
DANGER
Scintec
Scintec
Scintec
Scintec
DANGER

Application of Parametric Speaker to Wind Profiler/ RASS

Ahoro ADACHI[1] and Hiroyuki HASHIGUCHI[2]
1: Meteorological Research Institute, Japan Met. Agency
2: Research Institute for Sustainable Humanosphere

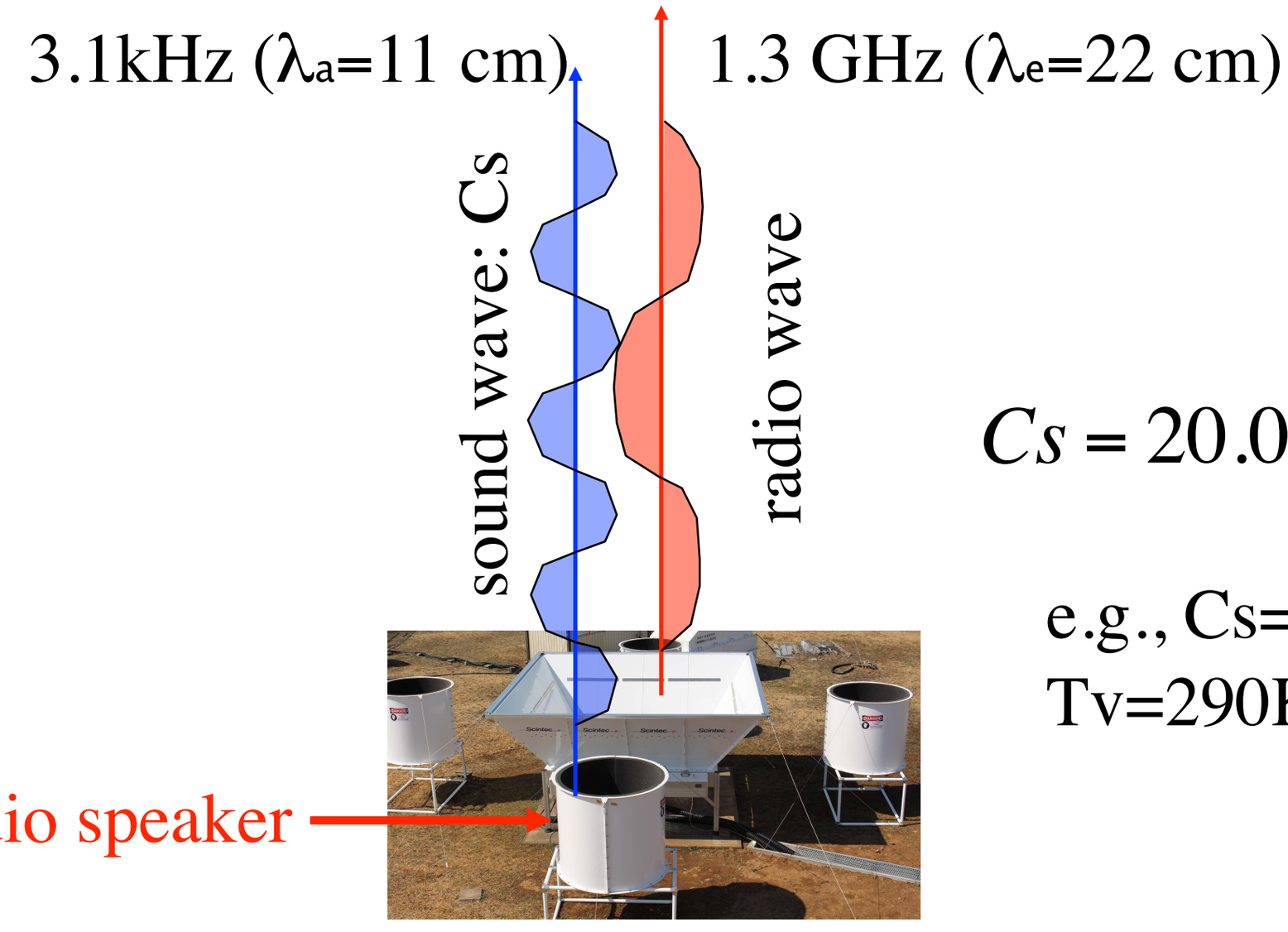
11th International Symposium on Tropospheric Profiling
21/May/2019

Table of Contents

RASS (Radio Acoustic Sounding System)

provides vertical profiles of virtual temperature in all weather conditions.

Bragg condition: λa (sound) = λe/2 (radio wave)



$$Cs = 20.048\sqrt{Tv}$$

e.g., Cs=340m/s when Tv=290K (=17°C)

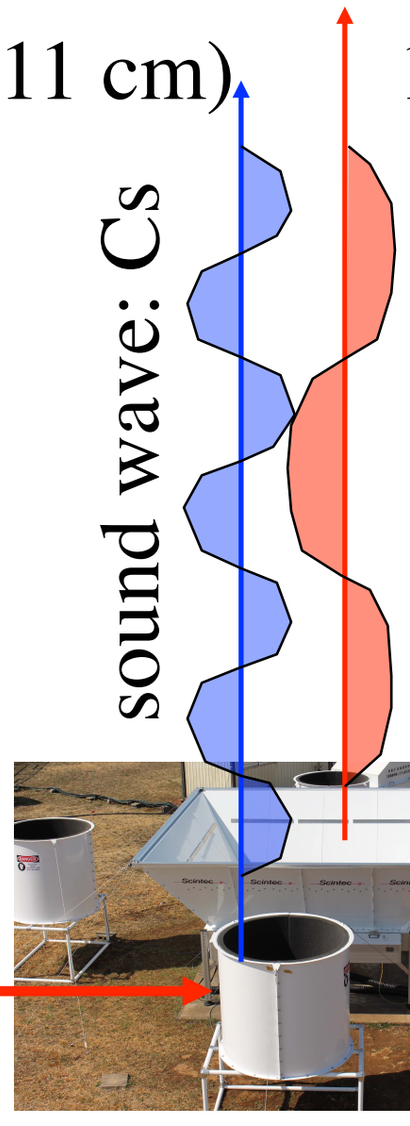
RASS (Radio Acoustic Sounding System)

provides vertical profiles of virtual temperature in all weather conditions.

Bragg condition: λa (sound) = λe/2 (radio wave)

3.1kHz (λ_a=11 cm)

1.3 GHz (λ_e=22 cm)

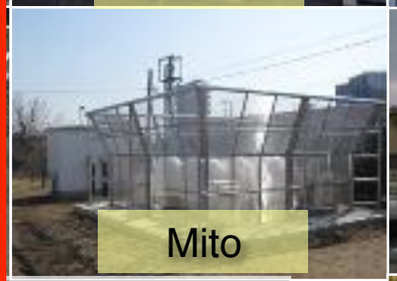


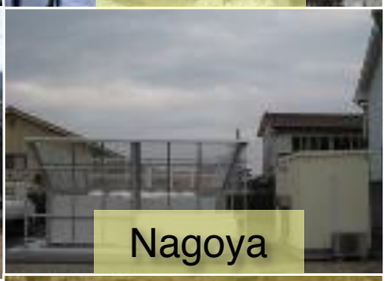
audio speaker

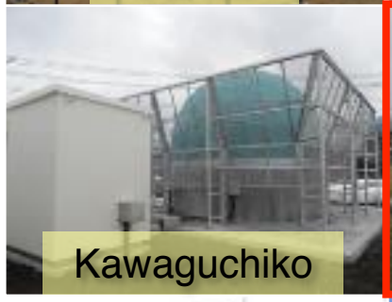
$$Cs = 20.048\sqrt{Tv}$$

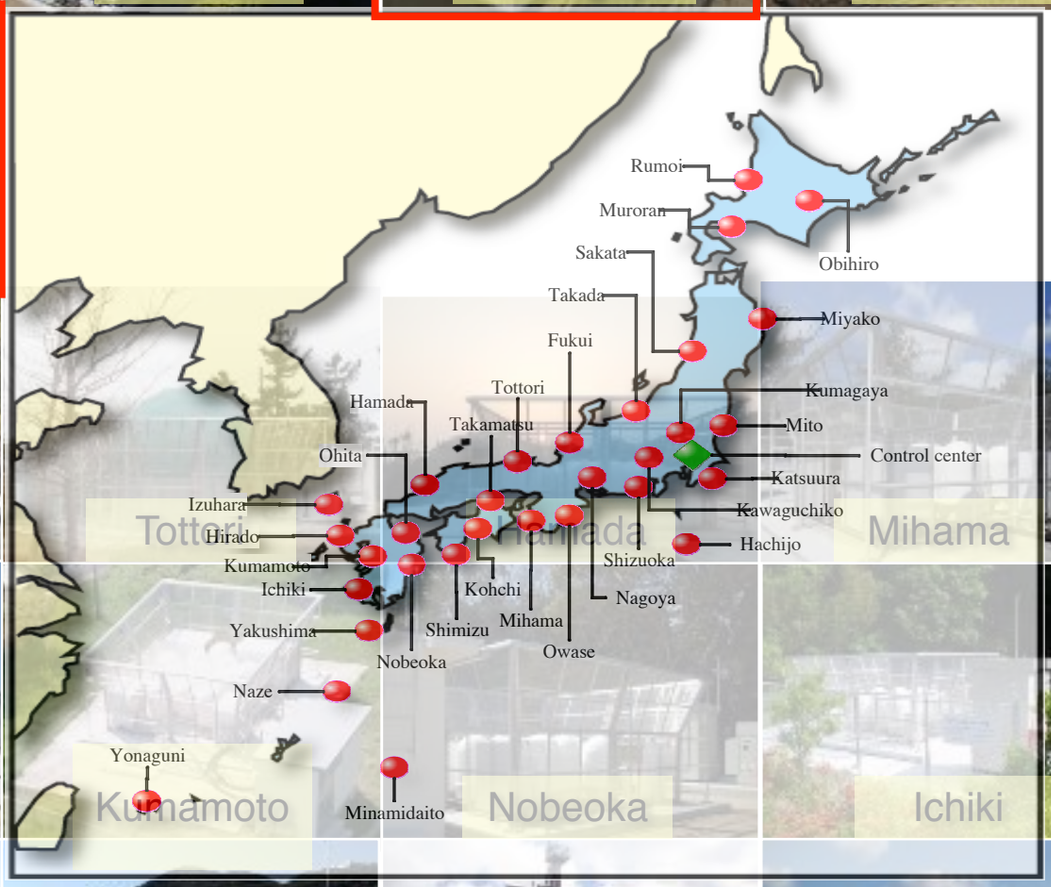
e.g., Cs=340m/s when Tv=290K (=17°C)

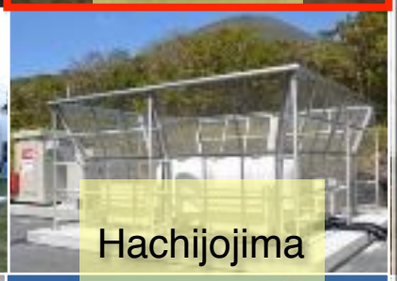
WINDAS *(Wind Profiler Network and Data Acquisition System)* since 2001, 33 L-band WPRs

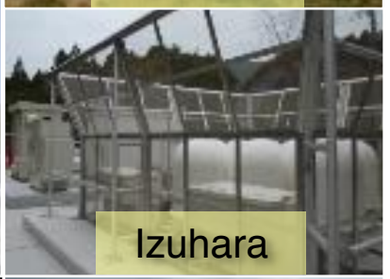


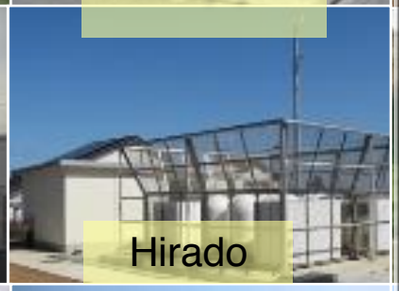


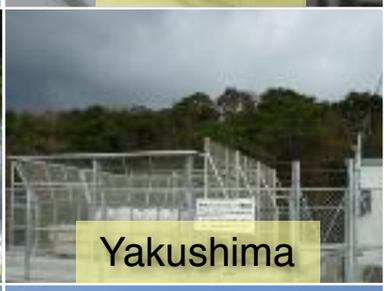


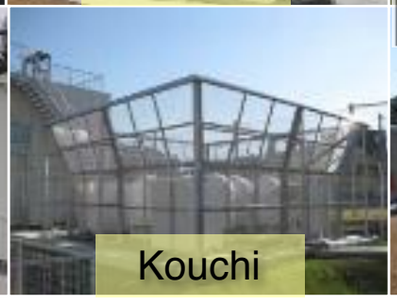


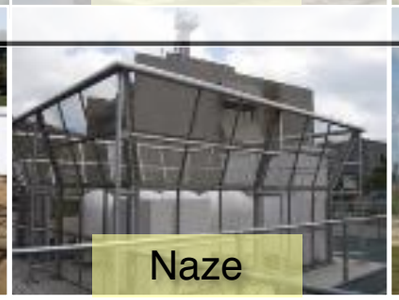


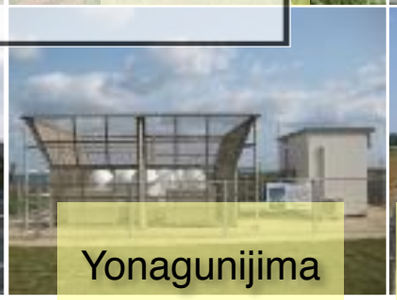










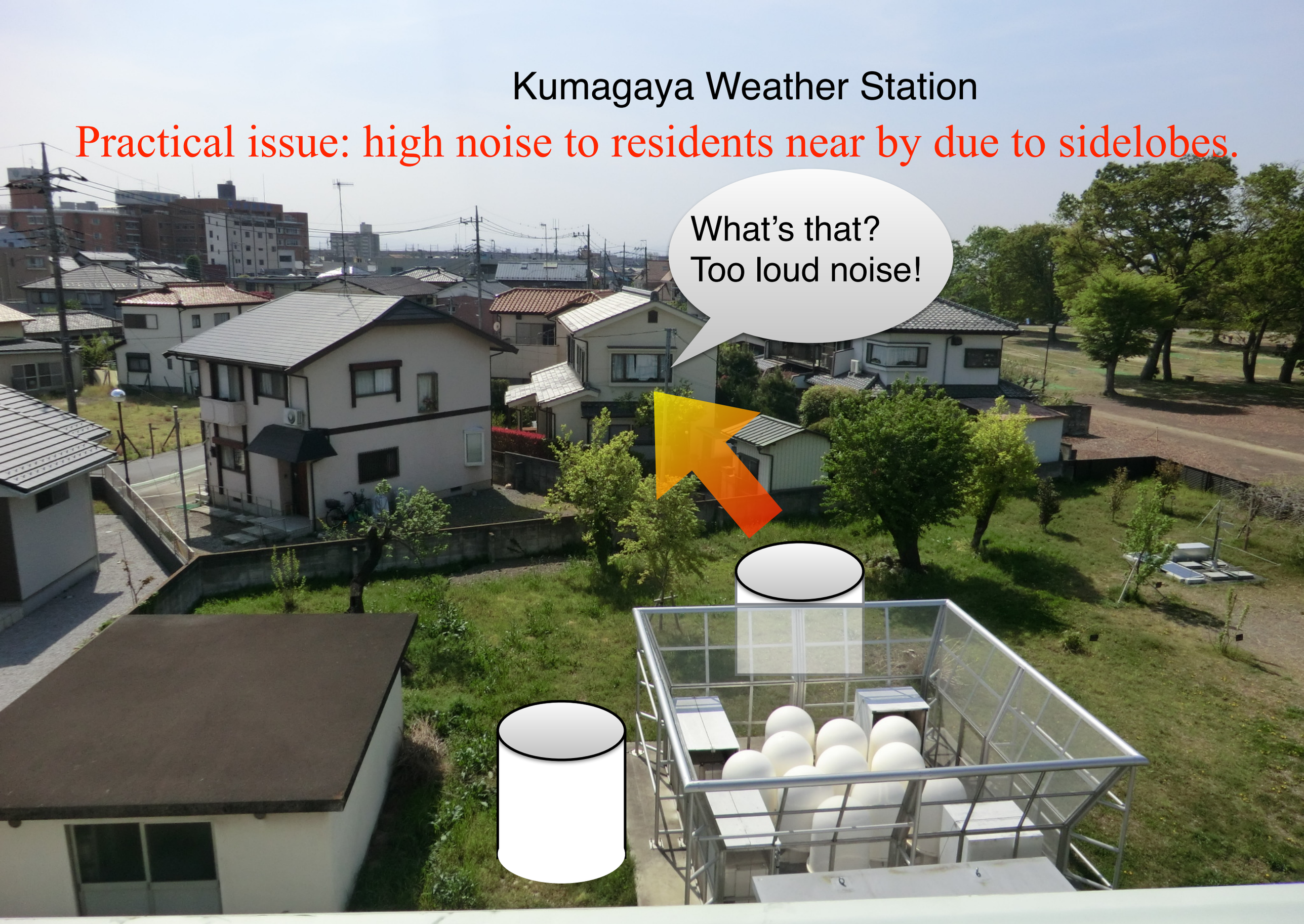


Courtesy of Mr. T. Hayashi of JMA

Kumagaya Weather Station

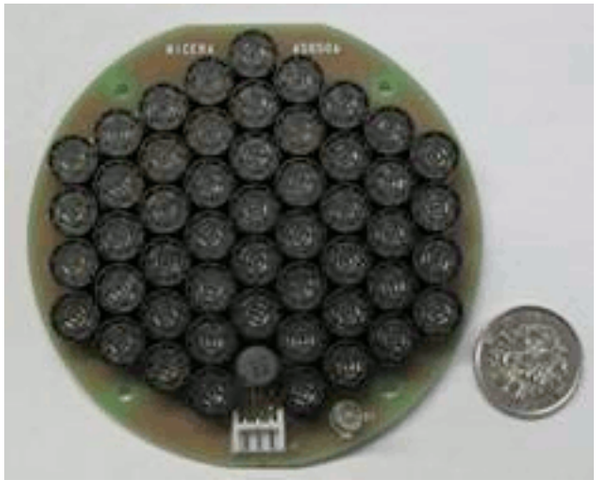
Kumagaya Weather Station

Practical issue: high noise to residents near by due to sidelobes.



