K&C Phase 3 – Brief project essentials

Combined Use of SAR, InSAR and Lidar for Measuring Forest Biomass and Structure in the Northeastern United States

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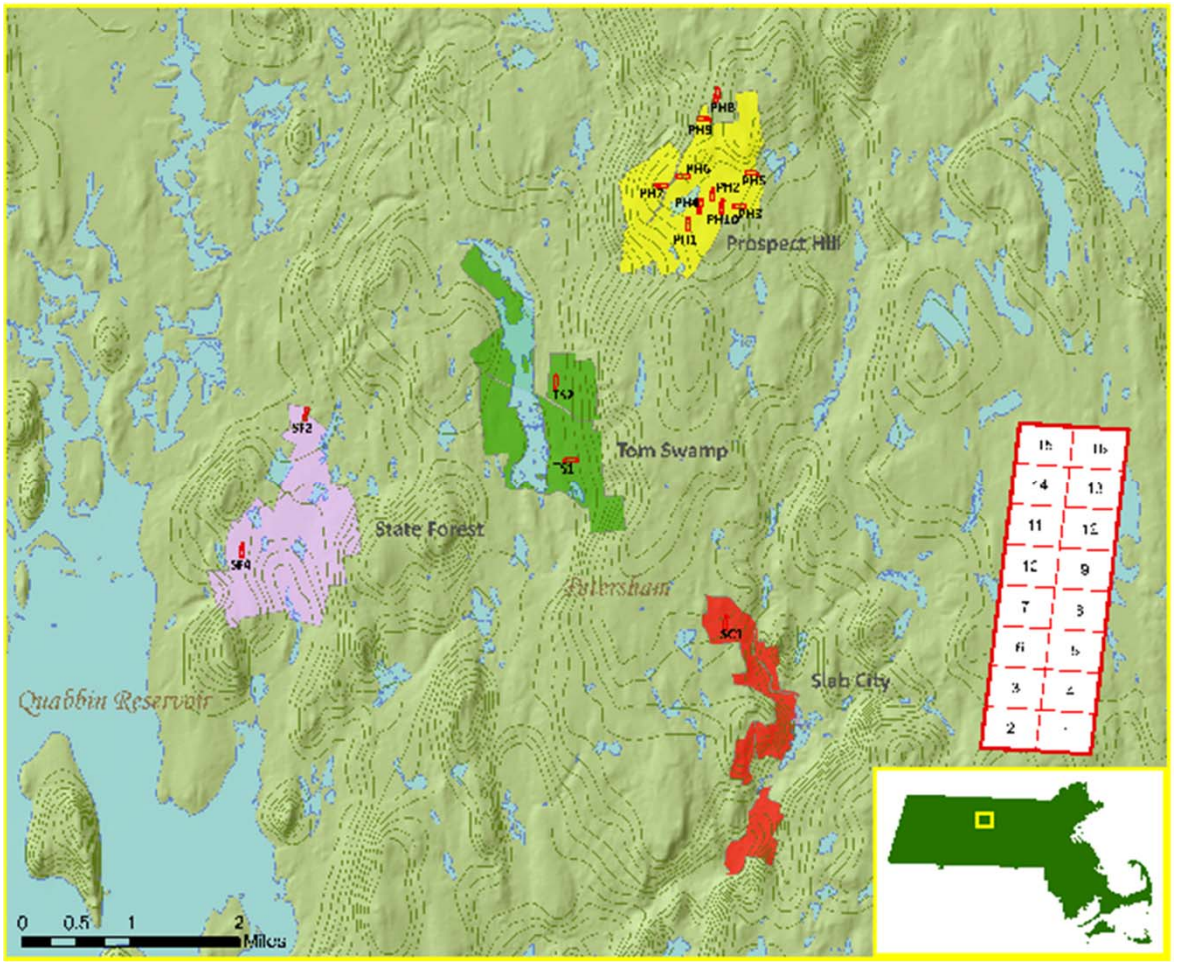
Science Team meeting #17 – Phase 3 Kick-off
JAXA TKSC/RESTEC HQ, Tokyo, March 27-29, 2012

Project area(s)

Use ALOS/PALSAR data for estimating forest physical characteristics of height, density and biomass. An assessment of the errors associated with these estimates is a critical part of this work. The principal remote sensing data type will be interferometric, but we are also looking at backscatter relationships as well.

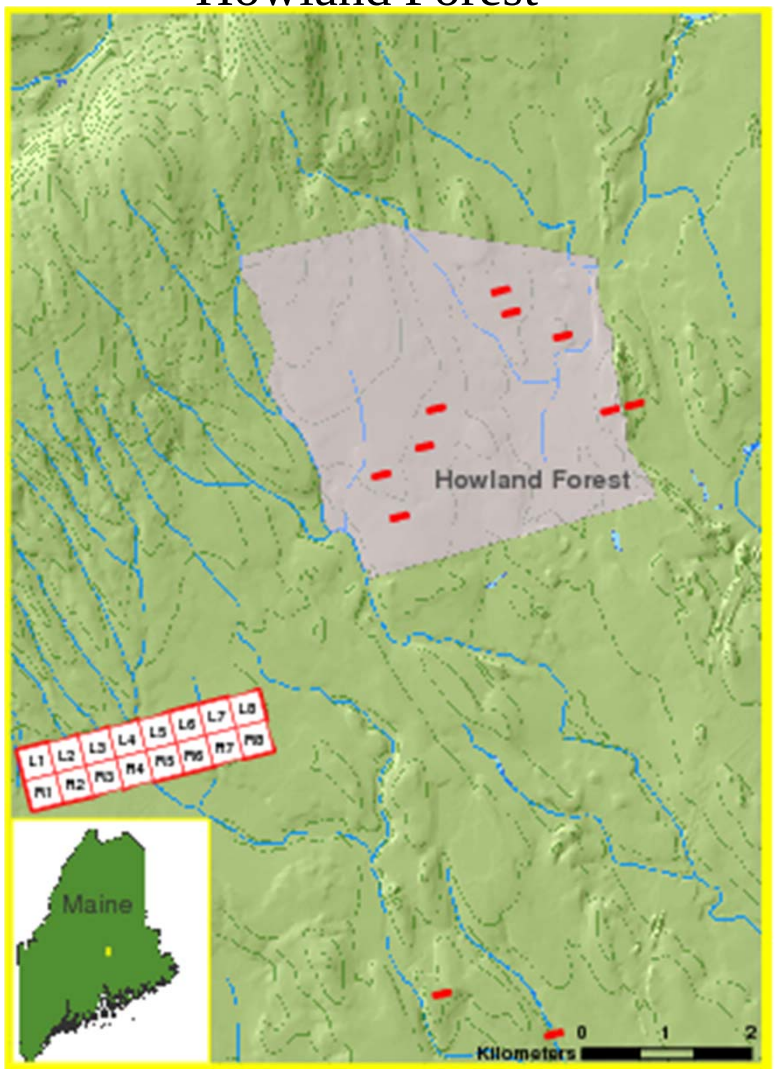
The primary location for this work is the Harvard Forest, but we also have been investigating the Howland forest in Maine and the Injune Landscape Collaborative Project in Queensland, Australia.

Study Sites

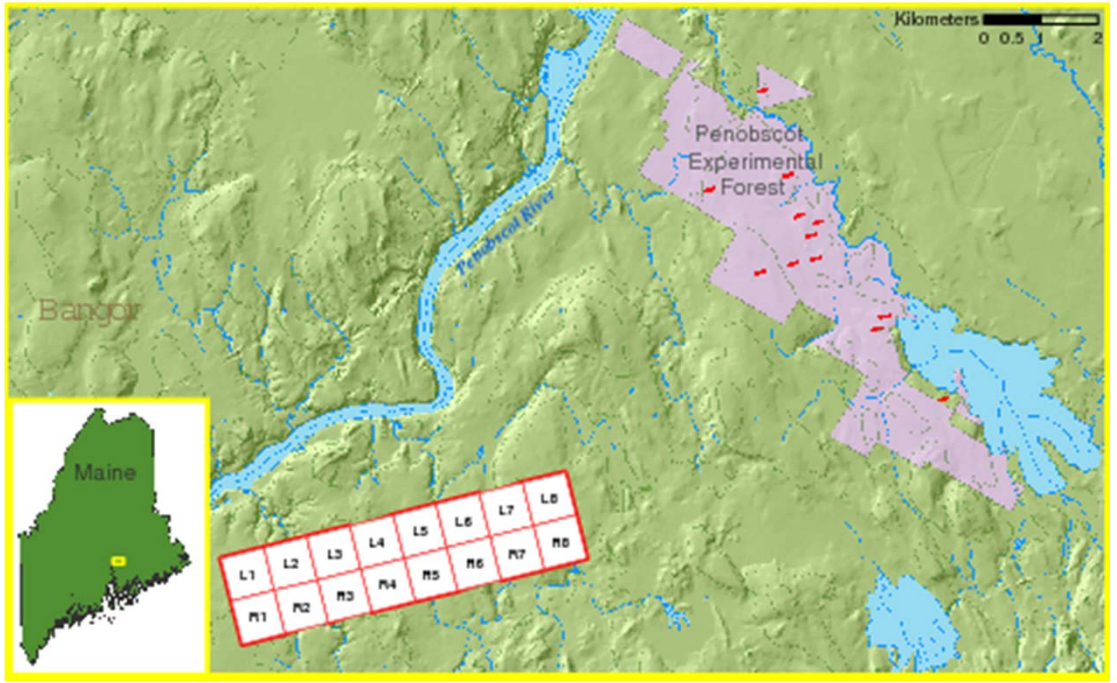


Harvard forest

Howland Forest



Study Sites



Howland Forest
(Penobscott)

Project objectives

The objectives of the project is to create algorithms that can be applied regionally and/or on a continental scale for estimating biomass and carbon storage. Hence, this work addresses the K&C thematic driver of **C**arbon cycle science.

Because carbon is estimated from forest structure, and forest structure can be used for characterizing forest ecology, this work also addresses the K&C thematic driver of Environmental **C**onservation.

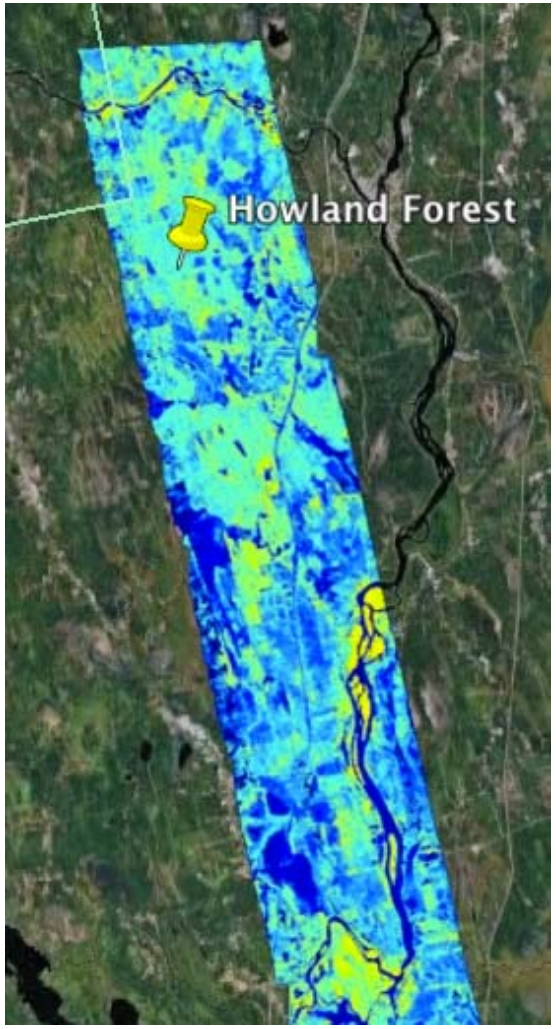
Project schedule

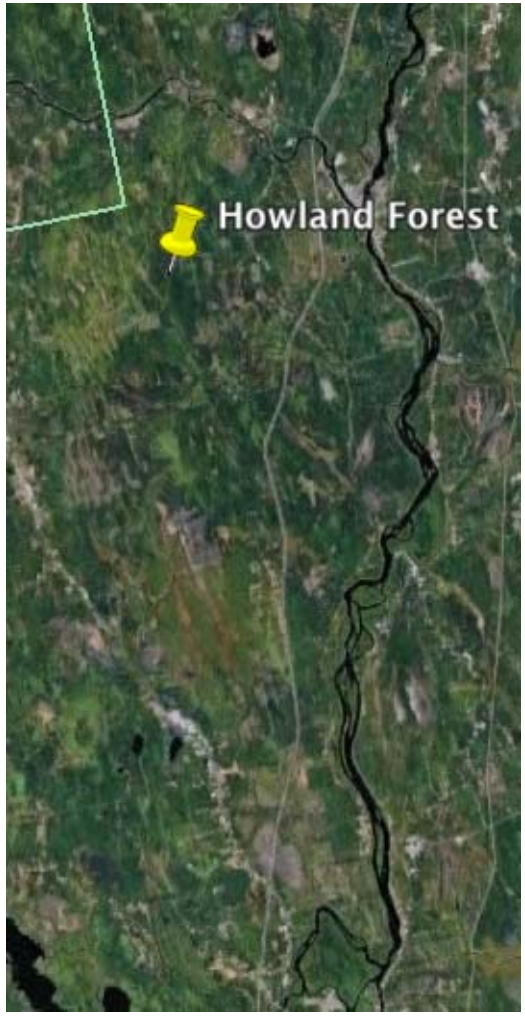
Milestone 1 (March 2012). Provide lidar derived topography and vegetation height map for the Harvard Forest region to JAXA.

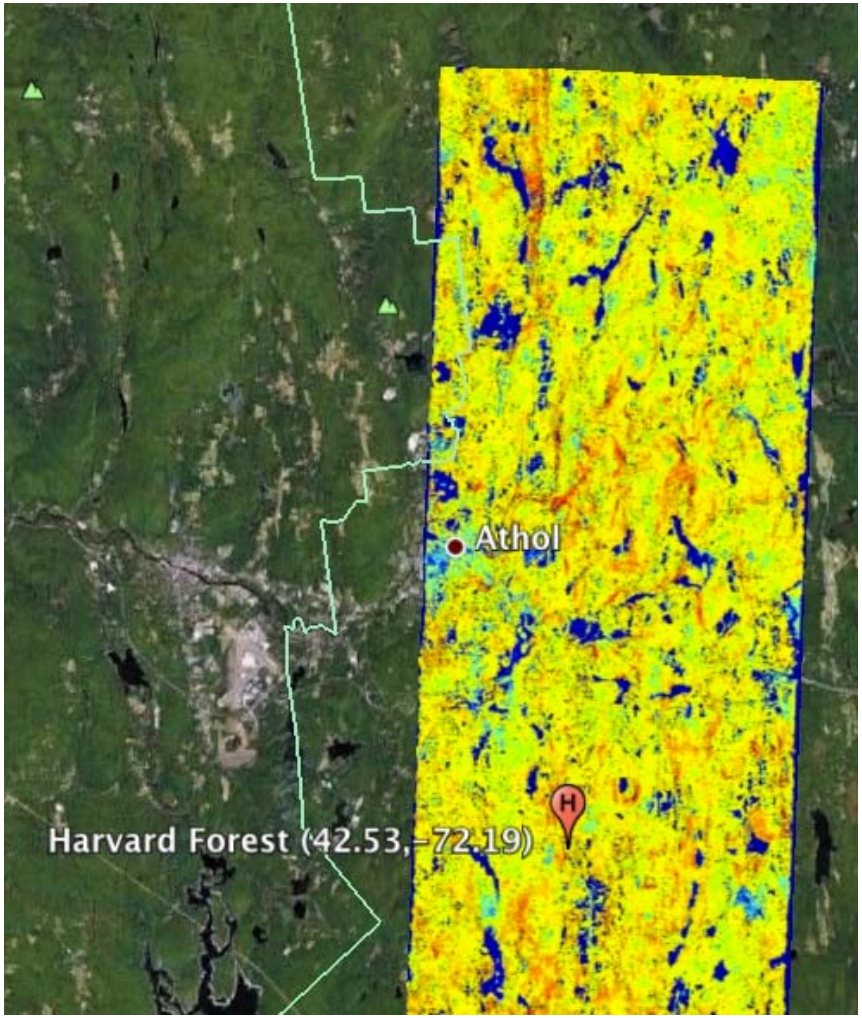
Milestone 2 (March 2013). Reporting of algorithm development and forest modeling effort ongoing in the Northeastern US.

