Fire induced changes in albedo and the associated radiative forcing:

a comparison of boreal Canada and Australia tropical savannas

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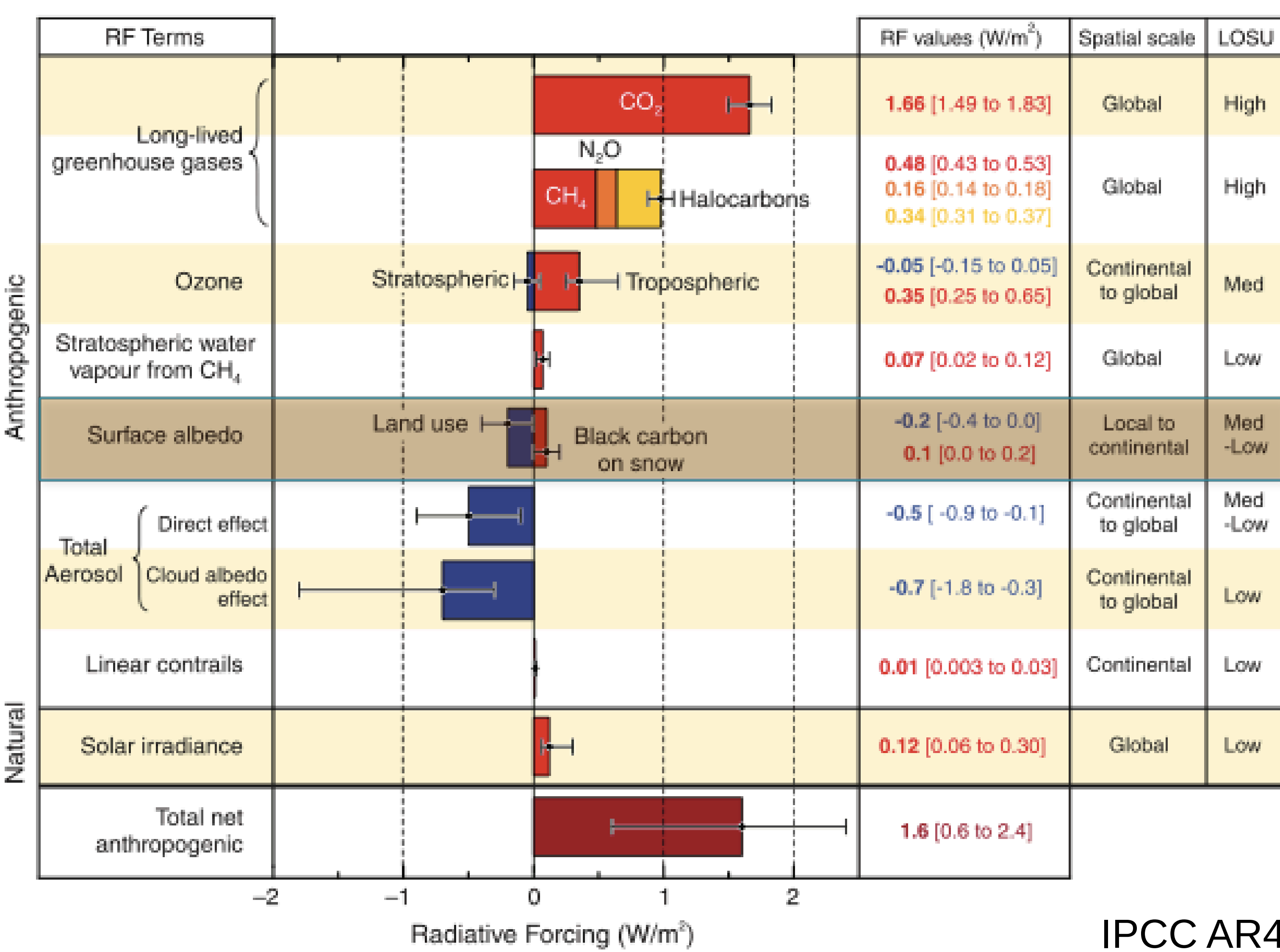
LCLUC, Bethesda, April 20-22, 2010

Albedo change from LCLUC: a significant RF agent

Global average RF in 2005 with respect to 1750



IPCC AR4, 2007

Integrated climate consequences of fire:

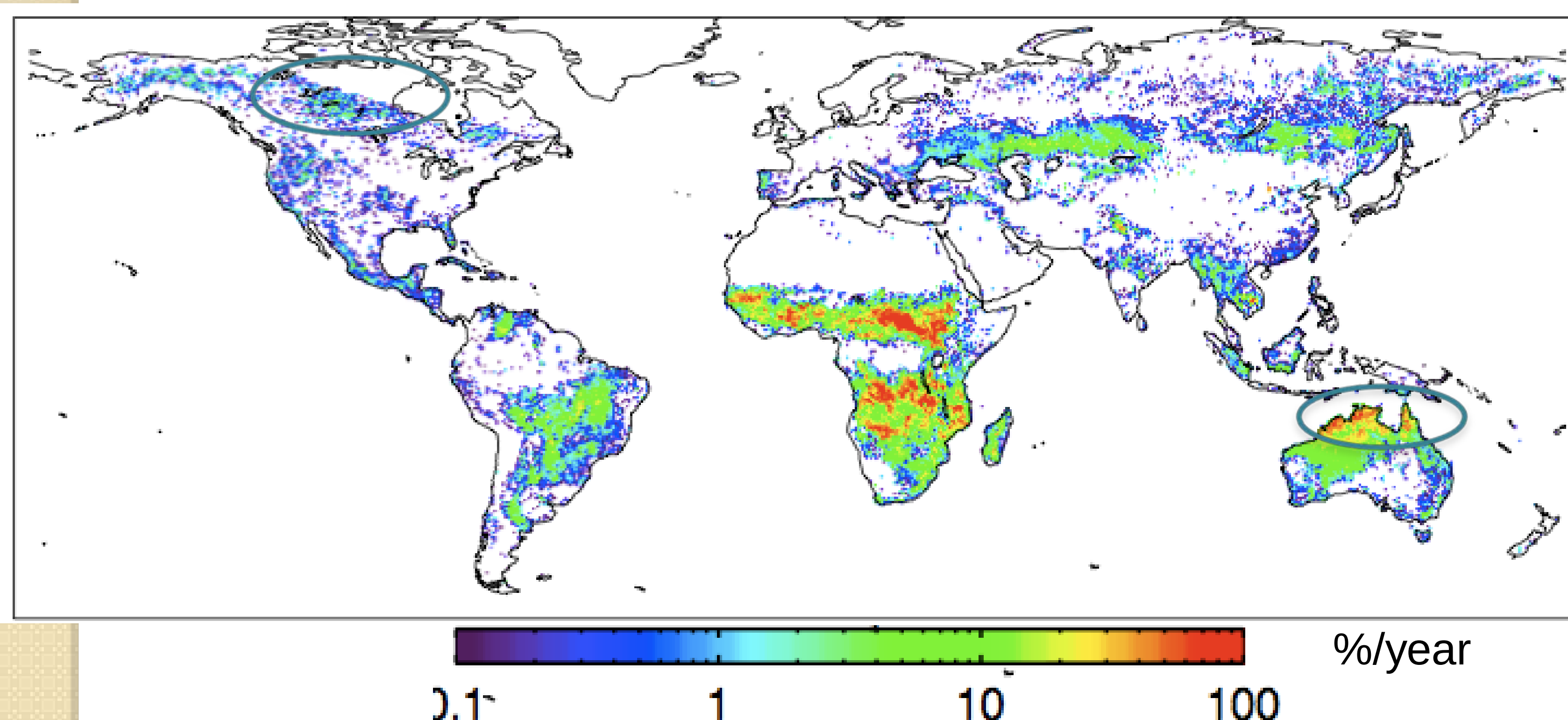
an example of 1999 Donnelly Flats fire in Alaska

- Elevated post-fire albedo lasts decades in boreal Alaska forest
- Negative forcing overweighs the positive forcing from GHG emissions
- Projected increase of fire activity in boreal forests may not accelerate climate warming
- Understanding the net effect is critical in managing northern forests

Forcing agent	Radiative forcing* [W $(m^2$ burned$)^{-1}$]	
	Year 1	Years 0 to 80 (mean)
Long-lived greenhouse gases (CH_4 and CO_2)	8 ± 3	1.6 ± 0.8
Ozone	6 ± 4	0.1 ± 0.1
Black carbon deposition on snow	3 ± 3	0.0 ± 0.0
Black carbon deposition on sea ice	5 ± 4	0.1 ± 0.1
Aerosols (direct radiative forcing)†	17 ± 30	0.2 ± 0.4
Changes in post-fire surface albedo	−5 ± 2	−4.2 ± 2.0
Total‡	34 ± 31	−2.3 ± 2.2

Randerson et al., *Science*, 2006

1997-2008 mean annual burned area



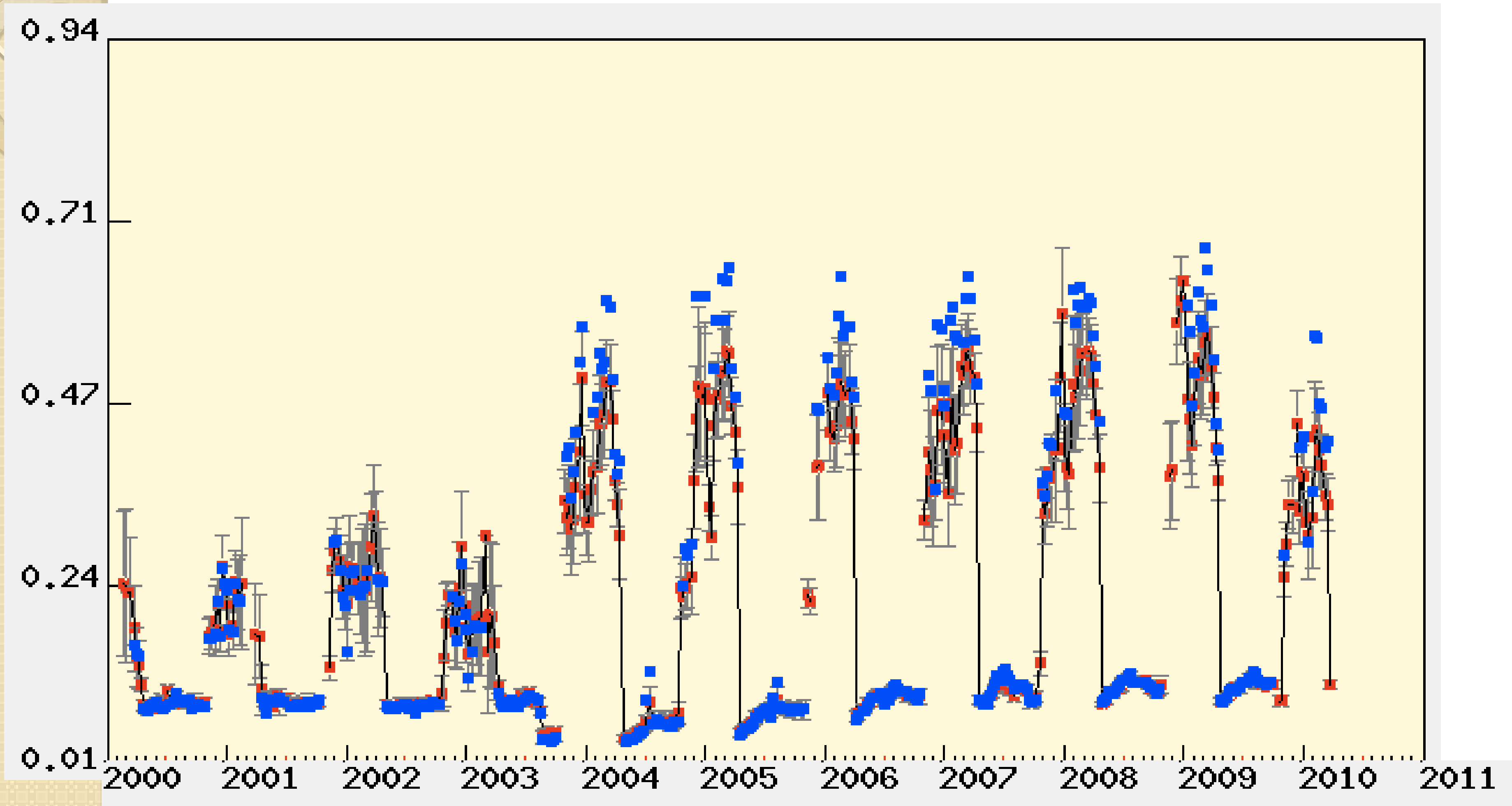
- Australia tropical savanna: 19% annually burned
- Boreal Canada: 0.7% of forested land burned annually
- Different fire regimes and vegetation recovery processes

