Norwegian
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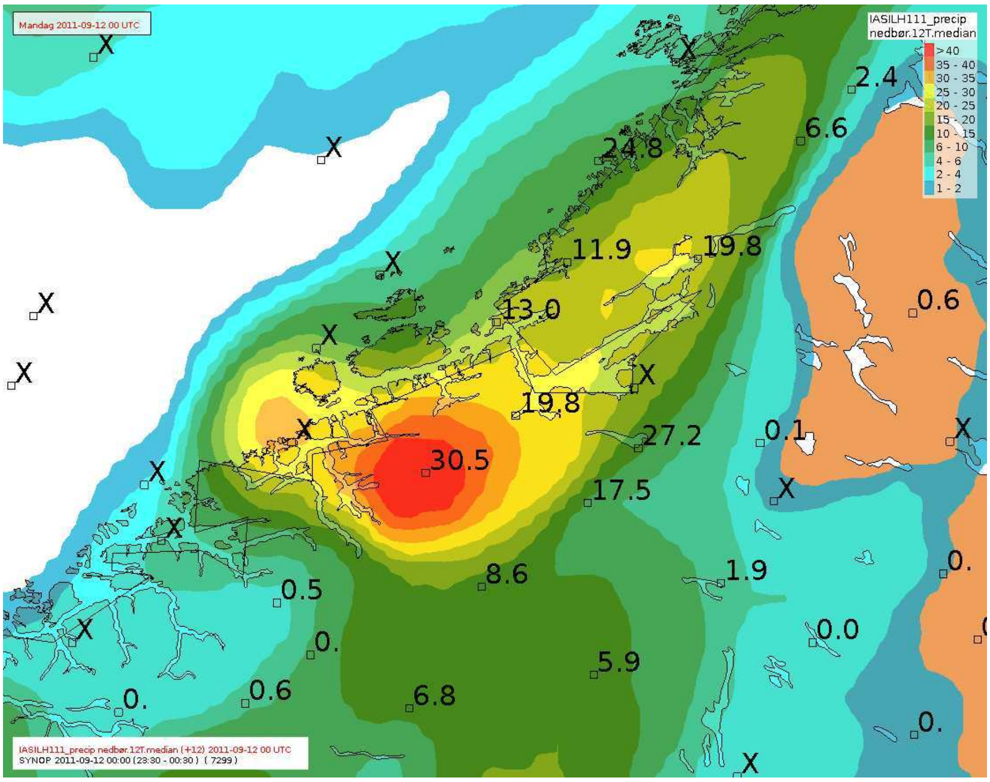
MET report

no. 20/2013
Numerical
Weather
Prediction

Assimilation and impact of IASI moisture channels

Roger Randriamampianina, Máté Mile and Harald Schyberg



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Abstract

This project deals with the assimilation of IASI radiances with the aim to monitor and forecast the water regime over our region of interest. The impact of the IASI data was evaluated using the non-hydrostatic AROME-Norway model and its assimilation system. While, after an accurate monitoring, the active temperature sensitive channels were selected avoiding vertical redundancy, our focus was on using as much as possible humidity sensitive IASI channels. Among 73 selected active channels, originally 38 humidity sensitive channels were selected. After a detailed impact study, a need of new set of humidity sensitive channels was necessary. In general, the impact of IASI data on surface parameters was found to be rather slightly positive than neutral. We have demonstrated that the accuracy of the radiance assimilation can be improved with accurate selection of the active channels. For example, avoiding channels that are sensitive to relatively thin atmospheric layers, had positive impact. The fact that IASI data are not used at 00 UTC due to their unavailability caused visible deficiencies in the forecast performance. Moreover, we also found through case studies that assimilating IASI radiances over cloudy conditions may be essential for a continuous and accurate model performance.

Keywords

IASI, humidity sensitive channels, data assimilation

Disiplinary signature

Responsible signature

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Abstract

This project deals with the assimilation of IASI radiances with the aim to monitor and forecast the water regime over our region of interest. The impact of the IASI data was evaluated using the non-hydrostatic AROME-Norway model and its assimilation system. While, after an accurate monitoring, the active temperature sensitive channels were selected avoiding vertical redundancy, our focus was on using as much as possible humidity sensitive IASI channels. Among 73 selected active channels, originally 38 humidity sensitive channels were selected. After a detailed impact study, a need of new set of humidity sensitive channels was necessary. In general, the impact of IASI data on surface parameters was found to be rather slightly positive than neutral. We have demonstrated that the accuracy of the radiance assimilation can be improved with accurate selection of the active channels. For example, avoiding channels that are sensitive to relatively thin atmospheric layers, had positive impact. The fact that IASI data are not used at 00 UTC in our area due to their unavailability caused visible deficiencies in the forecast performance. Moreover, we also found through case studies that assimilating IASI radiances over cloudy conditions may be essential for a continuous and accurate model performance.

Acknowledgements:

The verification work was done with help from Hirlam Colleagues, and in particular from Ulf Andræ and Xiaohua Yang. The case study was done with DIANA visualisation tool and enormous helps from Lisbeth Bergholt. We thank as well Christoffer A. Elo for providing the processed radar data for the case studies. We are grateful to Jørn Kristiansen for fruitful discussion and suggestions, which improved the quality of this report. Further, METCoOp[1] scientific group provided the background error statistics, which were used in this study.

1 METCoOp - **Met**eorological **Co**-operation on **Op**erational NWP

1. Introduction

Nowadays, it becomes more and more difficult to provide reliable weather forecasts without using numerical weather prediction (NWP) models. As member of the European Centre for Medium Range Weather Forecasting (ECMWF), the Norwegian Meteorological Institute (MET Norway) have real-time access to the ECMWF weather forecasts. These weather forecasts are issued twice a day in a global scale with a horizontal resolution of about 16 km. At MET-Norway we run also limited area models (LAM) for a better analysis and forecast of local phenomena and mesoscale processes.

The accuracy of a NWP model depends on the quality of its initial condition, which is usually the result of the so-called data assimilation procedure. The data assimilation process takes into account the available observations and a priori (called also first-guess or background, and usually a short-range model forecast) atmospheric state, as well as their respective uncertainties (observations and background error estimates). Accurate use of more (locale) observations certainly lead to improved initial condition. Norway and its area of interest cover ocean areas where relatively few conventional observations (here we mean for example different surface, radiosonde, and aircraft measurements) are available compared to what can be found over western Europe or north America. So, remotely sensed data, like satellite or radar observations are of great interest to improve the NWP model performance.

This work focuses on the use of the IASI (Infrared Atmospheric Sounding Interferometer) radiances (*Chalon et al.* , 2001) with the aim to monitor and predict the water cycle over our area of interest. Thanks to their good quality and their positive impact on NWP analyses and forecasts, IASI radiances are used in most of operational NWP models (*Collard et al.* , 2010; *Hilton et al.,* 2009; *Guidard et al.*, 2011). In frame of the Norwegian IPY-THORPEX project (*Kristjánsson et al.*, 2011), we have already demonstrated the positive impact of IASI radiances on HARMONIE[2]-Norway analyses and forecasts (*Randriamampianina et al., 2011*). However, only IASI data from temperature sensitive channels were used. Initial experiments (Aspelien et al, 2013) with an other version of the HARMONIE model showed a very small, but slightly positive, overall impact of IASI moisture channel assimilation. The small magnitude of the effect of the observations was probably because the experiments used a very limited set of moisture channels, covering the upper tropospheric region with relatively small moisture values only. In the present study, focusing further on the humidity sensitive channels, we attempt to be less conservative and more aggressive in selecting the active channels. Other important difference is that in the previous studies a hydrostatic model, based on the ALADIN[3] model (*Randriamampianina and Storto*, 2008), were used. Here we use a convection-resolving non-hydrostatic model AROME (*Seity et al.*, 2010) version of the HARMONIE system.

While usually the forecast of temperature and wind are the most requested, an accurate forecast of precipitation become more and more demanded not only for daily comfort but also for other important applications, e.g. agriculture. Precise short-range, and even better nowcasting (0-6 hour) forecast of precipitation is very important for hydrological applications, like for example hydropower management and regulation, early warning and disaster management.

This report is structured as follows. While the Section 2 gives an overview of the components of the NWP model used in this study, the Section 3 describes the performed experiments and discusses the obtained results. In Section 4 some conclusions are drawn and possible further development of the system is discussed.

2 HIRLAM ALADIN Research on Mesoscale Operational NWP In Euromed

3 Aire Limitée, Adaptation Dynamique Dévelopement InterNational

2. The AROME-Norway assimilation and forecast system

The characteristics of the AROME-Norway (using the AROME physical parametrisation) used in this experiment is very similar to one used operationally at MET Norway since 1 October[4]. As default setting in the Harmonie system, the spectral blending of the ECMWF field is used at zero-time step (Vignes, 2011). While the operational AROME-Norway model runs only with updated of surface parameters through optimal interpolation analysis scheme (OI_MAIN), in this experiment we update also the upper-air atmospheric fields using three-dimensional variational analysis (3D-VAR) scheme. Together with the conventional observations (surface, radiosondes, pilots, aircrafts) and IASI radiances, the ATOVS (AMSU-A, AMSU-B/MHS) data were also assimilated (see table 1 for more details). The horizontal resolution of model is 2.5 km (with 750x960 grid points) with 65 vertical atmospheric levels ranging from roughly 12 m (level 65) till 10 hPa (level 1). "Cheaper version" set-up was chosen, which means that the experiments were done with 6-hourly cycling, performing analyses at 00, 06, 12 and 18 UTC. Also, for verification purposes, longer forecasts ranges (48 hours) were performed at 00 and 12 UTC only. Version ***cy37h1.2*** of the Harmonie model was used in all experiments. In this experiment we used hourly ECMWF forecasts are used as lateral boundary conditions (LBC). Figure 1. shows the model domain extension.

Table 1: The use of different observations in the AROME-Norway assimilation system.

Type	Parameter (Channel)	Bias correction	Thinning
TEMP	U, V, T, Q, Z	Only T using ECMWF tables	No
SYNOP	Z	No	Temporal and spatial
PILOT (Europrof.)	U, V	No	Redundancy check against TEMP
DRIBU	Z	No	Temporal and spatial
AIREP	U, V, T	No	25 km horizontal
AMSU-A	5 to 10	Variational	80 km horizontal
AMSU-B, MHS	3, 4, 5	Variational	80 km horizontal
IASI	73 channels	Variational	80 km horizontal

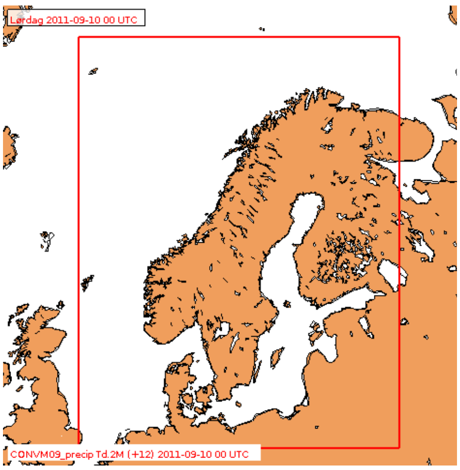


Figure 1. The AROME-Norway model domain extension.

