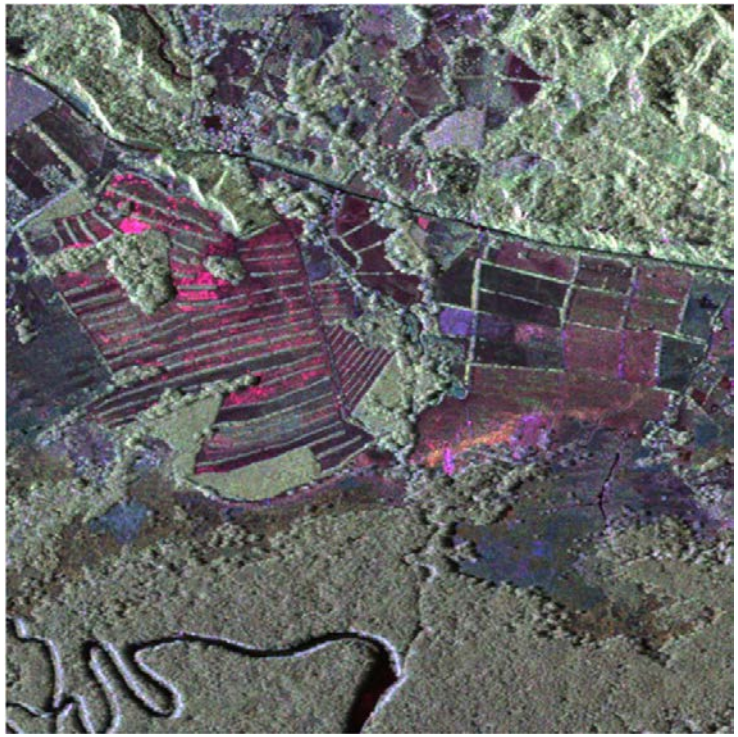
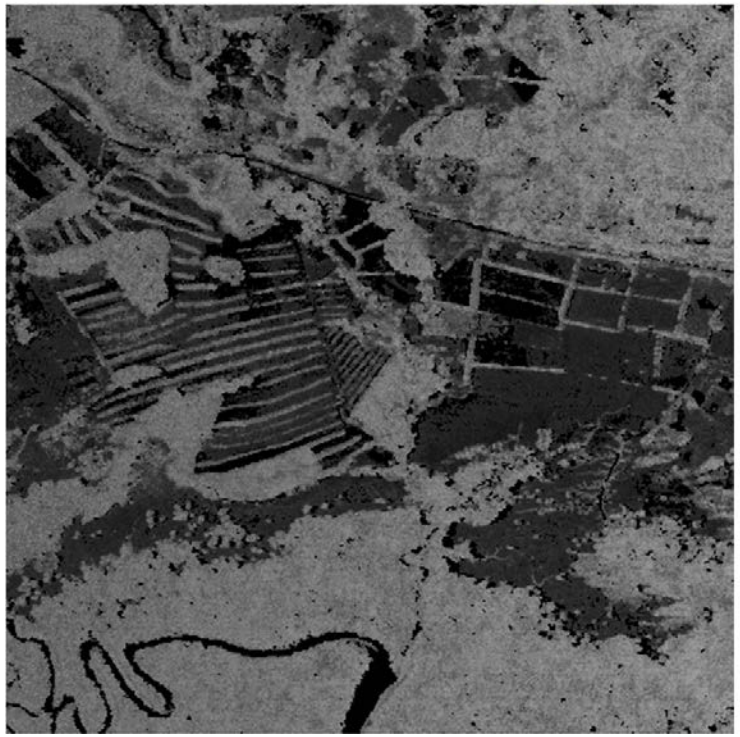
Polarimetric-Interferometric Studies at La Amistad International Park





by

Scott Hensley, Maxim Neumann, Thierry Michel, Marco Lavalle,
Bruce Chapman, Ron Muellerschoen, and Razi Ahmed

January 29, 2013

POLINSAR 2013 WORKSHOP

Frascati, Italy

Copyright 2013, California Institute of Technology, All Rights Reserved – Government Sponsorship Acknowledged

La Amistad International Park

- La Amistad International Park is a World Heritage Site and a Transboundary Protected Area in Latin America jointly managed by Costa Rica and Panama.
- The park covers 401,000 ha of tropical forest and is the largest nature reserve in Central America. The area with a 15 km buffer zone represents a major biodiversity resource at both regional and global levels.

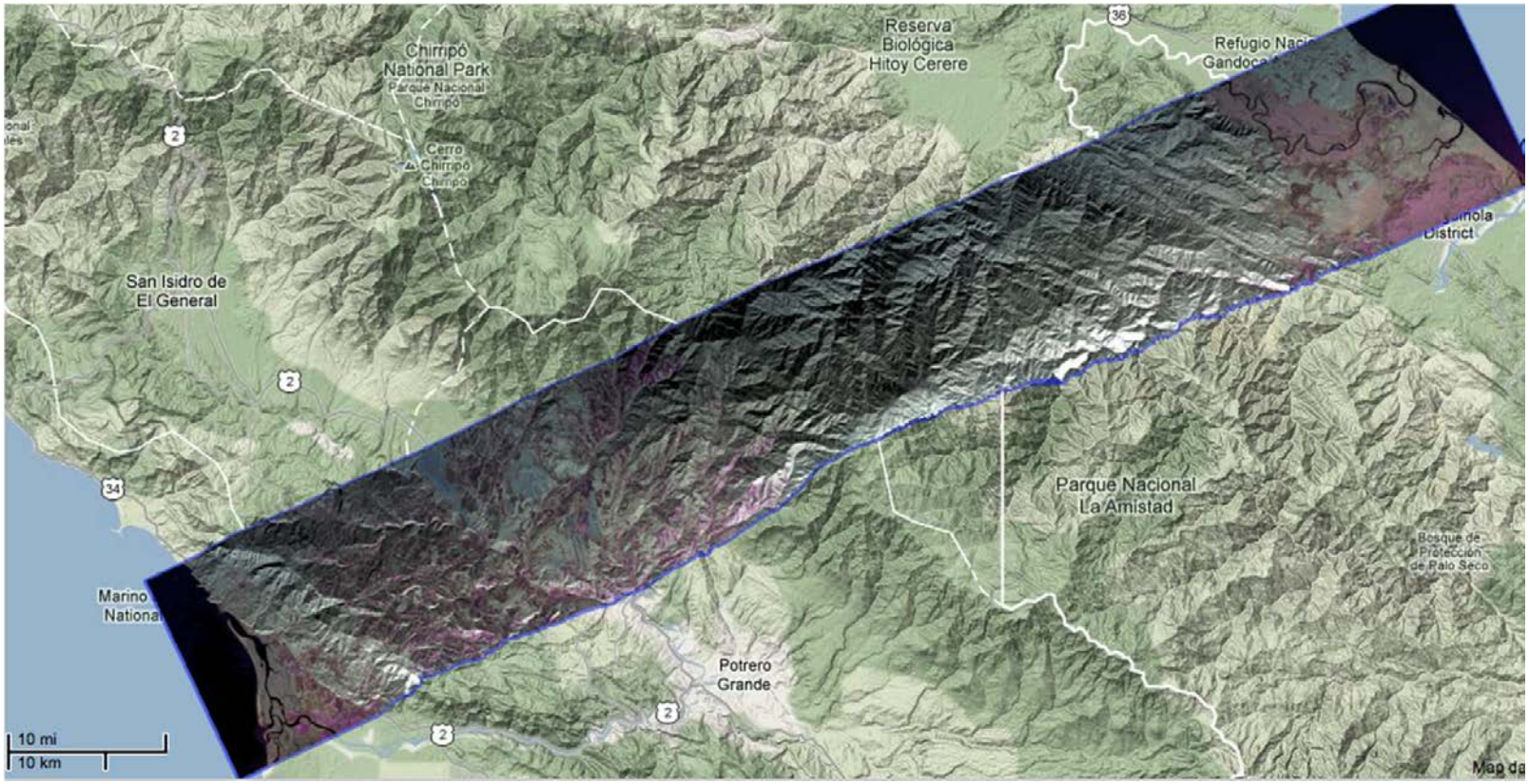
UAVSAR

- UAVSAR is an L-band fully polarimetric SAR employing an electronically scanned antenna that has been designed to support a wide range of science investigations.
  - The UAVSAR design incorporates:
  - A precision autopilot developed by NASA Dryden that allows the platform to fly repeat trajectories that are mostly within a 5 m tube.
  - Compensates for attitude angle changes during and between repeat tracks by electronically pointing the antenna based on attitude angle changes measured by the INU.

Parameter	Value
Frequency	L-Band 1217.5 to 1297.5 MHz
Bandwidth	80 MHz
Resolution	1.67 m Range, 0.8 m Azimuth
Polarization	Full Quad-Polarization
ADC Bits	2,4,6,8,10 & 12 bit selectable BFPQ, 180Mhz
Waveform	Nominal Chirp/Arbitrary Waveform
Antenna Aperture	0.5 m range/1.5 azimuth (electrical)
Azimuth Steering	Greater than ±20° (±45° goal)
Transmit Power	> 3.1 kW
Polarization Isolation	<-25 dB (<-30 dB goal)
Swath Width	> 23 km

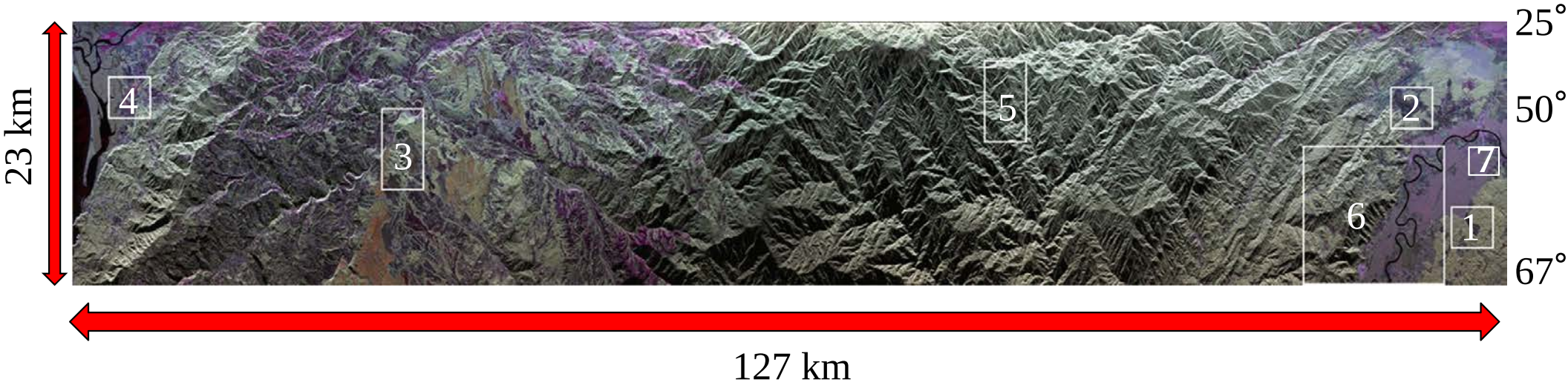
UAVSAR Data Collections La Amistad

- On February 8, 2010 UAVSAR collected a series of repeat pass lines with a variety of physical baselines. Baseline lengths varied from 20 m to 750 m.
- Data were collected from coast to coast to cover a wide range of biomes and terrains.
- Data were collected on opposite headings for look direction diversity.



Initial Study of La Amistad

- For our initial analysis we processed the short physical baseline pairs with lengths less than 100 m. This consisted of 5 tracks for a total of 10 interferometric pairs with physical baselines ranging from 1.6 to 100 m.
- Temporal baselines ranged from an half hour to three hours.
- From these pairs we picked 6 regions spanning a range of biomes, terrain types and incidence angle.
- Our initial study goals are:
  - Understand the variability of temporal correlation for short time repeat pass pairs in a tropical environment.
  - Check to consistency of PolinSAR inversions for a single baseline.



