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→ 3rd ADVANCED COURSE ON RADAR POLARIMETRY

PolSAR-Ap: Agriculture & Wetlands

Prof. Juan M. Lopez-Sanchez
juanma.lopez@ua.es

Universitat d'Alacant
Universidad de Alicante

19–23 January 2015 | ESA-ESRIN | Frascati (Rome), Italy

European Space Agency

Motivation: agriculture

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- Remote sensing for agriculture: a tool for **management** and **optimisation** of resources

End users	Product	Objective / Motivation
International and national authorities / agencies	Crop-type mapping and classification	Justification of subsidies, fraud detection, insurance claims, acreage, etc.
	Water resources consumption: soil moisture	Control in regions suffering droughts or with scarce water resources
	Yield prediction	Economic and ma
Farmers / farm managers (with extensive fields): Precision farming	Timely information about crop phenology	Planning and trigg specific phenological stages
	Irrigation requirements: soil moisture	Irrigation only when and where necessary
	Final crop productivity	Benefits

Crop-type classification
Crop phenology estimation
Soil moisture retrieval

- And:
  - Hydrology, environmental studies, sustainable agriculture, etc.

Motivation: wetlands & hazards

- Wetlands are fragile and complex ecosystems with key implications in:
  - – Biodiversity: wide variety of plant and animal species
  - – Hydrological functions: regulation of water flow, protection of the water quality, sustainable management of ecosystems, etc.
  - – Climate change and economy: carbon storage, nutrients filter, pollutants
- Required EO products:
  - – **Delineation** of existing and potential wetlands, with season dynamics
  - – Tropical wetlands: Characterisation and inventory of **vegetation**
  - – Peatland: Long term monitoring of **bog-fen transformations**

Motivation: effect of hazards

- Natural disasters occur frequently, causing significant loss of lives and leading to major geo-/bio-environmental and socio-economic costs
  - – Ground surveys are time consuming and manpower expensive
- EO product:
  - – **Mapping of the effects** of tsunamis and earthquakes

Showcases on Agriculture and Wetlands

Product	Authors (Institution)	Internal / External
Crop Phenology Estimation Using SAR Polarimetry	Juan M. Lopez-Sanchez, J. David Ballester-Berman, Fernando Vicente (University of Alicante), Shane Cloude (AELc)	Internal
Soil Moisture Estimation Under Vegetation Using SAR Polarimetry	Thomas Jagdhuber (DLR), Irena Hajnsek (DLR / ETH)	Internal
Crop Classification with C-Band PolSAR satellite data	Heather McNairn, Jiali Shang (Agriculture and Agri-Food Canada)	External
Crop Classification with L- and C-Band Multitemporal PolSAR Airborne data	Henning Skriver (Technical University of Denmark)	External
Wetland Delineation and Characterisation	E. Pottier, C. Marechal (University of Rennes 1) L. Hubert-Moy, S. Corgne (University of Rennes 2)	Internal
Tropical Wetland Characterisation with Polarimetric SAR	Shimon Wdowinski (University of Miami)	External
Sub-Arctic Peatland Characterisation and Monitoring	R. Touzi, G. Gosselin and R. Brooks (CCRS-NRC)	External
Monitoring the Effect of Tsunamis and Earthquakes by using a Fully Polarimetric Model-Based Decomposition	Yoshio Yamaguchi, Gulab Singh (Niigata University)	External

Methodology

	Covariance or coherency matrix computation	Speckle filter	Geocoding	Polarimetric observables (σ_0, decompositions)	Time series
Phenology	✓	✓	✓	General purpose	For analysis
Soil Moisture	✓	✓	✓	Ad hoc	
Classification Satellite	✓	✓	✓	General purpose	
Classification Airborne	✓	✓	✓	General purpose	✓
Wetland Delineation	✓	✓	✓	General purpose	For analysis
Tropical Wetland Characterisation	✓	✓	✓	Ad hoc	
Peatland	✓	✓	✓	General purpose	
Hazard Damages	✓	✓	✓	General purpose	2 images

