# JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2013

**Switzerland**

## 1. Summary of highlights

* A number of specific model applications based on the high resolution numerical weather prediction model COSMO are operated at MeteoSwiss. For example CN-MET, which is an integrated analysis and forecasting system providing meteorological information for dispersion calculations in the case of an accident in a nuclear power plant. As the planetary boundary layer (PBL) height is a crucial parameter in the dispersion calculation, the PBL height estimates of the COSMO-2 model have been extensively validated against observations
* A model relating solar UV radiation at the surface to human UV exposure was used in a study to estimate the contribution of work-related solar UV exposure to skin cancer, and was further developed to be used with more readily available source of information for the UV radiation.

## 2. Equipment in use

MeteoSwiss continued its strategy towards Linux for application servers. Therefore, the number of Solaris based installations decreased to 120 server installations, while RedHat (12 servers) and Ubuntu installations (30 servers) increased.

The server Hardware consists of SPARC Enterprise M-Series servers, and HP Blade and new Cisco UCS for both Linux and Windows based servers. Virtualization of servers continues, using VMware for Linux and Windows. We use Hitachi based SAN/NAS for storage.

A few still remaining Solaris based workstations were replaced and virtualized in 2013, centralizing them into the data centre in Zurich. Also, the majority of the workstations were migrated to Linux.

Ubuntu 12.04 LTS is the preferred Linux distribution - we think about skipping version 14 LTS, and to wait until version 16 LTS is available. As for RedHat, we use RedHat Enterprise Linux 6. Sun Solaris 10 is still in use for legacy applications, like e. g. the Data Warehouse, which is based on Oracle Database (11gR2). Windows Servers are on 2008 R2, and new installations on Windows Server 2012. SCCM 2012 is used for client SW deployment. operating system level.

All workplace machines are based on Windows 7 SP1, along with MS Office 2010. Starting in late 2013, all new installations are x64 based. Starting in 2013, PC’s normally get replaced by notebooks. We switched from Dell laptops to now HP laptops. As of now, there are no plans for Windows 8.1, nor Office 2013. Access to Solaris and Linux machines from client PC’s is via X-Windows, using Xmanager and/or X2go.

In 2013, MeteoSwiss successfully deployed 2 factor (smartcard) authentication to the entire user population, so all users now login with smartcards (enforced) and a PIN.

Application middleware is mainly based on Oracle Weblogic, migration to 12.4c will happen in 2014. We use Informatica PowerCenter as ETL tool. Icinga is used as open source monitoring tool, and BMC ARS Remedy workflow tool V. 8.0 for incidents and probelms.

Network equipment is based on mainly Cisco products.

The Swiss Government decided in late 2013, that office automation must to be transferred to a central (governmental) provider by 2018 at the latest, and network provisioning by end of 2014.

MeteoSwiss plans to transfer its datacentre to the MeteoSwiss location at Zürich Airport in late 2014, early 2015. Transfer is planned to happen without service interruption for the critical applications.

## 3. Data and Products from GTS in use

AUTHOR: ESTELLE GRÜTER

At present nearly all observational data from GTS are used. Further in use are GRIB data from Bracknell, Washington and Offenbach as well as T4-charts from Bracknell and Washington. Additionally most of MOTNE and OPMET data are used as well.

The number of incoming messages of the majority of the different types were about the same as last year. An slight increase can be reported for DRIFTER, METAR and AIREP/AMDAR messages, while the number of T4, BATHY/TESAC has decreased slightly, GRIB, TEMP and PILOT even to a remarkable amount.

Typical figures on message input for 24 hours are:

SYNOP, SYNOP Ship 32337

TEMP Part A + B 3309

PILOT Part A + B 1193

METAR 168751

TAF short/long 51595

AIREP/AMDAR 35211

GRIB 10551

T4 (BUFR, FAXG3) 25844

BATHY/TESAC 5146

DRIFTER 18090

## 4. Forecasting system

## 4.1 System run schedule and forecast ranges

In the operational forecasting service of MeteoSwiss several numerical models are used, depended on the forecasting range. For the very short range Cosmo-2 (non-hydrostatic) and Cosmo-7 (hydrostatic) are available. Cosmo-2 has a horizontal resolution of 2.2 km and Cosmo-7 has 6.6 km. Cosmo-7 is driven by the IFS (Boundary conditions) of ECMWF. Cosmo-2 is nested in Cosmo-7. Cosmo-7 runs three times a day, based on the 00, 06 and 12 UTC boundary conditions. Cosmo-2 has a lead time of 33 h, respectively 45 h for the 03 UTC run.

For the medium range forecasts and in part also for the short range the IFS of ECMWF with the high resolution model HRES and the ensemble system ENS are mainly used. Additionally the IFS results are compared with the American model GFS and the German model GME.

Furthermore the forecasters have access to post processed data like MOS (MOSMIX by DWD) and INCA by ZAMG.

For the interpretation by the forecasters the model data are presented with the visualization system Ninjo (developed by a consortium of several meteorological services). In addition the Cosmo fields can be visualized with a browser tool, and the ECMWF fields with ecCharts (an ECMWF webtool).

In the case of an incident the forecasters can start trajectory and diffusion calculations. For trajectories the so called Lagranto model provides calculations with input data of Cosmo-2, Cosmo-7 and ECMWF. And similar for diffusions there’s the Flexpart model based on Cosmo-2, Cosmo-7 and ECMWF input data. Additionally NOAA hysplit model results are available.

## 4.2 Medium range forecasting system (4-10 days)

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## 4.2.1 Data assimilation, objective analysis and initialization

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## 4.2.1.1 In operation

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## 4.2.1.2 Research performed in this field

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## 4.2.2 Model

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## 4.2.2.1 In operation

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## 4.2.2.2 Research performed in this field

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## 4.2.3 Operationally available Numerical Weather Prediction Products

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## 4.2.4 Operational techniques for application of NWP products (MOS, PPM, KF, Expert Systems, etc..)

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## 4.2.4.1 In operation

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## 4.2.4.2 Research performed in this field

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## 4.2.5 Ensemble Prediction System (EPS)

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## 4.2.5.1 In operation

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## 4.2.5.2 Research performed in this field

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## 4.2.5.3 Operationally available EPS Products

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## 4.3 Short-range forecasting system (0-72 hrs)

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## 4.3.1 Data assimilation, objective analysis and initialization

## 4.3.1.1 In operation

Data assimilation of COSMO is based on the nudging or Newtonian relaxation method, where the atmospheric fields are forced towards direct observations at the observation time. Balance terms are also included: (1) hydrostatic temperature increments balancing near-surface pressure analysis increments, (2) geostrophic wind increments balancing near-surface pressure analysis increments, (3) upper-air pressure increments balancing total analysis increments hydrostatically. A simple quality control using observation increments thresholds is in action.

