Establishing a global forest monitoring capability using multi-resolution and multi-temporal remotely sensed data sets

Matthew Hansen – South Dakota State University, Steve Stehman – SUNY-ESF, Tom Loveland – USGS/EROS,
Jim Vogelmann – USGS/EROS, Mark Cochrane – South Dakota State University

- Project's goals - Quantify rates and describe patterns of global forest cover change at the biome level
- Geographic area - Global per 5 biomes
- Data - MODIS 2000 to present, Landsat samples from March ~2000 and ~2005
- Methods – Generate 500m MODIS change indicator maps to stratify the land surface into regions of varying change likelihood. A probability-based sampling design is then employed using Landsat imagery to estimate change area.
- Results – 1) Prototyped method for Indonesia to produce country-wide forest cover loss estimates from 2000 to 2005, 2) Initial humid tropics change results obtained, 3) MODIS change indicator maps created for boreal biome
- Next steps – 1) Refine sampling procedure, 2) implement 250m MODIS change indicator product, 3) Complete humid tropical, boreal and dry tropical biomes
- Two papers in development on establishing rates of forest cover loss in the humid tropical and boreal biomes

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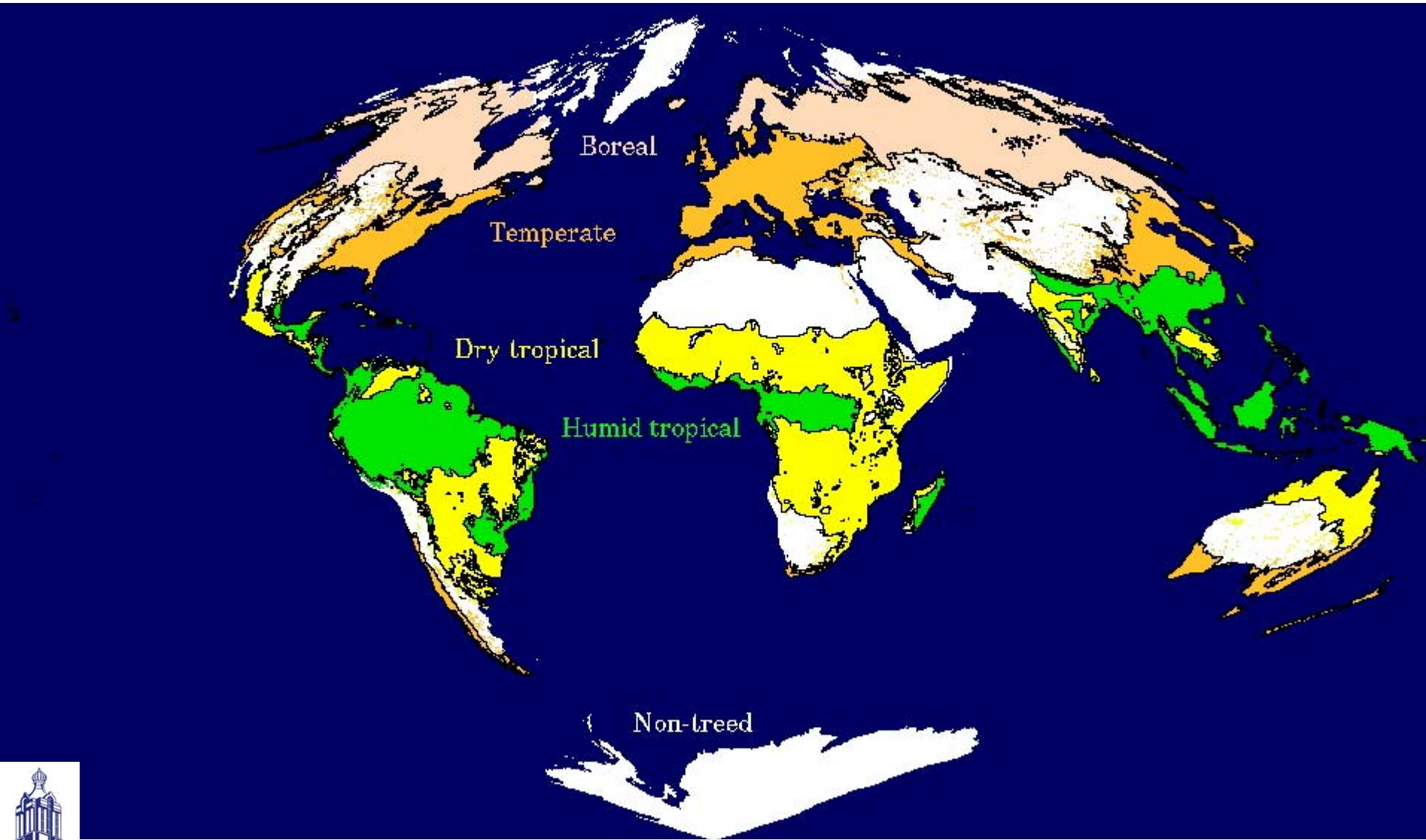
Global tree cover change assessment per dominant treed biome



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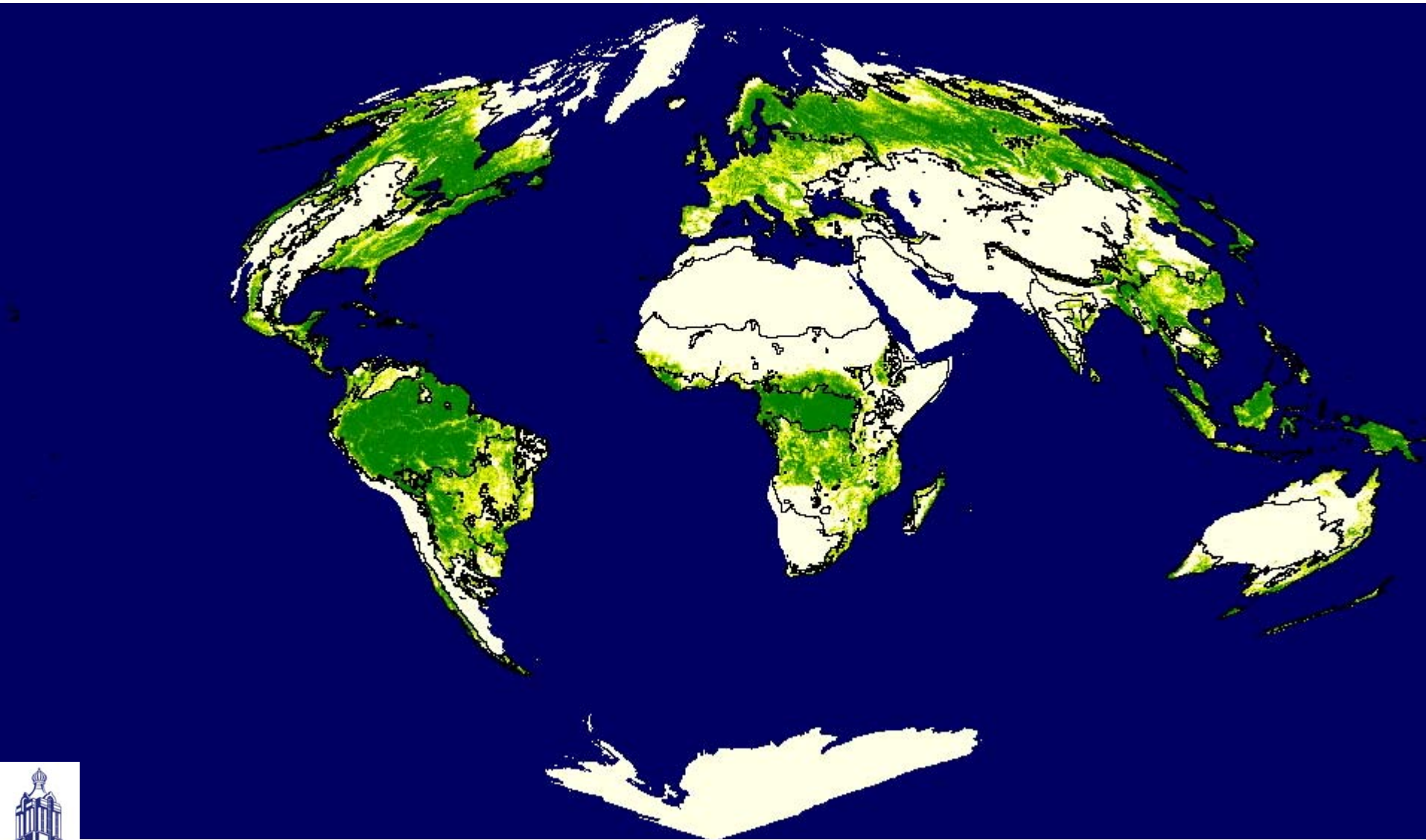
2000 percent tree cover



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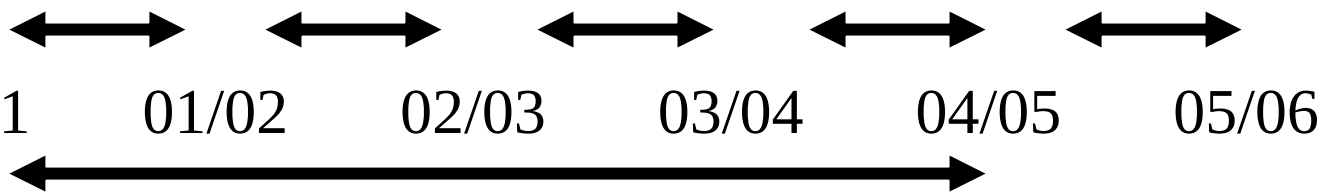
Change analysis using MODIS and Landsat data sets

- Supervised decision tree approach using MODIS-scale change (forest loss) and no change labels
- MODIS 500m annual time series data as inputs
  - March 2000/01, 2001/02, 2002/03, 2003/04, 2004/05, and 2005/06
- Use 00/01 to 04/05 interval training data to generate generic change model
- Apply model to individual years and 4-year interval



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Change analysis using MODIS and Landsat data sets

- Aggregate MODIS change over 4-year interval at 20km block scale to develop a stratified sampling frame (low/medium/high) for Landsat-scale analysis
- Purchase and interpret Landsat image pairs per stratum
- Use MODIS change and Landsat change in regression estimator approach to derive final change estimate
- Allocate change estimate spatially and temporally using annual MODIS change likelihood layers

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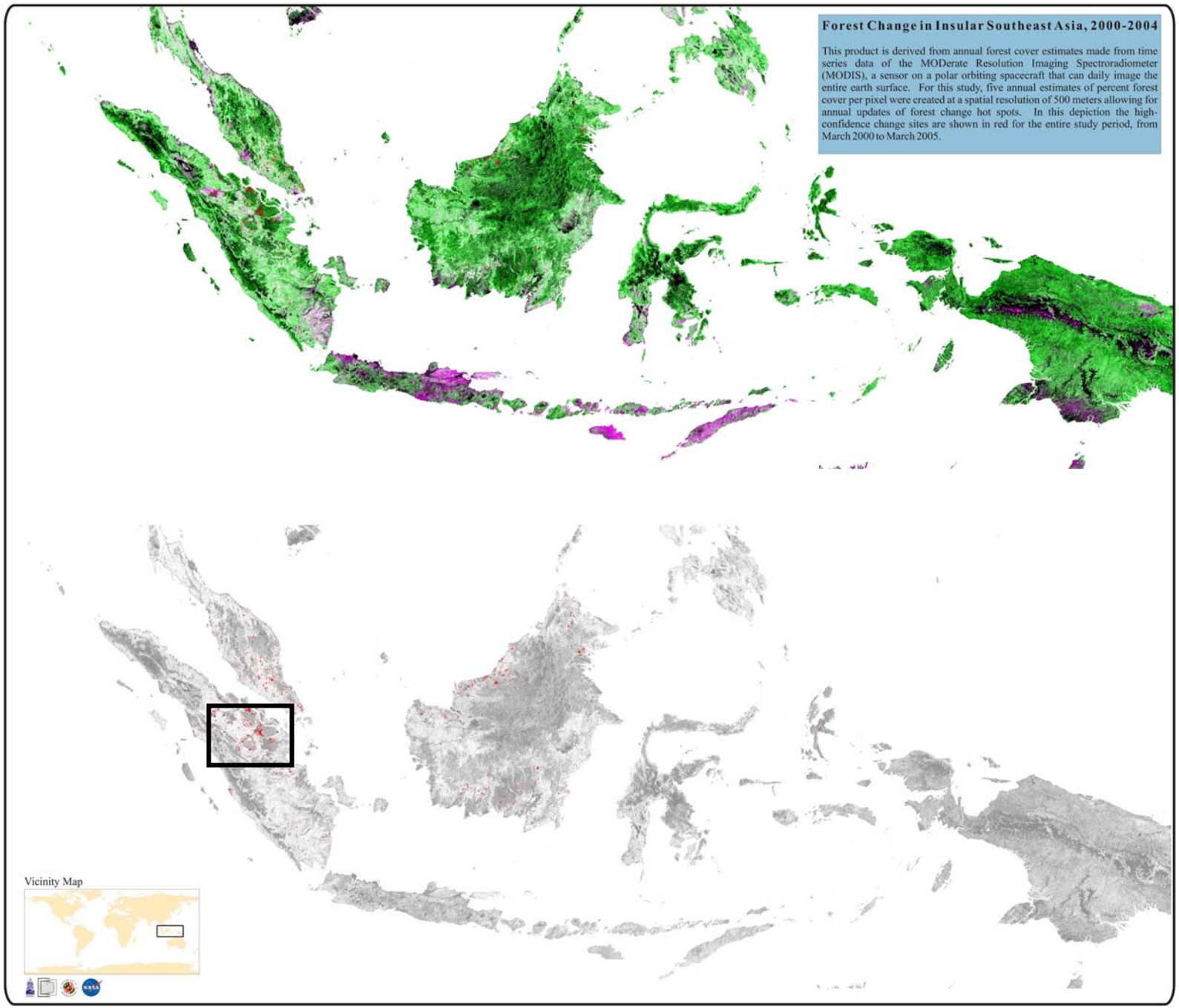

