

REQUEST FOR A SPECIAL PROJECT 2012–2014

MEMBER STATE: Norway

Principal Investigator¹: Trond Iversen
HIRLAM-B Project Leader for probabilistic forecasting

Affiliation: Norwegian Meteorological Institute

Address: P.O.Box 43, Blindern
0313 Oslo,
Norway
(My office is at present at ECMWF, but I work for met.no and Hirlam in this capacity.)

E-mail: trond.iversen@met.no

Other researchers: Kai Sattler, Inger-Lise Frogner, Jan Barkmeijer, Jose A. Garcia Moya, Carlos Santos, Ole Vignes, Alex Deckmyn, Henrik Feddersen, Åke Johansson, Jelena Bojarova, John Bjørnar Bremnes, AlastairMcKinstry, Sibbo vander Veen, Kees Kok, Geert Smet, Jørn Kristiansen, Lisa Bengtson, Xiaohua Yang

Project Title: **Hirlam - Aladin Probabilistic Systems:**
(Proposed acronym: SPNO HAPS)
(This is a follow-up of SPNO GEPS)

If this is a continuation of an existing project, please state the computer project account assigned previously.	SP _____	
Starting year: <small>(Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)</small>	2012	
Would you accept support for 1 year only, if necessary?	YES <input type="checkbox"/>	NO <input checked="" type="checkbox"/>

Computer resources required for 2012-2014: <small>(The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2014.)</small>	2012	2013	2014
High Performance Computing Facility (units)	8000000	8000000	8000000
Data storage capacity (total archive volume) (gigabytes)	50000	50000	50000

An electronic copy of this form **must be sent** via e-mail to: *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date): **28/04/2011**

Continue overleaf

¹ The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide an annual progress report of the project's activities, etc.

Principal Investigator: Prof. Trond Iversen
Project Title: SPNOHAPS (proposed title):
Hirlam - Aladin Probabilistic Systems

Extended abstract

Background

This proposed project is a follow-up of the GLAMEPS-project (SPNOGEPS) that ends during 2011. The user *zno* should be transferred to this project from SPNOGEPS provided the present proposal is supported.

The project utilizes strong competence in the Eumetnet SRNWP consortia Hirlam and Aladin for maintaining and developing probabilistic forecast capabilities for the short (up to ~60h) and very short (up to ~24h) forecast ranges in Europe. These plans are included in scientific plans for the next 3-5 years and the annual work plans. Both Hirlam and Aladin have recently entered into new phases. Probabilistic prediction in the short and very short ranges is a prominent component of the two consortia.

It is therefore emphasized that even though the present application is made on behalf of the Norwegian Meteorological Institute (met.no) and Norway, the entire project is applied for on behalf of all the member states in the two consortia. The proposed principal investigator (Trond Iversen) is the Hirlam project leader for probabilistic predictions and has led the development of GLAMEPS over the latter 4-5 years.

The development of probabilistic forecasting in Hirlam / Aladin presently consists of the elements:

Activity 1. Preparing for and establishing an operational pan-European *GLAMEPS_v1* for the short range, run as a Time-critical facility (TCF) Option 2 (TCF_2) at ECMWF;

Activity 2. Experimenting with options for extensions of GLAMEPS for upgrading to a second version (*GLAMEPS_v2*);

Activity 3. Experimenting scientifically and technically with ensembles of non-hydrostatic modelling with convection-permitting resolution (*HarmonEPS*) for the very short range in sub-European domains.

At present stage work is progressing on the activities 1 and 2 with support from SPNOGEPS and additional national resources. GLAMEPS is set up for producing a 51-member hydrostatic multi-model EPS on a pan-European integration domain for 54h forecasts with grid mesh width around 11 km. Work on task 3 has barely started by establishing script systems for running the non-hydrostatic Harmonie model with different choices of physical packages on sub-European domains up to 30h.