Test sites and data sets

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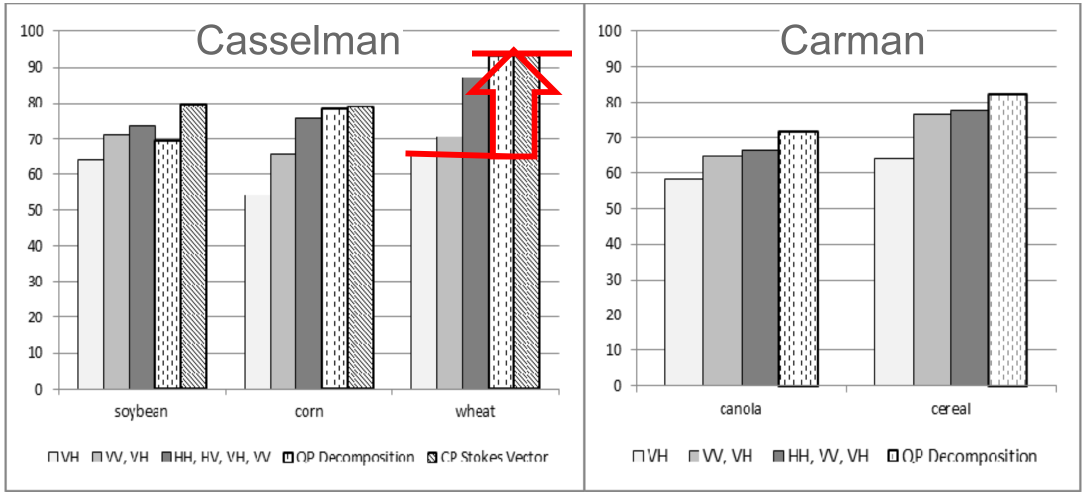
	Location	Data Origin	Sensor	Airborne / spaceborne	Band	Polarisation
Phenology	Indian Head (Canada)	AgriSAR2009	Radarsat-2	Satellite	C	Quad-pol
Soil Moisture	Indian Head (Canada), Flevoland (The Netherlands)	AgriSAR2009	Radarsat-2	Satellite	C	Quad-pol
Classification Satellite	Casselman, Carman and Indian Head (Canada)	Canadian gov.	Radarsat-2	Satellite	C	Quad-pol
Classification Airborne	Foulum (Denmark) Demmin (Germany)	Not specified AgriSAR2006	EMISAR E-SAR	Airborne	L, C	Quad-pol & Dual-pol
Wetland Delineation	Pleine Fougères (France)	SOAR-EU	Radarsat-2	Satellite	C	Quad-pol
Tropical Wetland Characterisation	Florida Everglades (USA)	Multiple	TerraSAR-X, Radarsat-2, ALOS, UAVSAR	Satellite & Airborne	L, C, X	Quad-pol
Peatland	Baie des Mines & Wapusk National Park (Canada)	JAXA	ALOS	Satellite	L	Quad-pol
Hazard Damages	Ishinomaki (Japan)	JAXA	ALOS	Satellite	L	Quad-pol

Results: Crop-type classification

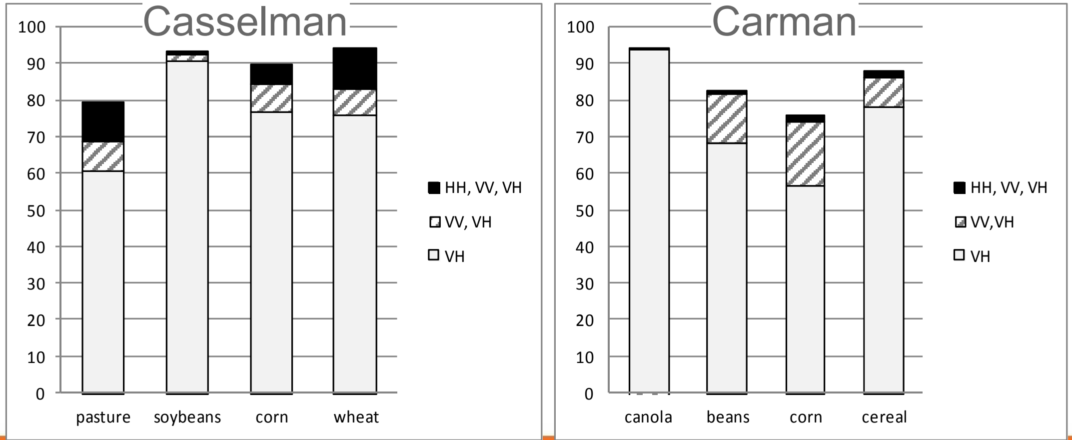
H. McNairn
J. Shang

- Classification accuracies at mid season:



Contribution of polarimetry: 15-30%

- Producer's accuracies for specific crop types:



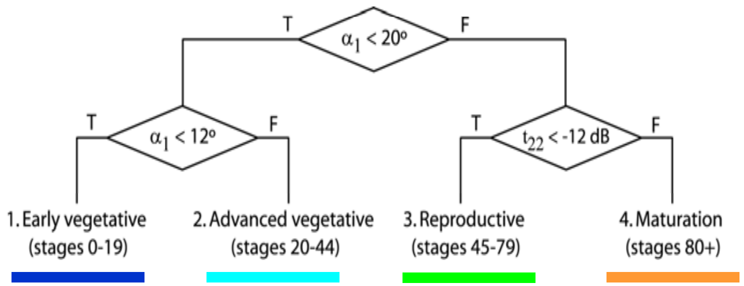
Contribution of polarimetry: up to 15%

Results: Crop phenology

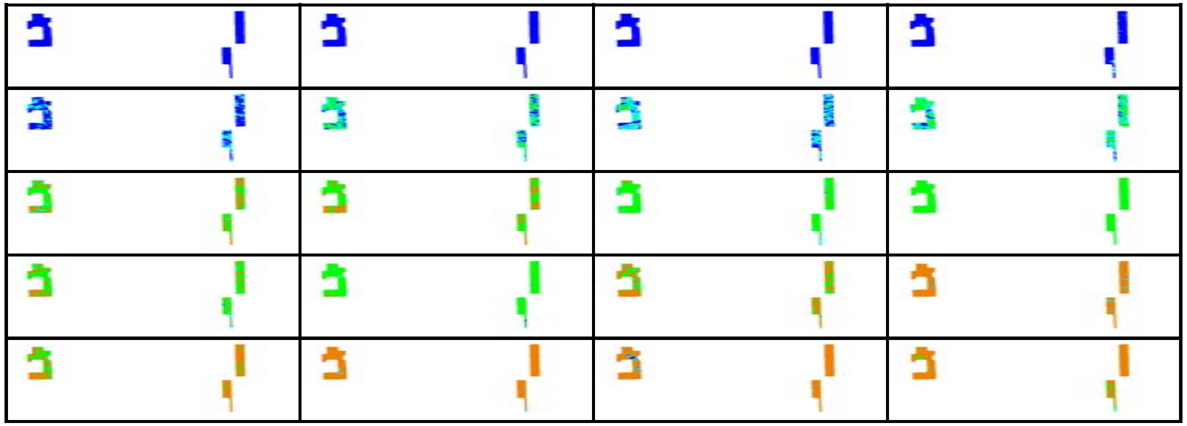
J.M. Lopez-Sanchez
J.D. Ballester-Berman
F. Vicente-Guijalba
S. R. Cloude

Example: barley

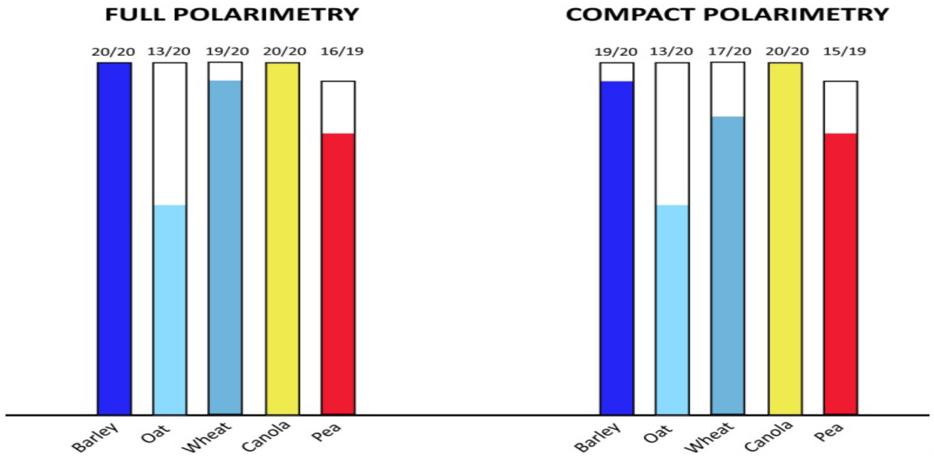
Retrieval algorithm



Result: Maps (mosaic with 20 dates)



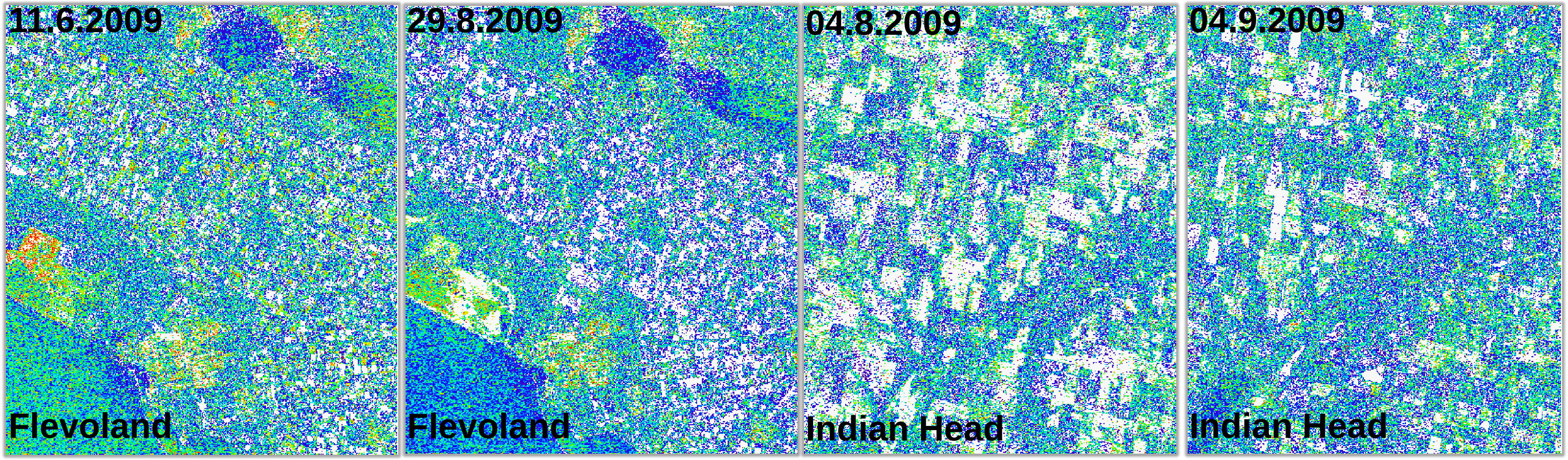
Validation at parcel level for all crops

