Earth observation with wet feet

Inaugural address

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TAO

Tao can be talked about, but not the Eternal Tao.
Names can be named, but not the Eternal Name.
As the origin of heaven-and-earth, it is nameless.
As the Mother of all things, it is nameable.
So, as ever hidden, we shall observe its inner essence.
As always manifest, we shall observe its outer utterance.
These both originate from the same source though named differently.
And both are called mysteries.
The Mystery of mysteries is the Door of all essence.
(Lao Tzu, Tao Teh Ching)[1]

The aim of science is not things themselves, as the dogmatists in their simplicity imagine, but the relations between things; outside those relations there is no reality knowable.
(Henri Poincaré, La Science et l'Hypothèse)

1 Based on translation by C.H. Wu: Lao Tsu, Tao Teh Ching. Shambhala Dragon Editions, 1989.

Dear Rector, Rector Magnificus, ladies and gentlemen,

Yu the Great, the founder of the Chinese Xia Dynasty 4,000 years ago, is remembered in history as a great water manager. He was the son of the water engineer Gun, who according to legend fought to control the great deluge by building dykes but was unable to control it in nine years. Because of his failure, Gun was executed, and his son took over. Unlike his father, Yu did not try to block the floodwaters. He travelled to the then nine provinces to observe and survey the great rivers and adopted the strategy of draining the water away by digging outlets in the nine mountains and dredging through the nine valley beds. He succeeded in managing the water in 13 years. [2]

In the 21st century, the security of water resources has again emerged as one of the key problems. Floods, droughts, water scarcity, water usage, water quality, water and ecosystem interactions, water and climate interactions are all issues of direct importance to our human society. The key to safeguarding the security of water resources is better water resources management. This in turn requires better understanding of the water cycle, water climate interactions and water ecosystem interactions.

The United Nations (UN) Millennium Declaration called on all members "to stop the unsustainable exploitation of water resources by developing water management strategies at the regional, national and local levels which promote both equitable access and adequate supplies". Improving water management can make a significant contribution to achieving most of the Millennium Development Goals established by the UN General Assembly in 2000, especially those dealing with poverty, hunger and major diseases. The World Summit on Sustainable Development (WSSD) in 2002 recognised this need. Water and sanitation in particular received great attention from the Summit. The recommendations in the Johannesburg Plan of Implementation regarding water and sanitation are to:

- improve water resources management and scientific understanding of the water cycle through joint cooperation and research, and for this purpose to promote knowledge sharing, provide capacity building and facilitate the transfer of technology, as mutually agreed, including remote sensing and satellite technologies, especially to developing countries and countries with economies in transition

2 S Ma Qian, 145 BC, Chinese History, Vol. 2, pp. 8-14. Yu Lu Publ., 1996.

- support developing countries and countries with economies in transition in their efforts to monitor and assess the quantity and quality of water resources, for example, by establishing and/or further developing national monitoring networks and water resources databases and by developing relevant national indicators.

The Johannesburg plan also adopted integrated water resources management (IWRM) as the overarching concept in addressing and solving water-related issues. As a result of the commitments made in the Johannesburg Plan of Implementation, several global and regional initiatives have emerged.

Current international initiatives such as the Global Monitoring for Environment and Security (GMES) programme of the European Commission and the European Space Agency (ESA), and the Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan [3] have all identified earth observation of the water cycle as the key in helping to solve the world's water problems. More specifically, the 10-year implementation plan states that "Enhanced prediction of the global water cycle variation based on improved understanding of hydrological processes and its close linkage with the energy cycle and its sustained monitoring capability is a key contribution to mitigation of water-related damages and sustainable human development. Improved monitoring and forecast information, whether of national or global origin, if used intelligently, can provide large benefits in terms of reduced human suffering, improved economic productivity, and the protection of life and property. In many cases, the combination of space-based data and high-resolution in-situ data provides a powerful combination for effectively addressing water management issues. Information on water quantity and quality and their variation is urgently needed for national policies and management strategies, as well as for UN conventions on climate and sustainable development, and the achievement of the Millennium Goals." [4]

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[3] The GEOSS 10-Year Implementation Plan was adopted on 16 February 2005 at the Third Earth Observation Summit in Brussels, which also established the intergovernmental Group on Earth Observations (GEO) for implementing GEOSS.

[4] GEOSS. 10-Year Implementation Plan. Reference Document, GEO 1000R, February 2005. p. 73.

The availability of spatial information on water quantity and quality will also enable closure of the water budget at river basin and continental scales to the point where effective water management is essential (e.g. as requested by the European Union's Water Framework Directive (WFD), as well as national policies [5]). Geo-information science and earth observation are vital in achieving a better understanding of the water cycle and better monitoring, analysis, prediction and management of the world's water resources.

Given the enormous complexity and importance of water resources management, I have chosen in my speech to concentrate on developing and transferring knowledge of geo-information science and earth observation for water resources management.

The water cycle

To solve the world's water problems, improved decision making in water resources management must be based on the essentially reliable prediction of future water resources. This in turn requires observations not only to define initial system conditions and boundary conditions but also to evaluate predictions. However, in order to make useful predictions by means of water resources system simulation, adequate access to observations to develop models and evaluate the simulation results is essential.

