ANNEX: Examples of EO applications for Water Resources Management

Space-based data and maps present major advantages for extensive resource management, such as water, in that they (among others):

- Provide a homogeneous overview of the whole area, facilitating integration of information from local to national to trans-boundary scale, as well as providing simple qualitative information (e.g. to guide the placement of in-situ devices / networks) ;
- Provide information on water quantity, quality, and consumption;
- Enable mapping/detection of features of hydrological importance also in remote, inaccessible or insecure areas;
- Enable changes of hydrological variables to be detected easily through repeat coverage
- Provide neutral information for integrated management of trans-boundary surface and ground water systems allowing the generation of common databases, inter-country comparable information and shared water management information systems.

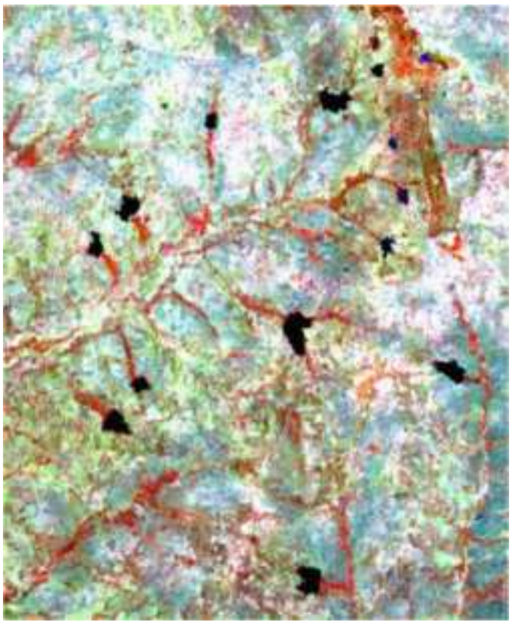
Satellite techniques have come of age, and now, thanks also to an increasing portfolio of missions and technical advances in the sensors offer sustainable data sources at different scale/resolution which may be useful for many different stakeholders in IWRM and which complement and integrate the information provided by the in-situ stations.

The following pages provide a few examples of application of satellite data for the retrieval of water-relevant information, within the priority domains identified by the 4 pilot countries.

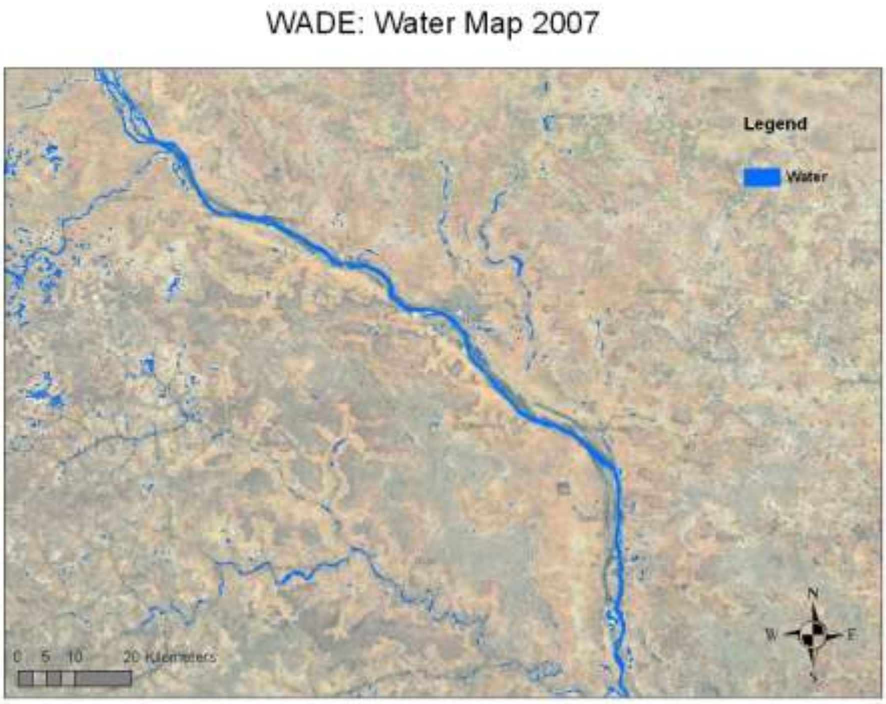
Mapping/Identification of Water bodies

Depending on areal size and the characteristics of the sensor acquiring the data, water bodies also of small size can be recognised and mapped from space.

