Topics in Environmental Software Systems

Ralf Denzer

Environmental Informatics Institute (EII), Gaiberg, Germany
`ralf.denzer@enviromatics.org`

Abstract. Environmental software systems (ESS) are software systems support-ing activities of environmental protection, environmental management, envi-ronmental policy and environmental sciences. ESS often overlap with adjacent application fields like security, agriculture, health or climate change. The ISESS conference series is one of several overlapping events which are devoted to en-vironmental modelling and software systems. ISESS is probably the one inter-national event which has the strongest focus on the software angle.

This paper gives a historic perspective of 20 years of ISESS conferences. Starting with a historic review of the development of the field named "envi-ronmental software systems", it puts the ISESS conference into the greater per-spective of similar activities. Using the original materials the paper identifies typical themes subsumed under ESS, and highlights typical topics for the time.

The paper is the only existing complete collection of activities of the IFIP working group 5.11 "Computers and Environment". Material of all events, ISESS conferences as well as co-organised workshops has been collected in one central place and will also to be kept up to date in the future.

Keywords: environmental software systems, ESS, environmental information systems, EIS, environmental decision support systems, EDSS, ISESS, environ-mental informatics, enviromatics.

1 Introduction

It is probably impossible to define a clear "problem space" or "discipline/domain boundary" for the ICT application domain named "environmental informatics" or "envi-ronmental software systems" (ESS). The more concrete one tries to capture these boundaries the larger the problem space seems to get and the boundaries become fuzzy and difficult to grasp. There have been discussions whether this is a "discipline" (a pure computer scientist will say: no), an "applied discipline", a "domain" and so forth. For the remainder of this article I shall call it "field of work" or just *"the field"* because this sounds neutral enough.

Starting early on, there have been attempts to classify what environmental software systems are, to provide an overview of research and application, like for instance in the first paper [1] of the first ISESS book [2]. An early book [3] is structuring the field according to the dividing line between technology and application [3]. Reading some of the material today reveals interesting aspects.

Seeing it today, some material looks naïve, but I have always been surprised how many of the hard problems which our field is dealing with today have already been identified 25 years ago, and on what impressive level, considering that informatics as a discipline was in its infancies. My own entry into the field was on September 30 and October 1, 1986, when my boss at the time, Dr. Andreas Jaeschke of KfK (today Karlsruhe Institute of Technology, KIT) organised the first recognised scientific event regarding environmental software systems, figure 1. It was my first day at work after university. The proceedings were published as a KfK report [4] and are probably the earliest proceedings published in the field.

I remember a talk in which a representative of a German federal state ministry

Fig. 1. First ESS proceedings [4]

reported about an analysis being carried out towards an integrated state-wide information system. That analysis had revealed that the state operated *several hundred information systems* relevant for environmental applications (unfortunately that statement was not published in the paper, so you just have to believe me). Needless to say that most of them were incompatible with each other – this just seems to be the way how ICT's grow in large organisations in an uncontrollable fashion – a situation which many readers today may be able to relate to.

Every book or proceedings on ESS has to find a way to structure the content, which is nothing else than *trying to structure the current status of the field*. Some books try to apply the *dividing line: methodology / application* while others don't, and clearly each volume is influenced by actual research and policy trends. For instance the 2013 and 2011 proceedings [5,6] have a mixed approach (technology chapters like *future internet* or *semantics* vs. application chapters like *risk management* or *climate change*) while the 2015 book [7] applies a pure ICT structuring approach as follows:

- context articles, including keynotes and discussion papers
- information systems, information modelling and semantics
- decision support tools and systems
- modelling and simulation systems
- architectures, infrastructures, platforms and services
- requirements, software engineering and software tools
- analytics and visualization
- high performance computing and BigData

During the late 1990's there have been on-going discussions whether an *environmental information system* (EIS) is something different than an *environmental decision support system* (EDSS). A workshop report [10] of ISESS 1999 [11] is trying to answer

that question. In order to avoid exclusions I have used myself the term "EIDSS" for *environmental information and decision support system*, a terrible acronym. I have personally gone back to the term *environmental software system*, because it is neutral enough and relatively clear: a software system supporting environmental applications.

