Status update on operational HIRLAM

Xiaohua Yang, DMI

This report is an annual update of the current status of the operational HIRLAM forecast system at the member services, with reference to the last of such review made at the HIRLAM all-staff meeting (Yang, 2006). Contact persons[1] at HIRLAM services are acknowledged for contributing with materials presented here. The focus of the report is on operational implementation of the synoptic-scale HIRLAM system.

1 Changes of the reference HIRLAM system

Since early 2004, reference HIRLAM system has been adopted by Finnish Meteorological Institute (FMI) as its operational NWP system. Following the agreement between FMI and HIRLAM project/programme, each of the official HIRLAM system releases, which is made approximately once a year, is launched simultaneously at FMI with implementation of the reference system in its Regular Cycle of Reference HIRLAM (RCR) in FMI's operational suite.

On March 28, 2007, FMI launched latest operational suite, RCR 7.1, coinciding with the release of HIRLAM version 7.1. This was later followed by a quick update following release of the bug-fix version, Hirlam 7.1.1, on May 30, 2007.

As reviewed in Yang (2007), Hirlam 7.1 contains numerous new features and technical improvements. Among them, the resolution increase in both horizontal and vertical, upgrade in physical parameterization such as introduction of moist CBR turbulence scheme and tuning of STRACO condensation scheme, improvement in 3D-VAR analysis scheme with introduction of statistical balance structure function and derivation of background error statistics from RCR's own forecast archive, replacement of 3-hourly assimilation cycle by that of 6 h, are believed to have contributed to the general improvement in forecast skills, especially that of precipitation, (see, e.g., validation notes by Eerola and Yang, 2007). The new release also enriches the HIRLAM product categories through introduction of dozens of direct model output for the benefit of end users, such as visibility, wind gust, surface wind and temperature maxima, precipitation categories, CAPE index etc.

2 National implementation

In terms of operational implementation at HIRLAM member services, it has been an eventful year with numerous new progresses. In particular, following highlights may be mentioned,

- During the past year, most operational centers have conducted various numerical tests using model system based on the recent reference releases (version 7.0 or 7.1) with a view for later operational upgrade. These tests have lead to new operational configurations at several of the operational centers;
- INM started regular real-time production with short range multi-model ensemble prediction system, reporting promising results;

[1] Bjarne Amstrup (DMI), Aarne Mannik (EMHI), Niko Sokka and Kalle Eerola (FMI), Estrella G. Marco (INM), Toon Moene (KNMI), Paulius Jalinskas (LHMS), Eoin Whelan (Met Eireann), John B. Bremnes and Morten Koltzow (met.no), Lars Meuller (SMHI).

- Met.no and KNMI have seen major upgrade in high performance computational capacities and hence possibility for a substantial operational upgrade to allow for more computation-demanding operational suites. At Met Eireann, an agreement has been signed with the Irish Center for High End Computing (ICHEC) to outsource the operational HIRLAM runs, bringing a big step forward with a significantly enhanced computational capacity;
- For the very high resolution modelling, DMI, FMI and SMHI continued with their real-time quasi-operational 2.5 km model runs using HARMONIE system (based on HIRLAM-ALADIN full code collaboration) and experimented with use of AROME forecast system. Similar activities have been in preparation (or plan stage) at other services such as KNMI, INM and met.no;
- Pre-operational HIRLAM runs have been started at two new HIRLAM member/acceding member services, EMHI (the Estonia weather service) and LHMS (the Lithuania weather service).
- More real-time operational products are made available via HIRLAM data portal. HIRLAM community can now access some of the near real-time HARMONIE forecast data at DMI, FMI and SMHI, as well as selected daily forecasts made at DMI, FMI and SMHI.

In the corresponding report last year (Yang 2006), special features and activities at HIRLAM member services were reviewed. In this report, we update the relevant information with starting point from that review.

Table **??** lists, similar to that appeared in the previous report (Yang, 2006), general operational model properties, with new features highlighted in bold fonts[2]. 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 lead-time of main cycles, host model for providing lateral boundaries, frequency of used lateral boundary, frequency of long forecast per day. Note that the reported information for EMHI, LHMS, met.no, Met Eireann are valid for real time suites, but these have not reached 'operational' status at the time of the writing.

In the following, we note some recent developments in the national implementations, compared to the situation as reviewed one year earlier (Yang 2006).