(2) Audible sound from ultrasound

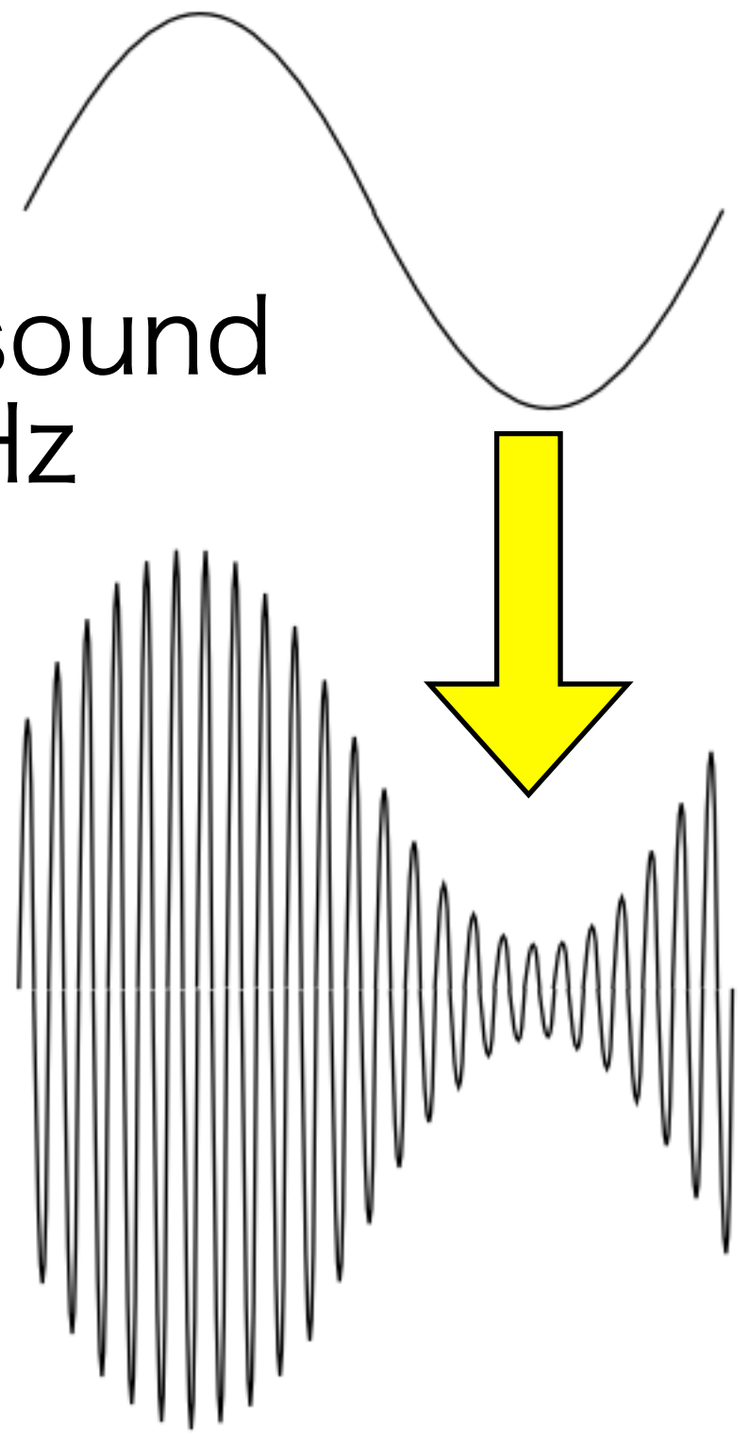
Amplitude modulation (AM) speaker



Ultrasound Speaker

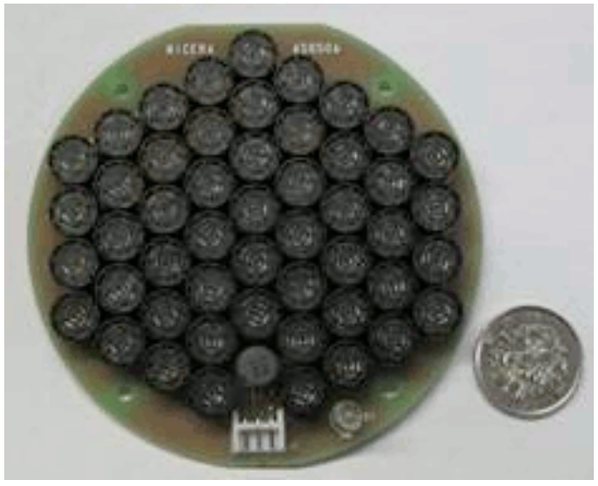
RASS sound
3kHz

Ultrasound
e.g., 40kHz

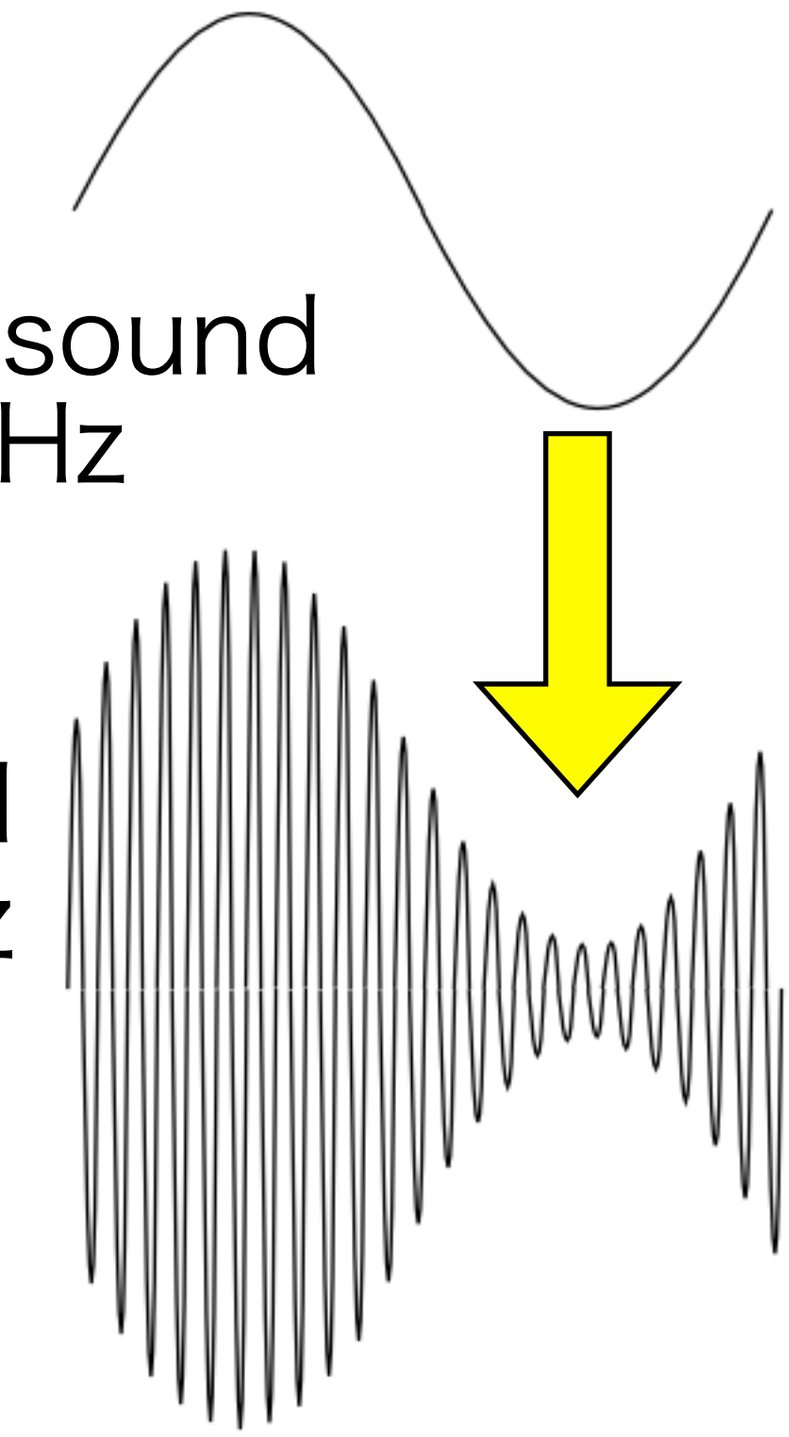


(2) Audible sound from ultrasound

Amplitude modulation (AM) speaker



Ultrasound Speaker

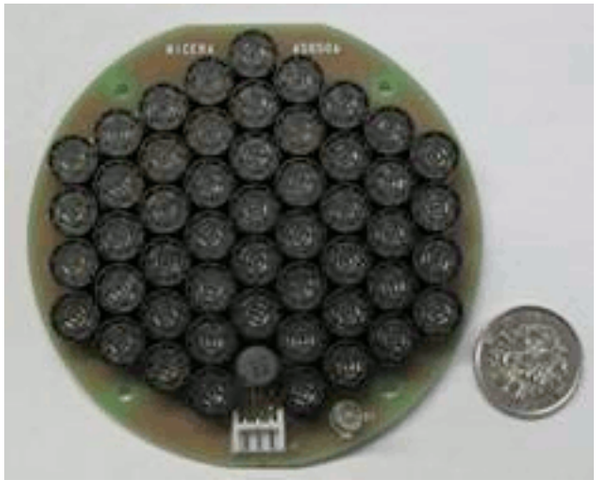


Audible sound carried by the ultrasound.

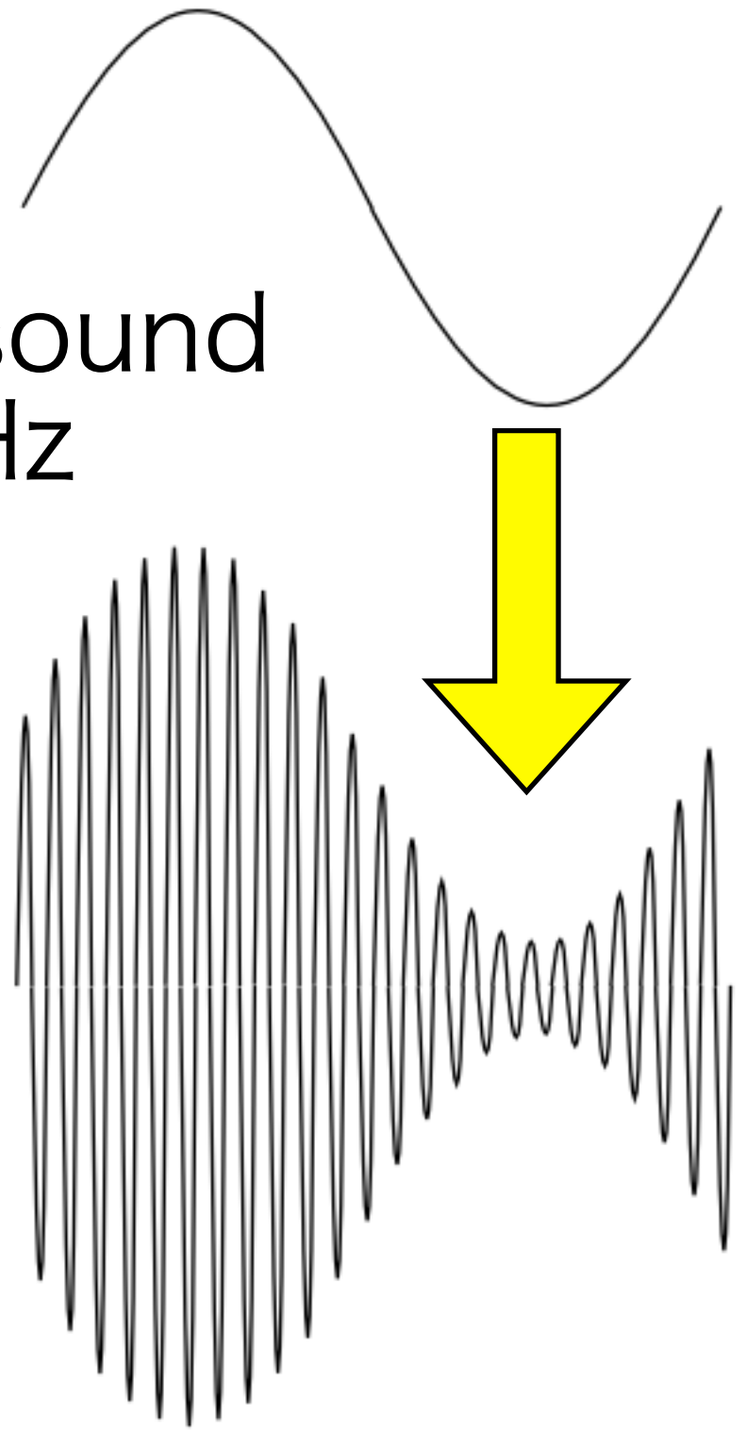
=> Narrow beam of the RASS sound.

(2) Audible sound from ultrasound

Amplitude modulation (AM) speaker



Ultrasound Speaker



Audible sound carried by the ultrasound.

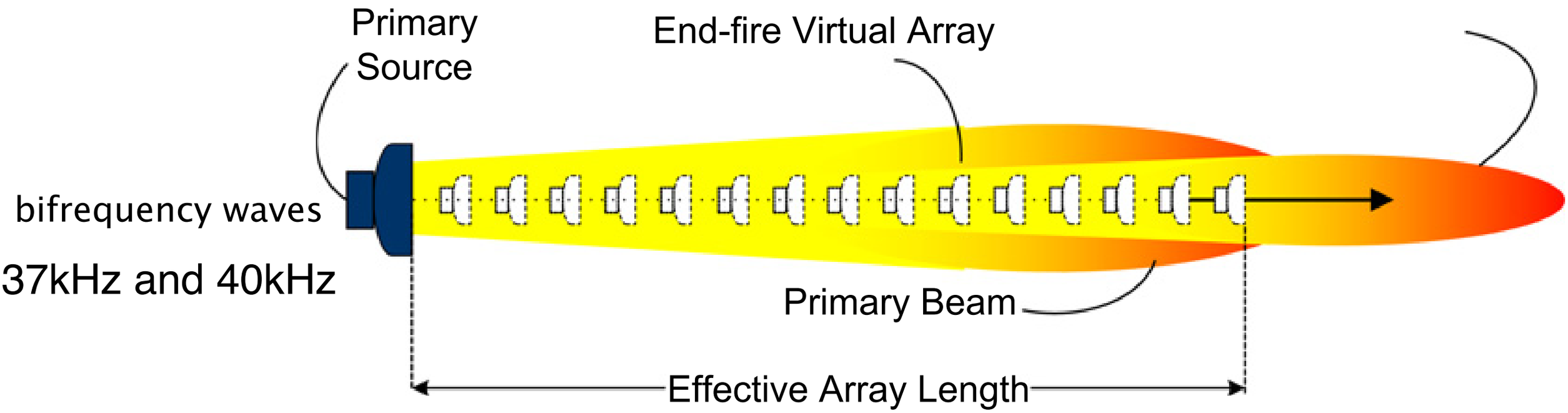
=> Narrow beam of the RASS sound.

RASS sound decreases with the dissipation of the ultrasound.

Audible sound from ultrasound

Parametric Acoustic Array

(PAA): high detectability and low sidelobes



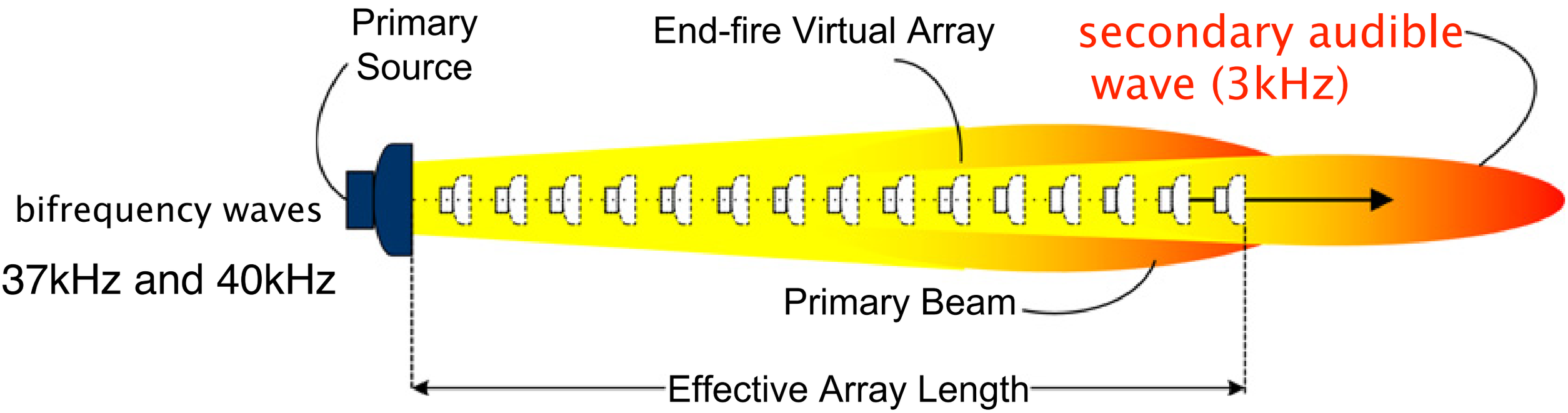
from W.-S. Gan et al.(2012)

37kHz ± 40kHz = 3kHz (+ 77kHz)

Audible sound from ultrasound

Parametric Acoustic Array

(PAA): high detectability and low sidelobes

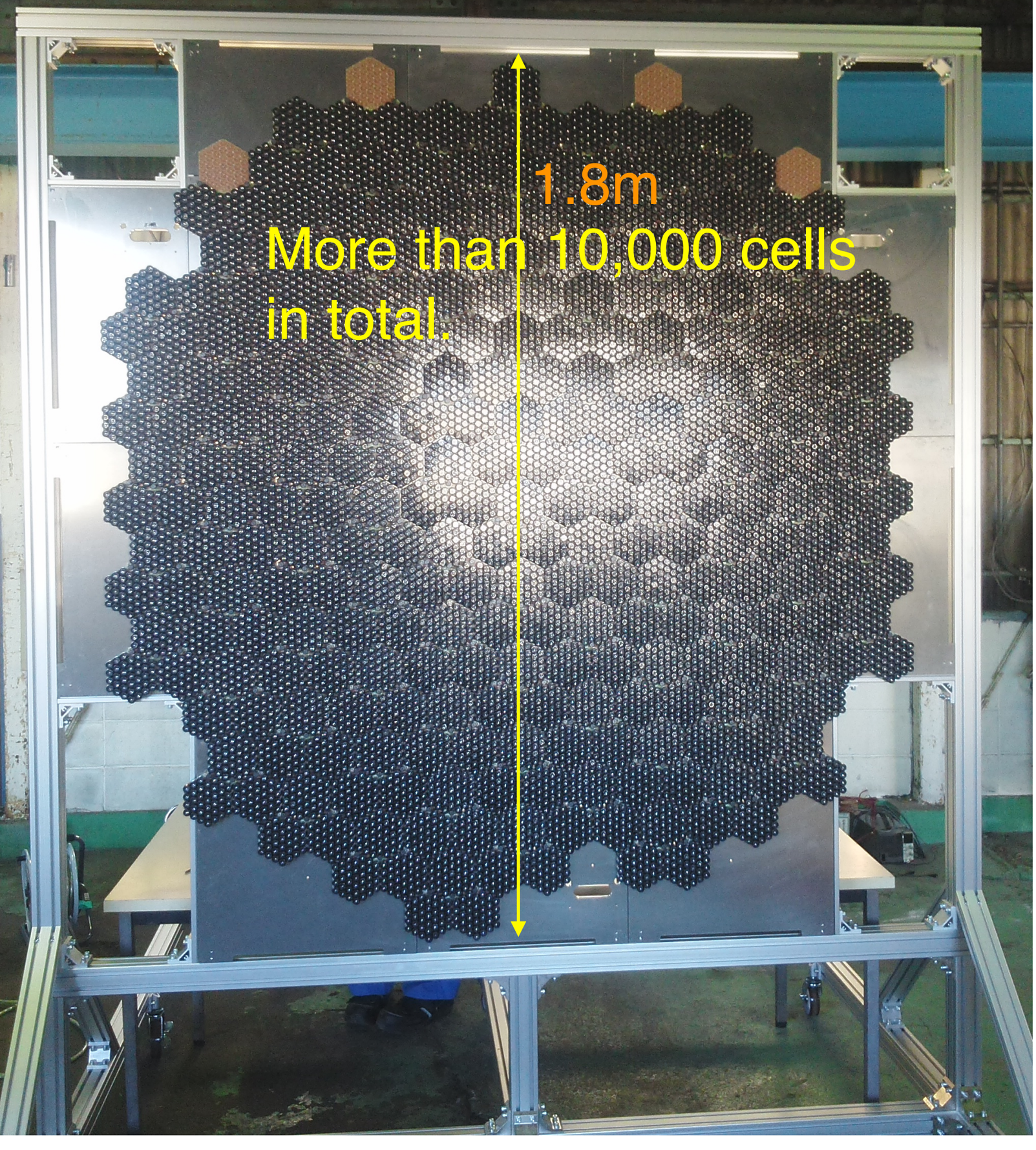


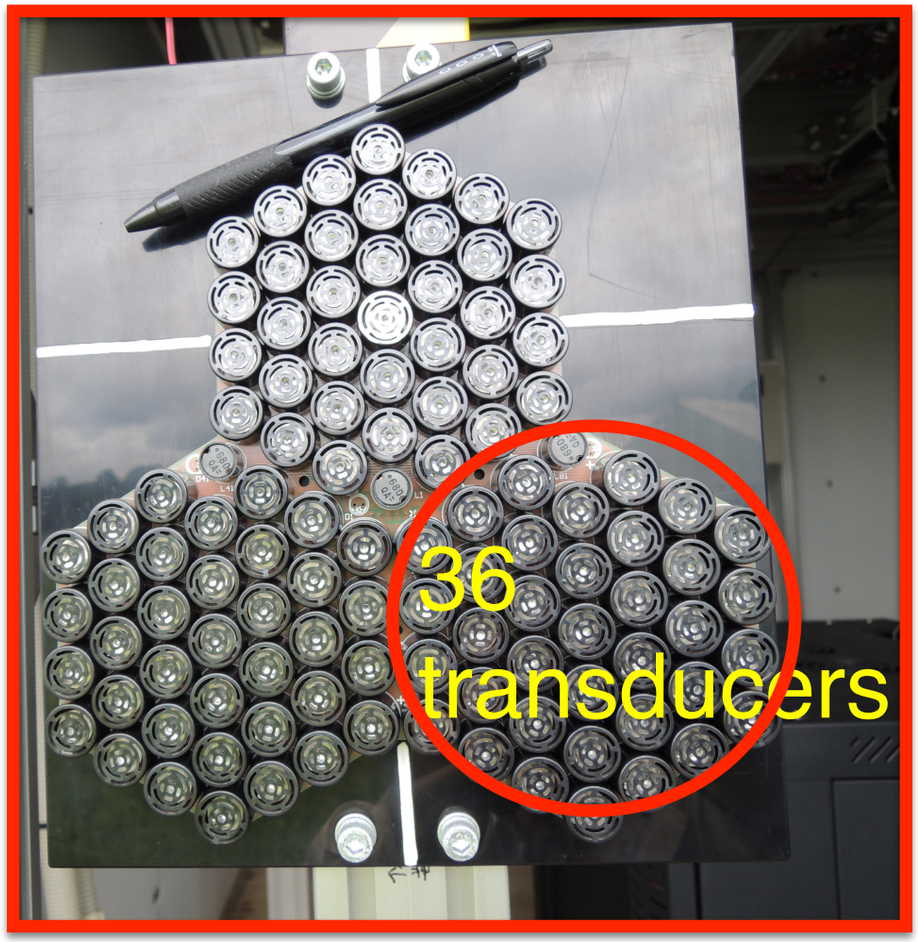
from W.-S. Gan et al.(2012)

37kHz ± 40kHz = 3kHz (+ 77kHz)

RASS sound (3kHz) can propagate long distance
even after the dissipation of the ultrasound.

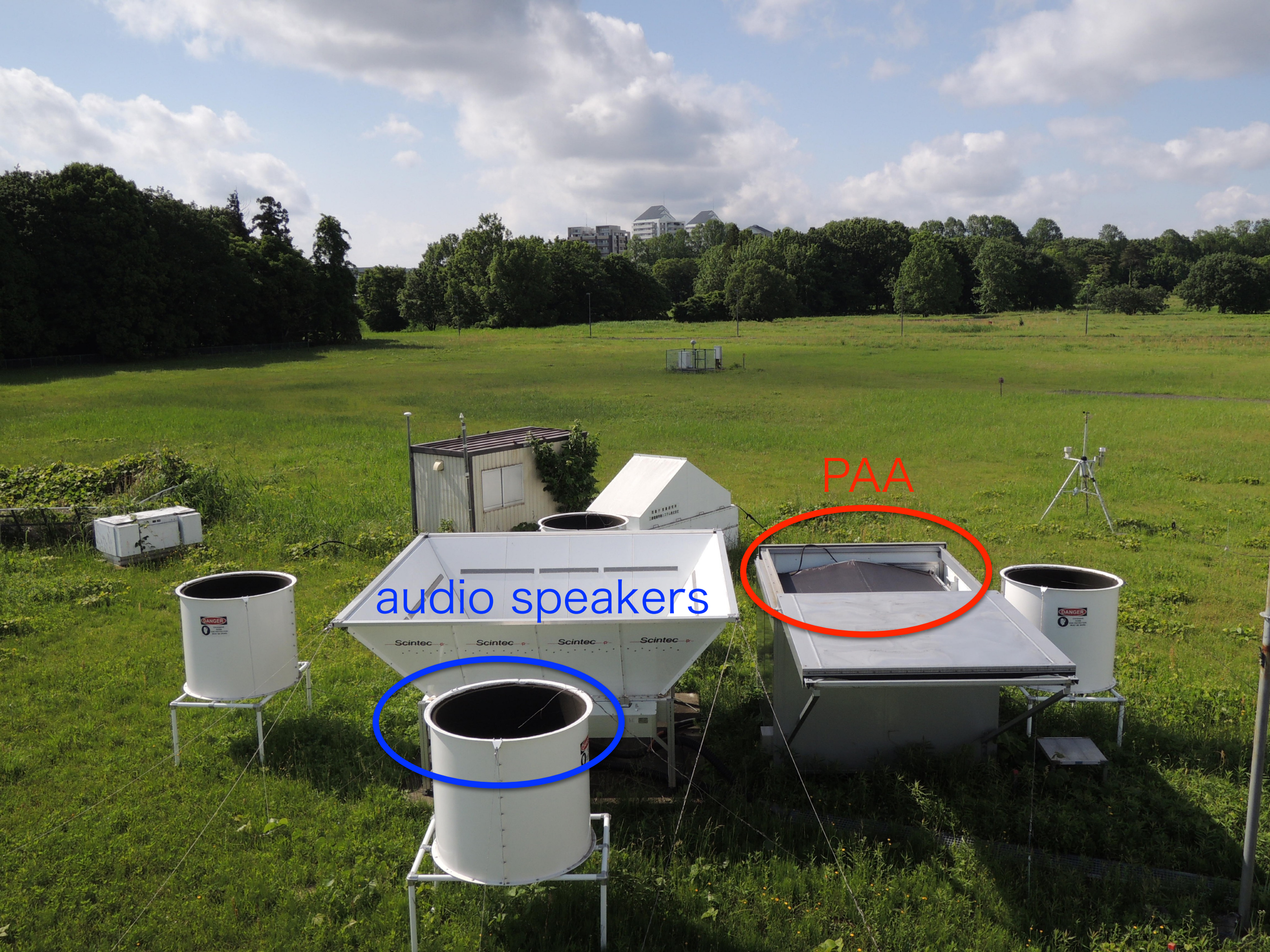
Parametirc acoustic array for RASS





36 trans. for a segment,

FPGA controls 278 segments.


