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STATISTICAL WEATHER FORECASTING AS A LINK BETWEEN NWP, SYNOPTICS AND THE CUSTOMER

Klaus Knüpffer *
Meteo Service GmbH Berlin, Germany

1. INTRODUCTION

Statistical weather forecasting systems are generally capable of producing the best automatical weather forecasts since they provide an intelligent feedback between numerical forecasts and observations. Furthermore, statistical weather forecasting can bridge the gap between NWP, operational weather forecasting and the customer. This will be demonstrated using Model Output Statistics (MOS) (Glahn and Lowry, 1972) and Kalman Filter (Simonsen, 1991) projects which Meteo Service has developed for and implemented at the German Weather Service (DWD) and the Swedish Meteorological and Hydrological Institute (Knüpffer, 1996).

2. NWP, STATISTICS AND SYNOPTICS

2.1 Operational MOS Forecasts

How useful is the output of a numerical model for the prediction of a certain element at a certain place for a certain lead time in a certain season? MOS answers this question each day individually as is demonstrated below. The MOS system has been developed using four years of observations and data from the DWD "Europa-Modell" (EM, horizontal resolution about 55 km). MOS forecasts are compared with corresponding EM-DMO (direct model output) forecasts. Monitoring these forecasts helps to explain the error characteristics of the numerical model and of MOS. This gives more structured insight into the advantages and shortcomings of the forecasting methods than general verifications can provide.

Weather situation: Strong gusts are expected in connection with a depression in the North Sea on 13Sep97. Thereafter rising pressure introduces an Indian Summer episode.

	Fr 12		Sa 13				So 14				Mo 15		
	12	18	00	06	12	18	00	06	12	18	00	06	rmse
Lübeck													
DMO	30	29	23	27	34	36	37	37	33	34	27	31	7.6*
MOS	26	27		16	27	31		17	23	27		15	1.7*
Obs	25	25		<25	27	29		<25	26	<25		<25	
List													
DMO	40	33	31	33	36	43	44	47	38	24	40	45	8.7
MOS	41	35	35	41	42	49	53	47	36	31	35	35	6.2
Obs	30	30	41	40	46	49	43	43	39	28	26	28	

Table 1: Maximum Gust Forecasts Issued at 12Sep97,06z for Lübeck (Baltic Sea coast) and List (North Sea)
*) Least error assumption for observations <25 kt

* *Corresponding author address:* Klaus Knüpffer, METEO SERVICE weather research GmbH, Teltower Damm 25, D-14169 Berlin, Germany; e-mail: <k.knuepffer@tina.met.fu-berlin.de>.

MOS forecasts in table 1 differ significantly from DMO. Heavy reductions are successfully applied for Lübeck (Reduction from 37 to 17 kt for Sunday, 06z) and for List on Monday. On the other hand, in the North Sea high DMO forecasts are succesfully corrected to even higher gusts. This shows that MOS does not avoid the extremes when they are predictable. A comparison of the rmse values shows the benefit of all corrections. Background information about MOS gust forecasts can be found in Knüpffer (1996).

EMOS Vorhersagen vom Sonntag 14.09.97 Ausgabe 6.30z
Station 10379 Potsdam 52:23 N 13:04 E 81 m

	So 14		Mo 15				Di 16				Mi 17		
	12	18	00	06	12	18	00	06	12	18	00	06	rmse
T2m/C													
DMO	16	12	9	8	18	13	9	8	21	15	11	11	1.5
MOS	16	13	9	8	18	16	11	10	20	18	14	12	1.1
Obs	15	14	9	8	18	14	10	8	22	18	14	12	
Td/C													
DMO	7	5	5	6	8	4	4	2	7	3	5	8	2.3
MOS	7	7	7	7	7	8	7	8	7	8	11	10	1.9
Obs	7	6	7	6	8	8	7	5	6	6	8	6	
FF/kt													
DMO	11	8	6	6	7	5	5	4	5	5	5	6	4.1
MOS	13	11	10	9	8	8	8	8	7	8	9	9	1.7
Obs	16	9	10	8	9	8	11	10	6	9	11	10	
N/Octa													
DMO	2	0	0	0	2	0	7	8	2	2	7	6	3.1
MOS	5	4	2	4	4	3	2	2	2	3	2	3	2.6
Obs	6	6	0	3	3	7	4	6	6	2	5	7	

Table 2: Indian Summer to come: DMO and MOS forecasts.

T2m: MOS successfully corrects generally too low DMO temperature forecasts for 18z at fair-weather days in the transition seasons.

Td: MOS successfully corrects generally too low night time dew point forecasts at fair-weather days.

FF: MOS successfully corrects systematically too low wind speeds of the DMO, especially at night time.

