Improving quality and reliability of Hokkaido radar data

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Outline

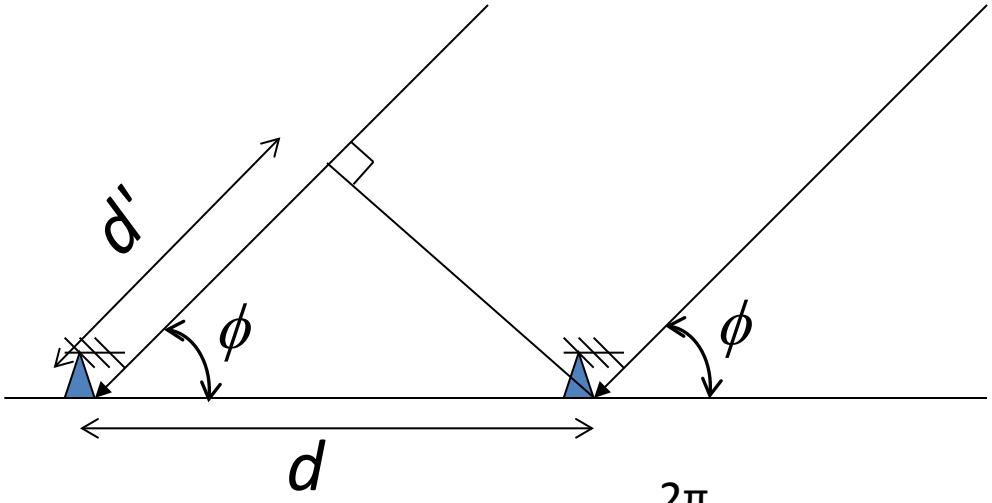
- Motivation
- Elevation/altitude errors
  - Phase offset
  - Range offset
- Velocity errors
- Conclusions and future work

Motivation

- **Elevation** is a very important parameter providing information on :
  - Scatter/reflection altitude
  - HF propagation mode
  - ionospheric plasma density (Secant Law)

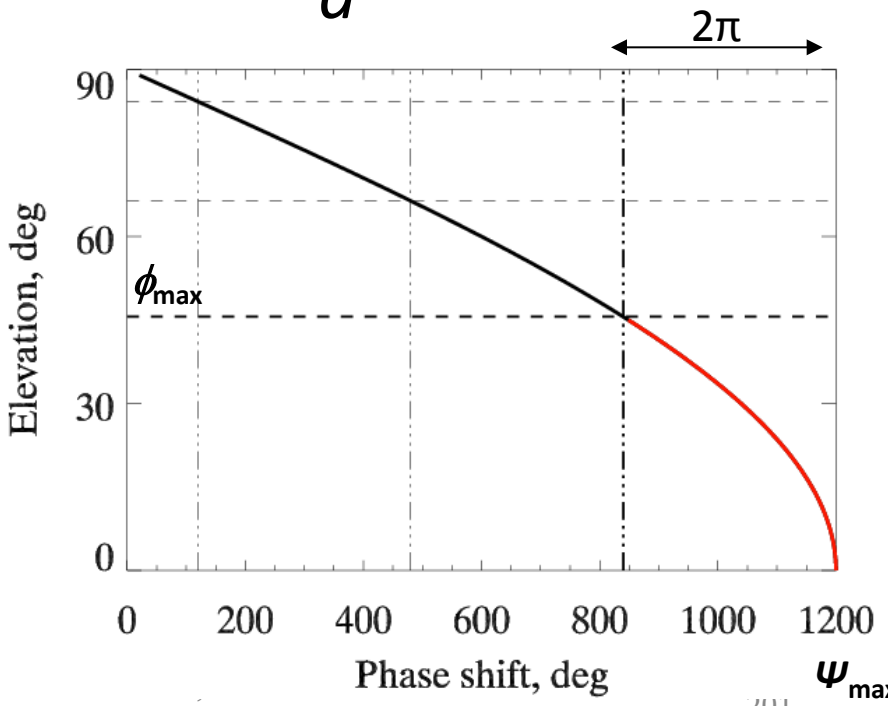
  However, it is generally unused due to problems with calibration and apparently unphysical behaviour.
- **Velocity** is the main information parameter, but the velocity errors provided by FITACF either too low or too high.