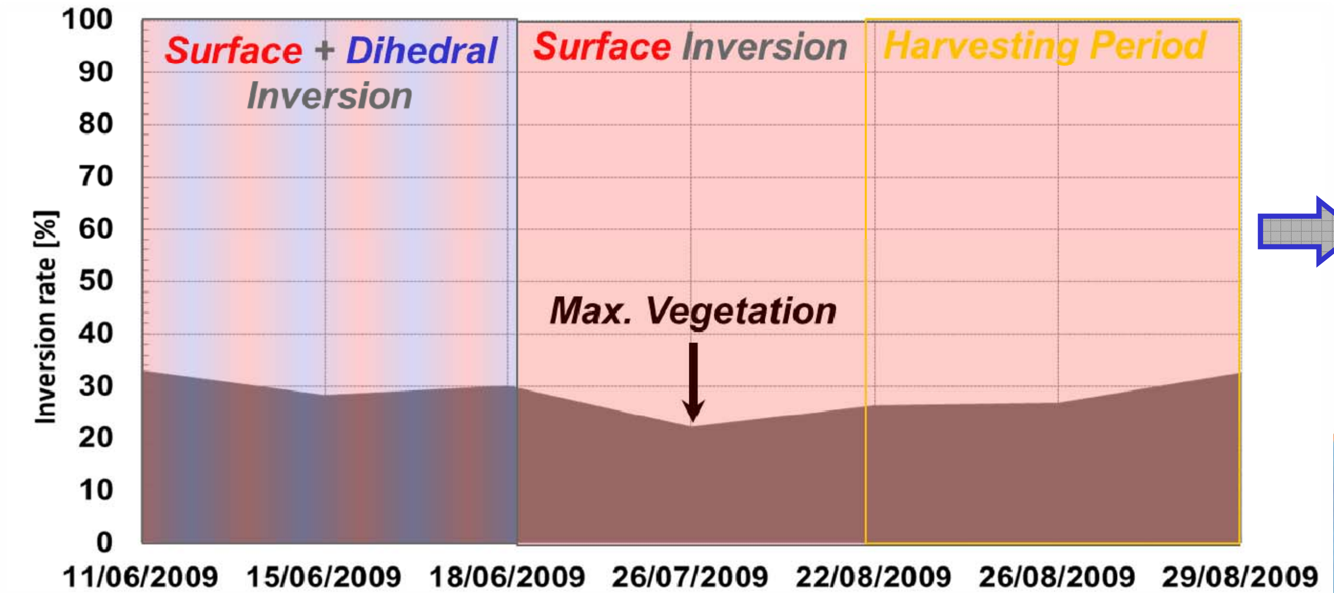


Results: Soil moisture under vegetation

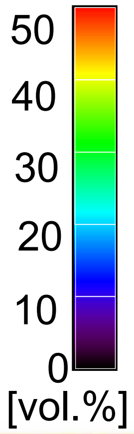
T. Jagdhuber
I. Hajnsek

Moisture maps and inversion rates (percentage of pixels satisfying the model)