PAA
audio speakers
Scintec
Scintec
Scintec
Scintec
DANGER
DANGER

f = 3 kHz

103dB (Audio SP)

100dB (PAA)

Audio Speaker

71dB@85°

PAA

52dB@30°

Background level (50dB)

Sound Pressure Level [dB at 25m]

110

100

90

80

70

60

-90

-60

-30

0

30

60

90

Zenith Angle [deg.]

f = 3 kHz

103dB (Audio SP)

100dB (PAA)

Audio Speaker

71dB@85°

PAA

52dB@30°

Background level (50dB)

Sound Pressure Level [dB at 25m]

110

100

90

80

70

60

-90

-60

-30

0

30

60

90

Zenith Angle [deg.]

f = 3 kHz

Sound Pressure Level [dB at 25m]

110
100
90
80
70
60

103dB (Audio SP)

100dB (PAA)

Audio Speaker

71dB@85°

PAA

52dB@30°

Background level (50dB)

-90 -60 -30 0 30 60 90

Zenith Angle [deg.]

f = 3 kHz

103dB (Audio SP)

100dB (PAA)

Audio Speaker

71dB@85°

PAA

52dB@30°

Background level (50dB)

Sound Pressure Level [dB at 25m]

110

100

90

80

70

60

-90

-60

-30

0

30

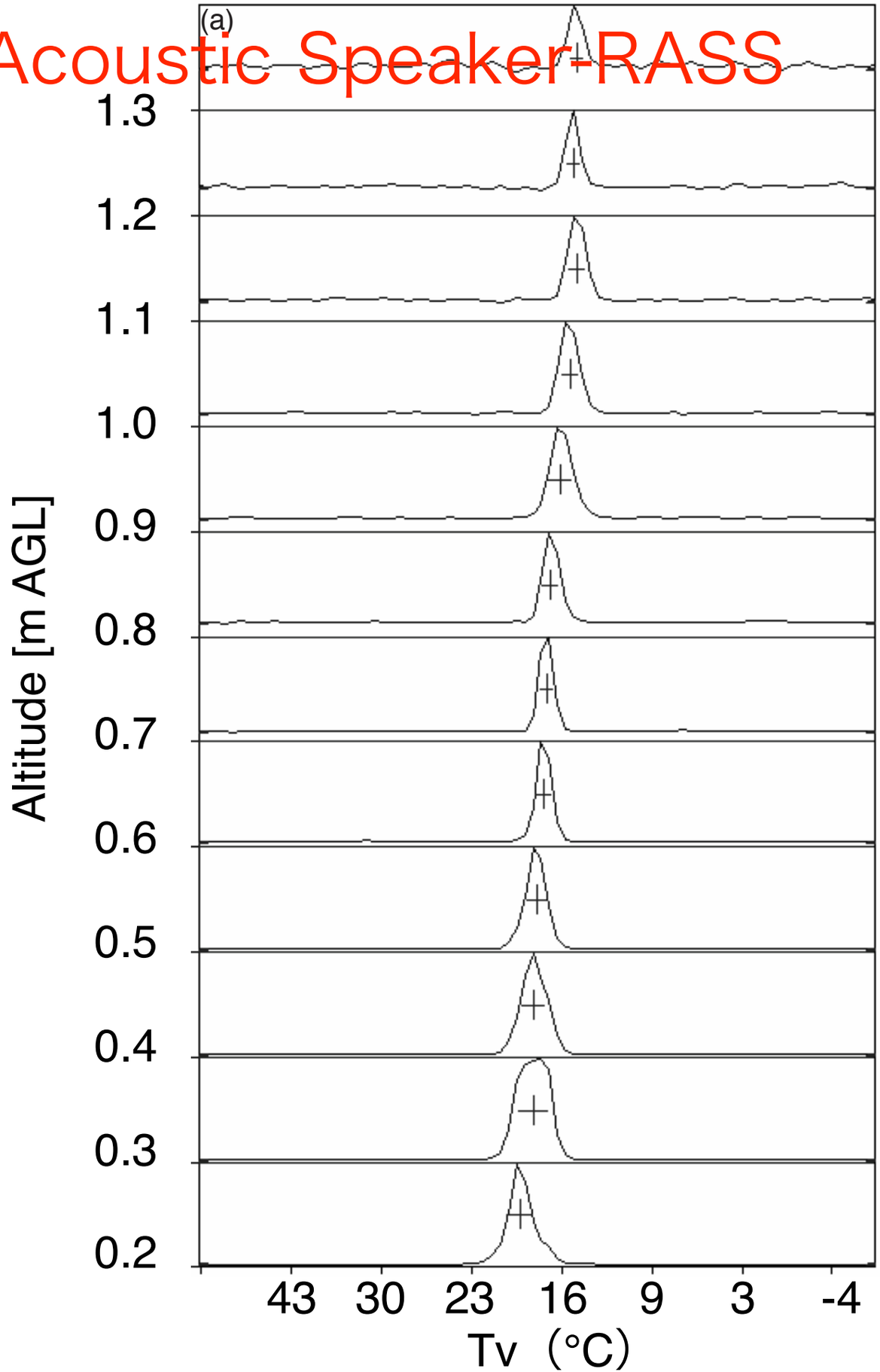
60

90

Zenith Angle [deg.]

19 Oct. 2016 08:30

Acoustic Speaker-RASS



19 Oct. 2016 08:30

19 Oct. 2016 08:31

(a)

Acoustic Speaker-RASS

(b)

PAA-RASS

Altitude [m AGL]

1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2

43 30 23 16 9 3 -4

Tv (°C)

TV (°C)

3. Evaluation of Parametric Acoustic Array

Comparison with radiosonde and conventional RASS

Period:

2016-2018 (23 days：no rain, light wind)

08:00AM-09:00 AM (60 min.)

Radio sonde launch: 08:30 AM (locates 400m from RASS)

Acoustic-RASS and PAA-RASS were switched every minute.

Time resolution: 2 min for each speaker system
Range resolution : 100 m (665ns)

3. Evaluation of Parametric Acoustic Array

Comparison with radiosonde and conventional RASS

Period:

2016-2018 (23 days：no rain, light wind)

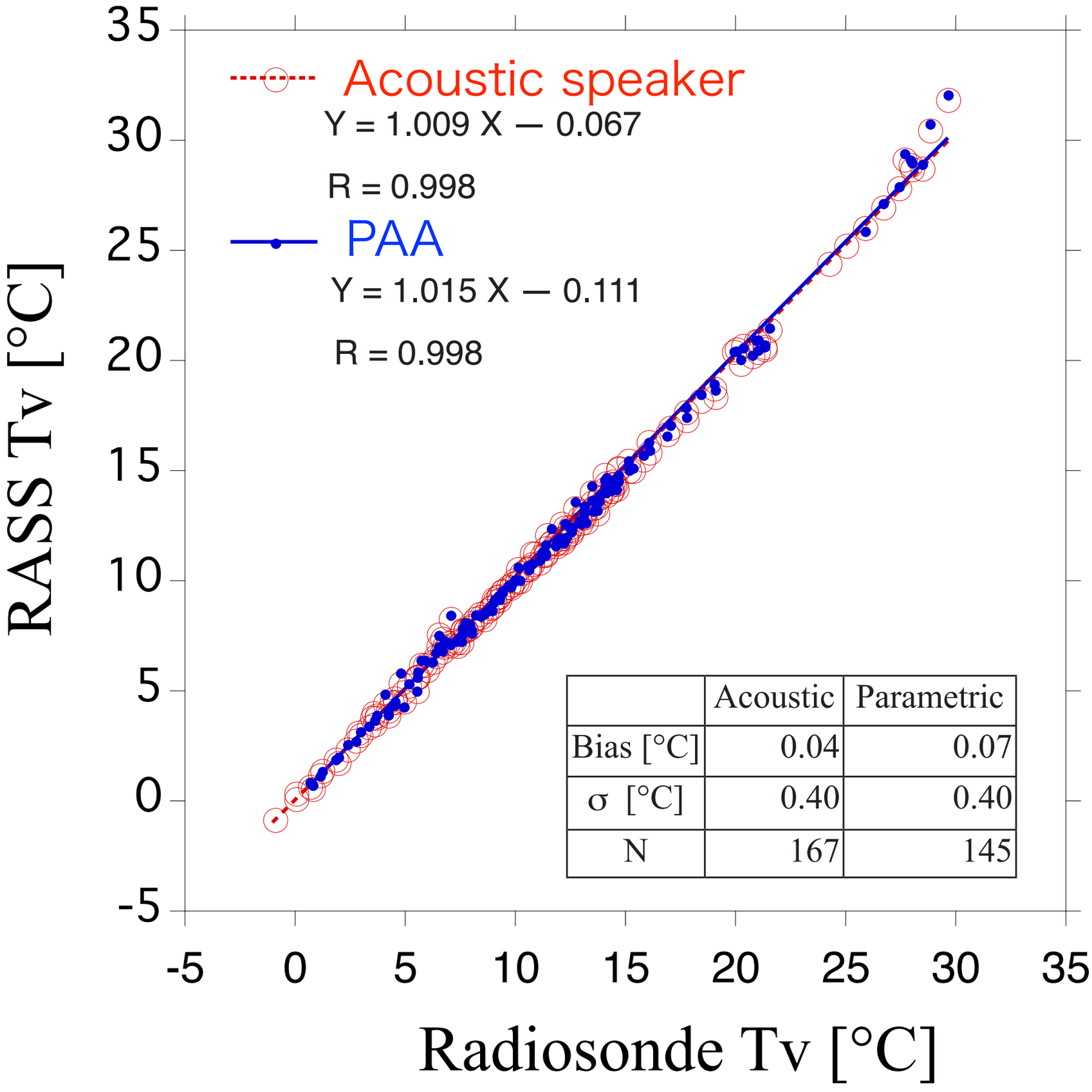
08:00AM-09:00 AM (60 min.)

Radio sonde launch: 08:30 AM (locates 400m from RASS)

Acoustic-RASS and PAA-RASS were switched every minute.

Time resolution: 2 min for each speaker system
Range resolution : 100 m (665ns)

Period：2016-2018 （23 days：hourly mean）



	Acoustic	Parametric
Bias [°C]	0.04	0.07
σ [°C]	0.40	0.40
N	167	145

Period：2016-2018 （23 days：1 min mean）

Y = 0.999 X + 0.095

R = 0.996

(a)

Bias [°C]	0.08
σ [°C]	0.43
N	2768

PAA Tv[°C]

Acoustic Speaker Tv [°C]

Probability[%]

Period：2016-2018 （23 days：1 min mean）

Y = 0.999 X + 0.095

R = 0.996

(a)

Bias [°C]	0.08
σ [°C]	0.43
N	2768

PAA Tv[°C]

Acoustic Speaker Tv [°C]

Probability[%]

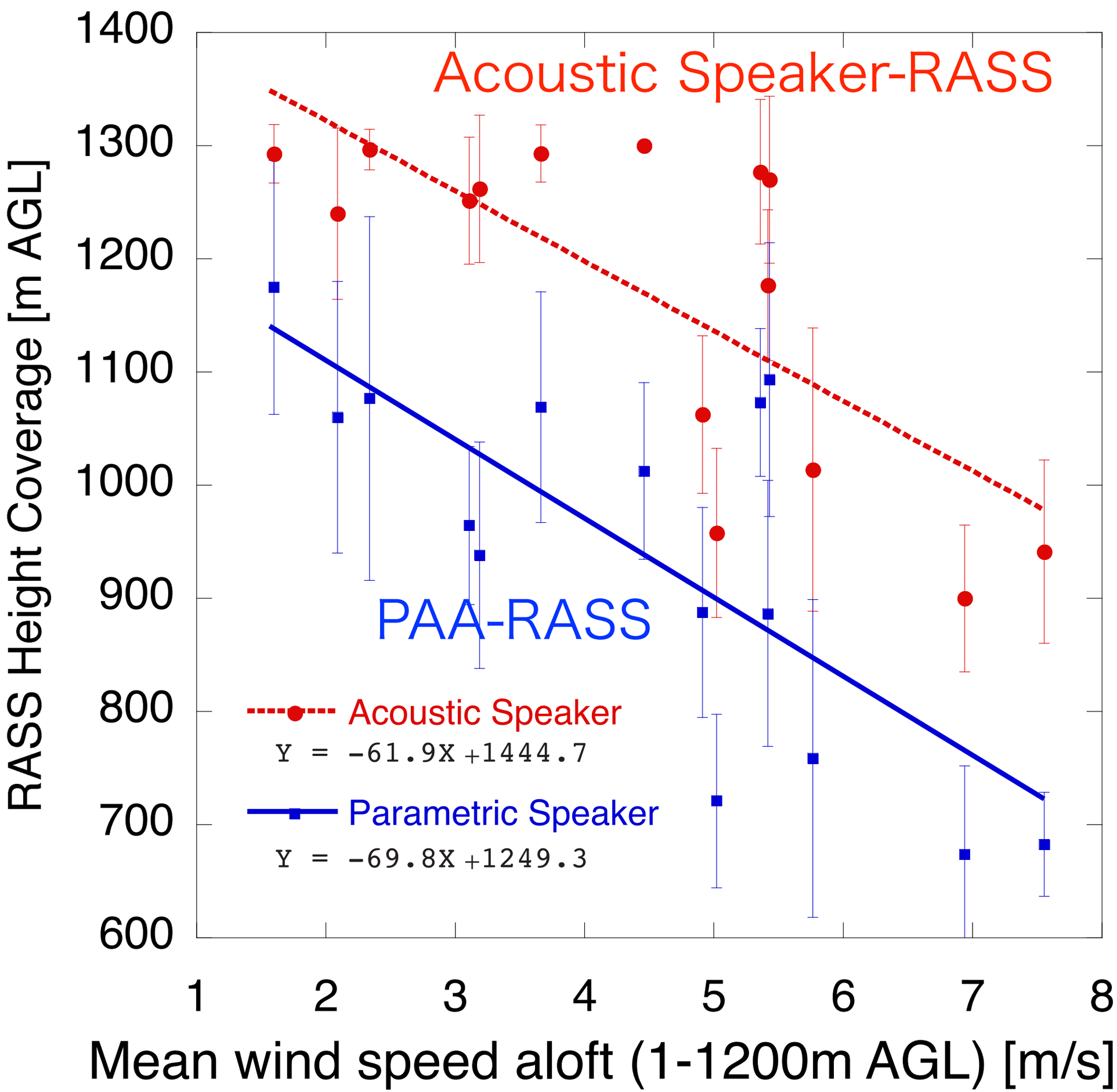
Conclusions（#1）

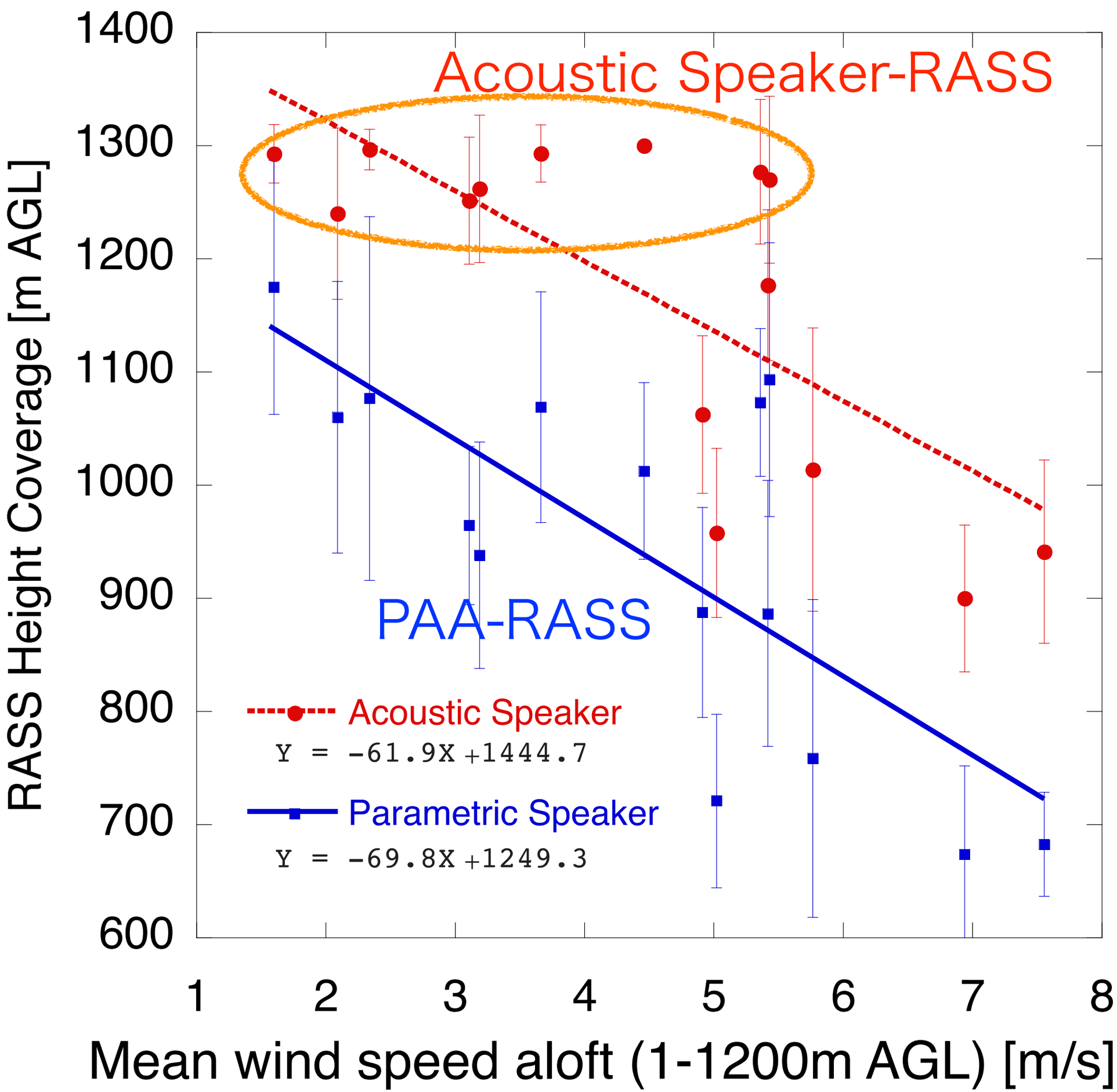
Parametric Acoustic Array is available for the RASS measurements.

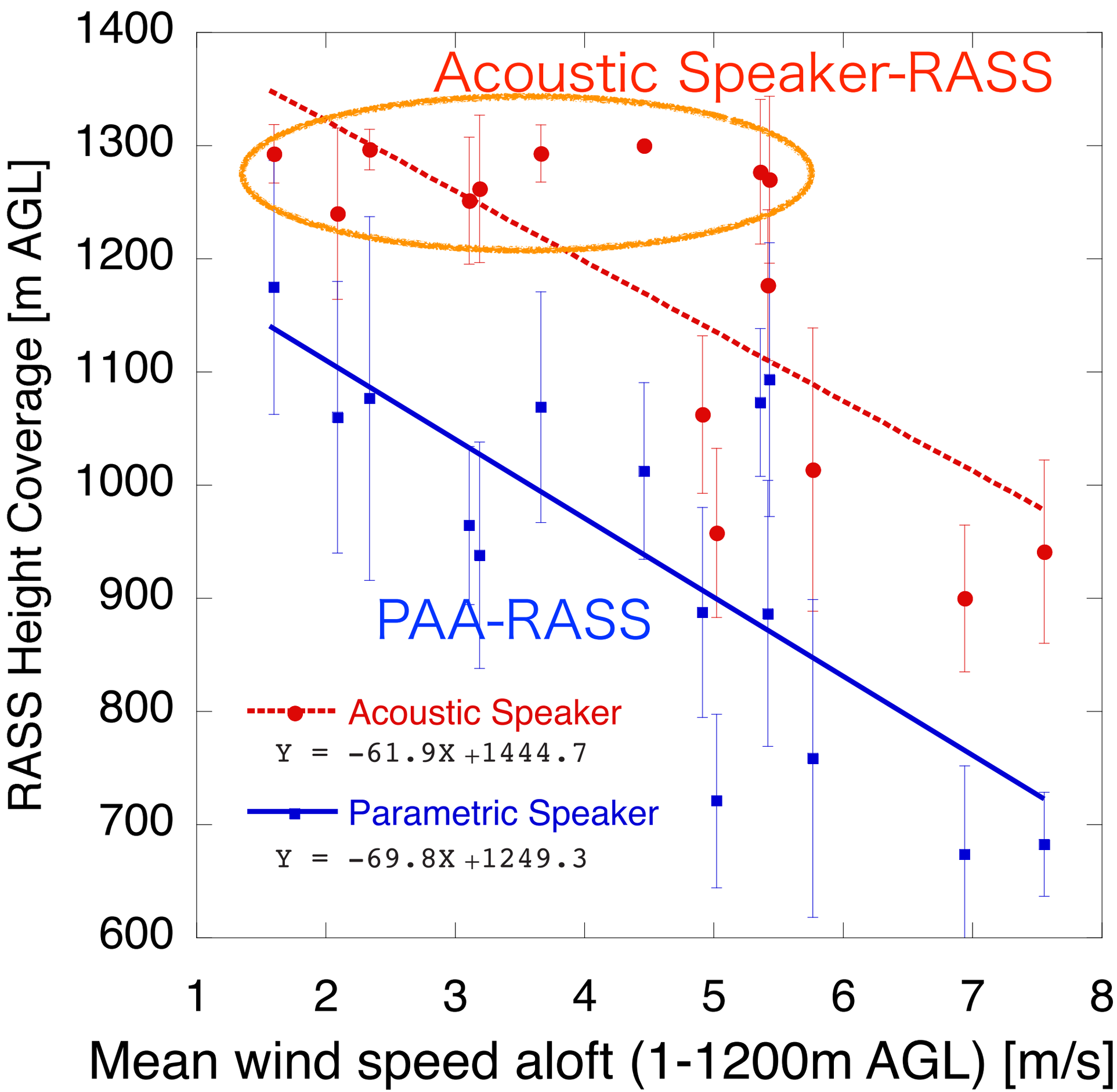
PAA has extremely low sidelobes and could be installed to wind profilers located in urban areas.