Following conventional observations are currently assimilated both for COSMO-7 and COSMO-2: synop/ship/buoys (surface pressure, 2m humidity, 10m wind for stations below 100 m above msl), temp/pilot (wind, temperature and humidity profiles), airep/amdar (wind, temperature) and wind profiler data. COSMO-2 additionally assimilates radar data, using the 2-dimension latent heat nudging scheme. An empirical quality function for radar quantitative precipitation estimates is in operation, which is based on the frequency of signal occurrence of a particular radar pixel (D. Leuenberger et al, 2010, and references therein).

MeteoSwiss uses its own snow analysis which is derived from MSG satellites combined with dense observations. A multi-layer soil model with 8 layers for energy and 6 for moisture is used. Finally, the vegetation and ozone fields are based on climatic values.

The MeteoSwiss Data Warehouse (DWH) is the operational data base for conventional observations. Data from DWH is retrieved at CSCS in BUFR format, and converted to the NetCDF format with the bufrx2netcdf software of DWD. The number of assimilated conventional observations is monitored.

## 4.3.1.2 Research performed in this field

An ensemble based data assimilation system with a convection-permitting mesh-size of about 2 km is in development in the framework of the MeteoSwiss project “COSMO-NExT”. The data assimilation system employs a Local Ensemble Transform Kalman Filter (LETKF) and will use about 40 members for the first guess ensemble. The data assimilation system will provide the initial data for an ensemble forecasting system (COSMO-E) at the same resolution as well as a deterministic forecast (COSMO-1) at 1 km mesh-size. It will also provide the initial condition perturbations for COSMO-E,

## 4.3.2 Model

## 4.3.2.1 In operation

A thorough description of the COSMO Model itself can be found on the COSMO web site (see section 7.1). It is a primitive equation model, non-hydrostatic, fully compressible, with no scale approximations. The prognostic variables both for COSMO-7 and COSMO-2 are the pressure perturbation, the Cartesian wind components, the temperature, the specific humidity, the liquid water content, cloud ice, rain, snow and turbulent kinetic energy. COSMO-2 furthermore uses a prognostic graupel (ice pellets) hydrometeor class in the microphysical parameterization. COSMO-7 uses the Tiedtke scheme to parameterize convection, whereas in COSMO-2 convection is parameterized by a shallow convection scheme, and the deep convection is explicitly computed.

The model equations are formulated on a rotated latitude/longitude Arakawa C-grid, with generalized terrain-following height coordinate and Lorenz vertical staggering. Spatial discretization is done using finite differences of at least second-order; time integration is based on a third-order Runge-Kutta split-explicit scheme. Advection of dynamic variables is performed using a fifth-order upstream discretization. Fourth-order linear horizontal diffusion with an orographic limiter is active for wind in COSMO-7 only. Rayleigh-damping is applied in the upper layers. For the advection of the humidity constituents a symmetric, Strang-splitted positive-definite advection scheme after Bott is used at each time step.

COSMO-7 is calculated on a 393 x 338 mesh with a 3/50° mesh size (about 6.6 km), on a domain covering most of Western Europe. 60 layers are implemented in the vertical, whereas the vertical resolution in the lowest 2 km of the atmosphere increases from about 10 m up to 250 m. The main time step is 60 seconds. COSMO-2 is calculated on a 520 x 350 mesh, with a 1/50° mesh size (about 2.2 km), on a domain which is centred on the Alps. The COSMO-7 mesh is chosen in such a way that on the integration domain of COSMO-2, each COSMO-7 grid point coincides with a grid point of COSMO-2. COSMO-2 uses the same vertical configuration as COSMO-7. The main time step is 20 seconds. Table 1 summarizes the specifications of the new COSMO system.

Table 1 Specification of COSMO-7 and COSMO-2

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| --- | --- | --- |
|  | COSMO-7 | COSMO-2 |
| Number of grid points and levels | 393 x 338, 60L | 520 x 350, 60L |
| Horizontal mesh size | 3/50° ~ 6.6km | 1/50° ~ 2.2km |
| Time step | 60s | 20s |
| Data Assimilation | Conv. Observations | Conv. Observations + Radar |

Since March 2011, MeteoSwiss also provides daily forecasts of birch pollen, which are based on the numerical pollen dispersion model COSMO-ART of the Karlsruhe Institute of Technology (KIT) (B. Vogel et al, 2009, and H. Vogel et al, 2008). Since spring 2012, grass pollen forecasts are also produced. COSMO-ART provides spatially and temporally highly resolved pollen forecasts hitherto not available.

## 4.3.2.2 Research performed in this field

Development of a deterministic 1 km implementation of COSMO

Many of the key physical processes of Alpine meteorology (valley winds, orographically influenced/triggered precipitation, convection, fog) remain partly unresolved in COSMO-2, which employs 2.2 km horizontal grid spacing. Apart from the canonical improvement of the resolution of topography and land-use, evidence from research (e.g. Langhans et al. 2012, Bryan et al. 2007) also suggests improvements in near-surface winds as well as convection and entailing precipitation. Thus, since beginning of 2012 and within the framework of the COSMO-NExT project, MeteoSwiss is developing a deterministic 1.1 km implementation of COSMO named COSMO-1. The domain will be similar to the COSMO-2 domain, spanning the greater Alpine region. The model will be implemented using a rapid update cycle (RUC) with a new forecast every 3h. Research currently focusses on turbulence parameterization (representation of turbulence in the “grey-zone”), improved external parameters (new datasets for topography and soil-type), as well as the tuning and validation of 1.1 km simulations against measurements in complex topography and LES (Large Eddy Simulations) references.

Redesign of the COSMO model code for future HPC architectures

The computing power available is the major constraint limiting the horizontal resolution, the complexity of the model system and the number of ensemble members. This is true for weather prediction and climate modelling. Due to the throughput of I/O subsystems, large ensembles of computing cores competing for resources such as memory and communication bandwidth allow only marginal performance improvements. In this respect, emerging supercomputing architectures such as heterogeneous computing nodes equipped with many-core GPU accelerators (Graphical Processor Units) are expected to bring breakthroughs. Accordingly, current weather prediction codes have to be updated in order to leverage such architectures.

HP2C COSMO and HP2C OPCODE, two projects carried out within the frame of the Swiss HP2C initiative (High Performance High Productivity Computing) and the COSMO priority project POMPA (Performance on Massively Parallel Architectures) aim at implementing the COSMO numerical weather prediction and regional climate model on such massively parallel multi-core machines and GPU heterogeneous systems. This code redesign shall enable a better management of the memory bandwidth, with the ability to run the same code on CPUs and GPUs, thus improving the I/O strategy.

