High-resolution estimates of SuperDARN elevation angle from IQ data

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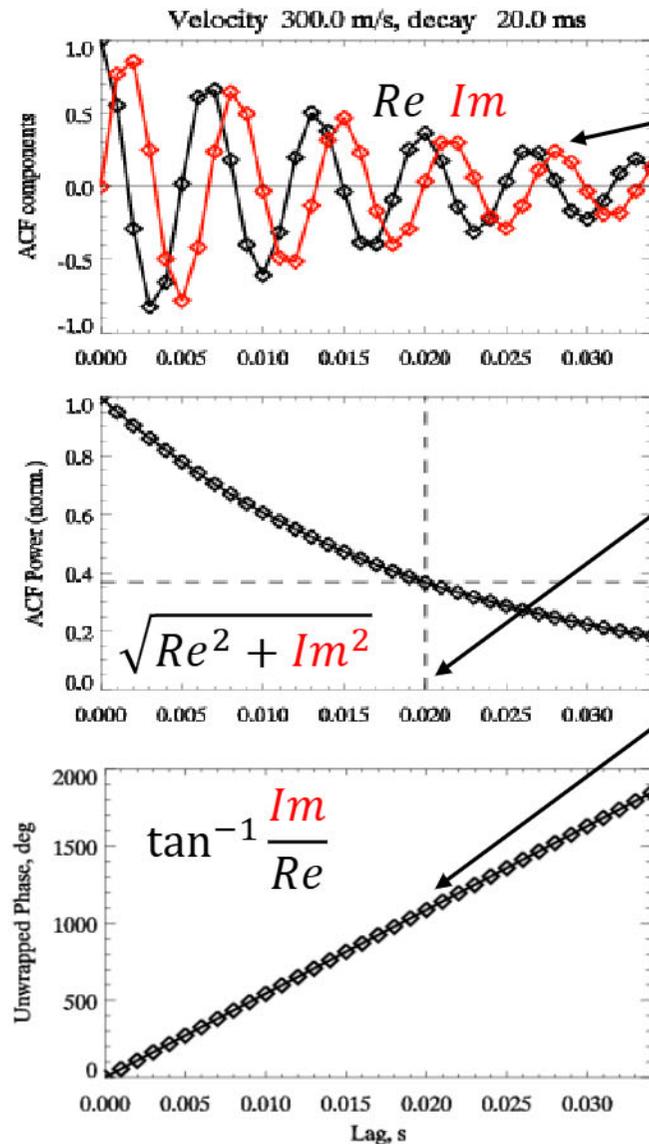
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Outline

- Introduction and motivation

- Experimental setup

- Comparison of IQ and fitted data

- Error analysis

- Conclusions

Introduction

Velocity 300.0 m/s, decay 20.0 ms
Re Im
$\sqrt{Re^2 + Im^2}$
$\tan^{-1}\dfrac{Im}{Re}$

- SuperDARN radars generate a <u>complex autocorrelation function</u> (ACF) for each beam/range cell using a <u>0.1-s multi-pulse sequence</u>

- From ACF power a decorrelation time (<u>spectral width</u>) is estimated by <u>fitting a model to all ACF lags</u>.

- With ACF phase, <u>Doppler velocity</u> is estimated from a slope of <u>a linear fit to all ACF lags</u>.

- In the multi-pulse regime, non-zero lags are affected by <u>cross-range interference</u> (CRI), which must be mitigated by <u>substantial averaging</u> (~3.5 s)

Motivation

- <u>Elevation angle</u> is a very important parameter providing information on <u>echo location and electron density</u> at the scatter point.

- In contrast to Doppler velocity and spectral width, it can be measured directly from a <u>lag 0 phase offset</u> between the main and interferometer arrays, which **is not affected by CRI**.

Fig. 1 Hokkaido East SuperDARN radar antennas
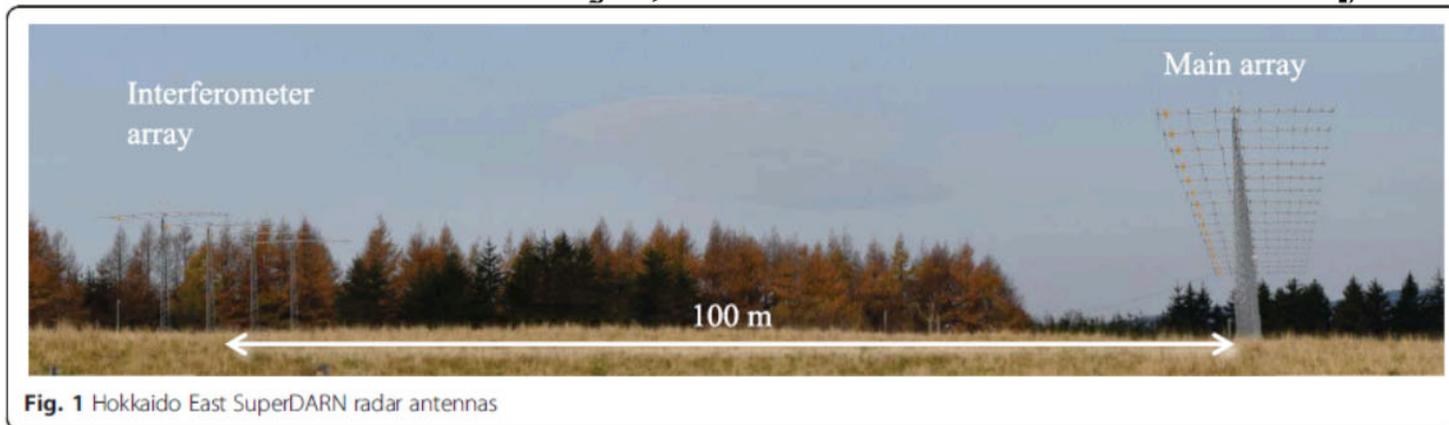
- If one uses <u>IQ data</u> [e.g., *Yukimatu & Tsutsumi, 2002*], then the sampling rate can be <u>shortened from 3.5 s to 0.1 s (!!!)</u>.

