J7.4 The Performance Of The Model System NOWVIV During the Field Campaign WakeOP

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1. Introduction

Todays major airport face severe capacity problems due to increasing air traffic. One limiting factor is the wake vortex (WV) hazard which requires prescribed separation distances according to the weight of the approaching aircraft. New wake–vortex related staggering procedures for approaching aircraft are sought which reduce the current separations and relax airport capacity shortages without lowering todays safety levels. Hence, a forecasting tool, which predicts the vortex positions and strengths along the flight path in a given or forecasted atmospheric environment, together with ground-based or airborne wake monitoring and detection tools might permit air-traffic controllers to ease some of the regulations without loss of safety.

From experience and research results gained during the past 30 years (Hallock et al., 1998, Spalart 1998, Gerz et al., 2001), it becomes evident that the separation standards seem overly conservative for a variety of meteorological situations. The atmosphere controls the wake vortex behavior, culminating in trajectory and structural changes. Under favorable atmospheric conditions, the vortices become unstable and decay quickly, or are transported out of the flight path of a following aircraft.

The essential key towards such a system is the knowledge about the meteorological conditions and their impact on the wake vortex behavior. In this paper we will introduce the model system NOWVIV which was tested during a field campaign accomplished at the Fairchild–Dornier airfield in Oberpfaffenhofen, Germany during April/May 2001. That campaign, named WakeOP, commonly driven by DLR's Wake Vortex Project ”Wirbelschleppe” and the European project ”C-Wake”, aimed at predicting, monitoring and characterizing the evolution of the wake of a given aircraft flying with prescribed configurations in various meteorological conditions. In the following we will investigate the quality of the NOWVIV wind prediction in comparison to observations from a wind profiler.

2. The model system NOWVIV

A hierarchy of weather forecast models is combined within the model system ”NOWVIV” - NOwcasting Wake Vortex Impact Variables -which run automatically at DLR in an operational mode during WakeOP. NOWVIV uses output data from the operational weather forecast model ”LM” of the German Weather Service which runs at a resolution of 7 km. LM on the other hand is driven by the global model ”GME” which runs at a resolution of 60 km. A core element of NOWVIV is the Penn State/NCAR mesoscale model ”MM5” (Grell et. al, 2000) which is used to predict atmospheric state variables within a 2.1 km grid around the airfield with an increasing vertical spacing from 25 to 50m throughout the boundary layer. Detailed terrain and landuse information is provided to NOWVIV. See figure 2 for the principle scheme of NOWVIV. The WakeOP terrain is heterogeneous with some orographic features such as lakes and hills embedded.

NOWVIV is initialized every 12 hours, 12 UTC and 0 UTC. Locally measured data have not been assimilated for this test, however this is planned in the near future. Output variables are vertical profiles of horizontal and vertical wind, u, v, w, virtual potential temperature θ_v and turbulent kinetic energy e.

During the WakeOP campaign, NOWVIV forecasts were used in the morning briefing to schedule flight tests and patterns.

A SODAR/RASS wind profiler (WPR) was operated at the airport providing profiles of wind and temperature in a nominal range of 40-500 m. Part of the system was a sonic anemometer mounted at 10 m height. The maximum height range was set to 500 m above ground in order obtain the highest possible vertical resolution of 10-20 m in the lower boundary layer, where the test flights were performed at a height of 150 m above ground. Available are 10 min averaged profiles. The WPR was running nearly continuously throughout the campaign. In addition data from a bistatic RADAR, radiosonde soundings and a wind LIDAR are available for comparison. For this study we focus on the comparison with the WPR because it provided quality controlled data on a 24 hr basis. In the following we will check the forecast quality of the cross wind relative to the runway and, as an indicator of wind direction error, the quality of the wind speed prediction.

A comparison of model data with observations is typically complicated due to different time/space averaging of meteorological data. To what extent it is meaningful to compare WPR data with model results can be simply estimated. Assume an air mass which is advected with 5 m/s into the sensing volume of the WPR. For the 10minute averaging period this airmass travels 3 km which corresponds roughly to the scale of the spatial model resolution (2.1x2.1 km^2). Subgrid features in the airport environment relative to the model resolution may influence the wind field for weak winds. This may cause larger differences between observation and prediction.

We analyse the forecast of wind speed u_a and runway cross wind u_c from 19 days comprising very different weather situations which gives an impression on the NOWVIV capabilities. As a simple measure of the error we have chosen the difference between observation and prediction (here for the cross wind u_c):

$$\Delta u_c = u_{c,WPR} - u_{c,NOWVIV} \quad (1)$$

and the root-mean-square error.