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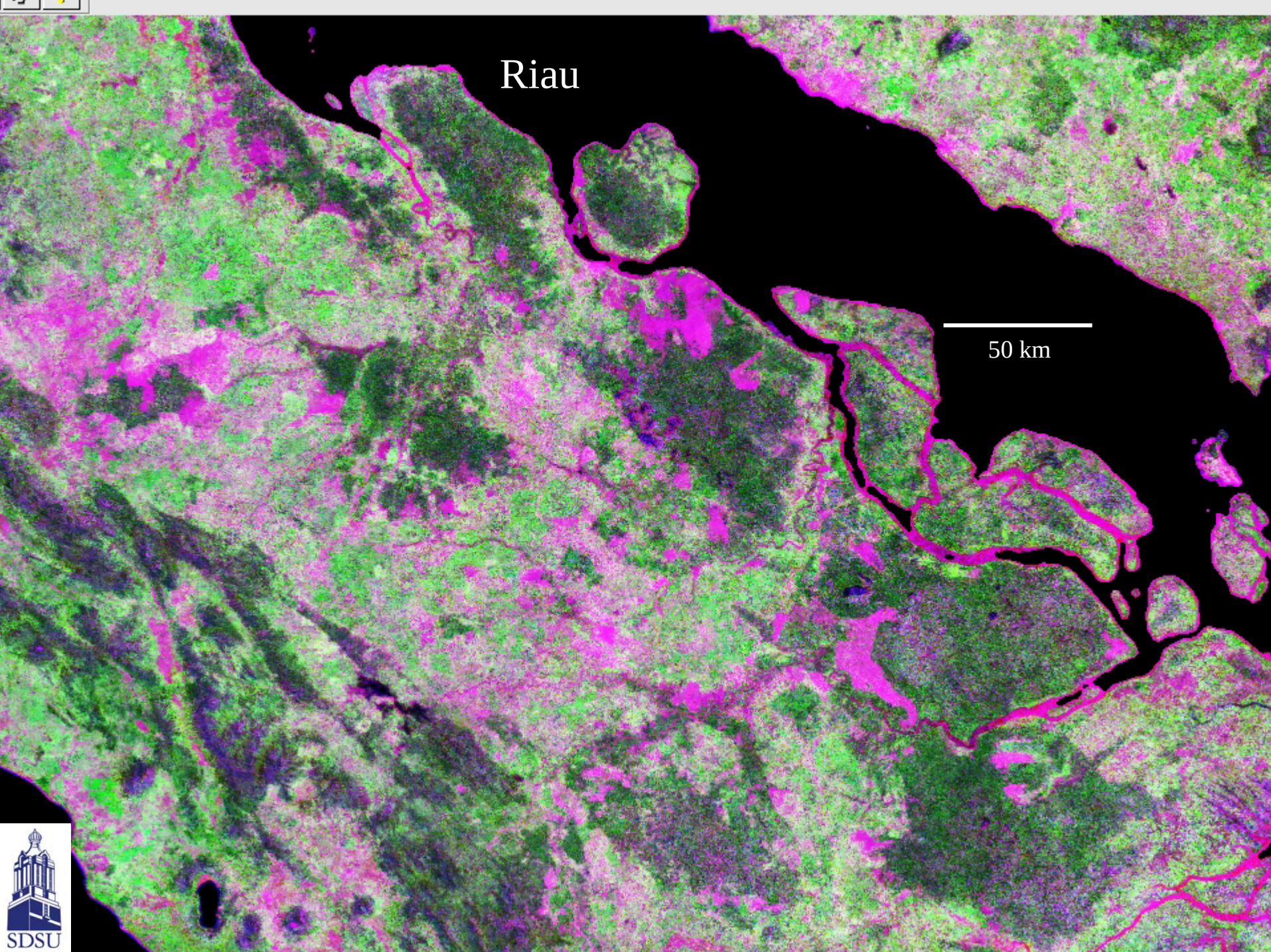
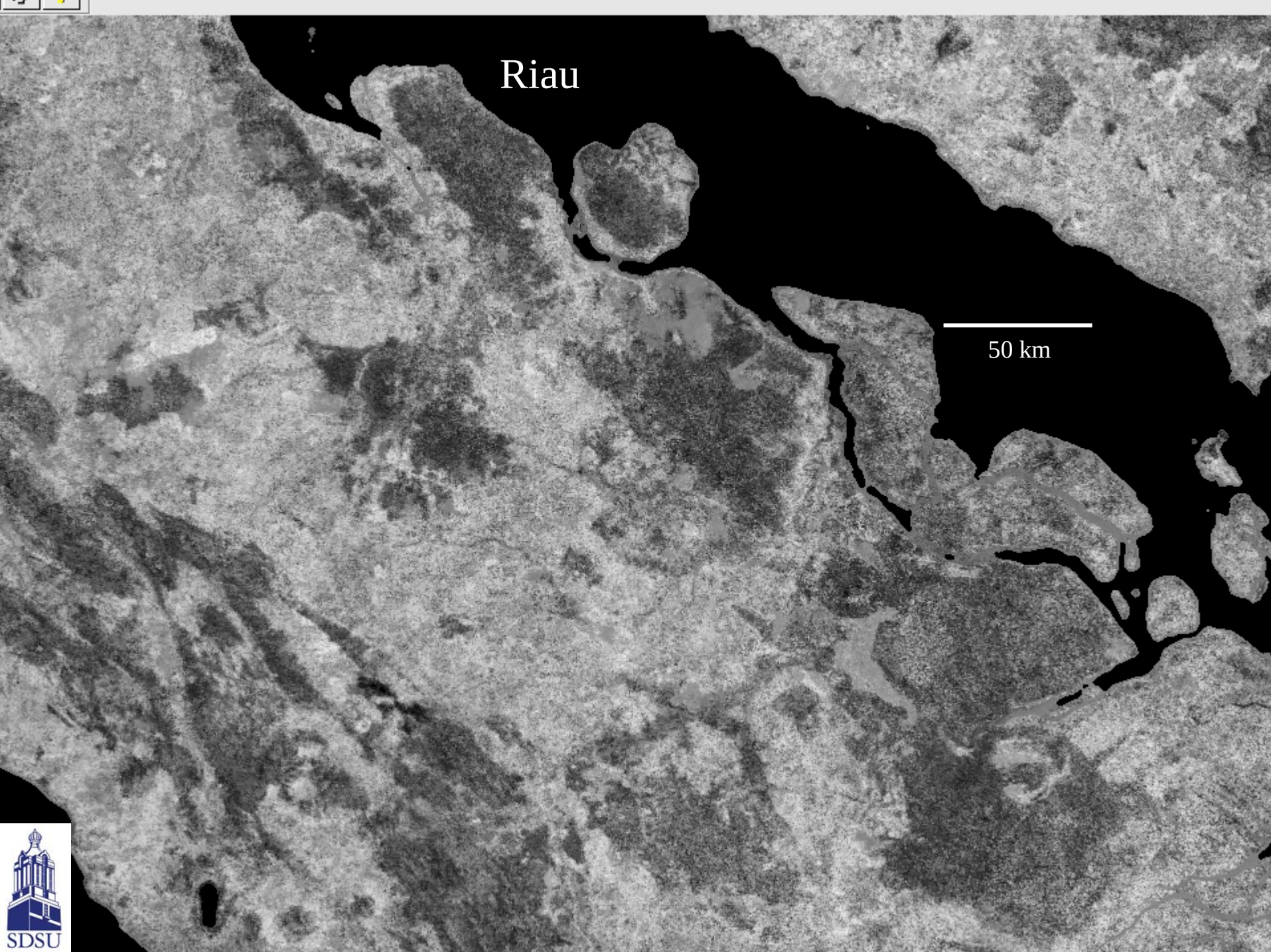
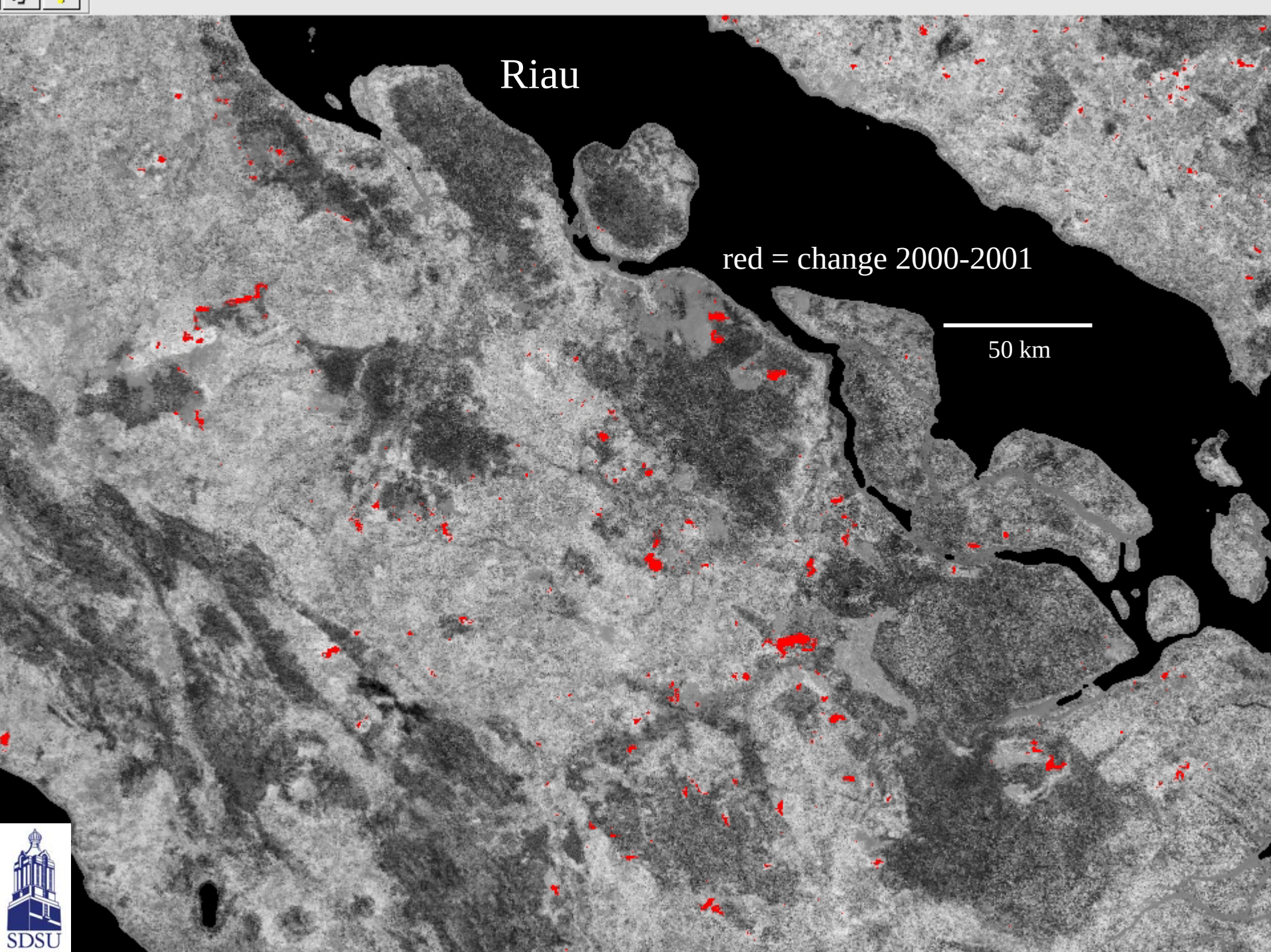
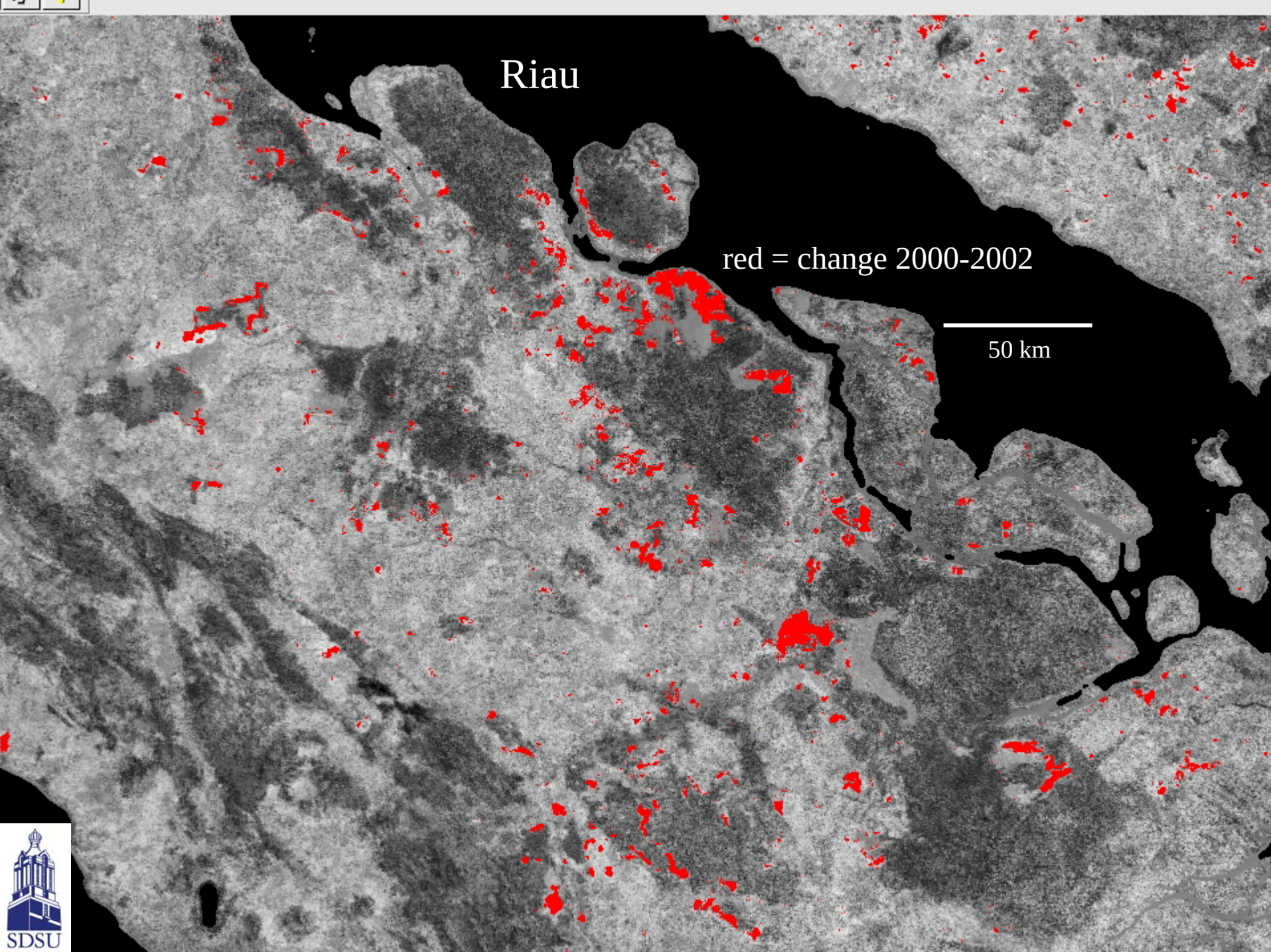
Forest Change in Insular Southeast Asia


