Multi-source imaging of time-serial tree and water cover at continental and global scales

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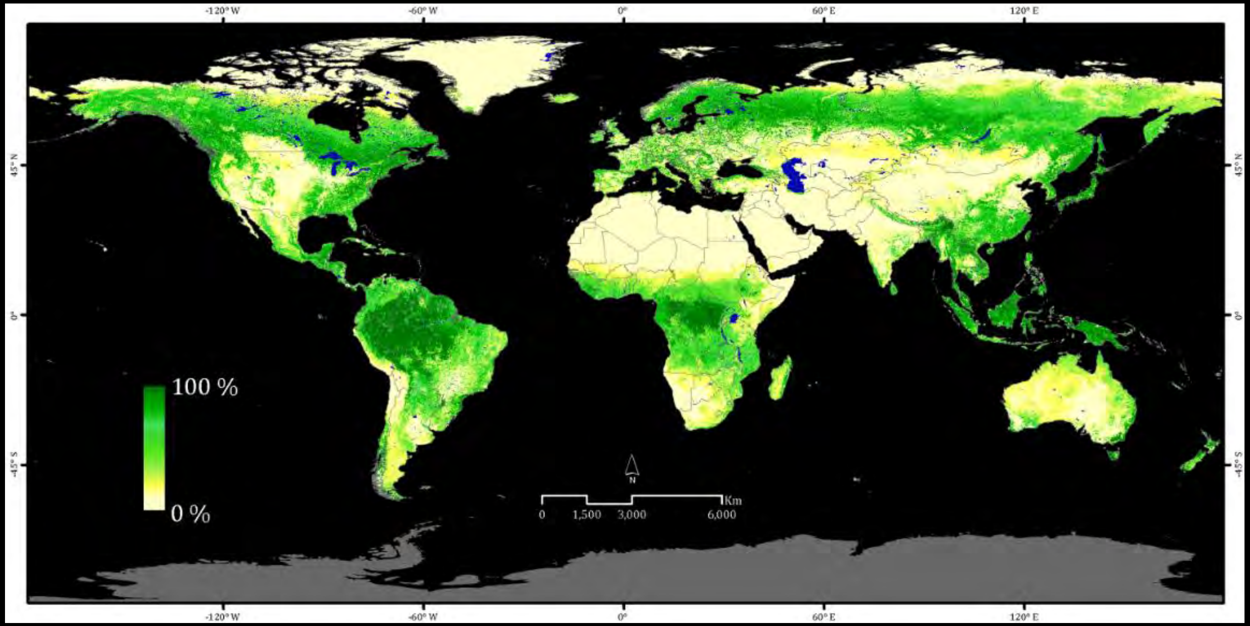
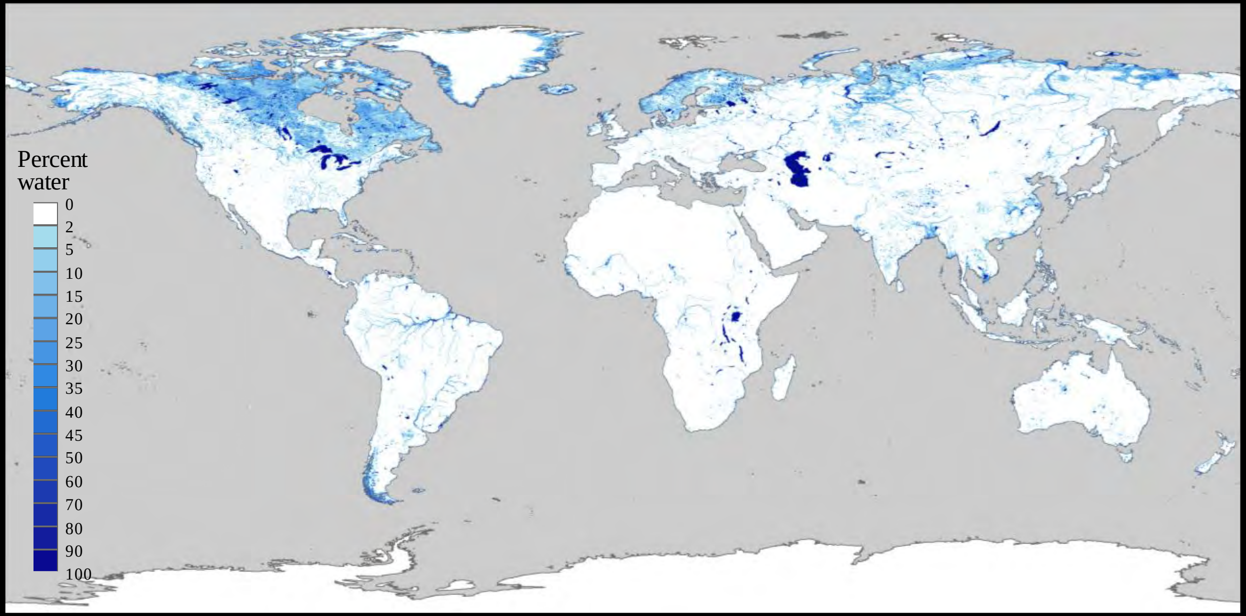




Objectives & Timeline

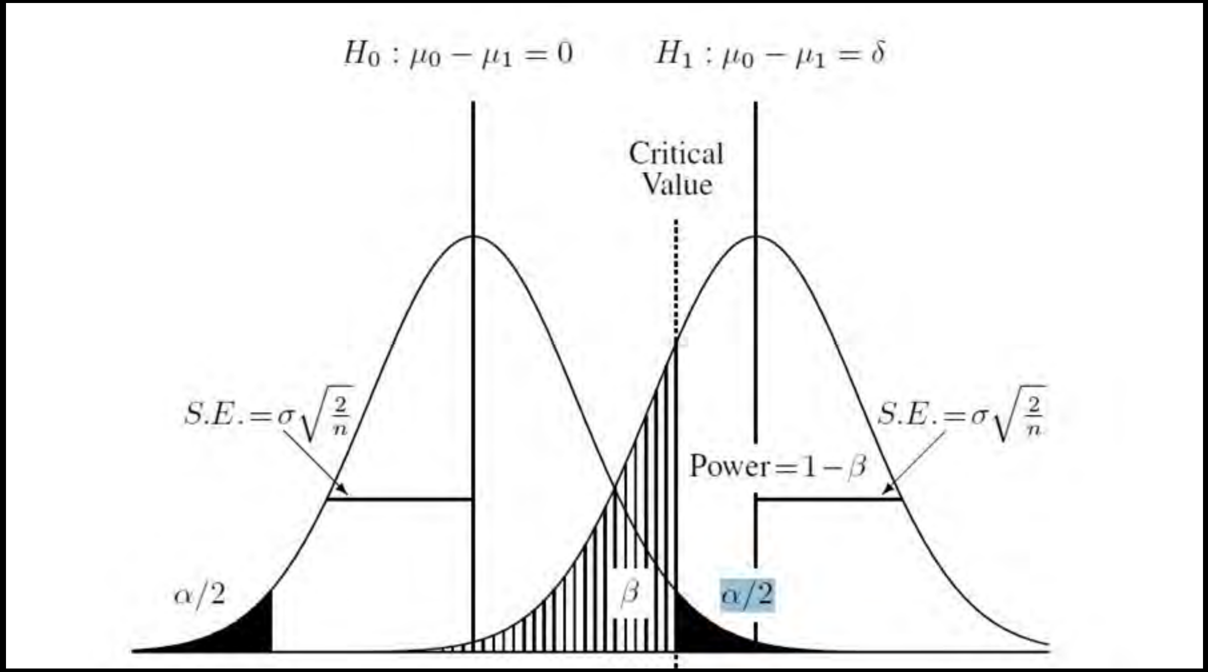
Product	Epochal	Annual	Uncertainty layer?
Tree cover (%)			
Continental		X	Y
Global	X		Y
Water Cover (binary)			
Continental		X	Y
Global	X		Y

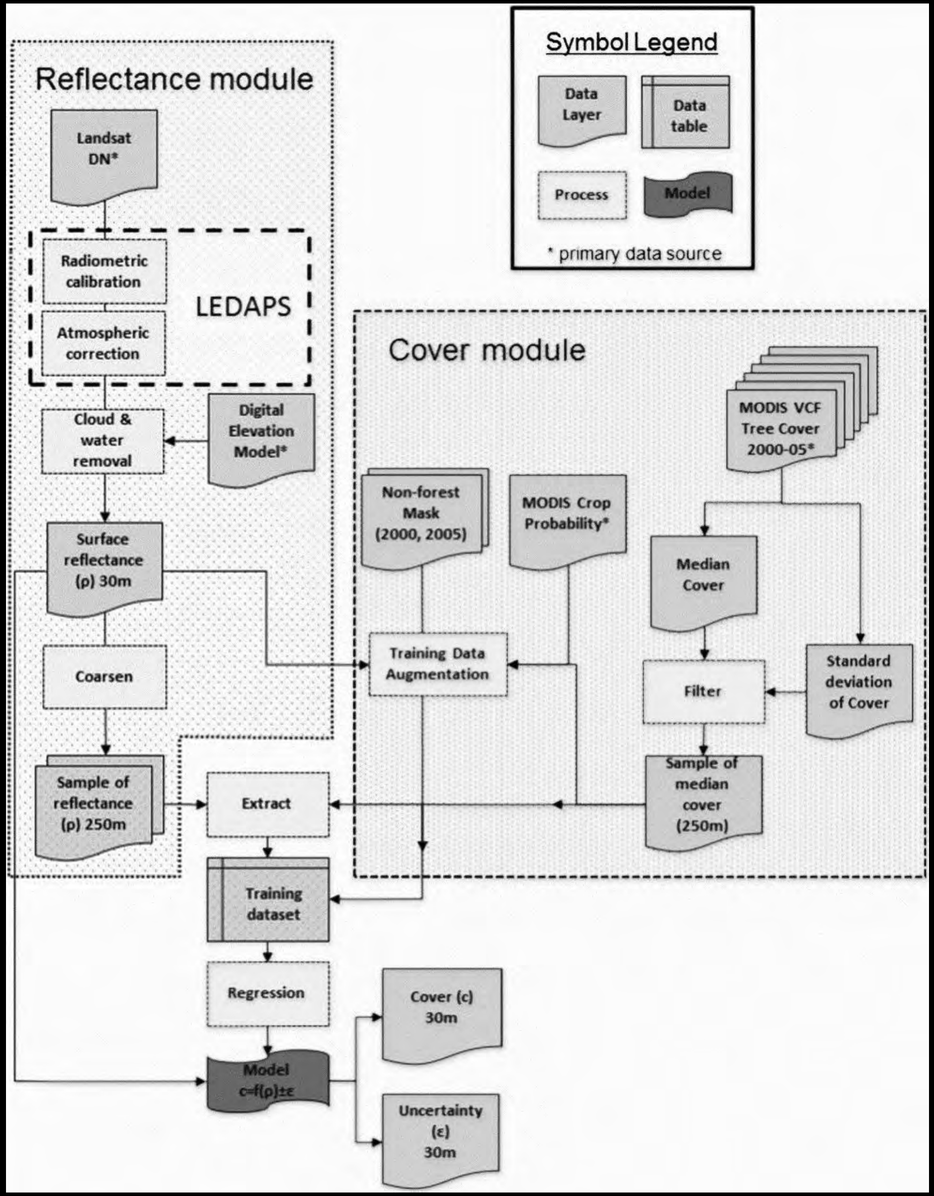
- Tree cover
  - 2010 & 2015 (epochal)
  - 2010-2015 over North & South America
- Water cover
  - 2010 & 2015 (epochal)
  - 2010-2015 over North & South America

	Year 1				Year 2				Year 3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Acquire data												
Landsat	X	X	X	X	X	X	X					
PALSAR	X											
Sentinel-2						X	X	X				
Small-footprint Lidar						X	X					
Develop algorithms												
Epochal tree cover		*	*	*	*	*	*					
Epochal water cover		*	*	*	*	*	*					
Annual tree cover		X	X	X	X	X	X	X	X	X	X	
Annual water cover		X	X	X	X	X	X	X	X	X	X	
Preliminary validation												
Epochal tree cover			X	X			X					
Epochal water cover									X	X	X	X
Annual tree cover											X	X
Annual water cover											X	X
Publication & distribution												
Epochal tree cover		X	XX	XX								
Epochal water cover												
Annual tree cover											X	X
Annual water cover											X	X

Algorithms

- Fusion of estimates: regression tree





Tree-cover estimation algorithm.

