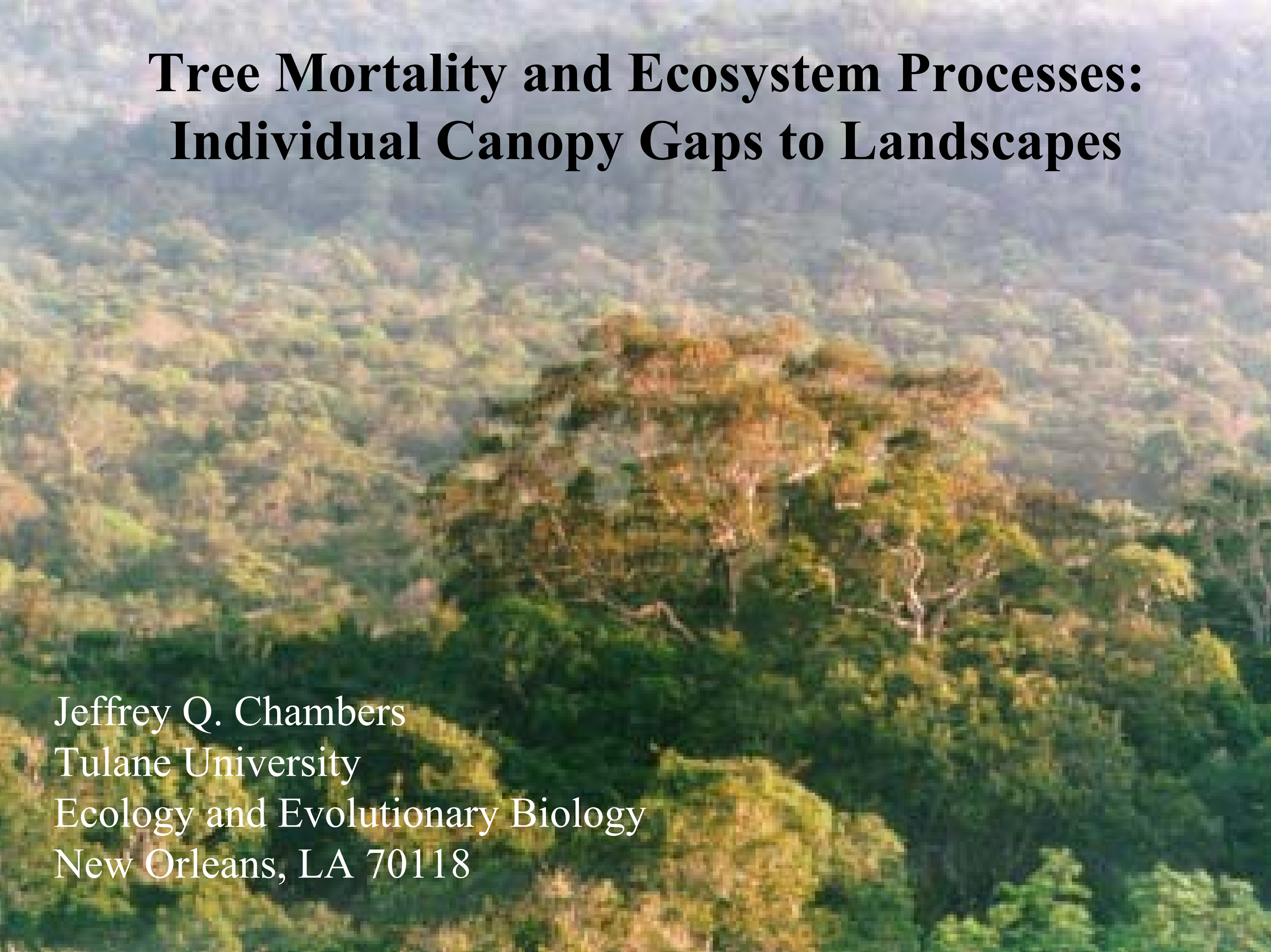

Tree Mortality and Ecosystem Processes: Individual Canopy Gaps to Landscapes

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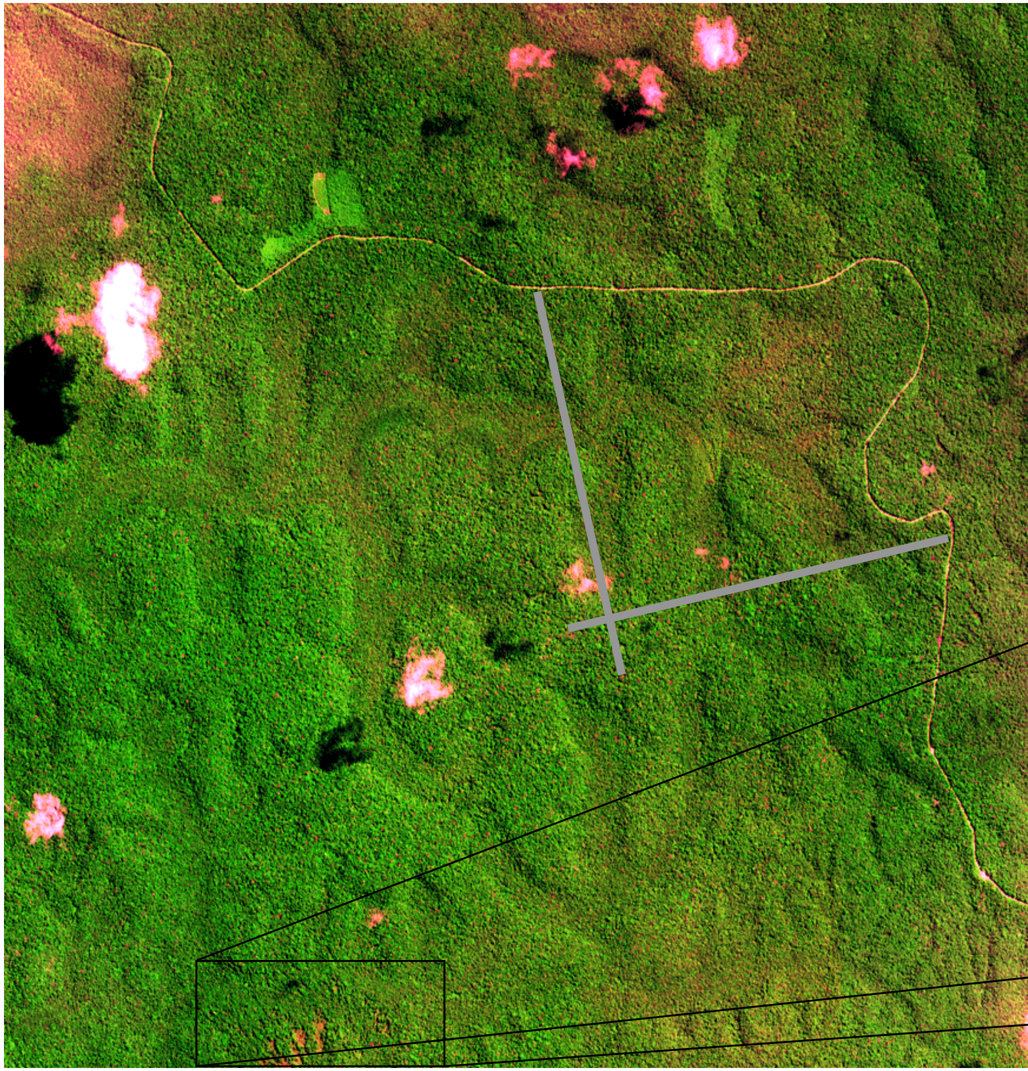
Background

