ALARO at 4 km forecast post processing using Kalman filter.

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Introduction.

The idea of using Kalman filter for correction of NWP model forecasts is about forty years old. The method is aiming at correction of slowly varying forecast departures from observations. Corrections are done for one meteorological station assuming that forecast departures from observations depend only on suitable subset of predicted variables and that this dependence is linear. Observations together with forecast are used by Kalman filter algorithm to update this linear dependence, namely it's coefficients, to local atmospheric conditions, defined by predictors.

Implementation.

The method was applied on ALARO-0 model with horizontal resolution of 4 km and 74 vertical levels.

Forecasts starting at 0 UTC were used.

Predictors were forecast departures from observations calculated for each hour of the first 12 hours of forecast. For each variable forecast departure was calculated at the times of observations and used as a predictor for calculation of forecast correction for all following forecast hours up to 24 hours of forecast time. For each forecast range coefficients were iterated separately. For today's correction at certain forecast range adjusted coefficients from yesterday's forecast of the same forecast range were used.

Test data.

The method was tested on one year of ALARO-0 forecast in year 2016. Data were taken from SYNOPs. Only forecasts starting at 0 UTC were used. Forecasts were available hourly and observations as well. Predictors were calculated for initial data and each hour up to 12 hour forecast range. Corrected were forecast for all succeesive hours after the predictors time until 24 hours forecast range. For example, forecast departure calculated at 0 UTC was used to calculate corrections of forecasts for 1 UTC to 24 UTC. At 1 UTC new departure is calculated and forecasts for 2 UTC to 24 UTC are corrected using this predictor, and so on.

The method.

Forecast departure from observationa: $b = x_f - x_o$

Predictors: $\mathbf{H} = [p_1 \ p_2 \ldots p_n]$

Coefficients: $\boldsymbol{\xi} = [\xi_0 \ \xi_1 \ \ldots \ \xi_n]^T$

Departure calculation: $b = \mathbf{H}\boldsymbol{\xi} + v \qquad v \sim N(0, V)$

Iteration index (counting consecutive NWP forecasts): k

Coefficients forecasting : $\boldsymbol{\xi}_k = \boldsymbol{\xi}_{k-1} + \mathbf{w} \qquad \mathbf{w} \sim N(\mathbf{0}, \mathbf{W})$

Iterations:

- coefficients forecast: $\boldsymbol{\xi}_{k|k-1} = \boldsymbol{\xi}_{k-1|k-1}$
- departure: $\hat{b}_k = \mathbf{H}_k \hat{\boldsymbol{\xi}}_{k|k-1}$
- correction: $x_c = x_f - b_k$
- adjusment: $\hat{\boldsymbol{\xi}}_{k|k-1} = \hat{\boldsymbol{\xi}}_{k|k} + K_k (b_k - \hat{b}_k)$, K is a Kalman gain.
- $\mathbf{W}_k$ and V_k are calculated from errors from previous M iterations.

Initial values: $\boldsymbol{\xi}_0 = \mathbf{0} \quad P_{0|0} = \varepsilon \mathbf{I} \quad V_0 = \varepsilon \mathbf{I}$, ε is a small positive number.

Verification.

Results were verified by comparison of forecast and corrected forecast biases and RMSEs. Decomposition of difference $RMSE_c^2 - RMSE_f^2 = Var(\hat{b}) - 2Cov(b, \hat{b}) + (B_c^2 - B_f^2)$ was examined too, because $RMSE$ can be reduced by bias term, $(B_c^2 - B_f^2)$ while variance term, $Var(\hat{b})$, is increased and covariance term, $2Cov(b, \hat{b})$, diminished. Successful correction is considered one with covariance term exceeding variance term and with negative bias term.

Meteorological stations.

Results shown are for two continental stations, Zagreb-Maksimir (ZGM) and Osijek (OSI), two coastal stations Opatija (OPA) and Dubrovnik, and two stations on islands, Rab (RAB) and Lastovo (LAS).

Predictors at 00 UTC.

