Deliverable D8.2: Report on methodologies for the quantification of ACTRIS multi-scale indirect impact

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1. Introduction

ACTRIS is a pan-European Research Infrastructure that unites the observations and related research on aerosols, clouds, and trace gases with final aim to provide high-quality research infrastructure services to a wider user community. Integrating European ground-based stations equipped with advanced atmospheric probing instrumentation, ACTRIS will have the essential role to support building of new knowledge as well as policy issues on climate change, air quality, and long-range transport of pollutants. The ESFRI Roadmap 2016 identified ACTRIS as a new important pan-European research infrastructure for the European scientific community. With ESFRI-status, ACTRIS shall further develop its organizational and operational framework, and long-term strategic goals. In this context, the ACTRIS PPP aims at defining the most appropriate and cost-efficient long-term organization of ACTRIS. The analysis of the socio-economic impacts attributed to ACTRIS could provide useful insights regarding the social return of the investment required for the development, operation and maintenance of this research infrastructure and the formulation of the appropriate operational scheme.

In general, ACTRIS, as any other research infrastructure, creates positive socio-economic effects through different impact pathways:

- At consortium level, as research institutes, universities, companies, etc., involved in the construction, development, maintenance and operation of the infrastructure in question, will benefit through knowledge creation, technological developments, human capital enhancement, creation of new jobs, etc.
- To the research community, as research teams, organizations and programs utilizing the outcomes provided by ACTRIS will improve their modelling, satellite data calibration / validation and atmospheric climate services and products.
- To the society, as local authorities, environmental protection agencies, industries, ministries, international organizations, weather services, etc., will utilize ACTRIS outcomes to optimize their environmental strategies and improve their decision-making processes.

The socio-economic impact generated to the ACTRIS consortium and associated business from the development, operation, and maintenance of the ACTRIS infrastructures (i.e., the first impact pathway among those identified above), were analysed during the 1st year of ACTRIS PPP. To this end, a set of Key Performance Indicators (KPIs) was developed quantifying the impacts of the Research Infrastructure (RI) in question to the development of human capital, creation of new scientific knowledge, enhancement of innovation, contribution to economic growth and employment, etc. The results of this analysis were presented in ACTRIS PPP deliverable 8.1 “Report on KPIs for the quantification of ACTRIS direct impact”.

This study aims at exploring the socio-economic impact generated to the research community outside ACTRIS consortium from the utilisation of ACTRIS generated data, outcomes, products and methodologies. Although the ACTRIS is under development, some of its products are already being used by the research community in a wide range of activities, such as modelling of the atmospheric environment, weather forecasting, climate modelling, etc. More specifically, this study will help to better understand the benefits generated to research groups and institutions that utilize ACTRIS-based information and data for improving or expanding their research activities. To the extent that these

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impacts will be quantified (and if possible monetised) it will provide useful insights for evaluating the social return of the investment required for developing and maintaining ACTRIS, facilitating an integrated cost-benefit analysis of the research infrastructure. Furthermore, it will give an indication of the value attributed to the information provided by ACTRIS, which could be utilized at a later stage for costing the various services that will be provided by the developers and operators of the research infrastructure.

The present report is structured as follows:

Chapter 2 provides a description of the methodological framework developed and implemented for analysing the socio-economic effects associated with ACTRIS at research community level. This comprises the design of a questionnaire survey that was distributed to and answered by research groups, governmental institutions and private companies that already use ACTRIS outcomes.

Chapter 3 presents the results of the survey, highlighting the main scientific and research activities in which data and products of the ACTRIS are used, providing quantitative estimates on the level of improvement of the above mentioned activities and the associated additional funds attracted from the respective research teams due to the utilization of ACTRIS outcomes, and analysing the contribution of ACTRIS in further development of scientific research, educational activities and supporting decision-making processes.

Finally, in *Chapter 4* the main findings of the study are summarised, and conclusions are drawn.

2. Methodological framework

2.1 Overview

Griniece et al. (2015) a detailed list of potential socioeconomic effects attributed to the investments in research infrastructures, further disaggregated to the design and construction phase and to the operational phase. Among them, it is acknowledged that impacts on scientific activities and technological innovations may be diffused to the entire research community creating significant social benefits.

The creation processes of these social benefits and how they can be integrated into the framework of cost-benefit analysis are described by Florio and Sirtori (2014). More specifically, new information generated at the RI is initially stored in computer memories or in other technical supports, and obviously in the brains of the scientists, and then it spawns a stream of specialized literature. The first wave of this literature may take the form of internal technical reports, preprints, eventually research papers in scientific journals and research monographs produced by all those scientists who directly use the RI and are involved in its operation and in the interpretation of first-hand evidence. But besides 'insider' scientists, there are also 'outsiders' who are the rest of scientific community, including those working in other fields, who use the evidence provided by the experiment, as explained and discussed in the insiders' papers, to produce other knowledge. Even if not direct users of the RI, to some extent they are

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also beneficiaries of the infrastructure. Other waves of knowledge production can follow, with different scientists using the findings of 'second round' papers as a basis to write their own paper, and so on. This process is virtually infinite. Bibliometric techniques, analyzing the patterns of the scientific literature generated over time around a research infrastructure or its experiments, e.g. through keywords, citations, and other pointers, can be conveniently exploited to associate a measure of scientific output to the RI.

A similar pattern of diffusion can also be imagined for technological innovations. Technological spillovers might occur from the work carried out not only by the RI staff, but also within the companies and laboratories along the RI's supply chain. Companies often do not have ready-made solutions to the types of problems that arise when involved in the design, construction or operation of a complex, high tech scientific instrument, for example related to the need of increasing precision of mechanical components, weight, other physical properties of materials, design of electronics, etc. (Florio and Sirtori, 2014). When a procurement contract for the RI is signed, an intense collaboration process between the supplier and the RI itself gets started aimed at effectively designing, testing and manufacturing the required product or service. These efforts give companies the opportunity of learning something new and to use the new skills for producing further technological advancement to be exploited. These advances are gradually spreading in society and in the production chain and utilized by several other companies and institutions.

ACTRIS is a pan-European RI that consolidates activities amongst European partners for observation of aerosols, clouds, and trace gases. ACTRIS focuses on producing high-quality observations of clouds and short-lived climate-forcing pollutants (SLCPs), which have a residence time in the atmosphere from hours to a week. More specifically, ACTRIS develops scientific and technological actions aiming to:

- integrate state-of-the-art European ground-based stations for long-term observations of aerosols, clouds and short-lived gases;
- improve systematic and timely collection, processing, and distribution of ACTRIS data and results for wide user communities; and
- provide network expertise and access to state-of-the-art research facilities in Europe enhanced virtual access to high-quality data and products through the ACTRIS Data Centre.

The development and operation of a research infrastructure like ACTRIS has a significant impact on the creation, further development, and diffusion of scientific knowledge. As already analysed in the ACTRIS PPP deliverable 8.1, organizations involved in the development and operation of ACTRIS Research Infrastructure are among the main beneficiaries, as they have direct access to the whole scientific information being gathered through the infrastructure. In addition, as a most of this information will be elaborated and published in scientific journals, conferences, etc., or will be available through international scientific databases, it can be used by the entire scientific community in relevant fields contributing to improvements of existing or developments of new methodologies, approaches, tools, practices, etc. This report aims at a preliminary analysis of these indirect impacts of the ACTRIS to the scientific community outside ACTRIS consortium. More specifically, it seeks to identify the fields and research groups that already use the products of ACTRIS and to assess the extent to which this

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exploitation has contributed to improve their research activities, increase the financial resources they attract, etc.

