Satellite monitoring and assessment of fire – Where are we and where do we go from here?

E. S. Kasischke
for the Remote Sensing
Fire Science Community

NASA Carbon Cycle & Ecosystems Joint Science Workshop
28-30 April 2008

Contributors/Fire Science Researchers

- S. Conard, W. Hao, D. McKenzie, R. Ottmar, B. Schwind: *USFS*
- J. Eidenshink, J. Harden: *USGS*
- J. Allen, B. Sorbel: *NPS*
- K. Murphy: *FWS*
- S. Trigg: Cranfield Univ., England
- W. de Groot, R. Hall, D. McRae: *Canadian Forest Service*
- G. van der Werf: Vrije Univ., Neth.
- A. Sukhinin, G. Ivanova: Sukachev Forest Instititute, Russia
- A. Setzer, K. Longo: INPE, Brazil
- Hicke, Asner: Stanford
- J. Johnstone –USK, UAF
- L. Curran: Yale
- N. French, L. Bourgeau-Chavez: MRTI
- S. Goetz, D. Nepstad, F. Brown: WHRC
- P. Gong, R. Pu: UC-Berkeley
- D. McGuire, D. Verbyla, S. Yi, M. Balshi: Univ. AK
- D. Mildrexler, S. Running: UMT
- D. Munroe: Ohio State
- D. Morton, C. Justice, I. Csiszar, T. Loboda, W. Schroeder, S. Korontzi, R. DeFries, J. McCarthy, E. Vermotte, J. Townshend, E. Hoy, Z. Li, G. Sun: UMD
- C. Neigh, C. Tucker, L. Giglio, J. Collatz, J. Morrissette: GSFC/SSAI
- C. Potter: NASA ARC
- K. O’Connell, S. Mitchell, M. Harmon: O. Krankina: Oregon State Univ.
- J. Randerson, E. Lyons, Y. Jin: UC-Irvine
- D. Roy, M. Cochrane: SDSU
- H. Shugart, N. Sherman: Univ. VA
- A. Soja, A. Westberg: NASA LRC
- M. Turetsky, E. Kane: Mich State

Presentation Outline

1. Summary of Results
2. Fire information products
3. Characterization of the fire regime
4. Improvement of biomass burning emission estimates and models of terrestrial carbon cycling
5. Assessment of post-fire environmental conditions and ecosystem processes
6. Recommendations and future directions

Summary of Results (represents > 35 projects)

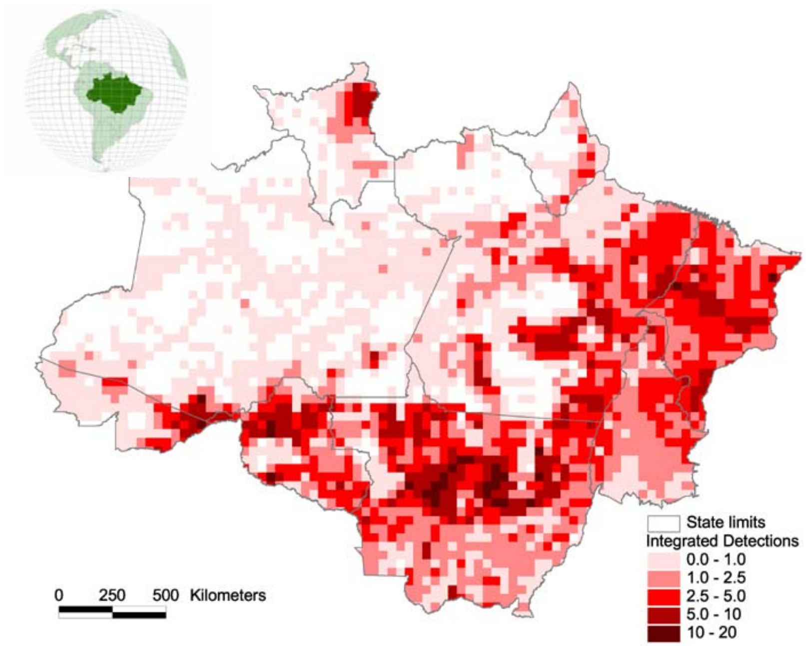
1. The development of new fire products from satellite remote sensing data continues, especially at regional scales
2. Integrated analyses of multiple remote sensing information products are leading to a clearer understanding of key characteristics of the fire regime at regional scales
3. Regional-scale studies have reduced uncertainties in estimates of biomass burning emissions, particularly in Brazil, Borneo, the Boreal Forest, the Western US, and from Agricultural Burning in the U.S.
4. Based upon integrated studies using field and satellite observations, new approaches are being developed to improve models that account for the impacts of fire on ecosystem processes and carbon cycling
5. Efforts are underway to develop new remote sensing products to assess and monitor the post-fire environment

Fire Information Products – Hot Spots, Burn Scars, Fire Intensity

1. MODIS Global Fire Products (Justice, Roy, Giglio, Csiszar et al. UMD)
2. TRMM VIRS Fire Products (Giglio, et al. SSAI)
3. Global MODIS Disturbance Product (Townshend, UMD **53**)
4. MODIS Global Fire Radiative Power Products (Vermotte et al., UMD **378**)
5. ASTER Fire Temperature Retrieval (Eckman, UCSB)
6. 12 year AVHRR Product for NA (Pu et al. UCB, UMD)
7. Regional MODIS Burn Scar Mapping - Russian Far East (Loboda, UMD: **159**)
8. US Agriculture Fire Products-MODIS (McCarthy, UMD)
9. MODIS Disturbance Index (Running et al. UMT **198**)
10. MODIS/GOES Regional Fire Monitoring – Brazil (Schroeder, Csiszar et al. UMD **234**)
11. AVHRR/MODIS Mapping of Fire Activity in Russia (Sukhinin, Soja, Kasischke et al. SFI **359, 360**)
12. Landsat Burned Area Product for the U.S. (MTBS Program - Eidenshink, USGS; Schwind, USFS)

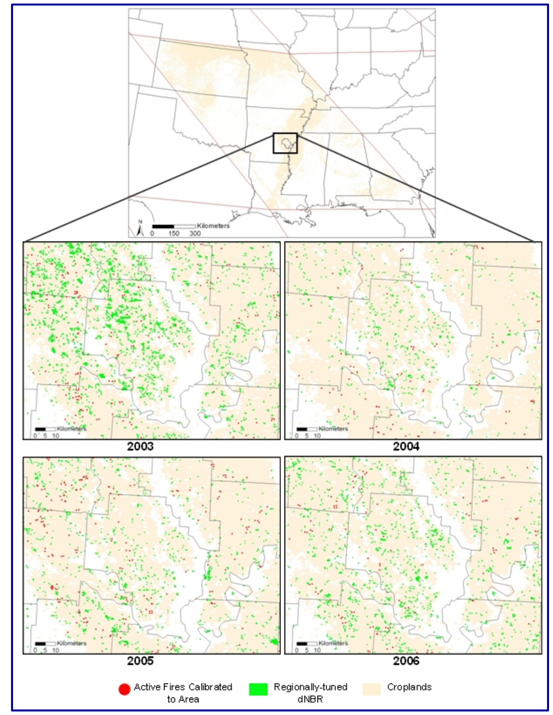
Regional Scale Fire Products

Schroeder et al. 234



Integrated fire product for Brazilian Amazonia using 2005 MODIS and GOES data showing average number of detection days per year.

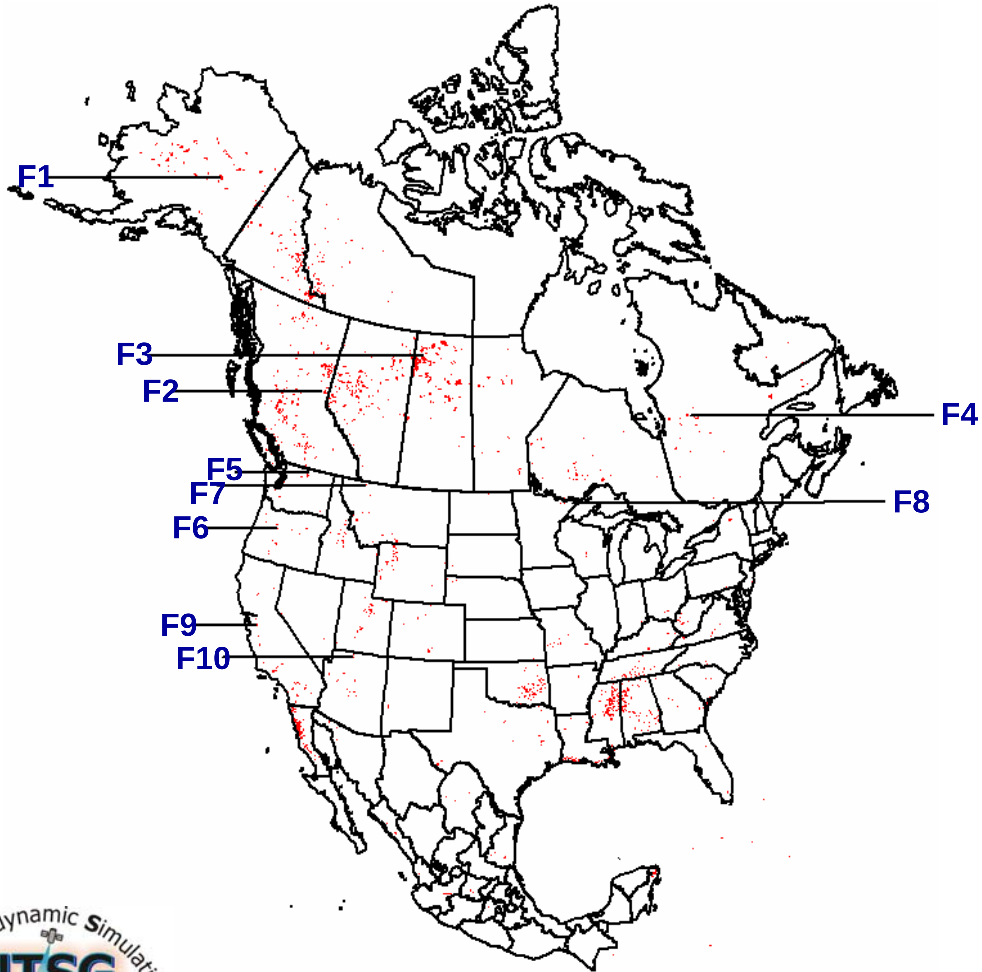
McCarthy et al.

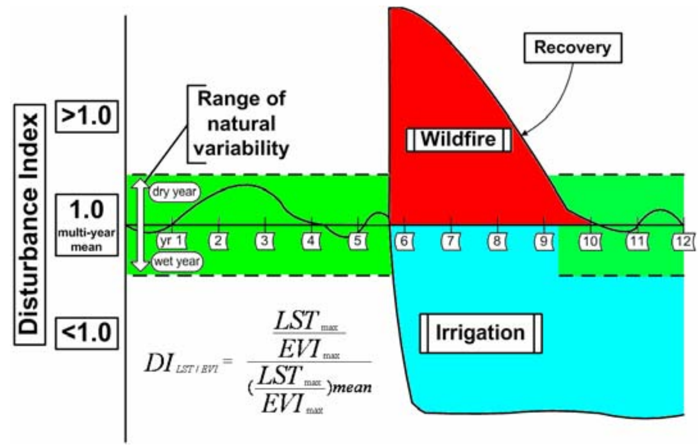


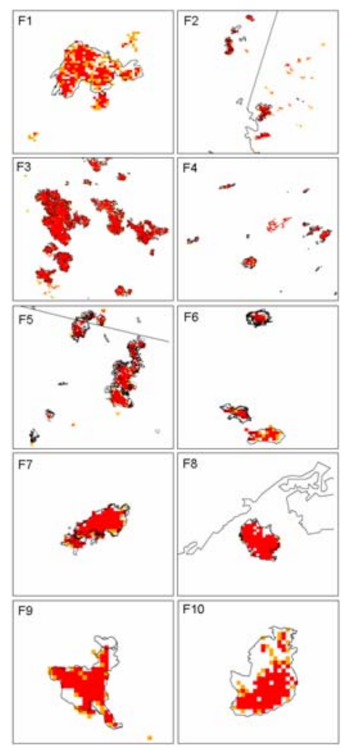
Example of hybrid approach to burned area estimation for crop residue burning: Fall harvest for Arkansas County, Arkansas.

