A Summary of Canadian Activities
Natural Resources Canada

A Report for the October 2003
Committee on Earth Observation Satellites (CEOS)
Working Group on Calibration and Validation (WGCV)
21st Plenary

Compiled by

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Earth Sciences Sector

Natural Resources Canada

The Canadian Overview

Overview:

At the 20th CEOS WGCV Plenary, the Hyperspectral Group (HYSPEC) and the In Situ Sensor Measurement Assimilation Program (ISSMAP) at the Canada Centre for Remote Sensing, Natural Resources Canada (CCRS/NRCan) presented a variety of activities which support the calibration and validation of remotely sensed data for application to areas such as geology, forestry, the environment, mine site restoration, and land use management.

At Natural Resources Canada, a variety of new programs and projects have been initiated. Of note to the WGCV is the new project *Ensuring Validated Earth Observation Datasets* which is part of the new *Geomatics for the Sustainable Development of Natural Resources* (GSDNR) Program. Part of this project directly supports the development of applications for the proposed Canadian Hyperspectral Mission, now known as H.E.R.O. (Hyperspectral Environment and Resource Observer). More information on the *Ensuring Validated Earth Observation Datasets* Project follow this overview.

Also at NRCan, the ISSMAP program continues. A report of ISSMAP activities is provided by Dr. Philippe M. Teillet and follows the GSDNR overview. This report highlights the perspectives and achievements of the ISSMAP team in support of the Natural Resources Canada's Earth Sciences Sector (ESS) activities in geomatics in several new programs.

Finally, a capsule collection of efforts and activities on calibration activities for remotely sensed data is provided. Put together by Dr. Philippe M. Teillet, the last 12 pages of this report provides overviews and references for the activities being done in Earth Observation towards broadband and hyperspectral image calibration.

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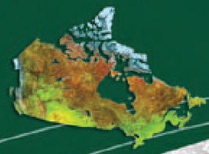

Earth Sciences Sector

Geomatics for the Sustainable Development of Natural Resources

The Earth Sciences Sector (ESS) of Natural Resources Canada (NRCan) has established a new program called **Geomatics for the Sustainable Development of Natural Resources (GSDNR)** to provide basic geospatial data and information. This program will support the actions and decisions required to sustain our resources.

The GSDNR program will provide consistent, reliable, accurate geomatics information, including well-defined property rights, to ensure that our clients and stakeholders have the capacity to make efficient and effective decisions on sustainable development issues at the national or community level.

This information will include an appropriate mix of digital maps; earth observation imagery (basic & value-added); tools and methodologies for extracting and integrating earth sciences data. On-going improvements will be made to the reliability and use of the information, incorporating new sources of data where applicable and moving toward integration with other reference sources of data.

GSDNR and it's associated portfolio of projects will provide some of the essential core sets of geospatial information required by a wide range of applications and decision processes related to the management of natural resources.

Based on consultation with clients and stakeholders, the program will be targeting three aspects essential to support more effective and efficient actions and decisions by stakeholders and clients with regards to their natural resources management issues:

- Geospatial data standardization to facilitate use and information exchange between stakeholders
- Data quality of core geospatial data for better decision-making
- Awareness of the use of geospatial information by decision makers involved in resource management.

Portfolio of Projects:

- Communications, Outreach and Assessment
- Ensuring Validated Earth Observation Datasets
- GeoBase – Altimetry and Hydrography
- GeoBase – Landsat-7 - National Imagery Coverage
- GeoBase – National Transportation Networks
- Geographical Names
- Geomatics Services to Clients in Support of National Parks and Offshore
- Integrated National Thematic Frameworks
- New Map Distribution Model
- Standards and Access for Geodetic Services

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La géomatique à l'appui du développement durable des ressources naturelles

Le Secteur des sciences de la Terre (SST) de Ressources naturelles Canada (RNCan) a établi un nouveau programme appelé **La Géomatique à l'appui du développement durable des ressources naturelles (GDDRN)**. Ce programme a pour but de fournir de l'information et des données géospatiales de base afin de contribuer à la saine gestion de nos ressources naturelles.

Le programme GDDRN produit des données géomatique de qualité, exacte, cohérente et fiable, y compris des droits fonciers bien définis, pour que les clients et les intervenants concernés puissent prendre des décisions pertinentes sur les enjeux du développement durable, tant au niveau national que communautaire.

L'information produite inclut une collection pertinente de données géospatiales numériques; d'imagerie d'observation de la Terre (de base et à valeur ajoutée); et d'outils et de méthodes d'extraction et d'intégration des données. Des améliorations en continue seront apportées aux processus de production et de traitement de de l'information, par l'utilisation de nouvelles sources de données et par l'intégration des données produites avec d'autres bases de données.

Le programme de la GDDRN et les projets qui lui sont associés , fourniront de l'information géospatiale de base utile à un grand nombre d'applications et de processus de prises de décision relatifs à la gestion des ressources naturelles.

Basé sur une consultation avec les clients et autres intervenants, le programme visera trois aspects essentiels pour soutenir ceux-ci dans leurs activités de gestion des ressources naturelles :

- normalisation des données géospatiales de façon à faciliter l'usage et l'échange de l'information
- qualité des données géospatiales de base pour favoriser de meilleures prises de décisions en matière de développement durable
- reconnaissance de la pertinence de l'information géospatiale par les décideurs impliqués dans la gestion des ressources naturelles.

Portfolio de projets :

- Communications, sensibilisation et évaluation
- Données-cadres pour les thèmes nationaux
- GéoBase - Altimétrie et hydrographie
- GéoBase - Couverture nationale d'imagerie - Landsat-7
- GéoBase - Réseaux de transport national
- Normes et accès pour les services géodésiques
- Nouveau modèle de distribution de cartes
- Services à la clientèle de Géomatique Canada à l'appui des parcs nationaux et des zones extracôtières
- Toponymes
- Validation de données satellitaires

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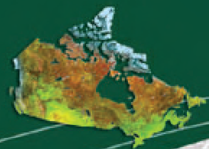

Earth Sciences Sector

Ensuring Validated Earth Observation Datasets

Geomatics for the Sustainable Development of Natural Resources

For sustainable resource management, decision-makers rely on consistent interpretations of Earth Observation (EO) data, often acquired over large areas, on different dates and from different sensor systems. When system-induced artifacts are present, erroneous interpretations may be made. However, many artifacts can be removed using standardized methodologies. To date, the non-existence of such methodologies has been a large stumbling block to the wider use of Earth observation for natural resources management.

The approaches to validating the calibration models for EO data must be standardized over time and space. Well-calibrated, validated and self-consistent digital geospatial data are essential for creating new knowledge relevant to sustainable development of natural resources issues.

The **Validated Earth Observation Datasets** Project will produce correction algorithms and tools that will remove artifacts related to the technical aspects of the EO process accompanied by supporting quality assessment reports. Emphasis will be placed on new environmental EO sensor systems that will be of importance in sustainable resource management strategies.

These include:

- spaceborne hyperspectral systems
- high spatial resolution and advanced radar systems and
- ground-based (in-situ) sensorwebs

Project Priorities:

- Generation of new tools for the characterization, correction and integration of EO data. An assessment will be made of the improvements resulting from application of the new correction tools on EO data products.
- Improvements to remote sensing data and standardization of new EO products through usage of sensorwebs, which are ground-based (in situ) networks of automated, intra-communicating sensors.
- Validation of users needs for calibrated earth observation data products.

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Validation de données satellitaires

La Géomatique à l'appui du développement durable des ressources naturelles

Les organisations impliquées dans le développement durable de ressources naturelles ont souvent recours à des images satellitaires multi-temporelles, provenant de différents capteurs et couvrant de grands territoires. Sans une calibration adéquate de ces données, il devient difficile d'en faire des interprétations justes et utiles. Plusieurs des artéfacts nuisant à la qualité des images peuvent être réduits significativement en utilisant des méthodologies normalisées de traitement d'images. L'absence de telles méthodologies constitue encore aujourd'hui un obstacle important à l'utilisation des données d'observation de la Terre pour la gestion des ressources naturelles.

L'harmonisation des approches de validation des modèles d'étalonnage des données d'observation de la Terre dans le temps et dans l'espace est essentielle pour résoudre efficacement les grandes questions relatives au développement durable des ressources naturelles.

Le projet **fourniture de jeux de données validées** fournira des algorithmes et des outils de correction afin de réduire les effets des artéfacts liés aux aspects techniques du processus d'observation de la Terre. Ce projet offrira aussi des rapports d'évaluation de qualité pour les algorithmes et outils de correction développés. L'accent sera mis sur les nouveaux capteurs de données d'observation de la Terre qui auront une grande importance dans les stratégies de gestion des ressources .

Ceux-ci comprennent :

- les capteurs hyperspectraux spatiaux
- les capteurs de haute résolution et les nouveaux capteurs radar
- les réseaux de capteurs au sol (in situ).

Priorités du projet :

- Production de nouveaux outils pour la caractérisation, la correction et l'intégration de données d'observation de la Terre. Évaluation des améliorations résultant de l'application de ces nouveaux outils.
- Amélioration et normalisation de la qualité des données de télédétection via l'utilisation d'information acquise grâce à des réseaux de capteurs au sol (in situ).
- Évaluation du besoin des utilisateurs en ce qui concerne la calibration des données de télédétection.

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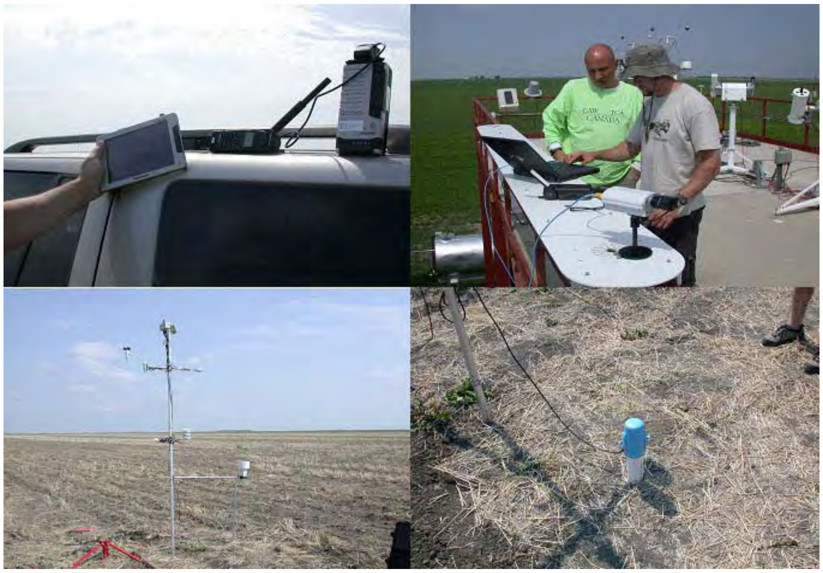
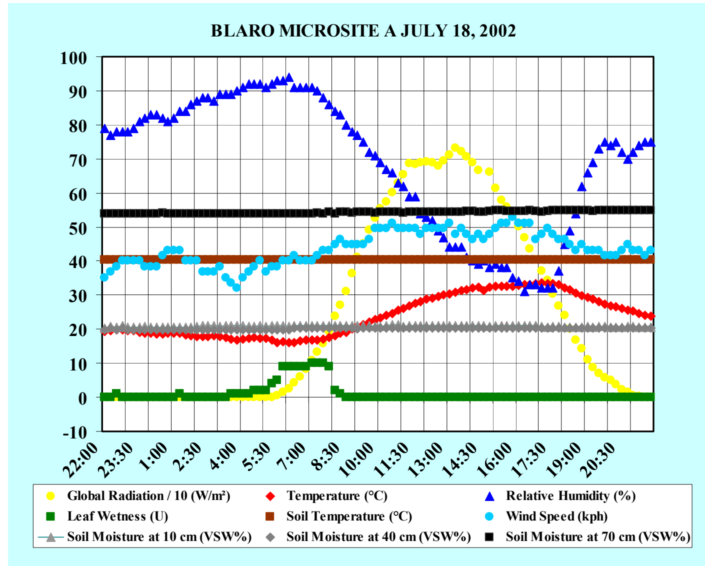
Natural Resources Canada
Ressources naturelles Canada





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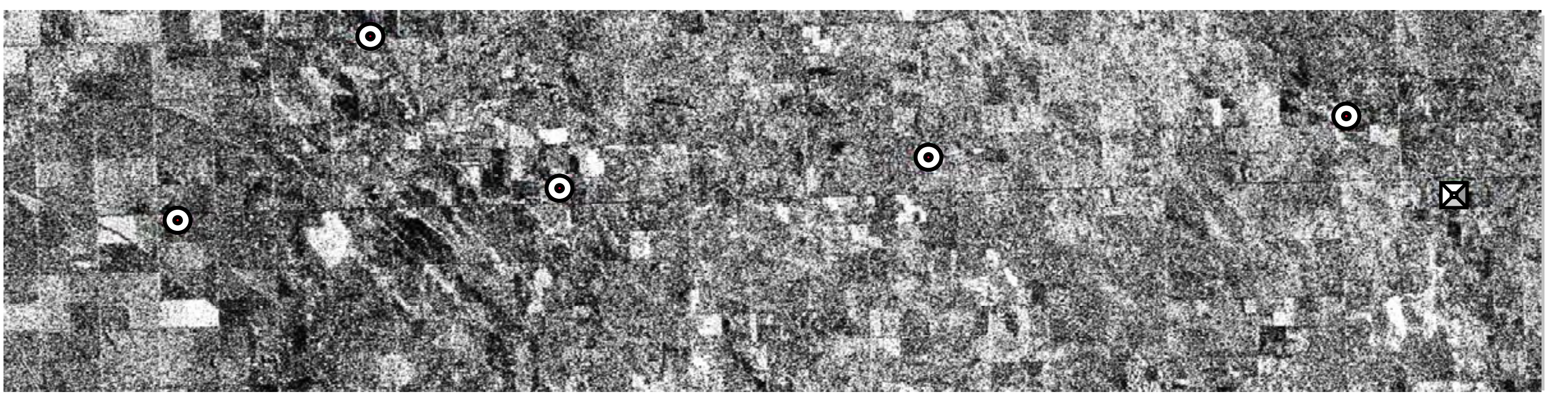
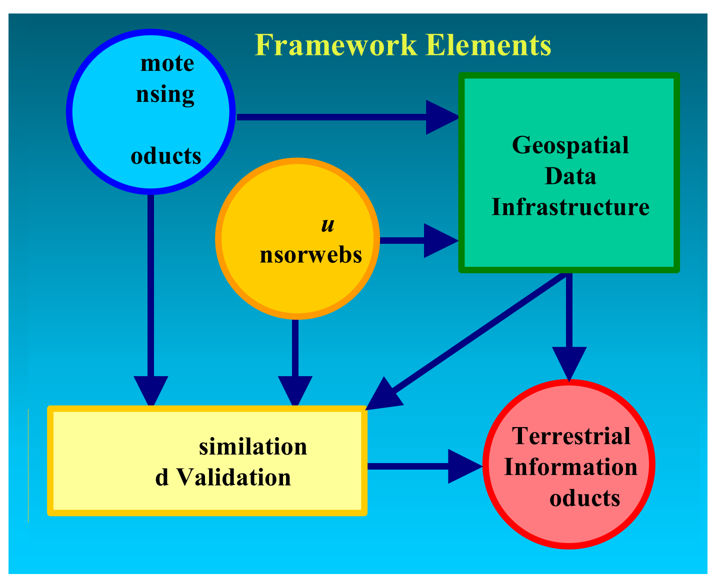
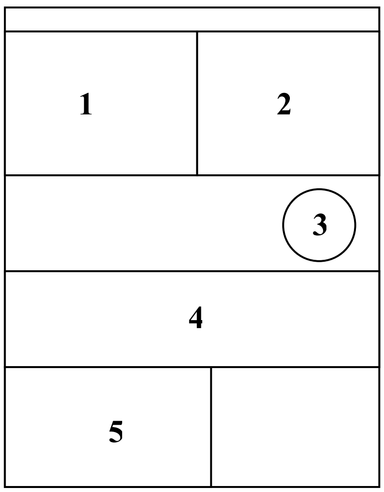




"In the next century, planet earth will don an electronic skin. It will use the Internet as a scaffold to support and transmit sensations. This skin is already being stitched together. It consists of millions of embedded electronic measuring devices: thermostats, pressure gauges, pollution detectors, cameras, microphones, glucose sensors, EKGs, electroencephalographs. These will probe and monitor cities and endangered species, the atmosphere, our ships, highways and fleets of trucks, our conversations, our bodies -- even our dreams."

Neil Gross, "The Earth Will Don An Electronic Skin", in "21 Ideas for the 21st Century", *BusinessWeek online*, August 30, 1999.



Key to the front cover illustrations

1. **In-situ sensorweb field deployment at Bratt's Lake, Saskatchewan.**
2. **In-situ sensorweb measurements from Bratt's Lake, Saskatchewan, July 18, 2002.**
3. **Symbol of the international Integrated Global Observing Strategy (IGOS).**
4. **Radarsat-1 SAR image (W1, ascending, 12 m pixels) of the Roseau Basin of the Red River, Manitoba on October 1, 2002. The sensorweb nodes and "hub" are indicated by the five circular and one square symbols, respectively.**
5. **In-situ sensorweb field deployment in the Roseau Basin of the Red River, Manitoba.**

Ce document est aussi disponible en français.

Towards Integrated Earth Sensing for Resource and Environmental Monitoring:

In Situ Sensor Measurement Assimilation Program (ISSMAP)

ISSMAP Report 2001-2002

Data Acquisition Division

Canada Centre for Remote Sensing

Earth Sciences Sector

Natural Resources Canada

Basic Elements of ISSMAP Activity

Overview:

The "First Canadian Workshop on On-Line In-Situ Quantitative Sensor Networks" in Ottawa in summer 1999 was a highly visible event attended by participants from industry, government and universities. The Canada Centre for Remote Sensing (CCRS) failed to take advantage of the momentum gained by the workshop. The strategic CCRS push towards in-situ sensor measurement and data assimilation was reinitiated in autumn 2000 and the In Situ Sensor Measurement Assimilation Program Definition Project (ISSMAP-DP) was established in the Applications Division of CCRS. An internal CCRS mini-workshop was held in November 2000 to help ensure that all parts of CCRS have a similar concept of what is being attempted with ISSMAP and to try to engage staff in this strategic activity.