N: MOS ignores DMO cloud cover forecasts. The correlation between MOS and DMO forecasts in this example is even negative (r = -0.5). Generally low predictability of cloud cover in this weather situation is considered by MOS with smooth forecasts in order to avoid big errors. MOS predicted the convective clouds on Sunday well. However, the high clouds on Tuesday morning and Wednesday morning were better forecast by DMO.

Investigations of predictors used in MOS equations provide hints how to remove the deficiencies of DMO forecasts. E.g., analytically transformed relative humidity predictors which are preferably used in MOS equations instead of the DMO cloud cover predictors may be used to improve the DMO cloud cover parametrization. Proposals for producing DMO for additional elements like probability of thunderstorm or visibility may be derived from similar statistical investigations.

What forms the relationship between MOS and NWP

(1) MOS selects (and ignores), corrects and weights the model output variables in a process of detecting and combining relevant signals. Regression coefficients implicitly reflect the error charactisics of the model with respect to the individual forecast situation: Systematical and random errors, dependent on the weather situation, lead time and season, are handled in a statistically optimum way: The rmse is minimized, which means that statistics first of all tries to avoid the big errors. The side products of this optimization are good forecasts also for the many cases in which no big errors have to be feared.

(2) MOS combines model output with the latest observations and with the climatological expectance of the predictands. Weights of persistency predictors decrease with increasing lead time, depending on the predictability and the auto-correlation of the predictand. Weights of climatological predictors depend on the predictability of the predictands and increase with increasing lead time.

The MOS system can be considered a synoptical knowledge base containing empirical knowledge in a form which is suitable for operational application. MOS systems are steadily improved by incorporation of new knowledge modules. This way synoptics and statistics may co-operate in the production and application of synoptical knowledge.

2.2 Kalman Filter For ECMWF Ensemble Predictions

Meteo Service has developed a Kalman Filter system for the DWD. Investigations on the behaviour of this system, applied to ECMWF Ensemble Predictions provides interesting insights. The only predictor in this system is the DMO. Processing steps are:

a) Develop the regression equation with constant regression coefficients: Reg=Constant+Factor*DMO
b) Daily adaption of Constant and Factor: Experiments with different adaption speeds;
c) Operationalize the Kalman Filter with optimum adaption speed: Kal = Constant(t) + Factor(t)*DMO

Forecasts for T2m at 12z from 01May97 - 10Sep97 are considered below. Results are averaged over 30 German stations.

Figure 1a shows the rmse of the following original and Kalman Filtered DMO variables:

EC - ECMWF Model (T213)
EP - ECMWF Ensemble Prediction (T159): Mean value of 50 Ensemble members

Figure 1a: rmse T2m

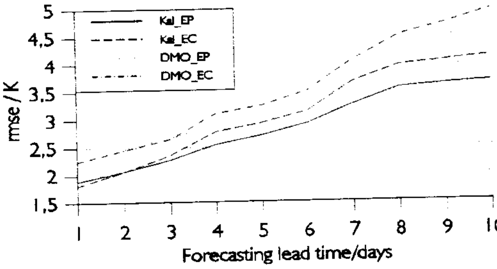


Figure 1b: Reduction of Variance T2m

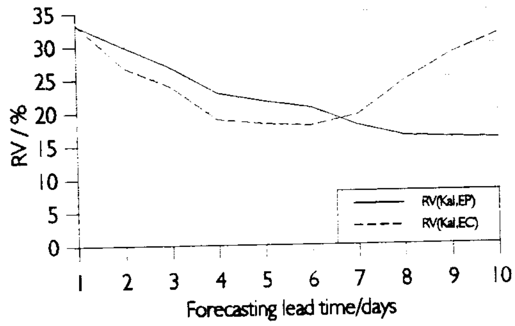
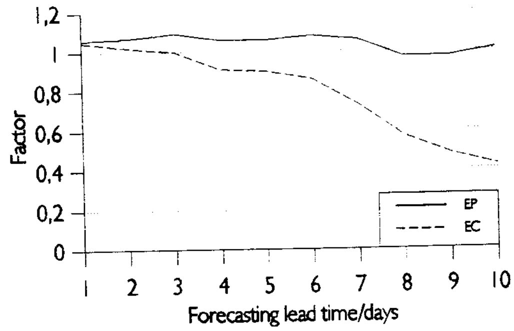


Figure 1c: Kalman Factor T2m



EP forecasts are better than EC, especially in the medium range.

Figure 1b shows the reduction of variance of Kalman Filtered forecasts in comparision to original EP (and EC):

$$RV(Kal,EP)=(1 - rmse^2(Kal) / rmse^2(EP))*100\%$$