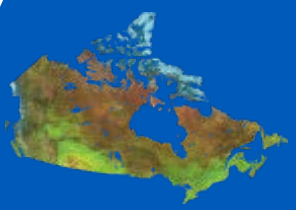
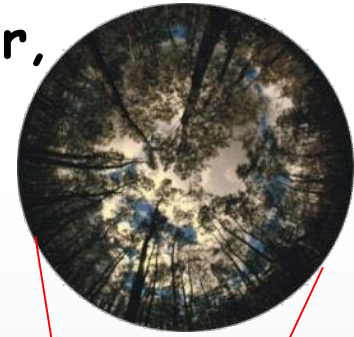
CFS CANADIAN FOREST SERVICE
SCF SERVICE CANADIEN DES FORÊTS
cfs-scf.nrcan-rncan.gc.ca

Update on Biomass Mapping Needs and EO Approaches in Canada



A. Beaudoin, R.J. Hall, M.A. Wulder, J. White,
P. Bernier, P. Villemaire, S. Tolszczuk-Leclerc,
L. Guindon, R. Skakun, H. Chen, D. Leckie, J. Luther,
G. Hobart, C. Boisvenue, G. Stinson.

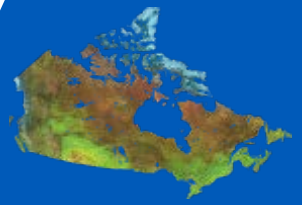


Canadian Forest Service,
Natural Resources Canada

CSA ASC

GlobBiomass 1st User Workshop
Vienna, Austria, 2-4 Feb 2016

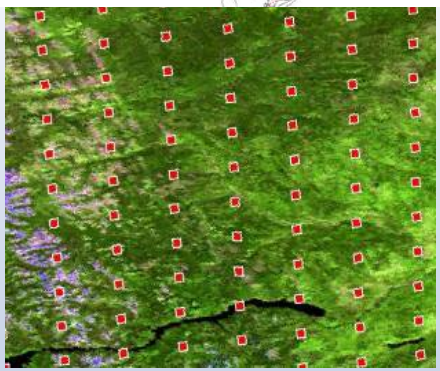
Outline



- 1. Context and Needs
- 2. Challenges
- 3. Mapping at 250 m (strategic purposes)
- 4. Mapping at ≈ 25 m (operational purposes)
- 5. Perspectives and Concluding Remarks
- 6. References and Acknowledgements

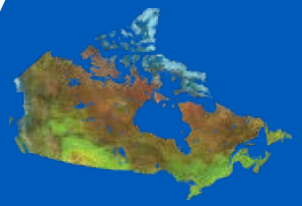
1. Context and Needs

- **Canada's forest context and EO:**
- 10% of the world's forest, treed area ≈ 4 Mkm^2
- Forest ecosystems cover ≈ 60%
- **NFI provides a framework for the collection of attributes:**
  - National systematic sample
  - 2km x 2km photo plots on a 20km grid (~20,000) = 1% sample
- **Monitoring Strategy:**
  - 5-year sample & reporting capability
  - Within a 10-year remeasurement cycle
  - Interagency collaboration



Gillis et al (2005)
For. Chron. 81:214-221

1. Context and Needs



- **EO is mandatory towards wall-to-wall mapping & monitoring at higher frequency:**
  - Cover types
  - Disturbance and recovery
  - Attributes including **biomass (AGB) -> carbon pools**

- CFS portfolio includes remote sensing R&D projects within a Nat'l NFI-based EO monitoring framework

- Supported by Can. Space Agency and various partners

- 3rd party biomass maps are sometimes:
  - Evaluated/compared for potential use
  - Developed with contributions from CFS (Biomasar-C…)

1. Context and Needs

- **Biomass needs:**
  - Canada State of Forest report: National Forest Inventory
  - Indicator of Carbon (C): CO_2 uptake & C indicator, potential inputs to calculate and forecast C budgets (CBM-CFS)
  - Resource assessment: bio-energy, forest productivity, forest state indicator
- **Key users:**
  - National Forest Inventory (NFI)
  - National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS)
  - Bio-energy sector

2. Challenges

- **General challenges:**
  - Using non-optimal Nat'l Cal/Val data sets:
    - Ground inventory plots
    - NFI photo plots
    - Surrogate LiDAR plots
  - Getting complete, repetitive, free archived & highly-processed EO imagery
  - Integrating multi-source optical/SAR EO time-series: Landsat, Palsar, Rsat-2…(synergism)
  - Decreasing processing burden
  - Mapping poorly-inventoried northern forests
  - Developing EO-based allometric equations

2. Challenges

- **Improving AGB map product specifications:**
  - From strategic to operational scales: 250 m -> 25 m res
  - From static to dynamic using EO time-series: integrating lc/disturbance/recovery with biomass loss/gain
  - From total AGB to AGB by species, by partitions → carbon pools
  - Assimilable in spatially-explicit version of Carbon Budget Model-CFS ?
  - Nested in a coherent & dynamic suite of forest properties
  - Uncertainty better assessed along with error maps

- **Overall, increasing relevance of AGB map products** for modelling assimilation & decision-making support

3. Mapping at 250 m: MODIS-based approach

Cal/Val sets

NFI photo-plots

EO sets (2001-2011 +)

250 m MODIS yearly time-series

(NRCan/CCRS)