In May 2001, CCRS initiated a new group to work on ISSMAP, the In Situ Measurement Development Section (ISMDS) in the Data Acquisition Division of CCRS. Having grown from one person to the current team (as of December 2002), ISMDS now consists of two Research Scientists (R.P. Gauthier, P.M. Teillet), two Systems Engineers (G. Ainsley, K.B. Fung), and two Physical Scientists (A. Chichagov, G. Fedosejevs). Selected research and development tasks were contracted out to specialists from Canadian industry (L. Campbell, B. Cho, M. Maloley). The Ground Station Operations Section and the Informatics and Computer Services Section of the Data Acquisition Division provided very valuable engineering and informatics support, respectively, to ISSMAP. Additional assistance was received in 2002 from Co-op students from the University of Ottawa (P. Curtis and Q. Zhang). Administrative support from C. Burke, K. Davis, C. Kizito, and P. Denemoustier is gratefully acknowledged.

This report outlines ISSMAP perspectives and achievements for 2001 and 2002 and includes a bibliography of publications. Henceforth, the efforts of the small but very active ISSMAP team will continue to be focused on projects and activities in Natural Resources Canada's Earth Sciences Sector (ESS) in the context of geomatics for sustainable development of natural resources, sustainable development through knowledge integration, and natural hazards and emergency response, among others.

Mandate:

ISSMAP's goal is to make significant advancements in the practical use of Earth observation data by developing intelligent in-situ measurement capabilities that open new pathways towards the generation of quantitative geophysical and biospheric information products.

Framework:

Because numerous independently managed networks and archives of in-situ sensors and data currently exist, ISSMAP focuses its activities carefully and leverages existing infrastructures wherever possible. Thus, ISSMAP activities must fit within the following framework (Teillet et al. 2001b). They must:

1. Lead to the generation of terrestrial information products that address clearly defined science and technology questions and/or user information requirements;
2. Utilize in-situ sensorwebs;
3. Utilize remote sensing data products;
4. Encompass data assimilation and validation components;
5. Routinely provide in-situ data products and/or metadata on in-situ data holdings to a geospatial data infrastructure.

Complementary to current efforts towards an Integrated Global Observing Strategy[1] and Global Monitoring for Environment and Security[2], the integrated Earth sensing concept being developed by ISSMAP provides a framework for the research and development of advanced data acquisition and integration elements of environmental monitoring/information systems used for local, regional, or global decision-making. In-situ sensor measurement assimilation efforts focus as a priority on issue-driven science and technology activities such as the monitoring of remote environments, risk assessment and hazard mapping, and time-critical decision-making (e.g., disaster and renewable resource information management).

Objectives:

1. Design and deploy autonomous networks of sensors (sensorwebs) for in-situ data acquisition.
2. Develop approaches to fuse in-situ and remote sensing data for assimilation into models that generate validated information products.
3. Facilitate the integration of in-situ sensor data and/or metadata into on-line geospatial data infrastructures.

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[1] IGOS, http://www.igospartners.org/
[2] GMES, http://gmes.jrc.it/

The State of the Earth and Its Environment

> **"It must be stated that space-derived information generally needs to be combined with in-situ measurements and models to obtain a holistic picture of the Earth's environment. … There is no Sustainable Development without adequate information about the state of the Earth and its environment".**
>
> Josef Aschbacher
> European Space Agency (ESA) and Committee on Earth Observation Satellites (CEOS)
> Economic and Social Council, Commission on Sustainable Development
> World Summit on Sustainable Development (2002)

Geomatics for Sustainable Development of Natural Resources and Knowledge Integration:

ISSMAP is endeavouring to provide new sources of data, techniques, and methodologies for improved characterization and integration of geomatics information to support sustainable development. ISSMAP's focus is on standardized autonomous ground-based (in-situ) sensorwebs that measure key geophysical and biospheric parameters to validate remote sensing data and contribute to the Canadian Geospatial Data Infrastructure (CGDI). Thus, the activities are in line with strategies to have digital geospatial data acknowledged as a definitive and essential source of information in Canada for sustainable development decisions.

ISSMAP is contributing advanced data acquisition capabilities to drought monitoring efforts and hence helping to integrate information for modeling and forecasting as input into decision-making. Significant components of ISSMAP are designed to transfer technology and build Canadian industrial capability in integrated Earth sensing. Many of the research activities are being undertaken by university groups, which will lead to the generation of highly qualified personnel in new areas involving converging technologies that support advanced resource and environmental monitoring.

Natural Hazards and Emergency Response:

ISSMAP is contributing advanced data acquisition capabilities to flood forecasting efforts and hence helping to provide detailed hazard assessments for Canadians in high-risk areas as well as information for emergency response to complex crisis events and emergencies.

Towards Integrated Earth Sensing

In Situ Sensing:

A short dictionary-based definition for **in-situ sensing** could be "sensing in place". Because many observations are made from nearby locations that are not strictly speaking in-situ, the expression **proximal sensing** has been adopted in a variety of disciplines to describe "sensing from close range" (as in close-range photogrammetry, for example). For the present purposes and in practice, in-situ sensing is considered to encompass proximal sensing as well. Networks of in-situ sensors continue to evolve even as unattended sensor and wireless telecommunication technologies advance at a rapid pace and new uses are invented. It is becoming increasingly feasible to provide quality-controlled network-wide data to users via the Internet in near real time and information products from data fusion and assimilation into models within hours or days.

Converging Technologies:

The converging technologies of sensors, micro-computers, and wireless telecommunications have led to new developments such as Wireless Integrated Network Sensors (WINS) (Asada et al. 1998) and smart networks of in-situ sensors called sensorwebs (Delin and Jackson 2001; Delin 2002). These systems form the technology base for new monitoring capability for a wide variety of applications in sectors such as transportation, manufacturing, health care, environmental monitoring, and safety and security. A sensorweb consists of spatially distributed sensor nodes that combine sensing, signal processing, smart systems, and wireless networking, i.e., a macro-instrument for coordinated sensing. With the advent of increasingly compact, low power, and relatively inexpensive devices, it will soon be possible to deploy large numbers of sensor pods (Pister et al. 1999; Hollar 2000). Combined with powerful geospatial visualization tools, these technologies will provide an ongoing virtual presence in remote locations and many monitoring uses will be developed.

Integrated Earth Sensing:

Satellite Earth observation sensors provide unique measurements of terrestrial variables. These measurements are critical because the Earth system changes constantly over a wide range of temporal and spatial scales. Nevertheless, it is recognized that ground data collection will always remain an essential source of information. Indeed, a growing perspective today is that significant advancements in Earth observation are expected to come about only by developing more systematic capabilities for the fusion of remote sensing observations and in-situ measurements to generate geophysical and biospheric information products. This integrated Earth sensing approach will include the deployment of autonomous sensorwebs on the surface of the Earth in various application contexts. Such systematic capabilities can provide essential validated information for decision-making if they involve interagency cooperation, common data processing standards, and timely access to data and information products on a long-term basis.

Initial ISSMAP Activities

ISSMAP is undertaking science and technology activities that contribute to sustainable development of natural resources and natural hazards and emergency response, and that have the potential to contribute to development of the north. Initial foci of attention include watershed monitoring, flood forecasting, drought monitoring, and disaster mitigation. The primary ISSMAP outputs and contributions will be autonomous in-situ sensorwebs, integrated moisture sensing, data fusion and assimilation methodologies, and enhanced CGDI data holdings.

ISSMAP's multi-faceted effort to develop an integrated Earth sensing capability in Canada involves a mixture of external and in-house R&D activities addressed by the following two activities, described in the material that follows.

- ***TREATIES*****: Towards Remote Environmental Assessment Through Integrated Earth Sensing**. The objective of TREATIES is to facilitate external investigations on in-situ sensing via contracts with industry, leveraged collaborations, various linkages, and R&D collaborations. TREATIES establishes ties and works with selected partners on integrated Earth sensing approaches to resource and environmental monitoring.
- ***ProWISE*****: Prototype Wireless Intelligent Sensorweb Evaluation**. ProWISE tackles the first objective of ISSMAP by deploying and testing unattended, wireless in-situ sensorwebs in Earth science applications contexts.

Towards Remote Environmental Assessment Through Integrated Earth Sensing (TREATIES)

Contracts to Canadian Industry:

- Prototype flood information management system (Isosceles Information Solutions, Inc.) - completed.
- Improved crop specific projections (Noetix Research, Inc.) - completed.
- Web services for atmospheric correction parameters (Centre for Research in Earth and Space Technology (CRESTech) and Université de Sherbrooke) - completed.
- Integrated wearable computer and satellite communications solutions (Halltech Atmospheric Services) - completed.
- Agriculture and hydrology remote sensing applications development and technology transfer (Noetix Research, Inc., with CCRS Applications Division) - completed.
- Integrated Earth sensing R&D support and technology transfer (ACG Space, Inc.) – in place.
- New data mining tools for monitoring land surface temperature using integrated Earth sensing data (GlobVision, Inc.) – March 2003 completion.

Leveraged Collaborations:

- Laser-induced fluorescence for in-situ chemical analysis in agriculture (with Agriculture and Agri-Food Canada (AAFC)).
- Concept studies on applications of integrated Earth sensing with emphasis on in-situ sensing (with CRESTech).
- Characterization of atmospheric aerosols across Canada in the context of climate change studies, using AEROCAN, a Canadian ground-based network of automated solar radiometer instrumentation (with Université de Sherbrooke, CRESTech, Environment Canada's Meteorological Service of Canada (MSC), Natural Sciences and Engineering Research Council (NSERC), and NASA's Goddard Space Flight Center (GSFC), among others).
- Study on satellite Earth observation in support of watershed management programs (with the Canadian Space Agency and Borstad Associates Ltd.) – March 2003 completion.
- Geomatics-enabled monitoring of geotechnical sites (with the Geomatics for Informed Decisions (GEOIDE) Network of Centres of Excellence (NCE) and Queen's University).
- Understanding soil moisture characteristics as a function of the spatial resolution of remote sensing systems and the spatial distribution of in-situ sensing systems (University of Ottawa).
- Intelligent sensorweb for integrated Earth sensing for enhanced drought monitoring (with Precarn Incorporated and MacDonald Dettwiler and Associates (MDA)).

Linkages:

- Procurement and evaluation (with applications development scientists at CCRS) of the ArcPad-iPAQ-GPS equipment combination.
- Provisions of technical and strategic advise to Indian Head Agricultural Research Foundation on its RoboScout initiative.
- Membership on the US Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) User Working Group.
- Membership on the international Committee on Earth Observation Satellites (CEOS) Working Group on Calibration and Validation (WGCV).

Additional R&D Partnerships:

- Enhanced geospatial information systems for timely and interoperable access, management and visualization in support of emergency planning and response (with various agencies).
- Mer Bleue wetlands carbon modelling (with Centre for Climate and Global Change Research, McGill University, and part of the Ameriflux network).
- Drought monitoring (with Water Institute for Semi-arid Ecosystems (WISE), Lethbridge University).
- Dialogues towards R&D partnerships with specialists at CCRS, the Geological Survey of Canada (GSC), the Canadian Space Agency (CSA), and the Communications Research Centre (CRC).

Prototype Wireless Intelligent Sensorweb Evaluation (ProWISE)

Prototype Sensorweb Overview:

The main objective of the Prototype Wireless Intelligent Sensorweb Evaluation (ProWISE) involves the field deployment of a sensorweb with full inter-nodal connectivity and remote access and control. The project is also testing and demonstrating remote webcam operations and telepresence at remote field sites. A technology test-bed is being used to integrate the various components of a sensorweb so that it can be remotely controlled and eventually remotely configured. The process involves solving the engineering problems associated with the interfaces between the sensors at a given node and the wireless telecommunications devices that will include the addition of smart control and decision drivers.

Field trials are taking place to evaluate deployment and remote operation issues as well as considerations relevant to the use of sensorwebs in specific data acquisition, information extraction and decision contexts. The initial prototype sensorweb consists of five nodes and a base station. The initial configuration for each node of the sensorweb consists of a compact mast with sensors recording temperature, relative humidity, downwelling solar radiation, rainfall, wind direction, wind speed, leaf wetness as appropriate, soil temperature, and soil moisture. Soil moisture in particular is considered a key parameter that can also be estimated by satellite radar data such as those from Canada's Radarsat. The microspectrometer subsystems for surface radiance and downwelling irradiance measurements are still in the integration and testing phases.

Different wireless telecommunication and telepresence strategies have been examined. Access and control are remotely operated and have been tested from the individual nodes to the Integrated Earth Sensing Workstation (IESW) in Ottawa (Internet web-enabled) as well as from the nodes to the base station and then to the IESW. Control of the microsensors is achieved through embedded systems specifically tailored to the geospatial application being investigated.

These deployments do not yet take advantage of fully miniaturized or smart systems, but they utilize commercial-off-the-shelf (COTS) technology in operational settings in remote environments. Smart inter-nodal communication is planned for the next phase of development. In that phase, the current style of nodes will likely become the base stations for local-area sensorwebs with the addition of more numerous, smaller sensor nodes. Thus, hierarchically, there will be (at least) two levels to the in-situ sensorweb. Even in its current form, the prototype sensorweb activity is ahead of the curve in many ways. Use of the sensorweb is being sought by numerous Earth science applications groups, including various government agencies. The capability represents a big step towards faster, denser, and more autonomous ground-based data acquisition, Earth observation data validation and, in due course, real-time triggering of alerts in appropriate contexts.

First Field Trials - Ottawa and Bratt's Lake 2002:

Early in 2002, a prototype network of sensors was deployed in an outdoor environment near Ottawa, Canada, to facilitate the debugging of the protocol conversion between the microsensor/microcontroller packages and the satellite transceivers. RF telemetry ranges were tested to identify possible distances and optimal area coverage for sensorweb deployments.

In July 2002, a test deployment was made at Bratt's Lake Atmospheric Radiation Observatory (BLARO) in Saskatchewan, Canada, in collaboration with Environment Canada's Meteorological Service of Canada (EC/MSC). This field campaign included tests of the full access/control system through the Integrated Earth Sensing Workstation (IESW) at CCRS in Ottawa. The initial sensorweb configuration consists of a compact mast with sensors recording temperature, relative humidity, downwelling solar radiation, rainfall, wind direction, wind speed, soil temperature, and soil moisture. Highlights of the BLARO deployment are as follows.

- First CCRS field deployment of a five-node prototype in-situ sensorweb, with near-real-time data accessible from the IESW in Ottawa via RF and satellite telecommunications.
- First CCRS use of microspectrometers over agriculture targets near BLARO, with data sent to the IESW in Ottawa via satellite.
- First CCRS field trial of telepresence at BLARO via webcam and satellite modem, with live image transmissions as well as remote trouble-shooting and resolution of webcam firmware problem via telepresence.
- Demonstration of data retrieval from the IESW database in Ottawa via satellite from BLARO.
- Validation of sensorweb meteorological and soil moisture data against independent measurements by EC/MSC/BLARO (in progress).

Red River Basin Deployment 2002-2003:

A more elaborate test deployment followed in autumn 2002 in the context of a flood forecasting application in the Roseau Basin of the Red River in Manitoba, Canada, in collaboration with CCRS hydrology specialists and the National Water Research Institute (NWRI) of Environment Canada (EC). Highlights are as follows.

- The five-node prototype in-situ sensorweb is currently deployed in the Roseau Basin of the Red River in Manitoba and will remain there through the flood season in the spring of 2003.
- The five-node sensorweb operates autonomously and standard meteorological parameters and soil moisture measurements are accessed remotely from the IESW in Ottawa. This is to be compared with the three bulkier met stations with data loggers and the labour-intensive soil moisture measurement techniques used by the hydrologists participating in the project.
- Validation of sensorweb meteorological and soil moisture data against independent measurements by CCRS and EC/NWRI (in progress).

Deployment of the current and possibly the next-phase sensorweb will be targeted at drought monitoring applications.

Benefits and Impacts

Commercial Impact:

Pilot projects have been completed with Canadian industry to demonstrate advanced information products in priority areas with operational and commercial benefits arising from the use of new technologies for in-situ data acquisition, archiving, fusion, and assimilation.

Cost Savings:

ISSMAP is demonstrating the utility of unattended wireless intelligent sensorwebs, leading to lower-cost and wider participation in what have traditionally been resource-intensive activities. Web-enabled access to resources in the field also has the potential to facilitate asset management and remote support of instrumentation when required.

Technology Transfer:

A significant proportion of the ISSMAP funding has been made available to develop in-situ data acquisition and integration capabilities in Canadian industry and universities. Pilot projects demonstrating the utility of the integration of in-situ and remote sensing data have directly involved operational agencies.

Partnerships:

ISSMAP projects have involved completely new synergistic partnerships between agencies to develop and archive Earth science information products that benefit from in-situ and remote sensing data acquisition and integration.

Knowledge Advance:

State-of-the-art in-situ data acquisition technologies and data processing systems are being adapted and optimized for selected Earth science utilizations of strategic significance. New data and information products are being developed and validated from the fusion and assimilation of remotely sensed data, in-situ measurements, and modelling. Access to a national data archive of in-situ measurements and to metadata on other in-situ data holdings facilitates new research and development in Earth science.

Building Capacity:

ISSMAP represents a strategic initiative into a new area involving converging technologies that support advanced resource and environmental monitoring. As such, it has created new opportunities to expand skills, capabilities, and reputation and to allow staff to participate in new, challenging, and career expanding work.

National Skill Base:

In the context of resource and environmental monitoring, ISSMAP has involved the converging technologies of micro-sensors, computers, and wireless telecommunications and new concepts such as in-situ sensorwebs, which should provide excellent opportunities for skill development in Canada in general and for the training of highly qualified personnel in particular.