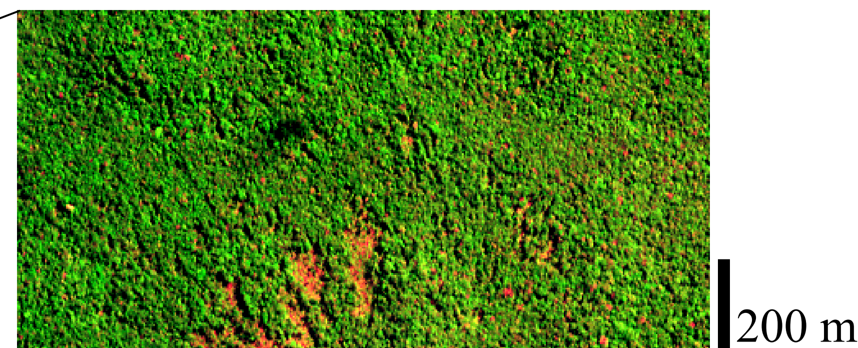
- **Forest inventory plots provide little information on catastrophic (gaps > 0.1 ha) mortality events.**
- **Example: Of 1284 gaps (in 50 ha plot) studied by Hubbell et al. (1999), only 9 were > 0.04 ha with the largest gap occupying just 0.11 ha (1100 m^2).**
- **Nelson et al. (1994) detected large natural gaps > 30 ha in size (*blowdowns* produced by high-velocity downburst winds) using spectral reflectance features in Landsat TM images across the Brazilian Amazon.**
- **Nelson et al. (1994) study: only 19 blowdowns had spectral properties indicative of new clearings, occupying 0.4% of scene area, leading Nelson et al. to predict that if these patches formed over a two-year period, and events did not strike the same area twice, forest turnover by large blowdowns would take about 5000 years [1/(0.0004/2)].**
- **However, in a more detailed analysis of one TM scene, inclusion of smaller blowdowns (5-30 ha) increased the number of disturbed patches by an order of magnitude.**
- **Critical gap in studies of mortality events ranging from 0.1 to 5 ha, and this scale is important for many ecological processes including the maintenance of tree species diversity and landscape carbon balance.**
- **What is the distribution function for mortality events ranging from individual tree deaths to 3,000 ha blowdowns?**

Catastrophic Tree Mortality and Microburst Winds

IKONOS image of a blowdown in the Central Amazon. Each large patch is 2-3 hectares in size, where most trees were instantly razed by intense downdraft winds from a microburst.

Grey bars indicate permanent forest inventory plots managed by INPA (2.5 km long), and the road is referred to as ZF-2.





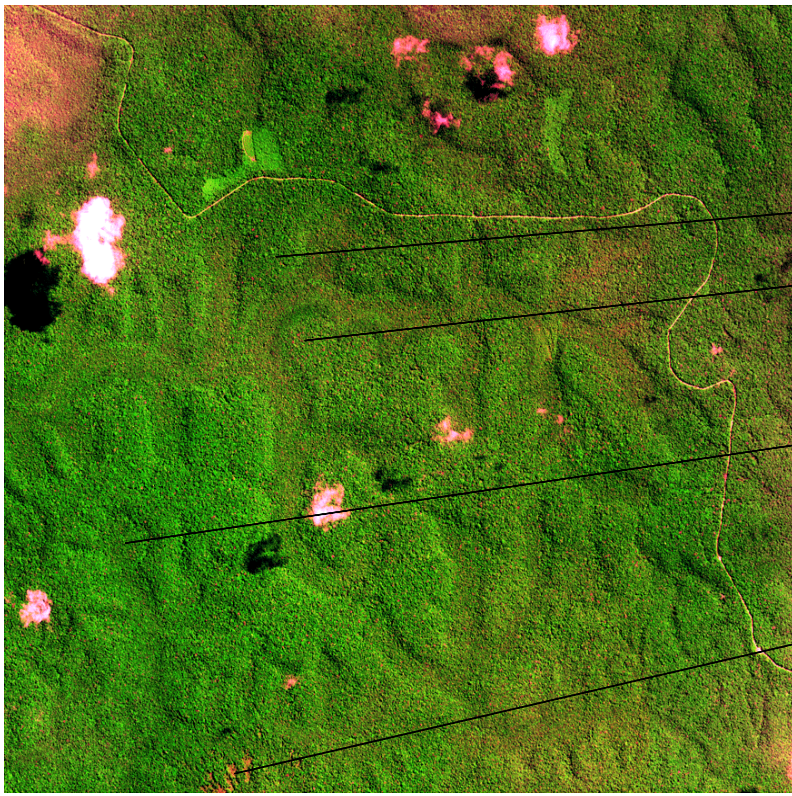
IKONOS image

Severe downdraft winds often associated with late dry season storms

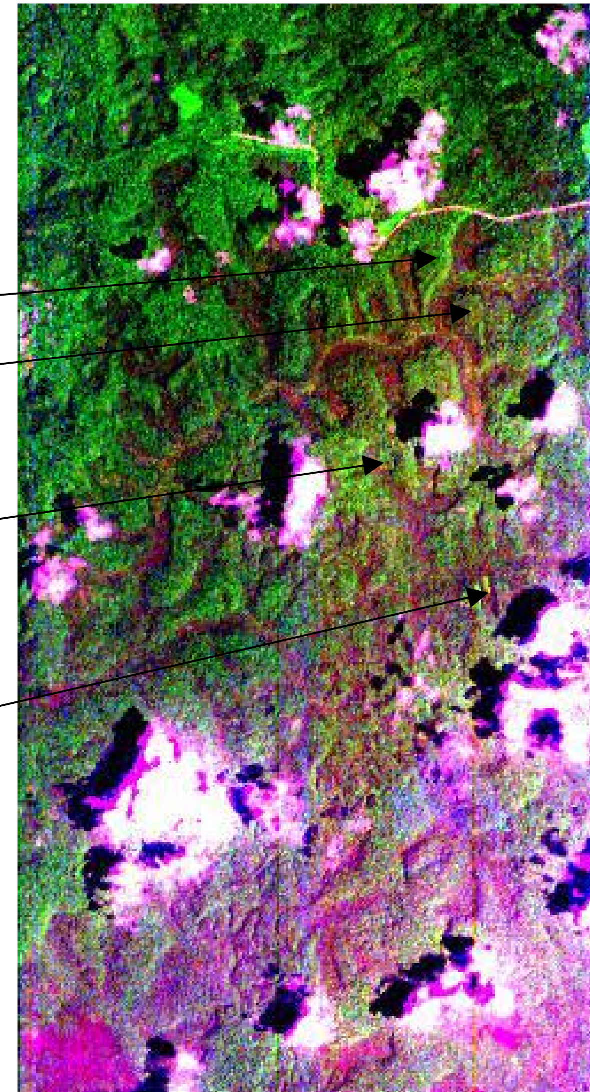
Mapping out relative abundance of blowdown-like vegetation using hyperspectral remote sensing data