For a preliminary analysis of these indirect effects, which are focused on the organizations utilising ACTRIS products, outcomes and services, a methodological framework has been developed and implemented, comprising the following steps:

1. Identification of organizations, research groups, companies or other entities that already utilize ACTRIS outcomes in their research and other activities.
2. Mapping out the main research areas and activities where ACTRIS outcomes have been utilized.
3. Define a set of key performance indicators (KPIs) at activity and/or institutional level that will allow the monitoring and quantification of the effects generated (to the users) due to the utilization of ACTRIS outcomes.
4. The necessary data for the quantification of the KPIs defined in the previous step were collected with a survey of the organizations used ACTRIS products, through the completion of an appropriately designed questionnaire.
5. The data collected from the survey, in conjunction with other relative information were compiled for the quantification of the selected KPIs. The analysis could provide aggregated results at both activity and institutional level.

More detailed information on the applied methodological framework is given in the following sections.

2.2 KPIs for quantifying the impact of ACTRIS Research Infrastructure on research activities

In the context of the 1st survey conducted for this project aiming to assess the socio-economic impact of the ACTRIS on the organizations involved in its development, the national contact points, which were responsible for completing the relevant questionnaires, provided information on the organizations and types of activities in each country that use the products and outcomes of ACTRIS to improve their research work.

The collected information is summarized in **Table 2.1**. In total, 52 users of ACTRIS products from 11 different countries were identified. These users were universities and research centers, national or regional agencies and governmental institutions, and private companies. In most cases ACTRIS products were used in weather forecasting, climate modelling, modelling of the atmospheric environment and satellite calibration and validation activities.

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Table 2.1: Overview of the research activities that utilize the outcomes of ACTRIS in selected European countries, based on information collected from a survey aiming to quantify the socioeconomic effects of ACTRIS on the organizations involved in its development and operation/maintenance.

Activity	Germany	UK	Spain	Finland	Poland	Greece	Romania	Italy	Bulgaria	France	Switzerland
Weather forecasting	x	x		x		x		x		x	x
Climate modeling	x	x	x	x		x	x	x		x	x
Modeling of the atmospheric environment	x		x	x	x	x	x	x		x	x
Satellite calibration / validation	x	x	x	x		x	x	x		x	x
Instrument intercomparisons / measurements	x										x
Research for renewable energies	x										
Monitoring of implementation and effectiveness of the Montreal protocol	x										
Advances in remote sensing	x										
Air quality	x	x	x					x			
Environmental monitoring	x										x
Health studies			x							x	
Educational/outreaching								x			
Safe use of nuclear energy and ionizing radiation									x		

The aim of the 2nd survey carried out in the context of the ACTRIS PPP program was to explore the contribution of ACTRIS products and services to the quality of research activities undertaken by the corresponding research groups (i.e., the users of the ACTRIS outcomes). To this end, several Key Performance Indicators (KPIs) were identified and are presented in **Table 2.2** below. These KPIs are basically calculated at the level of the organization which utilizes the products of the infrastructure in question. However, where appropriate, they may be aggregated at the research infrastructure level or be further disaggregated at the research activity level. Subject to data availability they have been selected to capturing the contribution of ACTRIS products to attracting new funding, publishing new scientific articles, developing educational activities, supporting decision-making, etc. Some of them are providing quantitative information while others are qualitative providing an indication of the impact of

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the ACTRIS outcomes on research activities. The necessary data for this analysis has been collected through a questionnaire that will be presented in the next section.

Table 2.2: Overview of Key Performance Indicators used to quantify the socioeconomic effects attributed to the ACTRIS due to the utilization of its products / outcomes from the research community.

Key Performance Indicators (KPIs)	Type of KPI	Remarks
Number of activities in which the ACTRIS products are utilized	Quantitative	The indicator can be estimated at national and / or research infrastructure level.
Level of improvement of existing activities due to the utilization of ACTRIS products	Qualitative	The indicator can be estimated at activity or institutional level
Increase of the funds attracted due to utilization of ACTRIS products	Qualitative	This indicator may be used in order to analyse the influence attributed to the utilization of ACTRIS products in both existing and new activities undertaken by potential users. The indicator can be estimated at activity or institutional level.
Number of graduates trained on issues utilizing ACTRIS outcomes	Quantitative	The indicator is estimated at institutional level
Percentage of publications that cite ACTRIS	Quantitative	The indicator is estimated at institutional level
Capacity improvements in supporting decision makers	Qualitative	The indicator is estimated at institutional level
Frequency in providing information to decision makers	Quantitative	The indicator is estimated at institutional level

2.3 Design of the survey

The analysis of the socio-economic impact of ACTRIS on the organizations utilizing the outcomes of the infrastructure under consideration was based on a survey and the completion of a properly designed questionnaire.

The questionnaire was initially designed by National Observatory of Athens (NOA) and a preliminary draft was sent to other partners engaged in Task 8.2 of ACTRIS PPP, namely the French National Centre for Scientific Research (CNRS), the National Research Council of Italy (CNR), the Romanian National Institute of R&D for Optoelectronics (INOE), and Universitat Politècnica de Catalunya (UPC) for possible comments, modifications, etc. The final version of the questionnaire was distributed to the national ACTRIS contact persons in each country with institutions participating in ACTRIS.

The national contact persons were responsible for coordinating the surveys in each country. In this context, they identified users of the outcomes derived by ACTRIS (data, methods, tools, etc.) in their country, and through the questionnaire they collected data on the activities on which the results of

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ACTRIS are being exploited and the effect they had on improving the activities of the users. The starting point in this process was the 52 users identified during the survey analysing the socio-economic impact at consortium level (Deliverable 8.1). The responses were collected by national contact persons and then sent to NOA for statistical analysis.

The time available to the national contact persons to undertake the survey was initially 3 months (July to September 2018), however some completed questionnaires were received later by the end of November 2018.

The developed questionnaire is presented in **Appendix I**. It contains 10 questions collecting data on the type of activities undertaken by ACTRIS users, to what extent ACTRIS products contributed in improving these activities, and the implications on funds attracted, educational activities and capacities to support decision makers, which are used to estimate the KPIs defined previously. Specifically:

- The questionnaire starts with two introductory questions asking the name and affiliation of the representative of the organisation participating in the survey. As already mentioned only organisations that already use some of the ACTRIS outcomes were asked to complete the questionnaires.
- Questions 3 and 4 identify all the activities undertaken by the participating organization in which ACTRIS products are utilized. Based on information collected from previous surveys there is a list of potential activities from which the potential respondent can select the most relevant ones to its organization. In addition, the respondent has the option to add new activities.
- Question 5 is one of the key questions of this survey by asking the potential respondent to provide some estimates to what extent the utilization of ACTRIS products and/or services has contributed to improvements in the accuracy of their modelling approaches, predictive capacity of their models, etc. This evaluation is done at activity level by using a qualitative scale with five bands.
- Questions 6 and 7 explore the economic implications of utilizing ACTRIS products in organization's activities. Again, a qualitative scale with five bands is used in order to evaluate to what extent the utilization of ACTRIS products resulted in an increase of the funds attracted by the organization in question.
- Question 8 explores to what extent the utilization of ACTRIS products and/or services by an organization results in an increase of educational activities and its overall outreach.
- The last two questions focus on the impact of ACTRIS products and/or services utilization in improving the capacity of organization to support decision makers.

