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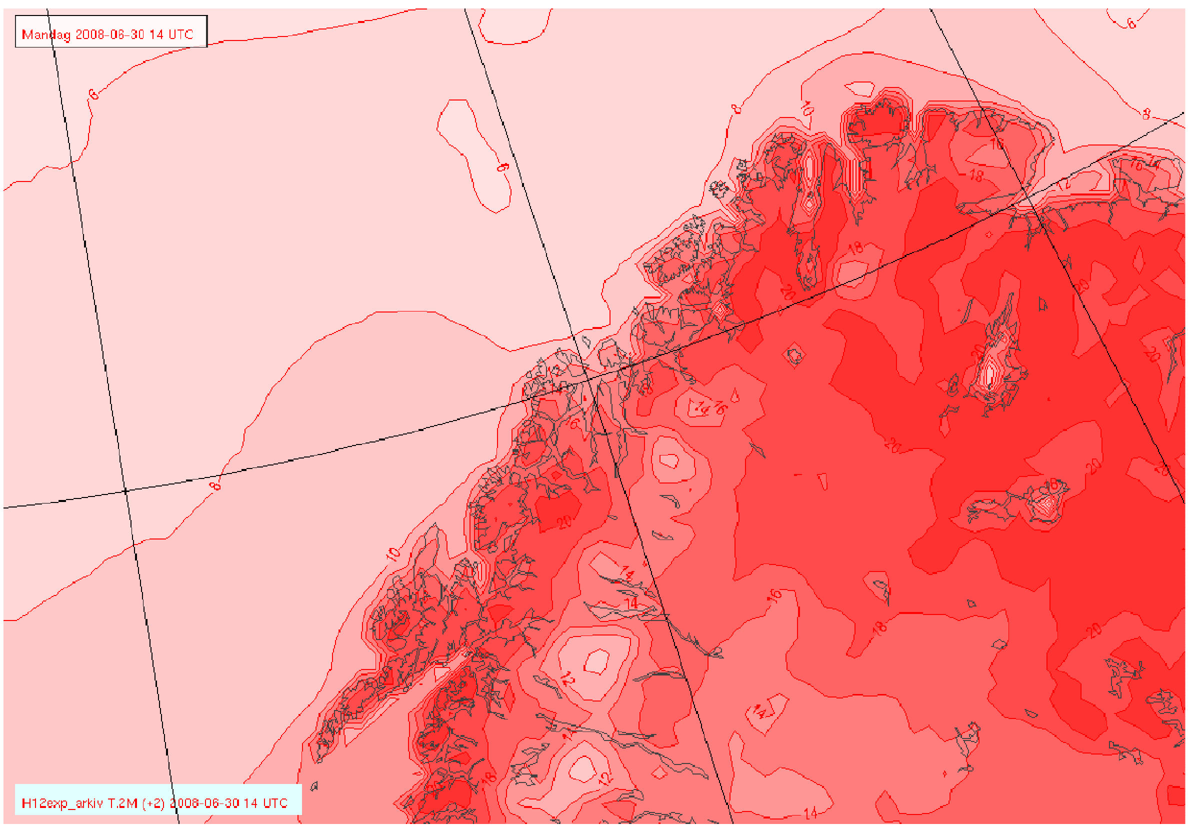

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report

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Abstract

HIRLAM's 2 meter temperature forecasts (T_{2m}) are too close to the sea surface temperature in coastal regions. In spring and early summer, the temperatures are too low and have too small diurnal amplitude. In autumn and winter the temperatures are too high when compared to observations. T_{2m} is an average of temperatures on 5 tiles, weighted linearly with respect to the fractions of each tile. $T_{2m,land}$, which is averaged over all tiles except water and ice, is closer to the observed temperatures in spring and early summer and gives better summary verifications results for this period than T_{2m}. $T_{2m,land}$ might however be much too cold in winter. T_{2m} show best summary results for this period. Experimental weighting of $T_{2m,land}$ and $T_{2m,sea}$ giving more but not **all** weight to $T_{2m,land}$ has been evaluated. Improved performance is demonstrated on Norwegian coastal synop stations.