HYPERION: ~160 bands

IKONOS: 5 bands

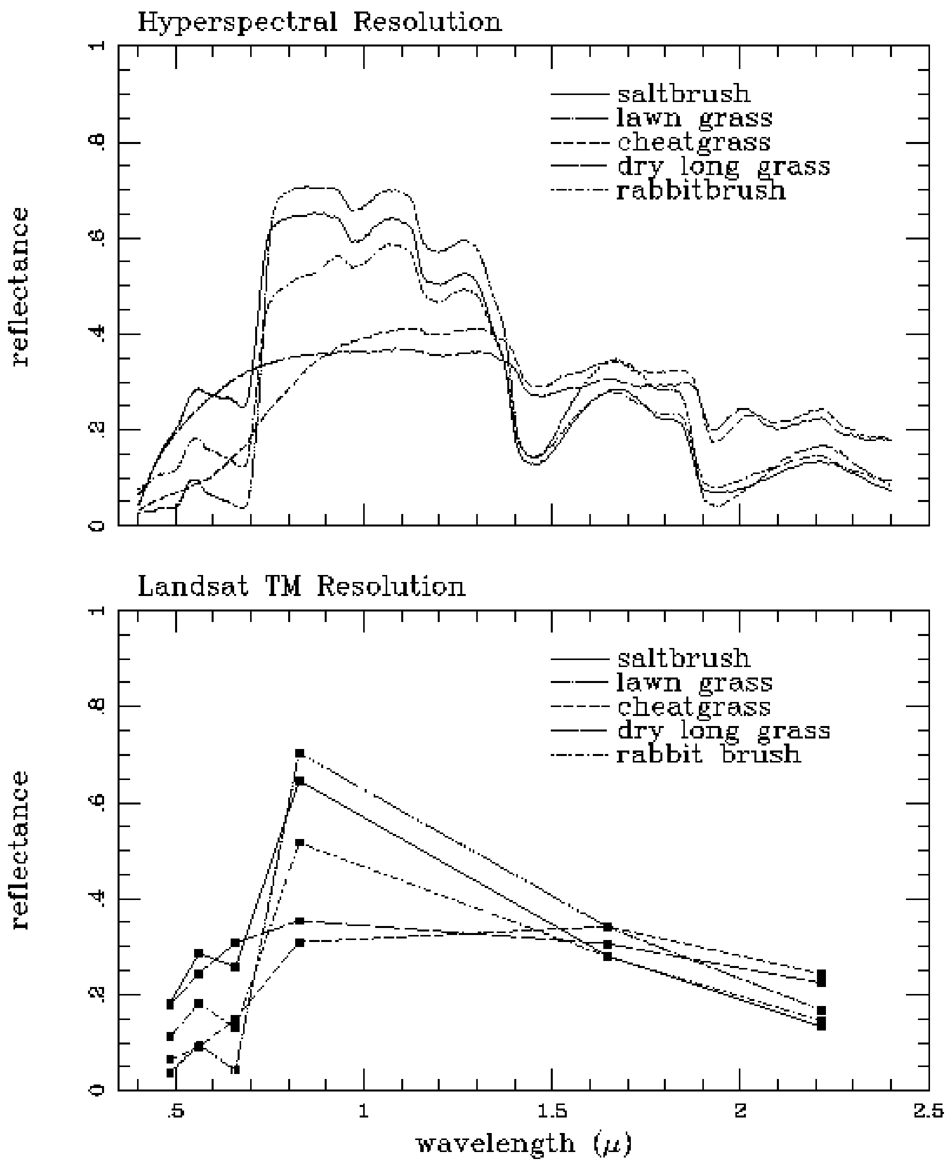


July 2000: blowdown + 9 months



Nov 2002: blowdown + 3 years

What are the advantages of using hyperspectral imagery for detecting forest disturbance?

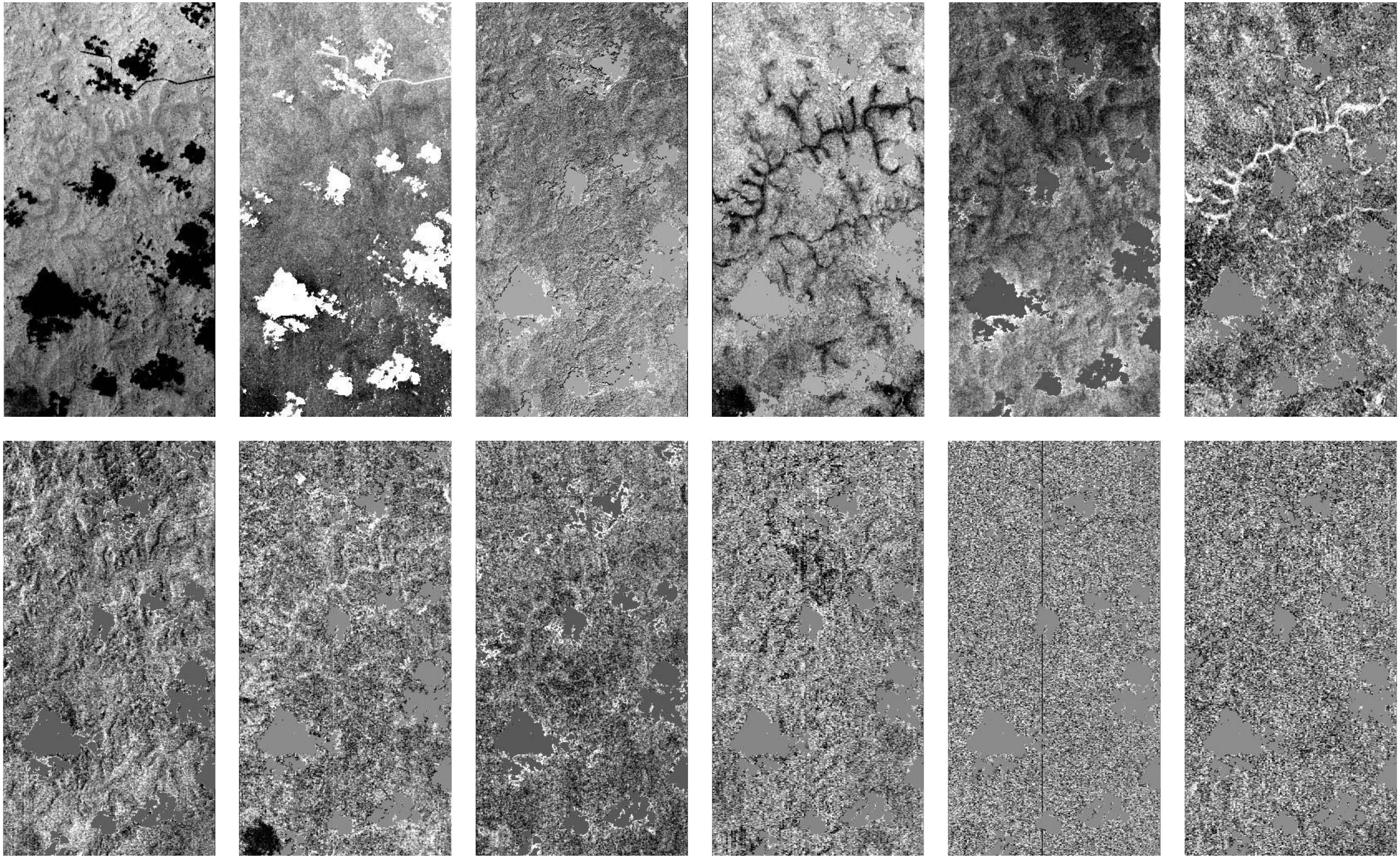


1. **Endmembers (targets of interest) spectrally "overdetermined"– allows mapping of vegetation having subtle spectral differences**
2. **Subpixel unmixing: determine within-pixel fractional abundance**
3. **Development of new remote sensing methods for addressing unique questions – e.g. how are 0.1 to 100 ha tree mortality events distributed across an Amazon forest landscape?**