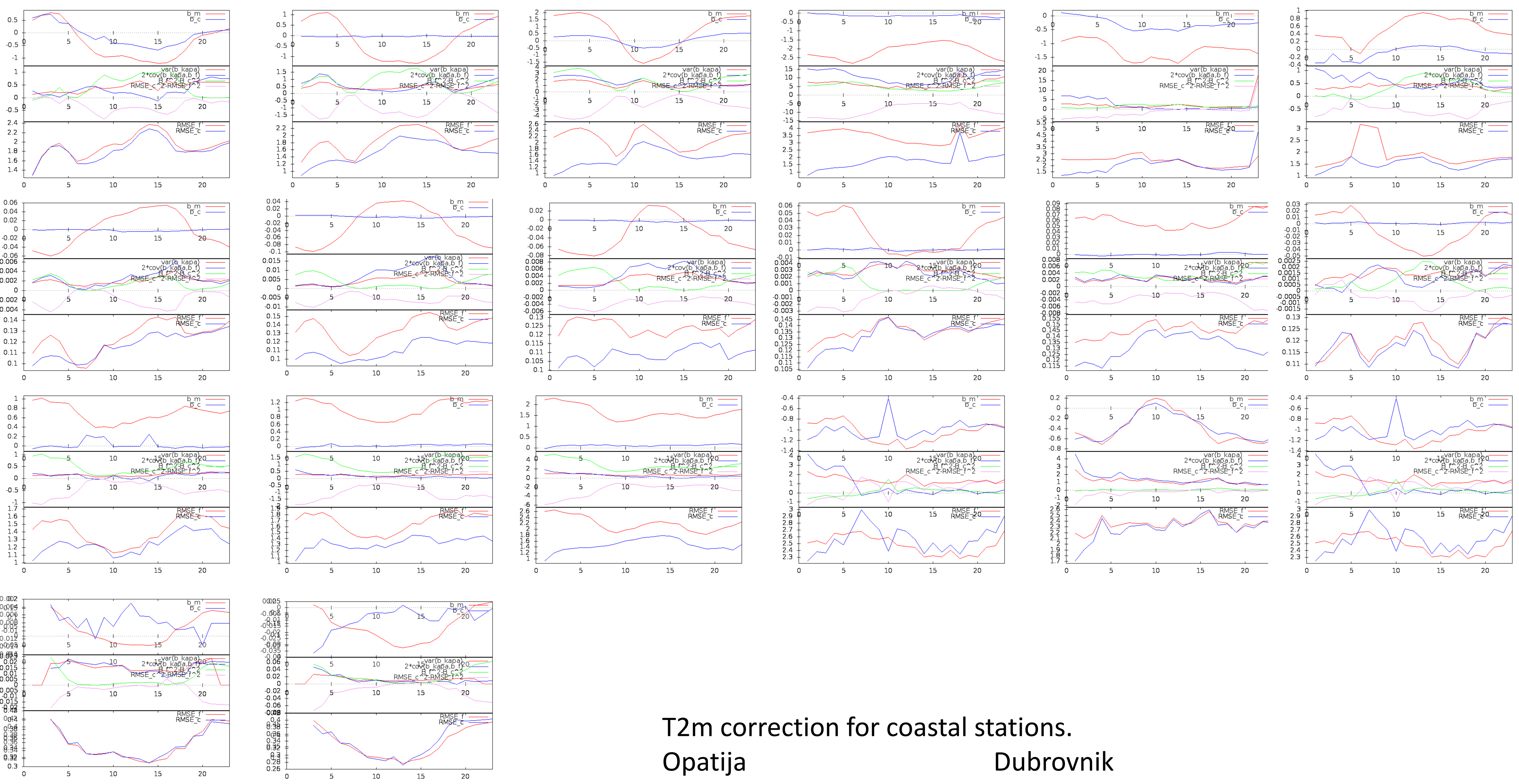
Zagreb-Maksimir Osijek Opatija Dubrovnik Rab Lastovo

