Norwegian Meteorological Institute

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Modification of AROME ICE3 cloud physics, a status report

Karl-Ivar Ivarsson

Front:

Shower of mixed rain and graupel near Norrköping May 4 2014 18 UTC. Due to dry air near the surface, only a small part of the precipitation reaches the ground. Photographer: Karl-Ivar Ivarsson

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Summary

HARMONIE with AROME- physics and cycle 38 has been tested with the original version and with a modified version for one cold winter period and one wet late summer period.

The modifications in the modified version is basically in the cloud physics (ICE3) and are intended to give better predictions of low clouds in winter, and some reduction of cirrus clouds for all seasons, since there is some overprediction of cirrus in the original version.

The modifications are mainly three:

1: A more clear separation of liquid- and ice processes.

2: Some tunings

3: Separate cloud calculations of clouds containing liquid water and clouds containing cloud ice only.

The experiment results show the following differences for the modified version compared to the original:

- Winter: Better 2m-temperature, clouds, cloud base and more realistic upper air relative humidity. Somewhat worse precipitation forecasts.
- Summer: Mainly neutral impact.

Although there are clear improvements seen with the modified scheme, some problems still remain:

- Slightly too low temperature in the lower troposphere in winter.
- Too much light precipitation (both snow and graupel) in winter.
- Too much very strong precipitation, especially in summer.

Acknowledgments:
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1 Background

Although the cloud physics in AROME (AROME is one of the physics schemes available in HARMONIE, for more details see Caniaux et al. [4] and Pinty and Jabouille [5]) is rather advanced and generally works well, there are some weaknesses that are being addressed. For instance it has been noticed that there is too much fog and low cloud, especially in spring and over the sea. There is also too much “on-off” behavior of both clouds and precipitation. Too much fog in spring and too much low cloud during this season are probably to a large degree related to turbulence and perhaps also to the surface scheme (SURFEX) and will not be considered here, except when discussing the results of the tests. The reasons for too much “on-off” behavior of clouds and precipitation are not well known and will not be discussed further.

However, there are two other weaknesses that may be related to the cloud microphysics, especially the ice- and mixed phase part:

1. Low cloud disappears too quickly in 'moderate' cold conditions (around 0 to -10°C)
2. Too much low cloud when it is 'very' cold, below ~ -20°C. There also seems to be a moderate over-prediction of cirrus clouds.

These two weaknesses will be examined further here, and some suggestions as to how to reduce the forecasts errors related to them will be given.

1.1 Proposed reasons for the weaknesses

- The first reason is that there is too little mixed-phase cloud. The probable reason for this is an overactive generation of cloud ice and solid precipitation, which removes moisture too quickly.
- The second reason is that there is too much ice cloud, such as cirrus, ice cloud or fog near the ground in cases with low temperatures. Clouds appear as soon as the relative humidity, with respect to ice, is close to 100%. In reality there are seldom clouds at ice saturation. The different physical properties of ice clouds compared to water clouds are not fully included in the model physics.

1.2 Problems related to treatment of the boundaries

The first test with the modified cloud physics often resulted in spurious precipitation near the boundary zone. It was caused by cloud condensation and precipitation that were renewed at each time step. In order to get rid of this precipitation and condensation, new settings in the configuration file for the boundaries were necessary. These settings are described in the table below: to the left the new settings and to the right the old settings. Only the changes of the settings for cloud liquid water are shown. Similar changes are done for all cloud condensate and precipitation in the model. The new settings are default for the HARMONIE AROME version Cy38h1.1

New settings:	Original, old settings:
'YL_NL%NCOUPLING' => '-1,', 'YL_NL%REFVALC' => '0.,', 'YL_NL%NREQIN' => '1,', 'YQ_NL%NCOUPLING' => '1,', 'YQ_NL%NREQIN' => '1,',	'YL_NL%NCOUPLING' => '0,', 'YL_NL%NREQIN' => '1,', 'YQ_NL%NREQIN' => '1,', Note: For MUSC (1D runs) it is important with 'YQ_NL%NCOUPLING' => '0,', (Default is 1)

Note that treatment for water vapor on the boundaries should be different for 1D runs and 3D runs.

2 Brief description of the changes in the ICE3-physics

In AROME the cloud physics scheme which handles the ice-phase is often referred to as the ICE3-scheme. This scheme is modified in the tests presented here.

It is apparent that one problem with the current version of the ICE3-physics scheme is that there is not enough separation of the liquid- and ice processes. The cloud liquid water processes are faster than the ice water processes, so a separation means that fast and slow processes are not handled simultaneously in the computations. In the modified version, a more rigorous separation of the two water phases is done. This means that:

- The statistical cloud-scheme only handles water- and mixed phase cloud cover. Only the amount of cloud-liquid is calculated from this scheme. (Instead of both water and ice simultaneously)
- The “Bergeron-Findeisen”process is derived as a conversion from vapor to ice. (Instead of from liquid to ice)

Also the treatment of cloud cover should be different for ice and water because of the different optical properties of water/mixed phase clouds and pure ice clouds:

- A separate ice cloud fraction is derived. It is related to the content of cloud ice water and to the relative humidity with respect to ice. Also the content of solid precipitation contributes, since the optical properties of solid precipitation are 'cloud-like' and not very different from the optical properties of cloud ice.
- Total cloud cover is the sum of the liquid fraction and ice fraction
- The ice cloud fraction is dependent on model thickness since ice clouds are generally a lot thinner optically than water clouds.

An overactive generation of cloud ice and solid precipitation is probably caused by assuming a less suitable type of ice crystals in the parameterization and/or a not very well tuned size distribution of the ice crystals. Also the prescribed ice nucleus (IN) concentration is important, since a large IN-concentration means more ice crystals and thus faster decay of the supercooled cloud water drops by the Bergeron-Findeisen process.

A comparison with the corresponding parameterization in the HIRLAM model reveals that for a prescribed IN-concentration, the crystal growth for both cloud ice water and for snow crystals is of the order 10 to 100 times faster with the ICE3-parameterization in HARMONIE AROME. The reason for this large difference is not fully understood, and further studies are needed. If the ice crystal growth was too slow in HIRLAM, this might be seen as an overprediction of mixed-phase clouds in HIRLAM. However no such overprediction is found. It could be that the prescribed IN-concentration in AROME is different to that in HIRLAM, but both models use the same formulation of the IN-concentration (from Meyers, 1992), so both models have the same order of IN-concentration.

For the moment, the ice crystal growth equations from HIRLAM are used for cloud ice water in the modified ICE3-version, whereas the original equations, reduced with a tuning factor, are used for snow and graupel.. Also the IN-concentration between 0 and -25 °C, is assumed to be parameterized to a lower value than in the original ICE3 (and thus also lower compared to what is used in HIRLAM). These solutions are to be regarded as temporary.

3 Verification results

The reference version is based on Cycle 38h1b3 and the experiment is called LM38h1b3. It is shown in red in the figures. The experiment LM38h1b3 is set up in the following way:

- Canari OI main
- 3DVAR with conventional observations
- 3 hours analysis cycle
- Reference version with CROUGH=Z01D
- Boundary frequency: 3h
- Forecast length 48 hours but only at 00 and 12 UTC.
- MetCoOp area Hires2, covering northwest Europe with 960x750 gridpoints and 65 levels

The test with the modified version is called KI38b3MIE8 and is based on the set up of LM38h1b3, but with modified cloud physics. Also the boundary treatment is changed according to the table above. It is shown in green in the figures. Changes in the treatment of the boundaries, but not the cloud physics, gives no notable difference in the forecast result (not shown). ([1] Þorsteinsson)

- Two test periods are used: November 15 – December 10 2010 (a cold winter type),
- August 10- to 23, 2011. (moist and rainy summer period)

For more information about the periods, see [3] Køltzow et.al.

Due to the spin up of the model, the verification starts at November 18 and August 12 respectively.

3.1 Mean sea level pressure (MSLP)

The result for mean sea level pressure (MSLP) and 2-meter temperature (T2M) for the cold winter period is seen in Figure 1.

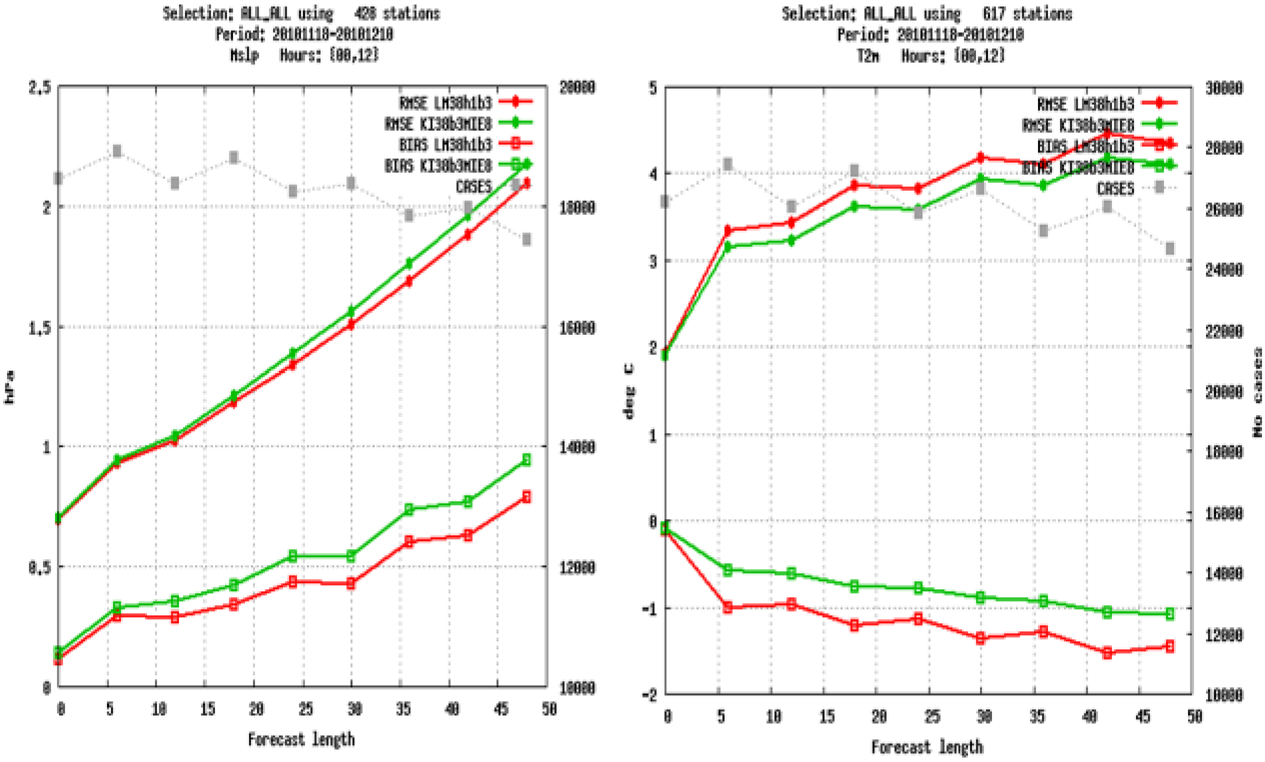

Figure 1. Root mean square error (RMSE) and mean error (bias) for different forecast lengths (18 November – 10 December 2010) MSLP to the left and T2M to the right. Red=reference forecast, green=modified version

An increasing positive bias for MSLP with increasing forecast length is seen for both experiments. The less cold T2M in the modified version should normally lead to a reduced MSLP bias, but here it is increased. The reason is probably that it is somewhat colder in the lower troposphere in the modified version than in the reference version.

