Remote Sensing Time Series Product Tool

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Introduction

The TSPT (Time Series Product Tool) software was custom-designed for NASA to rapidly create and display single-band and band-combination time series, such as NDVI (Normalized Difference Vegetation Index) images, for wide-area crop surveillance and other time-critical applications. The TSPT, developed in MATLAB®, allows users to create and display various MODIS (Moderate Resolution Imaging Spectroradiometer) or simulated VIIRS (Visible/Infrared Imager/Radiometer Suite) products as single images, as time series plots at a selected location, or as temporally processed image videos.

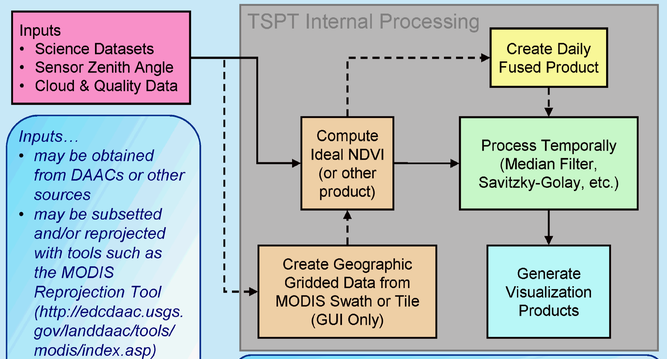
MODIS is ideal for monitoring large crop areas because of its high temporal revisit rate (twice daily), its near global coverage, and its relatively small ground sample distance (250 m). Because MODIS imagery is acquired daily, rapid changes in vegetative health can potentially be detected. With the TSPT, noise removal and temporal processing techniques allow users to create low-noise, daily time series plots and image videos. MODIS metadata is used to find and optionally to remove bad, cloudy, and suspect data. The TSPT features the important capability of fusing data from the MODIS instruments onboard the Aqua and Terra satellites, which nearly doubles the effective temporal resolution.

The TSPT GUI (graphical user interface) provides an interactive environment for crafting "what-if" scenarios by enabling a user to repeat product generation using different settings and thresholds. The TSPT Application Programming Interface provides more fine-tuned control of product generation, allowing experienced programmers to bypass the GUI to create more user-specific output products, such as comparison time plots or images.

This type of time series analysis tool for remotely sensed imagery could be the basis of a large-area vegetation surveillance system. The TSPT has been used to generate NDVI time series to monitor crop phenology in California and Argentina and to monitor forest health in an area of southeast Mississippi following Hurricane Katrina.

TSPT Data Flow

Multiple, temporally processed images can be created from single sensors or from fused Aqua and Terra data.



Inputs…
- *may be obtained from DAACs or other sources*
- *may be subsetted and/or reprojected with tools such as the MODIS Reprojection Tool (http://edcdaac.usgs.gov/landdaac/tools/modis/index.asp)*
- *may be simulated with Application Research Toolbox (Ross et al., 2006)*

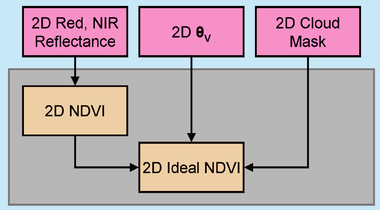
Visualization Products
- *1-D time series plots given a latitude, longitude, and date range*
- *2-D images given a region and a date*
- *3-D time series videos given a region and a date range*

Typical MODIS Input Datasets

- MOD02 Planetary Reflectance (Swath)
- MOD35 48-bit Cloud Mask
- MOD03 Sensor Zenith Angle
- MOD09 Surface Reflectance (Tile)
- MOD09 Metadata including Cloud Information
- MODMGGAD Sensor Zenith Angle

Ideal NDVI

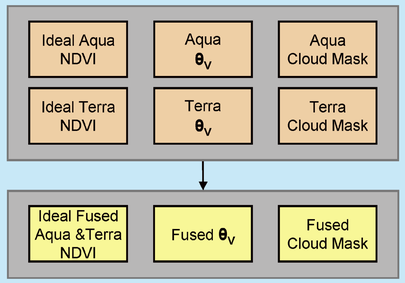
- Calculate NDVI from red and NIR (near-infrared) reflectances (*input can be planetary reflectance or surface reflectance*).
- Eliminate pixels acquired at high sensor zenith angle (θ_V).
- Eliminate bad, clouded, or otherwise suspect pixels.