Sexton, JO; X-P Song; M Feng; P Noojipady; A Anand; C Huang; D-H Kim; KM Collins; S Channan; C DiMiceli; JR Townshend; *International Journal of Digital Earth* **2013,** 6, 427-448.

Data

Covariates

- Optical
  - Landsat-5, -7, -8
    - GLS -> entire archive
    - Challenges:
      - Access
      - Misregistration
  - Sentinel-2
    - Original (non-harmonized)
    - HLS
  - MODIS

Covariates

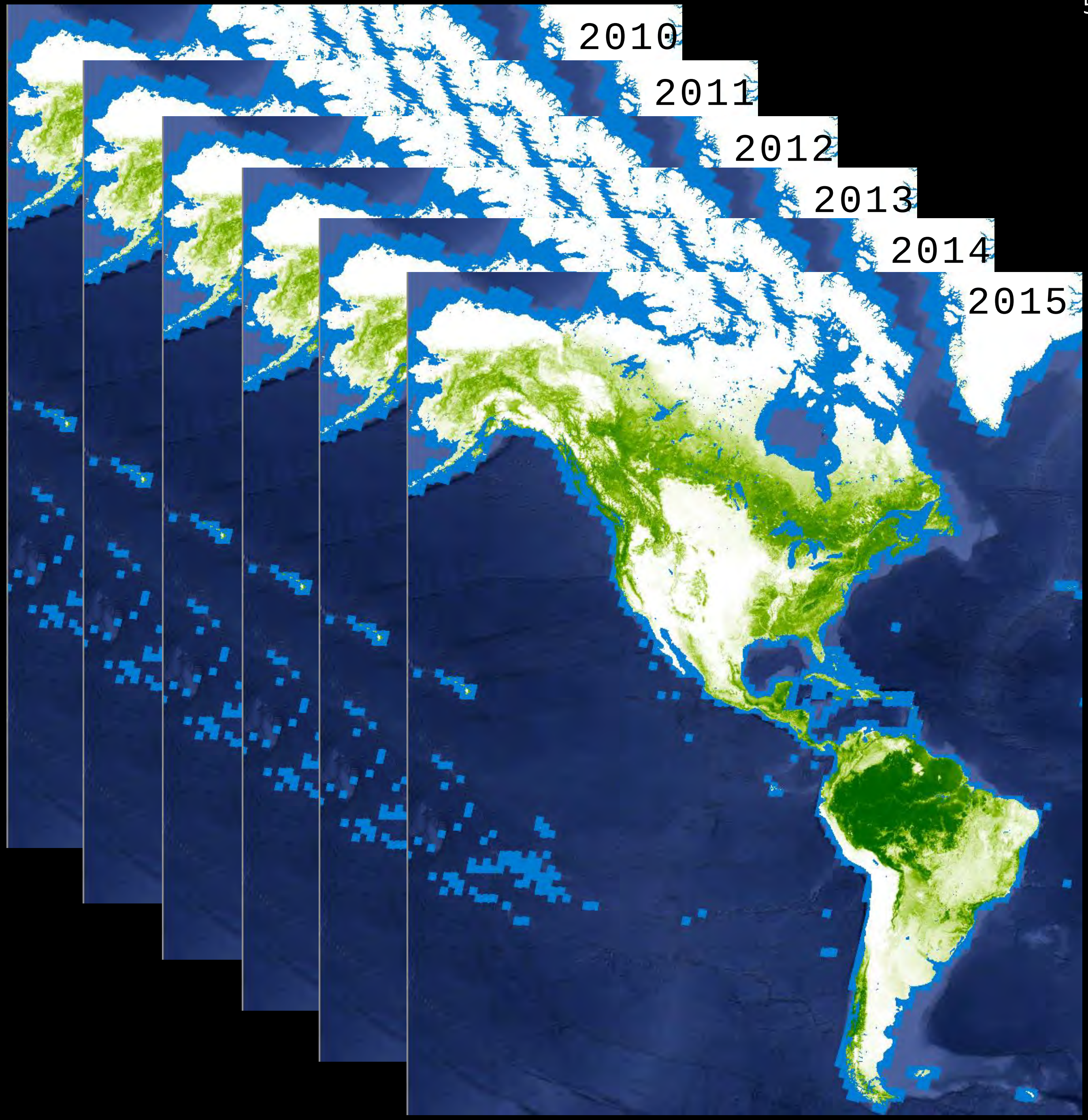
- SAR
  - Sentinel-1
    - Regional test—weak tree-cover signal
  - PALSAR-1
    - 2007-2011
  - UAVSAR

Response (tree cover)

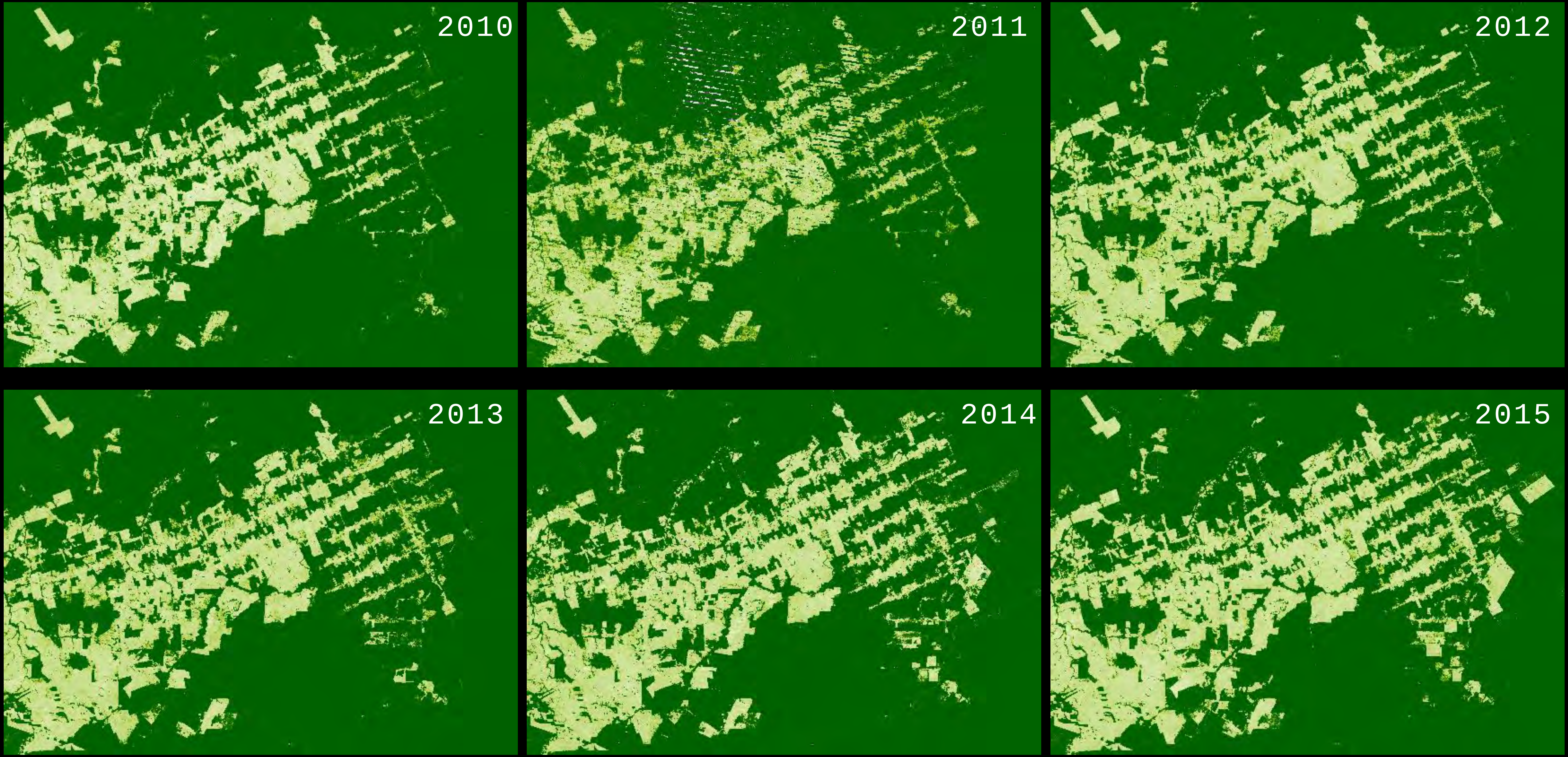
- LiDAR
  - G-LiHT
- Hi-Res
  - Quickbird
- Thematic
  - e.g., MODIS VCF

