# Progress on Kain-Fritsch/Rasch-Kristjansson

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## 1 Introduction

A new moist physics package has been under test in Hirlam for some time. The package is based on Kain and Fritsch (1990) convective scheme and Rasch and Kristjánsson (1998) parameterization for large scale cloud microphysics and precipitation. The cloud fraction parameterization is of diagnostic type. Large scale clouds depend on relative humidity following Slingo (1987), convective clouds are function of convective mass flux following Xu and Krueger (1991) and shallow clouds are described in Jones and Sánchez (2002). Recent progress on KF/RK is based on operational experience at SMHI and work within EURopean Cloud Systems Study (EUROCS) project. A special issue with the main EUROCS results will appear in the Q. J. R. Meteorol. Soc.

The aim of this communication is to compare the performance of the new moist physics package with the reference scheme known as STRACO (Sass, 1997). A major revision of this scheme (Sass and Yang, 2002)has been taken into account. We also intend to highlight the main differences between the schemes. Some effort has been made to assess the precipitation performance of the schemes.

## 2 Model set up and test periods

We use Hirlam version 6.2 which became the reference code in September 2003 (see table 1 for details of the set up). The integrations were performed over the area depicted in fig. 2 for 5 rainy weather periods in all seasons (see table 1).

Table 1: **Model configuration** **Test periods**

| | | | |
|---|---|---|---|
| **Model version:** | Hirlam 6.2 | 23 dec 1999-7 jan 2000 | 15 days |
| **Horizontal resolution:** | 0.20x0.20 | 1-15 may 1995 | 15 days |
| **Vertical levels:** | 40 | 1-15 aug 2001 | 15 days |
| **Dynamics:** | Semi Lagrangian | 15-30 sep 1994 | 15 days |
| **Time step:** | 6 minutes | 1-31 oct 2002 | 31 days |
| **Analysis cycle:** | 3Dvar every 6 hours | | |
| **Initialization:** | Digital Filters | | |
| **Forecast length:** | 24 hours | | |

## 3 Systematic differences

In trying to find systematic differences among the moist schemes we have computed averages and Root Mean Square Error (RMSE) of model output over all the periods. The most significant

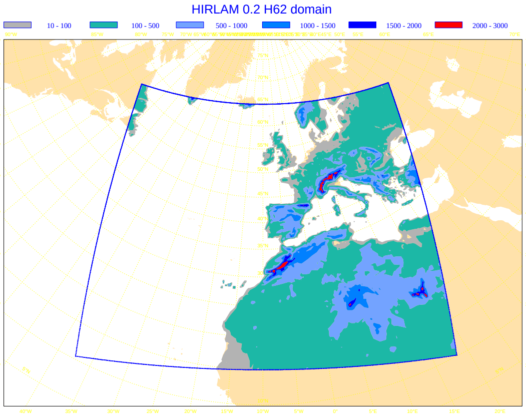

Figure 1: *Integration area at 0.20 degrees resolution*

differences are:

- Relative humidity at high levels: systematically higher in reference STRACO
- Mean sea level pressure (MSLP): KF/RK tend to produce deeper lows along the storm track. This could be due to deeper lows or lows filling more slowly. Fig. 3 RMSE of MSLP against its own analysis.
- Cloud cover: very similar structures but systematically higher amounts in STRACO.
- Precipitation: Similar patterns but very low amounts tend to be higher in KF/RK.

