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Propagation and remote sensing / Propagation et télédétection

Radio sciences and disaster management

Radios sciences et gestion des catastrophes

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ABSTRACT

Radio communication and observation services are critical at all levels of disaster management. Among the programmes to be introduced to reduce the impact of natural and human induced disasters, potential transfers from basic research in radio science to research in disaster management are examined. Two specific aspects are studied: (i) the transfer of image processing techniques, developed in other contexts, to risk management; and (ii) the use of knowledge gathered on the effects of variations in the space environment on trans-ionospheric propagation, to gauge the interest of integrating those effects into the exploitation of communications and observation systems. Four families of image processing techniques are shown to be particularly useful to the disaster manager: zoning, counting of objects, roads and network detection, and damage assessment resulting from a series of different radiometric and geometric methods. A brief review of the effects of ionospheric variations on radio propagation up to a few GHz shows both the potential impacts of those variations on communication systems and the importance of introducing ionospheric corrections into several observation services.

RÉSUMÉ

Les services de communication radio et d'observations radios sont essentiels dans toutes les phases de gestion de catastrophes. Parmi les programmes à engager pour réduire l'impact des catastrophes naturelles ou induites par l'activité humaine, on examine la possibilité de transferts de résultats d'études fondamentales, conduites dans le domaine des sciences radio, vers la recherche opérationnelle. Deux aspects particuliers sont étudiés : (i) le transfert de techniques de traitement d'images, développées dans d'autres contextes, dans la gestion des risques, et (ii) l'utilisation des connaissances acquises, sur les effets des variations de l'environnement spatial sur la propagation transionosphérique, pour évaluer l'intérêt d'une prise en compte de ces effets dans l'exploitation des services de communication et d'observation radio. On montre que quatre techniques de traitement d'image peuvent être extrêmement utiles à la gestion des catastrophes : le zonage, le comptage d'objets, la détection des routes et autres réseaux, et l'évaluation des dommages qui est le résultat de l'enchaînement de plusieurs traitements radiométrique et géométrique. Une brève revue des effets des variations de l'ionosphère sur la propagation des ondes radio, jusqu'à quelques GHz, permet d'évaluer les impacts potentiels sur

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les systèmes de communication et montre la nécessité d'introduire des corrections ionosphériques dans plusieurs services d'observation.

1. Introduction

Radio communication and observation services are critical at all levels of disaster management. Radio communications are essential for sending and distributing alarm messages, exchanging information between different teams/groups, defining and coordinating relief activities, and disseminating information and instructions to public and private services as well as to the public. Radio observation services (available 24h/24, whatever the weather conditions) are essential for assessing damages, detecting and tracking fast varying geophysical and hydro-meteorological events (earthquakes, tsunamis, hurricanes, typhoons, etc.), and for providing information for planning and conducting relief activities.

Measures to be taken in the field of radio communications for disaster prevention, mitigation and relief are within the scope of the International Telecommunication Union (ITU). Through the adoption of dedicated Resolutions, ITU issues recommendations and encouragements to national and international administrations for very specific actions. As an example, Resolution 646 (Geneva, 2003), dealt with public protection and disaster relief, Resolution 647 (Geneva, 2007) encouraged making immediately available pre-identified and pre-coordinated frequencies, and/or flexible technologies, to allow near-instantaneous decisions on the use of the available radio-frequency spectrum. Problems of interconnection and interoperability, particularly sensitive at the time of disaster, are dealt with through the ITU's telecommunication standards. In certain cases, when the "wired" telecommunication infrastructure is significantly or completely destroyed, ITU deploys satellite terminals to help restore vital communication links.

The access to observation data is facilitated by the International Charter "Space and major Disasters" signed by major space agencies. This charter aims at providing a unified system of data acquisition and delivery to those affected by natural or man-made disasters through authorised users. Most of the time, the only data are radio data, which are available in nighttime as well as in daytime, and for any weather condition (more than 60% of the Earth's surface is overcast with clouds on the average). Efforts are still to be made for the constitution of data bases dedicated to disaster management, i.e., of databases of the same nature allowing comparisons before and after a disaster. Access to ground-based data, often recorded continuously, is presently made through national and international data exchange programmes.

When available, images from remote sensing satellites are the best sources of information for disaster management. They can be acquired quickly and cover large geographical regions. Photo-interpreters use them to provide, as quickly as possible, maps summarising the information which may be used by organisations in charge of disaster management (for major risks: ministries, civil defence, regional and local administrations, UNO, NGO, etc.). For that purpose, several services for fast data handling have been set up in the world. As an example, in eight hours, SERTIT [1] (the French Regional Service of Images Processing and Remote Sensing Analysis) transforms satellite images of the stricken zone into damage assessing maps. According to the available data, they may be completed by more detailed maps of more restricted (or limited) areas, representing for instance the intensity of the events, the situation in real time, etc. In areas for which not much information is available, basic maps may help rescue teams to facilitate the victim's localisation, to locate potential refugee camps, to set up assistance facilities, etc. The main problem with satellite images is that there are still few reliable software tools for fast post processing. This means that satellite images are often visually analysed by photo-interpreters with a non-negligible probability of introducing bias in the interpretations. The use of automatic techniques could allow both a faster processing of images covering a very large area, and more objective ways of qualifying the results. Such data handling procedures are not new, but their application on satellite images in a complete chain, is still recent. One may expect that the present paper will draw interest on integrated chains of remote sensing images processing.

If numerous examples show that measures taken in the domain of radio communications and radio observations have clearly improved the situation for early warning and relief operations, statistics made on the occurrence of disasters and on the consequences in terms of number of people affected and damages [2] show that a lot has still to be done to reduce the impact of natural and human induced disasters. In the context of a future ICSU (International Council for Science) interdisciplinary program on "Integrated Research on Disaster Risks", all Scientific Unions have been invited to examine potential ways to contribute. The objective of the present paper is: (1) to show on a few examples that results obtained in the domain of radio science could be usefully used for disaster management, (2) to trigger studies on potential transfers from basic research to operational research in the domain of radio science.