SuperDARN Interferometry



$$\phi = \cos^{-1}\frac{d'}{d}$$

$$= \cos^{-1}\frac{\Psi}{\Psi_{\max}}$$



$$\Psi = kd', \quad \Psi_{max} = kd$$

$$d > k \rightarrow \Psi_{\max} > 2\pi$$

Sources of error

– Phase offset

– Range offset

Elevation:

$$\Delta \approx \cos^{-1} \frac{\Psi}{kd}$$

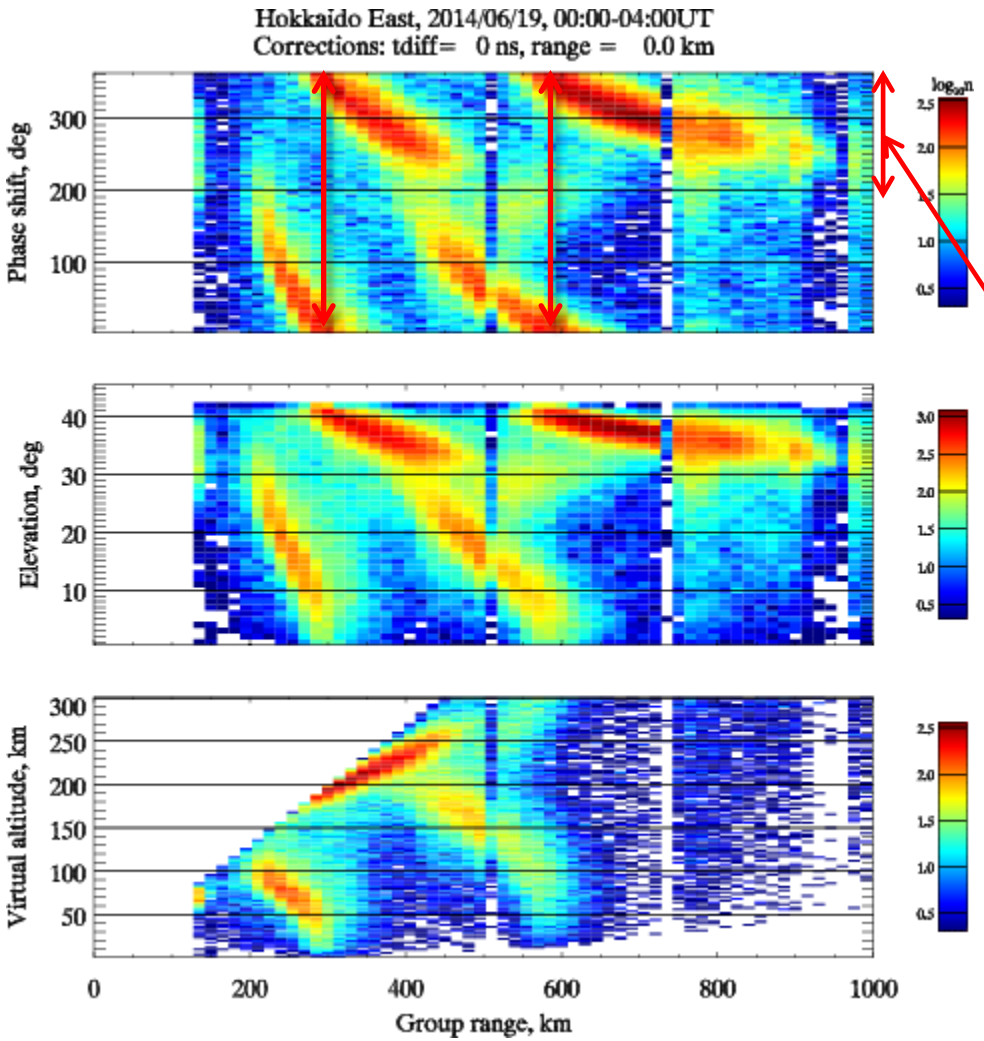
Altitude:

$$h \approx r \sin \Delta$$

Phase offset estimate

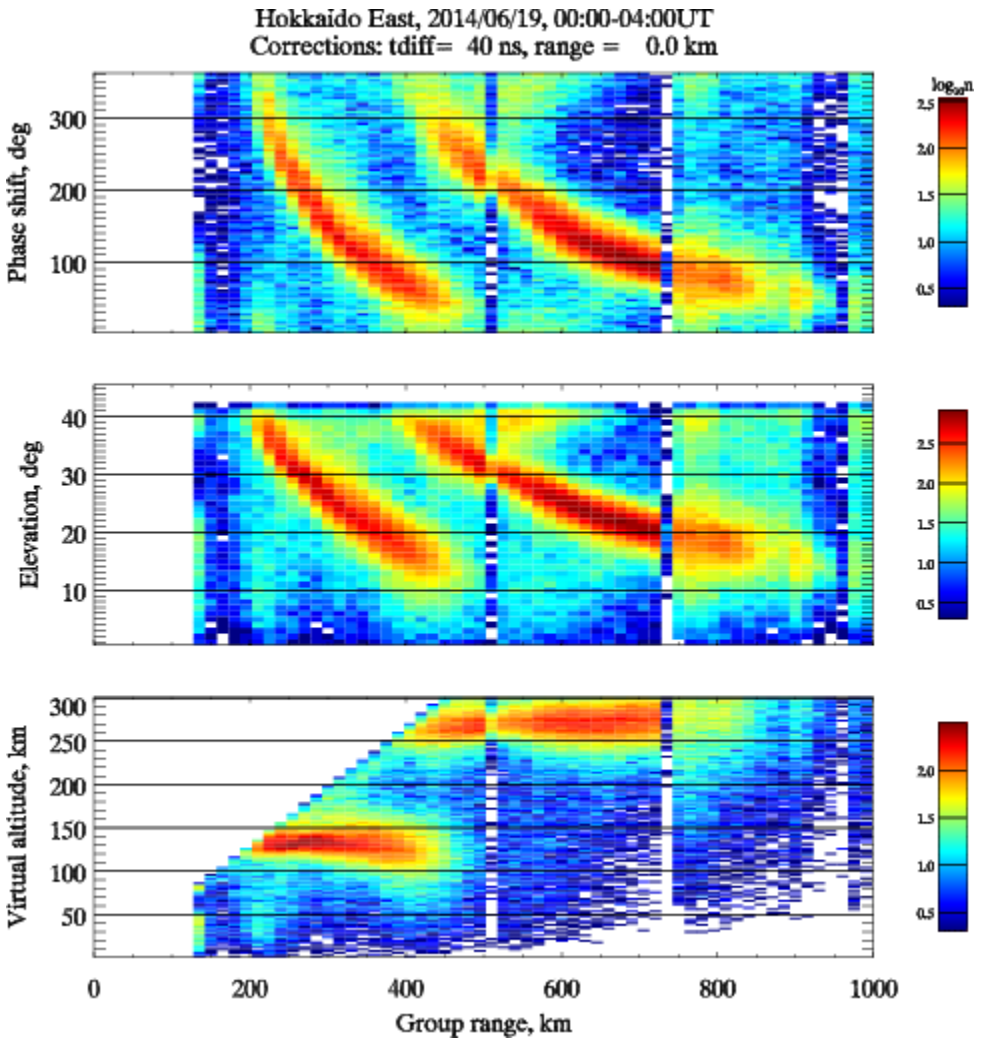
- This offset may arise from the difference between the interferometer and main antenna hardware (cabling, phasing matrices, etc).
- **Main idea:** ground scatter elevation has to decrease with increasing distance and to approach zero at large ranges.
- **The "correct" pattern** at large distances should contain near-zero values with isolated spots of the near-maximum elevation. The latter occur due to a combination of the phase statistical uncertainty and the 2π ambiguity arising from the multi-wavelength interferometer base.
- This calibration can be performed through gradually **adjusting the measured phase** by a constant shift at all ranges and re-calculating the elevation until it matches the expected pattern.

