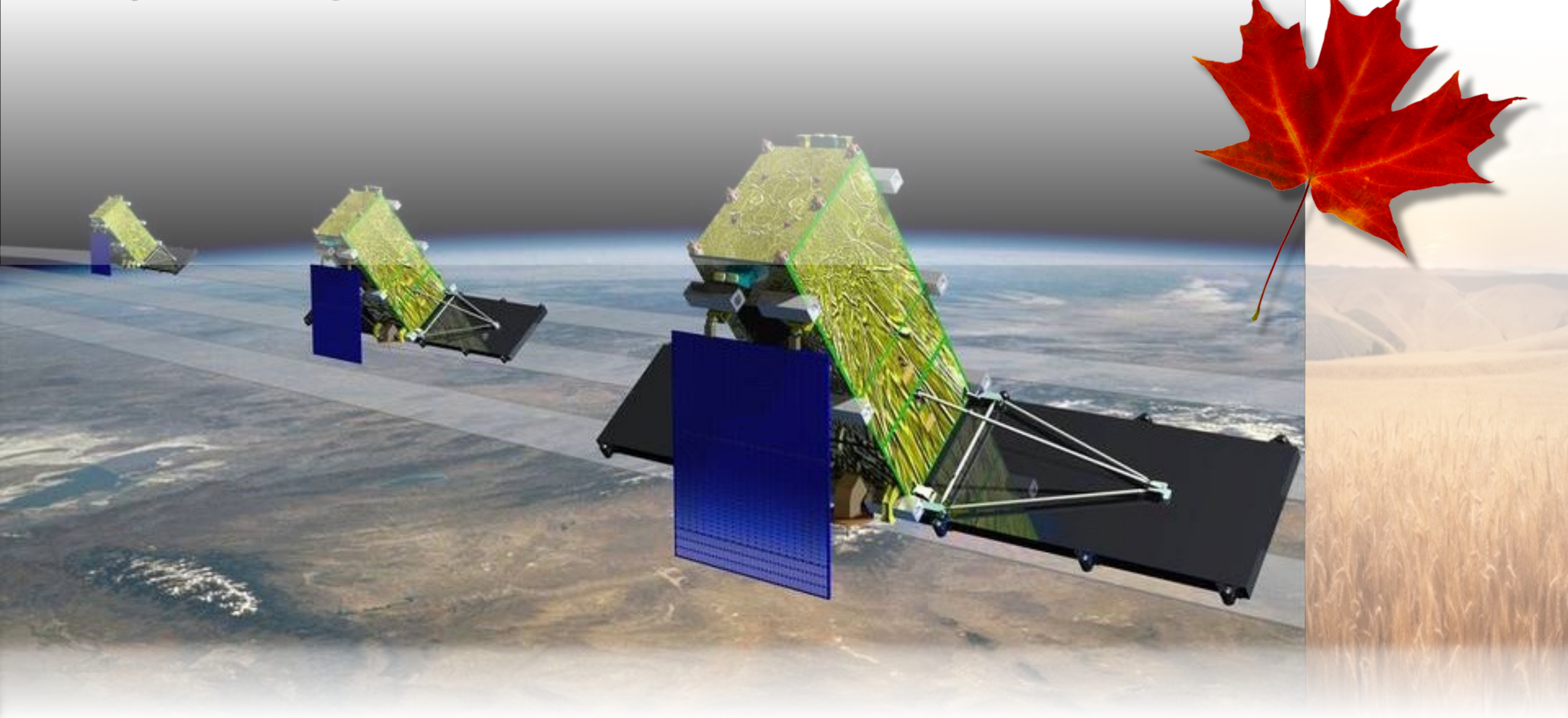


Virtual Constellations to Monitor Agriculture

Dr. Heather McNairn
Agriculture and Agri-Food Canada

Canada

Value of Virtual Constellations

Examples of research by AAFC-EORBT Team

- Crop classification
- Crop condition
- Crop phenology
- Soil tillage

Soil water using time series of Sentinel-1 (led by Dr. Anna Balenzano)

Hierarchy of Importance

Time

(covers growing season & at critical development stages)

