# Building and Operating a Station Network for Climatology and Hydrology

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**Abstract**
The German Meteorological Service (DWD) is modernizing its surface measurement networks. In addition to the synoptical station network an automatic network of 300 climatological stations as well as 500 precipitation stations and 90 wind stations is a part of them. A large number of these stations is in operation, together with a network center. For the remaining number the difficile process of acquiring the station location and the succeeding installation is going on. The sensor equipment will be explained as well as the feature that the voluntary station operators can input eye-observations into a handheld terminal. Other functions such as data transmission, central archiving and quality control of the data, alarm-management, monitoring and administrating the stations will be mentioned. Essential activities for a long-term operation of the system are to care for software maintenance and hardware replacement. The lecture will also show the station design and central network functions.

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## 1. Introduction

Along with the synoptical network [1] consisting partly of automatic stations and partly of stations with DWD-observers also the climatological network manned with voluntary observers at most stations is in the phase of reconstruction and reorganization. The internal name is AMDA III (Automatic Meteorological Data Acquisition System) and in relation to the number of measured variables it is a sub-quantity of the synoptical network, whose internal system name is AMDA I resp. AMDA II.

When planning the network the objectives were to automate most measurements, to have a fast availability of the data, to improve the data quality to be on the same level as the data from synoptical stations , the data should be archived in a central data bank. Also a network monitoring software running on any PC of the DWD IT-domain should facilitate the control of network operation. The voluntary observer who also provides the station area in his private estate will make additional eye observations and type them into a terminal connected to the station computer. You find observers at the climatological stations (internal name AMDA III (S)) and the hydrological stations (AMDA III (N)), whereas the wind stations (AMDA III (W) are unmanned.

## 2. Progress in building up the network

Meanwhile about 80 % of the planned stations are in operation. Along with building up the rest of the stations new steps have to be taken: supplementary user requirements have to be realized. That means to create new versions of the the station software. Because the system contractor is no more existent this is done by DWD-personnel. The current operation of the network is guaranteed by the data control and hardware maintenance done by DWD-personnel. On the long-term time-scale it is planned to replace the proprietary hardware by standard marketable components.

The establishment of a large number of stations will take much time and a lot of people are harnessed. The first step is to look for station sites. The site must fulfill certain conditions: it should fit into the geograhical distribution which covers all climatical particularities of the country, it has to be meteorologically representative for the surrounding local terrain with no obstacles that could impair wind or radiation, and you have to find an observer who will cede an area of his estate for the station and who will make eye observations on a regular base and on long term. This search is lengthy in Germany and is undertaken by some experienced DWD-employees and this is still going on.

The station hardware is then installed by a private company and ISDN-connection is provided by the telecommunication company. Technicians from DWD will review this work, configure and start the stations. Co-workers in the DWD-center will configure the data bank for a new station and finally will switch the station into the operational state and initiate data calls.

### 3. Station design

The station components are seen in figure 1. The Sensors are placed according to internal regulations [3] and to WMO recommendations. If wind is measured the mast is generally set apart. The height of the sunshine indicator is dependant of the horizon. The station computer has a proprietary design and it is put in a connection box in the field, see figure 3. In this box also the ISDN modem is installed. Stations measuring only precipitation have a half sized computer box, because the computer doesn' t need the components for acquisition of analog signals and wind signals. Outside the box a holder is fixed for a modem making the wireless transmission to a handheld terminal that will be inside the house of the observer. So a distance of generally 50m to 100m is spanned without laying a cable from the field into the house.
The station software is the same for all stations. It is LINUX-based, the essential functions are: data acquisition via sensor-interfaces, data exchange with the terminal, data processing including calculating sums and mean values, quality assurance algorithms, generating meteorological and technical alarms and error messages, local data archiving over 6 weeks, and the communication with the network center. A lot of parameters in the algorithms are configurable. A standard laptop with a service programme can be locally coupled to the station computer to allow for dialogue. This service programme can be loaded as an applet on any PC in the PC-net, so remote servicing of each station is possible. Other local users can be directly provided with actual data from the stations via serial interfaces fo instance to feed local displays.