2.1 Radiance data processing

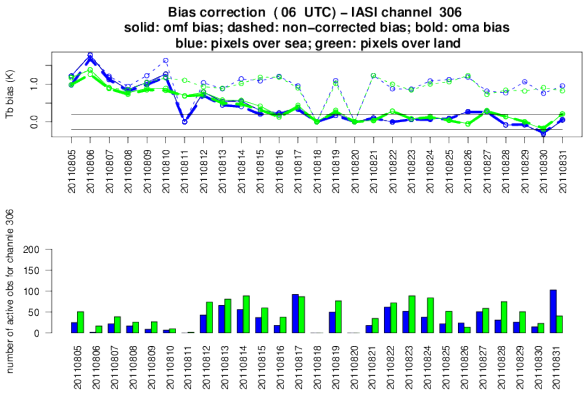
For the radiance data processing, version 9 of the RTTOV (radiative transfer for TOVS) model is used (*Matricardi et al.*, 2004). RTTOV uses coefficients calculated by training a regression with a

4 http://om.yr.no/2013/10/09/nytt-og-bedre-vaervarsel-for-norge-og-om-vaervarslet-for-resten-av-verden/

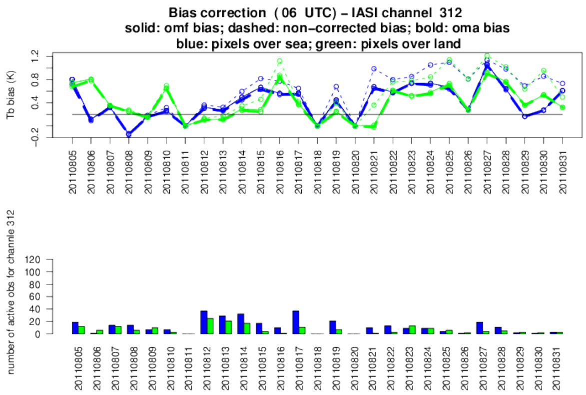
line-by-line model. The IASI radiances are processed using the coefficients derived from the line-by-line RTM (LBLRTM) (*Clough et al.* 1992; 2005). For radiance data simulation, 43 vertical levels are used, ranging from 0.1 – 1013.25 hPa. The microwave radiances are processed at their full resolution in the system according to *Randriamampianina* (2006). The same for IASI radiances, data from all IASI fields of views (FOVs) from all fields of regards (FOR) are used. In this study we followed the suggestions made by *Lindskog et al.* 2012, with respect to the computation and selection of the predictors for radiance bias correction. The "adaptivity" of the variational bias correction (VarBC) scheme was tuned so that the parameters nbg_AMSUA, nbg_AMSUB, nbg_MHS, and nbg_IASI were set to be 2500 instead of the default value (5000) in the system. Due to the fact that the model top is 10 hPa, the predictors 5 and 6 are not used for radiances bias computation. According to *Lindskog et al.* 2012, we do not use the predictor 2 in this experiment.

The coefficients for the VarBC were estimated for August 2011, while the experiments were done for September 2011. There are several reasons for doing this: 1) the radiance bias coefficients for the AROME-Norway domain were not available, and 2) to have as close as possible simulation of an operational system, where the coefficients ensure accounting for a continuous atmospheric flow influence.

a)



b)



Figures 2: Time series of bias from cold start: a) showing good convergence to the nominal bias (upper plot) – good for selection, and b) no convergence is observed (lower plot) – channel not good for selection.

The usage of the different ATOVS channels at different assimilation times was updated, compared to the default settings, taking into account the availability of the satellite paths inside the model domain. The radiance blacklisting information (the LISTE_LOC file) was also updated taking into account the model top. For example, for AMSU-A, only channels 5-10 were selected.

Similarly, IASI channels peaking above, or around 10 hPa were blacklisted. For secure and accurate estimate of the bias correction coefficients and channels selection, the passive assimilation of the IASI data was done twice. During the second estimate the updated ATOVS channels blacklisting are used. Since the bias coefficients were estimated with cold start, the radiance channels (both for ATOVS and IASI) were selected where smooth convergence to the nominal bias is observed (see for example the *Figs* 2. a-b).

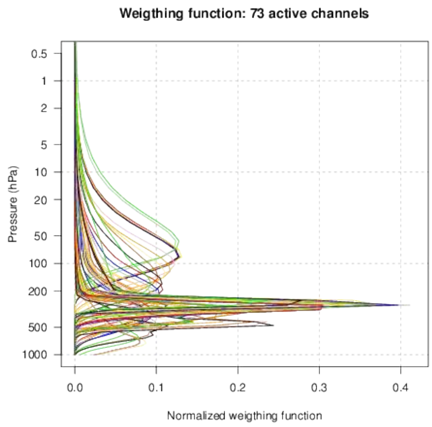
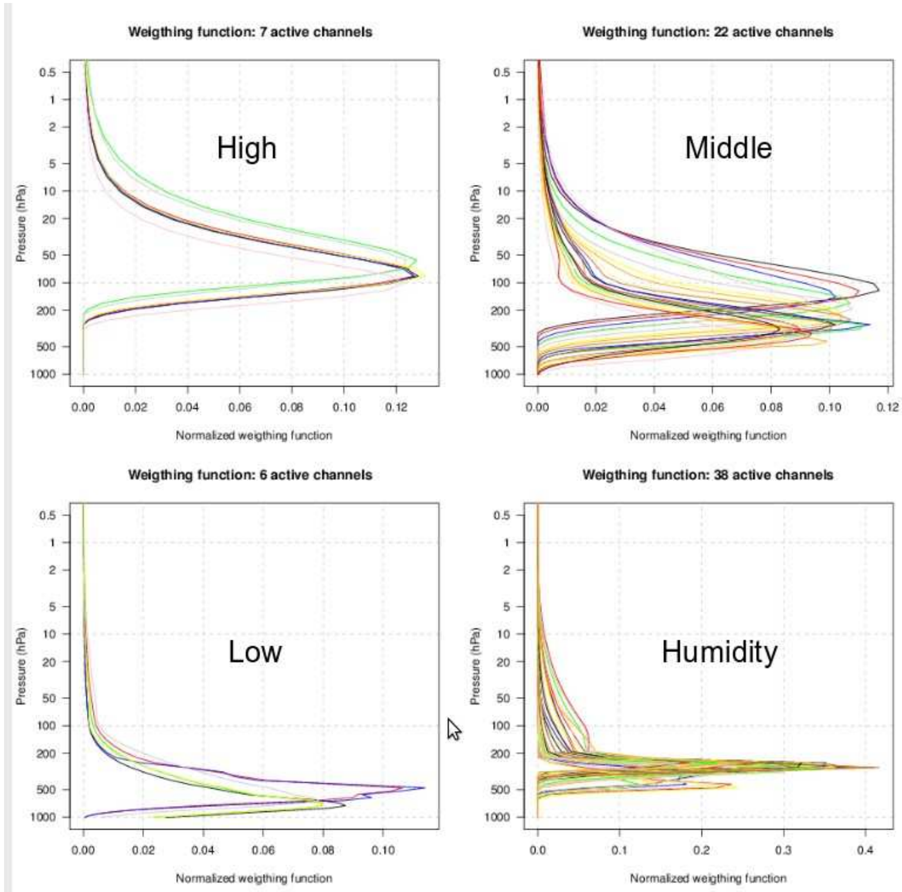


Figure 3: Weighting functions for all the selected 73 IASI channels



Figures 4: Weighting functions for IASI channels sensitive at different atmospheric layers and for the channels sensitive to the humidity.

As argued above, the humidity sensitive IASI channels all the “acceptable” channels were selected. The temperature sensitive channels were selected avoiding redundancy in the vertical. This means that from a set of good channels peaking at the same atmospheric level, only one is kept. This decision reduced the number active temperature sensitive channels by about 50%. *Figures* 3 and 4 show the selected active IASI channels.
The radiances bias correction coefficients are updated separately for different assimilation times, as suggested in *Randriamampianina et al.* 2011. It is worth also to mention that due to the fact that very few IASI data is available at 00 UTC, we decided to blacklist the use of IASI radiances for this particular assimilation time (to know more about the reason of this decision see *Randriamampianina et al.* 2011). Table 2 describes the use of the IASI data.

Table 2: The assimilation of the IASI channels

	High-peaking channels	Middle-peaking channels	Low-peaking channels	Humidity channels
Over sea	38 51 63 85 104 109 167	173, 180, 185, 193, 199, 205, 207, 212, 224, 230, 236, 239, 242, 243, 249, 252, 265, 275, 294, 296, 306, 386	333 337 345 352 389 432	2919, 3008, 3014, 3069, 3087, 3098, 3165, 3207, 3228, 3252, 3256, 3281, 3309, 3312, 3322, 3339, 3378, 3438, 3440, 3442, 3446, 3450, 3454, 3458, 3484, 3491, 3499, 3504, 3506, 3509, 3575, 3577, 3580, 3582, 3589, 3658, 3661, 4032
Over land	38 51 63 85 104 109 167	173, 180, 185, 193, 199, 205, 207, 212, 224, 230, 236, 239, 242, 243, 249, 252, 265, 275, 294, 296, 306, 386	389 432	2919, 3069, 3087, 3098, 3252, 3256, 3281, 3309, 3312, 3339, 3442, 3446, 3450, 3454, 3458, 3484, 3491, 3499, 3504, 3506, 3509, 3575, 3577, 3580, 3582, 3589, 3658, 3661, 4032
Over sea ice	None	None	None	None

3. Impact of the IASI radiances

The impact of the IASI data is discussed comparing the analyses and forecasts of the AROME-Norway model against in-situ observations and the ECMWF analyses. If we used “only” radiosonde data for such a purpose, this would be far from optimal, as it does not allow verification of model accuracy over sea. So, we can be confident regarding the obtained impact in case we find “comparable” results out of both verification references. To explain better the obtained verification results, we also highlight some interesting cases picked out from the studied period.

When verifying the model analyses and forecasts against the observations we checked among other skill scores the following ones. But, we will highlight only few of them in this report:

- bias and root-mean-square error (RMSE);
- time-series of bias and RMSE;
- significance test of the RMSE differences, using a two-sided 90% confidence interval;
- as well as Wilson diagram, False alarm ratio, Kuiper skill score, Frequency bias, Area index, Symmetric Extreme Dependency Score (SEDS), Extremal Dependency Index

(EDI), Symmetric Extremal Dependency Index (SEDI), and Equitable Threat Score (ETS). We can also evaluate the impact of IASI observations taking into account of different domains/regions of interest, as well as different sets of station networks. For example, we have the results of verification over the whole domain, but taking into account only the so-called "EWGLAM[5] stations". The reason of having such a comparison is that these stations are known to have consistently high quality and their list is fixed. One can occasionally access to a bit more data as seen in our case (see *Figs* 5). So, to reproduce our results other scientific groups, for example, should use the EWGLAM network as reference network for verification.

The impact of different sets of observations on the analyses and forecasts was evaluated by running the model with different sets of observations, as mentioned above, for September 2011. The first 4 days of each run were used as warming period. The verification period is then composed of 26 days.

As subject of this project, we focus our analysis on the impact of the sets of observations on the surface parameters, the humidity fields, and the precipitation forecasts.