The image on the right, created by Delft University of Technology provides an example of water bodies mapped from medium resolution satellite data: several small reservoirs are clearly visible.

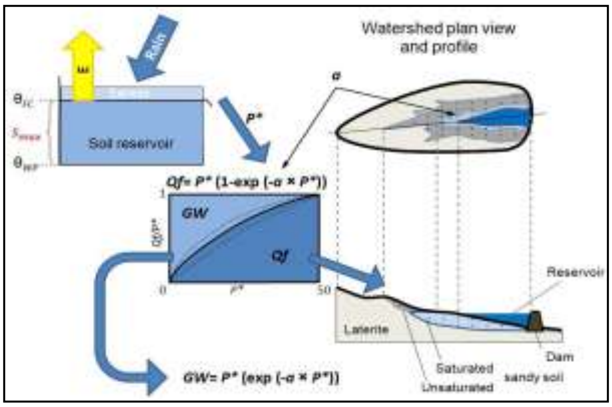


The map at bottom created by the WADE project shows the drainage network (small and ephemeral water bodies) at a specific date in 2007 over the Sahel, as derived from medium resolution radar data (25 m pixel size). The particular surface characteristics of water compared to land, make the use of spaceborne radar data very suitable for retrieving water surface bodies.



Estimating areal/volumetric changes from space

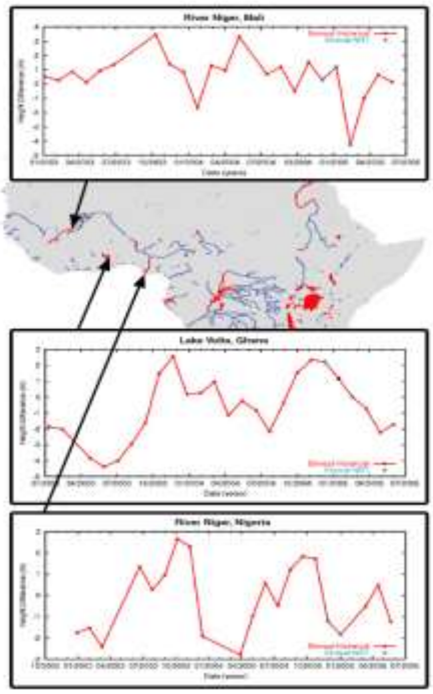
Repeated observations from space allow the creation of time series of basic essential information about location and variations of extent or height[1] of surface water bodies. For instance a model was



developed in the Volta basin (Africa) by Delft Technical University (image on the left) for correlating areal variations of small reservoirs detected from space with stored volumes (www.smallreservoirs.org/). Validation of the model showed that areal changes can explain 98% of the volume changes.

Possibility to look back in time, exploiting data already acquired[2], offers the opportunity to build time-series of historical observations which may reveal essential to understand hydrologic trends, to identify intervention areas for recovery/mitigation actions and to develop forecasts.

Monitoring heights of major water bodies



Radar altimetry allows to estimate the distance between the satellite and a target on the ground. As satellite's orbit are repetitive, the same location can be observed at different dates from exactly the same point in space. This allows the creation and estimation of average water body's heights and to monitor their evolution over time.

The image on the left shows an example of the outcome of the River and Lake project (http://earth.esa.int/riverandlake): "virtual" gauge measurements of average height variations are reconstructed from space and are made available as ASCII files in near real time over the main world's water bodies. These data have been proved useful to refine existing river discharge models.

