9.12 AUTOTREND – AUTOMATED GUIDANCE FOR SHORT-TERM AVIATION WEATHER FORECASTS

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1. INTRODUCTION

Although advancements in Numerical Weather Prediction (NWP) modeling have been substantial over the last decade, these models have not reached a state where clouds and precipitation can be resolved at the spatial and temporal resolutions needed for airport weather forecasts. Aviation forecasters compensate for these deficiencies using the model data in combination with detailed observation information, regarding recent and current weather developments, and topographical information of the airport and its vicinity. In particular, the quality of very short-term forecasts, up to two hours ahead and provided in the form of TREND bulletins, highly depends on the availability of local and upstream observations.

AUTOTREND aims at the development of methods, which objectively integrate available observations and topographical information with existing NWP model data. The main purpose is to develop and implement the methods in an operational environment, and use them to provide detailed numerical guidance on changes in the local weather conditions, such as winds, visibility, clouds and precipitation, that are forecast to occur and that affect air traffic at civil airports in the Netherlands. Basically, two new methods have been developed and evaluated for this purpose, and they are used to produce: 1) A numerical TREND guidance based on statistical and physical postprocessing of NWP model data and observations, and 2) A high-resolution spatial wind forecast based on refining grid-box averaged NWP model winds to local values.

2. NUMERICAL GUIDANCE PRODUCTS

2.1 The TREND guidance

In cooperation with the German company Meteo Service Weather Research (Knüppfer 1997) KNMI has developed a TREND guidance. The guidance contains site-specific information on the development of clouds, visibility, wind, and significant weather. This information is available in the guidance in standard deterministic, categorical, and probabilistic form. Figure 1 shows an example of forecasted cloud amounts in the TREND guidance.

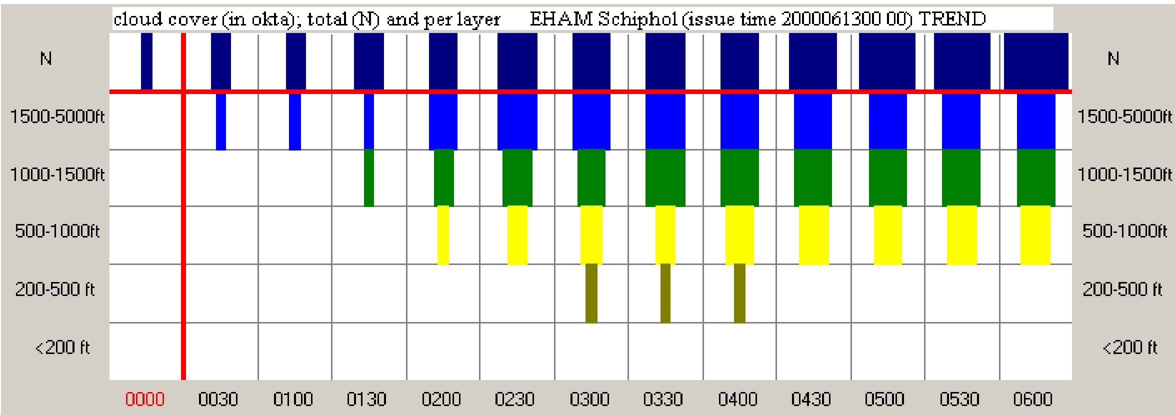

Figure 1: TREND guidance total cloud cover (N, upper panel) and cloud cover by layer (lower panels, abscissa indicate layer levels in ft) for Schiphol airport. The breadth of the bands indicates the number of oktas. This example shows an increase in cloud amount, due to advection of low stratus clouds from upstream locations.

The guidance is based on a combination of Direct Model Output (DMO) from KNMI's NWP model HIRLAM (Undén et al. 2002), physical postprocessing of DMO, and Model Output Statistics (MOS) (Glahn and Lowry 1972). The technique used for the statistical postprocessing is a multi-station version of the traditional single-station MOS. A new concept in the multi-station approach is the introduction of additional advections predictors, denoted as Adv_Trj, which account for the influence of upstream observations on short-term forecasts.

