

# Performance of Kain-Fritsch convection and Rasch-Kristjansson condensation scheme in Hirlam

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## Abstract

The performance of the Kain-Fritsch convection and Rasch-Kristjansson condensation scheme (KF+RaK) is compared with the STRACO scheme using various parallel runs covering different seasons. KF+ RaK clearly improves the humidity forecast. The cloud cover is only improved slightly due to a systematic negative bias. The scores of mean sea level pressure and geopotential height are deteriorated. The precipitation verification seems to slightly favour STRACO in contradiction with subjective verification. The results suggest a need of tuning of the new moist physics package and of other model components to adjust to the new scheme. The KF+ RaK needs to be optimised for vector computers.

## 1 Introduction

The reference scheme in Hirlam for moist processes is known as STRACO (Sass, 1997). In this work we are using a revised version of STRACO described in Sass and Yang (2002). Currently, we are looking for a new scheme more suitable for resolutions below 20 km. The Kain-Fritsch (KF) convective scheme (Kain and Fritsch, 1990) has been proved as suitable parameterization for mesoscale simulations and it is becoming very popular among high resolution modellers. We are testing KF with the Rasch-Kristjansson (RaK) large scale condensation, originally a Sundqvist scheme (Sundqvist *et al.*, 1989), revised and recoded by Rasch and Kristjansson (1990) for the CCM3 climatic model.

## 2 Model set up and test periods

For details of the model configuration see table 1. The model was very stable with both moist physics parameterizations. The results were compared against observations using the Hirlam verification package.

The integrations were performed at the ECMWF vpp700 computer by Sander Tijm (KNMI 1/2), Viel Odegard (DNMI 1/2), Jose A. Garcia-Moya (INM 1/2) and Javier Calvo (INM 3) using

Table 1: **Model configuration**

<b>Model version:</b>	Hirlam 5.1.4
<b>Horizontal resolution:</b>	0.20 x 0.20 degrees
<b>Vertical levels:</b>	40
<b>Dynamics:</b>	Semi Lagrangian
<b>Time step:</b>	6 minutes
<b>Orography:</b>	Smoothed (Raymond filter)
<b>Analysis cycle:</b>	OI every 6 hours
<b>Initialization:</b>	Digital Filters
<b>Forecast length:</b>	48 hours

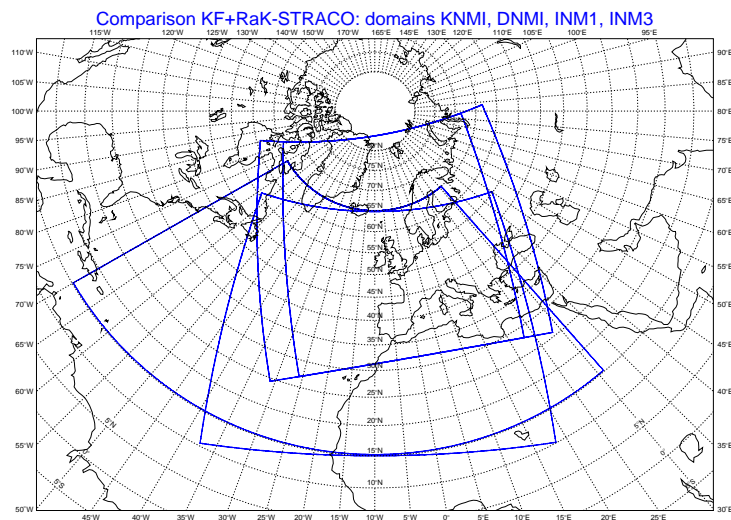


Figure 1: *Integration areas at 20 km horizontal resolution*

the areas depicted on figure 1. Four 48 hour forecast were run every day except for period INM 3 for which we only computed the 00 UTC forecast. This means that this period has less weight on the verification. The periods (table 2) tried to sample different rainy weather systems over different seasons. The Root Mean Square Error (RMSE) and Bias computed using data from all this periods can be shown on figures 2 and 4.