3.1 The performed experiments

We performed the following experiments to better understand the impact of the IASI data in general, and in particular this study focuses on the impact of humidity sensitive channels on the analyses and forecasts of the AROME-Norway model:

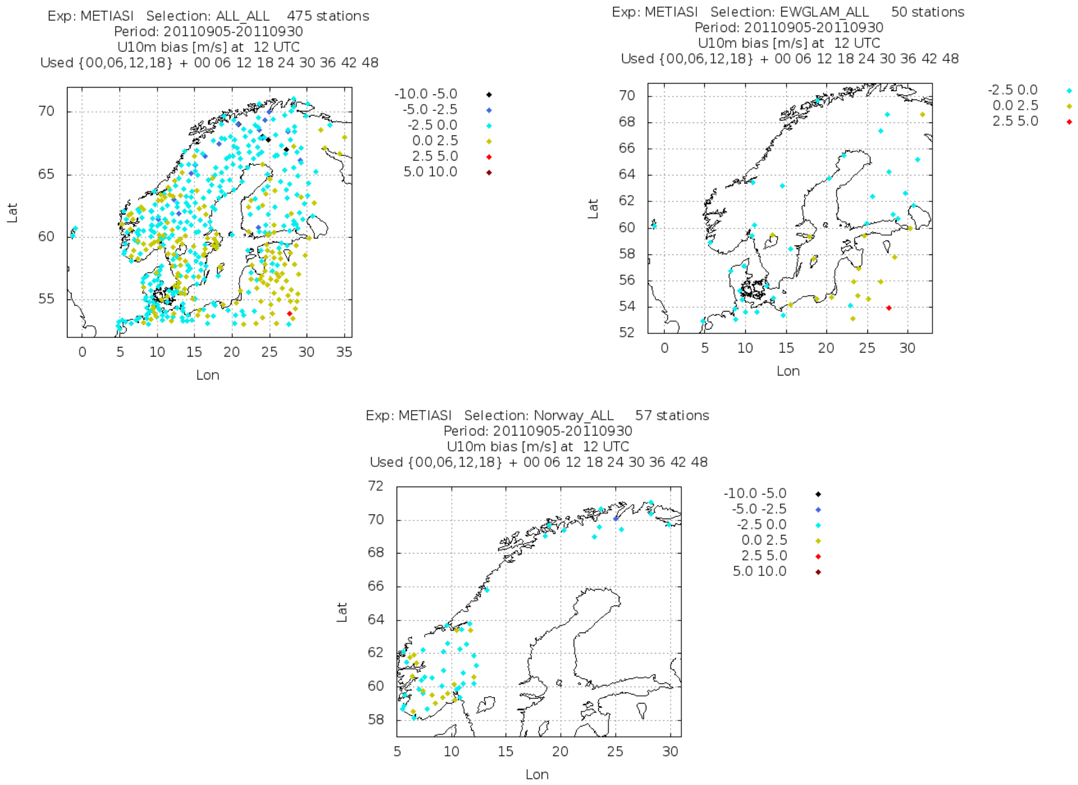
METATOV- Run with conventional and ATOVS (AMSU-A, AMSU-B/MHS) data (referred as reference run);

METIASI- Run with conventional, ATOVS, and all the selected IASI data (this set of the IASI data will be referred later as "full IASI data");

METIASHU- Run with conventional, ATOVS, and the humidity sensitive IASI data (this set of IASI data will be referred later as "full humidity IASI data";

METIASILH1- Run with conventional, ATOVS, and data composed with new selection set of humidity sensitive IASI channels (this set of IASI data will referred as "new humidity IASI data").

5 European Working Group for Limited Area Modelling



Figures 5: Different selections of stations networks. In the title of each plot, the definition of the stations and the used statistics have the following convention: “Selection <stations-network-name>_<assimilation_network_times>”. Where stations-network-name in our case can be “ALL” (using all the available stations), “EWGLAM” (using the EWGLAM stations), and “Norway” (using all the accessible Norwegian surface stations). And, assimilation_network_times can be “ALL” (in this study using 00 and 12 UTC outputs), “00” (using only 00 UTC results), and “12” (using only 12 UTC results).

3.2 Impact of full IASI data

3.2.1 Impact on the surface parameters

The impact of full IASI data is the results of comparing the outputs of the METATOV and METIASI experiments. The positive impact on the surface parameters, as seen for 2m temperature in Fig. 6, is similar our previous result (*Randriamampianina et. al.*, 2011), although the magnitude is relatively smaller.

The impact of full IASI data on the 12-h accumulated precipitation forecasts are presented in Fig. 7. Even though IASI data are not assimilated at 00 UTC there is clearly an indirect impact through the model first-guesses from the 18 UTC analyses. For some cases, the difference is considerable, as seen in the case studies below. There is a slightly different model performance over the selected observing networks. Using all the available observations, at 00 UTC the positive impact is significant for shorter forecast ranges (more precisely, for forecasts between 6 and 18 hour), while for forecasts from 12 UTC the longer forecast ranges (between 30 and 42 hour) seem to be more accurate. In case of 12 UTC run, where the IASI data are actually in use, there is failure of the model to predict certain events inside the model domain, because the verifications based on different stations networks do not show the same model behaviour. On one hand, one can see, for example, positive impact over the EWGLAM stations, even not significant all along the different forecast ranges for both the verified network runs (00 and 12 UTC). On the other hand, the impact is rather neutral over the available Norwegian stations, especially for the case of 00 UTC run, and even negative for longer forecast ranges for the 12 UTC run.

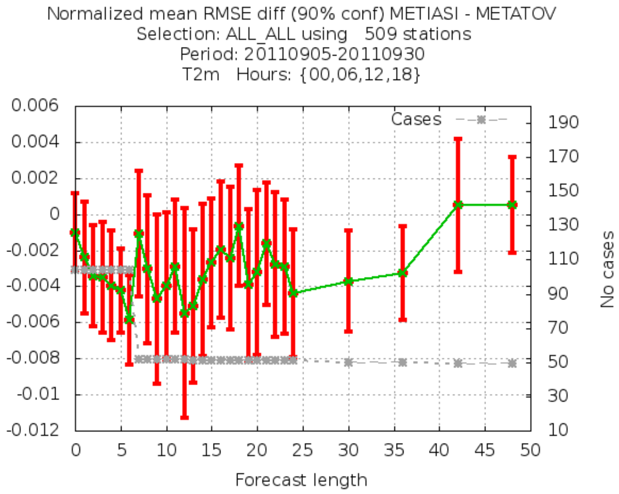
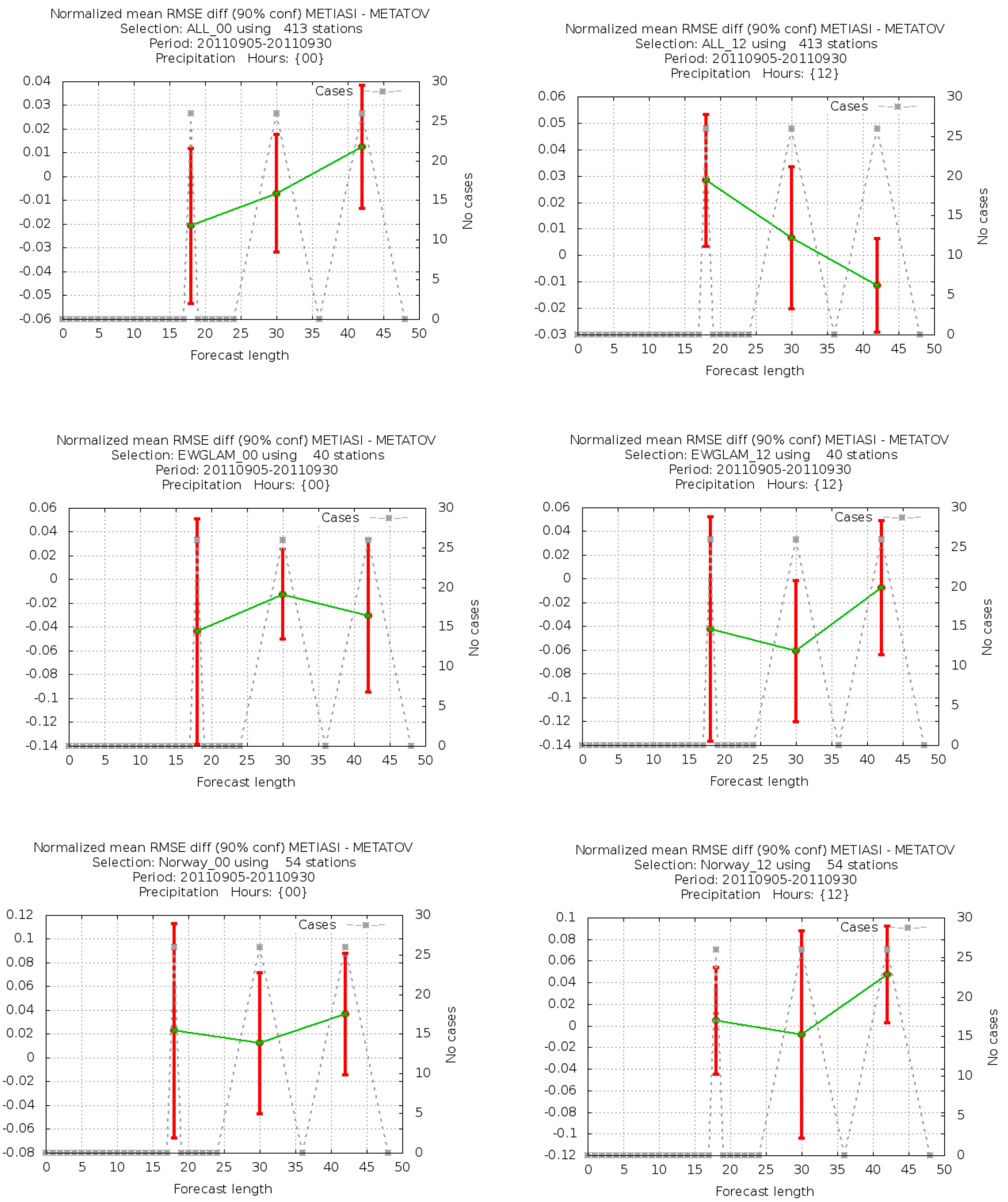
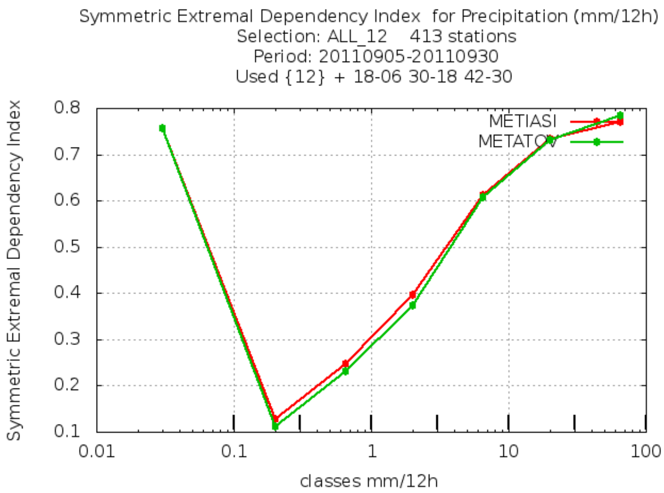


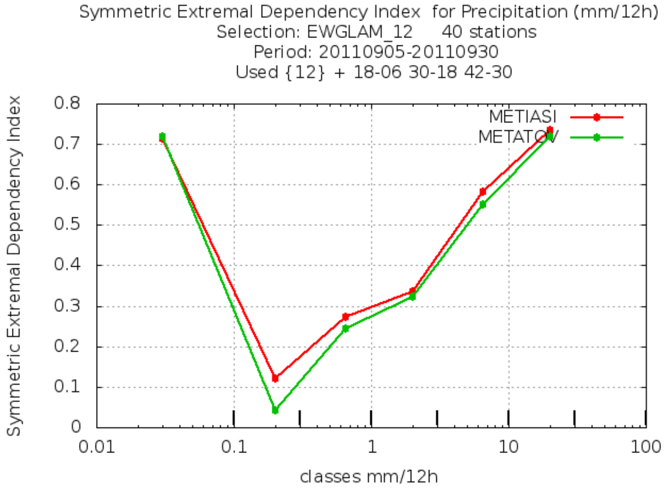
Figure 6: The significance test of the impact of full IASI data on the 2m temperature. Negative value means positive impact of the IASI data.

