Evaluation of the impact of the use of the ECOCLIMAP2 database on AROME operational forecasts.

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Contents

1 Introduction

ECOCLIMAP is a global database of land surface parameters at 1km resolution used in meteorological and climate models to initialize the soil-vegetation-atmosphere transfer schemes . The first version of ECOCLIMAP, realized in 2003 (Masson et al.,2003), was implemented in the METEO-FRANCE operational models. A second version, with numerous improvements over Europe, was implemented in 2008 into SURFEX, the operational surface scheme used in the LAM numerical weather prediction systems of METEO-FRANCE. This study aims at evaluating the impact of these improvements on the operational forecasts at screen-level issued from the coupled atmosphere-surface AROME LAM model.

2 Description of the ECOCLIMAP2 database

2.1 Main features of ECOCLIMAP1

The map for ECOCLIMAP1 was realized crossing information from Land Cover Maps (IGBP, UMD, CORINE1990) and a Climate Map (FIRS, 1995). The NDVI satellite data from AVHRR (1km resolution, monthly from April 1992 to March 1993) are then used to gather close ecosystems in regards to the NDVI. The LAI covers data are deduced from the NDVI data through a linear interpolation, imposing minimum and maximum values of the annual cycle.

2.2 The innovations of ECOCLIMAP2

The innovations of ECOCLIMAP2 are to use more recent input data for Land Cover Maps and NDVI data and to use an automatic classification method based on the k-means algorithm. Land cover data maps are GLC2000 and CORINE2000. NDVI data come from SPOT/VGT and range from 1999 to 2005, at 10-day frequency. The k-means algorithm gathers pixels with NDVI time series close in regards to the Euclidian Distance. The land cover maps are used to qualify the contents of the covers. The LAI covers data come from MODIS satellite data, 10-day frequency from 2002 to 2006.

2.3 Comparison of parameters over France

A comparison between characteristics of ECOCLIMAP1 and ECOCLIMAP2 was performed in order to find the origin of the differences in the AROME results. Here are presented only differences for LAI and Bare Soil, because these parameters are those that had a further impact on AROME simulations.

2.3.1 Leaf Area Index (LAI)

LAI maps of differences are plotted for each month (appendix A). The main differences observed are located on crops areas : in ECOCLIMAP2, crops begin to grow later (May / March), and maximum values are lower (July-August : -1.5). Other features are that LAI on mountains are lower in Winter (-1) and higher in Summer (+1.5). LAI for grasslands is quite higher in Summer (+1).

2.3.2 Bare Soil Fraction (fig.1)

In ECOCLIMAP2, bare soil is more present in crops regions, especially in South-West of France and in the Rhone valley (+15%) . It's generally more present on the West part of france (+5%). It's less present around the Mediterranee (+15%).

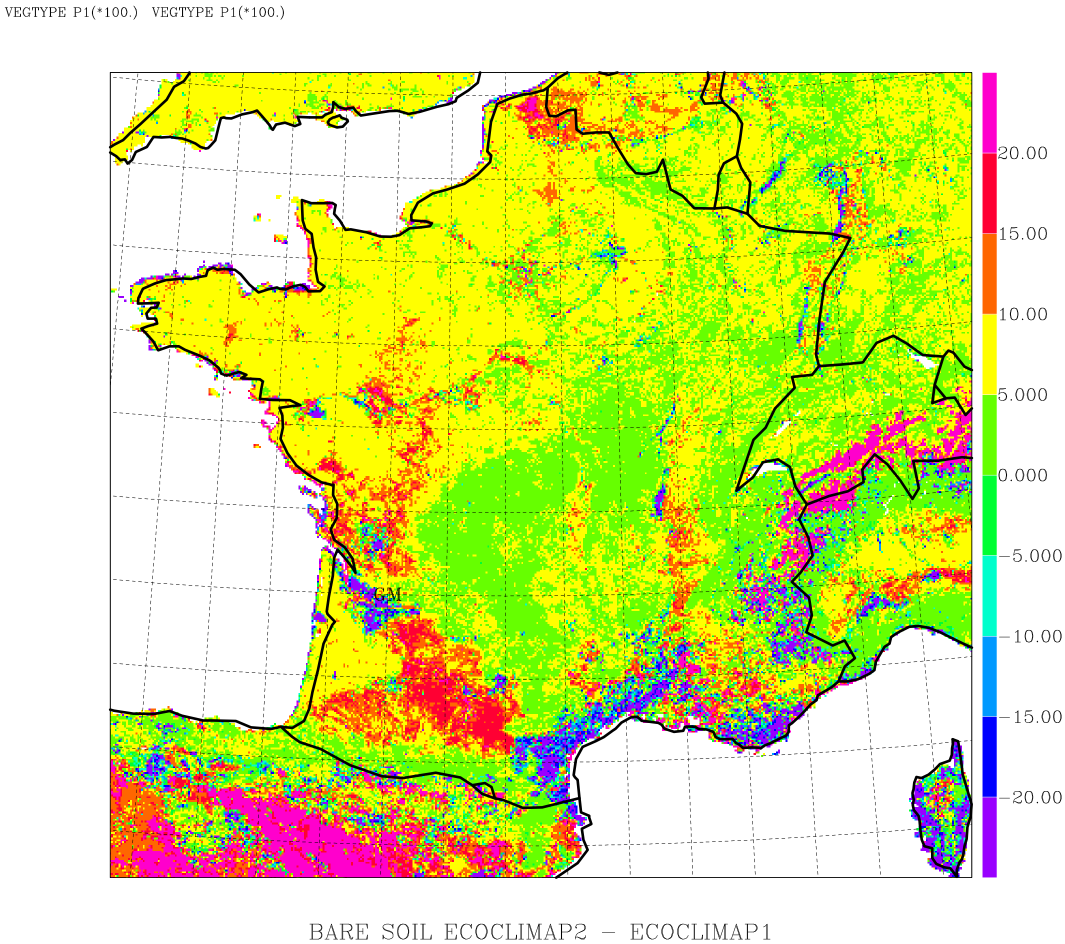


Figure 1: Bare soil fraction differences between ECOCLIMAP2 and ECOCLIMAP1

3 The ECOCLIMAP1/ECOCLIMAP2 evaluation protocol

3.1 The AROME/SURFEX modeling strategy

The simulations were performed with the AROME atmospheric model coupled with the SURFEX surface model.

All simulations use AROME in CY37T1 with surfex v6+ (surfex v6 plus some technical optimisations in I/O and setup). They are performed over the 2012 AROME-France operational domain FRANGP (750x720 points with horizontal resolution of 2,5km, 60 vertical levels with the lowest one at 10m, time step of 60s). Forecasts are done in spin-up mode (without data assimilation). They start at 0 TU, up to +30 hours. Lateral boundary conditions were provided every 3h by operational ALADIN-France for 2007 period, and every hours by ARPEGE in 2011and 2012. By default, surfex options are the one of AROME-France (CANOPY SBL scheme activated over sea and nature only, TEB scheme used for town areas, and ECUME activated over seas). Twelve days were selected (one day a month from January to December 2007) because of the meteorological conditions (clear sky and weak advection on the major part of France) ensuring an optimum coupling between the surface and the atmosphere, and thus an optimum impact of ECOCLIMAP on the atmosphere. The description of the weather conditions during the selected days is available in appendix B.

This list of sunny days was completed by two periods of 30 consecutive days with various meteorological situations, the first one in summer from 20110715 to 20110815, the second one in winter from 20120108 to 20120208.

For each day, two simulations were carried out: the first one called ECO1 with the AROME/ECOCL system, and the second one called ECO2 with the AROME/ECOCLIMAP2 system.

3.2 The observation data and scores used for validation

The performance of the two versions of ECOCLIMAP is evaluated by comparing 2 m air temperature (T2M), relative humidity (HU2M) and 10 m wind (DD10M, FF10M) forecasts to measured values at 1215 observation stations of the French real time network (fig.2), the scores against screen-level variables being considered as very informative of the quality of the simulation of the surface boundary layer.

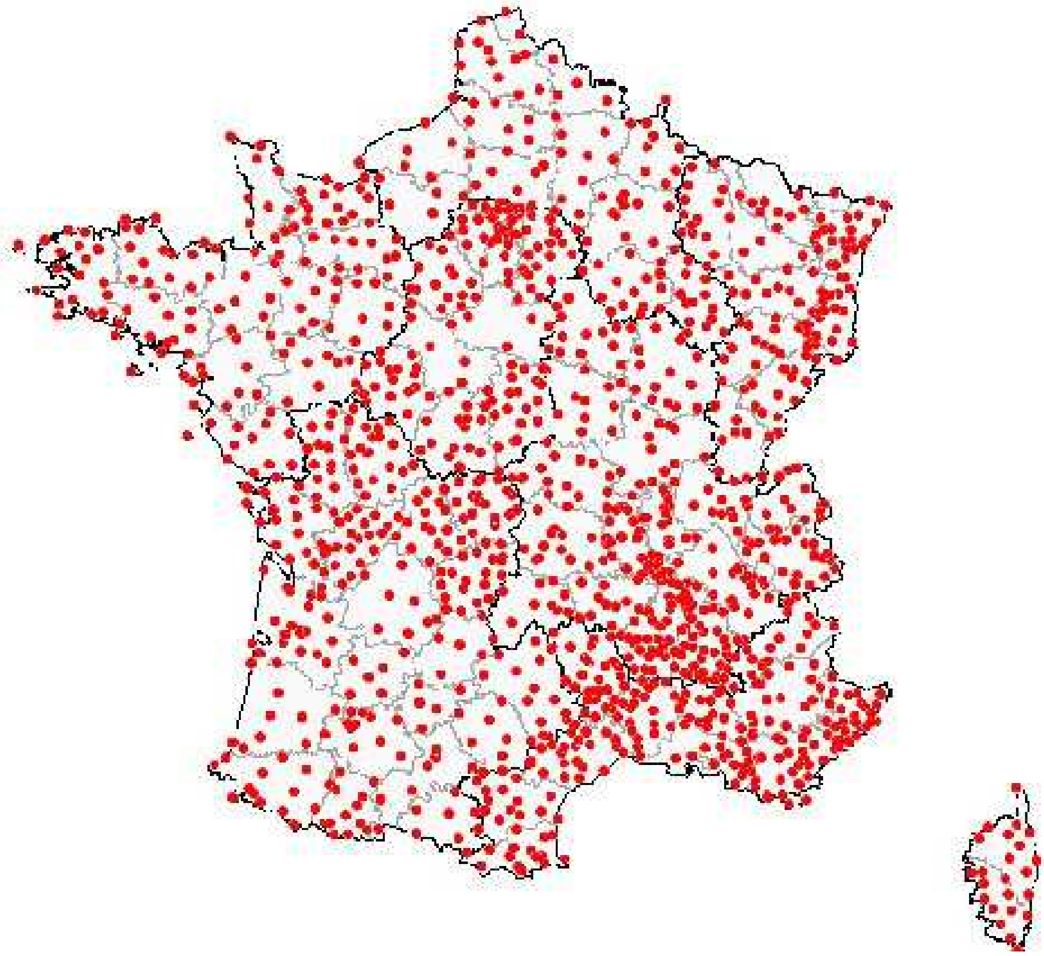


Figure 2: Observation stations network

T2M data are generally provided by all stations. HU2M and wind data are not always available, the number of observations taken into account for the calculation of scores is mentioned on the figures (about 1000 stations for HU2M and 550 stations for wind).

Additional scores are calculated at stations above 300m height, which represent approximately 35% of the stations over the whole France domain.

For each day of simulation of 2007, root-mean-square (RMS) and bias are calculated every 3 hours to characterize respectively the distance between the model and the observation, and the forecast error. An average of the scores over the 12 days of 2007 is also performed to provide a synthetic evaluation of the two series of simulations. For the two periods of 30 days in summer and winter, the statistics are computed every 3 hours for the 30 days, providing a synthesis of the mean RMS and bias over the whole period.

The observation database and the scores used in this study are exactly those which are used daily for the control and monitoring of the operational AROME model. The simulated values are extracted at the nearest grid point from the observation station, no interpolation is performed.

4 Results

4.1 Comparison of the ECO1 and ECO2 simulations

The synthesis of the mean RMS and biases over the 12 sunny days of 2007 is given figure 3.

Whereas no significant differences can be noticed on 10 m wind scores, systematic differences appear on screen-level temperature and humidity scores. Relatively little in the daytime, they generally become important during the night, especially in summer, ECO2 leading to a warmer and drier atmospheric boundary layer. This result, obtained at screen-level, is also confirmed at higher levels up to the top of the boundary layer.

The difference between the forecasts issued from ECO1 and ECO2 simulations is more important in March, April, and from July to October (appendix C). The maximum difference occurs in August, with a T2M bias and RMS increase of 0.5C , and a HU2M bias and RMS increase of 3 to 4% (fig.4) .

The spatial distribution of the difference between T2M ECO1 and T2M ECO2 is given figure 5a. The differences appear to be located on the areas where C3 crops is the dominant vegetation type (fig.5b).

Sensitivity tests were carried out to determine which parameter could be at the origin of such differences. Three parameters were considered: soil depth (DG), bare soil fraction into C3 crops vegtype, and LAI.

New ECO2 simulations were performed with different versions of ECOCLIMAP2 in which only one parameter had been modified. The impact on T2M and HU2M scores of a modification of DG in ECOCLIMAP2 turned out to be negligible. A modification of bare soil fraction into C3 crops vegtype only led to minor changes in scores. On the contrary, LAI modifications induced important changes in scores. Finally, a last test in which the ECOCLIMAP2 LAI had been set to the original ECOCLIMAP1 LAI value led to similar scores between ECO1 and ECO2.

As a conclusion, the differences observed in T2M and HU2M scores issued from ECO1 and ECO2 simulations are mainly due to LAI differences between ECOCLIMAP1 and ECOCLIMAP2.

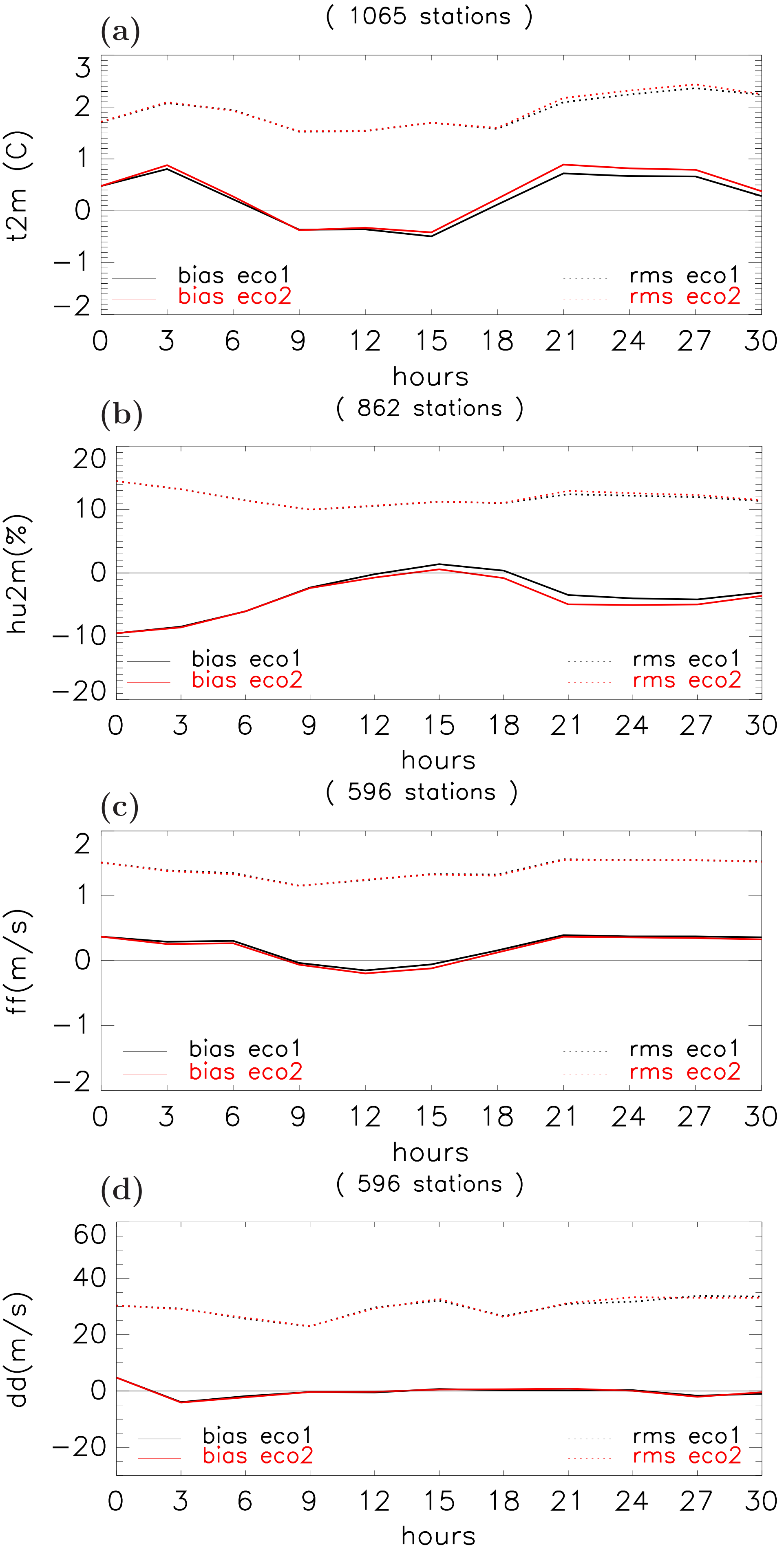


Figure 3: Mean rms (dashed line) and bias (solid line) of a)T2M b)HU2M c)FF10M d)DD10M over 12 days of 2007 for ECO1 (black line) and ECO2 (red line) simulations

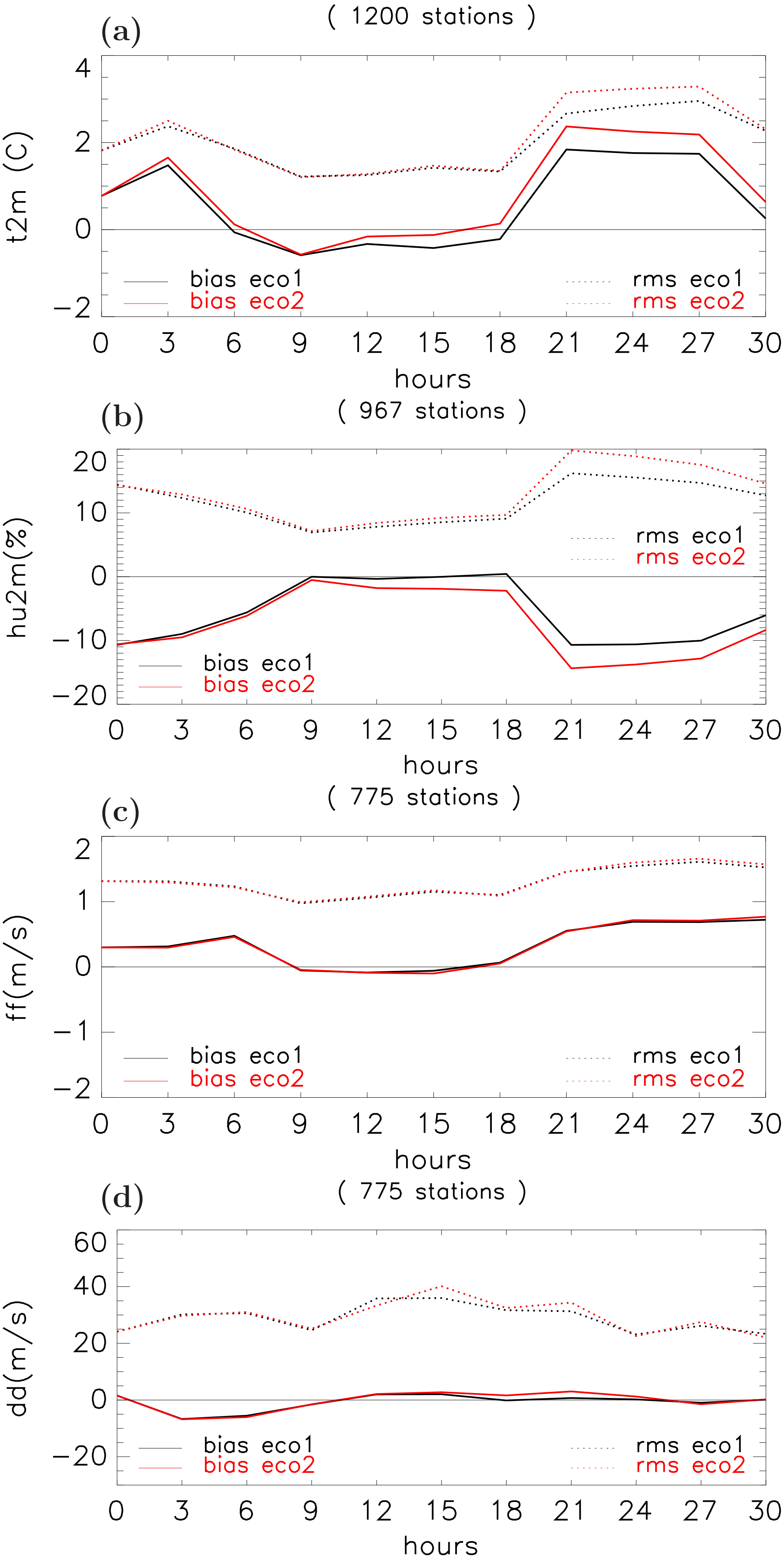
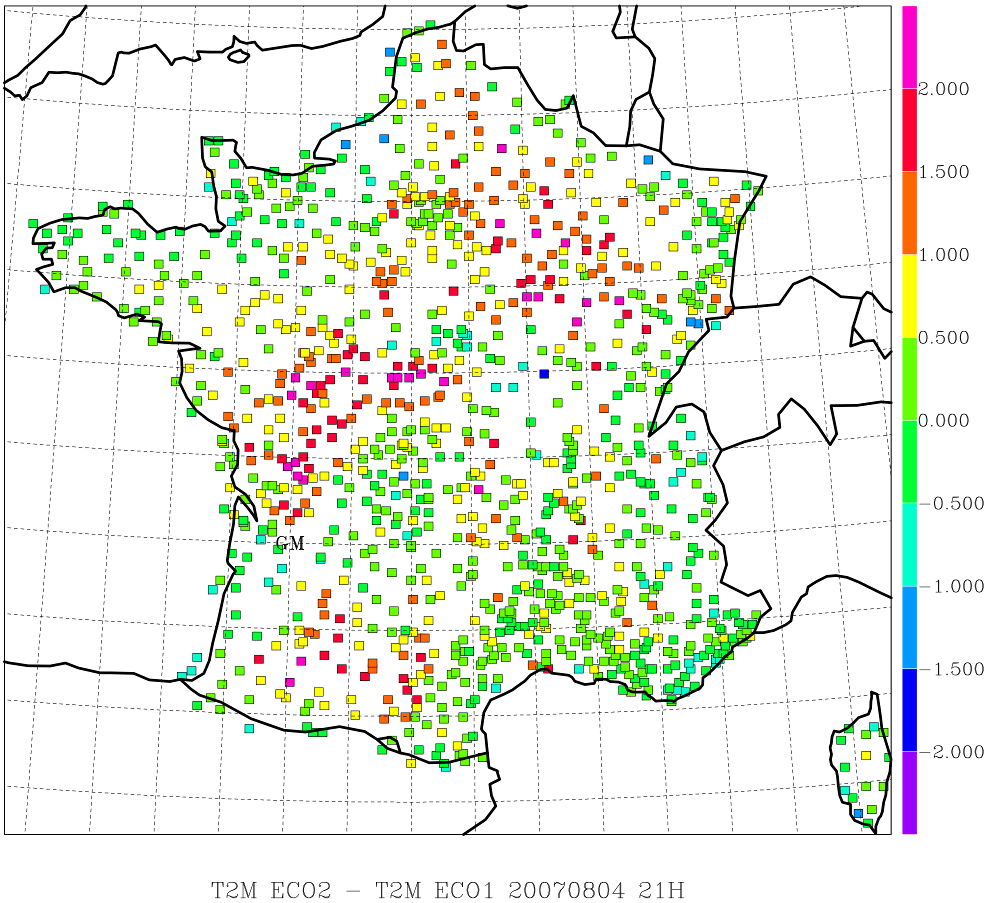


Figure 4: Mean rms (dashed line) and bias (solid line) of a)T2M b)HU2M c)FF10M d)DD10M on 20070804 for ECO1 (black line) and ECO2 (red line) simulations

(a)



(b)

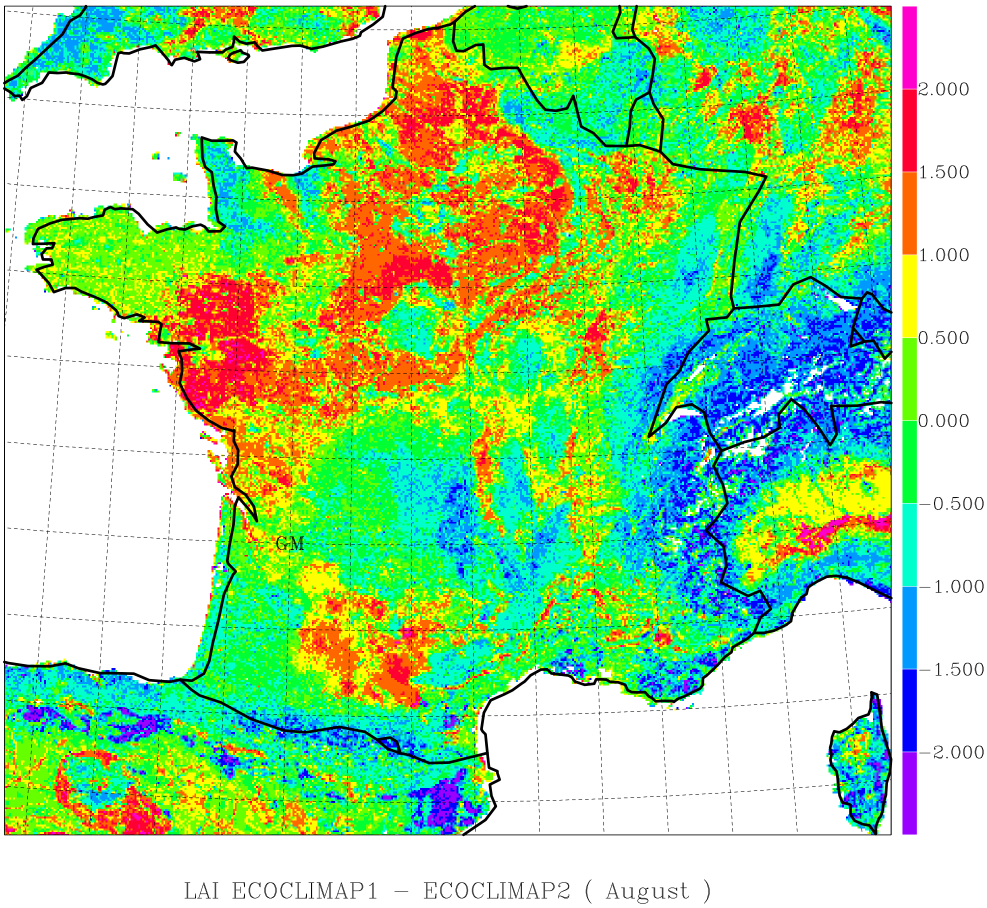


Figure 5: a) Difference between T2M ECO2 and T2M ECO1 on 20070804 b) Difference between LAI ecoclimap1 and LAI ecoclimap2 in August

4.2 Problem of night time overestimation of T2M and underestimation of HU2M.

In both cases (ECO1 and ECO2), one can notice during the night a systematic overestimation of T2M combined with an underestimation of HU2M (fig.3). A survey of the daily scores reveals that the scores are worse in summer than in winter (appendix C).

Suspecting a problem in the CANOPY surface boundary layer scheme, this point was then investigated by performing a new set of simulations without CANOPY, based upon ECOCLIMAP1 (hereafter called DIAG1). 2 m variables are no longer prognostic variables, they have to be estimated. In unstable and neutral case, they are diagnosed by an extrapolation downward from the atmospheric variables according to Paulson laws. In stable case, they are interpolated between the surface variables and the atmospheric variables at the lowest model level. The mean scores over the 12 days of 2007 (fig.6) confirm the role of CANOPY in the night time overestimation of T2M and underestimation of HU2M, the new DIAG1 simulations without CANOPY being characterized by a systematic underestimation of T2M.

This overestimation of T2M by CANOPY during the night is more important in summer, as shown in appendix D. The scores obtained in August provide a good illustration of the behaviour of the two configurations of the AROME/SURFEX model: whereas the ECO1 simulation leads to an important bias of T2M during the night (+1.74 to +1.84C), the DIAG simulation T2M bias varies from 0.2 to 0.4C. In the same way, the HU2M bias varies from 10.0 to 10.7% for the ECO1 simulation, against only 2.0 to 2.4% for the DIAG simulation.

The mean scores provided by another set of simulations over the two periods of 30 consecutive days in summer and winter are similar (fig.7), and confirm the results provided by the previous simulations.

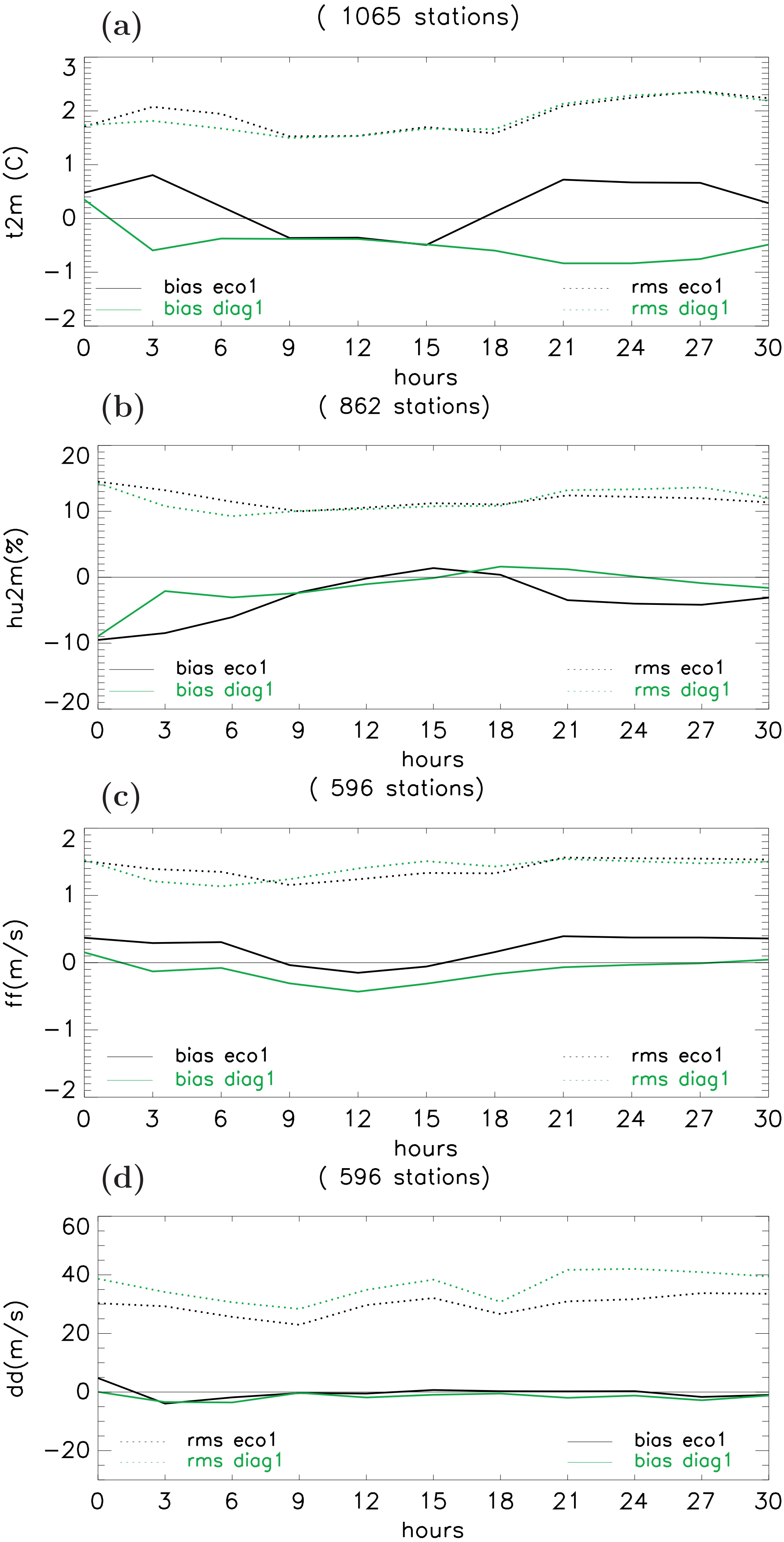


Figure 6: Mean rms (dashed line) and bias (solid line) of a)T2M b)HU2M over 12 days of 2007 for ECO1 (black line) and DIAG1 (green line) simulations

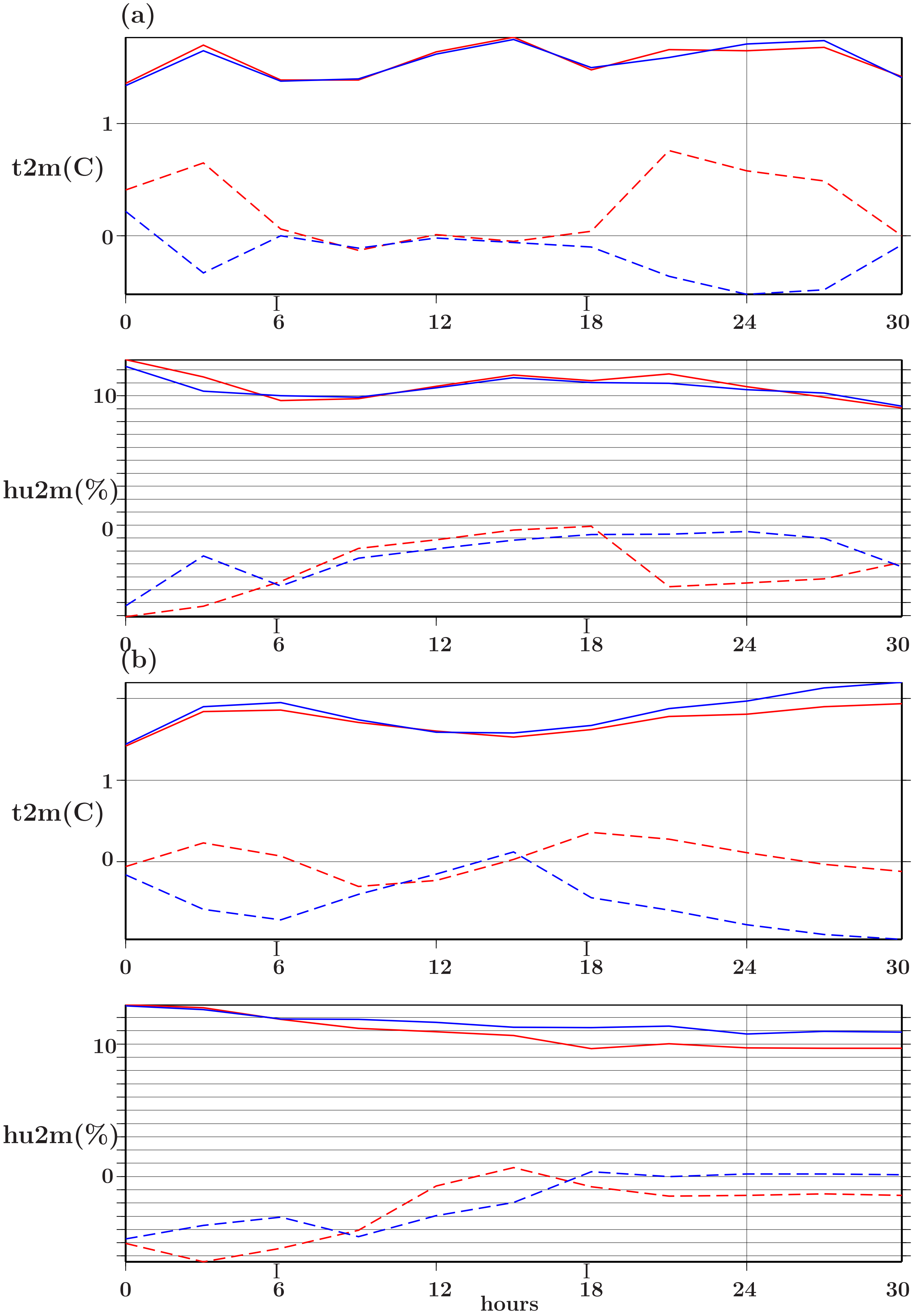


Figure 7: Mean rms (solid line) and bias (dashed line) of T2M and HU2M over 30 days of 2011 a) from 20110715 to 20110815 b) from 20120108 to 20120208 for ECO1 (red line) and DIAG1 (blue line) simulations

4.3 Test of a modification of RIMAX in CANOPY

The main objective of canopy is to add (simplified) atmospheric levels near the surface. By default, 5 levels are added between the surface and the atmospheric forcing level, the 6th canopy level one being co-localized with the later. The first canopy level is at 50cm above the surface, while the second one is at 2m. The latter provides the 2m temperature and humidity fields.

