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FjordVind

Using SAR for forecasting of winds in the coastal zone

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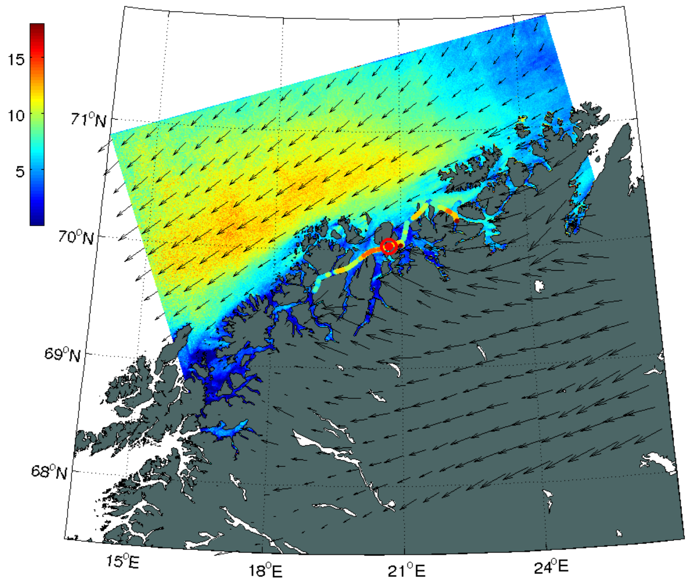

Wind map (wind speed [m/s] in colours) based on Envisat ASAR wide swath image on August 8, 2011 at 19:51 UTC and wind directions from NORA10. Observations from M/S Trollfjord (northbound) during a period of +/- 6hours around satellite passage are overlaid in the same colour scale. Ship location at satellite passage is indicated by the red circle.

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report

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Abstract

During the FjordVind project (2010-2012) (NRS project no. JOP.17.10.3 and JOP.17.11.3) wind sensors have been installed on M/S Trollfjord on the coastal route between Bergen and Kirkenes. The measurements are transmitted to land and are archived with the FerryBox data. During the project period 9 months of data from Trollfjord have been analysed and compared statistically and on basis of cases studies to wind maps from the Advanced Synthetic Aperture Radar (ASAR) onboard the Envisat satellite.

Co-located data (M/S Trollfjord – SAR) exhibit relatively large scatter that does not seem to be related to the averaging time of the Trollfjord measurements, but may be partly due to relatively low wind in a majority of the situations. The project has demonstrated how mean wind speed along the ship's route compared to the mean SAR wind maps may become an interesting way to verify SAR winds in the coastal zone, when a longer data series has been collected.

During the FjordVind project, we have developed routines to process Envisat ASAR scenes to wind fields using the geophysical C-band model function CMOD5 with input wind direction from either a numerical model (HIRLAM10) or from scatterometer. For operational use, processing of the data at met.no is necessary in order to reduce the time from satellite acquisition to having the SAR wind fields available in the meteorologist's analysis tool Diana.

A number of case studies are presented that further illustrates the scatter between the Trollfjord observations and the SAR winds. However, in some cases similar variability is found in the Trollfjord wind along the route as is seen in the corresponding transect in the SAR wind map and may thus confirm the observed SAR variability caused by local terrain. Wind directions and precipitation from HIRLAM10 is in good agreement with wind signatures and rain cells seen in SAR for the analysed cases.

Keywords

Coastal winds, SAR, Ferrybox, Hurtigruten Trollfjord,

Disiplinary signature	Responsible signature

Table of Contents

Introduction

Traditionally, coastal weather forecasts are transmitted as text forecasts via radio. With the use of internet, much higher spatial details can be communicated to the public as maps or meteograms by choice of any location. This development puts high demands on the background data, which per default is the model output. The forecaster on duty performs a quality control on the model forecast and has the opportunity to edit the wind field before it is published. Unfortunately there are very few wind observations compared to the rather long and complex Norwegian coast. In particular when the wind direction is from land, there are large variations in the coastal wind field related to fjords and other topographic features. The topographic effects can be traced in the wind field several hundred kilometres offshore. The ground stations are in many places not representative under these conditions.

With support from different projects (SatHav OOMM fase 3 - Norwegian Space Center project no. JOP.06.07.2, ArcChange – Norwegian Research Council project no. 178577) met.no and NERSC implemented in 2008 Envisat Advanced Synthetic Aperture Radar (ASAR) Wide Swath Mode (WSM) data (radar backscatter (σ^0), wind speed and wind direction) into met.no’s operational analysis tool Diana. With high spatial resolution these data are potentially interesting for use in forecasting since they provide an overview of wind variations during strong offshore or alongshore wind events. An example is shown in Figure 1.

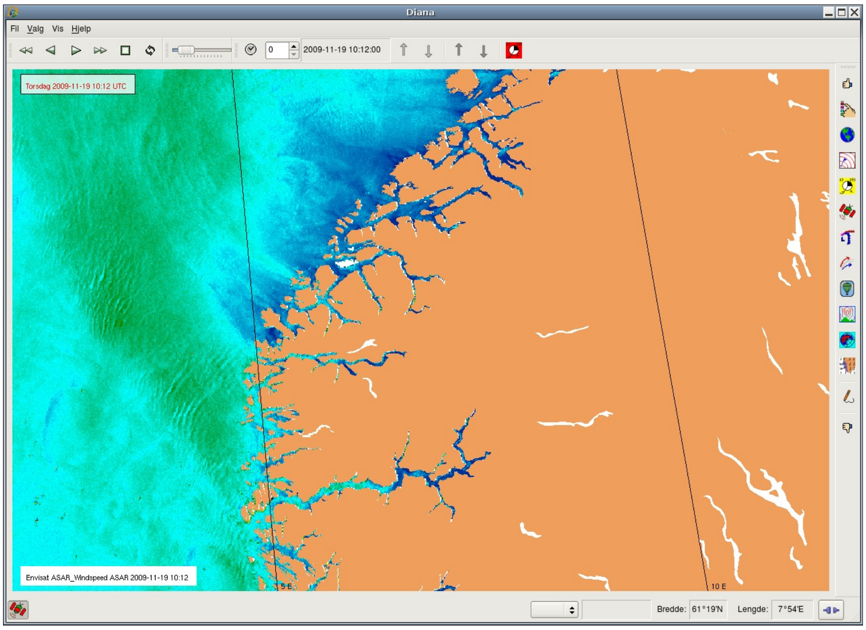


Figure 1: ENVISAT ASAR image of wind speed as presented in DIANA. In this situation wind is from land. Weak winds are dark blue. The strongest wind (green) is about 18m/s.

Validation of wind speed from SAR using C-band geophysical model functions (CMOD) has been extensively carried out over the ocean and SAR wind speed in most studies report a bias less than 0.5m/s and standard deviation between 1.2-2.0 m/s (Dagestad et al., 2012). At the Norwegian coast with many islands, narrow fjords, high cliffs and mountains there is reason to believe that the SAR winds may agree less well with ground stations. In fact, Dagestad et al. (2009) reported an root-mean-square error (rmse) of 2-3 m/s for SAR compared to coastal observations which is about 1m/s higher than over open ocean. The main reasons for the larger discrepancy are assumed to be that the onshore stations are affected by local topography and that there is a distance of some kilometres between the land station and the nearest SAR wind value. Without observations from buoys or ships it is not possible to investigate if the SAR winds are actually of lower quality – e.g. due to atmospheric stability issues, oil films and terrain effects, near the coast. Therefore the main goal of this study was to install wind sensors in connection with the existing FerryBox system on board the coastal route (Hurtigruten) vessel M/S Trollfjord. The coastal route goes between Bergen and Kirkenes (the round trip takes 11 days) through some of the most windy coastal areas of Norway. With continuous measurements, the wind variability along the ship's route and point verification data can be obtained for validation of SAR coastal winds as demonstrated by Furevik et al. (2002).

During FjordVind project phase I (2010-2011) (NRS project no. JOP.17.10.3) NIVA installed two wind anemometers on board M/S Trollfjord. In FjordVind phase II (2011-2012) (JOP.17.11.3) data collection and analysis of SAR wind speed and variability in the coastal zone was carried out.

Data collection

Wind measurements from SAR

SAR wind speed has been calculated from Envisat ASAR Wide Swath (WSM) images both at NERSC and at met.no. At NERSC data from the rolling archive are routinely processed using the CMOD4 algorithm with wind direction taken from the HIRLAM model. The wind speed is interpolated onto a grid with a pixel spacing of 500m, and all scenes 2007-2012 are averaged to produce a mean wind speed map.

Programs for processing Envisat ASAR winds have also been developed at met.no during the FjordVind project and the ESA Support to Science Element (STSE) project STARS (http://polarlow.met.no/stars) (project number EOP-SM/1900/CD-cd). The basic methodology is the same as employed at NERSC, but CMOD5[1] is used with wind directions from NORA10 (see below).

NORA10

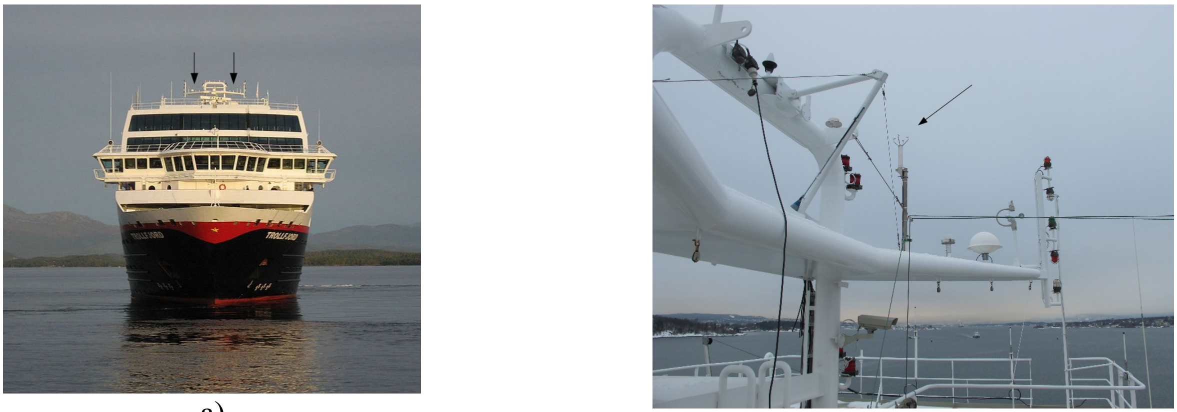
The Norwegian Reanalysis archive of wind and waves (NORA10) is a dynamic downscaling of ERA40 to 10-11 km spatial resolution for the North Sea, the Norwegian Sea and the Barents Sea (Reistad et al., 2011). Surface winds are available every hour and provides the input wind directions to the CMOD-algorithm.

Wind measurements on board M/S Trollfjord

Two ultrasonic anemometers of the type Gill WindObserver was mounted in the mast on M/S Trollfjord (Figure 2). Due to vessel movement (heading and speed) and possible drift due to wind and currents Geographic Positioning System (GPS)- and gyroscope-information is needed in order to calculate the true wind. A GPS is installed in the FerryBox system, while the gyro-data must be extracted from the vessel's gyro on the bridge. In order to do this, cables were pulled from deck 10 where the wind sensors are located to the bridge on deck 7 where a MOXA portserver receives data from the ship's Gyro. Cables have also been installed from the bridge to a central switch on deck 5 (Datasentral 5.1). From there it was planned to send the gyro data via the vessel's IT-network to the Ferrybox network, but it turned out that this is not possible due to problems in the vessel's IT system. Until certain parts have been upgraded, true wind is calculated without the use of gyro.

Since start-up in March 2011 the system has largely been functioning well. The majority of problems encountered, were related to the wireless connection between the wind sensor boxes and the FerryBox system. Ferrybox data, including wind data, are routinely sent to an ftp-server to be available for forecasting and for research and development.

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



a)

b)

Figure 2: a) M/S Trollfjord. Black arrows indicate the location of the wind sensors. b) Photograph of the mast with one of the Gill WindObserver instruments mounted.

Two types of output files are made available from the wind sensors onboard M/S Trollfjord:

- *final* files with true wind speed calculated and sampled every minute from measurements every second, and
- *raw* files which give only wind measurements relative to the ship, but every second.

To reduce noise in the data, the *raw* files have been used at NERSC to calculate values averaged over one minute intervals. The true velocity components of the wind are calculated according to:

$$u = u_s - w_s \sin(d_s + d_w)$$
$$v = v_s - w_s \cos(d_s + d_w)$$

where w_s and d_w are the wind speed and direction measured by the sensors relative to the ship velocity. u_s and v_s are the ship velocity components given by respectively $s \cdot \sin d_s$ and $s \cdot \cos d_s$, where s and d_s are the speed (in m/s) and heading of the ship. The calculated values are checked to be identical to corresponding values provided in the *final* files.

The ship direction should ideally be taken from the gyroscope on board M/S Trollfjord. However, as these data are not yet available due to technical difficulties, the heading estimated from the GPS log is used instead. For this reason, wind measurements are only used when the ship speed exceeded 5 m/s (~10 knots), when the GPS heading should be more accurate. Many of the *raw* output files have been discarded since they contain several lines with cryptic characters and sudden line shifts, which makes automated reading difficult. Data where one or both of the wind sensors give suspiciously zero wind speed relative to the ship for longer periods have also been discarded. The number of minute values left after these tests is shown in Figure 3. Except for periods in June/July and September/October the coverage is good.

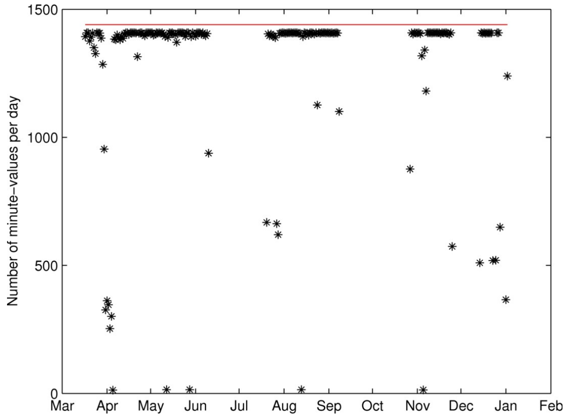


Figure 3: Number of minute averages of wind available per day in 2011 after quality screening. The red line indicates the total number of minutes per day (1440).

As a first check of the quality of the wind measurements, the measurements from the two wind sensors (left and right) onboard M/S Trollfjord are compared. The scatter-plots of wind speed and wind direction are shown in Figure 4. Given that the averaging time is as short as one minute, the agreement is very good. For the wind speed, the correlation is 0.87, the RMSD is 2.1 m/s and the bias is negligible (0.01 m/s). In the following analysis, an average of the two wind sensors is used to reduce the noise.

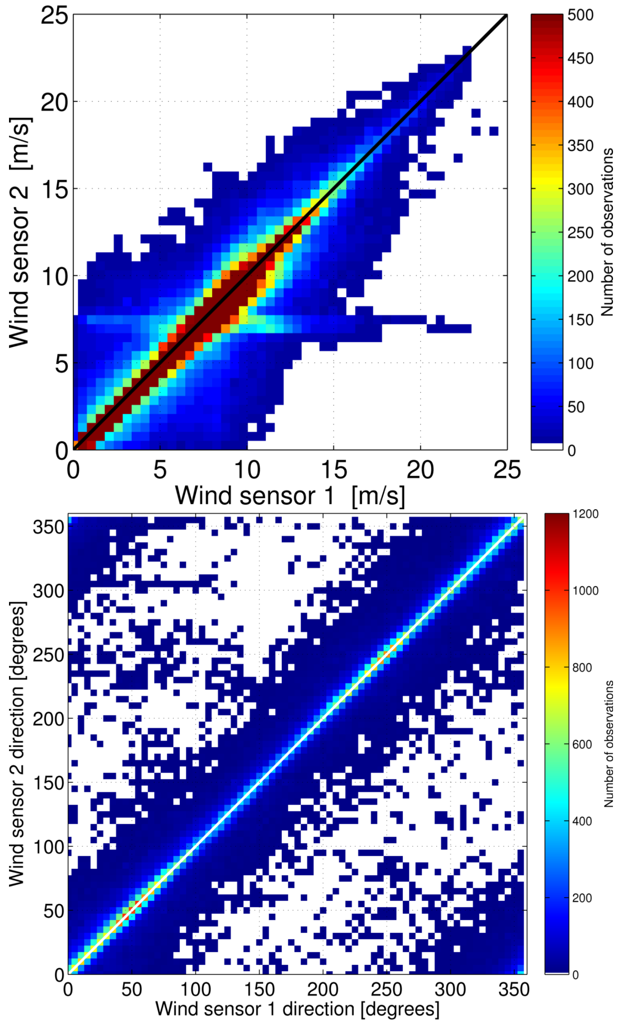


Figure 4: Scatterplot of wind speed (top) and direction (bottom) of the averaged minute values from the two wind sensors on board M/S Trollfjord.

