WEATHER RADAR
OPERATION & MAINTENANCE

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INTRODUCTION

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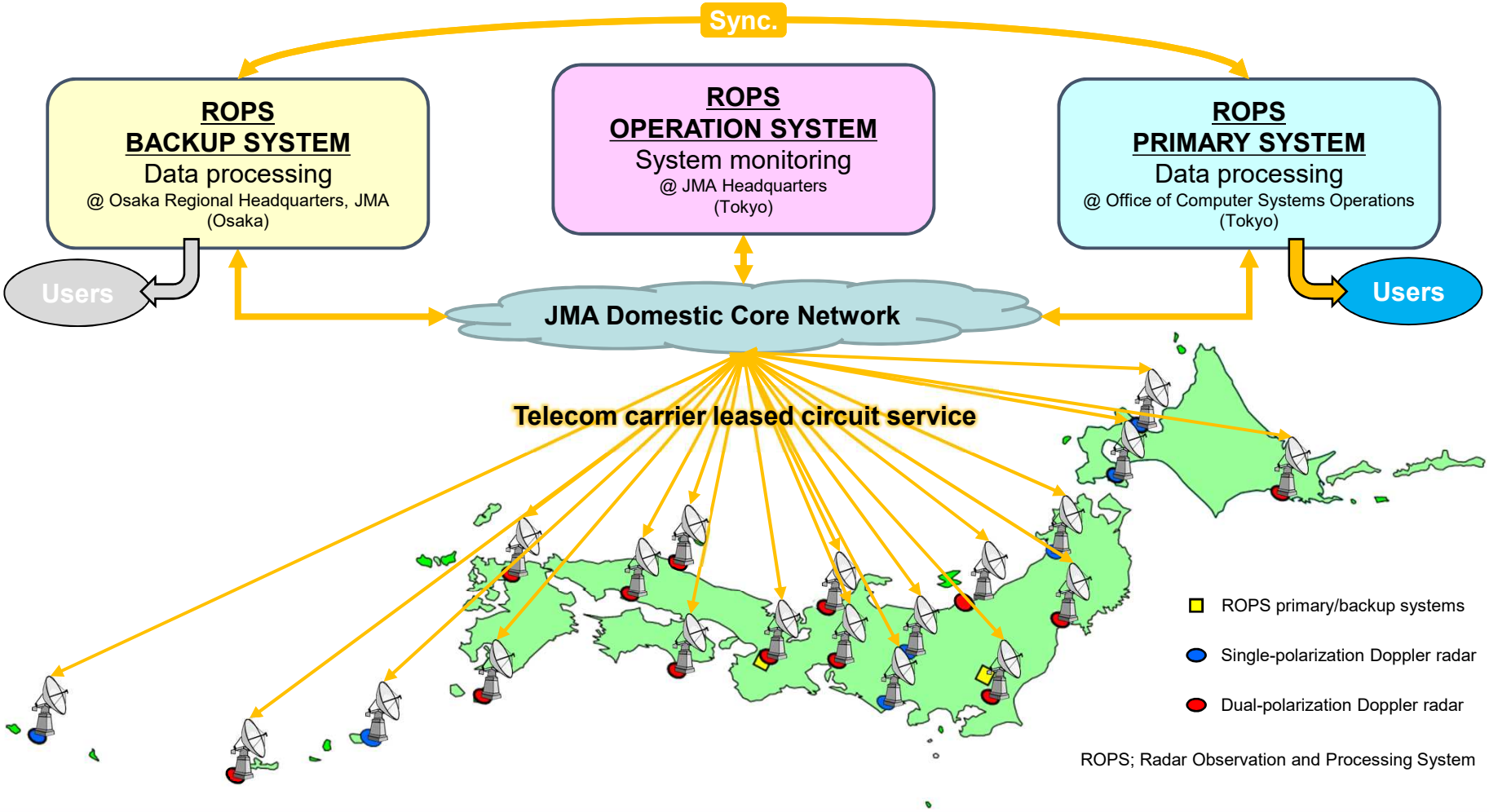
Overview of Weather Radar Observation

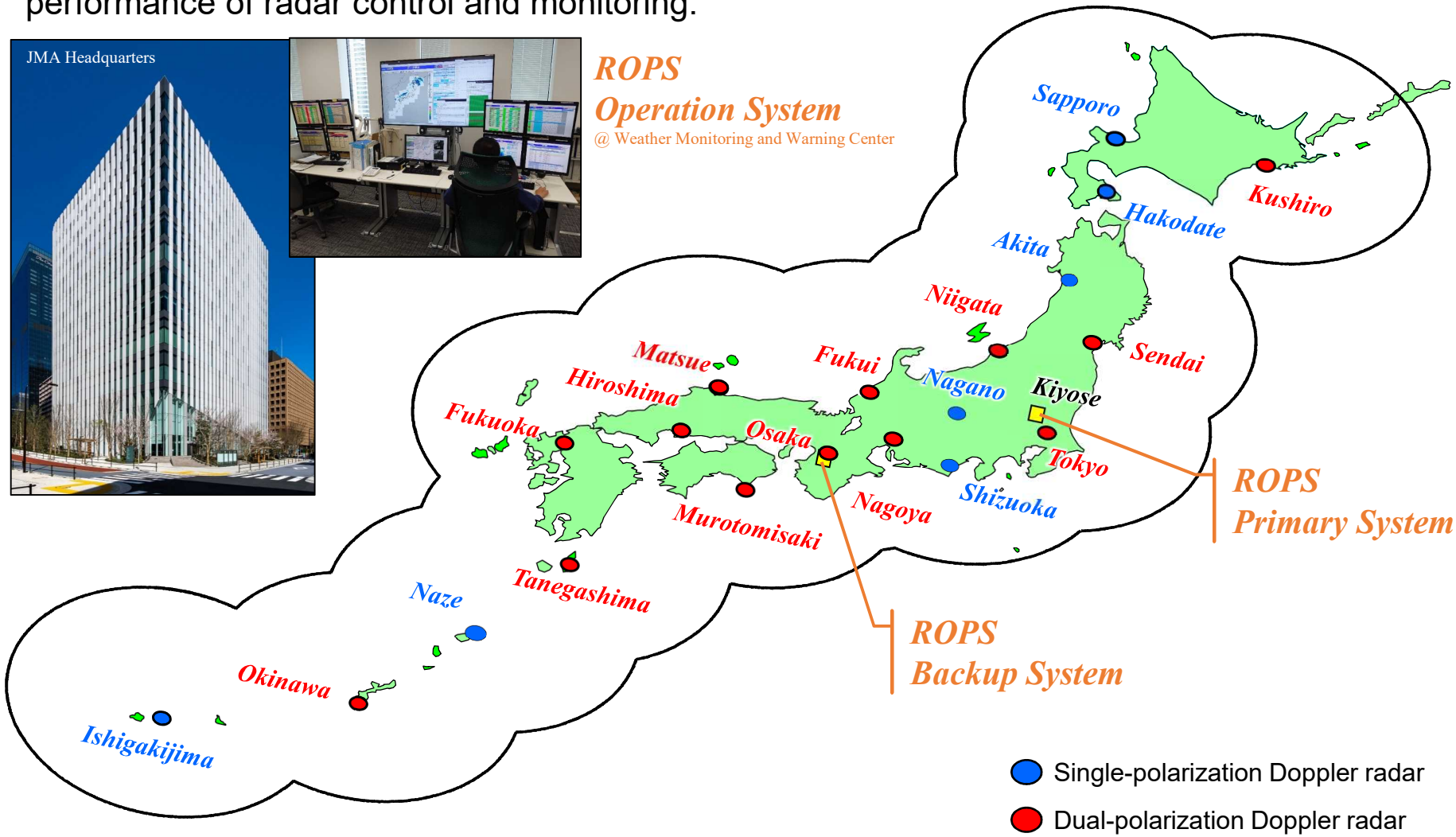
- The Japan Meteorological Agency (JMA) observes precipitation distribution throughout Japan using 20 Doppler radars.
- Radar observation data are sent to ROPS via JMA Domestic Core Network.
- The Tokyo operation center monitors the system as a whole.
- An Osaka-based backup system is used in the event of primary-system abnormalities.



ROPS (Radar Observation and Processing System)

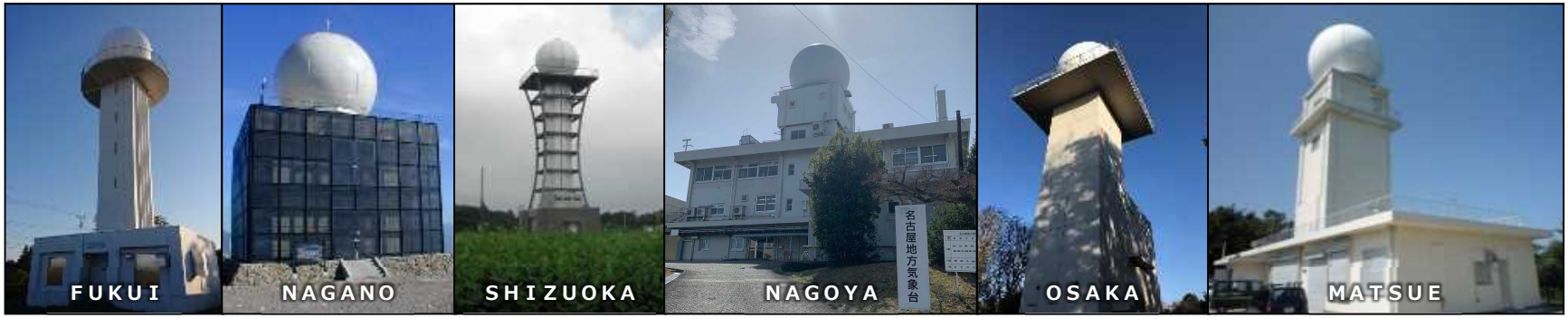
ROPS (consisting of primary, operation and backup systems) is a core facility used to collect data from all JMA radar observation sites, along with other information such as rain gauge recordings, to create various products for users and other systems. It supports JMA's remote performance of radar control and monitoring.

ROPS
Operation System
@ Weather Monitoring and Warning Center



JMA Weather Radar Sites

Photographed by Japan Radio Co., Ltd.



Sites are chosen with focus on high-altitude environments and elevated antennas to prevent radio-wave blocking. They are free-standing and uninhabited, except those at the radar-managing local offices in Akita, Sendai and Nagoya.

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New Weather Radars

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For accurate rainfall observation and cumulonimbus monitoring…

- Dual-polarization Doppler radar (adopted by JMA since 2020).
- Use of solid-state power amplifiers (SSPAs) in the transmitter of new weather radars to obtain high cost-performance.

Dual-polarization Doppler radar

- Accurate estimation of precipitation intensity without rain gauge correction
- Classification of precipitation particle types
- Enhanced observation data quality based on capacity to distinguish between precipitation particles and others

Solid-State Power Amplifiers (SSPAs)

- Safe, durable and economical
- Contribution to high-speed, high-precision radar observation
- Efficient use of radio wave resources

Dual-polarization Doppler radar

Benefits of dual-polarization data

- Ability for determination of precipitation intensity
- Capacity for hydrometeor classification
- Support for quality control

Precipitation particle

Vertical wave

Horizontal wave

Transmit

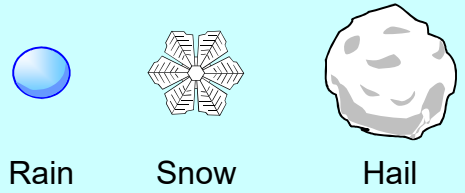
Receive

Dual-polarization Doppler radar

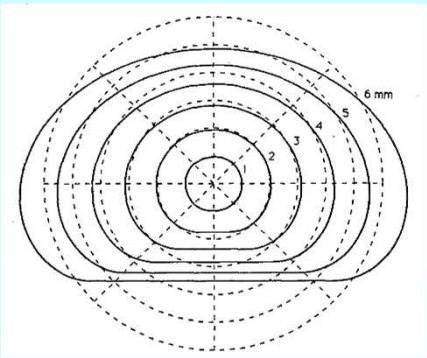
Amplitude ratio → Particle shape
Differential reflectivity: Z_{DR}

Phase shift → Precipitation intensity (Not affected by rain attenuation)
Differential phase: Φ_{DP}, Specific differential phase: K_{DP}

Precipitation particle types



Raindrop shapes



Beard K. V., and Chuang C. 1987: A new model for the equilibrium of raindrops, *J. Atmos. Sci.*, **44**, 1509-1524.