- Therefore, feasibility study of IQ elevation estimates would be highly desirable.
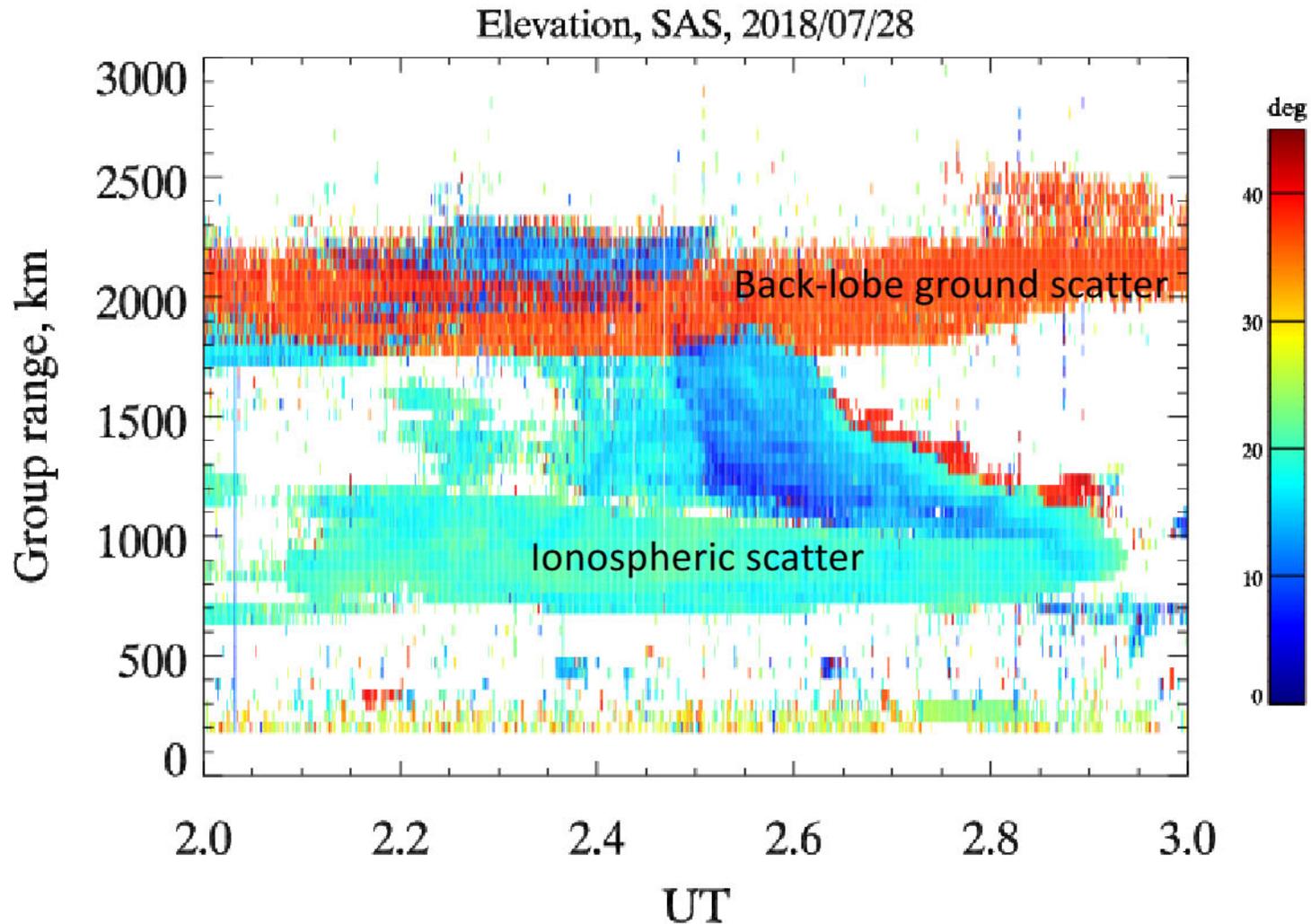
Experimental setup

