TÓPICOS AVANÇADOS

CAPÍTULO 6

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Tópicos avançados para a disciplina Meteorologia com Radar
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Radares Perfiladores de Vento

Wind Profiler Radars

Wind Profiler Radars

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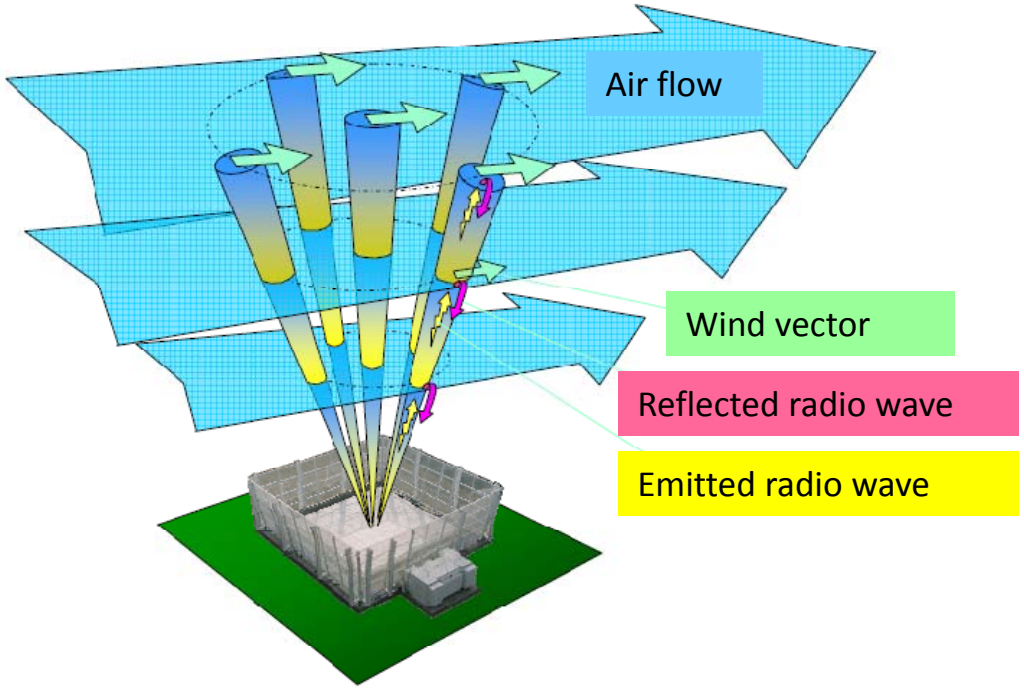
- Introduction
- User requirement
- Operational and frequency aspects
- Spectrum requirement
- Sharing aspects of wind profilers
- Japanese wind profiler network

INTRODUCTION

- What is a Wind Profiler Radar?
- Advantages of WPRs
- RASS

What is a wind profiler radar?

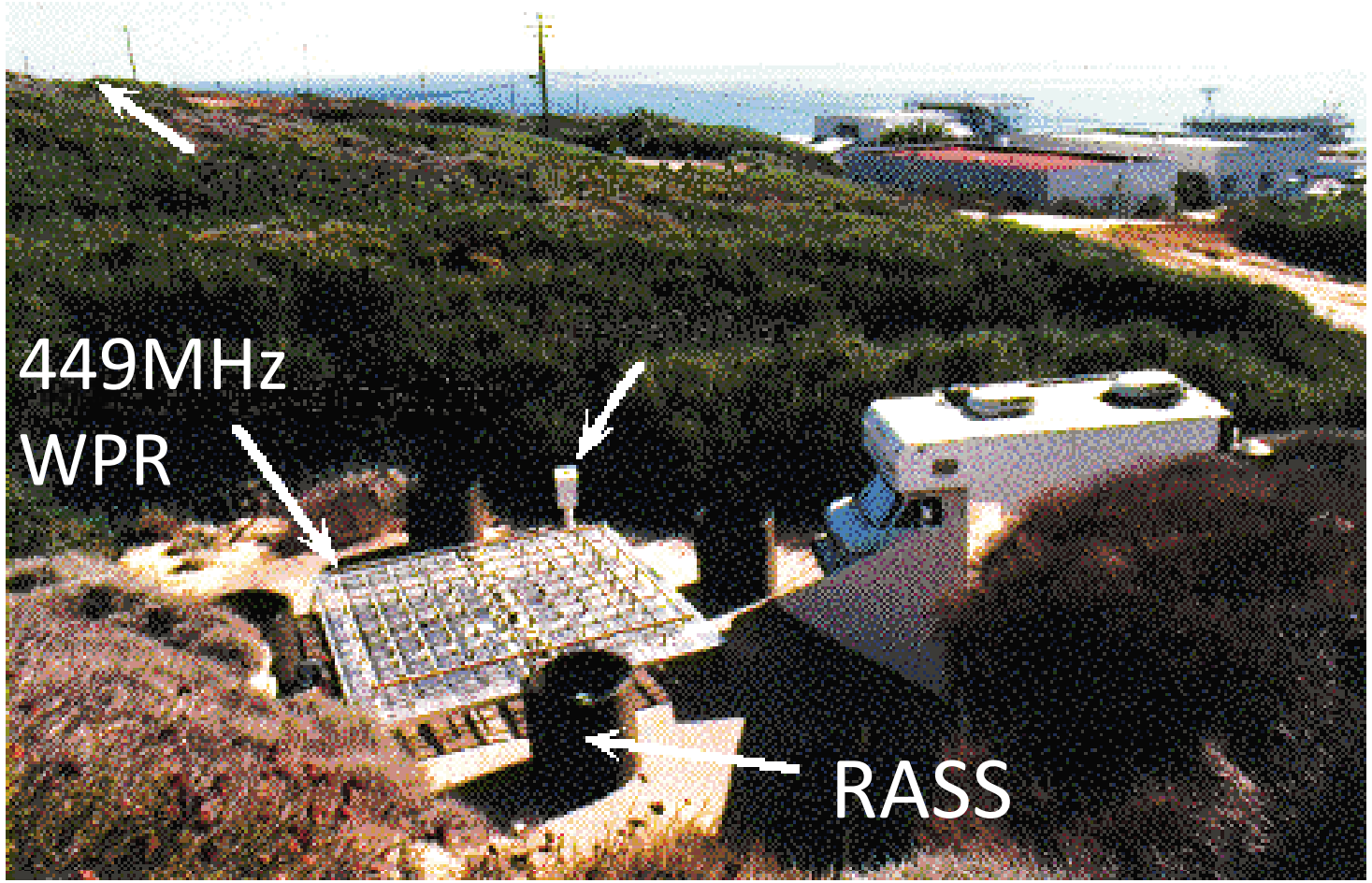
- Wind Profiler Radars (WPRs) are used to obtain the vertical profiles of the wind over an unattended and sometimes remote area by detecting the tiny fraction of emitted power backscattered from turbulence in the clear atmosphere.



Principle of measuring wind by WPRs

The frequency of reflected radio wave is changed by Doppler effect.

Example of wind profiler installation



This picture is from the Handbook(2008)

Example of wind profiler installation

General structure in Japan
(f = 1357.5MHz)

Snow covered area type
(f = 1357.5MHz)