Table 1: Simultaneous wind measurements from the wind sensor mounted at the Sotra Bridge (60.37255N, 5.1670E) and from M/S Trollfjord. The values are given in [m/s]. The measurements from the bridge are taken from http://vegklima.vegvesen.no/grafside.aspx?maalepktnr=M602

Time	Trollfjord	Sotra Bridge
31.10.2011 22:03	13.6	10.5
12.11.2011 00:35	6.7	1.0
22.11.2011 21:56	11.3	9.0
14.12.2011 21:56	10.7	10.0

Unfortunately there are not many available in situ measurements coincident in time and space against which to validate the measurements. One source is the wind sensor mounted on the Sotra Bridge in Bergen, nearby which the ship passes. Only the measurements from 4 months are available on the website, and only 4 coincident passings are found. As seen in Table 1, the agreement is quite good for the 3 cases with strong wind (9-13 m/s) and not so good for the case with low winds (6.7 vs 1.0 m/s). Although the measurements on the bridge can be highly influenced by the construction itself, this may also indicate that the ship's movement is not properly corrected for.

Statistical comparison with SAR wind measurements

The left part of Figure 5 shows average SAR wind speed for 4 years (2006-2009). 1007 ASAR Wide Swath scenes are used to calculate the composite, with 400-500 scenes covering any part of the given area, giving a robust average. The agreement with corresponding averages of wind speed from HIRLAM and NCEP (not shown) is good offshore but with some deviations closer to the coast and in the fjords, where the measurements from M/S Trollfjord are a unique resource for validation.

To allow for a comparison to the SAR wind climatology, the wind speed from M/S Trollfjord has been averaged for all measurements within boxes of 0.01 degrees of latitude and 0.02 degrees of longitude, corresponding to an area of approximately 1x1 km^2. As the wind sensors are located at the top deck at a height of 30 m above the sea surface, the measurements have been multiplied with a factor of 0.90 for conversion to 10 m height according to a neutrally stable atmosphere over water. The time coverage of the data is shown in Figure 3, and should be reasonably representative of the yearly average conditions.

The averaged winds for the coast of south western Norway are shown in the right part of Figure 5. A fair agreement with the SAR measurements is seen, with generally low average wind speeds (3-5 m/s) inside the fjords and higher winds (6-9 m/s) off the coast.

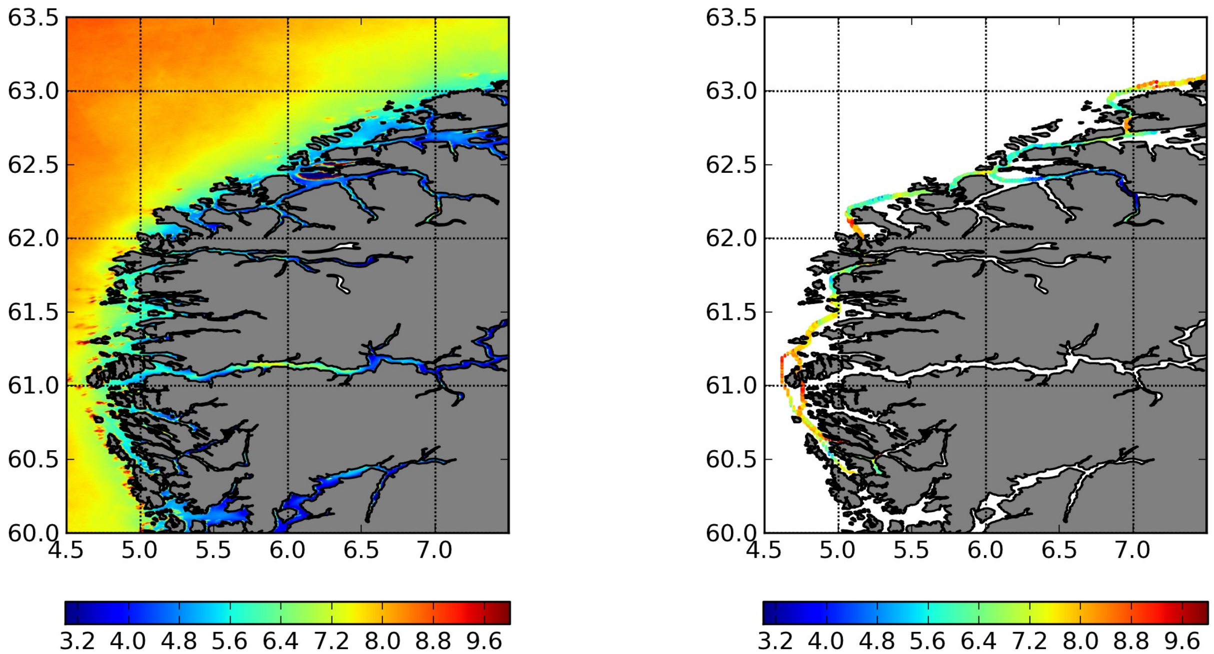


Figure 5: Mean wind speed from Envisat ASAR for the period 2006-2009 (left). Wind speed from M/S Trollfjord for the period March-December 2011, averaged over all measurements within boxes of 1x1 km^2 (right). The unit of the colour bar is m/s.

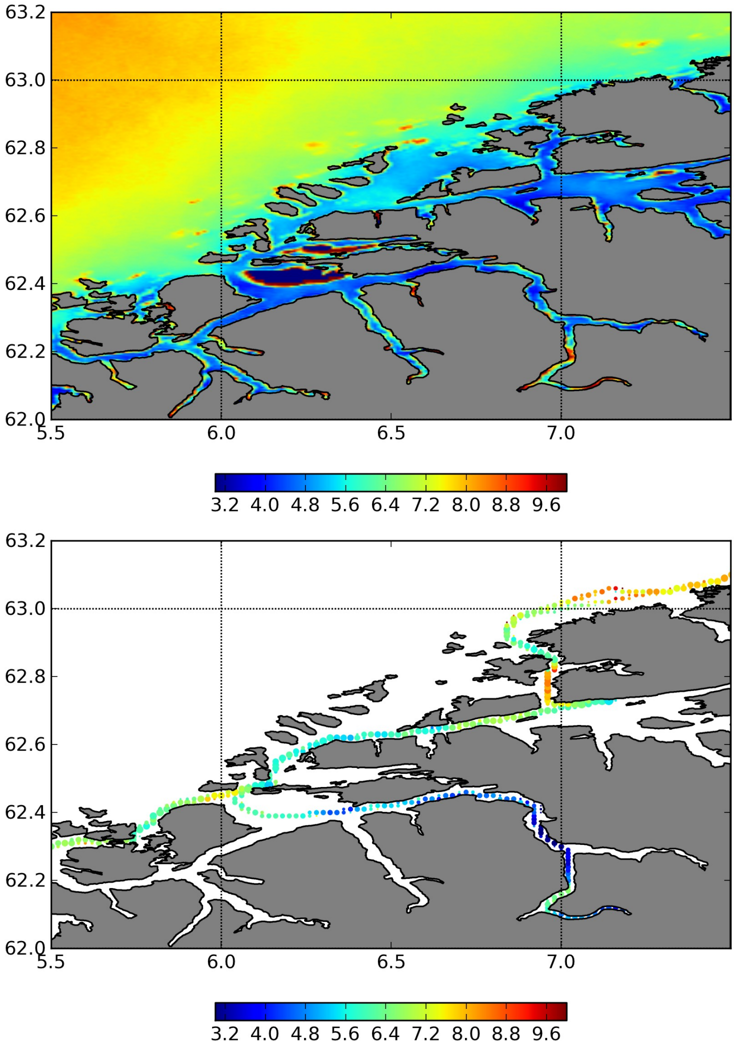


Figure 6: A subsection of Figure 5 around Møre.

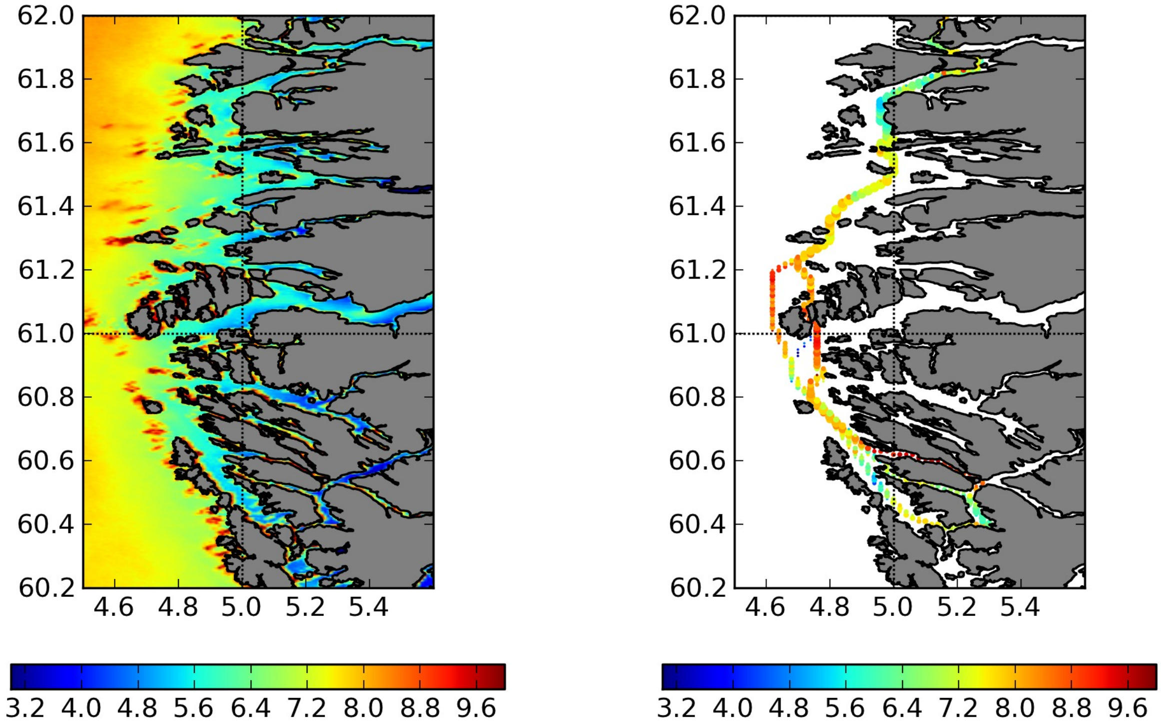


Figure 7: A subsection of Figure 5 along the west coast of southern Norway.

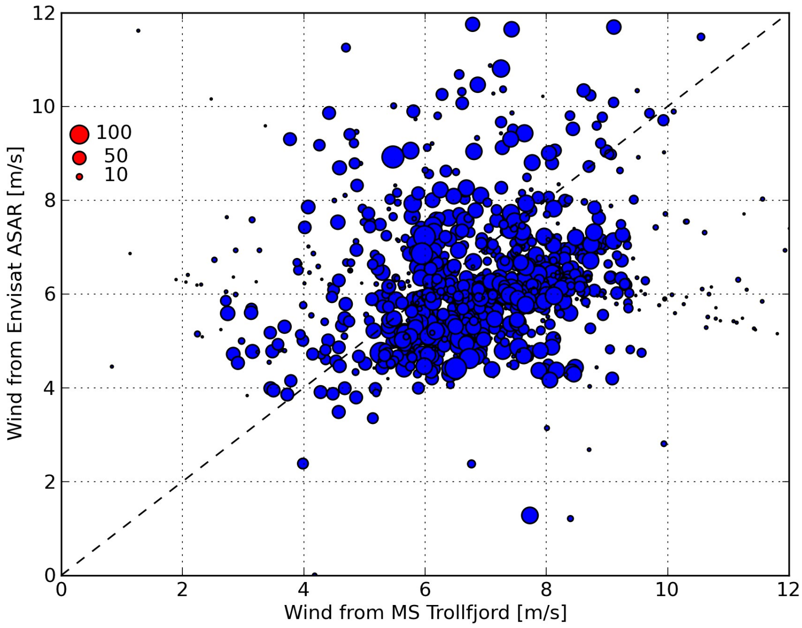


Figure 8: Scatterplot of the average wind measurements from M/S Trollfjord (x-axis) and the SAR wind speed at the same location (y-axis). The sizes of the circles indicate the number of minute values averaged within each of the boxes within which the ship wind speeds are averaged (0.01° of latitude and 0.02° of longitude).

Significant scatter is seen in the direct comparison of SAR mean wind speed and Trollfjord mean wind speed in Figure 8. Although most of the points contain more than 50 minute-averages, each point represents only on the order of 10 different days/situations, as many of the minute values are from the same passing of the ship. Hence, the averaged wind from M/S Trollfjord is highly dependent on the weather conditions at these specific passing times. Consequently, wind must probably be collected by M/S Trollfjord over a period of several years in able to produce a robust and climatologically representative wind speed.

The SAR wind maps exhibit many «red spots» of strong wind speed 9-10m/s in the sea-side of the outer coastline where the surrounding mean wind speed is much lower, around 7m/s. Comparing to the sea charts in Figure 9 and 10, we notice that the red spots are related to small islands or sub-sea rocks where ocean waves break. See for example Svinøy and Storholmen in Figure 9 and compare to Figure 5 and notice the narrow passage that M/S Trollfjord takes north of Fensfjord (compare Figure 8 and 10). The contaminated pixels should be removed using bathymetry data, possibly in combination with wave climate information.

That land and sub-sea rocks lead to a mean signature of high wind speed values in the SAR wind map means that we should ignore high values (SAR wind speed above 7-8m/s) in the scatter plot of Figure 8. The scatter of the remaining points is much less and part of it (SAR wind 4-8 m/s when Trollfjord winds are 10-12m/s) can be explained by the averaging time (bullet size is small). The remaining data points might indicate an underestimation of SAR compared to Trollfjord wind speeds.

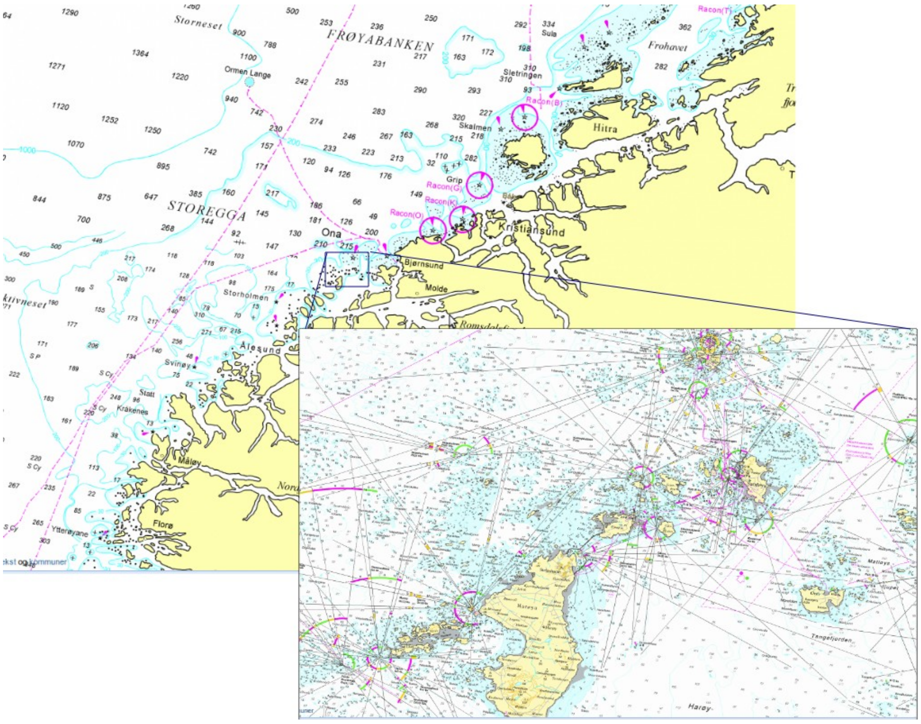


Figure 9: Map of the Norwegian coast from Stad to Trondheim with sea chart (insert) from the area of Harøya and Ona at about 62.8N 6.5E in Figure 7, showing the coastline and sub-sea rocks. Maps from http://kart.kystverket.no.

