# ESTABLISHING AN INFRASTRUCTURE FOR SPATIAL INFORMATION IN EUROPE: INSIGHT INTO INSPIRE DEVELOPMENTS FOR GMES ATMOSPHERIC DATA

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## ABSTRACT

Earth observation and modeling data on atmospheric composition and associated parameters typically lie within the scope of the INSPIRE Directive, which aims at shaping a common framework for the communication of spatial information throughout Europe. In the context of projects directly related to the GMES Atmospheric Service (GAS) and the GMES Space Component (GSC), the atmospheric community has liaised with the INSPIRE drafting teams during the shaping phase of several of the Directive Implementing Rules (IR), in an effort to convey key notions of geophysical science and data to be integrated into the INSPIRE scheme, as well as to arouse awareness of already existing international standards and practices in use. This paper provides an account of the progress achieved on the INSPIRE scene and outlines some remaining issues for the atmospheric thematic domain.

## 1. INTRODUCTION

The European Directive establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) [1] and its related subsequent Regulations and Decisions [2] [3] [4] [5] [6] [7] aim at shaping a common framework for the communication of spatial information throughout Europe. Together with the Global Monitoring for Environment and Security (GMES) Programme and the Galileo project to set up a European navigation system, they constitute a major contribution of the European Union (EU) to the Global Earth Observation System of Systems (GEOSS).

Earth observation and modeling data on atmospheric composition and associated parameters typically lie within the INSPIRE scope. Moreover, complying with INSPIRE rules has become a contractual requirement for scientific projects funded under the European Union (EU) Seventh Framework Programme (FP7), and is expected from projects funded by the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and national space agencies.

In the context of projects directly related to the GMES Atmospheric Service (GAS) and the GMES Space Component (GSC), and aware of the importance of data and service harmonisation not only for communication but also to meet the requirements of international legislation about adverse effects of air pollution [8] [9] [10] [11] [12] [13] [14], ozone depleting substances (ODS) [15] [16] [17] [18] [19] [20] and climate change [21] [22] [23] [17] [18] [24], the atmospheric community has liaised with the INSPIRE drafting teams during the shaping phase of several of its Implementing Rules (IR), in an effort to convey key notions of geophysical science and data to be integrated into the INSPIRE scheme, as well as to arouse awareness of already existing international standards and practices in use. Major interactions were related to the Directive scope, the notion of quality, the concepts of dataset and dimensionality, the prevalence of the information content on metadata formal aspects.

After providing a brief description of the two initiatives in Section 2, this paper describes and discusses issues that have been raised at the occasion of their interactions (Section 3). Section 4 concludes with some considerations on future perspectives.

## 2. INSPIRE and the GMES Atmospheric Service

### 2.1 INSPIRE

The INSPIRE Directive [1] was published in the Official Journal of the EU on the 25$^{th}$ of April 2007. It entered into force twenty days later. By the 15$^{th}$ of May 2009, Member States had to design and implement some administrative and legislative corpus to comply with its clauses.

The Directive scope encompasses any dataset with a social usefulness, which possesses a geographic extent or is related to some geographic location (which is the way "spatial" must be understood in this context). Its double objective is to harmonise such datasets over the European continent and to make them available to the community (citizens, administrations, agencies, universities, research institutions, hospitals, doctors, policy makers, etc.) all over Europe, through a network of information services. The targeted "data themes" are listed and grouped in the three annexes to the Directive. They include subject matters as diverse in nature as, for example, postal addresses, transport networks, epidemiology, biotopes and, in Annex III, a number of themes related to Earth science research.

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The INSPIRE Directive itself does not include any practical consideration regarding data or service specifications but rather foresees the upcoming definition of Implementing Rules (IR) in a series of follow-up Regulations and Decisions tackling particular practical aspects of datasets and information services. Implementing Rules have been published on various aspects of interoperability, namely high level ("discovery") metadata [2]; reporting by the member states about INSPIRE implementation [3]; minimal requirements expected from services in terms of performance, capacity, availability, types of operations [4]; data and service sharing [5]; etc. [6] [7]. The last set of documents to be endorsed by the European legislating bodies are in their final drafting phase. They address specifications for the data themes listed in the last two annexes (in general, there is one specification document per theme). Stakeholders, classified into Spatial Data Interest Communities (SDIC) and Legally Mandated Organisations (LMO), were invited to comment the various IR drafts through some formal mechanism.

