Third Aviation, Range and Aerospace Meteorology Special Symposium
on Weather-Air Traffic Management Integration

The Potential of 1.3GHz-Band Wind Profiler for Monitoring Atmospheric Turbulences on the Airways

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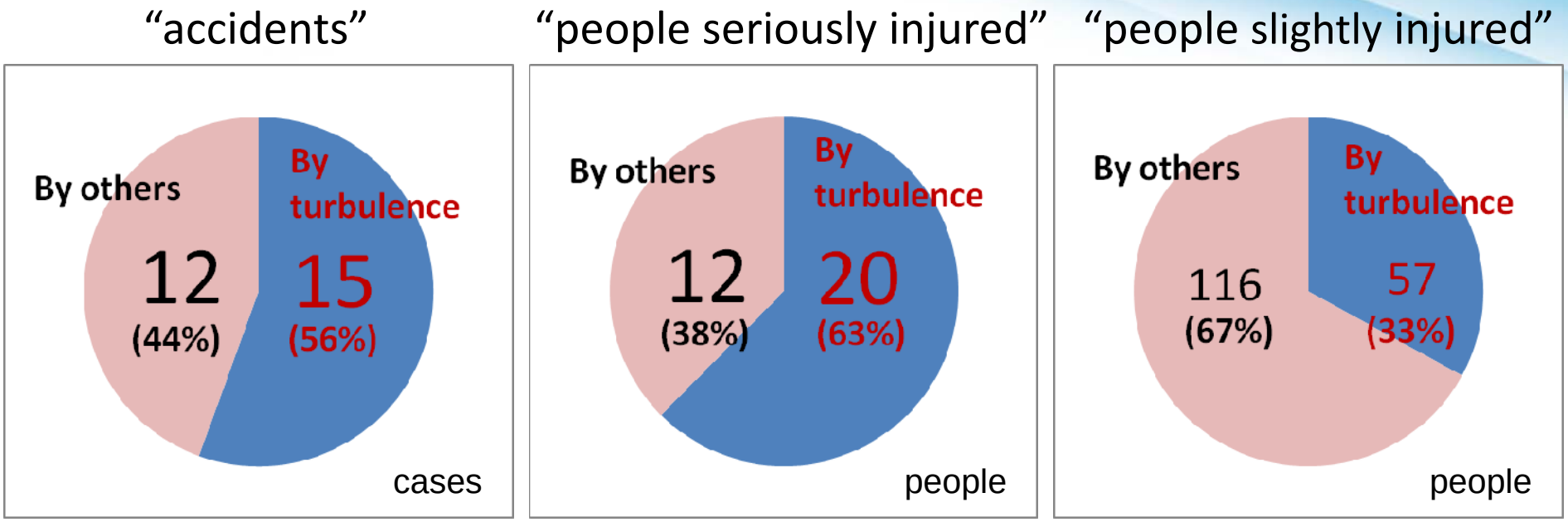
Table of Contents

Introduction

Turbulence in Japan

◯Aviation Accidents in Japan, 2000-2009



*From reports by Japan Transport Safety Board

◯Turbulence Observing Information

So far, information on turbulence is limited to **PIREP** (in Japan)

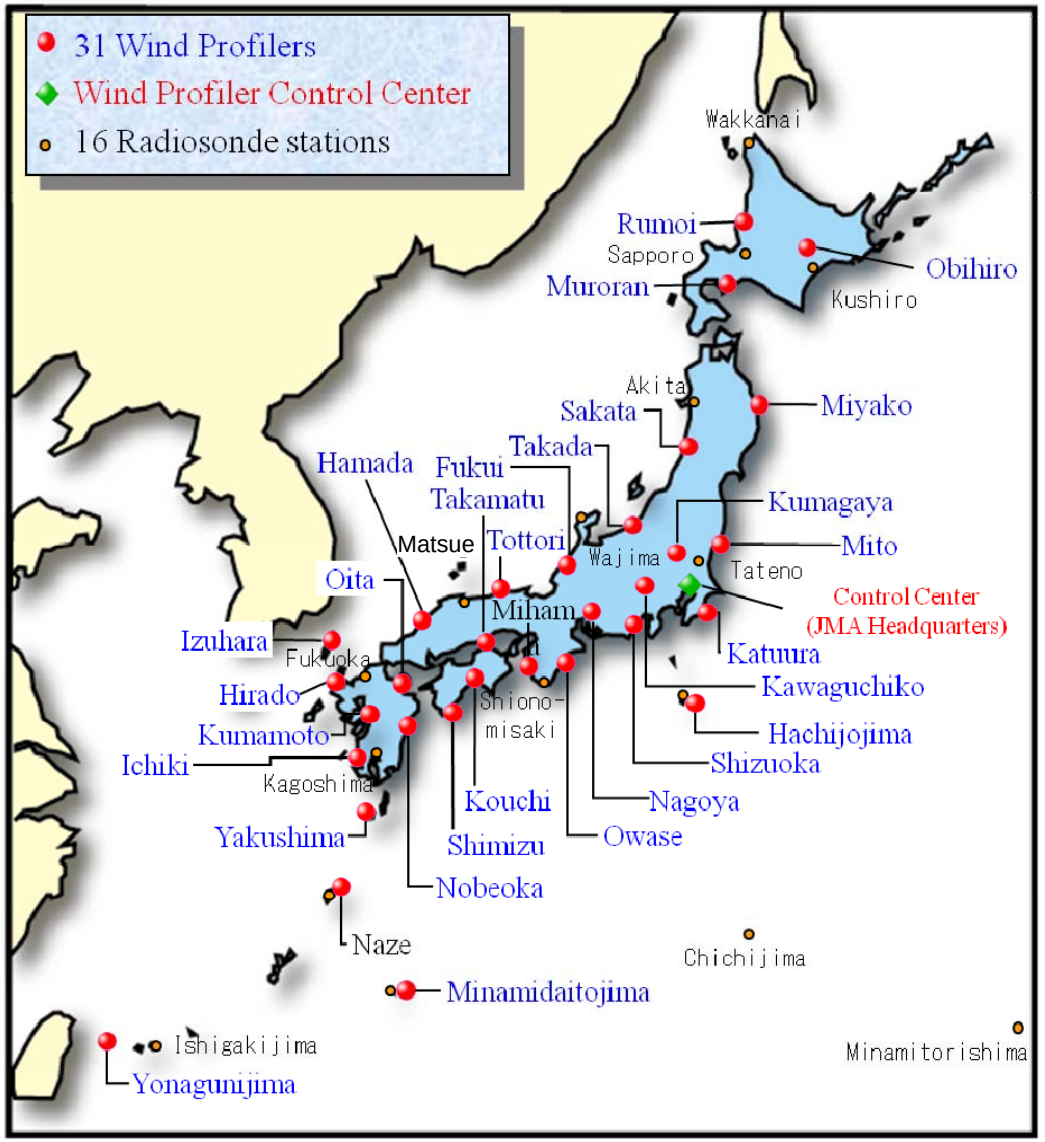
→ We need new techniques by remote sensing!