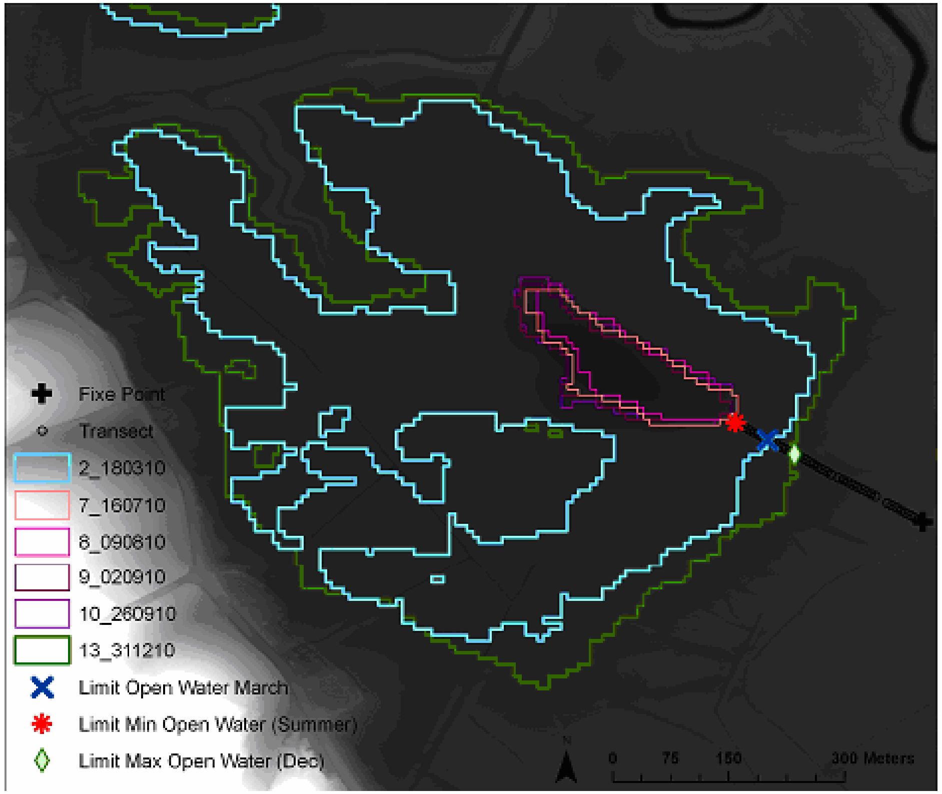


Highest inversion rates in the beginning and end of growing cycle at C-band

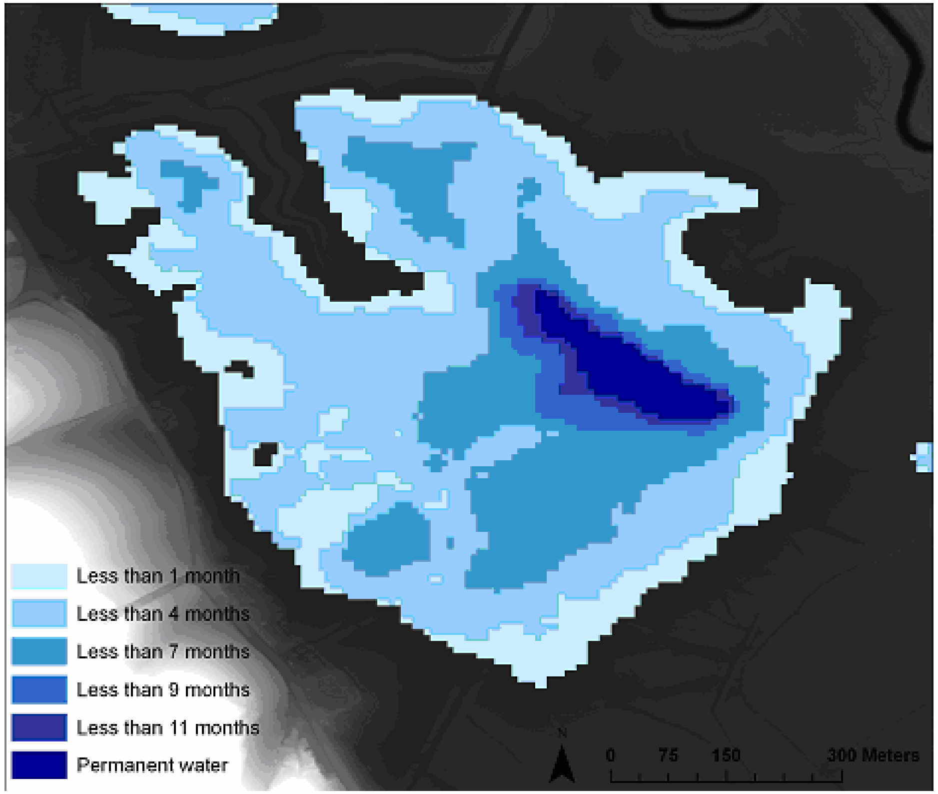


Results: Wetland delineation

E. Pottier
C. Marechal
L. Hubert-Moy
S. Corgne



Validation of the limits of the water table extracted from the segmented images (lines), and limits detected during the ground-truth campaigns (symbols)