15 km: uncorrected



$\Delta\Psi \approx 160°$

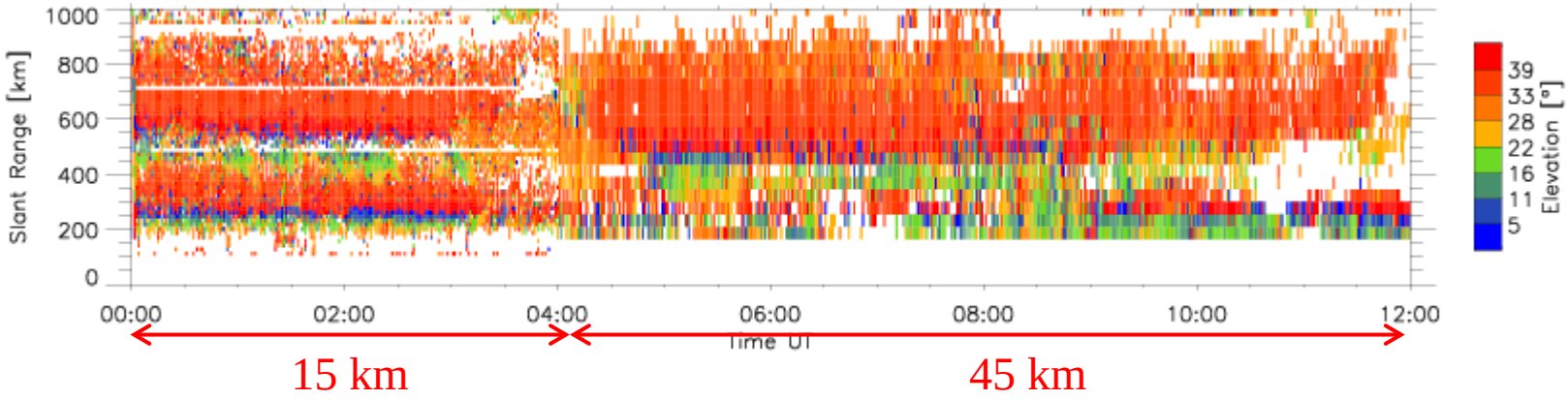
15 km: corrected phase



Range offset estimate

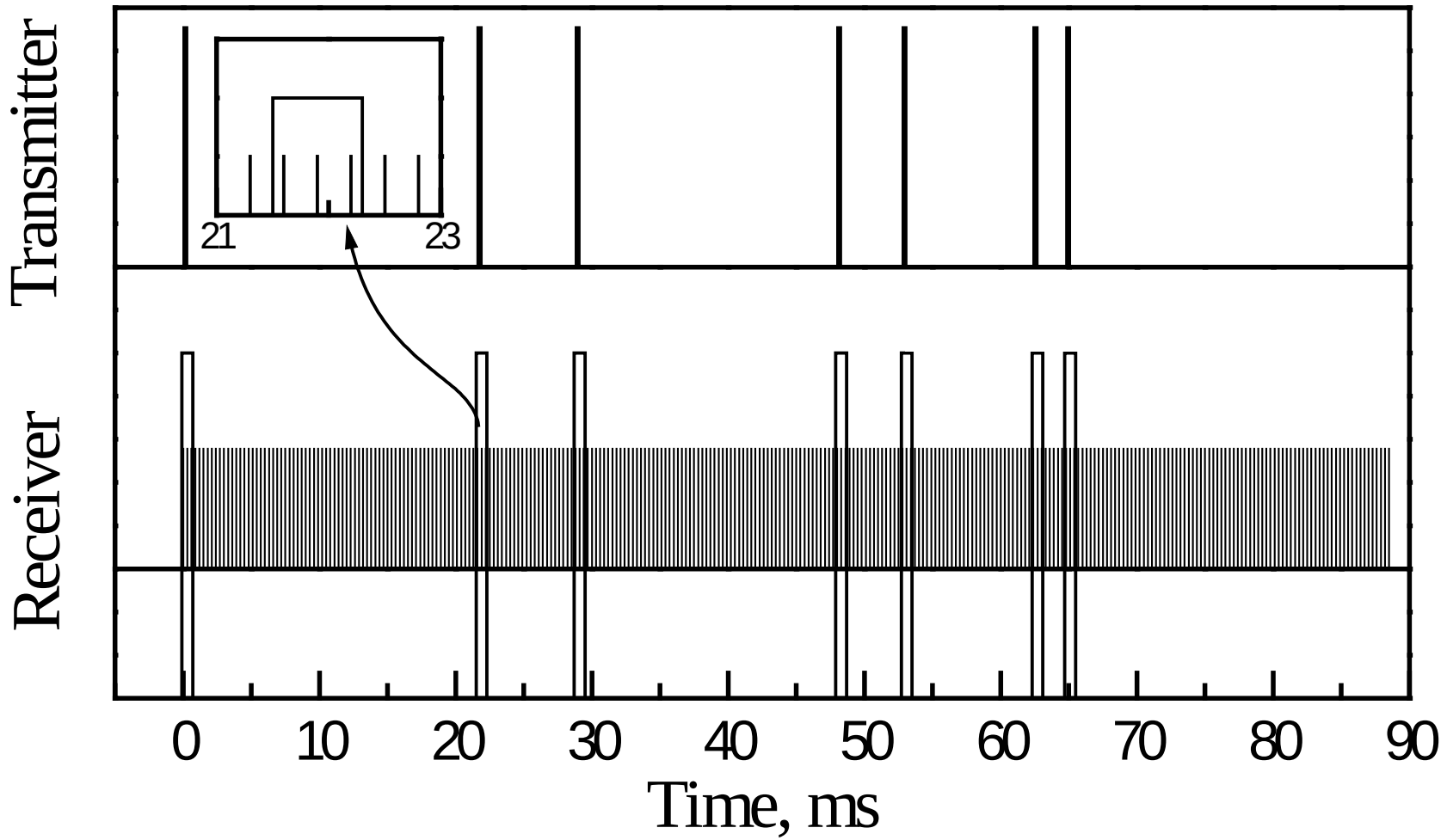
- This happens due to inaccurate estimate of the time delay caused by the receiver circuitry so that the sampling starts either earlier or later than required.
- Warning sign – presence of the data gaps at fixed ranges which are separated by a constant number of gates.