Multi-year kNN

Decision/regression trees

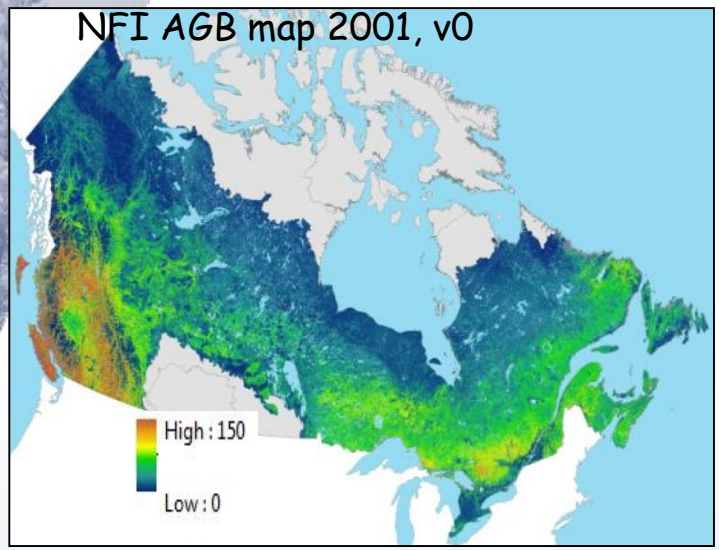
Output maps

Multi-year attribute maps

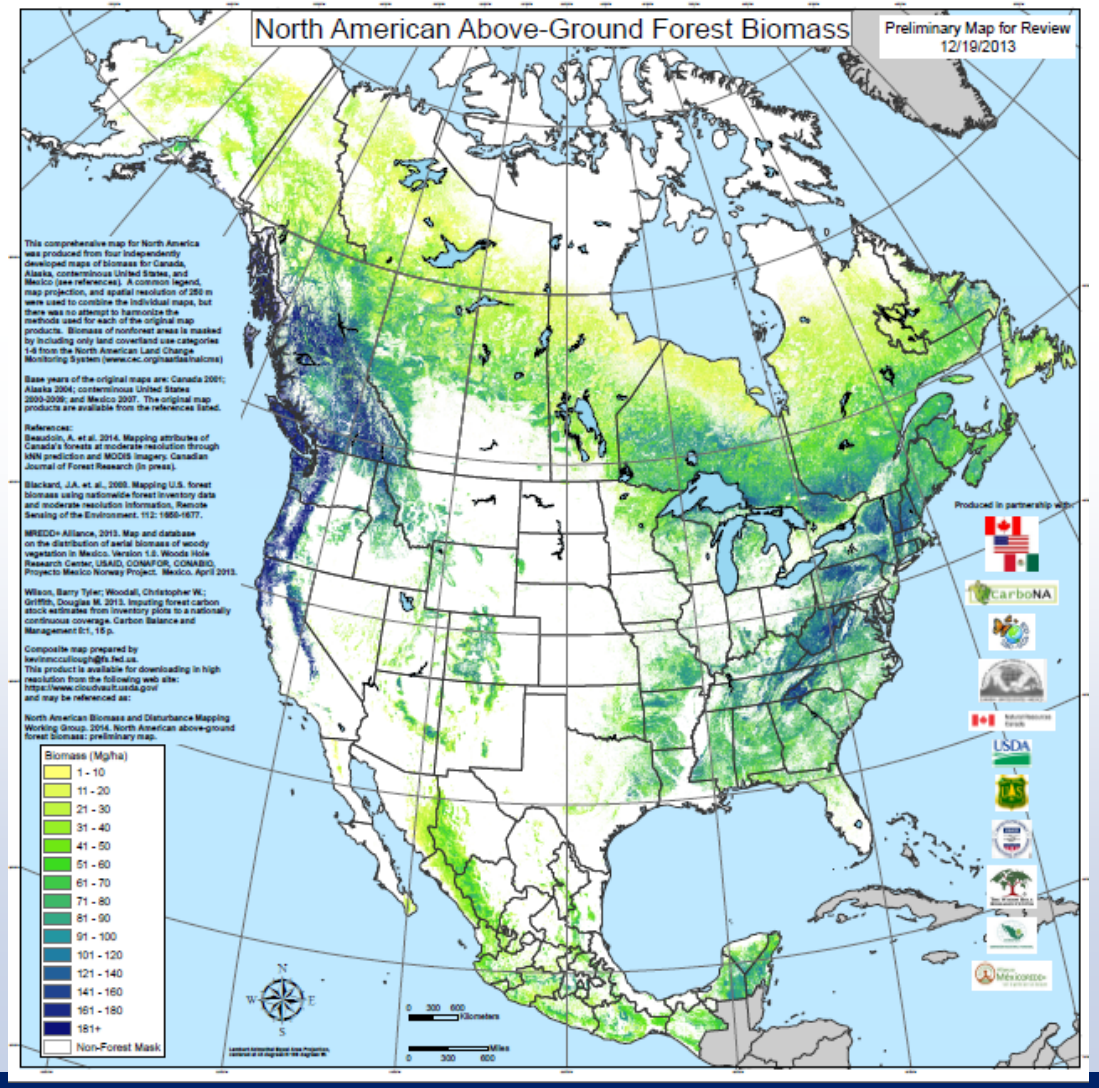
Change maps (type, year, fraction)

Attribute loss, recovery, rate

3. Mapping at 250 m: 2001 NFI AGB mapping

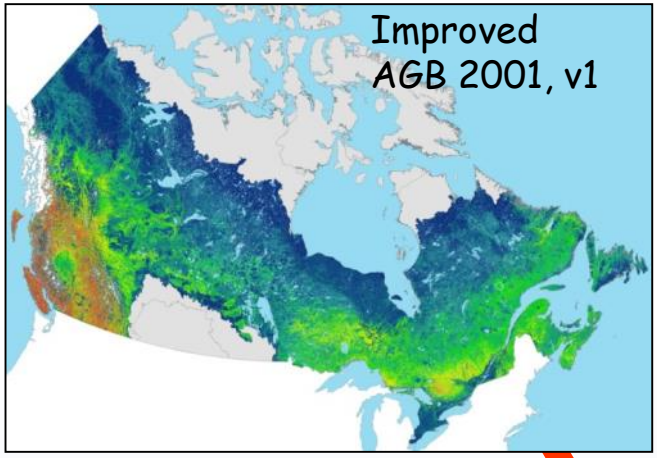


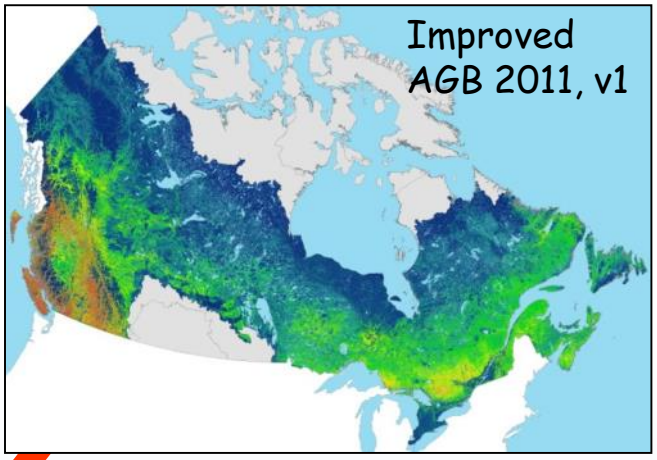
Beaudoin et al. (2014) CJFR 44:521-532
(see complete references at the end)