(e.g. the NEXRAD turbulence detection algorithm,

low-level EDR retrieved from wind profilers or LIDARs at Hong Kong)

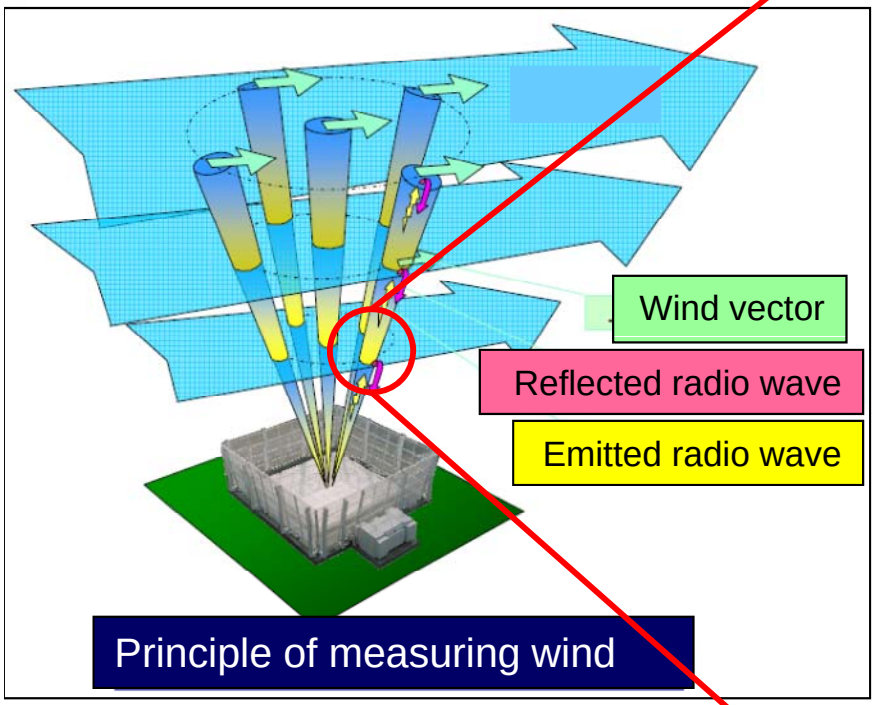
Wind profiler and Turbulence

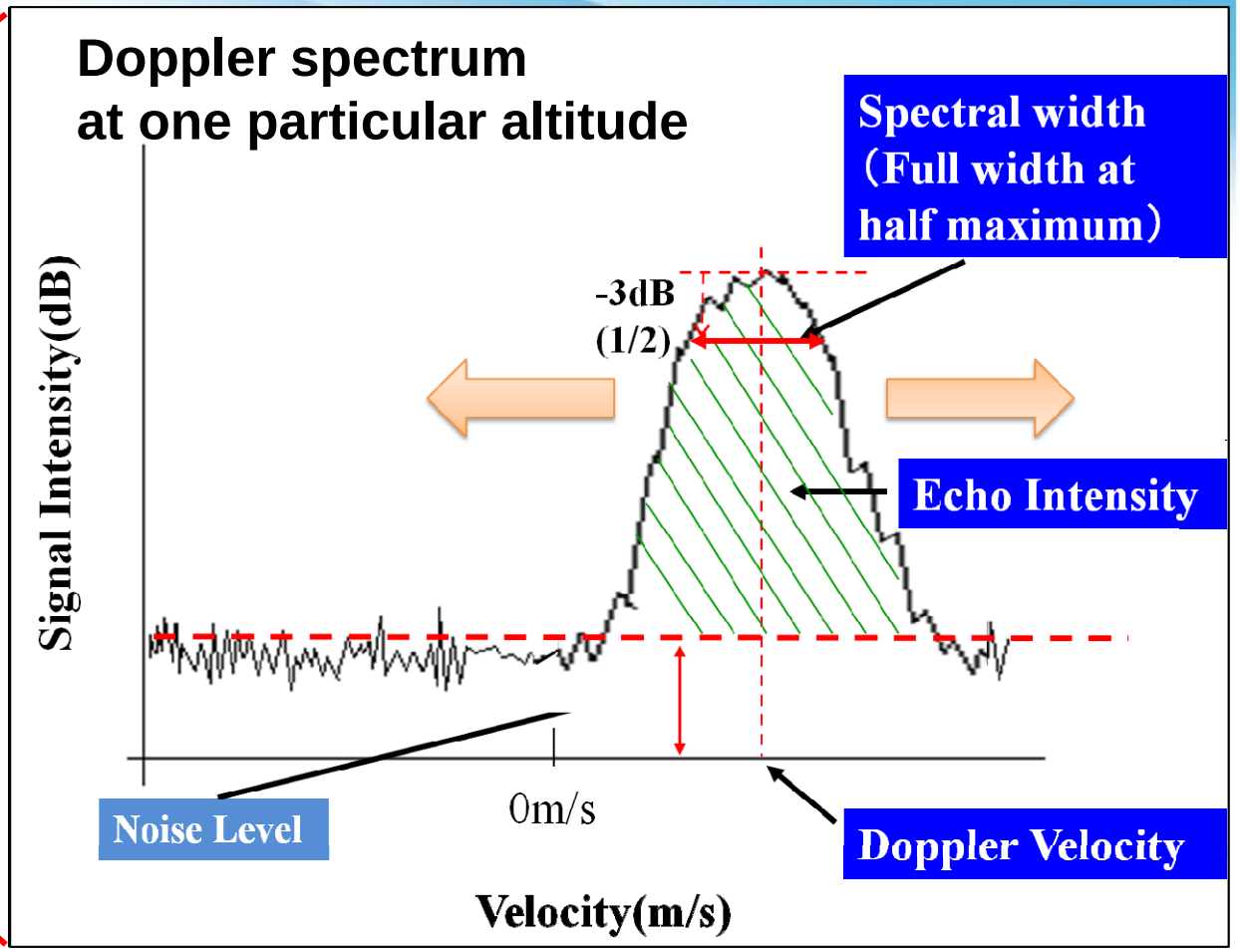
1.3GHz-Band Wind profilers in Japan (WINDAS)



	Operational Mode
Frequency	1357.5MHz
Antenna Gain	34dBi
Peak Power	1.8kW
Beam	5 (N, S, E, W, Zenith)
Pulse Length	2.0μs (+ 8bit Spano code)
PRF	10kHz
Resolution	Height: 296m Time: 1minute 10 minutes average
Height Coverage	9 km (maximum) ～5 km (annual average)

Spectral width and Turbulence





1. Clear Air Echo : Scattering from refractive index irregularity (Bragg scattering)

2. Precipitation Echo : Scattering from precipitate particles (Rayleigh scattering)

➔ **In either case, scattering body is influenced from turbulence intensity.**

Correction of Spectral width Broadening

Other factors of Spectral width broadening in 1.3GHz-Band

- Beam Broadening → by finite radar beam width
- Shear Broadening → by vertical shear in the scattering volume
- Time Broadening → by velocity fluctuation in dwell time(ex. gravity wave)
- Rain Broadening → by different fall velocity of raindrops

Main factor of JMA's wind profiler is the beam broadening without raindrops.

Simple correction for beam broadening

$$\sigma_{cor} = \sqrt{\sigma_{obs}^2 - \left(\frac{1}{\sqrt{2}}\theta_{1/2}V_h\right)^2}$$

Hocking(1985)

