JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2006

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1. Summary of highlights

The ALADIN model has been ported from SGI to NEC. The forecast range has been extended from 48 to 72 hrs, and two intermediate runs (06, 18Z) extending to +60 hrs have been added. An ALADIN-EPS suite has been implemented in pre-operational mode for testing.

2. Equipment in use

Computers used for the forecasting system are NEC and Linux clusters:

Computer	**Memory**	**Storage**
NEC SX-8R 16 CPU	128GB	4.4TB
2 Optron Linux clusters , 8 cpu each	16GB	3.5TB
Optron Linux cluster, 8 cpu	32GB	1TB

3. Data and Products from GTS in use

- SYNOP
- TEMP

4. Forecasting system

4.1 System run schedule and forecast ranges

ZAMG is running 4 LAM suites for the short range forecast as summarized below.

Suite	Analysis time + forecast range	Product availability
1	00UTC + 72 h	3:30 UTC
2	06UTC + 60 h	10:20 UTC
3	12UTC + 72 h	15:30 UTC
4	18UTC + 60h	22:20 UTC

4.2 Medium range forecasting system (4-10 days)

Medium range forecast data is received from ECMWF.

4.3 Short-range forecasting system (0-72 hrs)

4.3.1 Data assimilation, objective analysis and initialization

No operational data assimilation is performed at ZAMG, and as yet there is no research performed in this field. The analysis used for the LAM model at ZAMG (ALADIN-Austria) is obtained by dynamical downscaling of coupling files obtained from the French global model ARPEGE.

4.3.2 Model

4.3.2.1 In operation

The model system for the short range weather forecast used at ZAMG is ALADIN-Austria (Wang et al. 2006). It is a hydrostatic, spectral model with 9.6 km horizontal resolution and 45 levels in vertical. The domain of ALADIN-Austria is shown in Fig. 1. The main features of the model are the following:

- Pressure-based hybrid ccordinate
- 2-time-level SLSI time integration, 415 s time step

- DFI intialization, 4th order horizontal diffusion
- 3-hourly coupling with ARPEGE, Davis-Kallberg relaxation scheme
- Kessler-type scheme for large scale precipitation; Geleyn's scheme of shallow convection and simple radiation; Bougeault-type scheme of deep convection; Boer-type scheme of gravity wave drag; force-restore method for soil temperature and water; vertical exchange calculation taking into account a planetary boundary layer and a surface layer based on the Louis scheme.

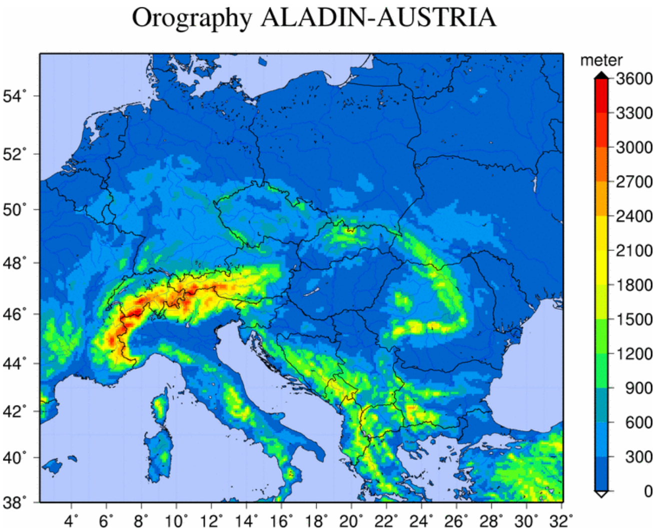

Figure 1: Domain and model topography of ALADIN-Austria.

