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CN-MET tool assessment study

Final report

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Version 1.0

Contents

CHAPTER 1 Purpose of the document

This report summarises the "**CN-MET tool and final assessment study** ". The "Centrales Nucléaires et Météorologie" CN-MET Project started in 2005 and will end in March 2010. The various phases of the project allowed the setting-up of a new integrated tool optimizing the meteorological surveillance of the four Swiss nuclear power plants of Mühleberg, Gösgen, Beznau and Leibstadt.

This report presents the setting-up and real-time operation of an integrated tool consisting of:

- new surface and upper-air meteorological observations over the Swiss Plateau,

- new high-resolution numerical weather prediction (NWP) model providing the optimum set of meteorological information and forecasts in the event of a nuclear release over the Swiss Plateau.

This report summarizes the assessment of the CN-MET tool based on the two validation studies performed in 2008 (Leibstadt – Kleindöttingen) and 2009 (Mühleberg – Wileroltigen) and the performance currently achieved with CN-MET.

The purpose of this document is to provide our client ENSI with our conclusions about the CN-MET tool performances at a time (September 2009) when the previous security tool (meteorological towers at each nuclear power plant) is no longer in operation.

CHAPTER 2 Management overview

In December 2005 ENSI (ex-HSK) and MeteoSwiss signed a contract for the renewal of the meteorological security tool in the event of a nuclear release from one of the power plants located on the Swiss Plateau.

Over the last 4 years MeteoSwiss has been committed to realising the new CN-MET tool. Early 2009 the new surface and upper air CN-MET network was put into full operation (test phase), and observation data were assimilated in quasi-real-time into the simultaneously developed high resolution COSMO-2 model of MeteoSwiss.

Two validation studies in 2008 (with a “partial” CN-MET observation network) and 2009 (with the completed CN-MET network) were conducted in order to assess the performance achieved by the CN-MET tool.

During 2009 the CN-MET operational organisation at MeteoSwiss and with our key partners (e.g. SWITCH, CSCS, NAZ and ENSI) was carefully upgraded and re-defined: the CN-MET project can now be completed. Early in September 2009, the 110 m meteorological mast at Gösgen was decommissioned and thus CN-MET is being used as the new security tool provided by MeteoSwiss to ENSI.

At MeteoSwiss the project organization will nevertheless be maintained until March 2010, the remaining time allowing for the final project reporting (including the final CN-MET operation manual).

CHAPTER 3 Starting point

A network of radioactivity sensors in Switzerland allows measuring any rapid increase of the mean radioactivity in Switzerland. In the event of a nuclear release (thus inducing higher than normal radioactivity values) an alarm organisation based on three different security areas around the nuclear power plants is in place: this ordinance is referred to as ”Notfallschutzverordnung” [1].

- The first area is defined as a circle of 3 to 5 km radius centered on each of the nuclear power plants in Switzerland (Mühleberg, Beznau Leibstadt, Gösgen): if there is a radioactivity event, the alarm is relayed to all inhabitants, villages or towns within this area. This area is referred to as Zone 1.
- Zone 2 is a circle of approx. 20 km radius. In this larger area, the alarm is sent only to villages or towns in specific sections of Zone 2 , depending on the wind conditions: these sectors are defined according to the output results of dispersion models currently in use at ENSI.
- Zone 3 includes the entire Swiss territory, and there is no predefined area in the event of a radioactivity increase: the alarm situation is considered on a case by case analysis.

Meteorological measurements required as input to ENSI dispersion models are defined by ENSI directive R-32 [2]: a meteorological tower in the vicinity of each of the power plants and operated by MeteoSwiss measures wind and temperature continually every 10 minutes at different heights along the tower (ref 15). These local observations are the essential initial conditions for the ENSI dispersion models [3] [4], the latter being used to define the different sectors in Zone 2.

Two major drawbacks for this security tool based on R-32 were already identified at the time of the meteorological studies supporting the development of this tool:

- The question of the radioactive plume dispersion in the vertical dimension: with the dispersion models, there is only a first assumption of the planetary boundary layer height, and essentially no information about the possible wind shear conditions below/resp. above the PBL height (or any inversion layer above the nuclear power plant). The dispersion model output defines a sector in accordance with the meteorological observation from the met tower and taking into account wind classes, but the radioactive plume at higher altitude may spread in a very different direction than near the surface.
- The question of the radioactive plume dispersion at longer time scale (typically over 24 hours): in an ideal case with low wind conditions, the radioactive plume may adequately be forecasted over the next 2-3 hours after the nuclear release using a simple dispersion model. Under more turbulent and windy conditions, as for example in summer with strongly convective conditions, its dispersion over a one-day time scale can only adequately be predicted by using a 3D dispersion model based on the 3D information from a NWP model assimilating 3D wind field observations.

The nuclear security tools were based on R-32 during about two decades until 30 August 2009: this is the “starting point” of the new meteorological tool CN-MET, and the present report summarizes the renewal and replacement of the meteorological information based on R-32 by the new CN-MET tool.

CHAPTER 4 Objectives and solutions

4.1 Goals

The project CN-MET aims at delivering the up-to-date meteorological information necessary for the population's safety in the event of a nuclear incident over the next two decades. It is the renewal of the R-32-based security tools in operation until 31 August 2009.

In CN-MET the necessary input data for the ENSI dispersion model are obtained directly as an output of the numerical weather forecast model COSMO-2, at each altitude range above the nuclear power plants. Local measurements at the nuclear power plant sites will only consist of a 10 m wind mast, a 10 m turbulence measurement mast, and standard surface measurements (temperature, humidity, pressure, radioactivity). The meteorological towers at each of the nuclear power plants (NPPs) are decommissioned during October 2009 (already done for Gösgen in September 2009).

The new system combines a specific measurement network (surface measurements as well as remote sensing upper-air measurements in the boundary layer) together with a numerical weather prediction model with high spatial and temporal resolution (COSMO-2 with 2.2 km horizontal resolution and 10-minute output interval).

The system opens new opportunities for ENSI and MeteoSwiss: it is ready for future requirements such as could be imposed by the construction of a new nuclear power plants on the Swiss Plateau. In the same way, CN-MET is a security tool that may serve new clients from other industries with similar needs (chemical industries, etc.).

4.2 Solutions

CN-MET takes advantage of the novel technologies in atmosphere science related to the numerical weather forecast models (COSMO model) and the remote sensing technologies (wind profiler, passive microwave temperature profiler). Such technologies were not available in the 1980's when the R-32 based tools were put in place and too time-consuming for real-time emergency application in the 1990's when WINDBANK was devised. Today they correspond to the best technology available for an optimum security tool that will be used and operated over the next two decades or so.

The new security tool relies on

- a dedicated surface and upper air network on the Swiss Plateau,
- a high resolution Numerical Weather Prediction model NWP COSMO-2.

This combined set of meteorological observations and numerical weather forecasts in CN-MET is directly realised and provided by MeteoSwiss. CN-MET also induced further development at ENSI by using the NWP model data as input to the latest version of the ENSI dispersion tool.

In this new CN-MET solution the input data to ENSI dispersion models is delivered by the NWP model output and no longer by the *in situ* observations from the meteorological towers.

4.3 Implemented solution

According to the specifications defined in appendix A1 of the ENSI-MeteoSwiss contract 2005, MeteoSwiss delivers the following services to ENSI:

- delivery of real-time measurements, as input to the model as well as for direct use by ENSI,
- delivery of 18 hours model forecast data from COSMO-2 every 3 hours,
- on-demand delivery of +6 hours model forecast data every 1 hour, in case of an accident, including test/training of this procedure at most twice a year,
- service management, including monitoring for problem identification and resolution, monitoring for performance evaluation and improvement.

These implemented solutions have required significant adaptations, upgrades and series of new requirements that have been put in place at MeteoSwiss over the last years. The details of this organisational aspect will be presented in the final report (due date March 2010), but not in this initial assessment report.

4.3.1 Delivery of real-time measurements: the CN-MET measurement network

In accordance with the CN-MET concept, the measurement network is constituted of (Figure 1)

- surface SwissMetNet (SMN) stations at NPP and including turbulence measurements,
- planetary boundary layer (PBL) stations,
- upper-air stations located at both ends of the Swiss Plateau (Payerne and Schaffhausen) as well as one site at its centre (Grenchen).

