Global warming, explosion of global food demand and pressure on land, energy crisis, environmental degradation, threats to biodiversity, etc. All these elements of our context weigh more heavily on our way of interacting with the world around us. Thus, climate change will profoundly modify the environmental conditions in which cultivated ecosystems grow, and we will have to adapt our production systems, including towards energy-efficient systems, or enhancing biodiversity. A possible increasing frequency of extreme events could affect even more terrestrial ecosystems. To meet these challenges, several missions work to better take into account the role of continental surfaces (soil, vegetation, mainland water) at regional and global scales.

**SMOS, mapping of soil moisture, a world first**

The successful launch of SMOS on November 2, 2009, followed by the deployment and ignition of its instrument on November 18 is a huge technological success in itself but it is also the beginning of work for all the researchers who awaited this event for years. Indeed, SMOS is the first space mission that can measure soil moisture from space, with a global coverage. This measurement will help increase the accuracy of weather forecasts and estimates, and thereby better manage the water resources of our planet. The first extractions of images during the calibration of this extremely innovative and complex mission are more than encouraging. The phase of flight operation is scheduled to last until June 2010.

In parallel, CNES is developing CATDS (SMOS Data Processing Center). These processing chains enable the delivery of moisture and salinity products.

**MISTIGRI, a mission dedicated to soil-vegetation-atmosphere exchanges**

No system currently provides data combining both high spatial resolution and good revisit capabilities, which would bring important perspectives of progress, and users still have to face a dilemma between high revisit/low resolution (with Meteosat, Goes, AVHRR, MODIS) and high resolution/low revisit (ASTER, Landsat ETM+). Moreover, none of the systems planned today will propose enhanced resolution and revisit at the same time. In this context CNES is currently developing in tight cooperation with Spain a project of microsatellite mission in the thermal infrared, MISTIGRI (MicroSatellite for Thermal Infrared GRound Surface Imaging). The definition of the mission is now entering a two-year phase A. Launch of MISTIGRI is expected in 2015. The main specificity of MISTIGRI is to combine both high spatial resolution (about 50 m) and a high revisit frequency (one or two days). They include several bands in the TIR and in the VIS/NIR domains. MISTIGRI is a precursor mission associated with a number of experimental sites on ground, a strategy similar to the Venus one in the optical domain. The first scientific priority of the mission lies in the monitoring of the continental biosphere and the validation of related methods and algorithms, with
a large range of applications in agriculture, water use, biogeochemical cycles, hydrology. A second priority is devoted to urban areas; and finally, coastal areas.

**SWOT, the future of altimetry and a first in hydrology!**

SWOT is being developed at the U.S. level as part of the Decadal Survey. Its objective is to measure the water level (and its spatio-temporal derivatives) of oceans, rivers, lakes and flooded areas, using a new technique: interferometric altimetry (wide swath), which provides a two-dimension image with a horizontal resolution of about 50 m to 100 m. This mission is the first mission designed in response to the specificity of inland surface water. It will allow the scientific community of river hydrologists and hydraulic engineers to progress in the spatial approach of river dynamics, from local scale to global scale. It is subject to a close cooperation between French and American scientists and is in line with the NASA/CNES radar altimetry (Topex/Poseidon, Jason). CNES has been undertaking a phase A study in collaboration with NASA and JPL since September 2008.

**Pleiades, a zoom on land**

The community looks forward to the Pleiades satellite, now ready to be launched. With its high spatial resolution, image quality and agility, its potential applications are land management, mapping and risk management. Thanks to the ORFEO preparatory program led by CNES since 2003, a number of important themes such as hydrology, agriculture and management of riparian and shoreline areas have shown the potential contribution of Pleiades for an environmental information system.

Indeed, acquisition of data at very high spatial resolution will account for heterogeneities and local conditions which greatly influence most hydrological processes, and the issues that are associated, particularly those relating to agricultural activities or environmental impacts (on riparian corridors for example) and hydro-climatic risks.

**VENµS, a GMES demonstrator and a precursor to Sentinel-2**

VENµS (Vegetation and Environment monitoring on a New Micro-Satellite) is jointly developed by CNES and ISA, the Israeli Space Agency. Its objectives are:

- to prepare the use of future operational EO missions, mainly Sentinel-2, for research and applications dealing with land surfaces (water and carbon fluxes, land cover and land use, agri-environment issues, ...),
- to investigate and demonstrate the benefit of frequent high-resolution remotely-sensed measurements acquired by a super spectral imaging radiometer,
- to develop and experiment a dedicated ground segment able to deliver state-of-the-art quality products.