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ROPS

Radar Observation and Processing System

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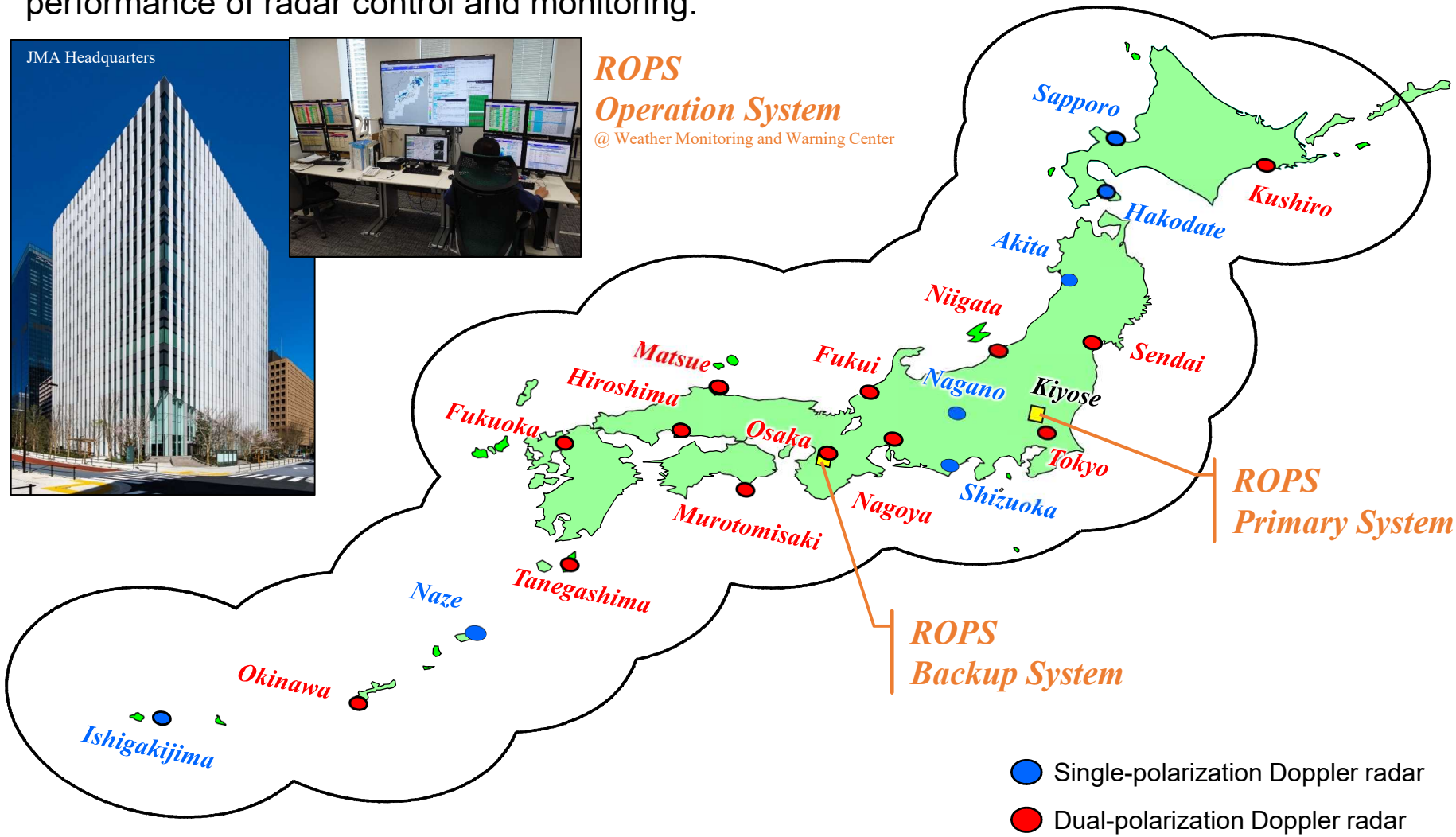

Data path from Weather Radar Sites to ROPS

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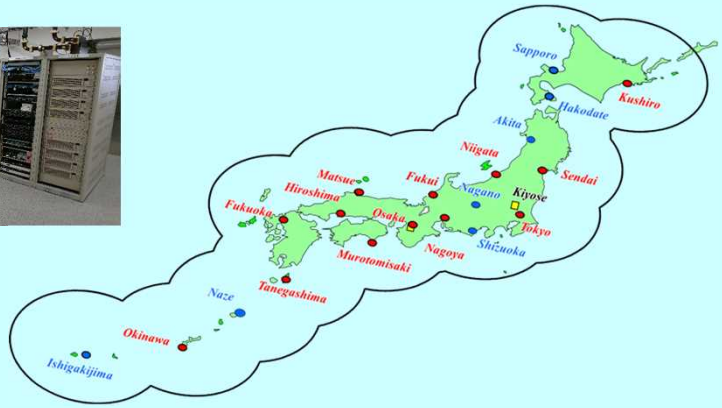
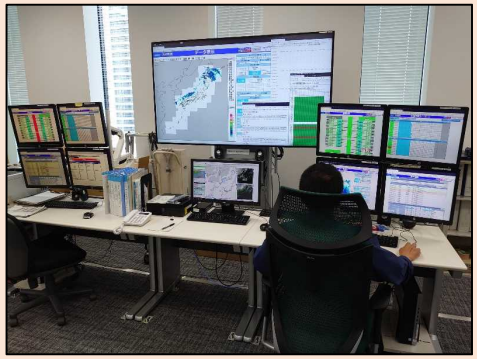
Weather Radar Site



RADAR-MANAGING LOCAL OFFICE

JMA Domestic Core Network



ROPS Operation System

Monitoring for weather radar systems

@ Weather Monitoring and Warning Center

ROPS Primary System

Data processing

@ Office of Computer Systems Operations

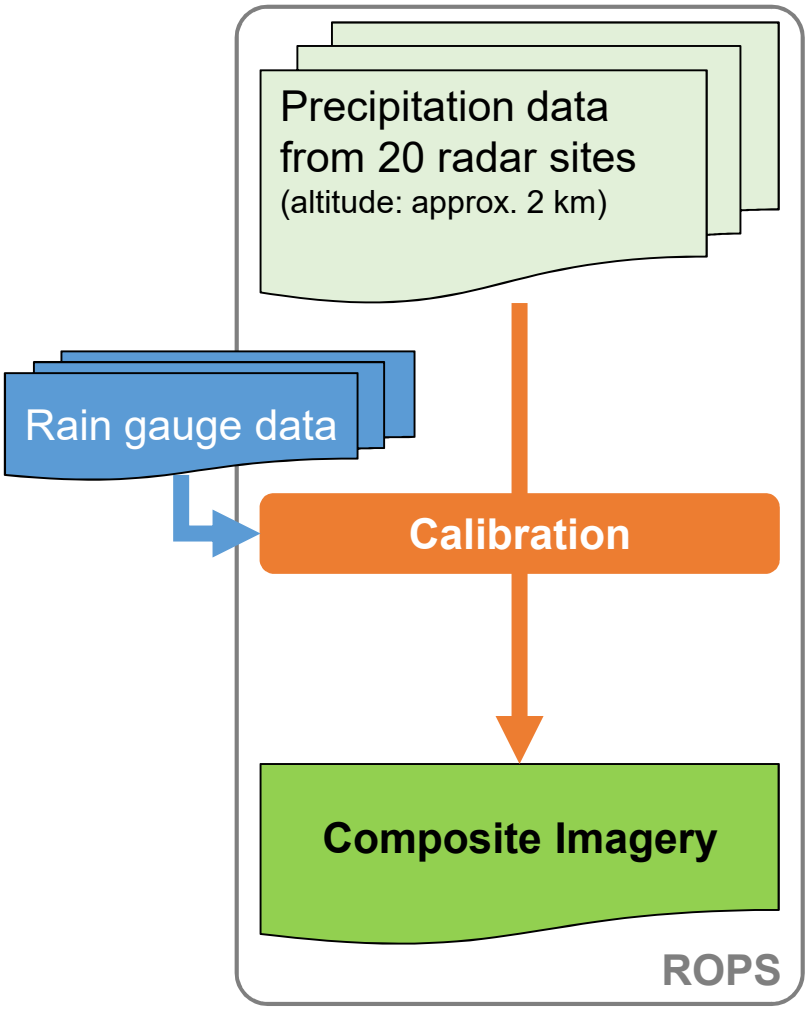
ROPS Backup System

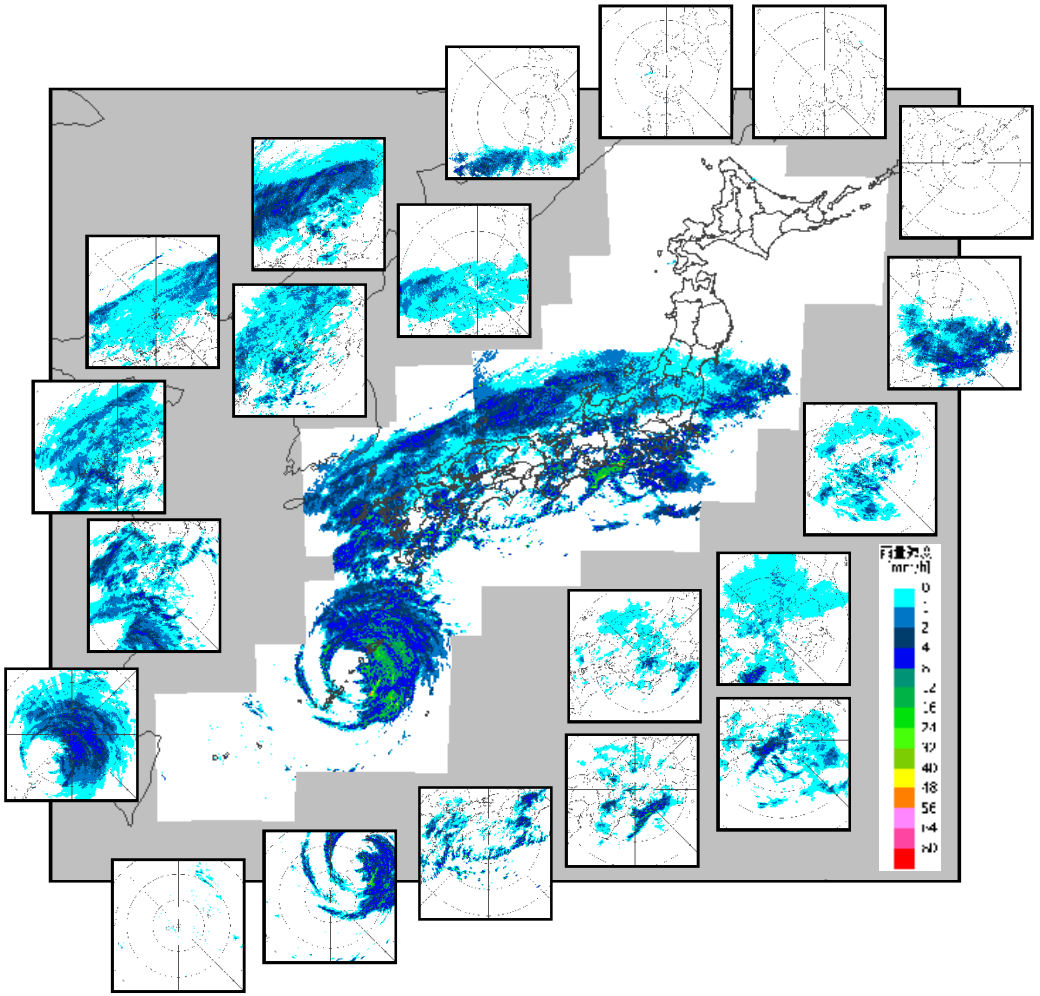
Data processing

@ Osaka Regional Headquarters

Composite Imagery

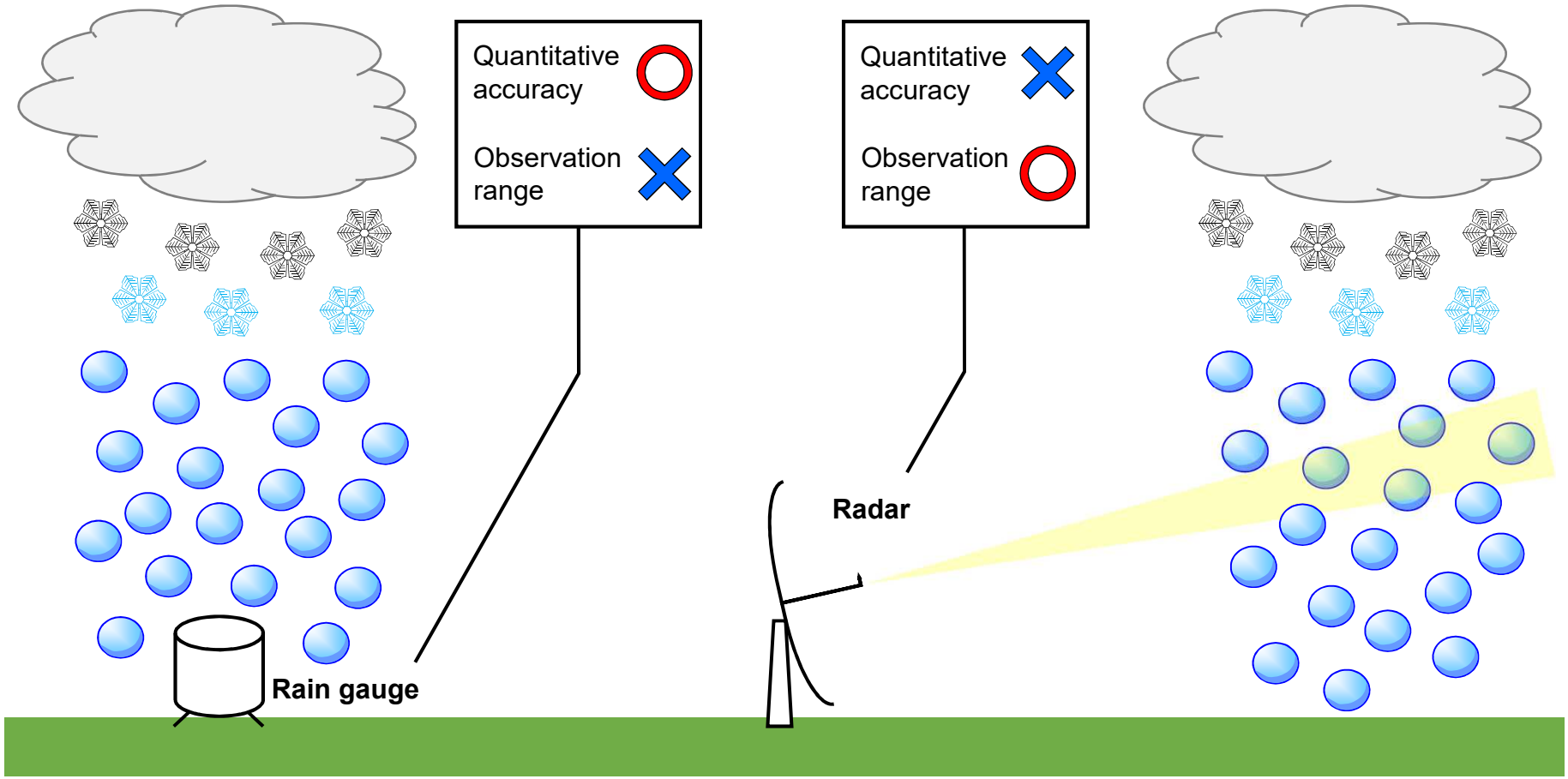
ROPS creates composite imagery using data from 20 JMA radars. The imagery closely represents precipitation at altitudes of around 2 km because the influence of topography is low and wide-range observation is possible. Response to ground conditions is also favorable.





