P9.17 USING SAR WINDS TO EVALUATE SYNOPTIC AND MESOSCALE FEATURES IN FORECAST OPERATIONS

Kenneth Chan, Brad Snyder, Laurie Neil
Meteorological Service of Canada, Vancouver, B.C., Canada

1. INTRODUCTION

A national project has been established to evaluate and plan for future adoption of synthetic aperture radar (SAR) derived winds for use on an operational basis by the Meteorological Service of Canada (MSC). A large number of SAR wind images are being obtained for MSC forecasters to assess the utility and be used for marine weather forecasting.

MSC's marine forecast areas in the Pacific waters are adjacent to the complex terrain and coastlines of British Columbia and subjected to localized terrain-driven winds. Sparse weather observations at the coast and offshore decrease the amount of upstream data and the accuracy in placing synoptic-scale and mesoscale meteorological features critical to analysis, thus making marine weather forecasting a challenging task. Many of the details visible in the SAR images do not exist within the observation network, scatterometer data, or in model data. High-resolution, accurate and timely wind fields like the SAR-based winds are desirable to improve marine weather forecast operations.

This work will present three cases over the British Columbia coastal waters of SAR-based winds, and we will compare those winds with Canada's GEM Regional model and LAM mesoscale model outputs, satellite images and surface observations in different weather patterns. The objective is to demonstrate the utility of the SAR-based winds in marine forecast operations on a national basis by improving initial analyses, identifying mesoscale and synoptic-scale features, and providing detailed wind patterns especially adjacent to complex terrain and coastlines.

2. DATA AND METHODOLOGY

The National SAR Winds Project (NSWP) strives to make ocean surface wind fields from RADARSAT available to atmosphere and ocean scientists, and to weather forecasters in Canada. Project partners include the Canadian Space Agency, Canadian Ice Service, Department of National Defense, Department of Fisheries and Oceans, and the MSC. Within the MSC, National Labs, Science and Technology Transfer managers, and operations focal points are involved in training and evaluation of SAR-based winds to the meteorological operations. Some of the objectives of the project include: identify best system architecture for prototype and national operational SAR wind processing facilities within MSC, encourage and facilitate collaboration between all users of SAR data, and conduct assessments and cost-benefit analysis regarding an on-going operational system.

The Canadian RADARSAT satellites use SAR sensors to provide active microwave imaging of Earth’s surface at a microwave frequency of 5.3 GHz in the C-band. The satellites are in sun-synchronous orbits at 798 kilometres above the Earth’s surface at periods of about 100 minutes. RADARSAT can image the Earth through clouds, precipitation etc. to the water surface, providing clear and precise information on location of surface features over water. The returned signal to the satellite is proportional to the backscatter from surface wavelets on the ocean.

Software developed for the MENTOR project [1] was used to create near real-time high resolution SAR wind images from the RADARSAT data. The software is composed of the Wind Information Processing System (WIPS) and a Web Portal delivery interface. It uses the CMC GEM-Regional and GEM-LAM numerical weather prediction models as sources of wind direction in the SAR wind fields. MSC forecasters can access the high-resolution SAR wind images on the web portal for forecasting, verification, and evaluation. For this study, SAR wind images were searched through the web portal’s archive, and the following three cases were selected to demonstrate the use of SAR-based winds for forecasting in the complex terrain of coastal B.C. (Figure 1)

3. CASE STUDIES

3.1 *Case 1: Localized Terrain-Driven Winds*

A localized terrain-driven wind called the “Qualicum” occurs when a ridge of high pressure west of Vancouver Island gives a southwesterly pressure gradient over the South Coast of B.C. A plume of southwest winds would push through the northeast-southwest oriented Alberni Inlet on the west coast of the Island towards Qualicum Beach on the east coast into the Strait of Georgia. Sometimes the Qualicum will start off as a sea breeze in Alberni Inlet, but other times it is driven by a ridge in the wake of a front. The nearby Sisters Island and Chrome Island in the Strait

* *Corresponding author address:* Kenneth Chan, Pacific Storm Prediction Centre, Environment Canada, 201-401 Burrard Street, Vancouver, B.C., Canada, V6C 3S5; e-mail: kenneth.chan@ec.gc.ca

of Georgia will report it as a southwest wind if the plume extends into these sites. The prediction of these “Qualicum Winds” has always been a challenge to marine forecasters, since the winds are at strengths that are hazardous to small craft and to commercial activities like log-towing. Verifying these events can be difficult as well since the winds sometimes do not extend across observing sites.

