VENµS: A Joint French Israeli Earth Observation Scientific Mission with High Spatial and Temporal Resolution Capabilities

G. Dedieu[1], A. Karnieli[2], O. Hagolle[3], H. Jeanjean[3], F. Cabot[3], P. Ferrier[3] and Y. Yaniv[4]

1 CESBIO, Unité mixte CNES-CNRS-IRD-UPS, 18, avenue Edouard Belin,
31401 Toulouse Cedex 4, France gerard.dedieu@cesbio.cnes.fr
2 The Remote Sensing Laboratory, Jacob Blaustein Inst. for Desert Research
Ben Gurion Univ. of the Negev, Sede Boker Campus 84990, Israel
3 CNES, 18 avenue Edouard Belin, 31401 TOULOUSE Cedex 4.
4 MBT Space Division, Israel Aircraft Industries Ltd., P.O.Box 105, Yehud Israel, 56000

ABSTRACT – A *recent initiative of the Israeli Space Agency (ISA) and the French space agency (CNES) is aimed at developing, manufacturing, and operating a new Earth observing satellite called `Vegetation and Environment monitoring on a New Micro-Satellite' (VENµS). The satellite is planned to be launched in early 2009, and the scientific mission should last at least two years.*

The general mission objectives are the provision of data for scientific studies dealing with the monitoring, analysis, and modelling of land surface functioning under the influences of environmental factors as well as human activities. The mission will acquire frequent, high resolution, multi-spectral images of sites of interest all around the world. The satellite will fly in a near polar sun-synchronous orbit at 720 km height. The whole system will be able to be tilted up to 30 degree along and across track. This configuration will result in a 2-days revisit time, 27 km swath, a camera resolution of 5.3 m, and the capability to observe any site under a constant view angle. The system will cross the equator at around 10:30 AM. The satellite will carry a super-spectral camera characterized by 12 narrow spectral bands ranging from 420 nm to 910 nm.

The baseline product is time composite images of geometrically registered surface reflectances at 10 m resolution. Strong efforts are devoted to provide high quality data, both in term of radiometry (e.g. SNR around 100), geometry (e.g. multitemporal registration better than 3 m), and atmospheric corrections.

1 INTRODUCTION

Venμs is a scientific Earth Observation (EO) mission which will provide 10 m resolution images in 12 shortwave spectral bands every two days over a set of scientific sites. This article presents the objectives of the mission, its main characteristics and products and the accompanying scientific program.

The roots of Venμs objectives lie in the general concerns for environment monitoring and sustainable development. Monitoring, predicting and possibly mitigating the impacts of global changes while managing the natural resources in a sustainable way are major issues for our societies. These issues raise a number of scientific and policy making issues which all require accurate, consistent, and long-lived observations of processes and of changes.

For land surfaces, EO satellites should provide measurements from which key information on the dynamics of land cover, land use and vegetation functioning can be derived at the various required temporal and spatial scales. Because of the dynamics of vegetation growth and of the short duration of phenological stages such as flowering, the availability of cloudfree data every five to ten days is highly desirable. A spatial resolution of less than 20 m is required to capture land surface heterogeneity and to observe rather homogenous targets, such as crop fields.

Coarse resolution land cover maps and indices of vegetation cycles can be retrieved globally from the data acquired by large field of view and high repetitivity sensors such as AVHRR, VEGETATION, MODIS or MERIS. This information proved useful for continental and global scale studies, such as global carbon cycle research and climate modeling. However, the rather coarse spatial resolutions of the data do not allow in most case to capture and to account for the heterogeneity of the land surface. This strongly limits their use, especially for regional scale applications such as detailed land cover mapping and land cover change monitoring, agri-environment policies, water management, vegetation primary productivity and yield estimates. All these applications are crucial for defining global change mitigation or adaptation policies.

On the opposite side in term of spatial resolutions, land observation resolution started with the 80m of Landsat-MSS in 1972, the 20 m of SPOT in 1986, and progressively decreases to about or less than 1m with Ikonos, Quickbird, Orbview or Pleiades. But in the same time, the technical constraints lead to a decrease of the swath from about 180 km to about 10 km.

