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Generating Clear-Sky Composites Over Canada From VIIRS

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1.Objectives

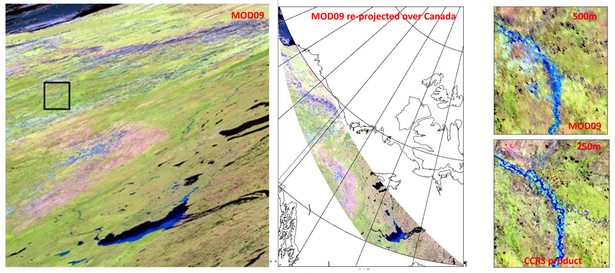
- **The final goal**: To **continue MODIS time series** generated by the Canada Centre for Remote Sensing (CCRS) over Canada landmass since 2000 with **compatible and advanced** products generated from **Visible/Infrared Imaging Radiometer Suit (VIIRS) imagery**
- VIIRS currently flies onboard the NOAA 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

2. CCRS Product Features

- **MODIS imagery** includes three types of spatial scales: 250m, 500m, 1000m (@nadir)
  - 250m – B1 (red) and B2 (NIR)
  - 500m – all solar bands B1 (blue) to B7 (SWIR -2.2μm)
  - 1000m – all bands B1(blue) to B36 (TIR-14.2μm)
  - Standard MODIS image output formats: swath and sinusoidal projection
  - Standard MODIS compositing period – 1-day and 16-day
- **VIIRS imagery** includes two types of spatial scales:
  - 375m (I-bands) – 5 bands
  - 750m (M-bands) -16 bands + DNB
  - Additional enhancement along the scan direction (3-sample, 2-sample and 1-sample aggregation) to compensate for the growth of pixel size with increase of the Viewing Zenith Angle (VZA)
- **CCRS MODIS processing** features:
  - Lambert Conic Conformal Projection (LCC) over Canada, Lambert Azimuthal Equal Area (LAEA) over the North America and Arctic circumpolar region
  - 10-day compositing intervals
  - Enhanced spatial resolution for all solar bands B1-B7 to 250m scale*
    - **250m** is a requirement for spatial resolution for several terrestrial ECVs: GCOS-154 (2011). "*Systematic observation requirements for satellite-based data products for climate. 2011 Update. Supplemental details to the satellite-based component of the "Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)".*
  - Product is generated directly from swath images, i.e. no extra re-projection steps
  - In-house scene ID mask: clear, cloud, cloud shadow
  - Two-value (Forward and Backward Scattering) in-house compositing scheme
- **CCRS VIIRS processing** features
  - LCC (and potentially LAEA) projections compatible with CCRS MODIS format
  - 10-day compositing intervals
  - Spatial resolution for output products
    - ✓ 250m for I-bands
    - ✓ 500m for M-bands
  - In-house scene ID-mask
  - In-house compositing scheme

3.Re-projection issues

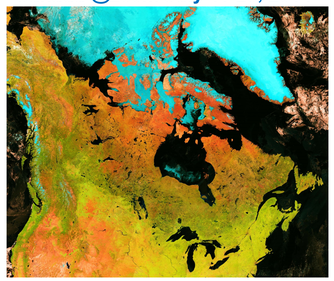
MODIS sinusoidal projection over the polar and mid-latitude regions of North America reduces the image quality and spatial resolution of the MODIS products. This motivated us to start from L1-swath level and to develop a corresponding re-projection techniques suitable for in-house large-volume processing



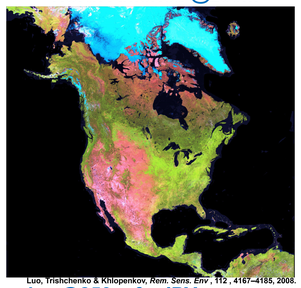
Khlopenkov & Trishchenko, 2008: IEEE TGRS, 46 (7), 2016-2027

4. Examples of CCRS MODIS products

Canada @250m July 11-20, 2014

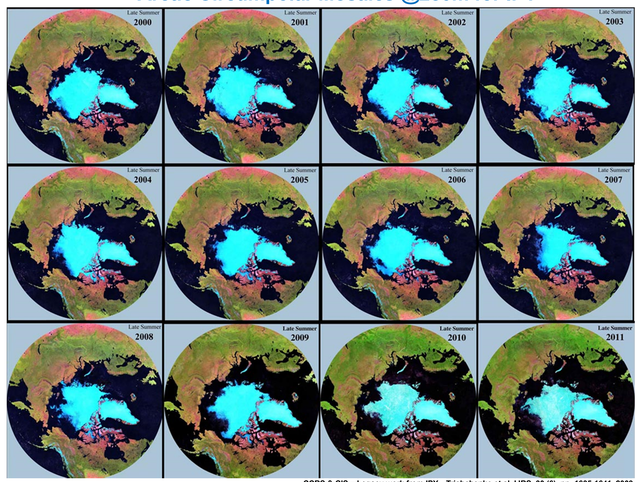


North America @250m



Luo, Trishchenko & Khlopenkov, *Rem. Sens. Env.*, 112 , 4167–4185, 2008.