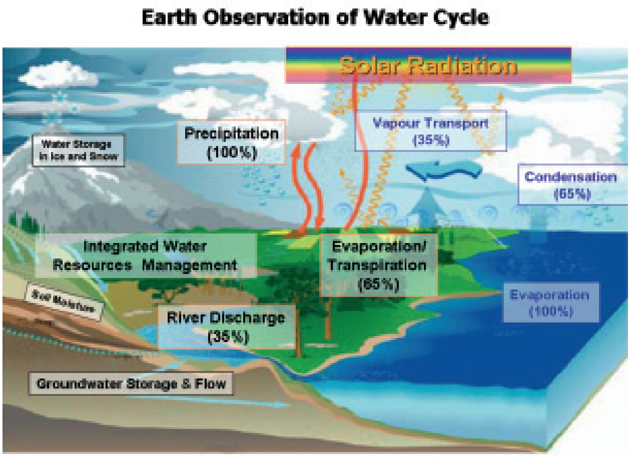

Figure 1 The water cycle components

5 *Water beleid voor de 21e eeuw* (WB21), for example.

The foundation of a realistic simulation is the understanding of system behaviour and processes, and must be based on observations for defining and testing hypotheses.

Given the above challenges, a number of key questions must be addressed:

- What system behaviour and processes underlie the major water resources issues (e.g. floods, droughts, water pollution)?
- To what extent do we understand the processes in the water cycle (fluxes, storages, interactions between land and atmosphere, surface water and groundwater, water and ecosystem, and land and ocean)?
- How can we improve the physical or conceptual description of the water cycle in space and time (using well parameterised mathematical models)?
- What tools can be developed or improved to describe the water cycle components (to measure, simulate and predict water cycle quantity and quality in space and time)?

Earth observation of the water cycle provides opportunities to address most of the above questions. Improved water resources simulation and prediction can be achieved by improving the capability to assimilate earth observation data in modelling via integrated decision support systems that can utilise the necessary geospatial data and socio-economic data. This may be characterised as developing information and modelling systems for water resources management that utilise observations for simulation and prediction.

The energy cycle

This year is the World Year of Physics and we celebrate the beginning of modern physics 100 years ago. In the year 1905, Albert Einstein published four extraordinary papers that exerted the most profound influence on the development of physics in the 20th century. In the paper entitled "A heuristic point of view concerning the production and transformation of light" [6], Einstein suggested that, from a thermodynamic perspective, light can be described as if it consists of independent quanta of energy. This hypothesis, which had been tentatively proposed by Max Planck a few years earlier, directly challenged the deeply ingrained wave theory of light. Einstein was able to use the idea to explain certain puzzles concerning the way that light or other electromagnetic radiation ejected electrons from a metal via the photo-electric effect.

[6] Ann. Phys., Lpz 17, 132-148.

Maxwell's electrodynamics could not, for example, explain why the energy of the ejected photo-electrons depended only on the frequency of the incident light and not on the intensity. However, this phenomenon was easy to understand if light of a certain frequency actually consisted of discrete packets or photons, all with the same energy. Einstein received his Nobel Prize in 1921, after his theory had been proven by measurements conducted by Robert Millikan, who actually considered Einstein's idea to be nonsense and set out to prove so by experiment. Alas, the experiment did not achieve its original purpose because it succeeded only in proving that Einstein was right, but, the experimenter was duly consoled by receiving his Nobel Prize in 1923. In earth observation, we mainly use electromagnetic waves as a means of measuring the properties of the Earth (we also use gravity for measuring mass changes). Here we use the ideas developed by Planck, Einstein and other pioneers. The use of these laws in earth observation is commonly known as "radiative transfer approaches dealing with photon-matter interactions".

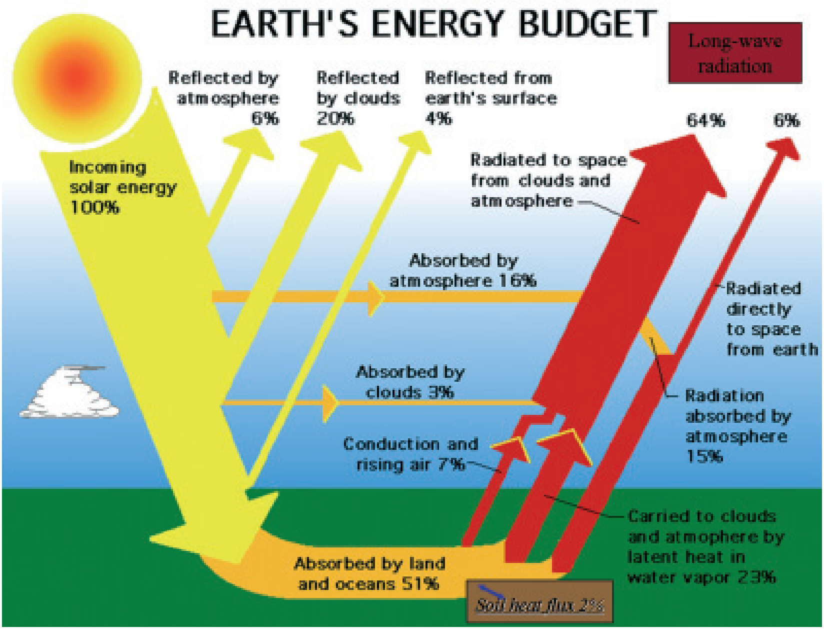

Figure 2 The energy budget of the Earth's system

The scientific challenge in earth observation of the water cycle is to determine turbulent, thermodynamic and fluid dynamic properties of the whole water cycle by using radiometric observations. We must therefore understand the underlying physical processes.