Societal/Policy Impact:

A more systematic and timely approach to capturing, archiving and integrating data makes it possible to provide validated information for strategic decision making in the context of resource and environmental monitoring.

Access to Information:

Better access to Earth science activities, data, and information via the Internet are high priorities for the Government of Canada. ISSMAP is contributing to the availability of in-situ data through the Canadian Geospatial Data Infrastructure (CGDI).

Transparency of Government and Connectivity of Canadians:

ISMAP is demonstrating how the public could have access to information about the field activities of government scientists and engineers and how the government could increase the visibility of these resources in action.

"The power of technological convergence will bring measurable benefits to each and every individual."
Douglas Mulhall, *Our Molecular Future*, 2002.

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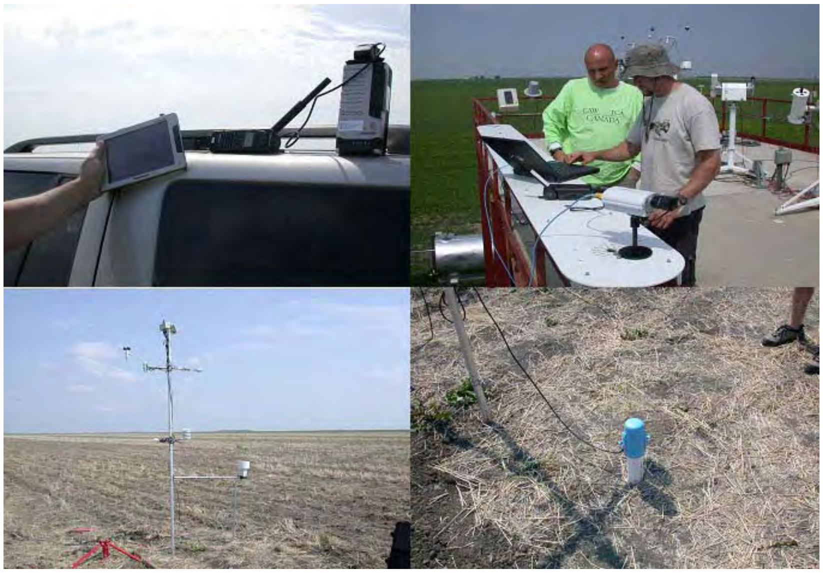

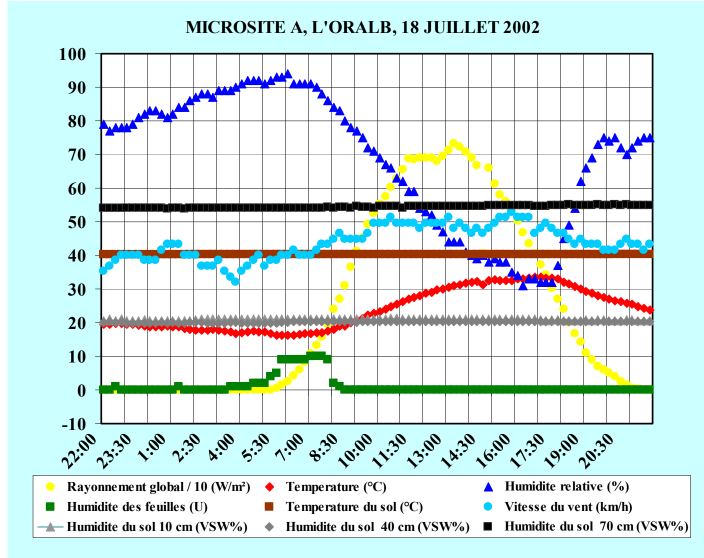

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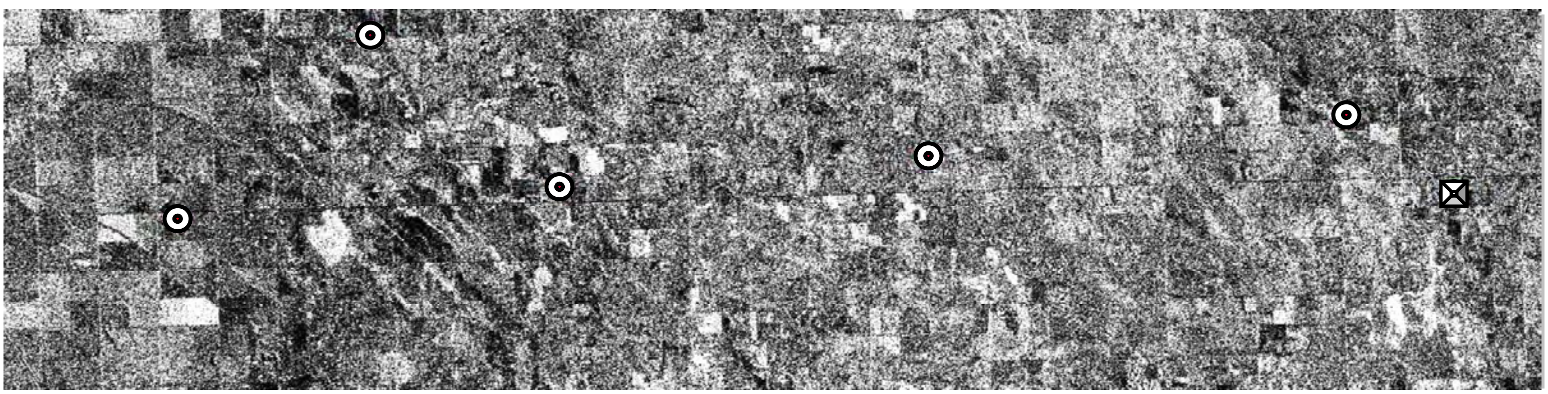
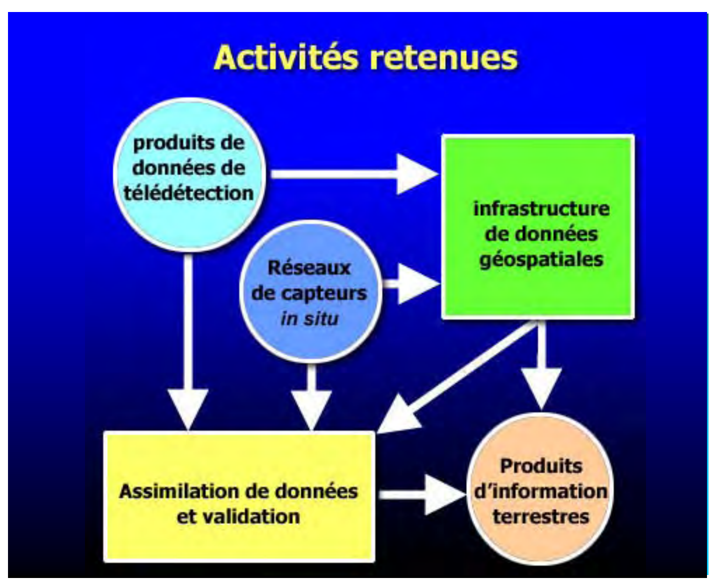
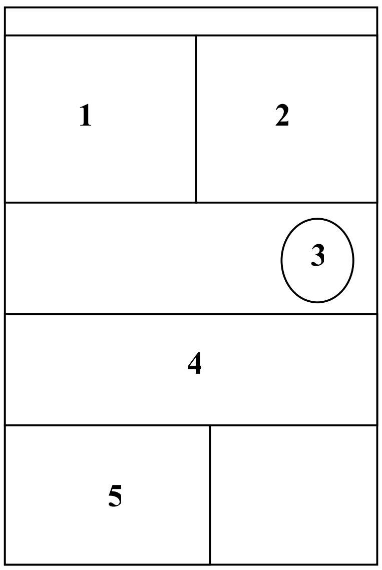




« Au cours du prochain siècle, la planète Terre se revêtira d'une peau électronique. Internet sera utilisé comme armature de soutien et de transmission des sensations. Cette peau est déjà en voie d'élaboration. Elle se compose de millions d'appareils électroniques de mesure embarqués : thermostats, manomètres, détecteurs de pollution, appareils photographiques, microphones, glucomètres, électrocardiographes, électroencéphalographes. De tels appareils permettront de sonder et de surveiller les villes et les espèces menacées, l'atmosphère, les navires, les routes et les flottes de camions, nos corps et même nos rêves. »

Neil Gross, « The Earth Will Don An Electronic Skin »,
dans « 21 Ideas for the 21st Century »,



Légendes des illustrations de la page de couverture

1. **Webcapteur *in-situ* installé sur le terrain au lac Bratt's (Saskatchewan).**
2. **Mesures avec le webcapteur *in-situ* au lac Bratt's (Saskatchewan), 18 juillet 2002.**
3. **Symbole de la Stratégie d'observation globale intégrée (IGOS) internationale.**
4. **Image du RSO du Radarsat-1 (W1, ascendant, pixels de 12 m) du bassin de la rivière Roseau tributaire de la rivière Rouge (Manitoba), 1er octobre 2002. Les nœuds et la «station pivot» du webcapteur sont représentés respectivement par les cinq cercles et le carré.**
5. **Installation du webcapteur *in situ* dans le bassin de la rivière Roseau tributaire de la rivière Rouge (Manitoba).**

This document is also available in English.

Vers une observation intégrée de la Terre pour la surveillance des ressources et de l'environnement :

Programme d'assimilation des mesures de capteurs in situ (PAMCIS)

Rapport du PAMCIS 2001 – 2002

Division de l'acquisition des données

Centre canadien de télédétection

Secteur des sciences de la Terre

Ressources naturelles Canada

Éléments fondamentaux des activités du PAMCIS

Aperçu

Le «Premier atelier canadien sur les réseaux de capteurs quantitatifs *in situ* en direct» (First Canadian Workshop on On-Line In-Situ Quantitative Sensor Networks) tenu à Ottawa en 1999 fut un événement très couru par des participants de l'industrie, des gouvernements et des universités. Le Centre canadien de télédétection (CCT) n'avait pas été en mesure à l'époque de tirer avantage de l'impulsion donnée par cet atelier. La démarche stratégique du CCT vers les mesures au moyen de capteurs *in situ* et l'assimilation de données a été reprise à l'automne de 2000 avec le lancement du Projet de définition du Programme d'assimilation des mesures de capteurs *in situ* (PD-PAMCIS) à la Division des applications du CCT. Un mini-atelier interne fut tenu en novembre 2000 afin d'exposer à tous les segments du CCT les objectifs du PAMCIS et de tenter d'impliquer le personnel dans cette activité stratégique.

En mai 2001, le CCT créait un nouveau groupe chargé du PAMCIS, la Section du développement des mesures *in situ* (SDMIS) de la Division de l'acquisition des données (DAD). La SDMIS, qui ne comptait au début qu'une seule personne, dispose maintenant (en décembre 2002) d'une équipe composée de deux chercheurs scientifiques (R.P. Gauthier, P.M. Teillet), de deux ingénieurs des systèmes (G. Ainsley, K.B. Fung) et de deux Spécialistes des sciences physiques (A. Chichagov, G. Fedosejevs). Des tâches choisies en recherche et développement ont été imparties à des spécialistes de l'industrie canadienne (L. Campbell, B. Cho, M. Maloley). La Section de l'opération des systèmes au sol et la Section de l'informatique et des services d'ordinateurs de la Division de l'acquisition des données ont fourni au PAMCIS un très précieux soutien, respectivement en génie et en informatique. En 2002, une aide supplémentaire a été reçue d'étudiants de l'Université d'Ottawa (P. Curtis et Q. Zhang) dans le cadre du Programme d'enseignement coopératif. Le soutien administratif fourni par C. Burke, K. Davis, C. Kizito et P. Denemoustier a été très apprécié.

Dans le présent rapport on souligne les perspectives et les succès du PAMCIS en 2001 et 2002; on présente en outre une bibliographie des publications. Dorénavant, les efforts de la petite mais très active équipe du PAMCIS seront concentrés sur des projets et des activités du Secteur des sciences de la Terres (SST) de Ressources naturelles Canada menés notamment dans la perspective d'une mise en valeur durable des ressources naturelles, d'un développement durable par l'intégration de connaissances ainsi que de l'étude des dangers naturels et de l' intervention d'urgence.

Mandat

Le PAMCIS a comme but l’accomplissement de progrès importants en utilisation pratique de données d’observation de la Terre par le développement de capacités intelligentes de mesure *in situ* ouvrant la voie à l’élaboration de produits d’information géophysique et biosphérique quantitative.

Cadre

En raison du grand nombre de réseaux gérés indépendamment les uns des autres et des innombrables archives de capteurs et de données *in situ* qui existent actuellement au Canada et ailleurs, le PAMCIS cible judicieusement ses activités et exploite dans toute la mesure du possible les infrastructures existantes. Ainsi, les activités menées dans le cadre du PAMCIS se conformeront au cadre exposé ci-après (Teillet et coll. 2001b). Les activités doivent :

1. mener à la génération de produits d'information terrestre qui répondent clairement à des problèmes scientifiques ou technologiques et/ou à des besoins définis d'utilisateurs;
2. utiliser des webcapteurs *in situ*;
3. utiliser des produits de données de télédétection;
4. englober des composantes d'assimilation et de validation de données;
5. fournir dans chaque cas des produits de données *in situ* et/ou des métadonnées sur les données *in situ* archivées à une infrastructure de données géospatiales.

Complément aux efforts courants dans le cadre de la Stratégie d'observation globale intégrée[1] et du Global Monitoring for Environment and Security[2], le concept d'observation intégrée de la Terre élaboré dans le cadre du PAMCIS fournit un cadre pour les travaux de recherche et développement sur les éléments évolués d'acquisition et d'intégration de données des systèmes de surveillance environnementale et d'information utilisés pour la prise de décisions aux échelles locale, régionale et planétaire. Les efforts d'assimilation de mesures effectuées au moyen de capteurs *in situ* sont prioritaires dans le cadre d'activités scientifiques et technologiques suscitées par des problèmes comme la surveillance de milieux éloignés, l'évaluation des risques, la cartographie des dangers et la prise de décisions critiques en fonction du temps (p. ex. gestion de l'information sur les catastrophes et les ressources renouvelables).

Objectifs

1. Concevoir et déployer des réseaux de capteurs (webcapteurs) autonomes pour l'acquisition de données *in situ*.
2. Élaborer des approches de fusion de données recueillies *in situ* et de données de télédétection à des fins d'assimilation dans des modèles générant des produits d'information validés.
3. Faciliter l'intégration de données et/ou de métadonnées de capteurs *in situ* aux infrastructures en direct de données géospatiales.

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[1] IGOS, http://www.igospartners.org/
[2] GMES, http://gmes.jrc.it/

L'état de la Terre et de son environnement

« Il doit être mentionné que l'information recueillie depuis l'espace doit généralement être combinée à des mesures *in situ* et à des modèles pour l'obtention d'une perspective holistique sur l'environnement de la Terre. … Il ne peut se faire aucun développement durable sans une information adéquate sur l'état de la Terre et de son environnement. »

Josef Aschbacher
Agence spatiale européenne (ASE) et Comité sur les satellites d'observation de la Terre (CEOS) Conseil économique et social, Commission du développement durable, Sommet mondial sur le développement durable (2002)

La géomatique pour la mise en valeur durable des ressources naturelles et l'intégration des connaissances

Le PAMCIS s'attache à fournir de nouvelles sources de données, techniques et méthodes visant à améliorer la caractérisation et l'intégration de l'information géomatique à l'appui du développement durable. Le PAMCIS est centré sur l'utilisation au sol de webcapteurs (*in situ*) normalisés et autonomes pour la mesure de paramètres géophysiques et biophysiques clés permettant la validation des données de télédétection et contribuant à l'Infrastructure canadienne des données géospatiales (ICDG). Les activités menées dans le cadre du programme sont ainsi alignées sur les stratégies visant la reconnaissance au Canada des données géospatiales numériques comme source d'information faisant autorité et essentielle pour la prise de décisions en matière de développement durable.

Le PAMCIS fournit des capacités évoluées d'acquisition de données dans le cadre d'efforts de surveillance de la sécheresse et aide ainsi à intégrer au processus de prise de décisions l'information nécessaire pour la modélisation et la prévision. Des composantes importantes du PAMCIS sont consacrées au transfert de technologie et à la mise en place au Canada d'une capacité industrielle en observation intégrée de la Terre. Un grand nombre des activités de recherche sont entreprises par des groupes universitaires, ce qui mènera à la formation de personnel hautement qualifié dans de nouveaux domaines issus de la convergence de technologies à l'appui d'une surveillance évoluée des ressources et de l'environnement.

Dangers naturels et intervention d'urgence

Le PAMCIS fournit des capacités évoluées d'acquisition de données dans le cadre d'efforts de prévision des inondations et aide ainsi à fournir des évaluations détaillées du danger pour les Canadiens habitant des secteurs à risque élevé et de l'information pour l'intervention d'urgence lors de crises et de situations d'urgence complexes.

Vers une observation intégrée de la Terre

Détection *in situ*

Une courte définition au dictionnaire de la **détection *in situ*** se lirait comme suit : « détection sur place ». Puisqu'un grand nombre de mesures ou d'observations sont effectuées depuis de courtes distances sans être à proprement parler *in situ*, l'expression **détection proximale** a été retenue par un grand nombre de disciplines pour décrire la « détection rapprochée » (comme dans le cas de la photogrammétrie rapprochée par exemple). Aux fins du présent rapport et en pratique on considèrera que la détection *in situ* englobe la détection proximale. Les réseaux de capteurs *in situ* continuent à évoluer au gré des progrès rapides des technologies des capteurs automatiques et des télécommunications sans fil et à mesure que sont inventées de nouvelles utilisations. Il devient de plus en plus possible d'offrir aux utilisateurs des données de réseaux de qualité contrôlée en temps quasi réel par Internet, et, en quelques heures ou en quelques jours, des produits d'information issus de la fusion et de l'assimilation de données dans des modèles.

