

CANADA'S NATURAL RESOURCES

NOW AND FOR THE FUTURE

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CCRS Soil Moisture and Permafrost Activities

F. Charbonneau ⁽¹⁾, ***A. Trichtchenko*** ⁽¹⁾, ***S. Wang*** ⁽¹⁾,
B. Brisco ⁽¹⁾, ***P. Budkewitsch*** ⁽¹⁾, ***N. Short*** ⁽¹⁾, ***M. Trudel*** ⁽²⁾

⁽¹⁾ Canada Centre for Remote Sensing (CCRS)
Natural Resources Canada, Ottawa, CA

⁽²⁾ École des technologies supérieures, Montréal, CA



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CCRS Context

- Part of Natural Resources Canada
- Programs Driven by Canadian Issues
 - Programs Specifically Related to Water
 - Groundwater Mapping
 - Enhancing Resilience in a Changing Climate
 - Environment Geoscience
 - Remote Sensing Sciences (focus on R&D)

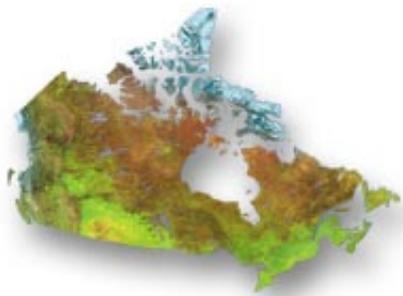


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Outline

- Active radar soil moisture
- Passive μ wave soil moisture
- Data assimilation
- Permafrost



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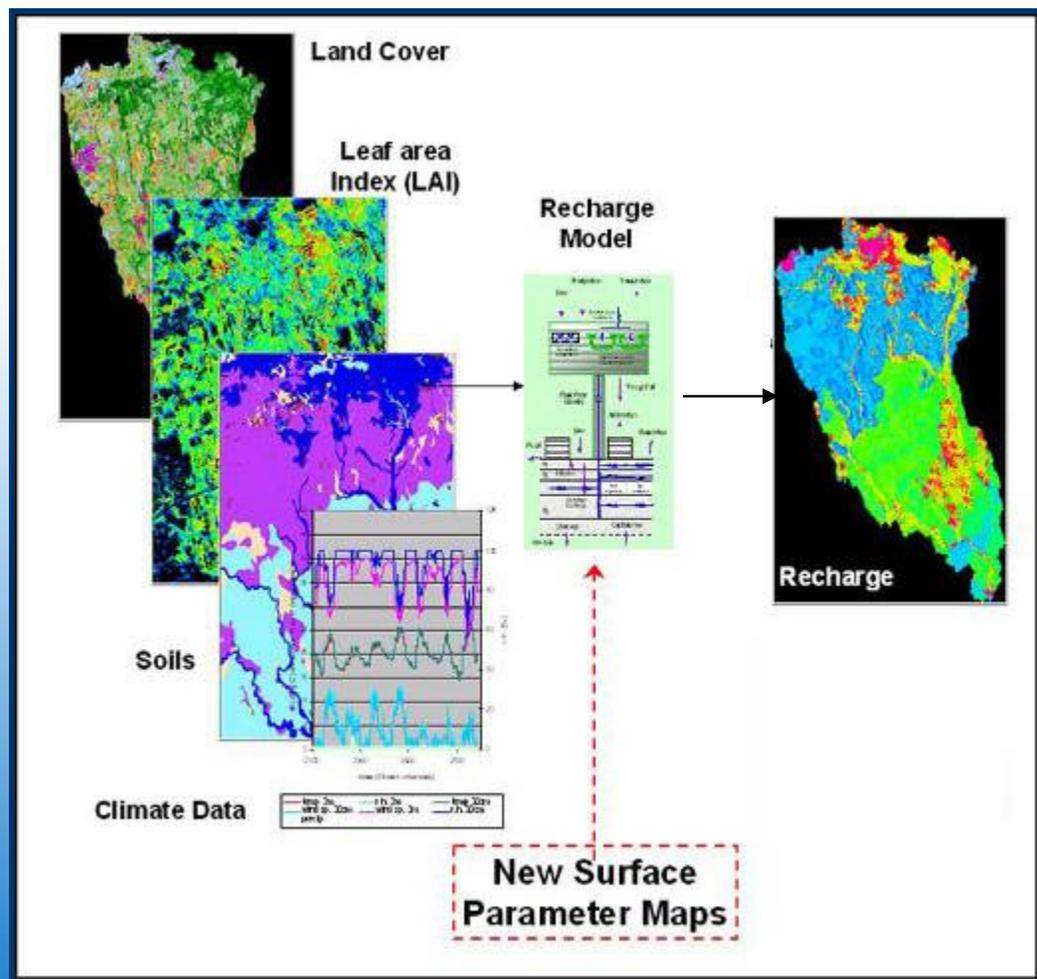
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Groudwater Project:

Recharge assessment using surface parameter maps

- Land Cover
- Leaf Area Index (LAI)
- Land Cover and LAI Time Series
- Soil Moisture Pattern
- Soil Water Sensitivity
- Specific Land Use Mapping





Active Radar: SWCS & Soil Moisture

F. Charbonneau and M. Trudel



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SAR vs Soil Surface

- **SAR intensity function:**
 - Soil moisture (M_v)
 - Surface roughness (RMS Height & correlation length)
 - Vegetation cover
 - Local slope

- **Bare surface characterization**
 - Problem:
 - 1 equation & 3 unknowns

 - Solutions:
 - Multi-Temporal
 - Multi-Polarization
 - Multi-Incidence





SAR Problematic (C-Band)

- Agriculture is dynamic,
 - low stability on surface condition
 - Multi-temporal and/or multi-incidence techniques are limited due to man practice
 - Hope contribution from Full-Quad

Snow

	April 10	April 26	May 24
Field 1	Pasture		
Field 2	Ploughed		Corn sown
Field 3	Ploughed	Barley sown	
Field 4	Pasture		
Field 5	Ploughed		Corn sown
Field 6	Ploughed		Corn sown
Field 7	Ploughed		Corn sown
Field 8	Pasture		
Field 9	Ploughed		Corn sown
Field 10	Ploughed		Soybean sown

Vegetation

3 different surface conditions in less than 2 months



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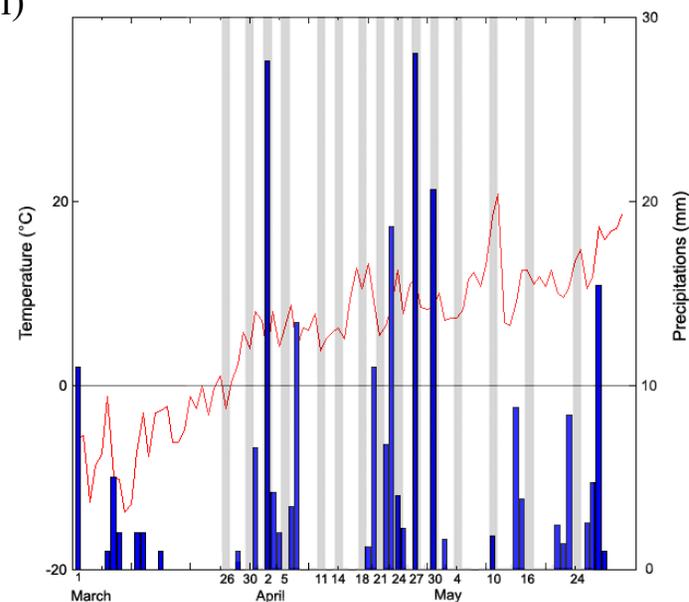
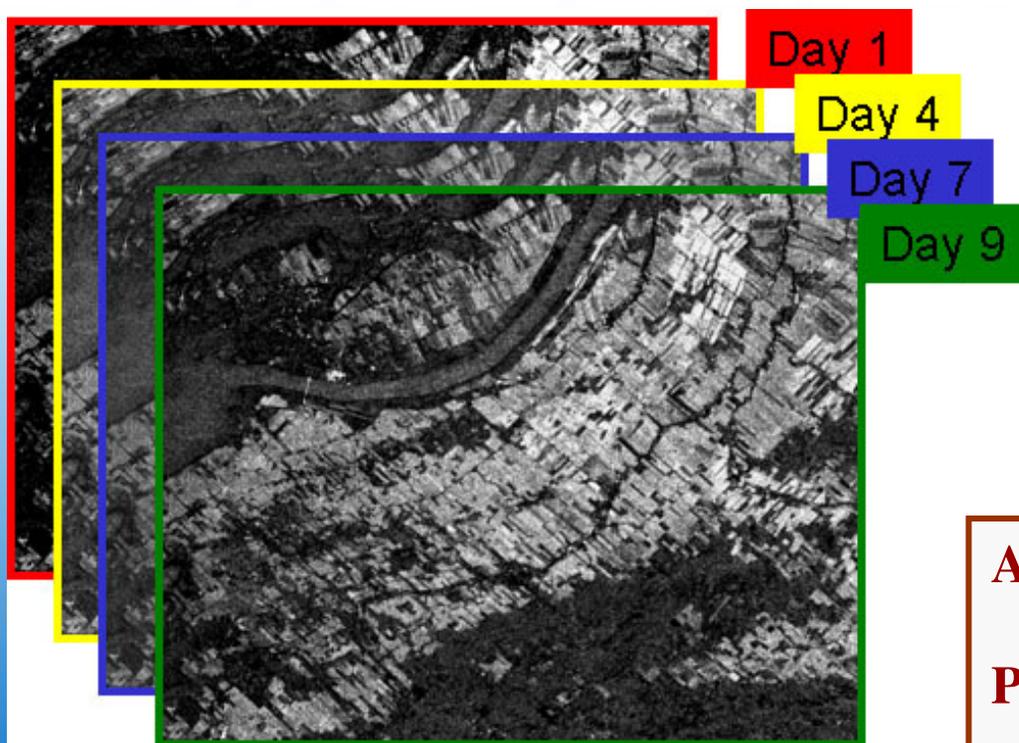
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Soil Water Content Sensitivity (SWCS)

Relative Change Detection

- The Target: Water content variation
- Intensive Synthetic aperture radar (SAR) monitoring (Dual-Pol)



Advantages:

Tracking short time changes

Precautions

Multi-incident angle correction

Vegetation effect



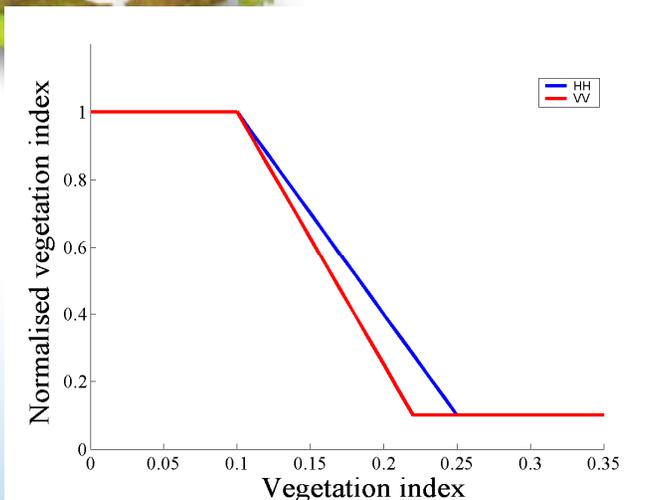
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Inverse Normalized Vegetation Index