Giglio et al., *Biogeoscience*, 2010

Objectives

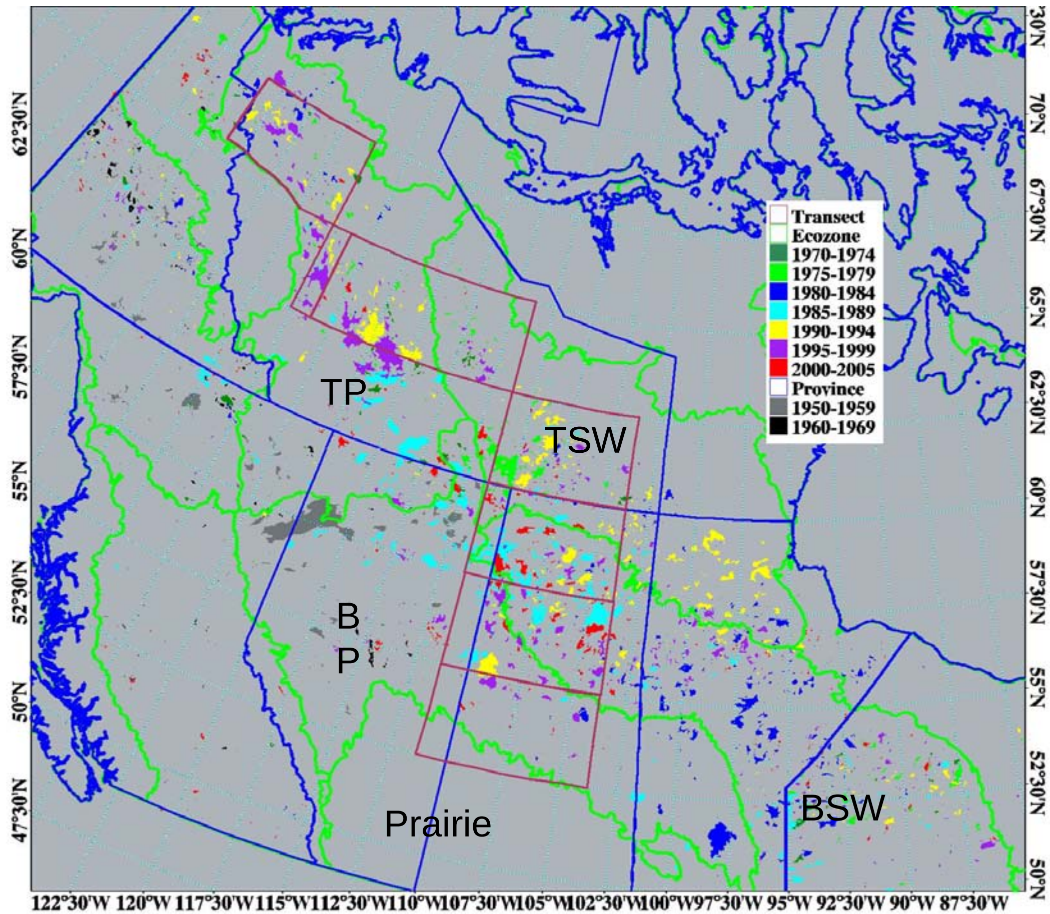
- Examine and compare the temporal evolution of post-fire albedo and LST in Canada boreal regions and Australia tropical savannas
- Analyze the impact of pre-burn vegetation and season of burning, on the pattern of post-fire albedo and LST trajectory
- Reconstruct the intermediate albedo based on MODIS albedo and fire chronosequence
- Compare the radiative forcing due to fire-induced change in albedo and LST over both regions

Post-fire albedo trajectory in boreal Canada



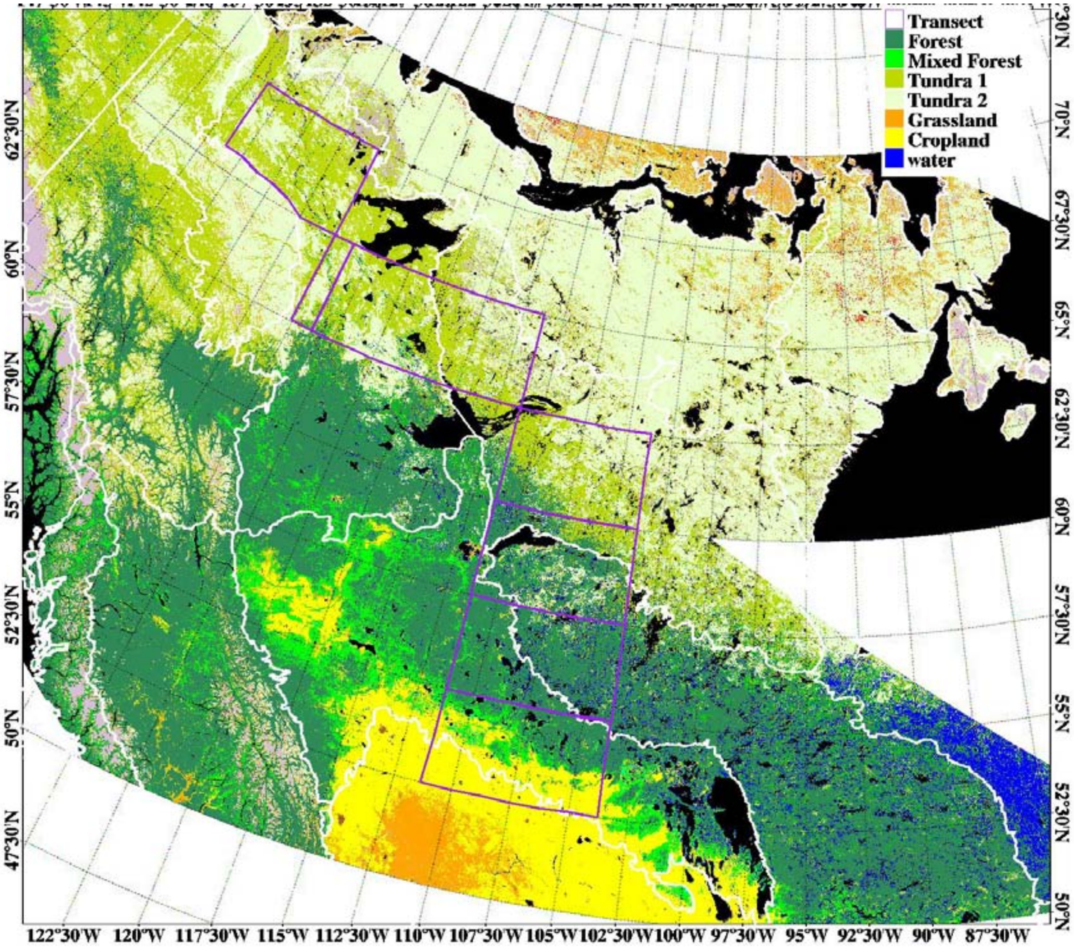
MODIS 500m albedo from Schaaf et al.

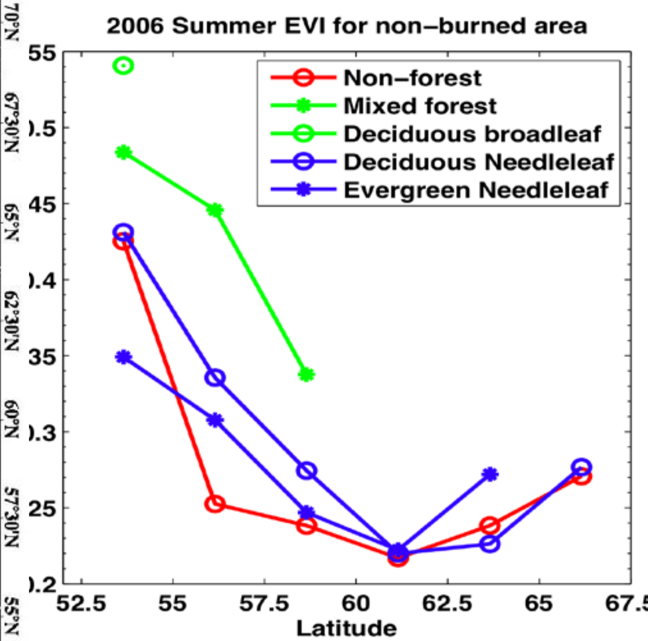
Long term albedo change from a fire chronosequence approach



Spatial and temporal distribution of large fires from Canadian LFDB (1950-2006)

S->N ecological and climatological transect





Factors controlling fire-induced RF

$$RF^{sw} = -(\alpha - \alpha_0) \cdot S^{\downarrow}$$

- Factors which reduce shortwave RF from south to north
  - solar radiation (-)
  - tree density (-)

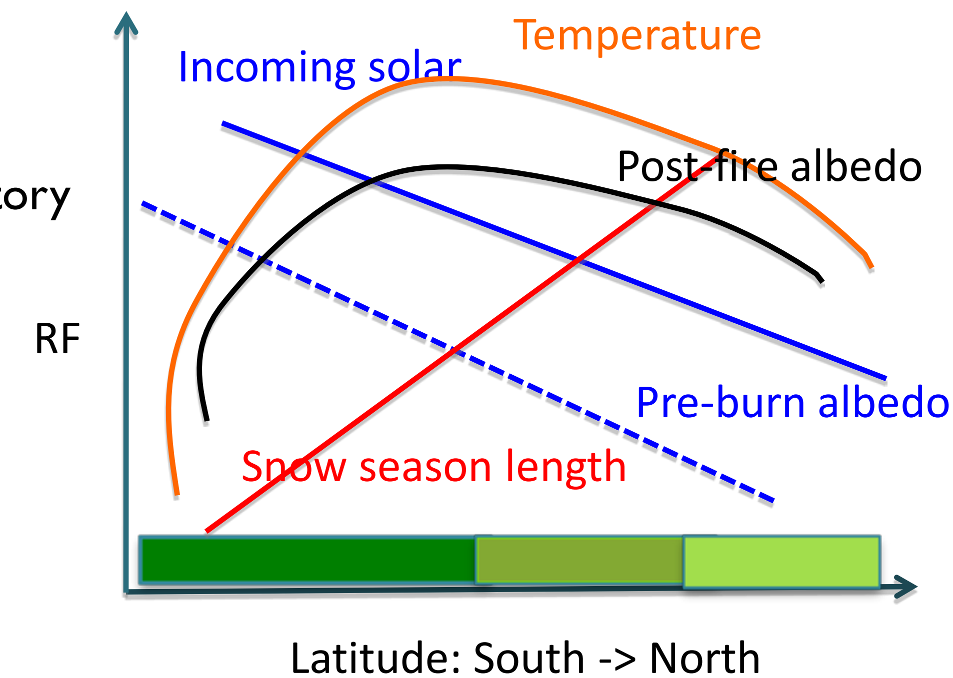
- Factors which increase shortwave RF
  - snow season (+)
  - post-fire albedo (+)

    vegetation composition (?)

