DISCUSSING SCIENTIFIC METHODS AND THE QUALITY OF METEOROLOGICAL DATA

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Abstract

Arguments for developing explicit ways of clarifying the scope of scientific methods are the content of the first paragraph. Then several concepts like phenomenon, parameter and model are defined and discussed. The well known general scientific method, the hypothetico-deductive principle is then discussed and given a more restrictive interpretation than usual, and the outcome of this discussion is a proposal of a documentation system of meteorological parameters, either measured parameters or parameters derived by model calculation. The concept of quality of meteorological data is then defined. The main lines of a system for automatic control of hourly data from an automated station network are shortly discussed. An example of the use of the proposed documentation system is presented, and in the last paragraph of the report some explicit recommendations for sets of meta-data connected to exchange of meteorological data between institutions are presented.

Key words : Meteorology; Quality of data; Scientific methods;

SCIENTIFIC METHODS IN HUMAN SOCIETIES

The scope of scientific methods is in this report defined as the validity in time and space of their results. Scientific methods have vast influence in modern societies. These methods are used for giving us reliable information about our selves, our society, our history and our relationships towards other biological organisms. These methods are used for giving us the background for our actions in the biological world around us, as well as for analysing the outcome of such actions. These methods have authority in the sense that we have confidence in the products of these methods. Very powerful and influential social organisations are using such methods. Many different products are created in this way. Each product has an identity, and this identity is connected to the organisations and persons involved in the processes giving us the product. Part of the identity is connected to the known competence of the persons involved, and part of the identity is connected to these persons ability of reflection and to internal discussion in the organisations concerning the scope of the methods they are actually using.

The confidence in the scientific methods can only be retained if the organisations and the social systems using these methods very seriously discuss their scope, and clarify their scope in practical situations.
The authority of the organisations will then reflect the internal discussion and level of understanding of what they are doing. Their authority should be built on two main attributes, confidence and respect. Respect means looking back. If you present a relevant problem for an organisation, then you will get an internal discussion, and a relevant answer. This is the only way of gaining confidence in the long run.

MEASUREMENTS AND MODELS

The starting point of reflection and logical reasoning concerning the scope of the hypothetico-deductive principle is the following two auxiliary statements:

'(a) The world of physical phenomena is a totality that cannot be separated from anyone's consciousness.
(b) The observed phenomena are not governed by abstract ideas like certain mathematical equations describing these phenomena'

The consciousness, or rather man's consciousness, is able to sense the physical world through the body of man, by seeing, hearing, touch by tactile sensations, smell and taste. Man is further more able to classify his sensations by comparison, and he may construct general abstract ideas about the phenomena he senses.
He is naming the different phenomena he encounters. By using modern object-oriented concepts, he is constructing classes, and each actual member of such a class he encounters, he may denote 'an object of this class' according to the terminology mentioned.

By using the concepts from set theory of modern mathematics the starting situation is man observing physical phenomena and classifying and giving names to the phenomena. Some of these physical phenomena are classified as sets, and a language of set theory is created. Creating a language means abstraction and comparing.

We may regard mathematical rules as formal extensions of mans ability to compare, aggregate and divide aggregates of objects (sets) in the physical world. The basic rules of comparison, considering sets and aggregates of sets, are: 'greater than', less than' and 'equal to'.

The implication of this consideration is that the physical world comes first, then comes the man creature (an observer manipulating elements of the physical world) able to physically compare objects and able to aggregate and divide objects, and then at last the formal extension of this

