Oslo Polar Low workshop 21-22 May 2012
Extended abstract

Synthetic Aperture Radar imaging of Polar Lows

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Forecasting polar lows is to a large degree based on satellite observations from NOAA Advanced very high resolution radiometer (AVHRR) and from Scatterometer winds in addition to synoptic observations and numerical models. Synthetic Aperture Radar brings higher resolution compared to these other remotely sensed sources of ocean wind such as the scatterometer data and passive microwave window channel wind products. We assess the added value in polar lows of SAR and of increased resolution in observed ocean wind information in general with respect to

1. Wind information content increase with resolution
2. Information availability close to coast

We have used the standard method for wind retrieval from SAR before gridding the wind fields and SAR backscatter images to the STARS-DAT grid. The Envisat ASAR images are calibrated to obtain the normalised radar cross section values (NRCS) and using external information for wind directions, wind speed is estimated from the scatterometer C-band geophysical model function CMOD5[1]. Wind direction input is taken from the met.no hindcast archive NORA10 (Reistad et al., 2011) based on HIRLAM with 10km spatial resolution. However, wind directions from scatterometer instead of a numerical model generally improve the SAR wind fields. When co-locations of ASCAT and ASAR WSM exists with a time difference of less than +/- 2hours, wind retrieval is also performed with these wind directions.

The analysis presented is work in progress, but describe two case studies to illustrate the possibilities and challenges of using SAR.

Case I: SAR early detection of a polar low?

From the AVHRR from 10 utc (Figure 1a), a fully developed polar low further northwest can be clearly identified, but in the area of 71N 012E, only an indeterminate cloud structure can be seen. From the actual 09z analysis this was indicated as a back bent occlusion to the rear of the passing synoptic low. Not until two hours later (Figure 1b), a first indication can be seen from the AVHRR; a feeble eye barely visible, but the waves in the cirrus to the west of this is an early warning that something is about to happen. At 14 utc (Figure 1c), a more clear signature in the AVHRR appears, the eye still only barely visible, but the cloud structures now have the distinct signature of a polar low. At 20utc (Figure 1d) the polar low is showing the typical cyclonic signature, with a cirrus shield with cloud tops at -52 to 55°C to the north of the center, and a cloud band with gradually lesser vertical extent leading in towards the center around the western part of the low.

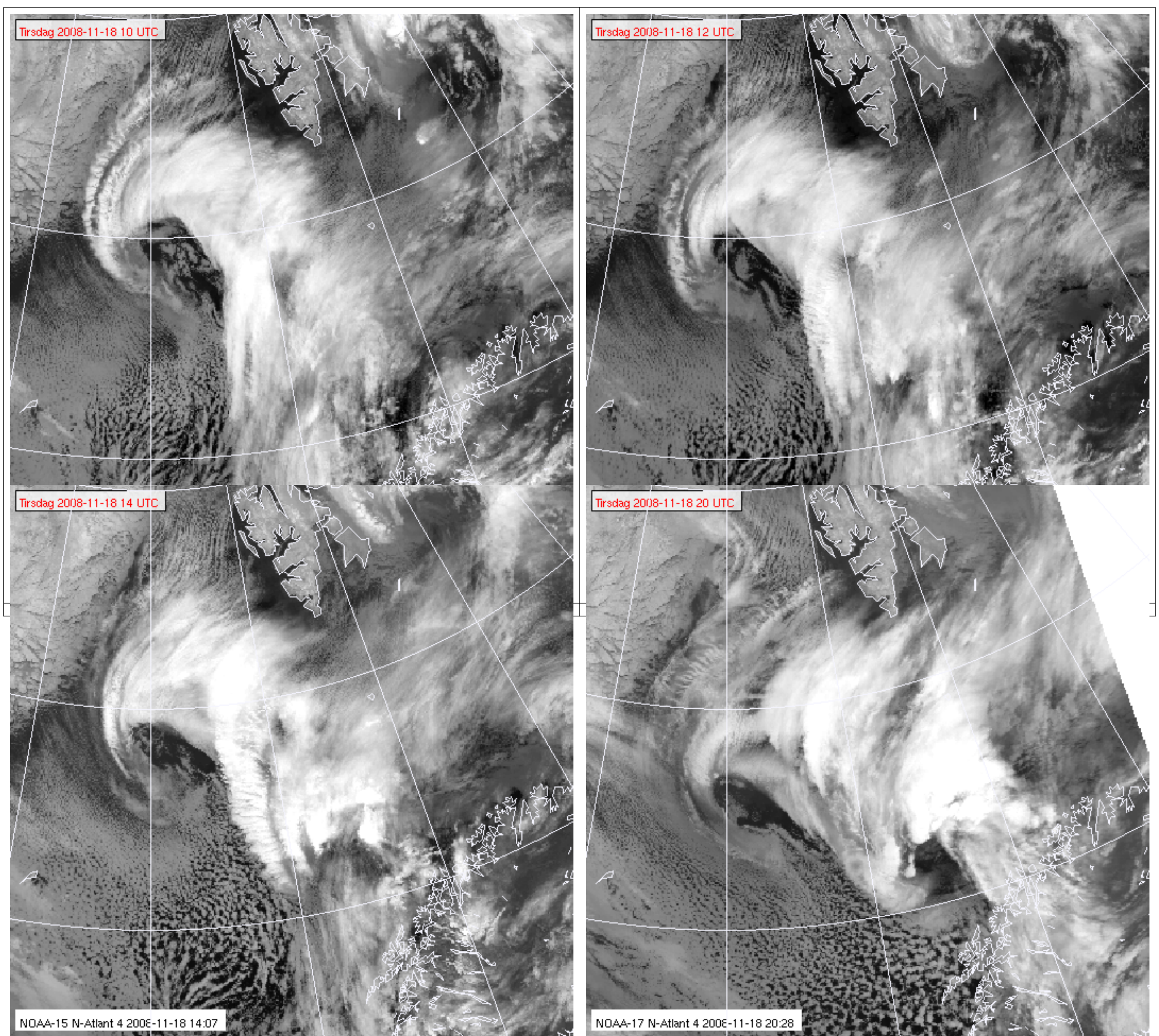
An ASAR image from 10:13utc (Figure 2a) displays a well defined area of stronger wind (with a magnitude of 28 m/s) to the west of a sharp shear zone at 71N, 12E. A shear zone of just a few km is separating this area from a more tranquil area to the east with winds of 15 m/s, and then even further