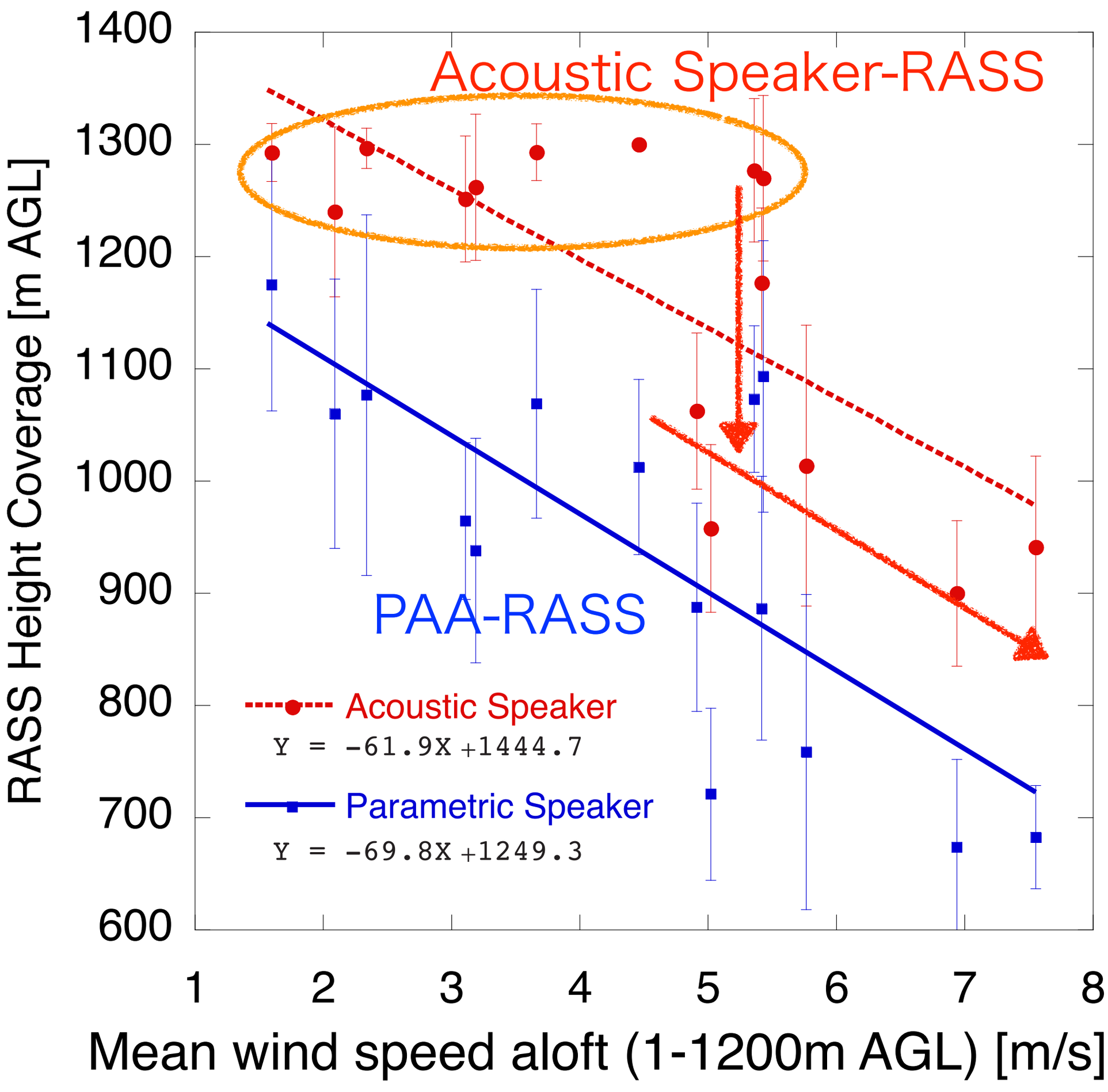
PAA-RASS has accuracy and precision comparable with acoustic speaker RASS.

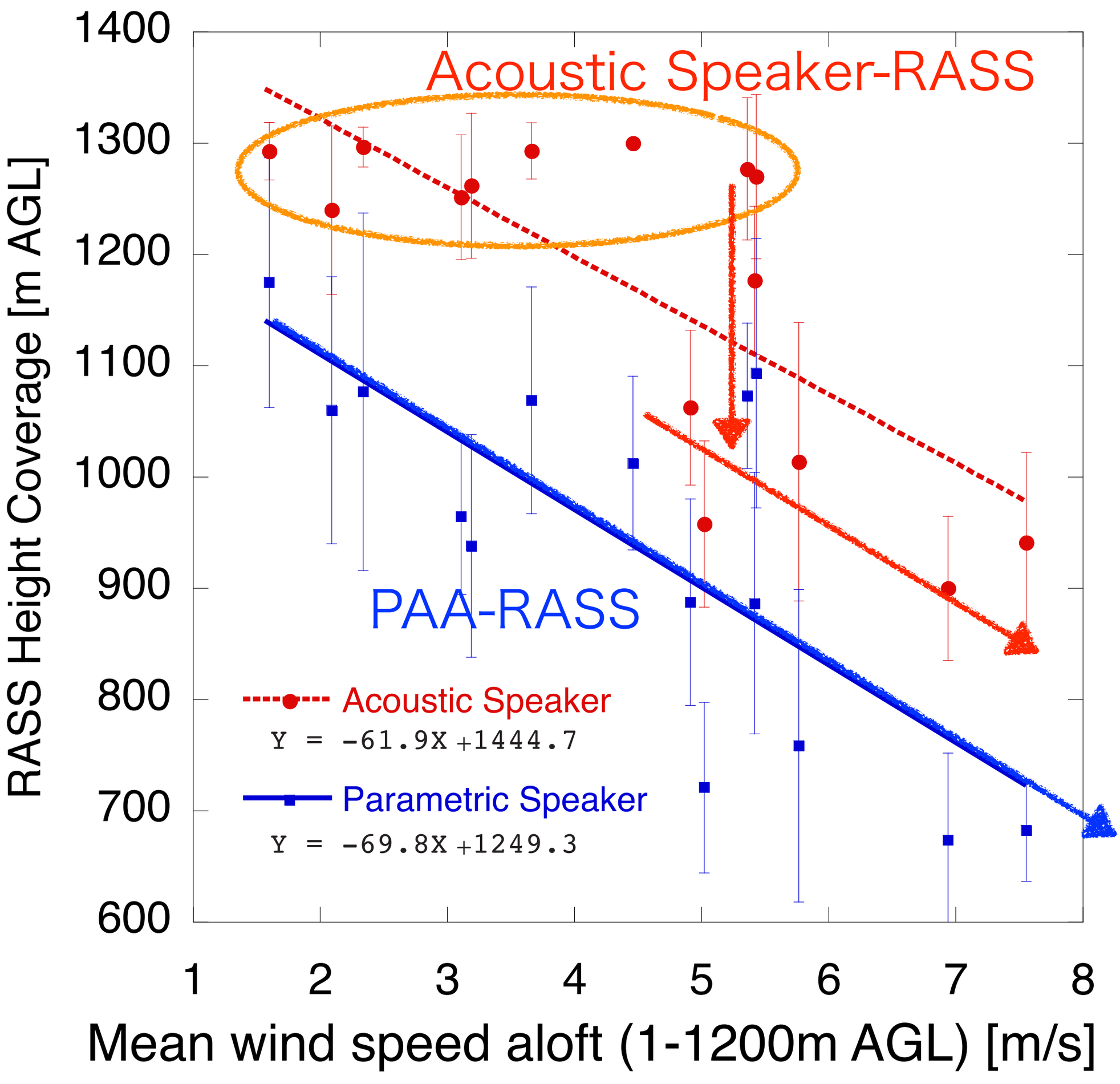
PAA-RASS is susceptible to horizontal winds due to the narrower acoustic beam.


Acoustic Speaker-RASS
PAA-RASS
Acoustic Speaker
Y = -61.9X +1444.7
Parametric Speaker
Y = -69.8X +1249.3
RASS Height Coverage [m AGL]
1400
1300
1200
1100
1000
900
800
700
600
1
2
3
4
5
6
7
8
Mean wind speed aloft (1-1200m AGL) [m/s]

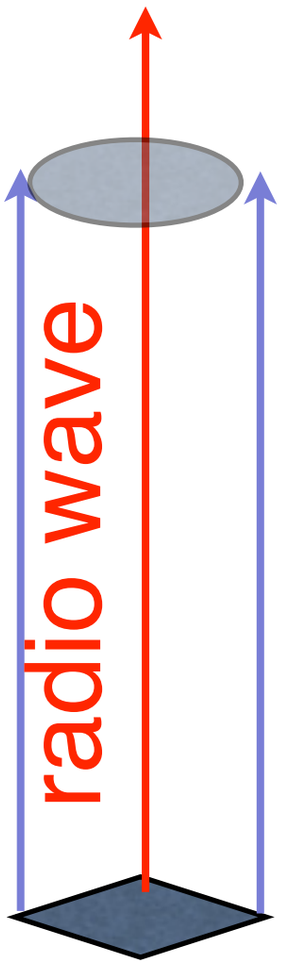

Acoustic Speaker-RASS
PAA-RASS
Acoustic Speaker
Y = -61.9X +1444.7
Parametric Speaker
Y = -69.8X +1249.3
RASS Height Coverage [m AGL]
1400
1300
1200
1100
1000
900
800
700
600
1
2
3
4
5
6
7
8
Mean wind speed aloft (1-1200m AGL) [m/s]


Acoustic Speaker-RASS
PAA-RASS
Acoustic Speaker
Y = -61.9X +1444.7
Parametric Speaker
Y = -69.8X +1249.3
RASS Height Coverage [m AGL]
1400
1300
1200
1100
1000
900
800
700
600
1
2
3
4
5
6
7
8
Mean wind speed aloft (1-1200m AGL) [m/s]

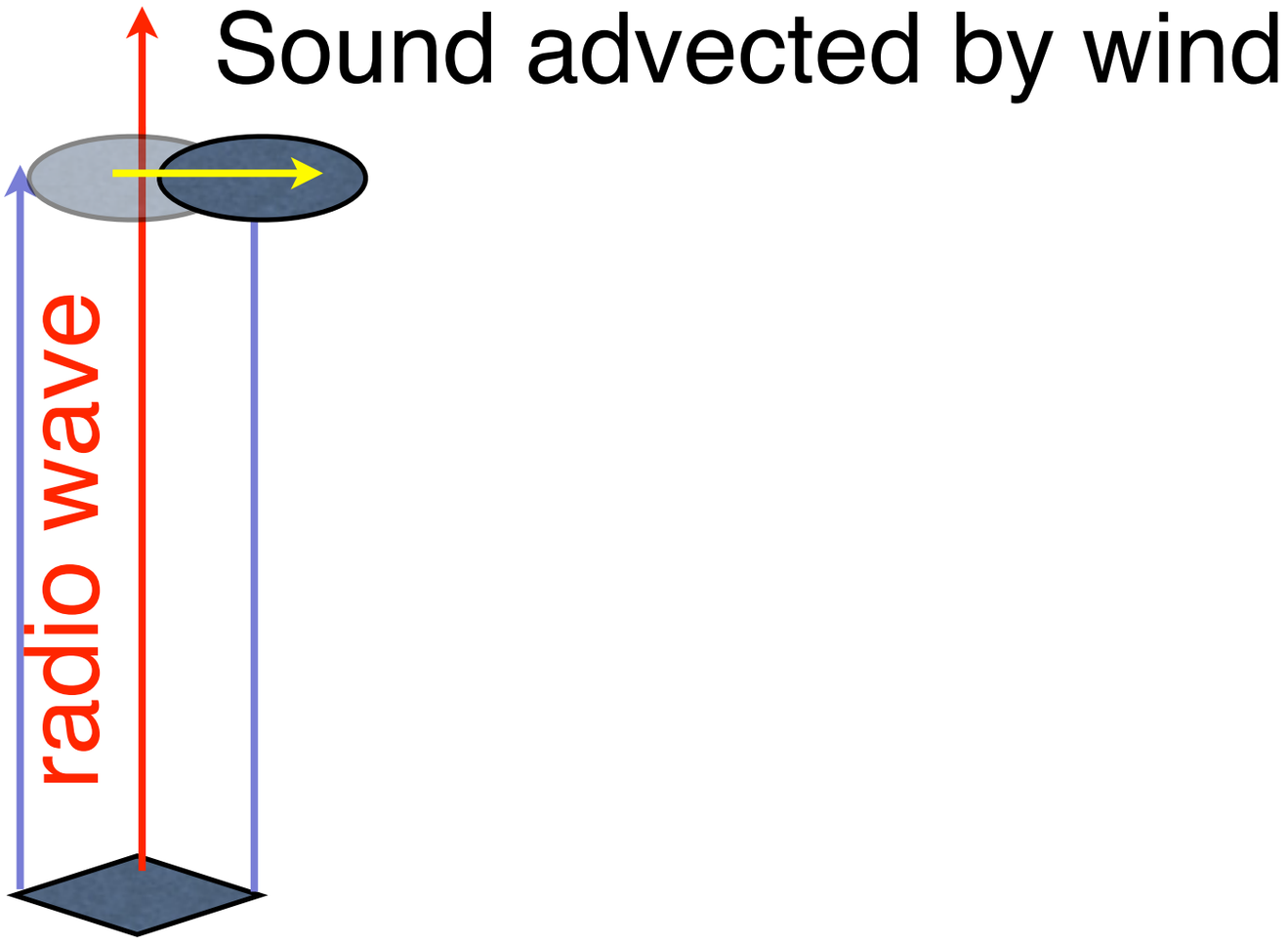

Acoustic Speaker-RASS
PAA-RASS
Acoustic Speaker
Y = -61.9X +1444.7
Parametric Speaker
Y = -69.8X +1249.3
RASS Height Coverage [m AGL]
1400
1300
1200
1100
1000
900
800
700
600
1
2
3
4
5
6
7
8
Mean wind speed aloft (1-1200m AGL) [m/s]


Acoustic Speaker-RASS
PAA-RASS
Acoustic Speaker
Y = -61.9X +1444.7
Parametric Speaker
Y = -69.8X +1249.3
RASS Height Coverage [m AGL]
1400
1300
1200
1100
1000
900
800
700
600
1
2
3
4
5
6
7
8
Mean wind speed aloft (1-1200m AGL) [m/s]