Keywords
HIRLAM, 2meter temperature, coastal regions

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1 Introduction

HIRLAM's 2 meter temperature (T_{2m}) forecasts are too close to the sea surface temperature (SST) in coastal regions. When compared to observations at coastal stations, the temperatures are too low and have reduced diurnal cycle in spring and early summer. In the autumn the forecasts are too warm. The problem has become evident to more users during the last year, when the forecasts have been made available on the web site yr.no, interpolated to user specified sites. Until spring 2007 the forecasts generated automatic to the public by the Norwegian Meteorological Institute were mainly presented as 'meteograms' at selected sites. At observation stations the T_{2m} forecasts were adjusted to the observed temperatures by a Kalman filter procedure. It is thus important to improve the T_{2m} forecasts in all grid points, not only in observation points. HIRLAM's T_{2m} is an average of temperatures on 5 tiles, or of $T_{2m,sea}$, $T_{2m,ice}$ and $T_{2m,land}$ where $T_{2m,land}$ is an average of the temperature on 3 tiles; no vegetation, low vegetation and forest [1]. In spring and early summer on days with sharp gradients along the coast line between high temperatures over land and still cold sea water, the observed temperatures at coastal stations are closer to $T_{2m,land}$ than T_{2m}. This was the background for replacing T_{2m} by $T_{2m,land}$ on yr.no from 20 June 2007. The quality of T_{2m} and $T_{2m,land}$ has been evaluated against observations from Norwegian synop stations from February 2007 to January 2008. $T_{2m,land}$ is closer to the observed temperature than T_{2m} at coastal stations in spring and early summer, but much too cold in some situations in winter. Experiments with modified weighting of $T_{2m,land}$ and $T_{2m,sea}$ have been performed and demonstrate improved results in coastal regions.

2 T_{2m} and $T_{2m,land}$ from Hirlam10

At met.no forecasts for the last year are available on disk for evaluation and experimentation. The forecasts from Hirlam10 include also T_{2m} on the 5 tiles. Based on these data the quality of T_{2m} and $T_{2m,land}$ has been evaluated at observing stations. The temperature forecasts presented at the external web are adjusted according to the topographical height error with -0.6^{o} pr. 100 m difference between model topography and real topography. Corresponding correction is applied to the temperature forecasts evaluated here.

The largest differences between T_{2m} and $T_{2m,land}$ are found at coastal stations close to open sea in early spring when the sun gives summer over land while the sea is still cold, see e.g. time series from Sola March 2007 and from Torsvåg lighthouse in July 2007, fig.1 and 2, where $T_{2m,land}$ is much closer to the observed. Examples of too cold $T_{2m,land}$ at coastal stations in winter are demonstrated by time series from Torsvåg lighthouse in January 2008, fig.3.

There might also be large differences between T_{2m} and $T_{2m,land}$ in some of the deep fjords, e.g. the Sognefjord and the Hardangerfjord where T_{2m} is closest to the observed, both in summer and winter, see e.g. time series from Vangsnes for March 2007, fig. 4.

Results summarized over coastal stations show that HIRLAM's T_{2m} is too cold in May, June and July and too warm in winter. $T_{2m,land}$ has mean errors close to or slightly below zero, see fig. 5 with monthly mean values (bottom) summarized over 33 stations where HIRLAM's 'Fraction of Land' (FRL) is less than 0.4 (and above 0.005). The mean errors of $T_{2m,land}$ at stations in the fjords (FRL between 0.4 and 0.7) are also close to zero, but slightly too warm, see fig.6. $T_{2m,land}$ has larger diurnal variation than T_{2m} and is often closer to the observed, reflected in lower SDE (Standard Deviation of Error), particularly in June and July. Summarized by MAE (Mean Absolute Error) will $T_{2m,land}$ give better results than T_{2m} most of the year, but slightly reduced quality from September to January, see fig. 5 and 6 (top).

3 Modified weighting of T2m in coastal regions

Replacing T_{2m} by $T_{2m,land}$ gives improved summary verification results in coastal regions, but $T_{2m,land}$ has too sharp gradients at the transition to pure sea grid points. $T_{2m,land}$ might also be too much below SST in some situations, particularly in winter. Further improvements of T_{2m} is possible by introducing a modified weighting of $T_{2m,land}$ and $T_{2m,sea}$. In the reference version of HIRLAM T_{2m} is weighted linearly as a function of FRL:

$$\mathbf{T_{2m}} = \mathbf{FRL} * \mathbf{T_{2m,land}} + (1 - \mathbf{FRL}) * \mathbf{T_{2m,sea}}$$

In stead of replacing T_{2m} with $T_{2m,land}$ the weight given to $T_{2m,land}$ can be increased:

$$\mathbf{T}_{\mathbf{2m},\mathrm{mod}} = \alpha(\mathbf{FRL}) * \mathbf{T_{2m,land}} + (1 - \alpha(\mathbf{FRL})) * \mathbf{T_{2m,sea}} \quad \text{where} \quad \alpha(\mathbf{FRL}) = 1 - \exp(-10 * \mathbf{FRL})$$