In total the questionnaire was filled by 32 organizations that use ACTRIS products and/or services in their activities. Given that in a preliminary stage of the project 52 users of ACTRIS outcomes were identified, the response rate of the survey was estimated at 62 %, which is quite satisfactory. Responses were received from organizations operating in Germany, United Kingdom, Romania, Czech Republic, Finland, Italy, Belgium, Indonesia, Greece, and Spain.

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3. Results

This Chapter presents the results of the survey conducted to assess the impact of the products and outcomes generated by ACTRIS on the research activities of different users, not included in the consortium of ACTRIS. Specifically, the survey involved a total of 32 research teams using ACTRIS products or data from 10 different countries. The geographical distribution of the participants in the survey is presented in **Figure 3.1**, showing that about 38 % of the responses come from Germany. Other countries with a significant number of users of ACTRIS products and outcomes who participated in the survey are Italy and Romania.

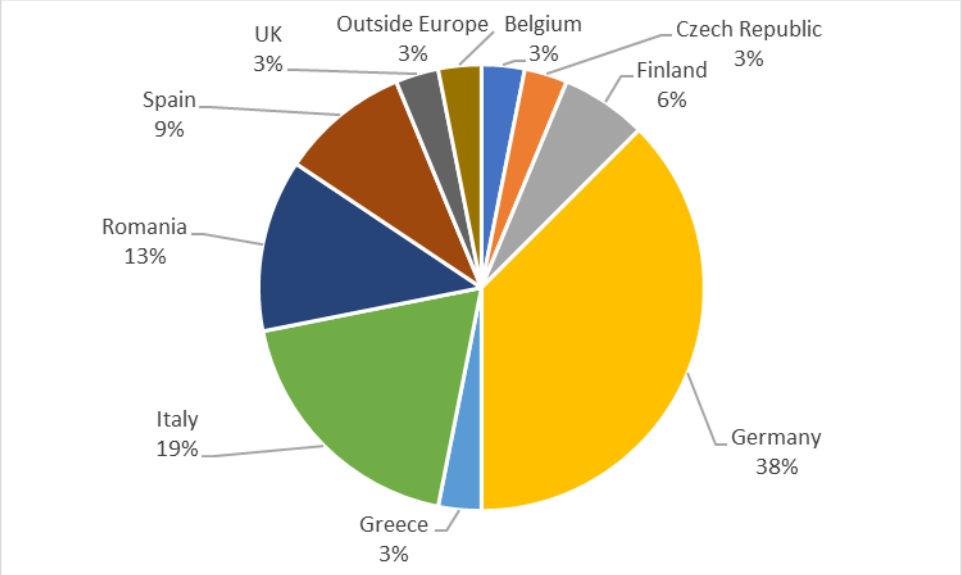

Figure 3.1: Geographical distribution of the users of the ACTRIS products and services that participated in the survey.

Two-thirds of the responses were received from research teams working in universities and research centers, while 28 % of the responses filled in from National / Regional Agencies and/or Governmental Institutions and only 6 % from private companies (**Figure 3.2**). Based on a preliminary examination of the profile of the participants in the survey, it seems that the products of ACTRIS are mainly used by research teams to improve existing or develop new scientific activities at universities and research centers. Also, as a significant percentage of the identified users (approximately 28 %) are national or regional authorities, it can be concluded that the products and outcomes of the research infrastructure in question are already used in activities directly or indirectly related to planning and decision-making processes. On the other hand, only a small percentage of the identified users are private companies, showing that at the time being the results of ACTRIS are exploited to a limited extent by private sector to develop specialized and high-quality products and services.

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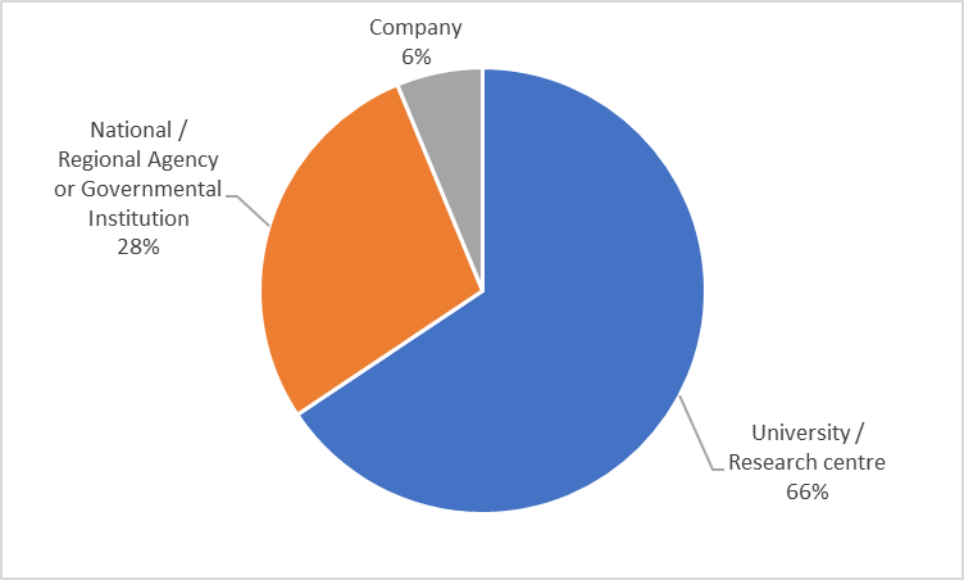

Figure 3.2: Type of organizations that use the ACTRIS products and services and participated in the survey.

In general, the entities participating in the survey utilize the products and services of ACTRIS in a wide range of scientific activities, namely:

- Weather forecasting
- Climate modeling
- Modeling of the atmospheric environment
- Satellite calibration and validation
- Instrument intercomparisons and measurements
- Research for renewable energies
- Monitoring of implementation and effectiveness of the Montreal Protocol
- Advances in remote sensing
- Air quality / environmental monitoring
- Educational and other outreach activities

More detailed information on the ways that ACTRIS related products utilized by the various users is presented in **Appendix II**.

Figure 3.3 presents the percentage of participants in this survey exploiting the products and services of ACTRIS in each of the aforementioned activities. According to the results of the analysis, over 70 % of the respondents use the ACTRIS and its outcomes for instrument intercomparisons and measurements as well as for monitoring the quality of the atmospheric environment. Also, two out of three participants in the survey use ACTRIS data for educational purposes and other outreach activities. Among the modelling activities, most users (over 40 %) exploit ACTRIS-related information and data to model the atmospheric environment and to a lesser extent in weather forecasting and climate modelling. It is also worth mentioning that the majority of survey participants use ACTRIS products in several parallel scientific activities. Specifically, among the 32 users examined, only four (i.e., 12.5 %) use the products and

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outcomes obtained in one activity; instead, the average user exploits this information in four different activities.

