An attempt to correct Eureka SKiYMET meteor radar wind data, Nov ’16-Jul ’17, for a twisted antenna.

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for

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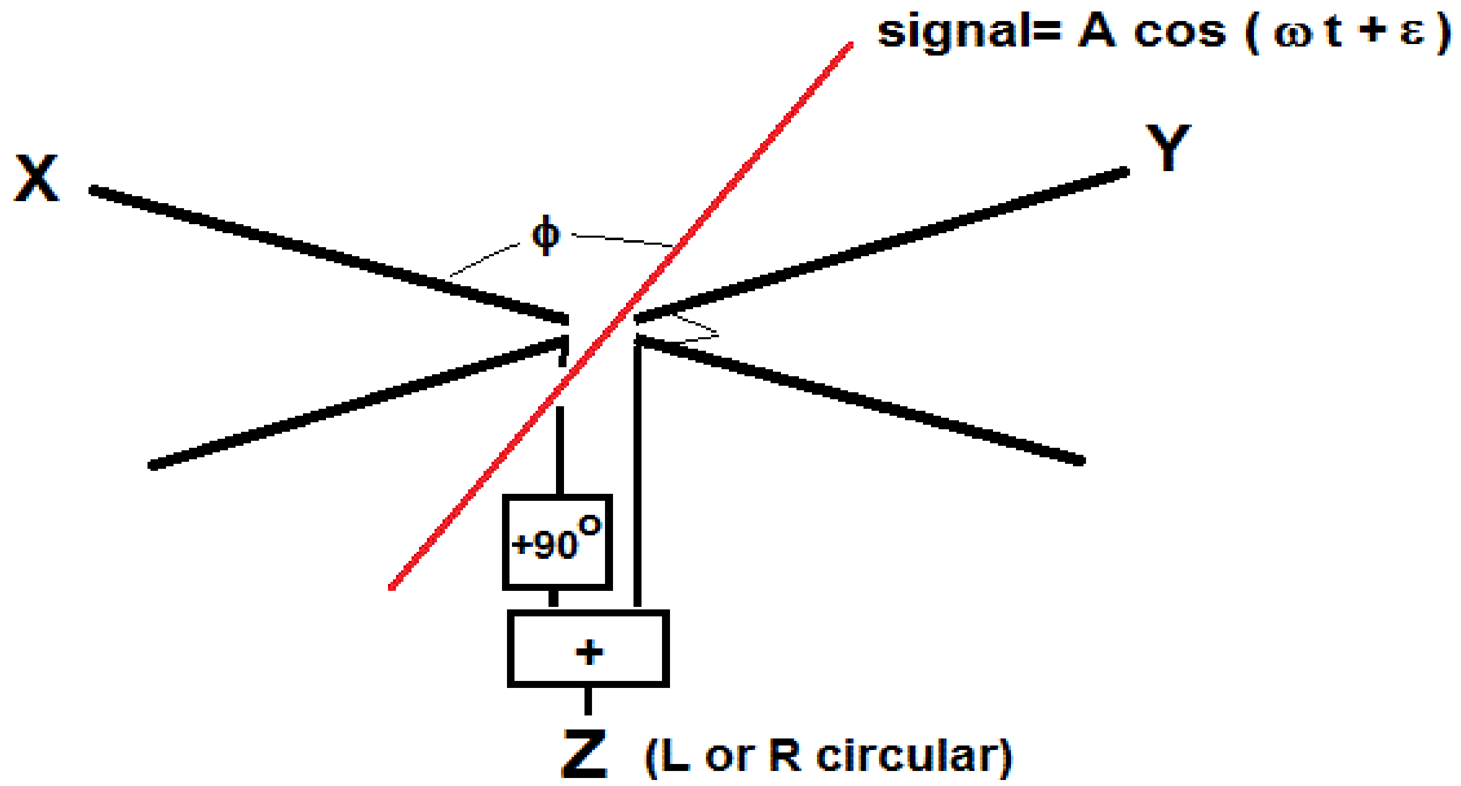
Secondary title: Should we “un-archive” the data

Photo credit: Liviu Ivanescu, Université de Sherbrooke, Qué.

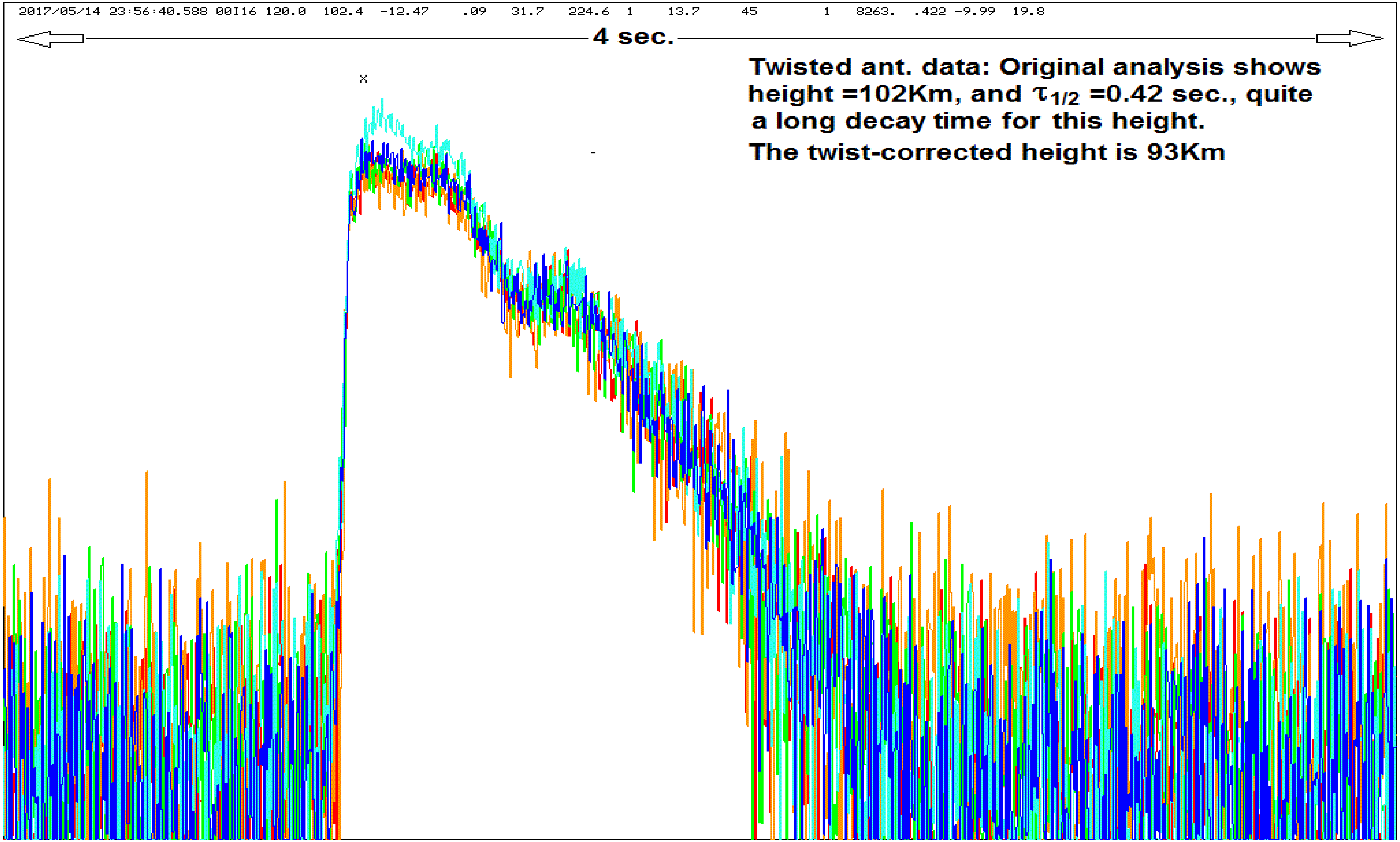
Showing that a circularly wired antenna will show a phase shift if rotated, even if the received signal is linearly polarized.

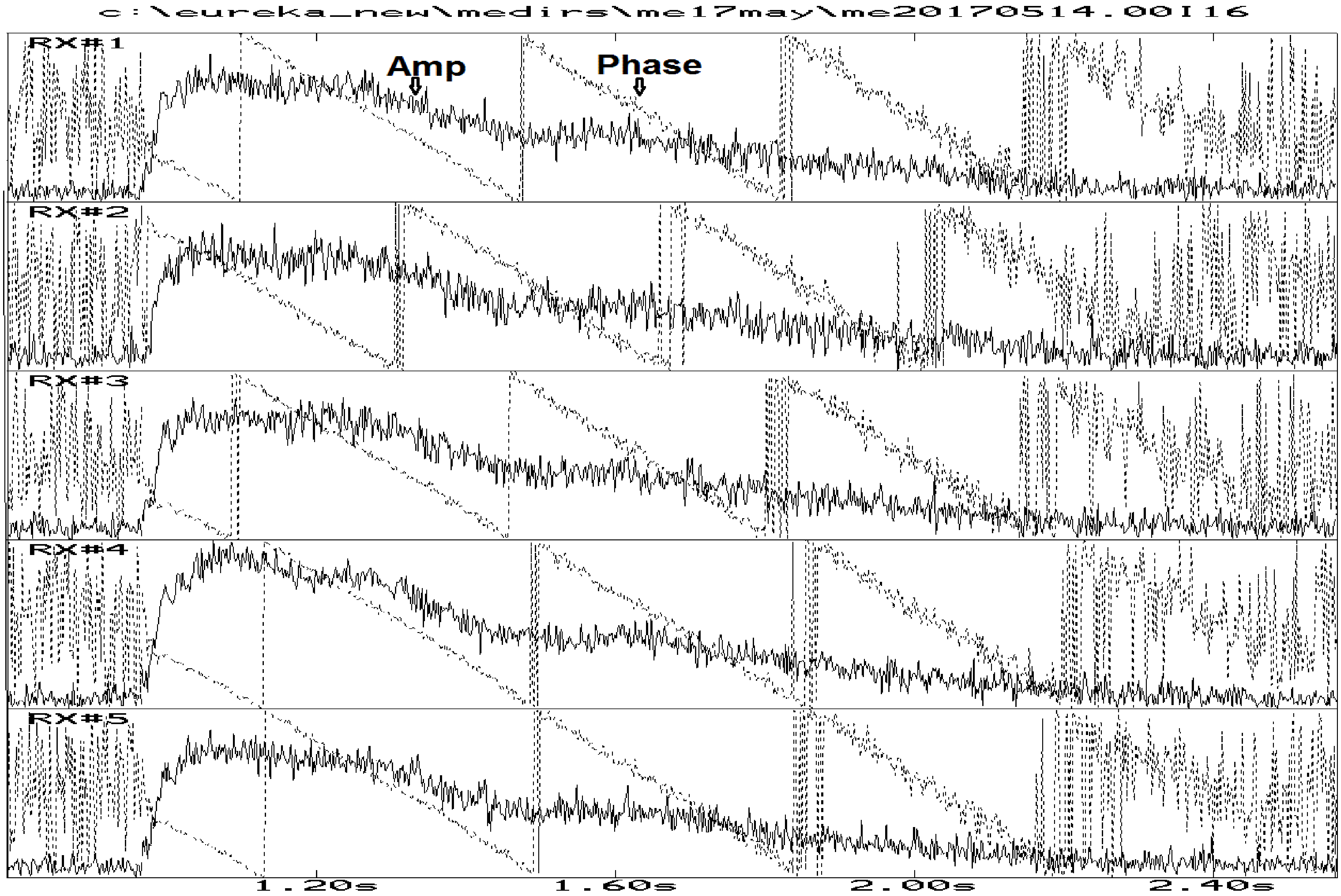


Signal X = $A \cos\phi \cos(\omega t + \varepsilon)$, Signal Y = $A \sin\phi \cos(\omega t + \varepsilon)$

