Meteorology and Security around the nuclear power plants in Switzerland

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The Nuclear power plants in Switzerland are currently equipped with meteorological towers (up to 110m height) and ground-based instruments which yield the basic data input to a gaussian-dispersion model. The latter is used as the meteorological security tool in case of a nuclear power plant accident.

MeteoSwiss is in charge of upgrading this security tool linked to the nuclear power plants for the next two decades. It is intended to take advantage / peculiarity of the fact that the four nuclear power plants are all located on the Swiss Plateau, where wind fields are channeled towards the NE and SW directions due to the presence of the Jura mountains on the NW and the Swiss Alps on the SE.

The project CN MET "Centrales Nucléaires et Météorologie" is directly addressing this issue: it is based on the development of a high resolution forecast model linked to a meteorological network of ground-based and remote sensing instruments. With CN MET, the description of the dynamics of the atmosphere will be covered for the entire planetary boundary layer (e.g. up to 2km above ground level) over the Swiss Plateau. It will be achieved by using remote sensing instruments such as wind profilers, passive microwave temperature instruments, as well as a sodar for low altitude wind measurements. These data will be used as input and boundary conditions for a new developed fine grid model. Two major goals are foreseen:

- *The meteorological security tool that includes the measurement network and the fine grid model will at any time (e.g. the time of a power plant accident) give the best picture of the evolution of the air masses for the next 24 hours over the entire Swiss Plateau.*

- *Furthermore the met security tool will generate the necessary data input for the local dispersion model, the latter being specifically set for each of the four nuclear power plants location respectively.*

This idea of combining a meteorological network with a fine grid forecast model for security purposes may represent the future for a number of similar issues worldwide.
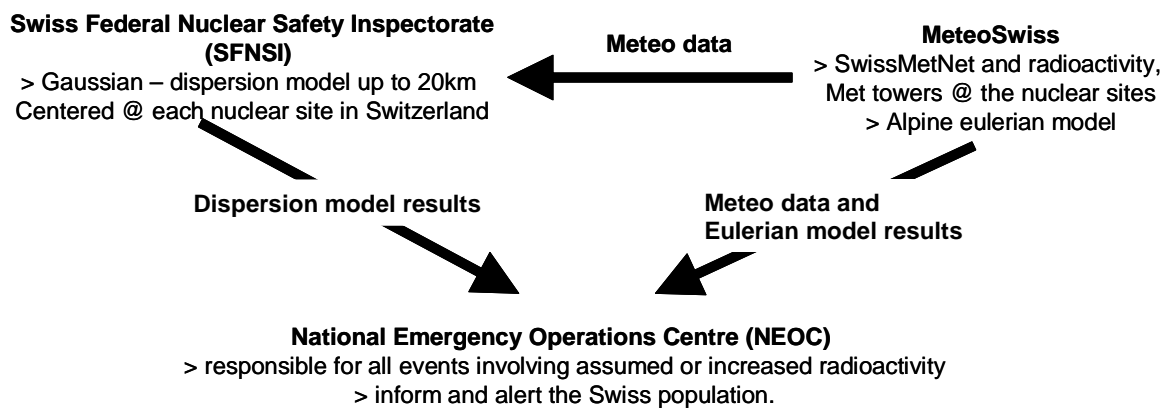
1. Introduction:

Four nuclear power plants generate ca. 40% of the total electricity in Switzerland. They are operated 24 hours a day. The Swiss Federal law defines the guidelines for their secured operation. In particular the Swiss Federal Nuclear Safety Inspectorate (SFNSI) is the public office in charge of the systematic control of the nuclear security and radioprotection in the nuclear power plants, as well as of the related equipment and nuclear waste storage. Among others, one of the SFNSI tasks is to provide an operational tool that allows at any time (eg. the time of a nuclear power plant accident) to forecast in the next few hours where and how the radioactive plume will evolve.

The results of the SFNSI models are directly transmitted to the National Emergency Operations Centre (NEOC) whose mission is to inform and alert the Swiss population (see Figure 1). The NEOC is responsible for all events involving assumed or increased radioactivity.

For the nuclear security, MeteoSwiss the Swiss Federal institute of meteorology and climatology is in charge of operating the mesoscale Eulerian forecast model (aLMo) in order to define the general meteorological situation over central Europe and the Alpine regions. MeteoSwiss acts also as the advisory center of expertise for meteorological model used for the SFNSI.

