

TEOS 07 North American Webcams

TEOS 07.1 People

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TEOS 07.2 Overview

Expanding on the plant phenology monitoring program established at the James Reserve, we have accumulated a list of over 1400 freely available webcam image streams on the Internet that include some sort of plant life in their field of view. We are collecting images twice daily from each of these cameras and will compare the spring “green-up” as observed with this ground-based system to that observed by standard, freely available remote sensing products.

TEOS 07.3 Approach

Webcams were collected using standard Internet search engines. Images were geo-located by IP address and other metadata and then assigned to a time zone. An image is retrieved at 10 am and 2 pm from each camera based on its local time zone. Archived images are now being processed to determine the “greenness” of the image with the per-pixel transformation of Excess Green. This greenness signal is then fit with a double sigmoid function similar to that used for fitting remote sensing data. Remote sensing data for the surrounding pixels associated with each camera will then be compared to this ground-based data. Analysis of faults and reliability of data compared to remote sensing products is one goal of this project.

TEOS 07.4 System(s) Description and/or Experiments

The URL of each camera and its associated metadata is stored in a MySQL database. Twice a day, a wget is scheduled to retrieve an image from each URL. Images were stored on the file system with a link to the image location and image metadata stored in a database. After each image is collected, the average excess green of the image is calculated and stored with the image metadata in the database. Excess green was calculated for each pixel as:

$$2G - R - B$$

where G is the green channel value of the pixel, R the red channel value, and B the blue channel value. This was calculated for the entire image and then averaged to receive a single value for each image.

For select cameras, a mask was created to separate out a specific vegetation types. For these images, only the pixels of the target region(vegetation) were averaged. If multiple masks exist for an image, the average excess green value of the image was calculated with each mask separately.

Remote Sensing

Satellite-derived vegetation metrics have enabled the detection of phenological events over large geographic extents. Among the highest temporal resolution remote sensing products are those from the MODIS (or Moderate Resolution Imaging Spectroradiometer) instrument aboard the Terra and Aqua satellites. These satellites make daily passes over the entire Earth’s surface, allowing for the production of daily remote sensing imagery. These daily products, however, are inherently noisy, as sensor malfunctions, cloud cover, atmospheric conditions, etc. reduce their functional temporal resolution. For biological processes where fine scale temporal shifts can have huge ecological impacts, such as the timing of phenological events, high quality daily monitoring is necessary. Internet webcams, which have the capacity to produce multiple images in a day and are likely to be less sensitive to cloudy weather and potentially certain atmospheric conditions, may have an important advantage over satellite imagery in detecting these fine scale shifts. In addition, they share a number of advantages over on the ground monitoring,

such as enabling the monitoring of remote or large areas at a high frequency with low man-power and cost. Currently, internet webcams represent an untapped resource in ecological and environmental monitoring.

Remote Sensing Data

We will compare camera “greenness” to satellite-based NDVI “greenness” calculated from three different MODIS products: 500m resolution daily surface reflectance (MOD09GA), 500m resolution 8 day composite surface reflectance (MOD09A1) and 500m resolution 16-day composite vegetation indices (MOD13A1).

MODIS data is freely available through the Warehouse Inventory Search Tool (WIST: <https://wist.echo.nasa.gov/~wist/api/imswelcome/>), a client for searching and ordering earth science data from various NASA and affiliated centers. All MODIS data products come in 10 x 10 degree (latitude x longitude) tiles, stored in a compressed data format HDF-EOS (Hierarchical Data Format – Earth Observing System). Each HDF file contains ‘science data sets’ (SDSs) that include product quality information by pixel. The 8-day surface reflectance composite product is available at an aggregated conterminous US coverage in WGS84 projection from the University of New Hampshire’s (UNH) Earth Science Information Partner (ESIP), EOS-WEBSTER (<http://eos-webster.sr.unh.edu>).

The MOD09GA and MOD09A1 products include surface reflectance in both the red (620nm–670nm) and near infrared (841–876nm) ranges, MODIS bands 1 and 2 respectively. A satellite-based Normalized Vegetation Index (NDVI) can be calculated as follows:

$$\text{NDVI} = (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED})$$

Where NIR = near-infrared reflectance and RED= red reflectance. The MOD13A1 16-day composite product includes two vegetation indices (VIs) that have been calculated from the MOD09 daily surface reflectance product: NDVI and enhanced vegetation index (EVI).

In the 8-day surface reflectance and 16-day vegetation index composite products, a filter has been applied to each pixel collected over the course of 8 or 16 days (respectively), so that only the highest quality, cloud free pixels are then retained in the final image. This is often necessary, as image quality is sensitive to numerous factors such as cloud cover, atmospheric conditions, and sensor malfunction, making it difficult to obtain high quality data at a daily temporal resolution. Because of their generally higher quality, these composite products are often more commonly used despite their lower temporal resolution. Temporal shifts in phenological events, by even just a few days, however, can be highly relevant biologically. Such fine scale changes would not be detectable from composite images and may be difficult to detect in the noisier daily satellite images.

By comparing green-up and senescence signals from camera and satellite imagery at a daily scale, we can compare data quality and reliability from both sources. We aim to illustrate the ability of webcams to detect fine scale phenological shifts. We will also compare green-up estimates of daily camera and satellite images with those from the ‘cleaner’ 8 day and 16 day composite satellite images to determine the cost of sensitivity with increased product quality.