VENµS’ observing capabilities are:

- Resolution: 5 m (L1) – 10 m (L2, L3), field of view: 27 km, twelve spectral bands from 412 to 910 nm, geometric revisit frequency: two days one useful product per ten days, systematic acquisition: around 100 sites, two stereoscopic bands with a low angle difference: cloud and surface altitudes and a constant viewing angle: minimization of directional effects, easier images registration.

A number of scientific and applied uses of high resolution times series are being investigated as part of the Venµs preparation with the scientific community. And a major improvement of the geometric and radiometric quality of image products from the acquisition of time series at constant view angle has already been demonstrated. Venµs will be launched in 2012.

**Biomass: quantifying the biomass of forests and its cycle (sources/sinks of carbon)**

The plant biomass is identified as a crucial information. The BIOMASS project was designed to overcome this problem, instigated by CESBIO (CEntré for Space Studies of the BIOsphere). It is a P-band radar that will "penetrate" the vegetation and thus better estimate its 3D structure in order to measure forest biomass repeatedly across the globe at a resolution of about 50 m to 1 ha.

The measurements will better quantify the sources and wells of carbon on the Earth’s surface to better understand the role of forest ecosystems in climate change. During the seminar of scientific prospective of CNES in March 2009, BIOMASS was considered a priority by the Science Programme Committee, which recommended strong support from CNES during the next phase A of the BIOMASS mission, particularly through a strong support of the scientific community. The goal is to assist in the selection of this mission in the Earth Explorer Program.

A measurement campaign called TROPISAR supported by CNES, ESA and ONERA was conducted in Guyana in August 2009. It performed test flights in the Guyana forest during three weeks. Once interpreted, the data will provide values of biomass and canopy height. They will simulate the data of the BIOMASS mission, and will be used to evaluate the performance of biomass estimation methods for tropical forests.

CNES has also introduced a phase A to provide support and expertise to help consolidate the specific requirements of the mission performance and to improve and validate methods for the correction of ionospheric perturbations of the P-band radar signal.

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*Fig. 1:* Image of brightness temperature over Scandinavia captured by SMOS.

*Fig. 2:* Impression of SMOS. SMOS’ mission is to observe at a global scale the superficial humidity of continental surfaces and the surface salinity of oceans.

*Fig. 3:* SMOS results. Brightness temperature over the Amazon.
Abstract

Snow volumes over the 1990-2006 period from the Special Sensor Microwave/Imager have been computed for all continental surfaces above 50° N, except Greenland. Annual snow volume trend over Eurasia is positive (but not significant), whereas it is negative and significant over North America. These opposite trends can be explained by different regional climatic conditions. Snow volume trend over the study domain converted into sea level corresponds to a negligible contribution to sea level rise.

Le volume de neige sur la période 1990-2006 a été calculé à partir des données du Special Sensor Microwave/Imager pour les latitudes supérieures à 50° N, Groenland exclu. La tendance de ce volume de neige est positive sur l’Eurasie (mais non significative) et négative (et significative) sur l’Amérique du Nord. Ces tendances opposées peuvent s’expliquer par des conditions climatiques différentes. Il est aussi montré que la neige des hautes latitudes ne contribue pas à la montée des océans.

High-latitude regions are the most affected by the current climate change. Therefore their observation is a crucial issue to better understand how they respond to this change. Yet, few in situ snow observations are available for high latitudes, thus providing a poor knowledge of global or regional Snow Depth (SD) fields. While remote-sensing techniques offer a useful alternative to scarce in situ measurements, most analyses have focused on snow extent change. In this study, we use satellite-based microwave observations to derive global high-latitude Snow Volume (SV) change over the 1990-2006 period to analyze its temporal evolution. The correlation between SV and climate indices has also been investigated.