On the other hand MeteoSwiss is the meteorological data provider: it is in charge of the radioactivity measurement network, and also of the local meteorological equipment located on each nuclear power plant site, the latter being equipped with a meteorological mast with wind measurements and temperature at three given heights (typ. up to 110m above ground level).

These data are distributed in real time to the SFNSI which uses them as initial conditions for their own gaussian and atmospheric dispersion models. Each of these model is centered respectively on the nuclear power plant's location. It represent a valuable tool for forecasting the evolution of a radioactive plume on the local scale, say over a radius of ca. 20km. The SFNSI's atmospheric dispersion model is based on the Random Displacement Method, designed as an operational tool directly linked to each of the four nuclear power plants with its site specific topography, and with output results used in real time.

Swiss Federal Nuclear Safety Inspectorate (SFNSI)
> Gaussian – dispersion model up to 20km
Centered @ each nuclear site in Switzerland

Meteo data

MeteoSwiss
> SwissMetNet and radioactivity, Met towers @ the nuclear sites
> Alpine eulerian model

Dispersion model results

Meteo data and Eulerian model results

National Emergency Operations Centre (NEOC)
> responsible for all events involving assumed or increased radioactivity
> inform and alert the Swiss population.

Figure 1: Information flow diagram between MeteoSwiss, the Swiss Federal Nuclear Safety Inspectorate (SFNSI), and the National Emergency Operations Centre (NEOC)

A number of parameterized meteorological conditions are used as input conditions for the SFNSI's atmospheric dispersion model such as the atmospheric stability, the boundary and the mixing layer height, and the turbulence parameters.

Basically the current nuclear security tools in Switzerland can be rated as satisfactory for the short range/short term prediction scales (eg. the development of a plume over the next 3-6 hours, and over ca. 20km radius), and also satisfactory for a general description of the synoptic conditions (eg. the meteorological conditions in central Europe over the next 3 -5 days).

"In between" or at a range of some hundreds of km and over a period of time of ca. 24 hours, the development of a radioactive plume is not ideally described. This point was already stated in the 80's at the end of the consolidation phase of the current security tool (Schneiter 89, 0). In particular the following remarks were highlighted:
- "…in case of a major radioactive emergency, there could be leaks at high temperature, with rising speed and upward motion that would develop into the planetary boundary layer and free troposphere.."
- "…the trajectories that are predicted at higher altitude do not necessarily match with the one measured and calculated at 110m above ground level…"
- "…the use of remote sensing method for wind field measurements at higher altitude would be useful information…"
- "…there is a need for additional predictive results based on a fine grid atmospheric model output…"

Even though the current security tool was designed in the 70-80's with well known intrinsic limitation, there was essentially no existing and robust solution at that time either for remote sensing measurements or for an operational use of a fine grid and real time atmospheric model. This is the background of the currently available meteorological security tool for the nuclear power plants in Switzerland.

Finally in the last years, a new fact triggered the start-up of CN MET: the SwissMetNet project, the renewal of the automatic and conventional meteorological networks operated in Switzerland (see the paper by Heimo et al.). This renewal directly impacts on the actual meteorological equipment around the nuclear power plants.

2. CN MET, a new project for "the meteorology and nuclear security" in Switzerland

The four nuclear power plants in operation in Switzertland are all located on the Swiss Plateau at a distance of ca. 100km or less one from the other: this essentially means that they undergo similar weather conditions, the Swiss Plateau consisting of a basin surrounded by mountains in the N-NW (Jura mountains) and by the Alps in the S-SE (Figure 2).