- Radar: Saskatoon, Canada
- Date: 00:00-24:00UT, 28/07/2018
- Single beam (#3)
- Frequency: 10.5 MHz
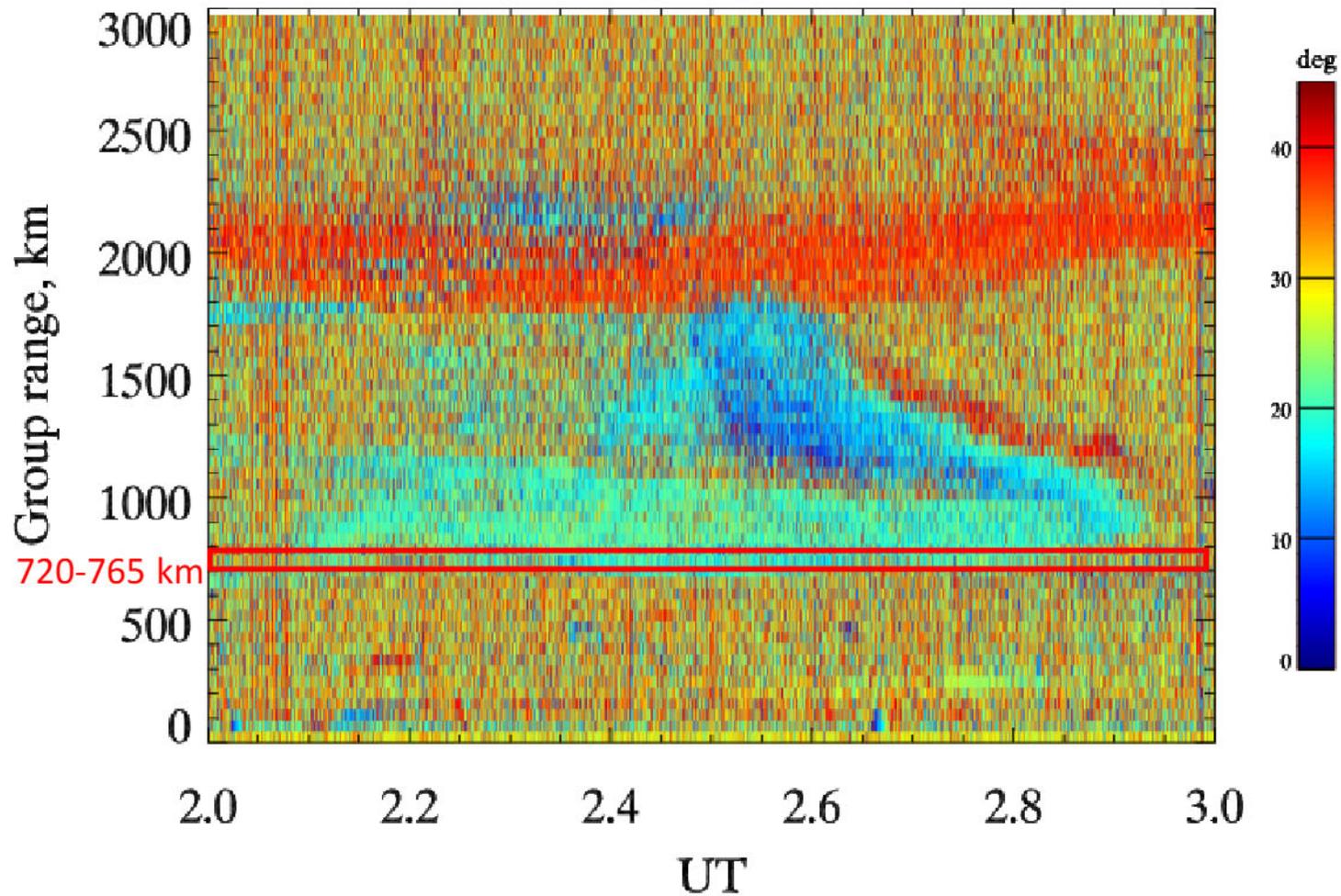- Recording both ACF and IQ data