Effect of wind and countermeasures

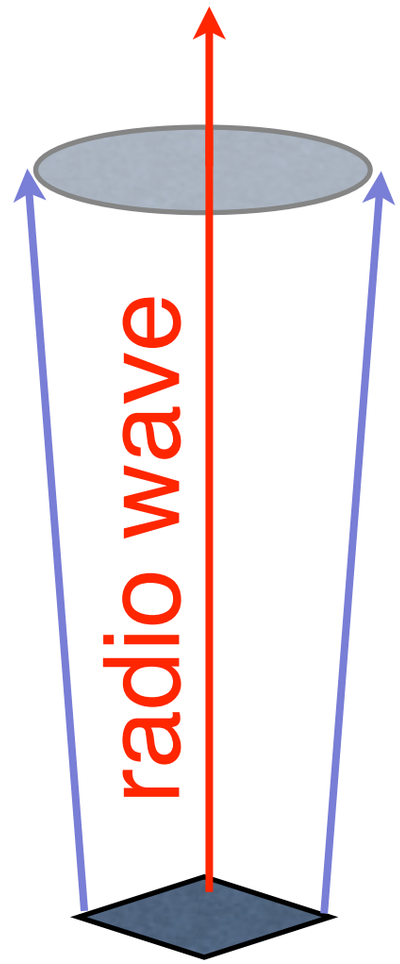


Effect of wind and countermeasures

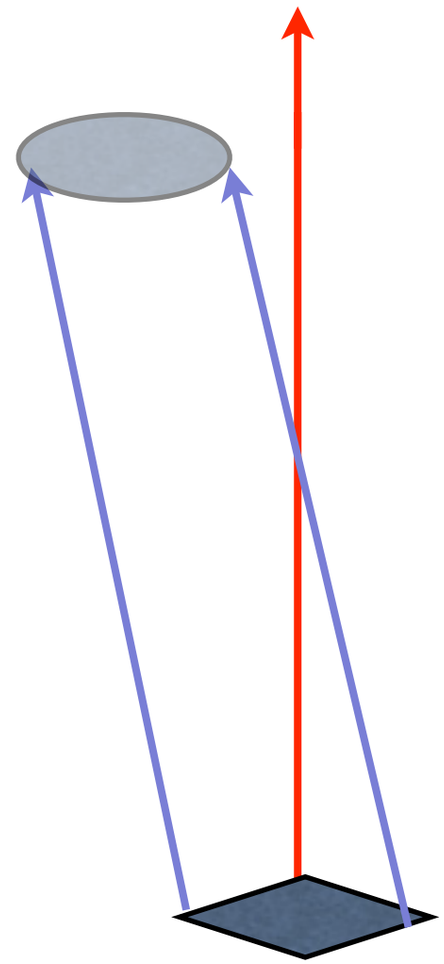


Effect of wind and countermeasures

(1) beam broadening

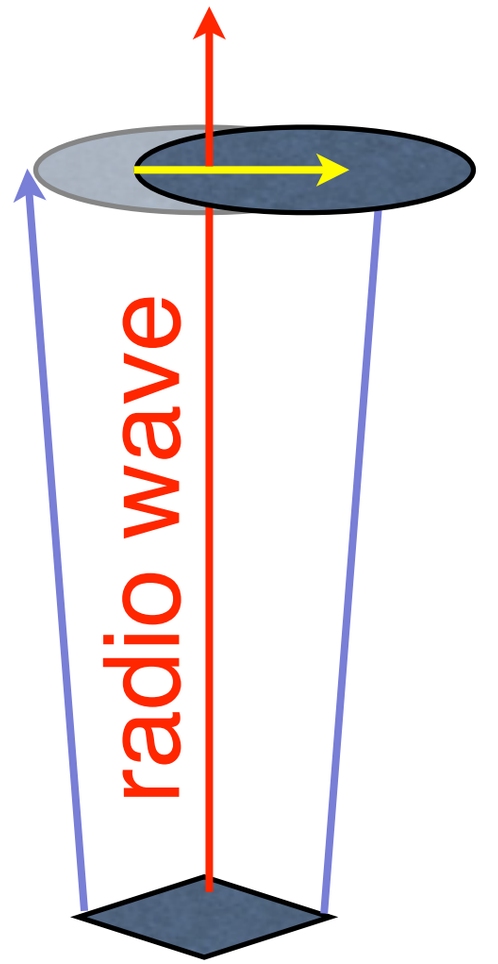


(2)beam steering

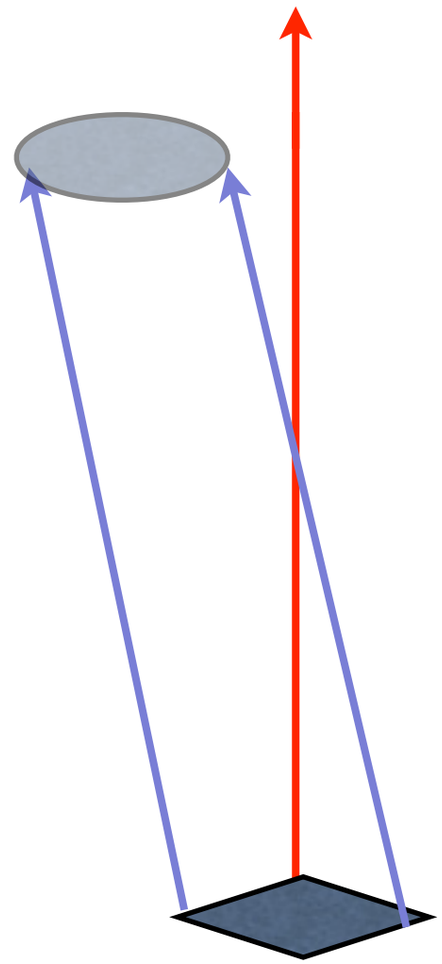


Effect of wind and countermeasures

(1) beam broadening

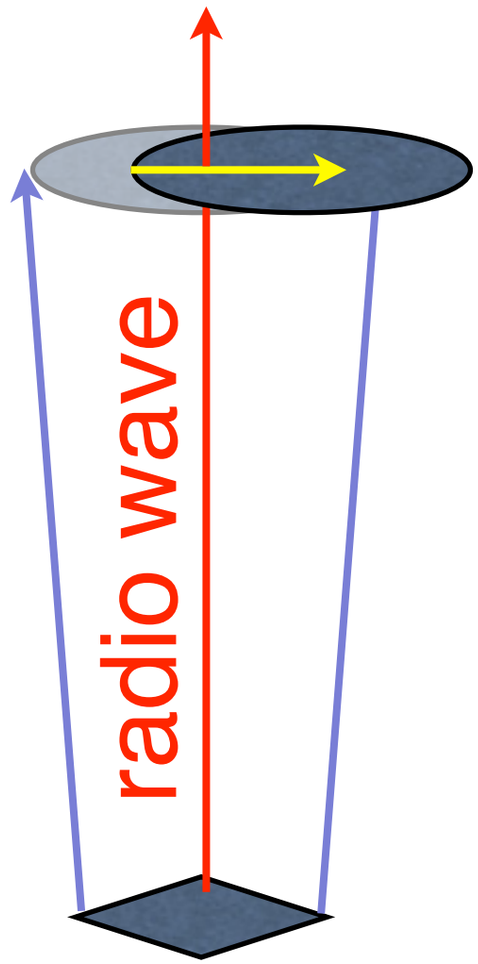


(2)beam steering

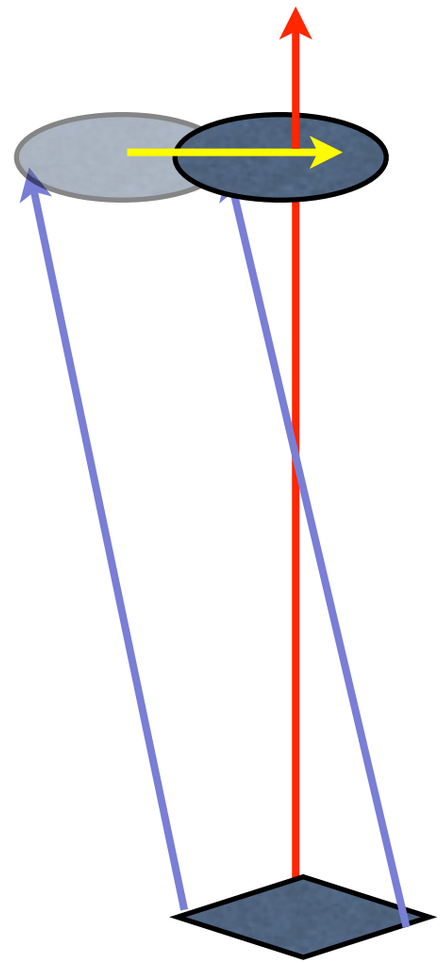


Effect of wind and countermeasures

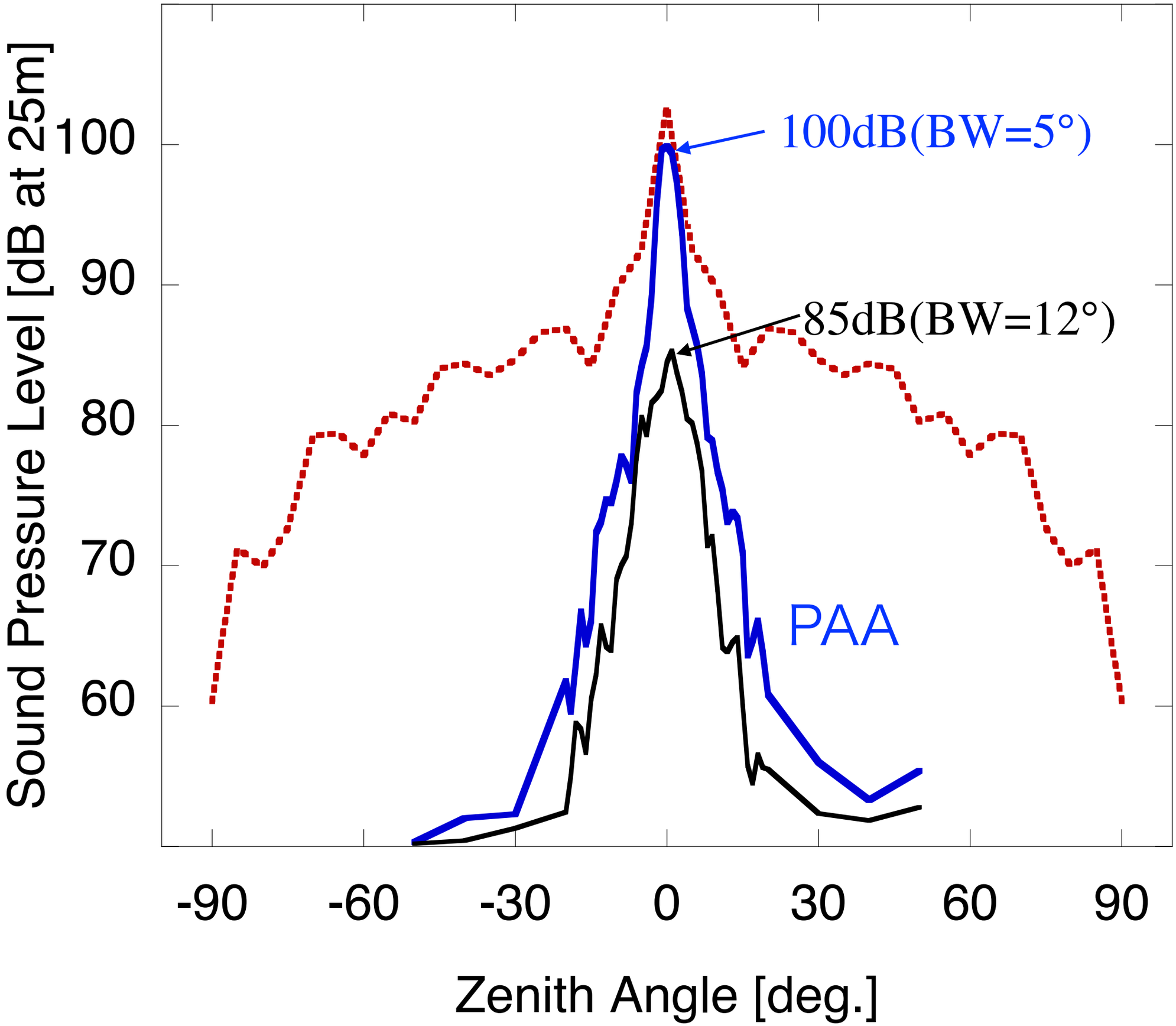
(1) beam broadening



(2)beam steering

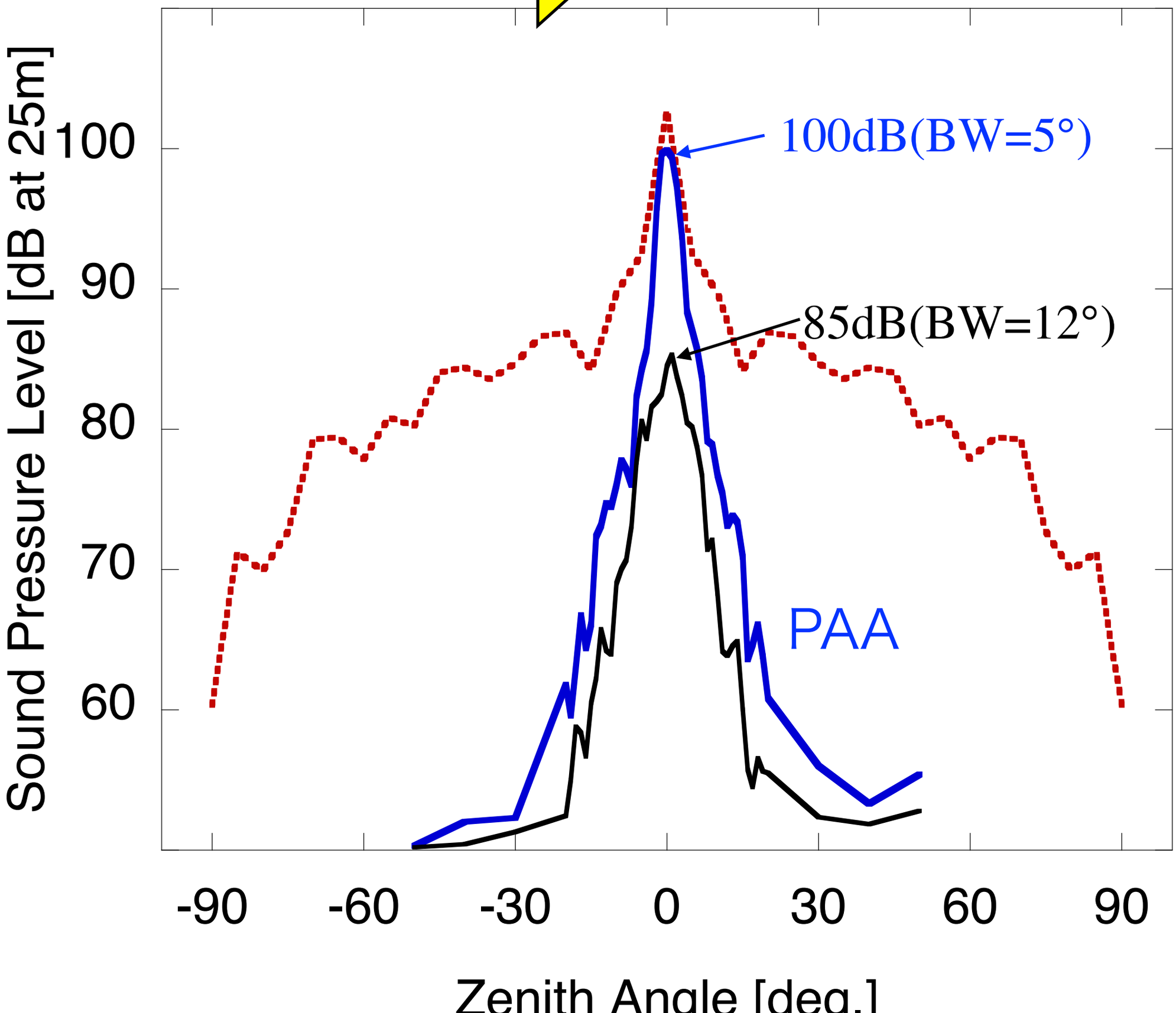


(1) beam broadening



(1) beam broadening

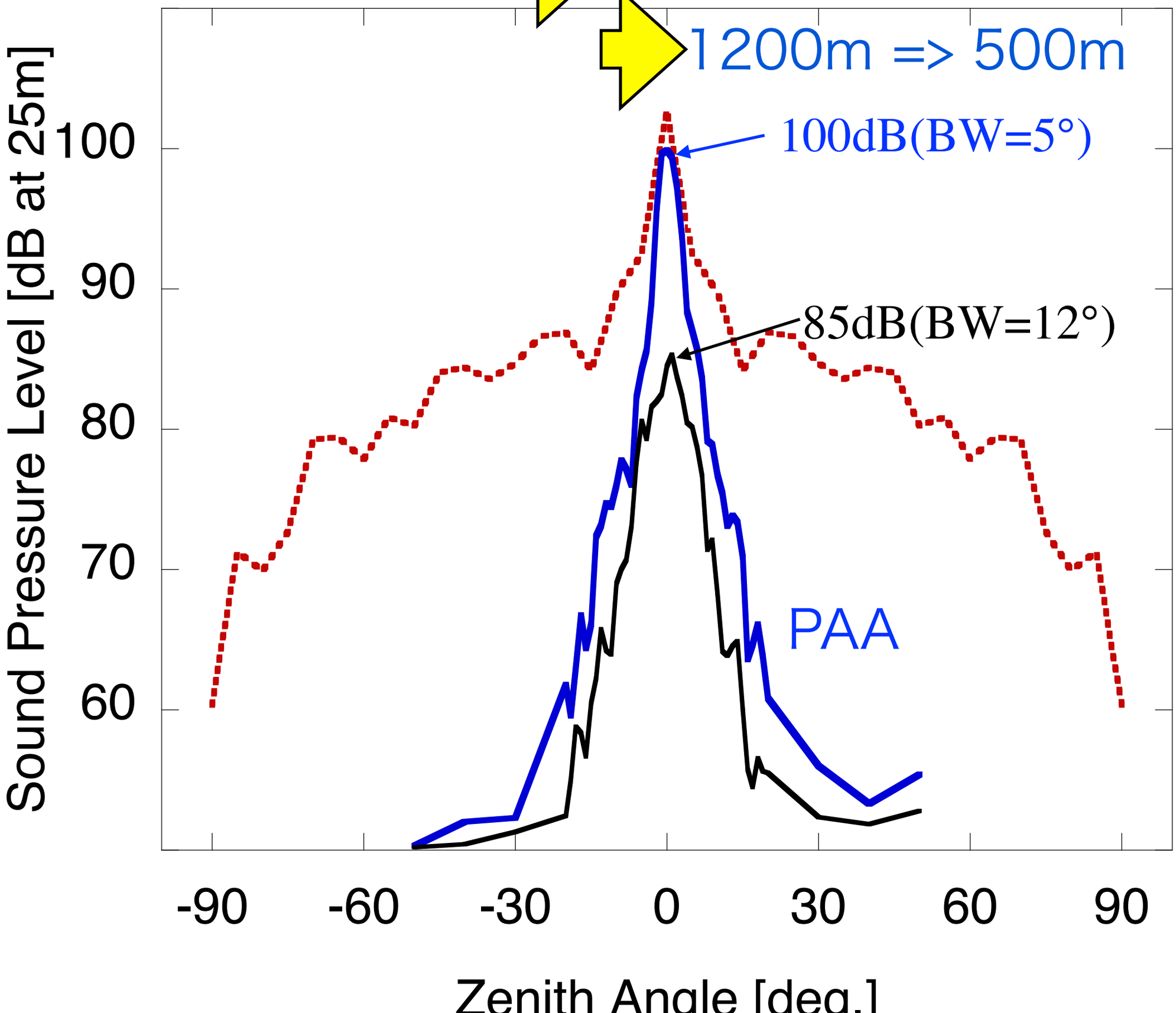
BW: 5° => 12°



(1) beam broadening

BW: 5° => 12°

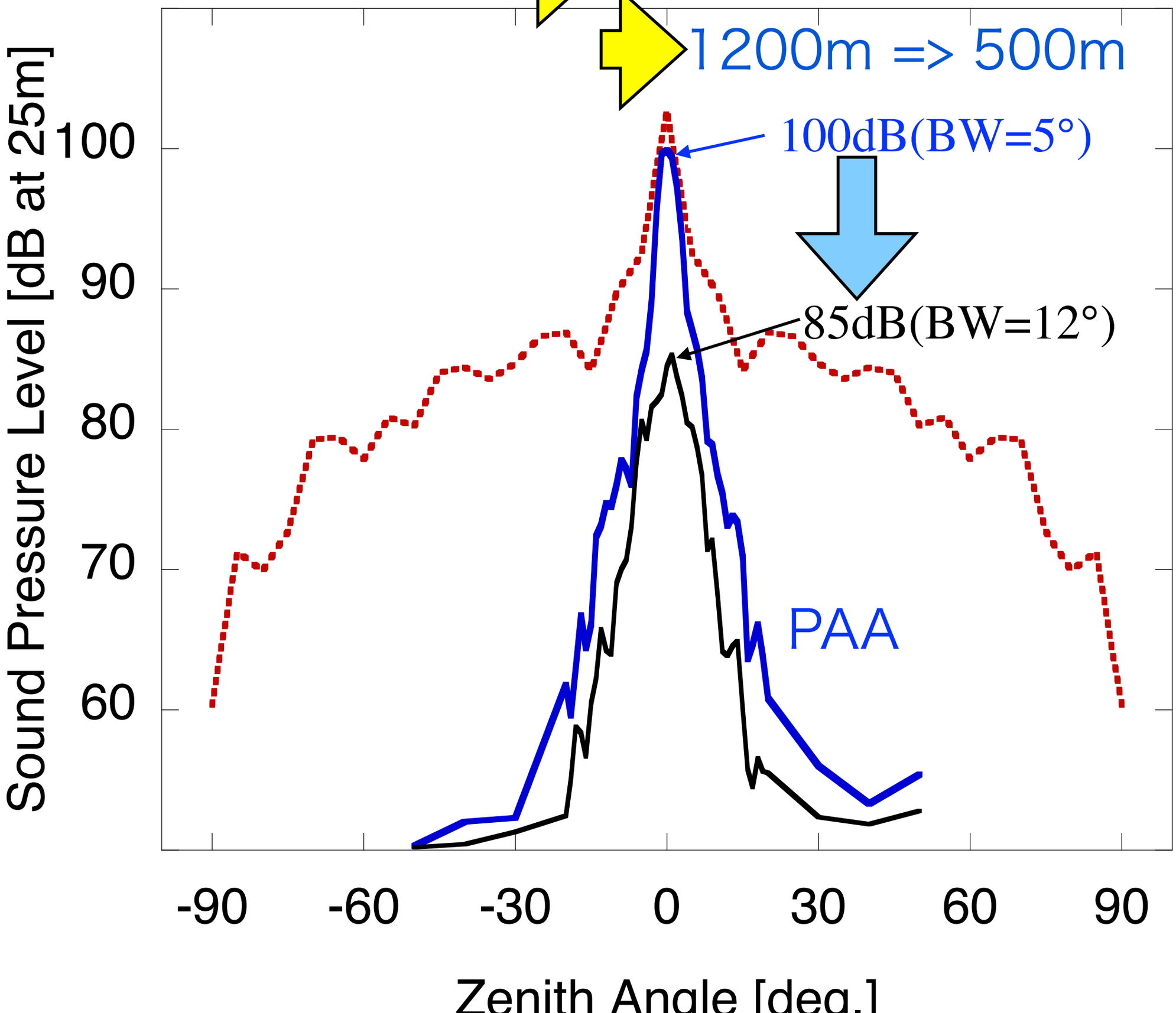
1200m => 500m



(1) beam broadening

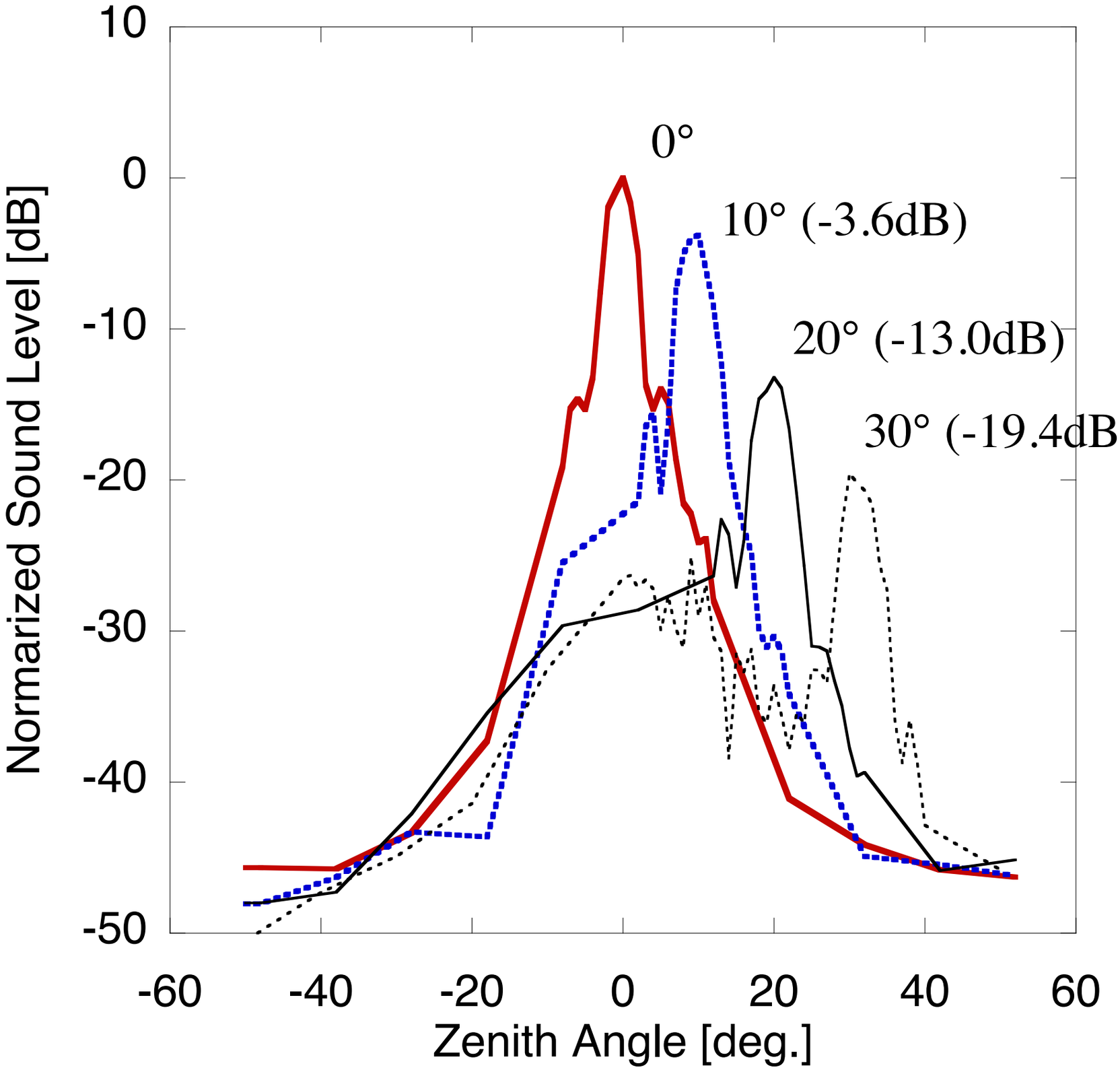