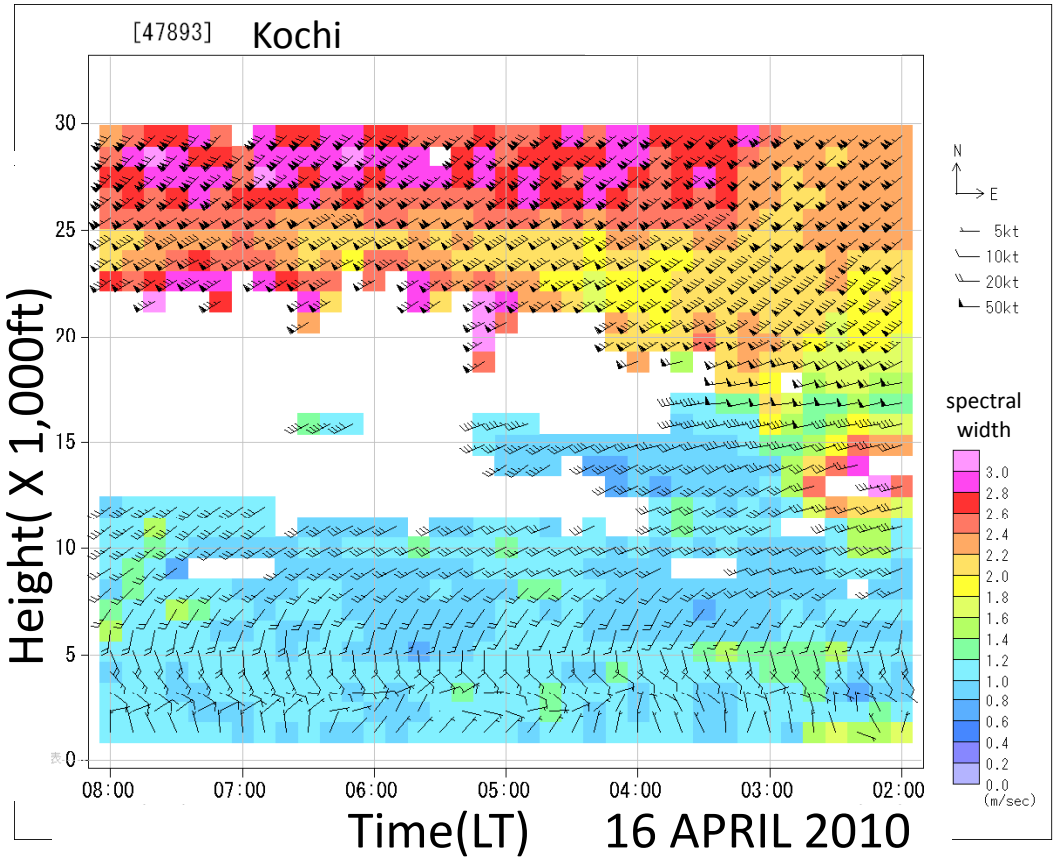
σ_{obs}: Observation Value(m/s)
$\theta_{1/2}$: 1-way beam width(Full)
V_h: Horizontal velocity(m/s)

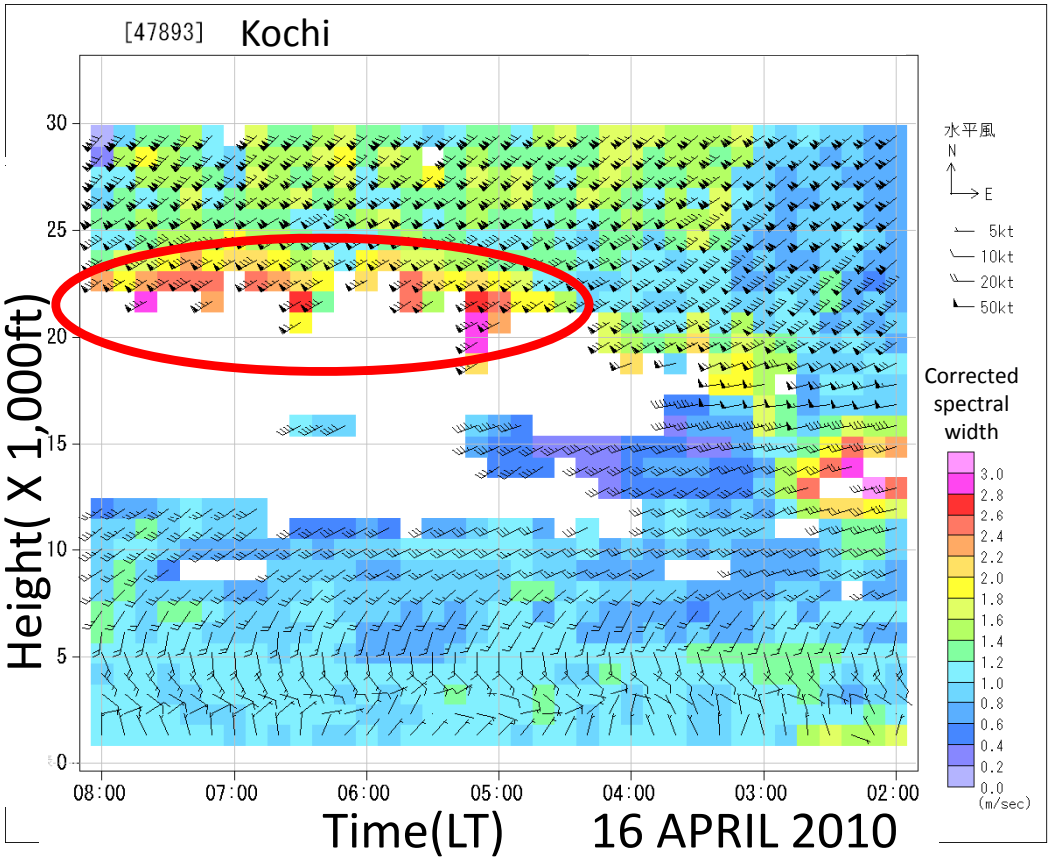
•If the number in the root is minus, σ_{cor} is regarded as 0.0m/s.

An example of Correction

Time-Height Cross Section in Spectral width

before → after





Red: Wider

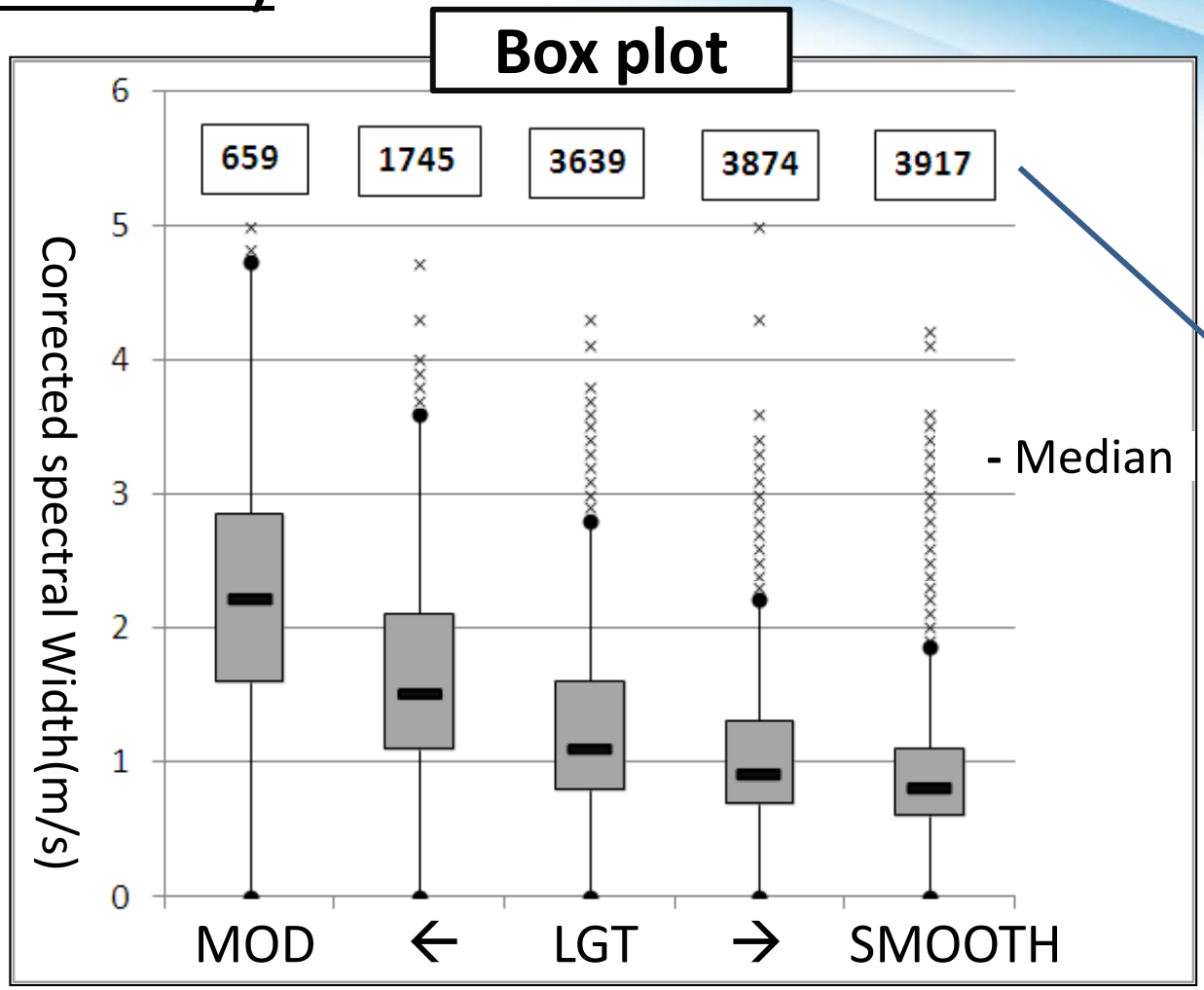
Blue: Narrower

Result

Comparing Wind profiler and PIREP data

Period	**2008 Jan - 2010 Dec**
Altitude	**surface - about 30,000ft**
Subject	**WPR: Corrected spectral width** (average value for 10 minutes, and we select maximum value in 9 data next to time and altitude.) **PIREP: turbulence intensity reported from PIREP**
Exception	・WPR data which is likely to be influenced with the rain broadening (we regarded it as data which has less than -2.0m/s vertical velocity) ・PIREP data which quality is likely to be bad