MODIS Disturbance Index
2006 wildfire detection across NACP domain

Mildrexler, Running et al. 198





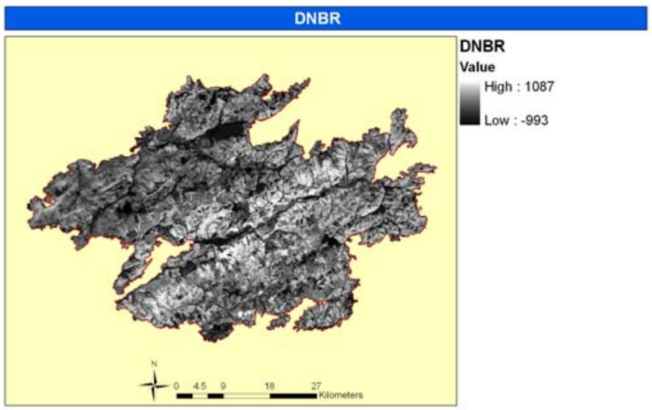


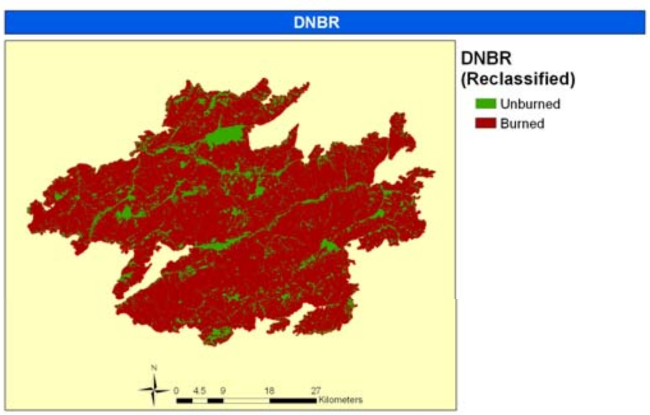
0-65% 65-100% 100+%

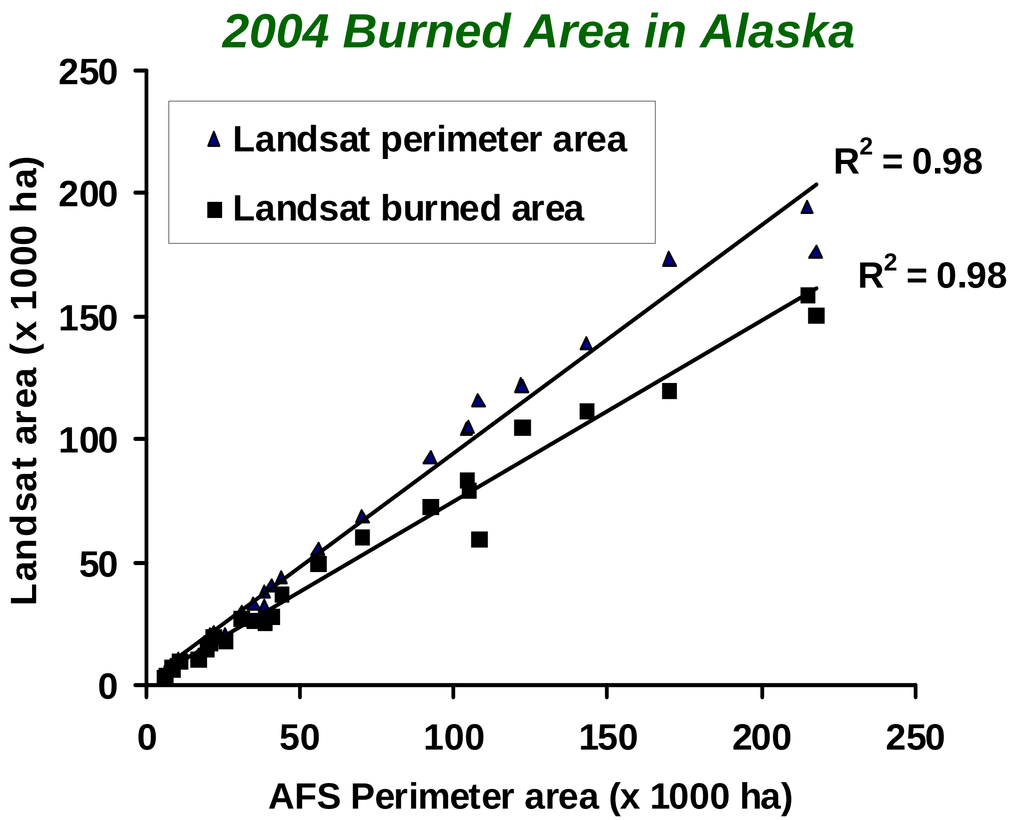
Numerical Terradynamic Simulation Group
NTSG
The University of Montana
Missoula Montana

Monitoring Trend in Burn Severity (MTBS) Program – USGS/USFS

The MTBS Program is using Landsat TM/ETM+ data to generate burn severity products for all large fires in the U.S. between 1984 and 2000







Characterization of the Fire Regime

1. Diurnal Fire Patterns from TRMM VIRS Data (L. Giglio et al., GSFC/SSAI)
2. Climate-Fire Relationships in the Russian Far East (Soja, Westberg, LRC; Sukhinin, SFI; et al. **359, 360**)
3. Fire Danger, Fire Risk, and Fire/Landscape Relationships in the Russian Far East (Loboda and Csiszar, UMD **159**)
4. Landsat Mapping of Burn Severity Across the U.S. (MTBS Program - Eidenshink, USGS; Schwind, USFS)
5. Assessment of Satellite Fire Severity Products (Hoy, Kasischke, UMD; French, MTRI; Hall, CFS; Verbyla, UAF; Allen, Sorbel,NPS; Murphy, NPS **24**)
6. Analysis of Agricultural Fires Across the U.S. (McCarthy, UMD)
7. Spatial/Temporal Analysis of the 2004 Fires in Alaska (Kasischke, Hoy et al.; UMD **151**)
8. Fire and Land Use Change in Borneo (van der Werf, Randerson, DeFries, Curran et al.: Vrie Univ.)

Characterizing the Diurnal Fire Cycle

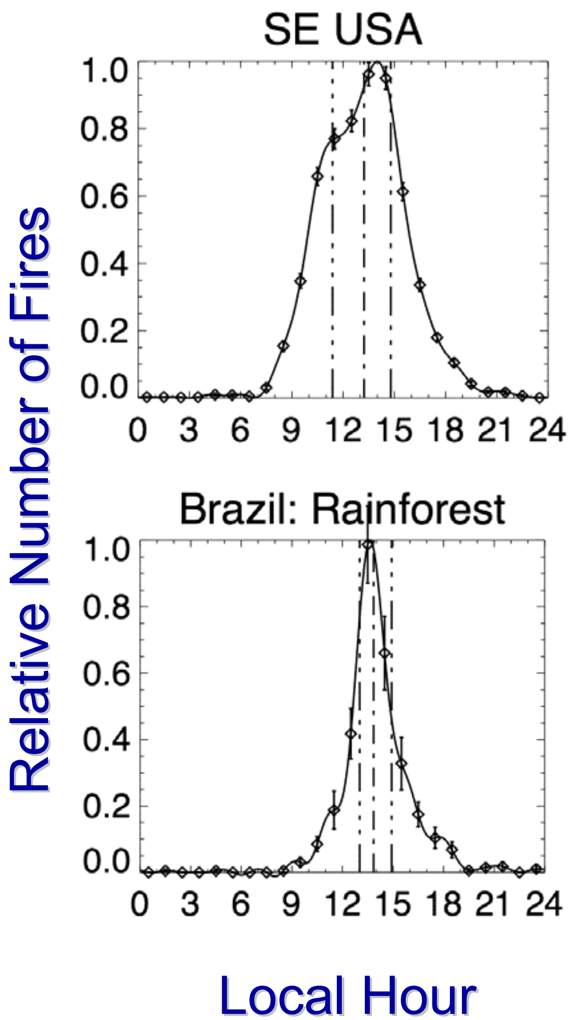
Approach

- Detect fires with TRMM VIRS sensor
- Exploit precessing TRMM orbit to sample diurnal fire cycle over time

Results

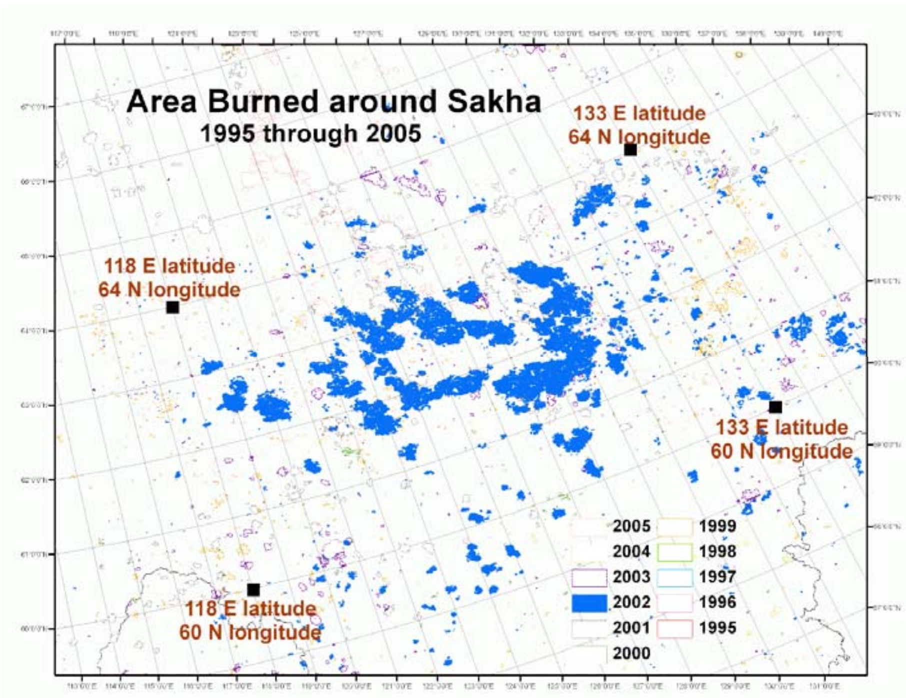
- Strong diurnal cycle in the tropics and sub-tropics
- Peak local time 13:00 to 18:30
- Peak width 1.3 h to 5.5 h
  - Higher tree cover → narrower peak

Giglio et al.



