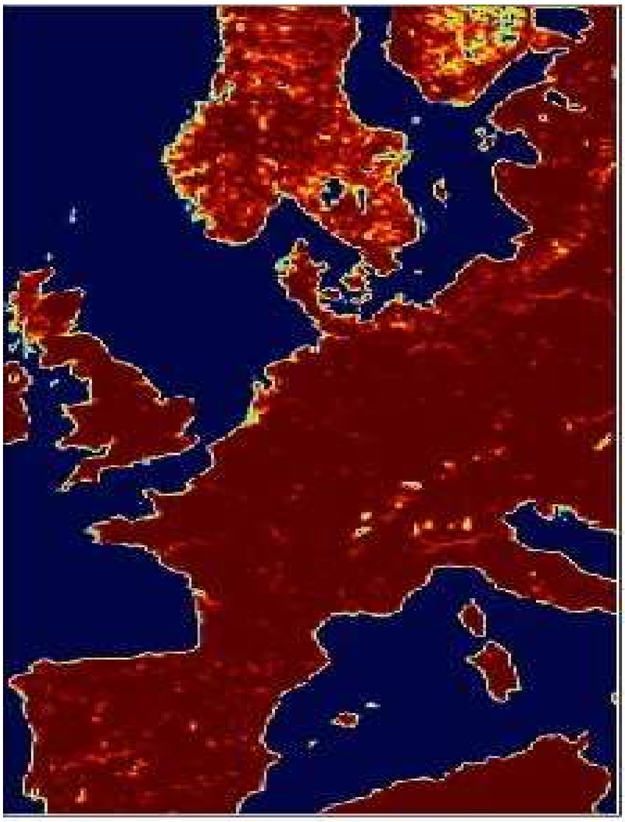
Water and Global Change

Technical Report No. 2

POOR MAN'S RE-ANALYSIS OVER EUROPE



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Date:2008-08-07

WATCH is an Integrated Project Funded by the European Commission under the Sixth Framework Programme, Global Change and Ecosystems Thematic Priority Area (contract number: 036946).
The WATCH project started 01/02/2007 and will continue for 4 years.

Title:	Poor Man's Re-analysis Over Europe
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Organisations:	DMI
Submission date:	2008-08-07
Function:	This report is an output from Work Block 1; task 1.1.3
Deliverable	WATCH deliverable D1.1.4

Abstract

In WB1-Task 1.1.3 we are constructing two re-analysis data sets, one for Europe and one for a selected region of the Indian sub-continent. The purpose of the re-analysis is to provide high-resolution forcing data for land-surface models, and for constructing tools for identifying and assessing hydrological extremes of the 20th century in WB4. The first of two re-analysis data sets for the WATCH project has now been constructed using a poor man's re-analysis on a 0.12 degree grid on a limited domain covering western Europe. With "poor man" we refer to the method of dynamically downscaling the re-analysis without performing any assimilation of data ourselves. The resulting data set compares well to observations for monthly means of both temperature and precipitation, although there is a positive bias of a few Kelvin and a few mmday-1, and in north-eastern Europe in wintertime. There is however a problem with the evaporation, albedo and other soil variables in southern Europe as there was an error in the soil type used in the model for this part of Europe. This may impact on the area around the Upper Guadiana river basin.

1. Introduction

The horizontal scale of the ERA40 re-analysis data set, with about a 200 km resolution, makes it impossible to simulate extreme events of any variable. The major reason for this is the spatial averaging that takes place due to the crude horizontal resolution , but also other effects such as the inability of the model to accurately resolve the orography and thereby lacks small-scale processes. A dynamical downscaling of the re-analysis data can contribute with a better representation of these processes as well as a smaller spatial averaging effect. The advantage of a dynamical compared to a statistical downscaling is that all the variables in the dynamical downscaling are physically consistent, at least to the extent of the limitations of the model itself. A limitation to the dynamical downscaling approach is to which extent the small-scales feed back to the large scales (an assumption of this kind of dynamical downscaling is that the small-scales should not feed back to the large scales) and the performance of the model in simulating the climate [Kanamitsu and Kanamaru, 2007]. In this report we describe the basics of how the re-analysis was performed in Section 2, and the model domain and data availability in Section 3. In Section 4 we present some results and show climatologies and analysis of a few selected output variables. We end with a discussion and conclusions of the results in Section 5.