Results & products

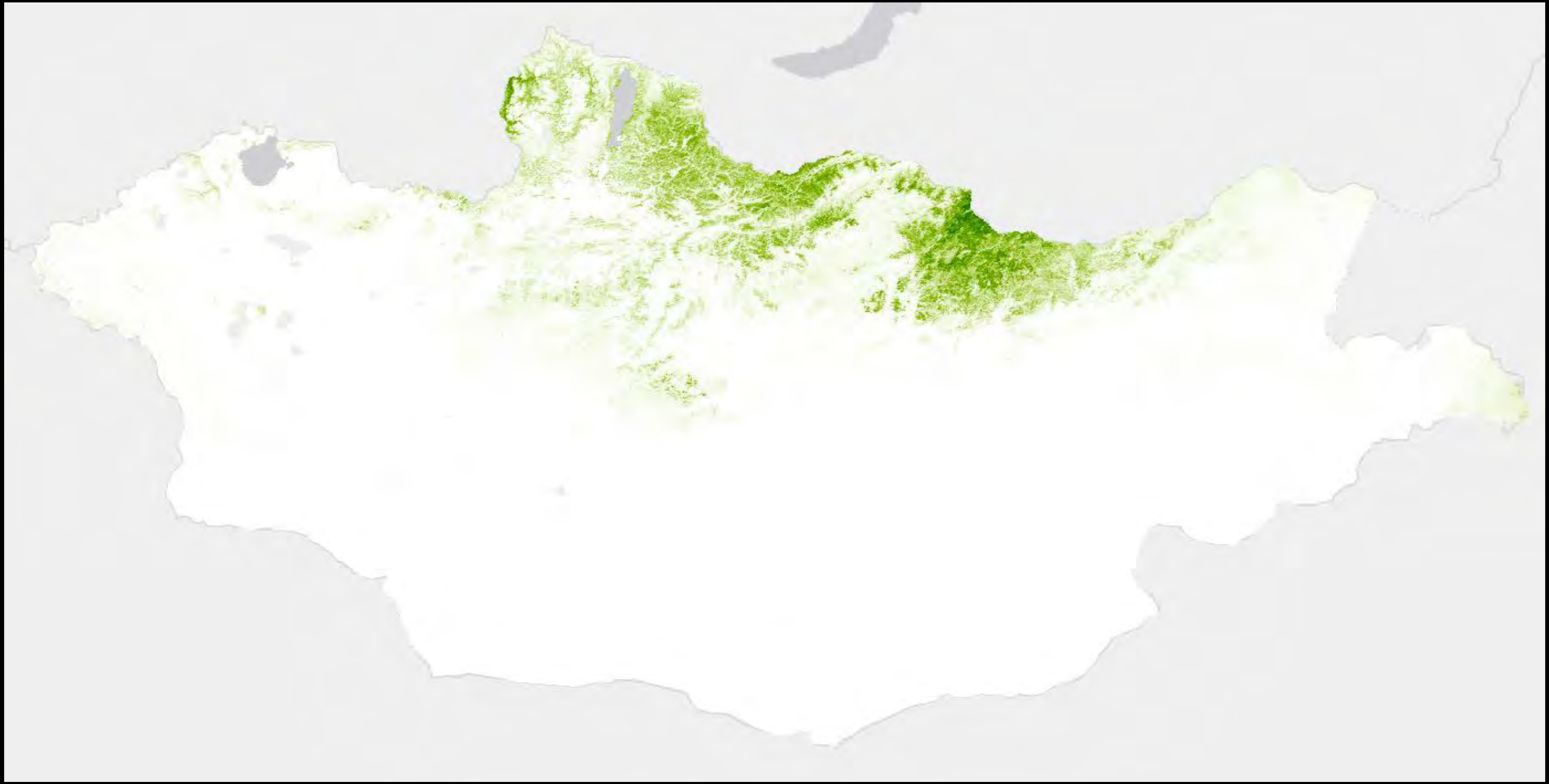
- Landsat-based
  - Tree cover
    - ✓Global 2010 & 2015
    - ✓Continental 2010-2015
  - Water cover
    - ✓Global 2010 & 2015
    - Continental 2010-2015



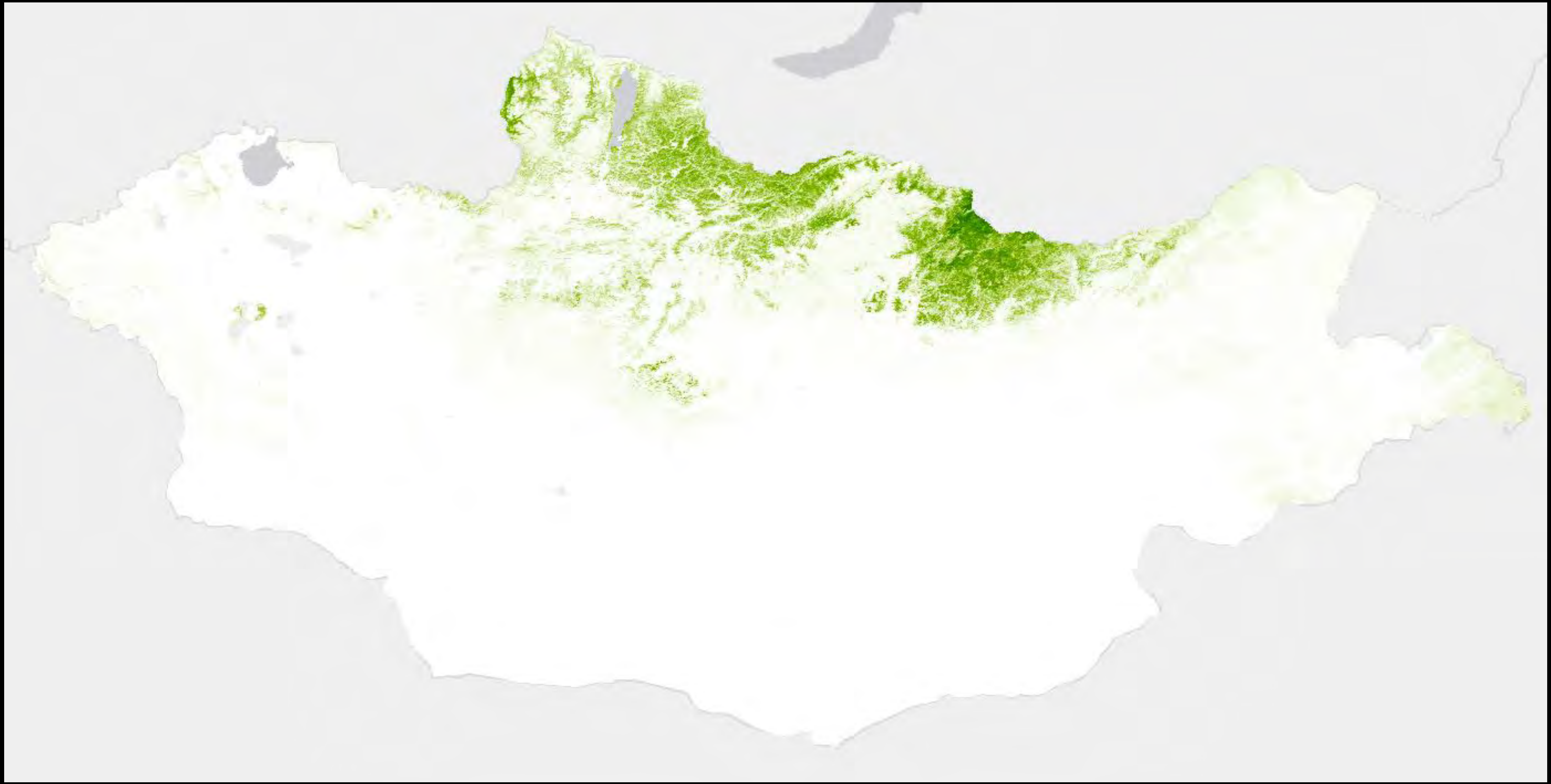
Lábrea, State of Amazonas, Brazil



Tree Cover in Mongolia (2010)

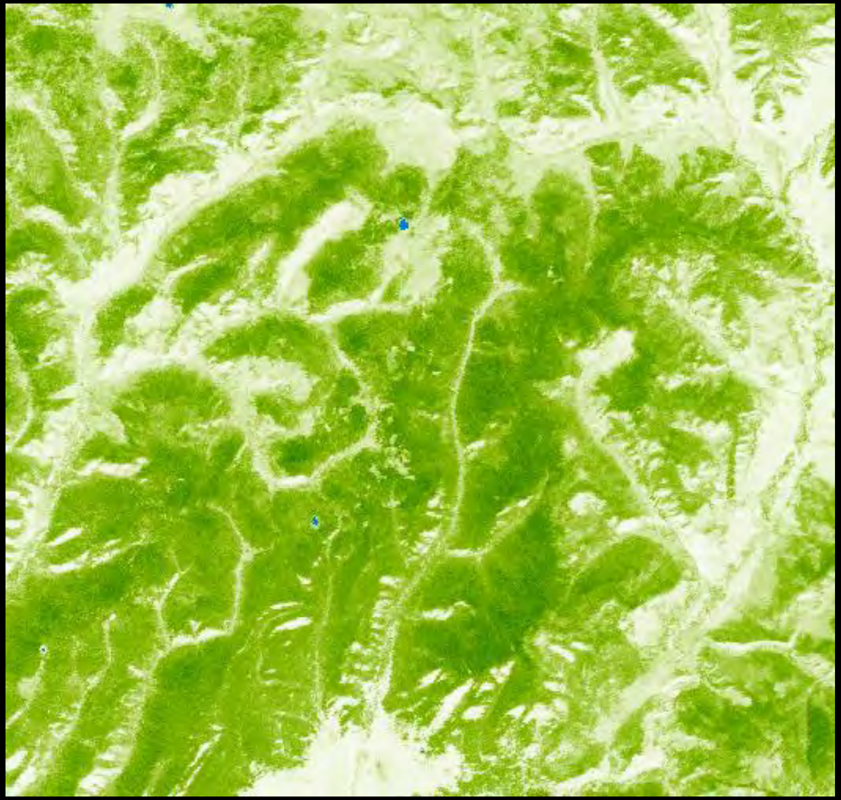


Tree Cover in Mongolia (2015)

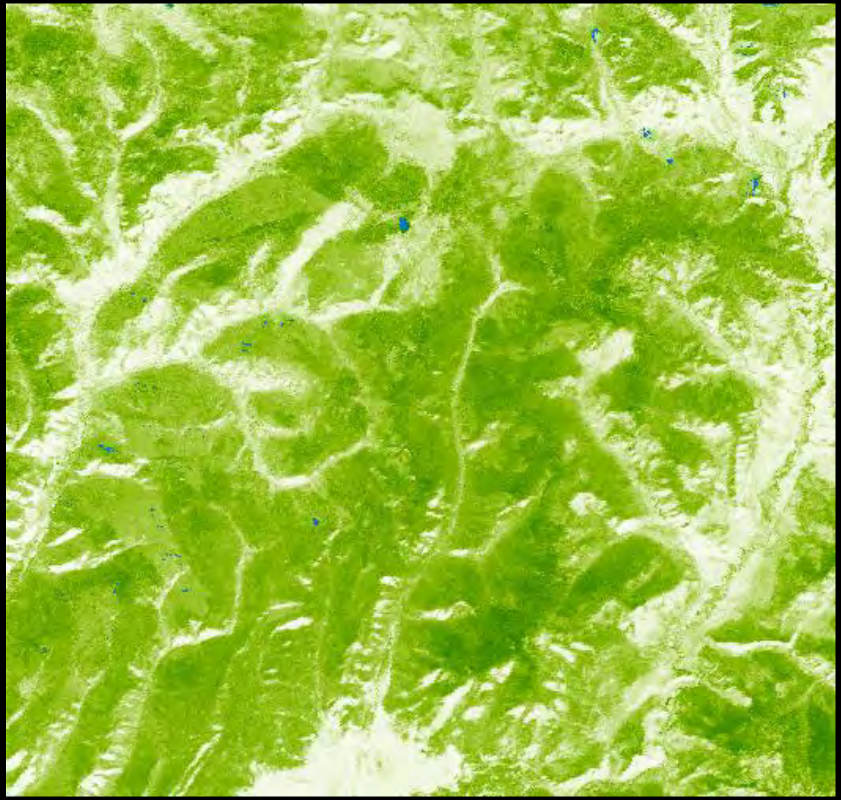


Tree Cover and Loss in Mongolia

Tree Cover (2010)



