Progress Report of the Operational HIRLAM

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Abstract

This report reviews the recent developments in the operational HIRLAM Forecast System (HFS) both in the reference implementation and those at member services since the last HIRLAM All Staff Meeting (ASM2005), and presents evidences showing recent progresses of the HFS in forecast skills.

1 Changes in the reference HIRLAM system

Two official HIRLAM versions have been released in the past year, version 6.4 on 13 June 2005 and version 7.0 on 2 May 2006.

The version 6.4 (Cats, 2005) implements numerous improvement on both physical parameterization and on model dynamics, such as rotation of the stress vector; smoother vertical diffusion; revision of the snow analysis scheme; Tanguay-Ritchie treatment of the temperature equation, revised physics/dynamics coupling following ECMWF approach; and a higher resolution climate data sets. Validation studies indicate that these changes have been efficient to improve forecasts of near-surface parameters and of profiles in the boundary layer, and at the same time improve on stability and accuracy of the time integrations. Evidence of the improvement in forecast quality are mentioned further in Section 3.

The version 7.0 (Yang 2006) implements several new features in model coupling, data assimilation, use of observations as well as physics, such as the re-forecast procedure at main synoptic hour to utilize large scale analyses to improve model background state; a reduced scaling of the background error structure function so that analysis is 'tilted' less toward observation and more toward model background; assimilation of AMSU-A brightness temperature over sea; modified stomatal resistance, leaf area index, vegetation index and vegetation dependent roughness. Validation studies indicate that the new system has a clear advantage in terms of root-mean-square scores of almost all key parameters, when compared to the equivalent results for 6.4. See also the discussion on improved model quality in Section 3.

On technical side, an integration of the HIRLAM variational code, "HIRVDA", with the rest of the reference system, was accomplished in late 2005. The integrated system is based on cvs version control, replacing the previous rcs system. This migration has also been accompanied by a few changes in the mini-SMS script system, which have resulted more convenience and efficiency for running the reference system on the ECMWF computer platforms. In early 2006, the cvs version control system was further upgraded to Subversion, which opened possibility for easier system administration and web integration.

2 National implementation

Currently 7 HIRLAM member services use HFS for operational NWP, DMI, FMI, INM, KNMI, Met Eireann, Met.no and SMHI. Among them, FMI operates in real time the 'Regular Cycle for Reference HIRLAM' (RCR) as its main production suite, providing the HIRLAM community with a valuable source for operational reference and quality monitoring about the state of the art HIRLAM system. As usual, the national implementations of the HIRLAM system feature various local "flavours", adapting to different local needs and constraints. In Table {refoprconfig, some selected general properties of the main operational implementations in national services have been summarised[2]. As seen from Tableref̃oprconfig, and the brief summary in the following, local deviations in operational implementations are sometimes quite significant and involve different aspects of the HIRLAM system, but in general, it is noted that there appears to be a continuous trend for a increased convergence toward the reference system and at a faster pace.

[1]Lars Meuller(SMHI), Ole Vignes(met.no), Ray McGrath(met.ie), Toon Moene and Sander Tijm(KNMI), Estrella G. Marco and Jose Antonio Garcia Moya(INM), Markku Kangas and Niko Sokka(FMI) and Kai Sattler(DMI), are acknowledged for contributing with materials about national implementation.

[2]HIRLAM readers are referred to the HIRLAM internal webpage on HexNet `https://hirlam.org/trac/wiki/HirlamSystemInventory/` for more detailed and updated information on national implementations.

Table 1: General properties of the operational Hirlam configurations as of May 2006. The table lists versions of HIRLAM releases that models are based on, the horizontal and vertical resolution, number of grid point in the horizontal, time stepping size, initialization scheme, forecast leadtime of main cycles, host model for providing lateral boundaries, frequency of available lateral boundary, frequency of long forecast per day.