Another important topic has been the "*meta thing*". In the early days, particularly in the German scene which was heavily data centric, there was a never ending discussion about *meta-data* or *meta-information*, for instance as far back as [8]. Sometimes the "meta things" are hyphened, sometimes written together, sometimes written apart, but the never ending mystery of what "the meta things" are has not ceased to exist, although some so-called "meta-data standards" are applied in everyday life today. Still, many colleagues have come to the conclusion that the distinction is artificial because whether something is "meta" or not depends on the use, as has been stated in [9]. Actual real world meta-data standards and some service interface designs probably do not hold for long under this viewpoint.

Then it has been obvious for a long time that there is a very strong connection to *environmental modelling and simulation*, as many applications, particularly those for decision support apply models to investigate alternatives, specifically policy alternatives and planning alternatives. Looking into existing conferences and journals one must acknowledge that there are many more articles about modelling than (at least high quality) articles about ESS, and the only relevant journal, *Environmental Modelling & Software*, which has first been driven from the modelling side, still finds it a challenge to attract high quality innovative software papers.

This paper is trying to put ISESS into an international context of several related activities, and also aims at identifying typical patterns appearing over and over again in ESS. Starting with the international landscape and a complete record of ISESS events, I will make an attempt to analyse typical ISESS topics, based on a rough review of all ISESS proceedings [2,5,6,7,11,12,13,14,15,16,17].

2   The Conference Landscape

2.1   EnviroInfo

The first symposium [4] developed from 1987 on into a conference named "Symposium Informatik im Umweltschutz" which later became the "EnviroInfo" conference series. In parallel a working group named "Informatik im Umweltschutz" (computer science for environmental protection)[1] was installed as a committee of the German Informatics Society [2]. That working group can be considered as the nucleus of the field in the early days. EnviroInfo has been held in Germany and neighbouring countries since 1997. For an overview dated in 2011 see [18].

2.2   ISESS

The IFIP working group WG 5.11 "Computers and Environment" was founded in 1992, and was the first attempt to make the field, which was very much dominated by

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[1] `http://enviroinfo.eu`
[2] `http://www.gi.de`

German speaking countries, more international. ISESS 1995 was the first event organised by the WG and it has been organised since on a biannual schedule. ISESS attempts to provide a world-wide coverage of ESS topics and has been held in North America, Europe and Australia / New Zealand (see sections 3 ff.)

2.3   MODSIM

The Modelling and Simulation Society of Australia and New Zealand (MSSANZ[3]) has been organising the MODSIM conference since the 1970's. MODSIM has a thematic relationship to our field in the sense that there are always sessions related to environmental modelling and for about 10 years there have been sessions related to environmental software which were co-organised by individuals of WG 5.11 in order to bridge the gap between the modelling and the software community. MODSIM is held in Australia and New Zealand, the last one being held in 2013 [19].

2.4   IEMSS

The International Environmental Modelling & Software Society[4] has been organising the IEMSS conference since 2002, and ISESS respectively WG5.11 have often co-organised sessions about environmental software at IEMSS. IEMSS has a strong focus on modelling, yet at the same time a considerable thematic overlap with ISESS in the field of software. IEMSS has a world-wide coverage of topics and has been held in Europe and North America. The last IEMSS conference was held in 2014 [20].

2.5   The White Spots on the Map

None of the above conferences has ever been held in South America, Africa or Asia. These parts of the world are to be covered yet.

3   The ISESS Conference Series

As illustrated above, the International Symposium on Environmental Software Systems (ISESS) is one of several overlapping forums discussing issues of *environmental information systems*, *environmental decision support systems*, *environmental software systems*, *environmental informatics*, *eco-informatics* or *enviromatics*.

ISESS was founded by Ralf Denzer and Gerald Schimak in 1995, with support from the German Informatics Society Working Group 4.6 "Computer Science for Environmental Protection", the International Federation for Information Processing (IFIP) Working Group 5.11 "Computers and Environment" and our friend David Russell at the Pennsylvania State University (PSU) campus in Malvern, PA. The first symposium received great support from PSU and turned out to be one of many success stories.