### 3 Results

#### *Relative humidity, cloud cover and temperature*

There is a significant reduction of the Root Mean Square Error (RMSE) of relative humidity

Table 2: **Test periods**

<b>DNMI 1</b>	1999-12-23 / 01-07
<b>DNMI 2</b>	1999-08-28 / 09-12
<b>KNMI 1</b>	2002-01-28 / 02-14
<b>KNMI 2</b>	2001-08-01 / 08-15
<b>INM 1</b>	1994-10-01 / 10-15
<b>INM 2</b>	1995-05-01 / 05-15
<b>INM 3</b>	1994-09-10 / 10-09

using KF+RaK which as STRACO shows a moist bias but of smaller magnitude. As a result, the RMSE of cloud cover is slightly lower in KF+RaK. We think it could be much lower if the systematic underestimation of cloud cover in KF+RaK is improved. This negative bias in cloud cover is also present in all the individual experiments. For STRACO the cloud cover bias is close to zero. Visual inspection of the cloud cover fields reveals that in general STRACO and KF+RaK show similar shapes but the STRACO cloudiness is systematically larger. This is specially the case for high level clouds and probably too for convective clouds.

The RMSE of temperature are larger above 850 hPa for KF+RaK showing a positive bias at all levels. The slight improvement in the RMSE on 2 meter temperature is probably related with the smaller RMSE of cloud cover. Figure 3 shows a typical time evolution of cloud cover and screen temperature for station 07010 over period DNMI 2.

#### *Geopotential and Mean Sea Level Pressure*

KF+RaK shows larger RMSE of geopotential height than STRACO. Both have a negative bias except in fall (not shown). For the MSLP, there is a clear deterioration of the RMSE in all seasons except in autumn. The impact of a moist scheme on MSLP and geopotential is not easy to interpret and it is probably related with the coupling with other model components that were tuned to be used with the reference STRACO scheme.

#### *Wind*

The impact of the new scheme on wind is very small. Here it is worth to mention that non of the schemes include a momentum parameterization.

We have shown results using all the data and periods and we have seen that the behaviour of the schemes depends very much on the periods and seasons. The results favour STRACO in winter and KF+RaK in autumn.

## 4 Precipitation verification

Precipitation forecasts have been verified against synop stations. Despite the limitations of this type of approach for verification of mesoscale models we expect to get a flavour of the performance

of the moist parameterization schemes for precipitation forecast. Figure 5 shows RMSE and Bias for precipitation forecast accumulated over 6 and 12 hours. The RMSE is slightly lower for KF+RaK during the first 24 hours.

We have also computed skill scores from the contingency tables defined for thresholds 0.1, 0.3, 1, 3, 10, 30 and 100 mm/6 hr. Figure 5 shows hit rate, probability of detection, false alarm rate and frequency bias. See Wilks (1995) for explanation of the scores. Somewhat more meaningful are the equitable threat score (Gheli and Lalaurette, 2000) and the true skill statistic or Hanssen-Kuipers discriminant (Wilks, 1995) shown on figure 6. All the scores except the bias are plotted to mean better results toward the top of the plot. The Hirlam multi-category contingency tables have been reduced to YESxNO tables for each category in order to compute this scores (see table 3). STRACO shows slightly better scores for categories 40 and 120 mm/24hr in contradiction with subjective evaluation. Many authors suggest that this verification penalise schemes which resolve smaller scale features. Tijm (2002) shows that the STRACO version that is used here sometimes overpredicts convective precipitation considerably. This overprediction can lead to monthly accumulated precipitation sums that are 50 to 100% too high over flat areas like the Netherlands. A remedy for this problem is proposed also in Tijm (2000).

	<b>o1</b>	<b>o2</b>	<b>o3</b>	<b>o4</b>
<b>f1</b>	d2	c2	d2	d2
<b>f2</b>	b2	a2	b2	b2
<b>f3</b>	d2	c2	d2	d2
<b>f4</b>	d2	c2	d2	d2

Table 3: Computation of a 2x2 contingency table from the multi-category table. Example for category 2. *a*=hits, *b*=false alarm, *c*=miss, *d*=correct rejection. *x*=observations and *y*=forecasts

## 5 Computer cost

The cost of current KF+RaK code on vector computers is a matter of concern. On the vpp700 the forecast takes around 50-70 % more computer time than STRACO. On the other hand, on non vector computers the increase of the cost is reasonable: 10 % on IBM (Ray Mcgrath) and 10-15 % on SGI (Karl-Ivar). As a reference a re-coded version of the KF code (Bechtold, 2001) takes 20 % more computer time on a vpp700 than the Bougeault mass-flux scheme (E. Bazile, personal communication).

