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Discussing a web-based system for administration, evaluation, and correction of meteorological and biological data in a perspective of actor-network theory

Tor Håkon Sivertsen[1] and Janis Gailis[2]

[1]*Norwegian Institute for Agricultural and Environmental Research, Høgskoleveien 7, N-1432 Ås, Norway; E-mail: thsivert@online.no*

[2]*Agder University College, Service Box 422, N-4604 Kristansand, Norway; E-mail: janis.gailis@hia.no*

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Abstract—The history of a web-based system for administrating data from a network of agrometeorological stations is shortly presented, and the module of this system containing the documentation of the instruments in this network is discussed in detail. The quality concept of meteorological data is the starting point for this discussion. The way of coupling the instruments and parameters on each meteorological station is shown, as well as the use of this information by controlling and correcting meteorological data.

Ideas of actor-network theory are discussed connected to the future challenges of data integration and use of data from different sources in applications.

Key-words: meteorological data, instruments, controlling data, documentation system, correcting meteorological data, actor-network theory

1. Introduction

The agrometeorological service of Norway is the owner of a network of agrometeorological stations, and during the growing season of 2006 the number of stations was 80. In 1998 and 1999 a web-based system for administration of this network of stations was developed, and this system was used operationally from May 2000 until March 2006. Documentation of the system, both the technical as well as theoretical parts, was published in an internal report at the Plant Protection Centre of The Norwegian Crop Research Institute in November 2002 (*Sivertsen* and *Gailis,* 2002), in Norwegian. The development of the software was based on ideas on object oriented analysis of the operational use of the results, put up by (*Brown*, 1997).

In January 2005 a description of the main theoretical elements of the system was published together with several ideas for refinement of the system to include methods for making measurements of meteorological parameters (networks of meteorological stations, weather radars, etc., as well as output from different models, meteorological prognoses on different spatial and temporal scales) (*Sivertsen,* 2005a).

Ideas for extending this system to include biological data, both long time series of measurements and model calculations were published in 2005 (*Sivertsen*, 2005b), together with technical information on constructing the most important tables of the database.

This system for administrating the stations contain a documentation system for meteorological parameters (*Sivertsen,* 2004, 2005a, c and d), and a documentation of instruments giving unique identification of each instrument at every station. In Section 2 the documentation of instruments, as well as the way the instruments and parameters are coupled, are described. The coupling of instrumentation and parameters is used for controlling the values of the meteorological parameters. Furthermore, routines for automated corrections of meteorological data, connected to the specific types of instruments is a part of this system.

The responsibility of the agrometeorological service of the Norwegian Institute for Agricultural and Environmental Research is to run the network of agrometeorological stations as well as to gather, store, control, and use meteorological and biological data originated from the stations and other sources to be used in applications for plant protection (for tactical and strategical decisions) and in research purposes on agricultural and environmental issues. Important future challenges are connected to the integration and use of data from different sources in an intelligent and optimal manner (*Sivertsen,* 2006).

A few elements of actor-network theory (*Latour*, 2005) are discussed in this paper. The ideas of this theory may be applied in inquiry of the exchange of data and applications on the internet by a heterogenous system of actors. Norwegian Institute for Agricultural and Environmental Research ought to act in this heterorgeneous world wide network according to the responsibility of the organization. When the institute is gathering data and information, this ought to be done according to an evaluation of what is needed for each specific task. The organization may demand specific quality on the data gathered and only use the data according to the known quality level of the data. When submitting data to other organizations and to the public, the Norwegian Institute for Agricultural and Environmental Research may explicitely document the quality and scope of these data. The institute may suggest in which context the information should be used and in which context the information should not be used.

Specifically, the Norwegian Institute for Agricultural and Environmental Research has been be engaged in standarazing formats for exchange of meteorological and biological data (*Sivertsen*, 2005c; *Mestre*, 2006). Such work is a task logically connected to the responsibility of the organization.