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[3]   http://www.mssanz.org.au
[4]   http://www.iemss.org

Since then the symposium has been held in the following countries: the United States, Canada, Austria, New Zealand, Portugal, the Czech Republic, Italy; in several years, joint sessions were held in conjunction with the biennial meeting of iEMSs (International Environmental Modelling and Software Society). ISESS has been an IFIP event since 1995 and is organized by WG 5.11.

Since its establishment WG 5.11 has been led by Giorgio Guariso (1991-1999), Ralf Denzer (1999-2005) and Dave Swayne (2005-2011). Since 2011 it is in the hands of Gerald Schimak. Several individuals have served as vice-chairs and secretaries of the WG and many members of the WG have been active supporters for a long time without holding an official position.

For more than two decades ISESS has brought together researchers dealing with environmental information challenges trying to provide solutions using forward-looking and leading-edge IT technology.

4   A Complete History of Events

4.1   ISESS Conferences

During the past 20 years we have seen the publisher of IFIP change several times and electronic publishing has become the most important medium for scientific publications. ISESS has followed this transition and therefore there is *not a single place* where all ISESS proceedings can be accessed.

The first and second proceedings (ISESS 1995, ISESS 1997) were published by IFIP publisher Chapman & Hall (C&H):

- R. Denzer, D. Russell, G. Schimak (eds.), Environmental Software Systems [2]
- R. Denzer, D. A. Swayne, G. Schimak (eds.), Environmental Software Systems Vol. 2 [12]

Then IFIP changed publisher and the third proceedings (ISESS 1999) were published by IFIP publisher Kluwer Academic Press:
- R. Denzer, D. A. Swayne, M. Purvis, G. Schimak (eds.), Environmental Software Systems Vol. 3 - Environmental Information and Environmental Decision Support, [11]

As print publications were becoming increasingly difficult (particularly their cost for smaller conferences), the fourth and fifth proceedings (ISESS 2001, ISESS 2003) were published by the organizers of the symposium under IFIP ISBN:

- D. A. Swayne, R. Denzer, G. Schimak (eds.), Environmental Software Systems Vol. 4 - Environmental Information and Indicators, International Federation for Information Processing [13]
- G. Schimak, D. A. Swayne, N.T. Quinn, R. Denzer (eds.), Environmental Software Systems Vol. 5 - Environmental Knowledge and Information Systems [14]

The sixth and seventh proceedings (ISESS 2005, ISESS 2007) were published, but this time as electronic versions under IFIP ISBN:

- D. A. Swayne, T. Jakeman (eds.), Environmental Software Systems, Vol. 6 - Environmental Risk Assessment Systems [15]
- D. A. Swayne, J. Hřebíček (eds.), Environmental Software Systems, Vol. 7 - Dimensions of Environmental Informatics [16]

The eight proceedings (ISESS 2009) were again published electronically, but not under IFIP ISBN:

- D. A. Swayne, R. Soncini-Sessa (eds.), Environmental Software Systems, Vol. 8, [17]

Today, Springer is the official IFIP publisher and ISESS is published by Springer in IFIP Advances in Information and Communication Technology (AICT)[5]. Proceedings number nine and ten were published as follows:

- J. Hřebíček, G. Schimak, R. Denzer (eds.), Environmental Software Systems, Vol. 9 - Frameworks of eEnvrionment, IFIP AICT 359 [5]
- J. Hřebíček, G. Schimak, M. Kubásek, A.E. Rizzoli (eds.), Environmental Software Systems, Vol. 10 - Fostering Information Sharing, IFIP AICT 413 [6]

and the current conference, ISESS 2015 in Melbourne is again a Springer book in the IFIP AICT series

- R. Denzer, R. M. Argent, G. Schimak, J. Hřebíček, (eds.), Environmental Software Systems, Vol. 11 – Infrastructures, Services and Applications, IFIP AICT 448 [7]