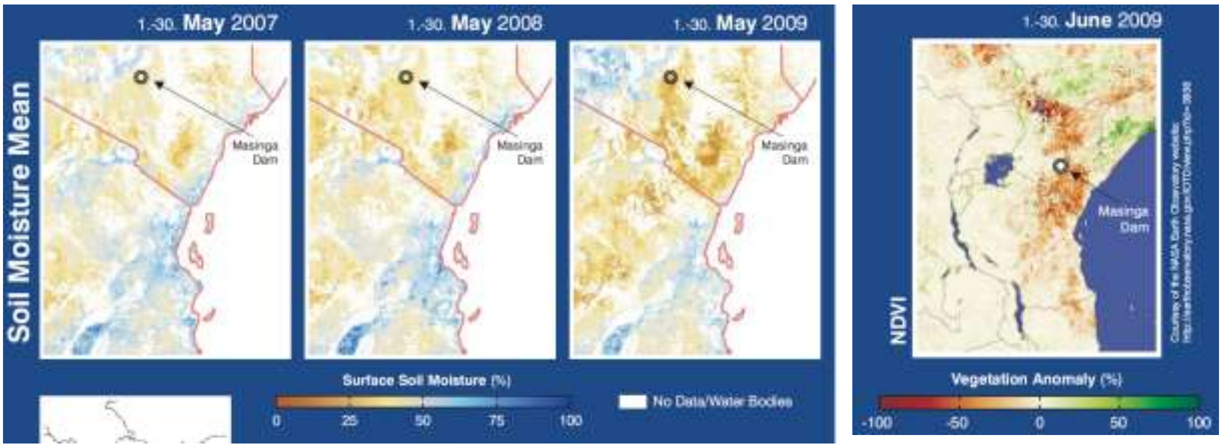
Retrieval of drought indicators

Satellite data allow monitoring of large areas, completing the information provided by the scattered in-situ network. Availability of data in near real time may facilitate the organization of warning systems, based on models and satellite data, which may have a variety of different purposes, ranging

[1] Average height measurements of large water bodies obtained from altimeter measurements differ in frequency of acquisitions and ground resolution based on the characteristics of the satellite and sensor used.

[2] Earth Observation mission data from different mission owners are available since the 70's

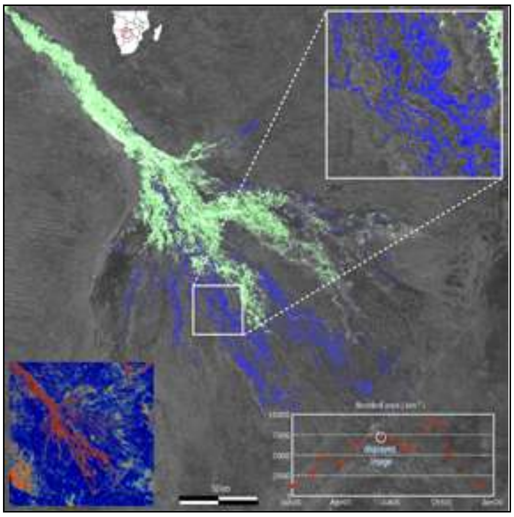
from flood prediction to drought forecasting. In the case of drought, several indicators of water stress, vegetation health or relative soil moisture can be derived from EO data. Space observations can also contribute to the evaluation of water balance by supporting the extraction of information related to evapotranspiration. The images at bottom (provided by Vienna University of Technology) show the evolution of average surface soil moisture from space over Kenya and a comparison with the vegetation index derived from EO data: areas with larger negative vegetation anomaly in June 2009 seem to correlate to areas with soil moisture values lower than usual in May 2009.