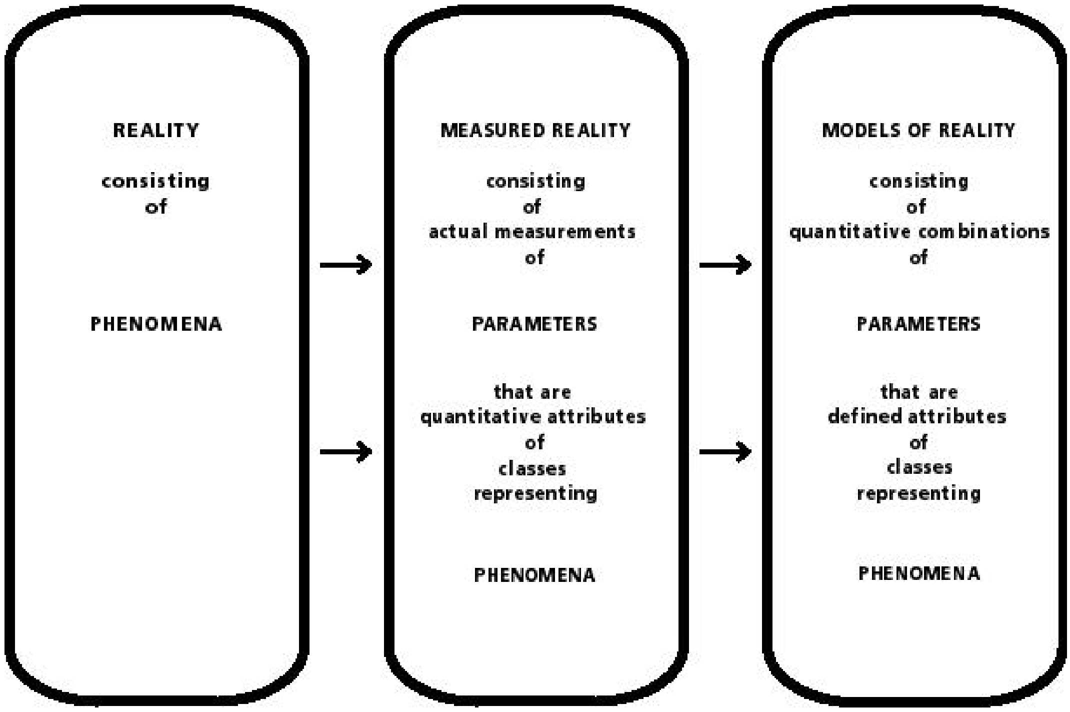

Fig.1 The Connection between the Concepts of Phenomena, measured Reality and Models

ability, which we call mathematics

The next two concepts considered of interest, are the interrelated concepts of parameter and measurement. A parameter is defined as one of the quantitative attributes of a phenomenon (described by classes of objects) obtained through the process of counting or through the process of measurement. A parameter has a name. It has a definition. It has a unit. One gets the numerical value through some process of direct or indirect measurement, by comparing the object or the interesting part of the object to a defined unit. Some sort of documentation system is also needed.

I will define the concept of a model in the following way:

'A model is a set of classes describing phenomena (in the object-oriented sense) and each phenomenon in the model is described by one or several classes containing quantitative numerical attributes.'

An attribute is then a parameter, and in order to actually pick out and study an object of a class connected to a phenomenon, one must be able to measure or calculate the values of the attributes of the class in some prescribed way.

A model is then an abstract entity, and by using our modern IT-methods a model may be documented and described very thoroughly. The mathematical equations connecting the different parameters (attributes), the methods of a numerical implemented system are according to object-oriented terminology considered integral parts of the objects (Brown, 1993).

In the context of this report I am considering meteorological models as well as biological models that with relevance may be combined to the meteorological models. Adequate systems for making measurements of time and space as input to the models are considered available, and only models relevant to be described by Galilean transformations of time and space are discussed.

The weather phenomena or biological phenomena studied are entities described by certain numerical attributes (parameters) defined in some prescribed way. In order to say something about the future development in time of an object of the phenomena considered, there must exist some procedures for actually measuring the parameters. We may then define the concept of measurement of a parameter, by characterizing the measurement procedure of an attribute of an object in the following way:

'The measurement procedure is the prescribed way of obtaining the numerical value of a certain attribute of an object of a class of a phenomenon (model), directly or indirectly.'

The measured value of a parameter may be used as input to a model, and the same procedure for making measurements might be used when obtaining independent values when testing the model.

In order for such calculations to tell us something useful about this object of a class, the measured values of the attributes (of the classes) of the phenomenon must be 'representative' of the parameters described in an abstract way by the model.

Concerning modern object-oriented terminology see Brown(1997) 'An Introduction to Object-Oriented Analysis'. The recent history of the concepts of object, class, the attribute of an object etc., as these concepts are used in information technology is discussed in this book.
Concerning set theory see Bevlin (1993, reprint from 1979) ' The Joy of Sets Fundamentals of Contemporary Set Theory'.

Fig.1 shows the connection between the concepts of phenomenon, measurements and models used in this report.

METEOROLOGY AND THE SCOPE OF THE SCIENTIFIC PRINCIPLE

In Fig.2 below an interpretation of the general scientific method called the hypothetico-deductive principle is depicted. The aim of this paragraph is to find out if some sort of systematic documentation system of numerical parameters used in meteorology can be constructed, in order to say something about the scope in time and space of numerical models used in meteorology and related topics. The definition of the input parameters to numerical models as well as the system for measuring the input parameters are considered integral parts of the scientific method.