Riau
50 km


Riau
50 km


Riau
red = change 2000-2001
50 km


Riau
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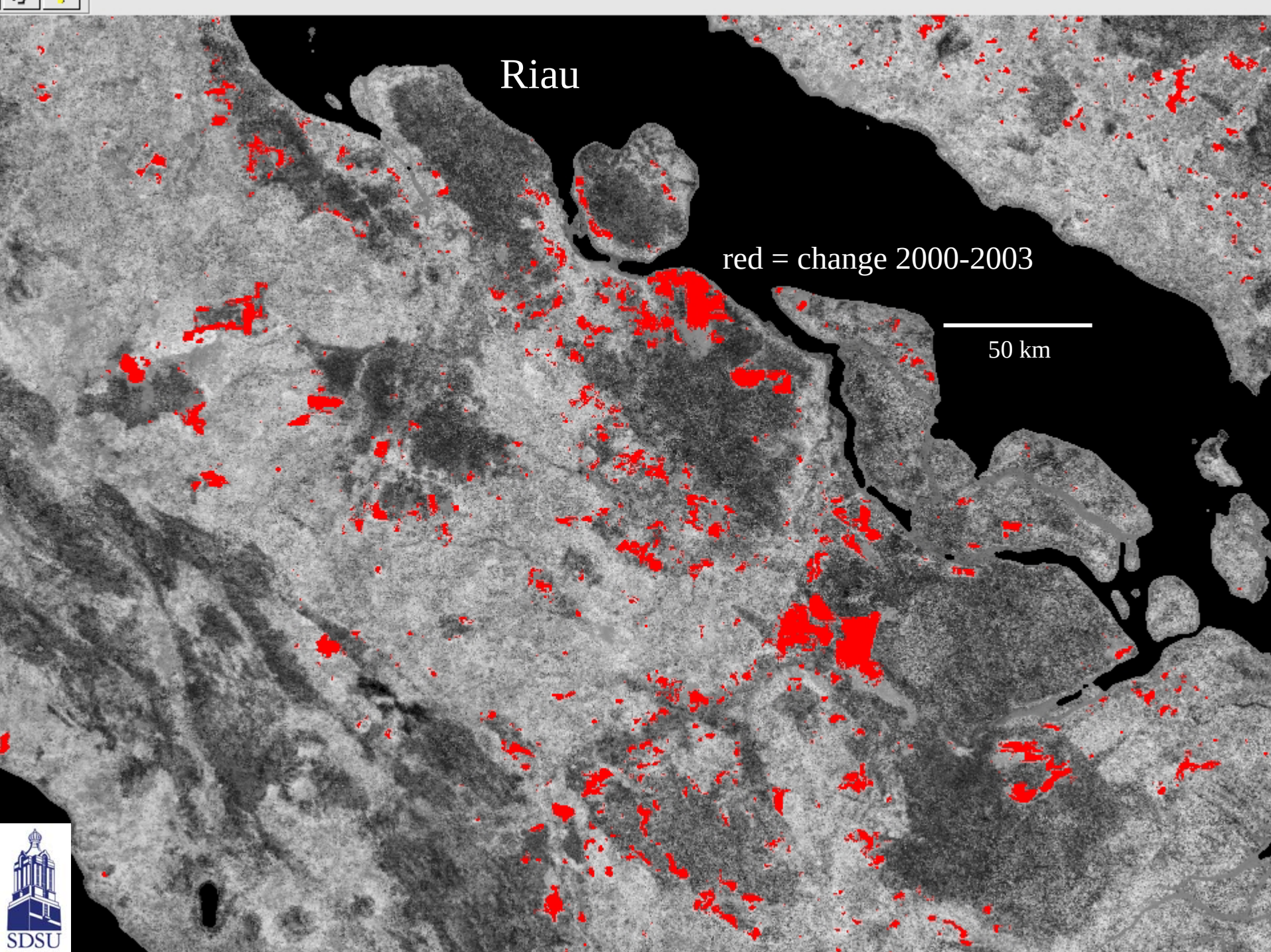
50 km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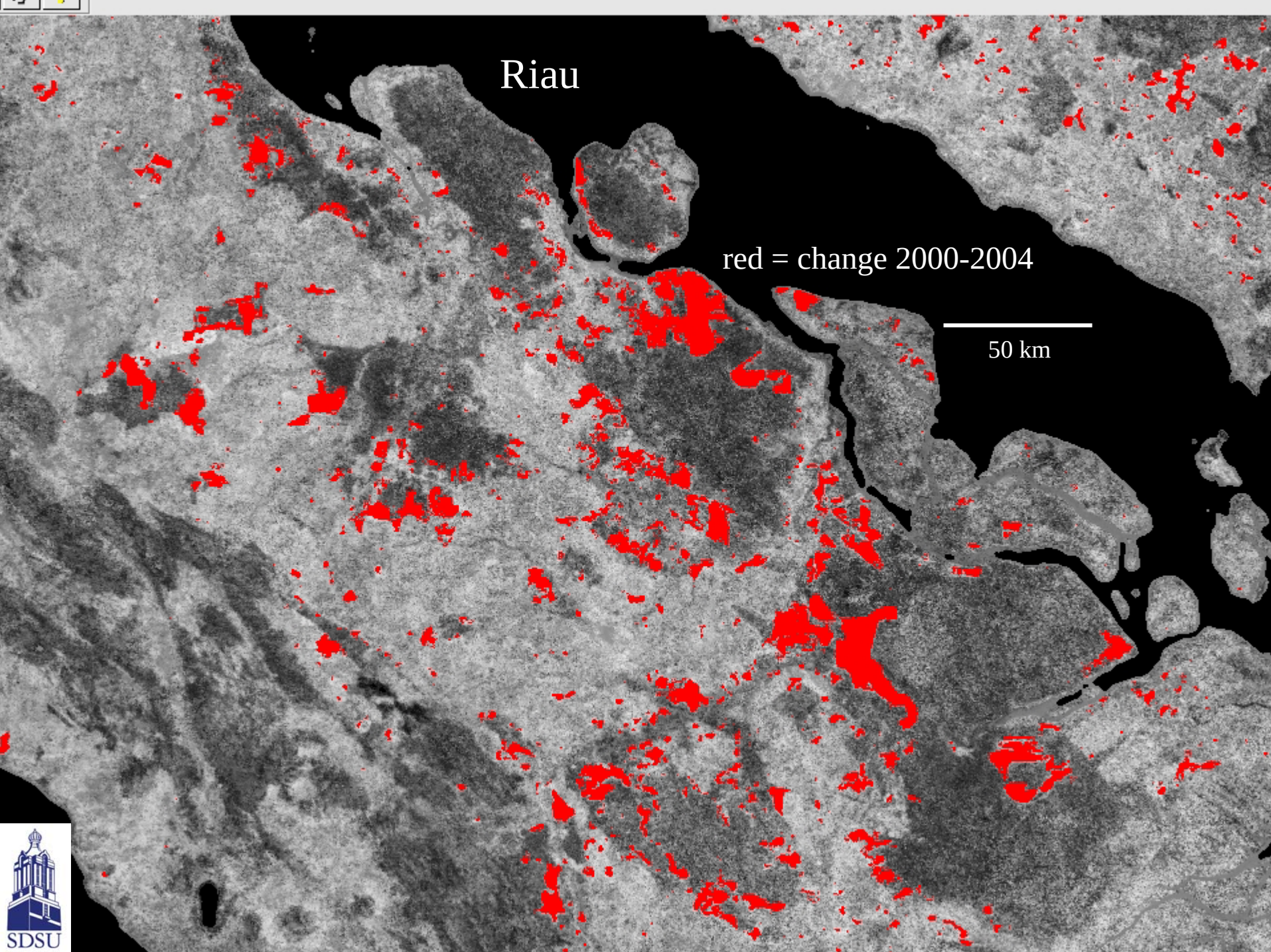
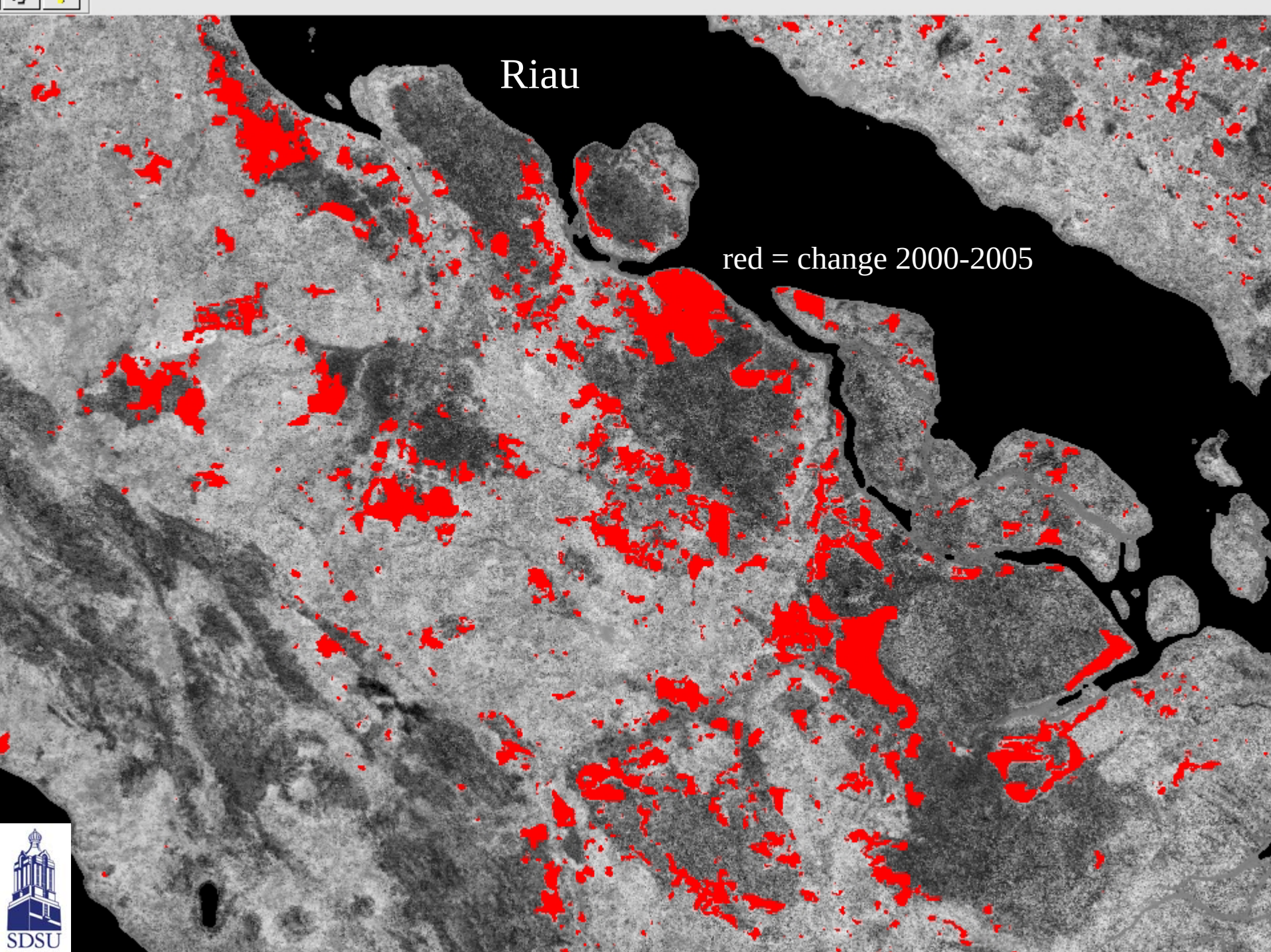
red = change 2000-2003
50 km

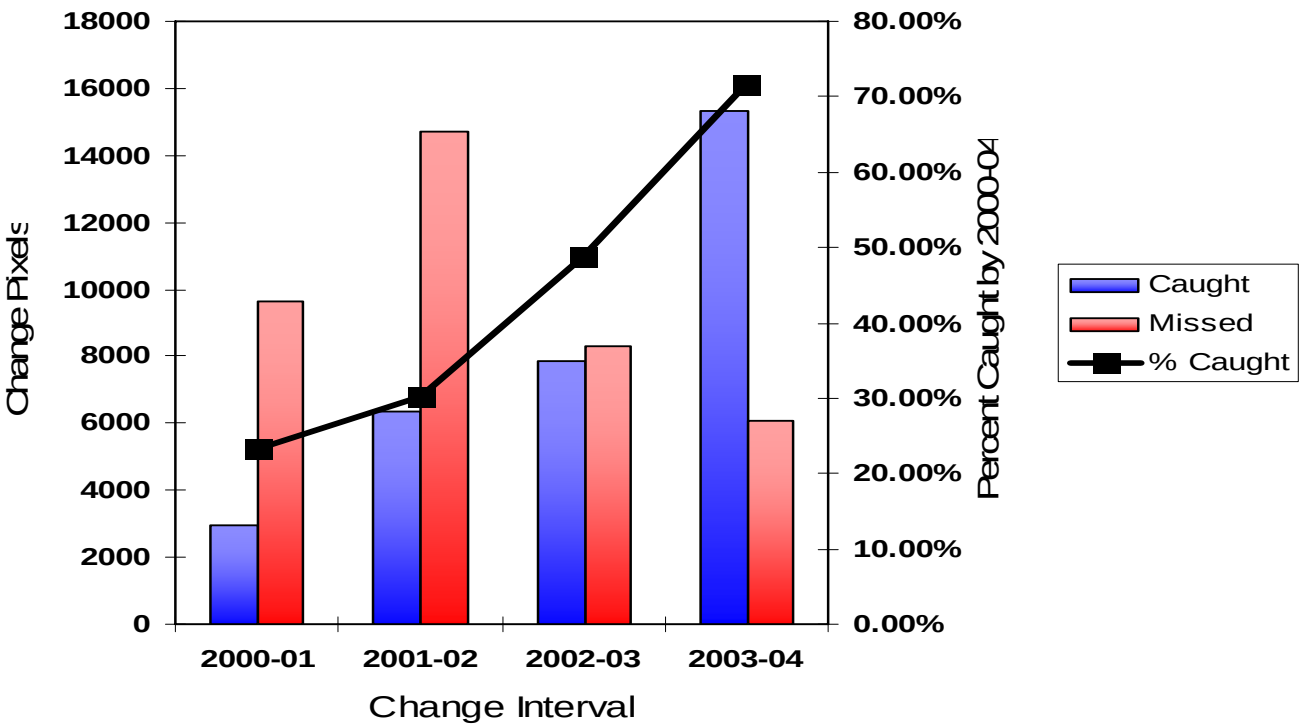

Riau
red = change 2000-2004
50 km


Riau
red = change 2000-2005

Comparison of Annual Change to 5-Year Interval

Change Interval	*Caught by 2000-04*	*Missed by 2000-04*	*% Caught*
2000-01	2942	9639	**23.28%**
2001-02	6335	14704	**30.11%**
2002-03	7871	8296	**48.69%**
2003-04	15299	6080	**71.56%**

Also note: 17,709 pixels (representing 19.9% of all detected change) were caught only by the 2000-04 interval and not caught by any annual interval



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MODIS change indicator map, resampled to 20km by 20km blocks