Physical/Temporal Baselines

Physical Baselines (m)

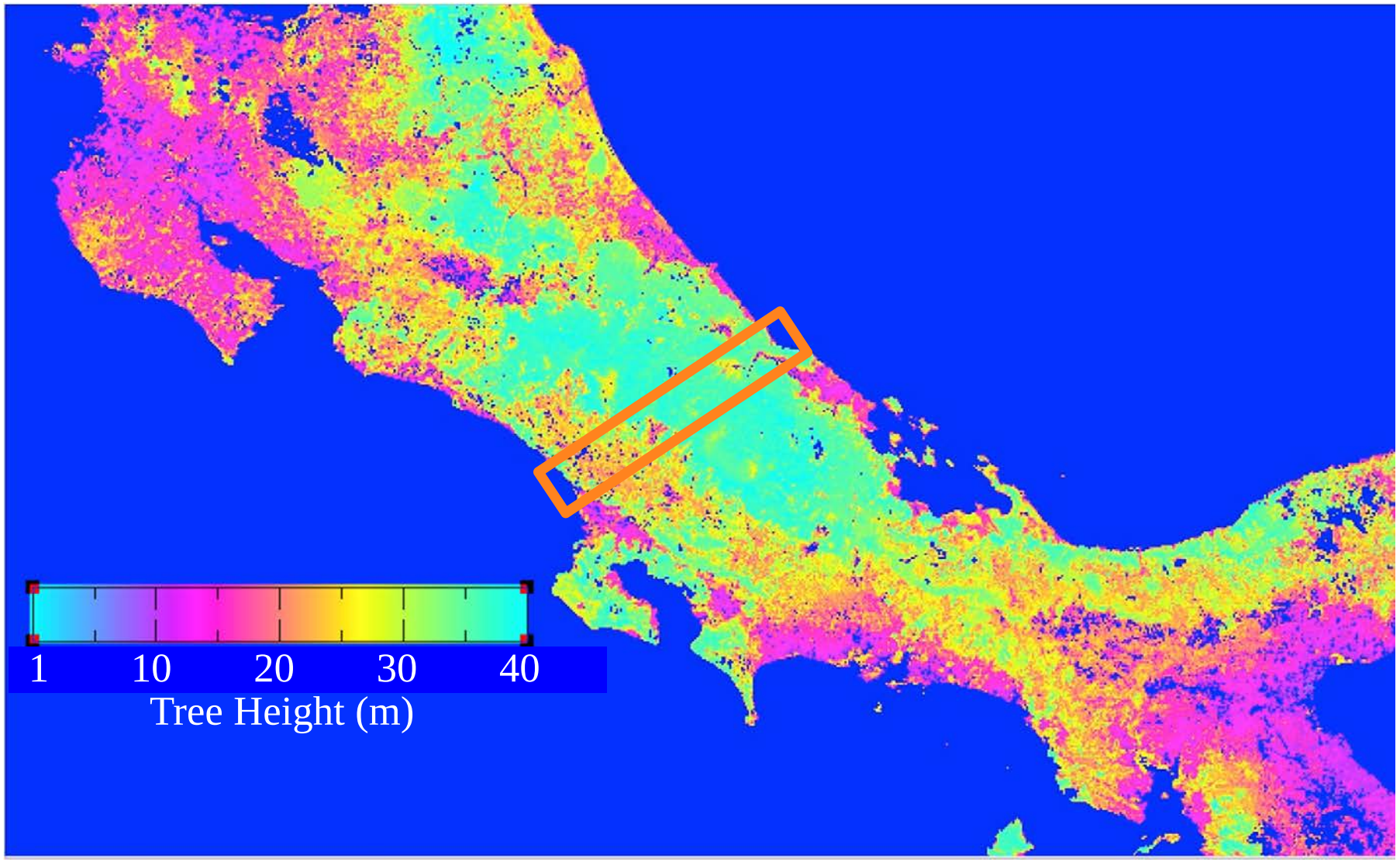
Track #	1	2	3	4	5
1		1.6	19.0	79.1	99.4
2			19.2	79.4	99.7
3				60.2	80.5
4					20.3
5					

Temporal Baselines (hr)

Track #	1	2	3	4	5
1		3.2	0.7	1.3	1.9
2			-2.6	-1.9	-1.3
3				0.7	1.3
4					0.6
5					

Tree Heights in La Amistad

- Tree heights at the 1 km scale derived by Marc Simard using IceSAT lidar are shown in the map below.
  - Largest tree height in 1 km cell



Baseline Summary Table and Nomenclature

c_t	r_t	Baseline #	Baseline Length	Temporal Interval
2	1	0	1.6	3.2
3	1	1	19.0	0.7
3	2	2	19.2	-2.6
4	1	3	79.1	1.3
4	2	4	79.4	-1.9
4	3	5	60.2	0.7
5	1	6	99.4	1.9
5	2	7	99.7	-1.3
5	3	8	80.5	1.3
5	4	9	20.3	0.6

Long Temporal Baseline

Short Physical Baseline

"Good Baselines"

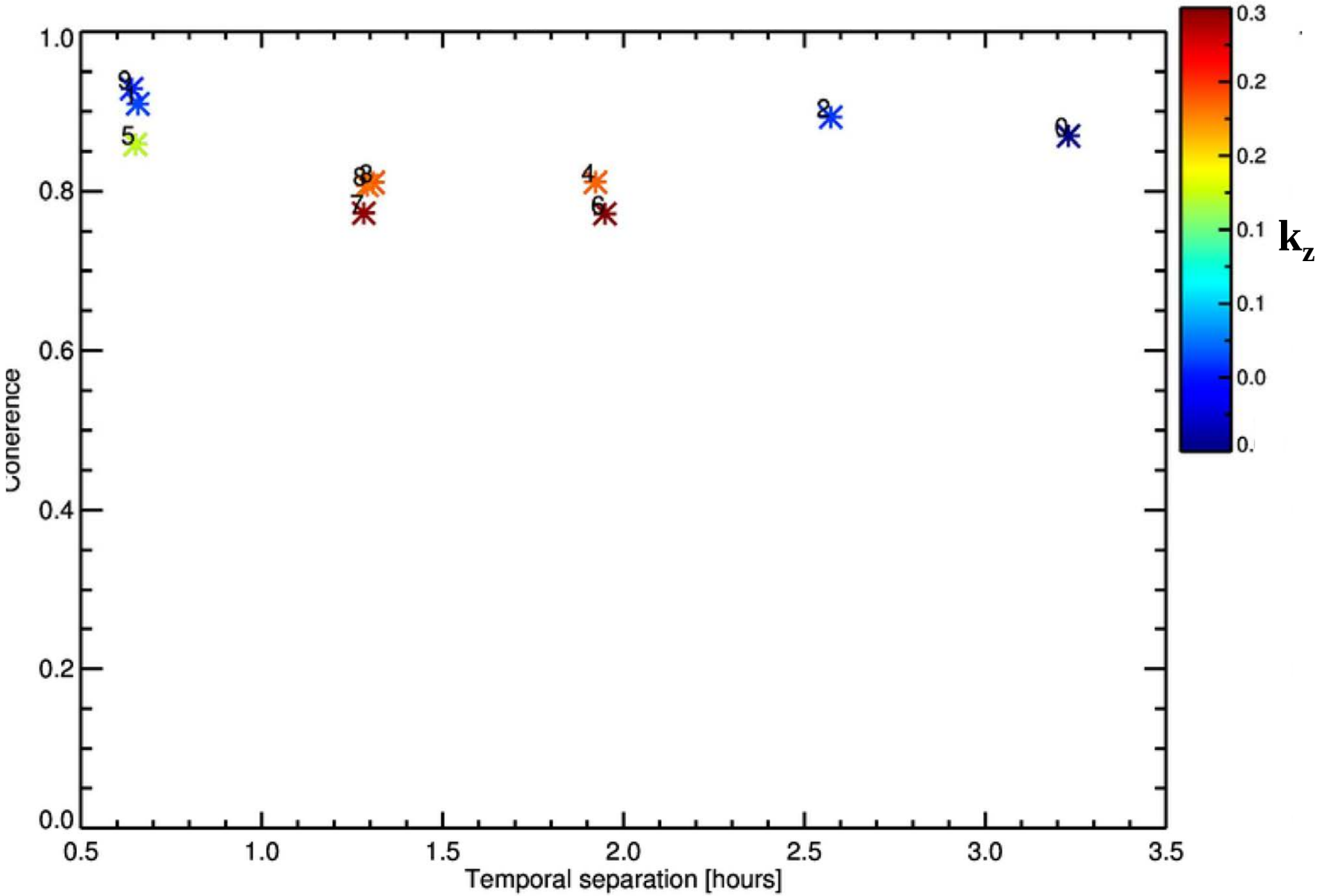
Short Physical Baseline

$$b_{\#} = \frac{(c_t - 1)(c_t - 2)}{2} + r_t - 1$$

	1	2	3	4	5
1		0	1	3	6
2			2	4	7
3				5	8
4					9
5					

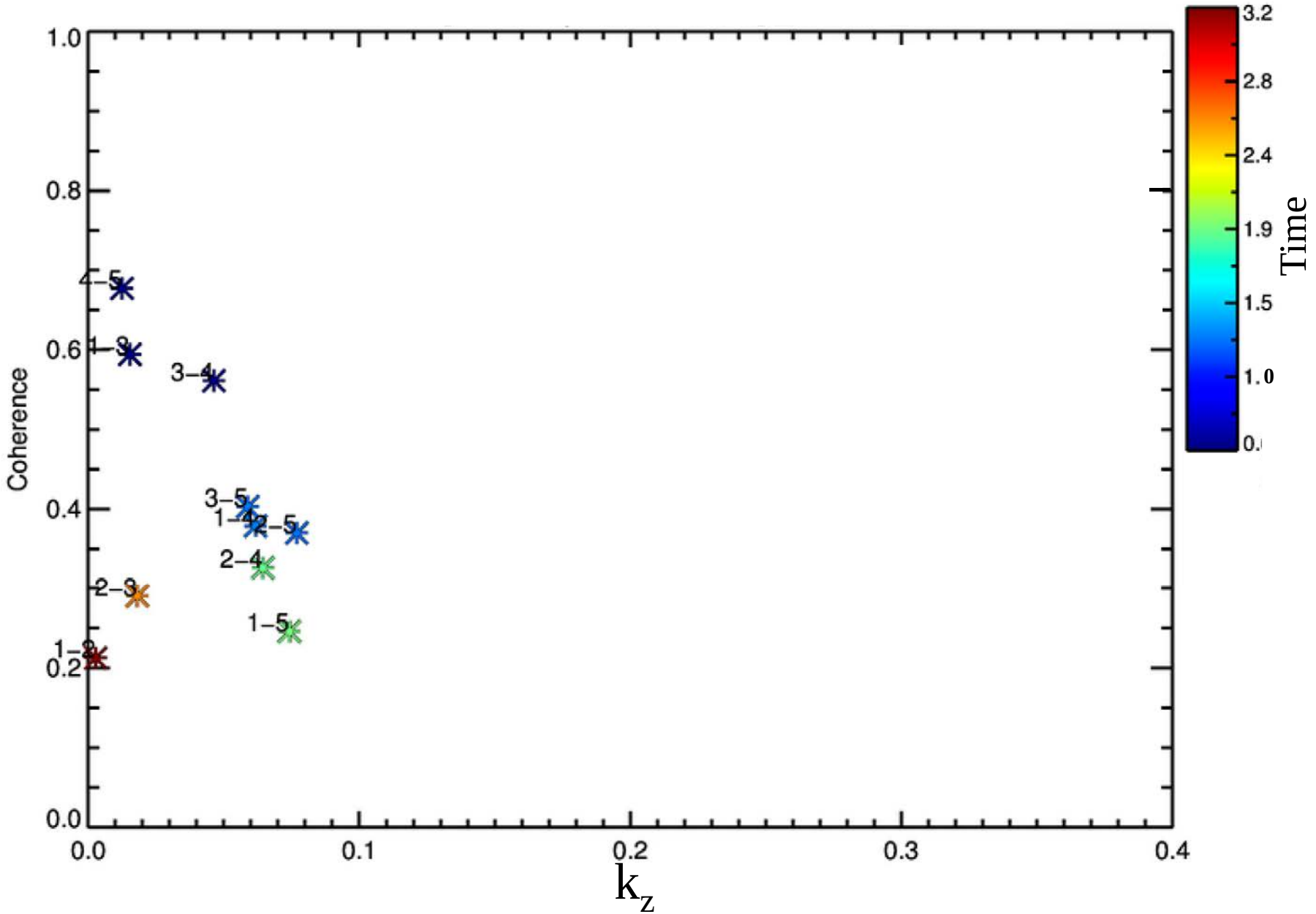
Correlation on Bare Surfaces

- Most bare surfaces stayed well correlated during the 3 hours spanning the data collection period.