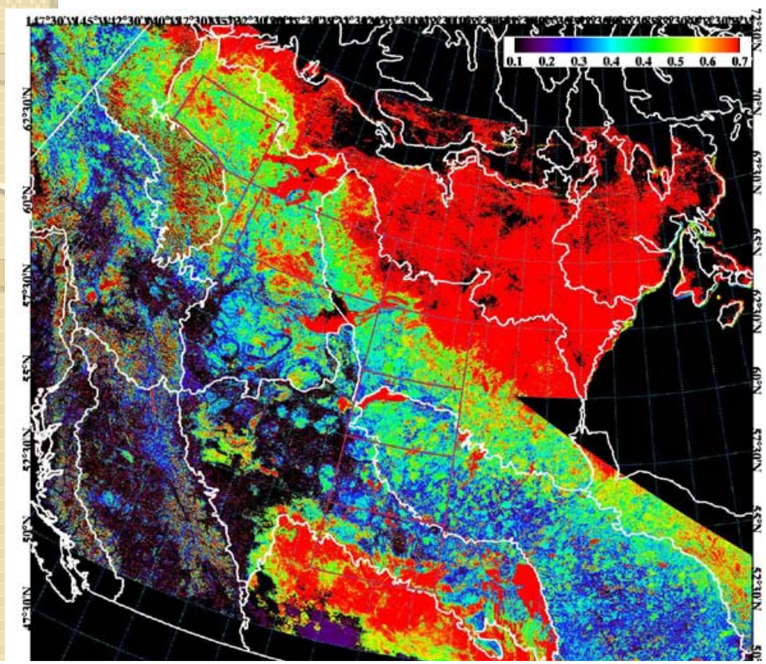
    vegetation succession trajectory

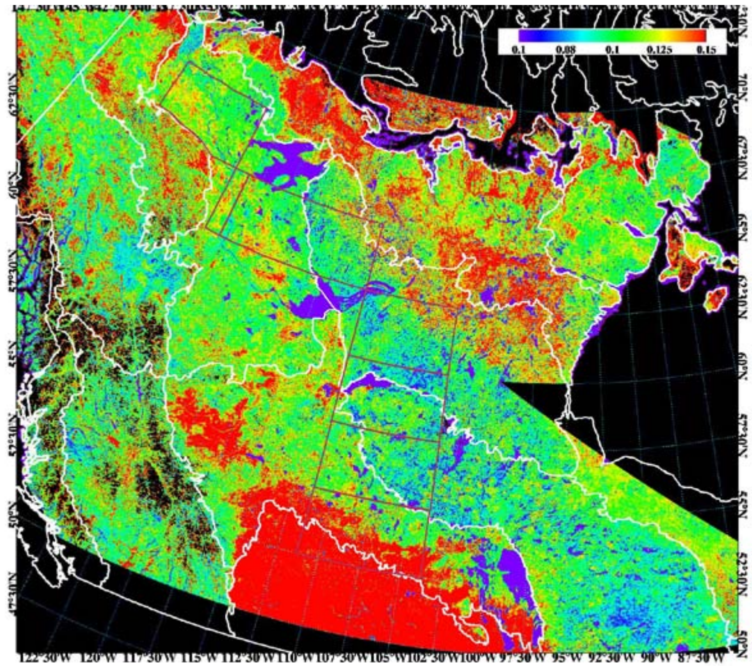
    vegetation recovery rates (?)

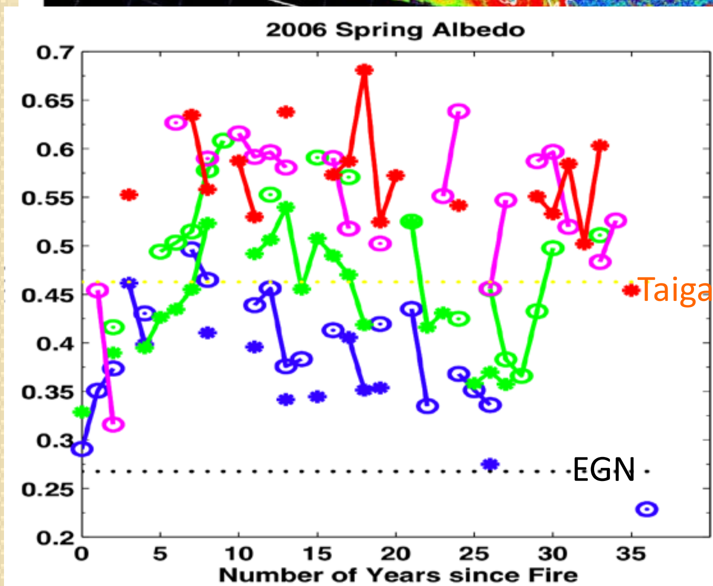
- Longwave RF
  - LST change
  - Emissivity