The starting point is the observer looking at the world and noting the appearance of different phenomena. The observer picks out a phenomenon observed many times, and he gives this phenomenon a name. The actual phenomenon picked out may be described by a set of classes according to object-oriented terminology. An instance of a class of this phenomenon is an object of the class, according to this terminology.

The next step consists of induction, abstraction and parameterisation. The observer is living in a society, and he knows how to count and connect numbers to definite physical entities or sets of such entities in the world surrounding him. The observer picks out several physical entities to which it is meaningful to connect to the phenomena he is studying. We call these entities the attributes of the classes of the phenomena. The attributes are his parameters. The values of the parameters are numbers. Every parameter has a definition, and the observer must have a prescribed system for measuring each of these attributes.

Then one or several preliminary hypotheses are constructed, consisting of mathematical equations combining the values of the parameters. In meteorology one of the parameters used is usually time, and by logical and mathematical reasoning and deduction (analytically or numerically), future values of the parameters connected to the classes of the phenomenon are predicted.

The next step is the test. The predicted values of the classes of the phenomena considered are compared to the observed attributes of the classes of the phenomena according to some sort of independent system for making measurements.

The remaining problem is to analyse the results of the testing and decide if the system constructed is sound. This includes the description of the classes of the phenomena by their numerical attributes (the parameters), the mathematical hypotheses combining the parameters (the theory) and the way of making measurements. The spatial and temporal scope of the whole system is often an important part of this.

Usually the hypothetico-deductive principle is interpreted less restrictive. The outcome of the test is considered mainly as information of the validity of the hypotheses (the theory). Certain hypotheses are sometimes considered very basic principles of nature, ‘laws of nature’.

A general discussion and presentation of the hypothetico-deductive principle may be found in the philosophical textbook ‘What is this thing called science’ by A.F. Chalmers (1998, reprint from 1991). Much of the discussion in this book is about the theories, if they are right or wrong, or the scope of these theories. The verification by a testing system is here as a rule interpreted as a testing of the theories, the hypotheses of the quantitative models of physical phenomena. Discussing the scope of the concept ‘falsification of the theories’ is another way of bringing up the theme in this textbook of philosophy. One main reference in the discussion is Karl Poppers substantial philosophical work

‘Logik der Forschung’ (1973, reprint from 1934).

A clear graphical presentation of this common interpretation of the hypothetico-deductive principle (especially connected to quantitative discussions in meteorology and related physical problems) may be found in a textbook of statistics for meteorologists by Carl Ludvig Godske (1966 in Norwegian). The formalism of Fig. 2 below is adapted from a figure of this textbook.

The next theme for discussion is the concept of a comprehensive numerical model of meteorology or of agro meteorology (including biological phenomena). When one or a few physical processes (some of the observed natural phenomena of interest) are studied in a laboratory, these processes are described by one or a few hypotheses of the parameters considered, possible to test in a laboratory. Bringing together several hypotheses in order to study several natural phenomena interacting in actual field situations of some spatial and temporal scope, one has created a comprehensive meteorological or agro meteorological model.

Two concepts that ought to be discussed in connection with comprehensive meteorological models and the testing of the models, are the concept of ‘scale’ and the concept of ‘representativeness’.

Temporal scale and spatial scale of meteorological and agro meteorological phenomena probably may be regarded as special parameters to be used as attributes of entities in models or sub-models of phenomena. There should exist some definition and measuring system to define the scale in each case, for the measurement procedures including some sort of calculation for each of the entities of interest.

The concept of ‘representativeness’ is connected to the actual use of a measured or calculated parameter value in a numerical model of a phenomenon or certain phenomena. The testing or the operational use of this object (or several objects) of the phenomenon tell us about the ‘representativeness’ of the input values of parameters, and the ‘representativeness’ of independent measured parameter values compared to the output of the model. A thorough description of the actual measuring systems of the different parameters is also of relevance for evaluating representativeness.

