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Validation of use of R-factor imagery in operational weather monitoring

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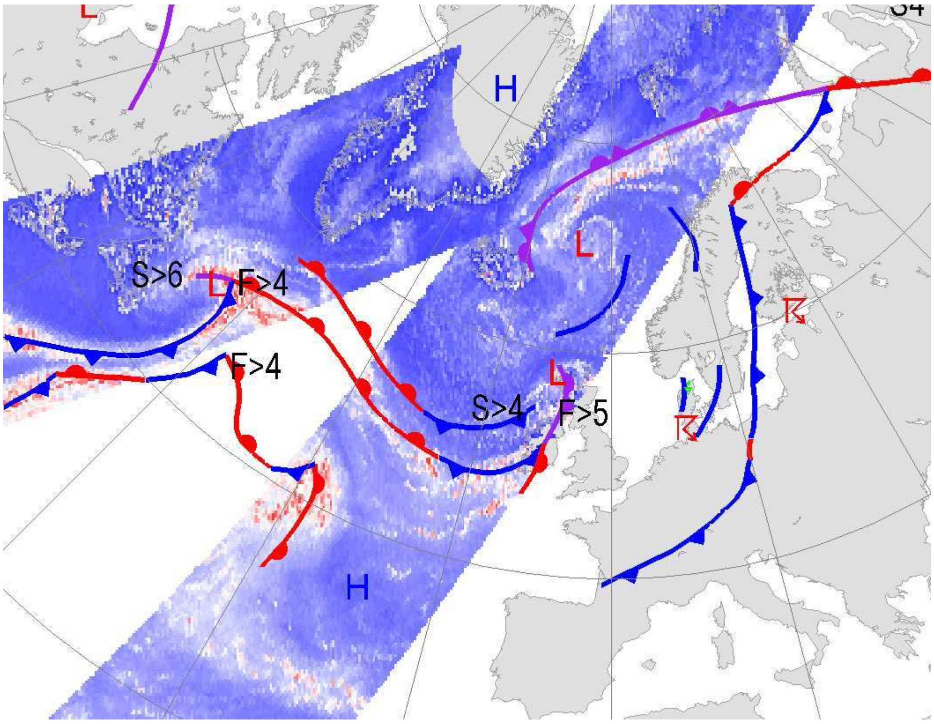

SSM/I R-factor imagery and forecaster's analysis valid 26 Sept 2005 18Z

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Abstract

The Norwegian Meteorological Institute has implemented visualization of the so-called R-factor cloud liquid water indicator using SSM/I imagery in its operational visualization system. The images have been monitored and investigated subjectively, as well as compared to corresponding weather prediction model output, AMSU-A cloud liquid water retrievals, radar imagery and forecasters' subjective analyses.

This validation shows these images to add useful information over ocean areas, and help identifying and locating fronts and other weather developments. The images seem to add little information on cloud water over sea ice.

It is recommended to make these images available to the operational forecasters after masking out land and sea ice, and educate forecasters on the use of them.

Keywords

Nowcasting, remote sensing, SSM/I

Disiplinary signature	**Responsible signature**

Contents

1 Introduction

One of the main goals of the IOMASA project is to improve Arctic weather forecasting. There are workpackages in the project to develop data assimilation methods for Arctic remote sensing data to improve numerical forecasts in the Arctic. In this report we describe another type of product, the so-called R-factor cloud imagery (Miao et al, 2000) which can be made available for duty forecasters for their subjective analysis and nowcasting.

Moisture, clouds and precipitation observations are not as well assimilated in present assimilation systems as one could wish. Clouds and precipitation are among the features usually used for identifying fronts by operational forecasters. This allows forecasters to identify areas of interesting weather and active weather developments as well as monitor the performance and accuracy of the numerical weather prediction (NWP) models.

The art of assimilating precipitation, cloud and moisture is still not a very mature science, for instance it is difficult to develop a satisfactory assimilation system giving feedback from cloud or precipitation field back to wind and mass fields. This would be an ideal situation which for instance could allow the assimilation scheme to move fronts in a consistent way. Because of these limitations there is still room for subjective analysis by weather forecasters using moisture and cloud information to add some value to the numerical forecast on short forecasting ranges, because these observations are still not be well exploited in NWP.