As a consequence, this peculiar situation allows to design a meteorological security tool based on the idea of a network of ground based and remote sensing stations that are measuring the instantaneous inflow / outflow conditions over the Swiss Plateau (and not anymore a meteorological mast located at each of the four nuclear sites), and brings the adequate database to a fine grid numerical weather prediction model (typ. 2km horizontal grid cell resolution) directly designed to provide the right tool for decision makers in case of a nuclear accident over the Swiss Plateau. In addition most of the Swiss population is living on the Swiss Plateau with six of the nine major cities located within a 50km radius of a nuclear power plant.
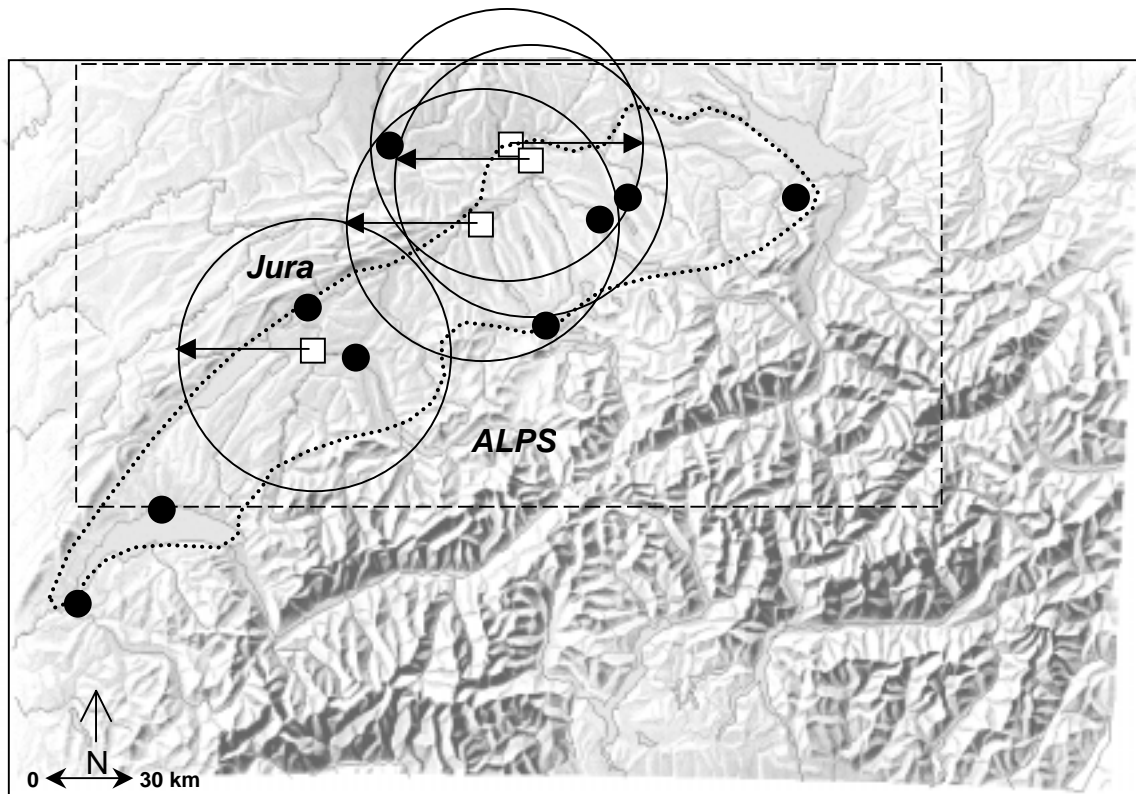
Figure 2. Topographical view of Switzerland with the Swiss Plateau (dotted line) surrounded by the Jura mountains to the north-west and the Alps to the south south-east. The solid dots represent the 9 major cities of the country, the white squares, the four Swiss nuclear power plants and their respective 50km (black arrows) radius circle. The dashed rectangle defines the domain used in Figure 3.

3. The CN MET measurement network

A combination of near-surface measurements and ground-based remote sensing techniques will constitute the CN-MET observation network. Three main types of instrumentation are planned.

1) Three low-tropospheric wind profilers 0 combined with three microwave radiometers provide a continuous observation of the vertical structure of the PBL over the Swiss Plateau. These wind-temperature profiles (e.g. Figure 3) will be located at three important spots in the domain: at the two main boundary conditions of the domain (in- respectively out-flow conditions) and one in the center of the domain for test comparison with model results. This center station will also give a realtime observation of the weather conditions close "in the middle" of the power plants. A fourth system (SODAR), will cover the area influenced by the local topography at one of the specific nuclear power plant location (Leibstadt).

2) The aerological radiosonde station in Payerne will provide the state of the atmosphere four times a day: twice with pressure, temperature, humidity and wind and twice with wind only.

3) At each nuclear power plant site (Mühleberg, Gösgen, Beznau, and Leibstadt), a SwissMetNet surface station will bring the needed meteorological observations for a correct description of the local weather conditions. It will also include turbulence