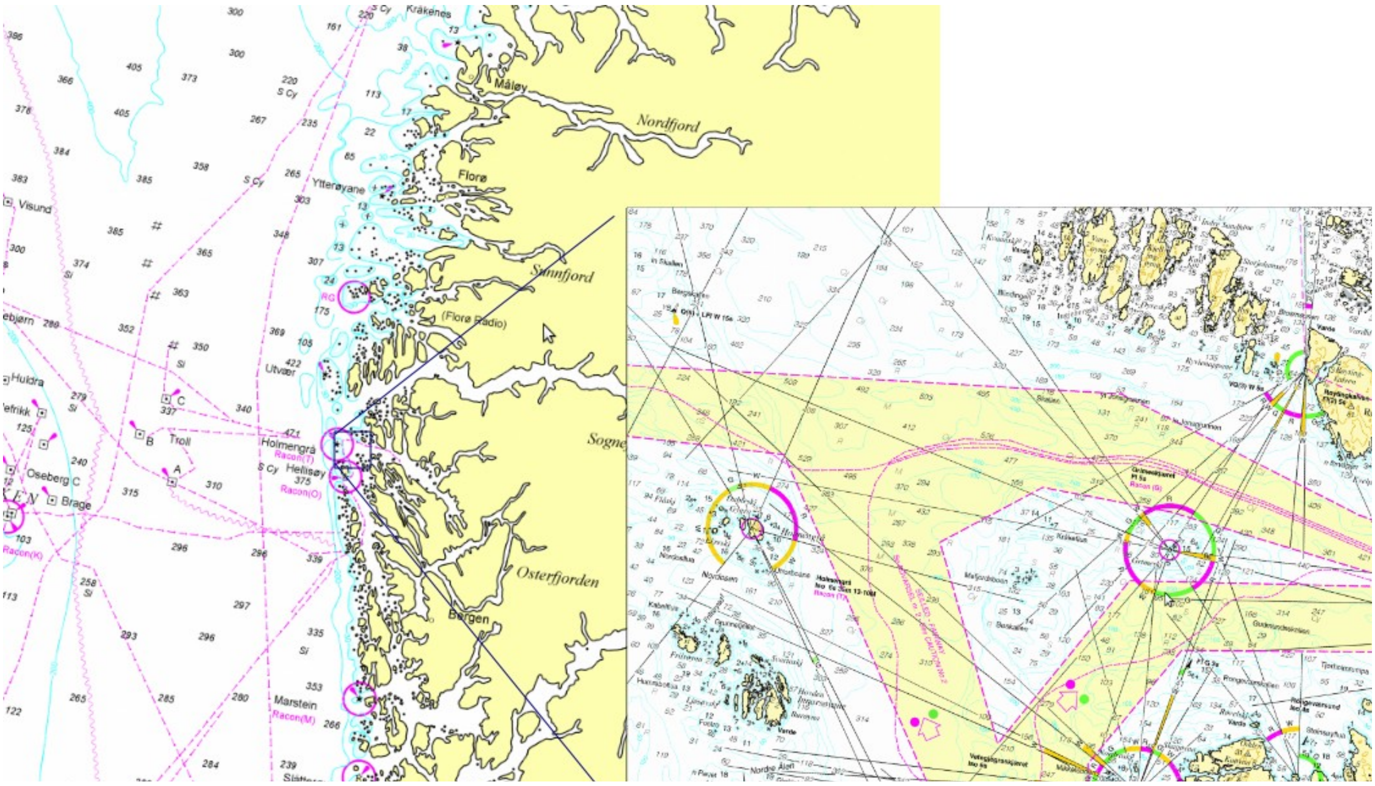


Figure 10: Map of the Norwegian coast from Hardanger to Stad with sea chart (insert) from the area of Fensfjord and Holmen Grå at about 60.8N 4.8E in Figure 7, showing the coastline and sub-sea rocks. Maps from http://kart.kystverket.no.

Case studies

In order to extract more information from the single collocations and investigate the potential for SAR to be used in forecasting, 32 Envisat ASAR scenes overlapping with the ship position were acquired for processing at met.no. The aim was to choose times when wind signatures, rather than ocean signatures, were dominating the SAR image, i.e. situations with wind speed over 6-7m/s. This selection was performed manually based on the visible signatures in the ASAR quick looks in EOLI-SA[2].

Due to the regularity both in the satellite path and the ship route, overlap occur primarily in three regions (approximately hours): In eastern Finnmark (ascending pass at 19 UTC), in Troms (ascending pass at 19:40 UTC and 20 UTC and descending pass at 09 UTC) and in Nordmøre (ascending pass 21 UTC and descending pass 10 UTC). All 32 wind maps with co-located wind observations from M/S Trollfjord are shown in the appendix. Based on these a number of case studies are presented in the following. They consist of a general presentation of the weather conditions based on NORA10, the Trollfjord measurements along a route from – 6 hours to + 6 hours relative to the satellite passage and the SAR wind map. The ships track is overlaid with the observed wind speed on board Trollfjord in the same colour scale as the SAR wind map. Trollfjord's position at the time of satellite passage is shown with red circles.

An insert time series plot show the wind speed from Trollfjord as black curve and the «space series» as a red curve extracted from the SAR wind map in the GPS-position recorded by the ship at that time. The wind speed from the ship has been reduced using a factor of 0.9 as before to account for the height difference of the ship (30 m) and the SAR wind equivalent height (10 m). The x-axis indicates the relative time difference between Trollfjord observations and the SAR aquisition time (SAT). A vertical grey line show the SAT. When the ship is not moving, SAR wind speed is constantly the same value (taken from the same point in the image), and thus the SAR wind speed shows a constant over this time period (horizontal red lines).

2 http://earth.esa.int/EOLi/EOLi.html

Case 1: June 3, 2011. 20:10 UTC

A low pressure 1000hPa located between Svalbard and Norway moved easterly in the hours before SAT and caused south-westerly winds over Lofoten. In the ship's location around -3 hours, a small intensification in the wind is seen in the model, which can explain the discrepancy between SAR and ship wind in the time-space plot in Figure 12. From -2 to 0 hours the wind speed is 5-10m/s from both SAR and ship, but without clear correlation in the wind speed variations.

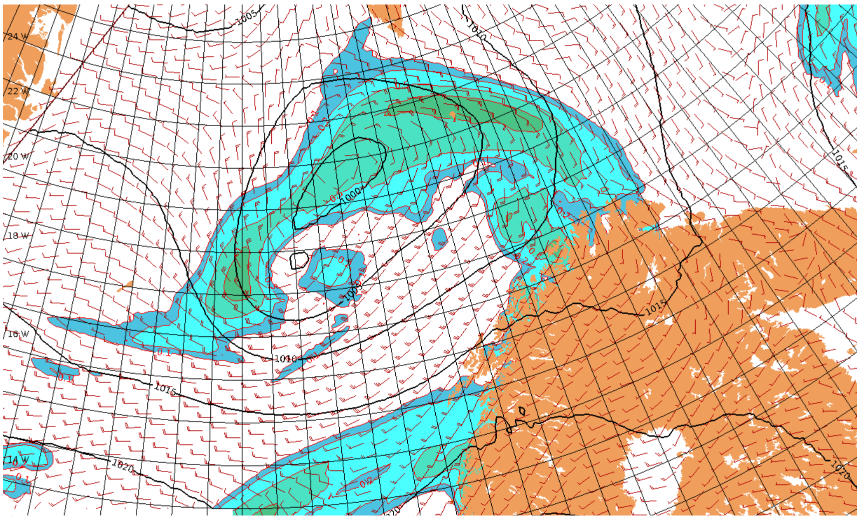


Figure 11: Mean sea level pressure (black isolines), surface wind (red arrows) and 1-hour precipitation from the NORA10 hindcast archive at the closest hour to SAT.

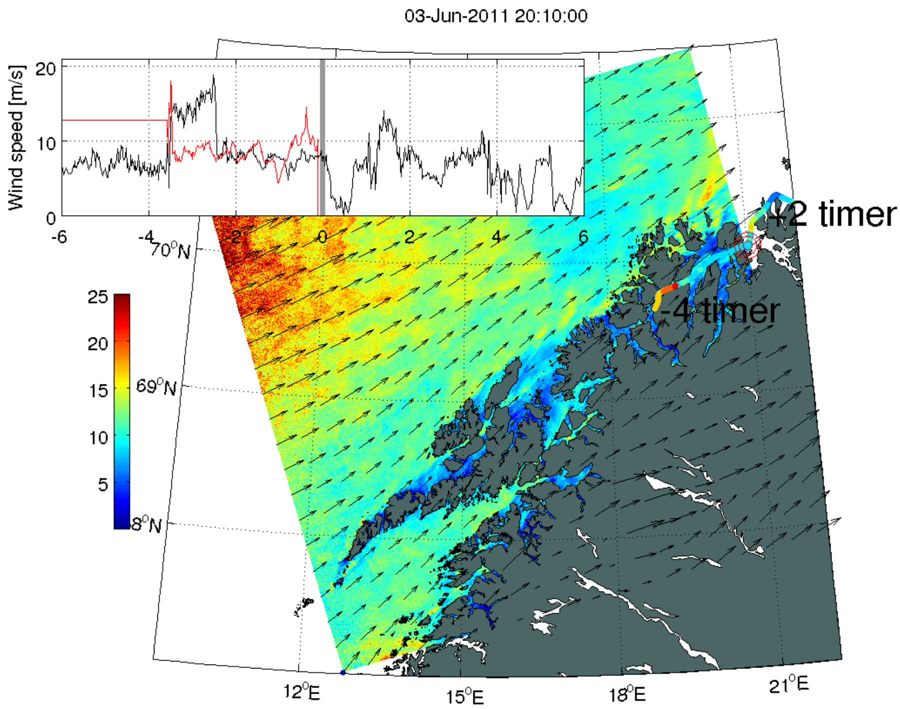


Figure 12: Wind speed from an Envisat ASAR image using wind directions from NORA10 (black arrows). The ship-track is overlaid with the observed wind speed in the same colour scale as the SAR wind map. Trollfjord's position at the time of satellite passage is shown with red circles. Insert is the time series from Trollfjord (black line) and the space series from SAR (red line). The relative time difference between Trollfjord observations and the SAR acquisition time (vertical grey line) is given below.

Case 2: July 28, 2011. 19:55 UTC

A small high pressure (1023 hPa) is located over Bjørnøya in the Barents Sea causing easterly air flow along the coast (Figure 13). According to the model there is no precipitation in the region. The SAR wind map (Figure 14) indicate an enhancement of the wind speed on the coast out to about 100km. A curving of the wind streaks in the SAR wind map confirms the presence of the high pressure. Ship recordings from the hours before SAT, agree somehow with the spatial extracted variability from the SAR wind map (-3 to 0 hours in Figure 14) but SAR wind is ~5m/s lower and there seems to be an offset in the variations of about half an hour or 14km assuming a ship speed of 15 knots. This difference could perhaps have been caused by a turning of the wind, but that is not indicated from NORA10.

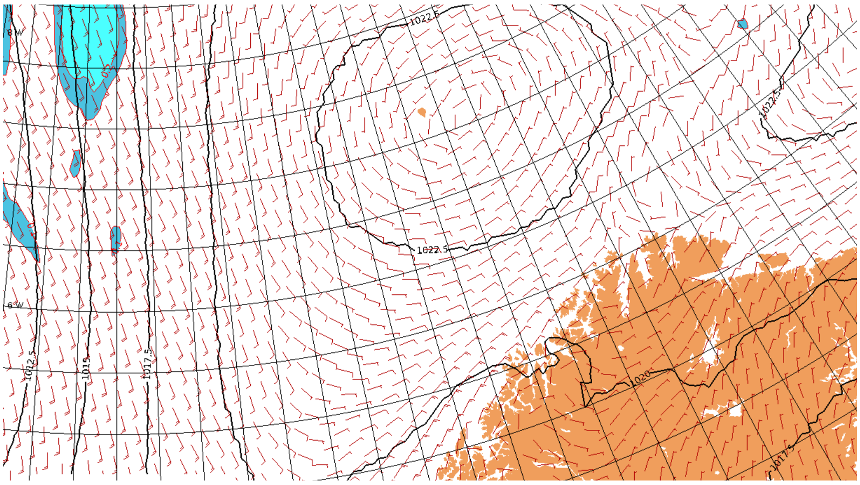


Figure 13: Mean sea level pressure (black isolines), surface wind (red arrows) and 1-hour precipitation from the NORA10 hindcast archive at the closest hour to SAT.

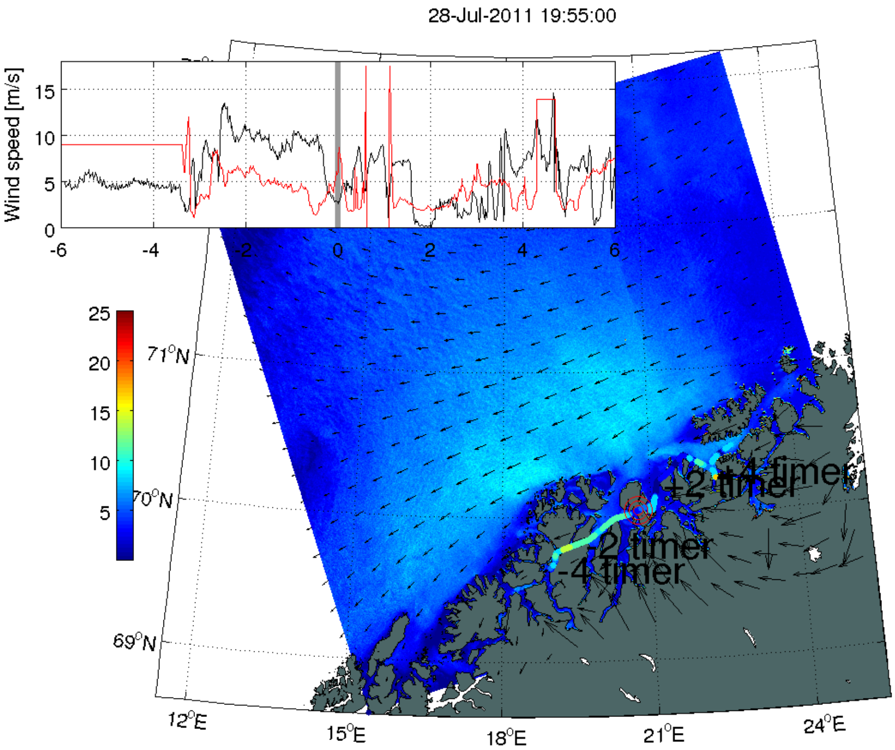


Figure 14: See Case 1 SAR wind map for explanation.

Case 3: August 30, 2011. 19:45 UTC

An airflow from the Barents Sea along Novaya Zemlya turning along the Norwegian coast brings along numerous precipitation cells which are also observed in the SAR wind map about 100km from the coast. The easterly flow is influenced by the coast and jets and lee areas can be seen in the area northeast of Tromsø (Lopphavet). Wind speed from ship and SAR seem to be in fairly good agreement until SAT+2 hours (except in Knøttsundet between Arnøya and the main land where the passage is too narrow to extract wind speed from the SAR).

At about +2.5 hours the ship pass the wake in Lopphavet, but here the ship records wind speeds of 10m/s. According to NORA10, a slight turning of the coastal wind from ESE at 20UTC to ENE at 23UTC takes place, which is enough to make the wake disappear at +2.5hours and cause other wakes which is maybe what shows up in the ship wind at +3.5hours.

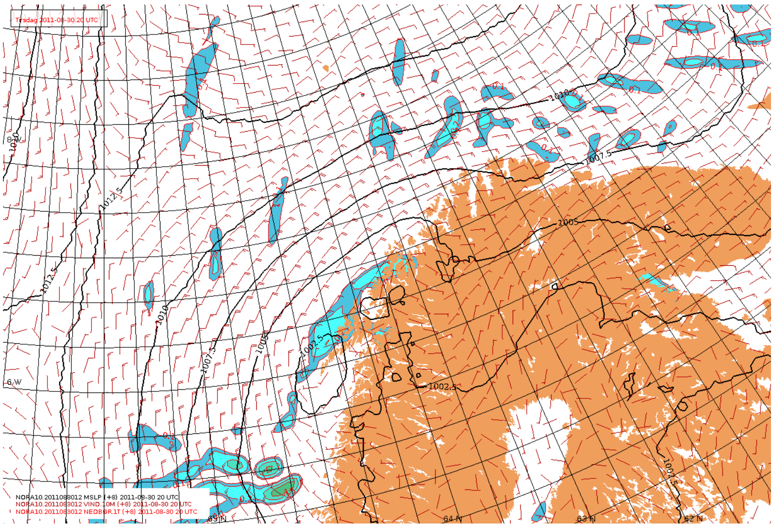


Figure 15: Mean sea level pressure (black isolines), surface wind (red arrows) and 1-hour precipitation from the NORA10 hindcast archive at the closest hour to SAT.

