→ POLINSAR 2013

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Time Series Decomposition Analysis for Compact Polarimetry

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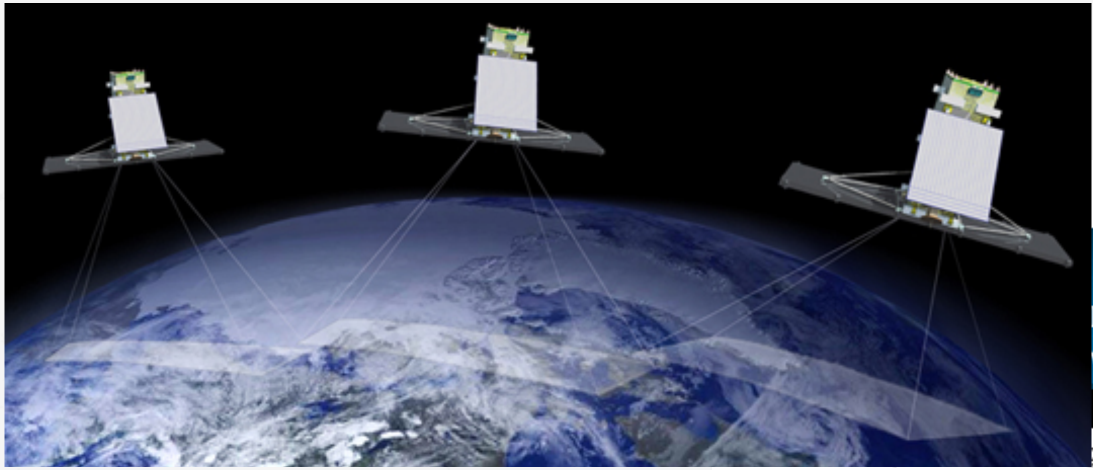
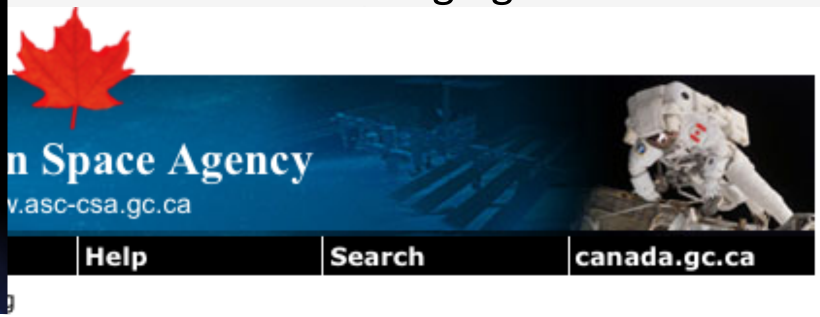
RCM : Radar for Forestry



- 3 satellite constellation
- Launch 2015-2017
- C-Band Imaging Radar



- •Maritime Surveillance
- •Disaster Monitoring
- •Eco-system Monitoring

…potentially using compact polarimetry: RHC transmit.. H&V receive…

Ecosystem Monitoring

User Requirements	Expected Results and Benefits	SAR Capabilities
Foresty		
• Clearcut harvest with partial cut detection. • Forest typing. • Biomass estimation. • Disturbance detection.	• Better assessment of forestry parameters. • Improved forestry management. • Better production capacity of forest lands. • Canadian international leadership in forest management and monitoring.	Monitoring riparian leave strips in forest clearcuts with multi-temporal RADARSAT Fine 2 mode image data. 

m-alpha Decomposition

Our approach..

Compact Decomposition

2-layer Vegetation Model

$$\underline{g} = 2m_v \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix} + \frac{m_s}{2} \begin{bmatrix} 1 \\ \sin 2\alpha_s \cos\phi \\ \sin 2\alpha_s \sin\phi \\ \cos 2\alpha_s \end{bmatrix}_{RHC} \rightarrow \begin{cases} m_v = \frac{1}{2} g_0 (1 - D_p) \\ m_s = 2 g_0 D_p \\ \alpha_s = \frac{1}{2}\tan^{-1}\left(\frac{\sqrt{g_1^2 + g_2^2}}{g_3}\right) \\ \phi = \arg(g_1 + i g_2) \end{cases}$$

Random Volume RV

Rank-1

Fully invertible model

1. S. R. Cloude, D. Goodenough, H. Chen, "Compact Decomposition Theory", IEEE Geoscience and Remote Sensing Letters, Vol. 9 (1), pp 28-32, Jan 2012

…but

Vegetation mapping = low coherence

HV is not directly measured in Compact…but it can be estimated from a model e.g.

$$t_{33} = 4\sigma_{HV} = \frac{1}{2} g_0 (1 - D_p) \Rightarrow \sigma_{HV} = \frac{1}{8} g_0 (1 - D_p)$$ Compact Crosspol estimation

D_p

0 ⟷ 1

Forested………………vegetation…………non-vegetated

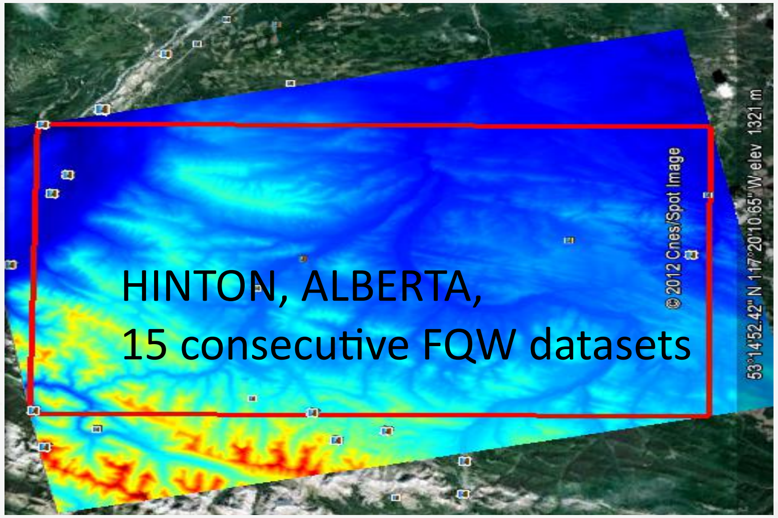
Notes :