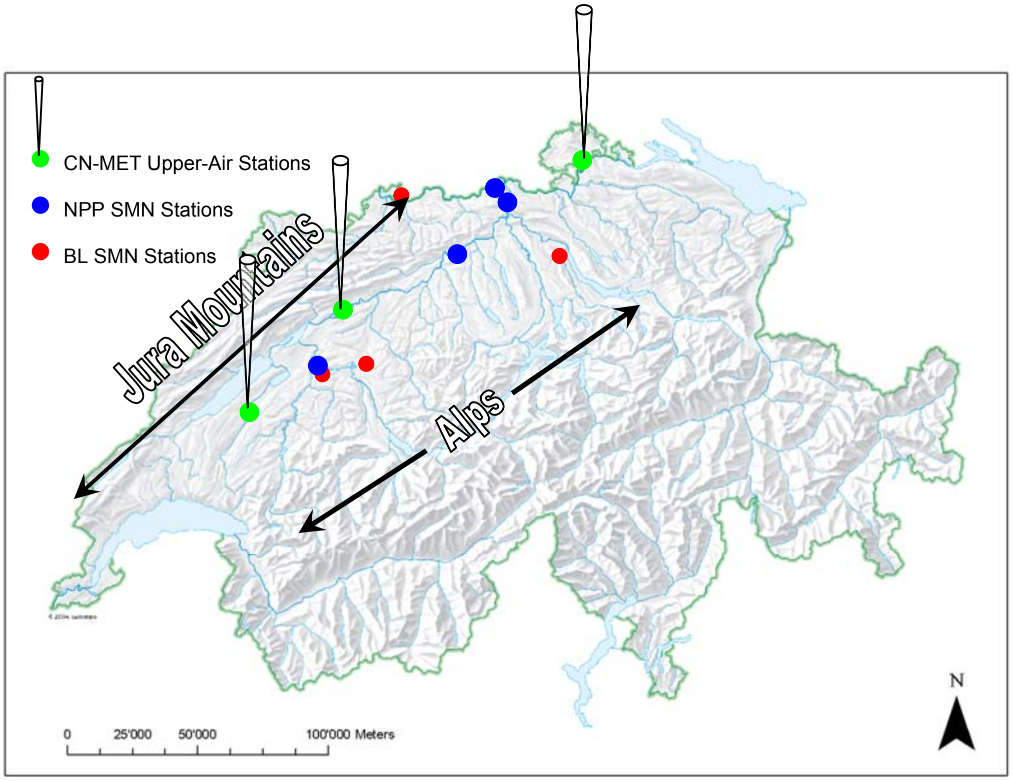

Figure 1: CN-MET measurement network. Blue dots correspond to the nuclear power plant locations with surface in-situ measurements, green dots to the three upper-air ground-based remote sensing sites with low-tropospheric wind profiler and microwave radiometer, and red dots to in-situ measurements located on radio towers (PBL sites).

4.3.1.1 The surface SMN stations

SwissMetNet is the new surface network of MeteoSwiss. It has a central platform (CDAS / NIMDAS) for collection and distribution of the meteorological and technical (housekeeping) parameters measured at each of the surface upper-air stations. This central platform also includes the new CN-MET sites and allows having on one network (one “monitoring display”) all the necessary on-line and real-time technical parameters for the network. This provides the opportunity of a high synergy between the specific CN-MET observation network requirements and the already existing surface network over Switzerland. The same maintenance team at the MeteoSwiss Aerological Station in Payerne (the national competence centre for SwissMetNet) will be in charge of the monitoring, maintenance and repair of the new CN-MET observation network. This integration of CN-MET into SMN is illustrated in the next figure where all surface stations are listed which could provide data to ENSI.

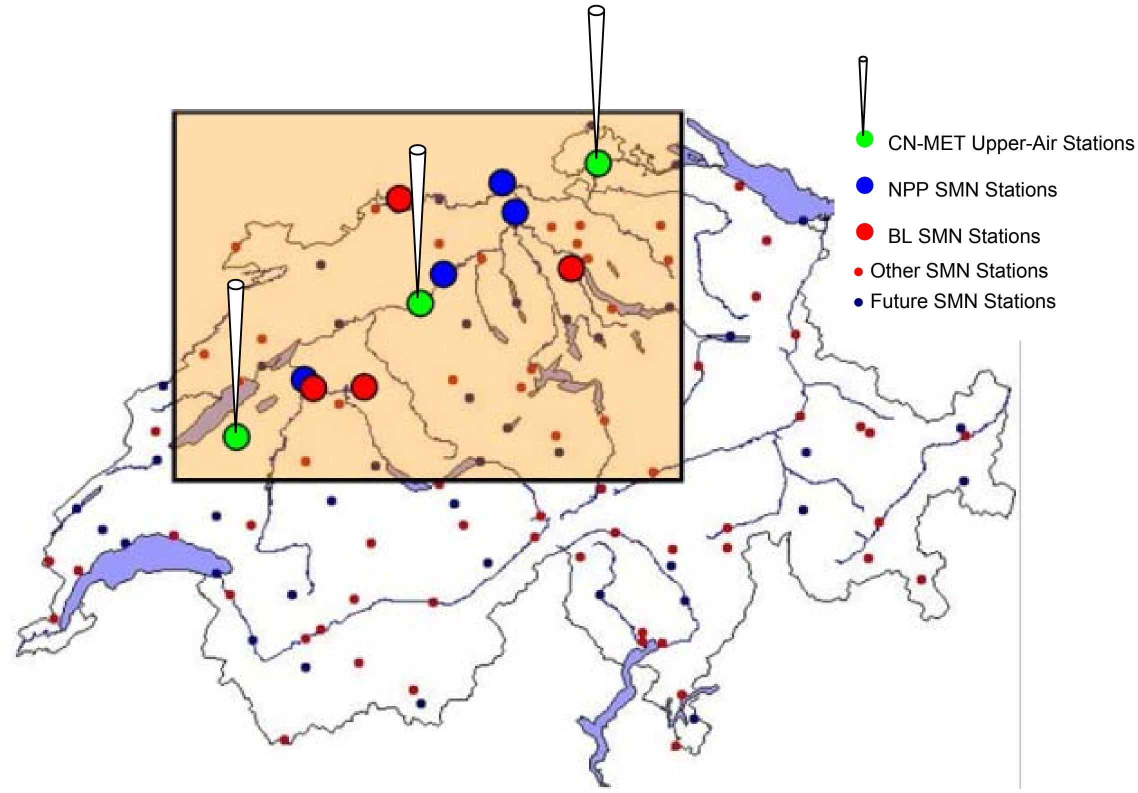

Figure 2: The SwissMetNet network over Switzerland, including the three remote sensing sites in CN-MET.

The SwissMetNet surface stations at the Nuclear Power Plants (MUB, GOE, BEZ and LEI in Figure 2) are also equipped with turbulence observation (high frequency sonic anemometer), a product of special importance for the client ENSI.

In CN-MET, the boundary layer (BL) surface stations (SCT, UEB, MSK and BAN) are located on top of high towers on the Swiss Plateau, as reference stations for comparisons with boundary-layer data from the NWP model.

Figure 3 : The four power plants' surface weather stations (including the turbulence measurement devices on a second meteo mast)

4.3.1.2 The upper-air stations

Two sites were selected in order to cover upwind and downwind meteorological conditions on the Swiss Plateau, taking into account the strong SW-NE orientation of the prevailing winds in this region. A third one was chosen more at the centre of the area concerned (blue dots in Figure 1).

Each of the stations is co-located with a SMN automatic weather station and consists of two main ground-based remote sensing systems:

- A low-tropospheric wind profiler: it is an automatic Doppler radar measuring 10-minute wind speed and direction profiles, from 100 m AGL up to 8'000 m AGL (depending on weather conditions). A pulse is emitted at 1290 MHz into five directions (one vertical and four 25^{o} tilted beams). The return signal is then analyzed and wind speed and wind direction are retrieved. The 10-minute profiles are the result of a moving averaging over 30 minutes by summing the last 20 minutes and the newly acquired 10 minutes data.