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The advection predictors are defined as:

$$Adv\_Trj = Obs + \sum_{i=1}^{5}\left[Obs(i) - Obs\right] \times W(i), \quad (1)$$

with *Obs* the observed predictand at the forecast site, *Obs(i), i* = 1,…5, the observed predictand at the five nearest upstream locations, and where $W(i)$ is the normalized relative station weight (in percent) for station i. A trajectory model is used to compute the path of the air mass displacements. In the trajectory model, HIRLAM model winds at levels 925 or 1000 hPa are used to compute the trajectory path. Locations nearest to the trajectory starting point are identified as the upstream locations. Stations weights depend on the geographical distance from this trajectory starting point.

In order to demonstrate the impact of advection predictors on short-term forecasts for low stratus clouds, we have presented a typical MOS forecast equation in table 1. The forecast equation corresponds to the example illustrated in figure 1. In the example the air flow at Schiphol airport was from the southwest. This results in the advection of low clouds observed at the upstream locations Rotterdam airport, Valkenburg, and Vlissingen, towards Schiphol airport. The table gives detailed predictor information on forecasting cloud amounts below 1500 feet at Schiphol airport 2 hours in advance. In the table cloud amounts are specified in percentage, where 100% equals 8 okta. In this summer equation only the 925 hPa advection predictor is selected. Upstream locations are presented in order of relevance, according to their relative station weights. The value of the advection predictor is determined by equation (1). This predictor, among several others, is finally weighted into the MOS forecast equation. According to the table, the forecast value is mainly determined by the relative humidity predictor RH_1000_90%_Bin and by the advection predictor. Persistence of the latest observation at the forecast site (Okta<1500ft(-2)Obs), plays only a minor role in the forecast, due to its relative low coefficient. In this case, the contribution is even zero due to the observed value. A list of predictors used in the TREND guidance can be obtained from Knüppfer (1997) and references therein. The inclusion of the advection predictors is a very successful new technique, which leads to an additional reduction of the variance for visibility and cloud base by 10 to 20%.

Location: Amsterdam airport Schiphol	Forecast lead time: +02h	Predictand: Okta < 1500 ft
Issue: 13 June 2000, 01h UTC	Season: Summer	

Trajectory: Adv_Trj_925 Trajectory start: lon = 3.42 lat = 51.54 $Obs(site) = 0.0$ (in %)

Upstream location	*Obs(upstr)* (in %)	*Weight* (in %)	*Value* (in %)
Rotterdam	75.0	35.1	26.4
Vlissingen	87.5	29.7	26.0
Valkenburg	75.0	21.6	16.2
Schiphol	0.0	8.1	0.0
Gilze Rijen	0.0	5.4	0.0

Predictor	*Value*	*Coefficient*	*Product*
RH_1000_90%_Bin	75.7	0.1859	14.0656
Rotation_1000	-12.5	0.1442	-1.8025
Sun_Alt_Sin	-4.9	0.1584	-0.7826
Okta<1500ft(-2)Obs	0.0	0.0907	0.0000
Adv_Trj_925	68.6	0.6910	47.3895
Constant		0.9565	0.9565
		Forecast:	59.8265 %

Table 1: MOS forecast equation for the short-term prediction of cloud amounts below 1500 feet in summer.

The TREND guidance is updated every 30 minutes with model data from HIRLAM, and recent local and upstream observations. Local airport observations are provided by the half-hourly conventional aerodrome observations (METARs and SPECI's). For practical use, the TREND code should be added to the actual METAR or SPECI instantaneously. However, when a new TREND code must be made, which is at the METAR or SPECI observation time, the TREND guidance based on this actual observation is not yet available. Therefore the TREND guidance of 30 minutes prior to the actual observation time must be used. In section 3 we will demonstrate that this 30-minute time lag has a large impact on the quality of the guidance forecasts. The TREND guidance has been supplemented with encoding software that translates the guidance parameters into the required aeronautical code. A graphical user interface with an integrated code editor enables the forecaster to modify the suggested 'first guess' code. Figure 2 shows how the TREND guidance and the TREND code have been integrated into the user interface.