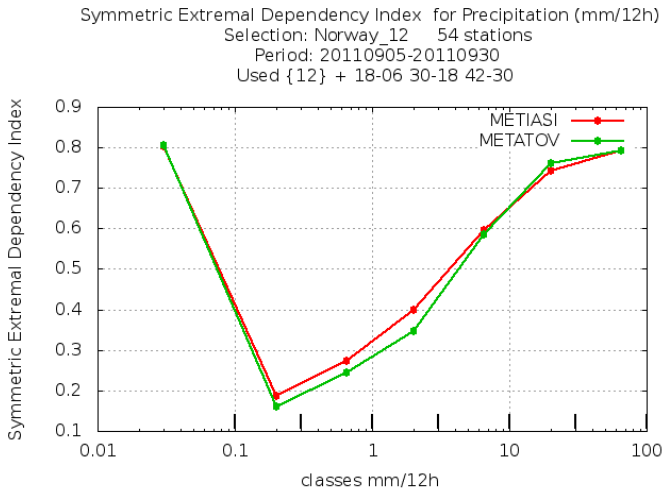
Analysing the forecast skills indicating the performance of the AROME-Norway, we find that the full IASI data improve mostly the forecasts of medium intensity events forecasts (*Fig.* 8). This is true for all the verification networks.



Figures 7: The significance test of the impact of full IASI data over different regions and observing networks. Remember we do not have IASI data at 00 UTC. At this assimilation time the impact comes from the updated guess, which is the 6 hour forecast from 18 UTC model run. Negative value means positive impact of the IASI data.



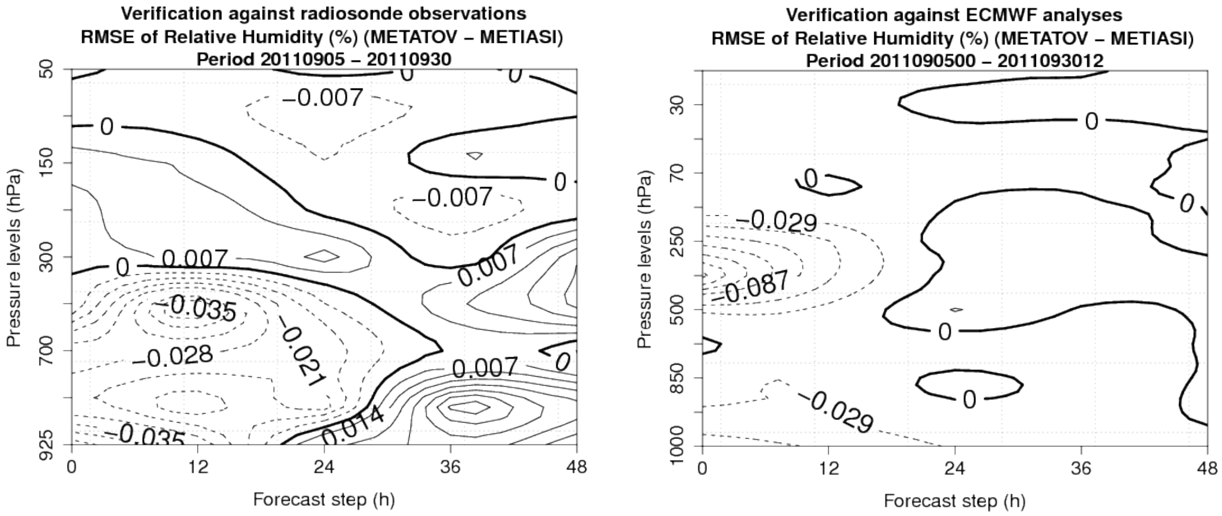




Figures 8: Skill score (SEDI) evaluated using 12-hour accumulated precipitation over different observing networks (all stations – top, EWGLAM stations – middle, and Norwegian stations – bottom). With this skill score the higher the value the better.

3.2.2 Impact on the upper-air fields

The full IASI data has a negative impact on the relative humidity fields in lower troposphere for the day-1 forecast, both when verified against observations and ECMWF analyses, *Fig* 9. The verification against observations shows a positive impact in general for day-2 forecasts. Verification against analyses showed a neutral impact of full IASI data on the other parameters. The verification against observations shows positive impact of full IASI data on day-1 geopotential in the lower troposphere (not shown).



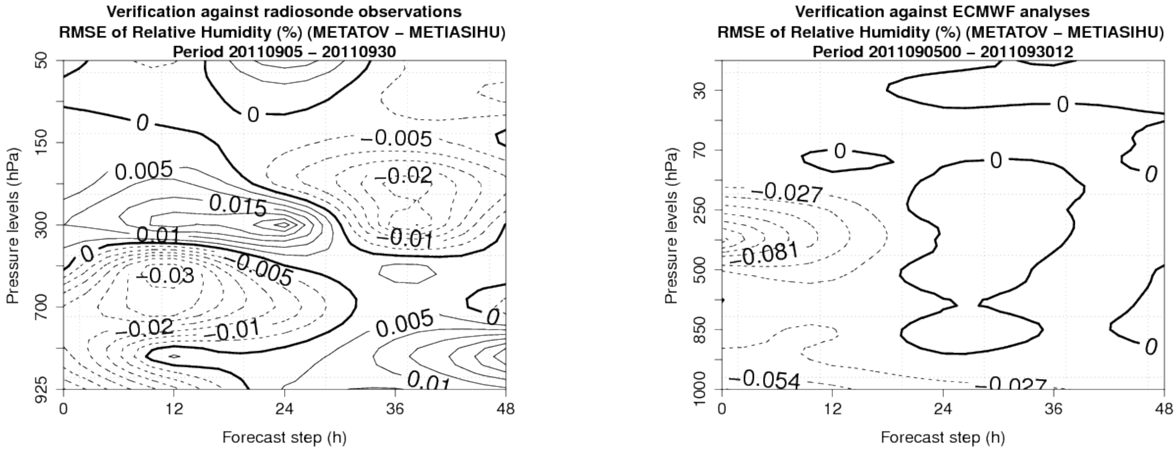
Figures 9: The impact of full IASI data on the upper-air fields estimated on verification against observations (left) and ECMWF analyses (right). Here, we have the RMSE differences. Positive value means positive impact of the IASI data.

3.3 Impact of humidity sensitive IASI channels

3.3.1 Impact on the upper-air humidity fields

Using the full set of the humidity sensitive IASI channels, we found similar negative impact on upper-air humidity fields (*Figs* 10) in lower troposphere for day-1. From the assimilation point of view, there are at least two problematic satellite channels: those which are sensitive to a relatively broad (thick) atmospheric thickness, and those which are sensitive to a relatively thin atmospheric thickness. For the humidity sensitive IASI channels, the latter problem is typical. We revised the list of the active humidity IASI channels avoiding channels sensitive to a relatively thin atmospheric thickness. This decision reduced the number of active humidity sensitive channels from 38 to 21.

The updated set of humidity sensitive channels have clear positive impact on the upper-air humidity fields detected in both the verifications against observations and against the ECMWF analyses (*Figs* 11). In addition, the importance of tuning is seen in Fig. 12. The tuning improves the quality of the day-1 tropospheric humidity fields, even thought the improvement is not always significant (*Figs* 13).



Figures 10: The impact of full humidity IASI data (38 channels) evaluated against observations (left) and against the ECMWF analyses (right). Positive values mean positive impact.