For the sake of convenience, the only considered aspects are the transfer of image processing techniques (developed in other contexts) to risk management, and effects (not presently taken into account) of variations in the space environment of the Earth on radio communication and observation services. The transfer of image processing techniques has as objective the development of integrated processing chains. The effects of variations in the space environment of the Earth include noise and interference from solar radiations, perturbations in radio propagation induced by disturbances of the ionosphere caused by X-ray emission from the Sun, effects of ionospheric scintillations on RNSS such as GPS (Global Positioning System), SAR imaging, and radio propagation across a fire front. The link between both aspects is to improve the quality and the number of radio images used for disaster management, in particular when looking for "hidden information" such as infrastructure conditions, victim localisation, potential refugee camps, etc.

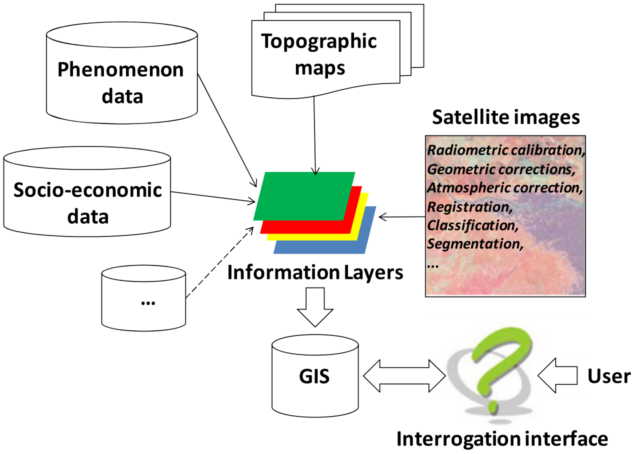

Fig. 1. Organisation of multi-source data.

Fig. 1. Organisation des données multi-sources.

The plan of the article is as follows. Section 2 is devoted to the architecture of an integrated processing chain of risk and to the required image processing techniques. Section 3 is dedicated to radio communication and observation systems (below a few GHz), and to effects associated with variations in the space environment of the Earth. Finally, a provisional conclusion is proposed in Section 4.

2. An integrated processing chain

At the time of a natural disaster in a populated zone, a fast and efficient organisation of disaster management is of primary importance for assisting the populations, reducing the number of victims and limiting economic damages. A lack of proper organisation induces delays in assistance operations, which may make operations more difficult, increase losses, and prevent potential return to a nominal situation. During a crisis, time is a critical factor [3]. As illustrated in Fig. 1, observation data, provided by all available remote sensing instruments at that time (generally radars and radiometers on the ground or onboard satellites and planes), need to be collected over relevant time intervals, entered into data handling chains, then transmitted via telecommunication channels to the experts, to the decision making authorities, to a number of relevant organisations and to the media.

New technological approaches are required to allow for a more efficient management of risk before, during and after a potential crisis. Therefore, they must take into account the specificity of the actions to be taken at each phase of the crisis and the specificity of the tools to be used. New methodologies are necessary to design systems combining the use of telecommunication tools (communication, remote sensing, computer science, information technology, etc.), databases organised as a function of the points in space and time, and regulations relevant for each location.

Risk prevention and crisis management imply to transmitting the right information to the right person in the shortest possible time. When risk becomes disaster, the crisis requires simultaneous access to numerous environmental and regulation databases. Structures and software used for the different databases, and for the transmission networks, may be different in terms of performance, architecture, etc. A mapping of the facilities and of their operating conditions is therefore a crucial element, which has to be available to the rescue teams as soon as possible. The implementation of such a system highlights two aspects of the evolution of risk. Firstly, the temporal aspect within which it is necessary to find an equilibrium between time scales to trigger alerts and other time scales to inform the population, set up assistance tools, close roads, etc. Secondly, the localisation of critical areas has to be clearly established.

2.1. A multi-level response

A system intended for risk must be able to provide answers at several levels [4,5]. Indeed, when analysing the sequence of events, which constitutes a crisis, one observes several successive phases [1]. At each phase, the priorities to be assigned are different. During the crisis, the obvious priority is the resolution of the crisis, not its study. Once the crisis has been overcome, and the situation practically stabilised, it is time to make a detailed analysis and to try to understand what happened. Taking account that information in future procedures may allow to eliminate the risk, or if it cannot be fully avoided, to facilitate the crisis management and to reduce its consequences.

The integration of a risk chain requires taking into account all the treatments and all the corrections, from satellite data acquisition until the intervention phase on the ground. The difficulty is that the operations to be done are not necessarily at the same level, and that they are not conducted by the same person or the same organisation. Figs. 2 to 5 present the various necessary actions.

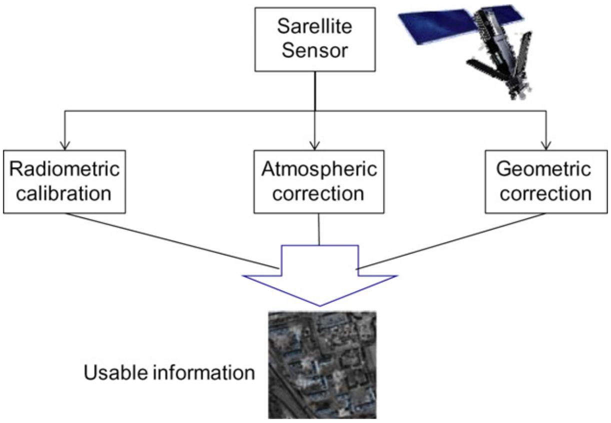

Fig. 2. Satellite segment.

Fig. 2. Segment satellite.