4.3.2.2 Research performed in this field

One research focus on ALADIN-Austria has been put on the improvement of the precipitation forecast over mountainous areas. Experiments have been carried out on the comparison of model configurations with different model physics, with and without data assimilation, and with the high resolution (deep convection resolving scale, 2.5 km) AROME model. Results show that the introduction of the micro-physics scheme of Lopez improves the model forecast over mountainous areas, and the Kain-Fritsch scheme produces convection which is more organised. The best performance of precipitation forecast has been obtained with the high resolution model AROME for the mountainous areas, but the model still has problem with light rainfall, especially over lowland, flat areas. Research on this subject is still going on.

4.3.3 Operationally available NWP products

The ALADIN-Austria products available operationally are
3D: wind, temperature, geopotential, relative humidity, vertical velocity, potential temperature.
2D: mean sea level pressure, 2m temperature and relative humidity, 10m wind, dew point, CAPE, surface temperature, precipitation (rain and snow) cloudiness (high, middle, low and convective), maximum and minimum temperature, etc.

4.3.4 Operational techniques for application of NWP products

4.3.4.1 In operation

A MOS/PPM-System is used to correct systematic errors in NWP model output.

4.3.4.2 Research performed in this field

4.3.5 Ensemble Prediction System

4.3.5.1 In operation

ZAMG has developed the limited area model EPS system ALADIN-LAEF (Limited Area Ensemble Forecasting) which has been put into pre-operational mode recently. The LAEF has 22 members, 18 km horizontal resolution, and 37 levels in the vertical. The forecast range is 54h. LAEF is run twice per day at 00 and 12UTC. The model used in LAEF is quite similar to the operational ALADIN–Austria configuration, but with the Lopez microphysics scheme switched on. ALADIN LAEF covers Europe and a large part of the

North Altlantic (Fig. 2). The initial perturbation is obtained by dynamical downscaling of the first ECMWF singular vector perturbation, and the perturbed lateral boundary conditions are from ECMWF EPS runs.

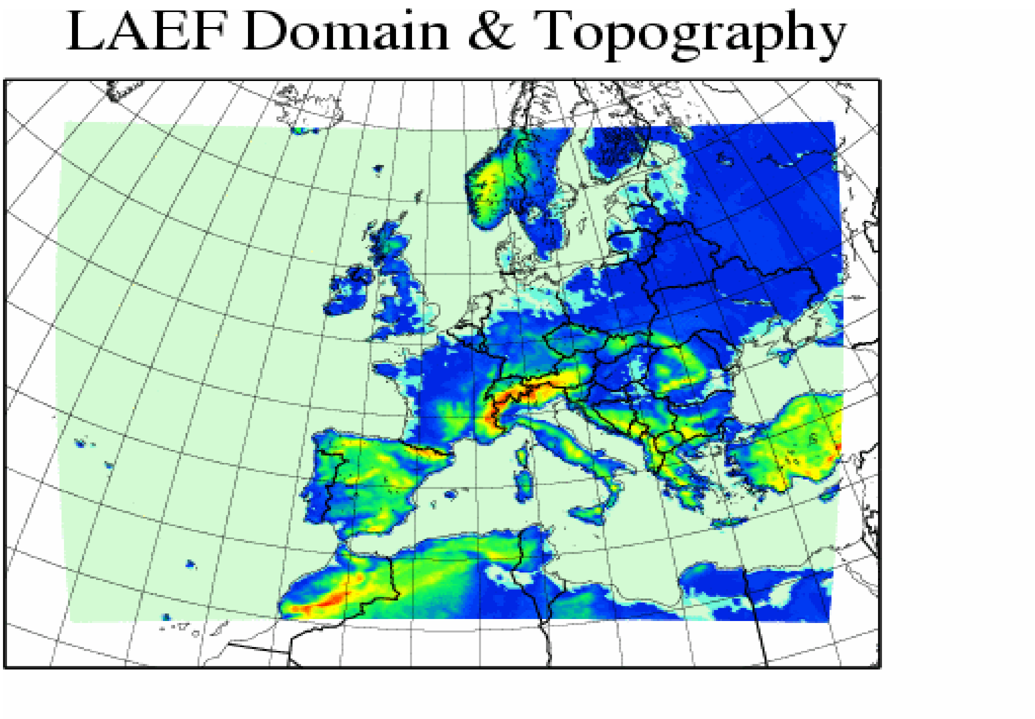

Figure 2: Domain and model topography of ALADIN-LAEF

4.3.5.2 Research performed in this field

This is a major field of research in NWP at ZAMG. Specific research subjects are listed below.