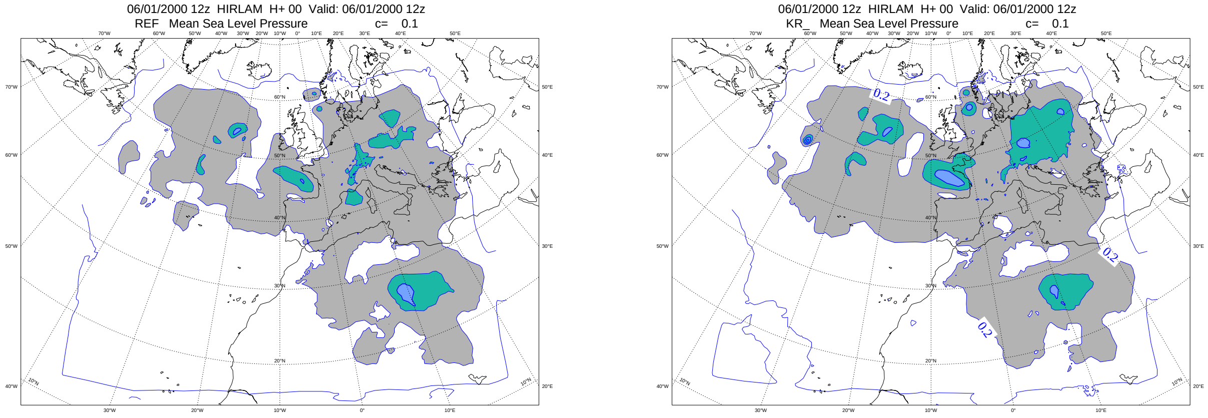

Figure 2: *RMSE against its own analysis:* (left) *reference STRACO and* (right) *KF/RK*

## 4 Verification against observations

We have computed objective scores of model output against EWGLAM observations . The most significant differences for surface parameters are found in MSLP, cloud cover and precipitation (see fig. 3). The new scheme degrades MSLP. For cloud cover an improvement is found although a significant negative bias is present. Related with the errors in MSLP and cloud cover, there is a slight degradation in 10 meter wind and a slight improvement in 2 meter temperature.

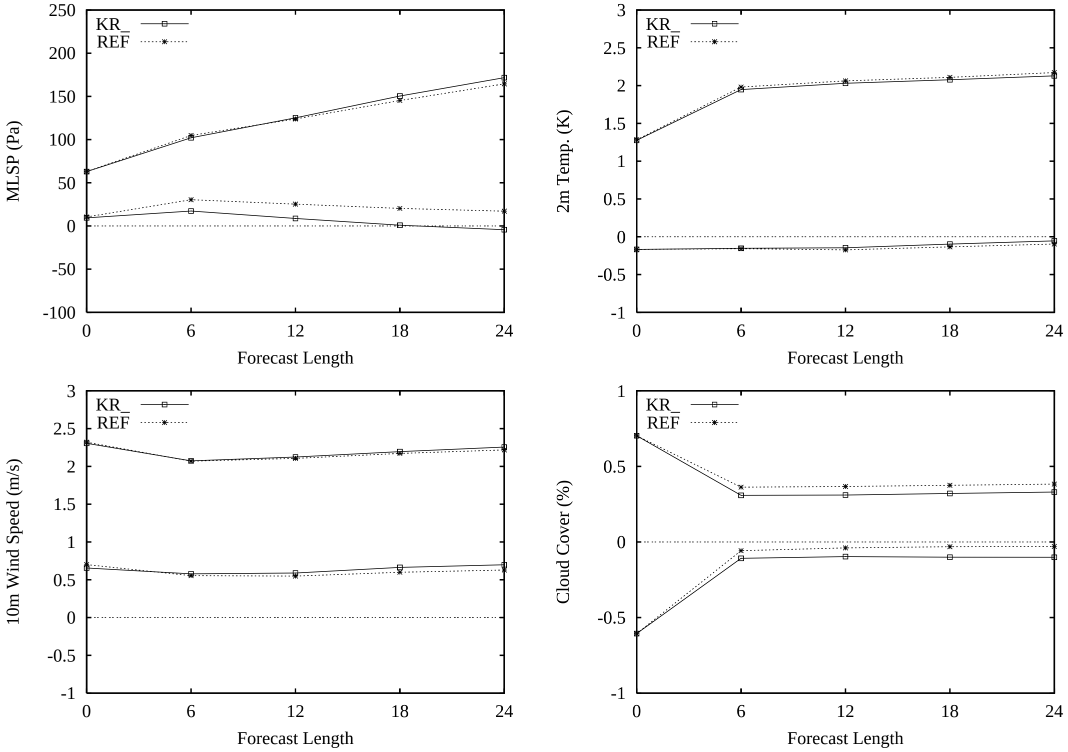

Figure 3: *Objective verification against surface observations. RMSE and Bias of (a) Mean Sea Level Pressure, (b) 2 m temperature, (c) 10 m wind speed and (d) cloud cover. REF/dash means reference STRACO and KR_/solid means KF/RK*