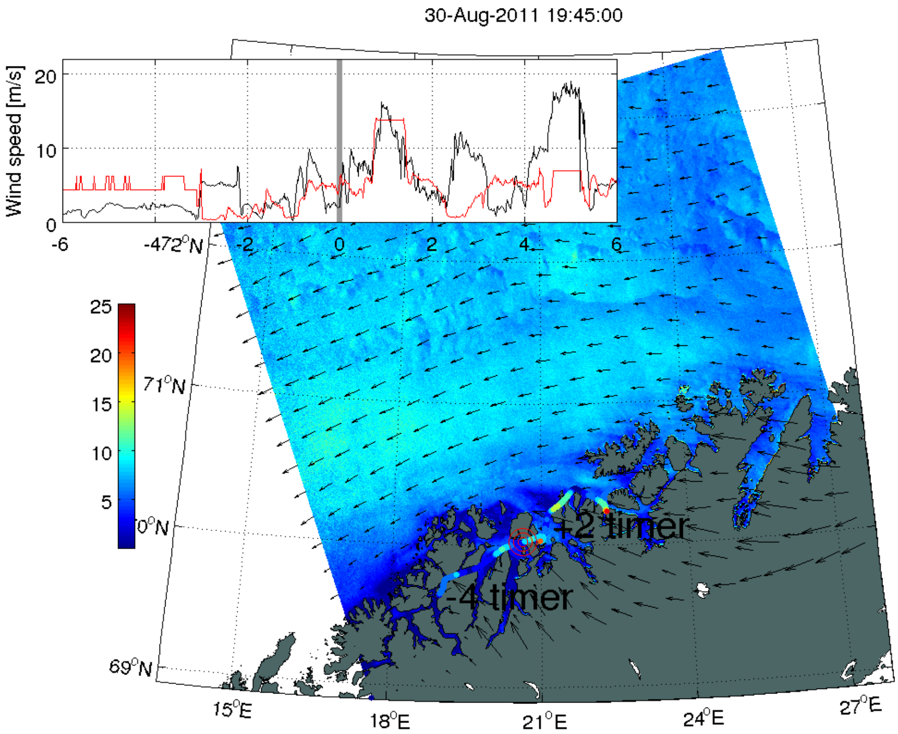


Figure 16: See Case 1 SAR wind map for explanation.

Case 4: October 27, 2011. 09:28 UTC

Unfortunately there are no data from Trollfjord while the ships moved through the interesting jets and wakes on the coast of north-east Finnmark (Figure 17). We see however large variability both in SAR and Trollfjord data some time after SAT after Trollfjord has passed Sørøya at +3 hours. The variations in wind speed are not in the same time/space place, but are comparable in maximum and minimum values and extent. Even if the time difference is large (+3 - +6 hours) the variations can be compared, since the wind conditions were quite stable with winds from land during the 6 hour period. Figure 18 shows the atmospheric situation from NORA10 at SAT (left) and after almost 6 hours (right).

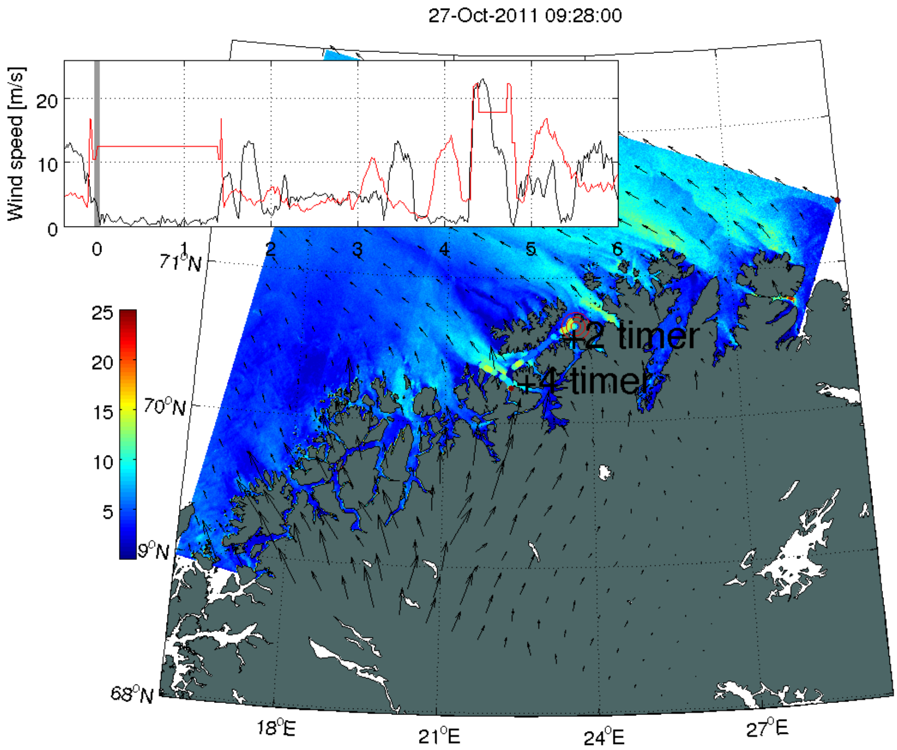
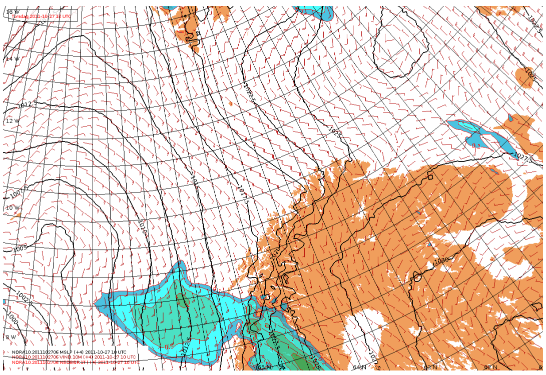


Figure 17: See Case 1 SAR wind map for explanation. No data have been recorded before SAT-0.5hours on this day with the Trollfjord sensors.



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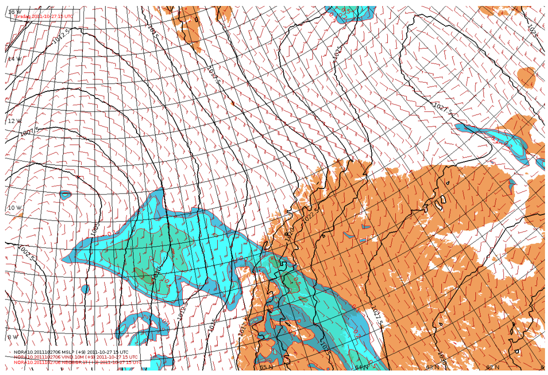

Figure 18: NORA10 MSLP, surface wind speed and precipitation at SAT+0.5 hours and SAT+5.5hours.

Case 5: November 23, 2011. 21 UTC

The last low pressure 2 days before the extreme weather “Berit”. The low is located in the Greenland sea causing winds of 35 knots on the coast in NORA10 (Figure 19). In the front (the bend on the MSLP isolines almost parallel to 0° longitude) the wind is more than 45 knots (~23m/s) which corresponds to the high wind area in the north-western part of the SAR wind map (Figure 20). The SAR winds are too high compared to the Trollfjord data. A possible explanation is the snow showers causing the local wind around the shower to change direction. Because of this, the wind direction from NORA10 used in CMOD5 is locally not correct, leading to erroneous high and low wind speeds in patches north and south of Kristiansund (Figure 21). Another reason for the discrepancy may be the ship moving along with the wind, causing disturbances which might lead to reduced quality of the anemometer recordings.

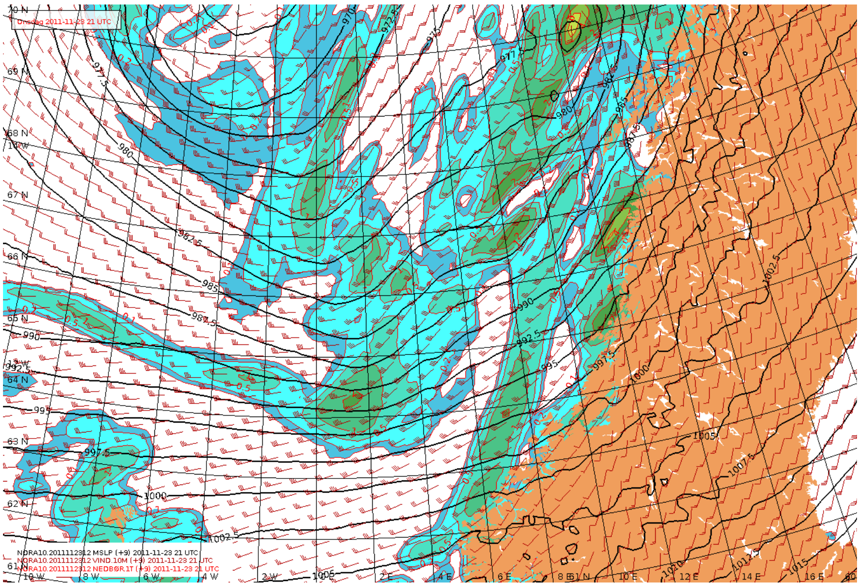

Figure 19: MSLP, surface winds and 1-hour precipitation from NORA10 on SAT.

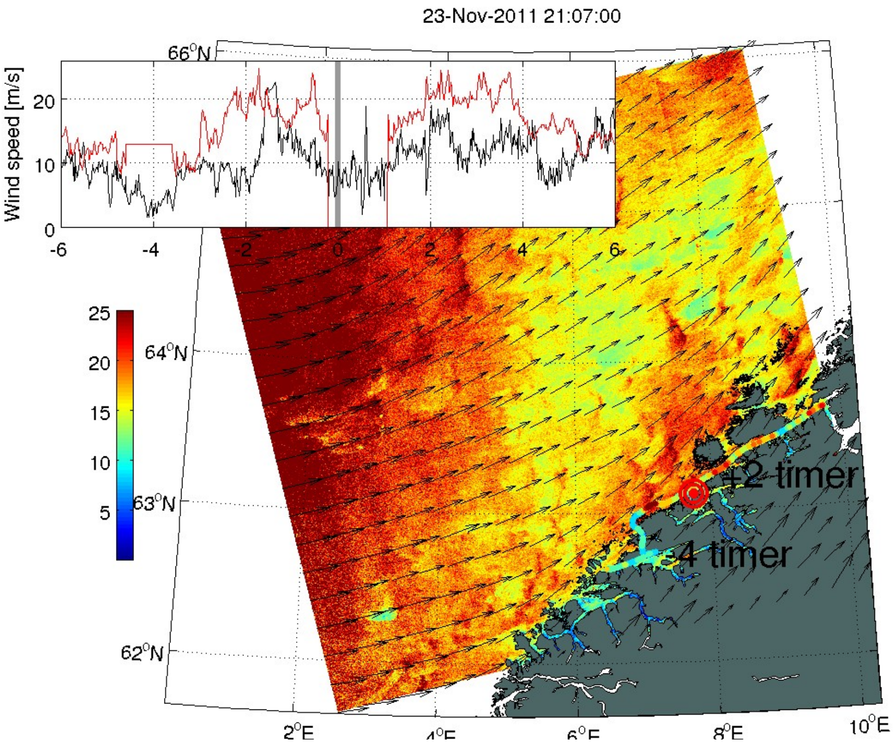

Figure 20: See Case 1 SAR wind map for explanation.

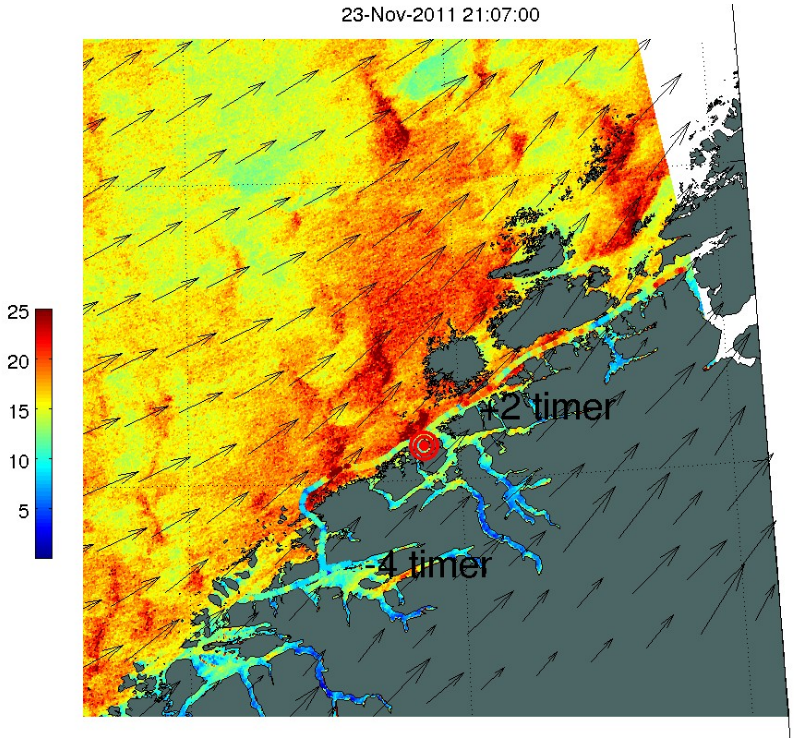

Figure 21: Detail of SAR wind map showing rain/snow showers.

Summary

Synthetic Aperture Radar wind maps have a potential in forecasting but there are a number of challenges to address. This project is focussed on verifying the large variability that can be observed in the coastal areas where in situ observations are few and located on points where the wind is lower than e.g. in the middle of the fjords. The idea of equipping the coastal route with wind sensors, is to obtain measurements across the fjords and in lee of the land points. We have compared the measurements with SAR wind maps statistically and by case studies.

Recording of Trollfjord winds started in March 2011 and were averaged along the ship's track during the period March-December 2011. It is possible to begin to see some features, such as the stronger wind offshore, but a larger data set is needed to be able to use it for verification. Large scatter in the comparison of the mean wind speed from Trollfjord with the mean wind statistics from ASAR (Figure 8) shows that sampling over several years is necessary. However, the project has demonstrated this possibility for verification. A careful selection of SAR points used in the comparison, to avoid contamination from land and areas with wave breaking over shallow areas will reduce the scatter significantly.

The data collection in 2011 did not provide very good wind cases to illustrate strong offshore or along shore winds in SAR and the Trollfjord data. The case studies illustrate both some of the challenges but also the potential of using SAR. Precipitation shows up in nice agreement with NORA10 in several cases (see case 3 and 5) and using the NORA10 wind directions as input to CMOD5 in general produce reasonably good wind maps. We have been able to show that the variability in terms of the wind speed range was comparable (see e.g. Case 4). However, there are large discrepancies between co-located Trollfjord and SAR wind measurements. A source of error is the influence of land in the SAR wind values, as Trollfjord is passing in narrow sounds or being in a harbour during the time of SAR acquisition. When comparing SAR and Trollfjord wind with a time lag (i.e. in the case studies), obviously additional errors arise from the development of the weather situation.

References

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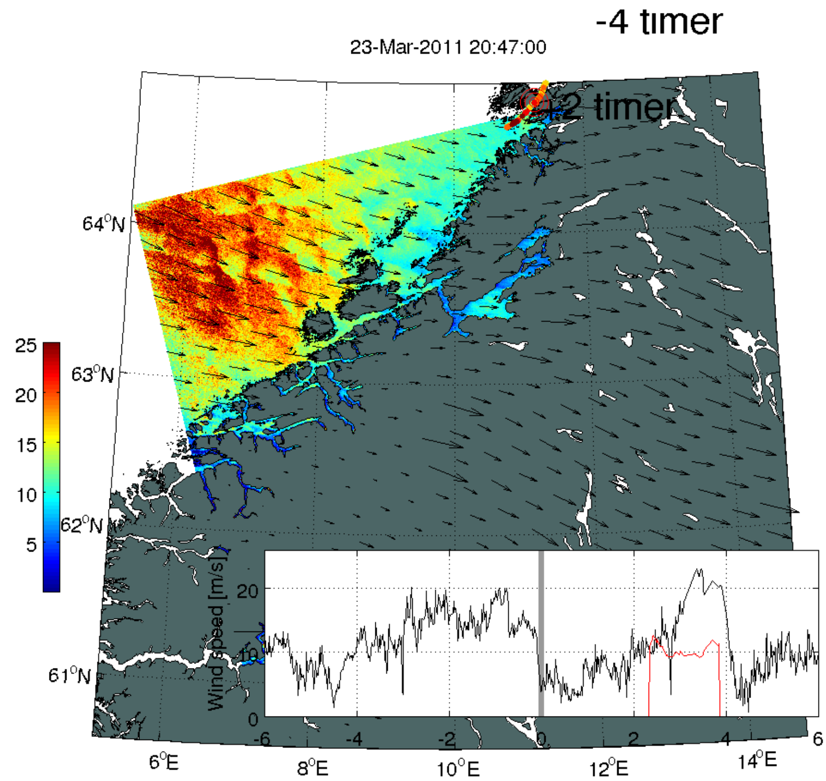
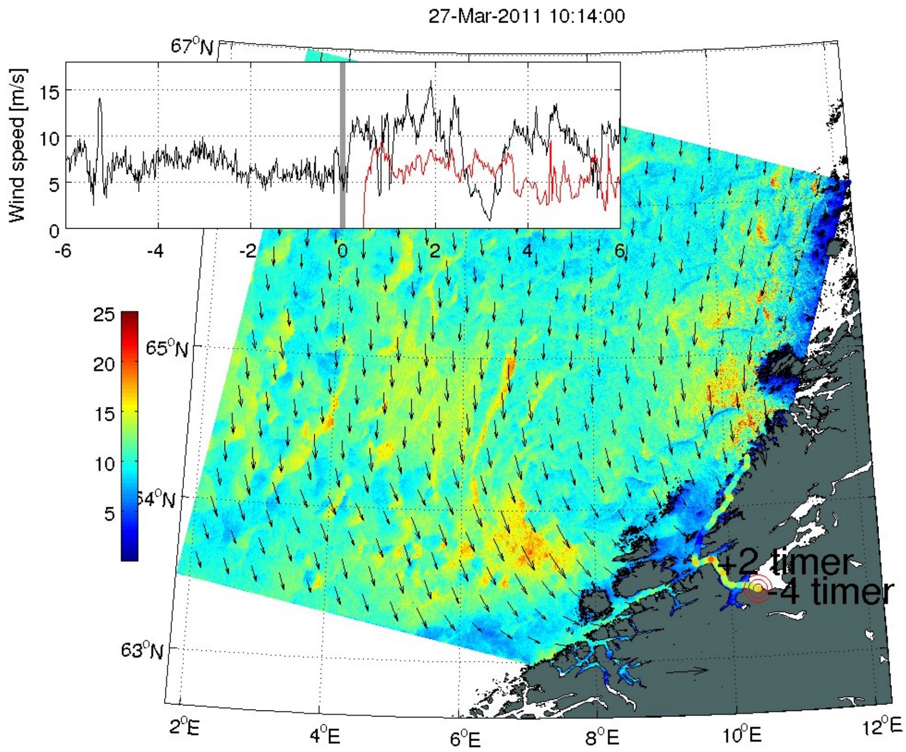
Furevik, B. R., O M Johannessen and A. D. Sandvik (2002) SAR-retrieved wind in Polar Regions – Comparison with in situ data and atmospheric model output, IEEE Transactions of Geoscience and Remote Sensing, vol. 40, no. 8.

