FORM TO BE COMPLETED BY PROJECT LEADER

MID TERM RESEARCH/TECHNOLOGY REPORT

REPORT NUMBER:

PERIOD COVERED: FROM 01/09/2008 UNTIL 31/08/2010 (DD/MM/YY)

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1. Project info

a) Project title:

Wind resources and forecasting in complex terrain of Croatia (WINDEX)

b) Name of the project leader and Co-applicant (if applicable)

Dr.sc. Kristian Horvath

c) Duration of the project (months) and type of the grant:

24 months	UKF 3A Young researchers and professionals

d) Leading Organization (full name, address, and contact person details):

1. Meteorological and Hydrological Service
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Web: http://radar.dhz.hr/~horvath

e) Other organizations involved
(full name, address, web address and contact person details):

2. Desert Research Institute
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3. RISØ National Laboratory – Technical University of Denmark
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4. Energy Institute Hrvoje Požar
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Contact person:
László Horváth, Head of Department for renewable energy sources and energy efficiency, Energy Institute Hrvoje Požar
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2. Work plan and timetable of the project

Word count: 1778

a) Milestones

please describe milestones realized; if not all the milestones are realized according to those stated in the original application form please explain why and what actions have been taken to resolve problems encountered (use Tahoma 11, max 2000 words, add word count)

During the first year of the project, the following milestones needed to be achieved:

- one year of downscaled data verified (month 2)
- wind resource maps at 2km resolution at 10m and 80m above the ground produced (month 9)
- a conference contribution and a professional paper submitted, intranet page launched (month 10)

The first implicitly included determination of a nesting strategy and model spin-up issues, regarding the full model ALADIN/HR run at 8 km resolution. Therefore, in order to achieve this milestone, extensive literature review was done, with a special emphasis on downscaling procedures within ALADIN community[1]. The most relevant experience chosen was from the surrounding countries with similar climates (e.g. Slovenia, Austria). The alternatives were either to use a singe nesting to resolution of 8 km, or to use an additional intermediary domain at ~30 km grid resolution. The up to date research on dynamical downscaling (Žagar et al., 2006; Beck et al., 2004) tested the use of intermediary domains in downscaling ERA-40 to final grid resolution of 10 km. Both studies found that the use of intermediary domain does not add value to the final climatology result, both for wind as well as precipitation fields, despite the fact that such a high nesting ratios (e.g. 1:12, 1:24), often used in climatology modeling, lead to poorer representation of spatial and temporal evolution of individual fine-scale phenomena (Denis et al., 2003). However, since our main goal is wind climatology, we have chosen to do a direct nesting to 8 km grid resolution.

Furthermore, transformation of the ERA-40 GRIB data format to ALADIN "FA" data format needed to be done, since "FA" file format is required for initial and boundary conditions to ALADIN/HR model runs. The transformation of format needs to be done for each analysis file. The work towards reaching the first milestone also included the tedious and time consuming task of making the inventory of DHMZ's station in the target year (2001), thus making "data about data". This included description of station locations, description of measurement methods and data, determination of missing data periods and evaluation of location and data representativity. This part of the task, performed mostly by DHMZ's coworkers on the project, is crucial for the quality of subsequent model verification.

After data was downscaled (year 2001), dynamical adaptation was performed (ALADIN/DADA) to 2 km target resolution. The process of dynamical adaptation is well described in Žagar et al., 1999. The preparation of model data for verification included transformation and manipulation of data among several formats (spectral and grid point) and computer systems.

