

International Civil Aviation Organization



ICAO

**THE THIRD MEETING OF MODE S DOWNLINKED
AIRCRAFT PARAMETERS WORKING GROUP
(MODE S DAPs WG/3)**

Web-conference, 12 – 15 May 2020

Agenda Item 3: Sharing of State's implementation on Mode S

UTILIZATION OF MODE-S DAPS DATA FOR WEATHER FORECAST

(Presented by Japan, Electronic Navigation Research Institute)

SUMMARY

This paper presents, in Attachment 1, experimental results for utilization of Mode-S DAPs data for weather forecast conducted in Japan. Experimental results indicated that Mode-S DAPs data have a potential to improve weather forecasts

1. INTRODUCTION

1.1 Downlink Aircraft Parameters (DAPs) is one of Secondary Surveillance Radar (SSR) Mode-S data-link functions. It enables a Mode-S ground station to obtain real-time aircraft information such as selected altitude and ground speed. DAPs is possible to improve efficiency, capacity, and safety of Air Traffic Management (ATM).

1.2 Advanced ATM, like Trajectory Based Operation (TBO), requires high-accurate trajectory prediction. One of major factors of estimated flight time error in TBO is weather uncertainty. Therefore, it is considered for TBO that more accurate weather forecast is needed.

1.3 On the other hand, DAPs data are expected to be useful for improving numerical weather prediction because temporal and spatial intervals of DAPs data are very short. Based on this expectation, Meteorological Research Institute and Electronic Navigation Research Institute conducted experiments for improving weather forecast accuracy utilizing DAPs data.

1.4 Experimental results indicated that Mode-S DAPs data have a potential to improve weather forecasts.

2. DISCUSSION

Attachment 1 presents experimental results for utilization of Mode-S DAPs data for weather forecast conducted in Japan.

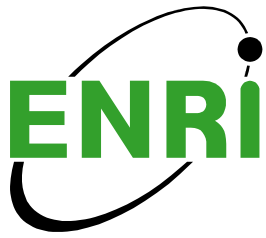
3. ACTION BY THE MEETING

3.1 The meeting is invited to:

- a) note the information contained in this paper; and
- b) discuss any relevant matter as appropriate.

ACKNOWLEDGEMENTS

This study was carried out by the collaborative research of Meteorological Research Institute and Electronic Navigation Research Institute. This study was also carried out using operational data of Japan Meteorological Agency.



Utilization of Mode-S DAPs data for weather forecast

Electronic Navigation Research Institute
H. Miyazaki A. Senoguchi

Contents

- Back ground
- Utilization of DAPs data for weather forecast
- Experimental results of DAPs utilization
- Conclusion

Advanced Air Traffic Management

4. Realizing Satellite-based Navigation for All Flight Phases

Aircraft can determine position and time accurately in all FIR of Japan by Satellite-based navigation

1. Realizing Trajectory-based Operation (TBO)

Fly regularly on a pre-coordinated trajectory from departure to arrival

3. Promoting Performance-based Operation (PBO)

5. Enhancing Situational Awareness on the Ground and in the Air

Cooperation between ground and air, Information sharing

Integrated ATC processing system

8. Realizing High-density Operation in Congested Airports and Airspace

2. Improving Predictability

The calculation of air traffic control capacity, Estimation of traffic flow, Improving of predictability of meteorological phenomena

