13B.7 DEVELOPMENT OF WEATHERNEWS' RADAR OPERATIONS

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1. INTRODUCTION

With operations on a global scale, Weathernews is faced with ingesting, analyzing, and producing radar products from many diverse sources. Data are currently ingested from the United States, Italy, China, Australia, Japan, Canada, Korea, Malaysia, Taiwan, England, France, Belgium, Netherlands, and Germany in a variety of ways including graphical images, real-time raw data, and pseudo-real-time derived products. An array of analyses and products are created for internal forecasters while real-time displays of radar data are used to service clients.

Timeliness and availability of data can vary greatly from country to country creating a paucity of observations in some regions such as Japan (Global Headquarters for Weathernews). Although a national radar network operated by the Japan Meteorological Agency (JMA) exists, adequate boundary layer coverage is lacking and most radars are non-Doppler though a conversion is in progress (see Section 2). Moreover, recent severe weather events in Japan, including multiple tornadoes, have brought to light the need for improvements in the nation's ability to detect localized weather hazards. Thus, Weathernews is planning to enhance the quality and quantity of radar observations through deployment of its own radar network.

2. JAPAN RADAR NETWORK AND WARNING SYSTEM

JMA presently operates a network of 20 C-band (5 cm wavelength) weather radars, 4 of which have been upgraded to Doppler with one or more due to be converted by the end of 2007 (Figure 1). In addition, 8 X-band Doppler radars are in operation at international airports: Sapporo, Narita, Haneda, Chubu, Osaka, Kansai, Fukuoka, and Naha. An additional radar at Kagoshima will begin operation in 2007. These Doppler data, however, are not available for direct distribution to private industry.

Japan presents a particularly unique challenge for the deployment of weather radars owing to its highly variable orography (see Figure 2) and the need to surveil offshore regions. Some of JMA's radars are sited at relatively high elevations, thus impeding the detection of fine-scale weather such as microbursts, tornadoes, gust fronts and other localized hazards. Furthermore, JMA only provides a derived quantitative precipitation product. Although JMA provides a useful service in support of a national network, there still exist certain limitations that Weathernews is seeking to address by examining the viability of a privately-owned radar network in Japan.

3. SEVERE WEATHER IN JAPAN

A variety of severe weather events impact Japan year round. Although typhoons certainly present a major weather hazard during late summer and early fall (Fujii 1998, Lin et al. 2001), significant severe weather occurs during the wet Baiu season in June and July and in winter as a result of strong convection along cold fronts as polar air masses interact with the relatively warm Sea of Japan.

Heavy rains are possible not only with typhoons but also from mesoscale convective complexes (MCSs) associated with the Baiu front (Watanabe and Ogura 1987, Nagata and Ogura 1991, Ninomiya and Akiyama 1992, Davidson et al. 1998). The Baiu front, or Mei-Yu front in China, is a