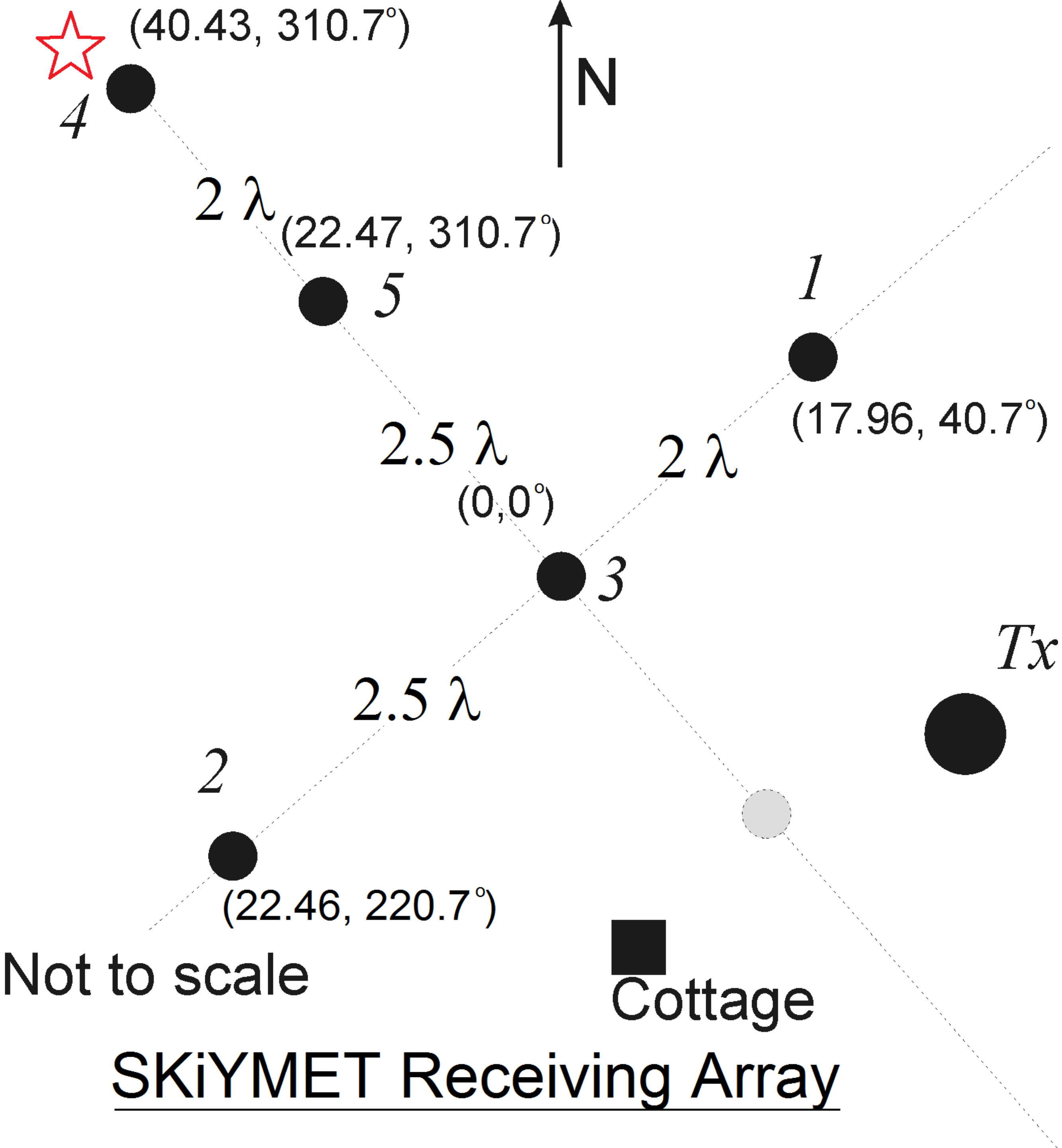
$$\text{Signal Z} = A \cos\phi \cos(\omega t + \varepsilon) + A \sin\phi \cos(\omega t + \varepsilon + 90^\circ)$$
$$= A \cos(\omega t + \varepsilon + \phi)$$

2017/05/14 23:56:40.588 00I16 #AMB=1 102KM, S/N=19 (SCALE DB= 51-TO- 81)



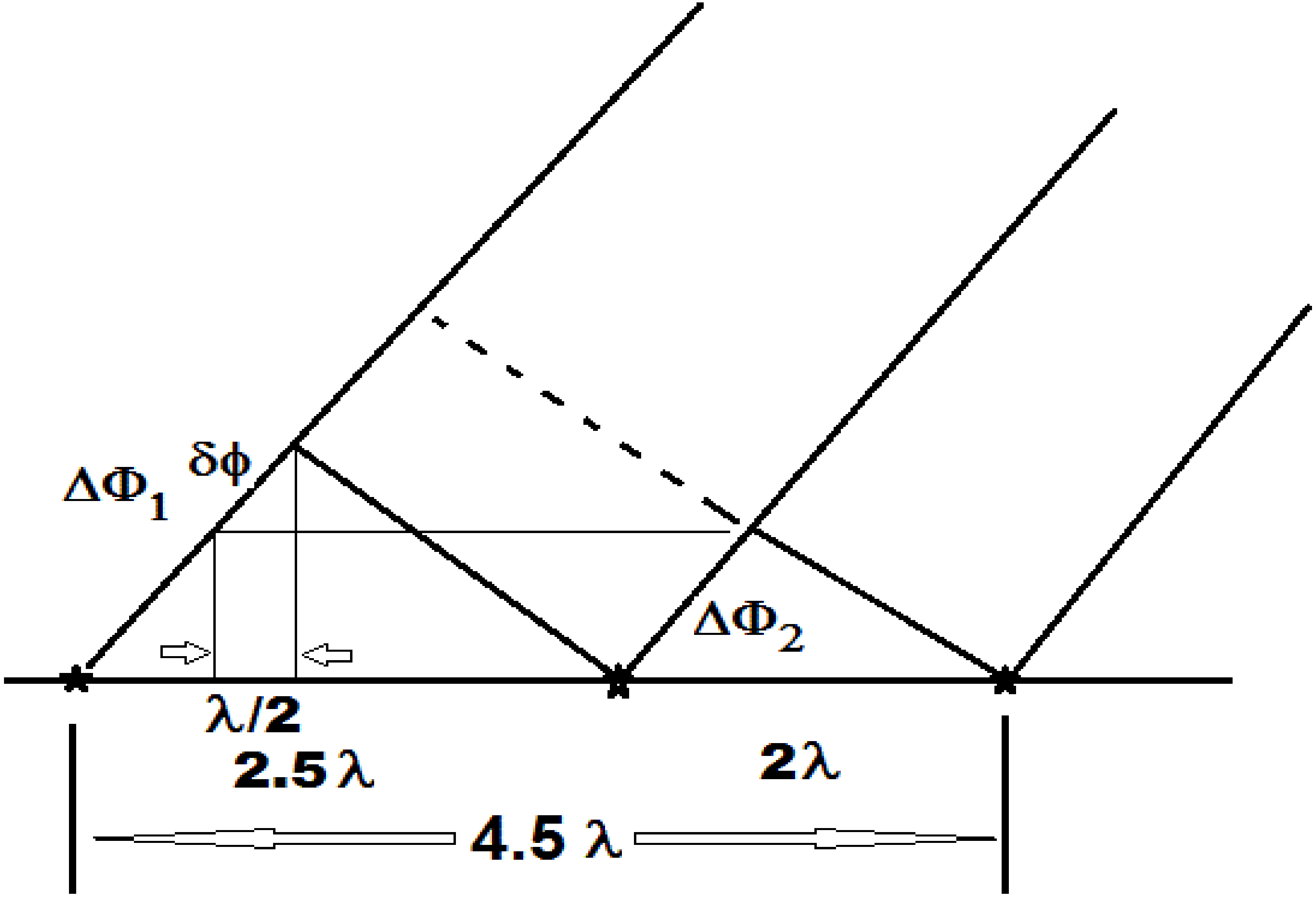

c:\eureka_new\medirs\me17may\me20170514.00I16
RX#1
Amp
Phase
RX#2
RX#3
RX#4
RX#5
1.20s
1.60s
2.00s
2.40s

Date	Time	File	Rge	Ht	Vrad	delvr	Theta	Phi0	Ambig	Delphase	ant pair	IREX	amax	Tau	vmet	snrdb
2018/04/11	0:01:12.106	00008	132.0	94.8	7.14	1.67	44.5	232.7	1	11.1	32	1	6735.	.028	-9.99	17.6
2018/04/11	0:01:12.106	00009	130.0	93.7	9.43	1.11	44.3	232.7	1	5.6	32	1	8783.	.031	-9.99	20.2
2018/04/11	0:01:16.315	0000A	189.9	93.2	29.97	.46	61.4	323.7	1	12.2	45	1	7339.	.032	-9.99	18.2
2018/04/11	0:01:16.317	0000B	187.9	93.5	40.65	.87	60.9	324.4	1	11.9	15	1	4399.	.052	-9.99	14.3
2018/04/11	0:01:18.478	0000D	92.0	89.9	4.18	.08	12.2	350.1	1	10.7	15	1	18174.	.127	28.43	24.8
2018/04/11	0:01:18.476	0000E	94.0	91.9	4.25	.08	12.2	350.2	1	10.3	15	1	20497.	.128	28.94	25.3
2018/04/11	0:02:07.619	0000L	114.0	80.7	-18.35	1.91	45.3	8.1	1	22.9	23	1	3227.	.356	-9.99	11.8
2018/04/11	0:02:07.621	0000M	112.0	79.4	-19.18	2.10	45.2	8.0	1	22.0	32	1	3052.	.341	-9.99	11.2
2018/04/11	0:02:28.886	0000O	130.0	95.6	38.71	1.30	43.0	310.9	1	12.5	53	1	8343.	.040	-9.99	20.1
2018/04/11	0:02:28.884	0000P	128.0	94.2	38.74	.78	43.0	310.8	1	10.2	35	1	10641.	.041	-9.99	21.7
2018/04/11	0:02:46.229	0000Q	114.0	92.0	15.71	.03	36.5	216.5	1	7.3	15	1	25591.	.116	28.82	28.8
2018/04/11	0:02:46.226	0000S	116.0	93.6	15.74	.04	36.5	216.5	1	7.4	15	1	30519.	.116	29.07	30.3
2018/04/11	0:02:46.220	0000T	118.0	95.4	15.69	.60	36.4	216.4	1	7.0	15	1	4279.	.127	-9.99	14.4
2018/04/11	0:03:29.659	0000Z	96.0	82.2	9.42	.59	31.3	258.7	1	9.3	35	1	4959.	.556	-9.99	15.2
2018/04/11	0:03:29.664	00010	94.0	80.3	9.20	1.41	31.5	258.7	1	17.3	32	1	3087.	.481	-9.99	11.1
2018/04/11	0:03:33.300	00011	122.0	89.8	-3.69	1.33	43.0	225.6	1	14.0	25	1	6819.	.048	-9.99	18.0
2018/04/11	0:03:34.134	00013	149.9	97.9	-1.98	.60	49.7	229.4	1	9.7	14	1	11532.	.029	-9.99	25.3
2018/04/11	0:03:34.132	00014	151.9	100.4	-3.48	2.24	49.2	226.6	1	18.0	41	1	4543.	.026	-9.99	14.0
2018/04/11	0:04:49.901	00019	122.0	93.2	36.68	1.19	40.5	308.2	1	11.6	35	1	6198.	.050	-9.99	17.4
2018/04/11	0:04:49.901	0001A	124.0	94.7	38.60	2.53	40.6	308.2	1	13.3	35	1	5614.	.058	-9.99	16.6
2018/04/11	0:05:03.034	0001C	130.0	99.9	58.96	2.49	40.1	266.0	1	12.1	51	1	3992.	.051	-9.99	13.6
			Range (Km)	Height (Km)	V_r (m/s)	σ_{vr} (m/s)	Zenith (deg)	Azimuth (deg)						τ (sec)		