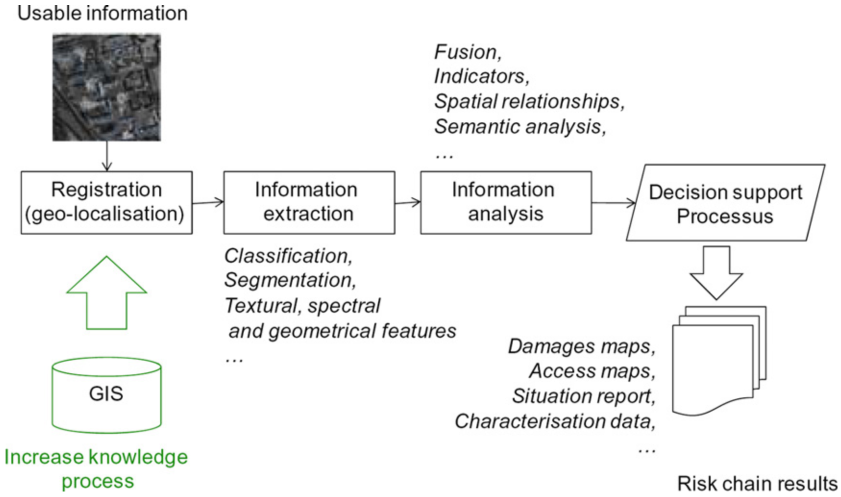

Fig. 3. Remote sensing segment.

Fig. 3. Segment treatment d'image.

Fig. 6 presents the temporal diagram of the operations. The agencies work with the images available at the beginning of the crisis. They produce detailed maps, which may give a wrong representation of the real situation. In this diagram, one sees that it is possible to have a feedback. This allows correcting and updating the maps produced at the beginning of crisis. It uses images and information provided by rescue teams. This feedback process is pursued throughout the crisis.

2.2. Image processing and disaster management

Fast access to the right information items is crucial at all stages of disaster management. The required information includes existing information and operational information. The existing information is mainly of administrative nature (location of buildings, roads, utility networks, etc.). The operational information consists of information collected during the disaster (disaster location, victims, building and road conditions, etc.). It has to be completed by the same type of information collected just before to allow reliable before–after comparisons. Existing information is a priori entered in well organised data bases. Operational information, requiring the acquisition of data from different types of sensors, is mostly geographically related and in a large part very dynamic. It is recorded in inhomogeneous spatiotemporal data bases. However, comprehensive analyses, involving very large data bases and experts from different disciplines [6], cannot be expected at the first stages of disaster management.

For providing useful answers to rescue teams, and assistance to persons on the site of a catastrophic event (earthquake, volcanic eruption, flood, etc.), it is necessary to extract synthetic (or tactical) information which may help to make fast decisions. For so doing, specific approaches, i.e. specific analyses, architectures and algorithms have to be developed, for each type of disaster: floods, earthquakes, tsunamis, etc.

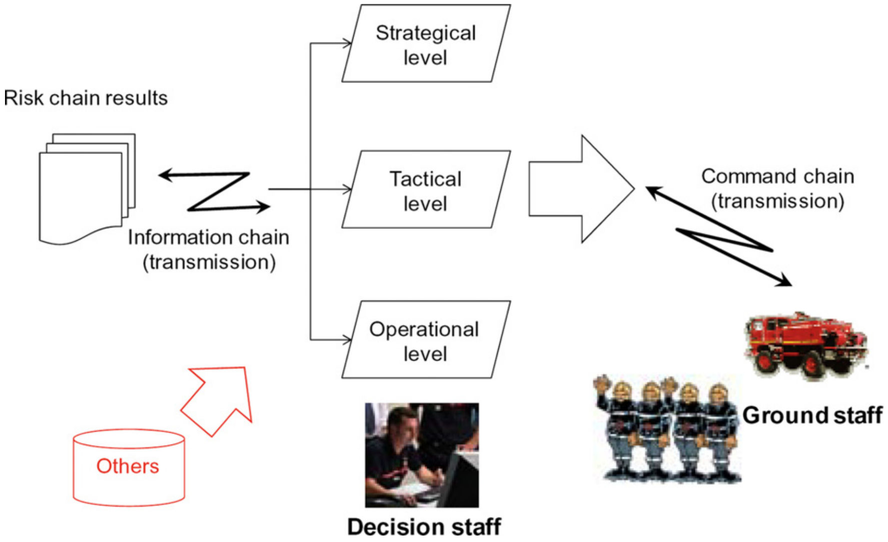

Fig. 4. Decisional segment.

Fig. 4. Segment decision.

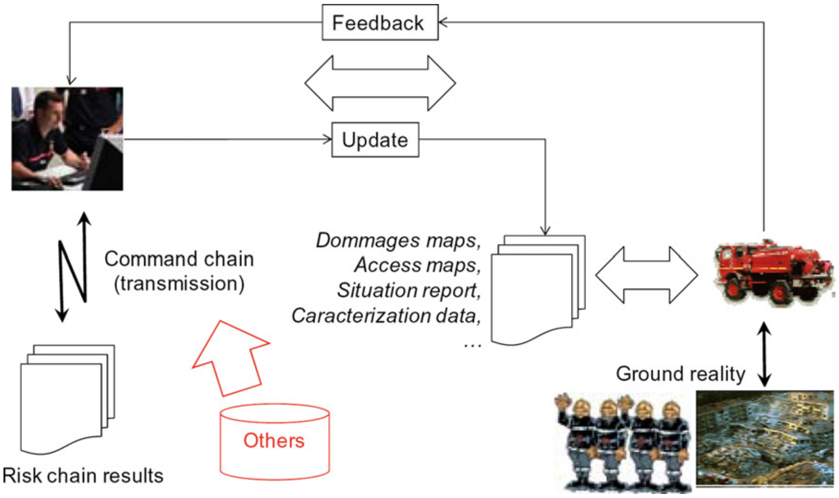

Fig. 5. Intervention segment.