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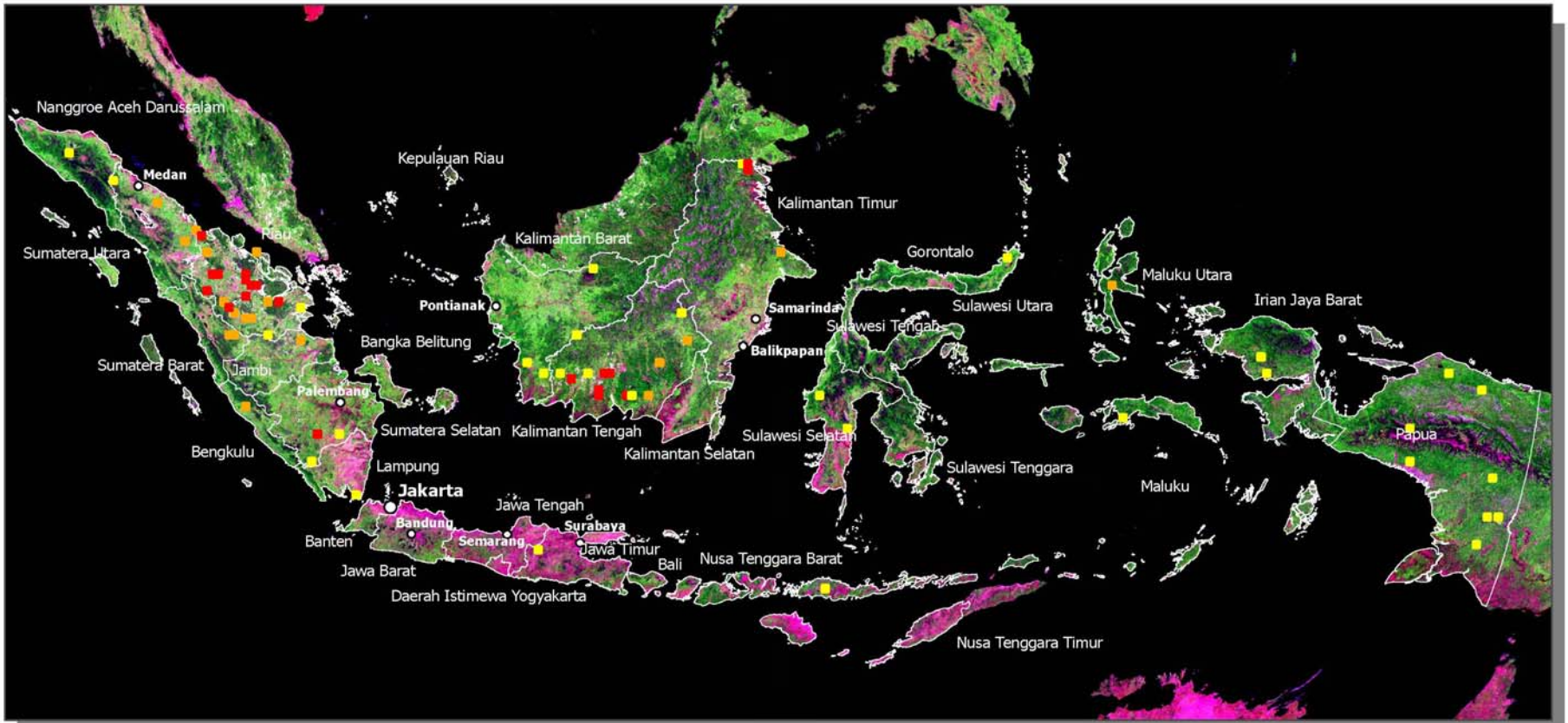
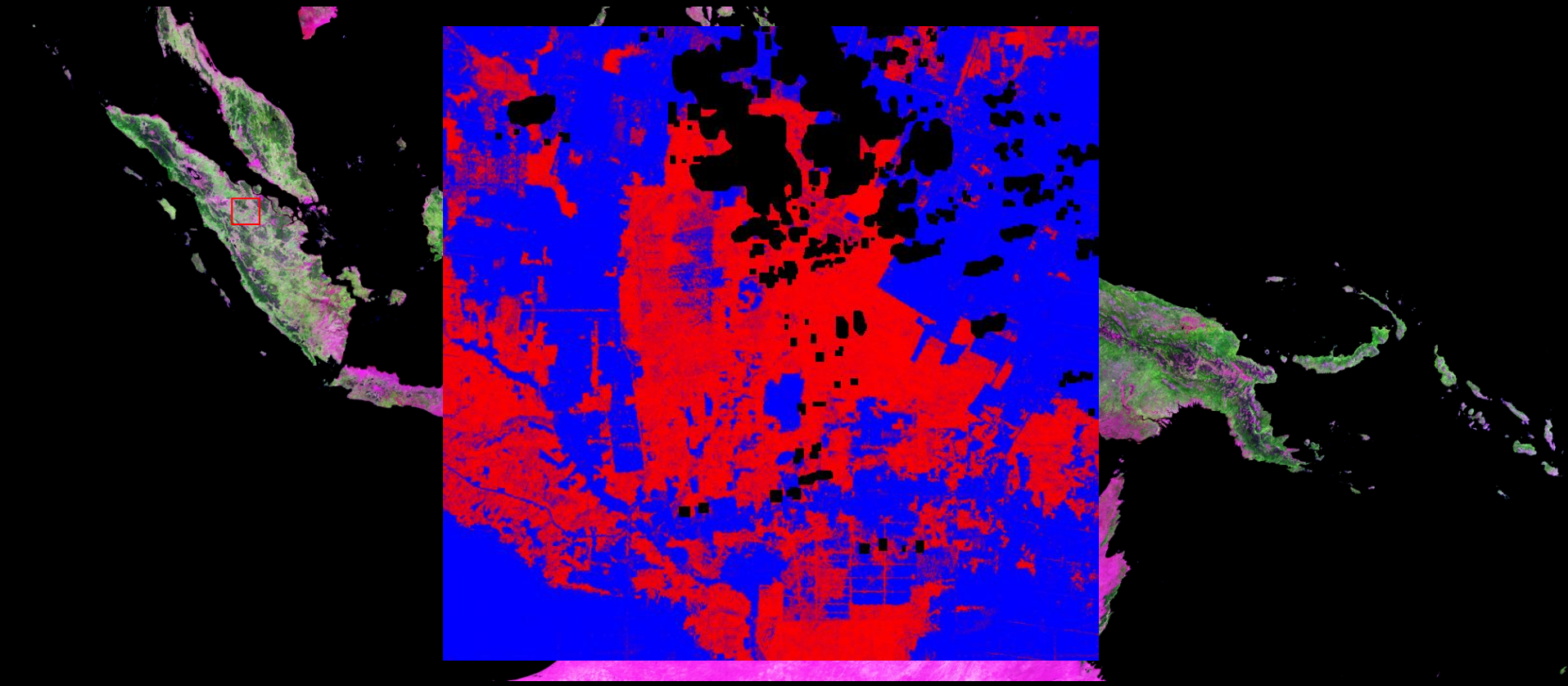
Decrease of forest cover in Indonesia 2000-2005: data verification sample blocks



Verification sample blocks

- Low forest cover change
- Medium forest cover change
- High forest cover change

MODIS analysis – SDSU/SUNY-ESF
Landsat analysis – SDSU/MoF
MODIS pre-processing – NASA/UMd/SDSU
Landsat data provision – USGS/GFW/UMd
Indonesia land cover – MoF



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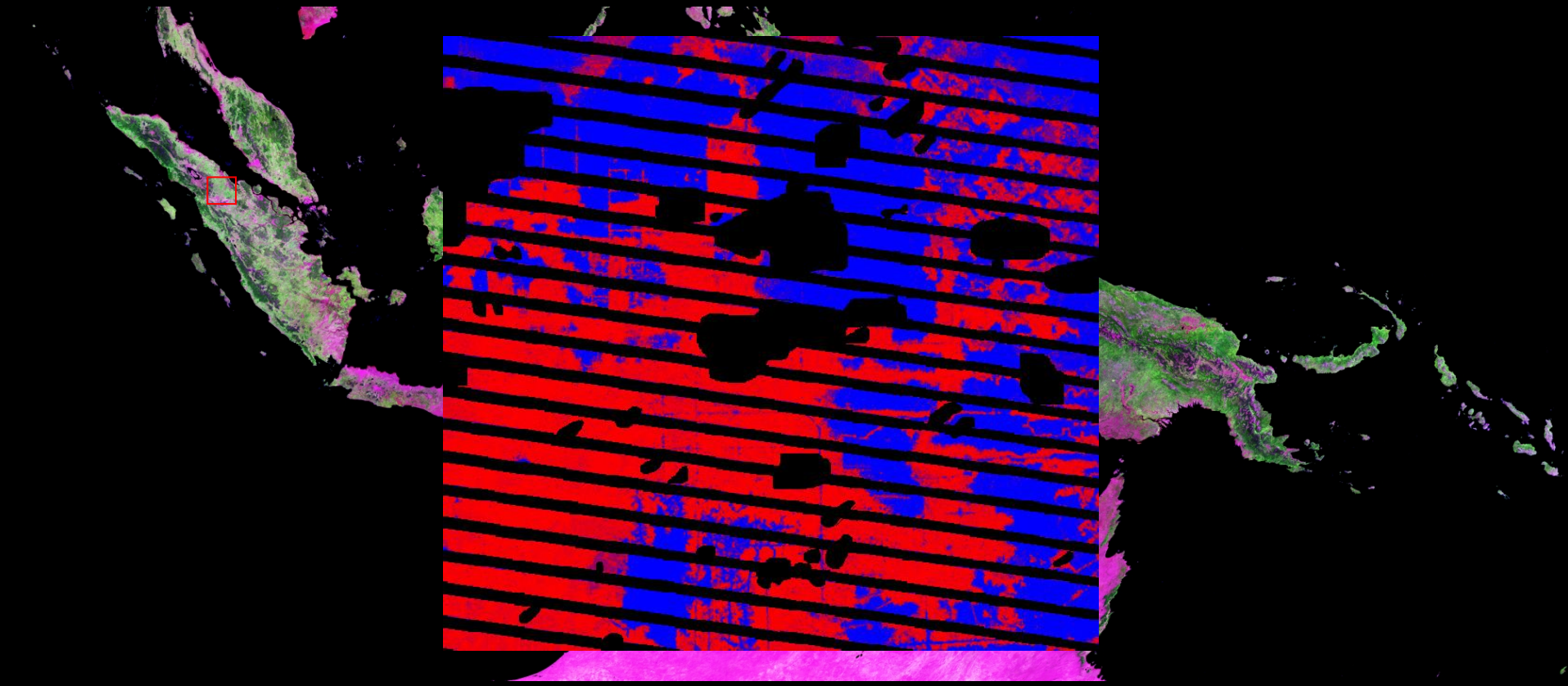

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Indonesia results

Overall estimated change is 1.70% with SE of 0.16%, ~0.8 million hectares per year
95% confidence interval for change is 1.38% to 2.02%

Per stratum standard errors for estimated change from Indonesia sample without and with regression estimator

Stratum	Without	With	N
0-2%	0.18	0.16	5273
3-9	1.69	1.51	186
10+	3.49	1.96	70
Overall	0.18	0.16	

Regression estimator advantageous within each stratum

Simple random sampling would require 5.76 times as many blocks as stratified design to achieve same standard error - 449 blocks for simple random sampling to match standard error of 88 blocks for stratified design

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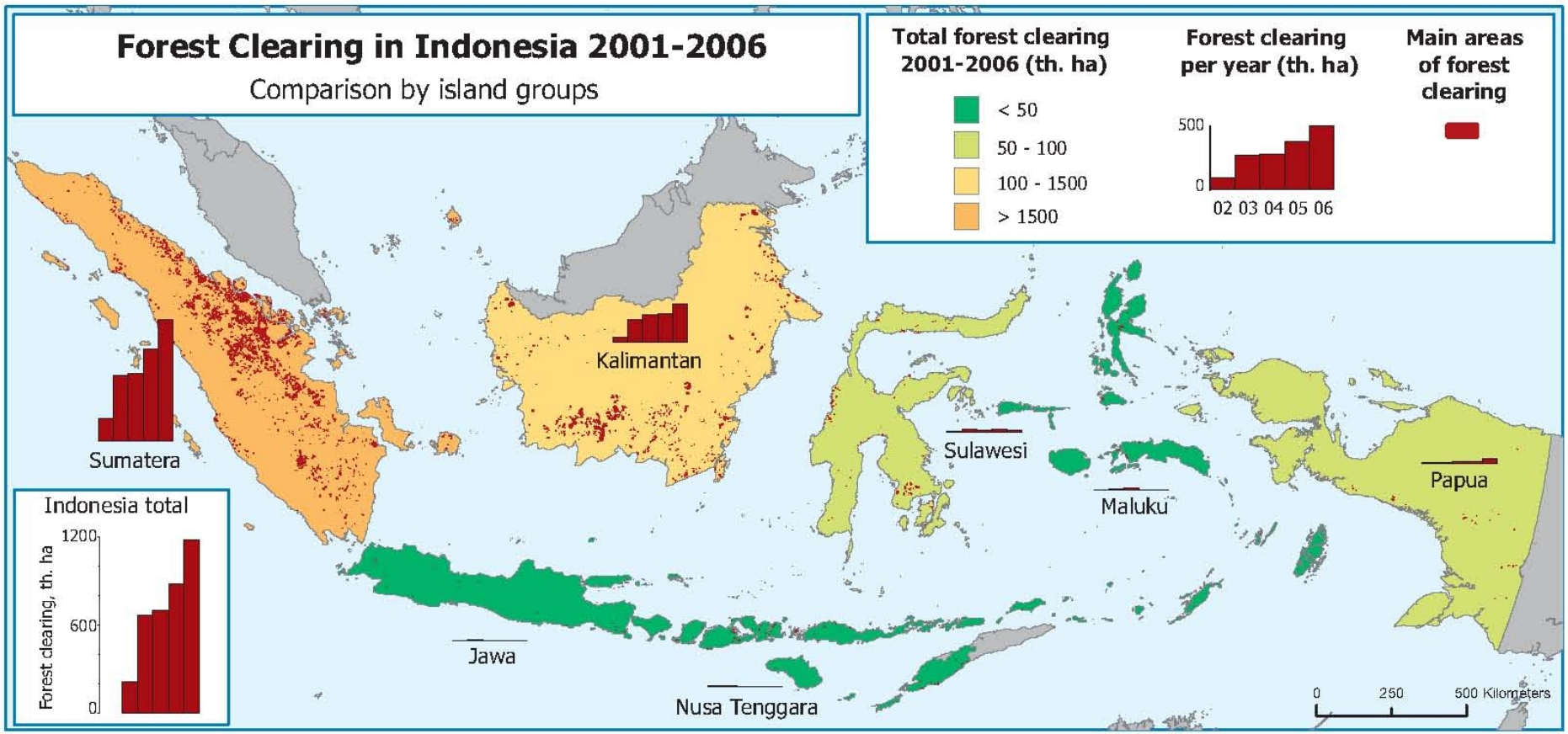
Forest Clearing in Indonesia 2001-2006
Comparison by island groups
Total forest clearing 2001-2006 (th. ha)
< 50
50 - 100
100 - 1500
> 1500
Forest clearing per year (th. ha)
500
0
02 03 04 05 06
Main areas of forest clearing
Sumatera
Kalimantan
Sulawesi
Maluku
Papua
Jawa
Nusa Tenggara
Indonesia total
Forest clearing, th. ha
1200
600
0
0
250
500 Kilometers

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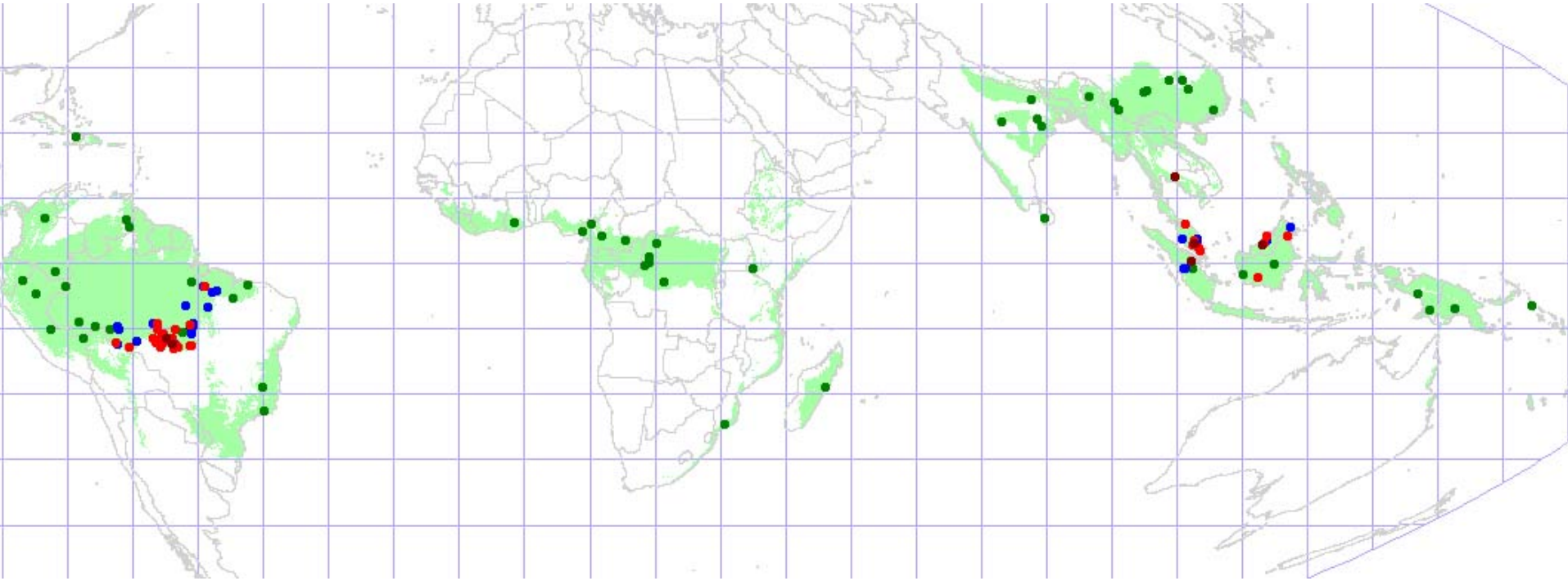
Humid tropical forest biome Landsat samples