Domain coverage and resolution

- During the past year, there has been no change of the outer-most, 'Atlantic-scale' domains in member services (Figure 1). However, Met.no, KNMI and FMI have enhanced their 'Atlantic-scale' model resolution substantially. While DMI maintains its lead on size of the outer-most model domain, KNMI, with its horizontal resolution doubled to 0.1d, has currently highest resolution Atlantic-scale model among HIRLAM-services. Met.no, with its outer-most model resolution increased from 0.2 d to 0.108d, runs with largest problem-size among operational models.
- Many operational suites (FMI, KNMI, Met Eireann, met.no, LHMS) have upgraded vertical resolution to 60 levels. DMI tests in its pre-operational suite a 61-level structure with model top at 5 hPa.
- Most services now run an internally nested HIRLAM model with a resolution of ca 0.05 d (Figure 2). EMHI, using non-hydrostatic dynamic core of HIRLAM, runs daily a 0.03 d model centering on Estonia.

System versions and upgrade activities

- Recent available HIRLAM releases are being adopted by member services in their operational upgrade. FMI-RCR runs the official HIRLAM release, thus has automatically the most up-to-date HIRLAM release, which is 7.1.1 at present. The two recent services that have made upgrade since the 7.1 release,

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

Table 1: General properties of the operational Hirlam suites as of mid-2007. The highlighted texts represents changes to that of the previous years.

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
EMHI-ETA	**6.2+**	**0.10**	**114x100**	**40**	**400**	**NMI**	**54**	**RCR**	**3**	**4**
EMHI-ETB	**6.2+**	**0.03**	**186x170**	**40**	**120**	**NMI**	**36**	**ETA**	**1**	**2**
FMI-RCR	**7.1**	**0.15**	**582x448**	**60**	**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-H11	**7.0**	**0.10**	**816x650**	**60**	**240**	**IDFI**	48	EC	**3**	4
LHMS	**7.1**	**0.08**	**156x146**	**60**	**300**	**IDFI**	**48**	**RCR**	**3**	**4**
met.ie OPR	**7.0**	0.147	438x284	**60**	**300**	DFI	48	EC	3	4
met.ie FIN	**7.0**	**0.05**	**438x395**	**60**	120	DFI	24	OPR	3	4
met.no-H12	**7.1**	**0.108**	**864x698**	**60**	**300**	**IDFI**	60	EC	**3**	4
met.no-H08	**7.1**	**0.072**	**344x555**	**66**	**300**	**IDFI**	60	EC	**3**	4
met.no H04	**7.1**	0.036	300x500	60	100	IDFI	48	H12	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

met.no and LHMS, use also the latest model version. Other services that have made the upgrade during the past year, KNMI, Met Eireann and EMHI, use version 7.0.

- SMHI and INM have also been testing for some time the recent versions of HIRLAM system. DMI focuses its tests on increased vertical resolution and 4D-VAR. EMHI bases its tests on an earlier HIRLAM release (6.4) but with non-hydrostatic dynamic core as developed at Tartu University.

Upper air data assimilation

- In the latest reference RCR (7.1), data assimilation cycle has been changed from 3 h to 6 h. The main reason behind the switch is the finding from the recent impact studies and operational experience at DMI, met.no and SMHI, which reveal little positive impact with a more frequent assimilation cycle. This is hypothesed to be associated with the difficulty due to limited availability of observation data at non-synoptic time, as well as the quality of structure function in 3D-VAR.
- Statistical balance structure function is introduced in the reference system 7.1. Currently DMI, FMI and INM use statistical balance structure functions derived from their respective forecast archives using NMC method. The importance of deriving background error statistics from native model data has been demonstrated in several recent numerical experiences, and especially so in change of vertical resolution.
- DMI started to assimilate NOAA 18 AMSU-A data using RTTOV 8 package. The package is being introduced into the coming reference system.
- Although 4D-VAR analysis scheme didn't make it to the reference system in 7.1, DMI and SMHI started parallel monitoring suite from autumn and winter 2006, respectively, to accumulate operational experiences.