Visualization of R-factor imagery was implemented in the summer of 2005, and data from the months of August, September and beginning of October 2005 was used in the study. The imagery was stored routinely for several days after production, and continously inspected and validated subjectively. In the following sections we give some background on the product and assess its quality and usefulness by comparison with other data sources, such as NWP output, quantitative cloud liquid water products from AMSU-A and radar precipitation products.

2 Background on the R-factor

The background theory and motivation for introduction of the "R-factor" is described in Miao et al, 2000. The idea was to use polarization differences at the two high frequency channels of the Special Sensor Microwave Imager (SSM/I) to use this quantity to detect cloud signatures under certain conditions.

The algorithm for computing the R-factor is based on the following simple code:

```
R=alog((iv37-ih37)/(iv85-ih85))
; iv37 is brightness temperature 37 GHz V-pol
; ih37, iv85, ih85 analogous for H-pol and 85 GHz
; 37 and 85 GHz have to be on the same grid. For SSM/I we use 12.5 km spacing
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Theoretically the R-factor can be shown to be a sum of two terms, one representing the ground surface signal and the other representing the contibution of total cloud liquid water (TCLW) and the atmospheric water vapor. It his here assumed that the TCLW term is the dominant contribution over open ocean.

The R-factor is not intended for use as an indicator for cloud water over land or high sea ice concentrations. It is however suggested as useful over low sea ice concentrations, such as in the Weddell Sea under Antarctic summer conditions. In the first implementation of the visualization of the R-factor at met.no, we have chosen not to screen out any areas over land or sea ice.

