Using Compact Doppler Radar (WITH Radar) Network to Detect Local Weather Phenomena

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ABSTRACT

In order to properly carry out winter road management operations like snow-removal and application of anti-freeze chemicals, forecasting and monitoring weather conditions on highways is critical. In order to provide such critical information, the first step is graphic representation of snow clouds detected by our proprietary radar infrastructure.

We have found this to be an extremely effective approach to forecasting and nowcasting for snow.

Meanwhile, characteristic topography of Japan which influences inflow of winds can bring heavy snowfall to ?"highly"? localized areas for brief periods. In addition, many roads in Japan are constructed between mountain slopes. Therefore, detecting local weather phenomena for maintaining optimum road conditions is a critical issue in Japan.

The radar used by the JMA (Japan Meteorological Agency) is currently considered to be an effective tool

for observation of snow clouds. These are fixed radar installations across Japan.

The detection range of one radar installation is about 250 km, and it can measure snow cloud heights from 2 km or higher.However, on highways which run through mountain slopes, JMA radars cannot detect lower-altitude snow clouds. This is a major concern for highway management companies. As a proposed solution, we set-up a network of compact Doppler radar (WITH Radar) at and key traffic points all over

Japan which covers the blind areas of the JMA’s radar network.

The main features of our Doppler radars are as follows:

・Three-dimensional scanning for rain snow clouds
・Wind speed measurement (Doppler speed)
・6-seconds scan frequency（vs. 5-minutes for JMA Radar）
・Precipitation phase differentiation (see case below)
・Cloud detection at altitudes below 2 km

INTRODUCTION

Forecasting and monitoring of weather conditions are critical in maintaining safe passage on highways in the winter, since information obtained through these actions are the basis for road management operations such as salting and snow removal. Utilization of weather radar is known to be one of the most effective means for this purpose. [1]

The undulating, mountainous topography which constitutes the majority of Japan's land area and its complex surface wind flow brings heavy snowfall to highly localized areas in the winter in this country. Consequently, the highways of Japan tend to be constructed in an environment where understanding of such regionally and seasonally limited meteorological phenomena is important in road maintenance.

In this paper, we report the possibility of applying compact Doppler radar, i.e. the WITH Radar, in addition to existing comprehensive radar network on behalf of optimizing winter road maintenance, by introducing a couple of model examples.

MATERIALS

The radar network established by the Japan Meteorological Agency (JMA) is commonly considered to be the most effective means for observation of snow clouds in Japan. This JMA radar network is installed throughout Japan. [2] Each radar has a horizontal detection range of approximately 250 km, and distinguishes clouds with a height of 2 km or higher. On the other hand, it is known that snowfalls could be observed on highways in mountainous areas even when JMA radars fail to detect any cloud.[1][3] This poses a major concern for the highway administrators, as the monitoring of snow clouds and the decisions for consequent road maintenance measures rely heavily on radar detection.

In order to detect such snowfalls and similar local mesoscale weather in the "blind areas" of JMA radar network, we established a compact Doppler radar (WITH Radar) network comprising 80 radar sites (Fig 1).[1]