In order to analyze the errors of MSLP we have plotted in fig. 4 the difference between the RMSE of KF/RK and the RMSE of STRACO. In 4a we show this difference for EWGLAM stations and including all the integration periods. Although the reference tends to have lower errors it seems that in warmer seasons the difference decreases or even reverses. In 4b we compare this difference for EWGLAM and Iberia stations including all periods. Whereas the RMSE of MSLP after 24 hours of integration is 7 Pa larger with the new scheme for EWGLAM stations, it is 4 Pa lower for Iberia stations. An interesting feature of the new scheme is that error grows more slowly during the first 6 hours suggesting less spin up problems.

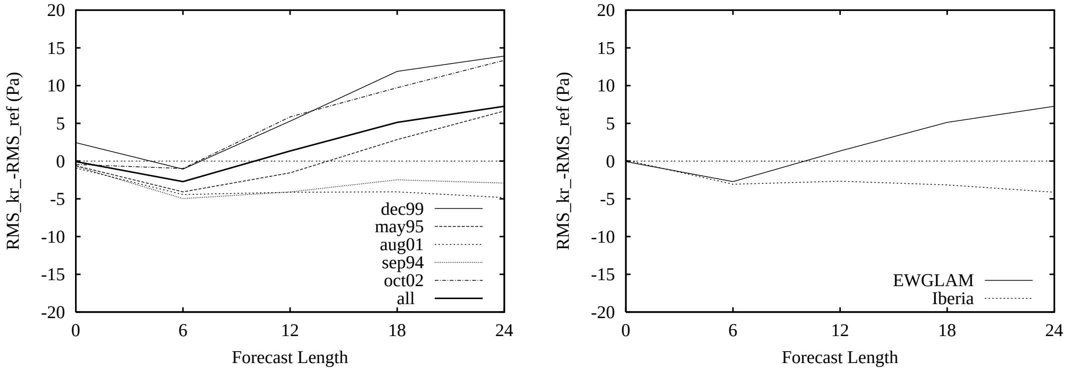

Figure 4: *Difference of MSLP RMSE between the two schemes. Positive differences mean that the RMSE is lower for the reference scheme whereas negative differences mean that the new scheme has lower RMSE. (left) Different periods for EWGLAM stations (right) EWGLAM versus Iberia stations for all periods*

Comparing against soundings (fig. 5), the biggest impact is found in relative humidity which improves clearly with the new scheme. It is interesting to note the big positive bias of both schemes at high levels. Probably most of the improvement in cloud cover is due to this improvement in relative humidity.