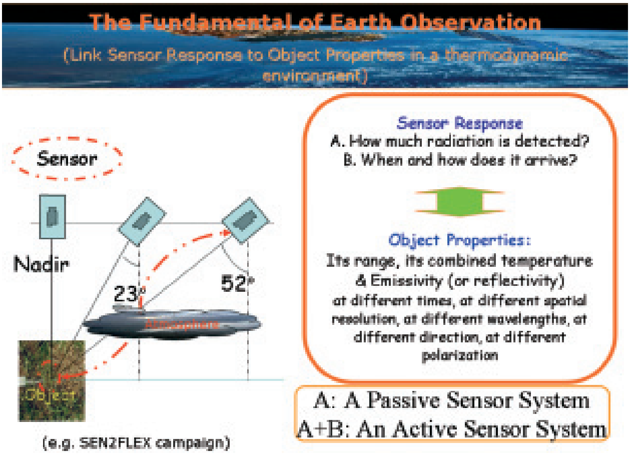

Figure 3 Sensor response and object properties

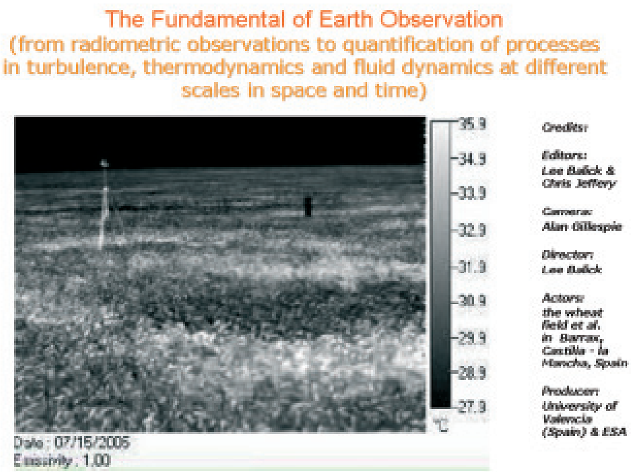

Figure 4 Radiometric observation and turbulence

Wet feet: from process understanding to applications

Given the diversity of the water-related problems facing human society and the political commitments made for the coming decade, there is an urgent need to develop quantitative knowledge through sound scientific research in hydrology and water resources, using geo-information science and earth observation, and to develop tools for effective water resources management. We shall follow the guiding principle advocated by Richard P. Feynman: "Observation, Reason and Experiment make up what we call the scientific method." We may start by asking the following relevant scientific questions related to variability, causes and consequences, and predictions in water resources.

Variability

- What are the dominating hydrological processes and their variability at different scales in space and time?
- How are variations in water resources related to global climate variation?
- Are the water cycle variations intensified at regional and global scales?
- What are the controlling effects of water resources in the variations of ecosystems?

Causes and consequences

- What are the mechanisms that link land surface hydrological processes to meteorological and climate dynamics in generating extreme hydrological events (floods and droughts)?
- How can the effects of human activity on the landscape (land use change), its ecology (changes in ecosystems) and hydrology (water management) be distinguished from natural climate variability?
- What are the feedbacks of intensified water cycle variations on regional and global climate?
- What are the feedbacks of intensified water cycle variations on ecosystems?

Predictions

- How well can long-term hydroclimatic trends be assessed or predicted?
- How can the lead-time and reliability of hydrological forecasts (e.g. for floods and droughts) be improved by new space-based observations, modelling and data assimilation?
- How can the feedback role played by the water cycle in a changing climate be predicted?

In order to answer these questions, we will have to strengthen the following knowledge fields:

- earth observation of the water cycle components
- modelling of hydrological processes, using earth observation and data assimilation methods
- development of water resources management tools using geo-information and earth observation.

These developments must focus on generating new knowledge to form the scientific basis for applications in solving water problems. On the other hand, we must strategically aim at real applications for land, water, climate and ecosystem problems. Only through this process shall we be able to generate opportunities to address urgent problems confronting human society – opportunities that were previously unattainable owing to the lack of quantitative information. This strategically-oriented approach is also an important means of generating opportunities for interdisciplinary and multidisciplinary collaboration, as well as new demands and requirements for fundamental research.

To measure in order to know: earth observation of the water cycle

This knowledge theme focuses on quantifying water cycle components by using earth observation data, including water fluxes and storages, radiation and heat fluxes, precipitation, evaporation/transpiration, river discharge, soil moisture, groundwater storage, recharge and discharge, water quality and hydrological land surface and river basin characteristics. The most important element is to establish field observation sites that are suitable for basic water cycle process studies, for earth observation process studies for validating and calibrating earth observation data and instruments, and for educational purposes.

Currently we are in the process of establishing ITC earth observation research and education sites.

- *Process studies in Regge and Dinkel in collaboration with the Water Board Regge and Dinkel and the Foundation Natuurmonumenten:* Our students have already started their fieldwork in the Hagmolenbeek catchment and, led by Arno van Lieshout, Gabriel Parodi and Remko Dost, have produced a baseline hydrological study this year.