Tree Cover (2012)

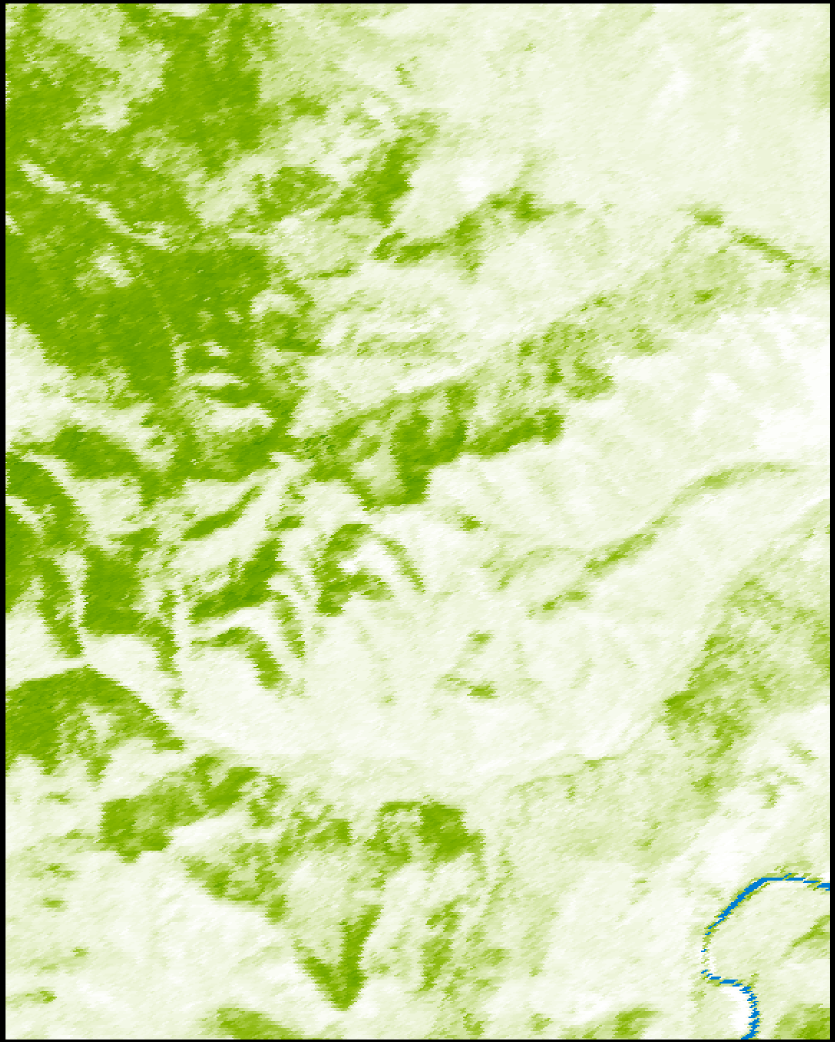


Tree Cover Loss (2010-2012)

Tsagaan-Uur
Mongolia

Tree Cover and Loss in Mongolia

Tree Cover (2010)



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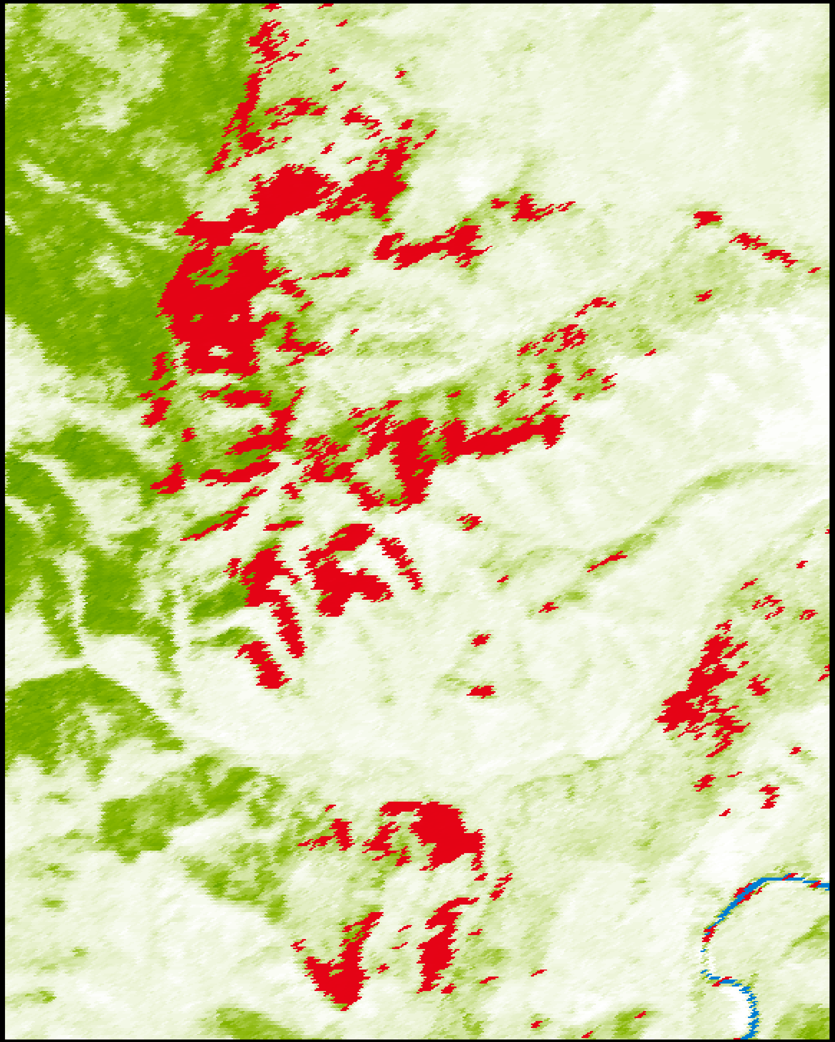

Google Maps (2016)

Onon-Balj Basin National Park, Mongolia

48.989228N, 111.680703E

King Fire

Dates: Sep 13, 2014 – Oct 9, 2014
Cause: Arson
Location: Pollock Pines, CA, USA
Injuries: 12
Burned area: 97,717 acres

2013

2015

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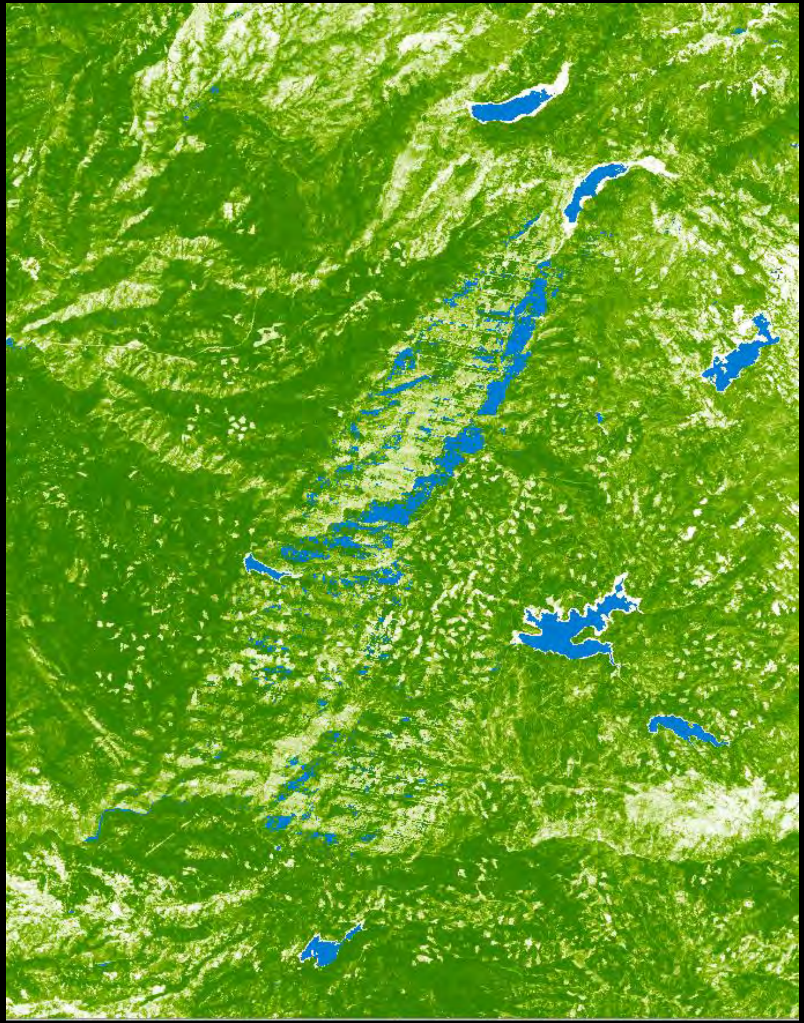
2014

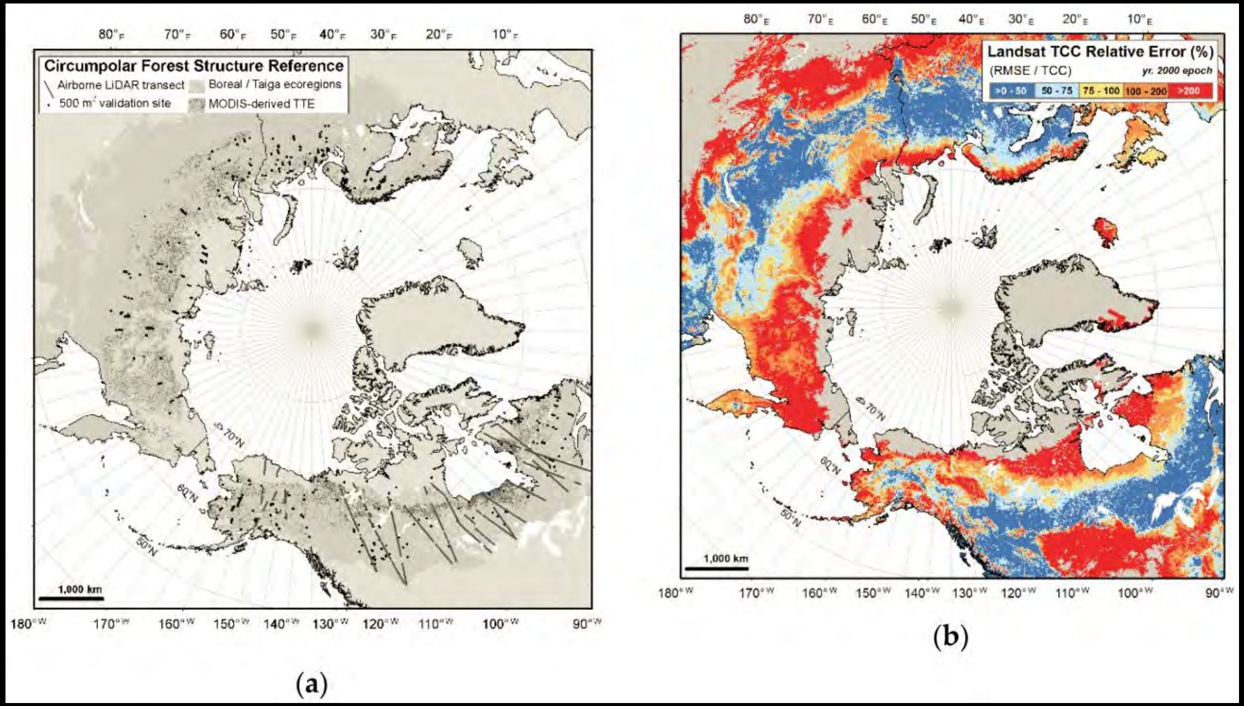


2015

- Annual composite using images before and after the change
- Fmask water mask commission errors

