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From the Editor...

by Tyler Mitchell

Welcome to the first edition of the OSGeo Journal for 2010! As a good kick-off to the new year this volume takes a few different perspectives on software development and design. Naturally the various issues related to typical development projects applies quite well to our open source geospatial specific interests. The articles cover a range of topics from a review of various software to a discussion of user-centered design. Along the way you'll also get to read some more technically meaty articles and some perspective pieces.

Each volume of the Journal takes several months of concerted effort by many individuals. Landon Blake played a lead editorial role in getting this volume pulled together so you can read it - thank you Landon! It's always a pleasure to have more section editors, LaTeX masters and reviewers come to help. Thank you to all the volunteers.

With our new online management system, any potential article can be submitted at anytime by simply filling in a form at http://osgeo.org/ojs. As well, over the next couple of months keep one eye open for the OSGeo 2009 Annual Report. Get your articles in soon if you have not already. Enjoy the articles!

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Project Introductions

GRASS Image Processing Environment

Application to Evapotranspiration Direct Readout

Yann Chemin, Thomas Alexandridis and Ines Cherif

Abstract

Satellite imagery provides a large amount of useful information. To extract this information takes understanding, processing and time. In GRASS GIS, a given professional of image processing can develop his/her own modules for processing satellite imagery. The aim of this paper is to communicate the main lines of the development of an automated Landsat 7ETM+ chain processing using modules of the GRASS Image Processing Environmment (GIPE). Specifically called Direct Readout [1], the target is real-time processing of Level 1B standard imagery (Digital Number) into evapotranspiration products (considered level 4 in MODIS).

Introduction

Satellite imagery is spatial information, it has spatial dimensions, but also radiometric, spectral and temporal resolutions. There is a large amount of data in this raw material already, but this needs quantification for supporting decision. Processing of satellite imagery is the science of bringing measurements, units to the satellite image pixel. These measurements are commonly found in terms of indices (vegetation indices especially), some more physically-based information can be derived and units are then starting to appear, reflected radiations in Watt per square meter (W/m2) are the first to be generated from the raw data received. Some more complex calculations, some would say modelling, can actually bring more tangible information for decision-makers. In this paper, we will deal with water evapotranspired, in terms of mm/day. This kind of information is critical in watershed analysis, water balance, and crop production[2][3].

Evapotranspiration monitoring is on a high priority on several decision-making entities agendas. Among those entities are various water resources management-related agencies, publicly or privately run. Of course, irrigated crop and environmental managers have dire interest in accurate, spatially discreet, standardized and temporally available water balance inputs. Also, natural resources managers use evapotranspiration for assessing agricultural water pressures and desertification risk[4][5]. For about 30 years, the steady rise of methods/models in satellite remote sensing has increasingly permitted easier and/or more precise calculations of ET from satellite imagery. As of the 1990s, thermo-dynamically-based energy balance models have been given some encouraging results, some reviews can be found in [6], [7], [8] and [9].

This paper is presenting the application of a *suite* of various GRASS GIS modules for the image processing requirements of evapotranspiration mapping. The *suite* was dubbed GRASS Image Processing Environment (GIPE), as it was created with the aim of fulfilling any step of the processing requirements independently of each other, if it is so desired by any future user for any other future processing needs. This explains the number and diversity of the modules developed within this GIPE.

Objectives

The main objectives are:

- Overview the GIPE
- Introduce the Landsat 7 ET script generator
- Produce some output of ET

Overview of the GIPE

The need of creating a set of modules in GRASS GIS to perform the regular satellite image processing tasks is required for any production or research work. The Grass Image Processing Environment tries to provide such tools at the atomistic and factory levels. Respectively, there should be a module for each step of any of the satellite imagery processing, but for some repetitive tasks when scripting can become too heavy, one module should provide the direct high-level output expected without losing too much on parameterization.

The functions developed were essentially in a few categories, pre-processing and products calculations. Respectively, preparation of raw satellite imagery into usable geodata (mostly radiometric correction) and preparation of given products like NDVI, Albedo, and higher-level ones like ET or soil moisture. In Figure. 1, a list of various developed modules is shortly described.