- A microwave radiometer: it is a passive ground-based remote sensing system measuring the microwave transmission of the atmosphere in the range 20-50GHz. Using a priori profiles and mathematical inversion methods, profiles of temperature and water vapour are retrieved. The temporal resolution is 10 minutes (with a moving average of 60 minutes in this case) and the vertical resolution is coarse because of its passive characteristics.

Payerne site : wind profiler

T/H profiler

Grenchen site : wind profiler

T profiler

Schaffhausen site : wind profiler

T/H profiler

Finally, at the Payerne location, an aerological radio sounding is operationally performed four times per day, 7 days a week, at 0 and 12UTC (pressure, temperature, humidity and wind) and at 18 and 6 UTC (wind). Table 1 describes the specifications of all these systems.

Wind profiler									
	minZ m AGL	maxZ m AGL	Δt min	ΔZ m	WS bias m/sec	WD bias deg			
Payerne Grenchen Schaffhausen	~100 ~100 ~100	~8'000 ~8'000 ~8'000	10 10 10	72 72 72	± 0.5 ± 0.5 ± 0.5	± 10 ± 10 ± 10			
Microwave radiometer									
	minZ m AGL	maxZ m AGL	Δt min	ΔZ m	T degC	RH %			
Payerne Grenchen Schaffhausen	50 50 50	5'000 5'000 5'000	10 10 10	50-600 50-600 50-600	± 1.5 ± 1.5 ± 1.5	± 25 ± 25 ± 25			
Radio sounding									
	minZ m AGL	maxZ m AGL	Δt hour	ΔZ m	WS m/sec	WD deg	P HPa	T degC	RH %
Payerne	2	~35'000	12/6	~40	± 0.5	±5	±1	±0.1	±5

Table 1 Technical specifications of the upper-air systems used in CN-MET: Z is the vertical axis in meter above ground level (m AGL), WS is wind speed, WD wind direction and RH relative humidity in %.

Figure 5 describes the performances of the operational wind profiler for wind speed at Payerne compared to the operational radio soundings performed four times a day at the same location and for 10 months of continuous measurements (November 2008 - August 2009).

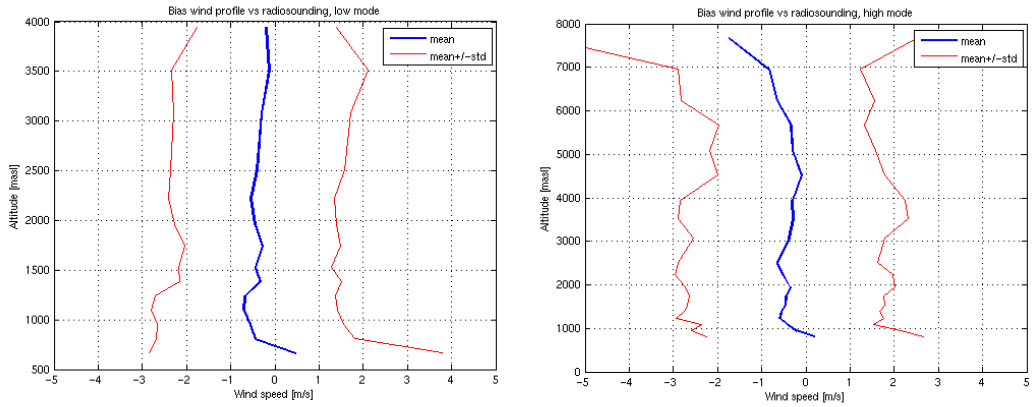

Figure 5 : Wind speed bias and standard deviation profiles, wind profiler vs. radio soundings, 1 November 2008 – 31 August 2009. Right panel: wind profiler low mode, left panel: wind profiler high mode. Note that sampling varies in function of height (less points on top of profiles) and integration in time between the two systems is different (instant radio sounding values vs 30-minute wind profiler consensus)

A typical example of wind speed, wind direction and temperature profiles is shown in the next figure.

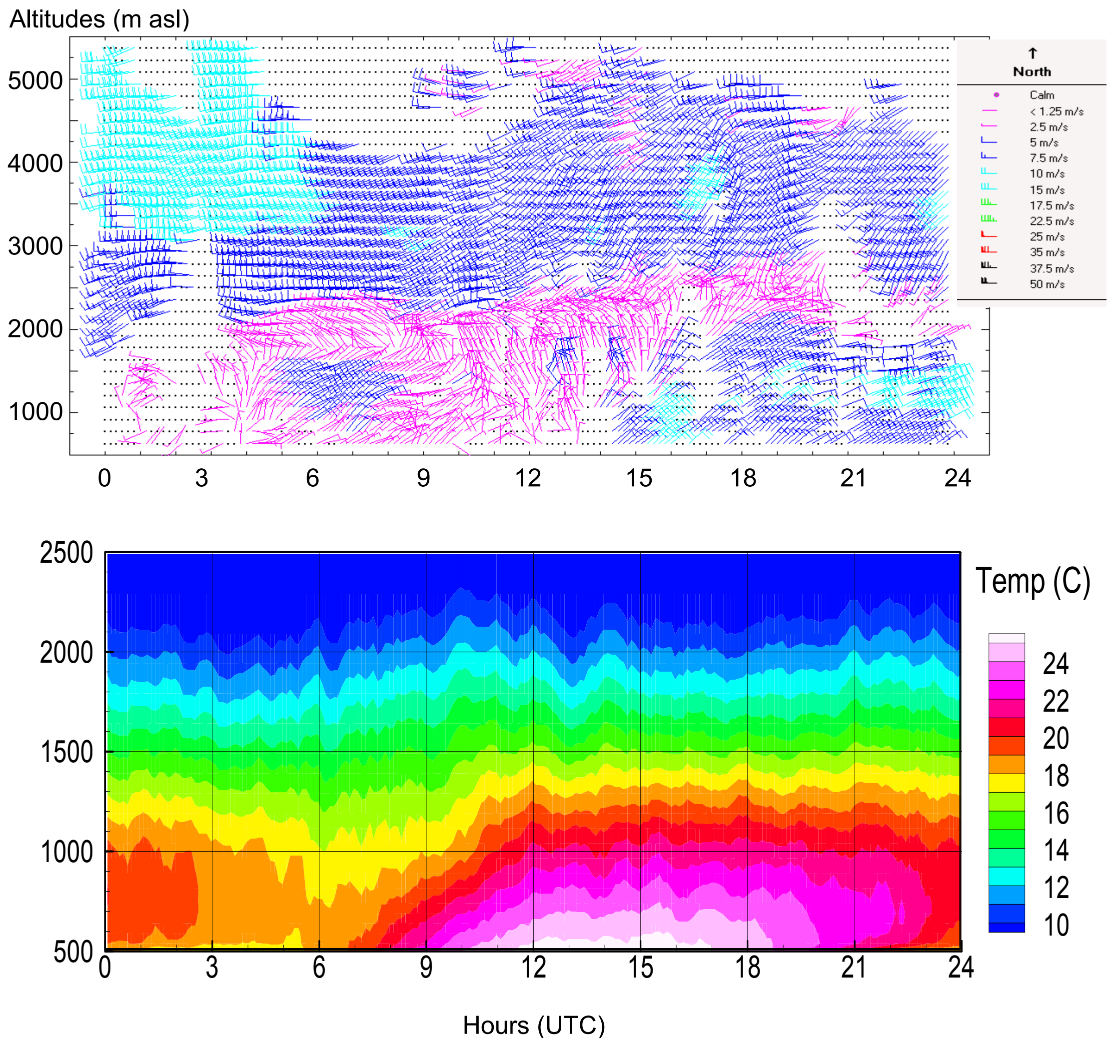

Figure 6: Time series of wind speed and direction (upper panel) and temperature profiles (bottom panel) at Payerne, on 30 June 2008.

The three CN-MET upper-air wind profiler data have recently been integrated into a European framework: these data are sent to the GTS and displayed within the European EUMETNET CWINDE hub[1] . This independent hub provides regular monthly statistics on availability and comparisons with models and radio soundings, as shown in the next figure.