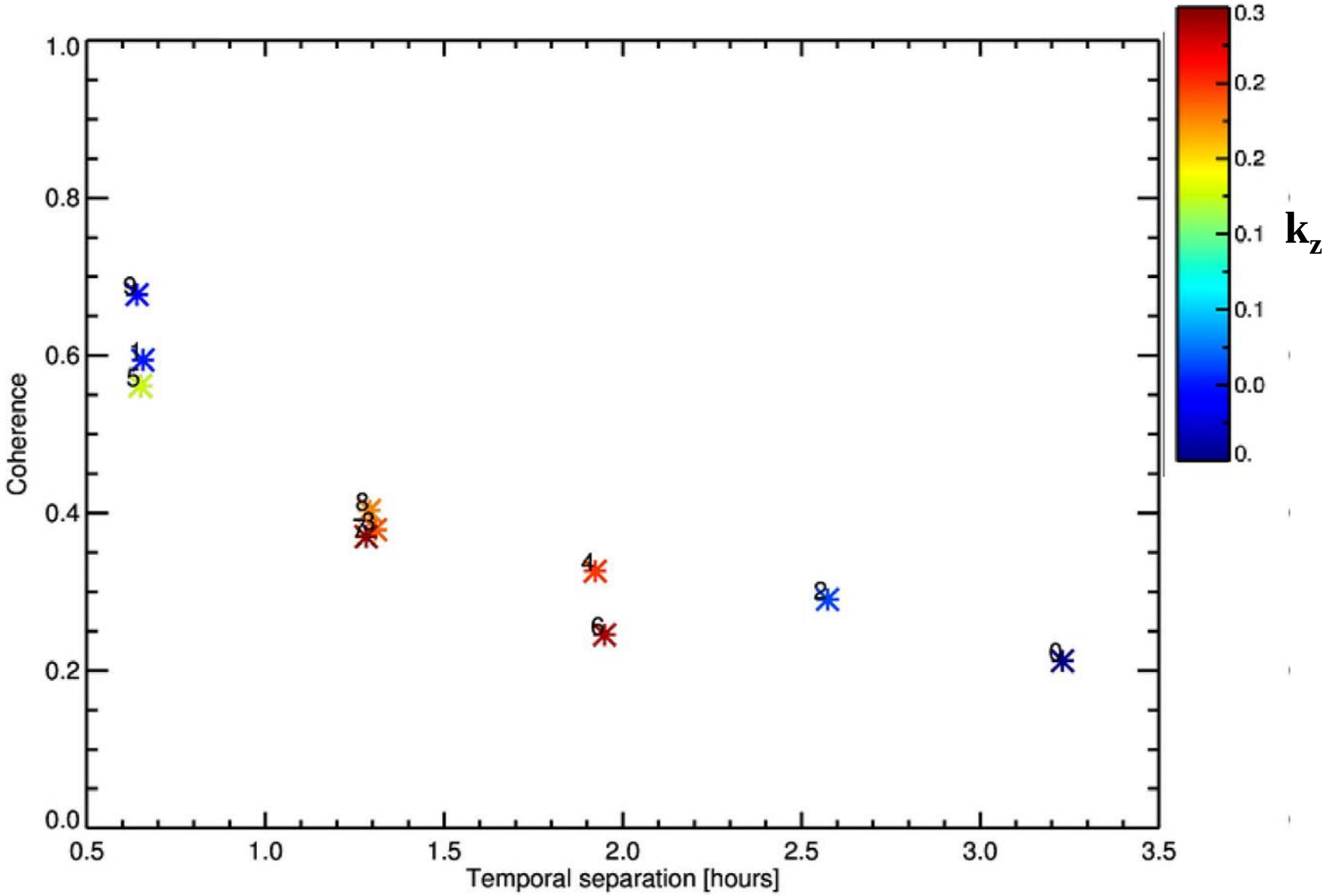
Correlation in Forested Areas – k_z

- Correlation in forested areas as a function of k_z.



Correlation in Forested Areas – Time

- Temporal decorrelation at La Amistad is substantial even for temporal baselines as short as a couple of hours. On the Δt=3 hour pair temporal decorrelation exceeded volumetric correlation even for the long baseline pairs.

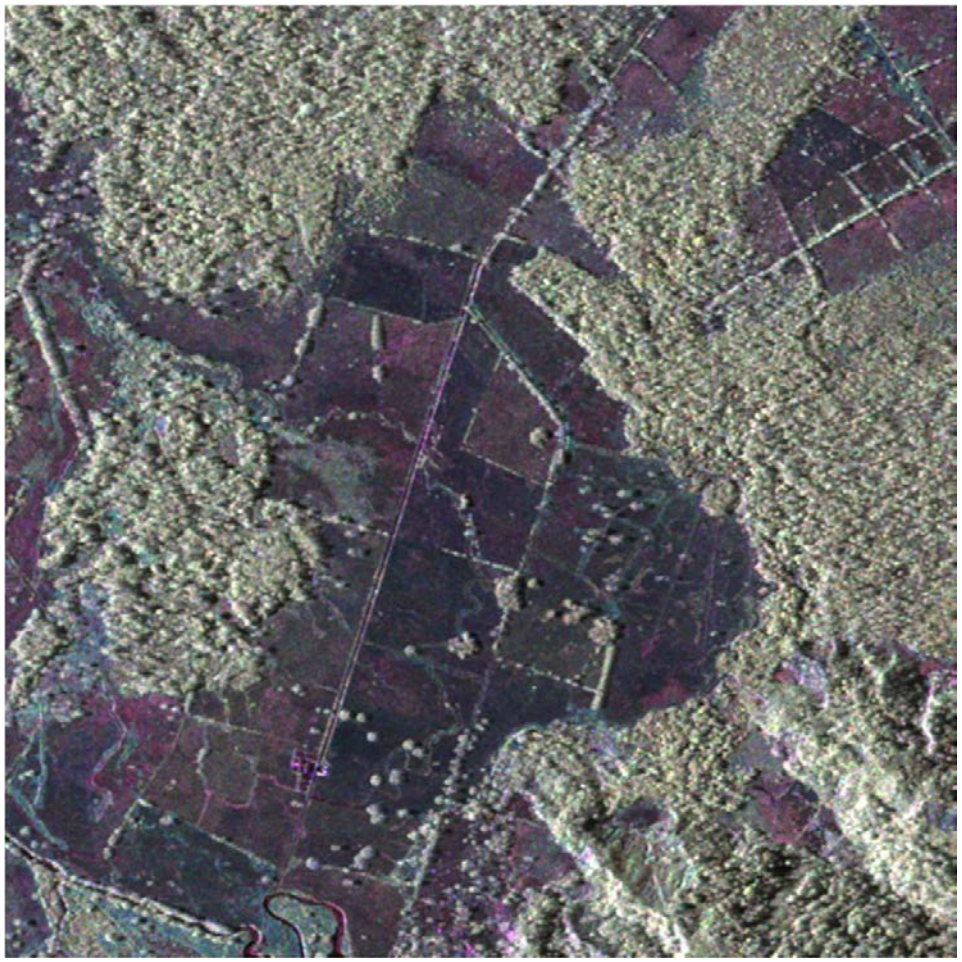


Area II

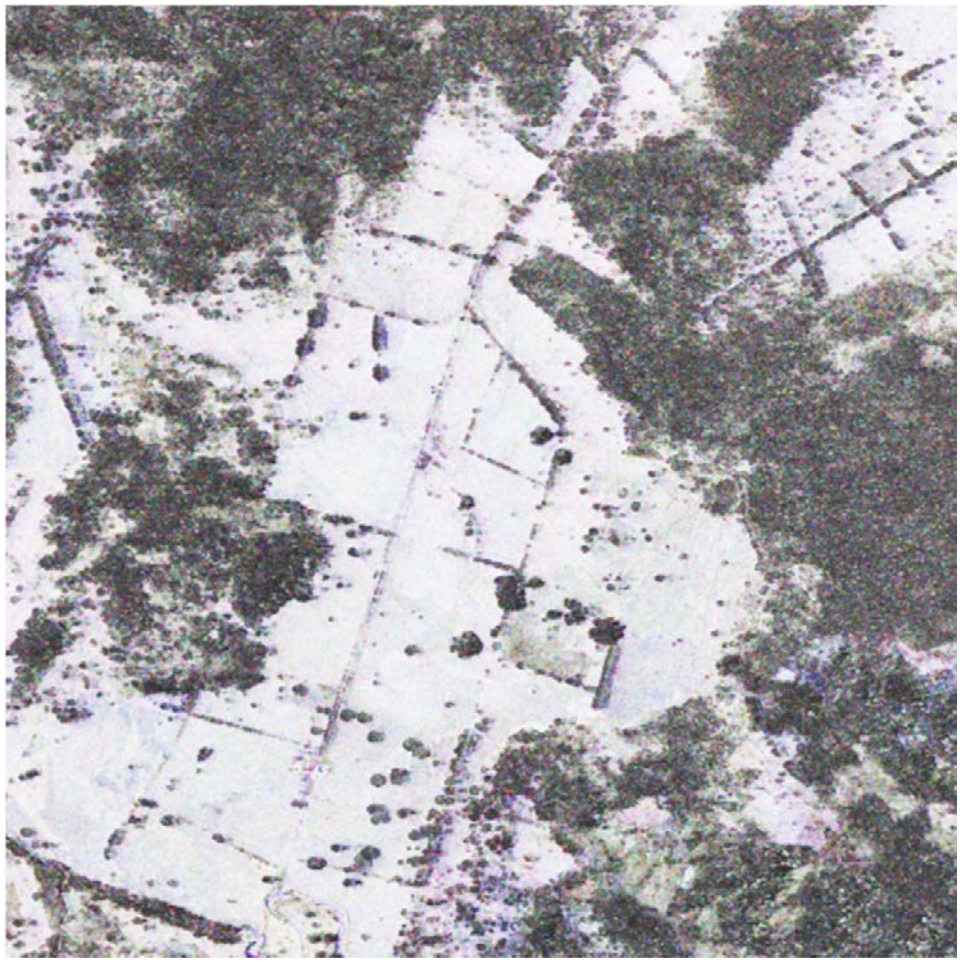
Average Backscatter and Correlation Images

- Average backscatter for all passes and average correlation over all interferometric pairs.