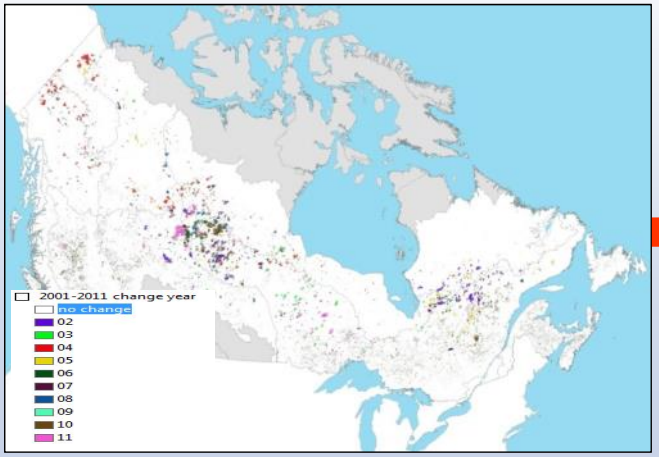
3. Mapping at 250 m: 2001-2011 NFI AGB change

temporal biomass

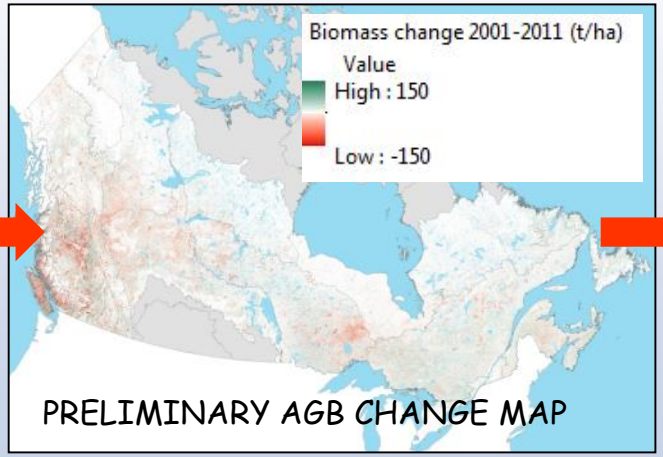




Disturbances



Guindon et al. (2014) CJFR 44:1545-1554

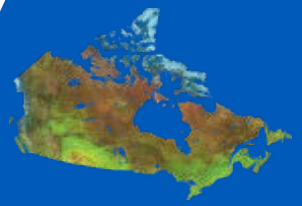


10-yr attributes loss/recovery

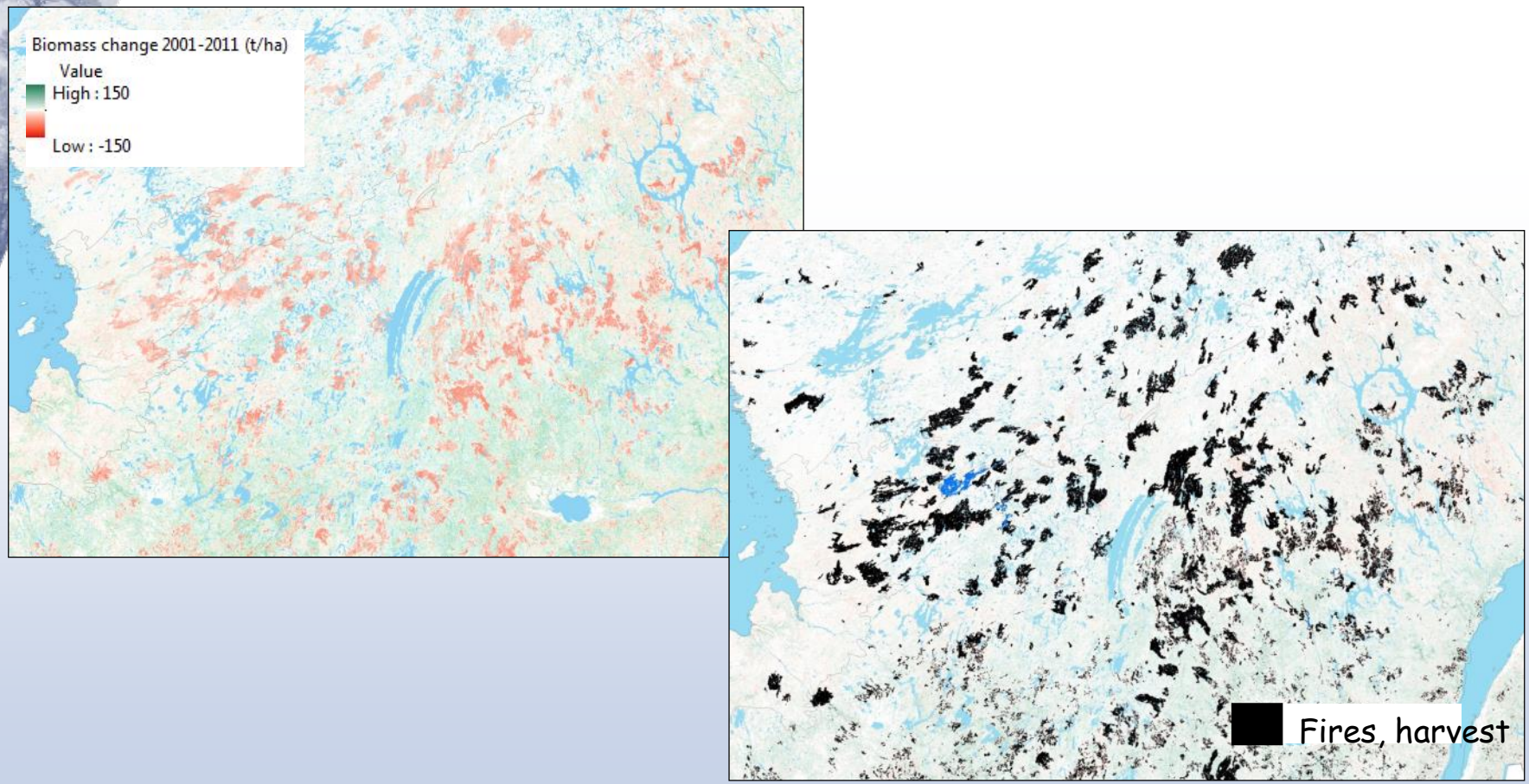
Total AGB,
AGB / species,
AGB / partitions