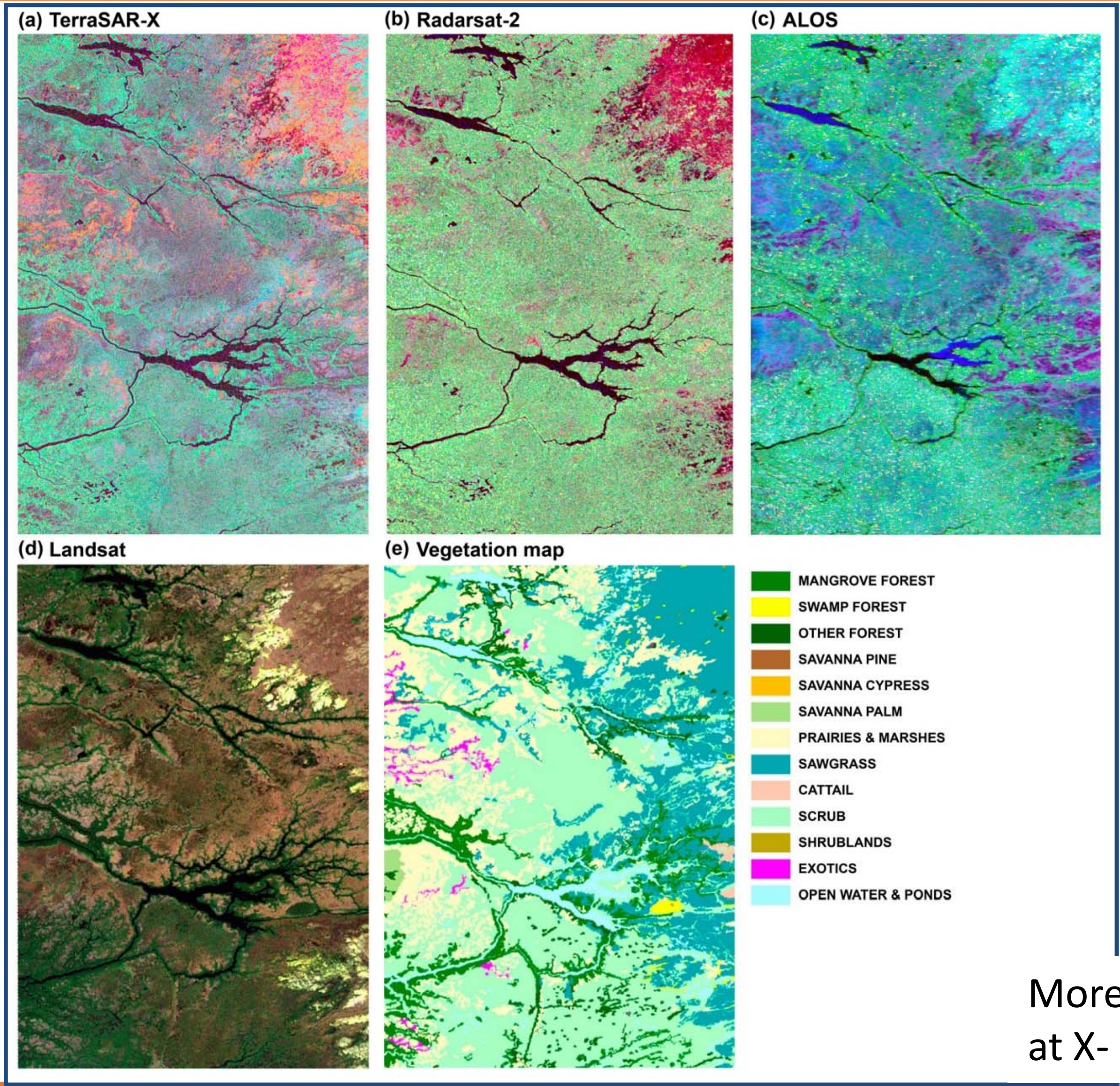


Variations of the water table over the wetland site from February 2010 to February 2011

