Using VIIRS to extend MODIS long-term clear-sky composites over Canada

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Outline

- MODIS processing at CCRS/NRCan as a component of **Long-Term Satellite Data Record (LTSDR) project**
- CCRS MODIS products and applications
- VIIRS processing at CCRS/NRCan
- Announcement of CJRS special issue on LTSDR
MODIS processing at CCRS

Motivation

• We would like to make the best use of MODIS data over Canada and to generate products compatible with other LTSDR time series (AVHRR etc)
• MODIS sinusoidal projection over the polar and mid-latitude regions of North America reduces the image quality and spatial resolution of the MODIS products

MODIS processing at CCRS

Motivation

**CCRS product**                               **Standard MOD09 Product**

- **Different projections**: LCC (CCRS) vs sinusoidal (MODIS). Need to minimize distortions due to multiple re-projections.
- **Different compositing intervals**: 10-day CCRS vs 8&16-day MODIS.
- **Enhance spatial resolution** of 500m bands to 250m.

Khlopenkov & Trishchenko, 2008: IEEE TGRS, 46 (7), 2016-2027
Key MODIS Processing Enhancements Implemented at CCRS

- Product is generated from original swath imagery (L1B level) and retains all spatial details, i.e. no multiple re-projection steps;
- Employs the correlation between 500m bands B3-B7 and B1,B2 and NDVI at 500m for generic surface types for each MODIS 5-min granule MOD02HKM and applies it at 250m;
- Generate the intermediate layers for bands B3-B7 at 250m resolution using B1, B2 and NDVI with 250m spatial resolution from MOD02QKM;
- Final normalization of intermediate 250m layers to 500m observed data at the local scale using spatial filter mimicking MODIS point spread function;
- We called this technique an Adaptive Regression and Normalization;
- 10-day compositing intervals instead of 16-day;
- Two-value (Forward & Backward scattering geometry) composites;
- Instead on MODIS SIN projection
  - Lambert Conic Conformal projection (LCC) for Canada (since 2000 up to now)
  - Lambert Azimuthal Equal Area (LAEA) projection for circumpolar Arctic (2000-2008)
  - Lambert Azimuthal Equal Area (LAEA) projection for North America (selected years)

MODIS Clear-Sky Composite July 2014

Canada-wide coverage at 250m spatial resolution using MODIS data processing at CCRS July 11-20, 2014

Lambert Conic Conformal Projection (LCC)

MODIS bands B1 to B7 all scaled to 250m

North America coverage at 250m spatial resolution using MODIS data processing at CCRS.

Lambert Azimuthal Equal-Area Projection (LAEA)

US-Canada-Mexico Land Cover Project

MODIS bands B1 to B7 all scaled to 250m

IPY MODIS Circumpolar Mosaics

CCRS & CIS – Legacy work from IPY. Trishchenko et al, IJRS, 2009:30 (6), pp. 1635-1641
On Uncertainties in Global Land Cover Data Related to Arctic Perennial Snow and Ice Map

CCRS MODIS times series at 250m produced for IPY over the circumpolar Arctic were used to evaluate the Perennial Snow and Ice (PSI) mapping in 2 popular global land cover datasets:

- Global Land Cover-2000 (GLC-2000)
- ESA Globcover GC-2005

GCL-2000 and GC-2005 PSI area in Canada North overestimated by 128% (59,000km²) and 129% (52,000km²) relative to CCRS 250m MODIS data! Errors for other regions span the range from -73% to +115%.

Other Applications of CCRS MODIS Data and Processing System

- Crop yield estimation, climate, radiative forcing, albedo and hydrology studies

- Ice monitoring at Canadian Ice Service, EC

- Inland water quality monitoring

- Land Cover (Canada, North America and Circumpolar Arctic – Arctic Council CAFF)
  - Talbot & Meades, 2011: CircumBoreal Vegetation Map (CBVM).
    - [http://library.arcticportal.org/1598/1/CBVM_lowres.pdf](http://library.arcticportal.org/1598/1/CBVM_lowres.pdf)
  - The North American Land Change Monitoring System (NALCMS)

- MODIS clear-sky composites and products are available from NRCan NEODF archive:
  - [https://neodf.nrcan.gc.ca/](https://neodf.nrcan.gc.ca/)
VIIRS General Features

Goal: To continue MODIS time series with compatible and advanced VIIRS products

- **VIIRS** stands for the Visible/Infrared Imaging Radiometer Suite and replaces AVHRR on NOAA satellites
- VIIRS flies onboard the NOAA Suomi National Polar-orbiting Partnership (SNPP) satellite
  - SNPP orbit: sun synch. (1:30pm), H=830km, VIIRS swath – 3040km
- SNPP is the first satellite of future US/NOAA Joint Polar Satellite System (JPSS) that will include JPSS-1 & 2 satellites etc all equipped with VIIRS

22 spectral bands
- 14 solar
- 7 thermal
- 1 Day/Night Band
- (DNB)

Band grouping:
- Imaging: I-bands - 5 bands @ 375m
- Moderate resolution: M-bands -16 bands @ 750m
- Day-Night band: DNB - 1 band @750m
Native swath VIIRS
July 4/2014 17:54 UT

Scan is obtained by
32 detectors in imaging bands (I-bands)
16 detectors in moderate resolution bands (M-bands)

Scanlines are overlapped off-nadir due to bow-tie effect.