2. The HIRHAM5 regional climate model and the re-analysis procedure

The HIRHAM5 regional climate model (RCM) of DMI is a recent upgrade from the HIRHAM4 model [Christensen et al., 1996]. The model is a combination of the dynamical core of the HIRLAM weather forecasting model [Machenhauer, 1998] and the climate physical core of the ECHAM5 GCM [Roeckner et al., 2003]. It has been constructed so that it easily can be upgraded with more recent versions of each of the core parts. The major changes from the HIRHAM4 model, which was used in e.g. the PRUDENCE project [Christensen and Christensen, 200?], are the upgrades of both of the core parts. From a computational perspective, the use of a Lagrangian scheme for the time step in HIRLAM7, instead of the earlier Eulerian, means an increase in computational performance. For the climate physics, the upgrade to the ECHAM5 from the earlier ECHAM4 model provides many improvements, e.g. in the treatment of aerosols and land-surface interaction with the atmosphere [Roeckner et al., 2003]. In this re-analysis simulation we only take changes in the atmospheric large scale forcings into account. For example changes in the greenhouse gases are not accounted for.

The dynamical downscaling is performed with the RCM nested into the ERA40 re-analysis data, using the horizontal winds, temperature and relative humidity at all atmospheric model levels, as well as the surface pressure field and sea surface temperatures as forcing at the boundaries. In this version of HIRHAM5 we do not use spectral nudging, so within the domain the model will be free to evolve with its own internal variability [e.g. Lucas-Picher et al., 2008]. This will cause a certain mismatch between the large scale fields at the outflow boundaries, so from the final product the boundary influenced parts of the domain are removed.

In this poor man's re-analysis simulation, from here on referred to as R12, HIRHAM5 is used with the ERA40 re-analysis with an update frequency of six hours. To keep the model from driving away from the ERA40 data within the domain, the atmosphere is reset once every model day. A scheme for the execution of the RCM is displayed in Figure 1. The model is started at 18 hours (CET) at day T-1d (i.e. at T-6hrs) and is spun-up for six hours. It is then run for another 24 hours before it is stopped. At time T+1d the state of the atmosphere and the soil is stored in a restart file. It then steps back six hours to T+1d-6hrs and spins up to reset the atmosphere. At time T+1d we mix the restart files of the spin-up with the earlier 24 hrs run. The new restart file has the atmospheric variables from the spin-up and the soil variables from the 24 hour simulation. In this way the soil and surface variables are kept in a continuous simulation while the atmosphere is kept close to the boundary conditions. This procedure is repeated throughout the simulation which we perform in two parts: 1958—1990, and 1988—2007. For the second part of the simulation we allow for a two year overlap to get the surface and soil variables initialized properly.

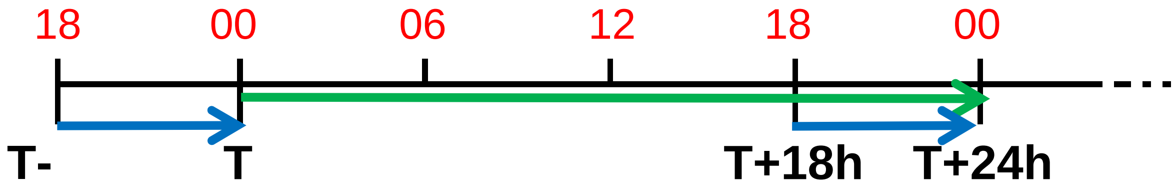

Figure 1: Schematic of the execution of the RCM for the re-analysis, as explained in the text.

The ERA40 re-analysis covers the period from August 1957 to August 2002. For the period from August 2002 until 2007 we originally planned to use the new ECMWF re-analysis called INTERIM, but as this data set was only available until 1999 as we finalized the re-analysis simulation, we were forced to use the ECMWF operational data instead. There are differences between these products, so word of caution therefore for the period after August 2002. As this period of the experiment is not performed at the time of writing this report, a second report will follow with details on the model performance in this period.