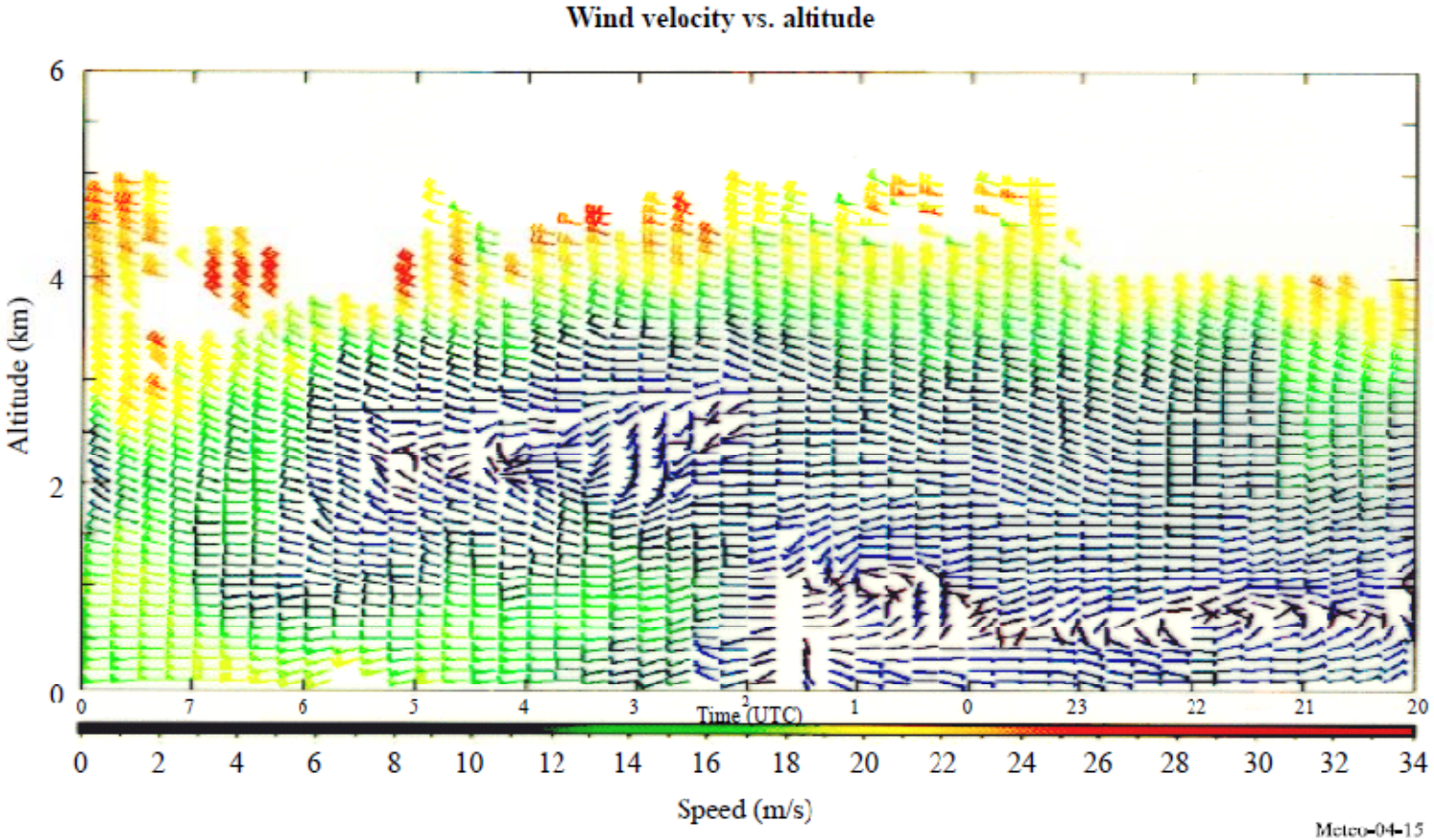
Redome: for antenna protection from snow

Advantages of WPRs

- One of the major advantages of wind profilers to other wind measurement systems is their ability to continuously monitor the wind field.
- they can also be used to
  - detect precipitation,
  - measure major disturbances in the vertical velocity,
  - measure the intensity turbulence,
  - measure atmospheric stability.

PRINCÍPIOS

Example of WPR's data



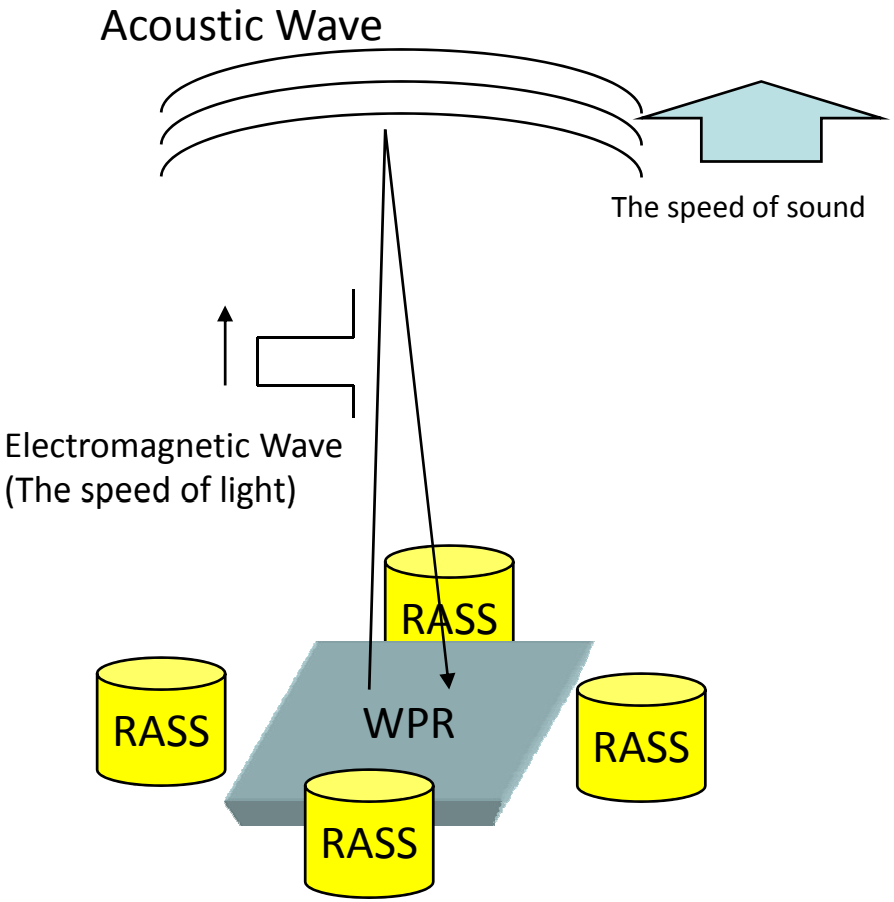
As an example mobile profiling system operating at 924 MHz produced the plot of wind velocity vs. altitude. The orientation of each flag represents wind direction as a function of altitude (vertical axis)and time (horizontal axis), while its colour represents wind speed.

Advantages of WPRs

- WPRs can also provide detailed information on atmospheric virtual temperature through the addition of a Radio Acoustic Sounding System (RASS)

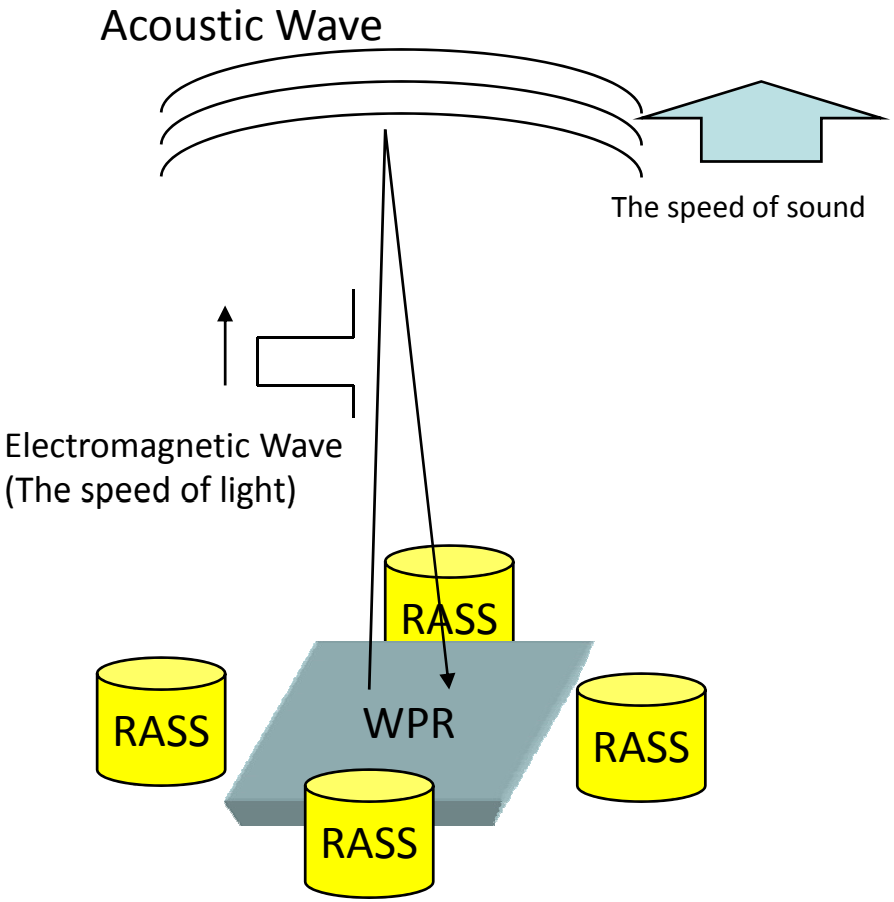
RASS

- RASS utilizes an acoustic source that is matched in frequency so that the wavelength of the acoustic wave is matched to half the wavelength of the radar transmitted electromagnetic wave.



RASS

- RASS measures the speed of the acoustic wave which is dependent upon temperature.
- In this way RASS provides a remote measurement of the atmospheric virtual temperature.



User requirement

A good way to examine the impact of user requirements upon wind profiler operating parameters and design is to consider the following equation rewritten from [Gossard and Strauch, 1983]:

$$SNR = \text{const} \frac{\overline{P}_t \, A_e \, \Delta_z \, \lambda^{1/6} \, t_{obs}^{1/2}}{T_{sys}} \frac{C_n^2}{z^2}$$

where:

$\overline{P}_t$: average transmitted power (W)

A_e: effective aperture (degrees)

Δ_z: height resolution (m)

z: height (m)

λ: wavelength (m)

t_{obs}: observation (averaging) time (s)

T_{sys}: system noise temperature (K)

C_n^2: structure parameter (dimensionless).