(a) Dealing with the uncertainties in analysis and lateral Boundary conditions (LBC)

Many studies have been done on predictability for global models. Comparatively little experience exists on predictability on the scale of limited area models. At Meteo-France and ZAMG some preliminary experiments for constructing analysis perturbations with targeted Singular Vector and Breeding methods have been carried out. The studies show some interesting and encouraging results but cannot be put into operational mode yet. More investigations on Breeding, e.g. one side Breeding and multi-physics Breeding, will be done; orthogonalization of the bred vector with using Ensemble Transform (ET) technique has been implemented. Another technique, Ensemble Transform Kalman Filter (ETKF), has also been implemented and tested. For ETKF, because the number of ensemble perturbations is much smaller than the number of directions to which the forecast error variance projects, the total analysis error variance will be significantly underestimated because of the lack of contribution from important parts of the error space. To ameliorate this problem, emphasis is put on how to inflate the analysis perturbation generated by ETKF. The generation of perturbation on LBC is one of the difficulties in LAMEPS. Tests of LAMEPS coupled with different global EPS systems are conducted.

A new idea, namely using the ALADIN blending technique (a digital filter and spectral analysis method) to combine the large-scale uncertainty from the global EPS members generated by Singular Vector (e.g., ARPEGE or ECMWF EPS) with the small-scale uncertainty generated by Breeding/ET in LAM has been implemented and evaluated. As expected, the small-scale uncertainty in the analysis is better described using the method. It is also expected that it reduces the inconsistency between the different perturbation methods used in global EPS which determine the perturbation at the boundaries and the initial analysis perturbation method used in LAMEPS.

(b) Dealing with the uncertainties in the model, in particular the model physics

One of the primary error sources is model physics. To deal with those uncertainties, the multi-physics parameterisation approach is used. Multiphysics experiments with ARPEGE coupling show a meaningful increase in spread. The stochastic physics scheme (ECMWF) and the stochastic kinetic energy backscatter algorithm SKEB (UKMO, ECMWF) will also be studied and evaluated.

4.3.5.3 Operationally available EPS Products

The following ALADIN-LAEF products are available with 3 h time resolution:

- Mean/spread/spaghetti/probability/post stamp chart:
  2m Temp, 10m Wind, 2m RH, Total Precipitation, Mslp, 500hPa Geopotential
- EPS-meteogram
- Mean/spread/probability/post stamp chart:
  250, 500, 700, 850, 925hPa, T, Wind, Geopotential, RH (lower Level),

4.4 Nowcasting and Very Short-range Forecasting Systems (0-6 hrs)

4.4.1 Nowcasting system

4.4.1.1 In operation

The high-resolution analysis and nowcasting system INCA (Integrated Nowcasting through Comprehensive Analysis) developed at the Austrian national weather service provides three-dimensional fields of temperature, humidity, and wind on an hourly basis, and two-dimensional fields of precipitation rate in 15 minute intervals. The system operates on a horizontal resolution of 1 km and a vertical resolution of 100-200 m. It combines surface station data, remote sensing data (radar, satellite), forecast fields of the numerical weather prediction model ALADIN, and high-resolution topographic data (Haiden et al., 2007).

