Adv. Sci. Res., 14, 335–340, 2018
https://doi.org/10.5194/asr-14-335-2018

Advances in Science & Research
Open Access Proceedings

An interoperable research data infrastructure to support climate service development

Tiziana De Filippis, Leandro Rocchi, and Elena Rapisardi

National Research Council, Institute of Biometeorology, Florence, 50145, Italy

Correspondence: Tiziana De Filippis (t.de.filippis@ibimet.cnr.it)

Received: 15 January 2017 – Revised: 29 November 2017 – Accepted: 9 December 2017 – Published: 1 February 2018

Abstract. Accessibility, availability, re-use and re-distribution of scientific data are prerequisites to build climate services across Europe. From this perspective the Institute of Biometeorology of the National Research Council (IBIMET-CNR), aiming at contributing to the sharing and integration of research data, has developed a research data infrastructure to support the scientific activities conducted in several national and international research projects. The proposed architecture uses open-source tools to ensure sustainability in the development and deployment of Web applications with geographic features and data analysis functionalities. The spatial data infrastructure components are organized in typical client–server architecture and interact from the data provider download data process to representation of the results to end users. The availability of structured raw data as customized information paves the way for building climate service "purveyors" to support adaptation, mitigation and risk management at different scales.

This work is a bottom-up collaborative initiative between different IBIMET-CNR research units (e.g. geomatics and information and communication technology – ICT; agricultural sustainability; international cooperation in least developed countries – LDCs) that embrace the same approach for sharing and re-use of research data and informatics solutions based on co-design, co-development and co-evaluation among different actors to support the production and application of climate services. During the development phase of Web applications, different users (internal and external) were involved in the whole process so as to better define user needs and suggest the implementation of specific custom functionalities. Indeed, the services are addressed to researchers, academics, public institutions and agencies – practitioners who can access data and findings from recent research in the field of applied meteorology and climatology.

1 Introduction

Accessibility, availability, re-use and re-distribution of scientific data are prerequisites to build climate services across Europe. In the framework of the "European Research and Innovation Roadmap for Climate Services" (European Commission, 2015) the research community is called upon to respond to a new challenge of producing raw data, as well as processed information to provide European climate services with high-quality and scientifically proven data.

A prerequisite for this is the development of infrastructure that ensures access to, management of and preservation of data; technical support for the coordinated and harmonious management of data in the framework of open data policies; and a data-driven research approach. The research data infrastructure must therefore not only provide the necessary tools for data discovery, access and manipulation but should also facilitate and enhance the collaboration between scientists of different backgrounds (Zhao et al., 2015). The use of a transdisciplinary research approach (Hadorn et al., 2008) is key to solving many problems related to the impact of climate change on the environment and agriculture.

From this perspective, the Institute of Biometeorology of the National Research Council (IBIMET-CNR), aiming at contributing to the sharing and integration of research data, has developed an interoperable research data infrastructure to support the scientific activities conducted in several national and international research projects.

The proposed architecture uses open-source tools and standards to ensure sustainability in the development and deployment of Web applications. The geo-referenced information and data analysis functions were developed through a process of "co-discovery", "co-development" and "co-evaluation" involving the providers, purveyors, researchers and users of climate information (Dilling and Lemos, 2011; Vaughan, 2010).

2 Objective

The aim of this work is to deploy an interoperable and open data climate service portal in order to help the scientific community to share relevant and timely products and services.

This initiative arises from the fact that researchers mainly store their data, as well as intermediate products processed for environmental and agro-meteorological investigations, in personal archives. However if these data were shared, they could be used for further applications in other research fields. For instance maps of atmospheric variables with related metadata, as well as indices derived from the variables, could be input data for geo-processing procedures of models used for crop monitoring, drought estimation or hydrological hazard assessment. Raw data, climate products, informatics procedures, code and pre-processed data on a geographical area of interest could thus be re-used, reducing the time and human resources necessary. The availability of an interoperable research data infrastructure to store and manage data could also facilitate and encourage the adoption of a data sharing approach. The purpose is therefore to advance geo-information best practices, knowledge sharing and capacity building for the improved sharing and application of climate information, tailored to users' needs.

3 Method

The spatial data infrastructure components (Fig. 1) are organized in typical client–server architecture and interact from the provider download data process to representation of the results to end users. The services for the dissemination of geo-referenced information adopt the OGC (Open Geospatial Consortium) specifications and standards.