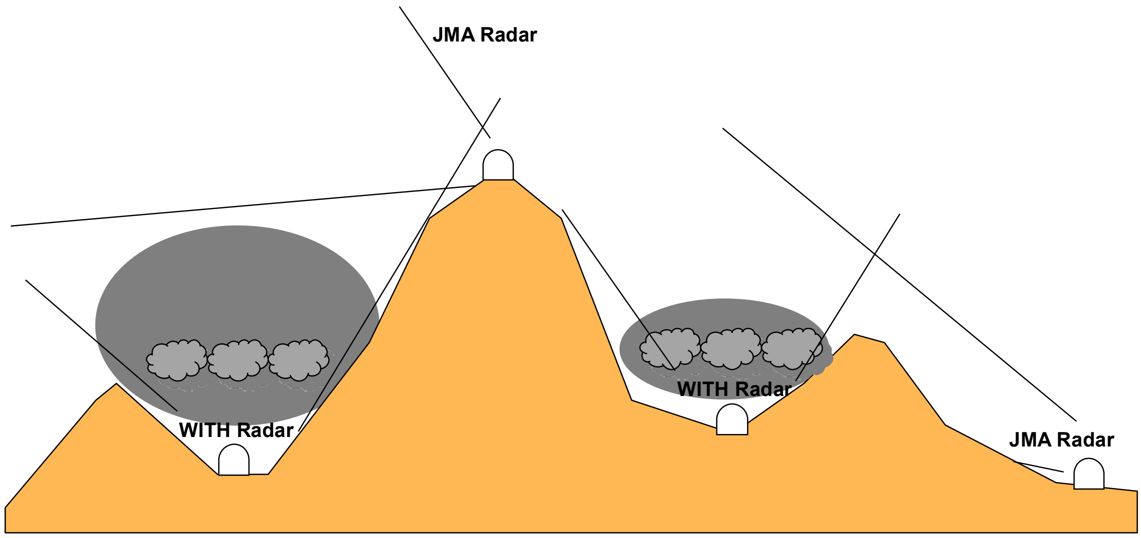

Figure 1: Illustration of WITH Radars installed in the blind areas of JMA Radar. While JMA Radars are installed throughout Japan, the undulating landscape of Japan allow for many blind areas (grey circles). WITH Radar network was established so as to clarify these areas.

The basis for WITH Radar (Fig 2) is the radar commonly mounted on aircrafts for recognizing clouds with potential possibility of turbulence, e.g. cumulonimbus clouds, during flight (Fig 3).

Figure 2: Exterior appearance of a WITH Radar.

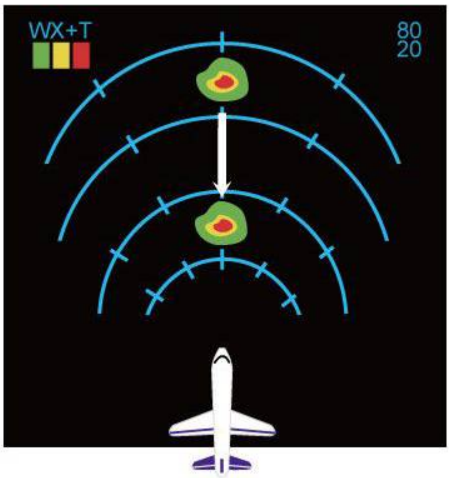

Figure 3: Illustration of an aircraft radar detecting clouds possibly accompanying turbulence.

Because this aircraft radar is required to detect such clouds without delay while the plane itself is travelling at a high speed, it is made to scan at a high rate of every 6 seconds. The technical particularities of WITH Radar are basically identical with those of the aircraft radar, and are described with regard to the JMA radar in Table 1.[2]

Table 1: Technical description of WITH Radar and JMA Radar

	WITH Radar (Aircraft Doppler radar)	**JMA Radar**
Minimum Observation Altitude (km)	0	2
Detection Range (km)	50	250
Observation Intervals (sec)	6	300
Resolution (m)	150	1,000
Observation Factors	- Precipitation intensity - Doppler speed - Precipitation phase	- Precipitation intensity - Doppler speed

CASE EXAMPLES

The practical application of WITH Radar in detecting localized weather is shown in the 2 model cases described below.

1. Detection of snowfall in blind areas of JMA radar

The Shin-Meishin Expressway serves as one of the transportation arteries of Japan, connecting Nagoya and Kansai areas, the 2 major economic areas in Japan. Because the number of days with snow is relatively small, the majority of the drivers use this expressway without changing tires in the winter. Under such circumstances, rigorous road management is required in order to prevent accidents.

At 23:40 on April 4, 2010, one of our WITH radar (Radar A) detected a snowstorm approaching the Shin-Meishin Expressway (Fig 4). The vertical radar image showed a cloud top height of approximately 2,000 m, suggesting a snowfall rate of 2-3 cm/h. This information was conveyed at once to the road administrators, and measures were taken 30 min beforehand.