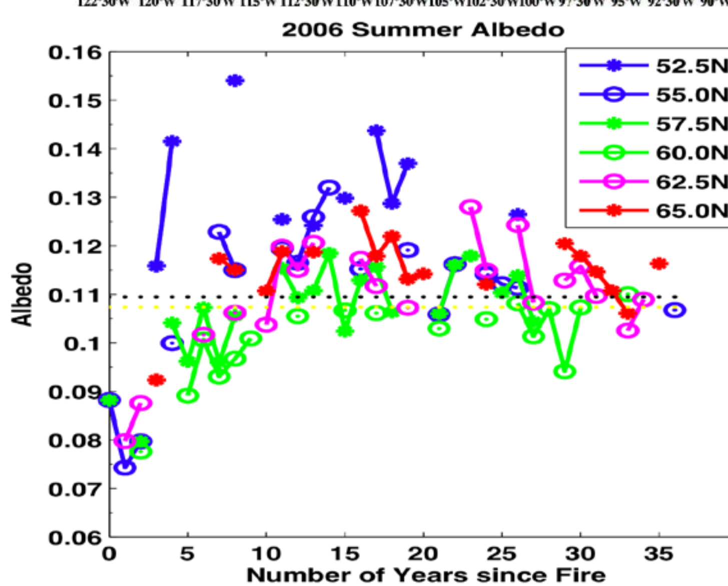


Spring and summer albedo

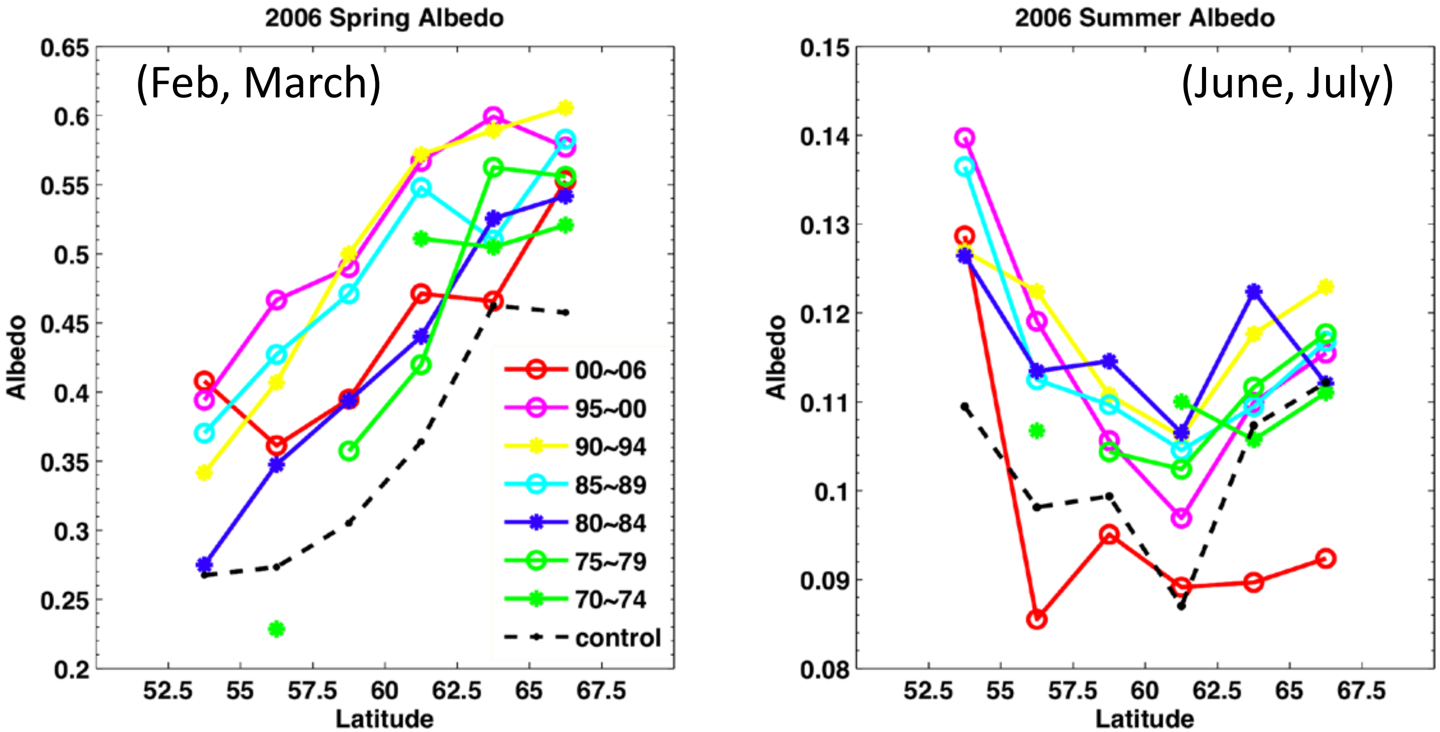






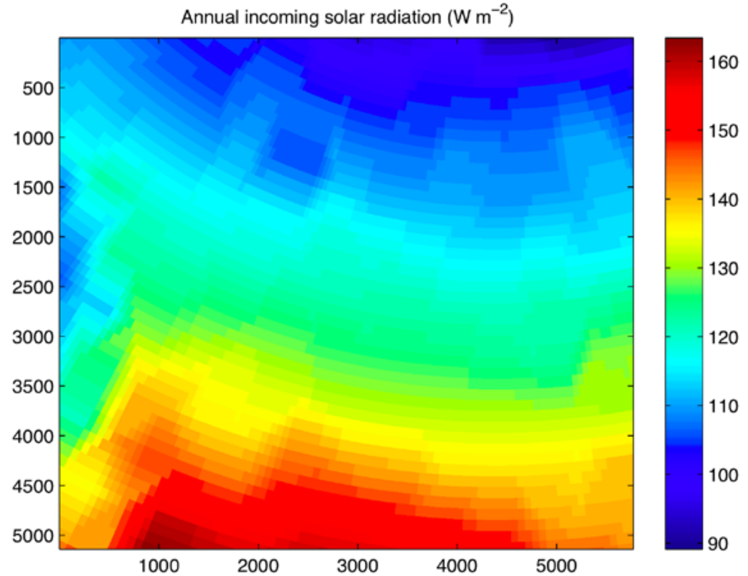


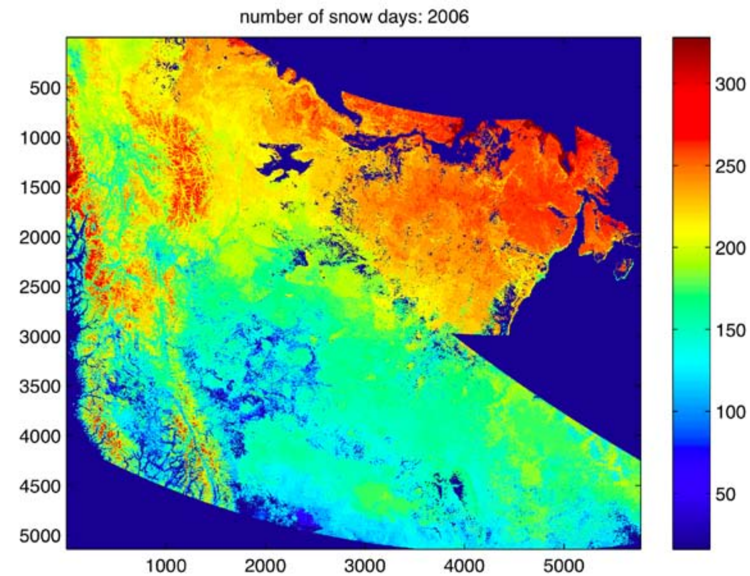
Albedo along the S-N transect

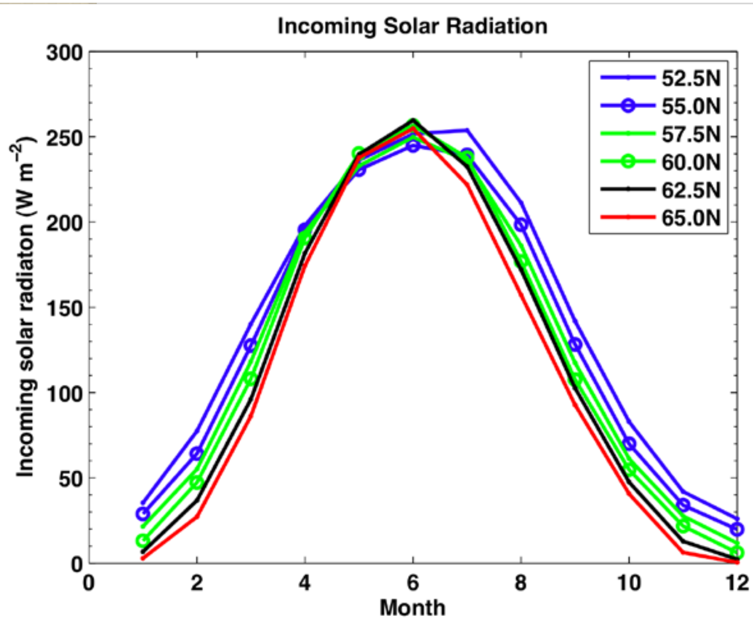


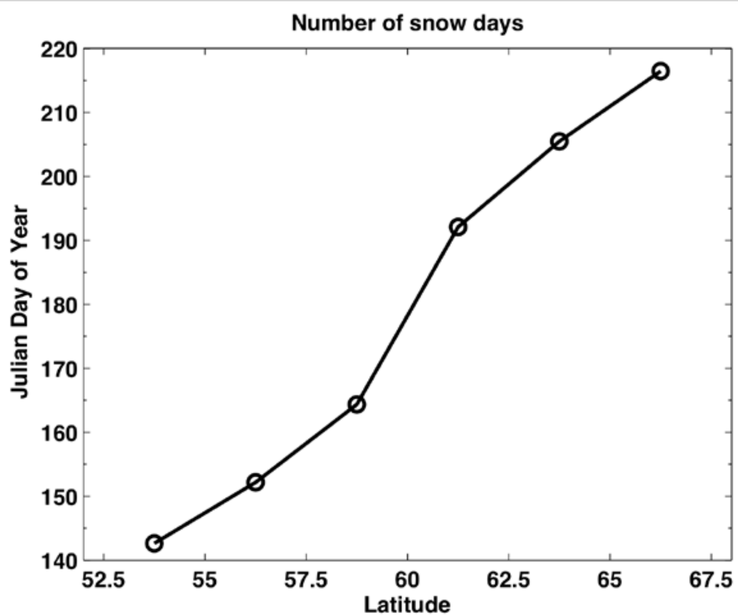
- Early spring: both pre- and post-fire albedo increases from south to north
- Summer: both pre- and post-fire albedo decreases first and then increases in Taiga
- No significant trend in post-fire albedo change

Solar radiation and snow season length

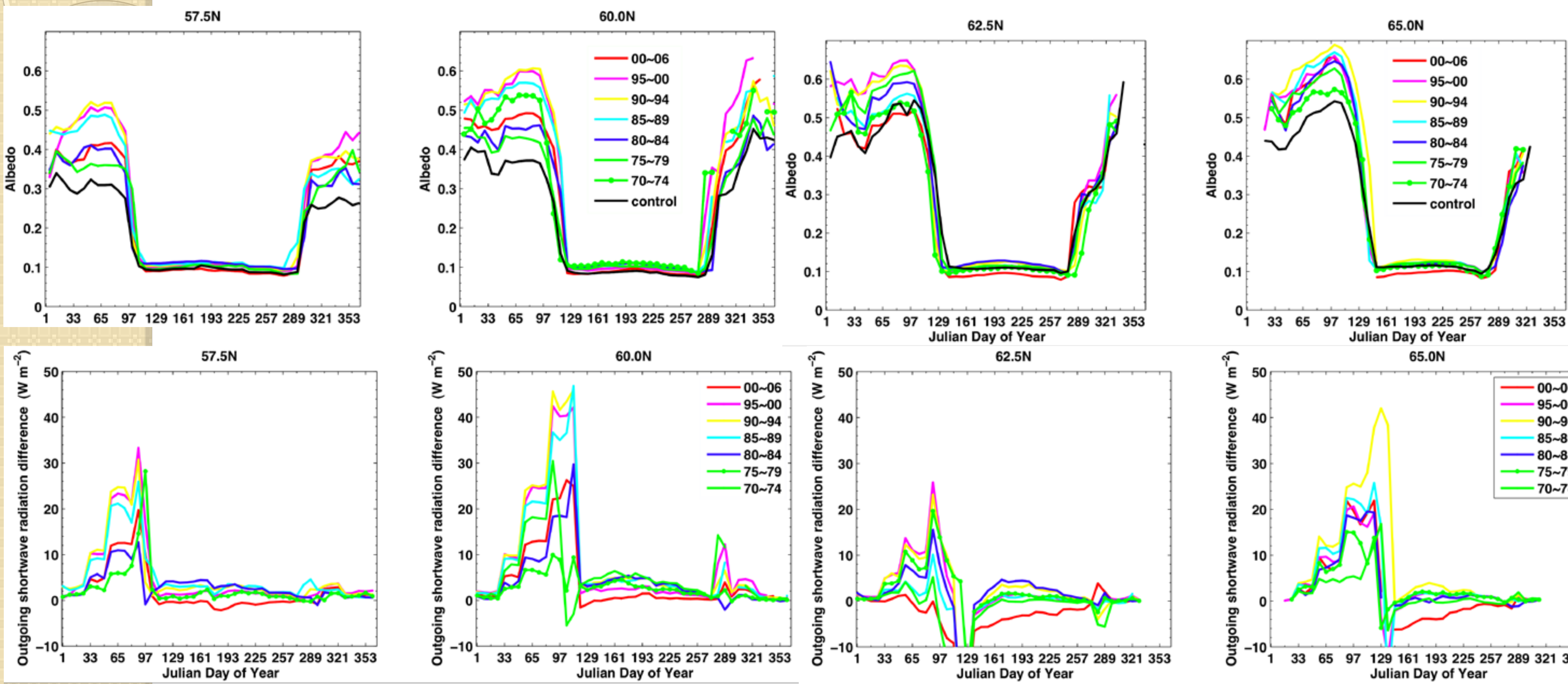






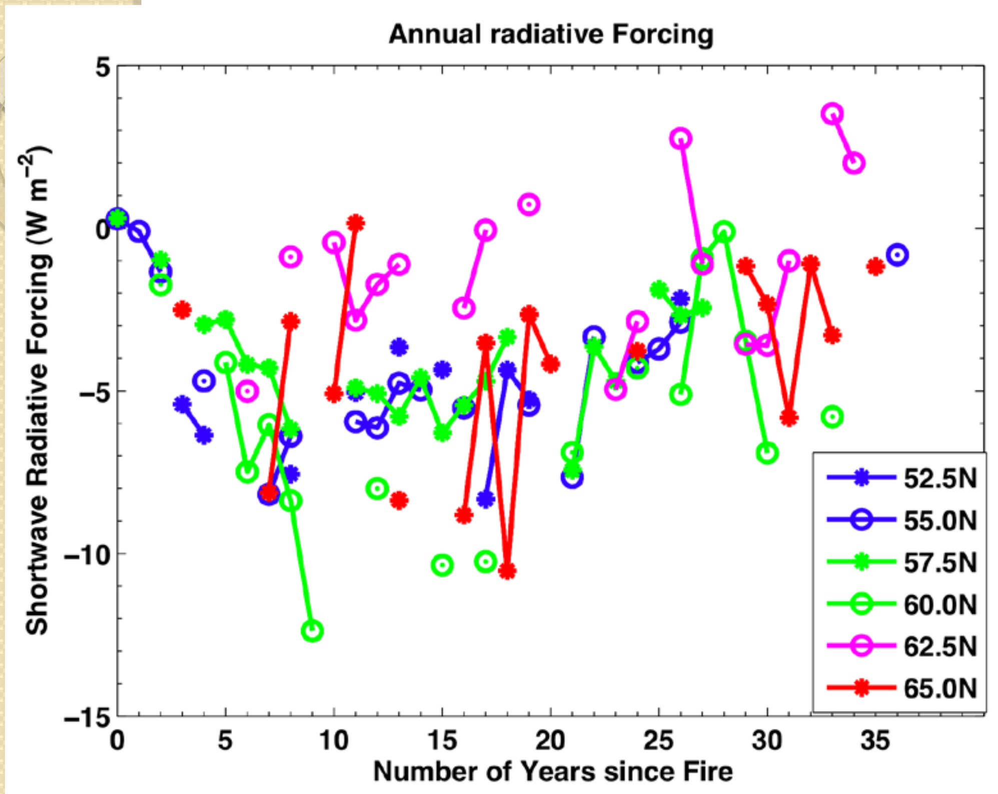


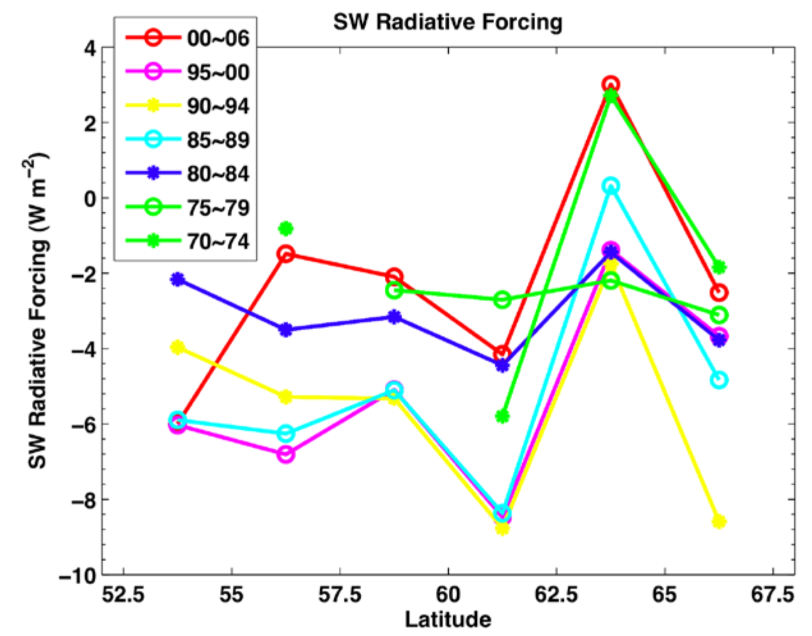
Seasonality of albedo and SW radiative forcing



- Late spring (April) controls magnitude of forcing
- Snow melting later after fire in forest zone: larger negative forcing
- Snow melting earlier in Taiga zone after fire (+): smaller annual negative forcing

