History of CGMS in the MARS project

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Origin of the MARS project

The MARS project (Monitoring Agriculture with Remote Sensing) was initiated by the European Commission (EC) in 1988 as a research programme in which three Directorates were involved: DG-Agriculture, Eurostat and the Joint Research Centre (JRC). An overview of the initial ten years of the MARS project is given by Meyer-Roux (2000). Its objective was to stimulate the application of space technology for the collection of regional agricultural production statistics. DG-Agri, in charge of managing the Common Agricultural Policy (CAP), was confronted with increasing overproduction of major crops (cereals, oilseeds, sugar beets) for which production-based subsidies had to be paid to the agricultural sector. Therefore, the EC needed a warning system that would provide estimates of regional and national crop production during the growing season. Most crucial were the end-of-season estimates on cropped area and yield, as a basis for regional crop production. Eurostat was especially interested in improved harmonized data collection methods, which would provide a common basis across the entire territory of the EU.

The main trigger to initiate such a programme was the feeling that Europe was behind the United States in space technology, and that a user-driven approach was needed to catch up the difference. The Agriculture Project, or the Pilot Project for the Application of Remote Sensing to Agricultural Statistics as was the official name of the MARS project until 1994, launched for its first phase of five years 1988-1993 a number of Actions. Within these actions various kinds of satellite images were used to help estimating the cropped area and the state of the vegetation and crops at different scales, within Europe. One Action, however, was designed to be independent from space-born data, so that its application could continue even after all satellites would have fallen down. This was Action 3 focusing on agro-meteorological models. The present account discusses the history of this Action, and within this action the development of the agro-meteorological model, later called the Crop Growth Monitoring System (CGMS).

Action 3

The aim of the Action 3 was to enable quantitative national yield forecasting and qualitative sub-national crop state monitoring. The proposed approach foresaw the development of a database with historical crop, soil and weather data, the development of a semi-deterministic biophysical crop simulation model to generate yield related indicators, and the development of crop-specific yield forecasting models to relate these indicators to yield statistics on a regional level (Meyer-Roux et al., 1989). The methodology combined components from earlier work by FAO on early crop yield assessment (Frere and Popov, 1986), and crop-soil-weather models developed in various European countries and the USA for the assessment of the production potential of land at regional and national scales. Vossen (1990) outlined the envisaged European yield forecasting and monitoring system and gave its spatial and temporal dimensions for the major input data. This data included time series of 30 years daily weather data on 250 stations, covering the EU12, real time weather data on 450 stations, soil and land use maps at scale 1:1 million (5 km resolution), and crop calendar data at 15 day accuracy. The model calculations at the most detailed level are followed by aggregation of results to statistical regions into yield indicators. These indicators are validated by statistical procedures, which include the quantification of the effect of all non-modeled factors. Such statistical yield models had already been developed in Gembloux for Eurostat (Palm and de Bast, 1988). The actual development of the agro-meteorological models, the collection and processing of data were outsourced by JRC through tender procedures. JRC supervised the execution of the contracts.

The contract for model development was awarded in 1989 to the Winand Staring Centre (SC-DLO) in Wageningen, a new institute born out of a merger of several Dutch agricultural research institutes including Stiboka on soil survey, and ICW on land and water management. Ten years later, in 1998, SC-DLO was replaced by Alterra, the research institute of the Environmental Science Group of Wageningen UR.

Background knowledge of SC-DLO

During the 1980s FAO developed Yield Forecasting and Early Warning systems at national and regional scale for drought-stricken countries and continents, as a tool to support famine relief measures and food security policies. FAO worked on a system for the African Real Time Environment Monitoring using Imaging Satellites (ARTEMIS) as part of its Global Information and Early Warning System (GIEWS). As an improvement of ARTEMIS the ICW (predecessor of SC-DLO and Alterra) proposed to link the crop model WOFOST, developed at the Centre for World Food Studies (van Keulen Wolf, 1986), to remote sensing data. The method was tested in Zambia in the Dutch funded MARS project (Monitoring Agro-ecological resources with remote sensing and Simulation). Although this pilot for setting up a national early warning for food shortage system was successful ICW did not obtain funding for a follow-up. In the context of food security research, the same WOFOST model was also applied in the

Sahel region by the AGRISK project of the Groningen State University to analyze the effects of variability of soil conditions and sowing dates as a way to identify risk spreading management strategies (Mellaart, 1989). In its tender to JRC, ICW offered to apply WOFOST as a component in the agro-meteorological subsystem now known as the Crop Growth Monitoring System (CGMS). In this way the WOFOST model, developed for drought monitoring in tropical field crops, became a tool for monitoring excess production in European agriculture.