The algorithm used to estimate SD was developed by Mognar et al. (2002)[1] and takes into account the temporal evolution of the snow grain size. The inputs for this algorithm are respectively:

- the difference between 19.35 GHz and 37 GHz brightness temperature in horizontal polarization measured by the Special Sensor Microwave/Imager (SSM/I) [2] at a 25 km² × 25 km² spatial resolution averaged over a 5-day time period,
- the air/snow interface temperatures from the National Centers for Environmental Prediction (NCEP) global reanalysis,
- the snow/ground interface temperatures modeled by the “Interaction between Soil-Biosphere-Atmosphere” (ISBA) land surface scheme.
For this study, we consider all continental surfaces above 50° N, Greenland excluded.

Interannual total SV time series (seasonal signal removed) from SSM/I have been computed over the 1990-2006 period, for Eurasia (0° E < longitude < 191° E, Fig. 1) and for North America (191° E < longitude < 360° E, Fig. 2). SV over Eurasia displays a positive trend of 4.7 km^3 yr^-1 ± 9.6 km^3 yr^-1, whereas over North America, the trend is negative and amounts to -9.4 km^3 yr^-1 ± 4.2 km^3 yr^-1. While the trend over North America is statistically significant, over Eurasia it is not (the p-value, which is the probability to obtain this coefficient by random chance whereas the variables are uncorrelated, is equal to 0.63). The trend of the yearly SV averaged over the whole study domain is also not statistically significant (-4.7 km^3 yr^-1 ± 11.1 km^3 yr^-1 and p-value = 0.68). Converted into equivalent sea level, this trend is very small (-0.004 mm yr^-1 ± 0.009 mm yr^-1) compared to the global mean sea-level trend (3.3 mm yr^-1 ± 0.4 mm yr^-1 over the satellite altimetry period 1993-2009) [3], showing that high-latitude snow does not play any significant role in the global mean sea-level rise.

Each climatic index used in this section has been downloaded from the UNESCO website* and has been averaged from January through March for each year. The Arctic Oscillation index (AO, leading mode from the Empirical Orthogonal Function analysis of monthly mean height anomalies at 1000-hPa, poleward of 20° N) is relatively well correlated with SV over North America (correlation = 0.51 and p-value = 0.03) and anti-correlated with SV over Eurasia (correlation = -0.57 and p-value = 0.01). Thus, the climatic conditions represented by the AO index (which is the dominant mode of interannual variability in the Northern Hemisphere) play a significant and opposite role over the two continents. It is worth mentioning that SSM/ISV over Eurasia and North America are not correlated (correlation = -0.07 and p-value = 0.80). Similar results are found for the North Atlantic Oscillation (NAO, the sea-level pressure difference between Iceland and the Azores), which is commonly seen as a regional manifestation of AO (over North America the correlation is 0.42 with p-value = 0.08 and over Eurasia the correlation is -0.58 with p-value = 0.01). Atlantic Multidecadal Oscillation (AMO, North Atlantic mean sea-surface temperature anomaly north of the Equator) and Pacific North American pattern (PNA, second component of the Northern Hemisphere extra tropical sea-level pressure anomalies) are anti-correlated with SV over North America (correlation = -0.59 with p-value = 0.01 and correlation = -0.66 with p-value < 0.01, respectively) and not, or only weakly, correlated with SV over Eurasia (correlation = 0.04 with p-value = 0.87 and correlation = 0.30 with p-value = 0.22, respectively).

The correlation coefficients between the yearly mean SV anomaly and all possible linear combinations of two different indices have also been computed. For Eurasia, the best correlation coefficient (0.69) is obtained for a linear combination between NAO and AMO (-577.AMO-323.NAO, dotted black curve in Fig. 1), whereas for North America the best correlation coefficient (0.75) is obtained for a linear combination between PNA and AMO (-235.AMO-92.PNA, dotted black curve in Fig. 2). Thus, these indices represent regional atmospheric processes influencing the most the two continents.

From satellite passive microwave data, it has been shown that over Eurasia the trend in the high-latitude mean annual SV is positive, but not statistically significant. Over North America the SV trend is negative and highly significant. This difference could be due to the influence of AO which correlates with North American SV and anti-correlates with Eurasian SV. These differences are also linked to regional climatic conditions as SV anomaly over Eurasia better correlates with a linear combination of the NAO and AMO indices, whereas over North America it better correlates with a linear combination of the PNA and AMO indices.

### References

* http://ioc3.unesco.org/oopc/state_of_the_ocean/atm


**Abstract**

Characterizing land use along rivers and its impact on river ecology is a key issue to define aquatic ecosystems preservation strategies (European Water Framework Directive). A three-step methodological approach has been developed: (1) river corridor land use mapping based on high spatial resolution imagery, (2) definition of indicators to quantify land use pressures on rivers, (3) design of models relating river ecological indicators with land use pressure indicators.