## 6 Conclusions and future work

The performance of the Kain-Fritsch convection and Rasch-Kristjansson large scale condensation scheme is compared with the STRACO scheme using various parallel runs covering different seasons. KF+RaK improves the humidity forecast. The cloud cover is only improved slightly due to a systematic negative bias. The results suggest that the cloud cover formulation has to be tuned. A deterioration in the MSLP and geopotential height forecast is shown from the parallel runs

pointing towards a need of tuning of the different components of the Hirlam model for the new moist physics parameterization. The precipitation verification against synop stations seems to slightly favour STRACO in contradiction with subjective verification.

The results vary significantly from one period to another, and specially from winter to autumn, suggesting the need of relatively long tests to assess the performance of a moist physics parameterization. The high cost of KF+RaK on vector computers makes the optimisation of the code a priority.

Currently, a revised cloud formulation has been coded (C. Jones, personal communication) and we intend to tune KF+RaK for resolutions below 20 km: the scheme was initially implemented in the Hirlam climatic model of the Rossby Center and it was only tuned for 50 km resolution. Some vector versions of the code are now available and we intend to test them in the near future.

## 7 References

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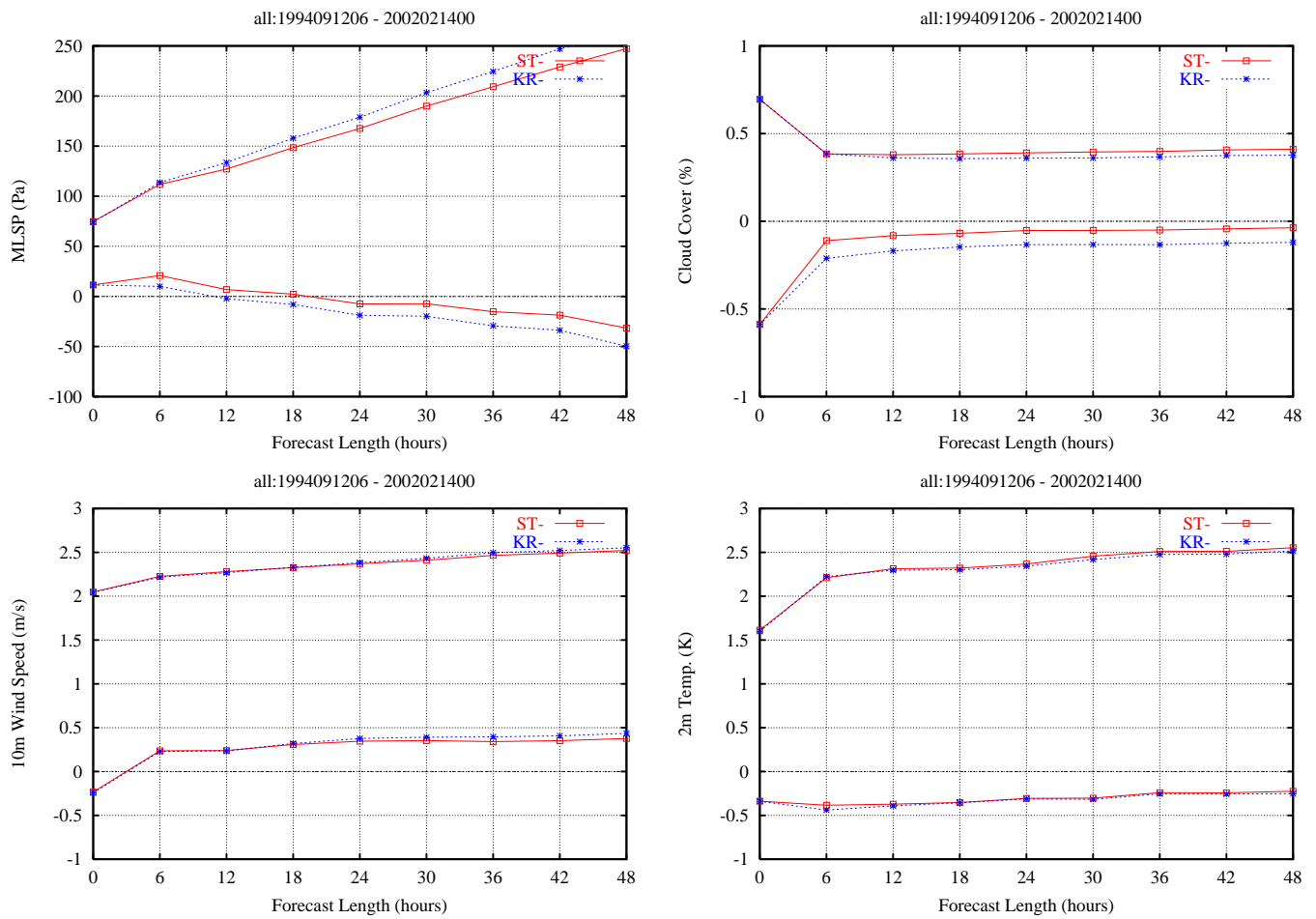
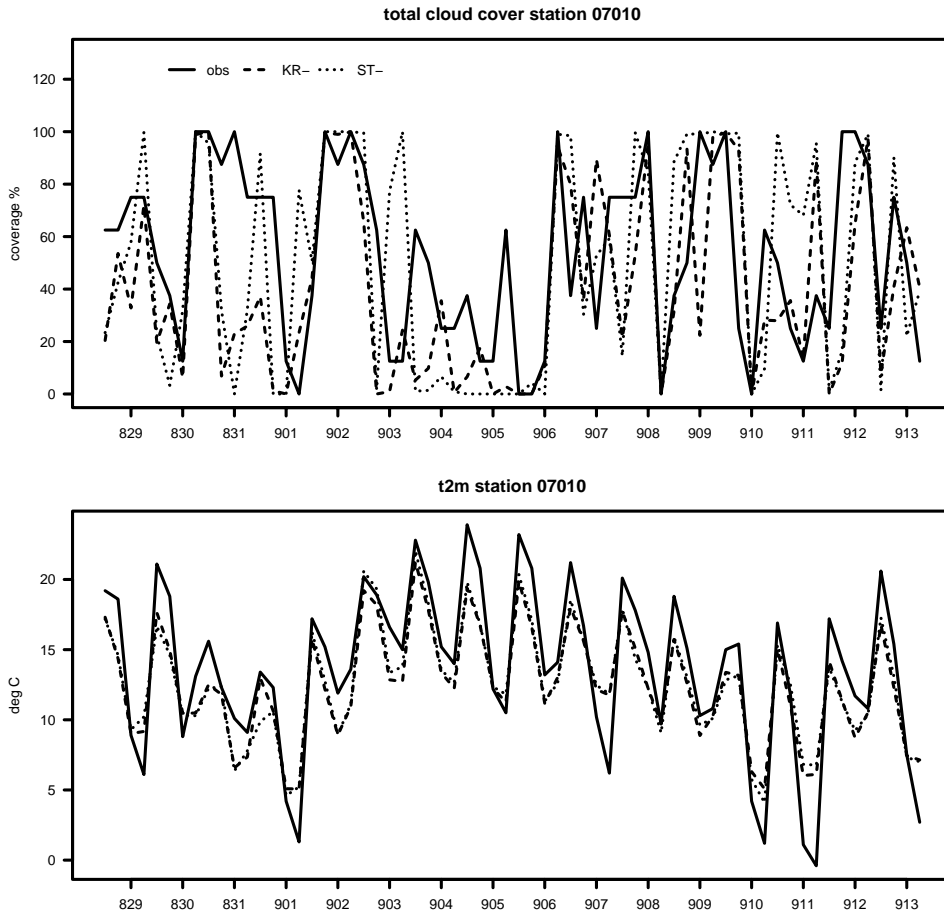


Figure 2: Objective verification against synop stations. Root Mean Square Error (RMSE) and Bias of (a) Mean Sea Level Pressure, (b) Cloud Cover, (c) 10 m wind speed, and (d) 2 m temperature. ST- means STRACO and KR- means KF+RaK



			bias	stde	rmse
ST-- synop	tcov	+12 +18 +24 +30	-3.8	41	41.2
ST-- synop	t2m	+12 +18 +24 +30	-1	2.6	2.8
KR-- synop	tcov	+12 +18 +24 +30	-13.4	33.6	36.2
KR-- synop	t2m	+12 +18 +24 +30	-1.1	2.6	2.8