model	ver	Res	mesh	lev	DT	ini	fclen	host	bdupd	fc/d
DMI-T15	6.3+	0.15	610x568	40	450	IDFI	60	EC	3	4
DMI-S05	6.3+	0.05	496x372	40	150	IDFI	54	T15	1	4
DMI-Q05	6.3+	0.05	550x378	40	150	IDFI	36	T15	1	4
FMI-RCR	7.0	0.20	438x336	40	360	IDFI	54	EC	3	4
FMI-MBE	6.2.1	0.08	406x306	40	180	IDFI	54	RCR	1	4
INM-ONR	6.2	0.16	582x424	40	240	IDFI	72	EC	6	4
INM-HNR	6.2	0.05	606x606	40	120	IDFI	36	ONR	6	4
INM-CNN	6.2	0.05	606x430	40	120	IDFI	36	ONR	6	4
KNMI-H20	6.3.7	0.20	406x324	40	360	DFL	48	EC	6	4
KNMI-H10	6.3.7	0.10	306x290	40	240	DFL	24	H20	6	8
met.ie I15	4.9/6.0	0.147	438x284	40	300	DFI	48	EC	3	4
met.ie I12	4.9/6.0	0.12	333x210	40		DFI	24	I15	3	4
met.no N20	6.4.2	0.20	468x378	40	450	IDFI	60	EC	3	4
met.no N10	6.4.2	0.10	248x400	40	240	IDFI	60	EC	3	2
met.no N04	6.4.2	0.036	300x500	40	100	IDFI	48	N10	1	2
SMHI-C22	6.3.5	0.20	306x306	40	600	IDFI	48	EC	3	4
SMHI-E11	6.3.5	0.10	258x288	40	300	IDFI	48	EC	3	4
SMHI-O05	6.3.5	0.05	294x441	60	150	IDFI	24	E11	1	4

In the following, we note some general trends and characteristics in the national implementations on various aspects.

Domain coverage and resolution

- All centers apply a multiple-nested domain configuration, in which the larger, 'Atlantic-scale' domains are used for main forecast production of 48 to 72 hours. In Figure 1, the geographical coverage of the main operational forecast domains are plotted together. The larger-domain operational suites use forecasts from the ECMWF Boundary Condition (BC) suite as lateral boundary condition and they often in turn provide boundary condition for internally nested models with higher resolution.

- The 'Atlantic-scale' HIRLAM model resolution is now quite similar in resolution, ranging from 0.147 degree (met.ie), 0.15 degree (DMI), 0.16 degree (INM) to 0.2 degree (FMI, RCR, SMHI), with 40 vertical levels up to 10 hPa.

- Internally nested models normally feature higher horizontal resolution, cover only main service territories at each service. Figure 2 plots the geographic domain coverage for the fine resolution HIRLAM suites. The high resolution configurations have a horizontal resolution ranging from 0.036 degree (met.no), 0.05 degree (DMI, INM, SMHI), 0.08 degree (FMI), 0.10 degree (KNMI) to 0.12 degree(met.ie), with vertical levels of 40 except for SMHI, where a 60-level structure has been chosen for the 0.05 d resolution domain.

System versions

- Most operational suites are based on the recent HIRLAM versions. FMI-RCR runs the official HIRLAM release, thus has automatically the most up-to-date HIRLAM release, which is 7.0 at present. This is followed by met.no (6.42), KNMI (6.3.7), SMHI (6.3.5). DMI's operational

