K&C Phase 4 – Status report

Land Cover Change and Forest Carbon Tracking with L-Band SAR and Optical Time Series Data

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Earth Big Data, LLC

Chris Holden, Curtis Woodcock, Pontus Oloffson
Boston University

Science Team meeting #23
Hatoyama, Japan, January 18-20, 2017

Project outline and objectives

Study on the use of optical and radar time series for activity data monitoring in a REDD+ context.

Study Sites: Southern USA, Colombia, Peru, Mexico

Project support all 4 C themes of the KC Project

Results and significant findings thus far

Most of our work is based on ALOS-1 data, since we have better time-series coverage available.

We demonstrate that L-band time series are an invaluable complement to optical data for monitoring deforestation and forest degradation events in countries frequented by cloud cover.

Also, the timing of deforestation/degradation onset is improved with the fusion of time series.

New algorithms for the fusion are developed which allow for signal-based fusion of the time series before analysis

Project milestones

Complete Fusion analysis work

Process ScanSAR mosaic time series for ALOS-2

Incorporate data results in an emissions scenario

Publish paper on fusion work

Generate change detection results

Deliverables etc.

- Time series based change maps with time steps of deforestation, degradation mapped
- Quantitative assessment of the accuracy of these classifications
- Recommendations for the density of L-Band SAR time series data

PALSAR/PALSAR-2 data access

Please list the PALSAR/PALSAR-2 data you have

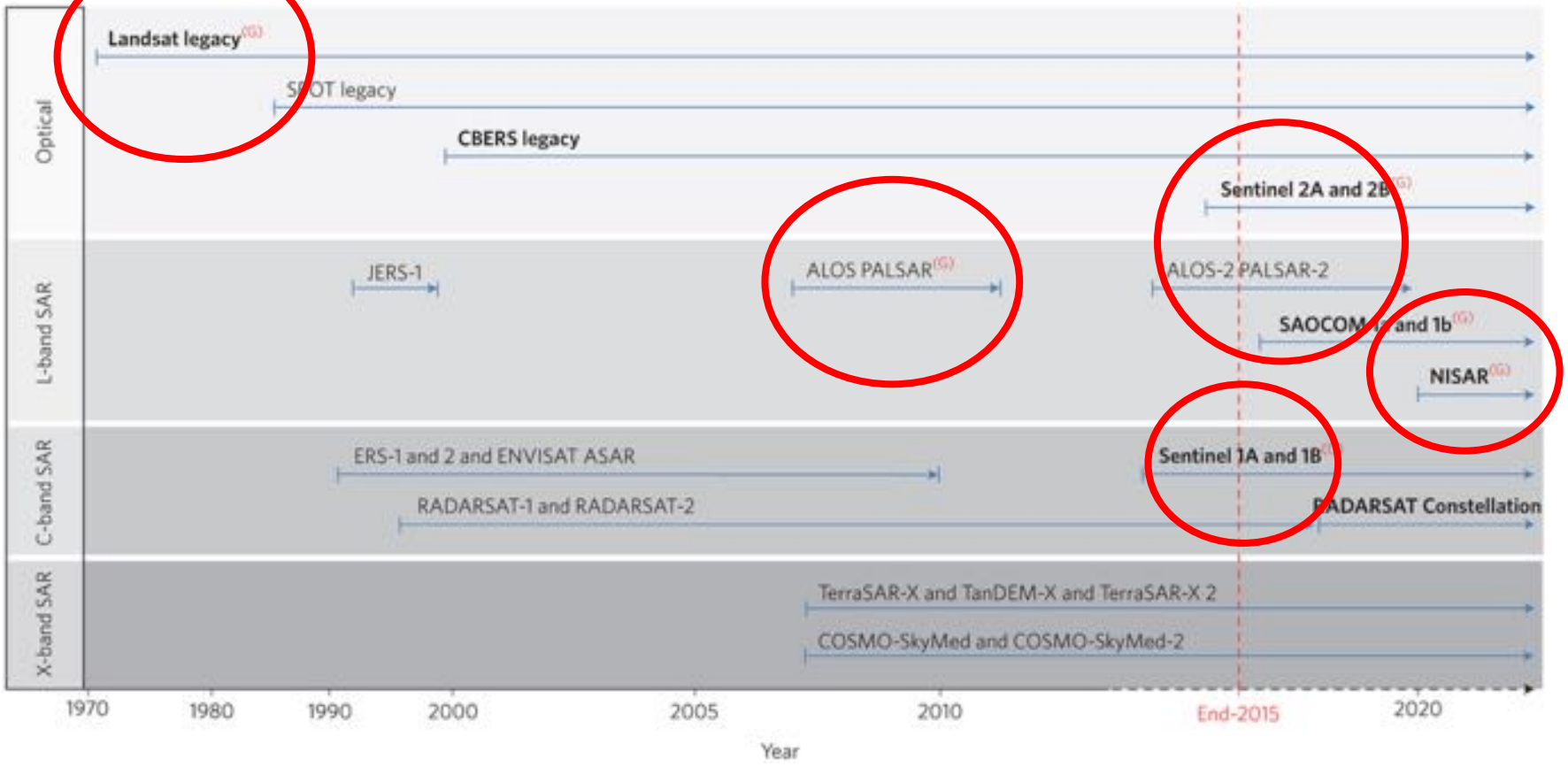
(1) 25

(2) 25.

Do you have sufficient data to complete your research (according to your K&C agreement)?

Yes, with some test site adjustment in location change

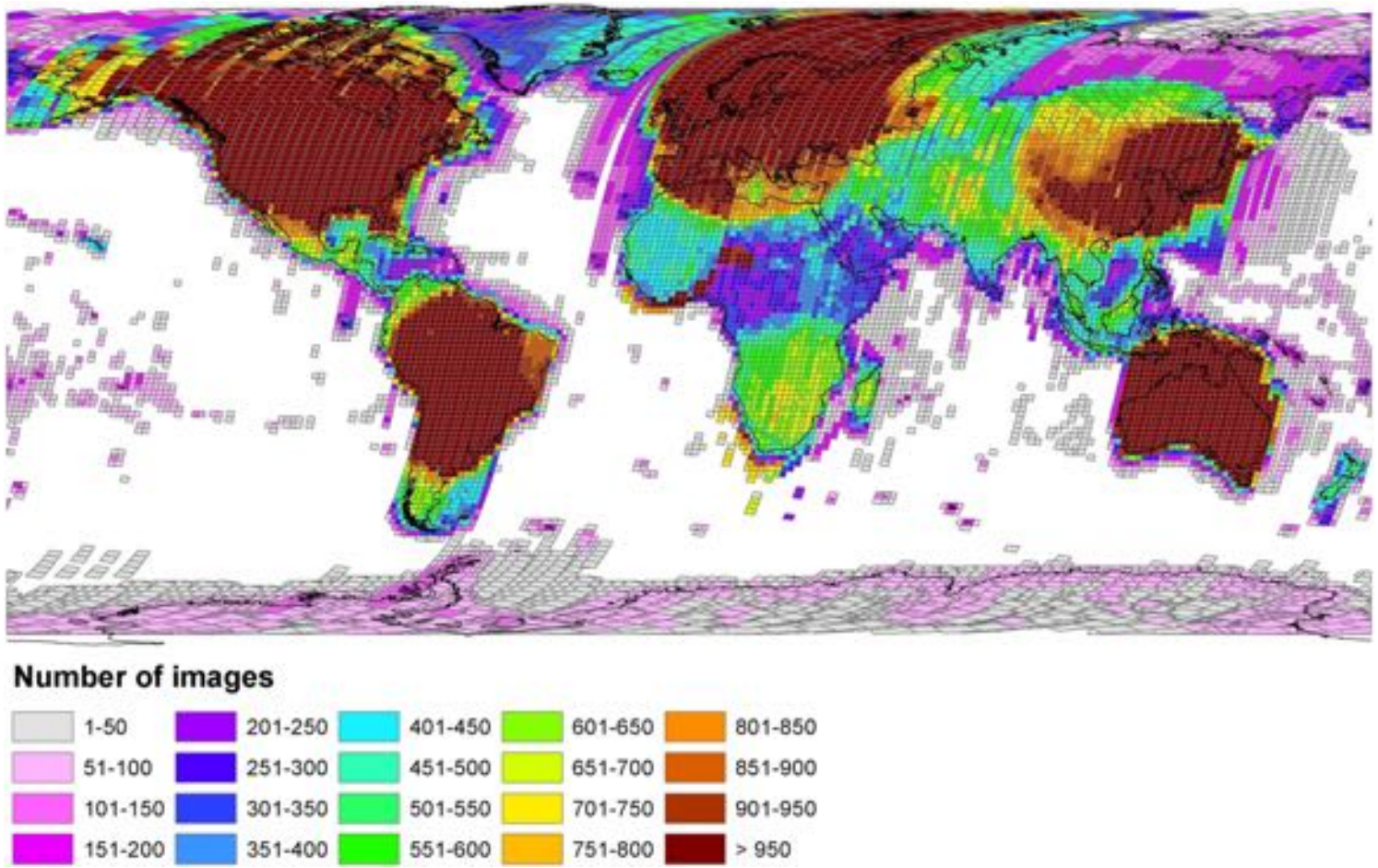
Medium Resolution Record



Reiche, *et al*. 2016. Combining satellite data for better tropical forest monitoring

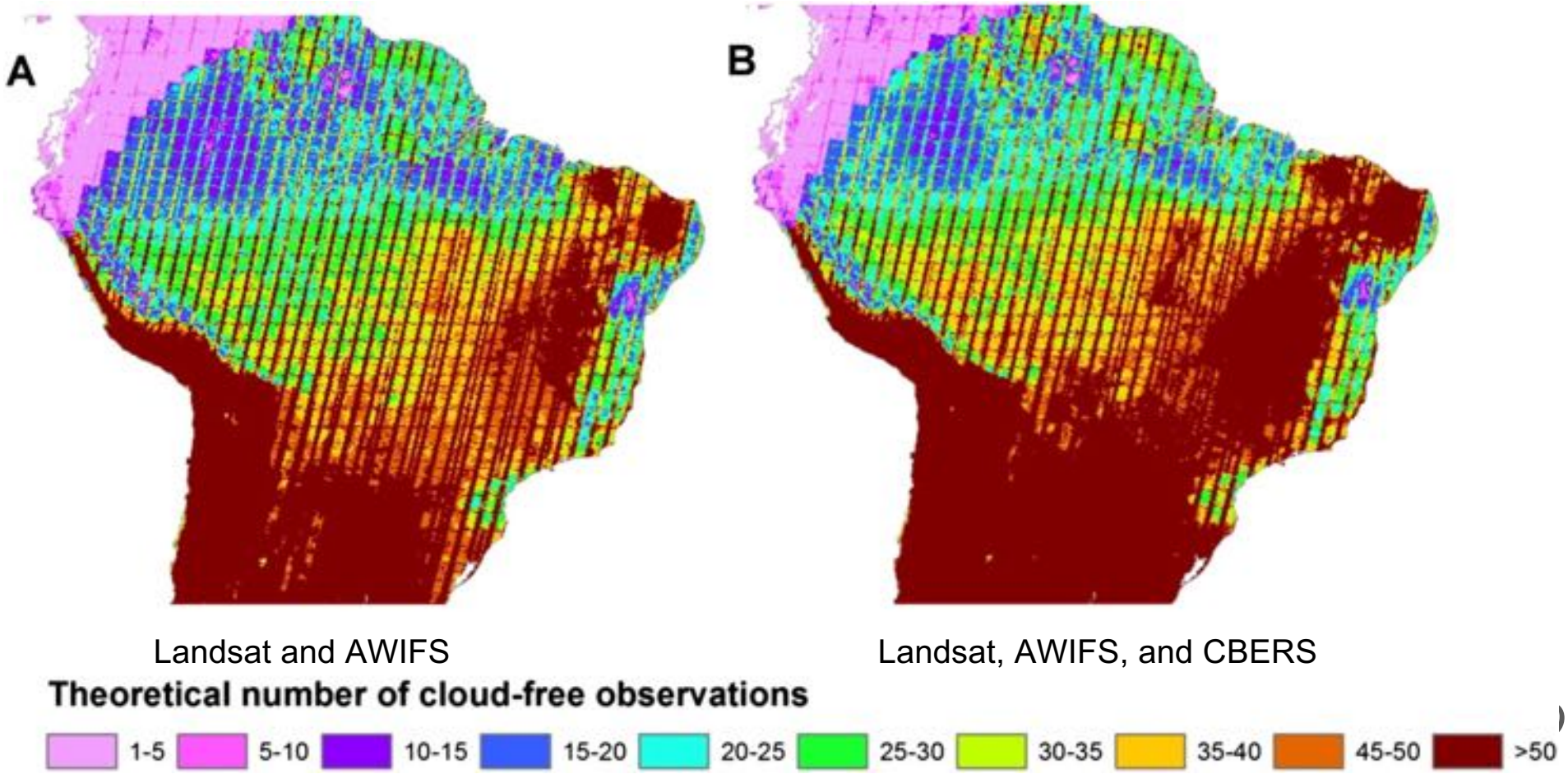
Wulder, *et al*. 2016. The global Landsat archive: Status, consolidation, and direction.