Range-time data

Saskatoon (fitACF)　　　Beam 03　　　28/Jul/2018
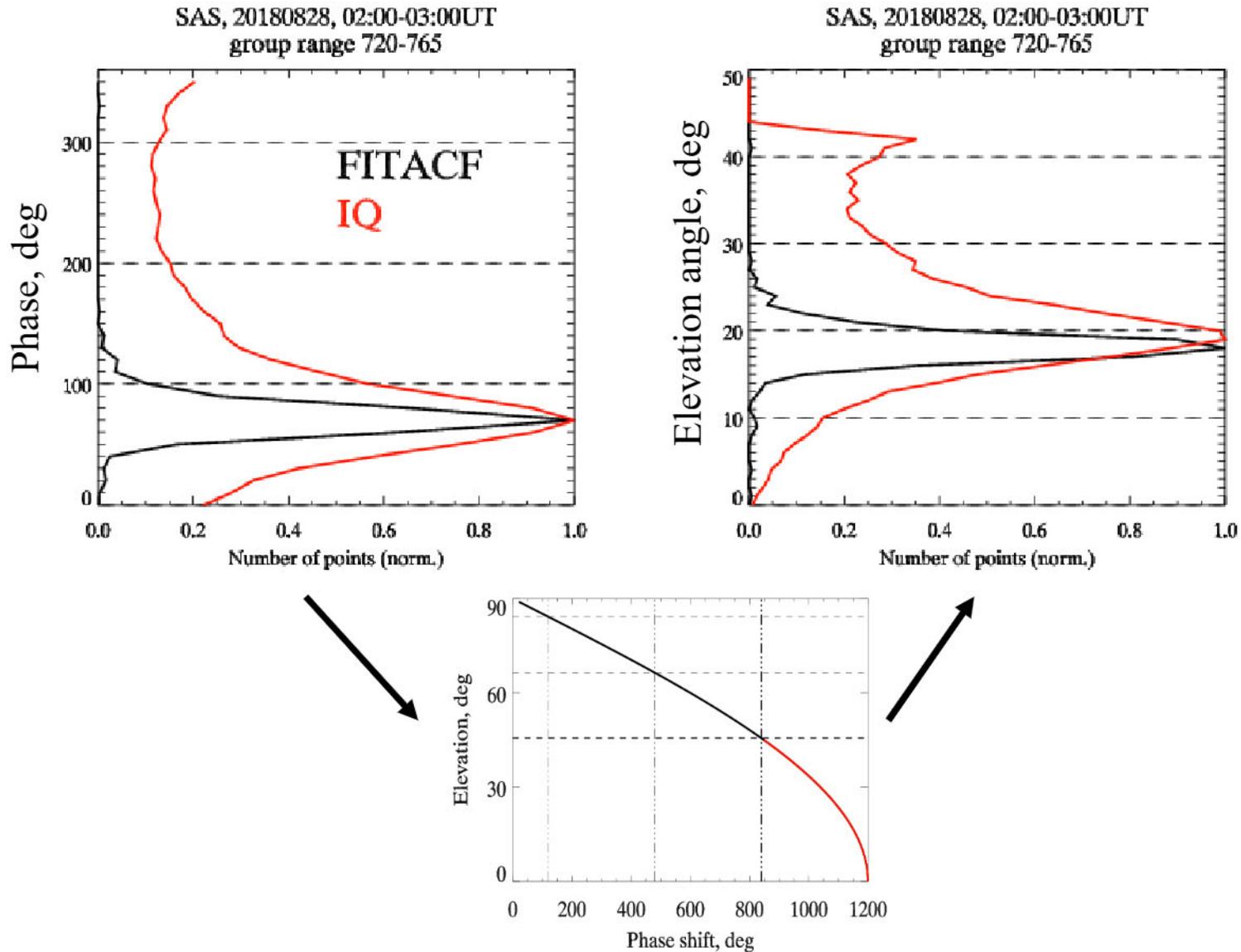
Analysed interval 2-3UT
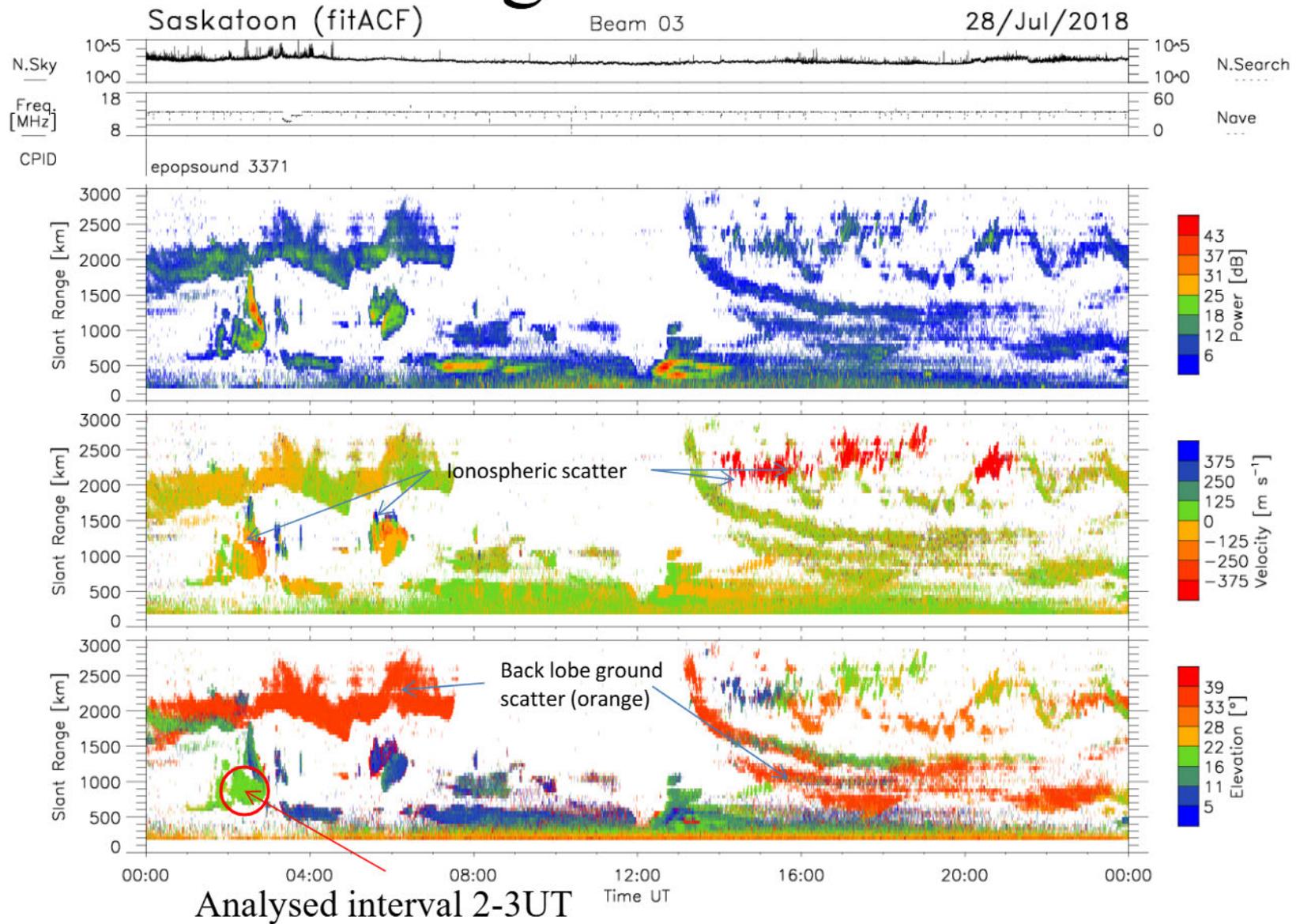
Conventional elevation angle