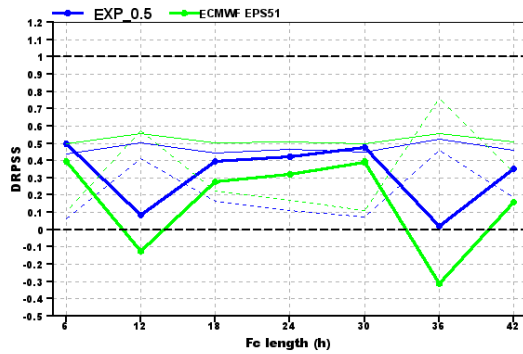
Activity 1: GLAMEPS_v1

The Grand Limited Area Modeling Ensemble Prediction System (GLAMEPS) is intended for operational production as a part of the cooperation between two European consortia for short-range NWP: High Resolution Limited Area Modeling (HIRLAM) and Aire Limitée Adaptation dynamique développement International (ALADIN). It aims at predicting atmospheric features on spatial scales intermediate between the synoptic, covered by leading global EPS, and the convection-permitting scales.

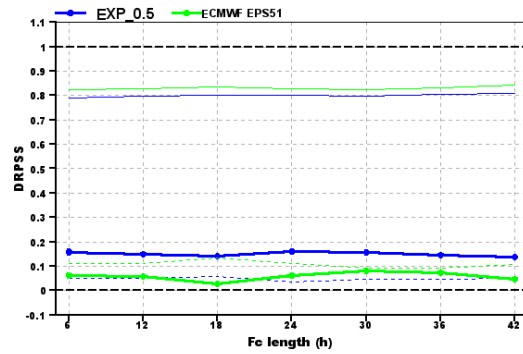
The challenge is to construct a well-calibrated, pan-European ensemble for short-range NWP by accounting for both initial state and model inaccuracies. Model uncertainties are presently taken into account by using a small number of different models and versions. Initial state uncertainties are taken into account in two ways. Ensemble perturbations are imported from the global ECMWF 51-member EPS. This system also provides perturbations at the lateral boundaries during the prediction period. Additional initial state perturbations are included by running three different assimilation cycles in parallel with different models and model versions, but without perturbing the observations.

Since March 2010, a test version of GLAMEPS ("version 0") has been run twice daily, using data from the operational EPS at resolution T639L62 at lateral boundaries. This was done as a follow-up of the relatively successful development of the first set of calibration experiments made on historical data over a seven-week period in winter 2009 (Iversen et al., 2011). In these experiments it was shown that the multi-model approach in GLAMEPS is an important element which benefits the probabilistic forecast quality compared to single-model ensembles of the same size. The benefits of taking lateral boundary data from a version of the global EPS which is enhanced with singular vector-based perturbations which are targeted to Europe (EuroTEPS, Frogner and Iversen, 2011), is considerably smaller, and have reduced further after the upgrades of the operational EPS with higher resolution and ensemble data assimilation (Frogner, 2011).

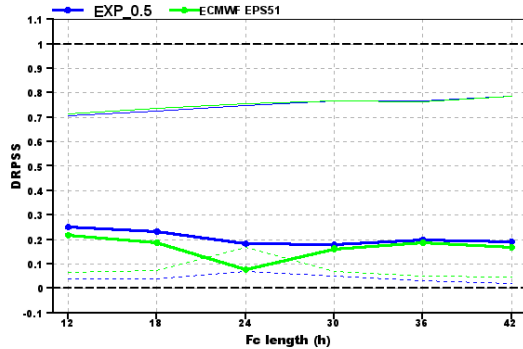
Based on the body of experimental results, we have decided to build *a first operational GLAMEPS_v1* which is multi-model, pan-European, and uses all the ensemble members of the operational



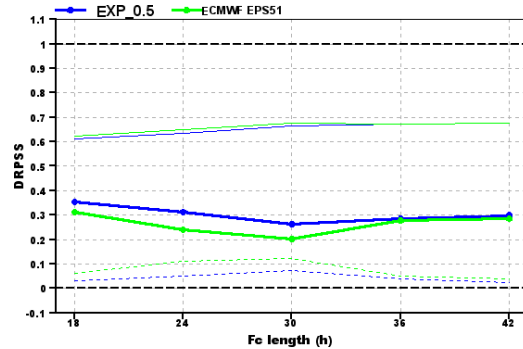
DPRSS for T2m as a function of forecast lead time for test-operational GLAMEPS_v0 (blue) and operational ECMWF EPS (green) for the months August-October 2010. Thin lines are decompositions into reliability (Rel) (dashed) and resolution (Res) (continuous). $DPRSS = 1 - Rel - Res$.



