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ON THE QUALITY OF WEATHER FORECASTS AND ICE CHARTS OFFSHORE NORTH EAST GREENLAND

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ABSTRACT

A research expedition took place with the Swedish Icebreaker Oden offshore North East Greenland within the period 15th to 25th of September 2012 (Oden Arctic Technology Research Cruise – OATRC12 – Lubbad et al., 2013). The occasion was used to provide data for evaluation of the quality of ice and weather forecasting services in the region. Information of forecasting skills is considered as extremely important for Arctic offshore operations.

Comparisons between forecasted parameters such as winds, air temperatures and visibility allows for evaluation of forecasting reliability within the specific time period. Comparisons between issued ice charts and ground truth observations of ice concentrations forms a basis for evaluation of the quality of some of the ice charting services available for industry.

Since the time duration of the expedition was limited, general conclusions on forecasting qualities cannot be made. The data indicate however that temperatures can be well forecasted up to 5 days, wind forecasting is more challenging and in particular with respect to directionality in mild conditions. Forecasting of visibility is complicated and not reliable. The quality of ice charts can be very good conditional proper sources are used when making the charts.

INTRODUCTION

Offshore oil and gas exploration and eventually exploitation activities are expected to take place in Arctic waters within the next decades. Since consequences of accidents in the Arctic are expected to be more severe than in more Southern waters, it will be required that the offshore industry ensures extremely low failure probabilities in the Arctic in order to keep the total risks at the same level or lower than in regions operated so far.

Predictability is one of the key elements in order to ensure unwanted incidents and weather forecasting capabilities is of high importance in this respect. Generally, weather forecasts in Arctic regions must be expected to be of lower quality compared to forecasts in "non-Arctic" regions partly due to phenomenon such as line squalls and polar lows but mainly due to lack of local data recordings to be assimilated into the forecasting models.

When planning marine operations in the Arctic a quantitative evaluation of the weather forecasting skills must be in place in order to consider the probability for failure. One example is ice management operations where ice breakers actively reduce the floe sizes upstream an offshore installation. If the ice drift direction change during the operation, the managed ice floes will miss the structure to be protected while unmanaged ice floes may hit the structure and potentially cause a dangerous situation.

Evaluation of forecasting quality in the Arctic has historically not been given much attention. Forecasts have been issued during different marine operations but the issued forecasts are normally not stored and not systematically compared with locally recorded data. In order to illustrate how such forecasting evaluations can be performed, forecasts of winds, air temperatures and visibility were requested during a 10-day expedition to the North East Greenland while the same parameters were logged continuously from the icebreaker Oden. Figure 1 shows the route travelled under the Oden Arctic Technology Research Cruise (OATRC12). Details form the expedition is presented by Lubbad et al., 2013.

In addition, ice charts where issued from two different sources and compared with local observations of the sea ice coverage. This paper presents the work done on evaluation of the forecasting data.