- *Studying the role of the Tibetan Plateau in the global climate, in collaboration with the Chinese Academy of Sciences (CAS):* I am pleased that Yaoming Ma, the leading scientist in the field monitoring and research of atmospheric processes on the Tibetan Plateau, has expressed a strong desire to collaborate with ITC. This is supported by a Memorandum of Understanding between ITC and CAS. We expect to excel in many research topics and will be exchanging students and facilities.
- *Monitoring water resources in Africa in collaboration with several African partners:* We will extend our current collaborative initiatives with several African partners by enhancing existing, and establishing new, field observation sites and by developing specific tools for water resources monitoring, assessment and prediction for the whole of Africa, using earth observation data.

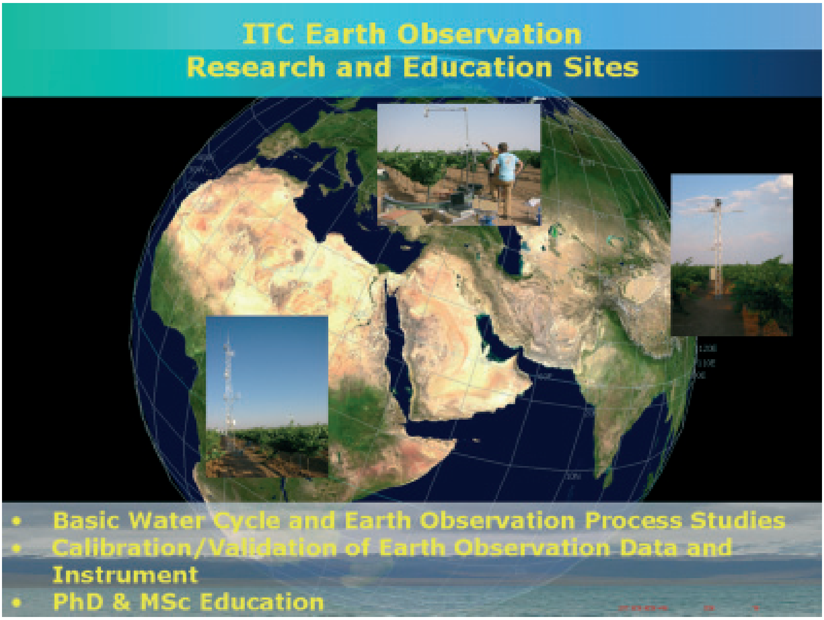

Figure 5 ITC research and education sites

The detailed observation, dependent on the locations of these distributed sites, may include variables for the determination of radiation and heat fluxes, precipitation, evaporation/transpiration, snow cover and snow water content, river discharge, soil moisture, groundwater storage and flow; mass transport and behaviour of surface waters in rivers, *lakes, estuaries and coastal zones in terms of temperature, transparency, turbidity, total suspended sediment, chlorophyll-a, and nutrients; and hydrological land surface characteristics (e.g. topographic variables, land cover distribution and dynamics, vegetation canopy structure, and surface roughness).*

A number of key activities can be specified:

- observational research on sensor-object relationships (field observation and remote sensing at selected sites are essential for understanding the physical processes involved in sensor-object relationships, as well as for calibrating and validating satellite observations)
- retrieval of geo-biophysical variables (on the basis of the established sensor-object relationship and including radiometric correction of signals/images, geometric corrections, as well as atmospheric corrections)
- radiative transfer modelling in the atmosphere-vegetation-soil continuum (from visible to microwave region, including directional effects)
- surface energy balance for determining surface turbulent heat fluxes and evaporation/transpiration
- estimation of soil moisture, soil salinity and biomass using combined microwave and optical data
- estimation of precipitation using earth observation data
- estimation of groundwater fluxes and storages using satellite gravity data
- retrieval of water quality indicators
- retrieval of hydrological land surface characteristics.

Given this long list, I would not be surprised if you feel stressed on my behalf. You may be asking yourself: "How is he going to get all this arranged?" In this context, intensive field experiments, code-named SPARC2004 and SEN2FLEX, led by Jose Moreno of the University of Valencia and supervised by Remo Bianchi of ESA, have provided us with excellent opportunities to study the detailed physical processes from field to regional scale.

The Water Cycle Research Cluster, including several ongoing and anticipated projects co-funded by ITC and external research funds, will be of great importance in this effort. These projects include the Ecosystem Radiative Transfer Modelling project supported by the Netherlands GO programme and managed by Rolf de Groot of NWO-SRON, the EAGLE project supported by EU FP6 GMES and managed by Peter Breger, and the

SMOS [7] Synergy project led by Andre Chanzy of INRA Avignon in France and supervised by Michael Berger of ESA.

Newly approved projects include Validation of SMOS Soil Moisture Products in Eurasia and Africa Using Long-term In-situ Observations, and initiatives recently submitted for the ESA Earth explorer programme Water Evaluation Recovery (WatER), led by Nelly Mognard of LEGOS in France and Doug Alsdorf of Ohio State University in the USA, for global measuring of terrestrial surface water storage changes in space and time, as well as the FLuorescence Explorer (FLEX) mission, led by Jose Moreno of the University of Valencia in Spain, for global monitoring of steady-state chlorophyll fluorescence in terrestrial vegetation.