[1] *http://www.metoffice.gov.uk/science/creating/working_together/index.html#/profiler/payerne.html , CWINDE, username : metscience password : sc1ence*

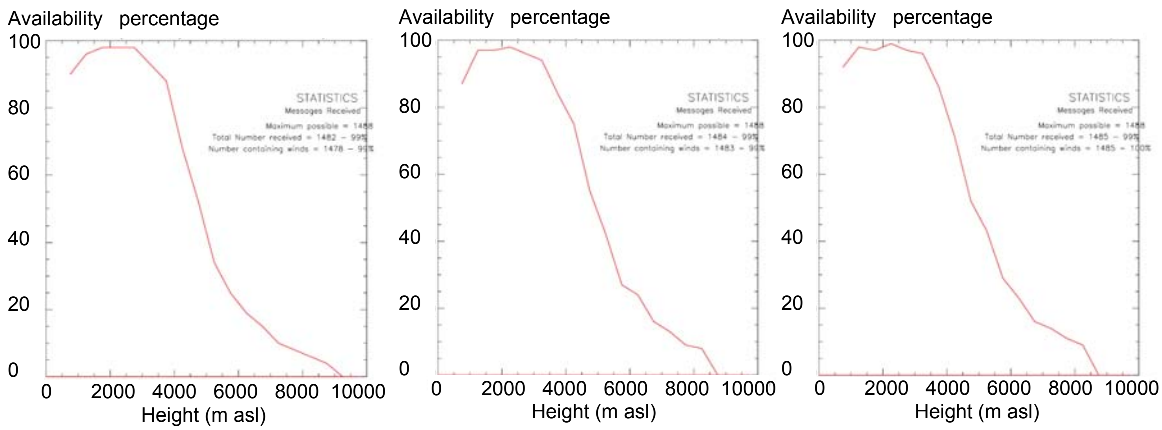

Figure 7 : EUMETNET monthly data availability for wind profiles (July 2009) for Payerne (left panel), Grenchen (central panel), and Schaffhausen (right panel)

This statistical analysis performed directly at the European level offers the opportunity of an independent quality assessment of the wind profiler data provided by MeteoSwiss over the Swiss Plateau in the frame of the CN-MET tool. These statistics indicate that the three Swiss wind profilers are ranking among the most reliable wind profilers in Europe. This is shown in the next figure, with a statistic over the last 6 months.

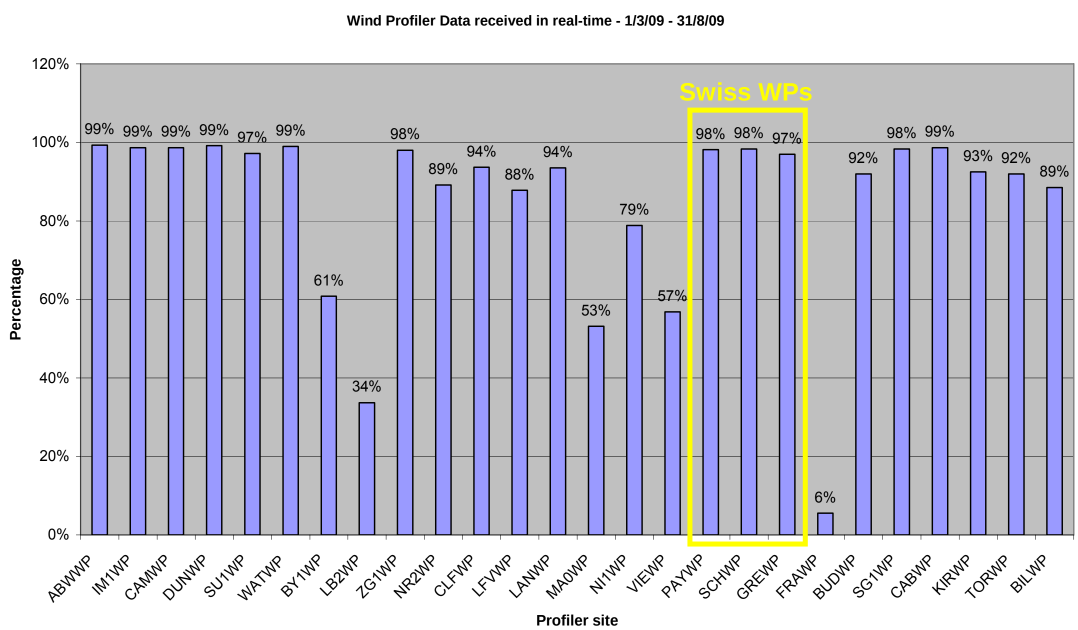

Figure 8 : EUMETNET Wind Profiler total data availability (March-August 2009): Payerne PAYWP, Grenchen GREWP, and Schaffhausen SCHWP.

4.3.1.3 Surface and upper-air data transmission

The SMN communication platform is used along the first section of the transmission path to transmit the data from the measurement sites to the entrance of the MeteoSwiss network. The total transmission path is made of three different networks labelled 1, 7 and 10 in the next figure.

The first network BV-Net interconnects all MeteoSwiss automatic weather stations inclusive the CN-MET stations. The CN-MET stations (2) include two computers for the wind profiler (WP) and one computer for the micro-wave radiometer (MWR). A wind profiler includes the acquisition computer (PCA) which produces the raw data and a processing computer (PCT) which produces the final wind measurements. The MWR host computer retrieves the raw and final temperature and humidity data from the embedded computer on the instrument.

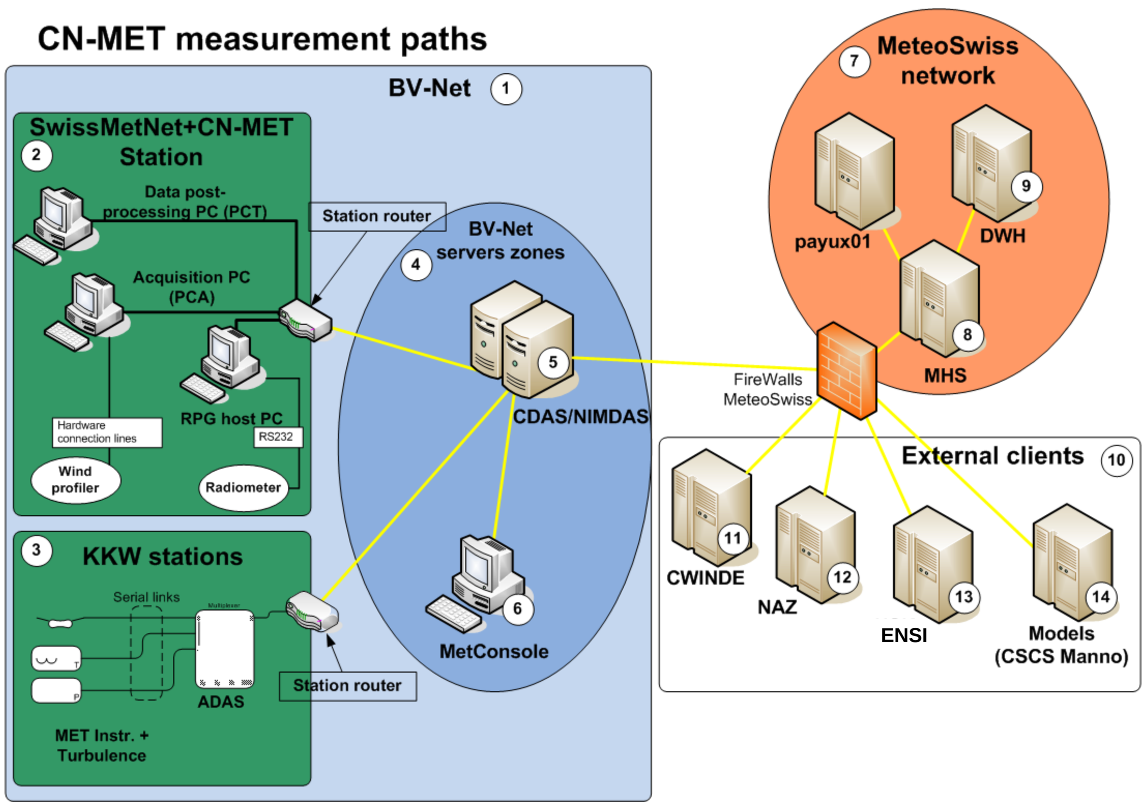

Figure 9: CN-MET/SMN measurement paths, from meteorological stations to final clients

Turbulence measurements by means of sonic anemometers at the location of the four NPPs (3) are connected to the regular SMN stations on a second wind mast. They are connected to the automatic logging devices of the station and are not accessible using IP protocols.