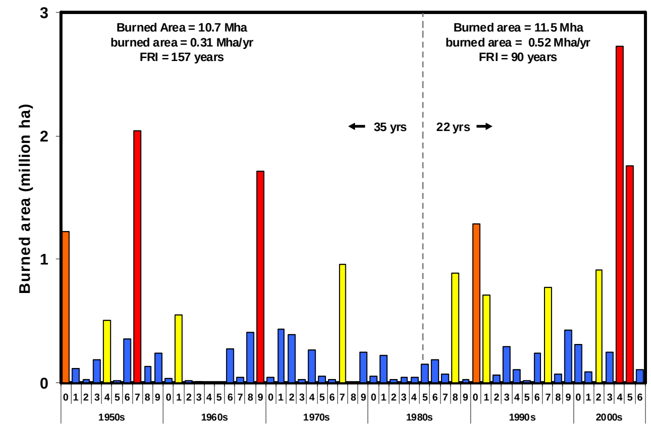
Episodic Fire Events at Sub-Continental Scales in the Boreal Forest

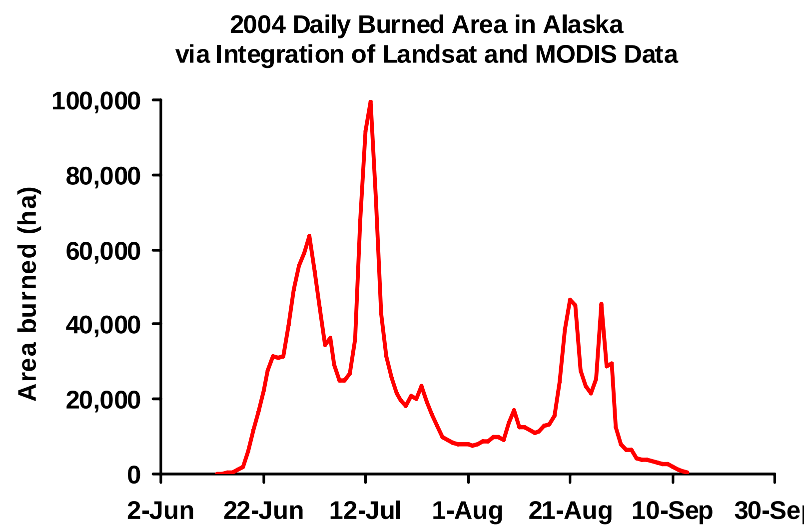
***Soja, Sukhinin et al.* 359,360**



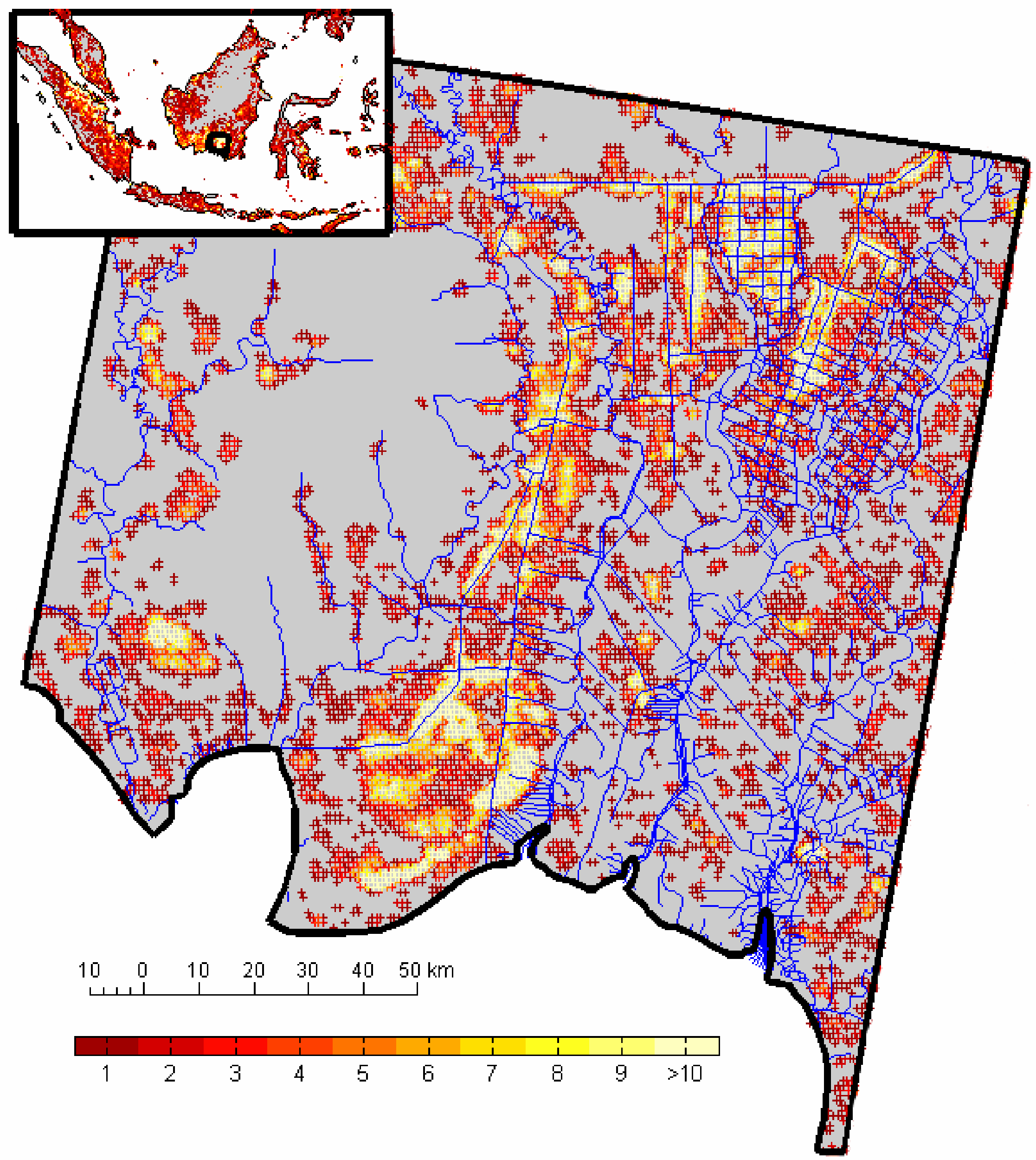
Fire activity in Northeastern Russia based on AVHRR/MODIS Fire Products

***Kasischke et al.* 151**





Fire impacted area in Alaska

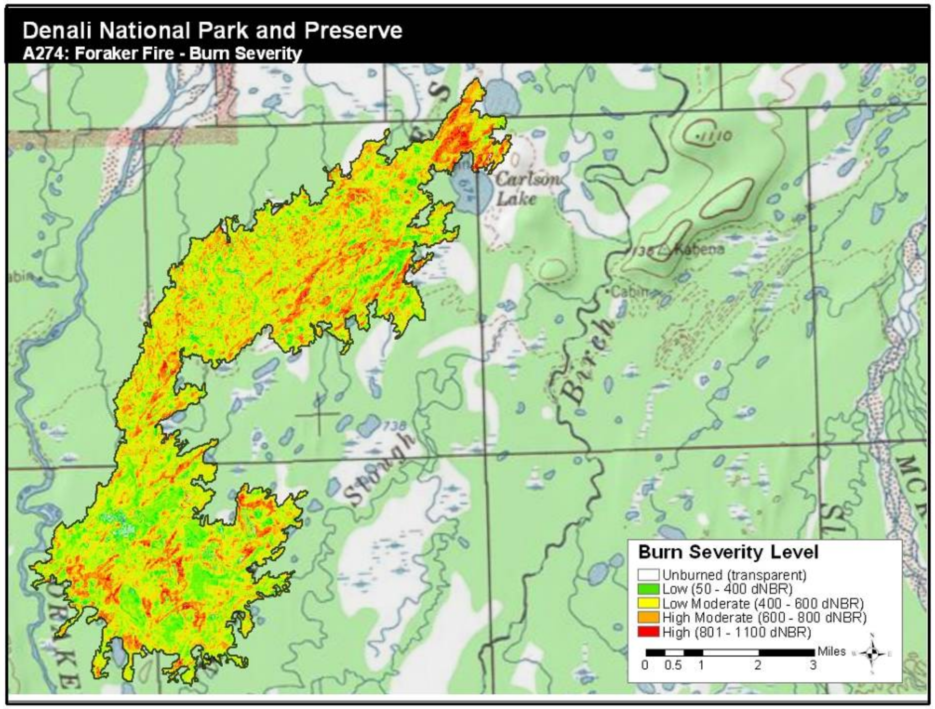


- **Southern Borneo mega rice project area (or just south of that)**
- **Blue: drainage based on Landsat data**
- **Red-orange: number of MODIS fire counts (2000-2006)**
- **Repeat fires (yellow) occur frequently in drained areas**
- **Van der Werf et al., in review**

Curran, Randerson, and DeFries Projects

Monitoring Trend in Burn Severity (MTBS) Program – USGS/USFS

The MTBS Program is using Landsat TM/ETM+ data to generate burn severity products for all large fires in the U.S. between 1984 and 2000



Allen, Sorbel: NPS

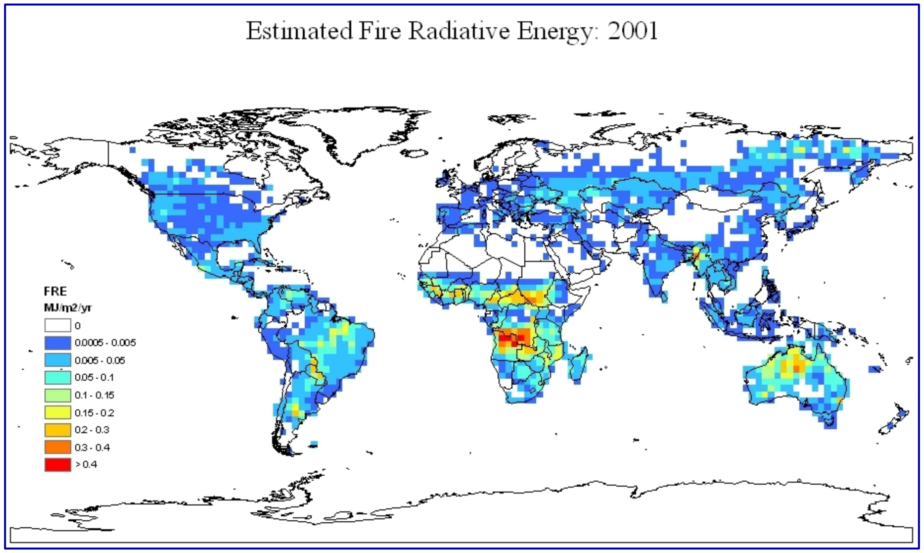
While numerous studies have shown that maps of burn severity can be generated from Landsat TM/ETM+ data for individual fire events, significant questions exist about using the dNBR/CBI approach to operationally map burn severity

Biomass Burning Emission Estimates and Carbon Cycling

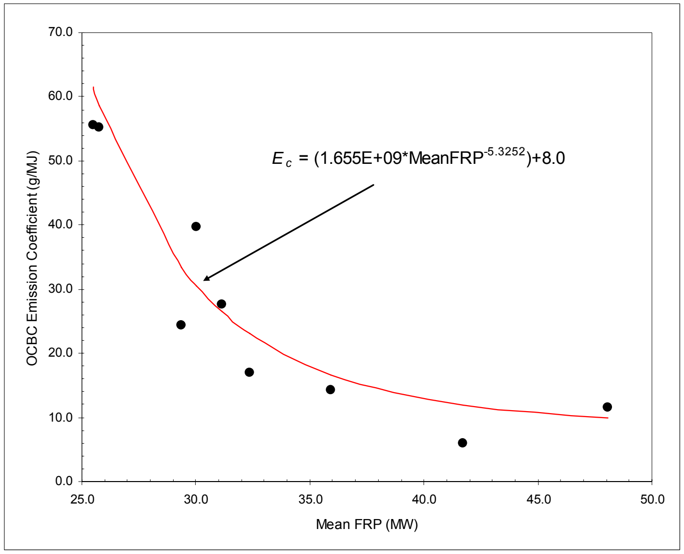
July 2002 NASA – GOFC/GOLD – BIBEX Workshop on Improving Estimates of Emissions from Biomass Burning