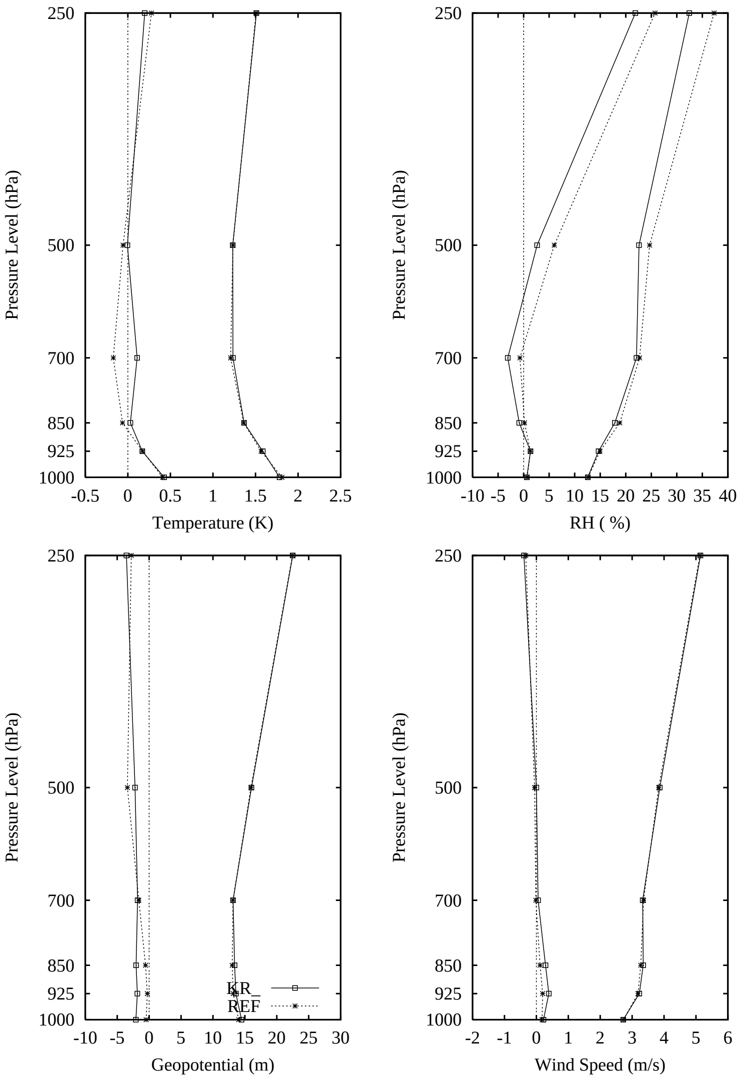

Figure 5: *Objective verification of the H+24 forecast against EWGLAM soundings. RMSE and Bias of (a) temperature, (b) relative humidity, (c) geopotential height and (d) wind speed. Lines as in fig. 4*

# 5 Precipitation verification

Precipitation forecast verification is a difficult task due to the discontinuous nature of precipitation, representation problems of observations and also phase related problems. Comparing geographical distribution of precipitation over long periods both schemes show similar patterns (fig. 6). The main difference is that KF/RK tends to overestimate small precipitation amounts. Both schemes seem to produce maxima over the mountains too often.

Comparing against observations we have computed contingency tables for thresholds 0.1, 0.3, 1, 3, 10, 30 and 100 mm/6 hr. The evaluation is carried out independently for 2 periods of