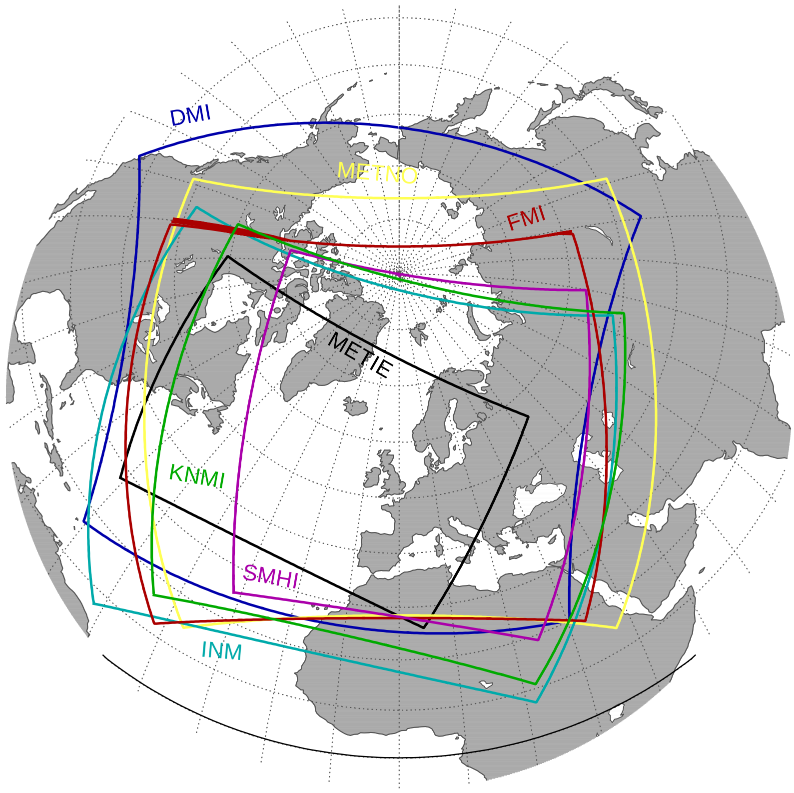

Figure 1: Geographic domain coverage of HIRLAM model at operational centers: coarse resolution domain.

Model coupling and initialization

- Among the operational suites that have made operational upgrade recently, most have adopted large-scale mixing via re-forecast scheme in the Atlantic-scale model. Met Eireann has so far not adopted the scheme.
- Met Eireann (as the last HIRLAM service) switched to dissemination of full-vertical resolution ECMWF BC data last summer and has since seen dramatic improvement in average bias of the surface pressure forecasts.
- Most centers use incremental DFI for forecast initialization. EMHI uses NMI in connection with the non-hydrostatic dynamic core.
- EMHI and LHMS use FMI-RCR as lateral boundaries for their operational models with relatively small domain. Both run independent data assimilation at high resolution.

Forecast Model

- In February 2007 several HIRLAM models experienced difficulty to handle unusually windy situation close to the model top at 10 hPa. The problem was later identified to be associated with a bug in the Semi-Lagrangian advection scheme. The bug fix, proposed by Aidan McDonald, has since been implemented in reference HIRLAM as well as most of the operational HIRLAM suites.