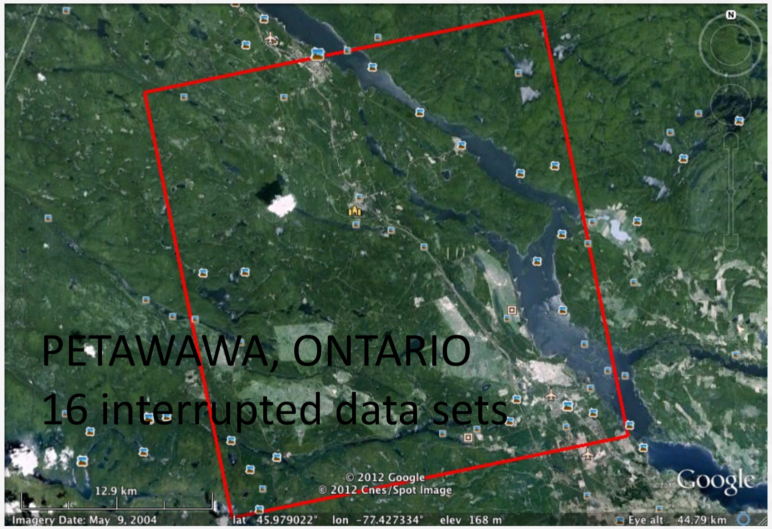
- HV estimate corresponds to volume scattering in Freeman-Durden* decomposition
- Dp is the degree of polarization (a coherence)

-VEGETATION MONITORING LEADS TO LOW COHERENCE STATISTICS

-FILTERING AND ESTIMATION NON-TRIVIAL….space-time filtering considered

*Freeman, A. and Durden, S.L., "A Three Component Model for Polarimetric SAR Data," IEEE Trans. GRSL, Vol. GE-36, pp 963-973 (1998)

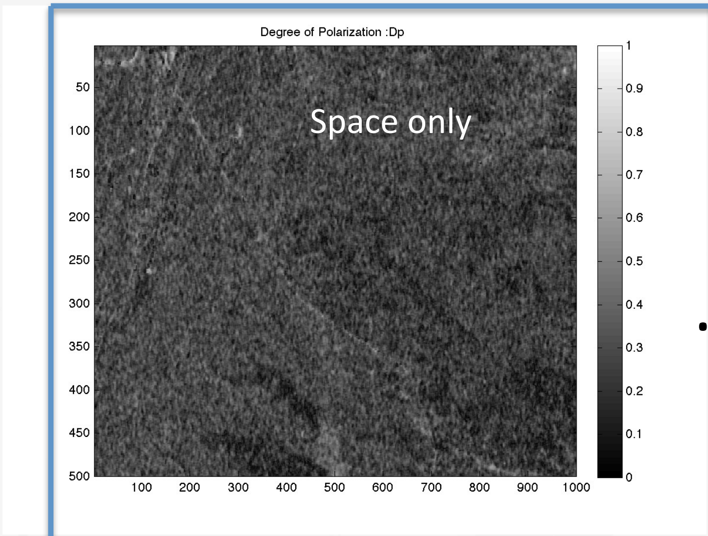


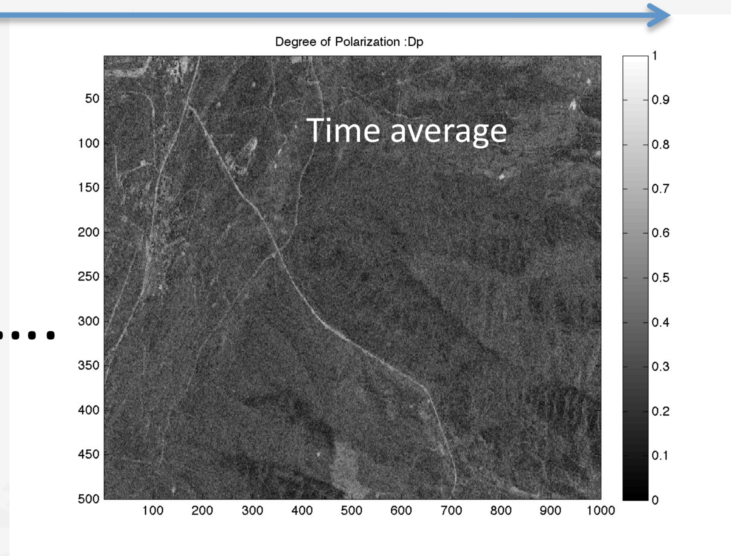


Track	Petawawa FQ9 (AOI=28°) A, 22:55 UTC	Petawawa Tmax/min (°C)	Hinton FQ10W (AOI=30°) D, 14:12 UTC	Hinton Tmax/min (°C)
1	31/12/08	-14.8/-21.3	09/09/11	30.4/1.1
2	24/01/09	-14.8/-25.8	03/10/11	13.4/2.7
3	17/02/09	-0.4/-16.8	27/10/11	4.4/-4.0
4	11/07/09	26.4/10.3	20/11/11	-4.3/-25.4
5	04/08/09	25.6/14.1	14/12/11	-2.5/-14.3
6	28/08/09	17.9/10.6	07/01/12	1.4/-5.9
7	21/09/09	21.2/0.9	31/01/12	6.0/-3.8
8	15/10/09	6.0/-4.8	24/02/12	-5.5/-13.8
9	08/11/09	16.7/-3.2	19/03/12	5.1/-12.3
10	02/12/09	6.8/-2.3	12/04/12	7.3/0.3
11	26/12/09	0.3/-2.5	06/05/12	14.9/-5.5
12	12/02/10	-7.8/-20	30/05/12	16.7/2.8
13	23/08/10	25.8/16.8	23/06/12	20.6/12.3
14	10/10/10	20.1/-3.4	17/07/12	29.1/10.2
15	03/11/10	8.7/-6.1	10/08/12	25.5/5.1
16	27/11/10	-1.6/-10.8		