Consequently, none of the existing Earth observation satellites is able to provide the data with the time and space resolutions as well as with the systematic large spatial coverage which are required to monitor and model the land surface at landscape and regional scales. Regarding the planned mission, only the European Sentinel-2[1] project will offer a systematic coverage at about 10m resolution which partly fits these needs, but with a too limited revisit period to sample vegetation cycles and fully exploit the time dimension of the signals.

Considering the current dilemma between time sampling versus spatial resolution, the primary objective of the Venµs mission is therefore to demonstrate that useful, cloudless, data obtained every 10 days with a spatial resolution of about 10 m will allow the development of new, innovative and useful utilization of EO measurements, for both science and applications.

[1]http://esamultimedia.esa.int/docs/GMES/MRD_Sentinel_2.pdf

2 THE VENµS MISSION

The Venµs program is jointly developed, manufactured and operated by CNES, the French space agency, and the Israel Space Agency (ISA). It consists of two missions:

- a Scientific Mission which goal is to operate a super spectral camera for land environment monitoring.

- a Technological Mission that aims at qualifying an Israeli electric propulsion technology (IHET) and to demonstrate its mission enhancement capabilities.

The satellite is planned to be launched in 2009, and the scientific mission should last at least 2.5 years.

Venµs unique features will be to acquire high resolution, multi-spectral images every two days with constant view angles over about 50 sites of interest all around the world. The satellite will fly in a near polar sun-synchronous orbit at 720 km height, leading to a 2-day orbital repeat cycle. Every two day, the satellite will be at the same place, at the same hour. The equator will be crossed by the satellite at around 10:30 AM local time.

The whole satellite may to be tilted up to 30 degree along and across track. Figure 1 shows the 29 nine orbits of Venµs 2 day repeat cycle, and the accessible zones. Within the accessible zones, the system will have the capability to observe each selected site under a constant view angle every second day.

The Venµs super-spectral camera will provide a ground resolution of 5.3 m over a 27 km swath, for 12 narrow spectral bands (see Table 1) from 420 to 910 nm. Most of the bands (565, 620, 670, 702, 742, 782, and 865 nm) are designed to characterise different parts of the chlorophyll spectrum: absorption features, red edge. Some bands are dedicated to atmospheric corrections: 910 nm (water vapour absorption), 420, 443, 490, and 620 nm (aerosol characterisation), some bands may be used for water colour studies in coastal or lake environments. Lastly, the 620 nm band has been duplicated with a slight observation angle difference (1.5°). This enables to determine the altitude of the pixels, with a sufficient accuracy to enable cloud detection.

Venµs will deliver high quality images with a signal to noise ratio at minimum radiance above 80 for 10 m resolution. The multispectral (resp. multitemporal) registration of Venµs images is specified to be better than 2 m (resp. 3m). Venµs has no on board calibration device, but nevertheless, its absolute calibration will be accurately monitored using desert sites (Hagolle et al 1999, Cabot et al 2000), a calibration site at La Crau (France), equipped for a daily characterisation of surface and atmospheric reflectance, and regular observations of the moon for multi-temporal monitoring of Venμs calibration.

bands	λ_0 *(μm)*	*Δλ (nm)*
B1	0.420	40
B2	0.443	40
B3	0.490	40
B4	0.555	40
B5	0.620	40
B6	0.620	40
B7	0.667	30
B8	0.702	16
B9	0.742	16
B10	0.782	16
B11	0.865	40
B12	0.910	20

Table 1: The central wavelengths, λ_0, and the widths, $\Delta\lambda$, of the 12 spectral bands of the Venμs camera.