The result for MSLP and T2M for the wet summer period is shown in Figure 2.

A somewhat larger RMSE is seen for the longest forecast with the modified version, in other respects the differences are generally small between the experiments.

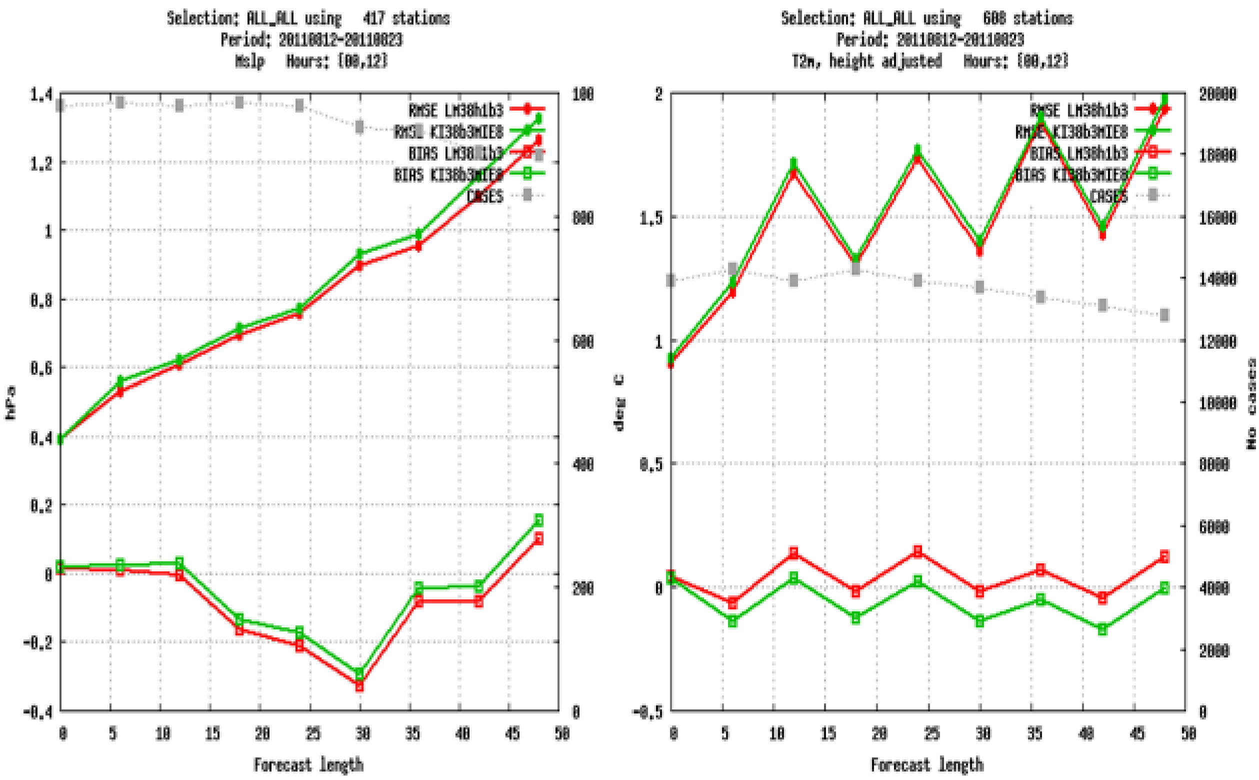

Figure 2. RMSE and mean error (bias) for different forecast lengths (12 -23 August 2011) MSLP to the left and T2M to the right. Red=reference forecast, green=modified version.

3.2 Dew point temperature (TD2M)

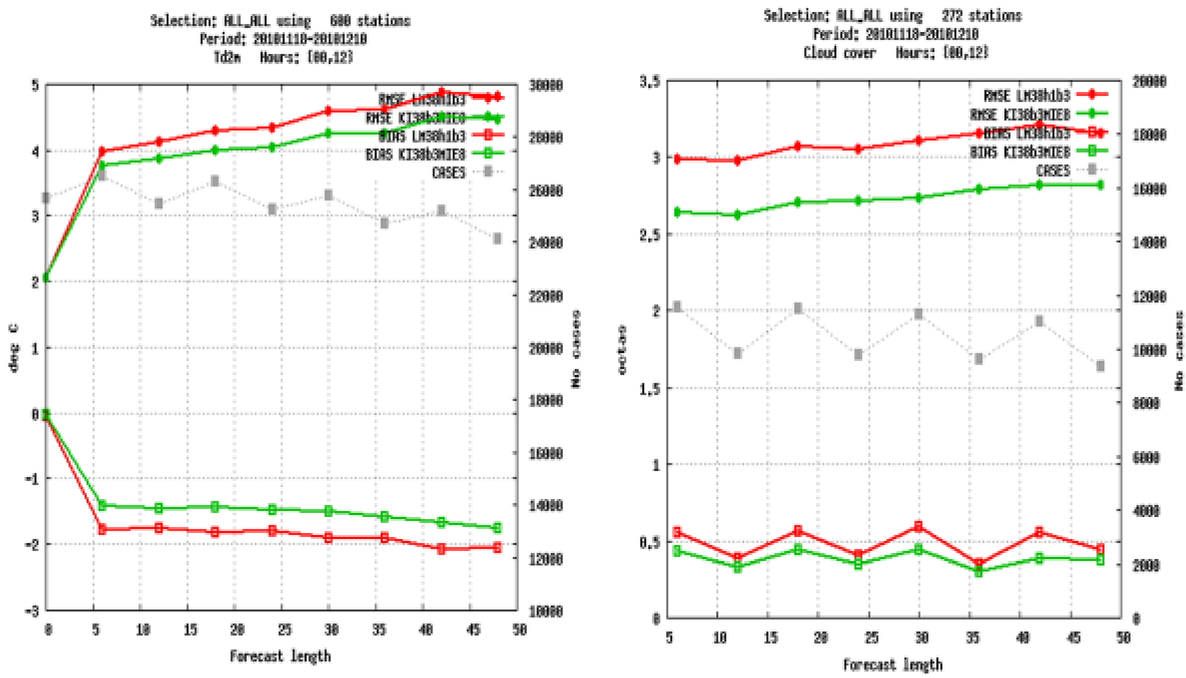

Figure 3. RMSE and mean error (bias) for different forecast lengths (18 November – 10 December 2010) TD2M to the left and total cloud cover to the right. Red=reference forecast, green=modified version.

The result for 2-meter dew point temperature (TD2M) and total cloud cover for the winter period is shown in Figure 3 and for the summer period is shown in Figure 4.

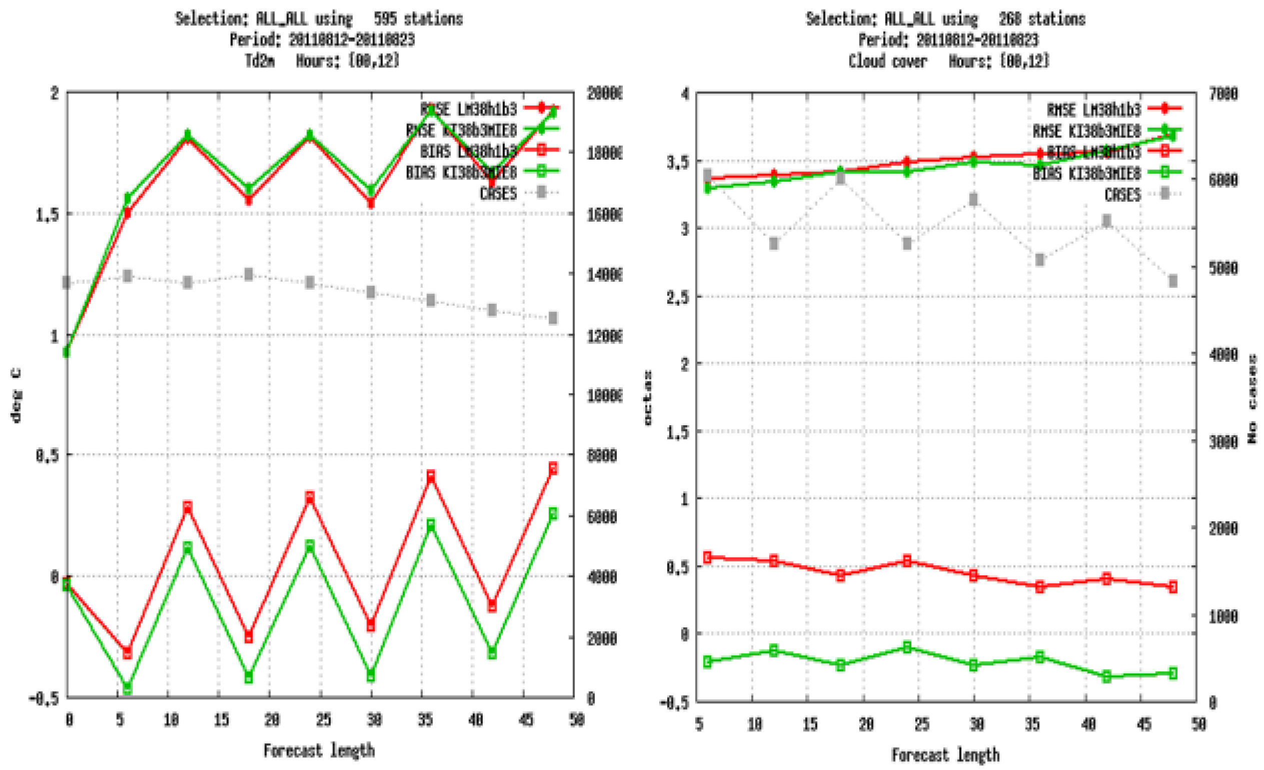

Figure 4. RMSE and mean error (bias) for different forecast lengths (12 -23 August 2011) TD2M to the left and total cloud cover to the right. Red=reference forecast, green=modified version.

The RMSE is smaller for TD2M and also for cloud cover for the modified version for the winter period, but the differences are generally small for the summer period.

The equitable threat score (ETS) for different thresholds of total cloud cover and low cloud (below 2.5 km) is seen in Figure 5 (winter period) and Figure 6 (summer period).

3.3 Cloud cover

Verification results for cloud cover are shown in Figure 5 for the winter period and in Figure 6 for the summer period.