The models discussed in this

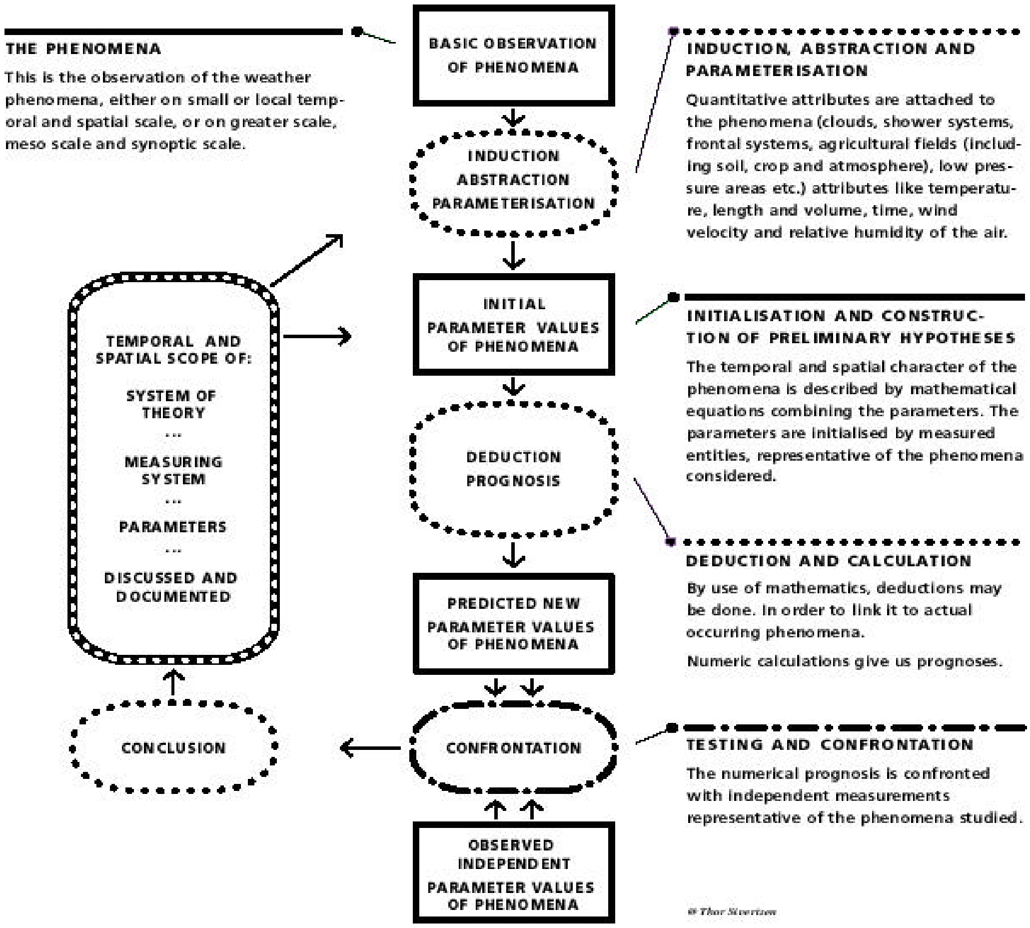

Fig. 2 An Interpretation of the Hypothetico-Deductive Principle

report are always connected to the influence of weather entities like air and precipitation and radiation on biological entities as crops and insects and fungi in time and space. The input and initial values of the parameters in models describing such phenomena are measured parameters. One ought to document the parameters in the original basic measuring systems different from the documentation of parameters originating from model calculations, climatic models, SVAT-models, weather prognosis and prognoses etc. These should be considered a different type of parameter. The first type of parameter one can categorize according to source and measuring system. The following attributes could be used in a data base documentation system:

Name of the parameter
Unit
Definition
Method(s) for measuring the parameter
Representativeness for certain phenomena (models)
Connection to measuring system

The attribute above called 'Representativeness' will link the actual measured parameter to the different models or phenomena, and this attribute together with the attribute 'Method(s) for measuring the parameter' tells us something about the temporal and spatial resolution of the parameter.

The second group of parameters, being outcome from model calculations, can be described in a similar manner:

Name of the parameter
Unit
Definition
Representativeness of the phenomena of the model considered
Representativeness for certain phenomena in other models
Connection to modelling system

In addition it is also sometimes considered relevant to use the values of one or several output parameters as input to an equation giving us another parameter. In this case we also need a documentation attribute of 'Calculation procedure', in addition to the list above.

A discussion of the concept of numerical modelling, very close to some parts of the discussion above may be found in the paper 'Simulation modelling and soil behaviour' (T.M. Addiscott, 1993). He is mainly working with soil physical modelling (SVAT-modelling focusing on energy and water in soil). Addiscott (1993) is further referring to (J.R. Philip ,1991), 'Soils, natural science and models'. Philip is in this paper very critical towards the modern numerical data modelling of the complex soil systems, while Addiscott is defending SVAT-modelling as a way of understanding and get useful prognostic information of phenomena described by such models. The contents of the discussion in this report may be regarded as a continuation of the discussion between these two authors.