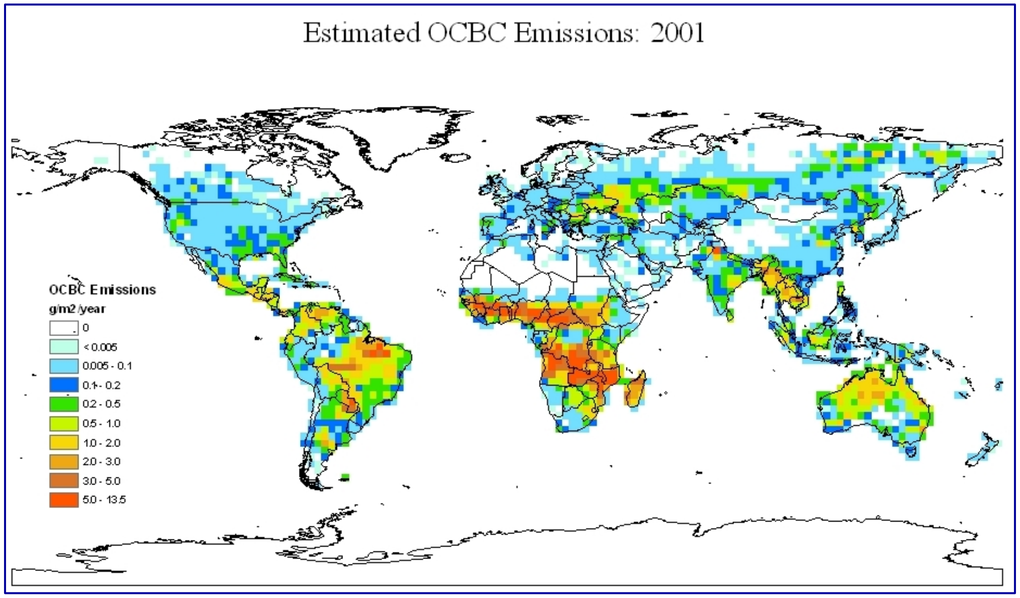
1. Global BB Emissions - GFED (van der Werf, Randerson, et al., UCI, Vrie Univ)
2. Global Estimates of BB Emissions using MODIS FRP (Vermotte et al., UMD **378**)
3. *BB Estimates for the Conterminous US (Hao et al., USFS)*
4. *Improved BB estimates for the NA Boreal Region (Kasischke, Hoy, UMD; de Groot, CFS; Turetsky, Kane, MSU et al.* ***150****)*
5. *Estimates of BB Emissions for the W.U.S. (French, MTRI; McKenzie, USFS* ***24, 271****)*
6. *Improved Estimates of BB Emissions from Deforestation in Brazil (DeFries, Morton, UMD* ***231****)*
7. *Improved Estimates of BB Emissions in African Savannas (Korontzi et al., UMD)*
8. *Estimates of BB Burning from US Agricultural Fires (McCarthy et al., UMD)*
9. *Fuel consumption/fire weather relationships in Russian forests (Conard, USFS; McRae, CFS; Sukhinin, Sukachev Forest Institute)*
10. *Impacts of Peatland Fires in Borneo on BB emissions: (van der Werf, Vrie Univ; Randerson UCI; Curran, Yale; Trigg, Cranfield Univ.; DeFries, Dempenwolf, UMD)*
11. *BB Emissions in Indonesia (Monroe et al. OSU* ***271****)*
12. Effects of Fire Management on Fuels Along Fire Regime and Forest Productivity Gradients in Oregon: Implications for Long-Term Carbon Dynamics (Mitchell, O'Connell, Harmon, Oregon State)
13. Impacts of Fire on the Carbon Budget of the Boreal Forest (McGuire, Yi, Balshi, et al. UAF **358**)
14. Impacts of Disturbance on Boreal Carbon Cycling (Neigh, Tucker, Collatz, GSFC/SSAI **287**)
15. Impacts of Disturbance on Terrestrial Carbon Storage in Russia (Krankina et al. OSU)
16. Fire and Biomass Mapping in NE Asia (Sun et al., UMD **278**)

Emission Estimates Based on MODIS FRP Measurements



Vermotte et al. **378**



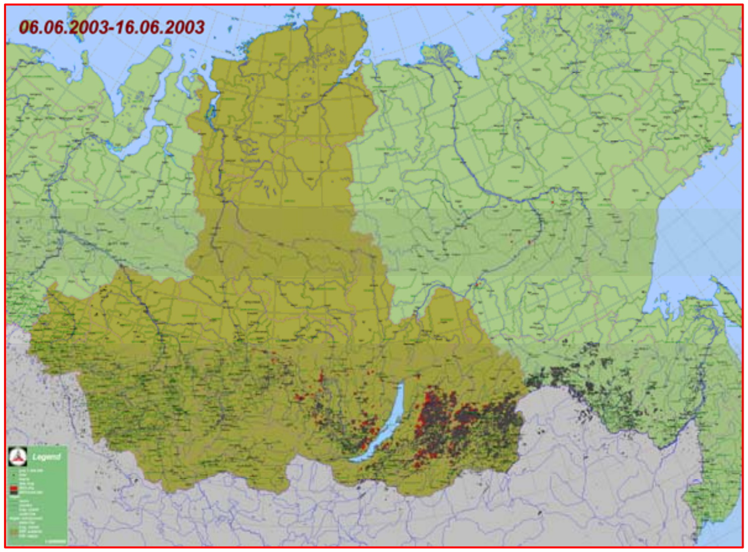


Collection of Additional Field Data to Reduce Uncertainties in Fuel Loads and Fuel Consumption

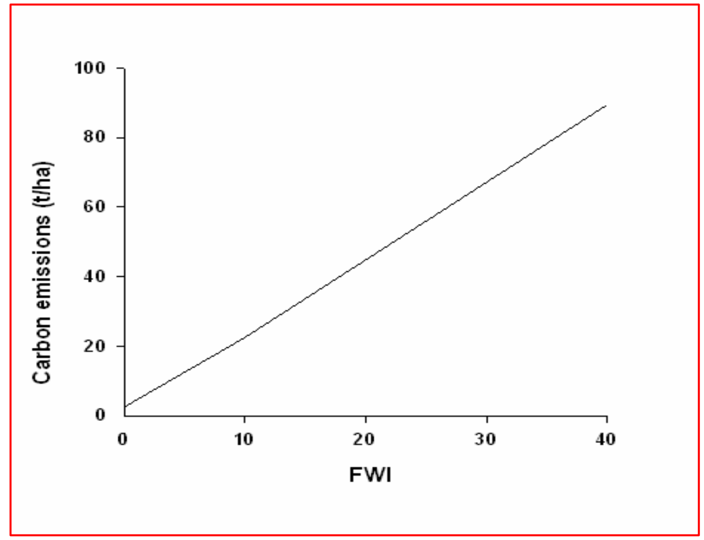
Ottmar et al. (Boreal)

Turetsky, Harden, et al. (Boreal) **150**

DeFries et al. (Tropical) **231**



Satellite Mapping of fire activity

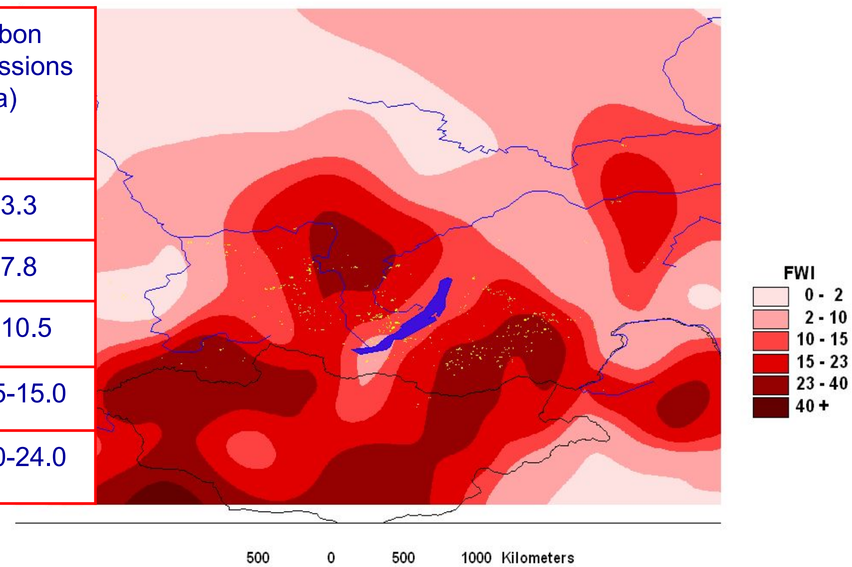


Field-based data relating fire weather indices and fuel consumption

Conard et al. USFS/SFI

Driving fuel consumption based on temporal/spatial variations in climate (fire weather)

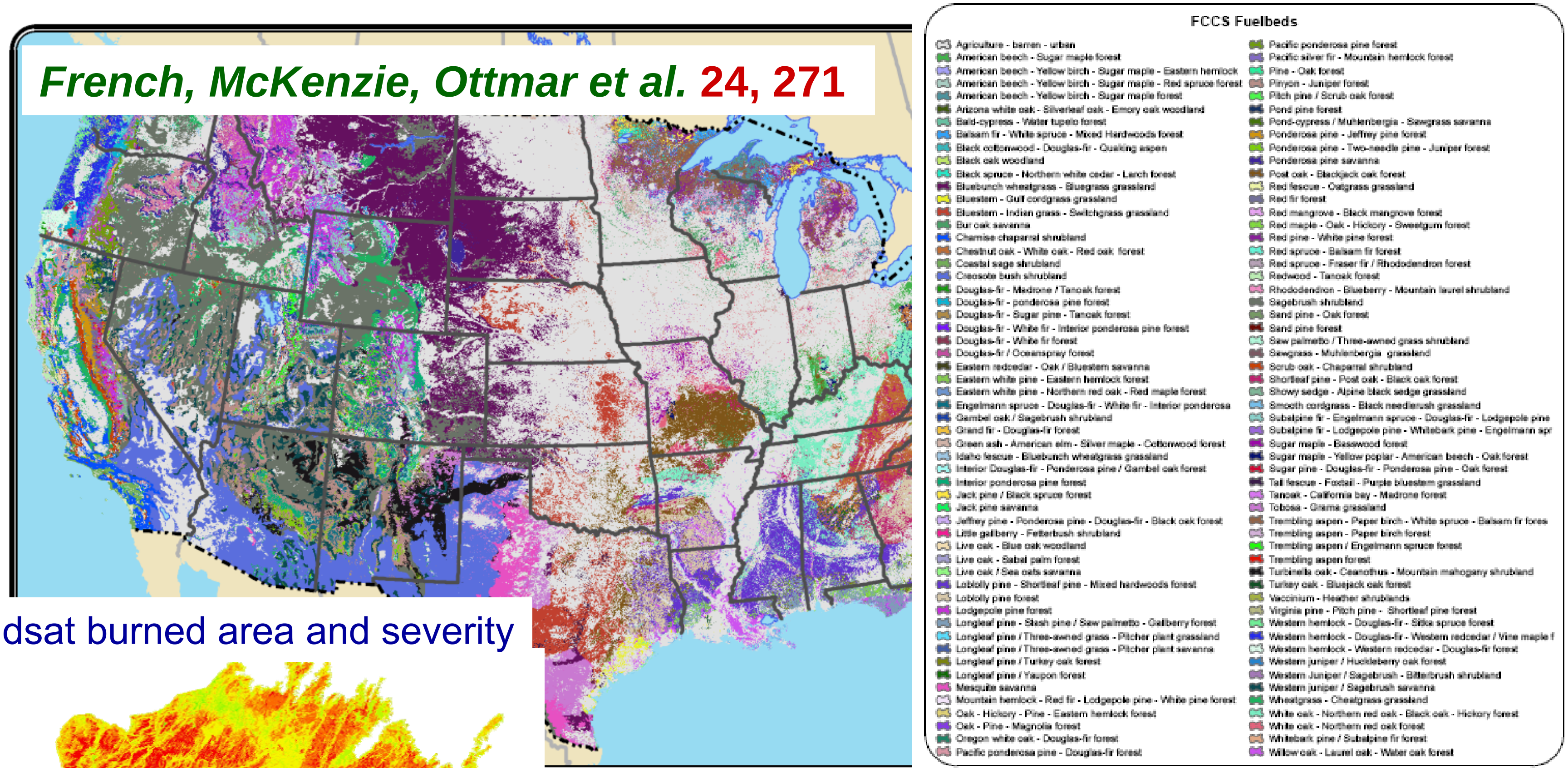
Fire Weather Index	Carbon emissions (t/ha)
0-2	2.2-3.3
2-10	3.3-7.8
10-15	7.8-10.5
15-23	10.5-15.0
23-40	15.0-24.0