Calibration & validation

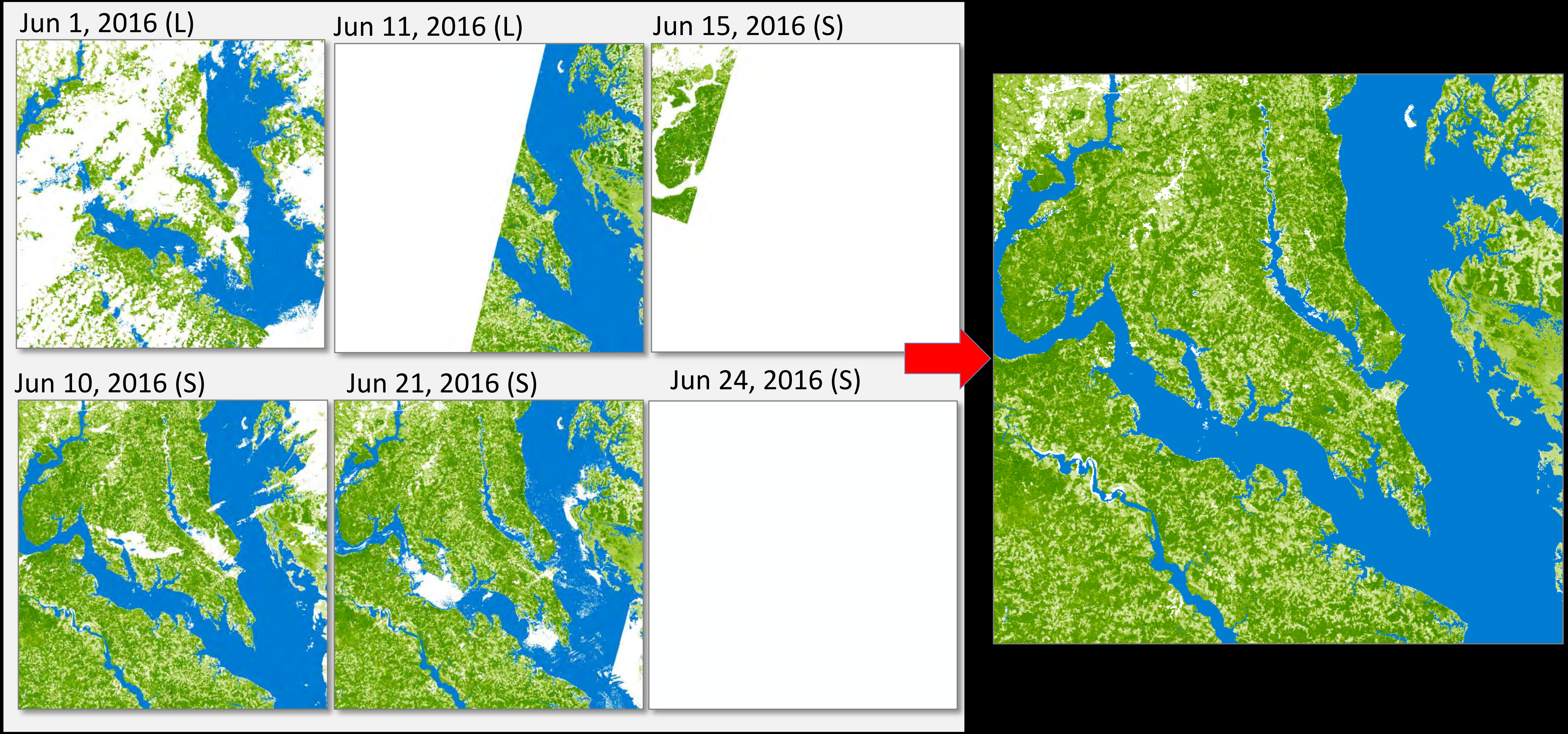
- Boreal taiga/tundra ecotone
  - Reference estimates:
    - High-resolution imagery
      - QuickBird
      - n = 425 across North America & Eurasia
    - LiDAR
      - PALS
      - n = 553,640 across North America
  - Removed saturation at >80% canopy cover
  - Reduced uncertainty (RMSE) by ~ 50%
  - More sensitive to cover of trees defined by > 2 m height
- Additional biomes in process
  - G-LiHT



Height Thresholds for Canopy	Landsat TCC Epoch	Intercept	Slope	R^2	RMSE	$RMSE_S$	$RMSE_U$
2 m	2000	11.5 (16.7)	0.81 (0.46)	0.49 (0.51)	29.0 (23.9)	8.2 (18.4)	27.8 (15.2)
	2005	10.2 (15.9)	0.84 (0.47)	0.54 (0.55)	27.1 (23.1)	7.2 (18.0)	26.1 (14.4)
	2010	10.8 (15.6)	0.85 (0.48)	0.47 (0.55)	31.1 (23.0)	7.6 (17.8)	30.1 (14.6)
5 m	2000	14.3 (22.3)	0.79 (0.48)	0.46 (0.42)	28.0 (25.4)	11.8 (19.3)	25.4 (16.4)
	2005	13.4 (21.8)	0.80 (0.49)	0.49 (0.45)	26.5 (24.7)	11.0 (18.9)	24.1 (15.9)
	2010	14.5 (21.7)	0.80 (0.49)	0.39 (0.44)	31.5 (24.9)	11.9 (18.8)	29.2 (16.3)

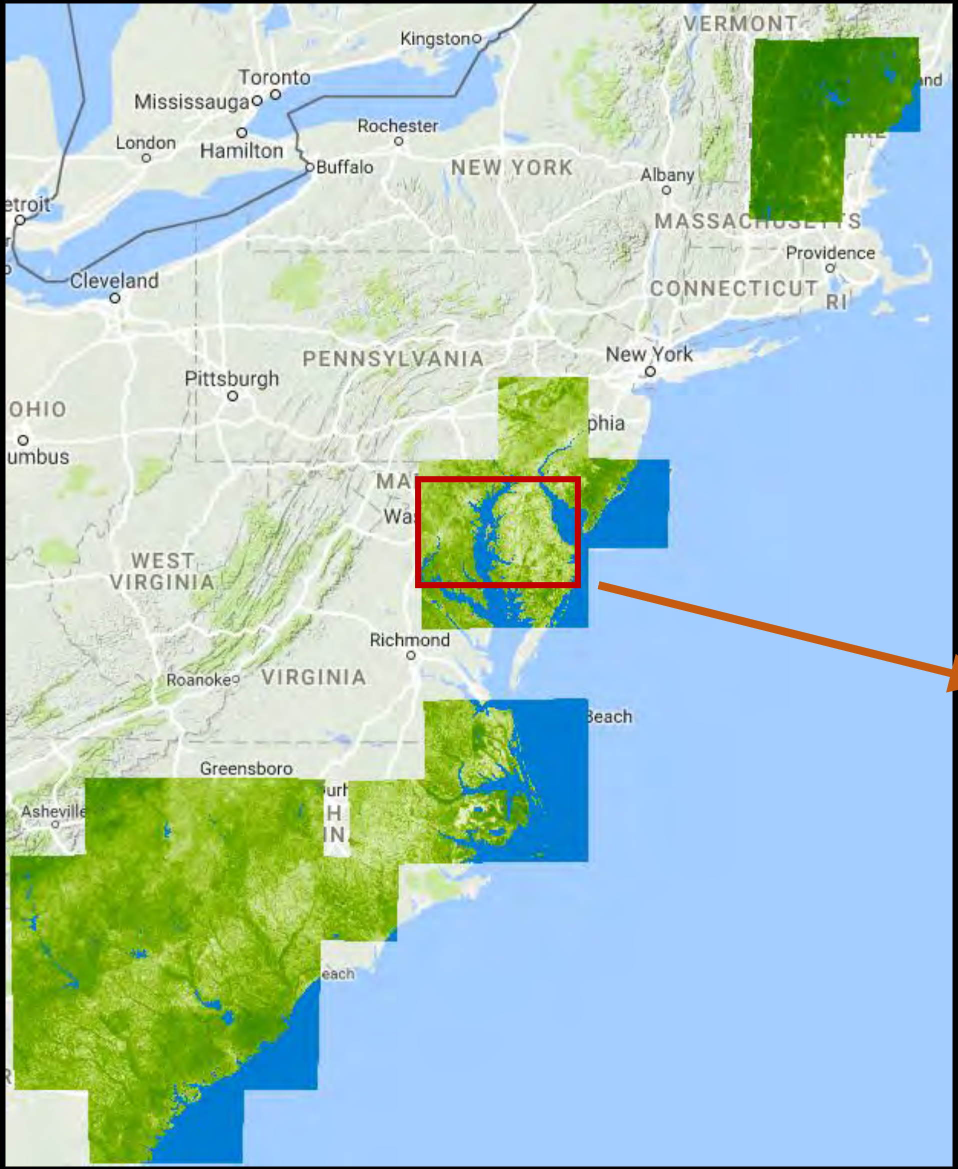
Montesano, P.M., C. Neigh, J.O. Sexton, M. Feng, S. Channan, K.J. Ranson, J.R. Townshend. 2016. Calibration and validation of Landsat tree cover in the taiga-tundra ecotone. *Remote Sensing* 8:551