Table 3: Meteorological fields analyzed and nowcasted in INCA (SFC = surface station data, SAT = satellite data, RAD = radar data)

Nowcasting field	**Required observations**	**Update**
Temperature	SFC: 2m temperature SAT: MSG cloud types (optional)	1 hour
Humidity	SFC: 2m humidity	1 hour
Wind	SFC: 10m wind	1 hour
Precipitation	SFC: precipitation RAD: radar precipitation	15 min
Precipitation type	Derived from precipitation and temperature nowcast	15 min
Cloudiness	SAT: MSG cloud types SFC: sunshine% (optional)	15 min
Global radiation	SAT: MSG cloud types SFC: global radiation	1 hour
Convective diagnostics	Derived from temperature, humidity and wind nowcast	1 hour

The most important applications of INCA products are flood prediction and warning, road weather prediction, and predictions for power grid management. Verification shows that the performance of INCA exceeds that of NWP models (ALADIN, ECMWF) on average for up to ~4 hours in the case of precipitation, and ~8 hours for temperature.

4.4.1.2 Research performed in this field

The INCA system is under continuing development. One research activity aims at predicting the evolution of convective cells (in addition to their translation, which is done by motion vectors) based on convective analysis fields like CAPE, CIN, trigger temperature deficit, moisture convergence etc. It was found that in some areas, where the initiation of convection is regularly associated with topographic features, some increase in predictive skill could be gained. However, more research is needed before the method can be made operational (Haiden and Steinheimer, 2007).

4.4.2 Models for Very Short-range Forecasting Systems

4.5 Specialized numerical predictions

4.6 Extended range forecasts (ERF) *(10 days to 30 days)*

4.6.1 Models

4.6.2 Operationally available NWP model and EPS ERF products

Results of the ECMWF monthly forecasting system are used with special emphasis on the Austrian region. For this purpose, quartiles of 2m-temperature, precipitation, 10m wind speed and total cloudiness are interpolated onto station locations and visualized as a function of forecast range. Figures 3 and 4 show examples of the probability distribution of 2m temperature and 10m wind speed forecasts in terms of quartiles. These products are available for operational purposes via web-interface in the intranet.

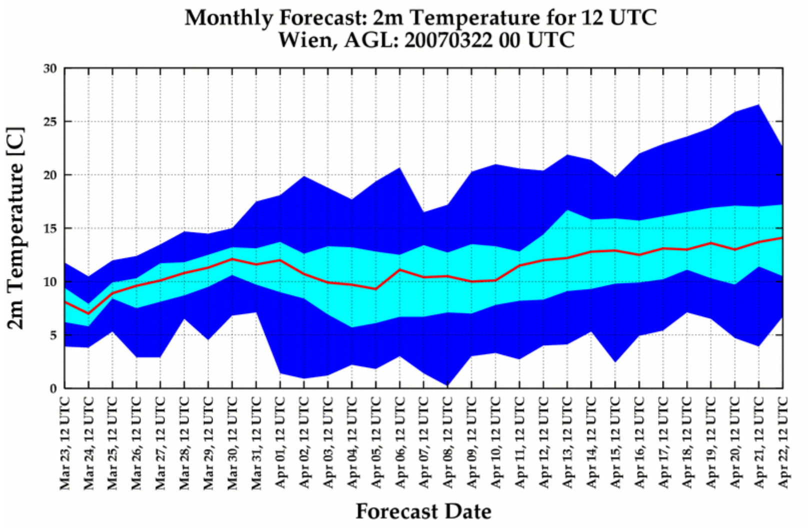

Figure 3: 5%, 25%, 50%, 75% and 95% percentiles of 2m temperature as a function of forecast range. Initialization date: 22.03.2007, 00UTC.