In this case, a cold front moved across the South Coast with a ridge of high pressure building in behind (Figure 2). The SAR wind image at 0153 UTC on May 19 (Figure 3) shows a plume of strong southwesterly winds (20-30 knots) exiting Vancouver Island near Qualicum Beach into the Strait of Georgia. 02 UTC observations in red show Qualicum winds went undetected. Later the observations at 03 UTC from Sisters and Chrome Islands showed the Qualicum winds. Therefore, there was advance detection of the Qualicum winds by the SAR image before the winds extend across the observing sites. SAR wind also helped in pinpointing location and extent of the plume. The GEM-LAM wind forecast for the same time (Figure 4) shows the plume of wind but is wider and stronger than in the SAR image.

Confirmation of these events by SAR winds is very valuable. Even in cases where the winds are expected, SAR winds can be used for refining the forecast (speed and extent) and for verification. Similar cases of mainland inlet outflow winds into Strait of Georgia and other locally strong winds along the B.C. coast can be detected by SAR.

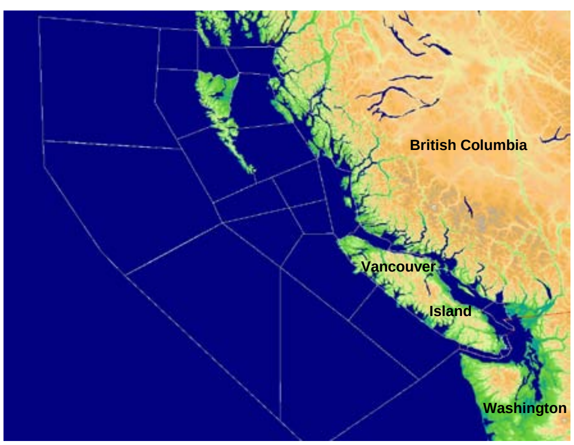

Figure 1: Topographical map of the British Columbia Coast, and the MSC's marine forecast region boundaries in the Pacific waters in white lines.

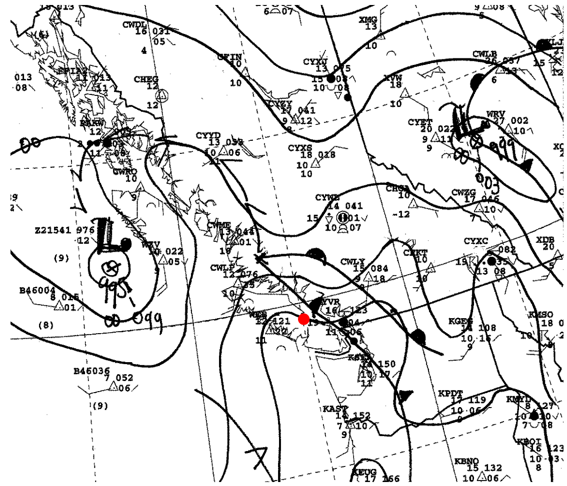

Figure 2: 00UTC May 19, 2010 surface weather map by the Pacific Storm Prediction Centre. Qualicum Beach is placed under the red dot.