$$VI_{pq} = \frac{\beta_{pq}^o}{\beta_{pq}^o + \beta_{pp}^o}$$

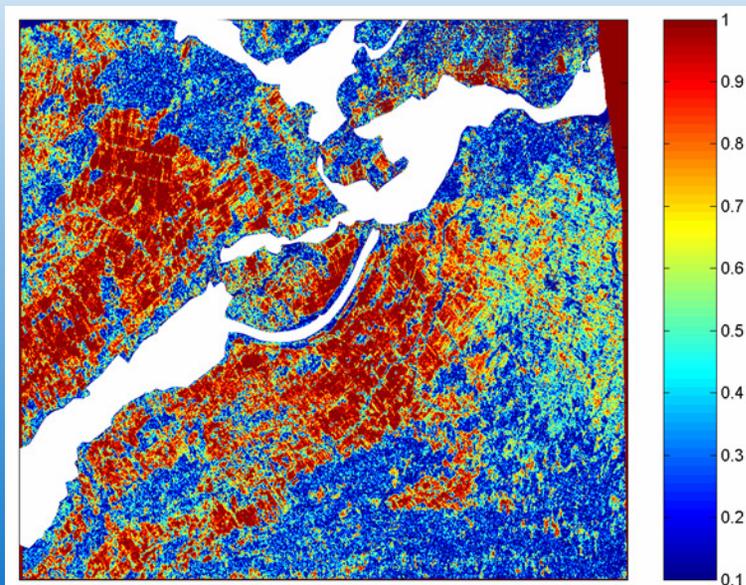
Bare soil

$VI < 0.1 \Rightarrow INVI = 1$

Forest

$VI_{HH} > 0.25 \Rightarrow INVI = 0.1$

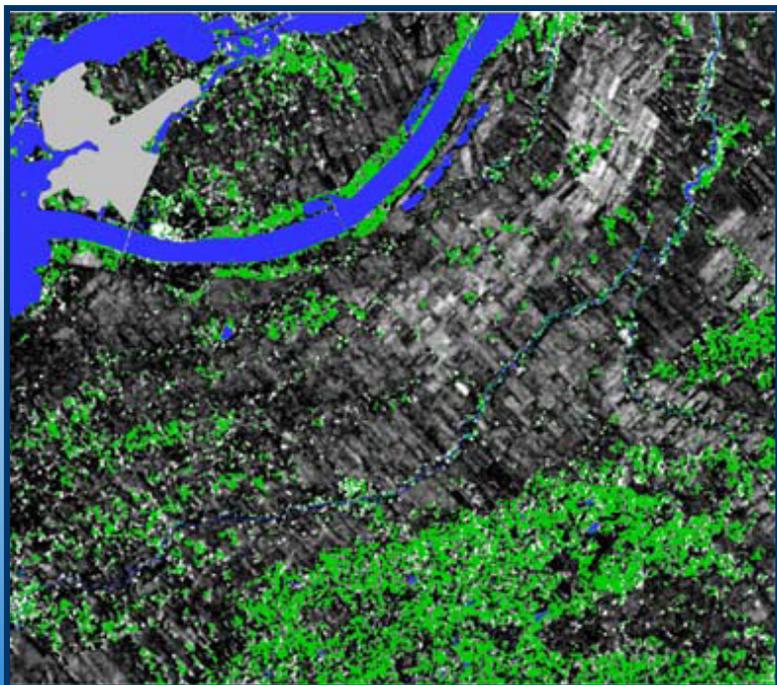
$VI_{VV} > 0.22 \Rightarrow INVI = 0.1$



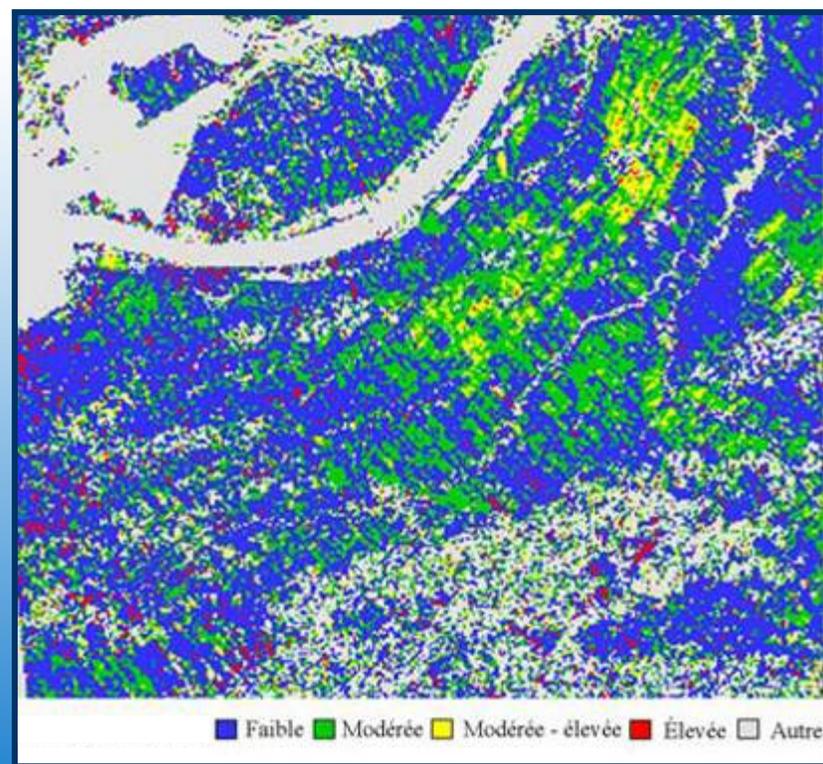


Soil Water Content Sensitivity ...

Relative Index



Water Content Sensitivity Map



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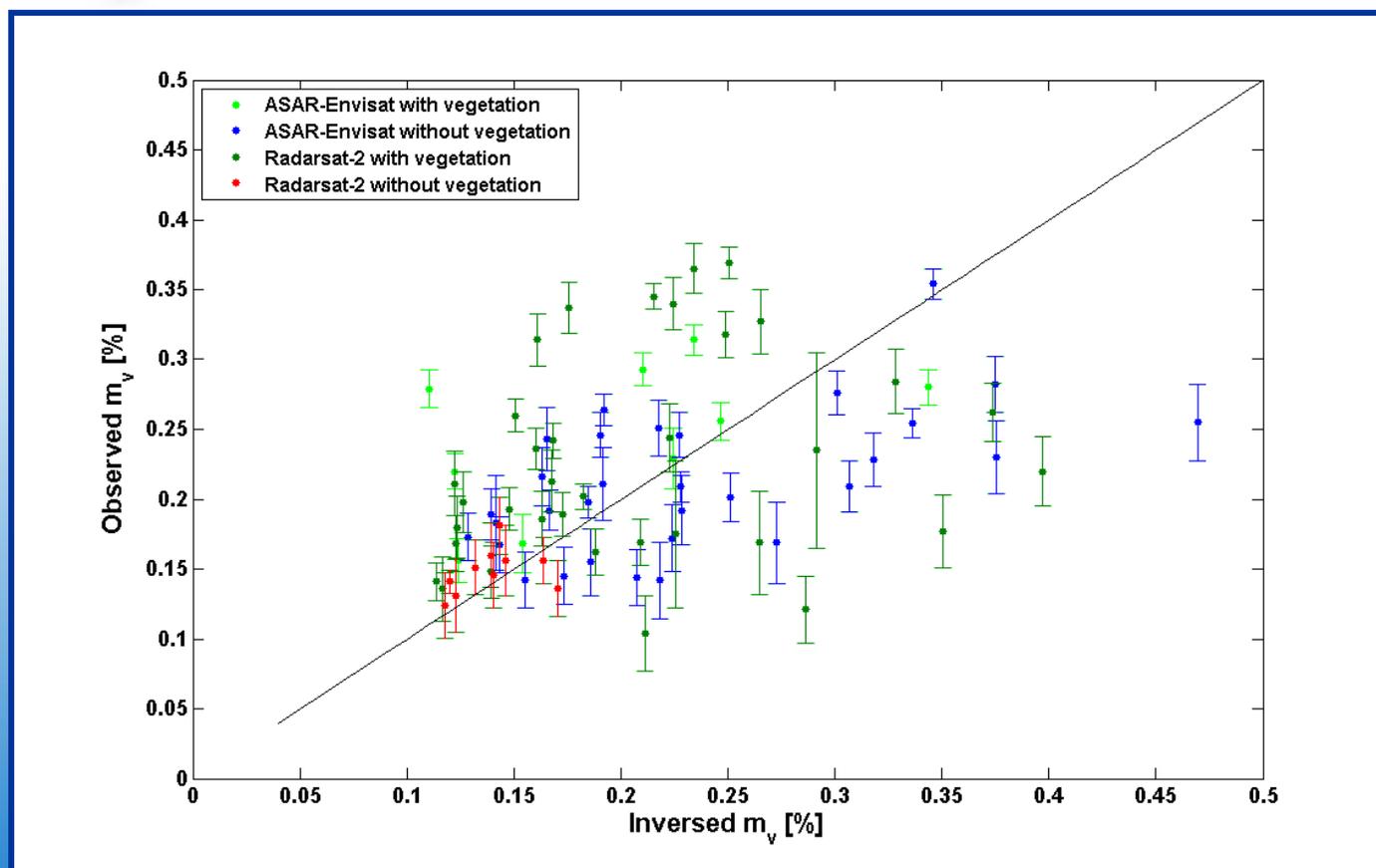
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M_v estimation at C-Band