Global Landsat Archive



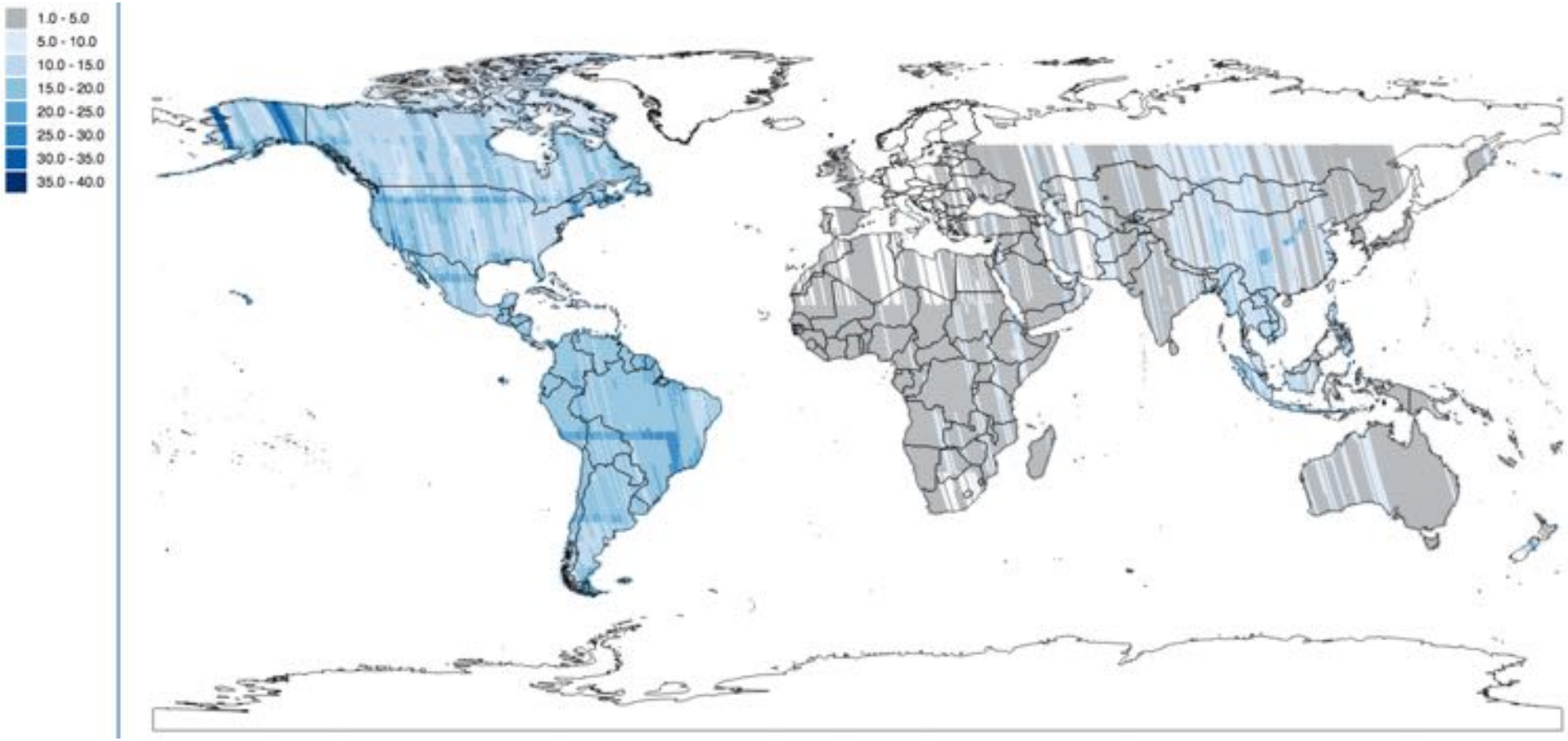
Wulder, *et al*. 2015. Virtual constellations for global terrestrial monitoring

Optical cloud-free observations per year



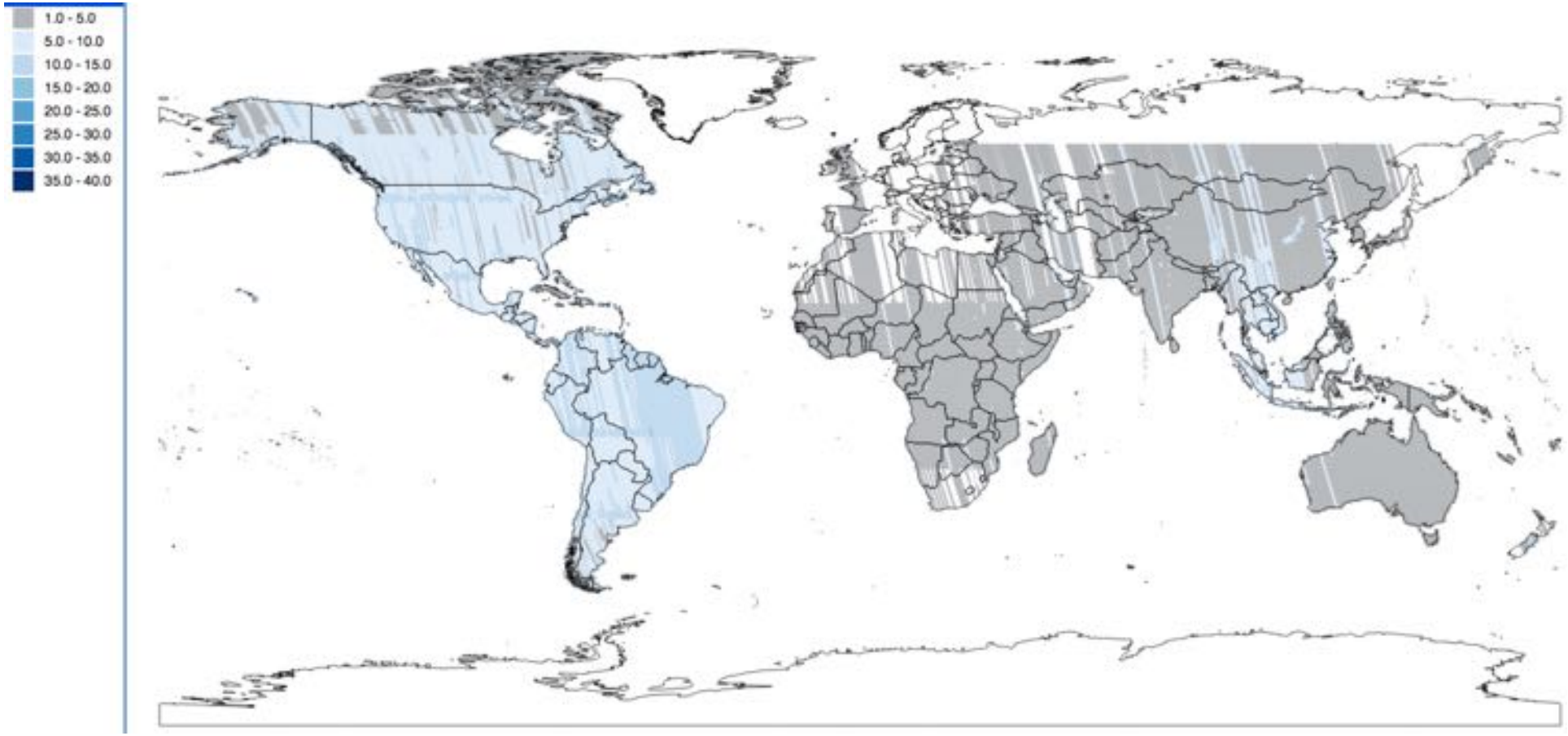
ASF Holdings visualized by Earth Big Data, LLC , Spatial Metadata Database (SMDDB)

- ALOS L-HH (FBD AND FBS) ASCENDING, 34.3 degree Incidence angle.



ASF Holdings visualized by Earth Big Data, LLC , Spatial Metadata Database (SMDDB)

- ALOS L-HV (FBD) ASCENDING, 34.3 degree Incidence angle.



Ecosystem Monitoring with Time Series

Time Steps
0 2006-12-04
1 2007-01-19
2 2007-03-06
3 2007-07-22
4 2007-10-22
5 2008-01-22
6 2008-03-08
7 2008-04-23
8 2008-06-08
9 2008-07-24
10 2008-09-08
11 2008-10-24
12 2009-01-24
13 2009-03-11
14 2009-07-27
15 2009-09-11
16 2009-10-27
17 2010-03-14
18 2010-04-29
19 2010-06-14
20 2010-07-30
21 2010-09-14
22 2010-12-15
23 2011-01-30
24 2011-03-17

L-Band HH Backscatter

Cerrado Area, Brazil
ALOS PALSAR DATA from
2006 to 2011

Abrupt drop in Backscatter

Gradual drop in Backscatter

Periodic patterns from seasonal flooding

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Ecosystem Monitoring with Time Series

Time Steps
0 2006-12-04
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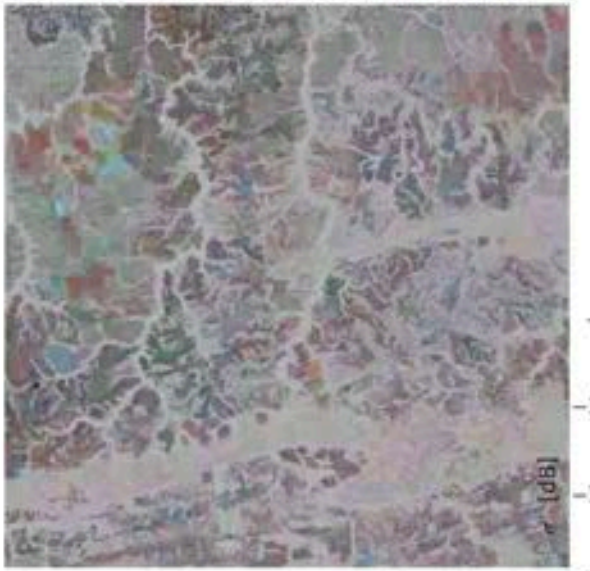
13 2009-03-11
14 2009-07-27
15 2009-09-11
16 2009-10-27
17 2010-03-14
18 2010-04-29
19 2010-06-14
20 2010-07-30
21 2010-09-14
22 2010-12-15
23 2011-01-30
24 2011-03-17

L-Band HH Backscatter

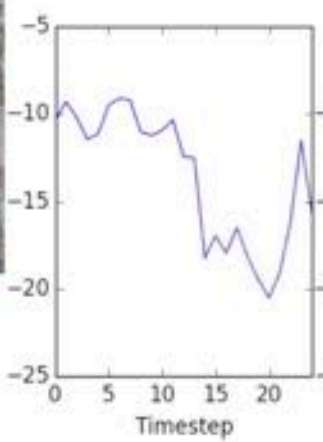
R=2006-12-04 G=2011-03-17 B=2011-03-17

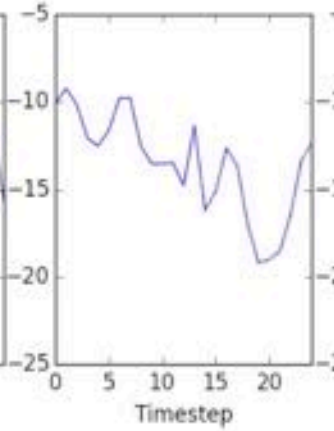


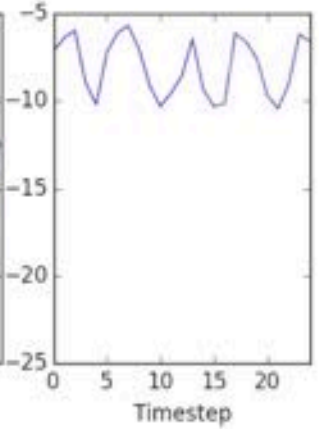
Deforestation

Degradation

Riparian Forest







Cerrado Area, Brazil
ALOS PALSAR DATA from
2006 to 2011

Abrupt drop in Backscatter

Gradual drop in Backscatter

Periodic patterns from seasonal flooding

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Fusion: “Residual Monitoring”

Create predictive model explaining time series observations and monitor for change in characteristic of forecast residuals

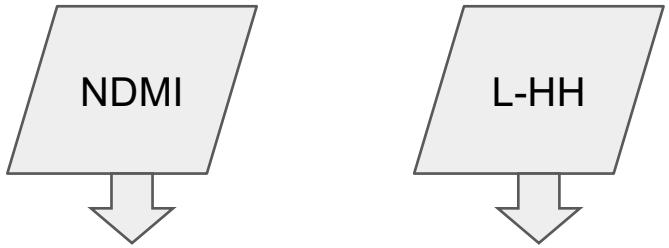
Lineage:

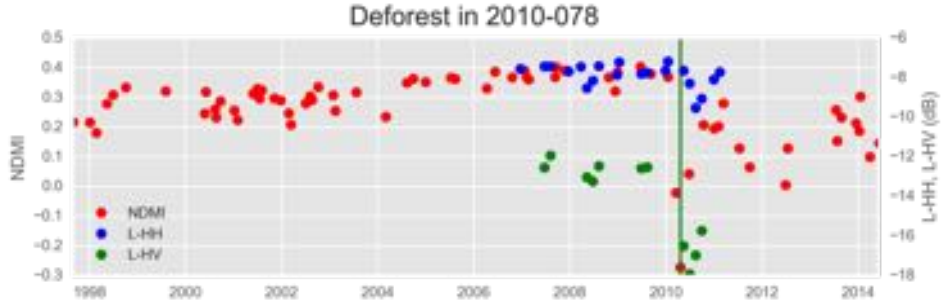
- Verbesselt *et al*., 2014: “BFAST Monitor”
  - Recursive MOSUM
- Brooks *et al*., 2014: “On-the-Fly Massively Multitemporal Change Detection”
  - Exponentially Weighted Moving Average (EWMA)
- Zhu and Woodcock, 2014: Continuous Change Detection and Classification
  - Scaled residuals heuristics

Fit different models based on characteristics of each data source

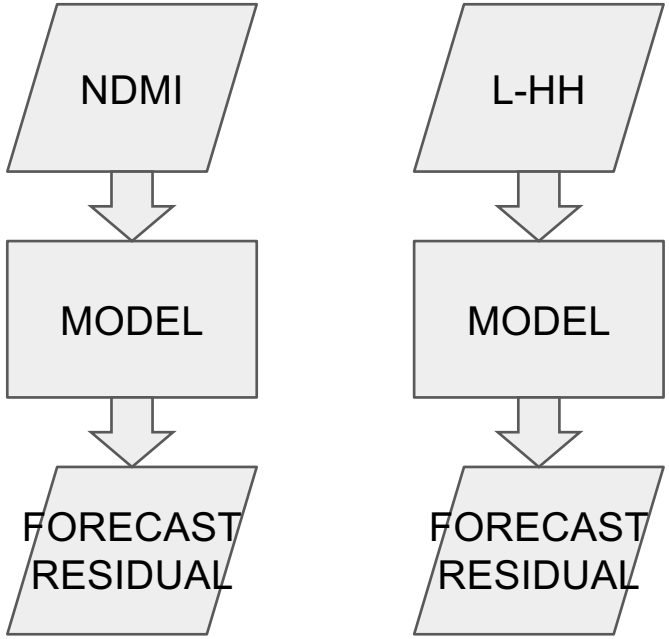
- Landsat: $y \sim 1 + \text{time} + \text{harmonic}$
- Radar: $y \sim 1 + \text{time}$