Elevation, SAS, 2018/07/28

Back-lobe ground scatter

Ionospheric scatter

IQ elevation angle

Elevation, SAS, 2018/07/28

720-765 km

Histograms at 720-765 km

SAS, 20180828, 02:00-03:00UT
group range 720-765
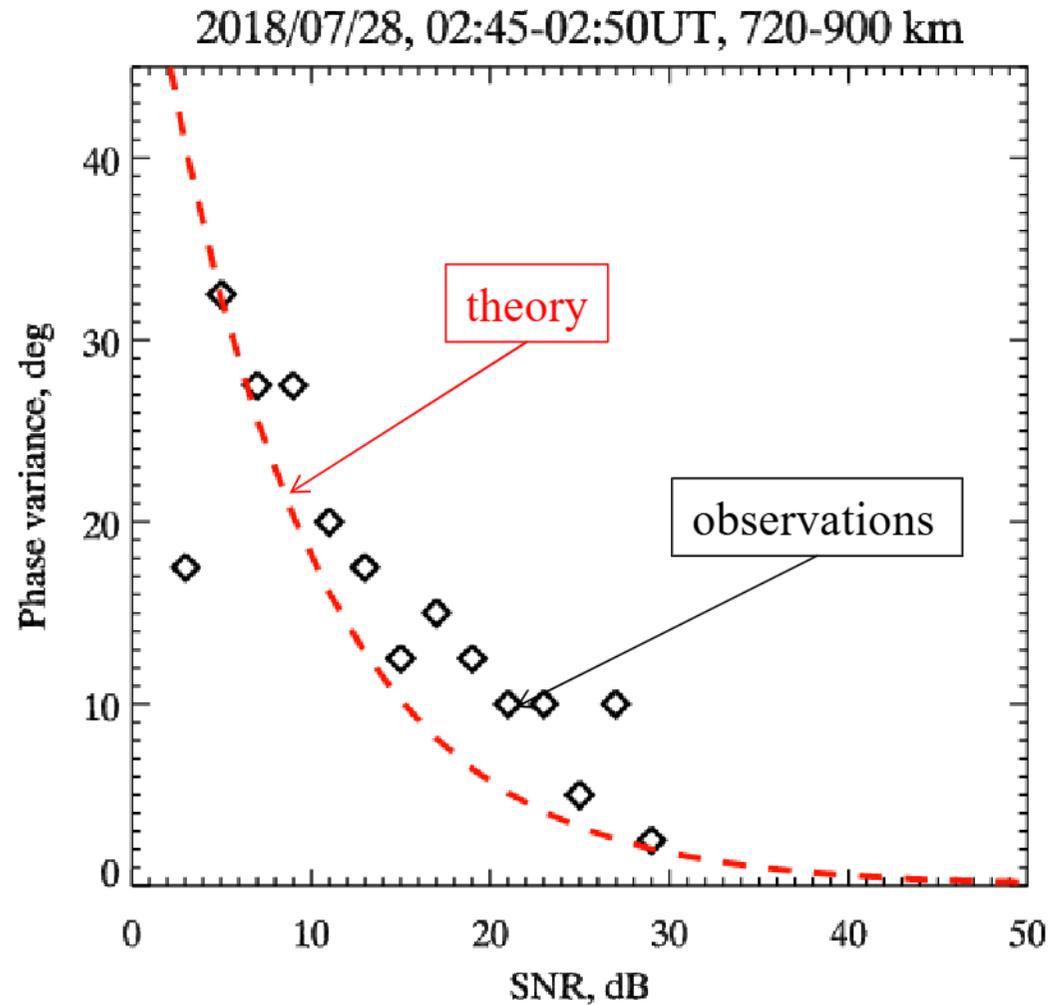
SAS, 20180828, 02:00-03:00UT
group range 720-765

FITACF
IQ

Phase variance analysis: Theory

Theoretically, at SNR>10 the signal phase distribution should be close to Gaussian with the phase variance proportional to the inverse of a square root from SNR:
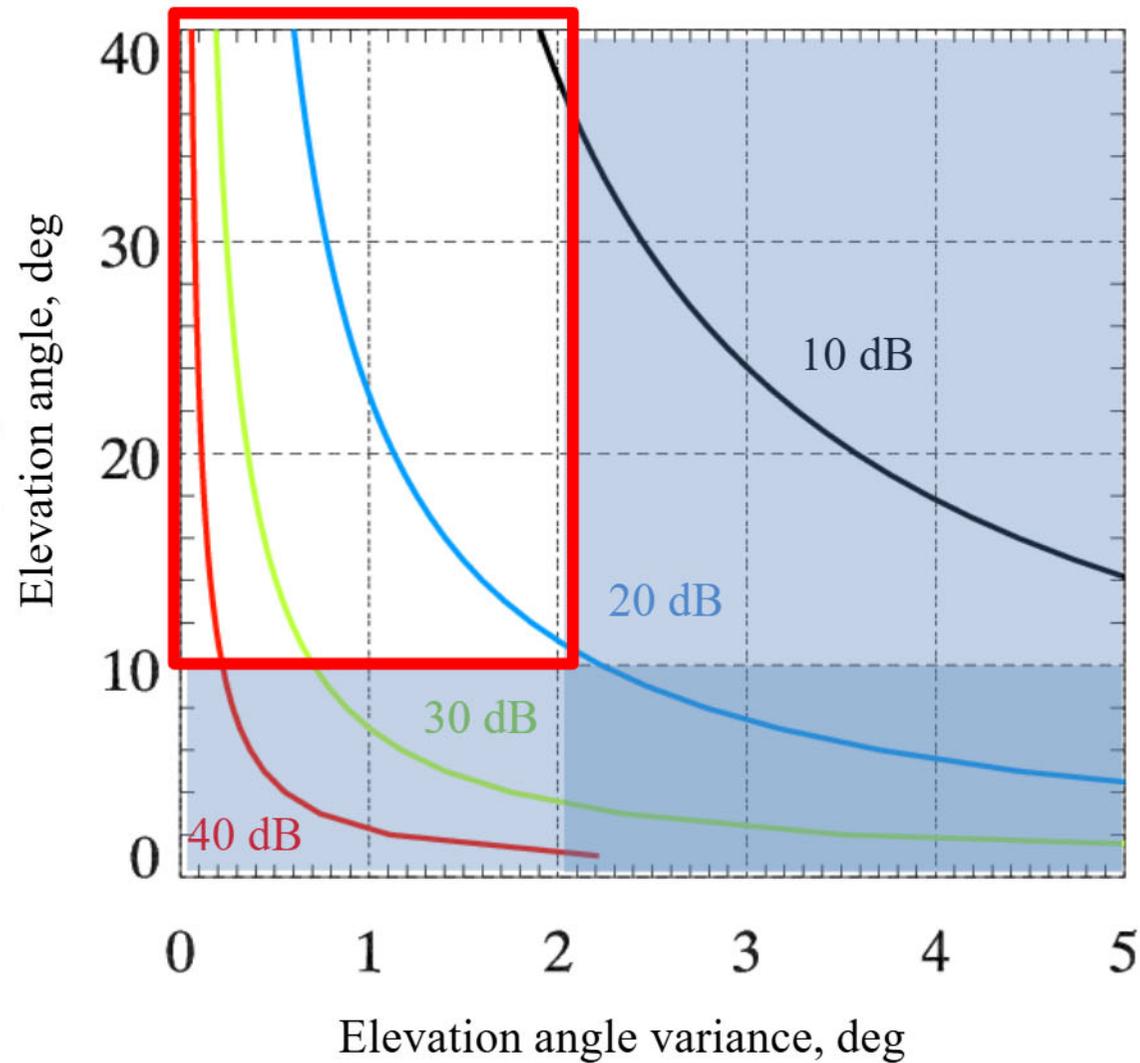
$$w(\varphi) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{q}{2} \frac{(\varphi - \varphi_0)^2}{2} \right)$$