Figure 6. Mouths of the Ganges

These projects have provided us with opportunities and instrumentation as a first step towards establishing the ITC education and research sites. And in this good cause, Ambro Gieske, Wim Timmermans, Joris Timmermans and Rogier van der Velde are getting their hands dirty and their feet wet.

[7] SMOS: Soil Moisture and Ocean Salinity satellite

Putting the puzzles together: modelling hydrological processes by using earth observation and data assimilation

"Science is built up with facts, as a house is with stones. But a collection of facts is no more a science than a heap of stones is a house."
(Henri Poincaré, La Science et l'Hypothèse)

The aim of this knowledge theme is to increase ability to model hydrological processes using earth observation data and data assimilation techniques. Given the challenges facing water resources management, we need to focus on understanding the hydrological processes at different scales in space and time so as to be able to predict the consequences of any management scenarios, using earth observation data and geo-information.

The detailed hydrological processes to be modelled may include radiation and energy balance and turbulent heat fluxes, precipitation, evaporation/transpiration, snowmelt, river discharge, soil moisture, groundwater storage, interaction of surface water and groundwater systems, interaction of land and atmosphere systems, interaction of water and agro-ecosystems, as well as interaction of land and coastal water systems.

The following activities will be pursued:

- coupled modelling system of radiation and energy balance and turbulent heat fluxes
- coupled modelling system that includes precipitation, evaporation/transpiration and snowmelt (energy balance), river discharge, soil moisture, groundwater storage, and interaction of surface and groundwater systems
- modelling system for the interaction of water and agro-ecosystems
- coupled modelling system for the interaction of land and atmosphere/climate systems
- modelling system for the interaction of land and coastal water systems.

Several projects contributing to this theme are underway, including the aforementioned Ecosystem Radiative Transfer Modeling project conducted by Joris Timmermans under the supervision of Ambro Giekse and with external advice from colleagues Li Jia, Wout Verhoef, Han Dolman and Massimo Menenti; the PhD project Coupled Land-Atmosphere Modelling for Turbulent Heat Flux Estimation by Wim Timmermans in collaboration with John Albertson of Duke University in the USA and Bill Kustas of the Agricultural Research Services of the US Department of Agriculture; the PhD projects Remote Sensing Upscaling of Sap Flow Measurements for Transpiration Mapping conducted by Diana Chavarro, and Integration of Remote Sensing-based Soil Moisture in Distributed Groundwater Models conducted by Fouad AlKhaier, both under the supervision of Maciek Lubczynski; and the PhD project Assimilating Satellite-derived Rainfall Data and Physically-based Rainfall-Runoff Modelling for Improved Watershed Management to be conducted by Alex Haile, supervised by Tom Rientjes and supported by NUFFIC. Joint PhD works include Integrating Spatial Simulation Models and Earth Observation Techniques for Surveying Complex Patterns of Top Soil Moisture conducted by Hans van der Kwast under the supervision of Steven de Jong and Victor Jetten.

Serving civil society: water resources management using geo-information and earth observation

What can we learn from the story of Yu the Great? The most important lesson is probably his water management philosophy following the natural law of water. Sustainable management of water resources is the future, as advocated by the Global Water Partnership. It is certainly not a minor detail to point out that we will very likely have a king who is interested and active in water management, given the current position of His Royal Highness Crown Prince Willem-Alexander [8] *of the Netherlands as the patron of the Global Water Partnership.*

In the same spirit, we shall develop useful knowledge and expertise in applying geo-information science and earth observation to monitoring, assessing and predicting - floods; droughts; water usage in agricultural systems; water quality in river basins, wetlands and coastal zones; desertification; water-climate interactions; and water-ecosystem interactions - all important issues concerning the sustainable management of water resources.

[8] See, for example, speech delivered by the Prince of Orange at the opening ceremony of the Yellow River Forum in Zhengzhou, China, on 18 Octoter 2005 (Professor Klaas Jan Beek is thanked for passing on a copy of this speech).

These applications may be divided into monitoring, assessment and prediction of water disasters; sustainable agricultural production, irrigation and drainage; integrated river basin and water resources management; monitoring, assessment and prediction of water quality, wetlands and integrated coastal zone management; monitoring, assessment and management of groundwater; integrated water information systems.

More specifically, the following topics can be listed.

- *Water disasters: monitoring, assessment and prediction*

In rainfall-runoff, flood and drought prediction, as well as in water-balance studies, the input of precipitation and meteorological data remains the most dynamic component with the highest uncertainty. Applied research into the use of new-generation weather satellites (e.g. Meteosat second generation) and radar data for both water balance studies as well as environmental watershed hydrological studies (runoff, floods, erosion, sediment transport and water quality) are urgently needed. One important instrument in this respect is the operational ITC MSG facility initiated by Ben Maathuis, which includes the development of operational rainfall monitoring over Africa.