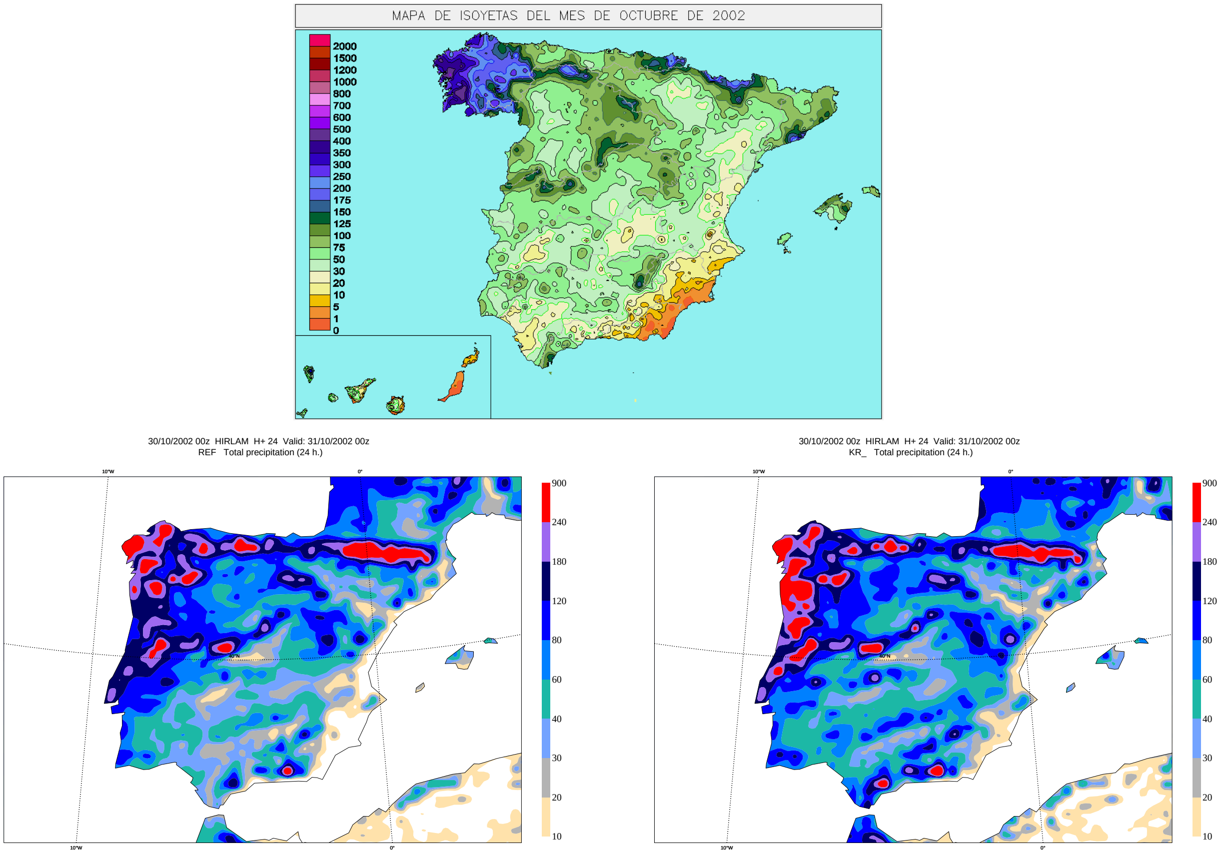

Figure 6: *October 2002 accumulated precipitation. (*top*) observations from 3000 stations (thanks to SAM, INM), (*lower left*) STRACO and (*lower right*) KF/RK. Contours are at 10, 20, 30, 40, 60, 80, 180 and 240 mm/month. Both forecasts are very similar and show a tendency to produce maxima over the mountains more often than observed*

accumulation, 6 and 12 hours. In fig. 7 we have contoured the number of events for the possible pairs of observed and forecast categories. The narrower the distribution is along the diagonal the better. For observations lower than 1 mm/day, KF/RK tends to overpredict the precipitation more than the reference STRACO. For precipitations in the range of 10 to 30 mm/day, KF/RK tend to be closer to observations.

In order to summarize all the information in these tables we have computed different scores using an open bound approach for the categories. See Wilks (1995) for further information about the scores. As an indication of the uncertainty introduced by these scores we have shown that the relative performance of the schemes differ with the scores used and also with the accumulation period selected (changing the accumulation period of the observations, the observations selected are changed and also the verifying categories). There is no perfect score, we will concentrate mainly on two scores designed to remove random and constant forecast and to give more weight to rare events: the True Skill Statistic (TSS) and the Equitable Threat Score (ETS). Using the notation for $a$, $b$, $c$ and $d$ of table 2.

The TSS is defined by

$$TSS = \frac{ad - bc}{(a+c)(b+d)} \tag{1}$$

It can be shown that TSS is the probability of detection $(a/(a+c)$ minus the false-alarm rate