Technologies convergentes

Les technologies convergentes des capteurs, des micro-ordinateurs et des télécommunications sans filont mené à de nouveaux progrès comme les capteurs sans fil intégrés en réseaux (Wireless Integrated Network Sensors (WINS)) (Asada et coll. 1998) et les réseaux intelligents de capteurs *in situ* appelés webcapteurs (Delin et Jackson 2001; Delin 2002). Ces systèmes constituent les fondements technologiques d'une nouvelle capacité de surveillance dans toute une gamme d'applications dans des secteurs aussi divers que les transports, la fabrication, les soins de santé,, la surveillance environnementale et la sécurité et protection. Un webcapteur consiste en nœuds de capteurs répartis dans l'espace et combinant la détection, le traitement des signaux, des systèmes intelligents et le réseautage sans fil, I.e., un instrument-macro pour la détection coordonnee. Avec l'avènement d'appareils de plus en plus petits, utilisant une faible puissance et relativement peu coûteux, il sera bientôt possible de déployer de grands nombres de nacelles de capteurs (Pister et coll. 1999; Hollar 2000). Combinées à de puissants outils de visualisation géospatiale, ces technologies permettront d'assurer une présence virtuelles ininterrompue à des endroits éloignés et un grand nombre d'applications en surveillance seront mises au point.

Observation intégrée de la Terre

Les capteurs d'observation de la Terre à bord de satellites fournissent des mesures sans pareilles de variables terrestres. Ces mesures sont critiques parce que le système Terre change constamment à toute une gamme d'échelles temporelles et spatiales. Il est néanmoins reconnu que la collecte de données au sol restera toujours une source essentielle d'information. En fait il est de mieux en mieux perçu de nos jours que des progrès importants ne seront accomplis en observation de la Terre que dans la mesure où il sera possible de fusionner de manière davantage systématique les observations de télédétection aux mesures effectuées *in situ* pour générer des produits d'information géophysiques et biosphériques. Cette approche intégrée d'observation de la Terre englobera le déploiement de webcapteurs autonomes à la surface de la planète dans divers contextes d'application. Cette systématisation aux possibilités décuplées peut offrir une information validée essentielles pour la prise de décisions pourvu qu'il y ait collaboration entre les organismes, qu'il existe des normes communes de traitement des données, et que soit assuré un accès en temps opportun et à long terme aux données et aux produits d'information.

Activités initiales dans le cadre du PAMCIS

Dans le cadre du PAMCIS on entreprend diverses activités scientifiques et technologiques contribuant à une mise en valeur durable des ressources naturelles, facilitant l'intervention d'urgence en réponse à des dangers naturels, et offrant une possibilité de contribution au développement du Nord. Les foyers initiaux d'attention sont la surveillance des bassins versants, la prévision des crues, la surveillance des sécheresses et l'atténuation des catastrophes. Les principaux résultats du PAMCIS seront axés sur les webcapteurs *in situ* autonomes, la détection intégrée de l'humidité, les méthodologies de fusion et d'assimilation de données et l'amélioration des archives de données de l'ICDG.

Le PAMCIS est un effort polyvalent d'élaboration d'une capacité intégrée d'observation de la Terre au Canada englobant un mélange d'activités de R et D à l'externe et à l'interne regroupées en deux volets décrits de manière plus détaillée dans les quelques pages suivantes.

- ***TREATIES* - Vers une évaluation à distance de l'environnement par l'observation intégrée de la Terre.** L'objectif du TREATIES est de faciliter les études à l'externe de la détection *in situ* par l'impartition à l'industrie, par des collaborations à effet de levier, par l'établissement de divers liens, et par des collaborations en R et D. Le TREATIES permet d'établir des liens par l'entremise de travaux avec des partenaires choisis sur les approches en observation intégrée de la Terre pour la surveillance des ressources et de l'environnement.
- ***ProWISE* - Évaluation de prototypes de webcapteurs sans fil intelligents.** Le ProWISE s'attache au premier objectif du PAMCIS par le déploiement *in situ* et la mise à l'épreuve de webcapteurs automatiques intelligents dans des contextes d'applications en sciences de la Terre.

Vers une évaluation à distance de l'environnement par l'observation intégrée de la Terre (TREATIES)

Contrats accordés à l'industrie canadienne

- Prototype de système de gestion de l'information sur les inondations (Isosceles Information Solutions, Inc.) - complété.
- Projections améliorées pour des cultures spécifiques (Noetix Research, Inc.) - complété.
- Services Web de paramètres pour la correction atmosphérique (Centre for Research in Earth and Space Technology (CRESTech) et Université de Sherbrooke) - complété.
- Solutions intégrant ordinateurs à porter et communications par satellites (Halltech Atmospheric Services) - complété.
- Développement d'applications de la télédétection en agriculture et en hydrologie et transfert de technologie (Noetix Research, Inc. Avec la Division des applications du CCT) - complété.
- Soutien à la R et D en observation intégrée de la Terre et transfert de technologie (ACG Space, Inc.) – en place.
- Nouveaux outils d'exploration de données pour la surveillance de la température de surface des étendues de terre d'après des données intégrées d'observation de la Terre (GlobVision, Inc.) – achèvement en mars 2003.

Collaborations à effet de levier

- Fluorescence induite par laser pour l'analyse chimique *in situ* en agriculture (avec Agriculture et Agroalimentaire Canada (AAC)).
- Études de concepts pour des applications en observation intégrée de la Terre avec emphase sur la détection *in situ* (avec le CRESTech).
- Caractérisation des aérosols atmosphériques sur le Canada dans le contexte des études du changement climatique au moyen de l'AEROCAN, un réseau canadien au sol de radiomètres solaires automatisés (avec l'Université de Sherbrooke, le CRESTech, le Service météorologique du Canada (SMC) d'Environnement Canada, le Conseil de recherches en sciences naturelles et en génie (CRSNG) et le Goddard Space Flight Center (GSFC) de la NASA, entre autres).
- Étude de l'observation de la Terre par satellites à l'appui de programme de gestion de bassins versants (avec l'Agence spatiale canadienne et Borstad Associates Ltd.) – achèvement en mars 2003.
- Surveillance géomatique de sites géotechniques (avec le Réseau des centres d'excellence (RCE) en Géomatique pour des interventions et des décisions éclairées (GÉOIDE) et l'Université Queen's).
- Étude des caractéristiques d'humidité des sols en fonction de la résolution spatiale des systèmes de télédétection et de la répartition spatiale des systèmes de détection *in situ* (Université d'Ottawa).
- Webcapteur intelligent d'observation intégrée de la Terre pour une surveillance améliorée des sécheresses (avec Precarn Incorporated et MacDonald Dettwiler and Associates (MDA)).

Liens

- Acquisition et évaluation (par des chercheurs scientifiques en développement d'applications au CCT) de l'ensemble ArcPad-iPAQ-GPS.
- Prestation de conseils techniques et stratégiques à la Fondation de recherche en agriculture du secteur Indian Head (Indian Head Agricultural Research Foundation) dans le cadre de son initiative RoboScout.
- Participation au groupe de travail d'usagers (User Working Group) du Distributed Active Archive Center (DAAC) de l'Oak Ridge National Laboratory (ORNL) des É.-U.
- Participation au Groupe de travail sur l'étalonnage et la validation (GTÉV) du Comité international des systèmes d'observation de la Terre (CSOT)

Autres partenariats en R et D

- Systèmes d'information géospatiale améliorés permettant l'accès, la gestion et la visualisation multi-plateformes à l'appui de la planification et de l'intervention d'urgence (avec divers organismes).
- Modélisation du cycle du carbone dans les terres humide de la Mer Bleue (avec le Centre de recherche sur le climat et les changements à l'échelle du globe (C²GCR) de l'Université McGill et une partie du réseau Ameriflux).
- Surveillance de la sécheresse (avec le Water Institute for Semi-arid Ecosystems (WISE) de l'Université de Lethbridge).
- Dialogues en vue de partenariats de R et D avec des spécialistes au CCT, à la Commission géologique du Canada (CGC), à l'Agence spatiale canadienne (ASE) et au Centre de recherches sur les communications (CRC).

Évaluation de prototypes de webcapteurs sans fil intelligents (ProWISE)

Aperçu du prototype de webcapteur

L'objectif principal de l'Évaluation de prototypes de webcapteurs sans fil intelligents (ProWISE) est le déploiement sur le terrain d'un webcapteur offrant une connectivité inter-nodale complète ainsi que l'accès et la commande à distance. En outre, dans le cadre du projet on met à l'épreuve et on fait la démonstration de l'exploitation de webcams et de la téléprésence à des emplacements sur le terrain éloignés. Un banc d'essai de technologies est utilisé pour intégrer les diverses composantes d'un webcapteur pour permettre de le commander à distance et éventuellement de le configurer à distance. Le processus exige la solution de problèmes de génie associés aux interfaces entre les capteurs en un nœud donné et les dispositifs de télécommunication sans fil qui comprendront des pilotes de contrôle et de décision intelligents.

Des essais sur le terrain sont menés afin d'évaluer des problèmes de déploiement et d'exploitation à distance ainsi que des considérations relatives à l'utilisation de webcapteurs dans des contextes spécifiques d'acquisiton de données, d'extraction d'information et de prise de décisions. Le prototype initial de webcapteur consiste en cinq nœuds et une station de base. Dans la configuration initiale, chacun des nœuds du webcapteur comprend un mât compact portant des capteurs enregistrant la température, l'humidité relative, le rayonnement solaire incident, les précipitations liquides, la vitesse et la direction du vent, l'humidité du feuillage le cas échéant, la température et l'humidité du sol. L'humidité du sol en particulier est considérée comme un paramètre clé qui peut également être estimé d'après les données de satellites radar comme le Radarsat canadien. Les sous-systèmes du microspectromètre utilisé pour les mesures de la luminance de la surface et l'irradiance incidente en sont encore aux stades de l'intégration et des essais.

Différentes stratégies de télécommunication et de téléprésence ont été examinées. L'accès et la commande sont effectués à distance et ont été éprouvés entre les nœuds individuels et la Station de travail pour l'observation intégrée de la Terre (STOIT) à Ottawa (exploitable par le Web sur Internet) ainsi qu'entre les nœuds et la station de base puis la STOI. Les microcapteurs sont commandés par des systèmes encastrés spécialement adaptés aux applications géospatiales étudiées.

Ces déploiements ne tirent pas encore avantage des systèmes entièrement miniaturisés ou intelligents, mais s'effectuent dans des cadres opérationnels dans des milieux éloignés avec des composantes standard disponibles sur le marché (CSDM). La prochaine étape sera l'introduction de la communication internodale intelligente. À ce stade, les nœuds actuels deviendront vraisemblablement les stations de base de webcapteurs locaux constitués par l'addition de nombreux nœuds capteurs plus petits. On disposera ainsi d'au moins deux niveaux hiérarchisés de webcapteurs *in situ*. Même sous sa forme actuelle, l'activité du prototype de webcapteur se situe à plusieurs égards à l'avant–garde. De nombreux groupes responsables d'applications en sciences de la Terre, dont divers organismes gouvernementaux, cherchent à utiliser des webcapteurs. Cette capacité constitue un grand pas vers l'acquisition au sol plus rapide, plus complète et plus autonome de données, vers la validation des données d'observation de la Terre et, éventuellement, vers le déclenchement d'alertes en temps réel dans des contextes appropriés.

Premiers essais sur le terrain - Ottawa et le lac Bratt's 2002

Au début de 2002, un prototype de réseau de capteurs a été déployé à l'extérieur près d'Ottawa au Canada afin de faciliter le débogage du protocole de conversion entre les ensembles de microcapteurs/microcontrôleurs et les émetteurs-récepteurs de données par satellites. Les portées des appareils de télémétrie RF ont été éprouvées afin d'identifier les distances possibles et les zones de couverture optimales en vue de déploiements de webcapteurs.

En juillet 2002 un déploiement expérimental a été effectué à l'Observatoire du rayonnement atmosphérique du lac Bratt's (ORALB) en Saskatchewan, en collaboration avec le Service météorologique du Canada d'Environnement Canada (SMC/EC). Cette campagne de travaux sur le terrain englobait des essais du système complet d'accès et de commande par la Station de travail d'observation intégrée de la Terre (STOI) au CCT à Ottawa. Dans la configuration initiale, chacun des nœuds du webcapteur comprend un mât compact portant des capteurs enregistrant la température, l'humidité relative, le rayonnement solaire incident, les précipitations liquides, la vitesse et la direction du vent, la température et l'humidité du sol. Les faits saillants du déploiement à l'ORALB sont exposés ci-après.

- Premier déploiement sur le terrain par le CCT d'un prototype de webcapteur *in situ* à cinq nœuds dont les données sont accessibles en temps quasi réel depuis la STOI à Ottawa par télécommunications RF et par satellites.
- Première utilisation par le CCT de microspectromètres sur des cibles agricoles près de l'ORALB avec acheminement des données par satellites à la STOI à Ottawa.
- Premier essai de téléprésence du CCT à l'ORALB par webcam et modem satellite avec transmission d'images en temps réel ainsi que dépannage et résolution de problèmes micrologiciels à distance par téléprésence.
- Démonstration d'extraction de données de la base de données de la STOI à Ottawa par satellite depuis l'ORALB.
- Validation des données météorologiques et d'humidité du sol recueillies par le webcapteur d'après des mesures indépendantes effectuées à l'ORALB par le SMC/EC (en cours).

Déploiement dans le bassin de la rivière Rouge en 2002-2003

Un déploiement expérimental plus complexe a suivi à l'automne de 2002 dans le contexte d'une application en prévision des crues dans le bassin de la rivière Roseau, un affluent de la rivière Rouge au Manitoba (Canada) en collaboration avec des spécialistes en hydrologie du CCT et de l'Institut national de recherche sur les eaux (INRE) d'Environnement Canada (EC). En voici les faits saillants.

- Le prototype de webcapteur *in situ* à cinq nœuds est actuellement déployé dans le bassin de la rivière Roseau, tributaire de la rivière Rouge au Manitoba, et y restera pendant la saison des crues au printemps de 2003.
- Le webcapteur à cinq nœuds fonctionne de manière autonome et on accède à distance depuis la STOI à Ottawa à des mesures des paramètres météorologiques ordinaires ainsi que de l'humidité du sol. Ces valeurs doivent être comparées à celles recueillies en trois stations météorologiques plus lourdes munies d'enregistreurs de données et à celles obtenues par des techniques exigeantes en main-d'œuvre appliquées par les hydrologues participant au projet.
- Validation des données météorologiques et d'humidité du sol recueillies au moyen du webcapteur d'après des mesures indépendantes effectuées par le CCT et l'INRE/EC (en cours).

Le déploiement du prochain webcapteur, et peut-être la prochaine phase des travaux, ciblera des applications en surveillance des sécheresses.

Avantages et impacts

Impact commercial

Des projets pilotes ont été complétés en collaboration avec l'industrie canadienne afin de faire la démonstration de produits d'information évolués dans des domaines prioritaires où des avantages opérationnels et commerciaux découlent de l'application de technologies nouvelles pour l'acquisition, l'archivage, la fusion et l'assimilation de données *in situ*.

Économies

Le PAMCIS démontre l'utilité des webcapteurs sans fil intelligents et autonomes qui permettent une plus grande participation à moindre coût à des activités ayant exigé jusqu'à maintenant beaucoup de ressources. L'accès par le Web à des ressources sur le terrain pourrait en outre faciliter la gestion des avoirs et l'entretien à distance des instruments lorsque nécessaire.

Transfert de technologie

Une proportion importante des fonds disponibles pour le PAMCIS a été consacrée au développement de capacités d'acquisition et d'intégration de données *in situ* par l'industrie et des universités au Canada. Des projets pilotes faisant la démonstration de l'utilité de l'intégration de données recueillies *in situ* et de données de télédétection ont été menés avec la participation directe d'organismes opérationnels.

Partenariats

Les projets exécutés dans le cadre du PAMCIS ont donné lieu à d'entièrement nouveaux partenariats synergistes entre organismes pour la mise au point et l'archivage de produits d'information en sciences de la Terre tirant avantage de l'acquisition et de l'intégration de données recueillies *in situ* et de données de télédétection.

Progression de la connaissance

Les technologies d'acquisition de données et les systèmes de traitement de données à la fine pointe des connaissances sont modifiées et optimisées à des fins choisies et d'importance stratégique en sciences de la Terre. De nouveaux produits d'information sont mis au point et validés en combinant la fusion et l'assimilation de données de télédétection et de mesures *in situ* avec la modélisation. L'accès à des archives nationales de mesures *in situ* et à des métadonnées sur d'autres archives de données *in situ* facilite de nouvelles recherches et les progrès en sciences de la Terre.

Accroissement des moyens

Le PAMCIS constitue une initiative stratégique dans un nouveau domaine faisant intervenir des technologies convergentes à l'appui d'une surveillance évoluée des ressources et de l'environnement. Il a à ce titre permis la création de nouvelles occasions d'étendre les aptitudes, les compétences et la réputation pour permettre au personnel de participer à de nouveaux travaux édifiants et prometteurs pour les carrières des intéressés.

Base nationale de compétences

Dans le contexte de la surveillance des ressources et de l'environnement, le PAMCIS marie les technologies convergentes des microcapteurs, de l'informatique et des télécommunications sans fil à de nouveaux concepts comme celui des webcapteurs *in situ* et devrait ainsi offrir d'excellentes occasions de perfectionnement professionnel au Canada en général et de formation d'un personnel hautement qualifié en particulier.

Impact sur la société et les politiques

Une approche davantage systématique et opportune pour la saisie, l'archivage et l'intégration des données permet la prestation d'une information validée pour la prise de décisions stratégiques dans le contexte de la surveillance des ressources et de l'environnement.

Accès à l'information

Un accès amélioré via Internet aux activités, aux données et à l'information en sciences de la Terre est hautement prioritaire pour le gouvernement du Canada. Le PAMCIS va accroître la disponibilité des données recueillies *in situ* par l'entremise de l'Infrastructure canadienne des données géospatiales (ICDG).