Optical fusion: Landsat and Sentinel-2

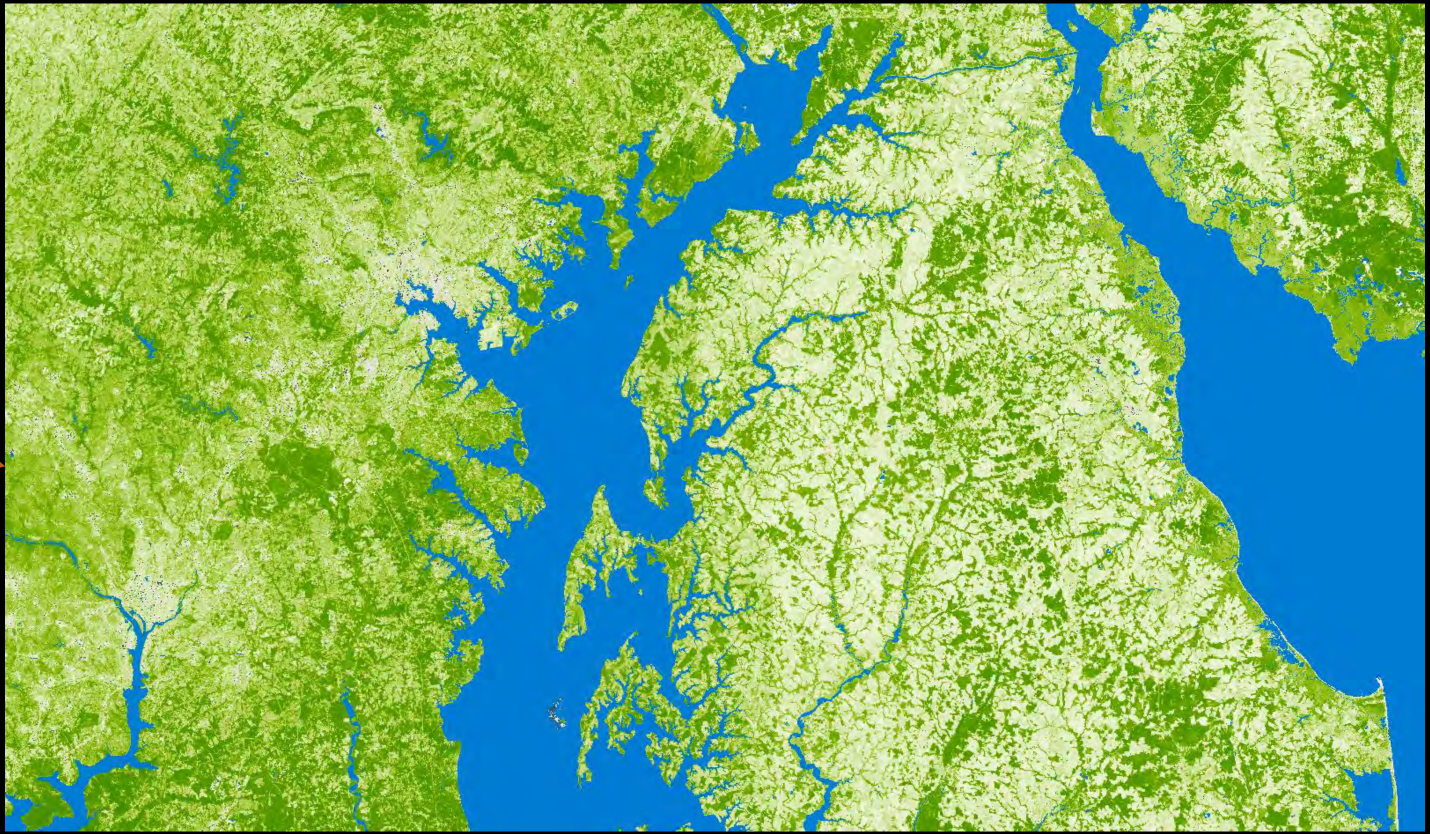


Optical fusion: Landsat and Sentinel-2

Fused tree-canopy cover (2016)



1,974 HLS Landsat and Sentinel-2 images were applied to estimate tree cover over the U.S. east coast

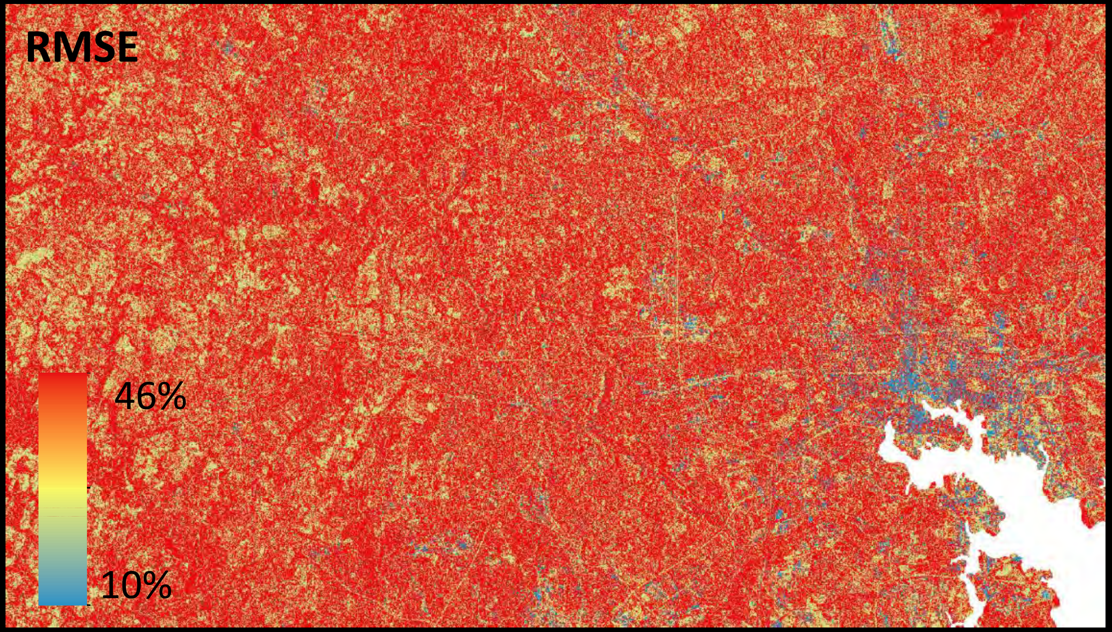


Toward optical-SAR fusion

TCC estimated from Sentinel-1 (C-band) VV & VH backscatter

- Estimate tree canopy cover
- Fill gaps (e.g., clouds) in optical estimates
- Discriminate natural forests from plantations

- C-band relationships
    - Insufficient tree-cover signal
        - Imprecise estimates
        - Little deviation from regional mean
    - Improves optical estimates, but not sufficient alone
        - Must combine with L-band and/or optical



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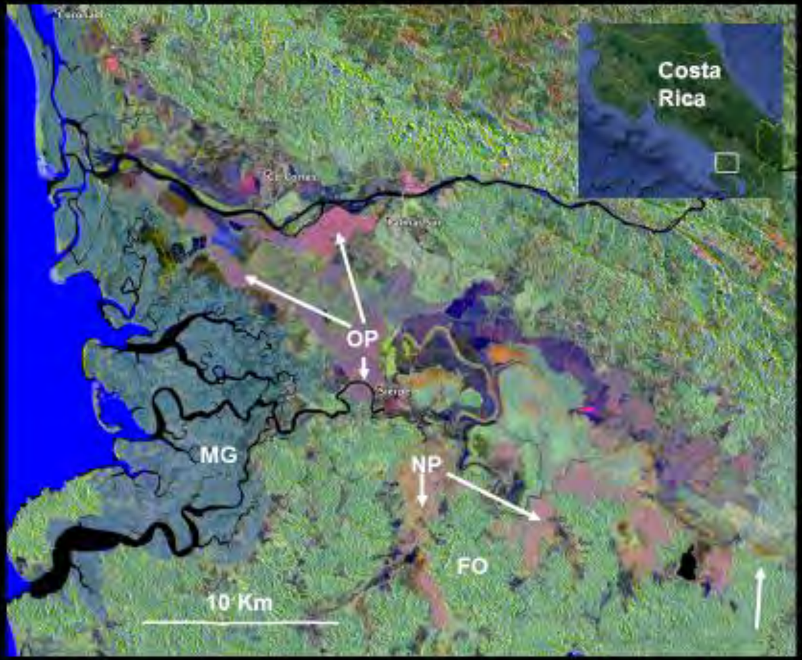
- Sentinel C-band backscatter & ratios
- UAVSAR L-band entropy

- Solely C-band models unlikely to discriminate forest types—need to incorporate with optical
- Possible L-band only model



Jan-June 2010

False Color RGB:

Red: ALOS1 HH

Green: ALOS1 HV

Blue: Sentinel VH

MG = Mangrove

NP = Native palm *Raphia spp.*

FO = Forest

OP = Oil palm

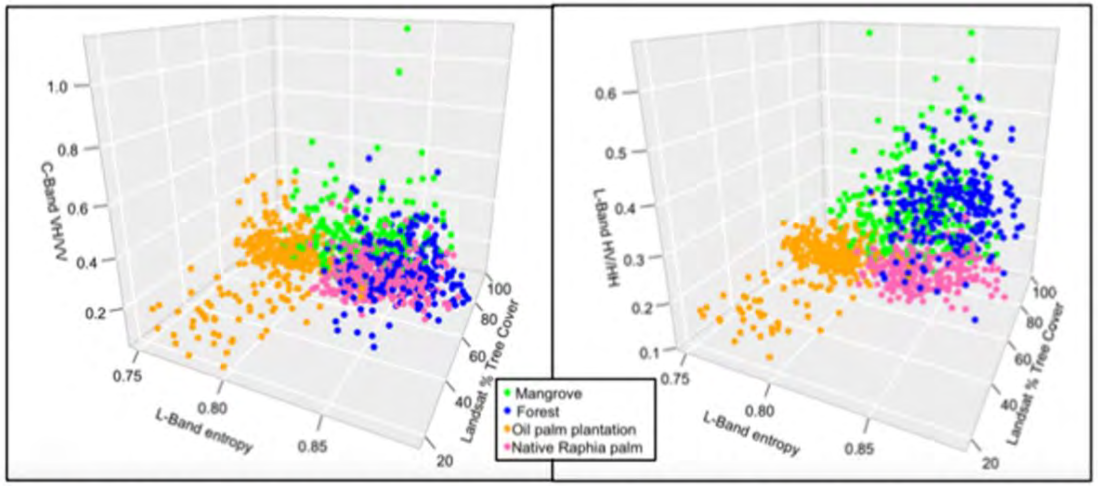


Fig. 5: Distribution of SAR and optical-derived %Tree Cover for four vegetation types in the Osa Peninsula, Costa Rica. Data derived from 16 training points buffered by 75 m. Note improved class separability with L-band volume ratios (Z axis on the right) vs. C-band ratios (Z axis on the left). Also, SAR entropy is lower in oil palm plantations, allowing us to distinguish them from native palm stands.

Pinto et al. *in prep*.