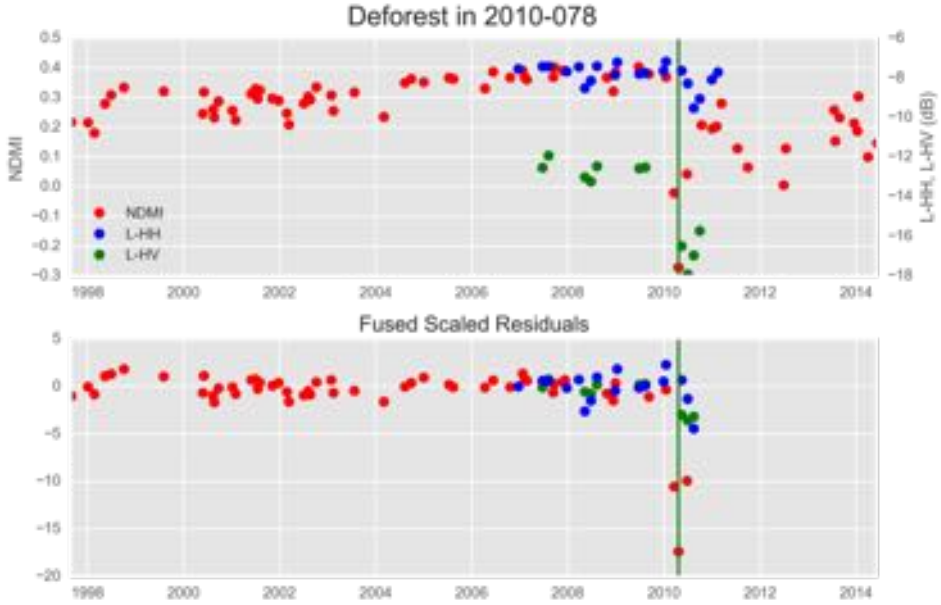
Fusion: “Residual Monitoring”



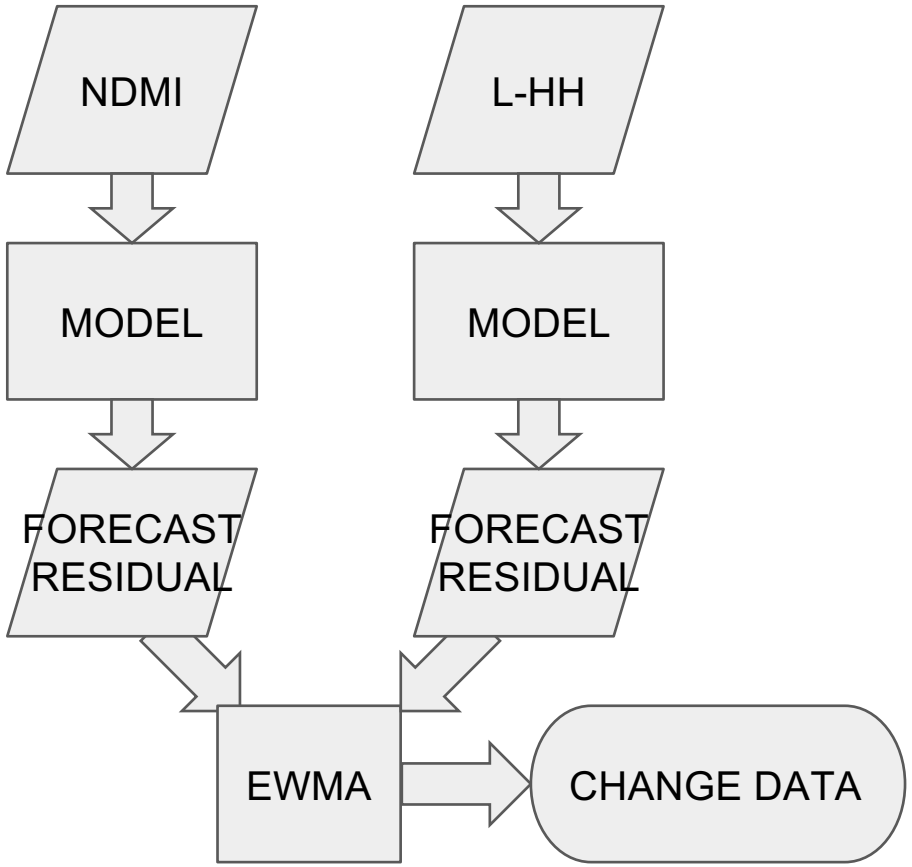


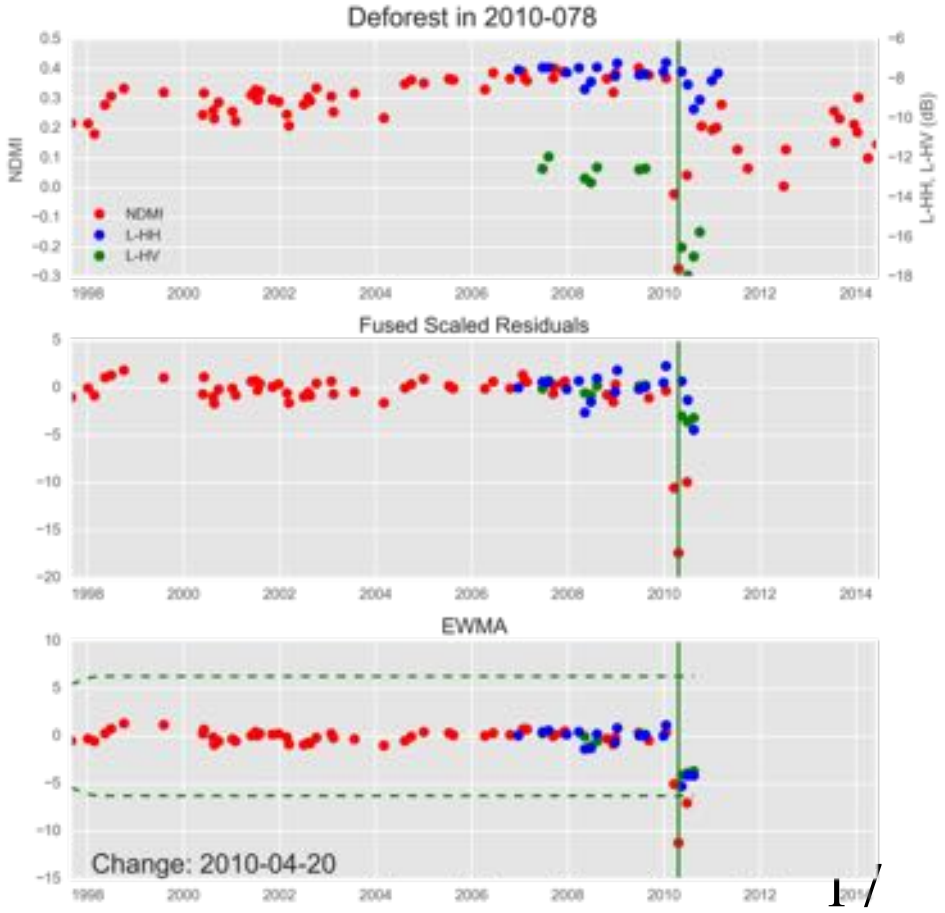
Fusion: “Residual Monitoring”





Fusion: “Residual Monitoring”





Fusion: “Probability Monitoring”

Create classification model predicting “forest likelihood” and monitor for change in characteristic of probabilities

Lineage:

Huang, *et al*. 2010: Vegetation Continuous Tracker

Monitor forest z-scores

Solberg and Huseby, 2008: MODIS and ENVISAT ASAR for snow state monitoring

Hidden Markov Model

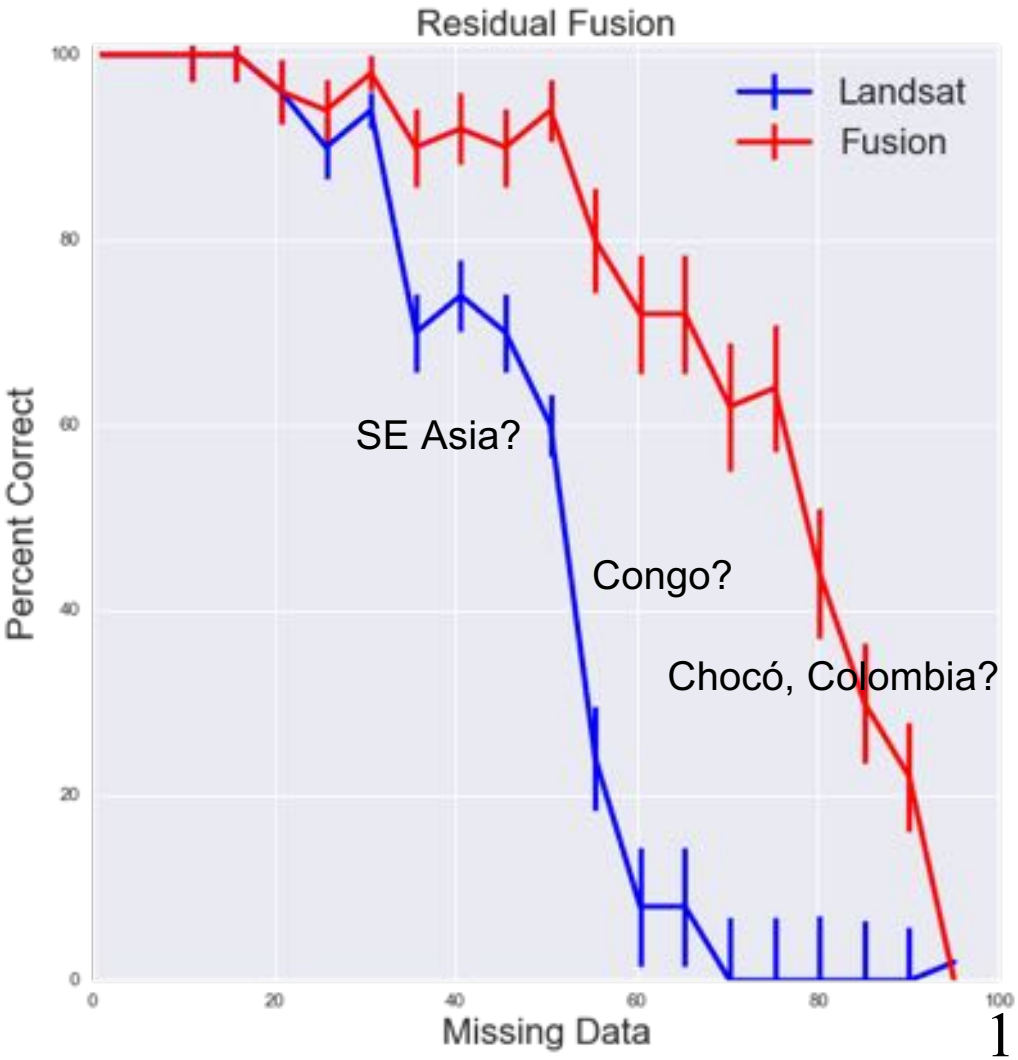
Reiche, *et al.* 2015: “A Bayesian Approach…”

Gather training data and estimate classification models for each data source

Does it matter?

Simulated other observing conditions

1. Randomly choose some percentage of Landsat data to throw out
2. Run algorithm on reduced Landsat time series with and without ALOS observations
3. Compare number of instances in each simulation that we found change correctly



EARTH BIG DATA
Where Solutions Begin.

Study Site Louisiana: Timber Management

ALOS PALSAR
Path 170 Row 610

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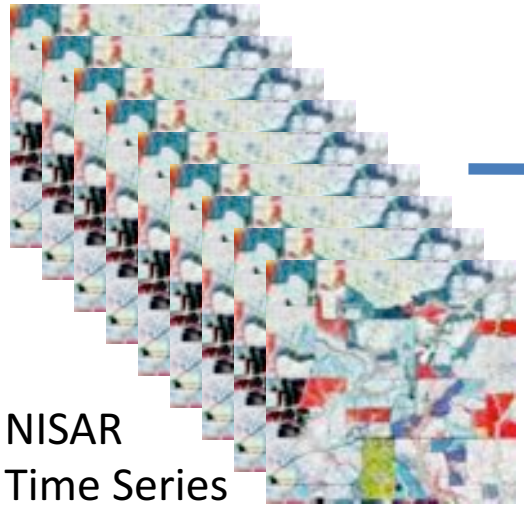
Study Site

- This area in Louisiana is home to intensive timer management with frequent logging and replanting operations.
- ALOS PALSAR data were acquired from 2006 to 2011
  - L-HH: 22 Observations
  - L-HV: 11 Observations

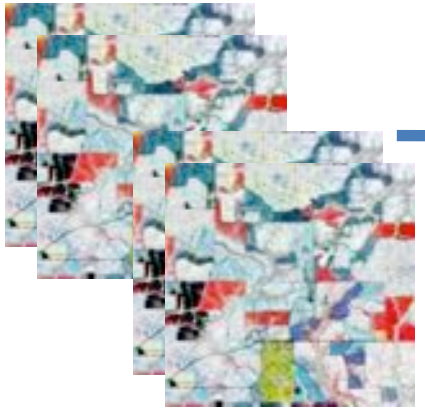
Disturbance Theoretical Basis: Classifier based on detected Change Points



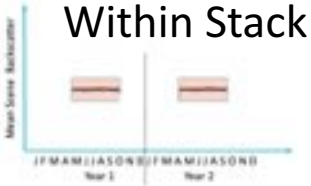
NISAR Time Series

Subsetting by Seasonality

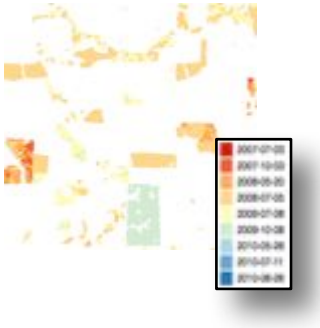
Unfrozen (e.g. Boreal Biome)