Fig. 5. Segment intervention.

Four families of functionalities are particularly useful to a disaster manager: zoning, counting of objects, roads and network detection, and damage assessment.

2.2.1. Zoning functionalities

Zoning has as objective to identify the main classes of land (e.g. urban, industrial, forested, agrarian zones, etc.) and networks (communication lines, power lines, roads, water ways, etc.). It can be conducted from a specific part of an image like, in the case of an urban area the dense urban area or the scattered urban area. The first step of the analysis consists in the elaboration of global maps representing the different zones derived from satellite images. Non-supervised classification [8] based on texture parameters (Gabor filter, Quadrature Mirror Filter (QMF) or Haralick coefficient [7]) and geometrical parameters (dimensions of the objects) provide rough maps of land occupation. They have the advantage of requiring limited intervention from the operator. More detailed classification of the infrastructures require supervised classification [9], i.e. much greater involvement of the operators. However, the results are of much better quality. The maps show classes of objects defined according to the interest that they represent for the implementation of assistance. Generally, these classes are: buildings, areas of destruction, roads and access means, open areas (waste land), vegetation and refugee camps.

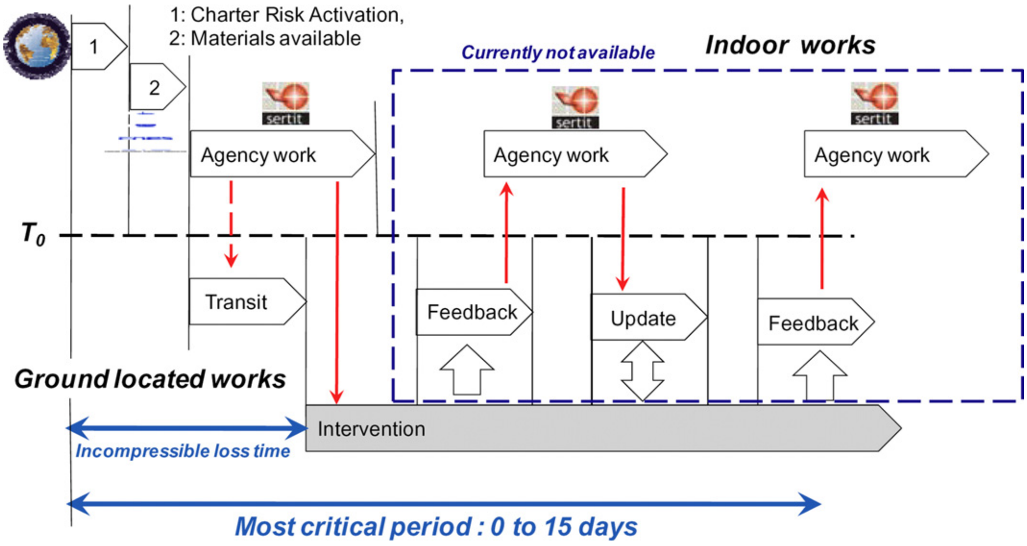

Fig. 6. Temporal schedule.

Fig. 6. Schéma temporel.

2.2.2. *Counting functionalities*

The counting of objects (habitations, industrial zones, refugee camps) present in a zone is of primary importance for the elaboration of an Assistance Action Plan. It is performed from combined analyses of several geometrical parameters such that: contours of the objects, shape, roundness, connectivity, etc. As an example, the ratio of the perimeter to the surface allows discriminating objects with similar contours.

The tools which are used are mainly segmentation algorithms. They allow determining zones with homogeneous radiometric aspect and contrasts as compared to their surroundings. The zones obtained are analysed according to their form, their texture and their location compared to the shades present in the image.

2.2.3. *Road detection*

Provided the conditions are well evaluated, the identification of roads and in general of transportation networks (roads, railways) provides key information to define access paths for the rescue teams. Wrong choices induce waste of time and delays in assistance. Generally, published papers on access paths don't correspond to disaster conditions. New approaches are needed for detection in disaster zones. A combination of radiometric attributes and texture attributes seems a good axis of work.

2.2.4. *Damage evaluation*

Damage evaluation in areas where rescue teams will have to operate is a very important phase for disaster management. The estimations are generally performed by crossing information extracted from satellite images with data provided by various external sources (databases, property registry survey, land occupation maps, etc.). They successively involved the use of zoning and counting operations similar to those used in other domains [10,11]. A series of different radiometric and geometric methods provides estimations of the damage level on housing, the number of deaths and of wounded and homeless persons, the availability of communication network, etc.

Detailed analyses may be used in a second assistance step. The analysis may show buildings, which present less significant damages, but may be dangerous. Such a situation may imply taking measures for preventing the occupants from returning to live in their houses, sometimes destroying them. Counting the tents in refugee camps allow checking in near real time the adequacy between assistance and needs, and if necessary, after discussions with the administrations involved, to make new decisions.

3. Radio science issues

At all stages of disaster management, it is essential to dispose of both reliable radio communication systems, to warrantee reliable exchanges of information between all the actors (administrative authorities, experts, rescue teams, victims, and public), and good quality observation data on the time and space evolution of the events in progress. While radio observations provide continuous monitoring (available 24h/24 and under all weather conditions), optical observations offer complementary information of great importance. In all cases, however, optical as well as radio observations are transmitted through radio channels.

As a consequence, radio science issues associated with disaster management are multiple. A few of them only can be introduced here. They will focus on the impacts on disaster management systems induced by degradations in the radio communication and observation systems caused by variations in the space environment of the Earth. As of today, such impacts have been considered as negligible. However, recent publications have shown that this is not always the case.

3.1. Radio communication and observation systems

Numerous published papers are available on radio communication and observation systems. The brief review given here has for objective to point out systems which are particularly sensitive to hydro-meteorological and geophysical disasters or/and to variations in the space environment of the Earth.