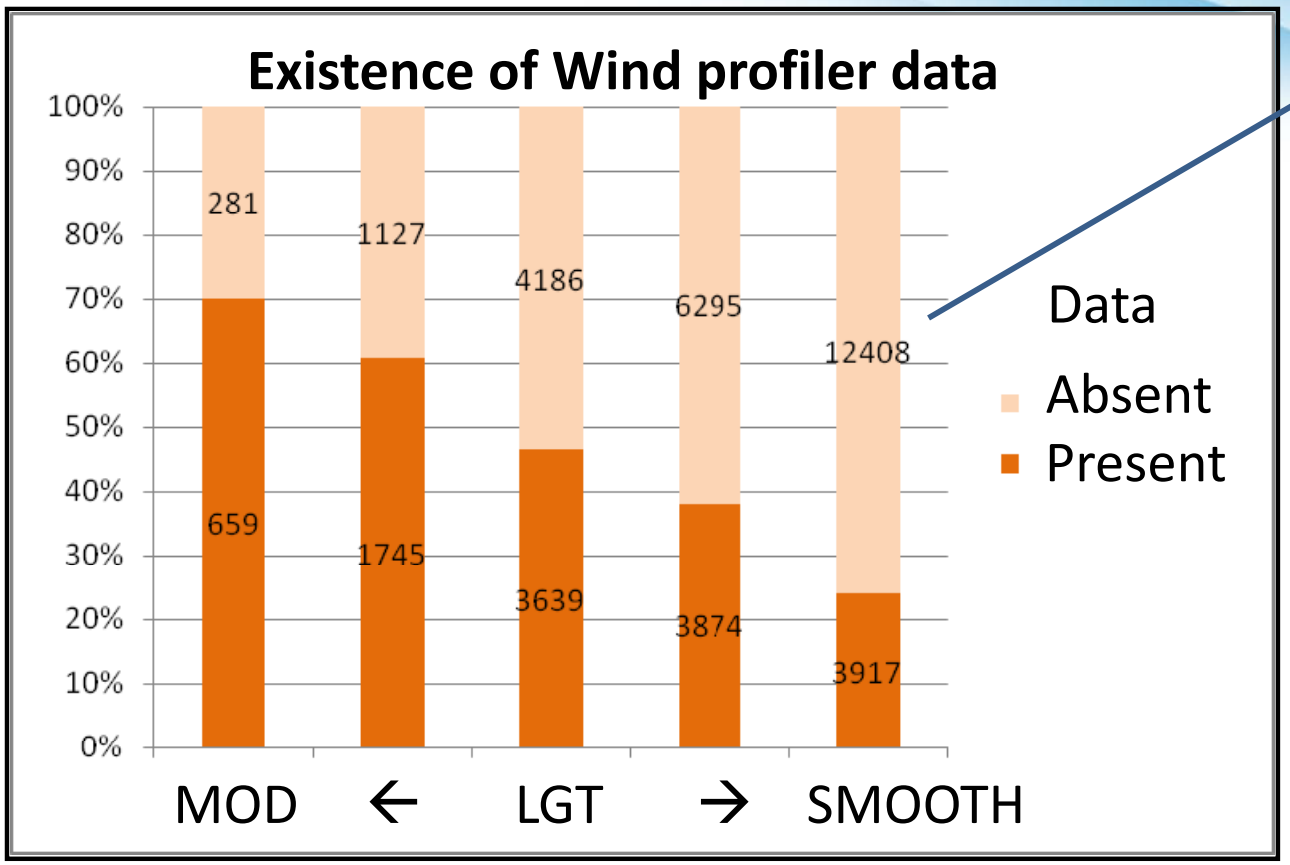
Turbulence reported near wind profilers (within 15km)



The number of PIREP data which we use

- **The wider the corrected spectral width, the stronger the reported turbulence!**

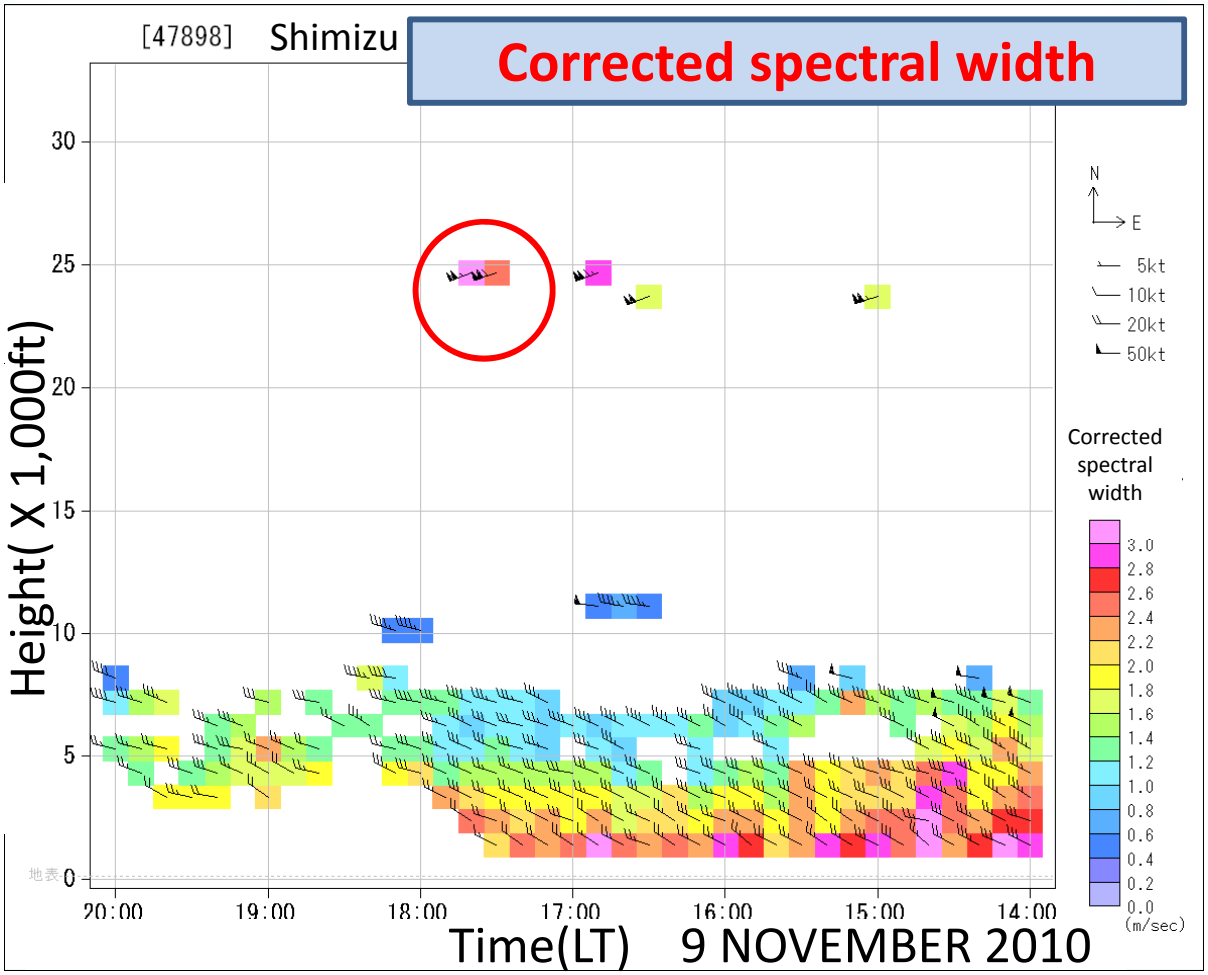
Turbulence reported near wind profilers (within 15km)



The number of PIREP data which we use

- Even in case of moderate turbulence,
  30% PIREP were accompanied with no wind profiler data.
- The weaker the turbulence,
  the less the observed wind profiler data.