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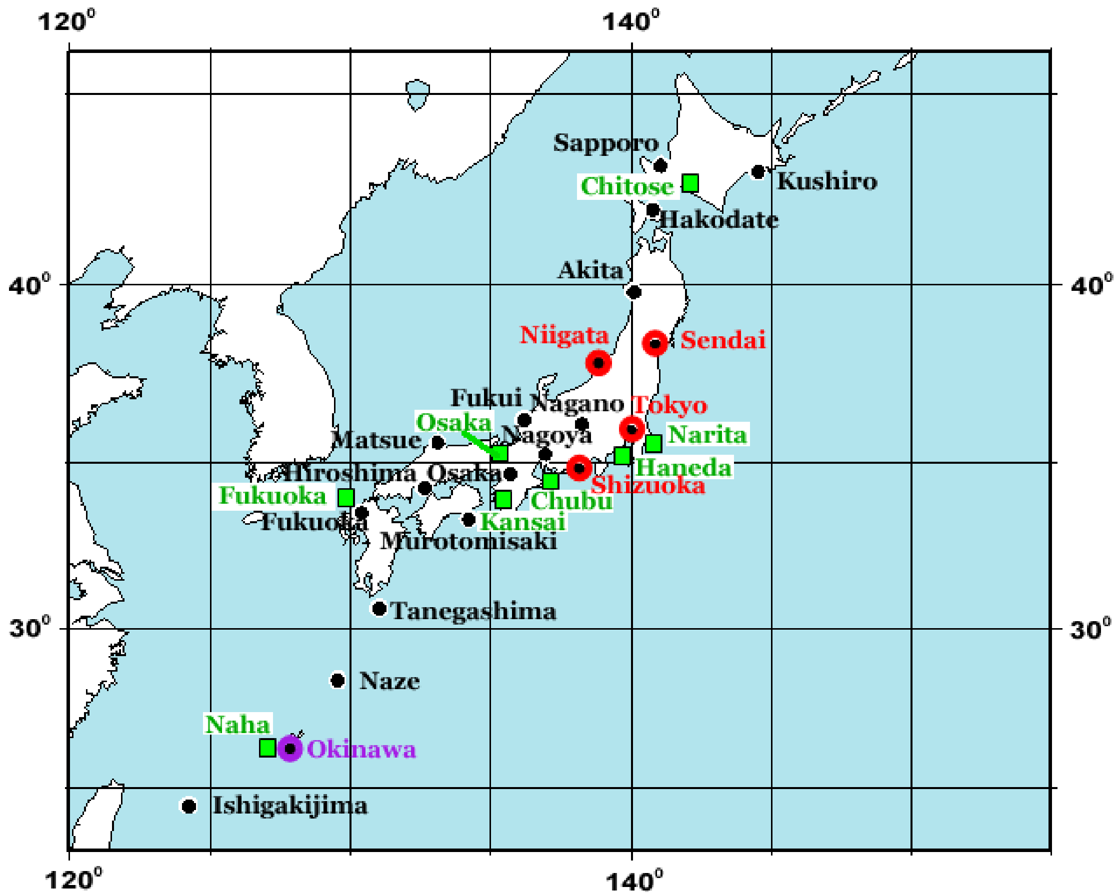

Fig. 1. JMA radar network comprising 20 C-band and 8 X-band radars. Four C-band radars have recently been converted to Doppler and are shown encircled in red. Existing non-Doppler C-band radars (black letters and dots), Doppler radars to be installed in 2007 (red letters and dots) and in 2008 (purple letters and dot), and X-band aviation weather radars (green letters and squares) also are shown. Reproduced from Ishihara et. al. (2006).

quasi-stationary front that typically develops in June and July along the northern boundary of the warm, moist subtropical high over the western Pacific. The front is typically marked by a horizontal moisture gradient and low-level wind shear. Heavy precipitation and well-defined low-level jets in the 850-700 mb layer are noteworthy features of MCSs embedded in weak, subsynoptic-scale surface lows that develop along the Baiu front (Nagata and Ogura 1991). Heavy rains associated with this front primarily affect the islands of Kyushu, Shikoku, and far southwestern regions of Honshu (particularly in the Chugoku region) as shown in Figure 2.

During winter, convective storms, intense snowstorms, and strong winds can be produced by cold fronts and “lake-effect” mechanisms (turbulent fluxes of heat and moisture) caused by the interaction of a Siberian cold air mass with the relatively warm waters of the Sea of Japan (Ninomiya 1989, Tsuboki and Asai 2004). In these events, surface mesoscale polar lows can form west of the Japanese islands over the Japan Sea. Most polar lows are observed in two regions of the Sea of Japan, as depicted in Figure 2. One region is the western Sea of Japan west of Honshu Island and southeast of the locally higher Korean terrain, and the other is off the west coast of Hokkaido Island, also southeast of another area of regionally higher terrain in Korea. These two regions correspond to the Japan-Sea Polar-Airmass Convergence Zone (JPCZ) (Asai 1988). Investigations have shown that the Korean topography and the thermal contrast between the Sea of Japan