Module	Description
i.albedo	Albedo (0.3-3micro.m)
i.biomass	Biomass growth (kg/day)
i.dn2full.l5/7	Landsat5/7 DN to Reflectance/Temperature
i.dn2potrad.l5/7	ET: Landsat5/7 DN to ET potential
i.dn2ref.ast	Aster DN to Reflectance
i.dn2ref.l7	Landsat7 DN to Reflectance (visible only)
i.emissivity	Generic emissivity for the thermal bands
i.evapo.MH	ET: Reference ET Hargreaves (2 types)
i.evapo.potrad	ET: Potential ET (radiative method)
i.evapo.PT	ET: Potential ET Priestley-Taylor
i.evapo.SENAY	ET: Actual ET Senay (2007)
i.latitude	Latitude map generation
i.longitude	Longitude map generation
i.sattime	Satellite overpass time map generation
i.sunhours	Sunshine hours (potential)
i.vi	Vegetation Indices (13 types)

Figure 1: GIPE modules listing: Various

Modules	Description
i.eb.deltat	Surface-air temperature difference
i.eb.disp	Displacement height
i.eb.eta	Actual ET
i.eb.evapfr	Evaporative Fraction
i.eb.g0	Soil Heat Flux
i.eb.h0	Sensible Heat Flux
i.eb.h_iter	Sensible Heat Flux Pawan04 model
i.eb.h_SEBAL95	Sensible Heat Flux SEBAL95 model
i.eb.molength	Monin-Obukov Length
i.eb.netrad	Net Radiation
i.eb.psi	Psichrometric factors
i.eb.rah	Aerodynamic resist. to heat flux
i.eb.rohair	Atmos. Air Density
i.eb.ublend	Wind speed@blending height
i.eb.ustar	Nominal Wind Speed
i.eb.z0m	Roughness length

Figure 2: GIPE modules listing: Energy Balance

Mostly Figure. 1 refers to known processing of satellite imagery. the module *i.vi* is also (but not in this table) available in parallel (*i.vi.mpi*) and in grid (*i.vi.grid*) developed for educational purpose in [10]. Additionally, it can be noticed in Figure. 1, there are many ET map generation modules. Three main groups of ET maps are available here. The first one is called the *Reference ET*, calibrated after a 20 cm reference height grass without water stress. The second one is the *Potential ET*, using all energy available in evapotranspiration, considering unlimited availability of water. At this point it is important to note that the GRASS HydroFOSS Add-on [11] is also having an ET module following the *Potential ET* methodology from Penman and Monteith (*h.evapo.PM*) that GIPE also installs by default. Finally, *Actual ET* is a more complex assessment of the environmental water stress to provide information on water that *actually* vaporized from water bodies and soil or transpired from vegetation.

Figure. 2 provides with specific energy balance modules created for the purpose of calculating actual evapotranspiration using mainly equations from [12] and [13]. Those are in fact two versions of the Surface Energy Balance Algorithm for Land (SEBAL) as named by [13].

Processing ET

Processing a satellite image for evapotranspiration is overviewed in Fig. 3

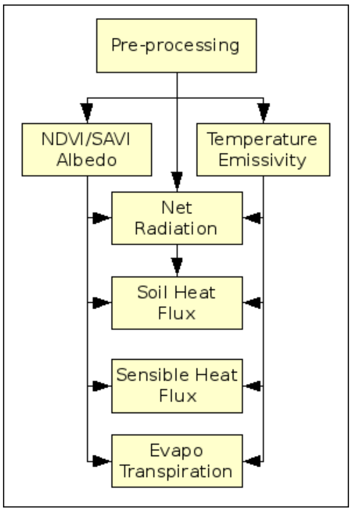

Figure 3: ET Processing Overview

Script generator: Landsat 7ETM+

The Landsat 7ETM+ script generator is a small program included in GIPE that creates a full processing of various ET maps by auto-configuring all the steps from importing/calibrating landsat bands up to the final products. Below is a small sample of the script after generation. It loads the .met metadata file, reads parameters from it, and then fills up the GIPE modules pertaining to the pre-processing and higher level processing of the data.