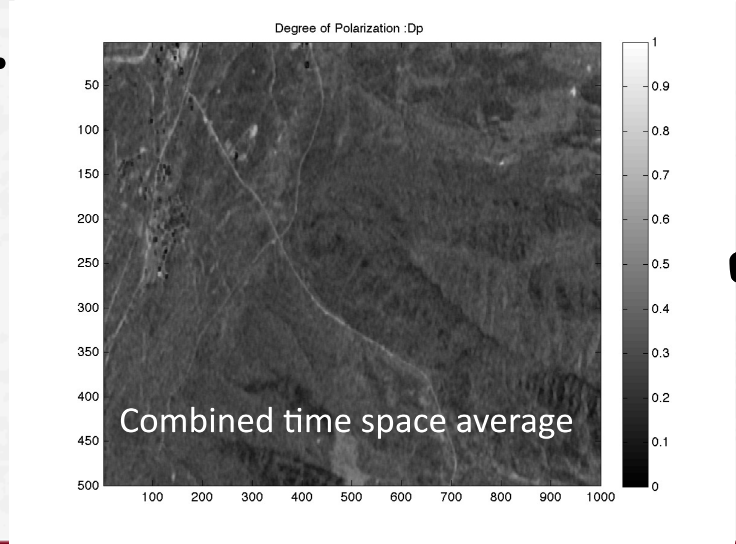
Space vs. Time Filtering of Compact Dp

time





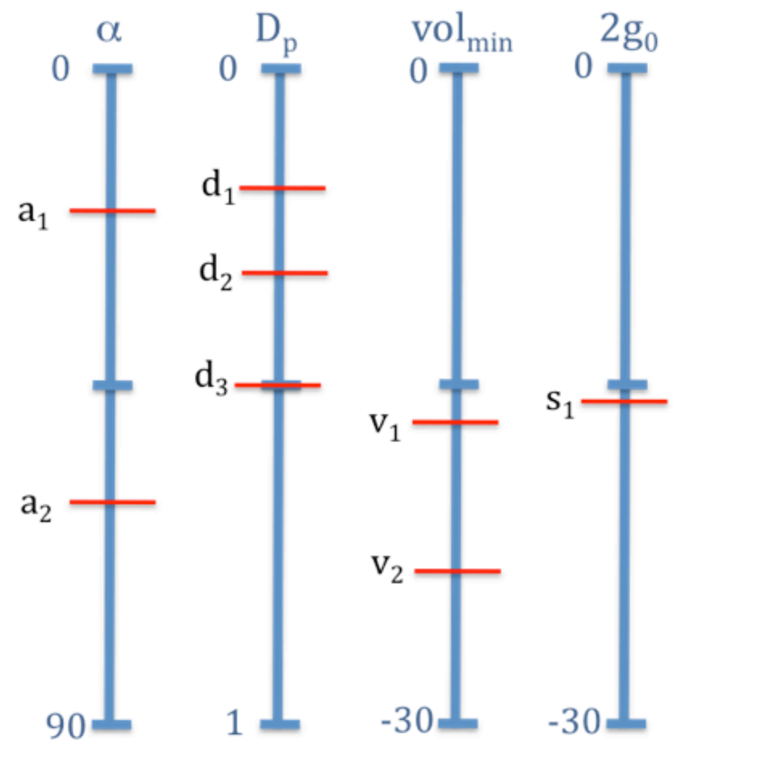
Degree of polarization



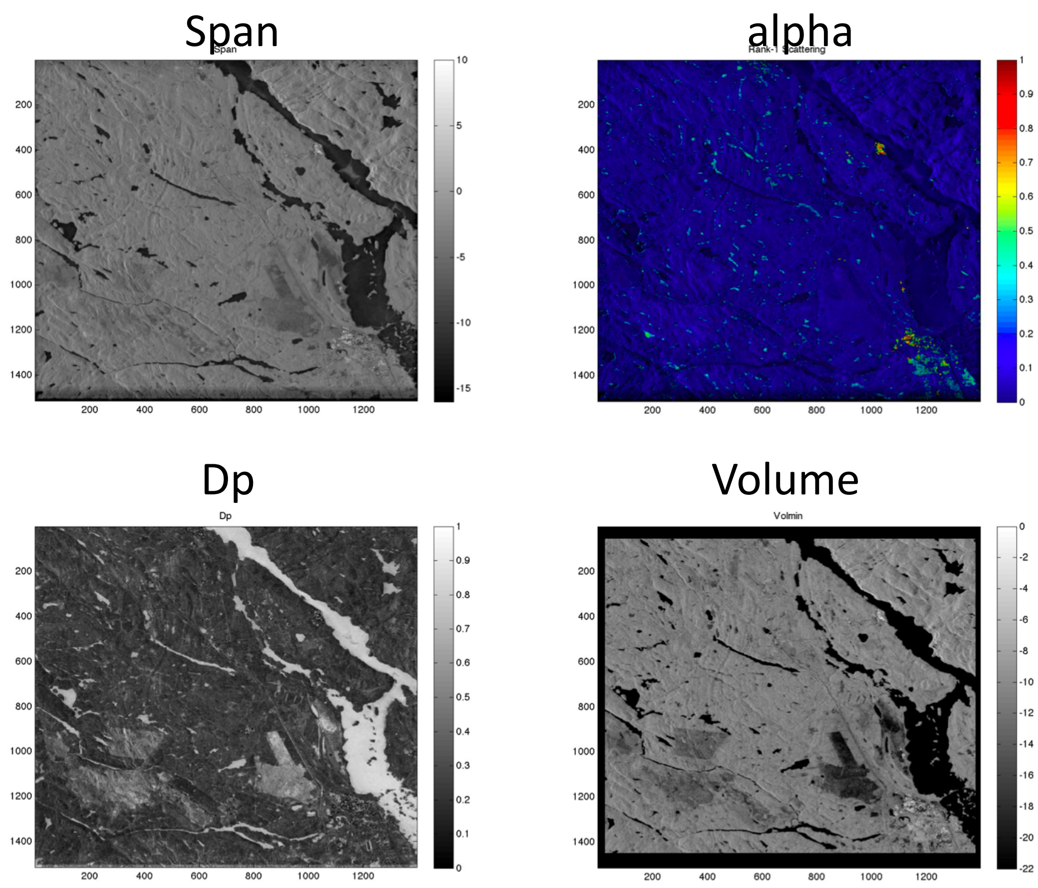
✔

space