## 2.2 The GMES Atmospheric Service (GAS)

The Global Monitoring for Environment and Security (GMES) Programme aims at setting up a European network of interconnected facilities dedicated to the monitoring and forecasting of the Earth's subsystems. Its double goal is to improve our understanding of terrestrial physical processes and provide adequate reliable environmental information to citizens and targeted stakeholders' communities throughout Europe. A particular focus of the GMES is the provision of support for policy decisions addressing environmental protection and for emergency response to sudden disasters. Central to the GMES is the notion of a service run by some provider and delivering "fit-for-purpose" information to its users. GMES services are developed along six thematic lines – namely land, marine and atmospheric environments, emergency response to natural hazards, human environmental security and climate change.

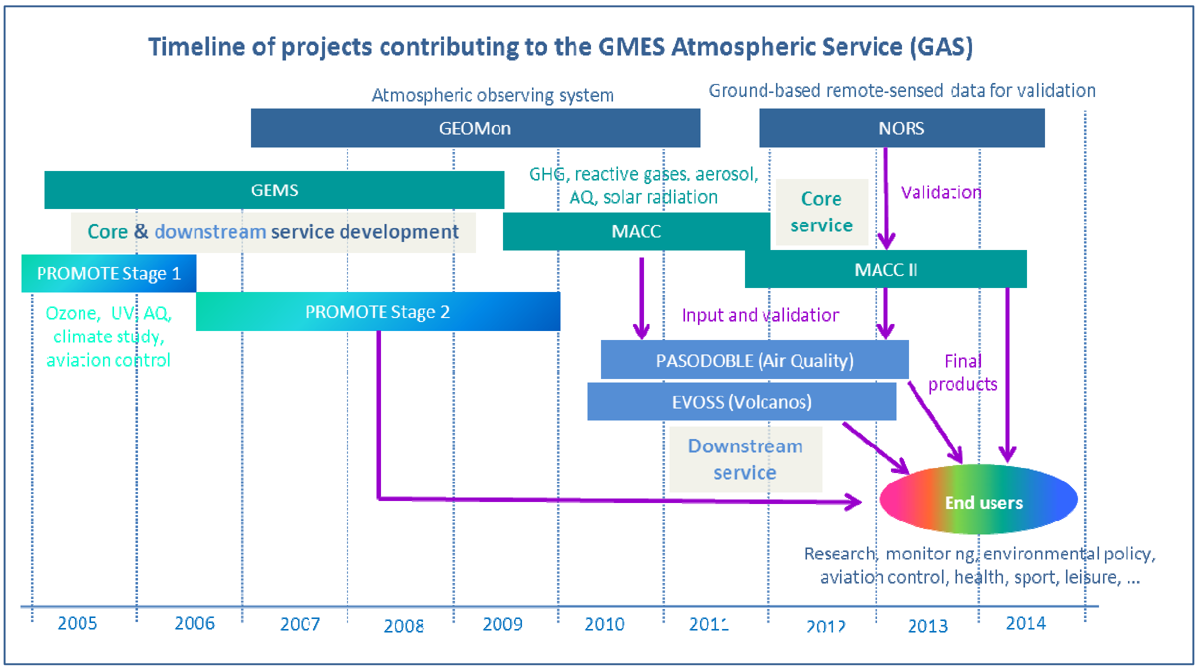


*Figure 1. Timeline of products that have contributed and are currently contributing to the GMES Atmospheric Service (GAS). In addition to the many external data sources feeding the projects, dedicated data flows (pictured by the purple arrows) occur between the services and from the services to the end users. The PROMOTE projects were funded by ESA as part of the GMES Services Element. The GEMS, GEOMon, MACC, EVOSS, PASODOBLE, MACC II and NORS projects were or are funded by the EC under the EU FP6 or FP7. – AQ stands for Air Quality, GHG for Greenhouse Gases, UV for Ultra-Violet.*