Relative Calibration Within Stack

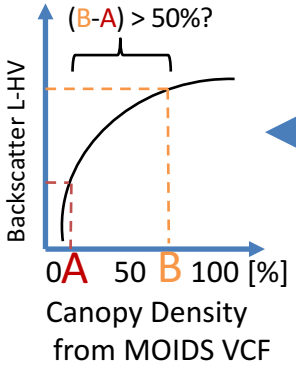


Change Point Analysis



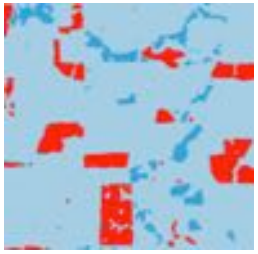
Mean After Change Point

Mean Before Change Point



Canopy Density from MOIDS VCF

Disturbance Mapped



Disturbance
Regrowth

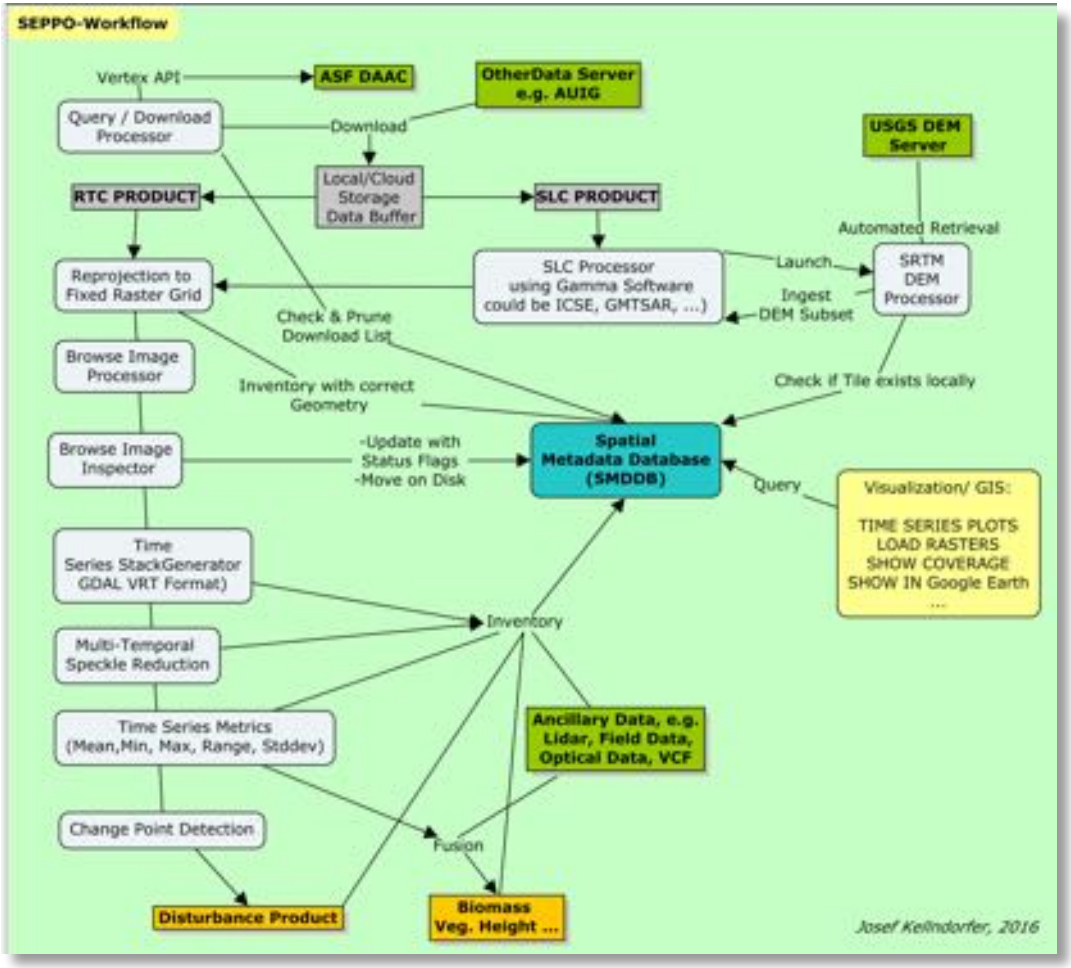
Example from ALOS Path/Row 170/610)

Process Automation

SEPPO

Software for
Earth Big Data
Processing,
Prediction Modeling,
and
Organization

Works well in cloud deployment



EARTH BIG DATA

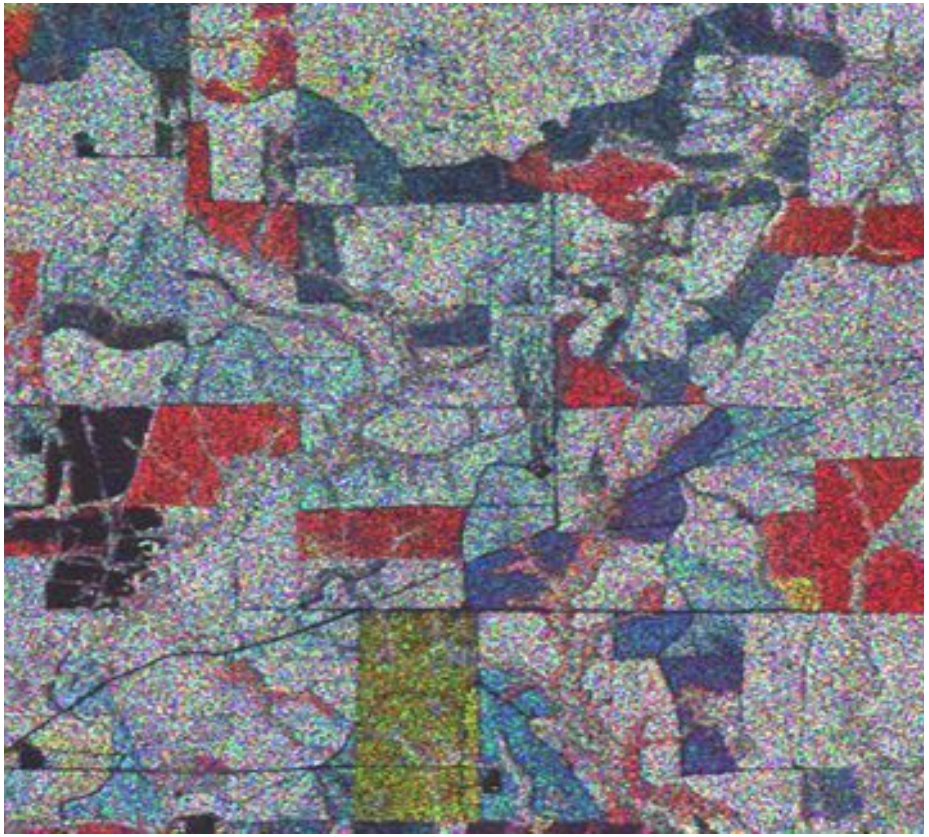
What is **SEPPO**?

- Software package for automation of large volume SAR, optical, and lidar data processing, largely based in Open Source components
- Automation of retrieval, pre-processing, and value-added processing
- Integrated with a spatial metadata database (Postgres/PostGIS) for management of all processing steps
- Unix/python3 API (bash, python, R, …)
- Commandline, scriptable modules
- Cloud deployable (Amazon Web Services)
- Documentation processor with Spinx
- Version control and collaboration via github.com

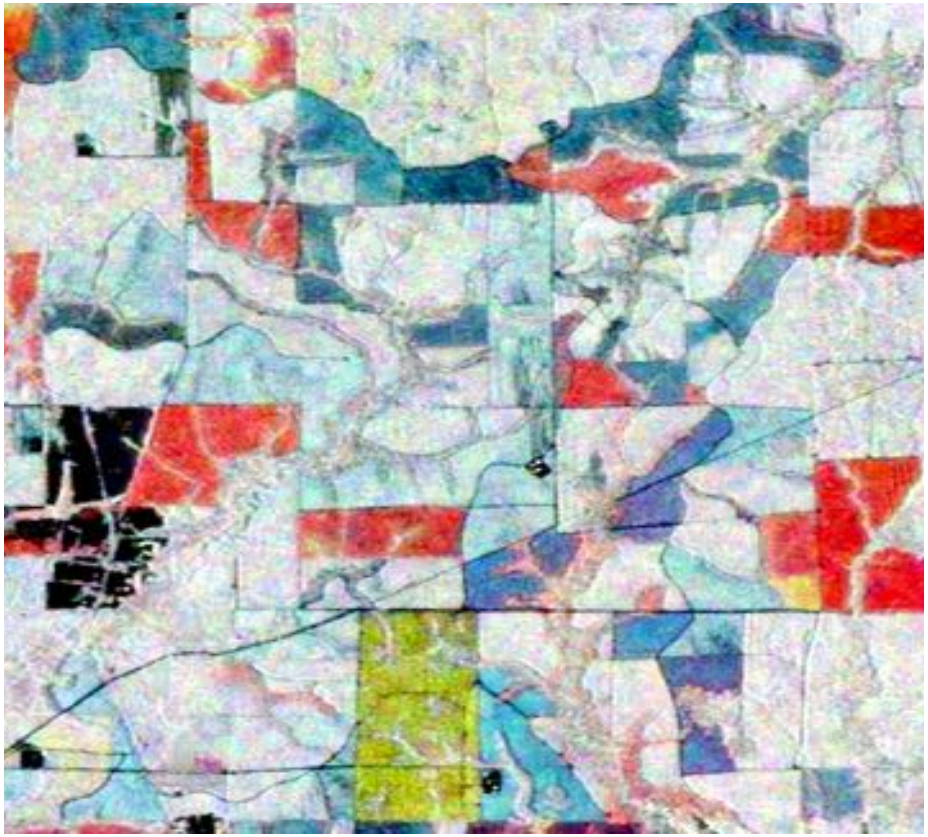
EARTH BIG DATA
Where Solutions Begin.

Signal Enhancement: Multi-temporal Speckle Noise Filter

Before Filter Application



After Filter Application



L-HV RGB: 2007-07-03 2009-07-08 2010-07-11

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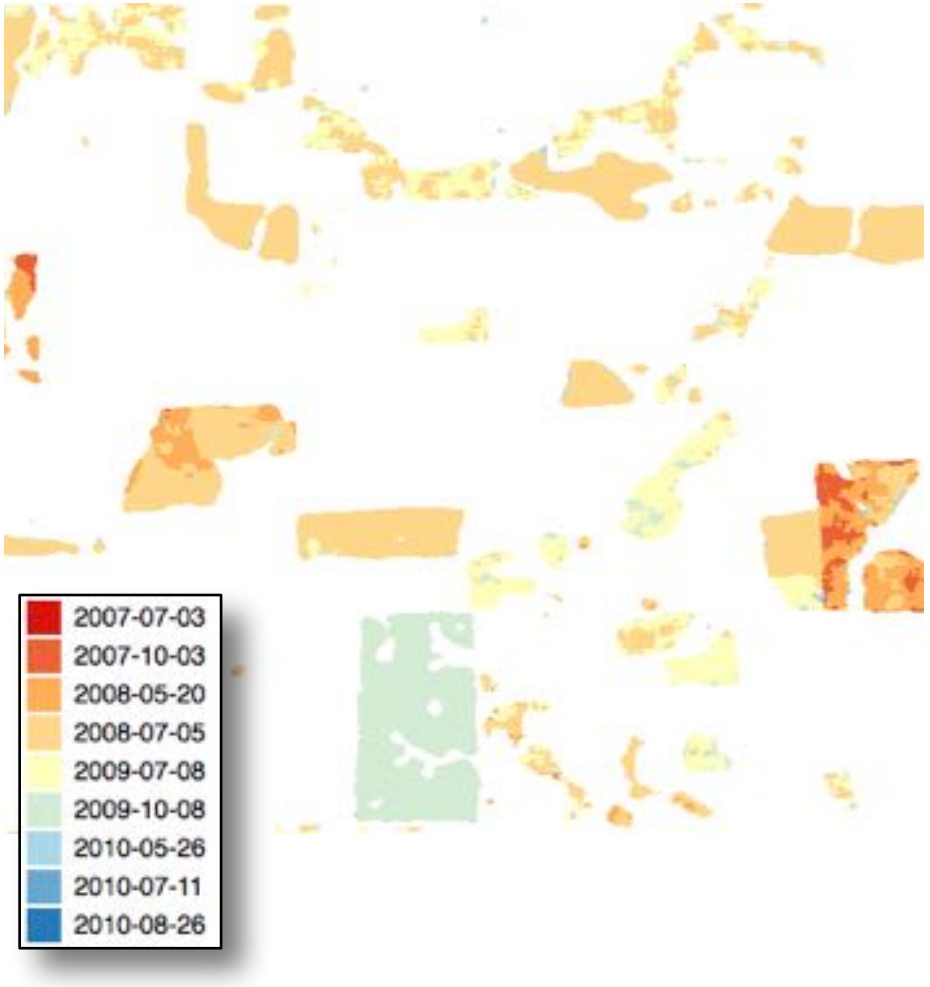
Where Solutions Begin.