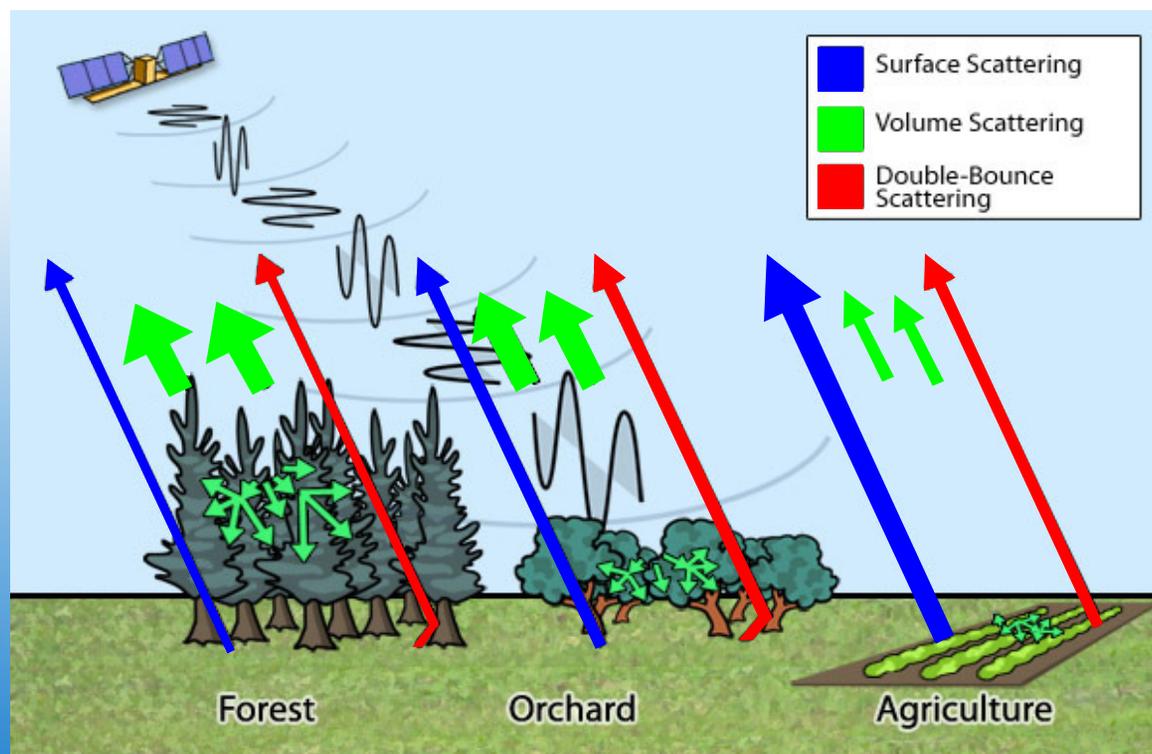
Need to reduce vegetation contribution





Scattering Mechanisms

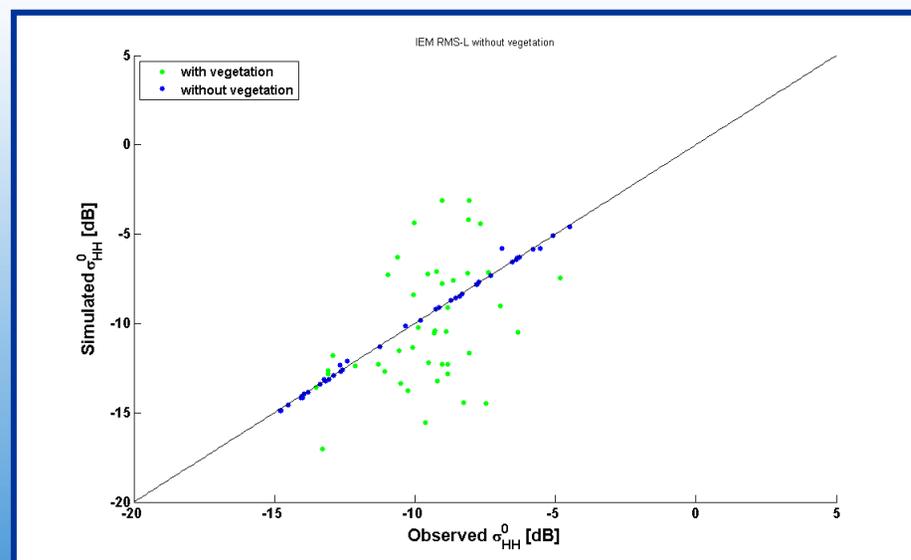
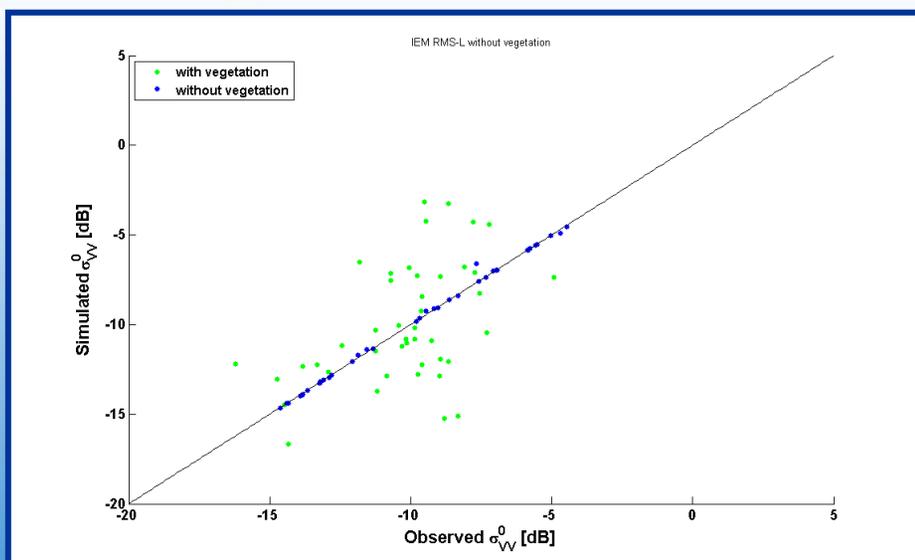
Fully polarimetric info





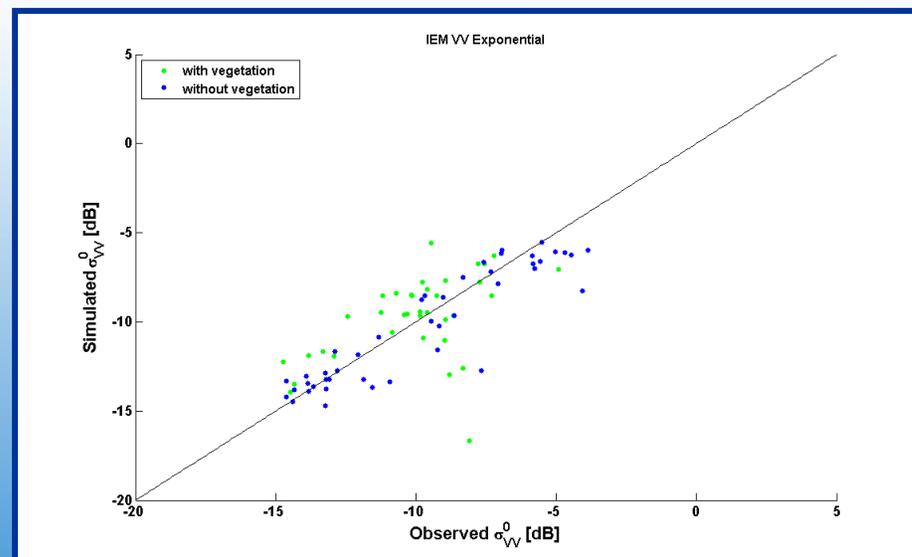
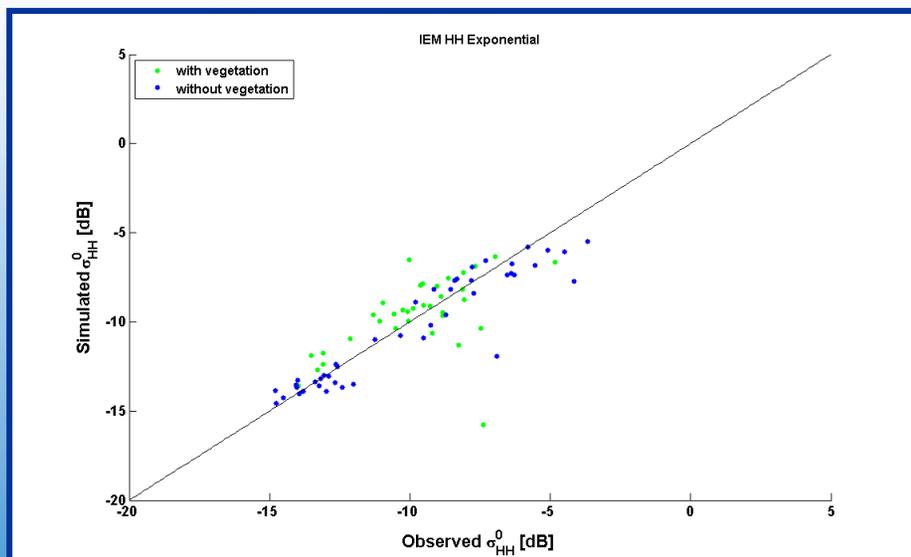
Vegetation Impact

- Using Pre-Veg Roughness Estimation + M_v measurements to observe vegetation impact





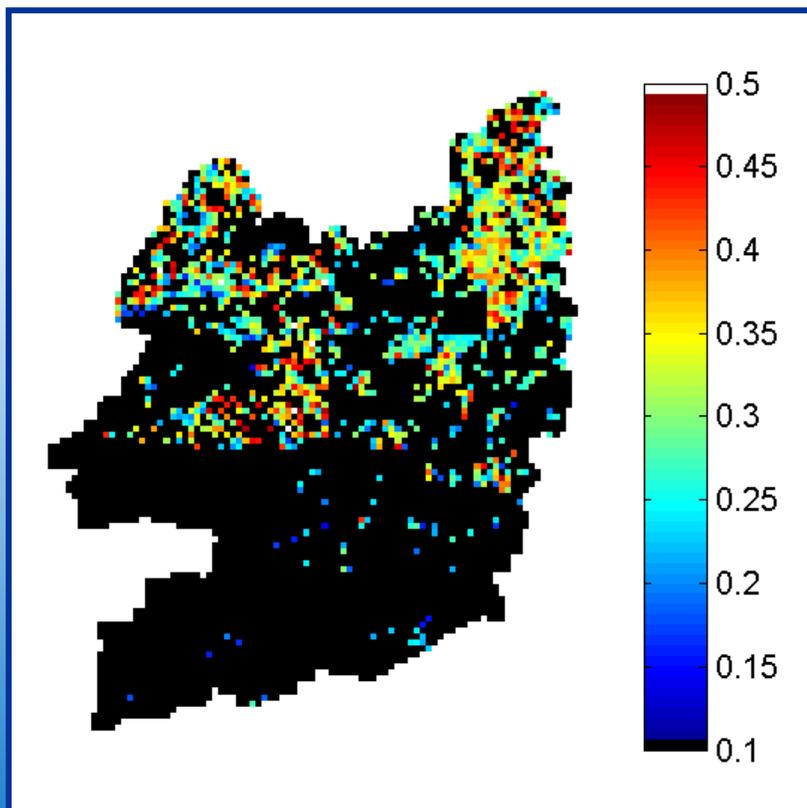
Volumetric & dihedrals contributions reduced



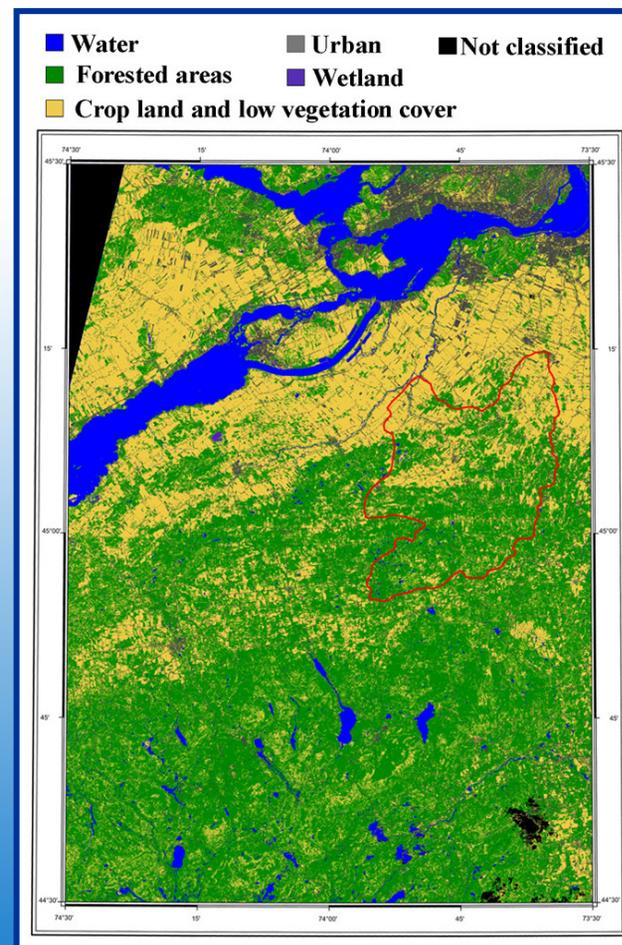


Moisture Map C-Band

M_v SAR



Land Cover



REF: Chateauguay Atlas



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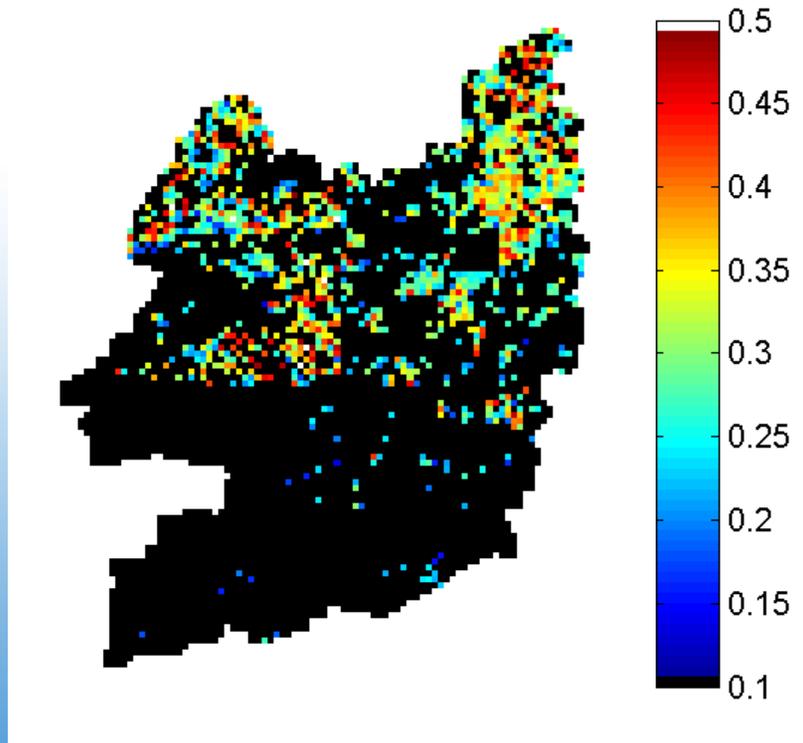
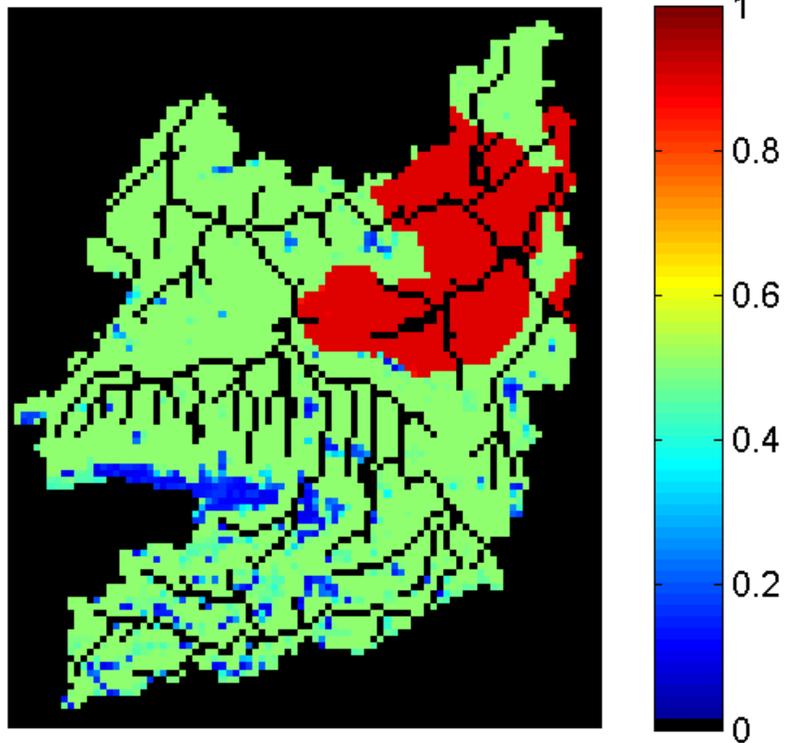
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CATHY vs SAR: Soil Moisture