Following the guidelines, principles and specifications of the Infrastructure for Spatial Information in Europe (INSPIRE) directive, the implementation service also includes

- information model: data model and encoding for system data acquisition;
- analysis of data flow and design of communication network;
- interface model and Web services for data flow management;
- use of a participative and interdisciplinary approach among institute research units;
- adoption of a user consultation process to design user Web interfaces (front end).

Infrastructure components

The results of research projects and data analysis procedures (Fig. 1-1) are fragmented among research units. Selected products (i.e. seasonal forecasts, agro-meteorological models, environmental monitoring procedures) and raw data are sent to the data server via RESTful servlet, APIs (access programming interfaces) or a standardized OGC Web service connection. All data are stored automatically by means of the Web services (Fig. 1-2) in the GeoDB following the data model implemented for each specific application. Conceptual design of the GeoDB is based on the entity-relation model (Fig. 1-3). UML (Unified Modeling Language) as the formal language adopted in the ISO/TC 211 context for geomatic data description has been used for formal dataset definition. The Web applications (Fig. 1-4), in the framework of IBIMET-CNR climate service initiatives, enable the user to view and analyse all data stored in the application GeoDB. The customized Web applications have been developed using J2EE technology with Java Server Faces and PrimeFaces library for graphic user interface (GUI) customization. Through a common Internet browser (Fig. 1-5), it is possible to view all collected data in table or chart format. Interface functions allow data to be exported and metadata visualized. Advanced and user-friendly data analysis tools are under development.

4 Climate service portal

The "climateservices.it" portal (www.climateservices.it/) is the access point (Fig. 2) to the services and informatics solutions implemented by IBIMET-CNR, to facilitate the use of climate products and geo-processing Web applications developed in the framework of other research projects. It also provides a selected bibliography, climate information for a general community of users, and advanced Web services to enable experts and practitioners to download climate products and metadata. It is structured in two main sections: services and solutions.

In the landscape of different climate service models developed in recent years, the following proposed services, which are research-oriented, imply the capability of using other data sources and different competences, which are not always available in meteorological services.

Instead, the solutions regard informatics solutions and general frameworks that could be applied in other contexts, changing the extent of the geographic area.

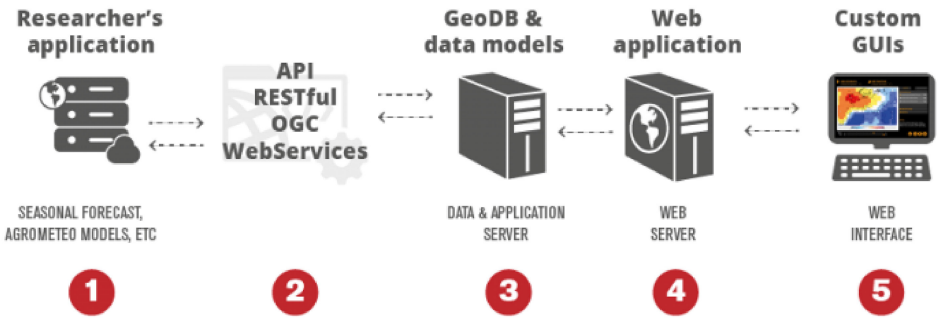

Figure 1. IBIMET-CNR infrastructure components of climate service applications.

4.1 Services

This section is focused on climate services that are provided regularly and consistently over a reasonably long time period. These are addressed to user communities involved in previous research projects, for instance to winegrowers in the case of the ECOVINO project, to public authorities in the case of the Web application for monitoring drought in the region of Tuscany or to researchers who use the climate information such as seasonal forecasts for further analysis and/or applications. The following services are currently available in the beta release:

Med.SEASONAL FORECAST: monthly outlooks, regarding rainfall and temperature anomalies over the Mediterranean basin, tuned for the summer period and based on the NCEP-NCAR Reanalysis dataset (Kistler et al., 2001). Seasonal forecasts for the Mediterranean contribute to the strengthening of the Mediterranean Climate Outlook Forum (MedCOF), North African Climate Outlook Forum (PRESANORD) and South East European Climate Outlook Forum (SEECOF) for the operational use of seasonal forecasts (http://medcof.aemet.es/).

ECOVINO: agro-meteorological advice for Precision Viticulture, based on weather forecasts and pathogens models, that is available during the crop season for Italy's major wine producing areas. These information services are realized through mathematical models that simulate the progress of vine growth (host) and insect generations (parasite) over the growing season. The Web application have a dual objective: to provide weather-phenological information to farmers in order to avoid calendar chemical treatments and optimize production costs; to provide farmers/producers (and wineries) with tools suitable for healthy vineyards, grape and wine production.