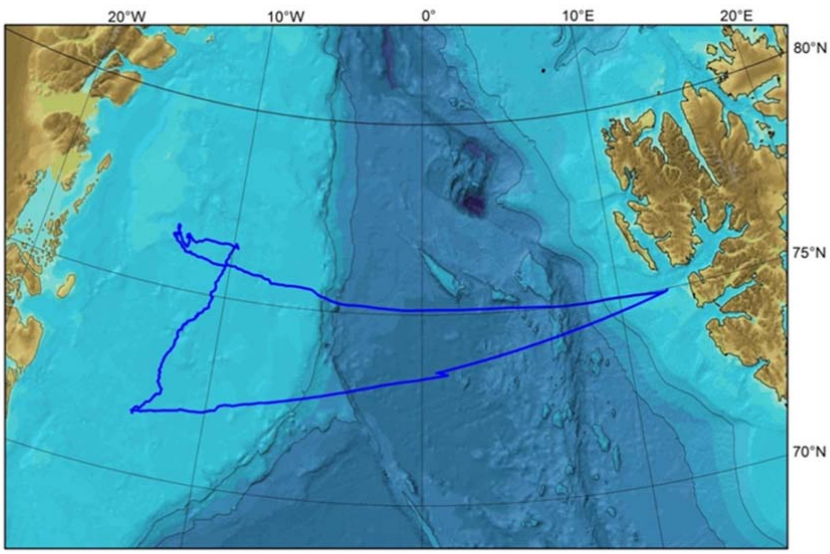

Figure 1. Track of the icebreaker Oden during the North East Greenland Expedition 15.09-25.09-2012. The southern leg is on the way over from Spitsbergen.

METHODOLOGY

General

The weather forecasts from two sources have been compared to the actual weather conditions, in order to determine the quality of the forecasts over 1 to 6 forecast days. In addition, ice charts from two different sources have been compared with ground truth data during the icebreaker expedition. The methodology and assessment criteria are provided in this section.

A method of assessment for wind forecast: WFA-2000

The method follows a gradual step-by-step validation for forecasted wind speed and direction by comparing with observed data, and consequently, a single value calculation for the forecast quality.

The method has been successfully tested in ice drift forecasting service for the Vityaz oil production complex at the north-eastern Sakhalin offshore for more than seven years (Pishchalnik, 2006).

To evaluate the reliability of a wind forecast two terms of conditions were applied:

- If the forecast is issued in a range of values for wind speed or direction, these values then have to be averaged to a single value for validation with 1 knot (0.5 m/sec), and half-cardinal compass-point (22.5°) accuracy respectively.
- The observed data are not averaged. Only the range of changes for wind direction and speed during the forecast period is being determined.

The assessment procedure consists of 3 steps and is carried out by evaluating the deviations of forecast values from observed wind speed and direction intervals.

The first step of evaluation for reliability of the wind direction is determined according to the criteria shown in Table 1. If minimum deviations of the forecast wind direction values from the observed values are bigger than 45° the forecast is considered as misleading and gets 0% evaluation. If minimum deviations of forecast values from the observed values are in the range from 22.5° to 45° the forecast gets 50% score (satisfactory). If the deviation between forecast and observation is less than ± 22.5° the forecast gets 100% evaluation (good) for wind direction.

Secondly, an evaluation of the wind speed forecast reliability is carried out according to the criteria shown in Table 1. If the forecast wind speed exceeds the allowed deviations (1-2 m/sec) for two determined gradations (<10 and >10 m/sec), the initial evaluation of wind forecast for direction is reduced by corresponding value.

Thirdly, the overall wind assessment is then determined by combining the rating of both the wind direction and wind speed assessments using the assessments in Table 2. Then the standard statistical procedure is applied to 3-hour validations.

Table 1. Criteria for evaluation of forecasted wind speed and wind direction

Score	Wind direction [°]	Wind speed [m/s]	
		≤ 10 m/s	>10 m/s
Good	±22.5	±1	±2
Satisfactory	±45	±2	±4

Table 2. Overall wind velocity forecasting assessment

Wind Speed Assessment	Wind Direction Assessment	Overall Assessment
Good	Good	Good
Good	Satisfactory	Satisfactory
Good	Bad	Bad
Satisfactory	Good	Satisfactory
Satisfactory	Satisfactory	Bad
Satisfactory	Bad	Bad
Bad	Good	Bad

Bad	Satisfactory	Bad
Bad	Bad	Bad

Assessment of air temperature and visibility forecasts

The quality of air temperature forecasts and visibility can be evaluated by the same procedures as for wind velocity and with the quality definitions as given in Table 3 and Table *4*. Finally, a count of the number of "Good", "Satisfactory" and "Bad" forecasts has been calculated for each of days of forecast period and a result was presented in histograms.