The GPU version of COSMO, making use of compiler directives in some parts and a domain-specific embedded language (DSEL) in others, is now regularly integrated for climate research purposes on a hybrid system named Piz Daint (Cray XC30). This GPU-version of the code brings significant benefits both in terms of time-to-solution as well as in energy-to-solution for typical use-cases of the COSMO model.

## 4.3.3 Operationally available NWP products

## 4.3.4 Operational techniques for application of NWP products

## 4.3.4.1 In operation

MeteoSwiss has developed and maintains a tool called "fieldextra", aimed at producing and delivering complex packages of numerical weather forecasts. This official COSMO software is used both as a pre- and post-processing instrument on the MeteoSwiss NWP production suite.

Designed as a toolbox, robustly written and thoroughly tested, fieldextra supports the manipulation of NWP model data, especially COSMO model data, and gridded observations. Input data is read once by the execution of the software. As many outputs packages as desired can be delivered. In between, a set of operators that can be combined in any meaningful way allows the construction of the aforementioned packages. The program is controlled by a collection of Fortran name-lists, stored in a control data file. Checks are performed on user defined parameters, with a diagnostic report delivered by the end of each execution. Simple data operation, as well as demanding processing is supported. As for example, selection of data satisfying convoluted constraints, the comparison and/or merging of multiple fields, horizontal and vertical re-gridding, computation of regional conditions, stability indices or EPS derived quantities are easily performed. Both point values and gridded fields can be generated. GRIB 1, GRIB 2, NetCDF and a rich set of ASCII formats are offered. Last but not the least, a major effort is continuously devoted to the optimization of both the memory footprint and the execution time.

## 4.3.4.2 Research performed in this field

Post-processing algorithms aimed at improving local forecasts, tailored to operate on limited area NWP models with frequent version releases are developed in the frame of the “COSMO-MOS” MeteoSwiss project. Two statistical approaches are implemented so far. Firstly, multiple linear regression schemes automatically selecting relevant predictors target variables (predictands) that can be transformed in approximate normal distributions (e.g. temperature, wind speed etc). Secondly, the extended logistic regression approach (as being suggested by Wilks, Meteorological Applications, 2009) is engaged for target variables related to hazard assessment, transforming deterministic forecasts in calibrated probability distributions. An array of sensitivity studies allows the definition of optimally suited set-ups for these systems, including sampling strategies, length of training period, selection of potential predictors and updating cycles.

Furthermore, more specific studies are ongoing, aimed at providing weather services with customer-tailored products for aviation (Clear Air Turbulence), energy management (photovoltaic, hydro-electricity) and decisional tools for surface transportation (road gridding: snow, icing), or even genetic algorithms for gale warnings.

## 4.3.4.2 Research performed in this field

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## 4.3.5 Ensemble Prediction System

## 4.3.5.1 In operation

## 4.3.5.2 Research performed in this field

An 20 members ensemble, convection-permitting system operated at mesh-size of 2.2 km is in development within the frame of the MeteoSwiss project “COSMO-NExT”. Ensemble initial conditions are provided firstly by a Local Ensemble Transform Kalman Filter (LETKF), secondly by ECMWF ENS (boundaries). They are consecutively submitted to a stochastic perturbation of their physical tendencies during the integration. The system shall be run on a forecast range of 120 hours twice a day up 2016.

## 4.3.5.3 Operationally available EPS Products

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## 4.4 Nowcasting and Very Short-range Forecasting Systems (0-6 hrs)

AUTHORS: Urs Germann / Alessandro Hering / Paolo Ambrosetti

## 4.4.1 Nowcasting system

## 4.4.1.1 In operation

Tracking and characterization of convective cells by radar (system TRT)

MeteoSwiss runs operationally the real-time object-oriented nowcasting tool TRT (Thunderstorms Radar Tracking), as a part of its severe thunderstorms nowcasting, warning and in-formation system.

For a detailed description see “WMO\_GDPS-Report\_2006”.

Quantitative precipitation estimation by radar (product RAIN)

The quantitative precipitation estimate (QPE) nowcasting radar product RAIN is the best radar estimation of precipitation amount on the ground in Switzerland.

For a detailed description see “WMO\_GDPS-Report\_2006”.

**Context and Scale Oriented Thunderstorm Satellite Predictors Development (COALITION)**

This heuristic model calculates probabilistic information about time, space and intensity evolution of severe convection for use by decision makers. Focus is given to early detection of severe storms over the European Alpine region.

For a detailed description see “WMO\_GDPS-Report\_2012” in the 4.4.1.2 Section “Research performed in this field”.

## 4.4.1.2 Research performed in this field

Ensemble technique for radar precipitation fields (technique REAL)

As part of the WMO-WWRP forecast demonstration project MAP D-PHASE and the European concerted research action COST-731 MeteoSwiss developed an ensemble technique to characterize the residual errors in radar precipitation fields. Each member of the radar ensemble is a possible realization of the unknown true precipitation field given the observed radar field and knowledge of the space-time error structure of radar precipitation estimates. Feeding the alternative realizations into a hydrological model yields a distribution of response values, the spread of which represents the sensitivity of runoff to uncertainties in the input radar precipitation field. The presented ensemble generator is based on singular value decomposition of the error covariance matrix, stochastic simulation using the LU decomposition algorithm, and autoregressive filtering. The real-time implementation of the radar ensemble generator coupled with a semi-distributed hydrological model in the framework of MAP DPHASE is one of the first experiments of this type worldwide.

For a detailed description see:

Germann et al, Q. J. R. Meteorol. Soc., 135, 445-456, 2009.

Nowcasting heavy orographic precipitation using Doppler radar and radiosounding (project COST-731)

MeteoSwiss developed as part of COST-731 a novel heuristic system for nowcasting heavy precipitation in the Alps. The system uses as input estimates of the mesoscale wind field as derived from real-time Doppler radar measurements and information on air mass stability from radio-soundings and ground stations. Both mesoscale flow and upstream air mass stability are predictors of the amounts and geographic distribution of heavy orographic precipitation, and can therefore be exploited for nowcasting. Since 2012 the system runs at MeteoSwiss in real-time, in a pre-operational mode.