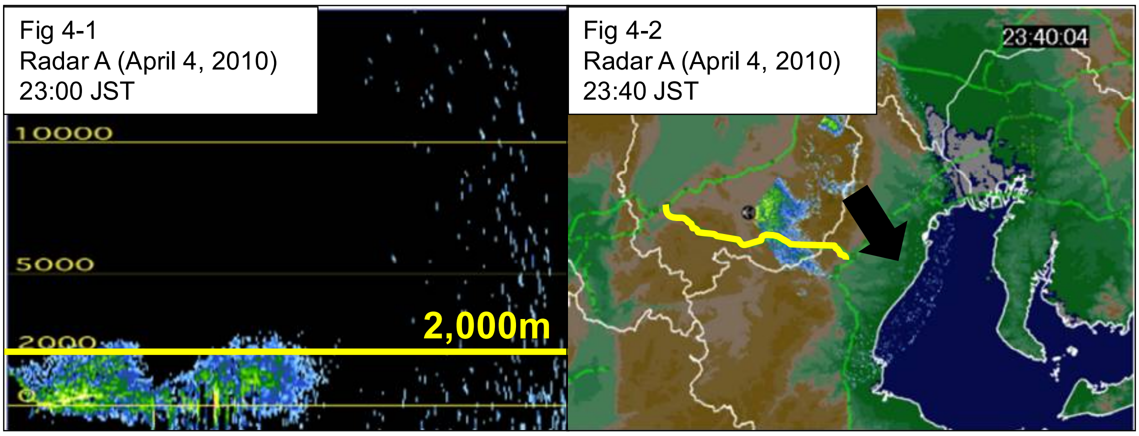

Figure 4: Detection of a regional snowstorm approaching Shin-Meishin Expressway. Fig 4-1: The vertical view of WITH Radar. Radar echoes shown in blue and green represent clouds. The altitude of 2,000 m is indicated in thick yellow line. Notice the height of the cloud top is approximately this height, suggesting a snowfall rate of 2-3 cm/h. Fig 4-2: The horizontal view of WITH Radar. Clouds are depicted in the same color as in Fig 4-1. The curved yellow line represents Shin-Meishin Expressway. The black arrow is the direction in which the clouds are moving.

Furthermore, at 0:15 the next day, the horizontal image from Radar A suggested a change in the estimated course of which the clouds were taking (Fig 5). This was confirmed by further tracking of this cloud using Radar B, another WITH Radar covering the same area from the opposite side as Radar A, until 1:30 on April 5 (Fig 6). This consecutive data enabled the administrators to perform a snow removal operation at the right time, and to concentrate resources on other areas with heavier snow.

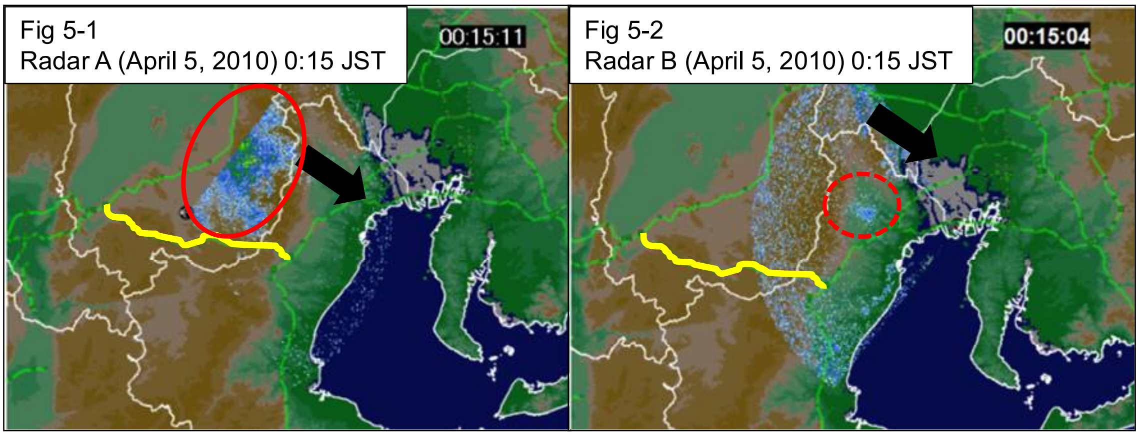

Figure 5: Change in the direction in which the clouds are moving. Black arrows indicate the direction. Yellow lines represent Shin-Meishin Expressway. Clouds no longer flow toward the highway. Radar B in Fig 5-2 cover the same area as Radar A from the opposite side. Notice that clouds detected by Radar A (Fig 5-1; red circle in solid line) are not captured by Radar B and vice versa (Fig 5-2; red circle in broken line).