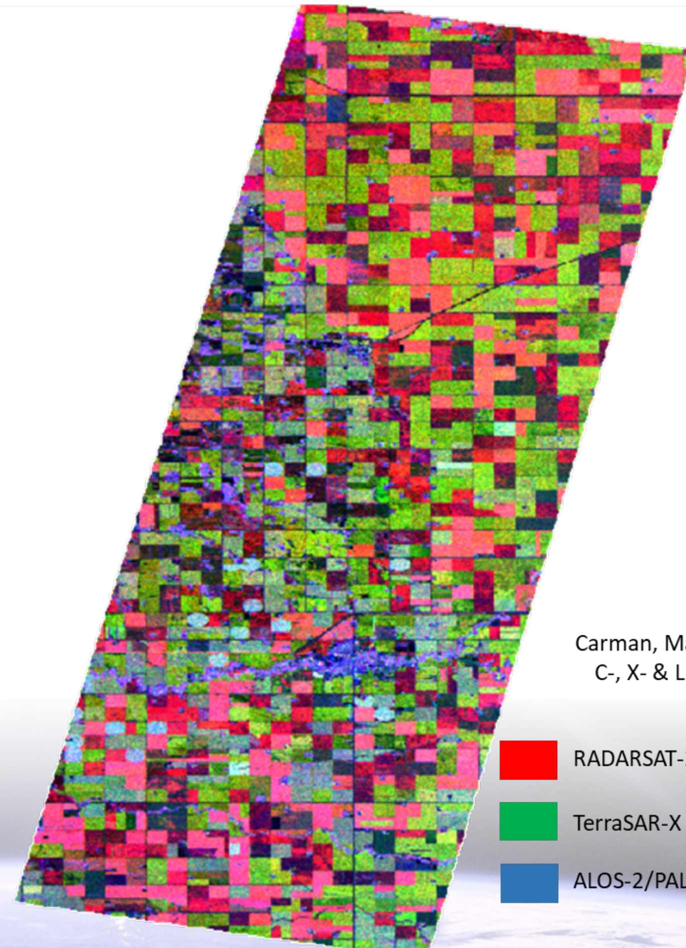
Frequency

(soils: lower is better
crops: need 2+ frequencies)

Polarization

(huge benefits with QP or CP)

Virtual Constellations



Carman, Manitoba 2016
C-, X- & L- band SAR.

RADARSAT-2 2016-07-27 VH
TerraSAR-X 2016 -07-26 VV
ALOS-2/PALSAR-2 2016-07-03 VH

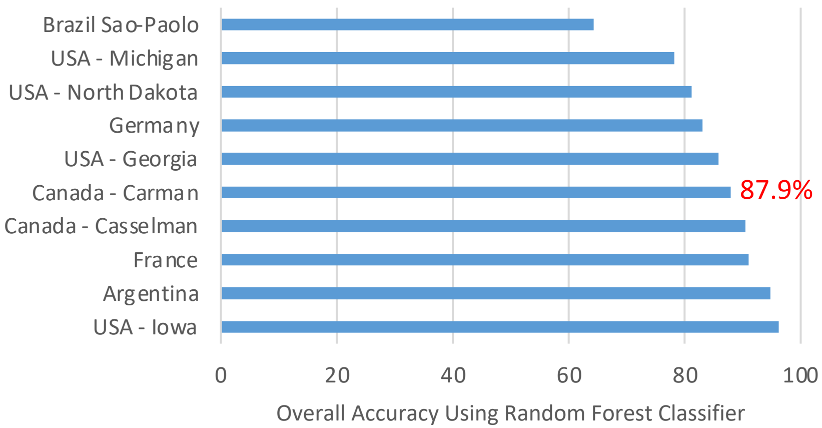
Virtual Constellations – AAFC Experience

	Crops			
	Classification	Growth Stage	Condition	Tillage
RADARSAT + Sentinel-1	Ready	Demonstrated	Demonstrated	In development
C-band + one or more other frequencies	Demonstrated	Demonstrated		In development

- Limitations to move from demonstrated to ready are mostly a function of availability of consistent coverage at wide swaths at multiple frequencies
- Green: science has demonstrated capability, repeatedly (more than one site and year)
- Implementation is lagging the science; many factors but one being data availability

Crop Classification
– Dense Time Series and SAR Polarization

Virtual Constellation
Dense time series
RADARSAT + Sentinel-1



Dingle Robertson, L., Davidson, A.M., McNairn, H., Hosseini, M., Mitchell, S., de Abelleyra, D., Verón, S., le Maire, G., Planells, M., Valero, S., Ahmadian, N., Coffin, A., Bosch, D., Cosh, M.H., Basso, B., and Saliendra, N. (2020). C-Band synthetic aperture radar (SAR) imagery for the classification of diverse cropping systems, International Journal of Remote Sensing, 41: 9628-9649.