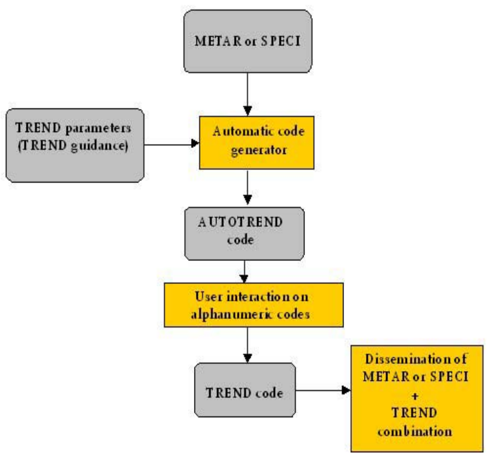


Figure 2: The TREND code integrated in the user interface.

2.2 The downscaling winds

NWP model data forecasts are grid box averaged values. Locally observed meteorological parameters, however, and in particular wind, can deviate significantly from the grid box averaged value, due to local differences in land use and surface roughness. The difference between the model grid box average and the observed local value is part of the model error, which is referred to as the representation mismatch (RM) (De Rooy and Kok 2004). For 10 m wind speed the RM is dominated by the difference between model (grid box averaged) roughness and local roughness.

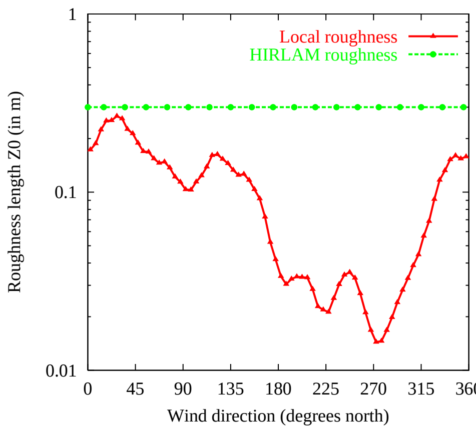


Figure 3. High-resolution, wind direction dependent, local roughness compared to uniform HIRLAM roughness for the synoptic wind measurement location at Schiphol airport.

In order to reduce the RM, a high-resolution wind transformation method, called downscaling, has been developed. Downscaling NWP model wind basically increases the representativeness of local wind forecasts on spatially small scales such as airports. The downscaling method is based on a physical two-layer model of the Planetary Boundary Layer (PBL) where the upper boundary condition is provided by NWP model data from HIRLAM, and where roughness information of the surface is derived from high-resolution land-use maps. The geographical variations in surface roughness in the land-use maps are averaged over the upstream area of the air flow. The resulting high-resolution roughness lengths are wind direction dependent, contrary to the uniform roughness lengths that HIRLAM uses in each model grid box (see figure 3).
The downscaling method has been validated for the computation of the +03 hour forecast of the average 10 m wind speed and wind direction at various locations at Schiphol airport. Figure 4 shows the verification results of the downscaling method and HIRLAM for the synoptic observation location at Schiphol airport, for different atmospheric stability conditions (unstable, neutral, and stable). In the figure, the mean error (ME) and standard deviation in the error (SD) in the wind speed are presented for each wind direction.

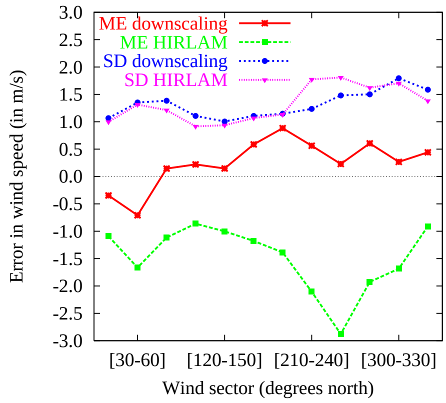


Figure 4. Wind speed error statistics in the computation of the +03h forecast average wind speed for Schiphol airport. The verification period is November 2001 – February 2002.

The impact of surface winds on the aircraft depends on the angle between the wind direction and the geographical orientation of the runway. In general, aircraft cannot take-off and land if the crosswind and tailwind components exceed certain threshold values. For practical use at the airport, the downscaling wind forecasts are tailored to several more runway specific products. One of these products is the crosswind and tailwind component at the touchdown positions at Schiphol airport. Figure 9 gives an example of a possible crosswind (perpendicular) and tailwind (parallel) forecast, up to +48 hours, for one of the touchdown positions (36R) at the airport.