Table 3. Criteria for evaluation of air temperature

Air Temperature Assessment	Allowed deviations, ºC
Good	± 1
Satisfactory	± 2
Bad	> 2

Table 4. Criteria for evaluation of visibility

Visibility Assessment	Average deviations, %
Good	≤ 10
Satisfactory	10-30
Bad	> 30

Validation of the ice charts

The ice data including ice concentration, ice floes size and ice type were extracted from the ice charts manually. The ice concentration values have been compared with ice observation onboard Oden. Then the difference between ice concentration on the ice charts and ground truth data was calculated and a result was presented graphically.

DATA AND FORECASTS

On site data recordings

Details regarding meteorological recording sensors on Oden are not considered as relevant for the reader of this paper as the objective is to illustrate an approach for forecasting validations. The amount of data collected locally during the cruise is unfortunately too limited to be used for conclusions on the forecasting qualities. Table 5 shows a list the relevant Oden sensors for this study

Table 5. Wind, temperature and visibility sensors at Oden

Parameter	Sensor	Location	Sampling	Comment
Wind	Gill WindSonic - heated	Starboard mast	10 min	Partly malfunctioning due to freezing fog
Air Temperature	PT100 Pentroic	Starboard and port – top of bridge	10 min	
Visibility	PWD 22 Vaisala	Top of Bridge	1 h	Only visual estimates applied

Regarding sea ice, two Marine Mammal Observers (MMOs) where continuously making observations for mammals during the daylight periods. The MMOs were also cautiously reporting the local ice conditions. Photos of the conditions in different directions were taken with 1 hour intervals and parameters such as floe size, ice concentration, ice edge and visibility were reported.

Weather forecasts

The Oden cruise was provided with weather forecasts from 2 organizations: commercial weather services company StormGeo and the Swedish Meteorological and Hydrological Institute (SMHI). Both forecasts were developed specifically for the NE Greenland. The forecasts of SMHI was based on the HIRLAM C11 and were provided for 2.5 days (60 hours). They provided wind forecasts every half-day and updated it every six hours. The weather forecast had graphical format and included the following prognostic elements: wind direction (bearing to north), wind speed (m/sec) and air pressure. The forecasts applied in this study from SMHI has not been evaluated or corrected by the local forecasters onboard Oden. In general, there were limited/no mismatches between the oral forecasts given by the vessel meteorologists and the graphical forecasts from the HIRLAM C11 model. StormGeo forecasts are presently the main forecasts for the Statoil offshore projects. The offshore forecasts are provided for six days. Forecasts in numerical format (csv-files) are given for every three hours, for all forecast elements. The forecasts were updated twice per day. The forecast elements provided are: air temperature (degrees C), horizontal visibility (km), wind direction (bearing from north), wind speed (m/s) and precipitation (mm).

Ice charts

Ice charts were available from different sources for the Oden expedition the Norwegian Meteorological Institute (on request from Statoil), the University of Bremen (on request from Oden) and the Danish Meteorological Institute (free from Website).

Met.no ice charts were obtained daily. They have a high resolution and provide ice concentration, ice floes size, ice type and ice drift, see Table 1. The ice charts used colour code to depict the different ice regions. Met.no had access to daily Radarsat -2 images from ScanSAR Wide mode with 100 m resolution.

The daily ice charts obtained from the University of Bremen has a low resolution and provide a general map of averaged ice conditions including ice concentration in the WMO colour code. The Bremen charts were based on the microwave radiometer SSMIS aboard the operational DMSP satellites.

The ice charts from the DMI are issued twice a week and provide ice type, total and partial ice concentration and ice floes size. They use the International Ice Codes and Symbols for the ice characteristics, Table 6.