Space/Time Average Compact Products

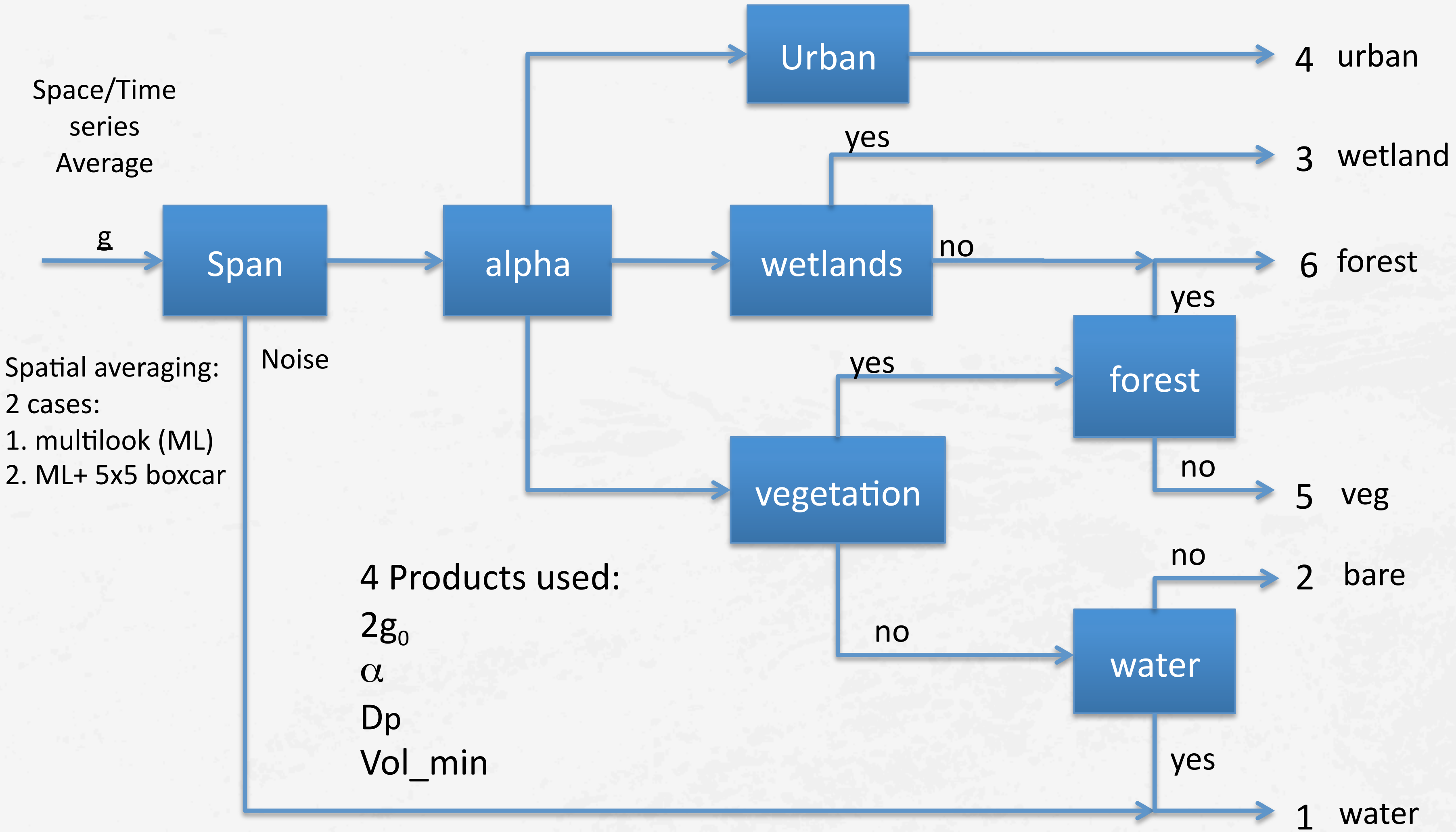


$$\underline{c} = [a_1 \quad a_2 \quad d_1 \quad d_2 \quad d_3 \quad v_1 \quad v_2 \quad s_1]$$



8 thresholds ..values set using physics of decomposition..