Figure 3: Time evolution of total cloud cover (top) and 2 meter temperature(bottom) for station 07010 over the period 1999-08-28:09-12 showing the typical tendency of KF+RaK to underestimate the cloud cover but having less RMSE than STRACO

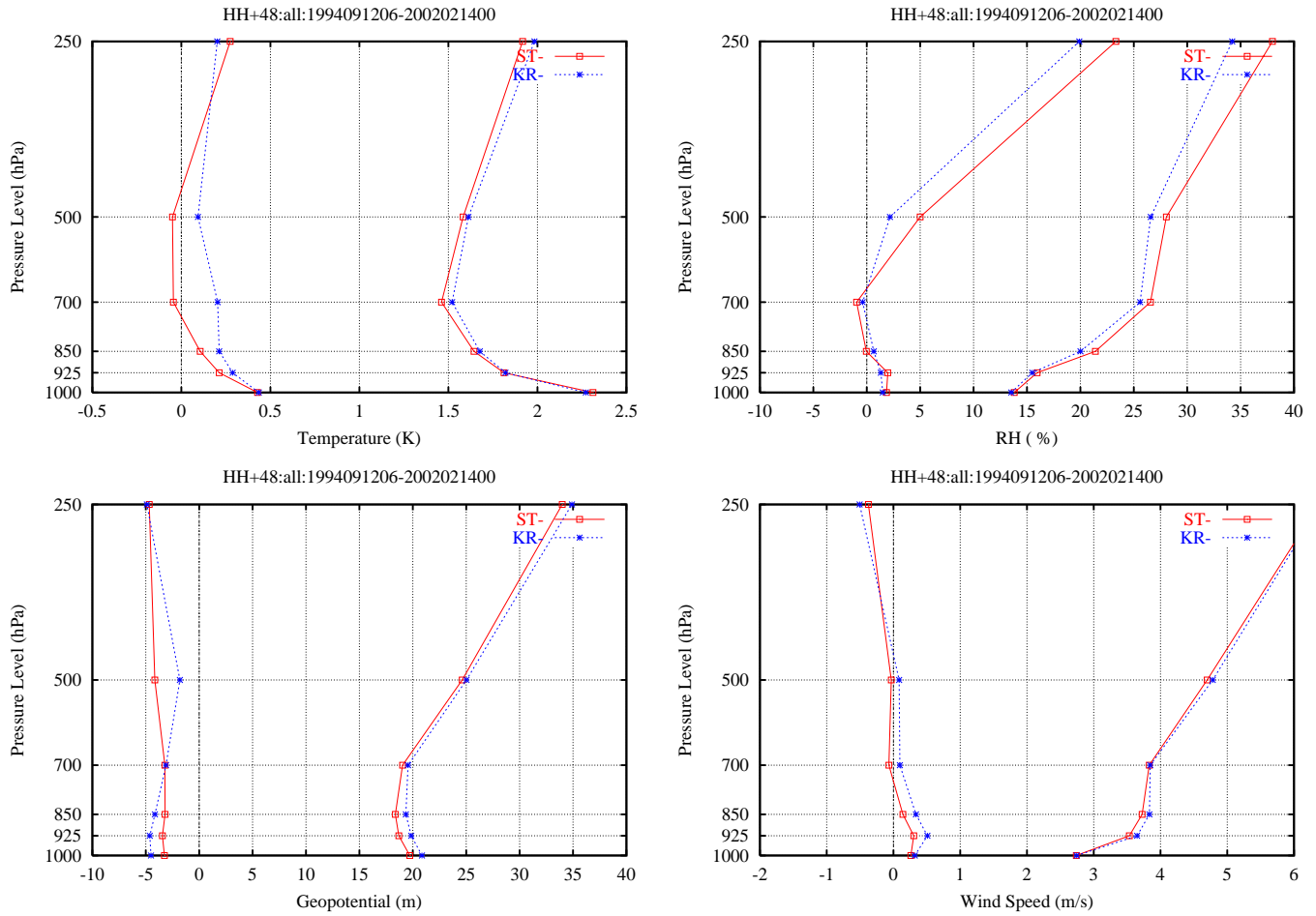


Figure 4: Objective verification of the H+48 forecast against soundings. RMSE and Bias of (a) temperature, (b) relative humidity, (c) geopotential height, and (d) wind speed. ST- means STRACO and KR- means KF+RaK