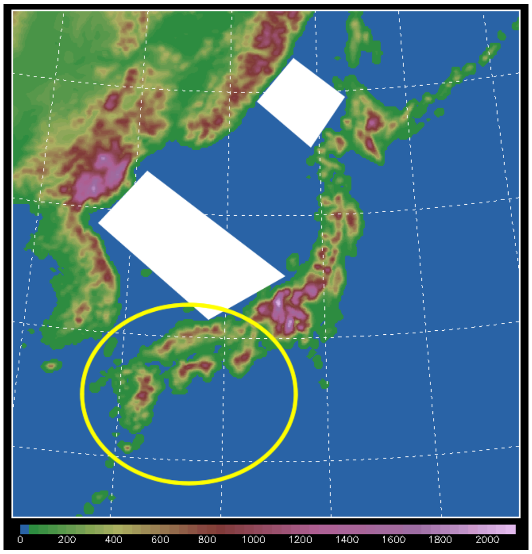

Fig. 2. Topography of Japan and the Korean Peninsula with color contours shown in meters. The region encircled in yellow is the typical region of heavy localized rains associated with the Baiu front including the Kyushu and Shikoku Japanese islands and the Chugoku region of Honshu, the main island of Japan. The white polygons outline the two preferred regions of JPCZ occurrences and polar low development across the Sea of Japan.

and the Korean Peninsula are the primary factors in polar low development and that most polar lows develop along the JPCZ. These cold-season weather scenarios can result in convective storms that produce heavy precipitation, damaging winds, and even tornadoes.

4. RECENT SEVERE WEATHER EVENTS

In recent years, several damaging wind and tornado events in Japan have resulted in significant property loss, economic disruption, injuries to people and even several deaths. In an 11-month period from December 2005 to November 2006, three different high-profile events in Japan have sparked a renewed interest in increasing the accuracy of predictions of tornadoes and damaging, convective wind events.

On December 25, 2005, a Japan Railway East passenger train derailed in northwest Japan as a result of very strong winds, killing 5 people and injuring 32 (Figure 3). On this date, a series of strong convective bands developed along a cold front passing over the Sea of Japan. Embedded in these convective bands were intense cells, some of which were capable of producing downbursts as evidenced by the analyzed weather data. Official observations in Sakata City, about 10 km from the accident location, indicated wind gusts up to 21.6 m/s around the time of the accident. Through damage assessment, winds are estimated to have exceeded 40 m/s at the actual accident site.

Recently, tornadoes also have significantly impacted Japan. During the past year alone, 12 people have been killed and over 400 injured by tornadoes. Two of the deadliest tornadoes in Japan since 1941 occurred within two months of one another. On September 17, 2006, a tornado struck Nobeoka, Miyazaki Prefecture in southern Japan killing 3, injuring 100, damaging 1800 buildings and derailing an express train. The tornado occurred in a rain band associated with Typhoon ShanShan. The second tornado on November 7, 2006 hit the town of Saroma, Hokkaido Prefecture in far northern Japan as a severe storm associated with a strong cold front moved through the area. Figure 4 shows radar reflectivity returns shortly before the tornado touched down. The tornado killed 9 people while damaging or destroying 40 buildings or homes (Figure 5).

A climatological record of tornadoes for Japan from 1961-1993 proves that tornadoes are not rare events in Japan (Niino, Fujitani, and Watanabe 1997). Figure 6 displays the locations of tornadoes in Japan between 1961 and 1993. On average, 21 tornadoes have struck Japan each year in that 33 year period representing a frequency (areal averaged) roughly 55% of that within the United States. A majority of tornadoes occur along the coastal regions (within 5 km of the coast) of Japan and approximately 23% of all tornadoes are associated with typhoons. More than half of all recorded tornadoes occur from July through October with a peak in September and more than 75% occur on Japan's Pacific coast (eastern and southern coast) as opposed to the coast along the Sea of Japan (western coast).