April 19, 2008



SAR results downsampled to CATHY scale
Spatial resolution: 350 m



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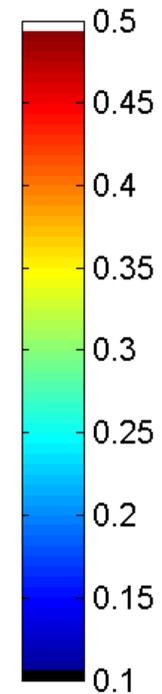
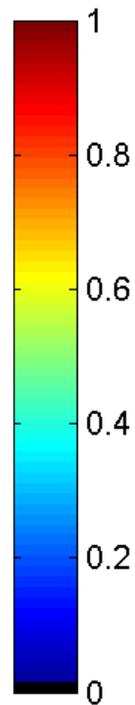
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CATHY vs SAR: Soil Moisture

May 30, 2008

Warning: Organic Soil



SAR results downsampled to CATHY scale
Spatial resolution: 350 m



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Passive Microwave

A.P. Trishchenko and S. Wang



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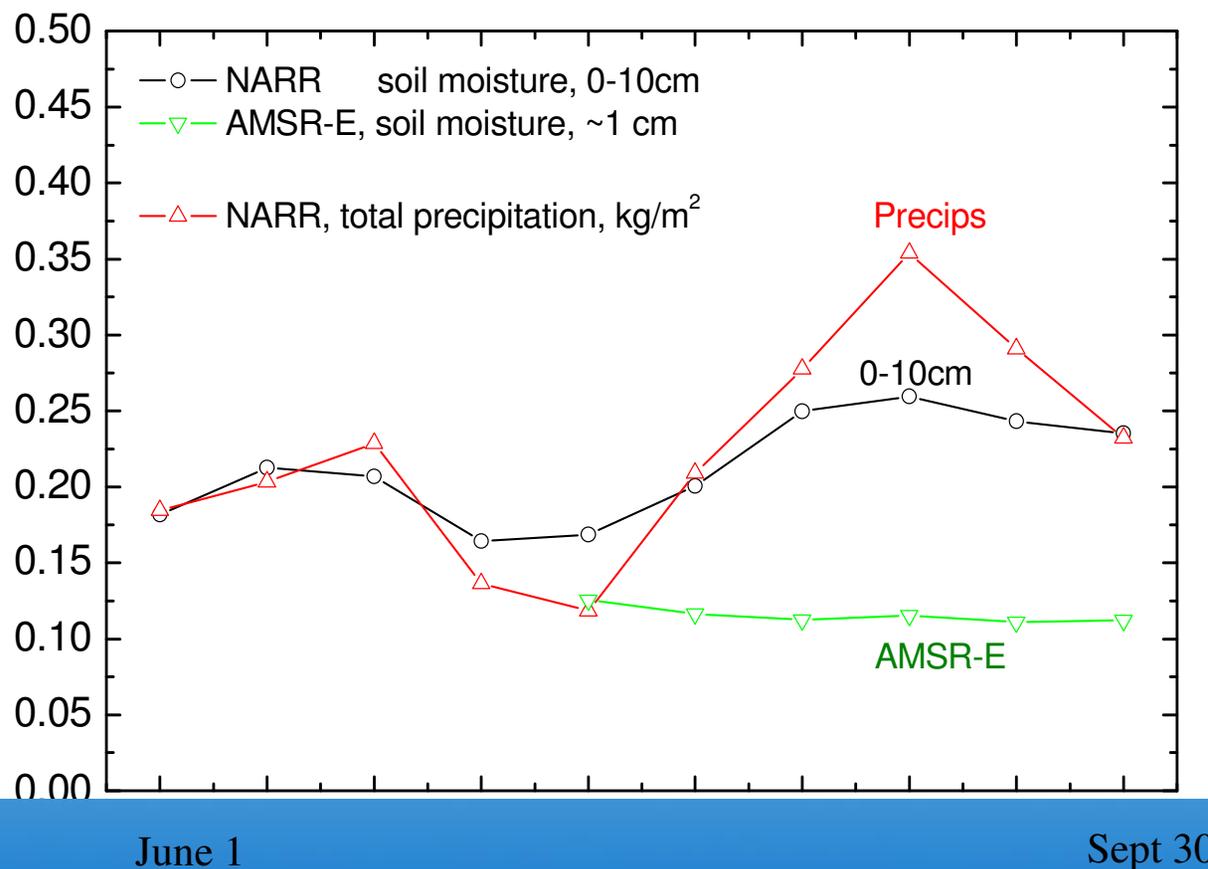
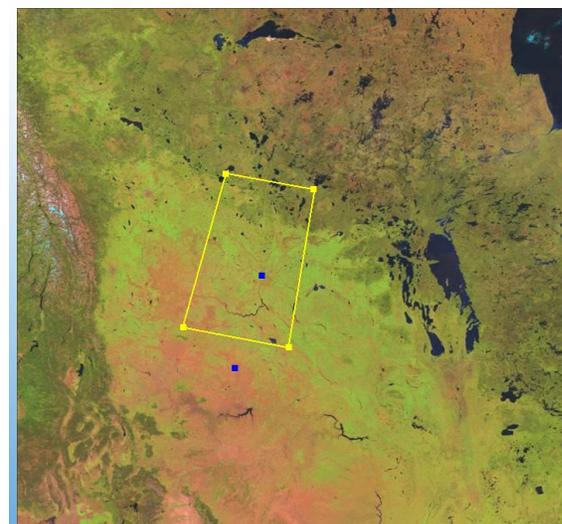
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Average soil moisture and precipitation amount June 1 - Sept 30

Region
lat = 50°N; 55°N
lon = 110°W, 105°W



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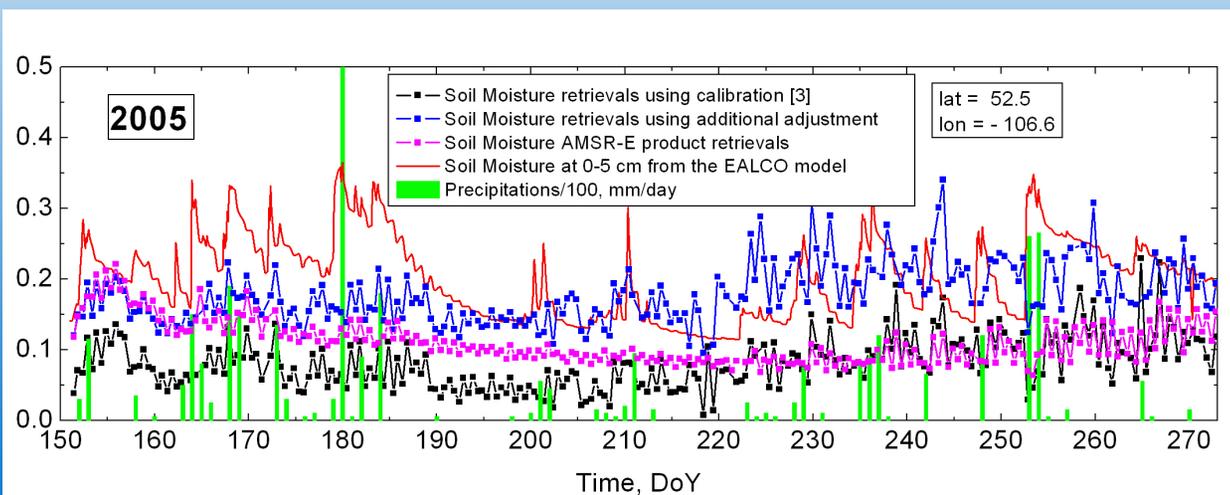
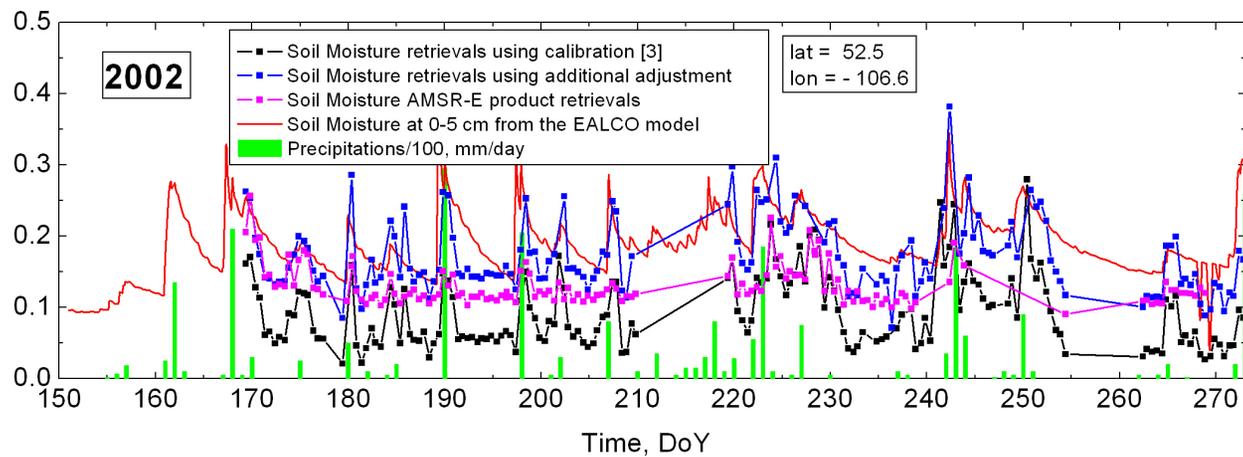
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AMSR-E Soil Moisture Retrieval



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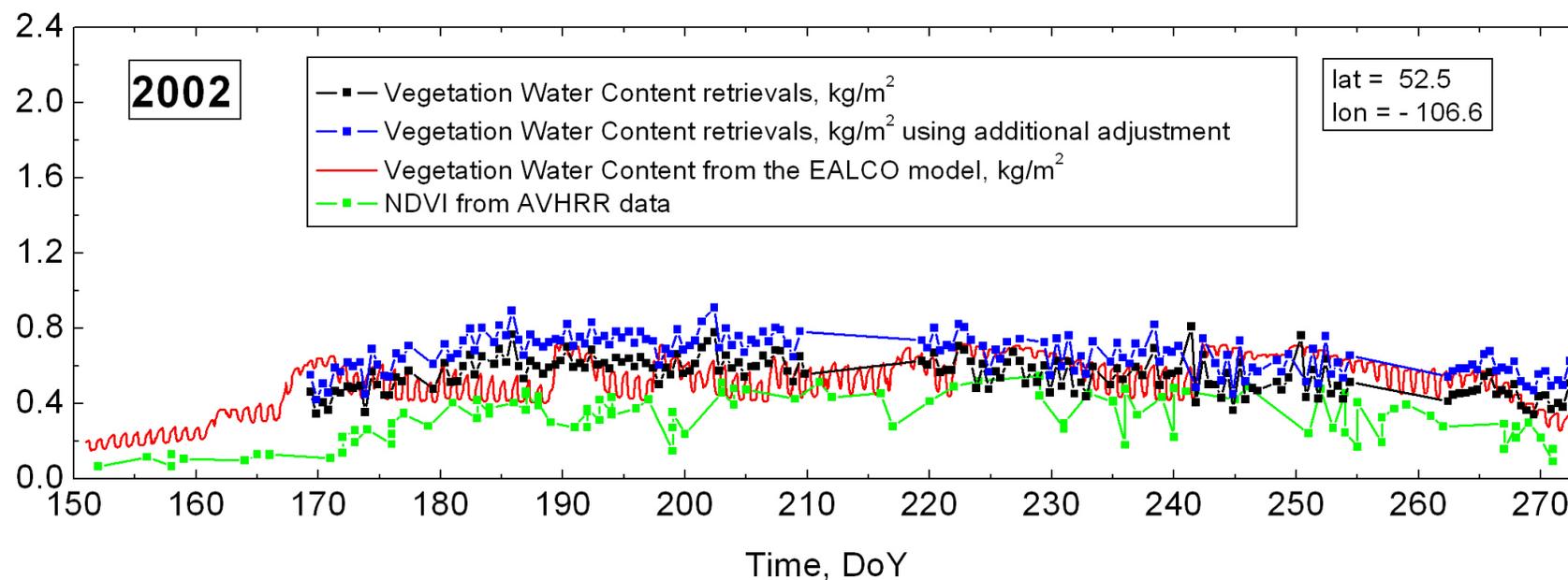
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AMSR-E: Vegetation Water Content