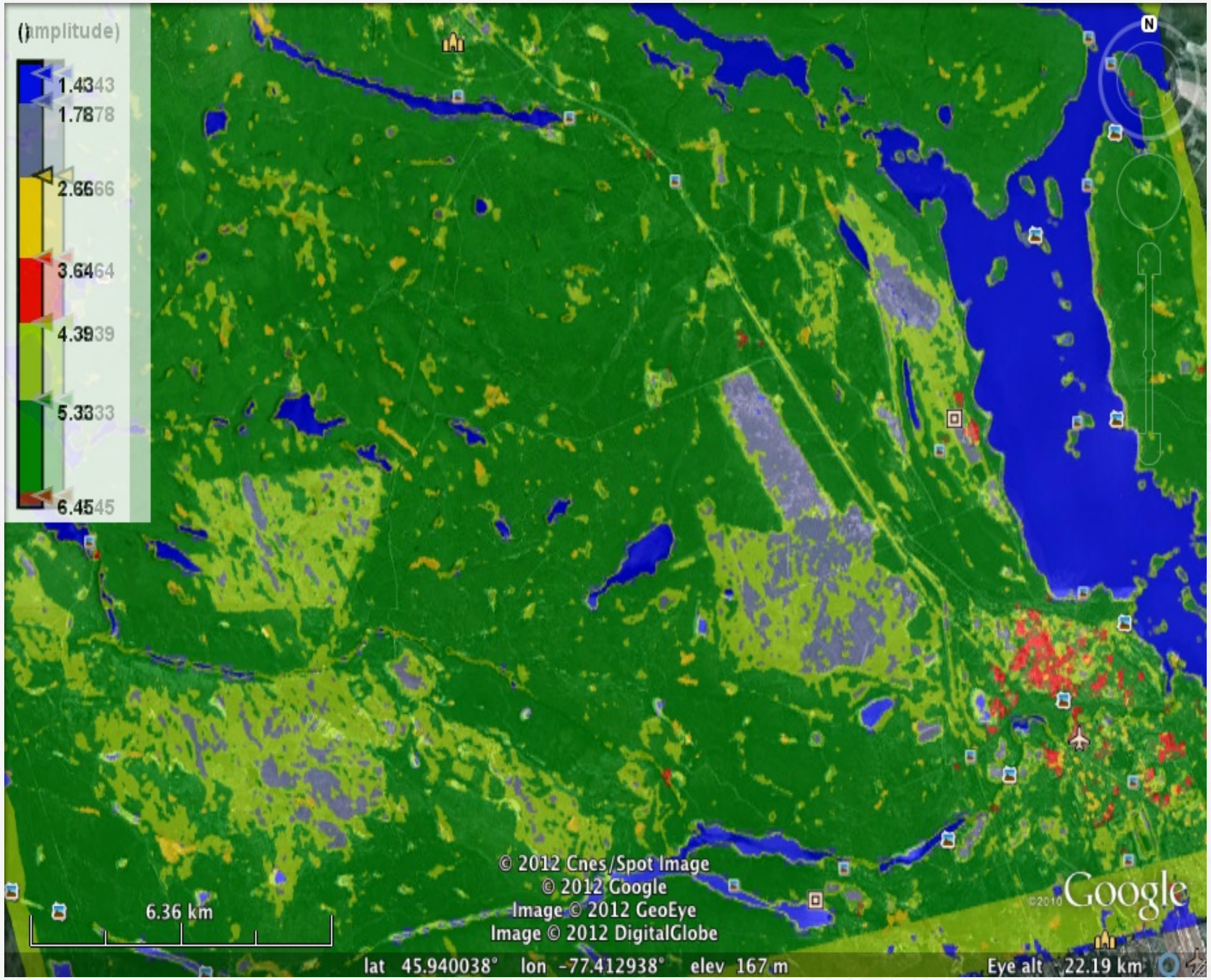
Rule Based Land-Use Classifier



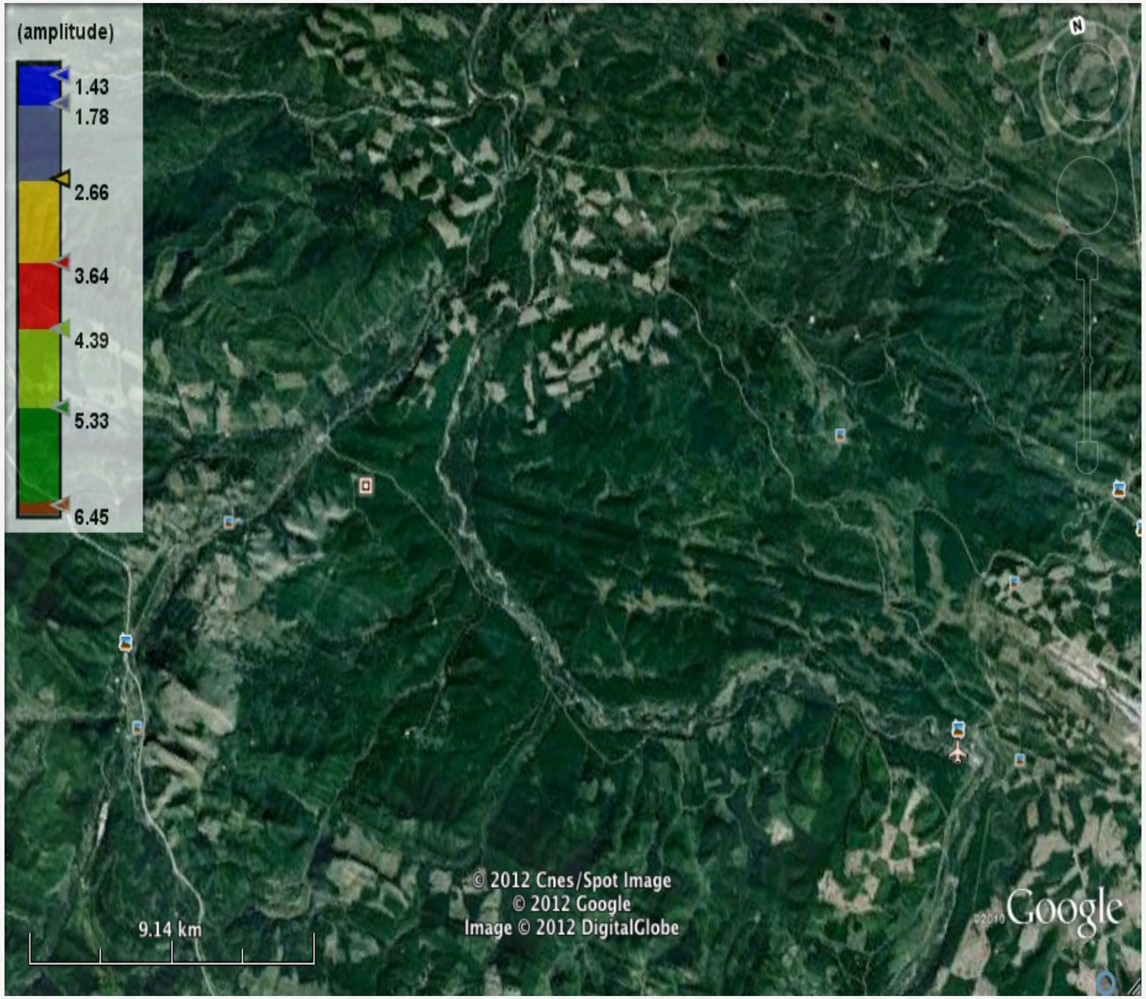
$$\underline{c} = [20 \quad 60 \quad 0.25 \quad 0.33 \quad 0.5 \quad -16 \quad -22 \quad -16]$$