Stratum 1
Stratum 2
Stratum 3
Stratum 4

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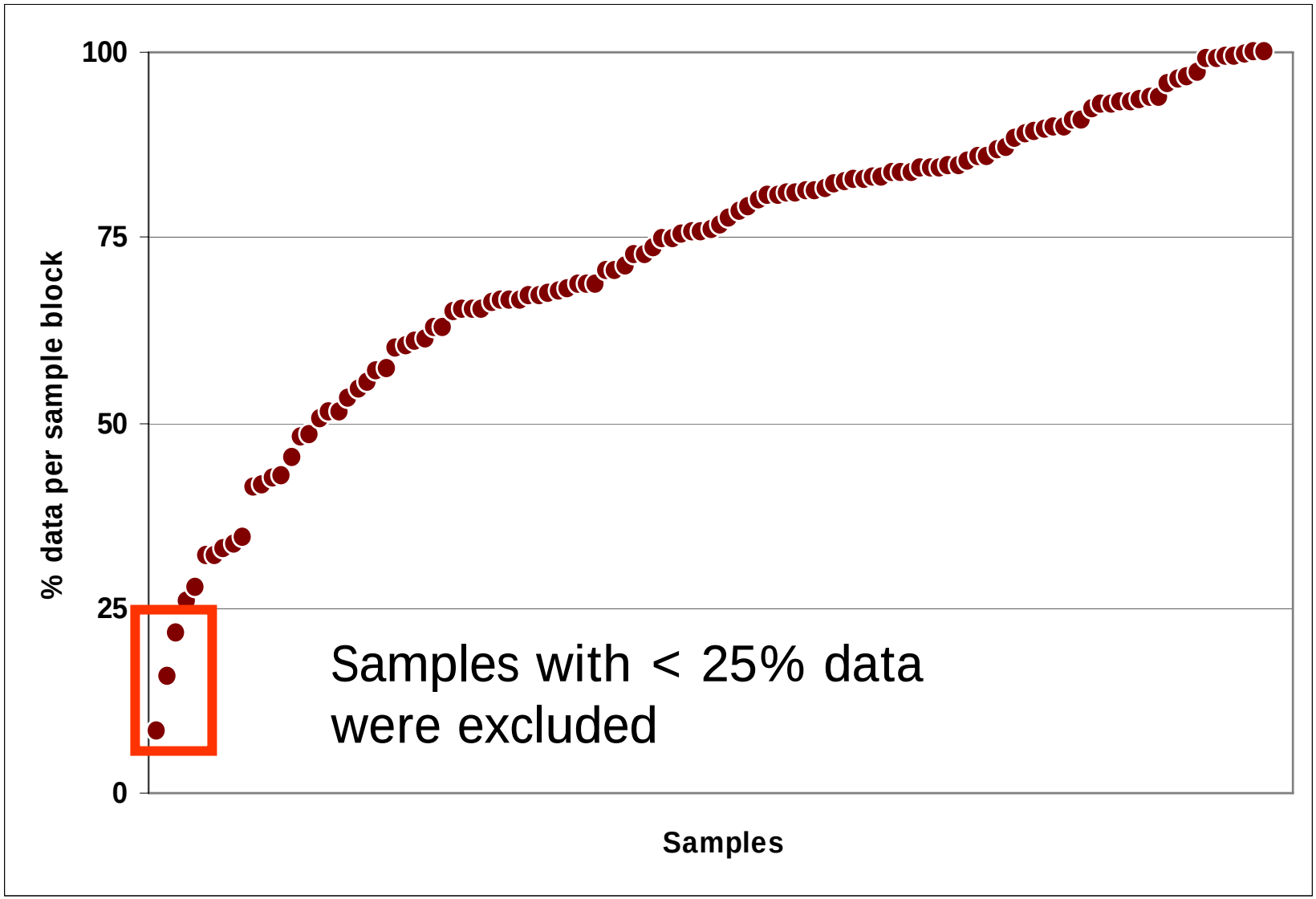
Clouds and slc-off gaps per sample block



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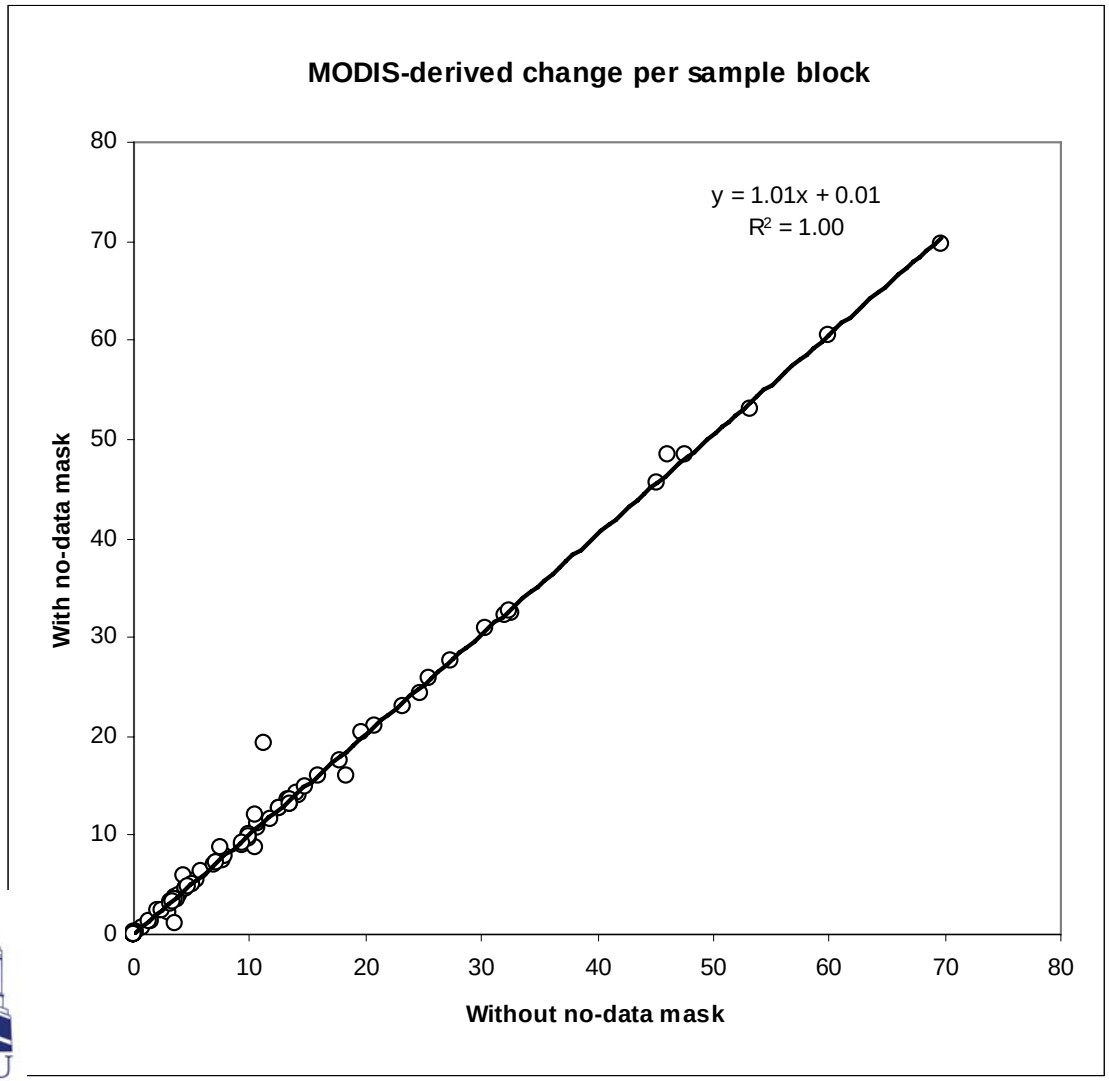
Comparison of MODIS change estimates within sample blocks with and without bad data masking



Conclusion: clouds and bad lines masking have no significant effect on % change per block estimations

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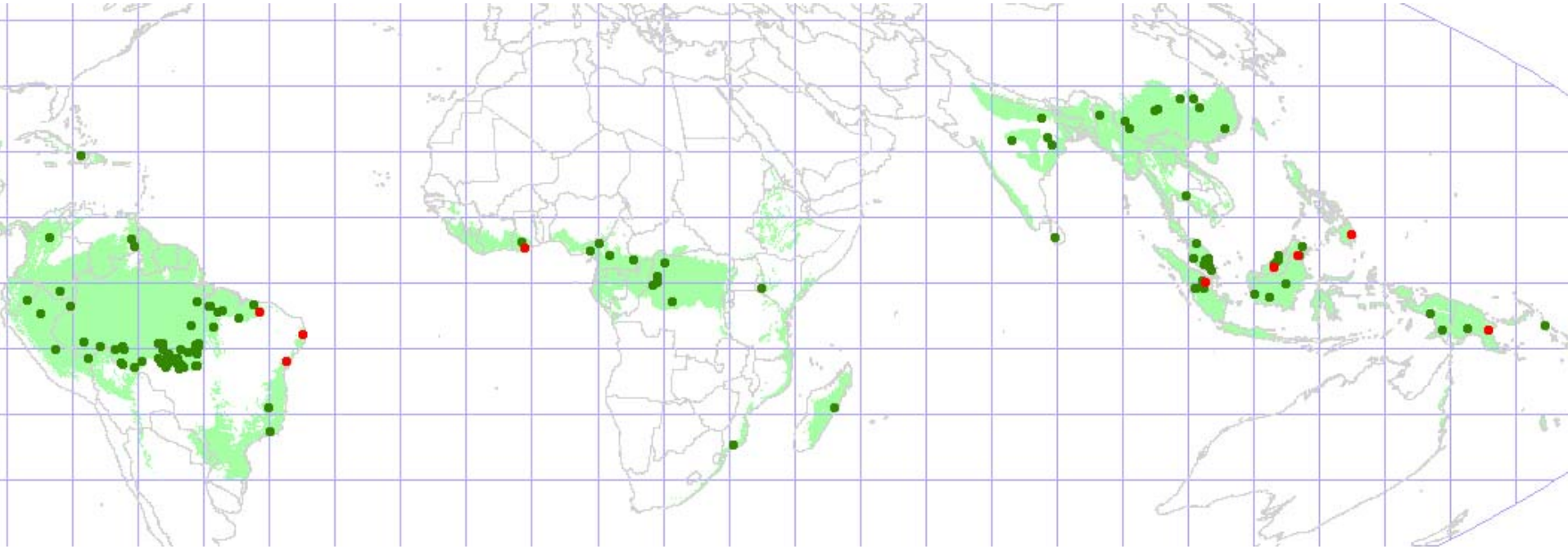
Humid tropical forest biome Landsat samples



Deleted samples (red)

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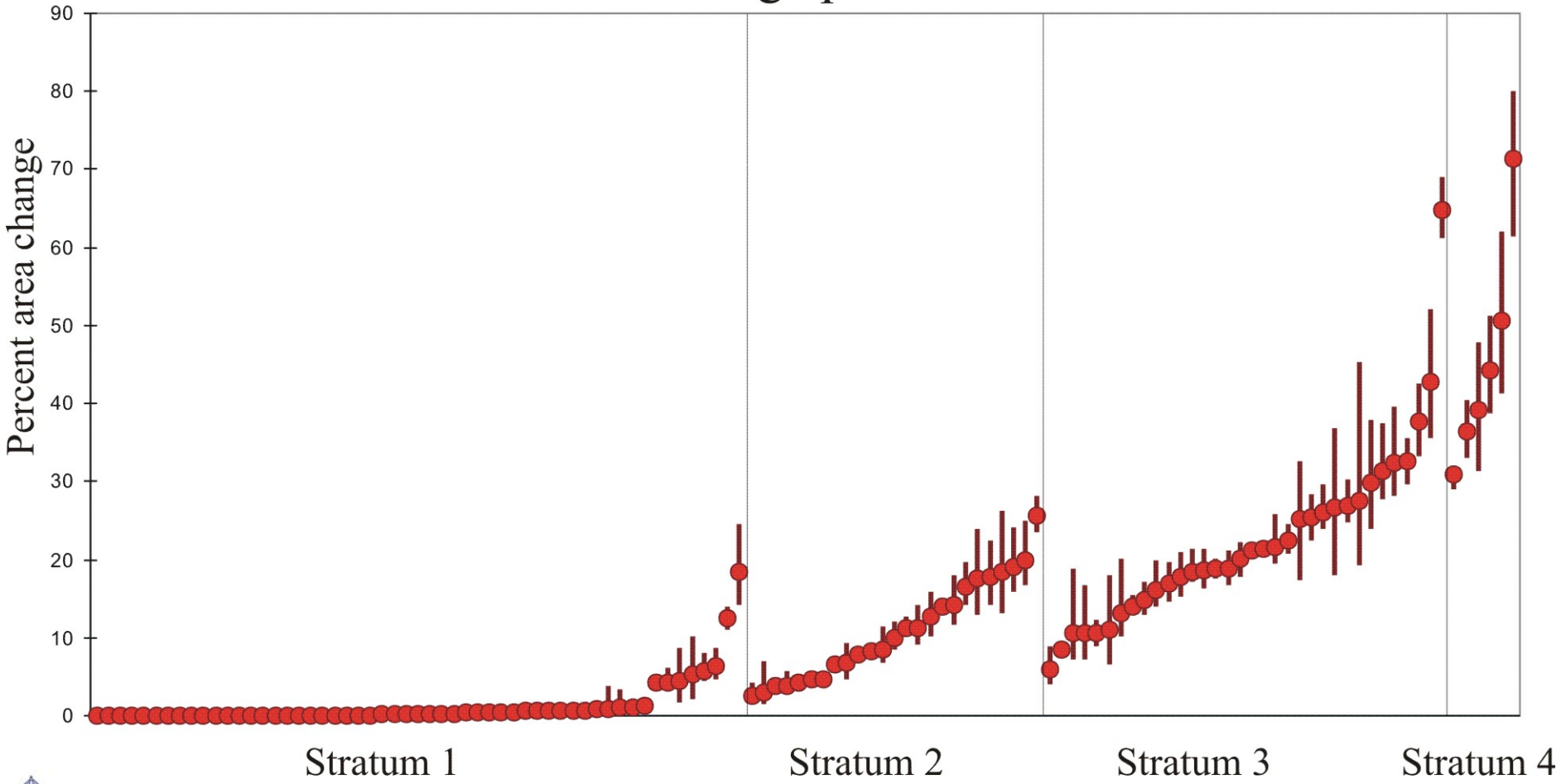
Humid tropical forest biome - Landsat estimated change per MODIS strata



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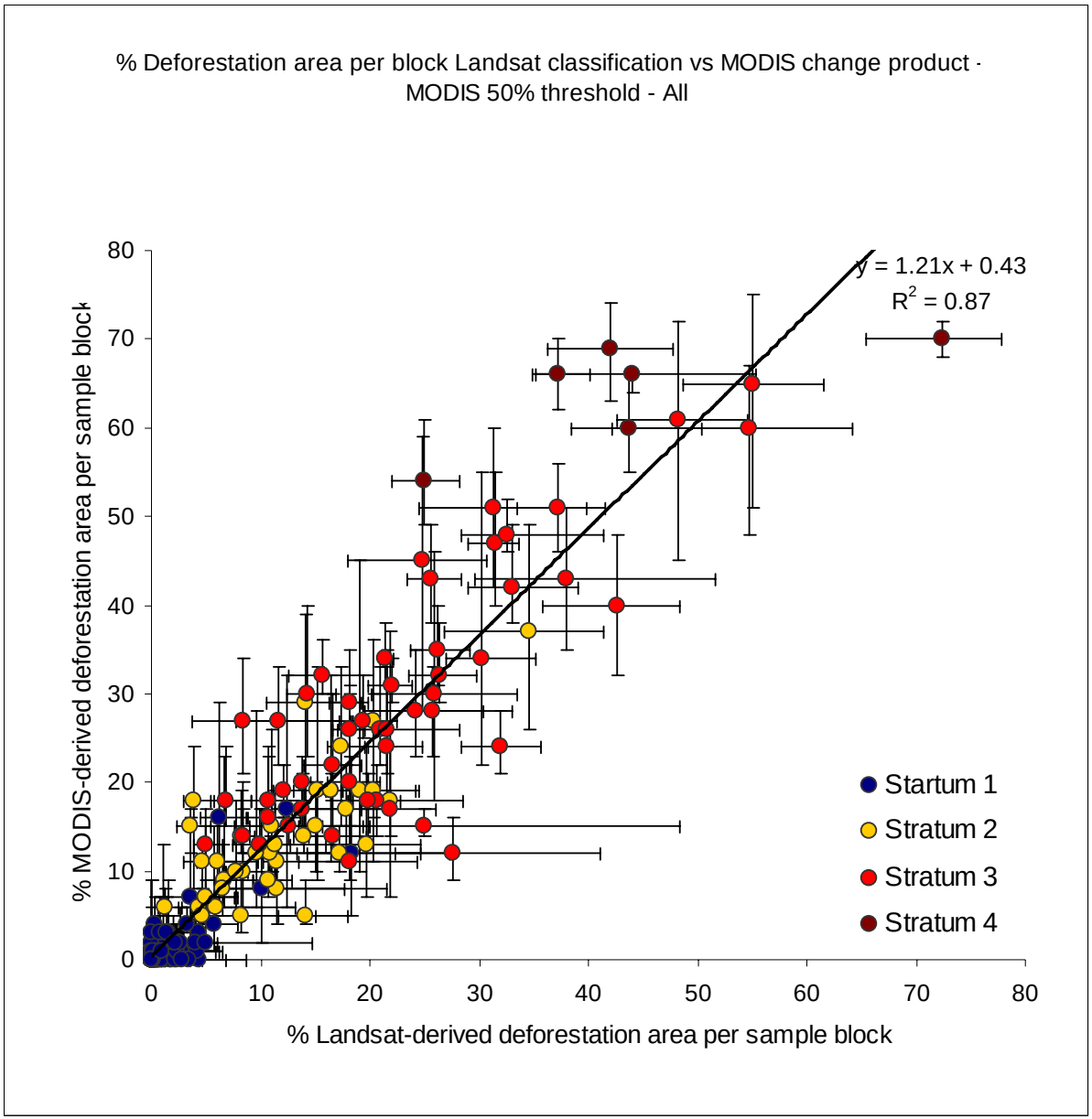
Comparison and aggregation of Indonesian and Pan-Tropical results

Landsat change vs MODIS change estimates using 50% likelihood threshold



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Humid tropical forest cover loss – preliminary results

- 5.59 million hectares per year for humid tropical forest biome (1.36% of biome +/- 0.16%)
- This value does not include dry tropical regions such as the chaco and cerrado of South America
- Accordingly, the overall tropical change estimate will be higher
- May indicate an increase in forest loss compared to the 90's, as opposed to the decreases described by FAO/FRA

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Comparison of net tree cover change of 8km and FAO Forest Resource Assessment data for 1980-2000.