Change Point Algorithm Result

CUMSUM SDIFF Image

Detected Change Points
(Change occurs <u>after</u> the labeled point)



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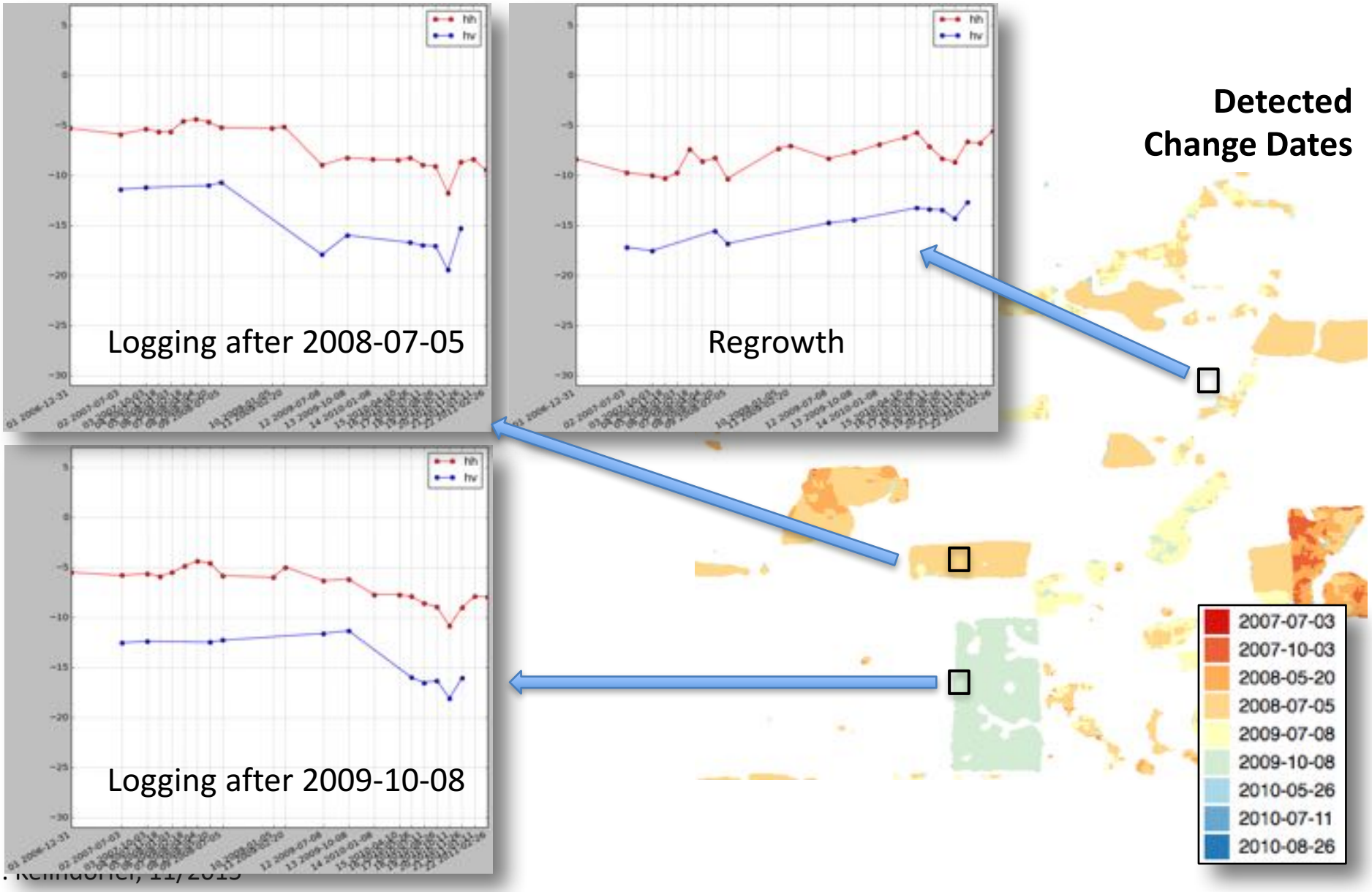
Time Series Example



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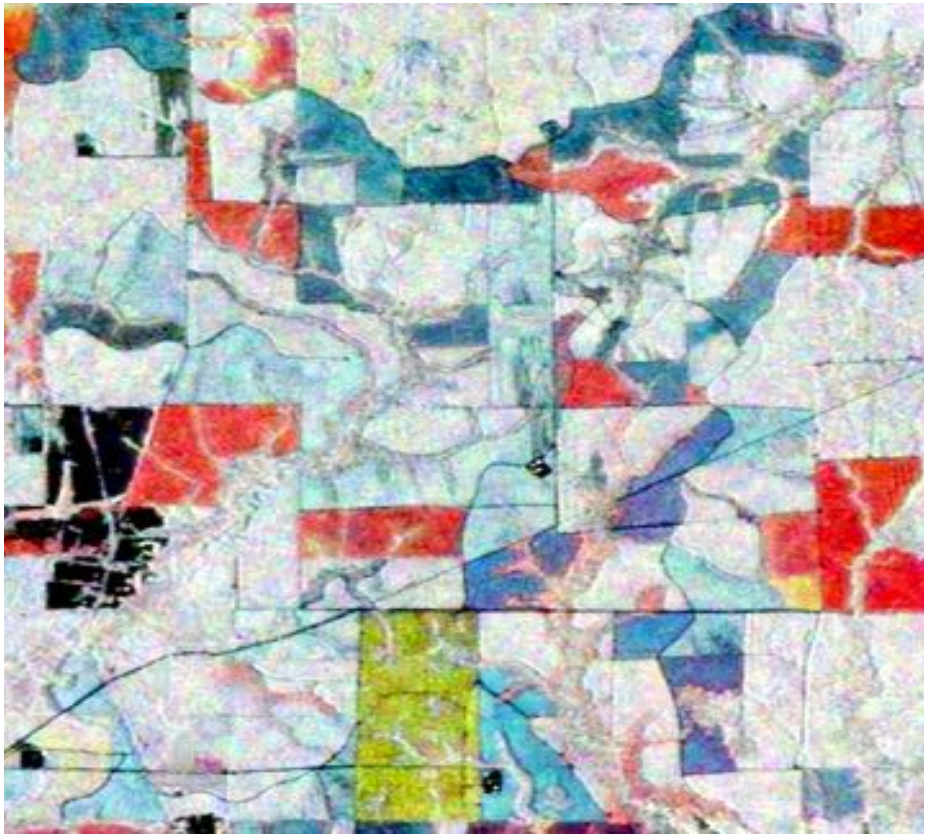
Classifier Result

L-HV RGB: 2007-07-03 2009-07-08 2010-07-11



Change Classes

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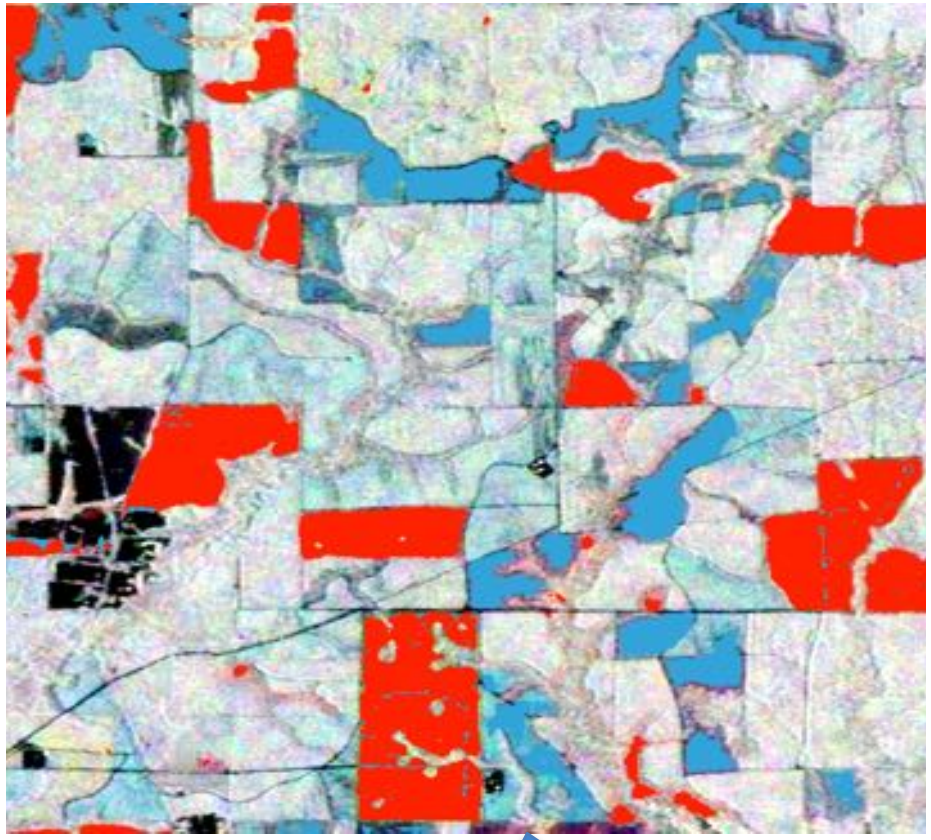
Classifier Result

L-HV RGB: 2007-07-03 2009-07-08 2010-07-11



Change Classes

Overlayed on Image

Deforestation
Regrowth

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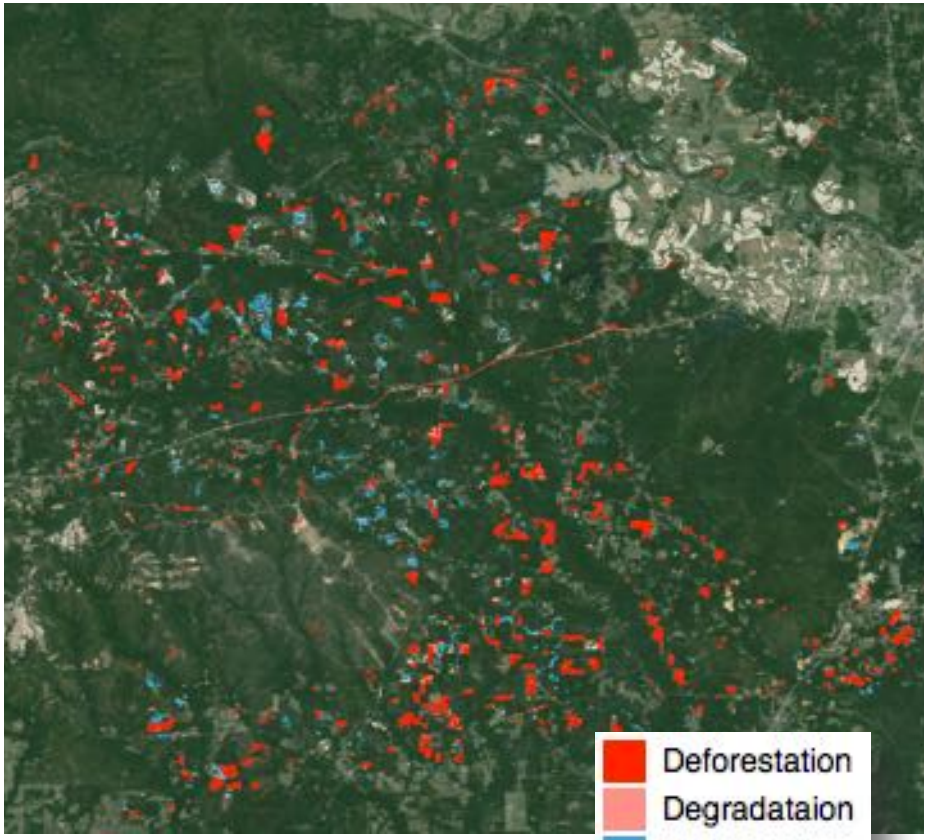
Change Point Classification for Full Image Stack