User requirement

- High temporal resolution
- High vertical resolution
- Obtaining wind data at high altitudes
- Reliable all-weather operation

User requirement

$$SNR = \text{const} \frac{\overline{P}_t A_e \Delta_z \lambda^{1/6} t_{obs}^{1/2}}{T_{sys}} \frac{C_n^2}{z^2}$$

- High temporal resolution
  1. Large aperture
  2. High peak power and high pulse repetition frequency (PRF)
  3. Long wave length
  4. Operation over a range of heights close to the radar
     - High PRF does not cause range ambiguity
     - Atmospheric backscattering are relatively large

User requirement

$$SNR = \text{const} \frac{\overline{P}_t A_e \Delta_z \lambda^{1/6} t_{obs}^{1/2}}{T_{sys}} \frac{C_n^2}{z^2}$$

- High vertical resolution
  - large aperture
  - high peak power, high PRF, and pulse compression to increase the average power
  - long wavelength
  - operation over a range of heights close to the radar where high PRF does not cause range ambiguity problems and where atmospheric backscattering and inverse-height-squared are relatively large

User requirement

$$SNR = \text{const} \frac{\overline{P}_t A_e \Delta_z \lambda^{1/6} t_{obs}^{1/2}}{T_{sys}} \frac{C_n^2}{z^2}$$

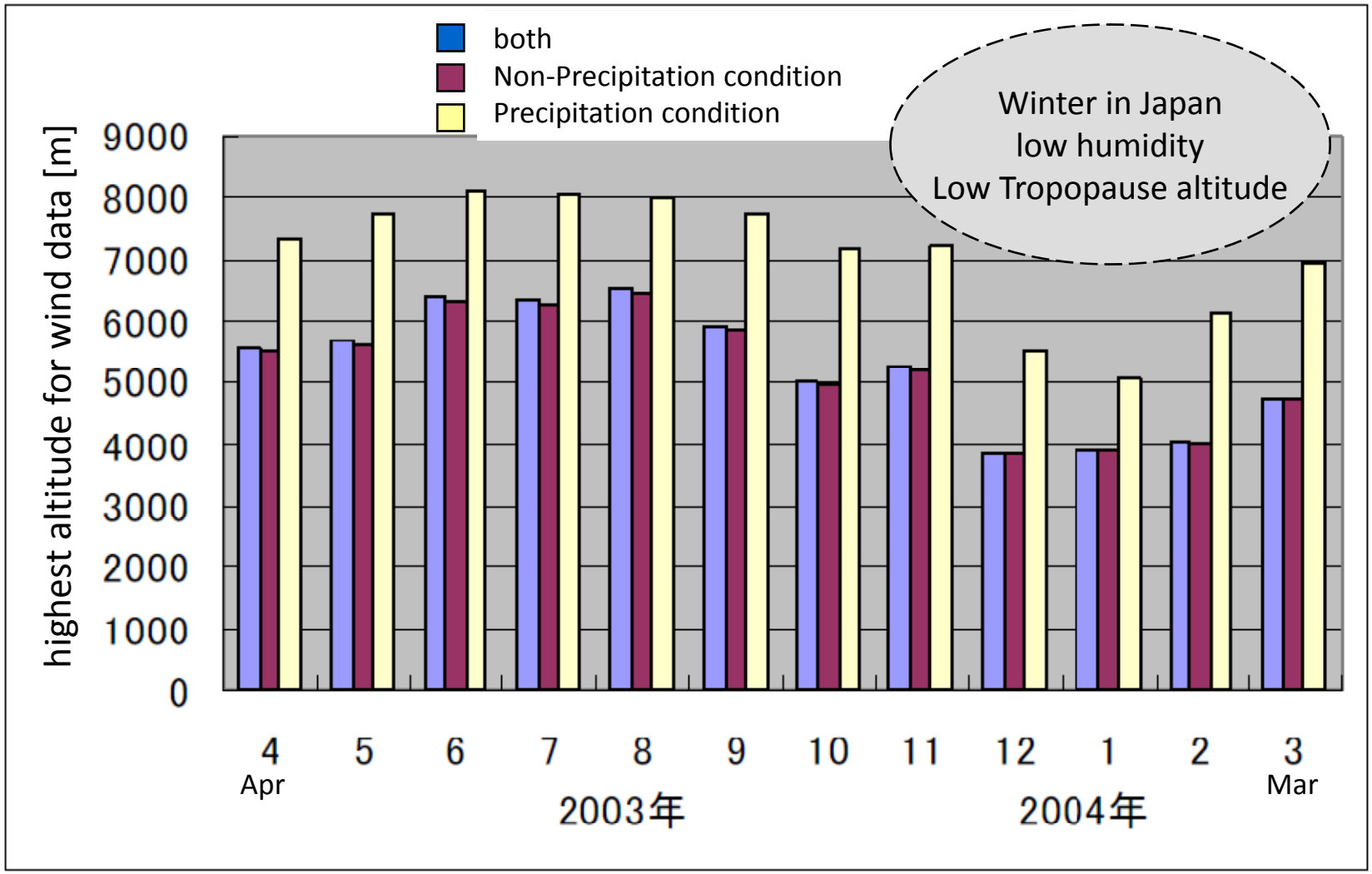
- Obtaining wind data at high altitudes
  - large aperture;
  - high peak power and pulse compression to increase the average power;
  - long wavelength;
  - large averaging times.

User requirement

$$SNR = \text{const} \frac{\overline{P}_t A_e \Delta_z \lambda^{1/6} t_{obs}^{1/2}}{T_{sys}} \frac{C_n^2}{z^2}$$

- Reliable all-weather operation even if low-scatter conditions
  - frequency band;
  - high average power and antenna aperture;
  - higher receiver sensitivity; and
  - low level of interference and system noise.

Monthly average of highest altitude for wind data

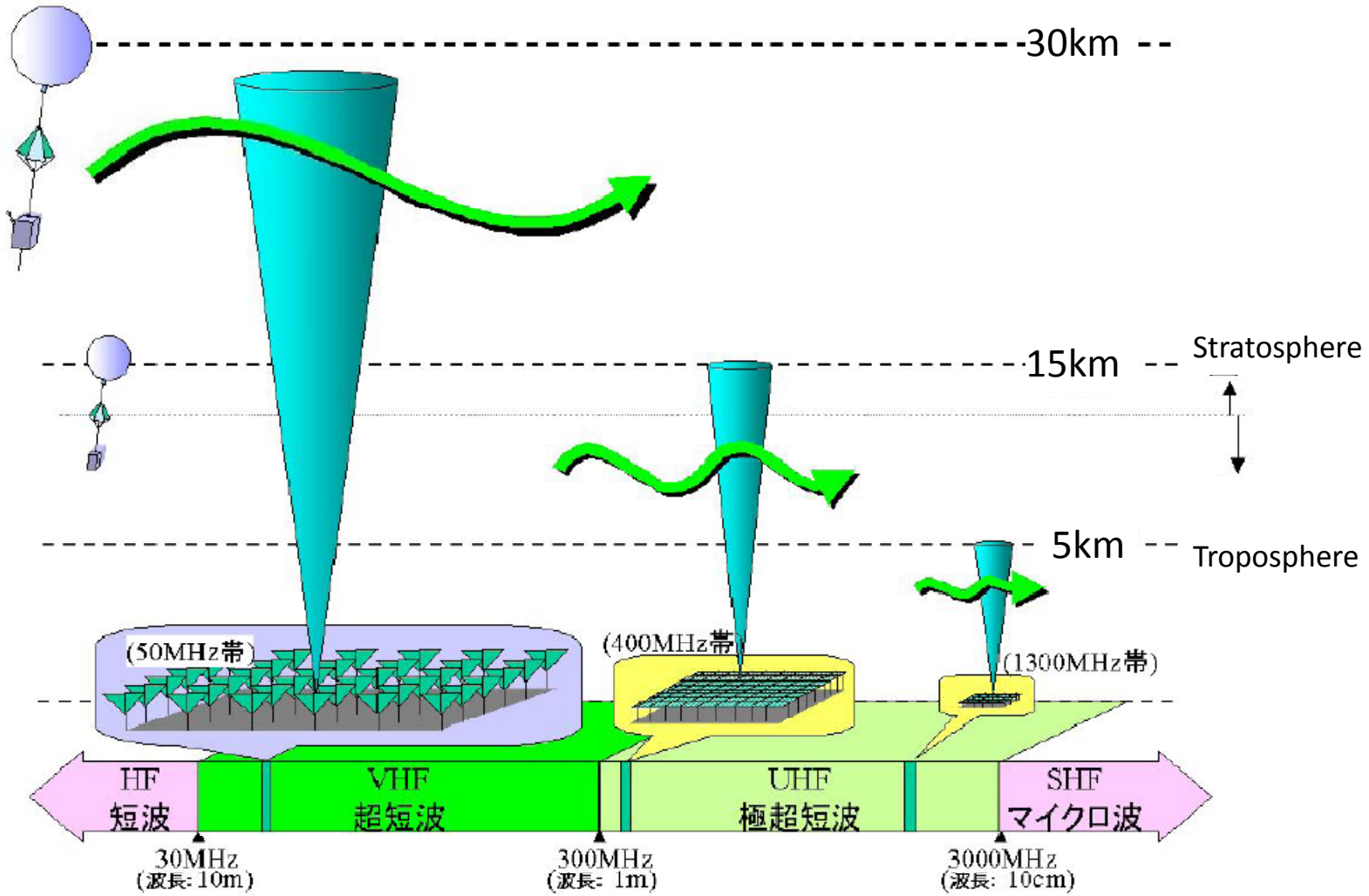


Operational and frequency aspects

- Three types of WPRs

- 50MHz band WPRs
  - Middle and Upper atmosphere radar
- 400MHz band WPRs
- 1000MHz or more band WPRs
  - Boundary layer radar