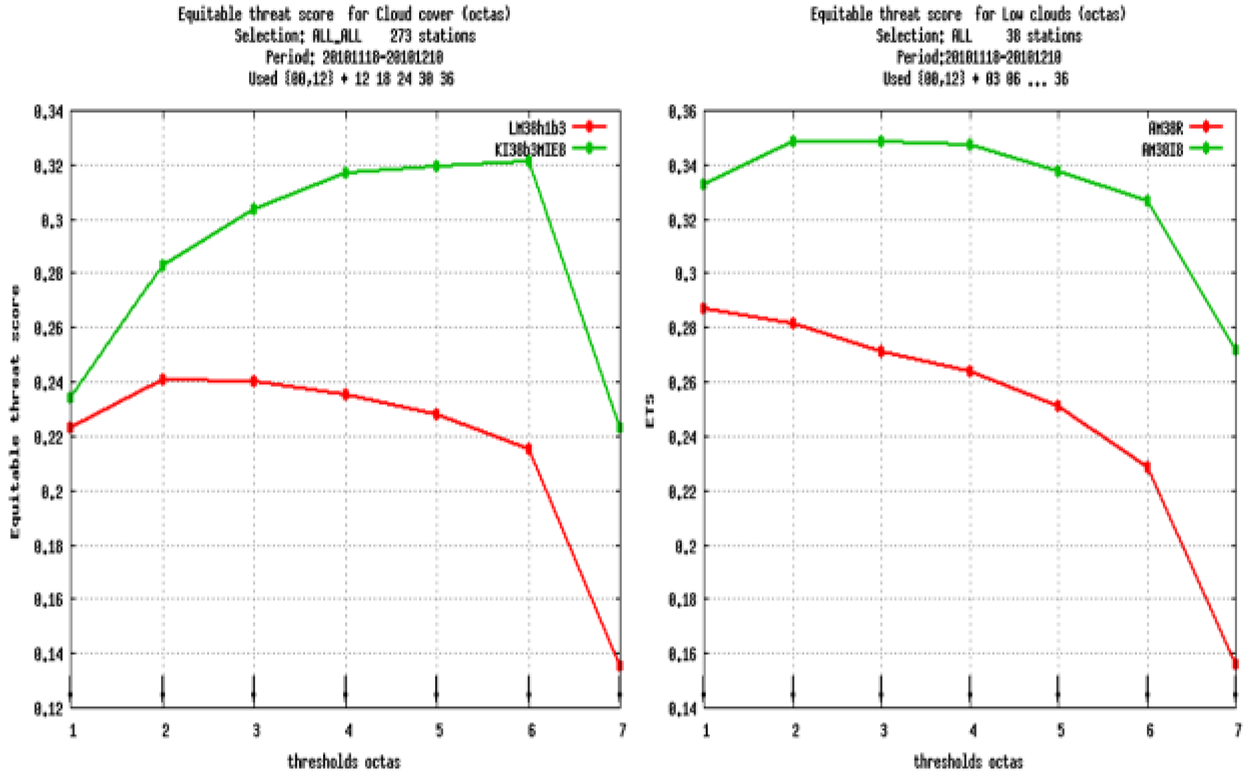

Figure 5. ETS for total cloud cover (left) and low clouds (right). Thresholds in octas on the horizontal axis and ETS value on the vertical axis. The observations of low cloud are based on selected Swedish automatic stations only (winter period).

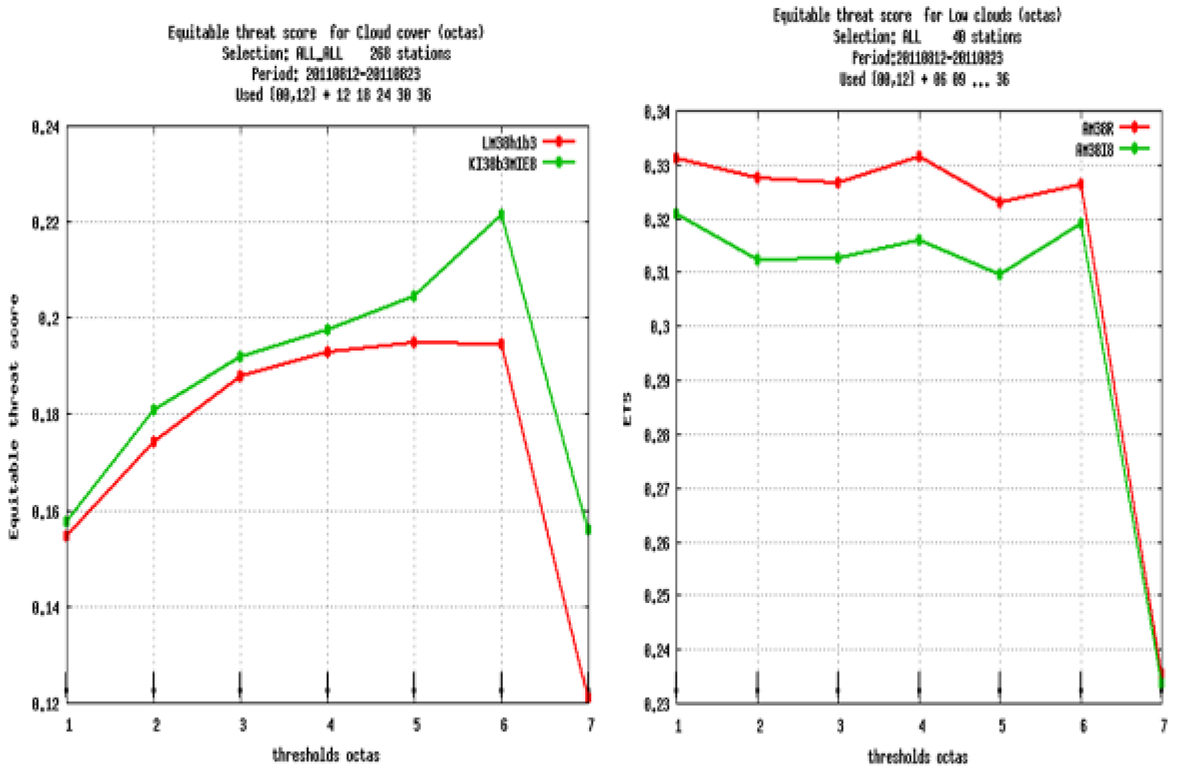

Figure 6. ETS for total cloud cover (left) and low clouds (right). Thresholds in octas on the horizontal axis and ETS value on the vertical axis. The observations of low cloud are based on selected Swedish automatic stations only (summer period).

The ETS is higher for both types of cloud cover for the winter period, but the result is mixed for the summer period. In the winter period the ETS is higher for the modified version low cloud, but the opposite is found in the summer period.

The frequency bias and ETS for cloud base is seen in Figure 7 and Figure 8. The result for the winter period is seen in Figure 7 and the result for the summer period in Figure 8.

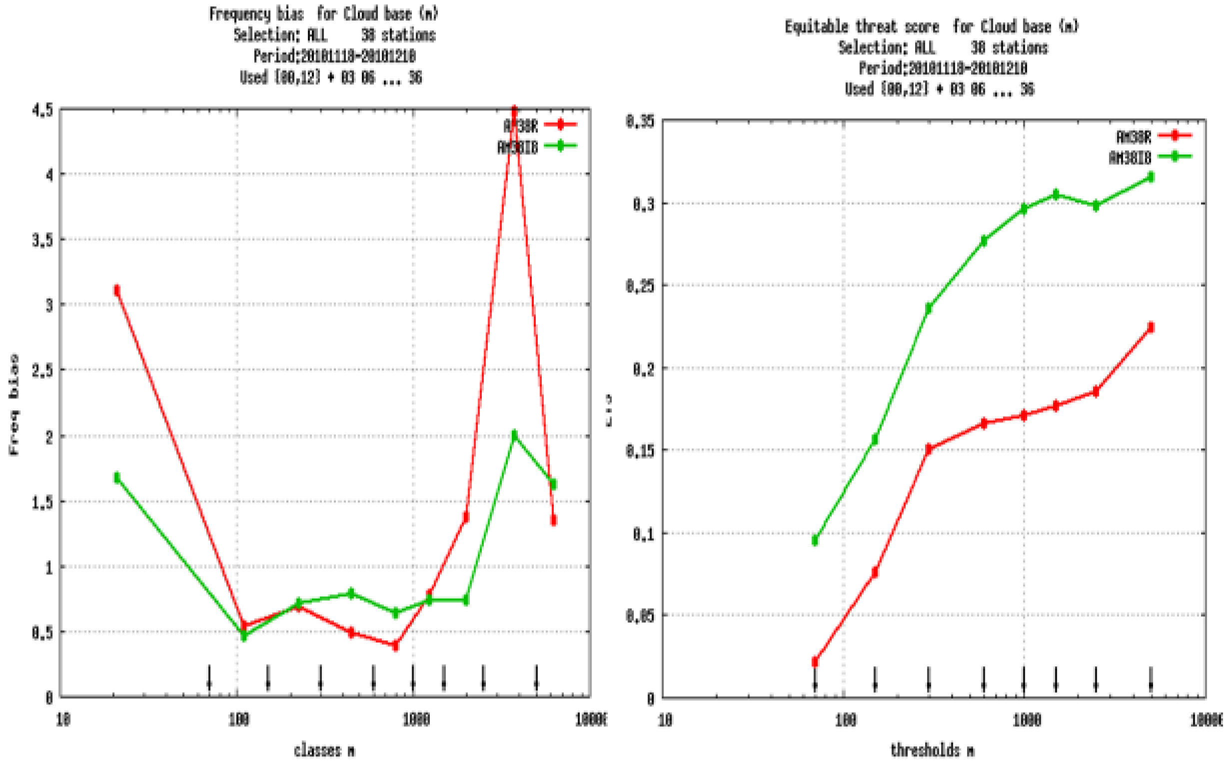

Figure 7. Left figure: Frequency bias for cloud base for different cloud bases. Cloud base on the horizontal axis and frequency bias on the vertical axis. Right figure: ETS for cloud base. Thresholds on the horizontal axis and ETS value on the vertical axis. The observations are based on selected Swedish automatic stations only (winter period).

The frequency biases are closer to one for the modified version in both winter (Figure 7) and summer (Figure 8), which means less systematic errors. The ETS values are higher for the modified version in winter and a little lower in summer.

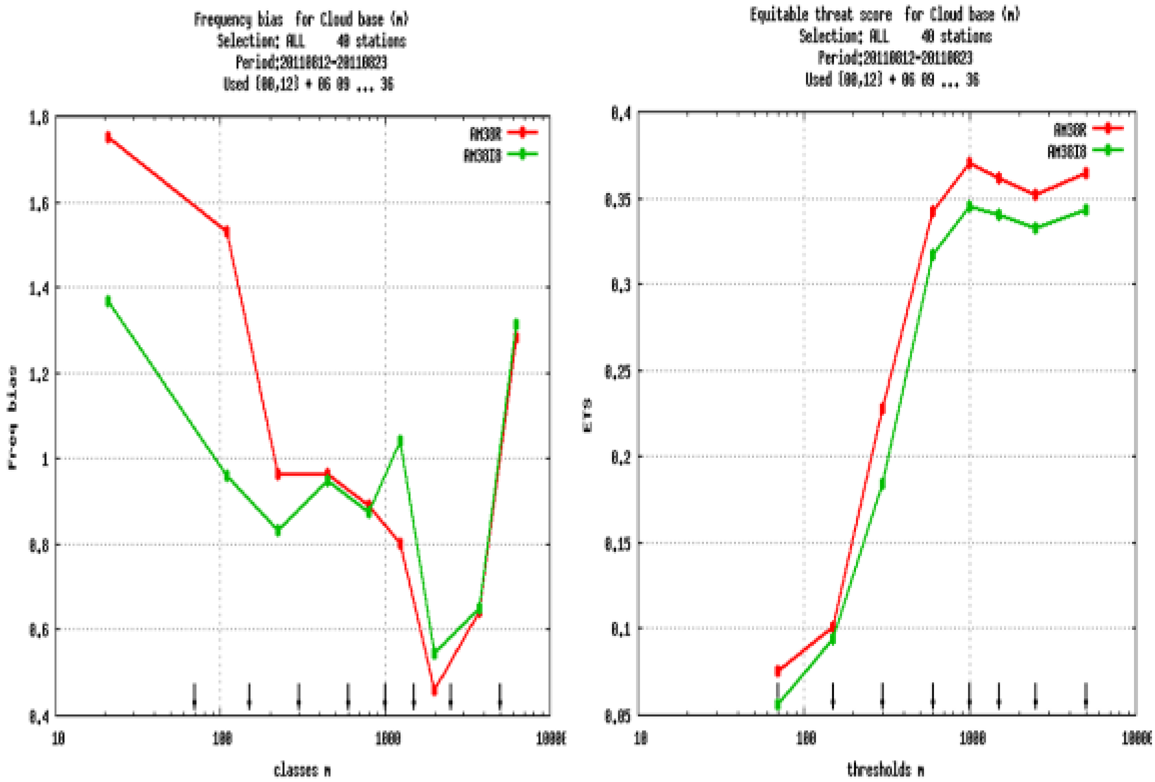

Figure 8. Left figure: Frequency bias for cloud base for different cloud bases. Cloud base on the horizontal axis and frequency bias on the vertical axis. Right figure: ETS for cloud base. Thresholds on the horizontal axis and ETS value on the vertical axis. The observations are based on selected Swedish automatic stations only (summer period).