	8km annual change estimate in 1000's of ha/yr		FRA annual change estimate in 1000's of ha/yr	
	80-90	90-00	80-90	90-00
Latin America	-4033 (-3746 to -4497)	-3909 (-3924 to -3883)	-7407	-4669
Tropical Africa	131 (-11 to 838)	53 (-4 to 450)	-4164	-5296
Tropical Asia	-1459 (-1450 to -1099)	-2307 (-2219 to -1913)	-1926	-2347
Developed Pacific	-64 (-28 to 1)	-13 (-2 to -74)	-126	-367
North America	-160 (-123 to -565)	-616 (-301 to -1054)	317	388
Europe	1106 (345 to 2259)	878 (225 to 1857)	191	427
North Africa & Middle East	25 (-7 to 116)	7 (-25 to 105)	-115	60
Former Soviet Union	-951 (-1176 to 571)	-1188 (-1185 to -252)	51	740
China and Mongolia	-257 (-101 to -966)	-342 (-159 to -774)	-400	1746
Total change	-5662 (-6296 to -3342)	-7437 (-7597 to -5539)	-13579	-9318
Percent difference in rate of change in forest cover	+31% (+21% to +66%)		-31%	

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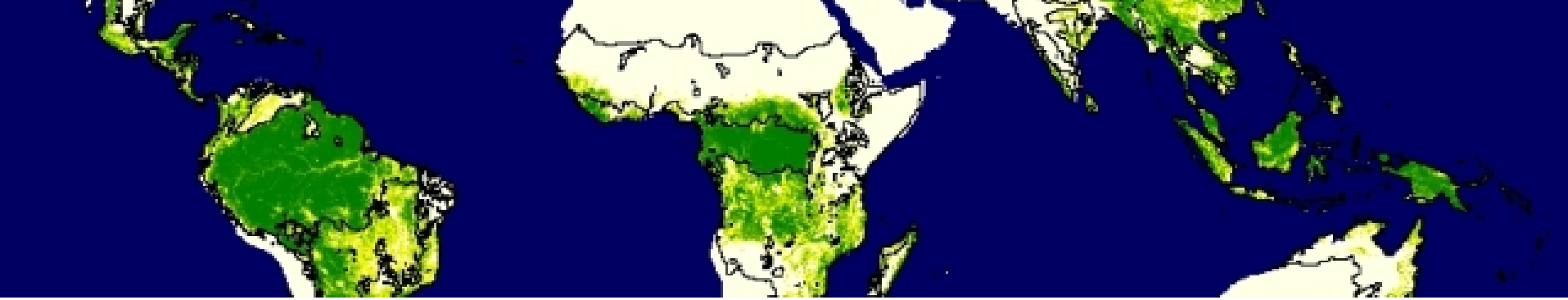

Tree canopy loss as a proportion of total global biome change estimate

- Brazil – 39%
- Indonesia – 15%
- Malaysia – 9%
- China – 4%
- Myanmar – 3%
- Paraguay – 2%
- Thailand – 2%

00/01 to 04/05 (preliminary)

Area loss as a proportion of 2000 national total forest cover

- Malaysia – 12%
- Paraguay – 8%
- Cambodia – 6%
- Thailand – 4%
- Indonesia – 3%
- Laos – 2%

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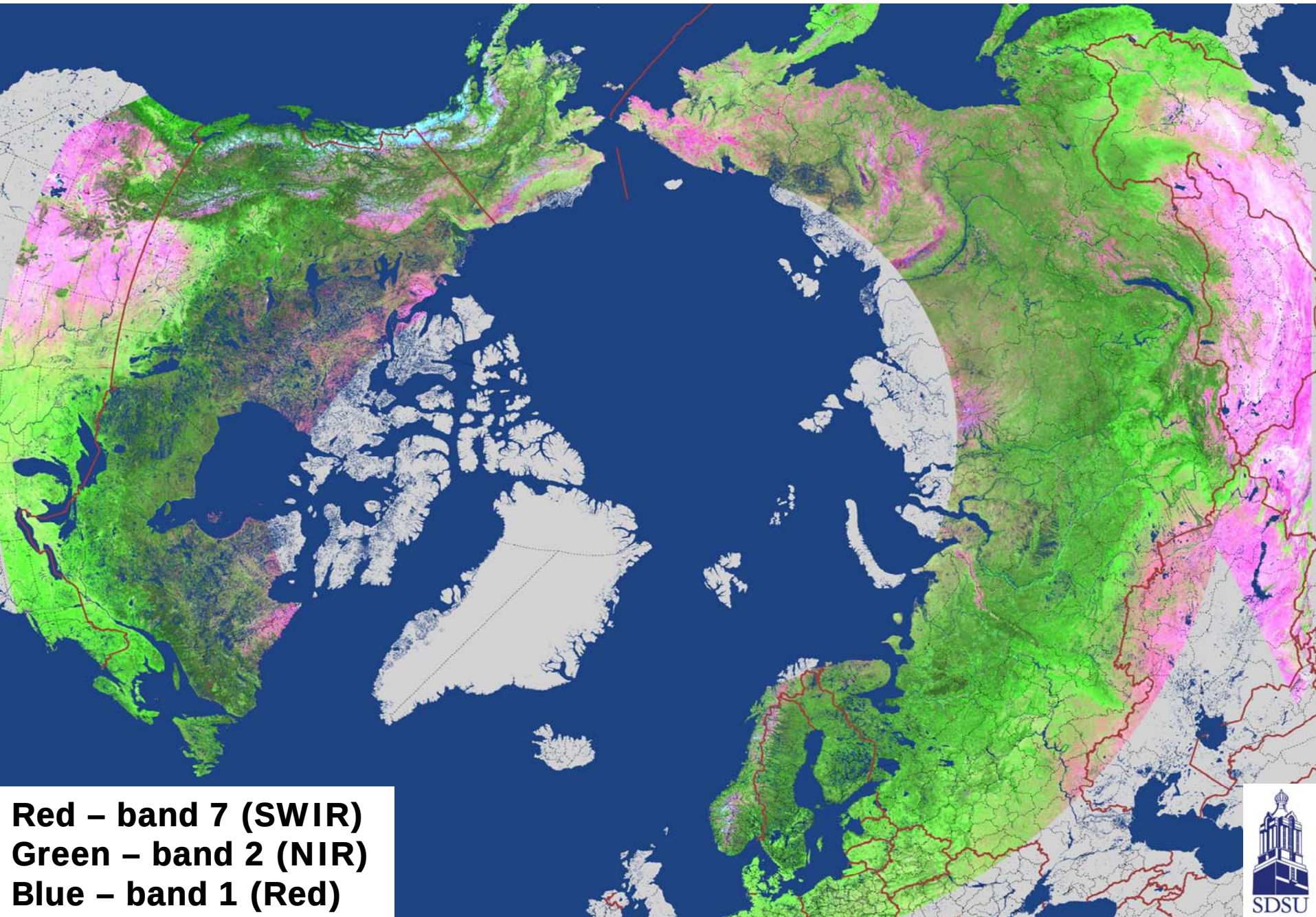
Where forest is defined as 2000 MODIS >=25% tree cover
Shown for countries with more than 100,000 ha of forest

MODIS data from boreal region



Red – band 7 (SWIR)
Green – band 2 (NIR)
Blue – band 1 (Red)

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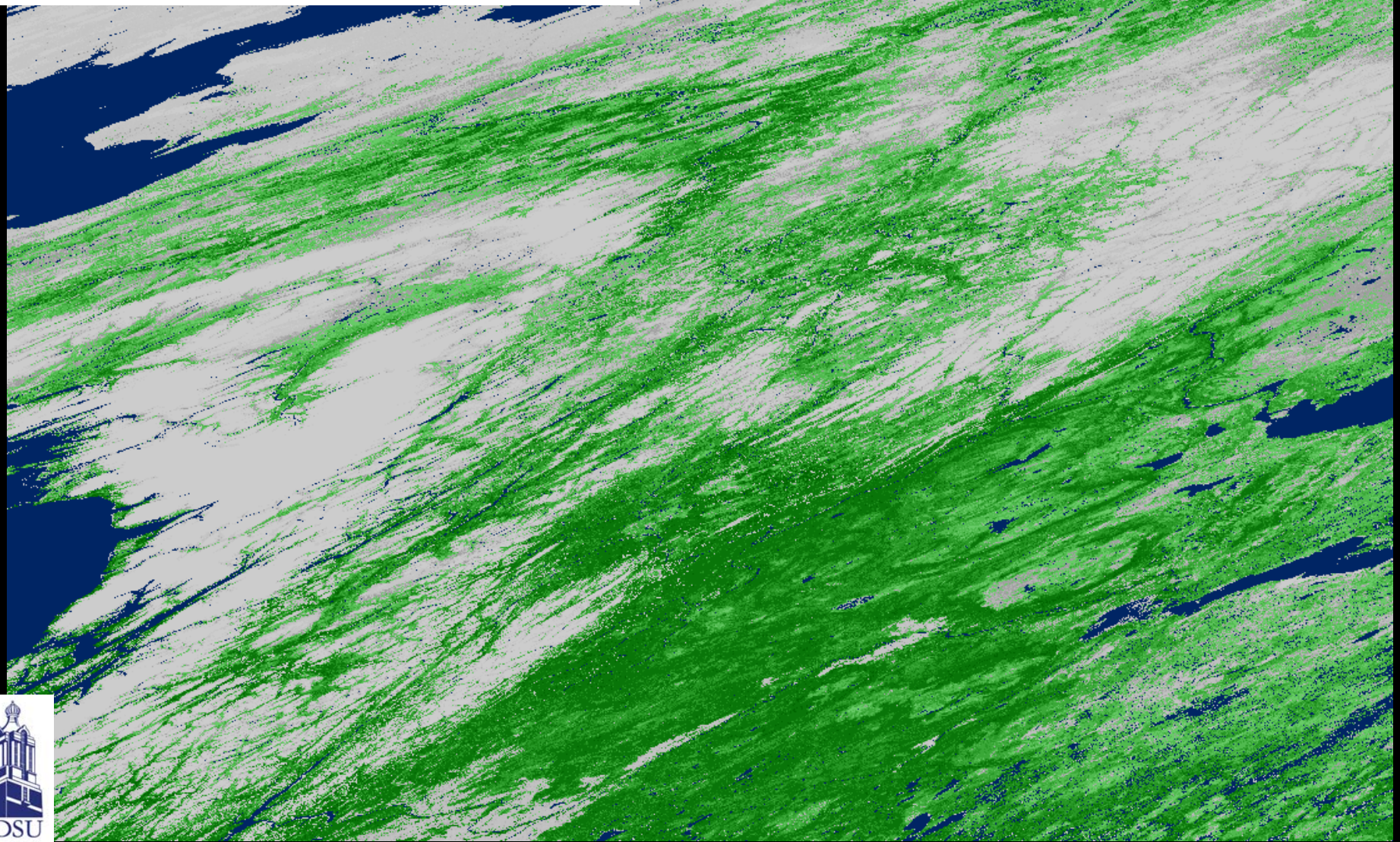
Annual forest canopy loss in Alaska (USA) and Yukon (Canada)

Cumulative areas of forest canopy loss

0% 100% **Tree canopy density***

*from Vegetation Continuous Fields dataset, 2000



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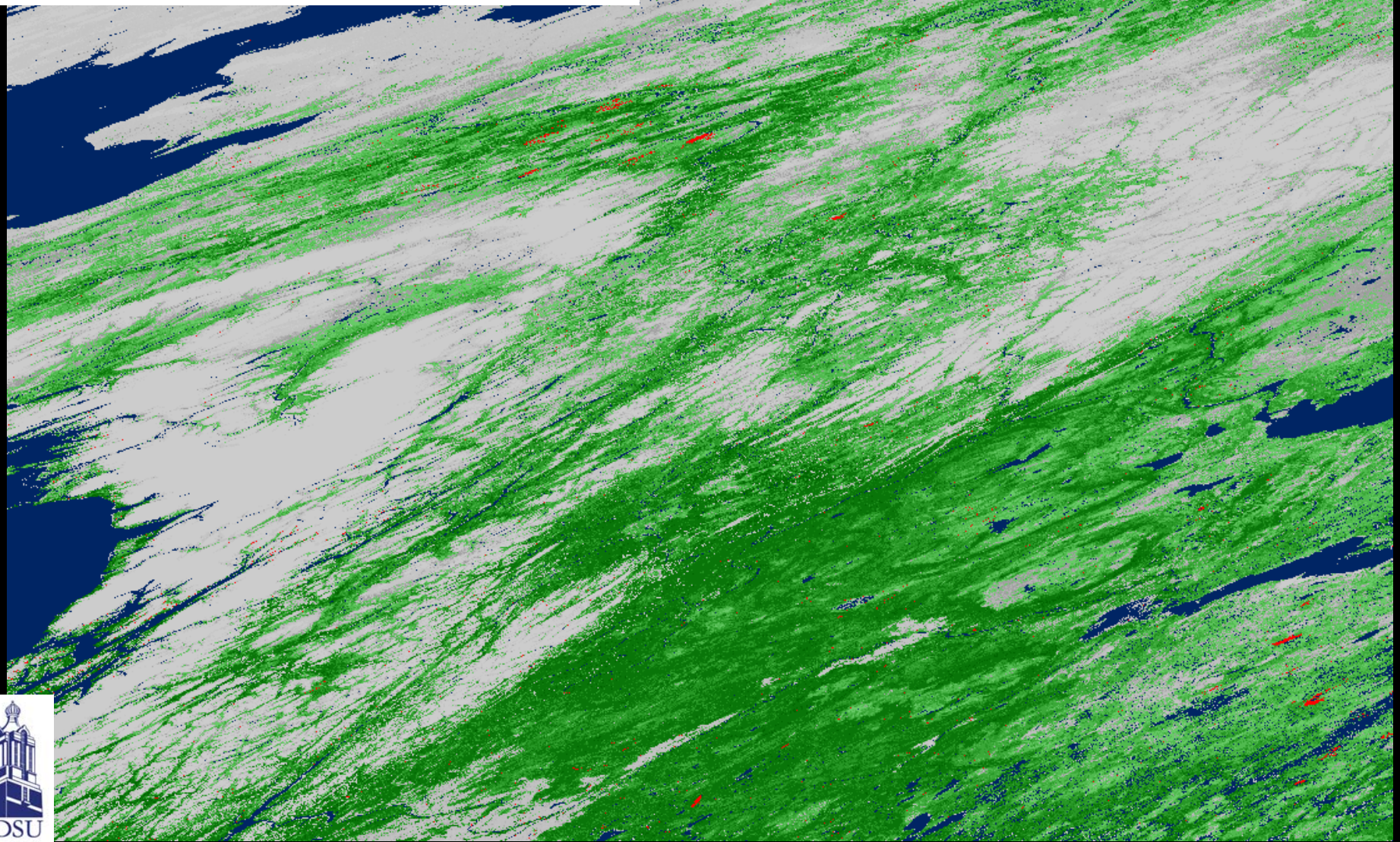