### 3.1 Sensors

All connectable sensors are listed in table 1. Sensors for air temperature and relative humidity are doubled. They are mounted in a cylindrical radiation shield with artificial ventilation developed at DWD. The air temperature sensor at 5 cm height is unprotected and used for nocturnal minimum temperature only. The user requirement of 0.2 K accuracy over the whole measurement range is fulfilled by taking PT100 sensors class 1/3 DIN and a specific analog data acquisition unit with temperature control. The sampling rate is 1 Hz, but for the cup anemometer and the wind vane it is 4 Hz. Recently also the connection of ultrasonics is enabled. Precipitation is measured by the weighting principle to fulfill the requirement of 0.03 mm and to have a time resolution of 1 min. This is done by a marketable device (figure 4) with particular DWD adaptions: a ring heating at the top of the collecting pot, automatic messaging when the pot is filled more than 70 %, internal smoothing algorithm with regard to gust sensitivity, and corrections for temperature induced expansion of mechanical components. A self-drain has been tested and will be built in at high precipitation stations.
The sensor list is the maximum equipment for the AMDA III (S) stations. Many of them have no wind, whereas the AMDA III(N) has only a precipitation sensor and the AMDA III(W) only the wind sensors.

### 3.2 Observer

Even though the station works automatically the observer is a part of the network. He carries out precipitation comparisons with the ‚Hellmann'-sampler, he records the present weather, enters data at a fixed clock time, he messages extra-ordinary incidents and undertakes certain maintenance tasks. He will no more write on paper sheets but type into a terminal so that the information is in the electronic data process. The terminal program design is such that the menue will guide the oberver unambigously to all necessary inputs, wrong inputs causing error messages. Data transmission is in an alphanumeric code. Time marks may be either defined day periods like ‚in the morning' or ‚at night' (that covers midnight) or exact clock times in terms of legal time. The observer can preselect a date and input observations till 6 weeks in the past. Figure 2 will show the main menue with the following facilities:

- Input meteorological information

1. Data at fixed terms
2. Continous determination of weather phenomena
   Fallen precipitation (liquid, solid, mixed, intensity, frequency) with date and time
   Settled and deposited precipitation, appearances of slippery ice
   Extraordinary wind conditions, electrical and optical phenomena, turbidity
3. Additional remarks: lightning-strokes, squalls, snowdrifts
4. Winter sports messages
5. Personal messages

- Numerical display of of actually measured quantities
- Graphical display of daily courses of certain quantities. This is made for the comfort of the observer.
- Display messages sent to the station computer.
- Display system informations and set status of sensors

**4. Facilities of the network**

Because of the large number of stations efforts were made in the network center to keep the stations calls briefly and so to save transmission costs. Figure 5 shows that routers are used to contact several stations via ISDN at the same time. Conversely the stations initiate transmission on alarms. Also the central data bank was optimized to store the data in a short time. The transmission protocol is the ‚Descriptive Data Protocol‘ (DDP) developed for environmental measurement networks in Germany. But DDP is no more supported.

The stations can also be called by data centers of federal states. Provisions are taken to prevent externals from unauthorized penetration into the network. External users receive data from the central data bank via a gateway and a firewall. Authorized personnel can use a supervision programme on any PC in DWD PC-network to have a geographical overview of the network with the status of the stations as coloured symbols (see figure 6). Among other useful functions configurations and updates of station software, even to the terminal and to sensors, can be uploaded by the center. They can select any station to have a look on the last data sets stored and with a service applet they can see more details: raw data, intermediate data, meta data and technical status. This is advantageous in the case of error detection.

Additional servers control the network operation and its fail over: the status in comparison to a complementary system is ascertained.

**4.1 Data flow**

The station provides different data sets for transmission:

Fixed time data sets sent on request of the center

- 1 min, 10 min, 1 h , 24 h and configurable time periods of precipitation increments
- 10 min data of wind , sunshine duration, relative humidity, air- and soil-temperatures
- observational data

datasets of certain incidents sent independantly by the station

- exceeding threshold values:precipitation, wind
- dangerous weather phenomena as seen and typed by the observer
- system errors, errors from data error management

Normally the center calls the stations at intervals of 3 h (AMDA III (S)) and 24 h (AMDA III(N)). The intervals can shortened on demand. Immediate calls on any station are possible.

