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

Paul Siqueira
University of Massachusetts, Amherst

Science Team meeting #20 – Phase 3
JAXA TKSC/RESTEC HQ, Tokyo, December 2-6, 2013

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. We have been using repeat-pass interferometric ALOS observations over extended areas for estimating Forest Stand Height (FSH).

We are also exploring the combination of recorded stem maps, Forest Growth and EM Scattering models for improving biomass estimates from optical, lidar and SAR remote sensing observations

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.

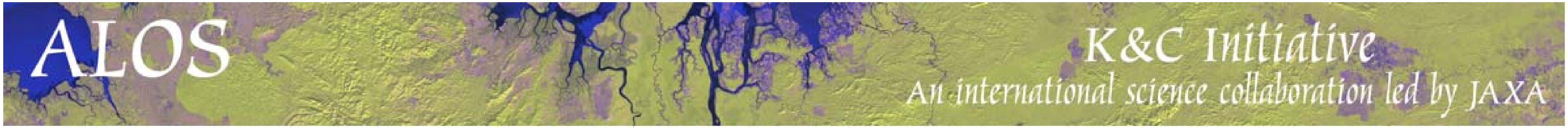
Project schedule

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.

- We are currently in the process of publishing the work, and finalizing its extension through Mosaicking.

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



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.

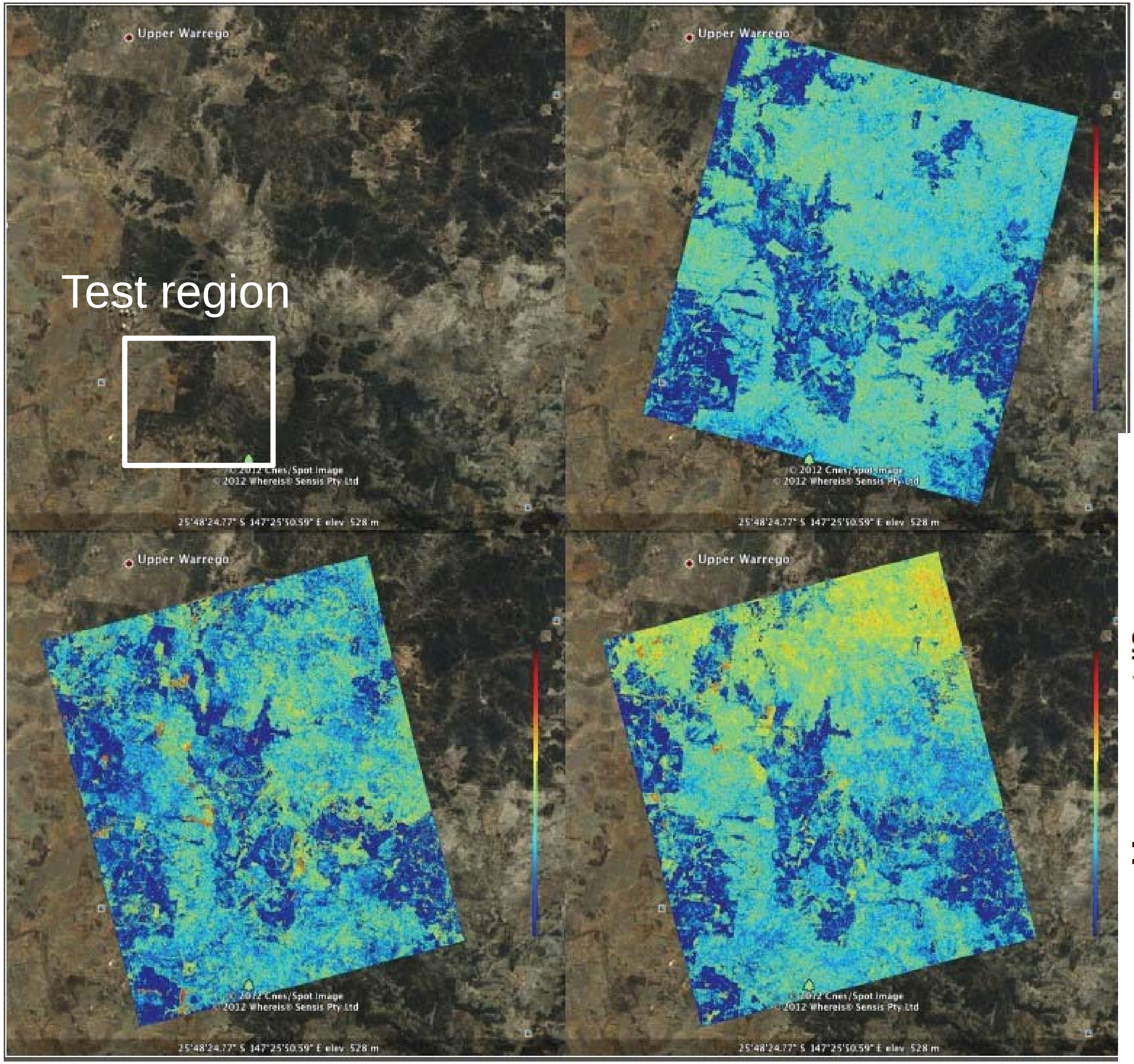
Deliverables

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
- In the spring, we will be able to provide JAXA with an FSH map for the US state of Maine

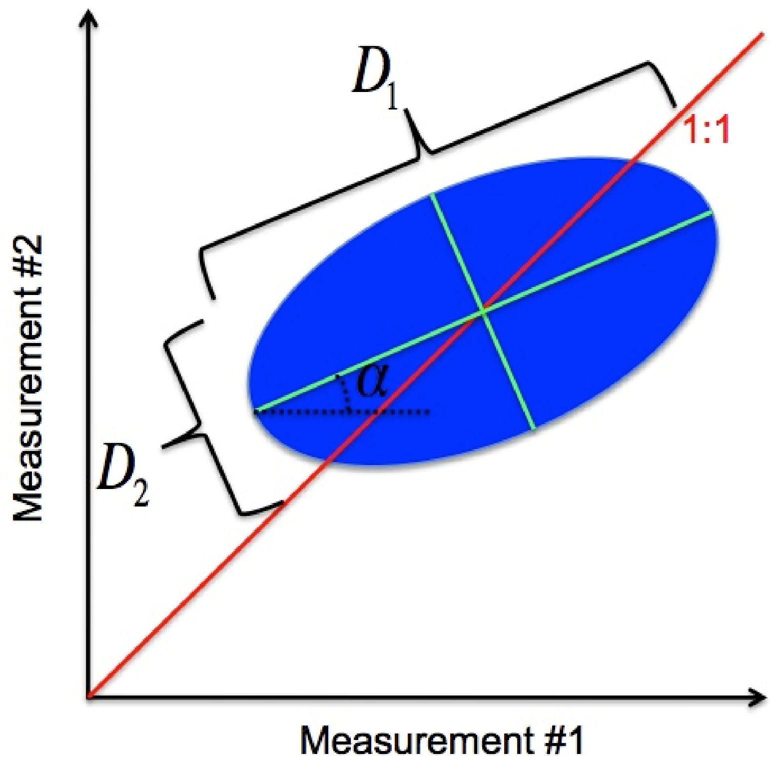
Interferometric Algorithm Development for "Forest Stand Height" (FSH)

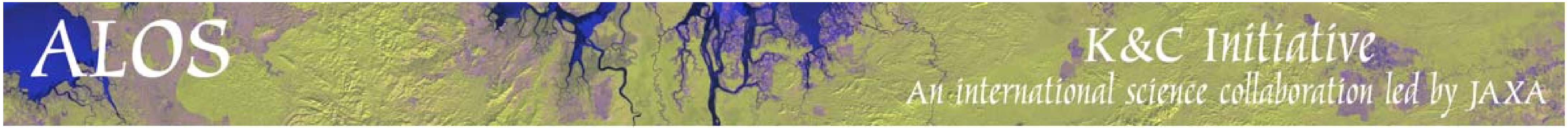
- Forest stand height (FSH) is meant to be a proxy for a combination of tree height and stand density. Metric is similar to the Lorey's height (basal area times height)
- One tree standing by itself, will have a smaller stand height than a group of trees next to one another.
- Use interferometric correlation that is corrected for
  - thermal noise effects (e.g. flat surfaces with poor SNR will have a similar decorrelation signature as a tall forest stand with good SNR)
  - temporal decorrelation (a dominant factor with a 46 day repeat observation)
- We begin with a well characterized dry savanna in Injune



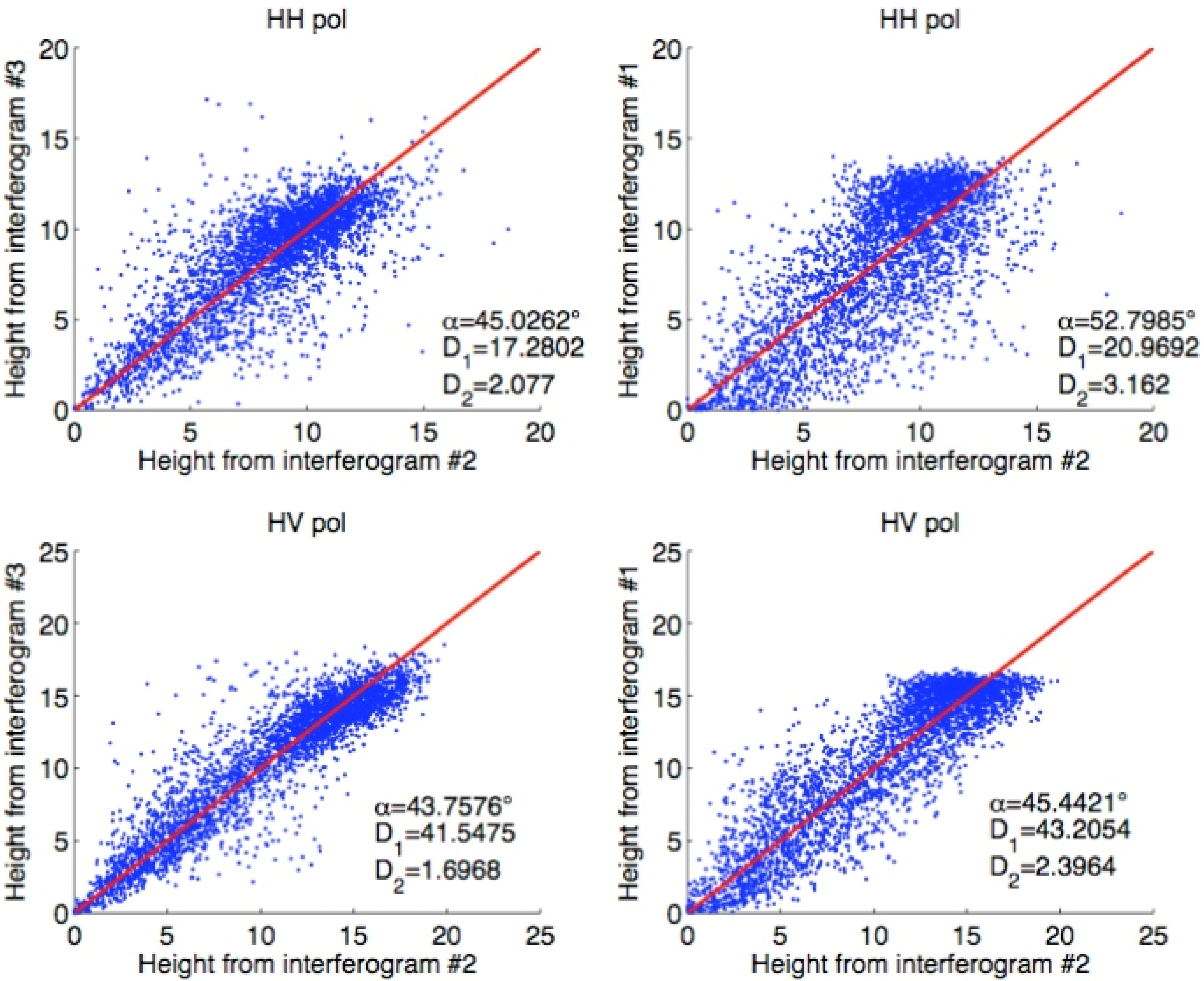
Estimate of heights between interferograms can be skewed because of temporal decorrelation effects.

Fit an ellipse to the skewed points to remove these errors





Comparison in Test region



- **Interferograms #1 & #2 have the least spread in estimated heights.**
- **Used for detecting selective logging and landcover change**
- **Use this mechanism as a prototype for regional mapping**

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

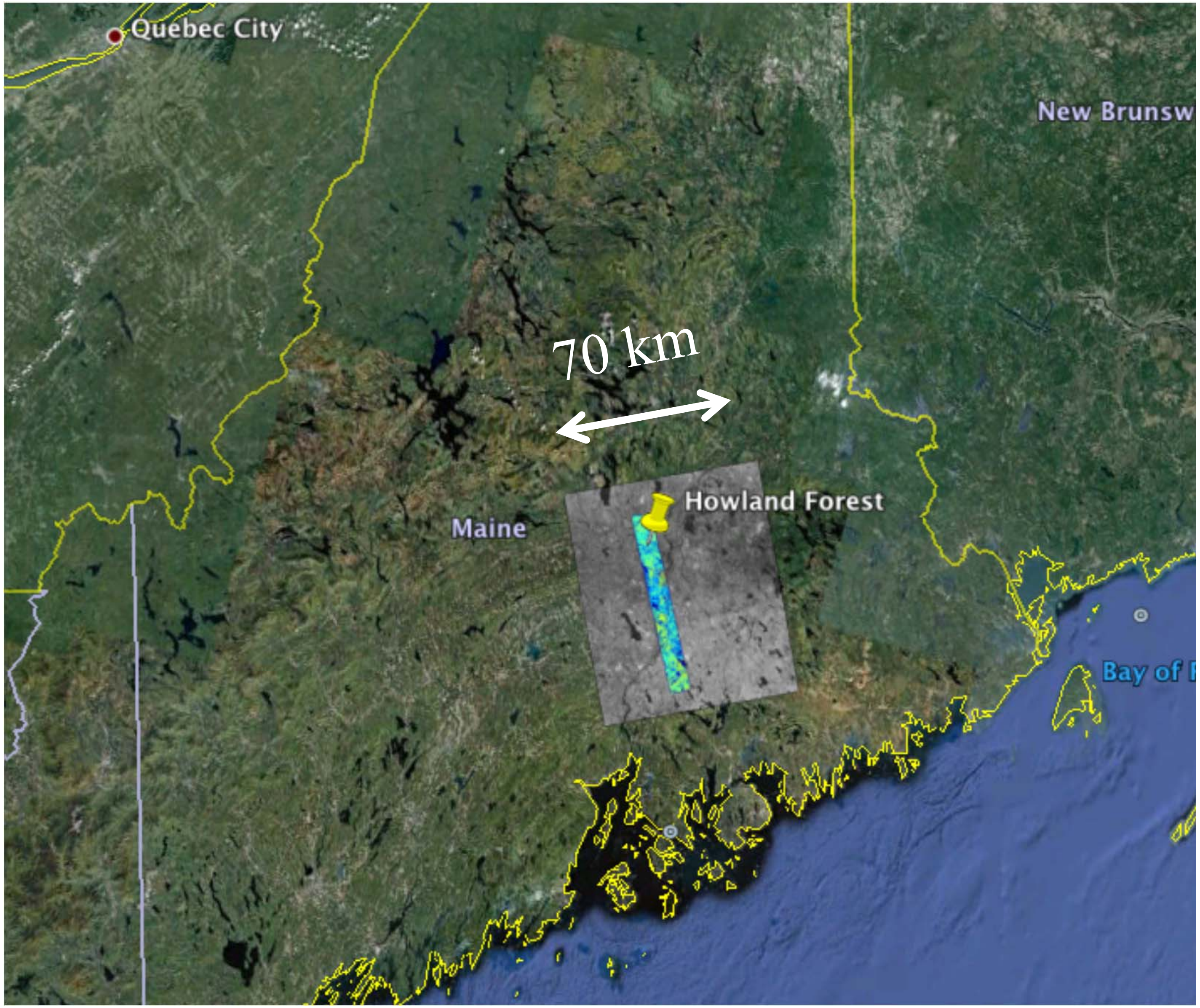
- The state of Maine is used as a test case because of the availability of LVIS tree height data and a large number of ALOS FBD and FBS scenes over a single area (18)