Beaudoin et al. (in prep)

3. Mapping at 250 m: 2001-2011 AGB change



Regional example: Central Quebec, preliminary 10-yr AGB change within fires and harvested areas



4. Mapping at 25 m: Key muti-source EO approaches

LiDAR Cal/Val sets

Opt /SAR time series

Airborne LiDAR Scanning

ICESAT -GLAS

Landsat dense time-series

PALSAR yearly time-series

Temporal Compositing

kNN modelling

Change detection, trend analysis

Emphasis on northern boreal forests

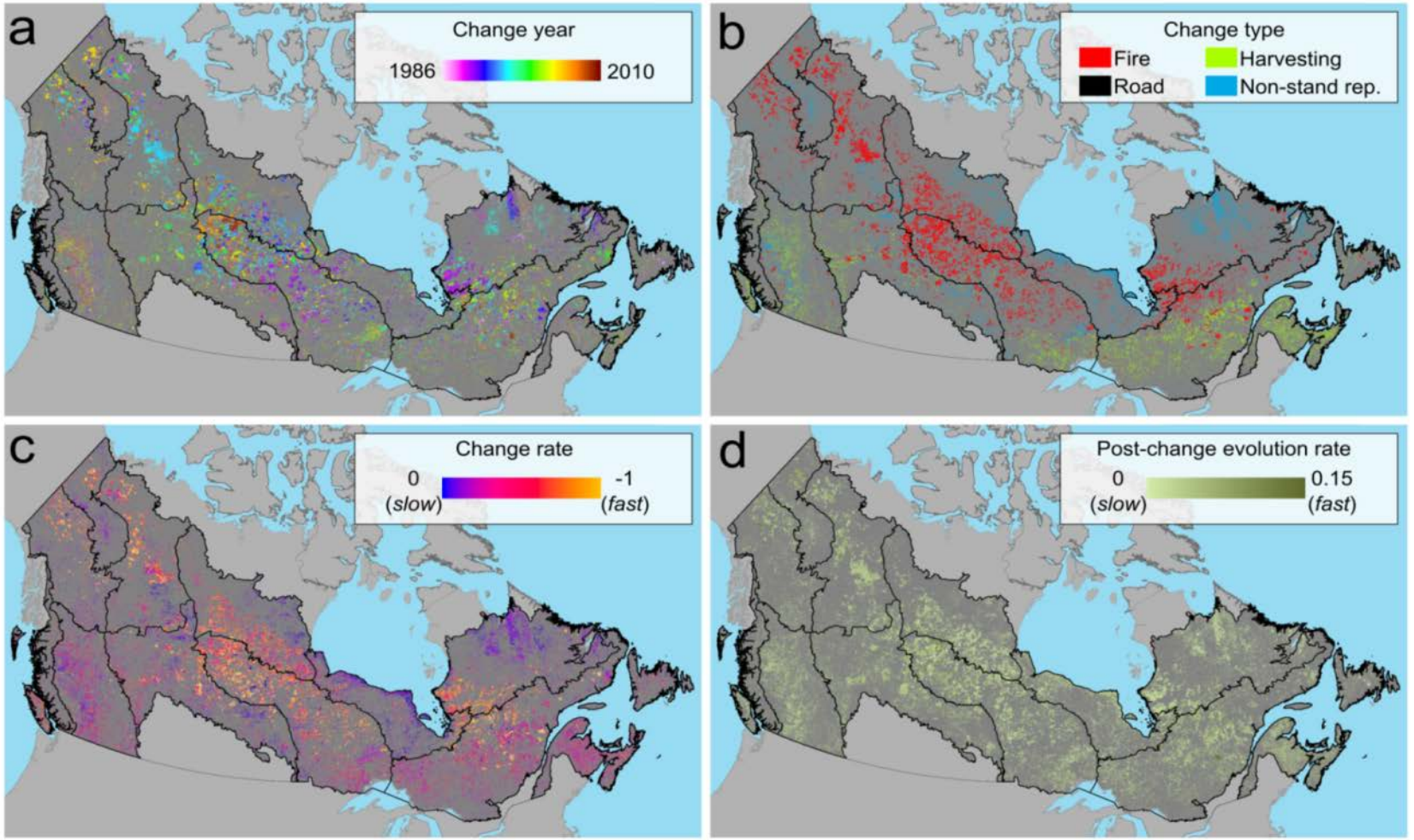
Output maps

Attributes

Changes & trends

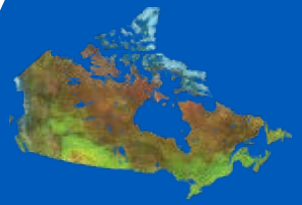
Attribute dynamics

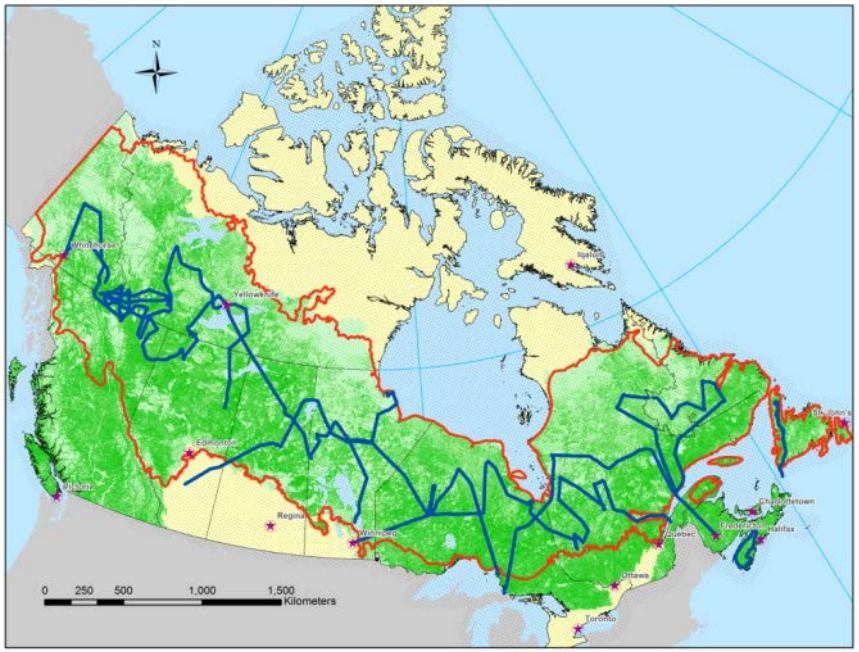
4. Mapping at 25 m: Nat'l Landsat trends in forest change