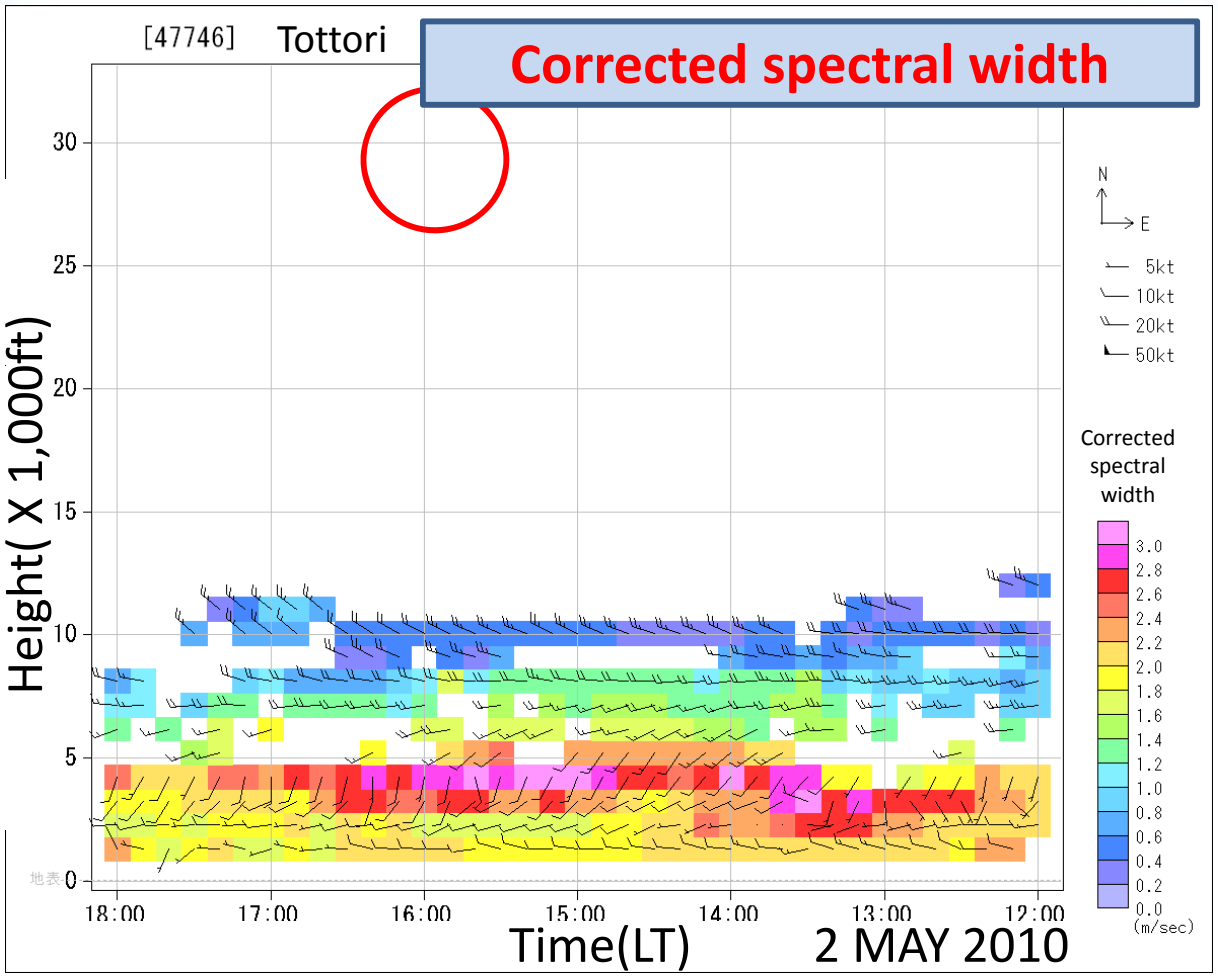
Good case（CAT 2010.11.9）



PIREP	
Name of near WPR	Shimizu
Turbulence intensity	Moderate
Distance	About 5 km to the north of WPR
Altitude	25,000-26,000ft
Time(LT)	17:39
Aircraft Type	B737-800

The value of the spectral width was over 3 m/s near the turbulence!

Data absent（CAT　2010.5.2）



PIREP	
Name of near WPR	Tottori
Turbulence intensity	Moderate
Distance	About 4 km to the west of WPR
Altitude	29,000ft
Time(LT)	15:57
Aircraft Type	B767-300

By radiosondes, it was very dry near 29,000ft of altitude.
→We cannot get any information about turbulence due to weak echo.

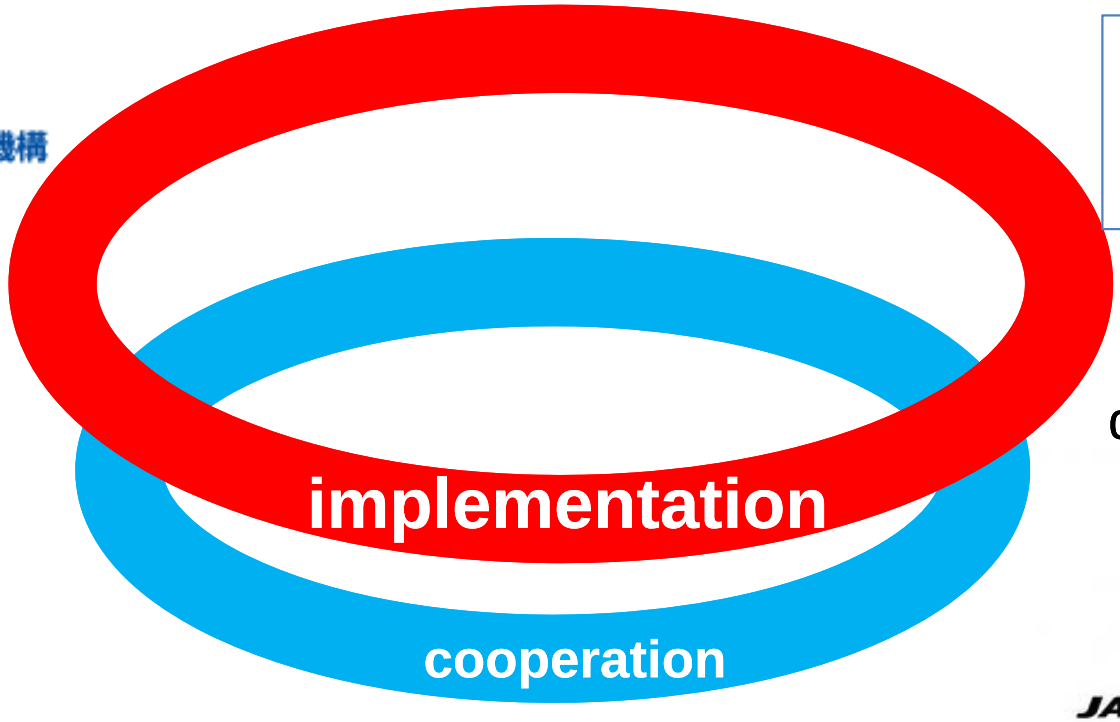
A new research project for better turbulence detection

Development of high-sensitivity
1.3GHz wind profiler (by software)

Kyoto University
RISH Research Institute for Sustainable Humanosphere

NICT 独立行政法人 情報通信研究機構

Development of
high-sensitivity
1.3GHz wind profiler
(by hardware)



Meteorological Research Institute

Development of
turbulence
detection algorism

JMA 気象庁 Japan Meteorological Agency

Provision of JMA's wind profiler data

JAL JAPAN AIRLINES

Provision of flight data

Why a Wind Profiler ?