Table 1. ISESS Conferences

Event and topic	Publisher	Pages	Papers
ISESS 2015: Environmental Software Systems Vol. 11 - **Infrastuctures, Services and Applications**, 25.3.-27.3.2015, Melbourne, Australia	Springer, IFIP AICT	611	61
ISESS 2013: Environmental Software Systems Vol. 10 - **Fostering Information Sharing**, 9.10.-11.10.2013, Neusiedl am See, Austria	Springer, IFIP AICT	696	65
ISESS 2011: Environmental Software Systems Vol. 9 - **Frameworks of eEnvironment**, 27.6.-29.6.2011, Brno Czech Republic	Springer, IFIP AICT	674	74
ISESS 2009: Environmental Software Systems Vol. 8, 6.10.-9.10.2009, Venice, Italy	IFIP Series	251	24
ISESS 2007: Environmental Software Systems Vol. 7 - **Dimensions of Environmental Informatics**, 22.-25.5.2007, Prague, CZ	IFIP Series	624	61
ISESS 2005 - Environmental Software Systems Vol. 6 - **Environmental Risk Assessment Systems**, 24.-27.5.2005, Sesimbra, PT	IFIP Series	243	26
ISESS 2003: Environmental Software Systems Vol. 5- **Environmental Knowledge and Information Systems**, 27.-30.5.2003, Semmering, AT	IFIP Series	470	43

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[5] http://www.springer.com/series/6102

ISESS 2001: Environmental Software Systems Vol. 4 - **Environmental Information and Indicators**, 22.-25.5.2001, Banff, CA	IFIP Series	235	24
ISESS 1999: Environmental Software Systems Vol. 3 - **Environmental Information and Decision Support**, 30.8.-2.9.1999, Dunedin, NZ	Kluwer	268	28
ISESS 1997**: Environmental Software Systems Vol. 2**, 28.4.-2.5.1997, Whistler, CA	C&H	360	45
ISESS 1995: **Environmental Software Systems**, 13.-15.6.1995, Malvern, US	C&H	290	25

Today Springer also has the rights of the early Kluwer and Chapman & Hall books (ISESS 1995, ISESS 1997, ISESS 1999), as Kluwer was merged with Springer in 2004 and Chapman & Hall had been bought by Kluwer in 1997. Therefore all proceedings which were published by a publishing house are in one place today and can be accessed through Springer and Springer Link. They are available as hard cover and/or soft cover, as eBooks and (most of them) as individual articles.

4.2   ISESS Workshops and Co-organised Events

In addition to the bi-annual conference in odd-numbered years, the ISESS community has organized workshops and co-organised events in most even-numbered years. These co-organized events were either published with IEMSS, or as best paper peer-reviewed journal issues.

From the events in 1998 and 2000, the best papers were invited to be extended and improved in a peer review process, and were published as special issues of Environmental Modelling and Software (EM&S) and Advances In Environmental Research (AIER):

- Journal Environmental Modelling & Software (EM&S), Volume 16 No. 5 (2001)
- Journal Advances in Environmental Research, Vol. 5 No. 4, November 2001

Along with the first IEMSS conference in Lugano, WG 5.11 co-organised a session which is available through IEMSS:

- ISESS Session at IEMSS 2002, Tool integration in environmental decision support systems, in [21], see www.iemss.org/iemss2002/special_sessions.phtml#isess, pp. 271-389

The 2004 workshop published a special issue of EM&S, again based on the best contributions at that workshop:

- Journal Environmental Modelling & Software (EM&S), Volume 22 No. 4 (2007), pp.415-448, Special Section : Environmental Risk and Emergency Management, for an introduction see [22]

In 2006, 2008, 2010 and 2014, WG 5.11 was again co-organizer of specific sessions at IEMSS conferences.

- ISESS Special Session at IEMSS 2006, Integrated software solutions for environmental problems - architecture, frameworks and data structures, in [23], see, www.iemss.org/iemss2006/sessions/s5.html
- ISESS Special Session and Workshop at IEMSS 2008, Session S1: Data and sensor networks and environmental modelling and Workshop W1: Creating robust sensor networks architecture and infrastructure, in [24], see www.iemss.org/iemss2008/index.php?n=Main.S1
- ISESS Special Session at IEMSS 2010, Interaction Design for Environmental Information Systems, in [25], see www.iemss.org/iemss2010/Volume3.pdf
- ISESS Special Sessions at IEMSS 2014, Session A4: Smart and Mobile Devices for Environmental Applications, Session A5: Parallel Simulation of Environmental Phenomena, Session A6: Semantics, Metadata and Ontologies of Natural Systems, in [26], volume 1, see: www.iemss.org/sites/iemss2014/papers/Volume_1_iEMSs2014_pp_1-602.pdf