A quality check to screen out values where the R-factor is unreliable as an indicator of cloud liquid water was also implemented following a suggestion from Kaleschke and Heygster (Univ. Bremen, pers. comm.).

SSM/I observations are received operationally at met.no, at present with a delay of 2-4 hours from observation. The system was set up to produce imagery once an hour for this validation study. There are possibilities for shortening the time before reception and to perform processing more frequently, which could be considered on a later stage for operational purposes.

3 Validation, possible operational usage

3.1 Visualization system, the forecaster's workstation

Most weather forecasting centres use a visualization tool for analyzing the weather situation. Met.no has its own in-house developed tool called DIANA ("Digital Analyse"). This is a system which can show maps of any field which are stored as output from the available numerical weather predicion models. There is also possibility of showing all types of meteorological observations, satellite images and other products. DIANA is also used for drawing the duty forecasters' analyses, indicating fronts and other analyzed weather elements. An important task of the duty forecasters is to draw such an "analysis" to get a conceptual picture of the weather situation. It is up to each forecaster to select which of the available products he would like to visualize as part of his analysis.

Implementation of the possibility of showing R-factor imagery in DIANA thus gives us possibility to compare this imagery with numerical weather prediction (NWP) products as well as with other satellite data and radar data. In the next section we present some intercomparisons with other data sources as well as examples of how the duty forecasters could use the R-factor imagery.

3.2 Examples on comparisions with other data sources