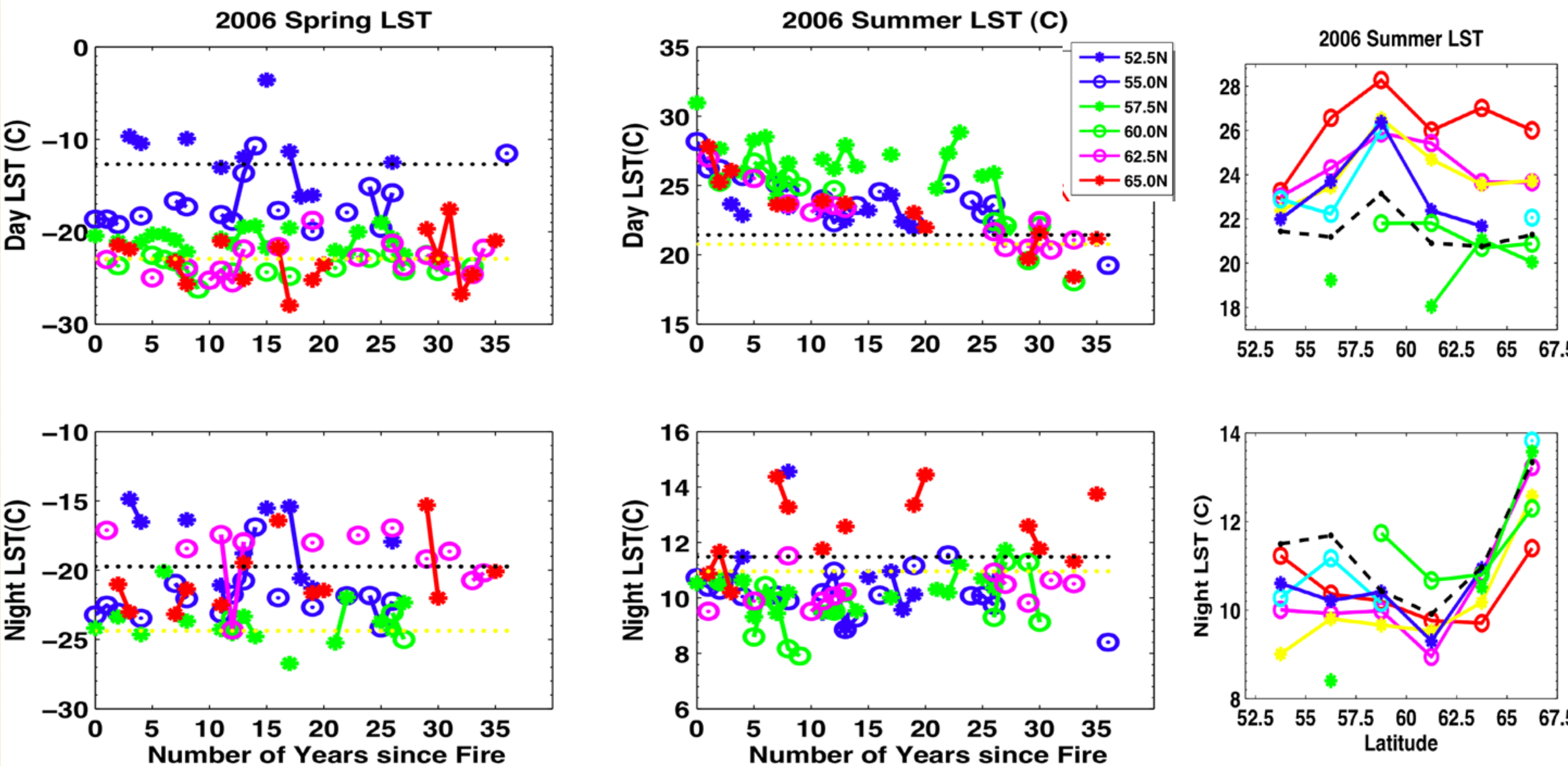
Shortwave radiative forcing $RF^{sw} = -(\alpha - \alpha_0) \cdot S^{\downarrow}$





- Magnitude of negative SWRF increases with stand age, peaks around 15-25 years
- Weak increasing trend in forests from S-N
- SWRF smaller in Taiga zones than forests due to smaller albedo difference in early spring and earlier snow melting in late spring

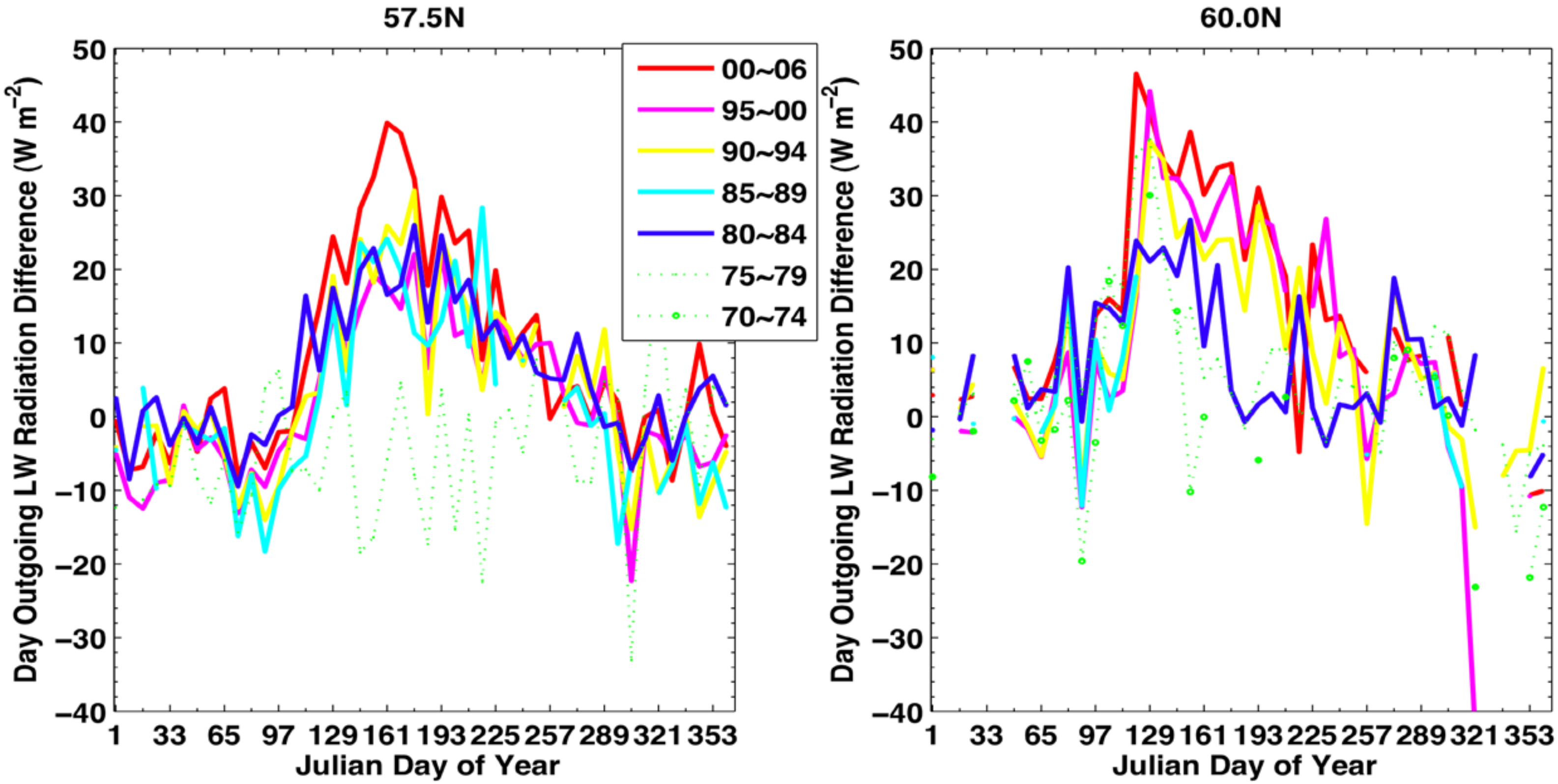
Fire effects on land surface temperature



- Day time temperature: increase in summer vs. decrease in winter
- Postfire day temperature change decreases with stand age in summer
- Day time temperature change: S-N increase for earlier succession;
  S-N decrease for late succession
- Night time temperature: decrease in summer

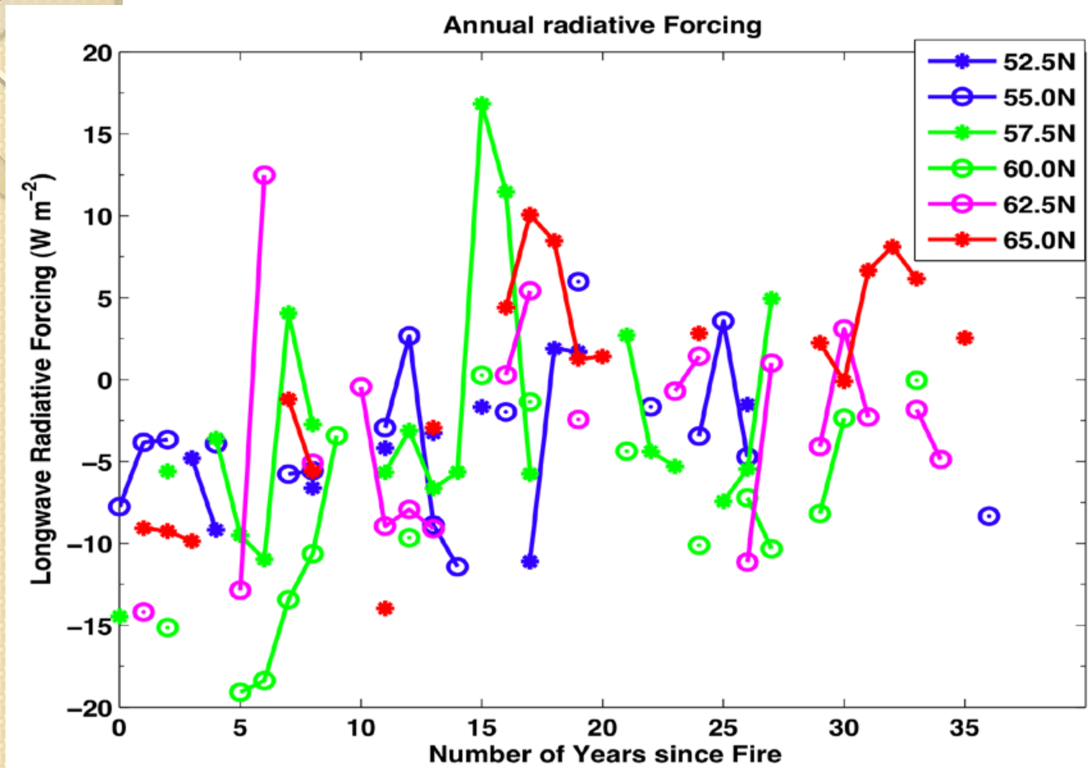
Seasonality of LW radiative forcing

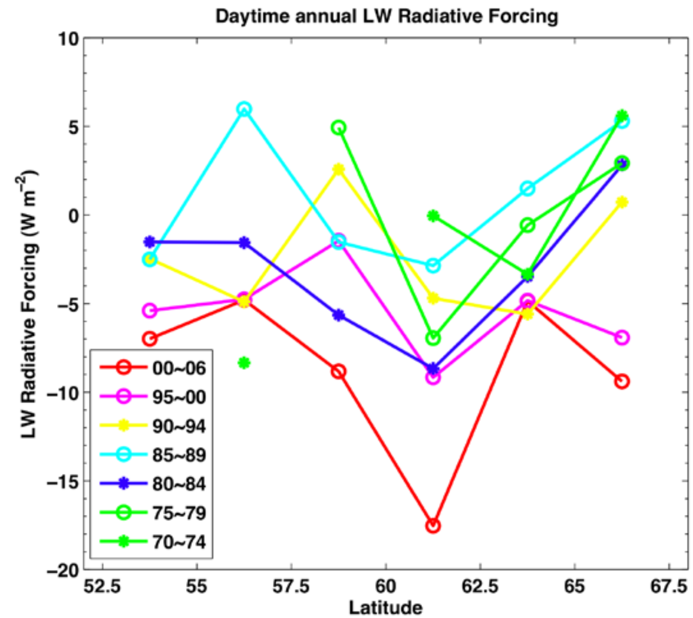
$$RF^{lw} = -\sigma \cdot (\varepsilon T^4 - \varepsilon_0 T_0^4)$$



- Negative forcing in summer (dominant) vs. in winter
- Positive forcing in late spring and winter