ALOS

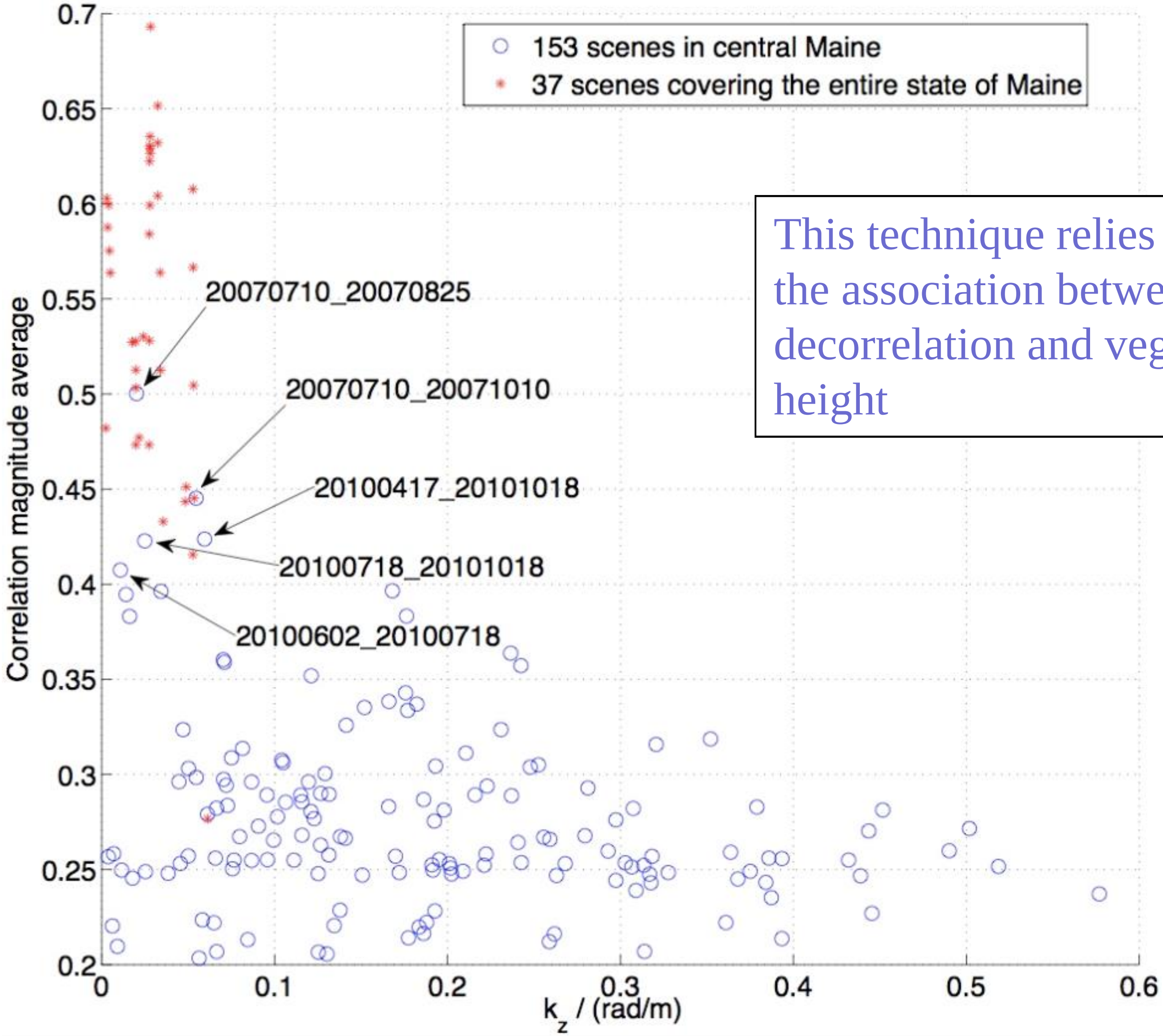
K&C Initiative

An international science collaboration led by JAXA

Correlation and LVIS imagery for 380_890



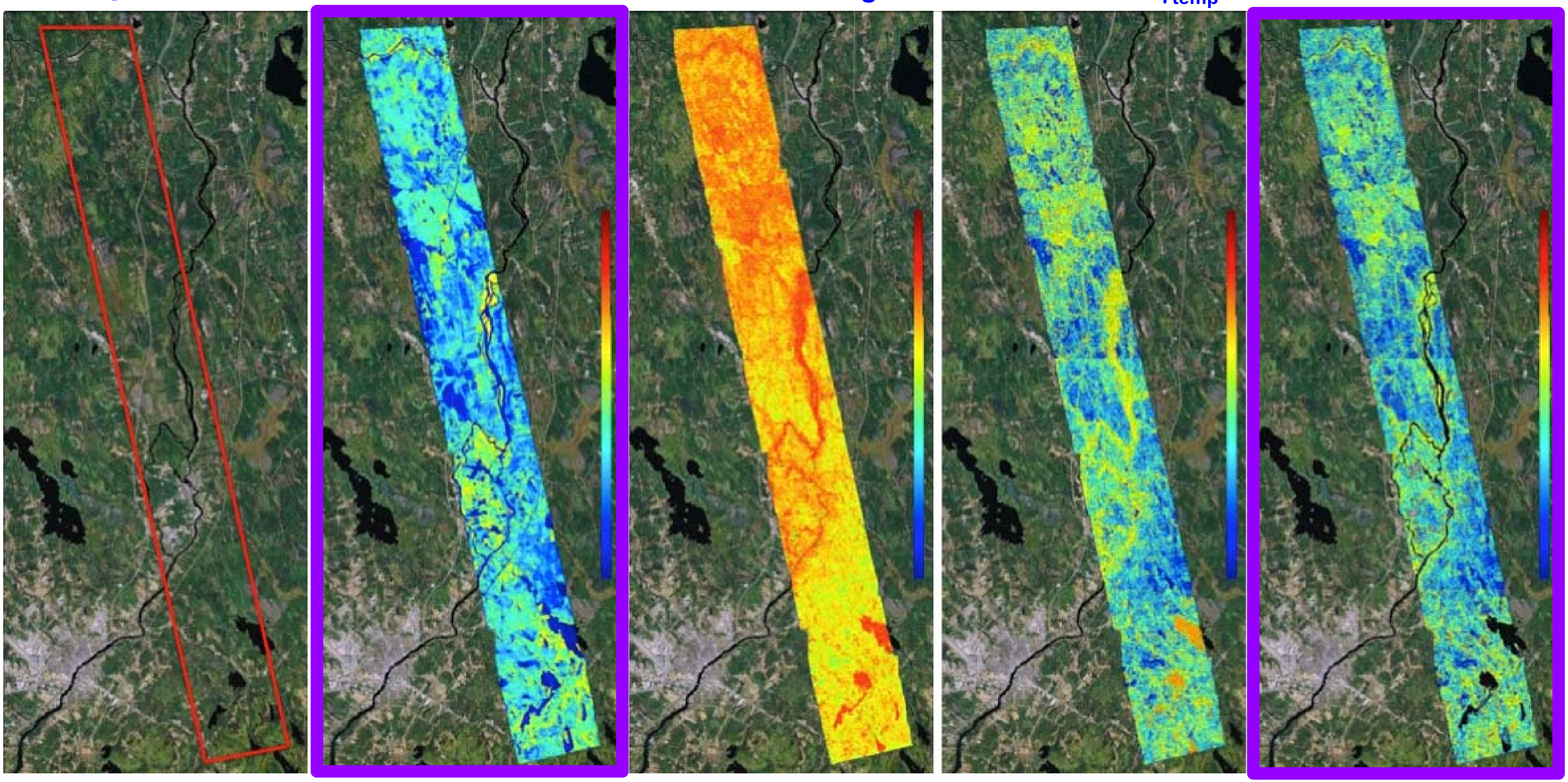
Average Correlation as a function of vertical wavenumber



This technique relies primarily on the association between temporal decorrelation and vegetation height

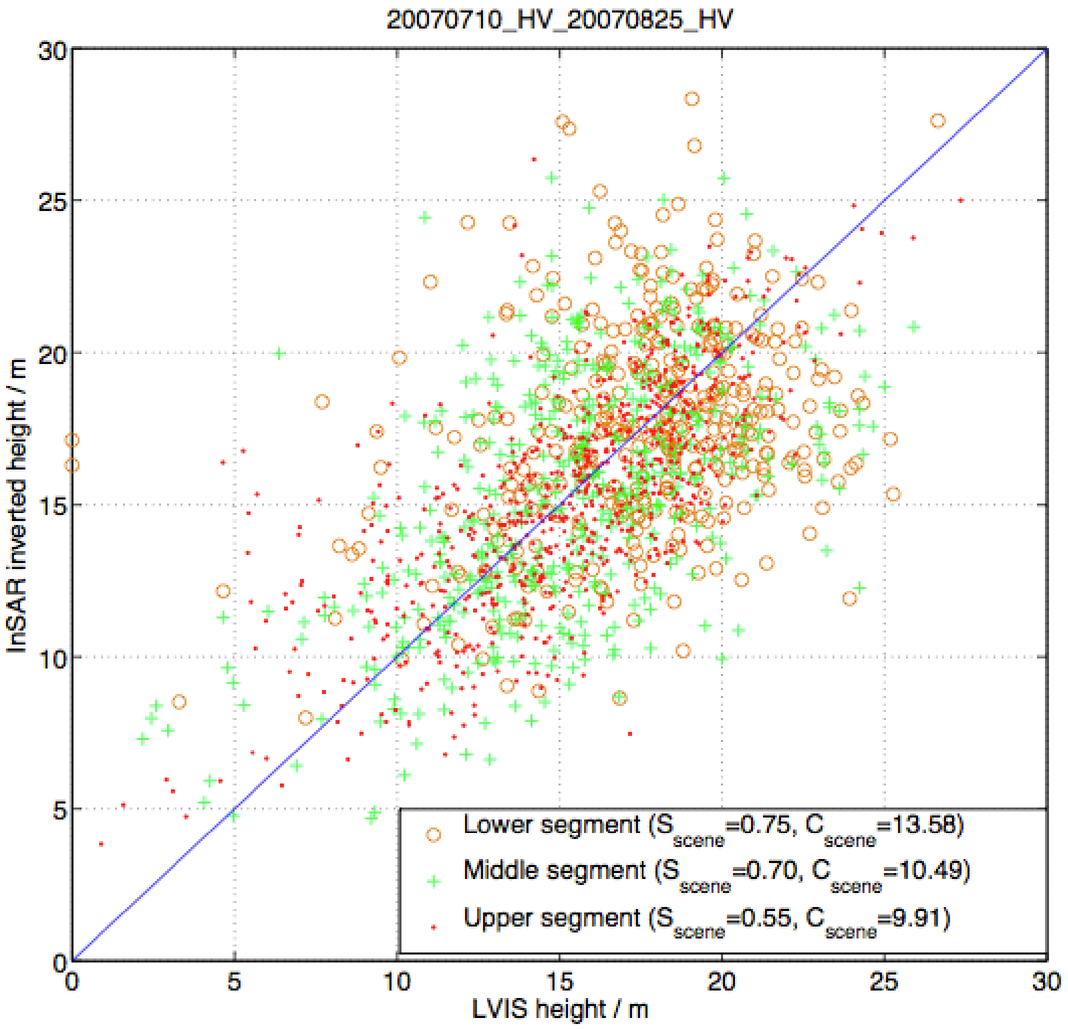
Visual comparison with LVIS heights

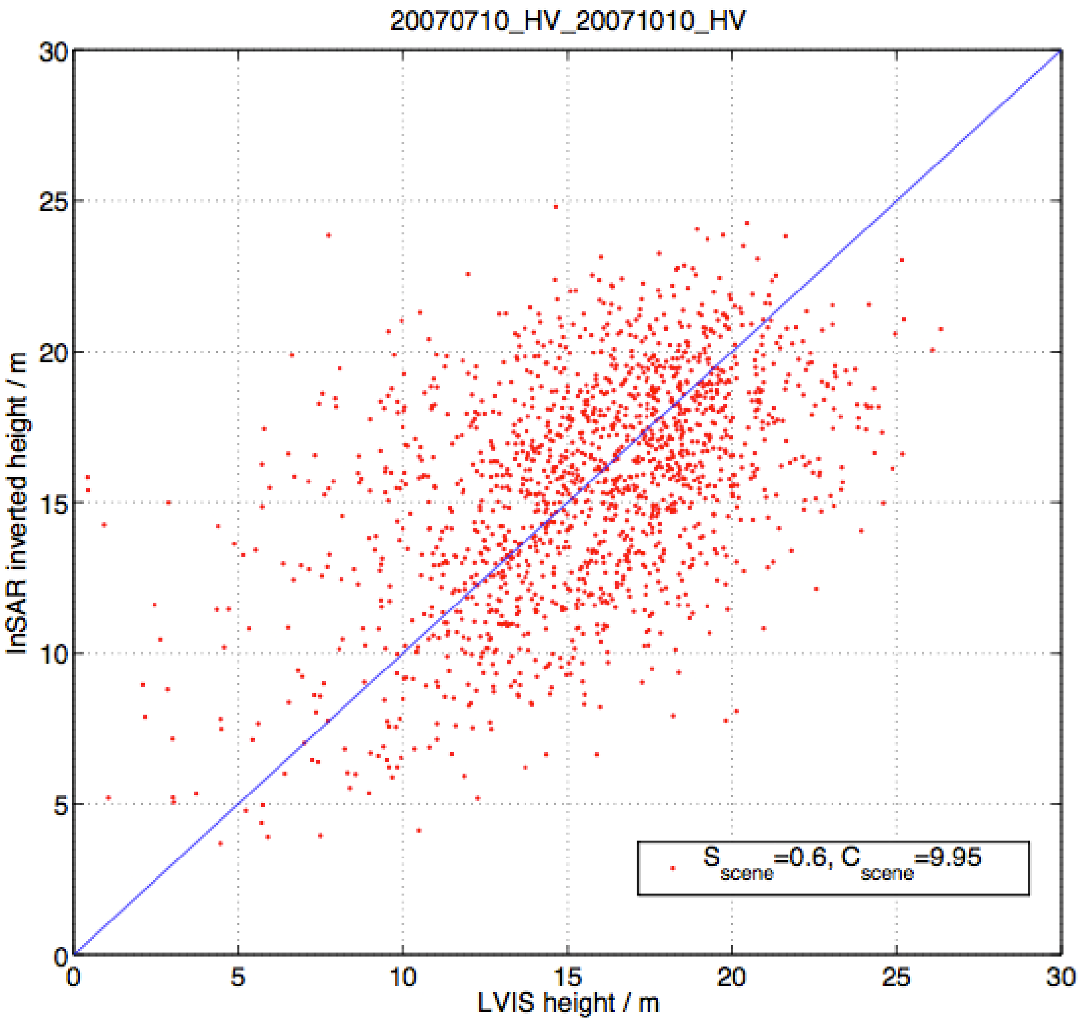
optical | LVIS | INSAR tree height | Corrected for γ_{temp} | classified water bodies