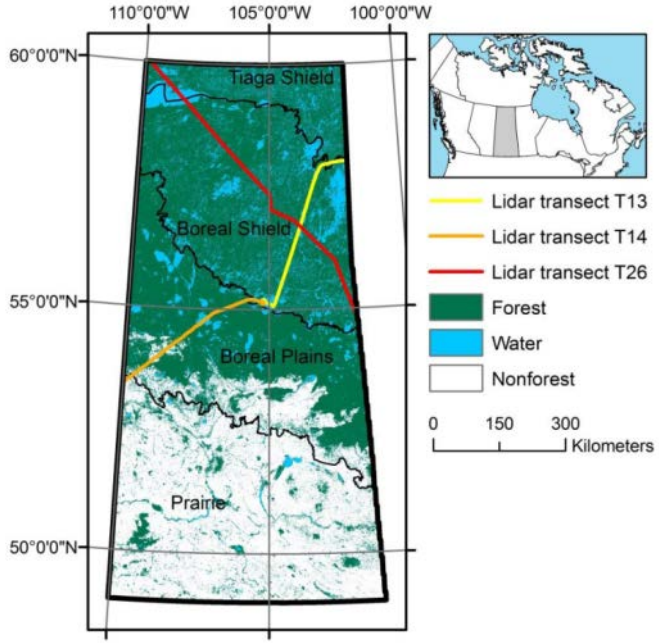


Hermosilla et al. (2015) RSE 158:220–234

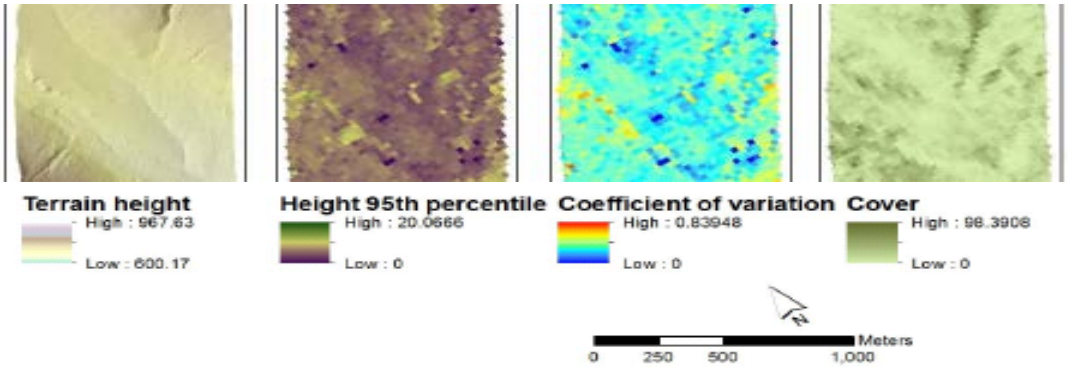
4. Mapping at 25 m: Airborne LiDAR plots