Transparence du gouvernement et connectivité des Canadiens

Le PAMCIS illustre comment le public pourrait avoir accès à l'information relative aux activités sur le terrain des scientifiques et des ingénieurs du gouvernement et comment le gouvernement pourrait accroître la visibilité de ces personnes à l'œuvre.

« La puissance de la convergence technologique
prodiguera des bienfaits appréciables à tous et chacun »
Douglas Mulhall, *Our Molecular Future*, 2002.

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A Lifetime Radiometric Calibration Record for the Landsat Thematic Mapper

1 Introduction

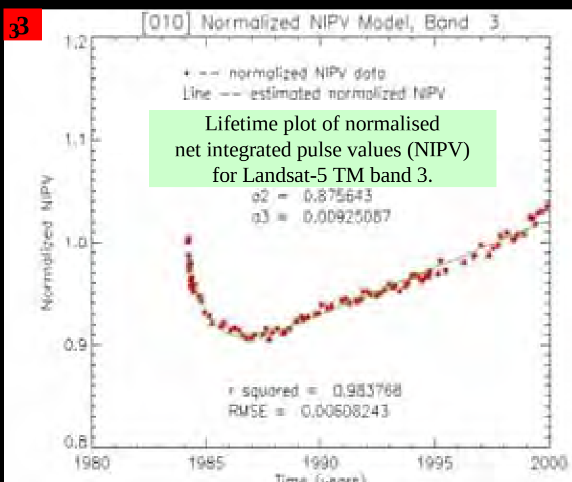
A primary goal of the Landsat program is to provide a means to place the current Landsat-7 Enhanced Thematic Mapper Plus (ETM+) and the Landsat-4/5 Thematic Mapper (TM) sensors on a comparable radiometric scale. This will allow the possibility of examining a continuous, near-global data set reaching back to 1982 with a view to monitoring global and regional land dynamics at a 30-m scale where both natural and anthropogenic disturbances can be assessed. The challenges include characterisation of the radiometric behaviour of the Landsat-5 TM over its 17-year lifetime since 1984, a collaborative effort between several agencies that is highlighted in this poster. Analogous work for the Landsat-4 TM is in progress.

2 TM Internal Calibrator Trend Analysis

South Dakota State University has developed techniques to analyse TM Internal Calibrator (IC) data for the lifetime of Landsat-5 (Helder et al., 1998). Analysis shows that only the IC pulses from reverse scans and lamp state #2 (010) should be used for trend characterisation and for radiometric processing during TM product generation. IC analysis results for the solar-reflective bands also indicate that the TM lifetime radiometric trend takes a combined exponential plus linear form. The exponential part is deemed to be a true change in the TM (likely due to outgassing from the spectral filters during the first few years after launch) and the subsequent linear increase is considered to be a change in the IC system (likely due to changes in the lamp characteristics) rather than a true TM change. Thus, the linear trend will be excluded from the trend characterisation based on the post-1988 fit.

Preliminary analysis of the IC data for the thermal band indicates that the calibration parameters provided with each calibrated product can be used to convert to radiance throughout the TM mission lifetime for products generated using IC data (which track temperature fluctuations in the system).

3



Lifetime plot of normalised net integrated pulse values (NIPV) for Landsat-5 TM band 3.

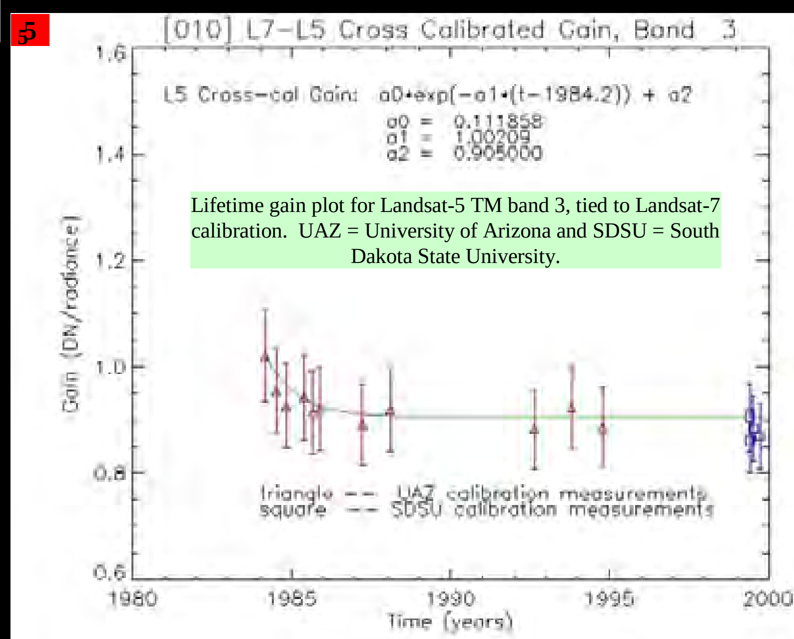
4 Improved Radiometric Calibration for Raw Solar-Reflective TM Data

The lifetime IC trend model for Landsat-5 TM has been scaled to match the Landsat-7 ETM+ gain coefficient in each spectral band, based on the 1999 tandem-based cross-calibration. The resulting curves are generally consistent with independent vicarious calibration results obtained by the University of Arizona over time and by South Dakota State University in 1999. The time-dependent equations for Landsat-5 TM gain as a function of year since launch, Gnew, applicable to raw data, take the form

$$Gnew(year) = a0*exp(-a1*(year - 1984.2)) + a2 .$$

Note that the TM gain coefficients in the solar reflective bands have been constant to within the accuracy of the methodology since about 1987. The challenge currently being addressed is specification and implementation of an operational radiometric processing algorithm that takes advantage of the improved calibration coefficients.

5



Lifetime gain plot for Landsat-5 TM band 3, tied to Landsat-7 calibration. UAZ = University of Arizona and SDSU = South Dakota State University.

6 Temporal Characterization of Landsat-5 TM Lifetime Gain, Gnew, Tied to Landsat-7:

Gnew(year)=a0*exp(-a1*(year-1984.2))+a2

where a0 and a2 are in counts/(W/(m2 sr μm)).

Spectral Band	a0	a1	a2
1	0.1457	0.9551	1.243
2	0.05865	0.836	0.6561
3	0.1119	1.002	0.905
4	0.1077	1.277	1.082
5	0.2434	1.207	7.944
7	0.4036	0.9991	14.52

7 Radiometric Recalibration of Existing Products

Over the Landsat-5 TM lifetime, significant investments have been made to collect radiometrically calibrated TM data over large geographic areas of interest. Therefore, equations have been developed to allow users to recalibrate image data from the original image product (Teillet et al., 2001). The key is knowledge of the original gain used to generate the product, which was presumably based on the IC pulse data in the original radiometric processing. To deal with cases when the original gains are not available for given products, a nominal gain history is being developed for North American processing systems based on IC trend characterisations.

8

R&D sponsored by:
Landsat Project Science Office, NASA/GSFC, Code 923, Greenbelt, Maryland 20771.

Publications:

• P.M. Teillet, D.L. Helder, J.L. Barker, B.L. Markham, K.J. Thome, R.Morfitt, J.R. Schott, and F.D. Palluconi, "A Lifetime Radiometric Calibration Record for the Landsat Thematic Mapper", in press, *Proc. of the 23rd Canadian Symposium on Remote Sensing*, August 2001, Quebec City, Quebec, Canada. (Available from CCRS: http://www.ccrs.nrcan.gc.ca/ccrs/eduref/ref/biblioe.html)

• Helder, D.L., Boncyk, W., and Morfitt, R. 1998. "Absolute Calibration of the Landsat Thematic Mapper Using the Internal Calibrator", Proc. of 1998 International Geoscience and Remote Sensing Symposium (IGARSS'98), Seattle, Washington, pp. 2716-2718.

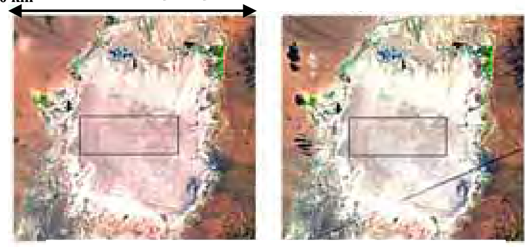
NASA Goddard Space Flight Center · Canada Centre for Remote Sensing · USGS · SDSU · ARIZONA · R·I·T · JPL

Radiometric Cross-Calibration of the Landsat-7 ETM+ and Landsat-5 TM Sensors Based on Tandem Data Sets

Overview of Methodology and Results of Radiometric Cross-Calibration Between Landsat-5 TM and Landsat-7 ETM+

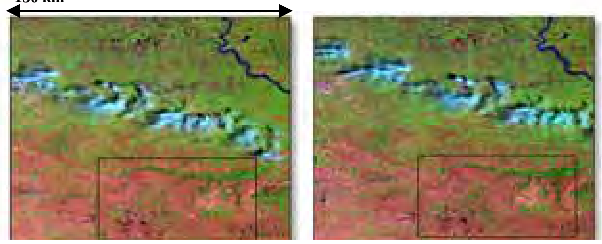
A cross-calibration methodology has been formulated and implemented to use image pairs from the Landsat-7 / Landsat-5 tandem configuration period in early June 1999 to radiometrically calibrate the Landsat-5 Thematic Mapper (TM) with respect to the well-calibrated Landsat-7 Enhanced Thematic Mapper Plus (ETM+). Results have been obtained from a grid-cell analysis of two different tandem image pairs for which ground reference data are available (Railroad Valley Playa, Nevada and Niobrara, Nebraska). The methodology benefits considerably from the combination of darker and brighter sites for radiometric calibration. The use of large areas common to both the ETM+ and TM image data successfully avoided radiometric effects due to residual image misregistration. The most limiting factor in the cross-calibration approach is the need to adjust for spectral band differences between the two sensors, which requires knowledge about the spectral content of the scene. It was found that spectral band difference effects are more dependent on the surface reflectance spectrum than on atmospheric and illumination conditions. The cross-calibration approach applied to the two tandem image pairs yielded repeatable results (within 1.6 % on average) for TM responsivity coefficients in the six solar reflective bands. For spectral bands 1-4, the tandem cross-calibration results compare closely (within 1.4 % on average) to independent methods and results obtained by other groups. Additional work is needed to reduce the disagreement in results (11 % on average) from different groups for the two short wave infrared bands. The thermal band 6 has not been addressed in this work.

~20 km **Railroad Valley Playa, Nevada, WRS 40/33, June 1, 1999**



Landsat-5 TM Bands 5, 4, 2 Landsat-7 ETM+

~150 km **Niobrara, Nebraska, WRS 31/30, June 2, 1999**

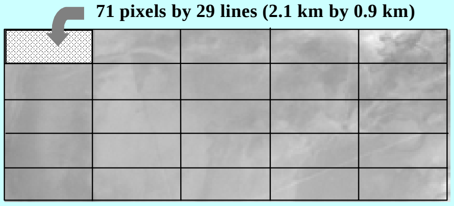


Landsat-5 TM Bands 5, 4, 2 Landsat-7 ETM+

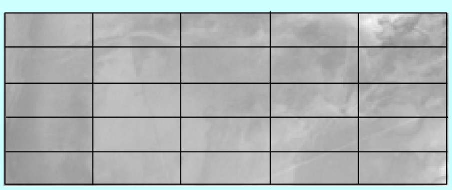
The long-term consistency of the Landsat data record relies heavily on the best efforts and co-operation of several agencies and universities for success. The user community deserves to have a consistent Landsat data record and the success of Landsat-7 is an opportunity to achieve this goal. The tandem cross-calibration approach provides a valuable "contemporary" calibration update for Landsat-5 TM based on the excellent radiometric performance of Landsat-7 ETM+. Once other, retrospective studies have been incorporated to establish a TM calibration record over its mission lifetime to date, an effort will have to be made to specify and implement algorithms for the proper calibration of archived raw TM data and, wherever possible, existing processed TM data sets.

Railroad Valley Playa, Nevada, June 1, 1999

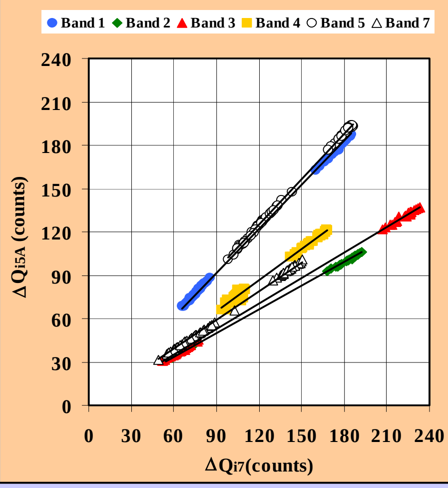
71 pixels by 29 lines (2.1 km by 0.9 km)



Landsat-7 ETM+ Sub-Scene Spectral Band 1



Landsat-5 TM Sub-Scene Spectral Band 1



The figure on the left illustrates the grid cell analysis scheme for the Railroad Valley Playa test site. The figure on the right plots grid-cell means for bias-corrected TM image counts adjusted for illumination and spectral band difference effects (ΔQi5A) versus bias-corrected ETM+ image counts (ΔQi7) for the two sub-scene pairs taken together. The lines are linear fits with zero-intercepts. TM responsivity Gi5 in spectral band i is given by Gi5 = Gi7 ΔQi5A / ΔQi7 , where Gi7 is ETM+ responsivity.

Spectral Band	1999 ETM+ Cross Calibration Gi5 (CPUR)	Prelaunch Laboratory Calibration Gi5 (CPUR)	Difference Relative to Prelaunch Gi5 (CPUR)
1	1.202	1.555	-23%
2	0.6540	0.786	-17%
3	0.8901	1.020	-13%
4	1.090	1.082	0.70%
5	7.929	7.875	0.69%
7	14.48	14.77	-1.9%

Gi5 = Landsat-5 TM responsivity in spectral band i in counts per unit radiance (CPUR), where radiance is in W/(m² sr µm). Responsivity coefficients from the tandem-based cross-calibration (using the Railroad Valley and Niobrara data sets taken together) are compared to prelaunch coefficients, where the percentage difference is with respect to the prelaunch values.

R&D sponsored by::

• Landsat Project Science Office, NASA/GSFC, Code 923, Greenbelt, Maryland 20771 USA

Publication:

• P.M. Teillet, J.L. Barker, B.L. Markham, R.R. Irish, G. Fedosejevs, and J.C. Storey, "Radiometric Cross-Calibration of the Landsat-7 ETM+ and Landsat-5 TM Sensors Based on Tandem Data Sets", in review, *Remote Sensing of Environment*, Special Issue on Landsat-7 Science.

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NASA Goddard Space Flight Center

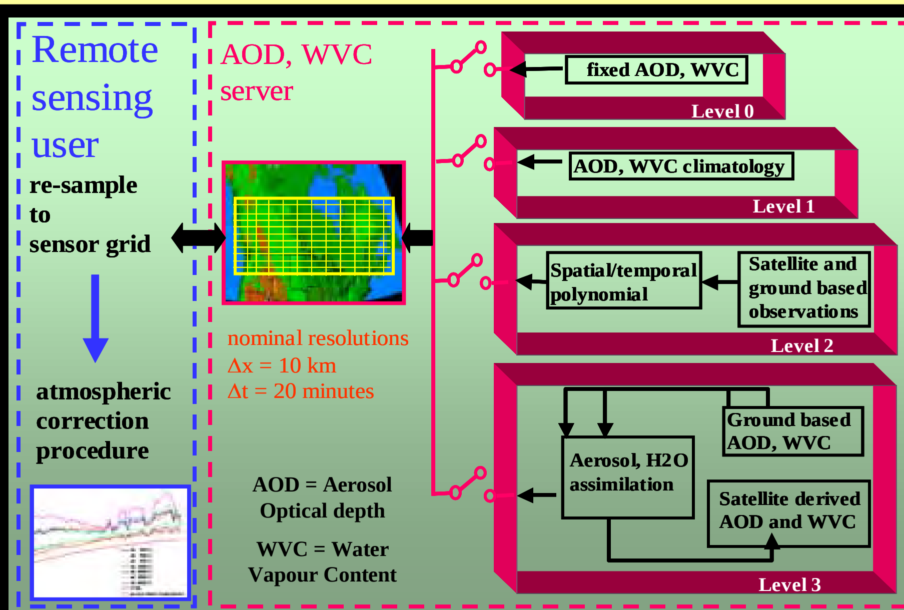
Canada Centre for Remote Sensing

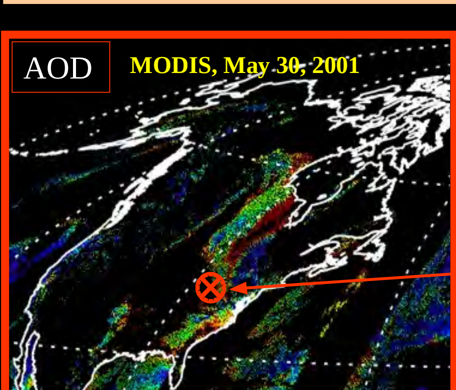
Atmospheric Optical Parameter Server for Atmospheric Corrections of Remote Sensing Data

O'Neill, N.T., A. Royer, M. Aubé, S. Thulasiraman, F. Vachon, P. M. Teillet, J. Freemantle, J-P. Blanchet, and S. Gong (2002). "Atmospheric Optical Parameter Server for Atmospheric Corrections of Remote Sensing Data ", *Proceedings of the 2002 IEEE Geoscience and Remote Sensing Symposium (IGARSS 2002) and the 24rd Canadian Symposium on Remote Sensing*, Toronto, Ontario, Volume V, pp. 2951-2953, also on CD-ROM.

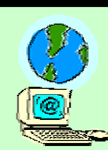
Freemantle, J., M. Versi, N.T. O'Neill, A. Royer, M. Aubé, S. Thulasiraman, F. Vachon, P.M. Teillet, J-P Blanchet, and S. Gong (2002). "Using Web Services for Atmospheric Correction of Remote Sensing Data ", *Proceedings of the 2002 IEEE Geoscience and Remote Sensing Symposium (IGARSS 2002) and the 24rd Canadian Symposium on Remote Sensing*, Toronto, Ontario, Volume V, pp. 2939-2941.