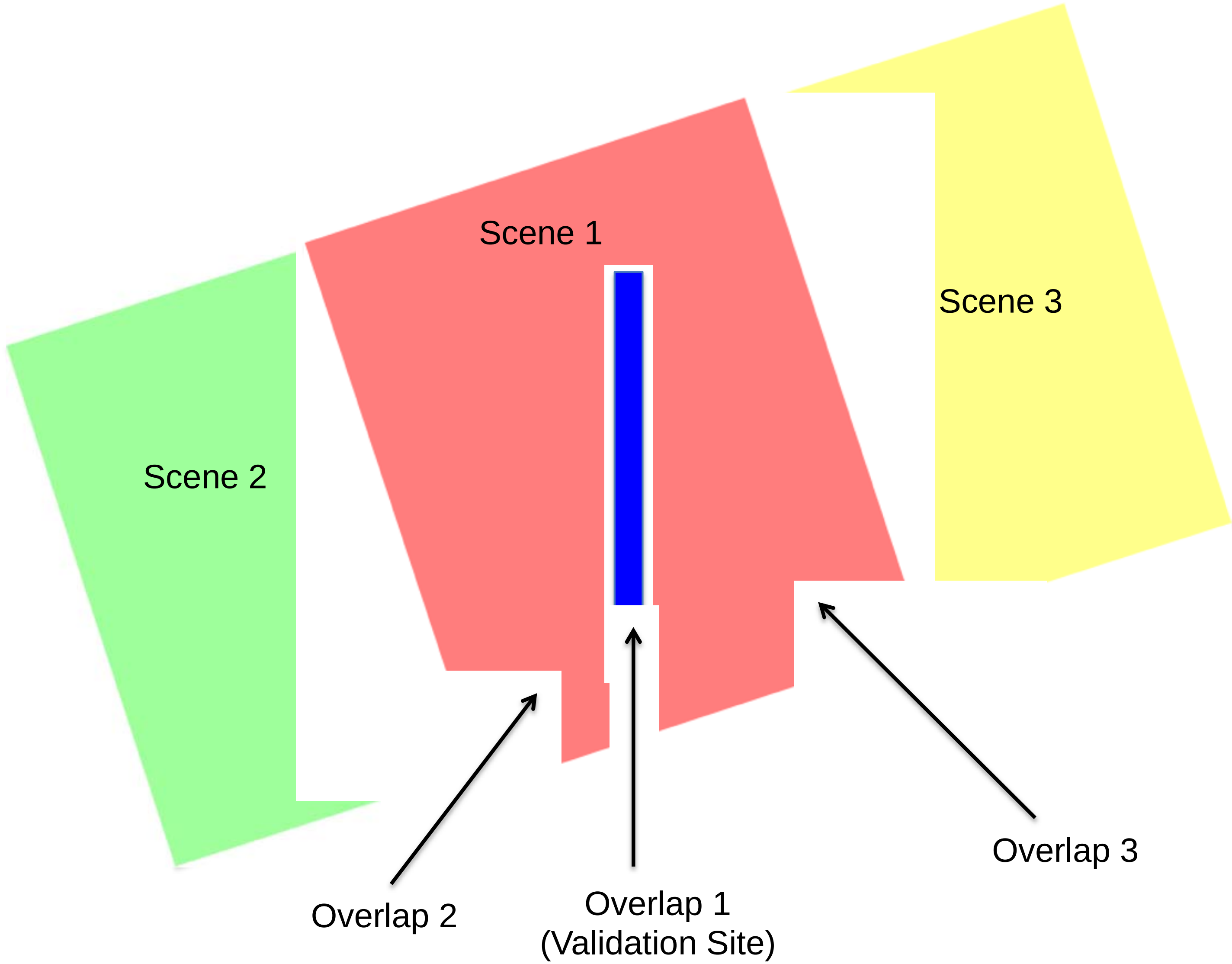
ALOS K&C Initiative
An international science collaboration led by JAXA

Quantitative comparison with LVIS





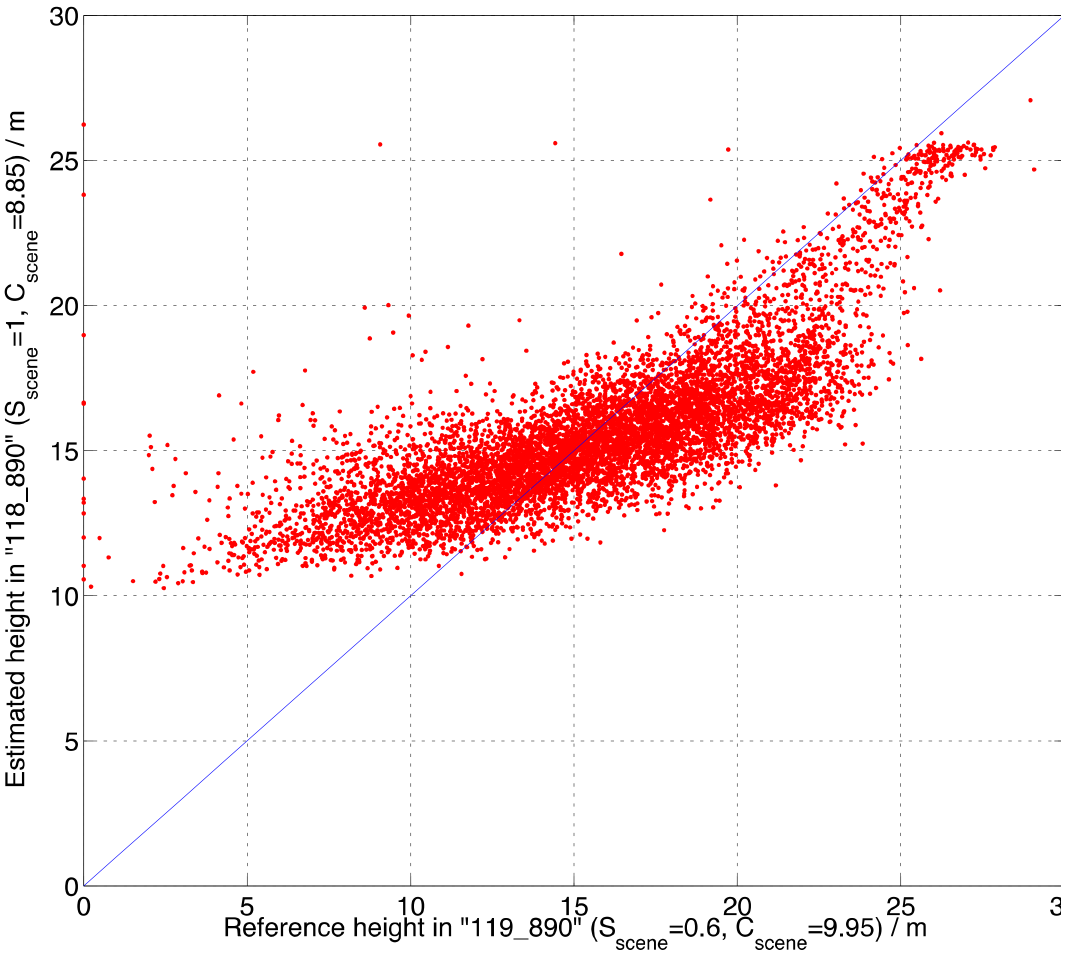
Use of overlap regions for propagating fit coefficients

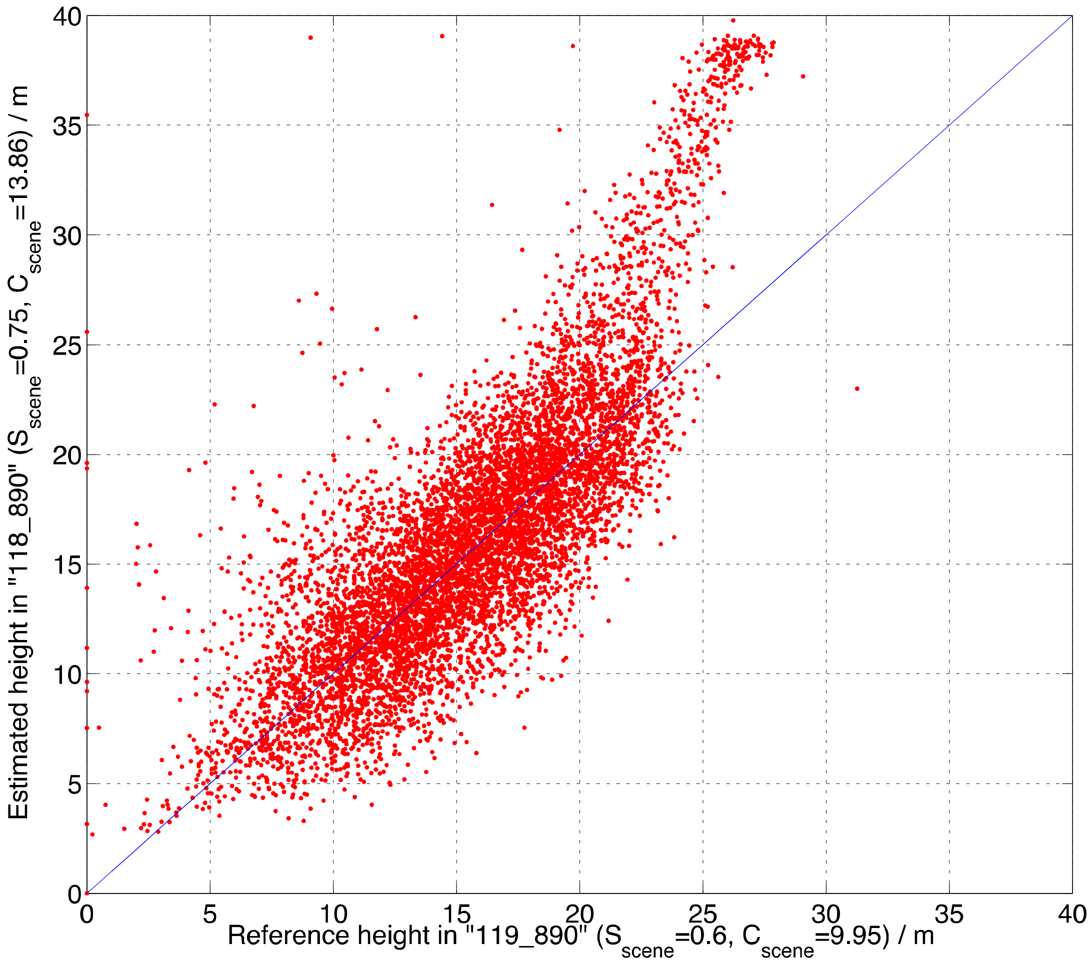


ALOS

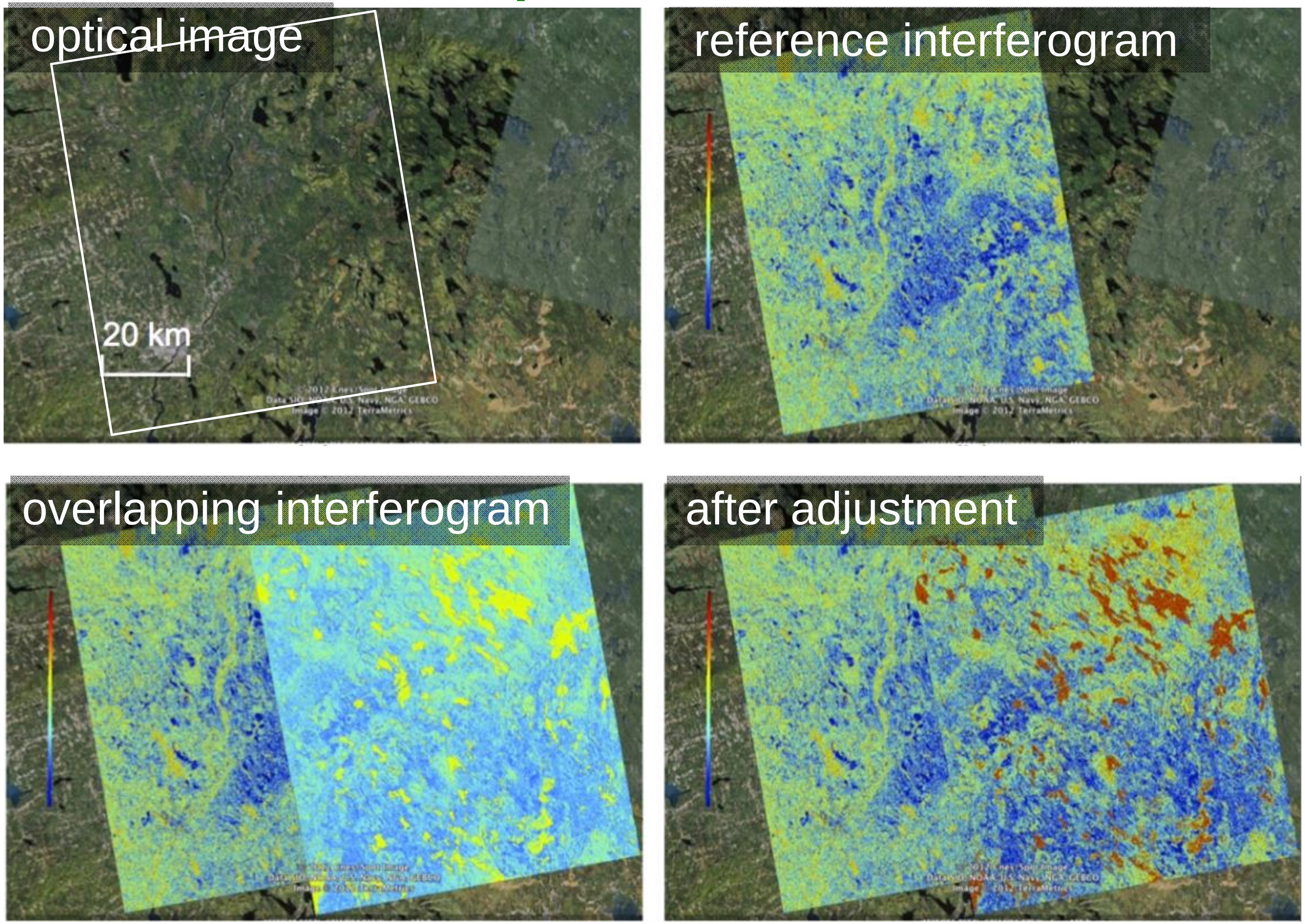
K&C Initiative
An international science collaboration led by JAXA

Adjustment for Temporal Decorrelation in the overlap regions





Visual comparison and adjustment for temporal decorrelation



A little of the mathematics

A simple model relates the effects of motion and dielectric changes to an invertible function

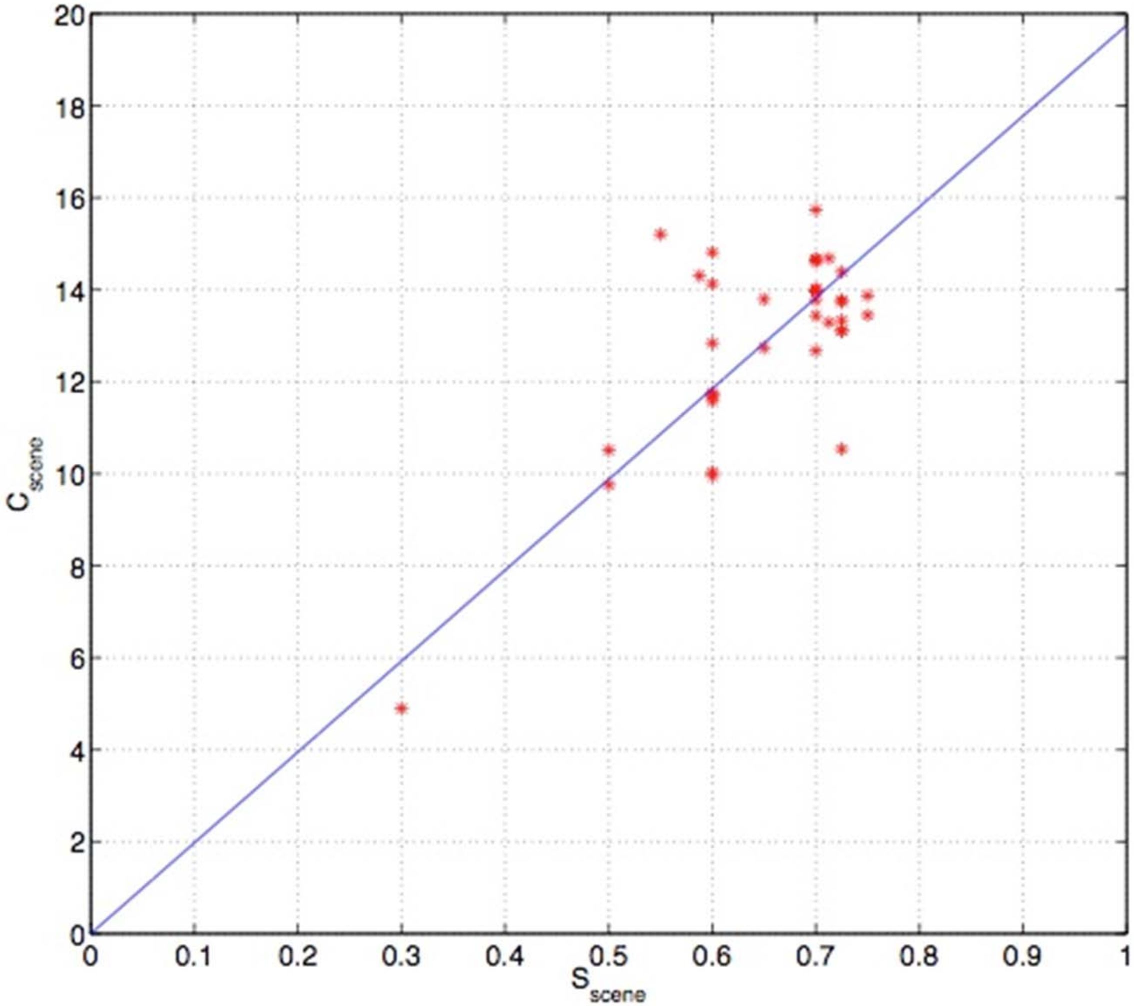
$$|\gamma_{v\&t}| \approx S_{scene}\ \mathrm{sinc}\left(\frac{h_v}{C_{scene}}\right)$$