Table 6. Characteristics of ice charts

Ice analysis	**Met.no**	**Bremen University**	**DMI**
Periodicity	Daily	Daily	Twice a week
Resolution	High	Low	High
Ice concentration	Yes	Yes	Yes
Ice type	No	No	Yes
Ice floes size	No	No	Yes
Ice drift	Yes	No	No

RESULTS OF COMPARISONS

Meteorology comparisons

The StormGeo weather forecasts have been assessed primarily for accuracy of wind speed and direction, but additionally for temperature and visibility. The assessment of wind has been performed using a method of assessment for wind forecast WFA-2000. StormGeo's night forecast issued at 00:00 has been used as a basis for all assessments. Three hour periods have been considered for all time frames in which data is available from the Oden. The three hour periods have been grouped into 1 through 6 day forecasts as appropriate and overall wind forecasts has been calculated for each of days of forecast period.

The HIRLAM C11 weather forecasting model run by SMHI have been compared with StormGeo forecast to determine if there are any systematically differences in the forecasts. The bar chart in Figure 2 presents the overall wind forecast validation results for the StormGeo forecast and the SMHI forecasts. In regard to practical use, the summary positive value for "good" and "satisfactory" estimations was applied.
The distribution of actual recorded wind force within the period 17th to 23rd of September 2012 is also shown in Figure 2 grouped in Light air (<2 m/s), Breeze (2-5 m/s), Fresh Breeze (5-10 m/s) and Strong winds (>10 m/s) .

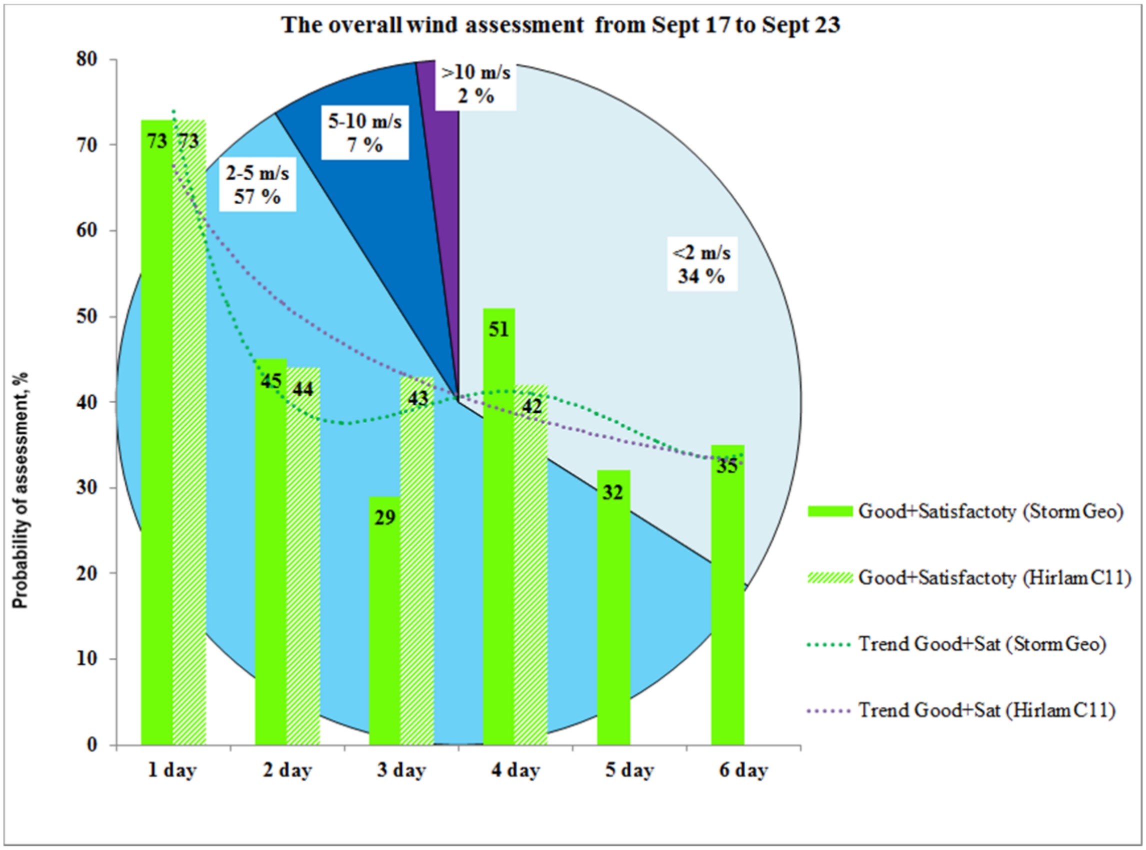

Figure 2. Validation results of the StormGeo and the SMHI (Hirlam C11) overall wind forecasts from September 17 to September 23, 2012