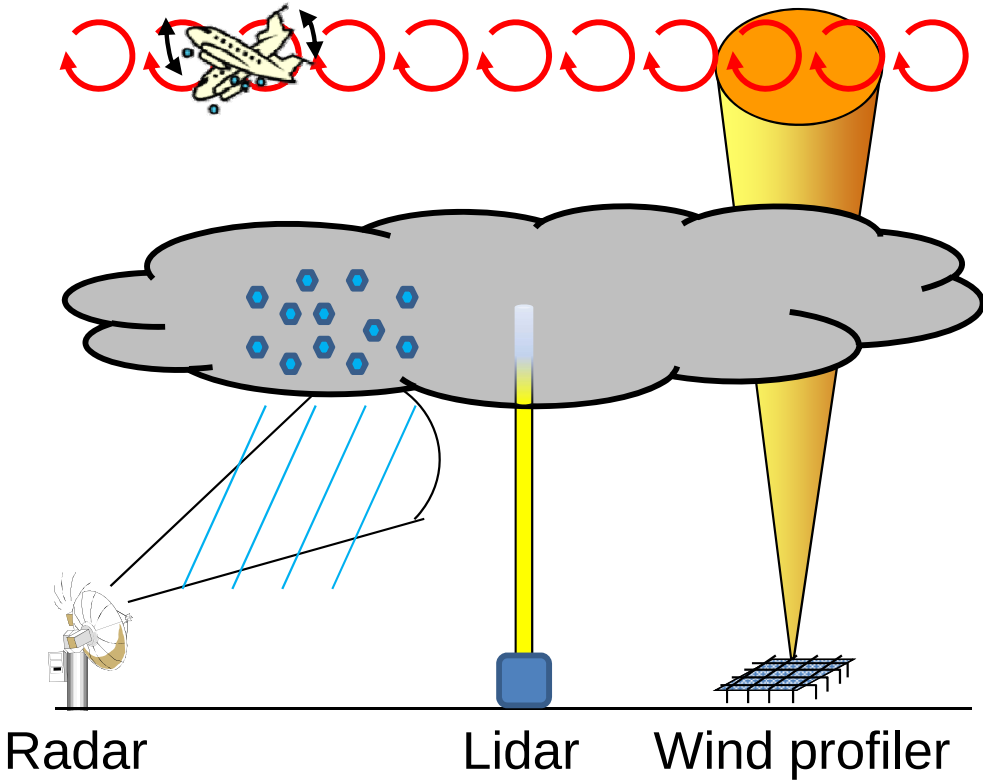
Three possibility for turbulence detection
- -Weather radar
- -LIDAR
- -Wind profiler

Wind profiler's Advantage

- Observable in any weather

Wind profiler's Disadvantage

- Horizontal distribution



Why a 1.3GHz-Band ?

Three categories of radio frequency for wind profiler
- -50MHz
- -400MHz
- -around 1000MHz(900MHz,1.3GHz, and …)

1.3GHz's Advantage

1. Lower cost
2. Smaller antenna size

1.3GHz's Disadvantage

1. Height coverage
2. Influence from raindrop

Able to overcome to some extent

Summary and Future Plans

--Summary--

Today, we have demonstrated the potential of 1.3GHz-Band wind profiler for monitoring turbulence:

- The wider the corrected spectral width,
  the stronger the reported turbulence.
- Spectral width can also detect turbulence
  which may not be related to vertical wind shear.
- But, we cannot get any information
  about turbulence in dry layers from the current wind profiler.

--Future Plan--

- Correction algorithm in rain region (now developing)
- Conversion to eddy(energy) dissipation rate
- Development of Next-generation(high sensitivity) wind profiler

Thank you very much
for your attention!

Any Questions?

Acknowledgments: The present study was supported by the Program for Promoting Fundamental Transport Technology Research from the Japan Railway Construction, Transport and Technology Agency (JRTT).

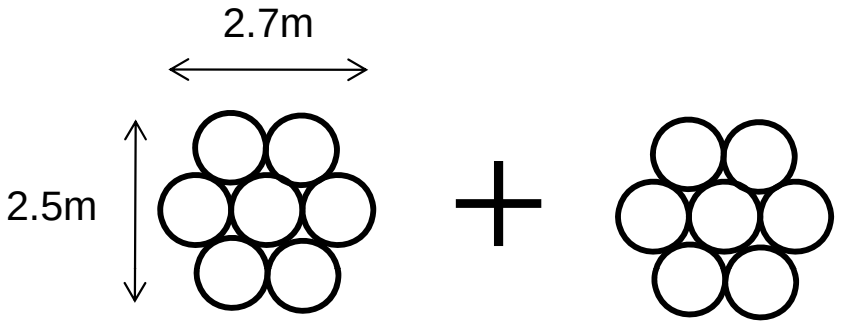
Increase of the transmission power(& antenna gain)

(a) WPR 1

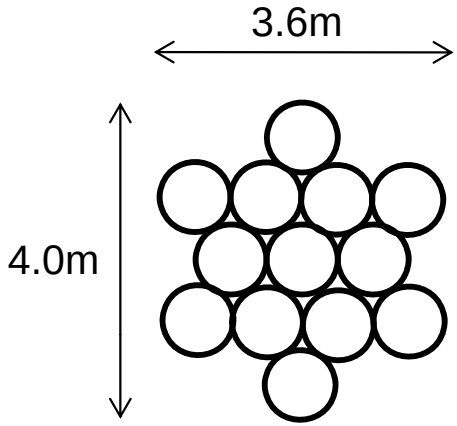
(b) WPR 2

Combine 2 small wind profiler

Peak Power
2.8kW



7 antenna



13 antenna

Peak Power
5.2kW

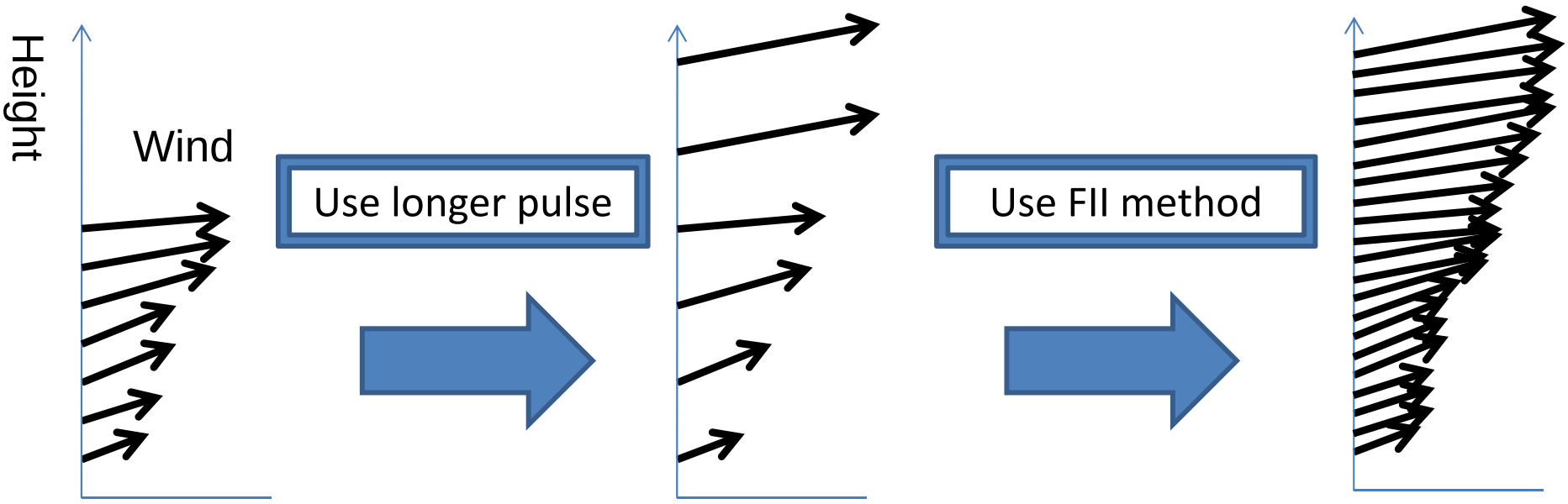
Advanced signal processing

◯Application of Frequency-domain Interferometric Imaging(FII)