BW: 5° => 12°

1200m => 500m



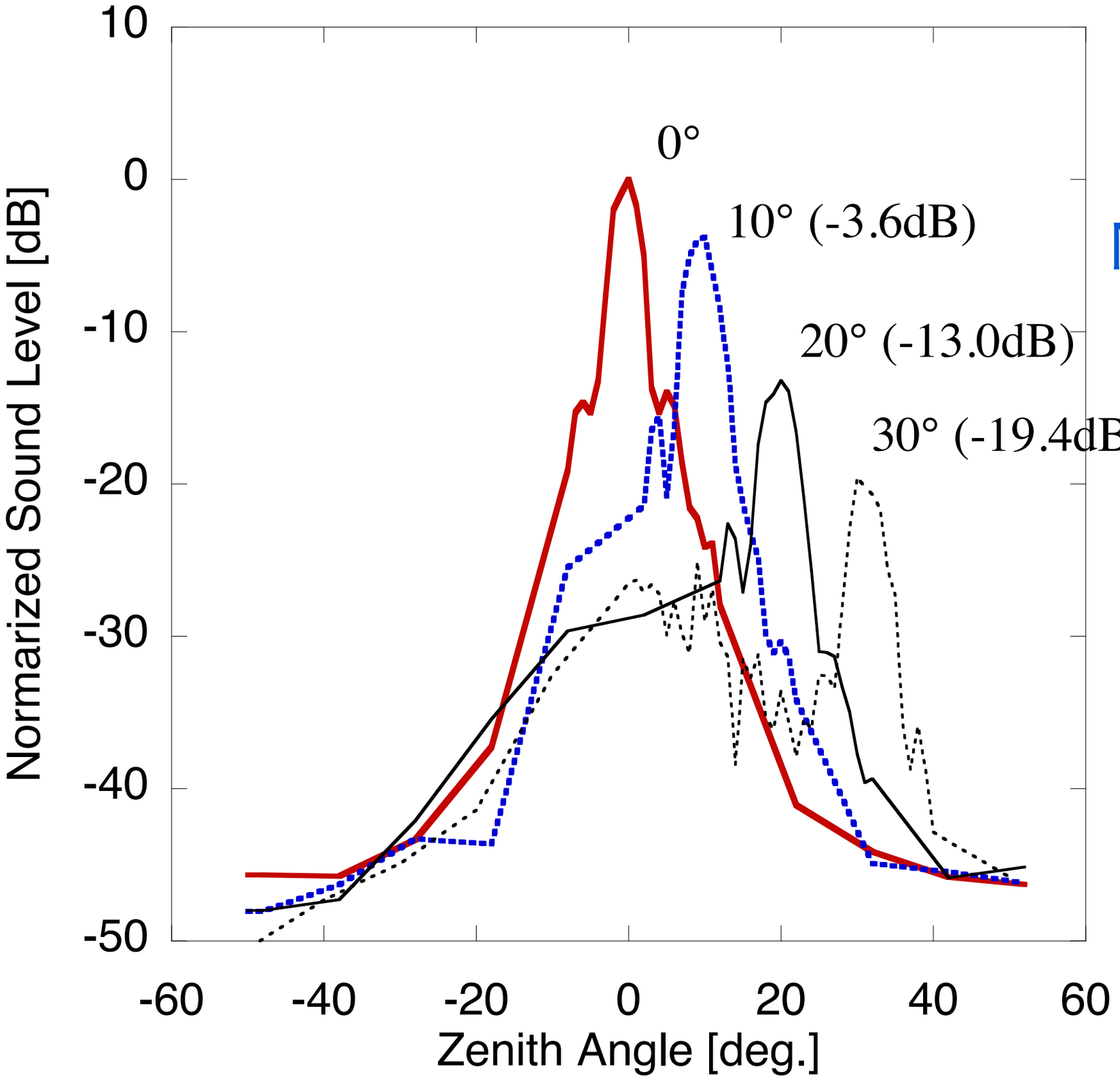
(2)beam steering

Steered 2° windward for wind speed of 12 m/s



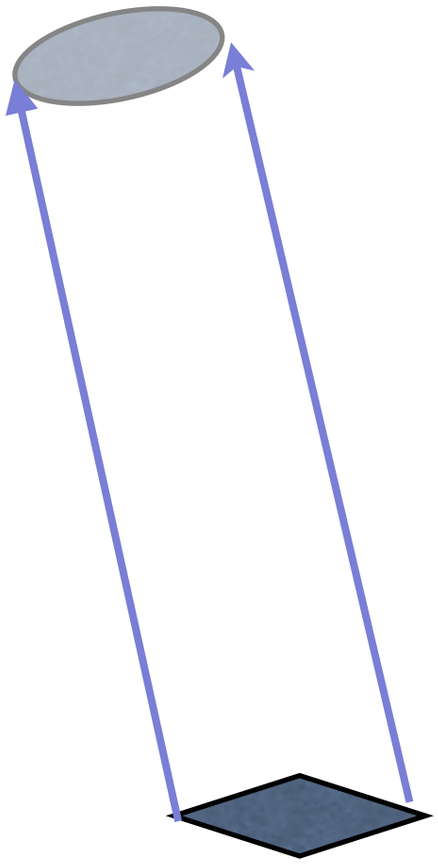
(2)beam steering

Steered 2° windward for wind speed of 12 m/s



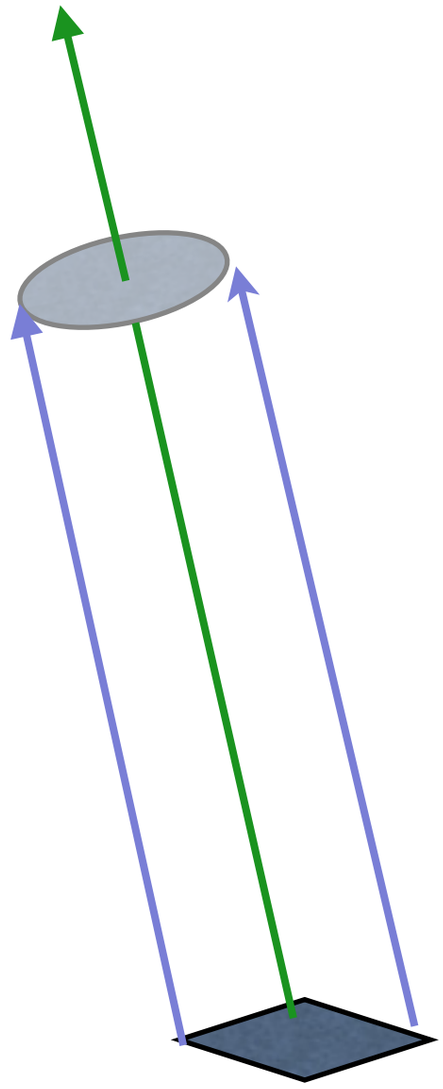
No RASS echo was observed

beam steering



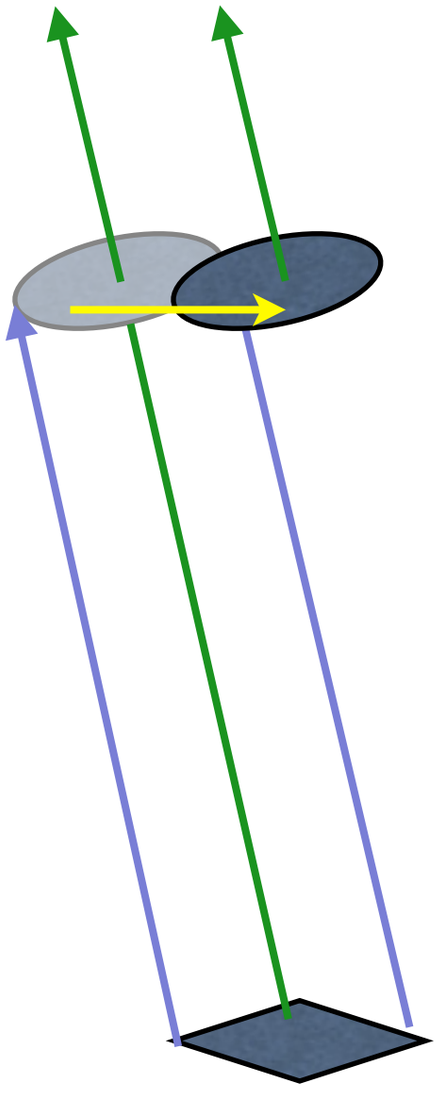
Effect of wind and countermeasures

beam steering



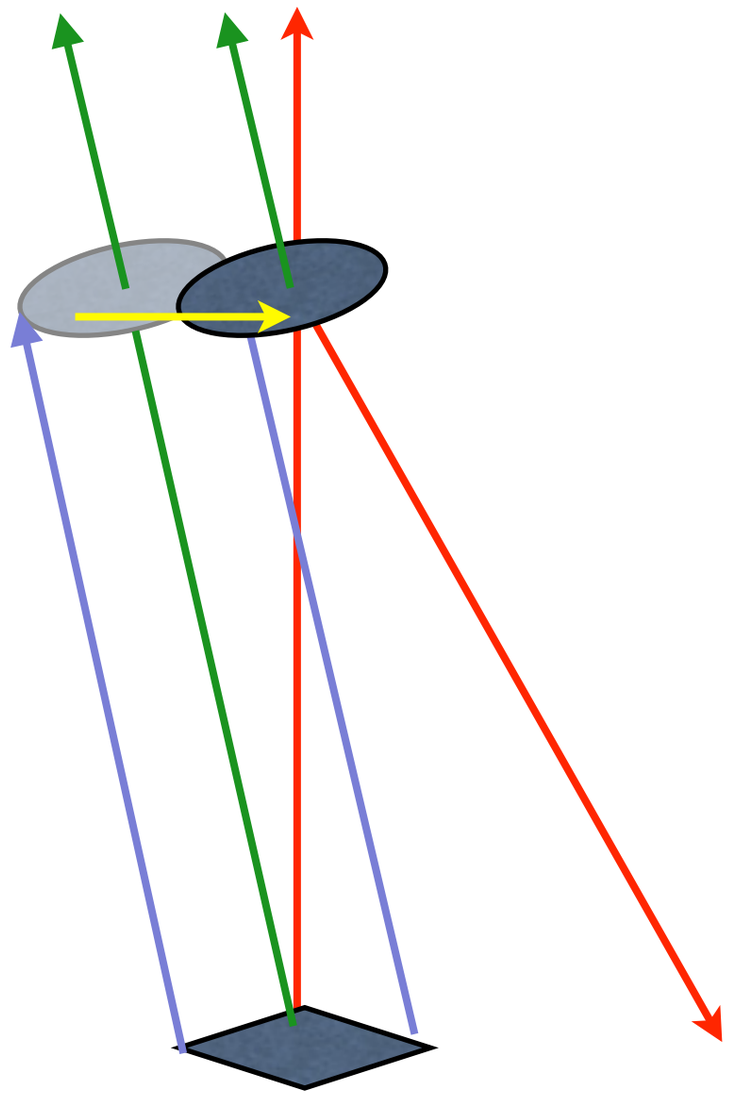
Effect of wind and countermeasures

beam steering

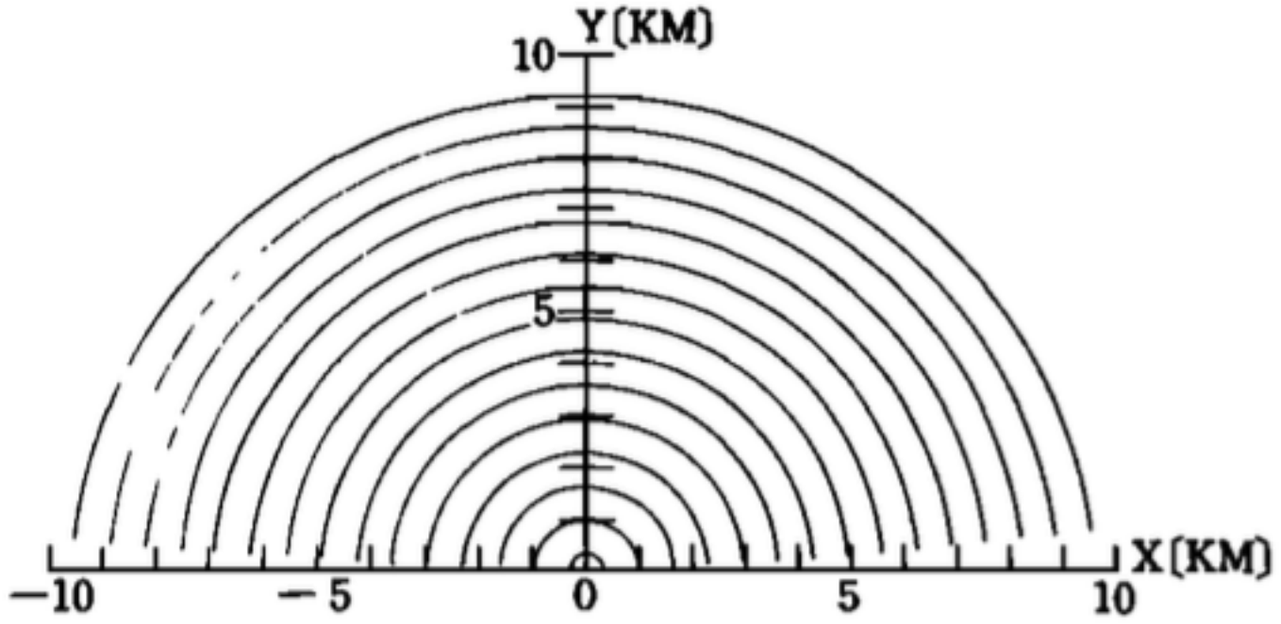


Effect of wind and countermeasures

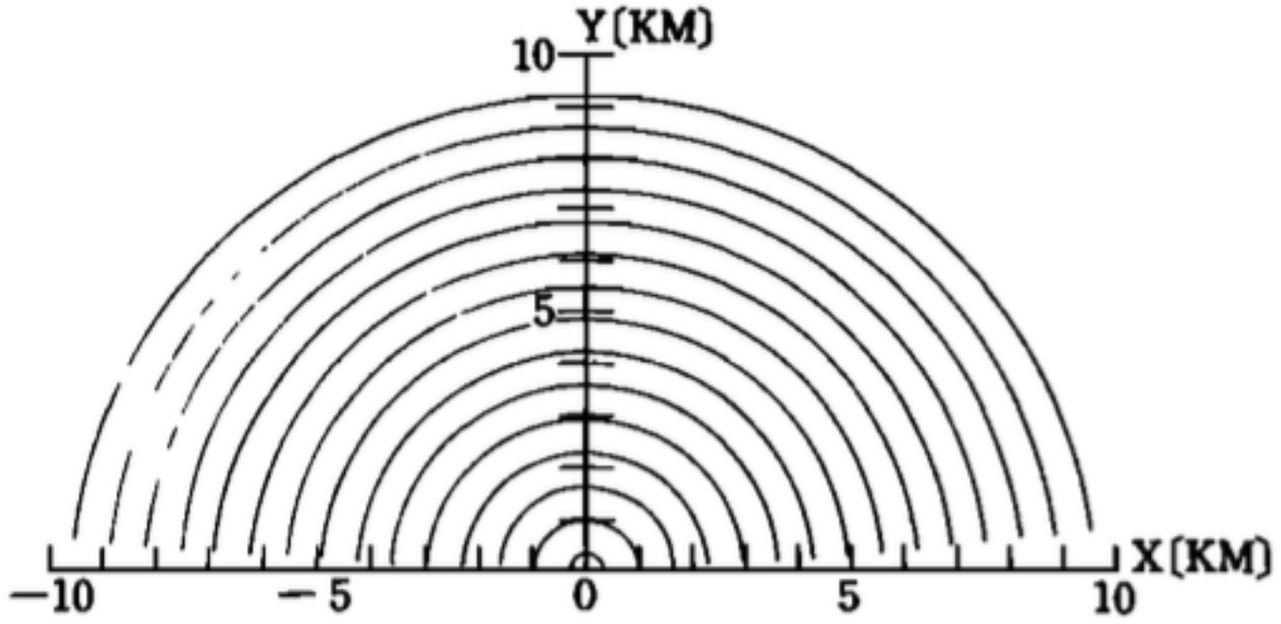
beam steering

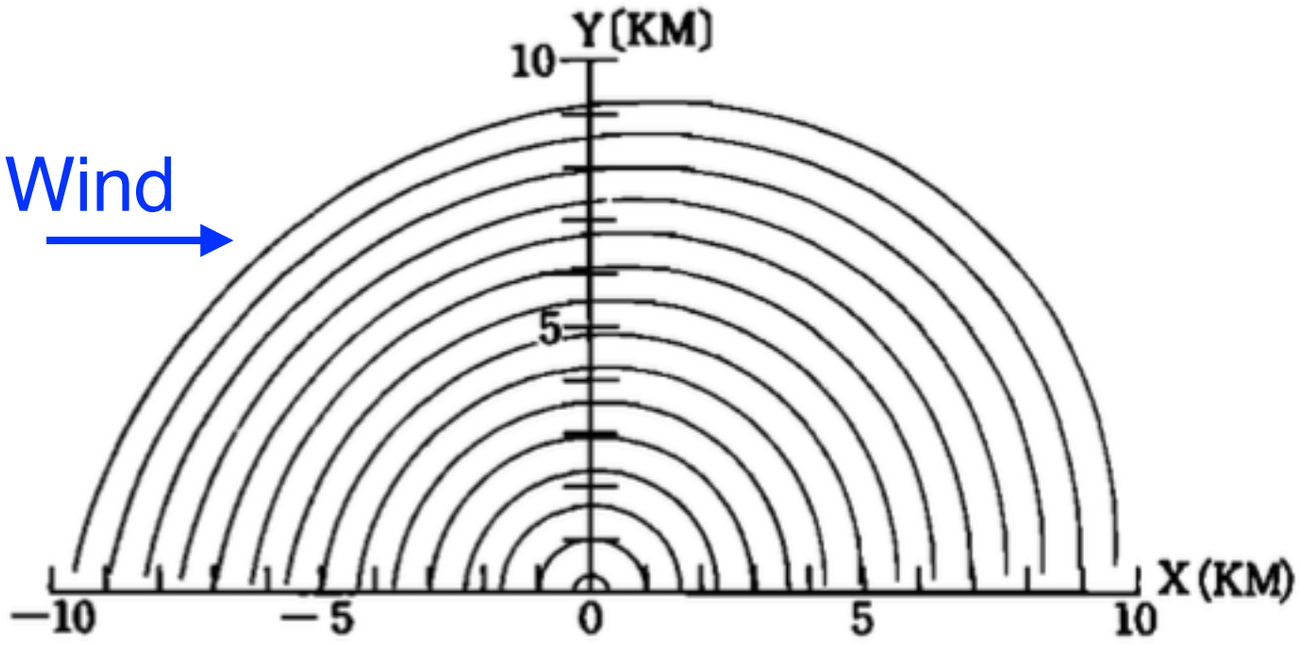


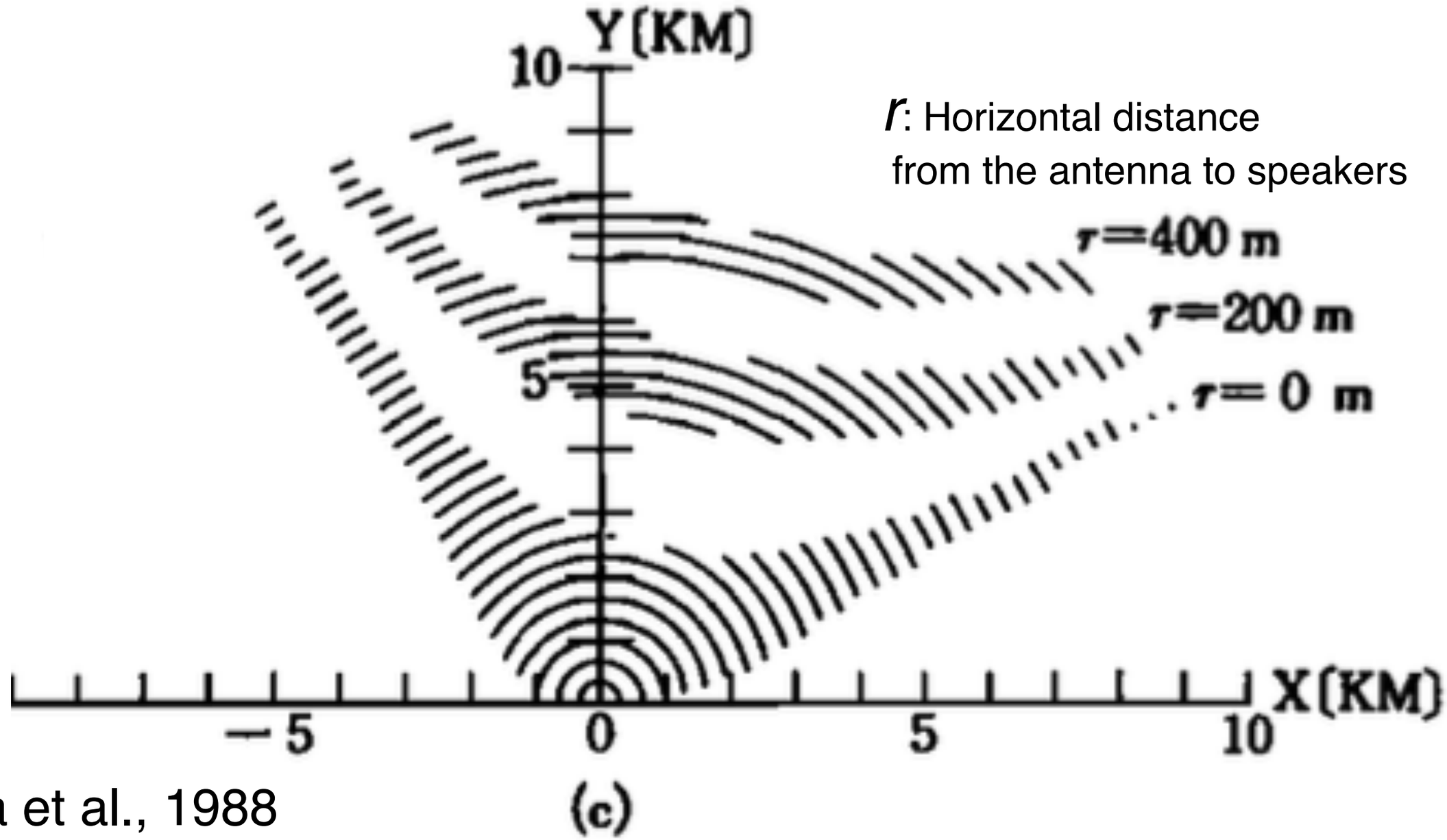
Masuda et al., 1988



Masuda et al., 1988



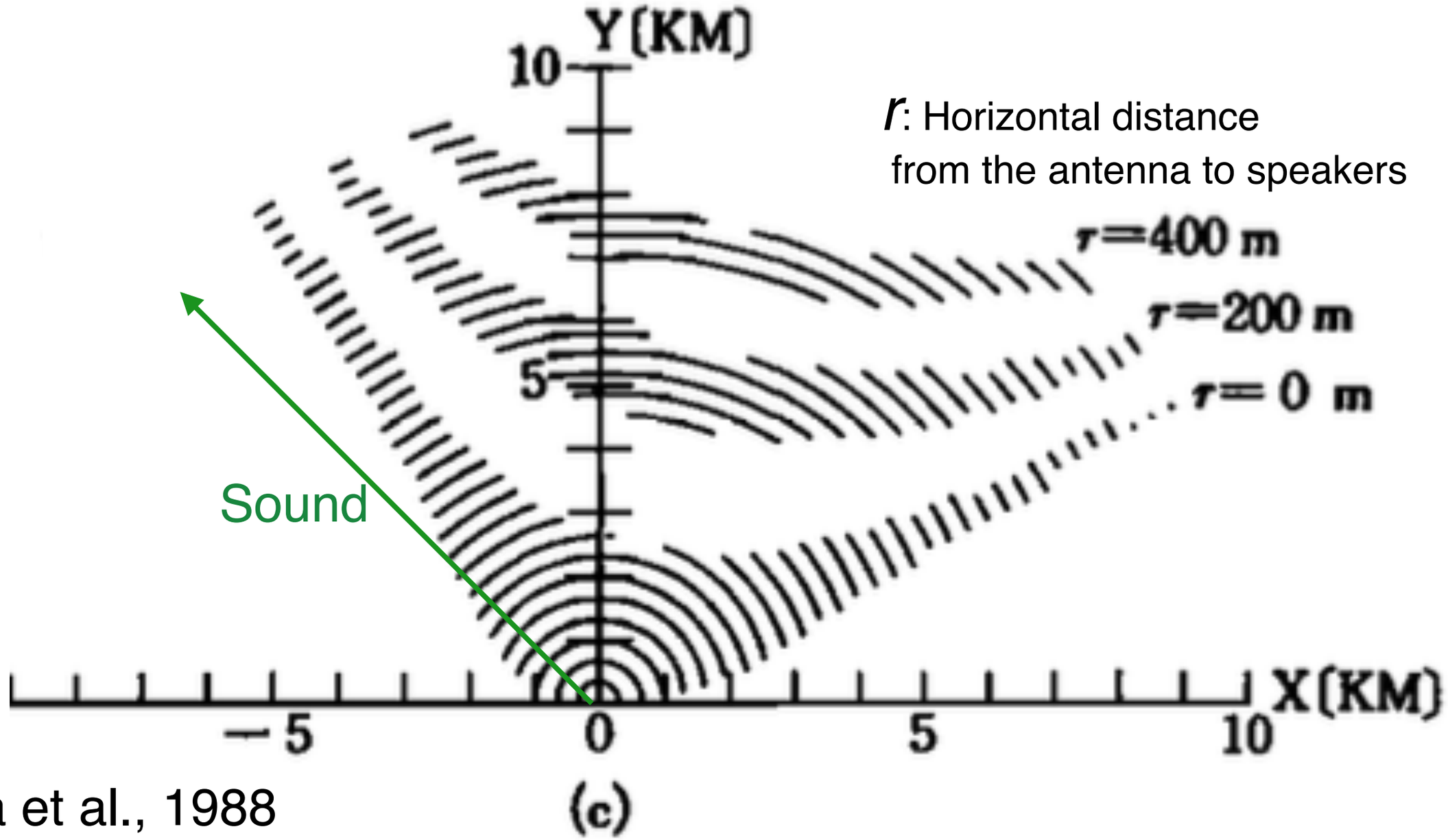




r: Horizontal distance
from the antenna to speakers

(c)