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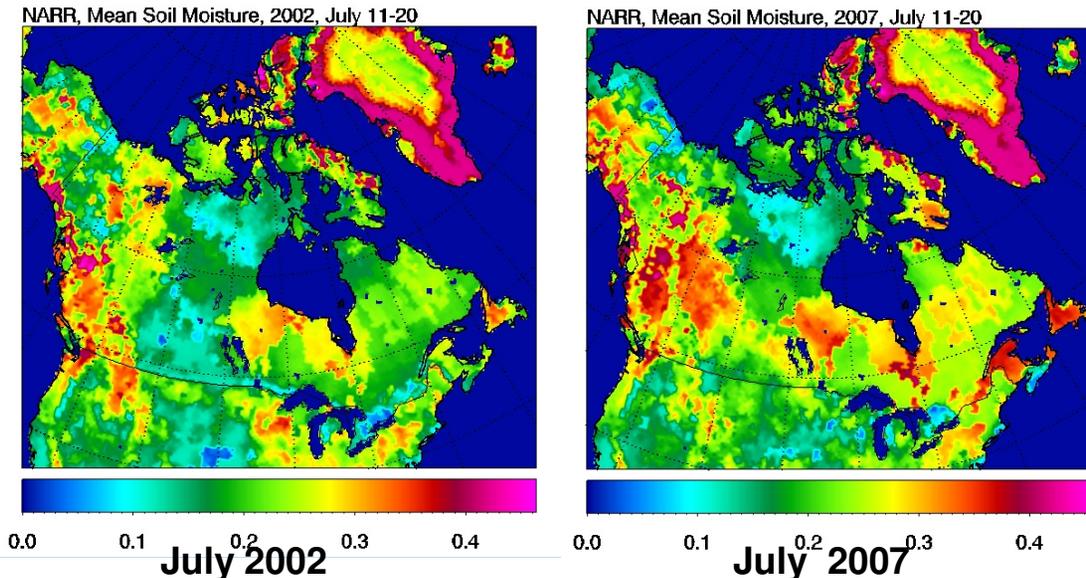
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Soil moisture from AMSR-E and NA Regional Reanalysis

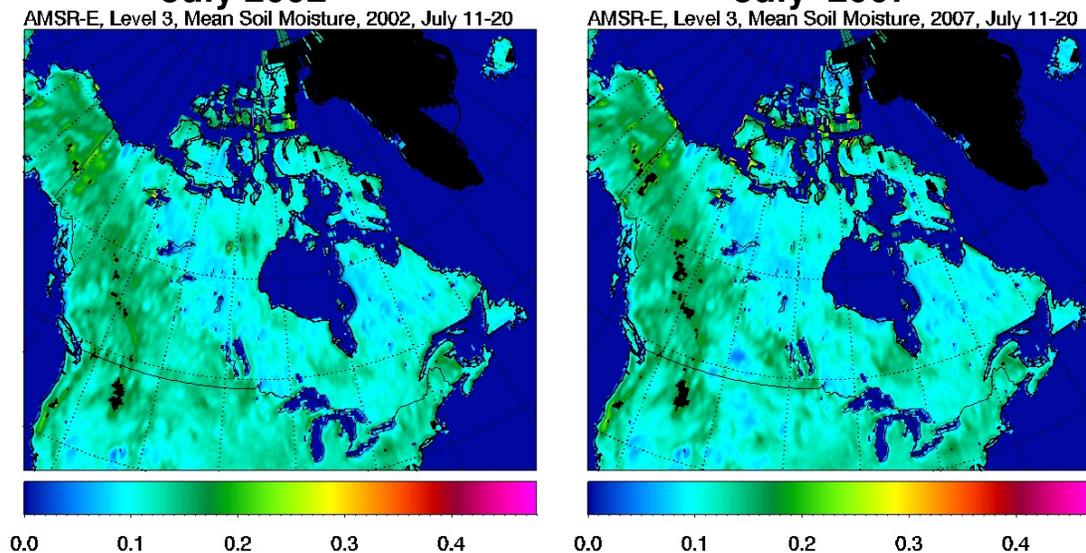
AMSR-E

NA Regional Reanalysis

NA Reanalysis



AMSR-E satellite data



1) AMSR-E retrievals underestimate NARR soil moisture

2) AMSR-E is mostly sensitive to ~ 1cm top layer conditions and affected by vegetation and roughness

3) NARR data are for 0-10cm top layer



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EALCO: Ecological Assimilation of Land and Climate

Shusen Wang



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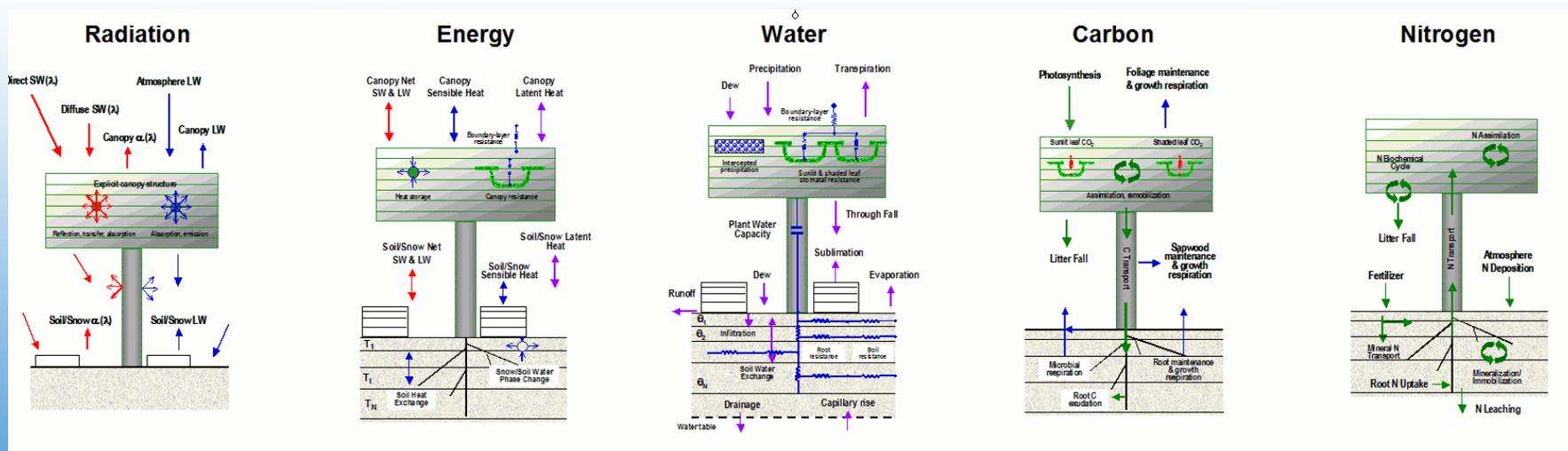
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EALCO: Ecological Assimilation of Land and Climate

EALCO is lands surface model, and has 4 close cycles – energy, water, carbon and nitrogen.



