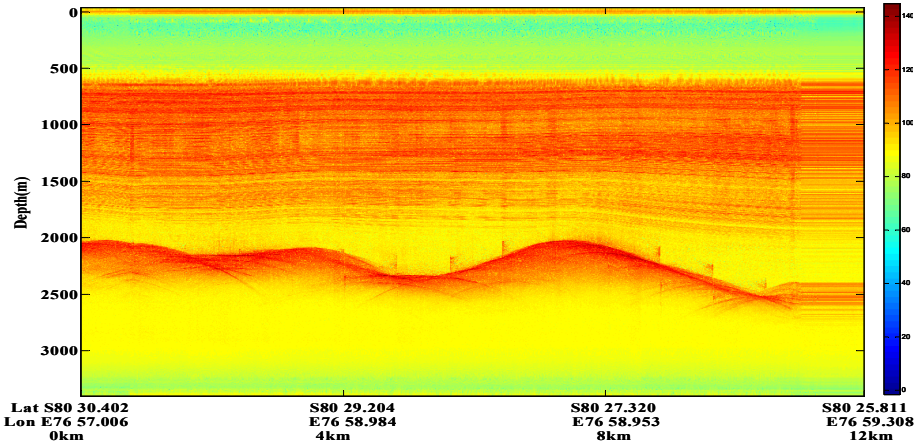
140
120
100
80
60
40
20
0
Lat S80 28.366
Lon E76 49.193
0km
S80 26.849
E76 49.201
3.7km
S80 25.876
E76 54.069
7.4km
S80 27.634
E76 54.024
11.1km
S80 29.490
E76 54.040
14.8km
S80 30.394
E76 54.722
18.5km


Depth(m)
0
500
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1500
2000
2500
3000
Lat S80 30.402
Lon E76 57.006
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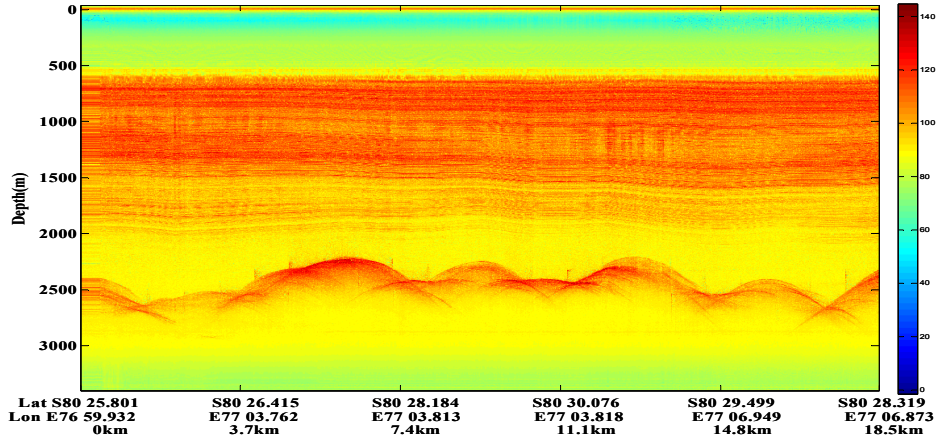
E76 58.953
8km
S80 25.811
E76 59.308
12km


Depth(m)
0
500
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140
120
100
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60
40
20
0
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Lon E76 59.932
0km
S80 26.415
E77 03.762
3.7km
S80 28.184
E77 03.813
7.4km
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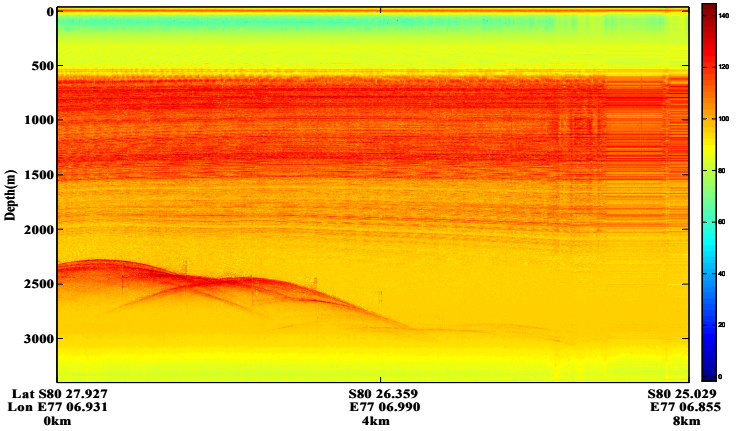
18.5km