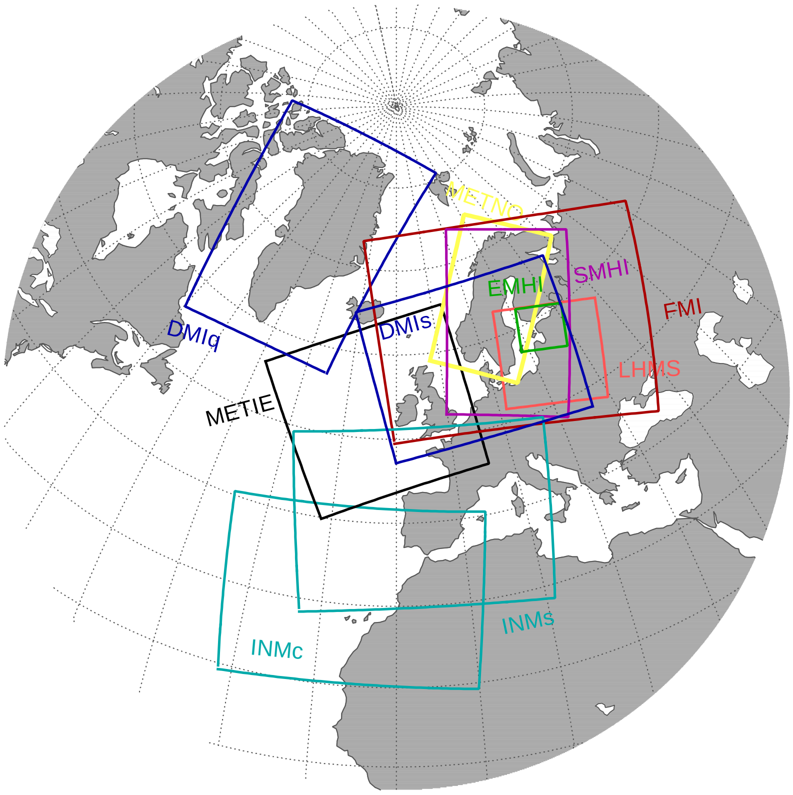

Figure 2: Same as Figure 1 but for the fine resolution domain.

3 Evidence of continued quality improvement with Hirlam

The past year has seen more evidence with long-term trend of an improved forecast skill with HIRLAM forecast system. At FMI, use of reference HIRLAM in its operational suite has been successful to bring forward major improvement in forecast qualities. In Figure 3 and Figure 4, e.g., evolution of FMI-HIRLAM 48 h verification scores of 2 m temperature and 10 m wind speed forecasts for EWGLAM-list during the past decade are shown, respectively, demonstrating a clearly positive trend for quality improvement in connection with the upgrade to the recent versions of reference HIRLAM. See also the corresponding plots for mean sea level pressure (MSLP) in Figure 1 of Eerola and Yang (2007).

Similar trend can be found in the selected plots representing long-term quality measures at several operational centers. In Figure 5, the monthly average of the 24 h MSLP forecast root mean square (rms) error for DMI-HIRLAM and ECMWF operational forecasts during the last decade are compared, showing a decreased gap between skills of the DMI-HIRLAM and ECMWF global model. In Figure 6, the monthly averaged 48h MSLP forecast rms scores from KNMI-HIRLAM forecasts reveals a remarkable reduction in the recent years, especially since the upgrade with Hirlam 6.4. In Figure 7, the monthly averaged 48h forecast rms scores for geopotential height in key vertical levels showed a significant error reduction in recent years, especially since 2005, following implementation of re-forecast scheme at met.no. Finally, in Figure 8, the locally defined forecast skill index demonstrates a consistent improvement with the SMHI-HIRLAM forecasts which stays competitive against that of ECMWF global forecasts.

It is interesting to note the huge diversity in the above selected quality plots submitted by member services. Due to absence of a common verification package for operational purpose, operational centers have developed their own verification measures to track forecast quality, and it has hence been difficult to conduct a direct quality comparison between various operational implementation at member services. It is hoped that with further development of the reference verification system and collection of forecast data via HIRLAM data portal, an