L-HV RGB: 2007-07-03 2009-07-08 2010-07-11

Classification Result



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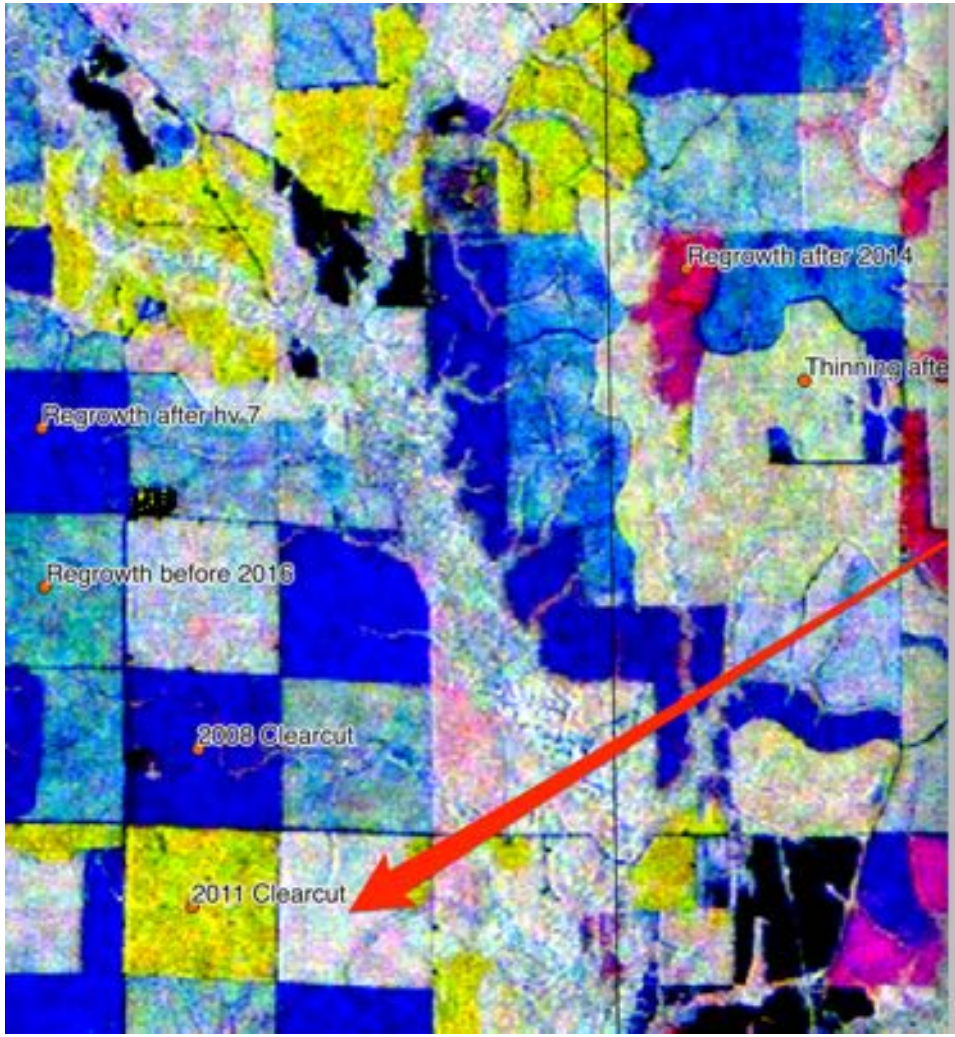
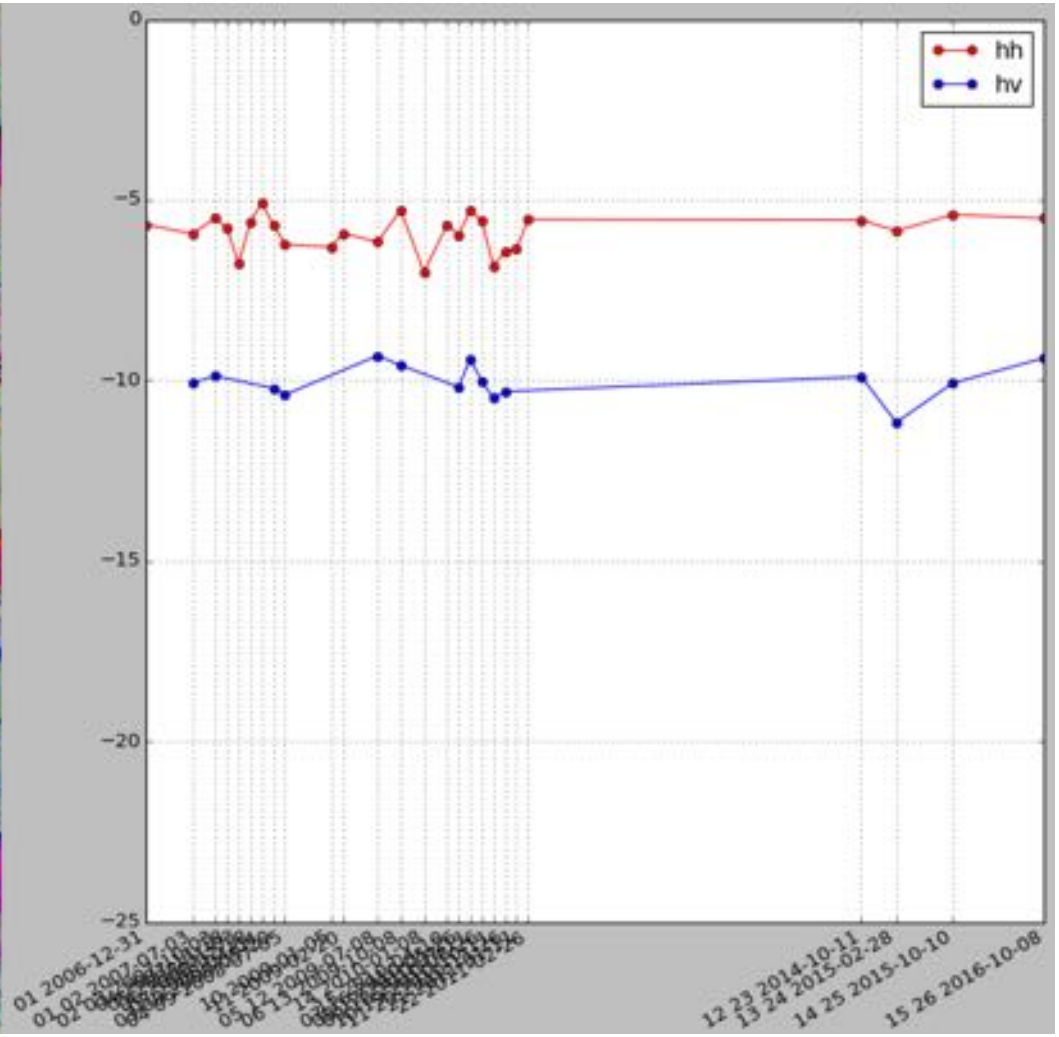
ALOS/ALOS2 Time Series: Stable Forest





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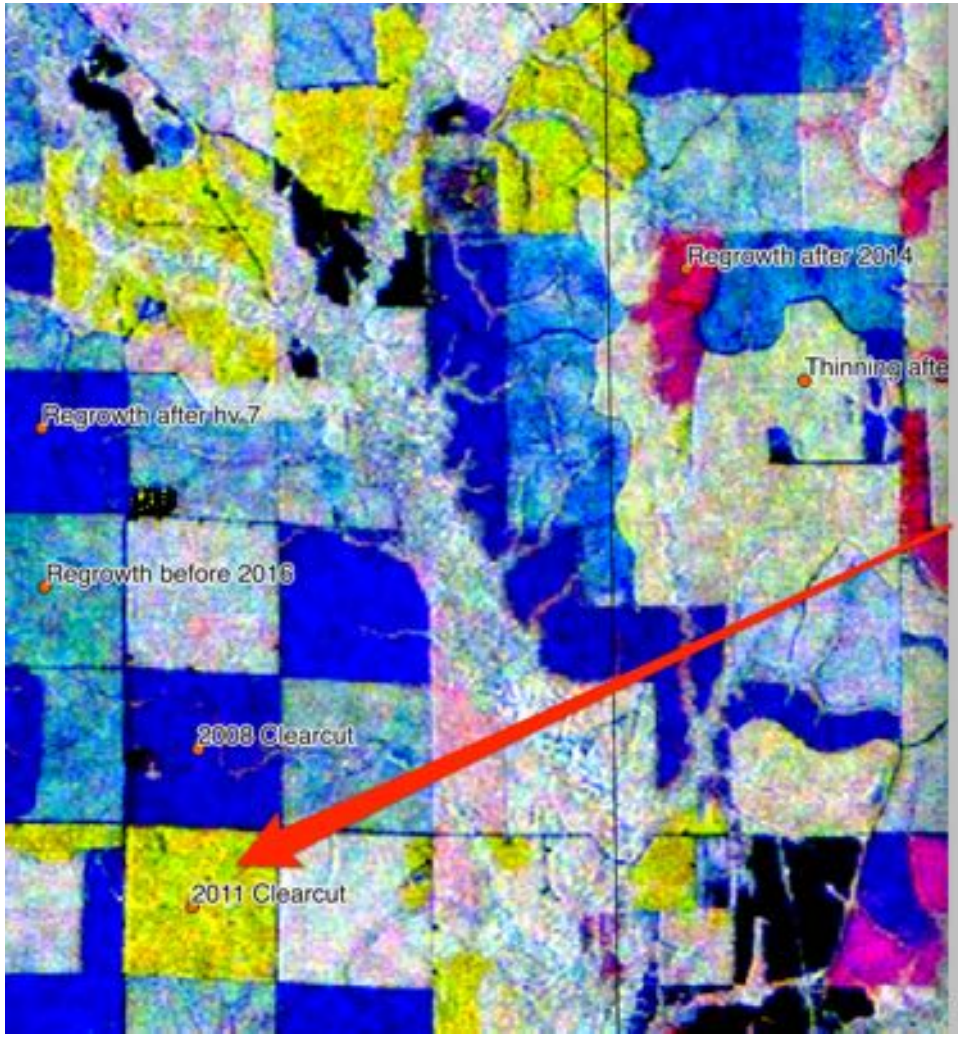
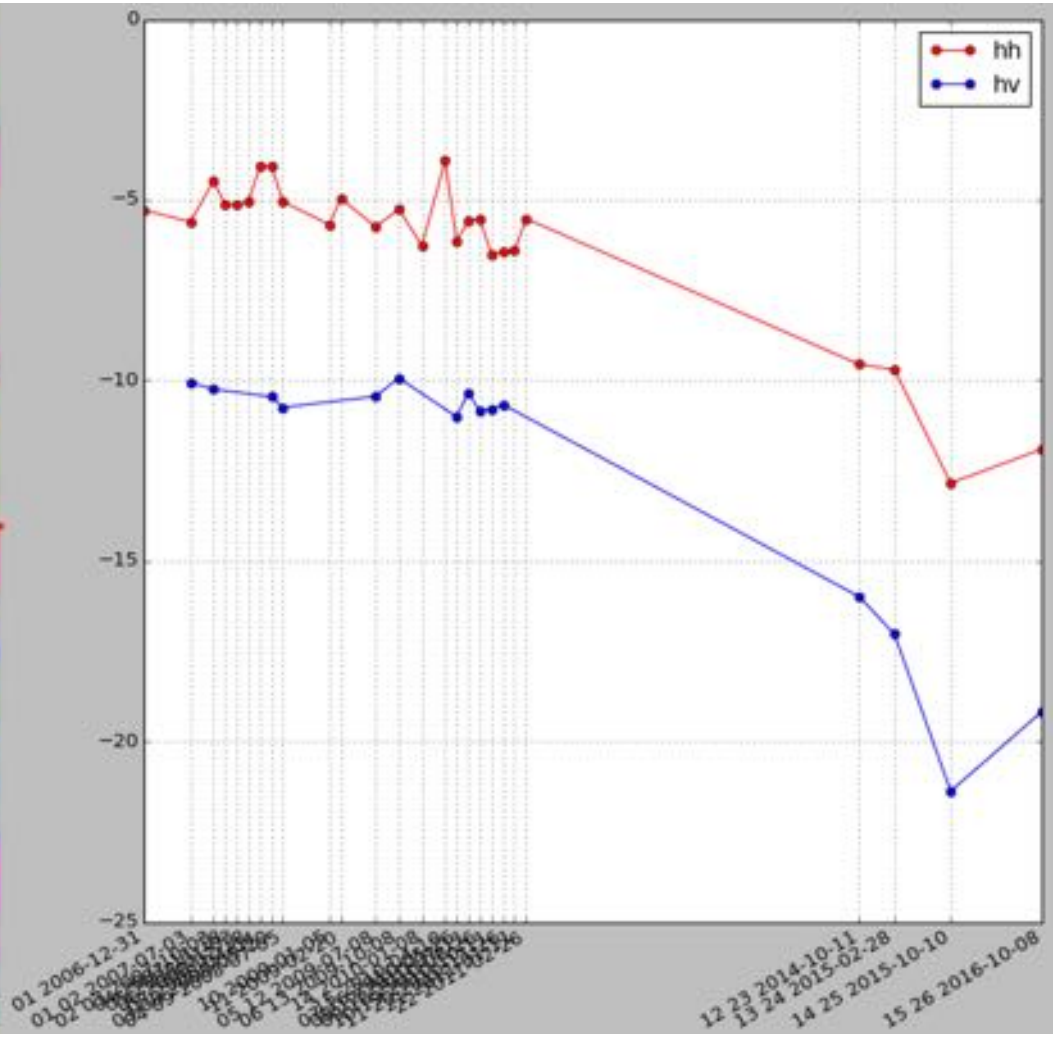
ALOS/ALOS2 Time Series: Deforestation seen in ALOS-2





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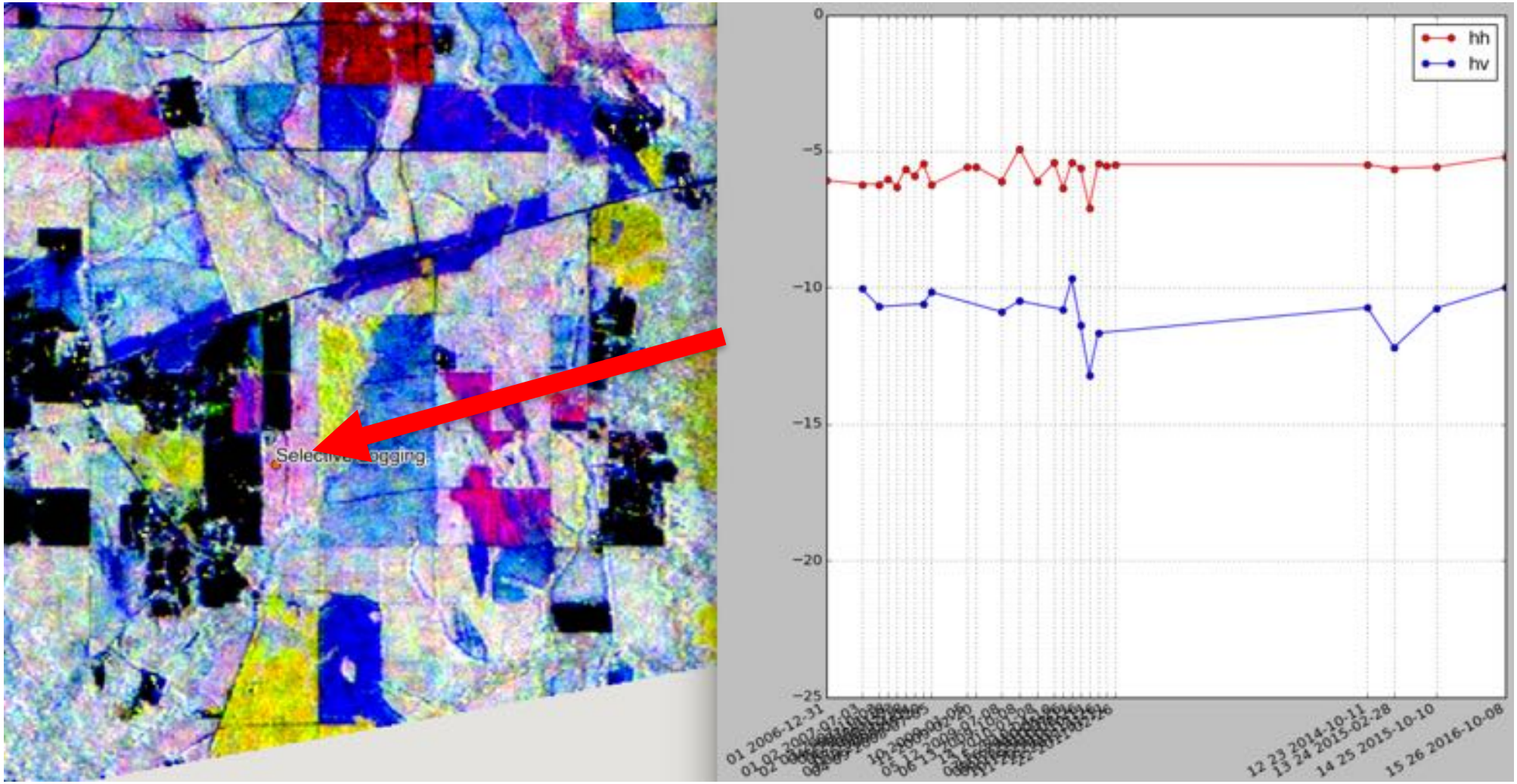
ALOS/ALOS2 Time Series: Selective Logging seen in ALOS-1