3. Model domain, output variables and data availability

Due to an, at the time of execution unsolved, issue with large domain sizes in HIRHAM5, we limited the simulation to about 200 by 300 grid boxes that covers the major river basins studied in the WATCH project, see the cover of the report. The major part of Europe is included, but parts of eastern Europe and especially south-eastern Europe are left out.

Table 1 lists the output fields of the simulation, as requested by the members of the WATCH project. Each of the soil as well as two meter temperature and ten meter winds are outputted every hour, while the atmospheric variables are outputted every six hours.

Table 1: Output variables from the re-analysis

Output variable	Output frequency	Level	Short name
Albedo	1 hr	Surface	as
Temperature	1 hr	2m	tas
Temperature, maximum	1 hr	2m	tas
Temperature, minimum	1 hr	2m	tas
Zonal wind speed	1 hr	10m	uas
Meridional wind speed	1 hr	10m	Vas
Precipitation	1 hr	surface	Pr
Evaporation	1 hr	surface	Evspsbl
Runoff	1 hr	surface	Mrros
Drainage	1 hr	surface	Mross
Soil moisture top 0.1 m	1 hr	surface	Mrsos
Soil moisture, total	1 hr	surface	Mrso
Specific humidity	1 hr	surface	Huss
Relative humidity	1 hr	surface	Hurs
Net SW radiation, surface	1 hr	surface	Rss
Net LW radiation	1 hr	surface	Rls
Downward SW radiation	1 hr	surface	Rsds
Downward LW radiation	1 hr	surface	Rlds
Dew point temperature	1 hr	2m	tdps
Snow depth	1 hr	surface	Snw
Snow fall	1 hr	surface	Prsn
Pressure, surface	1 hr	surface	Ps
Temperature	6 hrs	10/25/50/85/100 kPa	Ta
Zonal wind speed	6 hrs	10/25/50/85/100 kPa	Ua
Merdional wind speed	6 hrs	10/25/50/85/100 kPa	Va
Geopotential height	6 hrs	10/25/50/85/100 kPa	gph

The data are stored in NetCDF files in the format of [lon,lat,day,hour] or [lon,lat,level,day,hour] for each month of each year. The files are tar-balled and gzipped in monthly files and furthermore tar-balled in two-year files for easier download. The data can be accessed from the ENSEMBLES server at the address ensemblesrt3.dmi.dk/data/WATCH. The user name and password as earlier been distributed to the users, but can also be obtained by contacting Peter Berg (pbe@dmi.dk).

4. Results

In this section we compare the two meter temperature and precipitation of the R12 simulation to observations, and study the climatological means of additional variables. For daily values of two meter temperature and precipitation we use a data set of statistically gridded station data over Europe [Haylock et al, accepted for publication in JGR 2008]. We also study some additional fields without comparing to observational data.

For the two meter temperature we have a climatology for monthly values according to Figure 2. It is clear that R12 has a positive temperature bias of a few Kelvin's over north-eastern Europe during the winter months from November to March. This could be due to a problem with the formulation of the heat flux through sea ice as the Baltic ocean freezes during winter, but this must be further investigated. For the rest of the year the temperature of R12 follows the observations well.