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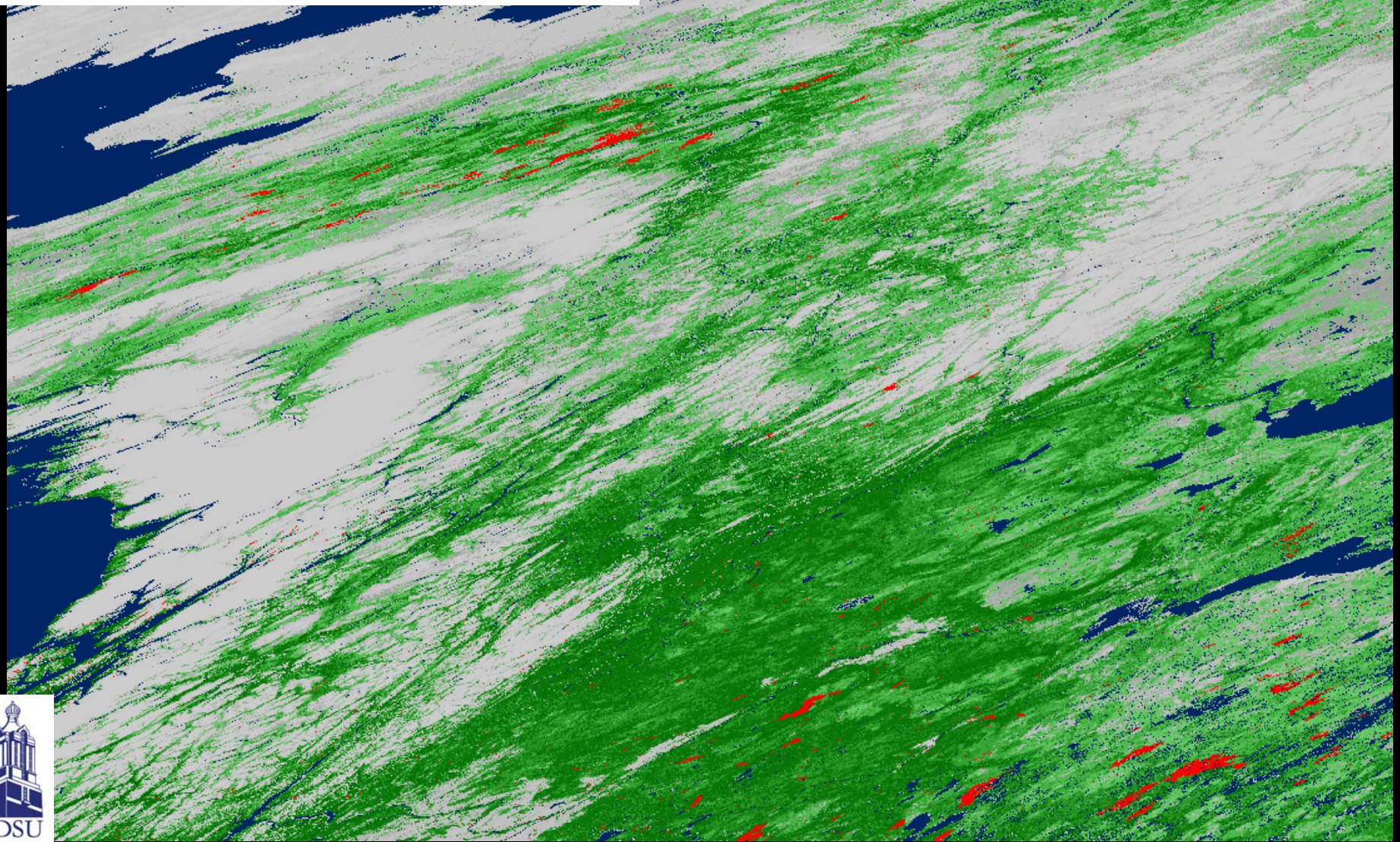

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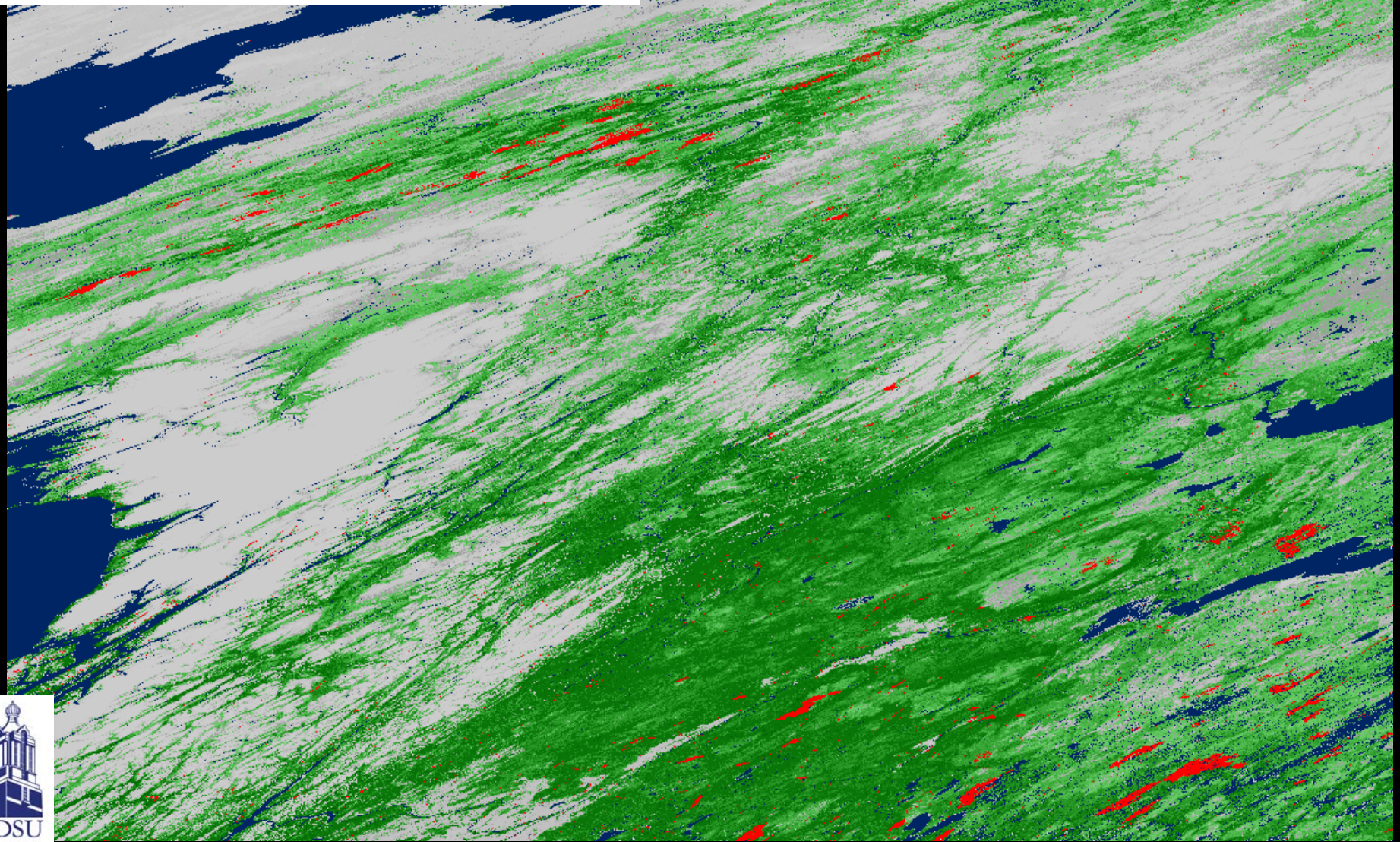

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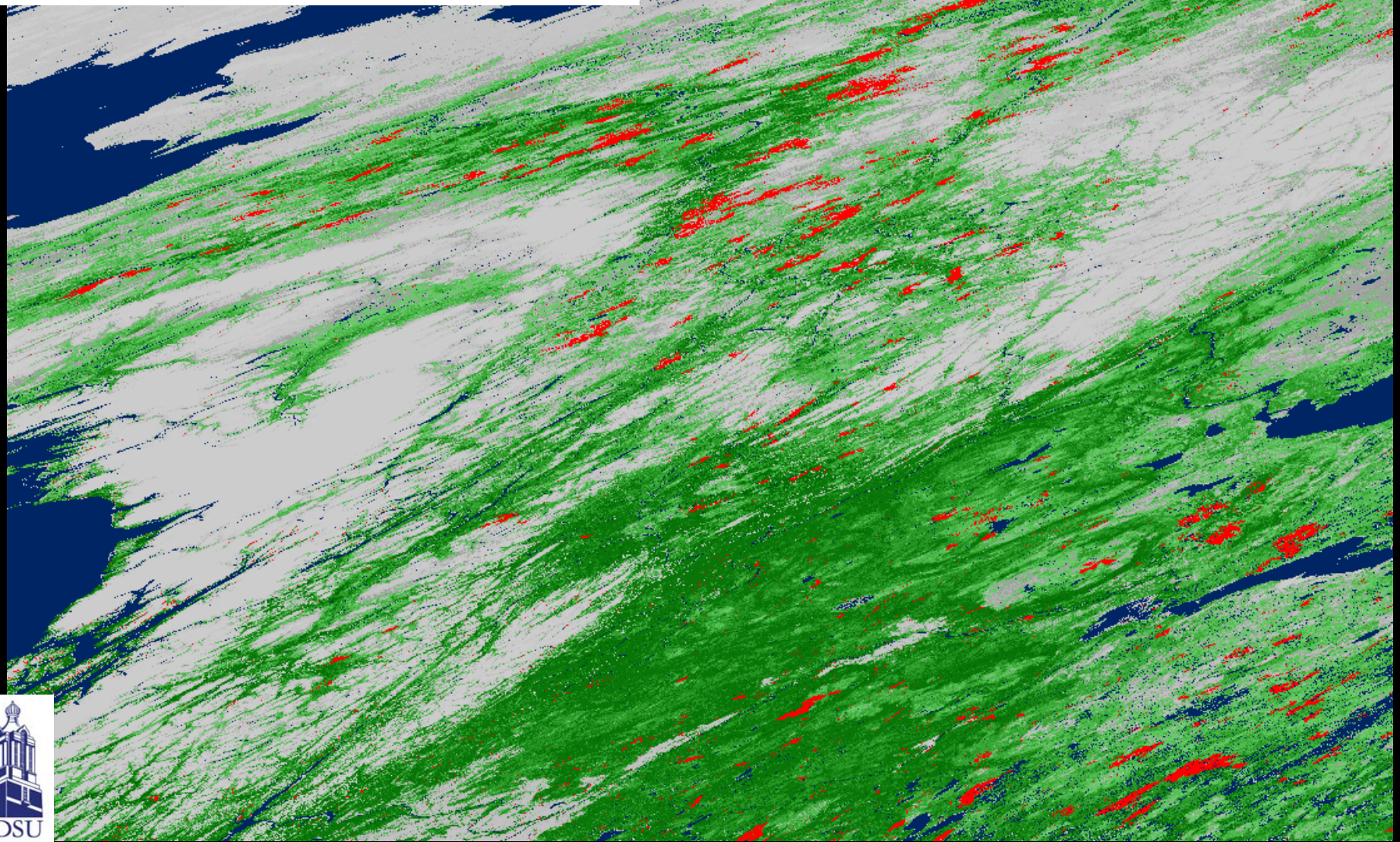

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Annual forest canopy loss in Alaska (USA) and Yukon (Canada)

Cumulative areas of forest canopy loss

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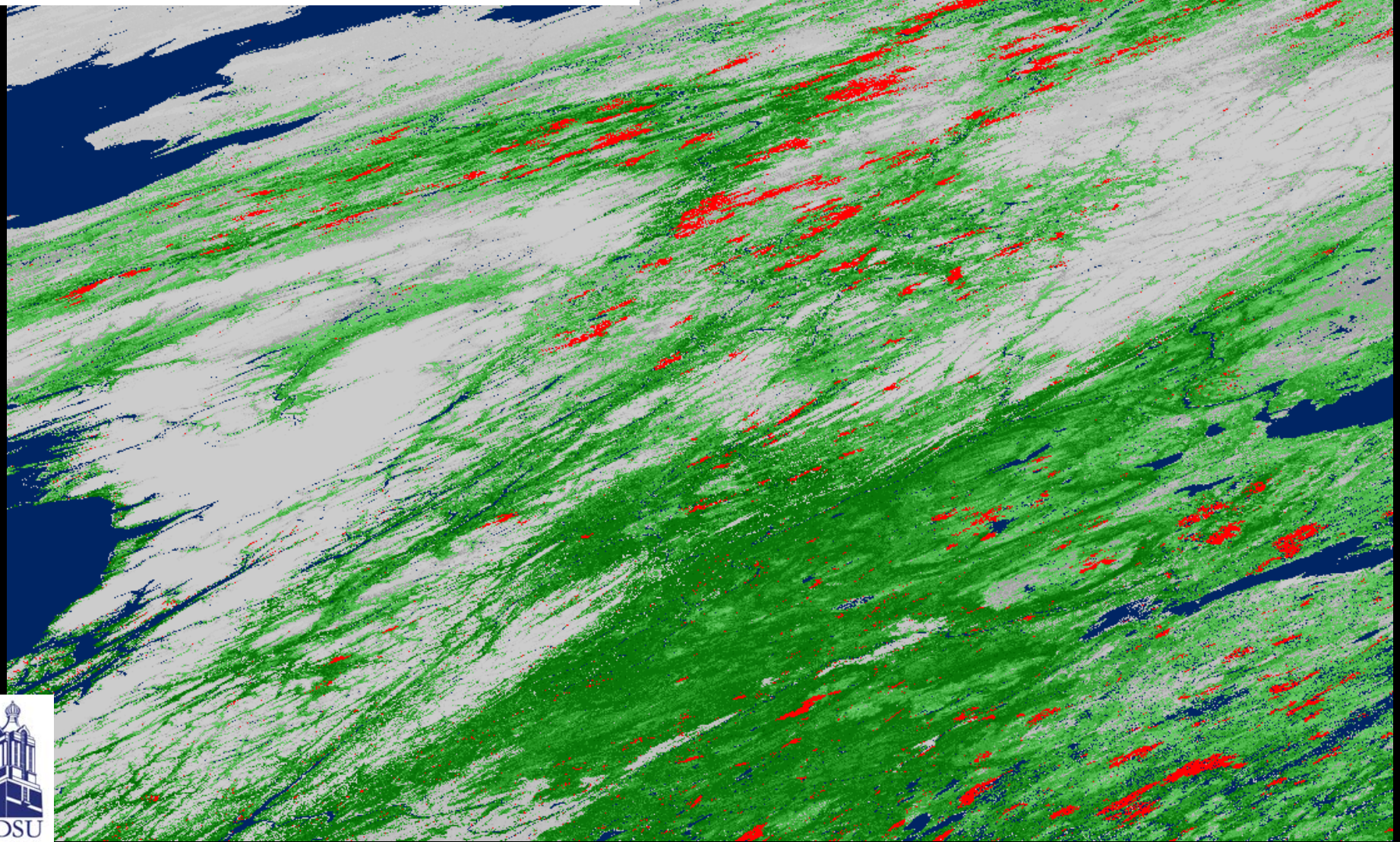