measurements at 10 m height by using sonic anemometers, the turbulence measurement being of vital need for the short scale dispersion model input. Four high towers in the surroundings of the nuclear sites (Stockeren, Bantiger, St.Chrischona, and Uetliberg) will remain equipped with wind and temperature sensors, and bring an additional set of data for the control of the model results.
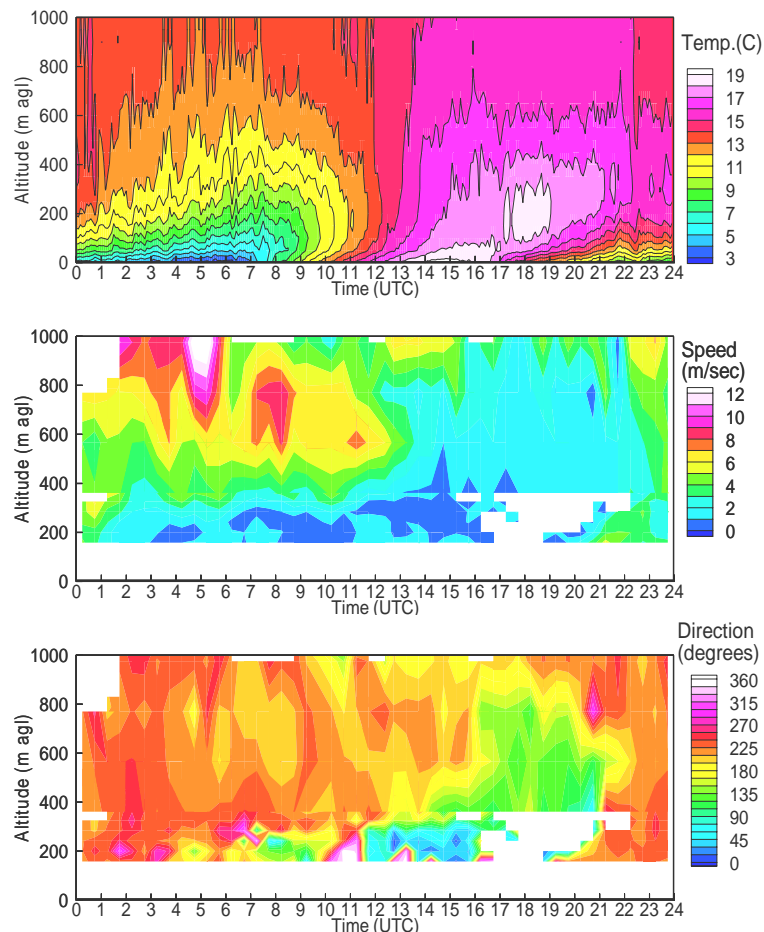
Figure 3. Typical set of vertical profiles time series within the planetary boundary layer as expected in CN MET: this example was measured in Payerne on March 17th 2004 during the TUC campaign. Temperature is measured by passive microwave radiometer, wind speed an direction by low tropospheric wind profiler.

4   The CN MET fine grid NWP model

Within the COSMO consortium [3], there is a strong impulse to improve the current horizontal resolution of the European Local Model (LM). The move from a grid of 7 km to a finer of ca. 2 km mesh is under way in Europe. The new Swiss NWP aLMo/2 (aLpine Model) will be a nested grid of the 7 km LM **Error! Reference source not found.**, centered over Switzerland, and encompassing the main alpine region (Figure 4). A rapid update cycle with quasi-real time data assimilation from the CN-MET network will be designed, and short term forecasts of up to 18 hours, renewed every 3 hours, will be provided.
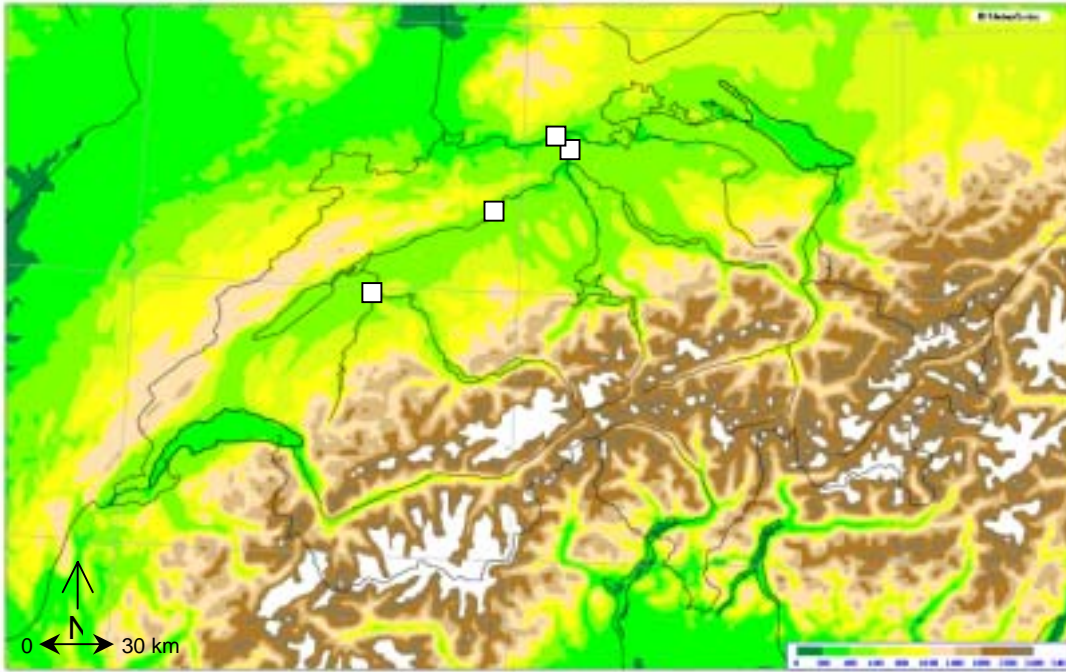
Figure 4. aLMo topography with a horizontal resolution of 2.2 km. White squares represent the four Swiss nuclear power plants.