2. Connecting measurable quantities to the scientific principle

2.1. The concept of a parameter and the quality of data

When any physical, meteorological, or biological phenomenon is described by attaching quantitative attributes to it, this is called 'parameterization' in this paper (*Sivertsen*, 2004, 2005c and e). The main attributes of documenting measured parameters and parameters of models are given in the following manner (*Sivertsen*, 2005a and b) and (*Mestre*, 2006):

Measured parameters:

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

Parameters in models:

Name of the parameter
Unit
Definition of the parameter
Representativeness for certain phenomena in other models.

The term quality is derived from the Latin word 'qualitas' meaning the nature (good or bad), properties, or condition of something. If we know the nature and sources of meteorological and biological data, the value of the data is known.

The quality of the meteorological data may in a very short manner be described in this way (*Sivertsen*, 2005b):

(a) Connection of the data to the objects of nature (*Sivertsen*, 2005d);
(b) Properties, conditions, and quantitative values of the data, including completeness and representativeness;
(c) Identity of the data that is linked to the social system producing the data (giving the data authority);
(d) Availability of the data; and
(e) Presentation and use of the data including the context of the presentation.

The meteorological data of interest for the use in models, etc., of course are the numerical values of the parameters. Nevertheless, for discussions connected to the scope of the model systems, contained in the interpretation of the scientific principle given in *Fig. 1* (*Sivertsen*, 2005e), the knowledge of the definition of the parameters, technical details of the measurements, and other attributes of the metadata are of interest. Thus, the points (a), (b), and (c) above connected to the quality of the data are of relevance for the discussion in this paper.