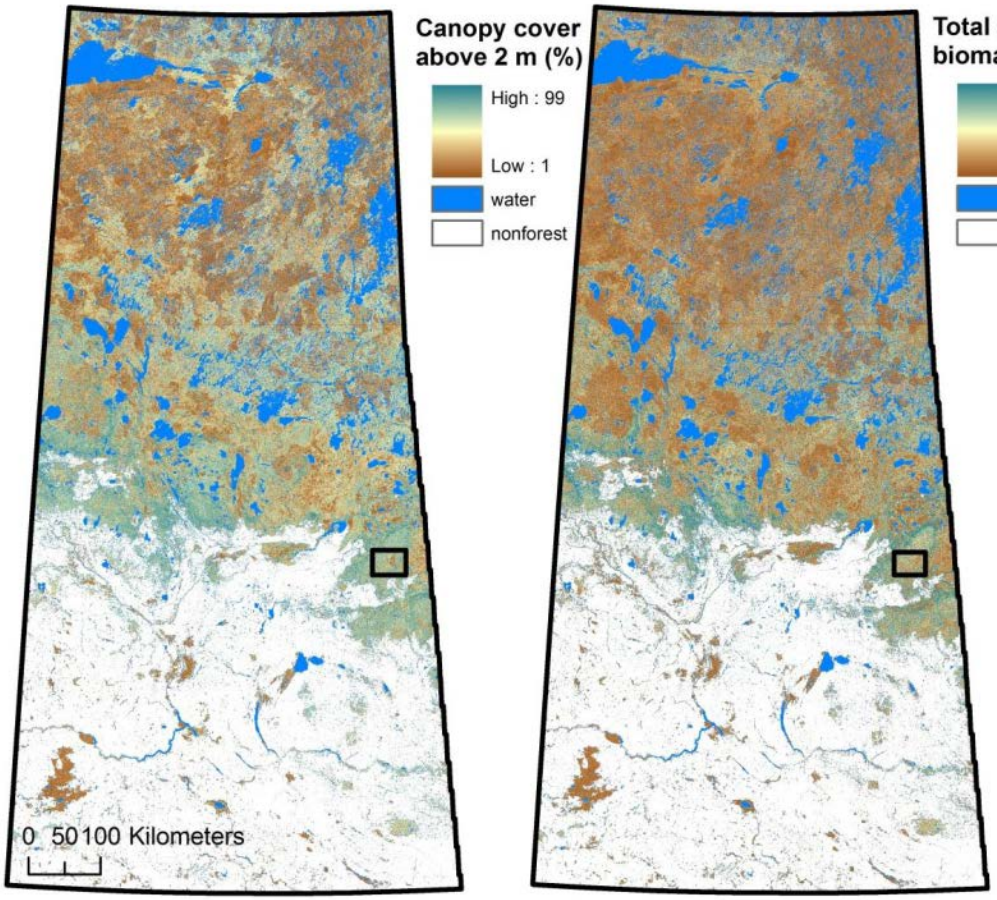


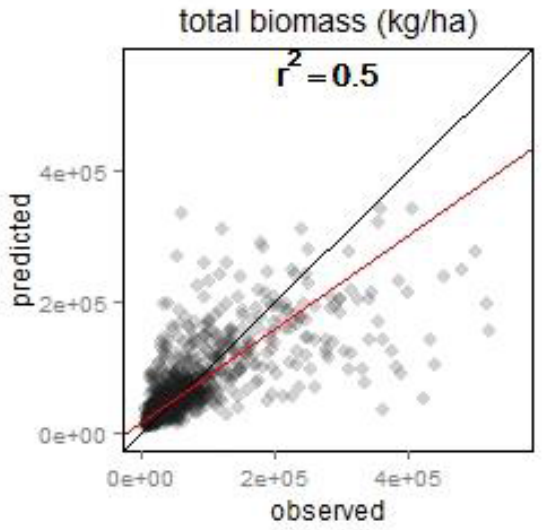


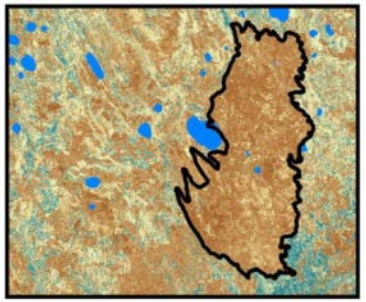
Wulder et al. (2012) CJRS 38(5):600-618



4. Mapping at 25 m: AGB/cover from LiDAR plots & Landsat

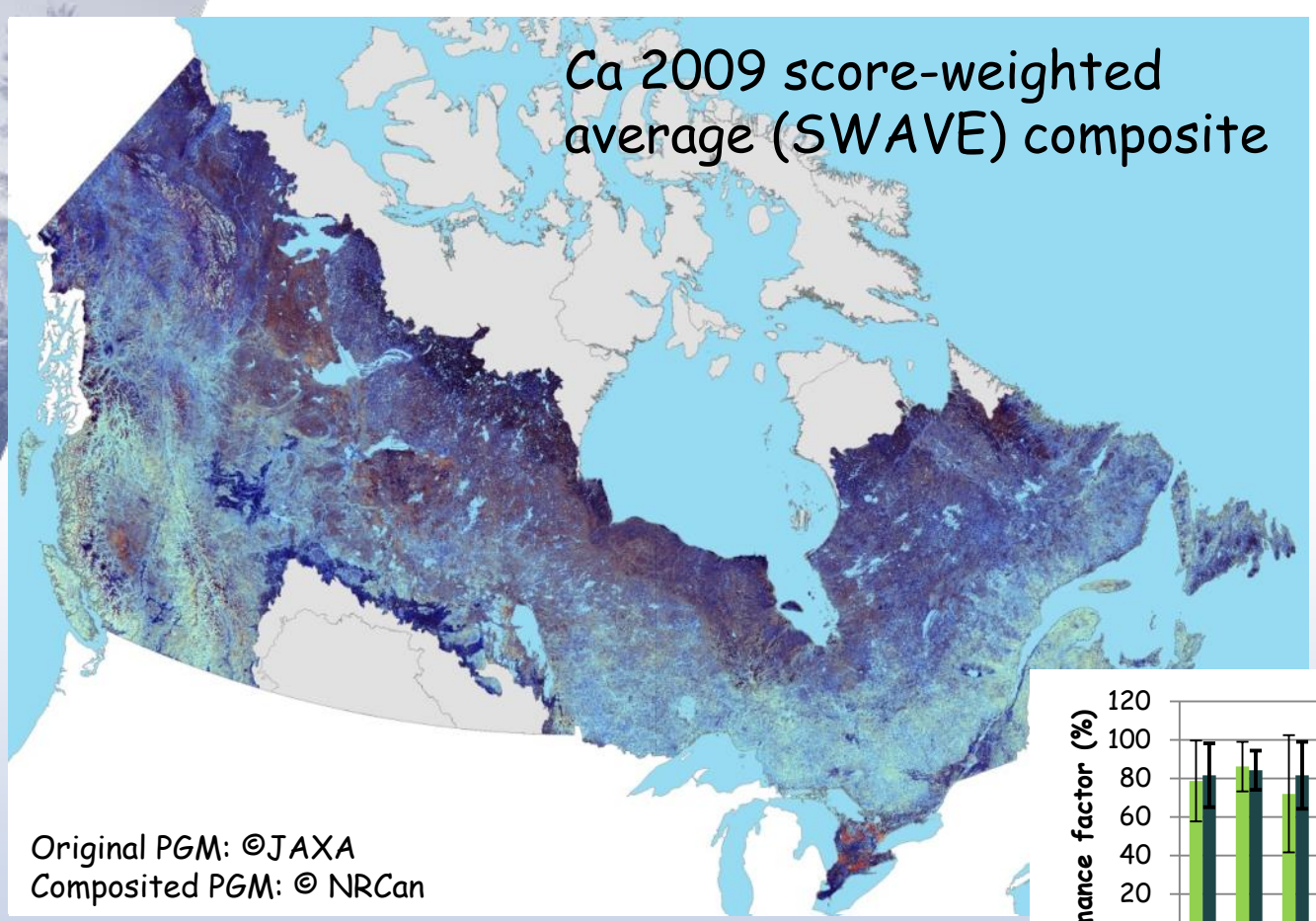


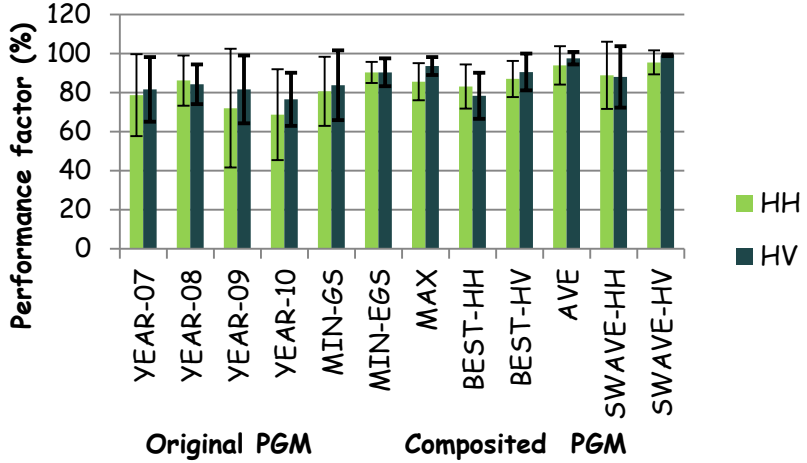




Zald et al. (2016) RSE 176:188-201

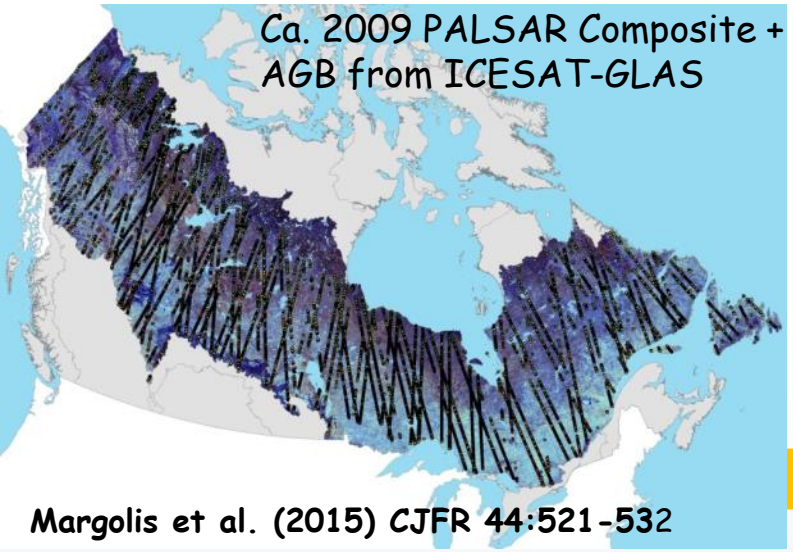