The assessment of air temperature and visibility has been performed in a similar way as for winds. The bar chart on Figure 3 presents the StormGeo air temperature forecast validation results. The bar chart on Figure 4 presents the StormGeo visibility forecast validation results.

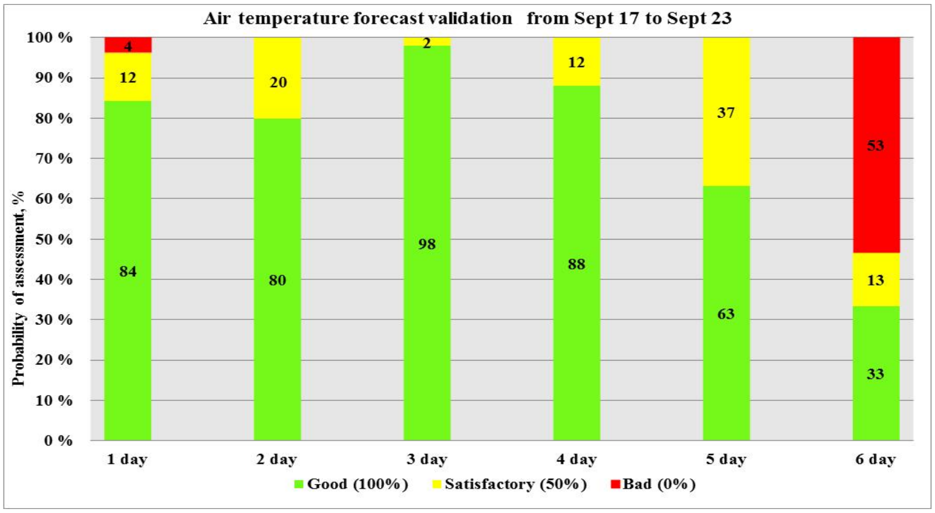

Figure 3. Validation results of the StormGeo air temperature forecast from September 17 to September 23, 2012

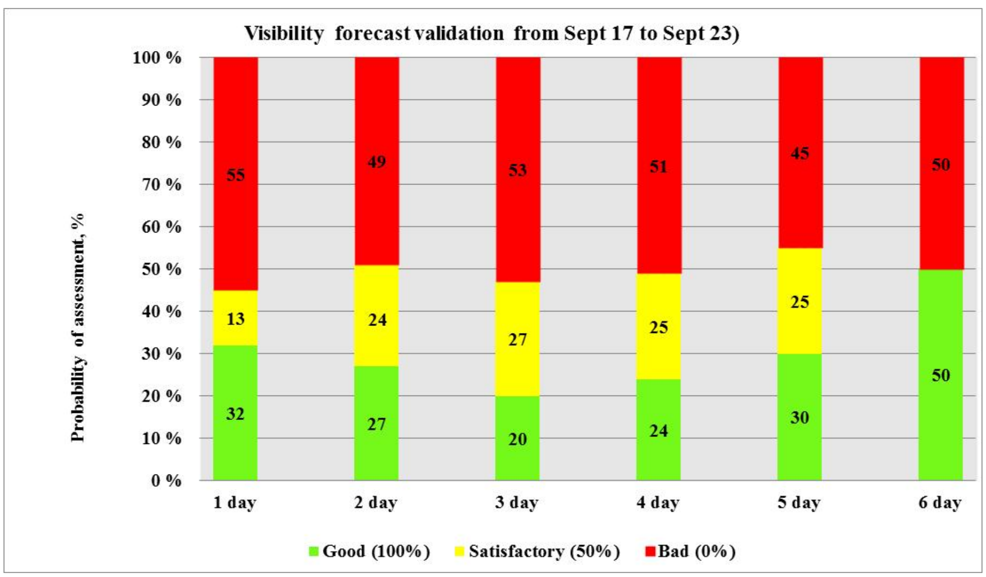

Figure 4. Validation results of the StormGeo visibility forecast from September 17 to September 23, 2012.