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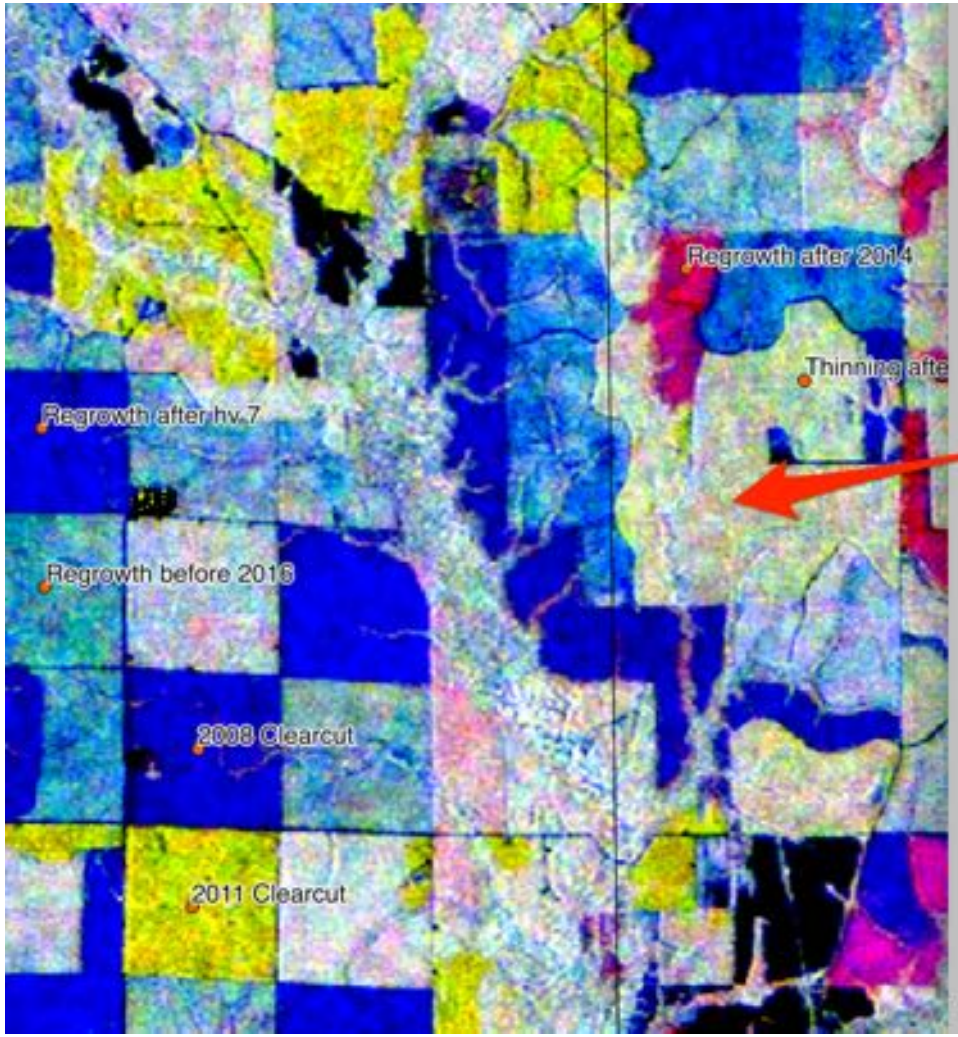
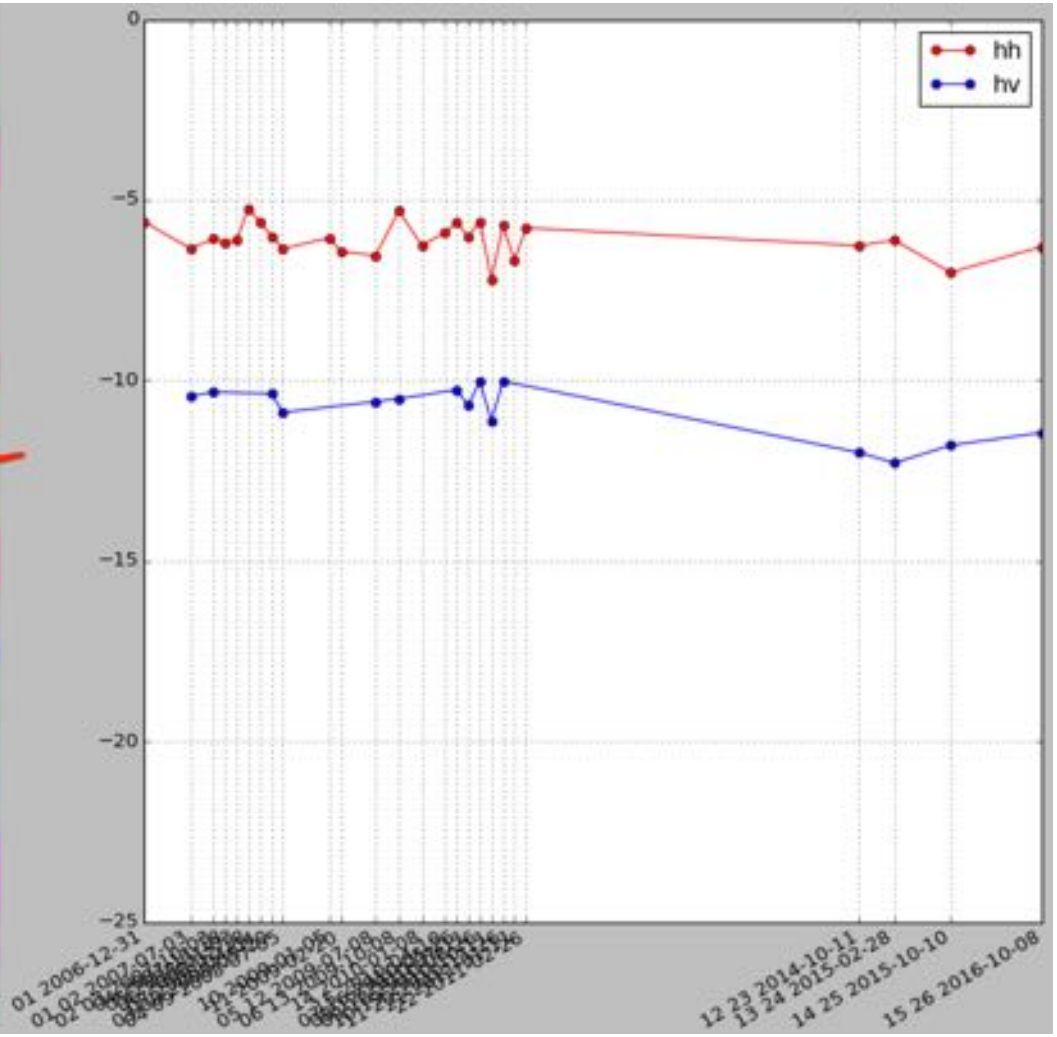
Where Solutions Begin.

ALOS/ALOS2 Time Series: Selective Logging seen in ALOS-2





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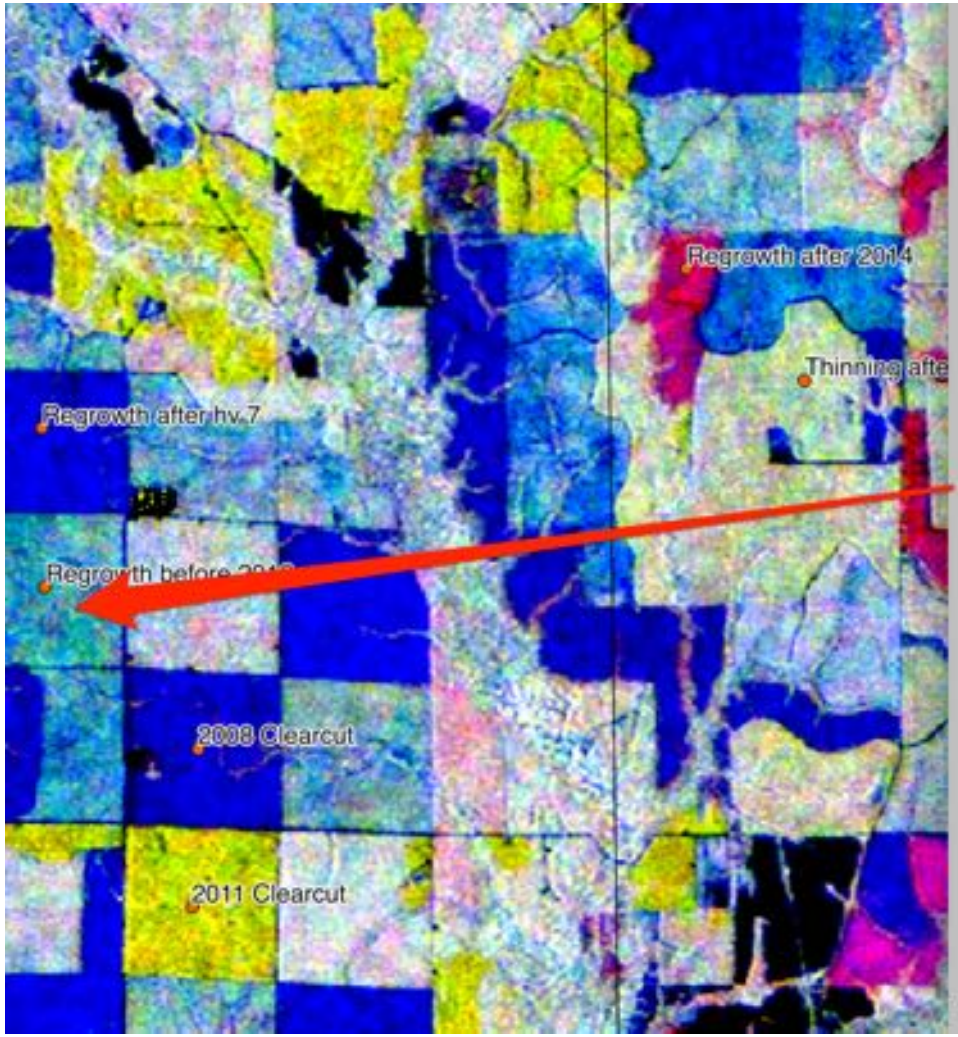
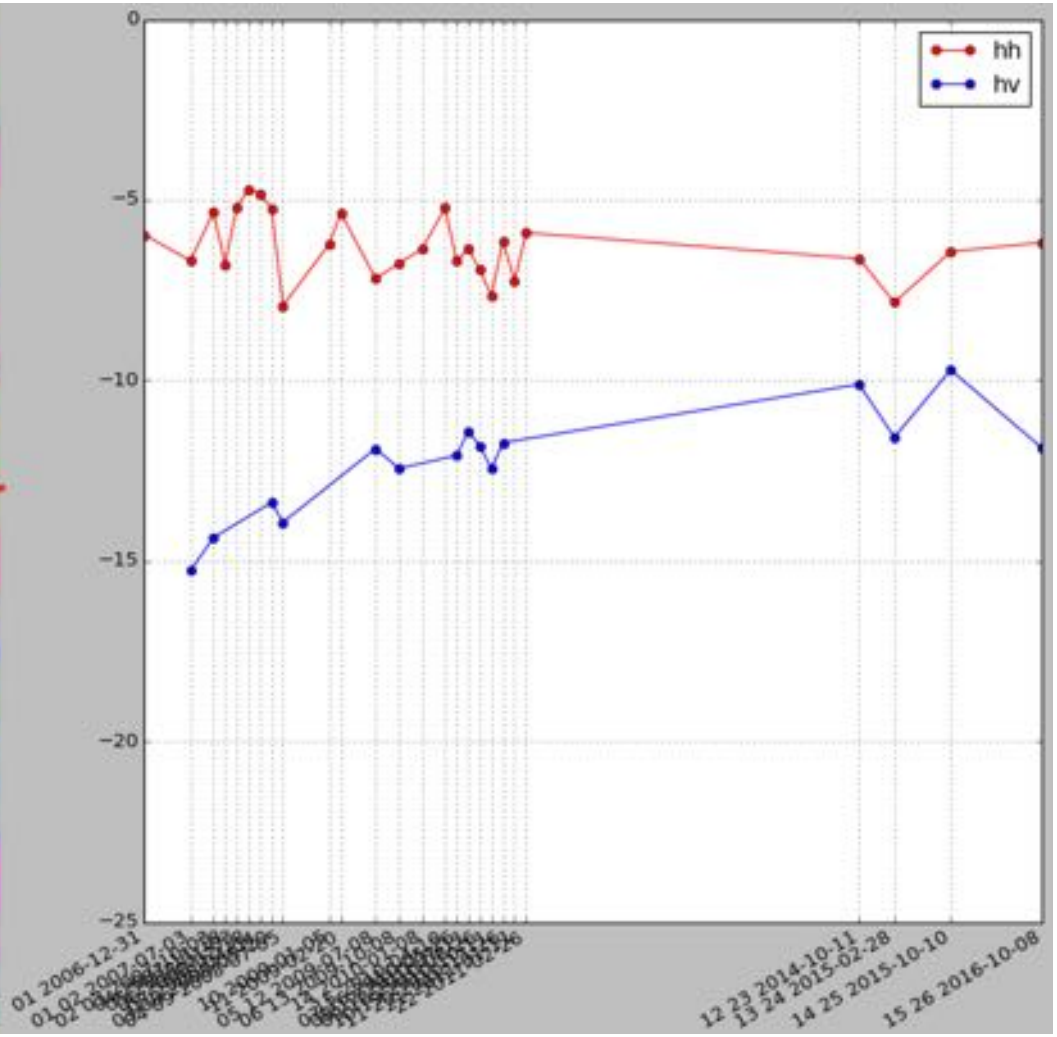
ALOS/ALOS2 Time Series: Regrowth seen in ALOS-1 - Sel. Logging in ALOS-2?