4. Mapping at 25 m: PALSAR Global Mosaic compositing



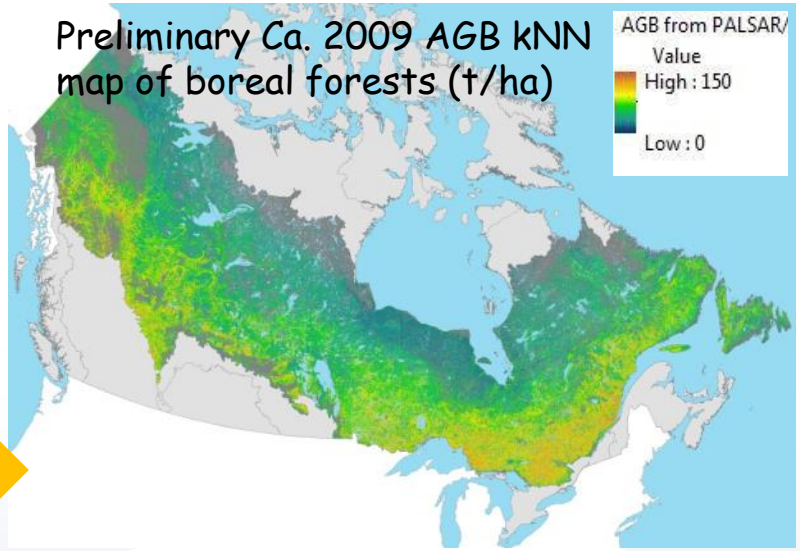


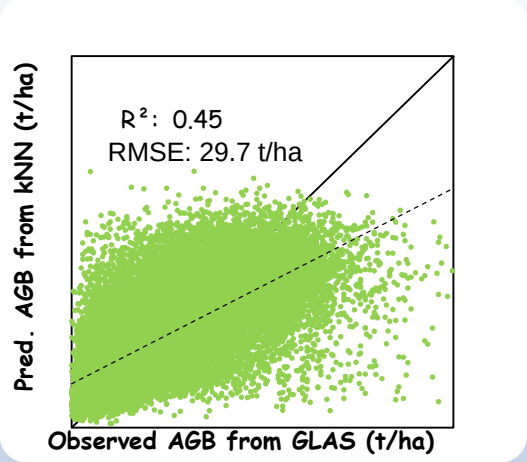
Beaudoin et al. (in prep)

4. Mapping at 25 m: AGB from PALSAR & ICESAT-GLAS



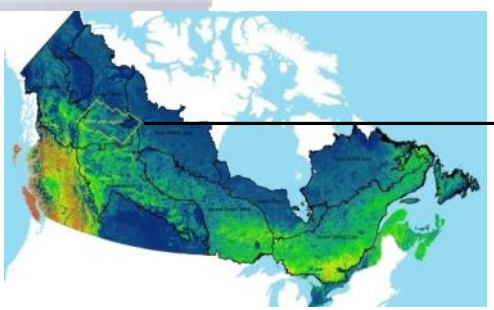
Margolis et al. (2015) CJFR 44:521-532



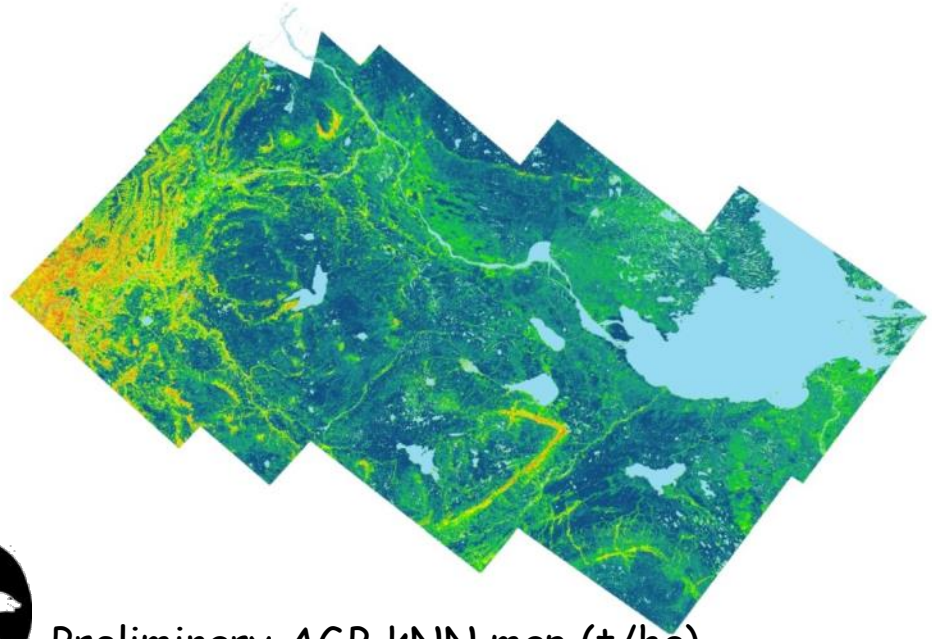


Beaudoin et al. (in prep)