The weight function α is shown in fig. 7 (green, labelled H=0) together with weight functions for T_{2m} (blue) and $T_{2m,land}$ (red). The alternative weighting α gives $T_{2m,land}$ in areas where FRL is above 0.5. This version improves the results in coastal regions close to open sea, but the temperatures in some of the deep fjords should be more influenced by SST. A modification of the weights dependent on the topography (H) is introduced to increase the weight given to $T_{2m,sea}$:

$$\alpha(\mathbf{FRL}, \mathbf{H}) = \mathbf{FRL} + (1 - \exp(-10 * \mathbf{FRL}) - \mathbf{FRL}) * \beta(\mathbf{H}), \text{ where } \beta(\mathbf{H}) = \exp(-0.003 * \mathbf{H})$$

Fig. 7 includes α as a function of FRL for different values of H.

Evaluated by summary statistics $T_{2m,mod}$ as presented above gives better results than $T_{2m,land}$ and $T_{2m,}$ through the year, see fig. 5 and 6. Results of the modified weighting are also demonstrated at some stations, see fig. 1-4 (green lines).

4 Conclucions

- HIRLAM's T_{2m} is too close to SST in coastal regions, the temperatures are too low and have too small diurnal amplitude in spring and summer, and are too high in autumn and winter.
- $T_{2m,land}$ is closer to the observed temperatures in spring and early summer, and gives better summary verification results for this period than T_{2m}.
- $T_{2m,land}$ can be too cold in autumn and winter. T_{2m} show best summary results for that period.
- $T_{2m,mod}$ calculated by a modified weighting of $T_{2m,land}$ and $T_{2m,sea}$ gives better results than $T_{2m,land}$ and T_{2m} when evaluated by summary statistics at Norwegian synop stations.

5 Discussion

The horizontal interpolation algorithm has been evaluated. What about the vertical interpolation algorithm? Is T_{2m} too close to SST also at pure sea grid points?

The modified weighting is evaluated for 10 km resolution, and has also been tested in parallel experiments on titan on the Hirlam12 domain for a summer period, with good results. The new T_{2m} will replace the current T_{2m} in the operational implementation, but the originally weighted T_{2m} will also be available with a new parameter number, and give good possibilities for monitoring the modified weighting, also for increased resolutions.

Acknowledgement

The modified weighting was introduced in the operational Hirlam12/8/4 runs from 26 August 2008 by Ole Vignes.

References

[1] HIRLAM-5 Scientific Documentation, Norrköping, December 2002. Available at www.hirlam.org