Petawawa Optical Image

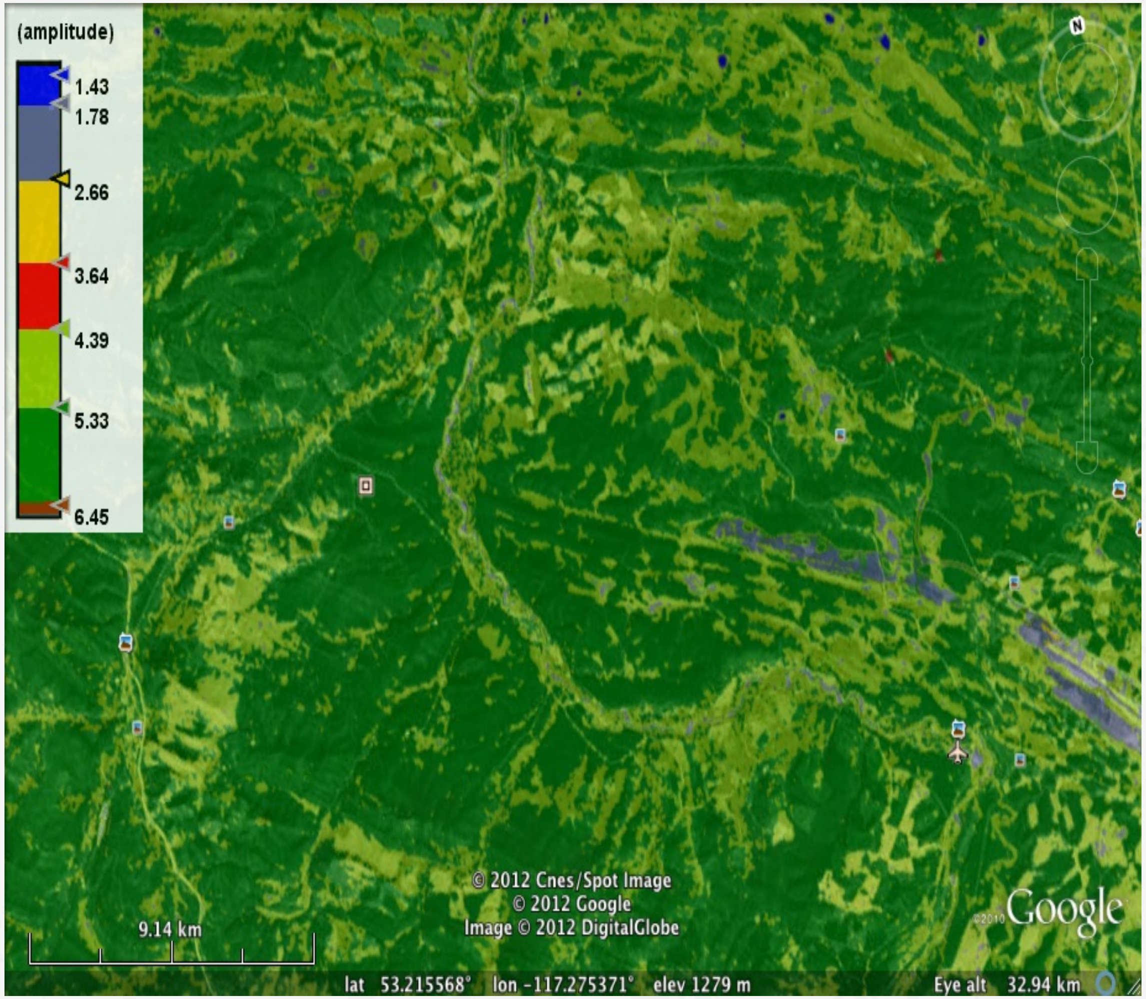
Petawawa C-Band Radar Classification



Hinton Optical Image



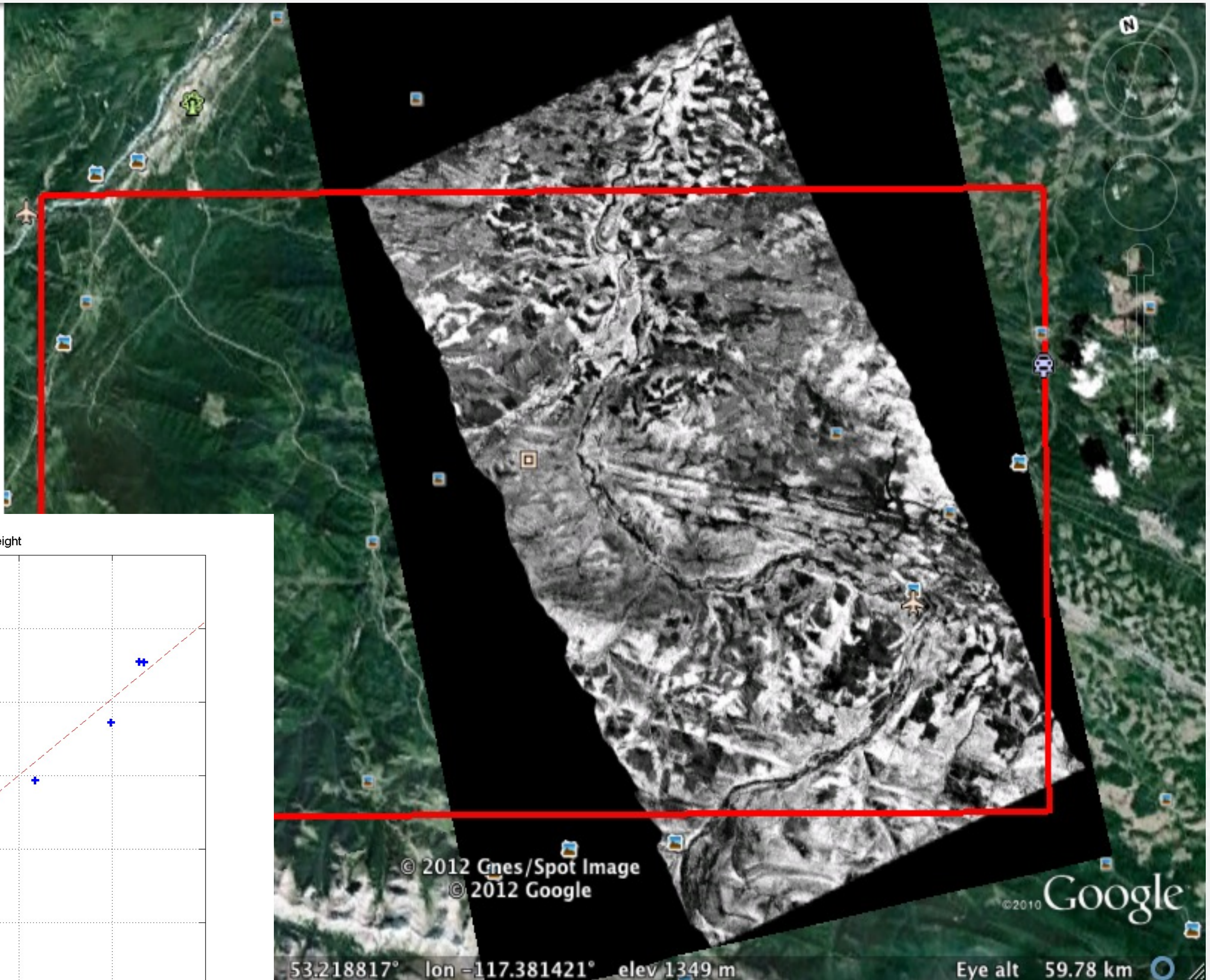
Hinton C-Band Radar Classification