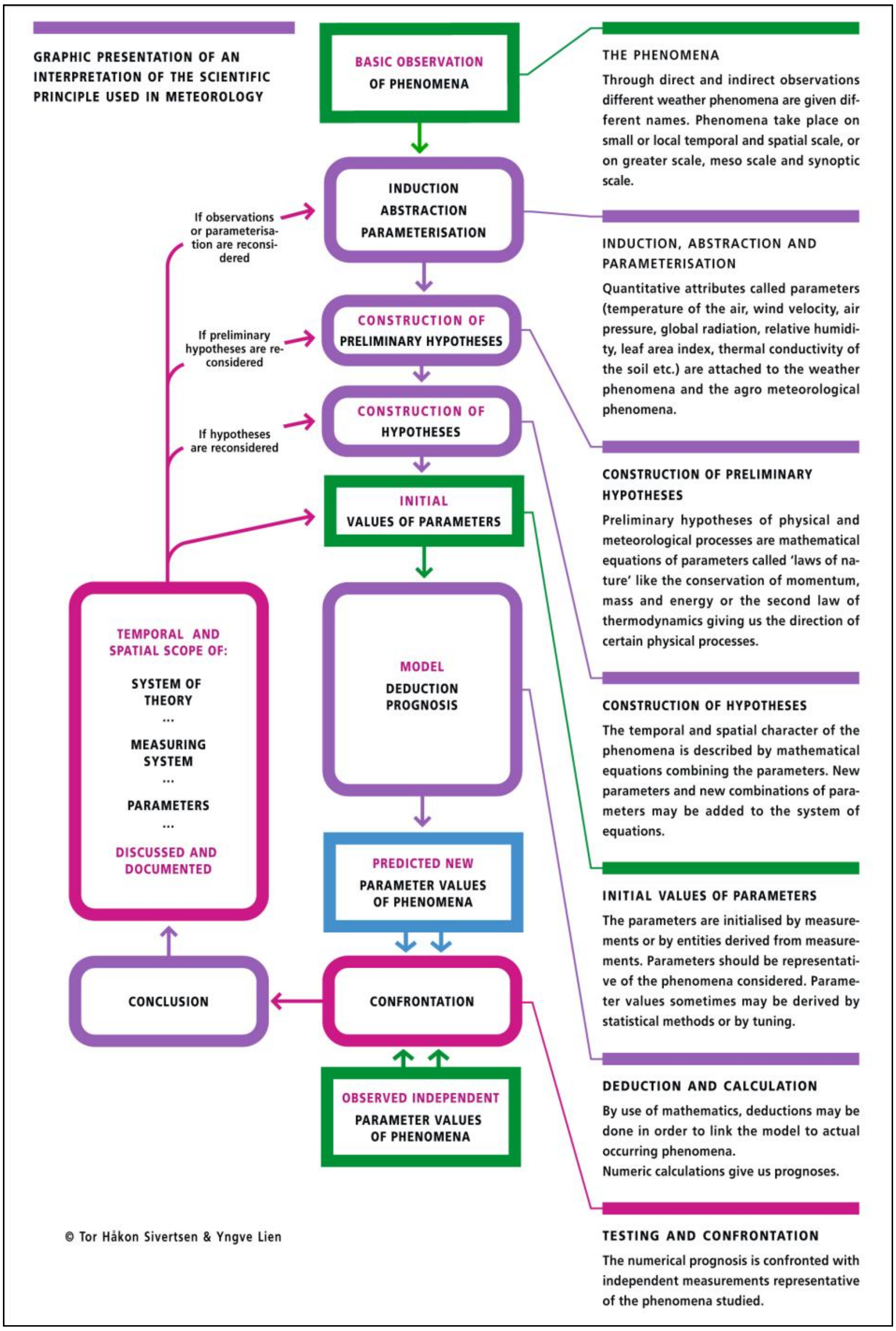

Fig. 1. Graphical representation of an interpretation of the scientific principle.

2.2. Documentation of the instruments

The instruments are documented in a hierarchy, and the four levels in this hierarchy have got the following names: (a) InstrumentType: the type name used by the producer of the instrumen, (b) SensorType: type of sensors connected to each type of instrument, (c) SensorGroupType: defined group of sensors connected to a certain type of instrument, and it may consist of only one type of sensor, (d) SensorGroup: the actual group of sensors connected to a type of instrument and a certain logger. This group of sensors (one sensor or several sensors) is used to measure one or several parameter values.

The highest level is the InstrumentType. This is a rather short description of the types of instruments used in the web-system. The instrument type is defined as the production name used by the company producing the instrument. Also the name of the producer, the country of the producing company, and a short description of the instrument are given as attributes in this table.

The second highest level is the SensorType. This level contains description of the different types of sensors connected to a certain type of instrument. An important part of the description, and the key of the table, is a short name, a symbolic name, constructed to give a very short description of the physical principle of the sensor. Here is a list of some short names used (the type of instrument and the producer's name are also given to clarify the system):

PHEV (photo electric vane) WAV15, Vaisala Oy, Finland

P2 (Pt 100) MP-100, Rotronic AG, Germany

CP (sensor measuring electric capacity of air) MP-100, Rotronic AG, Germany

TIPB (tipping bucket) ARG 100, Campbell Scientific, USA

P3 (Pt1000) HMP45A, Vaisala Oy, Finland

CPaa2 (sensor measuring electric capacity of air, second type) HMP45A, Vaisala Oy, Finland

TIPBH (tipping bucket, heated) ARG 100Heated, Campbell Scientific Ltd, USA

TIPBaa2 (tipping bucket, second instrumenttype) Rainmatic, Pronamic, Denmark

3CUP (3 cup anemometer) A100R, Vector Instruments, United Kingdom

3CUPH (3 cup anemometer, heated) WAA15, Vaisala Oy, Finland

3CUPHaa2 (3 cup anemometer, heated, second type) 432 Anemometer, Theodor Fiedrichs & Co, Germany

3CUPaa2 (3 cup anemometer, second type) Wind Speed Sensor 2740, Aanderaa Instrumnents, Norway.

In addition the calibration procedure of the sensor, the temperature range of usefulness, the measuring range, the precision of the measurement, if it can be used in darkness and if it is useful below 0 degrees Celsius, are given as attributes of the SensorType.

The third highest level is called SensorGroupType. This is a table of shortnames. Usually a few letters are added to the SensorType shortname or to a combination of SensorType short names to give an indication of which meteorological parameter are most usually recorded by an actual instrument with this SensorGroupType.