The important point about turbulence characteristics between the surface and canopy is that the first level is only 50cm above ground. Physically, this is so near the surface that there is no chance to have a significant effect of stability in the exchanges between the surface and this layer: the dynamical production should always prevail. This is enhanced by the fact that this layer has similar height as physical obstacles, so one is probably in the roughness sublayer, confirming the role of dynamically induced turbulence. Note that the exception to this should be the turbulence over extended surfaces of ice (but not in snow cover in France, where small scale obstacles are always present). However, the ISBA model does not take into account the details of this roughness sublayer, and the exchange coefficients formulation is able to take into account high stability effects even for a so small layer. This modifies the surface fluxes by night, because those are sensitive to net radiation and partition between sensible heat and storage : then surface temperature can easily be too cold if exchange coefficients are too small, while at the same time the 2m air temperature would be too warm. Therefore, one have to prevent this, in the case of canopy, in order to insure dynamically driven exchanges. This is done by limiting the Richardson number value to 0 (no stratification effect allowed).

Note that the unstable stratification effects have much less effect on the turbulent fluxes at the surface (that are primarily driven by the net radiation and Bowen ratio), so setting a minimum value to Richardson number is not necessary.

Tests were performed over the 12 days of 2007, with the ECOCLIMAP1 data base, the CANOPY surface boundary layer model, and different values of RIMAX, from 0.2 to 0.0. The value RIMAX=0, corresponding to a neutral layer between the surface and the first level of CANOPY, was finally kept as the best one.

Figure 8 gives a synthesis of the scores provided by the two versions of AROME-SURFEX: the operational one with RIMAX=0.2 (hereafter called REF) and the version with RIMAX=0 in CANOPY (hereafter called RIMAX0). Statistics reveal a significant improvement of T2M and HU2M forecasts from REF to RIMAX0 runs, during the night. The nocturne biases of T2M (+0.7 to +0.9 C) and HU2M (-4 to 5%) in REF runs are nearly removed in RIMAX0 runs, and RMS are significantly reduced.
The daily scores are presented in appendix E. The RIMAX0 runs lead to a significant improvement of T2M scores from March to October, the RMS being reduced and the nocturne bias highly improved, and frequently removed. The August scores are shown on figure 9. Bias and RMS are reduced by respectively 1C and 0.4 C for T2M, 5 and 3% for HU2M. Additional tests over the two periods of 30 consecutive days in summer and winter provide similar results (fig.10).

This series of tests allowed us to find the adequate configuration of the coupled SURFEX-AROME model, able to provide the best forecast of screen-level parameters.

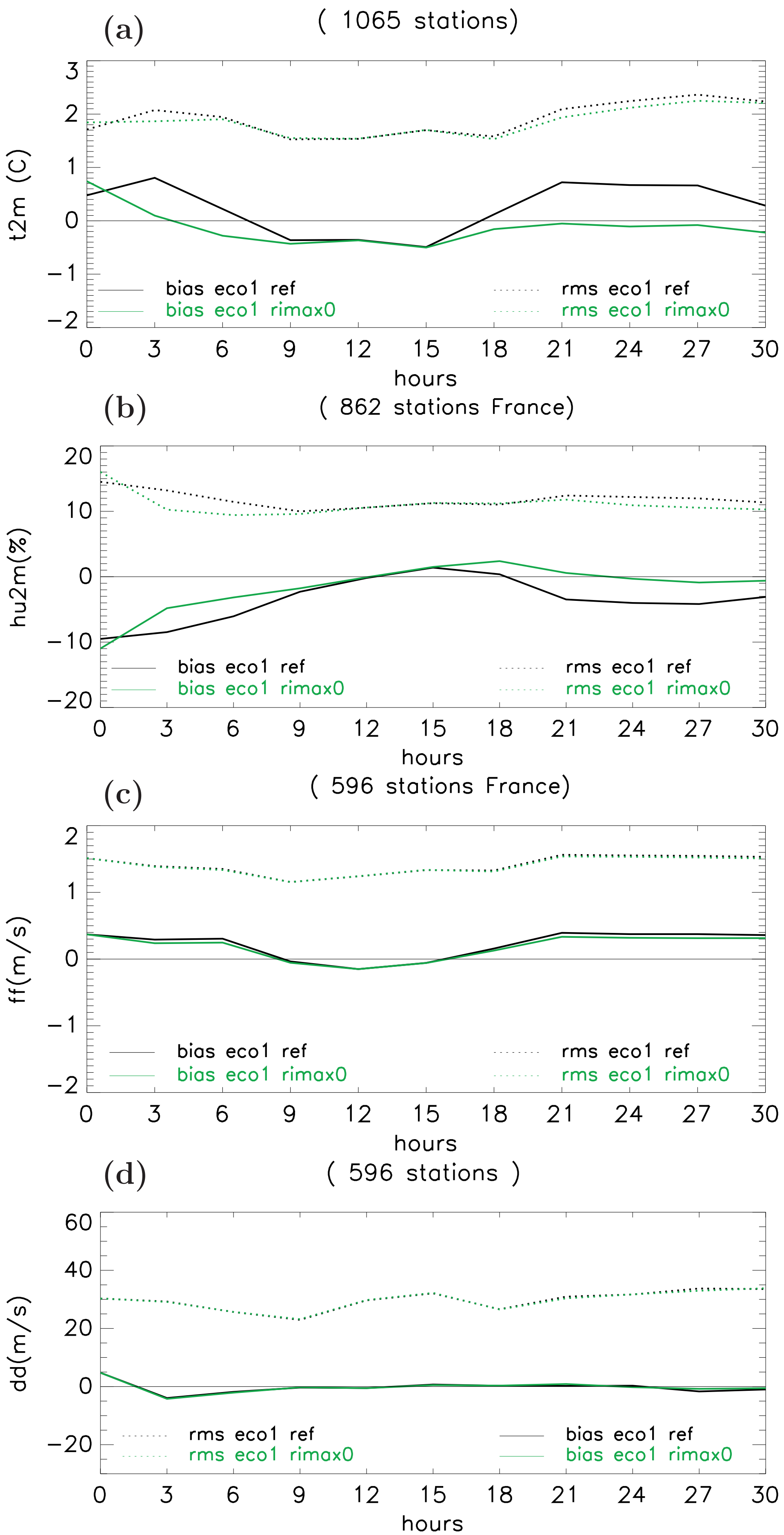


Figure 8: Mean rms (dashed line) and bias (solid line) of a)T2M b)HU2M over 12 days of 2007 for ECO1 (black line) and RIMAX0 (green line) simulations

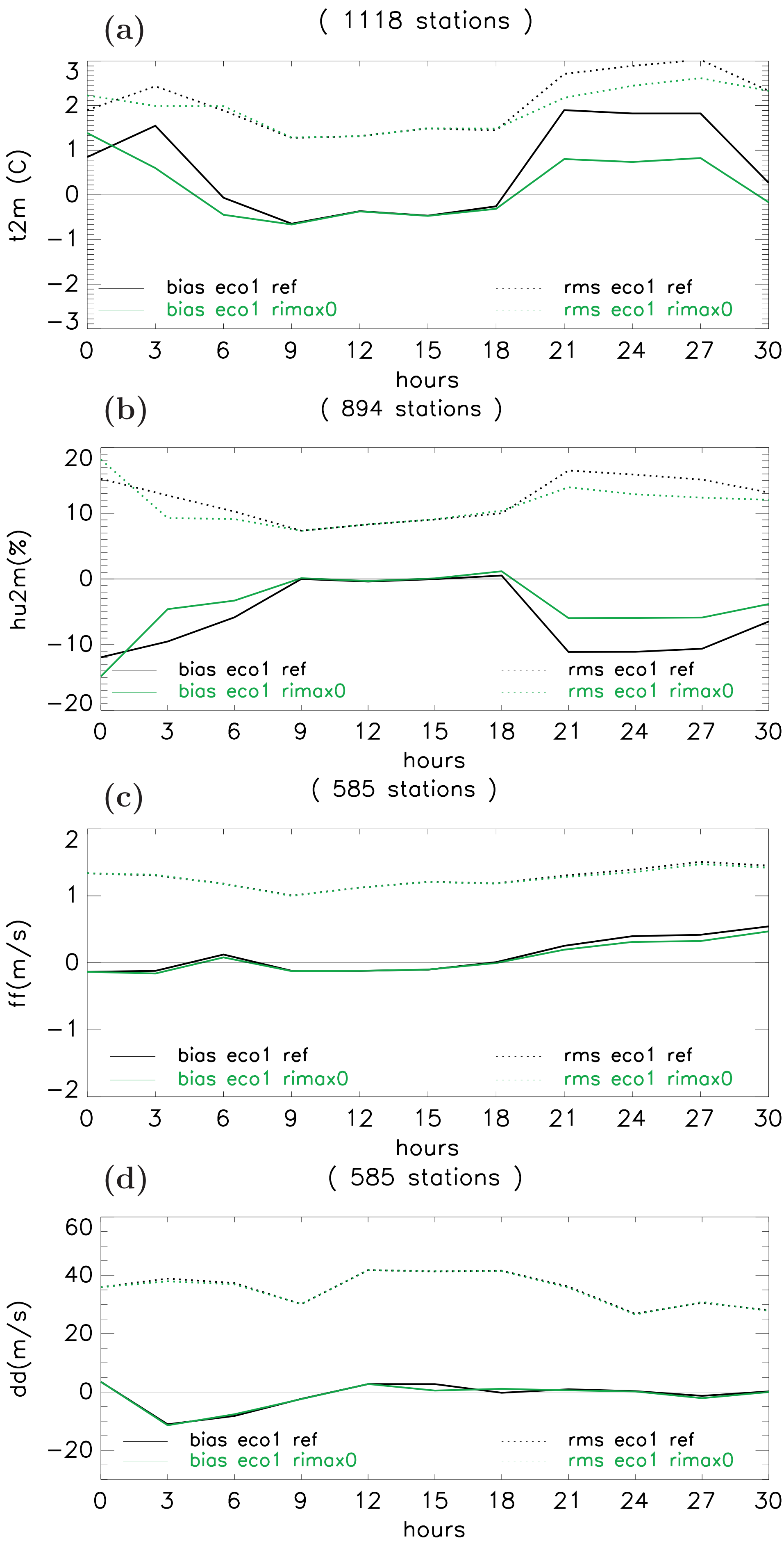


Figure 9: Mean rms (dashed line) and bias (solid line) of a)T2M b)HU2M c)FF10M d)DD10M on 20070804 for ECO1 (black line) and RIMAX0 (green line) simulations

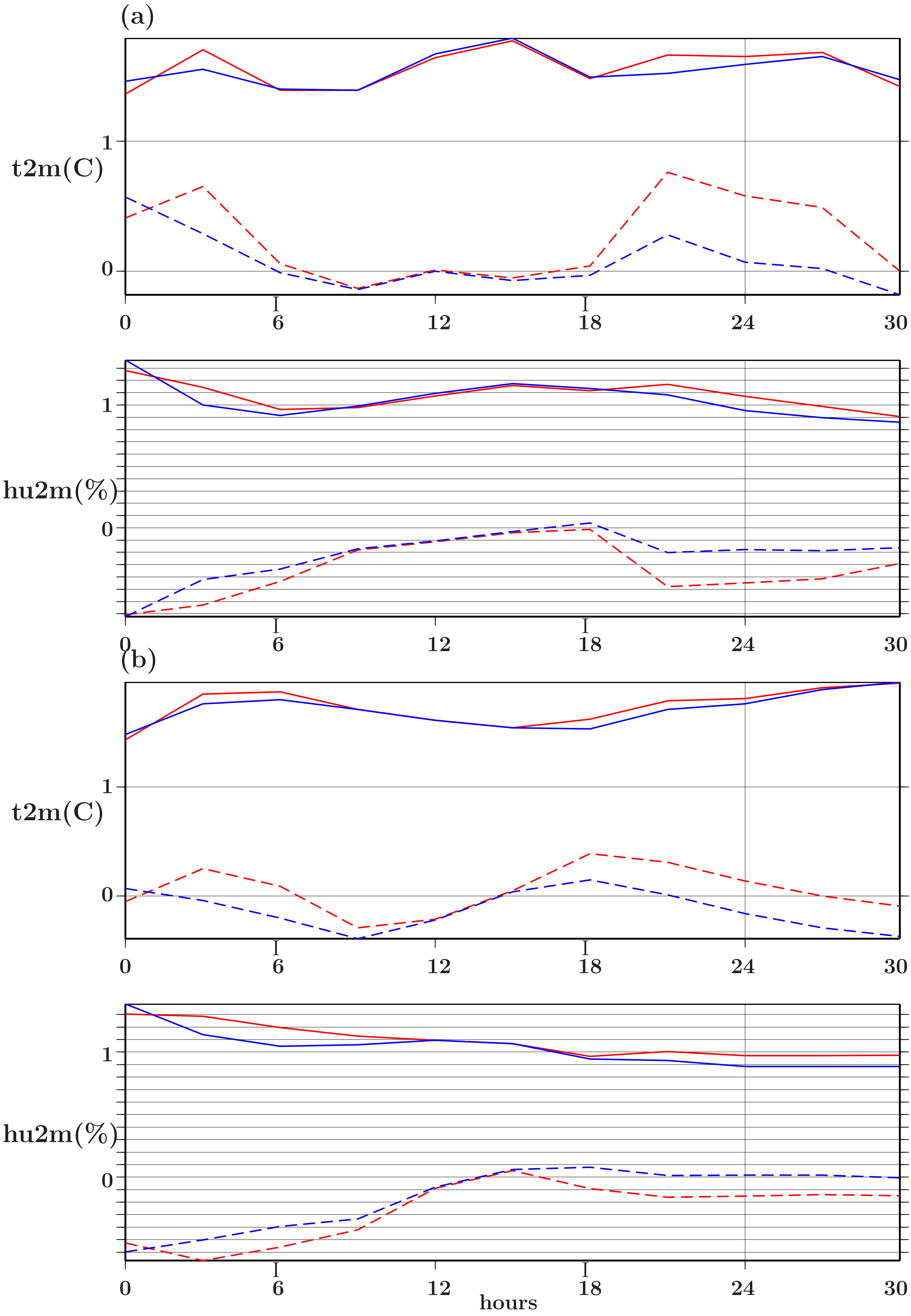


Figure 10: Mean rms (solid line) and bias (dashed line) of T2M and HU2M over 30 days of 2011 a) from 20110715 to 20110815 b) from 20120108 to 20120208 for ECO1 (red line) and RIMAX0 (blue line) simulations

4.4 Comparison of the ECO1 and ECO2 simulations with RIMAX=0 in CANOPY

The ECO1 and ECO2 simulations were carried out with the new configuration RIMAX0 of AROME-SURFEX, over the 12 sunny days of 2007.
As seen in section 4.1, among all parameters of ECOCLIMAP, LAI was proved to have the greatest influence on scores. So, the comparison between ECO1 and ECO2 allows to measure the impact of a modification of the LAI on the scores of screen-level variables.

The scores have been computed over the 1215 observation stations and also separately for areas of plains (781 stations below 300m) and mountains (434 stations above 300m). Their average over the 12 days of 2007 is displayed in figure 11 (all stations), figure 12 (stations below 300m) and figure 13 (stations above 300m).

It turns out that, on average over the 12 days, ECO1 and ECO2 scores of screen-level variables are very similar in the RIMAX0 configuration, in mountainous areas as well as in plain areas.

We have seen in section 2.3.1 that the main differences of LAI between ECOCLIMAP1 and ECOCLIMAP2 occur in March and April, and from July to October, LAI being weaker on C3 crops in ECOCLIMAP2. An accurate analysis for each month is necessary in order to evaluate the impact of this modification through the different seasons. The daily scores are displayed in appendix F.

As it was expected, T2M and HU2M bias and RMS are very similar in January, February, May, June, October and November.
The main differences occur in March, April, and from July to September. In March and April, ECO2 RIMAX0 provides best scores than ECO1 (bias reduced by 0.4 to 0.5C for T2M, and 2 to 3% for HU2M, RMS similar or slightly reduced), and in the daytime in July and August (bias reduced by 0.2 to 0.3C for T2M, and 2% for HU2M, RMS similar or slightly reduced).
In July, ECO2 RIMAX0 slightly improves the RMS, but the bias is slightly increased from 21H to 27H by 0.3C for T2M and by 1 to 3% for HU2M. In August and September, ECO2 RIMAX0 shows better scores from 06H to 18H (bias reduced by 0.1 to 0.3C), but leads to an increase of the nocturnal bias and RMS from 21H to 27H (bias increased by 0.4 to 0.5C for T2M, 3% to 5% for HU2M).
In December,for T2M, the scores are slightly improved during the day, but from 24H to 30H, the negative bias is increased by 0.2 C, whereas the RMS is similar or slightly increased.

As for 10m wind, averaged scores issued from ECO1 RIMAX0 and ECO2 RIMAX0 are identical. There is only little difference on FF10M bias in January, May, November and December, ECO2 producing a slightly weaker wind leading generally to a reduction of the nocturnal positive bias. In the daytime, ECO2 RIMAX0 simulations slightly improve FF10M bias in January, and slightly increase the negative bias in November and December. For the other months, ECO1 RIMAX0 and ECO2 RIMAX0 lead to identical results. DD10M scores only differ a little (by 5 degrees) from April to June during the night.

As a conclusion, the use of ECOCLIMAP2 instead of ECOCLIMAP1 in RIMAX0 configuration doesn't impact the screen level scores in most cases, improves the scores in March, April and in the daytime in July and August, slightly deteriorates the scores in September, and during the night in August and December. On average over the 12 months, the impact remains positive with a general improvement of the scores.

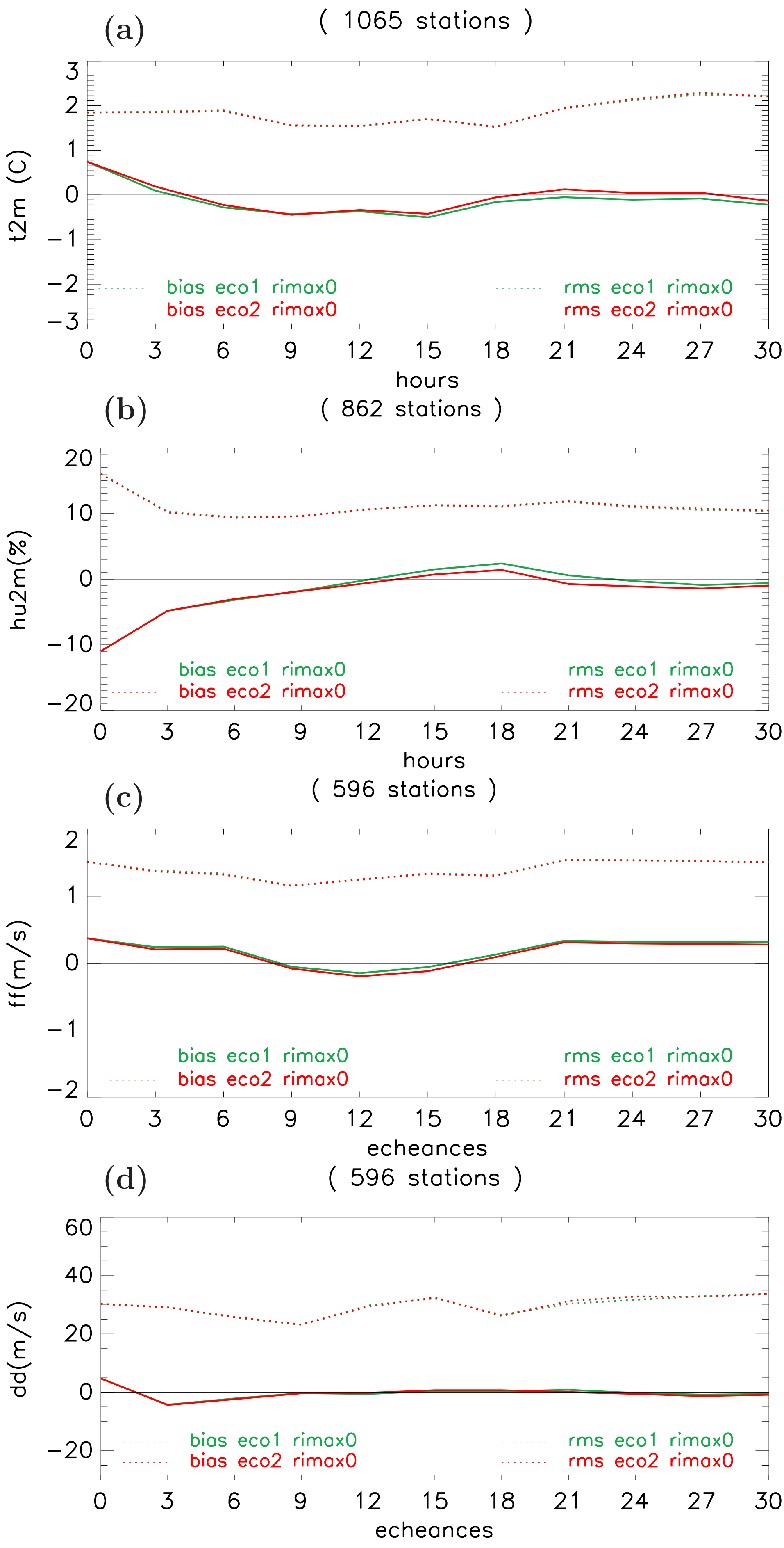


Figure 11: Mean rms (dashed line) and bias (solid line) of a)T2M b)HU2M c)FF10M d)DD10M over 12 days of 2007 for ECO1 RIMAX0 (green line) and ECO2 RIMAX0 (red line) simulations

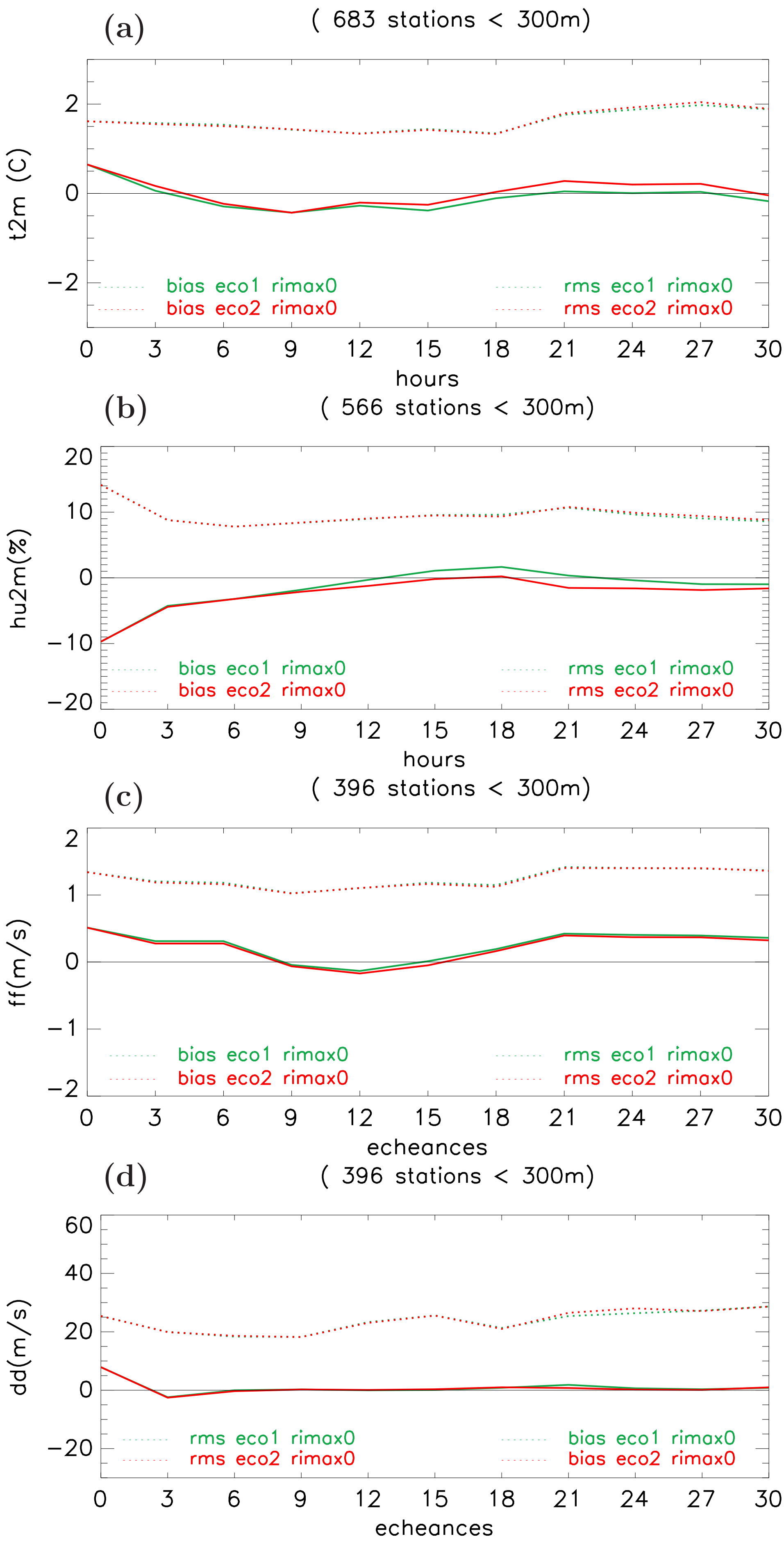


Figure 12: Mean rms (dashed line) and bias (solid line) of a)T2M b)HU2M c)FF10M d)DD10M on plains over 12 days of 2007 for ECO1 RIMAX0 (green line) and ECO2 RIMAX0 (red line) simulations

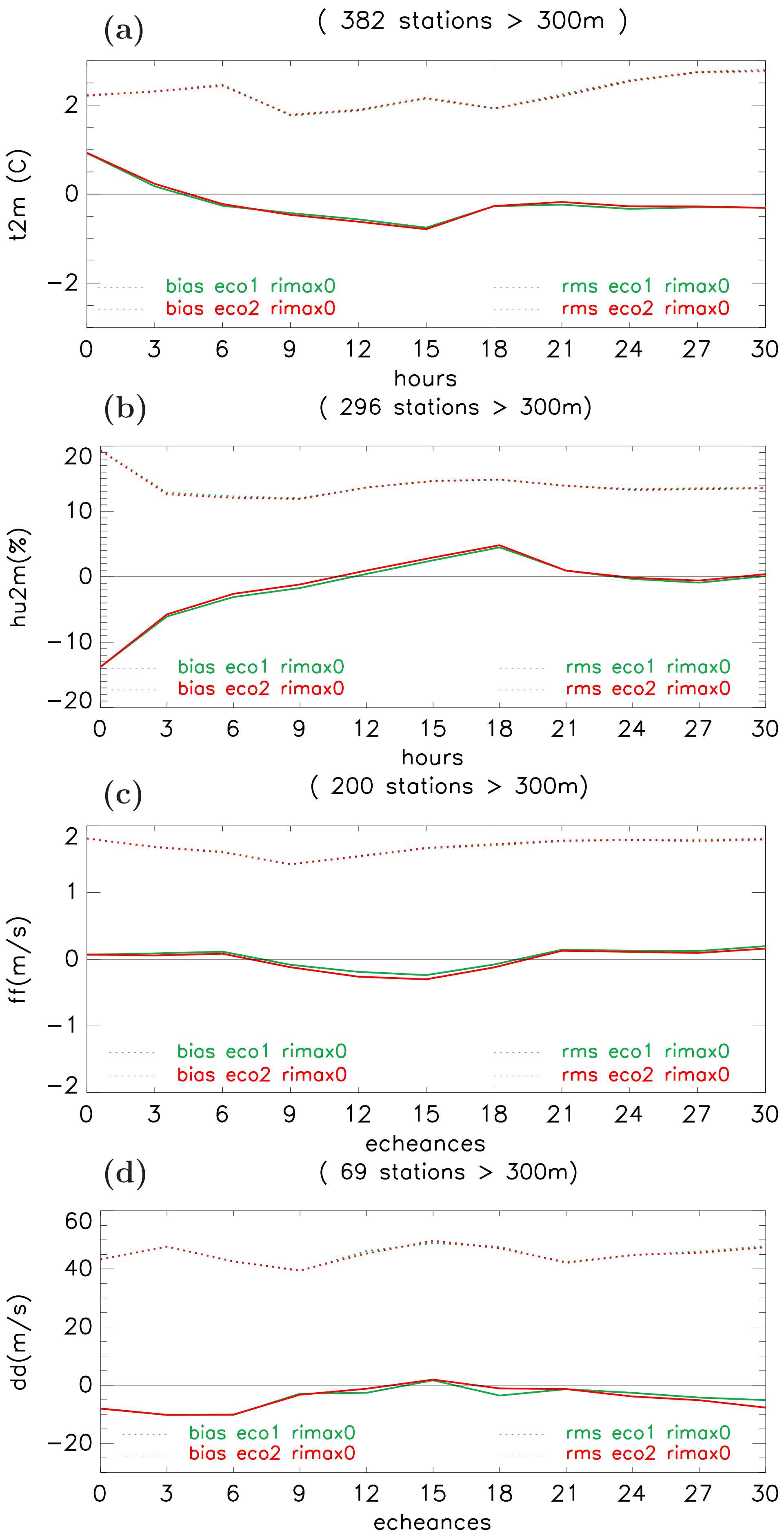


Figure 13: Mean rms (dashed line) and bias (solid line) of a)T2M b)HU2M c)FF10M d)DD10M on mountainous regions over 12 days of 2007 for ECO1 RIMAX0 (green line) and ECO2 RIMAX0 (red line) simulations

4.5 Comparison of the ECO1 REF and ECO2 RIMAX0 simulations

To complete the study, the ECO1 REF and ECO2 RIMAX0 simulations were performed over the 12 sunny days of 2007, in order to evaluate the impact of the implementation of ecoclimap2 in the operational model AROME in the RIMAX0 configuration. The statistical scores have been computed as usual over the 1215 observation stations and also separately for areas of plains and mountains. They are displayed in figure 14 (all stations), figure 15 (stations below 300m) and figure 16 (stations above 300m).

On average over the 12 selected days of 2007, the ECO2 RIMAX0 simulations lead to an improvement of the scores of T2M and HU2M, in plain regions as well as in mountainous regions. Identical scores are obtained in both cases for 10m wind.

However, the daily scores have to be carefully studied in order to qualify the behavior of the model during the different seasons. The results are displayed in appendix G.

4.5.1 T2M scores

From March to August and in October, ECO2 RIMAX0 systematically provides best scores than ECO1 REF for T2M, the nocturnal bias of T2M being reduced by 0.5 to 1.0 C, and the RMS slightly reduced.

In January, February, November and December, ECO2 RIMAX0 generally leads to better results. The two simulations provide similar results until 15H, then ECO2 RIMAX0 is generally better at 18H and 21H, removing the positive ECO1 REF bias of T2M and reducing the RMS. But during the night between 24H and 30H, ECO2 RIMAX0 induces a negative bias of T2M (-0.5 to -1.0C), whereas ECO1 produces a slightly positive bias (0. to 0.5 C). The RMS is only impacted at 27H and 30H in January and November.

In September, ECO2 RIMAX0 is not so good as ECO1 REF, with an increase of the T2M and HU2M RMS between 15H and 18H.

4.5.2 HU2M scores

As for HU2M, ECO2 RIMAX0 generally provides similar or better scores than ECO1 REF. In January, May, June, October, November, December, the bias is reduced by 0 to 5% and rms is reduced too. Scores are very similar in July and August.

From February to April, ECO2 RIMAX0 produces better scores from 00H to 06H, and from 27H to 30H. Scores are very similar for the two simulations from 09H to 15H or 18H. But at 21H and 24H, ECO1 REF is better, a positive bias of 0 to 5% being observed for ECO2 RIMAX0.

In September, ECO1 REF is better from 12H to 18H, whereas the scores issued from the two simulations remain similar during the rest of the day. .

4.5.3 10M wind scores

There is only little difference on FF10M bias in November, December, January and February, ECO2 RIMAX0 producing a slightly weaker wind leading generally to a reduction of the nocturnal positive bias. In the daytime, ECO2 RIMAX0 simulations slightly improve FF10M bias in January, and slightly increase the negative bias in November and December. For the other months, ECO1 REF and ECO2 RIMAX0 lead to identical results. DD10M scores only differ a little (by 5 degrees) from April to June during the night.

As a conclusion, the ECO2 RIMAX0 simulations generally improve the RMS and the bias of T2M and HU2M, except in September (deterioration of the T2M and HU2M RMS between 12H and 18H) and at 27H and 30H in January and November (negative bias of T2M and slight deterioration of the RMS).
FF10M and DD10M RMS remain similar in both cases.
FF10M is slightly weaker in winter in ECO2 RIMAX0 simulations, which tends to reduce slightly the ECO1 REF nocturnal bias from November to February, and to increase slightly the ECO1 REF negative diurnal bias in November and December.