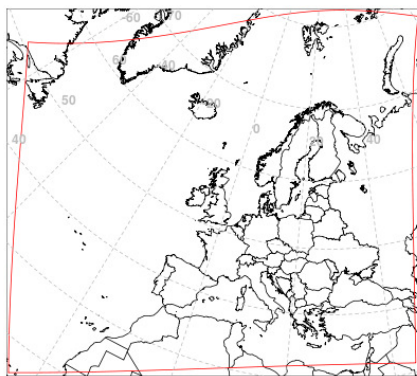
DPRSS for wind10m as a function of forecast lead time for test-operational GLAMEPS_v0 (blue) and operational ECMWF EPS (green) for the months August-October 2010. Thin lines are decompositions into reliability (Rel) (dashed) and resolution (Res) (continuous). $DPRSS = 1 - Rel - Res$.



DPRSS for Prec6h as a function of forecast lead time for test-operational GLAMEPS_v0 (blue) and operational ECMWF EPS (green) for the months August-October 2010. Thin lines are decompositions into reliability (Rel) (dashed) and resolution (Res) (continuous). $DPRSS = 1 - Rel - Res$.



DPRSS for Prec12h as a function of forecast lead time for test-operational GLAMEPS_v0 (blue) and operational ECMWF EPS (green) for the months August-October 2010. Thin lines are decompositions into reliability (Rel) (dashed) and resolution (Res) (continuous). $DPRSS = 1 - Rel - Res$.

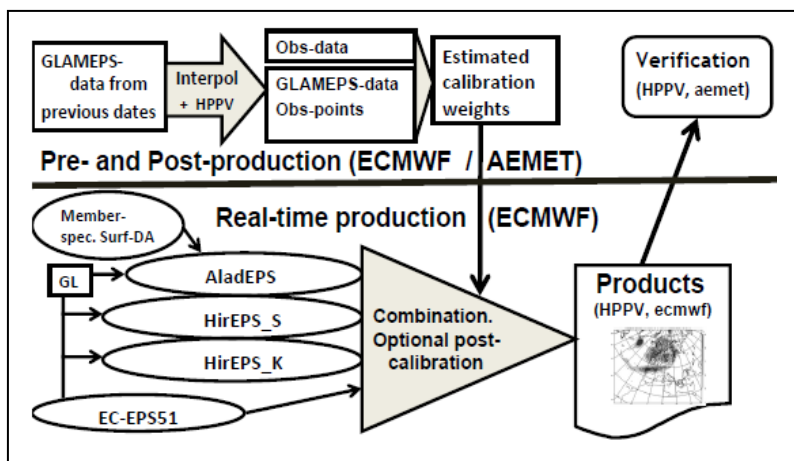


Aladin-domain (Black): Lambert conical grid
 clonlat=(-4.4,54.9), (nx,ny)=(629,529),
 dxdy=11.8km, reflat=43, reflon=28
Hirlam-domain (Red): Rotated lat-lon
 NLON=646, NLAT=492, d=0.10deg,
 POLON=30, POLAT= -46;
 (SO,WE,NO,EA) = (-11.5,-52.4,37.6,12.1).

ECMWF EPS. A three-month verification of the “version 0” shows considerable improvements over the upgraded ECMWF EPS for the first 42h, see the figures above.

We have therefore decided to build GLAMEPS_v1 on this system as a TCF_Option 2 at ECMWF. Main responsible for constructing the script system (SMS) is Kai Sattler at DMI with support from Ales Deckmyn (RMI) and Carlos Santos (AEMET). A discussion meeting was arranged with Umberto Modigliani and Dominique Lucas at ECMWF in November 2010 to prepare for the operational requirements as well other technical issues. Kai Sattler also writes a documentation of the script system. The progress with the script system is slightly delayed to extra work mainly associated quality assurance for upgraded model versions, set-up of surface data-assimilation, new model domains (see figure to the left), new selection of lateral boundary data, switching to 06 and 18 utc, switching from mini-SMS to SMS for Hirlam, and introducing grib2. The model versions planned for are Aladin cy36t1 and Hirlam 7.3 with some extensions. Both model versions run on single nodes at c1a per ensemble member with the specified domains.