It is also possible to work theoretically with objects and hypotheses (models) containing parameters not possible to measure (directly or indirectly), but the parameters must be defined in some sensible manner. Testing and later operational use of the model is only possible if one in addition may measure or indirectly calculate 'representative' values of the parameters.

THE QUALITY CONCEPT OF DATA

The term quality is derived from the Latin word (qualitas) meaning the nature (good or bad), the properties or the condition, in short the value of something. You know the value of meteorological data, if you know the nature of these data as well as their relations (the social context of their origin). In the previous paragraph a system for documenting meteorological parameters was proposed. Below the content of the documentation system and the social context of meteorological data will be discussed.

The meteorological data considered, are quantitative values of meteorological parameters.

In order to judge the quality of the meteorological data from a certain measuring system the following information ought to be known:

- The name of the parameter
- The unit of the parameter
- The definition of the parameter
- The actual method(s) for

measuring the parameter
- Representativeness of the parameter for certain phenomena
- The availability of the data

In order to judge the quality of the meteorological data, being the outcome of some model, the following information ought to be known:

- The name of the parameter
- The unit of the parameter
- The definition of the parameter
- Representativeness of the phenomena of the model considered
- Representativeness of the phenomena of other models
- The availability of the data

The attribute 'representativeness' and the attribute measurement procedure should contain certain information about the uncertainty of the quantitative parameter values.
The attribute 'representativeness' should further contain information about the 'completeness' of the data connected to certain phenomena.

Another information of importance is information about the social system producing the data. Do we have much confidence in the organisation producing the data, or do we not have much confidence in this organisation? This is telling us about 'identity' of the data and the 'authority' of the organisation producing the data.

The quality of measured data is dependent on how the measuring and transfer system for the data is functioning. We know very well by merely reflecting on it that the usefulness of the meteorological and biological data are dependent on the way the measuring instruments function, how they are mounted, the physical principles of the sensors etc. We furthermore know that the completeness of the series of data from the station network is of importance, as well as the robustness of the instruments (small change of the accuracy of the measuring systems over time, or during extreme weather conditions). We also know that the vegetation cover of the stations, the topography, near by buildings etc, will influence on the measurements.

Availability of the meteorological data as input to the models is of importance. Having a measuring system functioning well but an awkward way of making the data available to the different groups of users and the different applications, is not a good solution.

A practical consequence of the discussion above is the necessity of organising adequate social and technical systems for running and maintaining the instruments and the equipment of the meteorological stations, and also for constructing and using adequate control routines of the meteorological data output from meteorological networks.

In the context of this discussion about the use of concepts I would like to refer to the user manual of the database Munin, an internal database in present use at the Norwegian Pollution Control Authority, containing information about the environment and the conditions of the environment. Here the concepts 'completeness', 'uncertainty', 'representativeness' and 'identity' ('authority responsible') are used as attributes when defining the quality of data.

One last point of importance I would like to connect to the concept 'quality of meteorological data', is the way of presenting the data to the users, and the additional information and context of the presentation.

SOME ASPECTS OF THE CONCEPT OF AUTHORITY

The concept of authority connected to science is used several times in this report. This term is used as a possible attribute of the organisations and also of the people using the very powerful tools of science. The human societies ought to have confidence in these organisations, and also in their products. In order to achieve this, the organisations themselves and the people of these organisations must be able and willing to clarify and discuss the scope of their methods and the results of the implementation of the methods in practical situations in the human societies. There ought therefore to exist an attitude of reflection on their own position and significance inside the communities and organisations practicing science.

The concept 'validation' is often used for finding the value of quantitative models of science through testing. This is practically the same thing as finding the scope of the models.

Niederer (1991) presents the following abstract in the proceedings from the Symposium Geoval 90 concerning safety assessments of radioactive waste repositories, with the headigng "In search of truth: The regulatory necessity of validation":

"A look at modern ideas of how scientific truth is achieved shows that theories are not really proved but accepted by a consensus of the experts, borne out by often repeated experience showing a theory to work well. In the same sense acceptability of models in waste disposal is mostly based on consensus. To obtain consensus of the relevant experts, including regulators, all models which considerably influence the results of a safety assessment have to be validated. This is particularly important for the models of geospheric migration because scientific experience with the deep underground is scarce. Validation plays a special role in public acceptance where regulators and other groups, which act as intermediaries between the public and the project manager, have to be convinced that all the relevant models are correct."