**Riparian vegetation and river ecological status: contribution of high spatial resolution imagery.**

**Végétation rivulaire et écologie des cours d’eau : apport de l’imagerie à haute résolution spatiale.**

Research was implemented on two river systems: the Herault river (1 500 km; Mediterranean climate; lime table; forests, agriculture) and Lower Normandy rivers (6 000 km; oceanic climate, lime table; agriculture and pastures).

Two ortho-rectified High Spatial Resolution Imagery (HSRI) data sets available over the whole French territory were used to map river corridors: aerial photos (summer 2001; 0.5 m resolution; four visible bands; IGN®); SPOT 5 XS (summer 2004; four spectral bands; CNES®). CORINE Land Cover database (CLC) was used to characterize river basin land use. River grade surfaces...
ecological status indicators (EQR/IBGN) were obtained from the “Réseau de Contôle et de Suivi” (RCS, ONEMA).

Two land cover typologies were used: the 44 class CLC typology; a synthetic six-class typology based on a literature review [3] which includes water surfaces (C1), agricultural areas (C2), urban areas (C3), forested areas (C4), semi-natural herbaceous vegetation (C5) and natural bare soil (C6). C2–C3 cause the main alteration of stream ecological status, C4–C5 maintain biodiversity and regulate non-point source pollution, C1 & C6 help delineate water bodies. Object-based image analysis was implemented [4] to delineate riparian land cover objects and classify them using a class feature rule-based classification. Land cover map accuracy was assessed through a confusion matrix computed on a set of reference objects (2% of image objects; field truth May 2005).

Spatial indicators were built to synthesize river corridor land cover information and characterize pressures, among which three “area percentage” indicators: Linear Spatial Indicator (LSI, narrow buffer), Floodplain Spatial Indicator (FSI, floodplain buffer), and Contact Spatial Indicator (CSI, polygons in contact with the river). A Partial Least Square (PLS) approach was implemented over Lower Normandy rivers (155 ecological stations allowing relevant statistical analysis) to build multilinear models relating station ecological status indicators with pressure indicators.

Land cover classification from HSRI: Fig. 1 (top) illustrates the HSRI map over the Herault river corridor. Its accuracy is 70%. Water, agriculture, urban & forest areas are correctly classified (>70% accuracy) while herbaceous vegetation and bare soils present confusions and poor map accuracy (<40%). The lagtime between image acquisition (May 2004 for SPOT 5 XS; summer 2001 for orthophotos) explains part of these errors. In comparison CLC (overall map accuracy 54%) provides poorer information than HSRI and its resolution is clearly too low to detect the majority of forested elements in riparian areas.

Spatial indicators of land cover pressures: synthetic spatial indicators (linear LSI, floodplain FSI, contact CSI) were computed from HSRI maps for ten sections of the Herault river main reach (Fig. 1 bottom). LSI shows a predominant forested vegetation close to the river while FSI shows a predominance of agricultural areas in the floodplain. CSI enlightens complex urban patterns connected to the river. Indicators derived from HSRI maps, particularly LSI and CSI, appear to carry far more information than CLC derived indicators.

Pressure/impact models: resulting pressure/impact models built on Lower Normandy rivers show a 38% correlation between land cover pressure indicators and stream ecological status indicators (Fig. 2). Such correlation is significant in the domain of ecology, where a large diversity of factors and processes influence ecological status. Correlation falls down to 28% when using only CLC pressure indicators on the upstream basin. Urban and industrial land use causes main negative impacts at upstream basin and river corridor (300 m large) scales. Roads in the local river corridor appear to have a significant negative impact. Herbaceous vegetation brings main positive impacts at upstream basin and upstream river corridor (20 m–250 m large) scales. HSRI river corridor maps allow to both quantify the impact of river corridor land use patterns and identify their area of influence on river ecological status.

This study has demonstrated that HSRI using object-based image analysis allows the extraction of land cover information along river corridors with an acceptable degree of confidence (>70% accuracy), and that this information is relevant to assess the relative influence of riparian zones versus watershed on river biotic status. This prefigures the design of river preservation and restoration strategies.

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References