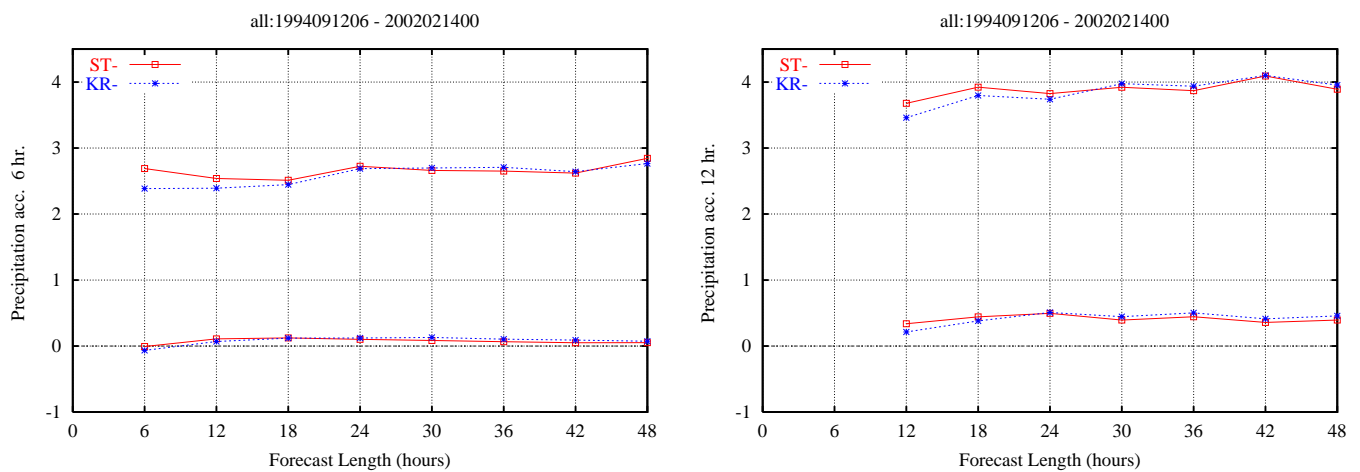


Figure 5: RMSE and Bias of the precipitation forecast accumulated over 6hr or 12 hr and verified against synops