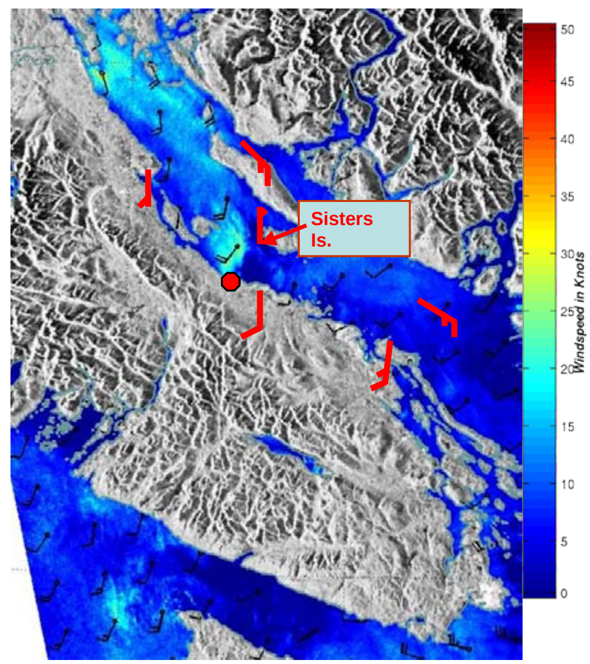

Figure 3: RADARSAT SAR image for May 19 2010 0153 UTC with GEM-LAM winds in black and surface wind observations in red barbs. Qualicum winds were undetected with these observations especially Sisters Island, which will usually report the strong winds.

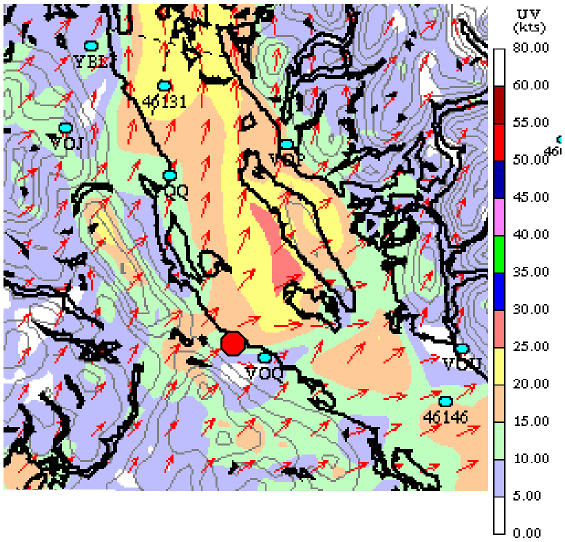

Figure 4: GEM-LAM West eta .995 wind forecast valid 02 UTC. Forecast shows the plume of wind but the forecast plume is wider and stronger than in the SAR wind image.

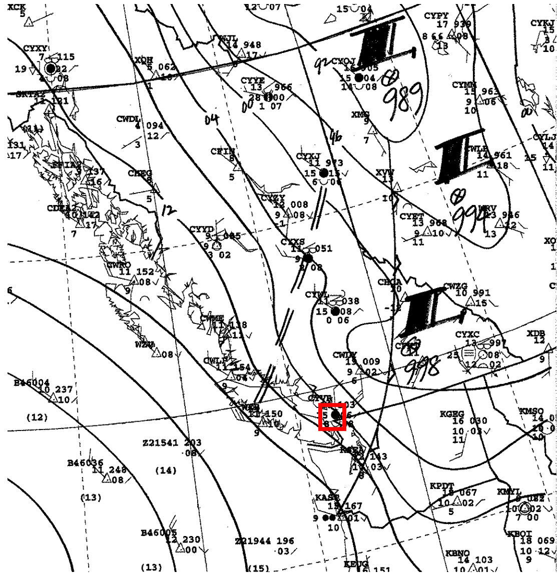

Figure 5: 12 UTC July 12, 2010 surface weather map by the Pacific Storm Prediction Centre. The area in question near Vancouver is placed inside the red square.

3.2 *Case 2: Gale Force Northwest Winds Near Vancouver*

In the morning of July 12, 2010, strong northwest winds developed over the South Coast of B.C. behind an upper cold front (Figure 5). Winds of 30 knots were forecast for the Strait of Georgia in the morning with strong pressure gradient and cold air advection as the cold front passed. Gale force winds (34 knots or more) were deemed possible based on the strong dynamics but it was not certain. Nonetheless, it was high-impact weather for the mariners in the area, as well as for the public in Metro Vancouver.