Comparison 50, 400, 1300MHz



Operational and frequency aspects

- MU radar(50MHz band) is very large, powerful and short pulse
  - About 10 000m^2,
  - 250kW or more peak, 12.5kW or more average
  - Pulse width: 1 microsecond

Operational and frequency aspects

- 400-500MHz Wind profiler have been designed to :
  - Measure wind profiles from about 0.5 - 16km
  - Vertical resolutions:
    - 250m(low altitude)
    - 1000m(high altitude)
  - Antenna gain is about 32dBi,
  - Mean power of:
    - about 500W(low altitude)
    - About 2000W(high altitude)
  - Necessary bandwidth of less than 2MHz

Operational and frequency aspects

- 915MHz and 1270-1375MHz Wind profiler have been designed to : boundary layer profiler,
  - Measure wind profiles up to about 5km
  - Vertical resolutions are about 100m
  - Antenna gain is below 30dBi,
  - Mean powers of about 50W
  - Necessary bandwidths of 8MHz or more

spectrum requirements

- Geographical separation and terrain shielding are effective protection against interference to and from other profilers.
- Hence, an affordable network of wind profilers, say separated by at least 50 km over level terrain – less over more rugged or treed terrain – could operate on the same frequency.

spectrum requirements

- It is generally agreed that 2 to 3 MHz of bandwidth are required near 400 MHz and 8 to 10 MHz near 1 000 MHz or 1 300 MHz

Sharing aspects of wind profilers

- The bands for profiler use allocated by WRC-97 were carefully selected to minimize the likelihood of interference to and from other users of these bands.

- 46-68 MHz in accordance with No. 5.162A
- 440-450 MHz
- 470-494 MHz in accordance with No. 5.291A
- 904-928 MHz in Region 2 only
- 1 270-1 295 MHz
- 1 300-1 375 MHz

An example of a WPR network

- The Japan Meteorological Agency (JMA) is operating a Wind profiler Network and Data Acquisition System (WINDAS) network.
- Consist of thirty-one 1.3GHz wind profiler

WINDAS

- Purpose of WINDAS
  - Monitoring and Predicting the severe weather
  - Initial value of JMA Numerical Weather Prediction models
  - Combined with another data to comprehensive Upper-air wind analysis

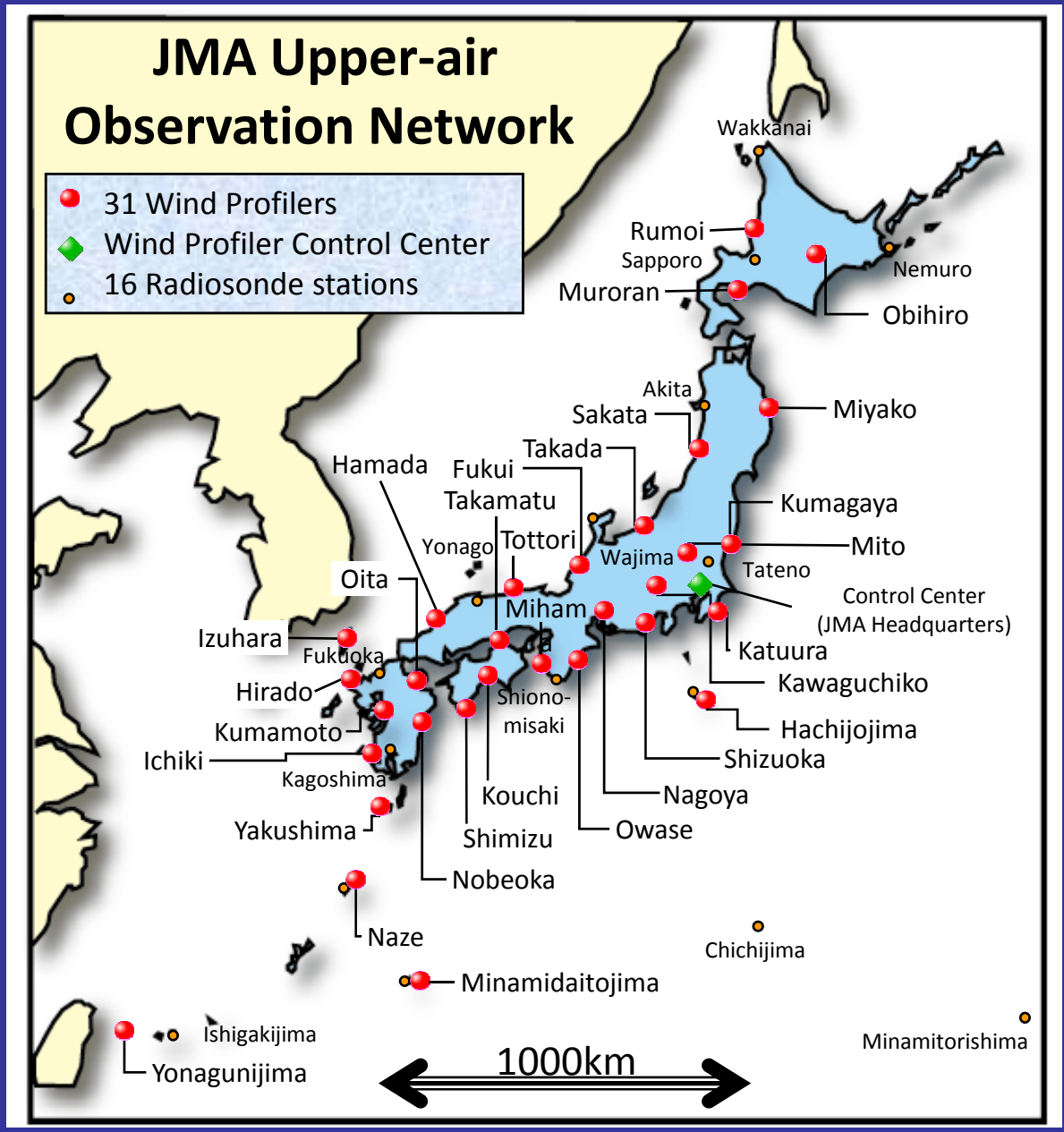
PRINCÍPIOS DE RADAR

WINDAS

Wind Profiler Network and Data Acquisition System

Prof. Oswaldo Massambani – Departamento Ciências Atmosféricas - Universidade de São Paulo – Brasil

PRINCÍPIOS DE RADAR



JMA upper-air observation network consisting of rawinsonde stations and wind profilers of WINDAS.

Upper-wind observations are made at the interval of about 120km.

Data Flow in WINDAS

WINDAS

Profiler 1

Profiler 2

Profiler 3

• • •

• •

Profiler 3 0

Profiler 3 1

10 minute values of Doppler velocity and signal intensity being sent every 1 hour

CONTROL CENTER (JMA Headquarters)

Data quality control and remote control of profilers being made

Horizontal and vertical components of wind and signal intensity being sent with BUFR code every 1 hour

COSMETS (JMA Central Computer)

NAPS

ADESS

Ever y 6 hours

Ever y 1 hour

10 minute data being sent every 1 hour

Forecast made with Mesoscale Model

Hourly analyzed atmospheric GPV

Wind profiler data

Appearance

General structure
(Kagoshima: Department observed Ichiki)

Snow-covered area
(Hokkaido: Department observed Obihiro)

Major equipment and signal flow

PRINCÍPI

Module Unit

Antenna System

Transmitter and Receiver System

Data Processer

CONTROL CENTER

Block Diagram of the JMA Wind Profiler Network (WINDAS)

Characteristics of the JMA Wind Profiler

Parameter	Characteristics of WINDAS
Antenna type	Active phased array
Antenna size	4 m x 4 m
Antenna gain	33 dBi
Antenna beam width	4 degree (both elevation and azimuth direction)
Antenna scan	Vertical and four directions (elevation angle 75-80 degree) - These four directions make a right angle. The beam direction changes to another every about 0.4 seconds.
Frequency	1357.5 MHz
Peak power	1.8 kW
Pulse width	0.67, 1.33, 2.00, 4.00 microseconds (selectable)
Pulse repetition frequency (PRF)	5, 10, 15, 20 kHz (selectable)
Pulse compression	8 bit
Observation range	300m – about 5 km in height
Observation interval	10 minutes (0.4 s x 5 beams x 28 times x 10 data of 1min)