S_{scene} is related to loss of correlation due to dielectric changes and C_{scene}, the height dependent effects of motion

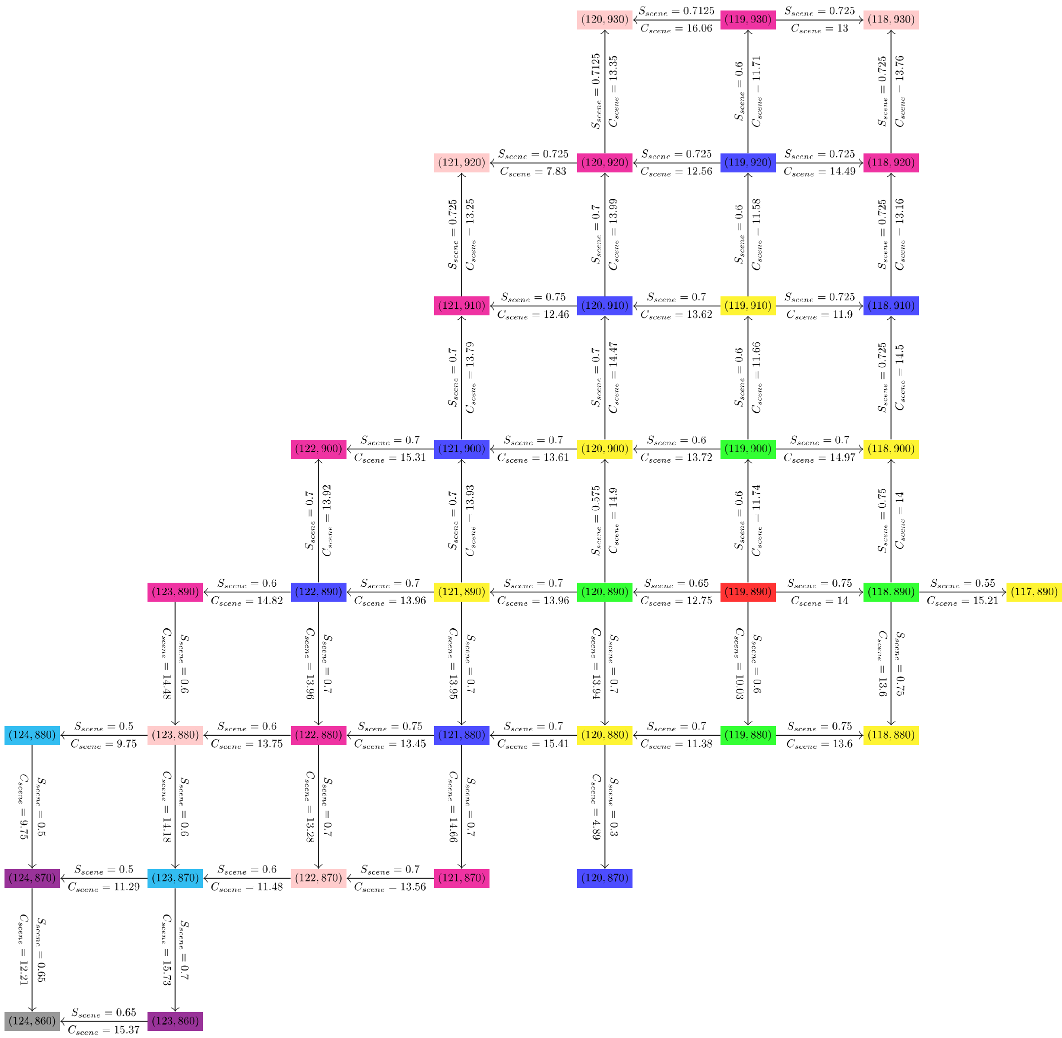
$$C_{scene} \approx \frac{\lambda h_r}{2\pi^2 \sigma_r}$$

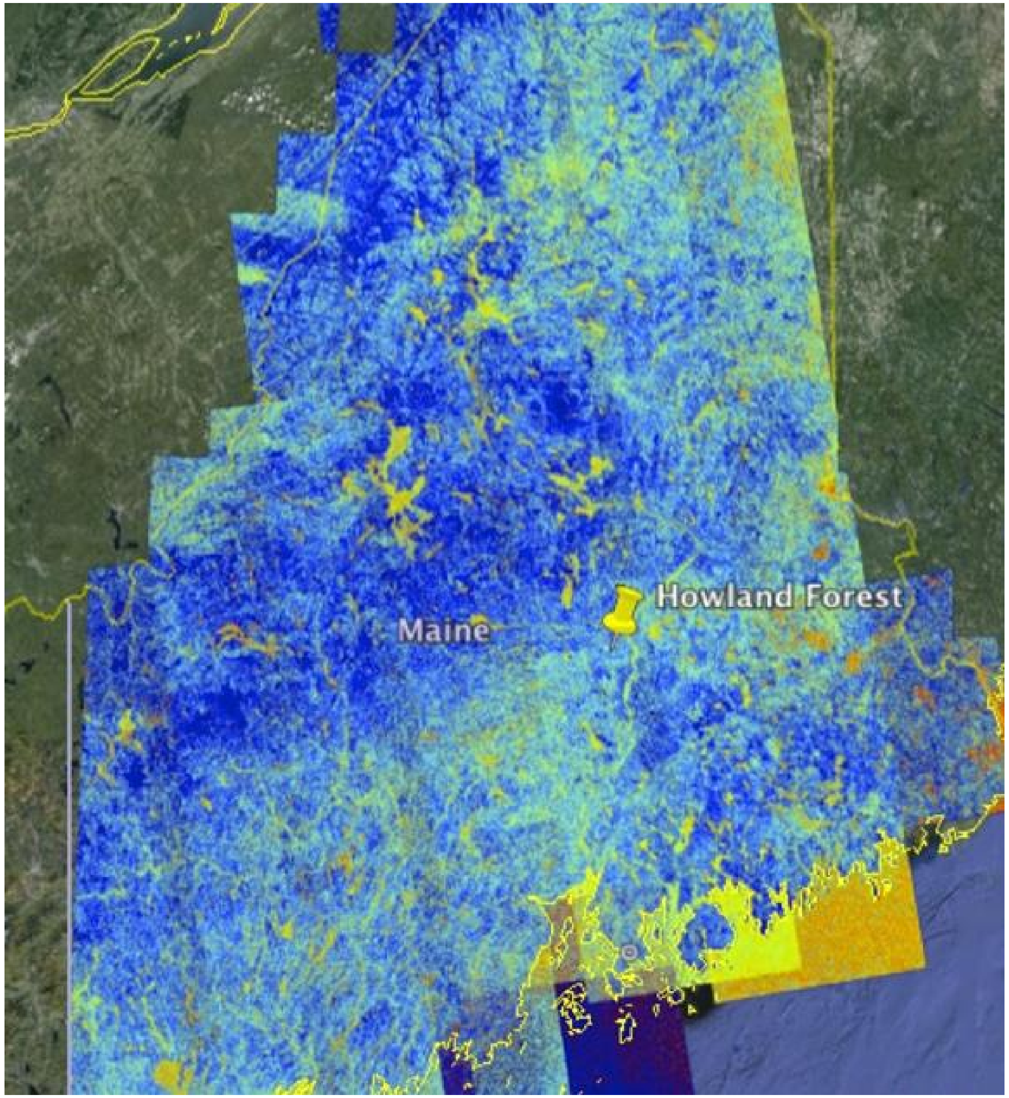
Take home message: Assuming consistency across the scene, only two coefficients need to be determined from overlap regions and ground validation

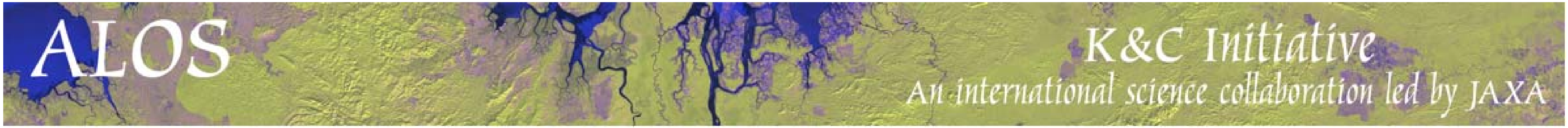
Values of C_{scene} and S_{scene} for the mosaic