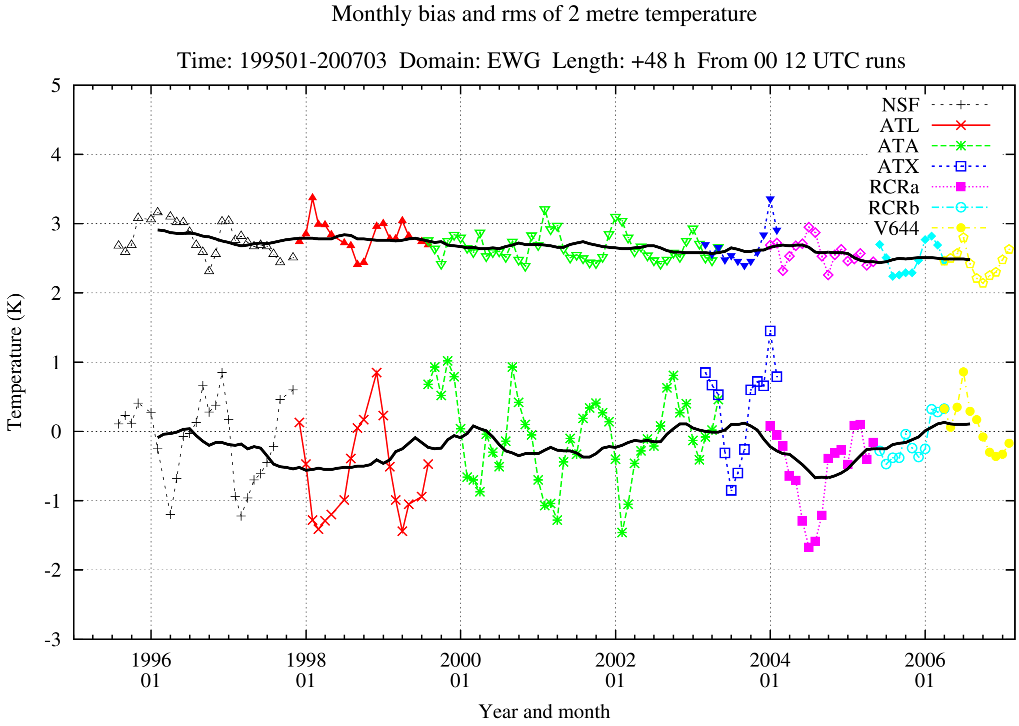

Figure 3: Time series of the monthly averaged bias (lower curves) and rms (upper curves) of the FMI-HIRLAM 48 h forecasts for 2 m temperature, verified against EWGLAM-station list, for period between 1997 and 2007. The colors represent different model versions of FMI-HIRLAM. Starting from 2004. FMI-HIRLAM is based on the reference HIRLAM. Courtesy of K. Eerola.

objective quality comparison between HIRLAM services will become possible in the near future.

4 References

Eerola, K. and X. Yang, 2007: *Some results of the validation tests of Hirlam 7.1* . Hirlam Newsletter, 52 (the current issue).

Yang, X., 2007: *Progress Report of the Operational HIRLAM*. Hirlam Newsletter, 51, 70-76.

Yang, X., 2007: *Status of the reference system*. Hirlam Newsletter, 52 (the current issue).

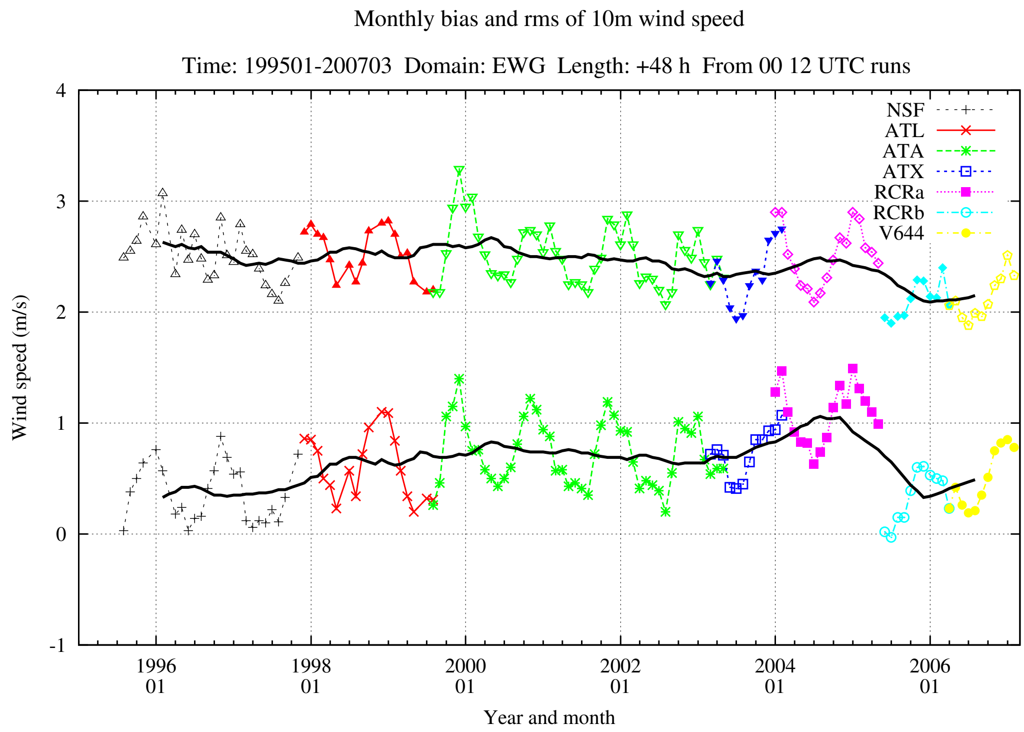

Figure 4: Same as Figure 3 but for 10 m wind speed.

