Applications of datastreams and products disseminated by EUMETSAT's EUMETCast system

The DevCoCast project – Applications for environmental and agricultural monitoring and impact on decision making processes in Latin America

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Abstract. Many Latin American countries face serious environmental risks and need accurate Earth Observation (EO) data and derived environmental information for their sustainable development. GEONETCast provides reliable, fast and low cost access to such EO products. The "GEONETCast for and by Developing Countries" (DevCoCast) project, funded by the European Community's 7th Framework Programme for Research (FP7) involves developing countries more closely in the GEONETCast initiative. Many EO data products, some produced in Latin America and Africa, are freely shared via GEONETCast. These products can be received using simple and low cost ground reception infrastructure. More importantly, the actual use of the products by a broad user community is supported through training and building on the existing networks and capacities. This is done across continents and application themes such as vegetation and agriculture, fires and floods, water resources and ocean and weather/climate. The goal is to embed GEONETCast and the data it offers into research, environmental monitoring and planning, and decision making processes, in support of sustainable development. This paper presents a few examples of the integration of operationally received DevCoCast and other GEONETCast data into decision making processes in Latin America, with focus on environmental and agricultural monitoring.

Keywords: Remote Sensing, environment, agriculture, Latin America, GEONETCast, DevCoCast

1. Introduction

As part of the core infrastructure of the Global Earth Observation System of Systems (GEOSS), GEONETCast reliably shares Earth Observation products worldwide using telecommunication satellites, by exchanging data between three broadcast systems: EUMETCast operated by EUMETSAT, GEONETCast-Americas operated by NOAA and CMACast operated by Chinese Meteorological Agency (CMA). The Russian Mitra system is being added. The broadcasted EO products can be received using simple and low cost ground reception infrastructure. The "GEONETCast for and by Developing Countries" (DevCoCast) project, funded by the European Community's 7th Framework Programme for Research (FP7), freely shares a wide variety of EO products, some produced in Africa or Latin America, through GEONETCast. In the case of Latin America, the data flow consists of environmental data produced by INTA (Argentina), INPE-CPTEC (Brazil) and by VITO (Belgium). The INTA products are derived from NOAA-AVHRR (NDVI, NDVI anomalies, evapotranspiration, fire risk), MODIS (flood, fire affected areas, hydric balance, pasture productivity) and GOES (hail affected area). INPE-CPTEC provides CBERS imagery, GOES-MSG composites, and products derived from GOES (fire detection, rainfall, forecasting of convective systems, lightning discharge, number of days without rain, ultra-violet index) and NOAA-AVHRR (fire detection and NDVI). The VITO products are derived from SPOT-Vegetation (NDVI, NDWI, dry matter productivity, LAI, green cover fraction, albedo, NDVI anomalies, burnt area, vegetation growth season). DevCoCast also supports the actual use of the products by a broad user community through the organization of training courses and the distribution of training materials. The ultimate goal of DevCoCast is to support sustainable development, through the continuous use of the variety of data distributed through GEONETCast for research, environmental monitoring and planning and decision making processes. This paper presents an example of the integration of operationally received DevCoCast data into decision making processes in Latin America, with focus on environmental and agricultural monitoring. In the following sections, first some examples of the use of GEONETCast data for environmental monitoring are described: (1) biomass and net primary production monitoring, (2) land degradation monitoring, (3) water cycle and evapotranspiration, (4) water cycle, early warning systems and water basin management, and (5) real time monitoring of insect populations. Then, two cases of agricultural monitoring are illustrated: (1) crop growth and yield monitoring in Brazil and Argentina, and (2) crop and food supply assessment in Southern Sudan, as an example of how GEONETCast data can be embedded in high level decision making processes.