Some edge pixels in each scanline are removed in 2-sample and 1-sample aggregation zones to save the data volume for satellite downlink.
Re-projected Swath VIIRS
July 4/2014 17:54 UT

Lambert Conic Conformal Projection (LCC)
compatible with MODIS and other CCRS products

Output VIIRS images
- I-bands scaled to 250m
- M-bands scaled to 500m

VIIRS image re-projection is based in MODIS concurrent gradient search method developed at CCRS by Khlopenkov and Trishchenko, IEEE TGRS, 2008, 46 (7), pp. 2016-2027
Subset of Re-projected Swath. July 4/2014 17:54 UT
Current Processing Chain

- Code currently consists of
  - > 60 modules
  - > 12,000 lines
  - Input data
    - I-band SDRs + geo
    - M-band SDRs + geo
    - VIIRS Cloud Mask (VCM) EDR

- Processing is defined by CONFIGuration file
- Various intermediate outputs can be generated for debugging, testing and QC purposes
  - Input images and geo-files
  - Gradients employed in re-projection
  - GCP chips and Correlation Matrices
  - GCP statistics
  - LOG-file with a record of all operations
Example of CCRS Scene ID Mask for VIIRS

July 4/2014 17:54 UT

Modified LTK scene ID scheme

Geolocation Quality Control

- VIIRS is an operational sensor
  - VIIRS image processing occurs in real or near-real time without reprocessing
  - Best ephemeris info available at the time of processing is used
  - Due to operational nature of VIIRS processing, the image navigation errors up to 1km are possible (Wolfe et al.: 2013, *JGR*, 118, 11,508–11,521, doi:10.1002/jgrd.50873)
- The geolocation control at CCRS is implemented to ensure that
  - 1) geolocation errors do not affect CCRS composites,
  - 2) VIIRS images are compatible with MODIS
- Geolocation control is conducted against MODIS monthly mean reflectance maps
- Geolocation control is implemented in VIIRS swath projection (pixel-line)
- Procedure was developed based on CCRS CAPS AVHRR processing system
- Correlation matrix is computed between VIIRS and MODIS image chips (49x 49 pixs)
- 4th degree polynomial is fitted and location of maximum is determined in pixel-line 2D-space, which gives the estimates of accuracy at sub-pixel level
MODIS Monthly Maps and GCP Data Base

- MODIS 12-year mean monthly clear-sky composites @250m are used as the mage reference maps;
- Variance maps (V-maps) were produced over the region of 49 x 49 pixels
- V-maps were used to generate the GCP data points by selecting maximum variance values over the region 55 km;
- MODIS Imagery is reprojected into VIIRS granule;
- MODIS image in VIIRS projection is matched with VIIRS imagery over the GCP areas
VIIRS vs Reference MODIS Swath
VIIRS vs MODIS

MODIS reference image in LCC projection is transformed into VIIRS swath pixel-line image
Polynomial Fitting to GCP Image Chip Correlation Matrix

SVD solution for linear system with pre-calculated matrices
Example of VIIRS GCP statistics

10-day period
July 11-20, 2014

Single scene

On average better than $\frac{1}{5}$ pixel
Example of VIIRS 10-day composite
July 11-20, 2014

10-day period
234 scenes
> 5,500 files)
> 770GB
Processing time
~ 40hrs
I/O is main limitation

Composites
1) Mixed geometry
   MIX-I (250m)
   MIX-M (500m)
2) Backward geom
   BKW-I (250m)
   BKW-M (500m)
3) Forward geom
   FRW-I (250m)
   FRW-M (500m)
4) Daily Snow files
   SnowI(M)DDMMYYYY (250&500m)
Further Plans

- Testing and analysis of various components
- Improving Scene ID and compositing schemes
- Start developing new BRDF/Albedo scheme based on “all clear-sky data points” rather than two-value compositing as implemented in MODIS processing
- Atmospheric correction
- Operational production of VIIRS products compatible with CCRS MODIS series

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- VIIRS data were acquired from the NOAA CLASS archive
- MODIS data were acquired from the NASA
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The satellite remote sensing provides important information about the Earth environment including land surface, cryosphere, ocean and atmosphere. Data from passive microwave and optical sensors have been collected for over 40 years. The measurements from active systems as well as gravity missions have also become valuable source of data for understanding the Earth system during last two decades.

The papers dealing with various aspects of processing techniques and analyses focusing on long-term applications are welcome for this special issue of the Canadian Journal of Remote Sensing. Specific themes include but are not limited to:

- Analysis of and processing techniques for long-term fundamental data (calibrated and quality-controlled sensor data) and thematic products (i.e. retrieved parameters of the surface, cryosphere, and atmosphere);
- Application of long-term satellite products for ecosystem, water cycle and climate studies;
- Long-term satellite products and applications for responsible resource development, emergency management, infrastructure monitoring and transportation safety.

Tentative deadline for submitting manuscripts: **End of May, 2015.**

Tentative date of publication: **End of December, 2015.**

Normal page charges ($USD 400 per research paper, $300 for a research note), peer-review, and editorial process will apply. Prospective authors should follow the regular guidelines of the CJRS available at [http://www.tandfonline.com/r/cjrs](http://www.tandfonline.com/r/cjrs). Papers should be submitted via the CJRS Manuscript Central website: [http://mc.manuscriptcentral.com/cjrs-jct](http://mc.manuscriptcentral.com/cjrs-jct)