RCM ***Compact Polarimetric***
Kenaston, Saskatchewan

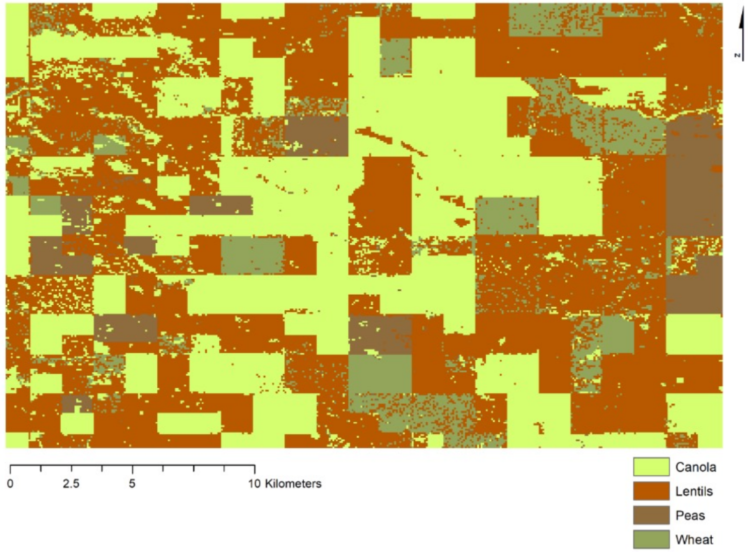
	User	Producer
Pasture/forage	91.48	86.31
Barley	94.36	91.81
Wheat	89.84	84.49
Canola	96.27	99.65
Flaxseed	98.77	49.97
Peas	99.16	87.83
Lentils	93.67	98.27
Overall	94.91	

17 CP 30m images
Stokes + m-chi parameters
Random Forest Classifier

Dingle Robertson, L., McNairn, H., Jiao, X., McNairn, C., and Ihuoma, S. Canadian Journal of Remote Sensing. Monitoring Crops Using Compact Polarimetry and the RADARSAT Constellation Mission, in press.

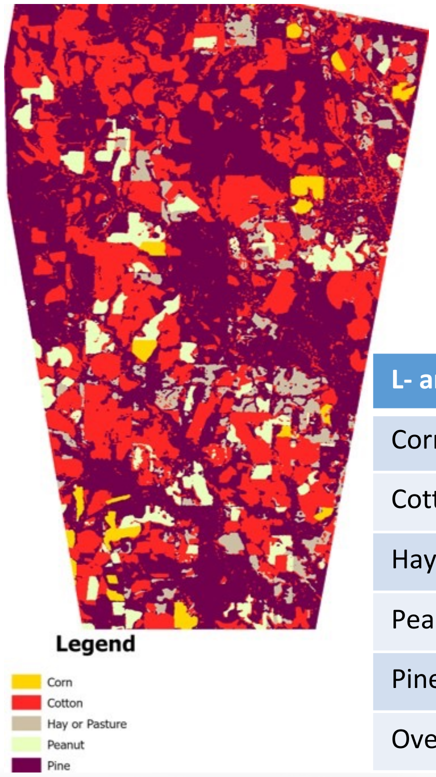
Crop Classification
– Dense Time Series and Multi-Frequency

Kenaston 2020 - ALOS L-Band, RADARSAT-2 C-Band, Sentinel-1 C-Band, TerraSAR-X X-Band



L-, C- and X-band	User	Producer
Wheat	73.6	92.9
Canola	95.5	87.8
Peas	100	72.1
Lentils	69.2	92.7
Overall	87.0	