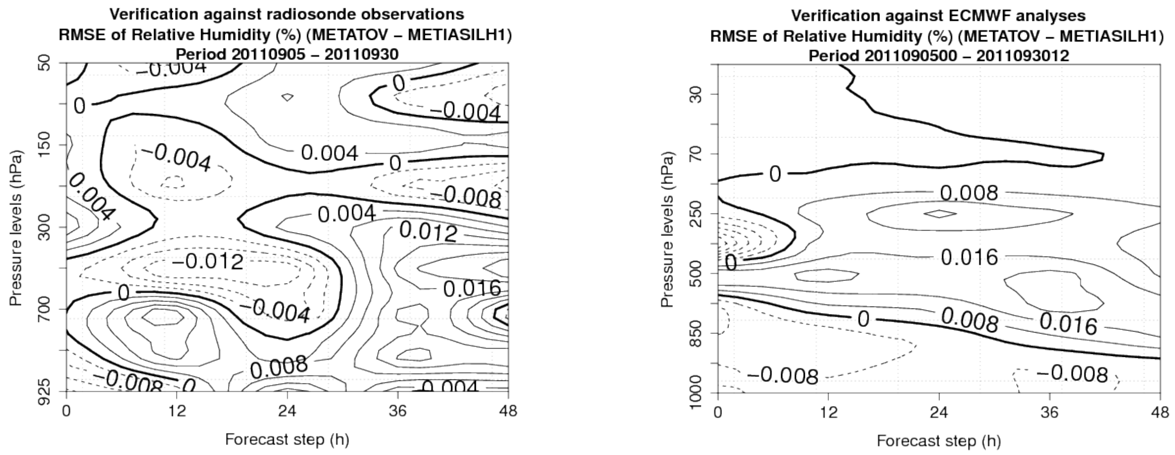
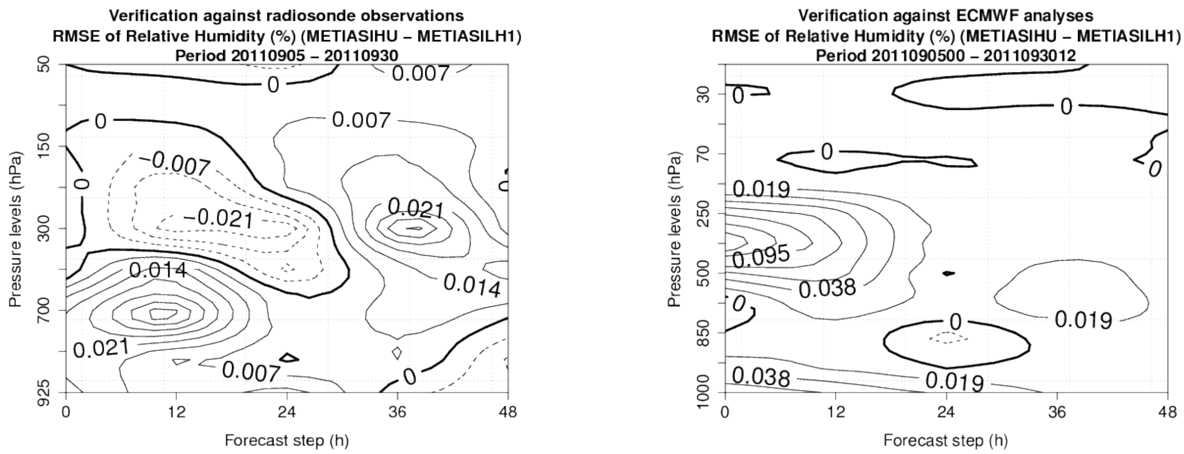
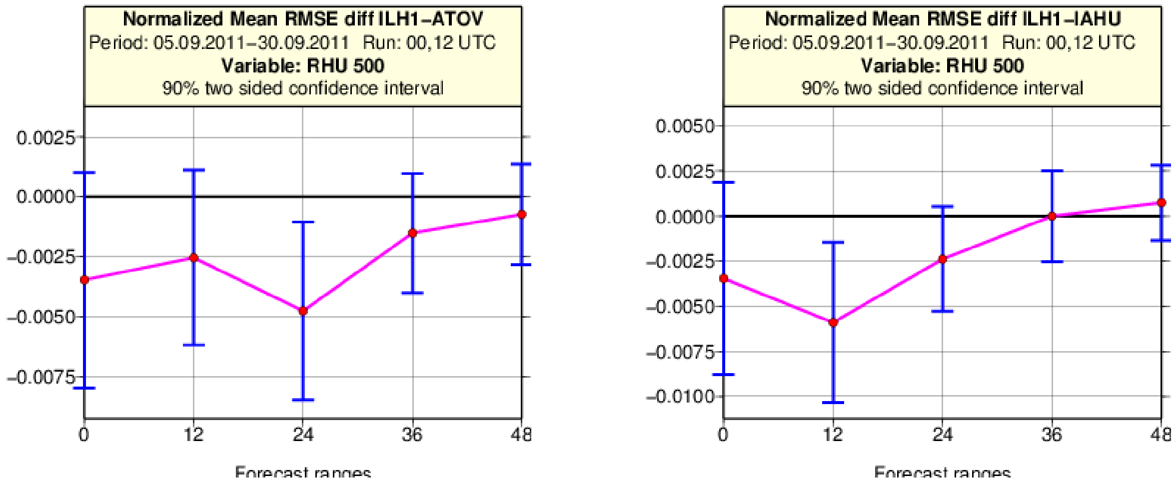


Figure 11: The impact of the new set (21 channels) of humidity sensitive IASI channels evaluated against observations (left) and against the ECMWF analyses (right). Positive values mean positive impact.



Figures 12: The impact of the tuning of the use of humidity sensitive IASI channels evaluated against observations (left) and against ECMWF analyses (right). Positive values mean positive impact.



Figures 13: The significance test of the tuned humidity sensitive channels (left) and significance test of the relative improvement (right) at 500 hPa. Note that for technical reason the experiment names were shorten: ATOV means METATOV, IAHU means METIASIHU, and ILH1 means METIASILH1 experiments.

3.3.2 Impact on the surface parameters

On the 2m temperature the impact of full humidity channels is slightly positive (not shown). The impact of the tuned humidity channels on 2m temperature turned to be neutral (not shown). Regarding the forecasting of the precipitation events, most of the skill scores show that use of the tuned channels list improves the forecast of medium intense and very intense precipitation. This is shared by the verifications over all the available stations, as well as over the available Norwegian stations (*Figs* 14).

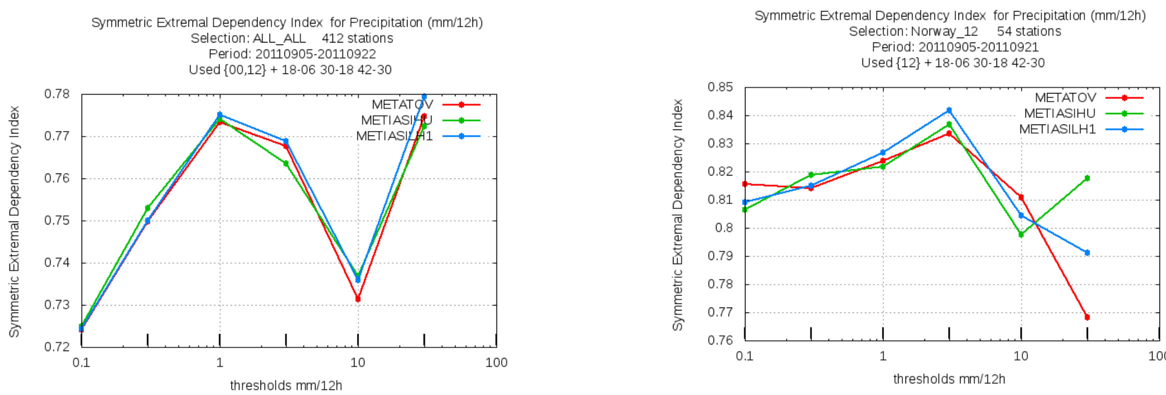


Figure 14: Impact of the humidity sensitive IASI channels (full set in green, and tuned set in blue) evaluated over all available stations (left), and over the available Norwegian stations (right). Note that for SEDI, the higher the skill value the better. Note also that the left plot is based on the two verified assimilation and production networks (00 and 12 UTC), while the right plot is based only on the 12 UTC run – the run using IASI data.

3.4 Case studies

3.4.1 Short description of the weather condition

In September 2011, the weather conditions over the AROME-Norway domain were dominated by successive low pressure systems (cyclones) entering the domain mainly from the west and the Atlantic Ocean. On the 10th a short-lived high-pressure (light anticyclone) formed giving a short-time blocking effect over the coastal part at middle of Norway. This blocking effect on 10th did not last too long, Fig. 15, and from 11th till the end of September at least a part of the domain was always under the influence of different cyclonic formations and developments and the associated rainy conditions. We have checked few days precipitation forecasting performance. In this report, we would like to highlight two of those cases.

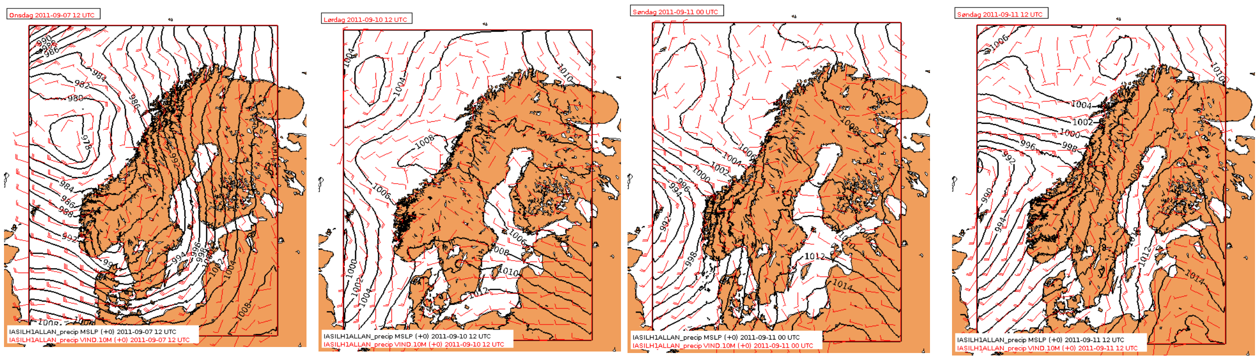
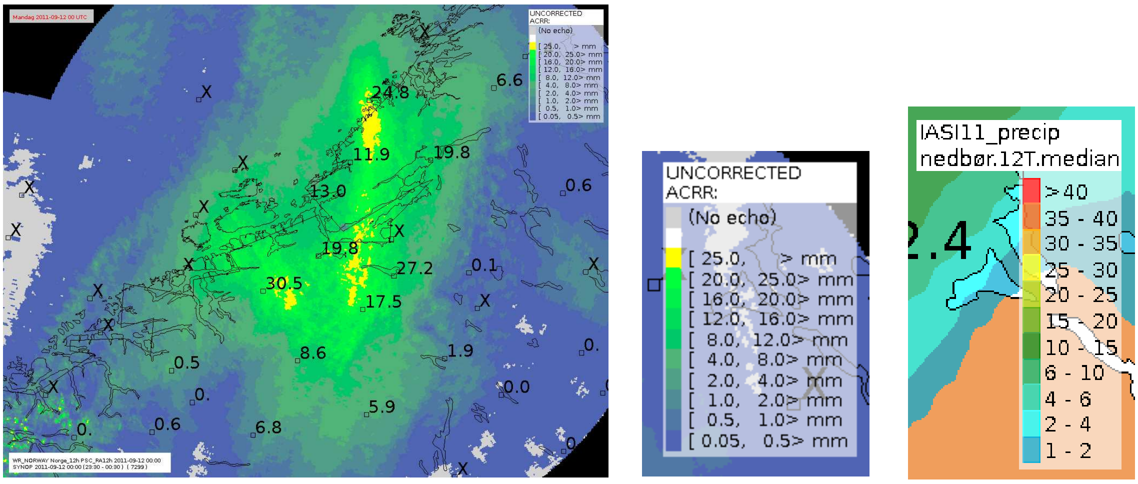


Figure 15: Mean sea level pressure charts describing the weather condition over the AROME-Norway model domain at the beginning of the studied period (7th of September at 12 UTC – extreme left), on 10th of September at 12 UTC (middle left), and on 11th of September, respectively at 00 and 12 UTC (middle and extreme right). The plots are from the analyses of the METIASILH1 runs.

3.4.2 Case of September 12

In this case, the weather condition over the south and western part Norway was influenced by a large cyclone (low pressure) developing over the southern part of the Norwegian Sea. Here, we will focus on a precipitating pattern over Trondheim-fjord and south Trøndelag. Further, we will discuss different forecasts of the 12-hour accumulated precipitation amount valid for September 12 at 00 UTC. The in-situ rain gauge and radar observations, suggest 3 highly precipitating areas (as seen also from the zoomed post-processed radar data, and see Fig 16 caption for more details).

Analysing the ***12-hour forecasts*** (i.e. initialized at 12 UTC 11 September) of the different experiments described in the Section 3.1, one can see that all missed the pattern number 1 (see Fig. 16 for details), although the run with new humidity IASI data (METIASILH1) forecast larger extension of high-precipitating area northward and a local maxima close to the in-situ observation of 19.8 mm/12-h. Judging the forecasting of patterns 2 and 3, one can say that both the reference and the run with full IASI data forecast only “one-eye” high-precipitating area. There is a shift in the position of highest precipitation amounts between the two runs. Both the runs with sets of humidity only IASI data forecast “two-eyes” high-precipitating areas. Hence, they have more local variability compared to the other two runs. From visual inspection the enhanced local variability seems consistent with the observations. Typically, this kind of horizontally shifted forecasts causes “double penalty” in the point verifications, which can be a reason for different skill scores attributed to the high-precipitating events reported above.



