Final Report – Part A

HYRESSA

HYperspectral REmote Sensing in Europe – specific Support Actions

Accompanying Measures

implemented as

Specific Support Action

Contract number: 026194

Project coordinator: Ils Reusen – VITO NV

Project website: http://www.hyressa.net

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Research Infrastructures Action

A. ACTIVITY REPORT

1.1 Project objectives

During 20 years Europe has gained high-level expertise in hyperspectral remote sensing. The last few years several hyperspectral flight campaigns with different kind of sensors have been performed and next-generation European airborne hyperspectral sensors (APEX and ARES) are under construction. These sensors are operated by different data providers across Europe and as a consequence flight campaign planning, sensor calibration, data processing, … are strongly variable at the expense of the user. The lack of agreed calibration, acquisition, processing and in-situ protocols and the relatively large costs of uncoordinated sensor deployment are barriers to exploit the full potential of hyperspectral imagery in Europe.

The aim of the HYRESSA Accompanying Measure "Hyperspectral REmote Sensing in Europe – specific Support Actions" is to move towards an improved access to hyperspectral data in Europe.

The HYRESSA objectives are:

- to identify European providers and users of hyperspectral data and to build a database.
- to investigate the Strengths-Weaknesses-Opportunities-Threats (SWOT) of the field of hyperspectral remote sensing in Europe.
- to identify the European User Needs of the hyperspectral remote sensing research community in terms of accuracy, quality, formats, protocols of and access to hyperspectral data.
- to explore strategies to build a European network of hyperspectral remote sensing facilities and to coordinate a future distributed European hyperspectral remote sensing Research Infrastructure and to investigate how to refine existing protocols in compliance with standards (cfr. EU initiative INSPIRE) .
- to review existing protocols related to acquisition, calibration, processing of hyperspectral data and in-situ measurements and to refine protocols in compliance with standards.
- to design a plan for future collaboration related to a distributed European hyperspectral remote sensing Research Infrastructure.
- To inform the hyperspectral remote sensing community about HYRESSA and to disseminate the results from the project.

1.2 Contractors

The 10 contractors involved in HYRESSA are users and/or providers of hyperspectral remote sensing data from 8 different EU member states and Switzerland and represent the academic and research communities.

Participant number (co-ordinator = N°1)	**Participant name** (Organisation, city, country)	**Short name**
1	Vlaamse Instelling voor Technologisch Onderzoek, Mol, Belgium	VITO NV
2	Deutsches Zentrum fuer Luft- und Raumfahrt e. V., Wessling, Germany	DLR
3	University of Zurich, Department of Geography, Remote Sensing Laboratory, Zurich, Switzerland	RSL
4	GeoForschungsZentrum Potsdam , Potsdam, Germany	GFZ
5	Wageningen Universiteit, Wageningen, Netherlands	WU
6	Instituto Nacional de Técnica Aeroespacial, Torrejon de Ardoz-Madrid, Spain	INTA
7	Institute of Systems Biology and Ecology, Academy of Sciences of the Czech Republic, Ceske Budejovice, Czech Republic	ISBE ASCR
8	Tartu Observatoorium, Tartumaa, Estonia	TO
9	Helsingin Yliopisto, Helsinki, Finland	U Helsinki
10	The University of Edinburgh, Edinburgh, United Kingdom	UEDIN

1.3 Work performed

In its first phase HYRESSA has identified European users and providers of hyperspectral remote sensing data and has been investigating the user needs of the European hyperspectral remote sensing research community with respect to access to hyperspectral data and products, and issues of accuracy, quality and conformity of hyperspectral imagery. This knowledge has been gathered using a variety of methods, from a SWOT and User Needs workshop, a Questionnaire on User Needs following the methodology of Value-Benefit Analysis (Zangemeister, C.) and an Exploratory workshop.

In its second phase HYRESSA has been evaluating strategies aimed at building a Europe-wide network of hyperspectral data providers and users and coordinating a user-oriented hyperspectral remote sensing Research Infrastructure. Furthermore, an overview of existing or foreseen protocols and standards with respect to data acquisition, campaign planning, calibration and validation, data processing, quality measures, distribution, and education and training was prepared and a number of key elements for refinement were identified and refinement proposed and performed.