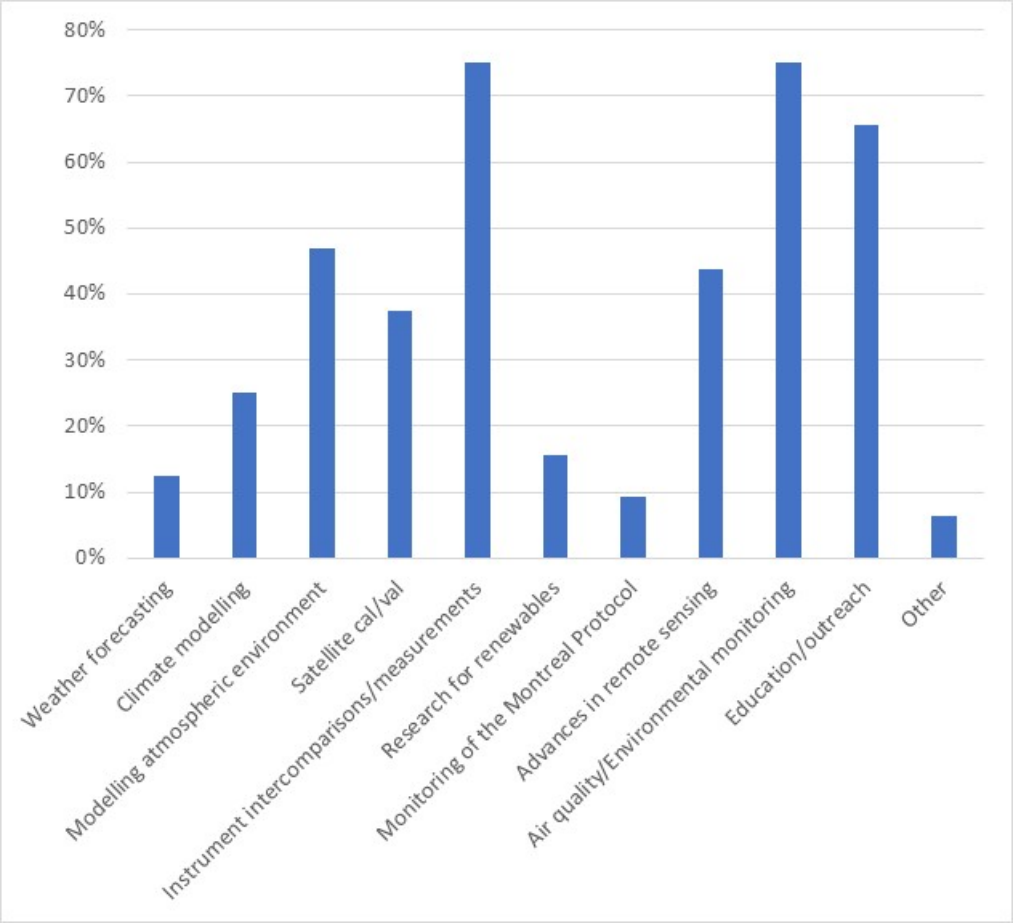

Figure 3.3: Activities in which the ACTRIS products and services are utilized. Percentages have been estimated on the basis of the number of organizations using the reference products/data in the specific activity in relation to the total number of organizations participated in the survey.

In the survey conducted, participants were asked to assess to what extent the use of ACTRIS products and services has contributed positively to their scientific activities through improvements in the accuracy of the implemented modeling approaches, predictive capacity of the used models, ability to monitor more substances, retrieving satellite data, etc. The analysis was performed by type of activity, in which ACTRIS products are utilized, on the basis of a 5-grade qualitative scale where the contribution of ACTRIS can be characterized as negligible, low, medium, high, and very high. The results of the analysis, namely the median and mean values of the assessments received by activity, are presented in **Table 3.1**. Using the median of the evaluations made by the participants, which usually gives more conservative results, the contribution of the ACTRIS was characterized as being “high” in all activities that ACTRIS related products have been utilized, except in the cases of climate modelling and research for renewables characterized as "medium to high" and "medium" respectively.

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Table 3.1: Evaluation of the ACTRIS products and/or services contribution to the scientific activities utilized. The evaluation was made on a five-level scale, where the potential improvements could be characterized as negligible, low, medium, high, and very high.

Activities	Median	Mean
Weather forecasting	High	Medium to high
Climate modelling	Medium to high	Medium to high
Modelling of the atmospheric environment	High	High
Satellite cal/val	High	High
Instrument intercomparisons / measurements	High	High to very high
Research for renewables	Medium	Medium to high
Monitoring of implementation and effectiveness of the Montreal Protocol	High	High
Advances in remote sensing	High	High
Air quality / Environmental monitoring	High	High to very high
Education / outreach	High	High to very high

In the context of this study, the economic evaluation of the impact of ACTRIS products utilization by the entities participated in the survey was also attempted. To this end, we first investigated the extent to which the use of ACTRIS products is linked to an increase in funding attracted by the research teams or other entities that use them. The analysis was performed by type of activity, using the same five-level quality scale as above and provided that there were at least two observations in the sample. The results of the analysis, namely the median and mean values of the assessments received by activity, are presented in **Table 3.2**. Using the median of the evaluations received, it is concluded that out of a total of 10 activities examined, the use of ACTRIS products has contributed to a "medium" increase in funding to three of them and to "high" for other six. In addition, there was insufficient documentation as regards the influence of the utilization of ACTRIS related outcomes in increasing the funding in weather forecasting activities.

Accordingly, using the mean of the evaluations received, The contribution of ACTRIS to increasing the funding of the entities using the products of the RI is characterized as “medium” in two activities (namely, Research for renewables and Monitoring of implementation and effectiveness of the Montreal Protocol), “medium to high” in five activities (Climate modelling, Modelling of the atmospheric environment, Instrument intercomparisons/measurements, Advances in remote sensing, Air quality / Environmental monitoring), “high” in the case of Satellite calibration/validation, and “high to very high” for Education/Outreach.

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Table 3.2: Evaluation of the contribution of ACTRIS products and/or services in increasing the attracted funds by the users of those products. The evaluation was made per research activity by using a five-level scale, where the potential impact could be characterized as negligible, low, medium, high, and very high.

Activities	Median	Mean
Weather forecasting	n.a.	n.a.
Climate modelling	High	Medium to high
Modelling of the atmospheric environment	High	Medium to high
Satellite cal/val	High	High
Instrument intercomparisons / measurements	Medium	Medium to high
Research for renewables	Medium	Medium
Monitoring of implementation and effectiveness of the Montreal Protocol	Medium	Medium
Advances in remote sensing	High	Medium to high
Air quality / Environmental monitoring	High	Medium to high
Education / outreach	High	High to very high

In total 23 out of 32 entities surveyed provided data on the average annual level of funds they had attracted in previous years in the scientific fields that ACTRIS products are utilized. Specifically, the annual amount of funding per entity varies substantially and ranges between € 2 000 and € 4 000 000. The median annual funding per entity for all ACTRIS related activities reach € 100,000, while the corresponding mean value was approximately estimated at € 390 000. As already mentioned above, the extent to which utilization of ACTRIS products and services contribute in increasing the attraction of funding per entity is characterized in most activities as “high” (using the median of the evaluations made by all groups participated in the survey) or “medium to high” (using respectively the mean of these evaluations). Considering that the "medium to high" contribution of ACTRIS to the increase in funding attracted by the users of its products corresponds to a percentage of 30 %, then the increase in attracted funding attributable to the examined infrastructure corresponds to € 30 000 - 117 000 per year and entity. Last, **Figure 3.4** provides a relation between the amount of funding attracted by each research entity participated in the survey (expressed as natural logarithm) and the stated level of contribution that ACTRIS related products had in the research activities undertaken. It appears that this contribution is more important to large research groups that are already attracting significant funding.