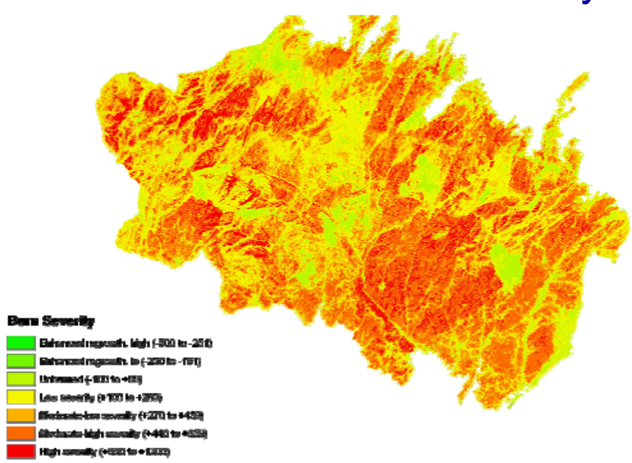
Estimating fuel consumption at regional scales

Integrated analysis of fuel consumption during fires

***French, McKenzie, Ottmar et al.* 24, 271**



Landsat burned area and severity

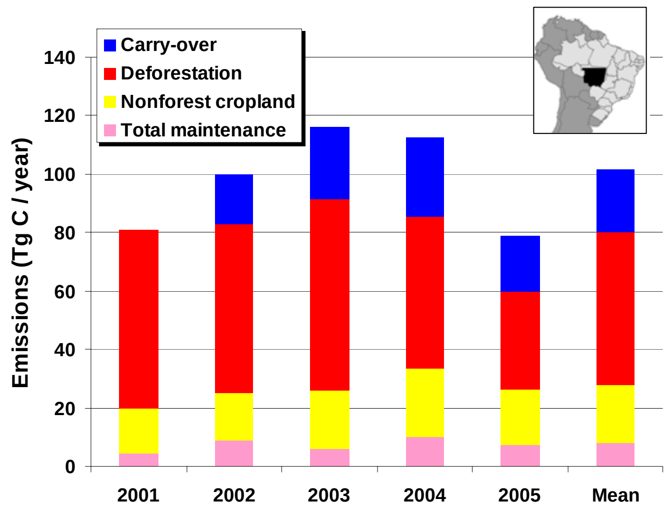


Fuel consumption:

- USFS CONSUME 3.0 for specific fuelbeds in fire sites
- Fire severity maps from MTBS program
- Assign consumption levels for specific fuelbeds from CONSUME 3.0 to remote sensing-derived severity maps

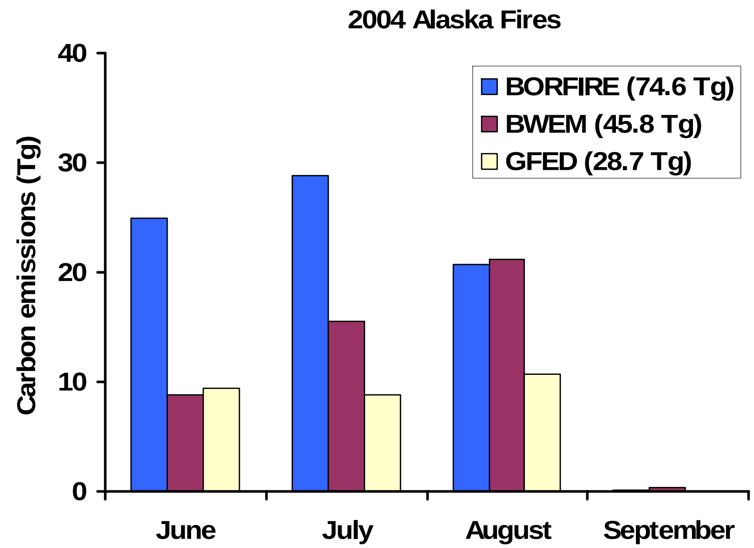
Integrated Regional-Scale Estimates of Biomass Burning Emissions

DECAF: DEforestation CArbon Fluxes in Brazil – *DeFries et al*. 231



- *Deforestation results in 73% of BB burning emissions*
- *Combustion completeness and duration of the deforestation process vary by land use.*
- *Carry-over emissions from deforestation in other years can be large (>20%).*

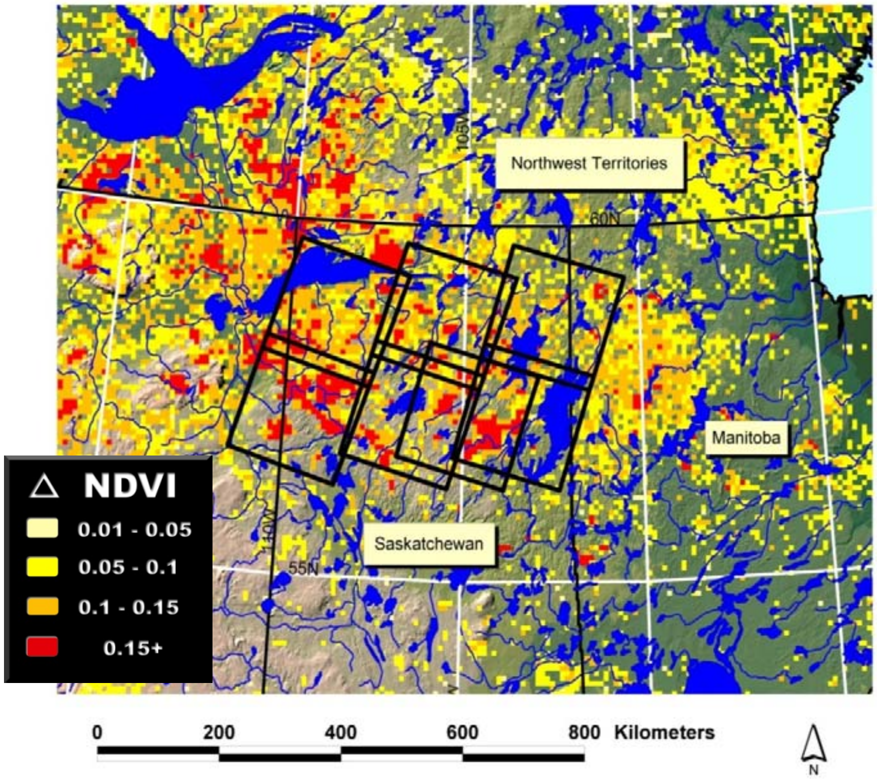
BORFIRE – AK
Kasischke, de Groot et al. 150

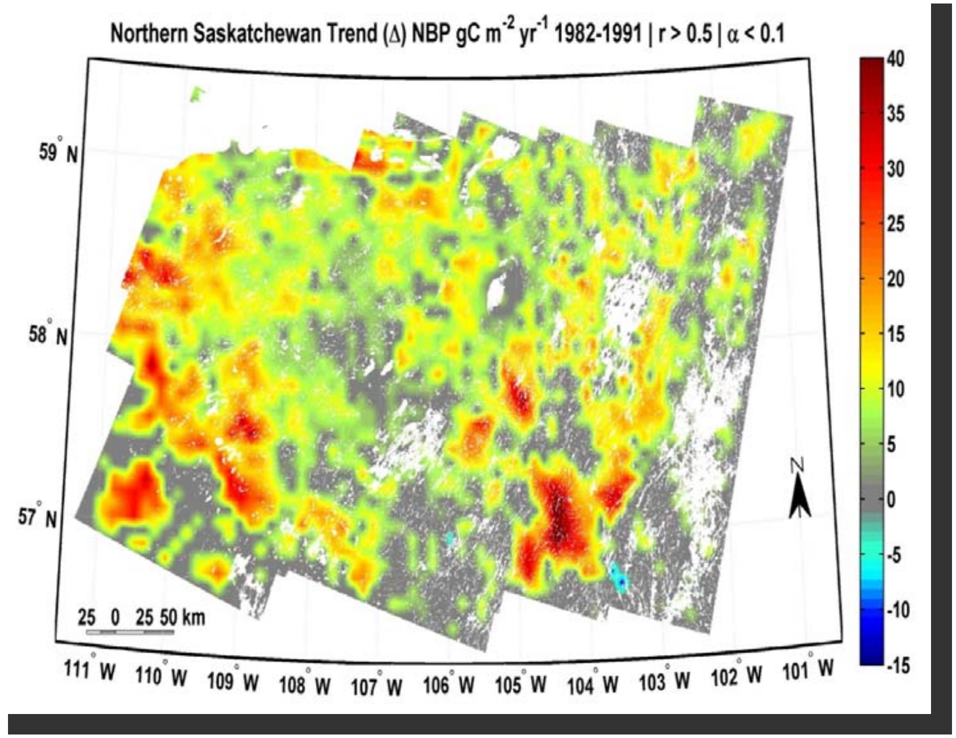


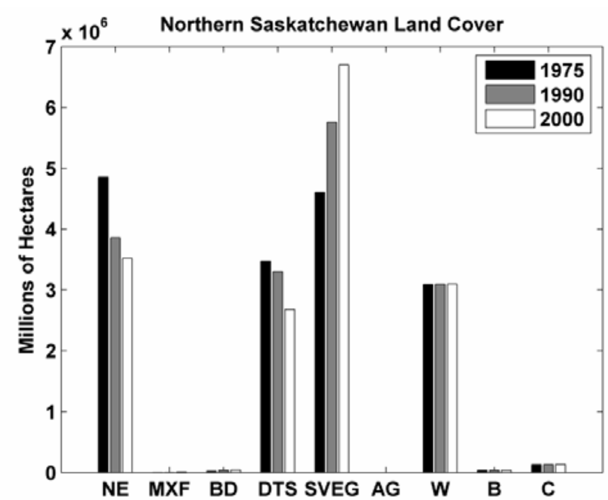
- *Previous models did not account for deep organic layer burning in black spruce forests*
- *Surface organic layer in BS forests accounts for 72% of emissions*

