ILMATIETEEN LAITOS
METEOROLOGISKA INSTITUTET
FINNISH METEOROLOGICAL INSTITUTE

SRNWP at FMI

Carl Fortelius and Kalle Eerola

Operational NWP suites

The Finnish national weather service relies on the ECMWF for synoptic-scale medium-range numerical weather forecasts. Deterministic short range forecasts are generated in house by two suites of the HIRLAM forecasting system (HFS), one for the synoptic scale (RCR) and one mainly for the meso-β scale (MB). Dynamic downscaling of the MB forecast to the meso-γ scale is carried out by using the AROME model of the HARMONIE Forecasting System. In support of very short range forecasting, we are also using the Local Analysis and Prediction System (LAPS, htttb://laps.noaa.gov) to generate hourly 2D and 3D-analyses of state variables including fractional cloud cover and precipitation.

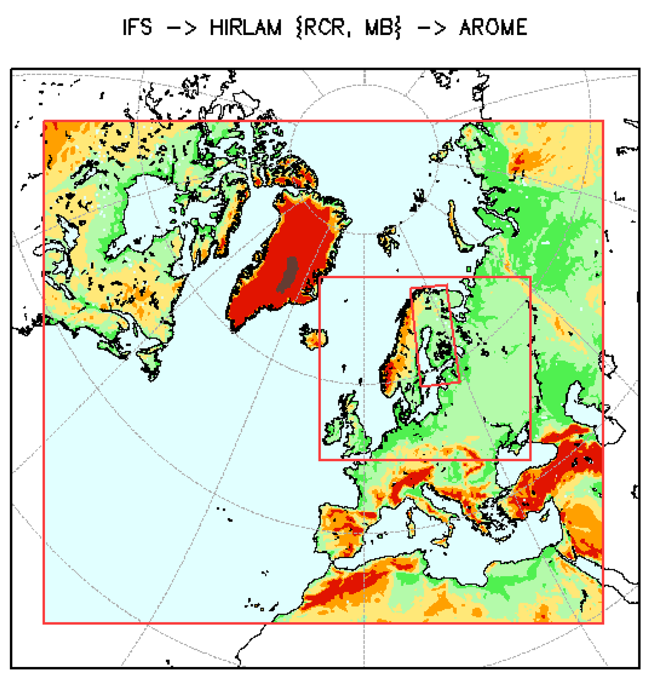

Figure 1. Operational domains in use at FMI

Numerical weather predictions provide guidance to duty forecasters, but they are also used as input to numerous automatic down stream applications forecasting road conditions, river discharge and flood risk, air quality, actual or potential dispersion of pollutants, concentration of allergenic pollen, sea waves, icing of ships or air craft, drifting of objects or oil spills, et. c.

Table 1. Details of the HFS reference system (HIRLAM 7.2) as implemented at FMI on the large domain (RCR).

Analysis		Forecast model	
Upper air analysis	4-dimensional variational data assimilation	**Forecast model**	Limited area grid point model
Version	HIRLAM 7.2	Version	HIRLAM 7.2
Parameters	surface pressure, wind components, temperature,	Basic equations	Primitive equations
	specific humidity		
Horizontal grid length	0.15 degrees on rotated lat-lon grid	Independent variables	longitude, latitude, hybrid level, time
Domain	582 x 448 grid points	Dependent variables	surface pressure, temperature, wind components
Levels	60 hybrid levels		sp. humidity, sp. cloud condensate, turbulent kinetic energy
Observation types	TEMP, PILOT, SYNOP, SHIP, BUOY, AIREP, AMDAR,	Horizontal grid	Arakawa-C
	ATOVS AMSU-A over sea	Horizontal grid length	0.15 degrees on rotated lat-lon grid
Background	3 h forecast from previous cycle	Integration domain	582 x 448 grid points
Assimilation window	6 hours	Levels	60 hybrid levels
Observation windows	1 hour	Integration scheme	Semi-Lagrangean semi-implicit, time step 360 s.
Data cut-off time	2 h for main cycles, 4 h 20 min for the re-analysis cycles	Orography	Hirlam physiographic data base, filtered
Assimilation cycle	6 h cycle, reanalysis step every 6 h to blend with large-scale	Physics	* Savijärvi radiation scheme
	features of the ECMWF analysis.		* Turbulence based on turbulent kinetic energy
Surface analysis	Separate analysis, consistent with the mosaic approach of the		* Rasch-Kristjansson condensation scheme
	surface/soil treatment		* Kain-Fritsch convection scheme
	* sea surface temperature, fraction of ice		* Surface fluxes according to drag formulation
	* snow depth		* Surface and soil processes using mosaic approach
	* screen level temperature and humidity	Horizontal diffusion	Implicit fourth order
	* soil temperature and moisture in two layers	Forecast length	54 hours
		Output frequency	Hourly
		Boundaries	* "Frame" boundaries from the ECMWF optional BC runs
			* Projected onto the HIRLAM grid at ECMWF
			* Boundary file frequency 3 hours
			* Updated four times daily

On the smaller domain in Figure 1, (MB) an earlier Hirlam version is still in use, with 3D-VAR FGAT data assimilation and STRACO moist physics. The MB-suite runs on the same levels as RCR, but on a denser horizontal grid of 0.068 by 0.068 degrees.