Milestone 3 (March 2014). Final report for algorithm development and error assessment over the Northeastern US.

Lidar derived heights: delivered!







Support to JAXA's global forest mapping effort

This project will aid in JAXA's global forest mapping effort through the development of algorithms that perform forest mapping using ALOS/PALSAR data. Since JAXA's global forest mapping effort will depend primarily on PALSAR data, this work will have a direct relevance to JAXA's work.

Ground validation for the Harvard Forest will be shared. This includes ground validation data and derived products from remote sensing data from LVIS and UAVSAR.

Derived products for other forest sites in the Northeastern US can be shared as well.

Deliverables

Planned output of the project:

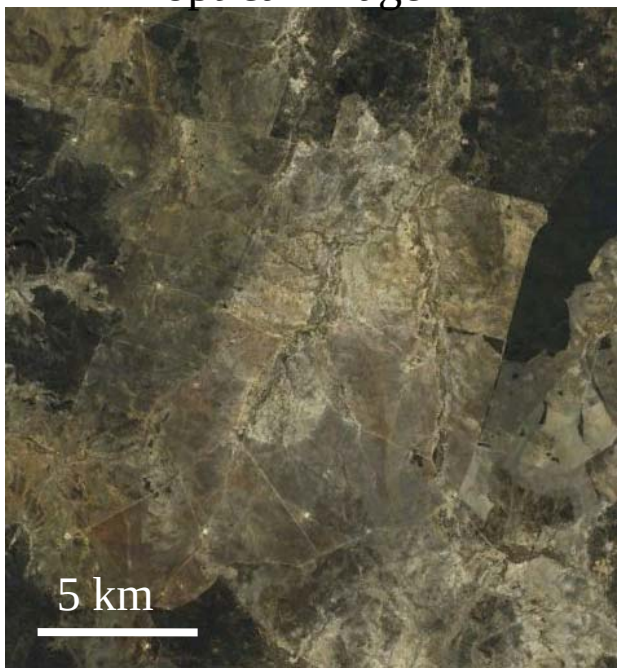
- Lidar derived vegetation height map for the Harvard and Howland Forests (done)

- Algorithm for using interferometric correlation for estimating effective vegetation heights

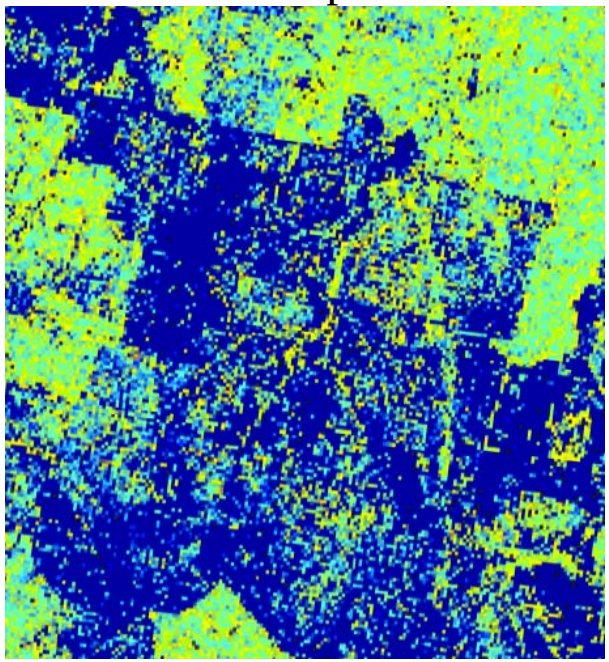
Something for REDD+

- SAR Interferometric correlation, corrected for thermal noise, can be used for sensitive detection of landcover change
- We have been using PALSAR interferometry at the Injune region (ILCP) to estimate “tree height” and detect degradation.
- A paper was presented at IGARSS 2012 and is in the RSE special issue

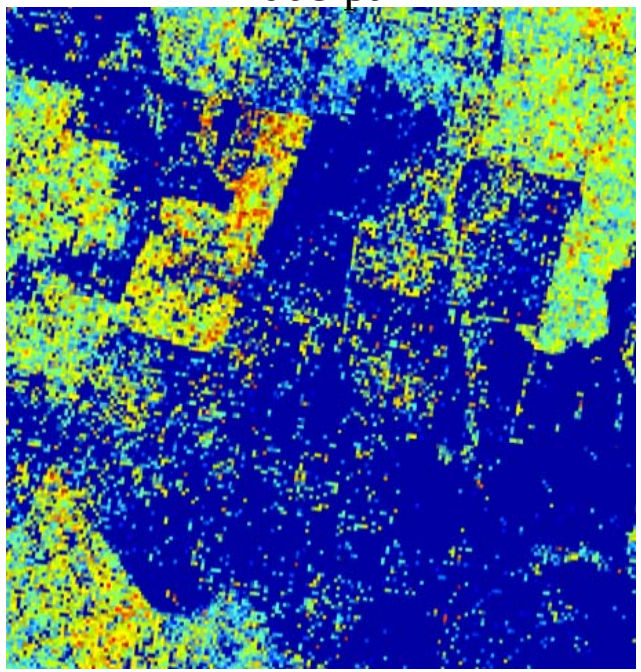
optical image



2007 pair



2008 pair



Research Update

Combined Use of SAR, InSAR and Lidar for Measuring Forest Biomass and Structure in the Northeastern United States

Methods

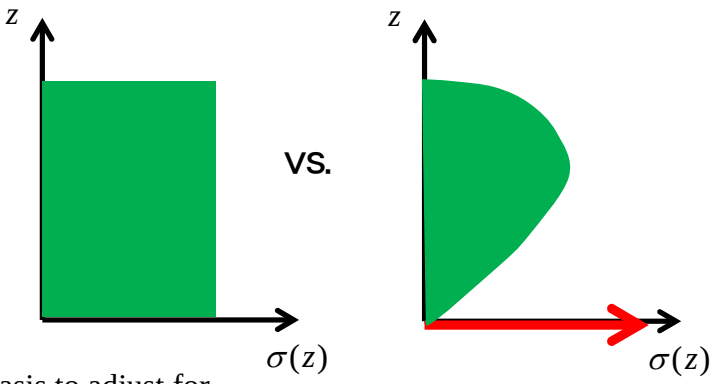
- **Use interferometric correlation and a simple model to remove baseline and thermal noise effects and estimate "tree height" over extended regions. This is an approximation!**

$$\gamma_{obs} = \gamma_{vol} \cdot \gamma_{geom} \cdot \gamma_{SNR} \cdot \gamma_{temporal}$$

$$\gamma_{vol}(k_z) = \frac{\int \sigma(z) exp^{-jk_z z} dz}{\int \sigma(z) dz} \qquad k_z = \frac{4\pi B_\perp}{\lambda R \sin\theta}$$

$$h_v \approx \frac{\sqrt{C_{scene}\left(1 - |\gamma_{vol}|\right)}}{k_z}$$

adjusted over a landscape basis to adjust for variations in vegetation density and account for temporal decorrelation



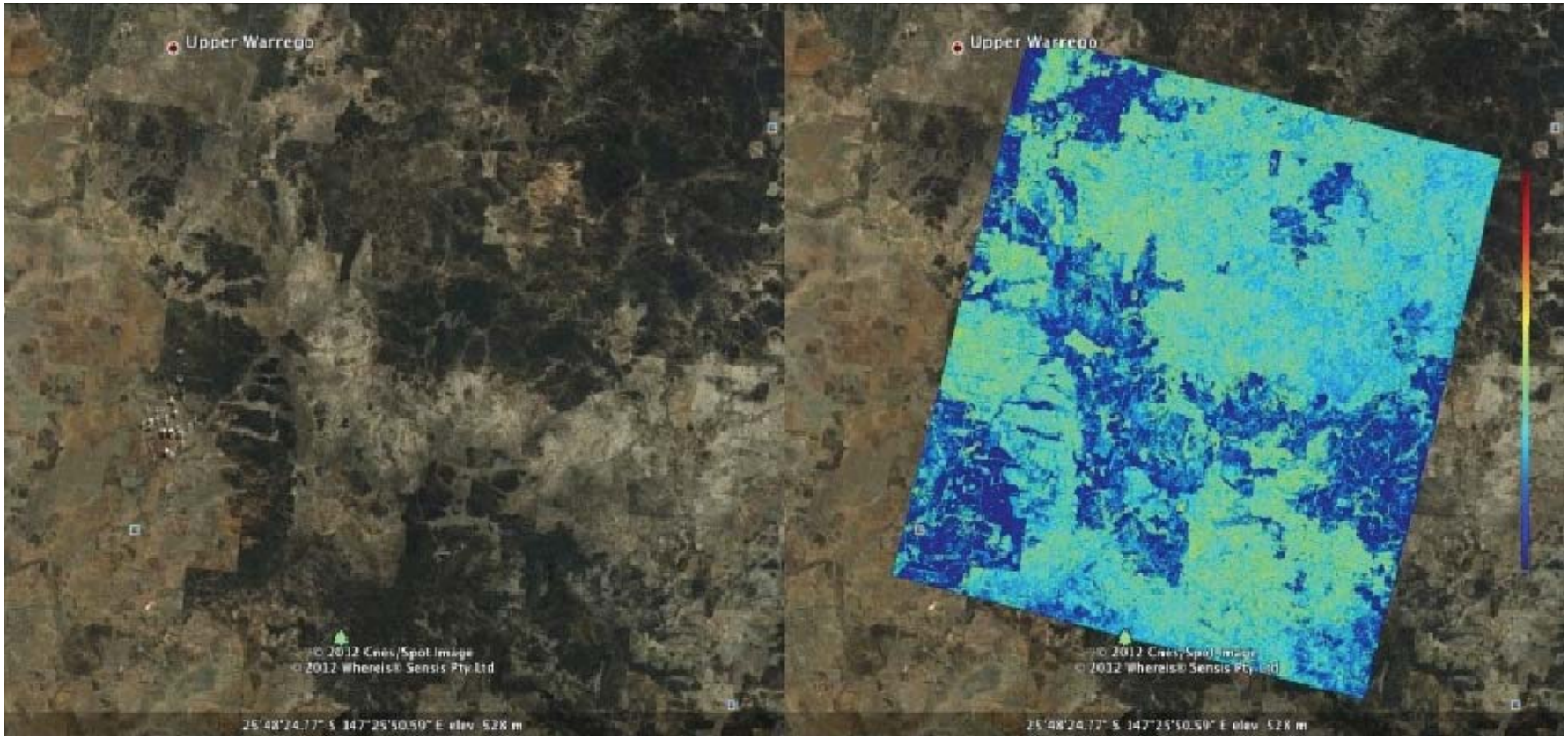
Test Site in Queensland

- **Six FBD PALSAR scenes over the Injune Landscape Collaborative Project (ILCP) were processed and used to form interferograms**

Interferogram	Dates of Collection	Flight Mode	Perpendicular Baseline
#1	Nov 10 2007, Dec 26 2007	Descending	530 m
#2	Jul 16 2007, Oct 16 2007	Ascending	434 m
#3	Sep 02 2008, Oct 18 2008	Ascending	309 m

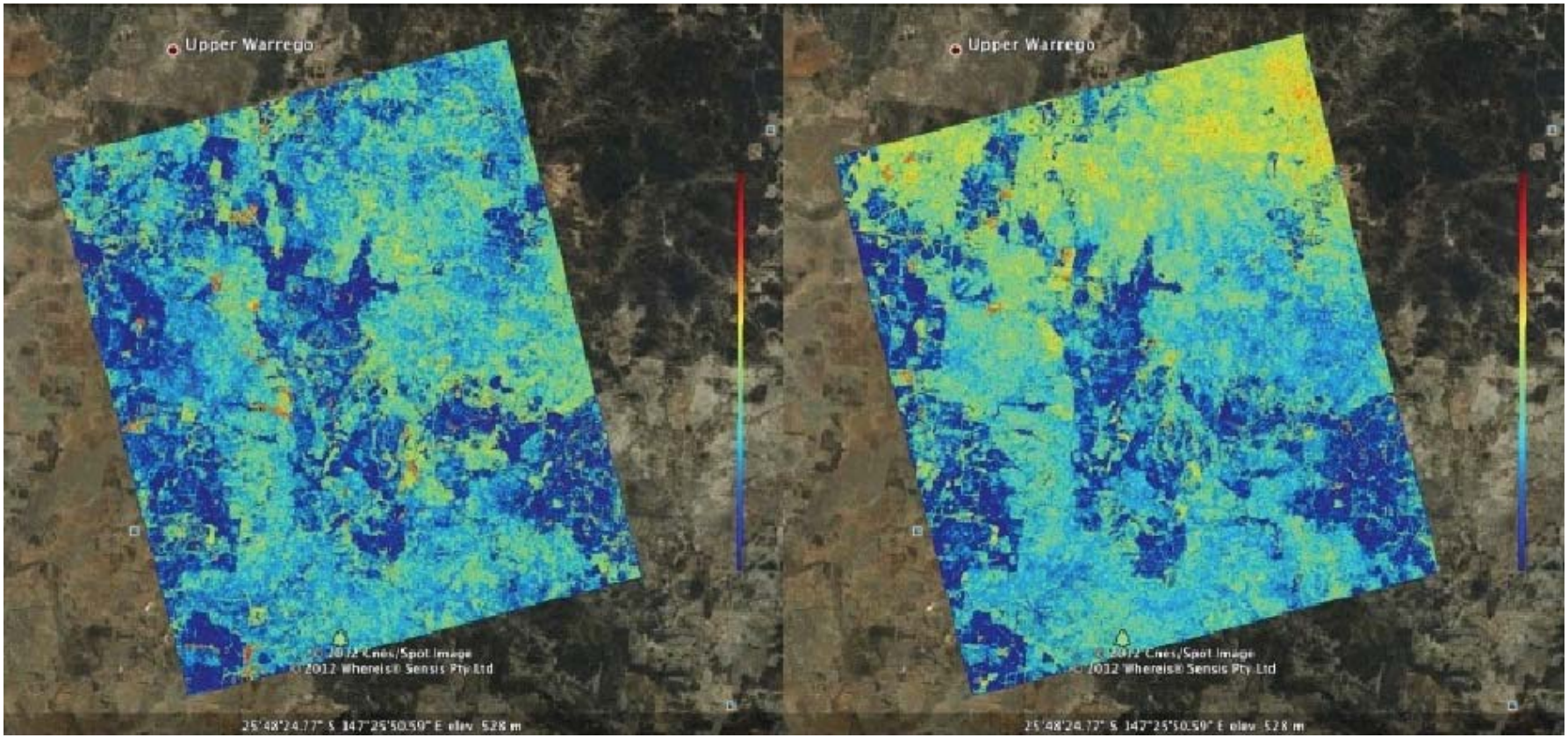
HH-Polarized "Heights"

- Below is shown a closeup of the ILCP and the estimated "height" from the descending interferometric pair
- The "height" is a combined product of the tree density and the actual height.