Table 1: Distribution of the difference between observation and prediction (NOWVIV) and the root mean square error (RMS).

Variable	1. Quartile	Median	3. Quartile	RMS
Δu_a (m/s)	-4.1	-2.3	-0.6	3.6
Δu_c (m/s)	-2.9	-1.2	-0.4	2.9

Table 2: Distribution of the difference between observation and prediction for NOWVIV and LM (in m/s).

	NOWVIV	LM
Δu_a 1st Quartile	-4.1	-6.0
Δu_a Median	-2.3	-3.7
Δu_a 3rd Quartile	-0.6	-1.5
Δu_a RMS	3.6	5.3
Δu_c 1st Quartile	-2.9	-4.5
Δu_c Median	-1.2	-2.3
Δu_c 3rd Quartile	-0.4	-0.1
Δu_c RMS	2.9	3.9

3. Model performance

The overall statistics for the NOWVIV forecast is shown in Table 1. The data in the table are representative for a height range of 10-500 m. On average we find an overestimation of the model predicted cross wind and wind speed. RMS errors for cross wind and wind speed have a similar magnitude which appears to be related with an error in predicted wind direction.

We now investigate the benefit in using a high resolution model. This is done by quantifying the error of the forecast from the routine weather service model LM against the NOWVIV forecast.

In general both NOWVIV and LM overestimates the average wind speed. Considering the median, this overstimation is reduced by about 40 % when using NOWVIV (Table 2). This improved forecast by NOWVIV is likely to be due to the higher spatial and vertical resolution of the model domain with a better representation of local orography and landuse. Figure 1 shows the height dependence of the RMS error for the LM and NOWVIV forecasts. An increase of the RMS error with height is found in both models.

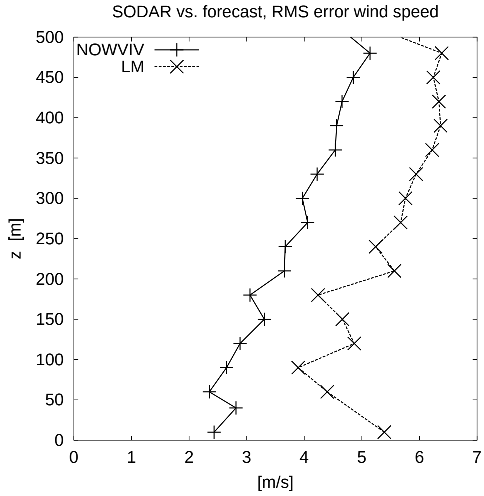

Figure 1: Profiles of the wind speed RMS error of the NWOVIV and LM forecasts.

The diurnal variation of the model errors has been investigated in more detail. We define morning (5:00-9:00 local time, LT), midday (12:00-15:00 LT), evening (17:00-20:00 LT) and night time (21:00-04:00 LT) periods and compute the corresponding error statistics.

The differences are not large (table 3). We find a slightly better forecast quality for the midday profiles. Larger differences in the upper layers are found for the morning and evening hours which represent transition times with unstationary boundary layers where for example components of the surface energy balance change rapidly.

For the midday, if the external forcing of the model is adequate, it is expected that the agreement is best, since we have a well developed, often quasi-stationary, boundary layer which can be captured well by existing boundary layer parameterizations. The largest error is found for the nocturnal profiles. The flow of a nocturnal boundary layer can be quite complex while it is known that e.g. existing turbulence parameterizations of the stable boundary layer are limited. This aspect is currently investigated in more detail

Table 3: Distribution of the difference between wind speed observation and prediction depending on the time of day. Data are representative for a height range of 10-500 m above ground.

Variable	1. Quartile	Median	3. Quartile	RMS
Δu_a (m/s) Morning	-3.0	-1.7	0.6	2.7
Δu_a (m/s) Midday	-2.1	-0.7	1.1	2.5
Δu_a (m/s) Evening	-3.1	-1.8	0.2	2.9
Δu_a (m/s) Night	-3.5	-1.7	-0.3	3.3

4. Summary

We have introduced NOWVIV, an operational model system to provide forecasts of meteorological parameters to predict wake vortex transport and behavior. The performance of the wind forecast during WAKEOP has been analysed and quantified for 19 days. In the future, model forecasts and in-situ observations will be combined within NOWVIV. Furthermore, an assessment of the turbulence kinetic energy and temperature forecast is currently carried out. Finally, WV predictions using NOWVIV data will be compared to observed trajectories of WVs from WakeOP.