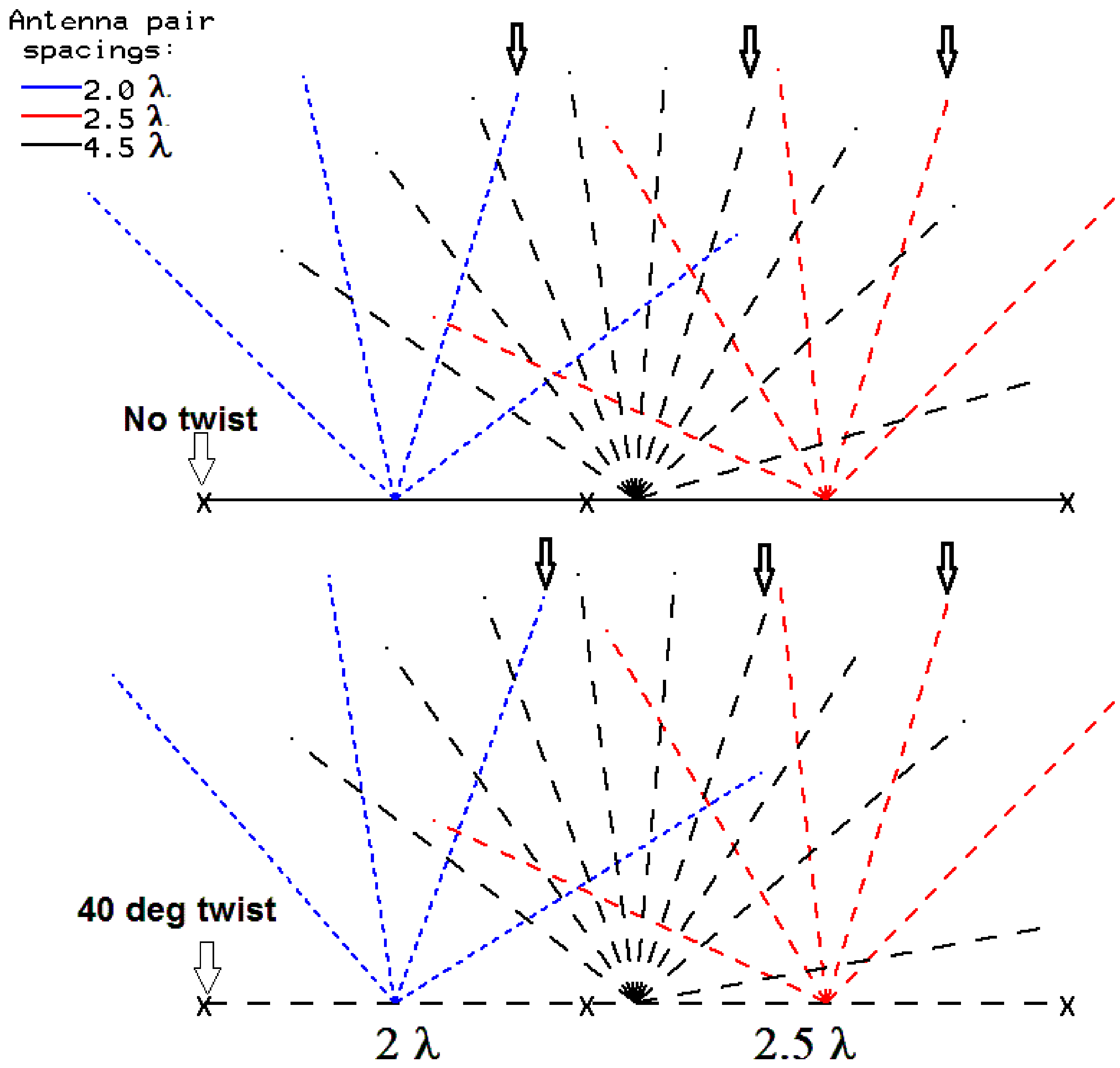
SKiYMET Receiving Array

A less accurate way to get angle of arrival

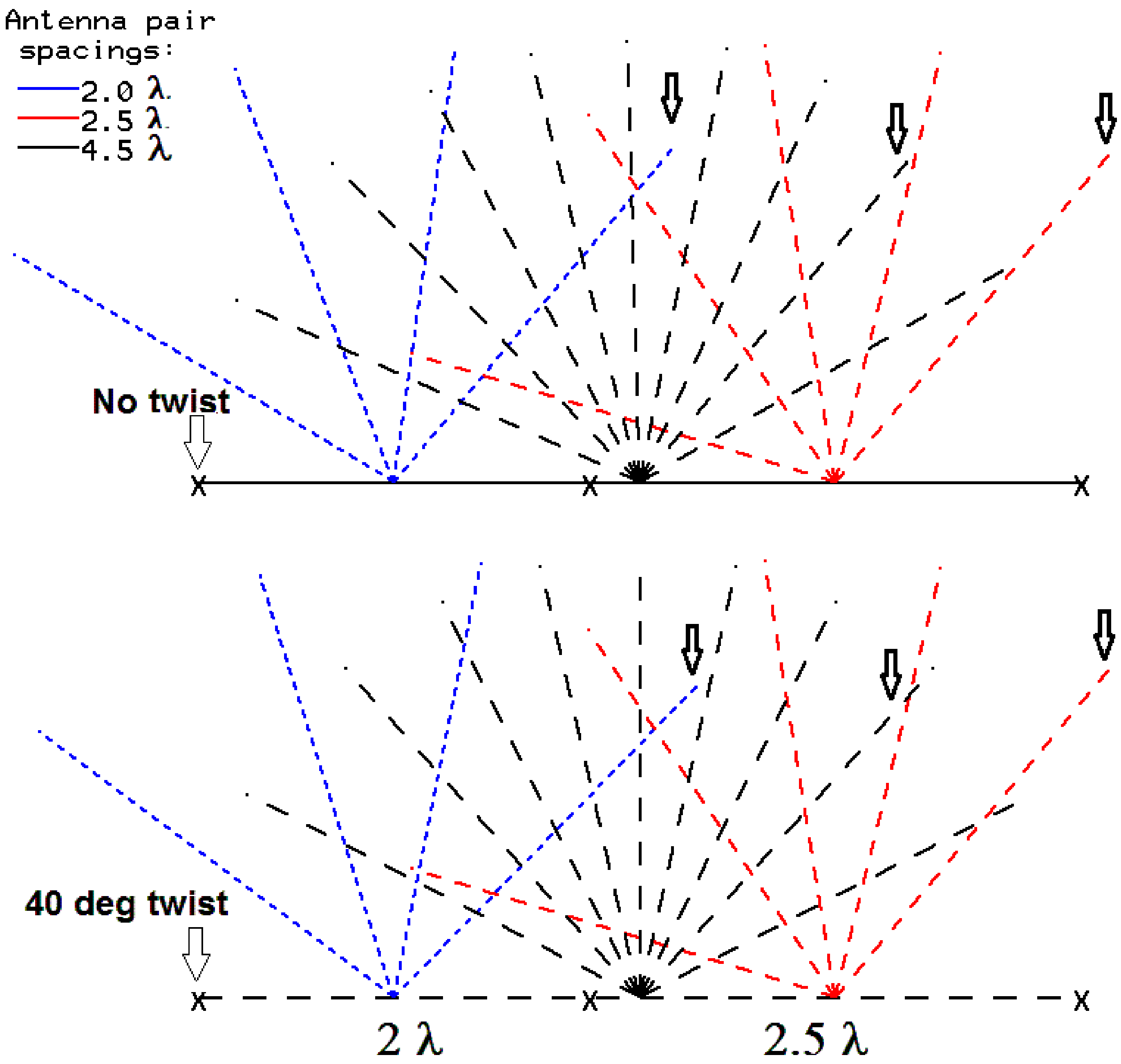


$\Delta\Phi_1 - \Delta\Phi_2$ is the expected phase diff. from a $\lambda/2$ spacing.

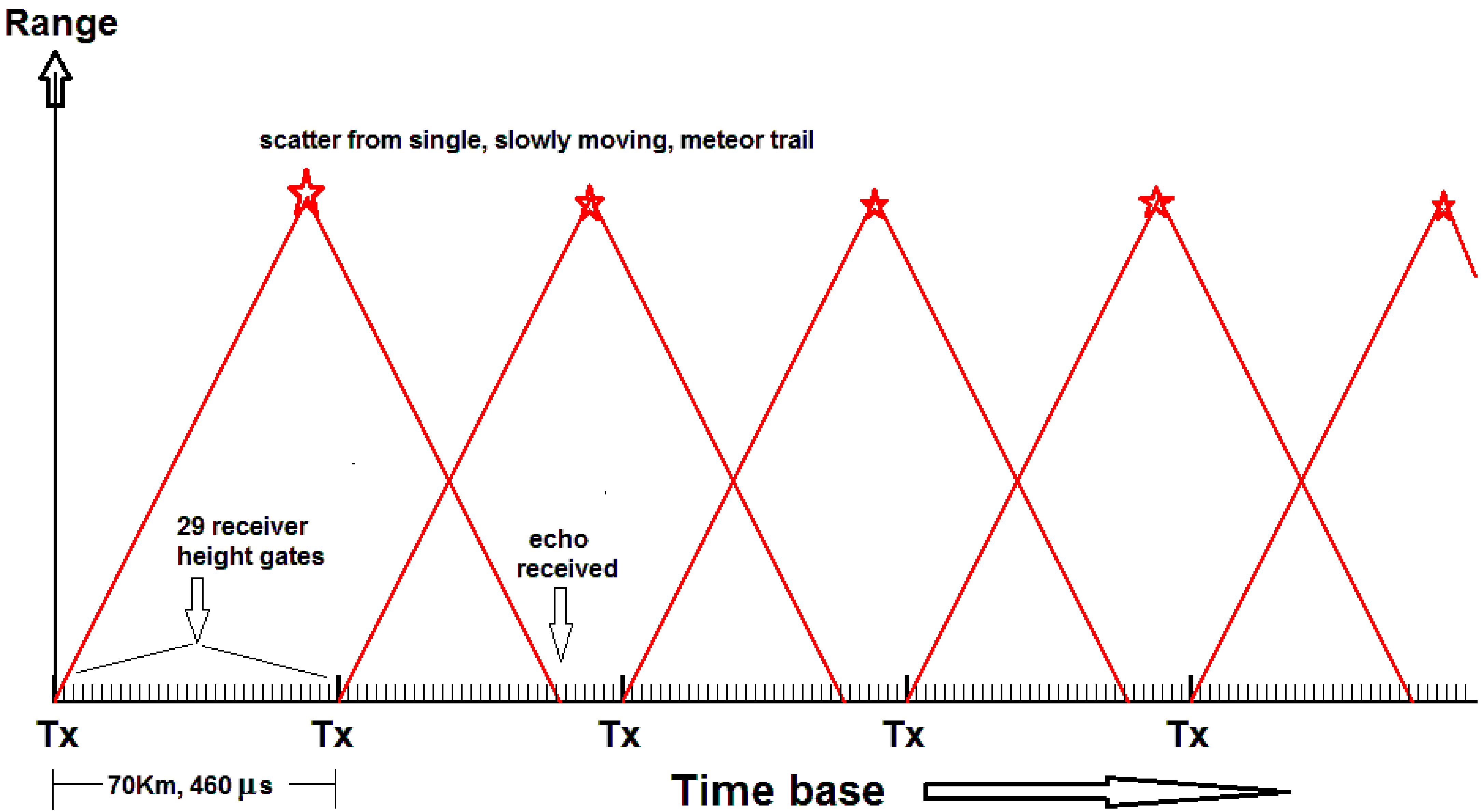
Zenith aliases when actual zenith angle = 17 deg.



Zenith aliases when actual zenith angle = 40 deg.

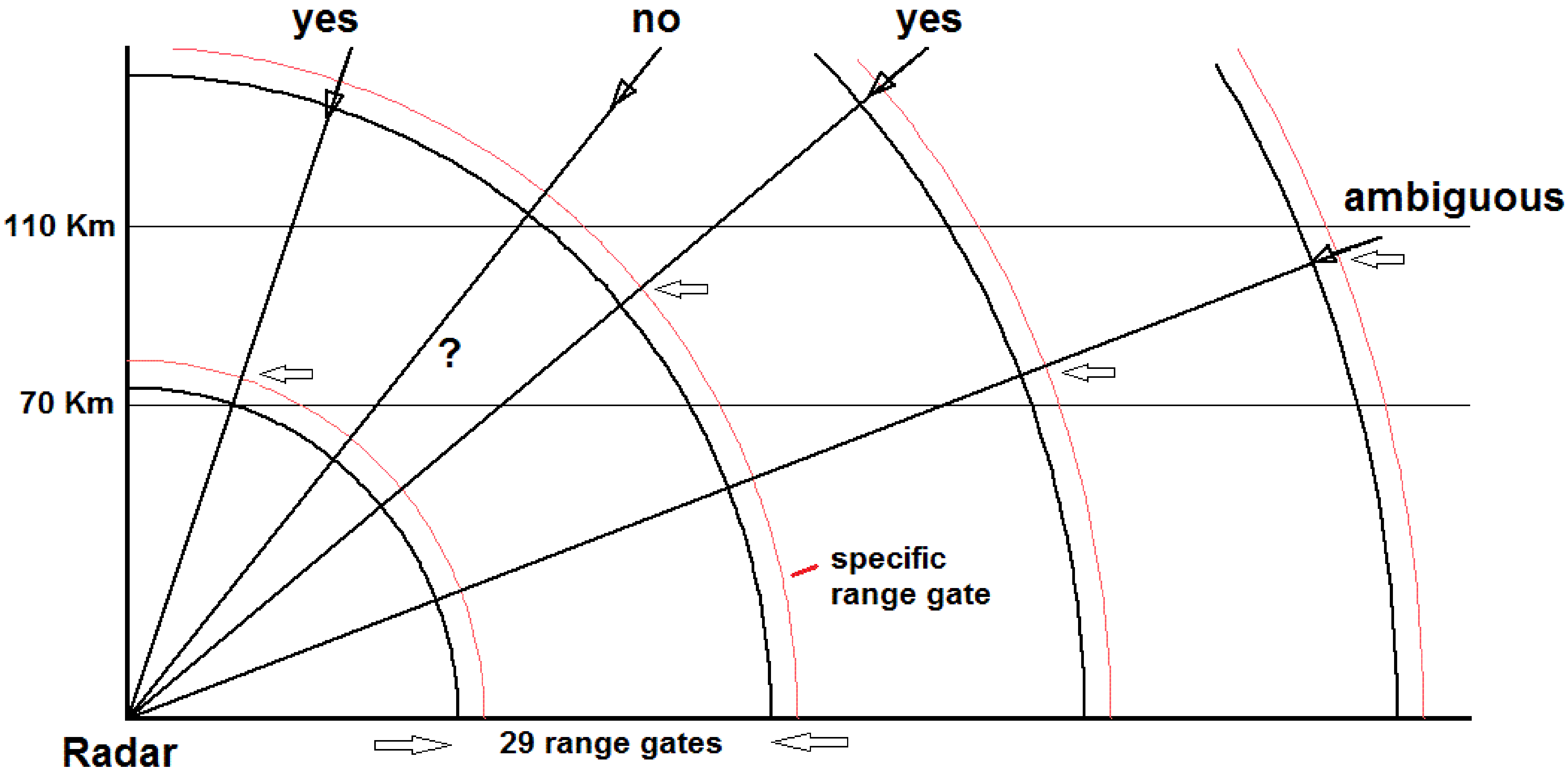


Echo Range is oversampled. How do you tell which Tx pulse caused it?