$\sigma_{hh} + \sigma_{vv}$ $\sigma_{hh} - \sigma_{vv}$ σ_{hv}



γ_{hh+vv} γ_{hh-vv} γ_{hv}



k_z and Ambiguity Heights for Site II

- k_z and ambiguity heights for the interferometric passes.

k_z

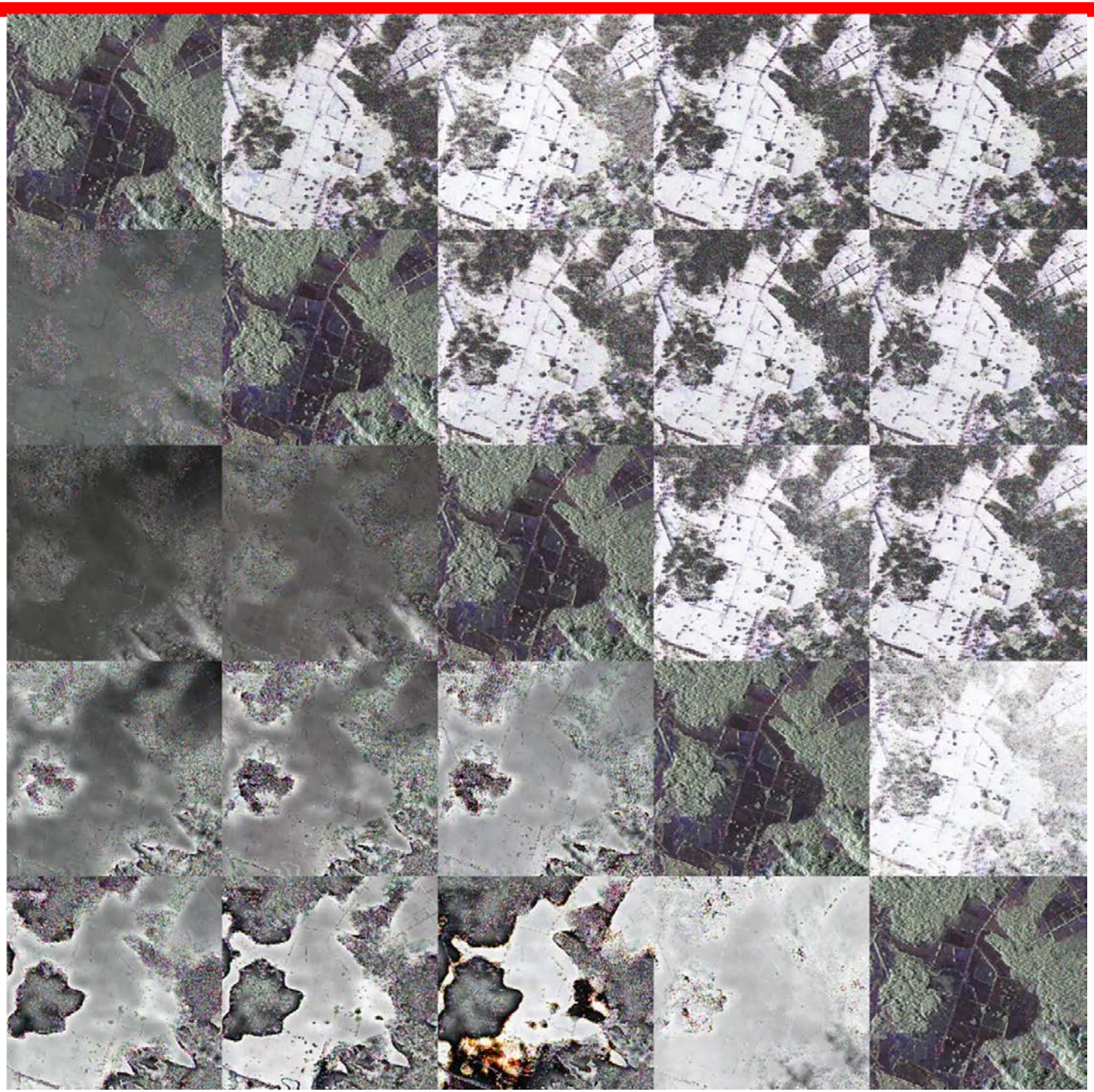
Track #	1	2	3	4	5
1		0.006	0.041	0.173	0.218
2			0.046	0.178	0.224
3				0.132	0.178
4					0.046
5					

Ambiguity Height

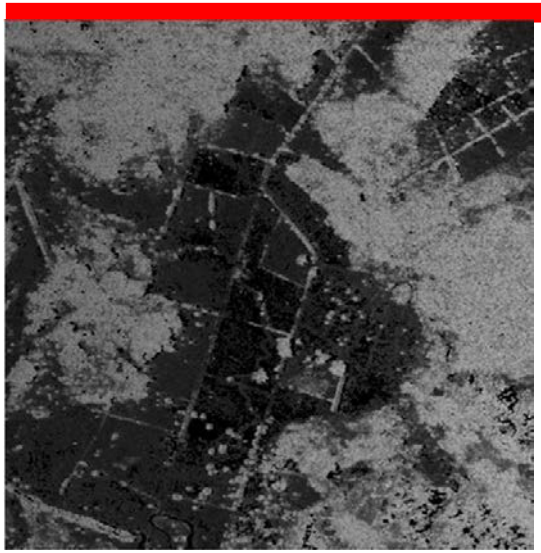
Track #	1	2	3	4	5
1		1139	155	36	29
2			136	35	28
3				48	35
4					137
5					

Note that for baselines 4, 5, 7, 8 that the ambiguity is smaller than the ICESAT vegetation height estimates.