The numerical results (e.g. Figure 5) from aLMo/2 will be used as a "now casting" tool over the Swiss Plateau and for the next few hours up to one day after a nuclear event, but they will also be used as initial input data for the atmospheric dispersion model in operation at the Swiss Federal Nuclear Safety Inspectorate (SFNSI): in particular, a three-dimensional snapshot of wind field and turbulence will greatly enhance the quality of the SFNSI's model output.

5   Conclusion

CN-MET is the combination of the aLMo/2 fine grid NWP model with the ideal network of meteorological observations, namely a network with observations at similar time and space resolution as the model resolution, designed as input and boundary conditions for the model.

Instead of having meteorological towers located at each individual nuclear power plant, CN-MET is based on a "global network" of in-situ and ground-based remote sensing systems covering the three dimensions of the entire region. By combining the measurements with a high resolution non-hydrostatic NWP model, the meteorological information will be available at each point of the grid cell, including the nuclear power plants' locations. Data from the observation network will be assimilated in real-time. Therefore, the model will provide a coherent image of the state of the atmosphere at and around the nuclear power plants and of its evolution in time and in space. A new 18 hours forecast will be issued every 3 hours, with a temporal resolution of 30 minutes, over the entire Swiss Plateau.
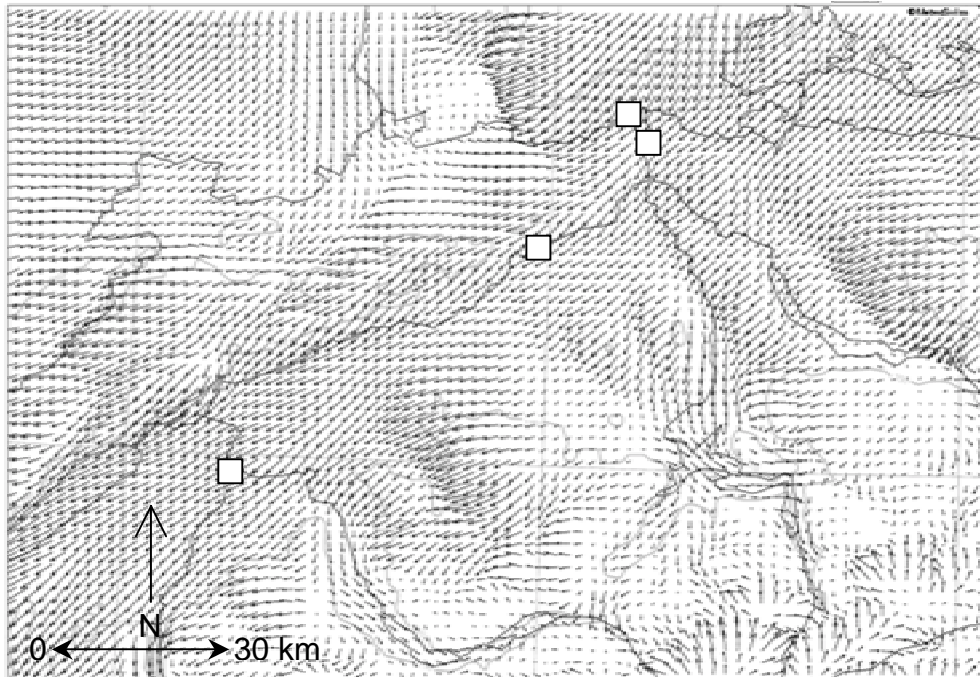
Figure 5. Example of wind field at 30 m agl, 27 March, 2004, 06UTC, calculated with the aLMo/2.2. White squares=nuclear power plants.

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