Tifton, Georgia – ALOS L-band, TerraSAR-X X-band



Sentinel-1 VV, VH
RADARSAT-2 Quad Pol
TerraSAR-X VV, VH
ALOS-2 HH, HV

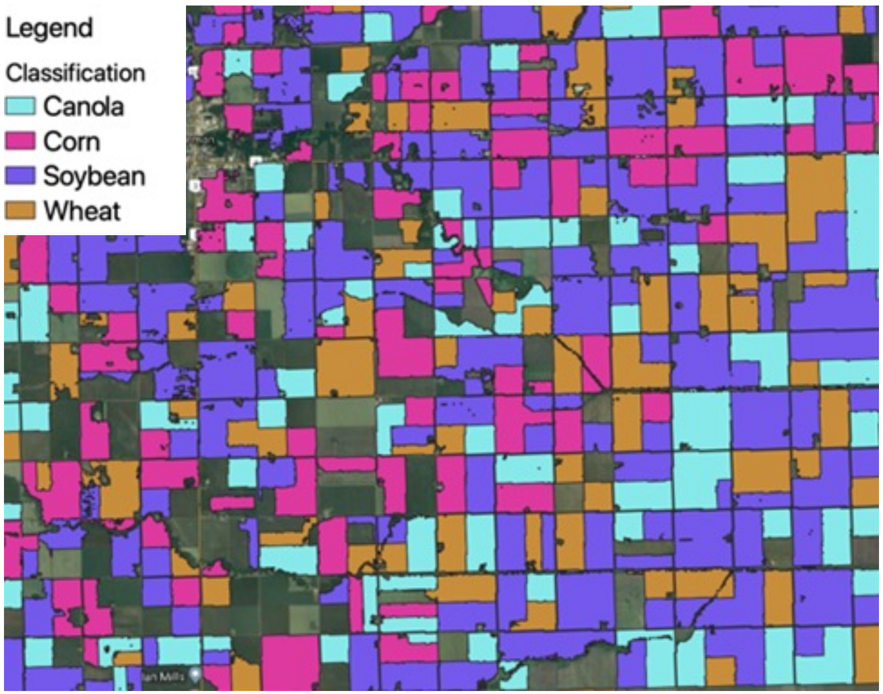
L- and X-band	User	Producer
Corn	99.9	96.9
Cotton	97.9	99.1
Hay/Pasture	99.2	88.3
Peanut	99.5	95.3
Pine	82.1	95.3
Overall	97.1	

Amee Lunger
Masters Student, Carleton University
(supervisor Dr. Scott Mitchell)

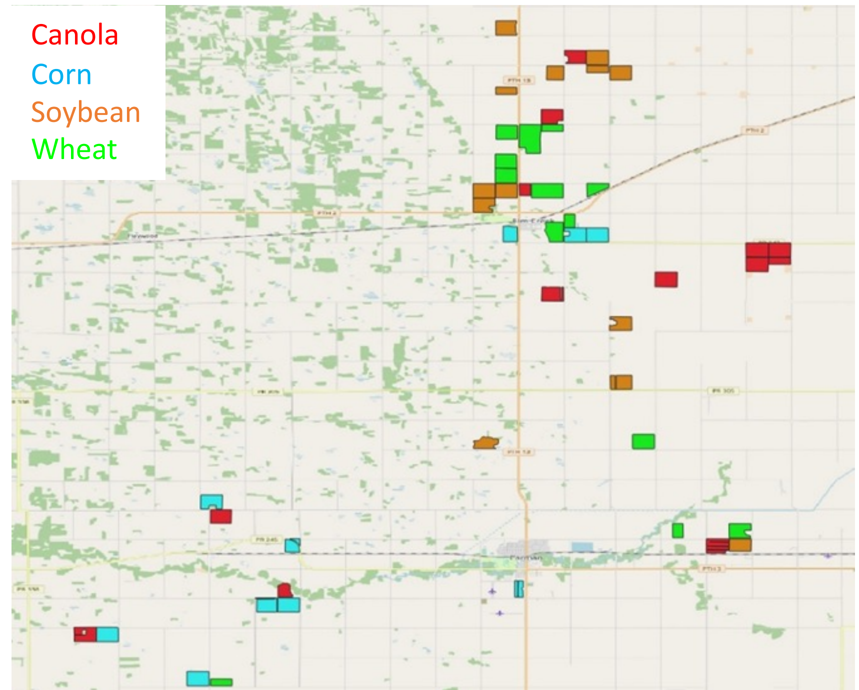
Early Season Crop Classification - Multi-frequency