Overall Image Analysis Approach

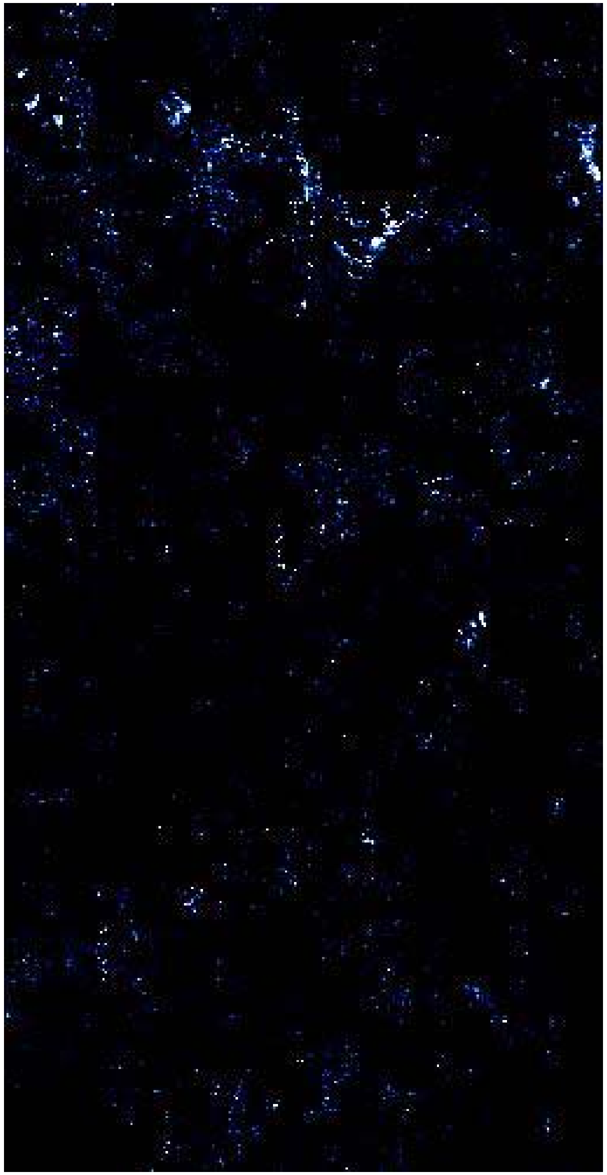
1. Subset Hyperion data for ZF2 blowdown scene – “Destreak” and run ACORN for radiance → apparent reflectance.
2. Minimum noise fraction (MNF) transformation and pixel purity index (PPI) to identify blowdown endmembers.
3. Create ROI from most spectrally pure blowdown pixels and use mixture tuned matched filter (MTMF) to map out fractional abundance of blowdown the entire scene.
4. Run “Destreak”, ACORN, and MNF for entire Hyperion scene (7 x 45 km) – use MTMF to map out fraction of landscape in large-gap (blowdown) recovery phase.
5. Establish inventory plots in pixels identified as recent blowdowns to determine stand structure and species composition.
6. Carry out this analysis across the Amazon basin at sites with widely differing dynamics.

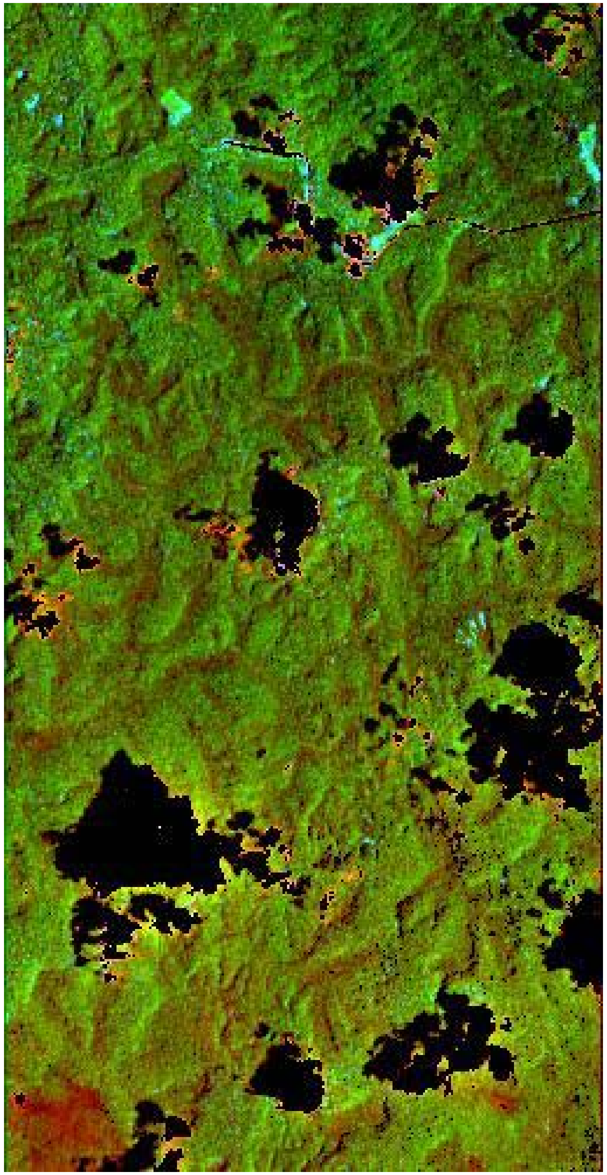
Minimum Noise Fraction Transformation



Reducing spectral data to lowest number of orthogonal data dimensions (similar to PCA) – transformed bands to generate pixel purity index (PPI).

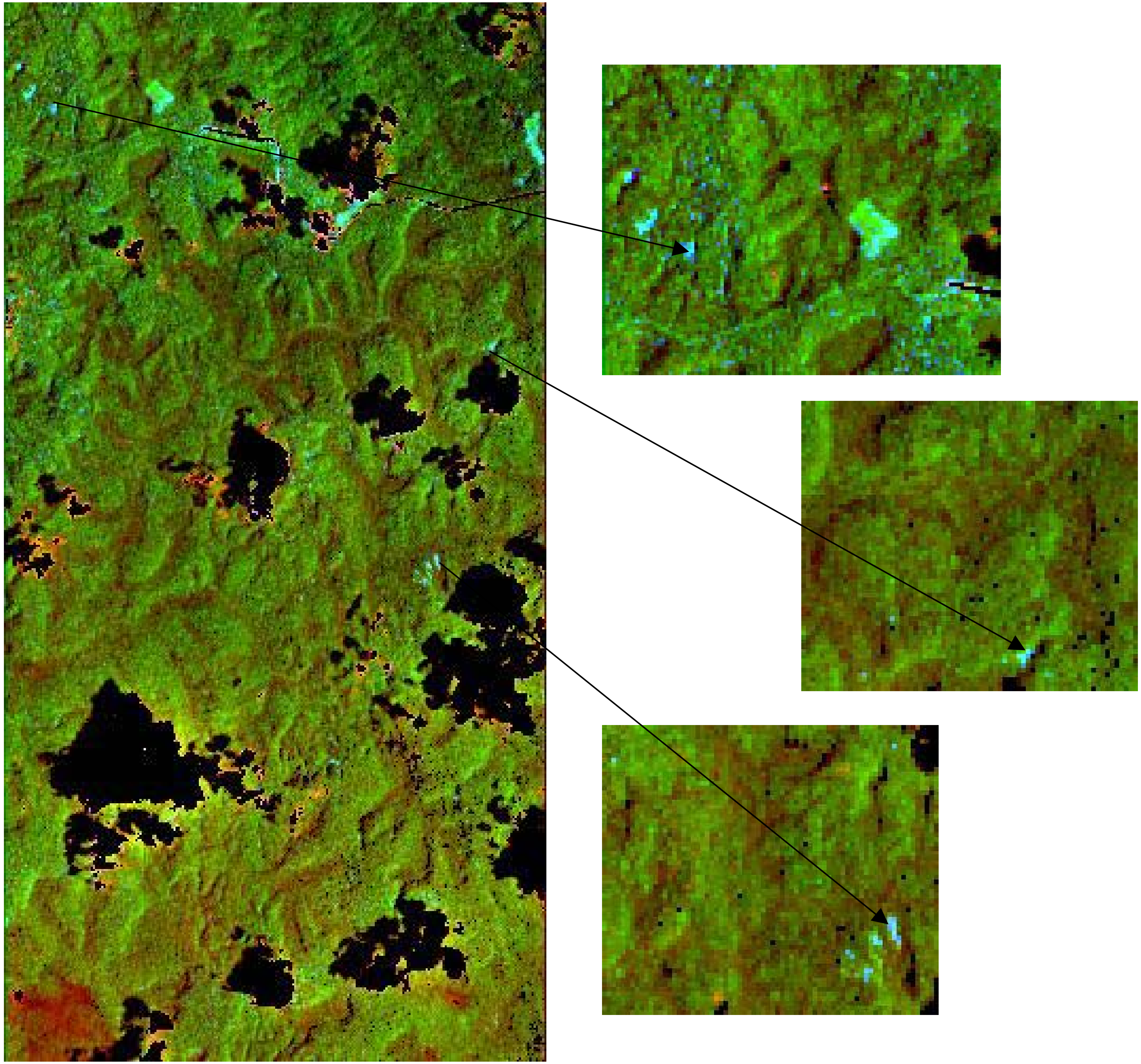
Blowdown Spectral Unmixing: Results from MTMF

