An Open Source Implementation of the DisALEXI ET Data Fusion Suite

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Abstract

Thermal remote sensing can be an effective tool for mapping evapotranspiration (ET) using the physical connection that exists between land surface temperature (LST) and evaporative cooling and the concepts of the Two-Source Energy Balance (TSEB) approach. The information needed to map high spatial resolution ET at higher frequency cannot be achieved by one satellite system alone. High frequency geostationary satellites generally have low spatial resolution (>1 km, 15 min) while moderate/high spatial resolution polar orbiting thermal imaging systems have infrequent repeat times (1km/30m, daily/16 day). The Atmosphere Land Exchange Inverse (ALEXI) model and associated disaggregation technique (DisALEXI) multi-scale ET and energy balance mapping system exploits this range in thermal imaging capacity. Combined, they enable a data fusion approach that optimizes the characteristics of both systems to provide high spatial and temporal resolution ET coverage. The ALEXI ET model specifically uses time differential LST measurements from geostationary or moderate resolution polar orbiting platforms to generate regional ET maps, reducing sensitivity to errors in absolution temperature retrieval. The DisALEXI model then disaggregates the regional ALEXI ET to finer scales using MODIS (1km) or VIIRS (375m; both near daily) or Landsat (30 m; biweekly). The DisALEXI modeling suite employs the Data Mining Sharpener (DMS) technique to sharpen Landsat's thermal infrared (TIR) data from its native resolution of 60-120 m to the 30 m resolution of the visible/near infrared bands. The MODIS/VIIRS/Landsat disaggregated ET is then fused to generate daily ET maps at 30m resolution, capable of resolving individual farm fields. To date the DisALEXI data fusion package has relied on proprietary software and is therefore not easily transferable to the ET community and water management stakeholders. The purpose of the presented work is to illustrate a new completely open source implementation of DisALEXI called PyDisALEXI. As the names indicates the new open source platform relies on Python. PyDisALEXI is built on the core python modules of NumPy, Pandas and SciPy as well as other highly specific modules (landsat-util, Pydap, Pytroll etc.,) that build on the core modules. The basic framework of the new platform is presented as well as the implementation and some initial results.

ALEXI/DisALEXI

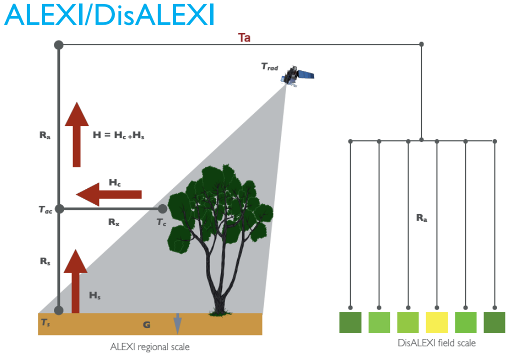


Figure 1. The ALEXI/DisALEXI multiscale flux modeling framework: (left) the ALEXI modeling sytem, using the morning temperature rise from geostationary satellites; (right) DisALEXI flux disaggregation system disaggreates ALEXI to field scale using LST from higher resolution sensors such as Landsat.

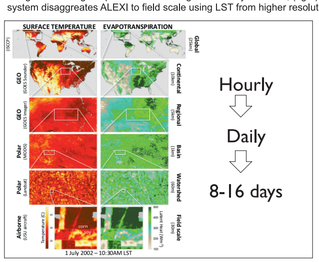
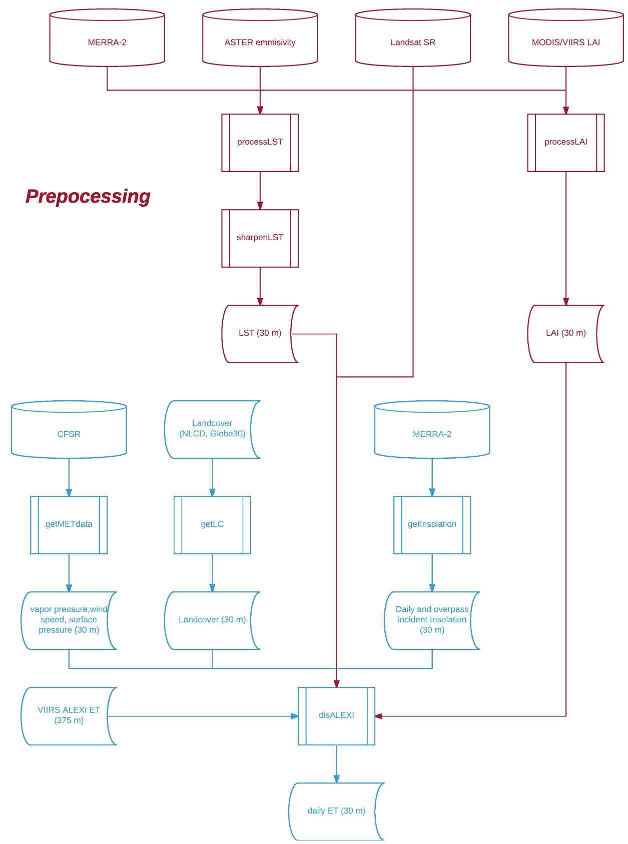


Figure 2. Multi-scale maps of ET produced with ALEXI/DisALEXI using LST data from GOES Sounder (10 km), GOES imager (5 km), MODIS (1 km), Landsat (60 km) and aircraft (30 m).