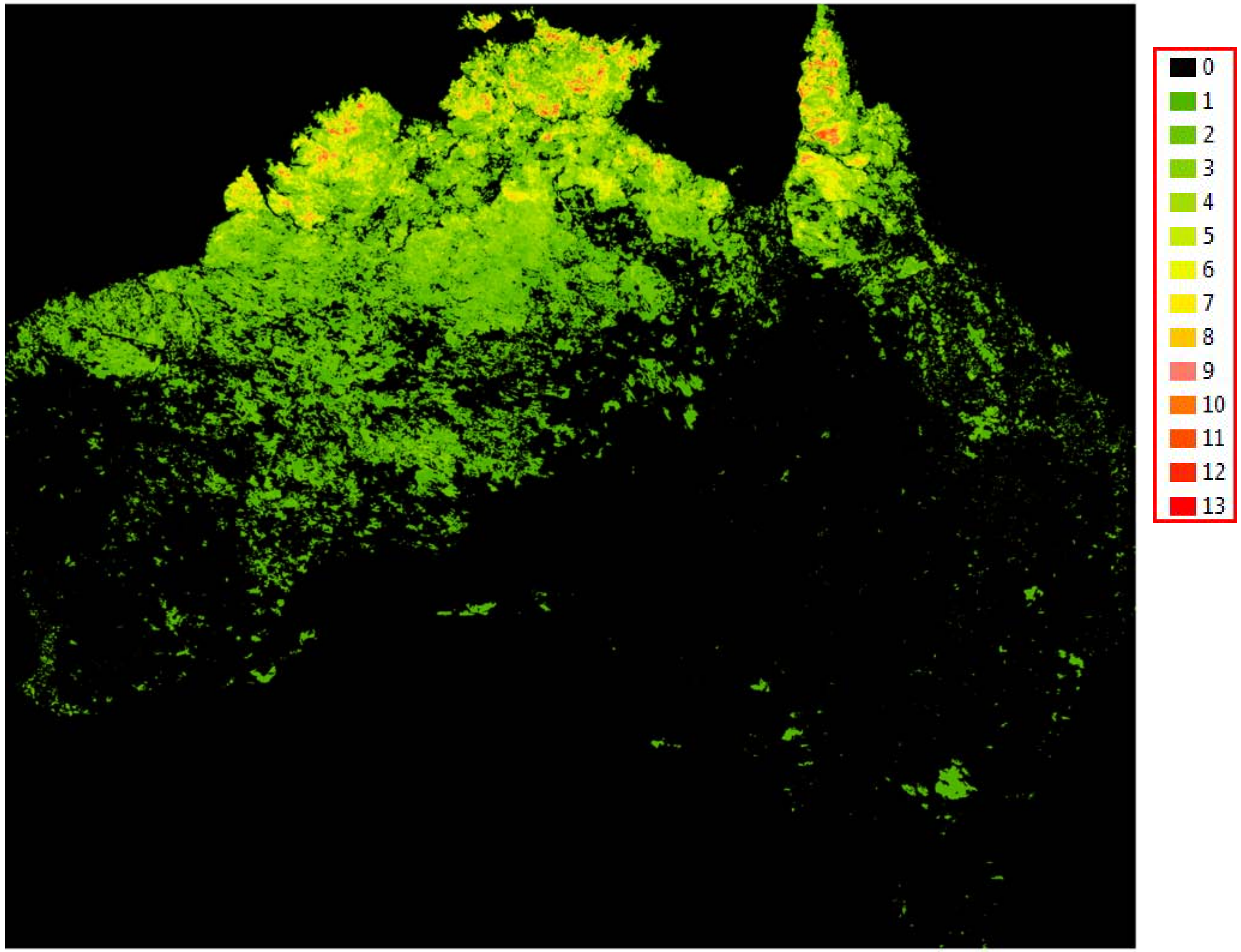
Annual longwave radiative forcing



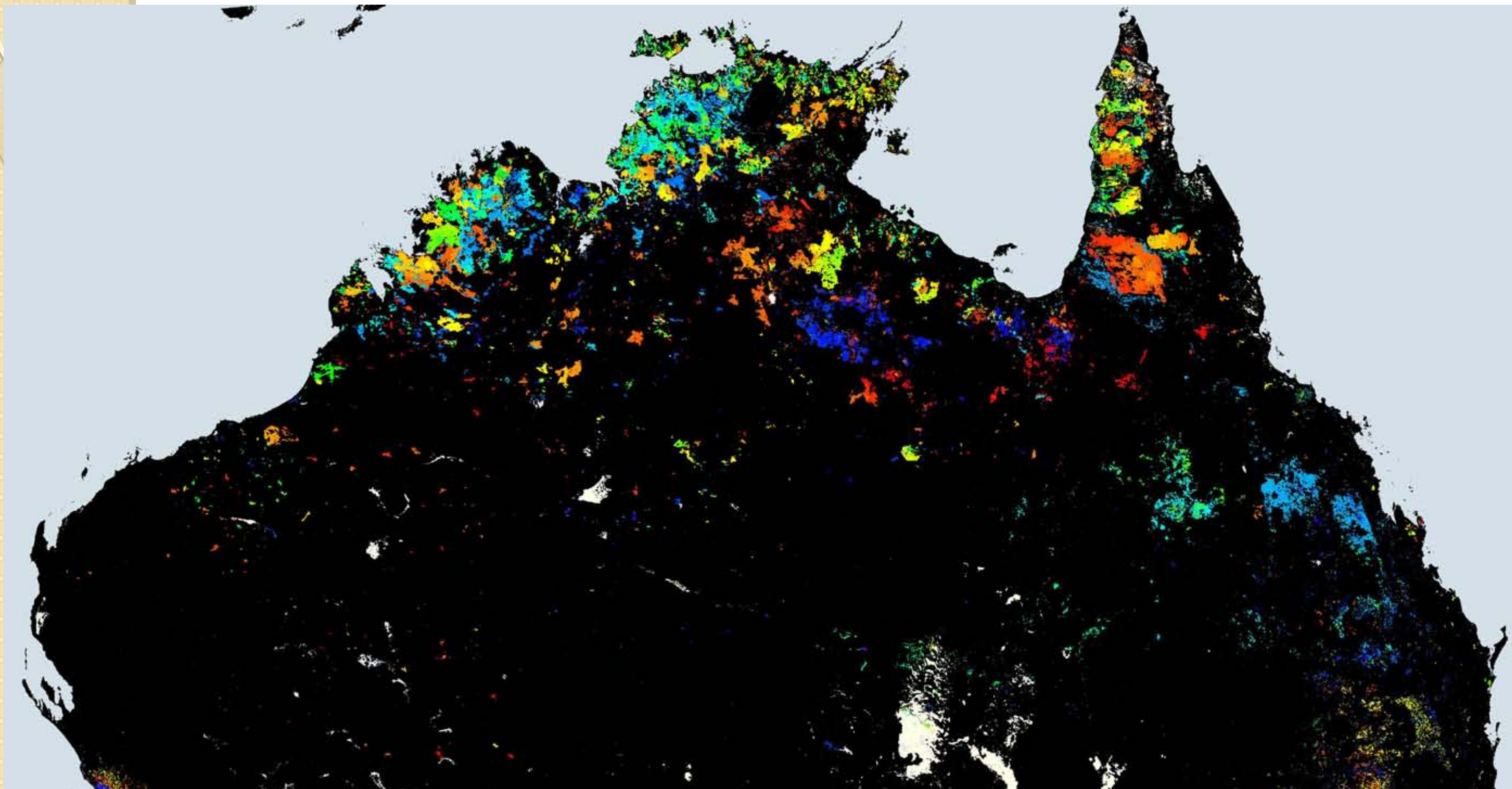


- Negative LWRF in general, except in Taiga (mid- to late succession)
- Magnitude of LWRF decreases with stand age
- Magnitude of LWRF increases from south to north in forested area
- Taiga/tundra has less negative LWRF

Fire frequency in Australia from 1997-2009



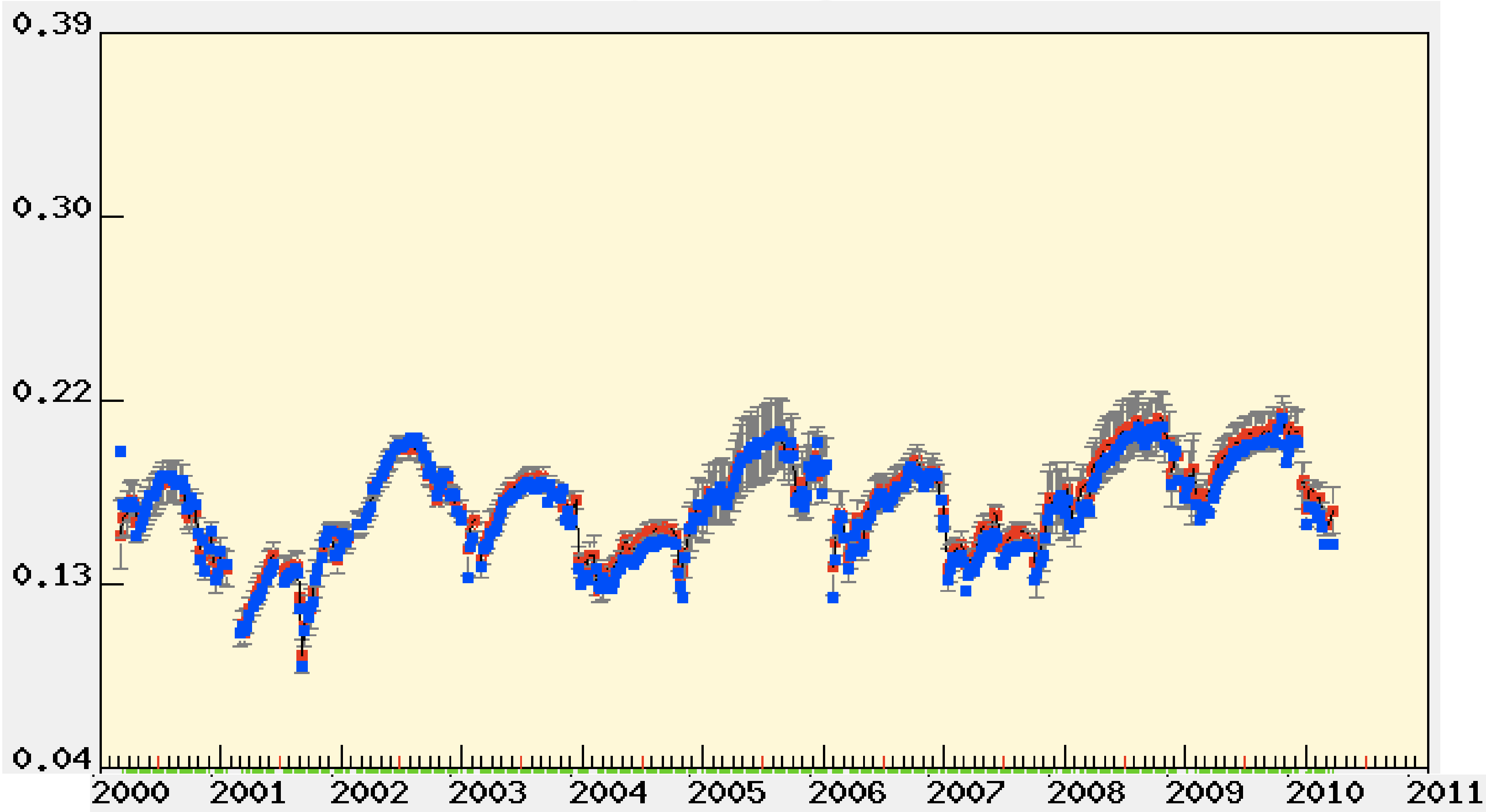
MODIS burned area 2003 (Mar– Nov) in N. Australia



March April May June July August September October November

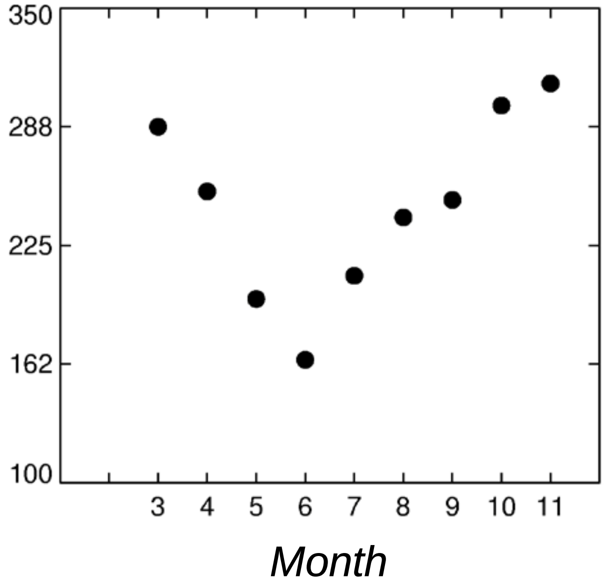
Australia north of 30°S

Post-fire albedo trajectory in N. Australia

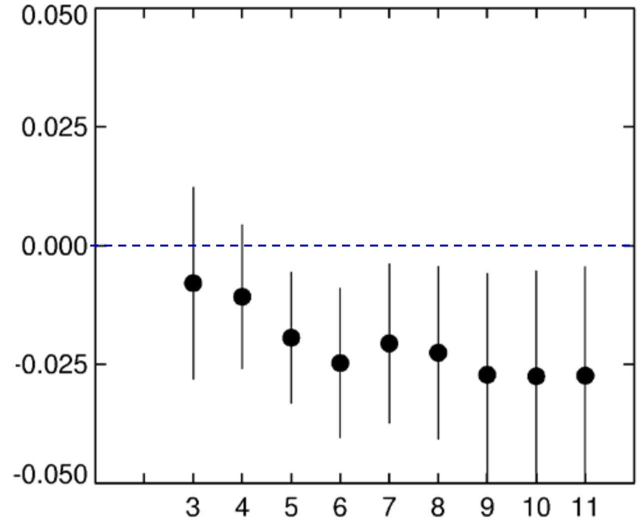


- Frequent burns
- Rapid recovery (one or two years after fire)
- Albedo decreases with small magnitude