Northern Saskatchewan Post-fire Recovery

Landsat Land Cover Change
Integrated in a Fire Module of CASA
Δ NDVI 1982-1991







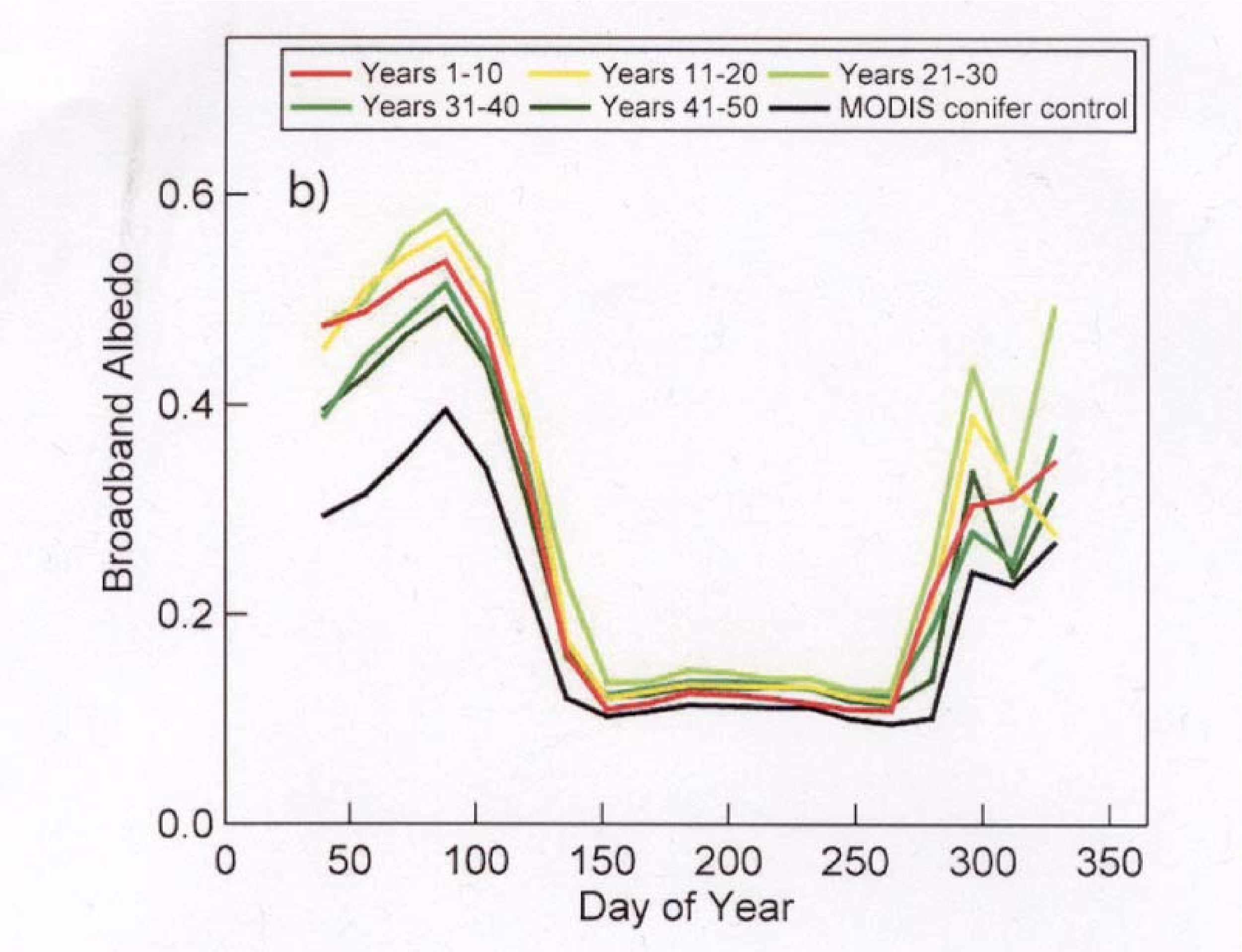
Identifying & Understanding Carbon Cycle Implications of North American Natural and Anthropogenic Disturbances: 1982-2005

Tucker, Neigh, Collatz NASA/GSFC **287**

Assessment of post-fire environmental conditions and ecosystem processes

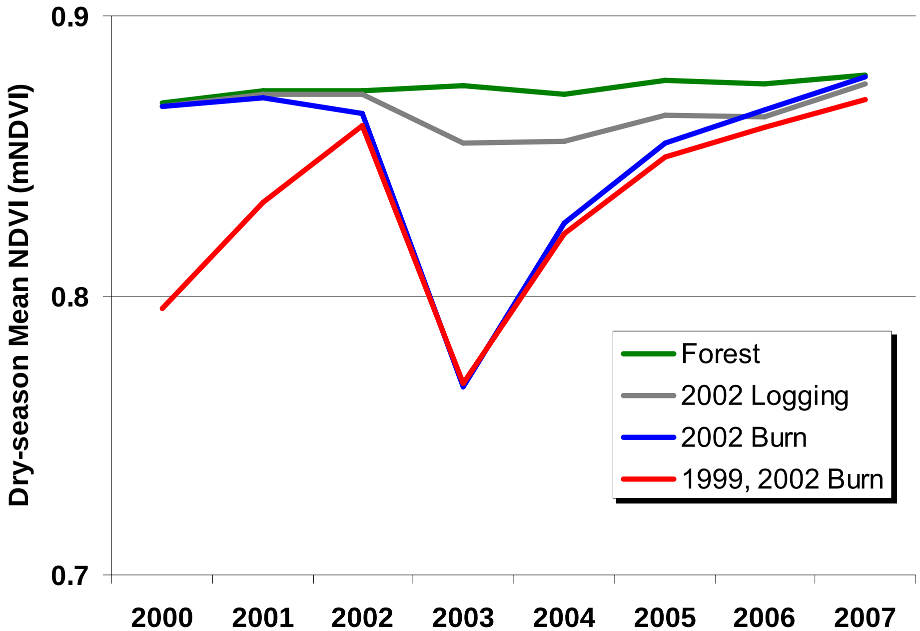
1. Effects of Fire on Vegetation Indices and GPP in Boreal NA (2 studies: Hicke et al. Stanford; Goetz et al., WHRC 28)
2. MODIS Observed Post-Fire Regeneration in Tropical Forests (Morton, DeFries, UMD)
3. Analysis of the Effects of Fire Severity, Forest Type, and Soil Moisture on Post-Fire MODIS VI Signatures (Kasischke, UMD, Bourgeau Chavez, MRTI, Johnstone, USask 151)
4. Post-fire regeneration in Canadian boreal forests (Gower et al., UW)
5. Post-fire Monitoring of Surface Albedo in Boreal Forests (Lyons, Randerson, UCI)
6. Effects of Fire on Forests in the Russian Far East (Sherman, Shugart et al. et al. UVA 160)
7. Variations in Post-Fire Soil Moisture in Boreal Forests (Bourgeau-Chavez, MRTI; Kasischke, UMD; Johnstone UAF)

Post-fire variations in albedo in boreal forests



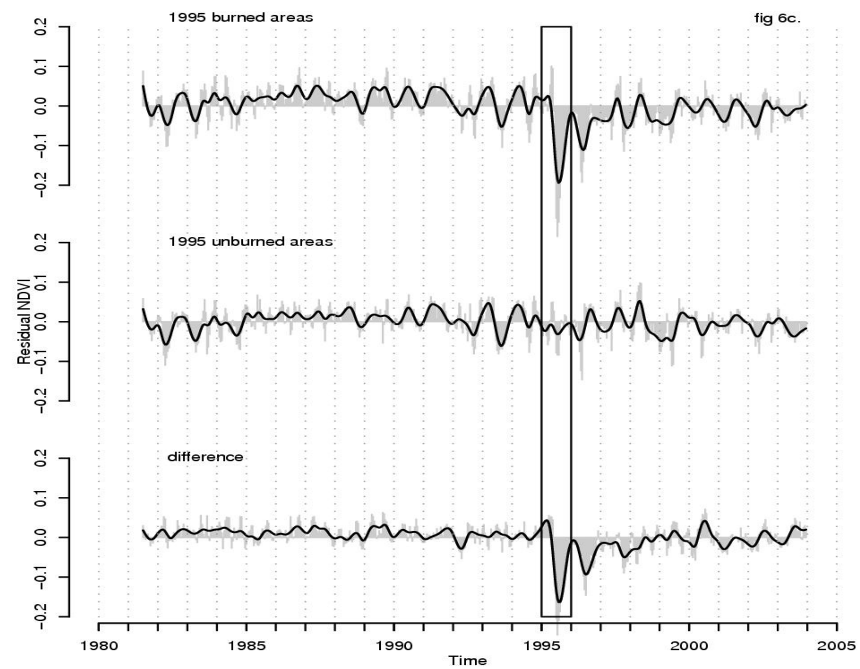
(Lyons, Randerson, Jin)