2. Environmental monitoring

2.1 Biomass and net primary production monitoring (Beget and Cristiano, 2010; Lima da Fonseca, 2010; Torresan, 2010)

The Pampa biome, with an extent of approximately 700,000 km², covering wide areas in Brazil, Uruguay and Argentina, has a unique kind of vegetation, characterized by C3 and C4 plants adapted to transition from subtropical to temperate climates. The main economic activity in the Pampa region is the beef and sheep cattle industry, based on natural grasslands. This “free range” grazing systems in natural pastures has been applied for more than two hundred years and is a form of economic use of natural grasslands, with low level of damage to the Pampa biome. Data from the Brazilian Ministry of Environment (2010) shows that in Brazil, the Pampa biome declined to 54% of its original area, mainly due to agricultural activities and forestry for cellulose industry in the last 30 years. The monitoring of the aboveground biomass or net primary production of vegetation in this region allows fitting cattle activity to the actual biomass production, allowing an adjustment of the number of livestock per area to enable the economic exploitation of these areas jointly with the conservation of natural vegetation and of the environment. Grassland above-ground net primary production (ANPP), a key figure that determines the entry of carbon and energy to ecosystems and their availability for herbivores (McNaughton et al., 1989), varies at different spatial scales (Posse et al., 2005). This variable allows characterizing an ecosystem, assessing their condition, evaluating and comparing their sustainability. Secondary productivity is partially determined by total primary productivity, the seasonal dynamics of primary productivity and vegetation quality (Larter and Nagy, 2001; McNaughton et al., 1991). At a regional analysis, livestock stocking rate is related to mean annual integrated Normalized Difference Vegetation Index (NDVI) (Oesterheld et al., 1998). The ANPP can also be estimated according with light use efficiency model of Monteith (1977), using radiation data, fAPAR estimations from vegetation indexes and biomass conversion efficiency models (Cristiano et al., submitted). A water stress factor from a water balance model and soil fertility is taken into account to model environmental stress. Products derived from the SPOT-Vegetation (SPOT-VGT) or MODIS sensors and distributed through GEONETCast are used to periodically quantify and monitor the aboveground biomass production for the natural grassland of the Pampa biome and to identify, map and monitor degradation of natural grasslands.

2.2 Land degradation monitoring in Argentina and Mexico (Abril, 2010; Douriet, 2010)

Deforestation and inadequate agriculture practices generate environment deterioration and land degradation, which is further enhanced by climatic variability. Major impacts are soil erosion, increased runoff, higher hydrological damages and reduced soil water reserves. The two main regions currently affected in Argentina are the highlands in Córdoba, which are important natural hydrological reservoirs, and the Pampas region as the major range- and cropland of the country (Abril, 2010). In Mexico, a target area is the water basin of the Culiacán River, where severe drought periods in recent history resulted in high productivity losses, water scarcity problems and forest fires (Douriet, 2010). It is highly relevant to generate monitoring strategies of soil/vegetation condition to allow continuously, timely and adequate decision-making for environment preservation and rehabilitation by the responsible institutions. SPOT-VGT, NOAA-AVHRR and CBERS data are used to generate active risk maps. There are continuously updated and distributed online for research and policy institutions.

2.3 Water cycle and evapotranspiration (Ferreira and Dantas, 2010; García, 2010)

The knowledge of the hydric balance and the water cycle is very important in decision making processes, both in irrigated and rain fed systems, in order to take actions in case of water deficit or excess. The estimation of evapotranspiration from remote sensing data offers opportunities to determine the water cycle and hydric balance over wide areas. Thanks to the higher access to data and imagery from meteorological satellites (METEOSAT, GOES, etc.) and land observing satellites (SPOT-VGT, MODIS, CBERS, etc.), new methods for the estimation of evapotranspiration are proposed in various studies. The estimation of hydric balance allows the evaluation of future consequences and the prevention of risk situation regarding crop and pasture productivity. Amongst other data, MSG, GOES, MODIS and SPOT-VGT products are used to estimate evapotranspiration and hydric balance and continuously generate maps for near real time monitoring of (irrigated) crops.

2.4 Water cycle, early warning systems and water basin management (García et al., submitted; Vila, 2010)

The spatial and temporal distribution of precipitation at regional scale is needed for a variety of scientific uses, such as climate diagnostic studies, and societal applications such as water management for agriculture and power, drought relief, flood control, and flood forecasting. The goal of this application is to deal with a very common aspect of hydrological monitoring in developing countries: the low density of rain gauge networks and the need of basin management for drought relief and flood control. In fact, the task of quantifying the distribution is complicated by the fact that no single, currently available estimate of precipitation has the necessary coverage and accuracy. The application is based on two aspects: (a) the development of a blended product based on a hydroestimator algorithm and daily rain gauge values using the Combined Scheme (CoSch) technique and (b) the calculation of daily areal average rainfall at catchment level for basin management. This blended technique is currently applied over the Río de la Plata basin using TRMM Multisatellite Precipitation Analysis. Water availability is crucial for vegetation growth, especially in dry areas. The linkage between water availability and vegetation growth is often investigated using time series of rainfall data and a vegetation index from satellite sensors (e.g. NDVI). However, recent studies concluded that rainfall alone is not sufficient to describe the available water for vegetation, and that other bio-geophysical factors need to be taken into account. The vegetation response to climatic variability is analyzed at water basin scale with focus on the optimal combination of bio-geophysical parameters. Hydrological response unites are delineated in the distributed hydrological model J2000, such that a complete water balance could be computed, and further analyzed in combination with an NDVI time series from SPOT-VGT. This information helps land management policies in the face of climate change, and can be used to regionalize hydrological parameters through backward modeling.