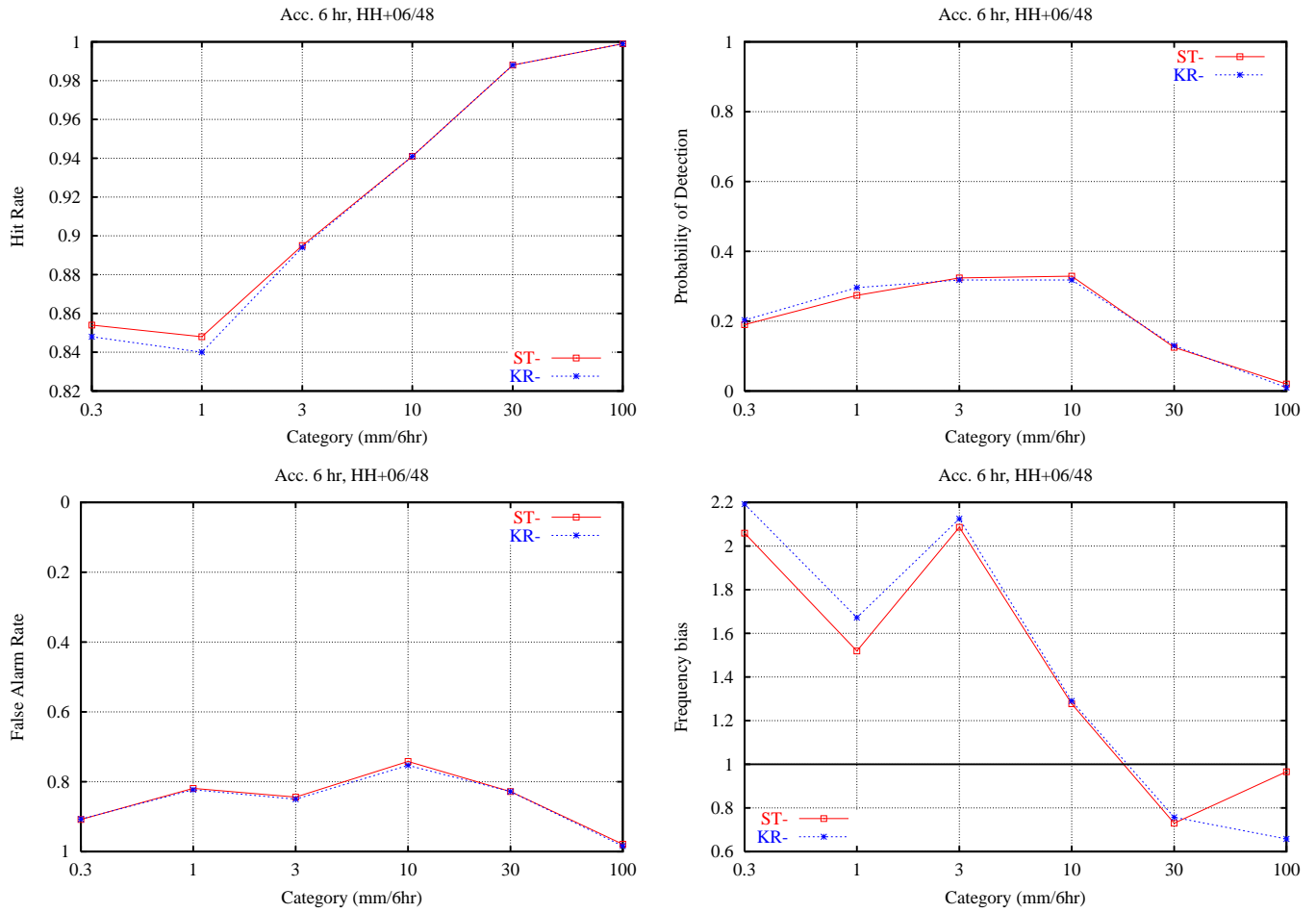


Figure 6: Scores of the precipitation forecast accumulated over 6 hours and verified against synop stations. (a) Hit rate, (b) Probability of detection, (c) False alarm rate, and (d) Frequency bias

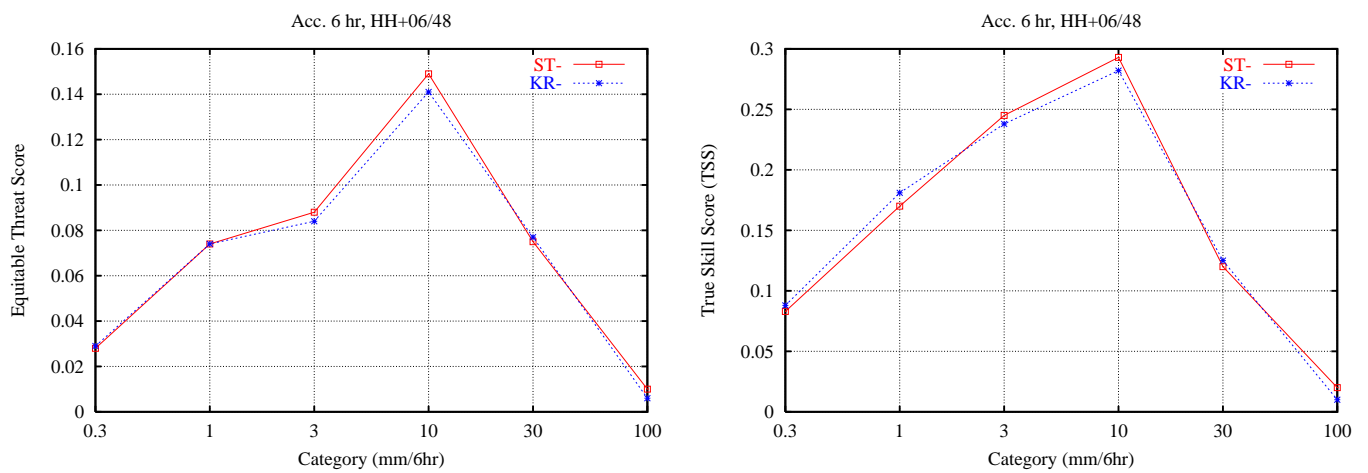


Figure 7: Equitable threat score and true skill statistic accumulated over 6 hours and verified against synop stations