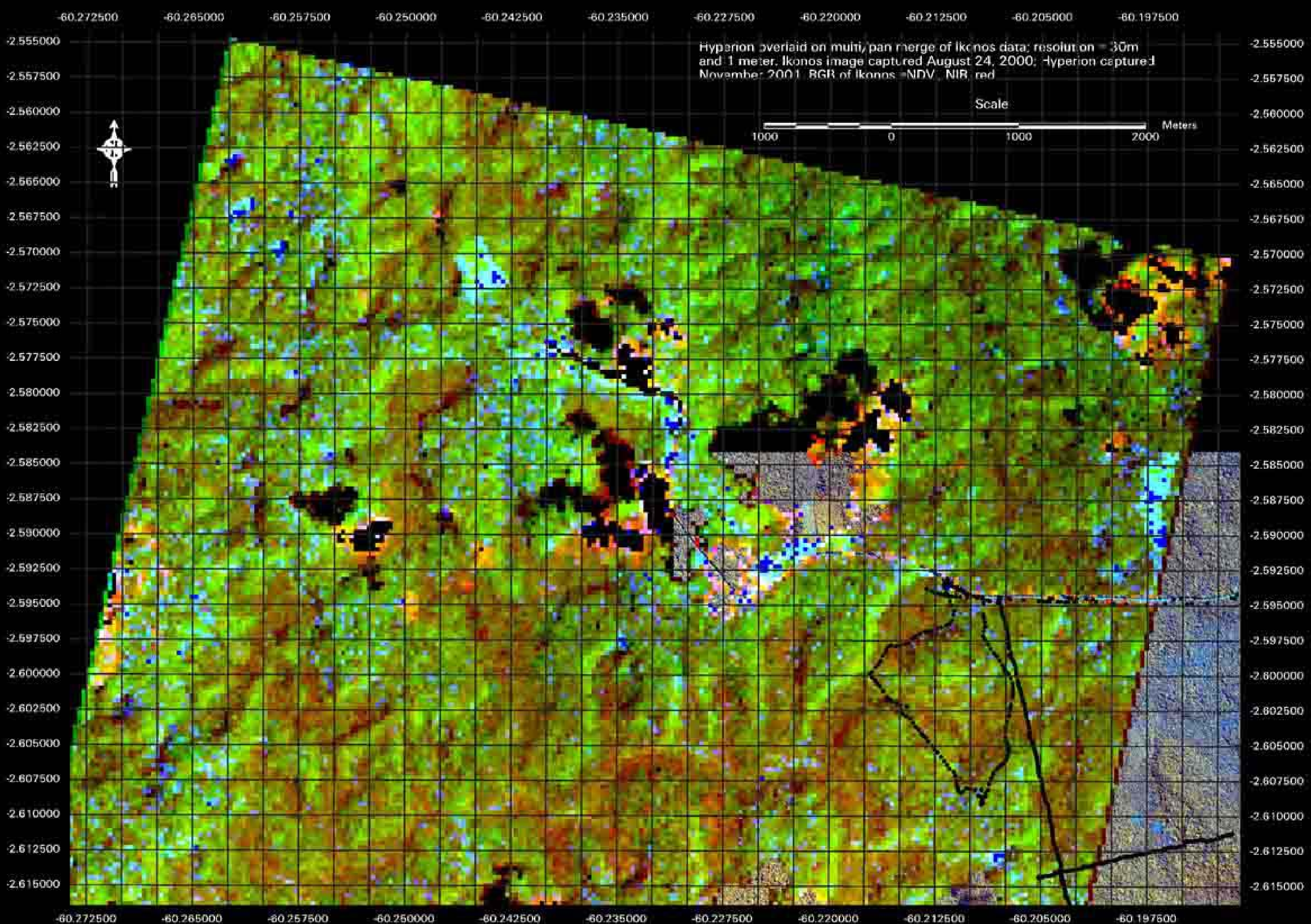




Brightest blue- white pixels represent areas with spectral reflectance most similar to blowdown pixels – these include land-use areas and other apparent canopy gap disturbances.

Intensity of blue represents fractional abundance of blowdown-like spectra in each unmixed pixel – threshold set at 40%.