ALEXI is based on the TSEB (Two-Source Energy Balance) model which partitions fluxes of latent and sensible heat using Land Surface Temperature (LST) as a key indicator of soil moisture content. ALEXI takes advantage of the morning rise in LST to further partition the fluxes, which has been shown to signicantly reduce the sensitivity to errors in LST retrievals. DisALEXI utilizes the information gained in ALEXI through disaggregating the ET fluxes by adjusting the air temperature at the blending layer. DisALEXI then uses the air temperature found in diaggregation along with high resolution biophysical parameters estimated using meaurements from instruments such as Landsat to produce field scale ET estimates.

Pythonic implementation of DisALEXI



PyDisALEXI is composed of 2 components: Preprocessing and DisALEXI. The Preprocessing component implements the Data Mining System (DMS) algorithm which is used to downscale MODIS/VIIRS LAI at coarse resolutions (500/375 m) to fine resolution sensors such as Landsat. DMS is also used sharpen Landsat LST (90 m) as calculated by the pyRTTOV atmospheric corection module to 30 m. The Landsat Surface Reflectance product used is ordered and downloaded using a python of implemention of espa-api provided by the USGS. The computation time of the preprocessing component largely depends on the latency of the Landsat SR order.

The DisALEXI component is a low latency component that ingests the LAI and LST from the prepocessing component and uses Landsat SR to calculate albedo. Metadata information from the Lansdat SR product is used to subset, resample and reproject both the Meteorological data from the Climate Forecast System Reanalysis (CFSR) and the ALEXI ET product. With all inputs prepared the disALEXI component is run in paralell using the joblib python module.

Initial results

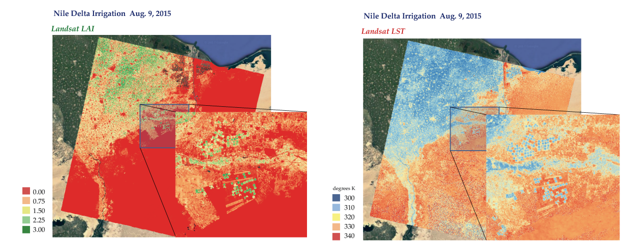


Figure 3. Landsat LAI (left) and LST (right) products over Nile Delta region on Aug. 9, 2015 as estimated from the DMS algorithm.

The ALEXI/DisALEXI modeling suite has been developed over the past decade and a half and has been written in a mixture of open (Fortran, shell and Perl) and proprietory software (IDL) software. PyDisALEXI utilizes purely open source languages (mostly python and C), which allows for easy access to collaborators and stakeholders. The pyDisALEXI program utilizes pyDap to access NASA and NOAA openDAP data service for preprocessing meteorological data as well as pyMODIS to access and process MODIS LAI. These services allow pyDisALEXI to simply access datasets for only the subsets and data layers required. Landsat Surface Reflectance products are ordered and downloaded using the espa-api-client python module. The module will wait for the order to complete and download. The process can be as short as 30 min and as long as 24 hrs.

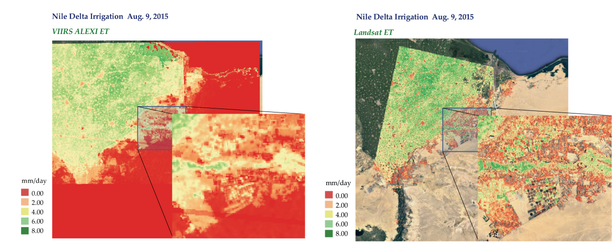


Figure 4. ALEXI/DisALEXI ET estimated over the Nile Delta on Aug. 9, 2015. The left panel illustrates initial results from VIIRS ALEXI ET product. The right panel shows the disaggregated ALEXI ET (left) using Landsat biophysical data.

PyDisALEXI utilizes the Joblib python module to run small subsets of a landsat scene in parallel. This allows for full access to all cores of the computing system thus providing an efficient means for computing a landsat scene. Early runs of pyDisALEXI on a 2016 dual-core Macbook Pro were completed in just over 1.5 hours, however when run on a 40-core 80 thread linux system the same scene takes only 15-20 minutes. Without parallelization it was shown that pyDisALEXI could not be run without running out of resources.

Future plans

- PyDisALEXI is still in development, however validation activities will commence in the early part of this year.
- Packaging and deployment is still being investigated.

References

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Acknowledgement:
Supported by NOAA grant NA14NES4320003 (Cooperative Institute for Climate and Satellites -CICS) at the University of Maryland/ESSIC.