Below a few examples are presented:

ALBSN (measuring 'albedo') consists of the sensor types TCUPaa4 and TCDO

GRPHDD (measuring 'global radiation') consists of the sensor type PHDD

GRTCUP (measuring 'global radiation') consists of the sensor type TCUP

LWARTL (measuring 'leaf wetness') consists of the sensor type ARTL

PBUSTRI (measuring 'precipitation') consists of the sensor type BUSTRI

TP2 (measuring 'the temperature of the air') consists of the sensor type P2.

The lowest level in the description and classification of the instruments is the SensorGroup, which is a unique registration of one particular group of sensor on one particular logger. Most of the loggers are permanently placed on a certain site. We, therefore, always add three unique letters to the 'SensorGroupType' short name to tell at which site the 'SensorGroup' is placed.

An example is given below:

GRTCUPUDN is the SensorGroup measuring global radiation on the logger number 14 placed at Udnes.

In the case of certain SensorGroups, for example sensor groups measuring the temperature of the soil in different depths, the name of the sensor group also indicates in which depth the instrument is placed.

Two examples are given below:

JT10TTHERMUDN is the SensorGroup belonging to the SensorGroupType TTHERM measuring soil temperature in 10 cm depth on the logger number 14 at Udnes.

JT20TTHERMUDN is the SensorGroup belonging to the SensorGroupType TTHERM measuring soil temperature in 20 cm depth on the logger number 14 at Udnes.

2.3. *Coupling of instruments and parameters*

Through a user interface the different meteorological parameters may be coupled to the SensorGroups defined on each logger, and each parameter is also defined by a shortname:

One example:

The SensorGroup TP2UDN is connected to four parameters:

TM: The hourly mean air temperature 2m above the soil surface.

TN: The hourly minimum air temperature 2m above the soil surface.

TX: The hourly maximum air temperature 2m above the soil surface.

TT: The instantaneous air temperature 2m above the soil surface in the end of the hourly interval considered.

2.4. *Data controlling and correction*

One special feature of the system is the development and implementation of the unique characteristics and naming of each instrument at every station, and the unique coupling of the instrument, denoted to a SensorGroup, to every parameter measured at the station. Six different types of tests and corrections exist:

R-test: This range test of parameter values is often connected to the climate at the different sites.

J-test: Jump test (this is a temporal test comparing the values of a parameter at one recorded measurement and the previous recorded measurement (usually connected to climate and season of the year).

L-test: Consistency test connected to the parameters of one single SensorGroup. An example is testing the logical consistency of four hourly values of air temperature, TM (average temperature), TN (minimum temperature), TX (maximum temperature), and TT (temperature measured in the last minute of the hour).

LT-test: Consistency test connected to the parameters of two different SensorGroups. An example is comparing leaf wetness duration, BT, and precipitation, RR. Two different sensors are used. When it is raining, the sensor for measuring leaf wetness shall indicate leaf wetness.

CI-correction: This is an automated test of the parameters of one SensorGroup, followed by an automated correction, specific for the unique SensorGroupType in question. An example is correcting different types of gauge for measuring precipitation, using different physical principles. The sensors, using the tipping bucket system, are existing functions only in the warm season with no snow or other types of hydrometeors precipitating from the clouds. These instruments normally need no corrections. At several sites the GEONOR instrument, using the principle of weigthing the snow or rain that is falling, is used. This instrument is functioning at all seasons, but the outcome will also have spurious small positive and negative values that ought to be corrected.

CTI-correction: This is an automated test of the parameters of two different SensorGroups, where the result from one group indicates the relevance of the results from the other. An example is: If the temperature of the air is below 0 degrees Celsius, this indicates that the parameter value of precipitation from the tipping bucket-systems are not correct.

The actual R, J, L, and LT tests are not very different from the tests used at other Nordic institutions in charge of running networks of meteorological stations (*Vejen et al.*, 2002). The main difference is that in the system described above, a test is defined as a test of the functioning of a SensorGroup, using values of the parameters connected to the SensorGroup as input. The knowledge of type of instrument also makes it easy to validate the results of the tests. The construction also makes it possible to implement the corrections named CI and CTI relatively easy.