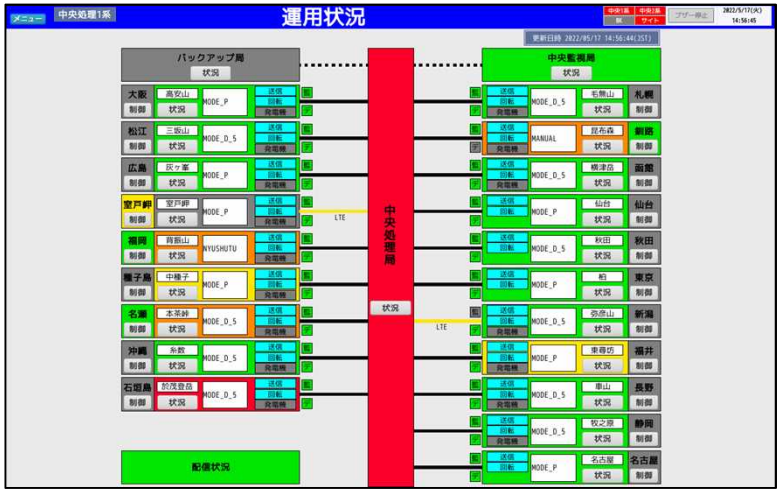
[Ref.] Calibration with Rain Gauge Data

While weather radar allows wide-ranging observation, estimation of precipitation amounts from the resulting data is not as accurate as that from single-point rain gauges. Accordingly, weather radar data are corrected against rain gauge data.



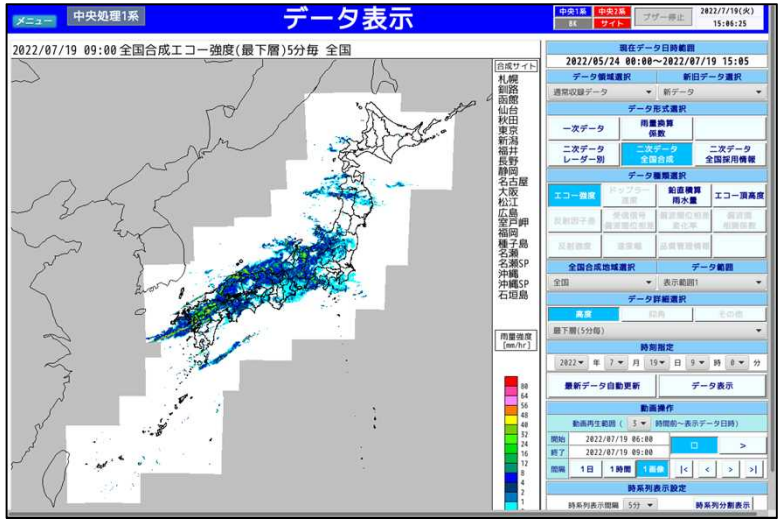
Real-time Monitoring

Weather Monitoring and Warning Center staff remotely monitor individual weather radars and support operation as needed.

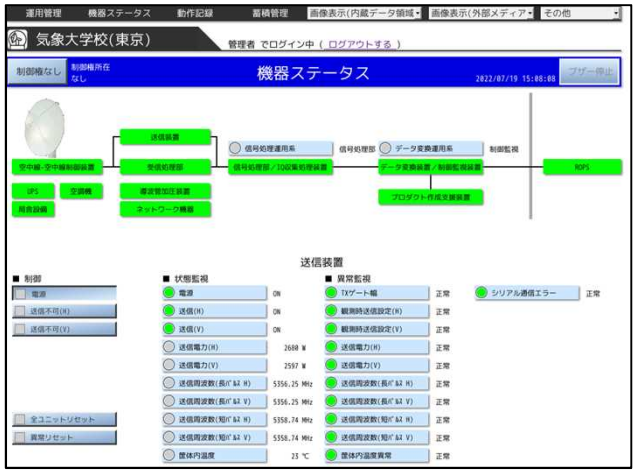


Operation situation

Operation record

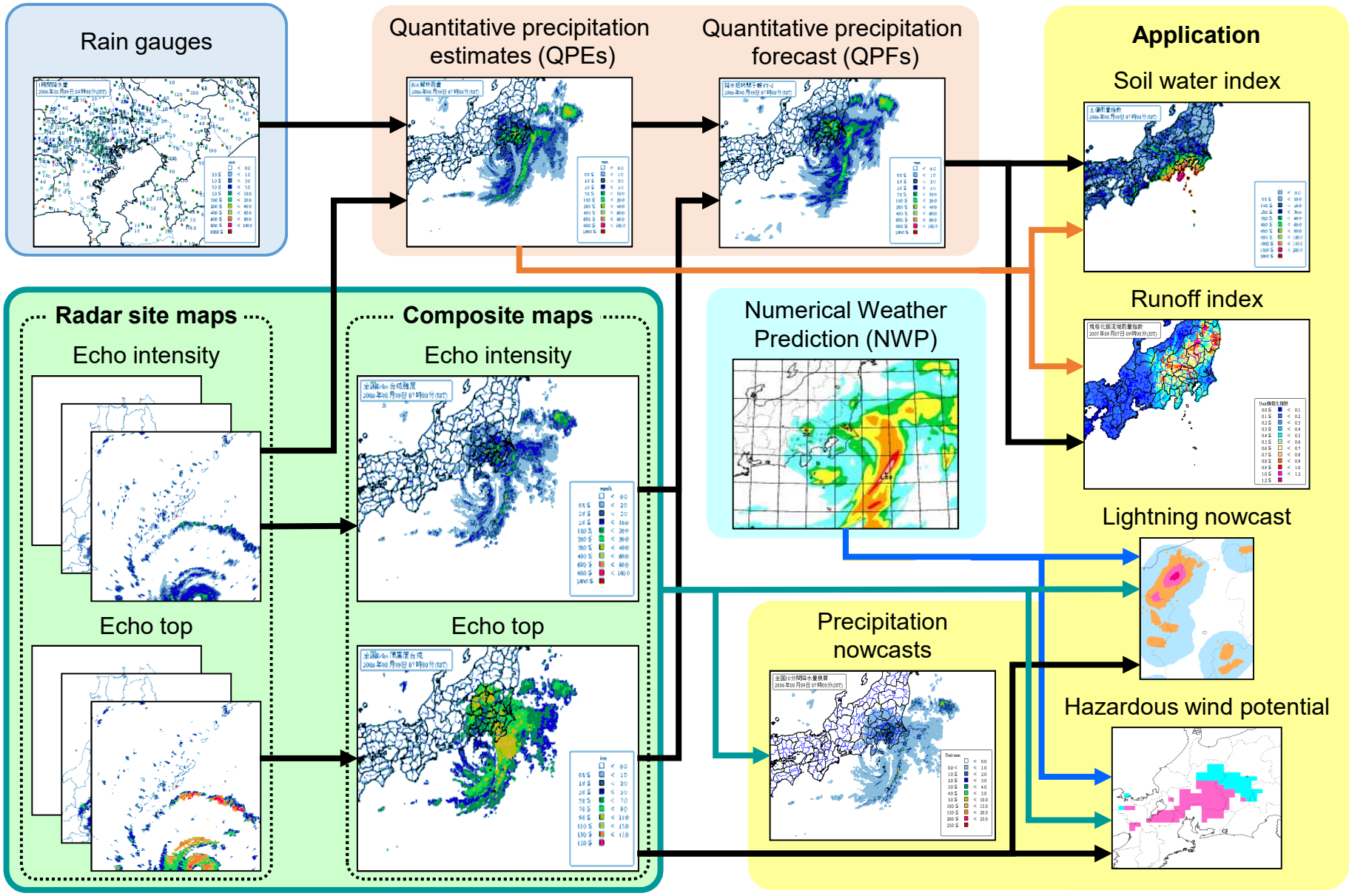


Observation data display



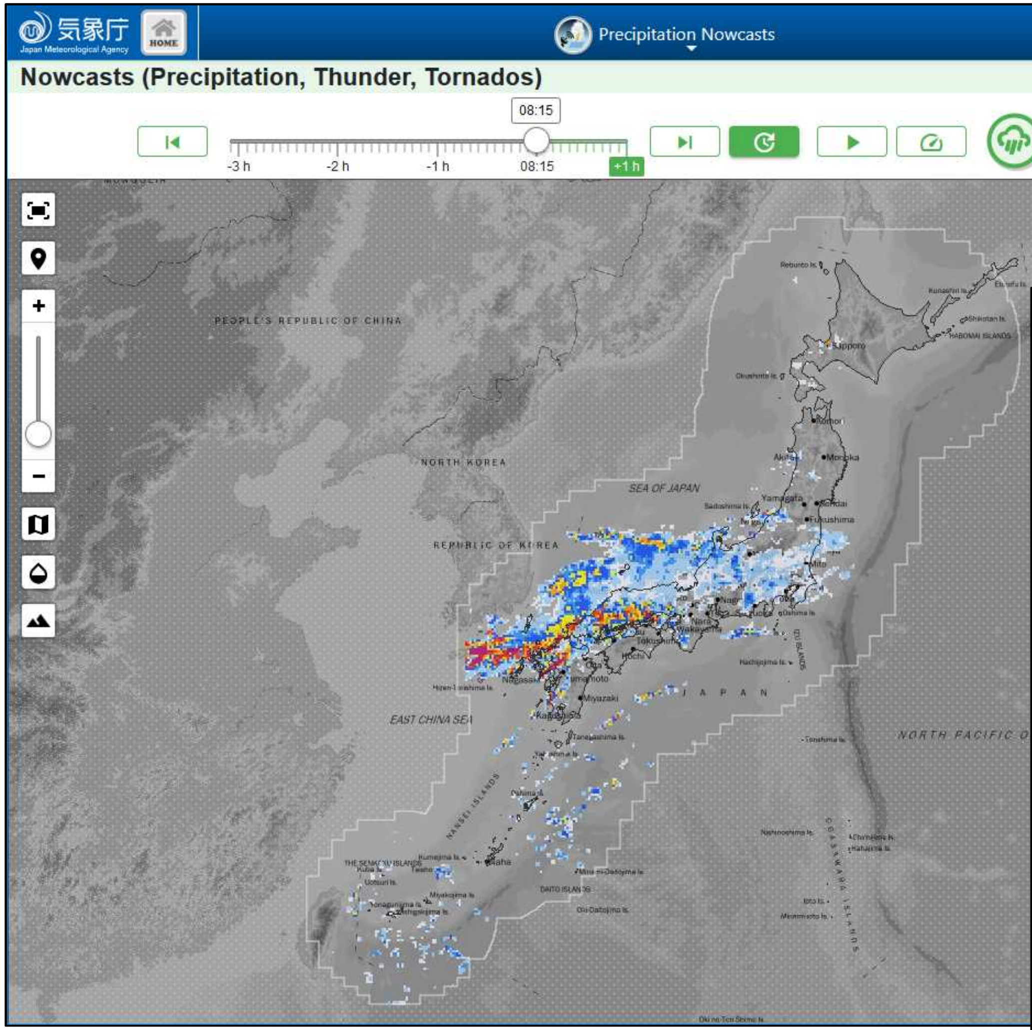
Operation screen for individual radars

Radar data flow diagram



Website

Precipitation information from 20 radar sites is published on JMA's website in real time along with operational information.



レーダー運用情報

年	2022																																					年
月	08																																					月
日	17																																					日
時	08			07													06												05									時
分	10	05	00	55	50	45	40	35	30	25	20	15	10	05	00	55	50	45	40	35	30	25	20	15	10	05	00	55	50	45	40	35	30	25	20	15	10	分
札幌	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	札幌
釧路	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	釧路
函館	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	函館
仙台	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	仙台
秋田	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	秋田
東京	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	東京
新潟	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	新潟
福井	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	福井
長野	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	長野
静岡	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	静岡
名古屋	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	名古屋
大阪	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	大阪
松江	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	松江
広島	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	広島
室戸岬	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	室戸岬
福岡	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	福岡
種子島	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	種子島
名瀬	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	名瀬
沖縄	x	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	沖縄
石垣島	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	石垣島

o: 運用, x: 休止.

Precipitation nowcasts (https://www.jma.go.jp/bosai/en_nowc/)

Radar operation (https://www.jma.go.jp/bosai/radar_operation/)

Details… https://www.jma.go.jp/jma/en/Activities/highres_nowcast.html

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NEW WEATHER RADARS

New Weather Radars

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For accurate rainfall observation and cumulonimbus monitoring…

- Dual-polarization Doppler radar (adopted by JMA since 2020).
- Use of solid-state power amplifiers (SSPAs) in the transmitter of new weather radars to obtain high cost-performance.