The RADARSAT SAR image taken at 1427 UTC that day indicates strong to gale force west-northwesterly winds (30 to 40 knots, yellow to orange colour) west of Vancouver over the Strait of Georgia and into English Bay (Figure 6). In the next couple of hours, Jericho Beach (green dot in Figure 6) had gusts reaching 40 knots, and unconfirmed reports by the Canadian Coast Guard in the area had winds gusting to 45 to 60 knots. GEM-LAM wind forecast of around the same time (Figure 7a) has similar winds but the winds have not yet spread into most of Metro Vancouver. LAM forecast valid at 17 UTC (Figure 7b) brought stronger northwest winds to Vancouver but the winds are slightly weaker than in the SAR image. LAM forecast tephigram for Vancouver International Airport (YVR) valid at 15 UTC (Figure 8) shows an unstable layer up to 600 metres above sea level with winds near 30 knots. Forecast tephigrams for subsequent forecast times show more cooling aloft near YVR.

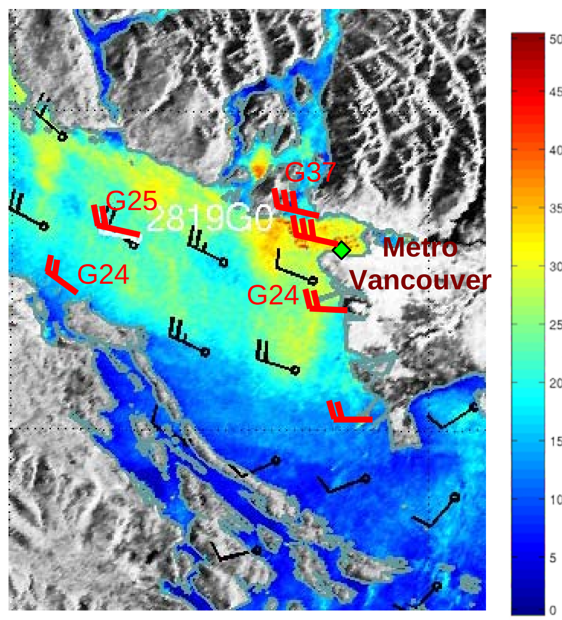

Figure 6: RADARSAT SAR wind image at 1427 UTC on July 12, 2010 over the Strait of Georgia near Vancouver, with colour wind scale on the right. Red wind barbs are surface and buoy wind observations at 14 to 15 UTC with the wind gusts indicated. Black barbs are GEM-LAM west .995 wind forecast valid at 14 UTC.

The GEM-LAM model has forecast strong northwest winds in the area near Vancouver but the timing is late and not as strong. Forecast winds aloft were also not as strong as the sustained winds or gusts from the instability. As seen in figure 6, no other surface stations or buoys indicate the gale force winds, even though they are immediately upstream. The SAR image also provide the extent of the gales and the lighter winds to the south where climatologically are in an area prone to strong northwest winds. This helps the forecasters to adjust the forecasts.

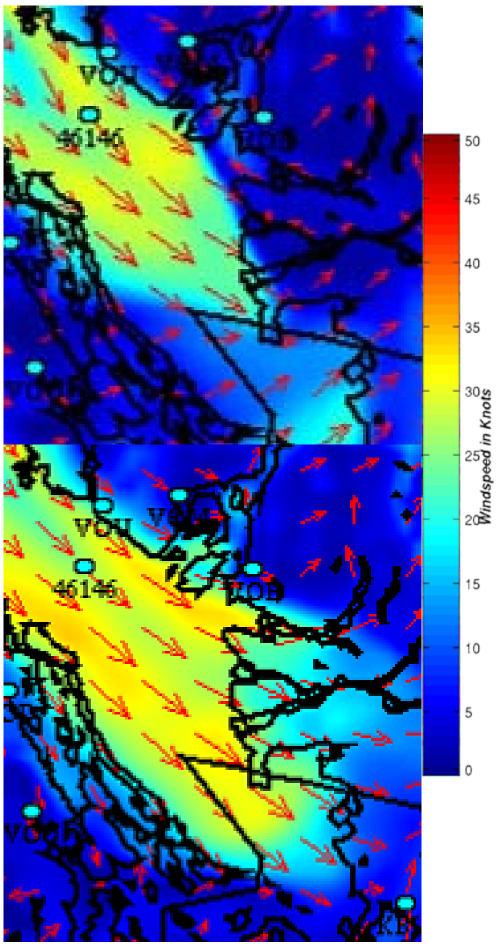

Figure 7a (top): GEM-LAM west .995 wind forecast valid 14 UTC for the area using same colour scale as SAR wind image for speed, and model wind direction are in red. Winds in the Strait are near 25 to 30 knots and have yet to spread into Metro Vancouver. **Figure 7b (bottom):** Same as figure 7a but for 17 UTC. The model brought stronger winds (25-35 knots) to Vancouver but slightly weaker than in the SAR wind image.