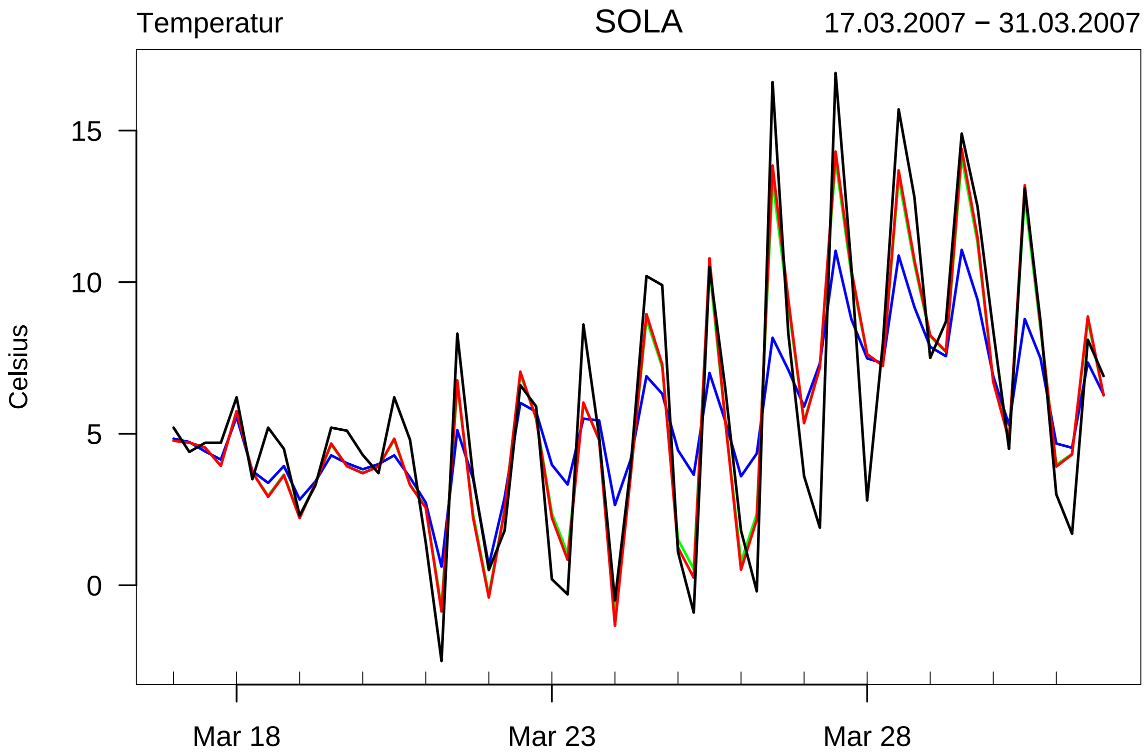

Figure 1. 2 meter temperature at Sola 17. - 31. March 2007. Observations (black), 00+6,12,18,24 forecasts from Hirlam10, T_{2m} (blue), $T_{2m,land}$ (red) and $T_{2m,mod}$ (green).

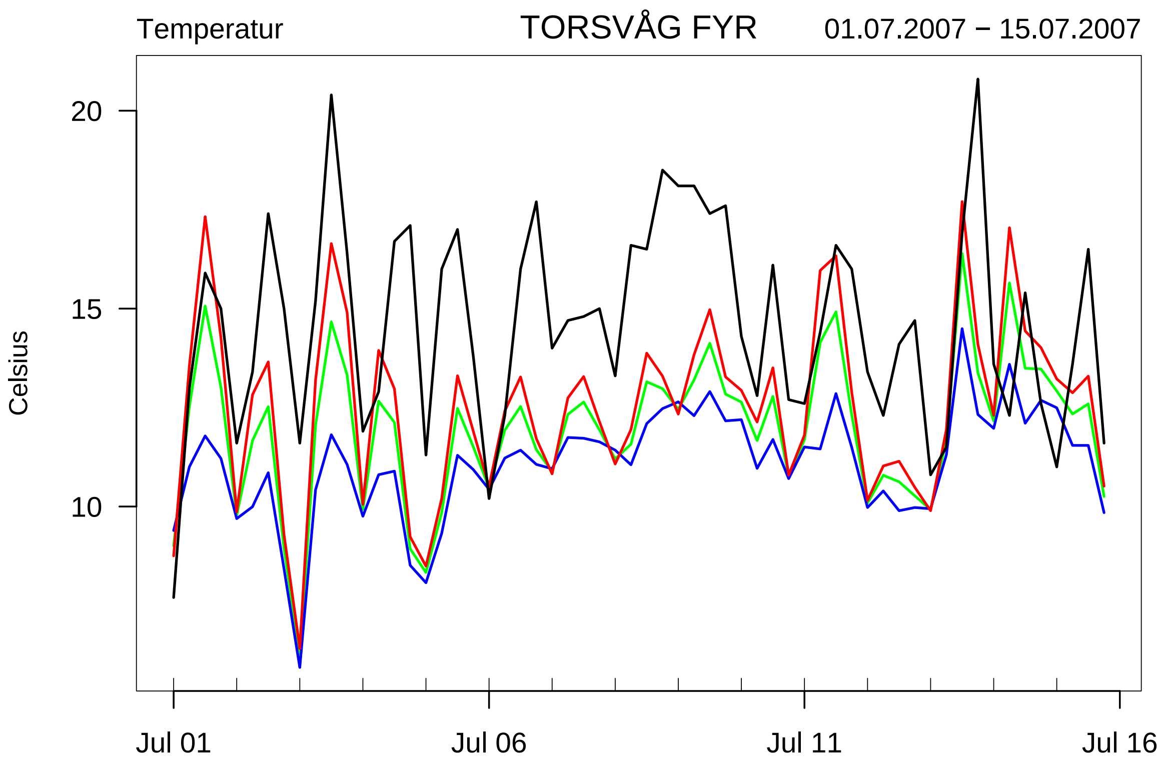

Figure 2. 2 meter temperature at Torsvåg lighthouse 17. - 31. March 2007. Observations (black), 00+6,12,18,24-forecasts from Hirlam10, T_{2m} (blue), $T_{2m,land}$ (red) and $T_{2m,mod}$ (green).