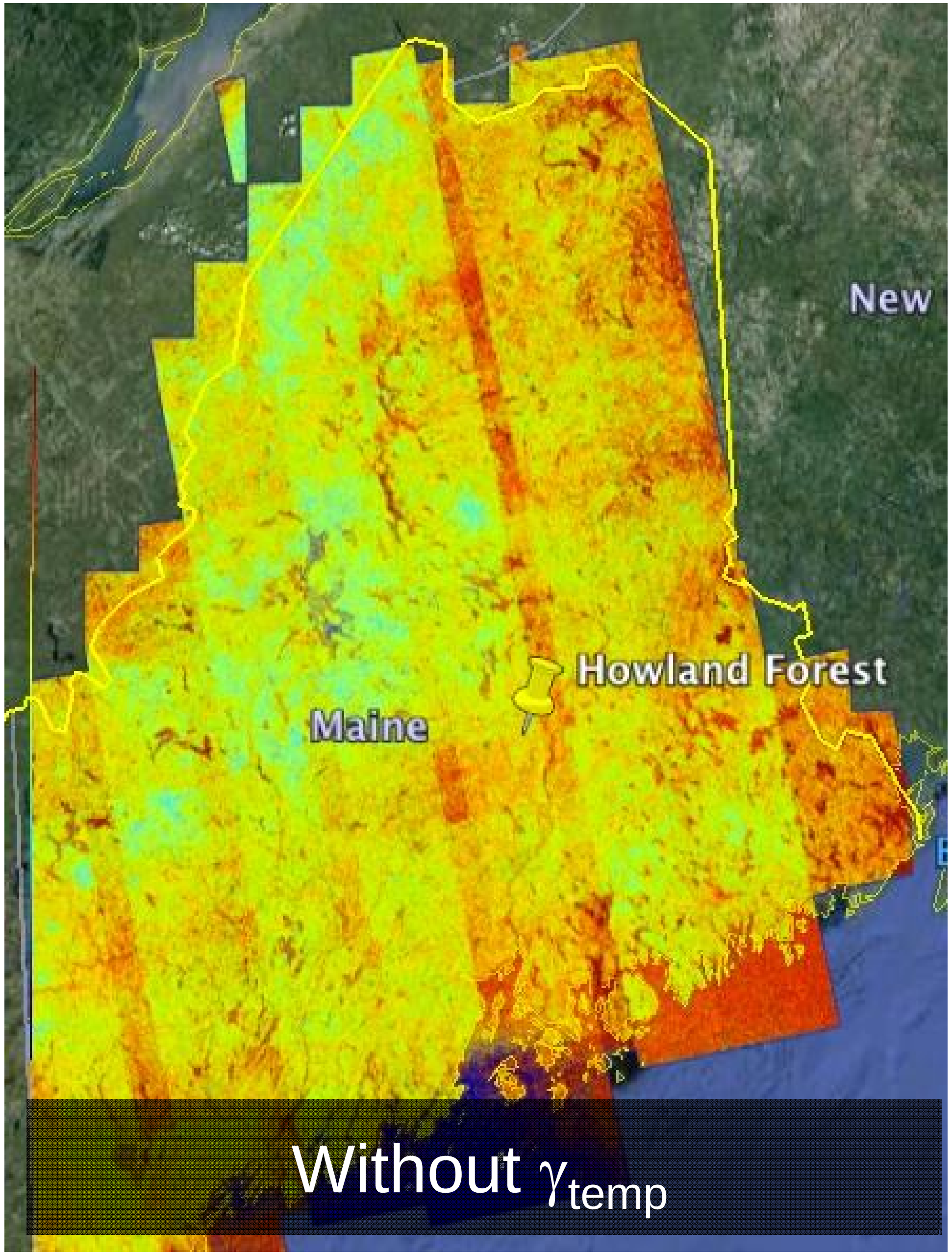


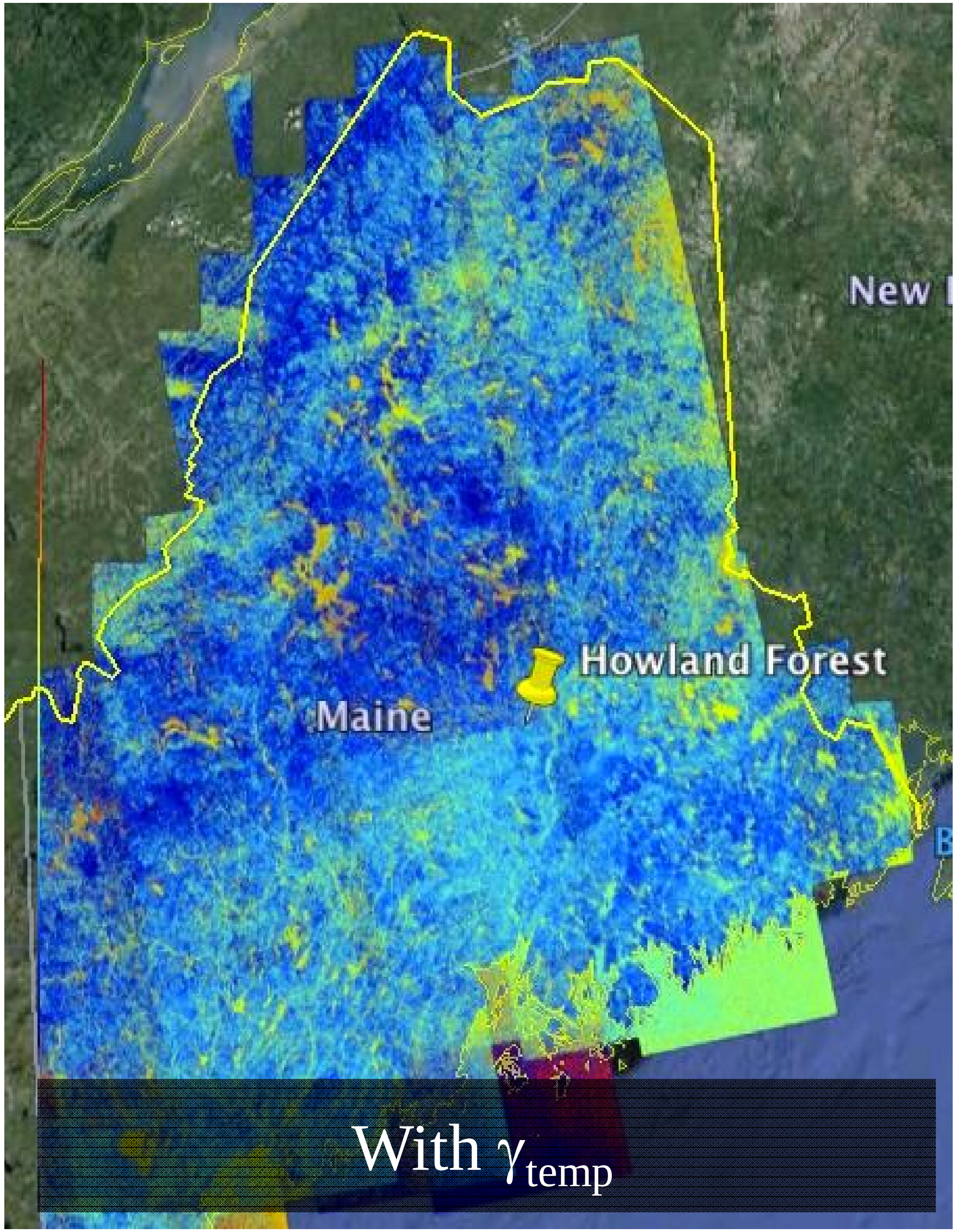
Assembling the Mosaic



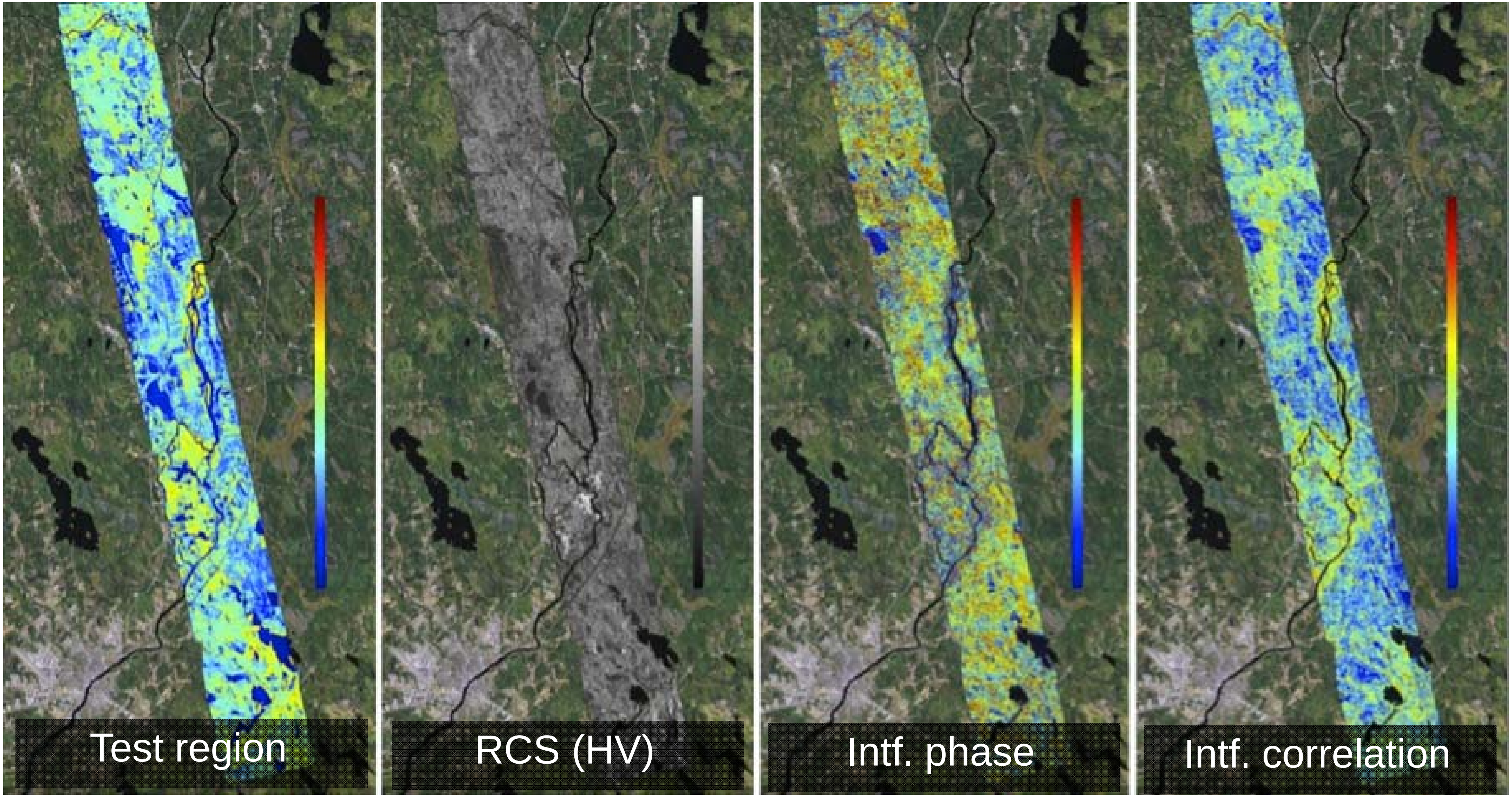



ALOS
K&C Initiative
An international science collaboration led by JAXA

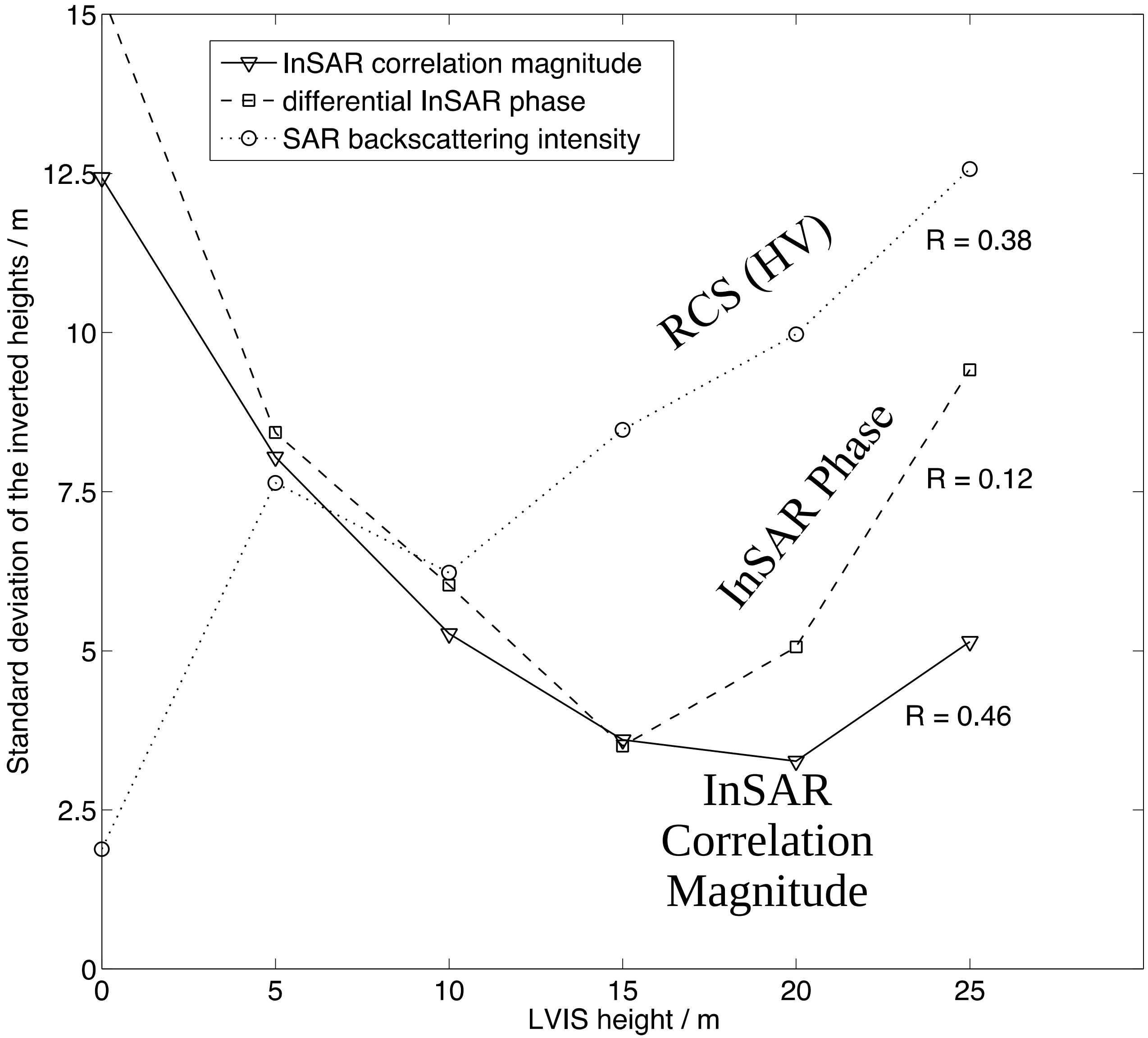

New
Howland Forest
Maine
Without γ_{temp}


New
Howland Forest
Maine
With γ_{temp}

Qualitative Comparison of Methods



Quantititave comparison

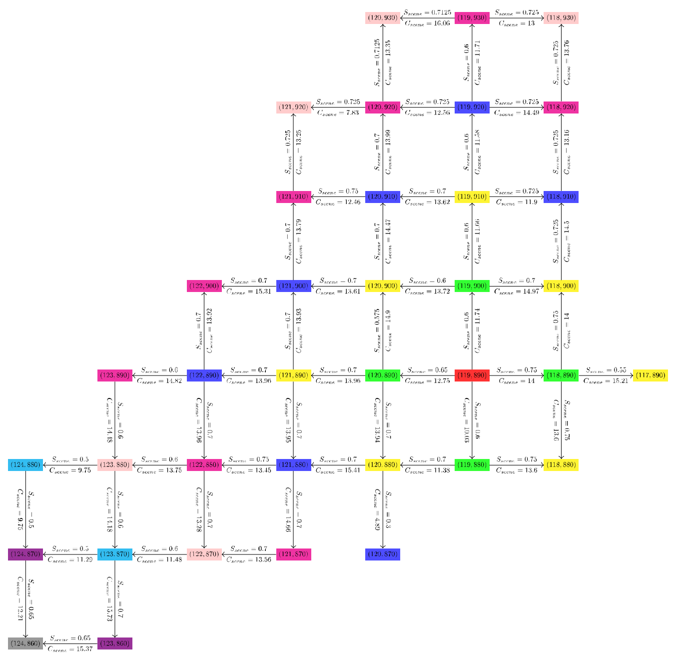


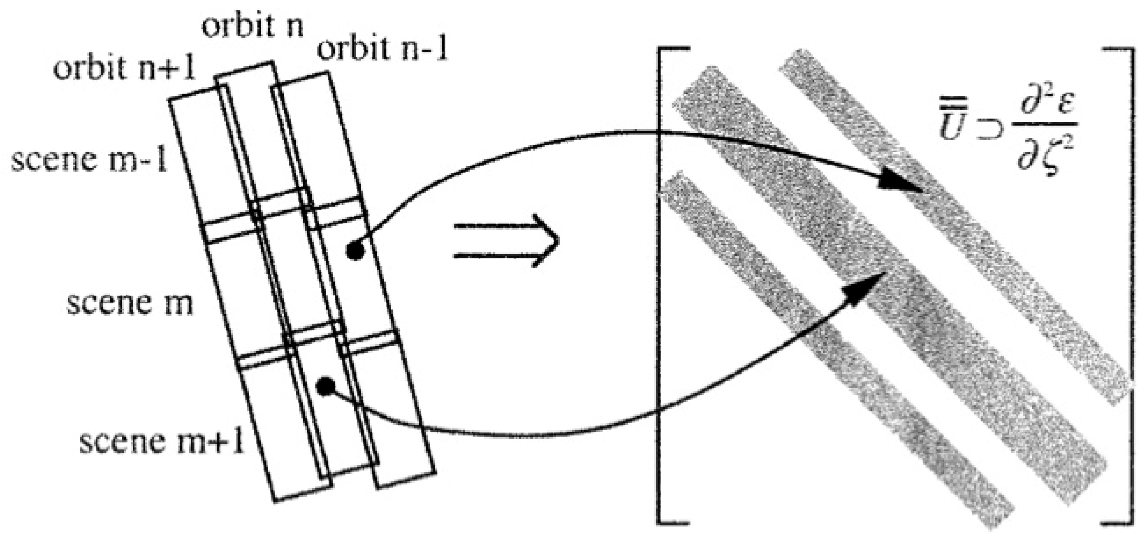
- Assuming that forest stand height (FSH) is a proxy for biomass, we can fit observations of RCS, InSAR differential height from the known DEM (phase) and the correlation magnitude height to the LVIS observed heights.
- Low heights work best with RCS.
- Large Heights have best performance with InSAR correlation magnitude

Use of Mosaicking

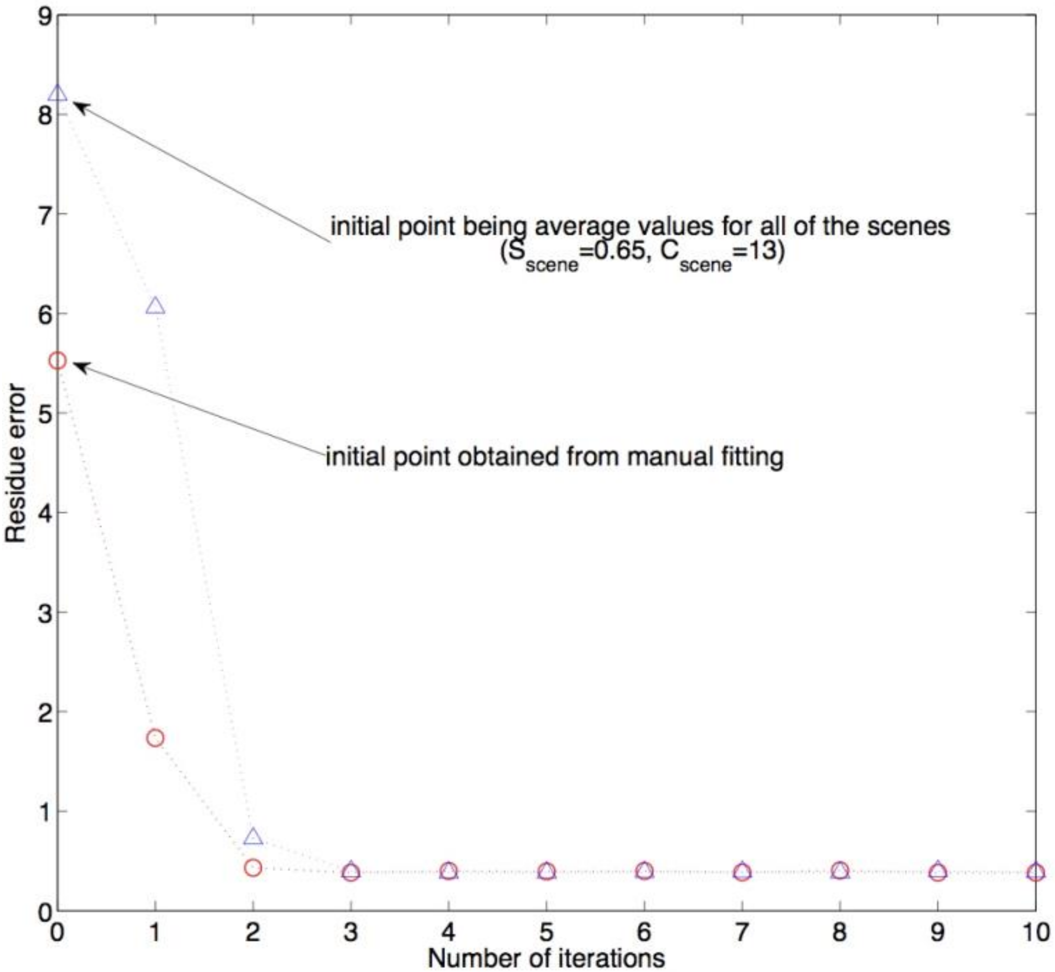
- Until recently, determination of scaling coefficients, Sscene and Cscene, have been done by scene-by-scene estimation using overlap regions

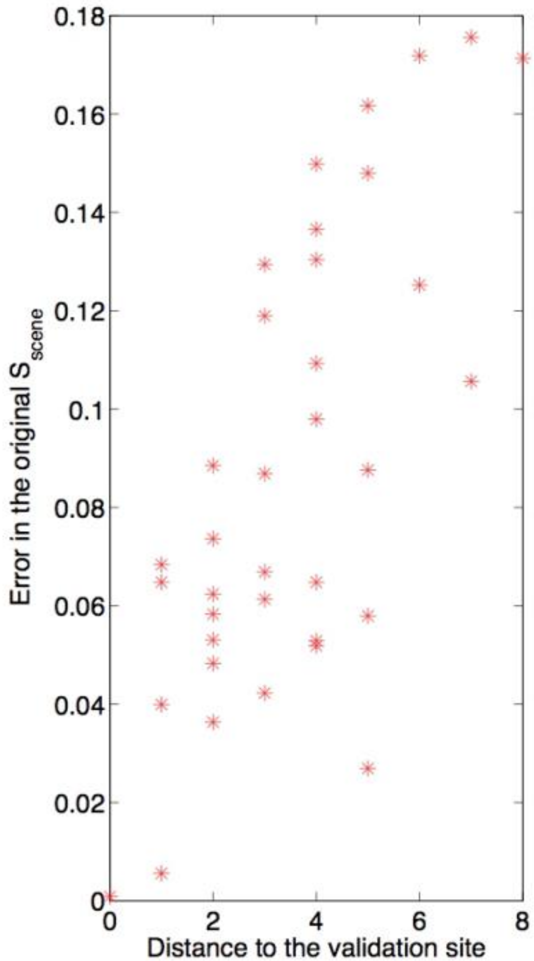
- We have developed a method for determining fit coefficients similar to what was done for the Amazon mosaic