Impact of the high winds include small boats anchored in English Bay broke off moorings and beached, and trees fell in the city and knocked out power. In this case, no other conventional wind observations nearby showed the gales. With the SAR image, advance notice of the gale force winds can help alerting the forecasters to amend the forecast and issue warnings for the appropriate forecast regions.

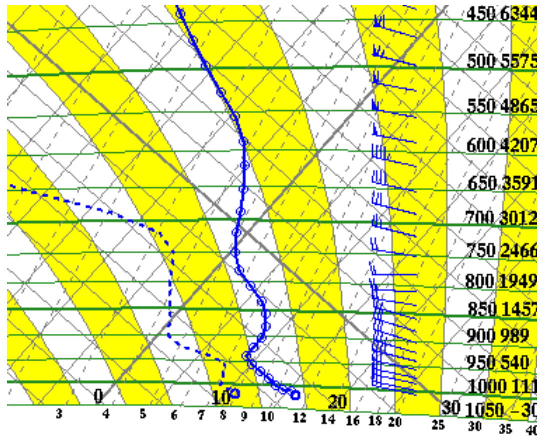

Figure 8: GEM-LAM west July 12 06UTC run prog tephigram for Vancouver Airport (YVR) valid 15 UTC July 12, 2010. Forecast temperatures with height are plotted in solid line and dew points in dashed line. Forecast winds are on the right.

3.3 *Case 3: Deep Low Pressure System*

In this case, a deep 974 hPa low pressure system approached Vancouver Island on April 2, 2010 (Figure 9) bringing very strong southeast winds up to 50 knots east of the system. Downed trees, damage to boats, as well as disruption of ferry sailings were widely reported over the South Coast of B.C. The SAR image before the storm hit was useful in determining the magnitude of the winds as well as position of the storm.

The processed SAR image (Figure 10) shows very strong southeast winds near Vancouver Island as the low and the associated surface front approached. Observations mostly supported the SAR wind speed and direction. The exception is where the LAM model (which was used to initialize the wind direction in processed SAR images) likely has the front too far east, resulting in SAR winds that are a bit too strong in the region between the real and modeled front, as the processing system (WIPS) compensated for less backscatter from a wind direction more normal to the SAR look direction [2, 3].

The raw SAR image (Figure 11) confirms the wind discontinuities (i.e. frontal boundary) should be to the west of the model's front as the intensity of the backscatter (brightness in image) differs markedly on the two sides of the boundary. In addition, satellite image (Figure 12) taken around the same time as the SAR image shows that the approximate location of the front from the cloud elements supports the SAR image's frontal location.

The slower low and front prolonged the wind event over the region and possibly caused more damages. Forecasters can incorporate the information from SAR in addition to the limited surface observations and satellite images to the surface analysis, and in turn improve the forecast from the model output.