1 http://www.knmi.nl/scatterometer/cmod5/

east, a signature similar to what could be expected from the eye of a polar low, with calm winds of magnitude of 5 m/s. The wind directions for this image are taken from an ASCAT passage almost 1.5 hours earlier (08:51utc) but the directions fit quite well with the wind signatures in the SAR image and the resulting wind speeds are believed to be quite good in this case.

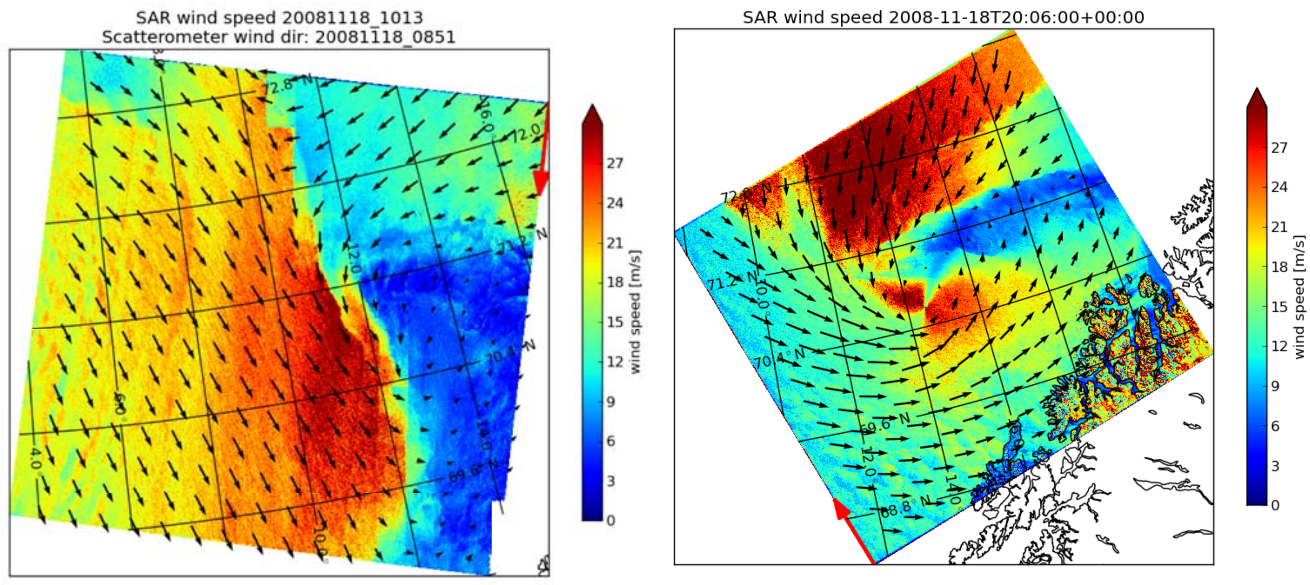
Unfortunately there are no ASCAT passage to cover the ASAR image in the evening at 20:06 (Figure 2b). But in spite of this, several interesting features can be seen. The most prominent is the sharp increase in wind in the northern sector of the low. The increase from a northeasterly fresh breeze at 12m/s to more than 25 m/s (absolute value is uncertain due to the model wind directions not aligned with the wind signatures in the SAR image) occurs in a zone of less that 3 km. The speed of propagation of the low was around 2,4 m/s at the time, which means that this increase would have taken approximately 20 minutes.