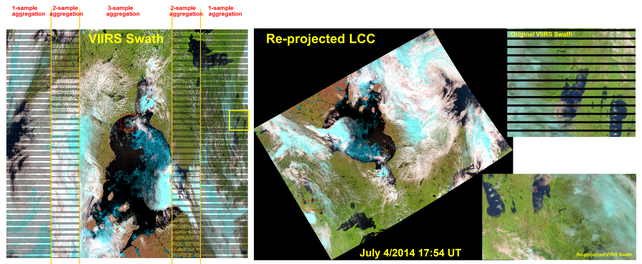
Arctic Circumpolar Mosaics @250m for IPY



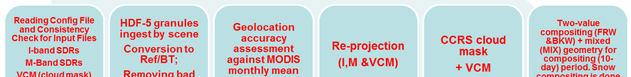
CCRS & CIS – Legacy work from IPY. Trishchenko et al, IJRS, 30 (6), pp. 1635-1641, 2009

5.VIIRS Re-projection

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



6. Current VIIRS Processing Chain at CCRS



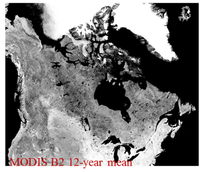
Code currently consists of
- > 60 modules
- > 12,000 lines

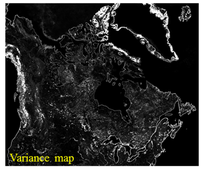
- Input data
  - ✓ I-band SDRs + geo
  - ✓ M-band SDRs + geo
  - ✓ VIIRS Cloud Mask (VCM) EDR

- Processing is defined by **CONFIG**uration 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

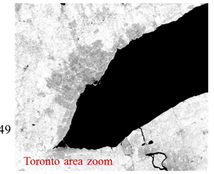
7. Geolocation Quality Control

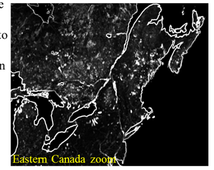
- VIIRS is an operational sensor
  - VIIRS image processing occurs in near or real-time without reprocessing
  - Best ephemeris info available at the time of processing is used
  - Due to operational nature of VIIRS processing, the image navigation errors up to 1km are possible (Wolfe et al.: 2013, *JGR*, **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

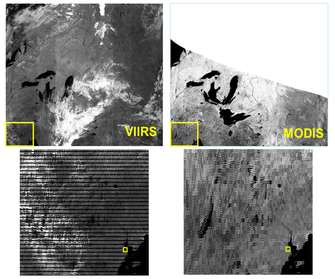


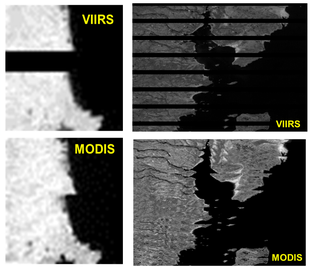


- MODIS 12-year mean monthly clear-sky composites @250m are used as the mage reference maps;
- Variance maps (V-maps) were produced over the region of 49 x 49 pixels
- V-maps were used to generate the GCP data points by selecting maximum variance values over the region 55 km;
- MODIS Imagery is reprojected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

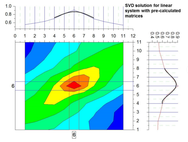




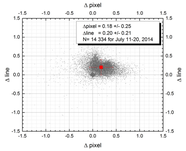




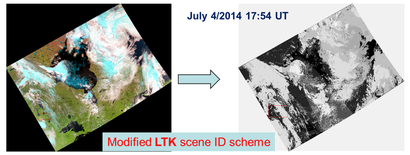
8. Geolocation Accuracy



10-day period: July 11-20, 2014
On average better than $^1/_5$ pixel

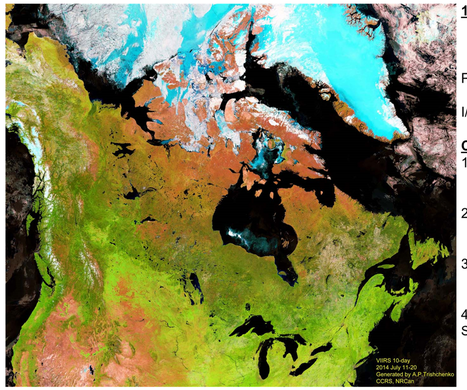


9. Scene ID



10. Example of VIIRS Clear-Sky 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
Snow(M)DDMMYYYY
(250&500m)

Future 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

Acknowledgements

- Work is conducted as part of CCRS project **Long-Term Satellite Data Records (LTSDR)**
- VIIRS data were acquired from the NOAA CLASS archive
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- MODIS circumpolar Arctic time series was supported by the International Polar Year
- MODIS work was conducted as part of ESS/NRCan projects J28 and J35 of the Climate Change Program
- MODIS data were acquired from the NASA
- Contribution of Dr. Yi Luo, Canadian Ice Service, Environment Canada and Dr. Konstantin Khlopenkov, Science Systems and Applications Inc. is acknowledged .