Depth(m)
0
500
1000
1500
2000
2500
3000
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Lon E77 06.931
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S80 26.359
E77 06.990
4km
S80 25.029
E77 06.855
8km

[close]

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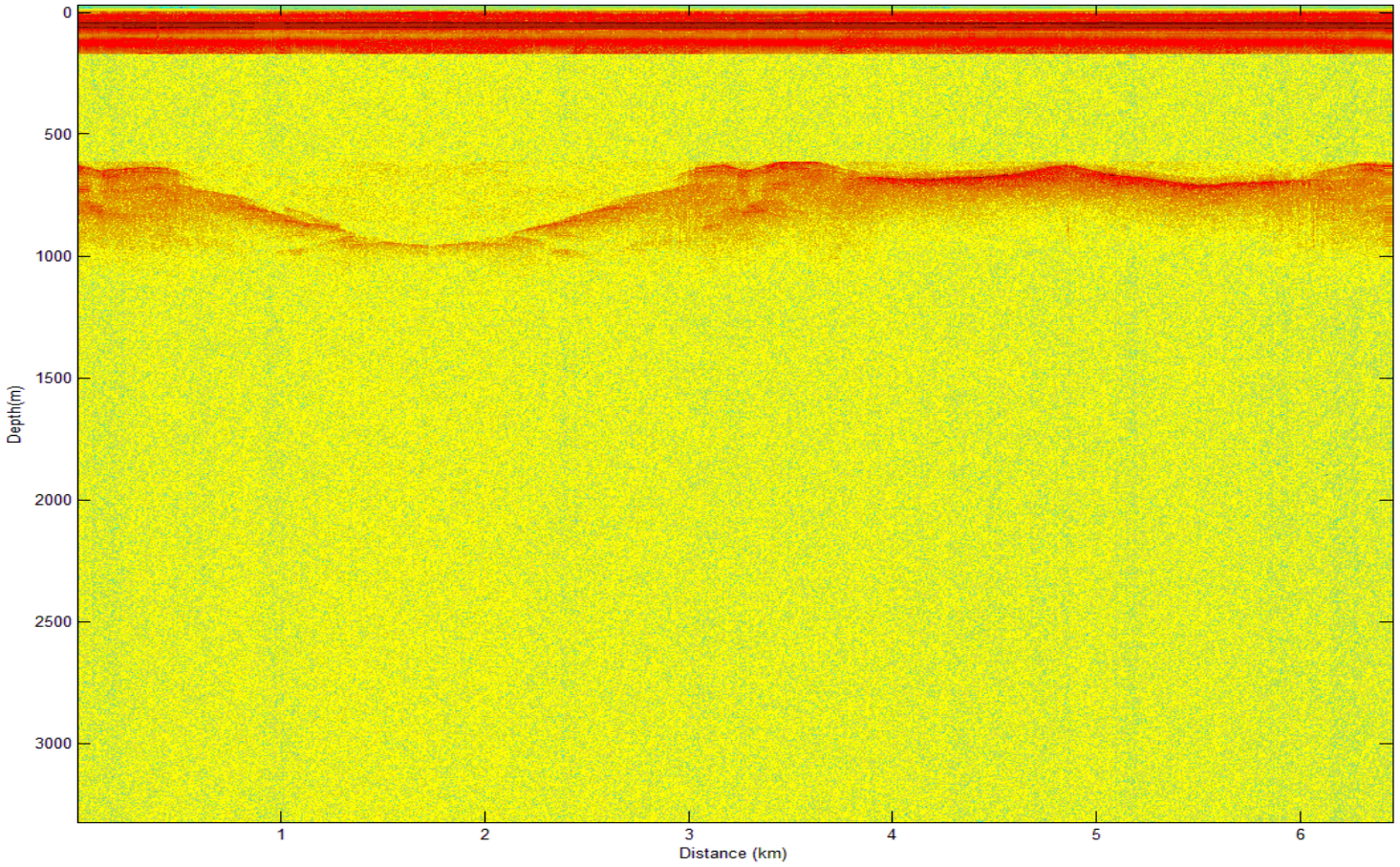