Reistad, M., Ø Breivik, H Haakenstad, O.J. Aarnes, B.R. Furevik and J.-R. Bidlot, 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.

APPENDIX



-4 timer
23-Mar-2011 20:47:00
+2 timer
64°N
63°N
62°N
61°N
25
20
15
10
5
Wind speed [m/s]
20
10
0
-6
-4
-2
0
2
4
6
6°E
8°E
10°E
12°E
14°E



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67°N
Wind speed [m/s]
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10
5
0
-6
-4
-2
0
2
4
6
25
20
15
10
5
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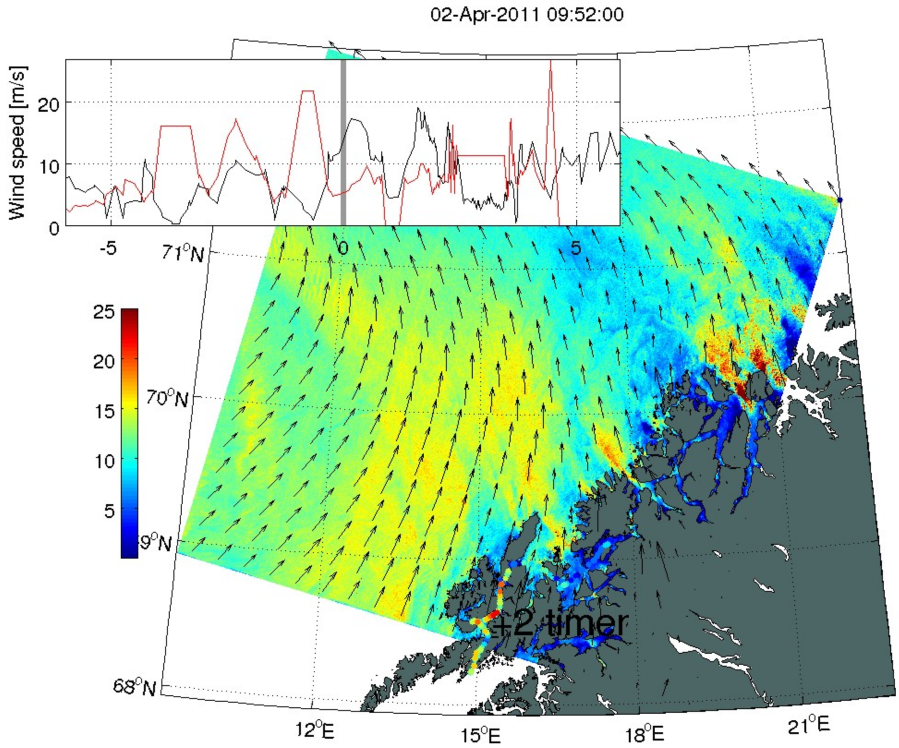
64°N
63°N
+2 timer
-4 timer
2°E
4°E
6°E
8°E
10°E
12°E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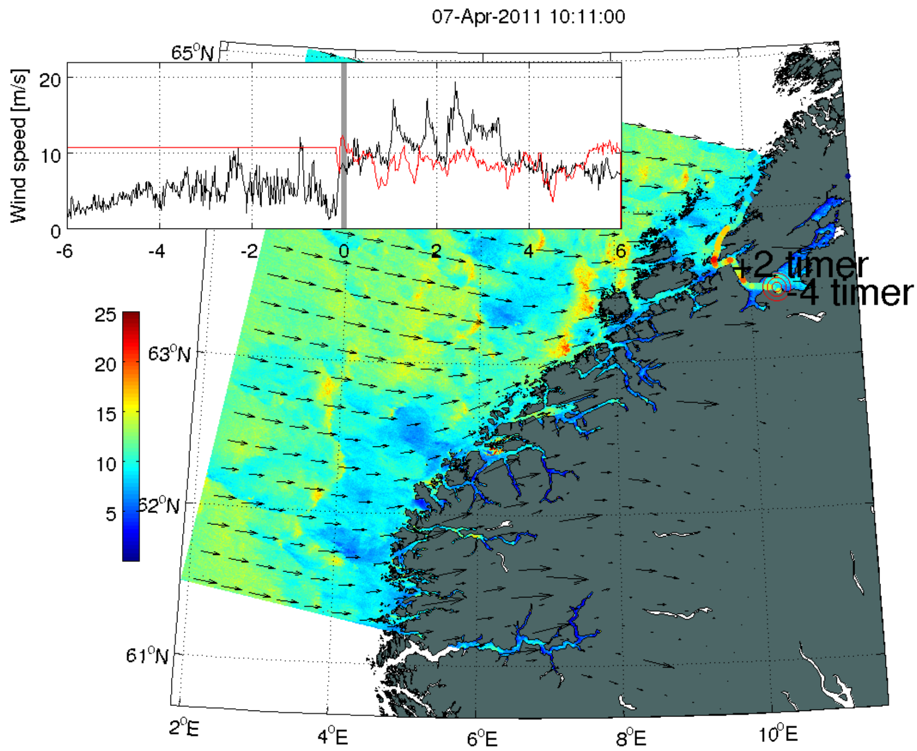
12°E
15°E
18°E
21°E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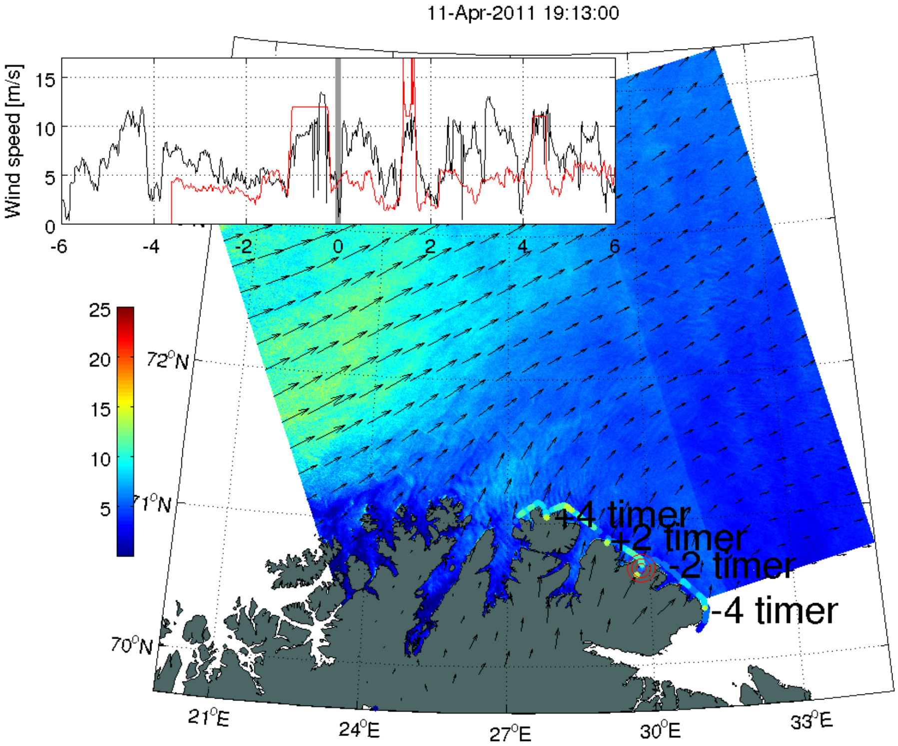
10°E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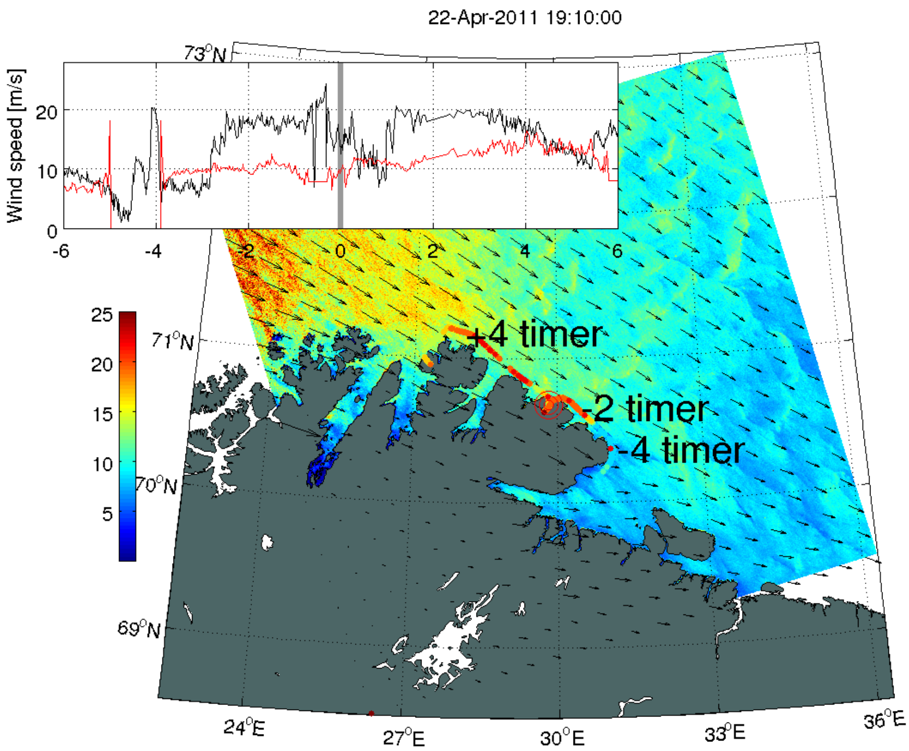
21°E
24°E
27°E
30°E
33°E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71°N
70°N
69°N
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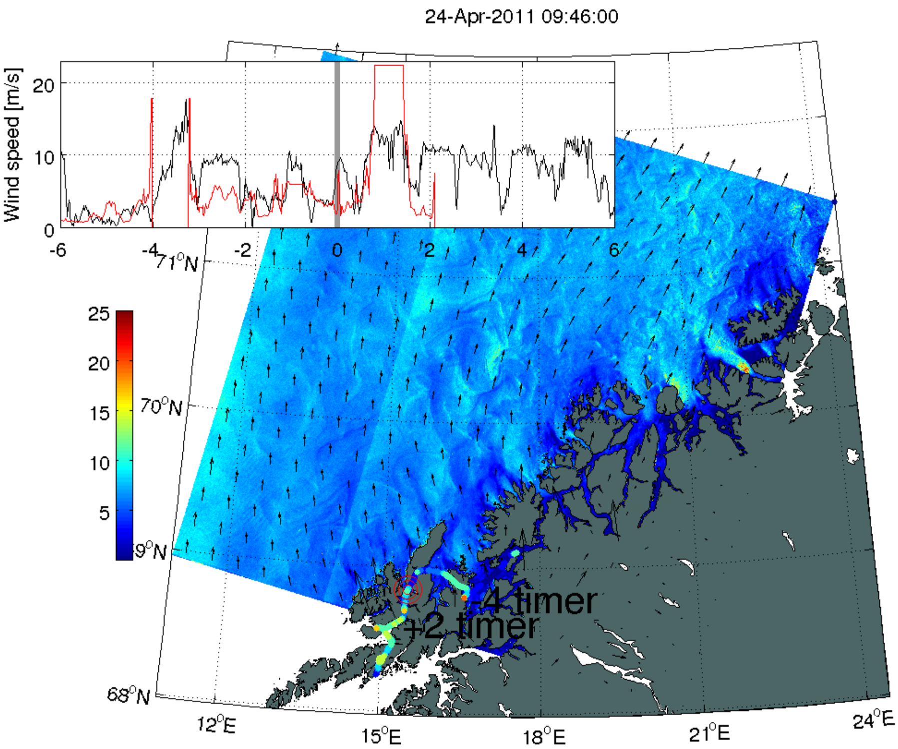
30°E
33°E
36°E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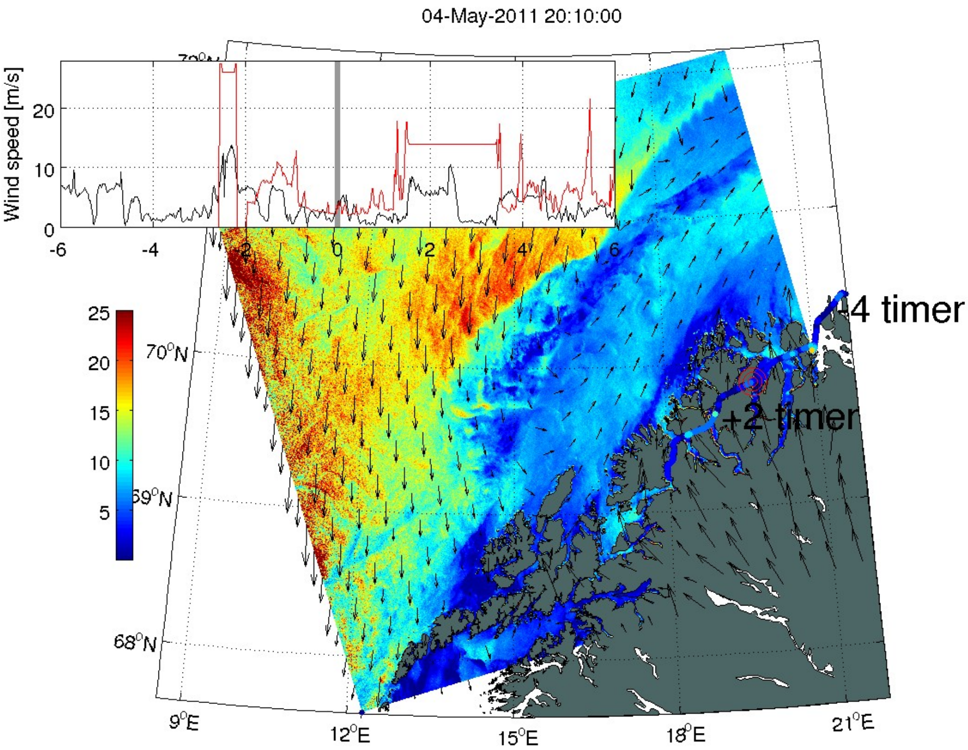
18°E
21°E
24°E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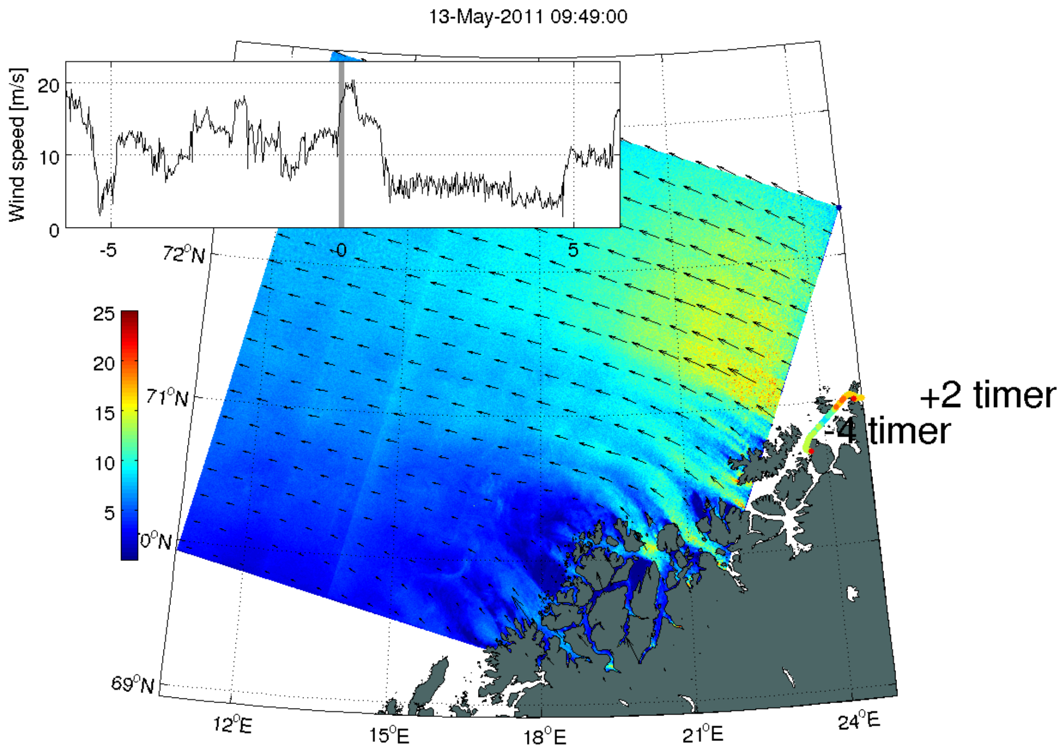
69°N
68°N
9°E
12°E
15°E
18°E
21°E