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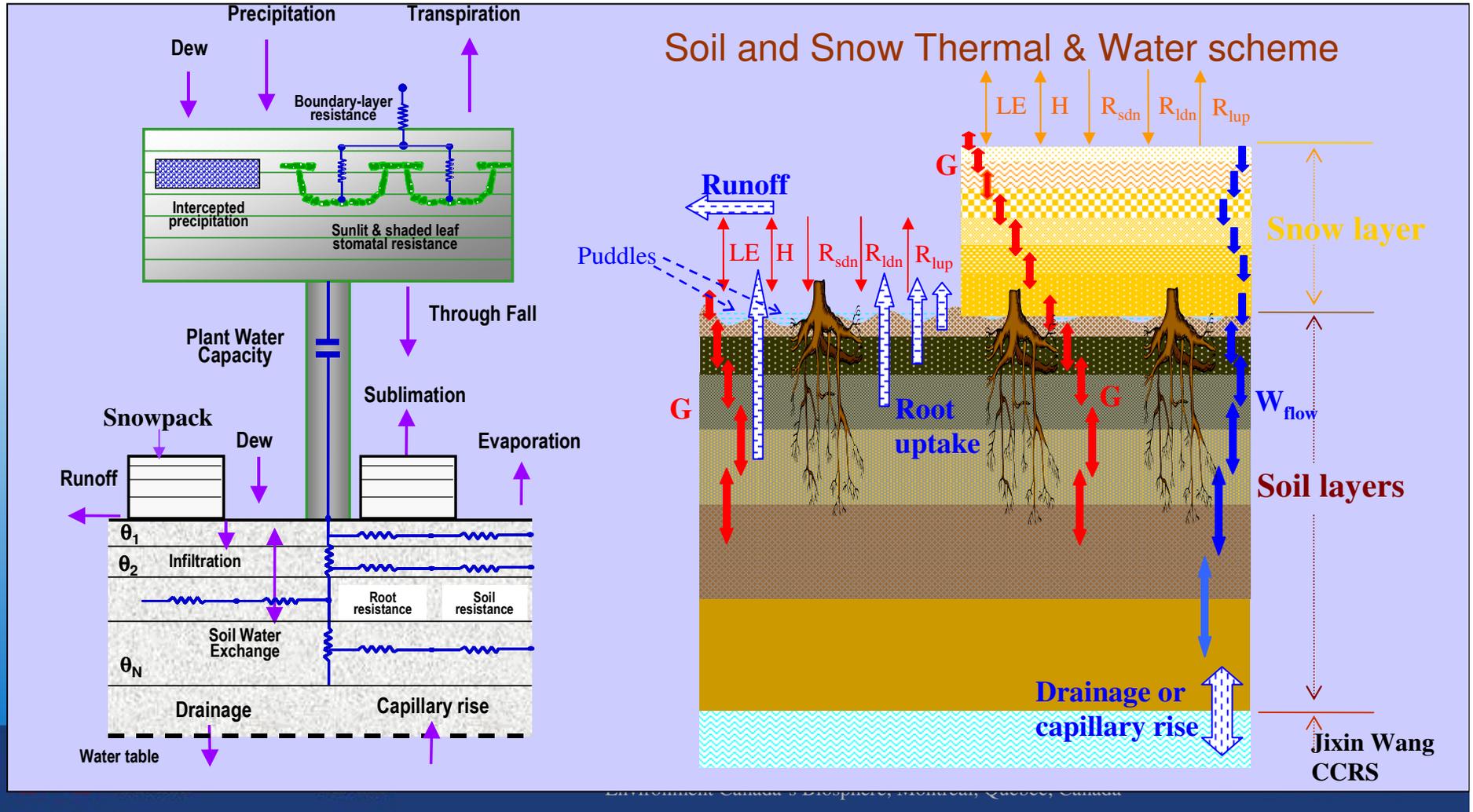
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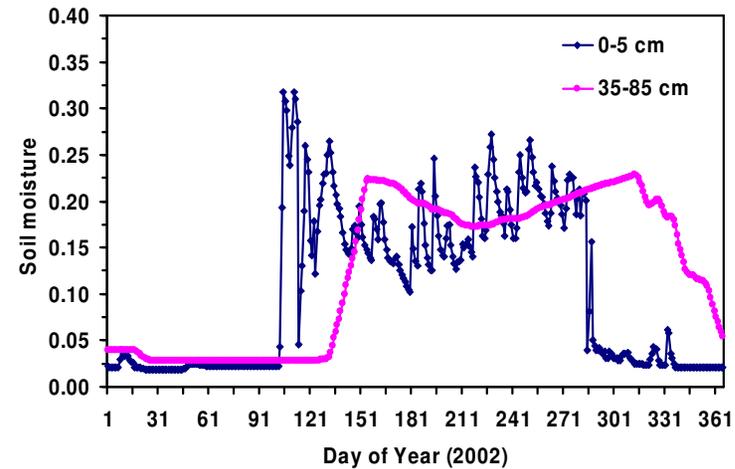
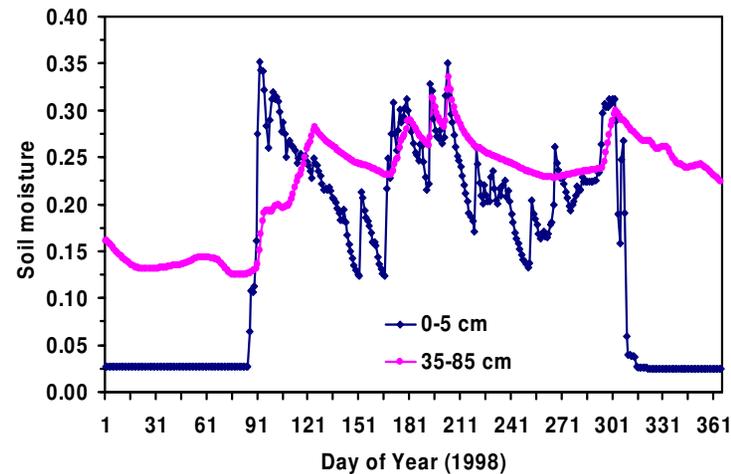
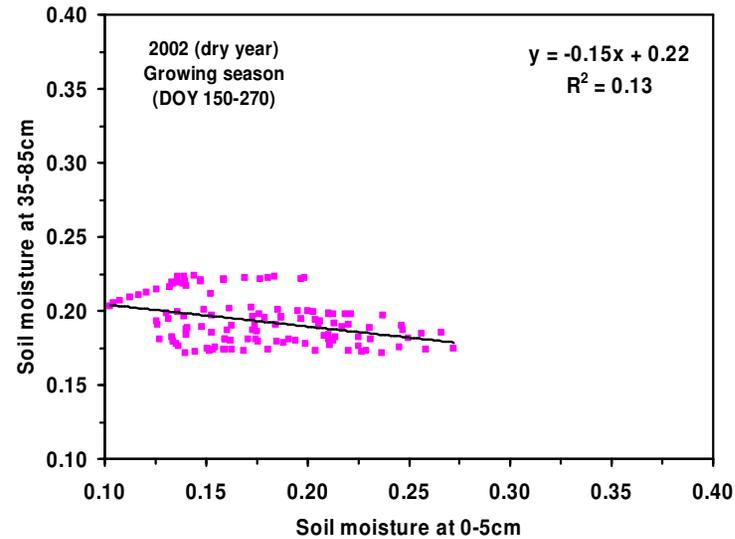
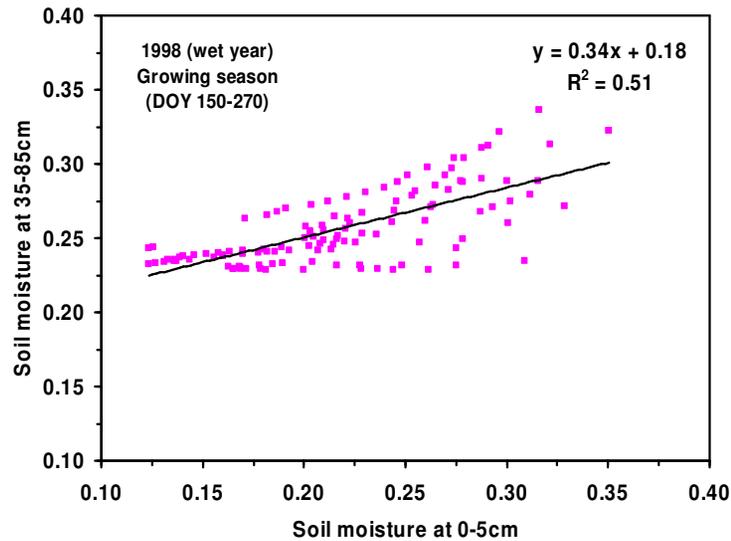
EALCO

Water Cycle Module





Modeling soil moisture using CCRS EALCO model



LAI=1

1) Weak correlation between top layer and deep layers

2) They are essentially decoupled during drought conditions

3) AMSR-E and C&X band systems have limited capabilities for SM mapping due to short λ (penetration depth)



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Permafrost – InSAR

N. Short, P. Budkewitsch and B. Brisco



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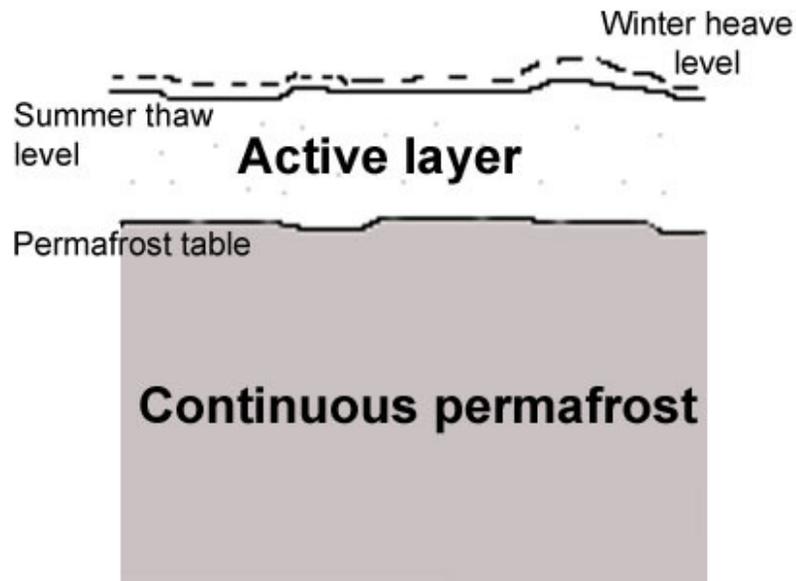
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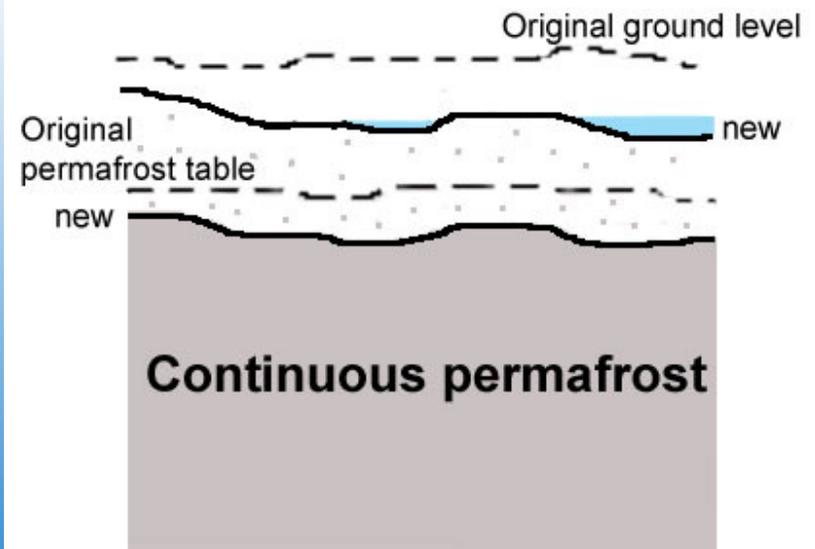


Permafrost and active layer

Seasonal

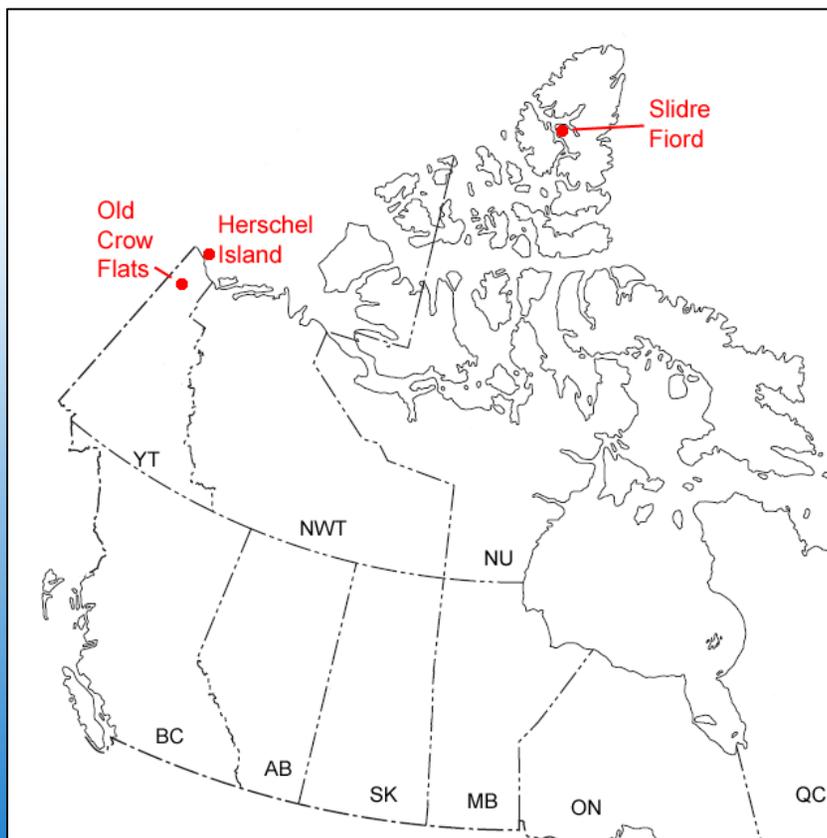


Long term degradation





Current Permafrost Sites Under Study (InSAR & Polarimetry)



Sites chosen to connect with university and Parks Canada partners.