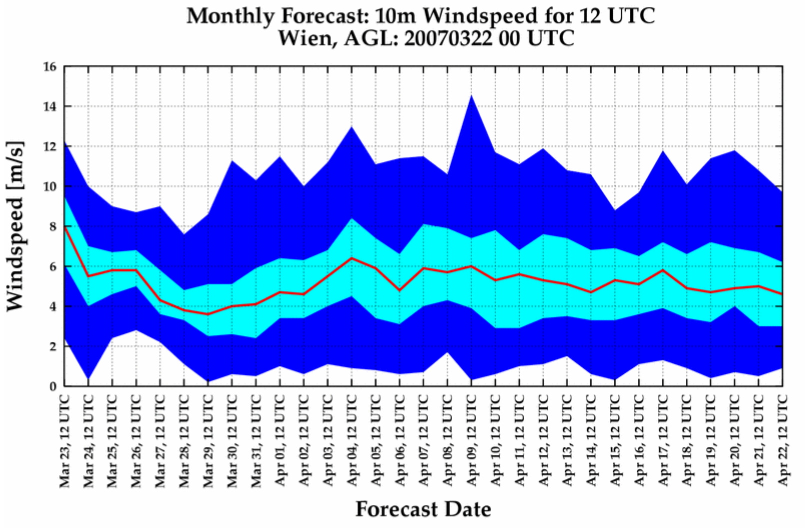

Figure 4: 5%, 25%, 50%, 75% and 95% percentiles of 10m wind speed as a function of forecast range. Initialization date: 22.03.2007, 00UTC.

4.7 Long range forecasts (LRF) *(30 days up to two years)*

4.7.1 In operation

4.7.2 Research performed in this field

4.7.3 Operationally available EPS LRF products

Covering the long range, the ECMWF seasonal forecast system is in operational use at ZAMG. Operationally, ‘climagrams’ are generated to visualize the model results. Figure 5 shows an example of an operational climagram with 2m temperature anomaly over Austria. The abscissa describes the integration time in months, the ordinate temperature (or precipitation-) anomaly averaged over a defined area covering Austria and surroundings. The climagrams do not show absolute values but deviations from the model climate. Used as a reference, the model climate is composed of the five members ensemble ocean analyses. This finally leads to 85 members for the hindcast period from 1987 to 2003.

Predicted monthly-mean values are represented in blue and model climatoligical values are in yellow/red. The climate extremes (95% and 5% precentile) are described by the limit of the yellow shading, the red band is limited by the 75% and 25% climate values and the climate median is the thick green line. The forecast ensemble distribution is represented by light blue boxes (candlesticks) with upper and lower values corresponding to 75% and 25% percentile, the forecast median is represented by the black line and forecast extremes (95% and 5% percentile) are realised by the whiskers. Climagrams for precipitation are treated analogously. In order to detect regional differences in signals, additional climagrams are generated covering the northern and the southern parts of the Alps separately.

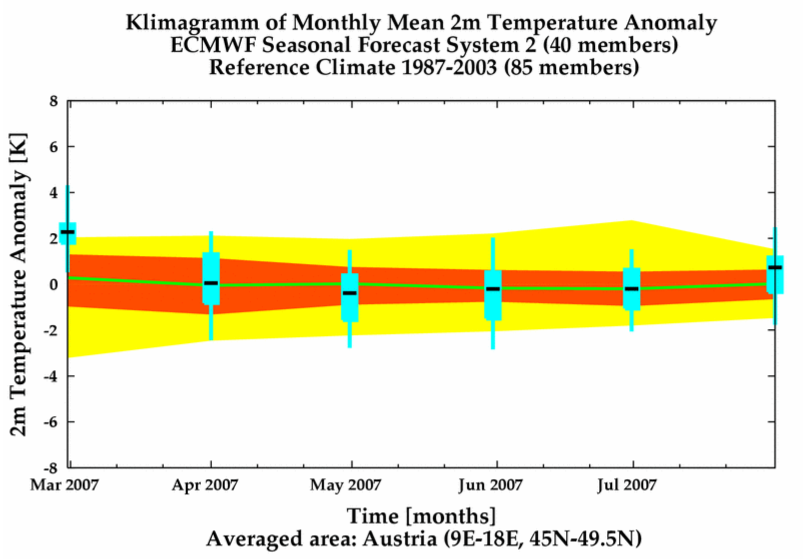

Figure 5: Climagram for 2m temperature for the region Austria (for explanation see text).