For a detailed description see:

Panziera L, Germann U. 2010. The relation between airflow and orographic precipitation on the south-ern side of the Alps as revealed by weather radar. Q. J. R. Meteorol. Soc. 136: 222–238. DOI:10.1002/qj.544

Context and Scale Oriented Thunderstorm Satellite Predictors Development (project COALITION)

Through a 3-year fellowship funded by EUMETSAT MeteoSwiss has developped a nowcasting applications into an entity-oriented model, which merges severe convection predictors retrieved from different sources (MSG, Weather Radars, NWP, lightning climatology and orographic gradients) with evolving thunderstorm properties. The heuristic model calculates probabilistic information about time, space and intensity evolution of severe convection for use by decision makers. Focus is given to early detection of severe storms over the European Alpine region. The project was terminated in 2012 and at MeteoSwiss the system runs now in real-time, in a operational mode.

For a detailed description see:

L. Nisi, P. Ambrosetti and L. Clementi, 2013. Nowcasting severe convection in the Alpine region: the COALITION approach. Q. J. R. Meteorol. Soc., published online. DOI: 10.1002/qj.2249.

Improving Preparedness and Risk Management for Flash Floods and Debris Flow Events (project IMPRINTS)

Over complex terrain such as the Alps current nowcasting systems based on Lagrangian persistence of radar precipitation fields fail to produce useful forecasts, because the orography interferes with the evolution of precipitation, in particular by means of blocking and enhancement. As part of the FP7 research project IMPRINTS (2009-2012), MeteoSwiss investigates orographic forcing of precipitation and incorporate the findings into current Lagrangian persistence nowcasting systems. If successful, the resulting radar nowcasting system will be implemented in the Swiss radar data processing chain and will be extended by ensemble techniques and an algorithm for blending radar nowcasts with NWP model output

For a detailed description see:

Panziera, L., U. Germann, M. Gabella and P. V. Mandapaka, 2011. NORA–Nowcasting of Orographic Rainfall by means of Analogues. Q. J. R. Meteorol. Soc. 137: 2106–2123

Mandapaka, P.V., U. Germann, L. Panziera and A. Hering, 2011. Can Lagrangian Extrapolation of Radar Fields Be Used for Precipitation Nowcasting over Complex Alpine Orography?, Weather and Forecasting, 27: 28-49

Mandapaka, P.V., U. Germann, L. Panziera, 2013. Diurnal cycle of precipitation over complex Alpine orography: inferences from high resolution radar observations. Quarterly Journal Royal Met. Soc. 139: 1025-1046. DOI: 10.1002/qj.2013.

Panziera, L., C. N. James and U. Germann, 2014. Mesoscale organization and structure of orographic precipitation producing flash floods in the Lago Maggiore region. Q. J. R. Meteorol. Soc., published online. DOI: 10.1002/qj.2351.

Real-time radar-raingauge merging (project CombiPrecip)

CombiPrecip aims to produce accurate precipitation estimation maps by combining raingauges and radar data in real-time. The underlying technology is geostatistical in nature, where both spatial and temporal information has been taken into account in a so called co-kriging with external drift modelling scheme. The technique is coupled with innovative engineering to mitigate artifacts in the extrapolation regime and in the presence of strong convective cells where lack of sufficient representativeness of raingauge data typically causes problems. CombiPrecip is running operationally at MeteoSwiss and shows a significant improvement over radar-only rainfall maps especially in terms of bias.

For a detailed description see:

Sideris I.V., M. Gabella, R. Erdin and U. Germann, 2014. Real-time radar-raingauge merging using spatiotemporal co-kriging with external drift in the alpine terrain of Switzerland, Q. J. Roy. Meteor. Soc. 140: 1097-1111.

## 4.4.2 Models for Very Short-range Forecasting Systems

## 4.4.2.1 In operation

Integrated Nowcasting through Comprehensive Analysis (INCA)

The nowcasting analysis and forecasting system INCA, developed by the Austrian NWS ZAMG is run operationally at MeteoSwiss. This novel approach produces meteorological fields, with high resolution in time and space (gridded values) for several parameters, incorporating available information like numerical models and diverse kinds of observation (both in-situ and remote sensed), as well as high resolution orography. Several customer oriented products have been developed und made operational, particularly for the rain and snow forecast of in the Nowcasting range (both internally and externally)

## 4.4.2.2 Research performed in this field

Integrated Nowcasting through Comprehensive Analysis (INCA)

Some optimization in the model data interpolation and new post-processing products in INCA have been introduced.

## 4.5 Specialized numerical predictions

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## 4.5.1 Assimilation of specific data, analysis and initialization (where applicable)

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## 4.5.1.1 In operation

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## 4.5.1.2 Research performed in this field

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## 4.5.2 Specific Models (as appropriate related to 4.5)

A) COSMO-ART provides spatially and temporally highly resolved pollen forecasts.

**B)** The dispersion of airborne radioactive nuclides is modelled using the FLEXPART model. FLEXPART is a freely available Lagrange particle dispersion model that has been adapted for use with the COSMO model input by the Swiss institute EMPA. The dispersion calculations are based on the two operational resolutions of the COSMO model at MeteoSwiss and are run in both routine and on-demand mode.

C) CN-MET is an integrated analysis and forecasting system consisting of a high resolution numerical weather prediction model and a dense observation network. CN-MET provides meteorological information for dispersion calculations in the case of an accident in a nuclear power plant.

## 4.5.2.1 In operation

A) The pollen module of the numerical dispersion model COSMO-ART (Vogel et al. 2008) was developed by the Karlsruhe Institute of Technology (KIT) in collaboration with MeteoSwiss. Since 2011 MeteoSwiss performs daily runs with COSMO-ART to provide high-resolution birch pollen forecasts. These were recently complemented by grass pollen forecasts. An example is given in Figure 1.

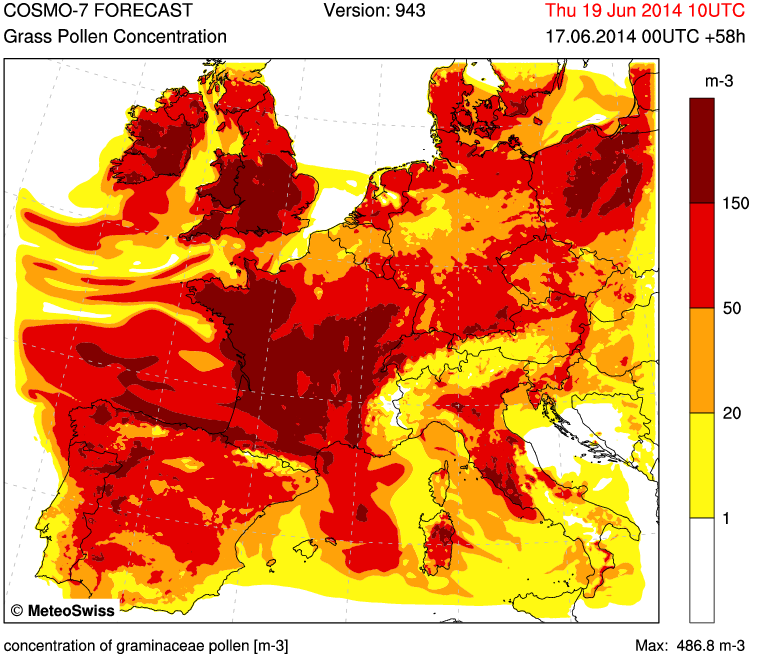


Figure 1 Forecast of grass pollen concentrations for central and southern Europe as generated by the numerical dispersion model COSMO-ART.