To illustrate range aliasing

We know the zenith angle and range gate # (red), can that represent a height between 70 and 110 Km?



Correction method # 1

1. Invert accepted trail AOA (zenith and azimuth) to get phase differences for the 3 antenna pairs in each line of 3.

2. Add 40 degrees to antenna #4 phase.

3. Calculate all zenith_component aliases for each antenna pair spacing in each line .

4. In each 3-antenna line, go though all 3-zenith alias combinations (4x5x9) and select the one with lowest variance.

5. Combine the 2 selected “zenith_components”, one from each antenna line, to get the corrected AOA. There is some loss to impossible cases, i.e. if both zenith_ components are too large.

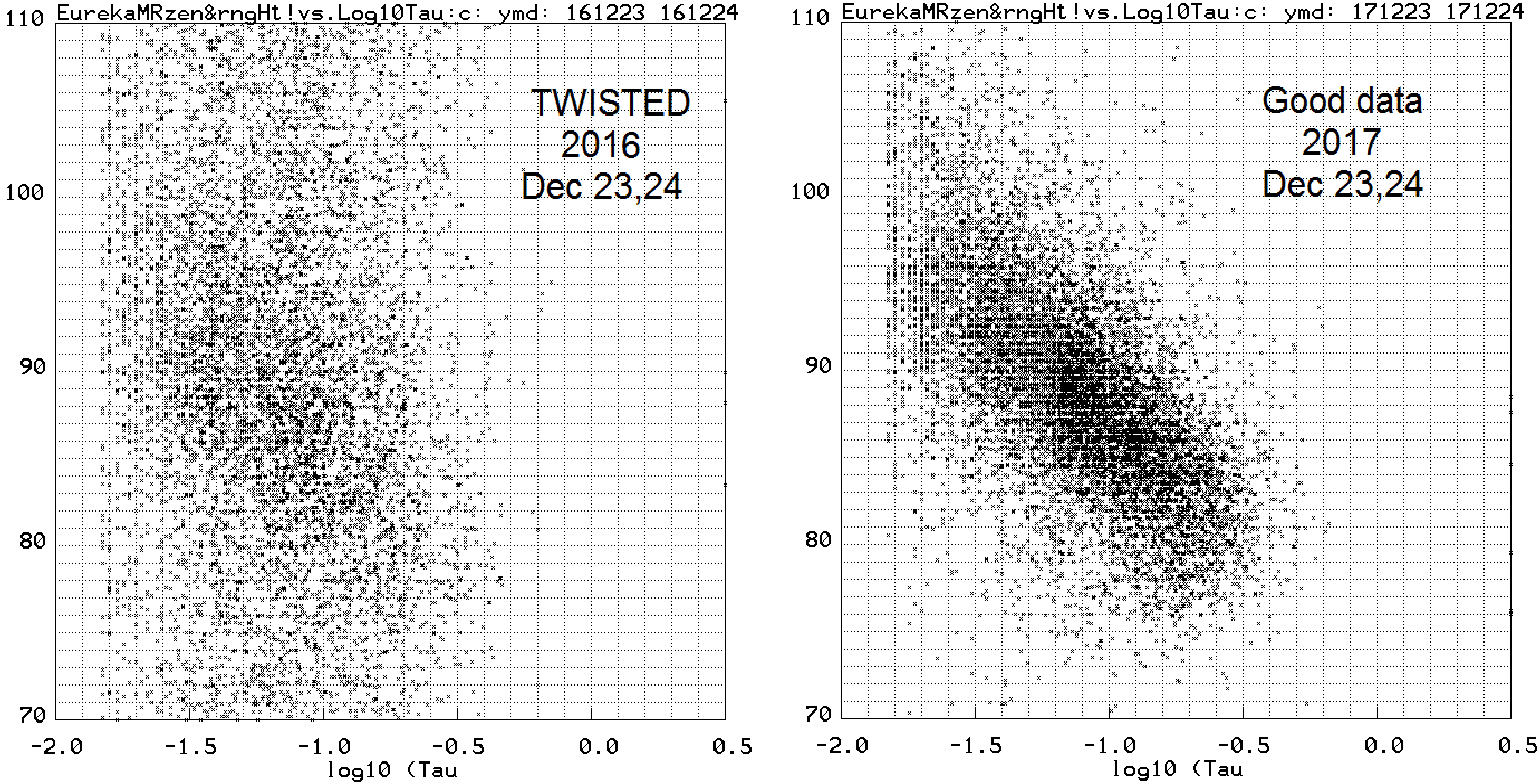
Correction method # 1 contd.

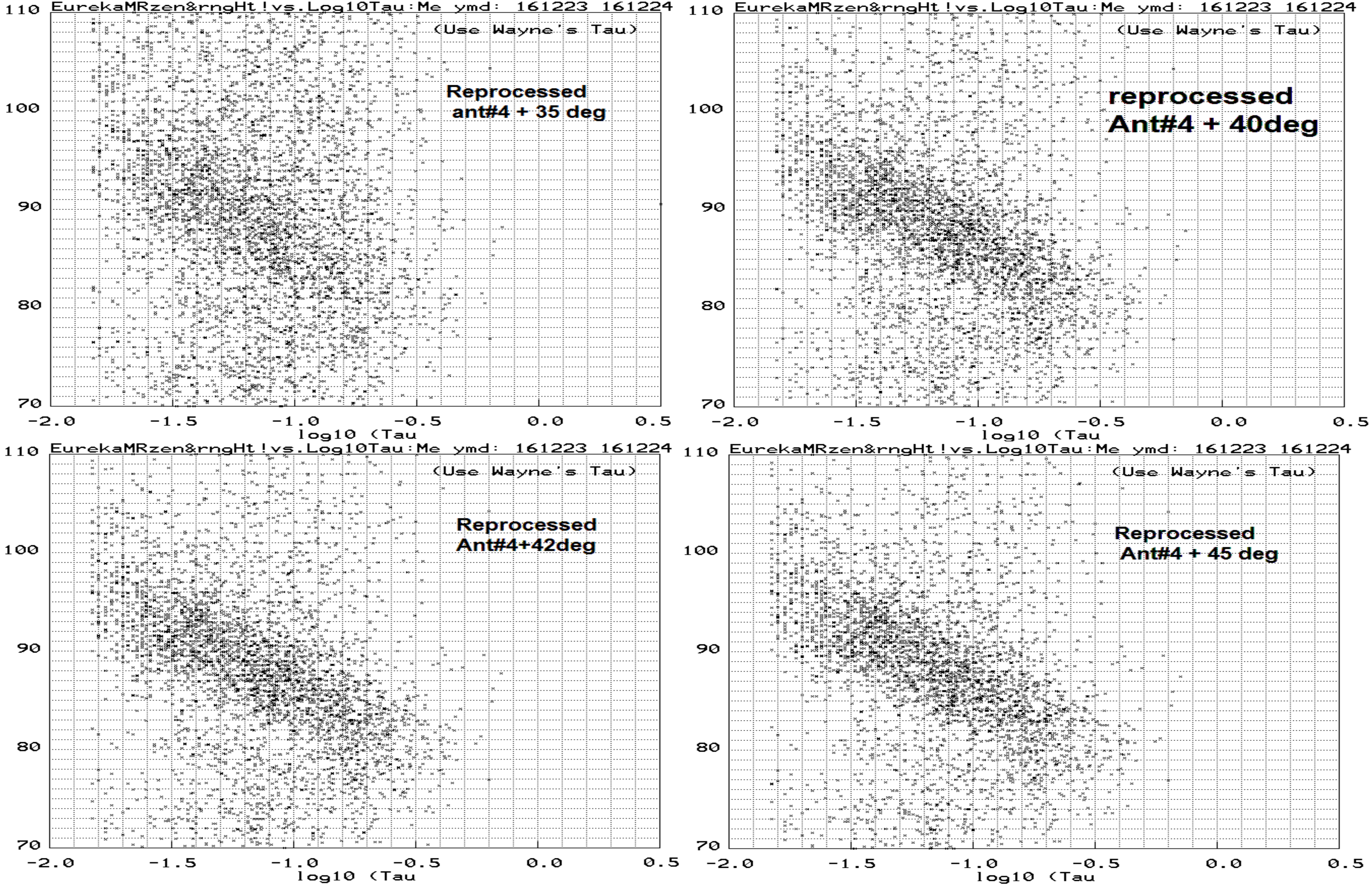
6. Work out range gate number from original (twisted) data

7. Check in the first 5 range aliases (to ~350Km, ~ 70 deg. zenith) whether this range gate plus the new AOA indicates a corrected_for_earth_curvature height (and only one) within 70-100 Km.

8. If ok, then plug the new range, height, and AOA into the original meteor parameter record (keeping the original radial velocity, decay time etc.) and we're done.