The verification of one year of downscaled data was performed on 5 stations representing different climates regimes in Croatia. Slavonski Brod was chosen to be representative for continental Croatia, very urban (continental) climate was represented by station Zagreb Maksimir and maritime climate was represented by Novalja, Split Marjan and Dubrovnik. The results were studied with the use of:

1. Mean error

$$ME = \frac{1}{N}\sum_{i=1}^{N}(VMOD_i - VOBS_i)$$

2. The relation of mean error and mean wind speed

$$\frac{ME}{\overline{VOBS}} = \frac{\frac{1}{N}\sum_{i=1}^{N}(VMOD_i - VOBS_i)}{\frac{1}{N}\sum_{i=1}^{N}VOBS_i}$$

	1	2	3	4	5	6	7	8	9	10	11	12	ANN
MBIAS													
ZGM	1.88	1.53	1.56	1.47	1.52	1.55	1.40	1.36	1.96	1.88	2.19	2.36	1.69
SLB	0.96	1.02	0.91	0.82	0.93	0.94	0.90	0.85	1.09	1.33	1.21	1.22	0.99
NOV	1.29	0.91	1.11	0.77	0.83	0.93	0.81	0.75	0.92	0.84	0.90	0.73	0.91
STM	0.86	0.86	0.76	0.82	0.85	0.90	0.81	1.02	0.88	0.93	0.91	0.94	0.87
DUB	0.91	0.96	0.82	0.92	0.90	0.89	0.90	0.95	0.79	0.93	0.89	0.90	0.90
RMSE													
ZGM	1.35	0.95	1.0	0.75	0.92	0.81	0.5	0.5	1.12	0.83	1.34	1.63	0.98
SLB	0.07	0.03	0.2	0.37	0.12	0.14	0.18	0.23	0.15	0.29	0.34	0.33	0.28
NOV	1.36	0.42	0.52	1.06	0.68	0.28	0.71	0.94	0.31	0.44	0.48	1.51	0.41
STM	0.82	0.79	1.31	0.8	0.55	0.36	0.68	0.06	0.47	0.19	0.48	0.37	0.56
DUB	0.35	0.14	0.73	0.25	0.28	0.32	0.27	0.11	0.66	0.16	0.44	0.46	0.35

Table 1: Multiplicative bias (no units) and root-mean square error (ms^{-1}) values for 5 selected verification stations (2001): Zagreb-Maksimir (ZGM), Slavonski Brod (SLB), Novalja (NOV), Split Marjan (STM) and Dubrovnik (DUB).

3. Mean absolute error

$$MAE = \frac{1}{N}\sum_{i=1}^{N}\left|VMOD_i - VOBS_i\right|$$

4. Multiplicative bias

$$MB = \frac{\frac{1}{N}\sum_{i=1}^{N} VMOD_i}{\frac{1}{N}\sum_{i=1}^{N} VOBS_i}$$

5. Root-mean square error

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(VMOD_i - VOBS_i\right)^2}$$

The results for MB and RMSE are shown in Table 1 and indicate that the dynamical downscaling was successful. On the yearly basis, BIAS less than 10% is recorded on all

