WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS
OPEN PROGRAMME AREA GROUP ON INTEGRATED
OBSERVING SYSTEMS

EXPERT TEAM ON REQUIREMENTS FOR DATA FROM
AUTOMATIC WEATHER STATIONS

FIFTH SESSION

GENEVA, SWITZERLAND, 5 MAY – 9 MAY 2008

CBS/OPAG-IOS (ET-AWS-5)/Doc. 7

(28.IV.2008)

ITEM: 7

Original: ENGLISH ONLY

ADDRESSING THE NEED FOR INTEGRATION OF POINT MEASUREMENTS WITH AREA MEASUREMENTS

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Summary and Purpose of Document

The document contains a description of strategic approach on the redesign of observing networks.

ACTION PROPOSED

The meeting is invited to consider the submitted approach in addressing the need for the integration AWS data with area measurements.

References:

1. Abridged Final Report, CBS-Ext. (2006), Seoul, Republic of Korea, 2006 (WMO-No. 1017)
2. Final report, CBS/OPAG-IOS ET-AWS-4, Geneva, 2006

Background

CBS-Ext. (2006) requested the ET AWS to address, in collaboration with CIMO, the need for integration of point measurements with area measurements and to develop guidelines and procedures for integration point measurements with area measurements.

The background information contains the document reproduced in the Annex 1. The meeting is invited to consider the suggested approach on the redesign of the observing networks when considering possibilities of how to integrate data from AWS with area measurements.

A modern strategic approach on the redesign of synoptical observations networks

Jitze van der Meulen

New developments in weather observations

By tradition in-situ measurements of the classic meteorological variables like temperature, pressure, wind, etc. are the backbone of the weather service. For more than a century these observations are carried out at weather stations, where skilled observers both perform instrument measurements and observe the various types of weather phenomena. Appropriate communications between weather stations worldwide enabled forecasters to inform on expected weather and the measurements were used to create weather maps. Typically, these maps were the basic source for any forecast.

During the last decades however, the introduction of (super-) computer technology and automatic measurement techniques has changed this traditional process significantly. Today computer simulation models describe the physical state of the atmosphere in all of its dynamics. The introduction of new, sophisticated observation technologies using these models has demonstrated high potential. This development is characterized by alternative technologies like active and passive remote sensing, from satellites or from the earth's surface. Moreover, the conventional instrument measurements and weather observations are fully automized using sophisticated optoelectronic sensor technologies, providing observational data in a digital format essential for input in computerized systems running dedicated applications.

These observations are performed automatically and unattended (1). System control is done remotely at a service centre. Although this development is not welcomed by all disciplines in meteorology and in particular climatology, the synoptical meteorology experiences many advantages. Apart from automation of all types of in-situ observations, unattended data-acquisition, transport, processing and dissemination require an ultimate level of high performance processing systems. The architecture of such systems must be specified providing appropriate quality control, data management and maintenance facilities. Such data systems are successfully implemented in 2002 in the Netherlands (2). Nevertheless, implementing the new techniques in the operational environment of forecasting services should be regarded as a great challenge.

Replacing human observations by automatic measurements has an impact on the performance of the observing system on the whole. Decrease of performance and quality is predicted when automizing a network and with a negative impact on the meteorological services as a consequence. In fact, the advantages of a uniform, fully automized and unattended observing networks prevail over the traditional situation provided that such a network is designed appropriately. There is not only advantage of more uniform observations without any subjectivity caused by human interpretation. Also data acquisition and dissemination is performed on a continuous and real time base. So instead of the one, three or six hourly reports, reports on the actual state of the atmosphere are available in real time. As a result the forecasted timing of upcoming (severe) weather phenomena is more accurate. Also rapid trends and changes in weather are registered and reported on line providing a more efficient weather information service.

Another advantage is the flexibility in appointing suitable locations for weather stations. For more than a century, such stations were chosen at sea shore locations, harbours, airfields, nearby buildings, etc. As a consequence poor and inadequate siting often resulted in low representativeness with regard to the surrounded area and distribution of these stations over the region of interest was not very homogeneous. Defining a new set of automatic weather stations for a synoptic network has become much easier and siting criteria are better met.

In the Netherlands, KNMI, the Royal Air Force and the Royal Navy organize the synoptical observing network together. In practice all stations are uniformly designed, so the observation techniques used in this network are identical for all locations. Therefore no special care has to be taken when designing the network, providing a relatively easy optimizing process. It turned out that after rearranging this network with fewer stations a better network homogeneity was established as well.