hok, beam 7, 19 June 2014



- These gaps arise from mis-labelling bad lags related to the transmitter pulse overlap.
- The Tx-affected lags have low power and, if not labelled, are picked up by an empiric “more_badlags” routine.
- The whole ACF is eliminated if there are more than 2 consecutive lags with “bad” (too low or too high) power.

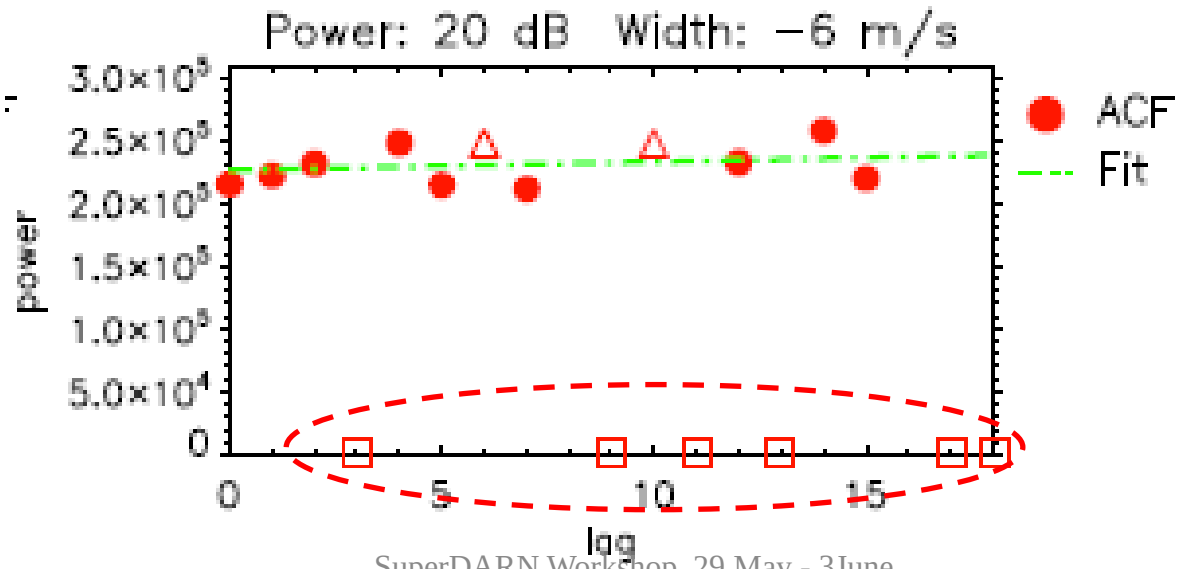
ACF sampling and Tx overlap



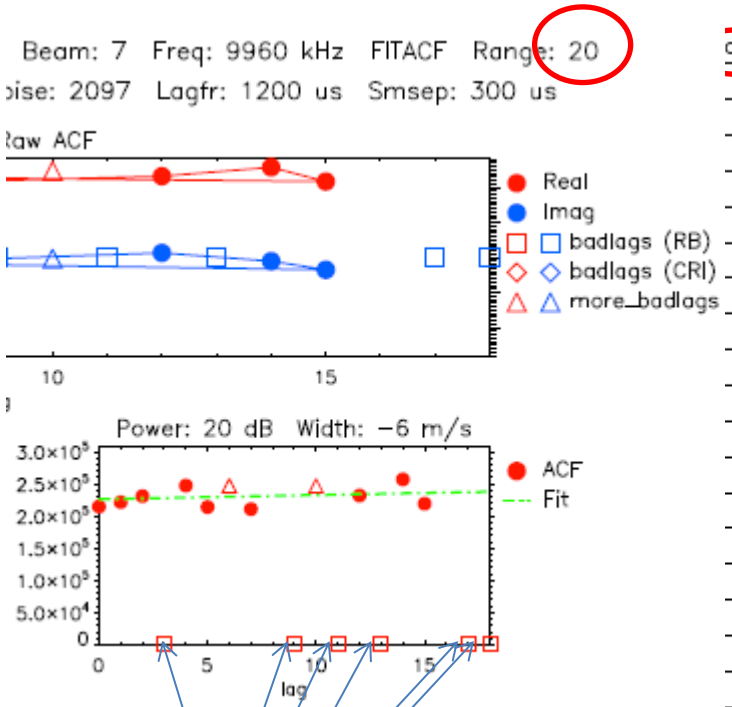
Tx overlap and power gaps