C) Yes

## 4.5.2.2 Research performed in this field

**A)** MeteoSwiss is involved in a number of research activities within the continuous development of COSMO-ART, focused on the modelling of pollen emission. As species reacts differently to meteorological conditions, the parameterization and the description of the pollen season of each species is required, including a precise prediction of the start and the end of the pollen season, as well as knowledge about the course of the season, where the reduced pollen production with increasing altitude is taken into account. Detailed plant distribution maps are a prerequisite for successful application of COSMO-ART. Pauling et al. (2012) developed a set of methods designed to provide this input to COSMO-ART. The available databases to derive the plant distributions are also species-specific. Reference: K. Zink, A. Pauling, M. W. Rotach, H. Vogel, P. Kaufmann, and B. Clot (2013): EMPOL 1.0: a new parameterization of pollen emission in numerical weather prediction models. Geosci. Model Dev. Discuss., 6, 3137–3178.

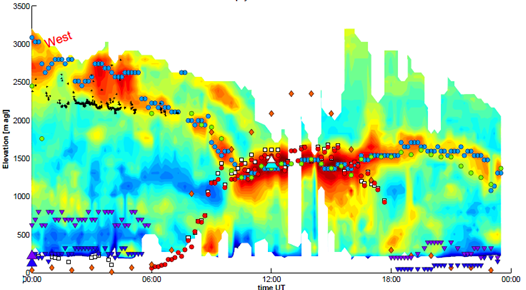
B) The meteorological monitoring of the four Swiss nuclear power plants is of cardinal importance in an area as densely populated as the Swiss Plateau. The project “Centrales Nucléaires et Météorologie“ CN-MET has provided a security tool based firstly on the development of the high resolution numerical weather forecasting COSMO-2 model, secondly on a dedicated network of surface and upper air observations including remote sensing instruments (wind profilers and temperature/humidity passive microwave radiometers). The latter provides crucial nowcasting information in case of a radioactive release from a nuclear power plant in Switzerland. This network is built upon three main sites optimally located for measuring the inflow/outflow and central conditions of the main wind field in the planetary boundary layer over the Swiss Plateau, as well as a number of automatic surface weather stations (AWS). Data provided by the network is assimilated in real-time into the COSMO-2 model using a rapid update cycle described in section 4.1. This set-up has replaced the former security system based on *in situ* observations (one meteorological mast at each of the power plants) and a local dispersion model. It is used to forecast the dynamics of the atmosphere in the planetary boundary layer (typically the first 4 km above ground layer) and over a time scale of 24 h. The new tool provides at any time (e.g. starting at the initial time of a nuclear power plant release) the best picture of the 24-h evolution of the air mass over the Swiss Plateau. It furthermore generates the input data (in the form of simulated values substituting in situ observations) required for the integration of dispersion models locally operated at each nuclear power plant.

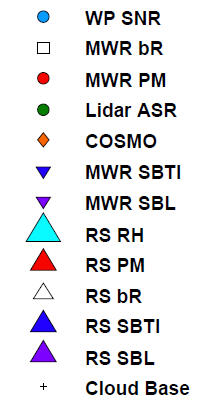
**B)** A model relating solar UV radiation at the surface to human UV exposure, which was described in the 2012 report was used for assessing work-related solar UV doses and its contribution to skin cancer risk. The exposure patterns and anatomical distribution were characterized, and the risk of squamous cell carcinoma (SCC) was estimated from an existing epidemiological model (Milon et al., 2014). Exposure to solar ultraviolet (UV) light is the main causative factor for skin cancer. Outdoor workers are at particular risk because they spend long working hours outside, may have little shade available and be bound to take their lunch at their workplace. Despite epidemiological evidence of a doubling in risk of squamous cell carcinoma in outdoor workers, the recognition of skin cancer as an occupational disease remains scarce. The study showed that work-related solar exposure contributes largely to the overall lifetime UV dose for outdoor worker, resulting in an excess risk of SCC. The magnitude of the estimated excess in risk supports the recognition of SCC as an occupational disease.

The original 3D numeric model was further developed so that it can be used with more readily available source of information for the UV radiation (Vernez et al, 2014). This development was based on a regression model for predicting the UV exposure ratio (ER, ratio between the anatomical dose and the corresponding ground level dose) for each body site without requiring individual measurements. The 3D numeric model (SimUVEx) was used to compute ER for various body sites and postures. A multiple fractional polynomial regression analysis was performed to identify predictors of ER. The regression model used simulation data and its performance was tested on an independent data set. Two input variables were sufficient to explain ER: the cosine of the maximal daily solar zenith angle and the fraction of the sky visible from the body site. The regression model was in good agreement with the simulated data ER (r2 = 0.988). Relative errors up to +20% and -10% were found in daily doses predictions, whereas an average relative error of only 2.4% (-0.03% to 5.4%) was found in yearly dose predictions. The regression model predicts accurately ER and UV doses on the basis of readily available data such as global UV erythemal irradiance measured at ground surface stations or inferred from satellite information. It renders the development of exposure data on a wide temporal and geographical scale possible and opens broad perspectives for epidemiological studies and skin cancer prevention.

**C)** The meteorological surveillance of the four nuclear power plants in Switzerland is of first importance in a densely populated area such as the Swiss Plateau. The project “Centrales Nucléaires et Météorologie“ CN-MET aimed at providing a new security tool based on one hand on the development of a high resolution numerical weather prediction (NWP) model. The latter is providing essential nowcasting information in case of a radioactive release from a nuclear power plant in Switzerland. On the other hand, the model input over the Swiss Plateau is generated by a dedicated network of surface and upper air observations including remote sensing instruments (wind profilers and temperature/humidity passive microwave radiometers). This network is built upon three main sites ideally located for measuring the inflow/outflow and central conditions of the main wind field in the planetary boundary layer over the Swiss Plateau, as well as a number of surface automatic weather stations (AWS). The network data are assimilated in real-time into the COSMO-2 high-resolution NWP model using a rapid update cycle described in section 4.1.