Another interesting aspect is the location of the strongest wind speed. This is not, as normally observed in the western quadrant, but rather north of the center, following the area of strongest convection and highest vertical extent of the cloud mass. However, since the wind directions are perhaps some 20-40 degrees mis-alinged with the wind streaks in the SAR image north and west of the polar low center, this result is uncertain.



c)	d)

Figure 1: AVHRR ch.4 image from a) 10utc, b) 12utc, b) 14utc and d) 20utc on November 18, 2008.



b)

Figure 2: a) ASAR surface wind signature from the incipient stages of a polar low, 18. November 2008 at 10UTC. Black arrows are wind directions from ASCAT 08:51utc. b) ASAR surface wind signature at 20:06utc using model wind directions from NORA10 (black arrows).

Following the impressions of the AVHRR, this polar low would probably first have been suspected at the 14 utc image, and not be identified with certainty until the 20utc image, by which time it would be too late for an effective warning. If the 10utc SAR image had been more readily available to the forecaster, even with a three hour delay time it would have proven a very useful additional source of information, and would most likely have had an impact on the timing and focus of the weather warnings on this polar low.

Case 2: Honningsvåg polar low

The AVHRR image from January 7, 2009 at 9utc (Figure 3) shows the visual (IR) appearance overlaid synoptic wind observations from a mature polar low as it hits the community of Honningsvaag at the coast of Northern Norway. The ASAR image (Figure 4a) shows the maximum wind area (bright area) coincident the clouds in the AVHRR image and a very sharp front to the low wind area. An “eye” is also visible. The highest wind speed is about 23 m/s based on this SAR image and ASCAT directions from 08:18utc (Figure 4b) with lower winds in the area east of the front of about 10m/s.

The synoptic observations seen in image 3 suggests that there are large differences in wind magnitude and direction from different parts of the low. Only by inspecting the SAR image in figure 4 can the sharpness of the transition zone be fully appreciated. In this case, the gradient of about 13m/s happens over a distance of about 1km. The low was slow moving compared to the typical speed of propagation for polar lows which is found to be 8 to 13 m/s. Given a typical speed of propagation of 10 m/s, and an orientation of the shear zone at a steeper angle to the direction of movement of the low, this change from breeze to storm can take from 1 to 15 minutes. Tales of such rapid changes in wind are frequently told by eye witnesses, but this is the first time that this is documented by observational data.

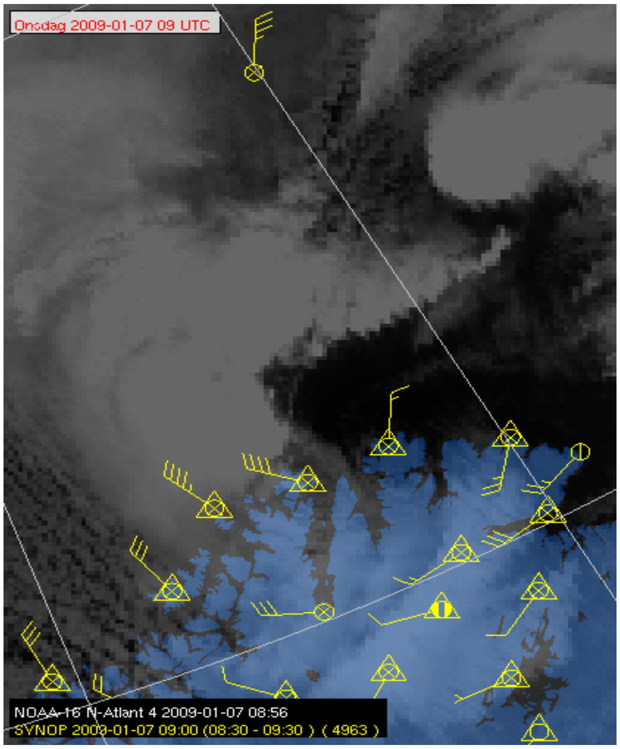


Figure 3: Closeup of the AVHRR image at 09utc with wind observations from the ground stations.