Ice chart comparisons

All available ice charts have been compared with ice observations made from Oden. The diagram in Figure 5 presents the comparison of average ice concentration on the ice charts obtained from Met.no, the Bremen University and DMI with ground truth data observed onboard Oden

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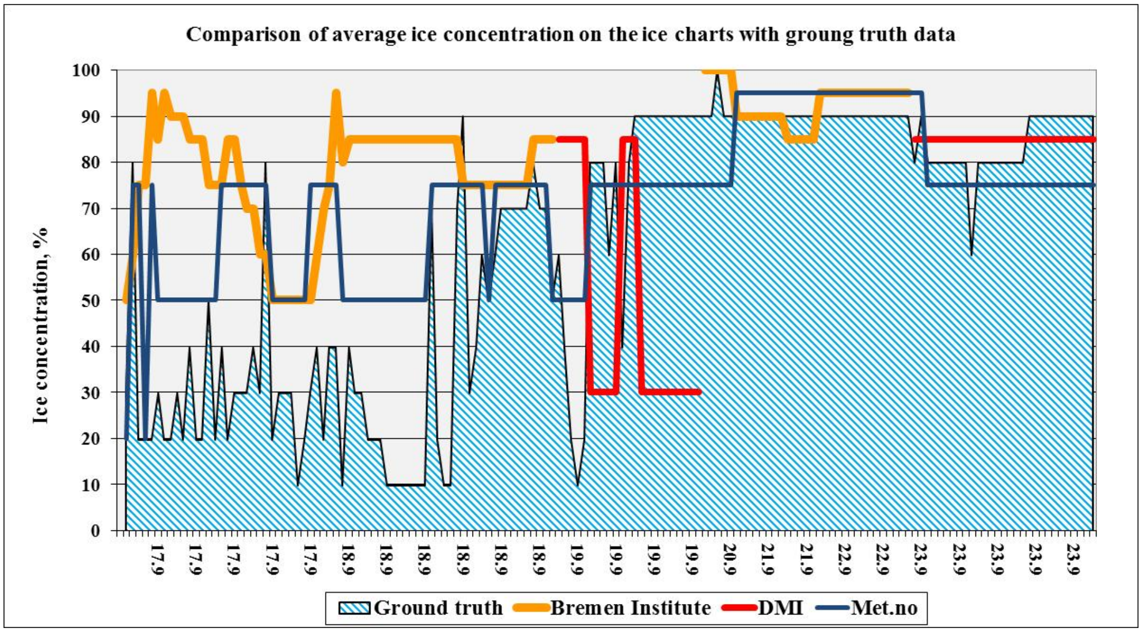

Figure 5. Comparison of results of the ice analyses on the ice charts with ground truth data

DISCUSSSIONS

The quality of the weather forecasts

Figure 2 shows that the quality of the StormGeo and HIRLAM C11 overall wind forecasts is relatively poor as there are possibly difficulties with prediction of weak unstable winds of the flat baric field above the NE Greenland over the period 20th to 23rd of September.
In case of using the summary positive value only the first day of overall wind forecasts from StormGeo and HIRLAM C11 are in a range of climatic occurrence as 73%. The value of probability lower than critical (50%) is on the second forecast day for both of forecasts.