The flow-chart below sketches the planned production and evaluation procedures for this first version intended as a TCF_Option 2. The strict real-time production flow is sketched below the horizontal line, while the processes above are not strictly time-critical and will be made independently of the production schedule. The real-time production flow can start as soon as the operational 51-member EPS is ready. Normally, the scheduling at ECMWF will only allow GLAMEPS to start around 8 hours after the main observation times at 00 and 12 utc.



The two Hirlam control forecasts (HirEPS_K and HirEPS_S are EPS from two Hirlam model versions with different cloud physics formulations) are produced starting with analyses from two separate data-assimilation cycles without perturbing observations. Since observations from 06 and 18 utc (respectively) will be available at the time GLAMEPS production can start, we will start the forecasts from those time (06 and 18), even if the perturbations at the lateral boundaries and at the initial time will be 6 hours older, and thus have higher amplitudes, than if started from 00 and 12 utc.

AladEPS is an EPS produced by downscaling global ensemble members with the Aladin model, i.e. no atmospheric data-assimilation is run for a separate Aladin control forecast. The software GL prepares the interface between atmospheric data from EC-EPS51 in model levels and the Aladin model. Surface data can not be provided in the same manner to Aladin, so initial data for the surface model in Aladin. It is planned to use the Extended Kalman Filter in Canari together with Canari, and that one separate surface analysis is made for each ensemble member produced by Aladin for AladEPS.

In order to make use of all 51 ensemble members from EC-EPS51, we plan to let each model version run on control + 12 unique ensemble members (HirEPS_S: members 00+01-12; HirEPS_K: members 00+13-24; AladEPS: members 00+25-36) and add the remaining 14 members (37-50) unchanged to the total ensemble set when making products. Notice that member 00 means a downscaling in the case of AladEPS, but boundary-data for two different Hirlam-specific control forecasts in the case of HirEPS_S and HirEPS_K. In total there will then be 53 ensemble members, including the Aladin-downscaled control and the two Hirlam controls.

For GLAMEPS_v1, there are at present no plans for a post-processed calibration. Preliminary tests with Bayesian Model Averaging (BMA) applied simultaneously over all observation sites in Europe do show slightly improved performance for normally occurring weather events. For extreme events, however, the negative impacts of not employing spatially inhomogeneous statistics become evident. Further experimentation is therefore planned for before any operational implementation, and in GLAMEPS_v1 we simply add all ensemble members together and make products directly with the Hppv-software developed at AEMET (Carlos Santos).

At present Hppv is also designed for probabilistic verification, but run at AEMET for the time being. Data relevant for verification are then submitted to AEMET immediately after they are produced. Daily contributions to probabilistic verification statistics is made, thus enabling a quick synthesis over periods like months, seasons, or years. The three-month verification shown above is made with Hppv.

Production and experiments. As soon as the model versions, all ingredients in the production suite, and the SMS scripts are ready, the TCF_Option 2 should start as soon as permitted by ECMWF. The computer system billing units will be taken from national allocations from Hirlam and Aladin countries.

In addition we plan to run an experimental production, *EXP_1.1*, in hindcast mode for two months in summer 2010 and to months in winter 2010-11. Data from EC-EPS51 with resolution T639L62 and with ensemble data assimilation (EDA) have already been prepared for these periods, since we plan to run selected further calibration experiments for potential GLAMEPS upgrades and for convection-permitting ensembles (see Activities 2 and 3 below). The basis for evaluating the new calibration experiments will be the runs with GLAMEPS_v1 as well as EC-EPS51 (and possibly other short-range EPS when available).