The BV-Net (1) hosts the central SMN servers (CDAS/NIMDAS) used to transmit the data to the outside world (10). They are in charge of scheduling the fetching of the data from all the different stations of the measurement networks. The sampling time is 10 minutes. Once downloaded into the servers the original data files are transformed into profile bulletin files which unify the data format. Those files are sent to the Message Handling System (8) operational servers which act as the postmen for all data transiting from and to MeteoSwiss. The availability of the data is automatically checked in real-time on the MetConsole running on a dedicated computer (6). The MetConsole issues warning if data files couldn't be downloaded or if the file format was not the expected one. This computer allows gaining access to all the computers on the CN-MET stations for control, maintenance and software upgrade.

Once transmitted to the MHS (8), the data enter the MeteoSwiss network (7) and are then sent to the customers. Some of those are inside MeteoSwiss network (7) like the DataWareHouse (DWH, 9) or outside (10) of MeteoSwiss (11 to 14).

All responsible teams on the data chain, from the data generation instruments down to the final clients are ready for supervising the data flow and send alarms in case of missing data. The data transmission events are logged at all important stages of the transmission which make it an effective task to pinpoint the reason for data failure at the end of the chain. Most of the data transmitting devices are made up of two hot redundant hardware units which can automatically switch from one device to the other in case of errors. This makes it a reliable and robust solution for highly sensitive data transmission.

This data chain allows MeteoSwiss to fulfil the necessary data availability and delivery in due time as requested for the CN-MET tool: in particular the direct data delivery to ENSI (13) and to CSCS (14) is crucial for the performance of CN-MET.

4.3.2 Delivery of model forecast data from COSMO-2 every 3 hours

4.3.2.1 The COSMO-2 model chain

Medium and extended range forecasting are based on external NWP sources, but MeteoSwiss runs its own short-range forecasting system. The core of this system is the non-hydrostatic Local Model COSMO (of the Consortium for Small-Scale Modeling currently composed of the National Weather Services of Germany, Switzerland, Italy, Greece, Poland and Romania – see www.cosmo-model.org).

On 27 February 2008, MeteoSwiss operationally introduced its new COSMO-suite, in which the model is running at two spatial scales: the regional model COSMO-7 with a horizontal resolution of about 6.6.km is driven by the ECMWF global model IFS. The local model COSMO-2, having a horizontal grid spacing of about 2.2 km, is nested in COSMO-7. The nesting of the NWP models is illustrated in Figure 10.

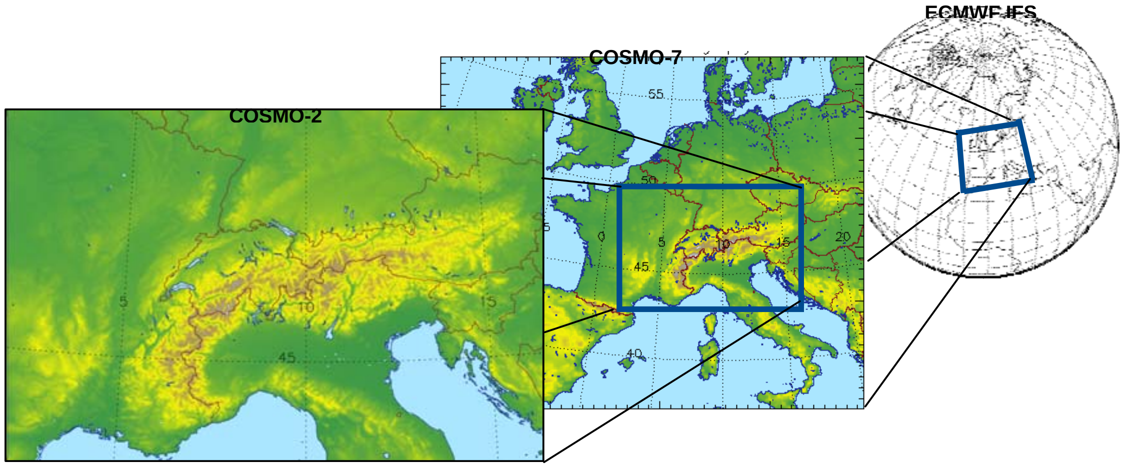

Figure 10: New NWP system of MeteoSwiss, the COSMO-2 production chain

The aim of COSMO-2 is to provide forecasts from the now-casting to the very short-range time scale, which makes it the primary tool for CN-MET.

Both COSMO-7 and COSMO-2 have their own assimilation cycle, which is updated in intervals of 3 hours. Two daily 72 hours COSMO-7 forecasts are calculated, based on the 00 and the 12 UTC analyses. Starting with the analysis at 00 UTC, one 24 hours COSMO-2 forecast is computed every 3 hours. The cut-off time for all forecasts is 45 minutes.

The time-critical forecast products for COSMO-7 are available in about 55 minutes. For COSMO-2 they are produced approximately within 36 minutes.

A sophisticated set of scripts controls the whole operational suite, and allows for a very high reliability of the system, with less than 2% of the forecasts requiring manual intervention. This same environment is also used to run parallel suites, to validate proposed modifications to the system and to facilitate experimentation by the modelling group.

The computing resources and expertise are provided by the Swiss National Supercomputing Centre (CSCS, see www.cscs.ch). COSMO-7 and COSMO-2 are calculated on a Cray XT4 equipped with AMD Opteron Dual Core processors, and achieve a sustained performance of 390 GFlops, (9% of the peak performance) on 804 computational cores. Pre- and post-processing run on the service nodes of the machine; a large multi-terabytes long-term storage is used for archiving purposes, and a 1 GBit/s link connects the MeteoSwiss main building with the CSCS.

A failover solution is in place at the CSCS with a second high-performance server that is made available for the operational use of MeteoSwiss in case of failure of the production server. This ensures the high availability required by ENSI for CN-MET purposes.

4.3.2.2 COSMO-2 output data for CN-MET

In the technical specification of the contract ENSI-MeteoSwiss 2005, the delivery of 18 hours forecast data every three hours (8 runs per day) was specified. This range has been extended in the course of the project to 24 hours of model forecast data (extension guaranteed as long as this forecast range is produced operationally).

COSMO-2 runs eight times a day at 00, 03, 06, 09, 12, 15, 18 and 21 UTC. COSMO-2 first assimilates meteorological observations, in particular many of the measurements coming from the CN-MET network, and then computes a forecast of the state of the atmosphere over a domain that extends from 42.72 N 2.25 E (lower left) to 49.76 N 17.25 E (upper right). It is covered by a grid of 520x350 grid points with a horizontal resolution of 2.2 km. In the vertical, the model extension fully includes the troposphere with 60 levels.

The post-processing package extracts sets of data, formats them and bundles them according to the product definitions. For ENSI, it is an area that includes all points within 50 km from the Swiss nuclear power plantsranging from ground level up to 2'000 m AGL. The next figure-map presents the domain covered for data delivery to ENSI.

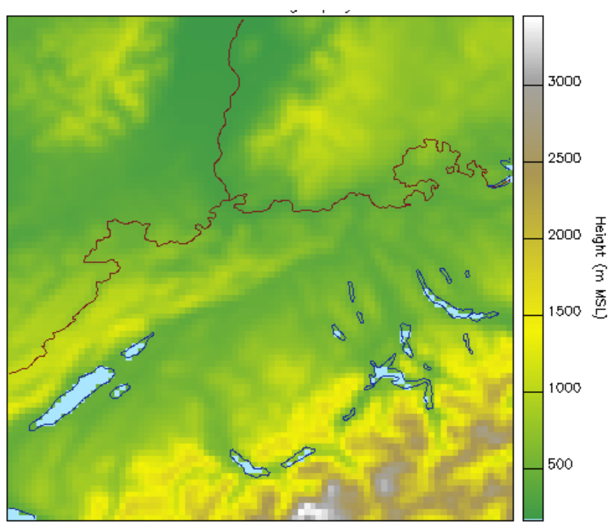

Figure 11: Large domain forecast: Lower left corner: 168/178, upper right corner: 252/255. Size of the domain: 85x85 grid points. Pixel size in picture is 2,2 km

Two sets of forecast data have been defined and are delivered by MeteoSwiss both covering ENSI's area of interest:

1) "large" forecasts with values for all grid points,

2) "small" forecasts with values at SMN and WINDBANK stations.