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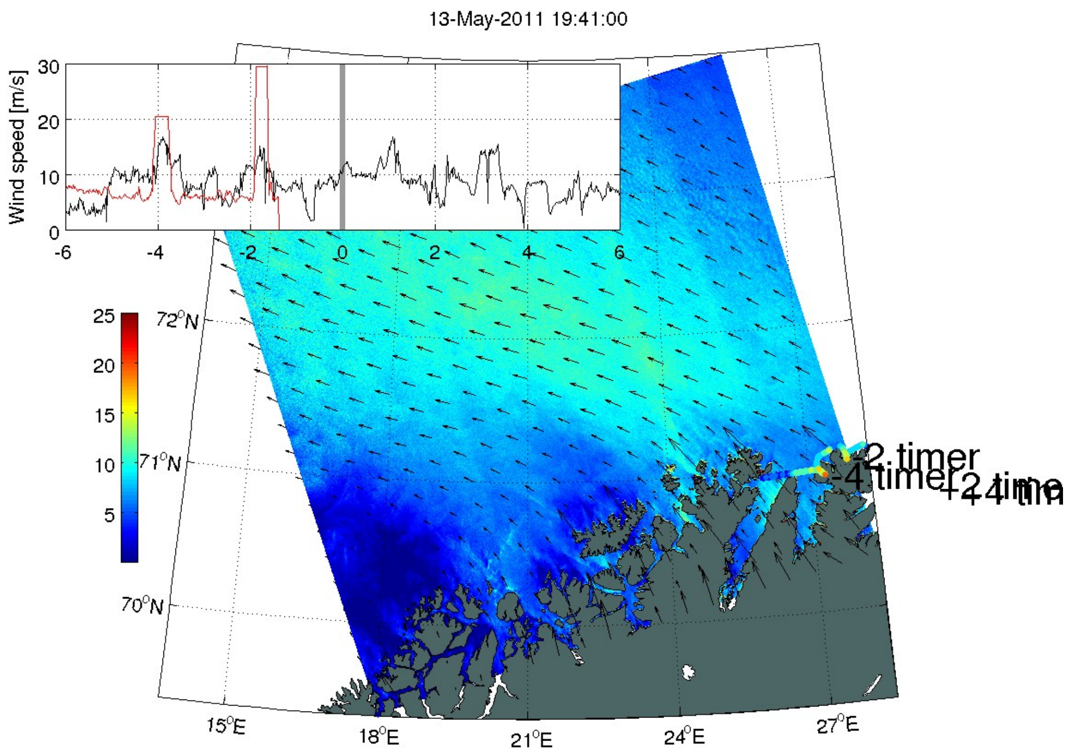
18°E
21°E
24°E



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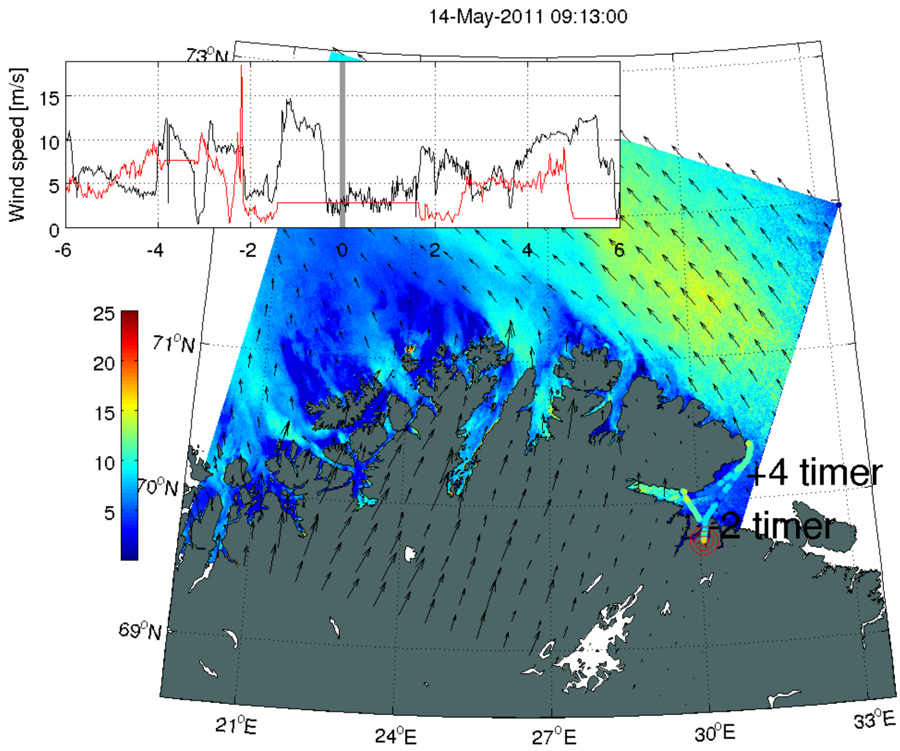
21°E
24°E
27°E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10
5
0
-6
-4
-2
0
2
4
6
25
20
15
10
5
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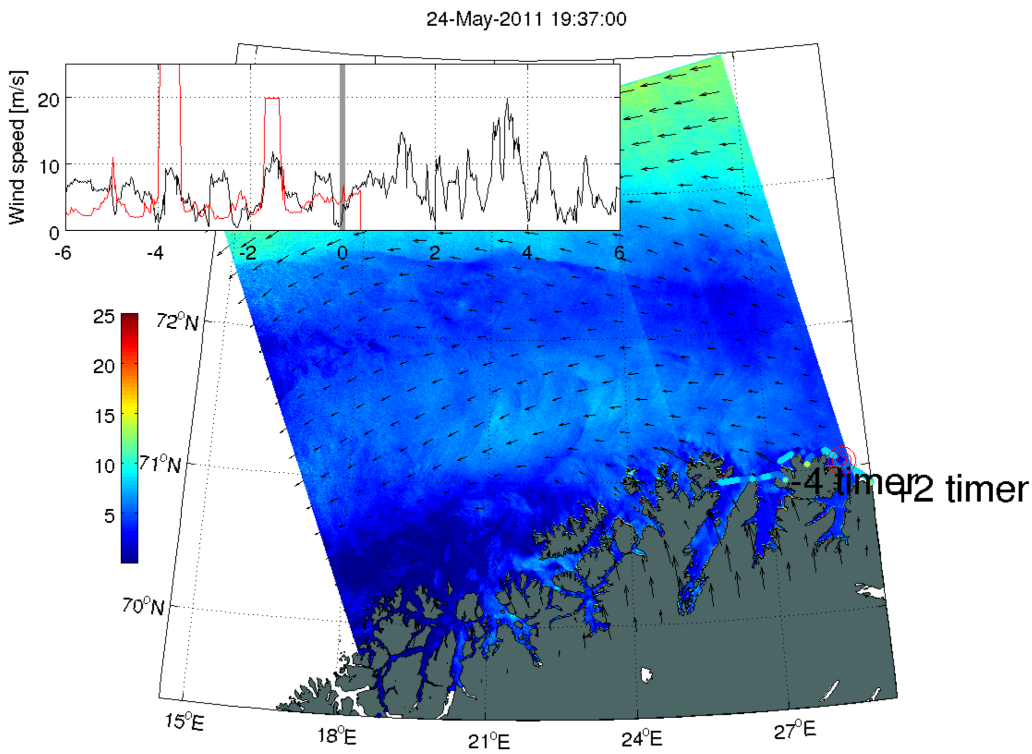
70°N
69°N
21°E
24°E
27°E
30°E
33°E
+4 timer
+2 timer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Wind speed [m/s]
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10
0
-6
-4
-2
0
2
4
6
25
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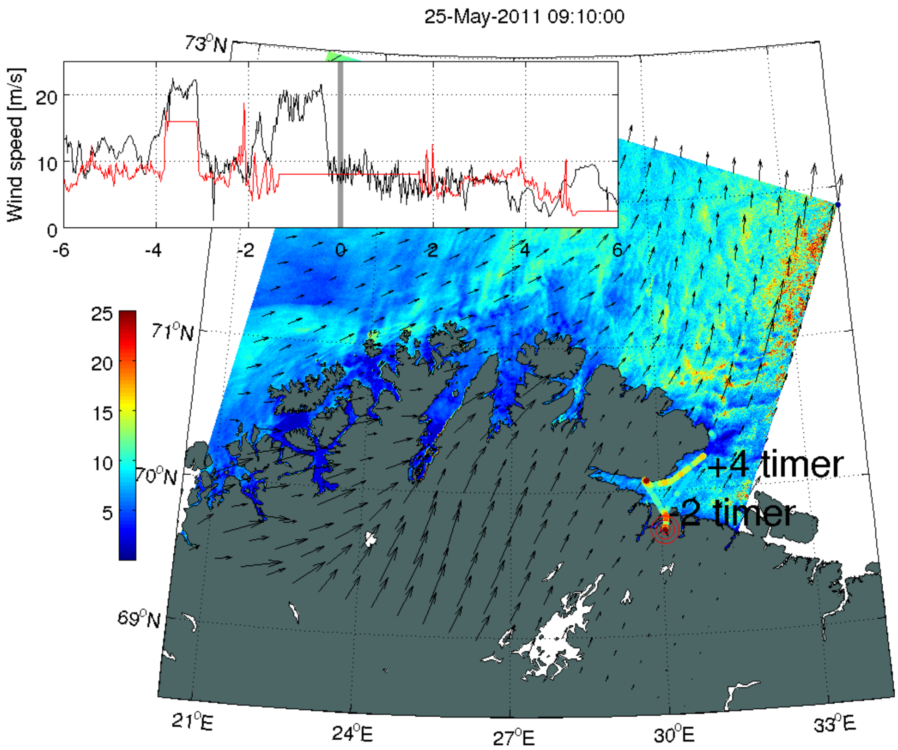
27°E
-4 timer
+2 timer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Wind speed [m/s]
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21°E
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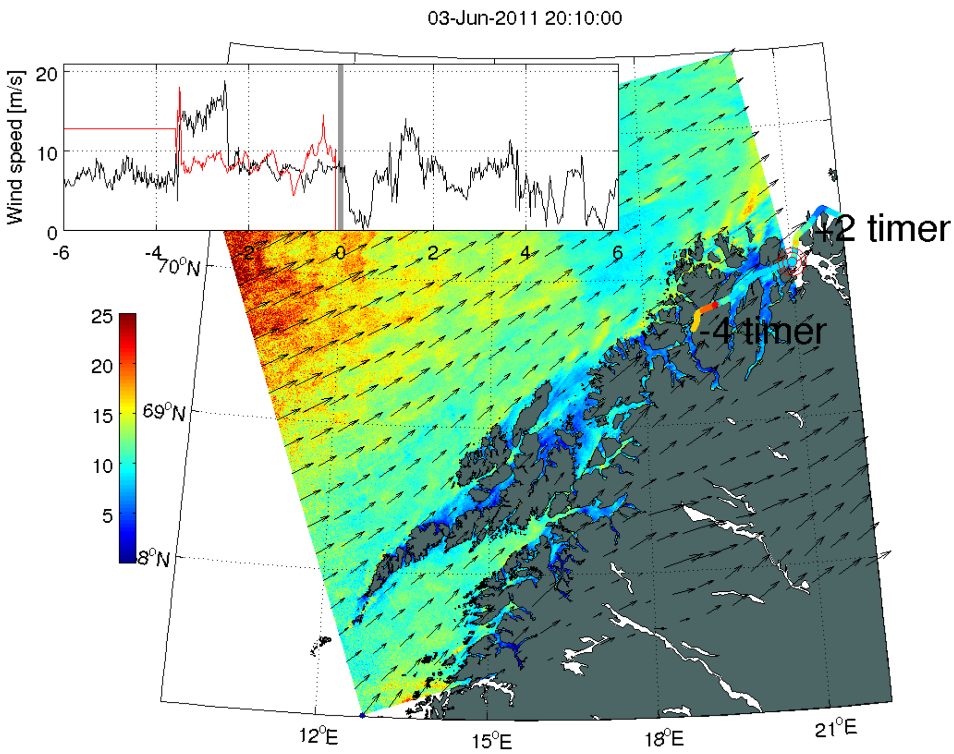
27°E
30°E
33°E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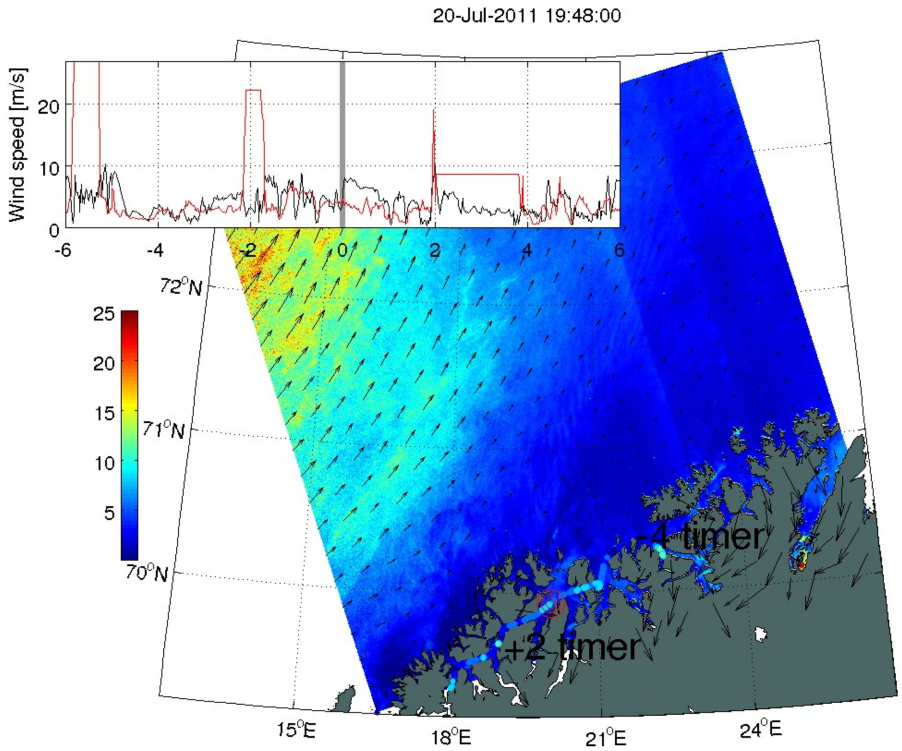
15°E
18°E
21°E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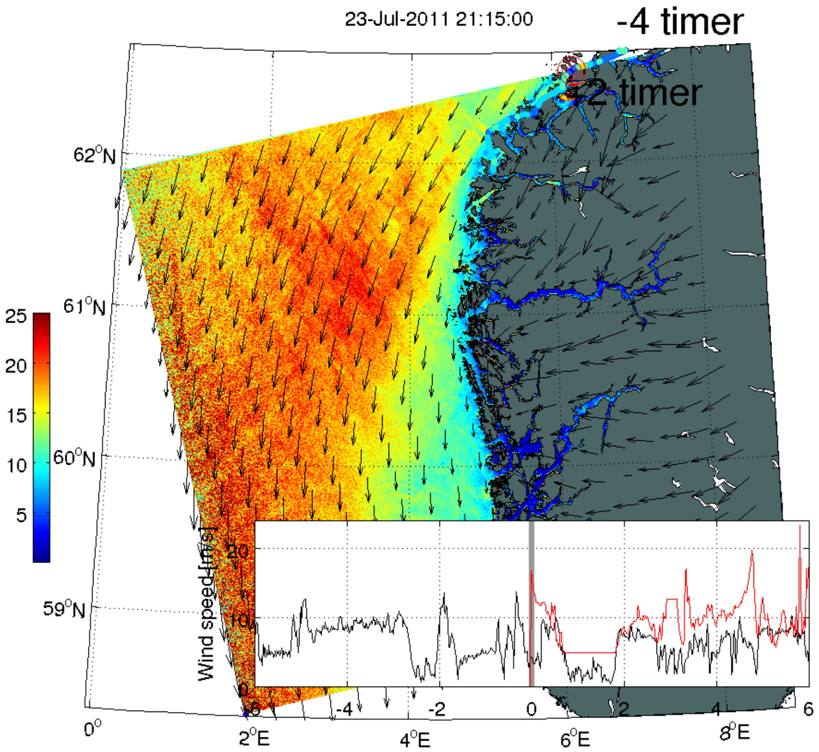
18°E
21°E
24°E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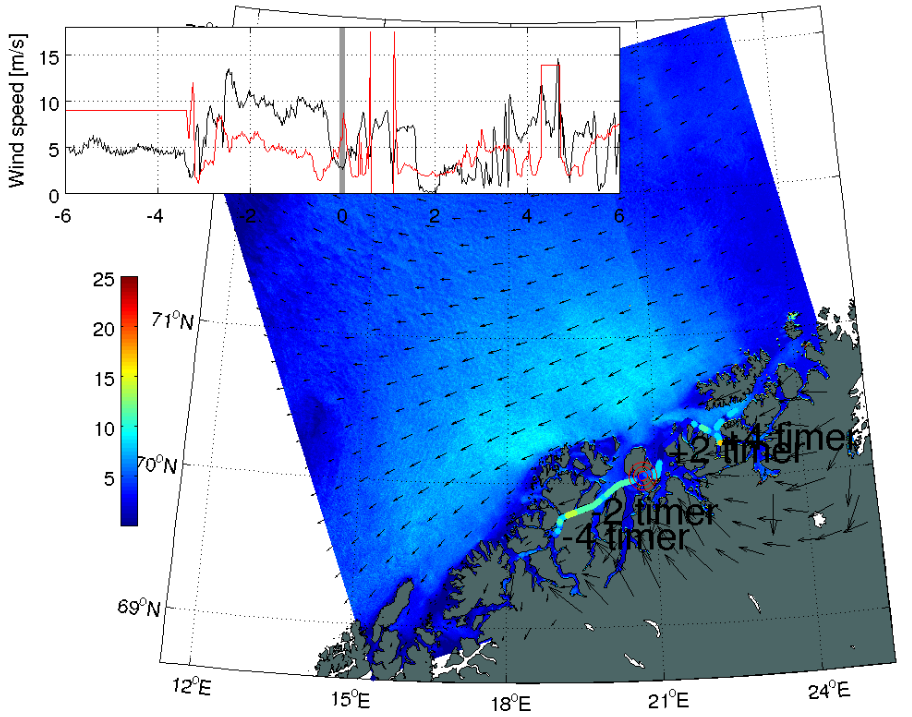
4°E
6°E
8°E