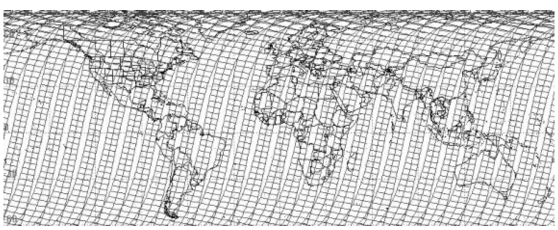

Figure 1: the 29 nine orbits of Venμs in 2 days and the accessible zones for ±30° across track tilt.

3 VENμS PRODUCTS

3.1 Level 1

The main feature of Venμs products is the high frequency of the observations which is also the main driver of Venμs product definition. Since the Venμs mission objectives emphasize the potential of data time series, the basic level 1 products must be geometrically registered and radiometrically calibrated. As a result, the Venμs level 1 products will be equivalent to SPOT level 3 products for geometry and superior for radiometry.

The Venμs level 1 will thus provide:

· geolocated top of atmosphere reflectances with a subpixel (requirement 3m) multi-date registration.

· a cloud mask at a coarse resolution

3.2 Level 2

For the level 2 products definition, we have to take account of the fact that Venμs data set is made of 50 different local data sets on 50 sites located around the world, and that there is no global data set. For this reasons, it does not seem relevant to develop complex inversion algorithms for bio-physical variables. This inversion would be a global algorithm that would not be optimized locally for the Venμs 50 sites with different vegetation characteristics and different applications.

We have thus decided to limit the level 2 processing to what will be common to most applications: cloud screening and atmospheric corrections.

The Venμs level 2 products will provide surface reflectances after cloud masking and atmospheric correction for all spectral bands. The algorithms used for level 2 processing take advantage of the 2 day revisit period with constant observation angles: most short term variations of TOA reflectance are due to atmosphere variations. For more information, see Hagolle et al, 2006.

3.3 Level 3

The aim of level 3 products is to reduce the data volume for users and to deliver a synthesis product that provides as far as possible cloud free data based on the cloud free pixels of the level 2 data gathered during a short period (7 to 10 days).

The Venμs level 3 will be a composite product of the same variables than Level 2, maximising the number of cloud free pixels.

3.4 Example

Formosat-2[2], a satellite owned by Taiwan National Space Organisation (NSPO), provides images with features close to Venμs'. The resolution of Formosat-2 multispectral images is 8m, for a field of view of 24 km. It provides images in 4 spectral bands, centred at 488, 555, 650 and 830 nm. Thanks to its orbital cycle of one

[2]http://www.nspo.org.tw/2005e/imagesell/SATproperty.htm

day, it is able to acquire data over a given site every day, with constant observation angles.

Formosat-2 was launched in May 2004. Its images can thus be used to simulate Venµs images. We have been able to obtain two data sets over two sites. These sites have been acquired every third day during 7 to 12 months. One of the sites is situated at an irrigated agricultural site in Morocco, the other one is an agricultural region, near Toulouse (France), with a mixture of winter and summer crops.

Figure 2 shows the time variations of surface reflectances for all Formosat-2 channels, before (top) and after (bottom) atmospheric corrections, for a fallow land pixel in Morocco. The smoothness of the reflectances is a good indicator of the quality of time series. It may be compared to a similar time series acquired with SPOT satellites over a wheat parcel in Romania (Figure 3), after atmospheric corrections. Spot observations are not obtained with constant observation angles, and variations of viewing angles (+/- 27 degrees) introduce sudden variations in reflectances. Moreover, reflectance variations prevent from detecting accurately thin clouds or cloud shadows that further degrade the time series.

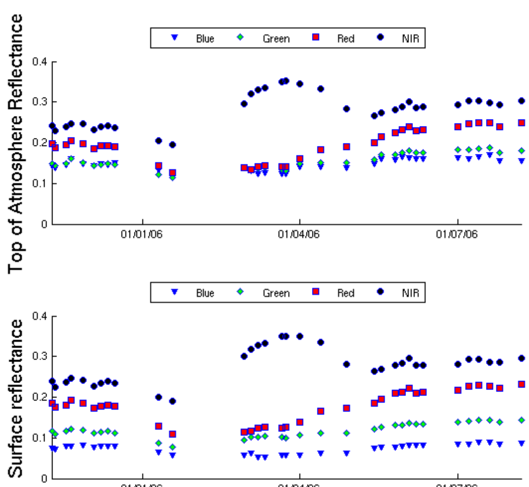

Figure 2: Top of atmosphere (top) and surface reflectances (bottom), from Formosat2 images, for a fallow pixel.). Data are acquired with constant viewing angles.