Design and development of CGMS

At the start software was available as heritage from earlier projects, notably WOFOST, and additional programs to generate input and to process output. Other procedures had to be developed from scratch such as data aggregation over time and over space. Some procedures like weather interpolation required methodological research before development of operational software could start. Initially, research software was developed as personal tools for interactive use with many options for parameter settings, methodological variants, and flexible output. However this was not regarded as a major problem as the first priority was to develop a functionally complete system, which would work correctly on at least a test data set, without caring too much about user-friendliness and user environment.

The design procedure was mainly through hand-written data flow diagrams of the whole processing chain. Fortran was the standard programming language, but common standards for coding and documentation were lacking. Each programmer followed his own personal preferences in the use of headers, comments, subroutines and I/O handling. All I/O handling was done inside the programs. As several programs used the same data sets, many redundancies existed in the various programs. Data were stored in binary and ASCII files, and here duplication existed, too. It took many discussions to arrive at a consistent directory structure and file name convention. The original programs were tested on relatively small data sets, and when the entire EU12 area had to be processed, performance and disk space problems appeared. Re-engineering was required to speed up data processing by making data handling more efficient, by developing libraries of Fortran subroutines etc. By the end of 1992 when most functional system requirements were achieved, the CGMS counted about 17000 lines of Fortran code.

During the first two years of initial system development three computer platforms were used, MS-DOS and VAX-VMS for development, Iris-UNIX for testing, while the final system had to be installed at JRC on SUN-UNIX. The transfer of software from one platform to another involved adaptations. In 1992 the complete Fortran-ARC/INFO based system was adapted and ported to JRC, Italy. During the last visit in