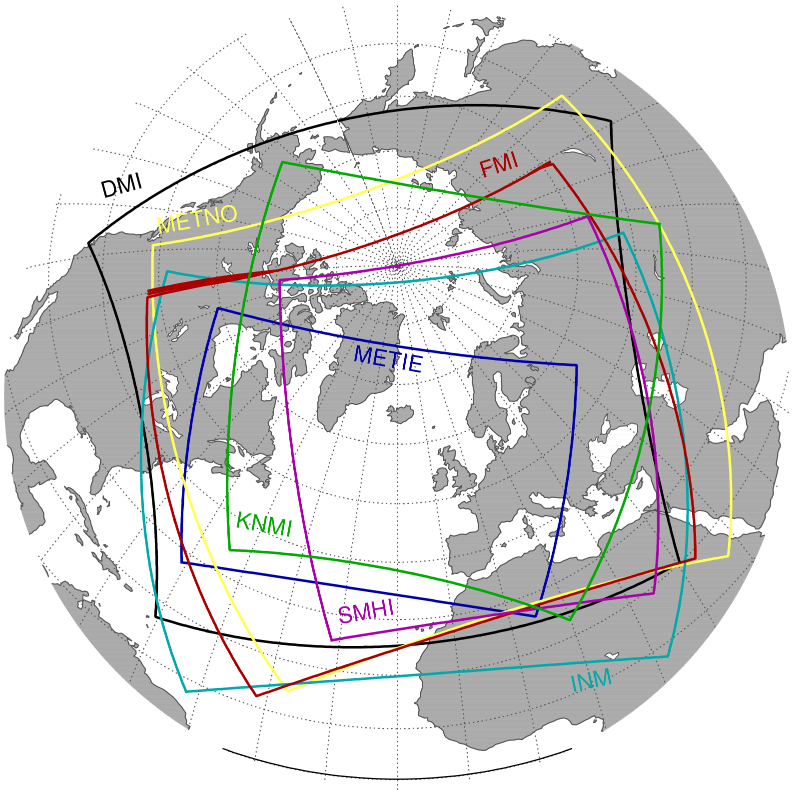

Figure 1: Geographic domain coverage of HIRLAM model at operational centers: coarse resolution domain.

suite traditionally has most deviations from the reference system on many components. Its current model version was based on 6.3 but has adopted many of the recent features in the reference system. INM's operational suite is based on 6.2, and met.ie has its forecast model based on older HIRLAM version, but has adapted analysis system to a recent version, (HIRLAM 6.4).

Climate generation

- Operational runs with versions newer than HIRLAM 6.3 applies climate generation with increased data resolution, smoothed orography and inflated orographic roughness. At DMI, reduced scaling for orographic roughness has been applied.
- DMI applies local modification on soil classfication for European area from "sand" to "loam".

Surface analysis

- All centers now run ISBA surface analysis.
- Snow depth analysis were changed after versions 6.3 in which the analysis method is changed from successive correction to optimal interpolation.
- For SST analysis, the reference HIRLAM assimilated ECMWF SST analysis (as pseudo observation) and ship data. FMI-RCR assimilates in addition the Baltic Sea SST observation. It also uses climatological temperature data for Finnish lakes as pseudo-observations. At DMI, in order to assimilate Ocean Sea Ice SAF SST data, modification has been made so that ECMWF SST analysis is now treated as background, and successive correction scheme is applied to thinned OSI-SAF SST data and ship observation. At met.no, SST and snow analysis are done in external module for which OSI-SAF data is included as data source. At SMHI, the high resolution SST and ice data for Baltic Sea from external ocean analysis is used.

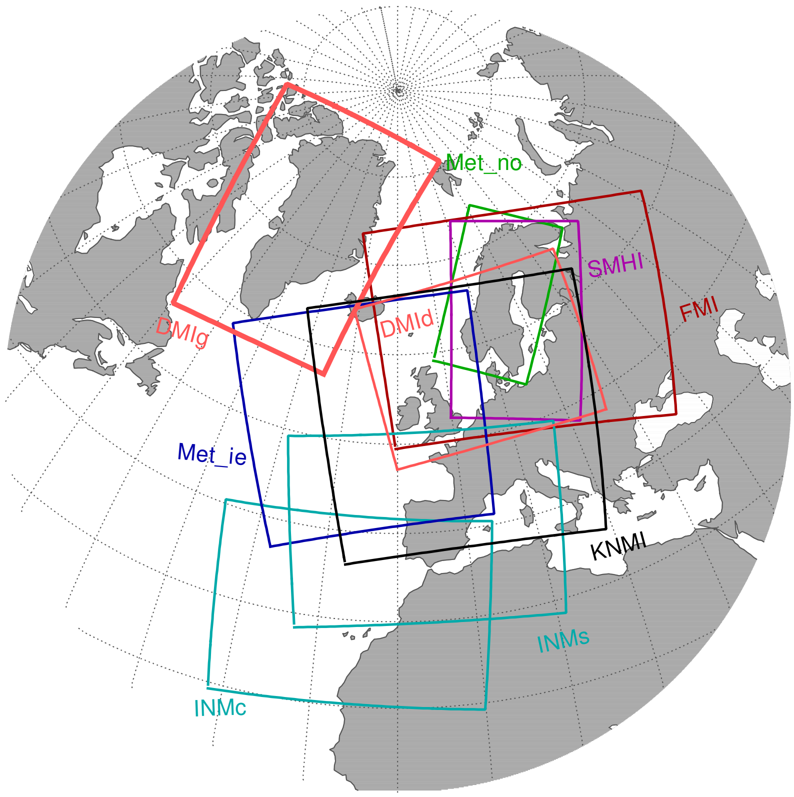

Figure 2: Same as Figure 1 but for the fine resolution domain.