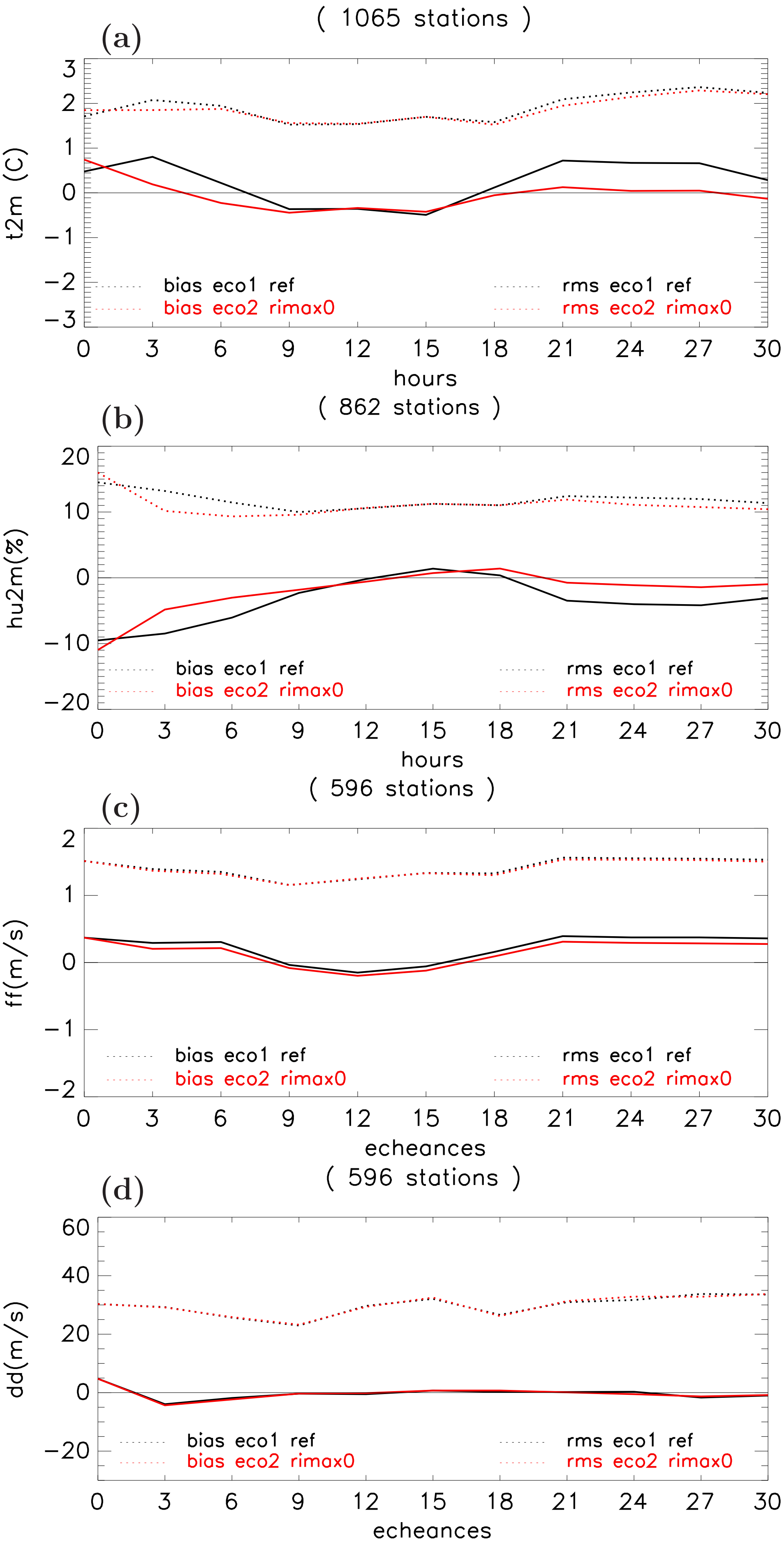


Figure 14: Mean rms (dashed line) and bias (solid line) of a)T2M b)HU2M c)FF10M d)DD10M over 12 days of 2007 for ECO1 RIMAX0 (green line) and ECO2 RIMAX0 (red line) simulations

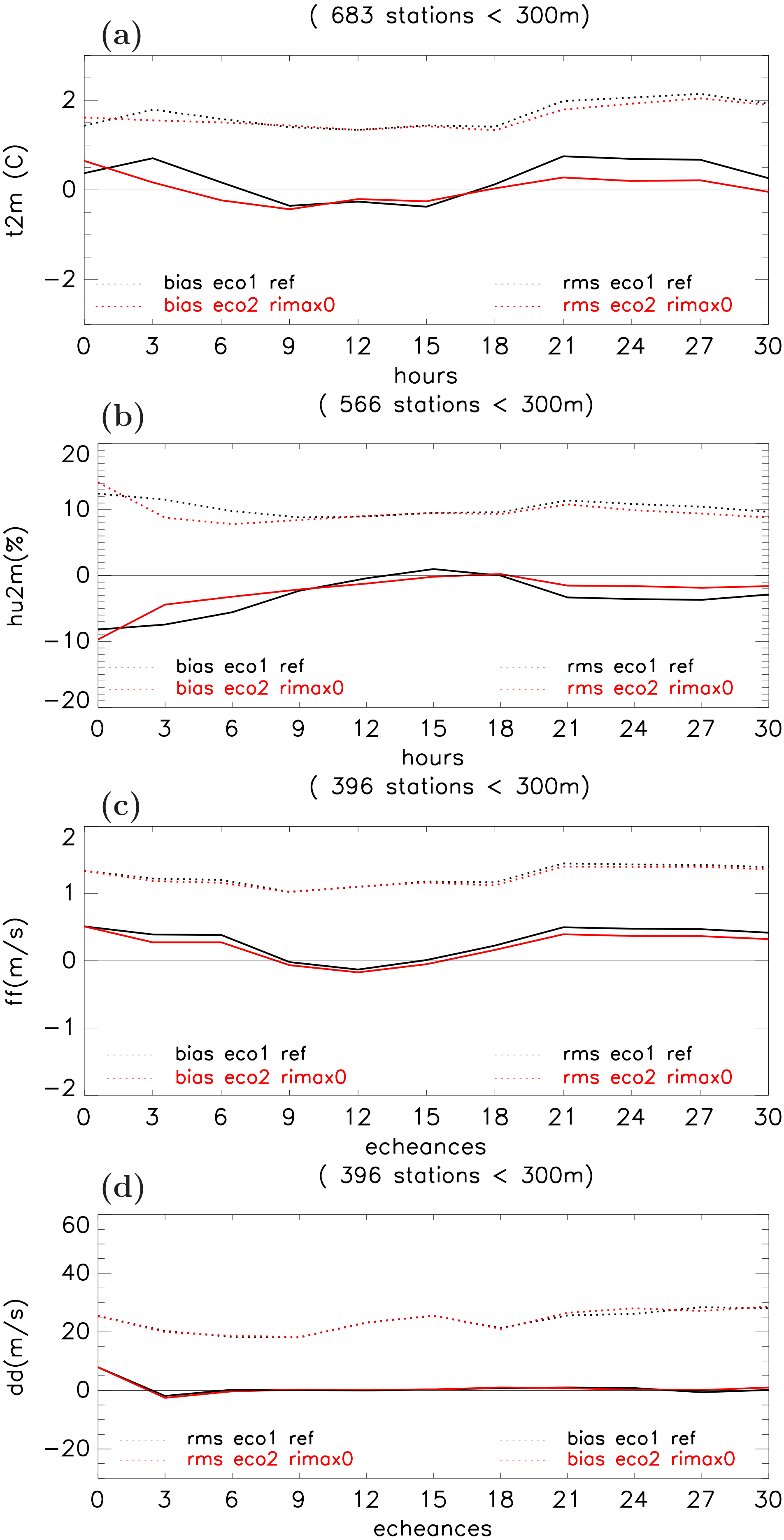


Figure 15: Mean rms (dashed line) and bias (solid line) of a)T2M b)HU2M c)FF10M d)DD10M on plains over 12 days of 2007 for ECO1 RIMAX0 (green line) and ECO2 RIMAX0 (red line) simulations

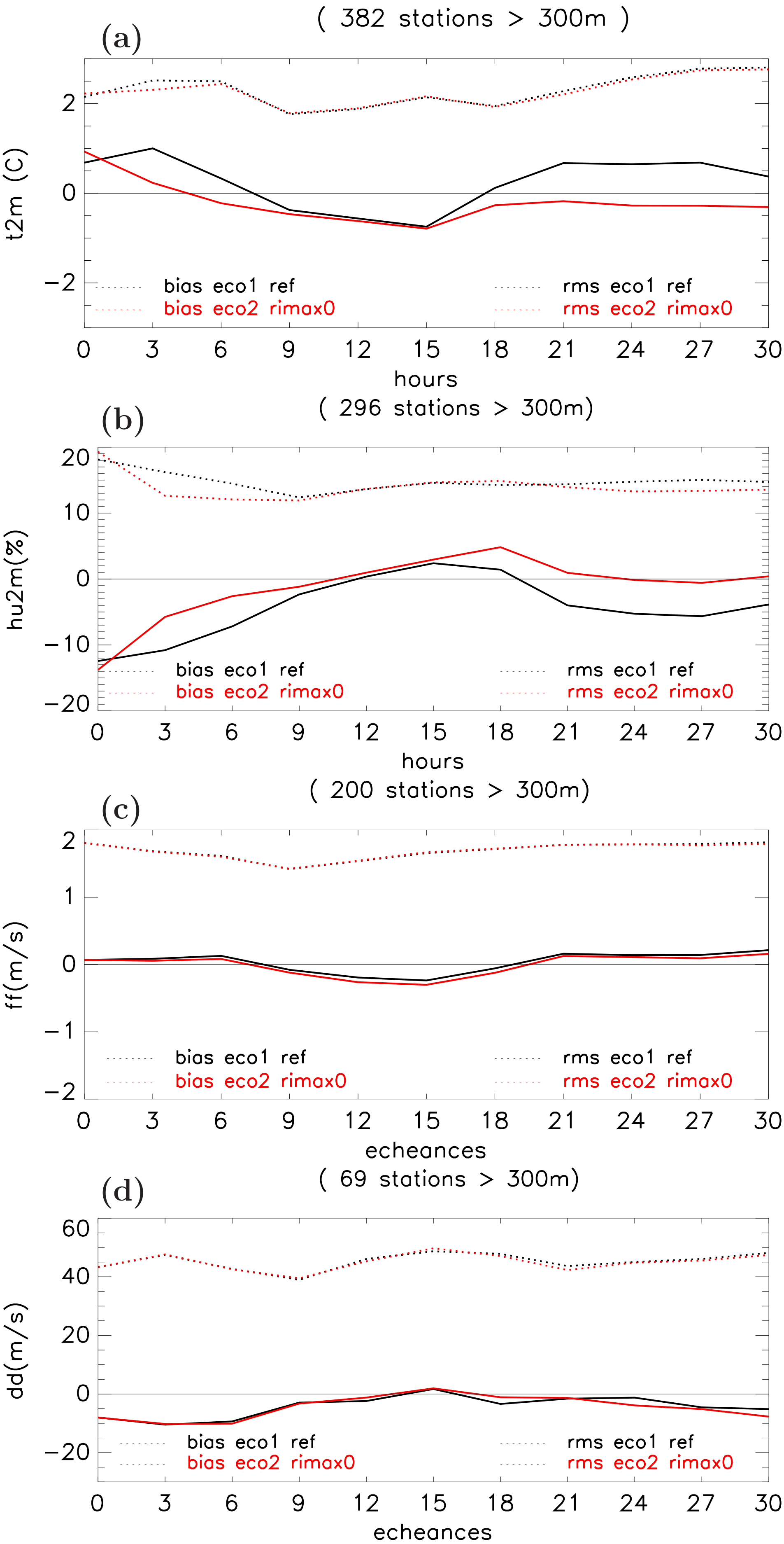


Figure 16: Mean rms (dashed line) and bias (solid line) of a)T2M b)HU2M c)FF10M d)DD10M on mountainous regions over 12 days of 2007 for ECO1 RIMAX0 (green line) and ECO2 RIMAX0 (red line) simulations

5 Conclusion

This study presents an assessment of the performance of two versions of ECOCLIMAP, the global database of land surface parameters used in METEO-FRANCE operational meteorological and climate models to initialize the soil-vegetation-atmosphere transfer schemes.

The AROME operational model was run on 12 selected days of 2007, for which the meteorological situation was characterized by anticyclonic conditions with light winds and clear sky, so that the impact of the surface on the atmospheric boundary layer could be preponderant. Simulations were also performed on two periods of 30 consecutive days of 2011 and 2012 (summer and winter) to test the behaviour of the model in various meteorological conditions.

The evaluations are based on screen-level observations (2m air temperature and relative humidity, 10m wind) available at 1200 stations of the French operational network, the scores against screen-level variables being considered as very informative of the quality of the simulation of the surface boundary layer.

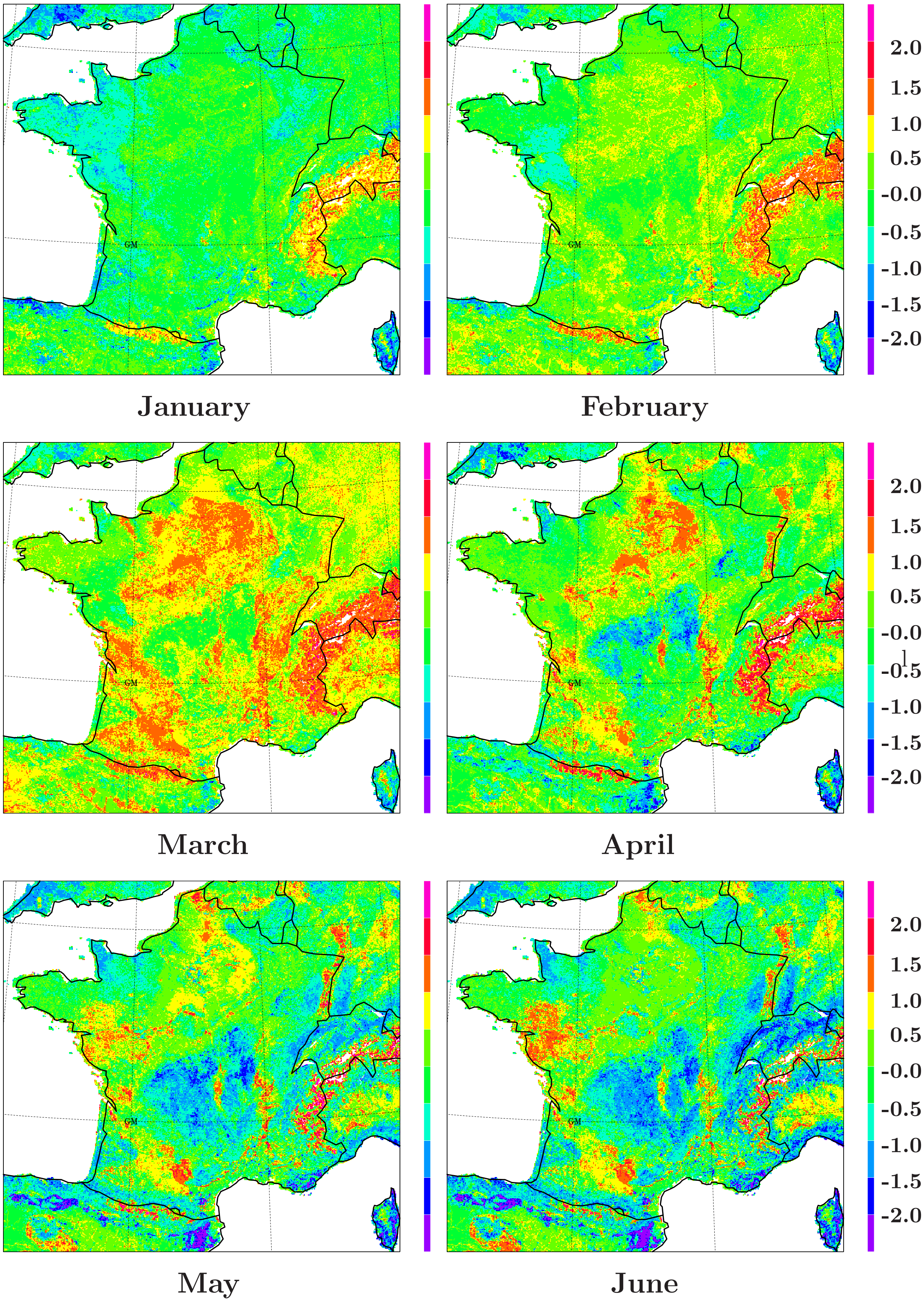
An important positive bias of T2M and negative bias of HU2M was observed during the night from spring to autumn in both sets of simulations, leading us to propose a modification of the RIMAX value in CANOPY, the multi-layer surface scheme used by AROME. This modification was able to correct significantly the night time positive bias of T2M and negative bias of HU2M computed by CANOPY, as well as the RMS associated.

Finally, it turns out that the use of ECOCLIMAP2 instead of ECOCLIMAP1 in the AROME-SURFEX system only induces minor modifications in operational scores of T2M, HU2M, and 10 m wind. These modifications, directly linked to the modification of the description of LAI in ECOCLIMAP, mainly occur in March, April and from July to September. They generally lead to an improvement of the scores, except in September and during the night in August and December.

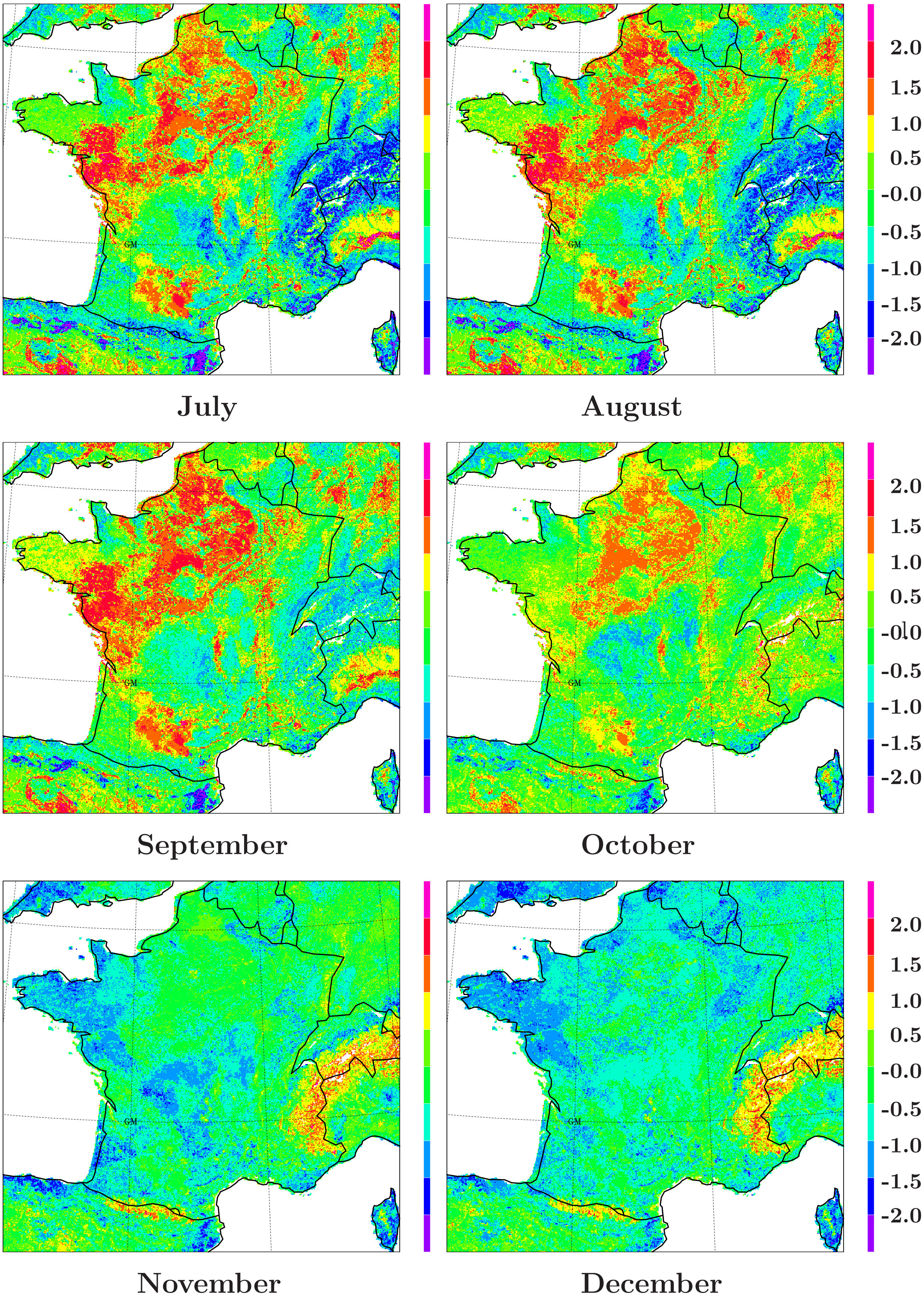
Compared to the actual configuration of the AROME-SURFEX system (ECOCLIMAP1 in SURFEX and RIMAX0̄.2 in CANOPY), the new configuration (ECOCLIMAP2 in SURFEX and RIMAX0̄ in CANOPY) generally brings improvements in screen-level variables RMS and bias, particularly by reducing the nocturnal positive bias of T2M and negative bias of HU2M. The impact on 10m wind is weak, and limited to the winter months.

ECOCLIMAP2 brings indeed important improvements compared with ECOCLIMAP1: a new set of covers has been defined from recent land cover maps (GLC2000, CLC2000), and the estimation of the LAI (Leaf Area Index)- addressed as a crucial parameter of SVAT models since it determines the plant transpiration - is derived from MODIS satellite data from 2002 to 2006. Further tests will have to be done to evaluate ECOCLIMAP2 in a fully operational context.

A Difference between LAI ECOCLIMAP1 and LAI ECOCLIMAP2 from January to December



LAI ECOCLIMAP1 - LAI ECOCLIMAP2



LAI ECOCLIMAP1 - LAI ECOCLIMAP2

B Description of the weather conditions during the 12 selected days of 2007

January, the 26th

Anticyclonic conditions prevail over France, because of a ridge of high pressure extending over the Atlantic Ocean. In the upper levels, a north-north-easterly flow brings very cold and dry air over the country. Minimum temperature, often negative, reaches 10 to 20C from center to east of France. Maximum temperature ranges from 4C to 4C in general, 8 to 12C near the coasts. Winds are weak, and all areas benefit from a very sunny weather.

February, the 15th

High pressure is dominating at all levels, between a cloudy system leaving the east of the country and another one arriving at night on the West of the country. A sunny weather prevails over France, with weak or moderate winds in general, except near the Mediterranean sea where Mistral and Tramontane exceed 100 km/h. Temperatures range from 1 to 5C in the morning, 11 to 20C from North to South in the afternoon (2 to 4C above the climatologic values)

March, the 15th

France benefits from anticyclonic conditions with high pressure at all levels. Clouds and rain are pushed off to the North of the British Isles. In the morning, mist and fog is often observed, with a minimum temperature ranging from 3C to 5C. In the afternoon, a sunny weather prevails, with weak winds, and temperatures reach 12C to 22C from North to South.

April, the 21st

As in March, high pressure is dominating and clouds and rain are pushed off to the North of Europe. In the afternoon, some showers and storms occur in mountainous areas. Minimum temperatures range from 4C to 12C from North to South, and maximum temperatures range from 16C to 28C from North to South, above the climatologic values.

May, the 24th

A flat low settles over France. The North-Westerly part of the country benefits from a sunny weather, whereas instability develops during the afternoon on the South-Easterly part of the country. Local storms occur from South-West to North-East and on the South-East of the country. Minimum temperatures generally range from 12 to 18C from North-West to South-East. Maximum temperatures, above the climatologic values, reach 25 to 33C from North to South.

June, the 9th

The weather is approximately the same as in May, with a flat low over the country and instability developing from South to North-East. Temperatures, ranging from 12 to 18C in the morning, reach 22 to 31C in the afternoon from North to South.

July, the 12th

High pressure is dominating at high level, and a South-Westerly flux brings warm and dry air over the country. The sky is generally clear, except on North-West where weather systems bring clouds and drizzle. Temperatures are running from 11/16C in the morning to 28/34C in the afternoon.

August, the 4th
High pressure is dominating at all levels, ensuring a warm and sunny weather over France. Wind is weak, temperatures range from 9/17C in the morning to 26/33C in the afternoon from North to South.

September, the 10th
A ridge of high pressure extends over the Atlantic Ocean, establishing a North-West flux over France. A weather system brings clouds and rain on The North and North-East of the country. Anticyclonic conditions prevail on the other areas, where the weather is sunny. Temperatures range from 6/13C in the morning, 16/18C near the Mediterranean coast, to 19/28C from North to South in the afternoon.

October, the 14th
A ridge of high pressure extends over France, so that weather systems are rejected over the British isles and Scandinavia. Fog, mist and low level clouds are often observed in the morning, but a warm and sunny weather generally takes place after their dissipation. Minimum temperatures generally range from 4C to 8C, except on the Mediterranean region with 10C to 14C. Maximum temperatures are often 2 to 7C above climatologic values, with 17 to 25C from North to South. Winds are weak, generally from South-East.

November, the 16th
A low pressure area over Sardinia generates a North-East flux over France. Anticyclonic conditions prevail at low level over the country, on which a cold and dry air mass is present. The weather is generally sunny, except in Corsica where storms occur. Mistral and Tramontane are very strong (100 km/h) near the Mediterranean sea, Easterly winds reach 100km/h in Corsica. Elsewhere, North or North-easterly wind is moderate. Severe frosts are generally observed (-1 to 11C), except near the Mediterranean sea and the Channel (3 to 7 C). In the afternoon, maximum temperatures are running from 0 ro 6C, 8 to 12C near the coasts.

December, the 16th
A low pressure area over Sardinia and a Ridge of high pressure from the Atlantic Ocean to the British Isles and Scandinavia generate a cold and dry North-East flux over France. The weather is sunny over the major part of the country, except in the South-West region and from Auvergne to Lyonnais where freezing fog or low clouds are often observed. In Corsica, clouds brig rain or snow till the evening. Temperatures are well below the climatologic values with a minimum of 3 to 11C, and a maximum of 1 to 6C, 8 to 11C near the Mediterranean sea.

C Mean rms and bias of T2M and HU2M on each of the twelve selected days of 2007 for ECO1 and ECO2 simulations

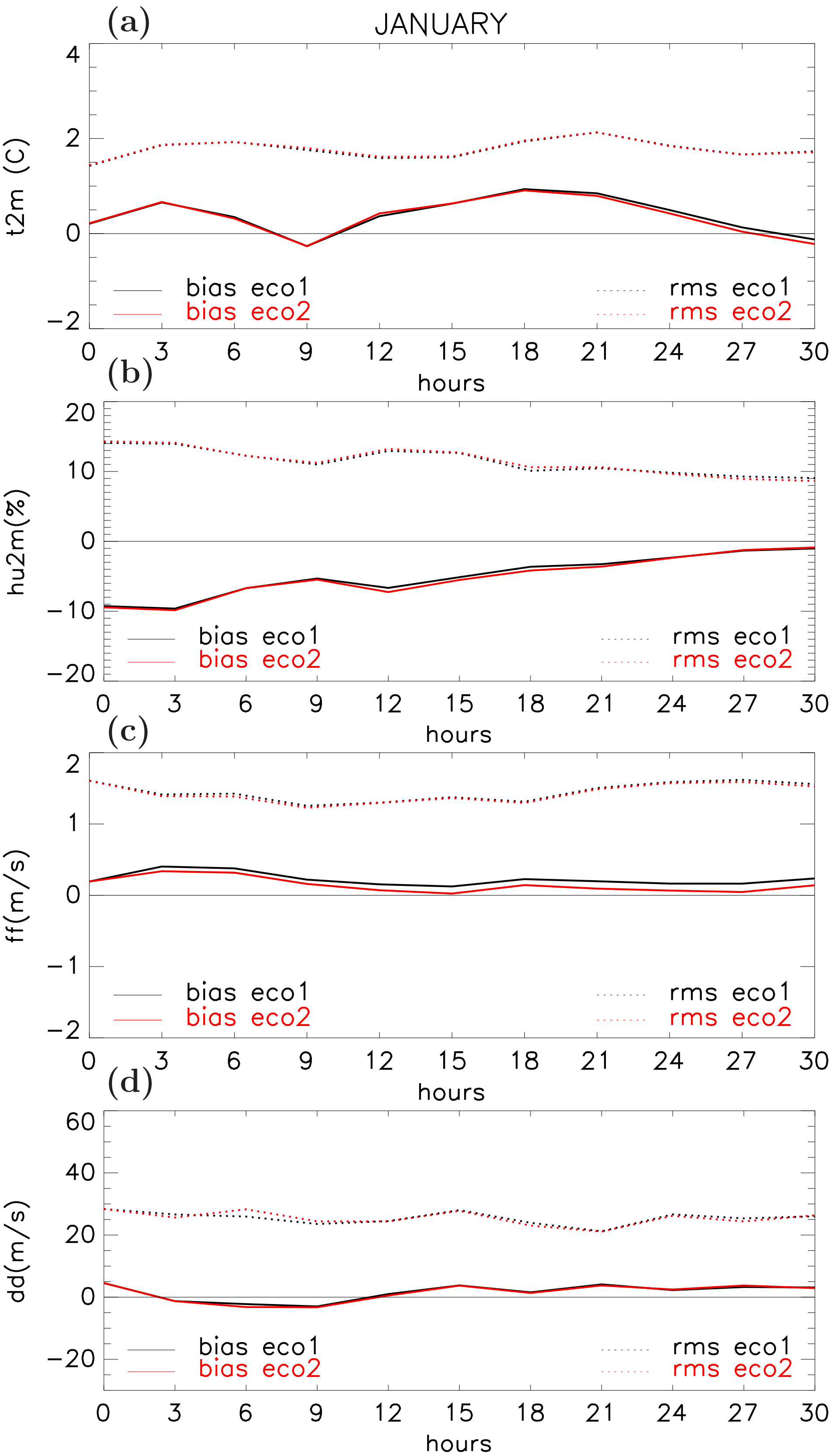


Figure 17: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070126 for ECO1 and ECO2 simulations

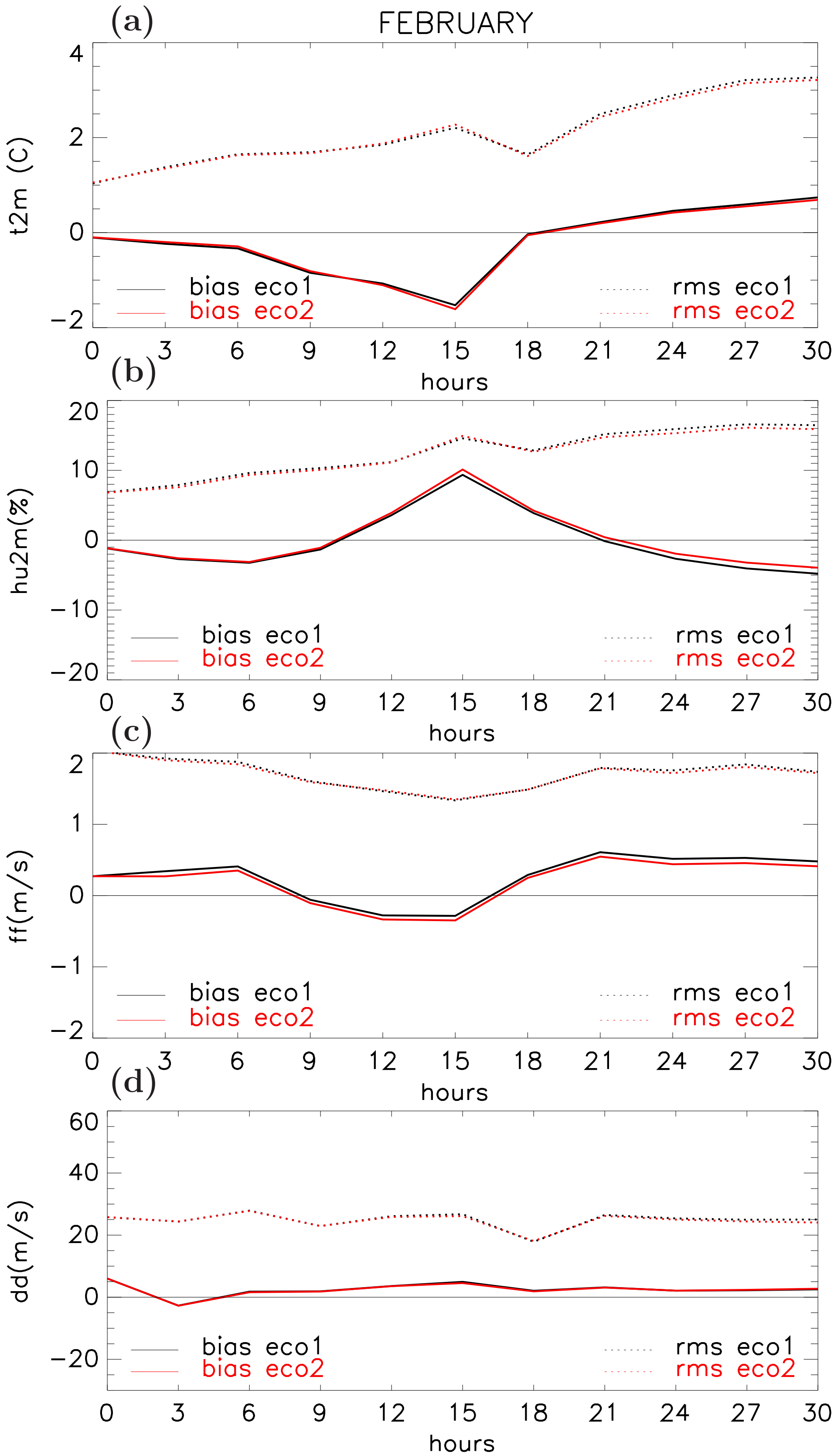


Figure 18: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070215 for ECO1 and ECO2 simulations

