Data Fusion and Multi-Resolution Data

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Meredith Gartner
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Data fusion and multi-resolution data

- Dark and Bram – MAUP and raster data
- Hilker et al. 2009 - data fusion to improve spatial and temporal resolution
- Neigh et al. 2008 - multi-resolution data used to investigate vegetation dynamics

- Discussion mixed throughout
- Potential effects of MAUP on raster data
- Relate back to previous topics
- How do issues relate to your research topic?
MAUP in physical geography

- Physical geography – for broad-scale analyses, often use data aggregated from small areas or collected at predefined scales
  - Remotely-sensed imagery aggregated
- MAUP largely ignored
- Example: Marceau et al. 1994 – best classification accuracy for each class achieved with different resolutions
  - Inconsistencies in accuracies among classes

“...changing the scale changes the patterns of reality, which has obvious implications for understanding.”
– Marceau et al. 1994
Dark and Bram 2007
MAUP in physical geography

Meddens et al. 2011 RSE

Effects of spatial aggregation of individual trees
Dark and Bram 2007
MAUP in physical geography

Meddens et al. 2011 RSE
Dark and Bram 2007
MAUP in physical geography

Meddens et al. 2011 RSE

![Diagram showing sunlit and shadow sides of trees at 30 cm and 2.4 m scales](image)
Dark and Bram 2007
MAUP in physical geography

• Connection between classification inconsistencies and MAUP

• Impact of resolution on modeling

• What is the appropriate resolution in a complex landscape for a pixel-based classification? How do you identify the ideal resolution?
  • E.g. Meddens’ approach?
  • Are single resolution classifications appropriate in complex landscapes or do they require a multi-scale approach?
Dark and Bram 2007
MAUP in physical geography

- Hydrologic modeling
  - Variation of flow accumulation is dependent on resolution of DEM
Potential solutions:
1. Ignore and hope for best (Openshaw 1984)
2. Identify basic entities (Fotheringham 1989) e.g. individual tree recognition
3. Object-specific approach (Hay et al. 2001)

Has your research used a specific approach to address MAUP in remotely sensed imagery?
Hilker et al. 2009
A new data fusion model for high spatial- and temporal-resolution mapping of forest disturbance based on Landsat and MODIS

- Detailed information of disturbances in important (e.g. carbon budgets, fire models)
- Sensor – trade-offs between spatial and temporal resolution
- Landsat – 30m, 185 km swath, 16 day revisit (more if cloudy)
- MODIS – 500 m, 2,330 km swath, 1-2 day revisit
Research goal: explore use of data fusion to monitor short-term land cover change/disturbance

- Combine high spatial resolution Landsat with high temporal resolution MODIS
- STAARCH – data fusion model – identify disturbance dates using MODIS

Study area - Alberta, Canada – 185 km²
Change Mask development

- Landsat scenes – beg and end
- Tasseled Cap indices (brightness greenness and wetness)
- Normalized using mean of vegetation class to reduce seasonal variation
- \( DI_{\text{Landsat}} = B_r - (G_r + W_r) \)
- Disturbed pixel if:
  - \( DI \) reaches threshold (2)
  - Neighbor must be disturbed
  - Brightness, wetness and NDVI don’t exceed thresholds
- Cloud and snow mask
Hilker et al. 2009
Methods - STAARCH

- Compute MODIS-derived Tasseled Cap data spaces
- $DI_{MODIS}$
- Used mean of all vegetation classes to normalize (mixed pixels)
- Calculates the DoD based on a moving average of the DI for 3 subsequent MODIS composites
- Compare the mean to threshold
Hilker et al. 2009
Methods - STAARCH

- Output – 30m
- All pixels within mask are dated with an interval corresponding to DoD/interval
Hilker et al. 2009
Methods – algorithm testing

LandsatTM images - 2002, 2005

MODIS composites - 110 eight-day, resampled to 30 m

STAARCH model

Validation – delineated stand-replacing disturbances – vector
Derived from Landsat TM and ETM+
Year of origin and type of disturbance
Assumption – transfer of methods to smaller time steps
Hilker et al. 2009
Results
Hilker et al. 2009
Results

Change mask
Hilker et al. 2009
Results

DI – MODIS
Hilker et al. 2009
Results - Validation

Mean area correctly classified:
2003 – 88%
2004 – 87%
2005 – 89%

Incorrectly classified – smaller time steps?

False positives – seasonal changes

IDed some disturbances not included in validations data

Mean area of correctly classified disturbances was 169,265 m$^2$ or 0.69 MODIS pixels (std dev 1.04 MODIS pixels)

Mean area of missed disturbances 47,408 m$^2$ or 0.19 MODIS pixels (std dev 0.17) ~50 Landsat pixels
Most disturbances occurred during summer months.
1. Validation data
   - Missed disturbances yet indicated 100% accuracy
   - Validation of Landsat mask and MODIS with Landsat-derived disturbances (what disturbances are missing from both?)

2. Not tested on gradual or low-severity disturbances
   - E.g. patchy insect outbreaks, low- or variable-severity fires

3. Signal sensitivity – what is the degree of change that is reflected in the method?
   - Mean area of missed disturbances 47,408 m² or 0.19 MODIS pixels (std dev 0.17)
   - What area or severity is required to be reflected in Landsat or MODIS imagery
Hilker et al. 2009
Notes

- Did they accomplish their goal - use data fusion to monitor short-term change/disturbance?