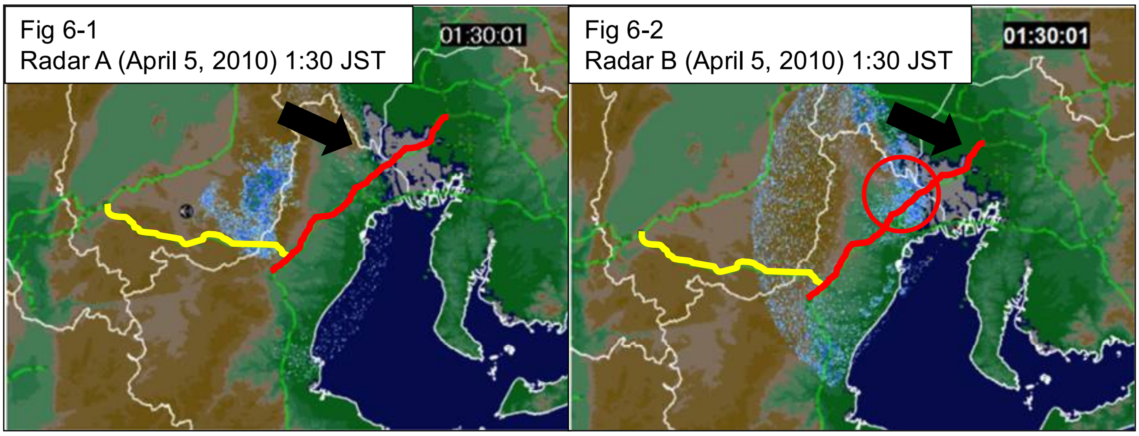

Figure 6: Radar images of clouds (red circle) that were originally approaching Shin-Meishin Expressway (yellow line) are now moving into a neighboring highway (red line). Black arrows indicate the direction in which the clouds are moving.

2. Identification of Precipitation Phase

Glaze, the smooth, transparent coating of ice on the road surface caused by freezing rain, is a challenge for road administrators in the Tokachi Plain of Hokkaido throughout November and December. At this time of the year, precipitation regime varies from rain to snow, including freezing rains. Determining the type of precipitation is critical, as subsequent road management operation differs with each precipitation.

On December 11, 2010, a developing low pressure accompanying a warm front was heading toward Hokkaido Area from the Sea of Japan. This warm front passed over Obihiro City, the central city in the Tokachi Plain, in the afternoon of the same day, which was later known to have been accompanied by a parcel of warm air over 0 degrees Celsius at the altitude of 200-700 m (Fig 7). This warm air made the precipitation to become a rain at this height, but since the surface air remained below freezing point, there was a possibility of freezing rain. Note that we were not able to actually observe this presence of an inversion layer beforehand.

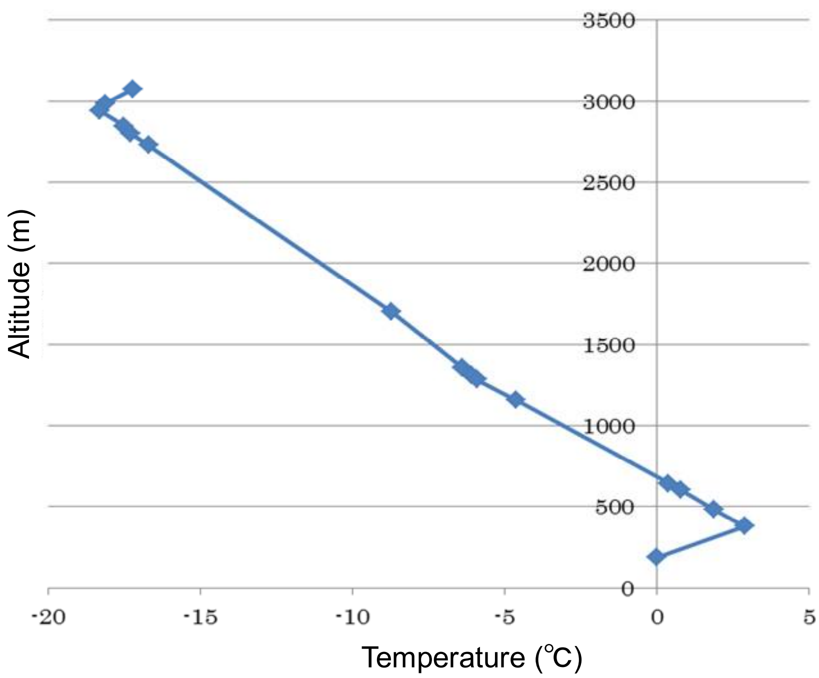

Figure 7: Estimated temperature over Obihiro at 21:00 JST on December 11, 2010, analyzed using data from JMA. Note the inversion layer near the height of 500 m.

Theoretically, a real-time monitoring of the inversion layer would be the ideal method for determining the precipitation regime; however, the JMA radar is not designed for such purpose (Fig 8).

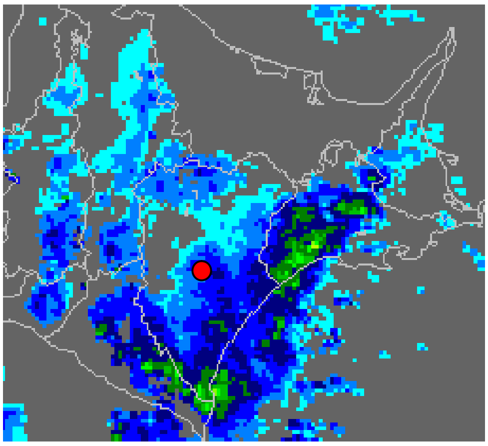

Figure 8: Image of JMA radar at 13:00 JST on December 11, 2010. Red dot represents the central part of Obihiro City. Note that neither the inversion layer nor the precipitation regime can be determined from this image.