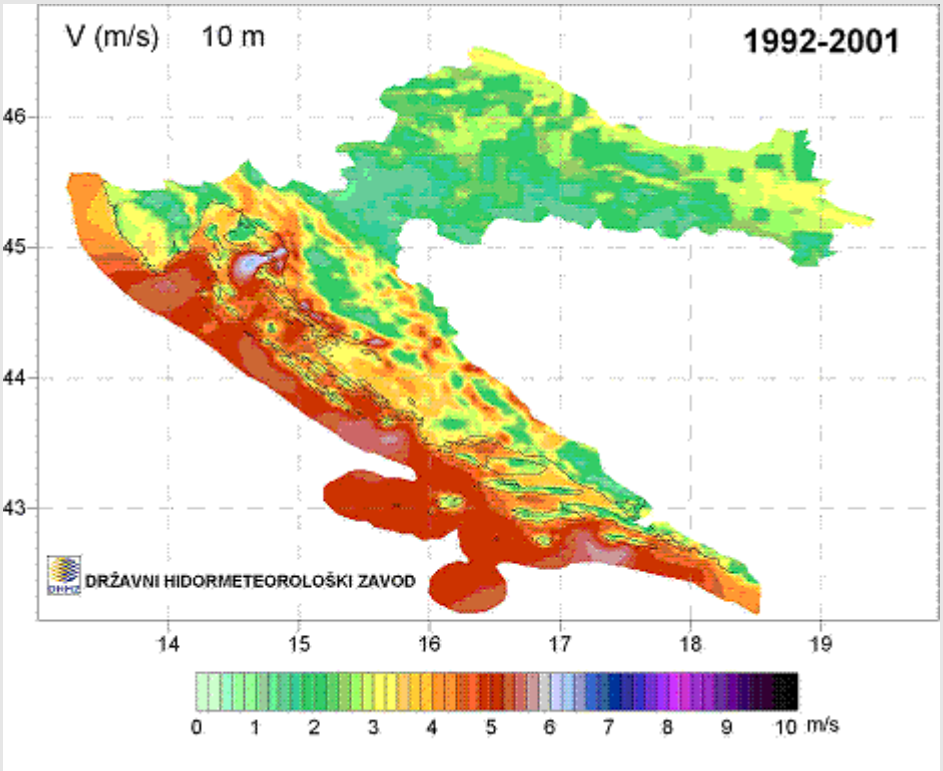

Figure 1: Spatial distribution (wind resource map) of a 10-yearly mean wind speed (1992-2001) [ms^{-1}] at 10 m AGL, as a direct model output of dynamical adaptation at 2 km horizontal grid resolution.

selected stations, except for station Zagreb Maksimir. The large overestimation of wind speed modeled on that station is indeed expected due to the strong sheltering by the surrounding obstacles (e.g. Kraš factory to the west). Root-mean square values are also largest at the aforementioned station and reach almost 1 ms^{-1} on the annual basis due to the same reason. However, on the other stations the root-mean square errors on the average range from 0.28 ms^{-1} at Slavnoski Brod to 0.58 ms^{-1} at Split Marjan. Since these errors are comparable with results obtained in other downscaling projects (e.g. see Žagar et al., 2006), procedure and preliminary results showed successful and applicable to the whole envisaged 10-year downscaling period.

The dynamical downscaling was performed over a 10-year period (1992-2001) with the same methodology as described above. For the needs of HEP (Croatian electric company), results were analyzed at 10 m and 80 m AGL. The spatial distribution of 10-yearly average wind speed is shown on the Fig. 1, indicating that the areas of the highest mean wind speed are 1) mountain tops, such as Velebit, Lička Plješivica and Dinara, due to their height and 2) western slopes of Velebit and nearby coastal region, due to frequency and strength of Bora in that region. On the other hand, the areas with the smallest wind speed values are parts of continental Croatia, the hinterland of Istria peninsula and Ploče area and the region of Ličko polje.

In addition to conventional verification, spectral verification was performed as a complementary way of evaluating the model performance. As an example, the spectral power of measured and modeled zonal wind component is shown for the station of Dubrovnik (Fig. 2), while plots for other variables and stations are shown in Horvath et al. (2009a) and Bajić et al. (2009). Overall, the spectral decomposition in temporal domain indicates a good model performance in primary maximum of spectral power related to synoptic systems, as well as the secondary diurnal and terciary semidiurnal maxima associated with the see/land breeze circulation. In contrast, the spectral power of diurnal circulations in continental Croatia is somewhat underestimated, as well as spectral power of periods less than semidiurnal, independently of the station location.

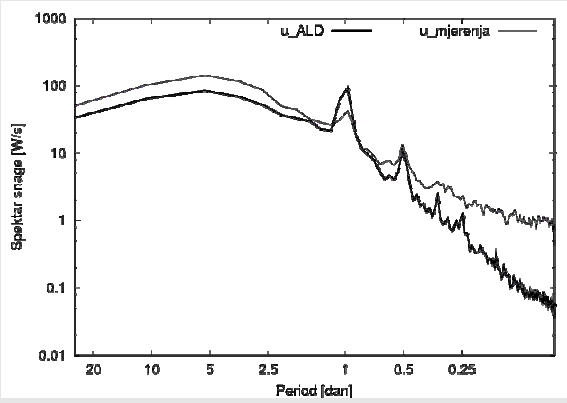

Figure 2: Power spectrum of measured and modeled zonal wind component (u) for station Dubrovnik.