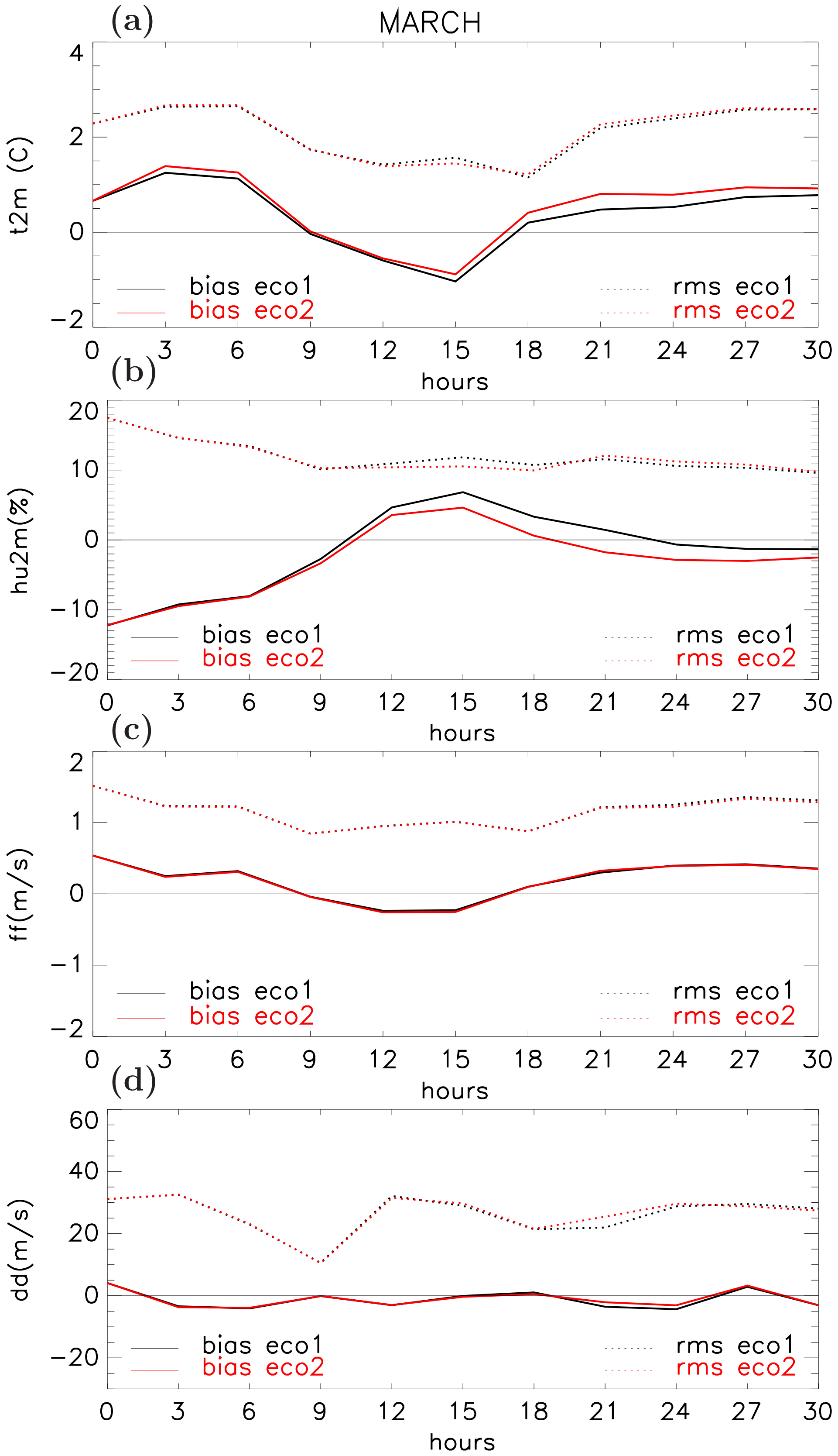


Figure 19: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070315 for ECO1 and ECO2 simulations

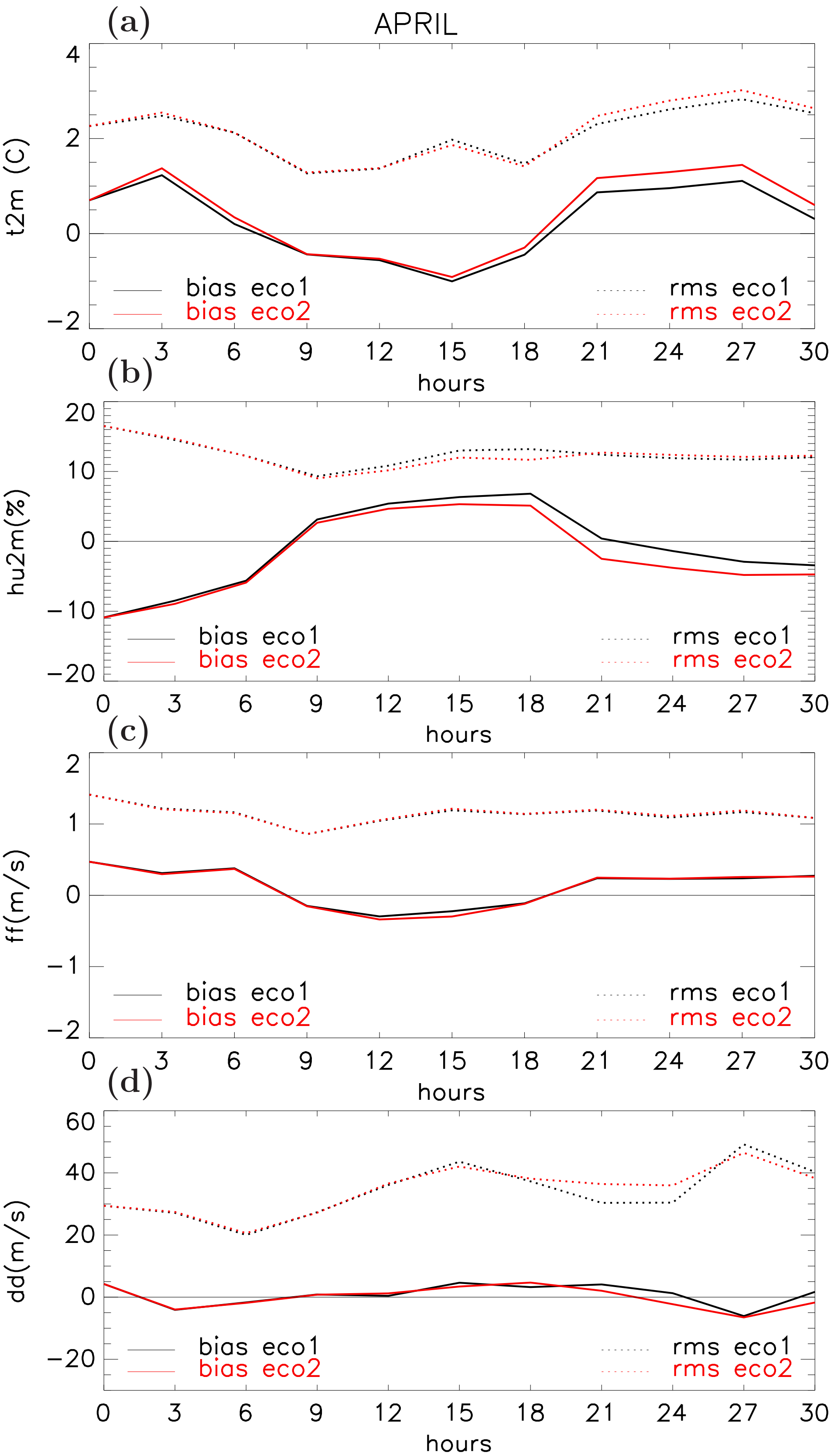


Figure 20: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070421 for ECO1 and ECO2 simulations

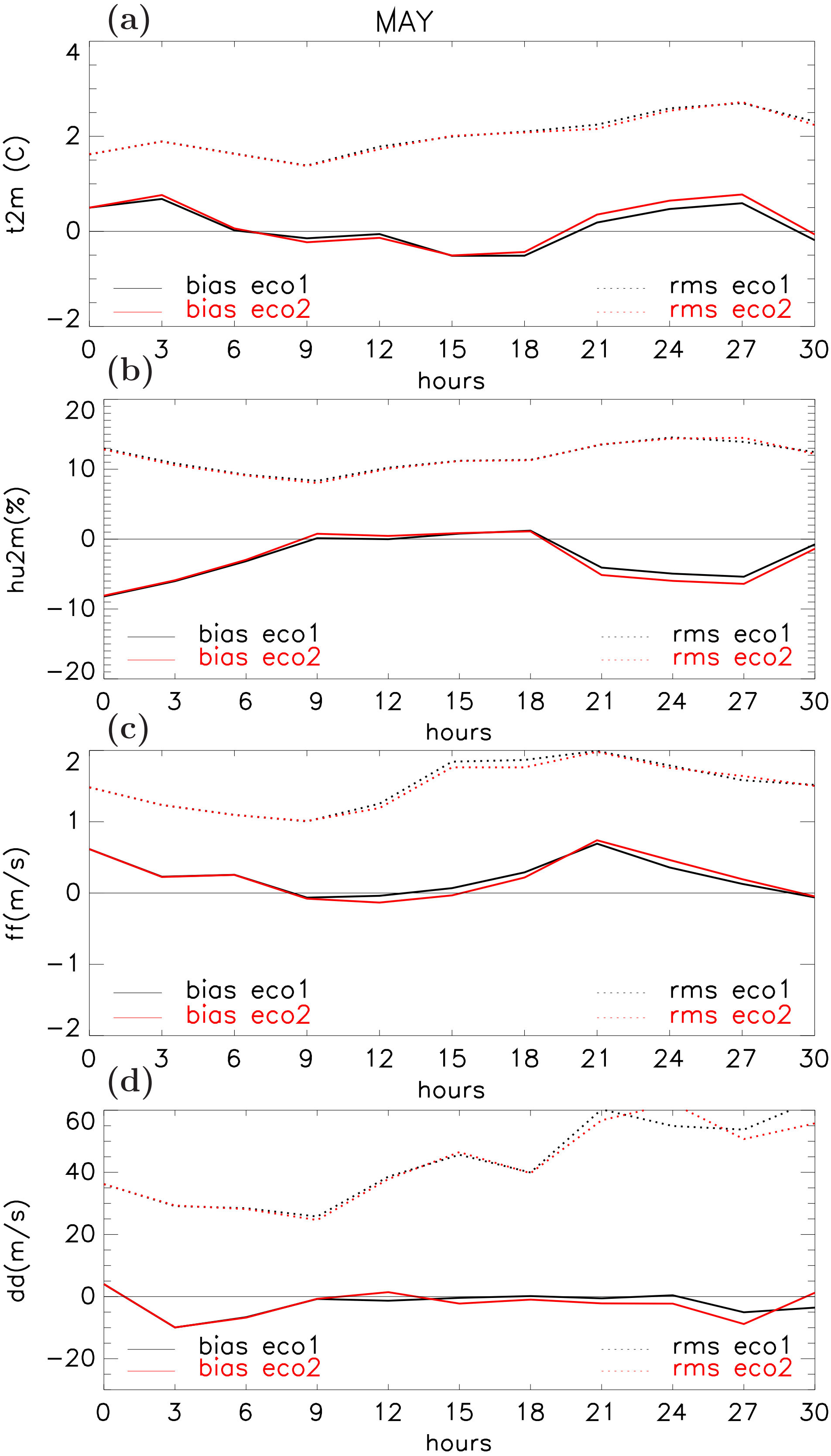


Figure 21: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070524 for ECO1 and ECO2 simulations

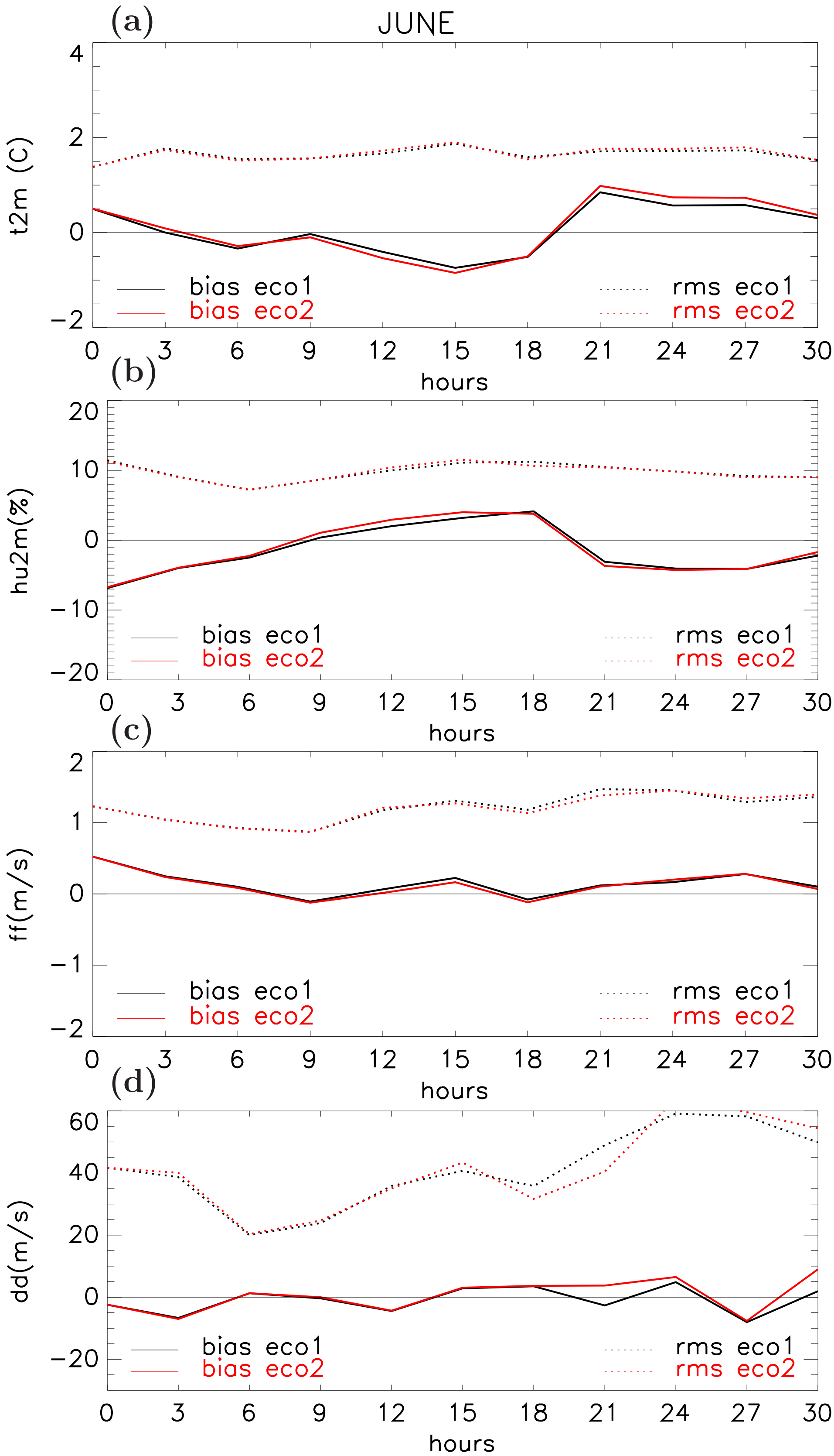


Figure 22: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070609 for ECO1 and ECO2 simulations

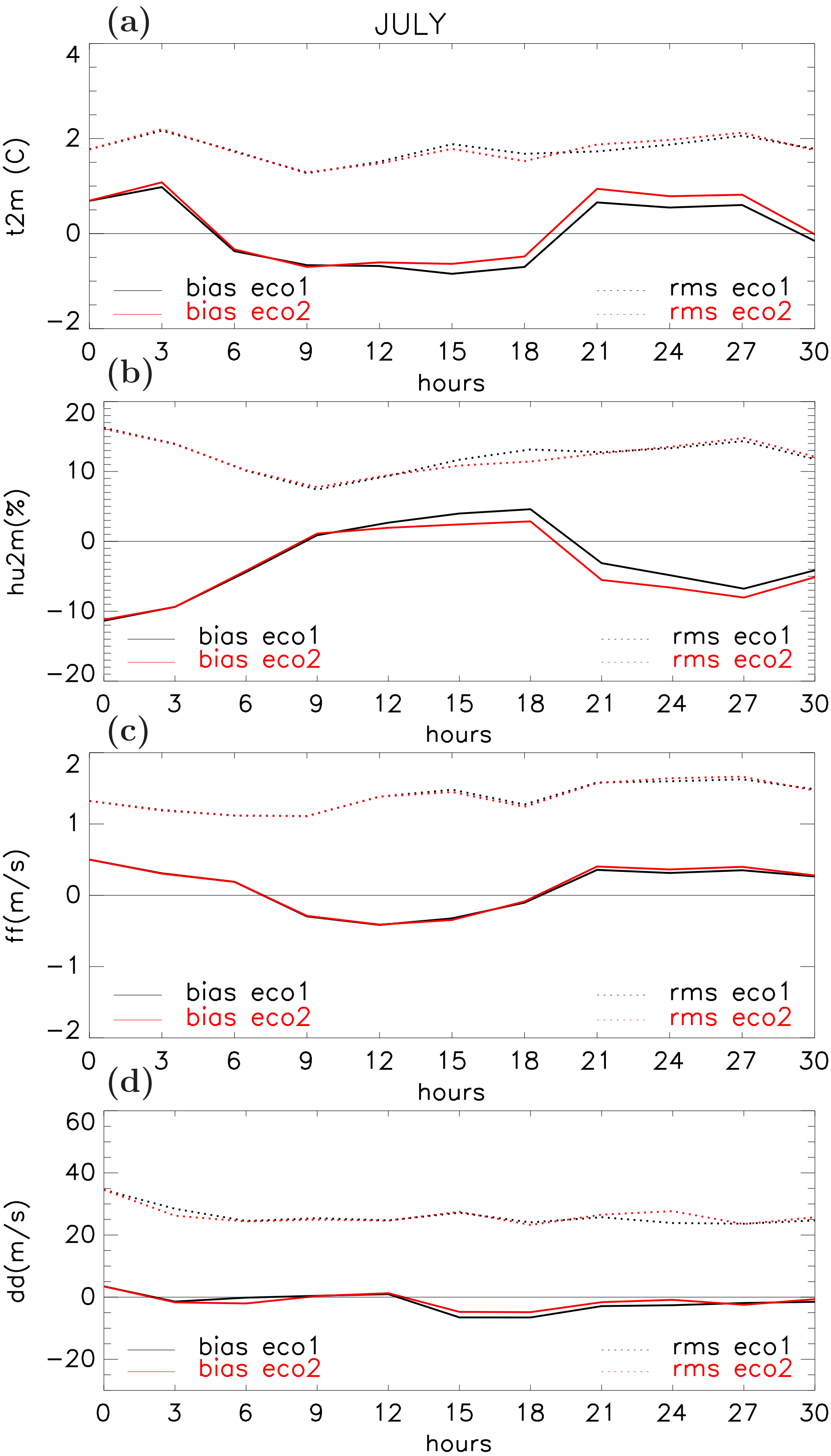


Figure 23: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070713 for ECO1 and ECO2 simulations

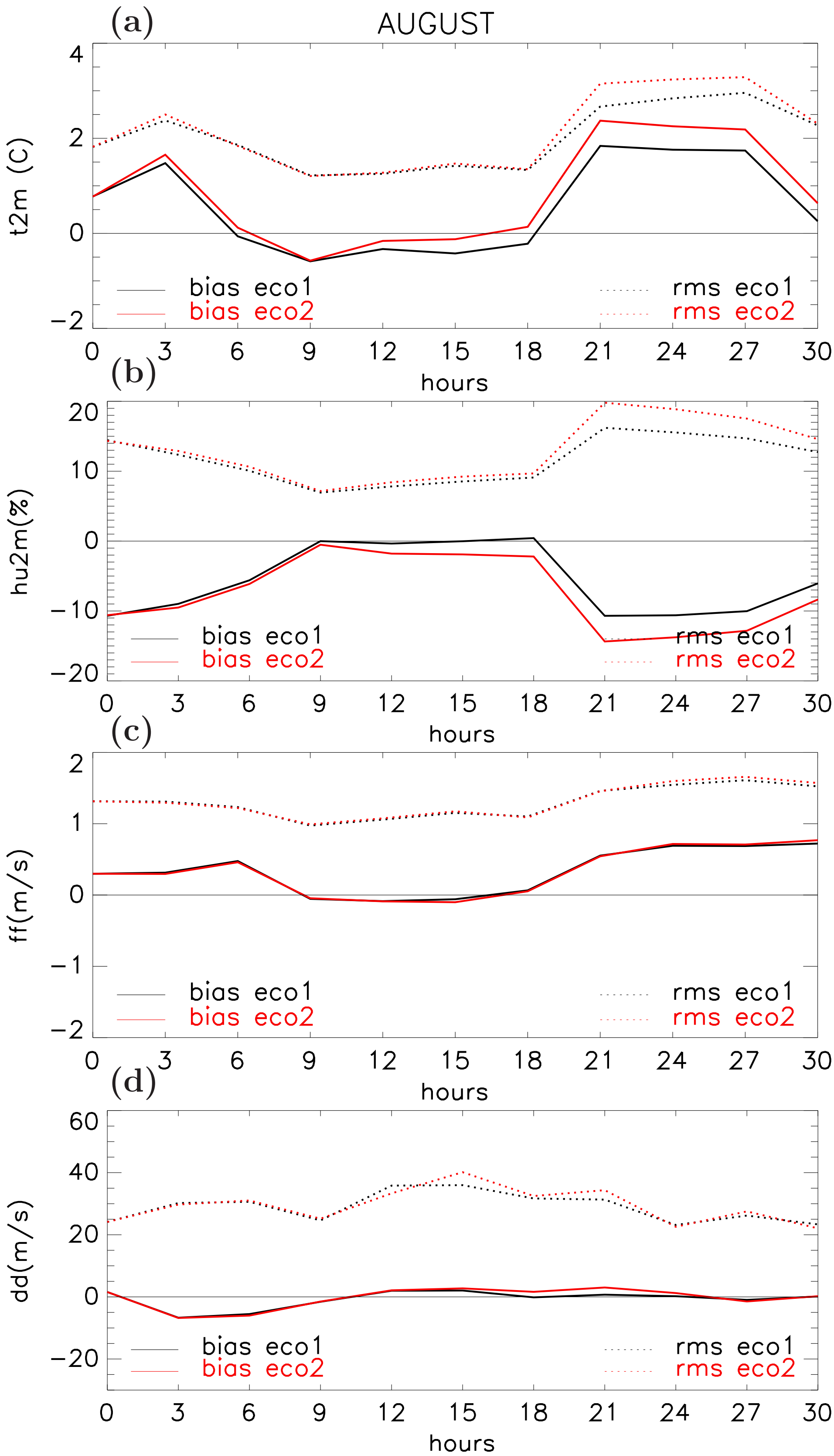


Figure 24: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070804 for ECO1 and ECO2 simulations

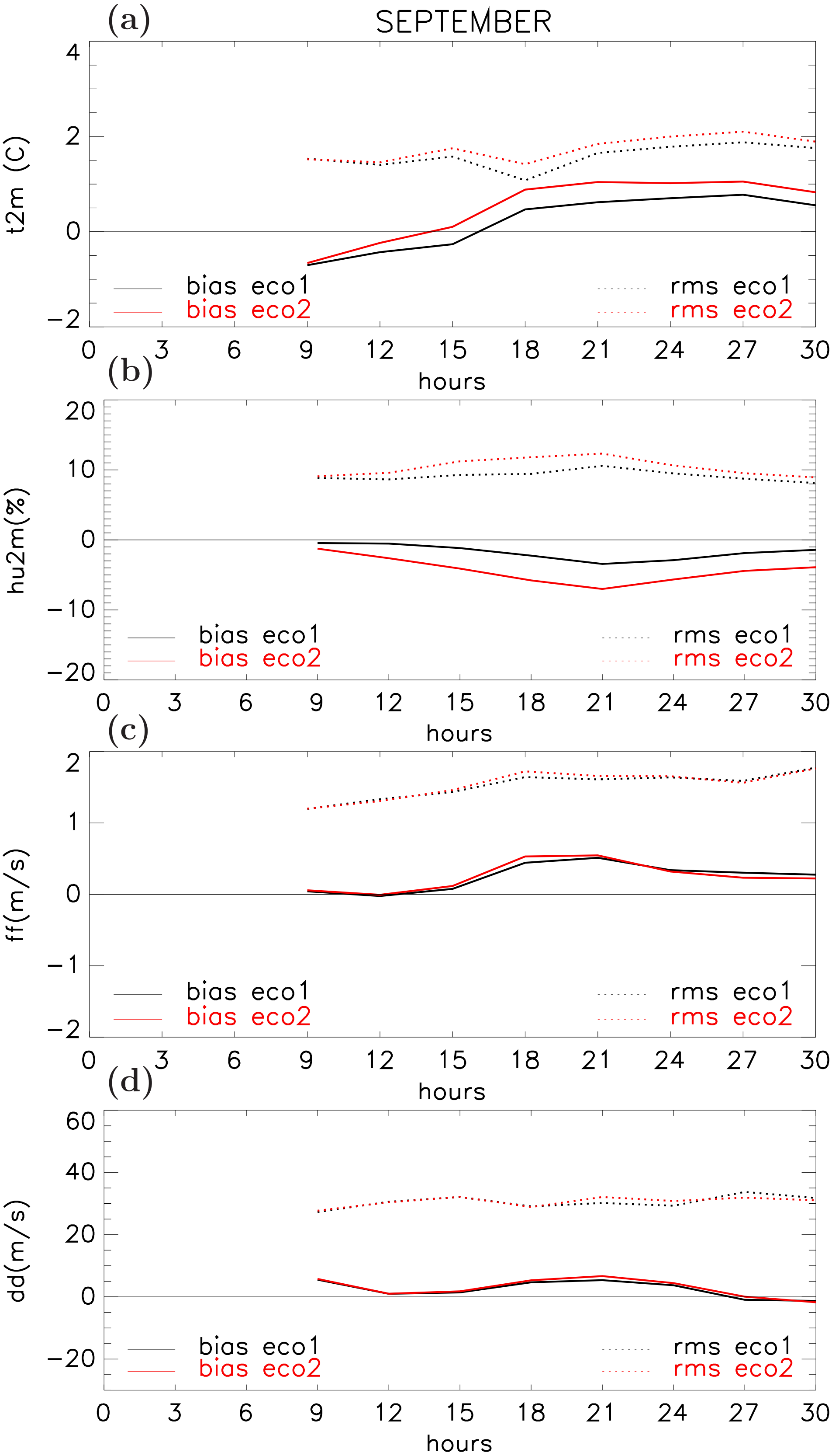


Figure 25: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070910 for ECO1 and ECO2 simulations

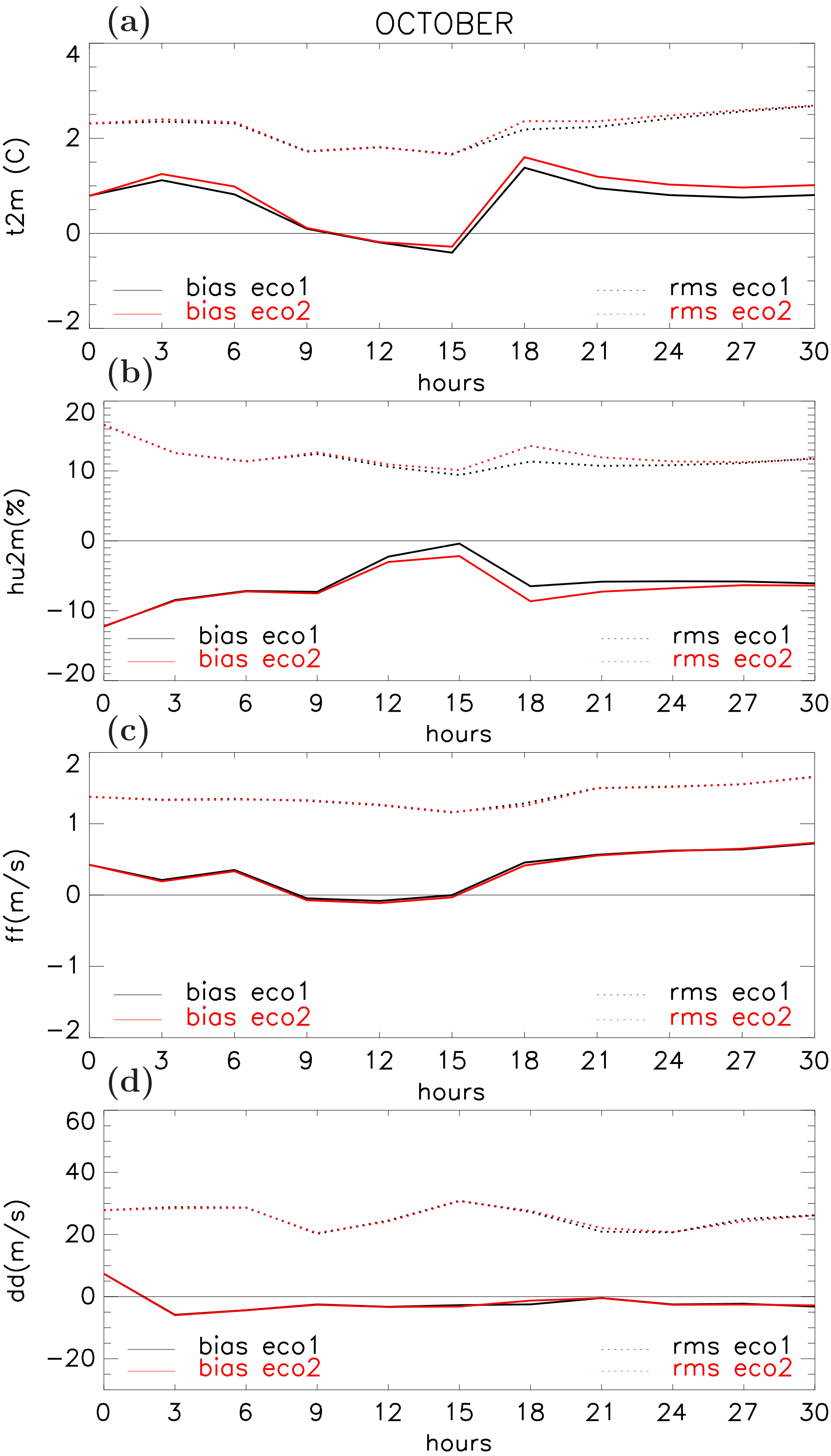


Figure 26: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20071014 for ECO1 and ECO2 simulations

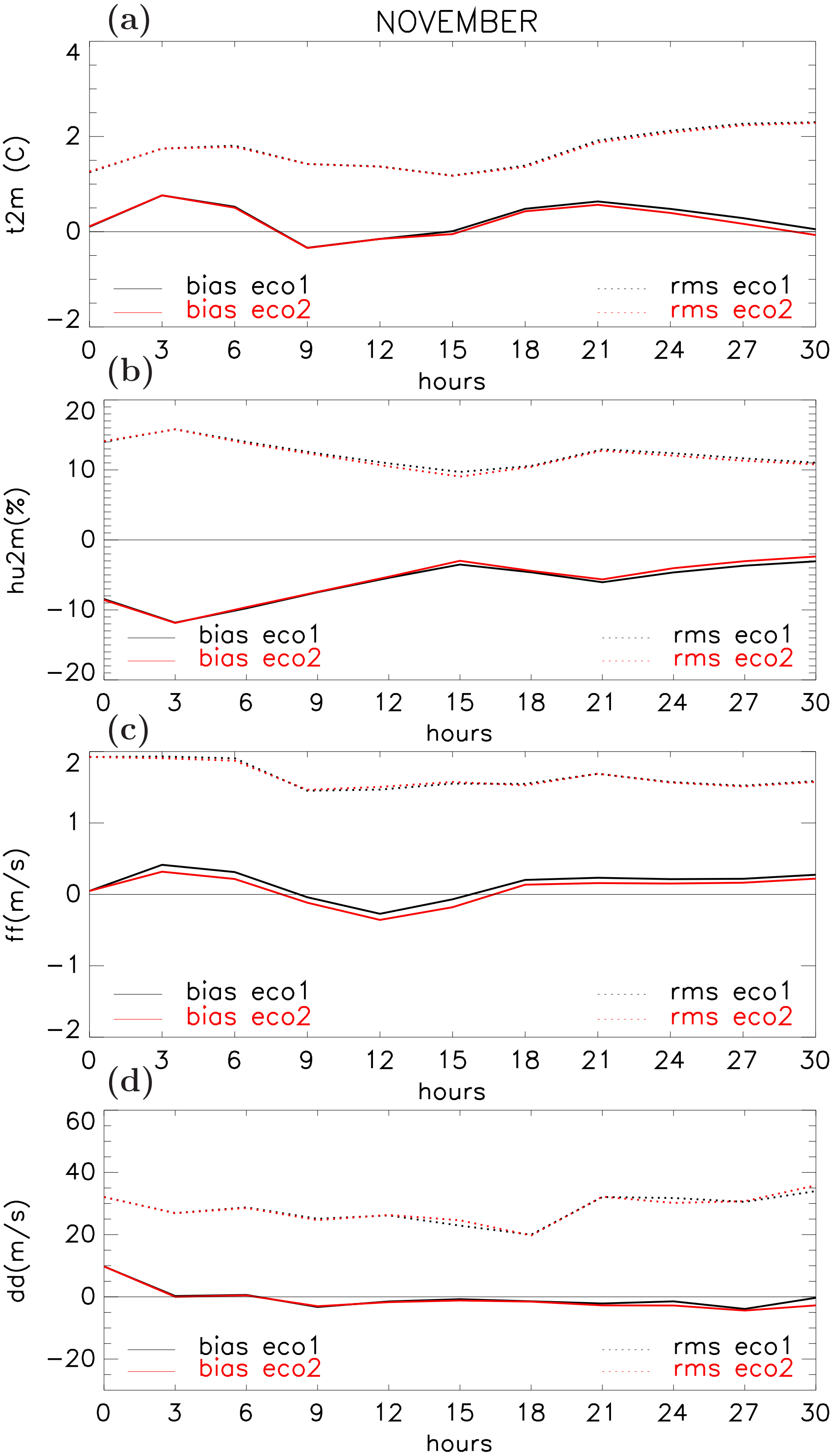


Figure 27: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20071116 for ECO1 and ECO2 simulations