Satellite Monitoring of Forest Re-growth Following Fire



Brazilian Tropical Forests

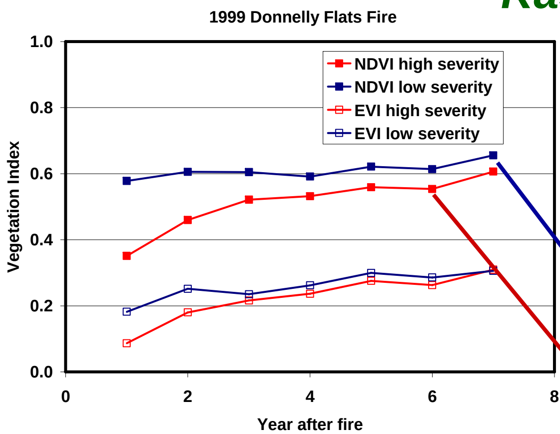
Morton

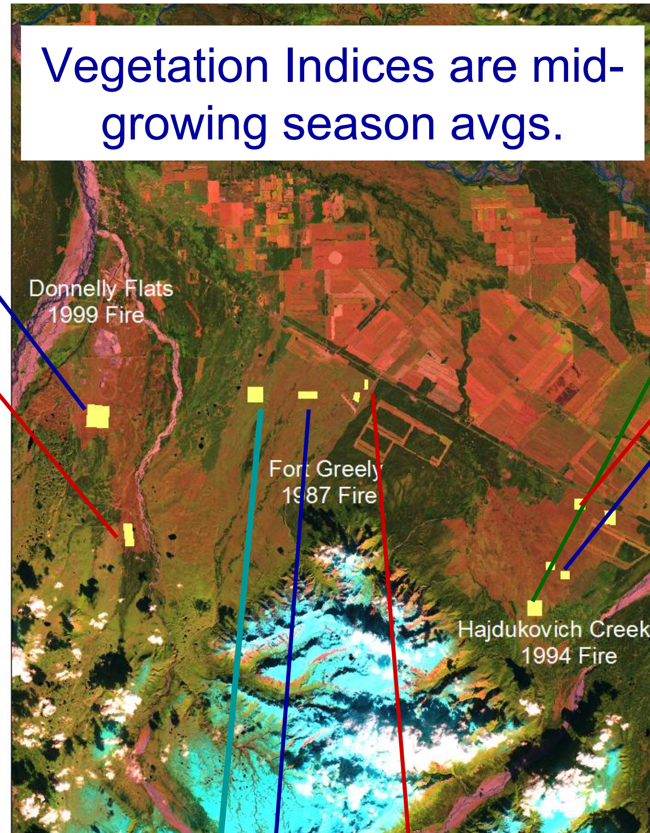


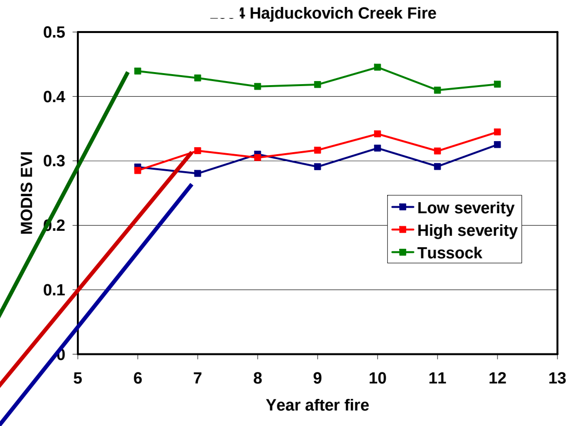
NA Boreal Forests

Goetz et al. **28**

Kasischke, Bourgeau-Chavez, Johstone 151



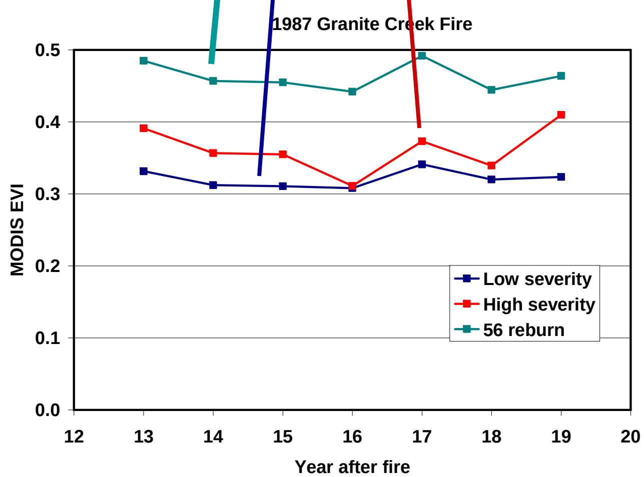




1987 Fire
18 years post-fire

Low Severity

High Severity

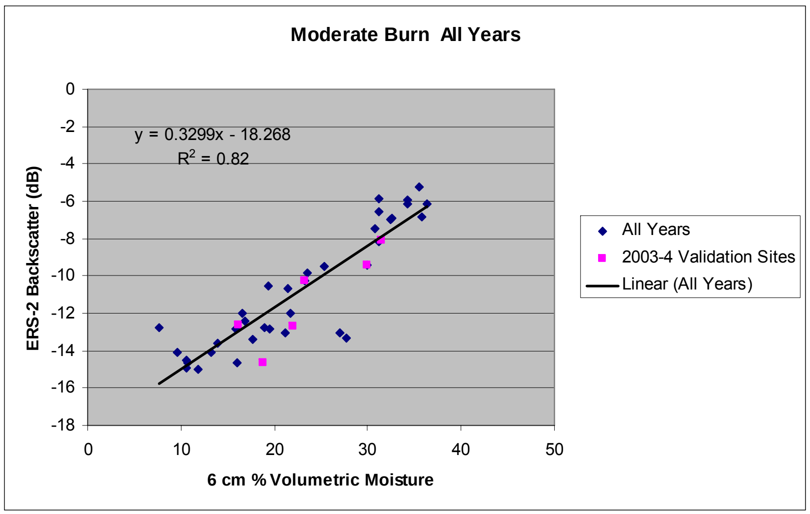


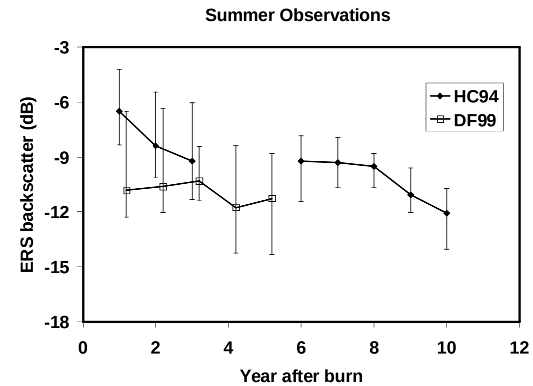
1994 Fire
9 years post-fire

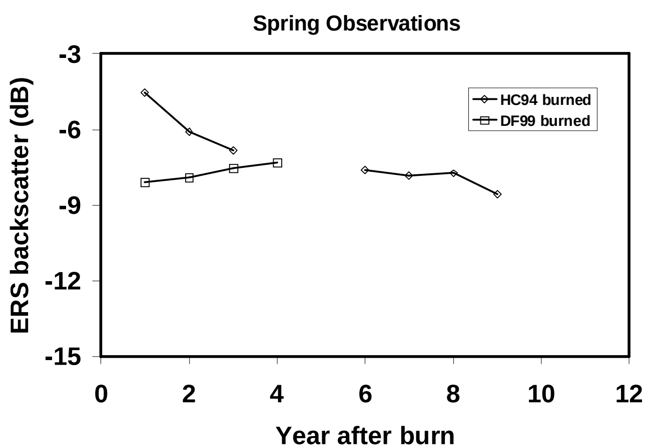
Low Severity

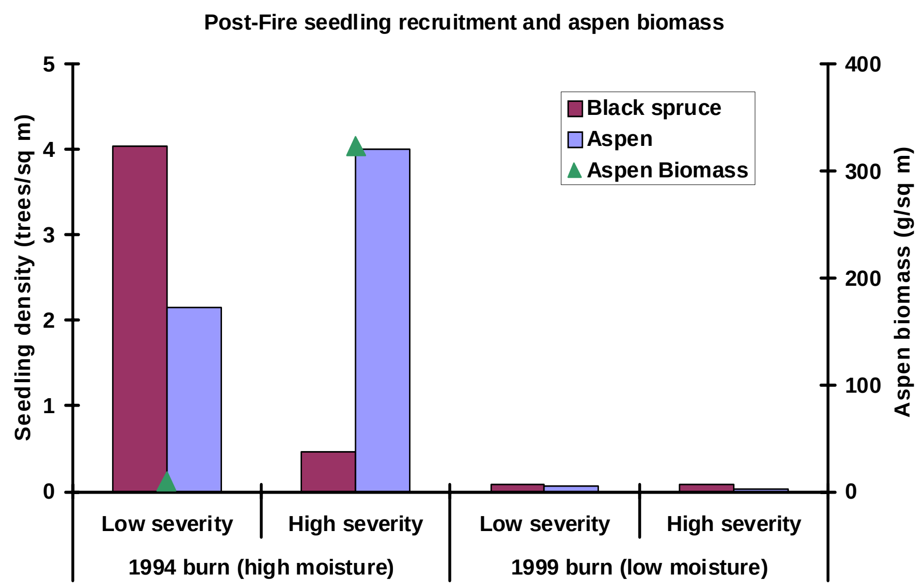
High Severity

Effects of fire severity and soil moisture on post-fire tree recruitment in boreal forests









Bourgeau-Chavez, Johnstone, Kasischke et al.