Data Quality Control

W P R Receiver

W P R Signal Processor

F F T / Wavelet White Noise Rejection

Ground Clutter

Rejection line Spectra Rejection

Multi-Peak Processing

Spectrum Data

1 Min. Doppler Velocity

W P R Data Processor

Receiving Power Check

Spectrum Width Check

Velocity Unfolding

Time-Height Check

10 Min. U,V,W

Network Center

Horizontal Buddy Check

Surface Wind Check

Quadratic Surface Check

Vertical Shear Check

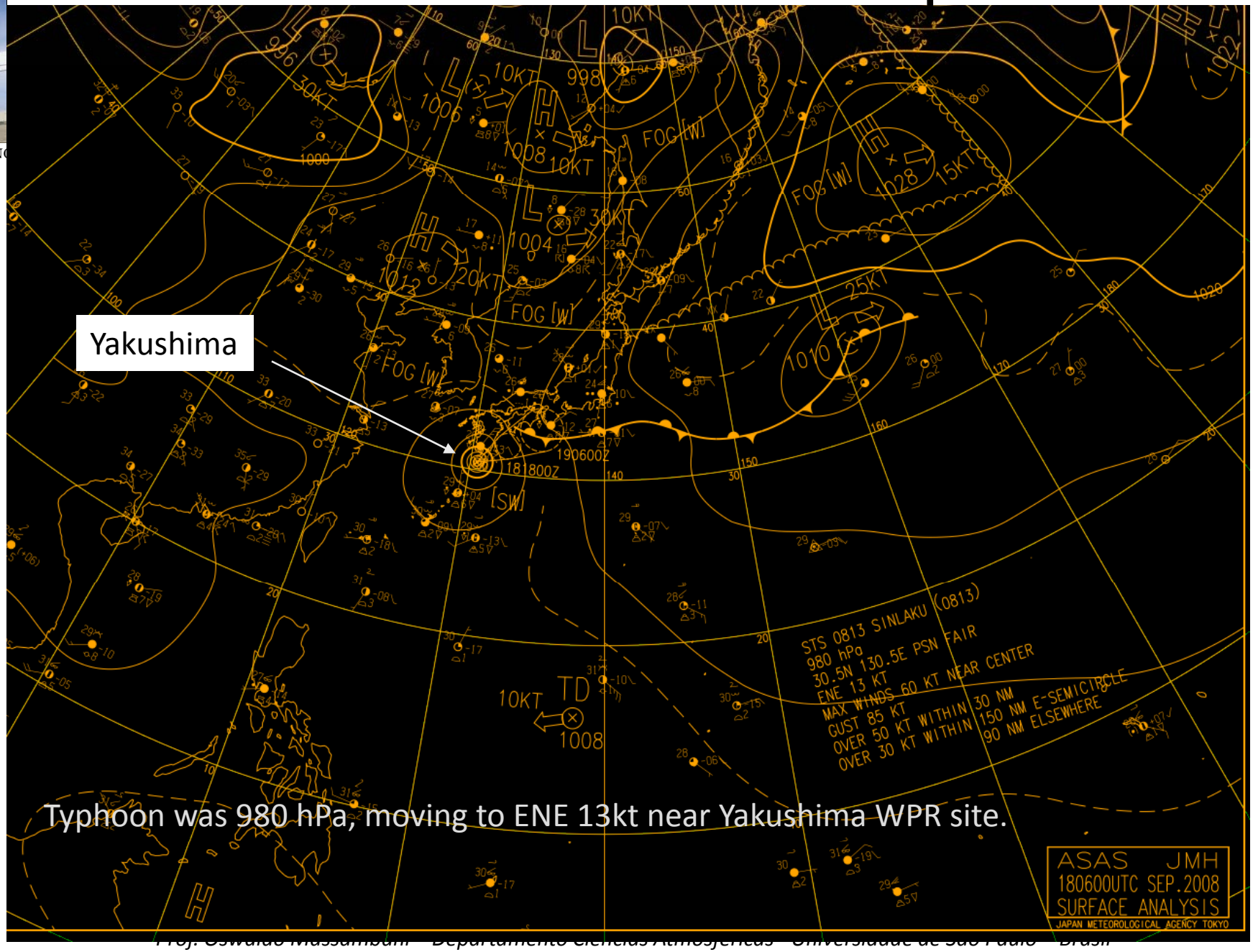
Development of QC Algorithm

10 Min. U,V,W

JMA Central Computer

Example of data

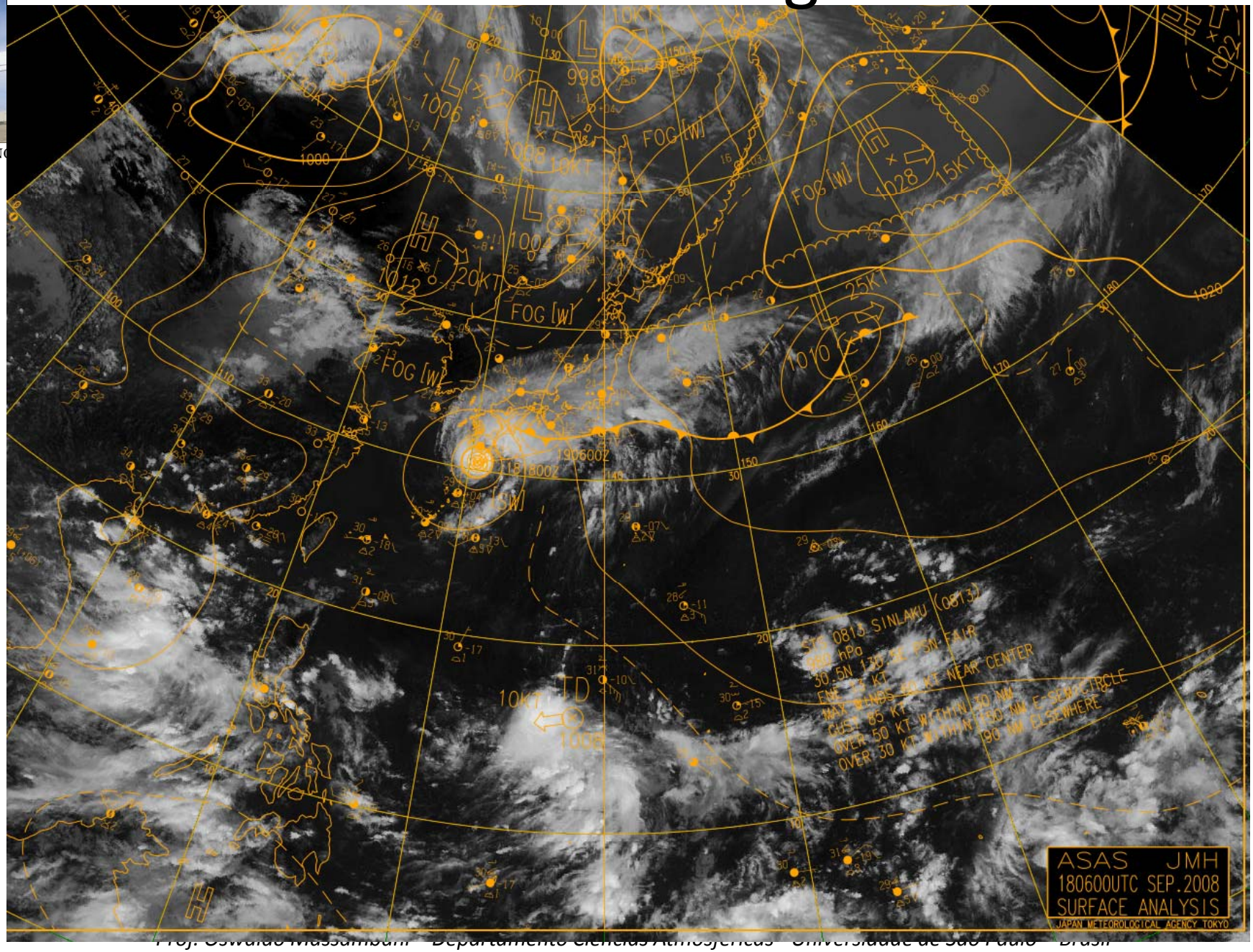
Surface weather map



Typhoon was 980 hPa, moving to ENE 13kt near Yakushima WPR site.