WAM FORECAST: West African monsoon (WAM) seasonal forecast of the Sudan-Sahel (10° W–10° E, 9–18° N) that uses a multi-linear regression method applied to sea surface temperature anomalies (SSTAs) in the tropics (Fontaine and Janicot, 1996). In sub-Saharan Africa this information is intended to support national meteorological services (NMSs) in charge of agro-hydro-meteorological monitoring and national early-warning systems (EWSs) for food security.

TOSCANA SICCITA' (DROUGHT IN TUSCANY): a comprehensive framework including climate-based, satellite-derived monitoring and a seasonal weather forecast is the most reliable way to identify drought occurrence and trends in order to provide accurate, timely and affordable support for policy making and impact management in the region of Tuscany (Magno et al., 2014). Rainfall-based indices (SPI – standardized precipitation index; EDI – effective drought index), satellite-derived indices (anomalies of NDVI – normalized difference vegetation index; VHI – vegetation health index) and a simplified water balance are issued regularly through the "Drought-GIS" Web application: online monthly bulletins are also published reporting the previous month's drought situation and outlook for the next months, through analysis of all indices, with particular attention on forest types and main tree crops during the growing season.

4.2 Solutions

The best cases of open-source informatics solutions and Web applications developed by the IBIMET-CNR geomatics and ICT (information and communication technology) research unit are presented here. These applications could be transferred to other similar contexts or adapted to different geographic areas by changing or updating the internal geodatabase or customizing the GUI and the functions required by the end users. For instance the whole framework source code of the underlying SensorWeb Hub (SWH) application is deployed on the GitHub platform at https://github.com/n3tmaster/SensorWebHub (Rocchi and De Filippis, 2018). At present the other applications are available upon request by contacting IBIMET-CNR directly or through the climate-services.it portal. Two examples of solutions are reported on the climateservices.it portal:

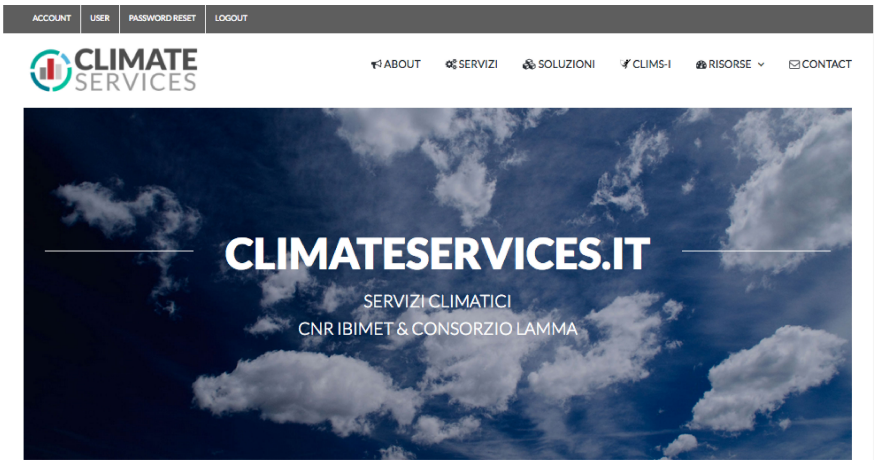

Figure 2. Home page of "climateservices.it" portal.

CRZMS: the Web application "Crop Risk Zones Monitoring System" for resilience to drought in the Sahel and the study case in Mali and Niger, which aims to evaluate impacts due to drought stress during the whole crop growth cycle, providing farmers with information in order to implement appropriate and timely response strategies that minimize risk exposure to food insecurity (Vignaroli et al., 2016).

SensorWeb Hub: Web application that manages both mobile and fixed open-source and low-cost sensor platforms to integrate the existing monitoring networks (De Filippis et al., 2015). This infrastructure, which is OGC-compliant, is currently focused on the following sensor data categories: agro-meteorological, meteorological, urban climate, renewable energy and indoor.