Overview: Significant atmospheric correction improvements can only be achieved by accurately representing the spatial and temporal variability of the intrinsic atmospheric optical parameters that serve as input to the radiative transfer model. The challenge is to render the existing array of ground and satellite based (input) atmospheric optical measurements coherent and standard. This is accomplished by assimilating the atmospheric optical measurements and their expected errors with a spatio-temporal atmospheric model driven by meteorological-scale wind fields. Such models act as intelligent interpolators in space and time, and as a tool for product QA and standardization. The concept of a meteorological scale optical parameter prediction system for atmospheric corrections (NOMAD for "Networked On-line Mapping of Atmospheric Data") has been developed. The system is viewed as multi-level in that it will output atmospheric optical parameter estimates ranging from the meteorological to climatological scales and from the synoptic scale to the lower mesoscale (coarse to detailed satellite spatial resolutions). The operational concept is that it will reside on a central server that will be accessible to any atmospheric correction system. Aside from the obvious advantage of atmospheric corrections operationalization, this concept transfers the responsibility of quality assuring atmospheric parameters from the user to the science and technical staff maintaining the atmospheric server.

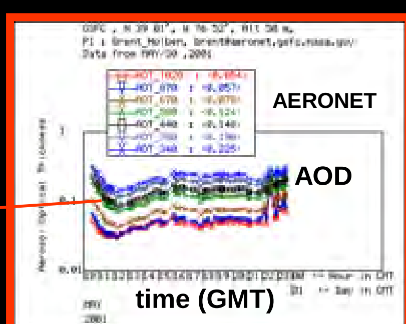




An atmospheric correction server:



- Is user transparent
- Uses intelligent, self-consistent, physically based, interpolation
- Has quality assured and traceable input parameters
- Is the only realistic approach to standardized atmospheric correction



Using Web Services for Atmospheric Correction: A prototype of the NOMAD central server has been developed. Using a Web Service (WS), atmospheric aerosol optical depths are transmitted via the network from a central WS server to a WS-aware atmospheric correction application. A best estimate of the aerosol optical depth at 500 nm is retrieved automatically from the central server database for the date and location of the image of interest. A WS approach was adopted to allow easy cross-platform development in multiple software languages. Using the Web Services Definition Language (WSDL) description of the atmospheric correction parameter server Web Service, application developers can make atmospheric correction applications "web aware". Initially, the WS will use a global database of climatological average values of aerosol optical depth at 500 nm. Simple client and server applications have been developed to illustrate how this service could be used. In the future, this service will expand to include other atmospheric optical parameters and more complex atmospheric aerosol models, as well as to find a long-term host for this WS.

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Environment Canada | Environnement Canada
Meteorological Service of Canada | Service météorologique du Canada

Natural Resources Canada | Ressources naturelles Canada
Canada Centre for Remote Sensing | Centre canadien de télédétection

AEROCAN: the Canadian Sun-Photometer Network

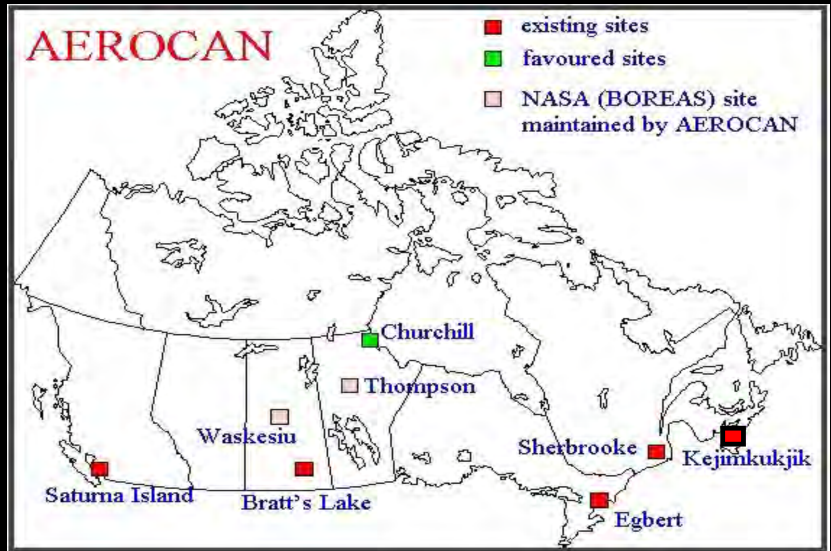
The Canadian sun-photometer network, AEROCAN, is a ground-based aerosol monitoring network of automatic sun and sky radiometers with a satellite data transmission system and centralized data processing.

AEROCAN is financed by Natural Resources Canada (Canada Centre for Remote Sensing) and managed by the University of Sherbrooke. It also receives operational support from Environment Canada (Atmospheric Environement Service) and from the National Aeronautic and Space Administration (Goddard Space Flight Center - NASA/GSFC). AEROCAN is a federated part of the world-wide Aerosol Robotic Network (AERONET) operated by NASA/GSFC. Free data access is provided via an integrated archival browser and processing system developed by NASA/GSFC.

The main objectives of AEROCAN are to:

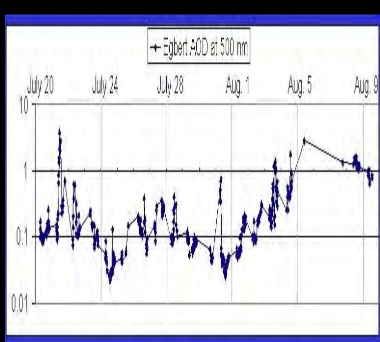
• provide is-situ data for validation of atmospheric optical properties derived from satellite sensors for use in image atmospheric correction and satellite aerosol retrieval

• validate transport and radiation budget models, including the Northern Aerosol Regional Climatic Model (NARCM) for improvemed assessment of climate forcing by aerosols

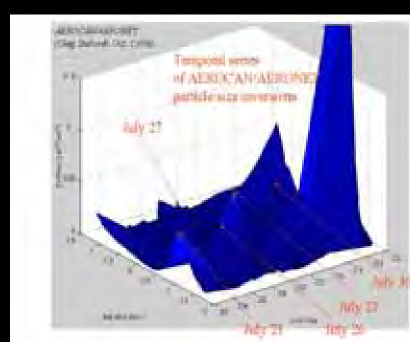


The CIMEL CE-318 auto-tracking radiometer measures sun and sky radiance in eight spectral bands. Combined solar extinction and scattering measurements allow the retrieval of aerosol optical thickness, particle size distribution, phase function, and real and imaginary parts of refractive index.

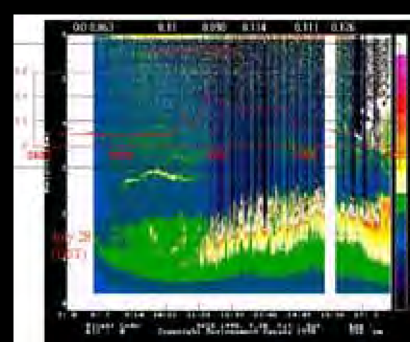
Samples of derived outputs from CIMEL measurements



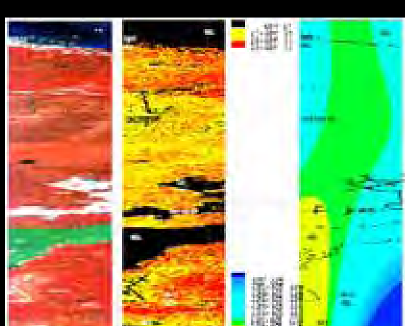
Aerosol optical depth (AOD),



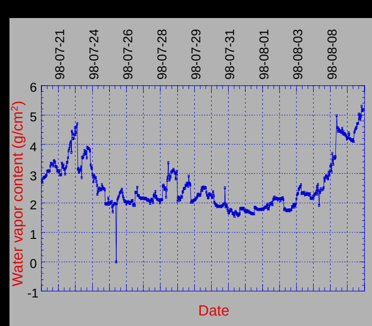
Particle size distribution



AOD vs LIDAR backscatter profile



BOREAS CASI image **Retrieved AOD**



Precipitable water vapour

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http://callisto.si.usherb.ca/~abokoye/Home

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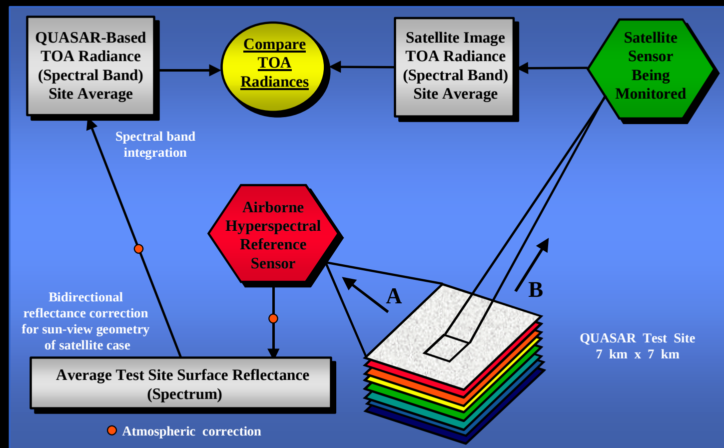
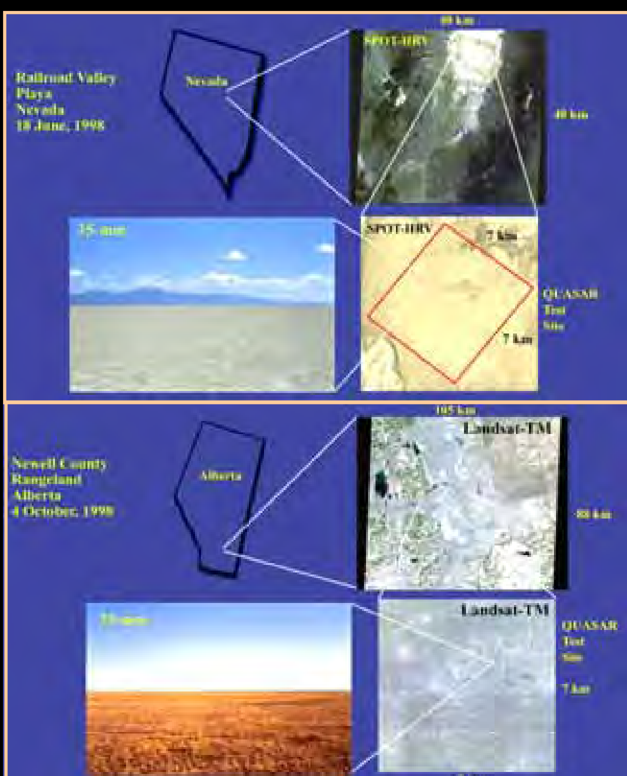
A Generalized Approach to the Vicarious Calibration of Multiple Earth Observation Sensors Using Hyperspectral Data

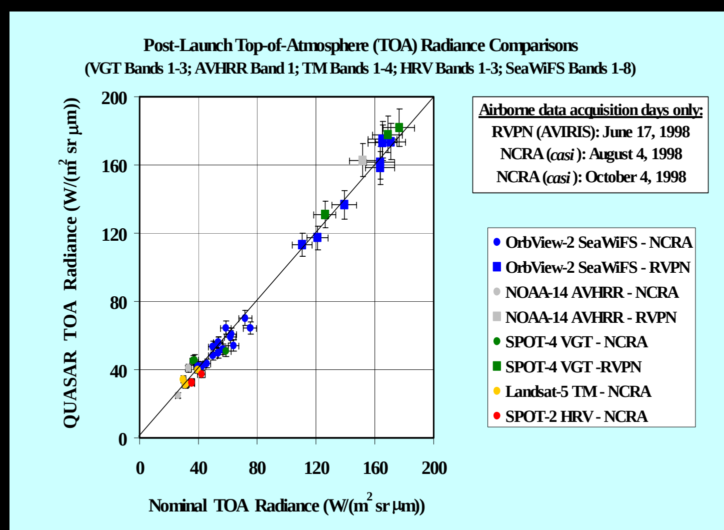
A Quality Assurance and Stability Reference (QUASAR) Monitoring Methodology for Sensor Radiometric Calibration

A new methodology has been developed to use spatially extensive hyperspectral imagery as reference data to carry out vicarious radiometric calibrations for multiple satellite sensors. The methodology has been validated using data from a campaign at the Railroad Valley playa test site in Nevada in June 1998. The proof of concept has been further tested based on data acquisition campaigns at the Newell County rangeland test site in Alberta in August and October 1998. All three campaigns included ground-based measurements, satellite imagery, and airborne hyperspectral data. The airborne data were acquired using the NASA/JPL AVIRIS at Railroad Valley and the Canadian *casi* in all three campaigns. Radiometric calibration monitoring results were obtained for five Earth observation sensors: NOAA-14 AVHRR, OrbView-2 SeaWiFS, SPOT-4 VGT, SPOT-1 HRV, and Landsat-5 TM. The results indicate that the nominal on-orbit radiometric calibrations of all the satellite sensors fit within their predicted uncertainties. The combination of both lower-reflectance and higher-reflectance test sites improves the quality of the calibration monitoring results. The greatest source of error is the bidirectional reflectance correction for the sun-view geometry for each satellite case.



The QUASAR concept for monitoring satellite sensor calibration. The main results consist of comparisons between top-of-atmosphere (TOA) radiances based on reference sensor data (A) and actual satellite sensor data (B).
The Railroad Valley playa in Nevada (referred to as RVPN) is situated at 38° 28’ N and 115° 41’ W and at an elevation of 1435 m above sea level (ASL).
The prairie rangeland test site is in Newell County, Alberta (referred to as NCRA), which is north-west of Medicine Hat, Alberta. The test site is located at 50° 18’ N and 111° 38’ W and has a terrain elevation of 750 m ASL.





Comparison of QUASAR-based and nominal top-of-atmosphere (TOA) radiances for the three airborne data acquisition days (one at the RVPN test site and two at the NCRA test site). The error bars represent ± 6 percent uncertainty levels. The diagonal line is the unity slope line. The linear fit of the radiance data points is $y = 1.026x – 1.26$, and $r^2 = 0.990$.

Contacts:
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• Kurtis J. Thome, Stuart F. Biggar: Remote Sensing Group, Optical Sciences Center, University of Arizona, Tucson, Arizona, USA 85721-0094
CCRS Web Site: http://www.ccrs.nrcan.gc.ca/

Publication: Teillet, P.M., G. Fedosejevs, R.P. Gauthier, N.T. O’Neill, K.J. Thome, S.F. Biggar, H. Ripley, and A. Meygret, 2000, "A Generalized Approach to the Vicarious Calibration of Multiple Earth Observation Sensors Using Hyperspectral Data", *Remote Sensing of Environment*, 77(3): 304-327.

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Remote Sensing Group

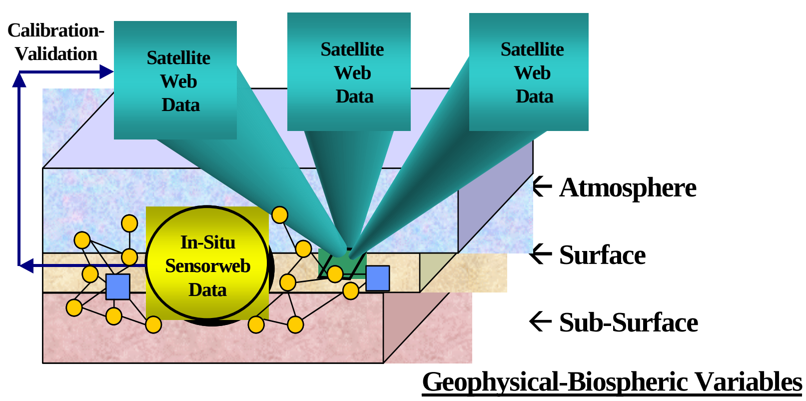
CCRS-CRESTech In-Situ Sensing Concept Study Program

Context: Integrated Earth Sensing:

Our monitoring requirements and responsibilities as nations and as members of the global community continue to multiply. We have some powerful science and technology tools at our disposal but it is not clear that we are using them effectively to tackle the issues before us. In many countries, government agencies in particular have long traditions of excellence in field data acquisition and more recently space-based observations of the Earth. However, such endeavours have been and largely remain resource-intensive activities. Innovative tools need to be developed to provide the time-critical and cost-effective monitoring of complex and dynamic systems essential to support effective decision-making.

At the 2002 World Summit on Sustainable Development, the point was made that "… space-derived information generally needs to be combined with in-situ measurements and models to obtain a holistic picture of the Earth's environment. … There is no Sustainable Development without adequate information about the state of the Earth and its environment". At the World Space Congress 2002, a Panel convened to explore "An Integrated Approach to Monitoring Planet Earth" noted that ground-based (in-situ) monitoring systems are inadequate by several orders of magnitude. The majority of space agencies represented on the Panel stated that an integrated approach to monitoring the Earth demands that the in-situ sensing be a funded part of the solution offered by space agencies. Indeed, the increasing confluence of advanced technologies for Earth-based sensorwebs, Earth science satellite webs, and the power of the Internet will soon provide a kind of global virtual presence or integrated Earth sensing. Indeed, the confluence of advanced technologies for Earth-based sensorwebs, Earth observation satellite webs, and the power of the Internet will soon provide integrated Earth sensing.

Integrated Earth Sensing



Concept Studies:

- Development of Remotely Deployed, *in situ* Sensing Devices for Real-time Monitoring of Environmental Parameters in Ecological Applications, University of Guelph.
- Integrating Geotechnical Sensor Systems and Stability Monitoring with Dynamic GIS, Queen's University.
- A Web-Based Distributed Geocomputing Architecture for Smart Sensor Webs, York University.
- A Mobile Environmental Monitoring System with Real-Time Database Updates, University of Windsor.
- A Drive-Point Probe for In-Situ Measurement of Groundwater Velocities, University of Waterloo.
- Integration of In-Situ Sensor Data into the NOMAD Atmospheric Correction Server, York University.
- Integration of In-Situ Meteorological Observations and Satellite Imagery, York University.