In Fig. 1 we present radar precipitation imagery from the Norwegian weather radar network. We find several of the precipitation areas seen in the radars outside the coast of Norway also as signatures in the R-factor imagery, so this validates some of the signatures seen in the R-factor imagery.

We see that the radar has better resolution in the products. However, it is also clearly illustrated here that the radar coverage is limited in space to a distance out from the coast, and that we get a highly interesting added coverage with the R-factor imagery.

In Fig. 2 we present AMSU-A (Advanced Microwave Sounding Unit) imagery as well as R-factor imagery presented togeter with NWP pressure and total cloud liquid water (TCLW) model output from HIRLAM (High-Resolution Limited Area Model). We see that there is good match between all three cloud liquid water products in shapes and intensities.

Several other examples with both AMSU-A TCLW imagery and HIRLAM TCLW forecast fields throughout the investigation period have been studied, and in general the R-factor seem a reliable indicator of column cloud liquid over ocean.

We see that the SSM/I R-factor products clearly add details by having better spatial resolution than the AMSU-A TCLW product. It also adds coverage, having wider swaths. It is generally seen in the investigation period that the number of DMSP satellites and swath width gives more coverage than AMSU-A, and it complements the AMSU data coverage in a nice way.

The only drawback of the SSM/I products relative to the AMSU is that the AMSU-A algorithm is calibrated and gives the TCLW quantitatively (colorscale for interpretation of the AMSU-A TCLW in terms of values in mass water per area is available, but not presented on the figure). This allows us to compare the AMSU products quantitatively with the HIRLAM TCLW values. This is not possible with the R-factor product. As will be seen below, however, this is not a crucial point in the use of such a product by duty forecasters.