At the later Symposium Geoval'94 also concerning safety assessments of radioactive waste repositories a part of the proceedings is called 'Validation through model testing'. The use of the term validation is discussed in the proceedings by three contributors, in connection to the use of models in field situations. One of these contributors, Pescatore (1994), presents three classes of definitions of the term validation:

"Class1: The purist view as a technical outcome of (in the first place) testing in a laboratory.

Class2: The operational view as a model in operational use.

Class3: Validation as a confidence building process in community/ society."

I refer to the content of the preceding paragraphs of this paper, and I would like to say that in the first place the scope of the scientific principle should be discussed inside the communities of science. Concerning numerical models and systems of numerical models implemented and used operationally, the implementation and use of documentation systems of all parameters like those principles presented in this paper also ought to be discussed!

The hypothetico-deductive principle may probably be regarded as basically a non-authoritarian principle. There is no human authority which guaranties that a scientific hypothesis including the system of measurement and parameterisation or a set of such hypotheses is true or useful. Only by actually defining and measuring the different parameters and testing the outcome of the constructed hypothesis may give us verification or non-verification of the system of parameterisation, measurements and hypothesis. This does not mean that the scientific principle is isolated from a social context. But the social systems could be more aware of the methods actually used and the basic character of this principle, especially those powerful organisations using these methods.

To give some input to the future discussion on the scope of the scientific method, the following statements are claimed compatible with the interpretation in this report regarding the hypothetico-deductive principle.

(a) The world is a totality that cannot be separated from anyone's consciousness. The world is therefore not an abstraction nor is it governed by abstract ideas or equations.
(b) By comparing two physical systems, one that is known, or rather defined, and one that is unknown, we can get abstract quantitative knowledge about attributes of phenomena. We are making measurements.
(c) Quantitative attributes of entities can be described and manipulated by logic and mathematics according to very strict rules. We can partly describe the reality and make prognoses of the attributes of phenomena by using mathematical equations and known starting values.
(d) It is probably not possible to construct and test a set of hypotheses describing all attributes of all known phenomena in the world.
(e) Hypotheses that are possible to test are very dependent on the temporal and spatial scale we are considering.
(f) There may occur phenomena that is not possible to identify by parameters and to measure and compare.

The discussion of this report is mainly confined to systems of meteorology and biology where the hypotheses are given by mathematical equations, using Galilean time coordinates and Cartesian space coordinates. But it would probably be relatively easy to extend the discussion to other coordinate systems and other types of scale.

CONTROL OF METEOROLOGICAL DATA

The administration system of meteorological data from any network of stations contains procedures for control of the data after the data are gathered and before the data is stored permanently. The results of the control are:

- removing of data unfit for use
- repair of data sets of dubious quality
- information to the technical part of the system to directly cheque the actual instrumentation

The control of the data is defined as a control of the functioning of the instrumentation at the stations, using the following information or part of it as input:

- The values of the meteorological parameters at a certain time of observation or at a certain interval of observation

-The values of the meteorological parameters at the former time of observation or the former interval of observation

- Knowledge of the possible climatic range of each parameter value at different times of the year at the geographic sites of the stations

- Knowledge of intervals between observations and possible jump from in these intervals

- Information about the actual instrumentation at the stations, and the technical range of this instrumentation

- Logical connections between the parameter values measured at a station

-Comparison of measurements taken at meteorological stations situated near each other

A system for administration of meteorological data developed at The Norwegian Crop Research Institute and in parts used during the growing seasons 2000, 2001 and 2002 is the main source for the following discussion.

R-test (range test) is a test connected to the defined possible range of each meteorological parameter. For several parameters this range can be defined as a climatologic attribute of an entity depending of the time of the year, the geographical latitude, the altitude above the sea level of the site, and the distance to the ocean etc. Several of the radiation parameters also have a possible range variation during the day in addition to the seasonal variation.

The J- test (jump test) is connected to the climatologic possible variation in each parameter from one hour to the next hour. This variation is also dependent on the season of the year, the geographical position of their site etc.

Some tests connected to one single instrument or part of an instrument, are called L-tests (logical tests). The reason for the use of this classification is of historical nature. When several different meteorological parameters are connected to one instrument, there exist certain logical connections between the values of these parameters. As an example the maximum hourly temperature of the air 2m above the soil surface (TX), the average hourly temperature of the air (TM), the minimum temperature of the air (TN), and the instantaneous value of temperature of the air in the end of the time interval considered (TT), are all measured by the same instrument. The following four logical expressions should then always be true:

TX >= TM
TX >= TN
TX >= TT
TM>= TN

Similar logical expressions also may be defined for parameters connected to other types of instruments, for example measurements of relative humidity or wind velocity.