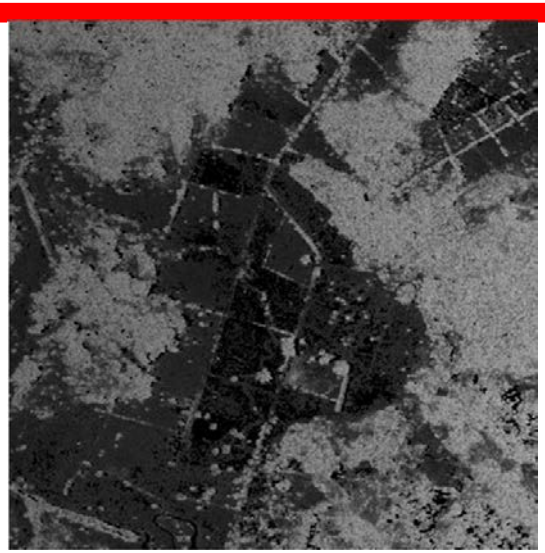
Correlation, Phase Image Matrix



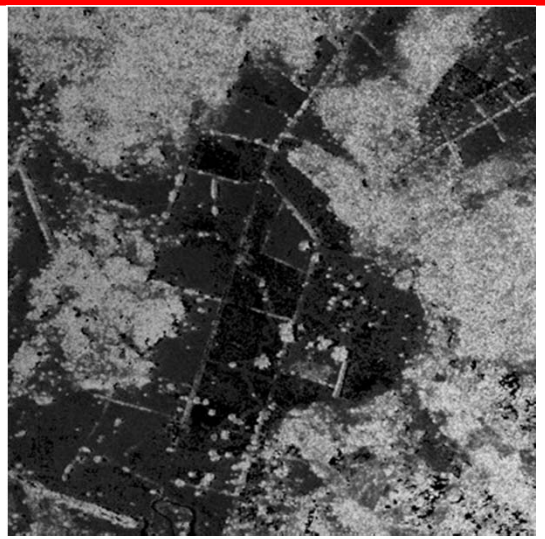
PolinSAR Vegetation Height Estimates



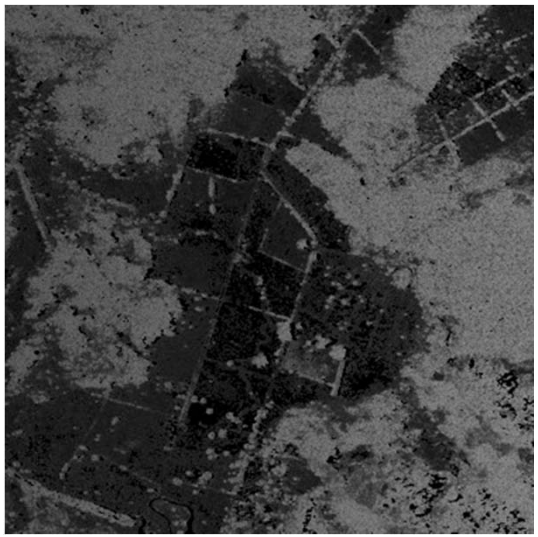
Baseline #: 3
B: 79 m
Δt: 1.3 h



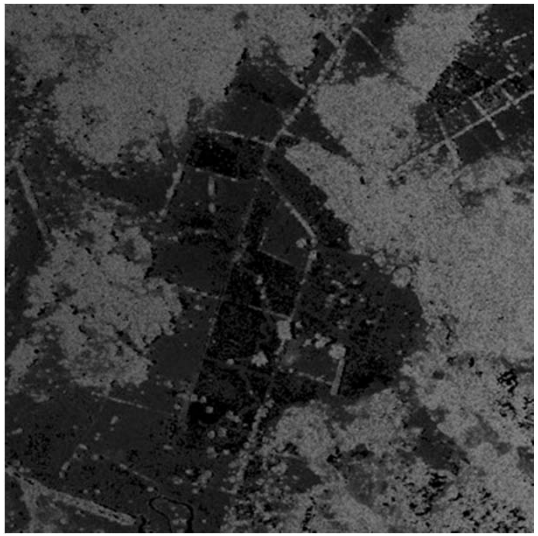
Baseline #: 4
B: 79 m
Δt: 1.9 h



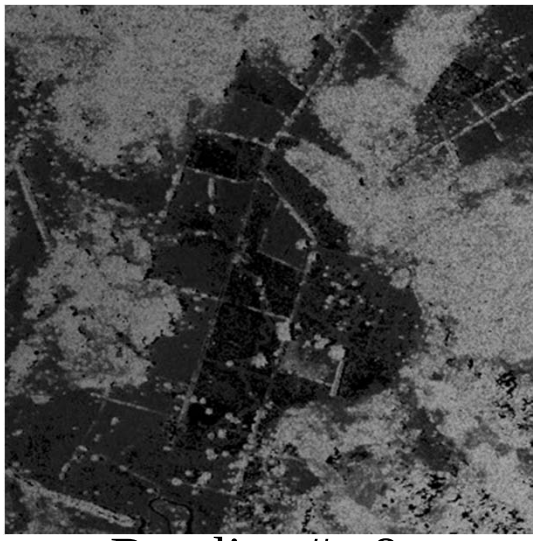
Baseline #: 5
B: 60 m
Δt: 0.7 h



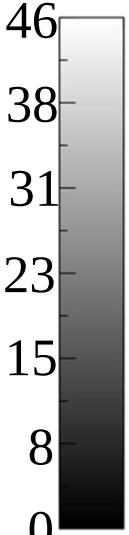
Baseline #: 6
B: 99 m
Δt: 1.9 h



Baseline #: 7
B: 99 m
Δt: 1.3 h

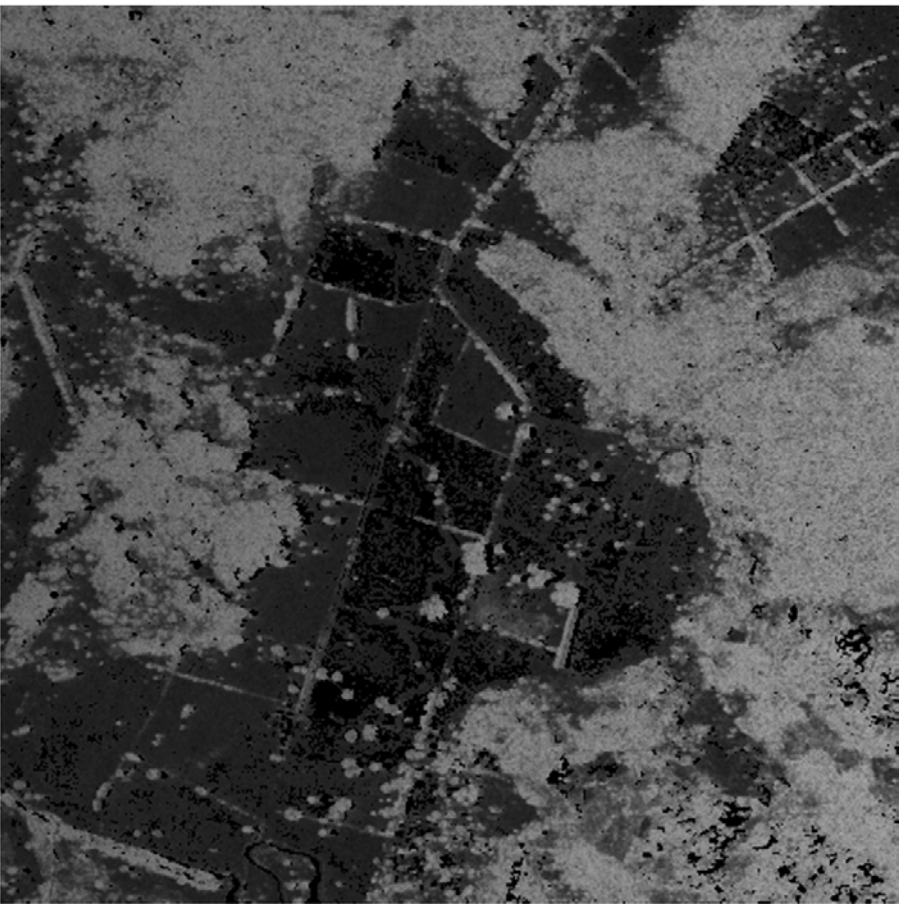


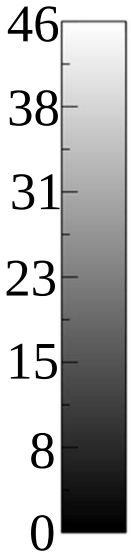
Baseline #: 8
B: 81 m
Δt: 1.3 h

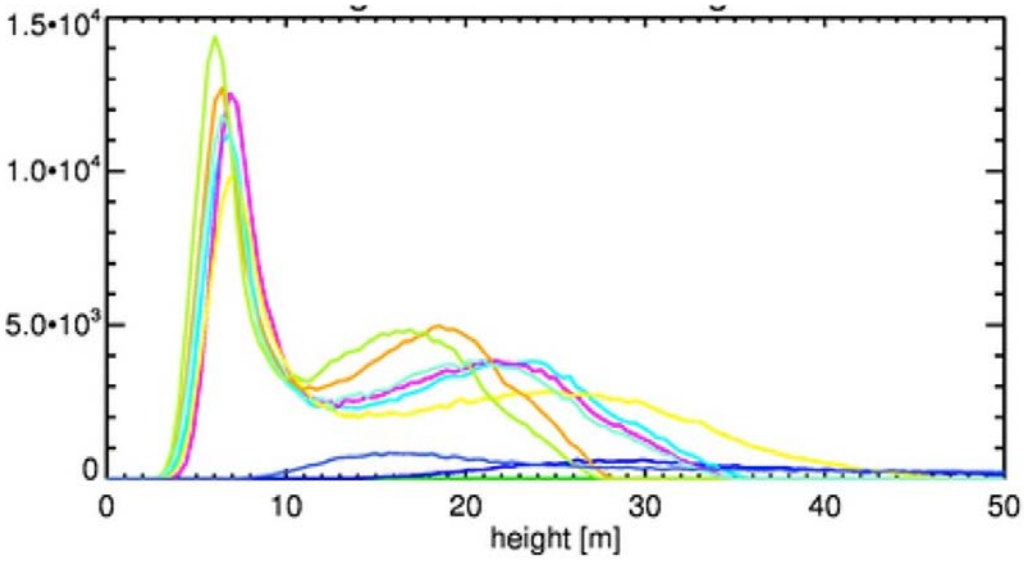


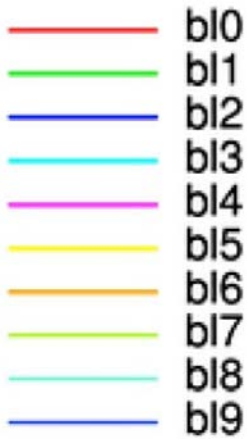
Average Height and Histograms

- Height estimate averaged over all interferometric pairs and height histograms for the various baselines.





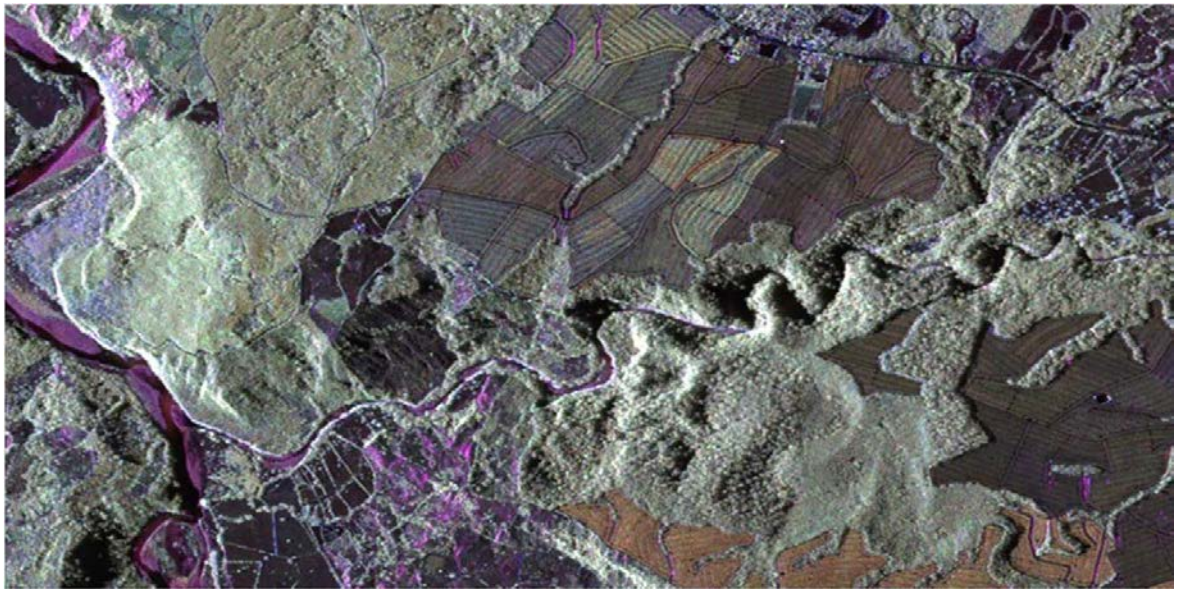


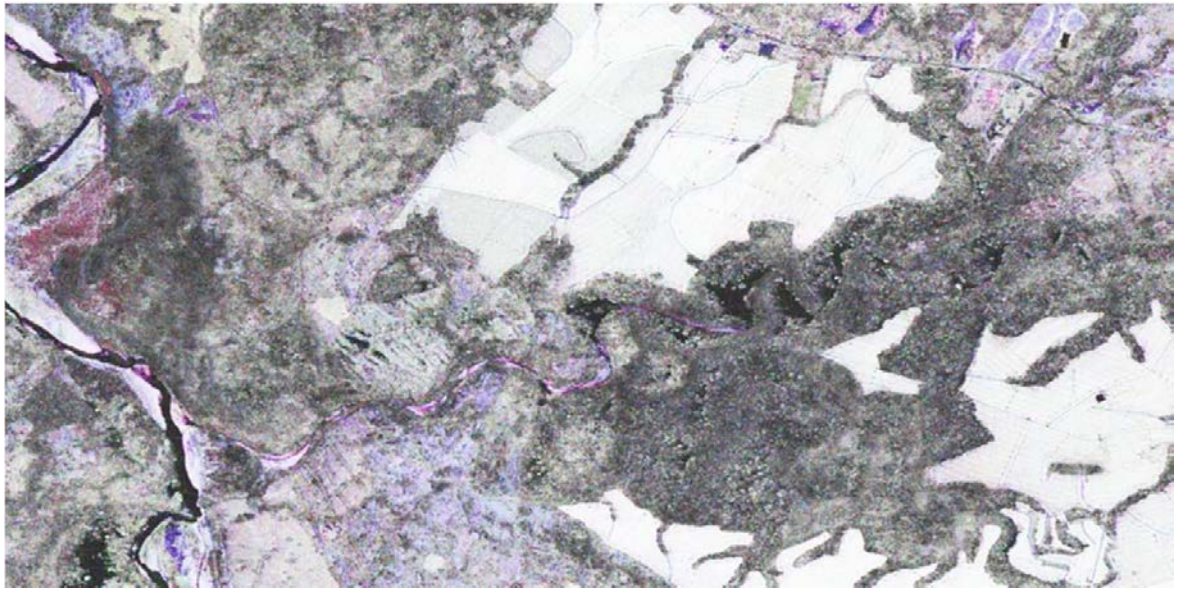


Area III

Average Backscatter and Correlation Images

$\sigma_{hh} + \sigma_{vv}$ $\sigma_{hh} - \sigma_{vv}$ σ_{hv}





γ_{hh+vv} γ_{hh-vv} γ_{hv}

- Average backscatter for all passes and average correlation over all interferometric pairs.

k_z and Ambiguity Heights for Site III

- k_z and ambiguity heights for the interferometric passes.

k_z

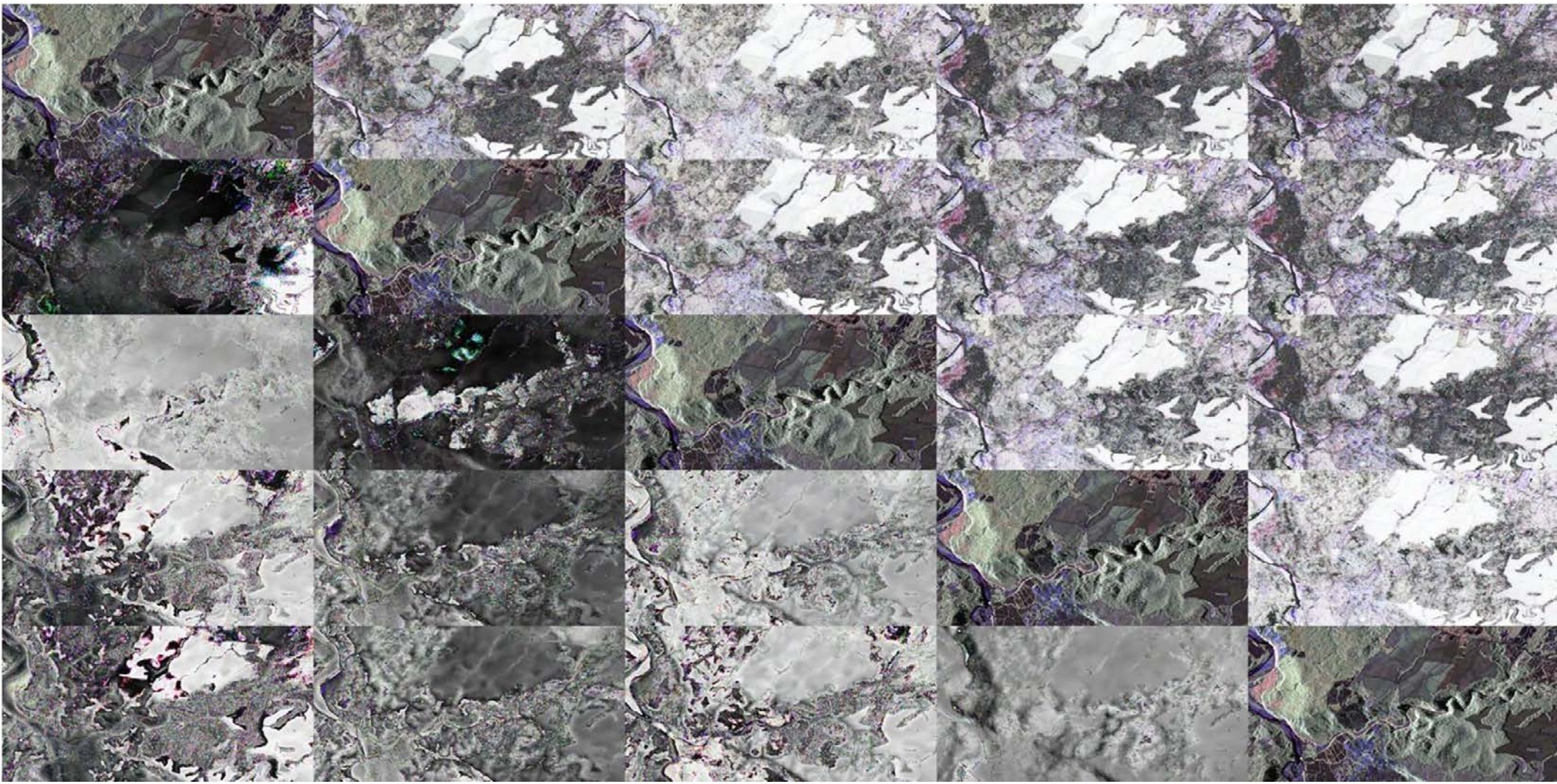
Track #	1	2	3	4	5
1		0.001	0.030	0.128	0.163
2			0.031	0.129	0.164
3				0.098	0.133
4					0.035
5					

Ambiguity Height

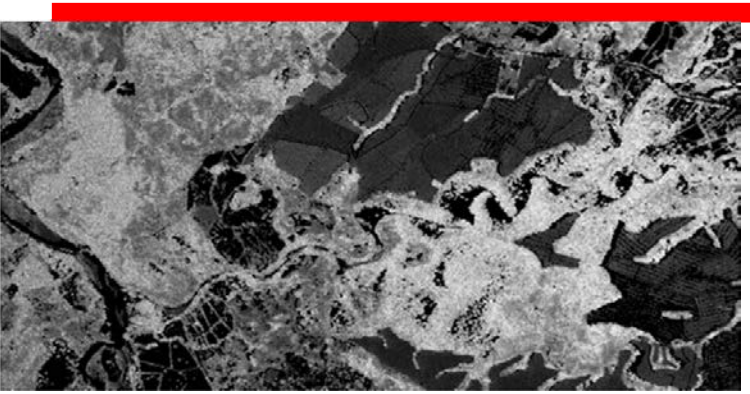
Track #	1	2	3	4	5
1		5090	211	49	39
2			204	48	38
3				64	47
4					180
5					

Note that for baselines 6,7 that the ambiguity height is very close the maximal lidar tree heights.