Activity 2: preparing for GLAMEPS_v2

Research and development for potentially further improved GLAMEPS without changing the resolution and keeping the pan-European scope gas already been made over the last 3-4 years. These activities are,

however, presently not sufficiently mature for including in GLAMEPS_v1, and further configuration experimentation in hindcast mode with a realistic setting compared to GLAMEPS_v2, is needed. There are several possible configuration experiments, and the details will have to await further decisions based on analysis of existing preliminary tests and further experience. The four proposals mentioned here are presently viewed as likely to be followed up, but amendments are possible. They will successively be numbered EXP_2.x, where x=1,2,3,... Experiments will predominantly be made for the prepared periods in summer 2010 or winter 2010-11. Additional experiments that test out ideas more *ad hoc* will normally be necessary before full-scale configuration experiments.

- **Calibration** The post-process calibration is under re-consideration, leaving the BMA-track (at least for the moment). R-scripts that read observations and model data (from Hppv) interpolated to stations for calibration purposes have been updated. The size of training data in R is about 1 MB for each point in time and parameter, i.e. training periods of a couple of months will hopefully be ok in terms of memory allocation at ecgate. A linear mixed model has been implemented to estimate linear calibration functions at all stations and models. The idea is that the model climatology should approximately equal the observed climatology. It is unclear how to best interpolate the calibration function parameters to a grid in order to compute calibrated members. The use of extended logistic regression (also used at knmi) has also been explored. Computationally it is far faster and also more robust than BMA. Calibration experiments in post-process mode do not require running new full ensembles, but it is unclear to what extent it will be useful run at supercomputers (in stead of ECGATE).
- **Blending with higher-resolution forecasts.** At present, GLAMEPS does not utilize the information provided by the high-resolution (T1279L92) deterministic forecast produced at ECMWF. This information could be exploited in several ways. The simplest would be to add the deterministic forecast as an extra ensemble member, with or without post-processing calibration. A slightly more advanced approach would be to use the deterministic forecast as boundary data for the control forecasts, i.e. switch member no. 00 mentioned above with the deterministic forecast. An even further approach could be to use the deterministic forecast also with a 12h time-lag, and to use these as boundary conditions for e.g. 4km versions of one or several of the model versions. The purpose of this is to obtain predictable components of the higher-resolution flows with particular emphasis on high-impact weather.
- **Blending with ETKF or ETKF-Hybrid.** Experiments on these aspects have so far proven promising in the sense that perturbations that are directly related to present analysis uncertainties are taken into account. Preliminary experiments show improvements in ensemble spread during the first 12-24h of the forecasts. Experiments have tentatively also been made in which the ensemble is used to estimate the actual flow dependant model error covariance matrix to be used in the 3D-Var analysis for Hirlam. This is called ETKF-Hybrid. Preliminary experiments have only been made with 12+1 ensemble members, and blending between ETKF-perturbations and EC-EPS51 boundary data are implemented.
- **Blending with Hirlam CAPE singular vectors.** Preliminary experiments have been made to calculate ensemble perturbations based on Hirlam Singular Vectors that maximize convective available potential energy over a target domain after 12h (CAPE SVs). The first set-up is soon ready for a full-scale testing of the inclusion of CAPE SVs in both Hirlam-versions. However, more work is needed on the blending of CAPE SVs with EPS boundary data.

Activity 3: HarmonEPS, convection-permitting EPS

HarmonEPS is the name of one or several ensemble prediction systems for the very short range (<30h) on so-called convection-permitting scales. The basic model tool will be a non-hydrostatic Harmonie with either Alaro or Arome physics, depending on the grid-mesh width that can be afforded. Harmonie is a name representing a range of model systems. In this case, it addresses the convection-permitting (~2 - ~4km).

The development towards a cloud-permitting, meso-scale model system (Harmonie) has had considerable progress, and the plan is to start the development of a prototype system for HarmonEPS. Experiments will be done on a few selected sub-European domains, thus gaining experience that can eventually lead to a prototype system that member countries can install at their home computers for their own purpose. Some experience has been gained in a few HIRLAM and ALADIN member countries, as well as in other European consortia, but a lot more is necessary, e.g. to develop in order to develop close links to meso-scale data assimilation, physics parameterizations, and the description of the land surface.