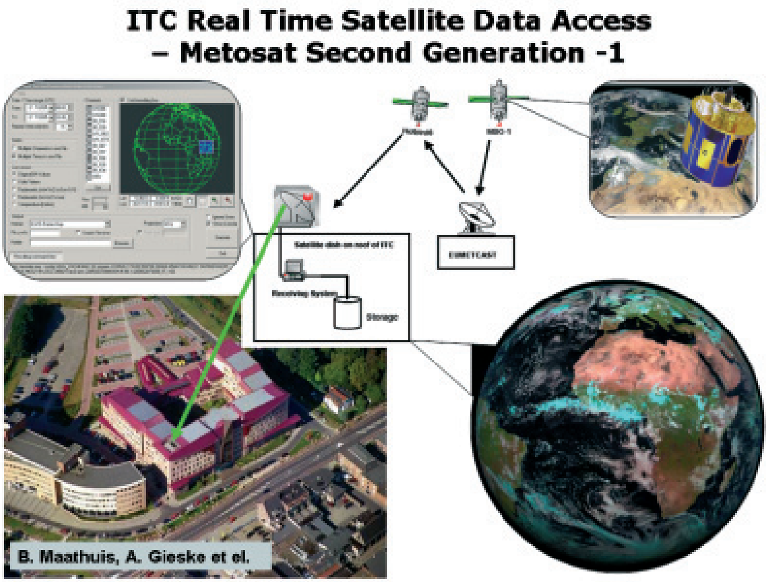

Figure 7 ITC MSG facility

The current expertise in drought monitoring must be further strengthened. The Dragon Programme project (drought monitoring and prediction in China), coordinated by Yves-Louis Desnos of ESA and Zengyuan Li of the National Remote Sensing Centre of China, is a good start in this direction and will be followed by the joint ESA/EUMETSAT EPS/MetOp Research Announcement of Opportunities in Drought Monitoring and Prediction on Global Scale Using EPS/MetOp Data.

- *Water for food and ecosystems: sustainable agricultural production and ecosystem water demand*

Operational use of earth observation data must be strengthened for assessing irrigation areas, water availability, water use, crop water productivity for agriculture, and water demands of ecosystems. The key elements here are satellite-based irrigation and drainage evaluation, remotely sensed and physically based crop yield and crop water productivity monitoring, and assessment of the water requirements of ecosystems. Furthermore, estimating evaporation and transpiration plays a key role. ITC has substantial expertise in this field and must ensure its optimal use and further development.

Several PhD research projects are underway supervised by Rien Bos. Other activities are being conducted with regard to quantifying ecosystem water use in arid and semi-arid environments, in collaboration with Li Wan of the China University of Geosciences; Jun Wen, Qiang Yu and Qinghuo Liu of the Chinese Academy of Sciences; Yanbo He of the China National Meteorological Center; and Benhu Gao of the China Institute for Water Resources and Hydropower Research.

- *Integrated river basin and water resources management*

Earth observation data can be used for extracting hydrological objects and landscape features, and can also facilitate the building of hydrological geospatial data models that describe the surface water flow system of the river basin. Such information can be integrated in hydrological models for purposes of solving surface water resources management issues in watersheds and river basins. Development of a linked earth observation data -GIS- hydrological and water management model must be pursued.

- *Groundwater fluxes: monitoring, assessment and management*

Current efforts in automated, in-situ (e.g. magnetic resonance sounding) and satellite-based remote data acquisition for monitoring groundwater reserves, recharges and discharges have considerable potential for improving groundwater resources management. ITC has experience as a front-runner in groundwater and environmental monitoring and must strive to further this development. The three PhD research projects dealing with groundwater and ecosystem interactions, led by Maciek Lubczynski, demonstrate moves in this direction.

- *Freshwater quality, wetlands and coastal zone management*

Earth observation can contribute significantly to detecting trends in the flow patterns of surface water masses and their chemical characteristics, and explain the processes of mixing and transporting water, nutrients and sediments. With the present wealth of sensors, this can be done for rivers, lakes and coastal waters in increasing spatial, temporal and spectral detail. The importance of time series of satellite imagery and derived products for monitoring trends in water quality is widely recognised, especially in relation to climatic variability (El Niño events). The innovative aspects in this field lie in developing multi-sensor methodologies to quantify hydrodynamic and morphodynamic characteristics and in using these in predictions. This involves applications of earth observation data ranging from local scale to regional and global scales. The impact of land use management on water quality (diffuse pollution) must be studied by means of integrated monitoring and modelling systems. Other emerging areas include the investigation of water and ecosystem interactions in wetlands and coastal waters.

Several projects led by Zoltan Vekerdy are of direct relevance to this topic. Another exciting project is the newly approved PhD project, Remote Sensing of the Berau River Delta and Coastal System, to be supervised by Chris Mannaerts, within the research cluster "From river to barrier reef: physical, biological and socio-economic aspects of the Berau System" coordinated by Piet Hoekstra of Utrecht University and funded by the East Kalimantan Programme of the Foundation for the Advancement of Tropical Research (WOTRO) and the Royal Netherlands Academy of Arts and Sciences (KNAW).