Dual-polarization Doppler radars

- Accurate estimation of precipitation intensity without rain gauge correction
- Classification of precipitation particle types
- Enhanced observation data quality based on capacity to distinguish between precipitation particles and others

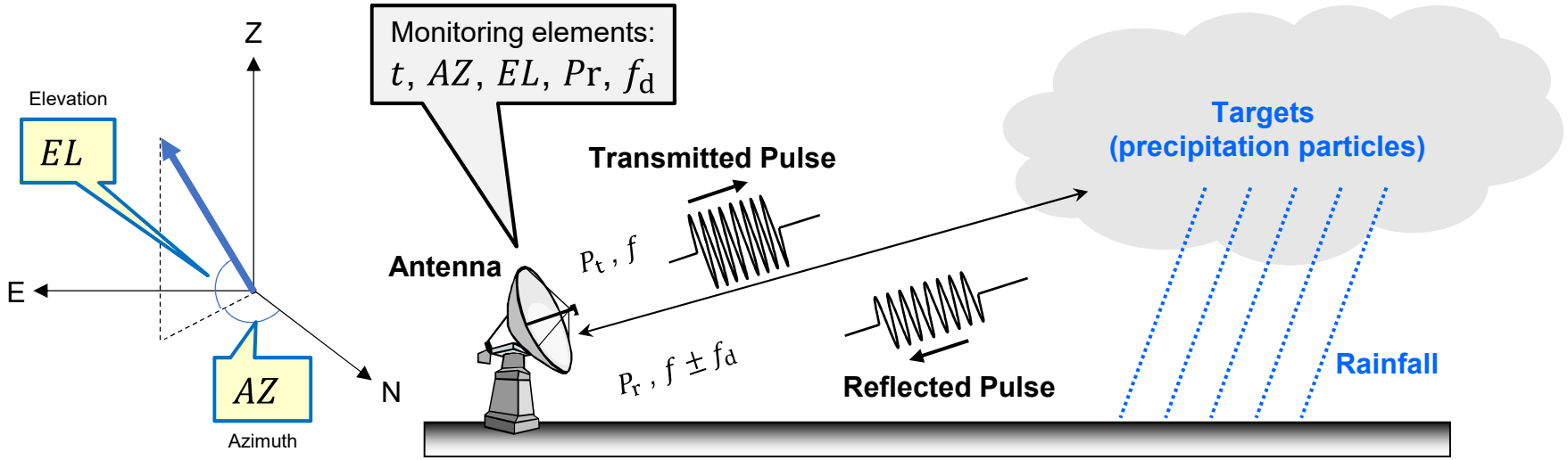
Solid-State Power Amplifiers (SSPAs)

- Safe, durable and economical
- Contribution to high-speed, high-precision radar observation
- Efficient use of radio wave resources

WEATHER RADAR

The rotating antennas of weather radar units emit micro radio waves to observe precipitation intensity over an area with a radius of several hundred kilometers.

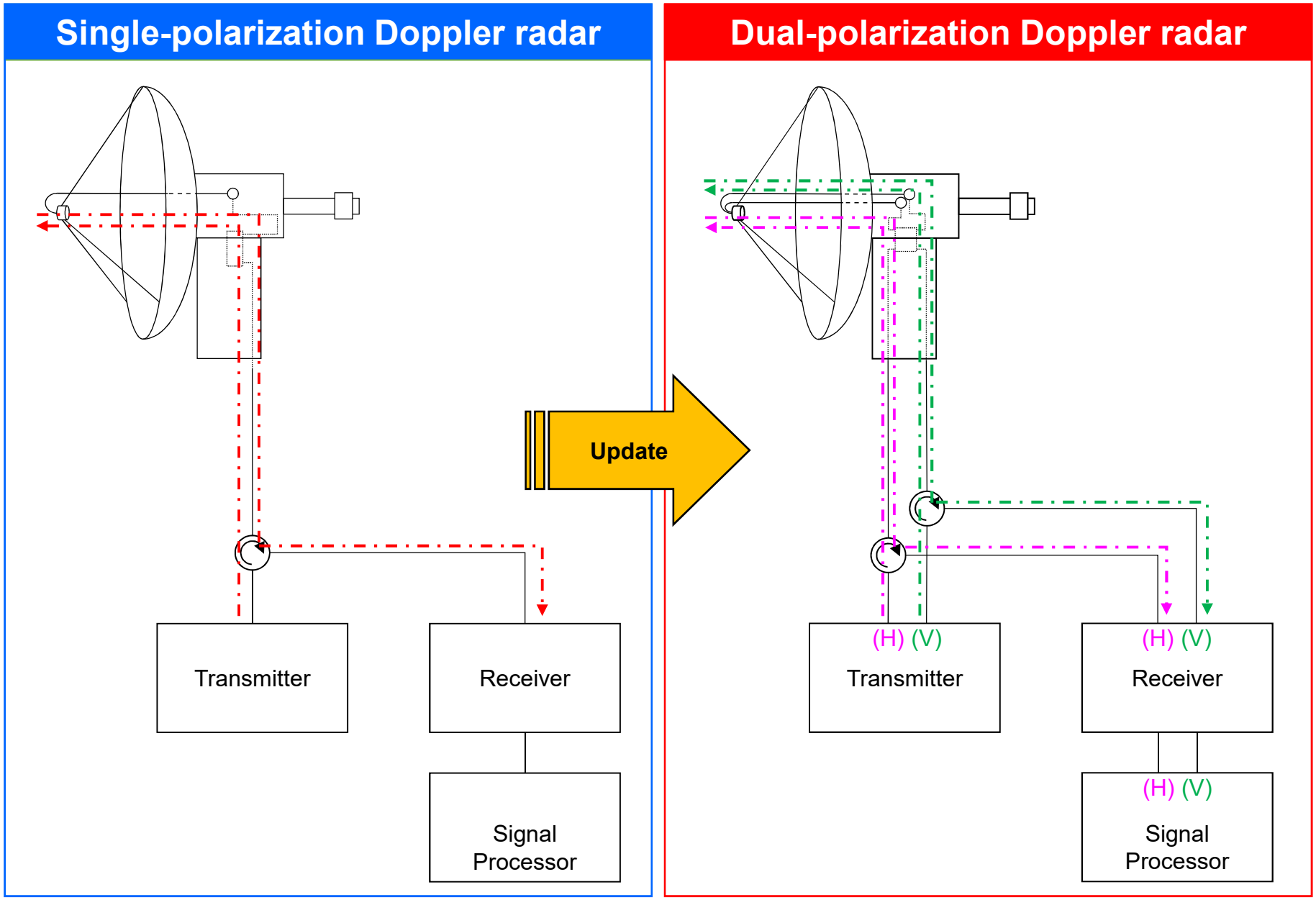
- **Time until emitted radio wave return** → **Distance to target**
- **Intensity of returned radio waves** → **Precipitation intensity**
- **Frequency shift of returned radio waves** → **Air flow in precipitation area**



- As radar waves travel in a straight line through the atmosphere, no bounce-back is obtained from behind obstacles such as mountains.
- As the earth is spherical, radio waves shoot off into the sky. This makes it difficult to observe low-lying rain and snow.

JMA's radars network is arranged to effectively cover most of Japan in consideration of these limitations.

JMA radar types



Dual-polarization Doppler radar

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Benefits of dual-polarization data

- Ability for determination of precipitation intensity
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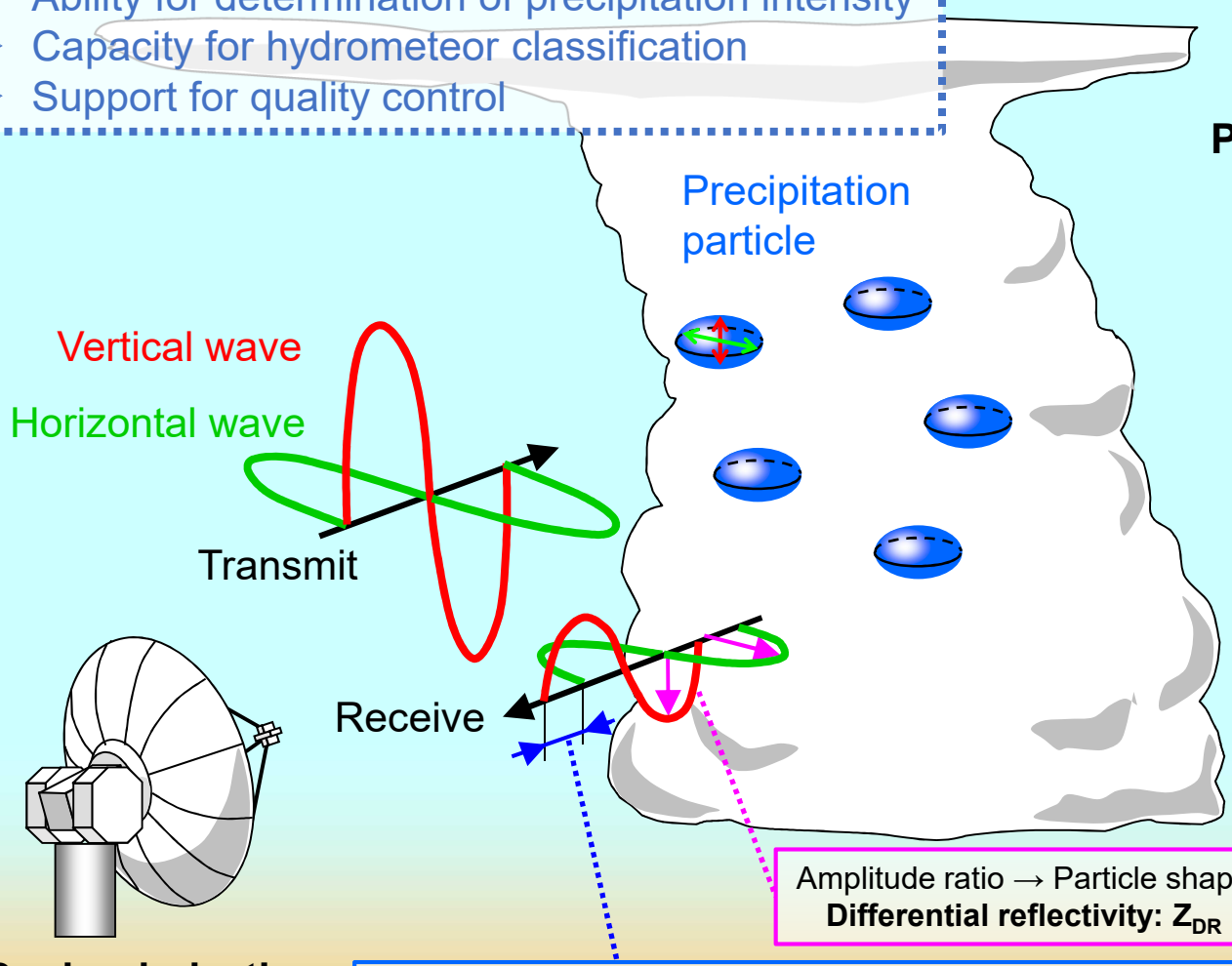
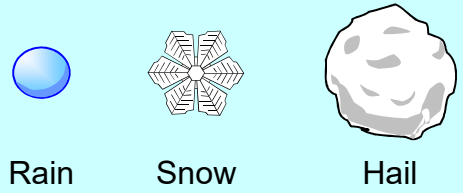
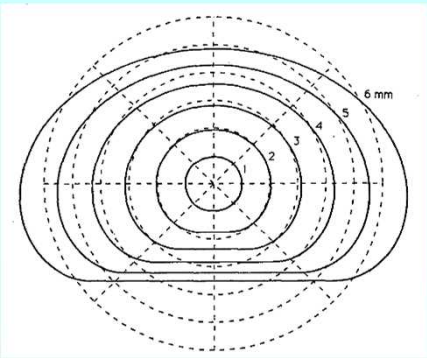


Precipitation particle types



Raindrop shapes



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Phase shift → Precipitation intensity (Not affected by rain attenuation)
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Dual-polarization Doppler radar

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Benefits of dual-polarization data — 1

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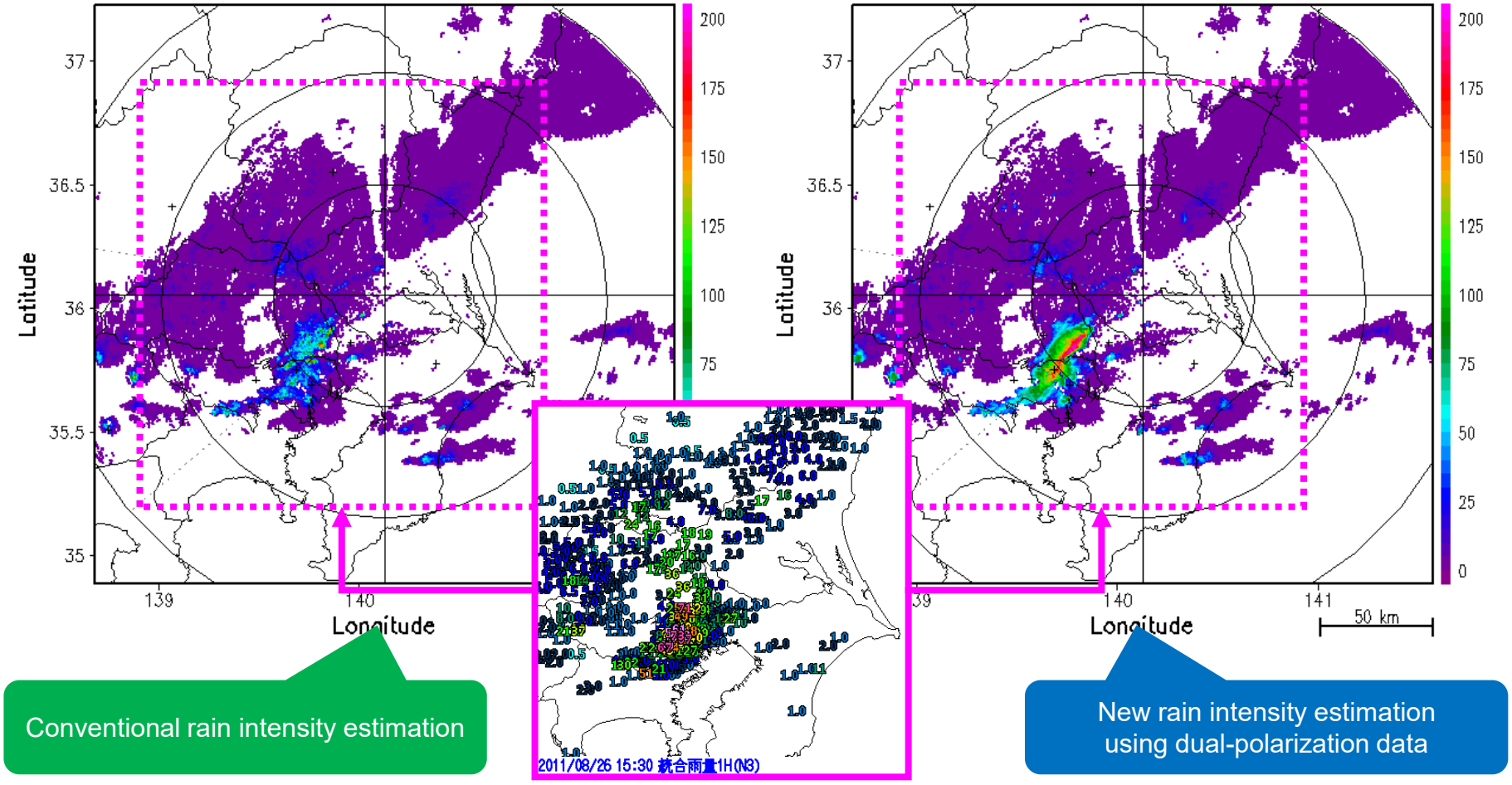
Accurate estimation of rainfall intensity without rain gauge correction

Radar observation is particularly effective for localized heavy rainfall in areas between rain gauges and heavy rain moving from gauge-free sea areas.