References

Gerz T., Holzäpfel F. & Darracq D. 2001: Aircraft wake vortices. A position paper. 43 pp. Available from http://www.pa.op.dlr.de/wirbelschleppe.

Grell et al. 2000, JGR 105, 29595-29608

Hallock J.N, Greene G.C. & Burnham D.C. 1998: Wake vortex research – a retrospective look. *Air Traff. Contr. Q.* **6**, 161–178.

Spalart P.R. 1998: Airplane trailing vortices. *Annu. Rev. Fluid Mech.* **30**, 107 — 138.

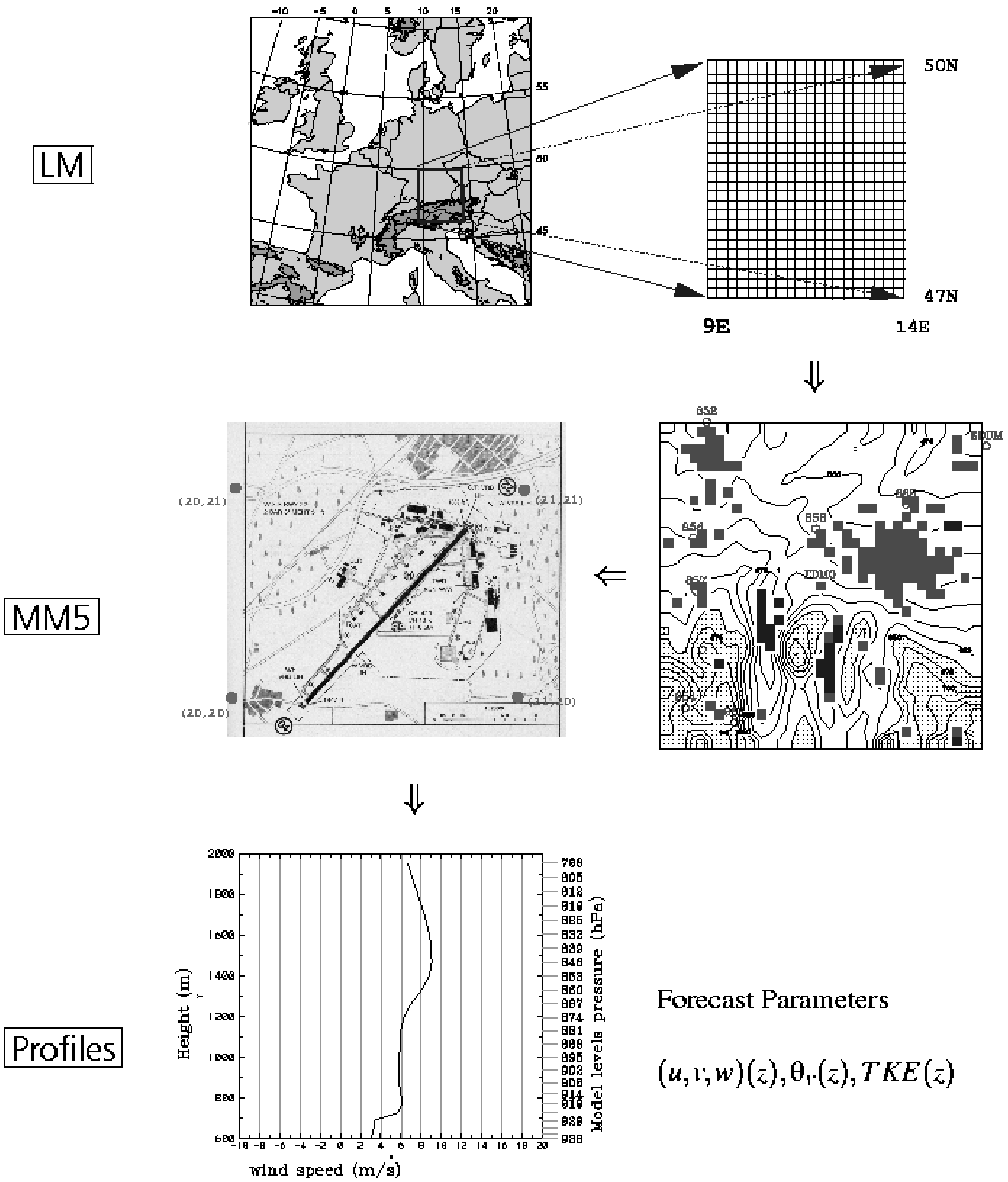

Figure 2: NOWVIV flowchart.