Finally, HYRESSA identified based on the user needs all essential building blocks for a hyperspectral remote sensing Research Infrastructure and established a plan for future collaboration.

The HYRESSA results were presented at scientific workshops (5th EARSeL SIG IS workshop, 10th Intl. Symposium on Physical Measurements and Signatures in Remote Sensing) and published in scientific literature (Nieke J. and Reusen I., Reusen I. et al).

The European hyperspectral remote sensing community has regularly been informed about the progress/results of HYRESSA through workshops/meetings and through the HYRESSA website http://www.hyressa.net.

1.4 Results

In the frame of the HYRESSA project European providers and/or users of hyperspectral data were identified and a European hyperspectral contact database containing about 700 providers and/or users of hyperspectral data originating from 27 countries (23 EU member states, Iceland, Norway, Switzerland and Croatia) was built. The organisation of flight campaigns with hyperspectral imaging sensors in Germany, Belgium and the United Kingdom on a yearly basis during the last decade might explain the large number of users in these countries. The example of Germany where hyperspectral flight campaigns have been supported and organized yearly since as far as 1994 is striking (strongest community of more than 130 users, yearly rising). This database was the starting point to invite experts to the SWOT and User Needs workshop and will be a good starting point to build a European network of users and/or providers of hyperspectral data in a follow-up project of HYRESSA.

On 5-6 July 2006 a SWOT and User Needs workshop was organized at DLR (15 mainly EU members states were represented) to investigate the Strengths-Weaknesses-Opportunities-Threats (SWOT) of the field of hyperspectral remote sensing in Europe and the user needs of the European hyperspectral research community. The main user needs identified during the SWOT and User Needs workshop are: standardization (especially for data processing and calibration), more transparency on calibration processes including quality measures, European platform for hyperspectral remote sensing (e.g. sensor pool, information about flight campaigns, data pool, spectral libraries, …), software tools for extracting information from hyperspectral data, education and training and the increase of the awareness of the added value of hyperspectral remote sensing.

The outcome of the SWOT and User Needs workshop was used to fine-tune a web-based Questionnaire on User Needs which was launched end of 2006 to the European scientific hyperspectral remote sensing community to investigate their user needs. Experts (users and providers) in hyperspectral remote sensing present at the SWOT and User Needs workshop but not involved in the HYRESSA project as partners expressed their interest in joining a follow-up project of HYRESSA. The 74 submitted Questionnaires on User Needs were evaluated and the results reported and published in Nieke J. and Reusen I. The main conclusions of the Questionnaires on User Needs are: improved services in terms of data delivery, reduced costs, help lines, software tools, workshops and training.

On 14-15 March 2007 an Exploratory workshop, to explore strategies to build a European network of hyperspectral remote sensing facilities and to coordinate a future distributed European hyperspectral remote sensing Research Infrastructure and to investigate how to refine existing protocols in compliance with standards, was organized in Davos, Switzerland as a special session of the 10th Intl. Symposium on Physical Measurements and Signatures in Remote Sensing. The plenary

session of the workshop gave an overview of existing research infrastructures or under construction like MODIS, NEON, etc. which possibly could serve as an example for the hyperspectral remote sensing Research Infrastructure. Through an interactive session, the requirements of a hyperspectral remote sensing Research Infrastructure were explored and grouped in themes: *Calibration, validation and quality control* (were considered critical for the delivery of high quality hyperspectral data, integration of in-situ, airborne data and spaceborne data (cfr. GEO)), *Development of products* (for a range of applications, established through extensive literature review with an emphasis on consistency, standards and quality measures), *Standards* (with a strong emphasis on documentation of agreed protocols, interoperability, common semantics and terminologies), *User community* (involving the development of an operational community through education and training, efficient use of already available knowledge and resources, near-real time product delivery and single data entry point).