3. Reflections on actor-network theory

The information system for administration of meteorological data, discussed in this paper was developed according to traditional (mainly object-oriented) methodologies (*Brown*, 1997). The whole concept is confined to the responsibility of the institute and the possible use of meteorological and biological models and data on the field of plant protection in the commercial agriculture of Norway.

Information technology provides an arena for network building in the global sense. The cooperation in such networks is essential for innovation. According to actor-network theory, the society consists of networks of heteorogeneous actors, both human and non-human. “Agents, texts, devices, architectures are all generated in forming part of, and are essential to, the network of the social” (*Law*, 1992).

In the Wikipedia one can read: “Actor-network theory is useful in exploration of why technologies, scientific theories, and/or social endeavours succeed or fail as the direct result of changes in their network integrity, in such an analysis the technologies or theory is positioned as token.”

The network of agrometeorological stations considered and the data produced by using the measurements are fully financed by the Norwegian Ministry of Agriculture and Food. The Norwegian Institute for Agricultural and Environmental Research may be considered one of the most important stakeholders of this system for managing and producing information beneficial for the Norwegian society. To a certain measure, stakeholders want to keep a network punctualized, where punctualization means that when a problem or issue is presented, the answer should be given inside the actual frame of the question. If the system is de-punctualized, the result may end in conflicts because stakeholders are loosing control. But a stakeholder do not have to define himself as a controlling agency. He merely may try to keep order in his relations in the processes of bringing up the problems and solving the problems, also through mobilisation of allies. But never the less it is in fact very difficult in the long run to act with integrity for any stakeholder. Integrity can not be retained without compassionate understanding of all the different relations.

4. Future challenges on integration of meteorological and biological data

When designing a system for administration of meteorological and biological data in the future, the requirements ought to be evaluated and presented by the Norwegian Institute for Agricultural and Environmental Research. The challenges seems to be the ability of creating a flexible and extendable system for administrating the data, containing the possibility of integrating, and utilizing data from different sources. In order to assure effective retrieval of data, cooperation with other organizations nationally and on the international level have to be organized. The processes/tasks of exchange of data from different sources as well as exchange of applications have to be organized through cooperation. The scientific and practical scope of the system may be discussed, also by allowing conceptual discussions.

Also the Norwegian Institute for Agricultural and Environmental Research may organize its own controlling system of data and document, the quality of the data produced by this organization, and the institute may make demands on the quality of the data produced by other organizations to define the usefulness of data from any source.

The exchange of meteorological data is formalized and may be further formalized through defining and using standardized schemes for exchange (*Sivertsen*, 2005e).

5. Conclusions

A documenting system of instruments may be used as a very effective feed back to the part of the organization in charge of the technical maintenance of the instrumentation.

Furthermore, meteorological data from agrometeorological networks of stations is used in many different meteorological and biological models. The models are often used for practical decisions, and they normally need correct and complete time series of data. Documenting the data is then a tool for deciding the scope of the use of the data. So, the first step is to construct a system telling the status of the data in the database. The next step is to construct relevant sets of data for each model when specific data from the systems for making measurement is lacking. The system described in this paper is mainly a presentation of how incorrect or questionable data may be indicated. A few additional corrections specific for certain types of instruments may be relatively easily implemented by using the system.

The further steps of constructing complete time series when data is lacking may be organized in two somewhat different ways. One way of doing this is that the people in charge of running a model is asking the people in charge of producing the data to deliver them complete time series of data. Another way of constructing complete time series is that the model-people themselves make the corrections of the input data. The second way is often the most practical one, and probably the input part of each model ought to contain a module containing corrections of the input data (or alternative data is used when data is lacking).

The responsibility of the agrometeorological service of the Norwegian Institute for Agricultural and Environmental Research is to manage a network of agrometeorological stations as well as gathering, storing, controlling, and using data from the stations and from other sources to be used in applications for plant protection and research purposes. Important future challenges are connected to the integration and use of data from different sources in an intelligent and optimal manner.

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