Hyperion overlaid on multi/pan merge of Ikonos data; resolution = 30m
and 1 meter. Ikonos image captured August 24, 2000; Hyperion captured
November 2001. RGB of Ikonos =NDV, NIR, red
Scale
1000
0
1000
2000
Meters
-60.272500
-60.265000
-60.257500
-60.250000
-60.242500
-60.235000
-60.227500
-60.220000
-60.212500
-60.205000
-60.197500
-2.555000
-2.557500
-2.560000
-2.562500
-2.565000
-2.567500
-2.570000
-2.572500
-2.575000
-2.577500
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-2.587500
-2.590000
-2.592500
-2.595000
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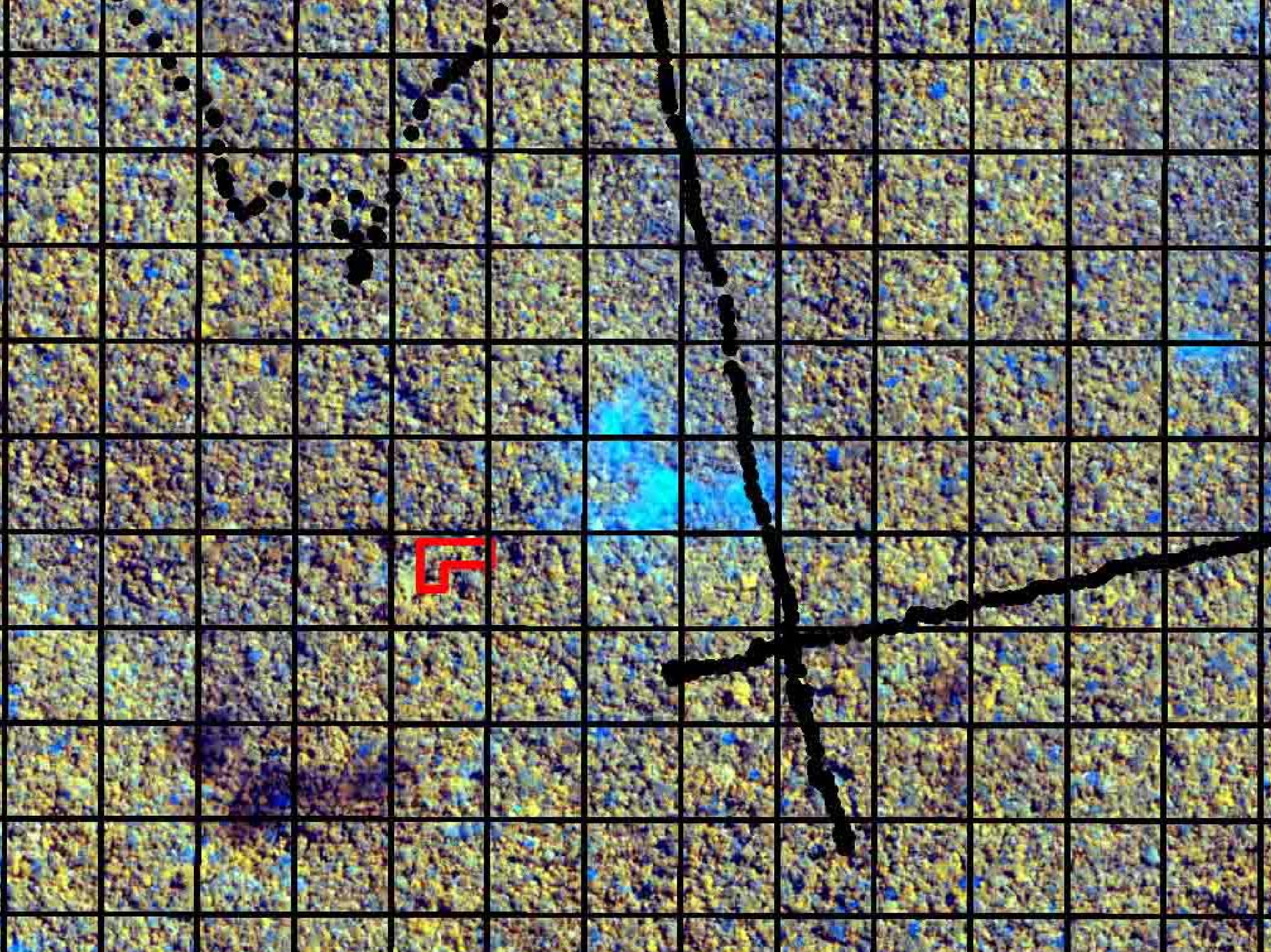
-2.612500
-2.615000