Table 2. ISESS workshops and co-organised events at IEMSS

Event and topic	Publisher	Pages	Papers
ISESS Sessions at IEMSS 2014, A4: **Smart and Mobile Devices for Environmental Applications**, Session A5: **Parallel Simulation of Environmental Phenomena**, Session A6: **Semantics, Metadata and Ontologies of Natural Systems**, 15.-19.6.2014, San diego, USA	IEMSS	125	17
ISESS Session at IEMSS 2010: **Interaction Design for Environmental Information Systems**, 6.7.2010, Ottawa, Canada	IEMSS	39	5
ISESS Session at IEMSS: **Data and Sensor Networks and Environmental Modelling**, 7.7.-10.7.2008, Barcelona Spain	IEMSS	96	14
ISESS Session at IEMSS 2006: **Integrated Software Solutions for Environmental Problems**, 9.-13.7.2006, Burlington, US	IEMSS	169	29
ISESS 2004 Workshop **Environmental Risk and Emergency Management**, 18.-21.5.2004, Harrisonburg, US	EM&S	33	6
ISESS Session at IEMSS 2002: **Tool Integration in Environmental Decision Support Systems**, 22.5.-25.5.2001, Lugano, Switzerland	IEMSS	119	20
ISESS 2000 Workshop: **Integration in Environmental Information Systems**, 28.5.-2.6.2000, Zell am See, AT	AIER	144	16
ISESS 1998 Workshop: **Design Principles for Environmental Information Systems**, 15.-18.6. 1998, St. Nikolai, AT	EM&S	50	8

5   ISESS 2001-2009 Second Editions and Enviromatics.org

The proceedings of 2001, 2003, 2005, 2007 and 2009 were published under IFIP copyright in different formats (print, CD, USB) and were neither available from Springer

nor on-line at one central place. Following an official request in November 2014, IFIP granted me the right to re-publish these proceedings. They are now available *as second-editions*, for now in a relatively simple form, as one downloadable PDF. They will be available permanently as follows:

- R. Denzer (ed.), Environmental Software Systems Vol. 4 - Environmental Information and Indicators, Second Edition [27]
- R. Denzer (ed.), Environmental Software Systems Vol. 5 - Environmental Knowledge and Information Systems, Second Edition [28]
- R. Denzer (ed.), Environmental Software Systems, Vol. 6 - Environmental Risk Assessment Systems, Second Edition [29]
- R. Denzer (ed.), Environmental Software Systems, Vol. 7 - Dimensions of Environmental Informatics, Second Edition [30]
- R. Denzer (ed.), Environmental Software Systems, Vol. 8, Second Edition, [31]

From March 2015 on, the website www.enviromatics.org will maintain a complete repository of these volumes and will point readers to all other ISESS related publication information.

6   A Review of ISESS Topics

A rough review of topics of all ISESS books presents the reader with a large variety of topics, software tools and applications. Table 3 shows the tables of content of each ISESS conference publication.

Table 3. ISESS tables of content (omitting keynotes, workshops and tutorials)

Event	Topics
1995	Environmental information systems Modelling and simulation Environmental management Decision support Distributed environmental information Artificial intelligence applications Environmental data visualization
1997	Ecological and agricultural applications Decision support Environmental information systems and meta information Industrial applications GIS applications Modelling and simulation Object orientation
1999	Environmental information systems tools and techniques Environmental information systems implementations Environmental decision support systems