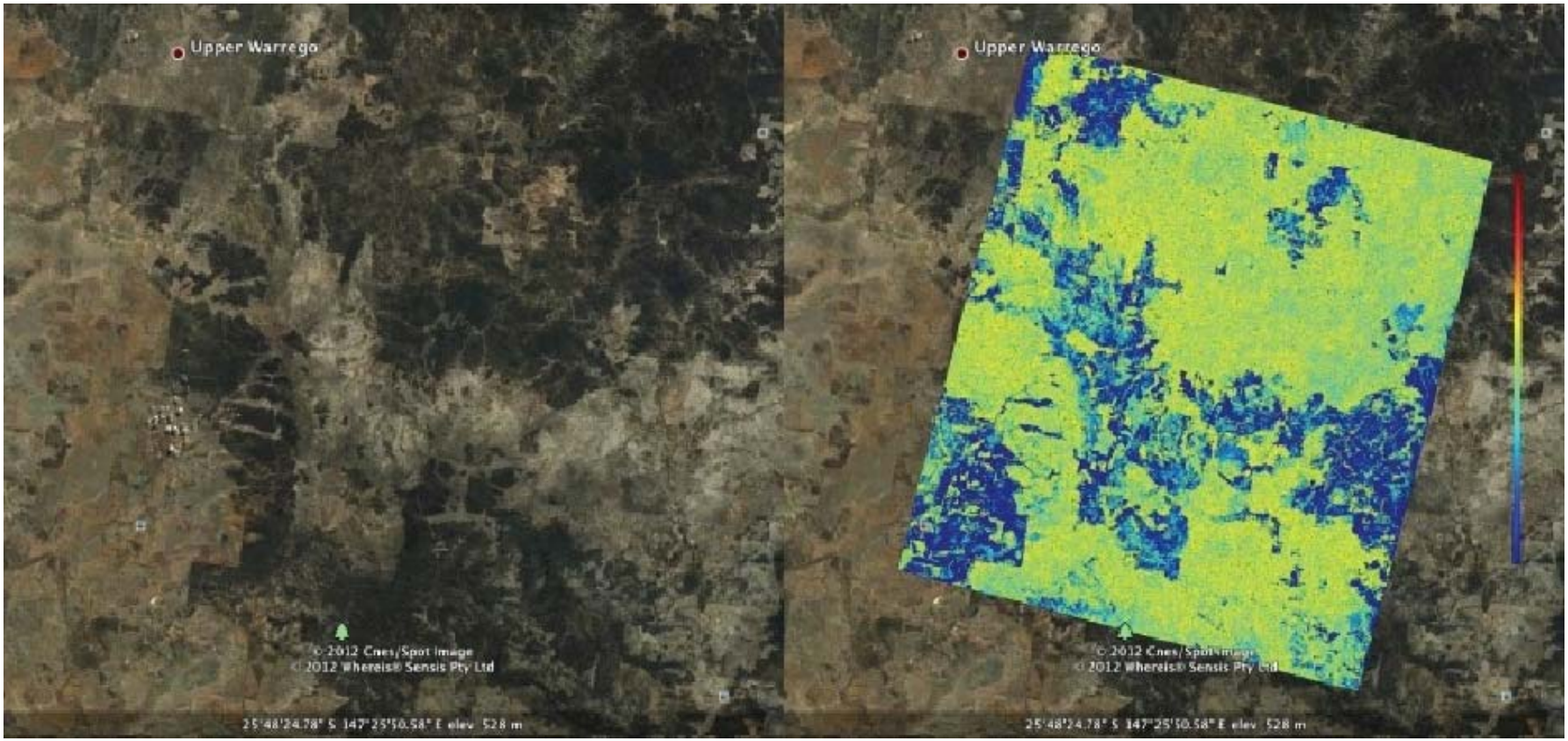
HH-Polarized “Heights”

- Temporal decorrelation is a confounding factor
- This is evident in the descending interferometric pair shown at right



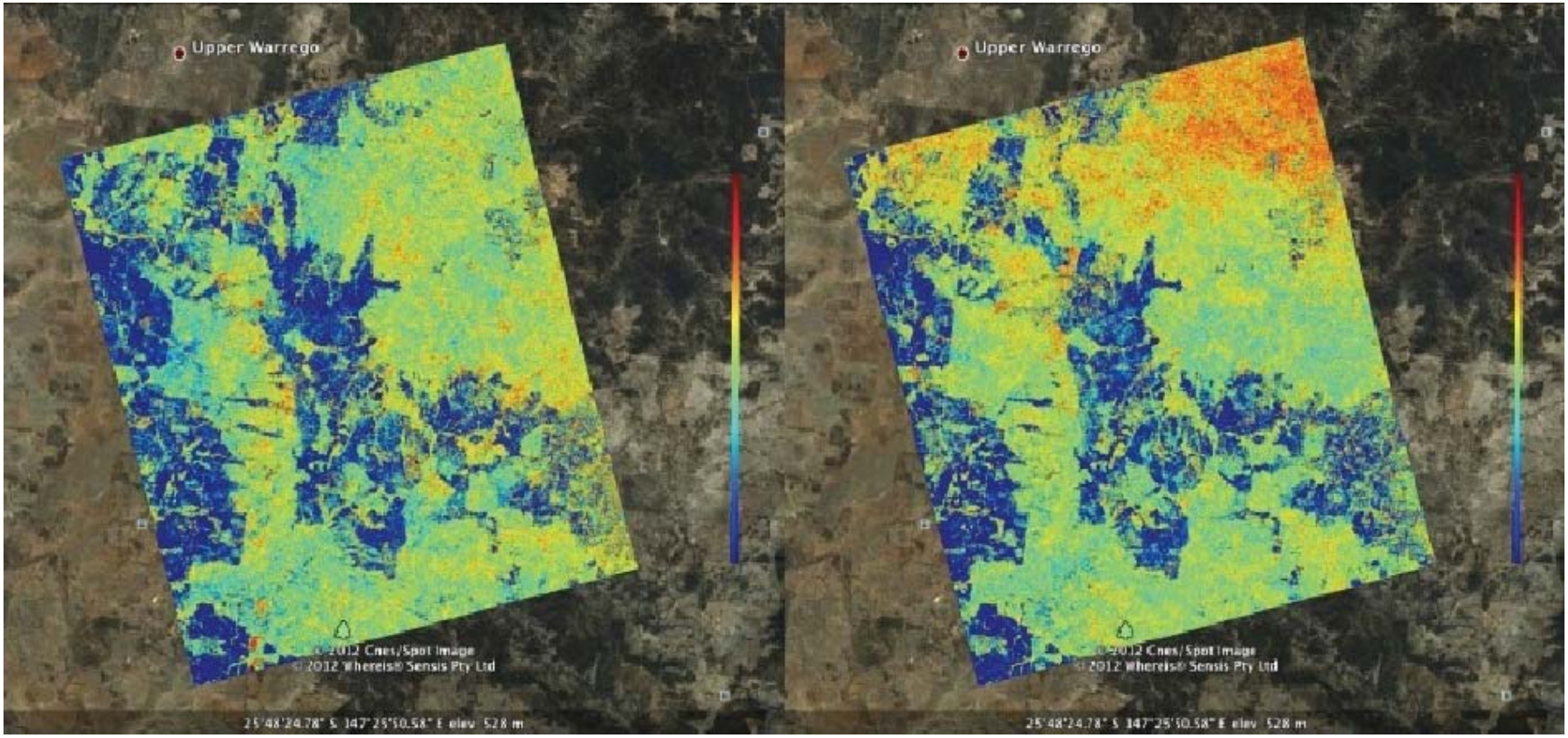
HV-Polarized "Heights"

- Cross-polarized heights can also be estimated, as shown here for the descending pass
- In this particular interferometric pair, the heights appear to be "saturated" due to the temporal decorrelation



HV-Polarized “Heights”

- The ascending passes show more of a signature of vegetation height that varies across the landscape
- Temporal decorrelation can still be seen in the image at right.



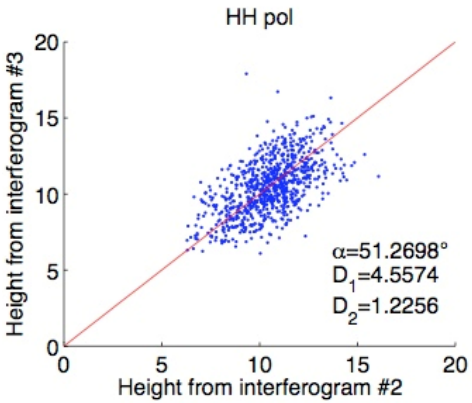
Quantitative Comparisons

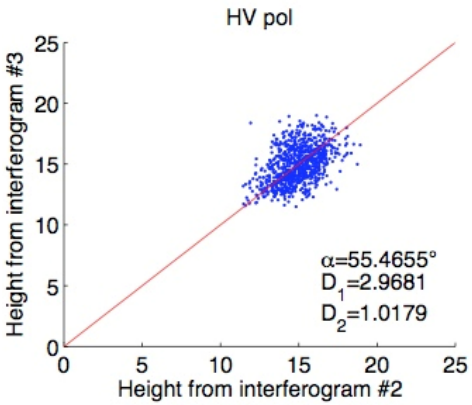
- Three vegetated regions used for comparison
- Plots of the estimated “tree height” made between the three interferograms to test for consistency
- Comparison with ICESAT tree heights made to test for absolute accuracy.

Comparisons of self-consistency (regions 1 & 2)