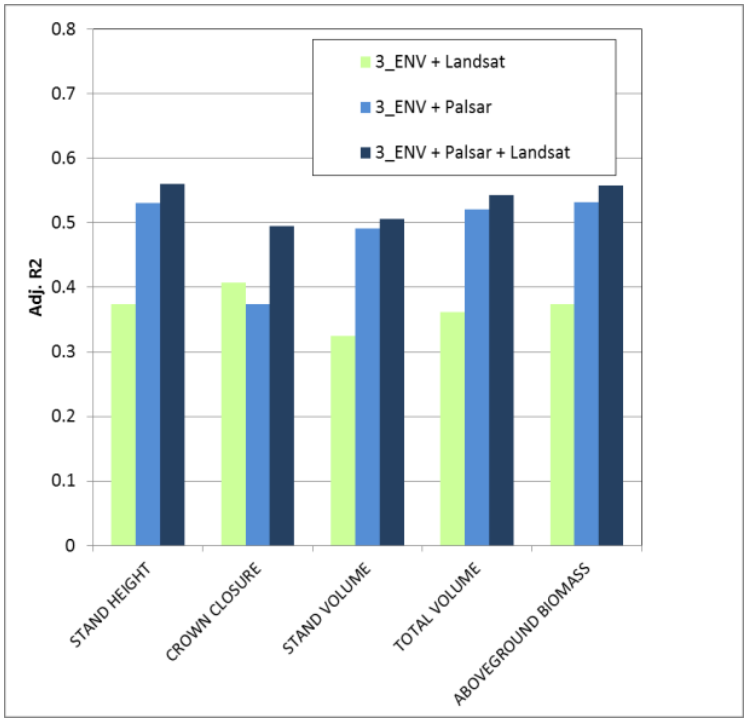
4. Mapping at 25 m: Regional mapping for inventory purposes



- 220 000 km², Northwest territories
- Ref set: Icesat GLAS-based attributes (5)
- Predictive variables:
  - 3 envir. Variables (3)
  - 2007 landsat (3) + Palsar (3)

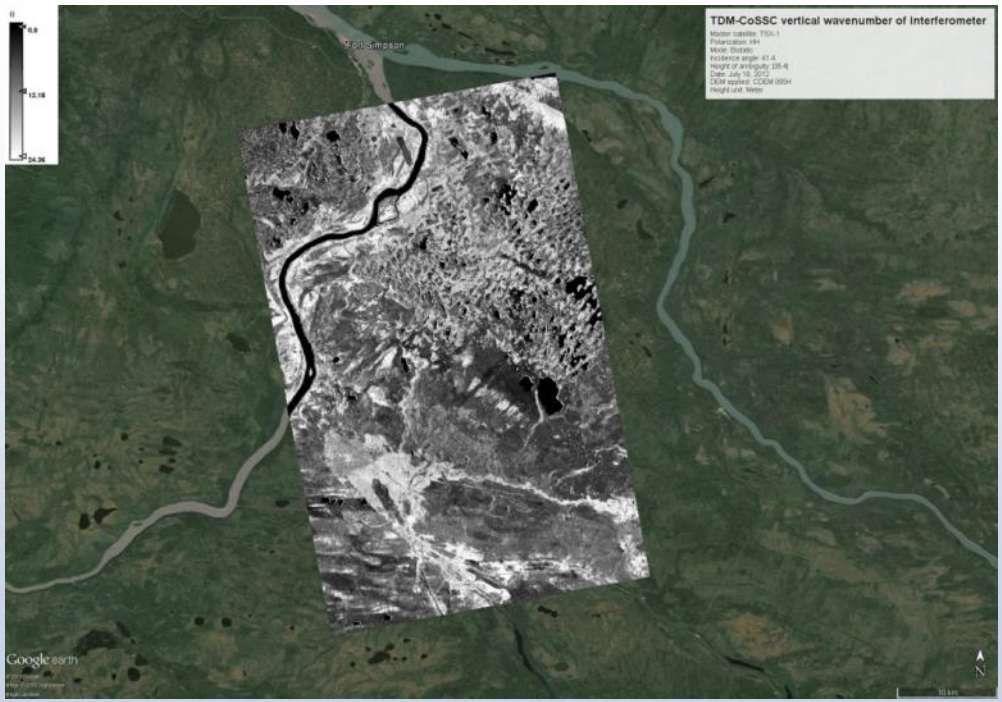


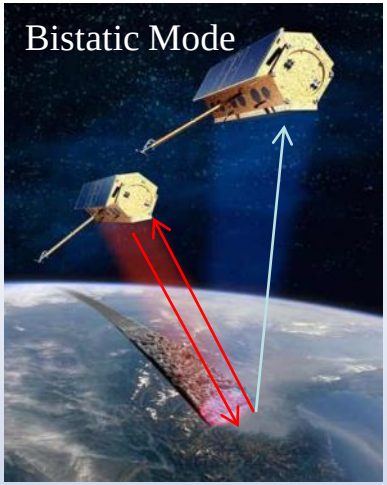
Preliminary AGB kNN map (t/ha)



4. Mapping at 25 m: SAR R&D for improved mapping

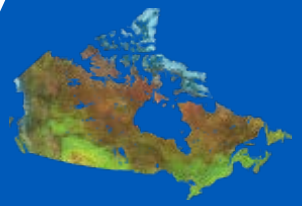
- TanDEM-X: a space-borne constellation of two X-band polarimetric interferometric SAR satellites
- An example of TanDEM-X forest canopy heights over NWT (CoSSC data provided courtesy of DLR)





H. Chen et al. (2015) IGARSS 2015

4. Perspectives & Summary Remarks



1. Wide range of biomass information needs in Canada
2. Calibration/Validation of large area estimates always a challenge, similarity among different methods/products can be an indicator
3. No single approach is optimal, objective is to integrate multi-source EO and best cal/val data sets, and allometric functions at 25 m resolution
4. Methods development is a dynamic process:
   - Greater use of active remote sensing technologies (eg., LiDAR, Radar: PALSAR, Rsat-2… BIOMASS ?)
   - Implement a land cover monitoring and disturbance update framework for national biomass monitoring and mapping

Acknowledgments

- Natural Resources Canada, Canadian Forest Service
- Government Related Initiatives Program (GRIP) of the Canadian Space Agency (3 on-going projects)
- Japanese Aerospace & eXploration Agency (Palsar Global Mosaics)
- Numerous provincial, industrial and crown corporations in support of NFI and EO-based inventory
- Collaboration with Canada Centre for Remote Sensing