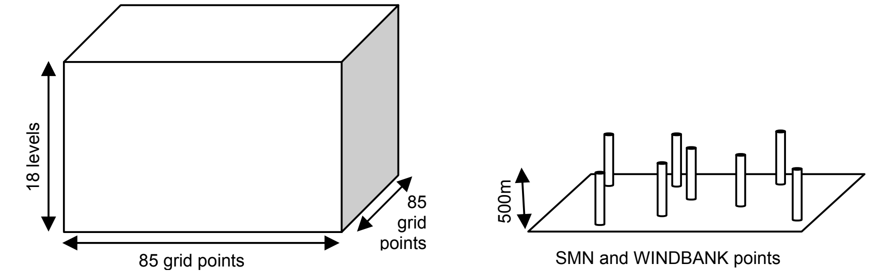

Figure12: large (left) and small (right) forecast data sets delivered to the ENSI

4.3.2.3 COSMO-2 grid-point files for “large” forecasts ("Grosse Prognosen")

In order to use the full forecast information, data for every grid-point of the COSMO-2 sub-domain is used for the “large” forecasts at ENSI. Considering the vertical dimension, data for the lowermost 2000 m above surface are of interest for ENSI. This layer includes 18 levels[2] in the current COSMO-2 setup. The output interval is 10 minutes. The data are provided in the GRIB format. GRIB (GRIdded Binary) is the World Meteorological Organization (WMO) standard for gridded meteorological data. Besides the forecast data, a grid record includes also meta information (e.g. initial time) in a standardised way.

One should be aware of the size of these grid-point files. With 30 model levels a GRIB file includes 100 records (64 with 18 levels). One value stored in GRIB requires 2 bytes. Hence, for the defined sub-domain one file has a size of 85*85*100*2 bytes = 1.38 MB. With a time resolution of 10 minutes, a 24 hours forecast produces 145 output files, corresponding to 200 MB per day.

4.3.2.4 COSMO-2 station files for “small” forecasts

The COSMO-2 model data are provided in ASCII files for the “small” forecasts domain. The file includes forecast data from COSMO-2 for all SMN and WINDBANK stations in a rectangle which is defined by a minimal distance of 50 km from a border to the nearest nuclear power plant. This sub-domain has a size of 85 x 85 grid points. The forecasts are delivered in a time resolution of 10 minutes currently covering 24 hours in total. As soon as one hour forecast has been computed a file is sent with this hour forecast.

The files contain the following model fields:

- wind direction/speed at 10, 70, 100, 110, 200, 500 m above ground
- temperature at 10, 70, 110, 200, 500 m above ground
- relative humidity at 70, 110 m above ground
- 2m temperature
- 2m relative humidity
- surface pressure

[2] *an increase to 30 levels is planned*

- total precipitation
- global radiation
- solar radiation at the surface
- surface sensible heat flux
- surface momentum flux (zonal and meridional)
- cloud cover

4.3.3 On-demand delivery of +6 hours model forecast data every 1 hour

The case of a nuclear accident is the key criterion forcing CN-MET to the most rapid update cycle in the assimilation of meteorological observations into COSMO-2. This is done as following:

In the so called “on-demand” mode the production cycle of COSMO-2 is set to 1 hour instead of 3 hours and performs forecasts over the next 6 hours instead of 24 hours. Moreover, ENSI can require this “on-demand” mode at any time on any day (the contract defines a maximum of two operational tests per year with a total of no more than 24 hours of on-demand production).

MeteoSwiss ensures that the necessary organisational structure and procedures are in place and ready for the “on demand” mode at the request of ENSI at any time, on a round-the-clock service basis.

Once requested, MeteoSwiss immediately sets up COSMO-2 such that it runs in 1 hour cycles. After having started the on-demand mode and until the ENSI requests to stop this service (return to standard every 3 hours operating mode), MeteoSwiss keeps in contact with ENSI in order to provide feedback on operation as necessary.

The remaining part of the process is identical (assimilation of meteorological observations, calculation, post-processing, transfer to MHS, and transfer to client).

For test purposes, twice a year and for at most 24 hours, ENSI may request hourly 6 h COSMO-2 forecasts (instead of every 3 hours 24 h forecasts). The first forecast will be started immediately after the request for this on-demand mode. The following forecasts will be started every full hour until the instruction to stop is received from ENSI. In case an operational COSMO-2 forecast is started routinely (every 3 hours), the data provided to ENSI will be taken from this forecast and no separate forecast will be started. The data will be provided in ASCII files as for the small forecasts.

4.3.4 Service support, including monitoring for problem identification and resolution, monitoring for performance evaluation and improvement

The different elements that ensure the service support required for CN-MET have been put in place over the last year. This chapter summarises this organisation. The details will be found in the final report. It consists of:

- **the helpdesk and first level support**: this support assumes the 24-hour a day alarm responsibility, ensures all necessary actions and communications in the event of a nuclear accident and initiates the crisis mode.

- **the second level support:** this support is directly in charge of the regular maintenance and operation of all the different components of the CN-MET tool. It covers in particular the surface and upper-air network, the COSMO-2 operation and the platform at MeteoSwiss for data delivery to ENSI.

- **the system monitoring and problem/change management:** the performance of CN-MET is continuously recorded at any of the different levels in the organisation. This provides direct input to the regular reporting activities defined in the contract between MeteoSwiss and ENSI. In the event of an incident on CN-MET or in the case of an upgrade of the infrastructure, a number of change management procedures have been devised.

The CN-MET service support is organised in such a manner that it can fulfil the general requirements defined by ENSI for CN-MET. Overall criteria (see next chapter, “key performance index”) are defined internally at MeteoSwiss in order to ensure the required CN-MET performances.

CHAPTER 5 CN-MET achievements

5.1 CN-MET key performance index and assessment

CN-MET is an operational tool combining measurements and modelling over the Swiss Plateau in order to obtain a three-dimensional picture of the atmosphere at any given time. Every three hours, at the time of the new COSMO-2 run, the model output supplies the “best picture” of the current atmospheric conditions: this is the so-called “analysis” mode and corresponds to the time when the latest observations have been assimilated into COSMO-2, and the model has reproduced the state of the atmosphere at any grid cell into the model. The weather forecasts are provided up to 24 hours lead time.

The current CN-MET tool performance is essentially based on two mandatory requests:

- the overall availability of CN-MET
- the quality assessment of CN-MET

The requirements on the **CN-MET data availability** were initially defined in the contract signed in 2005 between ENSI and MeteoSwiss. They are also related to the performance mandate (“Leistungs-auftrag”) of MeteoSwiss. Table 2 summarises these key performance indices.

Key performance index	**Target**
Maximum number of consecutively missing[3] COSMO-2 forecasts	max. 3
Used time for COSMO-2 forecast delivery after computation	max. 30 minutes
Number of COSMO-2 forecasts missing[3]	< 5% / year
Start of on-demand mode within 30 minutes from request	at any request
Real-time availability of measurements	> 96 % / year

[3] *A forecast is considered missing when its computation finishes only after the due time for the delivery of the next forecast according to the CN-MET schedule*

Table 2 Key performance indices for the CN-MET tool

These general requirements are also the criteria that will be used over the years for the regular reporting from MeteoSwiss to ENSI.

The **CN-MET assessment** is based on the results of the two field campaigns in Kleindöttingen/Leibstadt in autumn 2008 and Mühleberg in spring/summer 2009. They are the conclusion of intensive developments of new tools and equipments within the CN-MET project. They provide the basis to assess the quality of the CN-MET system relative to a mobile profiler and tower measurements (Leibstadt, Mühleberg, Stockeren, and Beznau meteorological towers).

<u>The comparison studies:</u> The performance of COSMO-2 output is estimated during a defined period of time (typically 2 x 3 months) and compared with one independent wind profiler observation, or more specifically one vertical profile. This is an intrinsic limitation of the assessment studies: the new CN-MET tool gives a 3D picture at any grid cell over the whole COSMO-2 CN-MET domain, both for the current weather conditions (the so-called "analysis mode") and for the forecasted values over the next 24 hours. This 3D(t) output (delivered to ENSI in the "large" forecast product) provides much more information than a subset of one 2D(t) vertical profile observation, while at the same time the whole validation study relies only upon the comparison of the COSMO-2 data with this subset of observation.