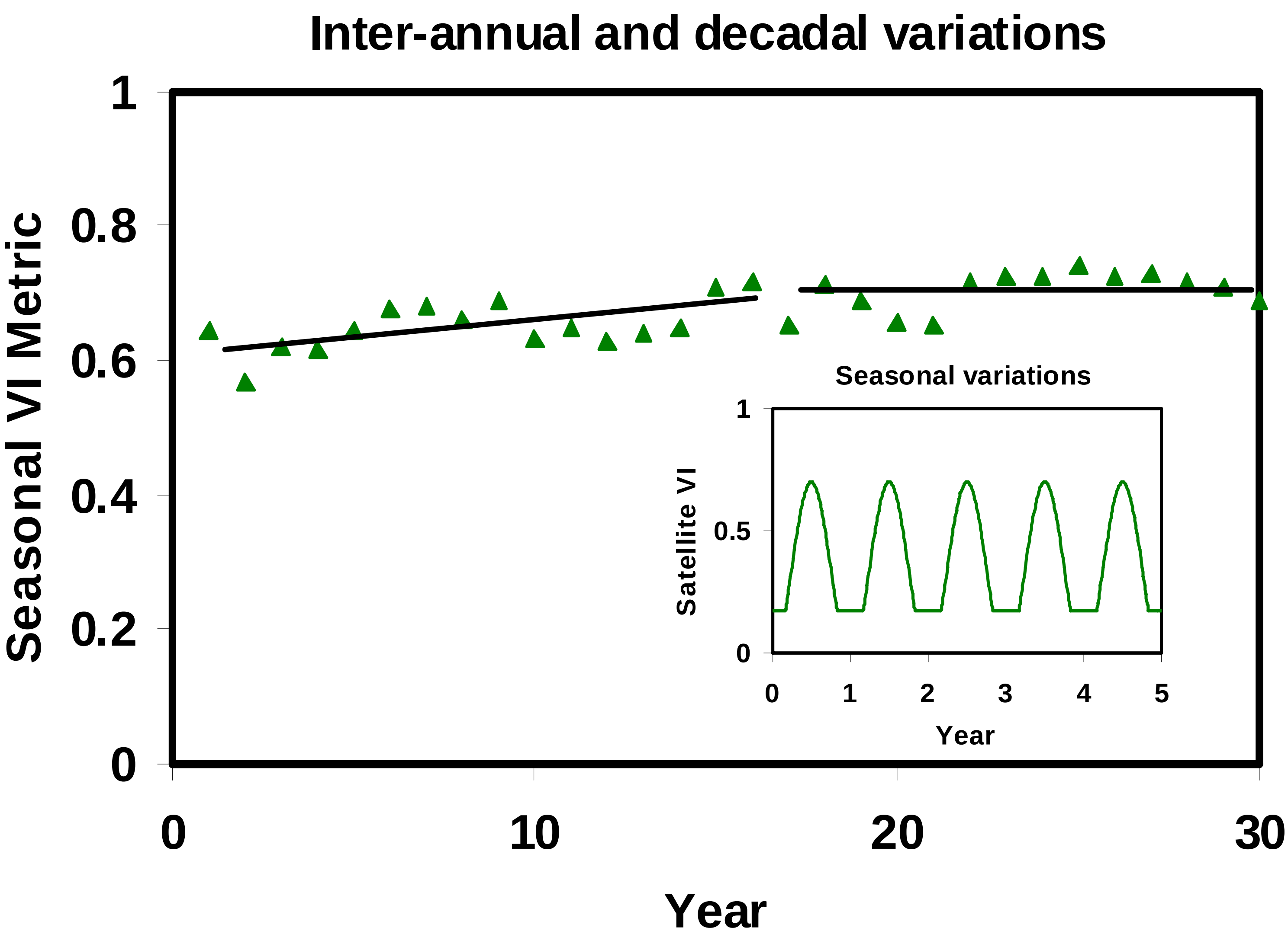
Future Directions

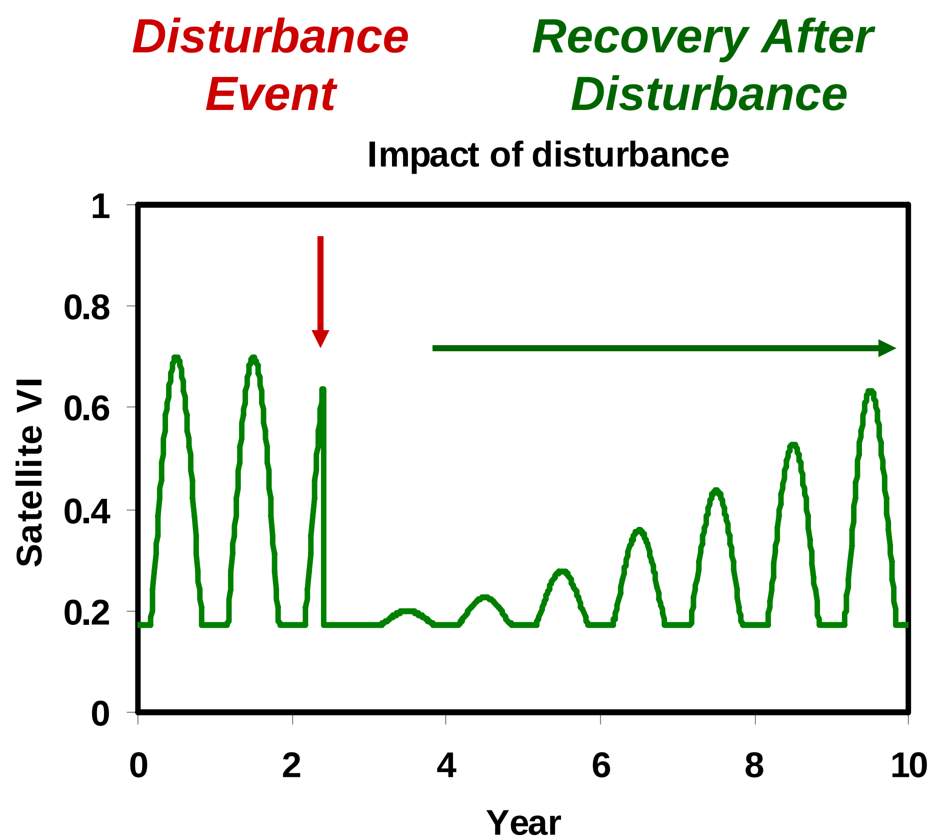
1. Recommendations from the NASA Fire Science Workshop – 20-22 Feb. 2008
2. The role of fire science in climate change and carbon cycle research
3. Integration of results from regional-scale studies into global-scale models (emissions and terrestrial carbon cycling)

Recommendations from the NASA Fire Science Workshop: 20-22 February 2008

1. Improve the availability, standardization, and utility of multi-resolution spaceborne, airborne, and surface data sets
2. Conduct a global remote sensing assessment of current fire regimes (over the existing satellite record), providing a baseline for monitoring future changes in fire regimes and their impacts.
3. Develop new airborne and space-based remote sensing capabilities that provide improved products and information on fuel structure and condition, fire and emissions characterization, burn severity, and post-fire impacts
4. Continue and accelerate approaches to include of fire characteristics within dynamic vegetation, ecosystem, biogeochemical cycling, and land-surface energy/water exchange models
5. Form a more cohesive, unified fire science community with better interaction between discipline sub-groups (e.g., fire danger, air quality, ecosystem effects, land use, and fire management) to provide a more holistic view of fire science.

Remote sensing of vegetation phenology: Monitoring effects of the climate continuum on characteristics of vegetation





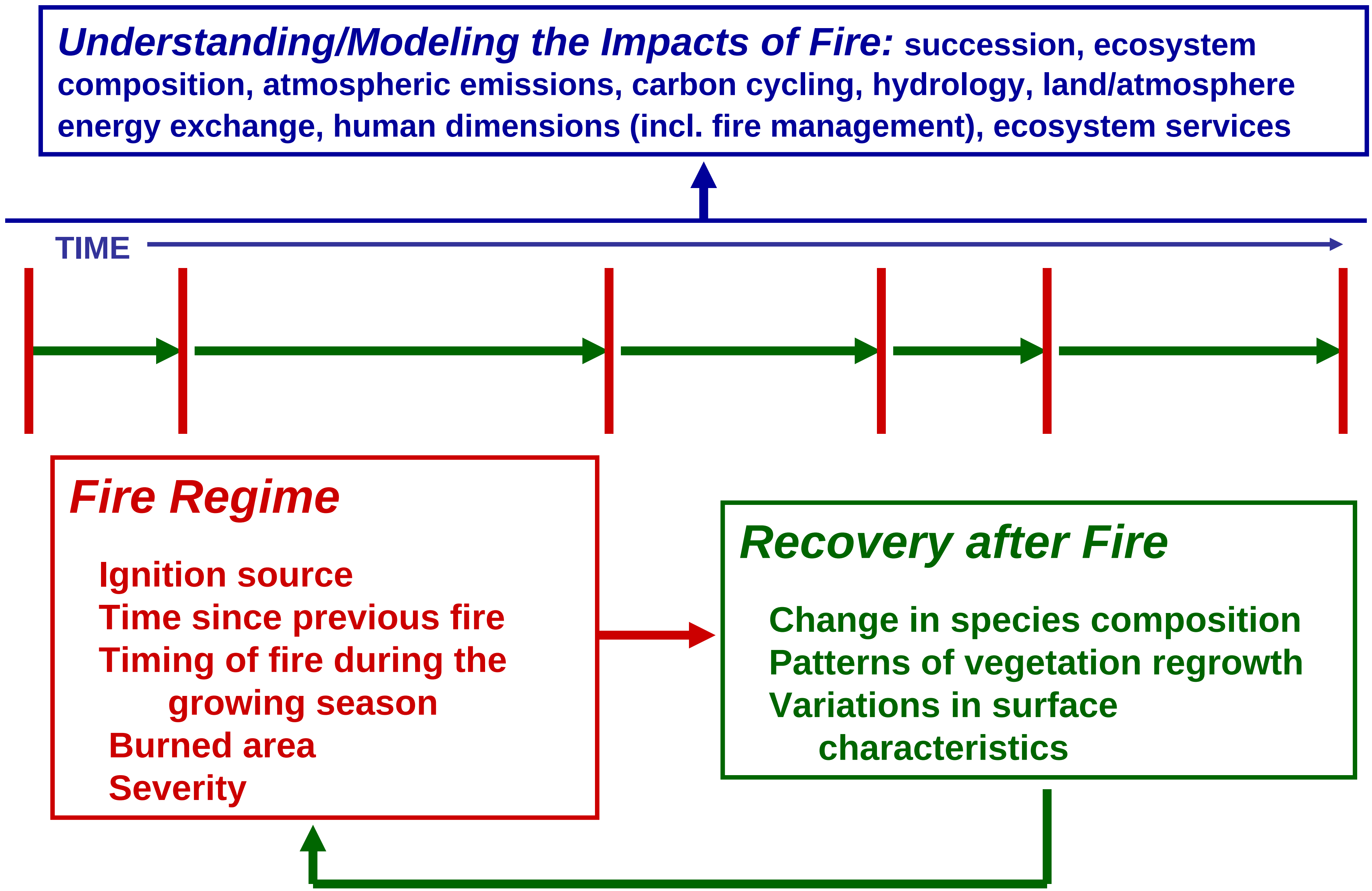
Importance of disturbance in carbon cycling

1. Disturbances cause significant short- and long-term variations of C flux to the atmosphere that are not captured through flux/ phenology measurements

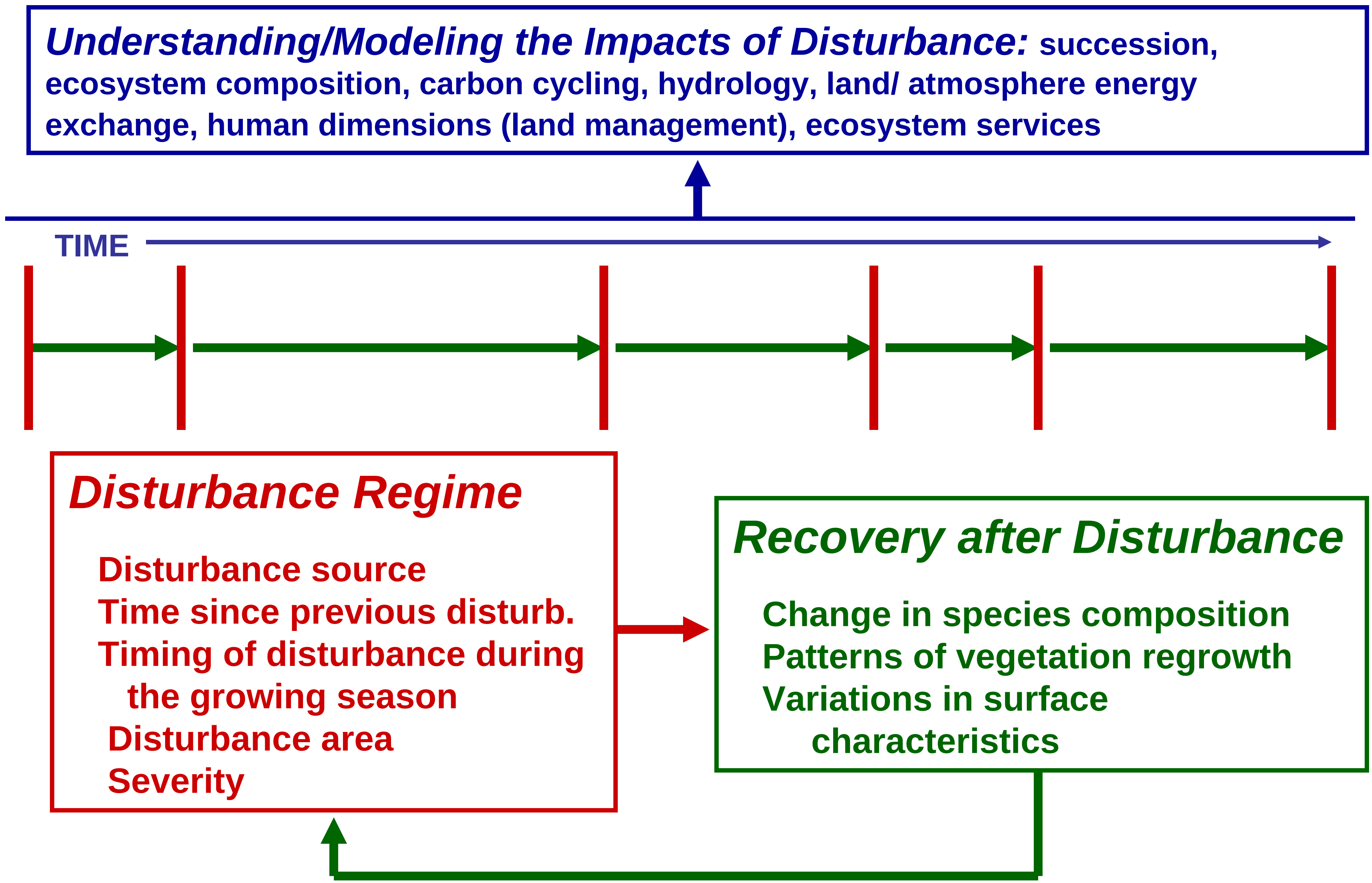
2. The disturbance regime of a region (including human modifications to the regime) results in important short and long-term legacy effects

3. The frequency and severity of many disturbances (fire, insects, storm damage) are climate driven – likely to change in the future

Monitoring and Assessing the Fire Disturbance Continuum



Monitoring and Assessing the Land Disturbance Continuum



Integration of Ongoing Efforts

1. Integration of regional scale studies of biomass burning emissions into global-scale models and Carbon Tracker –
   - Would support both carbon and atmospheric science communities
2. Integration of ongoing NACP/NASA projects (at least 12) that
   a. Continue to develop new approaches to document and monitor fire and disturbance
   b. Analyze the impacts of fire and disturbance on ecosystem processes and terrestrial carbon cycling


Any Questions??