**D)** The planetary boundary layer (PBL) height is a crucial parameter in the dispersion calculation. Therefore the PBL height estimates of the COSMO-2 model have been extensively validated against observations. For comparison PBL height estimates have been derived from measurements from radiosounding, microwave radiometer, windprofiler and Raman lidar using different definitions of the PBL based on atmospheric turbulence and mixing as well as on the thermal structure. The study revealed that the estimates derived from the observations agree with each other within +/- 100 m on average. Generally good performance of the PBL height estimates from COSMO-2 could be shown but on average the PBL height is overestimated by almost 300 m compared to the observations. The results have been published in Collaud et al., 2014. Efforts to understand this overestimation and to improve the model estimates are ongoing.





Several automatic detection of PBL height methods from ground-based remote sensing instruments, radiosounding (RS) and COSMO-2 model, Payerne, 31 July, 2012. Background is signal-to-noise ratio profiles from the wind profiler.

## 4.5.3 Specific products operationally available

A) Daily maps of mean pollen concentrations for Switzerland are available on the Website of MeteoSwiss. Similar maps are available for France and Italy on the Website of the aerobiological network of France (RNSA) and Italy (AIA) respectively.

B) The FLEXPART model results are delivered to the authorities for emergency response as geographical representations of affected area, time-integrated concentration, averaged concentration, and deposition on the ground.

#### 4.5.4 Operational techniques for application of specialized numerical prediction products (MOS, PPM, KF, Expert Systems, etc..) (as appropriate related to 4.5)

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## 4.5.4.1 In operation

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## 4.5.4.2 Research performed in this field

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## 4.5.5 Probabilistic predictions (where applicable)

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## 4.5.5.1 In operation

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## 4.5.5.2 Research performed in this field

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## 4.5.5.3 Operationally available probabilistic prediction products

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## 4.6 Extended range forecasts (ERF) (10 days to 30 days)

AUTHORS: CHRISTOPH SPIRIG / IRINA MAHLSTEIN / MARK LINIGER

## 4.6.1 Models

## 4.6.1.1 In operation

Within the framework of the national NCCR climate research programme, MeteoSwiss established an operational monthly forecasting system. This is based on forecast data from the ECMWF extended range prediction system. The system was deployed in autumn 2008 and has since become fully operational.

As part of the research activities described below, a quasi-operational system for post-processing ECMWF’s extended range forecast data at daily time resolution has been established.

## 4.6.1.2 Research performed in this field

In order to improve the usability of extended range forecasts, MeteoSwiss currently investigates the use of ECMWF’s extended range forecast data at daily time resolution. Daily data are required for deriving forecasts of user relevant indices (see also 4.7.2. for similar activities on the long range) and pose additional challenges for post-processing. Ongoing work includes skill analyses of extended range forecasts based on daily model output and experiments of visualization formats.

## 4.6.2 Operationally available NWP model and EPS ERF products

#### Operationally available NWP model and EPS ERF products

Operational products based on the ECMWF ensemble forecast system include maps of weekly categorical probability forecasts of surface temperature, precipitation and geopotential height over various regions as well as tercile data as tables for selected station locations and regional averages. These products are provided to commercial customers of MeteoSwiss upon request. Since beginning of 2013, probabilistic forecasts of average temperature and precipitation tendencies of the upcoming three weeks for three regions of Switzerland are made publicly available in the form of a “weekly climate outlook” on the [MeteoSwiss website](http://www.meteoswiss.admin.ch/web/en/climate/climate_tomorrow/weekly_climat_outlook.html) for all three national languages (see Figure 2).

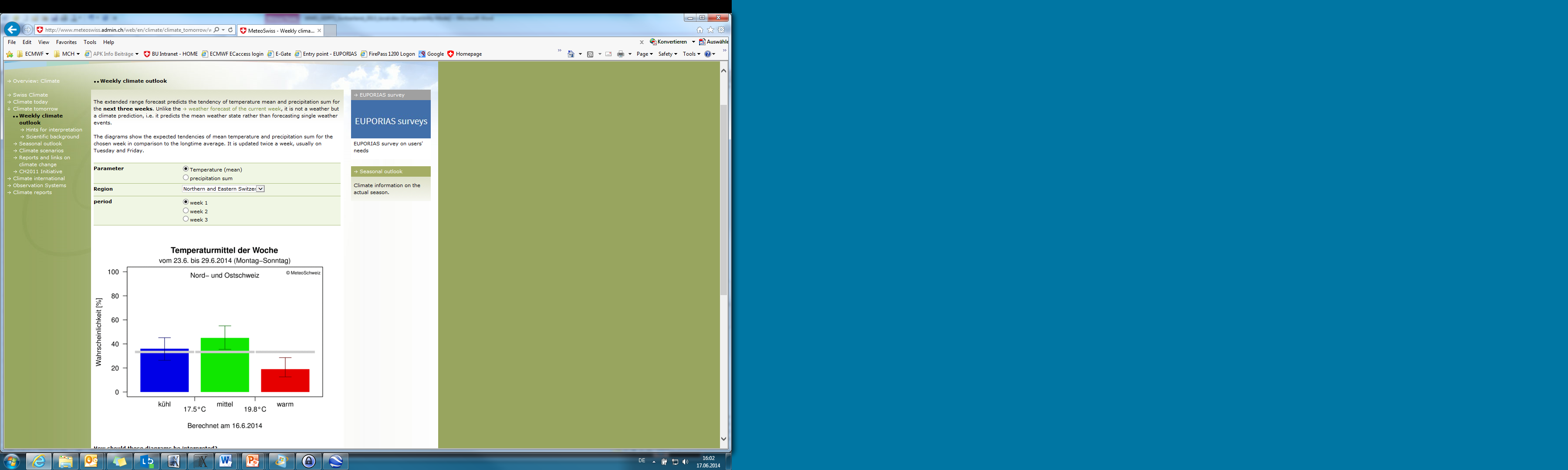


Figure 2: Screen shot of MeteoSwiss’ extended range forecasts on the web.

## 4.7 Long range forecasts (LRF) (30 days up to two years)

AUTHORS: CHRISTOPH SPIRIG / IRINA MAHLSTEIN / MARK LINIGER

## 4.7.1 In operation

MeteoSwiss issues long range forecasts (up to 7 months) on the basis of the ECMWF seasonal forecast model system (System 4). The model data are post-processed, evaluated and disseminated by MeteoSwiss. The post-processing technique of climate model output includes a climate-conserving recalibration technique (CCR), which has been developed by MeteoSwiss.

