Using MODIS Medium-Resolution Remote Sensing Data to Monitor Hydroclimatic Variability

Past and Future Hydroclimatic Variability: Applications to Water Resources Management in the Prairie Provinces,


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AAFC Policy Framework 2: Growing Forward

“ A profitable and innovative agriculture, agri-food and agri-based products industry that seizes opportunities in responding to market demands and contributes to the health and well-being of Canadians”

Policy Outcomes – A sector that:
(a) Is competitive and innovative;
(b) Contributes to society’s priorities
(c) Is proactive in managing risks
1. **Assess climate related risk to agriculture:**
   - Timely, state of the art monitoring, analysis and reporting of weather and climate related events that affect Canada’s agriculture industry.

2. **Improve management of climate related risk:**
   - Address client needs by enabling development of high quality, state of the art, relevant value-added products for decision and policy support to manage climate-related risk.

3. **Improve industry’s ability to adapt to climate change and variability:**
   - Address client needs by contributing analysis and interpretation to support Sustainable Production, Marketing, and Policy related to climate change impacts and adaptation.

   - Medium-resolution remote sensing will be valuable in supporting each of the above policy directions.
Remote sensing is the best way to monitor drought conditions of Canada’s agricultural landscapes.

RS has been shown to provide reliable and repeatable data on plant parameters relating to drought-influenced crop condition (e.g. Biomass).

RS crop monitoring is often based on the use of spectral vegetation indices (e.g. NDVI).

AAFC currently uses weekly AVHRR-derived 1km-resolution NDVI data for crop assessment.

However, these data are at a spatial resolution that is coarser than some of our applications require.

Use of weekly 250m-resolution NDVI data from MODIS would directly address these limitations.
Physiological Basis of the NDVI

- NDVI relationship with vegetation biophysical parameters (e.g. ALB, LAI, APAR) is based on inverse relation between R and NIR reflectance.

- As biomass increases, R reflectance decreases, NIR reflectance increases, and thus the NDVI increases.

NDVI = \frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72

NDVI = \frac{(0.40 - 0.30)}{(0.40 + 0.30)} = 0.14
NDVI Indicates Areas of Drought

- Differences in NDVI in Canadian prairies between drought and non-drought years.

General Aims and Specific Goals

- NLWIS aims to develop a production system to provide MODIS NDVI data on the internet.

- Our specific goals are to:
  
  a) demonstrate to NLWIS a system that uses MODIS data to create a weekly composite NDVI product that is ready for web posting (completed);

  b) provide an operational system that can create weekly NDVI and crop yield datasets with a 3-day lag for posting on the internet (ongoing).

# Weekly NDVI from MODIS daily reflectance data

<table>
<thead>
<tr>
<th>Dataset Shortname</th>
<th>Description</th>
<th>Level</th>
<th>When Available</th>
<th>Required Processing Steps for NDVI Composite Creation</th>
<th>Additional Datasets Required?</th>
<th>Post-download processing effort</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOD02QKM (250m)</td>
<td>Daily R and NIR TOA calibrated radiances (&quot;swath&quot;)</td>
<td>1B</td>
<td>Near-Real time?</td>
<td>Atmospheric, adjacency, and BRDF correction; QA/QC; Mosaicing; NDVI calculation and compositing</td>
<td>Cloud Mask (MOD35), aerosols (MOD04); precipitable water (MOD05); ozone (MOD07), surface BRDF (MOD43), Geolocation Angles (MOD09GA); Observation Pointers (MOD09GA), Ancillary data.</td>
<td>Most</td>
</tr>
<tr>
<td>MOD09GQK (250m)</td>
<td>Daily R and NIR surface reflectance</td>
<td>2G</td>
<td>2-days after acquisition?</td>
<td>QA/QC, Extracting; NDVI calculation and compositing; Mosaicing</td>
<td>Surface Reflectance and QC (MOD09GQ); QC State, Sensor Zenith, Observation Pointers (MOD09GA).</td>
<td></td>
</tr>
<tr>
<td>MOD09Q1 (250m)</td>
<td>8-day R and NIR surface reflectance</td>
<td>3</td>
<td>One week after acquisition?</td>
<td>Mosaicing; NDVI calculation.</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>MOD13Q1 (250m)</td>
<td>16-day NDVI</td>
<td>3</td>
<td>Two weeks after acquisition?</td>
<td>Mosaicing.</td>
<td>None</td>
<td></td>
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A L-2G Processing System for NDVI Compositing

(1) MODIS LEVEL-2G DAILY GRIDDED DATA PRODUCTS (V005)
- Acquisition of tiles from USGS LPDAAC ("L2G-Lite").
  (a) R and NIR Surface reflectance, band QA files (250m) [MOD09GQ]
  (b) Surface reflectance QC state (1Km), Geolocation file, Observation layer pointer file (500m) [MOD09GA]

(2) DATA EXTRACTION
- USGS MODIS Reprojection Tool (MRT):
  (a) Refl, QA, geolocation, pointer data extracted from each tile.
  (b) Data processed on a tile-by-tile basis.