- Currently, sea ice cover is diagnosed from SST analysis in the reference HIRLAM system and no sea ice data is assimilated. At DMI, ECMWF ice analysis is used, which also regulate the final SST analysis. At met.no, ice analysis is from external module.

Upper air data assimilation

- All centers now use HIRLAM 3D-VAR for main operational suite.

- Most centers use analytical balance structure function extrapolated from the original SMHI 31-level data and use reduced resolution in minimization. FMI-RCR and met.no now use reduced scaling for model background error as implemented in HIRLAM 7.0. DMI introduced since late last year the analytical balance structure function derived from its own operational data and apply a scaling factor tuned for that. In connection with that change, DMI now also uses full resolution in minimization. INM has since a few years back derived its own statistical balance structure function.

- FMI-RCR, KNMI and met.ie applies 3 h assimilation cycling. DMI, INM, met.no and SMHI apply 6 h assimilation cycling. met.ie runs in addition a hourly update cycle for nowcasting purpose, assimilating primarily aircraft data.

- AMSU-A is now assimilated in DMI, met.no, INM, SMHI and FMI. Methods for bias correction differ.

- Met.no and DMI assimilates QuikScat data, but using different methods.

- Meteosat 8 AMV wind data is used in DMI.

- Several centers have included newer observation types in the assimilation in passive mode, such as INM for radar VAD wind, ground-based GPS, surface relative humidity and surface wind data, SMHI for radar VAD wind.

- Reference HIRLAM uses RTTOV-7 radiative transfer module. DMI uses RTTOV-8.

Model coupling and initialization

- FMI and met.no apply re-forecast procedure using ECMWF analysis and incremental DFI method.
- DMI apply re-assimilation to redo HIRLAM analysis and apply analysis blending to mix ECMWF with HIRLAM analyses.
- Most centers use incremental DFI for forecast initialization. KNMI uses DFI launching.
- Most centers use coarser resolution model forecast as lateral boundaries for the internal nested high resolution runs. Exceptions are the intermediate resolution runs with 0.1 degree resolution in met.no and SMHI, for which the ECMWF analysis are used as lateral boundaries.
- Some centers choose to run 3D-VAR analysis even for highest resolution domain, such as INM for 0.05 degree and FMI for the 0.08 degree domain. Other centers use coarse resolution analysis for dynamic adaptation with help of IDFI.

Forecast Model

- Long forecast are made for 48h to 72 h.
- Most centers use 3-hourly lateral boundary update. Some still uses 6 h update.
- SMHI uses a version of moist CBR turbulence scheme and Kain Fritsh Rasch Kristjansson condensation scheme. DMI apply some local modifications to CBR, STRACO and surface schemes.
- DMI uses SETTLS semi lagrangian scheme for advection.
- All centers use implicit horizontal diffusion option. DMI uses 6th order, the other centers use 4th order.

3 Quality improvement in HFS

Forecast qualities are monitored in HIRLAM services with various methods and algorithms. An observation verification package developed at KNMI has been included in the reference system and used by FMI, KNMI and INM as a routine tool for operational quality monitoring. At DMI, met.ie, met.no and SMHI, different verification tools have been chosen. The choice of different verification tools in operational centers has made it less straightforward to compile intercomparison of forecast qualities between models. In view of importance of quality monitoring for forecasts products both for research and management perspective, enhanced efforts in HIRLAM-A are necessary to establish a regular, systematic framework to monitor and intercompare model qualities for the reference HIRLAM (FMI-RCR) and national implementations, and if possible, to extend such exercise to forecasts of other centers.

In order to give readers a perspective on the quality improvement of the reference HIRLAM system in recent years, we present here a recently updated observation verification time series for selected parameters comparing FMI RCR to the forecasts made at two leading global NWP centers ECMWF and UK Met Office (UKMO). Figure 3 is the plot for daily observation verification time series of the 24 h model forecasts for the mean sea level pressure (MSLP) in the recent periods since 2004, when the reference HIRLAM model was used for the first time in the operational NWP suite by FMI. Shown in the comparison plots are the verification data in standard deviation (std) and bias of the three forecasts, all of them calculated using DMI's verification software. The verification is done against EWGLAM station-list and observation data are quality controlled using ECMWF analysis. Through quality control procedure, the DMI verification tool ensure that forecasts from all models are compared to exactly same observation data. Note also that the global forecast data from ECMWF and UKMO are those available to DMI duty forecasters with reduced resolution (at around 100 km). It is estimated that the impact to scores due to such thinning may be insignificant for parameters representing mainly large scale features, such as MSLP and upper air quantities, but it may be more significant for parameters dominated by local