Standards and protocols were considered essential during the HYRESSA project and also for the follow-up project. A report giving an overview of existing protocols and standards including refinements of protocols and recommendations for the future is prepared by the HYRESSA partners and forms the basis for further improvement and implementation during a follow-up project.

HYRESSA produced knowledge from the SWOT and User Needs workshop, the evaluation of the Questionnaire on User Needs, the Exploratory workshop, the review and refinement of protocols is summarized below and was the basis for the work related to the Future collaboration plan.

1. There is a clear and urgent need for an improved Research Infrastructure and for the strengthening of capabilities in hyperspectral remote sensing at a European level.
2. High quality European capabilities exist at national levels in all aspects of the key areas required for a hyperspectral Research Infrastructure (including ground instrumentation, calibration, validation, sensors and sensor development, product development and data delivery).
3. A Research Infrastructure would significantly enhance European-wide capabilities in hyperspectral remote sensing by ensuring existing expertise outlined in 2 but held within specialist groups is available to all EU member states and in so doing reducing duplication, sharing and capacity building.
4. That such an infrastructure can be efficiently achieved through three lines of approach: Facilities, Protocols and Mechanisms. These are outlined as follows:

Facilities:
The Research Infrastructure requires improved and high quality facilities for:

- Access to state-of-the-art hyperspectral sensors
- Airborne sensor calibration
- Availability and calibration of field spectrometers
- Standardized data processing (product development with quality flags)
- Distribution and access to hyperspectral data and derived products

Protocols:
The Infrastructure requires:

- The establishment of standards in calibration, validation, data quality and data products
- A strong emphasis on documentation of agreed protocols, interoperability, common semantics and terminologies

Mechanisms:

. The goals of the Research Infrastructure can be met through:

- Science teams, involving the close collaboration with end-users for product development and for the provision of ground measurements for calibration and validation
- . Working groups (e.g. on future development)
- Education and training
- Awareness raising
- Near real-time data delivery
- Accessibility to knowledge and resources
- Single data entry point
- Software tools

All HYRESSA partners agreed that a hyperspectral remote sensing Research Infrastructure has a *unique character* related to its relatively long processing chain ranging from sensor development and calibration to the final distribution of derived products to a broad range of specialized users interested in different application fields (e.g., ecology, limnology, geology). The discussions on the Future collaboration plan resulted in the structured hub or chain approach which contains all the necessary elements to improve the access to hyperspectral imagery in Europe for the European hyperspectral remote sensing scientific community and to exploit the full potential of hyperspectral imagery in Europe. These elements are the essential building blocks for a European *user-oriented* hyperspectral remote sensing Research Infrastructure. The HYRESSA project has identified critical elements (hubs) which it considers are necessary for a hyperspectral remote sensing Research Infrastructure. These include:

- Quality control
- Education and training
- Field capabilities
- Data management
- Modelling
- Future sensor development
- Data assimilation
- Spaceborne sensors
- Calibration and validation
- Airborne sensors

A Research Infrastructure is needed to ensure this structure is efficiently coordinated and to assure consistency of data processing and quality. For several of the hubs knowledge and facilities are already operationally available within Europe.

The overall aim of a hyperspectral remote sensing Research Infrastructure is to develop and maintain a pan-European Research Infrastructure to integrate, and to build and maintain capacity in research in hyperspectral remote sensing technologies and to sustain and stimulate the use of hyperspectral data products. The infrastructure will address all aspects of the 'chain' from instrument development and calibration to the provision of quality flagged data products and will operate at multiple levels - from ground level, through the enhanced provision of calibrated ground instrumentation, to the availability of consistent products from airborne and spaceborne hyperspectral instruments.

One of the key conclusions of HYRESSA was that high level expertise is available in Europe (mainly in the member states operating a hyperspectral sensor) and building blocks (facilities) in all

aspects of the key areas required for a hyperspectral Research Infrastructure (including ground instrumentation, calibration, validation, sensors and sensor development, product development and data delivery) exist in Europe but are fragmented and operated at national level. Therefore a Research Infrastructure connecting all these building block is highly desirable to assure an efficient use of resources and to assure consistency of data format, data processing and quality for the different hyperspectral sensors available and across the borders (cfr. INSPIRE directive) and to open the access to scientists from member states currently not having access to hyperspectral sensors.