However, the separate analyses for wind speed and wind direction shows that the quality of StormGeo wind speed forecast is very good with a stable mean “good” assessment as about 90% for the whole 6- day forecast period. The quality of wind speed forecast is shown in Figure 6. The quality of HIRLAM C11 wind speed forecast is the same on the first day and has a tendency to decreasing from “good” for the first day to “satisfactory” on the second and fourth days with overshoot on the third day, Figure 6.

The quality of StormGeo wind direction forecast has a general tendency to decreasing from “good” on the first day to “satisfactory” on the second day and to “bad” assessment on the next forecast days with overshoot on the fourth day indicating that values have a high probably of being forecasted incorrectly, Figure 7. The quality of HIRLAM C11 wind direction forecast is slightly worse than the StormGeo, with the probably of having a good assessment 10% less. However, it has a stable trend to decreasing from “good” on the first day to “satisfactory” for the second and third day and “bad” on the fourth day of forecast period.

Regarding directionality of winds, the analyses performed on winds within various speed ranges show that the wind direction has been forecasted fairly accurately for the moderate and strong wind with wind speed more than 5 m/s while being less accurate for the very calm winds.

Regarding air temperatures, the forecasts from StormGeo are very good over 1 to 5 days of the forecast, Figure 3. The probability for the “good” assessment is in range 84-98% with a stable mean value as about 85% for the 4- day forecast period. On the fifth and sixth days the probabilities for the “good” assessment are 63% and 33% respectively.

The quality of StormGeo visibility forecast is poor with a stable mean positive value as about 50% for the whole 6- day forecast period, Figure 4.

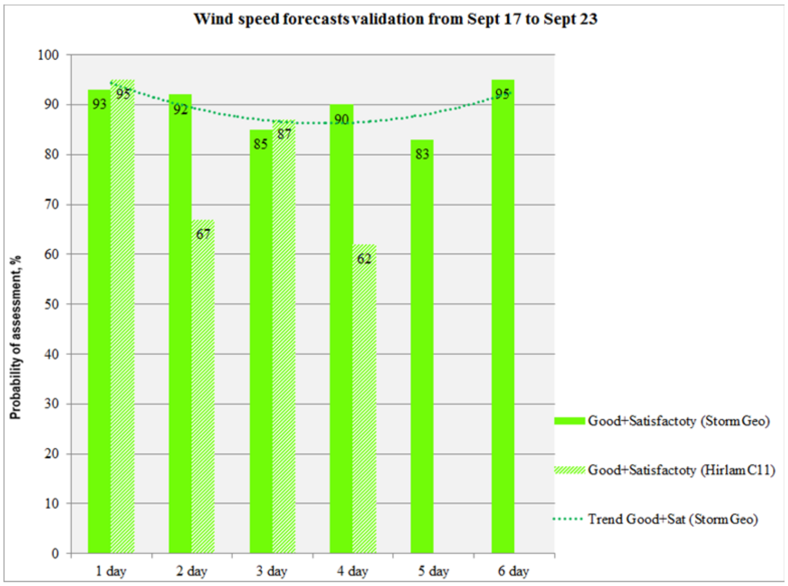

Figure 6. Validation results of the StormGeo and HIRLAM C11 wind speed forecasts from September 17 to September 23, 2012