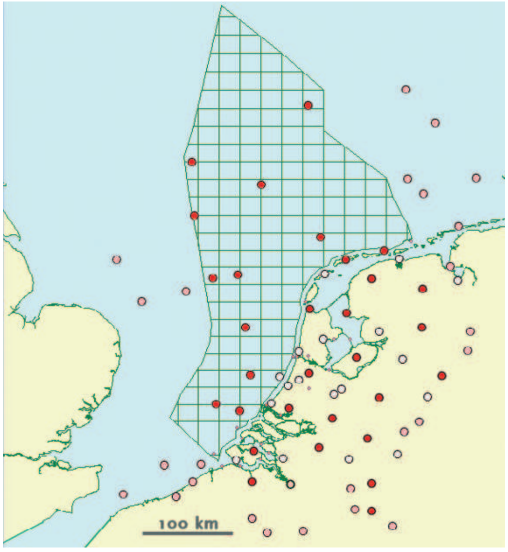

Figure 1. Synoptic Observations Network Netherlands 2005 (SWaNet-NL 2005)–design5): Red bullets (●): national synoptical stations, grey bullets (○): other national observing stations, pink bullets (○): foreign stations, small red dots (•): additional wind mast.

R (%) distance d /km	5	10	15	20	25	30	35	40	45	50	55	60	65
Previous (N=20)	**3.2**	**12.6**	**26.8**	**43.3**	**60.2**	**74.3**	**84.5**	**91.4**	96.3	99.0	99.9	100-	100
Recommended (N=18)	**3.1**	**12.4**	**27.1**	**46.5**	**66.6**	**82.1**	**92.0**	97.4	99.5	99.9	100	100	100

Table 1. Network homogeneity parameter R represents the relative amount (in %) of all distances from every location in the Netherlands to a nearby station shorter than a certain fixed distance. For instance R(d=5 km) = 3.2% means that 3.2% of all location are at a distance of shorter than 5 km of any station. Clearly the distance at which 95% of all locations is close to a nearby station is reduced with about 5 km (from about 43 km to about 38 km).

> *Recent technological developments enable the design of more efficient automated networks*

New functional design of a synoptic network
Nevertheless, the question of the density requirement itself has to be solved in the first place. In fact, such density dependents on the regional climate and all various meteorological variables require their own density. Typically, precipitation and wind require high density, while the density of a network of barometers may be quite low. Such density can be estimated on a simple way based on the prevailing wind or typical transport speeds of weather phenomena. A more sophisticated approach is based on statistical calculations of the covariance of the variable measured at the various locations assuming a sufficiently high correlation between these autonomous measurements. It is common experience that in practice the simple straightforward approach is sufficient. However, the latter approach, suggested in the leading WMO Guide on the Global Observing System [3], and its background reference 'The Planning of Meteorological Station Networks[4]' will result in inconsistencies, trivialities and undefined solutions and is therefore not suitable. Therefore, in the Netherlands the stated appropriate network density is based on prevailing wind speeds in combination with movement of fog and low-level clouds (about 25 km/h) and incoming fronts with showers with thunderstorms (about 50 km/h). Taking advantage of the real time functionality of the network, a spacing of about 50 km is found to be sufficient. Only for wind measurements a shorter distance is required (about 25 km) to meet the recommended correlation coefficient of 0.90 for two neighbouring stations. By placing some extra wind masts this requirement can be met in general. A network of precipitation measurements to measure daily amounts requires a small spacing of 15 km. This extreme requirement can only be met by using the ad-

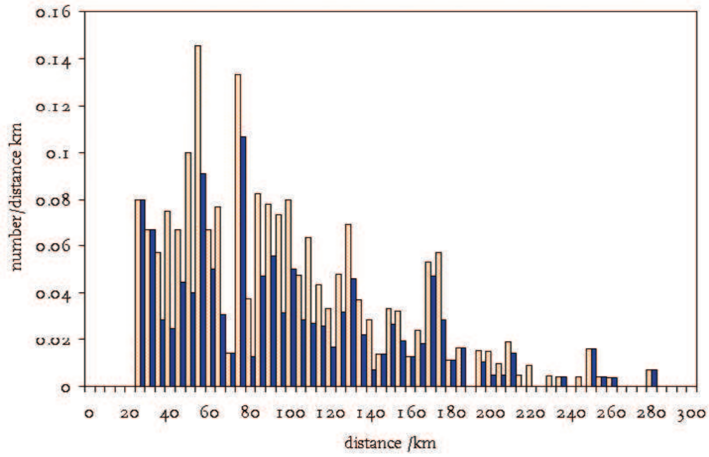

Figure 2. Clustered distributions for both the previous and the new design (/////: previous, ■: new). The distributions represent all mutual distances between all stations, but normalized. Because the number of stations is reduced from 20 to 18, the total number of distances is smaller for the distribution representing the new design.