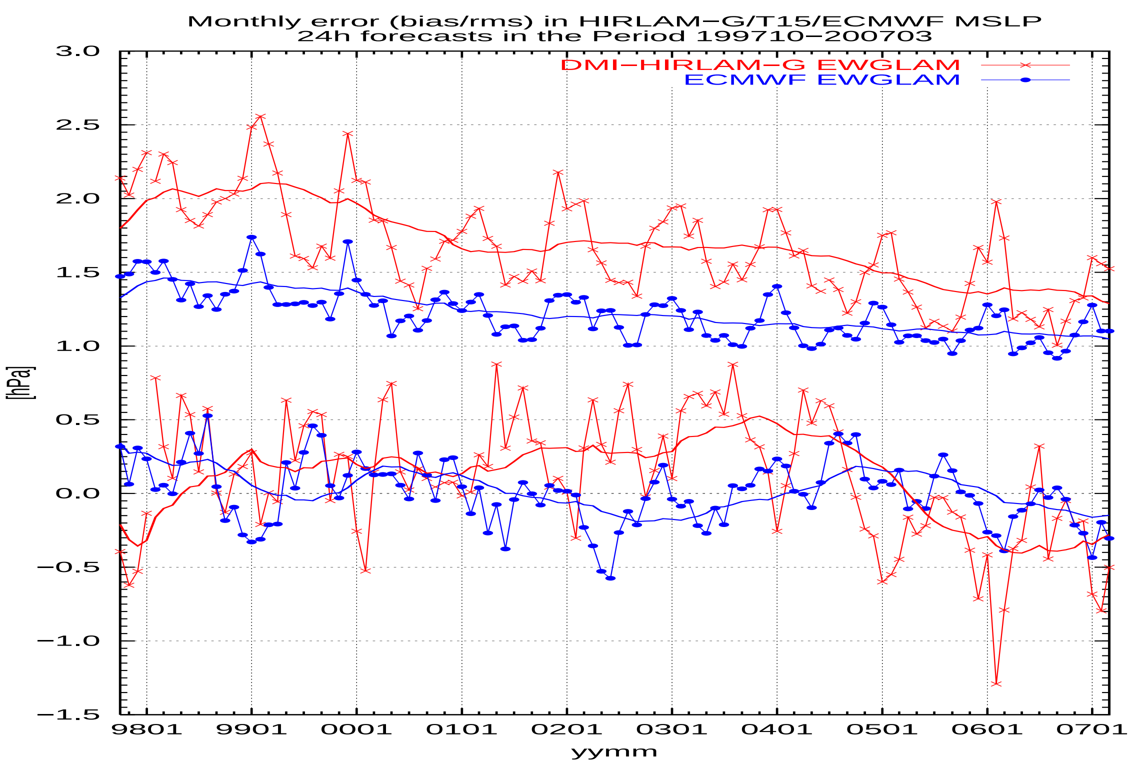

Figure 5: Time series of the monthly averaged bias (lower curves) and rms (upper curves) of the DMI-HIRLAM and EWGLAM 24 h forecasts for mean sea level pressure (MSLP), verified against EWGLAM-station list, for period between Oct 1997 and March 2007. Courtesy of B. Amstrup.