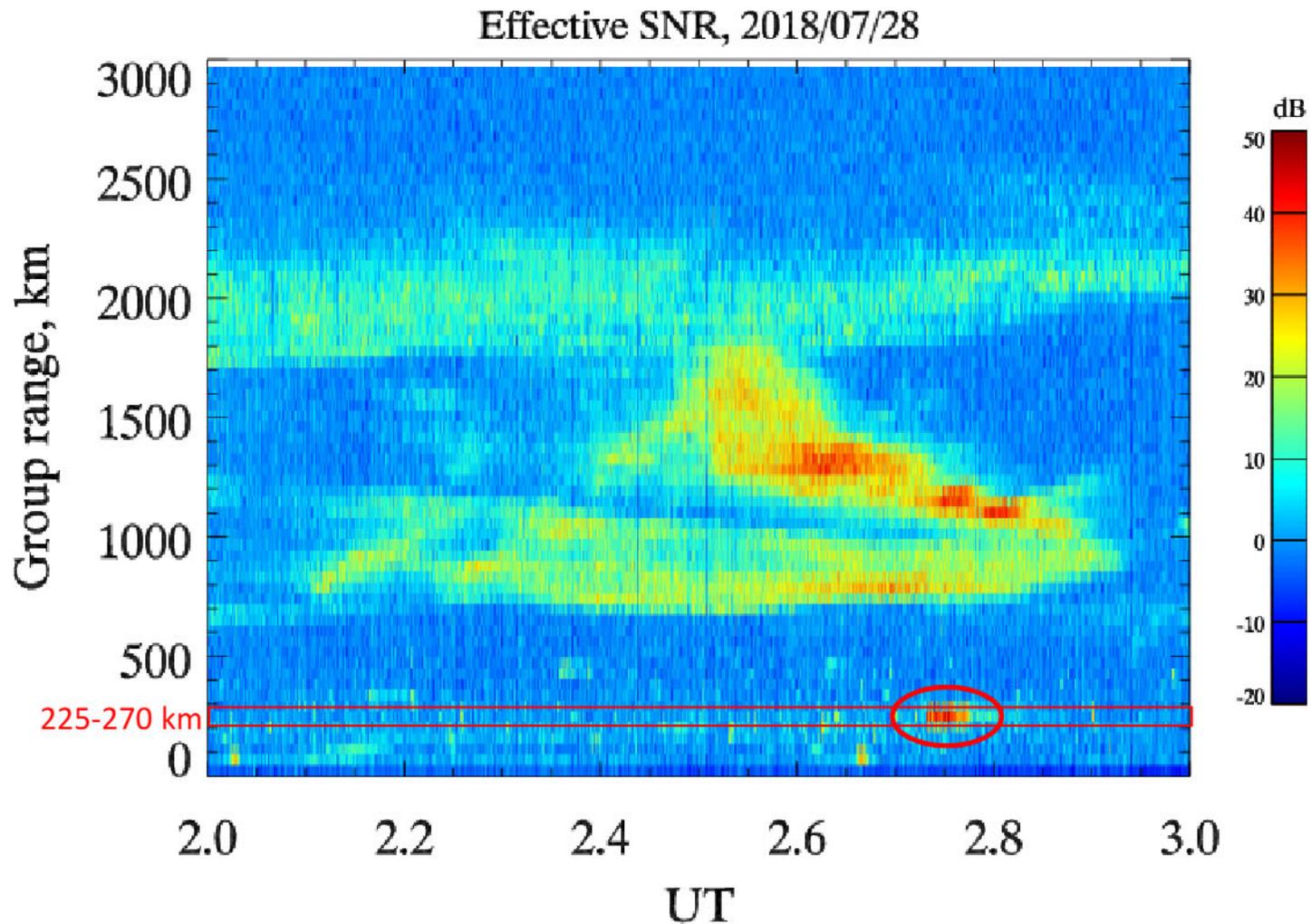where $q = P_{sig} / P_{noise} = 2/\sigma_\varphi^2$ is SNR.
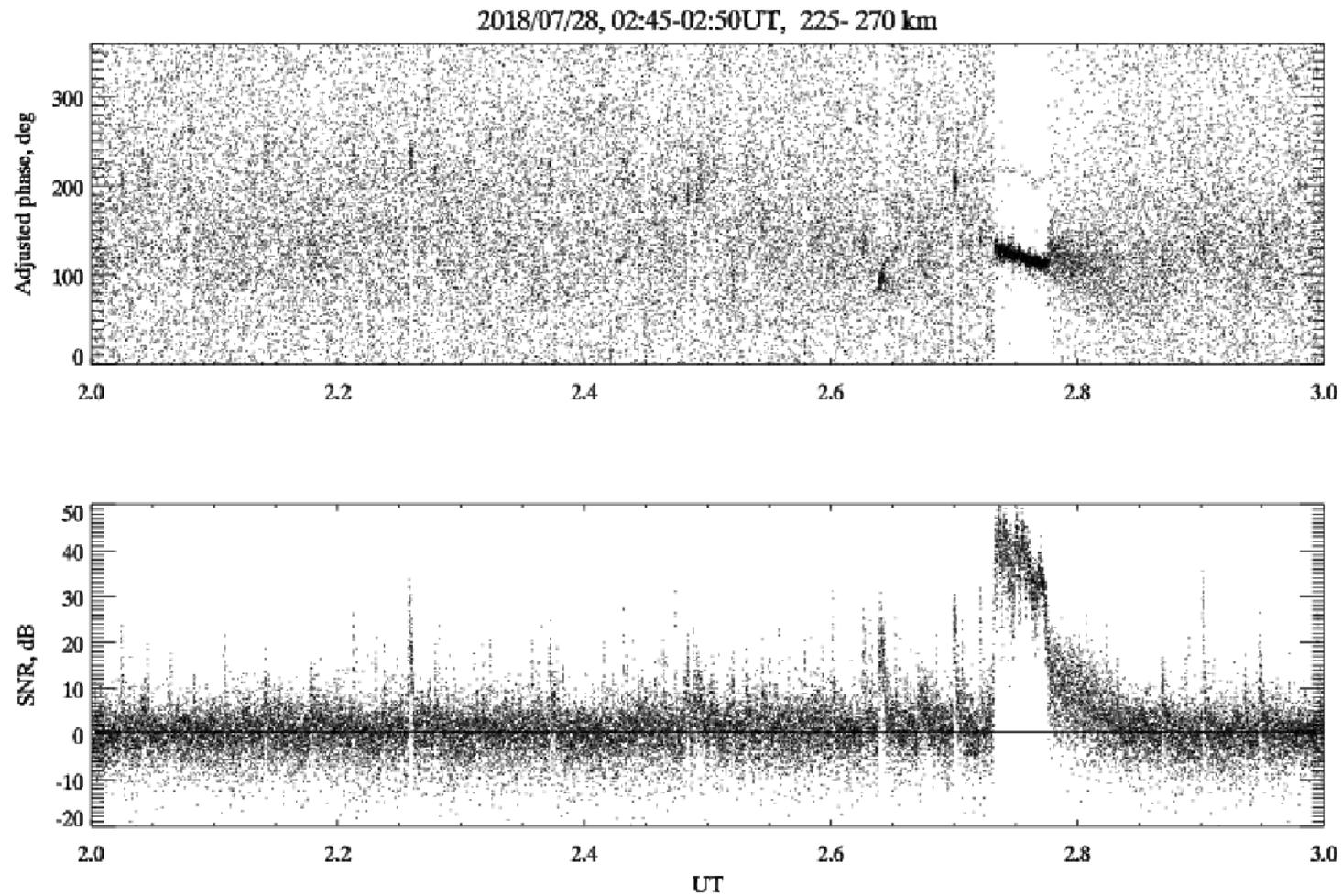
Comparison with observations