<u>The statistical criteria:</u> The assessment is based on the two following criteria:

- the study of the bias (mean deviation) between the model and the measured results,
- the study of the 95% quantile and percentage within threshold describing the spread (as opposed to the mean) of the deviation.

The first indicator, the bias, is a measure of the mean deviation between model and measurement over the entire duration of the field campaign, highlighting the amount of systematic disagreement between the two. The second indicator, the 95%-quantile (or 95th percentile) value, is a measure of the spread of the model deviations from the measurement. Since the target value for the quantile is set to 95%, it has to be expected that "outliers" will strongly influence the quantile as opposed to the mean value which is more robust. The percentage within threshold indicates the relative number of model values within the threshold targeted by the specification document.

A difficulty when comparing the model to different references is the incompatible measurement principle of a wind profiler measuring volume data and anemometer point measurements on a wind tower.

<u>Leibstadt 2008:</u> In the field campaign Leibstadt – Kleindöttingen 2008 the CN-MET upper-air network was not completed, with Grenchen still under construction and in test phase. Therefore only the remote sensing sites in Schaffhausen and Payerne were assimilated in COSMO-2. The first main conclusions of this study were twofold:

- The mean bias was reproduced with a very good accuracy by the model as compared with the observed data. This was true for both wind speed and wind direction.
- The second criterion (95% quantile) already underlined the two major limitations of the CN-MET tool: winds at low altitude levels (typically below 250 m AGL) and winds in rapidly changing weather conditions were simulated with larger deviations with respect to the wind profilers.

Mühleberg 2009: These conclusions were taken into account for the 2nd field campaign in Mühleberg 2009: the study was focused on the comparison of the “low mode” wind profiler data (or the data at higher spatial resolution and closer to the ground) against the modelled results. During this 2nd field campaign the full CN-MET network was realised and assimilated into COSMO-2 (this time including the measurements performed at Grenchen as well).

Even though the orography around the Mühleberg power plant is significantly more complex than in Leibstadt, this field campaign confirmed the excellent performance of CN-MET against the observed data for the mean bias even at low altitude: this was further supported by the excellent comparison obtained with the predicted values against both the *in situ* measurements at the top of the Mühleberg meteorological tower, and respectively the data obtained from the Stockeren meteorological tower.

In addition the comparison with the profiler in “high mode” typically up to 5’000 m AGL consistently yields better results than with the “low-mode” up to 1’200 m AGL. At higher altitude of the planetary boundary layer and in the lower part of the free troposphere the weather conditions successively become more large-scale and are better captured by COSMO-2. This result is linked with the current COSMO-2 grid resolution and its influence near the surface in case of complex orography. Average wind speeds in the lower troposphere are higher than near the surface and are associated with better defined wind directions (the lower the wind speed the broader the wind direction distribution): these are weather conditions for which the statistical criteria are by essence yielding better results. It also recalls that COSMO-2 provides the best picture over the entire Swiss Plateau, but with higher uncertainty at the kilometric scale in complex orography (e.g. the wind channelled in the Mühleberg power plant vicinity).

The COSMO-2 rapid update cycle: During this 2nd field campaign an important aspect of the performance of CN-MET was confirmed: the importance of the every 3 hours model runs (8 runs per day). In the case of Mühleberg in 2009, the shorter lead times (typically up to 3 hours) proved to give the best estimate between predicted and observed data. The model runs every 3 hours ensure that the newest and most accurate “picture” of the atmosphere from numerical model analysis and forecasts is used in an optimal way. This conclusion (the positive impact of this rapid update cycle) could also be observed and quantified during the MAP D-Phase campaign [10].

The 95% quantile and/or differential percentage values: The same limitations underlined in Leibstadt 2008 were shown in Mühleberg 2009: CN-MET shows some limitations using the “outliers criteria” for lower altitude and for changing weather conditions. For a further assessment of the performance of CN-MET at low altitude an additional study was conducted in 2009 using the data from the two meteorological towers Mühleberg (at 110 m AGL) and Stockeren. Very similar *in situ* observations as compared to the respective model results were obtained. This was not true for the 10m AGL wind measurements from the SwissMetNet station Mühleberg: in this case the local channelling of the wind is only partially reproduced by COSMO-2. This result in turn confirms the optimal design of the CN-MET network: on the one hand the new NPP weather stations are needed for a good observation of the local wind circulation, and on the other hand the data of the meteorological towers are adequately replaced by the output of CN-MET COSMO-2 data, the latter being constrained by the direct assimilation of the three upper air sites on the Swiss Plateau.

Further development of COSMO-2: For further improvement of COSMO-2 near the surface different developments are already undertaken: a new parameterization scheme was introduced at the beginning of September 2009 including the impact of sub-scale orographical features in the model (SSO). This scheme improves the quality of the forecast in the boundary layer. The vertical level distribution of COSMO is also under investigation. A finer vertical spacing of the grid levels close to the ground will provide more accurate values in the boundary layer. Finally in a few years the next

COSMO generation with a higher horizontal grid cell resolution will be made available. Note that such development will depend upon improved computing performances to be made available at the CSCS.

CN-MET September 2009: After 4 years of development the new meteorological security tool in Switzerland is in full operation. It has replaced the previous R-32-based tool with some essential changes: the local measurements are no longer used as data input for the dispersion models. In CN-MET the surface and upper-air measurements are assimilated into the newly developed very high-resolution COSMO-2, and the latter defines the input conditions for the local dispersion models. This directly impacted the design of the new CN-MET network. The most important measurements are no longer located at the site of the nuclear power plants, but up- respectively down-wind from these sites. These measurements no longer take into account the altitude range of the nuclear power plants' cooling towers, but the entire planetary boundary layer and the lower free troposphere.

The final acceptance by all bodies concerned can now take place, while the final CN-MET project report will be completed by March 2010.

5.2 Initial specifications and achievements

The Annex A of the contract between ENSI and MeteoSwiss (19 December2005) defines the tasks to be undertaken by MeteoSwiss within CN-MET.

5.2.1 Overview

The CN-MET concept is based on a replacement of meteorological towers at the nuclear power plants' locations by a combination of a measurement network with a high resolution NWP model. Table 3 describes the main defined tasks and their status at the end of the project.

TASK	STATUS	COMMENT
Installation of three upper-air measurement sites up-wind, down-wind and at the centre of the Swiss Plateau. These three sites have to measure wind speed and wind direction as well as temperature profiles up to the top of the planetary boundary layer	The three ground-based remote sensing sites are built and are operational	OK, with an update of the system in Payerne in order to homogenize the network
Optional installation of a fourth system in Leibstadt to measure wind speed and wind direction	Study showed that a fourth system would not improve the local forecasts	In agreement with ENSI, the fourth system was not installed

TASK	STATUS	COMMENT
Four planetary boundary layer stations providing point measurements of wind speed and wind direction as well as temperature within the planetary boundary layer	One station (Stockeren) built while the three others are planned for 2010, but provide already 60-minute meteorological data	To be updated within SMN2 in 2010
A SwissMetNet type surface meteorological station at each of the nuclear power plants' location	Four SMN surface stations built with turbulence measurements at 10m AGL at each site	OK
Assimilation of measured data from the network into a numerical weather prediction model providing a coherent view of the atmosphere	Wind measurements from the three sites operationally assimilated in COSMO-2	OK
Eighteen-hour forecasts every three hours with a temporal resolution of 10 minutes with a NWP model of about 2.2km horizontal resolution	COSMO-2 operational computing every three hours with a temporal resolution of 10 minutes and 2.2 km horizontal resolution	Twenty four-hour forecasts delivered to ENSI instead of eighteen-hour forecasts (as long as the actual schedule is kept, i.e. more than 18 hours are computed)
Calculation of meteorological dispersion parameters necessary for the ENSI dispersion models	Dispersion parameters operationally delivered to ENSI	OK

Table 3 Overview of CN-MET goals, status and comments

5.2.2 Validation of the tool

The validation of the tool CN-MET was supposed to follow the planning and procedures defined in Annex 1 of the Annex A of the contract between ENSI and MeteoSwiss (19 December 2005). Meanwhile, the minutes of the ENSI-MeteoSwiss meeting of 9 April 2008 defines a new way of validating the COSMO-2 products. The main changes from the initial plan are shown below:

- both parties agreed that COSMO-2 comparisons with mast measurements do not make much sense (it was still partly done, but not systematically);

- two three-month periods (at different locations and seasons) will be performed instead of a 9-month COSMO-2 wind profiler comparison with a mobile wind profiler (provided by MeteoSwiss) will be used as an independent reference for the comparison;

- a comparison of COSMO-2 with WINDBANK performance will be done during the 1st campaign.