6 Making Maximum Use of the Capability of Human Beings and Machines

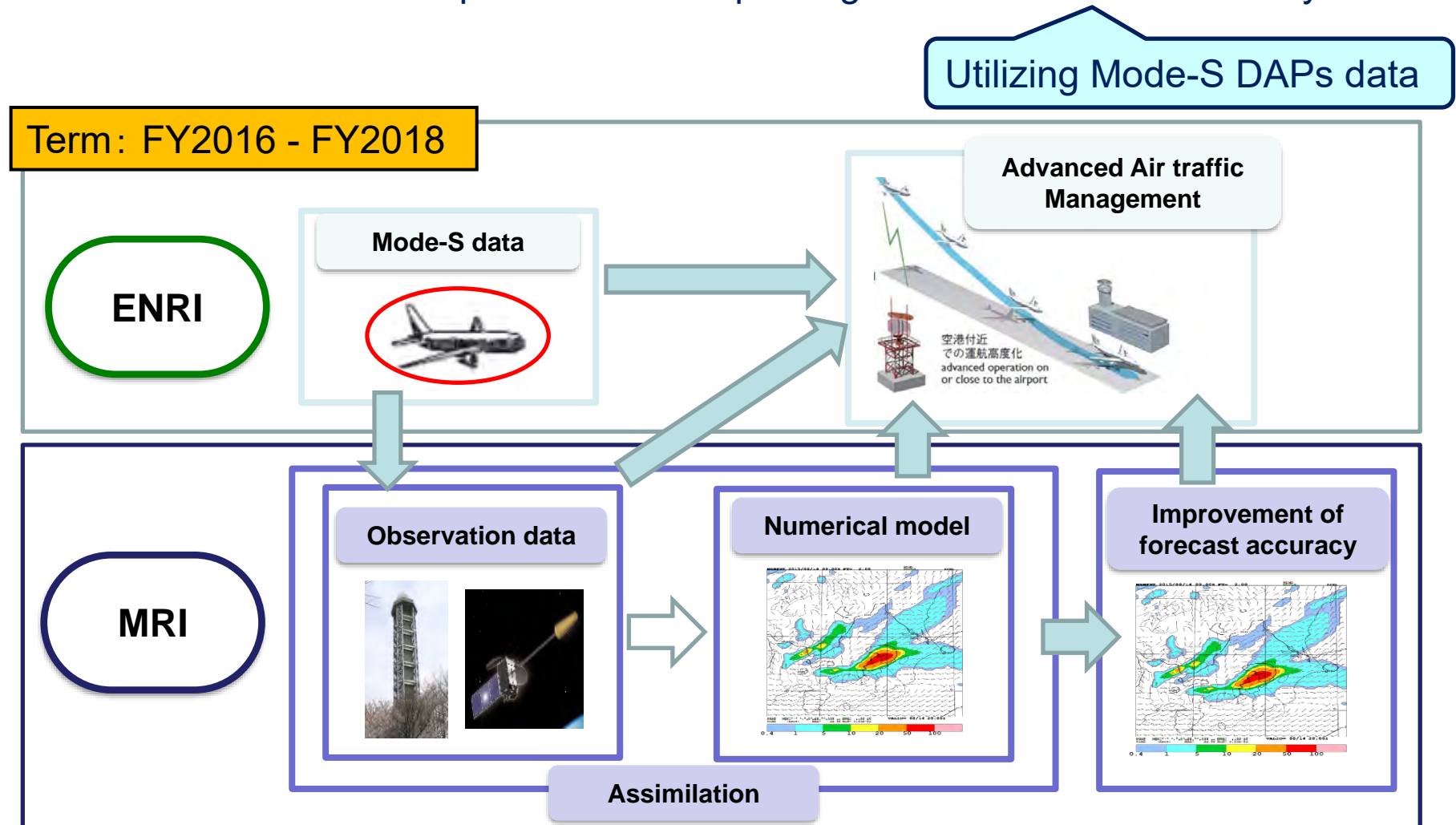
7. Complete information-sharing and Collaborative Decision-Making

Trajectory prediction

- TBO: Keeping coordinated route & time in flight
 - #Supported by high-accurate trajectory prediction
- Major factors of estimated flight time error
 - #Operational Intent: Aircraft performance model
 - #Weather uncertainty: Weather forecast data
- More accurate weather forecast is important for TBO
 - #Mode-S DAPs data are expected to be useful for improving numerical weather prediction
 - #Temporal and spatial intervals of DAPs data are very short

Collaborative research by MRI & ENRI

MRI & ENRI conducted experiments for improving weather forecast accuracy

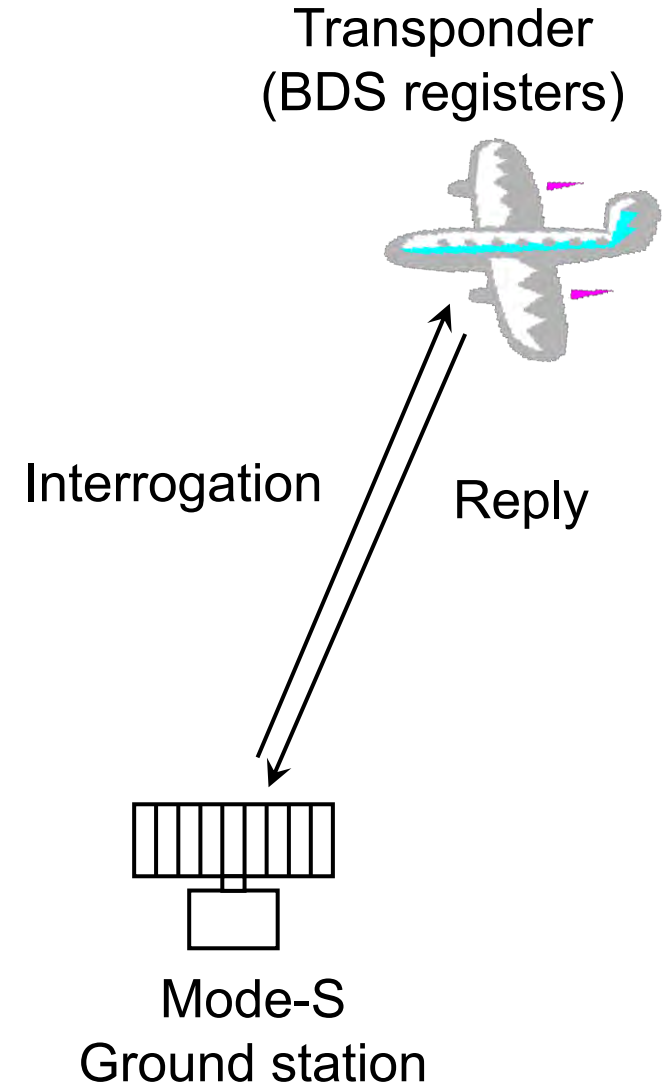


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SSR Mode-S DAPs

- Mode-S Ground station sends an interrogation to aircraft.
- 255 registers (BDS registers) connected to the aircraft avionics, storing aircraft parameters
- Responding to the interrogation requesting the BDS register, the transponder sends back a reply with the BDS register value.