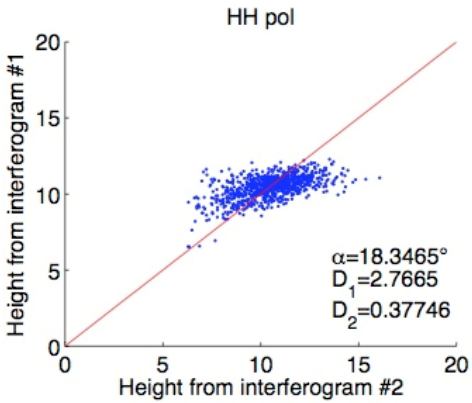
region 1

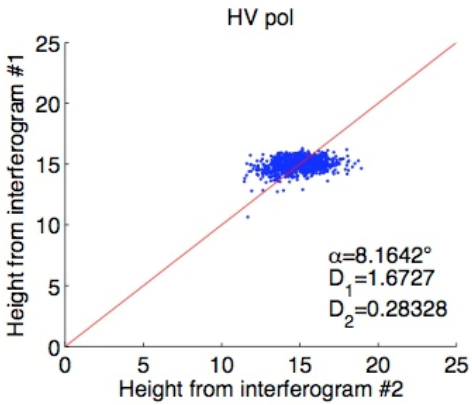
interferograms 2 & 3





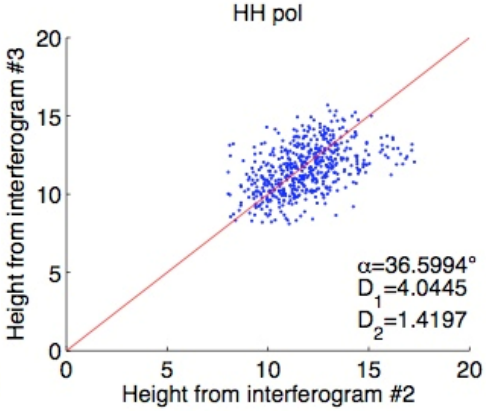
interferograms 1 & 2

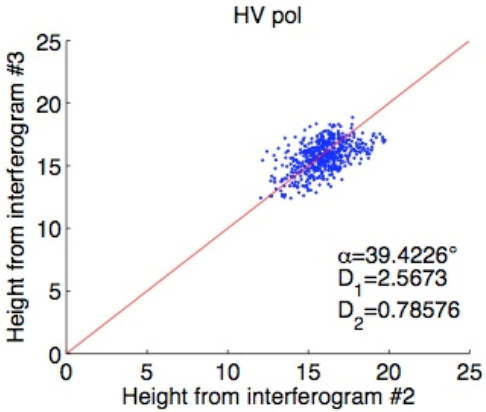




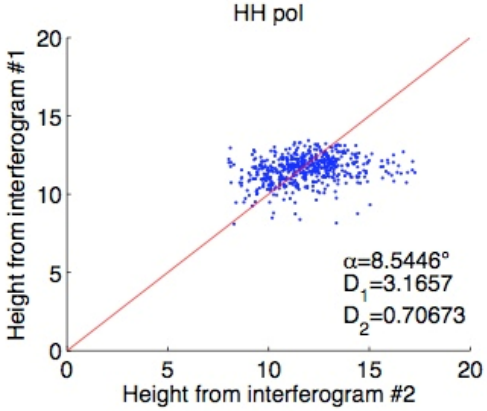
region 2

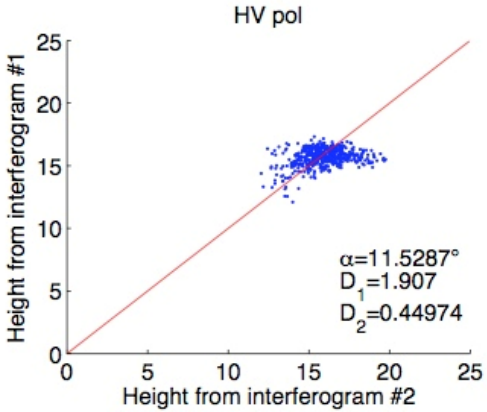
interferograms 2 & 3



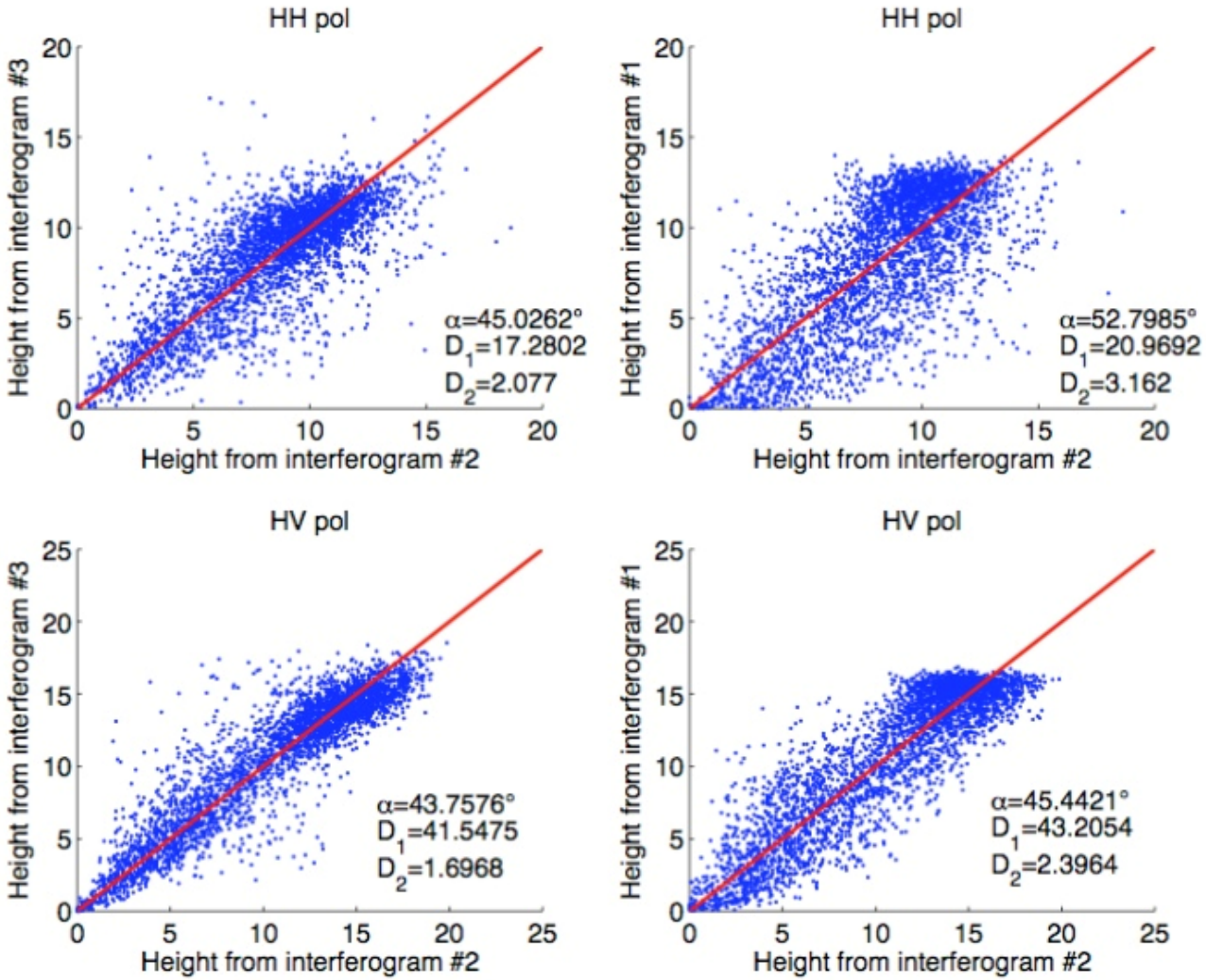


interferograms 1 & 2



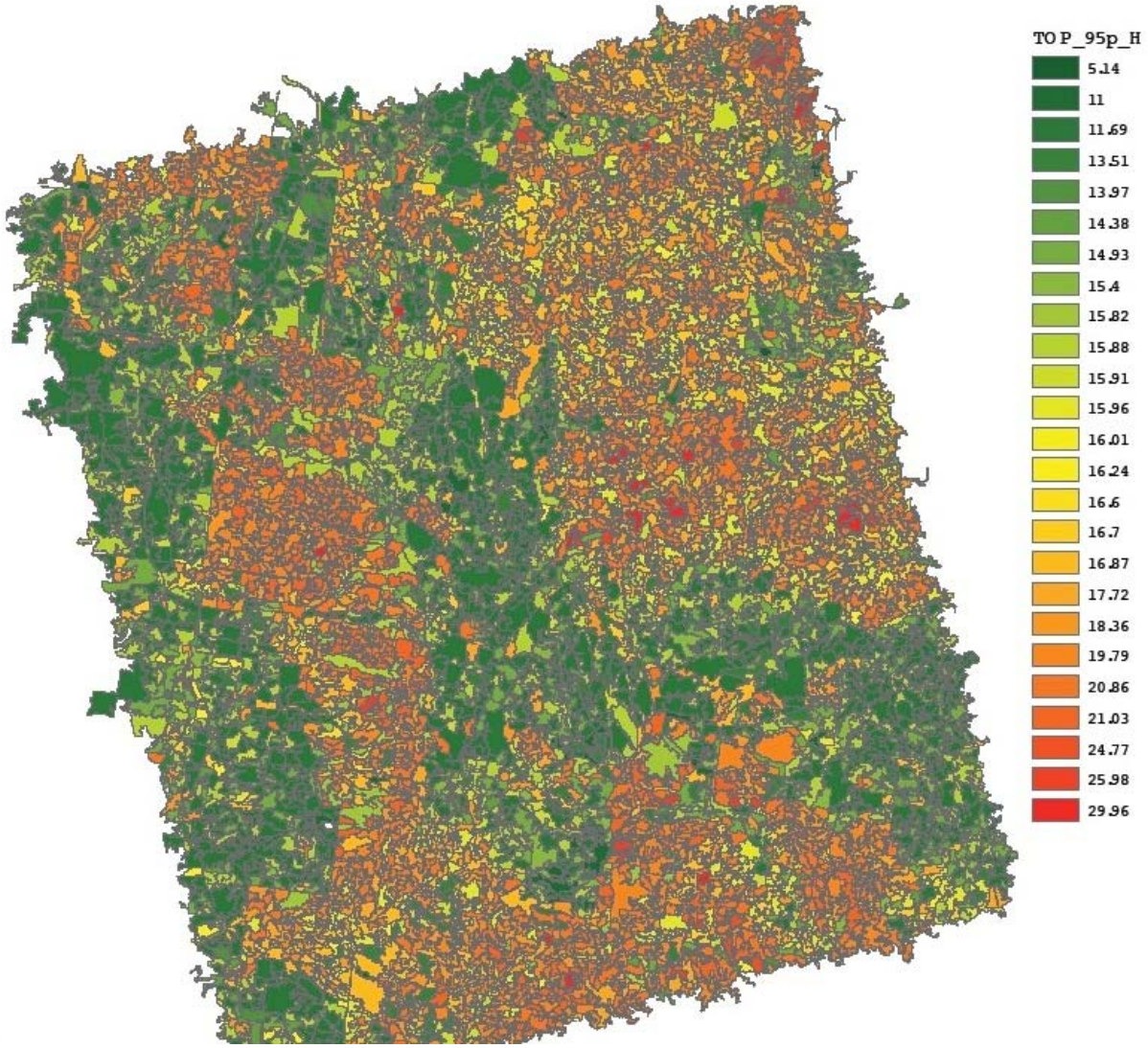


Region 3 Comparison



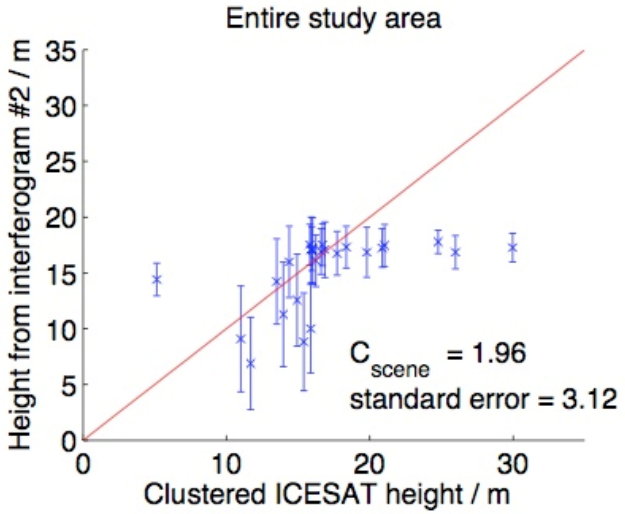
- Larger diversity in heights than the other two regions
- Consistency between interferograms indicates consistency in height estimates
- Interferogram #1 appears saturated, as noted in the imagery as well.

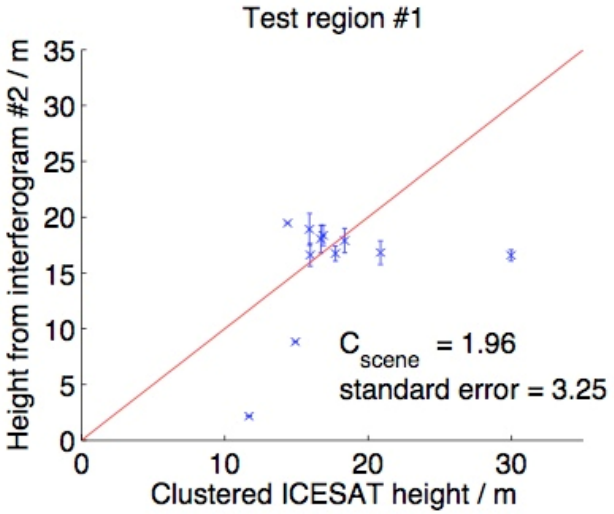
Comparison with ICESAT heights

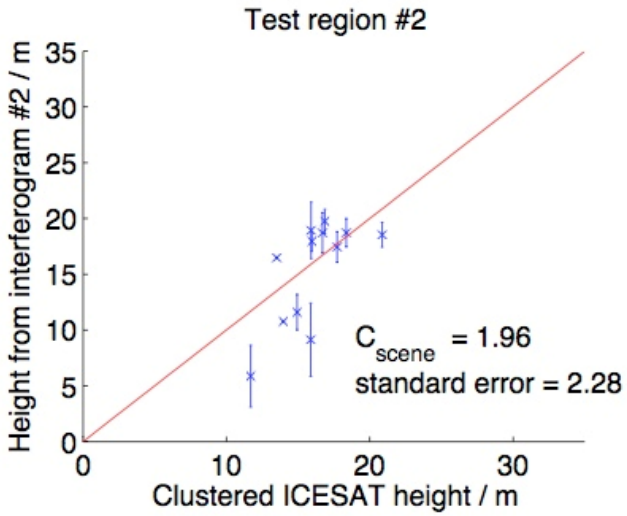


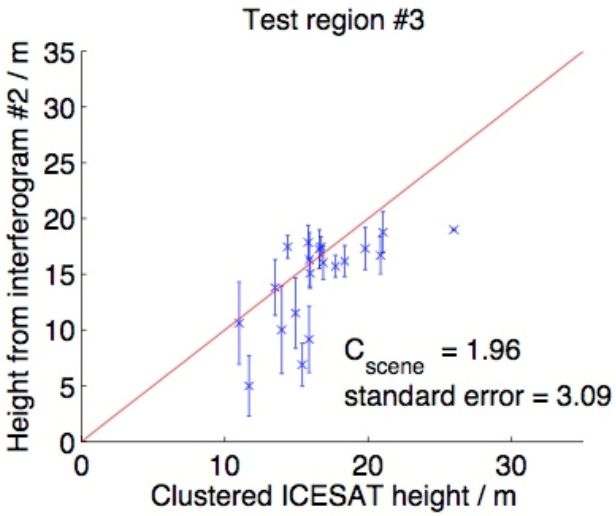
- PALSAR segmentation used to identify regions of like behavior
- ICESAT heights assigned to the segments
- Comparison made between these derived heights and the correlation-based estimates

Comparison between ICESAT and Correlation "heights"





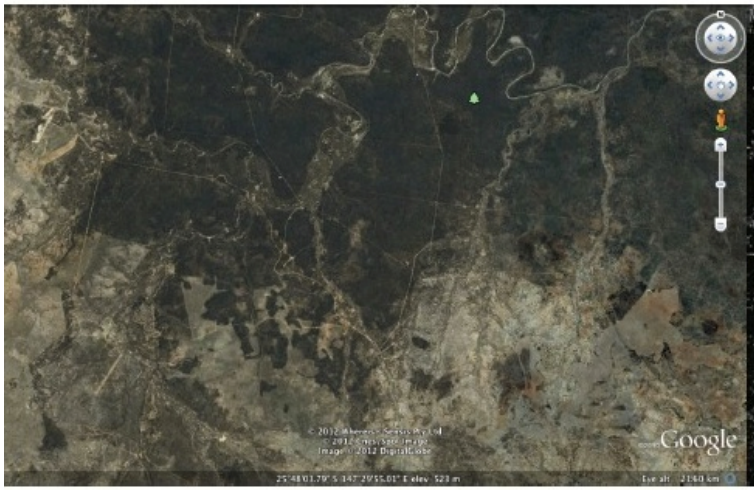




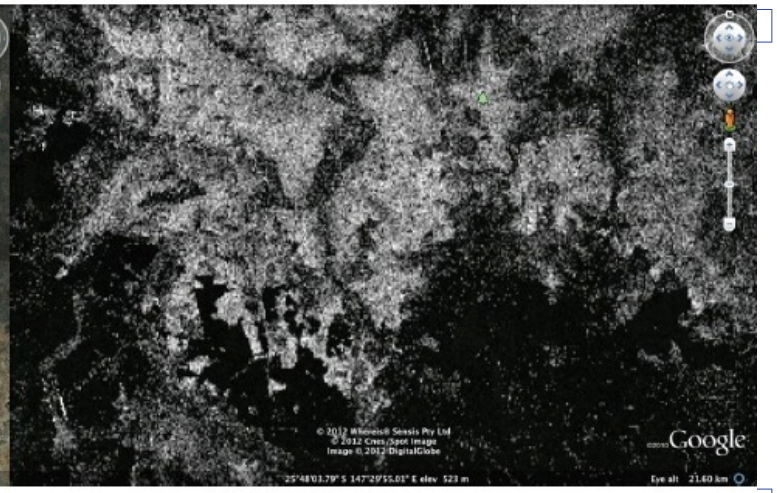
- Interferometric correlation derived heights are compared with segmented ICESAT data
- Results are shown for the three test regions and the entire study area
- We are investigating differences between the two height estimates. May be due to ICESAT or correlation method (eg: no ICESAT heights less than 10m)