The full technical description of the procedure, results of downscaling and its verification are given in Horvath et al. (2009a) and Bajić et al. (2009).

Preliminary results in ALADIN&CFD "coupling" were achieved in cooperation with the Energy Institute "Hrvoje Požar", using an ALADIN mesoscale model and a CFD based WindSim software for simulation of the wind flow over terrain. For the modelling experiment, a case study of Bora over an isolated Adriatic island with complex orography was selected, in order to minimise errors at the boundaries of the 3D computational domain. Hourly wind speed and direction time series were obtained by 3-day forecast range ALADIN/HR run and used to initialise the WindSim model at the top of the 3D domain. The model was initialized at the wind speed and direction PBL height derived from the ALADIN model at each selected time instant and run to reach the stationary state. The sample result for one time instant is shown on Figure 3, while the preliminary study was submitted and accepted as a conference contribution (Horvath et al, 2009b).

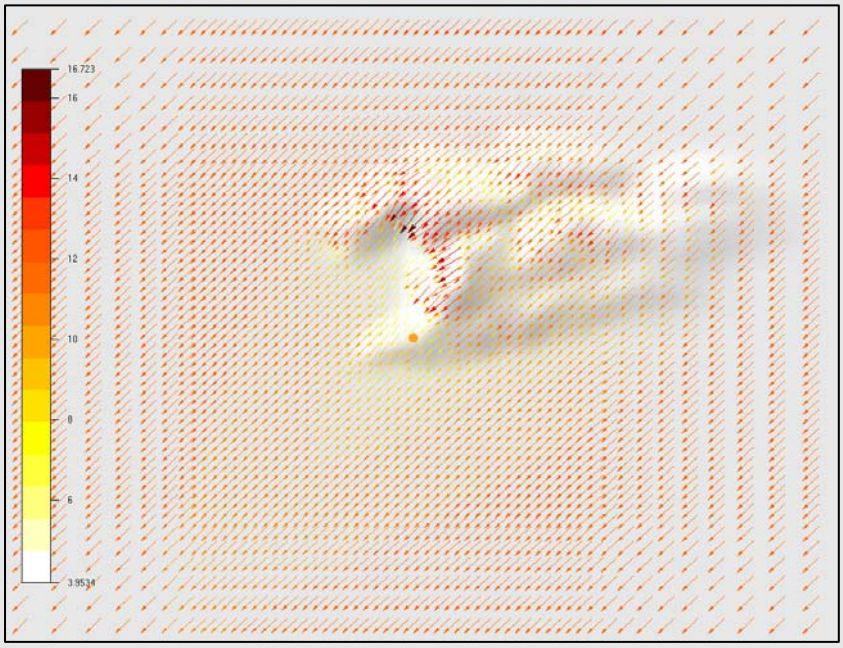

Figure 3: Wind field at one time instant at 40 m AGL above the island of Vis with the finest horizontal resolution of 25 m, simulated during the Bora episode ($V_{model\ top}$=15.3 ms^{-1}; dir=47°).

Problems we have faced during the preliminary testing phase include:

- determination of the ABL height and conditions for Bora events;
- application of the nesting technique for selected wind directions of the outer model was not understood well;
- full converged solution not achieved for calculations with up to 300 iterations;
- the issue of static stability, important for dynamics of stratified flows over

mountains (such as Bora) was not tackled within the microscale model.

The issue of ALADIN/CFD coupling is being further tested. Furthermore, WRF was installed and test runs were performed.