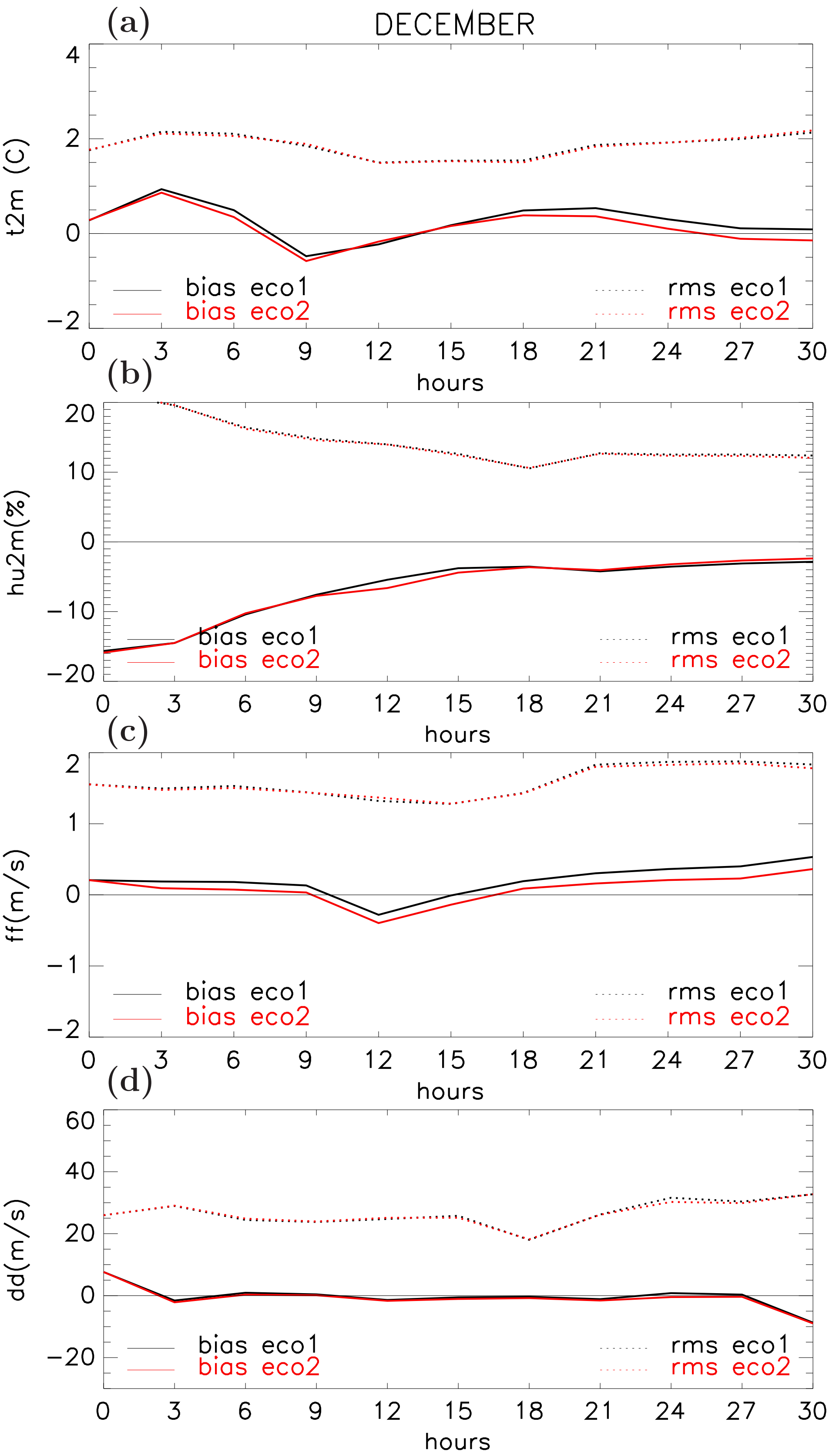


Figure 28: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20071216 for ECO1 and ECO2 simulations

D Mean rms and bias of T2M and HU2M from April to December for the selected days of 2007 for ECO1 and DIAG1 simulations

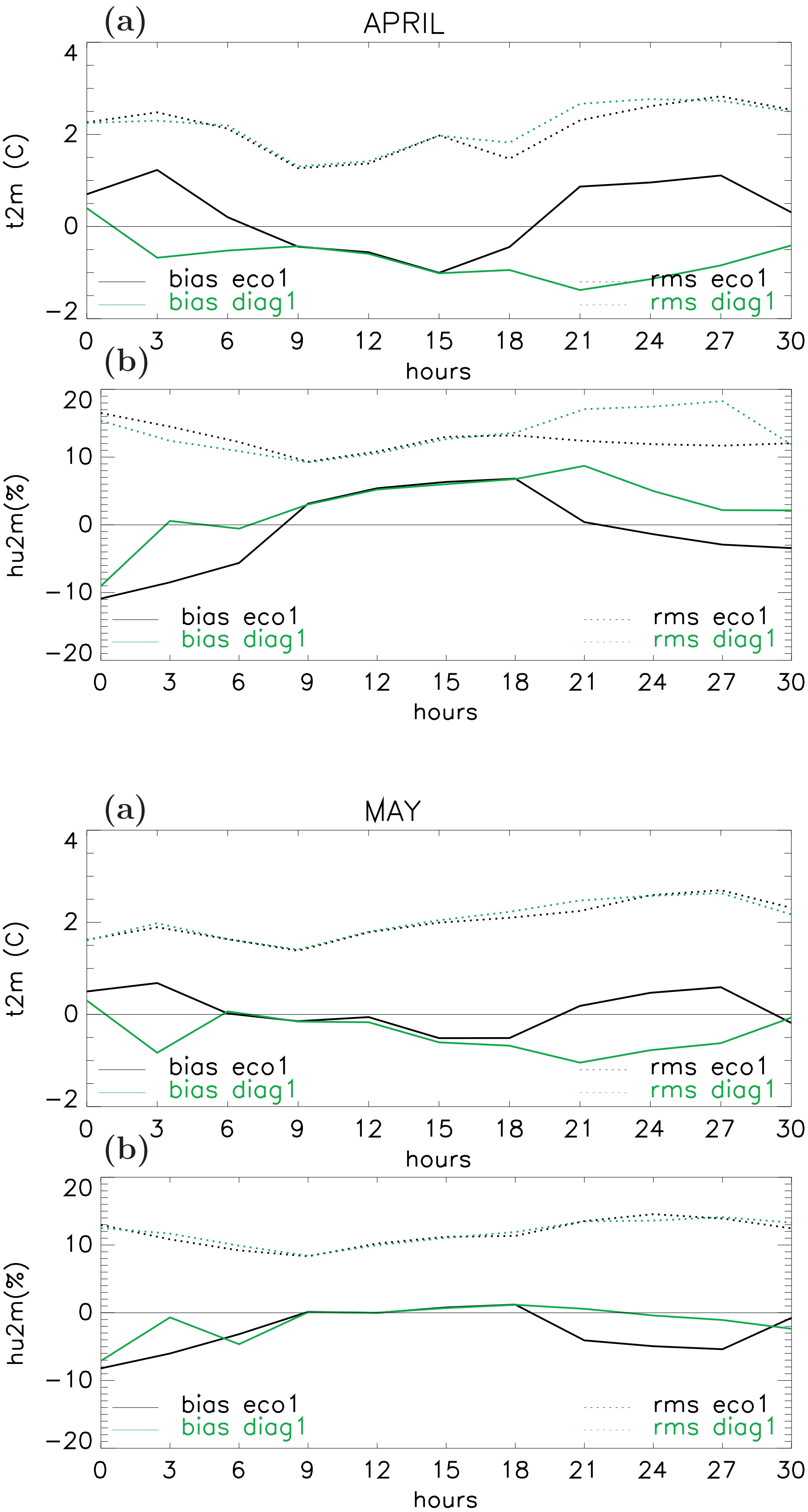
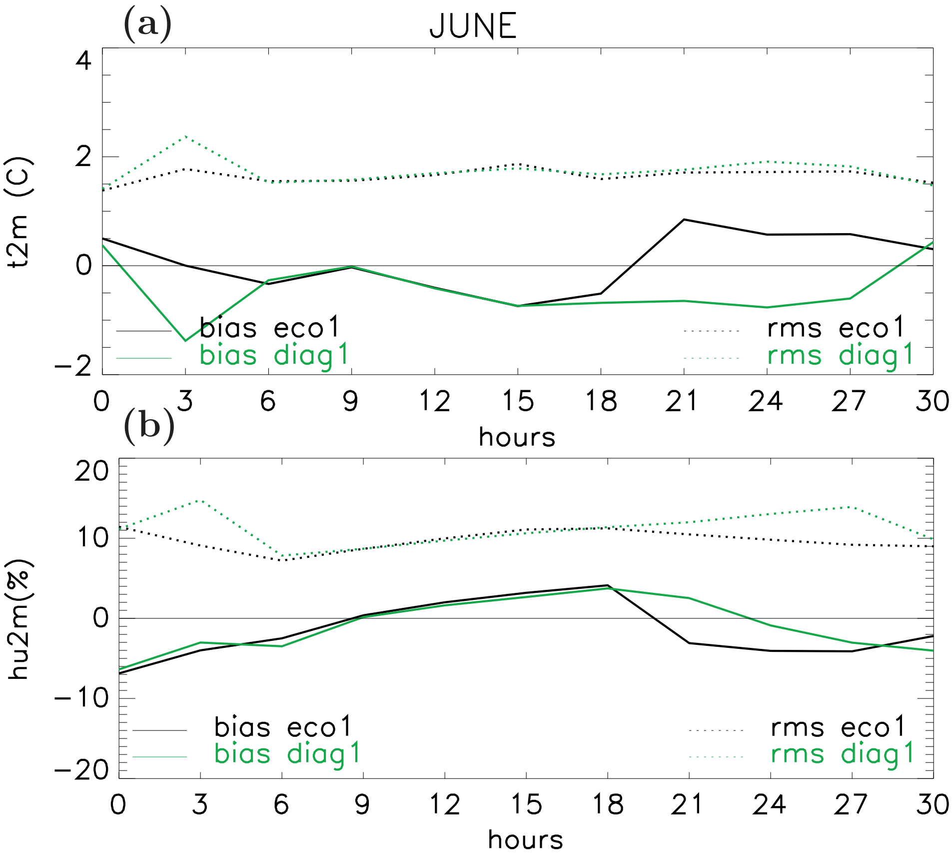


Figure 29: Mean rms (dashed line) and bias (solid line) of a)T2M and b)HU2M for ECO1 (black line) and ECO2 (red line) simulations



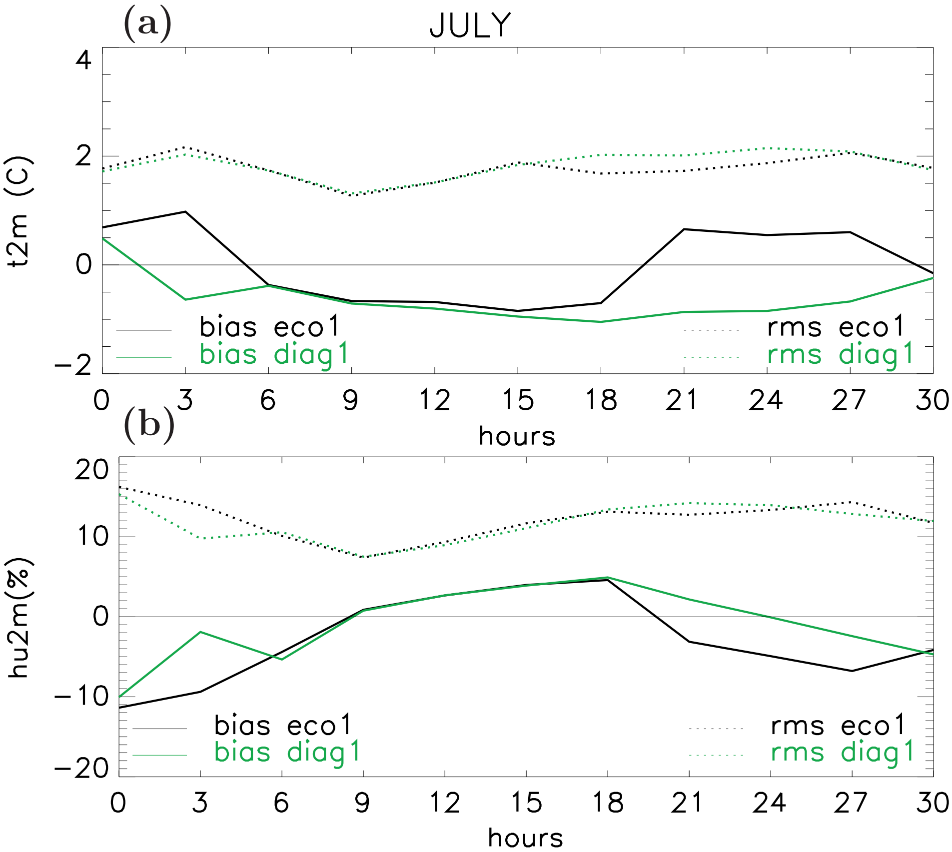


Figure 30: Mean rms (dashed line) and bias (solid line) of a)T2M and b)HU2M for ECO1 (black line) and DIAG1 (green line) simulations

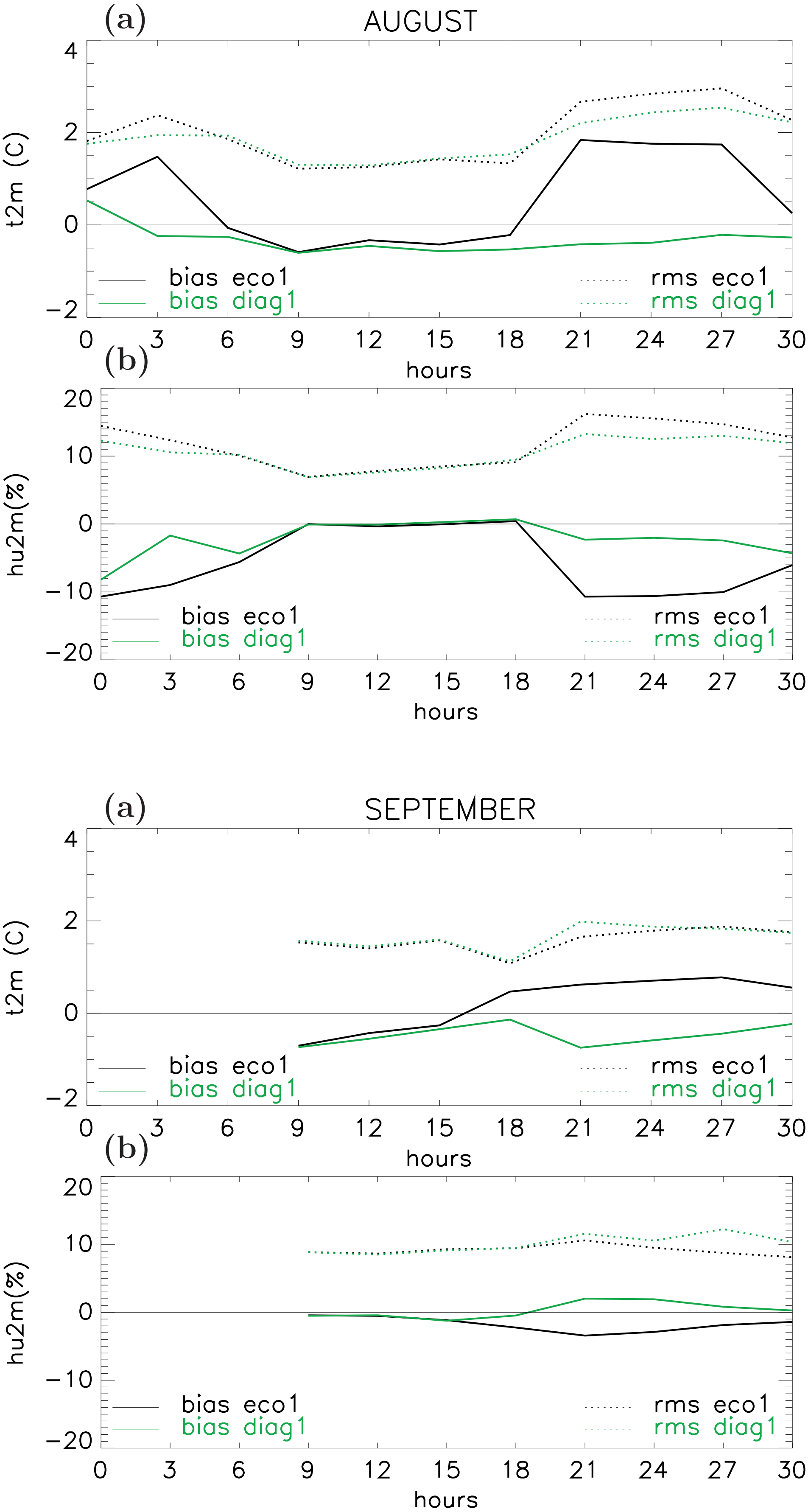


Figure 31: Mean rms (dashed line) and bias (solid line) of a)T2M and b)HU2M for ECO1 (black line) and DIAG1 (green line) simulations

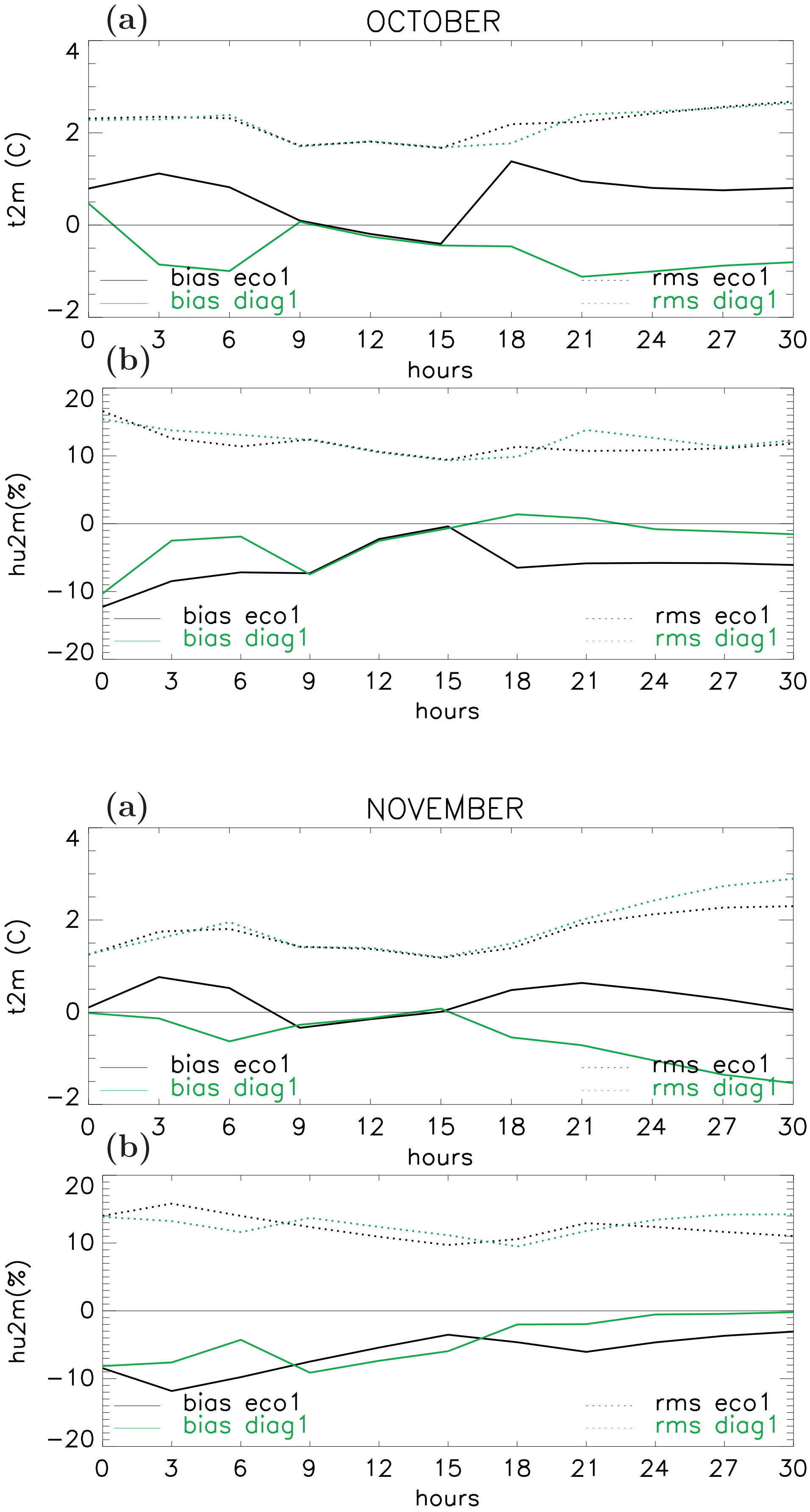


Figure 32: Mean rms (dashed line) and bias (solid line) of a)T2M and b)HU2M for ECO1 (black line) and DIAG1 (green line) simulations

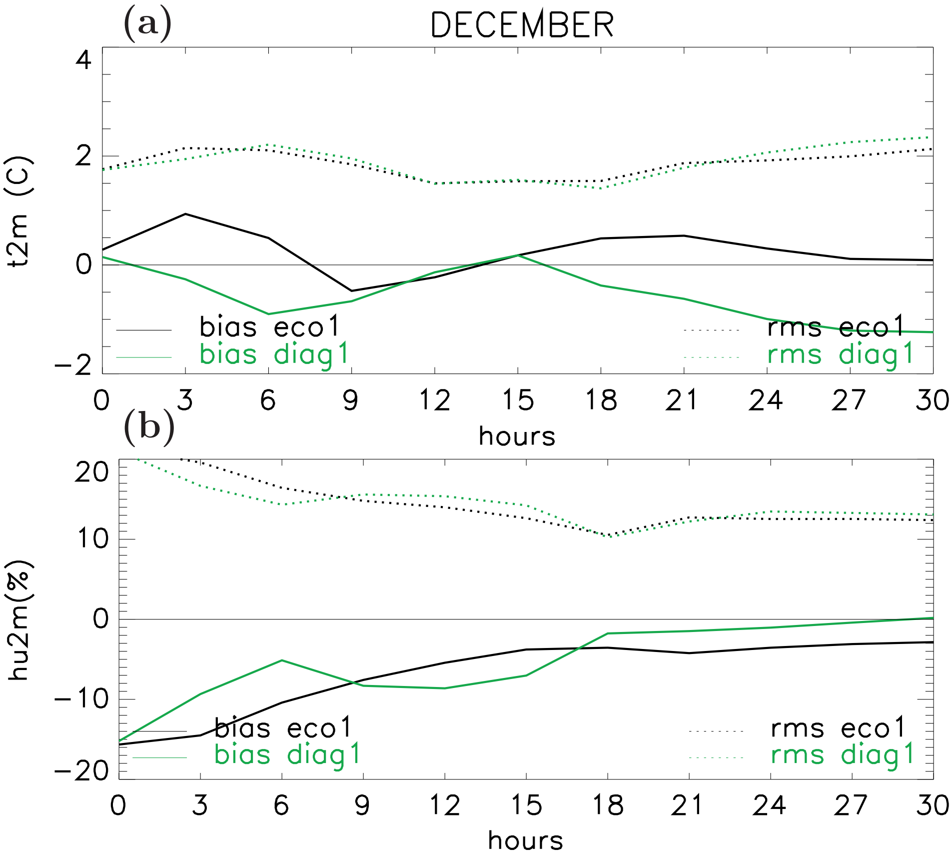


Figure 33: Mean rms (dashed line) and bias (solid line) of a)T2M and b)HU2M for ECO1 (black line) and DIAG1 (green line) simulations

E Mean rms and bias of T2M and HU2M on each of the twelve selected days of 2007 for ECO1 REF and ECO1 RIMAX0 simulations

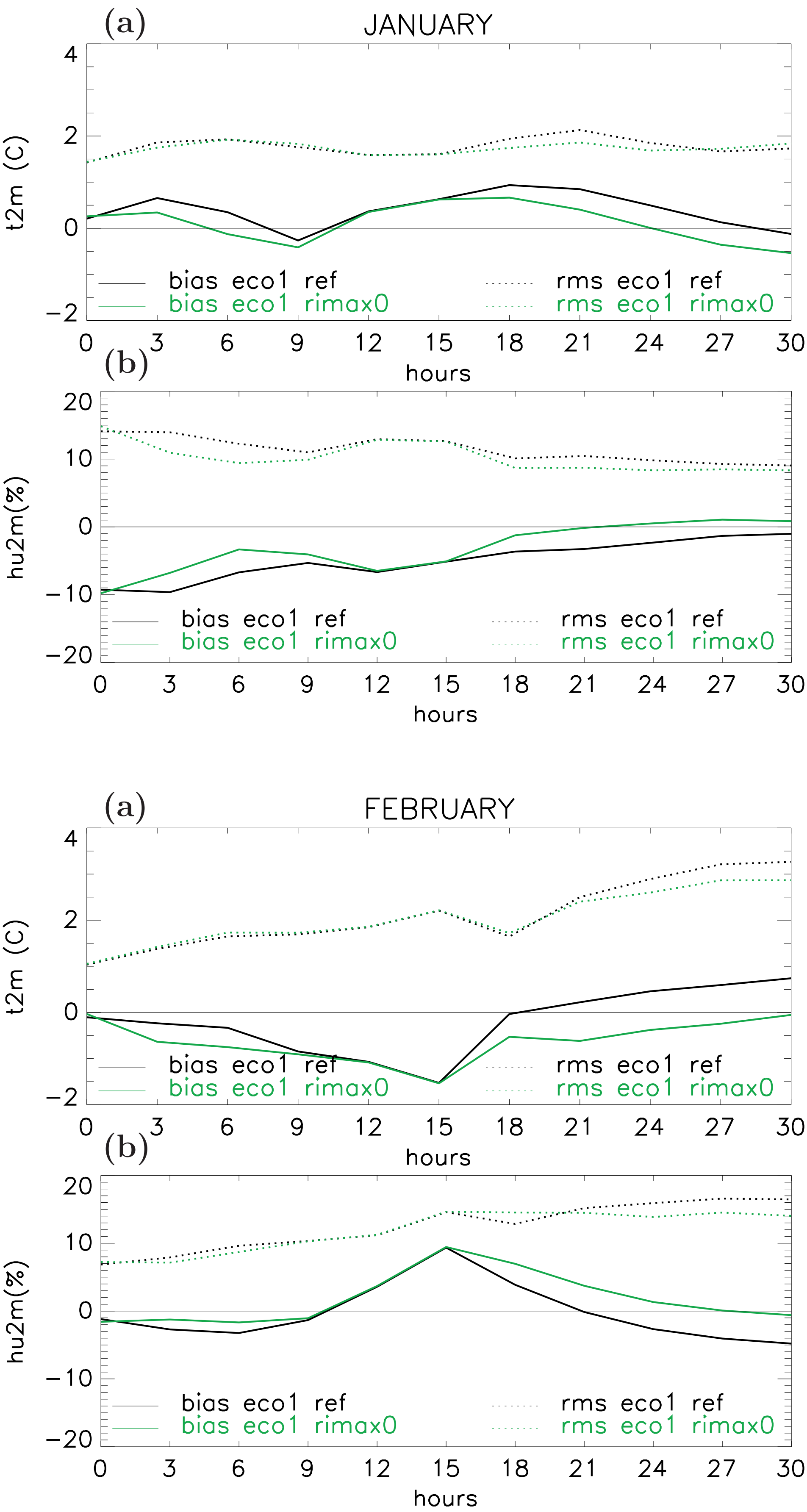
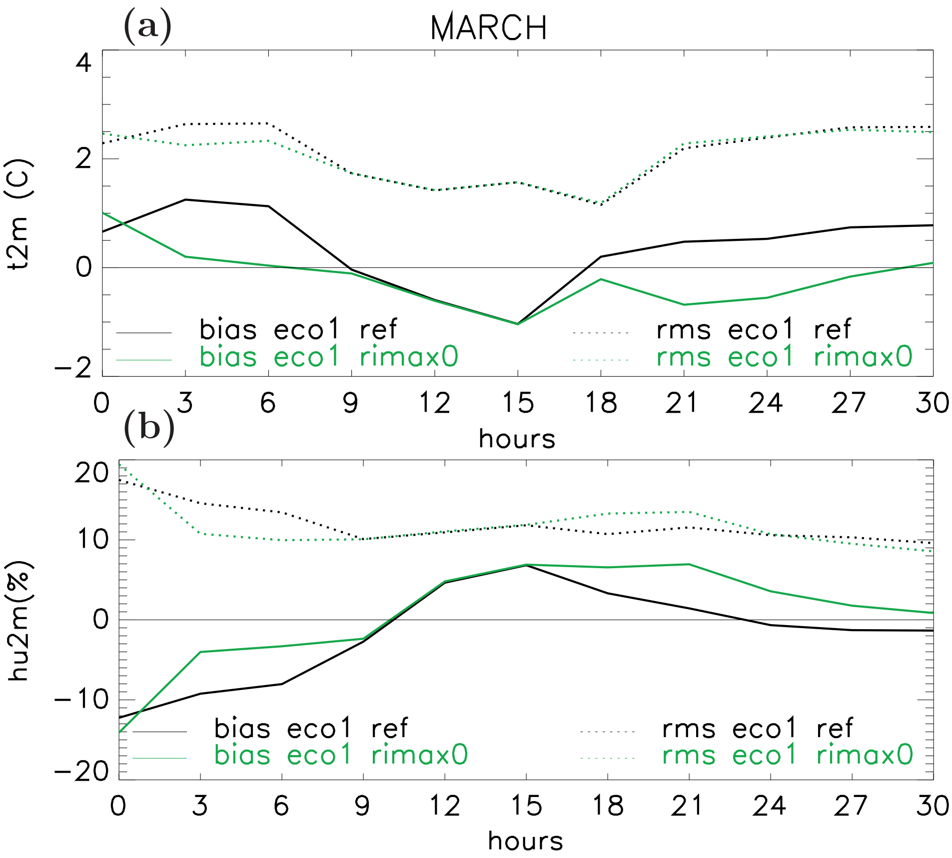


Figure 34: Mean rms and bias of a)T2M and b)HU2M on each of the twelve selected days of 2007 for ECO1 REF and ECO1 RIMAX0 simulations



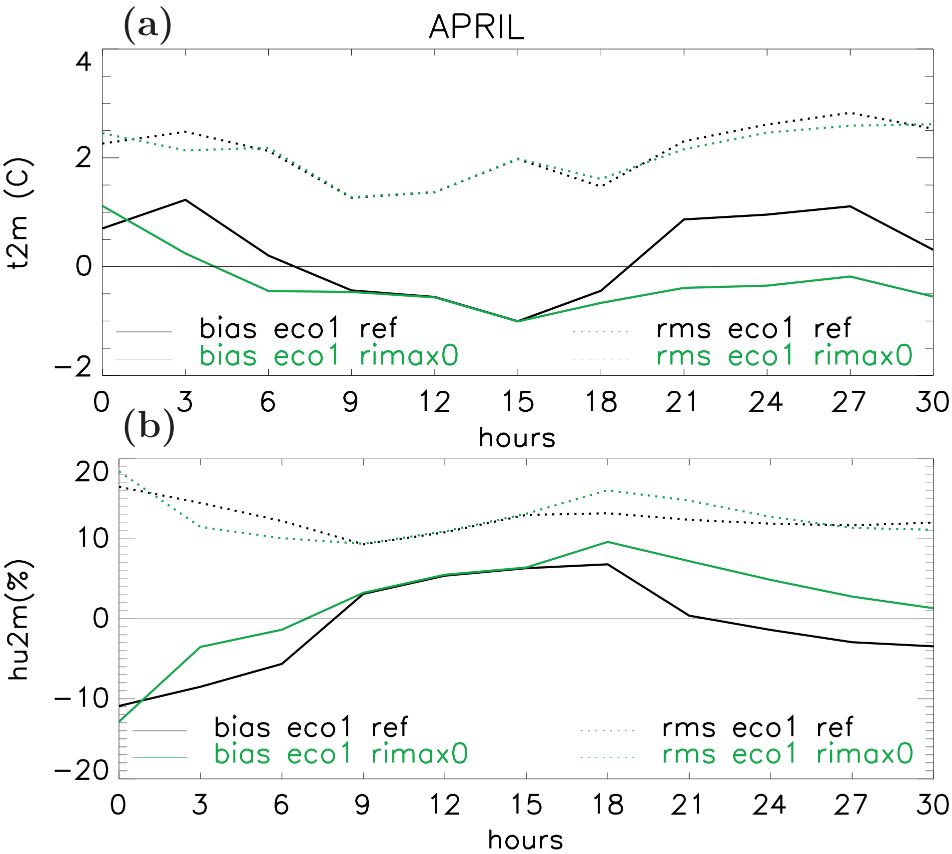


Figure 35: Mean rms and bias of a)T2M and b)HU2M on each of the twelve selected days of 2007 for ECO1 REF and ECO1 RIMAX0 simulations

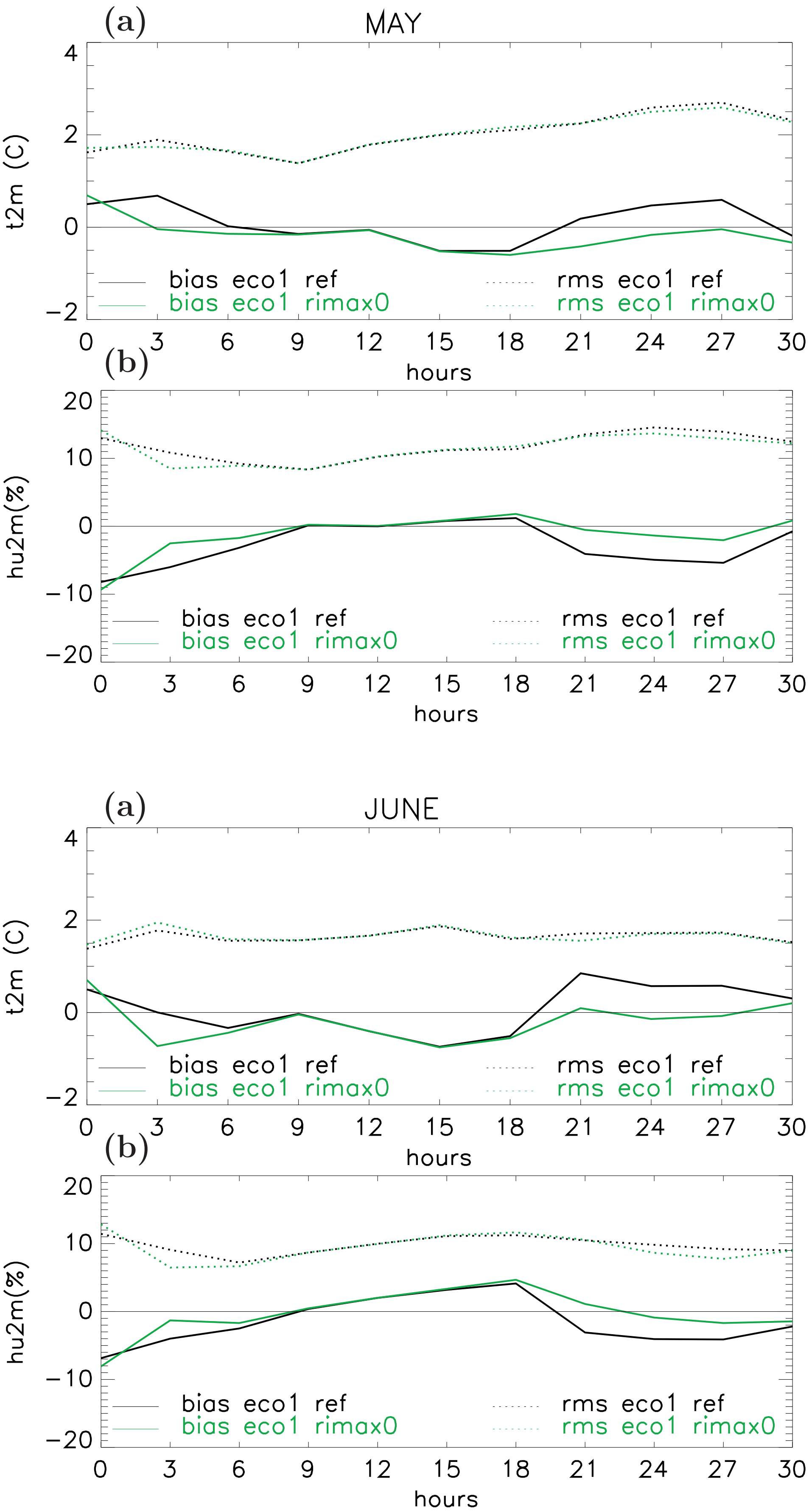


Figure 36: Mean rms and bias of a)T2M and b)HU2M on each of the twelve selected days of 2007 for ECO1 REF and ECO1 RIMAX0 simulations