Satellite image

PRINC



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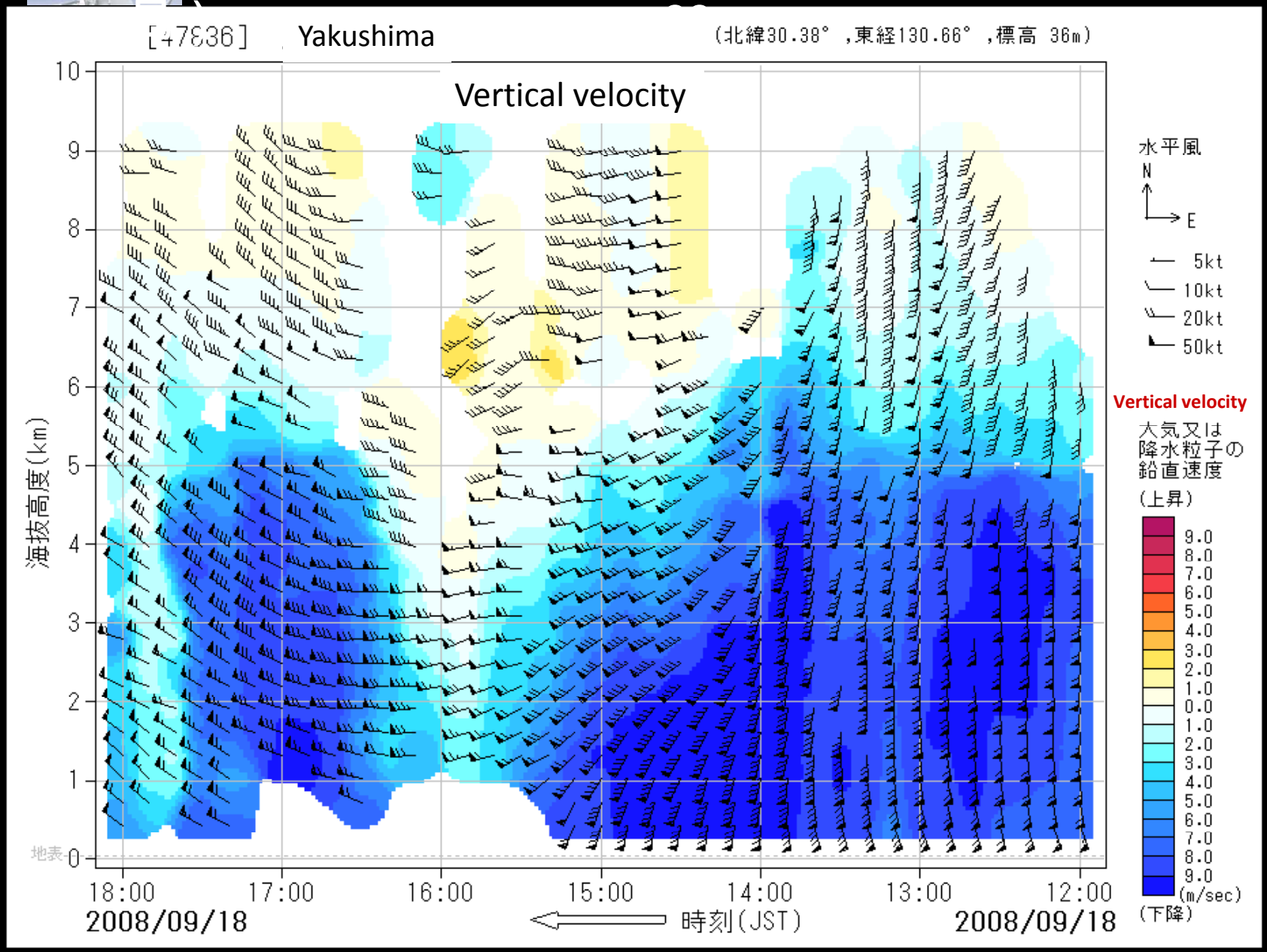

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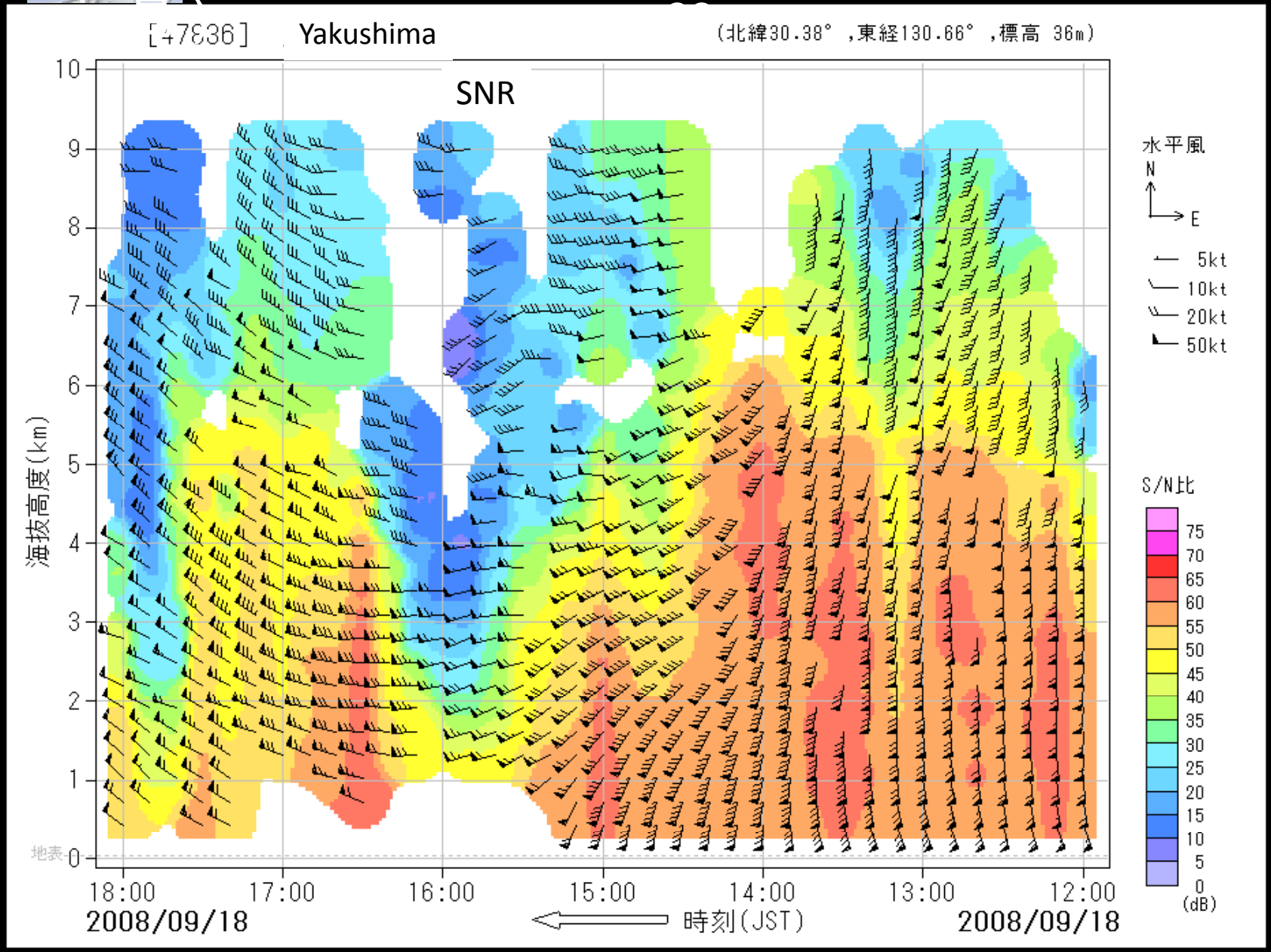