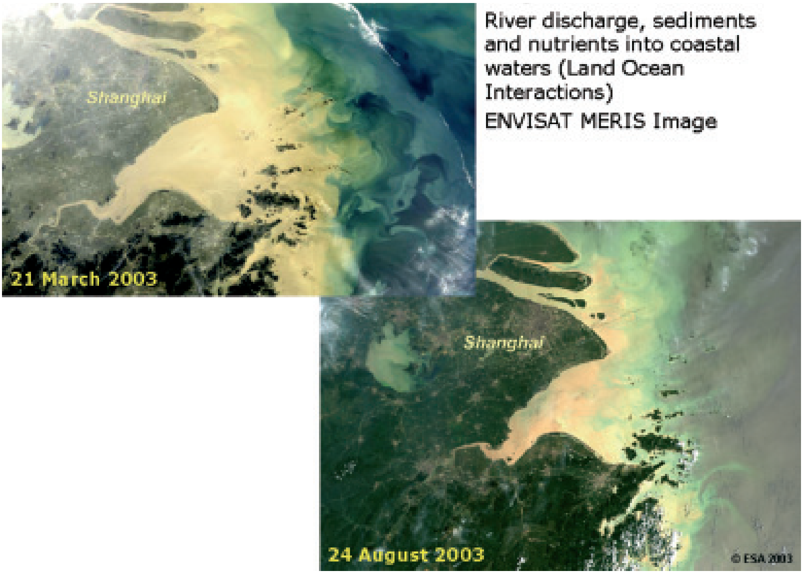

Figure 8 River discharge, sediments and nutrients into coastal waters

- *Integrated water information systems*

Dedicated geo-information systems for water resources and environment management using earth observation data and hydrological models are much needed in our education and projects. Current developments and new efforts must be continued and further supported from both the scientific and technical perspective. ILWIS applications are being used in actual water resources management worldwide, and in this context we collaborate with the professional organisations involved by providing the necessary targeted training and knowledge and system updates.

The most recent example is our rapid response (within hours by Zoltan Vekerdy) to a request from UN experts concerning the formulation and negotiation of the water article (water rights of different provinces) in the newly approved Iraqi constitution. Our service proved to be a key factor in breaking the deadlock in the negotiations.

Current information and communication technologies have provided unprecedented opportunities for processing and presenting information for various purposes. We shall keep pace with these developments and make optimal use of them. One idea is to develop dedicated tools for water resources management as plug-ins in the NASA World Wind software.

Education

"If you give a man a fish, you feed him for a day. If you teach a man to fish, you feed him for a lifetime," said the great teacher and philosopher Confucius more than 2,400 years ago.

In education, we will adopt an integrated approach to developing research capability and curricula, relying on available courses and developing new emerging ones. This will be realised though joint research projects, PhD research, education, training and projects. Sandwich PhD constructions with our collaboration partners will be an important instrument.

With the aim of offering state-of-the-art knowledge in hydrology and water resources by using earth observation and geo-information, we will continually add new emerging scientific elements to our education in order to cope with new demands and new opportunities. MSc research will be embedded, wherever possible, in ongoing research projects. Besides educating individuals, we will actively strengthen collaboration with professional organisations involved in water resources management. Instruments for this purpose will include joint educational programmes, joint short courses and joint projects. Similarly, our education will focus on quantitative studies of processes for better water resources management using geo-information and earth observation. This should be done with the aim of transferring research results to real-world applications. Serious efforts will be made to obtain funding to stimulate excellent MSc students to pursue PhD research.

The aim is to increase the science and technology capability of our collaboration partners and our students. To realise this aim, the approach must not only incorporate classroom teaching but also engage students in active research projects by encouraging their participation in field campaigns, experiments and research projects, so that physical problems and processes can be understood and new problems can be tackled. This calls for the establishment of research and educational field sites, as already mentioned, and the collaboration with partners.

I am very happy to report on the recent establishment of education exchange between the Water Engineering and Management Group, led by Suzanne Hulscher and Arjen Hoekstra, of the Faculty of Engineering Technology of the University of Twente and our department. This initiative, which aims to provide complementary opportunities for students on both sides, is strongly supported by the dean of the Faculty of Engineering Technology, Henk Grootenboer, and by both rectors.

In addition to strengthening the current Water Resources and Environmental Management (WREM) MSc programme, in which the Department of Water Resources plays a major role, we will also organise short courses in advanced topics. The recent Dragon Advanced Training Course in Land Remote Sensing, supported by ESA and the Ministry of Science and Technology of China and conducted at the Capital Normal University in Beijing, China, from 10 to 15 October 2005, is a good example.

Other forms of education will include refresher courses and joint education programmes, such as the one currently under development with the China University of Geosciences.

For many applications in water resources and global change, it is essential to deal with physical quantities of remotely sensed data. This requires quantitative knowledge of sensors and their calibration, atmospheric corrections, the effects of solar illumination, sensor and object relationships, the relationships between radiometric measurements and the physical properties of objects, as well as retrieval of bio-geophysical variables from limited sampling in spectral, radiometric and directional measurements.

An advanced earth observation course is urgently needed in order to be able to offer some of ITC's activities at the most advanced scientific levels (e.g. in its research programme, in international research networks, and in national research schools). Such a course can serve as a component in a European construction, and can be offered as a contribution to the GMES and GEOSS capacity-building activities. We shall actively seek support from colleagues and sponsors, for example from ESA, the EU and GEO. Here the contribution of the to-be-nominated ITC visiting professor of advanced earth observation is eagerly awaited.