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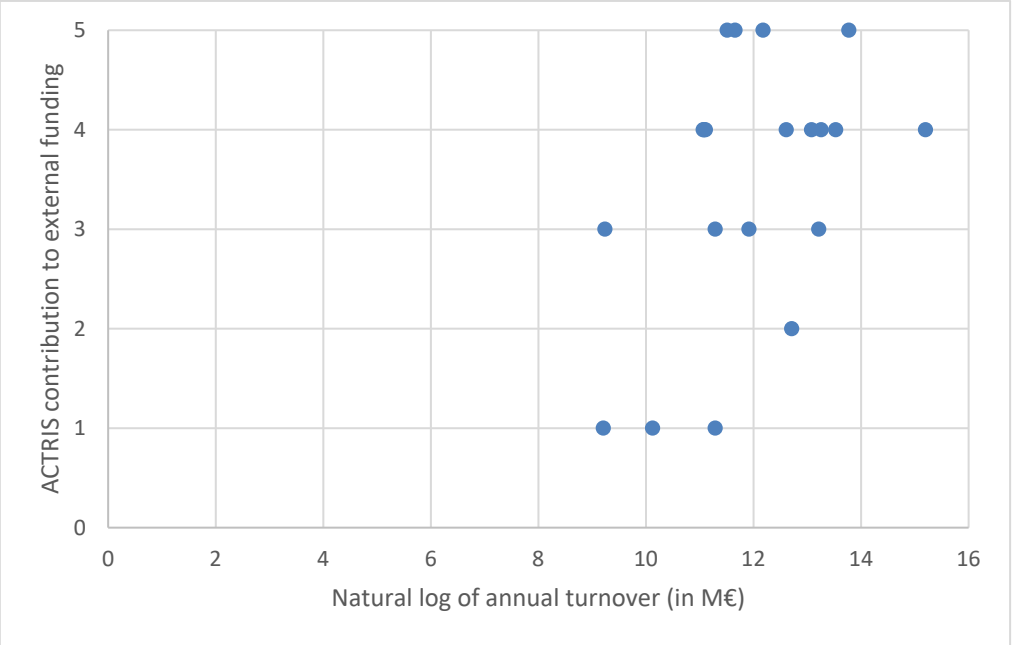

Figure 3.4: Total annual amount of funding attracted by research teams surveyed (X-axis, expressed in natural logarithm of turnover in M€) vs. the stated contribution of ACTRIS products (Y-Axis: 1=negligible, 2=low, 3=medium, 4=high, 5=very high).

As various research groups use ACTRIS products and data in their activities, a significant number of publications generated by these groups refer to ACTRIS. **Figure 3.5** presents the breakdown of the research teams using ACTRIS products in relation to the percentage of their total publications that cite ACTRIS. According to the results obtained, about one-third of the research groups surveyed refer to ACTRIS in more than 40 % of their publications. Particularly for those groups, ACTRIS-related products appear to be essential elements of their work and overall research activity. The statistical analysis of the data gathered showed that the median percentage of the publications of each group that refers to ACTRIS is 25 %, while the mean is estimated at 38 %.

In addition, many groups participated in the survey reported an increase in the number of graduates trained on issues utilizing ACTRIS outcomes. However, as the quantitative data were provided in different forms, the calculation of aggregated indicators was not possible.

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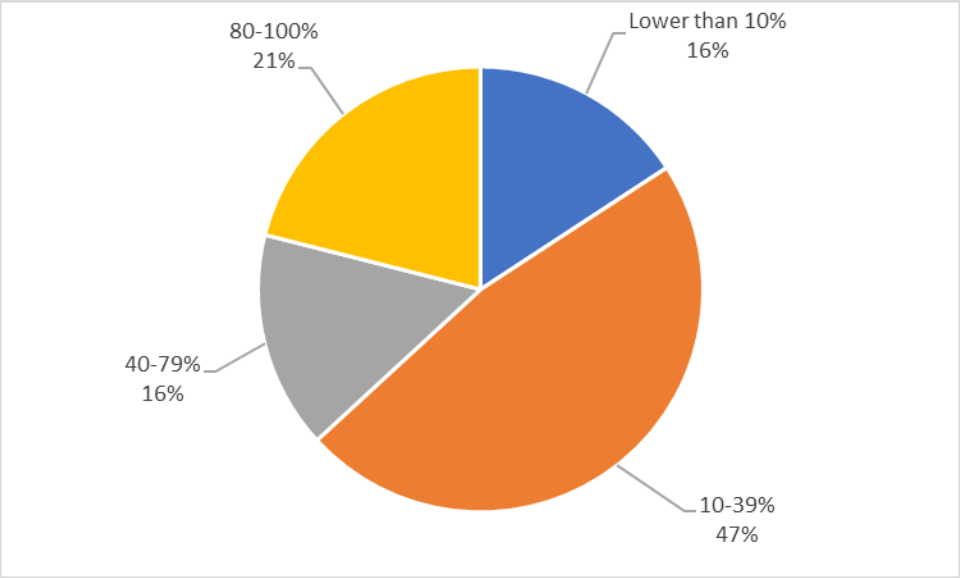

Figure 3.5: Breakdown of research teams surveyed based on the percentage of their publications that cite ACTRIS.

Finally, in the context of this study we explored to what extent the exploitation of ACTRIS products and services increase the capacity of the users to support decision makers. Approximately 41 % of users said that this improvement was negligible or low, about 34 % medium and about 25 % high or very high (**Figure 3.6**). With regard to the frequency of provision of such support services by the research groups participated in the survey, about 25 % claimed that they did not provide such services, 53 % said they provide support services about once a year at a maximum, 16 % 2 to 3 times a year, and about 6 % on a monthly basis or continuously (**Figure 3.7**).

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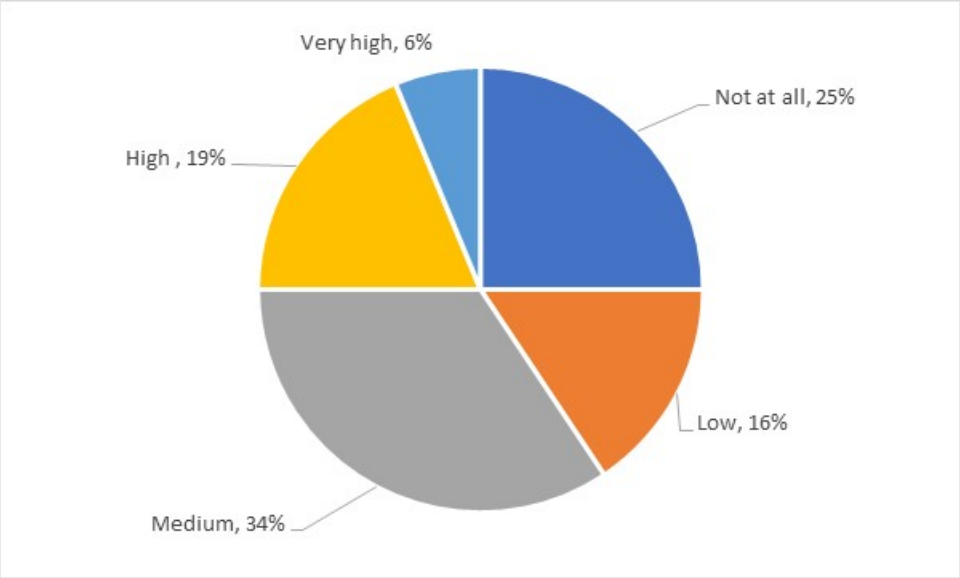

Figure 3.6: Assessment of the contribution of ACTRIS-related products and services to providing support services to decision-makers, from the entities participated in the survey.