- If one of the pulses is “blanked” (i.e. it has very low power) then the respective ACF lags should also have low power.

$$\cancel{|R(\tau)|} = \langle |x(t)||\cancel{x(t+\tau)}| \exp(i\Delta\varphi(\tau)) \rangle$$



Gap locations are pre-determined



old) mpinc=8 lagfr=4 nrang=70 nblnk=2

18		43		68	0,9,12
19		44	2,6,7,11	69	0,9,12
20	3,9,11,13,17,18	45	2,6,7,11		
21	3,9,11,13,17,18	46			
22		47			
23		48			
24		49			

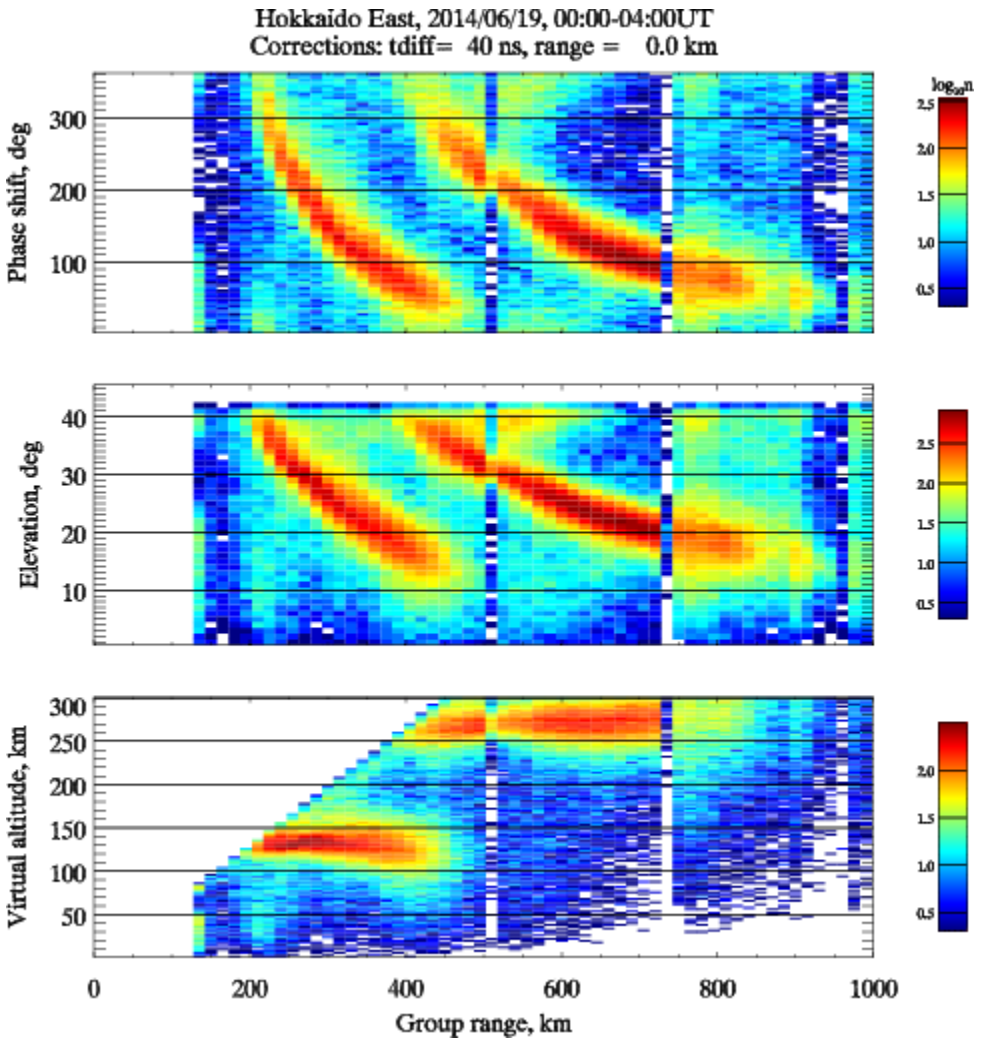
50	
51	
52	2,6,7,11
53	2,6,7,11
54	
55	
56	
57	
58	
59	
60	3,10,12,14,15
61	3,10,12,14,15
62	
63	
64	
65	
66	
67	