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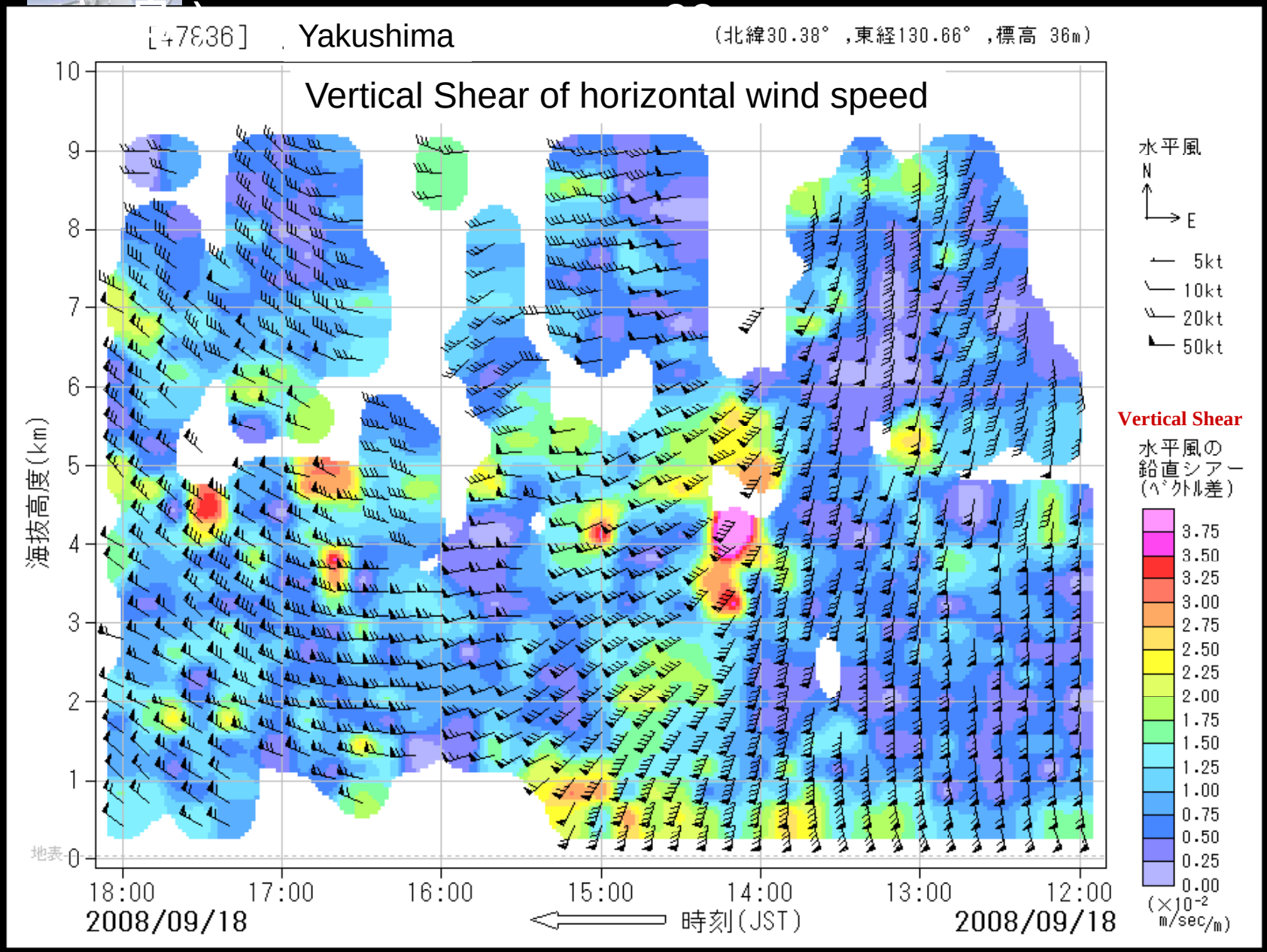

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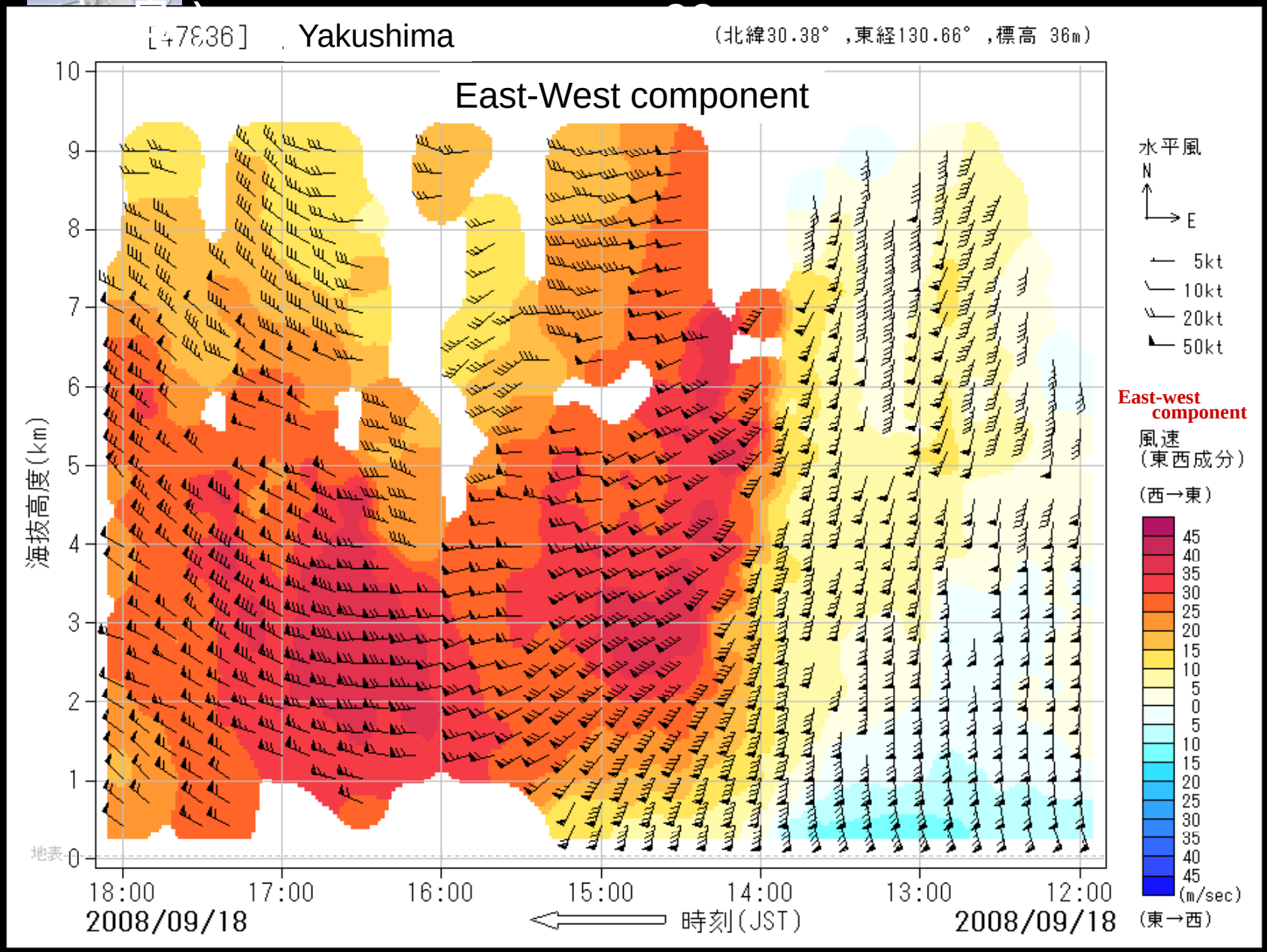

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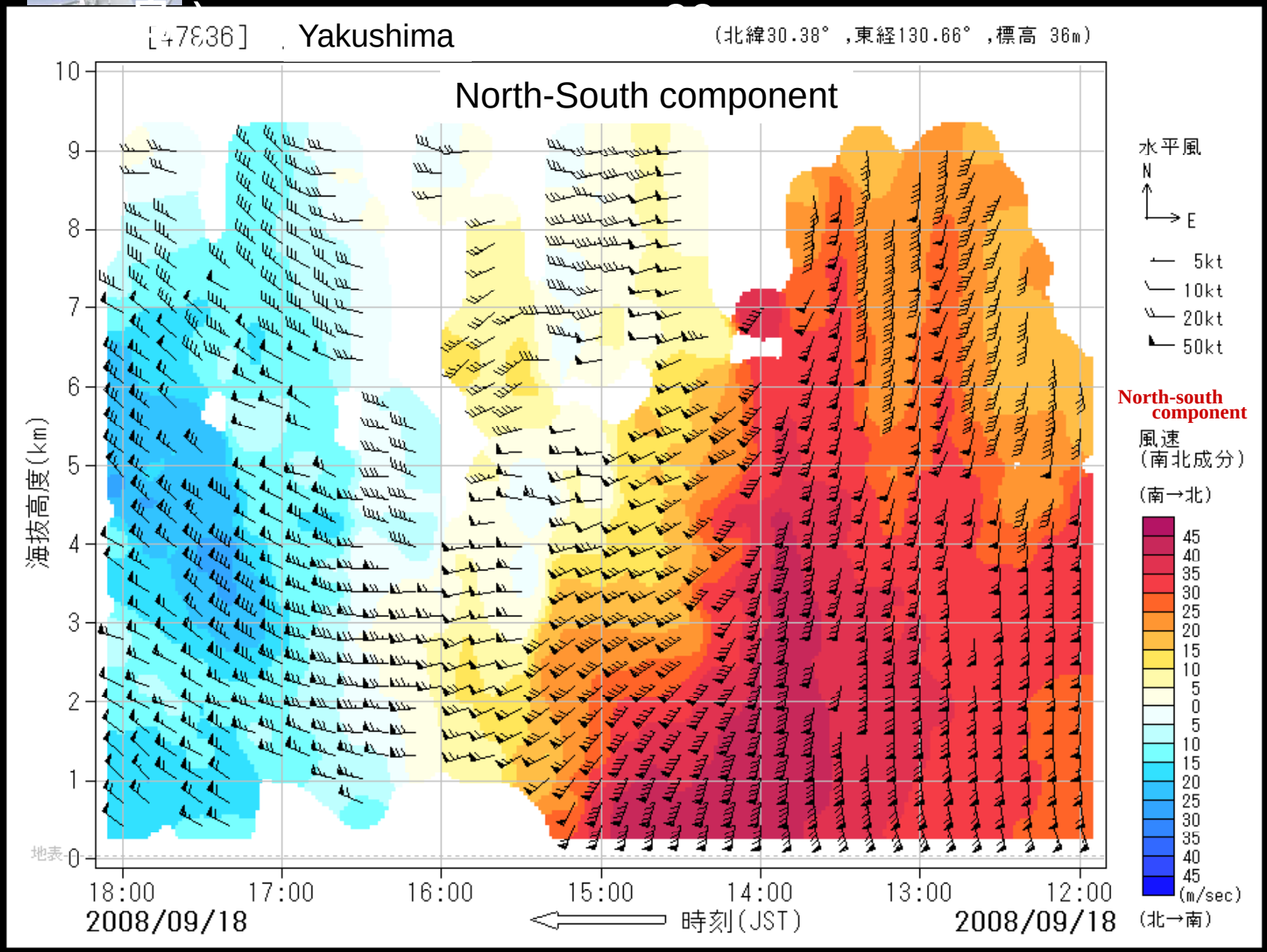