- Temporal resolution - argue this process will work at finer than annual time steps. Concerns about their assumption about fine-temporal application of model?
  - Seasonality
  - Gradual disturbances

- Mainly tested in forested ecosystem. Applications in other systems?
Neigh et al. 2008
North American vegetation dynamics observed with multi-resolution satellite data

- Explore primary production patterns at a continental scale for North America and investigate patterns and mechanisms at regional/local scale

- NDVI anomalies (pos trends) – strong relationship with net primary productivity

- AVHRR NDVI product 8km resolution starting in 1981 (bimonthly)

\[ \text{NDVI} = \frac{\text{Channel}_2 - \text{Channel}_1}{\text{Channel}_2 - \text{Channel}_1} \]
Identify AVHRR NDVI anomalies
   1) Contiguous region greater than 2000 km$^2$ with a May-Sept NDVI trend > 0.1
   2) High-resolution imagery and validation data available

Landsat acquired for anomaly locations
   Thematic maps of land cover and change
     Base map (2000) red, NIR and MIR
     ISODATA classification - ~50 classes then aggregated into 9 IGBP land cover types
Identify AVHRR NDVI anomalies
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Landsat acquired for anomaly locations
- Base map (2000) red, NIR and MIR
- ISODATA classification - ~50 classes then aggregated into 9 IGBP land cover types
- Tasseled Cap transformation to multi-date images (1975, 1990, 2000)
- ISODATA unsupervised clustering into change/no change clusters
- Compare with 2000 basemap
Neigh et al. 2008
Methods - Validation

• Nested hierarchical partitions to stratify sampling distribution
  – Study areas 8-18 mill ha (6 study regions, 3 temporal periods)

• Validation data
  – Aerial photos (0.5-2 m)
  – Ikonos (1-4 m)
  – In situ field plot surveys with aerial flight GPS

• Validation of land cover classifications for each sensor (MSS, TM, ETM+)
Data:

- Fire, logging (annual by ha)
- Agriculture (county, crop type, production method)
- Temperature, precipitation (daily meteorological station data used to calculate growing season and drought)
Neigh et al. 2008
Results

6 areas identified

Mackenzie River Delta
Southern Saskatchewan
Oklahoma Panhandle
Northern Saskatchewan
Southern Quebec
Newfoundland

Newfoundland

Newfoundland
Neigh et al. 2008
Results – Mackenzie River Delta

- NDVI increase from 1982 – 2005
- Aerial photos available for entire AVHRR record
- Alpine tundra, lichen woodland
- Temperature - permafrost - vegetation patterns
Neigh et al. 2008
Results – Mackenzie

Land cover change – minor

- Map accuracy 92.8-94.5 % using air photo and Ikonos data

- Dwarf trees and shrubs increased by 720 km² (< 1%)

- Short veg grassland declines ~950 km² (-1%)

- Barren lands increased due to fire ~710 km²

- They interpret as expansion – but say they do not have confidence in ability to identify subtle veg growth (shrub expansion?)
Neigh et al. 2008
Results – Mackenzie River Delta

Temperature and precipitation

Increase growing season length
Increase monthly temperature
Increased mean NDVI
Neigh et al. 2008
Results – Oklahoma Panhandle

- Agriculture and pasture land
- Precipitation is limiting to vegetation growth
- Temporal variation in crop types
Neigh et al. 2008
Results – Oklahoma Panhandle

Land cover
• Map accuracy – 87.6-91.7% (air photos and Ikonos)
• Increase in agricultural (+23%)
• Decline in short veg grassland
Neigh et al. 2008
Results – Oklahoma Panhandle

Increase in corn yields

Increase in NDVI and center-pivot irrigation

1989                                           1999

Increase in NDVI and center-pivot irrigation
Neigh et al. 2008
Results – Oklahoma Panhandle

• Abiotic variability – no impact on vegetation in the region
  – Droughts common – agricultural areas not impacted (irrigation)

• Verify lack of abiotic changes on increased NDVI, examined the NASS USDA crop records
  – Counties in NDVI anomaly area had increased corn production
  – Counties without increase in NDVI did not have increased corn production

• Conversion from wheat to corn and center pivot irrigation – NDVI increase in AVHRR imagery
  – Visible in Landsat
Neigh et al. 2008

Notes

1. Broad-scale vegetation patterns understood through multi-resolution datasets (scale of mechanism)
   1. Local scale drivers of coarse scale trends
   2. NDVI anomalies influences by interacting factors
2. Identified meaningful relationships between NDVI and variables
3. Only identified positive NDVI trends (droughts, insect outbreaks)
4. Validation of land cover maps
   1. 2000 imagery had most validation pts
   2. 1975 and 1990 - digital aerial photography
   3. Some rare land covers not/under represented in error matrices
Neigh et al. 2008
Questions

1. Were their interpretations valid?

2. Did the multi-scale approach address MAUP concerns?
   1. AVHRR>Landsat>Aerial photos>Ancillary data

3. Opportunities to perform a multi-scale analysis with your research projects?