Change Detection

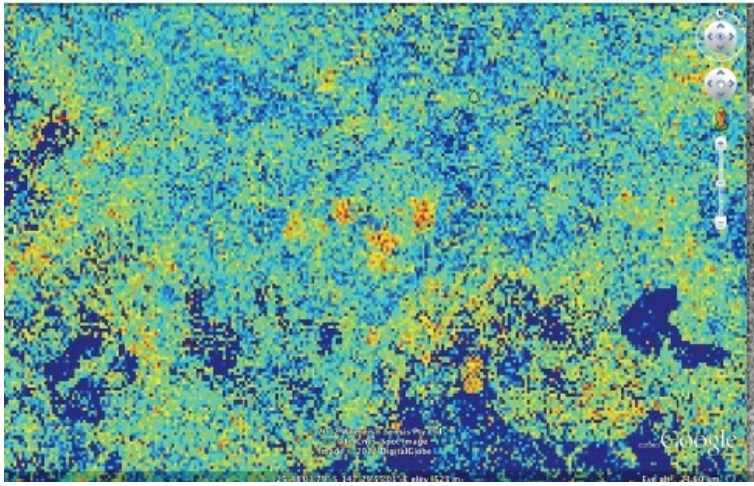
Optical Image



RCS



Interferometric Change



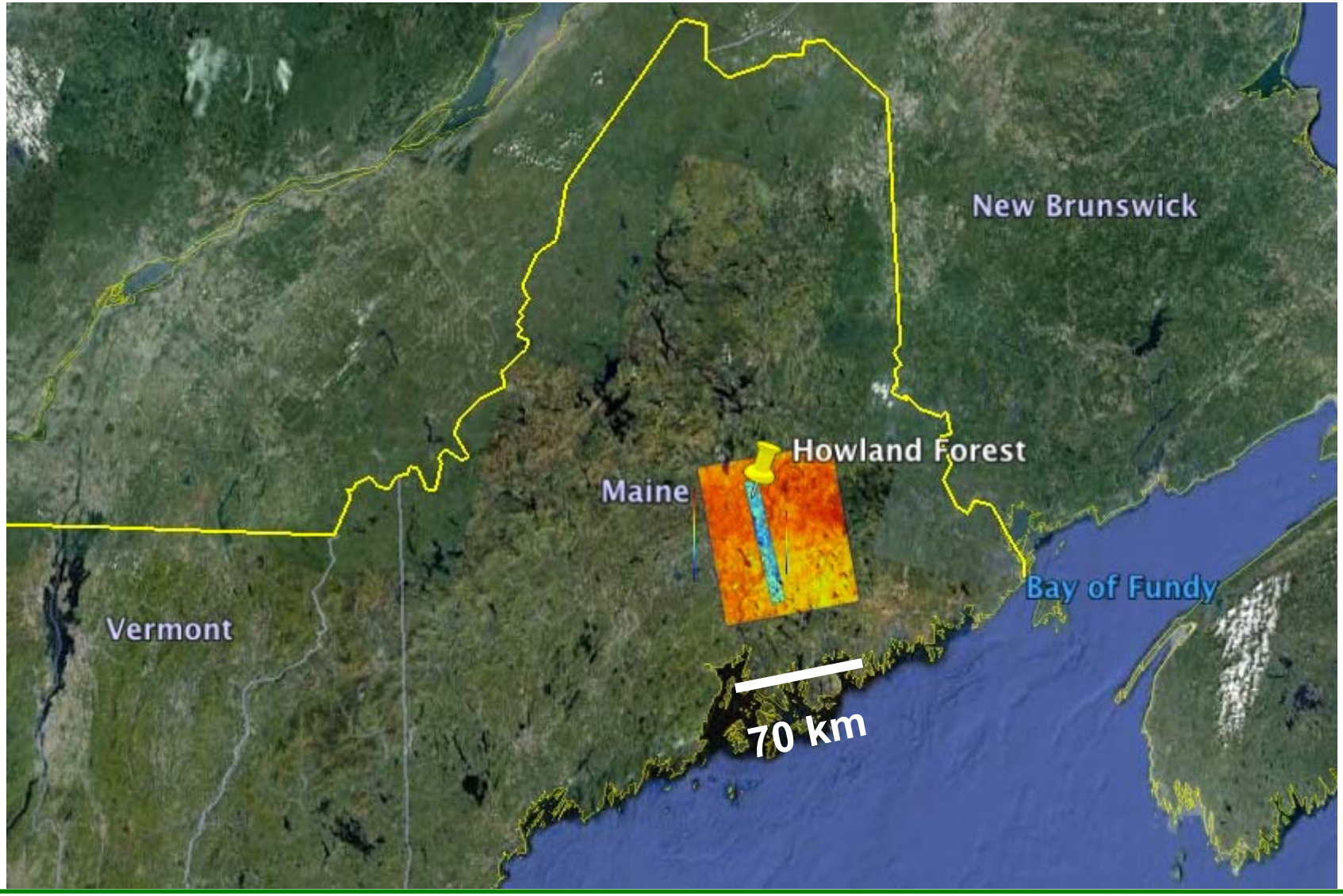
RCS Change

- Areas of unusually large trees indicate the the correlation signature is dominated by temporal changes.
- May be used as a method for change detection not detectable using changes in the radar cross section

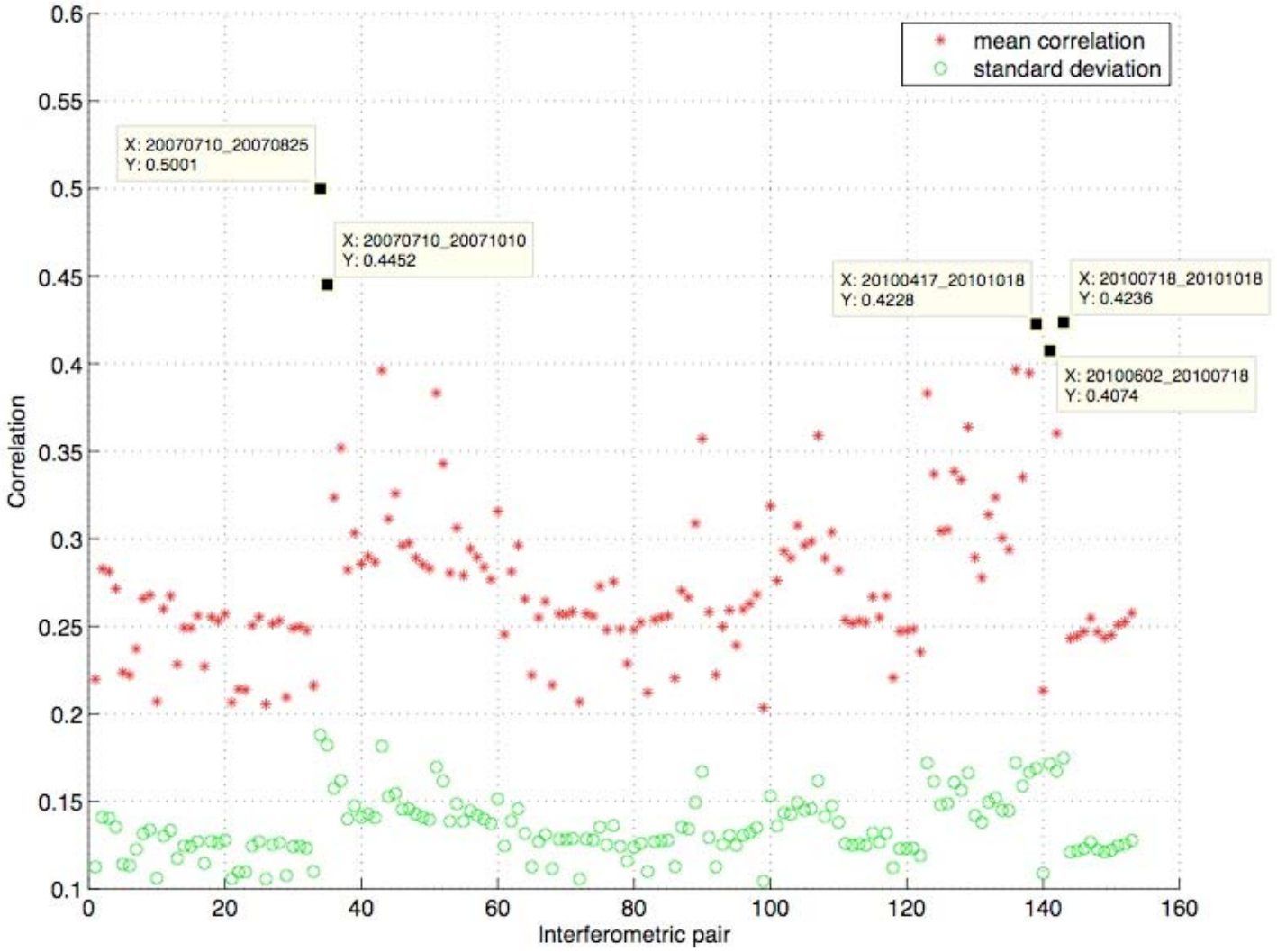
Regional Mapping

- The ILCP was initially chosen because of the relatively dry landscape and low vegetation density
- There remains a desire to expand the algorithm to a larger geographic context in order to provide large scale mapping, similar to the RCS mosaics
- The state of Maine is used as a test case because of the availability of LVIS tree height data and a large number of ALOS FBD and FBS scenes over a single area (18)

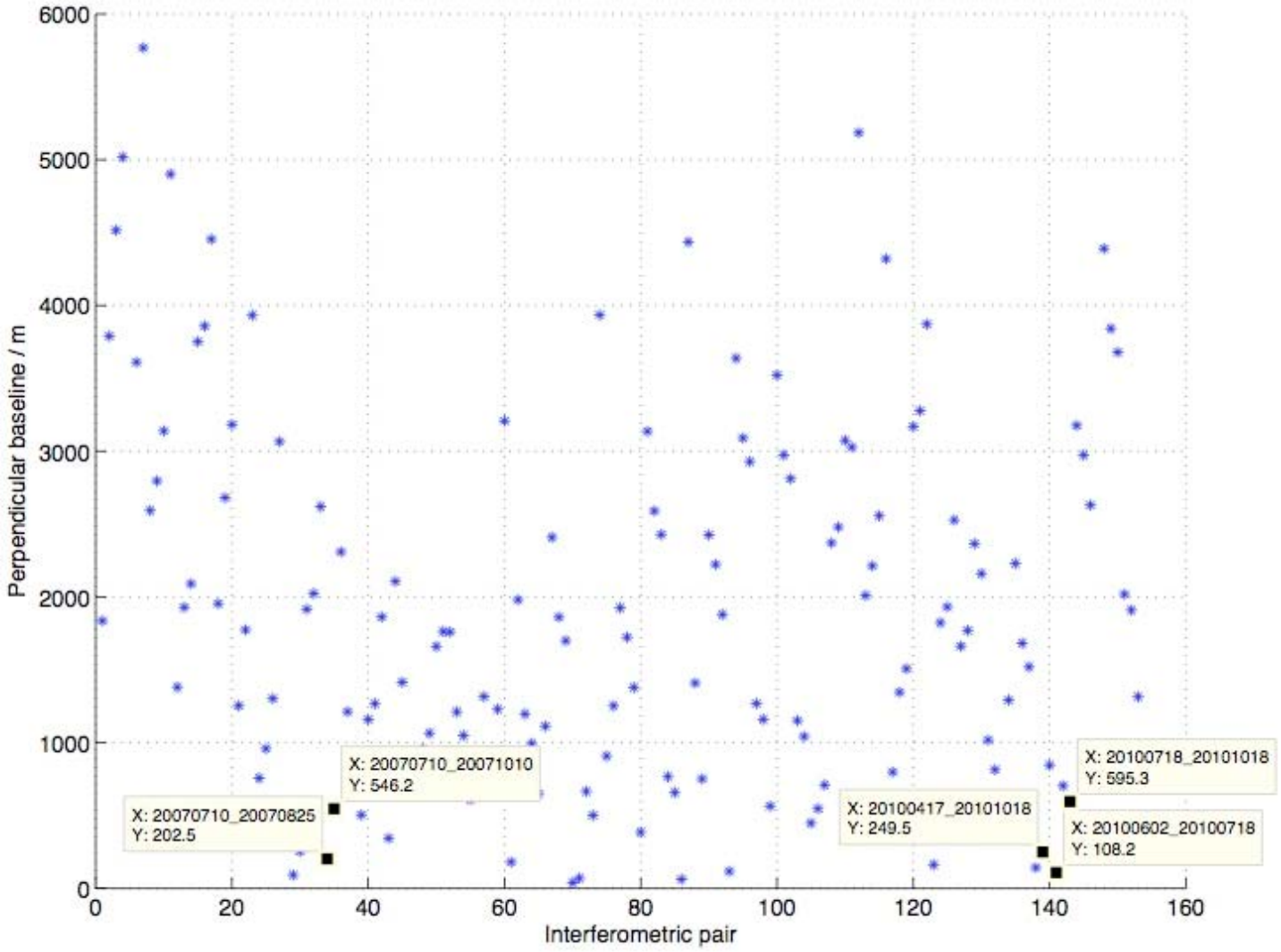
Correlation and LVIS imagery for 380_890