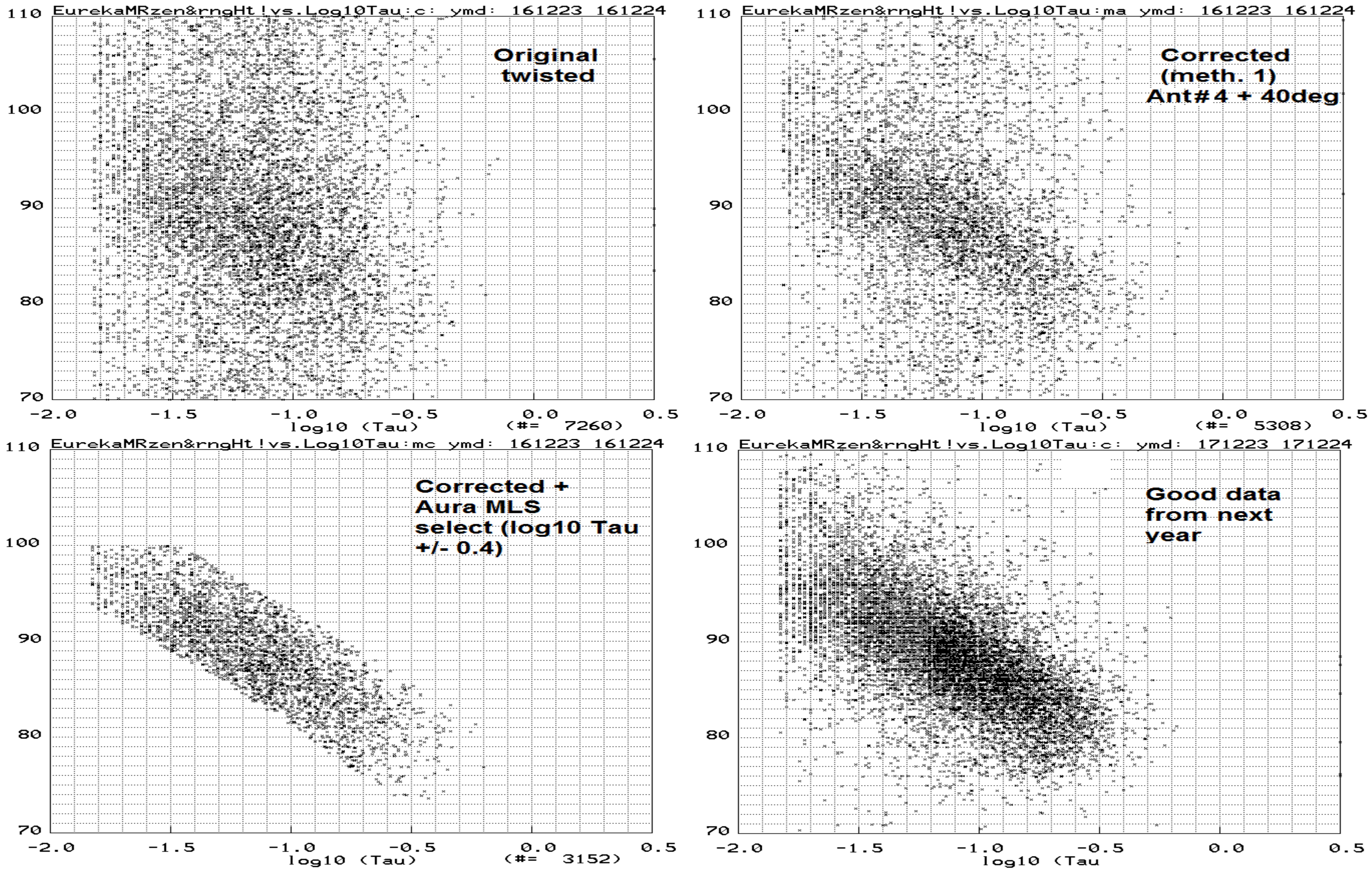
Height vs. log10 decay time

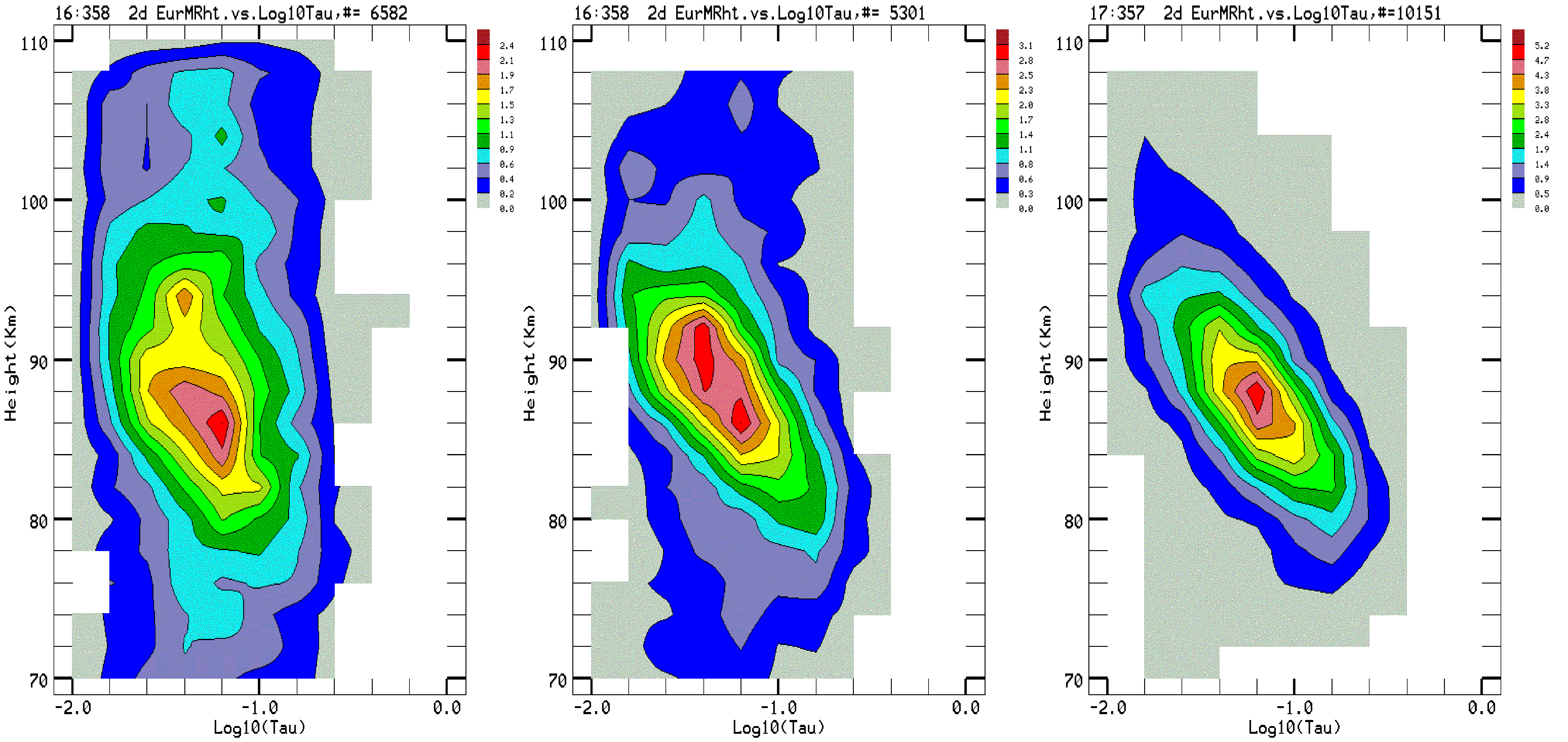




Meteor height vs. log10 (decay time) vs. amount of antenna corr.

Compare decay-time (tau) vs. h for orig. and corrected MWR, 2016 Dec23,24





Twisted antenna

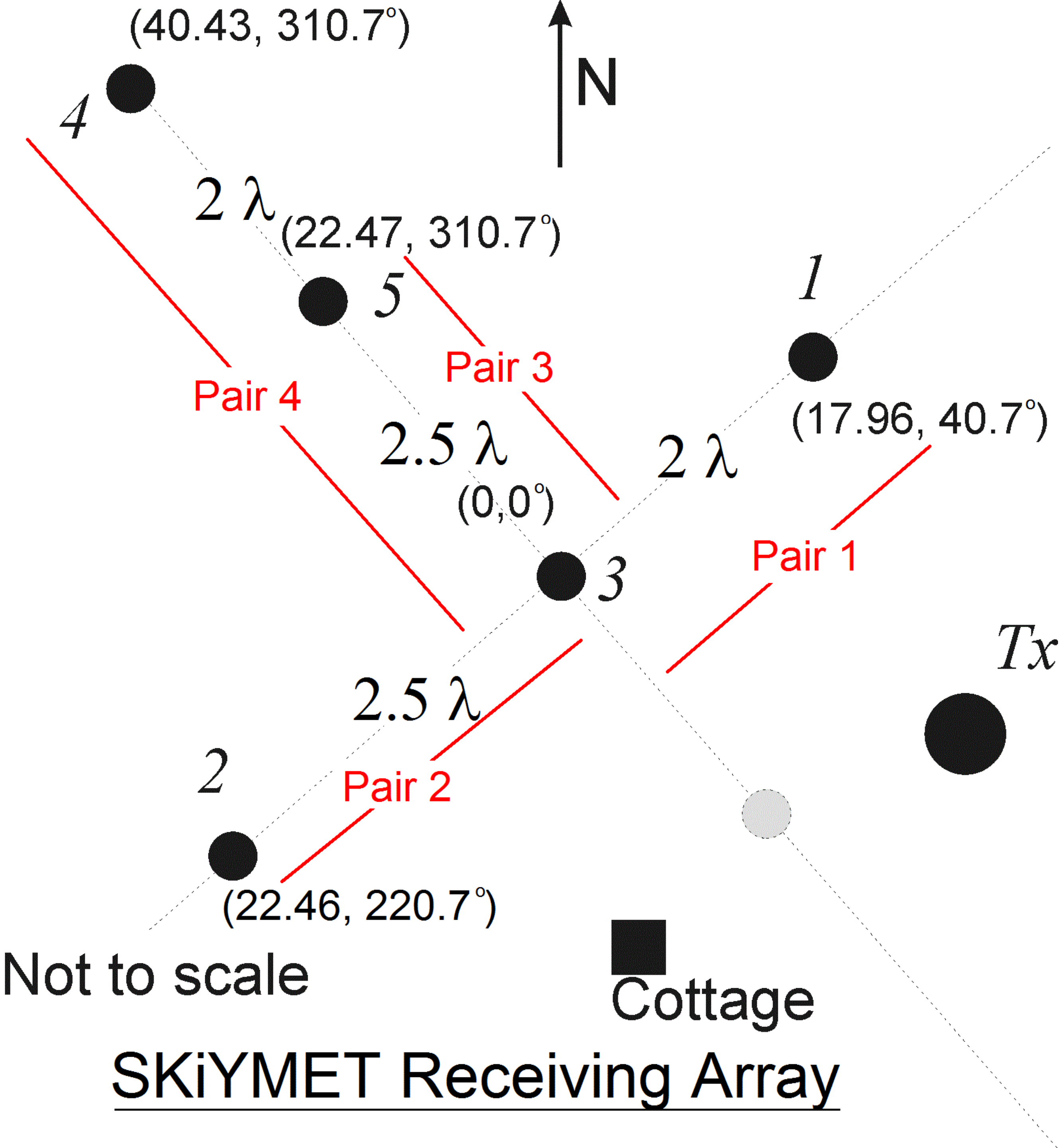
2016 Dec 23,24

Antenna #4 phase corr.: +40 deg

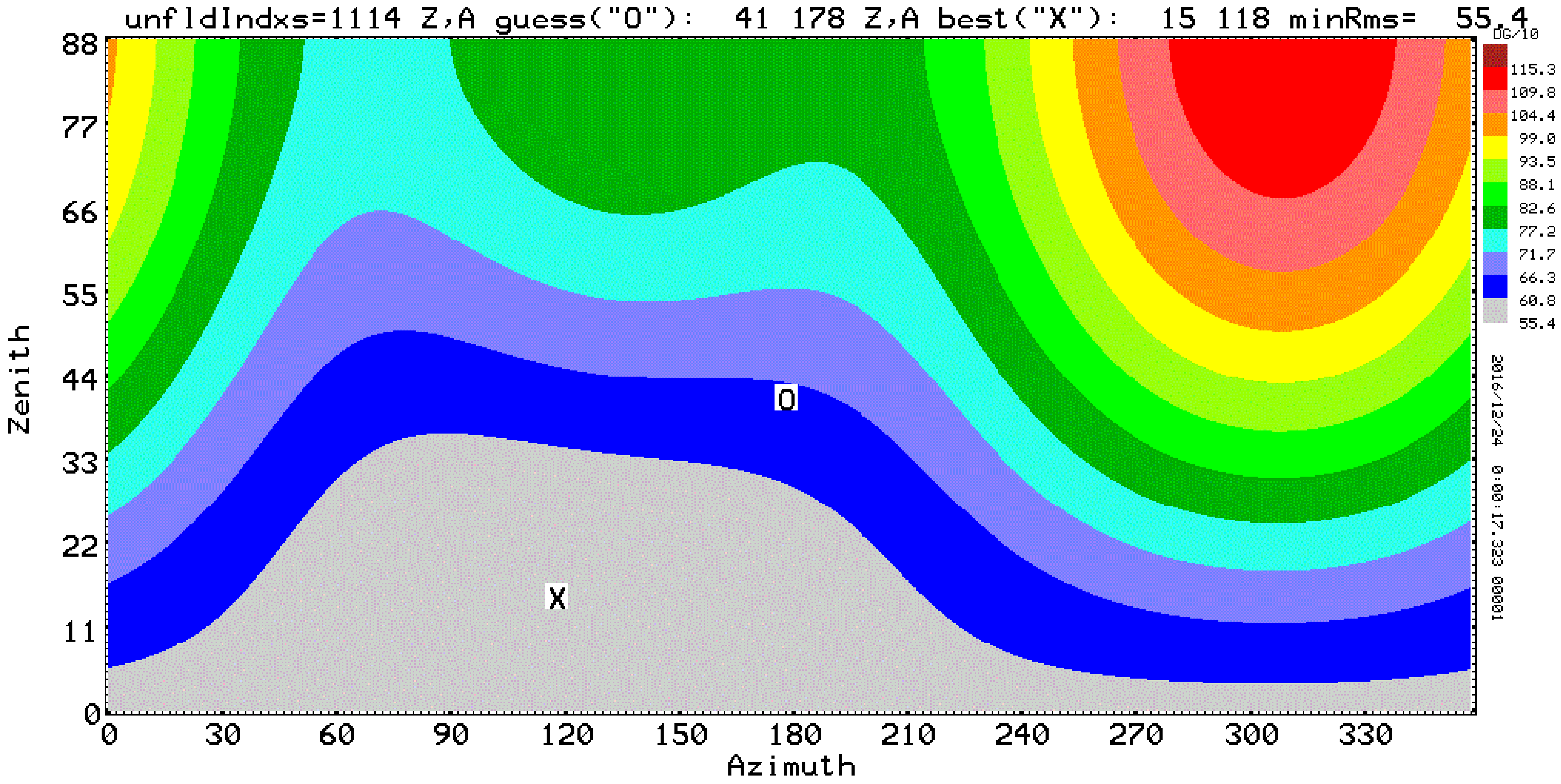
Good data (2017 Dec 23,24)