Results: Wetland characterisation

S. Wdowinski

Shark River Slough

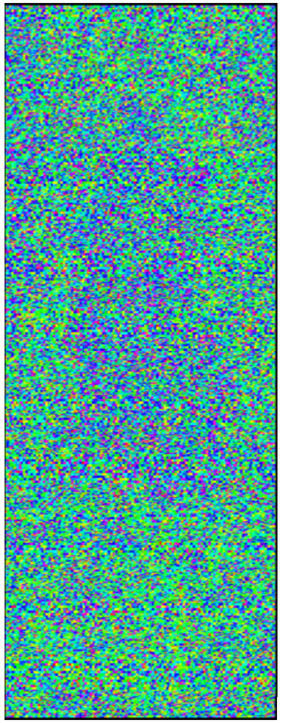


More agreement at X- and L-band

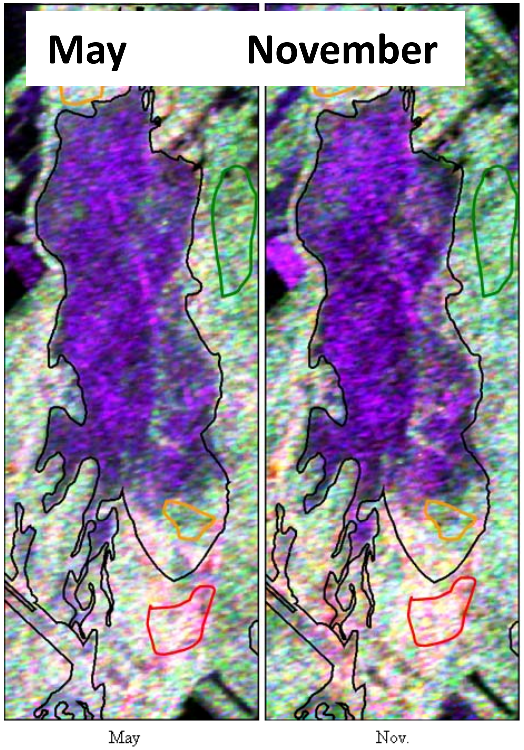
Results: Peatland monitoring

R. Touzi
G. Gosselin
R. Brooks

Baie des Mines Peatland

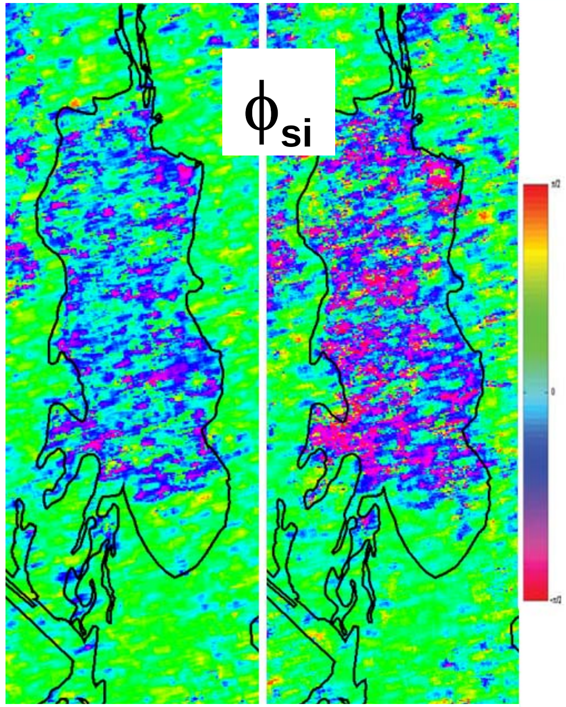


1-look ϕ_{si}



Intensity: HH, HV, VV

- Variations of the water flow beneath the peat surface
- Bog (blue)-fen (pink) discrimination easier under dry conditions (May)

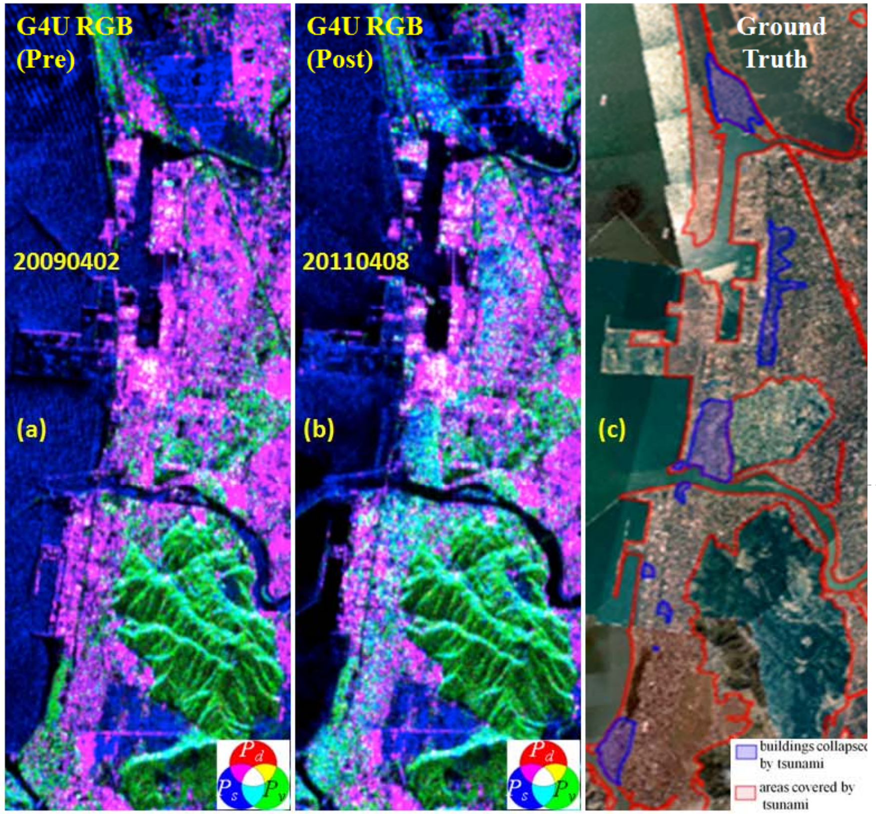


May **November**

Class	Φαs1 (deg)	αs1(deg)	HH (dB)	VV(dB)	HV(dB)
Open Bog	-18º ±3º	6º ± 3º	-6.8 ±1	-7.1 ±1	-17.5 ±1
Poor Fen	-60º ±3º	6º ±3º	-6.8±1	-7.2 ±1	-17 ±1
Treed-Bog	30º ±3º	15º ±3º	-5 ±1	-6.5 ±1	-12 ±1
swamp	31º ±3º	40º ±3º	-2.5 ±1	-5.6 ±1	-11 ±1
Forest	30º ±3º	25º ±3º	-5 ±1	-6.5 ±1	-12 ±1