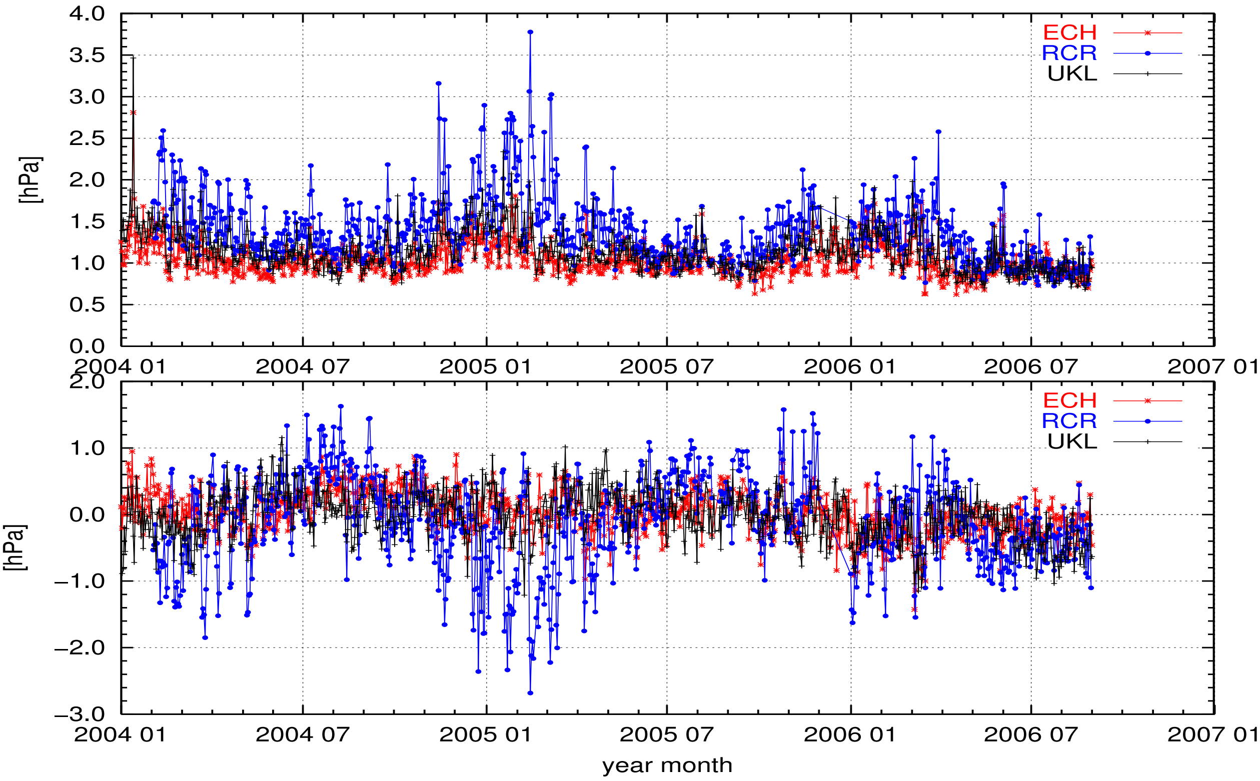

Figure 3: Time series of the daily std (upper panel) and bias (lower panel) error against of 24h MSLP [hPa] forecasts initiated at 00 UTC, validating against the EWGLAM station-list during 2004-2006. 'ECH' stands for thinned forecast from ECMWF, 'UKL' for thinned forecast from UKMO and 'RCR' for the reference HIRLAM forecasts. Note that data gaps are due to missing record in the archive. DMI's verification software has been used, using verifying ECMWF analyses in quality control. Note the significantly reduced amount of forecast busts and an increasingly closer comparability of the HIRLAM forecasts with those of the ECMWF and UKMO ones.

features such as surface wind and temperature. The data for FMI-RCR are those obtained by applying DMI software to the RCR model level data as archived at ECMWF. Some data holes exist, due to incomplete data in that archive.

Following observations can be made from Figure 3:

- Global model forecasts of key synoptic parameter MSLP has an obvious lead compared to HIRLAM forecast, especially in terms of standard deviation. Similar trend is also apparent for upper air scores of wind, temperature and geopotential heights, (not shown here).