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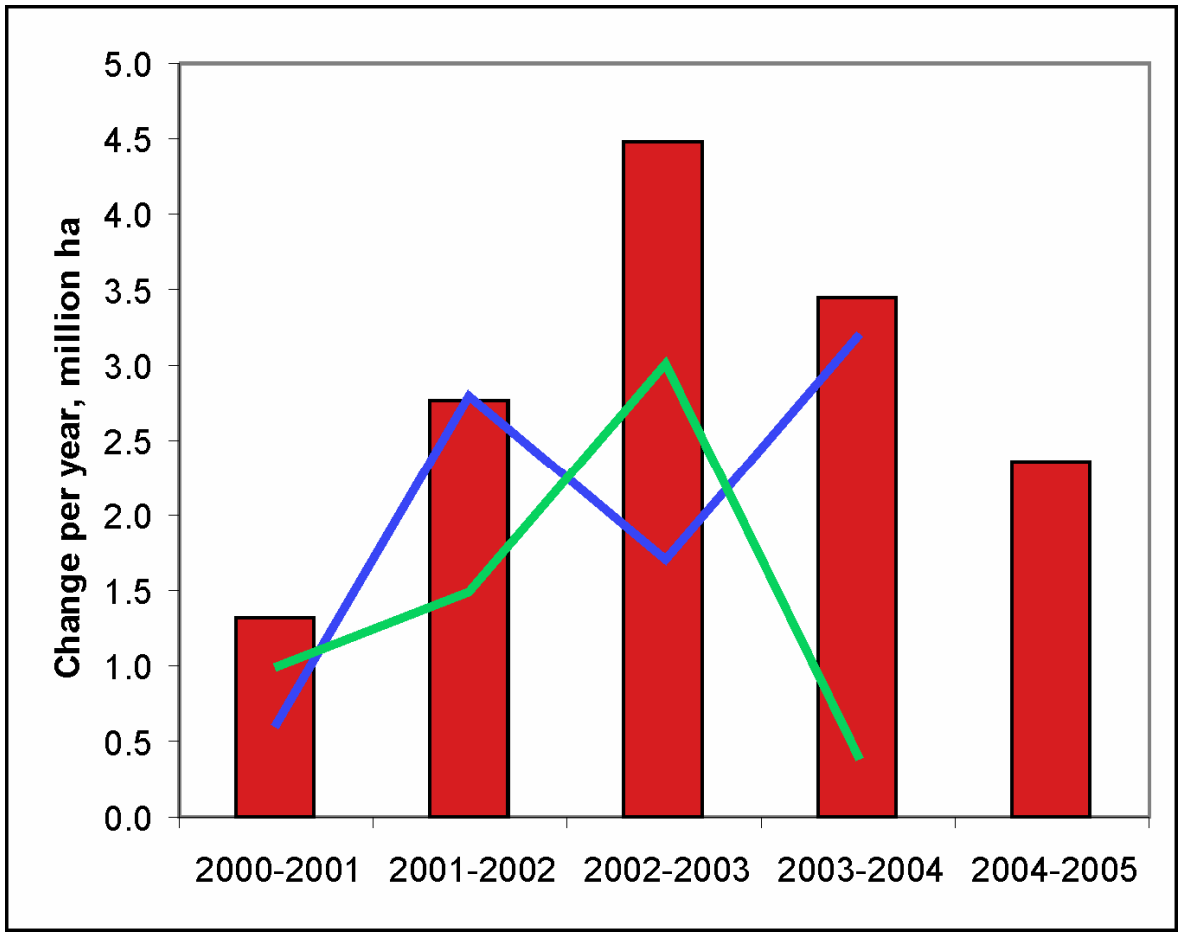
Annual forest change area 2000-2005 for boreal biome (preliminary result)

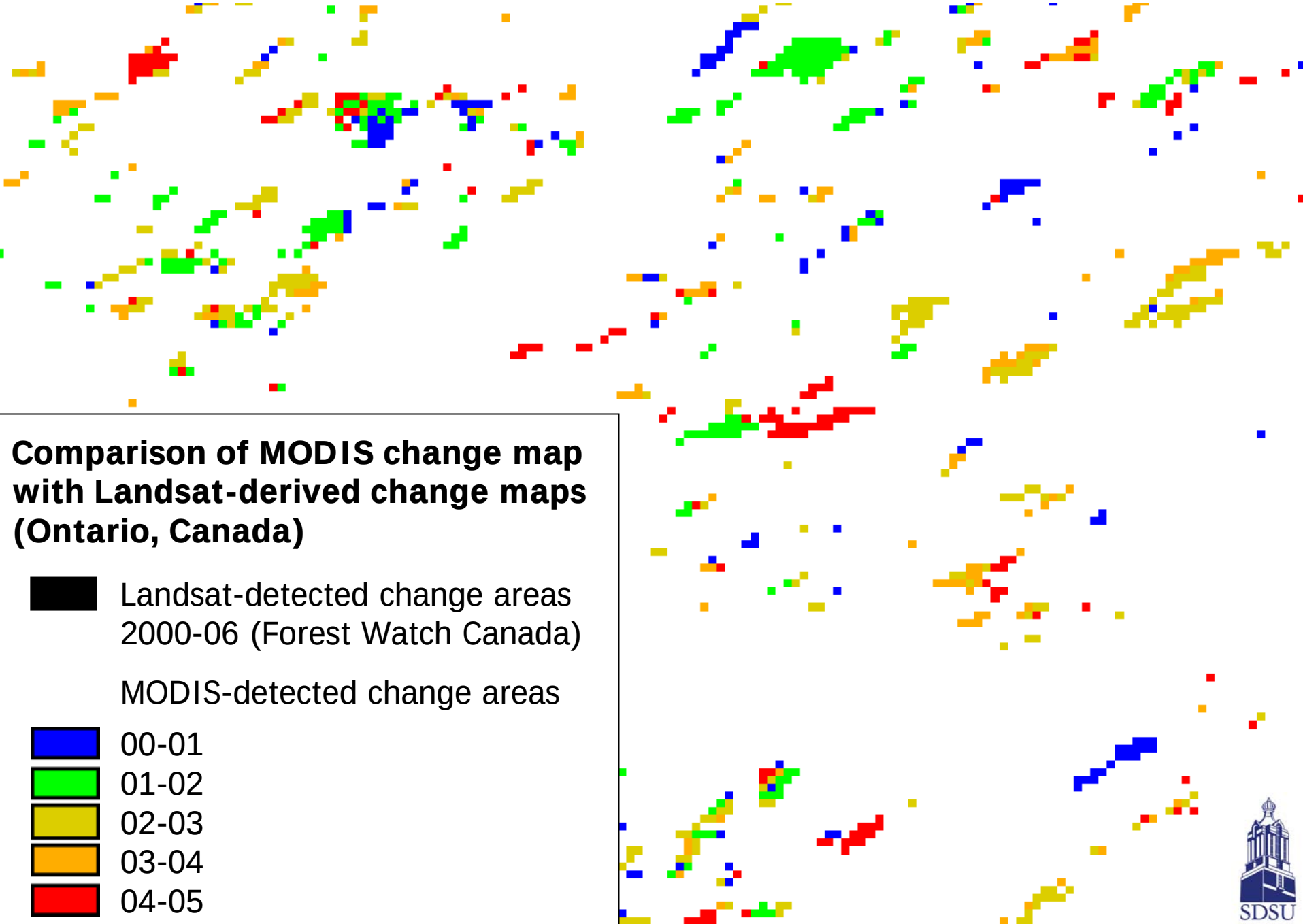


Total change area (Current research)

Burned forest area in Canada
(Canadian Forest Service)

Burned forest area in Russia
(Russian Ministry of Natural Resources)

Logging example - comparison with Landsat-scale change products



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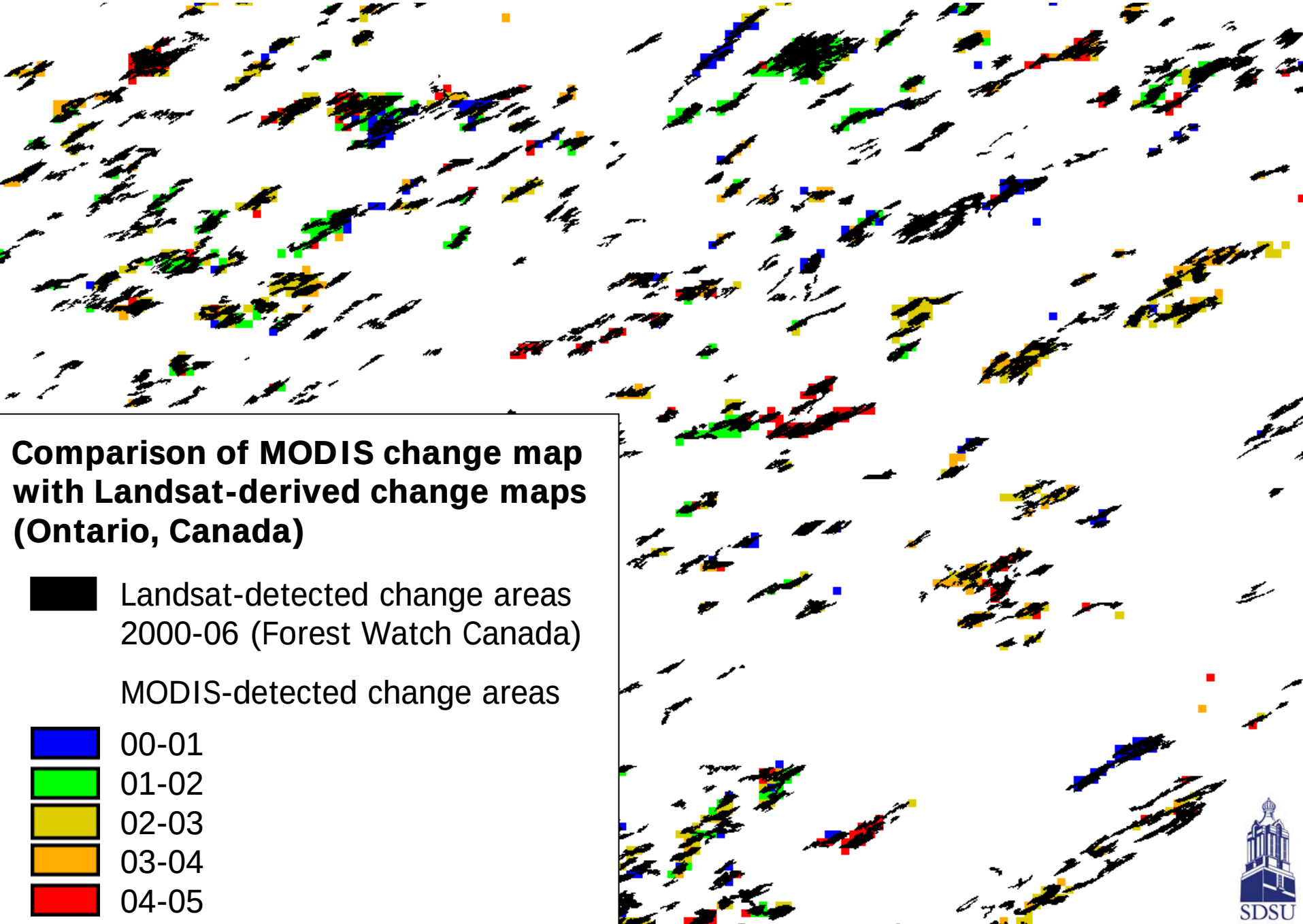

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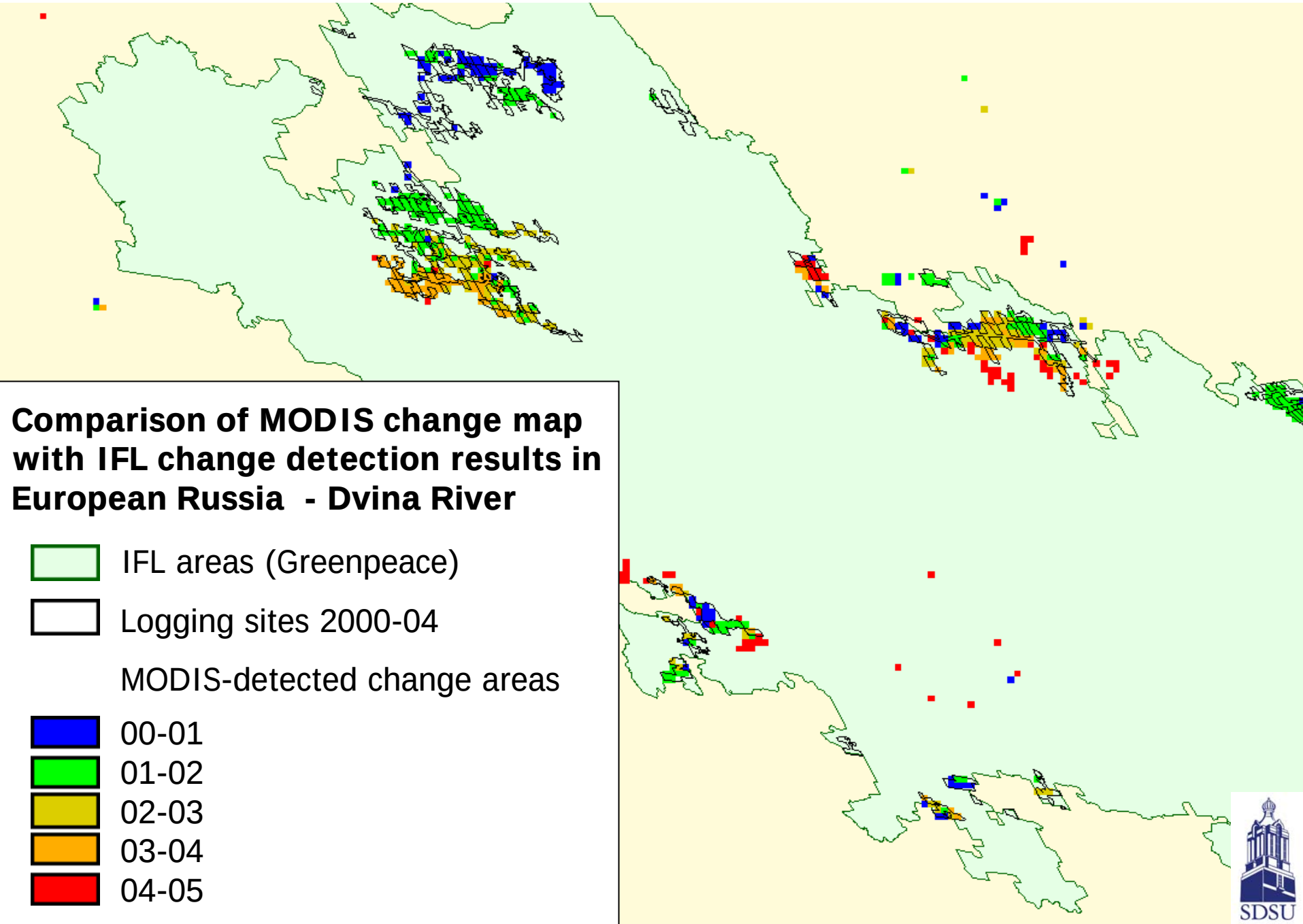

Next steps

- To finalize the method for spatially and temporally allocating Landsat-estimated change using the MODIS change indicator layers
- Produce 250 meter MODIS change indicator maps, 2000 to present using collection 5 data
- Exploit QA flags in mapping calibrated MODIS change
- Complete boreal and dry tropics in 2007
- Complete global survey with temperate biome in 2008

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Research partners

- Steve Stehman, SUNY-ESF
- Peter Potapov, Kyle Pittman, Mark Cochrane, SDSU
- Tom Loveland, Jim Vogelmann, EROS
- John Townshend, Mark Carroll, Charlene Dimiceli, Ruth DeFries, Rob Sohlberg, UMd
- Fred Stolle, Lars Laestadius and others, WRI

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