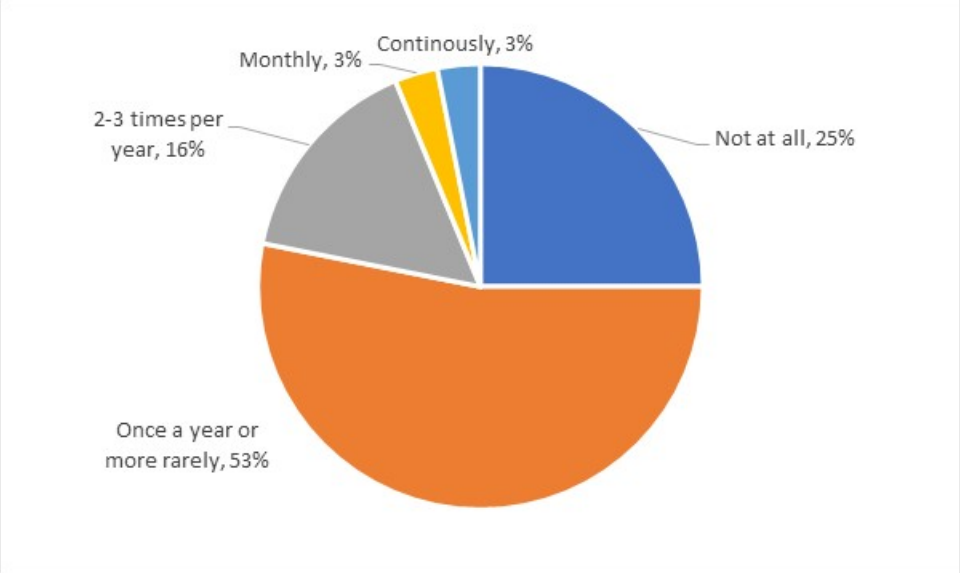

Figure 3.7: Frequency of providing support services to decision-makers by the research groups surveyed, utilizing ACTRIS products and outcomes.

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4. Concluding remarks

This study explores the socio-economic impact generated to the research community outside ACTRIS consortium from the utilisation of ACTRIS generated data, outcomes, products and methodologies. More specifically, it attempts to improve our understanding on the potential benefits generated to research groups and institutions that utilize ACTRIS-based information and data for improving or expanding their research activities. The analysis is based on a survey and the completion of a properly designed questionnaire by the users of ACTRIS-related products.

Table 4.1 summarizes the results of this analysis. It was found that the products and services of ACTRIS are being used in a wide range of activities, including weather forecasting, climate modelling, modelling of the atmospheric environment, satellite calibration and validation, instrument intercomparisons and measurements, research for renewable energies, monitoring of the Montreal Protocol, advances in remote sensing, air quality / environmental monitoring, educational and other outreach activities, etc. Based on user evaluations, the contribution of ACTRIS related products and services to improving the research being conducted is characterized as "high" in eight out of the ten fields mentioned above, and only in two cases as "medium" or "medium to high". Accordingly, the contribution of ACTRIS related products/services to attracting additional funding is characterized as "high" in six fields and as "medium" in three others, while there was insufficient information on other activities that utilize ACTRIS information.

The significant contribution of ACTRIS products to research activities is also apparent from the fact that 25-38 % of the publications produced by the respective scientific groups cite ACTRIS. On the other hand, the contribution of these products to improving the capacity of the users to support decision makers, is characterized as "medium", with more than three-quarters of entities examined to provide relevant services up to once a year.

Table 4.1: Summary of the socio-economic effects of ACTIS infrastructure at research activities of users.

Definition of Key Performance Indicators (KPIs)	KPI estimation	Remarks
Number of activities in which the ACTRIS products are utilized	12	These activities comprise: weather forecasting, climate modeling, modeling of the atmospheric environment, satellite calibration and validation, instrument intercomparisons and measurements, research for renewable energies, monitoring of the Montreal Protocol, advances in remote sensing, air quality / environmental monitoring, educational and other outreach activities, studying microphysical processes in clouds, development of new products from the measurements.
Level of improvement of existing activities due to the utilization of ACTRIS products - Weather forecasting - Climate modelling	 High Medium to high	Median estimates are presented.

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- Modelling of the atmospheric environment - Satellite cal/val - Instrument intercomparisons / measurements - Research for renewables - Monitoring of the Montreal Protocol - Advances in remote sensing - Air quality / Environmental monitoring - Education / outreach	High High High Medium High High High High	
Increase of the funds attracted due to utilization of ACTRIS products - Weather forecasting - Climate modelling - Modelling of the atmospheric environment - Satellite cal/val - Instrument intercomparisons / measurements - Research for renewables - Monitoring of the Montreal Protocol - Advances in remote sensing - Air quality / Environmental monitoring - Education / outreach	 n.a. High High High Medium Medium Medium High High High	Median estimates are presented.
Number of graduates trained on issues utilizing ACTRIS outcomes	n.a.	The indicator is estimated at institutional level
Percentage of publications that cite ACTRIS	25 % 38 %	Median estimate Mean estimate
Capacity improvements in supporting decision makers	Medium	Median and mean estimate
Frequency in providing information to decision makers	Once a year or more rarely	Median estimate

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Appendix I

Questionnaire of Task 8.2

EVALUATING THE EFFECTS OF ACTRIS TO RESEARCH ACTIVITIES

Information about this survey

The Research Infrastructure ACTRIS is a pan-European initiative that unites the observations and related research of aerosols, clouds, and trace gases amongst European partners to provide high-quality research infrastructure services to a wider user community. The ESFRI Roadmap 2016 identified ACTRIS as a new important pan-European research infrastructure for the European scientific community. With ESFRI-status, ACTRIS shall further develop its organizational and operational framework, and long-term strategic goals, towards a legal model ERIC - European Research Infrastructure Consortium. In this context, the ACTRIS Preparatory Phase Project (ACTRIS PPP) aims at defining the most appropriate and cost-efficient long-term organization of ACTRIS. The analysis of the socio-economic impacts attributed to ACTRIS will provide useful insights regarding the societal return of the investment required for the development, operation and maintenance of this research infrastructure and the formulation of the appropriate operational scheme.

The purpose of this survey is to better understand the benefits generated to research groups, organizations and institutions that utilize the products and services of a large research infrastructure like ACTRIS. In this context, it will provide useful insights for evaluating the societal return of the investment required for developing and maintaining ACTRIS infrastructure.

The questionnaire should be completed by authorized researchers that use ACTRIS products and services in their research, and educational activities. The national ACTRIS contact persons in each country participating in ACTRIS (see the ACTRIS Stakeholder Handbook) will be responsible collecting the filled questionnaires in each country.

The deadline for answering the questionnaire is September 30, 2018. Your participation to the survey is voluntary.

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Your Participation and Informed Consent

Your participation in this study will consist of a completion of a questionnaire. You will be asked some questions about the influence of the products and services of ACTRIS on your research activities. Please feel free to co-operate with colleagues when answering the questionnaire, if you think it is necessary. Your participation to the survey is fully voluntary, and you may pass on any question that makes you feel uncomfortable. You are encouraged to ask questions or raise concerns at any time about the nature of the study or the methods used.

The only personal details that will be asked from you will be your name and position in your organization. Insights gathered by you and other participants will be used in writing a research report for the socio-economic impacts of ACTRIS. All gathered information will be grouped together at research activity level such that no personal data will be traceable from the end product. The individual answers and informed consent forms will be stored by NOA until the end of the project. All of your information and responses to the questionnaire will be kept confidential.

By signing below, I acknowledge that I have read and understood the above information. Please print and sign this page and send a scanned copy of it to the e-mail address below.