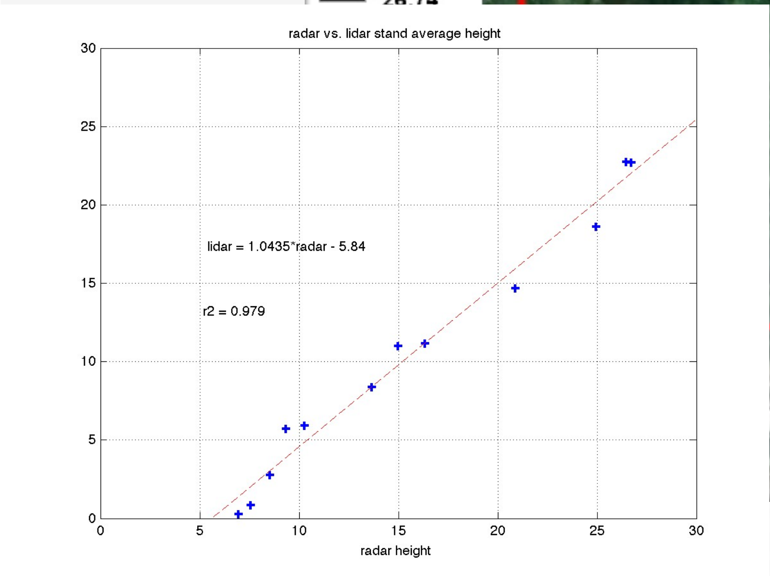


Good general performance but poor biomass discrimination..

..augment C-band with X-band data..

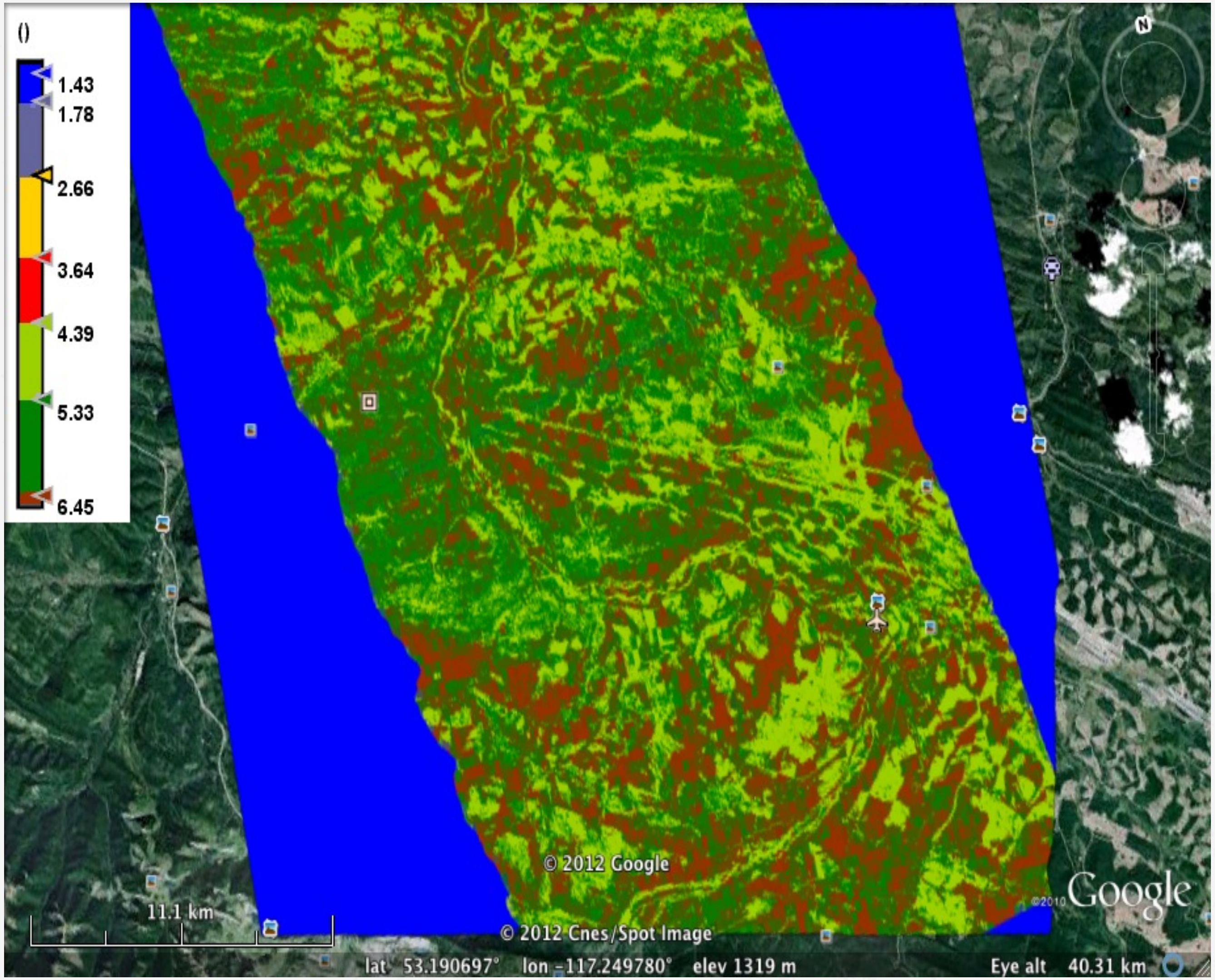
POLInSAR Forest Height product : Tandem-X