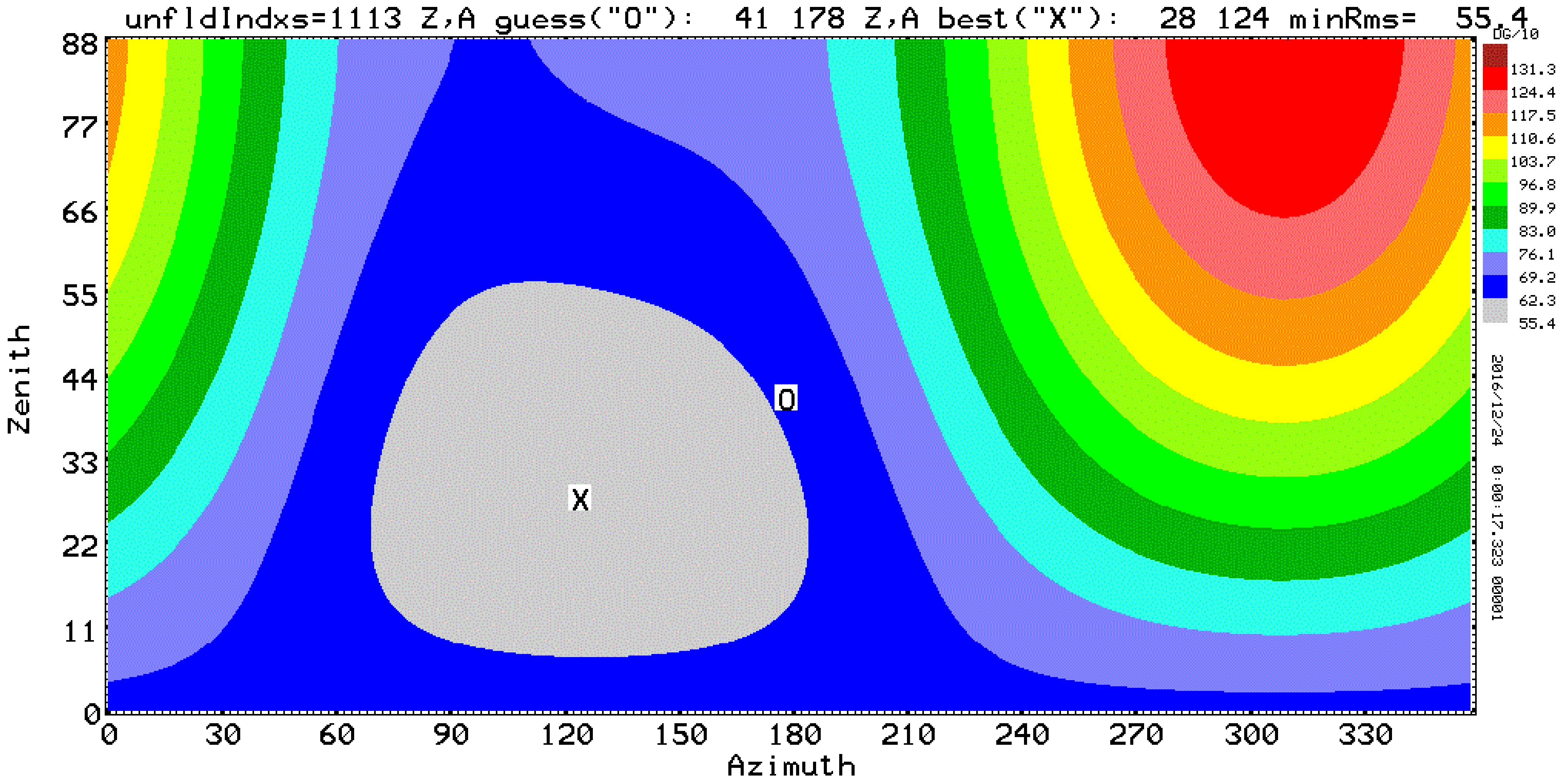
Correction Method 2 :

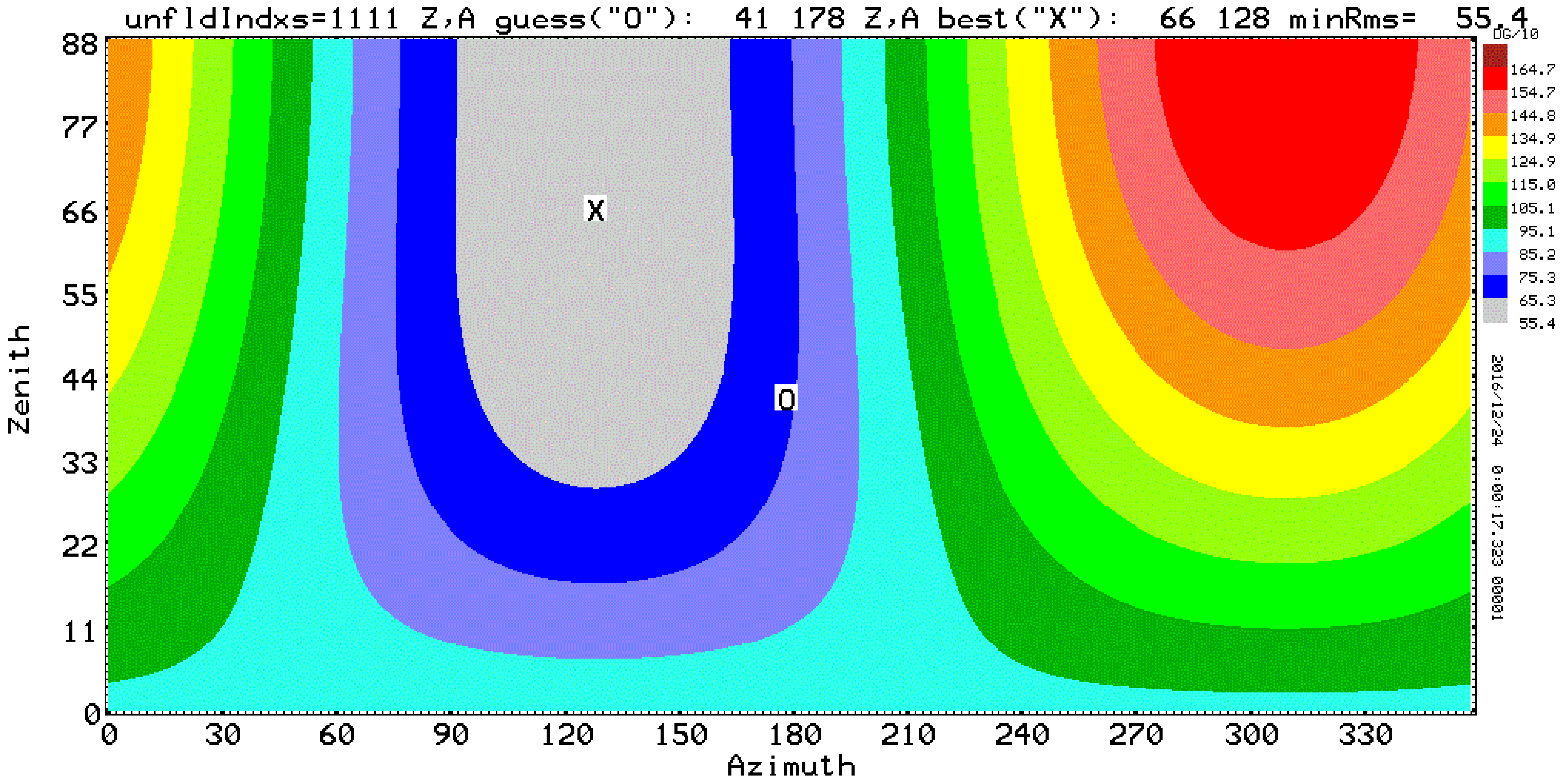
Non-linear fit of zenith and azimuth to 4 selected antenna pair phase differences. The fit must be done for each set of phase aliases (here 4x5x5x9) to find the one with the lowest error. It is an interesting in that the zenith and azimuth are not bounded – but means the zenith must be "unwound" afterwards.



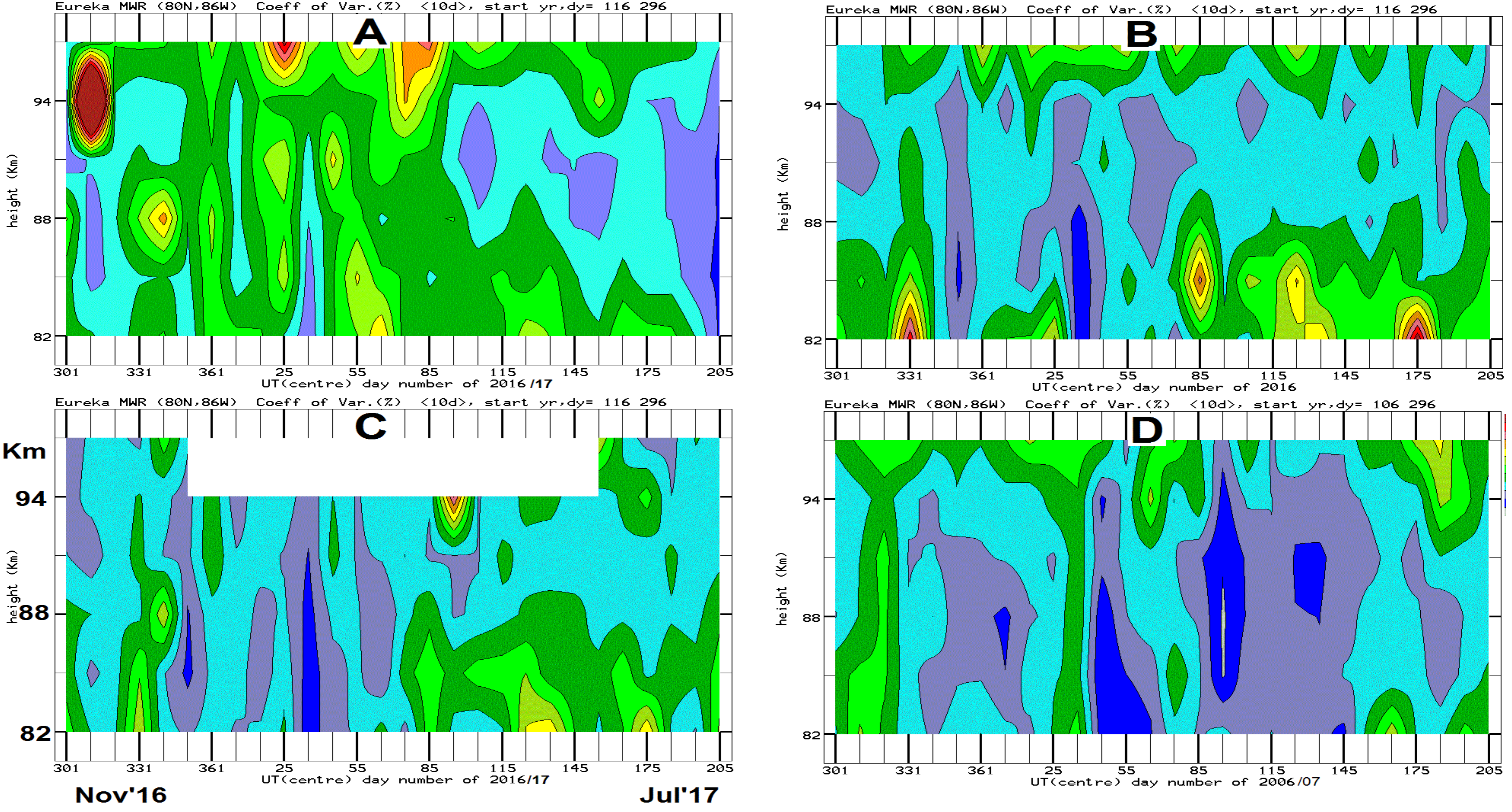
SKiYMET Receiving Array


unfldIndxs=1114 Z,A guess("O"): 41 178 Z,A best("X"): 15 118 minRms= 55.4
Zenith
Azimuth
0 30 60 90 120 150 180 210 240 270 300 330
0 11 22 33 44 55 66 77 88
DG/10
115.3
109.8
104.4
99.0
93.5
88.1
82.6
77.2
71.7
66.3
60.8
55.4
2016/12/24 0:00:17.323 00001
O
X


unfldIndxs=1113 Z,A guess("O"): 41 178 Z,A best("X"): 28 124 minRms= 55.4
Zenith
Azimuth
0
11
22
33
44
55
66
77
88
0
30
60
90
120
150
180
210
240
270
300
330
O
X
DG/10
131.3
124.4
117.5
110.6
103.7
96.8
89.9
83.0
76.1
69.2
62.3
55.4
2016/12/24 0:00:17.323 00001