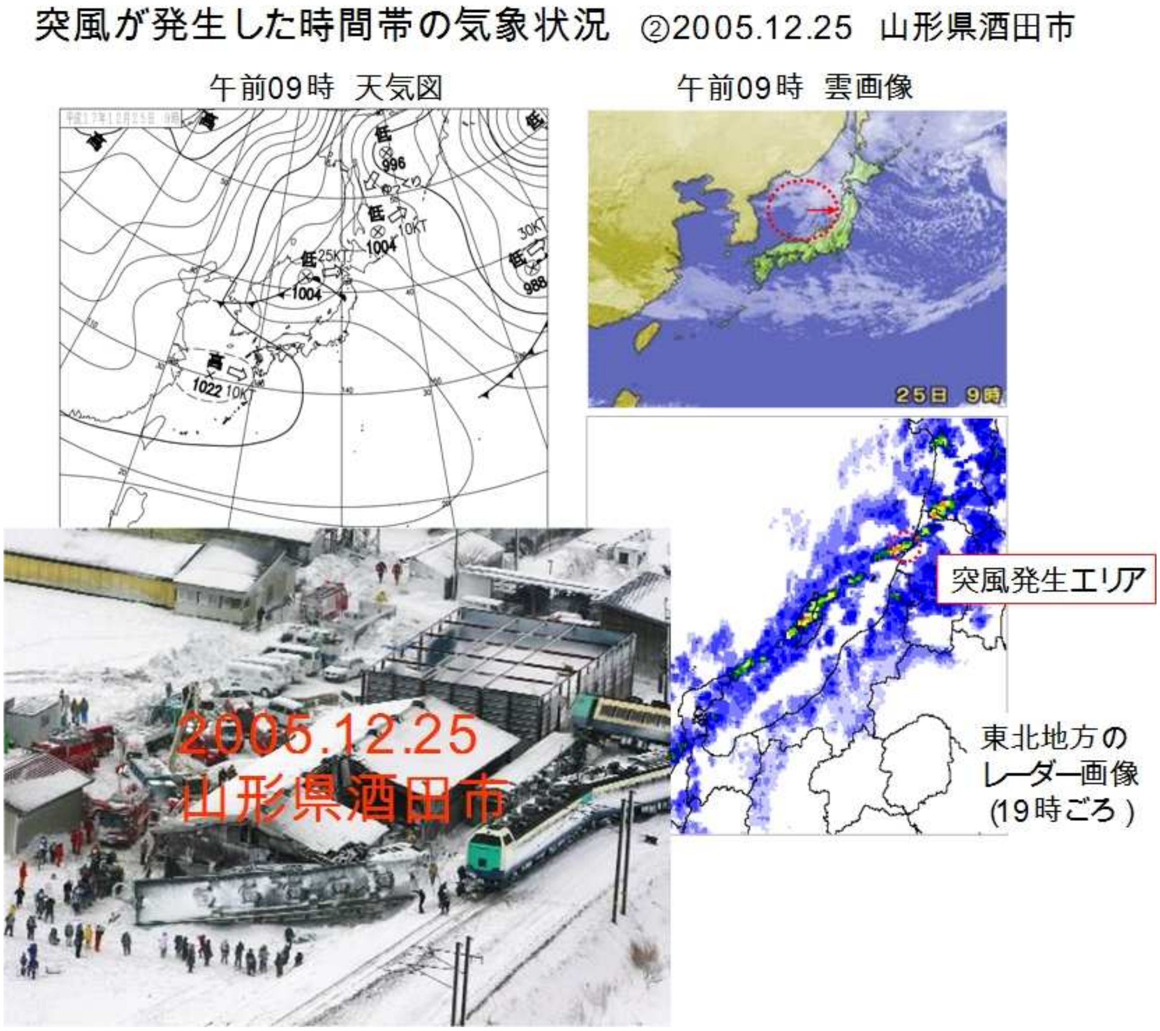

Fig. 3. The train derailment accident near Sakata city in Yamagata prefecture on 12/25/05 is shown in the lower-left photo. The weather situation is depicted (clockwise from left to right) by a synoptic chart at 9:00 JST that shows a surface low over the Sea of Japan and analyzed cold front, a satellite image at the same time, and radar reflectivity that shows the line of strong convection approaching the western Japan coast around 19:00 JST, the general time of the accident. The red circle in this last image depicts the cell that is associated with the microburst.