The intention of a hyperspectral remote sensing Research Infrastructure is to bring together a comprehensive consortium of stakeholders from a range of backgrounds, to improve coordination of related activities, enhance capabilities and exploit and develop synergies in order to meet user needs. The identified hubs were translated into the key elements or activities contributing to a Research Infrastructure, namely networking activities (NA), transnational and service activities (TA), and joint research activities (JRA).

Opportunities for collaboration with EUFAR were identified early during the HYRESSA project at the Exploratory workshop. EUFAR (with focus on aircraft and atmosphere) and HYRESSA (with focus on sensors, data quality, land and water applications) are highly complementary in emphasis. Both have a common emphasis on extending and improving the capabilities at the European level in the field of airborne research.

1.5 Impact on European scientific community and its research or industry sector

The HYRESSA project was well-received by the European hyperspectral remote sensing community at the SWOT and User Needs workshop, the Exploratory workshop and the 5th EARSeL SIG IS workshop. The level of interaction and contribution from the participants and panel at the HYRESSA workshops was higher than expected and illustrated that there is a clear and urgent need for a European hyperspectral remote sensing Research Infrastructure. A number of participants showed interest in joining a follow-up project. Especially the user-driven and structured hub approach of HYRESSA was highly appreciated.

The HYRESSA project stimulated the dialogue between users and providers of hyperspectral data and provided focus (to e.g. agreed standards, protocols, quality). HYRESSA produced knowledge initiated a number of activities/projects at national level to improve the access to hyperspectral remote sensing data in terms of reduced costs and increased efficiency. To give a few examples, in preparation of next-generation sensors DLR, VITO, RSL and INTA have developed central data processing chains for near-real time processing of hyperspectral data to level 2 (Biesemans J.) and level 3 products (Schlaepfer D. and Nieke J). This also includes procedures for automated generation of metadata for quality control (Bachmann et al). These developments could result in a considerable reduction in time and costs.

Furthermore, HYRESSA encouraged further cooperation between the HYRESSA partners and other stakeholders and as a consequence will reduce duplications of effort and optimize the use of resources. Building further on achievements from HYRESSA (knowledge produced through the SWOT and User Needs workshop, the Questionnaire on User Needs, the Exploratory workshop, the review and refinement of protocols and the Future collaboration plan), HYRESSA has paved the way for further cooperation with EUFAR. As an example, the lack of standards and protocols was experienced by the users as a weakness of hyperspectral remote sensing in Europe. Within HYRESSA a review of existing protocols and standards was performed and a refinement of protocols was initiated. Within EUFAR this work towards an improvement and harmonization of

protocols could possibly be continued. By a further development of common protocols, the exchange of the data and the transparency will be improved for the benefit of the users. Another weakness identified during the HYRESSA project is insufficient transparency on data processing and quality. EUFAR intends to develop harmonized quality layers for airborne hyperspectral imagery and higher level data products (directly responding to the INSPIRE directive on metadata including quality). And finally, the development of software tools and higher level products will facilitate research activities by users that are not advanced remote sensing specialists (like climate change and ecosystem modelers) and will allow to solve actual European environmental issues in a more efficient way. This will wider the user community of hyperspectral data products to new scientific domains.

At the longer term the impact of the proposed hyperspectral remote sensing Research Infrastructure includes:

- Enhancement and development of European scale facilities for the calibration, validation, acquisition, processing and timely delivery of hyperspectral data and data products to agreed standards, qualities and protocols. The focus on the hyperspectral remote sensing Research Infrastructure is thus on *evolution*; meaning the optimal use and development of existing high quality facilities across Europe for the wider benefit.

- Transfer of existing expertise held within specialist groups to all EU member states, through awareness raising, working groups, training and workshops.