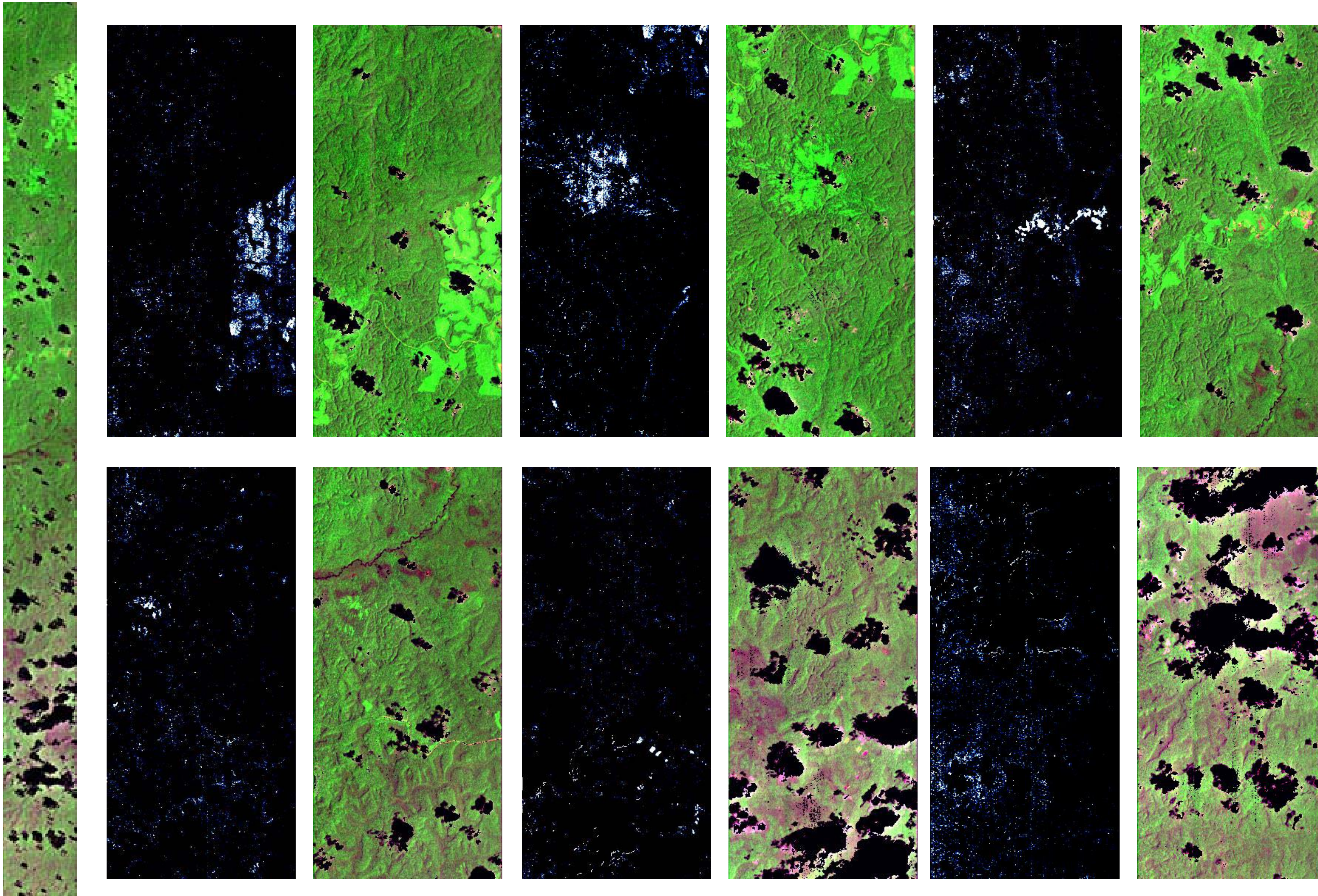


Species List for Hyperion-Identified Blowdown

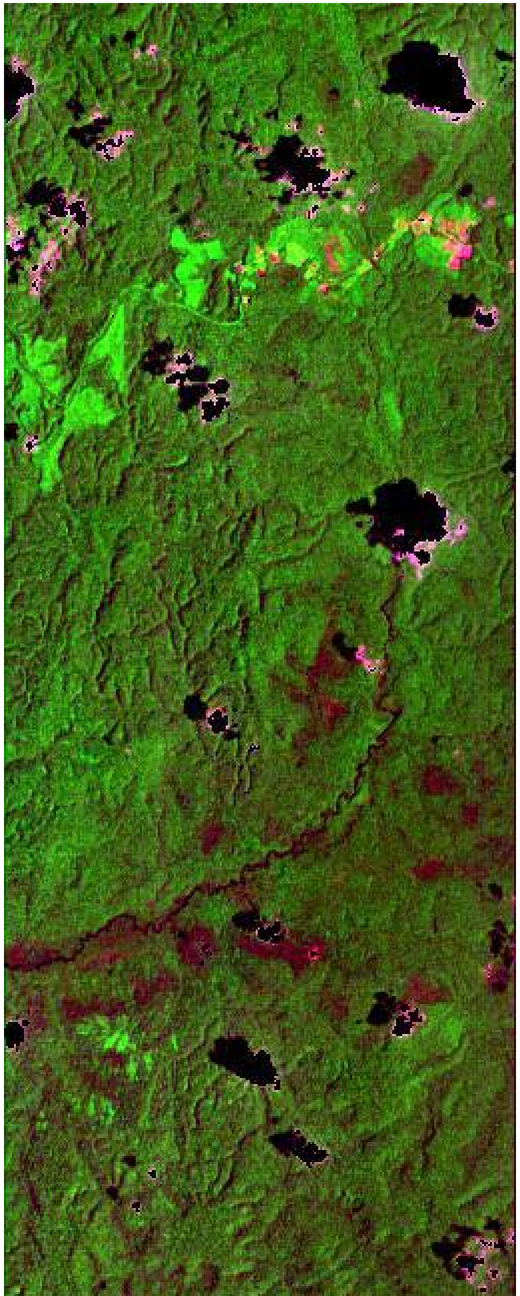
No	DBH	Family	Species	No	DBH	Family	Species
1	6.8	Melastomataceae	*Bellucia dichotoma* Cogn.	31	5.4a/4.6b	Leg. Mimosoideae	*Inga thibaldiana* DC. ssp. *thibaldiana*
2	5.7	Rubiaceae	*Capirona dicorticans* Spruce	32	8.7	Violaceae	*Leonia glycycarpa* Ruiz & Pav.
3	8.5a/7.6b	Flacourtiaceae	*Casearia pitumba* Sleumer	33	5.1	Melastomataceae	*Loureya spruceana* Benth. ex Triana
4	16.6	Cecropiaceae	*Cecropia sciadophylla* Mart.	34	18.6	Euphorbiaceae	*Mabea speciosa* Müll. Arg.
5	13.5	Cecropiaceae	*Cecropia sciadophylla* Mart.	35	14.6	Euphorbiaceae	*Mabea speciosa* Müll. Arg.
6	7.5	Cecropiaceae	*Cecropia sciadophylla* Mart.	36	7.6	Leg. Caesalpinioideae	*Macrolobium* sp. 2
7	7.5	Cecropiaceae	*Cecropia sciadophylla* Mart.	37	14.6	Sapotaceae	*Micropholis venulosa* (Mart. & Eichler) Pierre
8	7.2	Cecropiaceae	*Cecropia sciadophylla* Mart.	38	6.8	Olacaceae	*Minquartia guianensis* Aubl.
9	5.3	Cecropiaceae	*Cecropia sciadophylla* Mart.	39	9.2	Myrtaceae	*Myrcia* cf. *fallax* (Rich.) DC.
10	6.7	Cecropiaceae	*Cecropia sciadophylla* Mart.	40	11.5	Nyctaginaceae	*Neea floribunda* Poepp. & Endl.
11	10.7	Euphorbiaceae	*Conceveiba* cf. *guianensis* Aubl.	41	9.6	Cecropiaceae	*Pourouma ferruginea* Standl.
12	8.8	Euphorbiaceae	*Croton draconoides* Müll. Arg.	42	29.2	Cecropiaceae	*Pourouma ovata* Trécul
13	9.4	Euphorbiaceae	*Croton lanjouwensis* Jabl.	43	9.7	Sapotaceae	*Pouteria venosa* (Mart.) Baehni ssp. *amazonica* T.D.Penn
14	5.9	Euphorbiaceae	*Croton lanjouwensis* Jabl.	44	8	Sapotaceae	*Pouteria venosa* (Mart.) Baehni ssp. *amazonica* T.D.Penn
15	5	Euphorbiaceae	*Croton lanjouwensis* Jabl.	45	6.6	Burseraceae	*Protium apiculatum* Swart
16	5.2	Lecythidaceae	*Eschweilera coriacea* (DC.) Mart. ex Berg.	46	6.8	Burseraceae	*Protium* cf. *rubrum* Cuatrec.
17	7	Lecythidaceae	*Eschweilera grandiflora* (Aulb.) Sandwith	47	8.2	Burseraceae	*Protium spruceanum* (Benth) Engl.
18	18.3	Lecythidaceae	*Eschweilera rhododendrifolia* (Kunth) A.C.Sm.	48	7.6	Burseraceae	*Protium spruceanum* (Benth) Engl.
19	11.4	Lecythidaceae	*Eschweilera tessmannii* Kunth	49	9.1	Annonaceae	*Rollinia insignis* R.E.Fr.
20	5.2	Myrtaceae	*Eugenia* sp.	50	9.1	Annonaceae	*Rollinia insignis* R.E.Fr.
21	10.4	Annonaceae	*Guatteria guianensis* (Aubl.) R.E.Fr.	51	12.4	Leg. Caesalpinioideae	*Sclerolobium* sp. 6
22	9.2	Annonaceae	*Guatteria guianensis* (Aubl.) R.E.Fr.	52	6.3	Siparunaceae	*Siparuna glycycarpa* (Ducke) S.S.Renner
23	7.2	Annonaceae	*Guatteria guianensis* (Aubl.) R.E.Fr.	53	6	Siparunaceae	*Siparuna poeppigii* (Tul.) A.DC.
24	7.1	Annonaceae	*Guatteria guianensis* (Aubl.) R.E.Fr.	54	6.2	Siparunaceae	*Siparuna sarmentosa* Perkins
25	5.5	Annonaceae	*Guatteria guianensis* (Aubl.) R.E.Fr.	55	7	Leg. Papilionoideae	*Swartzia reticulata* Ducke
26	13.5	Annonaceae	*Guatteria* sp. 3	56	6.4	Sapindaceae	*Talisia* cf. *praealta* Radlk
27	13.6	Moraceae	*Helicostylis tomentosa* (Planch. & Endl.) Rusby	57	6.3	Clusiaceae	*Vismia guianensis* (Aubl.) Choisy
28	5.7	Leg. Mimosoideae	*Inga paraensis* Ducke	58	6.1	Clusiaceae	*Vismia guianensis* (Aubl.) Choisy
29	6.5a/5.8b	Leg.Mimosoideae	*Inga pezizifera* Benth.	59	5.5	Clusiaceae	*Vismia guianensis* (Aubl.) Choisy
30	8.4	Leg. Mimosoideae	*Inga* sp	60	5.5	Leg. Mimosoideae	*Zygia racemosa* (Ducke) Barneby & J.W.Grimes

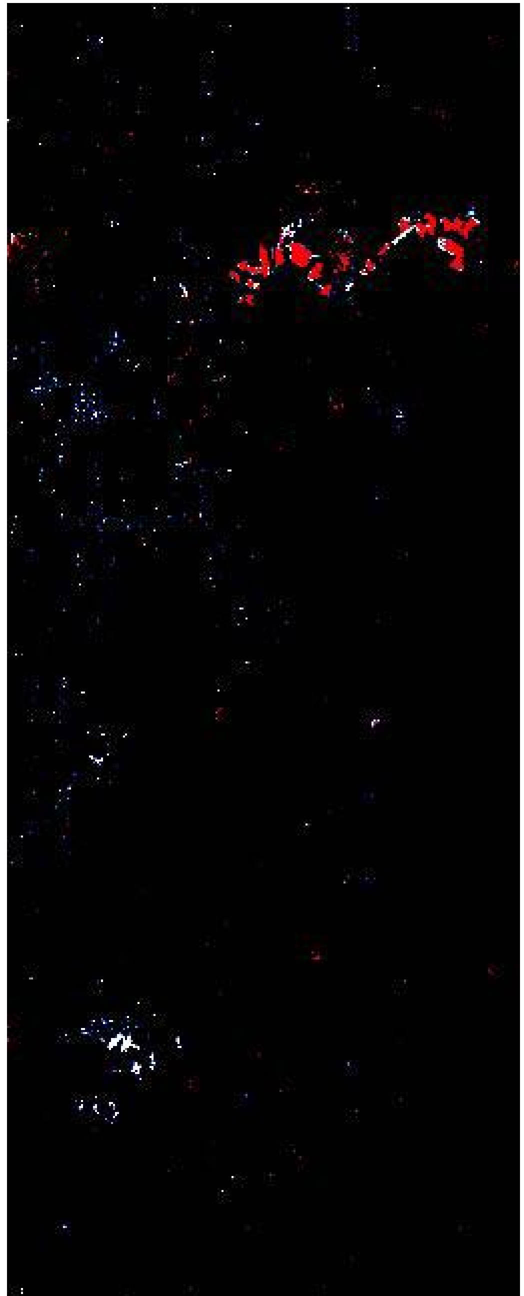
Classic pioneer species in genera *Cecropia* and *Vismia* represented 20% of stems > 5 cm DBH in this initial 400 m^2 plot, whereas in a nearby 9 ha plot these genera were only 1.3% – other blowdown sites has similar species composition.