Until the Nobeoka (3 killed) and Saroma (9 killed) tornadoes, which occurred in the span of two months, multiple-fatality tornadoes were rare. Since 1961, no recorded tornado had caused the death of more than 2 people. And only 3 of 591 tornadoes had resulted in two fatalities each. The average damage path length of tornadoes in Japan is 3.2 km, about one-half of that in the United States, and the average lifetime of tornadoes in Japan is approximately 12 minutes.

Nearly one-quarter of all tornadoes in Japan are associated with typhoons. Tornadoes in storms associated with tropical cyclones typically have shorter vertical extents along with narrower updrafts, smaller mesoscyclones, as well as smaller reflectivity echo patterns (McCaul et al. 2004). These same characteristics have also been found in storms associated with typhoons that have struck Japan (Suzuki et al. 2000). In fact, as part of their findings, which included results from tornadic storms associated with extratropical cyclones, Suzuki et al. (2000) stated that “a significant fraction of tornado-producing storms in Japan are mini-supercells”. Furthermore,

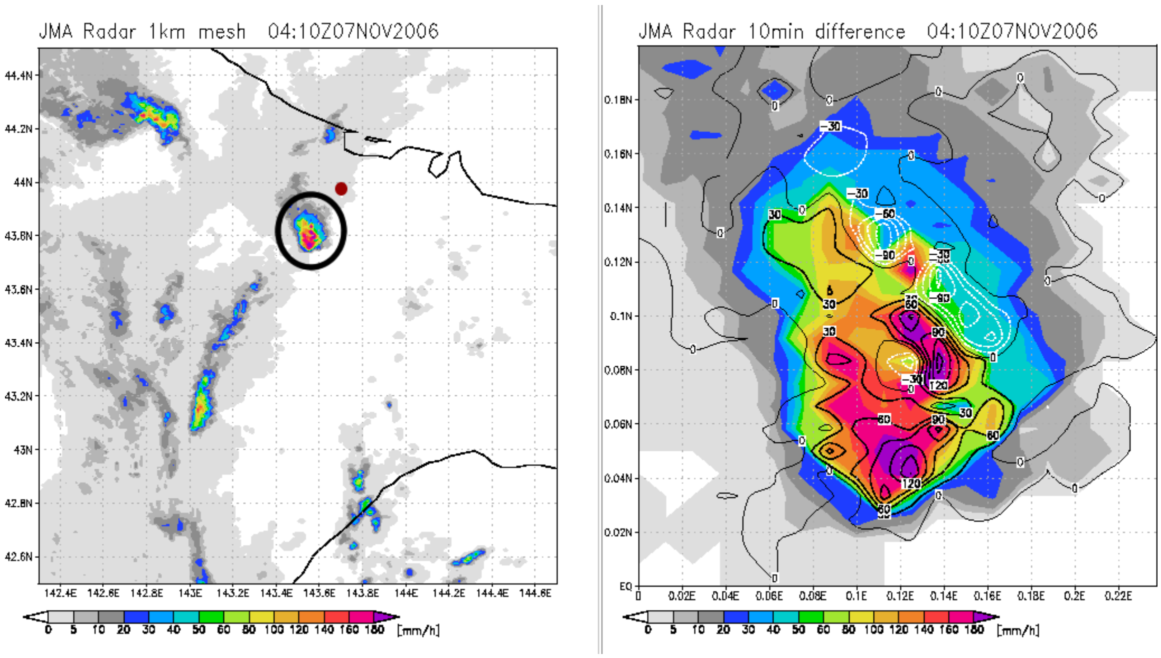

Fig. 4. JMA radar image shortly before a tornado struck Samora, Hokkaido, Japan. The storm cell of interest is encircled by the black ring on the image to the left. The maroon dot northeast of the cell marks the location of Samora. A closer look at the image is provided on the right. Contours of the difference in reflectivity within the storm cell from 10 minutes prior are shown in solid black (positive difference) or broken white (negative difference).

the type of synoptic systems during the winter that produced the rail car derailment near Sakata City as well as the Saroma tornado are reminiscent of severe storms associated with cold core 500-mb lows. A preliminary examination of surface data from these two events reveal conditions similar to what Davies (2006) found to be associated with tornadic storms close in proximity to midlevel closed lows with a core of cold temperatures aloft. In these situations, the tornadoes are often connected to low-topped or mini-supercell storms.