## 4.7.2 Research performed in this field

MeteoSwiss is part of the EU-FP7 project EUPORIAS ([www.euporias.eu](http://www.euporias.eu)) aiming at improving the usability of climate services based on long range forecasts. As part of these activities, MeteoSwiss carries out two main tasks, 1) getting a better understanding of the users’ needs with the help of customer surveys and interviews and 2) development of seasonal forecasts of climate information indices with relevance for the energy and finance sector. As these forecasts of indices require seasonal forecasts at daily resolution as well as bias-corrected forecasts, substantial efforts were put into the development of appropriate post-processing techniques. First verification analyses suggest similar skill of such indices forecasts as compared to forecasts of the underlying meteorological variables. Figure 3 shows a skill analysis for seasonal prediction of heating degree days (HDD), an indicator used in the energy sector as a proxy for the energy consumption for heating of buildings.

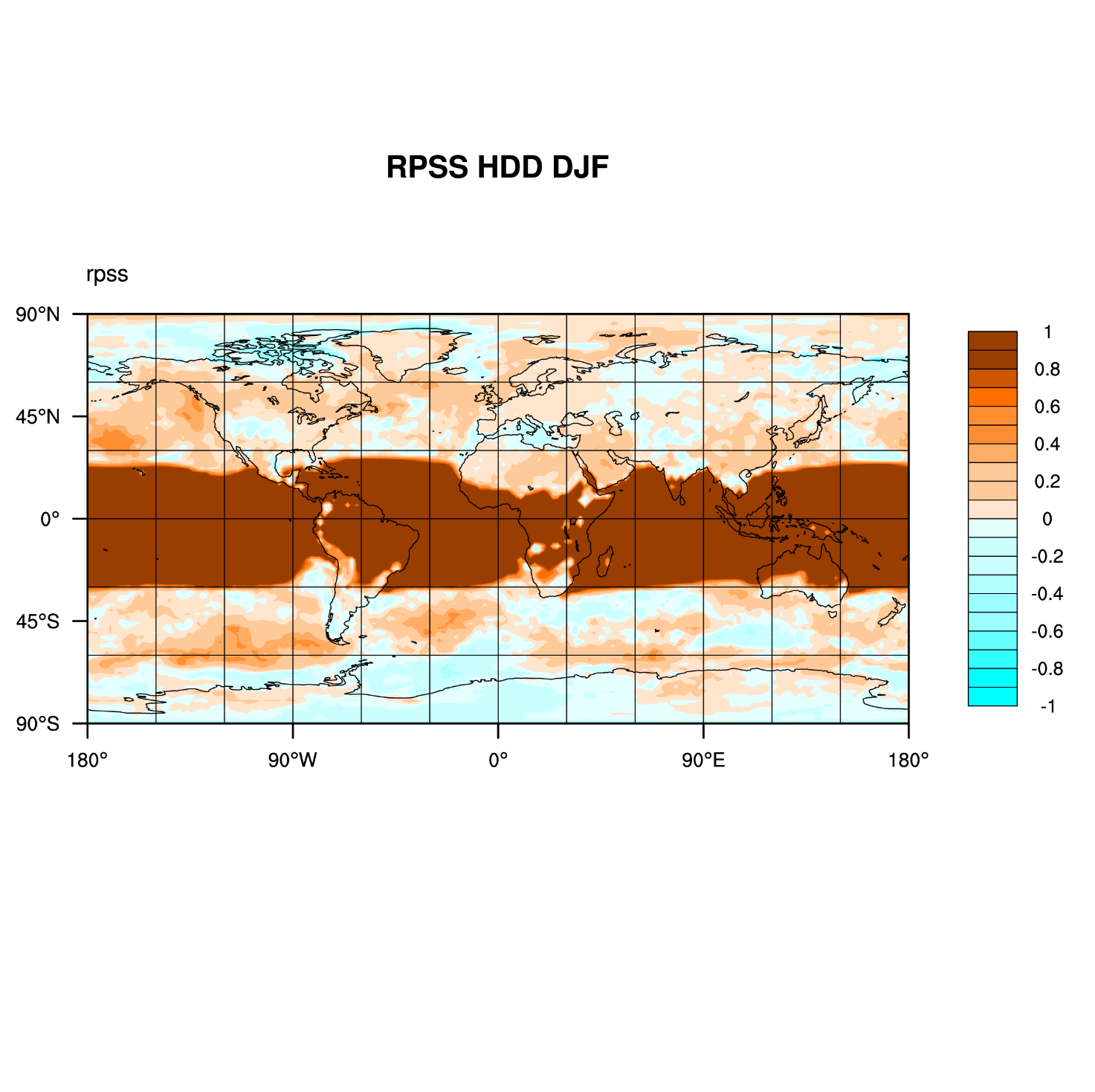


Figure 3: Ranked probability skill score of predicting HDD for the months December through February with the forecast initialized on November 1st. Positive values indicate skilful forecasts as compared to using climatology as a reference.

## 4.7.2 Operationally available EPS LRF products

The operational products of seasonal forecasts (up to 7 months) include climagrams, probability charts and tercile data for surface temperature, precipitation and geopotential height. The skill of seasonal temperature forecasts is also monitored and is provided in the form of skill maps. The recalibrated seasonal forecast products (using the method of CCR, Weigel et al., 2009) are available for surface temperature and issued as climagrams, probability charts and tercile data. For the wider public, probabilistic seasonal forecast information on temperature is issued in form of a quarterly climate outlook for Switzerland. It is published on the MeteoSwiss website in an analogous manner as the monthly outlook (Figure 2).

## 5. Verification of prognostic products

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## 5.1 -

## 5.2 Research performed in this field

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## 6. Plans for the future (next 4 years)

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## 6.1 Development of the GDPFS

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## 6.1.1 -

## 6.1.2 -

## 6.2 Planned research Activities in NWP, Nowcasting, Long-range Forecasting and Specialized Numerical Predictions

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## 6.2.1 Planned Research Activities in NWP

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## 6.2.2 Planned Research Activities in Nowcasting

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## 6.2.3 Planned Research Activities in Long-range Forecasting

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## 6.2.4 Planned Research Activities in Specialized Numerical Predictions

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## 7. Consortium

Authors: Philippe Steiner / Detlev Majewski

COSMO stands for **CO**nsortium for **S**mall-scale **MO**delling. The general goal of COSMO is to develop, improve and maintain a non-hydrostatic limited-area atmospheric model, the COSMO-model, which is used both for operational and for research applications by the members of the consortium. The consortium was formed in **October 1998** at the regular annual DWD (Germany) and MeteoSwiss (Switzerland) meeting.