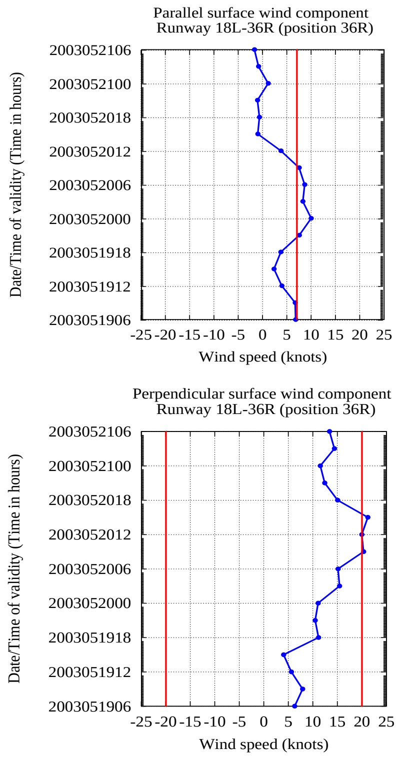
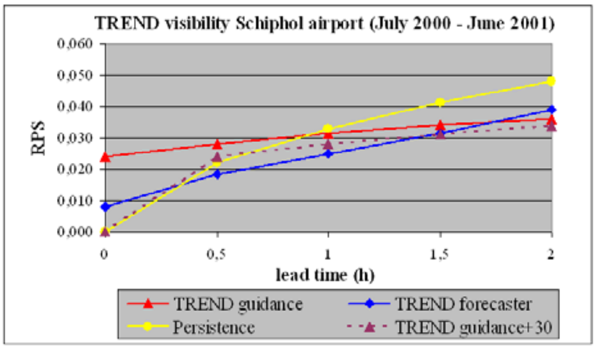


Figure 9. Forecast crosswind (lower) and tailwind (upper) at touchdown position 36R at Schiphol airport. The threshold values for tailwind, 7 knots, and crosswind, 20 knots are shown by straight vertical lines.

3. VERIFICATION RESULTS

In the automated TREND production system the TREND guidance is produced as an intermediary product. The final product consists of the automatically produced TREND code and the forecasters' TREND. In figure 10 verification results for TREND guidance visibility and cloud ceiling forecasts are presented in terms of the Ranked Probability (skill) Score (RPS) (Gordon 1989). In the figure the TREND guidance is compared to the forecasters' TREND code, to the persistence of the observations at issue time, and to the guidance based on the actual observation (TREND guidance + 30 in figure 10). Note that lower RPS values represent a better forecast skill.



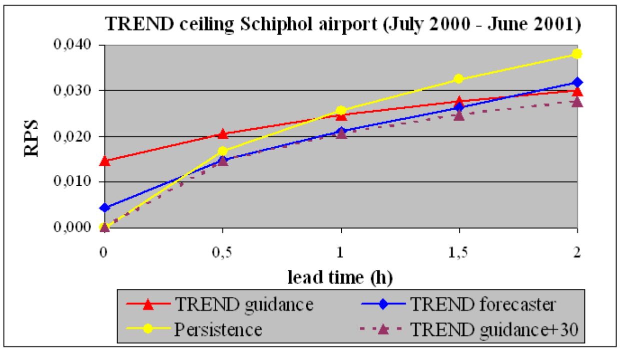


Figure 10. Verification results for TREND visibility (left) and cloud ceiling (right) forecasts at Schiphol airport.

4. CONCLUSIONS

A guidance system consisting of postprocessing of NWP model data in combination with local and upstream observations, and topographical information of the airport terrain and its vicinity, is able to provide more detailed and accurate meteorological information on changing weather conditions at airports. By presenting this guidance to the forecaster, aviation weather forecasts can be produced more efficiently. For short-term, visibility and cloud ceiling forecasts, the forecast skill, however, is reduced significantly when the guidance depends on observations which are too old. In order to benefit optimally from the detailed information available in the guidance, the update frequency of the guidance needs to be increased and the delay times minimized.

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