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MetCoOp

SMHI

Modification of Arome ICE3 cloud physics

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Short background to the modifications:

Although the cloud physics in the AROME is rather advanced and generally work well, there are two weaknesses that are addressed here:

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

The two weaknesses are assumed to be related to:

- The first one is because there is too little of mixed-phase clouds. The reason is probably that there is a too active generation of cloud ice and solid precipitation, which too quickly removes moisture. (by the Bergeron-Findeisen process)
- The second one is because there is too much of ice clouds. (such as cirrus, ice clouds or fog near ground in winter in case of low temperatures) Clouds appears as soon as the relative humidity is close to 100%. The different physical properties of ice clouds compared to water clouds are not fully included in the model physics.

Brief description of the changes of the ICE3 physics

- More rigorous separation of fast cloud liquid water related processes from slower ice water processes. This is achieved by:
- The statistical cloud-scheme only handles water- and mixed phase cloud cover. Only the amount of cloud-liquid is now calculated from this scheme.
- The Bergeron-Findeisen process is derived as a conversion from vapour to ice.
- 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 to the cloud fraction, since the optical properties of solid precipitation are 'cloud-like' and not too different from that of cloud ice.
- Total cloud cover is the sum of the liquid fraction and ice fraction.

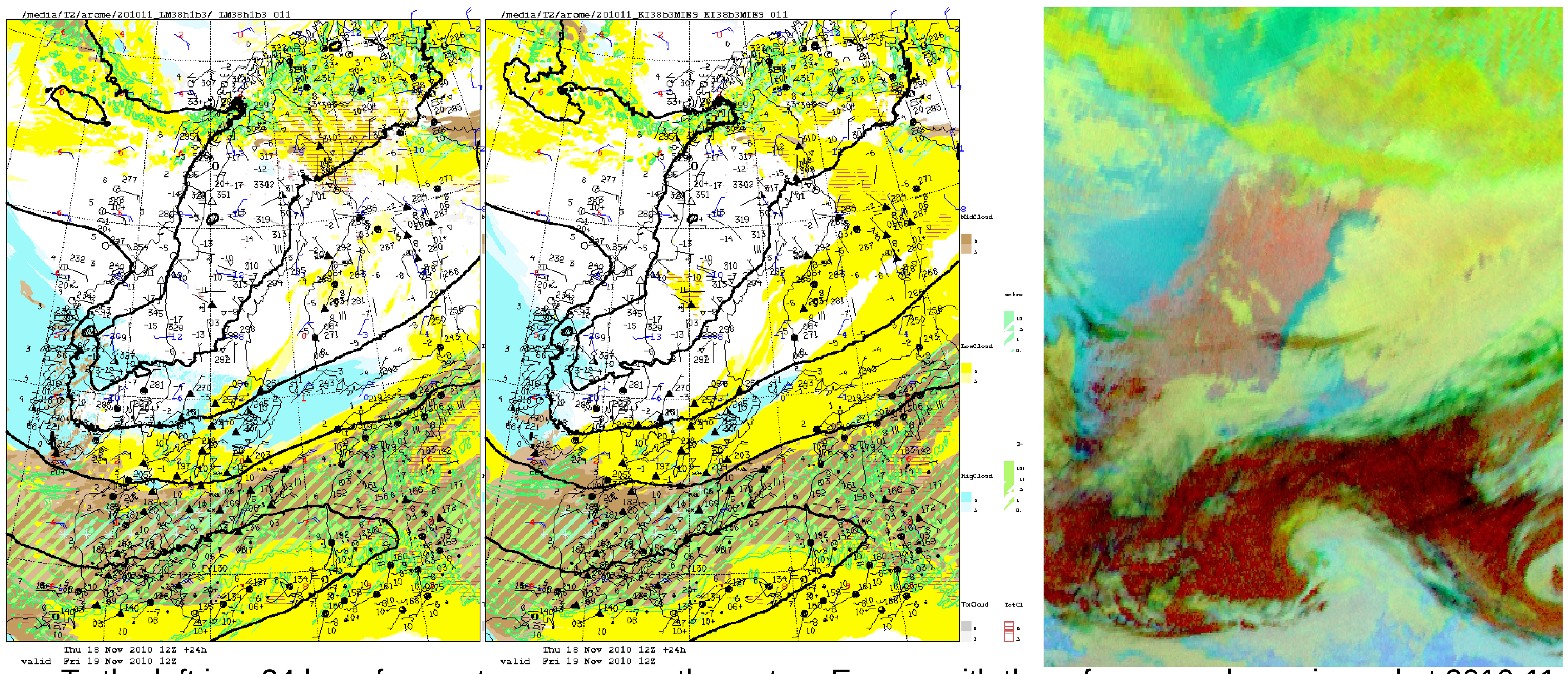
The ice cloud fraction used for post-processing and radiation is dependent of model thickness, since ice clouds are generally considerable optical thinner than water clouds.