5 Results and conclusions

IBIMET-CNR has developed the beta release of a research data infrastructure to support an interoperable and open data climate service portal. The portal climateservices.it is the access point to services and informatics solutions derived from IBIMET-CNR research activities. The infrastructure is designed to manage further IBIMET-CNR climate products and services derived from advances in research in applied meteorology and climatology. The use of open-source tools and standardized interoperable Web services ensures sustainability in the development and deployment of Web applications with geo-referenced data and customized territorial analysis that could be connected to other interoperable climate services. Indeed, the development of climate services that provide products tailored to different users implies the capability of using multiple data sources and mastering of competencies, which are not always available in national meteorological services.

Moreover, the whole infrastructure framework code is open-source and can be shared to foster cooperation among software and interface designer, experts, practitioners and researchers. Further details are available by contacting IBIMET-CNR directly, even if uploading the code on the GitHub platform is foreseen for the next updated release.

This initiative is conceived to respond to the increasing demand for customized climate-related tools, products and information tailored to end users, i.e. the "services" and "solutions" available on the climateservices.it portal.

As different types of climate services have been developed worldwide in recent years (CMCC, 2012), different reference models are available providing services and products. They include climate change scenario platforms (Sigel et al., 2016) and Web portals where physical data and climate-related products like maps and charts, synthesis reports, guidance documents, advice and bulletins are available. An ongoing initiative of categorization of climate service providers is the "Climate Knowledge Hub" (http://www.climate-knowledge-hub.org), which allows users to explore the profiles of climate service providers in the network.

In Italy, as described in the CMCC (Centro euro-Mediterraneo Cambiamenti Climatici) report (CMCC, 2014), the work on climate services usually focuses on local climate scenarios or profiles, and data are mainly on temperature, precipitation and derived indicators, and/or "station statistical tables grid maps trends": means, medians percentiles and return times. Many climate services are also project-linked, so difficulties emerge in temporal planning due to uncertainties in future funding. Others purveyors of climate-related products are local or national public institutes that offer climate services as an institutional duty to provide information to a specific sector, mainly agriculture, water and energy. Some of these Web platforms are static and provide only reports or maps (data in non-exploitable format) for download. The interoperable Web services and direct open

access to databases are not sufficiently developed to allow a policy of re-use of their data in other computational chains and innovative IT applications.

In this scenario, the IBIMET-CNR climate service platform presents a model where researchers are both internal users and purveyors of climate products and solutions, developed in the framework of national and international research projects, and tailored to the needs of end users involved in the related activities. In addition, the adoption of interoperable Web services facilitates data sharing and their re-use.

The aim is to turn scientific information from climate monitoring, research and modelling into operationally available information and services as recommended by WMO (World Meteorological Organization) for the priority areas indicated in the GFCS (Global Framework for Climate Services), in particular the agriculture and food security area, with a regional focus on Africa.

The initiative also aims to support capacity building, including supportive training, of meteorological offices in least developed countries (LDCs) that collaborate with IBIMET-CNR in the context of international cooperation activities and that do not have the resources and advanced skills to manage, for instance, agro-meteorological models or to compute meteorological indices derived from meteorological remote-sensing data (e.g. CRZMS solution). The challenge is also to attract more internal researchers to share their data and quality-checked climate products easily through an available data infrastructure, for further interdisciplinary investigations.

Lastly, the availability of an interoperable and open-source infrastructure enhances both the timeliness and quality of information provided and offers a technical bridge that enables open sharing of data following the guidelines and principles of the research data infrastructure actions under the umbrella of RDA (Research Data Alliance, https://www.rd-alliance.org) and the GFCS pillars to support the production and application of climate services.

Code availability. The whole infrastructure framework code is open-source and can be shared to foster cooperation among software and interface designers, experts, practitioners and researchers. Further details are available by contacting IBIMET-CNR directly. At present only the source code of the SensorWeb Hub application is deployed on the GitHub platform at https://github.com/n3tmaster/SensorWebHub (Rocchi and De Filippis, 2018).

Data availability. The Web application data are available (in Italy) in the IBIMET-CNR research data infrastructure from the data curator, Leandro Rocchi (l.rocchi@ibimet.cnr.it), for API and RESTful Web service delivery.

Author contributions. TDF conceived and designed the infrastructure, planned the paper and did the writing. LR wrote the code; implemented the spatial data infrastructure, the data model and the standard Web services; and contributed to the paper writing. ER designed the Web user interface and conceived information product design; she also contributed to the paper writing.

Competing interests. The authors declare that they have no conflict of interest.

Special issue statement. This article is part of the special issue "16th EMS Annual Meeting & 11th European Conference on Applied Climatology (ECAC)". It is a result of the 16th EMS Annual Meeting & 11th European Conference on Applied Climatology (ECAC), Trieste, Italy, 12–16 September 2016.