3.1.1. Communication systems

A universal communication system allowing communications at any time and between any points in space does not exist. For several reasons (security, cost, remote areas, etc.) several communication systems are presently used. They mainly include: fixed-voice telephony, HF (3–30 MHz) and VHF (30–300 MHz) communications, mobile phones (connected to cellular networks of specialised base stations or to orbiting satellites), etc. LF frequencies (0.3–3 MHz) are still used for navigation by several countries, in particular to back up the RNSS.

According to the sensitivity of communication infrastructures to hydro-meteorological and geophysical disasters, and of radio propagation to spatial environment conditions, redundancy, when it exists, may be very useful. However, such a redundancy is far from being the rule. Access to telecommunications and radio broadcasting is still very limited in rural and remote areas of developing countries [12]. Despite the efforts accomplished to enhance telecommunication infrastructures, including transmitting communications through power lines [13,14], the probability of the absence of reliable communication systems at the time of a crisis is not negligible. Obviously, no actions, except forecast, may be taken for radio blackouts in remote regions where the only available communications are HF communications.

The most direct way to mitigate the absence of reliable communication systems, due to destructions of infrastructures caused by meteorological or/and geophysical disasters is to provide hand-held satellite phones or/and satellite terminals to help restore vital communication links. However, when the disaster management requires interoperations of satellite and terrestrial communications, the only way to operate is to deploy mobile ad-hoc networks [15]. A mobile ad-hoc network is a self-organising network of mobile devices (or nodes), connected by wireless links, that does not require any fixed entity or/and any existing infrastructure. The absence of infrastructure imposes to the nodes to behave as routers, which contribute to the definition and configurations of routes for other nodes. Communications between nodes may be direct or via nodes used as relay. Such a capability allows setting up information networks and command systems required for crisis management.

The specificity of the ad-hoc network is that it does not require any fixed infrastructure and so is easy and fast to deploy. Ad-Hoc technologies are ideal for tactical applications as aid operations, military operations and exploration. As an illustration of the use of the ad-hoc technology, one may mention:

- Emergency services: search and rescue operations, earthquakes, fires, floods (the objective is to replace – or to extend – wire networks);
- Wireless sensor networks: environmental applications (climate, monitoring the Earth, monitoring animal movements, etc.) or remote control of domestic equipments;
- Mobile networks: embarked informatics equipments, communicating vehicles;
- Mesh networks: emerging technology allowing to extend distances or densities.

The information network dedicated to the local authorities and, via the media, to the public is deployed behind the tactical communication network. Tests performed, for example in the context of the European program OASIS (see http://www.oasis-fp-.org/documents.html), show that if ad-hoc networks are ideal for crisis management in the absence of fixed infrastructures, flexibility may limit performances. As an example, the use of omni-directional antennas, allowing communication between nodes in all directions, limits the network capacity and facilitates external intrusions. Moreover, according to the continuous growth of the demands for allocated frequencies, the search for a vacant frequency band, i.e. for an unoccupied frequency band free of interferences, may be a serious problem for the use of mobile ad-hoc networks. However, one may expect that future cognitive radio devices will be able to seek and use in a dynamic way the frequencies for network access [16].

3.1.2. Observation systems

The radio observations services are mainly based on ground-based and space-based radiometers and radars.

Ground-based observations are mainly performed by radars and radiometers, which provide continuous and complementary information. As an example, a review of surface-based microwave and millimetre-wave radiometric remote sensing of the troposphere is given in [17]. The correction of propagation effects is done by analysis of RNSS signal often included in ground-based techniques. In a few year time they have led to an observation technique, called “GPS meteorology”, which consists in monitoring characteristic parameters of the medium (electronic density, atmospheric density, temperature, humidity, etc.) from variations in the phase or/and amplitude of GPS signals received at the ground [18,19]. Steam constitutes the main atmospheric parameter derived from this technology. It does not measure temperature. However, the measurement of the steam composition is an essential parameter for the prediction of specific events like flooded rivers such as "Crues Cévenoles", in France.

Examples of applications are the detection of thunderstorms in their first phases of development [20] or the monitoring of a tsunami in progress [21]. Obviously, the same type of method can be used for space-based RNSS measurements on board Earth orbiting satellites. An application to the global probing of the entire vertical electron density structure from a low Earth orbiting satellite is given in [22].

Measurements performed from airborne and space-borne platforms have been reviewed by several authors [17,4]. They give access to land parameters as well as to meteorological parameters such as the atmosphere temperature (troposphere, stratosphere), the snow parameters, etc. Presently, they are assimilated on an operational way in meteorological prediction models. A review of those aspects is given in [41].

As mentioned in the introductive part, images from remote sensing satellites are the best sources of information [40]. The problem of access to the data is now partly solved by the international charter "Space and Major Disasters" signed to day by the main space agencies (see http://www.disasterscharter.org/). Authorised users can call a single number to request mobilisation of the space and associated ground resources (RADASAT, ERS, ENVISAT, SPOT, IRS, SAC-C, satellites NOAA, LANDSAT, ALOS, DMC satellites and others). Among the remaining difficulties to be solved are: differences in calibration techniques adopted for each instrument, access to data prior to the disaster in order to have reference images, and coordinated programmes to decrease time intervals between satellite passes over critical regions.

3.2. Environmental effects

Basically, communication and radio systems are sensitive to variations of the ionosphere and the atmosphere properties generated on a more or less direct way by variations in the solar activity, i.e. by space weather events. For the sake of completeness more specific points, like communication at the vicinity of a fire, may be added.