Major BDS register item

BDS code	Item	Applications
05	Extended squitter airborne position	ADS-B
10	Datalink capability report	ELS/EHS
17	Common usage BDS capability report	ELS/EHS
20	Aircraft identification	ELS/EHS
30	ACAS active Resolution Advisory	ACAS
40	Selected vertical intention	EHS
44	Meteorological report: Routine information	future use
45	Meteorological report: Hazard information	future use
50	Track and turn report (True Track Angle, Ground Speed, True Airspeed)	EHS
60	Heading and speed report (Magnetic Heading, Mach Number)	EHS

To estimate horizontal wind and temperature from these DAPs information

Estimation of weather data

1. Temperature

Calculating from **Mach number** and **True Airspeed**

$$T = \frac{1}{\gamma R} \left(\frac{V_{TAS}}{M} \right)^2$$

Wv (North - South)

2. Wind Speed & Direction (Wu and Wv)

(1) Converting **Magnetic Heading** to **True Heading**

$$\Psi_{HDG} = \Psi_{MAG} - D2010$$

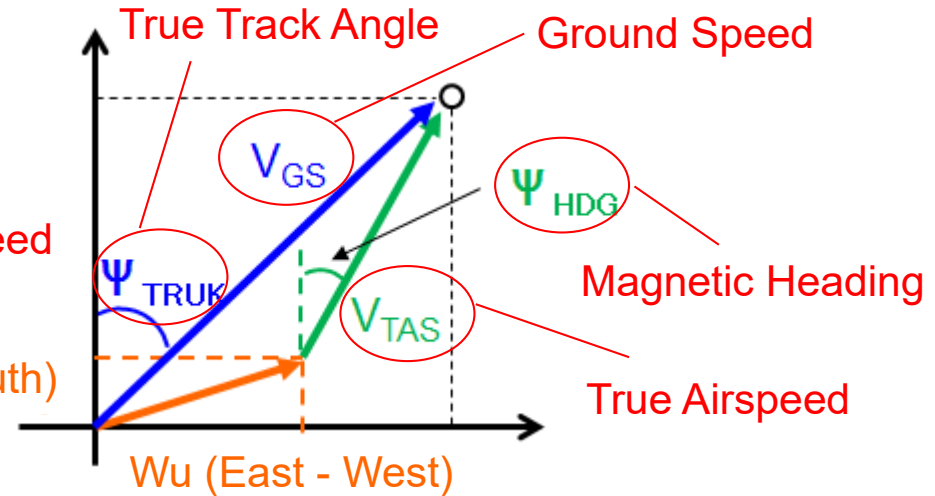
$$D2010 = 7^{\circ}40.585' + 19.003'\Delta\phi - 6.265'\Delta\lambda + 0.009'\Delta\phi^2 + 0.024'\Delta\phi\Delta\lambda - 0.591'\Delta\lambda^2$$

ただし, $\Delta\phi = \phi - 37^{\circ}N$ $\Delta\lambda = \lambda - 138^{\circ}E$

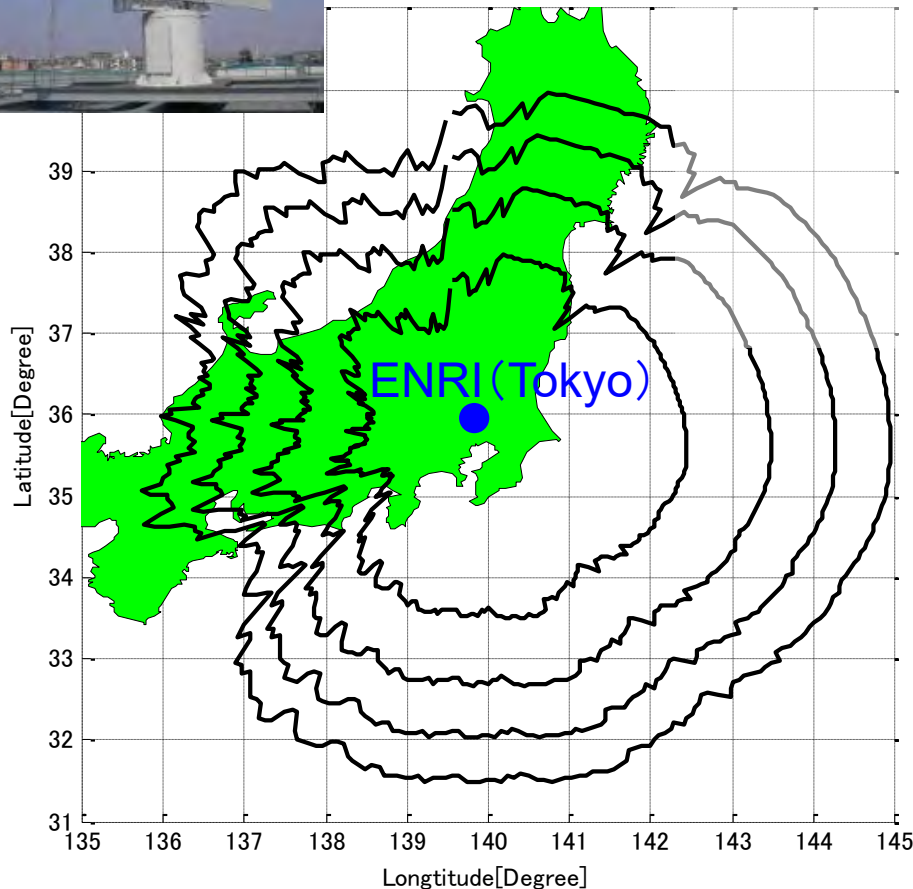
(2) Calculating **Wu** and **Wv** by subtracting **True Airspeed** from **Ground Speed**