3.4 Precipitation

The frequency bias and ETS for 12 hours precipitation are seen in Figure 9 (winter) and in Figure 10 (summer).

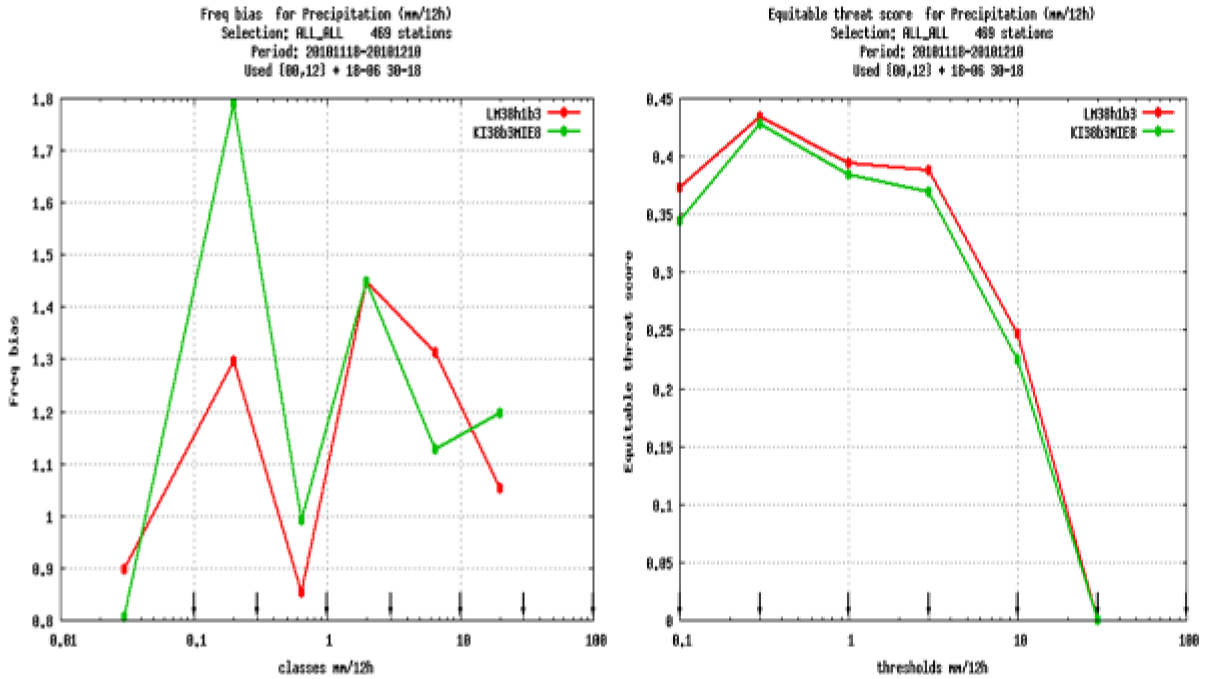

Figure 9. Left figure: Frequency bias for 12h precipitation for different amounts of precipitation. Amount of precipitation on the horizontal axis and frequency bias on the vertical axis. Right figure: ETS for 12 hour precipitation. Thresholds on the horizontal axis and ETS value on the vertical axis (winter period).

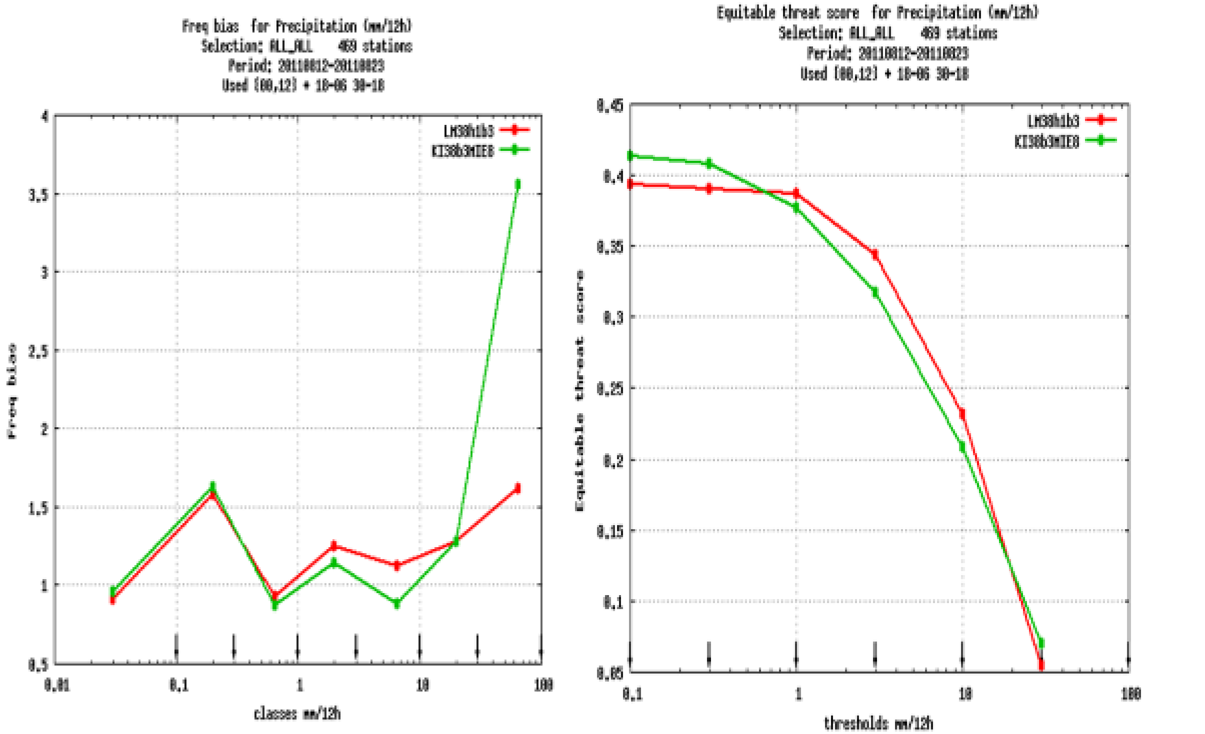

Figure 10. Left figure: Frequency bias for 12h precipitation for different amounts of precipitation. Amount of precipitation on the horizontal axis and frequency bias on the vertical axis. Right figure: ETS for 12 hour precipitation. Thresholds on the horizontal axis and ETS value on the vertical axis (summer period).

12 hours precipitation between 0.1 and 0.3 mm is too frequent for the winter period for the modified version while no large frequency bias is apparent for the reference version. In summer, none of the experiments have large frequency bias, except for precipitation larger than 30 mm for the modified version. There are mainly small differences of the ETS between the models.

The frequency bias and ETS for 3 hours precipitation are seen in Figure 11(winter) and Figure 12(summer).

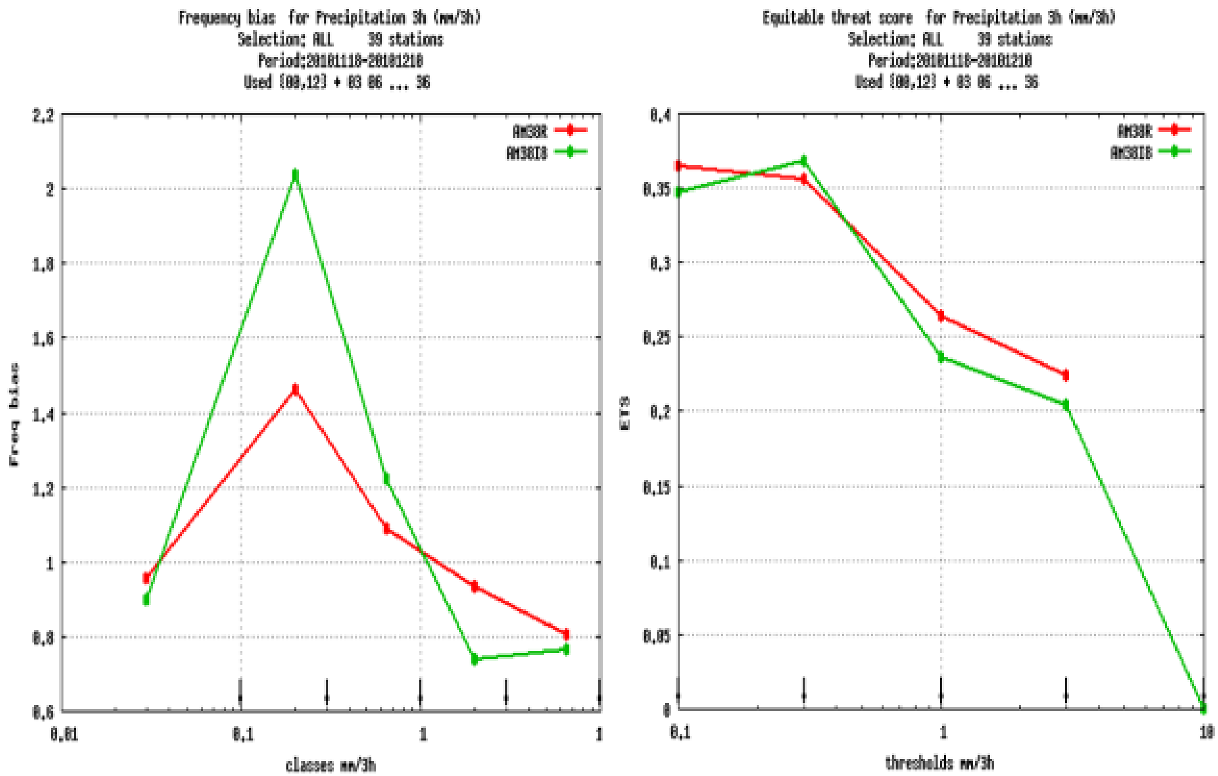

Figure 11. Left figure: Frequency bias for 3h precipitation for different amounts of precipitation. Amount of precipitation on the horizontal axis and frequency bias on the vertical axis. Right figure: ETS for 3 hour precipitation. Thresholds on the horizontal axis and ETS value on the vertical axis (summer period). The observations selected are Swedish automatic stations.