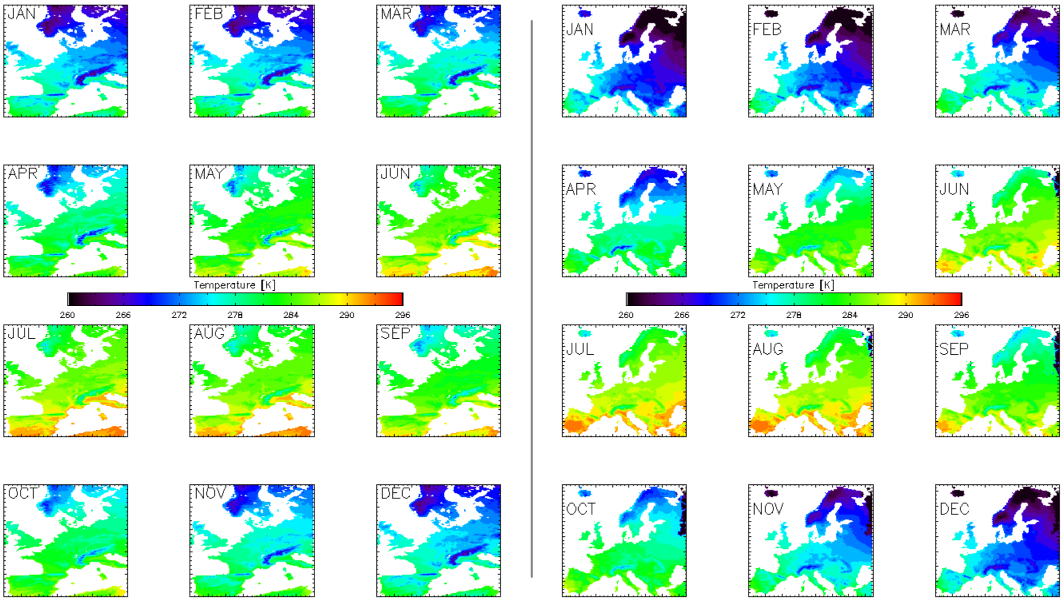

Figure 2: Monthly mean climatology for two meter temperature [K] of R12 (left) and the gridded observations (right).

For precipitation, Figure 3, we find that there is a general trend of more precipitation over the mountains in R12. From this analysis we cannot tell whether this is due to the model producing too much precipitation, or whether it is the statistical gridding technique of the observational data set that produce too weak mean precipitation. The precipitation is overestimated in northern Europe during winter, which is probably related to the positive temperature bias at this time of the year. Another bias is that of a few mm/day in southern France, just north of the Pyrenees. This might be due to the model not being able to simulate the orographic impacts in this region, but that needs to be investigated further.

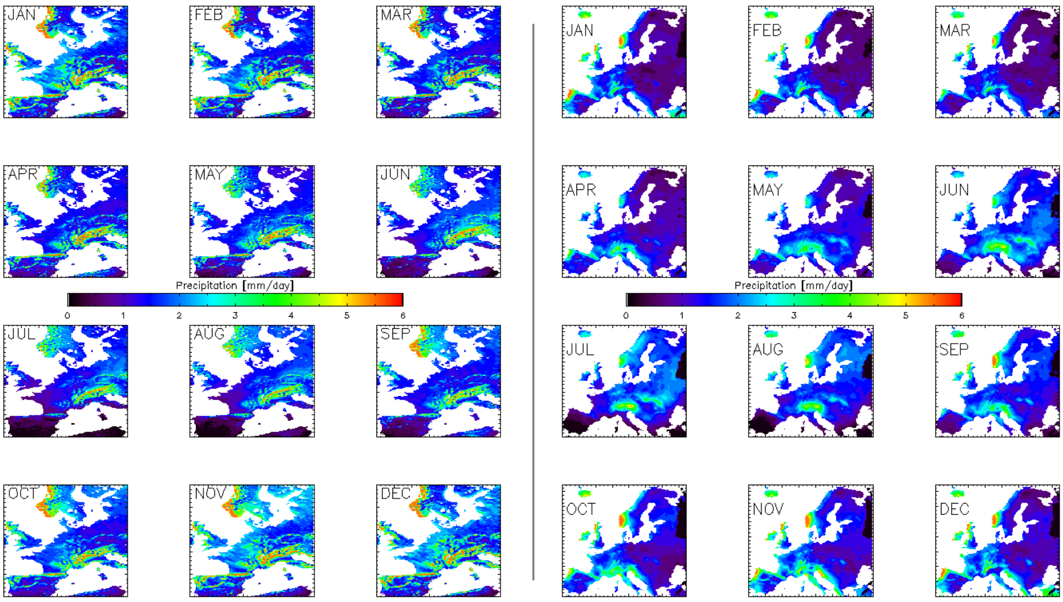

Figure 3: Monthly mean climatology for precipitation [mm/day] of R12 (left) and the gridded observations (right).