Benefits of dual-polarization data — 2

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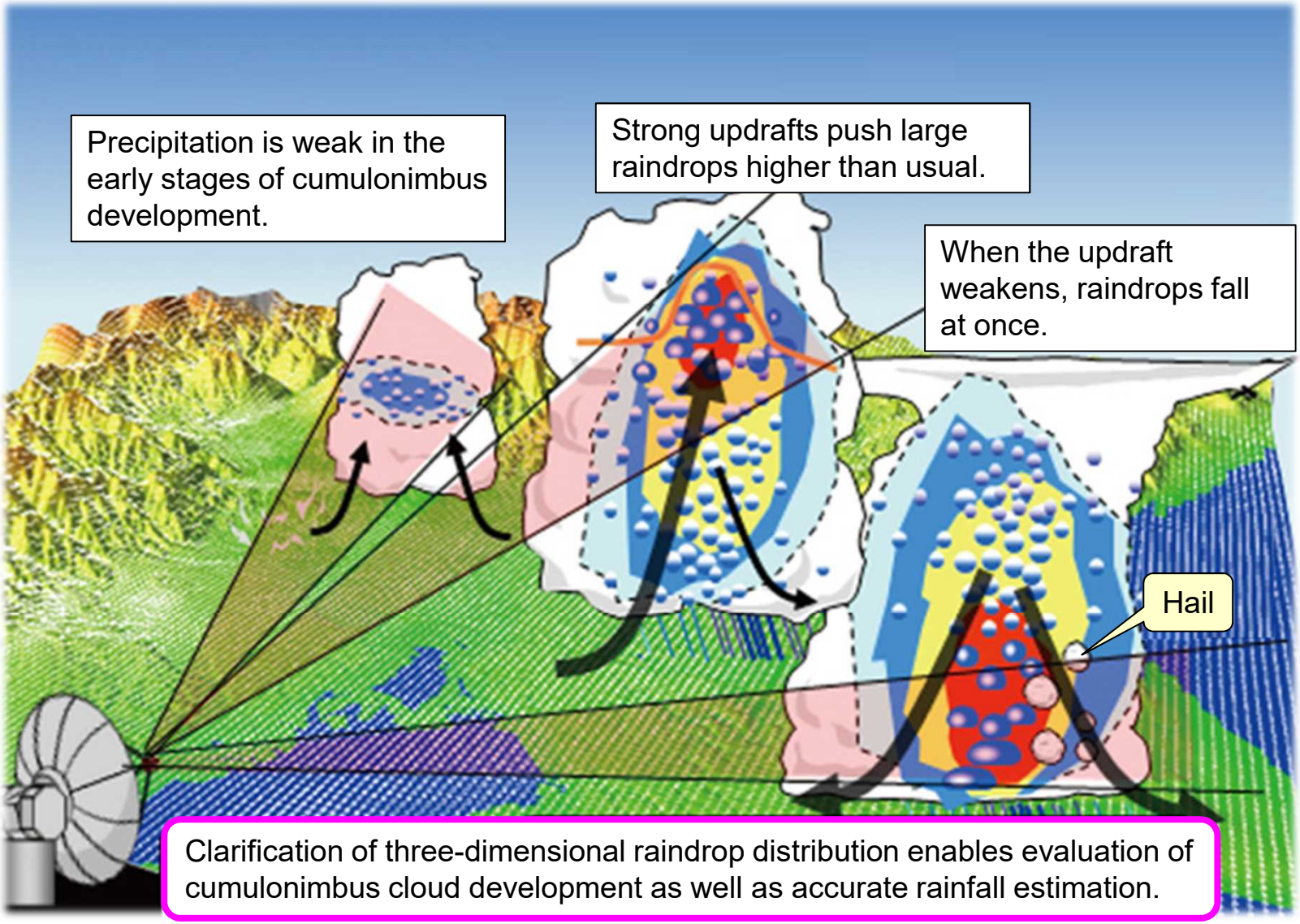
Classification of precipitation particle types



Clarification of three-dimensional raindrop distribution enables evaluation of cumulonimbus cloud development as well as accurate rainfall estimation.

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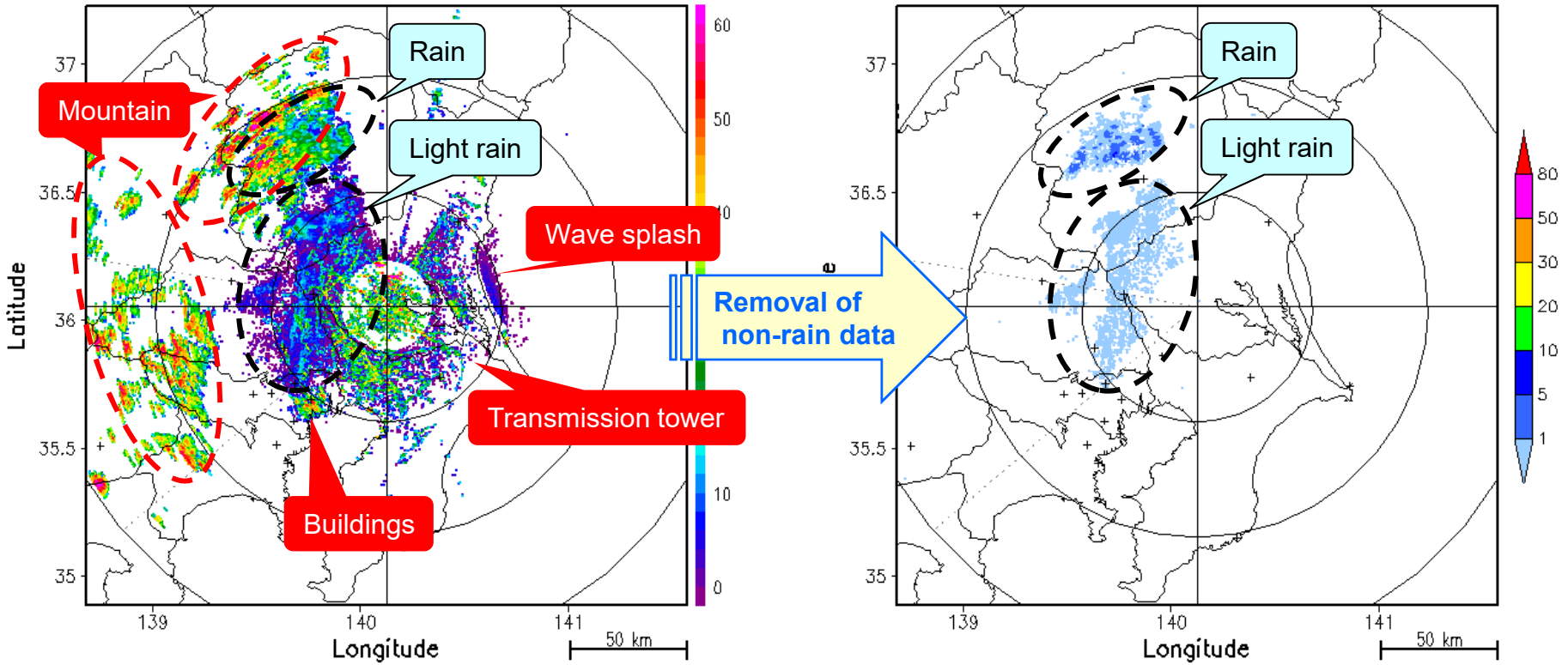
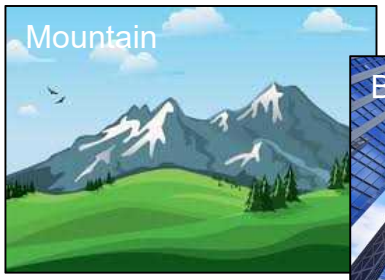
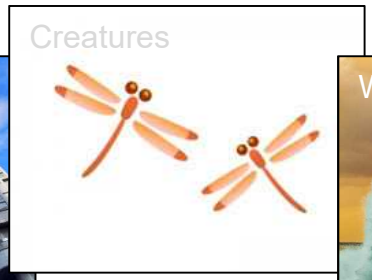
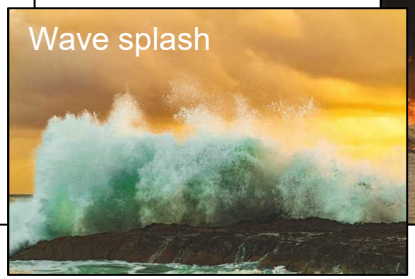
Benefits of dual-polarization data — 3

Improved observation data based on radar's ability to distinguish precipitation from other particle types









New Weather Radars

気象庁 Japan Meteorological Agency

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Solid-State Power Amplifiers (SSPAs)

- Safe, durable and economical
- Contribution to high-speed, high-precision radar observation
- Efficient use of radio wave resources

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Solid-State Power Amplifiers (SSPAs)

- ✓ **Japan pioneered transmitter development using SSPAs for weather radar.**
- ✓ **It also led progress in SSPA usage for operational C-band dual-polarization weather radar.**

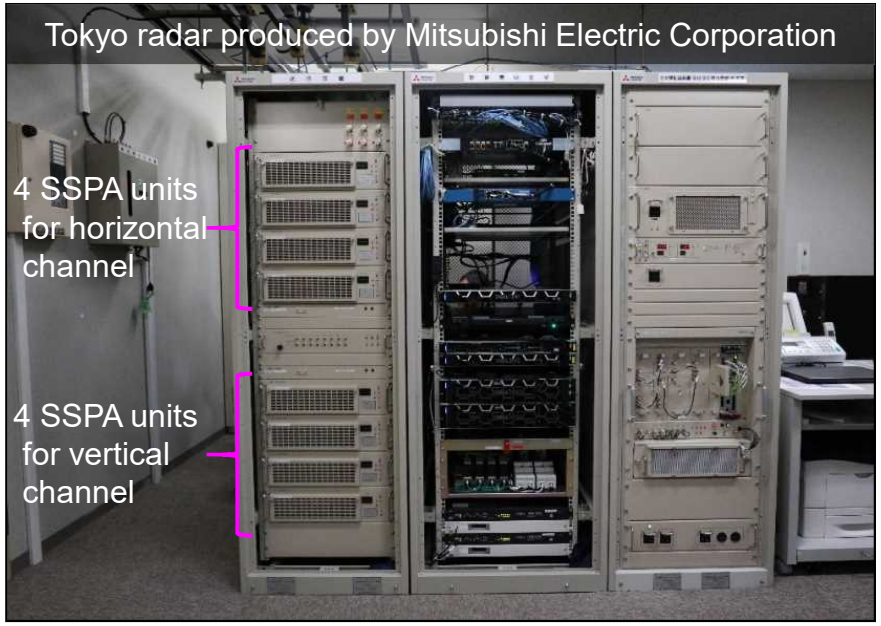
Safety, durability, economic efficiency

- Omission of high-voltage components makes SSPAs safe, durable and economically viable.


SSPA Unit

Operational continuity

- Failed SSPA units can be easily replaced during radar operation.
- Radar observation can be continued in the event of unit failure.



Effective use of radio wave resources

- As SSPA signal amplification is possible without significant bandwidth widening, radio frequency interference is less likely.


© Toshiba

SSPAs have numerous individual transistors for radio wave amplification.

Benefits of SSPA — 1

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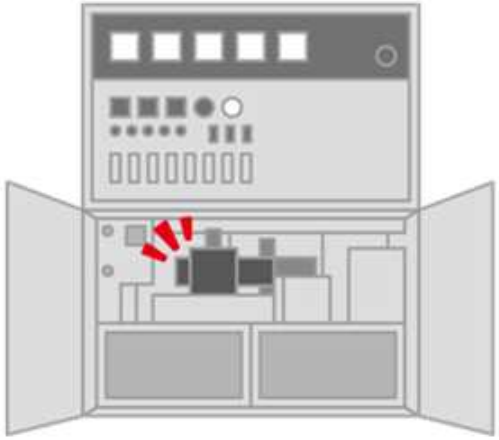
Simple replacement of failed SSPA units without radar operation outage



Electron tube transmitters

- Radar operation cannot continue in the event of electron tube malfunction.
- The system must be shut down for electron tube replacement.