CCRS-CRESTech In-Situ Sensing Concept Study Program:

Given the increasing importance of fusing both in-situ and remote sensing data for strategic use in many applications, the Centre for Research in Earth and Space Technology (CRESTech) and the Canada Centre for Remote Sensing (CCRS) joined together in 2002 to offer a collaborative research initiative focused on concept studies. CCRS and CRESTech jointly funded seven concept studies, selected via a CRESTech Request for Proposals (RFP) competition, to better understand how the rapidly evolving field of in situ sensing can contribute to the generation of geoscience and geospatial information about Canada. In addition to the concept study reports, CRESTech also host a workshop for the concept study researchers to present and share their results. The concept studies allowed CCRS and CRESTech to:

- Acquire knowledge about the state-of-the-art in in situ sensing.
- Better direct program funding and technology transfer toward R & D activities demonstrating the utility of combined remote and in situ measurements.
- Identify new potential partnerships.
- Identify new geoscience and geospatial information products that support decision-making in areas of societal/policy impact.
- Assist in the development of highly qualified personnel.

Workshop:

On October 1, 2002, the concept study researchers presented their results in a special session at the CRESTech Innovation Network 2002 conference in Toronto, Ontario. For the benefit of Canada's in-situ sensing community, the research presentations and poster displays from the workshop are compiled in a CD-ROM to encourage new potential partnerships and knowledge sharing. To obtain a copy of the CD, please contact Dr. Philippe M. Teillet at CCRS.

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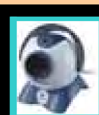
CRESTech

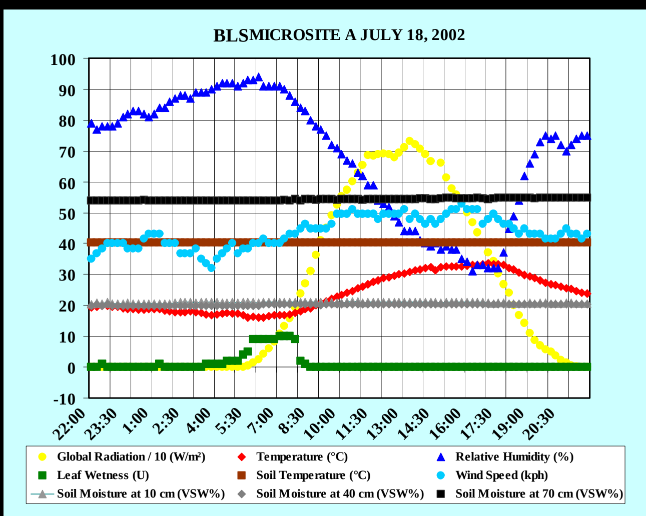
Canada

A Soil Moisture Monitoring Sensorweb Demonstration in the Context of Integrated Earth Sensing

Overview

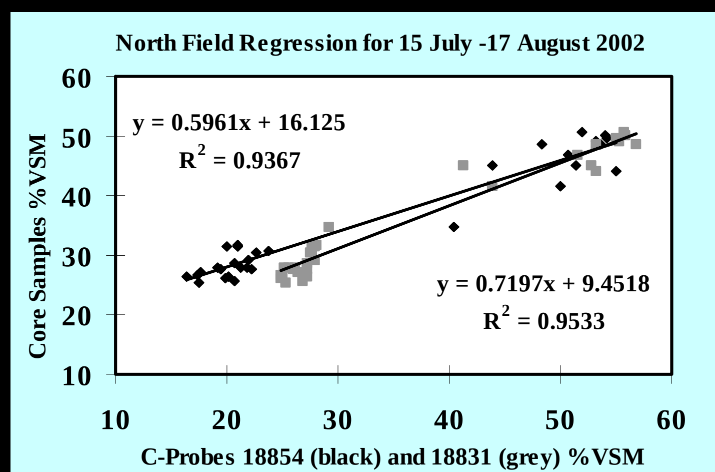
A prototype in-situ sensorweb in autonomous remote operation was demonstrated in the context of soil moisture monitoring for the Natural Hazards and Emergency Response Program of the Earth Sciences Sector at Natural Resources Canada. The five-node prototype sensorweb was deployed and tested at Bratt's Lake Station (BLS) in Saskatchewan in 2002 in collaboration with the Meteorological Service of Canada, Environment Canada. BLS was selected for its ideal deployment and radio frequency (RF) conditions: homogeneous Chernozem soil; < 2 m elevation change between sites; station infrastructure. The sensorweb operated autonomously and standard meteorological parameters and soil moisture measurements were accessed remotely via land line and/or satellite from the Integrated Earth Sensing Workstation (IESW) at the Canada Centre for Remote Sensing (CCRS) in Ottawa.





Measurements

- Global radiation.
- Surface spectral radiance (OCLI micro-spectrometers).
- Leaf wetness. Relative humidity and precipitation.
- Wind speed and direction. Air and soil temperature.
- Soil moisture (Adcon C-Probes with sensors at 15, 45, 75 cm depths deployed spatially to match soil core sampling locations).



Prototype Sensorweb Results

- Field deployment of an autonomous five-node prototype in-situ sensorweb, with real-time data access from the IESW in Ottawa via land line and/or satellite telecommunications.
- Sensorweb not yet fully miniaturized systems but commercial-off-the-shelf (COTS) technology deployed in real application environments.
- Test of micro-spectrometers over agriculture targets near BLS, with data sent to the IESW in Ottawa via satellite.
- Telepresence field trial at BLS via webcam and satellite modem, with live image transmissions, remote trouble-shooting and resolution of problems.
- Demonstration of data retrieval from the IESW database via satellite from the field at BLS.
- Validation of sensorweb meteorological and soil moisture data against independent measurements by Environment Canada at BLS.

Soil Moisture Validation Results

- C-Probe soil moisture data for 10-20 cm depth range valid.
- Soil moisture spatial variances are high even at BLS.
- C-Probe differences generally within spatial sampling variance.
- High correlations but significant differences between methods.
- Further investigations required: dramatic increase in variance after a rain event; full range of soil moisture not captured; validation of C-Probe sensor data for depths below 25 cm.

Conference Paper

Teillet, P.M., R.P. Gauthier, G. Fedosejevs, M. Maloley, A. Chichagov, and G. Ainsley (2003). "A Soil Moisture Monitoring Sensorweb Demonstration in the Context of Integrated Earth Sensing", *Proceedings of SPIE Conference 5151 on Earth Observing Systems VIII*, San Diego, California, 11 pages, in press. (Available from CCRS: http://www.ccrs.nrcan.gc.ca/ccrs/eduref/ref/biblioe.html)

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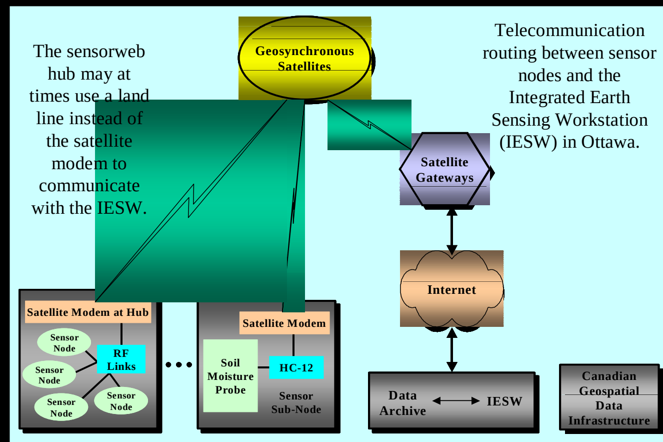
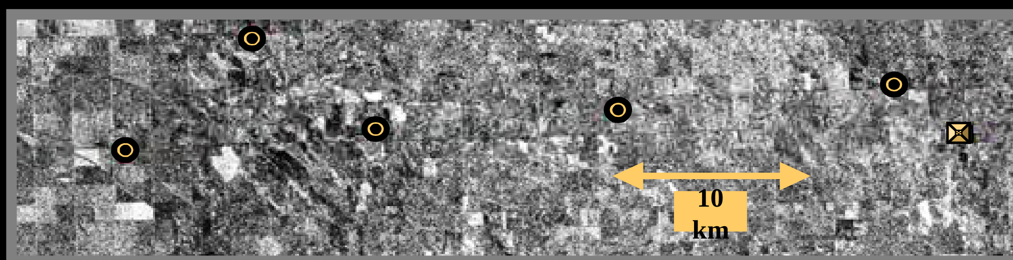
Canada

A Soil Moisture Sensorweb for Use in Flood Forecasting Applications

Overview

In the context of the Natural Hazards and Emergency Response Program of the Earth Sciences Sector at Natural Resources Canada, work has begun towards building an integrated Earth sensing capability. This particular investigation focused demonstrating a prototype in-situ sensorweb in remote operation in support of flood forecasting. A five-node sensorweb was deployed in the Roseau River Sub-Basin of the Red River Watershed in Manitoba in September 2002 and remained there until the end of June 2003. The sensorweb operated autonomously, with soil moisture measurements and standard meteorological parameters accessed remotely via land line and/or satellite from the Integrated Earth Sensing Workstation (IESW) at the Canada Centre for Remote Sensing (CCRS) in Ottawa. Independent soil moisture data were acquired from grab samples and field-portable sensors on Radarsat and Envisat Synthetic Aperture Radar (SAR) data acquisitions days. The in-situ data were used to help generate spatial soil moisture estimates from the SAR data for use in a hydrological model for flood forecasting.

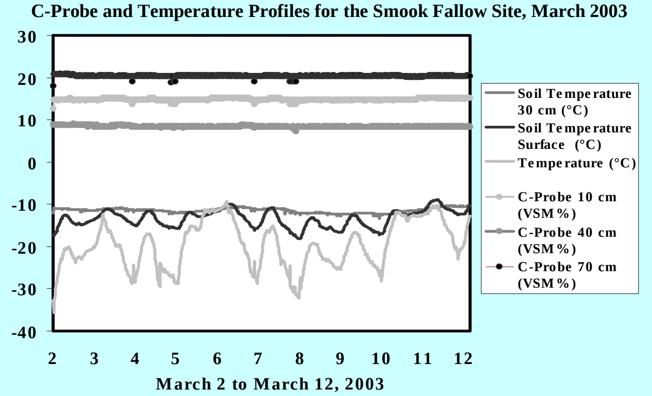




Flood Hazard Monitoring

- Flood hazards from spring melt and/or heavy rains require monitoring to protect people/property. Flood hazard potential is related to soil moisture content, hence flood forecast modelling based on soil moisture maps and other parameters on regional scales.
- C-band radar backscatter is correlated with soil moisture (0-5 cm), texture and surface roughness. Thus, satellite-based soil moisture maps and strategically deployed in situ sensorwebs can monitor soil moisture changes in space and time without field sampling.

C-Probe and Temperature Profiles for the Smook Fallow Site, March 2003



Soil Moisture Sensorweb Results

- Field deployment in Roseau River Sub-Basin of the Red River Watershed in Manitoba with real-time data access via land line and/or satellite modem telecommunications from the IESW in Ottawa for flood monitoring.
- Autonomous in-situ sensorweb operation 24/7, September 2002 – June 2003:
  - Met parameters, soil moisture and temperature at 15-minute intervals.
  - Soil moisture readings at 10, 20, 40 and 70 cm depths.
  - Soil temperature readings at 5 and 30 cm depths.
- Validation of sensorweb meteorological and soil moisture data against multiple independent in-situ measurements and satellite-based estimates.
- In-situ data used to generate spatial soil moisture estimates from radar image data for use in WATFLOOD hydrological model for flood hazard monitoring.

Publication

Teillet, P.M. R.P. Gauthier, T.J. Pultz, A. Deschamps, G. Fedosejevs, M. Maloley, G. Ainsley, A. Chichagov (2003). "A Soil Moisture Sensorweb for Use in Flood Forecasting Applications ", *Proceedings of SPIE Conference 5232 on Remote Sensing for Agriculture, Ecosystems, and Hydrology V*, Barcelona, Spain, 12 pages, in press.

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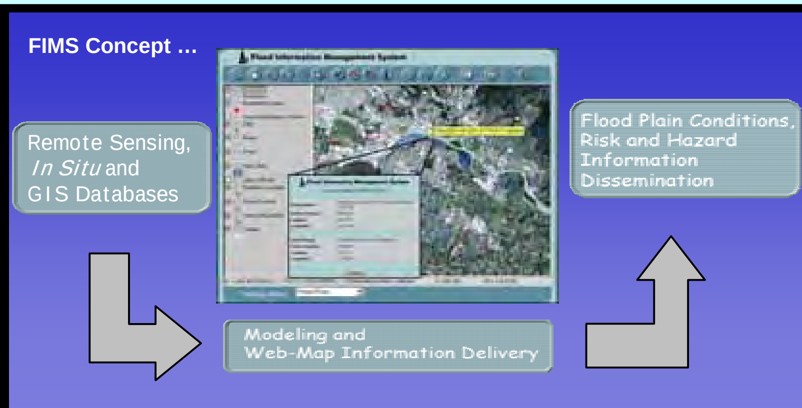
Canada

Integration of Remote and *In Situ* Data: Prototype Flood Information Management System

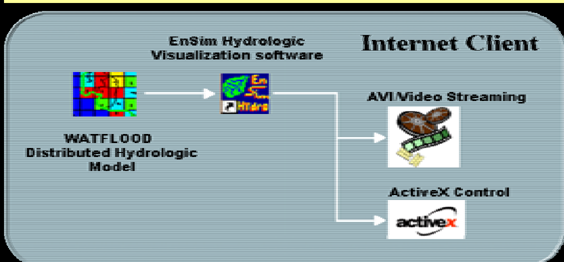
Wood, M.D., I. Henderson, T.J. Pultz, P.M. Teillet, J.G. Zakrevsky, N. Crookshank, J. Cranton, and A. Jeena (2002). "Integration of Remote and *In Situ* Data: Prototype Flood Information Management System", *Proceedings of the 2002 IEEE Geoscience and Remote Sensing Symposium (IGARSS 2002) and the 24rd Canadian Symposium on Remote Sensing*, Toronto, Ontario, Volume III, pp. 1694-1696.

Introduction: The Flood Information Management System (FIMS) represents the confluence of several cutting edge technologies and methodologies. The FIMS web site combines real-time *in situ* data; internationally recognized hydraulic and hydrologic models; multi-resolution remotely sensed images; and a customized web interface all within one coherent and easily accessible Internet location. The FIMS prototype development focused on two river basins with active river monitoring programs, the Fraser River in British Columbia and the St. John River in New Brunswick. Real and near-real-time sensors in both of these river basins provided FIMS with water quantity baseline data. Web-based software engineering provided the bridge between hydraulic/ hydrologic models and the graphical user interfaces (GUI) used to display the near-real-time geospatial results on the Internet. Users are able to interactively visualize IKONOS, RADARSAT, and Landsat image maps, visualize hydrometric station locations and actual flow data, and then run models that show flood hazard, risk and extents based on current and predicted flows.

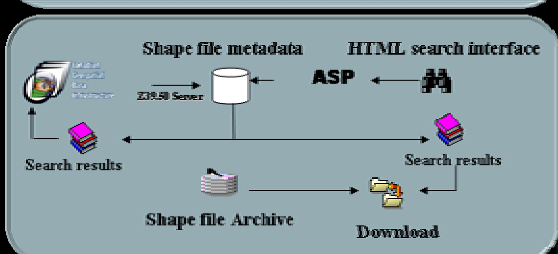
- The FIMS Hydrologic module allows the user to visualize watershed scale modelled flood events. FIMS utilizes WATFLOOD, a grid-based distributed hydrological model.
- The FIMS Hydraulic module manipulates *in situ* data that are automatically collected and harvested in near real-time from servers maintained by the Meteorological Service of Canada (MSC), Environment Canada.
- The FIMS Resource web page module provides various functions to the client, including a Shapefile archive searching function and a web-enabled mapping interface.



Technical Components:
- FIMS can connect to an Environment Canada ftp server and in near real-time retrieve water level and stream flow data acquired by stations operated by Environment Canada.
- A COTS hydraulic modelling product is utilized to run a simple HEC-RAS hydraulic model based on a DEM and *in situ* stream data. HEC-RAS is a river water surface profile model developed by the US Army Corps of Engineers.
- A COTS Internet mapping package from AutoDesk (MapGuide 6.0) and a custom-built GUI were used to provide the interactive mapping functionality required to view the near real-time river conditions.
- Images from IKONOS, Landsat, and RADARSAT provide information on land use activities vital to FIMS.
- EnSim, the Canadian Hydraulics Centre's environmental simulation software environment, provides an integrated user interface designed to meet the advanced needs of environmental prediction and decision support systems.
- FIMS uses a distributed metadata search protocol called Z39.50 and Federal Geographic Data Committee (FGDC) standards.



Results: FIMS successfully integrates near real-time *in situ* data with modelling to produce web-distributed geospatial products, integrated remotely sensed products and a standards-based distributed search mechanism and connection to the Canadian Geospatial Data Infrastructure. The FIMS prototype was demonstrated to the representative provincial river forecasting agencies in both participating provinces. It was widely accepted as having a great potential as a data dissemination tool. The web-mapping interface provides a comprehensive tool to visualize, interpret and analyze flood related information.



Conclusions: FIMS illustrates the techniques and methodologies required to successfully integrate *in situ* data, remote sensing, and web enabled GIS to provide useful information to a large scale audience via the Internet. FIMS provides the framework on which subsequent flood information systems can build upon to improve the accuracy of hydraulic modelling and bring the *in situ* information to the end user. FIMS represents a complete web delivery tool that is scalable, flexible, and customizable. As the *in situ* infrastructure develops, FIMS will be able to evolve and adapt to new environmental issues.