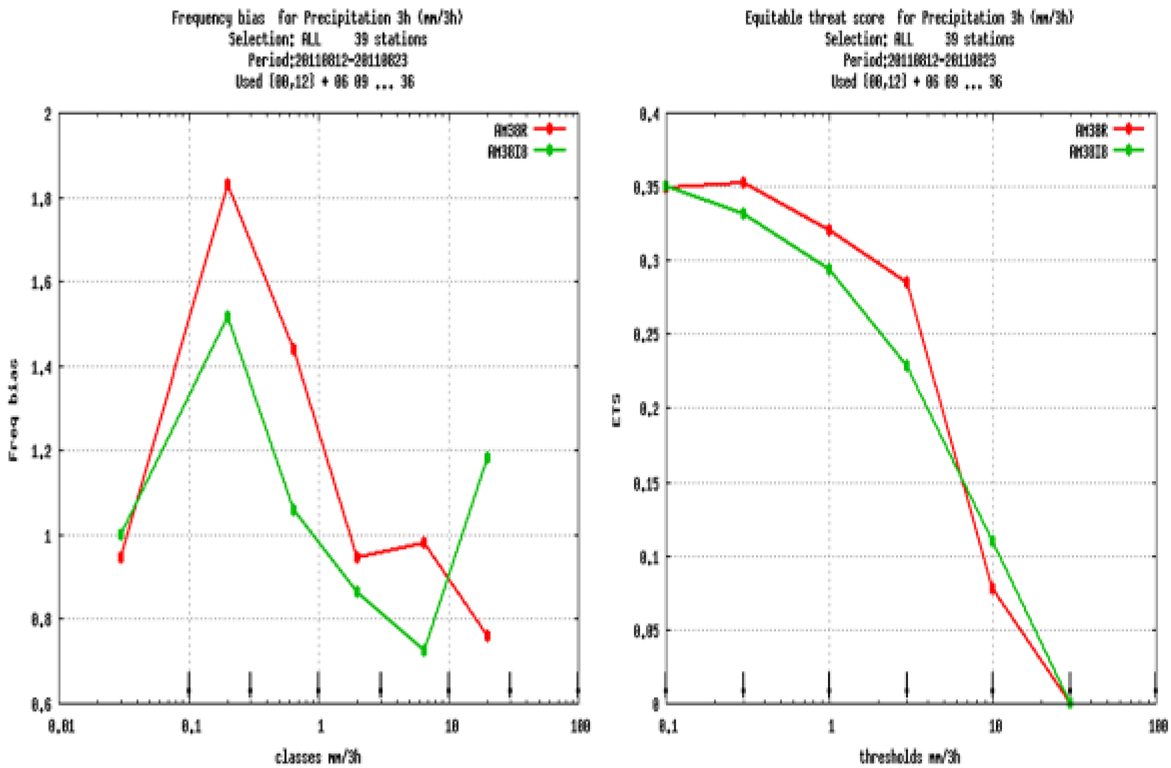

Figure 12. Left figure: Frequency bias for 3h precipitation for different amounts of precipitation.. Amount of precipitation on the horizontal axis and frequency bias on the vertical axis. Right figure: ETS for 3 hour precipitation. Thresholds on the horizontal axis and ETS value on the vertical axis (summer period). The observations selected are Swedish automatic stations (summer period).

3 hours precipitation between 0.1 and 0.3 mm is too frequent for the winter period for the modified version, but no large frequency bias is apparent for the reference version. In summer, the reference version has too often precipitation between 0.1 and 1 mm, but there is less bias for the modified version. Generally, there are somewhat lower ETS values for the modified version.

The 24 hour precipitation is verified using the Fractions Brier Skill Score (FBSS) and rain gauge measurements from a dense network of climate stations over Norway and Sweden. The FBSS captures the ability to give spatial information about the precipitation field for areas of different size.

The FBSS for the winter-and summer-period is seen in Figure 13.

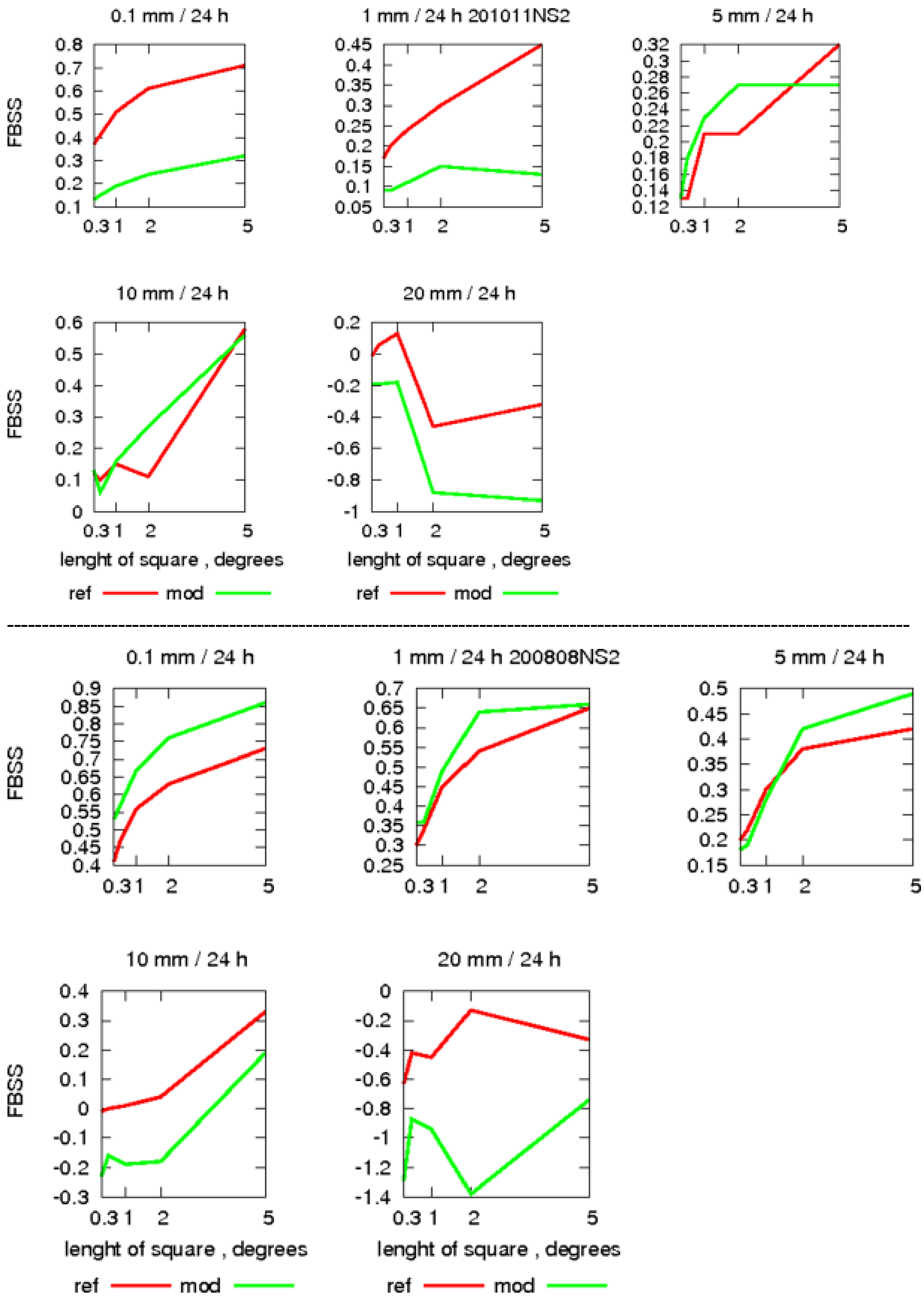

Figure 13. FBSS for different thresholds using Norwegian and Swedish climate stations. Different areas at the horizontal axis as length of squares in degrees latitude. One degree corresponds to a square of 111 x 111 km. FBSS at the vertical axis. The reference forecast is ECMWF. Upper panel: Winter period. Lower panel: Summer period

The results differ a lot between the winter period and the summer period, at least for low thresholds of precipitation. For the winter period, there is a clear deterioration of the FBSS for small precipitation amounts (up to 1 mm) with the modified scheme, but the opposite is seen for the summer period. For 5 mm threshold, some improvement is seen for both winter and summer with the modified scheme. For higher precipitation amounts there is a tendency for somewhat worse results with the modified scheme. Possible reasons for these contradicting results will be discussed later.

3.5 Upper air temperature and relative humidity

The upper air verification of temperature is seen in Figure 14.

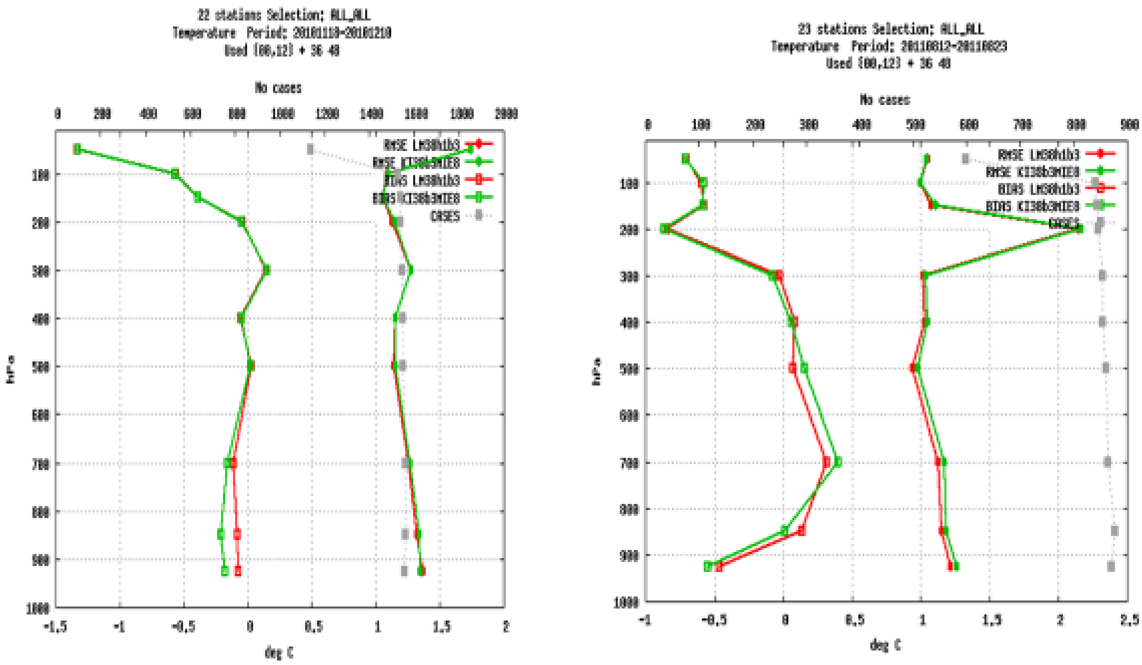

Figure 14. Upper air verification of temperature (against soundings). Winter period to the left and summer period to the right. Bias and RMSE at the horizontal axis and different pressure levels at the vertical axis.

The results of the upper air verification are not very different between the two experiments. However, worth mentioning is that a small cooling is seen in the lower troposphere with the modified scheme for the winter period. Since colder air has a higher density than warm, this cooling would lead to somewhat higher surface pressure. The larger positive bias for MSLP with the modified scheme seen in Figure 1 could therefore partly be explained by this cooling. For the summer period, there are small differences.

The upper air verification of relative humidity is seen in Figure 14.