- There are obviously more frequent occurrences with forecast busts, i.e., cases with large errors in std and bias, in HIRLAM forecasts.

- However, the gap between forecast quality of global models and HIRLAM is reducing rather rapidly. Interestingly, there appears to be quite noticeable imprints of the latest two system upgrade of RCR from the plot for the MSLP scores. Following June 2005 upgrade to 6.4, there appears to be a reduced errorsfor RCR in both std and bias. Since the May 2006 upgrade to 7.0, the level of std for MSLP has been reduced to be much more comparable to that of the ECMWF and UKMO. The occurrence of forecast busts also appear to be significantly reduced.

In Figure 4 and Figure 5, the corresponding time series for screen level temperature and wind speed are presented, respectively. In comparison to the global model,

- HIRLAM system is obviously competitive in predicting evolution of both surface temperature and wind forecast, and the advantage in std is becoming more obvious following the two recent upgrades in 6.4 and 7.0.

- The improvement due to the June 2005 upgrade in the HIRLAM model is especially obvious in the forecast for 10 m wind. The upgrade cured effectively the previously severe positive wind bias problem in HIRLAM model and enhanced HIRLAM's advantage for surface wind forecast. For 2-m temperature, the previous night-time positive bias in HIRLAM forecast is now changed to a positive bias.

The relative score comparisons between HIRLAM and global forecasts, as shown in Figure 4 and Figure 5, demonstrate a significantly improved forecast skills of the HIRLAM system. We should emphasize here that in addition to the competitive forecast quality of HIRLAM model, there are a few factors worth mentioning which are not directly visible in these figures, that is, given similar skill scores, the HIRLAM forecasts has additional added values due to its higher spatial resolution, a better production frequency and delivery schedule, and has all the flexibility to tailor the local needs.

4 References

Cats, G., 2005: Reference system status December 2005, *HIRLAM Newsletter*, **49**, 105-106.
Yang, X. 2004: Status of the HIRLAM reference system. *HIRLAM Newsletter*, **50**, 49-51.