A gateway to knowledge, a gateway to the world

The role of our department is to develop and transfer quantitative knowledge for solving water-related problems in society by means of geo-information science and earth observation. To achieve our goals, active alliances in research and education with other universities and partners will be essential. Such partners are the hydrology, water engineering and management, and remote sensing chair groups of the University of Twente, the University of Utrecht, Wageningen University and Research Centre, Delft University of Technology, the Free University Amsterdam and UNESCO-IHE, as well as other research institutes in the Netherlands (e.g. NLR, KNMI, Delft Hydraulics).

In Enschede a significant step would be the establishment of the Twente Centre for Water Systems and Governance. This is currently in the preparation stage and is strongly supported by Wouter van Rossum, director of the Institute for Governance Studies (IGS) of the University of Twente. This centre will focus on understanding the relations between issues of flooding, water scarcity and ecosystem changes, on the one side, and human development, on the other, taking a multidisciplinary perspective. The possible participating chairs are both IGS and the Institute of Mechanics, Processes and Control-Twente (IMPACT) of the University of Twente and ITC.

It is particularly stimulating that the Boussinesq Centre for Hydrology has recently been launched in the Netherlands. The Centre will implement the priority themes recommended by the KNAW Foresight Committee on Hydrological Science in its report Turning the Water Wheel Inside Out, namely:

- hydrology and climate
- hydrology and geo-ecosystems
- hydrology and geo-environment.

The participating chair groups in the Centre are from Delft University of Technology (Huub Savenije/Niek van de Giesen), the Free University Amsterdam (Han Dolman), Wageningen University (Peter Troch/Roel Dijksma, Sjoerd van der Zee), Utrecht University (Majid Hassanizadeh, Marc Bierkens), the UNESCO-IHE Institute for Water Education (Stefan Ulenbrook), and ITC (Bob Su).

With our European partners (e.g. ESA, the University of Valencia, INRA and the University of Strasbourg), we will be involved in quantitative earth observation and water resources research across the whole of Europe. Partners in emerging economies will include those with whom we have already established strong collaborative relationships (e.g. in China, Botswana/South Africa, Kenya, Mexico and Eastern Europe). Our collaboration partners in less developed countries will be reached through our alumni network and enhanced through refresher courses and collaborative projects. Other important international partners include the International Water Management Institute (IWMI), Princeton University and the US Department of Agriculture. Efforts will be made to collaborate with important Dutch research schools and centres such as the C.T. de Wit Graduate School for Production Ecology and Resource Conservation, and the Netherlands Center for River Studies.

With our relentless efforts and the strong support of our collaboration partners, I am convinced that ITC can play an important role in supporting current international initiatives, such as GMES and GEOSS, as well as in helping to achieve the Millennium Development Goals – in particular in the areas of capacity building, science and technology [9]. We shall also make our due contribution to the Global Energy and Water Cycle Experiment (GEWEX) and the Integrated Global Water Cycle Observations (IGWCO) theme of the Integrated Global Observing Strategy Partnership (IGOS-P). In order to face these grand challenges with resolution, the Dutch earth observation community needs to be united [10].

[9] I thank in particular Stephen Briggs of ESA and Joan Fitzpatrick, in repacement of Jose Achache, of the GEO-secretariat, who have today spoken at our symposium "Global earth observation strategies".

[10] I thank Steven de Jong, who is here today and has spoken at our symposium.

Acknowledgements

I thank the Rector, the Rector Magnificus, the members of the Supervisory Board, the members of the Scientific Council and the members of the Selection Advisory Committee for entrusting me with the position of professor of spatial hydrology and water resources management. I hope that I have made it clear what such a title actually means and that I shall not disappoint you in the coming 20 years or so.

I thank Allard Meijerink for leaving behind a highly motivated and energetic team, and I hope that I can build further on the awareness, responsibility and engagement of the "water boys", and possibly also the "water girls", for the benefit of the "water world" at large.

Though I and my colleagues at the Department of Water Resources complain a lot about almost everything, we always achieve the highest standards when it comes to our work. If we complained less, we would discover another world, a world full of enjoyment as a result of our excellent work. Thanks a lot, and now get your feet wet!

Ladies and gentlemen, life is to live and to love. Without the encouragement of colleagues, friends and family, I would not be standing here today. I am very gratified that so many of you are here.

Ester, Janine, Judith, without you my life would be simply a disaster.

Finally I shall cite a parable.

Long long ago, the Zen master Joji travelled to the Kobe valley. One day, he saw a man at work in a stone pit. Curious, he walked up to the worker and asked him what he was doing. Being busy, the man did not look up but growled, "You can see for yourself, can't you? I'm cutting stones." The traveller continued on his way.

After some hours, he came again to a stone pit and saw another man at work, surrounded by a large pile of stones. Joji asked him about the nature of his labour. He looked up, smiled and said, "I cut stones in this stone pit and with this work I feed myself and my family." The traveller thanked him and went on his way.

When the sun had arrived at its highest point, Joji sought out the shade of a third stone pit. Here too there was a man at work, surrounded by still higher heaps of stones, and Joji asked *this man what he was doing. The man stood up, offered the guest water and said, "I take stones out of this pit and form them into building blocks. With the money I earn I feed myself, my family and my mother-in-law, who has just moved in with us. But if you really want to know what I am doing, you must travel further for two days more. There they are building a splendid holy temple with my stones."*

Thank you. I have spoken.