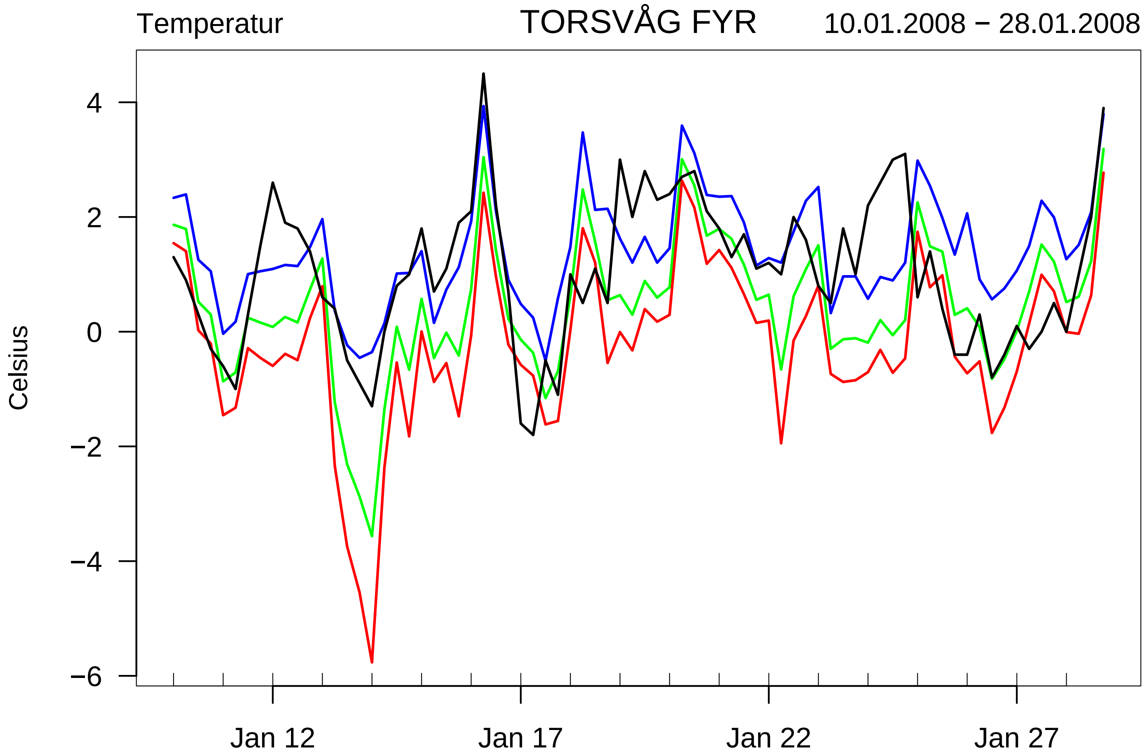

Figure 3. 2 meter temperature at Torsvåg lighthouse 10. - 28. January 2008. Observations (black), 00+6,12,18,24-forecasts from Hirlam10, T_{2m} (blue), $T_{2m,land}$ (red) and $T_{2m,mod}$ (green).