Average Correlation as a function of pair number

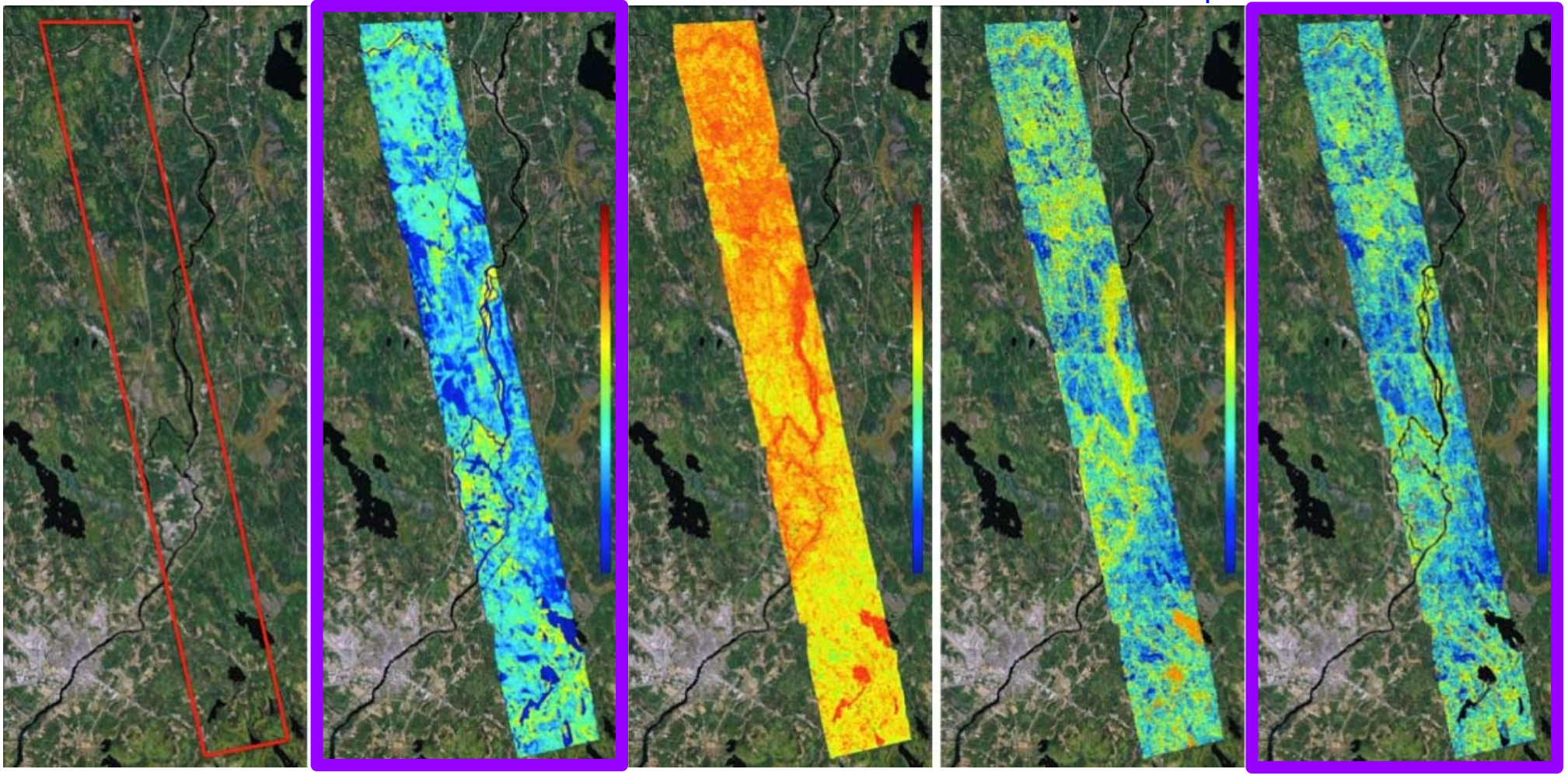


Average Correlation as a function of perpendicular baseline

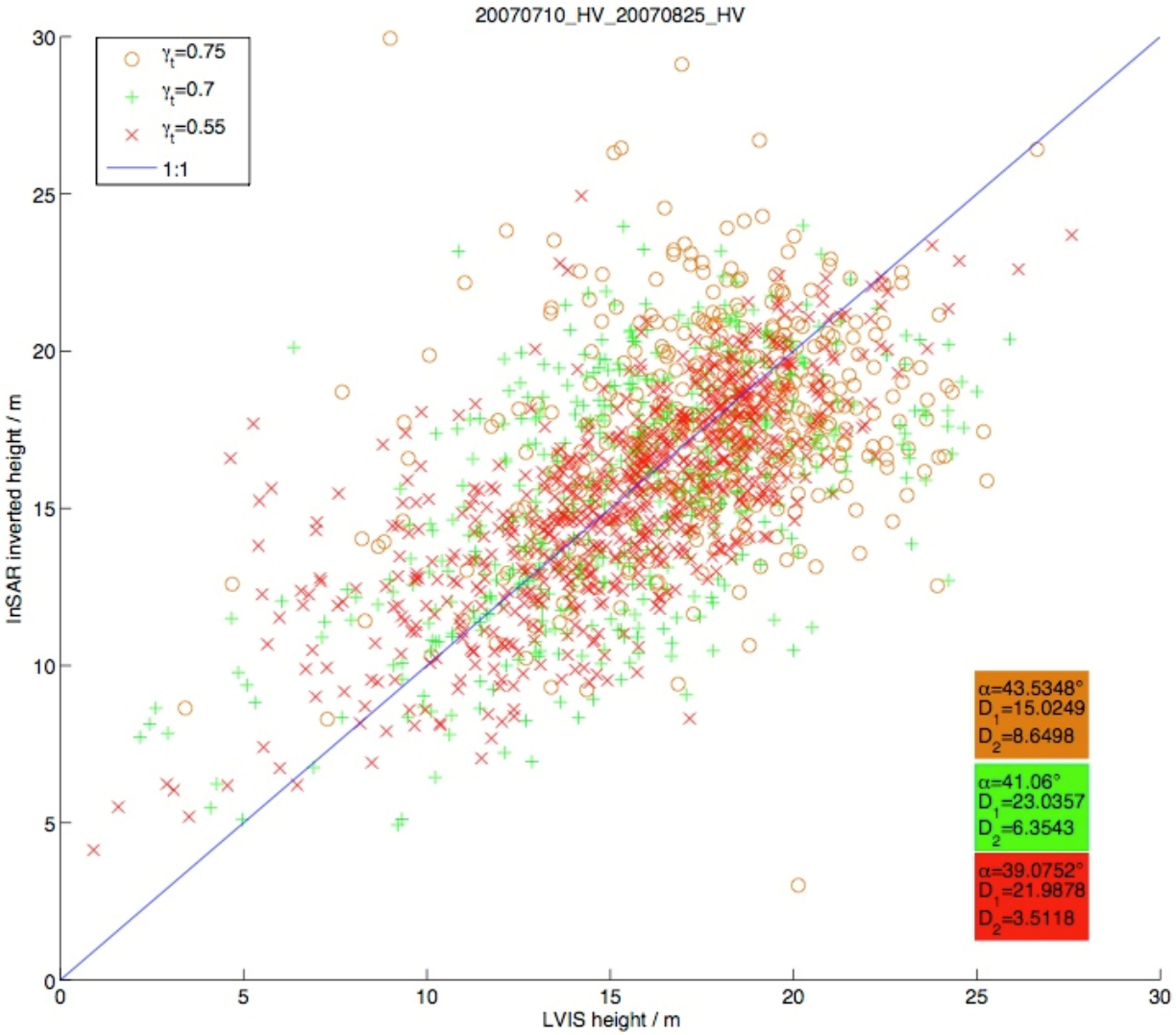


Visual comparison with LVIS heights

optical | LVIS | INSAR tree height | Corrected for γ_{temp} | classified water bodies



Quantitative comparison with LVIS

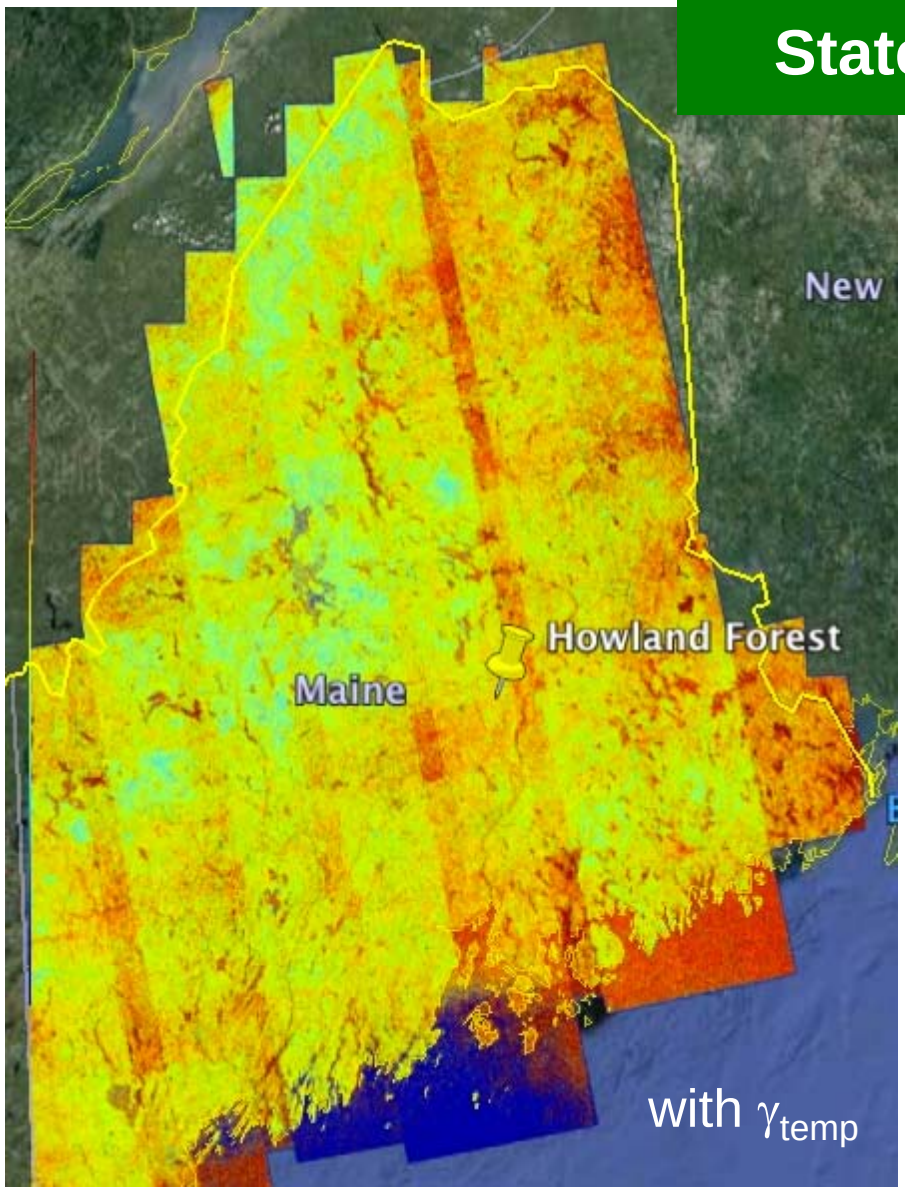


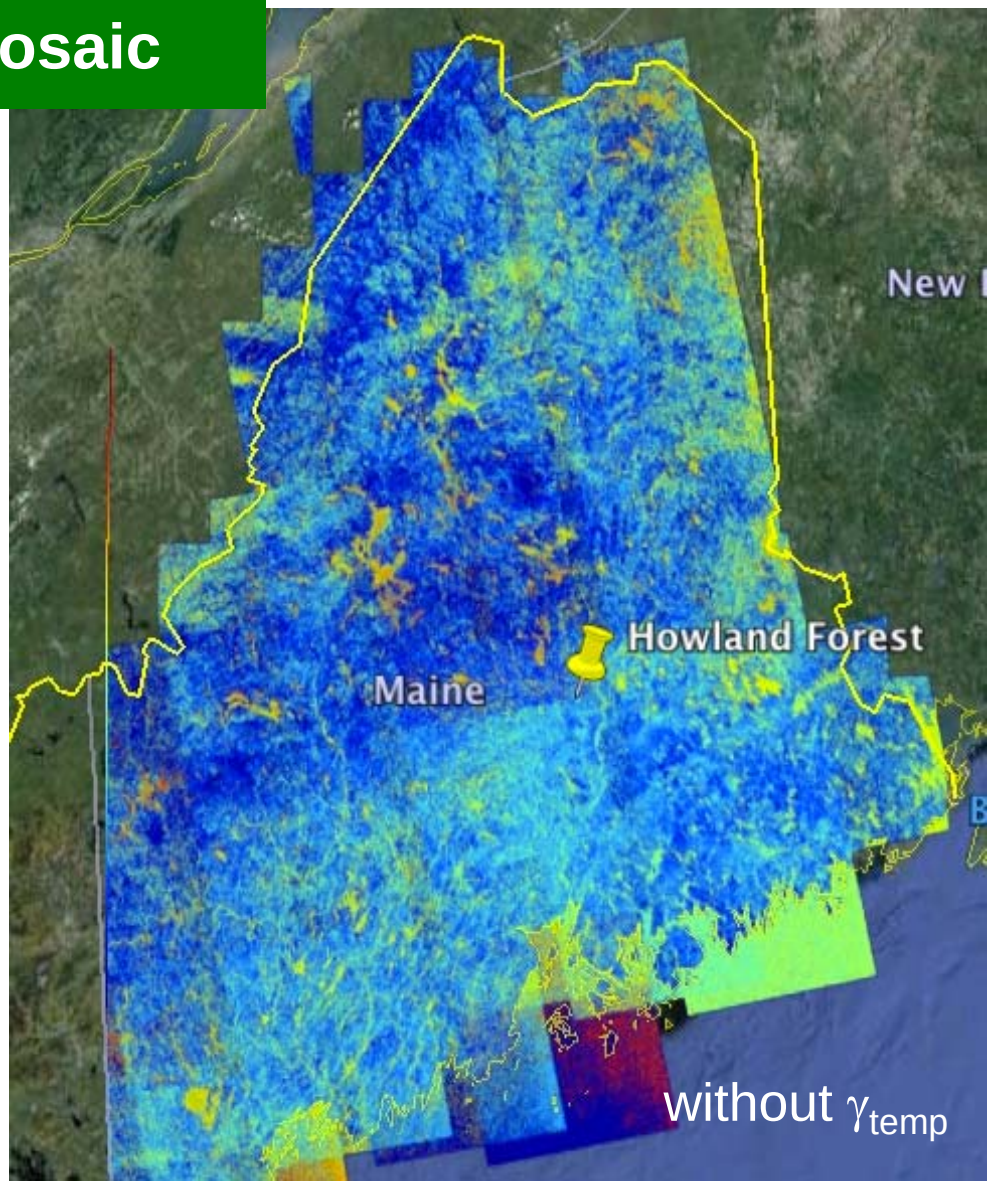
ALOS

K&C Initiative

An international science collaboration led by JAXA

State Mosaic





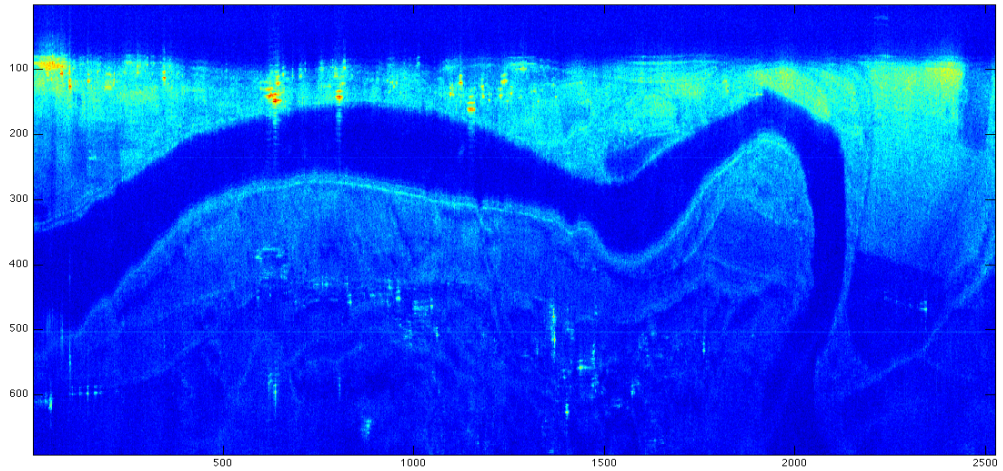
Summary

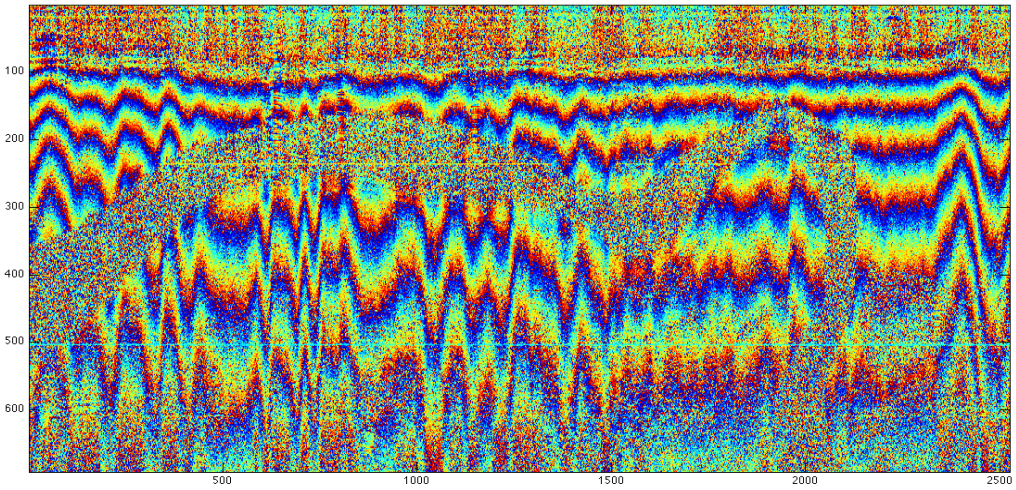
- Developing a simple method for using interferometric correlations for estimating vegetation effective height
- Interestingly, some of the best correlations are observed in the June-October timeframe for the Northeastern US (connifer dominated landscape?)
- Created an effective height map for the state of Maine
- Results compared qualitatively and quantitatively with LVIS