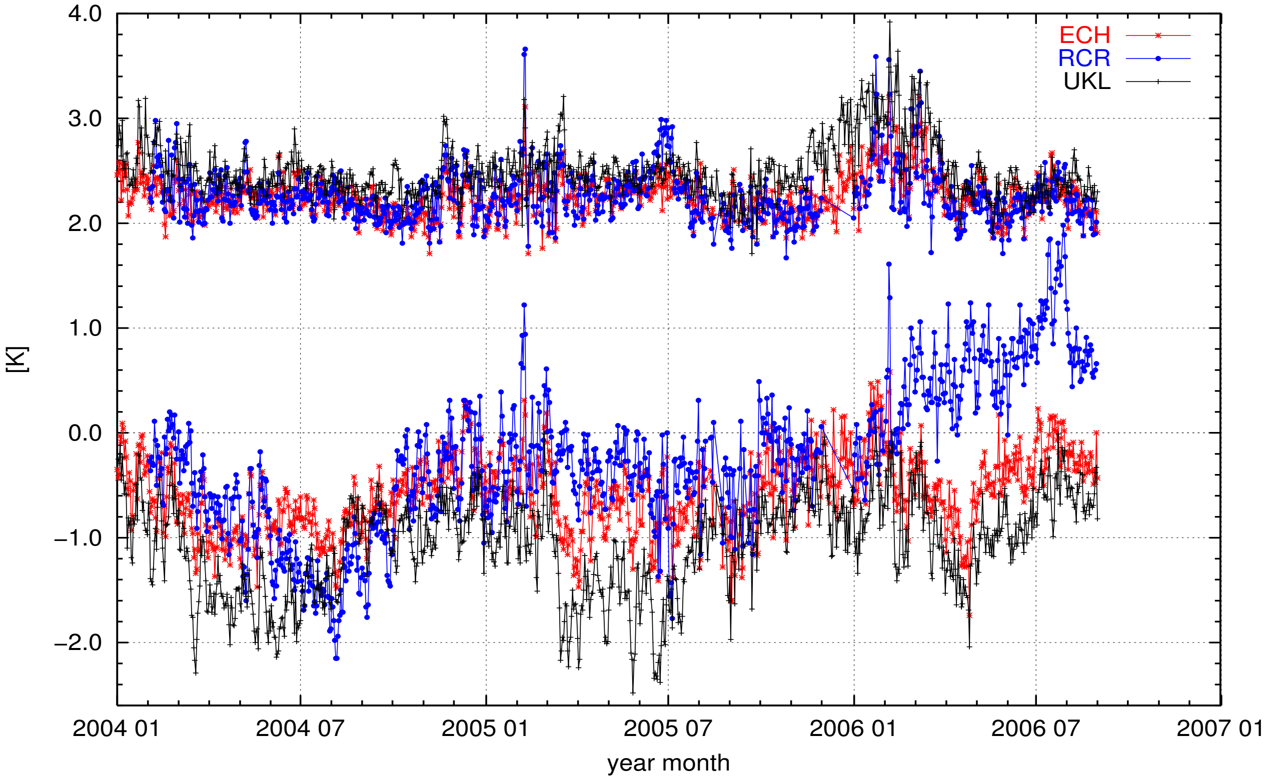

Figure 4: same as in Figure 3 but for 2-m temperature.

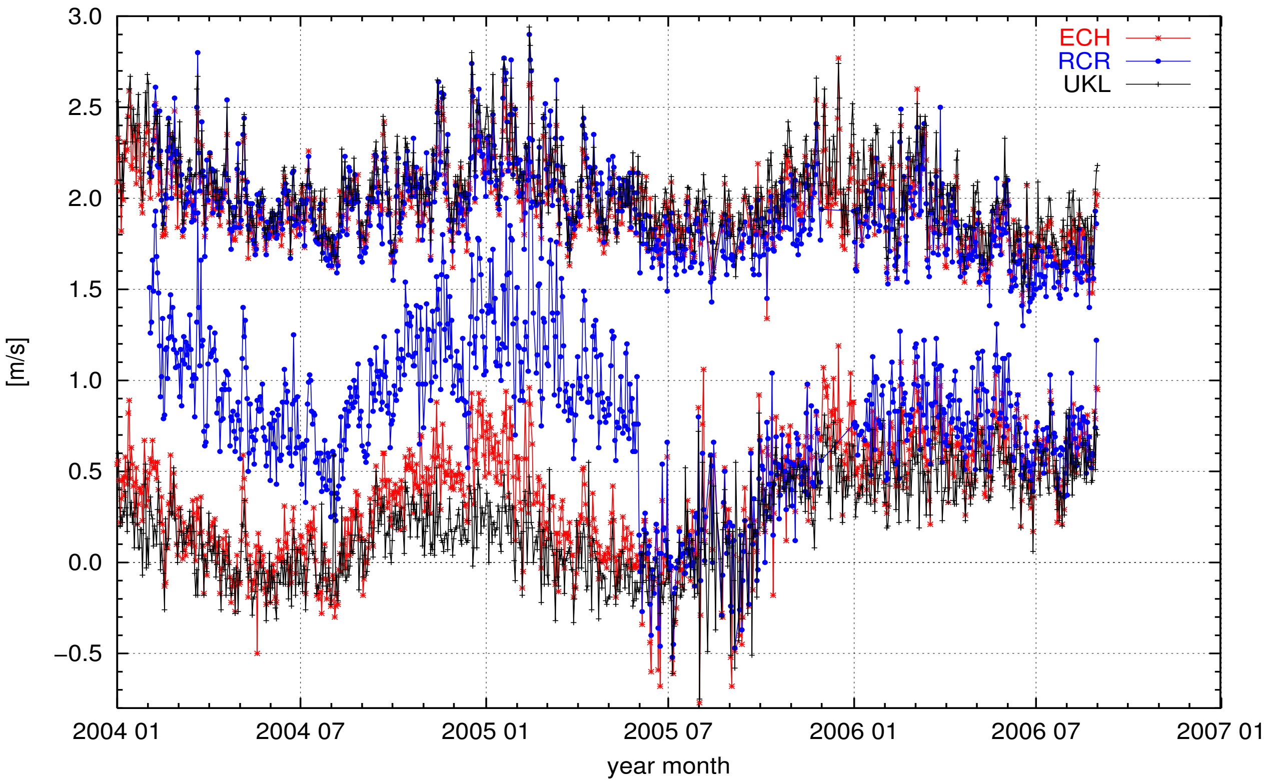

Figure 5: same as in Figure 3 but for 10-m wind.