The flowchart in Figure 13 describes the main steps of this validation.

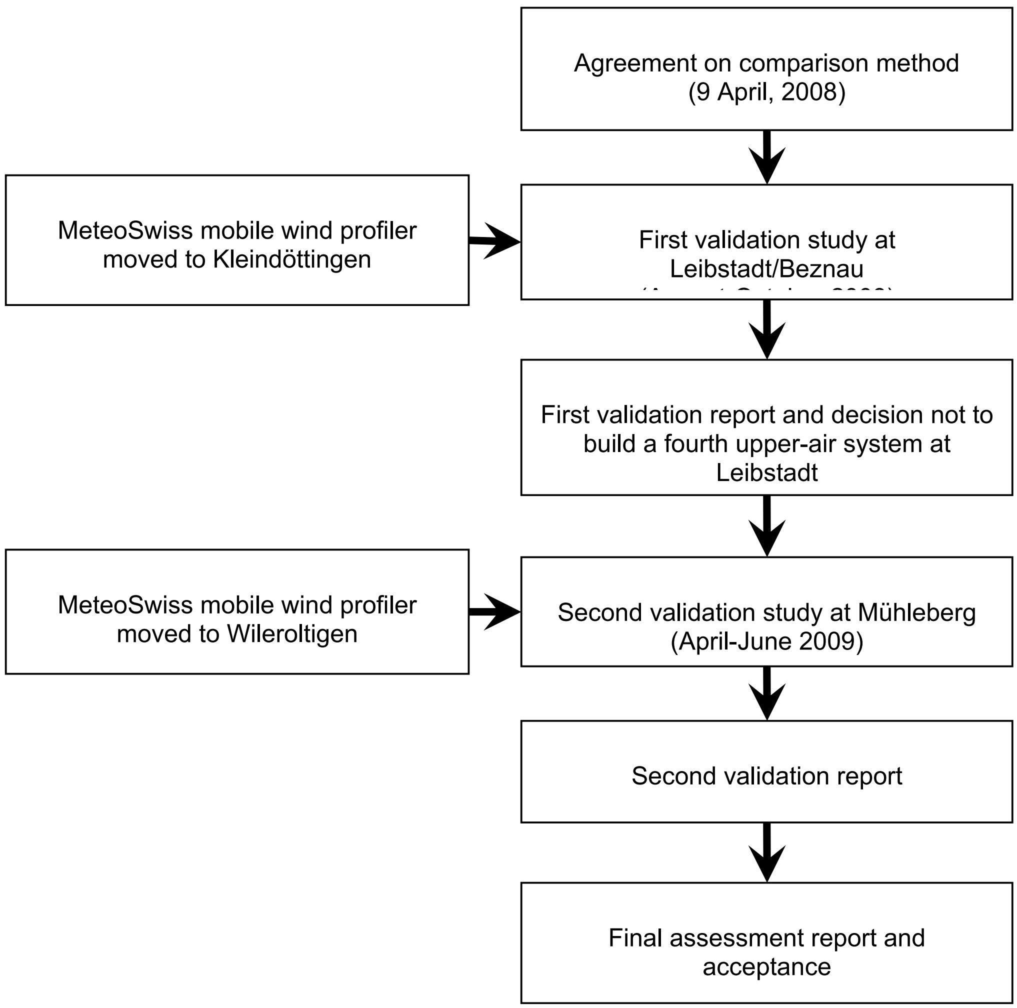

Figure 13: Flow chart of the steps used for the COSMO-2 validation

5.2.3 Requirements

5.2.3.1 Parameters

The products to be delivered can be found in Table 4.

PARAMETER	STATUS	COMMENT
Measured data from SMN at nuclear power plants	Wind speed and direction Temperature Precipitation	OK OK OK
Measured data from remote sensing sites (wind and temperature)	Available	Delivery to ENSI no longer requested
Turbulence measurements at nuclear power plants	10 m turbulence parameters from a sonic anemometer at each nuclear power plant station	OK, as well as at Payerne
Supplementary data as defined in Table 5 of Concept V5.3	All data available except temporal resolution for three PBL stations	PBL stations to be updated within SMN2 in 2010
Profiles of wind and temperature at nuclear power plants	COSMO-2 data provided to ENSI for 10, 70, 100, 110, 200 and 500 m above ground	OK
Weather categories (stability classes)	Derived from COSMO-2 data by ENSI	OK, derived from COSMO-2 data by ENSI
Other parameters necessary as input parameters for dispersion models	COSMO2 data provided to ENSI for a domain containing all 50 km circles around the NPPs: - Wind speed and direction - Temperature - Relative humidity - Surface pressure - Precipitation - Global radiation - Solar radiation at surface - Surface sensible heat flux - Surface momentum flux - Cloud cover	OK

PARAMETER	STATUS	COMMENT
Derived values for dispersion models	Values derived from COSMO-2 data by ENSI : - Temperature gradients - Weather category - Turbulence parameters - Standard deviation profiles for wind speed - Exponent of power law for wind speed in surface boundary layer - PBL height	OK, derived from COSMO-2 data by ENSI PBL height is already available internally at MeteoSwiss but requires further checking before being available for external users.

Table 4 Parameters to be delivered to ENSI, status and comments

5.2.3.2 Accuracy of measurements and model data

Both measured and modelled data must fulfil defined specifications as shown in Table 5.

SPECIFICATION	STATUS	COMMENT
Measured data within CIMO-WMO specifications	Operationally supervised internally and at European level, see 4.3.1.2	OK
COSMO-2 wind data are within $\pm 20^{o}$ for wind direction and ± 1m/s for wind speed (10% for wind speeds > 10m/s) for speed > 2 m/s in 95% of cases, when compared with measurements.	Comparison of COSMO-2 with independent wind profiler data shows Q95% values between 80° and 100° for wind direction and around 4.5 m/s for wind speed.	The comparison could not meet the required values. A comparison with tower data showed significant better agreement. The comparison of devices on different levels on the same tower showed similar performance as the one between model and wind profiler. This indicates that the targeted values correspond more to a measurement device accuracy under ideal and controlled conditions and do not relate to comparison between model and instruments.

Table 5 Expected precisions, status and comments.

5.2.3.3 Availability and delivery times

The key performance indices as defined in the “CN-MET Operating Concept” are summarised in Table 6 and show that COSMO-2 availability and delivery criteria meet the requirements.

The currently achieved delivery times of COSMO-2 runs is within 1h00 for the first forecast time and 1h20 for the latest lead time.

Key performance index	**Q1-Q3/2009**
Maximum number of consecutive missing[4] of COSMO-2 forecasts	3[5]
Used time for COSMO-2 forecasts delivery after computation	max. 4 min[6]
Number of COSMO-2 forecasts missing[4]	0.2 %
Start of on-demand mode within 30 minutes from request	1 / 1
Real-time availability of measurements	98%

Table 6 Key performance indices defined in the CN-MET Operating Concept during Q1-Q3/2009

5.2.4 Data delivery

The delivery of end products to ENSI follows a data transmission scheme which was the result of an agreement between the partners. The redundancy of the connections has been favoured over a solution using relatively slow dedicated lines.

The chosen solution allows a fast transmission of the information to the client. The current transfer rate is 1 Gbit/s provided through the redundant Switch connection of CSCS, MeteoSwiss and PSI.

[4] *Delivered with a delay greater than 3 hours*

[5] *One occurrence: Delivery of 05.01.09 21 UTC, 06. 01.09 00 UTC and 06. 01.09 03 UTC forecasts completed with more than three hours delay*

[6] *After computation of 24h forecast and based on log-files for September 2009 and delivery to meteo1.ensi.ch only.*

CHAPTER 6 References

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