2001	Environmental indicators Environmental modelling Environmental information systems Environmental decision support systems
2003	Environmental information systems Environmental information services Environmental assessment, modelling and simulation Integration Environmental knowledge and decision support systems EC 5th framework applications
2005	Special session on successes and failures Corporate and public environment information systems Tools and techniques Wide scale monitoring Risk management State information systems Applied decision support systems Integrative tools
2007	Next generation of environmental information and risk management systems ICT tools for ecological and human risk assessment Artificial and computational intelligence for environmental modelling Open source GIS and environmental modelling systems Environmental engineering education, presentation of environmental information to nonscientists Software tools and component-based environmental modelling Integrated modelling and decision support systems for watershed and lake management Human factors in enviromatics Distributed and parallel environmental modelling paradigms
2009	Software systems for policy analysis Sensor webs and sensor networks Human factors in environmental information systems
2011	eEnvironment and cross-border services in digital agenda for Europe Environmental information systems and services – infrastructures and platforms Semantics and environment Information tools for global environmental assessment Climate services and environmental tools for urban planning and climate change applications and services
2013	Environmental applications in the scope of the future internet Smart and mobile devices used for environmental applications Information tools for global environmental assessment Environmental applications in risk and crisis management SEIS as a part of the 7th environment action programme of the EU Human interaction and human factors driving future EIS / EDSS developments Environmental management, accounting and statistics Information systems and applications
2015	Information systems, information modelling and semantics Decision support tools and systems Modelling and simulation systems Architectures, infrastructures, platforms and services Requirements, software engineering and software tools Analytics and visualization High performance computing and BigData

In the sequel I would like to point the reader to a selection of papers from each of the proceedings, which I think were typical for the developments at the time:

- 1995
  - [32]: gives an introduction into requirements of integrated information systems from an ecological point of view
  - [33]: identifies early on the problems of processing large amounts of earth observation data
  - [34]: based on the example of ecological monitoring, the paper shows how hard it can be to analyse environmental data, and that it may be difficult to grasp; the paper identifies methods and tools from artificial intelligence
  - [35]: shows the use evolving methodologies of scientific data visualization
- 1997
  - [36]: shows the needs and system design challenges for integrated decision support based on GIS, visualisation, models and data management components
  - [37]: demonstrates an early application of web technologies
  - [38]: is one of the first environmental planning applications demonstrating the integration across national borders
  - [39]: shows the need to integrate models into information systems for environmental research
- 1999
  - [40]: identifies real time processing needs for water quality management in a catchment involving many stakeholders with conflicting interests
  - [41]: is one of the early papers discussing distributed design of information systems, integrating spatial and fact information coming from different data sources over networks
  - [42]: discusses the integration of simulation models for flood management into decision support
  - [43]: is a workshop report discussing problems and solutions for water-related software systems
  - [10]: is a workshop report discussing the boundaries between environmental information systems and environmental decision support systems
- 2001
  - [44]: discusses the fundamental role of indicators in the generation of higher level information suitable for decision support
  - [45,46]: show typical system designs for environmental monitoring systems
  - [47]: identifies decision theory as baseline for decision support systems
  - [48]: presents requirements and use cases for participatory processes involving a wide stakeholder audience
- 2003
  - [49]: discusses integration efforts on the way from data to knowledge
  - [50]: shows the use of services to wrap simulation models
  - [51]: presents GPS based tracking for the optimisation of logistics processes
  - [52]: is a discussion of workflow systems for environmental administrations
  - [53]: presents the reader with a discussion of complexity issues related to human factors of ESS

- — [54]: is one of the early papers describing multi governmental reporting, in this case for the European Water Framework Directive; this paper was one of several papers related to projects of the European research framework program, which became an important research driver at the time [55]
- 2005
  - — [56,57]: give a good perspective on typical government information systems at state and national level
  - — [58]: is one of the first papers discussing sensor web enablement
  - — [59]: discusses integrated modelling toolkits and their frameworks
  - — [60]: shows how the combination of analysis and visualisation methods are embraced towards interactive environmental data analytics
  - — [61]: is the first publication of a series of research papers towards environmental service infrastructures - research which has dominated the ESS part of the European 6th framework research program, see also [62]
- 2007
  - — the first papers on semantics and ontologies appear, both for use in the data and in the modelling sphere [63,64,65,66]
  - — [67] is a large project to progress sensor web enablement and its standards
  - — [68] is one example out of a class of applications devoted to risk management, a DSS integrating various tools, based on free software
  - — [69,70] are two of several articles discussing the communication of information to the public
  - — [71,72] are papers on evolving open source software in the area of geographical information systems
- 2009
  - — [73] describes the ICT-Ensure project, which has amongst others established a literature repository around the EnviroInfo community[6]
  - — [74] discusses coupling of models using OpenMI
  - — [75] is one of the first papers on crisis management; ISESS here and there overlaps with the community on ICT for crisis management [7]; see also [76]
  - — [77] is one of many papers to come (and yet to come) on climate change
- 2011
  - — in Europe, the landscape is progressively understood as part of the Digital Agenda for Europe and the so-called Single Information Space for the Environment [78]; many papers in the 2001 proceedings [5] are in relationship to this theme
  - — along this line, there is a number of articles related to platforms and standards allowing the composition of services, e.g. [79,80,81]
  - — this includes infrastructures for semantics [82]
  - — climate change applications are progressing more and more, see e.g. [83]