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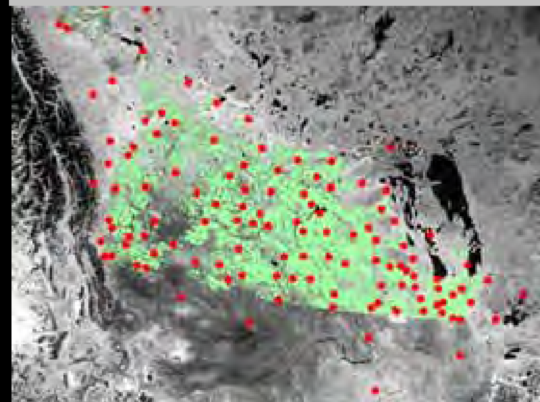
Improved Crop Specific Projections from the Integration of *In Situ* and Remote Sensing Data in an Agrometeorological Model

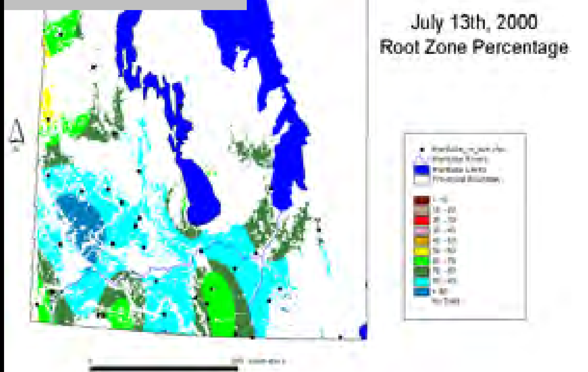
Hochheim, K.P., T. Hirose, J. Bennett, P.R. Bullock, R.L. Raddatz, G. Fedosejevs, and P.M. Teillet (2002). "Improved Crop Specific Projections from the Integration of In Situ and Remote Sensing Data in an Agrometeorological Model", *Proceedings of the 2002 IEEE Geoscience and Remote Sensing Symposium (IGARSS 2002) and the 24rd Canadian Symposium on Remote Sensing*, Toronto, Ontario, Volume IV, pp. 2391-2393.

Western Canada Crop Mask and TCM Locations

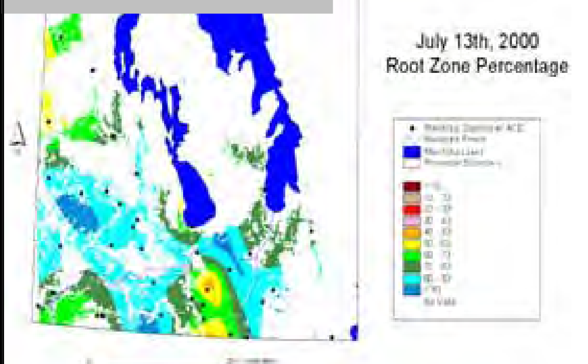


Introduction: The Prairie Agrometeorological Model (AGMET) developed at Environment Canada has been adapted to use both *in situ* data from a distributed network of meteorological stations (original mode) and NOAA Advanced Very High Resolution Radiometer (AVHRR) data output from the GeoComp-N processor at the Manitoba Remote Sensing Centre. Two parameters previously approximated by the model have been modified with AVHRR-derived information: fractional leaf area (f_LA) and skin temperature. Model outputs were ingested into a GIS to generate maps of crop growth stage expressed as biometeorological time (BMT), actual evapotranspiration or crop water use (ET), top zone (TpZ) and root zone (RtZ) soil moisture for a test area in southern Manitoba for the year 2000 growing season.

From AGMET Model



From Modified AGMET Model



Methods: The AGMET model was modified to use both AVHRR data and *in situ* data. The agrometeorological *in situ* data consisted of Timely Climate Monitoring (TCM) data from Environment Canada and data from Manitoba's Agrometeorological Centre of Excellence (ACE) for the same time period. The AVHRR parameters used by the crop model were surface temperature and Normalized Difference Vegetation Index (NDVI), which was used to initialize the model for 2) skin temperature of the plant and soil and 2) fractional leaf area. In the remote sensing assimilation case, air temperature was substituted by AVHRR-based skin temperature. The modified model reads the canopy temperature derived from AVHRR data and incorporates it into the component of the model that calculates the vapour pressure deficit, which drives evapotranspiration. The f_LA is used to partition the evaporation and transpiration components, as well as determine the canopy resistance, and the portion of evapotranspiration removed from the top zone. Both the meteorological data and AVHRR data were collected from April 1 to September 30, 2000 on a daily time step at 38 meteorological station locations. To ensure that extracted AVHRR data were representative of a cultivated surface, a crop mask derived from Landsat Thematic Mapper (TM) data was used as a reference.

Results: The AVHRR-derived surface temperatures were generally 5° C higher than the maximum air temperatures observed early in the growing season. Temperatures later in the growing season, under more closed canopy conditions, generally mimicked air temperatures within the uncertainty of the measurement. The f_LA was highly correlated to NDVI. Differences in the relationships between early (DOY 125-194) and late season (DOY 194-240) NDVIs and f_LA necessitated seasonal regression coefficients. Early season relationships between NDVIs and f_LA where highly correlated (adjusted $R^2 = 0.95$). Late season coefficients of determination were somewhat lower (adjusted $R^2 = 0.83$). The model results incorporating the AVHRR data have higher estimates of evapotranspiration and subsequently lower estimates of top zone and root moisture due to higher estimates of surface temperature. Validation work will be necessary in order to understand and address these differences in results.

Conclusions: The results of this study demonstrate that the AVHRR data could be effectively incorporated into an existing agrometeorological model with some modifications and validation. The high correlations between NDVI and f_LA (and crop phenology) demonstrate the potential of AVHRR data to provide spatial information on a weekly time step. The use of both *in situ* data from a distributed network of meteorological stations and input parameters derived from AVHRR data, specifically fractional leaf area (f_LA) and surface temperature, has the potential to generate improved crop specific projections.

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Noetix Research

University of Manitoba

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Canada Centre for Remote Sensing — Centre canadien de télédétection

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Artificial Intelligence Analysis of Temperature Measurements from Integrated Remote and In-Situ Sensing

Introduction

Data mining methodologies were exploited to integrate and increase understanding of the relationship between in-situ measurements of near surface air temperature at meteorological stations and remotely sensed data. The remote sensing data consisted of thermal infrared data from the Advanced Very High Resolution Radiometer (AVHRR) sensors on NOAA-14 and NOAA-16. The surface data were obtained from Environment Canada meteorological stations. A neural network approach was used to develop a variety of models that generated temperature estimates guided by both surface measurements and remote sensing data. Such estimates were obtained at a resolution of one square kilometre over a region encompassing the Island of Montreal, Canada. Results were obtained in terms of the best combinations of input remote sensing parameters for optimum performance in estimating temperature, as well as in terms of different spatial and temporal cases involving grouped and single meteorological stations.

The seven meteorological station locations:

Mirabel
St Anicet
Ste Clothilde
Montreal
McTavish
Dorval
Ste Anne be Bellevue

Table 1. Spatial data configuration for neural network training, where S_m is station number m (m = 1 to 7) and t_n is time step n. $B4_{mn}$ is AVHRR B4, $B5_{mn}$ is AVHRR B5, $(B4\text{-}B5)_{mn}$ is B4-B5, and $TEMP_{mn}$ is pixel temperature, all for station m and time step n.

S_1t_1	$B4_{11}$	$B5_{11}$	$(B4-B5)_{11}$	LAT_{11}	$LONG_{11}$	$TEMP_{11}$
S_2t_1	$B4_{21}$	$B5_{21}$	$(B4-B5)_{21}$	LAT_{21}	$LONG_{21}$	$TEMP_{21}$
S_3t_1	$B4_{31}$	$B5_{31}$	$(B4-B5)_{31}$	LAT_{31}	$LONG_{31}$	$TEMP_{31}$
.	.	.	.	.	.	.
S_7t_1	$B4_{71}$	$B5_{71}$	$(B4-B5)_{71}$	LAT_{71}	$LONG_{71}$	$TEMP_{71}$
S_1t_2	$B4_{12}$	$B5_{12}$	$(B4-B5)_{12}$	LAT_{12}	$LONG_{12}$	$TEMP_{12}$
S_2t_2	$B4_{22}$	$B5_{22}$	$(B4-B5)_{22}$	LAT_{22}	$LONG_{22}$	$TEMP_{22}$
.	.	.	.	.	.	.
S_7t_2	$B4_{72}$	$B5_{72}$	$(B4-B5)_{72}$	LAT_{72}	$LONG_{72}$	$TEMP_{72}$
.	.	.	.	.	.	.
.	.	.	.	.	.	.
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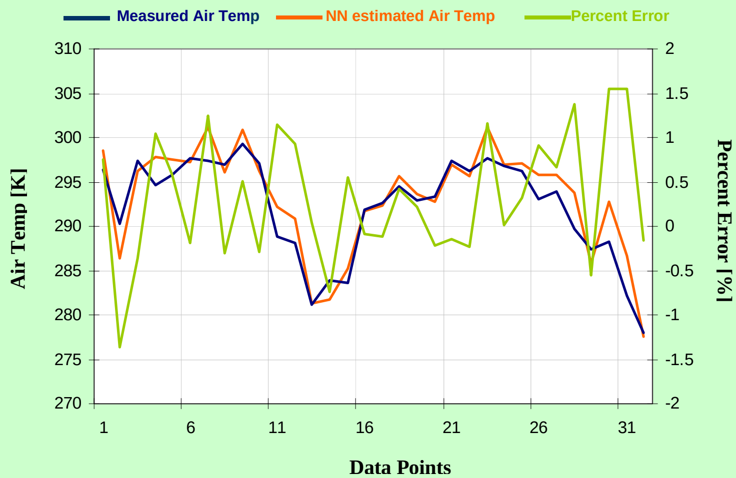
S_1t_n	$B4_{1n}$	$B5_{1n}$	$(B4-B5)_{1n}$	LAT_{1n}	$LONG_{1n}$	$TEMP_{1n}$
S_2t_n	$B4_{2n}$	$B5_{2n}$	$(B4-B5)_{2n}$	LAT_{2n}	$LONG_{2n}$	$TEMP_{2n}$
.	.	.	.	.	.	.
S_7t_n	$B4_{7n}$	$B5_{7n}$	$(B4-B5)_{7n}$	LAT_{7n}	$LONG_{7n}$	$TEMP_{7n}$



Estimated versus measured temperature for the isolated station case (Ste Clothilde) for NOAA-14

Results and Conclusions

- Despite limited data available to train the neural network models, integrated AI - remote sensing estimated temperatures generally agree with the temperatures measured in-situ.
- Best input parameter combinations for optimum model performances are B4, B5 and B4-B5 for NOAA-14 and B4, B5, B4-B5 and NDVI for NOAA-16.
- RMSEs are in the 2 to 3 K range, which may be acceptable for seasonal climate modelling but not for diurnal process models.
- Analysis of variance of temperatures in the test area over the study period revealed no significant spatial variability across the study area, whereas there is significant temporal variability over the growing season as expected.
- In the various cases involving the grouped stations (spatial and temporal) and single stations (temporal), prediction models based on NOAA-16 AVHRR data showed superior performance over models based on NOAA-14 AVHRR data.
- The spatial analysis results indicate that the number of training stations affects the range of accuracy in output estimates for an isolated meteorological station, but not for a station located close to other stations.
- The AI approach uses dynamic learning such that network performance will improve over time. The method can be used to mimic various in-situ and remote sensing data. It is easy to automate and set up for on-line use and it has the capability of handling large volumes of data.

Publication

Garabedian, A., M. Dagnew, G. Bitsuamlak, N. BandariNejad, S. Veillete, K.B. Fung, G. Fedosejevs, R. Latifovic, W. Park, and P.M. Teillet (2003). "Artificial Intelligence Analysis of Integrated Remote and In-Situ Sensing Measurements of Near Surface Air Temperature", *Proc. of the 25th Canadian Symposium on Remote Sensing and the 11th Congress of the Association québécoise de télédétection*, Montreal, Quebec, 10 pages, in press.

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A Framework for *In Situ* Sensor Measurement Assimilation in Remote Sensing

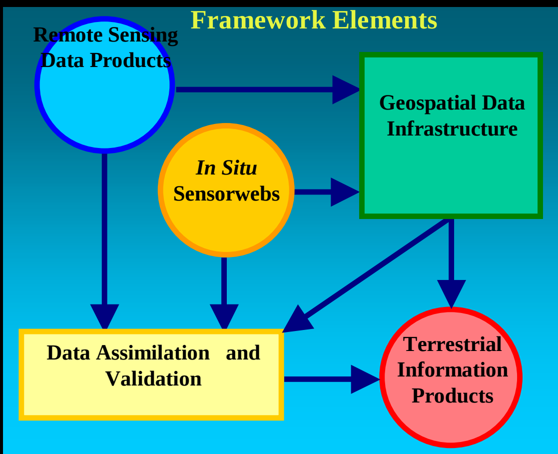
Towards Integrated Earth Sensing

***In situ* sensing** can be defined as a group of techniques to acquire information about an object by detecting energy reflected or emitted by that object when the distance between the object and the sensor is comparable to or smaller than any linear dimension of the sensor. A short dictionary-based definition for *in situ* sensing could be "sensing in place". Because many measurements or observations are made from nearby locations that are not strictly speaking *in situ*, the expression proximal sensing has been adopted in a wide variety of disciplines. A short dictionary-based definition for proximal sensing could be "sensing from close range" (as in close-range photogrammetry, for example). For the present purposes and in practice, *in situ* sensing is considered to encompass proximal sensing.

Networks of *in situ* sensors have been in place for decades in a variety of contexts, perhaps the most prevalent being meteorological stations. However, these networks continue to evolve as unattended sensor and wireless telecommunication technologies advance at a rapid pace and new applications are invented. It is becoming increasingly feasible to provide quality-controlled network-wide data to users via the Internet in near real time and information products from data assimilation into models within hours. Given the increasing importance of *in situ* data and their assimilation into models that also use remote sensing data, the Canada Centre for Remote Sensing (CCRS) has initiated an *in situ* Sensor Measurement Assimilation Program (ISSMAP) to be led by a new *In Situ* Measurement Development Section (ISMDS) in the Data Acquisition Division of CCRS.

The **objectives** for the overall program, currently in a definition phase at CCRS, are as follows. For selected biospheric applications, ISSMAP will collaborate with other agencies, the private sector and universities to:

- **Design and deploy intelligent sensor networks for *in situ* data acquisition.**
- **Develop methods to assimilate *in situ* and remote sensing data into models that generate validated information products.**
- **Facilitate the integration of *in situ* sensor data and/or metadata into on-line geospatial data infrastructures.**



Framework

Because many independently managed networks and archives of *in situ* sensors and data currently exist in Canada and elsewhere, it will be important to focus activities carefully and leverage existing infrastructures wherever possible. It is proposed that selected ISSMAP activities conform to the following framework. ISSMAP activities must:

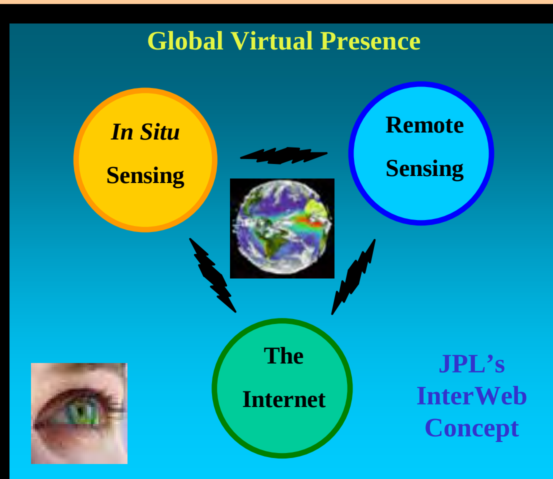
- Lead to the generation of biospheric information products that address clearly defined science questions and/or user information requirements.
- Utilize *in situ* sensor networks.
- Utilize remote sensing data products.
- Encompass data assimilation, modeling, and validation components.
- Routinely provide *in situ* data products and/or metadata on *in situ* data holdings to a geospatial data infrastructure.

Priority will be given to *in situ* data acquisition technologies that leverage existing automated networks, operate in an unattended manner, use wireless telecommunications, use centralized or common methods for data processing, and establish standards or data sets for validation and measurement protocols.

Sensor Pods and Sensor Webs

The framework will help guide the new *in situ* sensing initiative to advance the use of *in situ* measurements in the context of remote sensing applications. Looking ahead to where this strategic initiative can lead, one can identify innovative technologies that will be important for ISSMAP to investigate. In particular, the emerging technology of sensor webs and sensor pods holds considerable promise for *in situ* sensing. A sensor web is a wireless network of independent sensor pods deployed to monitor parameters of interest (Delin and Jackson, 2001). With the capability of providing an ongoing virtual presence in remote locations, many sensor web applications can be envisaged in the context of environmental monitoring. Delin and Jackson state that the key insight about sensor webs is that "a node can be a web itself, which leads to an "interweb" concept of linked webs". From this perspective, they see the advent of *in situ* sensor webs, together with NASA's Earth science vision of satellite sensor webs and the Internet, as providing a kind of global virtual presence.

"In the next century, planet Earth will don an electronic skin", Neil Gross, "21 Ideas for the 21st Century", *BusinessWeek online*, August 30, 1999.



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Canada Centre for Remote Sensing

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Natural Resources Canada

• Teillet, P.M., Dudelzak, A.E., Pultz, T.J., McNairn, H., and Chichagov, A. (2001). "A Framework for in situ Sensor Measurement Assimilation in Remote Sensing", *Proceedings of the 23rd Canadian Symposium on Remote Sensing*, Sainte-Foy, Québec, pp. 111-118.
(Available from CCRS: http://www.ccrs.nrcan.gc.ca/ccrs/eduref/ref/biblioe.html)

•Delin, K.A., and Jackson, S.P. (2001). "The Sensor Web: A New Instrument Concept", *Proceedings of SPIE's Symposium on Integrated Optics*, San Jose, California, January 2001, 9 pages.