- Open access to facilities and scientifically useful data collected for improved environmental monitoring and prediction of climate, ecological, earth and ocean systems changes, to enable long-term and sustainable monitoring of environmental processes related to ecosystem life and evolution, global changes and geo-hazards.

- Fertile platform from which new areas of interest, in the form of technologies, applications, protocols, are developed to maximize European capabilities in the field of hyperspectral remote sensing.

- Collaboration between the academic, governmental research agency and industry for the development and exploitation of hyperspectral and related technologies.

- Extension of the capability to users who are not advanced remote sensing specialists in terms of technical or applications ability (like climate change and ecosystem modelers).

Further information (reports, presentations and publications) can be found at the HYRESSA website http://www.hyressa.net.

Annexes

Annex 1 - References

Bachmann M., Habermeyer M., Holzwarth S., Richter R.and Müller A., (2007), Including Quality Measures in an Automated Processing Chain for Airborne Hyperspectral Data. In: Proceeding 5th EARSeL SIG IS Workshop, Bruges, Belgium, edited by I. Reusen.

Biesemans J., Sterckx S, Knaeps E., Vreys K., Adriaensen S, Hooyberghs J.and Deronde B, (2007), Image processing workflows for airborne remote sensing. In: Proceedings 5th EARSeL SIG IS Workshop, Bruges, Belgium, edited by I. Reusen.

Nieke J. and Reusen I., (2007), A New Method to Retrieve the Data Requirements of the Remote Sensing Community – Exemplarily Demonstrated for Hyperspectral user needs, *Sensors* 2007, *7*, 1546-1558.

Reusen I., Holzwarth S., Nieke J., Kooistra L., Malthus T., Chabrillat S., Kaufmann H., Gomez-Sanchez J., Homolova L., Itten K., Malenovsky Z., Meuleman K., de Miguel E, Mottus M., Mueller A., Pellikka P. and Schaepman M., (2007), Towards an improved access to hyperspectral data across Europe (HYRESSA), In: Proceedings 5th EARSeL SIG IS Workshop, Bruges, Belgium, edited by I. Reusen.

Schlaepfer D. and Nieke J., (2007), Optimizing the workflow for APEX LEVEL2/3 processing. In: Proceedings 5th EARSeL SIG IS Workshop, Bruges, Belgium, edited by I. Reusen.

Zangemeister, C. (1970), Nutzwertanalyse in der Systemtechnik. Eine Methodik zur multidimensionalen Bewertung und Auswahl von Projektalternativen. München, 370 S.

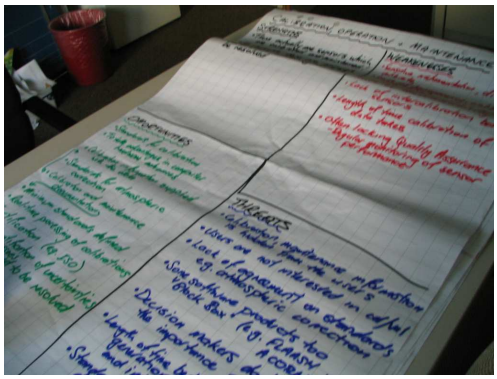
Annex 2 - Pictures

SWOT and User Needs workshop, DLR, Oberpfaffenhofen, 5-6 July 2006

a. 

b. 

c. 

d. 

a,b,c: discussion in splinter groups
d: result of splinter group discussion

Exploratory workshop, Davos, 12-15 March 2007

a. 

b. 

c. 

d. 

e. 

f. 

a: Presentation Brigitte Weiss (EC) Working Session Thursday 15 March 2007
b: Chair Ils Reusen Interactive Session Wednesday 14 March 2007
c: Panel during Interactive Session Wednesday 14 March 2007
d: Participants Working Session Thursday 15 March 2007
e: Participants Working Session Thursday 15 March 2007
f: Presentation Tim Malthus Working Session Thursday 15 March 2007

Future Collaboration Meeting, University of Edinburgh, 8-9 November 2007

a. 

a: Presentation Tim Malthus