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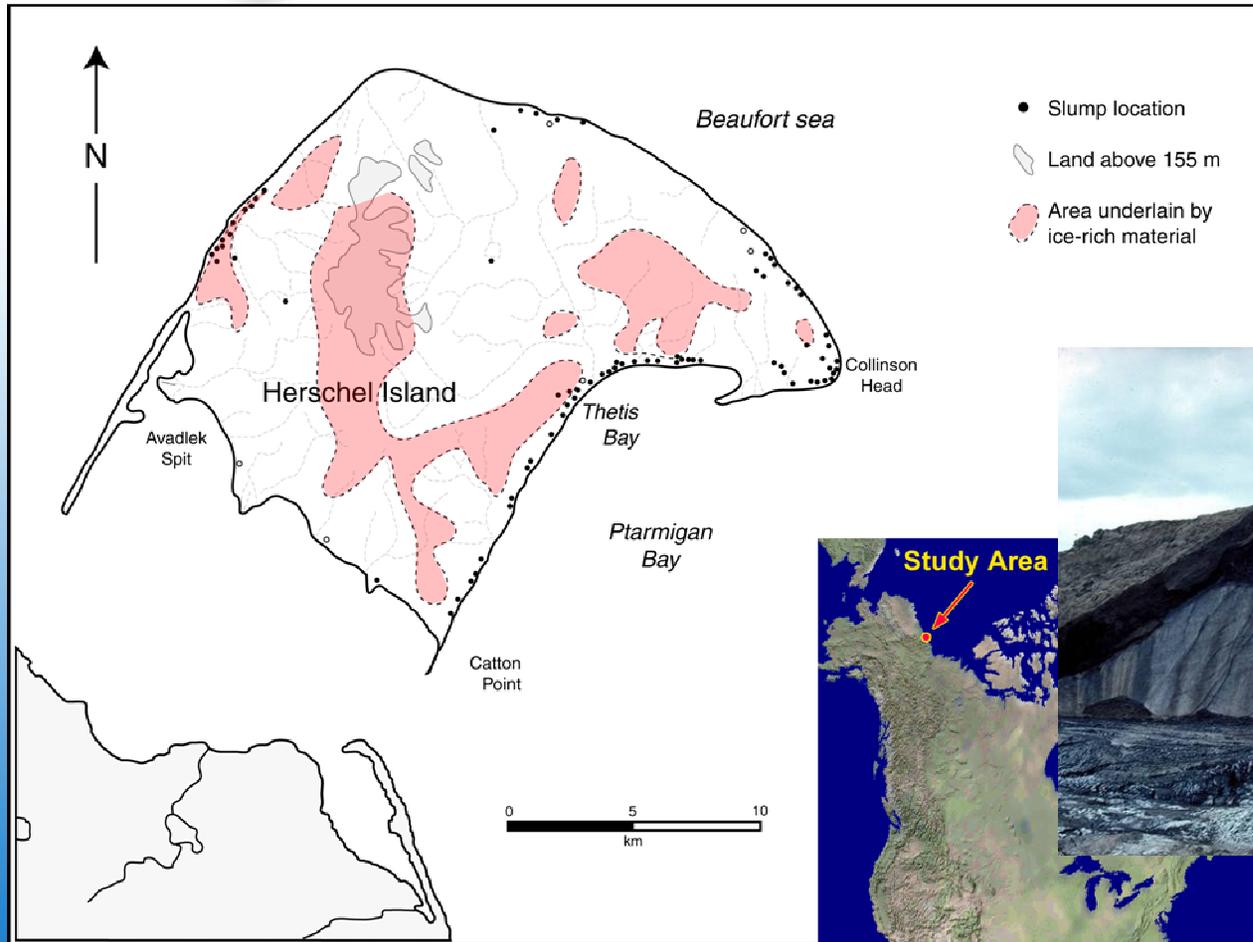
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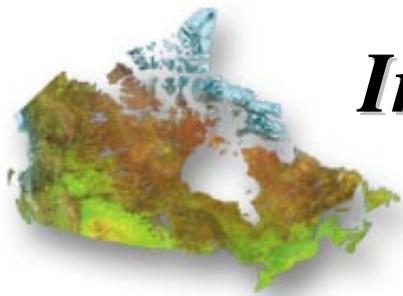
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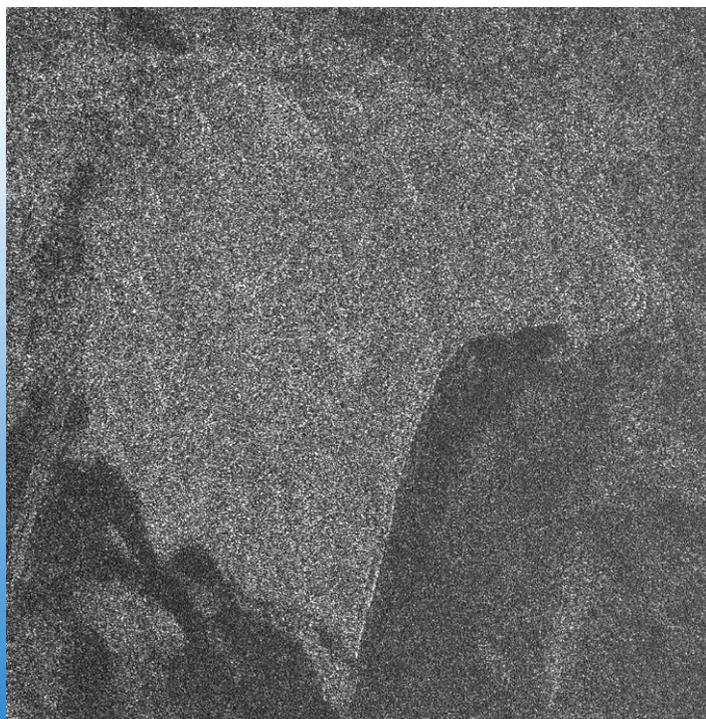
Massive ground ice locations at Herschel Island, Yukon Territory, Canada





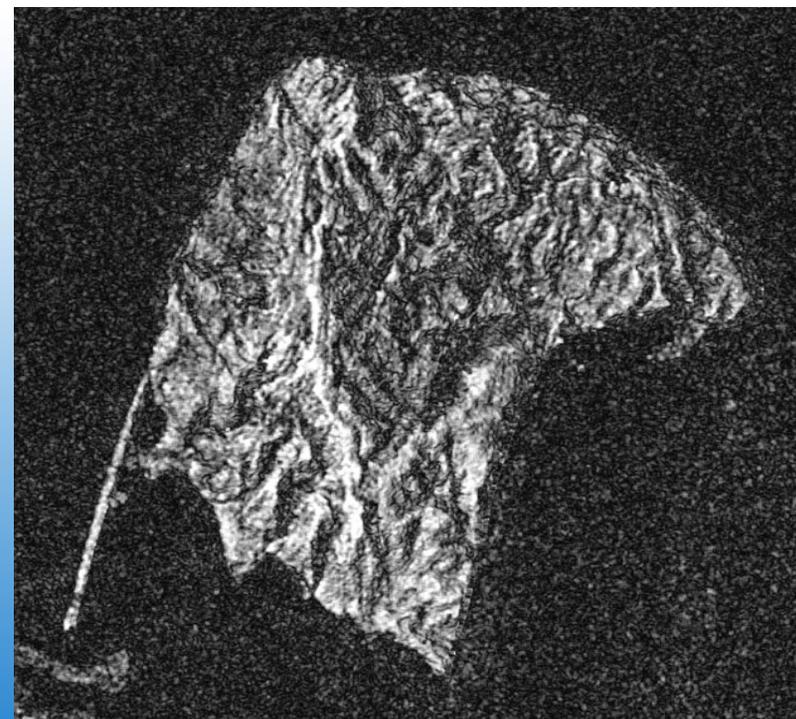
Interferometric Radar Data

**RADARSAT-1
detected image**



December 4, 2000

**Scene coherence
Fine Beam (F1) 24-day**

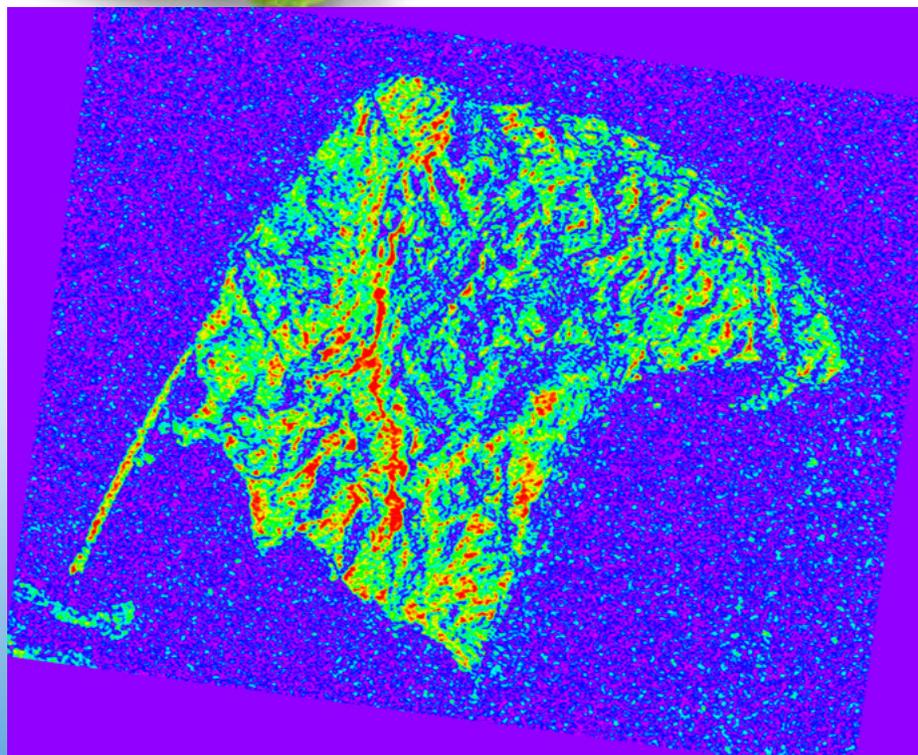


4-28 December 2000

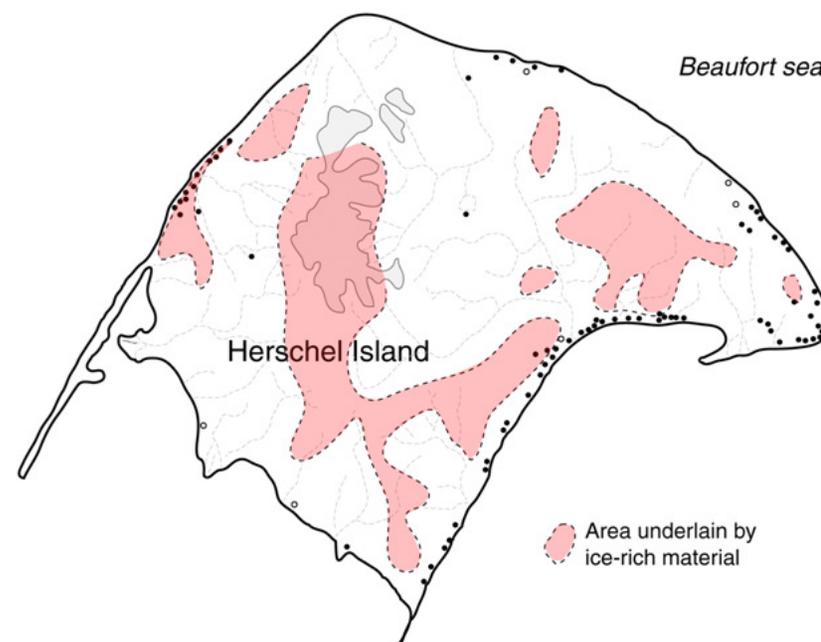
Budkewitsch, P., W.H. Pollard, F. Leduc, C. Omelon, E. Gauthier and K. Molch (2004) **Monitoring Active Layer Processes and Mapping Permafrost Degradation From SAR and High-resolution Satellite Data**, In Proceedings of the Fifth Circumpolar Ecosystems Conference and Workshop, Churchill, Manitoba, Canada, February 25-29 2004