In Fig. 3 we present a case of R-factor imagery together with a forecaster's analysis and a short-range total cloud liquid water (TCLW) forecast from HIRLAM. There is a low pressure system west of Spitzbergen with some corresponding precipitation as well as a front indicated in the analysis. We also present the corresponding Ocean and Sea Ice Satellite Application Facility (OSISAF) sea ice edge product. We find no indication on the R-factor imagery of neither the front indicated by the forecaster nor the cloud water indicated by HIRLAM over the closed sea ice. We do however see a signal from the surface sea ice, which matches that of the OSISAF sea ice edge product. Throughout the investigation period it was difficult to identify any cloud signatures in the R-factor over the Arctic sea ice. The signatures we found was more stable in time than typical weather systems, indicating that the surface was responsible for the signatures.

The R-factor imagery was intended for use in areas of low sea ice concentrations only. However the region of low concentration is usually, like in the case presented here, small with relatively narrow zones where the concentration increases from 0 to 100 %. Over the large and observation data sparse areas over the closed ice, where cloud signature information would have been useful, most of the signal in the R-factor seems to be related to surface effects and not to cloud water, so we should probably mask out these areas from the product.

3.3 Example on use in synoptic analysis

In Fig. 4 we present a weather situation where the forecaster's analysis closely matches a short-range forecast output from HIRLAM. There is a low pressure system east of Iceland, and probably few observations in the area to help the forecaster locate any front. We see that it follows closely the position which would be depicted by for instance the precipitation output from the model. If we look at the R-factor imagery (lower panel), we see clearly, however, that the occluded front is misplaced and should be further back. Looking at R-factor imagery from earlier the same day, we also found a consistent misplacement of the occluded front in earlier analyses.