The GMES Atmospheric Service (GAS) has been shaped up by projects funded by the ESA – under the GMES Services Element (GSE) and the Data User Programme (DUP) of the Data User Element (DUE) – and by the European Commission (EC) – under the EU FP6 and FP7. Current FP7 projects MACC II

(Monitoring Atmospheric Composition and Climate – Interim Implementation), PASODOBLE (PROMOTE Air Quality Services Integrating Observations – Development of Basic Localised Information for Europe), EVOSS (European Volcano Observatory Space Services), NORS (Network of Remote Sensing Ground-Based Observations in support of the GMES Atmospheric Service) build up on foundations laid by their precursors PROMOTE (Protocol Monitoring for the GMES Service Element Atmosphere), GEMS (Global and Regional Earth-System (Atmosphere) Monitoring Using Satellite and In-Situ Data), MACC (Monitoring and Forecasting of Global Atmospheric Composition) and GEOmon (Global Earth Observation and Monitoring of the Atmosphere) by improving or extending existing services, upgrading prototypes to operational stage and developing new sectors of activity (Fig. 1).

Atmospheric topical matters addressed by the GAS include tropospheric and stratospheric processes, atmospheric dynamics (meteorology) and chemical composition, gaseous species and airborne particles, reactive and inert (greenhouse) gases, natural and man-induced phenomena. Services ingest observational data of various natures and origins (*in situ* and remote-sensed) into assimilation schemes using different methods. They deliver data products at different validation stages and in different temporal modes – forecast, near-real time (NRT), consolidated, reanalysed. These products are intended to a broad spectrum of applications and users (research, monitoring, climate and air quality policies, aviation control, health, sport, leisure, etc.).

### 2.3 Link and interaction between INSPIRE and the GAS

The relationship between INSPIRE and GMES is stated explicitly among the preliminary considerations of the Directive. It is expected that the two initiatives will be mutually beneficial, and the INSPIRE Directive is seen as *adding value* to the 2004-2008 Action Plan to establish a GMES capacity in Europe [25]. Furthermore, it is now required from EU FP7 projects that contribute to the elaboration of the GMES services to set up utilities and deliver products that comply with INSPIRE specifications.

Under the umbrella of the PROMOTE, MACC, PASODOBLE and EVOSS projects, experts from the atmospheric community have responded to the INSPIRE calls for feedback on various draft documents [26] [27] [28].

Several INSPIRE data themes are addressed by the GAS in a way or another. Among them, Items 13 and 14 of Annex III, Atmospheric Conditions (AC) and Meteorological Geographical Features (MF), are of particular relevance. These two themes have jointly been the subject of a single INSPIRE draft data specification [29], which was reviewed and commented in October 2011 on behalf of MACC and PASODOLE partners [27].

## 3. STANDARDISING

Interoperability of the different components of a system requires some standardisation of the methods applied by the actors involved in the system. In this respect, standardisation is essential to the operation of vast networks such as the ones which are being set up by the GMES and, at an even broader scale, by INSPIRE. However, pitfalls are set along the way for such enterprise, and if great care is not taken, harmonisation does not always lead to harmony. A number of issues that arose at the occasion of the INSPIRE reviews performed on behalf of the GAS are listed and illustrated below. They are related to metadata and data specifications.

### 3.1 Top-down or bottom-up ?

In the design of the Directive [1] as well as of the metadata IR [2] or the data specification for AC and MF [29], the INSPIRE methodology relies on the choice of a particular example. The method is valid at the condition that the concepts derived from that example are later checked against examples of a different nature, then possibly replaced by more suitable ones if they do not capture the general case. Given the large scope of the INSPIRE Directive, the preliminary design of a scheme general enough to encompass all data themes would perhaps have avoided some of the difficulties met in applying the scheme to atmospheric datasets (or to any dataset describing some feature of the Earth physical system).