Airborne Underwater Geophysical Signals

Using RADARSAT-2 and TerraSAR-X (90% accuracy)



Using RCM CP (81% accuracy)

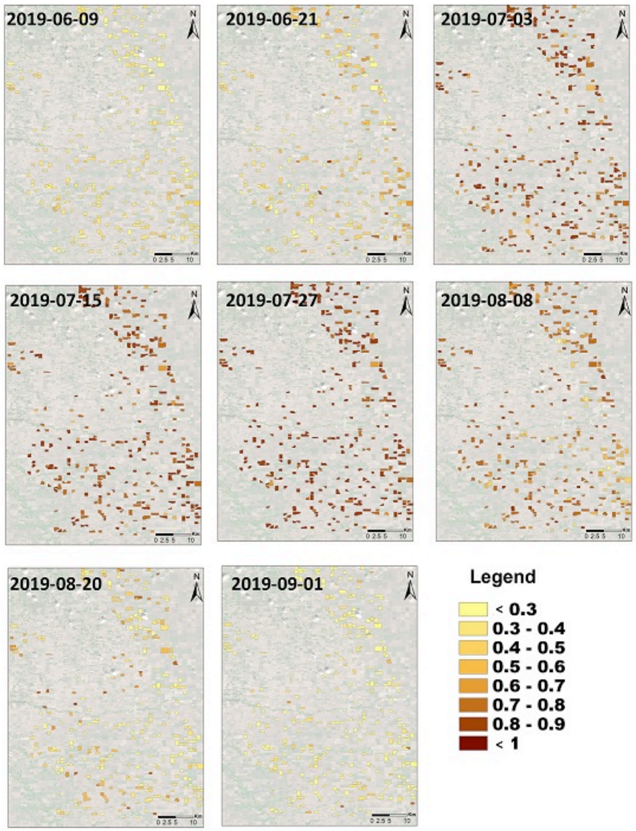


- Using machine learning classifiers
- Testing for sites in Manitoba, Saskatchewan and Alberta
- Currently estimates are for mid July but testing on-going to move this date earlier

Agri-Science Project 121 - Develop a novel crop disease risk assessment tool using remote sensing
Lead: Dr. George Lampropoulos (President and CEO) and team at AUG Signals Ltd.
AAFC Lead: Dr. Heather McNairn

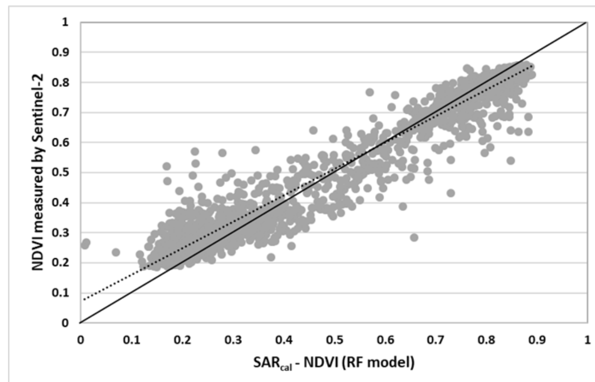
Crop Condition
– Sentinel-1 Pseudo-Polarimetric Parameters

SAR_{cal}-NDVI created using quasi-pol parameters from Sentinel-1 SLC

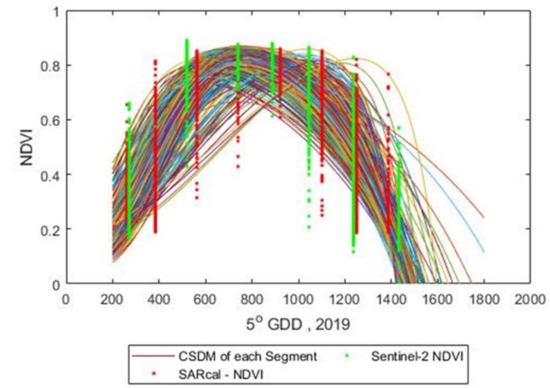


SAR_{cal}-NDVI for each Sentinel-1 acquisition
Canola crops, Carman Manitoba

Machine Learning Regressor



Daily Crop Condition



Correlation (R^2)