Here we also plot a few fields of particular interest for showing important features of the experiment. Other variables are plotted for completeness in Appendix 1. In Figure 4 we display the monthly mean albedo and evaporation. One error of the experiment is clearly seen in the evaporation in a section through middle France, where there is a sharp unphysical cutoff in the field. Since the evaporation is weak during the winter months it is not as noticeable then, but for summer it is strong. We have found that this cutoff is due to an unfortunate mistake as the input climatological files was made, as there was an error in the program associated with the migration between two super computers. The result was an error in the soil types, causing everything below the line through middle France and Italy to be set invariably to sand, rather than loamy clay or clay. This feeds back into several variables such as albedo, evaporation, surface humidity, etc. However it does not seem to feed back significantly to the precipitation, two meter temperature and the atmospheric variables. The extent of the error will impact on the Upper Guadiana river basin, but for the other basins it will not have any significant effect as they are quite remote to the erroneous region.

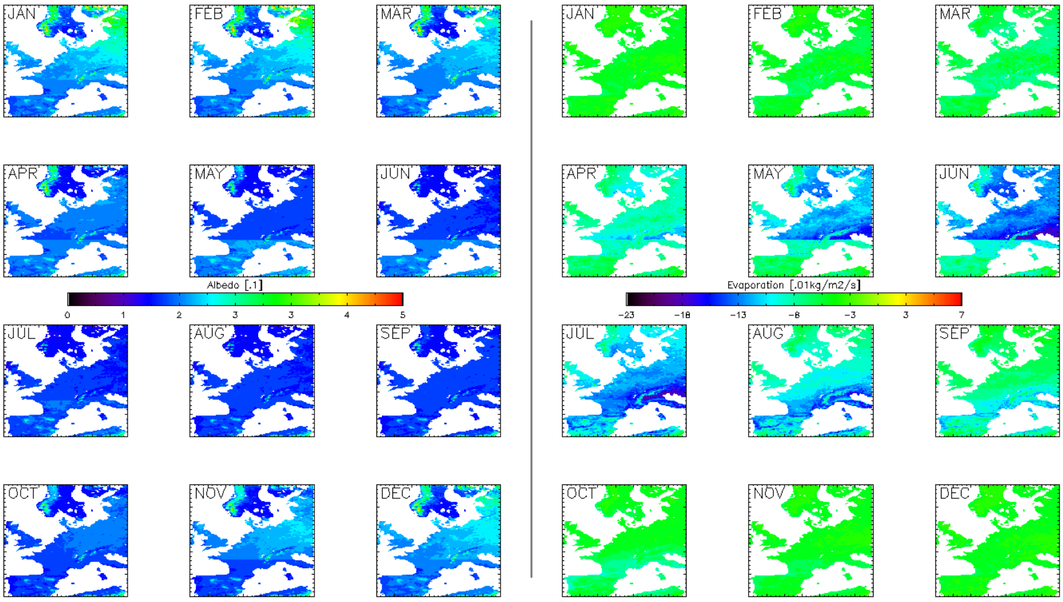

Figure 4: Monthly mean climatology for surface albedo (left) and evapotranspiration (right) from the R12 simulation.

5. Discussion and conclusions

We have performed a dynamical downscaling of re-analysis data, i.e. a so called poor man's reanalysis, over a reduced domain over Europe for the period 1960—2007. The approach used is to reset the atmospheric variables every day at midnight, while keeping the soil parameters in a continuous simulation. For the period January 1960 to August 2002 the ERA40 re-analysis was used for boundary conditions, and thereafter ECMWF operational data were used.

In general, the monthly mean two meter temperature is well simulated throughout Europe except for the winter months, when there is a positive bias. This bias might be related to a bug which allows for ocean heat flux to penetrate the ice-cover in the Baltic and thereby increase the temperature in this region. The mean monthly precipitation also compares well to observations, except for an overestimation over north eastern Europe over winter, connected to the bias in temperature, and smaller local bias.