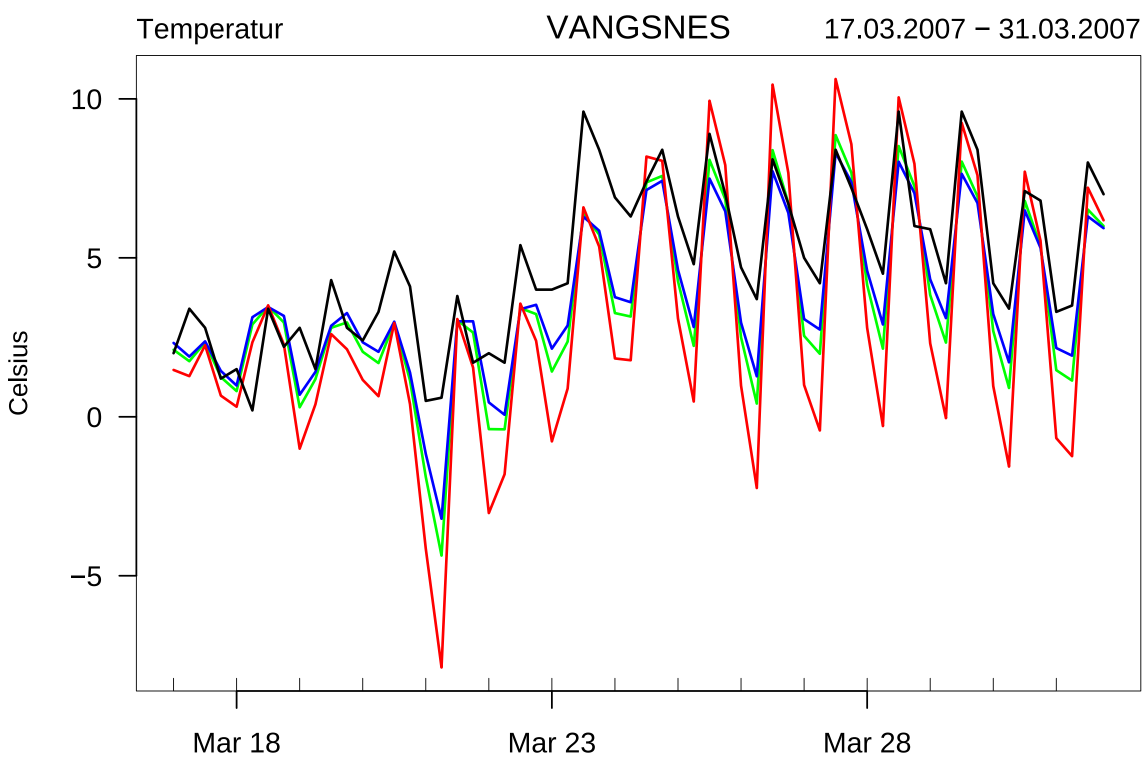

Figure 4. 2 meter temperature at V. in the Sognefjord 17. – 31. March 2007. Observations (black), 00+6,12,18,24 forecasts from Hirlam10, T_{2m} (blue), $T_{2m,land}$ (red) and $T_{2m,mod}$ (green).