2.5 Real time monitoring of insect populations (Grilli and Gleiser, 2010)

The development of tools for insect population monitoring is relevant, since insect populations may lead to economic losses or higher risks of disease transmission. Satellite imagery provide continuous information on environmental variables (‘proxies’) over large geographic areas, that may directly or indirectly influence the distribution and abundance of different insect species.

The first example of real time monitoring of insect populations is the monitoring of an agricultural insect vector in Córdoba, Argentina. *Delphacodes kuscheli* (Fennah) is the economically most important delphacid (plant hopper) species in Argentina because of its ability to transmit what was initially thought to be a local strain of the Maize Rough Dwarf Virus (MRDV–RC) named Río Cuarto Disease (March et al., 1995). The insect does not reproduce on maize, but can transmit the virus when feeding on maize plants. If the infection occurs during the first 3 weeks after plant emergence, the disease can be severe and, in some cases, lead to plant death. *D. kuscheli* has a limited range of hosts, and can breed on winter crops such as rye, wheat or oats. The latter are the most important overwintering hosts as they are sown by the end of the summer and not harvested until spring, becoming the main source from which *D. kuscheli* migrates to maize fields. The species has a wide distribution and historically the only effective way for diseases management was avoiding the maximum abundance of dispersing *D. kuscheli* individuals in the field during the first three weeks after maize plants emergence. Previous results (Grilli and Gorla, 1997) showed that in the endemic area, the NDVI derived from NOAA-AVHRR satellite images is a good indicator of the evolution of host patches, and indirectly it can be use to predict the abundance of dispersing *D. kuscheli* almost 40 days ahead, through to November each year (predicting what is going to occur until January). The distribution and abundance of dispersing D. kuscheli in a region depends on factors related to the presence and configuration of host patches (Grilli, 2008). The automatic computation of temporal changes for different satellite derived parameters is a useful tool not only to monitor mosquito populations, but also other animal species (mostly pest species) whose abundance fluctuations are highly dependent on environmental conditions.

Secondly, the real time monitoring of mosquitoes (disease vectors and nuisance pests) is done through the generation of dynamic maps of the relative abundance of floodwater mosquitoes in urban and rural/natural environments of the Córdoba Province, Argentina. Mosquitoes are insects of medical, veterinary and economic concern due to their role as vectors of diseases to human and other vertebrate animals (such as Yellow fever, Dengue and Malaria). All mosquitoes require stagnant/standing water to complete their life cycle. Species such as *Culex quinquefasciatus* and *Anopheles* lay their eggs directly on the water. Floodwater mosquitoes such as *Aedes albifasciatus* lay drought resistant eggs on the ground that hatch when covered by water for 24-48 h. Thus, fluctuations of the flooding levels triggers hatching. Larval abundance of *Ae. albifasciatus* can be estimated as a function of rainfall, mean temperature and time since the last rain, which combined are referred to as ‘water index’. Adult abundance at any time is related to the larval abundance 7± 15 days earlier, showing pronounced seasonal peaks that are higher in areas prone to flooding, such as wetlands, probably because they offer a higher availability of breeding sites for this mosquito (Gleiser et al., 2002). A study in the Mar Chiquita area (Córdoba, central Argentina) showed that changes in NOAA-AVHRR NDVI are positively related to changes in the water index, and more interestingly, to larval density and to adult abundance a week in advance (Gleiser et al., 1997). A linear discriminant analysis, using data on NDVI, rainfall and temperature, accurately identified periods with and without pre-adults. Currently, the network of ground meteorological station is scarce, thus satellite derived estimations of rainfall and land surface temperatures are enticing proxies of meteorological variables that may improve prediction models of mosquito abundance. Besides meteorological conditions, larval habitat availability, access to suitable hosts, and refuge for adults influence mosquito abundance and distribution. Observations in Mar Chiquita showed a significant relationship between the abundance of *Oc. albifasciatus* and land cover characteristics (Gleiser et al., 2002). The first component of an principal components analysis of an NDVI time series was significant in the discriminant function between two mosquito abundance categories (above and below an economic threshold), as well as components of land surface temperature and water vapor, suggesting that besides changes in the phenotype of the vegetation, the temporal variation at a regional scale in temperature and humidity may be of particular relevance in terms of mosquito production (Gleiser and Gorla, 2007).