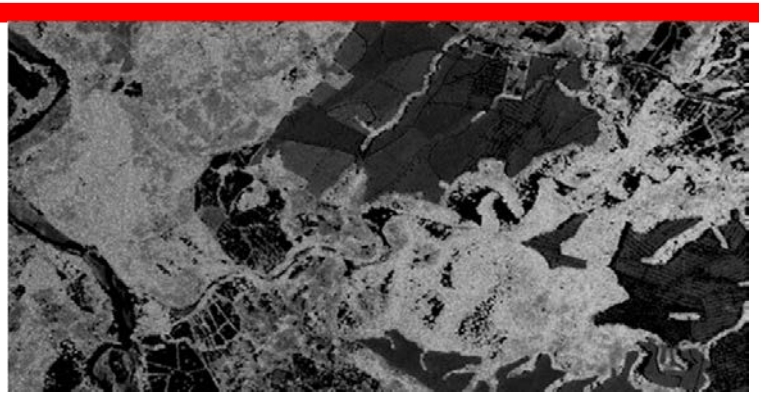
Correlation, Phase Image Matrix



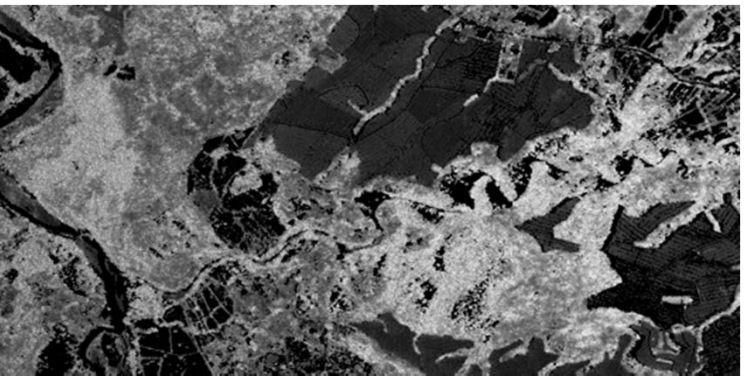
PolinSAR Vegetation Height Estimates



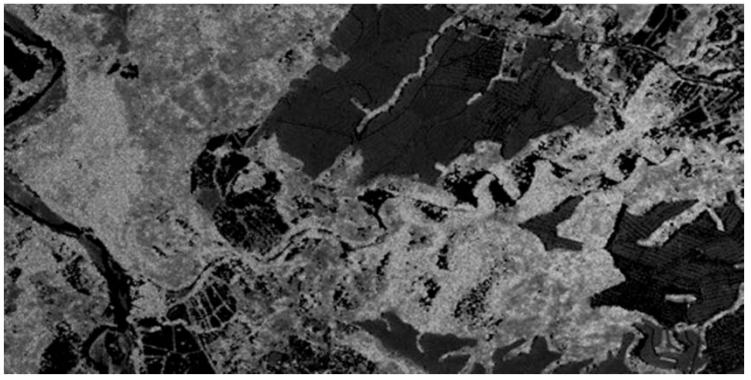
Baseline #: 3
B: 79 m
Δt: 1.3 h



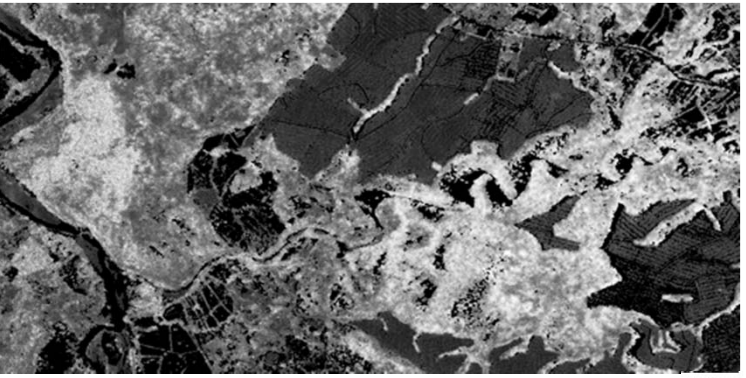
Baseline #: 6
B: 99 m
Δt: 1.9 h



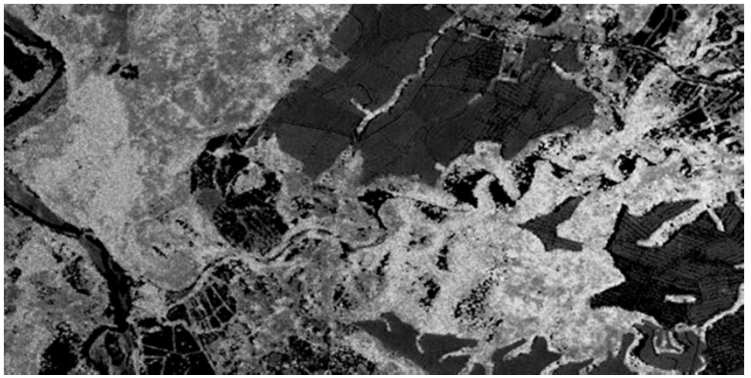
Baseline #: 4
B: 79 m
Δt: 1.9 h



Baseline #: 7
B: 99 m
Δt: 1.3 h



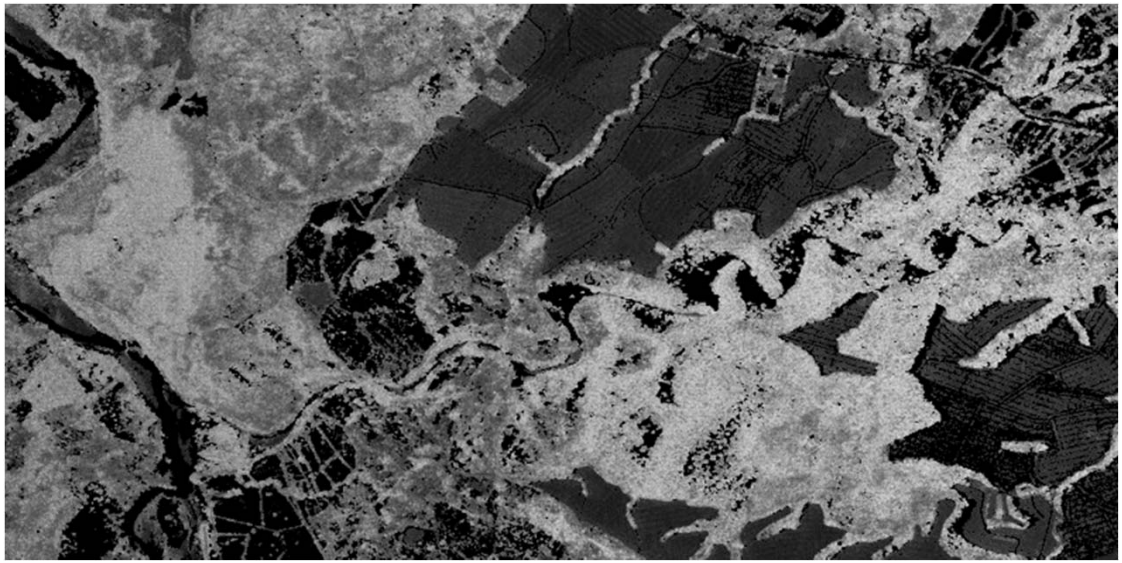
Baseline #: 5
B: 60 m
Δt: 0.7 h

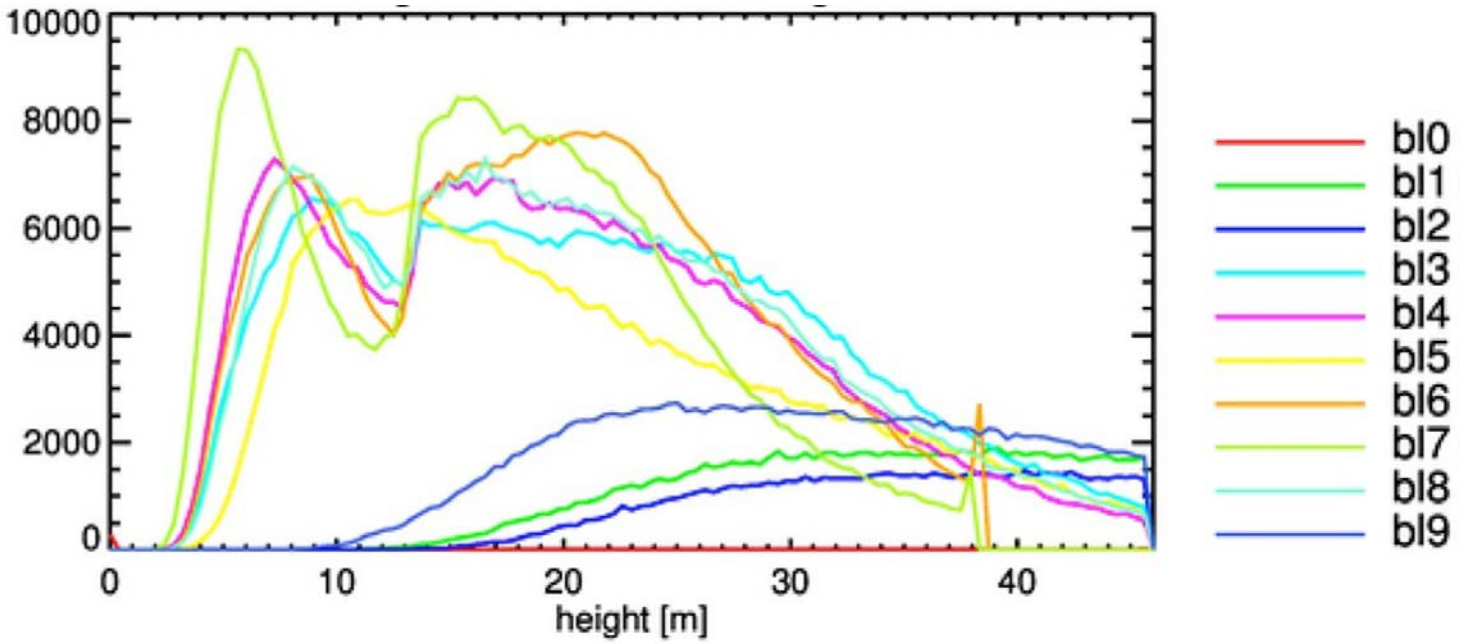


Baseline #: 8
B: 81 m
Δt: 1.3 h

Average Height and Histograms

- Height estimate averaged over all interferometric pairs and height histograms for the various baselines.