Preliminary results

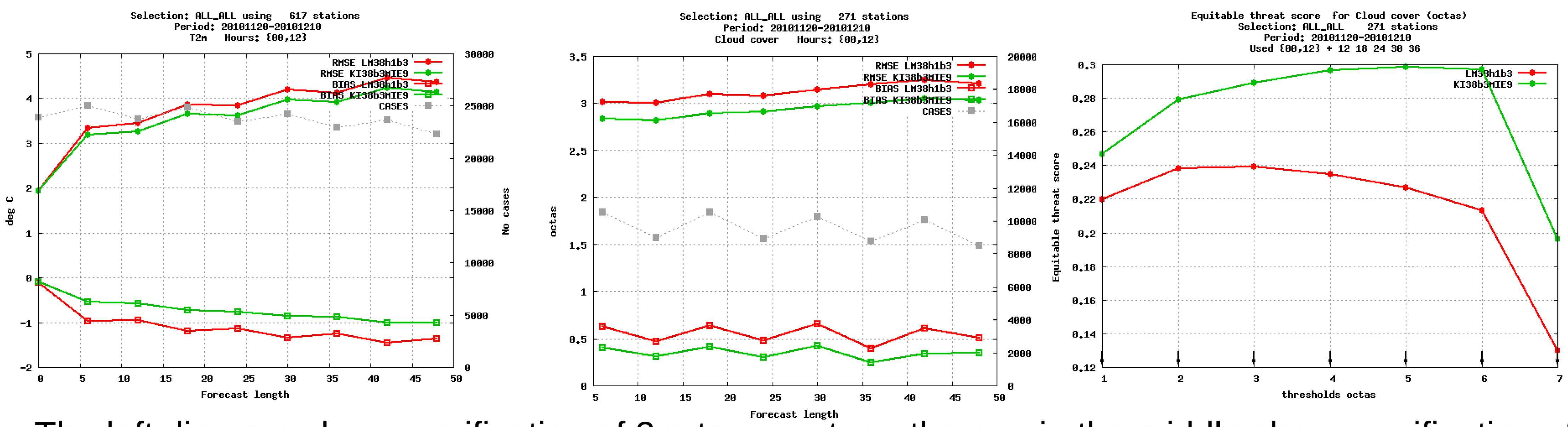
- Winter: Better T2m, clouds, cloud base and more realistic upper air relative humidity, (but not lower RMSE). But a little worse precipitation forecasts.
- Summer: Mainly neutral impact.