Figures 16: The observed 12-hour accumulated precipitation amount from surface (SYNOP – indicated as numbers) overlapped with the post-processed radar data (coloured patterns). The surface rain gauge measurements report 3 places with high amounts of precipitations: north of Trondheim – 24 mm, in the text referred as pattern number 1; a bit south-east of Trondheim – 27.2 mm, in text referred as pattern number 2; and south-west of Trondheim – 30.5 mm, in the text referred as patter number 3. One can see also the legends for the accumulated radar (middle) and modelled forecasts (right).

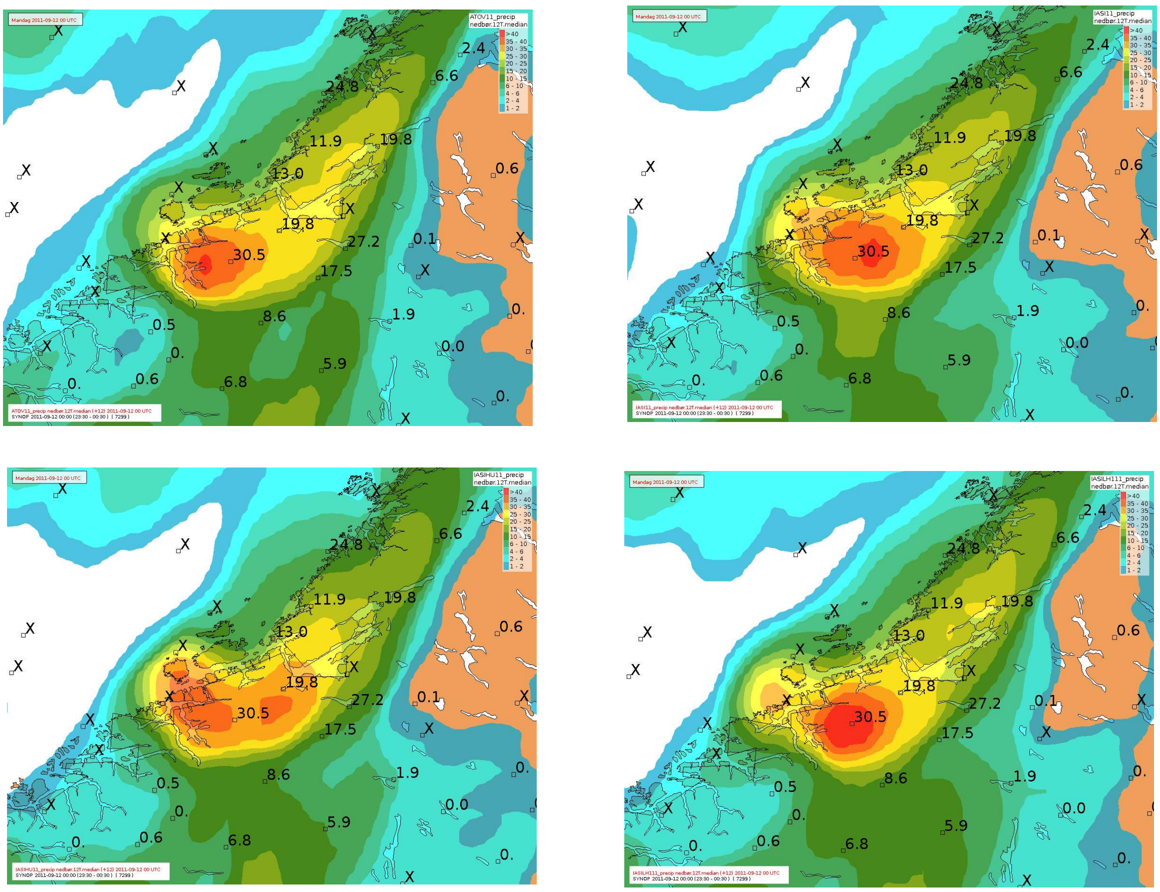
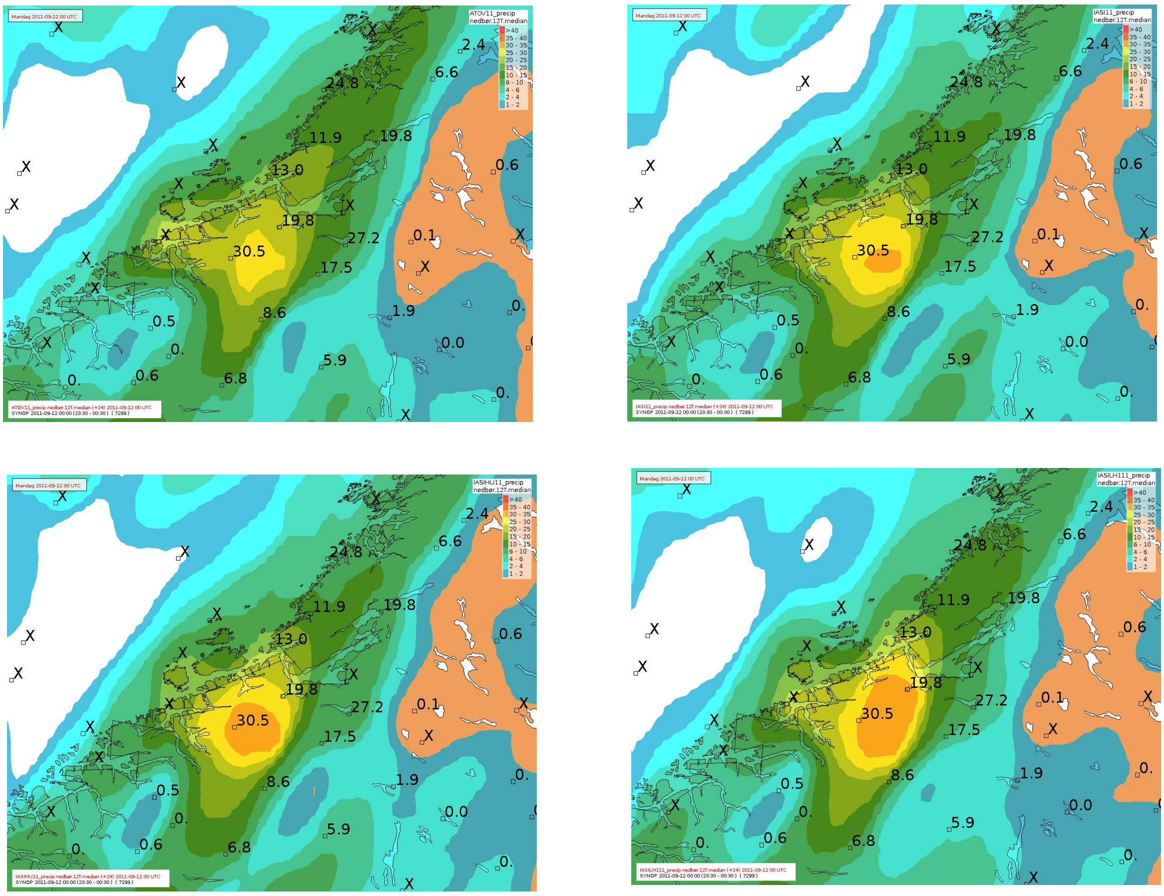


Figure 17: 12-hour forecasts of 12-hour accumulated precipitation amount from different model runs superposed with surface rain gauge measurements (the numbers): reference run (top left); run with full IASI data (top right); run with full humidity sensitive IASI data (bottom left); and run with new humidity IASI data (bottom right).

Regarding the ***24-hour forecasts*** (i.e. initialized at 00 UTC 11 September when IASI data are not available for assimilation, but the first-guess includes IASI observations), all of the runs forecast only "one-eye" high-precipitating pattern, Fig. 18. The runs with IASI data forecast more realistic (higher) rain rates than the reference.



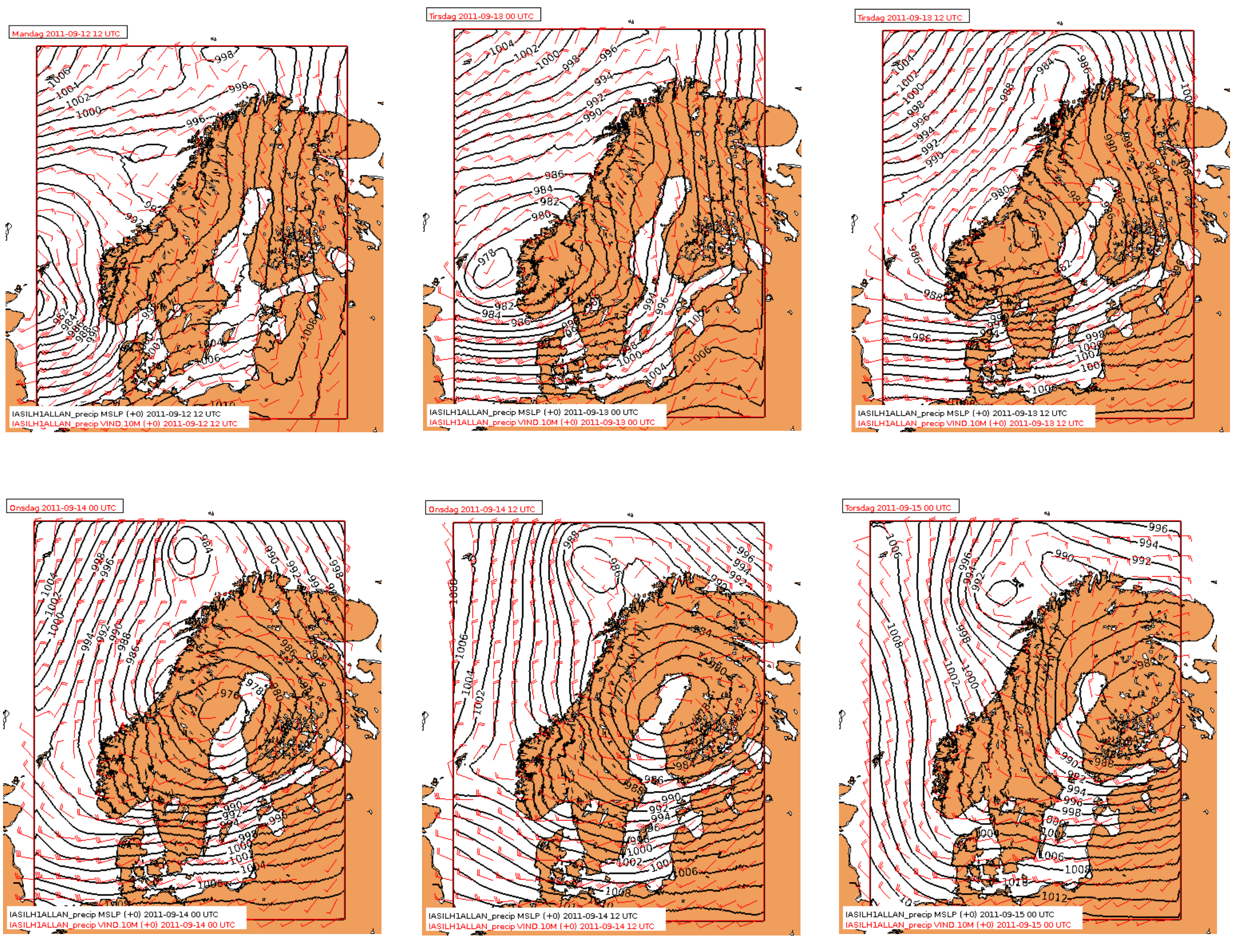
Figures 18: 24-hour forecasts of 12-hour accumulated precipitation amount from different model runs superposed with surface rain gauge measurements (numbers, and 6-hour rain rates are displayed, see text for more details): reference run (top left); run with full IASI data (top right); run with full humidity sensitive IASI data (bottom left); and run with new humidity IASI data (bottom right).