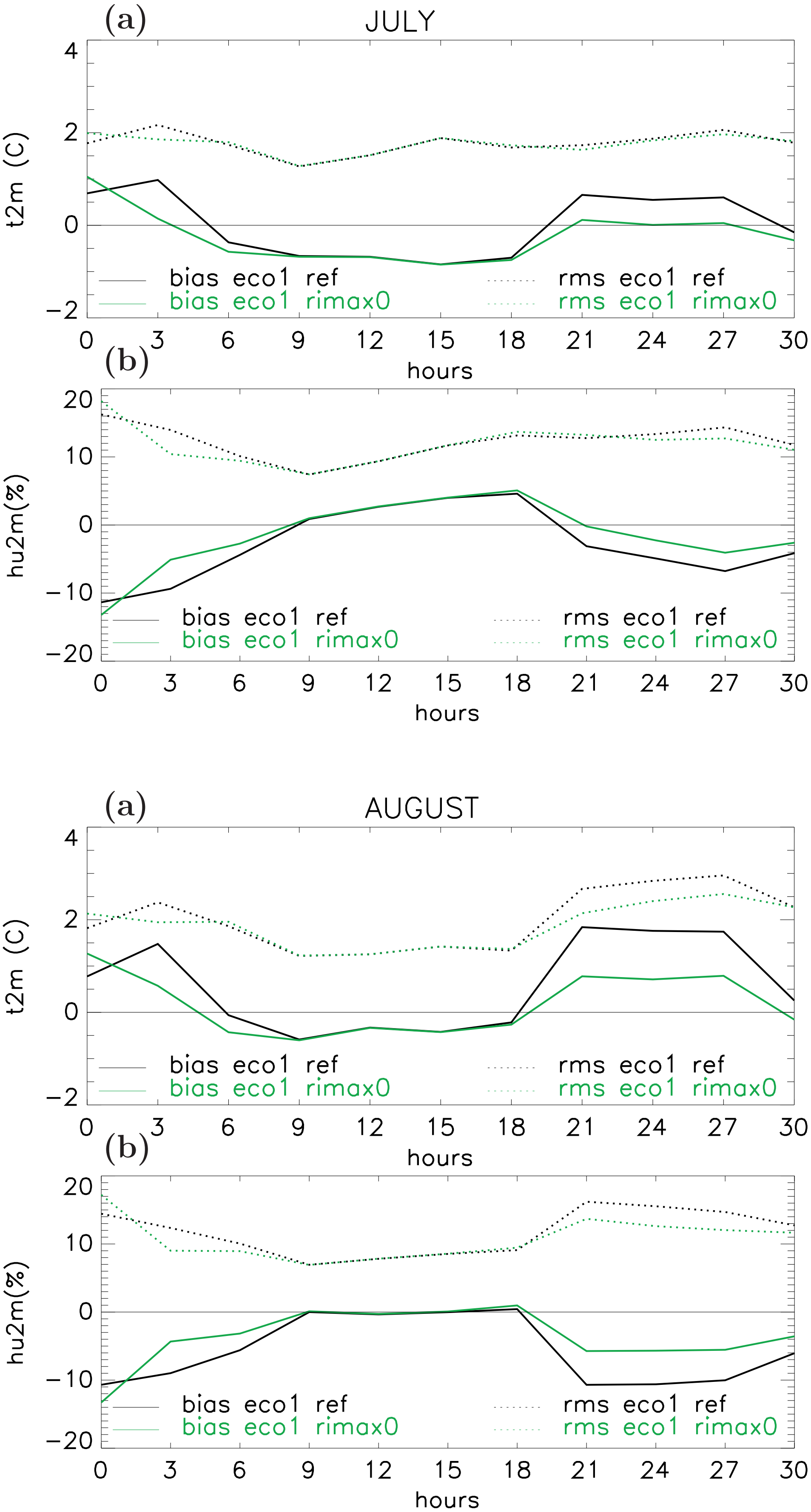


Figure 37: Mean rms and bias of a)T2M and b)HU2M on each of the twelve selected days of 2007 for ECO1 REF and ECO1 RIMAX0 simulations

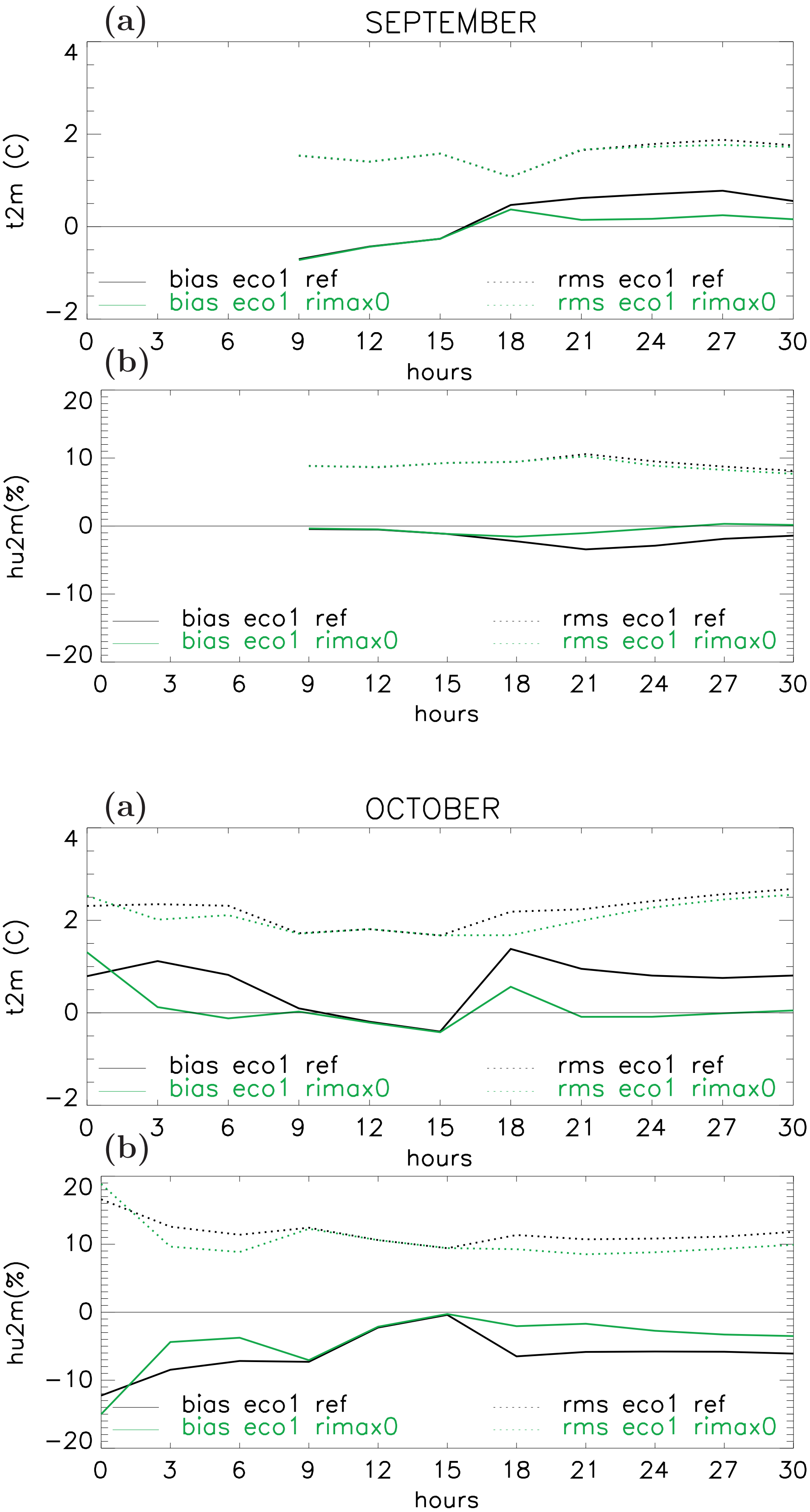


Figure 38: Mean rms and bias of a)T2M and b)HU2M on each of the twelve selected days of 2007 for ECO1 REF and ECO1 RIMAX0 simulations

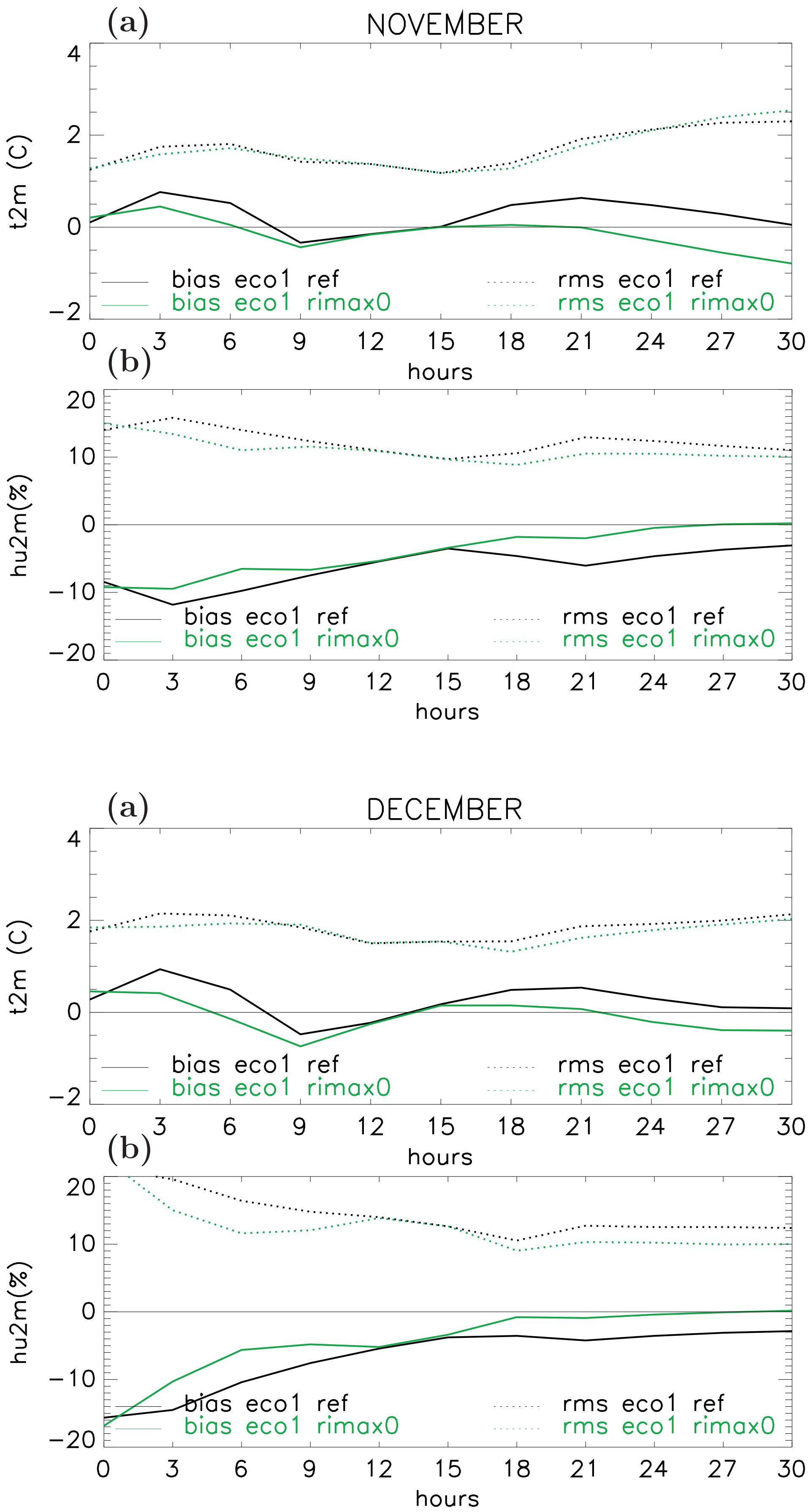


Figure 39: Mean rms and bias of a)T2M and b)HU2M on each of the twelve selected days of 2007 for ECO1 REF and ECO1 RIMAX0 simulations

F Mean rms and bias of T2M, HU2M, DD10M, FF10M on each of the twelve selected days of 2007 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

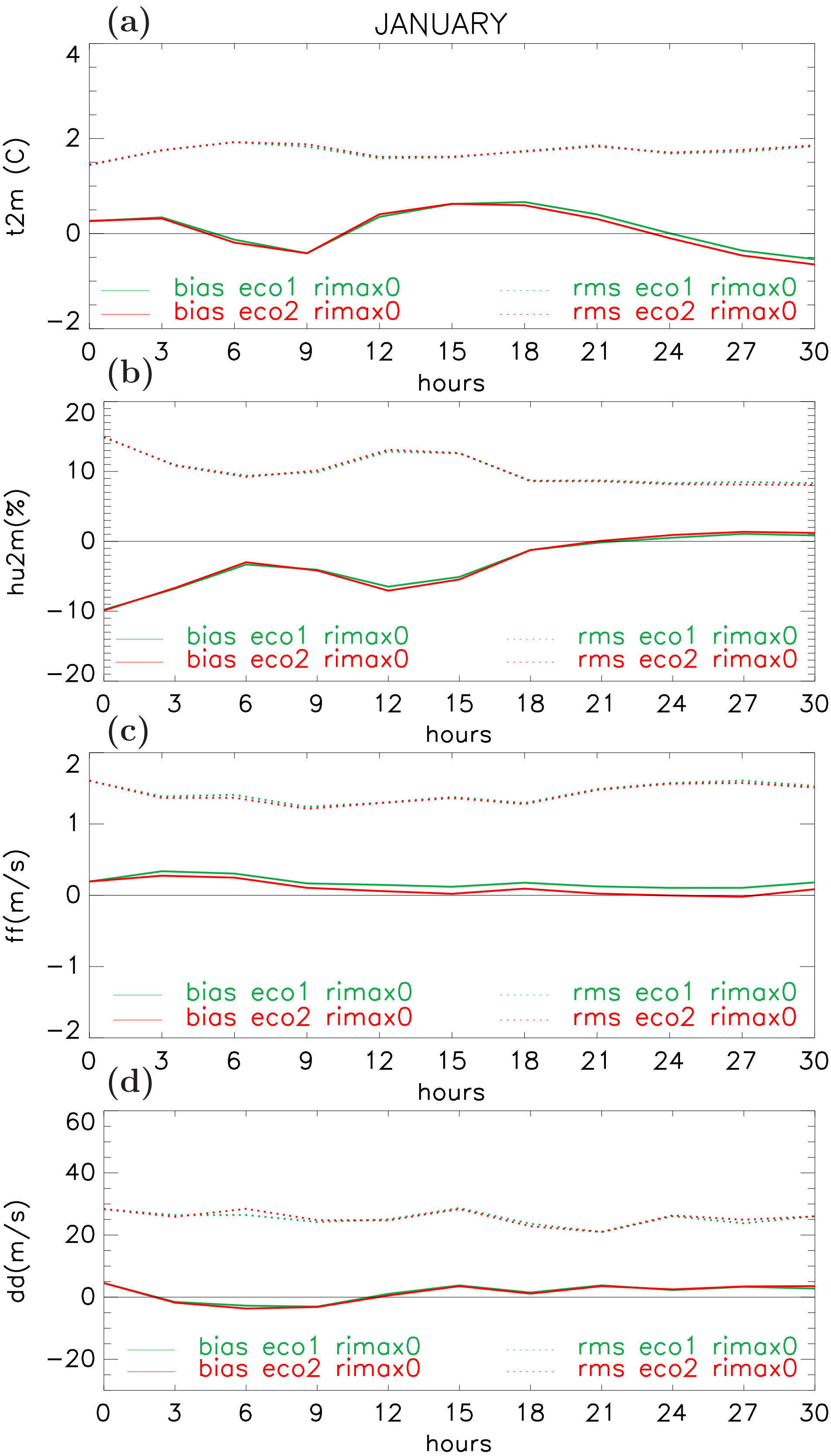


Figure 40: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070126 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

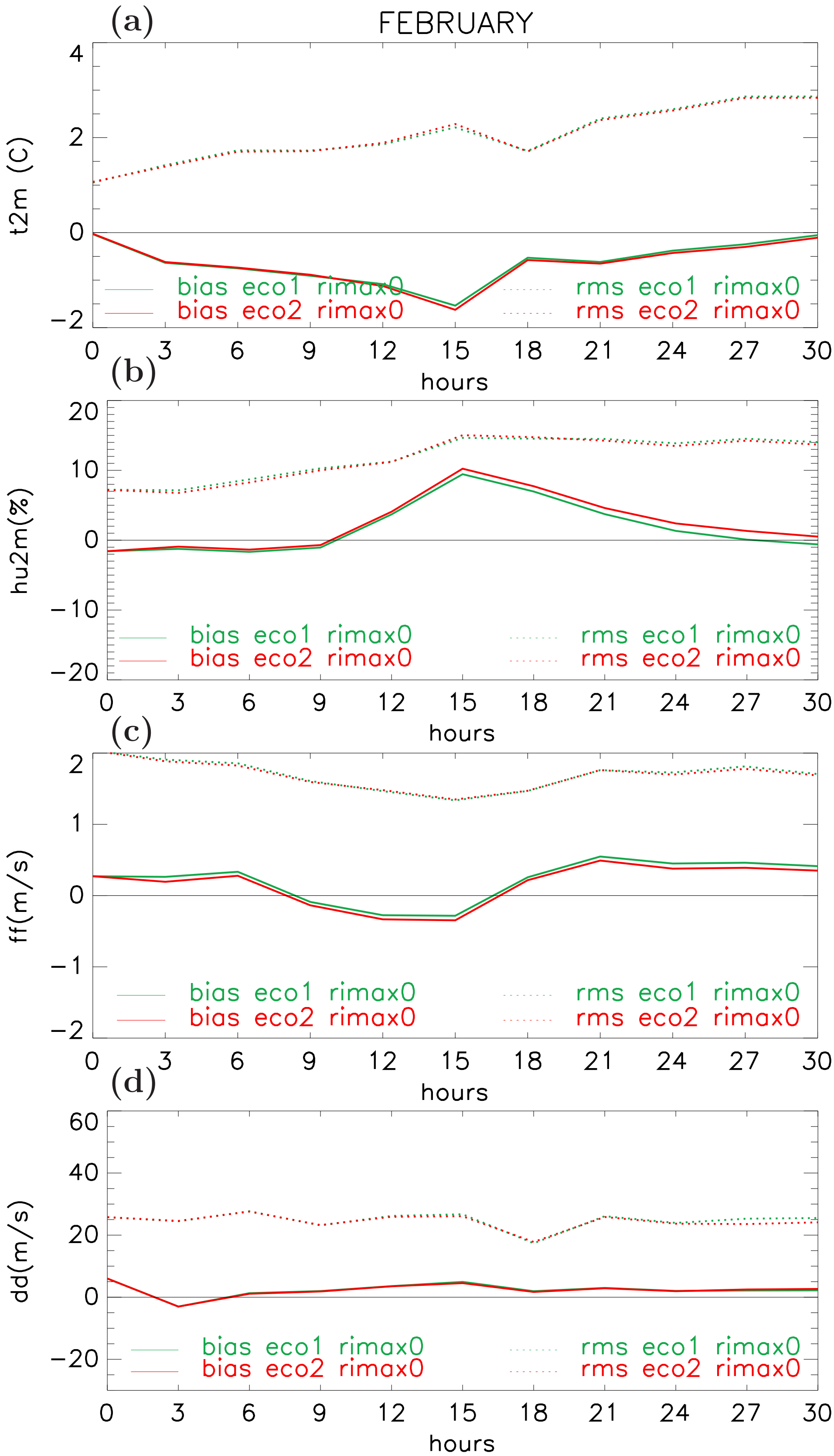


Figure 41: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070215 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

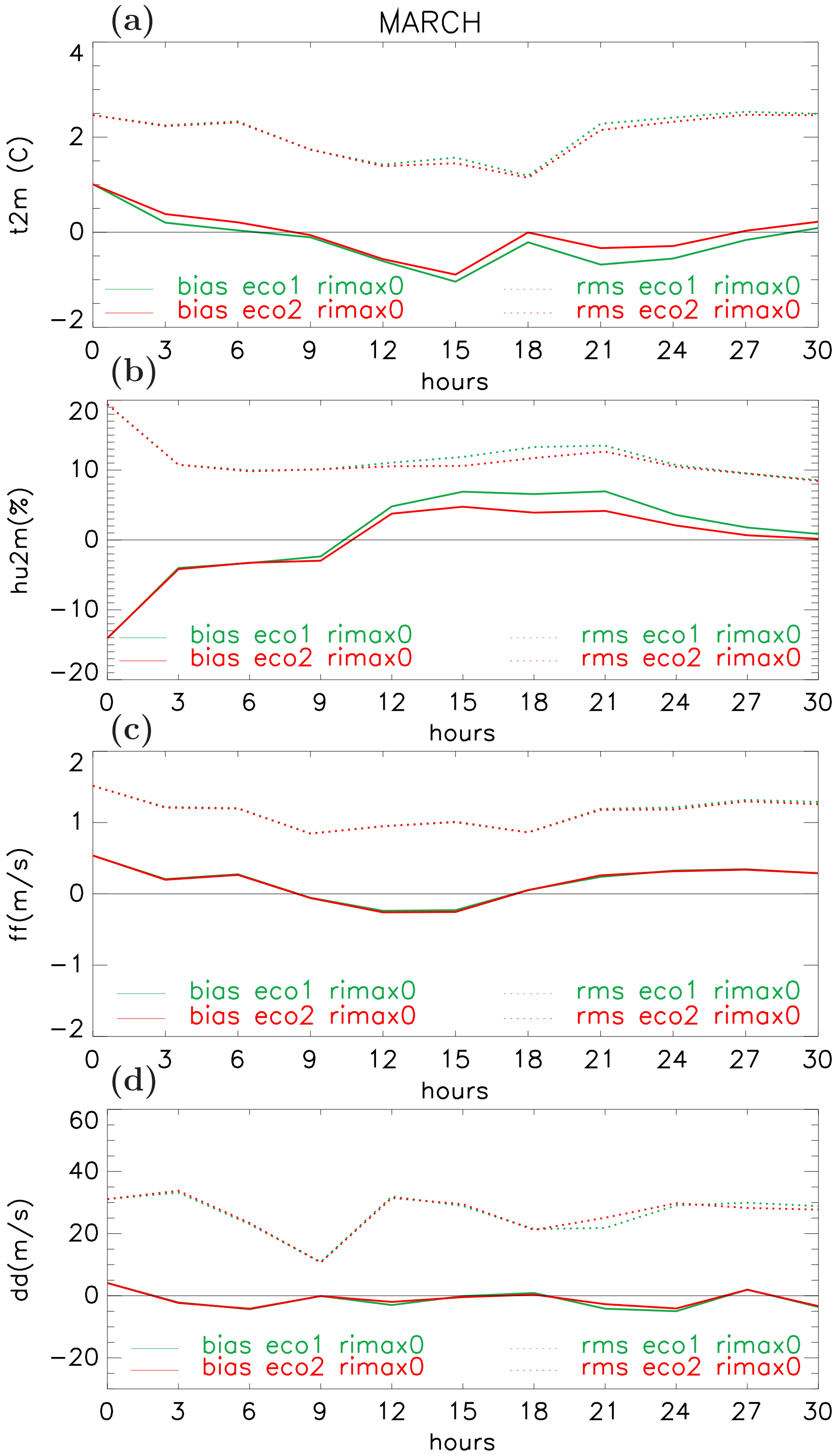


Figure 42: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070315 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

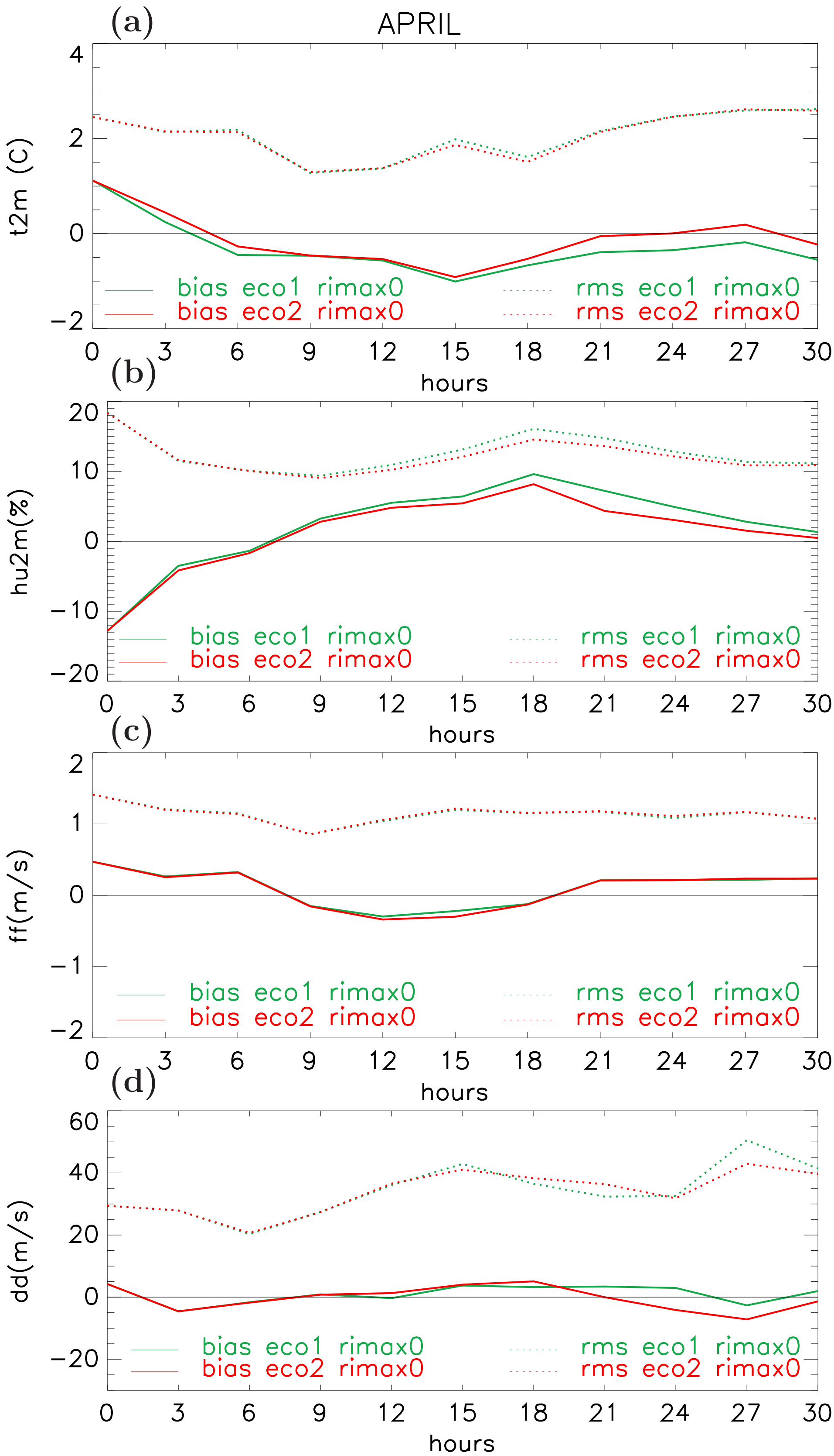


Figure 43: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070421 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

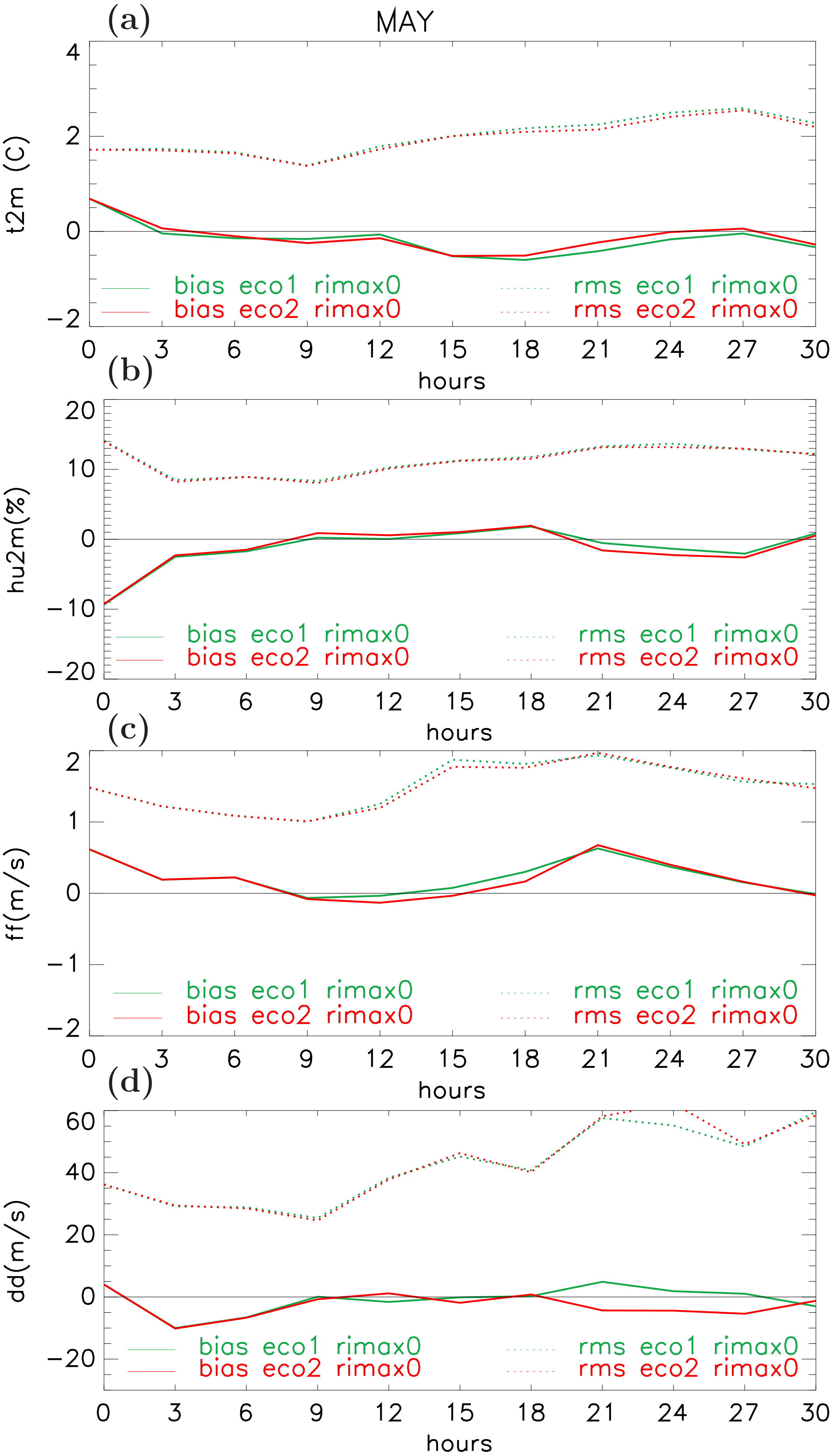


Figure 44: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070524 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

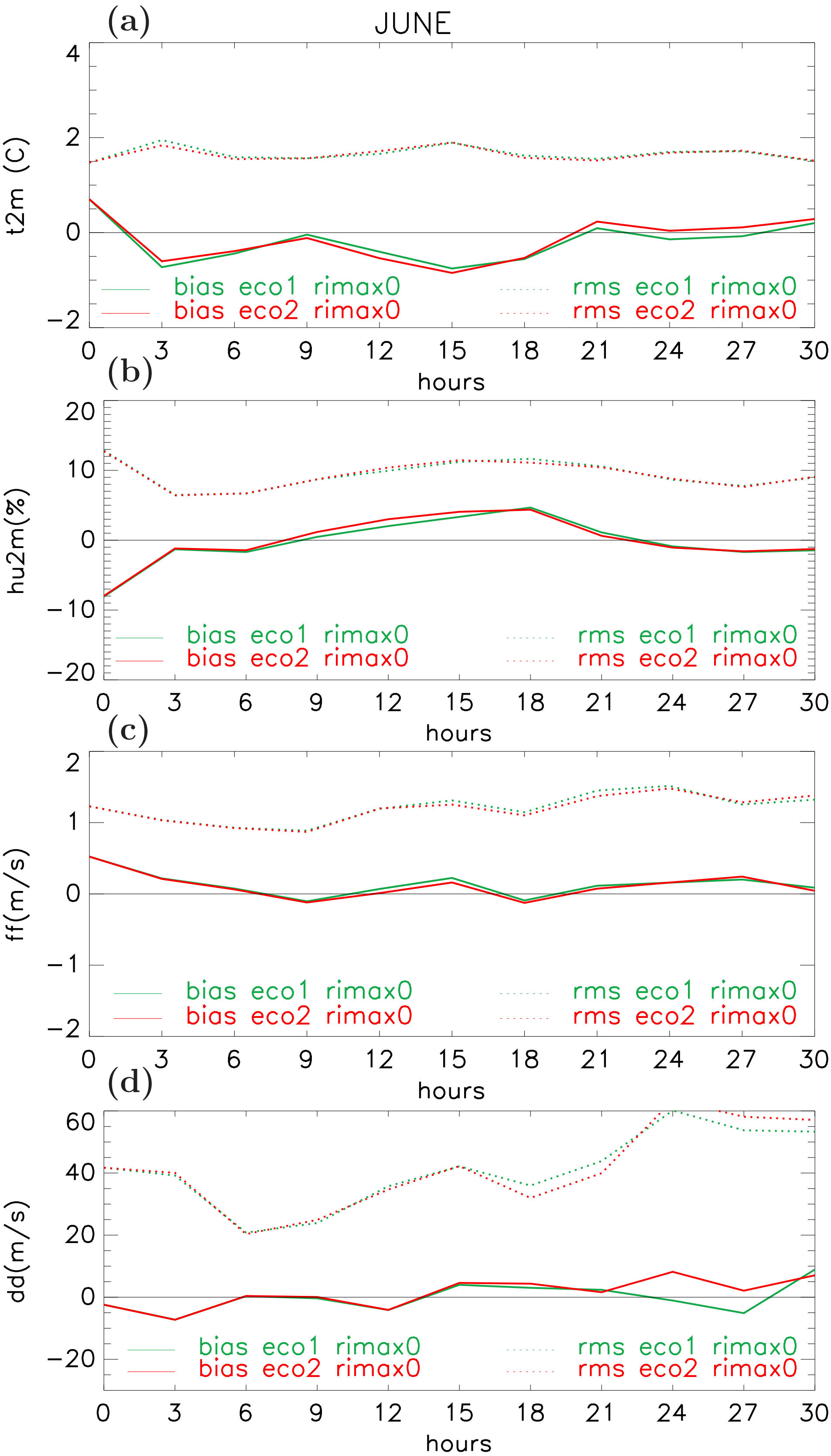


Figure 45: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070609 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