Remaining problems:

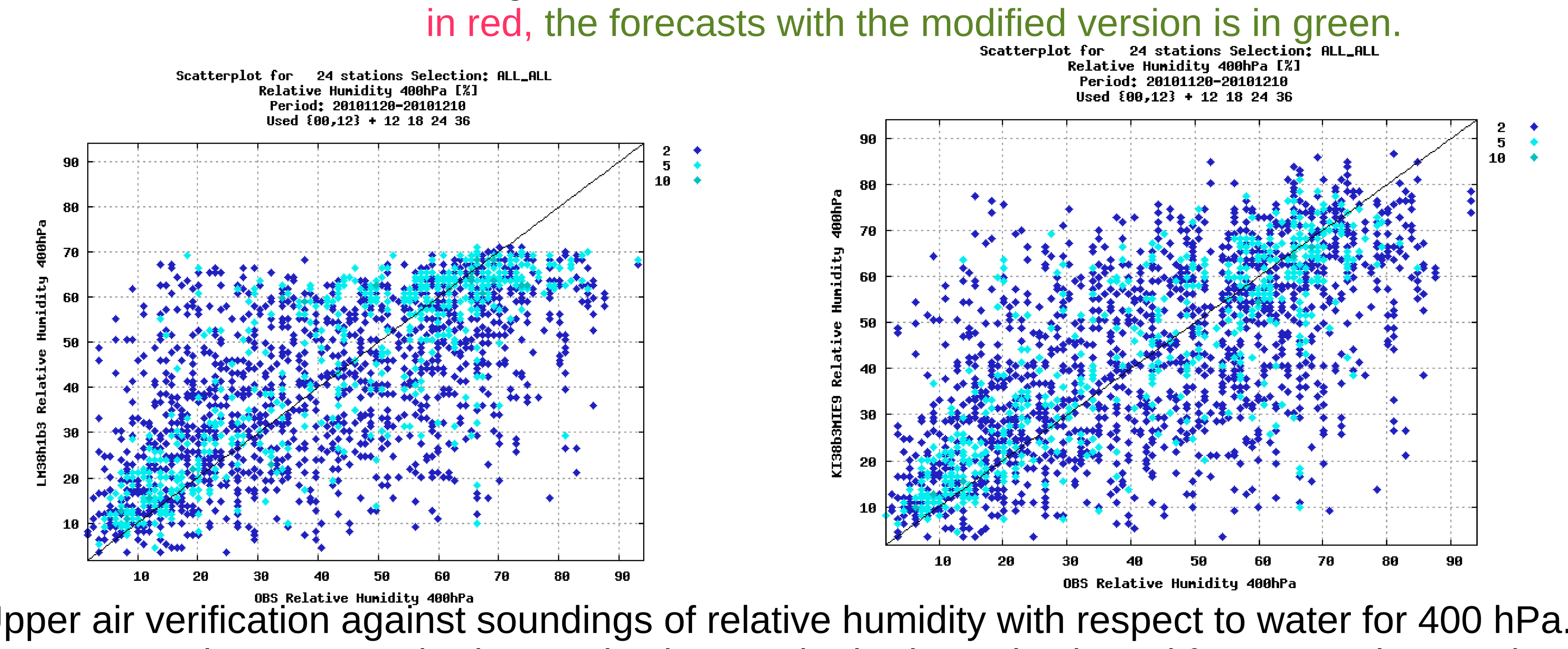
- A little too cold lower troposphere in winter. (Negative bias increased from -0.1 to -0.2 K for 36-48 hours forecasts) Probably a reason for a slightly worse MSLP. (Radiation?, too little of cloud condensate?, turbulence?)
- Too much of light precipitation (=snow, graupel) in winter (could be a cloud top entrainment problem, since moisture that should be removed by vertical mixing at the cloud top, instead falls out as precipitation)
- Too much of very strong precipitation, especially in summer.