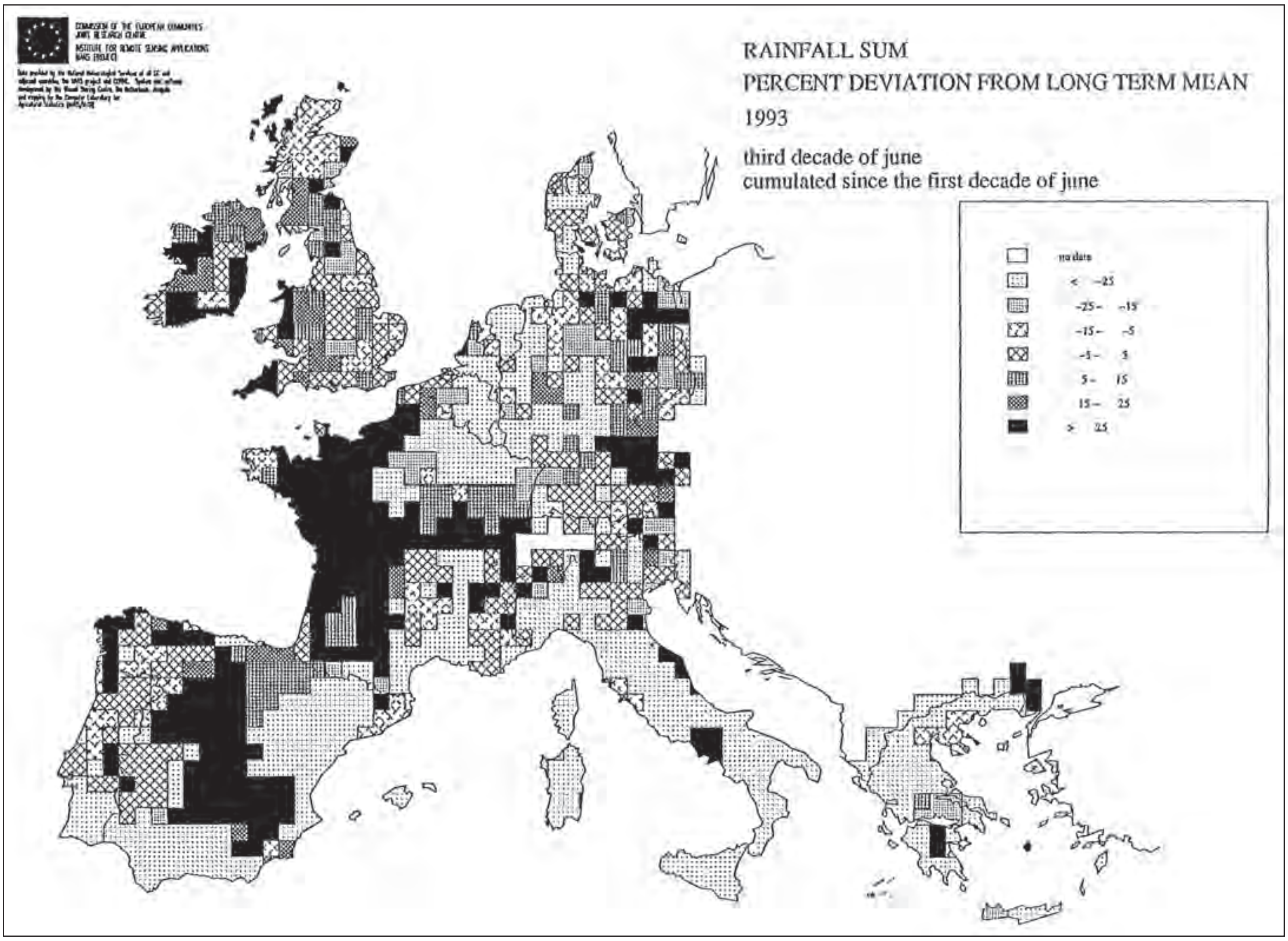

Figure 1 Rainfall in June 1993 in comparison with the long term average (taken from the first experimental bulletin of JRC in 1993