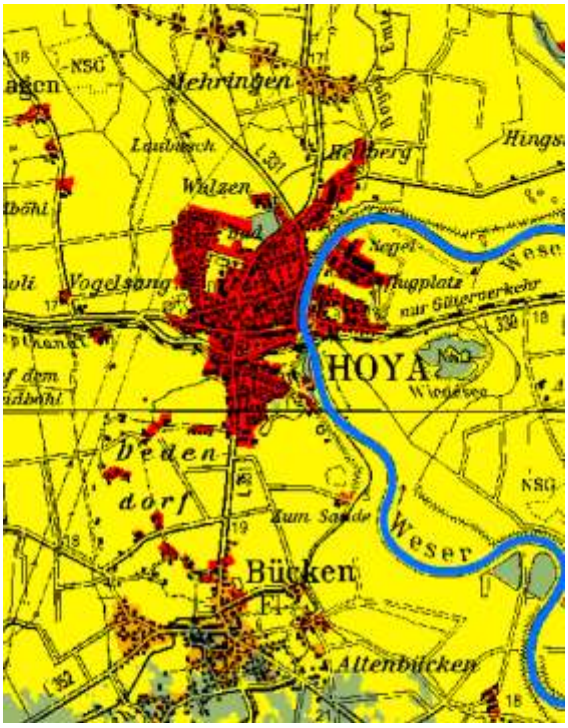


Floods

Spaceborne data may offer the capability to directly derive from the analysis of observations key flooding parameters such as: flood maximum extent, flood duration, flood frequency both from new and archive acquisitions. This information, jointly with other updated information -also derivable from EO data such as watershed characteristics (vegetation, morphology, geology, moisture)- is of uttermost importance in defining flooding hazard maps, supporting simulations and refining hydrological models. For instance, in the case of flash flooding, normally raingauges are used jointly with models exploiting DEMS, moisture and vegetation

Flooding patterns of the Okavango Delta Wetlands have been derived by EO data by ETH (right). Open water surfaces are shown in blue, water surfaces covered by vegetation in green. The spatial resolution of 150 m captures small scale flooding patterns such as channels and lagoons precisely. Thirteen images were analyzed for the year 2005: for each image water extension was mapped. The small inset on the left bottom shows temporal pixel variance, used to remove ambiguities (red=high, blue=low). The gathered information is being used for ecosystem studies.





Flood Risk Maps show the potential adverse consequences associated with flood scenarios. The assessment of damages and losses is based on the combination of land use data and statistical data with flood extend, using actual (current or historic) or potential (simulated) flood events. The image on the left, realized by the RISK-EOS Consortium, shows an example of a flood risk map (low potential damage in yellow, medium in orange and high in red) obtained by integrating hydrologic models with an EO-derived landcover classification.

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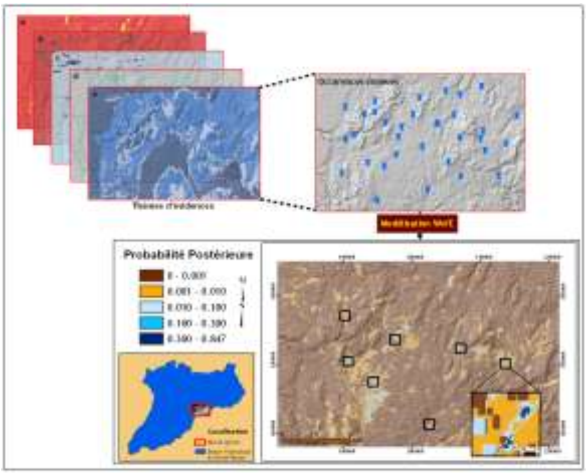
Groundwaters

The detection and assessment of ground waters is one of the most complex applications of remote sensing data since they are not directly "portrayed" on the data; geo-hydrologists must infer subsurface hydrological conditions from surface indicators such as geological features and structures, vegetation, streamflow characteristics, soil and soil moisture anomalies, vegetation types and distribution, springs…



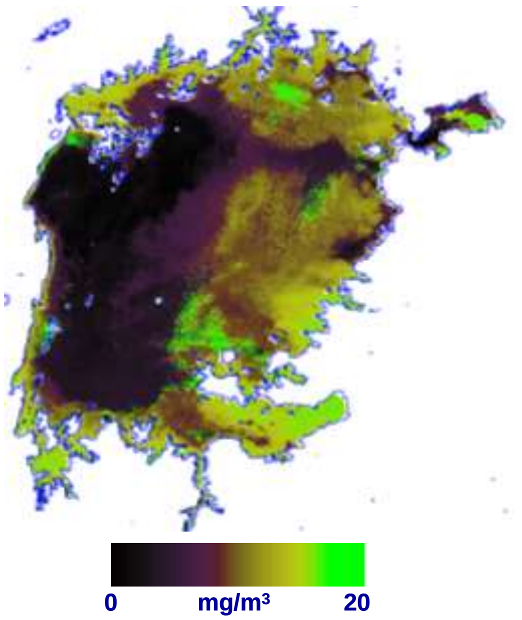
The image on the right provides an example of Ground water prospecting performed by CTRS: several different layers (permeability, soil moisture, lineaments DEM, hydrologic network, and existing wells) have been used to model the posterior probability to find groundwater in a part of Morocco.