3.2.1. Direct effects of solar radio noise

Sun outage, or interruption of geostationary satellite signals caused by interference from solar activity, is a well known phenomenon [23]. It occurs when the sun is just behind the spacecraft and when solar radiations enter the beam of the downlink receiving antenna and produce noise or/and interferences. Generally sun outages occur in February, March, September and October, i.e. around the time of equinoxes. Transmissions in K band (around 20 GHz) are more affected than in C band (around 4 GHz). Solar radio bursts were first discovered as the result of their interference in early defensive radar systems during the Second World War [24]. They are produced in association with solar flares. They cover a broad frequency range that interferes with frequencies used by RNSS (Radio Navigation Satellite Systems) and other navigation systems. Effects of solar radio bursts on GPS signals have been reported by [25], including during the solar minimum [26]. The solar burst was exceptionally intense and seriously impacted GPS operations. The occurrence of intense radio bursts has not been established so far.

Solar radio bursts also affect wireless technologies [3]. Statistical studies have shown that there is a solar radio burst ($f \sim 1$ GHz and greater), with amplitudes $> 10^3$ solar flux units, every few days during solar maximum conditions, and so that they can cause problems (noisy signal or signal interruption) in contemporary wireless systems [24].

3.2.2. Ionospheric effects

Environmental effects on HF (radio contacts) and LF (radio navigation system mainly used as a backup and land-based alternative to GPS and other RNSS systems) radio communications are well documented in the NOAA document on Space Weather Scales [27]. Disturbances of the ionosphere, caused by X-ray emissions from the Sun, are at the origin of radio blackouts classed from minor (around 950 days per solar cycle) to extreme (less than 1 per cycle). Extreme events initiate extreme effects with complete radio blackouts on the entire sunlit side of the Earth, lasting for a number of hours, during which no HF radio contacts are possible and LF navigation signals experience outages causing loss in positioning. A better way to evaluate the risk is probably to consider moderate (around 350 days per solar cycle) to strong (around 140 days per solar cycle) radio blackouts. They are observed on large to very large regions on the sunlit side of the Earth. HF radio contacts are lost from tens of minutes to one hour. LF navigation signals are degraded over the same time intervals. As a consequence, taking around 400 disasters per year, with continuous survey during around one week per disaster, we reach numbers suggesting that the probability of loss in radio contacts and degradation in navigation signals, at the crucial time of a disaster, are non-negligible. Provided there are available in the region considered, other communication systems may be used. But numerous disasters take place in remote areas were the only communication channel is HF radio. Recent studies have shown the interest of taking into account the environmental effects in the conception of the HF systems [28].

Effects of ionospheric scintillations on communication signals in the VHF and UHF (300 MHz–3 GHz) frequency bands have been known since the end of the seventies [29]. They are caused by the crossing of ionisation density anomalies mainly observed (in geomagnetic latitudes) near the magnetic equator ($\pm 10^\circ$) and within the auroral oval (65°–75°) and polar cap ($> 75^\circ$) [30]. The scintillation amplitudes are maximum at the solar maximum. The equatorial scintillations demonstrate a seasonal dependence, depending on the longitude. The need to model ionospheric data is at the origin of the C/NOFS satellite launched in 2008 [31].

As explained in [32], GPS signals, transmitted at ∼ 1.6 and 1.2 GHz, are also vulnerable to ionospheric scintillations. GPS is a weak signal system and scintillation can degrade GPS receiver operation. Degradation occurs when phase scintillations introduce ranging errors or when loss of tracking and failure to acquire signals increases the dilution of precision. GPS scintillations are frequently observed. They have been shown to occur most often near the magnetic equator and during solar maximum, but can occur anywhere on Earth during any phase of the solar cycle, including during geomagnetic quiet days. Impacts can be particularly severe at low magnetic latitudes in the post sunset hours. As noted by the authors, "understanding the effects of scintillations on GPS receivers and creating strategies to mitigate those effects requires an understanding of ionospheric science and GPS receiver engineering".

As stated in [33], "to a greater or lesser extent, the ionosphere affects all trans-ionospheric radio frequency communication, surveillance, and navigation systems operating at frequencies below ∼ 2 GHz. The largest effects are seen at the lower frequencies; however, sensitive systems with long integration times can also be affected by the ionosphere with operating frequencies as high as 10 GHz."

3.2.3. *Environmental effects on SAR imaging*

The ionospheric effects are more severe for systems using multi point observations, like Synthetic Aperture Radars (SAR), Interferometric Synthetic Aperture Radars (InSAR) and SAR Polarimetry, than for satellite communications which involve only one-way path through ionised regularities. The ionosphere can affect the electromagnetic propagation in a number of ways including reflection, refraction, frequency dispersion, time delay and Faraday rotation. Those effects are generally stronger at lower frequencies but variations in ionospheric electron density can be important for propagation at frequencies up to about 10 GHz. If prediction, detection, and correction of Faraday rotation have been developed for a SAR operated in the L band (1–2 GHz) [23], a reliable model still needs to be established for the evaluation of ionospheric effects on SAR imaging in VHF/UHF band [34].

Atmospheric effects need to be taken into account from the L band up. From around 2 GHz up, the water vapour distribution in the lower thermosphere is one of the major limitations for interferometric SAR. Methods for atmospheric corrections are presented in [35] and [36]. Other atmospheric effects, in particular resonant absorption at specific frequencies, oxygen included, take place above 20 GHz.

3.2.4. *Radio communications at the proximity of a fire*

Difficulties encountered by firemans at close proximity of high intensity fires, in particular for communications in HF-VHF bands across the fire front, are of an entirely different nature. Studies shown that the signal attenuations are due: (1) to radio wave absorption and refractions in layers of slightly ionised gas (fire plumes), and (2) in radio wave refraction caused by gradients in pressure, temperature and ionisation in the propagation medium [37–39]. Propagation experiments in moderate intensity fires show that the X-band frequencies were the most affected with maximum attenuation rate of 4.5 dB/meter [39]. It is likely that the frequencies that are the most attenuated depend on the type of fire and more specifically on the chemical species involved.