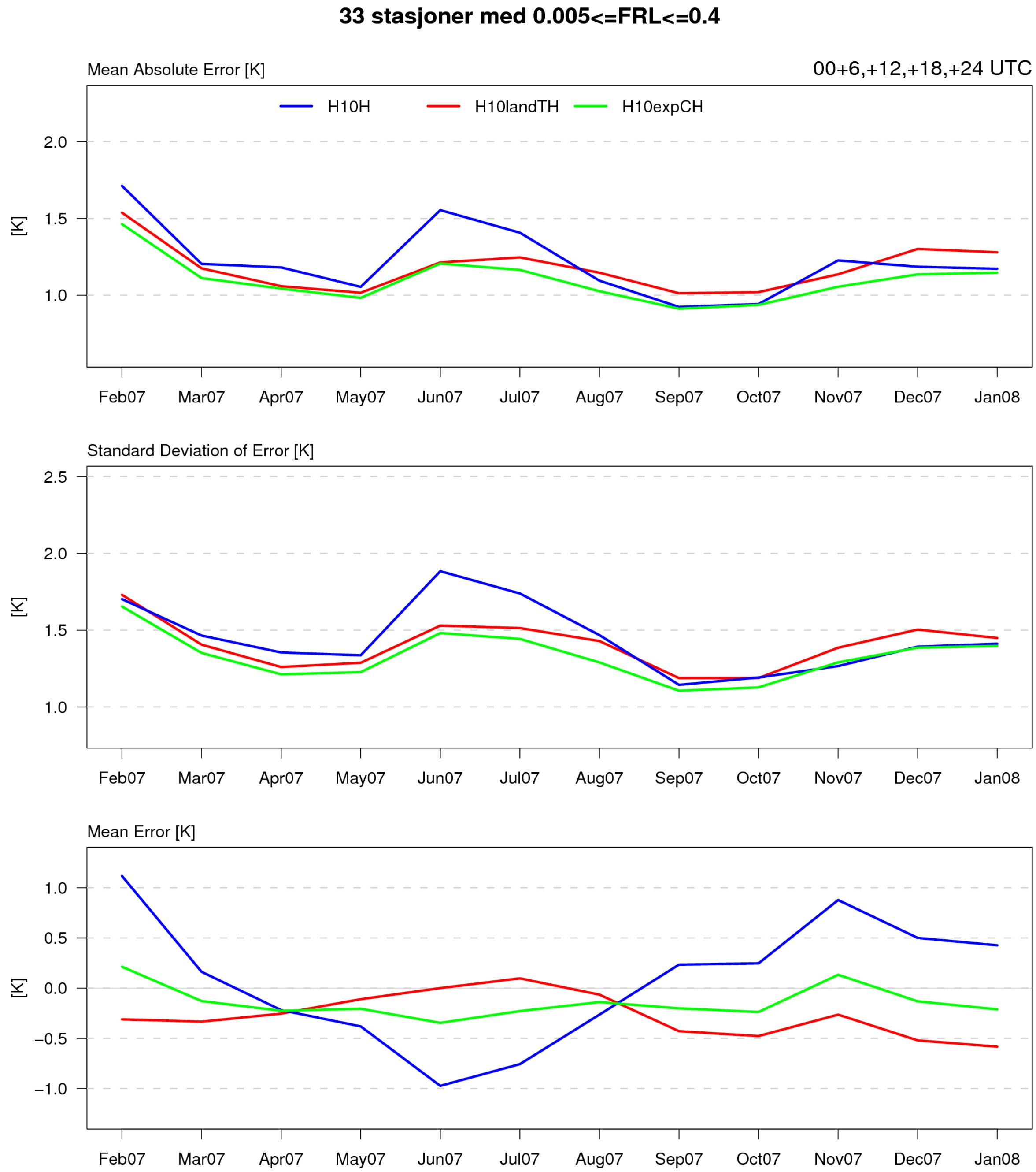

Figure 5. Summary results for temperature forecasts from Hirlam10 for 33 stations with 'Fraction of Land' between 0.005 and 0.4. Monthly MAE (Mean Absolute Error, top), SDE (Standard Deviation of Error, middle) and ME (Mean Error, bottom) from February 2007 to January 2008. H10H (blue) is T_{2m}, H10landTH (red) is $T_{2m,land}$ and H10expCH (green) is an experimentally weighted version, $T_{2m,mod}$. All versions are adjusted according to the topographical height error by -0.06^{o} pr. 100 m.