5. Verification of prognostic products

5.1 Annual verification summary

The operational ALADIN-Austria model results are verified against ARPEGE analyses on a regular basis since 01/01/2005. The verifying parameters are temperature, geopotential, wind speed and relative humidity at 500hPa and 850hPa. Verification scores are mean error, mean absolute error and root mean square error.

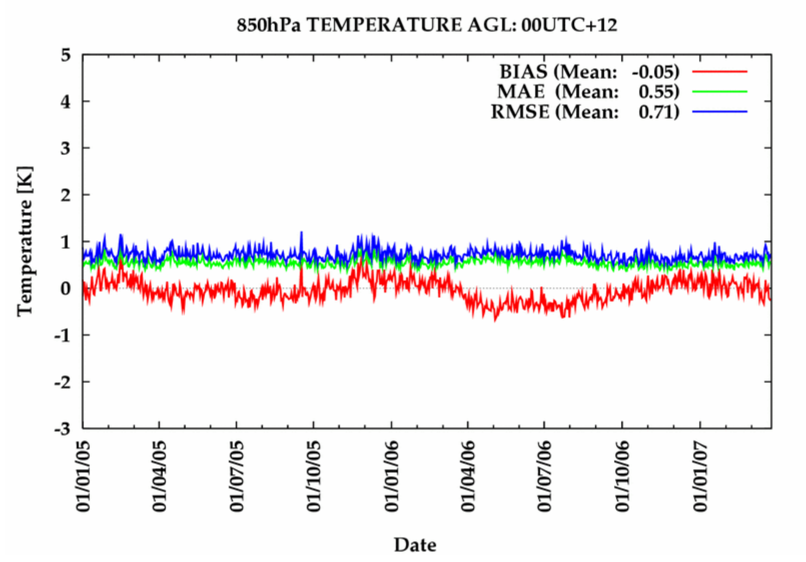

Figure 6: Bias, MAE and RMSE as a function of initialization date for temperature in 850hPa, forecast range +12h.

Regarding temperature in 850hPa in Figure 6, the forecast appears rather unbiased (mean bias about -0.05 K) although seasonal variations exist. The mean absolute error is 0.55 K, the root mean square error 0.71 K. Extending the forecast range to +48 hours in Figure 7, the model tends to have a mean (positive) bias of 0.4 K, the MAE has increased to 0.98 K and the RMSE to 1.24 K. Concerning Geopotential in 500 hPa (Figure 8), the model shows only a slight positive mean bias (2.73 gpdm). The mean absolute error is 6.71gpdm, the root mean square error 8.43 gpdm.

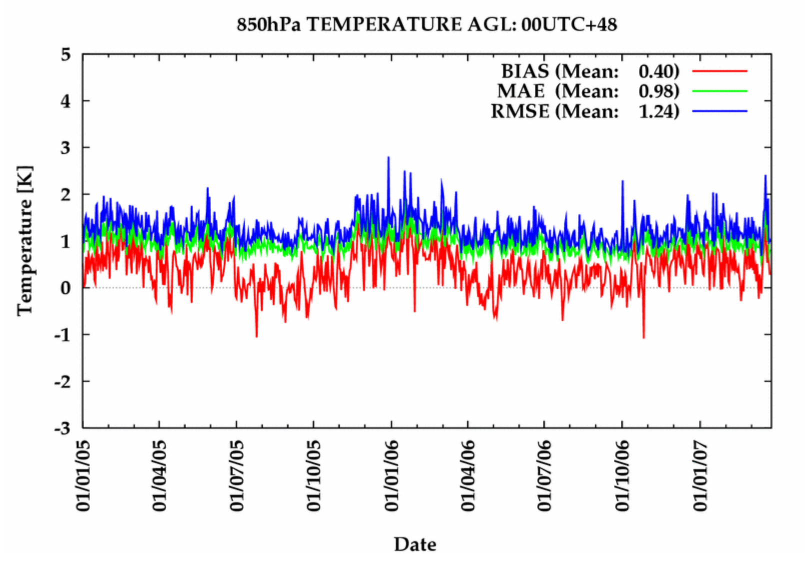

Figure 7: Bias, MAE and RMSE as a function of initialization date for Temperature in 850hPa, forecast range +48h.