T

RH

V

N

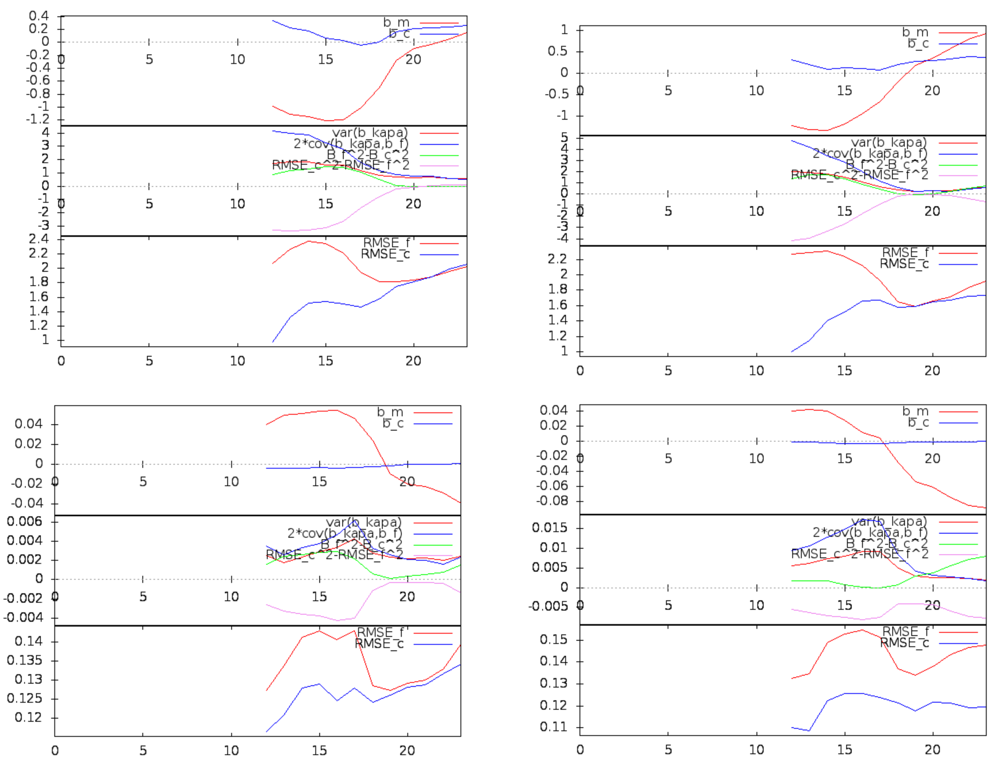


Predictor at 11 UTC.

Zagreb-Maksimir Osijek

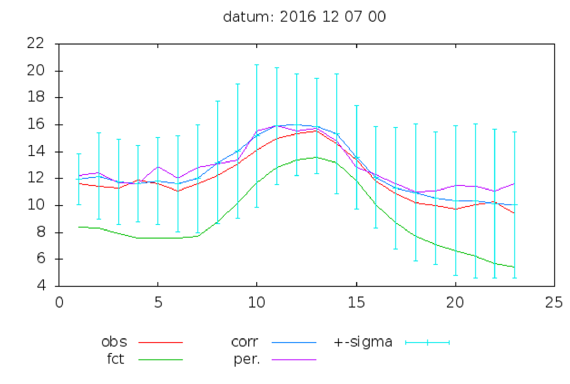
T

RH

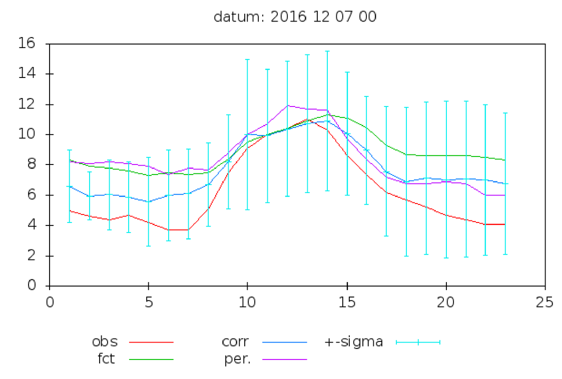


T2m correction for coastal stations.

Opatija



Dubrovnik



Problem with to small forecast - observation difference in initial data.

Opatija