2018/07/28, 02:45-02:50UT, 720-900 km
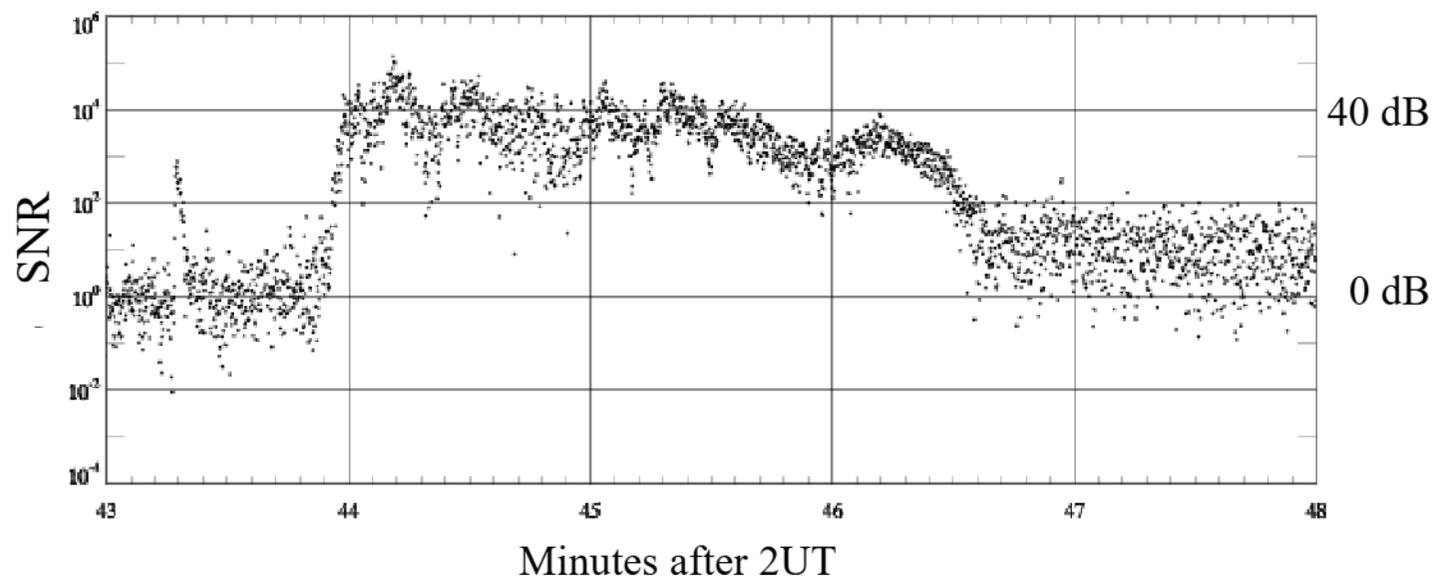
Elevation angle errors *vs* SNR

High-SNR event

Effective SNR, 2018/07/28

High-SNR event (cont.)