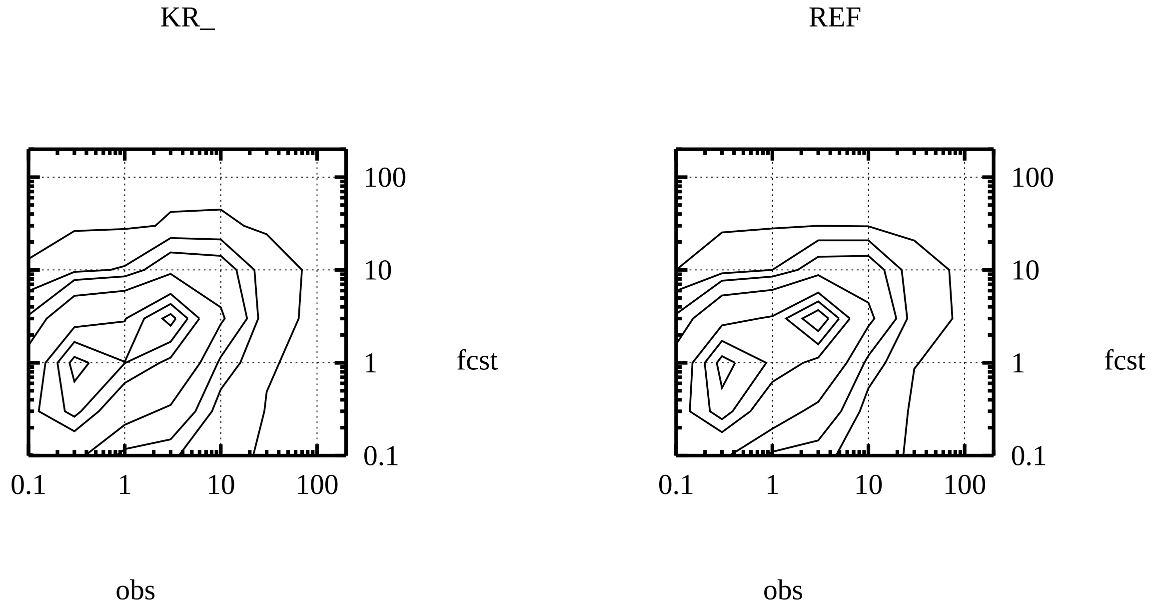

Figure 7: *Number of events for the different pairs of observed and forecast categories. (*left*) KF/RK and (*right*) reference*

| | Observed YES | Observed NO |
|---|---|---|
| Forecast YES | a | b |
| Forecast NO | c | d |

Table 2: Contingency table for observed and forecast categories

(*b/(b+d)*. Removing random and 'no' forecast for consideration, the ETS is

$$ETS = \frac{a - R(a)}{(a+b+c-R(a)} \quad where\, random\, forecast \quad R(a) = \frac{(a+b)(a+c)}{(a+b+b+d)} \tag{2}$$

The Bias (B), or the ratio of number of 'yes' forecasts to the number of 'yes'observations is

$$B = \frac{a+b}{a+c} \tag{3}$$

Note that $B$ is not an accuracy measure but gives un idea of the tendency of the model to overforecast or underforecast the precipitation. In fig. 8a we see that the new scheme tends to produce larger precipitation amounts than the reference. Looking at the average of TSS and ETS in fig. 8b and taking into account both accumulations, we see that KF/RK produces slightly better scores in the range 3-30 mm/day and worst scores for amounts smaller than 2 mm/day.

In fig. 9 we try to assess the geographical distribution of the scores comparing the verification over Iberian Peninsula with the verification including all EWGLAM stations. Over Iberia we find improvement for all categories except below 1 mm/day. The better performance of the new scheme towards the south, also seen in MSLP, could be associated with the relative importance