4. Conclusion

The disaster management systems still need to be considerably improved. A very simple formulation of the paradigm to be solved may be summarised by: "to provide the right information, to the right person, at the right time, and for the right decision". In practice, this consists in providing the experts and rescue teams with technical solutions, which allow them to be informed of any evolution in real time, to have at their disposal the relevant assistance tools (cartographic supports, simulations, etc.), to have a good view of the operation in progress, etc. This requires the deployment of sophisticated solutions based both on competences from risk specialists and competences from Information technology (e.g. for the structuring of information and decision chains). As shown in Section 2, the use of simple functionalities in signal processing (zoning, counting of objects, roads and network detection, and damage assessment resulting from a series of different radiometric and geometric methods) is very useful for providing quantitative information to the crisis cell.

Examples of effects on radio communication and observation systems, of variations in the space environment of the Earth, have pointed out caveats in the functioning of disaster management systems. The four main ones are probably:

- the risks of perturbation or even interruption in communication systems used by part of the actors following hydro-meteorological or geophysical events or a variation in the ionosphere;
- the risks of positioning errors due to RNSS scintillations;
- the risk of "holes" in observation data due to too inadequate validation thresholds for the data transmission, or the risk of degradations in the quality of images due to the absence of corrections for ionospheric effects.

Prevention measures may be taken at different levels.

Risks on communication systems are handled differently for hydro-meteorological and geophysical events and for ionospheric events. For the first type of events, where infrastructures are destroyed, the only way to mitigate the absence of reliable communication systems is to provide hand-held satellite phones or/and satellite terminals to help restore vital communication links. However, when disaster management requires interoperation of satellite and terrestrial communications the only way to operate is to deploy mobile ad-hoc networks, which supposes the existence of unoccupied frequency bands free of interferences. Effects associated with ionospheric events mainly concern the HF/VHF communication systems. In the absence of any other communication links the only possible action is to check for space weather alerts.

Risks on RNSS are linked with space weather events. However, although errors are more severe during solar maximum, perturbations may be observed at any time, even during solar minimum. For critical applications, at a threshold to be defined, it could be unwise to rely on RNSS alone for navigation. By the end of the C/NOFS mission one may expect to have a better view of the physics controlling the geomagnetic low latitude ionosphere and to have all elements to nowcast and forecast scintillations in this region.

Risks on observation systems are clearly associated with space weather events. They must be handled differently if the decision to be taken is to use or to reject the collected data, or if it is to try to make the best use of them. In the first case, warning and forecast provided by space weather centers may be sufficient to stop data analyses. In the second case corrections must be applied. Most of remote sensing images being obtained above ~ 1 GHz, i.e. in frequency bands where ionospheric events are supposed to have negligible effects, the only corrections presently applied are radiometric and atmospheric corrections. However, sensitive systems with long integration times being affected by the ionosphere with operating frequencies as high as 10 GHz [33], the question about ionospheric corrections need to be reconsidered. Presently it is not clear if corrections are easier to make on the output data or if, as suggested in [34] instrumental devices have to be developed to minimise the effects induced by ionospheric events.

Numerous other potential transfers from basic research to operational research in the domain of radio science need to be examined. An obvious direction is the improvement of remote sensing techniques already used for the acquisition of information on the displacements of meteorological phenomena (cyclones, hurricanes, cloudbursts, etc.), the evaluation of the consequences in terms of hydro-meteorological catastrophes (see 2009 flood at Bombay), the modifications in various landscapes, and confirmation of the scenario during and after disaster. Other directions concern high time and space resolution measurements at the time of a disaster, electronic and photonic devices, etc. The authors hope that the very preliminary analysis presented here triggers exhaustive studies on the contribution of radio science to disaster management.

References

[1] T.J. Tanzi, S. Servigne, A crisis management information system, in: Proceedings of the International Emergency Management and Engineering Society, TIEMEC'98, Washington DC, May 19–22, 1998, pp. 211–220.

[2] J. Rodriguez, V. Femke, R. Below, D. Gupar-Sapir, Annual disaster statistical review 2008, the numbers and trends, Centre for Research on the Epidemiology of Disasters, 2009.

[3] B. Bala, L.J. Lanzerotti, D.E. Gary, D.J. Thomson, Noise in wireless systems produced by solar radio bursts, Radio Sci. 37 (2) (2002) 1018, doi:10.1029/2001RS002481.

[4] T.J. Tanzi, S. Servigne, Vers un système spatial temps réel d'aide à la décision, Journée SIGURA octobre 1997, Rev. Internat. Géomatique 8 (3) (1998) 33–46.

[5] R. Laurini, La TéléGéomatique : Problématique et Perspectives, Journées Cassini 1998, Marne la vallée 25–27 novembre 1998.

[6] T.J. Tanzi, P. Perrot, Télécoms pour l'ingénierie du risque. Collection technique et scientifique des telecoms, Hermes Editions, Paris, 2009.

[7] R.M. Haralick, K. Shanmugan, I. Dinstein, Textural features for image classification, IEEESMC 3 (6) (November 1973) 610–621.

[8] M. Campedel, I. Kyrgyzov, H. Maître, Unsupervised feature selection applied to spot5 satellite images indexing, in: JMLR, Proceedings FSDM, Anvers (Belgique), 2008.

[9] J. Rissanen, Modeling by shortest data description, Automatica 14 (1978) 465–471.

[10] Envenimation scorpionique, rapport annuel, sur la situation épidémiologique en Algérie année 2000, Technical report, Institut national de sante publique, République algérienne démocratique et populaire, ministère de la sante, de la population et de la reforme hospitalière, 2001.

[11] Répartition de la population par répartition par sexe, Année 2008, Technical report, CIA, CIA World Factbook, Mai 16, 2008.

[12] Y. Kawasumi, Communications for rural and remote areas, ITU News Magazine 05 (2004).

[13] X. Carcelle, An introduction to power line communications, in: MySQL Conference and Expo, Santa Clara, CA, April 14–17, 2008.