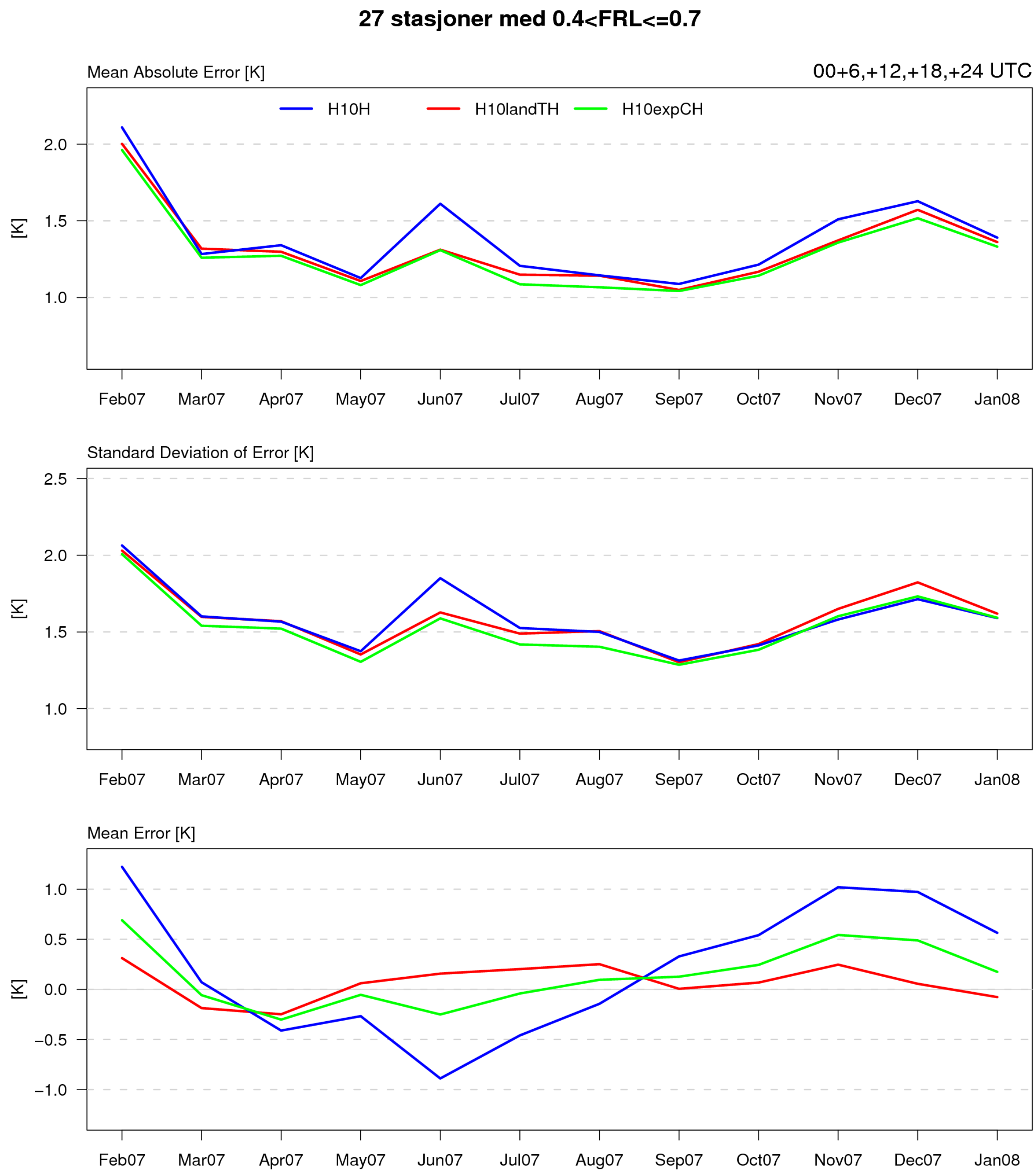

Figure 6. Summary results for temperature forecasts from Hirlam10 for 27 stations with 'Fraction of Land' between 0.4 and 0.7. Monthly MAE (Mean Absolute Error, top), SDE (Standard Deviation of Error, middle) and ME (Mean Error, bottom) from February 2007 to January 2008. H10H (blue) is T_{2m}, H10landTH (red) is $T_{2m,land}$ and H10expCH (green) is an experimentally weighted version, $T_{2m,mod}$. All versions are adjusted according to the topographical height error -0.06^{o} pr. 100 m.

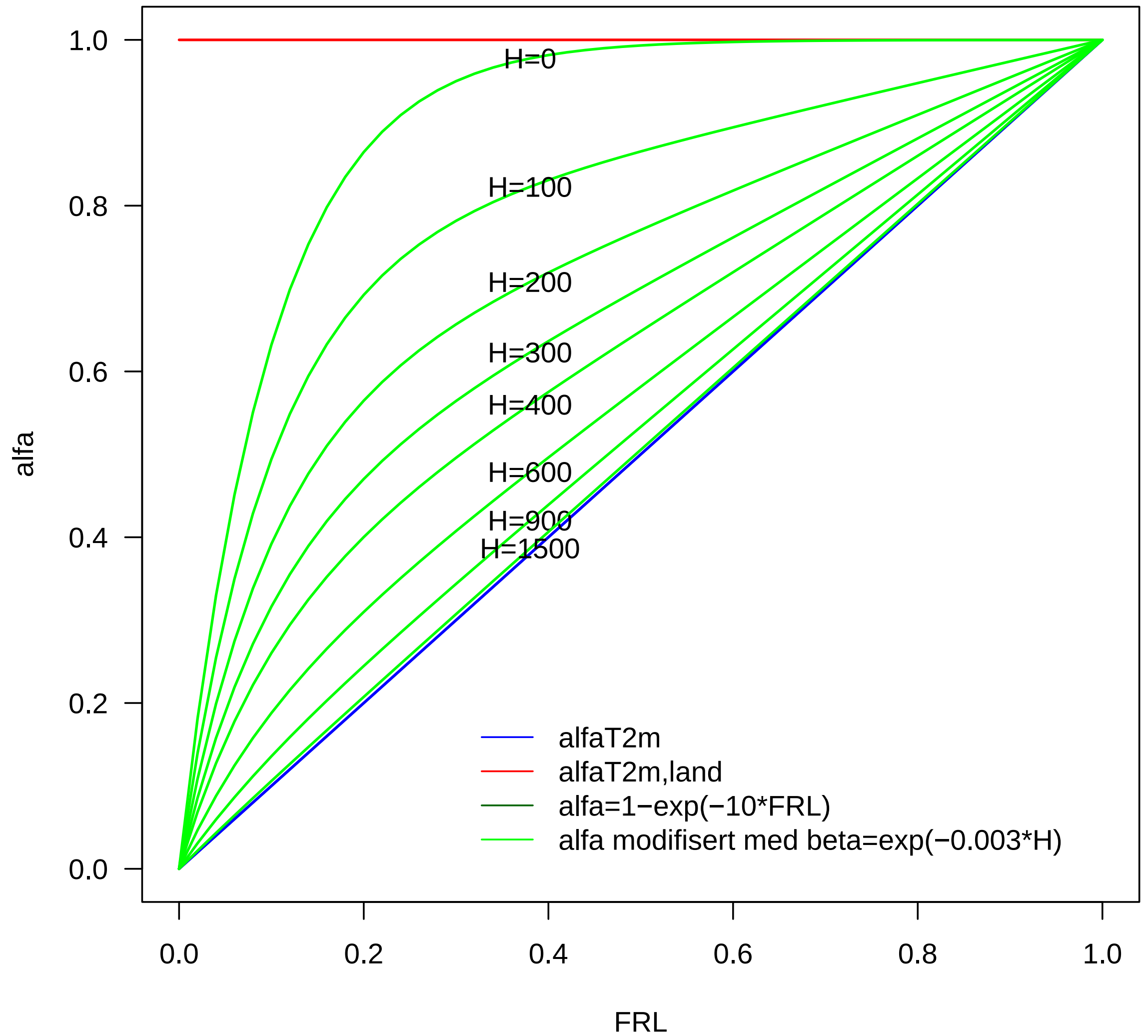

Figure 7. Alternative weight functions for calculation of $T_{2m,}$