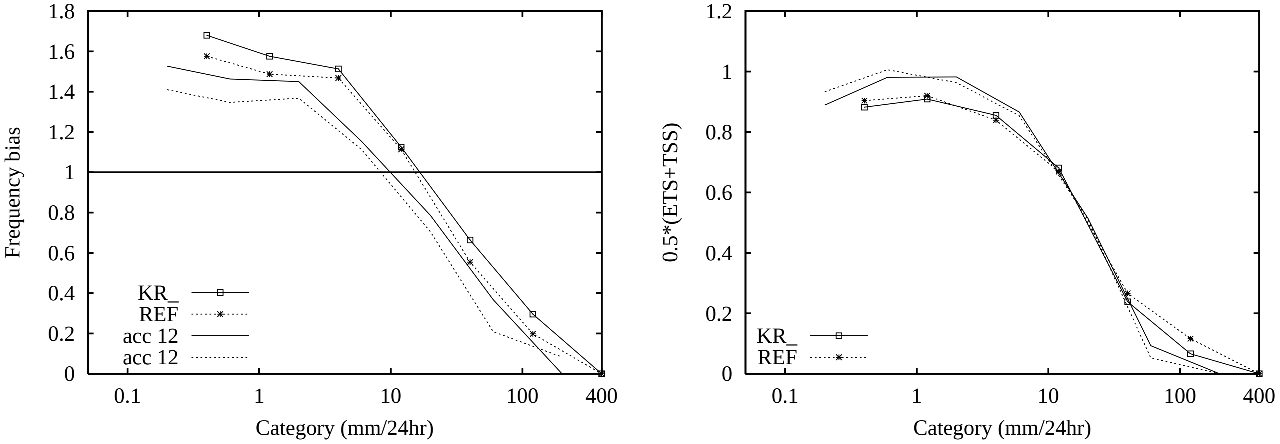

Figure 8: *Frequency Bias (left) and average of ETS and TSS (right) for precipitation verification against EWGLAM stations including all periods. With solid lines KF/RK and with dash lines reference. Dotted lines correspond to forecasts and observations accumulated in 6 hr. and not dotted in 12 hr.*

of convective or large scale processes. Weather systems tend to be more convective in lower latitudes and the Kain-Fritsch convective part would be more active there. Thus, we could infer that there is better room for improvement in the large scale cloud and microphysics part of the new moist scheme.

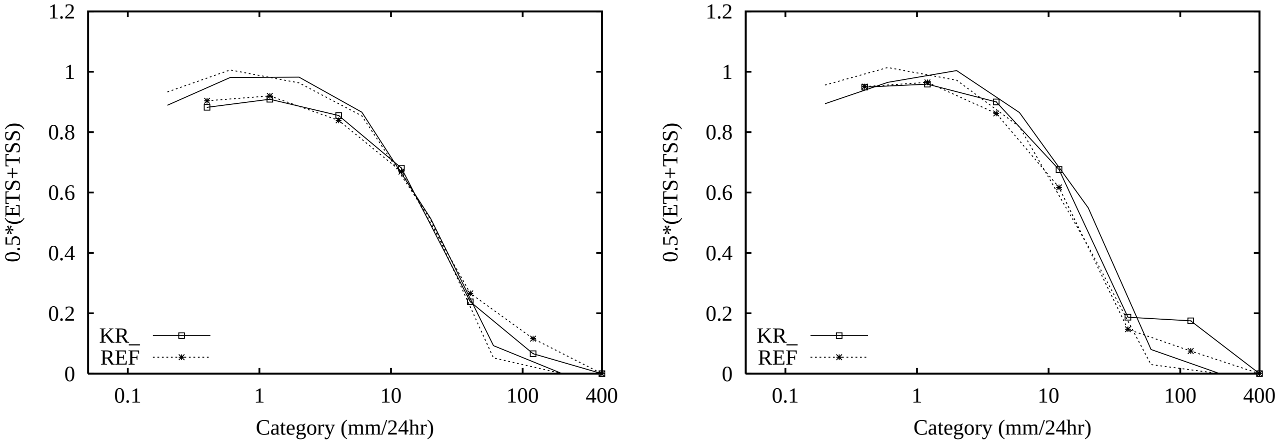

Figure 9: *Average of ETS and TSS over EWGLAM stations (left) and Iberia stations (right). Lines as in fig. 8*

## 6 Conclusions and perspectives

The performance of the a new moist physics scheme based on Kain-Fritsch convection and Rasch-Kristjansson large scale condensation scheme has been compared with the reference STRACO scheme for different seasons. The new scheme improves the forecast of moisture related variables in the model, specially relative humidity but also clouds and precipitation. The cost is a deterioration of MSLP and a 10-20 % increase of computer time at the ECMWF/IBM computer system.

We think that the new moist physics scheme could be included in the reference system as an option to alow a wider use within the HIRLAM community. This could led to a faster improvement an tuning of the scheme. Some known problems as the overestimation of small precipitation amounts and the poor performance of the new system in vector machines will be address in the near future.

## References

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