Ground deformation can be assessed and quantified from space, enabling the modeling of volumes of fluids extracted from shallow aquifers[3]

Water quality

Retrieval of bio-geophysical parameters such as water temperature, turbidity (indicator of the amount of suspended sediment in the water) or chlorophyll content (indicator of the degree of eutrophication –amount of phytoplankton in the water) is possible from Earth Observation data.

[3] This is possible only in case of primary porosity

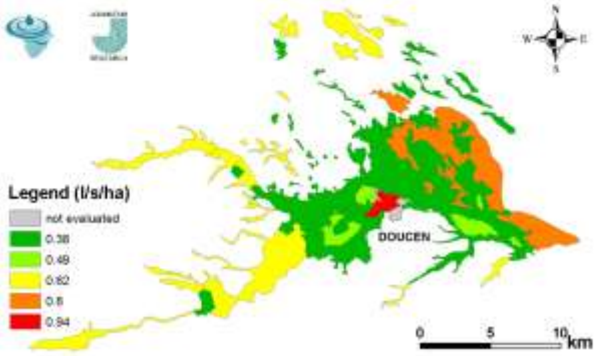


This information is essential for monitoring the evolution of water quality, complementing and extending to larger areas the information provided by in-situ networks.

The image shown on the left provides an example of EO-based chlorophyll content estimation (in mg/m^3) over lake Victoria at a date in 2006. The work was performed by Vexcel with the support of RCMRD. Color coding ranges from brown (no chlorophyll) to green (larger amounts of chlorophyll).

Whereas the product shown on the left was produced with data acquired in the optical domain[4], some sensors can acquire information independently from weather conditions, hence allowing to monitor the propagation of invasive weeds in waters.

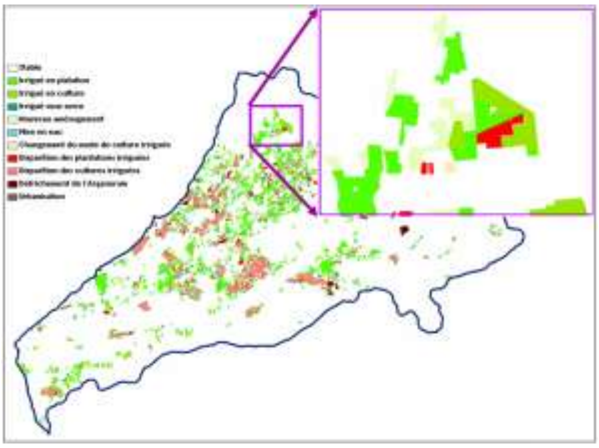
Water Use and Agriculture



EO data can be used to map extent and type of cultivation, its health, evolution over time, the overall biomass and to assess/model irrigation needs.

The image on the left shows an example of irrigation water requirements estimated over an oasis in Africa by Johanneum Research: depending on the different type of cultivation, different volumes of water are needed.

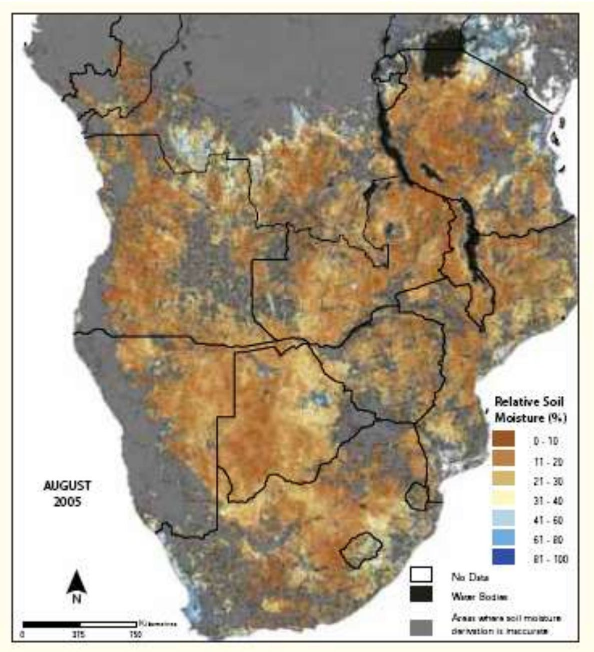
The map on the right realised by CRTS shows an analysis of different landuses over an area in Morocco, jointly with information about changes in landuse practices derived from the analysis of timeseries of EO data. In addition, location of springs or water extraction structures can be monitored from space to avoid potentially polluting practices and inventories of small ponds and dams used for cattle/local agricultural practices can be derived..