$$W_u = V_{GS} \cdot \sin \Psi_{TRUK} - V_{TAS} \cdot \sin \Psi_{HDG}$$

$$W_v = V_{GS} \cdot \cos \Psi_{TRUK} - V_{TAS} \cdot \cos \Psi_{HDG}$$



SSR Mode-S experimental station



Coverage at Altitude

- 10,000 ft
- 20,000 ft
- 30,000 ft
- 40,000 ft

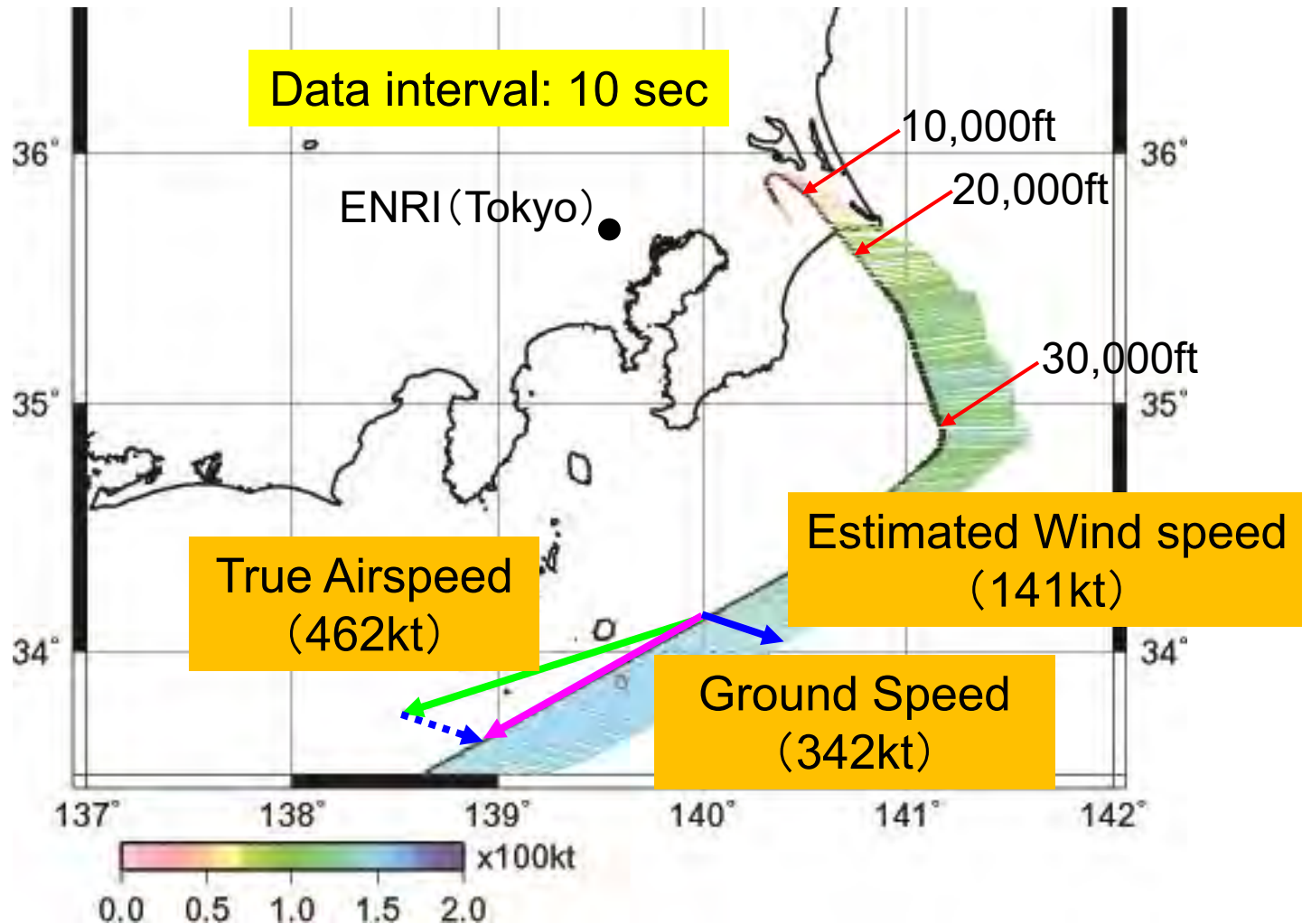
Location: ENRI, Tokyo

Coverage: ~250NM

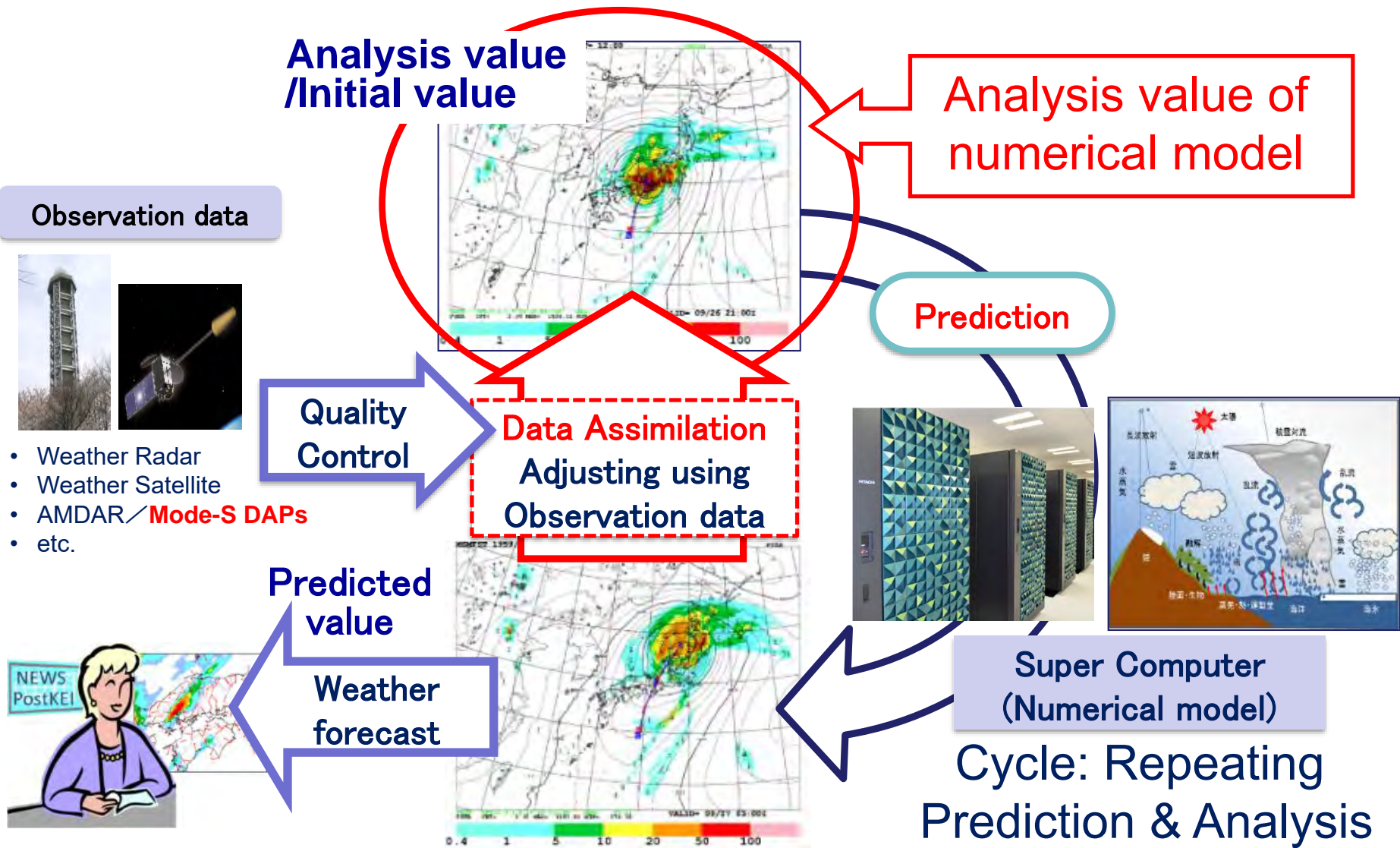
Rotation Period: 10sec

Power: 1.5kW max.