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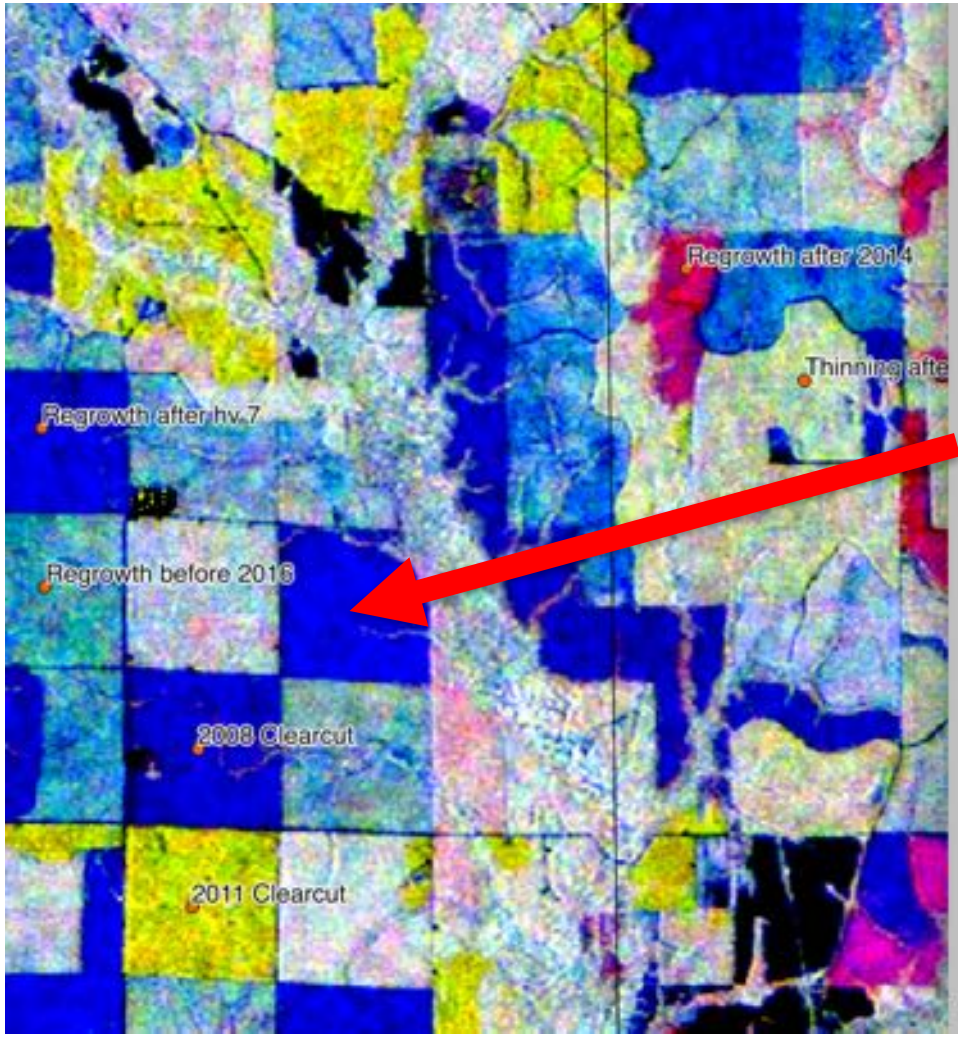
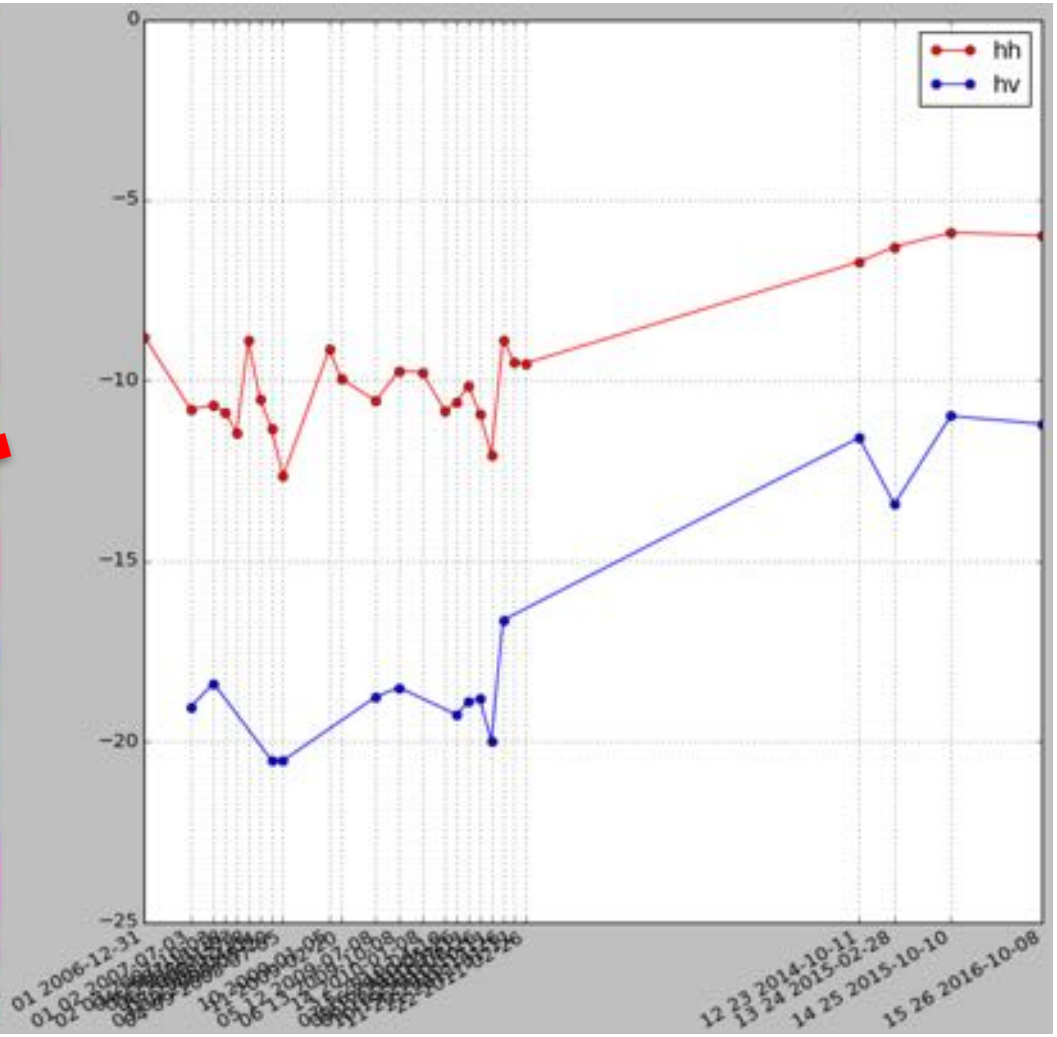
EARTH BIG DATA
Where Solutions Begin.

ALOS/ALOS2 Time Series: Late Regrowth





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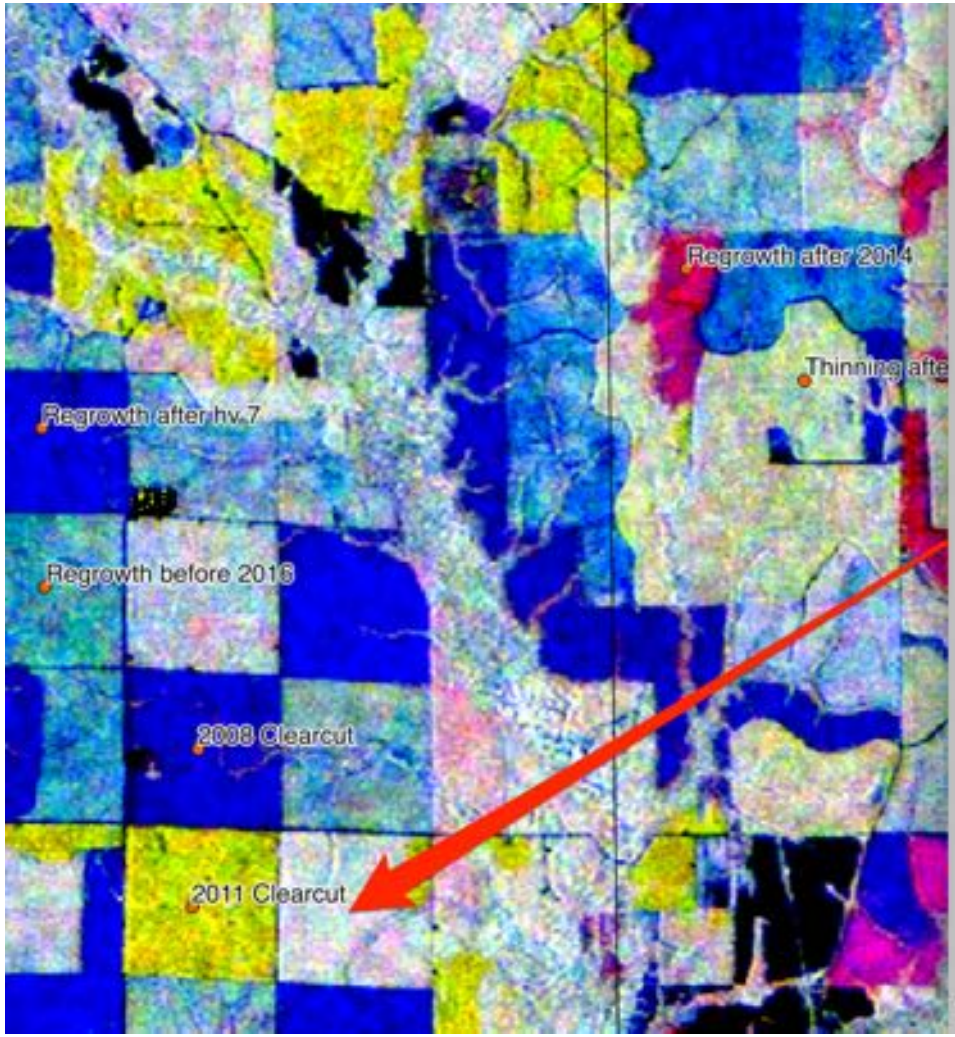
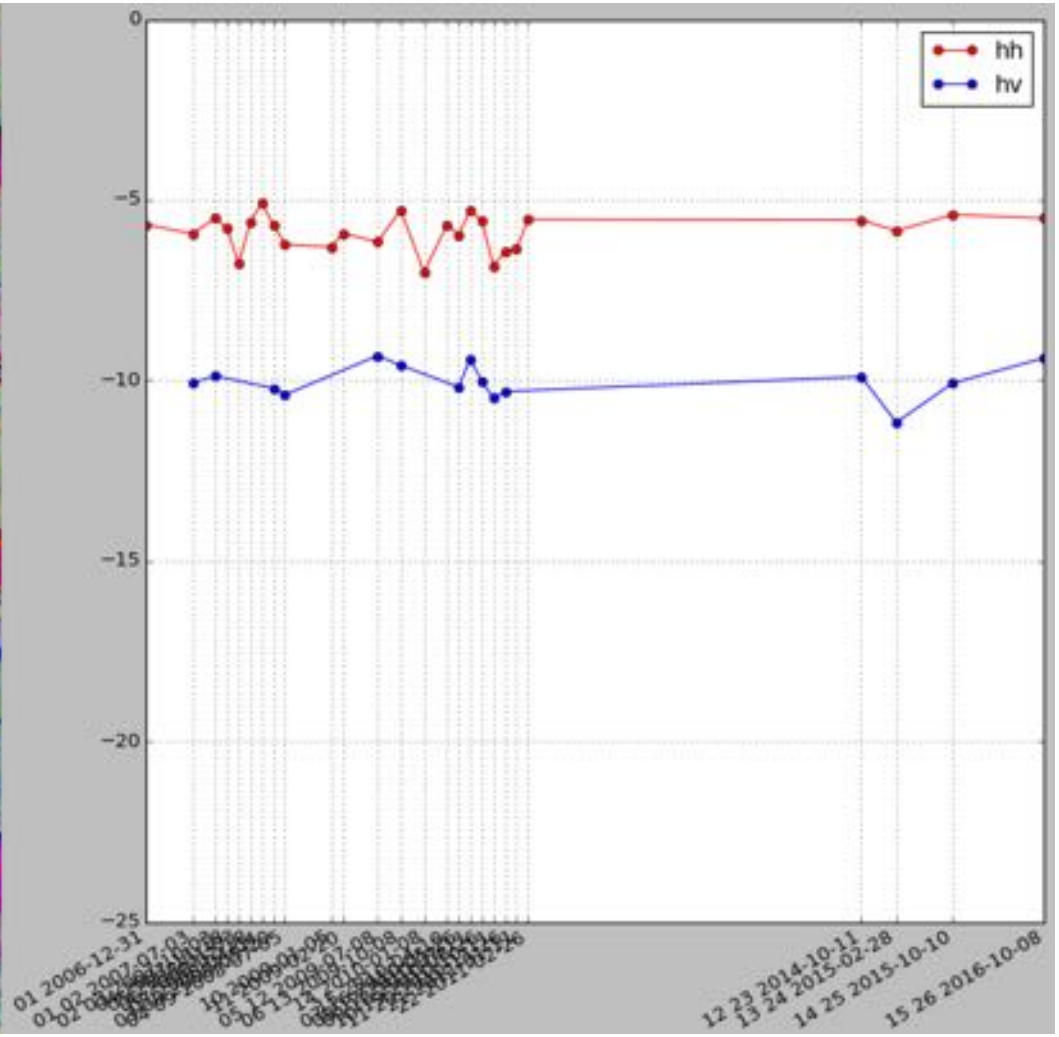
ALOS/ALOS2 Time Series: Stable Forest





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Conclusions

- Timeseries! Timeseries! Timeseries!
- Recommendation:
  - Increase Fine-beam time series with observations strategy
  - Increase data volume for studies
- Next Steps:
  - Focus on C-Band Data from Sentinel-1 as we get the dense timeseries observations to allow for time series based algorthims
  - Will analyze 1000nds of scenes in test sites with large study areas to compare with results from optical data in a meaningful way.
  - Asseess ScanSAR mosaics for time series analysis steps

Thank you.

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