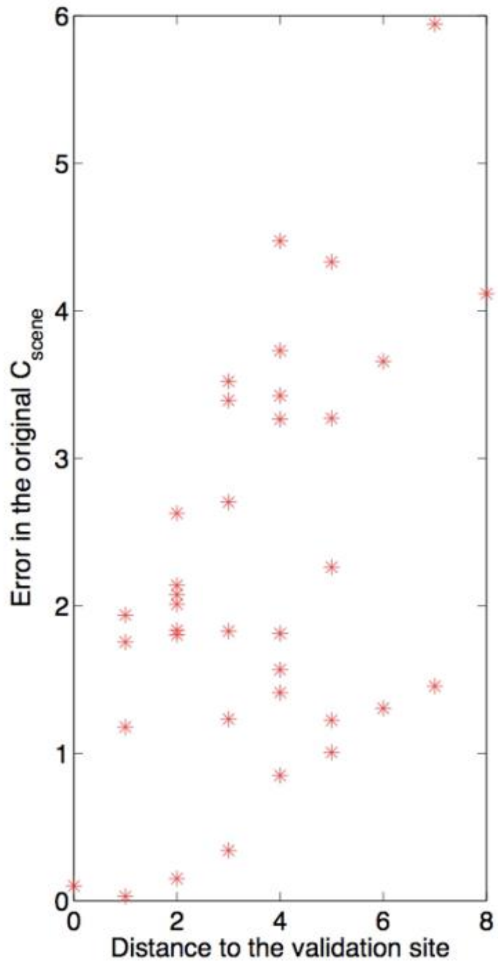


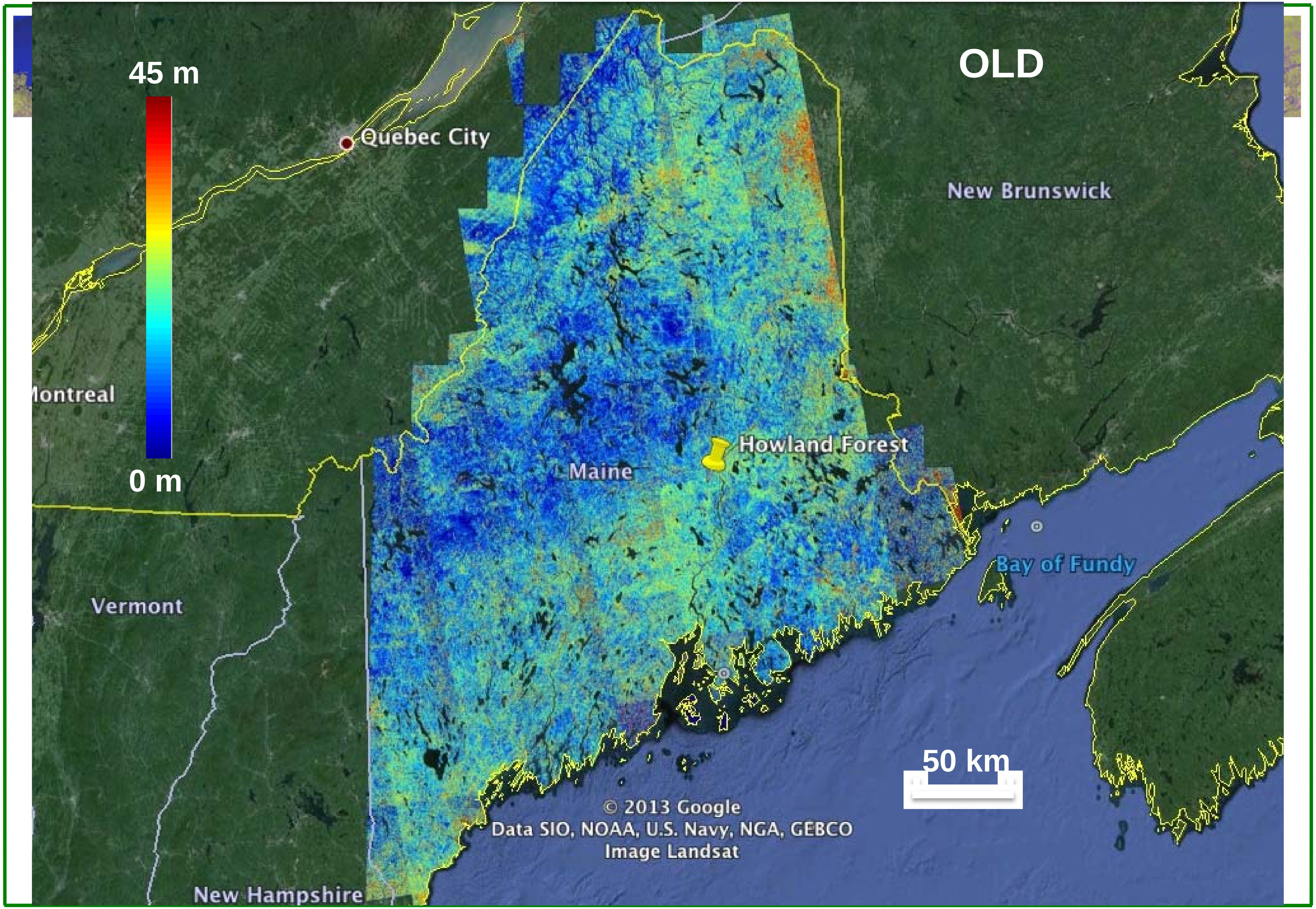


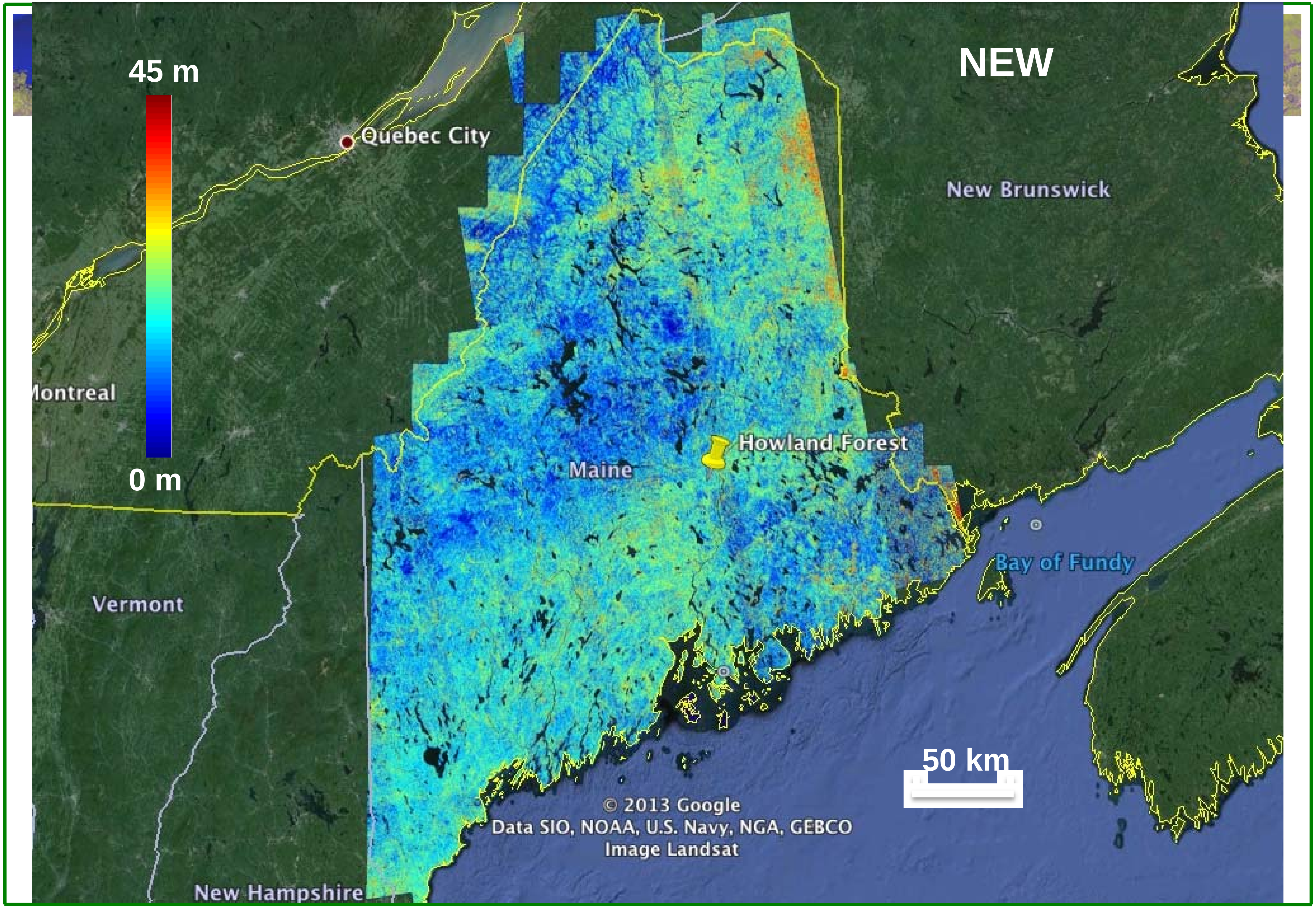
Iterative minimization of interscene differences



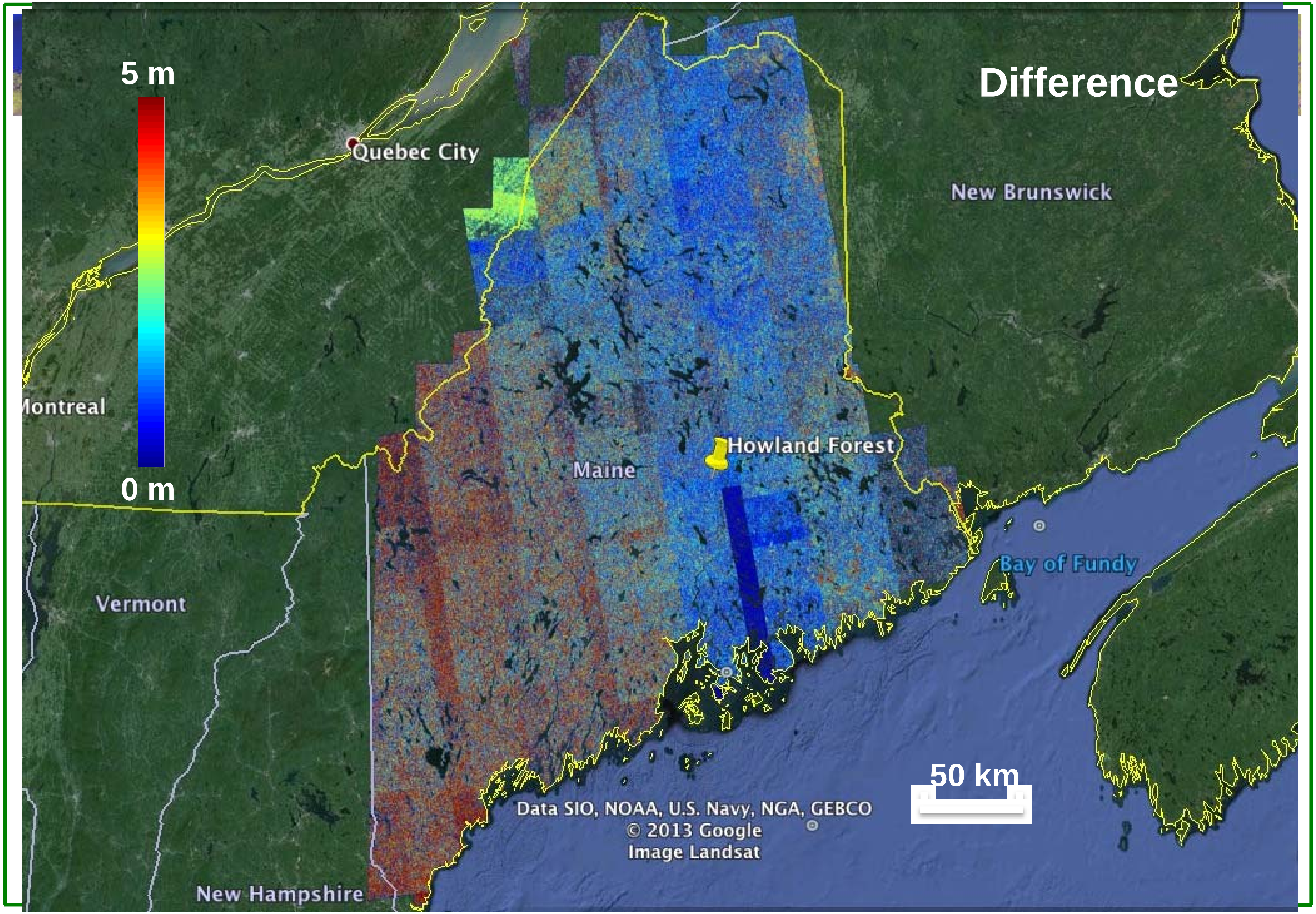





OLD
45 m
0 m
Quebec City
New Brunswick
Montreal
Howland Forest
Maine
Bay of Fundy
Vermont
50 km
© 2013 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat
New Hampshire



45 m
0 m
NEW
Quebec City
Montreal
New Brunswick
Howland Forest
Maine
Bay of Fundy
Vermont
New Hampshire
50 km
© 2013 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat

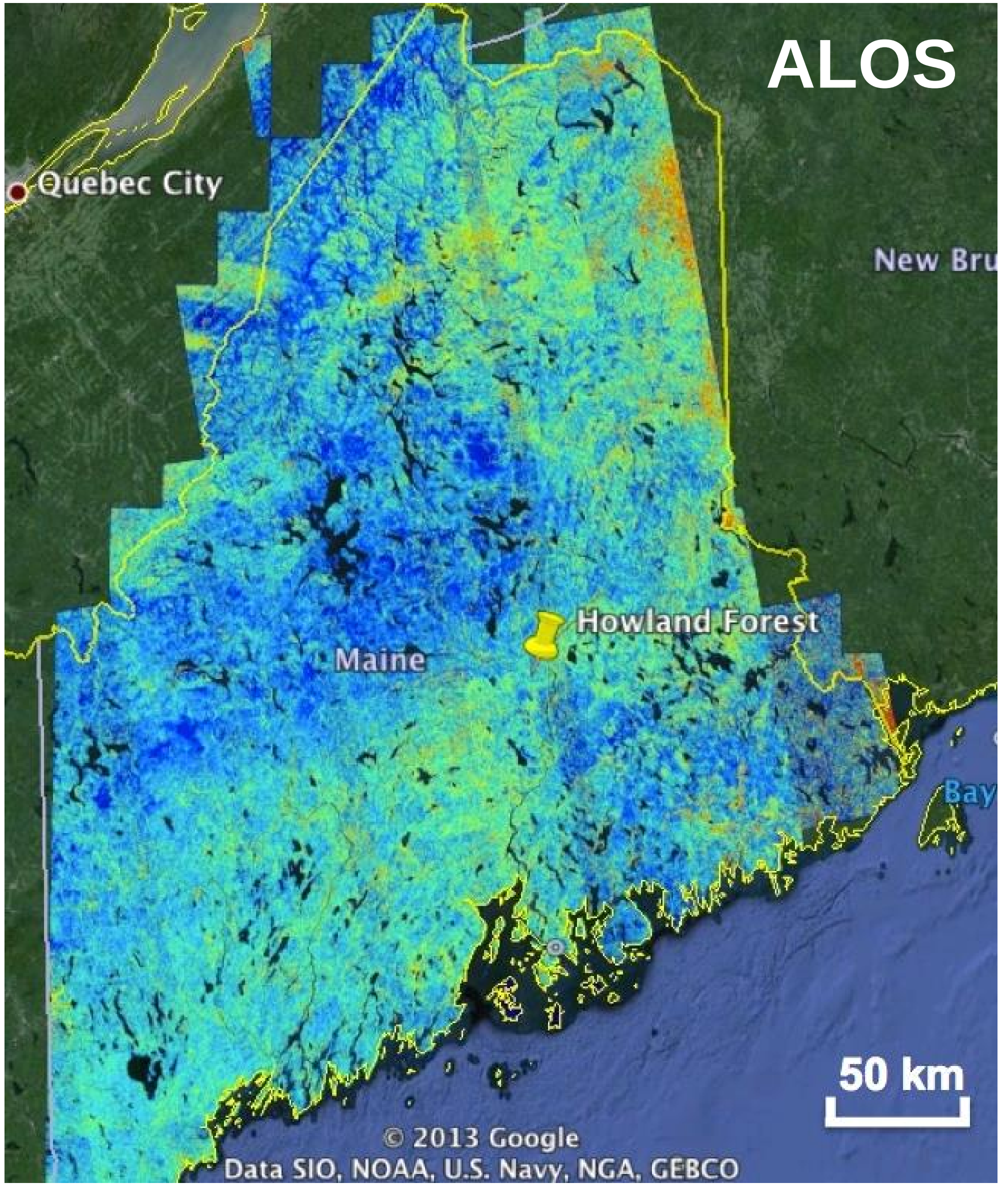


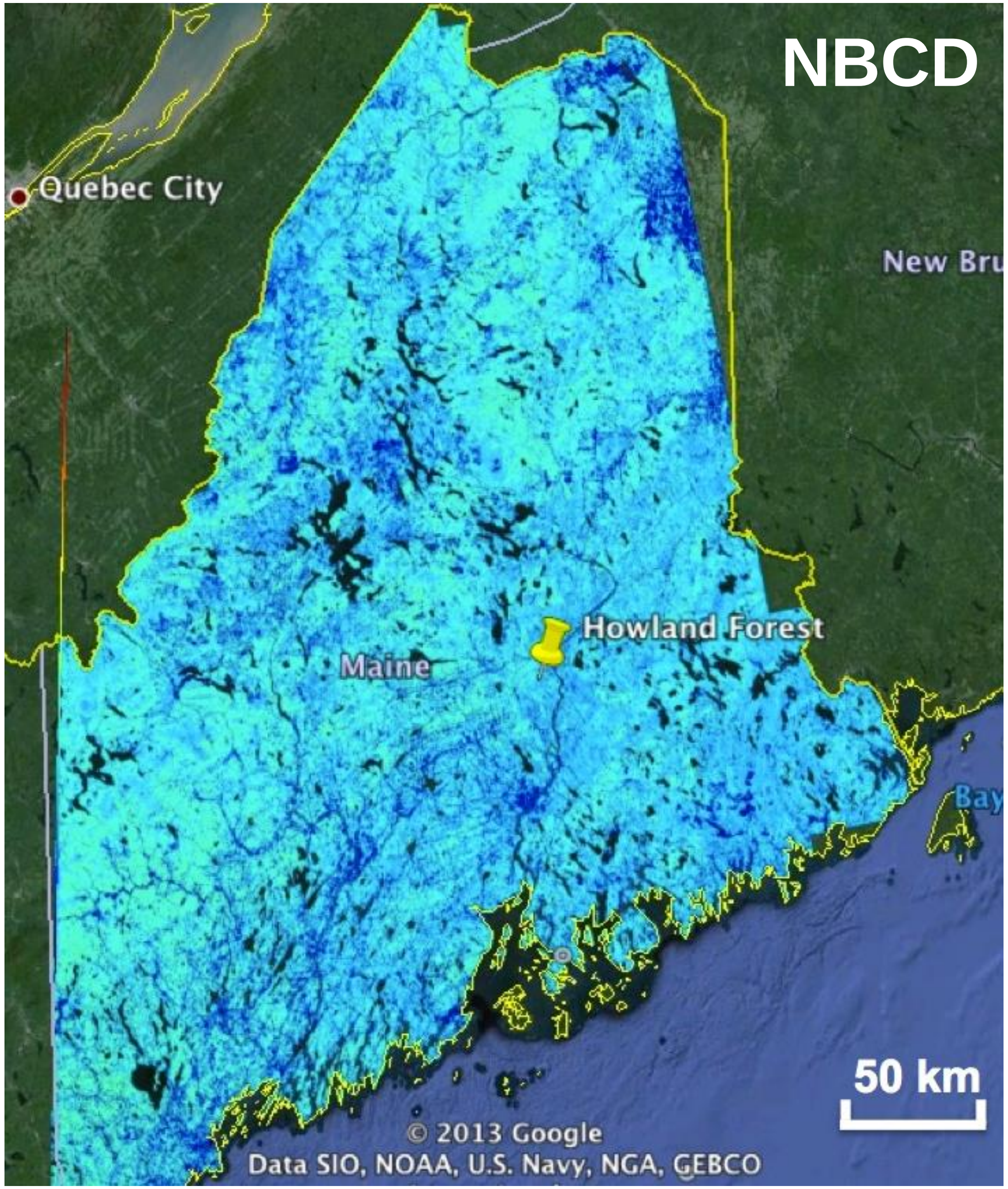
5 m
0 m
Difference
Quebec City
New Brunswick
Montreal
Howland Forest
Maine
Bay of Fundy
Vermont
50 km
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2013 Google
Image Landsat
New Hampshire

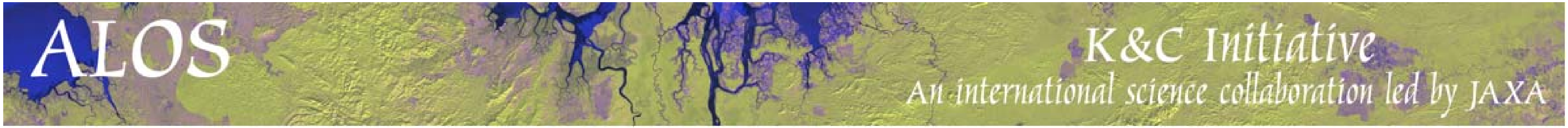
ALOS

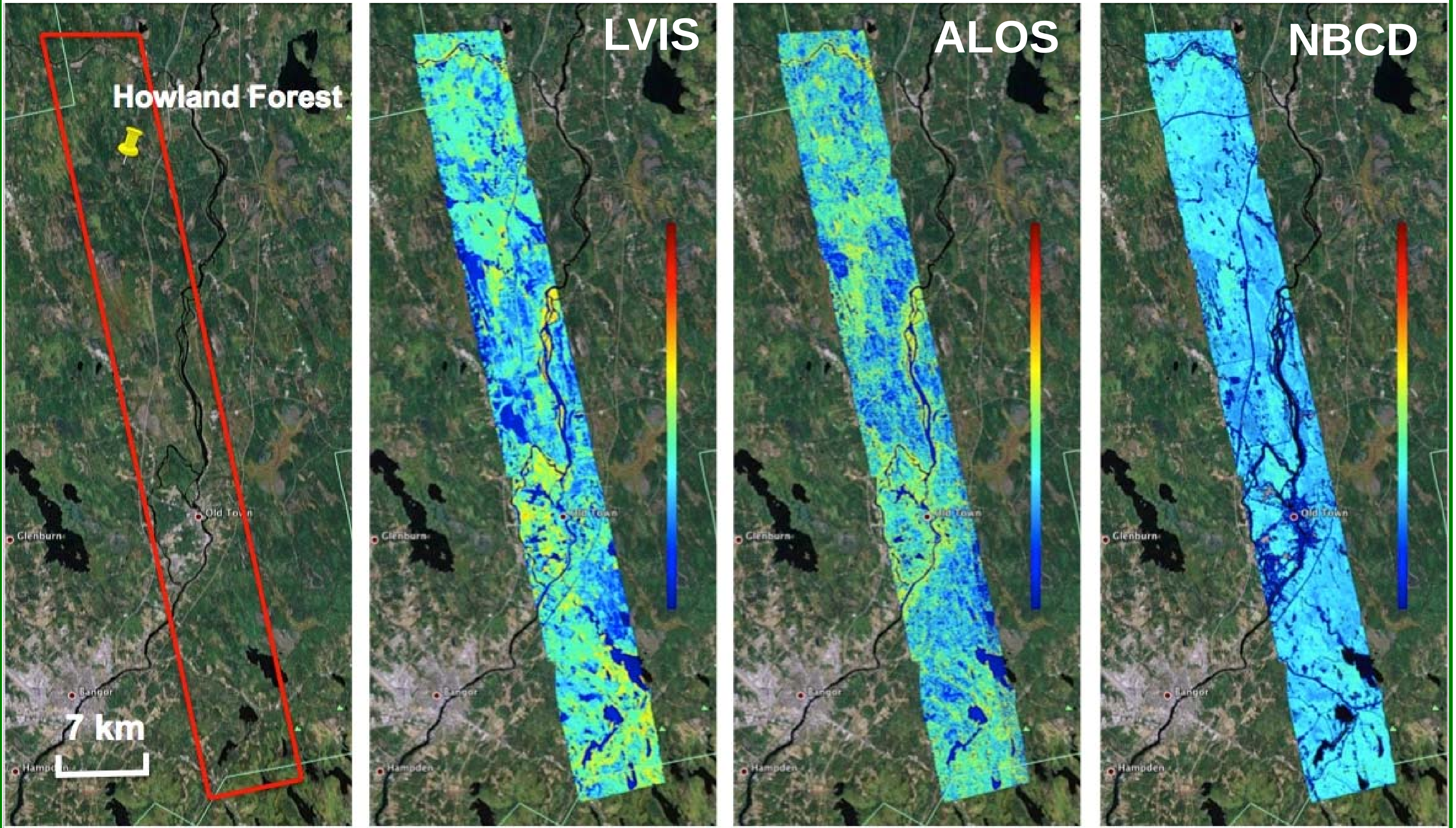
K&C Initiative
An international science collaboration led by JAXA

Comparison to other state-wide metrics






ALOS
K&C Initiative
An international science collaboration led by JAXA

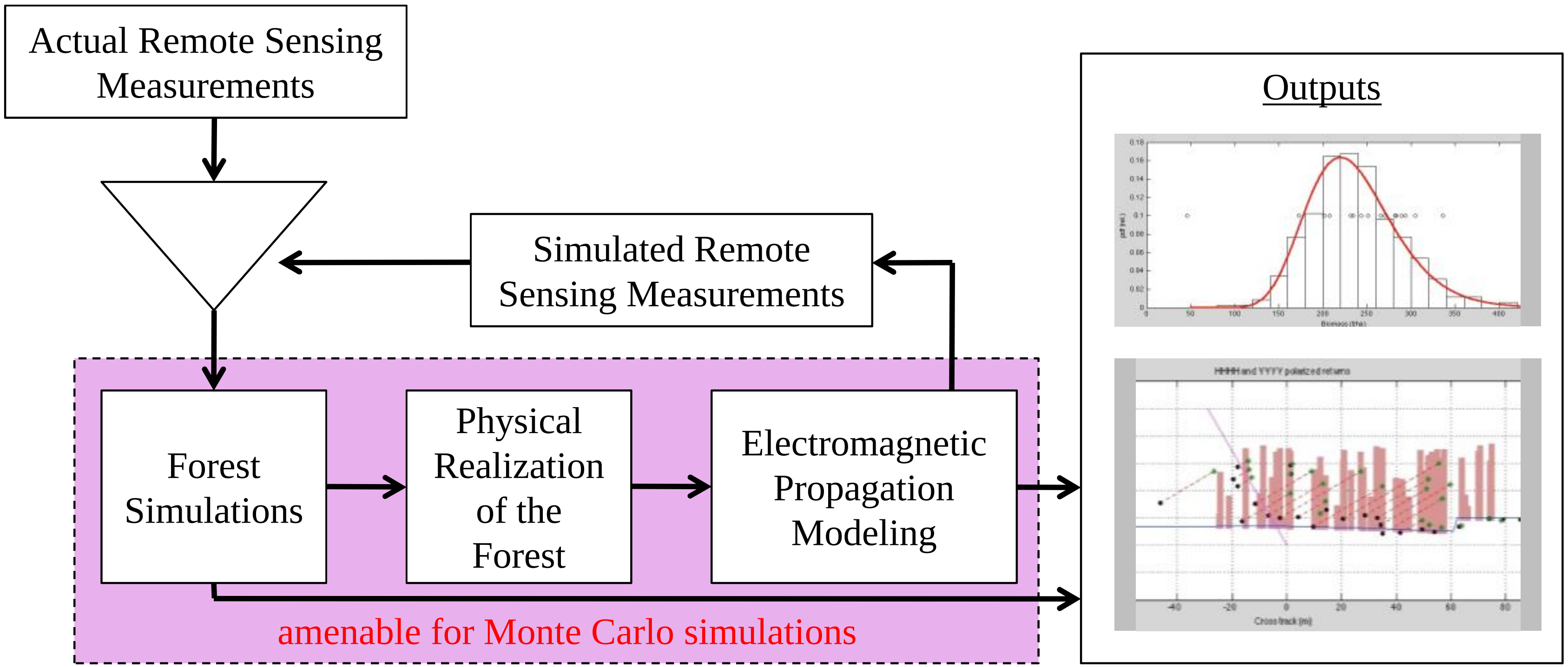

Howland Forest
Old Town
Glenburn
Bangor
Hampden
7 km
LVIS
ALOS
NBCD

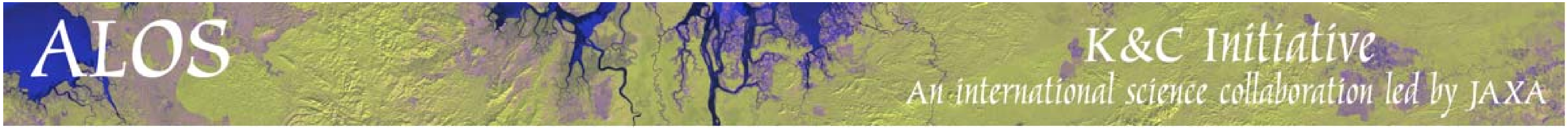
Conclusions

- We have created a method for using repeat pass interferometry for estimating FSH.
- Results are scalable and are amenable to optimization through mosaicking.
- Even though it seems that the results should speak for themselves, it is turning out to be surprisingly hard to publish the technique. Part of the problem is that many reviewers take issue with the mathematics or the likelihood of having a spatially varying temporal decorrelation.
- While it is likely that the temporal decorrelation does vary spatially, the mean behavior is sufficiently consistent so as to provide useful results. This is made clear by the quantitative and qualitative comparison of the results.

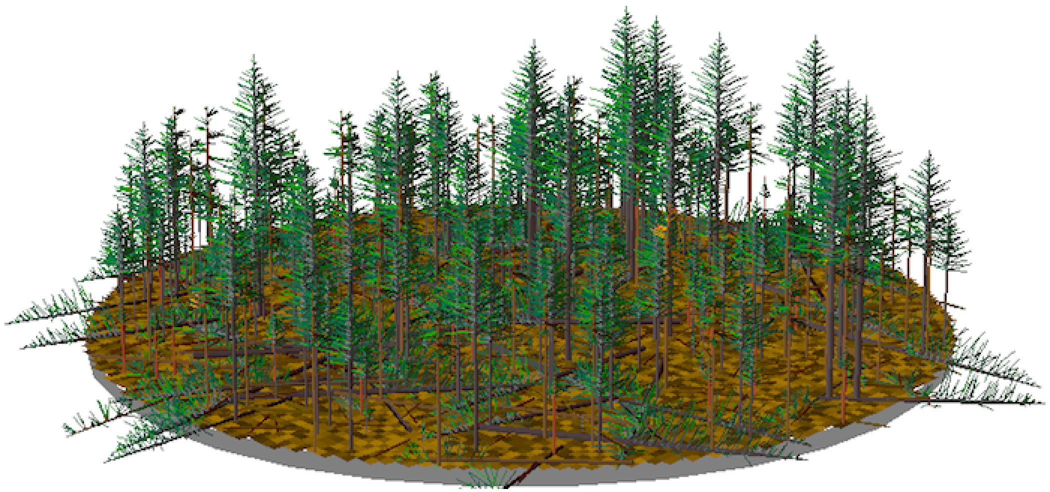
Other Efforts

- **In addition to this height mapping from PALSAR Interferometry, we are using forest growth models in conjunction with EM modeling in order to determine forest metrics directly derived from the ecologically-based growth models.**