A more severe error is that of an erroneous soil type used for the southern part of the domain, where the only existing soil type is sand, as opposed to loamy clay or clay as is normally used for this region. This has impacts on the surface variables, but does not seem to have any effect on the atmospheric

variables, precipitation and two meter temperature. As far as the river basins are concerned, this will basically only impact on the Upper Guadiana basin in Spain.
The modeling procedure of daily resetting the atmosphere to stay close to the ERA40 boundary data has proved to work well. There are no large deviations from the driving data within the rather narrow region modeled here. On the downside, the procedure is time consuming as it has a 25% overhead computing time due to the daily six hour spin up of the atmosphere, and also due to offline computing where the restart files from the continuous soil and surface variables are mixed with the new atmospheric variables. For the re-analysis downscaling over the Ganges river basin in India we will try to use a different approach where the large scales of the atmospheric variables in the upper atmospheric levels of the model are relaxed to the driving data. This will keep the internal variability low and should have a similar effect as the constant restart of the atmosphere in the current simulation [Lo et al., 2008].

Appendix 1

Here we present some climatologies for other variables than those presented above. These figures are made for overview purposes and are not analysed in detail.

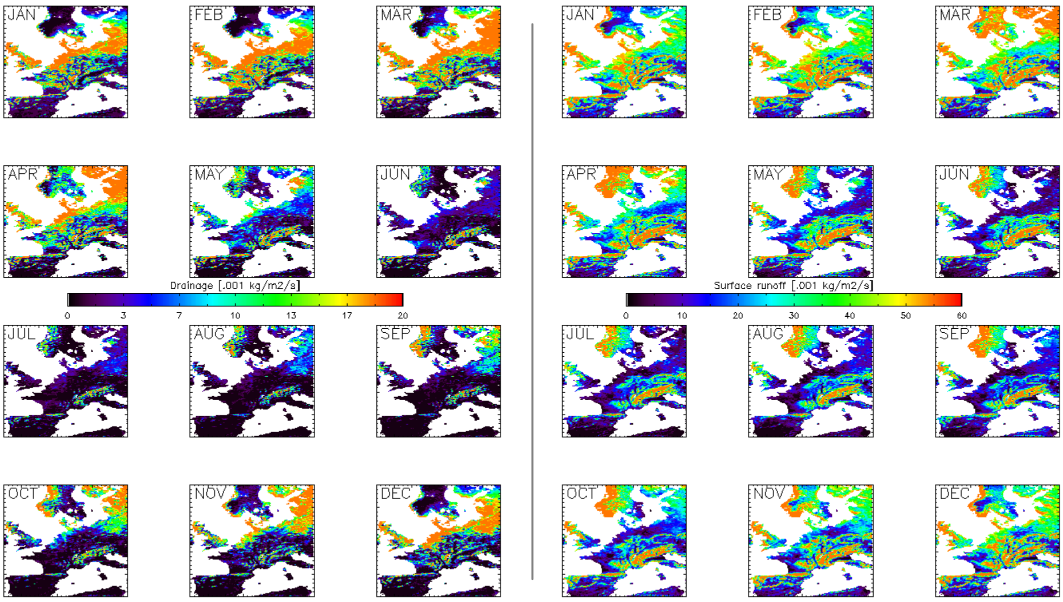

Figure 5: Monthly mean climatology for drainage (left) and surface runoff (right).

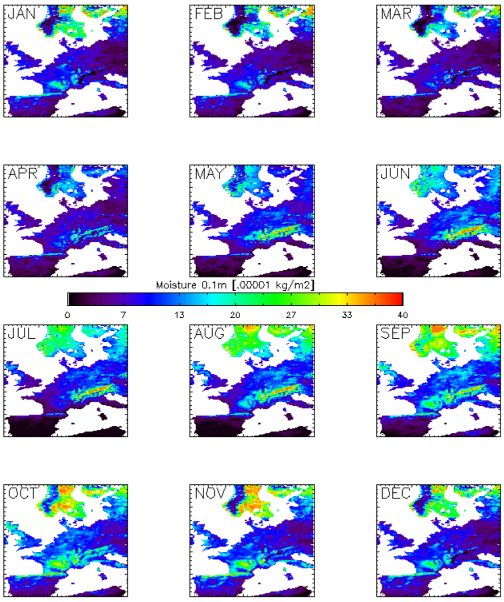

Figure 6: Monthly mean climatology for moisture content in the upper 0.1 meters of the soil.