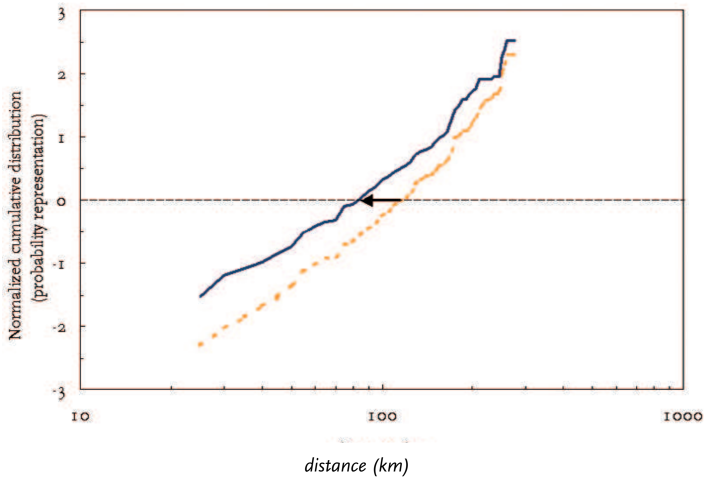

Figure 3. Cumulative representation of the normalized distributions shown in Figure 3 but in probability representation and with the distances on a logarithmic scale (dashed - - -: old, straight line —: new). Both distributions show a smooth behaviour indicating a sufficient high level of network homogeneity. Nevertheless, the new situation clearly indicates a distance improvement of about 25%.

ditional separate, autonomous network of 315 volunteering observers because a network with automatic gauges cannot be funded. Moreover the introduction of new precipitation radar systems will provide more redundancy. This solution has a great benefit because the high refreshment rate of radar systems provides an optimal real-time data source, extremely useful for synoptic practices.

Optimizing the meteorological station network

For an optimal network design the required level of homogeneity is the first constraint to be considered. Other relevant constraints are appropriate siting and representativity issues. A measure for the level of optimizing a network should be expressed best by a simple, well-defined single parameter. For a first order approximation such a parameter is chosen based on a statistical analysis of the distance between every position in the Netherlands and its nearby station. This parameter represents for instance the percentage of all locations on a distance larger than a certain distance from any station. It is found that with the new network design for the stations on land the 95% cumulative level will be between 35 and 40 km. In the previous situation with 20 land stations this distance was within 40 and 45 km (see Table 1). For the new network design[5] 99.9% of all positions on land are at a distance smaller than 50 km from a nearby station, fulfilling the requirement and providing sufficient redundancy. Over sea this requirement cannot be fulfilled due to the lack of suitable off shore locations (oil platforms), but a spacing of about 100 km should be acceptable for all practices (see Figure 1).

Other statistical techniques used for network design analysis are based on the mutual distances between all stations or between neighbouring stations only (e.g. sets of triangles of three neighbours). The latter technique is common practice to demonstrate the level of representativeness or the uncertainty of a derived interpolated variable valid for a location within such a triangle. However, for an overall impression of the homogeneity of a network, a statistical analysis of all mutual distances of the stations can be carried out. Optimizing the normalized (cumulative) distribution of these sets of distances is then the first target (distribution are normalized by dividing the number by the distance). In Figure 2 an example is given for two of such distributions, one for the previous set of stations on land an the other for the new design. From each distribution a cumulative distribution can be derived and showing in so-called probability representation will give an impression of the homogeneity. Figure 3 presents such a cumulative distribution as a function of distance, presented logarithmically. The figure shows a rather smooth and linear behaviour for both the past and the new situation. Although both lines are very comparable, an improvement (in terms of distances) is obtained by about 25%, a non-trivial and remarkable result because the number of stations is reduced by 10%.

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1) Wauben, W., F. Kuik and T. Haig, 2002. *The New Meteorological Observation Network in The Netherlands*, WMO/TD-No. 1123, par. 1.1(6), WMO, Geneva, Switzerland, 4pp, available on CD-ROM

2) Wauben, W. and D. Hart. *The New Meteorological Observation Network in The Netherlands; Status and Operational Experience*. Submitted to WMO.

3) World Meteorological Organization, *Guide on the Global Observing System*. WMO - No. 488, WMO, Geneva, Switzerland, 191 pp.

4) Gandin, L.S., 1970. *The Planning of Meteorological Station Networks*. WMO-No. 265, TP. 149, WMO, Geneva, Switzerland, 35 pp.

5) Van der Meulen, J.P., 2005. *Synoptisch Waarneemnet Nederland 2005*. KNMI, De Bilt, the Netherlands, 23 pp. *www.knmi.nl/~meulenvd/projects/SwaNet2005*