At the local site the station provides continuously data for local users via a standard digital intersection

**5. Quality assurance of data**

Along with steps for a high availability of data the accuracy of data and the positioning of the sensors is according to WMO recommendations and national rules. The station software has built-in algorithms to check the plausibility of data. The result is a quality byte added to each output value. On defined conditions meteorological or technical alarms are triggered. Quality assurance measures at the station are one part of the data quality assurance concept that is realized [2].

## 6. Organization of software- and hardware-maintenance

Shortly after the start of the aerial building up of stations there was a delay because the general contractor for the system software development and hardware supply got insolvent. To save the project DWD-Personnel took care of the difficult task to clear software faults being left and to control hardware production and supply. The completeness of the software sources had to be checked and interaction of the components to be studied and understood. So the software can be modified now to have regard to new user requirements, for instance ultrasonic anemometers can be coupled now. Unfortunately the system design contains some proprietary components that limit the replacement by marketing components resp. the modification and the number of the original replacement parts is low.

In order to achieve a long durability of the network of about twenty years which is much longer than the availability of many IT-components efforts are made to transport software compiling to a marketing operating system (LINUX). Also new hardware is searched capable to run with the actual software.

## 7. Final remarks

The concept of the climatological-hydrological network relies on measurement- and information techniques on the state of the art. The fast availability of data supports additional users: actual data of the AMDA III (S) are useful for forecasting, they get synop-coded in the data center, actual data of AMDA III (N) are useful for flood forecasts. The spatial density of station data is helpful to validate regional meteorological effects and to detect erroneous data.

## Literature


[1] Klapheck, K.and Wolff, K. (2005). The new synoptic-climatological station of the primary network of Deutscher Wetterdienst, in *Proc. WMO Techn. Conf. on Meteorol. and Environm. Instrum. and Methods of Observ.,* Bucharest, WMO/TD-No. 1265 Genf

[2] Spengler, R. (2002). The new quality control and monitoring system of the Deutscher Wetterdienst, in *Proc. WMO Techn. Conf. on Meteorol. and Environm. Instrum. and Methods of Observ.,* Bratislava , WMO/TD-No. 1123 Genf

[3] Deutscher Wetterdienst, Abt. Messnetze und Daten (2001). RICHTLINIE für AUTOMATISCHE KLIMASTATIONEN.Offenbach/M.


## Tables and figures

| Measured variable | Accuracy | Sensor type | Intersection |
|---|---|---|---|
| Air temperature, height 2m | 0,2 K | Pt100 resistance | analogous |
| Relative humidity, height 2m | 3% | Capacitive sensor HMP 45 A<br>Louvred shield with fan acc. to DWD,<br>Pt100 and HMP 25A by twos | analogous |
| Air temperature, height 5cm | 0,2 K | Pt100 resistance | analogous |
| Soil temperature 5 cm | 0,2 K | Pt100 resistance | analogous |
| Soil temperature 10 cm | 0,2 K | Pt100 resistance | analogous |
| Soil temperature 20 cm | 0,2 K | Pt100 resistance | analogous |
| Soil temperature 50 cm | 0,2 K | Pt100 resistance | analogous |
| Soil temperature 100 cm | 0,2 K | Pt100 resistance | analogous |
| Amount of precipitation | 0,03 mm | Precipitation weighing 'Pluvio' | RS485 |
| Temperature at 'Pluvio' | 0,3 K | Pt100 resistance | RS485 |
| Sunshine duration | < 1 min/h | El. sunsh. indicator acc. to DWD | RS422 |
| Wind direction | 5° | Wind vane | digital: Gray-C. |
| Wind speed | 0,3 m/s | Cup anemometer | digital: pulses |