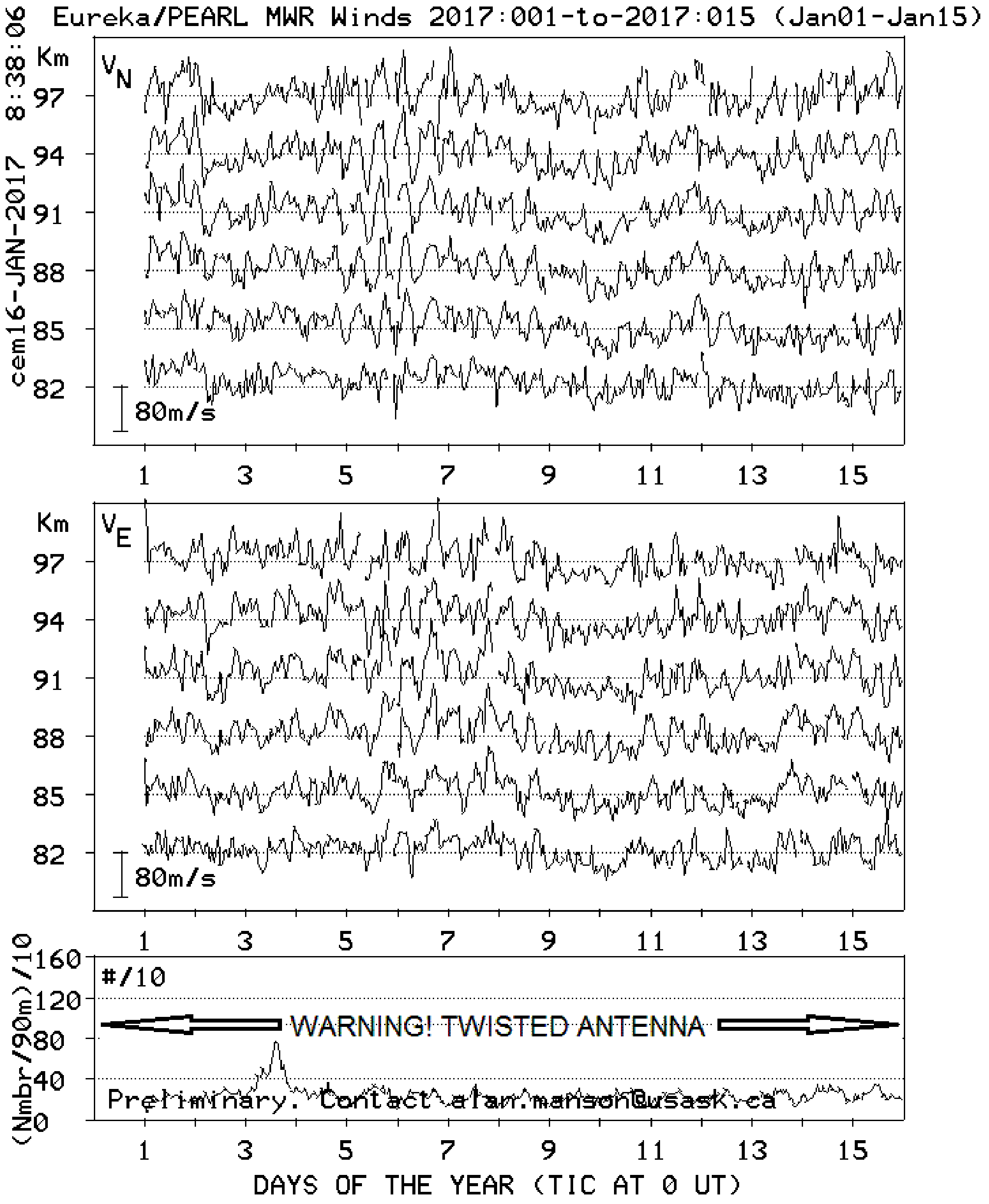

unfldIndxs=1111 Z,A guess("O"): 41 178 Z,A best("X"): 66 128 minRms= 55.4
Zenith
Azimuth
0
11
22
33
44
55
66
77
88
0
30
60
90
120
150
180
210
240
270
300
330
X
O
DG/10
164.7
154.7
144.8
134.9
124.9
115.0
105.1
95.1
85.2
75.3
65.3
55.4
2016/12/24 0:00:17.323 00001

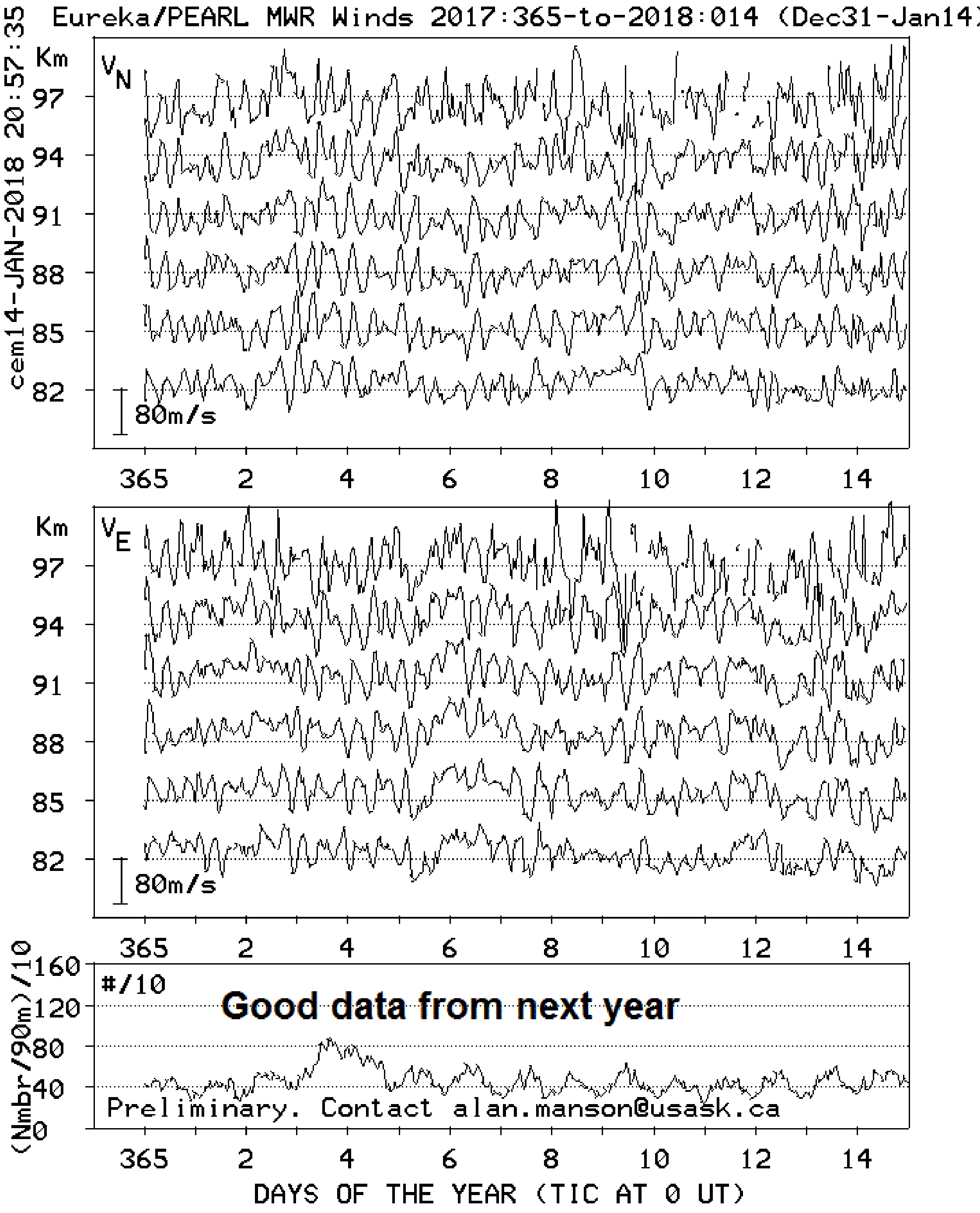
Eureka meteor radar: compare quality of corrected antenna-twisted data to original

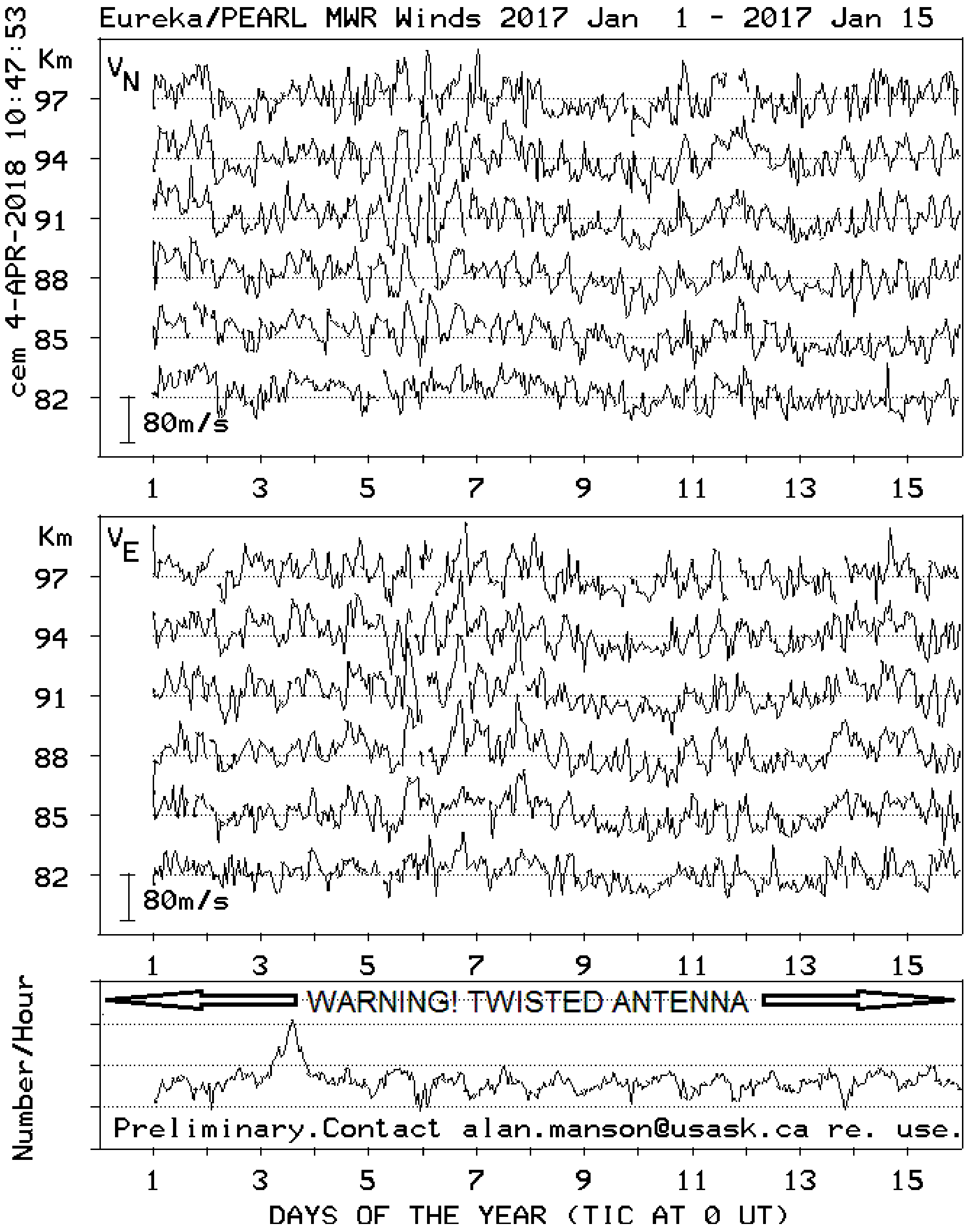


Hourly difference wind: coefficient of variation (%) 20 – 130 **[SMALL IS GOOD!]**