Fused Aqua and Terra

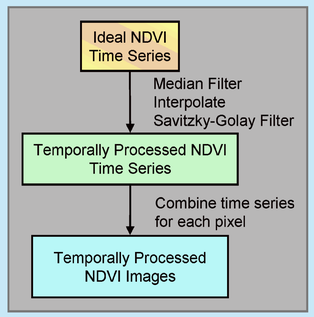
For each pixel, use θ_V, cloud data, and other metadata to choose between Aqua and Terra

- PER PIXEL: If Aqua is chosen, use Aqua NDVI, θ_V, and cloud data
- PER PIXEL: If Terra is chosen, use Terra NDVI, θ_V, and cloud data

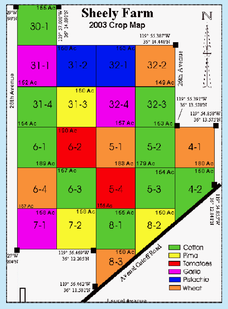


Temporally Processed NDVI

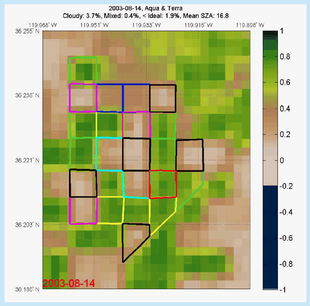
- Input can be from Aqua, Terra, or Fused Aqua & Terra NDVI. Similarly, for simulated VIIRS, the input could be VIIRS 1030, VIIRS 1330, or Fused 1030 & 1330 VIIRS.
- Processing is performed in time dimension only.
- Although handled internally as 3-D arrays, the processed outputs are 2-D raster grids (one for each day).



Sheely Farm (2003)

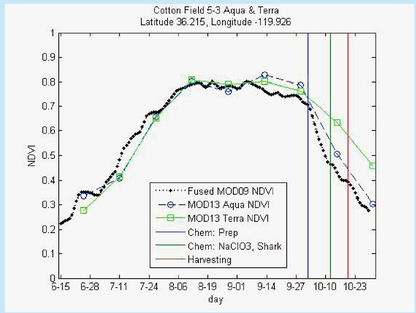


Color-coded Sheely Farm Crop Map



Fused and temporally processed NDVI from MOD02 (Planetary Reflectance), MOD03 (includes θ_V), and MOD35 (Cloud Mask). Planted cotton and pima fields stand out from other Sheely Farm crop fields (8-14-2003).

Fused Daily NDVI vs. MOD13 16-Day NDVI

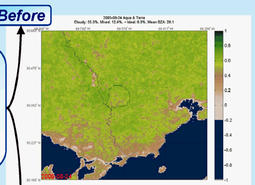


Fused and temporally processed NDVI using MOD09 and MODMGGAD, with MOD13 16-day Aqua and Terra NDVIs shown for comparison.

Note that the daily NDVI shows a drop off more than 10 days before MOD13. This difference would be critical in early detection of sudden threats to crop health.

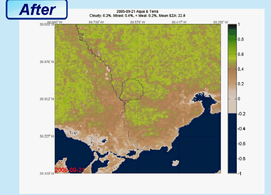
Katrina (2005)

Before

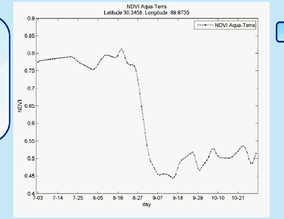


On right, fused and temporally processed Aqua and Terra NDVI from MOD02, MOD03, and MOD35 before the storm on 8-24-2005 and after the storm on 9-21-2005. The eye passed over Stennis Space Center, outlined in black, adjacent to the Mississippi-Louisiana border. Bay Saint Louis is on right.

After



NDVI plot at latitude 30.3458 and longitude -89.6735, a few miles southwest of Stennis.



Summary

- The TSPT provides a wide range of multitemporal analysis and visualization tools for detecting rapid changes in vegetation vigor via remote sensing imagery.
- The TSPT makes judicious use of available metadata to locate and optionally to eliminate bad, cloudy, or otherwise suspect pixels.
- The TSPT enables fusion of cross-calibrated sensors.

Future Development

- To support rapid prototyping efforts, integration with the Application Research Toolbox, used to simulate future data sources (Ross et al., 2006), is underway.
- To provide easier integration with other tools, portions of the TSPT are being extracted as separate, stand-alone modules able to input and output common data file formats, such as GeoTIFF, ENVI® BSQ (band sequential), and HDF (Hierarchical Data Format).

Related Poster & Presentation

- Ross, K.W., J. Russell, and R.E. Ryan, 2006. Simulating Visible/Infrared Imager Radiometer Suite Normalized Difference Vegetation Index data using Hyperion and MODIS. *Eos Transactions AGU*, 87(52), Fall Meeting Supplement, Abstract IN33B-1340. *(poster)*
- O'Hara, C.G., R. Moorhead, D. Shaw, B. Shrestha, K.W. Ross, D. Prados, J. Russell, R.E. Ryan, 2006. Integrated use of tools and technologies for rapidly prototyping simulated data products of future NASA observing systems for evaluation in application of national importance. *Eos Transactions AGU*, 87(52), Fall Meeting Supplement, Abstract IN32A-05. *(presentation, Session IN32A, Wednesday, Dec. 13, 11:20)*

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14. ABSTRACT

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