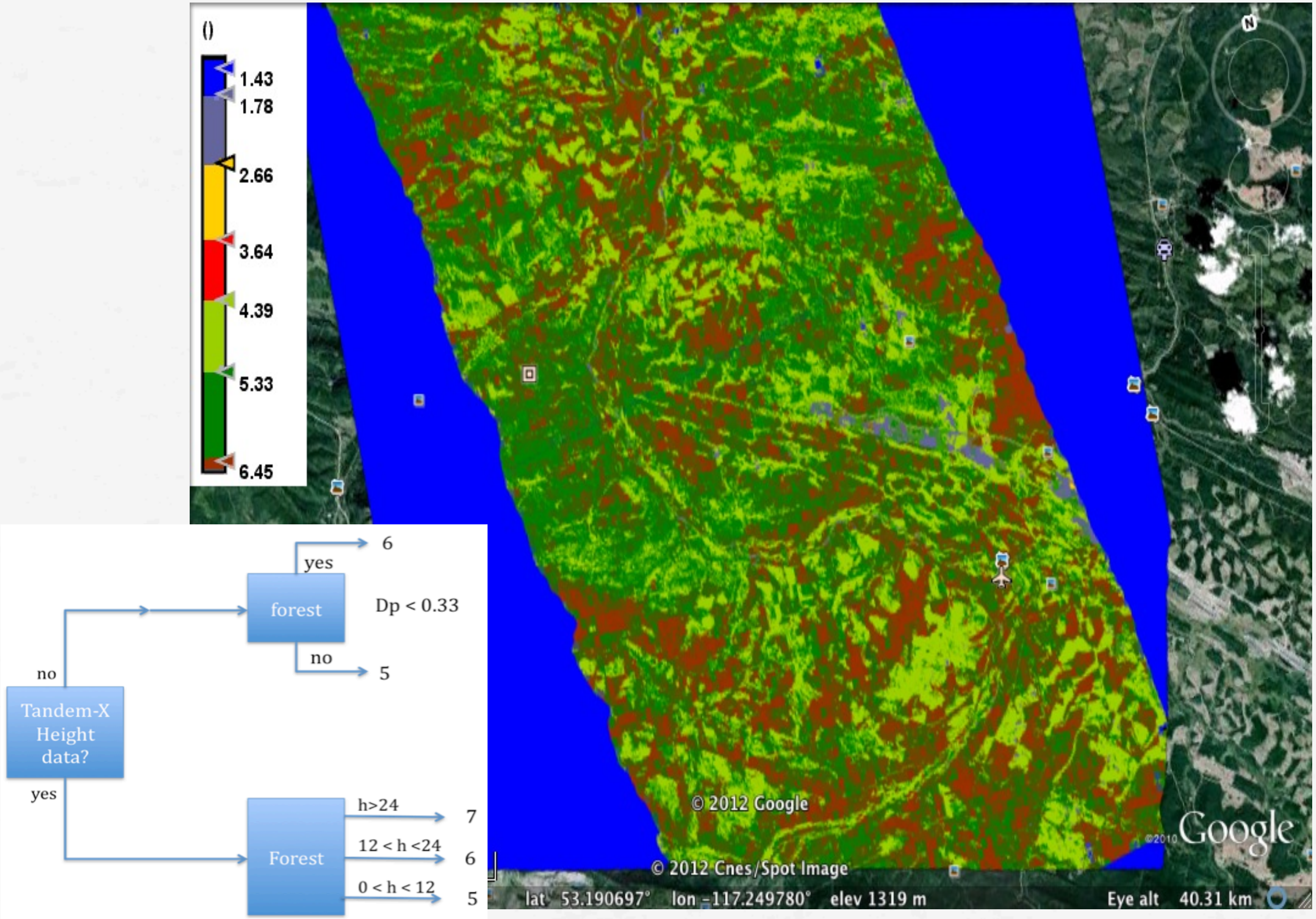


good for forest height…poor for other land-use types

3 –level Forest Height Classifier : Tandem-X only



Merged C-Band Compact + Tandem-X Height



Conclusions

- Compact Mode leads to low coherence estimation for vegetation monitoring
  requires combined space-time filtering…
  ..we found time filtering to be useful, even over long periods..
- Good Filtering leads to design of robust rule-based classifier
  we used one test site (Petawawa) to train and then
  another (Hinton) for validation
- Found good general performance but poor discrimination of forest biomass
  so augmented by Tandem-X POLInSAR height estimate..
  3-level high biomass classes
- Merged products into consistent classifier X-Band POlInSAR + C-band compact
- Could be used to augment forest coverage of other sensors e.g. ESA-BIOMASS

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