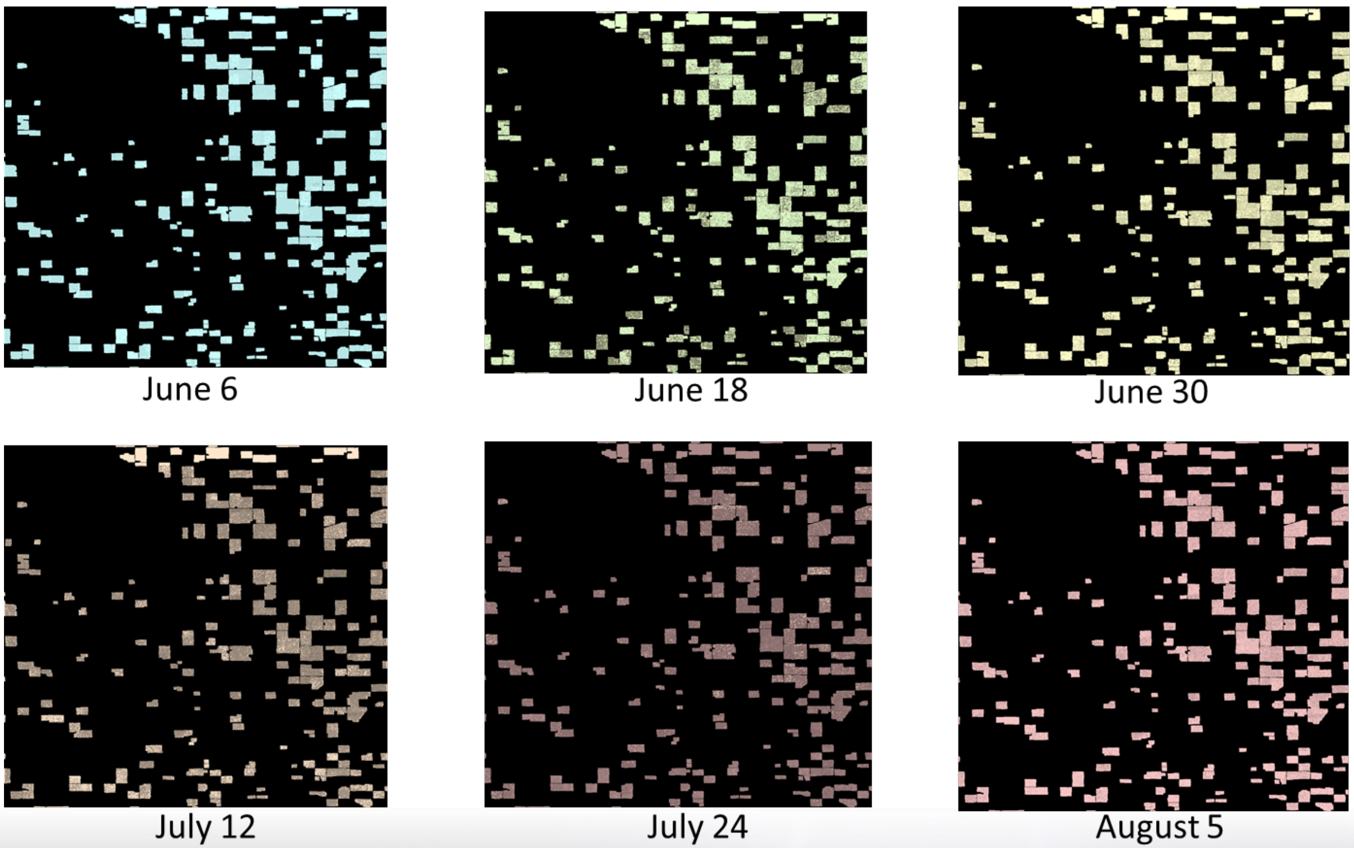
SAR and optical VI	0.89
SAR_{cal}-NDVI and biomass	0.88 (early to mid) 0.42 (mid to late)

Jiao, X., McNairn, H., and Dingle Robertson, L. (2021). Monitoring crop growth using a canopy structure dynamic model and time series of Synthetic Aperture Radar (SAR) data, International Journal of Remote Sensing, 42:6437-6464, doi: 10.1080/01431161.2021.1938739.

Jiao, X., McNairn, H., Yekkehkhany, B., Dingle Robertson, L., and Ihuoma, S. "Integrating Sentinel-1 SAR and Sentinel-2 optical imagery with a crop structure dynamics model to track crop condition", in revision.