Ungzip all Landsat bands, import/create new location, set region to temperature map. *DN to Radiance to Reflectance Top of Atmosphere:*

```
i.dn2full.l7 metfile=pXXrXX.met
output=pr
```

[skipping...Albedo, Pre-ET Potential, Download-/Import SRTM, Slope/Aspect...]
Potential ET:

```
i.evapo.potrad -r albedo=pr.albedo tempk=pr.61 \
 lat=pr.latitude doy=pr.doy tsw=pr.tsw etpot=pr.etpot
rnetd=pr.rnetd
```

NDVI, SAVI:

```
i.vi viname=ndvi red=pr.3 nir=pr.4
vi=pr.ndvi
```

[skipping...Pre-ET stuff, Net radiation,...]
Soil heat flux:

```
i.eb.g0 albedo=pr.albedo ndvi=pr.ndvi tempk=pr.61 \
 rnet=pr.rnet time=pr.sath g0=pr.g0
```

[skipping...Displacement height, Atmospheric air density,..]
Sensible heat flux [12]:

```
   i.eb.h_iter rohair=pr.rohair cp=1004.16 dtair=pr.delta
tempk=pr.61 disp=pr.disp z0m=pr.z0m z0h=pr.z0h  u2m=u2
h0=pr.h0
```

Soil Moisture:

```
i.eb.evapfr -m rnet=pr.rnet g0=pr.g0 h0=pr.h0 \
 evapfr=pr.evapfr theta=pr.theta
```

Actual ET:

```
i.eb.eta rnetday=pr.rnetd evapfr=pr.evapfr \
 tempk=pr.61 eta=pr.eta
```

Experimental Results

The study area is in the area of Strimonas river basin in Greece [14]. Strimonas river basin is a transboundary river basin situated in north Greece (Serres). A large reservoir (Lake Kerkini) had been constructed in the 1930's to store and regulate water in the Greek part, and has now become a wetland of International Importance by the Ramsar Convention, and is included in the Natura 2000 network. An extensive irrigation system taps water from the reservoir and river diversion dams, and distributes water using open canals. Local groundwater pumping stations provide supplementary water to account for the inefficient operation of the irrigation system. Irrigated area exceeds 100,000 ha, dominated by rice, maize and cotton.

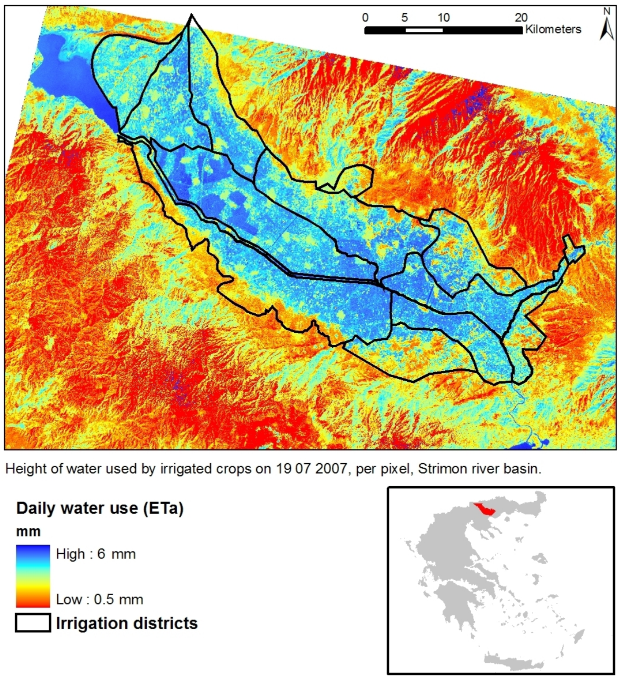

Figure 4: ETa map of Strimonas Basin after SEBAL95

Actual ET

A first SEBAL processing by [13] yielded to an evapotranspiration map (v1995, using i.eb.h_SEBAL95 to estimate sensible heat flux) in Fig.4, similarly, another map was created following SEBAL version as seen in [12] (using i.eb.h_iter instead). The determination of the sensible heat flux by iteration being the specificity of this model, the main module used has been cited above. Another module (i.eb.h0) is an atomic equation that does not perform anything else than h0 calculation. Using shell scripting and i.eb.h0 and other i.eb.*, one can reconstruct complex models like i.eb.h_SEBAL95 or i.eb.h_iter or any other at their will.