Table 1: List of the maximum setting of sensors at the station

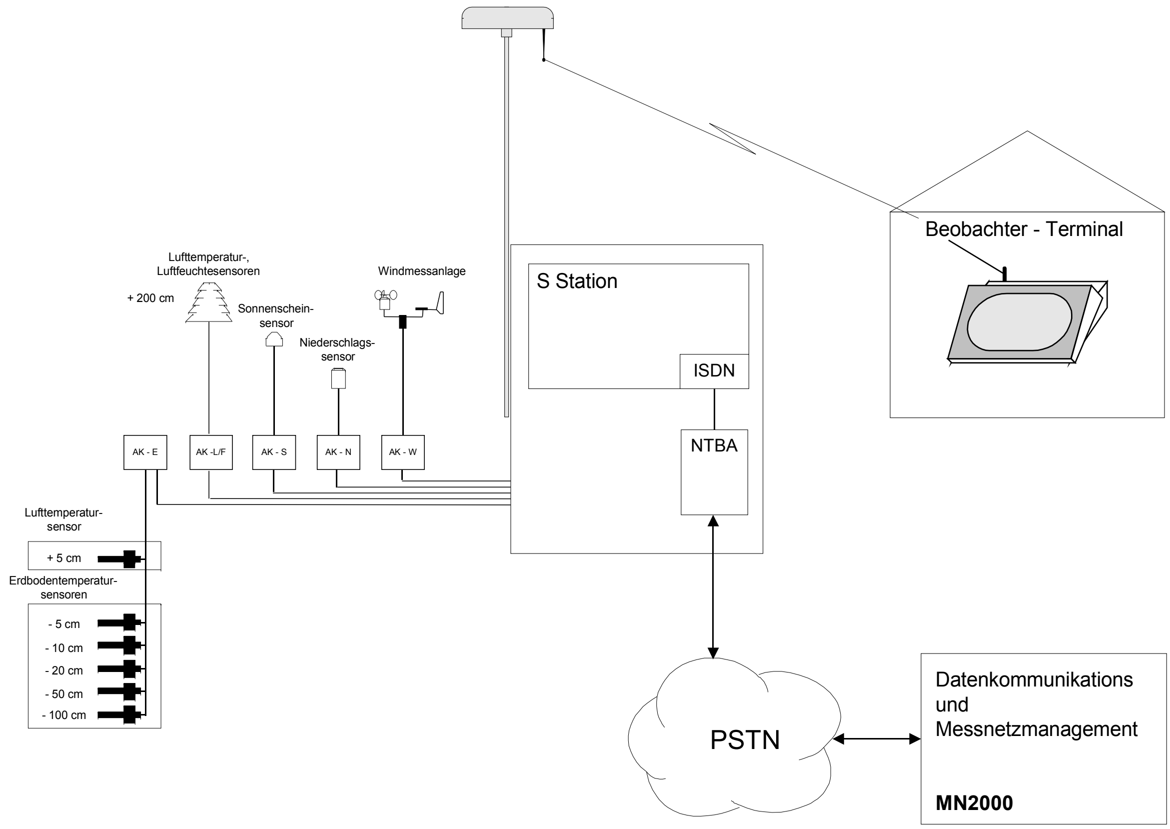


Figure 1: Hardware-scheme of the AMDA III(S) station.