Crop Phenology
- RCM, Sentinel-1 and Sentinel-2

Airborne Underwater Geophysical Signals



Color code

- Planted
- Leaf Development
- Bud Development
- Flowering
- Pod Development
- Ripening

Lighter means more advanced stage

Feature response model: Update of crop maturity (from accumulated GDD) based on the deviation between expected and measured polarimetric features

Manitoba 2021 RCM: (22 Stripmap and 78 ScanSAR)

RCM CP only: standard error of 6.9 days

RCM + Sentinel-1 + Sentinel-2: standard error of 5.5 days

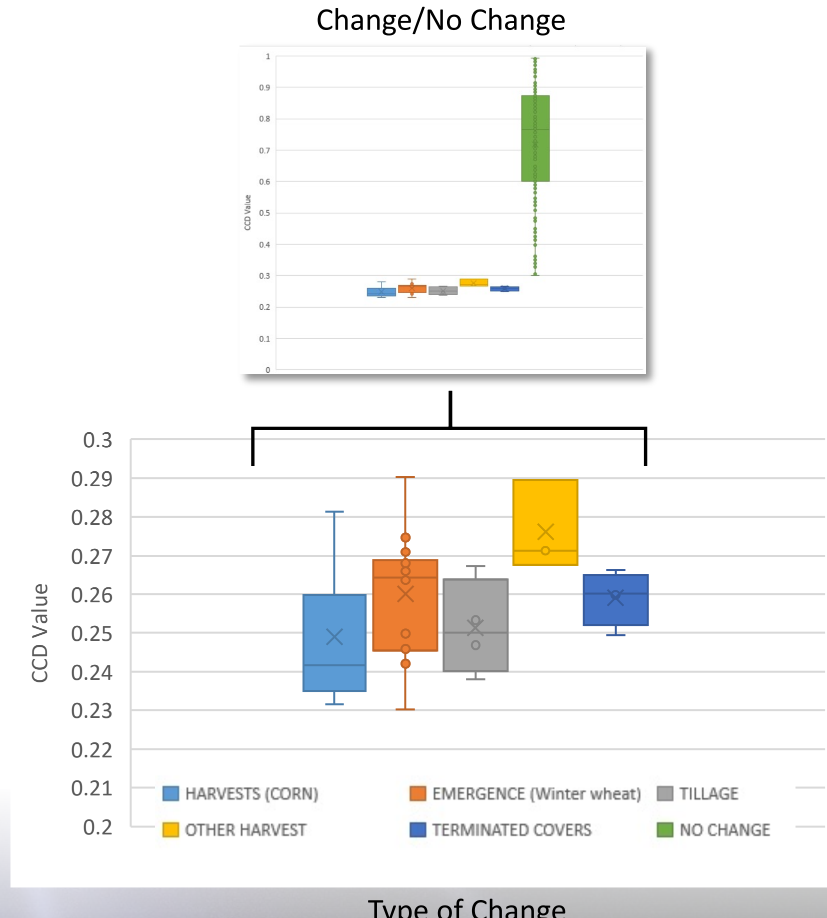
McNairn, H., Jiao, X., Pacheco, A., Sinha, A., Tan, W., and Li, Y. (2018). Estimating canola phenology using synthetic aperture radar, Remote Sensing of Environment, 219: 196-205.

Detecting Tillage
- RCM + Sentinel-1 + TerraSAR-X

Not tilling fields, or reducing tillage, promotes healthy and productive soils. This Best Management Practice (BMP) also reduces soil erosion and off site runoff.

It is important to promote these best management practices.

Pairs of RCM images (dark fields represent change)