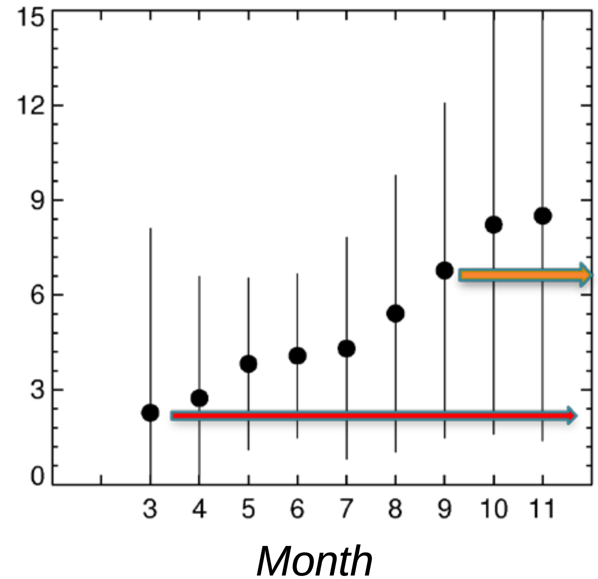
Incoming solar radiation (Wm^{-2})



Δ Albedo



Instantaneous RF (Wm^{-2})



Working with David Roy on similar analysis to study RF (early vs. late season burning) in support of WALFA project

Jin and Roy, *GRL*, 2006

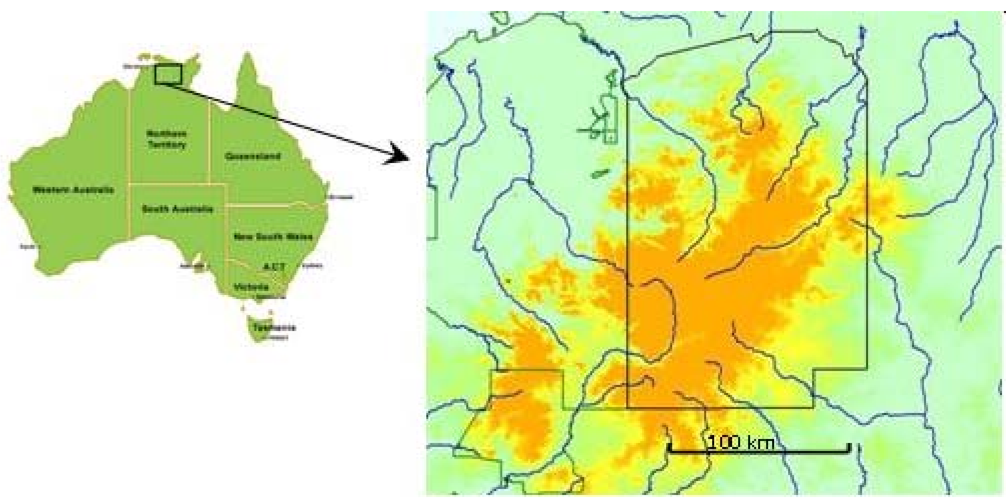
The West Arnhem Land Fire Abatement Project (WALFA)

- The WALFA project led to a landmark greenhouse gas offset agreement between ConocoPhillips, the Northern Territory Government, Northern Land Council, and Traditional Owners in west Arnhem Land, Northern Territory, Australia.

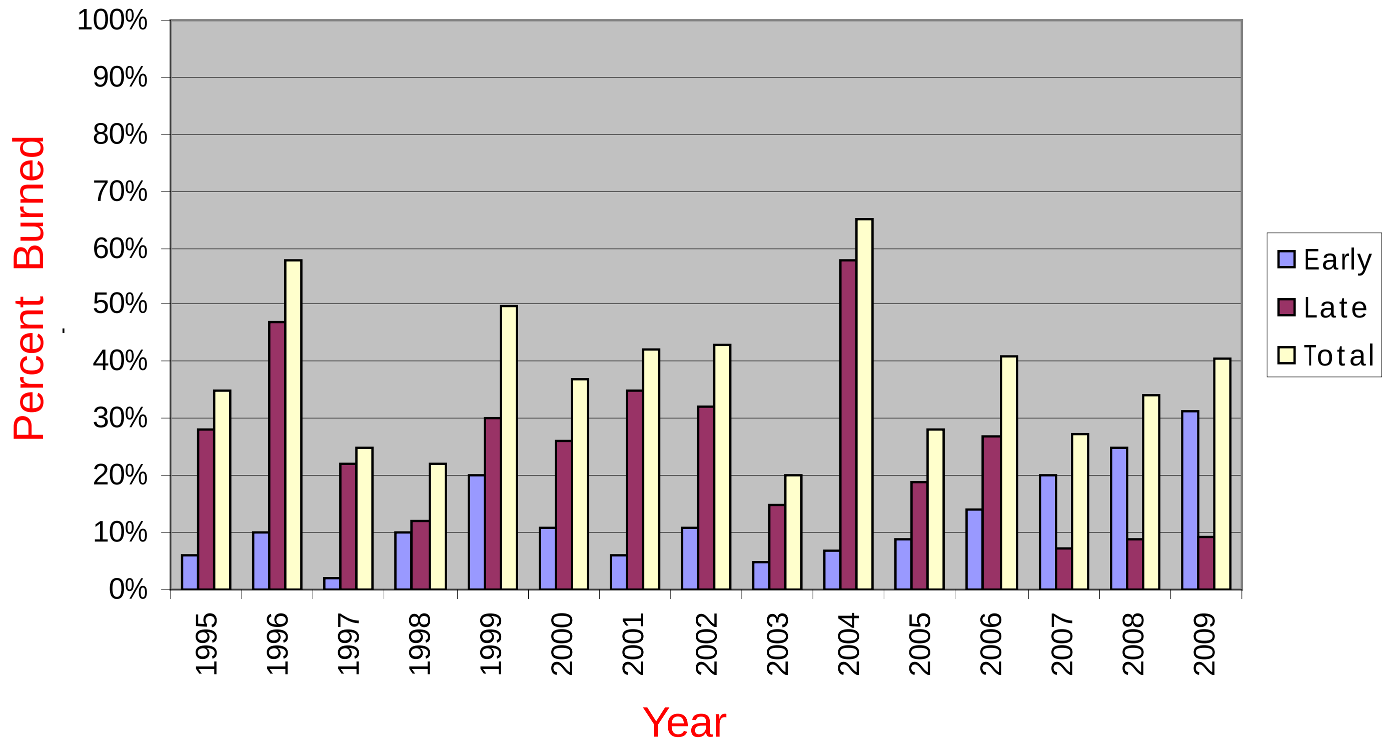
- Through this partnership Indigenous Ranger groups are implementing strategic fire management across 28,000 km^2 of Western Arnhem Land

- ConocoPhillips is paying A$1 million per year into the project for 17 years.

- WALFA is now reducing greenhouse gas emissions by the equivalent of over 100,000 tonnes of CO_2 per year.



The West Arnhem Land Fire Abatement Project (WALFA)

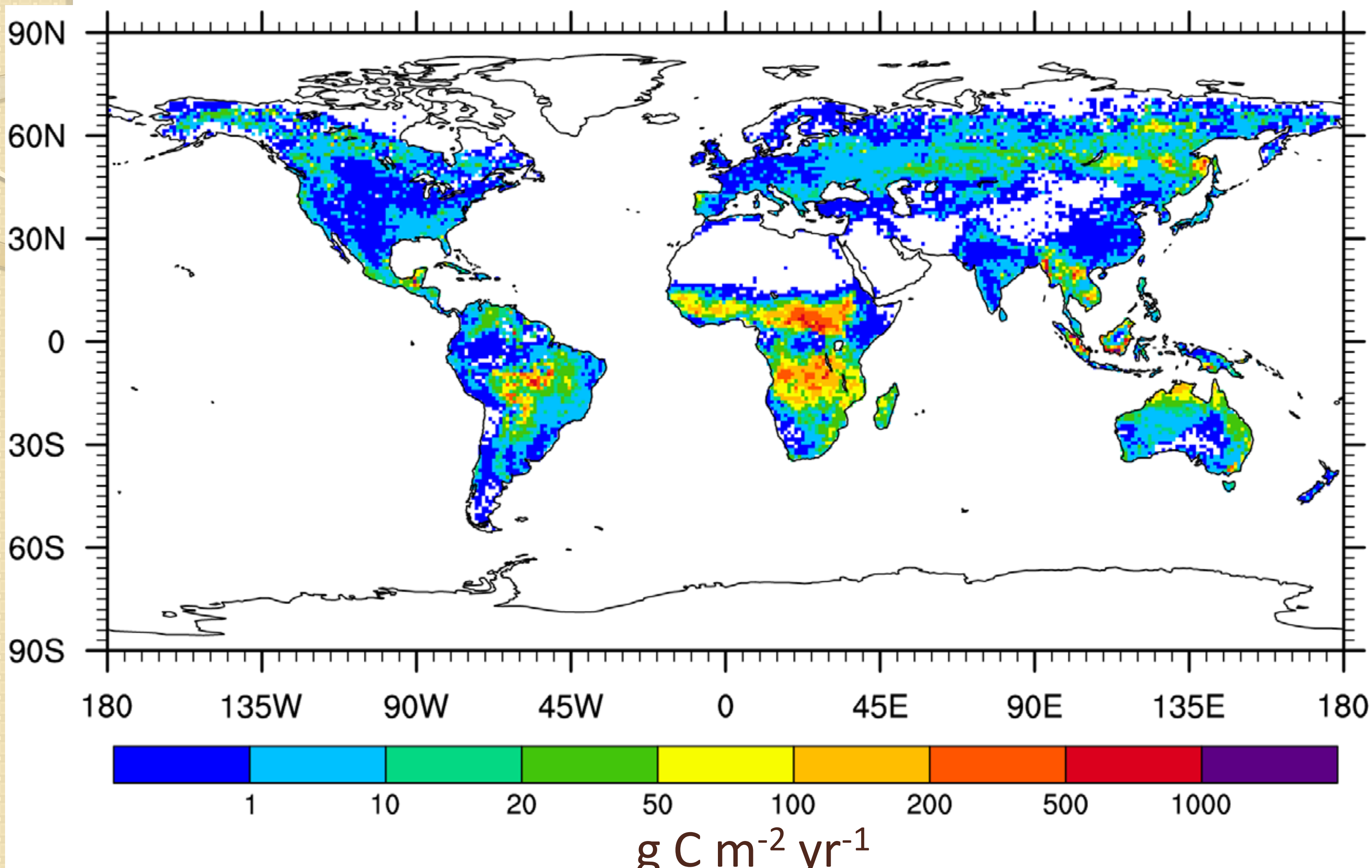


By 2007 strategic fire management early in the dry season is *reducing* the size & extent of wildfires in the late dry season.

WALFA is now reducing greenhouse gas emissions by the equivalent of over 100,000 tonnes of CO_2 per year.