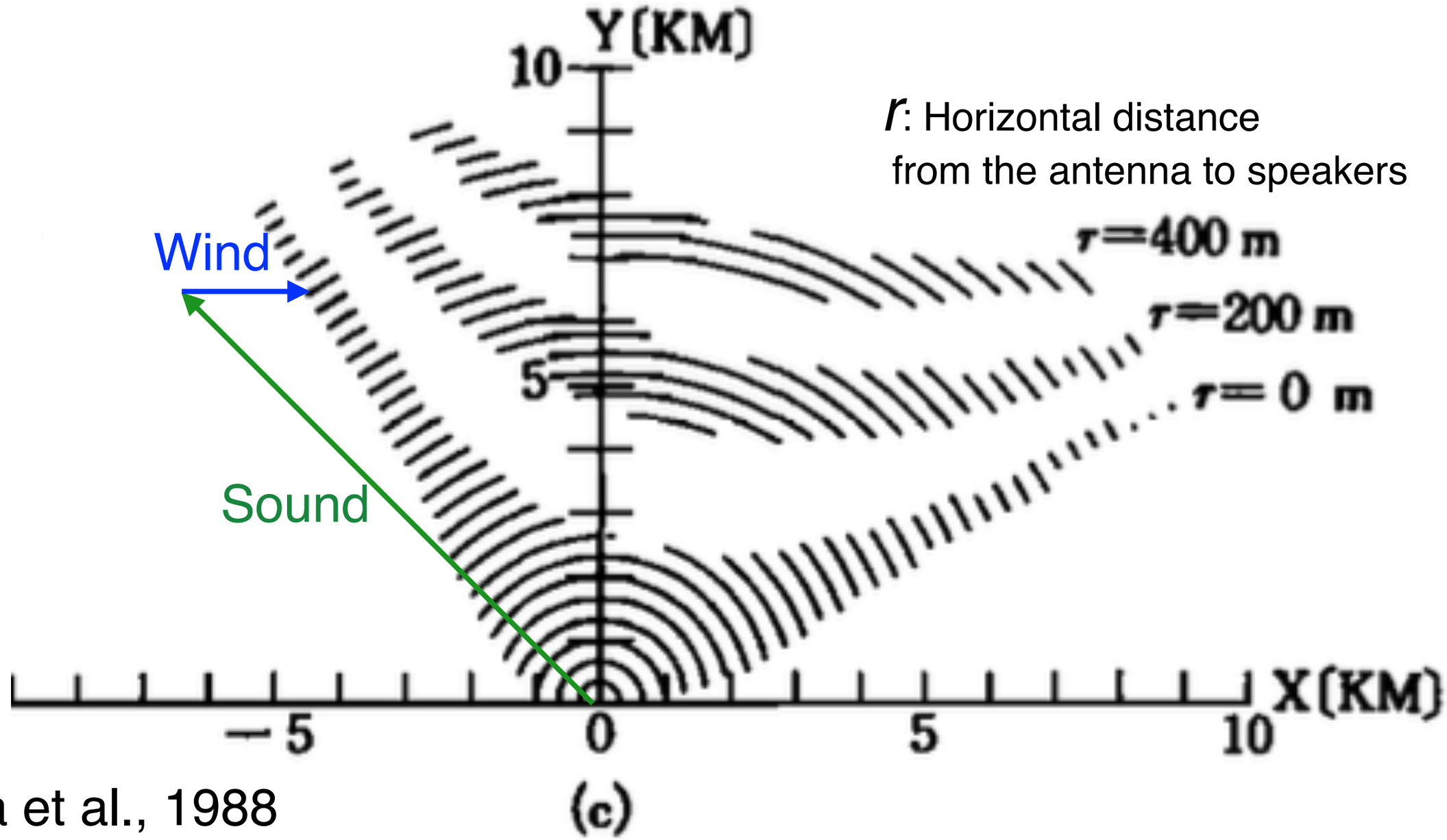
Masuda et al., 1988



r: Horizontal distance
from the antenna to speakers

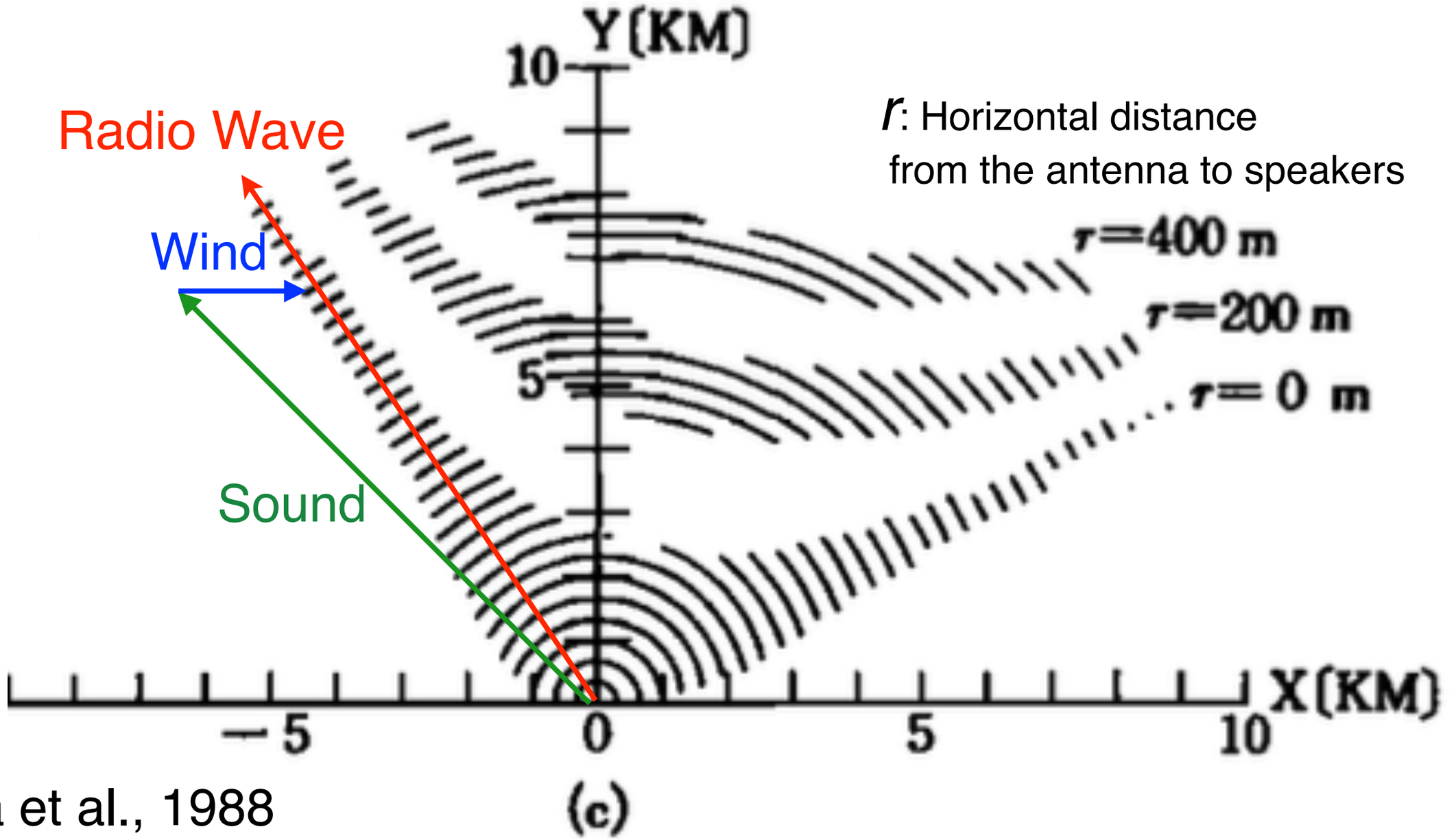
Masuda et al., 1988

(c)



r: Horizontal distance
from the antenna to speakers

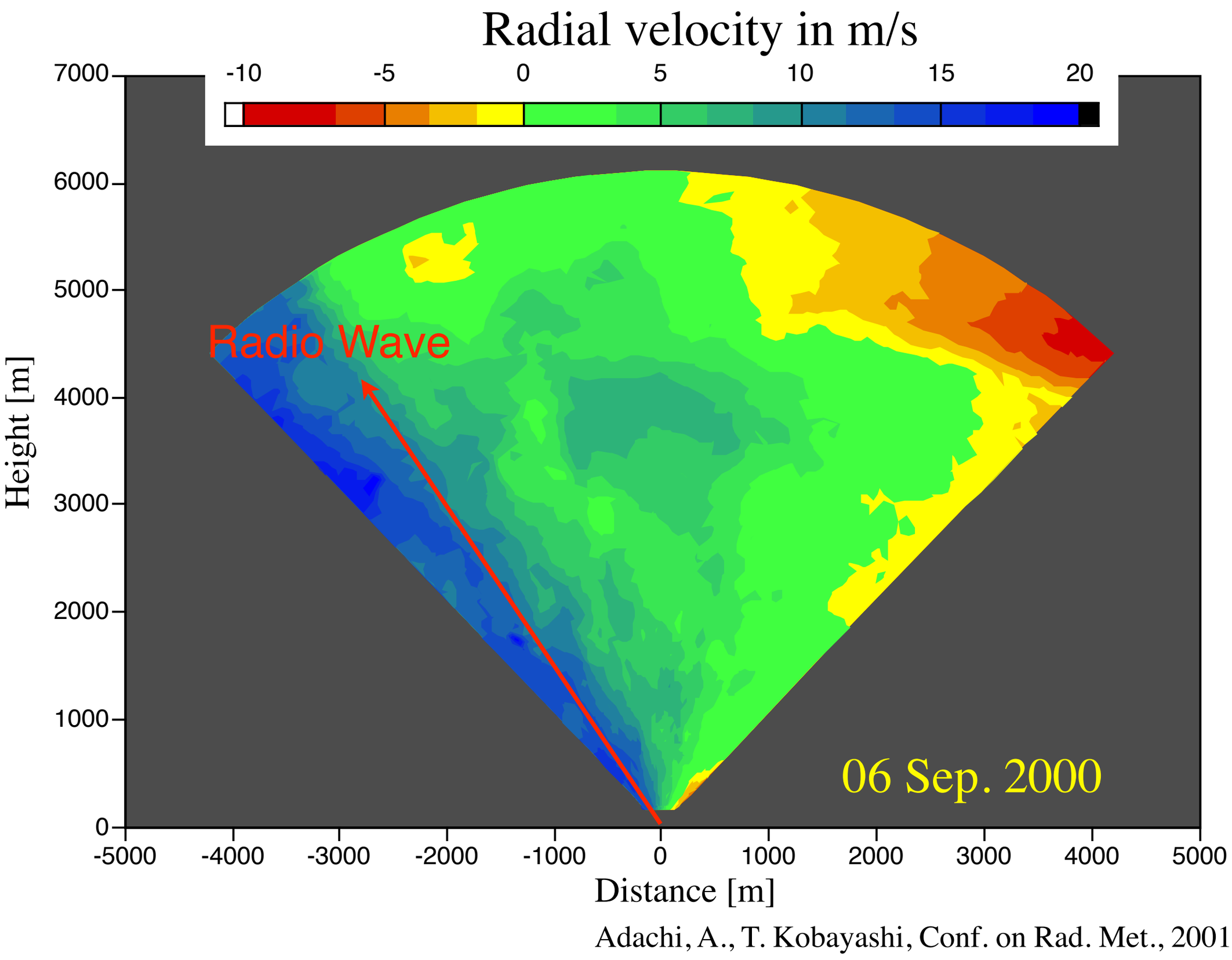
Masuda et al., 1988



r: Horizontal distance
from the antenna to speakers

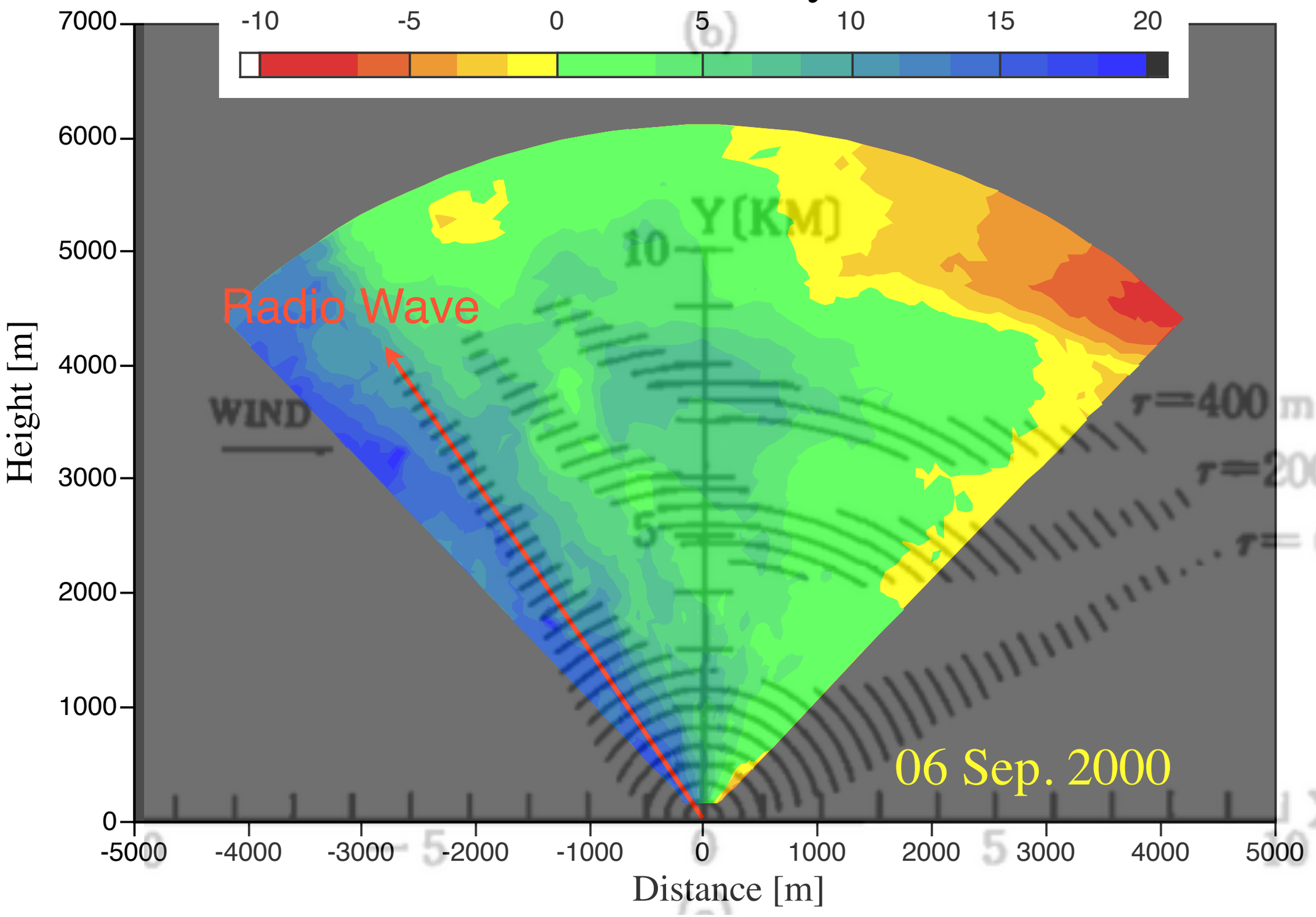
Masuda et al., 1988

RHI observation of Doppler velocity with a wind profiler



Adachi, A., T. Kobayashi, Conf. on Rad. Met., 2001

RHI observation of Doppler velocity with a wind profiler



Adachi, A., T. Kobayashi, Conf. on Rad. Met., 2001

Conclusions（#2）

Parametric Acoustic Array is available for the RASS measurements.

PAA has extremely low sidelobes and could be installed to wind profilers located in urban areas.

PAA-RASS has accuracy and precision comparable with acoustic speaker RASS.

PAA-RASS height coverage may be comparable with that of conventional RASS by use of advanced profiler.

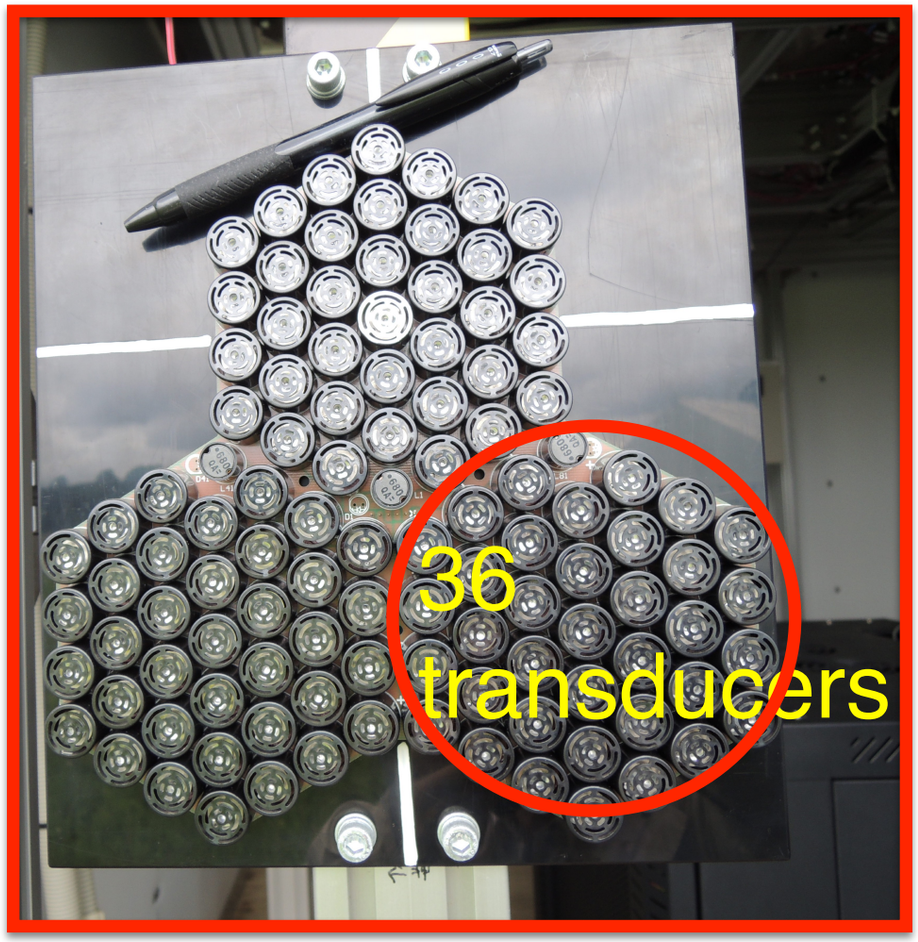
Thank you for your attention!

Adachi and Hashiguchi, AMTD, 2019

Mitsubishi Wind Profiler

Parametirc acoustic array for RASS

20,000,000JPY w/o FPGA
~183,100 USD
~162,941.35 EUR

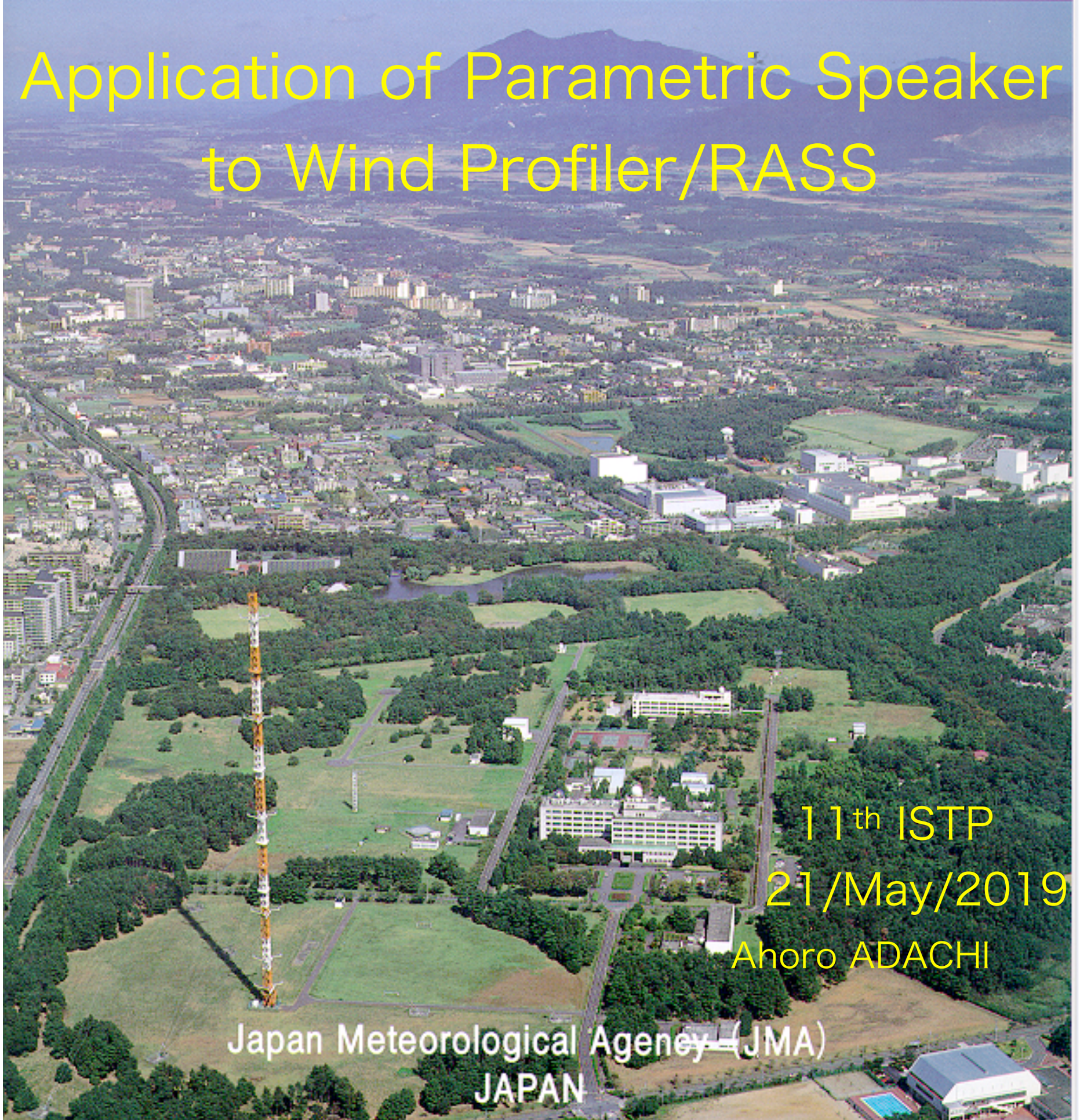


36 trans. for a segment,

FPGA controls 278 segments.

More than 10000 cells in total.