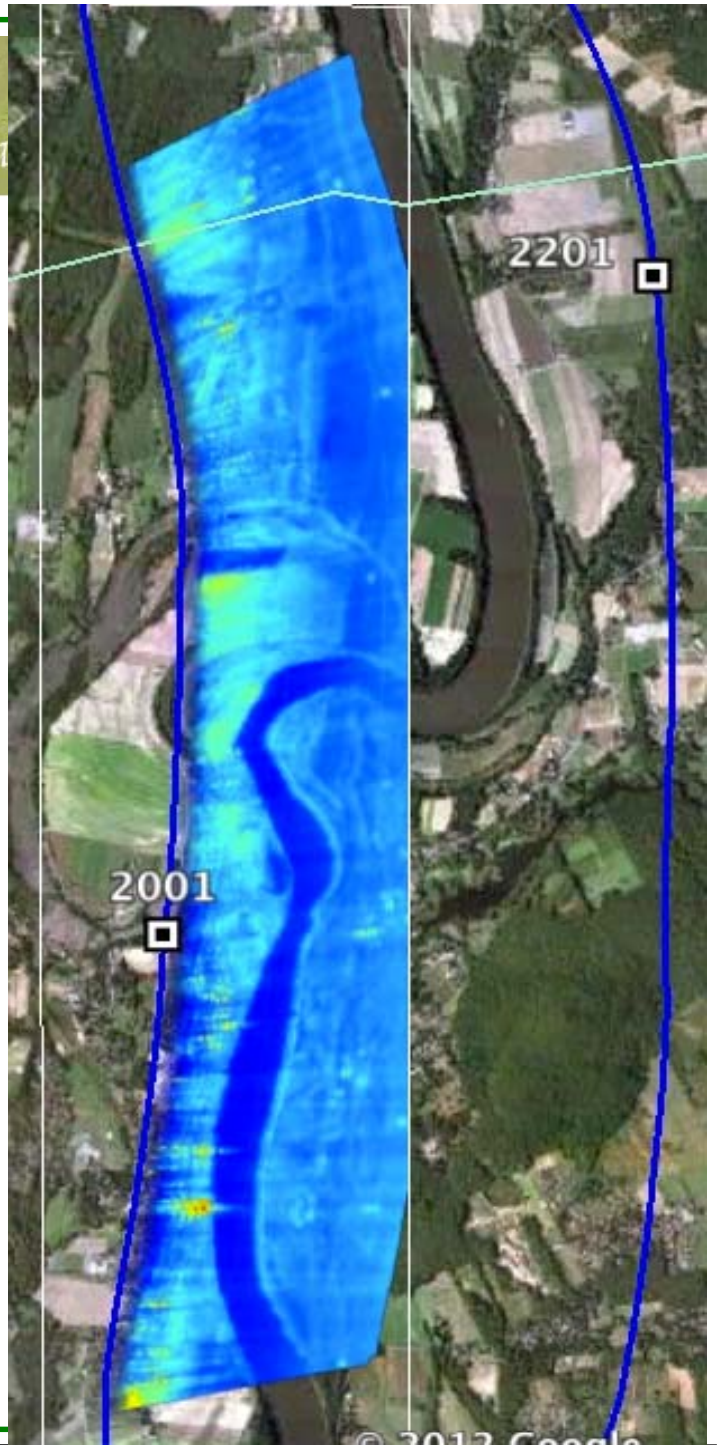
New Developments

We have been flying a 35 GHz interferometer on a Cessna 206 platform with very good results both for SAR focusing and interferometric generaation
We intend to outfit the platform with nadir-looking hyperspectral and lidar.

First airborne results

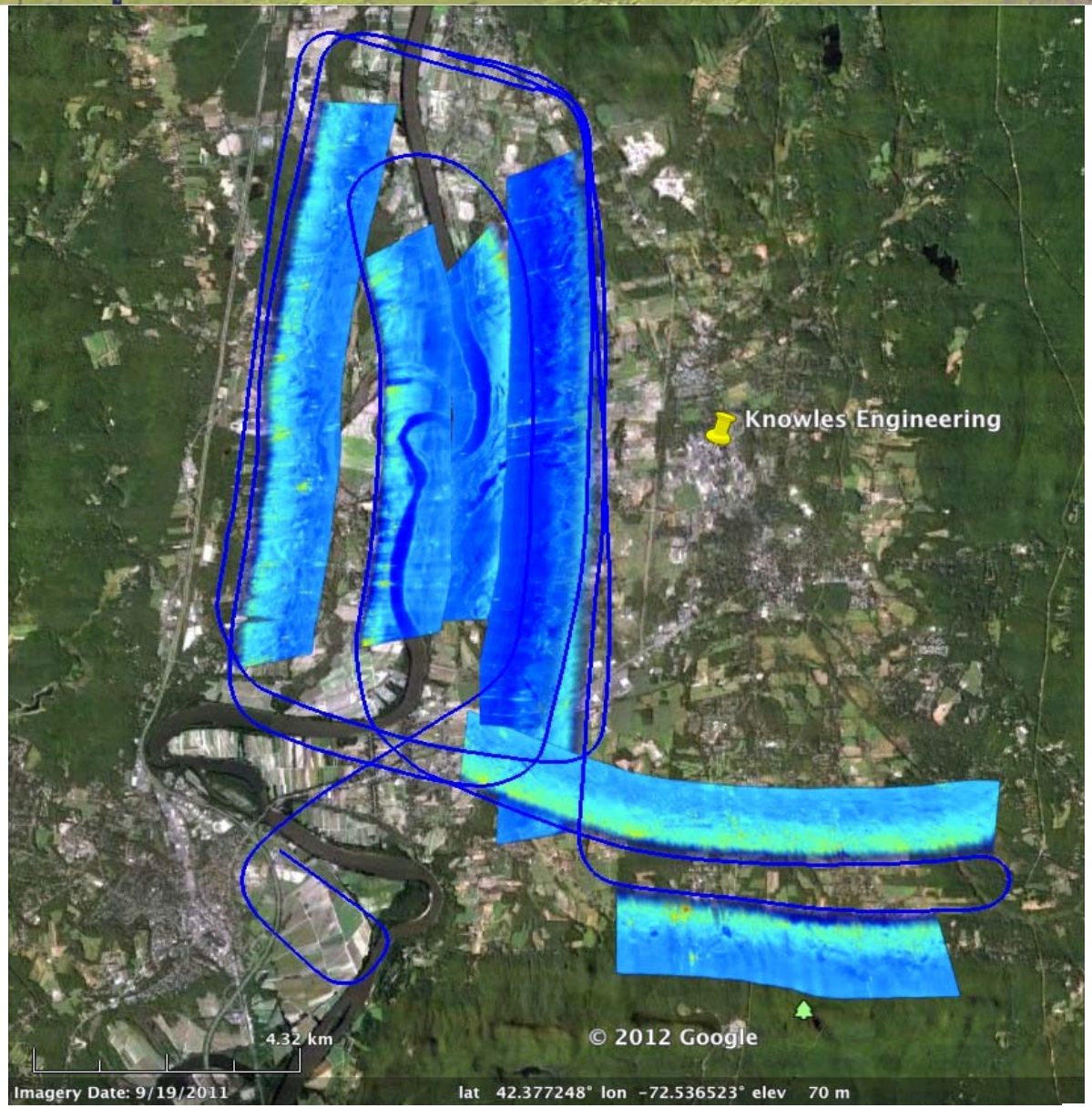




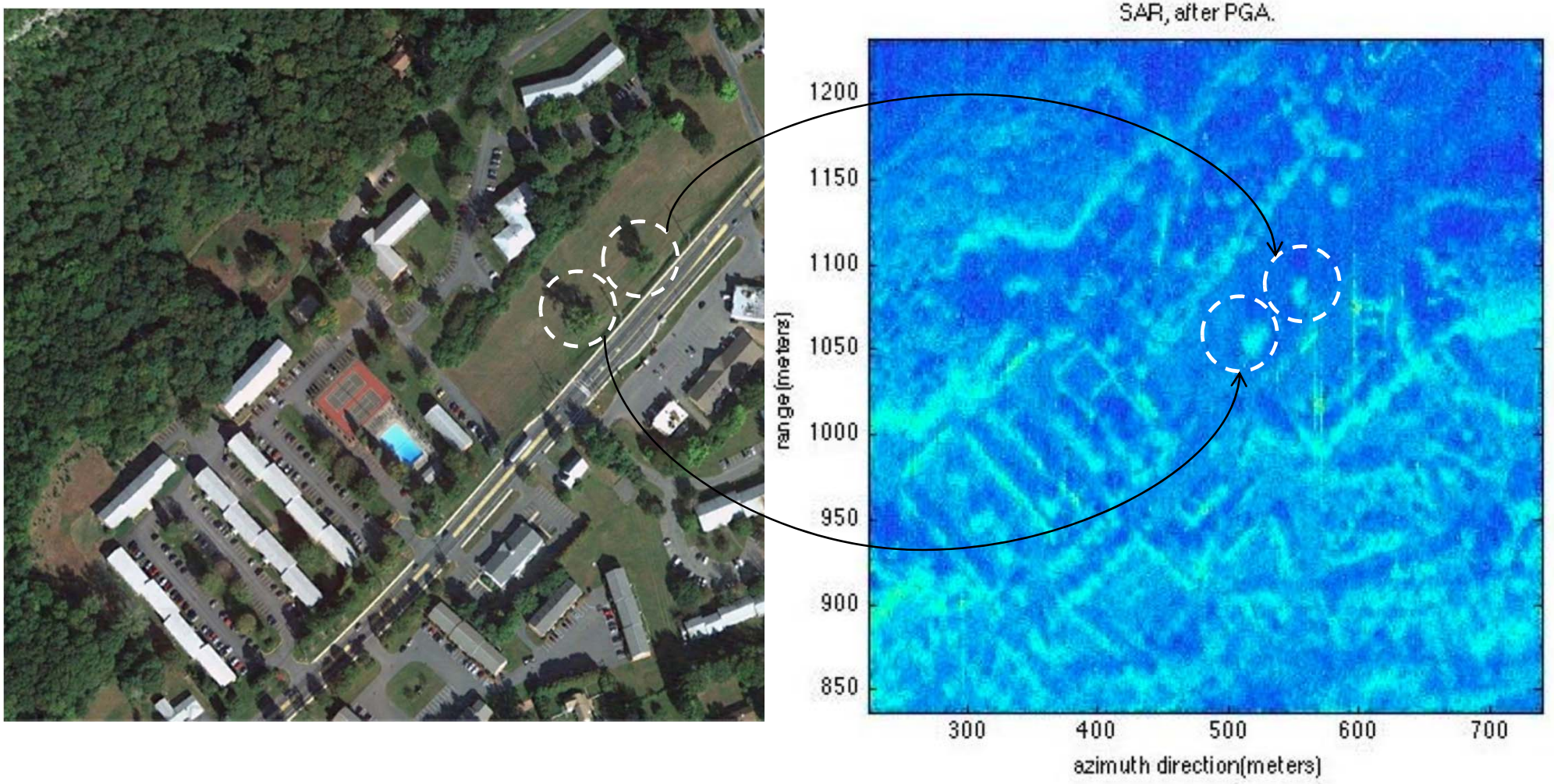


Large Scale Mapping Capability

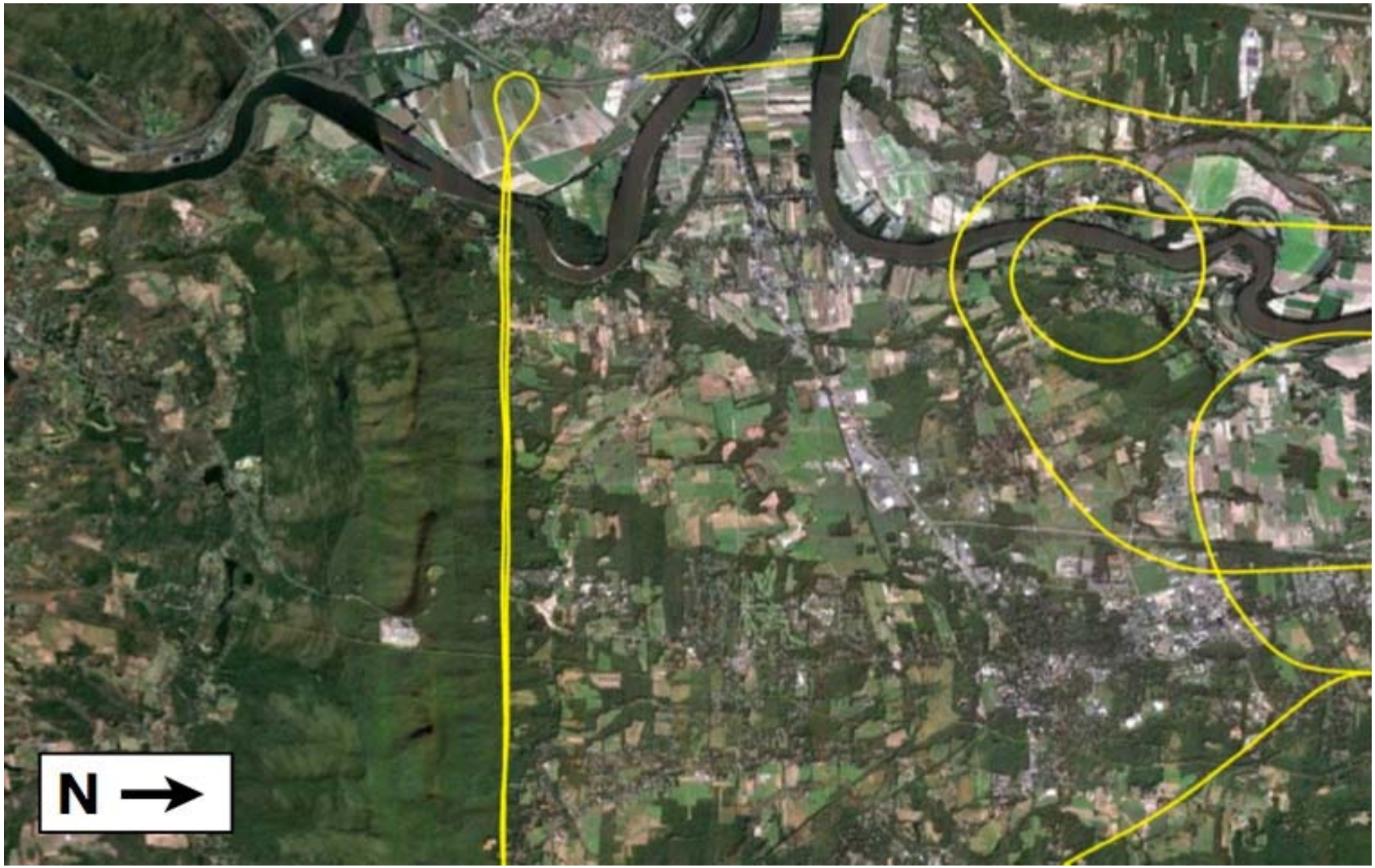
- The image at right was collected in under one hour
- Swath width is greater than 1 km
- Currently only limited by transmit power