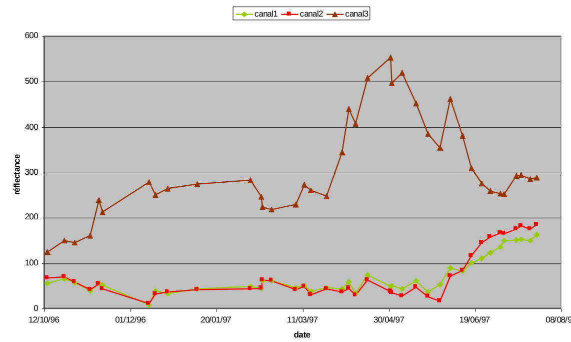

*Figure 3: Surface reflectances (*1000) from a SPOT time series in Romania (Wheat pixel), data are acquired with varying viewing angles. Top plot is near infra-red band, the two other plots correspond to green and red bands.*

4. THE SCIENTIFIC PROGRAMME

In order to select the scientific sites which will be observed by Venµs, an international call for proposals was released in May 2006[3]. The scientific merit of the proposals is now being evaluated, taking also into account technological constraints. The selected teams will receive within one month after acquisition the data they requested over one or several sites, free of charge. In most case, the products will be provided for the whole mission duration. Levels 2 and 3 and possibly Level 1 products will be available three months after the acquisitions to any scientist who does not belong to a selected team.

Several re-processing of the full set of data are planned and taken into account in the design of the ground segment. Venµs mission will provide a new kind of data and requirements on the quality of the products are high. The algorithms currently designed on the basis of the SPOT and Formosat-2 existing data will have to be checked in a variety of conditions and we expect that some upgrades of the initial algorithms will be necessary.

5. CONCLUSIONS

Only the commercial Formosat-2 satellite currently offers some of the characteristics the Venµs mission will offer.

Venµs will be the first scientific mission to simultaneously provide high spatial resolution data in 12

[3] http://smsc.cnes.fr/VENUS/

spectral bands every two days with constant viewing angles and slowly varying solar angles. In addition, Venµs acquisitions will be totally devoted to the scientific sites which will be selected. When required, continuous observations will be performed all along the scientific mission duration.

It is expected that Venµs will contribute to the advancement of land sciences and to the test of new user oriented services based on EO data. Venµs will also help to define future operational mission designed to monitor land surface with the required temporal and spatial resolutions.

6. REFERENCES

Cabot F., Hagolle, O, Henry, P., Relative and multitemporal calibration of AVHRR, SeaWiFS, and VEGETATION using POLDER characterization of desert sites, in: Geoscience and Remote Sensing Symposium, 2000. Proceedings. IGARSS 2000, pp 2188-2190 vol.5

Hagolle O., P. Goloub, P.-Y. Deschamps, H. Cosnefroy, X. Briottet, T. Bailleul, J.-M. Nicolas, F. Parol, B. Lafrance, and M. Herman. 1999. Results of POLDER in-flight calibration. *IEEE Transactions on Geoscience and Remote Sensing*, 37:1550-1566.

Hagolle O., H. Tromp, G. Dedieu, B. Mougenot, V. Simonneaux, B. Duchemin, I. Benhadj: Atmospheric correction of multi-temporal mono-directional images :VENµS level 2 algorithms applied to Formosat-2 images, RAQRS II conference (this conference)

7 ACKNOWLEDGEMENTS

The authors would like to thank Spot-Image and the NSPO for their help and collaboration regarding the programming of Formosat-2 and the delivery of the images.