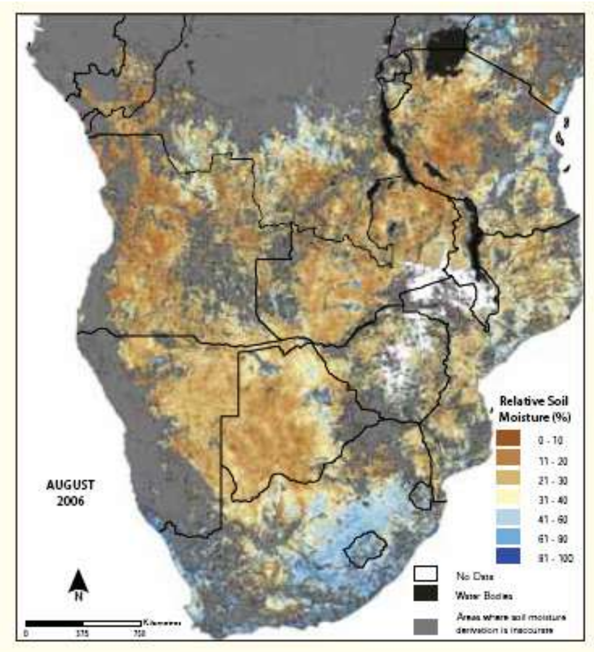


[4] Sensitive to cloud presence

Soil moisture and snow water equivalents

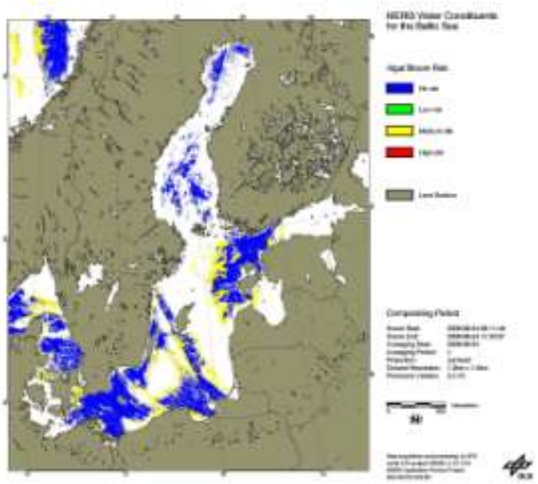
Advanced retrieval techniques allow derivation of soil moisture or snow water equivalent information from spaceborne data. Such inputs may represent an important portion of the total water balance of the earth-atmosphere system and are of foremost importance in hydrologic and agricultural models. The image at bottom obtained by Vienna university of Technology shows an example of relative soil moisture maps over Southern Africa derived from radar data in 2005 and 2006.





Coastal zones management

Different marine indexes can be derived from EO data of coastal zones, allowing to better obtain ocean characterization, and prevent potential arrival of harmful bacteria related to upwelling events. The image on the right shows an example derived from the MARCOAST Project and illustrating the risk of algal blooms in the Northern Sea, derived from satellite optical images. Water quality, chlorophyll content, turbidity or surface temperature can be extracted, similarly to the existing algorithms for inland waters



Base maps

A large variety of basemaps can be derived and updated from EO data. Those include amongst the others: hydrographic networks, digital elevation models, geology and lineaments, land cover, soil moisture, vegetation, agriculture and forestry, soil sealing, urbanisation, infrastructures…

The image on the right provides an example of inputs generated by CTRS for the management of a water basin. Those include: a) Urbanization, b) Soils degradation, c) Groundwater over-exploitation, d) Groundwater conservation, e) Densification of irrigated zones, f) Growing irrigated zones, g) Forest.