Given the need for urgent products in real time, it is not envisaged that HarmonEPS should rely on a double nesting strategy (EPS → GLAMEPS → HarmonEPS). An important element of the development of feasible solutions for HarmonEPS will therefore be to prepare the proper boundary data for Harmonie. A

~16km resolution global EPS, could be an adequate solution for a first version of HarmonEPS which basically will be a dynamical downscaling. A range of predictability studies will be made in order to study the predictability as a function of spatial scale, as well as more technical issues like finding a proper balance between the range of forecast lead time, domain size, ensemble size, and spatial resolution.

Preparatory activities have started by making a script system for running Harmonie in ensemble mode. The next step will be to select a few integration domains. But before any runs can be made, global ensemble data are needed for downscaling. Activities have started in connection with the SRNWP expert team on short-range EPS. Martin Leutbecher at ECMWF is in the process of generating some test-data that will have the required resolution for the first 1-2 days. It is expected that more experiments will be needed on this subject, and we plan to develop some alternative data-sets. Harmonie has also been equipped with the possibility to calculate singular vectors, which will be useful in connection with predictability studies.

It is expected that first longer-term configuration experiments with HarmonEPS will start early in 2012. First experiments will tentatively be made by permuting model set-ups as follows:

1. Two model domains designed for the same area of interest
 - a. large (still regionally sub-European)
 - b. small (minimum size for 24h forecasts)
2. Two grid resolutions with three different set-ups for model physics
 - a. ~4km with Alaro
 - b. ~2km with Alaro
 - c. ~2km with Arome
3. Two different choices for ensemble size, choice depending on available boundary data, e.g.
 - a. 12+1 (incl. 6 out of 10 EDA-perturbations)
 - b. 20+1 (incl. a full set of 10 EDA-perturbations)

The forecasts will be downscaling of ~16km EPS from ECMWF, with maximum 20+1 ensemble members with lead-time up to 24h.

This may produce up to 12 configurations for HarmonEPS, but it is unlikely that all combinations will be run. We need to determine the actual cost before we can decide exactly which sub-selections to choose. The following combinations should be a minimum:

- EXP_resolution: (1a,2a,3a) compared to (1a,2b,3a)
- EXP_domain: (1a,2a,3a) compared to (1b,2a,3a)
- EXP_physics: (1a,2b,3a) compared to (1a,2c,3a).
This experiment will also investigate the benefits of combining Alaro and Arome in one ensemble.
- EXP_ensemble: (1a,2a,3a) compared to (1a,2a,3b)

This requires 4 separate experiments as opposed to all 12. Nevertheless this may be too costly to perform within one single year. In addition we would wish to make one combination that should provide a benchmark for any of the experiments:

- EXP_benchmark: (1a,2b&2c,3b), where 2b&2c is Alaro and Arome combined.

Next steps after the above experiments are done, will be to develop Harmonie-specific analyses including initial state perturbations. This should be done in close co-operation with those developing data-assimilation for Harmonie. Likewise, perturbations of model tendencies and the lower boundary surface parameters should be made in close contact with the relevant experts in those areas. All in all, considerable experimentation will be needed, involving high forecast frequency (Rapid Update Cycling). Tools that are easy to use to obtain basic diagnosis of forecast quality are essential, with an emphasis on weather elements relevant for the meso-scale. Further details concerning these next steps will be described in later applications for continuation of the proposed project.

In Summary

We hope to start operational GLAMEPS_v1, paid by national SBUs. Estimated requirement is 12-14 MSBUs per year. The first 6-12 months will be a test-period in which we expect to make adjustments as further experience is gained. For EXP_1.1 and the proposed EXP_2.x in hindcast mode, a major part of the costs will need to be taken from this project. 4-5 MSBUs per year is expected. The remaining 3-4 MSBUs applied for will be allocated to the HarmonEPS experiments, including possible need for generating high-resolution (~16km) EPS or EurpTEPS as driving conditions for HarmonEPS.

Storage. From previous GLAMEPS experiments the experience is that access to a fast-access disk system is necessary in order to be able to make realistic configuration experiments. Experiments need to be made over at least a few weeks, and it must be possible to test a few configurations more or less simultaneously. Disk-space up to 10 TB is needed.