In the Norwegian system considered there are also constructed some tests connected to the specific construction of some instruments. These tests are called LC-tests (logical tests followed by corrections)

Example:
The GEONOR precipitation gauge measures both rain and hail and snow as precipitation. This instrument consists of a bucket containing a liquid and it is suspended in strings, and the content of the bucket is weighted by a sensor system connected to the strings. Sometimes this instrument records spurious positive and negative values of precipitation due to the movement of the bucket by wind. The negative values are eliminated by an averaging process. In contrast 'The tipping bucket rain gauges' in the system never record negative values, and the range of possible hourly values is therefore different for the different types of instrument in use. So the range test of the system is modified in the LC-test taking the actual instrument used at a logger into account.

Example:
The instruments measuring global radiation in this system often record negative values in darkness during the night. One has chosen to correct all these negative values to zero.

It is also possible to define logical tests of parameters connected to two different instruments. One may call them LT-tests (logical tests connected to two instruments). An example of such a test is the comparison of a parameter connected to an instrument measuring precipitation and a parameter connected to an instrument measuring leaf wetness. If there is precipitation, the leaf wetness sensor should be wet.

It is furthermore also possible to define logical tests of parameters connected to two different instruments, and the positive outcome of the test results in an immediate correction of a value or flagging of a value. We call these tests LTC-tests (logical tests of parameters connected to two instruments, with correction).
An example of this sort of test is an elimination of information connected to instruments not functioning in cold weather (during the winter season with temperature below 0° C).

Other descriptions of control systems for automated station networks may be found in the folling papers (Øgland ,1995, 1996) ,(Zollfrank, 2000) and (Sivertsen,2000).

EXAMPLE OF DESCRIPTION OF ONE MEASURED PARAMETER

To show the usefulness of documentation system proposed above, an example of describing one single parameter measured at an automated network of meteorological stations is presented below.

Name of the parameter:
'Average air temperature of an hour, measured 2m above the ground'

Unit:
'°C'

Definition:
'TM is defined as the hourly mean of the air temperature at a certain spatial position 2m above the ground surface. It is the outcome of a measuring system consisting of a recording sensor of temperature, placed 2m above the ground and shielded against radiation errors by some sort of screen. The sensor of recording is placed at an automated meteorological station. The site of the station should as a rule consist of some flat vegetated area covered with grass (that is cut short during the growing season).

The temperature scale used is the Celsius scale, which may be uniquely mapped to the thermodynamic temperature scale measured in K (Kelvin).

The measuring system is constructed in such a way that the outcome could be used in a thermodynamic system with the air as the gas medium, usually defined as an ideal gas mixture of nitrogen (N_2), oxygen (O_2), argon (A), carbon dioxide (CO_2), and water vapour (H_2O). '

Method(s) for measuring the parameter:
'Sensors recording air temperature are all placed 2m above the ground at automated agro meteorological stations. The sensor is in each case shielded against short wave radiation, and it is placed inside some sort of radiation shield, that allows easy passage of the surrounding air. This may be a wooden Stevenson screen, (0.700 x 0.500 x 0.600) m^3, or some shielding of much smaller dimension.

The sensors used are either resistance thermometers, Pt 100, Pt 500 or Pt 1000, or it may be thermistors of some sort. The dimension of the resistance thermometers Pt 500 and the thermistors used are as a rule strings of length 10cm and diameter 6mm. The dimensions of the Pt 100 and Pt 1000 sensors inside the different combined humidity-air temperature instruments (from Väisälä and Rotronic) are as a rule much smaller, with strings of length about 2cm and diameter 2mm.

The principle of the resistance thermometers is the known monotonic increase of the electrical resistance with the temperature of the sensors of pure metal, (Szeicz ,1975), within the range of the temperature considered. The thermistors (semiconductors composed of sintered mixtures of metallic oxides) has a known monotonic decrease of the electrical resistance within the range of temperature (Szeicz, 1975).

As a rule the temperature is recorded each 5^{th} second, and then the average temperature each minute is calculated and recorded. The mean temperature of an hour is then sampled as the mean of the 60 recorded calculations this hour.'