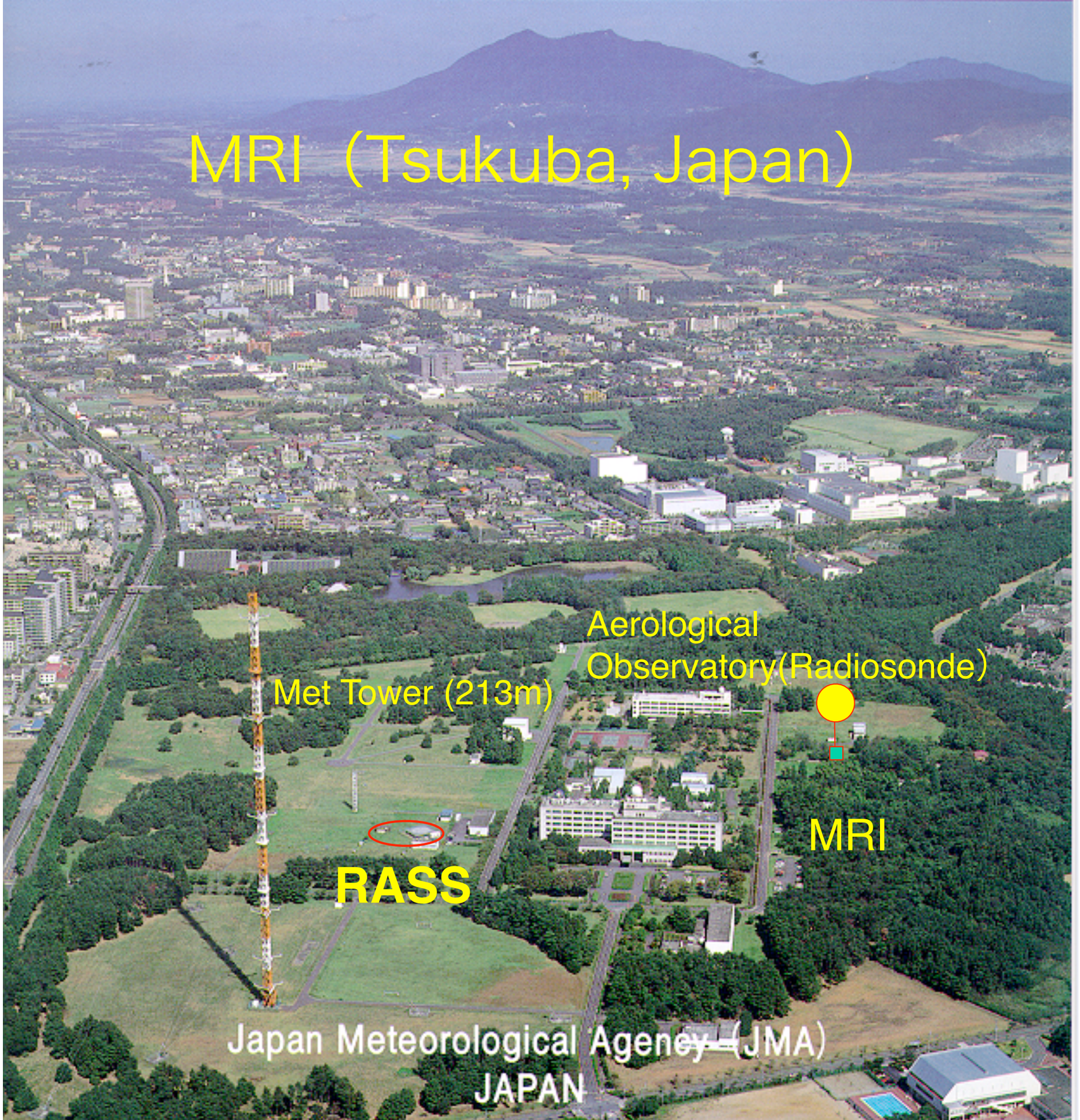
Application of Parametric Speaker to Wind Profiler/RASS

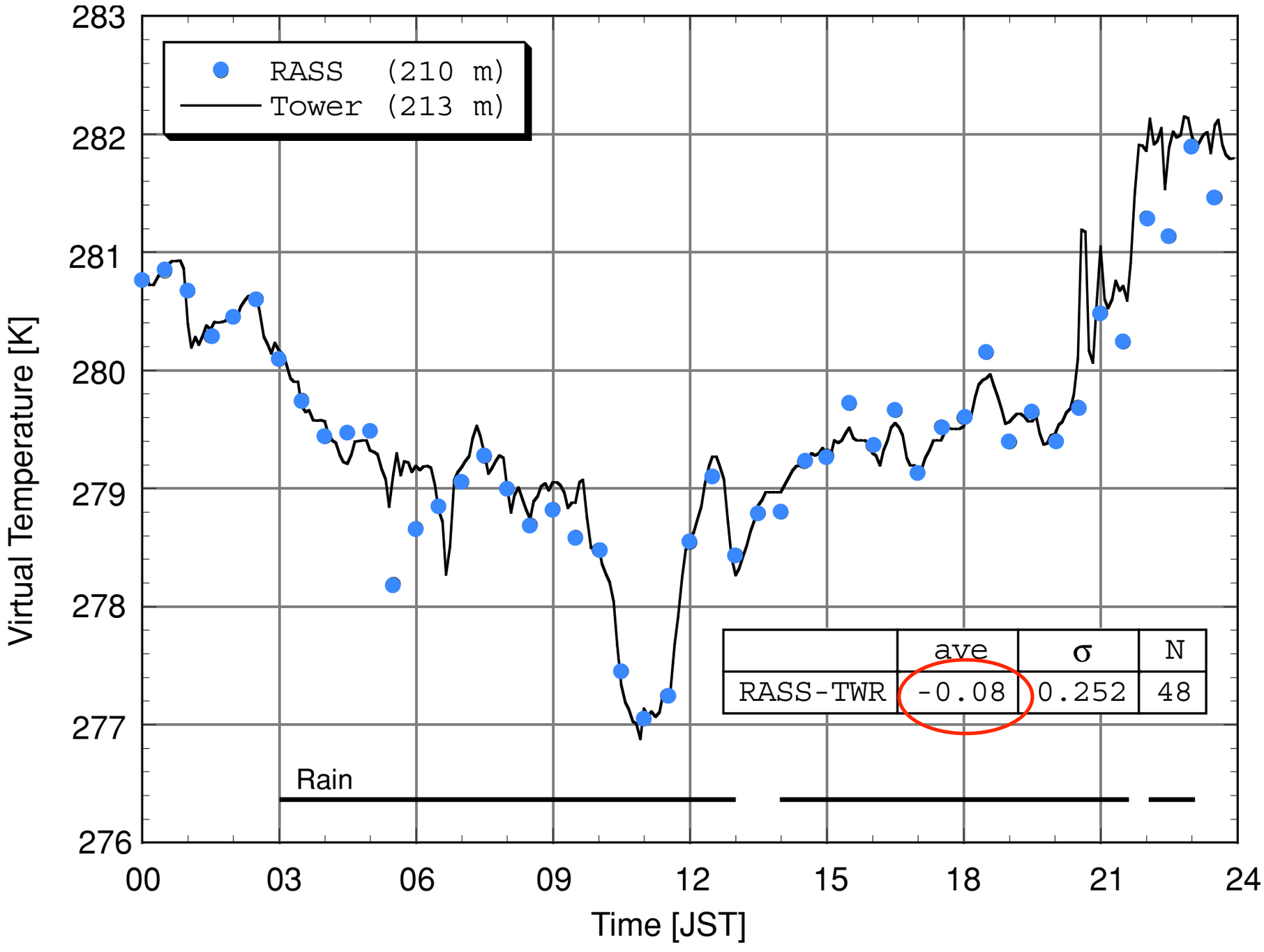


11th ISTP

21/May/2019

Ahoro ADACHI


MRI (Tsukuba, Japan)
Aerological
Observatory(Radiosonde)
Met Tower (213m)
MRI
RASS
Japan Meteorological Agency (JMA)
JAPAN



Adachi. et al., 2004

100dB

f_a =3kHz

Issue of RASS

=>too noisy!

80-90dB

($\lambda_a = \lambda_e/2$)

Ear protection required!

7 Sep. 2017

ゾンデ (08:30)

音響RASS (1時間平均)

超音波RASS (1時間平均)

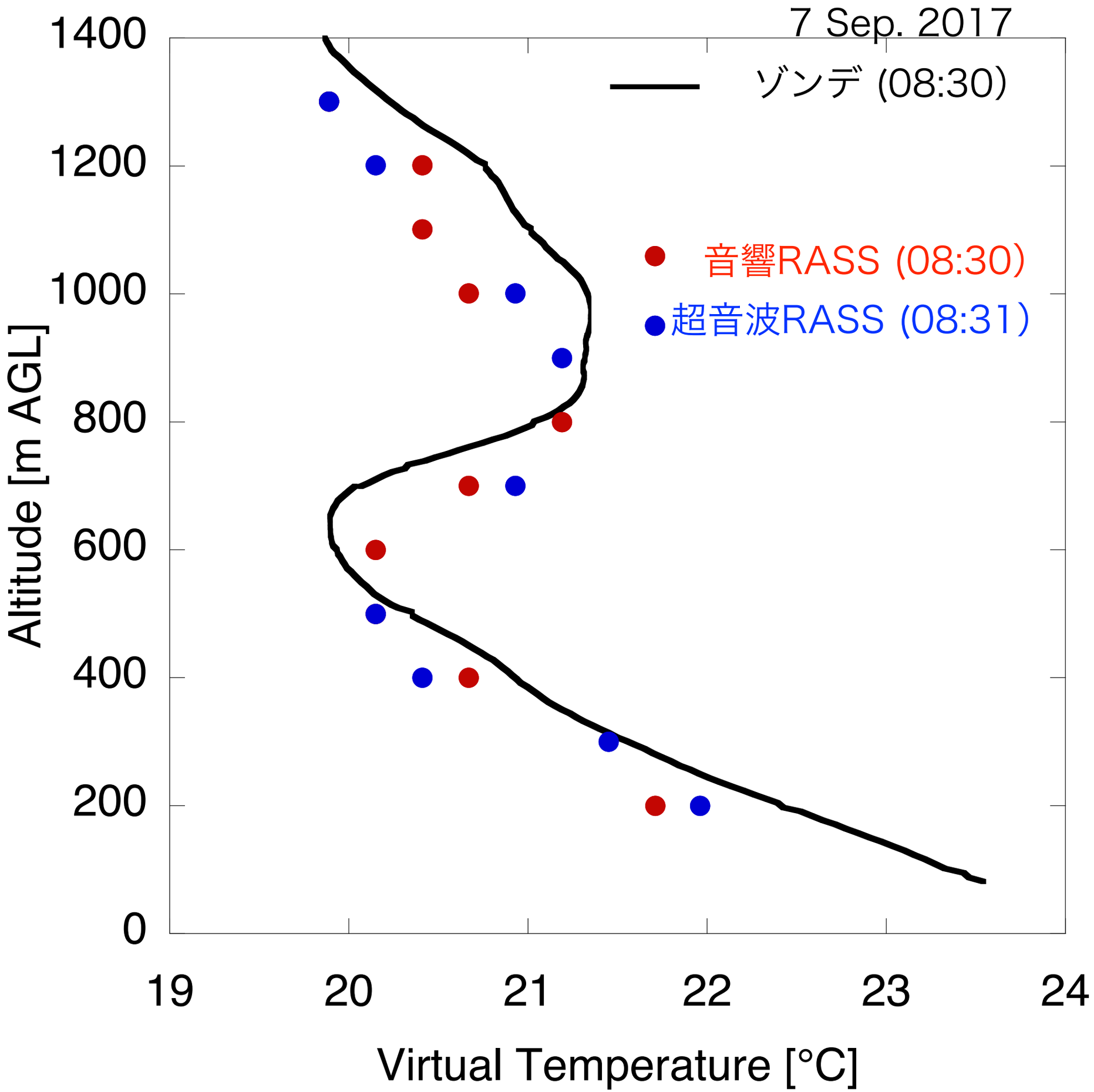
	Acoustic	Parametric
Bias [°C]	—0.21	—0.16
σ [°C]	0.42	0.43
N	295	253

Altitude [m AGL]

1400
1200
1000
800
600
400
200
0

19
20
21
22
23
24

Virtual Temperature [°C]


7 Sep. 2017
ゾンデ (08:30)
音響RASS (08:30)
超音波RASS (08:31)
Altitude [m AGL]
1400
1200
1000
800
600
400
200
0
19
20
21
22
23
24
Virtual Temperature [°C]

Masada et al., 1988

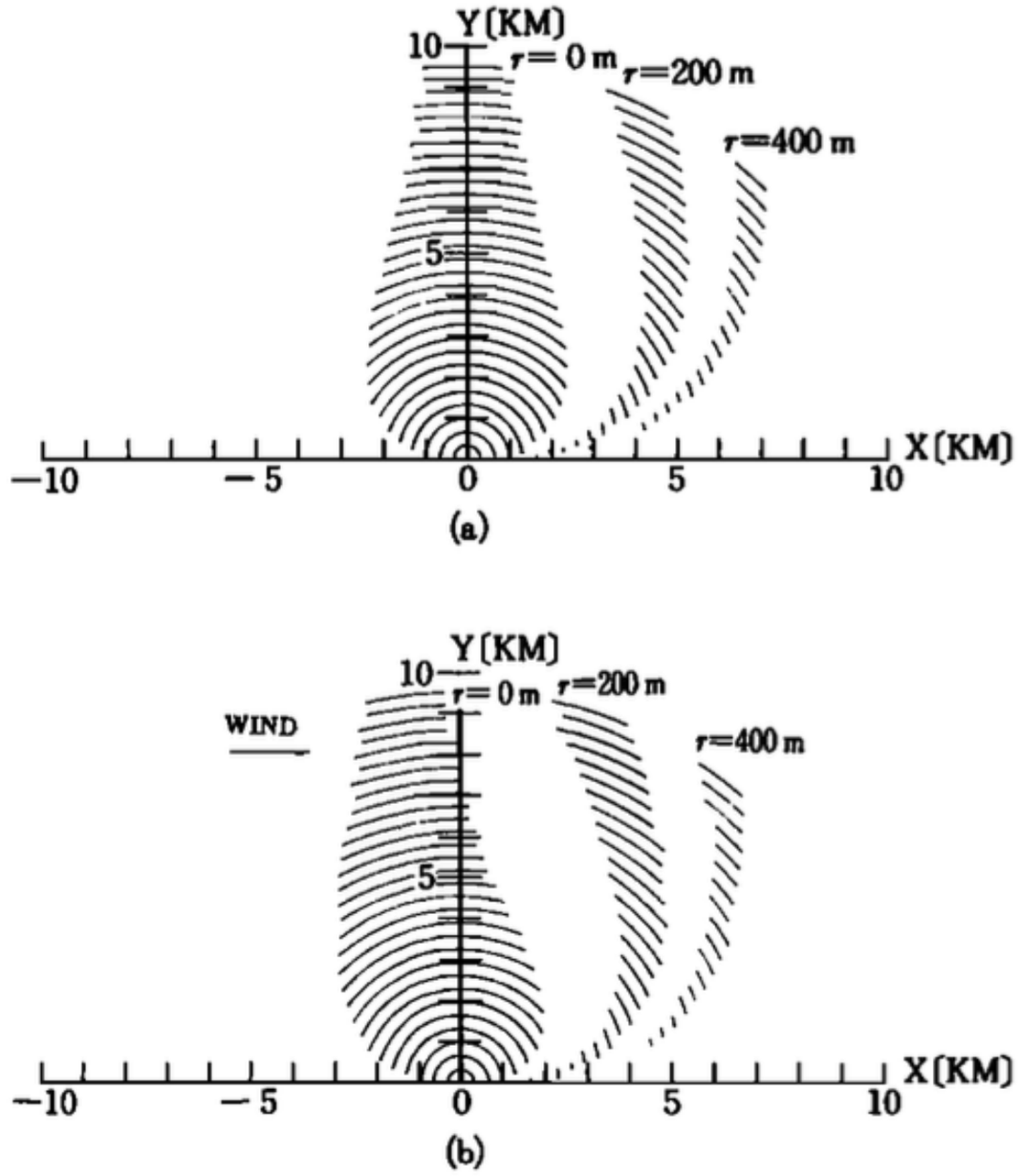


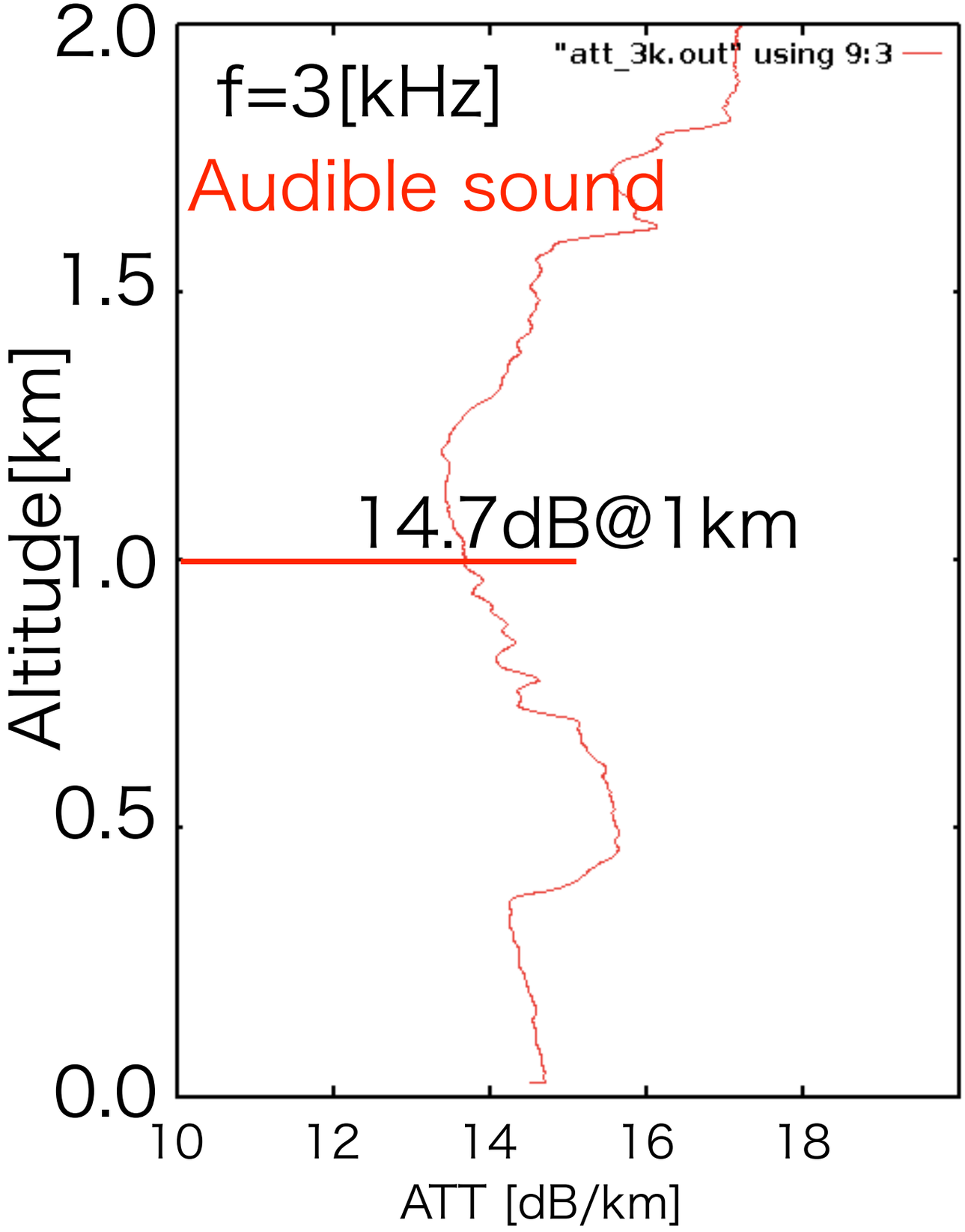
Fig. 3. Shape of the backscatter region assuming constant gradients of acoustic and wind speed. (*a*) $C_0 = 331$ m s^{-1}, $C' = 0.0028$ s^{-1}, and $U = 0.0$ m s^{-1}, (*b*) $C' = 0.0028$ s^{-1} and $U' = 0.00056$ s^{-1}. (*c*) $C' = 0.0028$ s^{-1} and $U' = 0.0045$ s^{-1}. The radar antenna is located leeward a distance of r from the acoustic source.

Shizuoka Weather Station

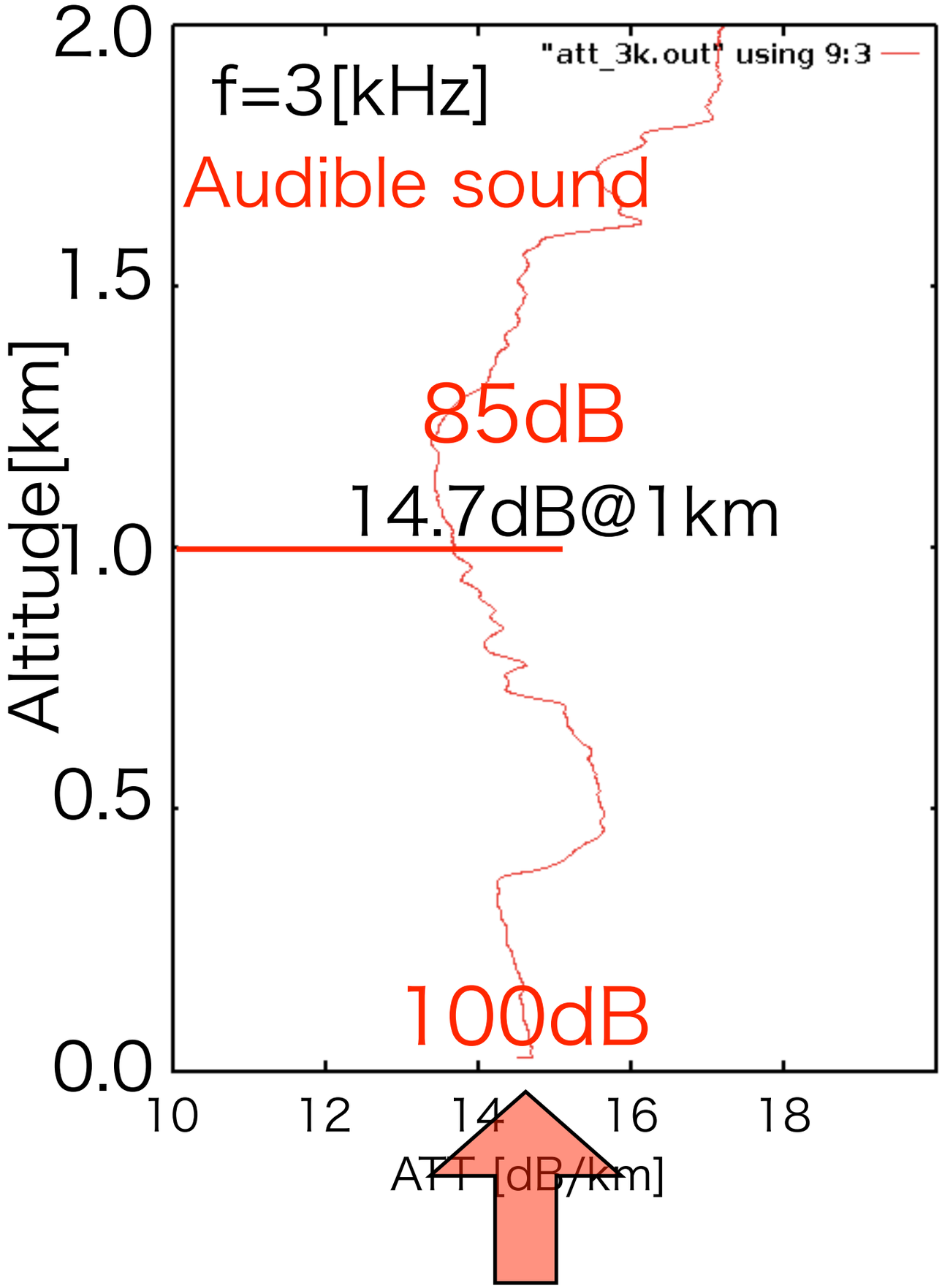
Shizuoka Weather Station

Technical issue of RASS: high noise to residents due to sidelobes.

19. Oct. 2016　08:30



19. Oct. 2016　08:30



2016.10.19　08:30

f=3[kHz]

Audible sound

"att_3k.out" using 9:3

85dB

14.7dB@1km

100dB

f=40[kHz]

Ultrasound

"att_40k.out" using 9:3

1256dB@1km

200dB@160m

Altitude[km]

2.0
1.5
1.0
0.5
0.0

10 12 14 16 18

ATT [dB/km]

1120 1160 1200 1240 1280

ATT [dB/km]

2016.10.19　08:30

f=3[kHz]

Audible sound

"att_3k.out" using 9:3

85dB

14.7dB@1km

100dB

Altitude[km]

ATT [dB/km]

f=40[kHz]

Ultrasound

"att_40k.out" using 9:3

1256dB@1km

200dB@160m ~ 0dB ?

200dB

ATT [dB/km]

Period：2016-2018 （23 days：hourly mean）

Y = 0.999 X + 0.095

R = 0.996

(a)

Bias [°C]	0.08
σ [°C]	0.43
N	2768

(b)

Bias [°C]	0.06
σ [°C]	0.16
N	145

Y = 1.003 X + 0.033

R = 0.9997

PAA Tv[°C]

Acoustic Speaker Tv [°C]

Probability[%]

0 5 10 15 20 25 30 35

0 10 20 30 40 50 60 70 80 90 100

Period：2016-2018 （23 days：hourly mean）

Y = 0.999 X + 0.095

R = 0.996

(a)

Bias [°C]	0.08
σ [°C]	0.43
N	2768

(b)

Bias [°C]	0.06
σ [°C]	0.16
N	145

Y = 1.003 X + 0.033

R = 0.9997

PAA Tv[°C]

Acoustic Speaker Tv [°C]

Probability[%]

0 5 10 15 20 25 30 35

0 10 20 30 40 50 60 70 80 90 100