Acknowledgements. Thanks to IBIMET-CNR and LaMMA Consortium researchers who have supported this initiative by sharing data and resources: Massimiliano Pasqui, Vieri Tarchiani, Patrizio Vignaroli, Maurizio Bacci, Ramona Magno and Piero Toscano.

Edited by: Tomas Halenka
Reviewed by: Federica Rossi and one anonymous referee

References

CMCC: Centro euro-Mediterraneo Cambiamenti Climatici, Overview of the main international climate services, available at: www.cmcc.it/it/publications/rp0134-overview-of-the-main-international-climate-services (last access: 12 September 2017), June 2012.

CMCC: Centro euro-Mediterraneo Cambiamenti Climatici, Mapping of climate service providers in Italy: summary report, available at: www.cmcc.it/wp-content/uploads/2014/03/rp0213-serc-02-2014.pdf (last access: 12 September 2017), February 2014.

De Filippis, T., Rocchi, L., and Rapisardi, E.: SensorWeb Hub infrastructure for open access to scientific research data, Geophys. Res. Abstr., 17, EGU2015-7847-2, EGU General Assembly, Vienna, Austria, 2015.

Dilling, L. and Lemos, M. C.: Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy, Global Environ. Chang., 21, 680–689, https://doi.org/10.1016/j.gloenvcha.2010.11.006, 2011.

European Commission: Directorate-General for Research and Innovation, European Union 2015, A European Research and Innovation Roadmap for Climate Services, Print: ISBN 978-92-79-44341-1, https://doi.org/10.2777/702151, KI0614177ENC; PDF, ISBN 978-92-79-44342-8, https://doi.org/10.2777/750202, KI0614177ENN, available at: https://publications.europa.eu/en/publication-detail/-/publication/73d73b26-4a3c-4c55-bd50-54fd22752a39 (last access: 23 January 2017), 2015.

Fontaine, B. and Janicot, S.: Sea surface temperature fields associated with West African rainfall anomaly types,

J. Climate, 9, 2935–2940, https://doi.org/10.1175/1520-0442(1996)009<2935:SSTFAW>2.0.CO;2, 1996.

Hadorn, G. H., Hoffman-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., Wiesmann, U., and Zemp, E. (Eds): Handbook of Transdisciplinary Research, Springer, 2008.

Kistler, R., Kalnay, E., Collins, W., Saha, S., White, G., Woollen, J., Chelliah, M., Ebisuzaki, W., Kanamitsu, M., Kousky, V., Van Den Dool, H., Jenne, R., and Fiorino, M.: The NCEP–NCAR 50-Year Reanalysis: Monthly Means CD-ROM and Documentation, B. Am. Meteorol. Soc., 82, 247–268, 2001.

Magno, R., Angeli, L., Chiesi, M., and Pasqui, M.: Prototype of a drought monitoring and forecasting system for the Tuscany region, Adv. Sci. Res., 11, 7–10, https://doi.org/10.5194/asr-11-7-2014, 2014.

Rocchi, L. and De Filippis, T.: n3tmaster/SensorWebHub: SensorWeb Hub, https://doi.org/10.5281/zenodo.1158617, 2018.

Sigel, M., Fischer, A., Zubler, E., and Liniger, M.: Dissemination of climate change scenarios – a review of existing scenario platforms, Technical Report MeteoSwiss, 257, 88 pp., Federal Office of Meteorology and Climatology, Meteo Swiss, 2016.

Vaughan, L.: Workshop on International Climate Services: Understanding and Responding to the Needs of Decision Makers Summary Report, Washington, DC, 2010.

Vignaroli, P., Rocchi, L., De Filippis, T., Tarchiani, V., Bacci, M., Toscano, P., Pasqui, M., and Rapisardi, E.: The Crop Risk Zones Monitoring System for resilience to drought in the Sahel, Geophys. Res. Abstr., 18, EGU2016-16616-3, EGU General Assembly, Vienna, Austria, 2016.

Zhao, Z., Martin, P., Grosso, P., Los, W., de Laat, C., Jeffrey, K., Hardisty, A., Vermeulen, A., Castelli, D., Legre, Y., and Kutsch, W.: Reference Model Guided System Design and Implementation for Interoperable Environmental Research Infrastructures, 2015 IEEE 11th International Conference on e-Science, Munich, Germany, https://doi.org/10.1109/eScience.2015.41, 2015.