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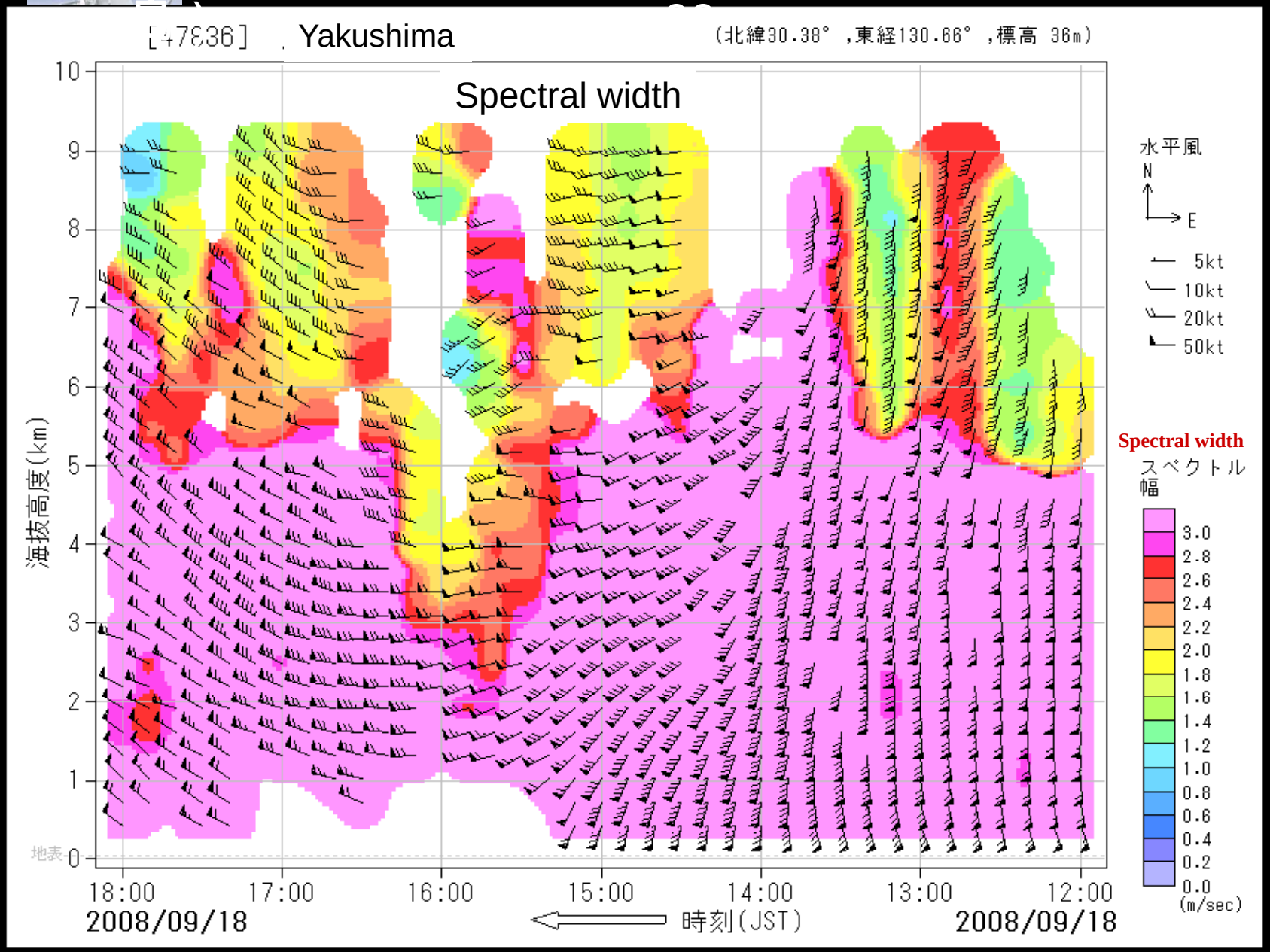

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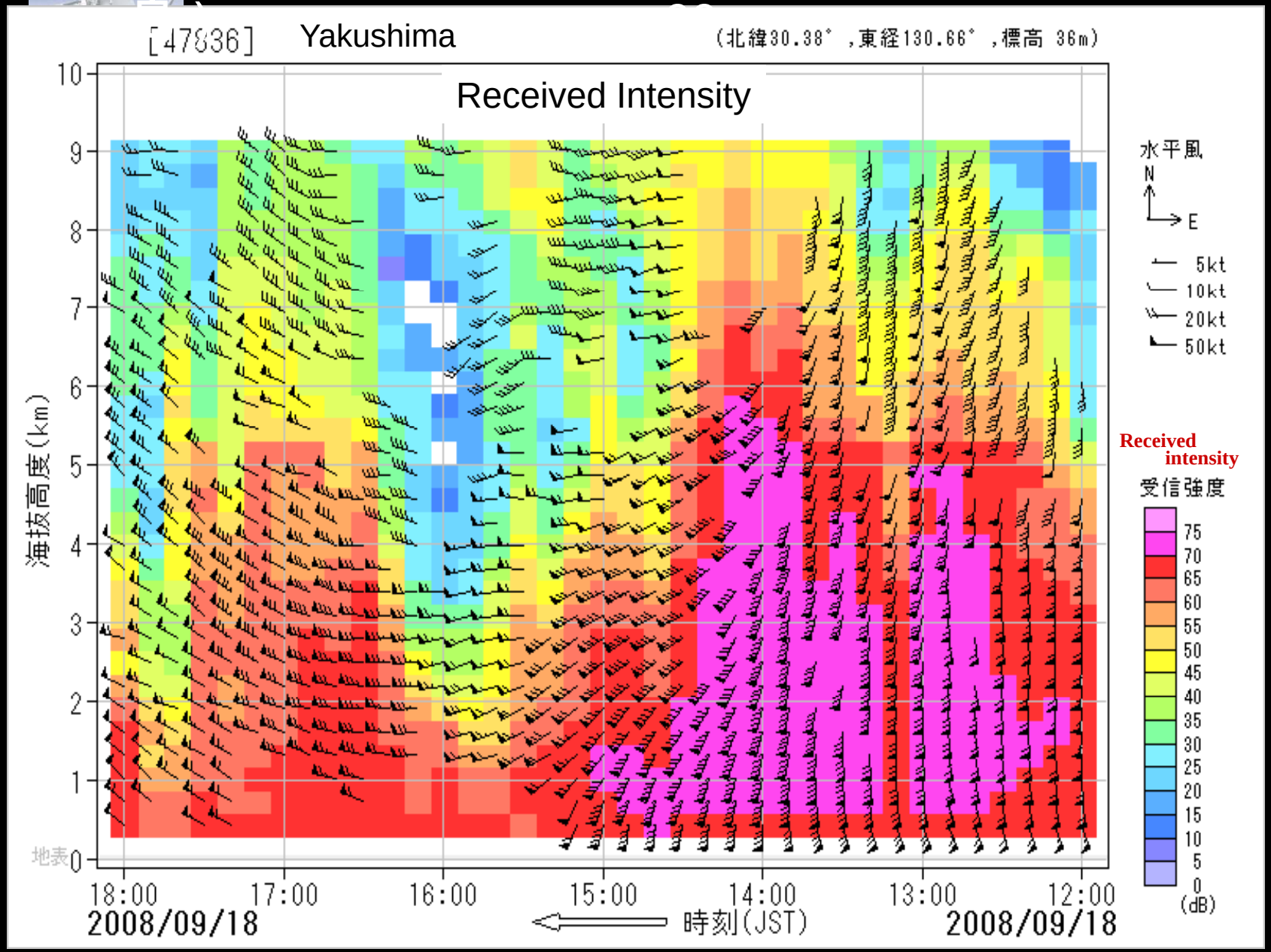

SUMMARY

- WPRs are used to obtain the upper-air wind and other useful data continuously.
- WPRs contains various type, and they use 50MHz band , 400-500MHz band or 900-1400MHz band.
- In Japan, data of WPRs are used in various scenes, and very useful.

Sucesso para cada um de vocês !

Obrigado !

Prof. Oswaldo Massambani