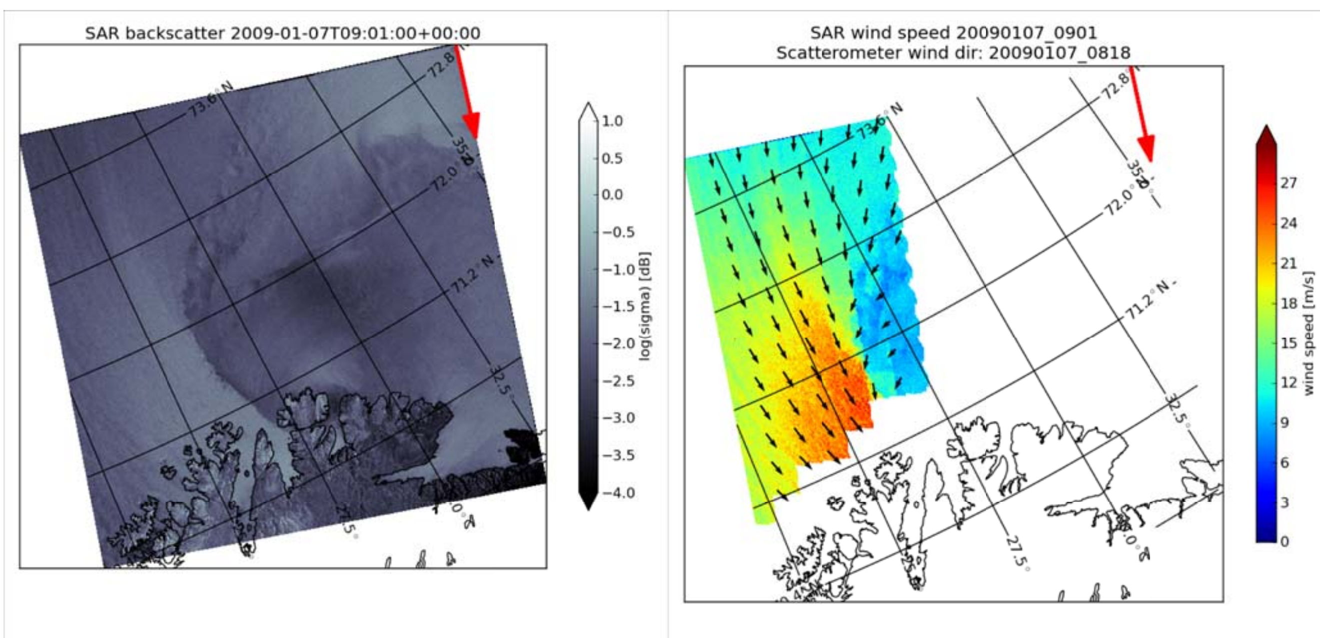


Figure 4: a) ASAR WSM from January 7, 2009 09:01utc. b) ASAR surface wind speed using wind directions from ASCAT at 08:18 utc.

Summary

Early detection of a polar low (November 18, 2008) with ASAR has been identified and discussed. As the SAR observes the wind at the surface, is gives a more direct information on surface wind patterns, perhaps also at an earlier time than what can be indirectly inferred from cloud top observing satellites. Fine scale features of the polar low can be seen with the high resolution SAR images. The sharp transition zone from the 'wind' side to the 'quiet' side of a polar low is documented in this study.

Further work

The scatterometer wind directions improve the resulting winds from SAR compared to using a numerical model, which was expected. The example in Figure 4b shows however that we need to test and possibly use the ASCAT coastal product in order to get SAR wind speed near the coast.

Further work will also be to establish a comparison procedure to assess and quantify added fine scale wind information in SAR as compared to scatterometer footprints.

References

Reistad, M., Ø. Breivik, H. Haakenstad, O.J. Aarnes, B.R. Furevik and J.-R. Bidlot (2011) A high-resolution hindcast of wind and waves for the North Sea, the Norwegian Sea and the Barents Sea, *Journal of Geophysical Research*, VOL. 116, C05019, doi:10.1029/2010JC006402, 2011