Improved continuity

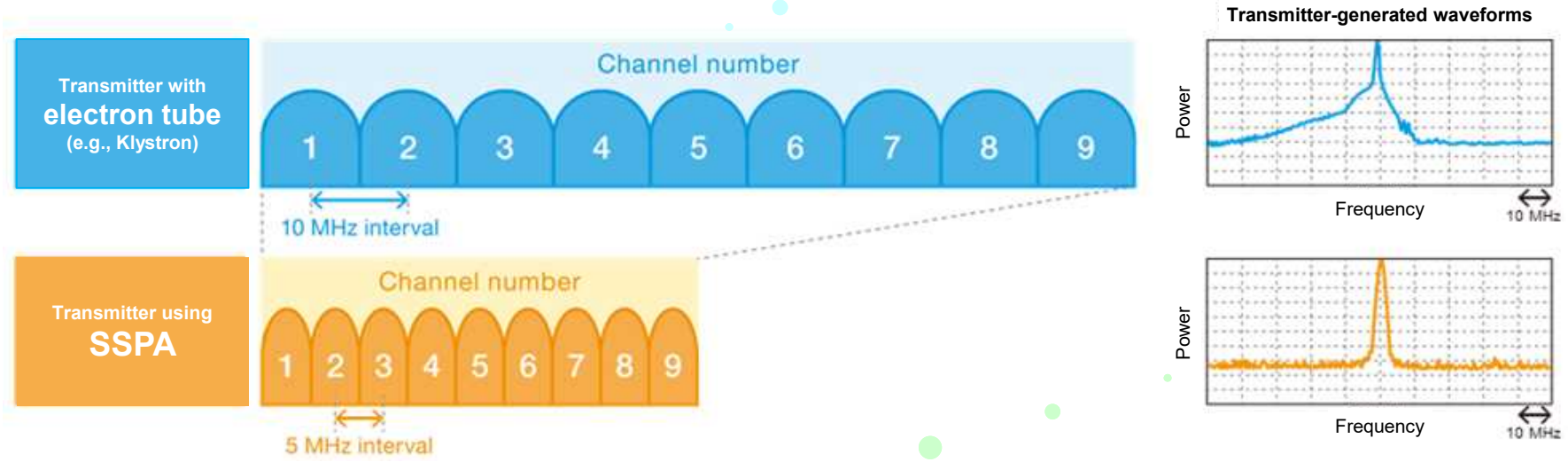
Solid-state transmitters

- If a problem arises with a modular part, operation can be continued with reduced output.
- It is unnecessary to shut down the system during replacement, and adjustments can be easily made due to the low voltage used.
- Solid-state transmitters are around half the size of electron tube transmitters.

Benefits of SSPA — 2

Efficient use of radio wave resources

Potential for narrowing of bandwidth intervals allocated to weather radar



Waveforms can be easily shaped using solid-state transmitters.

- As SSPA signal amplification is possible without significant bandwidth widening, radio station interference is less likely.
- High-quality radio waves can be transmitted.

Performance comparison

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	Dual-pol radar	Single-pol radar
Transmission frequency	Short pulse: AF +1.25 MHz Long pulse: AF −1.25 MHz	Assignment frequency
Amplification	SSPA	Klystron
Peak power	6 – 10kW (3 – 5kW for each polarized wave) ＊Manufacturer-dependent	250 kW
Pulse width	Short pulse: 1 us Long pulse: 32, 64, 128us	1, 2.5 us
Pulse repetition frequency	Low PRF: 345, 330 Hz Middle PRF: 535 Hz High PDF: 756/630, 888/740, 1,080/900, 1,830/1,525 Hz	Low PRF: 330 Hz Middle PRF: 600/480 Hz High PDF: 940/752 Hz
Maximum observation range	400 km	400 km
Range resolution	Short pulse: 150 m or less Long pulse: 125 m or less (pulse compression)	1 us: 150 m 2.5 us: 375 m
Bearing resolution	Normal: 0.7031 deg (360/512 deg) High resolution: 0.3516 deg (360/1,024 deg)	0.7031 deg

JMA WEATHER RADAR OPERATION

Radar Operation Staff

気象庁 Japan Meteorological Agency

WEATHER RADAR SITES

TROUBLE SHOOTING

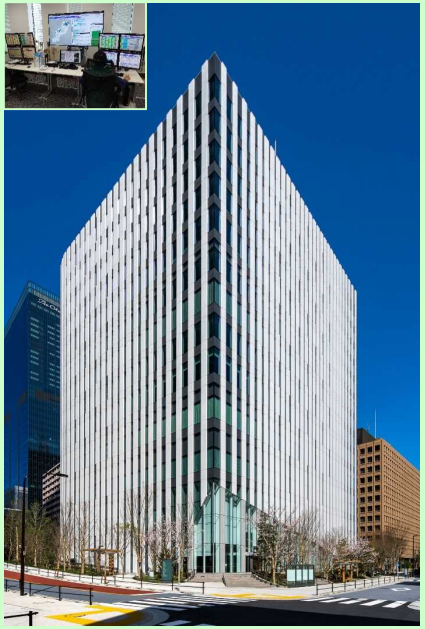
RADAR-MANAGING LOCAL OFFICES

Radar-managing staff x 1

MONITORING
24 hours a day, 365 days a year

INSPECTION

HEADQUARTERS (HQ)



System management (8 staff)

- Inspection scheduling
- Troubleshooting
- Quality control
- Support for branch office radar management

Weather Monitoring and Warning Center (5 staff)

- System monitoring 24 hours a day, 365 days a year

Day shift
8:30－17:00

Night shift
16:00－9:30

Radar Operation Staff

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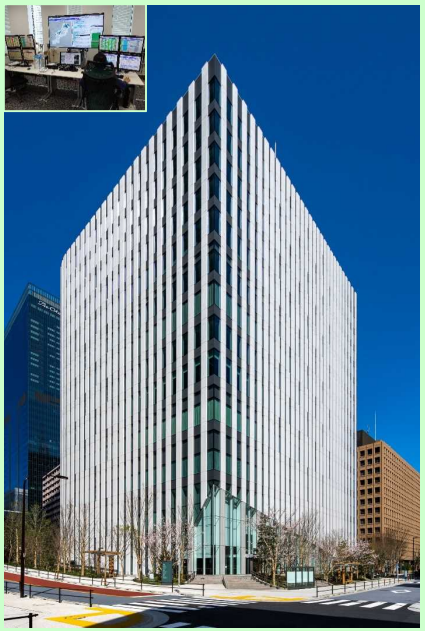

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1 2 3 4 5 1 ...

5 1 2 3 4 5

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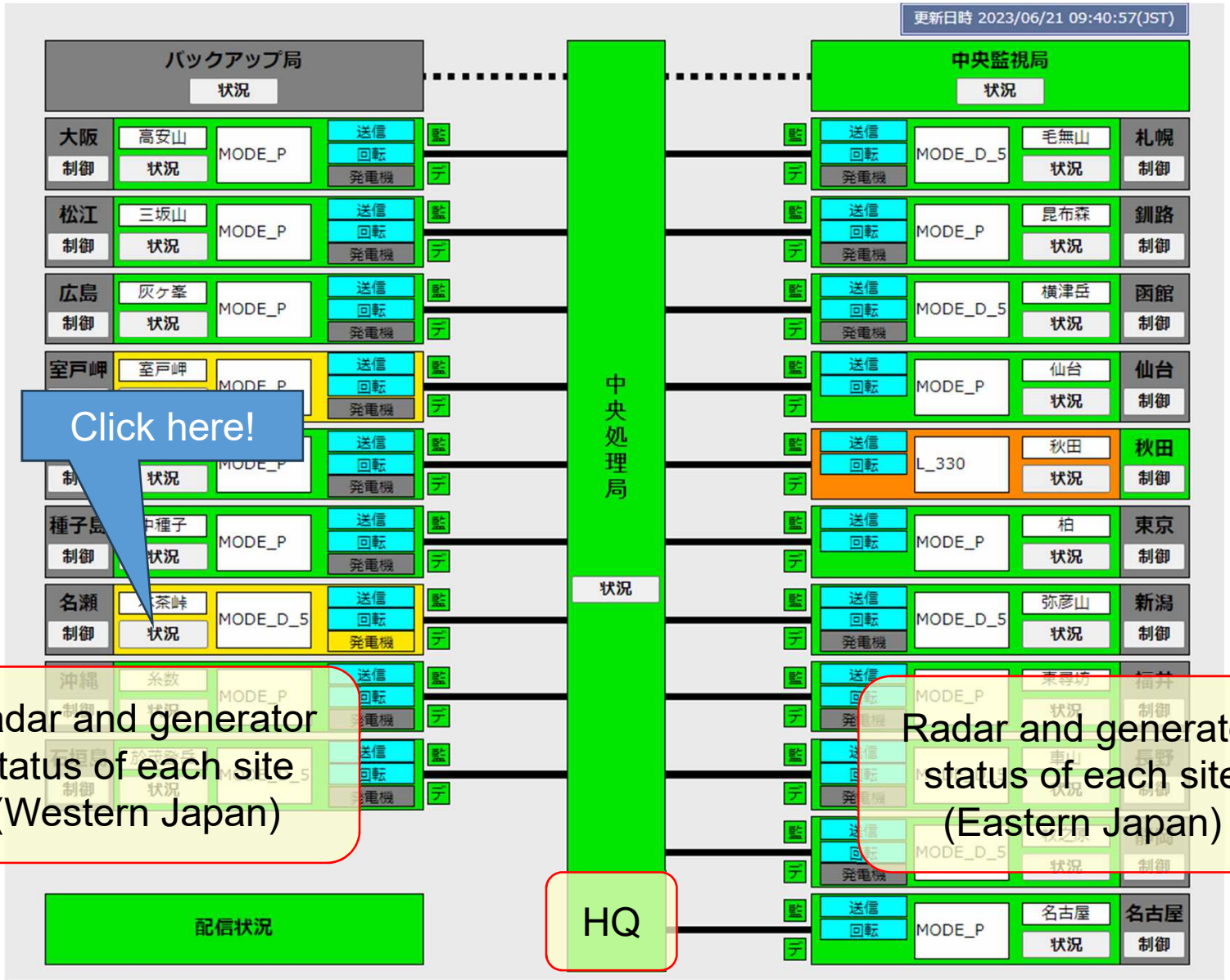
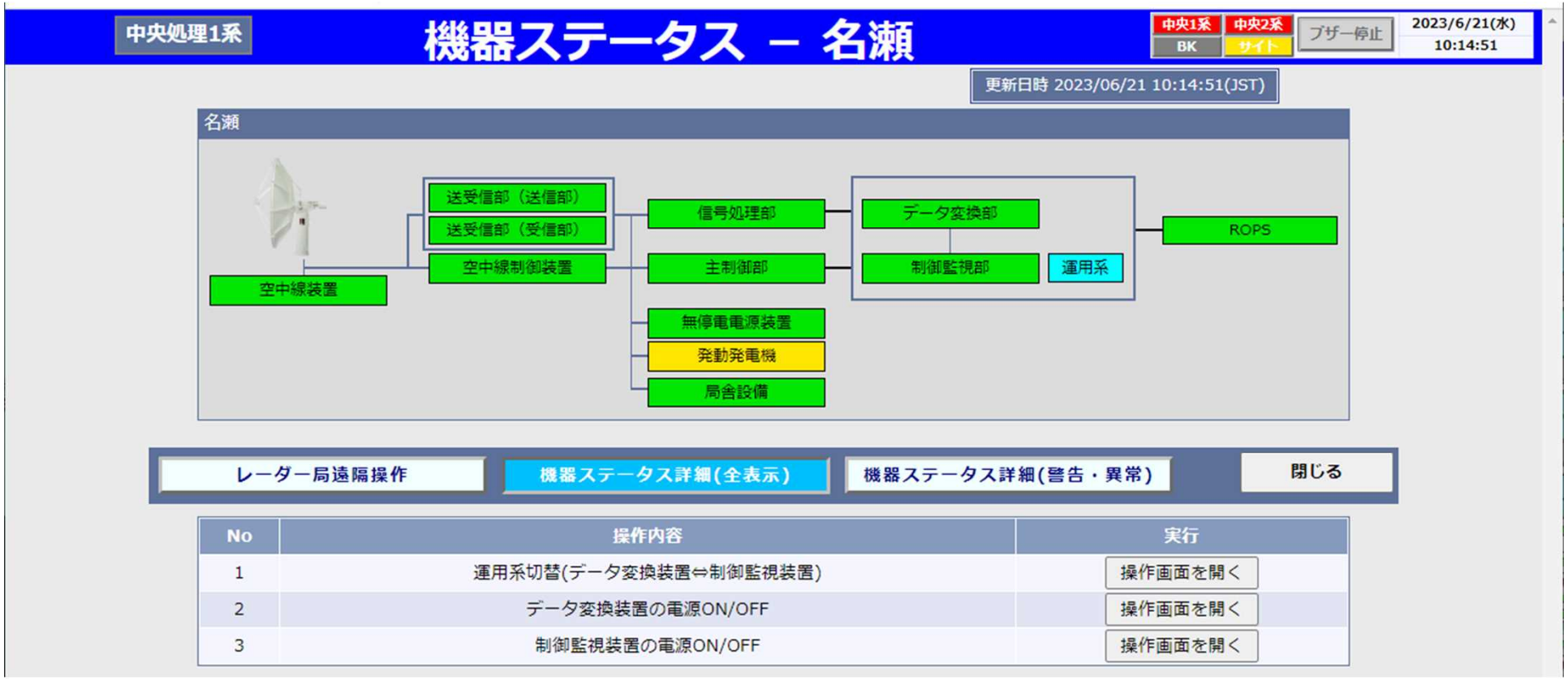
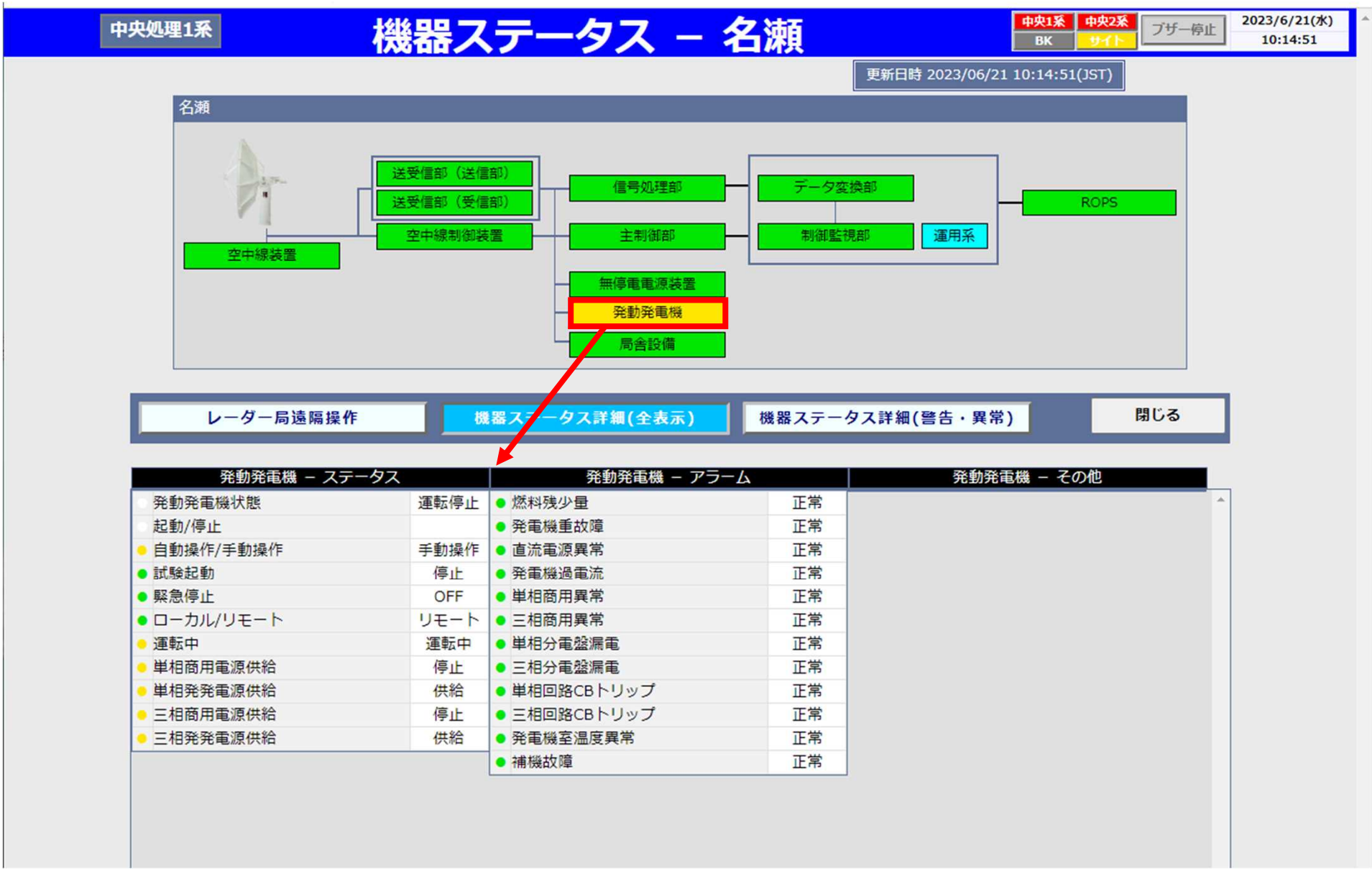
Radar Hardware and ROPS Status