Instead, we used the WITH Radar to visualize the vertical layers of the cloud (Fig 9). As a result, a layer with high radar echogenicity, known as the bright band, was observed. This is characteristic feature is known to indicate the melting layer within the cloud. The surface temperature, as mentioned above, was below 0 degrees Celsius. Together, they suggested the approach of a freezing rain. This insight into the precipitation phase allowed the road administrators to salt their road beforehand, and they succeeded in preventing the road from glaze.

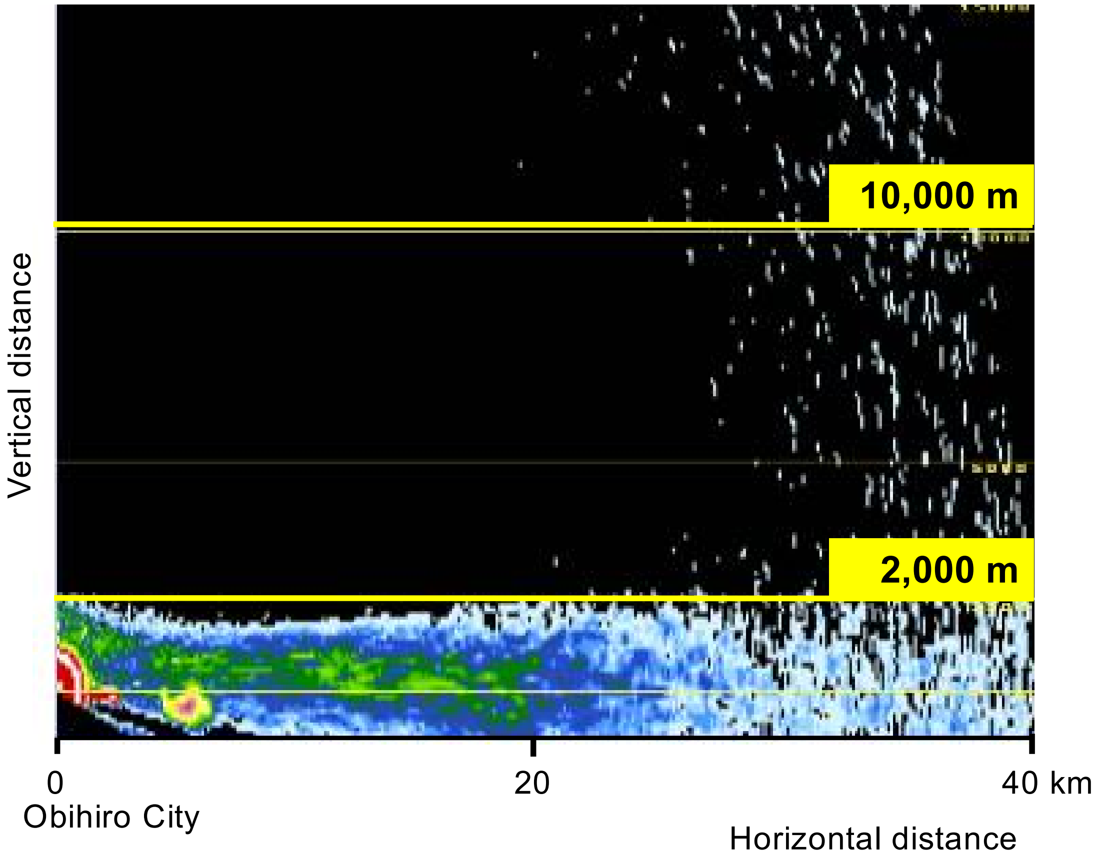

Figure 9: Vertical image of WITH Radar at 13:00 JST on December 11, 2010. Note the green layer of highly echogenic cloud near the altitude of 1,000 m called "bright band," suggesting the presence of a melting layer within the cloud.

CONCLUSION

We have shown that WITH Radar, a compact Doppler radar network, is capable of detecting snow and distinguishing precipitation regime in areas where such insight were previously not obtained from the JMA radar. As such information has a large impact on the road maintenance in the winter, a further case sampling and analysis of observation data is warranted.

REFERENCES

[1] Aruga, T. et al. (2013). Application of compact radar network in the detection of snowstorms. 25th Yukimirai congress, p.69

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