Estimation example of horizontal wind



Flow of numerical weather forecast



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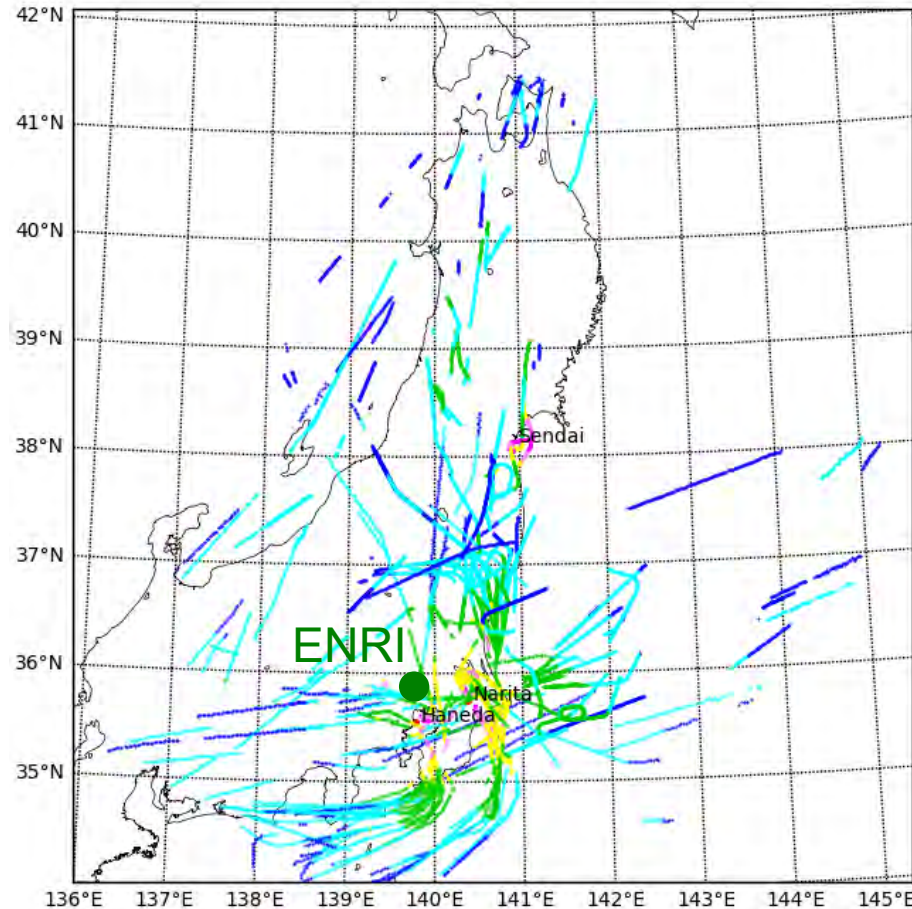
Conditions of experiment

- Evaluation event was that intense rainfall and shear-lines passed on Haneda and Narita International airports
#Flight operations were affected by this rainfall event
- Rainfall and shear-lines were reproduced by predictions from the initial conditions
#Initial conditions were obtained by using the operational data only and by adding the DAPs data to operational data
- Grid intervals of forecast and assimilation are 5km and 15km
- DAPs data on the hour – 10min was used as the hour data in assimilation
- Temperature was corrected 1 degree as Bias error
- Temperature above height of 3 km was used in assimilation
- Effect of DAPs data were evaluated by comparison with the observed data



DAPs

DAPs data using on the experiment



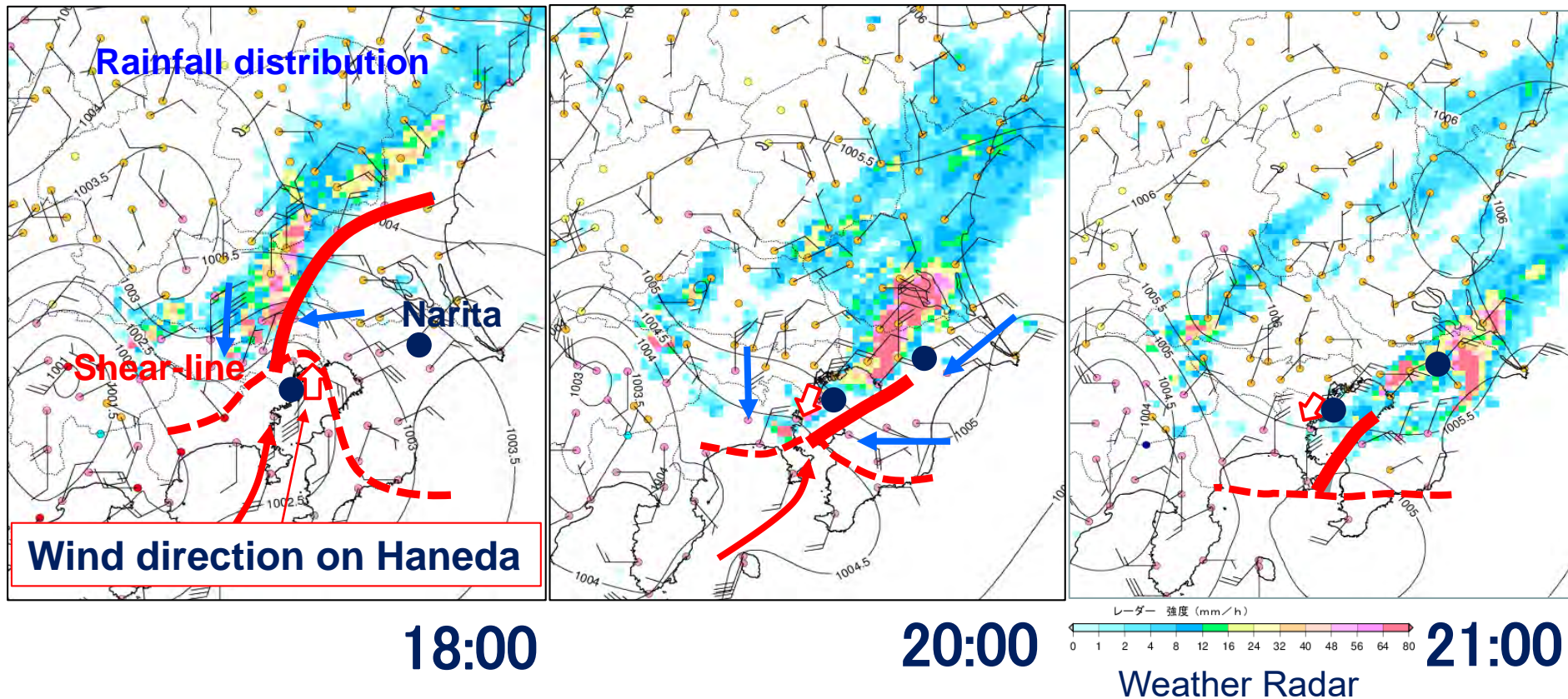
Barometric pressure:

< 300hPa	Blue
300 - 500hPa	Cyan
500 - 700hPa	Green
700 - 850hPa	Yellow
850 - 925hPa	Magenta
925hPa <	Red

- The number of aircraft for data utilization was limited as a system constraint
- Much data during cruising was utilized as a result of prioritizing far aircraft

Evaluation event (Observed data)

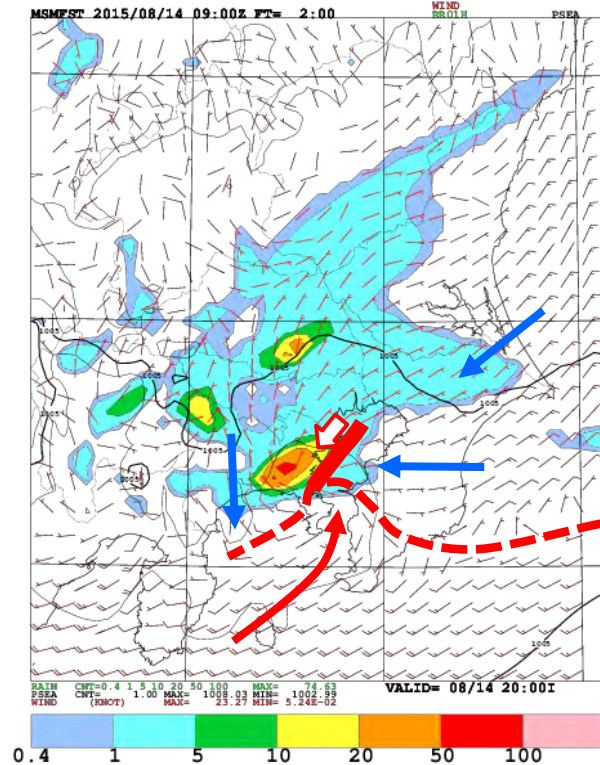
Rainfall distributions and wind directions in 14 Aug 2015



- Intense rainfall passed on Haneda and Narita airports at 19:00 – 21:00
- Aim is to predict wind changes and intense rainfall areas more accurately

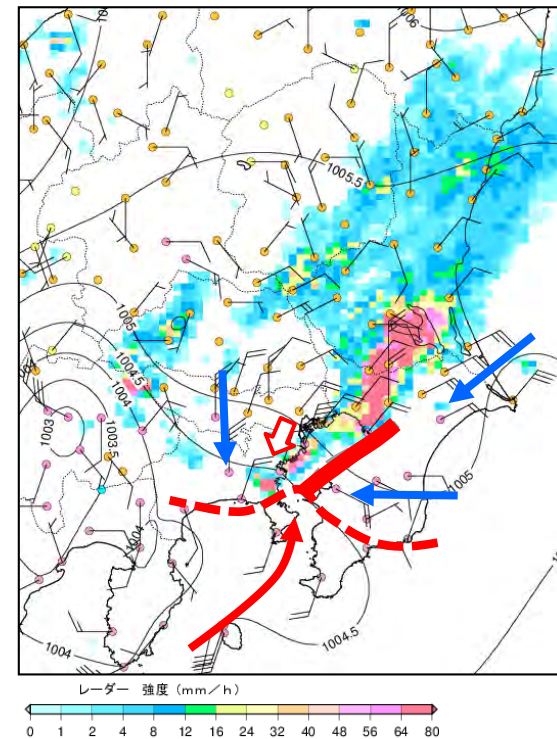
Experimental results (without DAPs)