Radar Hardware Status Overview



Radar Hardware Status Details



Trouble Shooting of Radar system

気象庁 Japan Meteorological Agency

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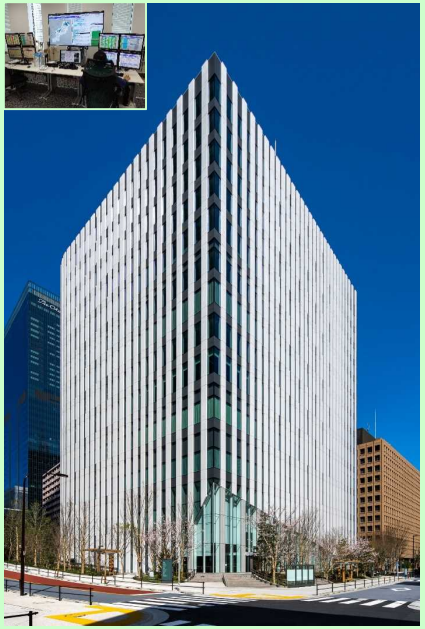

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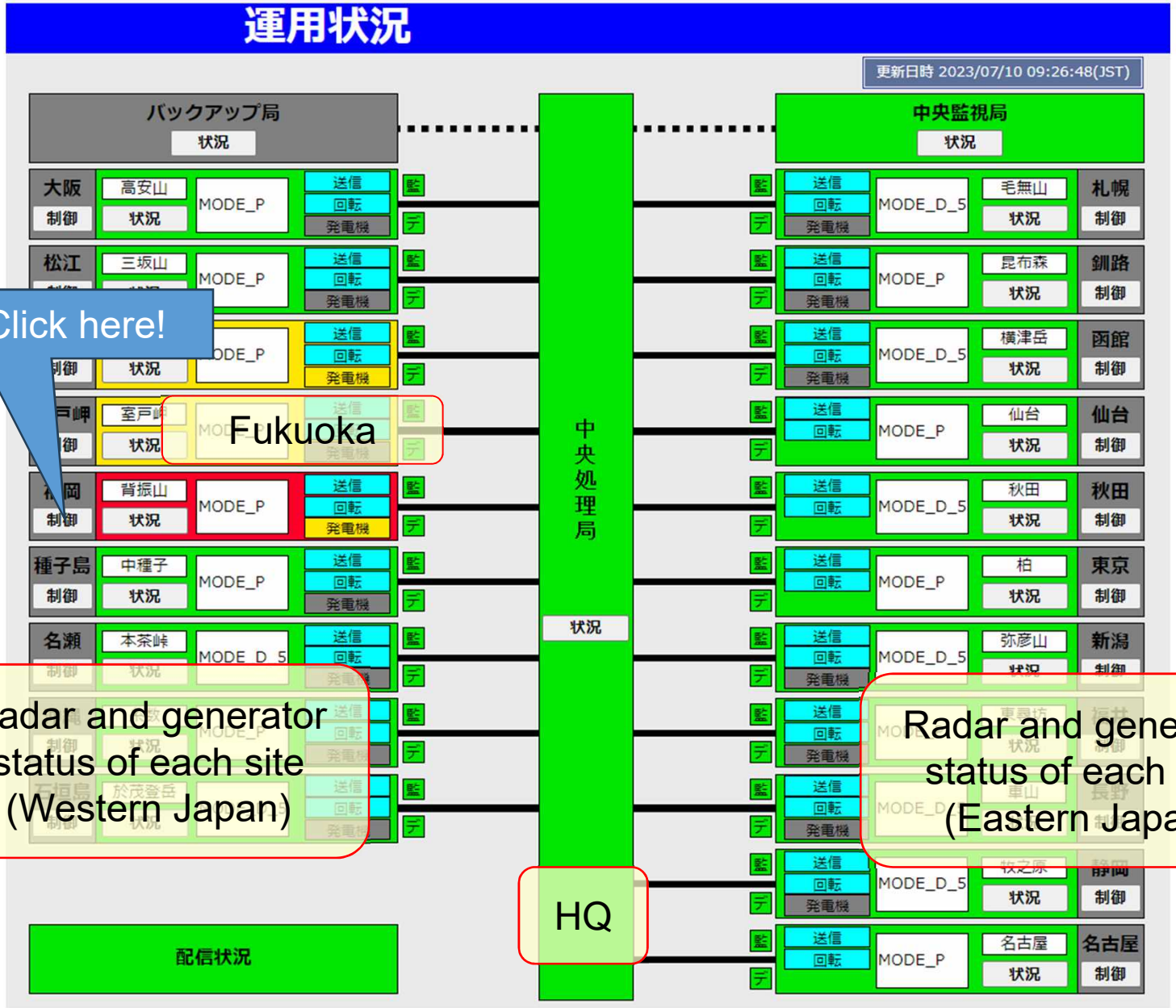
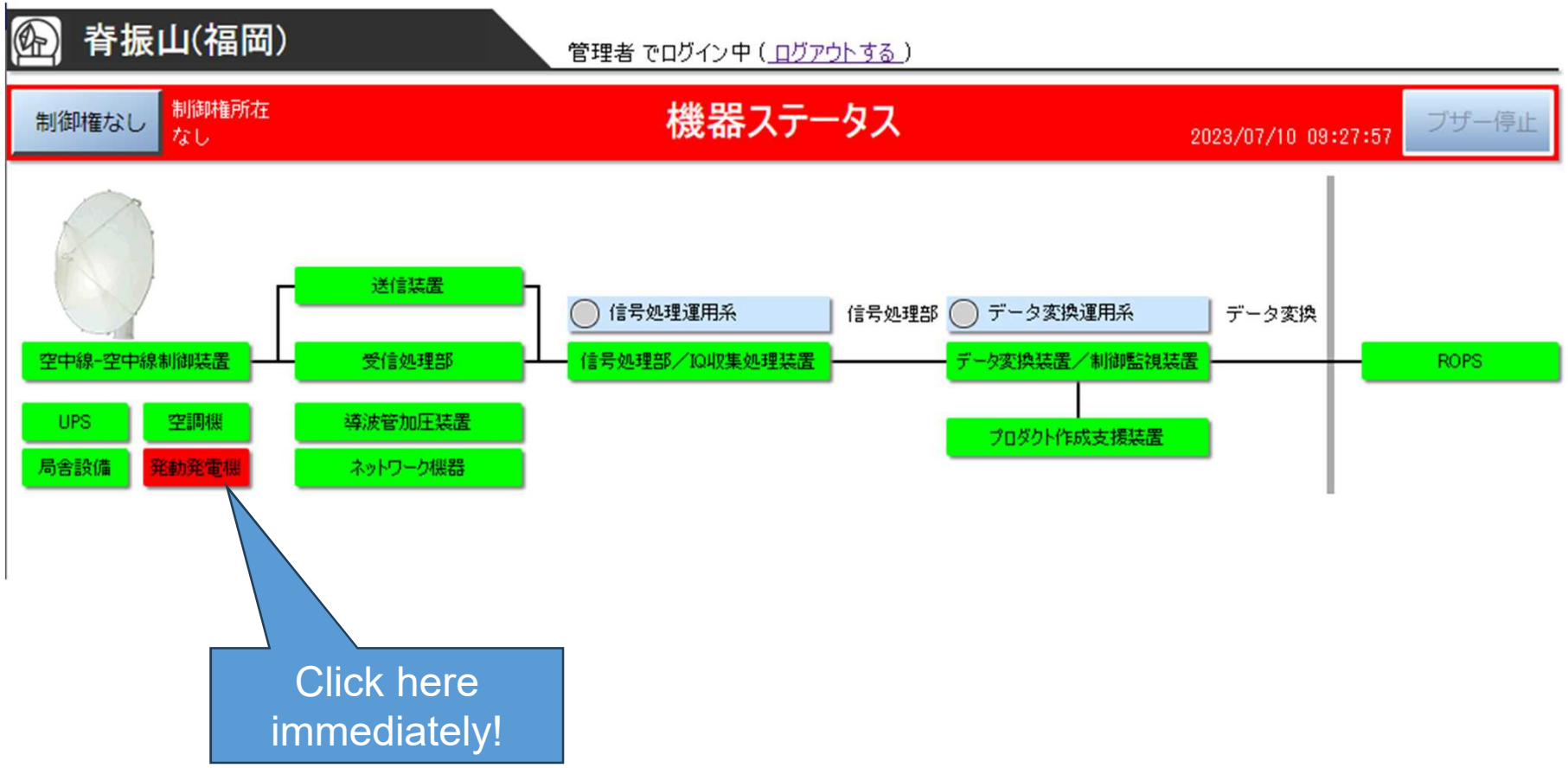
If failure happened



Check the failure instruments Immediately



Check the failure details

Trouble Shooting of Radar system

気象庁 Japan Meteorological Agency

Failure happened

First step (JMA staff)
1. Remote checking
2. Reset alert
3. Report to Management team

JMA HQ Operation center

recovered

Management team order the radar-managing staff to go to the radar site

Not recovered

Second step (JMA staff)
1. Checking radar system on site
2. System reset, exchange some parts
3. Report to Management team

Radar site

recovered

Trouble Shooting finished

Not recovered

to the third step (next slide)

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Trouble Shooting of Radar system

気象庁 Japan Meteorological Agency

When the failure isn't recovered, management team staff order the manufacturer to recover it.
(If radar hardware is broken, repair contract is necessary)

Third step (manufacturer)
1. Remote check and prepare to go to site
2. Checking and repair the radar system on site
3. Report to radar-managing staff and Management team

Radar site

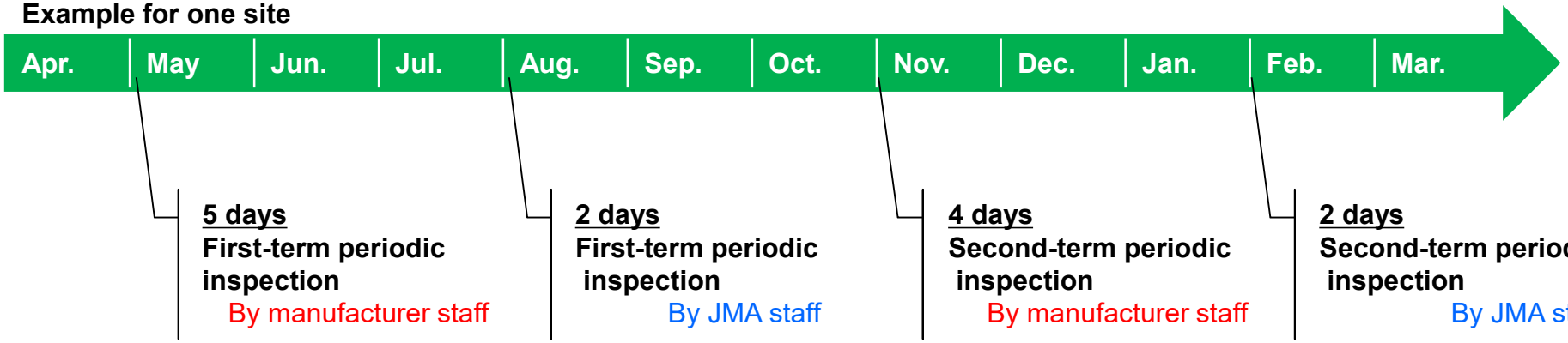
recovered

Trouble Shooting finished

Periodic Maintenance of Radar system

気象庁 Japan Meteorological Agency

Example for one site



Weekly Inspection JMA remote checking of radar status (wave transmission, antenna operation, etc.)