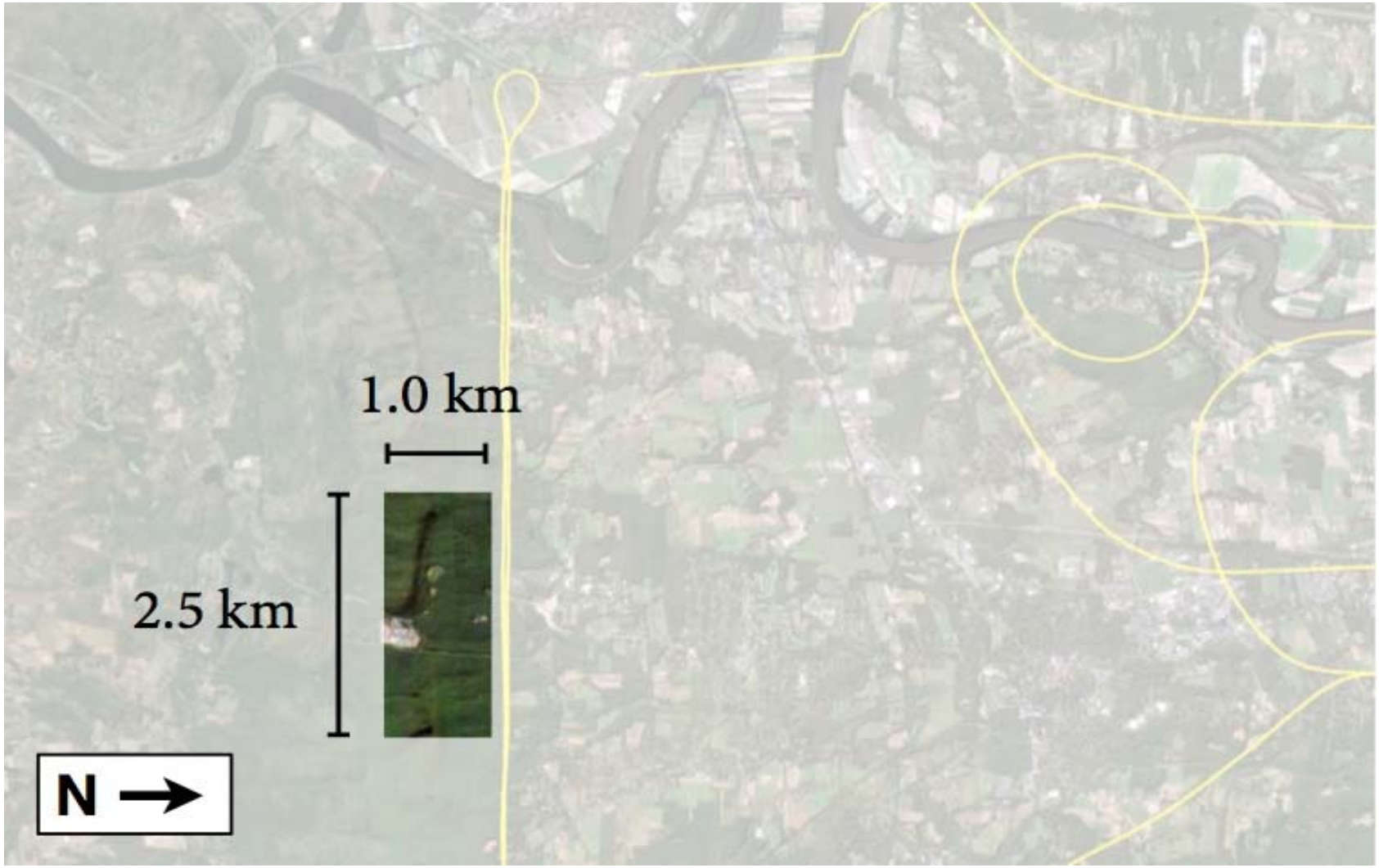
SAR Focusing (multi-look resolution ~1m x 2m)

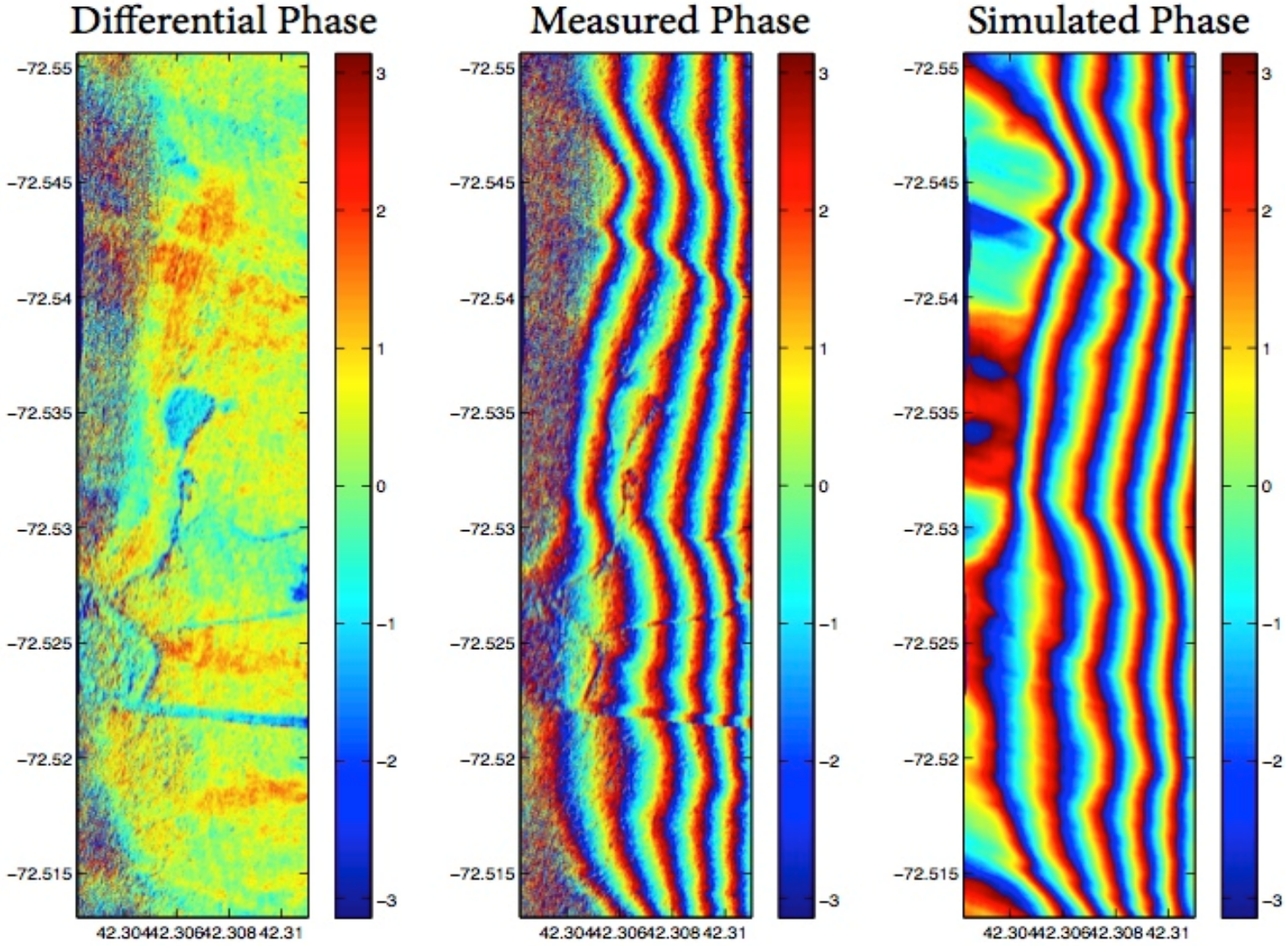


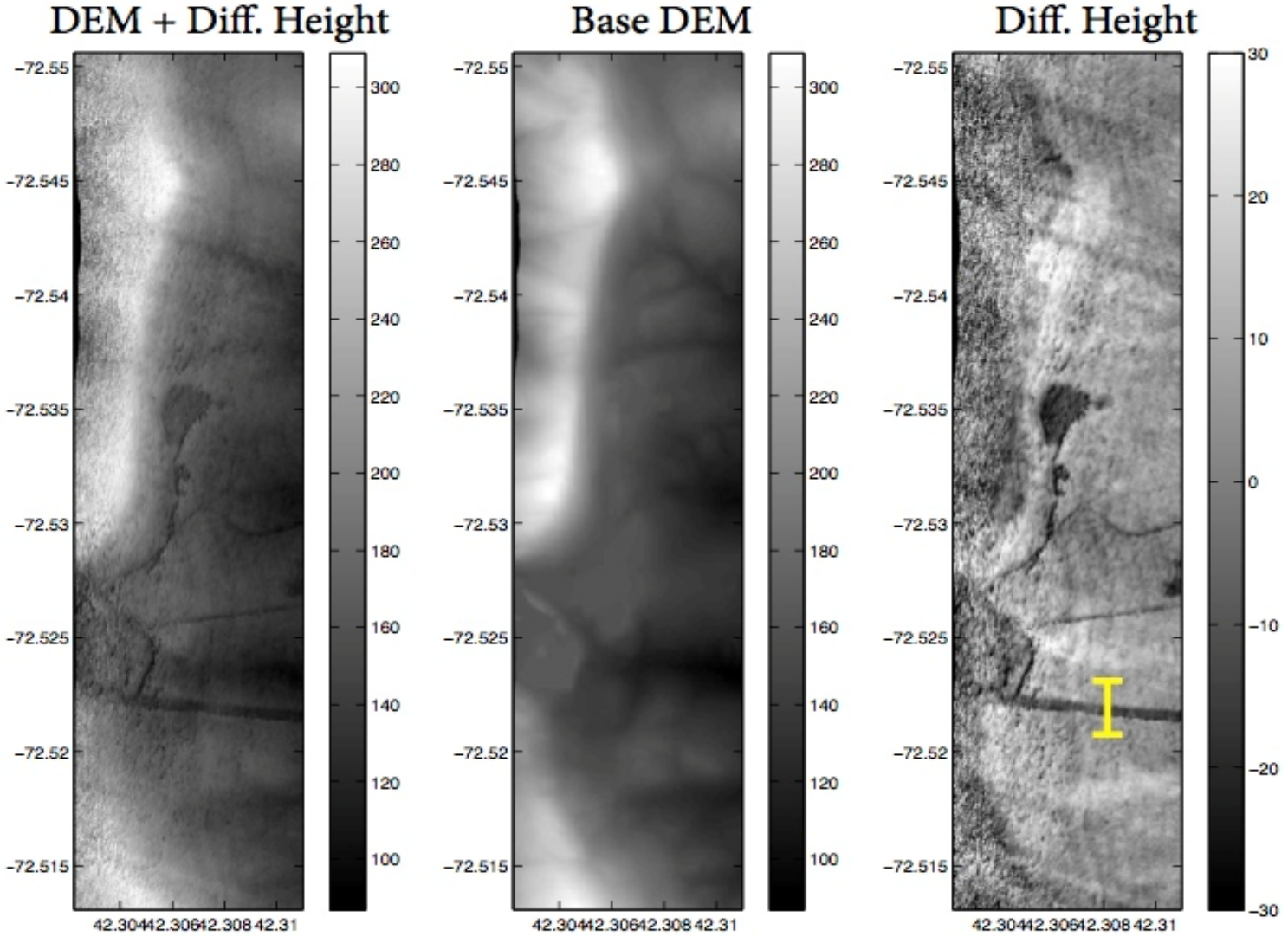
Closeup of the Holyoke Range



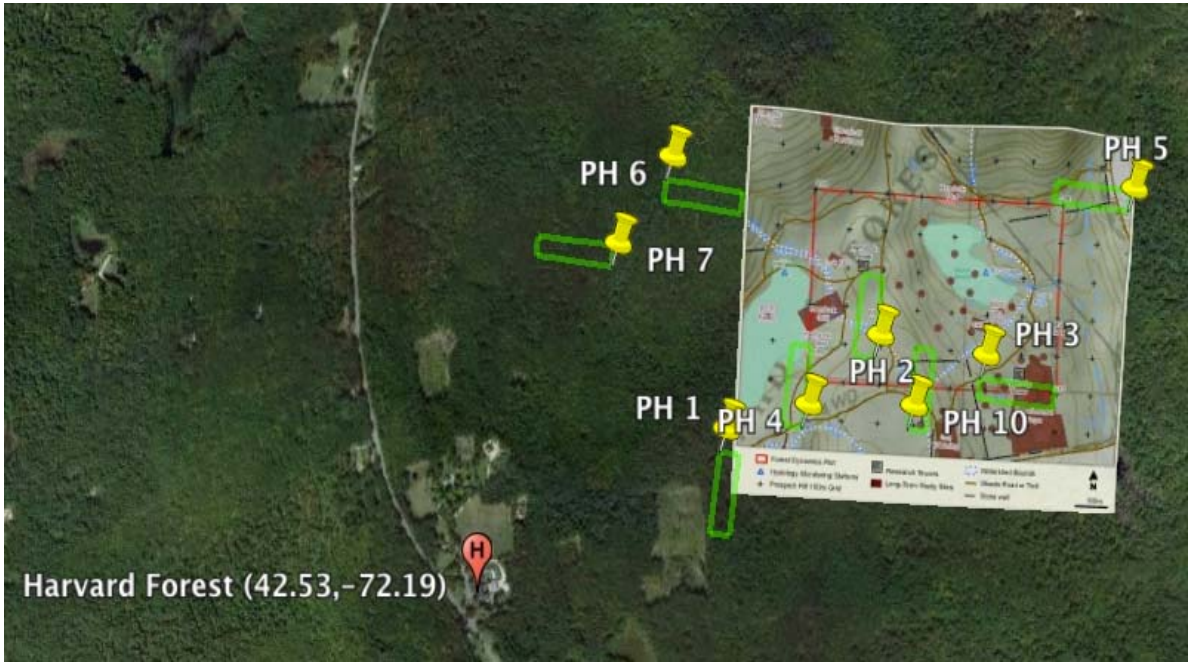
Area of Interest




Differential Phase
Measured Phase
Simulated Phase
−72.55
−72.545
−72.54
−72.535
−72.53
−72.525
−72.52
−72.515
42.304
42.306
42.308
42.31
3
2
1
0
−1
−2
−3


DEM + Diff. Height
Base DEM
Diff. Height
-72.55
-72.545
-72.54
-72.535
-72.53
-72.525
-72.52
-72.515
42.304
42.306
42.308
42.31
300
280
260
240
220
200
180
160
140
120
100
30
20
10
0
-10
-20
-30

L-band forest instrumentation



- The HF is looking to put an instrument trolley that runs between two towers that are part of a 35 ha region that has been stem mapped.
- We are in the process of designing a small L-band radar to put on the trolley

- An L-band radar run throughout the day and over seasons can be used to monitor sap flow and tree health
- Complemented by in-situ measurements attached to trees.