Image processing and data extraction

One disadvantage of satellite imagery products is that they are often available in data formats that are difficult to manipulate and require a number of processing steps before they can be utilized in a geographic information system (GIS) or before data can be extracted from them. The native sinusoidal projection of MODIS data products can be difficult to work with. For the daily surface reflectance and 16-day vegetation index products, all data files must first be reprojected to a more standard projection (wgs84) using free software MODIS Reprojection Tool (MRT v 4.0; https://lpdaac.usgs.gov/lpdaac/tools/modis_reprojection_tool).

Some processing is performed on MOD09 daily and 8 day products (and thus the derived MOD13 vegetation index product) prior to their distribution to correct for atmospheric scattering and absorption and fine cirrus clouds (Vermote and Vermeulen 1999). Quality assurance data sets about initial atmospheric conditions, cloud cover, sensor function, etc. are available for each product, stored as an additional SDS within the HDF file. These files are in a bit-format and include information for the images pixel by pixel and must be ‘unpacked’ before data extraction.

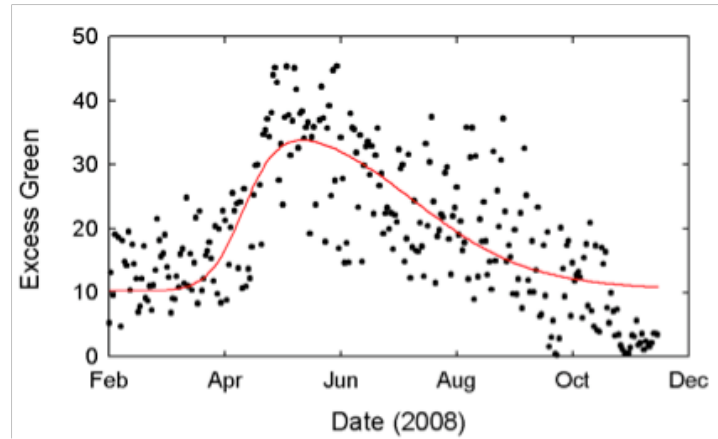
We used free software tools to unpack data quality information available through the MODIS Land quality assessment group (LDOPE tools; Roy et al. 2002).

All HDF files must then be converted to a more 'readable' format before data corresponding to our webcam locations can be extracted. We are using a script to run ncdump (downloaded software) to extract the data in the HDF files into human readable ascii files. Surface reflectance, vegetation index, and quality information can then be extracted from each pixel corresponding to the geographic location of each georeferenced webcam. For MOD09 surface reflectance products we extract values for band 1 and band 2, then calculate an NDVI value following the above equation. For the MOD16 vegetation index product, we extract the pre-calculated NDVI value.

The quality information for each product can be used to set a minimum threshold for acceptable quality of satellite-based measures. This cleaned data can then be curve-fit and compared to webcam green-up and senescence signals.

Satellite Product Quality Information:

Following Soudani et al. (2008) we fit a double sigmoid function to the extracted NDVI values



Cloud state	Aerosol Qanttty	Cirrus Clouds	Snow/Ice
cloud	climatology	none	present
clear	low	small	absent
mixed	average	average	
not set (assumed clear)	high	high	

to extrapolate dates for phenological events. The same approach is applied to the Excess Green measurements per camera. The double sigmoid is calculated as:

$$NDVI = (w_1 + w_2) + 0.5 * (w_1 - w_2) * [\tanh(w_3 * (t - u)) - \tanh(w_4 * (t - v))]$$

Where tanh is the hyperbolic tangent, t is the time (day of year), $(w_1 + w_2)$ is the NDVI minimum in the non-leafy season, $(w_1 - w_2)$ is the total amplitude of the NDVI signal, u and v are the dates corresponding to the highest rates of change of NDVI equal to the dates of the two inflection points when NDVI increases (date of spring) and decreases (data of fall).

TEOS 07.5 Accomplishments

We have successfully collected images twice daily from about 1400 webcams across the continental US and Canada since February 15th, 2008. We are continuing to collect data from these cameras.

A subset of the cameras has been chosen to test out methods for data extraction. Masks were created to remove portions of the image that were not vegetation in order to reduce signal noise. One such data stream is indicated in Figure 2, where Excess Green has been calculated for the areas that include

Band Quality

- highest quality
- dead detector
- solar zenith >= 85 degrees
- solar zenith >= 85 degrees and < 86
- missing input
- missing climatological data
- value out of bounds
- faulty raw data
- not processed due to deep clouds

vegetation and a double hyperbolic function to calculate NDVI has been fitted to the data (in red). We are now working on manually separating deciduous from evergreen species in this subset of images in order to clean the signal even further. An Intel Scholar student is working on simple filters, akin to the filters used in remote sensing, to further clean the data.

We have downloaded 8-day composite surface reflectance images from February 1, 2008- December 31, 2008 from EOS-WEBSTER and prepped files for data extraction by pixel. We requested daily surface reflectance and 16-day vegetation index composite images by tile for February 1, 2008 to present from WIST. We have also performed preliminary image processing steps for the first month's worth of data for the daily surface reflectance product.

TEOS 07.6 Future Directions

Once some simple filters for the ground-based images have been established to provide a cleaner data set, we will apply them to the 1400 webcams to create a larger data set of ground-based NDVI values. We will then make a comparison of ground-based and remote sensing estimates of spring. We wish to compare the reliability statistics of ground-based imaging with satellite observations, the pros and cons, and where each system has its strengths and weaknesses.