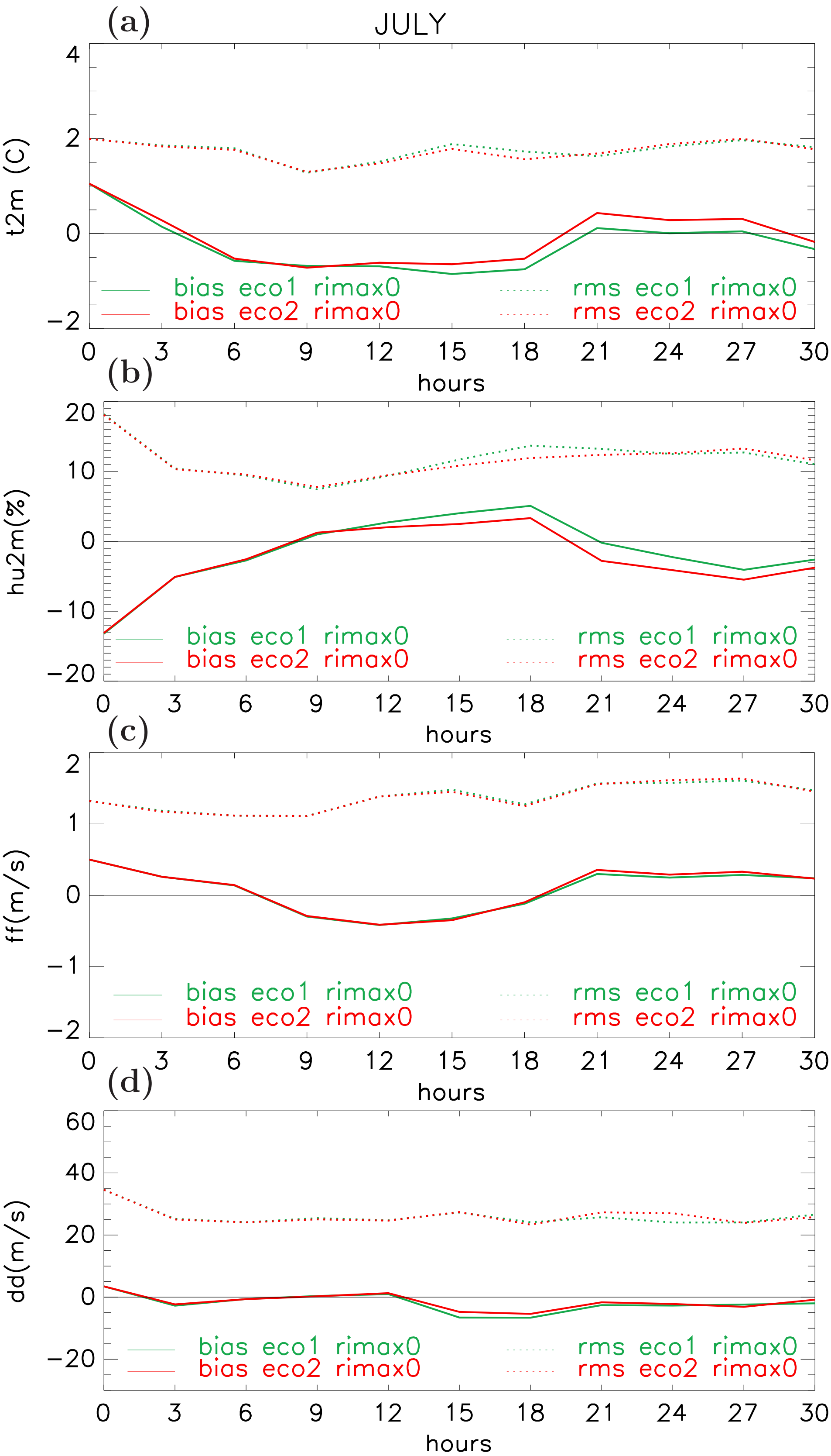


Figure 46: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070713 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

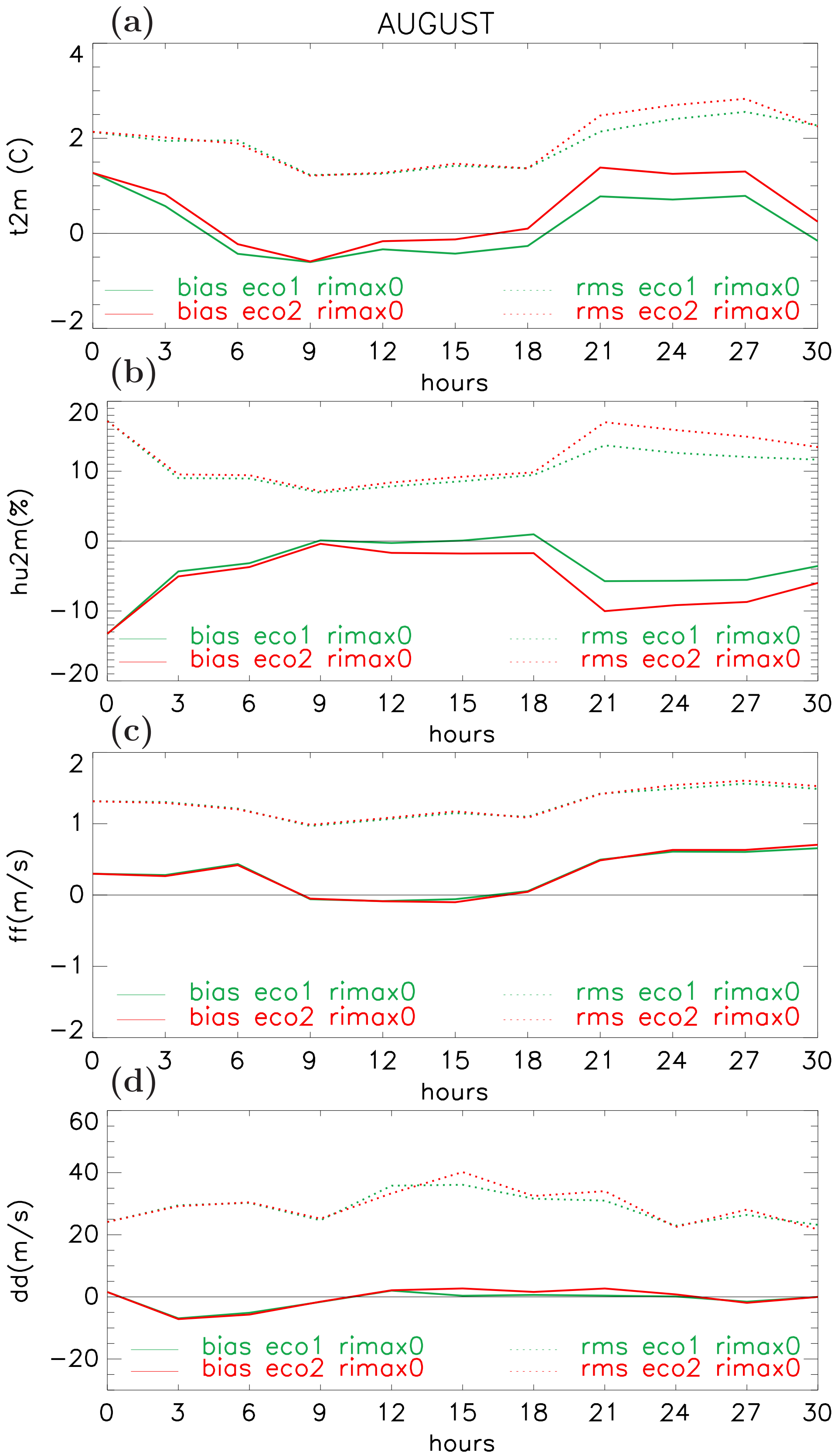


Figure 47: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070804 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

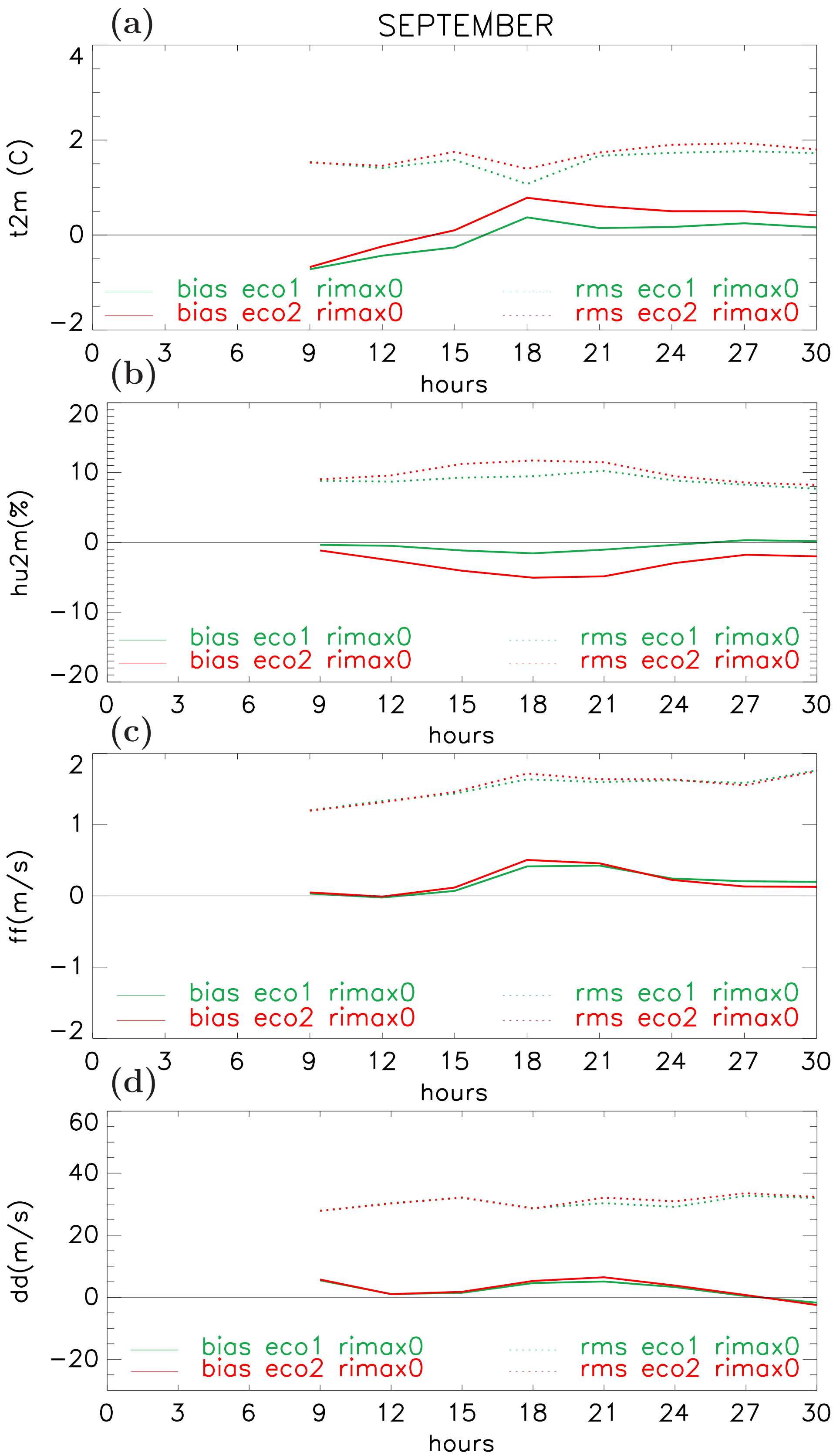


Figure 48: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070910 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

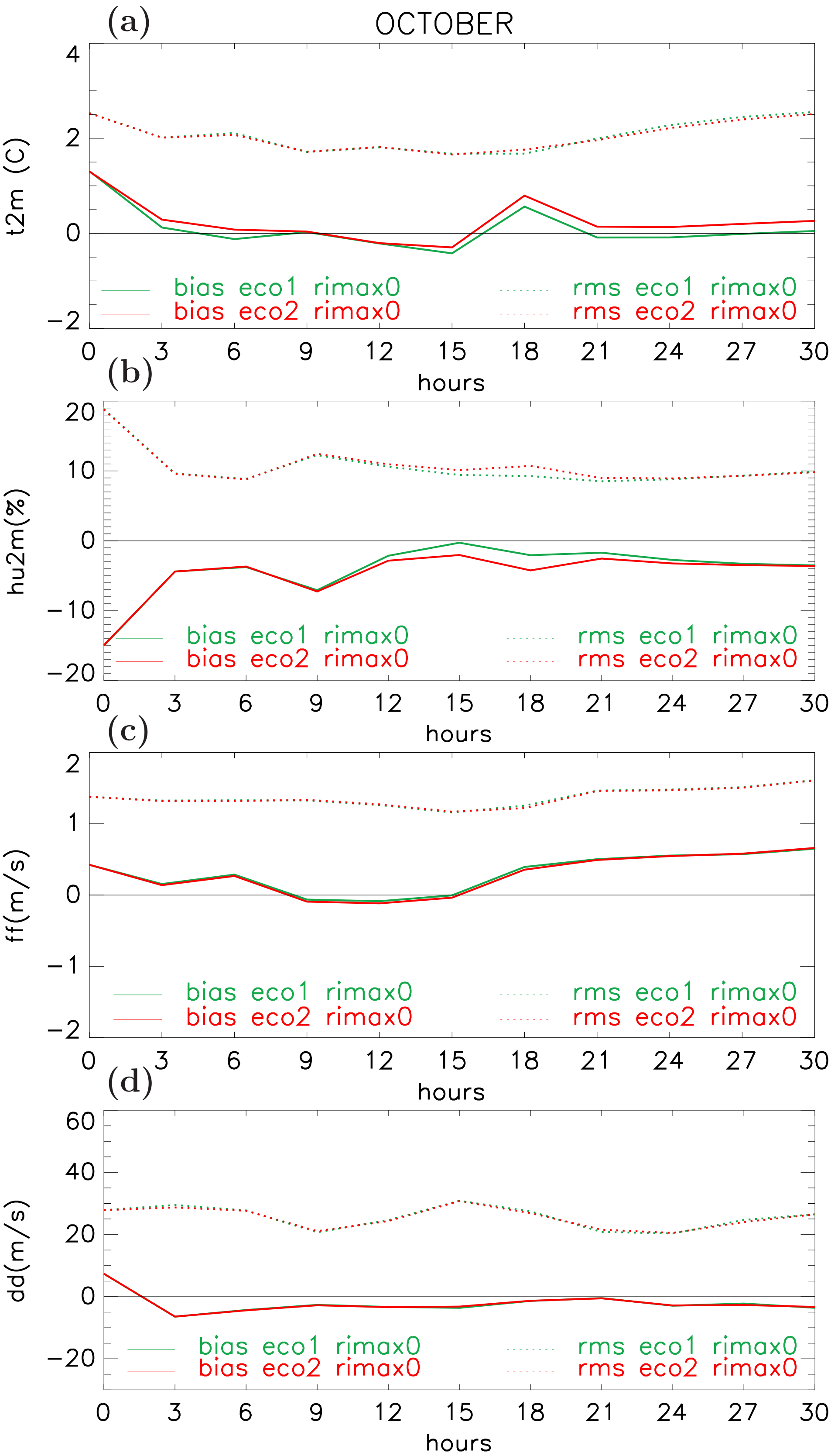


Figure 49: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20071014 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

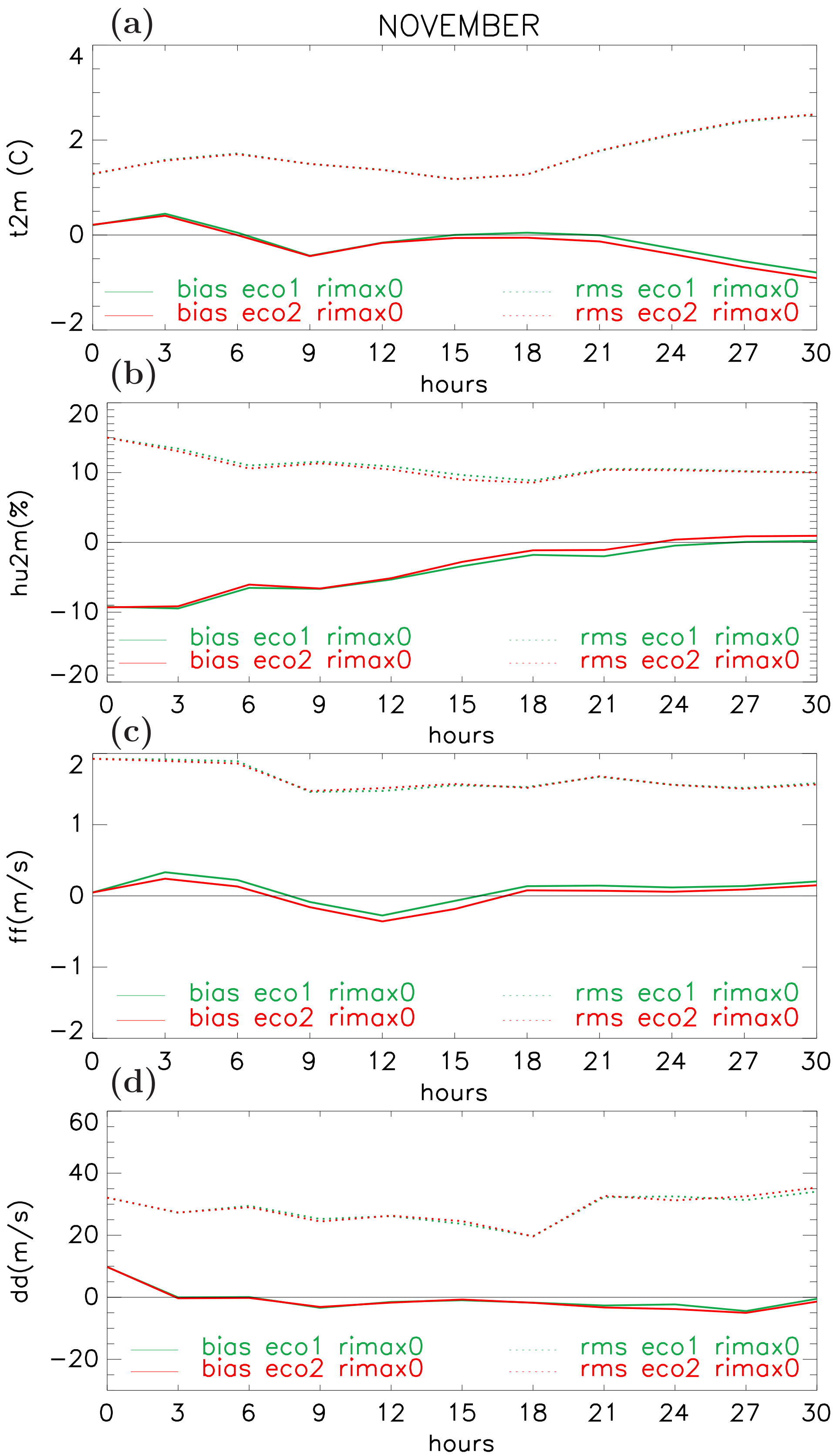


Figure 50: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20071116 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

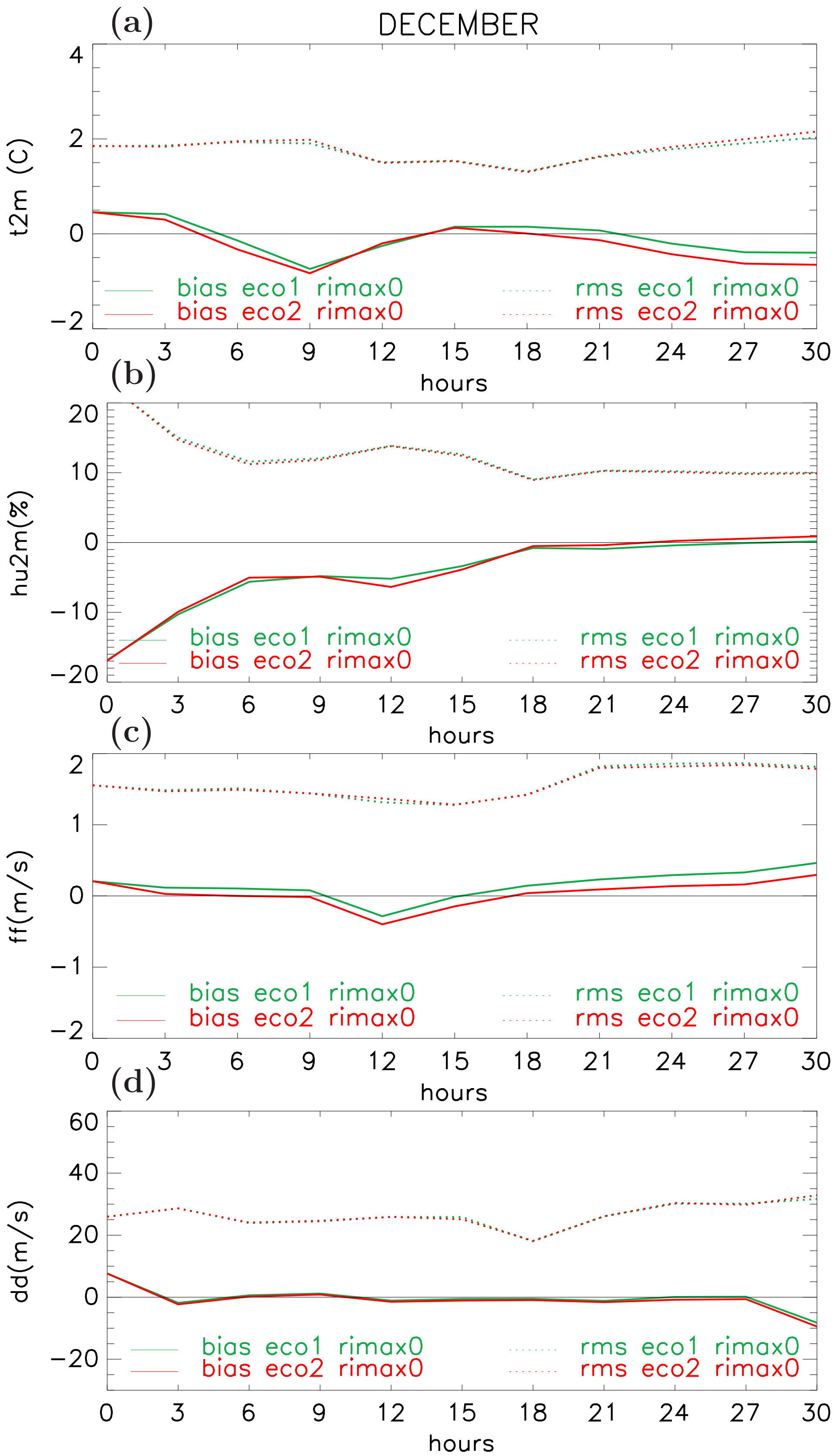


Figure 51: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20071216 for ECO1 RIMAX0 and ECO2 RIMAX0 simulations

G Mean rms and bias of T2M, HU2M, FF10M, DD10M on each of the twelve selected days of 2007 for ECO1 REF and ECO2 RIMAX0 simulations

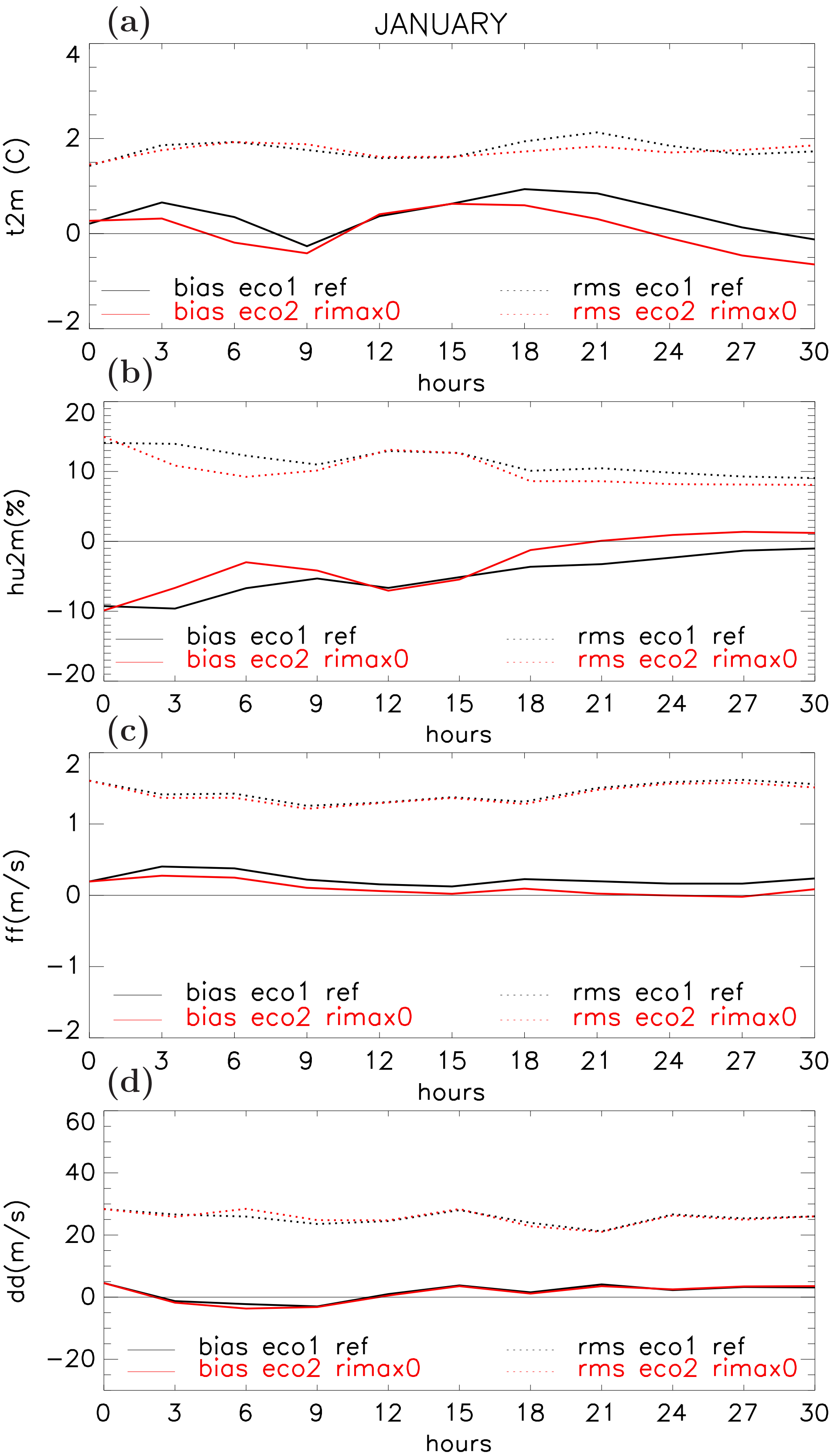


Figure 52: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070126 for ECO1 REF and ECO2 RIMAX0 simulations

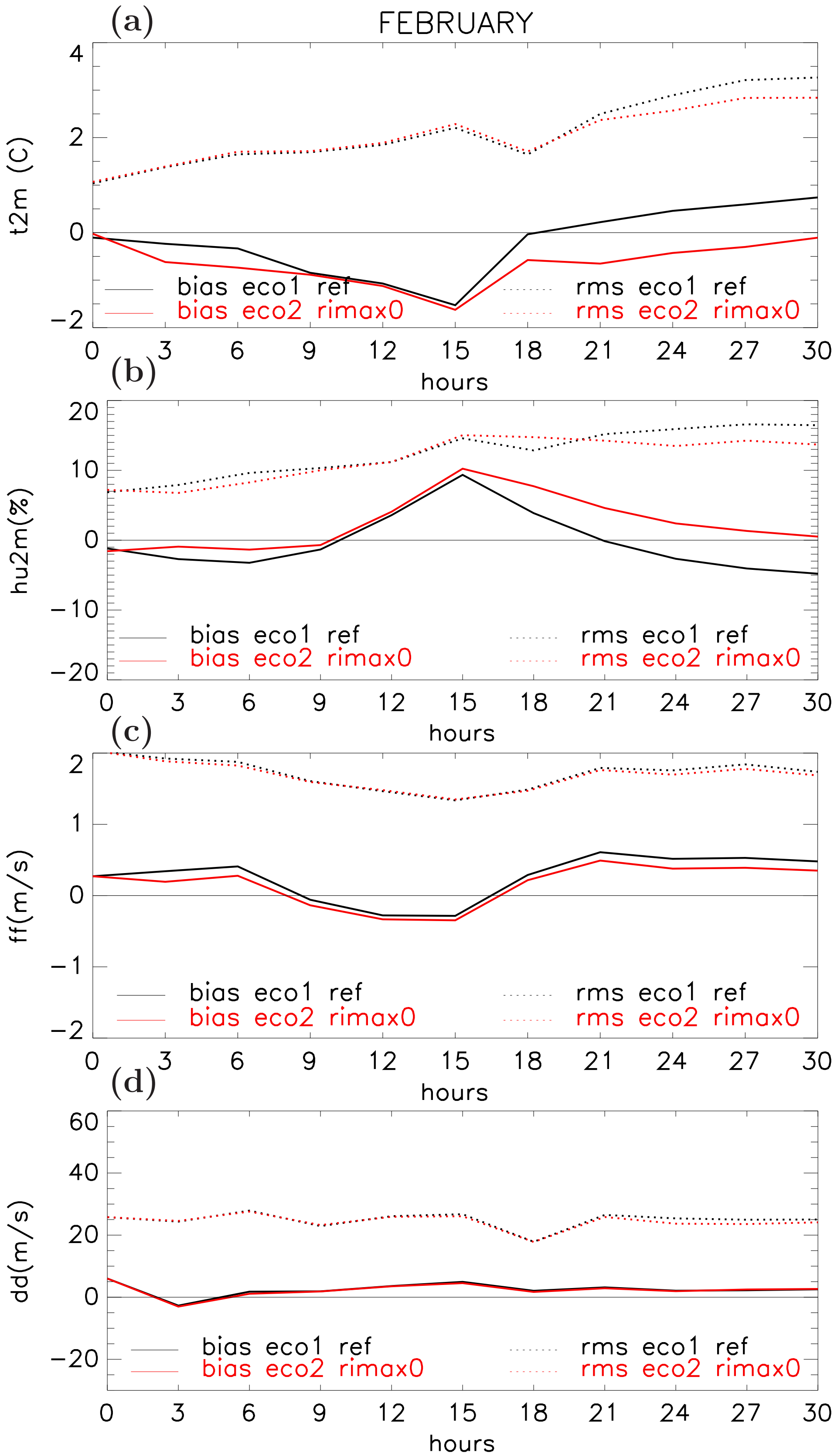


Figure 53: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070215 for ECO1 REF and ECO2 RIMAX0 simulations

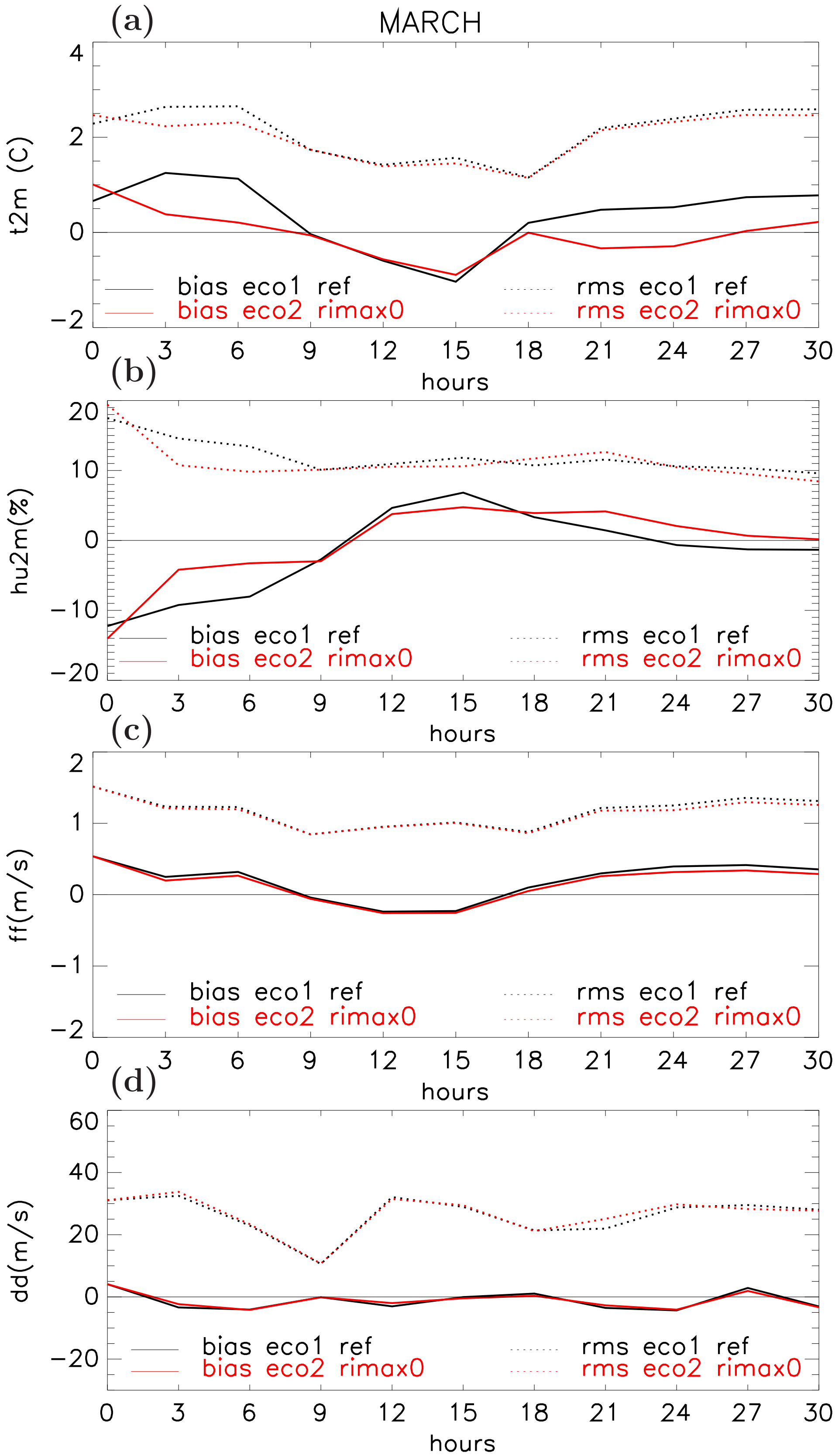


Figure 54: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070315 for ECO1 REF and ECO2 RIMAX0 simulations