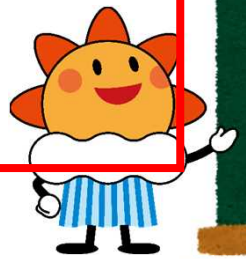
Manufacturer inspection

Thorough inspection of the entire radar system (transmitters, receivers, antenna control units, antenna units, etc.) by manufacturers, and equipment adjustment as necessary

During the first term of manufacturer inspection, staff are provided with weather radar system information.

JMA staff inspection

JMA checking of radar status
- Appropriate transmitter emission of radio waves
- Appropriate receiver signal processing
- Antenna noise issues
- Site equipment issues



Purpose of inspection

- To ensure favorable collection of observation data
- To support radar system operation in line with radio regulations and relevant laws
- To prevent critical system/equipment failure

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JMA Inspection Items

(1) Daily Inspection (remote)

- Date and time of each device
- Operation record of each device
- Operation status and communication status

(2) Weekly Inspection (remote)

- Condition of processing system
- Condition of antenna unit

(3) Monthly Inspection (remote)

- Radar unit (antenna, transmitted signal, dehydrator)
- Processing system
- Facilities, power supply

(4)6 monthly Inspection (including monthly inspection) on site

- Radar unit (antenna, transmitted signal, waveguide, Received signal)
- System parameters
- Facilities, power supply
- Instructions to radar-managing staff

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Periodic Maintenance of Radar system

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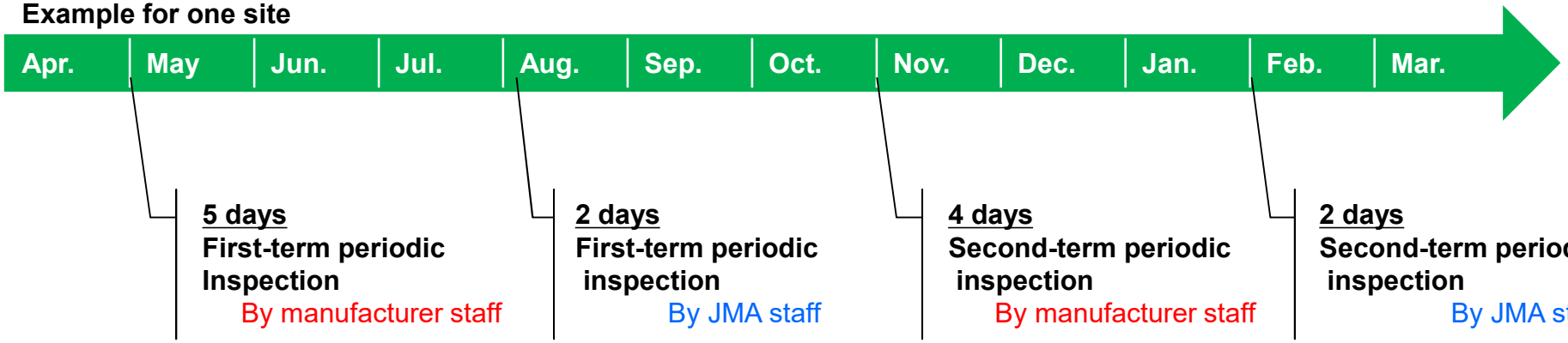
Example for one site



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Manufacturer support

(1) 6- Monthly Heavy Inspection (on site)

- System checking
- Spare parts checking
- Exchanging expendables (ex; Gear oil, Klystron)
- Technical training for JMA radar-managing staff (first term only)

(2) 6- Monthly Heavy Inspection (ROPS)

- System checking (system log, system parameters)
- Hardware/Software checking

(3) Special maintenance (around every 5 years)

- Antenna motor and gearbox exchange
- Radome repair
- power supply unit heavy maintenance

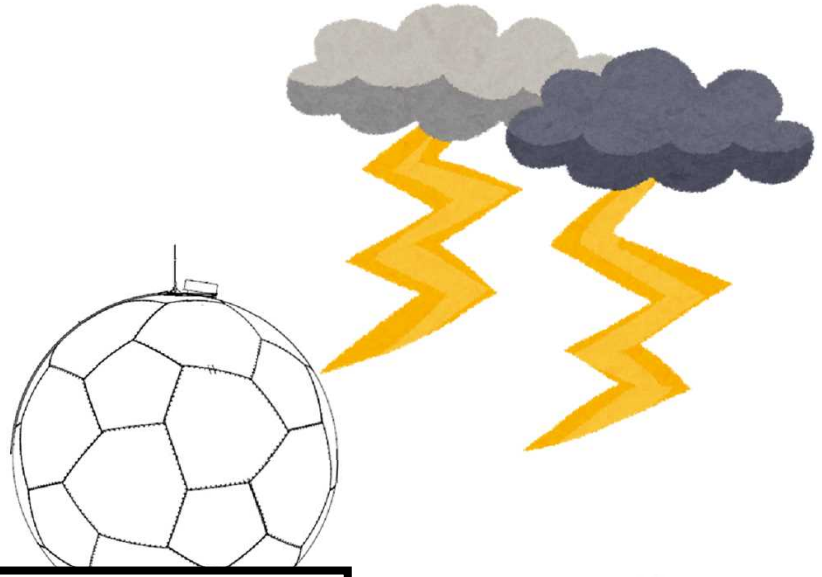
(4) Recover from failure

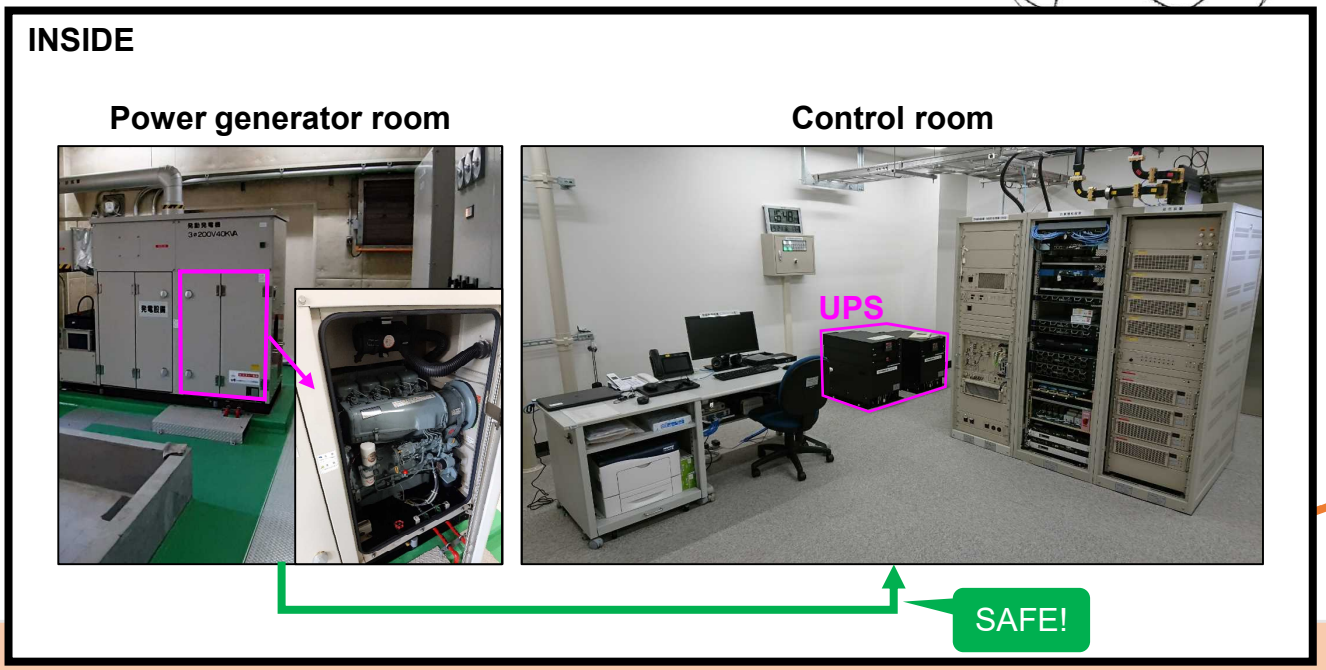
- Remote check (system reset)
- Repair the radar hardware (include exchanging spare parts)

Private Power Generator

- Private generators take over if power to a weather radar site is lost.
- Radar equipment must be protected from lightning surges (induced lightning), so when lightning is close to the site, the operator switches from commercial power to a private power source in advance.

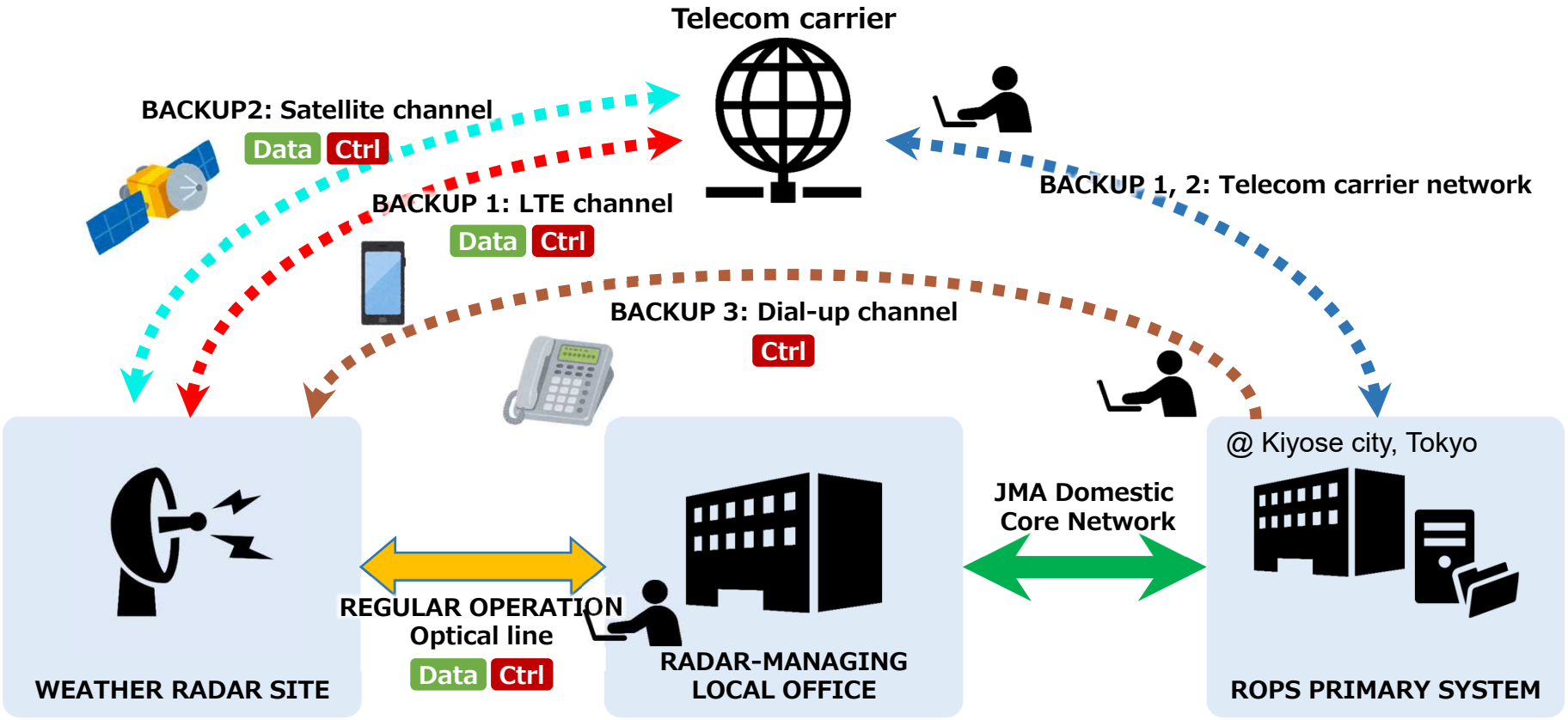
An uninterruptable power source unit is used for periods of switching between commercial and private provision.





Backup Communication Lines

- Weather radar data are usually sent to ROPS via local offices, which are connected to radar sites by optical lines and to ROPS by the Domestic Core Network.
- In the event of network abnormalities, backup communication options (LTE, satellite or dial-up depending on site conditions) are used for data transmission and radar control.



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Summary

- Operation of JMA weather radar by headquarters (HQ) staff
  - The central system, ROPS, makes this operation.
  - The HQ staff is composed of 2 teams.

- Trouble shooting procedure
  - JMA radar-managing and HQ staff deal with troubles together in early step.
  - Manufacturer supports JMA at severe breakdown.

- Regular inspections and measures
  - The inspections on site are conducted about every 3 months.
  - Private Power generator and Backup Communication line are available.

- Two major characteristics of new JMA weather radar
  - Dual-polarization Doppler radar
  - Solid-State Power Amplifiers (SSPAs)

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Thank you for your attention.