Two conference contributions and a professional paper were submitted and accepted in the year 1 of the project (Horvath et al., 2009a, Horvath at al., 2009b, Bajić et al., 2009) as well as presented on 19th ALADIN workshop. A HR-V domain www.windex.hr was acquired from CARNET for the project web site and web space for internal cooperation is secured on http://radar.dhz.hr/~horvath/collabs.html to ease the distance collaboration that will take part in year 2 of the project.

Finally, establishment of a contact with national wind turbine producer (Končar group) was one of the Key performance indicators, to be reached in first 6 months of the project. A contact was established on presentation held on 08.01.2009 in the headquarters of the Končar group. Several subsequent meetings were held in 2009 towards the realization of co-operation in terms of support in organization of field experiment at the location of Pometeno Brdo, a location of future Končar's windfarm. Also, a preparation of Cooperation agreement is in progress.

References:

Bajić, A., Ivatek-Šahdan, S. and K. Horvath, 2009: Prostorna razdioba brzine vjetra na području Hrvatske dobivena numeričkim modelom atmosfere ALADIN. *Hrvatski meteorološki časopis (Croatian Meteorological Journal), accepted.*

Denis, B., Larprise , R. and D. Caya, 2003: Sensitivity of a regional climate model to the resolution of the lateral boundary conditions. *Clim. Dyn.*, **20**, 107-126.

Horvath, K., Bajić, A. and S. Ivaktek-Šahdan, 2009a: Dynamical downscaling of wind resources in complex terrain of Croatia. *Proceedings of the European Wind Energy Conference & Exhibition, EWEC 2009*, available online at http://www.ewec2009proceedings.info/proceedings/index.php?page=info2&id=105&id2=539&ordre=97&tr=&searchin=3&what=&searchtext=&day=&top=&fil1=&fil2=&fil2&ord1=&sess=#top.

Horvath, L., Horvath K., Karadža, N. and A. Bajić, 2009b: A preliminary testing of integrated wind modelling system in complex terrain. *Proceedings of the European Wind Energy Conference & Exhibition, EWEC 2009*, available online at http://www.ewec2009proceedings.info/proceedings/index.php?page=info2&id=105&id2=590&ordre=99&tr=&searchin=3&what=&searchtext=&day=&top=&fil1=&fil2=&fil2&ord1=&sess=#top.

Žagar M. and J. Rakovec, 1999: Small-scale surface wind prediction using dynamic adaptation. *Tellus*, **51**, 489-504.

Žagar N., M. Žagar, J. Cedilnik, G. Gregorič and J. Rakovec, 2006: Validation of mesoscale low-level winds obtained by dynamical downscaling of ERA-40 over complex terrain. *Tellus*, **58**, 445-455.

b) Key performance indicators (quantitative development towards key project goals – quarterly achievements).

Please show KPI cumulatively, i.e. always add KPI from previous period to new period. e.g. if your KPI in 1st half year is 3 in vivo experiments, in 2nd half-year another 6 in vivo experiments, your KPI in 2nd half-year is 9.

please insert KPI realized

Key performance indicator	1st half-year	2nd half-year	3rd half-year	4th half-year
Years of downscaled data	7 (70%)	10 (100%)		
Establishment of a contact with a national wind turbine producer for possible co-financing	1(100%)	1 (100%)		
Wind and turbulence data collected	0 (0%)	0 (0%)		
Number of tested model couplings (WP2) 0 (0%) 0 (0%)	0 (0%)	0 (0%)		
Number of publications and conference contributions submitted	0 (0%)	3 (75%)		

if not all the KPI are realized according to those stated in the original application form please explain why and what actions have been taken to resolve problems encountered (use Tahoma 11, max 1000 words, add word count)