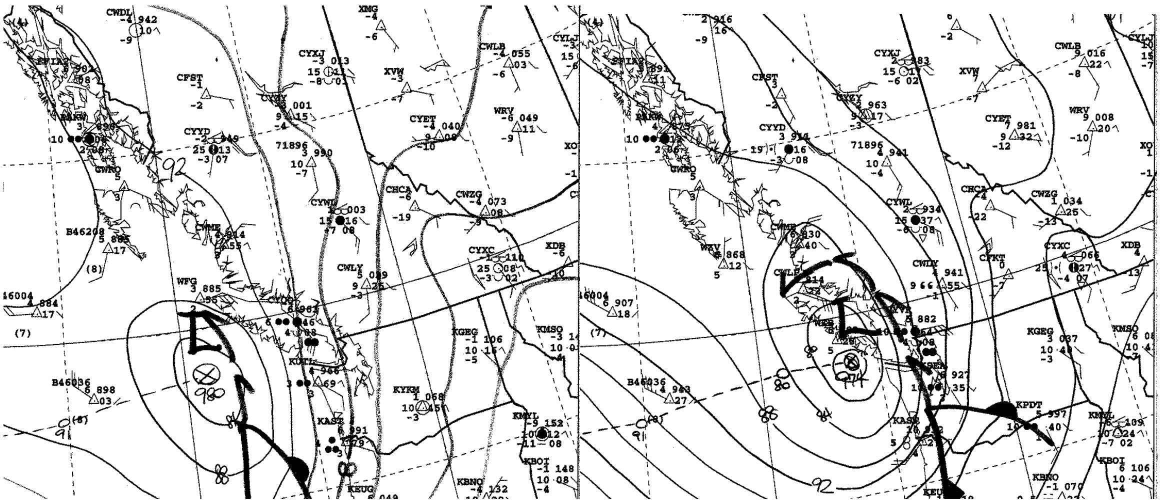

Figure 9: 12 UTC (left) and 18 UTC (right) April 2. 2010 surface weather maps by the Pacific Storm Prediction Centre. The deepening low was approaching Vancouver Island and the South Coast of B.C.

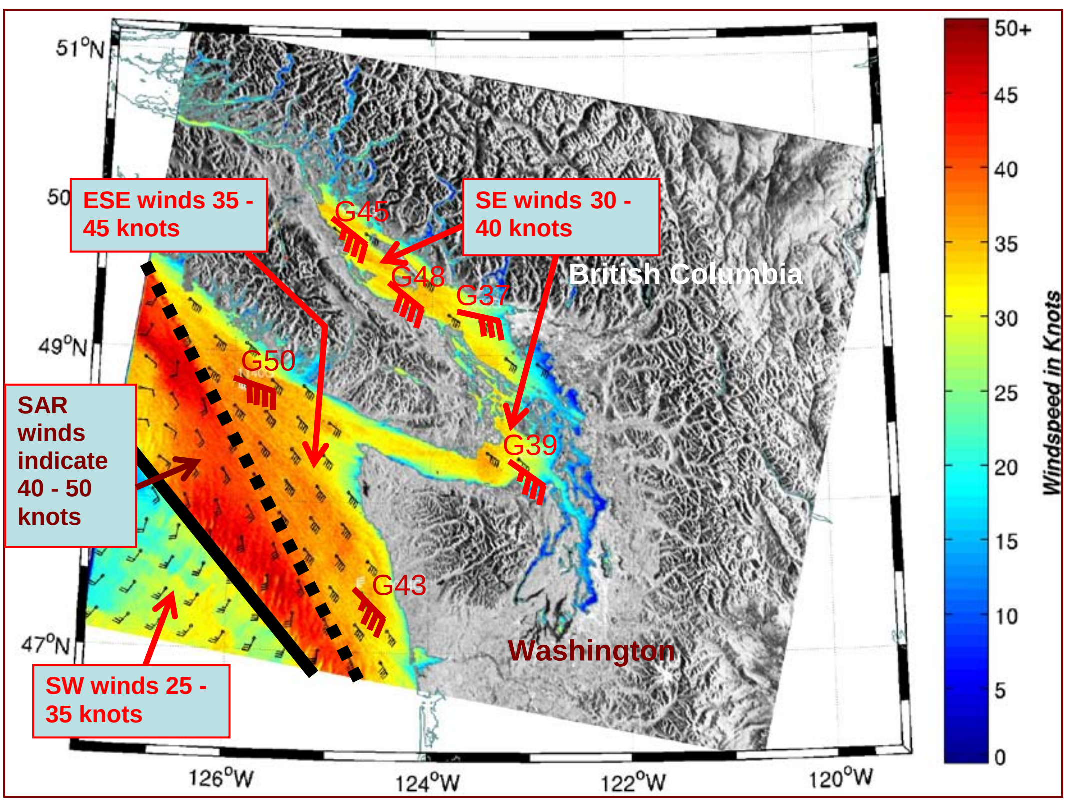

Figure 10: RADARSAT-2 SAR wind image at 1425 UTC April 2, 2010, with colour scale on the right. Red wind barbs are surface and buoy wind observations at 14 UTC with the wind gusts (G) indicated. Black barbs are GEM-LAM west 0.995 level wind forecast valid at 14 UTC. The bold black line near the bottom left of the figure suggests the SAR wind speed and direction discontinuities, where the dashed black line east of it suggests the model's wind speed and direction discontinuities.