Table 2. Details of the HARMONIE/AROME system applied over Finland.

AROME	
Forecast model	Non hydrostatic limited area spectral model
Version	HARMONIE cycle35h1
Basic equations	Laprise-type compressible dynamic equations
Independent variables	Bi-fourier wave numbers, hybrid level, time
Dependent variables	horizontal wind vector, vertical divergence, non hydrostatic pressure departure,
	temperature, specific humidity, 5 species of condensed water, cloud cover, TKE
Horizontal discretizatio	bi-Fourier spectral transform method
Horizontal grid length	2.5 km
Integration domain	300 x 600 grid points
Levels	60 hybrid levels
Integration scheme	Semi-Lagrangean semi-implicit, time step 60 s.
Physics	* ICE3 cloud microphysics and precipitation scheme
	* Turbulence based on turbulent kinetic energy
	* EDKF shallow convection
	* RRTM/FM radiation scheme
	* SURFEX surface module with CANOPY scheme
	* ECOCLIMAP surface physiographies
Horizontal diffusion	linear spectral diffusion

All operational computing and data handling are controlled by the SMS system monitoring and scheduling software, produced and maintained by the ECMWF.

Computing and data handling

The operational forecasts are produced in-house on a system of two identical Cray XT5m clusters:

- •Peak performance 17.3 TFlop/s for each, ca 35 Tflops/s total
- •Hex-core AMD Opteron 2.2GHz Istanbul chip
  - •12 (= 2 x 6) cores in a shared memory node
  - •8.8 GFlop/s peak per core, 105.6 Gflop/s peak per node1
  - •64 nodes x 12 cores = 1968 cores per each cluster
  - •16 GB shared memory per node (~1.3GB per core)
- •2D-torus SeaStar-1 interconnection network
- •Local Lustre file-system on each cluster: 2 X 60TB raw == 2 X 43TB formatted
- •Suse Linux operating system
- •PBS batch job control

A cycle of the HIRLAM RCR suite is ready in about one hour, with 45 minutes for the 4D-VAR analysis on 90 cores, and 12 minutes for the forecast on 484 cores. The independent HIRLAM MB cycle is run simultaneously with HIRLAM RCR.

A 24-hour forecast of the HARMONIE/AROME suite takes about 30 minutes using 625 cores. CSC – IT Center for Science Ltd.,(Espoo, Finland) was responsible for migrating and optimizing AROME to the Cray XT5. A substantial reduction in elapsed time was achieved by using multi-way OpenMP and weakly asynchronous I/O , as well as a reduction in the output frequency of SURFEX fields (Fig. 2)