Missing Lags 8,16

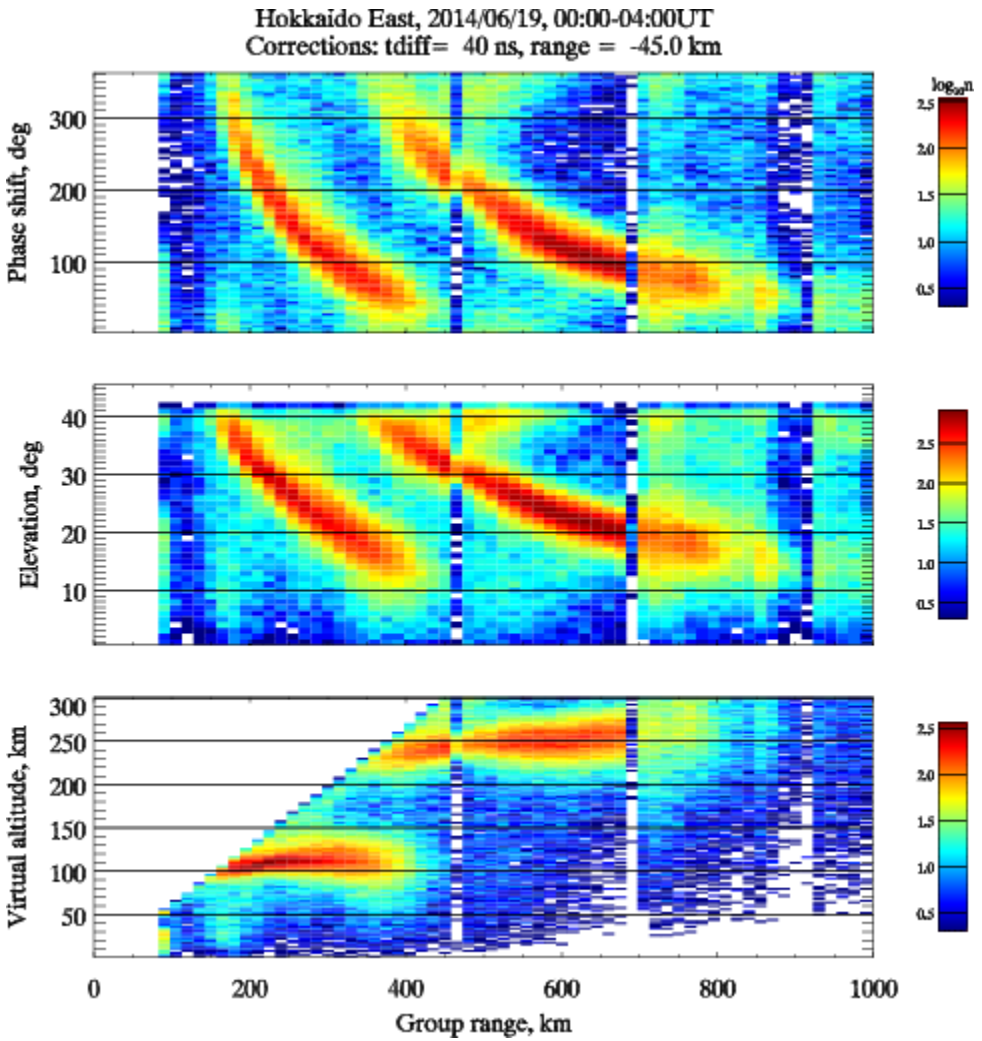
How to estimate range offset

- It is very simple: by comparing expected and actual range/lag patterns of the Tx-overlap power gaps.
- The accuracy of this method is limited by the range resolution (actually, by the blanking pulse length and shape) so that the high-resolution mode allows for more precise estimates of the range offset.