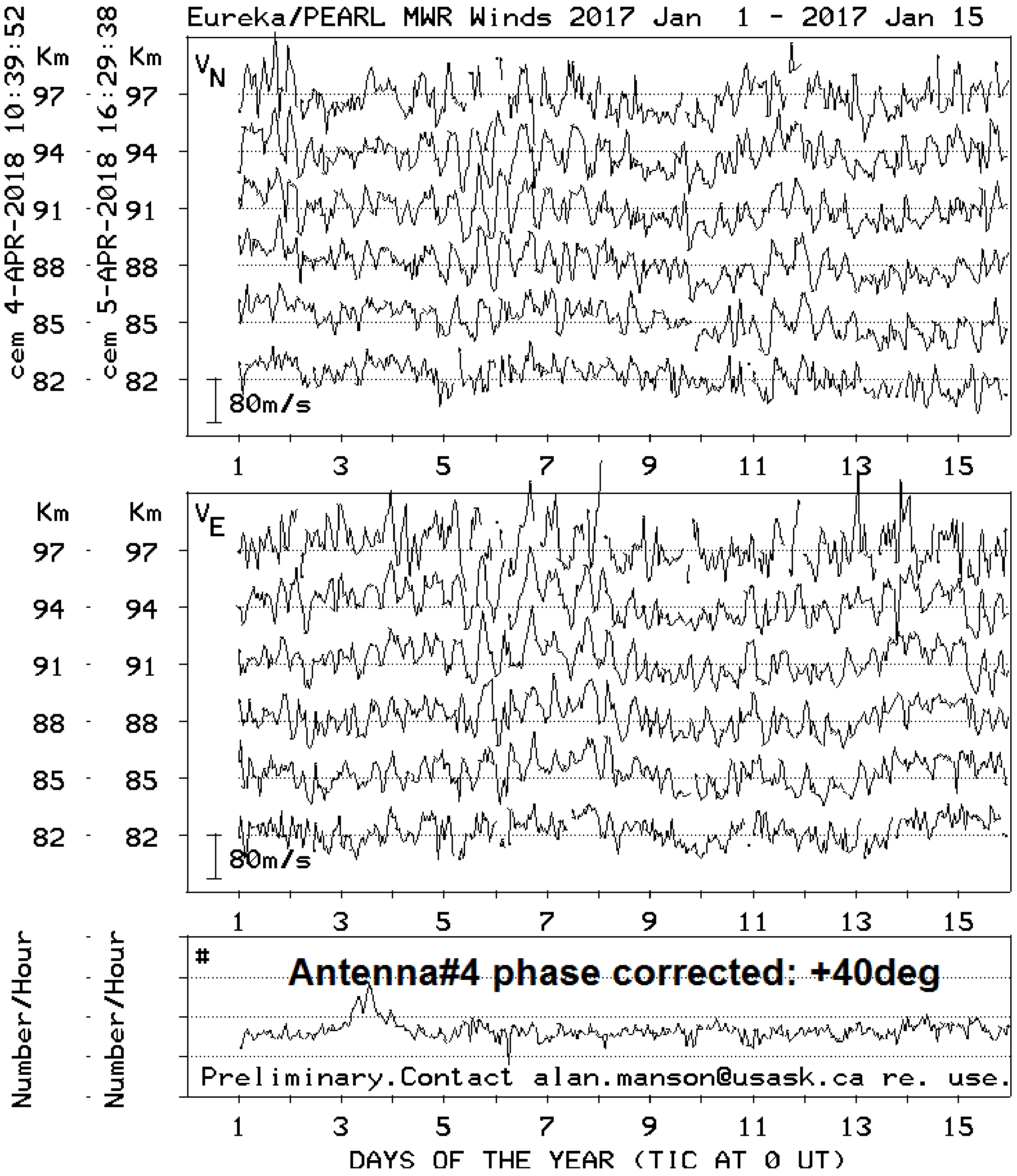
A: orignal, twisted **B: corrected (meth. 1)** **C: B plus AuraMLS select** **D: Good data(2006/7)**


Eureka/PEARL MWR Winds 2017:001-to-2017:015 (Jan01-Jan15)
cem16-JAN-2017 8:38:06
Km
V_N
97
94
91
88
85
82
80m/s
1 3 5 7 9 11 13 15
V_E
(Nmbr/90m)/10
160
120
80
40
0
#/10
WARNING! TWISTED ANTENNA
Preliminary. Contact alan.manson@usask.ca
DAYS OF THE YEAR (TIC AT 0 UT)


Eureka/PEARL MWR Winds 2017:365-to-2018:014 (Dec31-Jan14)
cem14-JAN-2018 20:57:35
Km
V_N
97
94
91
88
85
82
80m/s
365 2 4 6 8 10 12 14
V_E
(Nmbr/90m)/10
160
120
80
40
0
#/10
Good data from next year
Preliminary. Contact alan.manson@usask.ca
DAYS OF THE YEAR (TIC AT 0 UT)

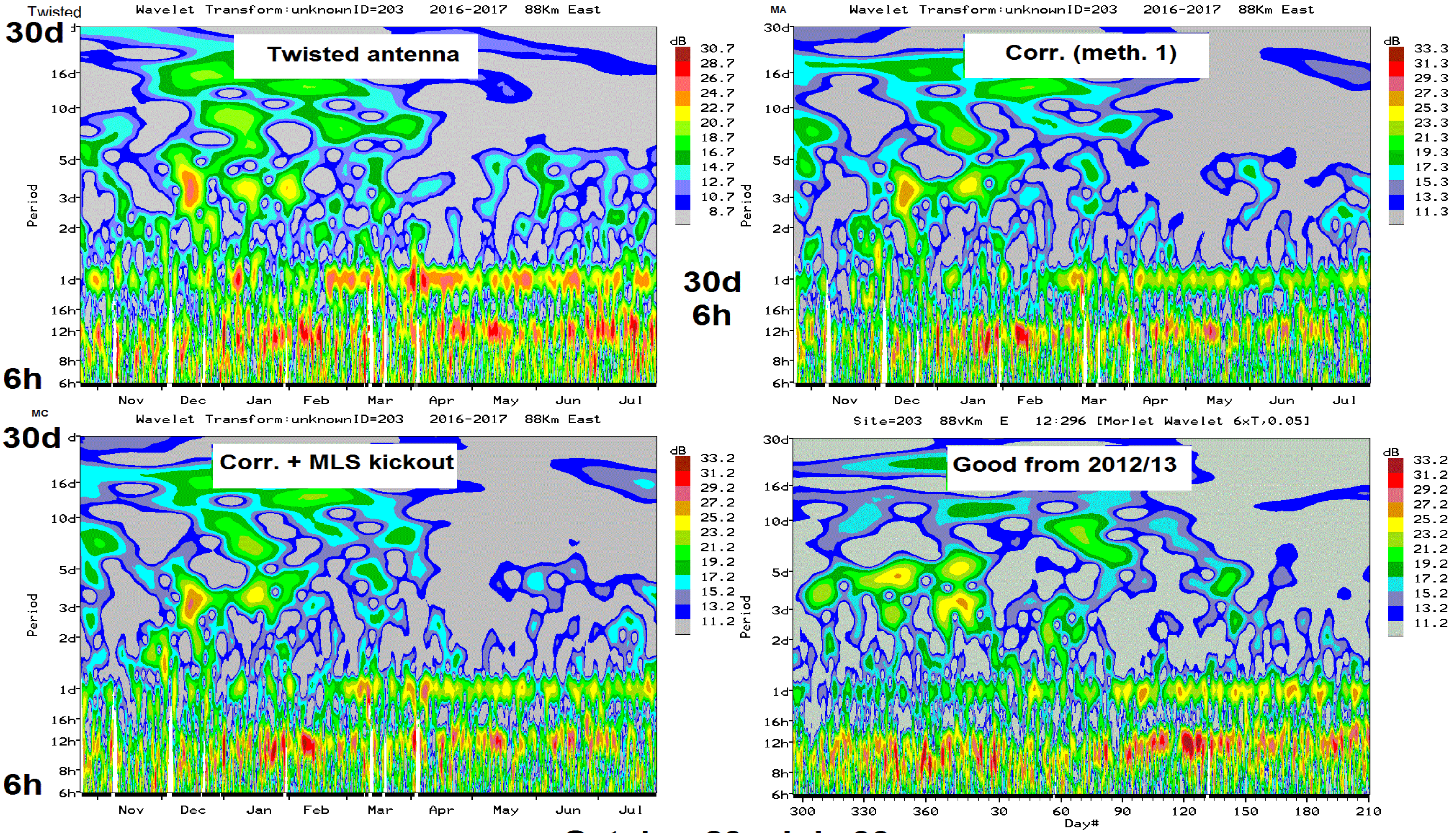


Eureka/PEARL MWR Winds 2017 Jan 1 - 2017 Jan 15
cem 4-APR-2018 10:47:53
Km
V_N
97
94
91
88
85
82
80m/s
V_E
Number/Hour
WARNING! TWISTED ANTENNA
Preliminary.Contact alan.manson@usask.ca re. use.
1 3 5 7 9 11 13 15
DAYS OF THE YEAR (TIC AT 0 UT)



Eureka/PEARL MWR Winds 2017 Jan 1 - 2017 Jan 15
cem 4-APR-2018 10:39:52
cem 5-APR-2018 16:29:38
Km
V_N
97
94
91
88
85
82
80m/s
V_E
Number/Hour
#
Antenna#4 phase corrected: +40deg
Preliminary.Contact alan.manson@usask.ca re. use.
1 3 5 7 9 11 13 15
DAYS OF THE YEAR (TIC AT 0 UT)

Comparison by wavelets @ 88Km (diff dB scales)



October 23 - July 30

Conclusion:

Since there is no way to test the correction methods without the actual SKiYMET analysis program I cannot recommend use of these data.

Thank you for listening!

Slide 5. Sample of signals at 5 antennas during twisted antenna interval

Slide 6. extracted amplitude and phase from trail in slide 5. The phase slope gives the Doppler shift (radial velocity). Before and after the trail, data are noise- "zero" amplitude and random phase.

Slide 7. sample of final o/p trail data. Correction modified the azimuth and zenith and uses these to determine the range and height (not always successfully)

Slide 8. antenna coordinates in m, (RF= 33.4 MHz) - a "Jones array" configuration. The relatively large spacing is to minimize antenna coupling - which would distort the AOA, and also produces a more accurate AOA because of the large spacings. But the drawback is that it produces AOA aliases.

Slide 9. A direct 0.5 lambda spacing can be simulated by subtracting the 2.5λ and 2λ lambda phase, but given that phase measurements have errors and subtracting double them (with a short spacing phase errors have a much bigger effect on the AOA.)

Slide 10. Shows zenith aliases for different antenna pair spacings given a real zenith angle. Adjacent aliases are 360 deg apart in antenna phase difference (of course the absolute phase difference cannot be measured: measured phase differences must be between -180° and +180°.

Slide 11. as in slide 10, but bigger real zenith. Results look similar.

Slide 12. In fact the echoes from 4 consecutive pulses are averaged coherently to increase S/N. A high PRF is necessary to catch weak (short duration) trails, which leads to range aliasing. A "meteor rule of thumb" is that each meteor size-range has the same total mass.

Slide 13. The red arc shows the range aliases for a particular range gate. E.g. here it appears to be range#3. Depending on zenith angle (which has "de-twisted" by this time) there may be 1, no or more than 1 possible heights between 70 and 110 Km.

__**Slide 18.**__ These have all been corrected, the phase correction was varied to see what was best. Visually 35° is worse. 40, 42, 45° look similar. (By the way, the 40° value was Wayne's estimate when he was there manually untwisting. The sign I found by trial.)

__**Slide 19.**__ This shows the progress from original, to corrected, to MLS selected. "MLS selected" means the meteor $\log_{10} \tau_{1/2}$ was within ±0.4 of the (daily Eureka) MLS-calculated value (at the corrected height). Use of MLS temperatures is not recommended above 0.001 hPa (~90 Km) so the temperature-GPH was extrapolated to 100 Km This slide shows winter data for which extrapolation is probably fine, but summer is not because of the large temperature changes near the mesopause, so MLS selection was an interesting thought but likely w will not be used.

Slide 21 In order to do a proper job, all pairs and all aliases should be used. There are ten such, of which two need (3-4,1-2) need 9 unfolds (3v4,1v2), and two (4v2, 1v4) probably 10. That adds up a humungous number of cases - at least 10x10x9x9x4x4x4x5x5 cases per meteor! - each of which needs a non-linear fit. There maybe some way of combining alias sets - that is, choice of aliases in some pairs may rule out some other pair aliases - I'll leave that as an exercise. Simple - like Fermat's last theorem.

But to un-digress, the non-linear fit looks for a mimimum in the rms phase errors (phases regenerated from the original AOA, and the 40° "fix" put in) for the 4 chosen spacings) over zenith-azimuth space. The interesting part is that no angle limits are used, i.e. it is an unboumded surface. So it happens that the zenith can wander +ve or -ve to any size (I just show the part of the surface in slide 22 for zenith = 0-90 ° - which is the only unique part of the surface. "O" shows the first guess, and "X" shows the minimum (over all unfolds). The only tricky part is "unwrapping" the zenith so that the height can be found.

Why method 2.? Method 1 keeps the N-E antenna line phases calculated from the twisted AOA result (so it keeps the same zenith component). Only the N-W line is modified.

Considering that all original phase measurements have errors, keeping one line of antennas fixed is not desirable. Method 2 all antenna par phase differences to vary. However - which is better? - that's difficult to say.

Slide 25. Hourly differences consists of real differences (e.g. tides) and noise. Tides don't change much in an hour, so the rms differences are expected to be a measure of noise. Noise occurs if, e.g., a meteor trail is placed at the wrong height and/or in the wrong direction (both of which depend on the AOA) - because it carries the radial velocity for its real height and direction

The whole "twisted" 9 month interval is shown (top left - twisted; top right - meth. 1.; bottom left - meth.1. + MLS selection; bottom-right good data from a different year.

The MLS-selected version looks a little better; and seems to take care of a few spurious (10d) values in the basic meth. 1. correction

Slide 26. Winds plots: twisted (15d, Jan '17) and good (15d, Jan '18) from a different year: the twisted data look a bit noisier, but otherwise the features look similar. That's the reason I didn't spot the problem. Wayne did see that there was problem right away because he was looking at daily stats. and height-$\log_{10}\tau$ plots. No-one suspected a twisted antenna!

Slide 27. Compares orignal (twisted) and corrected (meth. 1.) data for the same interval - they are the same in character over days, but sometimes quite different in short term detail - so what to do? And we know that the corrected is better in the short term (e.g. within a day) - but how mcuh better? Useably better?

Slide 28. Morlet wavelets for the whole 9 month interval, 88Km. A Gaussian (down to 0.1) window of 6 x period is used. Same organization as Slide 25.

FINITO