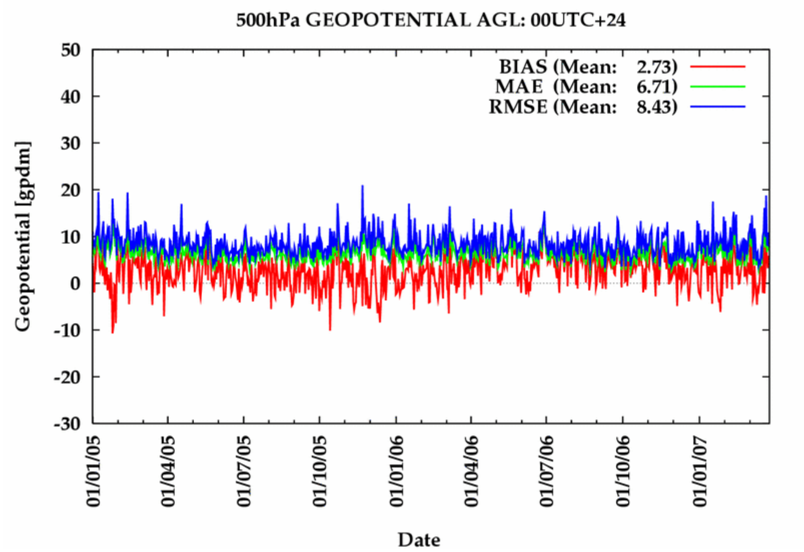

Figure 8: Bias, MAE and RMSE as a function of initialization date for Geopotential in 500hPa, forecast range +24h.

5.2 Research performed in this field

6. Plans for the future *(next 4 years)*

6.1 Development of the GDPFS

6.2 Planned research Activities in NWP, Nowcasting and Long-range Forecasting

6.2.1 Planned Research Activities in NWP

The ALARO and AROME prototypes will be tested, and possible improvements in the cloud physics parameterization will be suggested based on experience gathered in alpine areas. With regard to ensemble prediction, the idea of blending of perturbations will be followed and the multiphysics approach will be tested more comprehensively. It is also planned to take part in the Beijing Olympics 2008 forecast demonstration experiment.

6.2.2 Planned Research Activities in Nowcasting

The analysis and nowcasting system INCA will be further developed, in particular with regard to wind nowcasting, where a dynamical tendency will be computed based on the temperature forecast. Cloudiness will be analyzed and nowcasted in 3-D, by combining the humidity analysis with satellite information. The possibility of prediction of convective evolution (beyond pure translation of cells) based on INCA convective analysis fields will be further studied. A multilateral Central and Eastern European project will be started aiming at the development of a common nowcasting system in this area based on the INCA framework.

6.2.3 Planned Research Activities in Long-range Forecasting

7. References

Haiden, T., and M. Steinheimer, 2007: Improved nowcasting of precipitation based on convective analysis fields. Adv. Geosci. (in press)

Haiden, T., A. Kann, K. Stadlbacher, M. Steinheimer, and C. Wittmann, 2007: Integrated Nowcasting through Comprehensive Analysis (INCA) - System overview, 49p. http://www.zamg.ac.at/fix/INCA_system.doc

Wang, Y., T. Haiden, and A. Kann 2006: The operational Limited Area Modelling system at ZAMG: Aladin-Austria. *Österreichische Beiträge zu Meteorologie und Geophysik*, **37**, ISSN 1016-6254.