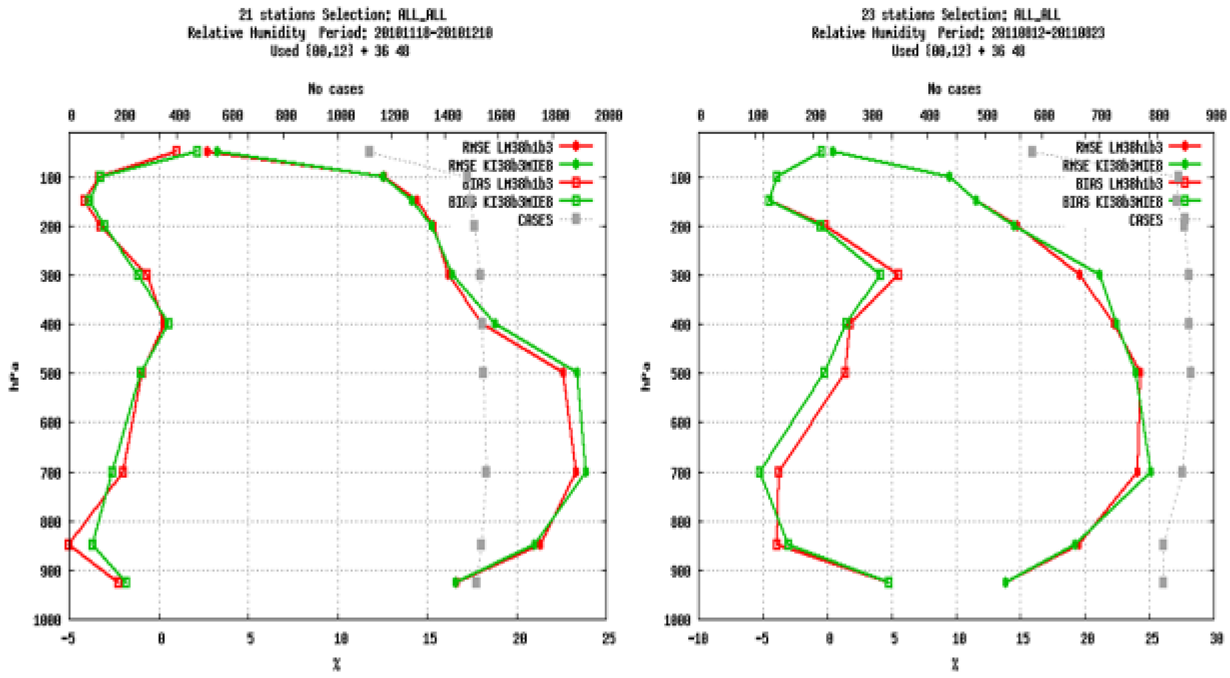

Figure 15. Upper air verification of relative humidity with respect to water. Winter period to the left and summer period to the right. Bias and RMSE at the horizontal axis and different pressure levels at the vertical axis

The reference version has a dry bias of about 5 % at 850 hPa. It is somewhat reduced with the modified version. The reduced bias is probably caused by a reduced drying effect of cloud ice, snow and graupel in regions where there is supersaturation with respect to ice. The increased negative bias seen with the modified scheme for the summer period is more difficult to explain. It may be caused by too intense updrafts of convective cells. If so, the corresponding subsidence will be somewhat more pronounced, leading to more dry air. This could also explain the small relative warming seen with the modified scheme at 700 and 500 hPa due to increased heat release by condensation. (Figure 14, left picture), and perhaps also a larger total error (RMSE).A larger RMSE may also be an effect of a higher spread of the forecast values. The reference version is unable to predict supersaturation with respect to ice for low temperatures, which leads to an erroneously low spread. An example is seen in Figure 16.

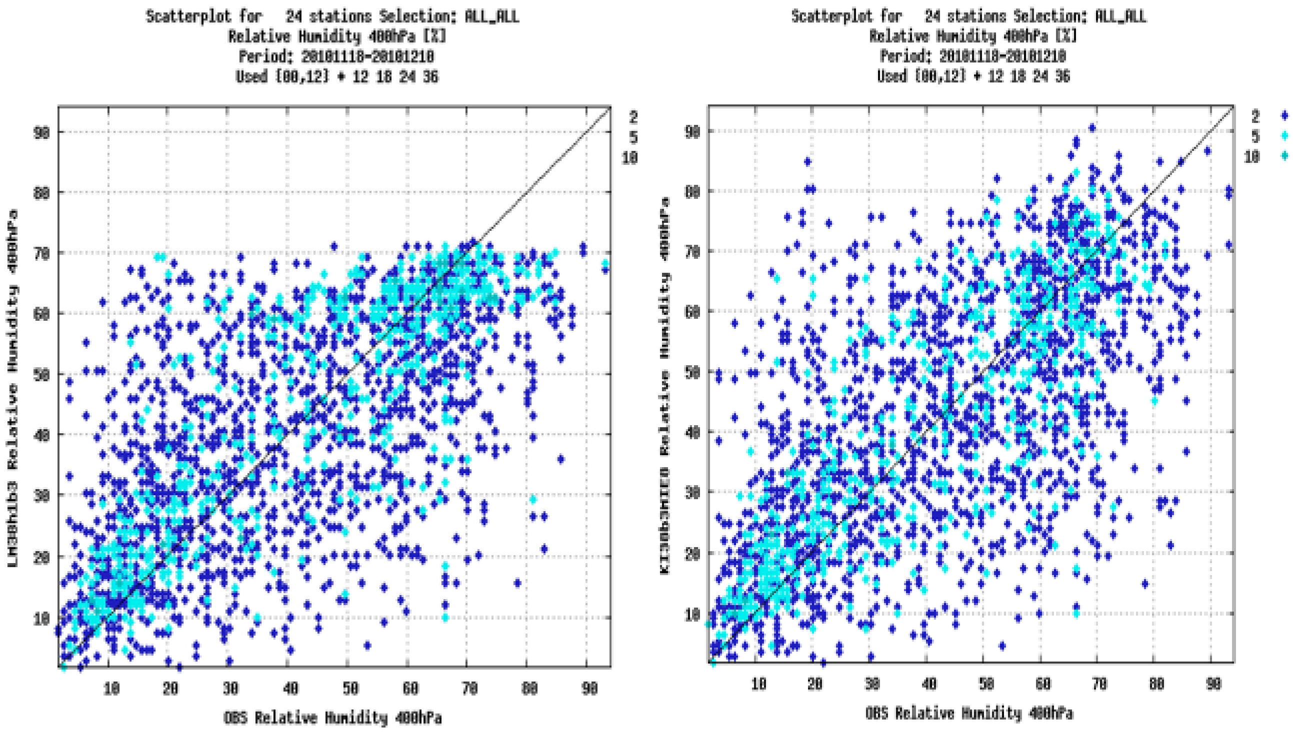

Figure 16. Scatter plot of relative humidity with respect to water at 400 hPa for the winter period. Reference version to the left and modified version to the right. Observations at the horizontal axis and forecast at the vertical axis.

The temperatures are between -30°C and -55°C in this case, and a relative humidity with respect to ice at around -30°C corresponds to a relative humidity with respect water of about 70 %. So the reference version has no forecasts above approximately 70%, although observations may be over 90 %. Forecasts with about 90% are seen with the modified version, thus, the modified version is able to predict ice supersaturation at low temperatures.

3.6 Example of a typical winter case

Figure 17 and Figure 18 show an example of a typical winter case with low stratus at moderate cold conditions, 2m temperatures around -5°C.

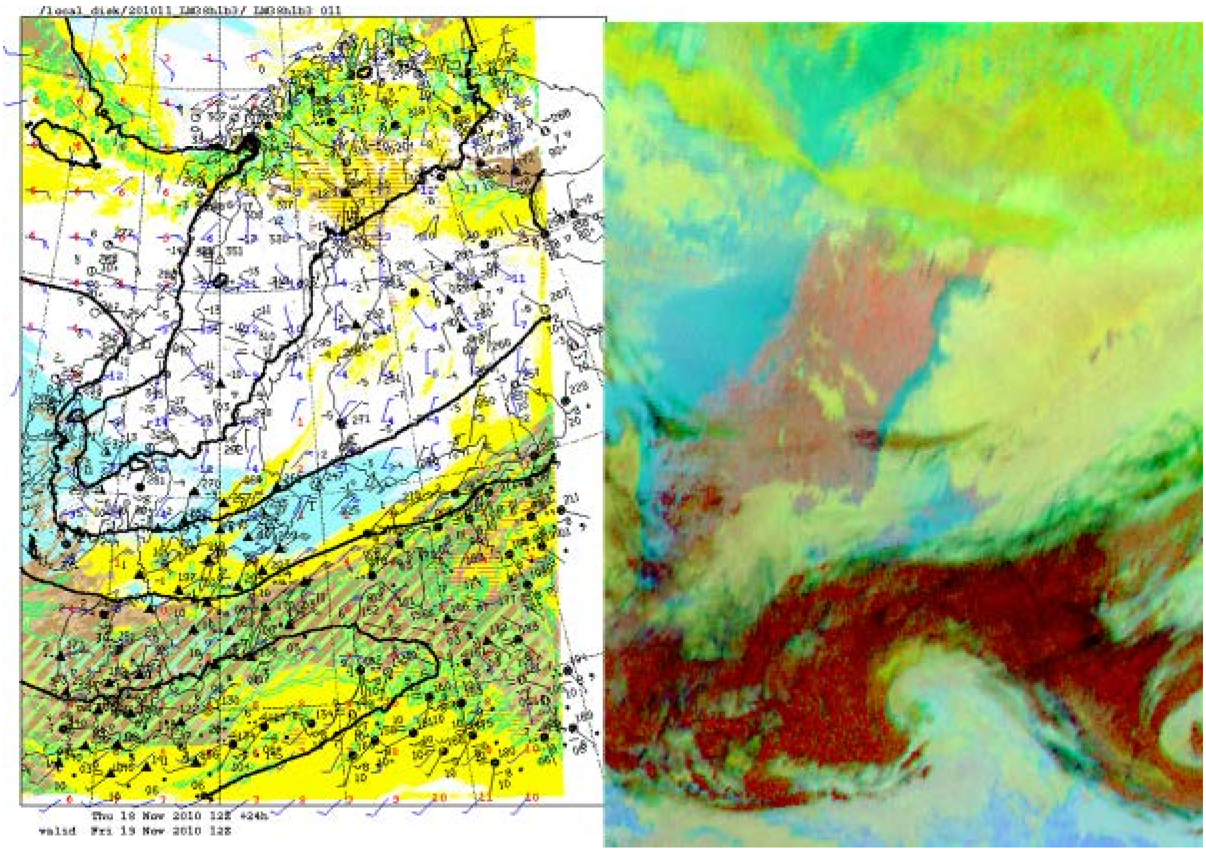

Figure 17 To the left is the reference forecast issued at November 18 2010, 12 UTC and valid 24 hours later. Low clouds are yellow, middle level clouds brown and high clouds blue. To the right is the satellite picture at valid time. Low clouds are yellow, middle level clouds are yellow, light brown or dark red dependent on the temperature and the type of cloud condensate. High clouds are black or dark red.

The large area of low clouds (stratus) covering Finland is nearly absent in the reference forecast (Figure 17), whereas other clouds are well predicted, except for too much cirrus over some parts of central Sweden and southern Norway.