(3) WEEKLY MAX-NDVI COMPOSITING
- MAX-NDVI Compositing:
  (a) Daily NDVI calculated from highest quality R & NIR data.
  (b) Weekly Max-NDVI is Max daily NDVI in 7-day period.
  (c) Day-of-week week grids show DoW max-NDVI correspond to.
  (d) Individual tiles mosaicked to cover CAE.
  (e) All composites provided in ESRI grid format.
- NLWIS METADATA EDITING TOOL
  (a) Metadata generation.

(4) SERVICES AND APPLICATIONS
- WEB SERVICES:
  (a) User-controlled on-the-fly output.
  (b) Temporal and spatial statistics calculation.
  (c) Data download options (e.g. file format; reprojection).
- INPUT TO OTHER APPLICATIONS.

(5) ARCHIVING AND STORAGE
- Storage of HDF-EOS tiles, intermediary and final products

Input (SIN Projection):
- Twelve tiles per day per dataset cover CAE.
- Tiles in HDF-EOS format.
- Tile size = Refl (250m = 280MB), (1km, 500m = 85MB).

Output (SIN Projection):
- Weekly Max-NDVI and DoW rasters (GeoTIFF).
- Metadata.
L-2G NDVI Products

(a) Intermediary Products:
- Daily R, NIR and NDVI composites. Necessary to create final output.

(b) Weekly NDVI Products:
- Maximum-NDVI weekly composites for Canada south of 60°N. Uses best quality reflectances.
- Day-of-week composites show day (1-7) NDVI values are from. Additional information for user.

(c) Custom Products:
- Custom n-day NDVI and reflectance data for AAFC-related projects.
- Manitoba Pilot project of digital soil mapping (Canadian Soil Information System, CANSIS).
- Manitoba Soil Moisture Experimental Project (Red River) (PFRA).
Transition to CCRS L-1B NDVI Products

AAFC, CGEO and Canada’s Remote Sensing Community of Practice:

- Duplication of products undesirable, as per CGEO.
- CCRS mandated to be Canada’s centre of excellence in remote sensing. Should be the organization responsible for remote sensing development.
- Other organizations (EC, DFO, StatCan, AAFC) role as subject matter experts to derive value-added products.

Transition to NRT-EODM for MODIS processing:

- National coverage available in true NRT
- New geocorrection, BRDF and cloud screening schemes that improve spatial feature representation.
- Downscaling of five 500m bands to 250m, allowing derivation of indices that use SWIR bands (NDWI).
- Can process other Med-Res data (AVHRR, MERIS).
- Allows AAFC to focus on creation of value-added products for programs.
Web-Delivered Analytical Products

Delivery through NLWIS web portal scheduled for summer 2008 / Spring 2009.

(a) User-Controlled “On-the-Fly” Output
- Reprojection handled on-the-fly.
- Masking of lakes and oceans, Canada’s agric extent, crop area vs pasture.
- Various other functionalities proposed.

(b) Temporal and Spatial Statistics Calculation
- Spatial analysis: Calculation of mean, max, min, SD of NDVI by CAR, CSD, DA, user-defined units.
- Temporal analysis: Compare current NDVI to previous week, to same week in previous year or MODIS historical baseline mean.

(c) Data Download
- User data download options. Download data in various formats with complete metadata.
Challenges, Current and Future Plans

(a) Identify Best Data Management Practices
• Working on identifying best ways to archive and store large volumes of raster data.

(b) Contingency Plan for Failure of Sensor
• Working on a contingency plan if MODIS Terra sensor fails (e.g. use of MODIS Aqua, MERIS, AVHRR).

(c) Data Continuity
• Need plan for continuity of data stream after MODIS lifecycle expires.

(d) Extend the historical record pre-MODIS
• Need to extend MODIS record back beyond 2000 if weekly NDVI is truly to be put into historical context.
• To do this, we must calibrate MODIS data with data from other medium-resolution sensors (e.g. AVHRR).

(e) Addition of other Indices and Data
• Useful to generate other vegetation indices (EVI, NDII)?
• Useful to generate other MODIS products (LST, snow)?