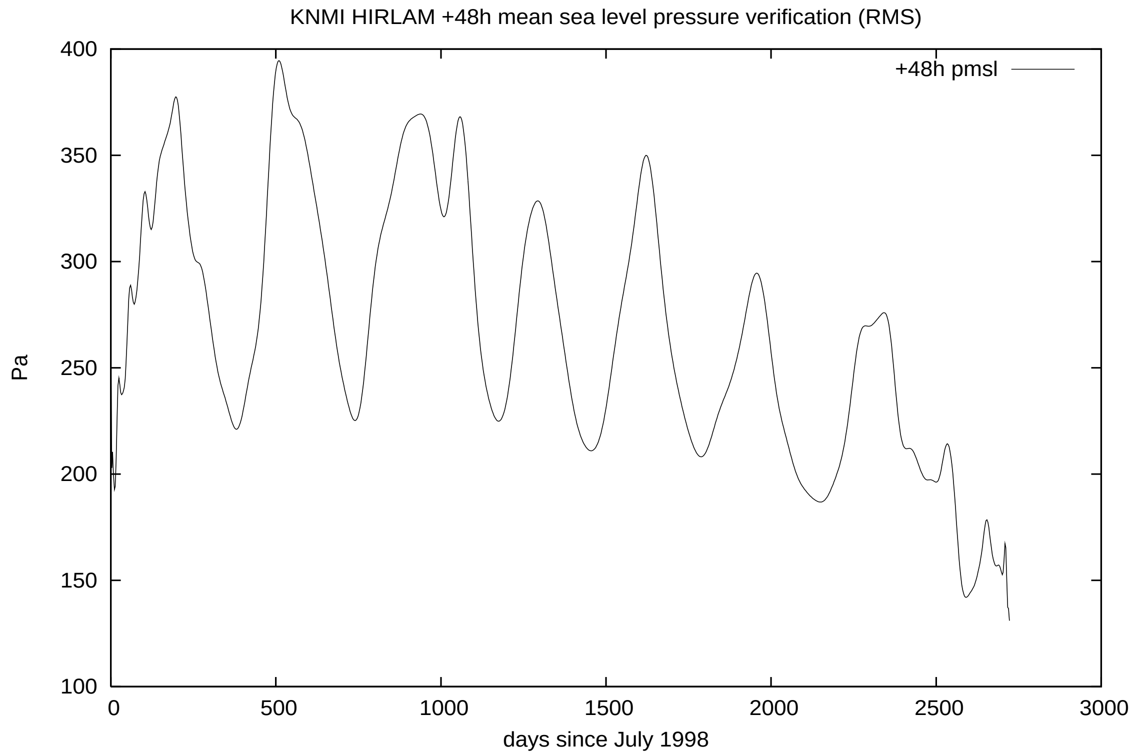

Figure 6: Time series of the monthly averaged bias (lower curves) and rms (upper curves) of the KNMI-HIRLAM 48 h forecasts for MSLP, verified against EWGLAM-station list, for period between July 1 1998 and early 2007. Courtesy of T. Moene.