The ***36-hour forecasts*** are issued from analyses using IASI data at 12 UTC. The runs with sets humidity sensitive IASI channels (METIASIHU and METIASILH1) forecast a “two-eyes” precipitating area, although the patterns are more shifted to south-west than what are seen in 12-hour forecasts (not shown).

It is worth to mention that the visualisation tool used to display the meteorological charts showed in this study is not able to compute the 12-hour accumulated precipitation from the rain gauges when measurements are missing in the observation files. This means that 12-hour accumulated precipitation are available at 06 and 18 UTC only, while at 00 and 12 UTC, we can see only the accumulated precipitation amount for the last 6 hours. However, in this case the most of the precipitation happened between 18 UTC 11 September and 00 UTC 12 September and can be displayed. The radar rain rate is for 12-hour accumulated precipitation.

3.4.2 Case of September 14

This case is, in fact, when the above described cyclone pass through the model domain producing heavy precipitation along its path. It was a relatively fast moving cyclone entering the model domain at about 12 UTC 12 September from the south-west, passing over Norway and Sweden, and leaving at the north-east of the model domain at about 12 UTC 15 September (see Fig 19). The possible reason for its long life was probably the fact that from the afternoon of September 13, the cyclone got an “energy resupply” from another low system developing over the northern part of the Norwegian Sea. The cyclone reached his mature stage around 00 UTC 14 September. We are interested in the associated weather conditions when the cyclone was mature and the dissipation precess was very slow.



Figures 19: Synoptic charts of mean sea level pressure (black lines) superposed with 10 m wind (wind barbs) describing the weather condition over the AROME-Norway domain from September 12 12 UTC (upper left) until September 15 00 UTC (bottom right). The analysis fields (from the METIASILH1 run) are displayed every 12 hours.

In contrary to the previous case, here, most the precipitation happened between 00 and 06 UTC 14 September. As explained above, to have the exact amount of 12-hour accumulated precipitation at 12 UTC, we took into account the rain rates available in the 00, 06, and 12 UTC observation files. Fig. 20 shows the estimated 12-hour accumulated precipitation at a few stations around Trondheim, which are printed in bold numbers on the panel at the bottom left.

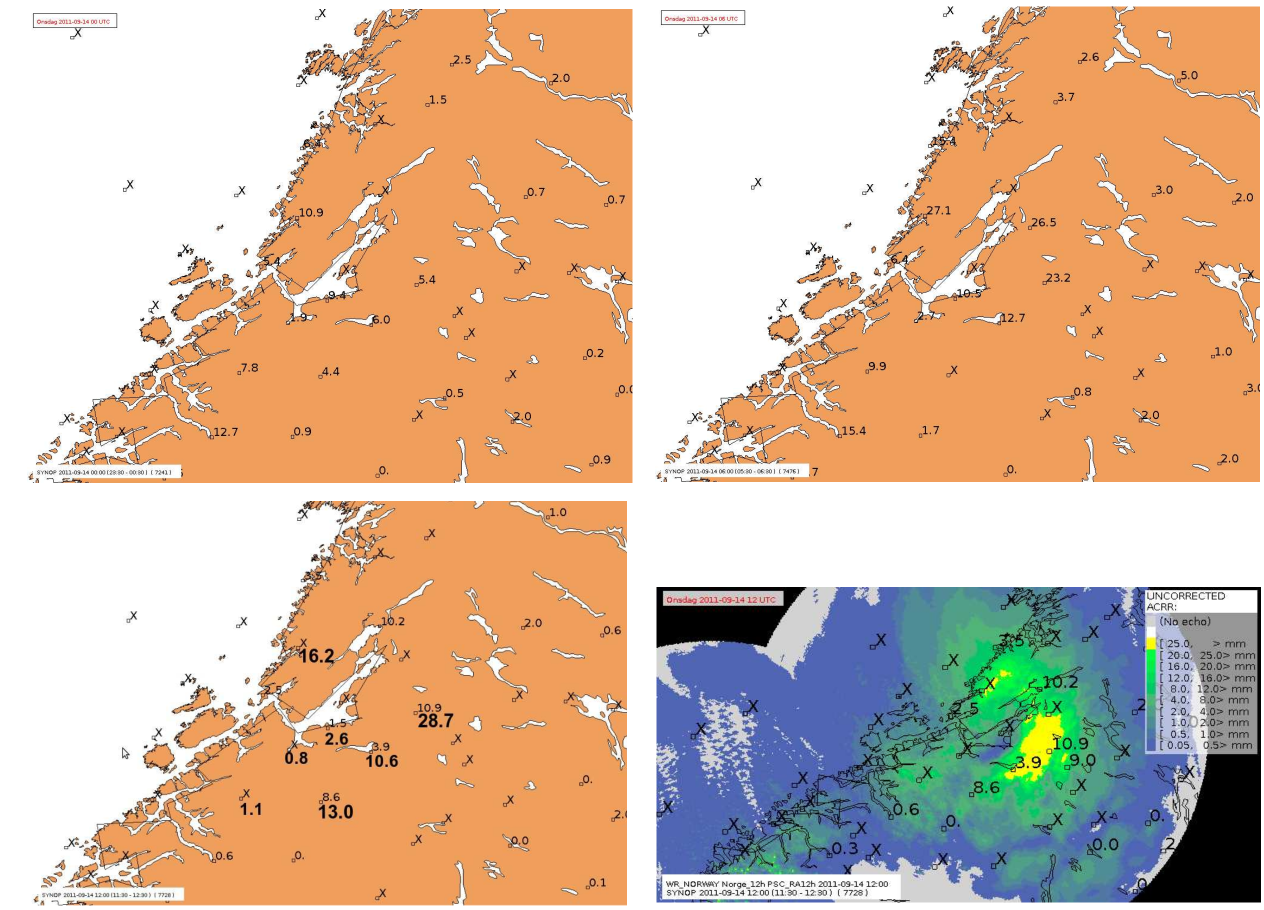


Figure 20: Different accumulated precipitation measurements (top left – 6-hour for 00 UTC; top right – 12-hour for 06 UTC; bottom left – 6-hour for 12 UTC, where few stations we have computed the 12-hour precipitation amounts (bold numbers); and bottom right – post-processed 12-hour accumulated radar precipitation valid at 12 UTC September 14, 2011.

We concentrate on forecasting of the precipitation on both sides of the Trondheim-fjord. Both the rain gauges and radar data show maximums in both sides of the fjord. All the ***12-hour forecasts*** (initialized at 00 UTC 14 October) predicted well this event with slight differences in the maximum amount, perhaps with a slight overestimation of the precipitation amount. Other interesting thing in this case is that the accuracy of the different forecasts depends much on the composition of the observations used during the data assimilation. Looking to the Fig. 19, the AROME model domain was under influence of a large cyclone with expected large extend of clouds. The radiance data are assimilated with precaution in cloudy conditions. The microwave data are well used over cloudy conditions, but with restriction over precipitating areas. Only IASI channels having peaking level above the cloud top are assimilated in cloudy condition. These restrictions reduce quite a lot the number of active radiances (both ATOVS and IASI) over convective areas, so in our opinion on 13th and 14th of September relatively few radiances were assimilated (fact not verified). While for 12th of September, the restrictions discussed above should not effect much rejection of data, due to the different stage in the development of the synoptic situation. The arguments above can explain why ***48-hour forecasts*** look more accurate than the shorter forecast ranges.

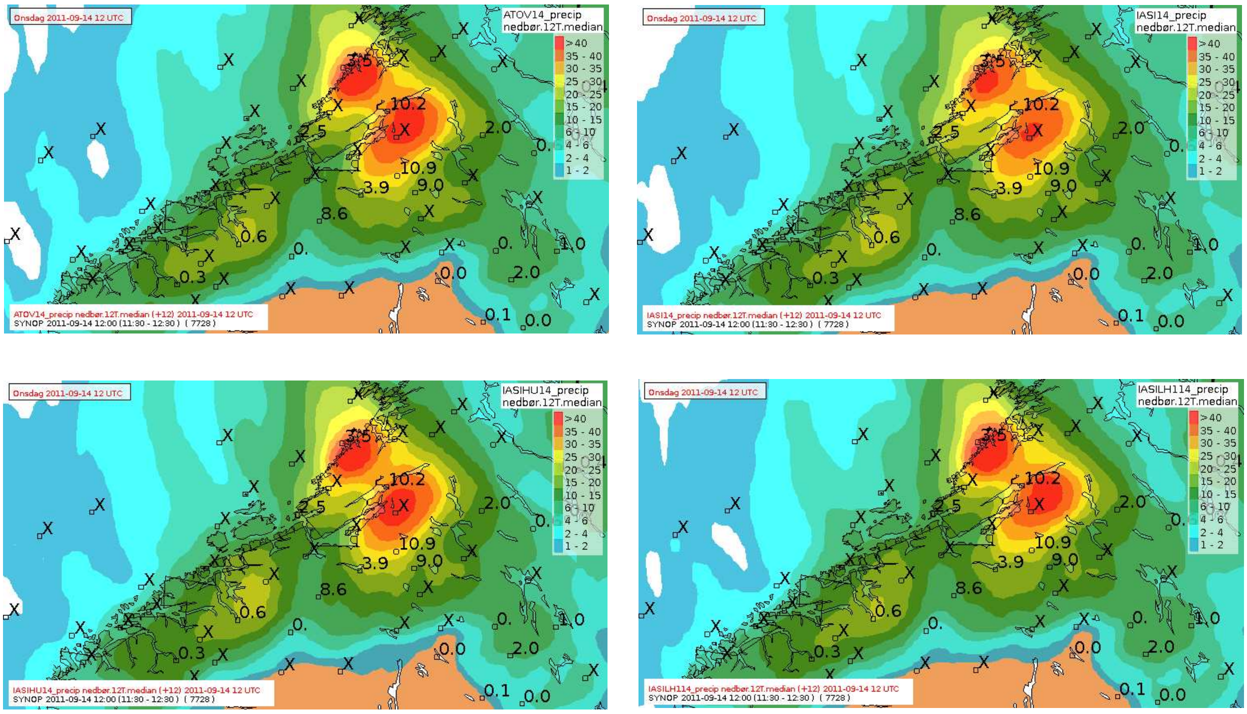


Figure 21: 12-hour accumulated forecasts: top left – reference run; top right – run with full IASI data; bottom left – run with full humidity IASI data; and bottom right – run with new humidity IASI data