Blowdown Spectral Unmixing: Results from MTMF



Infeasibility Score: Avoiding False Positives





Spectral unmixing methods can produce false positives when endmembers are considered additive instead of replacement targets – a common occurrence for data w/ subtle spectral contrasts.

Valid detections must be feasible mixtures of the target materials and background distribution.

Use of the unfeasibility score shown in red in MTMF map: generally landuse areas and other distinct vegetation types give false positives.

Changing Dynamics of Tropical Forests

Phillips, O. L., and A. H. Gentry. 1994. Increasing turnover through time in tropical forests. **Science** 263:954-958. (Also Phillips et al. 2004) → Forest turnover ([recruitment + mortality]/2) doubled from 1975-1990

Phillips, O. L et al.. 1998. Changes in the carbon balance of tropical forests: evidence from long-term plots. **Science** 282:439-442. (Also Baker et al. 2004) → Tree biomass has increased in Neotropics since 1980 at about 0.5 Mg C ha^{-1} yr^{-1}

Phillips, O. L. et al. 2002. Increasing dominance of large lianas in Amazonian forests. **Nature** 418:770-774. → Relative dominance of lianas/trees has doubled over the past 20 years

Laurance, W.F. et al. 2004. Pervasive alteration of tree communities in undisturbed Amazonian forests. **Nature** 428 171-175 → Changes widely cited as driven by increasing atmospheric CO_2

What is causing this non-equilibrium behavior?

Oecologia (2004) 141: 596–614
DOI 10.1007/s00442-004-1676-2

ECOSYSTEM ECOLOGY

Jeffrey Q. Chambers · Niro Higuchi ·
Liliane M. Teixeira · Joaquim dos Santos ·
Susan G. Laurance · Susan E. Trumbore

Response of tree biomass and wood litter to disturbance in a Central Amazon forest

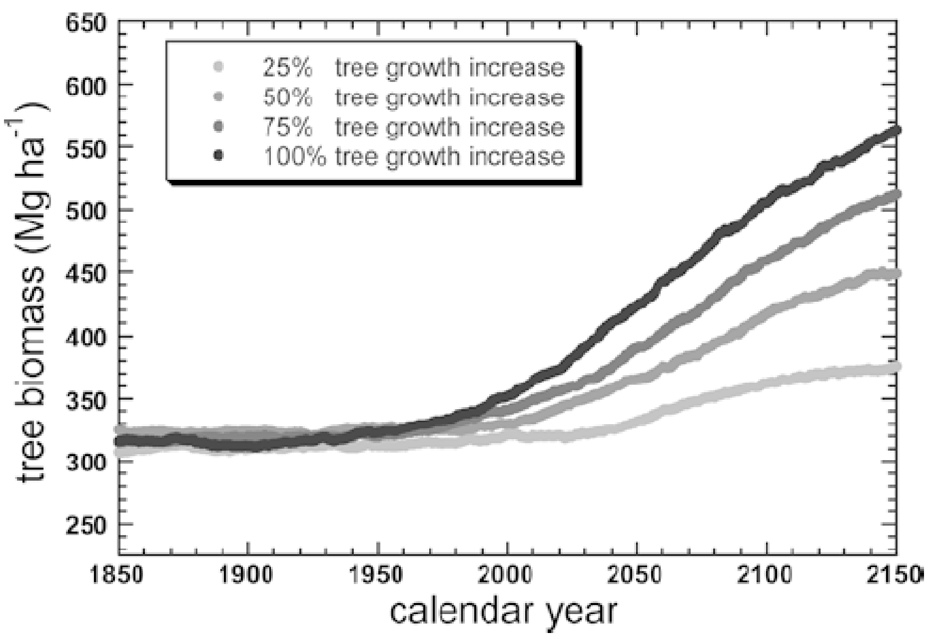
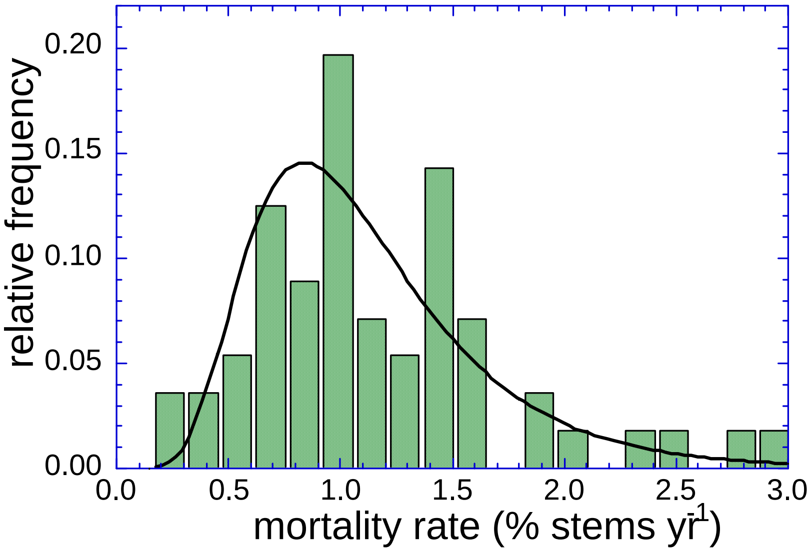


Fig. 6 Predicted response of above-ground tree biomass over time with different assumed CO_2 fertilization rates. Response was linked to the known and expected increase in atmospheric CO_2, and elevated growth was modeled using a ß function, as described in the text

Tree Mortality Probability Distribution Function

The temporal and spatial distribution of mortality events at the landscape scale can have important control over regional carbon balance.

How frequently does a catastrophic mortality event initiating secondary succession strike a given patch of forest?



There is an important spatial dimension to mortality events

Summary

- Most canopy gaps occurring within forest inventory plots (e.g. RAINFOR, STRI, etc.) are not of sufficient size to initiate classic secondary successional processes and changes in tree species composition.

- How do catastrophic mortality events (varying from about 0.1 to 5 ha in size) affect ecological and ecosystem processes?

- What is causing changes in forest dynamics and species composition observed in Amazon forests?

- Perhaps most forest patches are in some stage of recovery from past disturbance (30-100 years ago), generally acting as relatively small sinks for atmospheric CO_2, punctuated by a few years of large carbon release, which also impacts tree species composition and turnover.

- Hyperspectral remote sensing methods appear useful for detecting subtle vegetation features associated with recovery processes in large canopy gaps i.e. > 0.1 ha), and the distribution of disturbance and recovery processes at the appropriate landscape scale.

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