Corrected phase

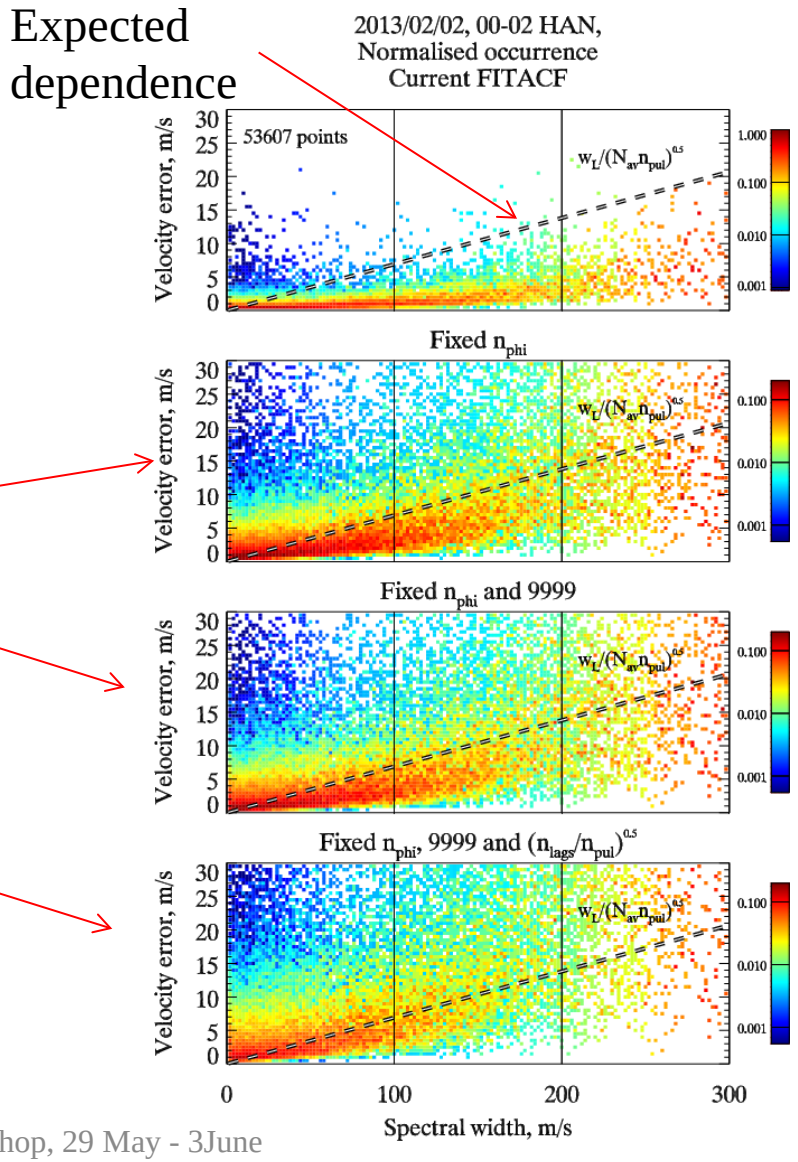


Corrected phase & range (3 gates)



Velocity errors

- With help of T. Hori, we fixed several problems describe in the tutorial at SD'13 (Moose Jaw, Canada):
  - Missing number of lags term (coding error)
  - Mis-interpreted "bad phase" flag (9999)
  - Corrected number of degrees of freedom (number of pulses rather than number of lags)



Summary and conclusions

- Physics-based procedures were applied for estimating phase and range offset in radar data.
- Velocity error calculation was modified to account for coding errors and imprecise assumptions.
- Applied corrections resulted in a realistic values and behaviour of the corrected parameters which improved reliability of the data and expanded SD diagnostic capabilities.

Future work

- Origins of near-range echoes
- Propagation characteristics of HOK echoes
  - Monitoring the regular ionosphere parameters
  - Accurate location and magnitude of ionospheric perturbations (MSTID etc)