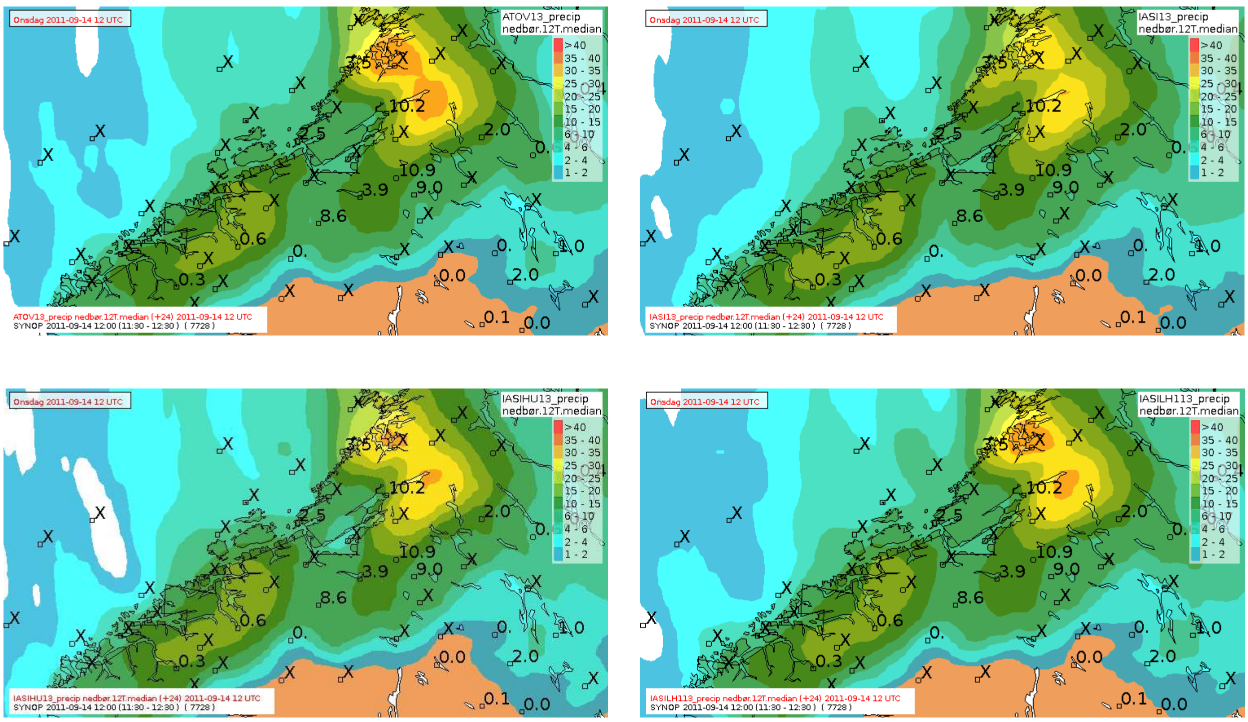


Figure 22: The same as Figs 20, but for 24-hour forecasts.

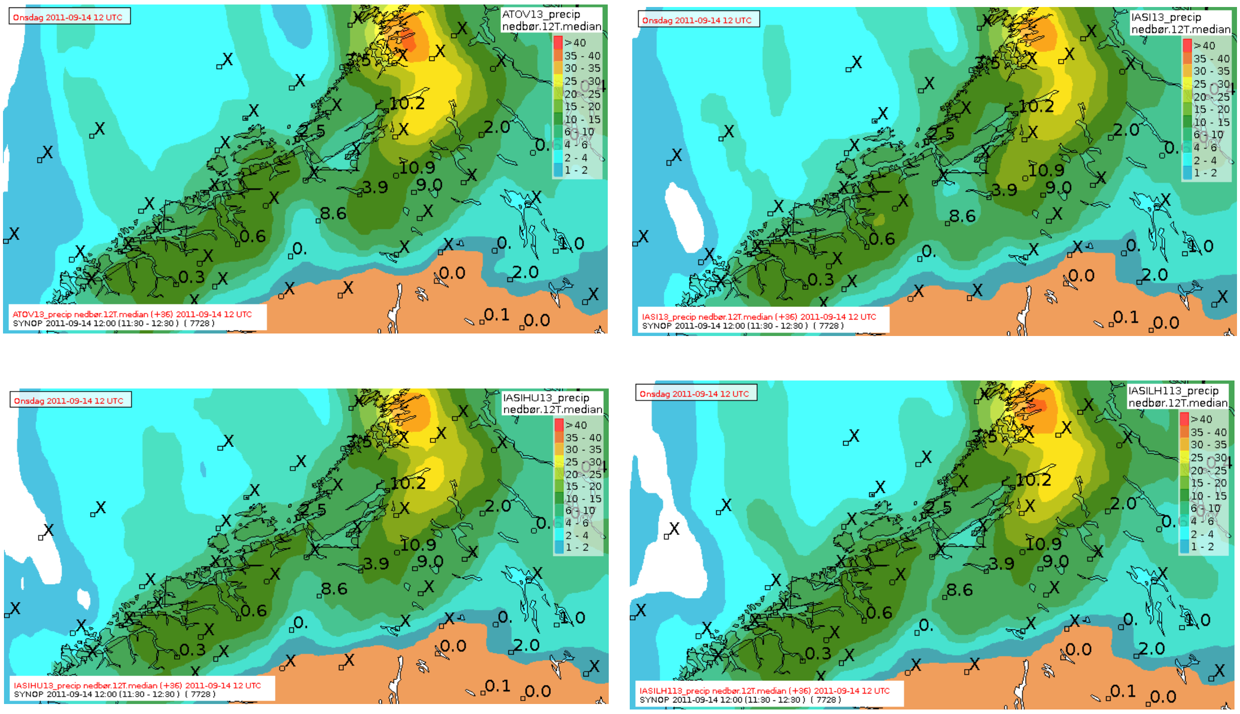


Figure 23: The same as Figs 20, but for 36-hour forecasts.

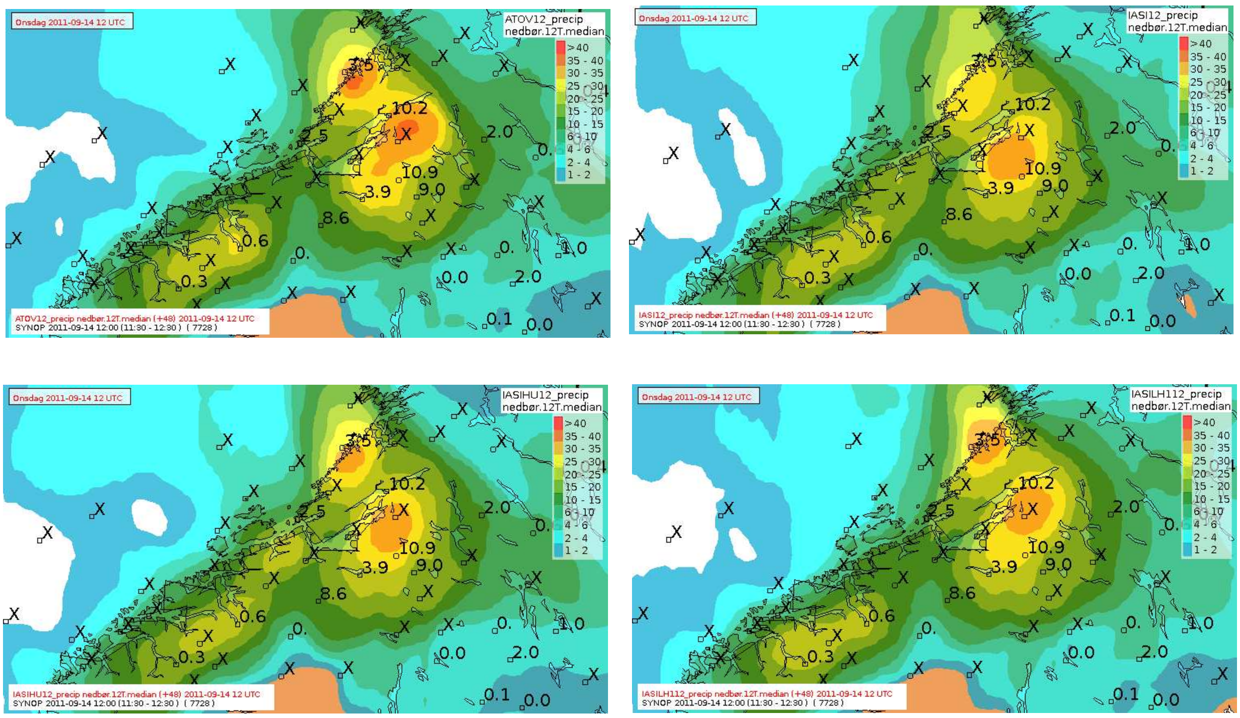


Figure 24: The same as Figs 20, but for 48-hour forecasts.

4. Concluding remarks

We have studied the use of IASI radiances, with special focus on humidity sensitive channels, to monitor and forecast water regime using the AROME-Norway non-hydrostatic model. Based on an accurate monitoring of the radiance usage, useful active ATOVS and IASI channels were selected for assimilation into the model system to improve the forecasts. While positive impact of IASI data was detected, even better impact on the upper-air fields, in particular the humidity, was reached after a revision/tuning of the active channels list.

While we find the results of these impact studies encouraging, there are still quite a few areas where we believe there is a potential for further improvement.

In this study, we obviously gave relatively more weight to the humidity sensitive channels, avoiding some potential temperature sensitive ones. It would be nice to check the impact of using those channels. But, first, all the above separated channels blocks should be similarly checked and, if needed, revised.

The extraction of IASI data based on all available FOVs from all FORs can have a weakness. ECMWF has found reason to decide to avoid, in any case, the use of the FOV number 4 from each FOR. This choice should also be tested after the tuning of all the above discussed channels selection procedure is finished. Then, normally, one should find better impact of the IASI data on analyses and forecasts.

Although, we have shown that the radiances have positive impact on forecasting the precipitating events, their use is very limited under cloudy conditions. Therefore, for an accurate system (assimilation and forecasting) observations which are available under cloudy conditions are of interest. In the HARMONIE system there have been developed solutions to use IASI and AIRS data under cloudy conditions (see for ex. *Mc Nally* (2009) and *Guidard et al.*, 2011). These solutions need to be tested. Other observations, like for example GPS[6] (both ground based or radio occultation) and radar observations (radial winds and reflectivity) are also available under cloudy conditions. At MET-Norway we have ongoing activity dealing with radar data assimilation in AROME model.

One of the weakness of our IASI radiances set-up is that we do not use these data at 00 UTC due to their unavailability (too small extension of paths). We have used only data from one MetOp satellite. Today, we have two operational MetOp satellites – MetOp-A and MetOp-B. *Cameron et. al.*, 2013 reported positive impact of the MetOp-B data. According their study, MetOp-B complements the MetOp-A satellite. The question is, will it provide more IASI data inside our model domain at 00 UTC?

To get advantage of all large scale ECMWF analysis, in the HARMONIE system we use spectral blending at large scale. This scheme is known to have positive impact on most of surface and upper-air parameters. A discussion is now open on the fact that this scheme may have strong effect on the small scales, which may cause problem with assimilation at mesoscale. The question is, does this explain the relatively small impact of radiances in this study?

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6 Global Positioning System

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