

Verification of different precipitation forecasts during extended winter-season in Estonia

Aarne Männik and Merike Merilain
Estonian Meteorological and Hydrological Institute
Tallinn, Estonia

1 Introduction

Estonian Meteorological Hydrological Institute (EMHI) is the national weather service with all its duties in operational weather monitoring and forecasting. Estonia has recently joined the European Centre for Medium Range Forecasting (ECMWF) and HIRLAM (High Resolution Limited Area Model) Consortium and is developing its NWP capabilities and introduces them to operational activities. Therefore the interest of actual model performance and quality in applications over Estonian area is understandable and growing. Unfortunately EMHI has no system for duty forecaster quality assessment yet and current study is one step towards creating one. Obtaining first quantitative measures is important for further planning and development. The aim of the study was to get such a measure for wintertime precipitation and compare all available forecasting tools. Such an information can have significant economical impact by helping to plan the road maintenance work in winter.

An extended winter period from November 2006 to March 2007 was chosen to accumulate the forecasts and observations and perform the analysis. Concentrating on winter period was necessary to be able to assess precipitation phase - rain, snow and sleet forecasts. Using statistics from the whole year would decrease the importance of correct phase prediction as snow and sleet are extremely rare during other part of the year.

2 Models and methods

EMHI's main operational model is currently ECMWF deterministic operational model. IFS Cycle 31r1 was operational since September 2006 at ECMWF. This is global model with approximately 25 km horizontal resolution and 91 vertical layers. The model output is provided by ECMWF twice a day with start-times at 00 and 12 GMT. To specify the precipitation phase following simple scheme was used. If the amount of snow was non-zero and total precipitation minus amount of snow was larger than $\varepsilon = 0.05 \text{ mm (12 h)}^{-1}$, the phase was determined as sleet. This essentially means that if any rain was present in model output during 12 hour period the precipitation phase was identified as sleet.

At the same time EMHI develops its own limited area NWP environment. The environment is based on the NWP model of HIRLAM Consortium and also on its nonhydrostatic (NH) extension, developed at University of Tartu (Rõõm et al 2007a, 2007b, Männik et al 2003). Acronym NHHIRLAM is used to denote this development while it must be said that this is not the official high resolution NH model of HIRLAM Consortium. The NWP model, which is employed in the environment, is HIRLAM version 6.4.0 with minor modifications.

Unfortunately, HIRLAM 6.4.0 and subsequently NHHIRLAM support only rain and snow precipitation phases which are mutually exclusive. This did not allow the application of simple diagnostic scheme similar to the case of ECMWF output and as no clear idea of implementation was around the HIRLAM output was used as it was. This definitely affected the skill scores of the model, but was not a critical limitation when the model was

used as guidance. Results of the study, however, hint how a diagnostic scheme might be implemented.

The integration domains of HIRLAM-based NWP system are presented in Figure 1. Modelling area code-

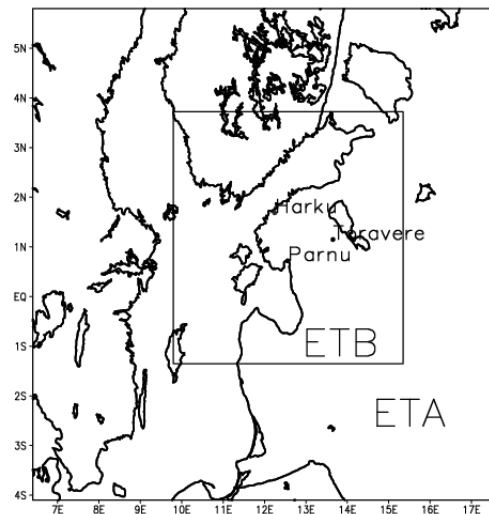


Figure 1: HIRLAM modelling domains and observation sites. .

named ETA is based on hydrostatic model with 11 km horizontal resolution and 40 vertical layers. The ETB area has 3.3 km horizontal resolution and applies NH model with 40 layers as well. Boundary fields to ETA are provided from Finnish Meteorological Institute operational model four times a day. The time frequency of boundary fields for ETA is 3h. The time frequency of boundary fields for ETB area is 3h as well. Four times a day 54h forecasts are produced in ETA area. Starting times for forecast and analysis cycles are 00, 06, 12 and 18 GMT. The ETB area uses forecasts of ETA area as lateral boundaries. 36h forecasts are produced twice per day with start at 00 and 12 GMT. To maintain analysis cycle 6h forecasts are produced at 06 and 18 GMT. The run-system described here was started in December 2006. As the ETA forecasts were shorter earlier this has affected also the comparison sample sizes. It must be noted that while ETA model is aiming for operational quality, ETB is kept purely for future development purposes.