Word count: 174

The KPI "Wind and turbulence data collected" is not realized according to original application form, since the measurement campaign needed to be postponed. The delay is caused by the nature of the problem (and longer-then expected project review and negotiation process), since high quality measurements of Bora, which are the most crucial for the success of the field campaign, are much more likely to be gathered in winter (due to Boras much higher frequency and stronger intensity in

cold part of the year). Therefore, the measurement campaign originally scheduled for (May-July 2009) needed to be postponed (to November 2009 – January 2010). This issue is not critical for the project success, since in order to keep the project on track, work plan is modified in such a way that WP2 tasks which are not dependant on the field measurement campaign will be performed prior to the field experiment. This includes:
-development and testing of ALADIN/CDF coupling methodology
-development and testing of the MOS wind forecasting technique
-development and testing of ALADIN/WRF and WRF-LES coupling methodology for sub-kilometer resolution simulations
-development of procedures for analysis of the SODAR data

c) Equipment/Personel costs

please state if all equipment was procured as planned and list activities performed which are related to personel costs such as travel/trips/name of the researcher, possible new personel engaged, etc (use Tahoma 11, max 2000 words, add word count)

All equipment was procured as planned:
1. *acquirement of PC hard disks*
2. upgrade of the supercomputer (SGI)
3. upgrade of the massive storage system (MSA)

Activities performed related to costs:
1. *preparation of the measurement system for the field experiment by EIHP*
2. repair of the PL's PC
3. participation on EU summer academy summer school
4. *3 day-travels to the location of Pometeno brdo (inspection and planning of the field experiment)*
5. *airplane ticket and per-diem for the research stay at DRI*
6. *consultancy costs*
7. participation on 19th ALADIN workshop and dissemination of WP1 results of a co-worker

Salary costs&supplements are not mentioned here. UKF funding is in *italic.*
Envisaged DHMZ's financial contribution in terms of PL's salary was not gained in year 1 at all due to delay in the employment procedure (therefore, PL is still funded by MZOS). PL's employment by DHMZ is expected by the end of 2009 (beginning of 2010).

Word count: 157

3. Composition of the research group and partnership

a) please state if all the personnel listed in the original application form is engaged on project according to the plan; are there any problems encountered in relation with composition of research group; if yes what actions have been taken to resolve these problems (use Tahoma 11, max 1000 words, add word count)

Word count: 30

All personnel listed in the Application form (Alica Bajić and Emil Ivanković) is engaged on project according to the plan. No problems encountered in relation with composition of research group.

b) please state (not mandatory to fill in -only if applicable) if the cooperation with other organization is going according to the plan; problems encountered if yes what actions have been taken to resolve these problems (use Tahoma 11, max 1000 words, add word count)

Word count:

1. Due to objective reasons, DHMZ was not able to secure a permanent position for Project Leader, who is still funded by MZOS. Nevertheless, dr.sc. Branka Ivančan-Picek, director assistant, is permanently putting considerable efforts to fulfill this DHMZ's obligation. It is expected that K. Horvath will get permanent position in November 2009.
2. HEP is being late with payment, therefore DHMZ has invested funds (in financial report denoted "HEP (DHMZ on behalf of late HEP's payment)") necessary for project implementation which should be reimbursed to DHMZ upon HEP's payment. According to HEP, they are to pay the due by the end of the year 2009.

4. Any other comment in relation with scientific/technological aspect of your project(not mandatory to fill in)

(use Tahoma 11, max 1500 words, add word count)

Word count: 43

1. A 2,5-monthly research stay at DRI was reorganized in two 5-weekly stays due to busy schedules and better organization of work. The first stay will be from Aug 29 – Oct 03 2009., and the second in Feb-March 2010. Funding for additional air-ticket secured.

Attached additional documents:

1. A letter about the status of HEP payment (in Croatian)
2. A letter about the status of PL's employment (in Croatian)

Name of the Project Leader	**Kristian Horvath**
Signature	Kristian Horvath
Date	**30.8.2009.**

Leading Organization Stamp DRŽAVNI HIDROMETEOROLOŠKI ZAVOD ZAGREB — GRIČ br. 3