Jeremy Russell-Smith

Annual mean fire emissions 1997-2008



- On a regional scale, fire emission may be relatively more important in Australia tropical savannas

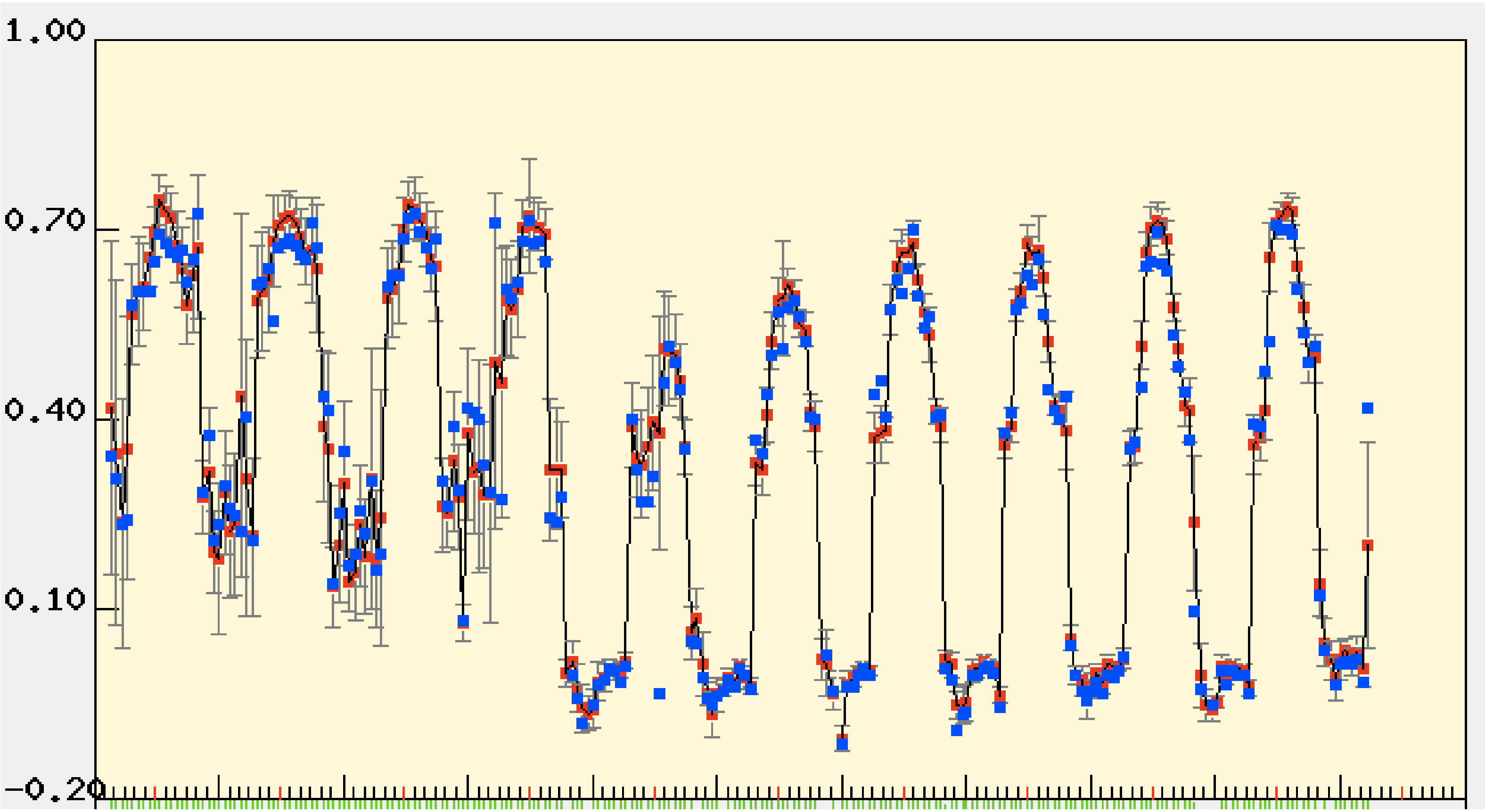
Randerson et al., GFED v3

Conclusions

- Fire reduces both annual net shortwave (dominated by spring albedo increase) and longwave radiation (dominated by summer surface temperature increase) in boreal Canada.
- SW radiative forcing decreases from south to north forests, mainly due to later snow melting in the north.
- Summer daytime surface temperature increases after fire, and the increase is larger in northern forests, leading to an increasing LW RF.
- The magnitude of SW and LW RF is similar (-2 ~ -6 W m^{-2}) in boreal forests.
- The RF due to albedo change in Australian savannas is positive and depends on season of burning (+1~ +6 W m^{-2}).
- Net regional impacts in Australian savannas may be not less significant than boreal Canada.

Acknowledgements

- Support from NASA New Investigator program
- Mike Flannigan for Canadian Large Fire Database
- Crystal Schaaf for MODIS BRDF/Albedo
- MODIS Land Surface Temperature and Vegetation Index teams



1.00
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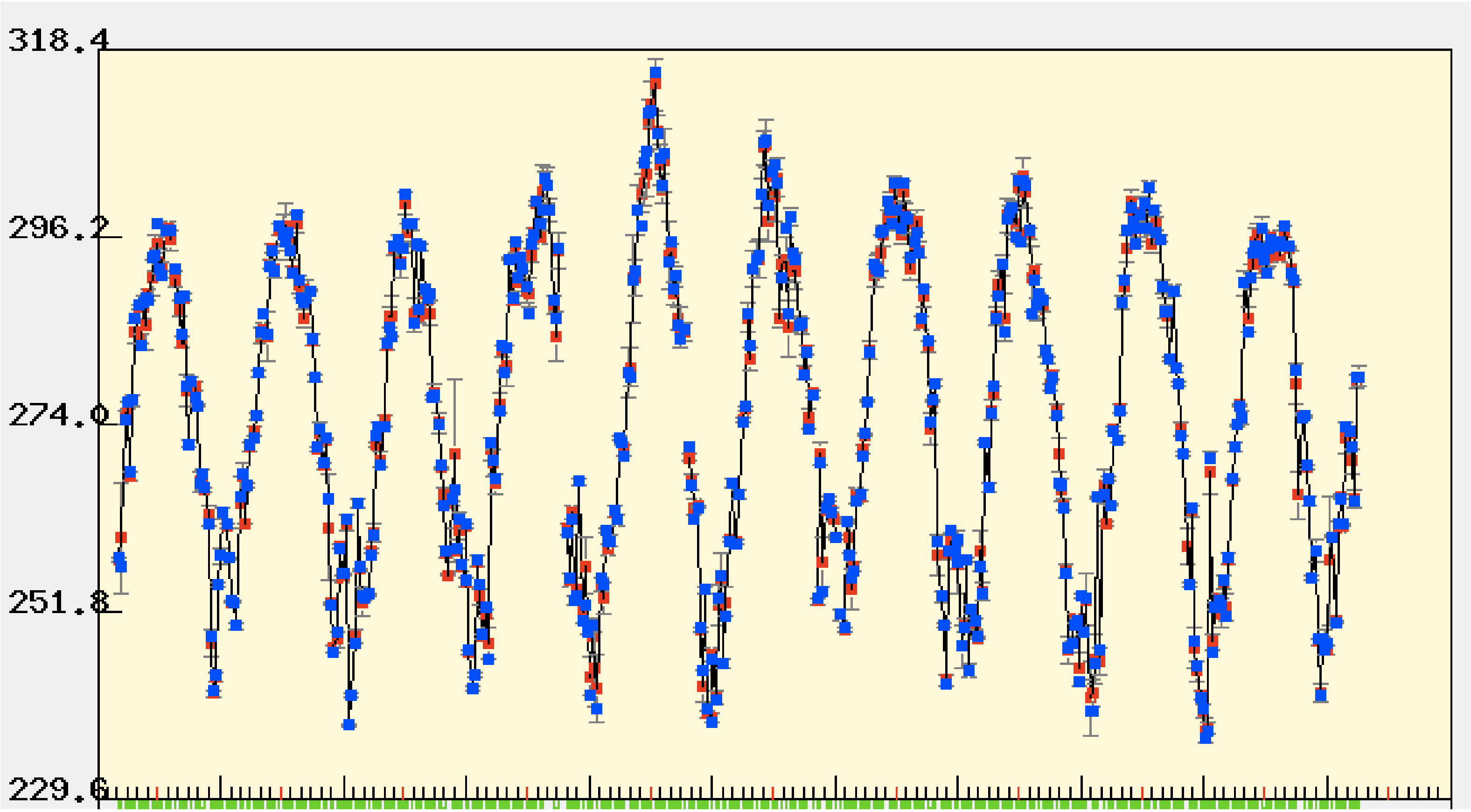

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296.2
274.0
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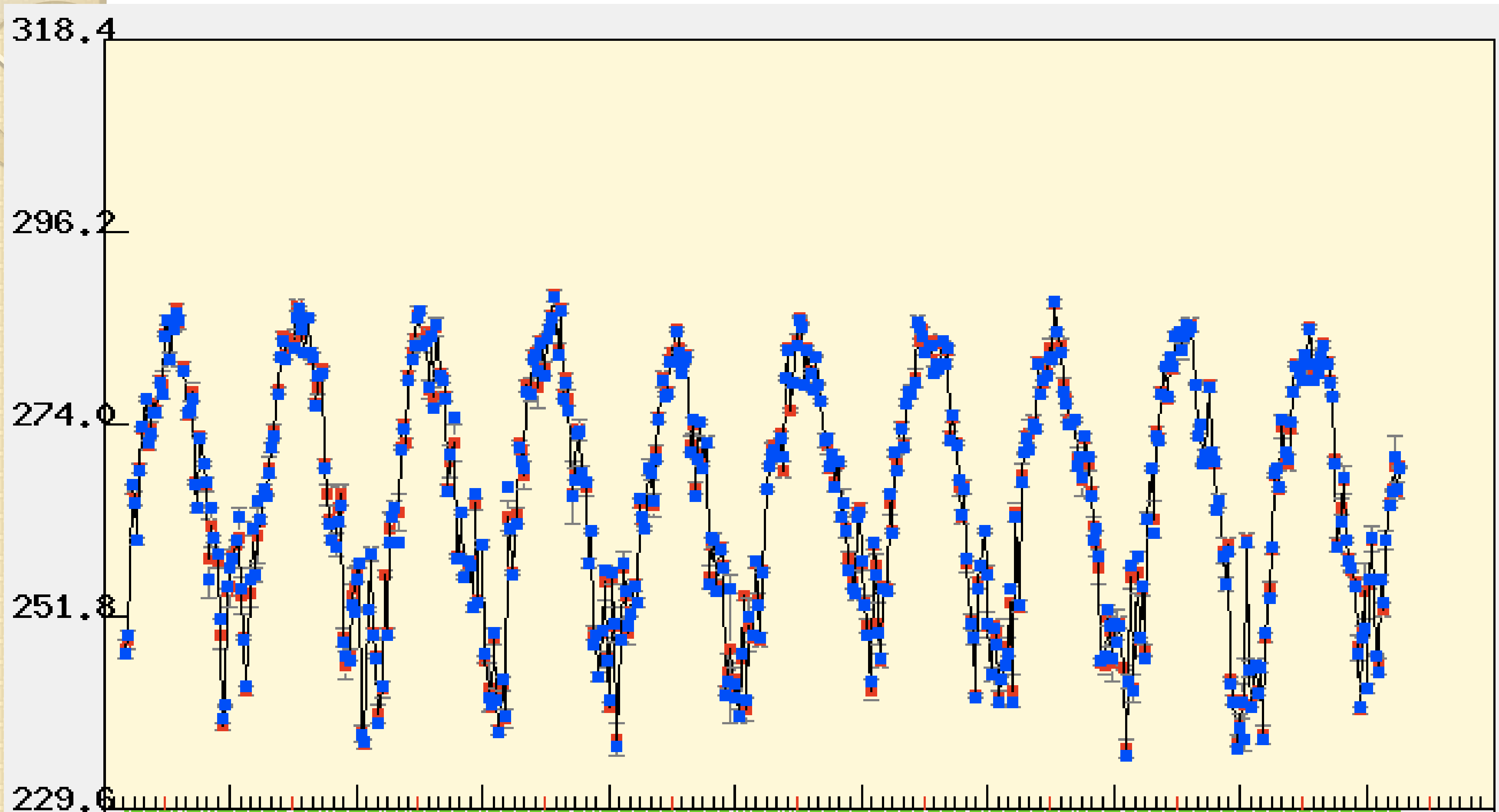

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