- use 5 radio frequency

  e.g.　f (1357.5MHz), f±250kHz, f±500kHz

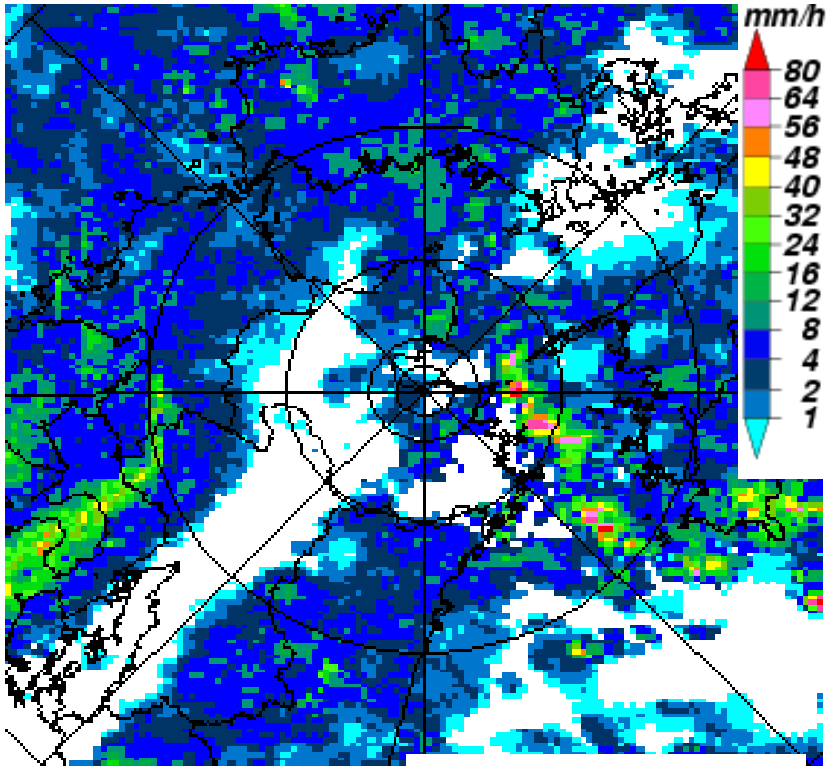
- enable us to get very high resolution

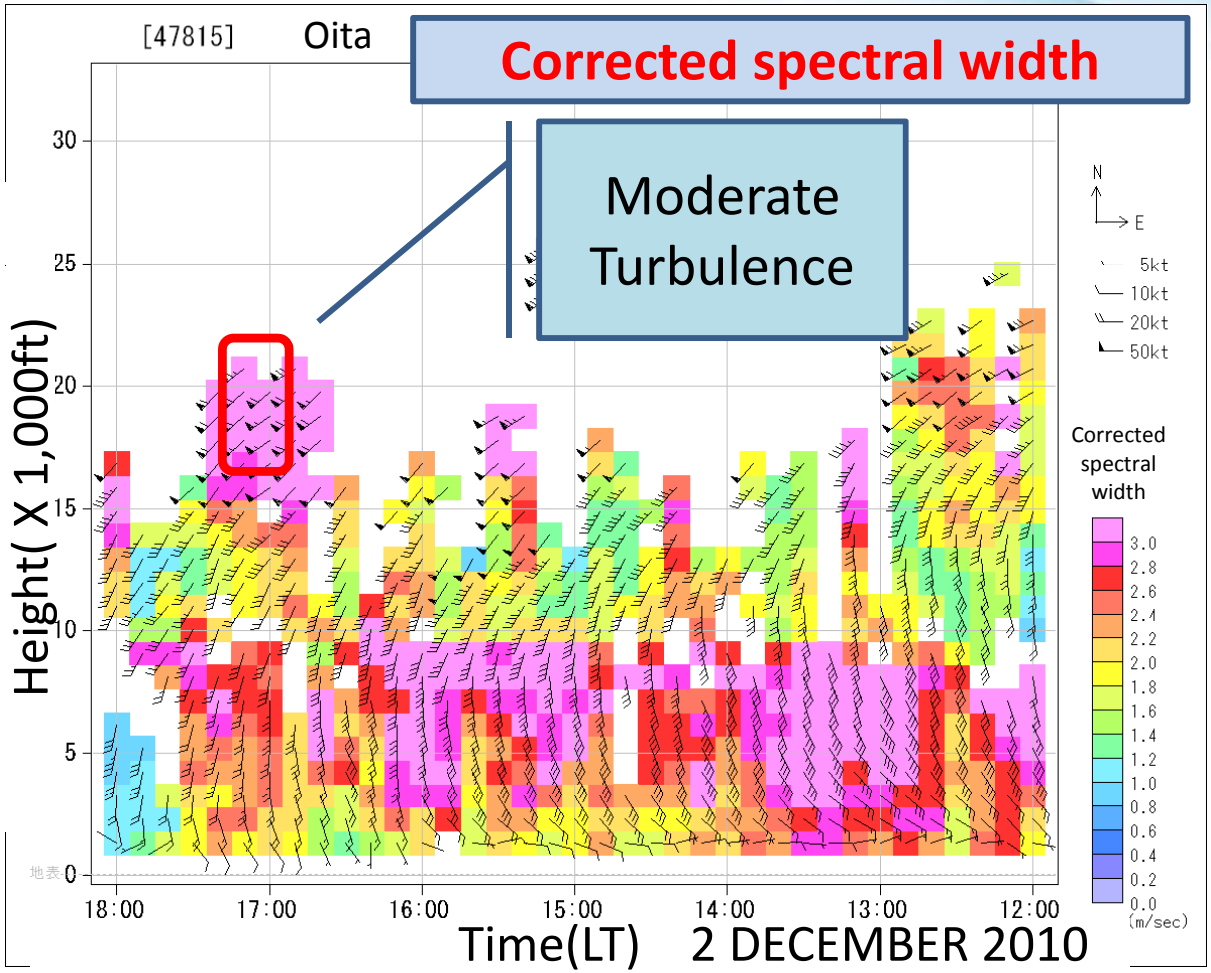


- increase height coverage
- decrease height resolution

- increase height resolution