The secondary fronts depicted by the forecasters are also of different shape and position than indicated, if one looks for lines of high cloud water in the R-factor imagery.

This is just one of many similar examples which was seen during the period of the availability of this product. Several could have been presented, and the impression is that this imagery can be a useful tool in locating fronts. We have also seen examples showing waves on fronts indicating new low pressure system developments in the R-factor imagery, where these waves have not been found in the forecaster's analysis. Such waves often occur in areas in the Northeast Atlantic with sparse conventional observation coverage. Availability and use of these data by forecasters in these ocean regions would therefore have significant potential usefulness.

4 Conclusions

The R-factor cloud water imagery complements other data sources such as radar imagery and AMSU-A TCLW imagery well. It adds information over ocean areas where the only other major observational source of total column liquid water data is AMSU-A imagery. It has, however, higher resolution than AMSU-A, giving more details in fronts and weather systems. On the other hand it it not a quantitative measure, but this is not crucial for the use by operational forecasters. It can be an important tool in identifying low pressure developments over open ocean areas and for identifying misplaced fronts in the numerical weather prediction model products.

If the subjective analysis performed by operational weather forecasters should have any role and add something to numerical forecasts, one way of doing that is to identify errors, weather system displacements or deficiencies in the numerical forecasts. R-factor imagery is clearly a tool which can help with this. There is still no mature method for assimilation of such imagery, so in this respect this is the only way the information contained in the R-factor product can be well used.

The use of the R-factor is, however, of little help over large areas of closed sea ice in the Arctic ocean. The areas in the marginal ice zone with sufficiently small ice concentrations to enable use of the product, are generally too small to be of any significance.

Given the quality, resolution and usefulness of the R-factor imagery, it is recommended to exploit the possibility of making the SSM/I data available more timely, and to make these images available for the operational forecasters. Land and sea ice should be masked out and duty forecasters should be educated on the use of these images.

Acknowledgements

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List of Figures

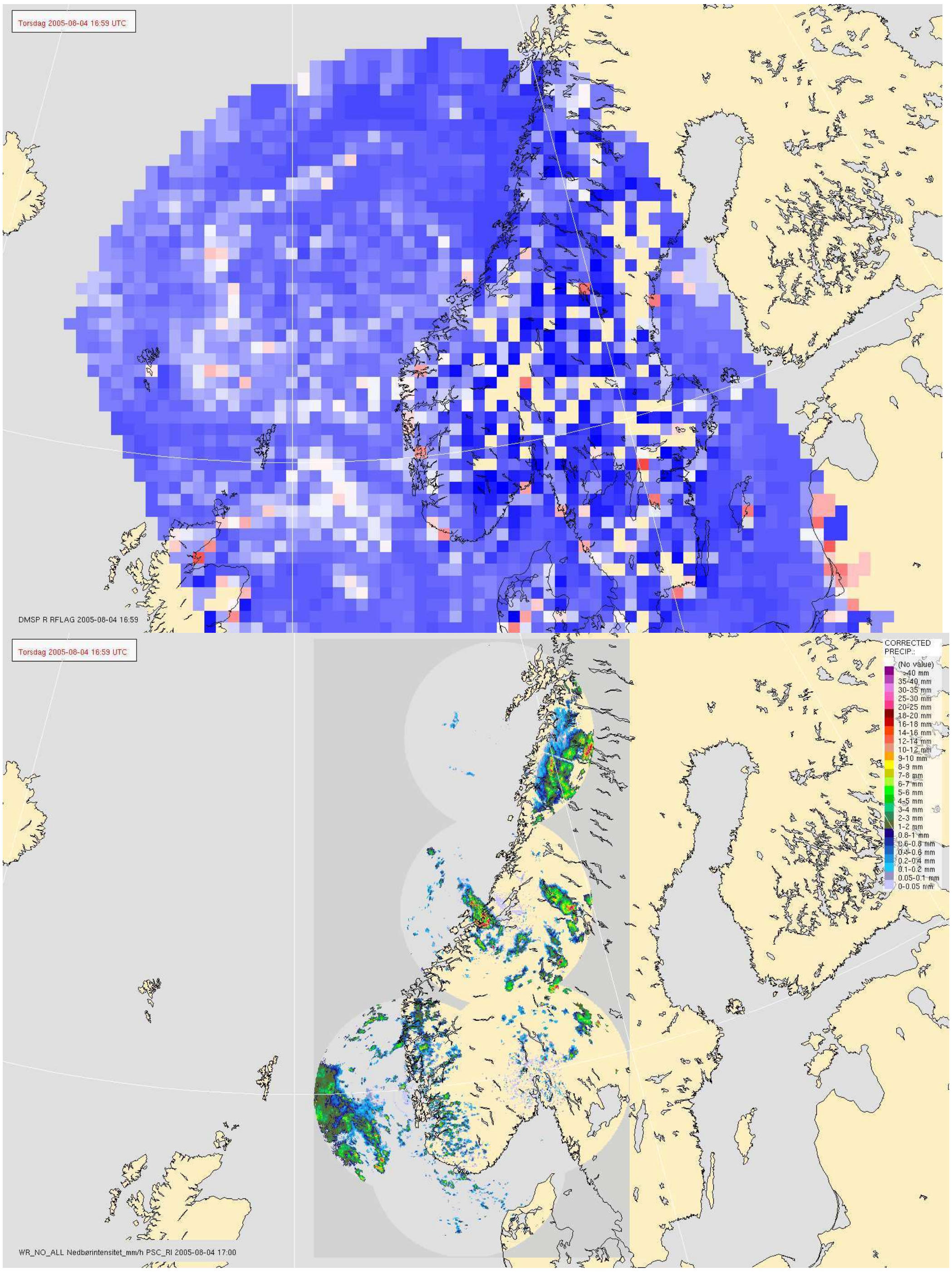

Figure 1: Weather situation on 4 August 2005 17Z. Upper panel: R-factor imagery. Lower panel: Radar precipitation imagery.

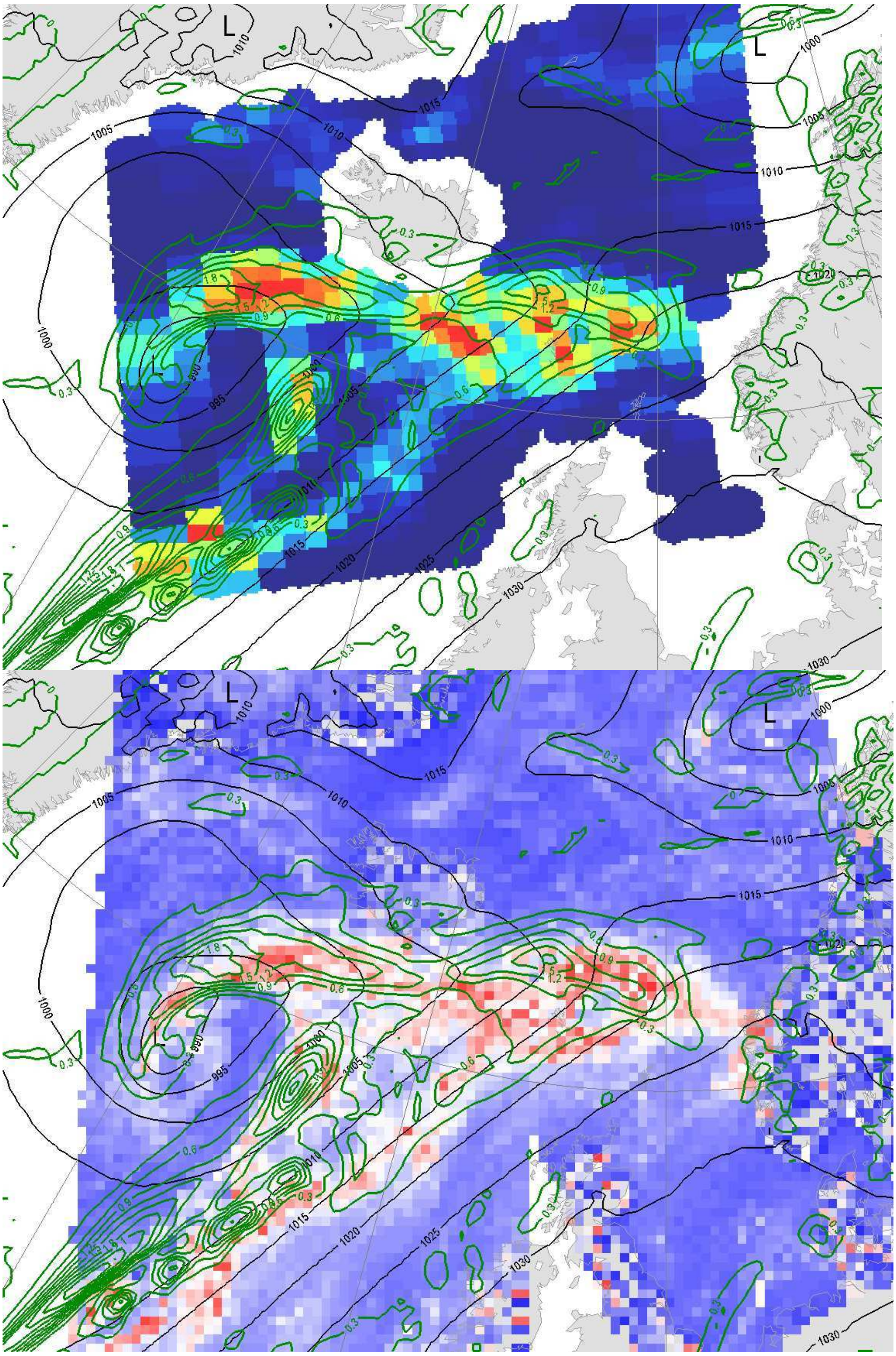

Figure 2: Weather situation on 3 October 18Z. Upper panel: AMSU-A TCLW imagery with overlaid HIRLAM pressure analysis analysis and a short-range TCLW forecast. Lower panel: As above, but with R-factor imagery instead of AMSU-A TCLW imagery.

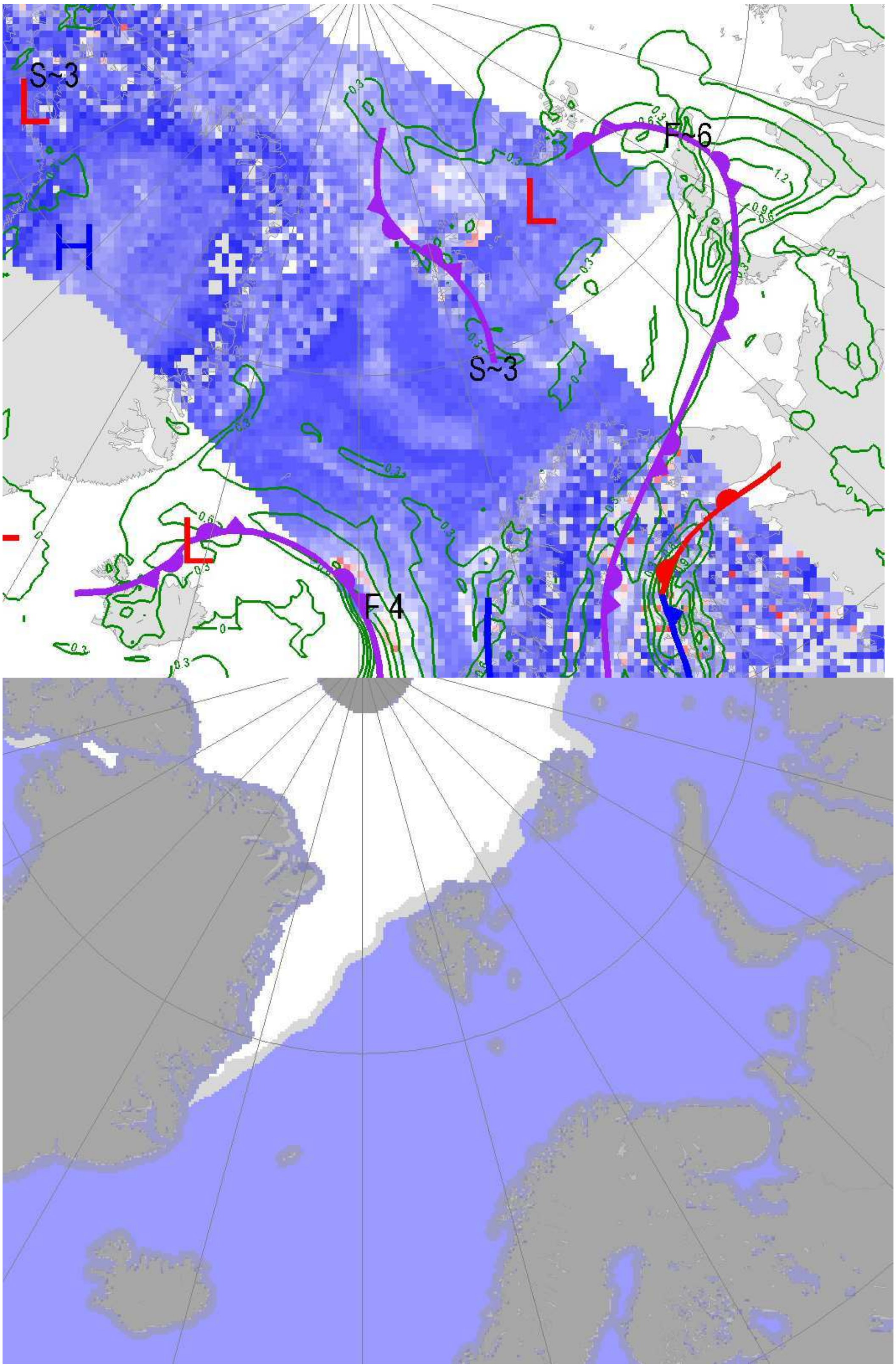

Figure 3: Weather situation on 2 October 2005 15Z. Upper panel: R-factor with a 3hrs forecast of total column liquid water from HIRLAM as well as forecaster's subjective analysis. Lower panel: Sea ice edge product from the Ocean and Sea ice SAF

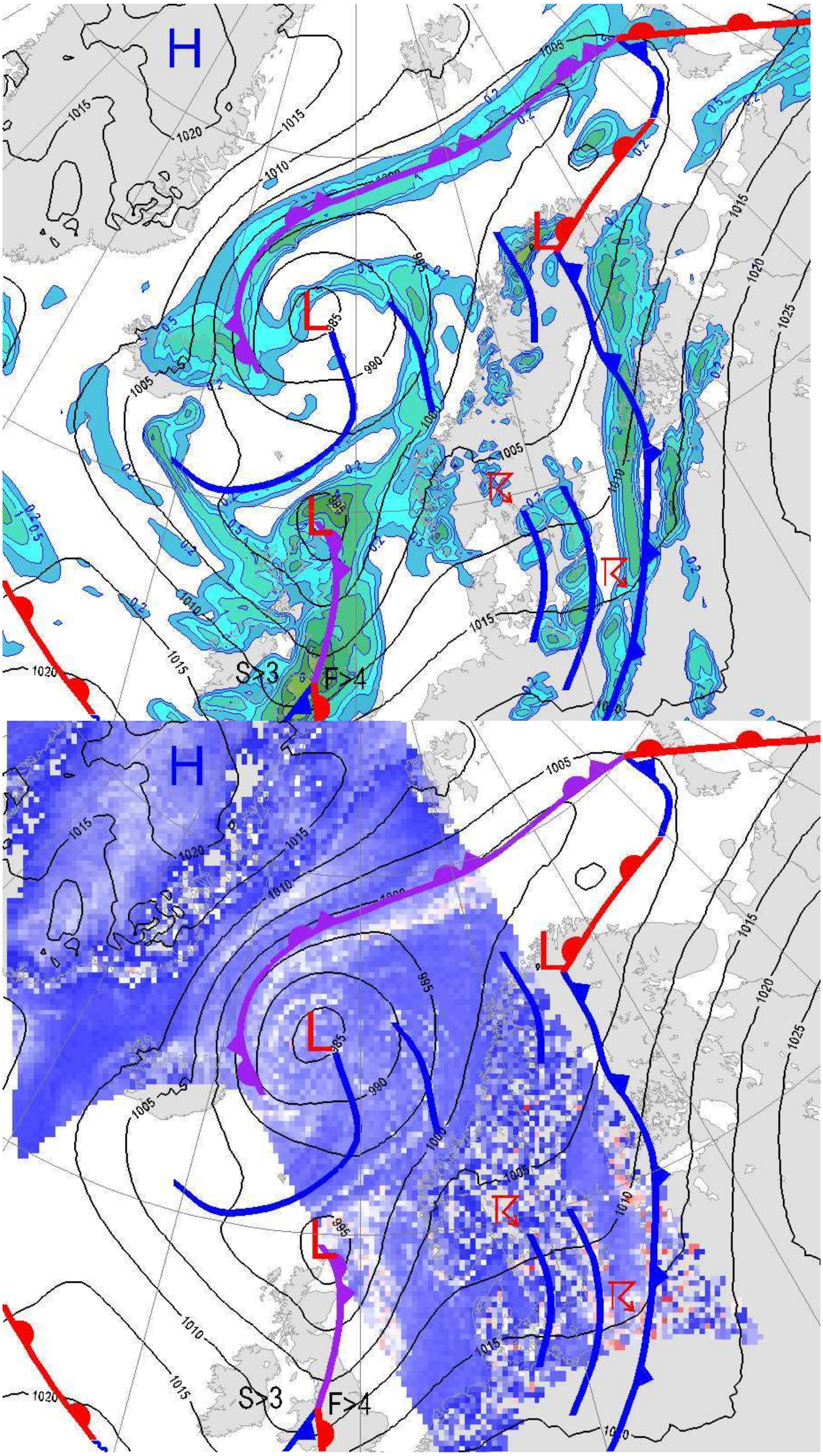

Figure 4: Weather situation on 28 September 18Z. Upper panel: HIRLAM pressure analysis, forecaster's analysis and a short range precipitation forecast. Lower panel: As above, but with R-factor imagery instead of precipitation forecast.