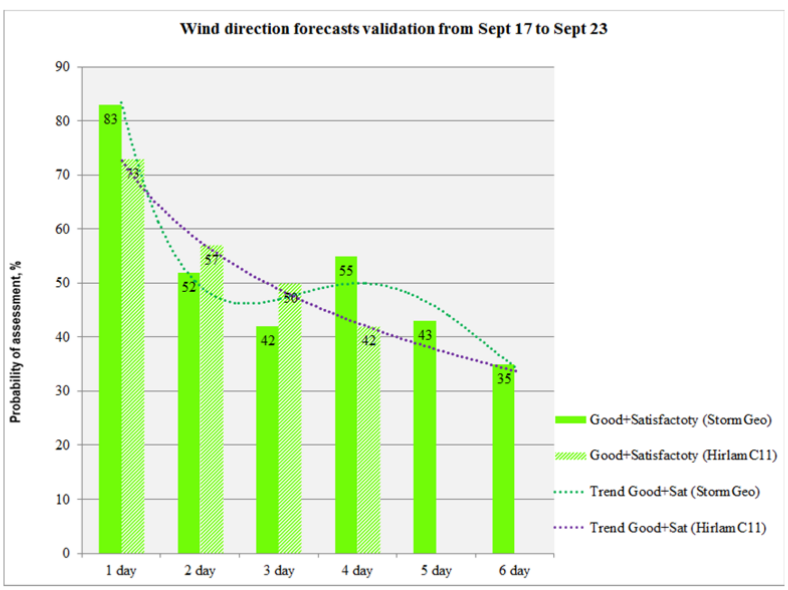

Figure 7. Validation results of the StormGeo and HIRLAM C11 wind direction forecasts from September 17 to September 23, 2012

The quality of ice charts

The diagram on the Figure 8 presents the difference between ice concentration on the ice charts and ground truth data observed onboard Oden. The assessment of ice charts indicates that the quality of Met.no ice analysis is much better than from the other sources. A likely explanation of this is that the ice services at Met.no had access to good satellite data sources and knew the charts would be applied on board a vessel in operation.

The average deviation of ice concentration from the ground truth data is 11.9% for Met.no, 19.0% for DMI and 25.5% for Bremen University. DMI ice analysis is most detailed regarding ice concentration, ice type and ice floes size but has less periodicity and data validity. The ice charts from the Bremen University has a low resolution and poor data validity.

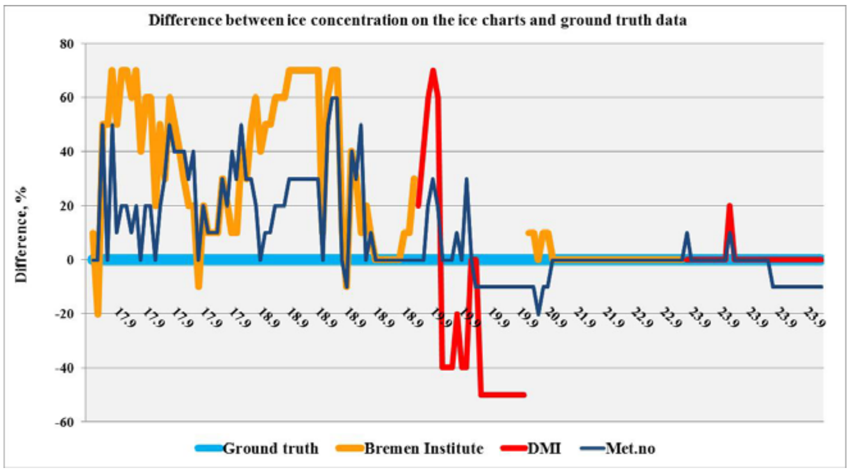

Figure 8. Difference between ice concentration on the ice charts and ground truth data

CONCLUSIONS

Firstly, it must be emphasized that the amount of data applied in this study is far from sufficient to conclude on forecasting skills in general or for comparisons of different forecasting agencies. The main objective has been to demonstrate an approach which can be applied for forecasting evaluations and to highlight the need for good quality in forecasting services in Arctic offshore operations.

Some specific conclusions can however with minor reservations be made:

- The quality of StormGeo air temperature forecast is very good up to five days ahead.
- The quality of StormGeo visibility forecast is poor and forecasting of visibility in the waters offshore North East Greenland during summertime is expected to be difficult.
- The errors in both wind forecasts during the Oden expedition in 2012 was most likely caused by constantly varying wind directions over the period 20th to 23rd of September as a result of the flat baric field above the NE Greenland.
- The assessment of ice charts indicates definitely that quality of ice charts delivered from Met.no was good and that access to reliable satellite images over the region of interest is an important contribution to the ice chart services.

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