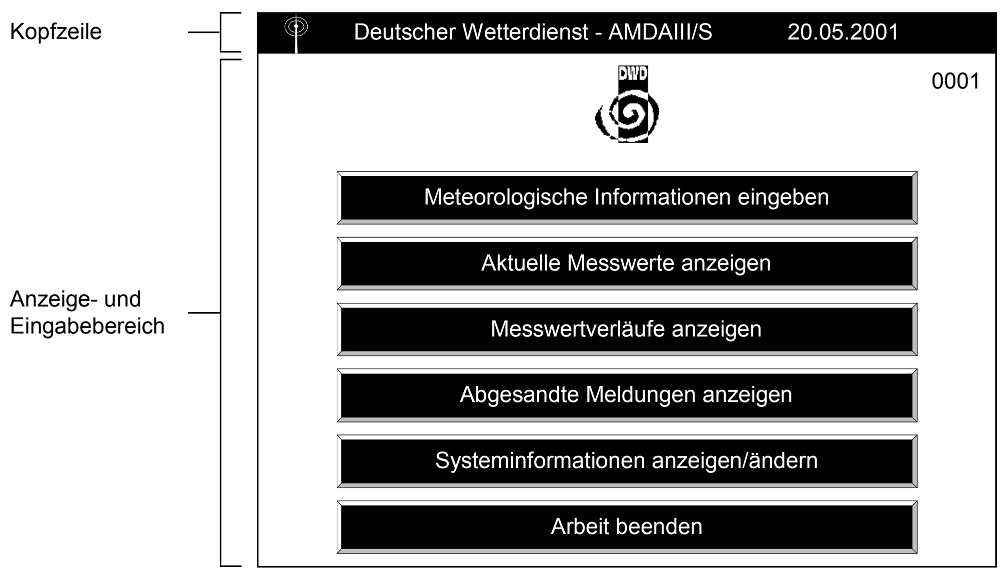


Figure 2: Main menue of hand held observer terminal.

Figure 3: View of the station area, from left: automatic precipitation sensor, Hellmann-sampler, box with AMDA-computer inside and wireless set, area for soil temperature sensors, mast with radiation shield for air temperature and relative humidity sensors and sunshine duration sensor.

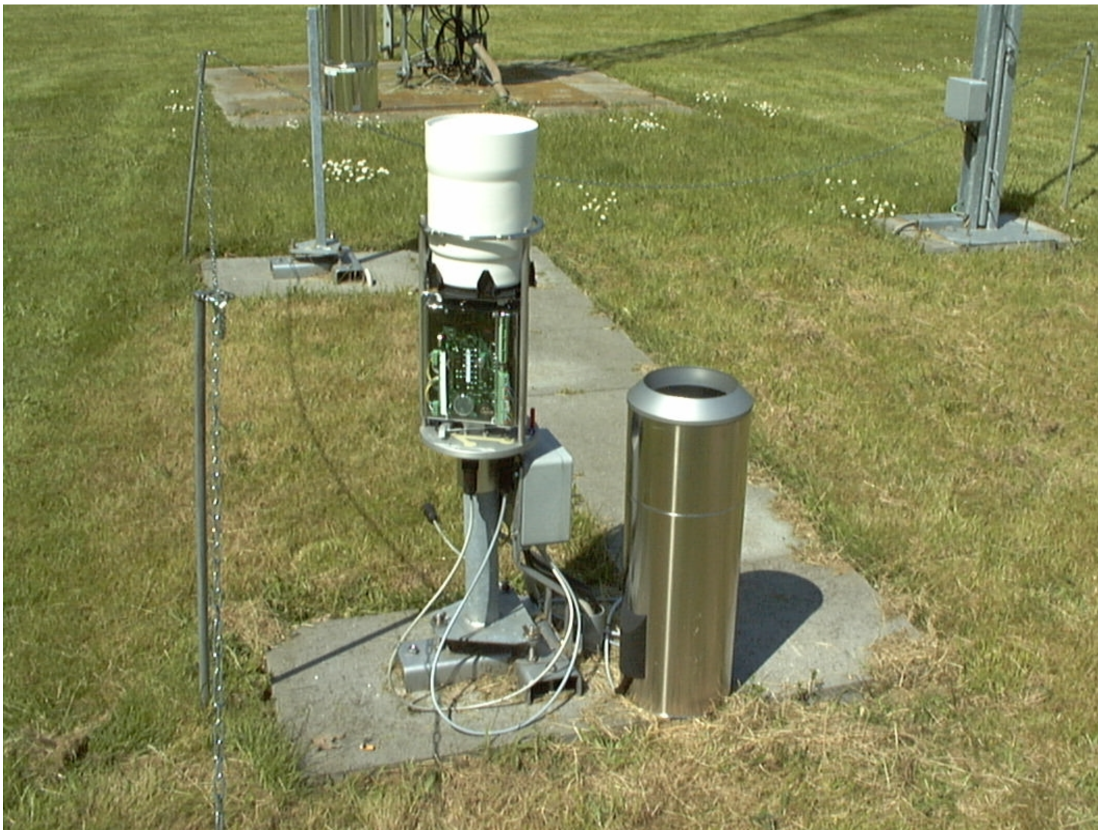

Figure 4: Precipitation sensor, protective tube with ring heating taken off.