EMHI does not use numeric values when issuing precipitation forecast. Instead of that only phase and categorised intensity are given. The forecast is given according specified points for the whole county. Table 1 shows ranges for precipitation amount categories which EMHI uses in operations.

Table 1: Precipitation range classes.

Precipitation type	Weak (mm/12 hr)	Moderate (mm/12 hr)	Heavy (mm/12 hr)
Rain	$0.1 \leq x < 4$	$4 \leq x < 15$	$x \geq 15$
Sleet	$0.1 \leq x < 3$	$3 \leq x < 7$	$x \geq 7$
Snow	$0.1 \leq x < 3$	$3 \leq x < 7$	$x \geq 7$

The comparison is based on forecasts of HIRLAM, NHHIRLAM and ECMWF model output with 00 GMT start-up time. Duty forecaster prognosis is the prognosis given to the national television for the night time (18 to 06 GMT) and the next day (06 to 18 GMT) at 14:00 by local time using model output as guidance.

Three stations Harku, Pärnu and Tõravere were selected as main observation and comparison points. Stations of Harku and Pärnu are quite close to coastal zone while Tõravere is inland station (see Figure 1). The rain-gauge 12h precipitation collected at 06 and 18 GMT were used as basis for comparison. Precipitation phase was taken from observation diaries and if more than one phase was observed, the coldest category was used. Accordingly

12h accumulated precipitation forecasts were used from models output.

3 Results

To analyse the results, contingency tables for every station and daytime were created to see if remarkable temporal and spatial variations exist in the forecasting quality. After that summary contingency tables were created for each forecast producer. These contingency tables are presented in the form of observation hit-miss frequency diagrams. Figures 2 and 3 present hits and misses from used operational models and duty forecasters, where data from all observation points and both day time forecasts were summed up.

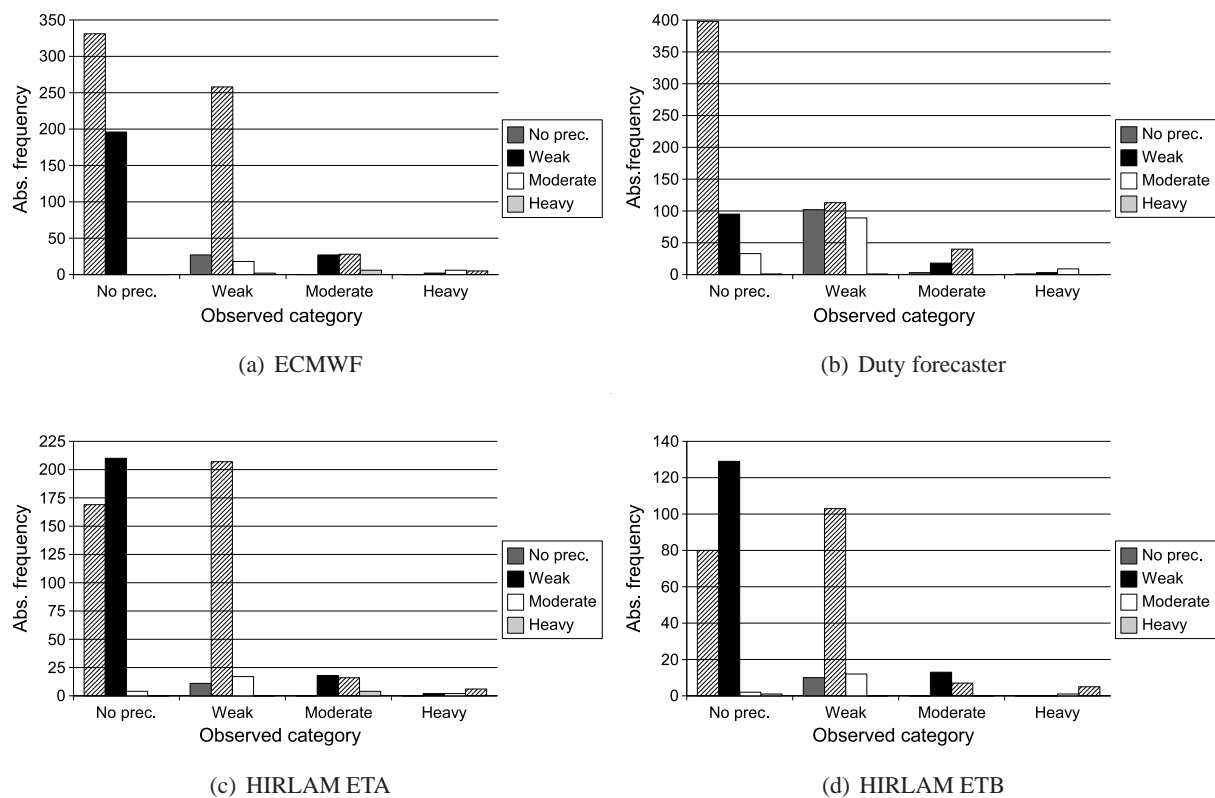


Figure 2: Precipitation intensity hits and misses for different forecasts: (a) ECMWF operational model, (b) duty forecaster, (c) hydrostatic HIRLAM ETA area and (d) nonhydrostatic HIRLAM ETB area. The bars are hatched when prediction coincides with observation. When the category was misforecasted gray-scale colorbars show what was predicted instead.