28-Jul-2011 19:55:00



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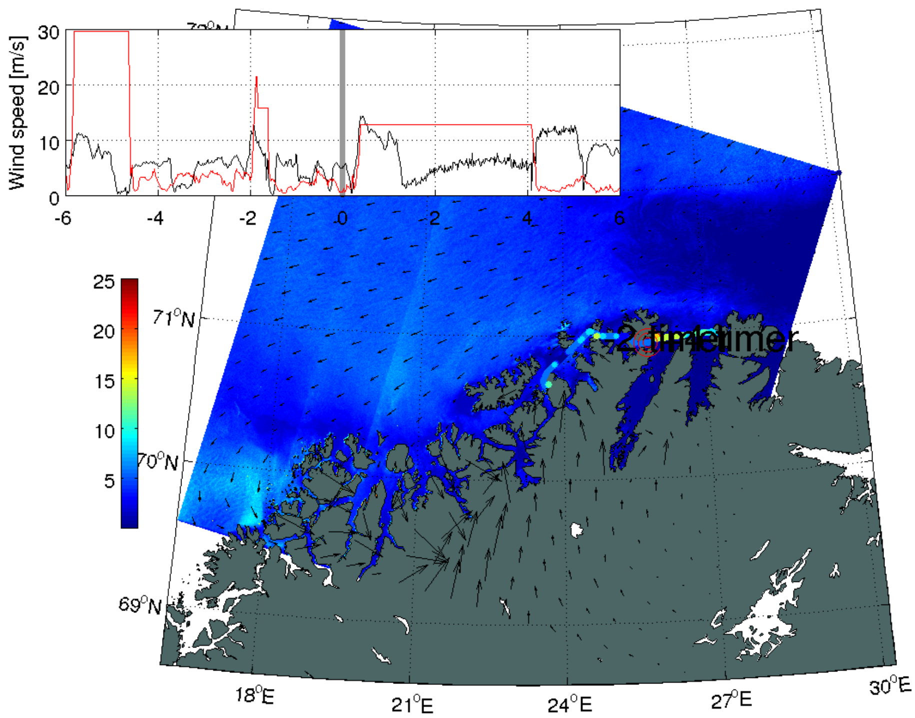

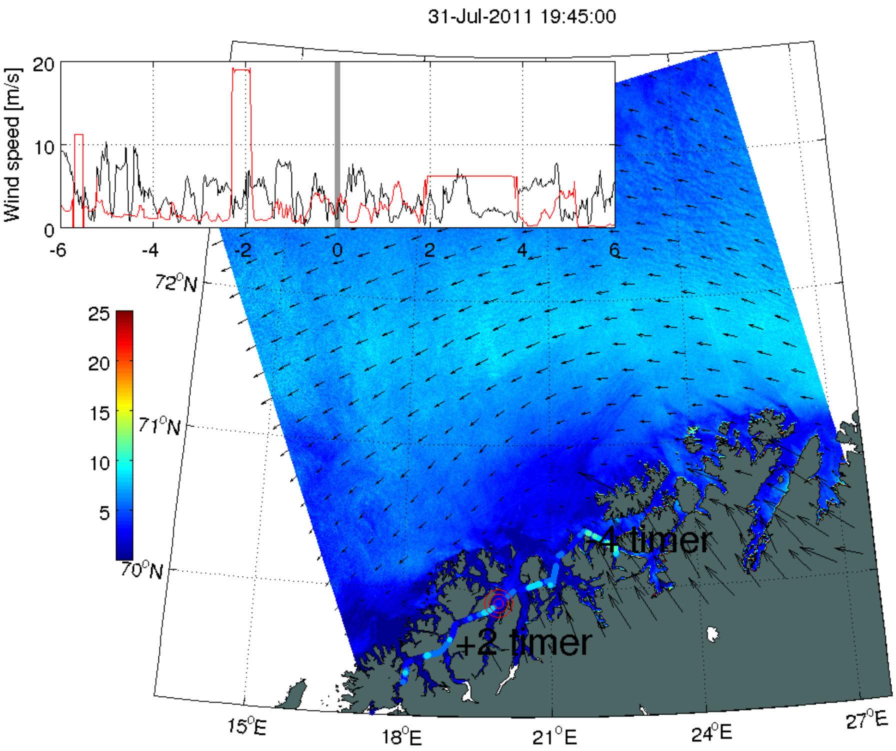
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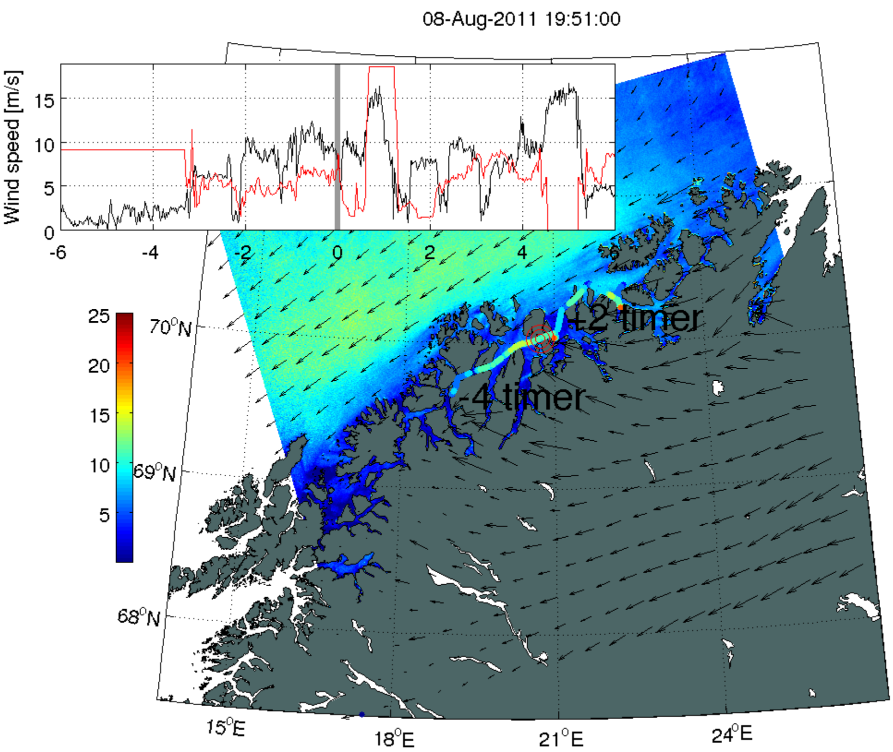
21°E
24°E
27°E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18°E
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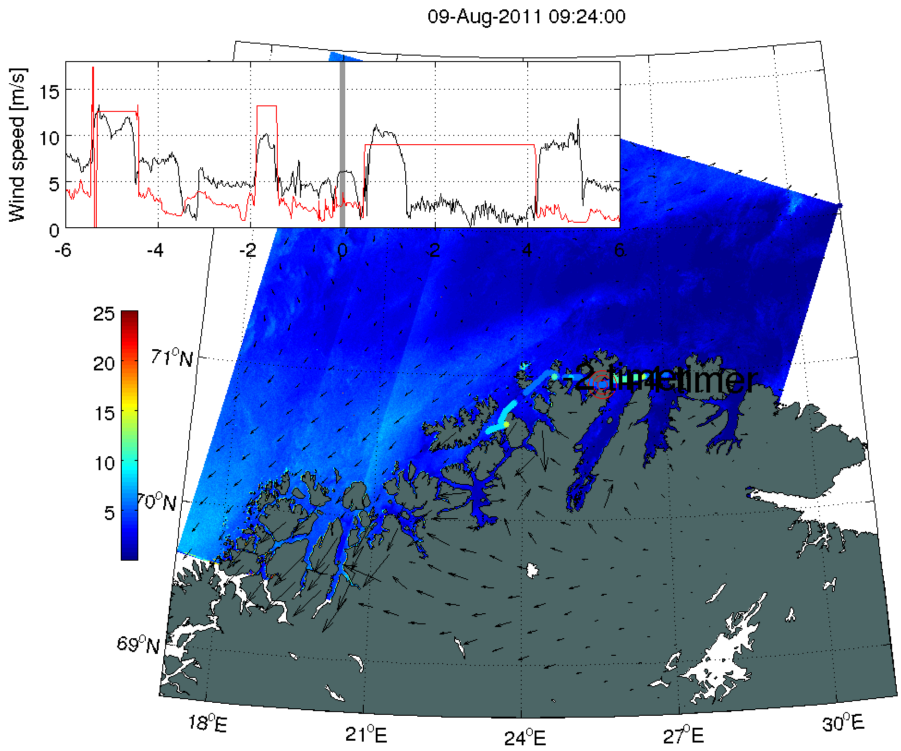
24°E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-4
-2
0
2
4
6
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15
10
5
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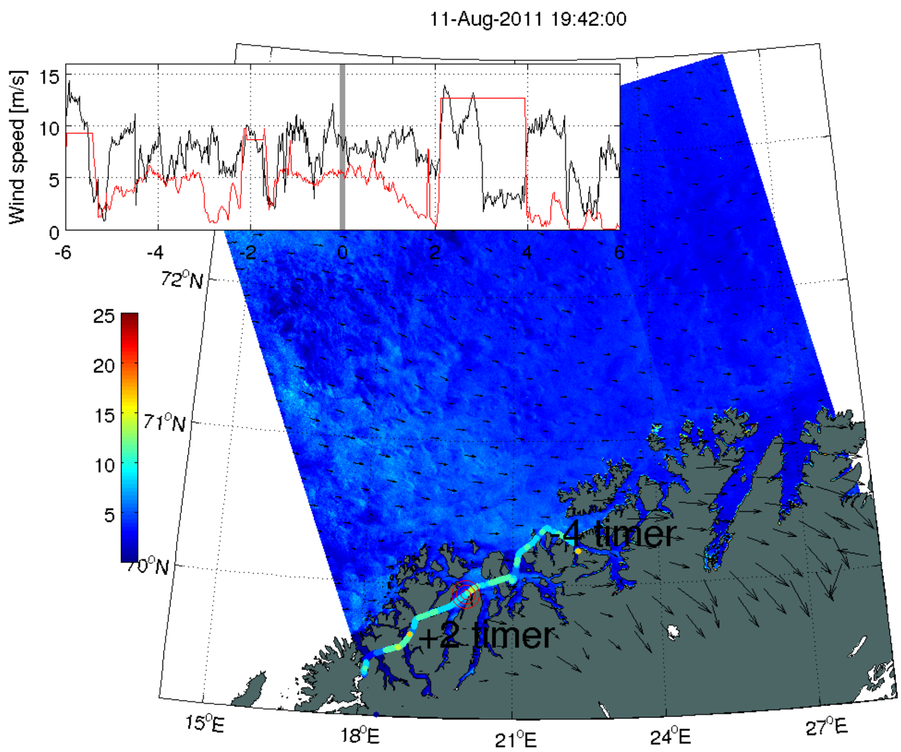
70°N
69°N
18°E
21°E
24°E
27°E
30°E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-2
0
2
4
6
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10
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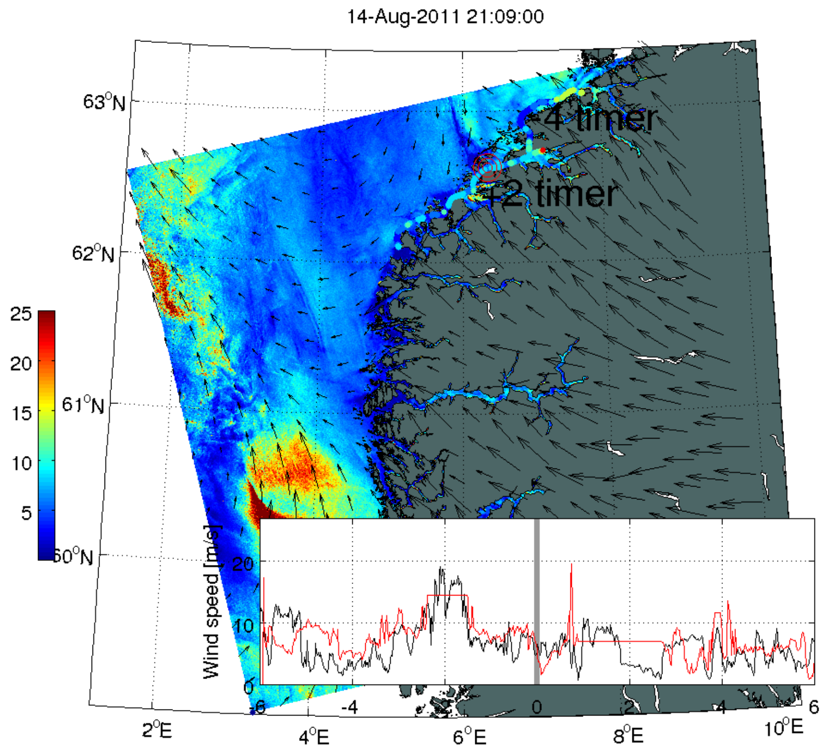
+2 timer
15°E
18°E
21°E
24°E
27°E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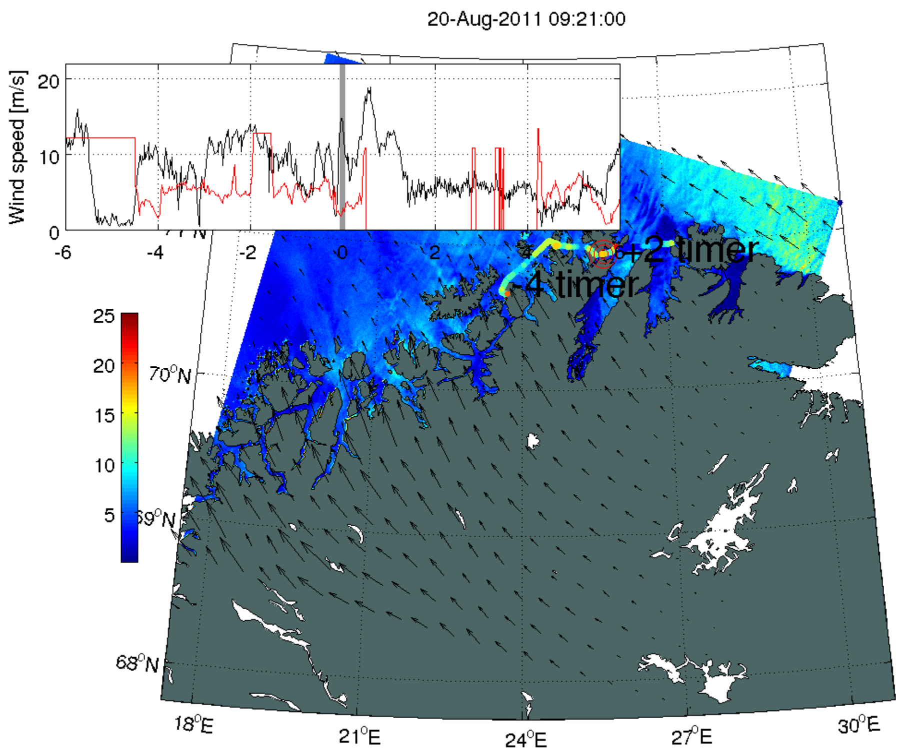
62°N
61°N
60°N
2°E
4°E
6°E
8°E
10°E
25
20
15
10
5
+4 timer
+2 timer
Wind speed [m/s]
20
10
0
-6
-4
0
2
4
6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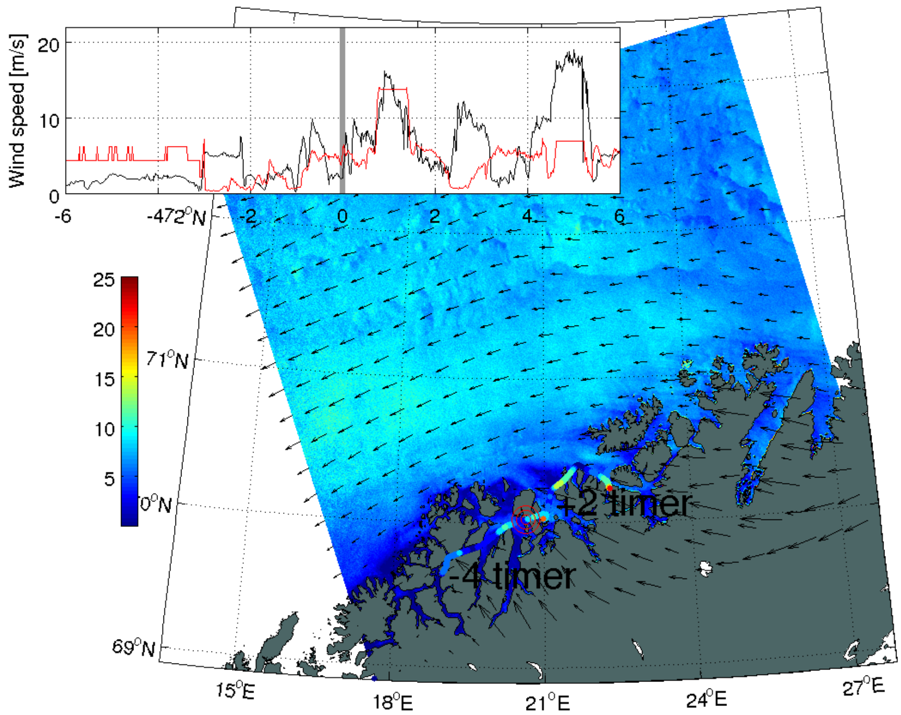
-4
-2
-0
2
+2 timer
+4 timer
25
20
15
10
5
70°N
69°N
68°N
18°E
21°E
24°E
27°E
30°E