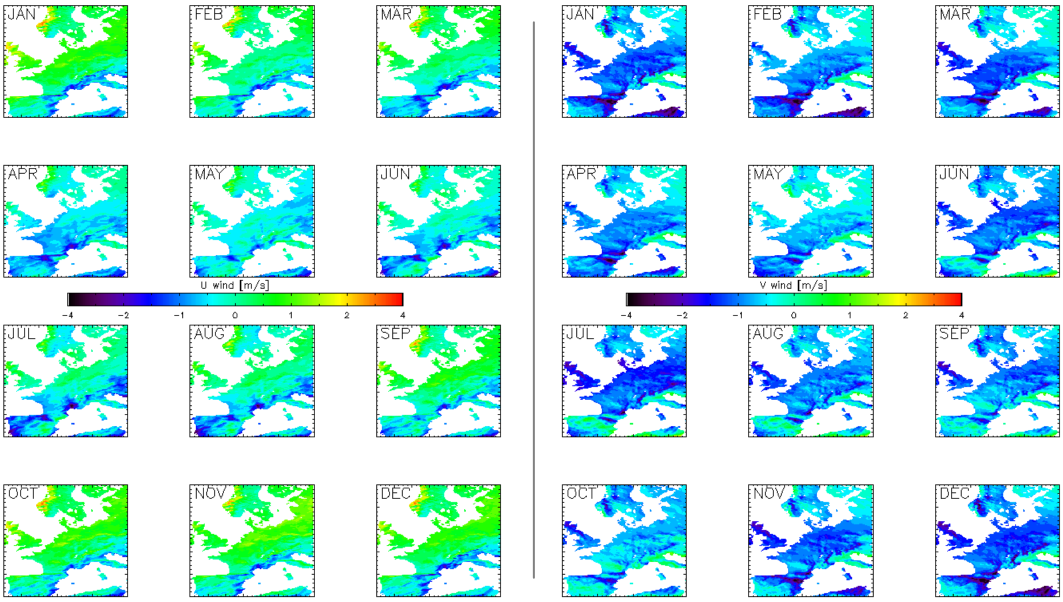

Figure 7: Monthly mean climatology for zonal (left) and meridional (right) wind.

References

Christensen, J.H., O.B. Christensen, P. Lopez, E. van Maijgaard, and M. Botzet, The HIRHAM4 regional atmospheric climate model, Sci. Rep. 96-4, 51 pp., DMI, Copenhagen, 1996.

Christensen, J.H., and O.B. Christensen, A summary of the PRUDENCE model projections of changes in European climate by the end of the century, Climatic Change, vol. 81, 7—30, 2007.

Haylock, M.R, N. Hofstra, A. M. G. Klein Tank, E. J. Klok, P.D. Jones, M. New, A European daily high-resolution gridded dataset of surface temperature and precipitation for 1950—2006, accepted for publication in JGR, 2008.

Lucas-Picher, P., D. Caya, R. de Elía, and R. Laprise, Investigation of regional climate models' internal variability with a ten-member ensemble of 10-year simulations over a large domain, Clim. Dyn., DOI:10.1007/s00382-008-0384-8, 2008.
Kanamitsu, M., and H. Kanamaru, Fifty-seven-year California reanalysis downscaling at 10 km (CaRD10). Part I: System detail and validation with observations, J. Clim., DOI:10.1175/2007JCLI1482.1, 2008.
Machenhauer, B., M. Windelband, M. Botzet, J. Hesselbjerg, M. Déqué, G.R. Jones, P.M. Ruti, and G. Visconti, Validation and analysis of regional present-day climate change simulations over Europe.
Roeckner E., G. Bäuml, L. Bonaventura, R. Brokopf, M. Esch, M. Giorgetta, S. Hagemann, I. Kirchner, L. Kornblueh, E. Manzini, A. Rhodin, U. Schlese, U. Schulzweida, and A. Tompkins, The atmospheric general circulation model ECHAM5, Max-Planck-Institut für Meteorologie, Hamburg, November 2003.