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[6] http://www.iai.kit.edu/ictensure
[7] http://www.iscramlive.org

- 2013
  - ESS pick up developments of the Future Internet initiative, see e.g. [84]
  - mobile applications on smart mobile devices play an increasingly important role; in [85] an example is given to use crowd sourcing to cope with illegal waste dumping
  - again many papers are in relationship to pan national information infrastructures, e.g. for reporting [86]
  - [87] is giving an introduction into visual analytics methods and tools

The most obvious new theme in the 2015 edition of ISESS is High Performance Computing. A workshop is organised in collaboration with the Australian NCI (National Computing Initiative)[8].

7   Patterns in Environmental Software Systems?

It is difficult to draw more fundamental conclusions about the nature of the field without a more in-depth analysis. ESS are often defined as software systems, a) which contain heterogeneous space-time information, often geospatial multi-dimensional scientific information with some uncertainty, b) which often support complex decision making processes, c) which often use different software tools and methodologies to solve a problem, d) which often have to integrate data across boundaries of various sorts, e) where often information is re-used beyond its original intention, f) where it is necessary to bridge the gap between science and practical application.

Although there are several overview papers of the field, I have not found a real classification or taxonomy in the literature.

One approach to look at it which I would like to repeat here is one which was developed in a project to define a curriculum on environmental informatics, as part of an EU-Canadian education project [88]. While this curriculum was never implemented in terms of course modules, the structure defined by the project is probably still somewhat useful, though some terms may be outdated and it is probably not complete. The idea is to structure the information processing in terms of a level-of-complexity approach, which clearly distinguishes between situations in which information is produced, processed, integrated and re-used. Table 4 shows this proposal.

Whether there are typical patterns in ESS or not, one point is becoming very clear when going through the history of ISESS from back to front, namely that:

> The field which we call Environmental Software Systems is progressively defined as a synthesis of infrastructures, platforms, re-usable services and tools which provide end users with local-to-global transparent access to information and services; the challenge remains to supply software developers with improved means to build reliable, integrated, multi-tool systems at reasonable cost.

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[8] `http://nci.org.au`

Table 4. Proposed enviromatics curriculum, taken from [89]

I: WHY ENVIROMATICS ?
1. History of Enviromatics Developments
2. Application Areas
3. Introduction into the ECCEI Course
4. Introduction into the Common Example

II: ENVIROMATICS BASE METHODS
II.A Problem Definition and System Analysis
5. Problem Definition
6. System Analysis
II.B Data Management / Information Modelling
7. Environmental Data, Data Preparation and Acquisition
8. Monitoring
9. Environmental Databases and Environmental Information Systems (EIS)
10. Information Modelling
11. Meta Information in Environmental Databases
II.C Data Analysis
12. Environmental Statistics
13. Geographical Information Systems
14. Visualization
II.D Diagnosis and Interpretation
15. Environmental Risk and Impact Assessment
16. Environmental Models
17. Environmental Indicators
18. Diagnosis and Artificial Intelligence

II.E Decision Support
19. Target Groups for Decision Support
20. IT Techniques and Systems for Decision Support
21. Scenarios
22. Presentation in DSS

III: ENVIROMATICS INTEGRATION METHODS
III.F EIS Interoperability
23. Integration Problems
24. Environmental Data Standards
25. Building and Managing Environmental Data Networks
III.G Meta Information Systems
26. Properties of Meta Information
27. Environmental Data Catalogs
28. Environmental Catalogs on the World Wide Web
29. Multilingual Information Systems
III.H Open EIS Architectures
30. Properties of Open EIS Architectures
31. Review of Architectures
32. Generic EIS Infrastructures

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