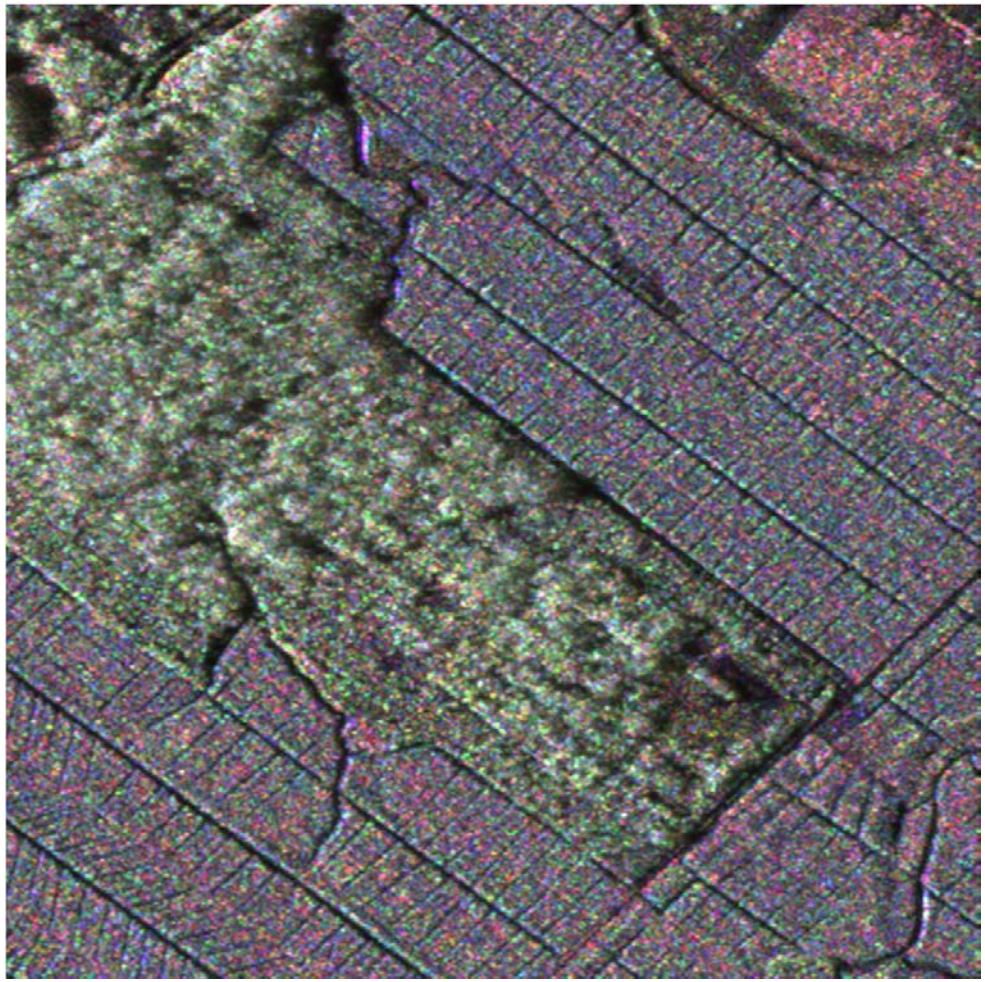


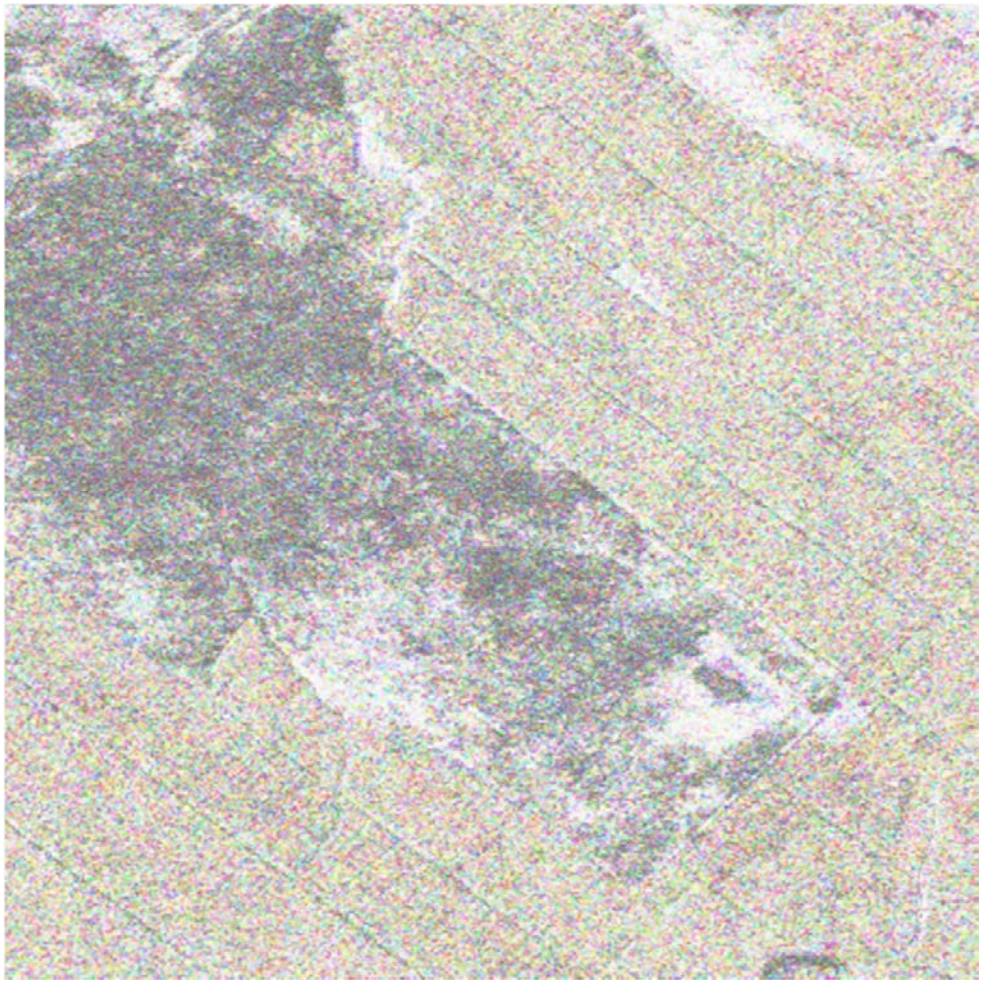
Area VII

Average Backscatter and Correlation Images

- Average backscatter for all passes and average correlation over all interferometric pairs.

$\sigma_{hh} + \sigma_{vv}$ $\sigma_{hh} - \sigma_{vv}$ σ_{hv} γ_{hh+vv} γ_{hh-vv} γ_{hv}





k_z and Ambiguity Heights for Site VI

- k_z and ambiguity heights for the interferometric passes.

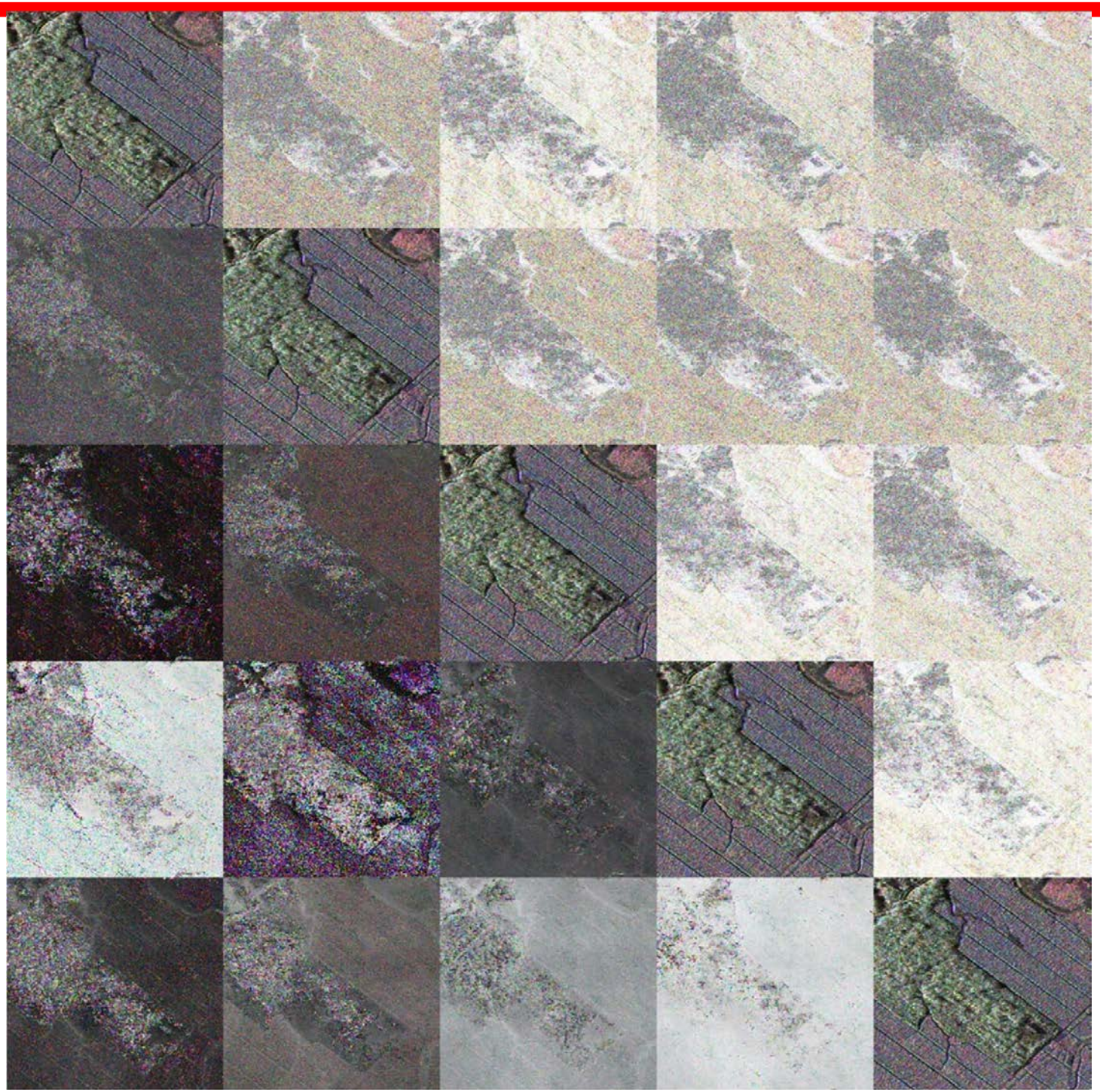
k_z

Track #	1	2	3	4	5
1		0.004	0.027	0.115	0.140
2			0.031	0.120	0.145
3				0.088	0.113
4					0.025
5					