It indeed may be possible that a significant number of tornadoes in Japan are associated with smaller storm cells and mesoscyclones. Furthermore, the damage path length and lifetimes of the cells are shorter than those in the United States. All these facts greatly emphasize the importance of developing a radar network than can observe meteorological phenomena on smaller spatial and temporal scales compared to storms that have been extensively studied in the United States.

5. DESIGN OF POTENTIAL RADAR NETWORK IN JAPAN

Weathernews highly values the acquisition and internal development of leading-edge forecast technology in addition to providing the best weather services possible. For example, Weathernews has constructed a mesoscale numerical forecast system, the Original Weather Numerator (OWN) (Shaw, Lee, and Sakamoto, 2006) to provide numerical forecasts across the world. With a desire also to improve its base of weather observations, Weathernews is taking a lead role in addressing limitations of the national weather radar network in Japan. The series of severe weather events discussed previously emphasize the pressing need to develop a radar network especially considering the lack of a warning system within Japan to alert the public of impending hazards such as tornadoes or damaging wind events.

Fig. 5. Saroma, Hokaiddo, Japan tornado, November 7, 2006, and resulting damage. Photos courtesy of AFP/AFP/Getty Images and Yahoo.

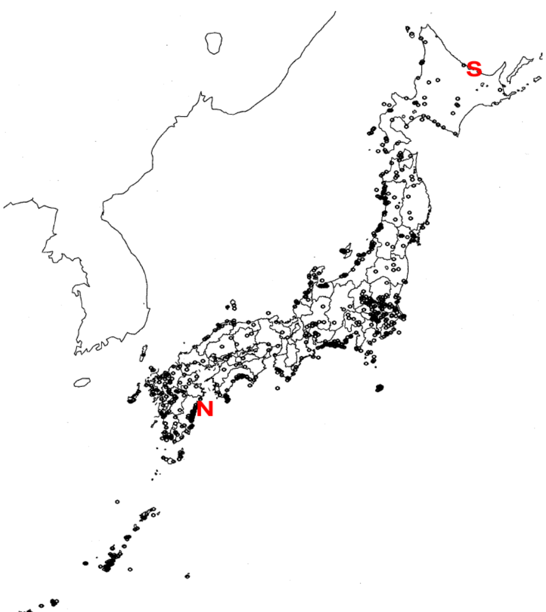

Fig. 6. Documented tornado and waterspout occurrences in Japan from 1961 to 1993. (Niino, Fujitani, and Watanabe 1997). The location of the Nobeoka tornado is given in the red "N" and the location of the Saroma tornado given in the red "S".

The development of a privately-owned radar network is being pursued primarily so that Weathernews can meet the specific needs of its clients. This type of network will provide much-needed additional radar data in general and could be developed to improve the ability to detect small-scale weather hazards close to the surface of the Earth that the current JMA radar network could potentially miss. Many questions and aspects of the potential network need to be considered. For example, if severe localized weather events such as tornadoes and damaging downburst winds are of primary importance, the network will require relatively small spacing (< 50 km) in order to mitigate problems due to the curvature of the Earth. Using radars spaced that closely allows for the use of smaller, lower-cost X-band radars, yet potential attenuation problems will have to be considered. Japan also has highly variable terrain over short distances and properly locating radars will be important. Range and power specifications of the radars become an issue when considering how to provide coverage over the Pacific Ocean and Sea of Japan.

Of course other types of issues will also arise in deploying a new radar network such as: ease of accessibility and distance from main operations center to address maintenance issues; availability of IT connections and dependable electric power sources; historical precedents of accidents due to local weather hazards; proximity to other observational networks or platforms, for verification purposes; restrictions or guidelines by government regulations or policies, etc.

Given the particular aspects of severe localized weather in Japan as well as the unique needs of Weathernews' clients that need to be fulfilled, the deployment of a radar network in Japan will be an interesting and challenging endeavor.

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