To compare the results from different forecast producers proportion correct (PC) and Hanssen-Kuipers skill scores (KSS) were computed among many others. Figure 4 present and PC and KSS of all models and duty forecasters in different stations and for different forecast time.

One of the most important demands to operational forecasting is the ability to forecast heavy precipitation. Therefore we try to show additional scores to just hit/miss diagrams for heavy precipitation. Table 2 shows probability of detection (POD), false alarm ratio (FAR) and equitable threat score (ETS) of heavy intensity events of all forecast producers. The worst performer here is duty forecaster who issued only two heavy precipitation forecasts which were wrong. The best result is given by high resolution NHHIRLAM capturing 5 events out of 6. It is important to note that the number of the events in the sample is different. ETS should present the scores when hit by chance is removed which however does not change the results much.

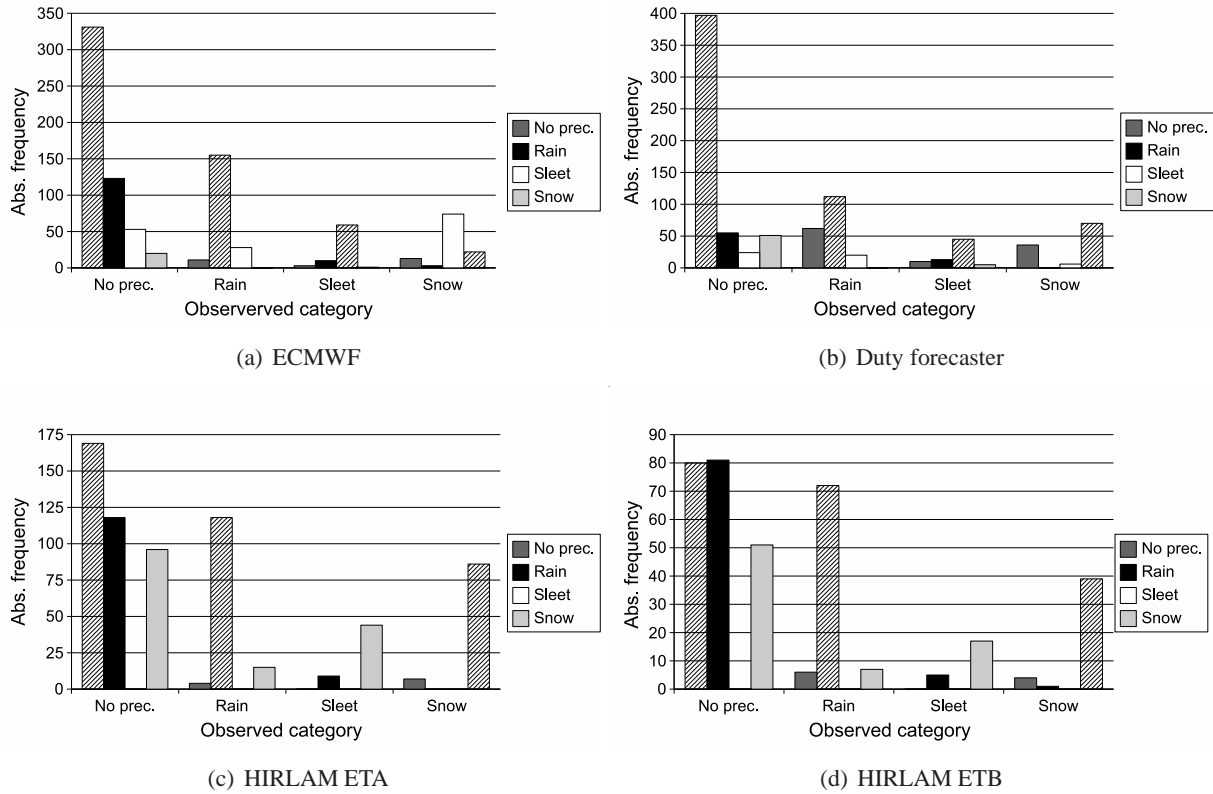


Figure 3: Precipitation phase hits and misses for different forecasts: (a) ECMWF operational model, (b) duty forecaster, (c) hydrostatic HIRLAM ETA area and (d) nonhydrostatic HIRLAM ETB area. The bars are hatched when prediction coincides with observation. When the category was misforecasted gray-scale colorbars show what was predicted instead.