A Memorandum of Understanding (MoU) on the scientific collaboration in the field of non-hydrostatic modeling was signed by the Directors of DWD (Germany), MeteoSwiss (Switzerland), USAM (Italy, then named UGM) and HNMS (Greece) in March/April 1999. The MoU has been replaced by an official COSMO [Agreement](http://cosmo-model.org/content/consortium/agreement.htm), which was signed by the Directors of these four national meteorological services on 3 October 2001.

In 2002, the national weather service of Poland (IMGW) joined the Consortium in effect from 4 July. The National Institute of Meteorology and Hydrology (NMA) of Romania and the Federal Service for Hydrometeorology and Environmental Monitoring of the Russian Federation joined the Consortium in effect from 21 September 2009.

## 7.1. System and/or Model

The COSMO model (<http://cosmo-model.org/content/model/general/default.htm>) is a non-hydrostatic limited-area atmospheric prediction model. It has been designed for both operational numerical weather prediction (NWP) and various scientific applications on the meso-β and meso-γ scale. The COSMO model is based on the primitive thermo-hydro-dynamical equations describing compressible flow in a moist atmosphere. The model equations are formulated in rotated geographical coordinates and a generalized terrain following height coordinate. A variety of physical processes are taken into account by parameterization schemes.

Besides the forecast model itself, a number of additional components such as data assimilation, interpolation of boundary conditions from a driving model, and post-processing utilities are required to run the model in NWP-mode, climate mode or for case studies.

## 7.1.1. In operation

Regional numerical weather prediction at MeteoSwiss is entirely based on the COSMO-Model. COSMO-7 (see sections 4.1, 4.3.1 and 4.3.2) covers most of western Europe with 393x338 grid points/layer at a grid spacing of 6.6 km and 60 layers, and the convection-resolving model COSMO-2, covers the Alpine region with a grid spacing of 2.2 km, 520x350 grid points/layer and 60 layers.

[ARPA-SIMC](http://www.arpa.emr.it/sim/) operates on behalf of COSMO the regional ensemble prediction system **COSMO-LEPS** (<http://www.cosmo-model.org/content/tasks/operational/leps/default.htm>) at the European Centre for Medium Range Weather Forecasts (ECMWF) in the “Framework for Member-State time-critical applications”. COSMO-LEPS is the Limited Area Ensemble Prediction System developed within the COSMO consortium in order to improve the short-to-medium range forecast of extreme and localized weather events. It is made up of 16 integrations of the COSMO model, which is nested on selected members of ECMWF EPS.

COSMO-LEPS covers Central and Southern Europe with 511x415 grid points/layer at a grid spacing of 7 km and 40 layers. The system runs twice a day, starting at 00 and 12UTC with a forecast range of 132 hours.

## 7.1.2. Research performed in this field

The joint research and development is mainly undertaken in the eight working groups (<http://cosmo-model.org/content/consortium/structure.htm>) and a number of priority projects and priority tasks. The current priority projects are: “Kilometre-Scale Ensemble-Based Data Assimilation” (KENDA), see section 7.4.1, “COSMO-EULAG Operationalization” (CELO) which aim is to get an operational version of COSMO model employing dynamical core with explicit conservative properties for very-high model resolutions, “Calibration of COSMO Model” (CALMO) which aims at development of automatic, multivariate and based on objective methods calibration of parameterizations of physical processes for the model, “Verification System Unified Survey 2” (VERSUS2) developing an operational verification package for deterministic and ensemble forecasting, “Performance On Massively Parallel Architectures” (POMPA) for preparation of the COSMO model code for running on future high performance computing systems and architectures, and “Consolidation of Operation and Research Results for the Sochi Olympic Games” (CORSO) for enhancing and demonstrating COSMO-based NWP systems in winter conditions and for mountainous terrain. The priority task “NWP Test Suite’ focuses on preparation of software environment to perform controlled and thorough testing for any released version of the COSMO model, according to the “COSMO Standards for Source Code Development”. Environmental prediction aspects of the model involving chemistry, aerosol effects and transport (COSMO ART) are developed in close cooperation with Karlsruhe Institute for Technology (KIT) in Germany.

## 7.2. System run schedule and forecast ranges

See section 4.3.2**.**

## 7.3. List of countries participating in the Consortium

A new COSMO Agreement aiming at future challenges in high resolution regional numerical weather prediction as well as climate and environmental applications was accepted in 2013 by the Directors of the COSMO members. It will be signed before the end of 2014.

The following national meteorological services are currently COSMO members:

|  |  |  |
| --- | --- | --- |
| Germany | [DWD](http://www.dwd.de/) | Deutscher Wetterdienst |
| Switzerland | [MCH](http://www.sma.ch/) | MeteoSchweiz |
| Italy | [USAM](http://www.meteoam.it/) | Ufficio Generale Spazio Aereo e Meteorologia |
| Greece | [HNMS](http://www.hnms.gr/) | Hellenic National Meteorological Service |
| Poland | [IMGW](http://www.imgw.pl/) | Institute of Meteorology and Water Management |
| Romania | [NMA](http://www.inmh.ro/) | National Meteorological Administration |
| Russia | [RHM](http://www.meteorf.ru/en_default.aspx) | Federal Service for Hydrometeorology and Environmental  Monitoring. |

Within the member states, following regional and military services are also participating:

|  |  |  |
| --- | --- | --- |
| Germany | [AGeoBw](http://www.streitkraefteunterstuetzungskommando.bundeswehr.de/) | Amt für GeoInformationswesen der Bundeswehr |
| Italy | [CIRA](http://www.cira.it/) | Centro Italiano Ricerche Aerospaziali |
| Italy | [ARPA-SIMC](http://www.arpa.emr.it/sim) | ARPA Emilia Romagna Servizio Idro Meteo Clima |
| Italy | [ARPA Piemonte](http://www.arpa.piemonte.it/) | Agenzia Regionale per la Protezione Ambientale  Piemonte |

The Meteorological Service of Israel (IMS) became applicant member of COSMO in 2013.

Six national meteorological services, namely the Botswana Department of Meteorological Services, INMET (Brazil), DHN (Brazil), Namibia Meteorological Service, DGMAN (Oman) and NCMS (United Arab Emirates) as well as the regional meteorological service of Catalunya (Spain) use the COSMO model in the framework of an operational licence agreement including a license fee.

National meteorological services in developing countries (e.g. Egypt, Indonesia, Kenya, Mozam-bique, Nigeria, Philippines, Rwanda, Tanzania, Vietnam) can use the COSMO model free of charge.

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