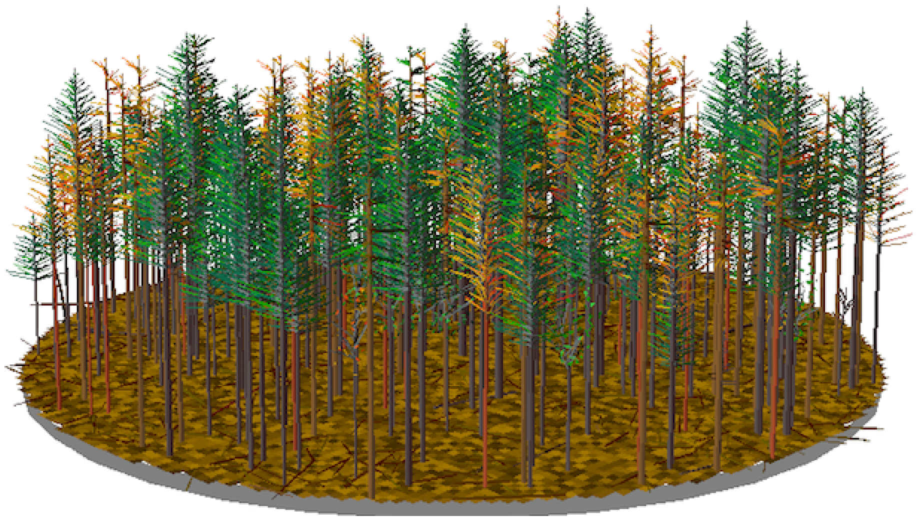




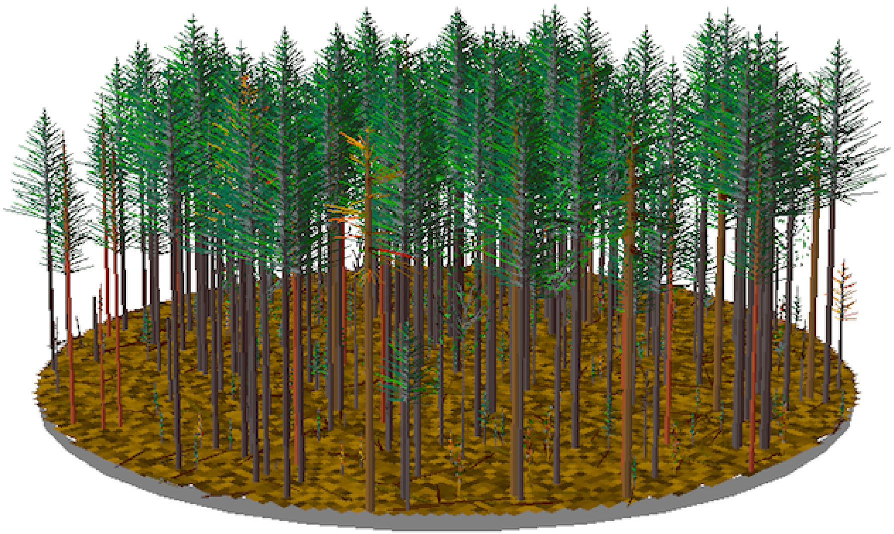
Forest Growth Model (FVS)



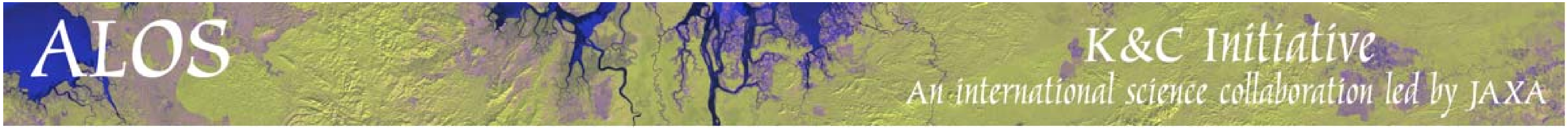
hurricane damage



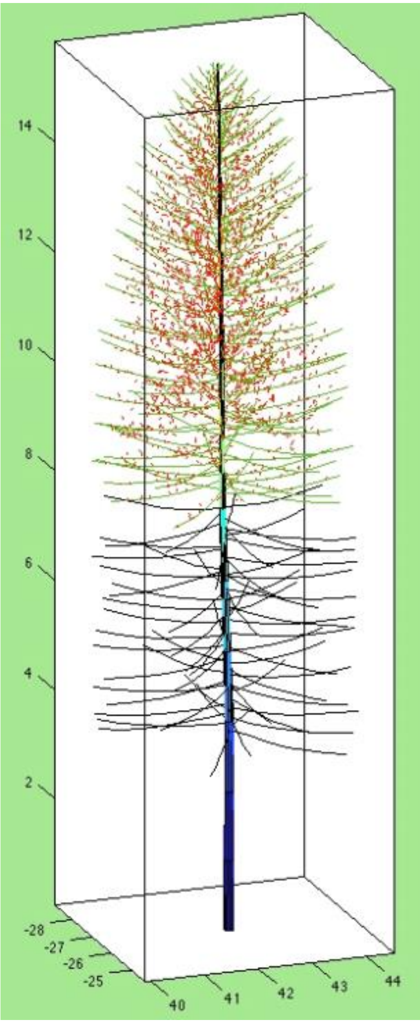
regrowth and competition

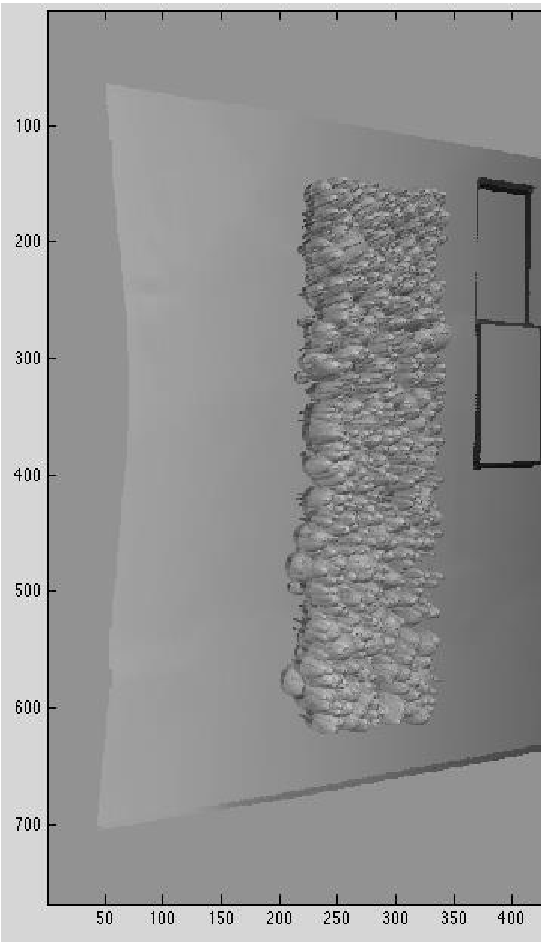


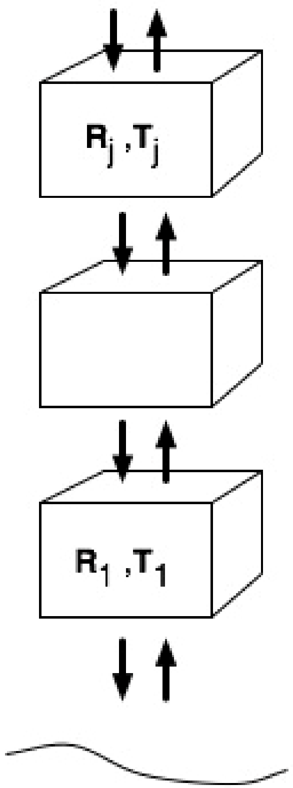
Today's conditions (can be compared to stem maps from FIA and/or UMass collected)

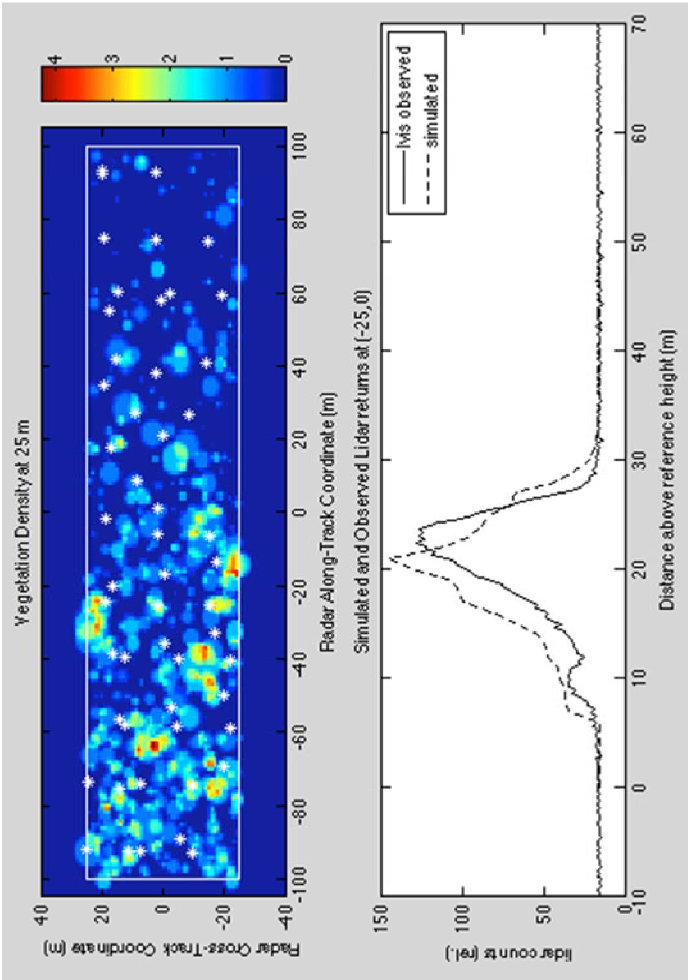


Use of PolSARproSIM for modeling radar return and a simple ray tracing algorithm for the lidar

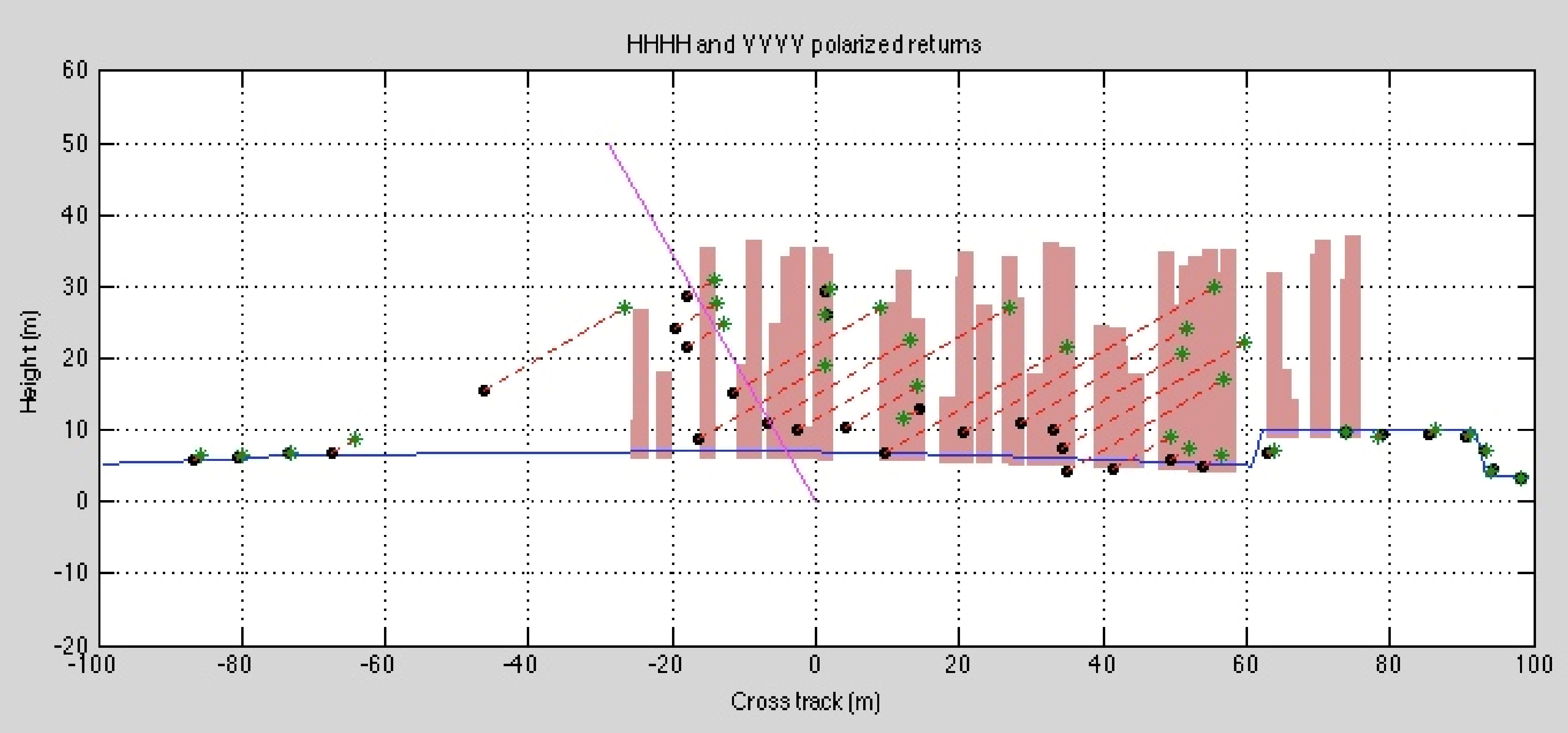


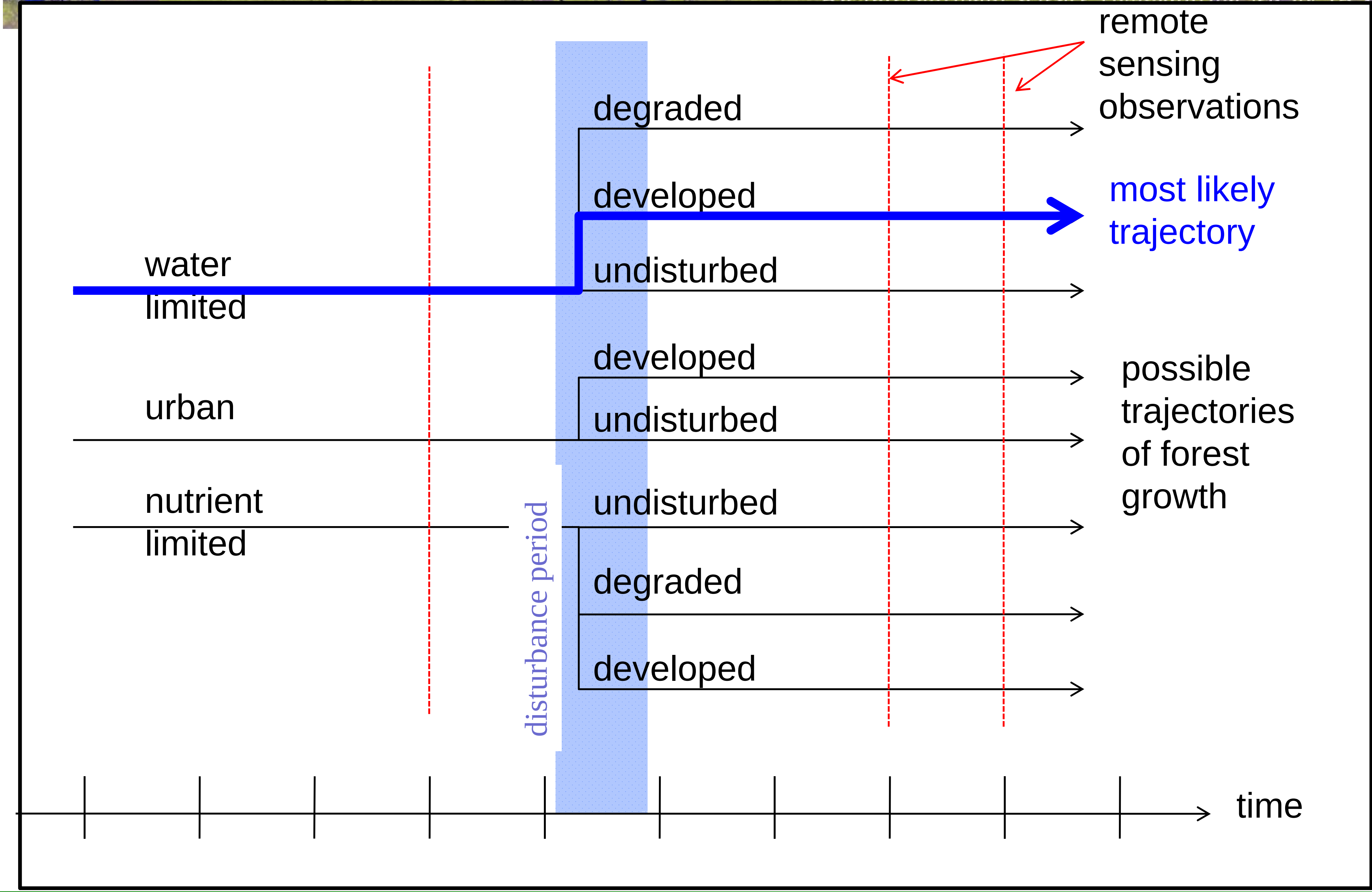






PolSARproSIM interferometric results using a stem map




remote sensing observations
degraded
developed
most likely trajectory
water limited
undisturbed
developed
urban
undisturbed
possible trajectories of forest growth
nutrient limited
disturbance period
undisturbed
degraded
developed
time