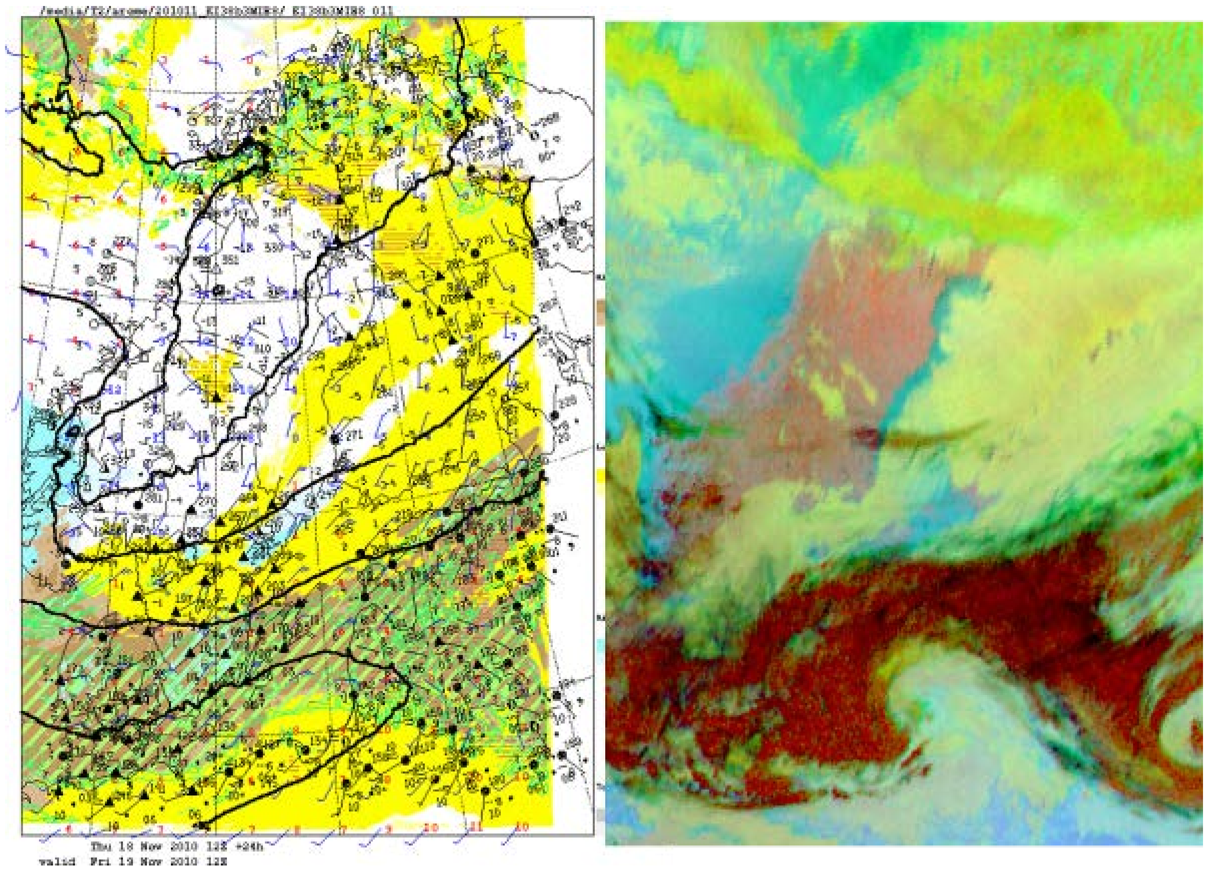

Figure 18. To the left is the forecast with the modified scheme issued at November 18 2010, 12 UTC and valid 24 hours later. Low clouds are yellow, middle level clouds brown and high clouds blue. To the right is the satellite picture at valid time. Low clouds are yellow, middle level clouds are yellow, light brown or dark red dependent on the temperature and the type of cloud condensate. High clouds are black or dark red.

The same comparison with the modified scheme (Figure 18) shows that low cloud over Finland is quite accurately predicted and the cirrus clouds over southern Norway and central Sweden are reduced compared to the reference forecast. The forecast is therefore more similar to the satellite picture.

A similar comparison as in Figure 17 and Figure 18 is done in Figure 19 and Figure 20. This is a situation with colder weather compared to the previous one, where the 2m temperatures are about 10-20 °C below freezing.

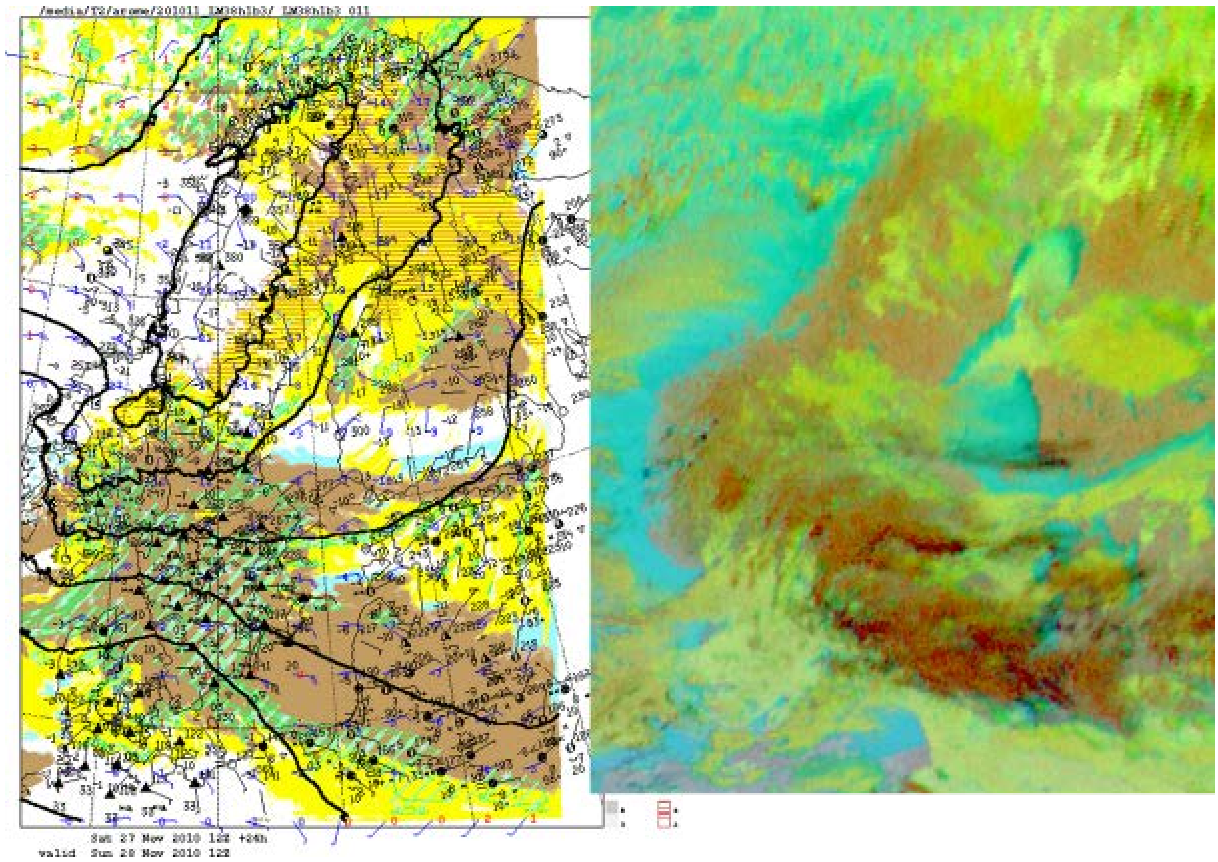

Figure 19. To the left is the reference forecast issued at November 27 2010, 12 UTC and valid 24 hours later. Low clouds are yellow, middle level clouds brown and high clouds blue. To the right is the satellite picture at valid time. Low clouds are yellow, middle level clouds are yellow, light brown or dark red dependent on the temperature and the type of cloud condensate. High clouds are black or dark red.

Over southern parts of Norway and Sweden there is easterly wind with some areas of heavy snowfall.. Over Finland and northern Sweden there are patches of low cloud but also several areas with clear sky. The reference forecast has large areas with cloud cover at the lowest model level, which may be interpreted as ice-fog.

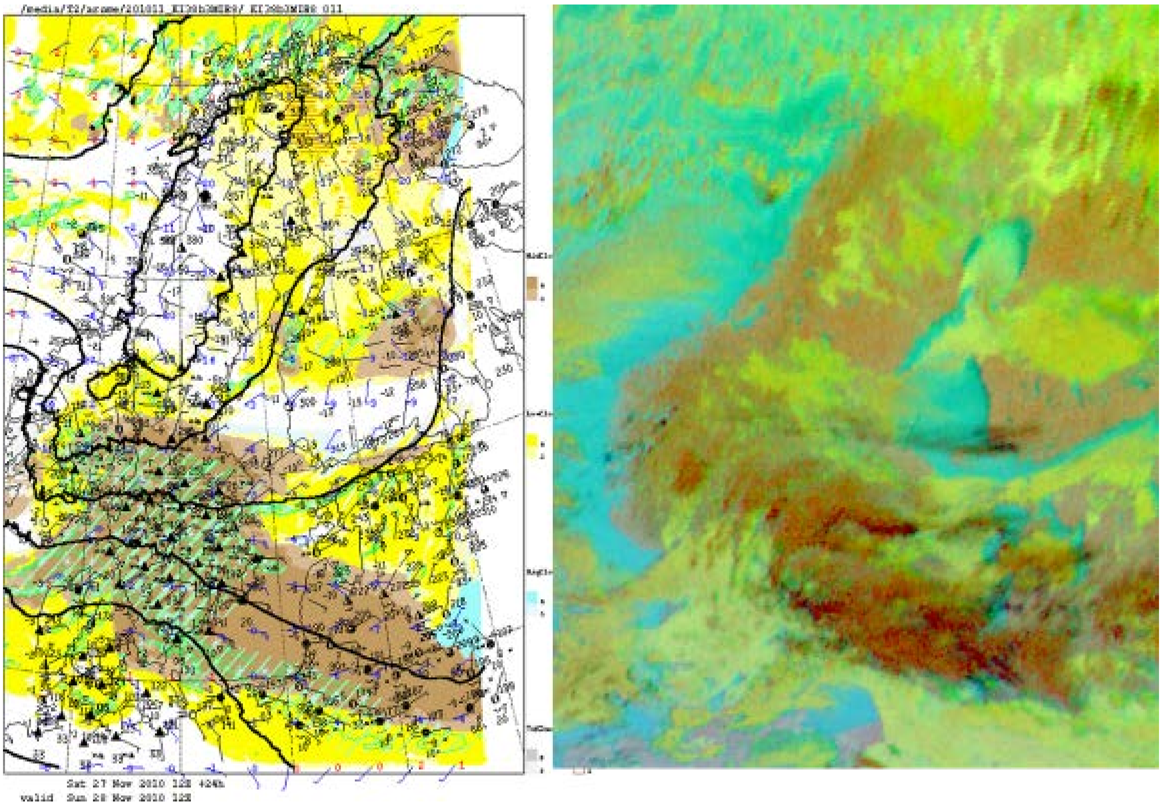

Figure 20. To the left is the forecast with the modified scheme issued at November 27 2010, 12 UTC and valid 24 hours later. Low clouds are yellow, middle level clouds brown and high clouds blue. To the right is the satellite picture at valid time. Low clouds are yellow, middle level clouds are yellow, light brown or dark red dependent on the temperature and the type of cloud condensate. High clouds are black or dark red.

The modified forecast (Figure 20) has much smaller areas with cloud cover at the lowest model level and also less low clouds over Finland and northern Scandinavia, than the reference forecast (Figure 19). Although this modified version of the forecast is far from perfect, the errors regarding low clouds are reduced compared to the reference forecast.

The 12 hours precipitation for the experiments at November 28 is compared with observations in Figure 21.