30-Aug-2011 19:45:00



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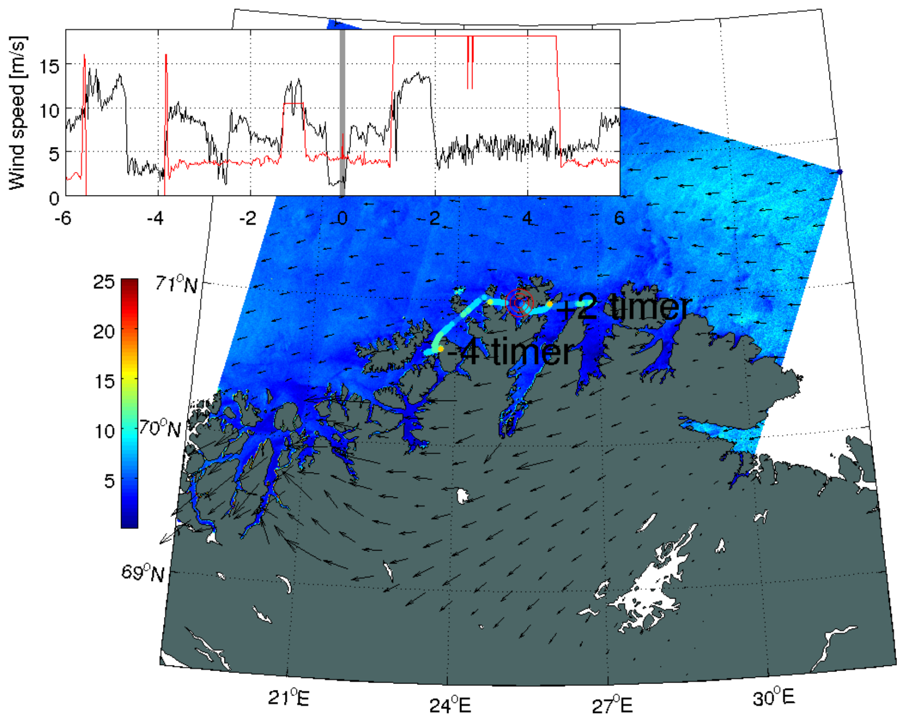

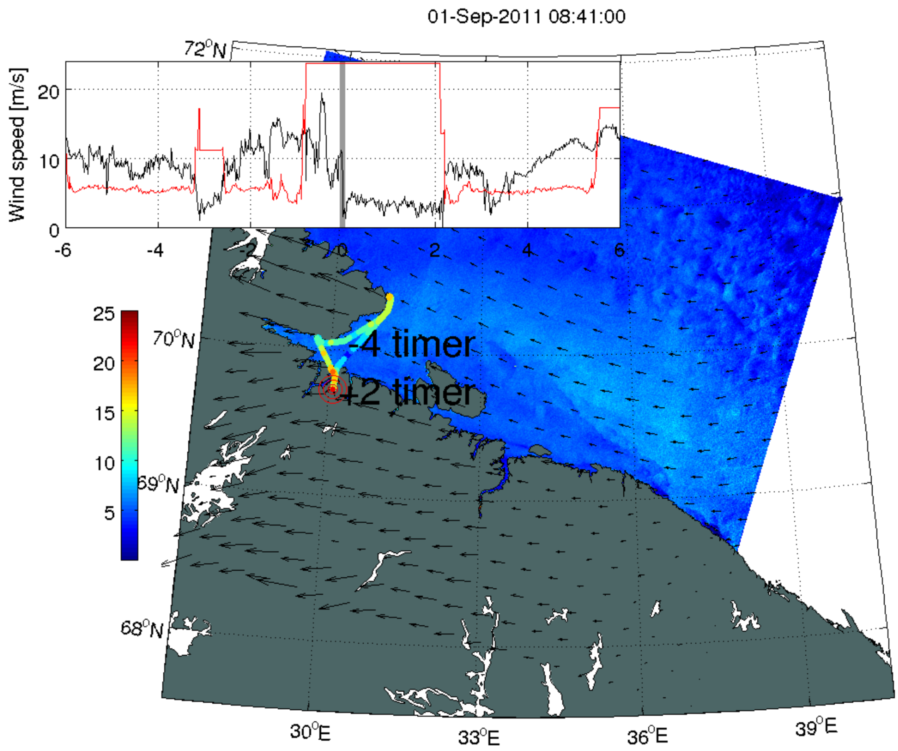
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69°N
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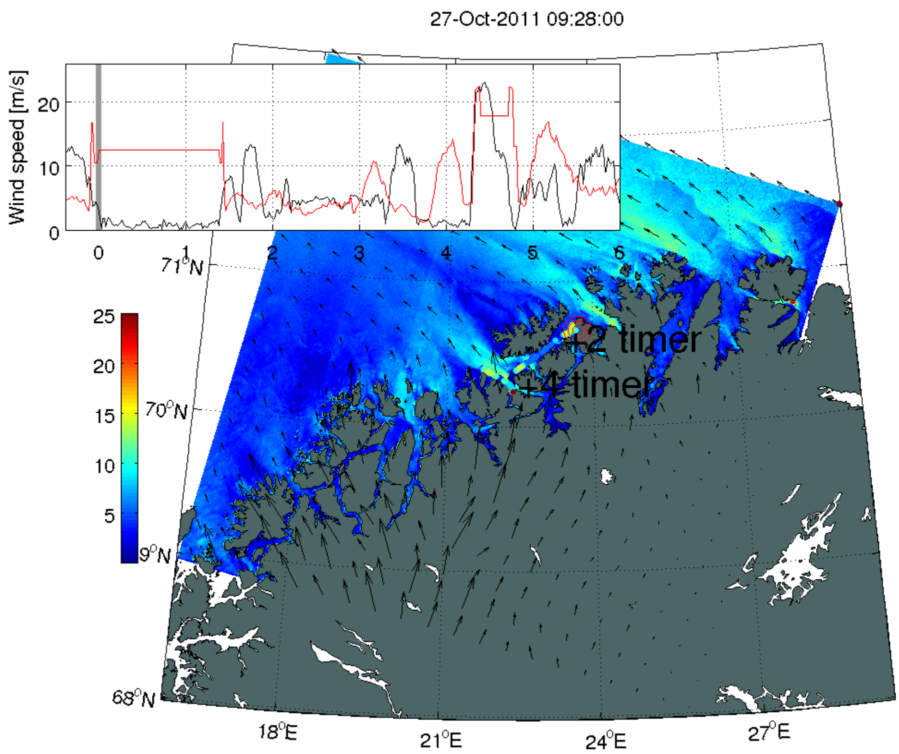
33°E
36°E
39°E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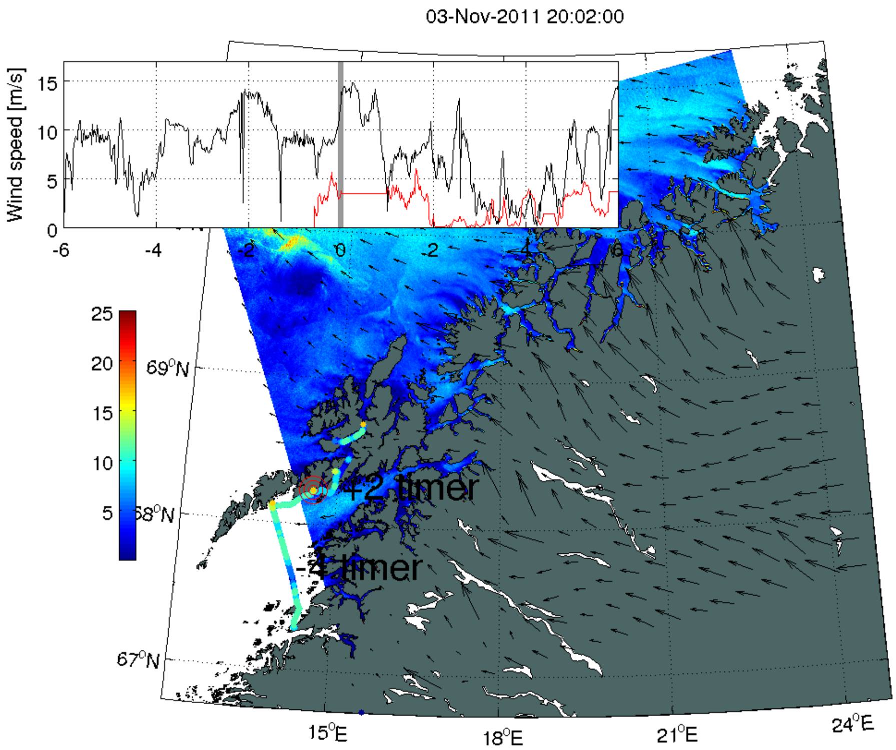
24°E
27°E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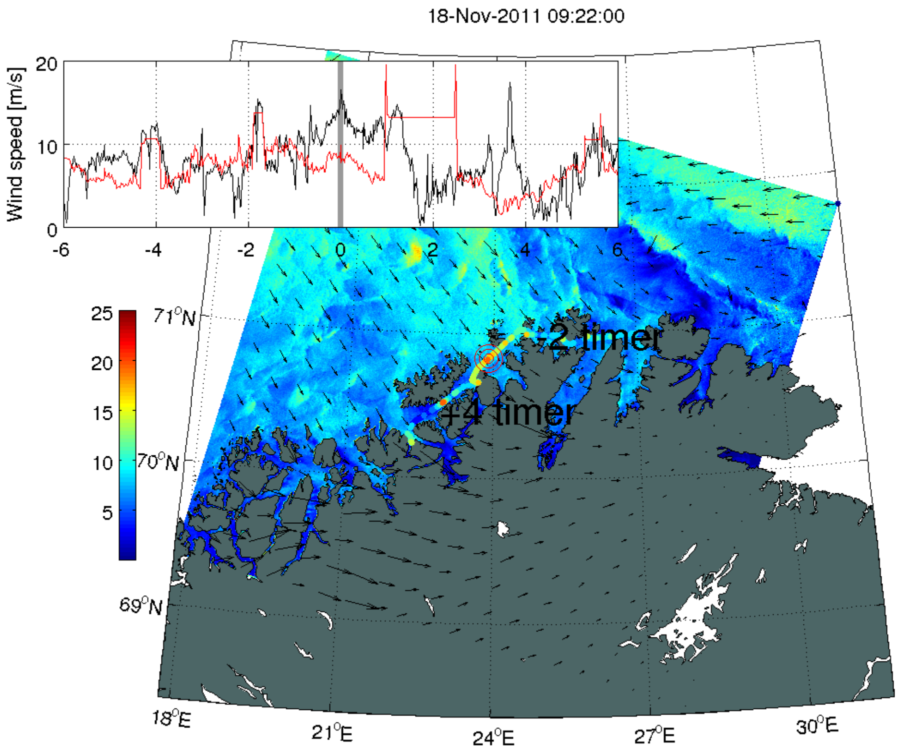
24°E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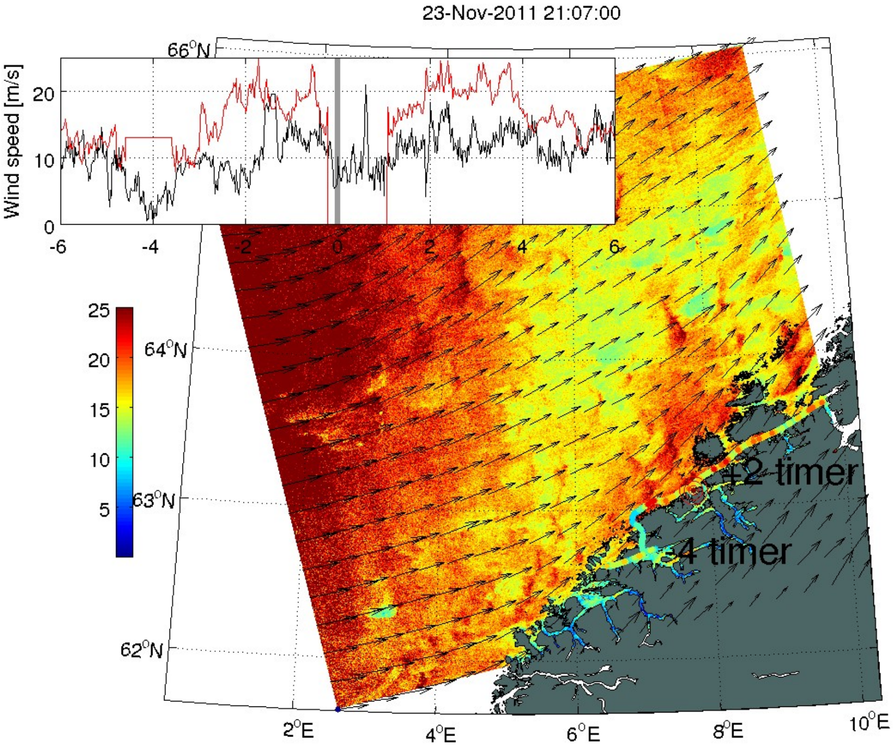
27°E
30°E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63°N
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6°E
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10°E
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