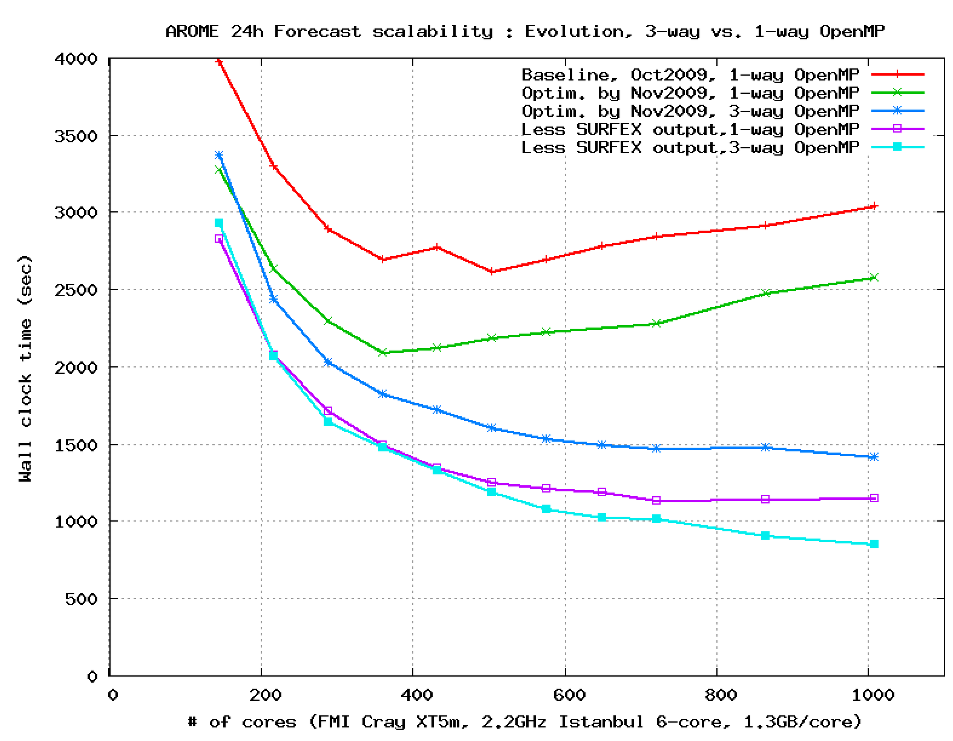

Figure 2. Elapsed time as a function of number of cores for a 24-hour forecast of the FMI HARMONIE/AROME suite. From: Niemelä, S., N. Sokka, and S. Saarinen: AROME forecast migration & optimization at FMI, HIRLAM all staff meeting in Krakow, 13-16 April 2010, www.cnrm.meteo.fr/aladin/spip.php?action=autoriser&arg=1594 .

20 years of HIRLAM

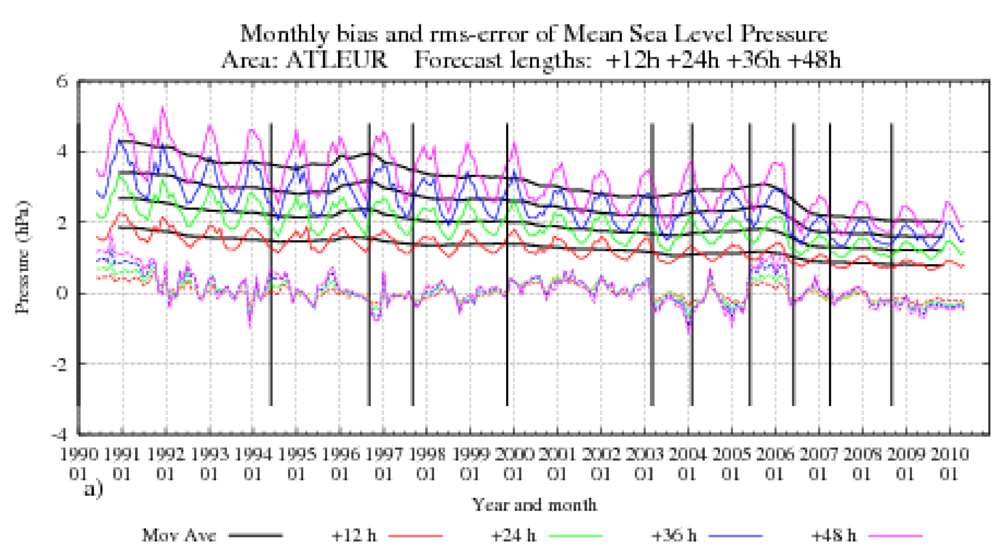

Figure 3. Monthly bias and rms-error values of mean sea level pressure in the FMI Hirlam forecasts from June 1990 to December 2009. The scores of +12, +24and +48 hours' forecasts are shown for the Atlantic-European area. The vertical lines show the implementation times of new versions and thick black curve is a 12 months' moving average.

Name	Period	nx *ny	Dx	Nlev	Version	Remarks
FIN	1990-94	130 x 100	0.5	16	Hirlam 1	31 levs from 1992
SFI	1994-96	130 x 100	0.5	31	Hirlam 2	Savijärvi radiation New physiography
NSF	1996-97	194 x 140	0.4	31	Hirlam 2.1	
ATL	1997-99	194 x 140	0.4	31	Hirlam 2.5	
ATA	1999-03	194 x 140	0.4	31	Hirlam 4.6.2	CBR turbulence ECMWF bdires 4 time daily
ATX	2003-04	256 x 186	0.3	40	Hirlam 5.1.4	3D-VAR, ISBA Semi-Lagrangian adv.ection
V621	2004-05	436 x 336	0.2	40	Hirlam 6.3	FGAT, 1st RCR
V637	2005-06	438 x 336	0.2	40	Hirlam 6.4	Turning of the surface stress vector
V641	2006-07	438 x 336	0.2	40	Hirlam 7.0	LSMIX concept
V71	2007-08	583 x 448	0.15	60	Hirlam 7.1	
V72	2008-	538 x 448	0.15	60	Hirlam 7.2	4D-VAR

TABLE 3. HIRLAM suites covering the North Atlantic-European sector.

The HIRLAM forecasting system has been in service at FMI since the beginning of 1990. Table 3 gives a list of models suites providing forecasts for the North Atlantic and Europe over the past 20 years, hinting at a tremendous development in resolution and meteorological sophistication. Figure 3 shows how the forecast error in the surface pressure field has evolved in response