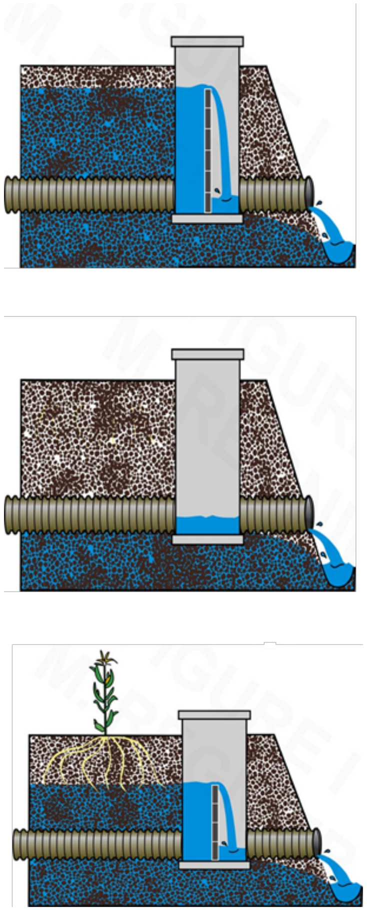


November 2_November 10, 2021 RCM 5m CP CH CCD pair
November 10, 2021 Sentinel 2 NDVI image

Collaborators: INSARSAT Inc. (Dr. Guy Seguin) and Vanderkooij Consult (Dr. Marco Vanderkooij)

Soil Water (Drainage)

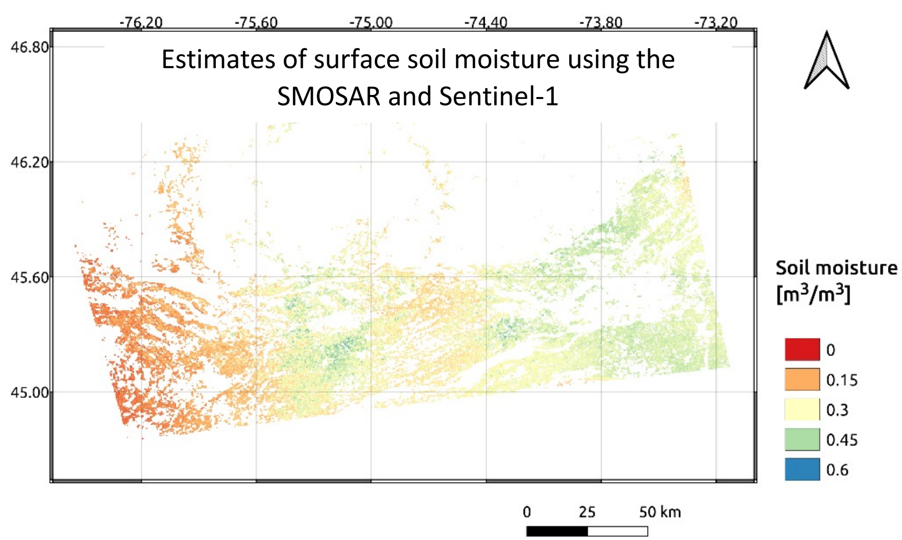
Controlled Tile Drainage
Dr. David Lapen (AAFC)



Rod Bonnett (president of the Canadian Federation of Agriculture):
"Canada is one of the few countries where climate change may create some opportunities for growing crops in northern latitudes."

In one zone of clay soil stretching from Cochrane, Ontario to Abitibi Country in neighbouring Quebec province, climate change could bring 10 million acres (about 4 million hectares) of new farmland – an area larger than Belgium – into production[1]

Soil moisture map by SMOSAR on 2018/07/30



Estimating soil moisture using Sentinel-1 time series

Balenzano, A., Mattia, F., Satalino, G., Lovergine, F.P., Palmisano, D., Peng, J., Marzahn, P., Wegmüller, U., Cartus, O., Dabrowska-Zielińska, K., Musial, J.P., Davidson, M.W.J., Pauwels, V.R.N., Cosh, M.H., McNairn, H., Johnson, J.T., Walker, J.P., Yueh, S.H., Entekhabi, D., Kerr, Y.H., and Jackson, T.J. (2021). Sentinel-1 soil moisture at 1km resolution: a validation study, Remote Sensing of Environment, 263, doi.org/10.1016/j.rse.2021.112554

[1]In Canada, climate change could open new farmland to the plow, Chris Arsenault, Thomson Reuters Foundation, 24 September 2017

Take Home Message

Research has clearly demonstrated

- Virtual constellations provide huge benefits by populating temporal data stacks, even if limited to one frequency
- Multi-frequency and multi-polarization data add critical data in particular to determine crop condition
- Multi-frequency in particular, is needed because biomass varies from crop to crop, and as crops grow (thus need differential penetration capability)

Challenges

- Require access to "consistent" wide area coverages of multi-frequency data
- Training of user communities on polarimetry