Predicted data



20:00

Observed data



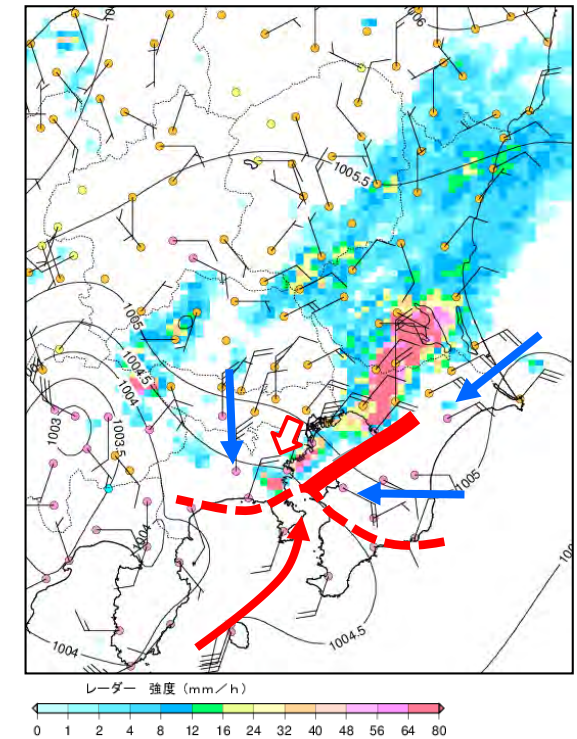
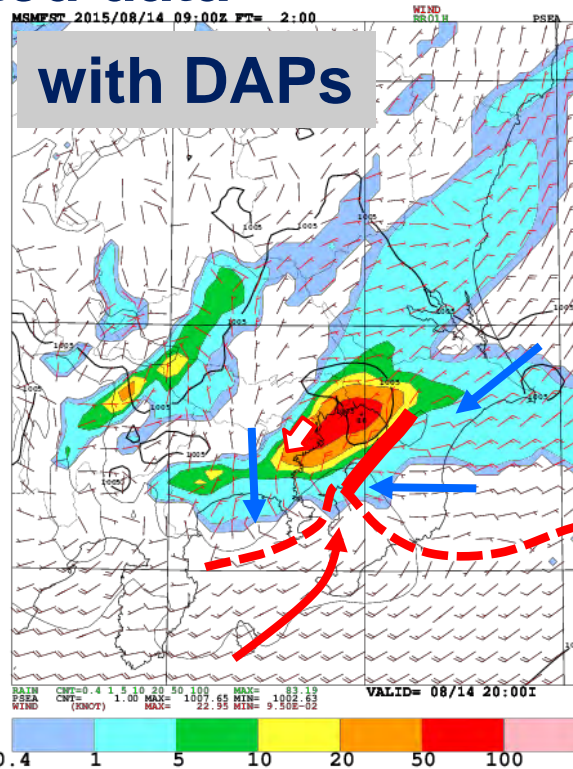
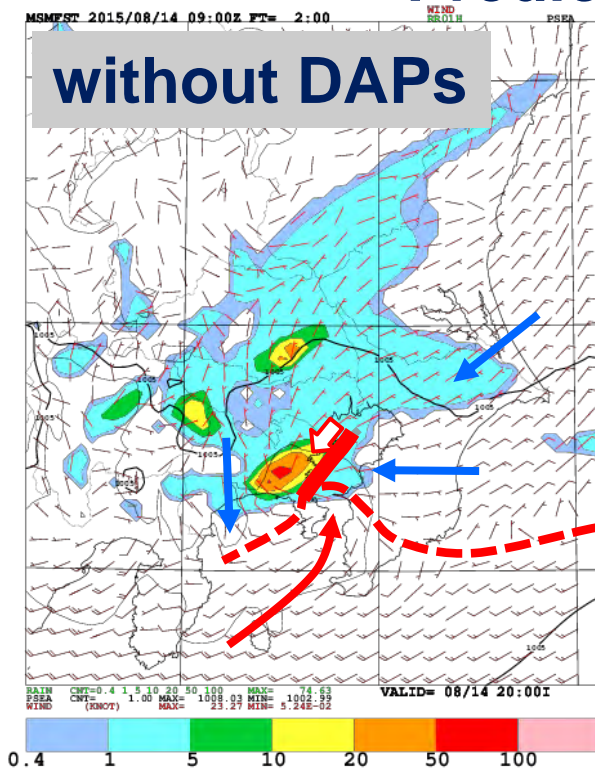
Weather Radar

- Predicted intense rainfall region was smaller than the observed region
- Predicted rainfall region was generated on the western side of shear-line (Red thick solid lines).

Experimental results (with DAPs)

Predicted data 20:00

Observed data



Weather Radar

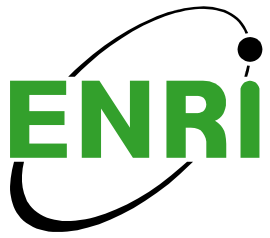
- Position of intense rainfall region became more similar to the observed one
- Position of shear-line was improved by the assimilation of DAPs data

Conclusion

Experimental results indicate that Mode-S DAPs data have a potential to improve forecasts of rainfalls and shear-lines

Acknowledgements

This study was carried out by the collaborative research of **Meteorological Research Institute** and **Electronic Navigation Research Institute**. This study was also carried out using operational data of Japan Meteorological Agency.



Thank you for your attention!
Any questions?