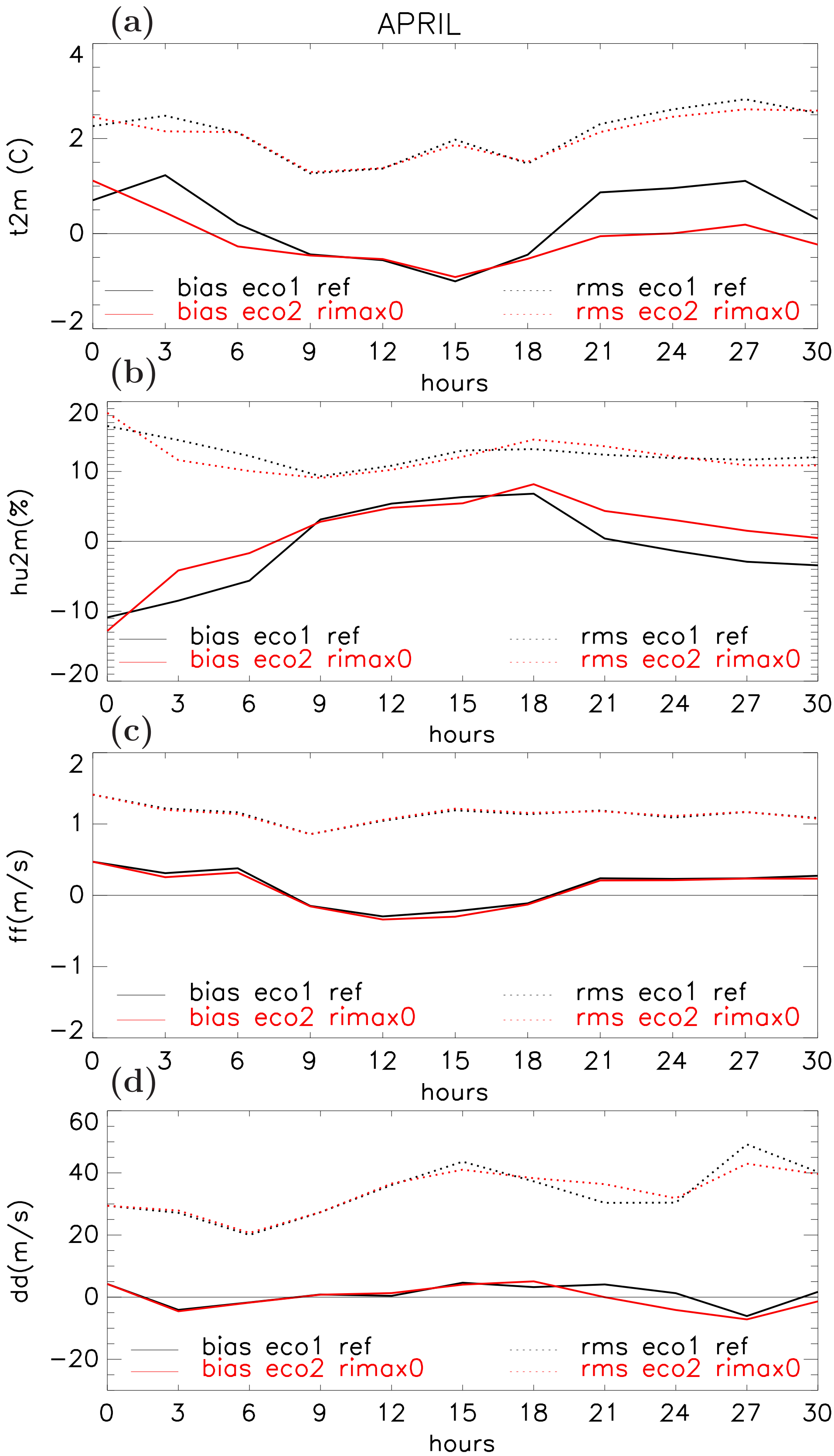


Figure 55: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070421 for ECO1 REF and ECO2 RIMAX0 simulations

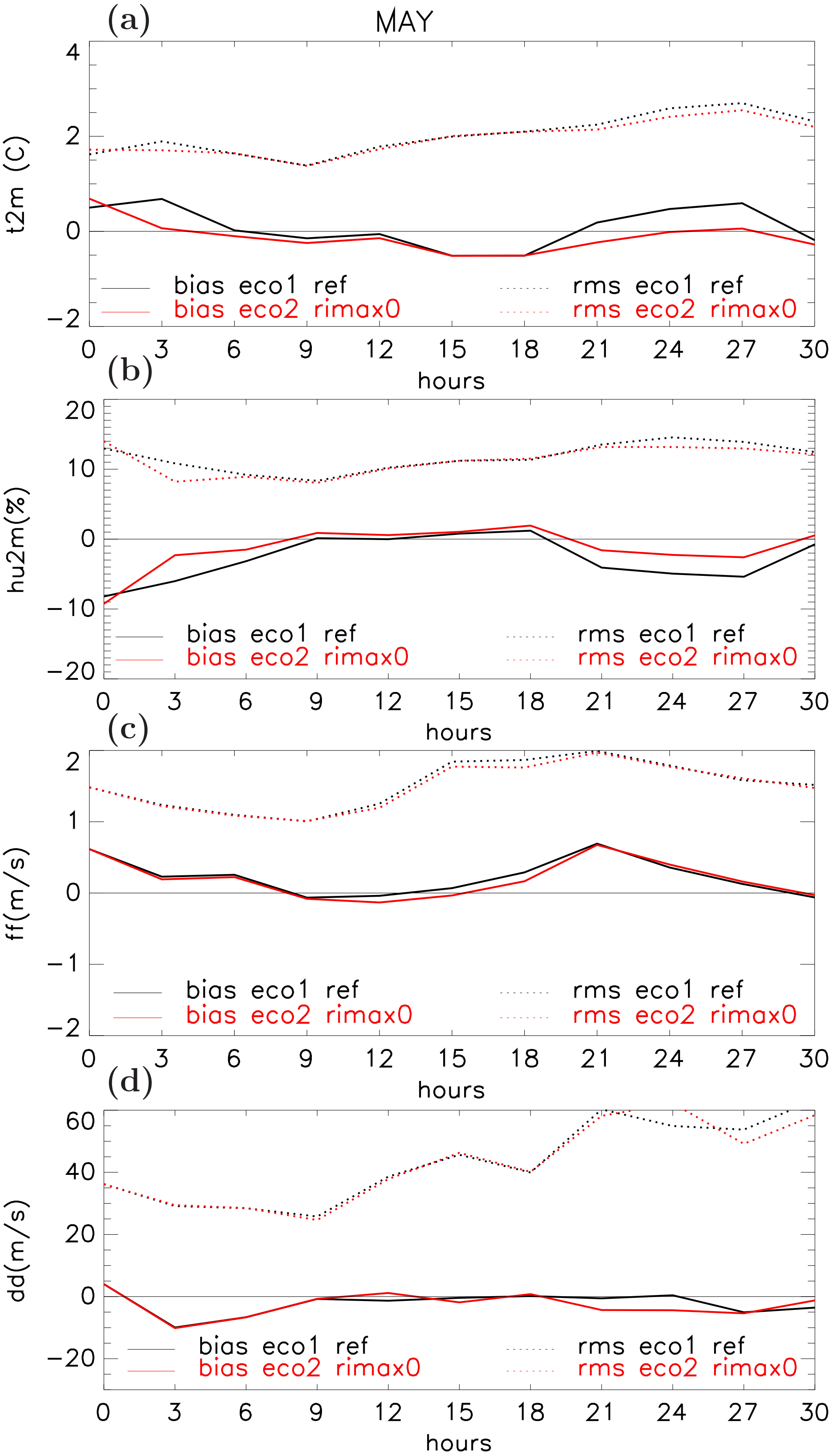


Figure 56: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070524 for ECO1 REF and ECO2 RIMAX0 simulations

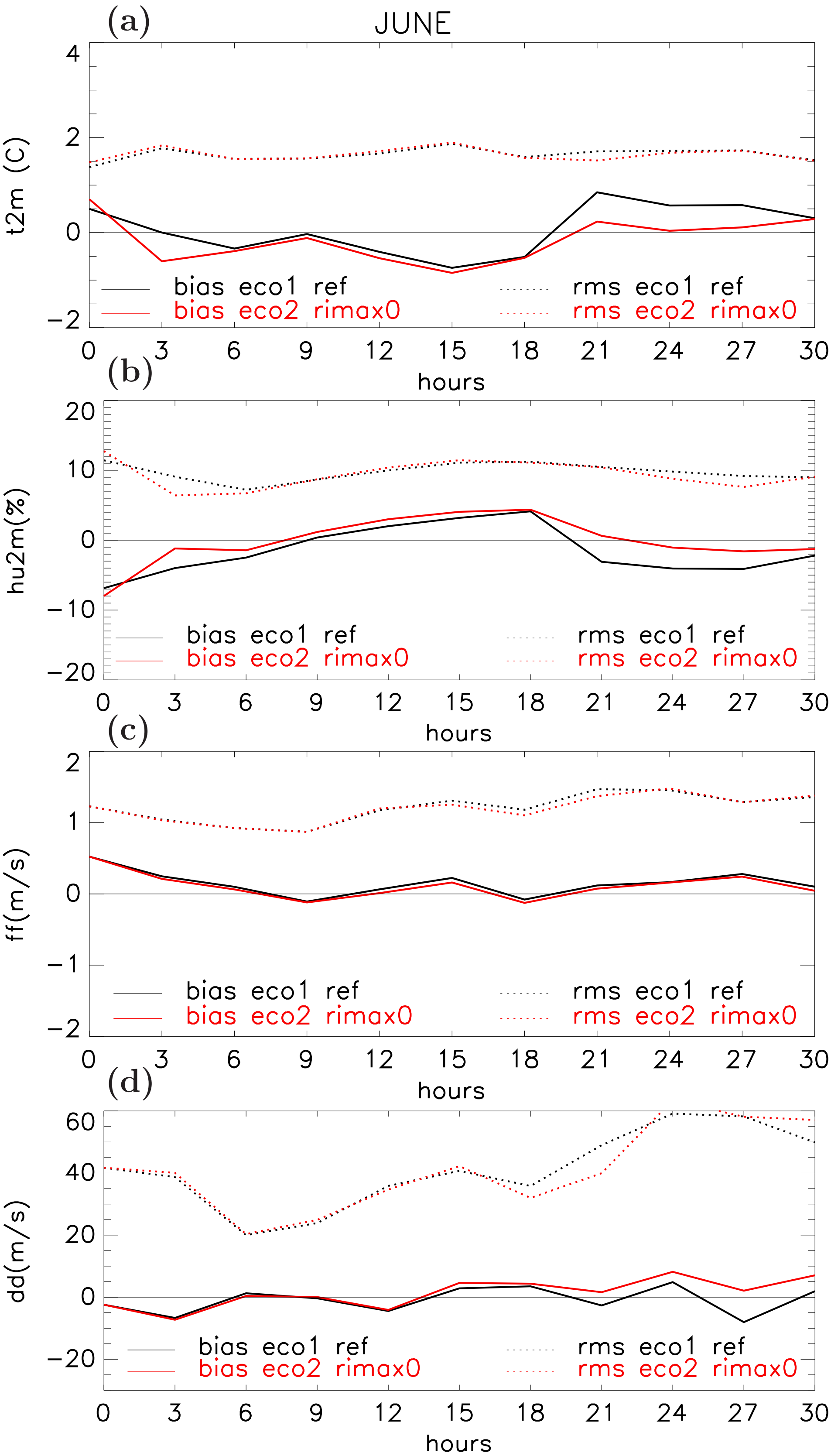


Figure 57: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070609 for ECO1 REF and ECO2 RIMAX0 simulations

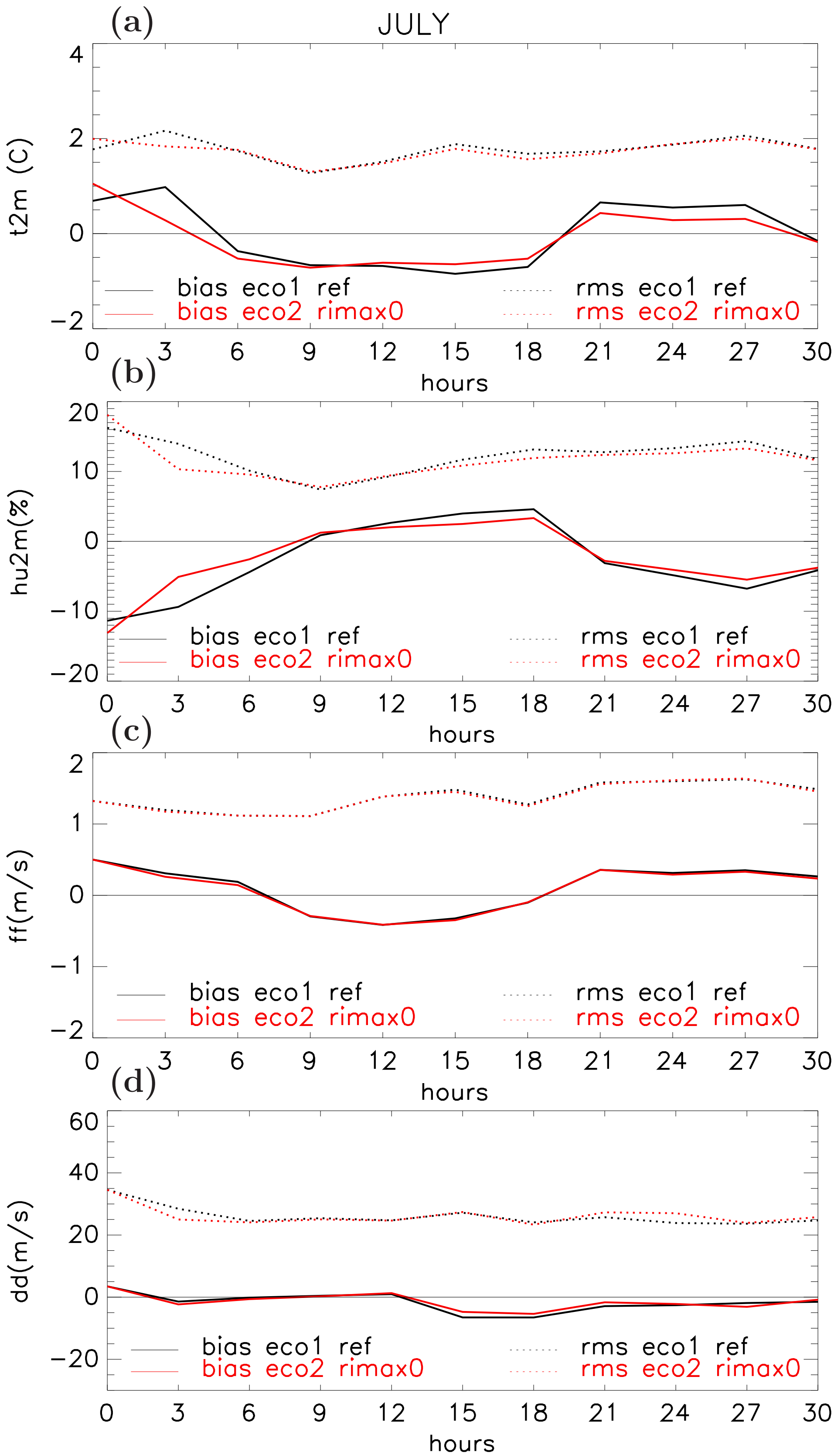


Figure 58: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070713 for ECO1 REF and ECO2 RIMAX0 simulations

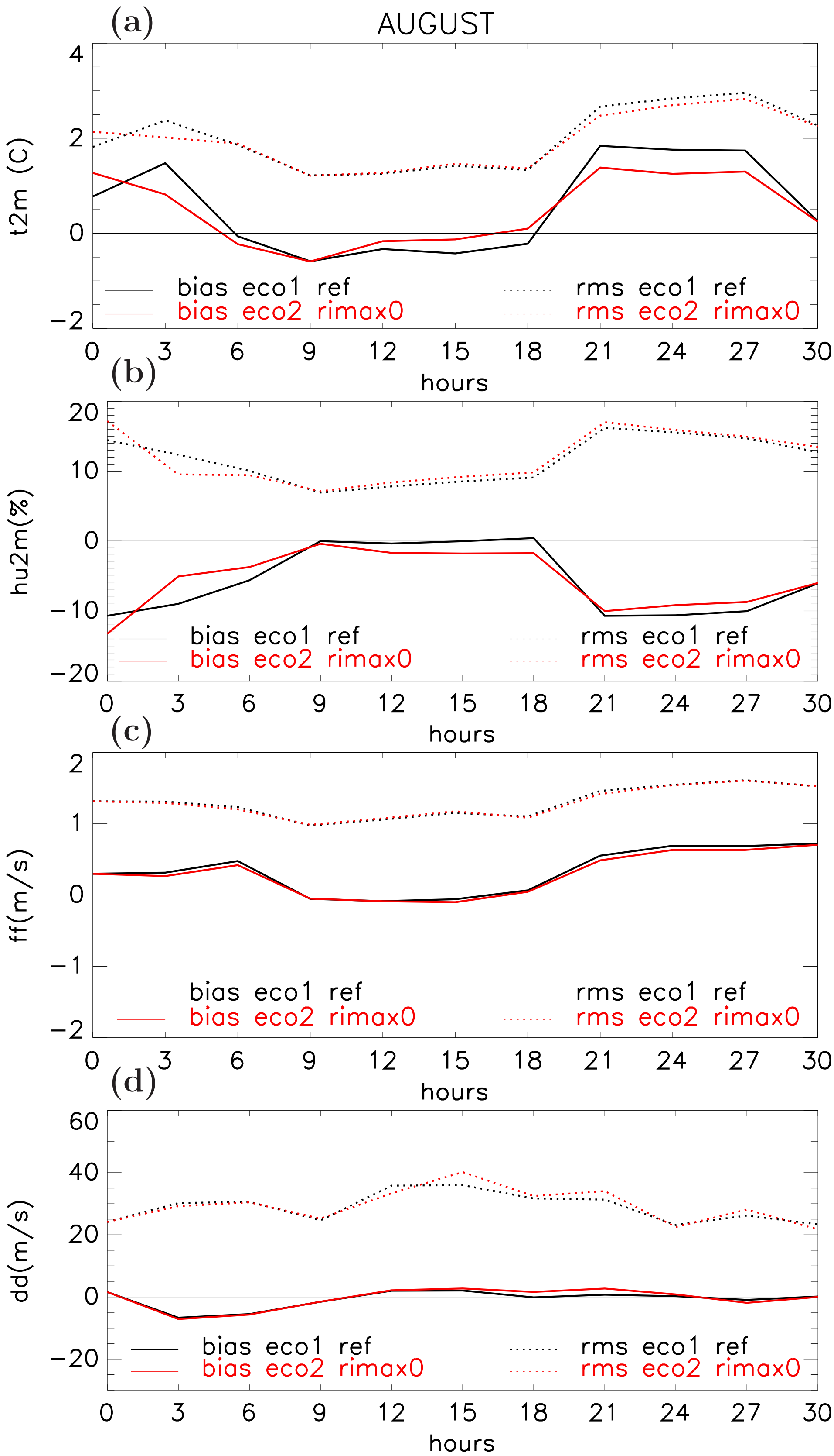


Figure 59: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070804 for ECO1 REF and ECO2 RIMAX0 simulations

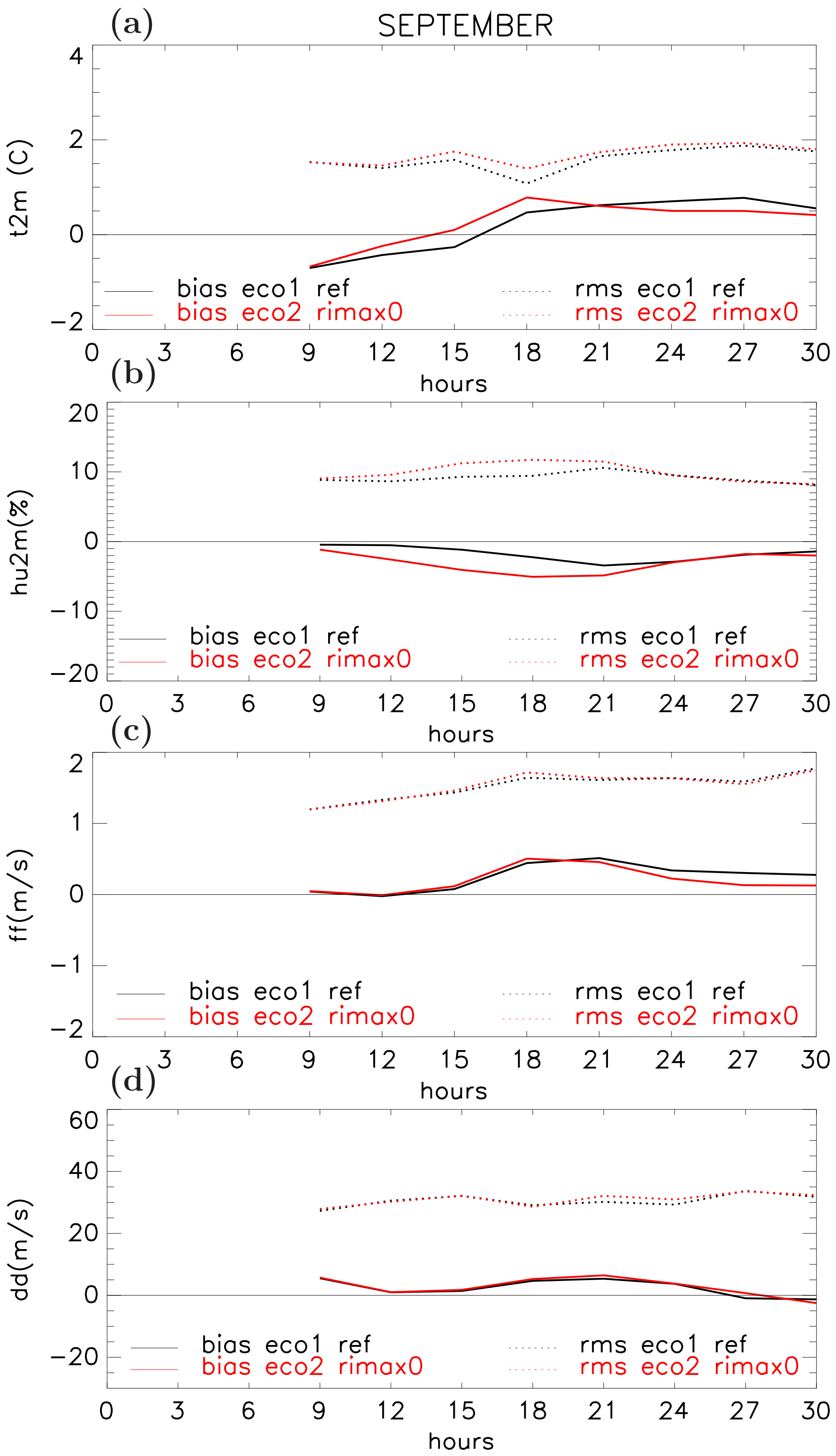


Figure 60: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20070910 for ECO1 REF and ECO2 RIMAX0 simulations

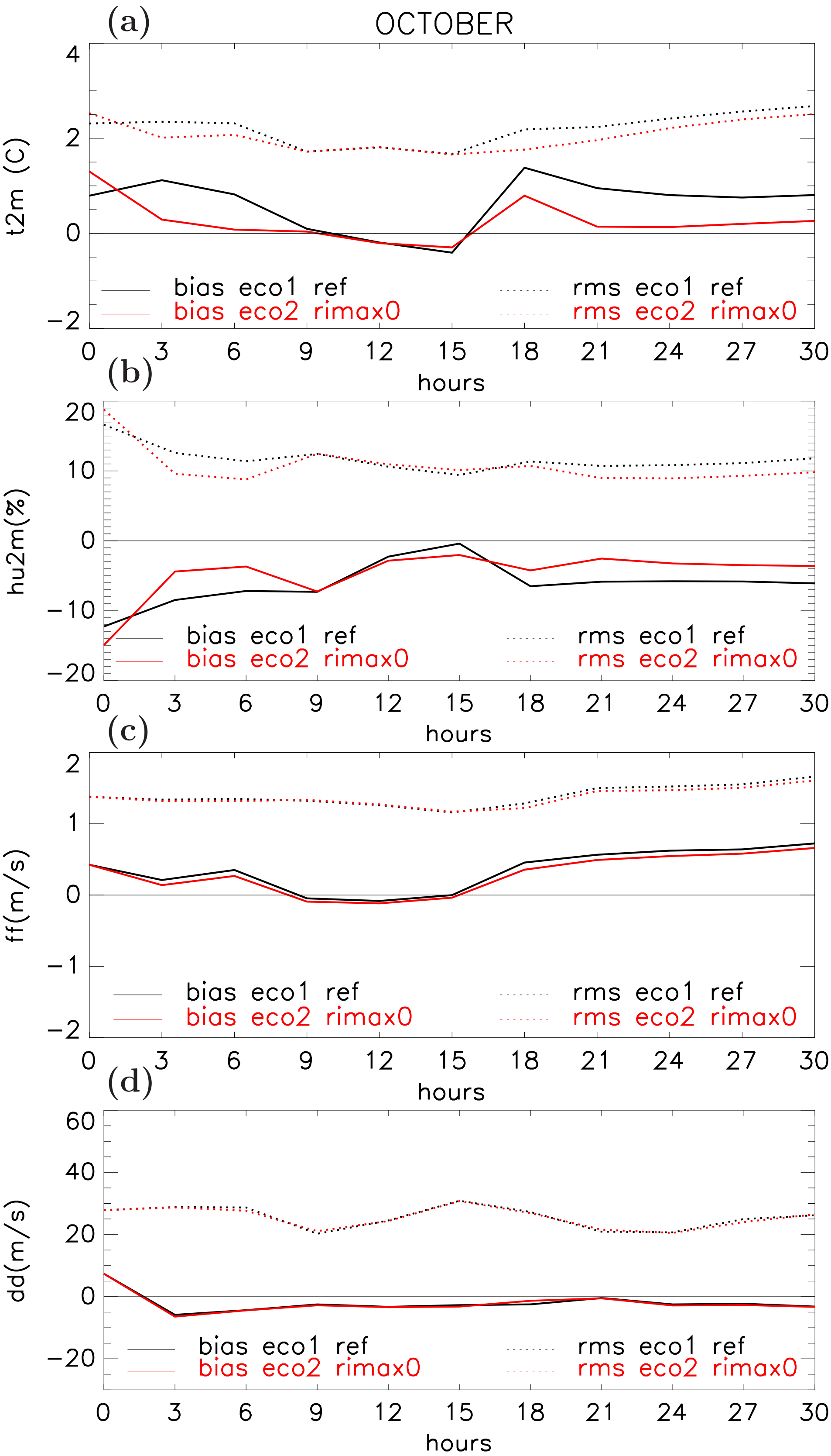


Figure 61: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20071014 for ECO1 REF and ECO2 RIMAX0 simulations

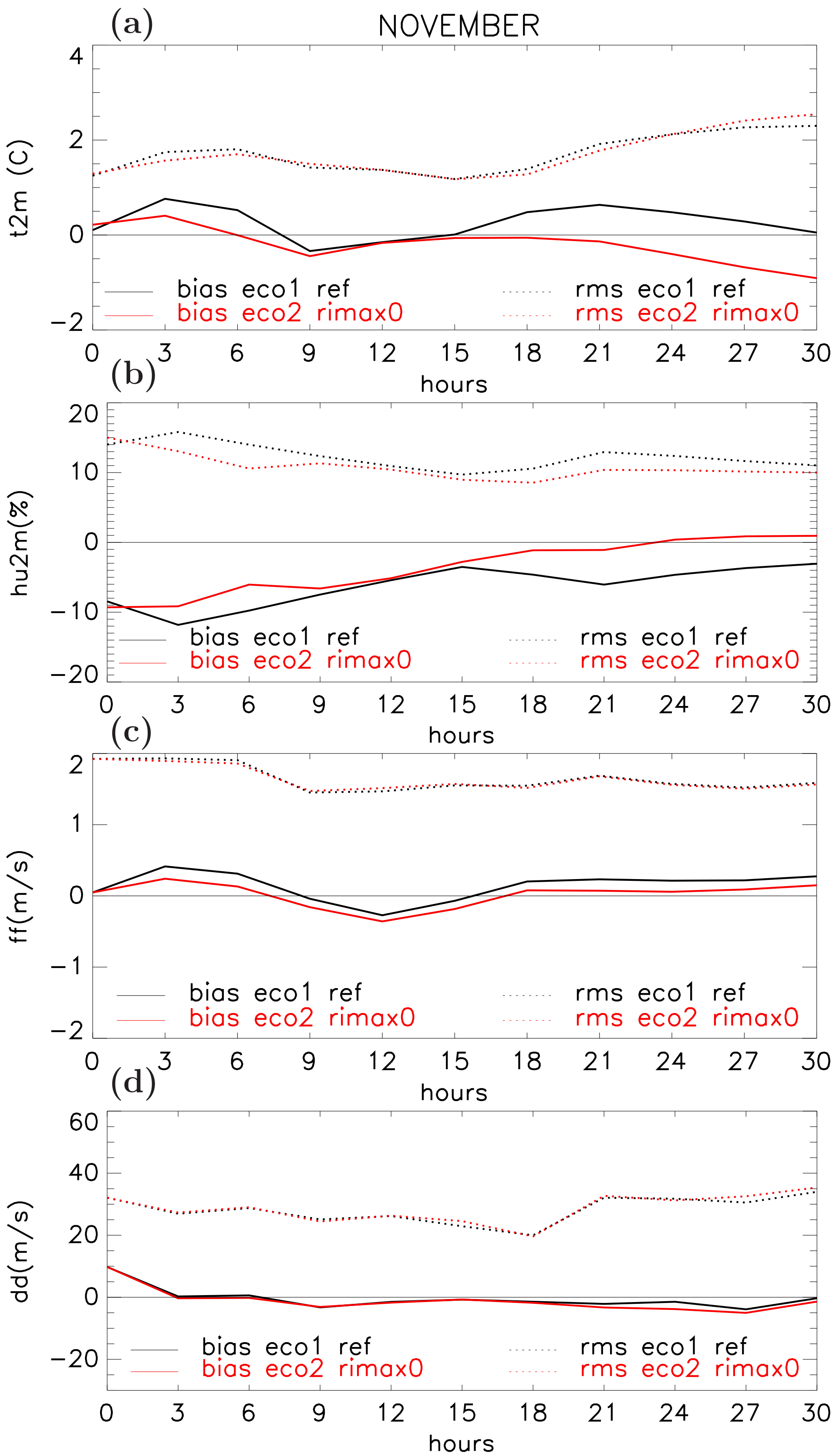


Figure 62: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20071116 for ECO1 REF and ECO2 RIMAX0 simulations

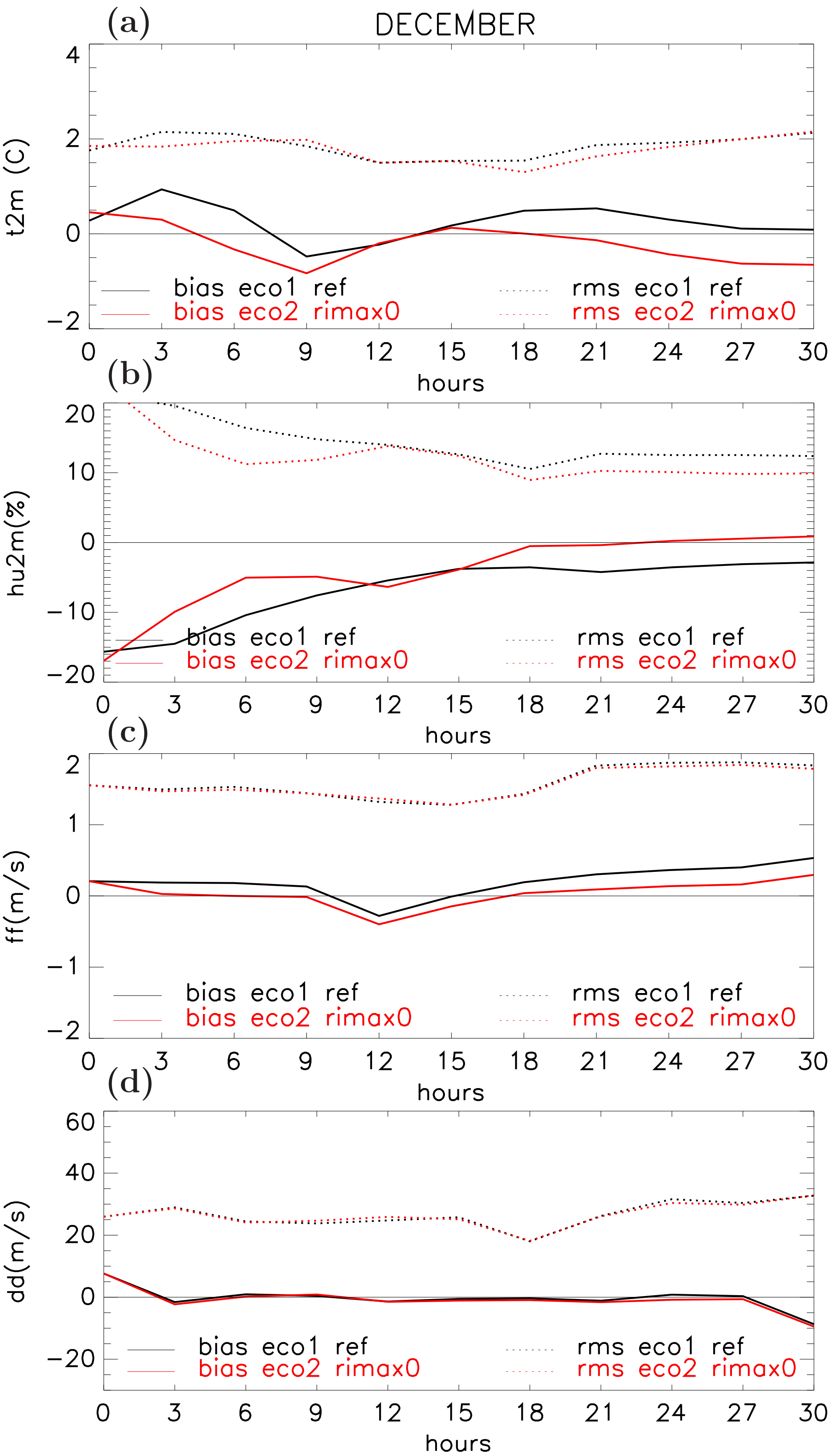


Figure 63: Mean rms and bias of a)T2M and b)HU2M c)FF10M d)DD10M on 20071216 for ECO1 REF and ECO2 RIMAX0 simulations