2018/07/28, 02:45-02:50UT, 225- 270 km

Zoom in…
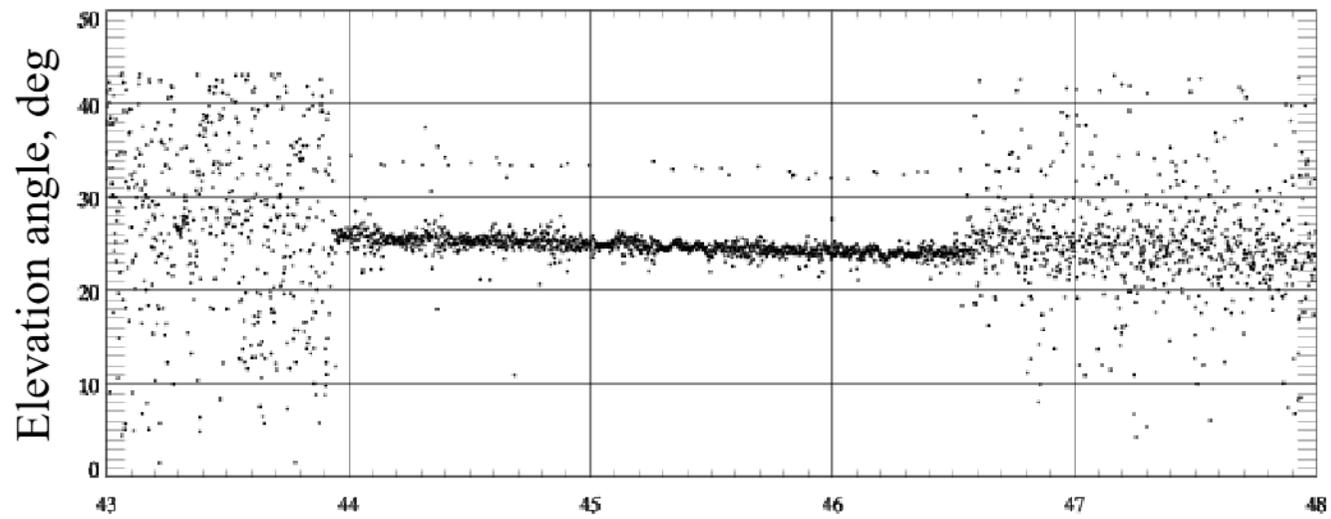
Virtual altitude variations

2018/07/28 SAS, beam 7, 10.5 MHz

Minutes after 2UT
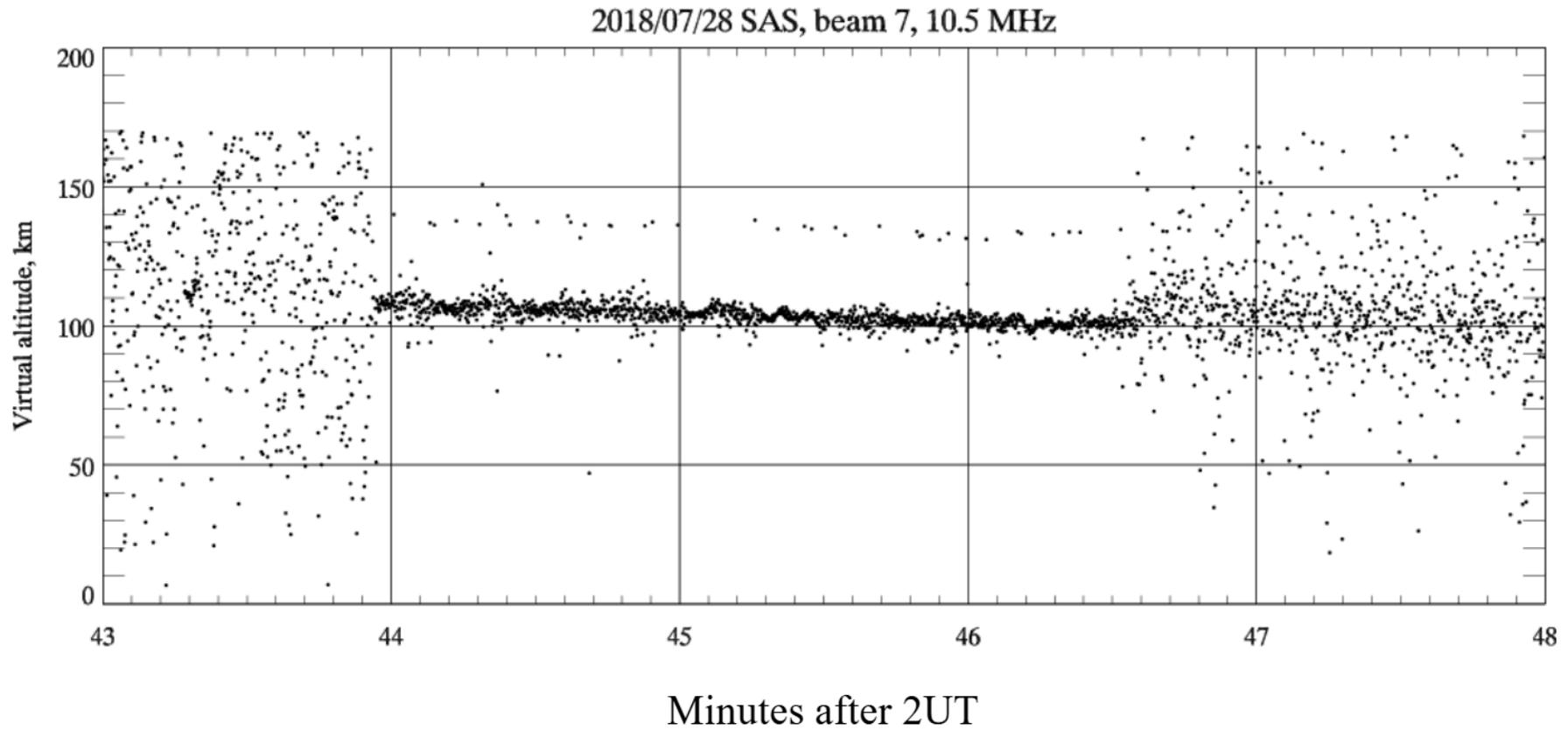
Conclusions

- Elevation angle from IQ data show well-defined spatio-temporal patterns closely resembling those in the conventional FITACF data but with much higher sampling rate, 0.1 s vs 3.5 s.

- On the other hand, their statistical variance is noticeably higher as there is no averaging applied. As expected from theory, the variance decreases with increasing SNR. It shows acceptable levels of < 2 ° for SNR ≥ 20 dB and elevation angles > 10°.