The most striking example of such a consequence is related to the notion of dimensionality. The focus of the Directive being on features that can be described in terms of geography and drawn on maps, it was natural that the first preoccupation of the INSPIRE designers would be to define appropriate two-dimensional referentials. However, since the Directive explicitly includes Earth science (atmosphere, ocean, climate) data and ambitions to set up a conceptual and practical framework supporting the monitoring of the Earth system evolution, it would have been a wise precaution to envisage, right from the beginning, the case of the full three-dimensional space and of time-dependent variables. Instead, the INSPIRE Data Specification for AC and MF [29] relies on a static ISO geographic standard [30]. Following remarks by scientists from the oceanic and atmospheric fields, this model has been somewhat extended in order to accept, as occasional attributes, the vertical and time dimensions, in order to allow the description of 4-dimensional variables. However, the result is somewhat awkward. In this scheme, 4-dimensional features surprisingly appear as particular cases of 2-dimensional objects, and some asymmetry between the independent variables is artificially introduced. Moreover, the INSPIRE top-level metadata model [2] does not provide any room for the description of independent variables different from longitude and latitude.

### 3.2 Speaking a common language

Gathering experts from varied fields who practise various idioms poses a challenge to communication – adopting a common language is indeed part of the harmonisation effort. A text which is meant to federate communities with different habits should endeavour to adopt a language which will be understood in the same way by all its readers, or at least provide accurate definitions of terms that may assume different meanings depending on the specific communities that use them. The INSPIRE texts use the geographic terminology, which may lead to predictable misunderstandings when communicating with experts from other fields.

An example is provided by the term "space". In INSPIRE, it implicitly denotes the horizontal subspace, which can bring confusion when communicating with (3-D) space scientists.

The concept of "scale" is another example, which may have more important consequences. It is implicitly used in INSPIRE with its geographic meaning, namely the ratio of the representation dimension to the represented object dimension (that is, the scale of a map, for example 1/100 000). The larger the scale, the more detailed the representation. Atmospheric scientists are not interested in the ratio between image and reality, if only because their representations of horizontal fields are rarely drawn on paper – and even when they are, they remain essentially stretchable: their information content is not affected by the scale in the geographic sense. On the other hand, atmospheric scientists commonly resort to the word "scale" to describe the magnitude of a considered phenomenon. For example, they speak of the global, the continental, the regional, the local scales, to which they associate grid cells of different dimensions. The larger the scale, the less detailed the representation. These opposite meanings are worth to be underlined if the two communities wish to understand each other – but the problem has got an easy solution.

In some cases, the misunderstanding may be of some deeper consequence and cannot be solved only by making the use of a word explicit. Language indeed is not only a formal tool that allows us to describe a common reality – and hence to understand each other as we refer to that reality. It also reflects the way we think, the concepts that we use to structure and conduct our thought. What is at stake here depends on more than the definition of a word. For example, to refer and handle datasets, scientists use the notions of vector space and function. A dataset is seen as a function of a certain number of independent variables (in geosciences, often – but not always – longitude, latitude, height or depth and time). These notions seem to be absent from the conceptual background of INSPIRE and of the ISO standards to which INSPIRE refers. Hence the difficulty of establishing some mapping between the two conceptual models.

Finally, inside the community of the Earth system scientists itself, habits widely differ regarding preferred units, terms used to call variables, etc. In the field of metrology, which applies to all observation sciences, these different customs lead to ambiguities, in spite of the existence of a common standard [31]. As the aim of INSPIRE is to harmonise practise, the implementation of the Directive should be an opportunity to promote the use of common conceptual frameworks and their associated vocabulary.