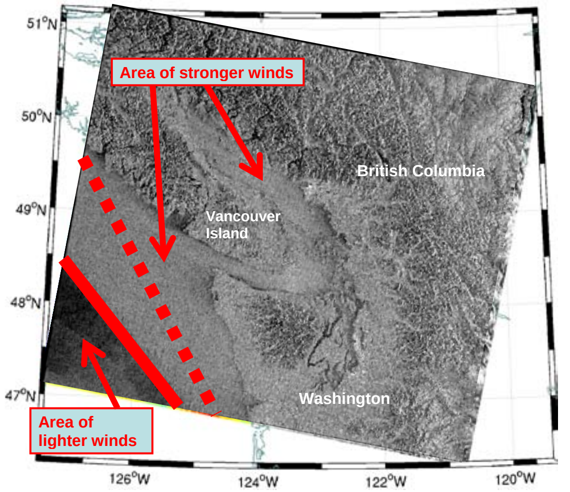

Figure 11: Raw SAR image taken at 1427 UTC April 2, 2010. The bold red line at the bottom left suggests the SAR wind speed and direction discontinuities, where the dashed red line suggests the model's wind speed and direction discontinuities.

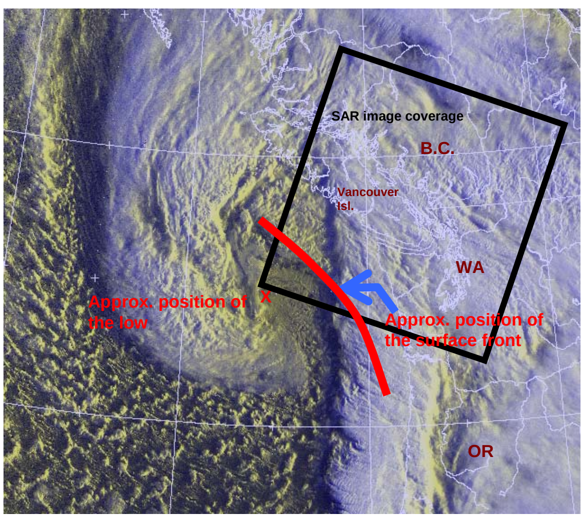

Figure 12: Composite visible and IR satellite image by GOES-West at 1500 UTC April 2, 2010.

4. CONCLUSION

Synthetic Aperture Radar "sees" through clouds, precipitation etc. to the water surface, providing clear and precise information on location of surface features such as fronts and localized winds over water. Many of the high-resolution details visible in the SAR images do not exist within the observation network, scatterometer data, or in model data, especially in coastal straits and inlets. High-resolution, accurate and timely wind fields like the SAR-based winds are desirable to improve marine weather forecast operations especially in the coastal areas.

We presented three cases where SAR wind images had provided values to the forecast operations in Canada. More cases demonstrating the uses in operations were continued to be archived within MSC. SAR can also contribute to the understanding of dynamic and thermodynamic atmospheric processes as more meteorological and cerographical features can be identified using the high-resolution dataset. More studies using the SAR wind images are recommended for the benefits of meteorological research and operations.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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[2] Vachon, P., F. Dobson, 2000: Wind Retrieval from RADARSAT SAR Images: Selection of a Suitable C-Band HH Polarization Wind Retrieval Model, Can. J. Rem. Sens., 26(4), 306 – 313.

[3] Beal, R., *et al*., 2005: High Resolution Wind Monitoring with Wide Swath SAR: A User's Guide. National Oceanic and Atmospheric Administration, 155 pp.