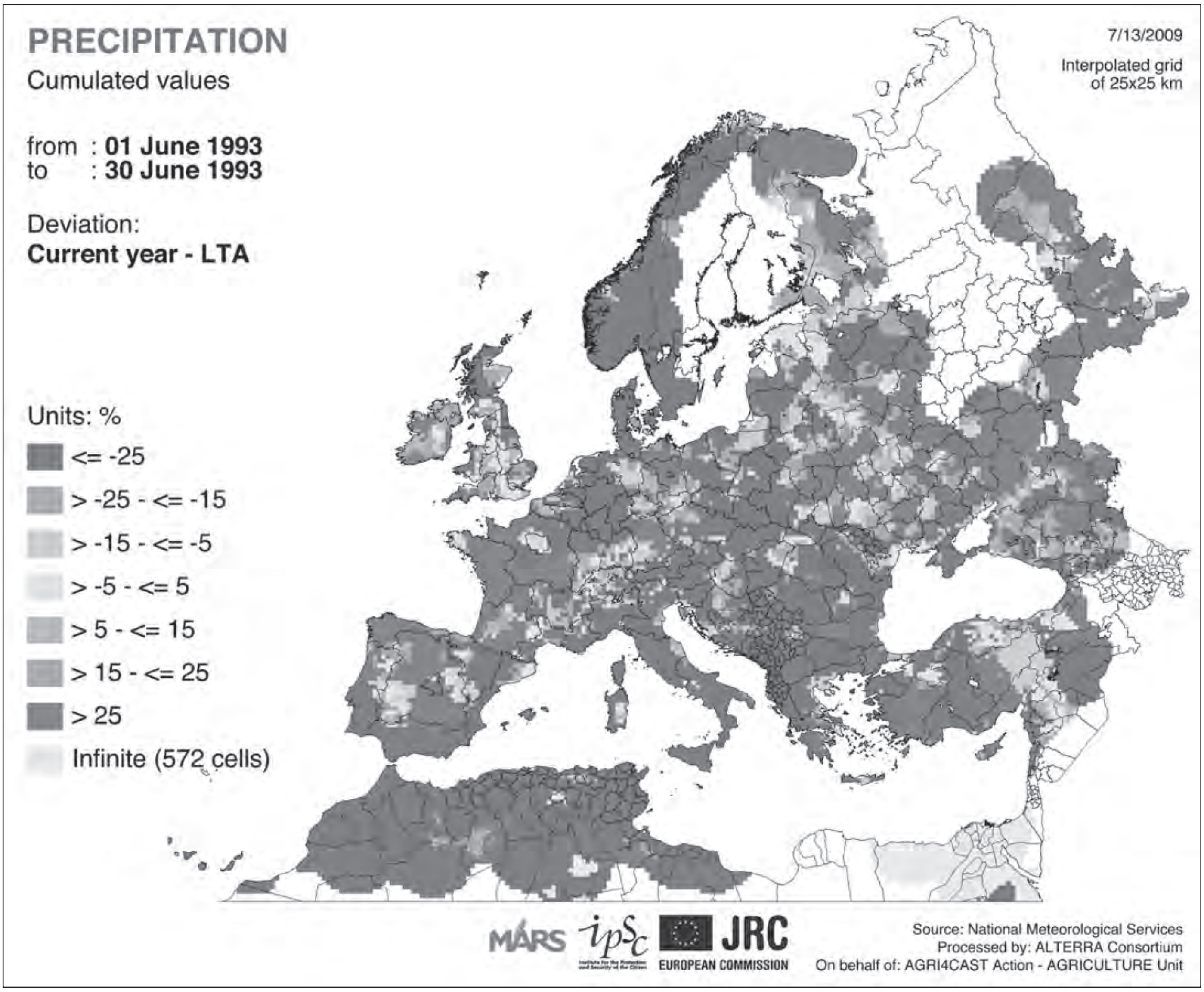

Figure 2 Rainfall in June 1993 in comparison with the long term average (produced by new viewers and based on the current database)

December 1992 for the first time in this project e-mail was used for sending repaired source codes. Figure 1 shows one map of a first experimental weather and crop monitoring bulletin produced by JRC on June 1993.

The thematic and technical documentation on CGMS version 1 was fragmented and incomplete and maintenance was complicated. Begin 1992 the software company Q-Ray was called in to make a redesign using a clear software development cycle of analysis, design, coding and testing. It was decided to build an ORACLE database (ORACLE version 4), and to buy a new SUN-Sparcs-10-Unix work station. The conversion to ORACLE was a revolution, as it was opposite to the original wish of JRC, while earlier tests indicated that data handling in ORACLE would be a factor 5 to 50 times slower than through binary data files. But as the file based system had become difficult to manage and maintain the move was approved by JRC. The redesign was a clear case of reverse engineering. The existing system served as major reference, and was documented as part of the design process. A relational database scheme was made using ORACLE-CASE, and all Fortran code for data handling was replaced by pro-Fortran or SQL-plus scripts. The size and type of operations in CGMS was about the maximum that could be handled by ORACLE and required intensive tuning and optimizing work. The complete CGMS version 3.1 was installed at JRC at the end of 1993 and included around 5 GB. The redesign and documentation marked a major step forward in awareness and realization of software quality at the SC-DLO, and a shift from individual work to team work.

Maintenance, expansion and consolidation of CGMS

During the period 1994-1999 CGMS was tested, operated, used and developed further by JRC, while the SC-DLO had a supporting role in maintenance. Analytical procedures for synthesis of the results were developed and the MARS Bulletin was issued monthly during the season (Genovese, 1995). The CGMS and its components were presented and discussed at many conferences, and a large number of papers was published, e.g Vossen and Rijks, 1995. The covered area expanded from the initial EU12 to pan-Europe up to the Ural and including Turkey in 1997. The number of weather stations increased from 500 to 2000, the number of 50x50 km grid cells from 1400 to over 5000. Meanwhile, JRC undertook a complete redesign and recoding of the software, following a decision to move in the future from the Unix to Windows operating system and from Fortran to C++.

In 2000 the operational task of running and maintaining the CGMS was outsourced to Alterra-CGI. Software and database were transferred to Wageningen and an operational production line was started. The operational requirement included the creation of a large number of maps of crop and weather indicators including an archive of around half a million maps. It was foreseen that a web based tool would be developed to create maps on the fly, in addition to the bulk production of maps. But at that time no such tools were available. All the maps in the archive were made according to fixed predefined criteria and one fixed lay-out. It was in 2006 that database viewers have been developed that could create such maps on the fly, which made the archive redundant and at the same time offering a greater flexibility in map definition, for instance the start and end period and map lay-out for instance changing a logo. Simultaneously map zooming functionality and dynamic legends were introduced. Nowadays new viewers are being developed exploring a database of around 15 TB covering different applications (see Lokers et al. in this issue). One of the application is the classic CGMS in Europe which now includes around 3000 stations with data interpolated to a 25 km grid covering pan-Europe. The same map as was created in 1993 (see Figure 1) has now been produced by the new viewers and based on the current database with a more fine grid and a larger extent (see Figure 2). This example visualizes the technical progress that has been made during the last 15 years.

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