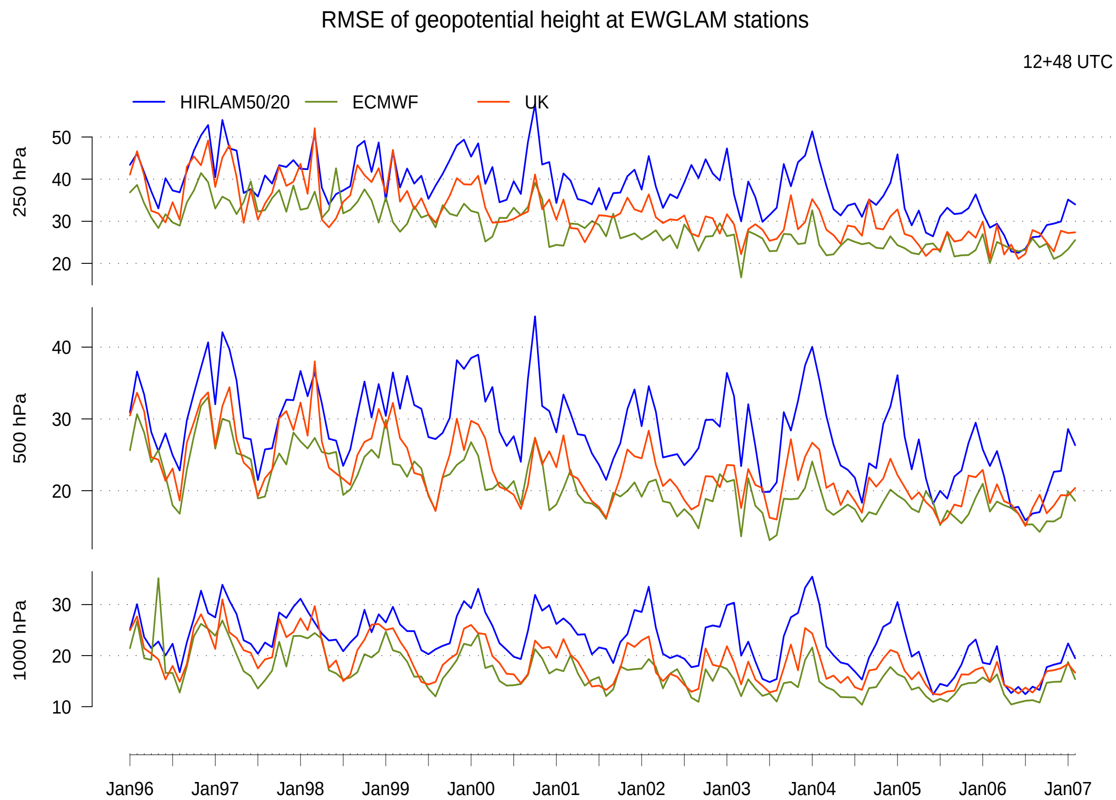

Figure 7: Time series of the monthly averaged rms of the met.no-HIRLAM 48 h forecasts for geopotential height at 250 hPa (upper panel), 500 hPa (middle) and 1000 hPa (lower), verified against EWGLAM-station list, for period between January 1996 and 2007. Courtesy of J. B. Bremnes.

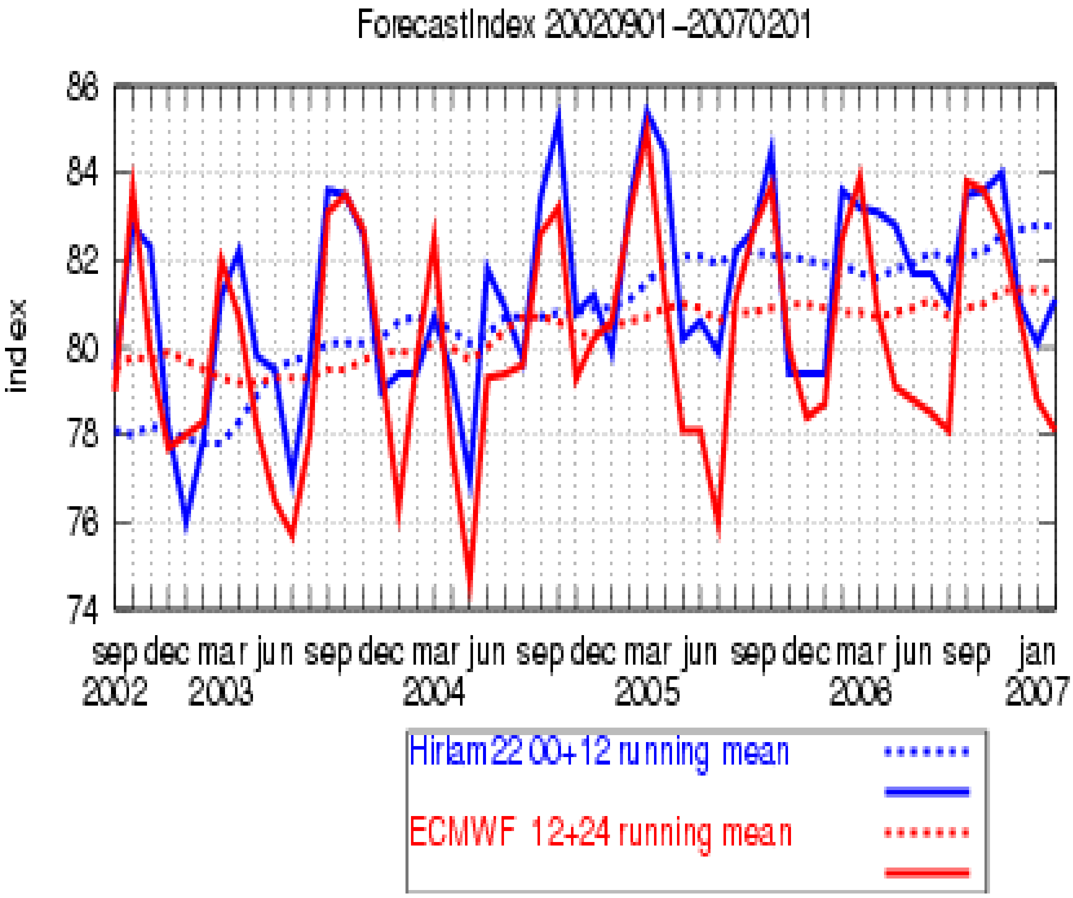

Figure 8: Time series of the locally defined forecast quality index at SMHI (L. Meuller, personal communication), comparing SMHI-HIRLAM with that of ECMWF operational forecasts between Sept 2002 and Feb 2007. Courtesy of L. Meuller.