Results: Effects of tsunami & earthquake

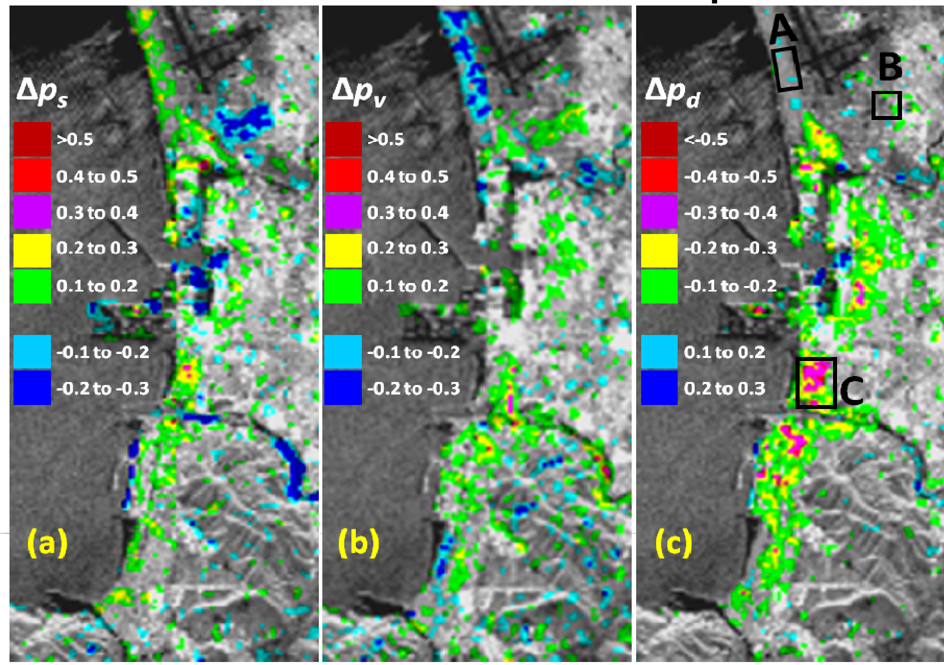
Y. Yamaguchi
G. Singh



Full-pol (decomposition)

Optical (ground-truth)

Differences for each component



	Scattering component	Mean	Std. Dev.	Number of pixels
Patch A	Δp_s	0.107	0.070	100
	Δp_v	-0.154	0.066	
	Δp_d	0.047	0.054	
	Δp_c	-0.000	0.015	
Patch B	Δp_s	-0.222	0.050	75
	Δp_v	0.145	0.046	
	Δp_d	0.061	0.031	
	Δp_c	0.016	0.008	
Patch C	Δp_s	0.136	0.132	112
	Δp_v	0.150	0.093	
	Δp_d	-0.280	0.075	
	Δp_c	-0.006	0.018	

Role of polarimetry

Performance as a function of polarimetric mode

All techniques are based on single acquisitions (time series are not considered here)

	Full-pol	Compact-pol	Co-co dual-pol	Co-cross dual-pol	Single-pol
Phenology	✓	Similar performance	Less stages	Less stages	-
Soil Moisture	✓	-	-	-	-
Classification Satellite	✓	✓	*Not tested*	Requires time-series	-
Classification Airborne	✓	*Not tested*	*Not tested*	Requires time-series	-
Wetland Delineation	✓	✓	*Not tested*	✓	-
Tropical Wetland Characterisation	>10 classes	*Not tested*	*Not tested*	6-7 classes	3-4 classes
Peatland	✓	-	-	-	-
Hazard Damages	✓	*Not tested*	-	-	-

Conclusions (summary)

The final products from each showcase are summarised as follows:

- **Crop phenology:** Phenology map with more than 90% reliability (4-5 intervals)
- **Soil moisture under vegetation:** Map for a wide variety of crops (15-33% inversion rate)
- **Crop type classification:** Crop classification with more than 80% accuracy
- **Wetland delineation:** Map of water table at any time along one year period
- **Wetland characterisation:** Map with up to 10 vegetation classes
- **Peatland monitoring:** Map of water flow variations beneath the peat surface
- **Hazard damages:** Map of damaged areas for assessment/localisation of hazard effects