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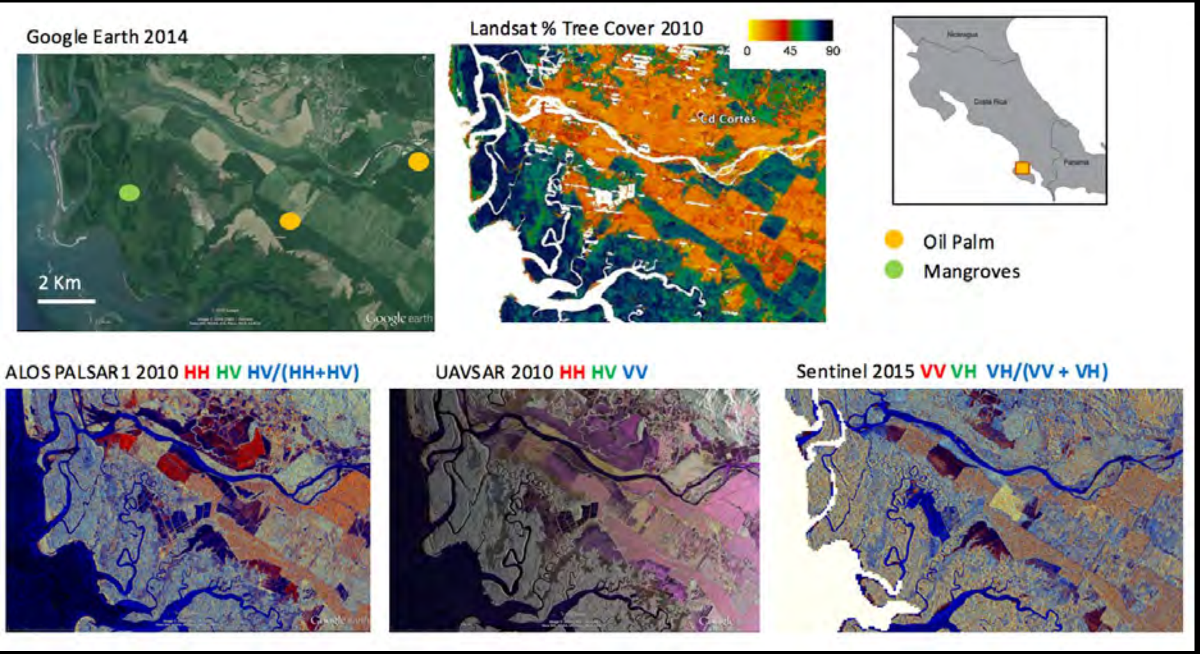

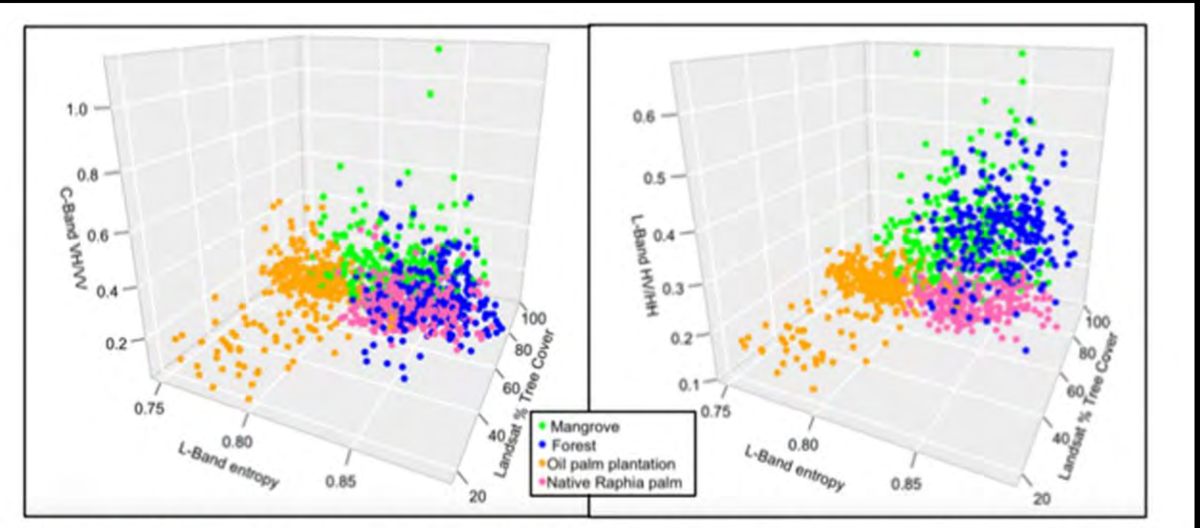

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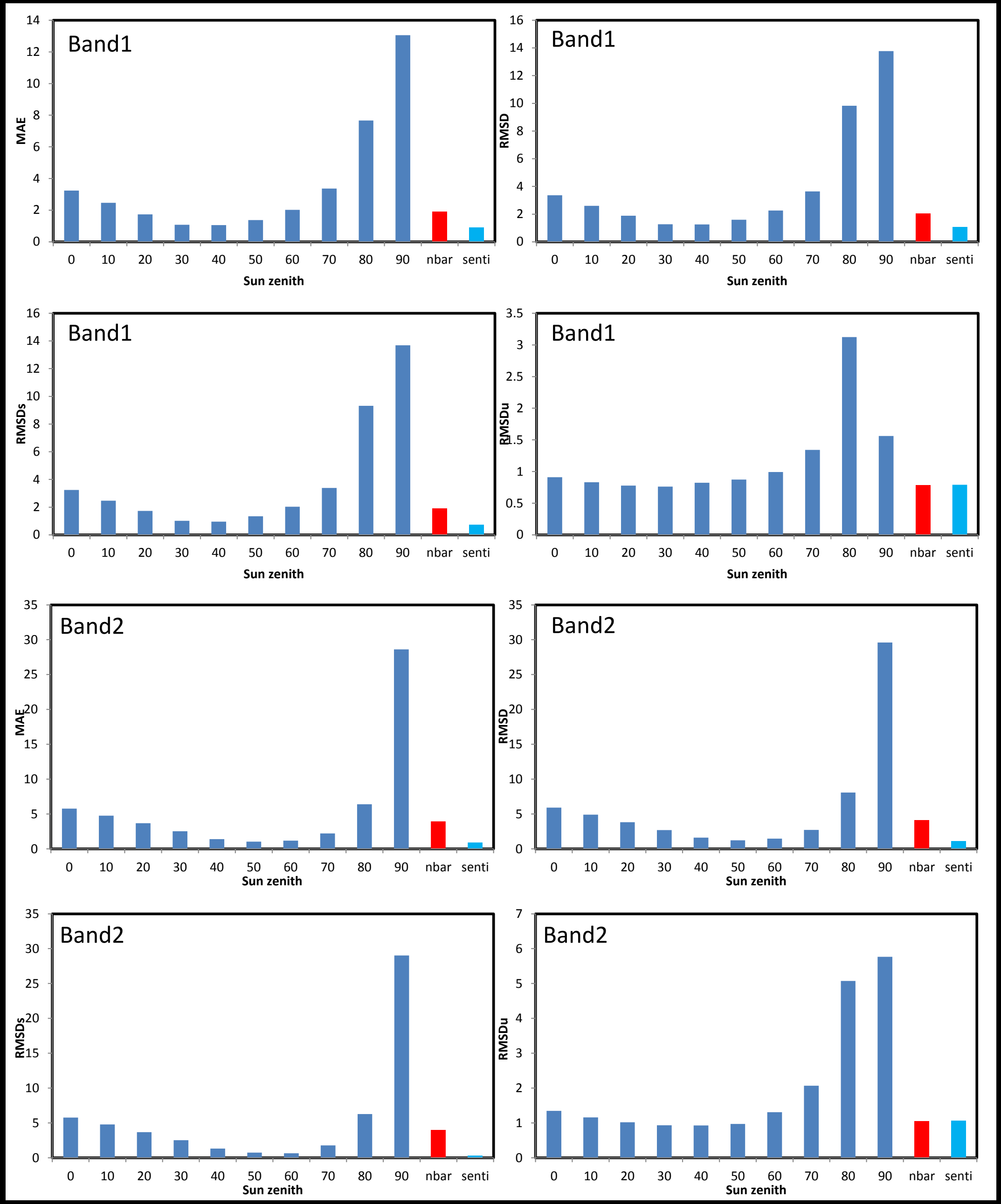
Algorithms

- Fusion of estimates: regression tree
- Fusion of covariates: spectral library

Fusion of covariates: spectral library

- Objective:
  - Model of cover ~ reflectance
    - Robust across scales
    - Robust across seasons
    - Robust across environments
- Requirement:
  - Harmonize SR across sensors
    - MODIS, Landsat, and Sentinel-2
    - Standardize solar zenith angle

- MODIS NBAR has highest correlation to Landsat-7 ETM+ reflectance
- Correction of MOD09GA SR to coincident solar-zenith angle results in higher correlation to Sentinel-2 estimates of SR



Difference (RMSD) between Sentinel-2 estimates of surface reflectance and raw and corrected MODIS SR (MOD09GA) is highest when illumination angles are corrected. Correlation of Sentinel-2 SR to corrected MODIS-based SR is greater than it is to MODIS NBAR.

Che, X. & J.O. Sexton, *in prep.*

Fusion of covariates: spectral library

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  - Model of cover ~ reflectance
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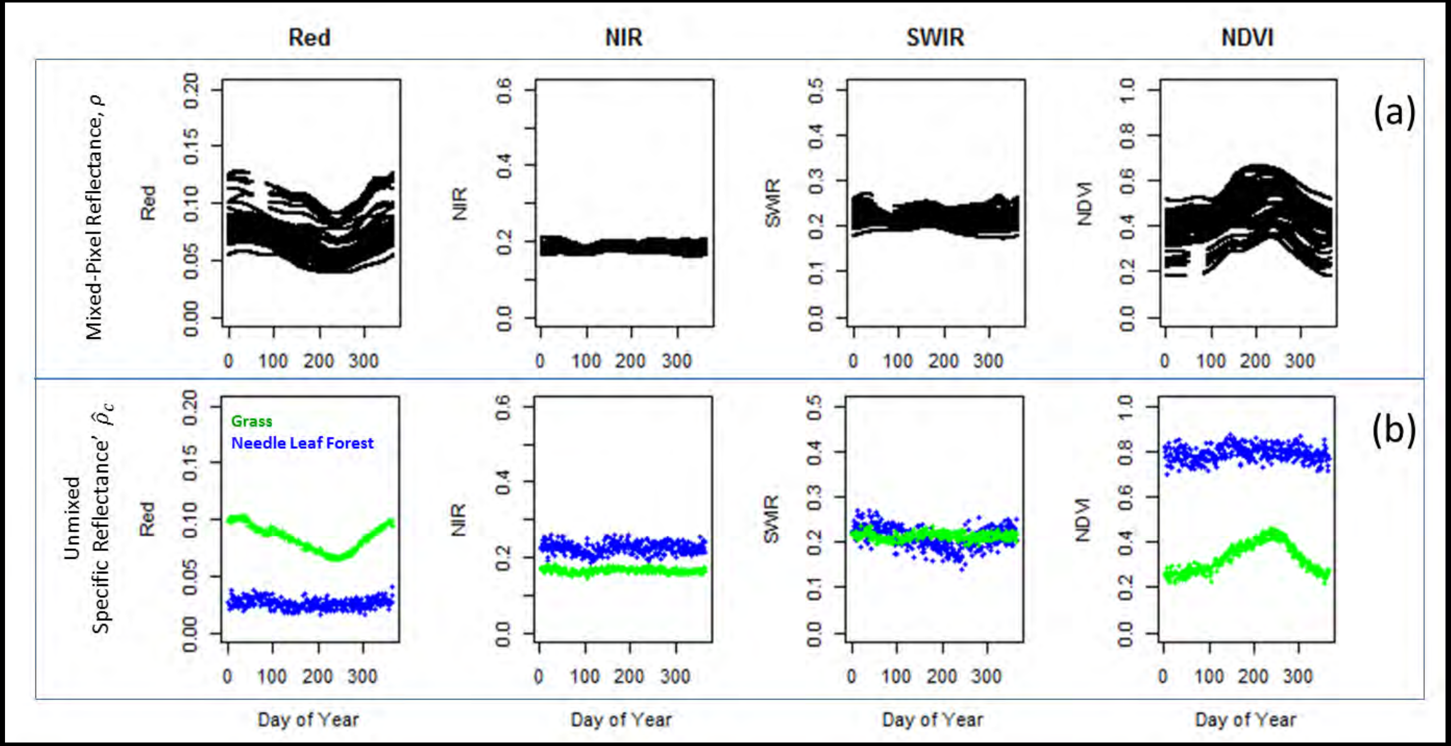
    - Robust across seasons
    - Robust across environments
- Requirement:
  - Harmonize SR across sensors
    - MODIS, Landsat, and Sentinel-2
    - Standardize solar zenith angle
- Inverting linear mixture model using high-resolution land cover and low-resolution reflectance provides estimates of pure-type reflectance