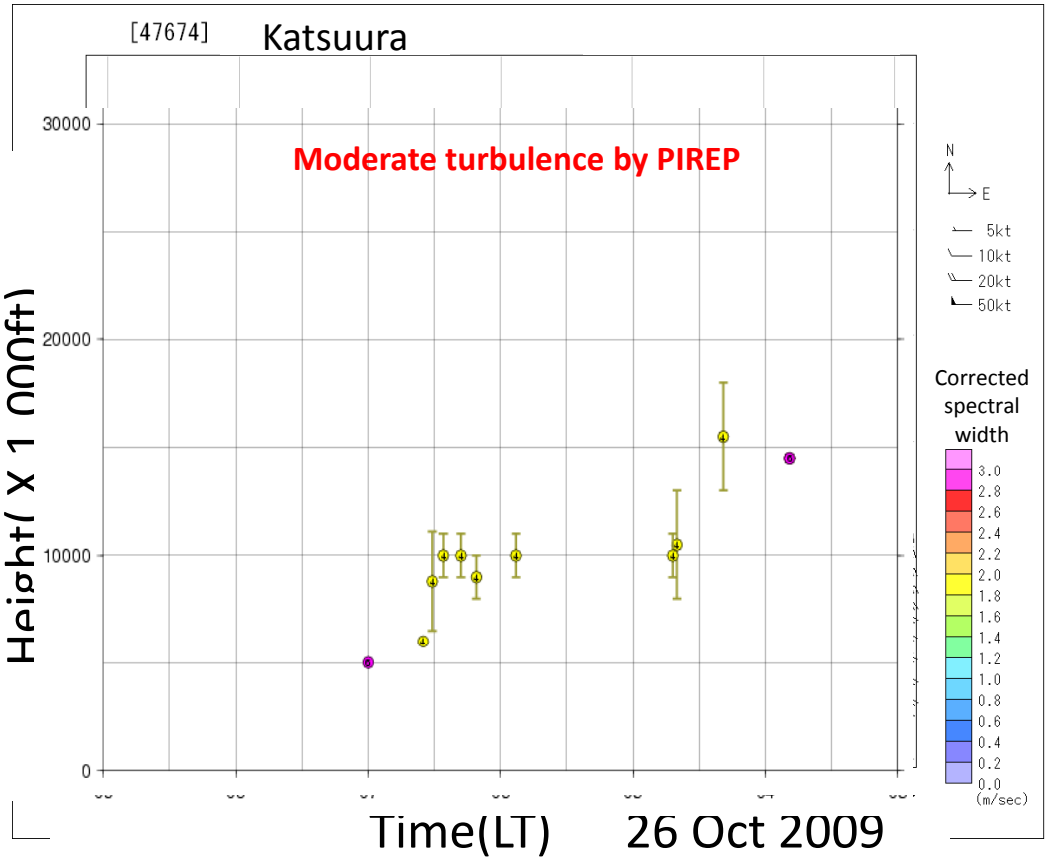
Good case（Cloud Top 2010.12.2）

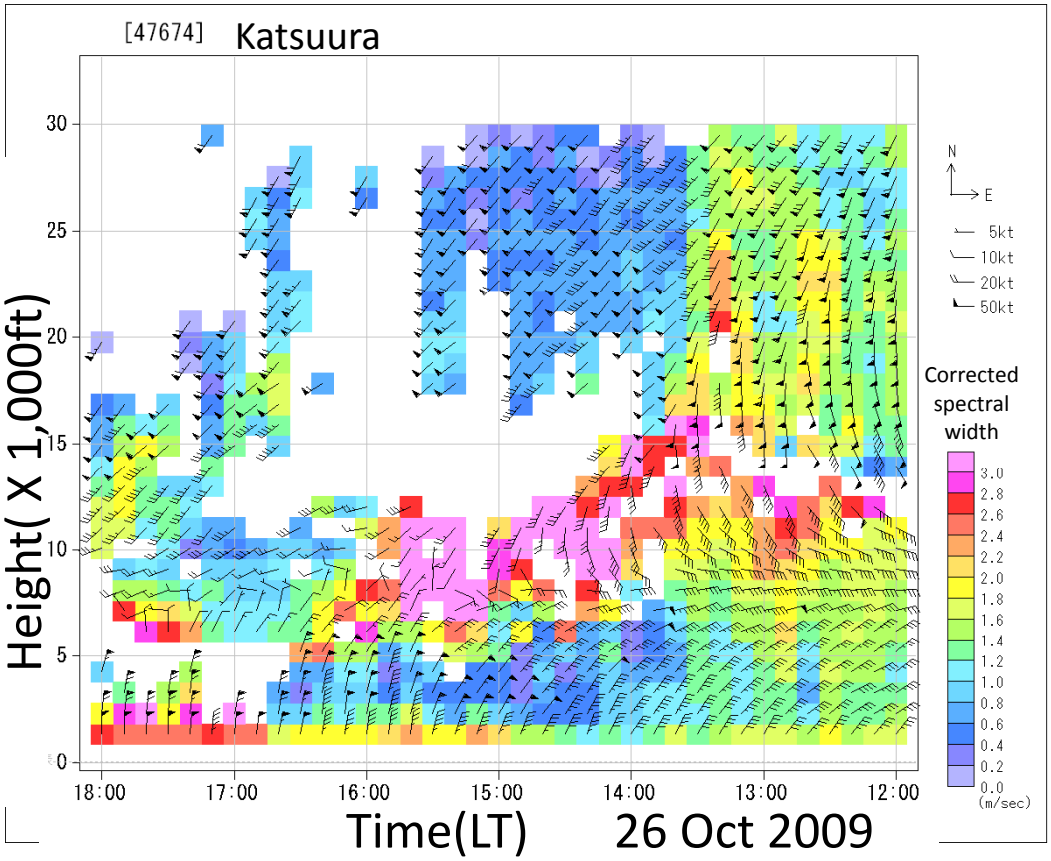




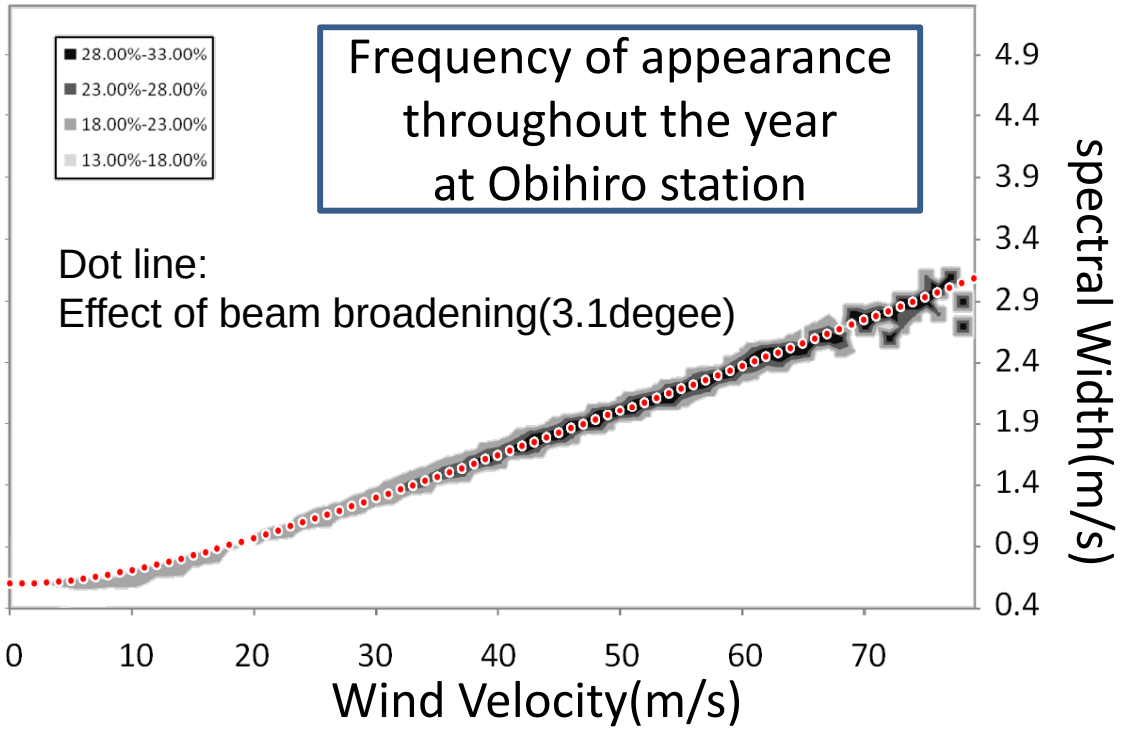
Correction of rain broadening

before → after





Correction of Spectral width Broadening



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