Representativeness for certain phenomena (models):

'In this case each model of interest must be tested or operationally used in order to find the representativeness for the phenomena described by the model using this parameter.

Connection to measuring system:
'A system for measuring this parameter is the automated network of 52 agro meteorological stations in Norway, owned by the Norwegian Crop Research Institute.'

SOME RECOMMENDATIONS

One of the important needs of agro meteorology is to know the quality of the input data to the models used by the agro meteorologists and cooperating biologists as well as the quality of the output data from the different models they are using.
Types of models relevant for discussion in this text are
SVAT-models used in agro meteorology as well as some sort of SVAT-modelling combined with development of biological phenomena in time. Examples are models describing the development of pests and diseases in field crops and in horticultural orchards. Phenological development of field crops and horticultural trees and bushes usually also will be elements of such modelling systems. Also a description of climatologic parameters is of interest, daily, monthly and yearly sums and averages, and spatial distribution of phenomena as precipitation, air temperature and sun shine.

Recommendations for the use of data in models from automated networks of meteorological stations are therefore included in this text. The problem can be defined as a problem of documentation of the input data to the models, a problem of documentation of the testing data and a problem of documentation of the output data from the models.

The description of input data to models from automated station networks and measurement from station network with manual recordings can generally be given by the following list of attributes:

Name of the parameter
Unit
Definition
Measurement procedures
Representativeness for certain phenomena (in models)
Connection to measuring system

The attribute called 'Representativeness for certain phenomena (in models)' can in fact only be derived by the use of the input data in the different models of interest, or compare the actual data source of input data to the test data of the models. The other attributes proposed above for description of each parameter are properties derived from the measurement system considered and the geographical coordinates of the measuring system.

To discuss the concept of 'representativeness' generally and specially for different measurements used in different models, may be considered as future tasks of research in agro meteorology. In the first place the models considered ought to be documented according to what sort of input data has been used in testing the models. The testing data then ought to be described in the way proposed above. But to discuss the ‘representativeness’ of the different parameters one also ougth to include descriptions of the sites where the stations are placed, the cover of the ground, the buildings and vegetation in the neighbourhood of the site as well as the topography in the area. This sort of information can in modern times be provided on www for different networks of meteorological stations, but it demands care and time and resources to actually gather and present such sort of information.

The density of the station networks should be evaluated also by looking at the models using input data from these stations. The techniques used for interpolation in time and space and spatialisation of measured meteorological parameters are of importance, as well as the construction of average values and accumulated values of different measured parameters. Such mathematical and statistical methods should probably be regarded as elements of the system for making measurements.

The operational use of models may also be considered as extending the testing of the models or a possibility of extending the testing of the models. The quantitative model output may then be documented according to the proposal above of documentation of parameters derived from models:

Name of the parameter
Unit
Definition
Representativeness for certain phenomena on in the models
Representativeness for certain phenomena on other scales (other models)

Connection to modelling system

Often the meteorological data used as input to models of interest is not the simple parameter values coming from the primary data source of the station network, either automated or equipped with manually recorded instruments. The raw data output from such stations are as a rule averaged or accumulated parameter values of an hour, measurements taken four times in a day etc.

It is often the case that the data of interest rather are degree sums of air temperature, averaged values of a day or a month or a year, accumulated values of a day or a month or several days or a year etc. of some parameter. These types of input data may be treated in the same way as the simple input data discussed above. One can use the same list of attributes for documenting the data as above, but the definition of the data will be different from the attributes of the simple data.

These types of data may be interpreted as objects (having some temporal or spatial resolution and connected to some place and some temporal periods) of the classes of phenomena described as average air temperature of a month or the accumulated precipitation of a year etc. The measurement methods then will include the techniques of calculation used (temporal averages, spatial averages).

In a similar manner the spatialisation techniques may be defined as an extension of the methods for making measurements, identifying and describing actual objects of phenomena. The outcome of the spatialisation of rainfall may be the extension of point registrations, in the area considered and covered by some stations. This might be the derivation of the accumulated rainfall in the whole area considered in the period of interest.

In the actual world responsibility for documentation of meteorological data either from measuring systems or from model calculations also would be dependent on the social systems and how the tasks of administrating the measuring systems are organized. As a rule the responsibility of disseminating the results from the numerical weather prognoses is an affair of the national meteorological institutes, while the quality and representativeness of the model output from irrigation models or plant disease prognosis is the responsibility of some other organisation. The conclusion is that the attributes of the documentation systems proposed are somewhat universal, but the responsibility of each attribute is dependent on the social context.

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