3. Agricultural monitoring

3.1 Crop growth and yield monitoring in Brazil and Argentina (de la Casa and Ovando, 2010; Rocha, 2010; Souza, 2010)

The real time monitoring of agricultural crops throughout the growing season may provide information to make predictions of crop performance before harvest time, important for decision making at various levels and for logistic and commercial activities (Rizzi and Rudorff, 2004). Conventional methods to establish statistics of agricultural production are based on field surveys to determine the area planted/harvested, yield and production: time and labour consuming methods that do not generate results as quickly as required by the markets (Rosenthal et al., 1998). Remote sensing provides extensive spatial information about the actual status of crops and has been widely used to support the parameterization of crop models (Guérif and Duke, 2000). The advantages of remote sensing for monitoring vegetation and assess the impact of drought on crop yield have been widely studied in recent years. In a first stage, the rate of normalized difference vegetation (NDVI) was used directly to indicate the status and vigor of vegetation (Hatfield et al., 2008). Funk and Budde (2009) present a detailed breakdown of the studies on the NDVI and crop yield, and sustain the desirability of tuning the relationship between drought and productivity on the basis of phenological data (De la Casa, 2010). Zhang et al. (2005) used the MODIS LAI and NDVI products as basis for an index of the impact of climate variability. According to the energy balance, the surface temperature should represent drought conditions in advance to the response of the plant. Moran et al. (1994) proposed the trapezoid method, which combines the vegetation index with surface temperature, for the purpose of applying the theory of the rate of crop water stress (CWSI) on surfaces partially covered by vegetation. Based on this method they developed the water deficit index (WDI) to assess the evapotranspiration rate, in places completely covered by vegetation and with partial coverage. Ghulam et al. (2008) evaluated water stress condition on wheat data from near infrared (NIR) and medium (SWIR) reflectance. Investigated the effect of drought on fuel moisture content (FMC) and developed a water stress index of vegetation (VWSI). The continuous flow of environmental data (NOAA-AVHRR, SPOT-

VGT and MODIS derived products) through GEONETCast/EUMETCast provides a huge opportunity to assess the evolution of crops during the season and to estimate crop yields at regional level and in near real time.

3.2 Crop and food supply assessment, an example from Sudan (Royer et al., 2009)

An example of how the environmental data transmitted via DevCoCast can be used to monitor agricultural production, VITO developed and tested a methodology over Southern Sudan to support the Crop and Food Supply Assessment Mission (CFSAM) experts in their analysis. Each year the UN-FAO and UN-WFP receive the request from African governments to perform a CFSAM. These missions are performed by a team of international and national experts making an assessment of the agricultural and food supply situation in a specific country resulting in a report that supports the national government(s) in their decisions influencing the agriculture in the country. The CFSAM support kit (Royer et al., 2009) consists of both a qualitative analysis and quantitative yield estimates, with a synoptic overview of the different products based upon time series graphics and maps. Although this specific example shows how the analysis is done in an African region prone to food supply problems, the methods presented can be used for crop assessment in other regions of the world, for example soy bean or maize production assessment in Brazil or Argentina. The qualitative analysis was mainly focused on the detection of anomalies (vegetation stress, excess or lack of water, …), based on 3 sources of information distributed through GEONETCast: vegetation indicators (NDVI) from SPOT-VGT, water body detection from SPOT-VGT (source: "Small Water Body Product, Developed by the Joint Research Centre, produced by VITO, with contribution from the Geoland 1 and 2, and VGT4Africa projects (FP6 and FP7)), phenology detection from SPOT-VGT (source: "Phenology Product, Developed by the Joint Research Centre, produced by VITO, with contribution from the Geoland 1 and 2, and VGT4Africa projects (FP6 and FP7)); and rainfall estimates from MSG (source: FEWS NET).

4. Conclusions

Within the DevCoCast project, the GEONETCast receiving capability in Latin America is further expanded by supporting the installation of additional receivers in South America, and by the production and dissemination of several, relevant environmental products. A lot of effort goes towards building the human capacity, by further supporting the actual use of the provided data through several training workshops, outreach and distance education training material, developments of free tools and a central help desk. Partners are invited to integrate the received data into their applications and share their experiences through local capacity building and networking. Therefore, the ambitions of the DevCoCast project are: to further expand the user community, to strengthen GEONETCast and the involvement of Developing Countries, and to have relevant, environmental information, broadcasted through GEONETCast, embedded in a systematic manner into reporting systems in support of research, planning and decision making processes. This paper presents a wide variety of examples of integration of operationally received DevCoCast and other GEONETCast data into decision making processes in Latin America. This effort will enable authorities in Developing Countries in fulfilling their increasing monitoring and reporting obligations and help them to better manage their natural resources through their sustainable development policies.

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