A different location, southwest Southwestern of Strimonas study area, is also used to demonstrate the comparison capacity of having several models targeting the same processing into a single processing GRASS environment. A disparity map (in Fig.5) was made as [ETa_v1995 - ETa_v2004] in mm/day of difference across the two versions. One can see that if the map is positive, then the ETa_v1995 version is overestimating and if negative, ETa_v1995 is underestimating.

Additionally, a histogram (in Fig.6) of the disparity map shows the amount and value of the disparity in terms of pixel count and ETa difference (mm/-day). The equation is disparity_eta=[eta_SEBAL95 - eta_Pawan04], which incidentally has a lot to do with the way both estimate h0 parameter through (i.eb.h_SEBAL95 or i.eb.h_iter).

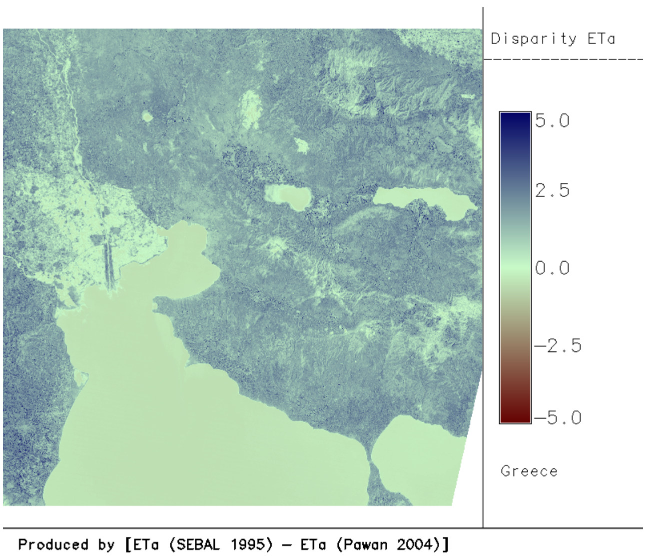

Figure 5: ETa disparity map

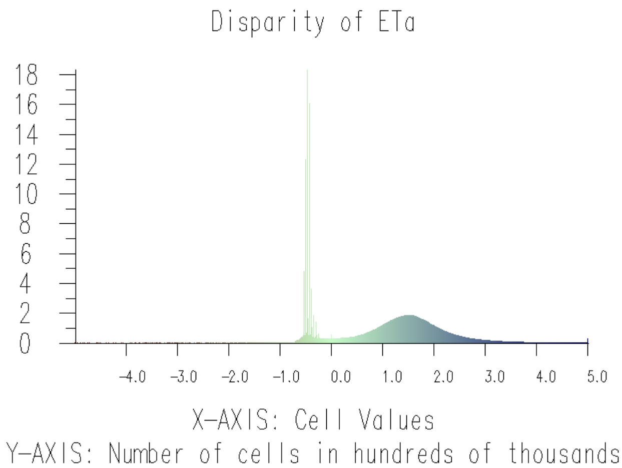

Figure 6: ET disparity histogram (v1995-v2004)

One can witness in Fig.6 that both methods being from the same origin, yet the newer implementation by [12] (esp. i.eb.h_iter) differs from the original [13] (see i.eb.h_SEBAL95). The high peak on the negative side near 0.0mm/d difference is the water pixels estimations, which are quite concurrent. However the smooth distribution on the positive side indicates that SEBAL from Bastiaanssen in 1995 has higher land-based estimations than the version of Pawan in 2004. This is certainly due to the re-assessment of the [TsoilTair] and aerodynamic roughness of momentum heat (rah) during the iterations of i.eb.h_SEBAL95, which do not occur in i.eb.h_iter [12].

Conclusion

The GRASS Image Processing Environment (GIPE) is a set of Add-Ons for GRASS GIS to process various satellite imagery into higher-level products. Landsat example above is but one of regular satellite imagery that can be (pre)processed in GIPE. Currently, specific satellite pre-processing found in GIPE includes the following sensors: ASTER, MODIS, AVHRR, Landsat 5/7. Higher-level processing is sensor independent, as long as spectral or temporal requirements are met. Finally, there are additional modules not listed here, mostly because of unfinished state to the day of this reporting.

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