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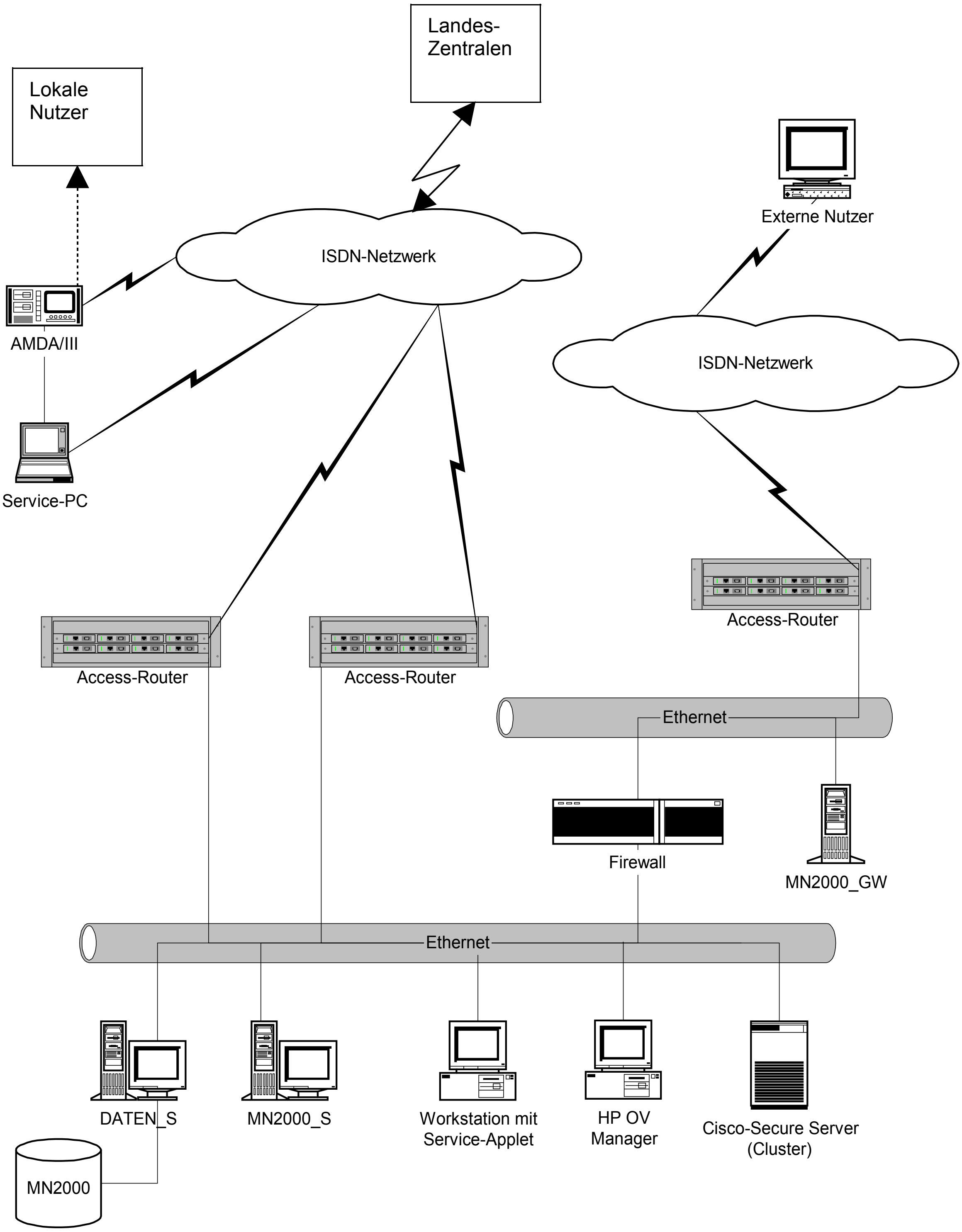