Signature_____ Date_____

If you have any questions please contact Prof. Nikos Mihalopoulos (nmihalo@noa.gr, +30 210 8109121)

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1. What is your name:

_____

2. Affiliation and country (please specify if your organization is University/Research center, National/ Regional Agency or Governmental Institution, Company, etc.):

_____

_____

_____

_____

3. Please identify all possible activities for which your group / organization utilizes ACTRIS products and/or services.

(please, tick one or more of the boxes; if necessary add additional activities)

- Weather forecasting ☐
- Climate modeling ☐
- Modeling of the atmospheric environment ☐
- Satellite cal/val ☐
- Instrument intercomparisons / measurements ☐
- Research for renewable energies ☐
- Monitoring of implementation and effectiveness of the Montreal Protocol ☐
- Advances in remote sensing ☐
- Air quality/ Environmental monitoring ☐
- Educational/outreach ☐
- Safe use of nuclear energy and ionizing radiation ☐

Other (please specify)

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4. Please give some information on how ACTRIS products and/or services are utilized by your group in the activities identified in the previous question. Could you also provide one or several good example(s)?

This question should be seen in relation to the previous question. If applicable, provide some additional information on how ACTRIS products contributed to your research activities previously identified (e.g., in improving a specific module in weather forecasting modelling).

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5. Could you provide some quantitative estimates as regards to what extent the utilization of ACTRIS products and/or services has contributed to improvements in the accuracy of your modeling approaches, predictive capacity of your models, your ability to monitor more substances, retrieving your satellite data, etc.?

Type of activities	**Determination and/or Improvement**				
	Not at all	*Low*	*Medium*	*High*	*Very high*

6. Could you give an indication of the average annual amount of funds attracted by your group on ACTRIS related activities during the last 5-10 years?

Type of activities	**Research funds attracted (€)**

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7. To what extent the utilization of ACTRIS products and/or services (i.e., the database of ACTRIS parameters, the calibration of instruments, the SOP developments, etc.) resulted in an increase of the funds attracted by your group?

Type of activities	**Increases in the funds attracted**				
	Not at all	*Low*	*Medium*	*High*	*Very high*

8. To what extent the utilization of ACTRIS products and/or services resulted in an increase of your educational activities and overall outreach of your organization? Please give some quantitative estimates:

- Increase in the number of graduates trained by your group on issues utilizing ACTRIS outcomes

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- Percentage of the publications of your group that cites ACTRIS.

- Other…

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9. To what extent the utilization of ACTRIS products and/or services resulted in an increase of your capacity to support decision makers?

(please, tick one or more of the boxes; if necessary add additional activities)

- Not at all ☐
- Low ☐
- Medium ☐
- High ☐
- Very high ☐

10. Please report how often do you provide such information to decision makers and give if possible some characteristic examples.

(please, tick one or more of the boxes; if necessary add additional activities)

- Once a year or more rarely ☐
- 2-3 times per year ☐
- On a monthly basis ☐
- Continuously ☐

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Appendix II

Additional information on the activities utilized ACTRIS products and/or services by the users.

This Appendix presents more detailed information on the activities and fields utilized ACTRIS related products and services, based on the relative data provided by the entities participated in the survey. This information is presented per country and entity.

G1

Calibration of in-situ aerosol measurements to perform high-quality aerosol research studies and to educate PhD and young scientists.

G2

Monitoring and campaign data are used for GAW, for volcanic ash quantification and warning, for photo-voltaic yield forecasts, as supplementary data in ICOS inverse modelling, in atmospheric chemistry process studies, in gas-aerosol-cloud process understanding, in development of the operational observation network for ground based remote sensing of meteorological parameters, in parametrization of NWF-models, etc.

G3

- Use of EARLINET lidar data for the validation of AEOLUS (ESA space mission).
- Use of ACTRIS lidar calibration center guidelines to assure high quality of our lidar measurements (e.g., regular telecover test, depolarization calibration).
- Use of ACTRIS lidar calibration center for detail characterization of optical elements.
- Use data from our lidars but also from other EARLINET stations to perform research, e.g. on the
- existence and effects of smoke transported from far sources like North America.
- Use of ACTRIS ground-based in-situ data to obtain closure with ACTRIS remote sensing instruments (e.g. Melpitz column experiment, ACTRIS JRA-1).
- Cal/val activities of several satellites, e.g. CALIPSO, Sentinel 5p, Aeolus, and future EarthCARE
- Utilization of algorithms developed for wind lidars within Cloudnet to optimize the scanning strategy for our wind lidar systems, which is useful for Aeolus Cal/Val and cloud studies.
- Algorithms developed for EarthCARE are based on ACTRIS algorithms for ground-based instruments.
- Use of the Single Calculus Chain to process our operational lidar data.
- Validation of new instruments for extinction measurements
- Use of ACTRIS knowledge to investigate the global mineral dust cycle and discriminate between
- different types of Aeolian dust.
- Based on the high-quality depolarization measurements new algorithms developed to obtain cloud condensation nuclei and ice nuclei concentrations from lidar measurements

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G4

- Improvement of data quality of OC/EC and NOx measurements
- Instrument intercomparison in the framework of TNA evaluation of data quality of HONO measurements by MARGA
- Comparison, evaluation and trend analysis for air quality measurements (e.g. EMEP, GUAN)

G5

Cloudnet data (from the ACCEPT field experiment in Cabauw, Netherland, Fall 2014) are used to study the occurrence of supercooled liquid layers within mixed-phase clouds. To be more exact, cloud radar Doppler spectra is used to infer the occurrence of liquid with an artificial neural network. The work is still ongoing, preliminary results hint to the improvement of liquid-detection beyond lidar extinction in areas of low cloud turbulence with this method which might help to improve the Cloudnet target classification, i.e., the classification of liquid beyond lidar extinction.

In the future, the Cloudnet processing will be applied to our newly acquired 94 GHz cloud radar (LIMRAD94) within the context of the DACAPO-PESO field experiment in Punta Arenas in which dual-wavelength (35GHz of the TROPOS-LACROS station and 94 GHz) cloud radar data will be gathered. Focus of the field experiment will be to contrast the observations in the pristine midlatitudes of the Southern Hemisphere, especially at sub-zero temperatures with available Northern Hemispheric data to see the influence of aerosol load on cloud type, freezing temperature and different microphysical growth processes (riming vs. aggregation).

G6

Various ACTRIS products are regularly used to evaluate and improve the range of our model simulations on aerosol - chemistry transport and aerosol – cloud interactions at process, regional and global scale.

Specifically, AERONET sun photometer, EARLINET aerosol lidar and EMEP aerosol in-situ measurements are the valuable basis for the ongoing comprehensive evaluation of the TROPOS' aerosol-chemistry and transport model, e.g. for simulations of Saharan dust events, volcanic ash eruptions or urban air-quality applications.

Also, CLOUDNET products have helped interpreting and evaluating results within a modelling study on the impact of Saharan dust on ice cloud formation.

G7

Weather forecasting: (i) evaluation of the accuracy of weather forecasts under certain aerosol conditions; (ii) evaluation of the ice formation scheme incorporated in the newly developed German weather forecast model ICON.

Modelling of the atmospheric environment: based on lidar observations, a relationship between aerosol extinction coefficient, aerosol particle number concentration and the concentration of ice nucleating particles was derived for volcanic ash. This parameterization was applied in modeling studies to investigate the impact of volcanic aerosol on ice nucleation.

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Satellite cal/val: cloud geometrical properties (base and top height, cloud fraction) as well as cloud microphysical properties (ice and liquid water content, cloud droplet number concentration) retrieved with ground-based remote sensing were used to evaluate respective retrievals from the geostationary satellite Meteosat Second Generation (MSG).