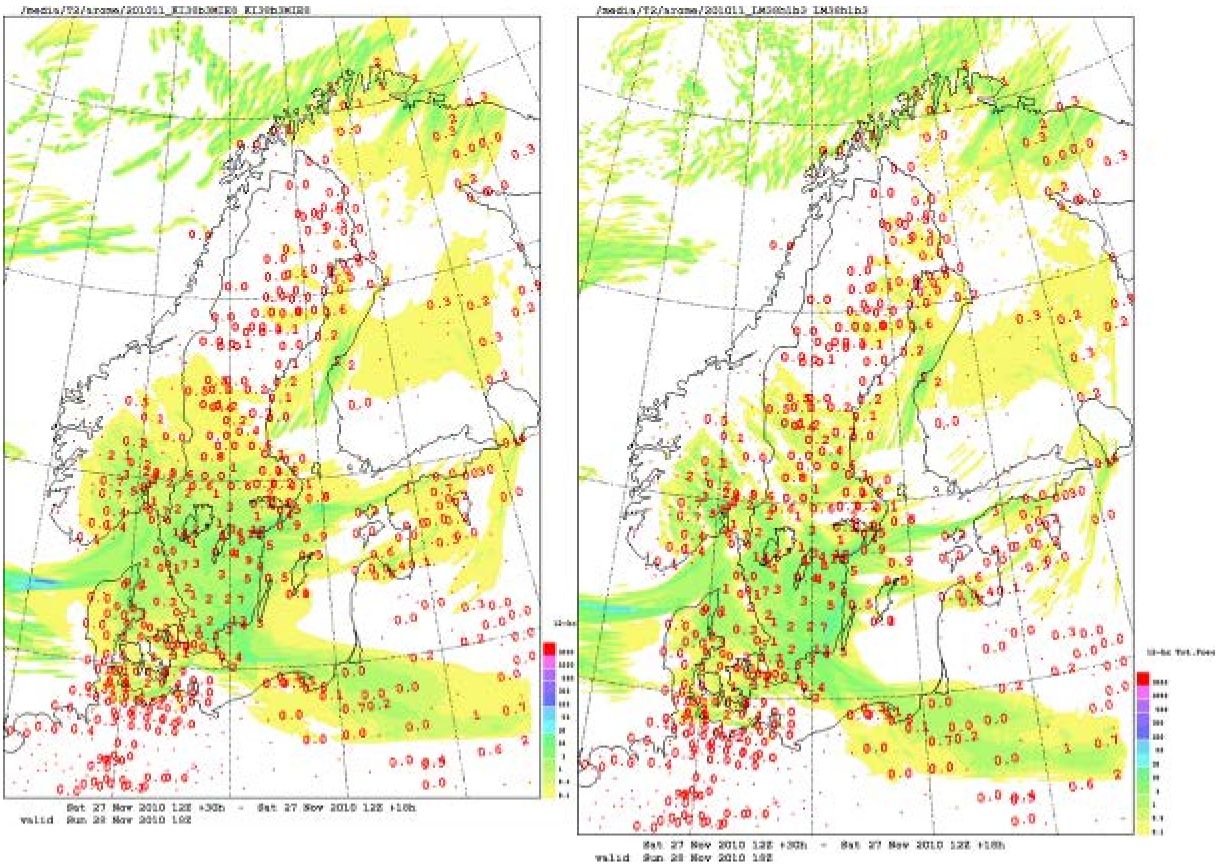

Figure 21. Forecast of 12h precipitation issued at November 27 2010 at 12 UTC and valid between 06 and 18 UTC the following day. The forecast precipitation is illustrated with different colors and the observations are as red numbers. To the left is the modified version and to the right is the reference version.

The widespread area with snowfall which contains parts with heavy snowfall is well captured in both forecasts. Both forecasts suffer from having large areas with light precipitation, which according the observations are not present. Those areas are seen in Figure 21, for example over central Finland and southeast Norway, and are somewhat more widespread with the modified scheme (to the left)

3.7 Example from the summer period

24-hours precipitation from the two experiments is compared with observations from climate stations over Norway and Sweden in Figure 22.

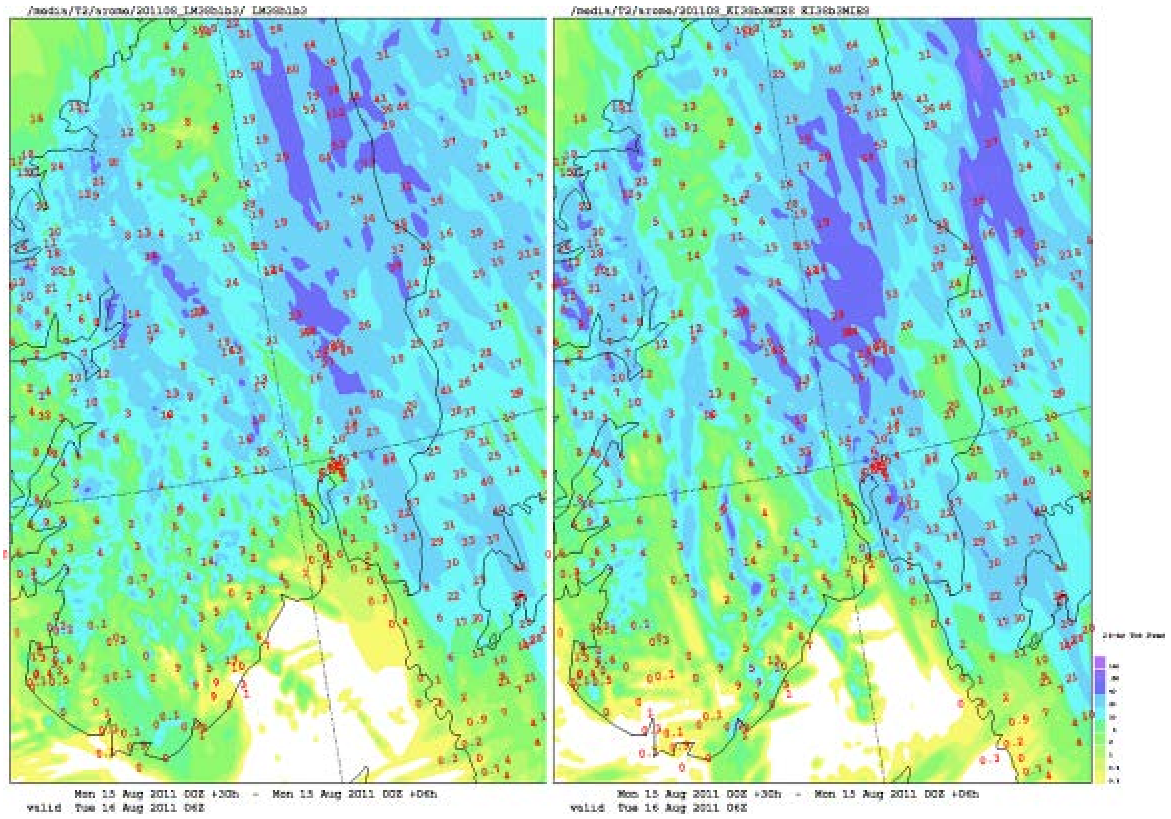

Figure 22. 24 h precipitation August 15 06 UTC to 16 06 UTC over south Norway and parts of southwest Sweden. Rain gauge measurements with red numbers, and forecast precipitation illustrated with different colors. The reference forecast to the left and the forecast with the modified ICE3 scheme to the right.

None of the forecasts shown in Figure 22 are able to place locally high amounts of precipitation to the right positions, but in general both versions capture the area where the highest precipitation is located. High amount of precipitation is too frequent with the modified scheme, and one example of this is seen here over southeast Sweden. The reference version gives too often small or moderate amounts of precipitation, exemplified here by the precipitation pattern over the southernmost part of Norway.

4 Summary

<u>Score card</u>: 38h1b3 mod ICE vs 38h1b3 ref (basic material) for the **summer period August 2011.**

Explanation: **0 :** equal, **(+), (-)**: slightly better, worse, **+ -** : better, worse

38h1b3 mod ICE vs 38h1b3 ref. **2011-08**	param	Norway	Sweden	Whole	Comments
R2M	RMSE	(-)	-	(-)	
10m wind	RMSE	(-)	(-)	(-)	
	FB	0	0	0	
	ETS8	(-)	(-)	(-)	
	ETS14	0	0	0	
Precipitation	3h ETS		(-)		Only Sweden
	FB 12h	(-)	(+)	(-)	Overforcasted large precipitation amounts using modified scheme
	12h ETS 0.3mm	(+)	(+)	+	Better FBSS for lower precipitation amounts for the modified scheme
	12h ETS 3mm	(-)	-	-	
	12h ETS 10mm	-	-	-	
T2M	ETS	(-)	(-)	(-)	
	RMSE	-	(-)	(-)	Slightly lower temp. in mod
Cloud base			-		Only Sweden (ETS + FB)
Total Cloud Cover	FB	(+)	+	(+)	
	ETS	(+)	+	+	

Score card: 38h1b3 mod ICE vs 38h1b3 ref (basic material) for the **winter period Nov-Dec 2010.**

Explanation: **0 :** equal, **(+), (-)**: slightly better, worse, **+ -** : better, worse

38h1b3 mod ICE vs 38h1b3 ref. **2010-11/12**	param	Norway	Sweden	Whole	Comments
R2M	RMSE	0	(+)	(+)	Both too dry
10m wind	RMSE	(+)	(-)	0	
	FB	(+)	(+)	(+)	
	ETS8	(+)	(+)	(+)	
	ETS14	+	(-)	(+)	
Precipitation	3h ETS		(-)		Only Sweden
	FB 12h	-	0	-	
	12h ETS 0.3mm	-	(-)	(-)	Worse FBSS for lower precipitation amounts for the modified scheme
	12h ETS 3mm	-	0	(-)	
	12h ETS 10mm	-	(-)	(-)	
T2M	ETS	(+)	(+)	(+)	
	RMSE	0	+	+	
Cloud base			++		Only Sweden
Total Cloud Cover	FB	++	+	(+)	
	ETS	+	++	++	

AROME has been run with the reference version 38h1b3 for one summer period and one winter period, and the same version of AROME with some modifications of the ICE3 scheme. The results for the tested modified scheme can be summarized in the following way:

- Summer: Mainly neutral impact.
- Winter: Better 2m-temperature, clouds, cloud base and more realistic upper air relative humidity. Somewhat worse precipitation forecasts.

4.1 Remaining problems

Although there are clear improvements seen with the modified scheme, some problems still remain:

- Slightly too low temperature in the lower troposphere in winter.
- Too much light precipitation (both snow and graupel) in winter.
- Too much very strong precipitation, especially in summer.

The moderate negative bias of temperature in the lower troposphere may be related to radiation or to too little cloud condensate at higher levels that blocks outgoing longwave radiation. There is also a possibility that it is related to an error in the vertical mixing. The slightly worse MSLP seen with the modified scheme is also likely to be coupled with this cold bias.

The overprediction of light precipitation in winter found when using the modified ICE3-scheme is not understood. It could partly be a cloud top entrainment problem, which means that moisture that in reality is removed upwards from the boundary layer by turbulent mixing, is in the model transported downwards as light precipitation. The overprediction of light precipitation is less pronounced with the reference version. This is probably due to the rapid removal of moisture in the boundary layer by precipitation. This leads to either no precipitation, since the clouds are already diluted, or to higher intensity of precipitation if clouds are still present. This may explain the larger frequency bias for 3-10mm/12h with the reference scheme (Figure 9) than with the modified scheme.

The overprediction of very heavy precipitation, seen especially in summer with the modified scheme, may be related to the ability to predict higher supersaturation with respect to ice. This may lead to more released precipitation locally.

4.2 Plans after March 2014

The cloud-physics work within MetCoOp ended in March, but continues within the Hirlam cooperative. Issues planned and/or ongoing are:

Test to include modifications of the turbulence scheme, suggested by Wim de Rooy, KNMI.

Test to increase maximum cloud thickness in EDMF scheme. (Now set to 4000m, a higher value seems to reduce the too-high frequency-bias of large precipitation amounts seen in summer)

Continued studies of the microphysical processes, tunings (Such as constants used for qamma functions etc) Collision efficiency factor for cloud droplets <– >snow , graupel currently set to 1. Should rather be dependent on cloud droplet size as in e.g. Hirlam. The same for accretion (=liquid collected by rain).

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6 Figures and tables

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