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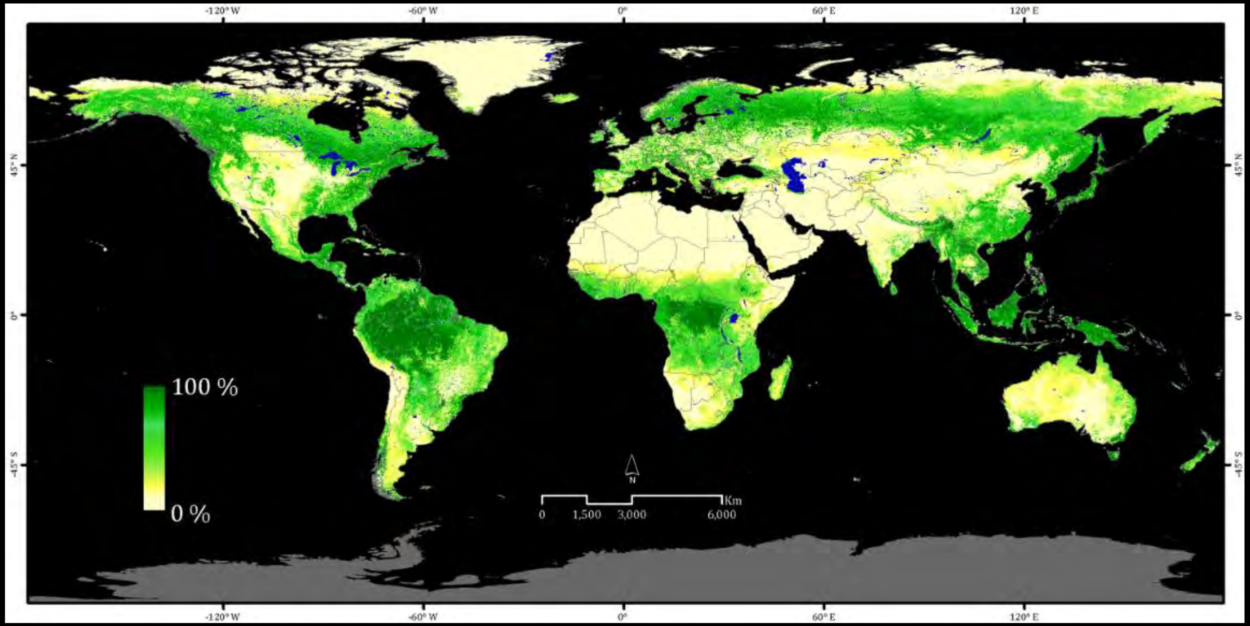
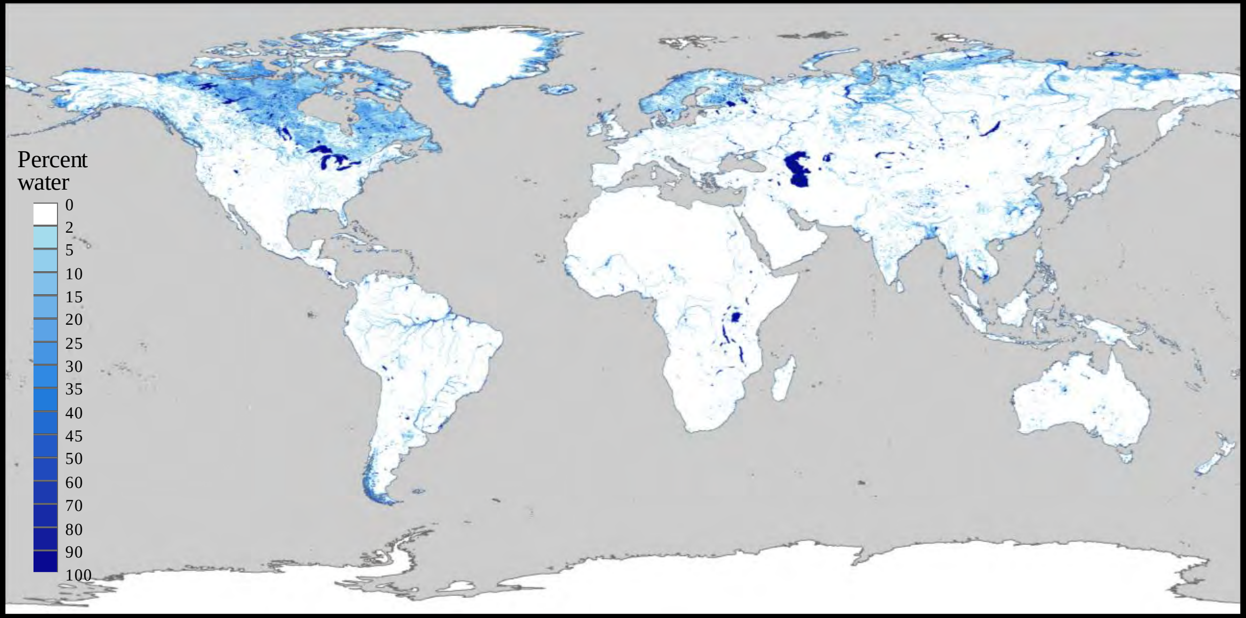
Nagol, J. J.O. Sexton, A. Anand, R. Sahajpal. *In press.* Extraction of end-member phenology by spectral unmixing. *International Journal of Digital Earth.*

Conclusions

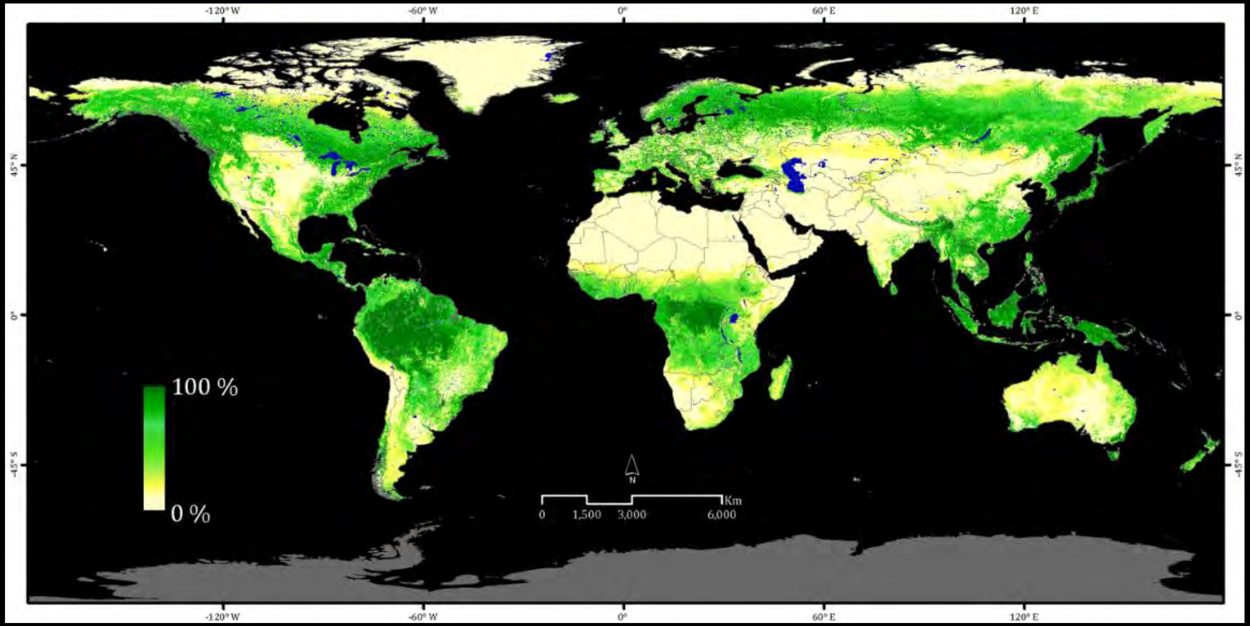
- Fusion of multi-sensor optical estimates of tree-canopy and surface-water cover straightforward
  - Landsat-based datasets in production
- C-band alone not useful for estimating tree cover
  - Must be combined with optical or other SAR wavelengths
- L-band polarimetry appears useful for estimating tree cover and discriminating natural from plantation forests

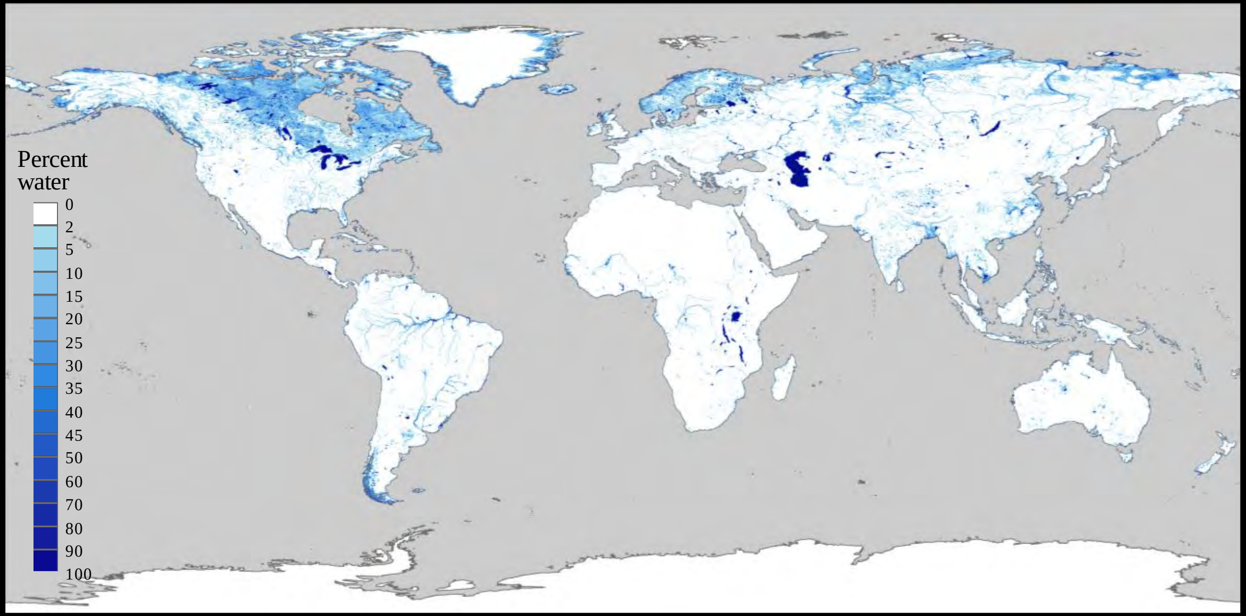
- First results of cross-scale models appear promising (stay tuned…)





Questions?





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