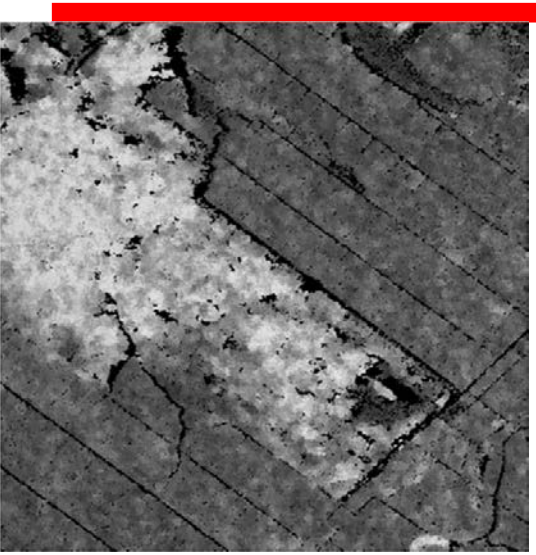
Ambiguity Height

Track #	1	2	3	4	5
1		1443	233	54	44
2			200	52	43
3				71	55
4					251
5					

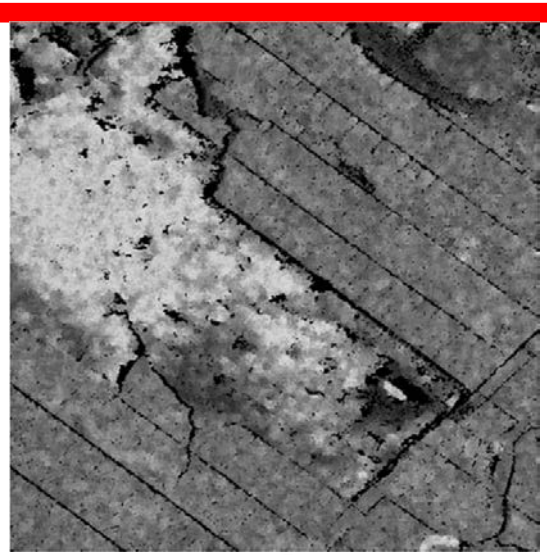
Correlation, Phase Image Matrix



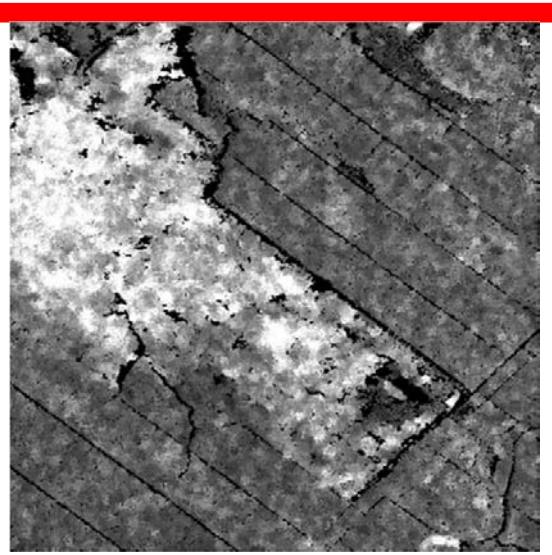
PolinSAR Vegetation Height Estimates



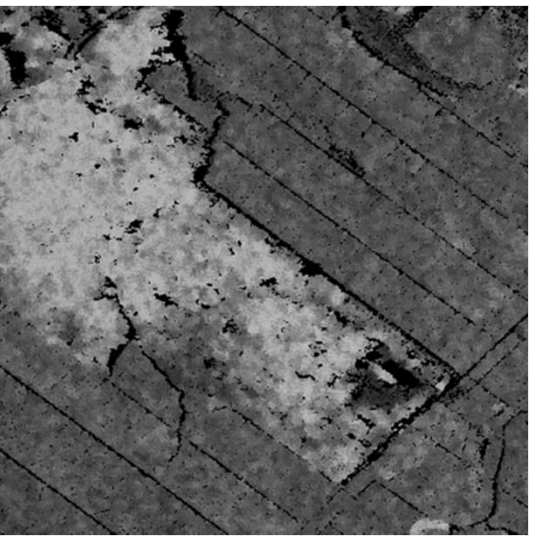
Baseline #: 3
B: 79 m
Δt: 1.3 h



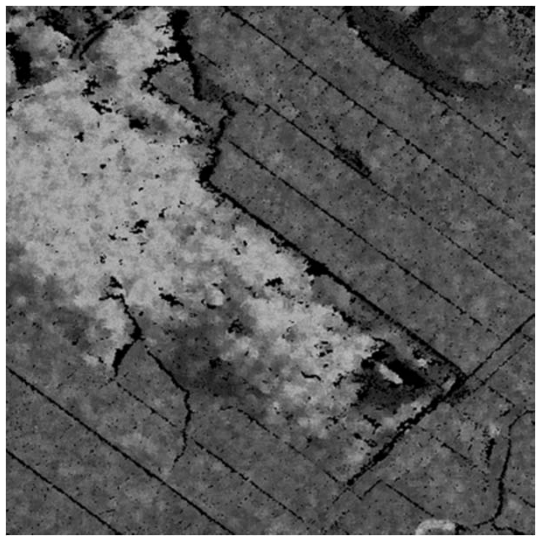
Baseline #: 4
B: 79 m
Δt: 1.9 h



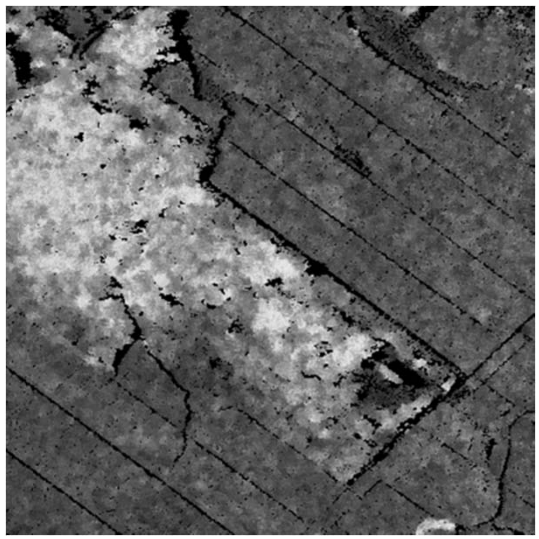
Baseline #: 5
B: 60 m
Δt: 0.7 h



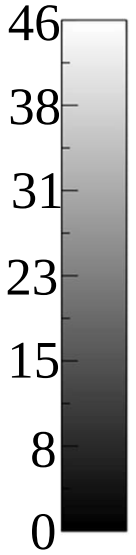
Baseline #: 6
B: 99 m
Δt: 1.9 h



Baseline #: 7
B: 99 m
Δt: 1.3 h

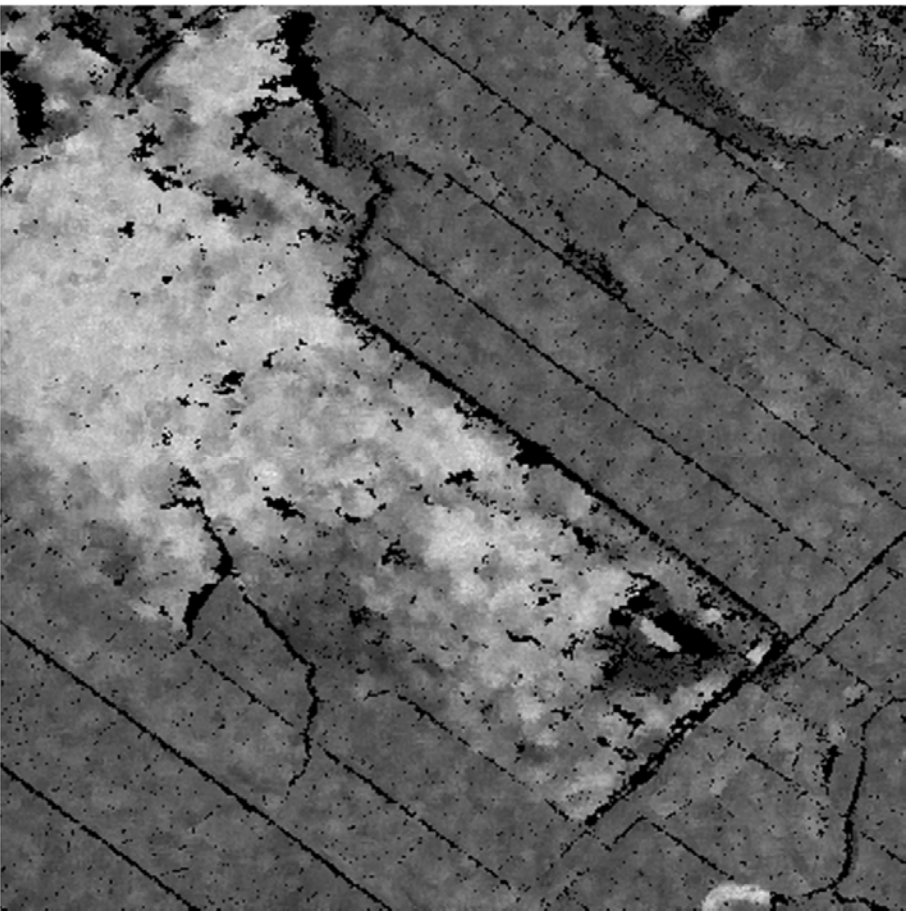


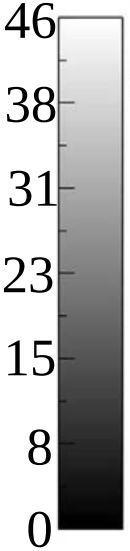
Baseline #: 8
B: 81 m
Δt: 1.3 h

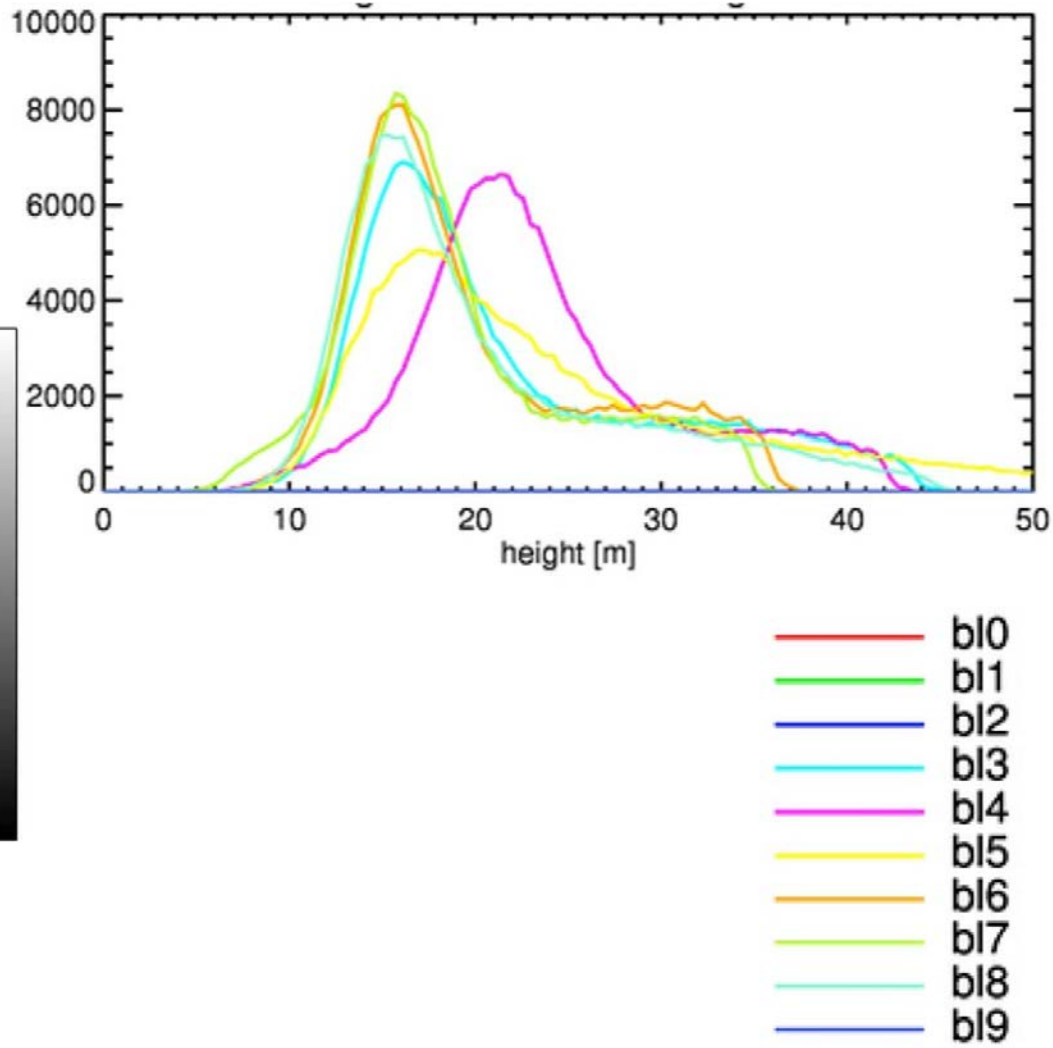


Average Height and Histograms

- Height estimate averaged over all interferometric pairs and height histograms for the various baselines.







Conclusions

- UAVSAR imaged La Amistad with multiple physical and temporal baselines at La Amistad national park.
- Temporal decorrelation, even for temporal baselines in the range of a few hours, impacted the PolinSAR inversions at La Amistad.
- Need greater baseline diversity to get good k_z diversity for all incidence angles for the range of vegetation heights in this area. Larger baselines have ambiguity heights smaller the larger tree height and smallest baselines do not have enough sensitivity.
- Shapes of histogram of tree height for the different baselines look fairly similar in most cases, however they are shifted and scaled, most likely due to temporal decorrelation.
  - When the baselines are small, we observe higher inverted heights because the decorrelation inverted heights scale with a larger height ambiguity.