Figure 5: Scheme of the network composition

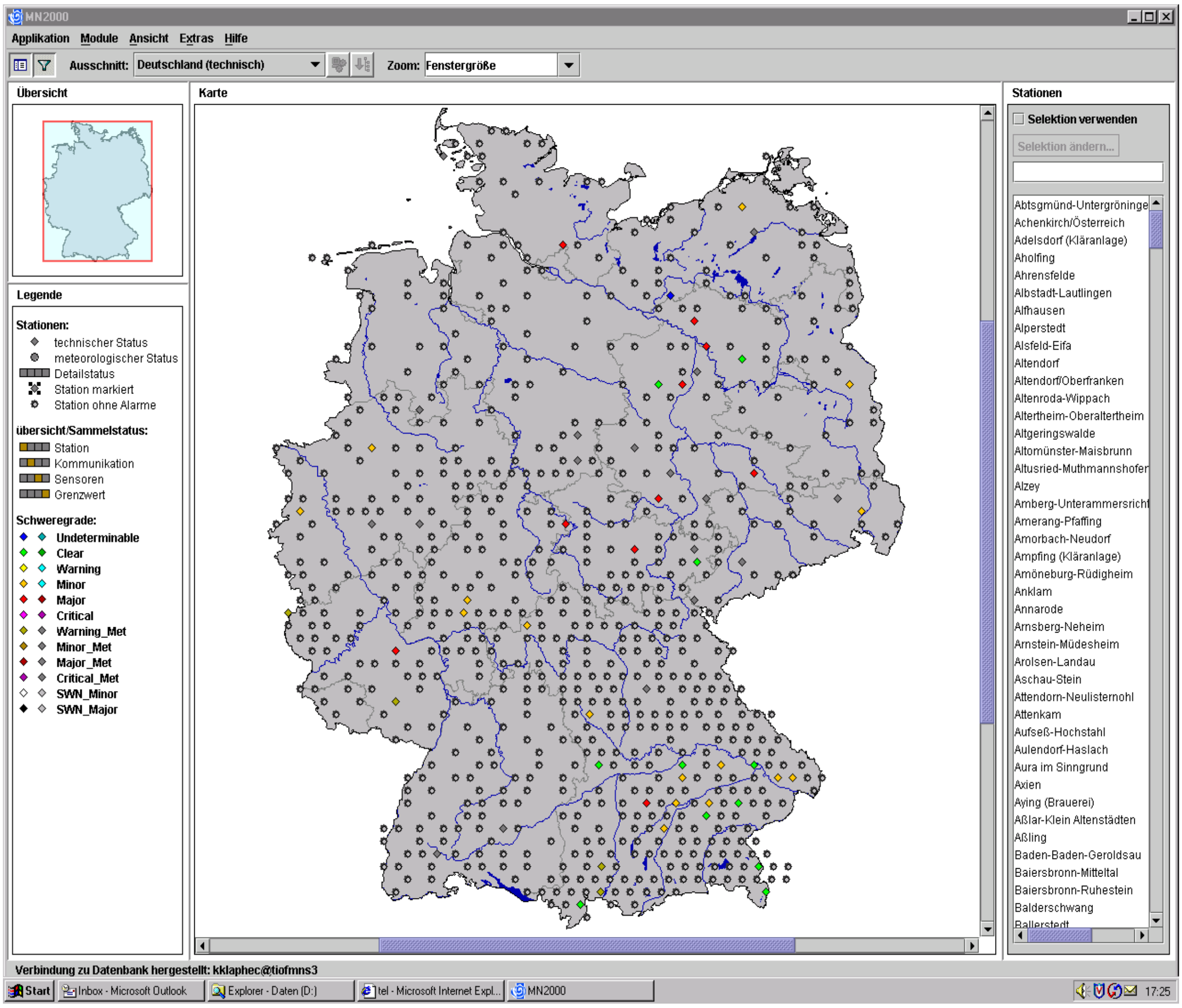


Figure 6: Main window of the supervision programme.