Instrument intercomparisons: (i) intercomparison of multiple cloud-radar systems; (ii) intercomparison of multiple microwave radiometer systems.

Advances in remote sensing: (i) development of novel radar techniques (35-GHz hybrid-mode cloud radar); (ii) development of retrievals of cloud microphysical properties (effective radius, number concentration); (iii) closure studies between lidar-derived concentrations of ice nucleating particles and radar/lidar derived ice crystal number concentrations.

Air quality / environmental monitoring: investigation of cloud and specifically ice formation processes and their susceptibility to variations in the aerosol properties

Education & outreach: (i) hands-on training in instrument handling and calibration; (ii) presentation of measurements and techniques during guided tours at TROPOS (e.g., Chaos Communication Congress; Leipzig Science Night).

G8

- Assessment of the source/sink relationships in the atmosphere of VOC from oil/gas exploration platforms.
- Trends of VOC distributions in the global/regional atmosphere for scientific/educational purposes.
- Assessment of the effectiveness of clean air measures based on regional trend analysis.
- Checking/improving analytical instrument performance and data quality for VOC based on measurement guidelines.
- Consulting/training in VOC analysis of gas samples.
- Audits on VOC and corresponding data analysis for assessing the performance of monitoring networks

G9

Cloudnet products used in:

- Small- and large-scale model evaluations.
- Development of micro-physical retrievals for cloud properties.
- Better understanding of atmospheric boundary layer physics.
- Radiation assessment for renewable energy applications.
- Cloud-surface interaction processes.

G10

- Analysis of aerosol-cloud interactions and associated effective radiative forcing, with emphasis in analysis of trends related to surface solar radiation and weekly cycles.
- Climate model evaluation.
- Cloud-resolving model evaluation.

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- Development/evaluation of new satellite retrievals.

G11

Aerosol chemical (ions) and physical (PM mass concentration) parameters are used for the interpretation of our own (off-line) chemical characterization at the ACTRIS site, Kosetice. Meteorological data from the ACTRIS observatory are also needed for data interpretation. For data interpretation chemical (thermodynamic) models are applied.

G12

Data related to wind speed, wind direction, particle and gas measurements are analyzed to evaluate the transport of the pollution, both horizontal and vertical, in the region. The data are collected from all the available altitudes and then the mathematical methods based on frequency analysis, spatial-temporal correlation (e.g., POD) and wavelet analysis are performed. Two types of the prevailing pollution transports, namely a long-term horizontal advection and a short-term vertical flux associated with the thermal convection are detected and statistically assessed.

G13

Detailed chemistry-aerosol simulations with several models starting from zero-dimensional to the 3-D regional range are performed. Most of the models are applying measured data as input (partly from ACTRIS) and some data are used for model evaluation

Also, ACTRIS products are used for:

- Obtaining data for emission studies.
- Getting boundary conditions and validating data for air quality modelling.

G14

- The field measurements follow ACTRIS guidelines and SOPs for harmonized data in Europe.
- Students attend ACTRIS aerosol in situ measurement course.
- ACTRIS data is used for research purposes, such as aerosol-climate feedback analysis.
- In research and development, aerosol data and other observations from the ACTRIS observation sites are used for suitable satellite cal/val activities and provide input data for air quality and climate models.

G15

- Improving lidar instrument performance
- Implementing QA/QC procedure
- Providing lidar QC data to end users (e.g. modellers, weather forecasting)
- Improving educational outreach activities
- Evaluating satellite data

G16

- Utilization of calibration capabilities of ACTRIS.
- Installation and alignment of a special camera to ensure optimized measurements.

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G17

ACTRIS Lidar training program.

G18

The ACTRIS activities concerning the instruments' quality checks are utilized, which are quite effective in designing and testing of new remote sensing apparatus.

G19

PM measurements are used to make comparisons between PM levels recorded at different stations and to evaluate the transferability of an algorithm using satellite-derived products to estimate PM concentrations at ground level.

G20

The Cimel sunphotometer CE318 was installed at the ENEA Climate Observatory in Lampedusa in 2010 (although operative since 2003). It is identified as #172 of the AERONET network, and it entered the AERONET-EUROPE network in 2013. Since then, it is yearly calibrated by the Group of Atmospheric Optics (GOA) of the University of Valladolid thanks to the TransNational Access opportunity provided by ACTRIS. All the measurements as well as the information regarding calibrations are available through the CÆLIS tool (www.caelis.uva.es) provided by the GOA.

G21

Statistical and climatological analysis using ACTRIS data in order to improve the air quality monitoring.

G22

Use of demo device for experimentation and comparison with other instrument.

G23

Lidar measurements are used to validate a new image-based methodology to retrieve AOD from High-Resolution satellite measurements (e.g. Landsat, Sentinel). The retrieved AOD were compared with lidar AOD, to assess quantitative discrepancies, especially at different altitudes.

G24

ACTRIS products/services used for data quality assurance for both in situ and remote sensing measurements as well knowledge transfer to other networks. Also, outreach activities such as trainings, workshops and summer school were organized having as objective EARLINET/ ACTRIS measurements, procedure and quality assurance.

G25

ACTRIS products and services contributed to set and assure highest quality standards for in situ and remote sensing measurements of owned instruments. Also, knowledge transfer from ACTRIS expert groups to new network members resulted in strengthening the position of newly members and encouraged to provide highly qualitative data products.

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By outreach activities as training, workshops and summer schools the human resource were highly trained, and the carries of young researcher in atmospheric remote sensing boosted.

G26

ACTRIS products/services used for carrying on part of research, comparison with models/other datasets or between various instruments, in situ and remote sensing. Also outreach activities such as teaching, training, publication, conferences were based partly on ACTRIS services/data and procedures.

G27

ACTRIS products/ services used to develop scientific applications for BSc, MSc and PhD students as well as in the development of scientific publications. Furthermore, they used for calibration of the sun-photometer and optimization of the CLOP multiwavelength Raman and depolarization LIDAR.

G28

- Analysis of measurements of solar radiation and its modulating factors.
- Use in radiative transfer models.
- Climatology of aerosols in the Iberian Peninsula.
- Education pre and postdoctoral / Outreach activities.

G29

The research team carries out epidemiological studies in which the impact of chemical atmospheric pollution is analysed. Disposing of information of the prediction the possible concentrations of these pollutants is key for the articulation of prevention plans. Also, knowing the trajectories of the natural sources of pollutants such as the combustion of biomass or the evolution of the plumes in forest fires can be of special interest from the point of view of minimizing the impact on the health of citizens.

G30

The data developed within ACTRIS is relevant to improve atmospheric composition datasets that are used as forcing in climate models. This is also utilized in outreach/information activities.
Also, I coordinate an observational network (GuMNet: www.ucm.es/gumnet) and the procedures and and policies of ACTRIS are a good example to consider in our own case. The GuMNet network may be a potential contributor to ACTRIS in the future

G31

The group has used the cloud remote-sensing data sets and products for several years to investigate cloud processes (especially those involving the ice phase) and to evaluate how those processes are represented in numerical weather prediction models. The group also takes advantage of the long-term data set to investigate these effects on a statistical level rather than only case studies. This has proved very valuable.

We frequently use images/data from ACTRIS/Cloudnet for teaching purposes, to illustrate various phenomena related to cloud physics and the atmosphere generally.

We have used data from ACTRIS to develop and test a lidar formed model for ice clouds.

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