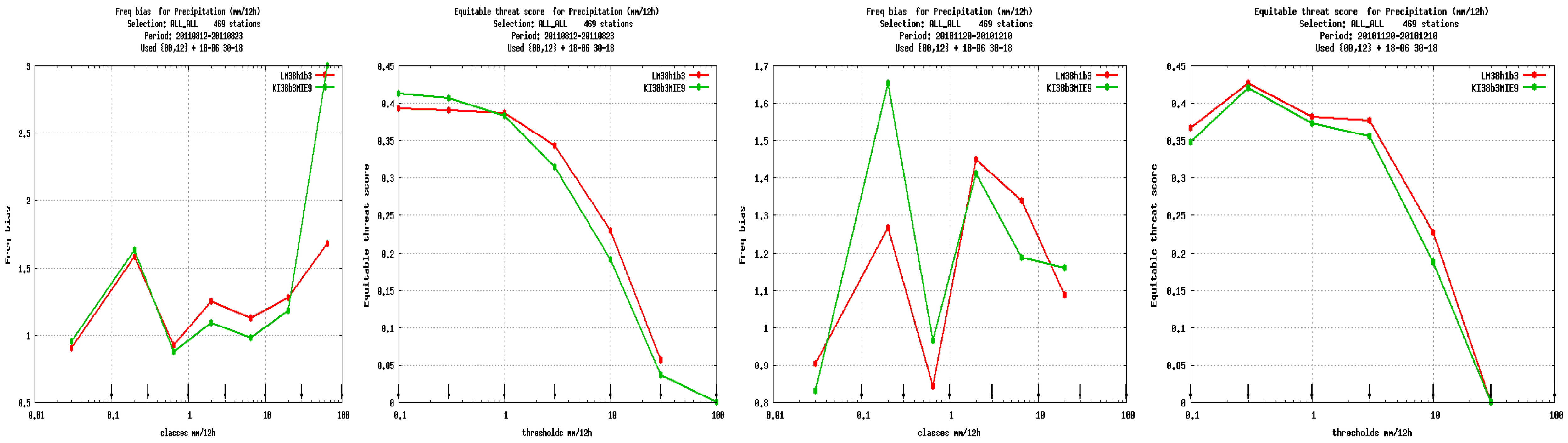
To the left is a 24 hour forecast map over north-western Europe with the reference scheme issued at 2010-11-18 12 UTC. In middle is the corresponding forecast maps with the modified scheme. To the right is a satellite picture for the valid time. Low water clouds are yellow in both the forecast maps and the satellite picture. High clouds are blue in the forecast maps, but black or brown in the satellite picture. Forecasts of middle level clouds are brown, but may be everything from dark-yellow to black on the satellite picture, dependent on height and of the type of cloud condensate. The low clouds are less under-predicted with the modified scheme.



The left diagram shows verification of 2m-temperature, the one in the middle shows verification of total cloud cover. RMSE and bias at vertical axis and forecast lengths at horizontal axis. Both the bias and the RMSE are reduced with the modified scheme. The model domain is north-western Europe and the period is November 18 to December 10, 2010. To the right is cloud cover forecasts verified with the Equitable Treat Score (ETS) for different thresholds in octas. Thresholds in octas at the horizontal axis and ETS values at the vertical axis. Higher ETS, means better forecast. The forecasts with the reference version is in red, the forecasts with the modified version is in green.



Upper air verification against soundings of relative humidity with respect to water for 400 hPa. (November 18 to December 10, 2010) Observed values at the horizontal axis and forecast values at the vertical axis. The number of cases are illustrated by different colours. To the left is result with reference scheme, and to the right is with the modified scheme. The reference scheme is unable to predict supersaturation with respect to ice for temperatures at this pressure level in winter. (about -30 to -55 C), so humidities roughly above 70% are missing, but are present with the modified scheme, as well as in the observations.



Verification of 12-hours precipitation shows two still unresolved weaknesses of the modified scheme. The two diagrams to the left are verification results for at wet summer period, August 12 – 23, 2011. To the very left is the frequency bias for different amounts of precipitation. The amount of precipitation is at horizontal axis and the frequency bias at vertical axis. The other diagram to the left shows ETS for different thresholds of precipitation. The two diagrams to the right has the same information but for the period November 18 to December 10, 2010. The forecasts with the reference version is in red, the forecasts with the modified version is in green. The frequency bias should be near one, but the modified version has too large frequency bias for the highest amount of precipitation (about 3 for 30-100mm/ 12h) for the summer period, In winter, an over-forecasting is seen for precipitation amounts between 0.3 and 1 mm. However, the ETS values are not very different between the two experiments.