[14] M. Liennard, M. Olicas Carrion, V. Degardin, P. Degauque, Modeling and analysis of in-vehicle power line communication channels, IEEE Trans. Vehicular Technol. 57 (2) (2008) 670–679.

[15] G. Iapichino, O. del Rio Herrero, C. Bonnet, C. Baudoin, I. Buret, A mobile ad-hoc satellite and wireless mesh networking approach for public safety communications, in: 10th International Workshop on Signal Processing for Space Communications, SPC 2008, 25 Nov 2008, pp. 1–6.

[16] M. Ghozzi, M. Dohler, F. Max, J. Palicot, Cognitive radio: Methods for the detection of free bands, C. R. Physique 7 (2006) 794–804.

[17] R. Westwater, S. Crewell, C. Mätzler, A review of surface-based microwave and millimetre wave radiometric remote sensing of the troposphere, Radio Sci. Bull. 310 (Sept 2004) 59–80.

[18] M. Bevis, S. Businger, T.A. Herring, C. Rockon, R.A. Anthes, R.H. Ware, Remote sensing of atmospheric water vapour using the global positioning system, J. Geophys. Res. 97 (1992) 15787–15801.

[19] S. Businger, S.S.R. Chiswell, M. Bevis, J. Duan, R. Anthes, C. Rocken, R.H. Ware, T.M. Exner, T. Van Hove, F. Solheim, The promise of GPS in atmospheric monitoring, Bull. Amer. Mt. Soc. 77 (1996) 5–17.

[20] E. Doerflinger, Les applications météorologiques du système de positionnement satellitaire GPS, Navigation 56 (223) (2008) 15–40.

[21] G.A. Occhipinti, A. Komjathy, P. Logonné, Tsunami detection by GPS: How ionospheric observations might improve the Global Warning System, GPS World 50–56 (Feb 2008).

[22] N. Jakowski, Radio occultation techniques for probing the ionosphere, Radio Sci. Bull. 314 (2005) 4–15.

[23] F.J. Meyer, J.B. Nicoll, Prediction, detection and correction of Faraday rotation in full-polarimetric L-band SAR data, IEEE Trans. Geosci. Remote Sens. 6 (10) (2008) 3076–3086.

[24] L.J. Lanzerotti, D.E. Gary, G.M. Nita, D.J. Thomson, C.G. Maclennan, Noise in wireless systems produced by solar radio bursts, Adv. Space. Res. 36 (2005) 2253–2257.

[25] A.P. Cerruti, P.M. Kintner, D.E. Gary, A.J. Mannucci, J. Anthony, R.F. Meyer, P. Doherty, A.J. Coster, Effect of intense December 2006 solar radio burst on GPS receivers, Space Weather 6 (10) (2008).

[26] P.P.M. Kintner, B. O'Handlov, D.E. Gary, P.M.S. Kintner, Global positioning system and solar radio burst forensics, Radio Sci. 44 (2) (2009).

[27] NOAA space weather scale, http://www.swpc.noaa.gov/NOAAscales/.

[28] L. Bertel, C. Brousseau, Y. Ehrel, D. Lemur, F. Marie, M. Oger, New improvements in HF ionospheric communication and direction finding systems, in: J. Lilensten (Ed.), Space Weather, Research towards Applications in Europe, ESA, COST 724, Springer, 2007, pp. 147–168.

[29] H.E. Whitney, S. Basu, The effect of ionospheric scintillation VHF/UHF satellite communication, Radio Sci. 12 (1977) 123–133.

[30] S. Basu, E. Mackenzie, Su. Basu, Ionospheric constraints on VHF/UHF communication links during solar maximum and minimum periods, Radio Sci. 23 (1988) 363–378.

[31] O. De la Beaujardière, and the C/NOFS Science Definition Team, C/NOFS: a mission to forecast scintillations, J. Atm. Sol. Terr. Phys. 66 (2004) 1573–1591.

[32] P.M. Kintner, B.M. Ledvina, E.R. de Paula, GPS and ionospheric scintillations, J. Geophys. Res. Space Weather 5 (2007) S09003, doi:10.1029/2006SW000260.

[33] P.S. Cannon, K. Groves, D.J. Fraser, W.J. Donelly, K. Perrier, Signal distortion on VHF/UHF trans-ionospheric paths: First results from the wideband ionospheric distortion experiment, Radio Sci. 41 (2006) RS5S40.

[34] Z.-W. Xu, J. Wu, Z.-S. Wu, Potential effects of the ionosphere on space-based SAR imaging, IEEE Trans. Antennas Propag. 56 (7) (2008) 1968–1975.

[35] F. Meyer, B. Kamper, R. Bamler, J. Fischer, Methods for atmospheric corrections in InSAR data, in: Proceedings of Fringe 05, Frescati, Italy, 2005.

[36] Z. Li, E.J. Fielding, P. Cross, J.P. Muller, Interferometric synthetic aperture radar atmospheric correction: Medium resolution imaging spectrometer and advanced synthetic aperture radar integration, Geophys. Res. Lett. 33 (2006) L06816.

[37] J. Boan, Radio experiment with fire, IEEE Antennas Wireless Propag. Lett. 6 (2007) 411–414.

[38] C. Coleman, J. Boan, A Kirchhoff integral approach to radio wave propagation in fire, in: Antennas and Propagation Society International Symposium, 9–15 June 2007, IEEE, 2007, pp. 3752–3755.

[39] K.M. Mphale, Radiowave propagation measurements and prediction in bushfires, PhD thesis, James Cook University, Australia, 2008.

[40] P. Pampaloni, K. Saranboni, Microwave remote sensing of land, Radio Sci. Bull. 308 (March 2004) 30–46.

[41] F. Barlier, Galileo, a strategical, scientific and technical stake, in: Harmattan (Ed.), Collection Strategical Perspectives, February 2008.