### 3.3 The spirit versus the letter

In some instances, the INSPIRE model favours the formal aspect of metadata elements at the expense of their information content. For example, the provision of any time stamp (with the restriction that it must be a date) is mandatory in order to comply with the INSPIRE rule, but that requirement will be fulfilled whether the provided date is the date of first observation, of creation, of revision, of publication..., which makes this element of little use for the dataset user. Presumably, this bias is driven by the concern of making information readable by automated devices, but the two requirements – automation and preservation of the information content – could certainly be reconciled.

### 3.4 Quality

The notion of quality suffers from the drawback related to the bottom-up approach followed by INSPIRE (cf. Section 3.1). In the INSPIRE metadata model, the only mandatory element presented as a factor of quality is the dataset horizontal resolution (there is another "quality" element, called "lineage", which is made mandatory, but anything like the dataset history, its legal status or any kind of validation statement – for example, "the dataset has been validated" – satisfies its requirement for provision, so that, like the time stamp, this element is emptied of any sensible meaning).

For cartographers and photographers, who reckon that they faithfully reproduce truth, the resolution of the reproduction is indeed usually what determines its quality: the finer the resolution, the more detailed (and useful) the representation.

For scientists who measure variables with instruments and sometimes infer the required information *via* quite indirect algorithms, the essential factor of quality is the magnitude of the uncertainty affecting the observation (to some extent and with care, this may also be transposed to model results, for example to forecasts). Scientists do know that what they see is not the truth and that it is crucial to attempt to assess how accurate their observation is, that is, how close it is to truth. The core requirement of the Quality Assurance Framework for Earth Observation (QA4EO) [32] is indeed the provision, together with any data, of some quality indicator(s) fulfilling that role. A finer resolution may of course improve the fitness-for-purpose of the dataset to some targeted application, but only if the dataset is robust enough to stand such a refinement (that is, if the uncertainty is small enough), failing which refining the resolution only multiplies the errors. Furthermore, there is generally a threshold beyond which the benefit of a finer resolution is outshined by the creation of additional noise.

As mentioned in Section 2.2, fitness-for-purpose is a key notion underpinning GMES services. Even the accuracy requirement will depend on the targeted application: the same dataset, affected by the same uncertainty, may be perfectly suitable to some application and useless for another application – the same applies to the resolution requirement when it is a requirement. By considering resolution as the main, if not exclusive, factor of quality, INSPIRE generalises the fitness-for-purpose requirement specific to cartographic applications to any application, and obliterates the actual quality requirements of these non-cartographic applications.

### 3.5 The Directive scope

Finally, although "Atmospheric Conditions" is stated in the title of the document, the draft Data Specification on AC and MF [29] only tackles the case of meteorological variables. The data specification scheme proposed in this document might be applicable to atmospheric composition and 3-D dynamics but it is not demonstrated and some ambiguity is left as to the extent to which the provided list of variables (meteorological variables at ground level) is mandatory – if this reveals to be the case, it means that atmospheric resources cannot be accounted for in INSPIRE terms.

## 4. CONCLUSIONS

The INSPIRE initiative has doubtlessly powerful potential assets. A common infrastructure for data and services issued from Earth observation is necessary to ensure the interoperability of these services at the continental scale. However, to make the best out of this significant endeavour, remaining crucial issues regarding atmospheric resources – some of which have already been addressed at various occasions in previous years, for example in the context of GIGAS (GEOSS, INSPIRE and GMES, an Action in Support) – should be addressed and solved. The main issues are related to dimensionality, the conveyed information content, the proper account of quality indicators and the actual scope of the Directive. Regarding the latter, it has been suggested to the INSPIRE Thematic Working Group (TWG) on AC and MF to include, in the specification, an explicit definition of what AC cover, and such a definition has been proposed [27]. One may hope that the brainstorming effort of the atmospheric community on metadata, namely in the context of the Air Quality (AQ) Community of Practice (CoP) of the Group on Earth Observation (GEO) will help these crucial concepts to be ingested into the INSPIRE scheme. Unless the INSPIRE implementation is modified, the last opportunity to fix the current lacks is the issue of the final version of the Data Specification on AC and MF.

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