Investigation of InSAR data for mapping permafrost terrain

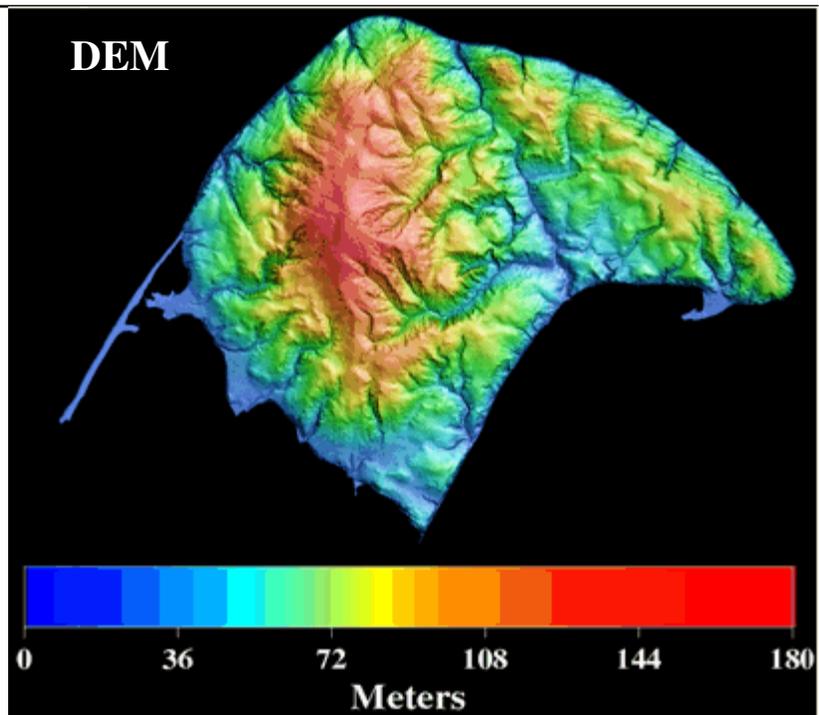
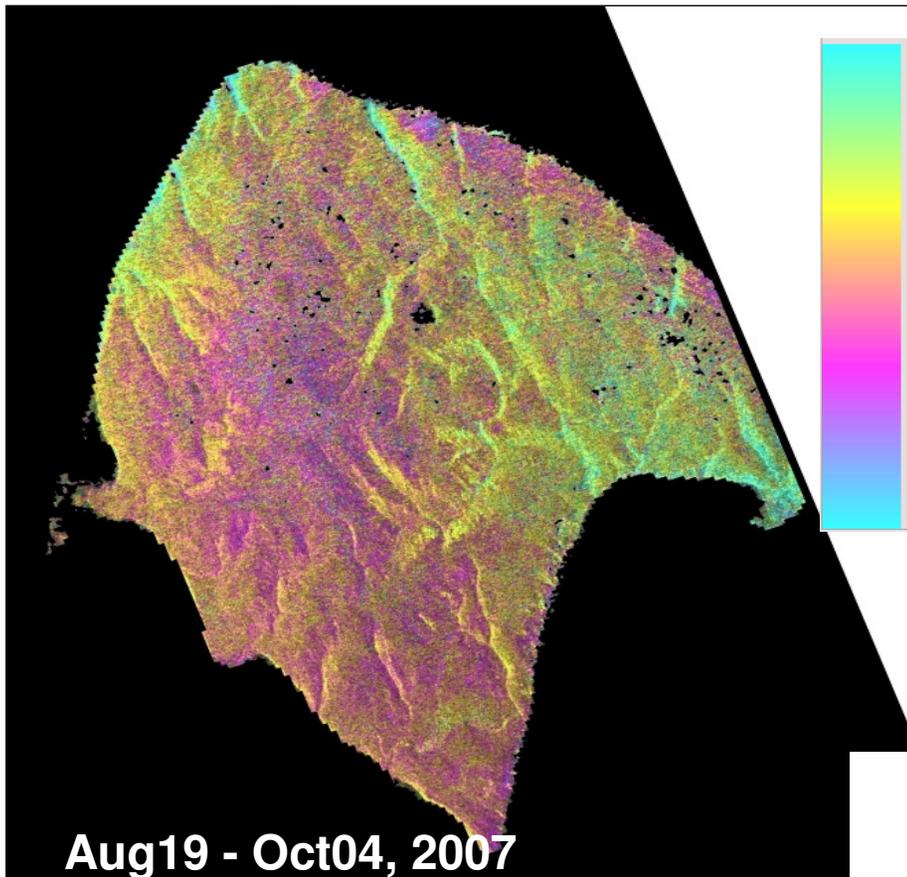


**radar scene coherence data
from a December 2000
24-day pair**



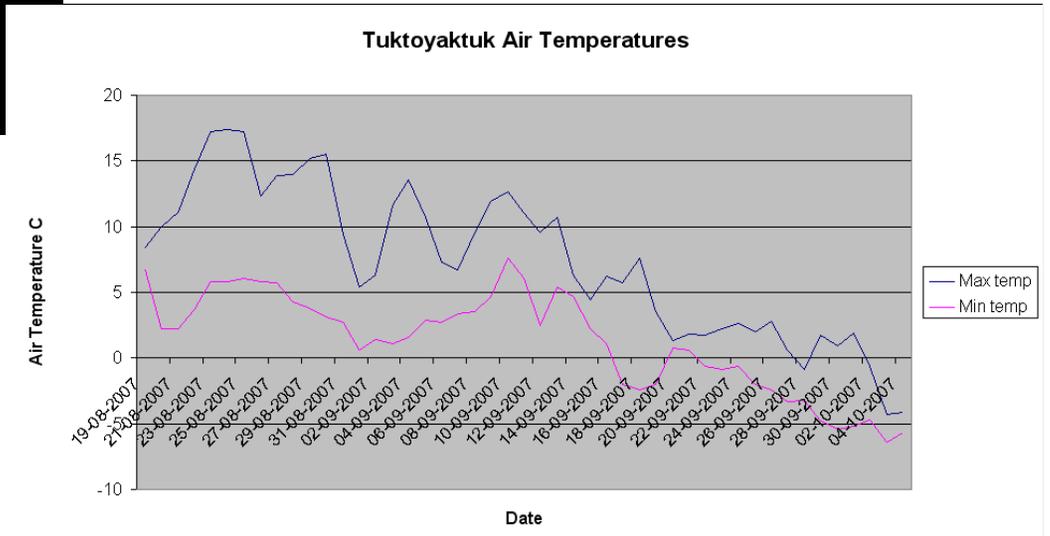
***Correlation of high scene
coherence (red) with areas of
massive ground ice is fairly
consistent.***





Aug19 - Oct04, 2007

*Maximum subsidence on exposed hilltops ~7cm.
 Positive air temperatures until end of September.
 Rykhus & Lu, (2008) saw <10cm thaw settlement July – end Sep.*



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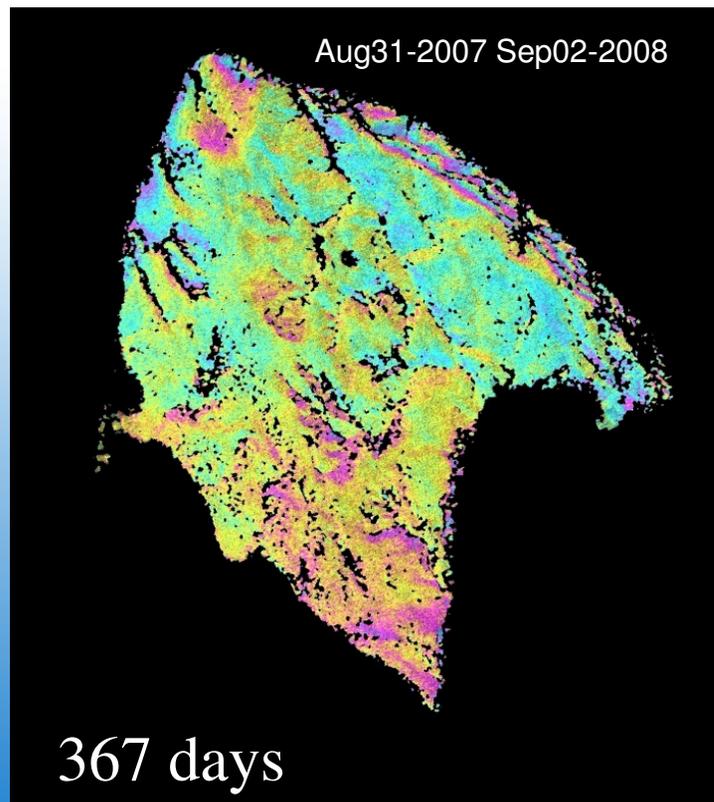
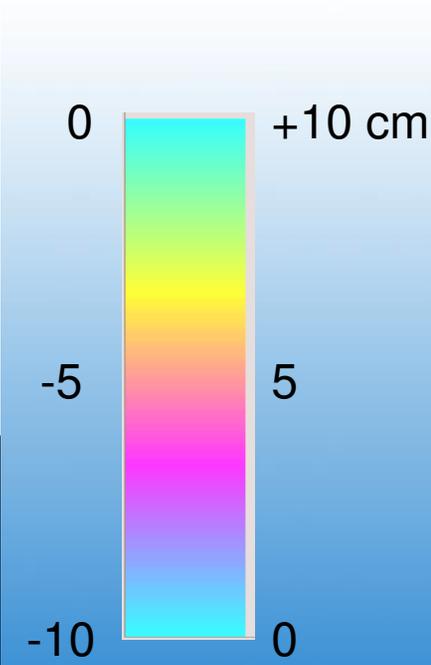
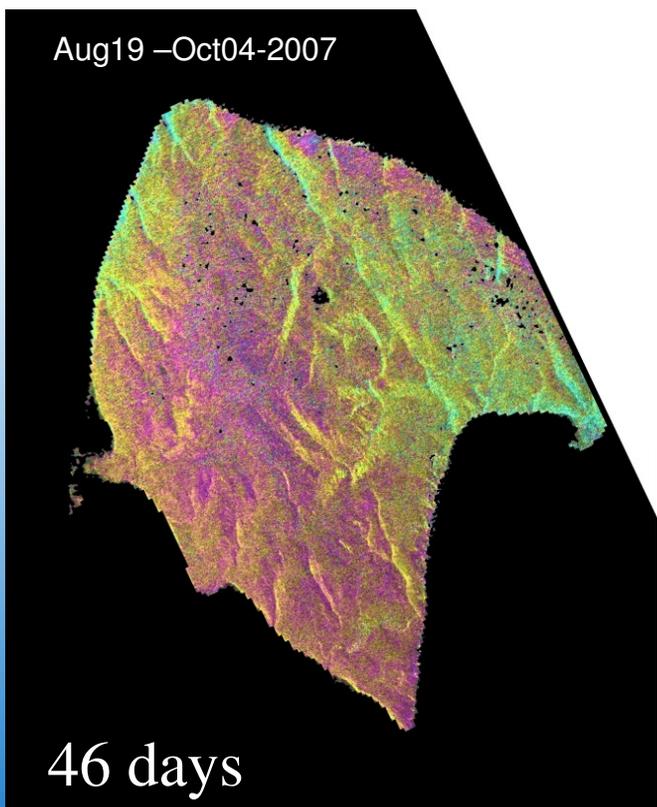
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Ground displacement from ALOS - InSAR



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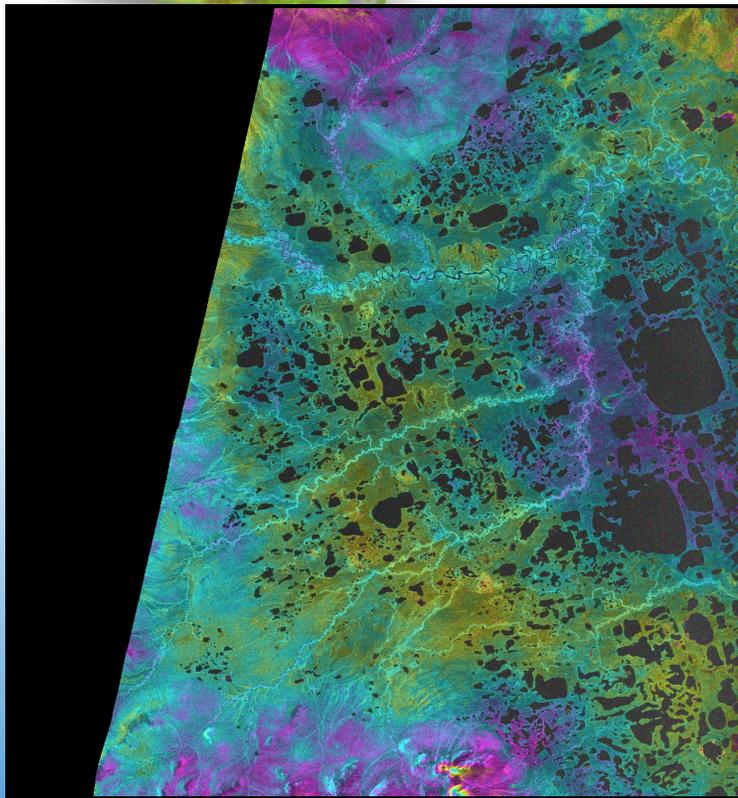
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Old Crow Flats

July 26 – September 10, 2007



Surface Displacement

Yellow = -2.5 cm

Green = -1.5 cm

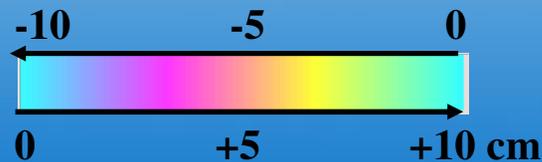
Turquoise = +/- 0.2 cm essentially ~0

Purple in centre of flats = +2.5 cm

Mountains, full fringe cycle = +11.8 cm

DEM error of 20 m → displacement error of 11cm

DEM error of 2 m → displacement error of 1.14cm



Artefacts:

Tropospheric effects? Water vapour?

Ionospheric effects: No.



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CCRS Potential Contributions to SMAP

- Radar soil moisture/vegetation modeling
- Support in field campaign
- Cross validation products from SAR/InSAR/Polarimetry (Radarsat-2, ALOS, TerraSAR-X)
- Strong radar antenna calibration expertise
- Integration of SMAP information into cryospheric applications



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