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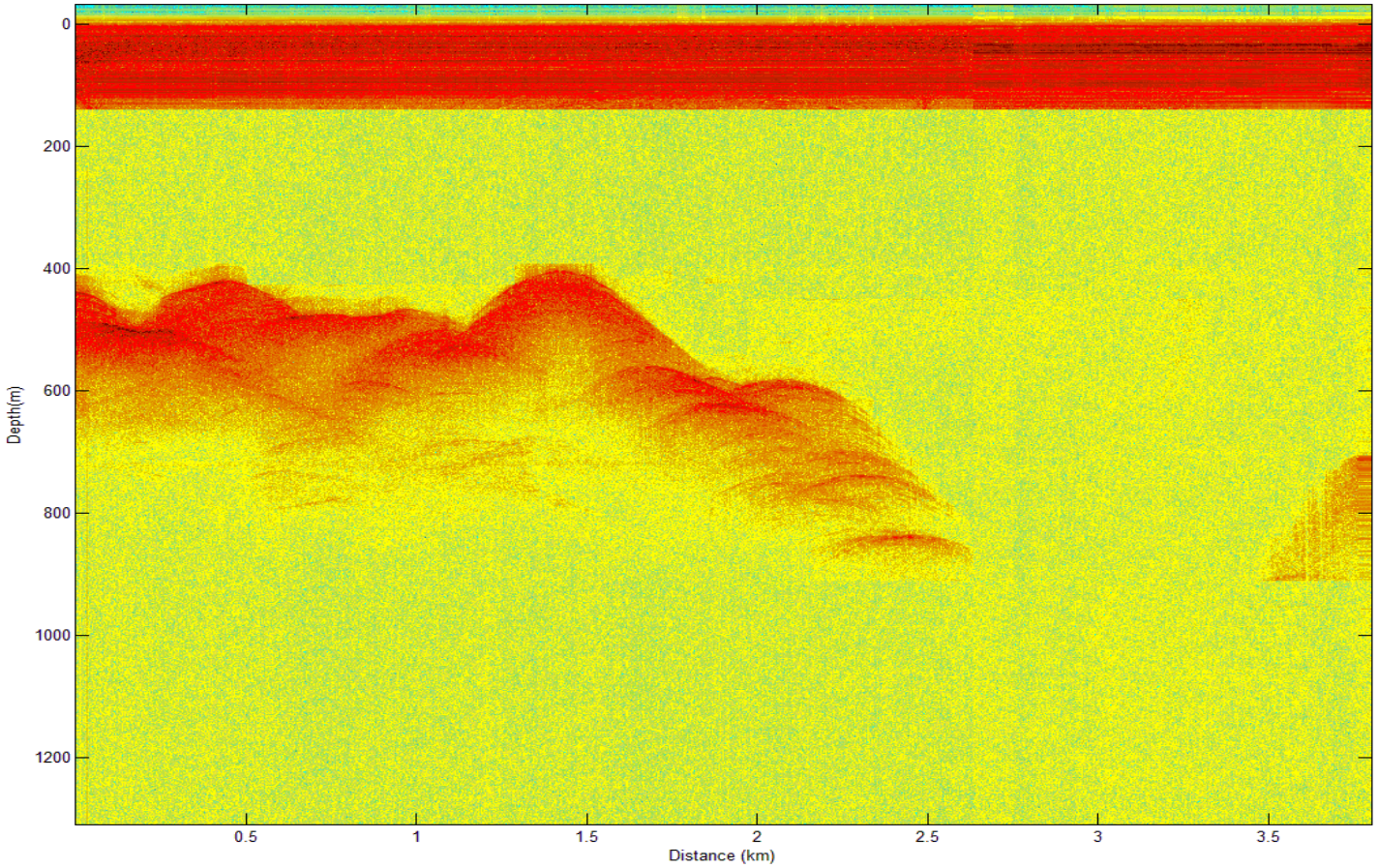

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