4 Conclusions

The results of the study are fresh and preliminary. The idea of the study was to obtain first insights to the problem of precipitation forecasting verification in EMHI. Based on current analysis following conclusions can be drawn. Percentage of correct forecasts for precipitation intensity and phase is approximately 69 %. Duty forecasters add value to precipitation phase forecast and also can reduce number of predicting weak precipitation when there is none. According to KSS numbers all models outperform duty forecasters when precipitation intensity is evaluated which is not the case when PC score is used. Then only ECMWF is showing better scores over duty forecasters. Models do not have specialised built in framework to distinguish sleet from snow and rain, but it seems that application of a relatively simple diagnostic schemes to NWP output might improve the quality of forecasting separate precipitation phases. HIRLAM heavily over-predicts weak intensity instead of no precipitation events while heavy precipitation events are captured very well. High resolution model NHHIRLAM suffers from the same problems as lower resolution HIRLAM and even in greater extent. Duty forecasters under-predict weak precipitation ranges preferring to use moderate or no precipitation categories. In addition they tend to neglect heavy precipitation ranges.

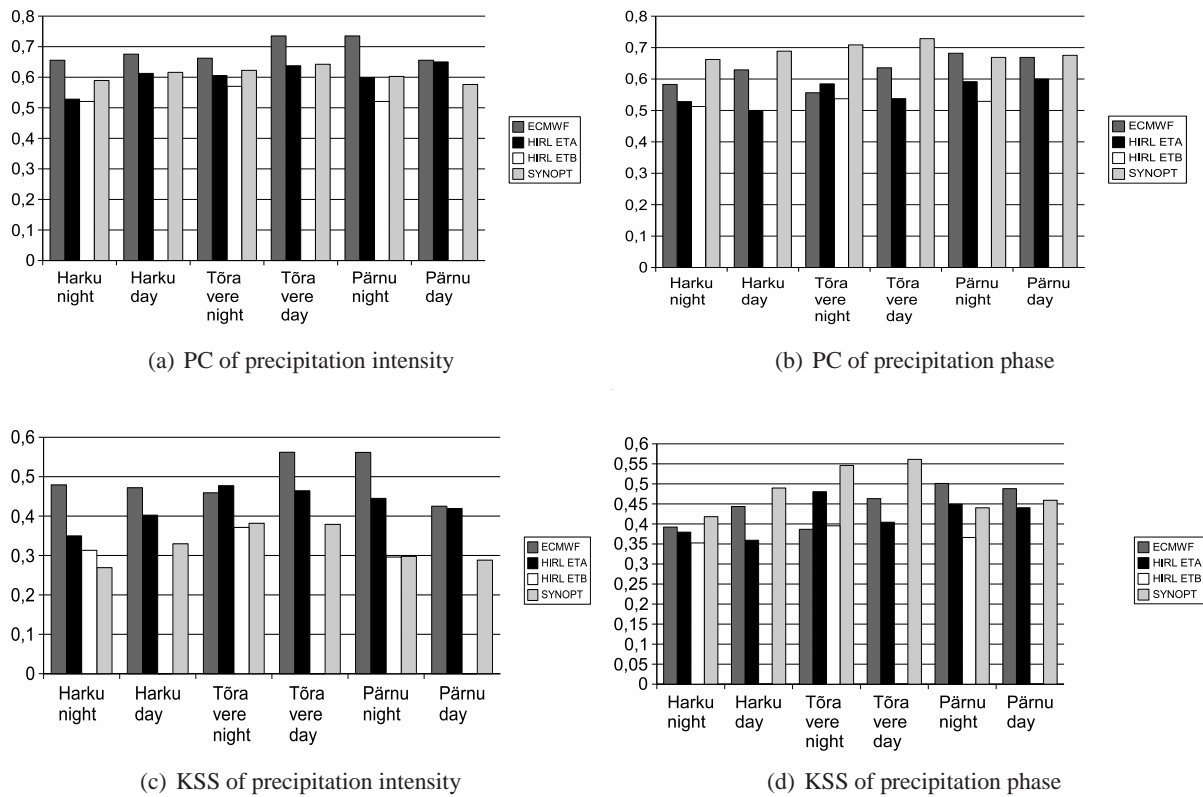


Figure 4: PC and KSS scores for precipitation intensity and phase in three observing stations for day and night forecasts. The gray-scale colorbars show scores of different forecast issuer at specified observing station according to the legend.

Table 2: Skill scores of heavy precipitation of models and duty forecasters.

Forecasts by	POD	FAR	ETS	Number of events
ECMWF	0.38	0.72	0.23	13
Duty forecaster	0.0	1.0	0.0	13
HIRLAM ETA	0.6	0.4	0.42	10
HIRLAM ETB	0.83	0.17	0.71	6

5 References

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