Satellite observations of fire-induced albedo changes and the associated radiative forcing: A comparison of boreal forest and tropical savanna

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Introduction

- An integrated accounting of radiative forcing by all agents from fire is necessary for decisions on carbon/fire management and climate-change policy. In regions with intensive burning, the local forcing due to albedo change may outweigh that due to fire-emitted greenhouse gases, e.g., in boreal region under snow conditions.

- In contrast to the well known warming effect of fire-emitted greenhouse gases, much less is known about the temporal evolution of post-fire albedo over a full annual cycle and over various vegetation succession stages after fire, especially at regional and continental scale.

- The tropical and boreal regions experience some of the most extensive biomass burning in the world. Fires in these regions have significant impacts on global carbon dynamics and climate.

- Tropical savannas burn around every two years and vegetation usually regrows within months after fire (Fig 1). Boreal fires often return at individual sites every 40 to 150 years, are usually high in intensity, and large in area. The vegetation succession goes through phases of grasses/shrubs, deciduous aspen trees, and evergreen forests (Fig 2).

- The field studies showed the significant difference of post-fire albedo and energy budget in different stages of vegetation succession after fire disturbance, but are limited to sparse spatial and temporal sampling. Satellite observation provides an efficient way for regional and global studies over entire fire cycle due to its large spatial and temporal coverage.

Fig 1. Stages in the regowth of dry sclerophyll vegetation at Ridgeway, Australia, after a fire in January 1998.

Fig 2.Vegetation succession in Alaska. At 3 years after fire, the dead spruce trees are still standing with grasses and small shrubs dominating. Deciduous aspen trees dominate the landscape after 16 years. After about 80 years, the evergreen black spruce trees have returned.

Data and Methods

- This study used the burned area product in Australia derived from MODIS observations since 2000 (Fig 3) and the fire perimeters from the Alaska Fire Service back to 1950s and to identify the location and approximate time of burning.

- The16-day 2000-2005 albedo product at 1 km resolution from MODIS Terra satellite was used for post-fire albedo change analysis. The actual albedo at local solar noon were calculated as a weighted sum of the black sky albedo by the direct incoming fraction and the white sky albedo by the diffuse incoming fraction.

- To account for rapid change of albedo, we also derived albedo right before and after fire in northern Australia using the MODIS BRDF/Albedo retrieval algorithm.

- The study areas are Australia north of 30S and the Alaskan interior. A three pixel buffer was removed around each fire to limit georegistration errors. Pixels were also removed near roads to limit interference from humans, as well as for lakes, rivers, and barren regions (Fig 4).

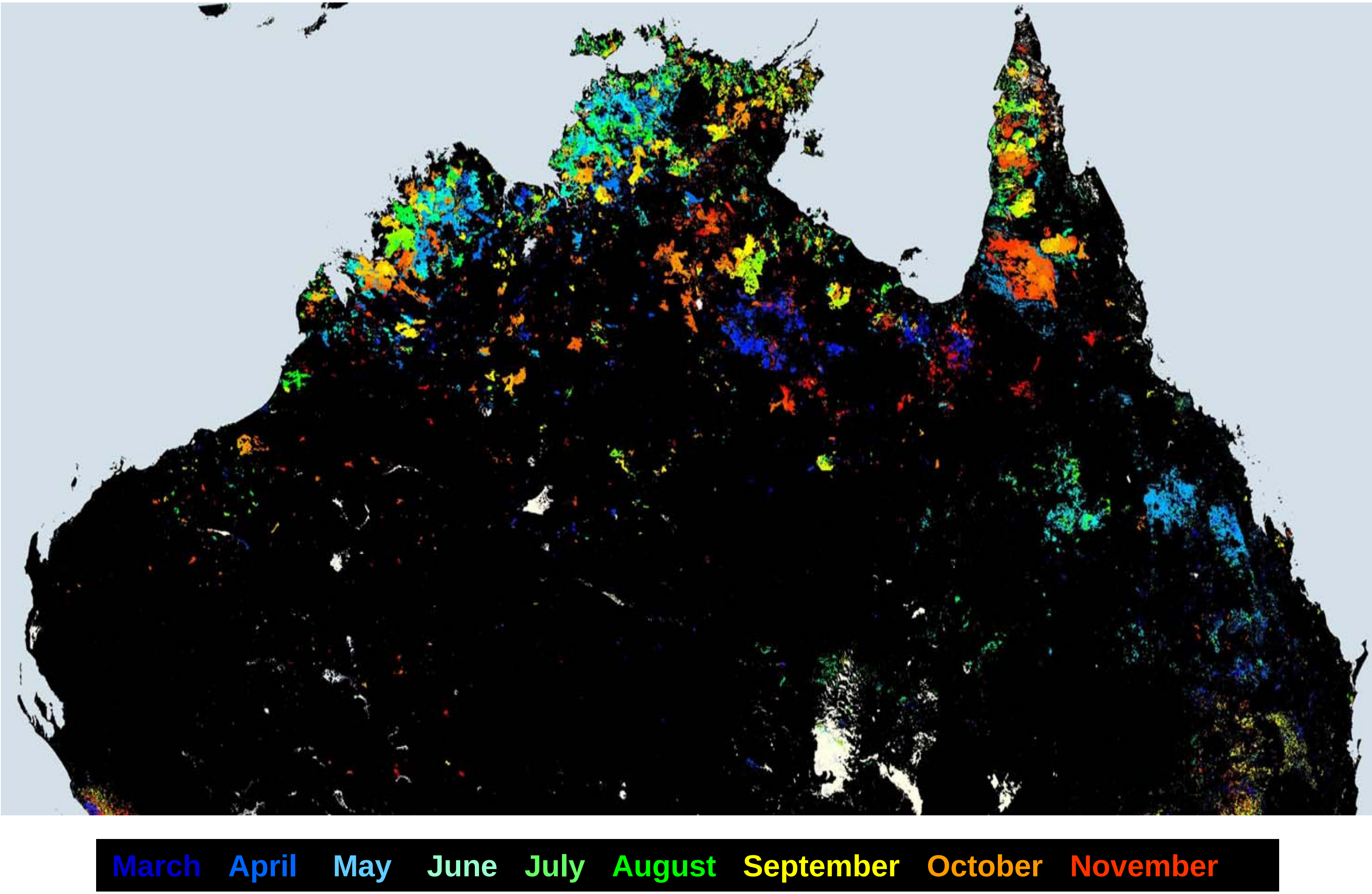

Fig 3. The burned area in 2003 fire season in northern Australia, derived from MODIS time series surface reflectance data. The color represents the date of burning.

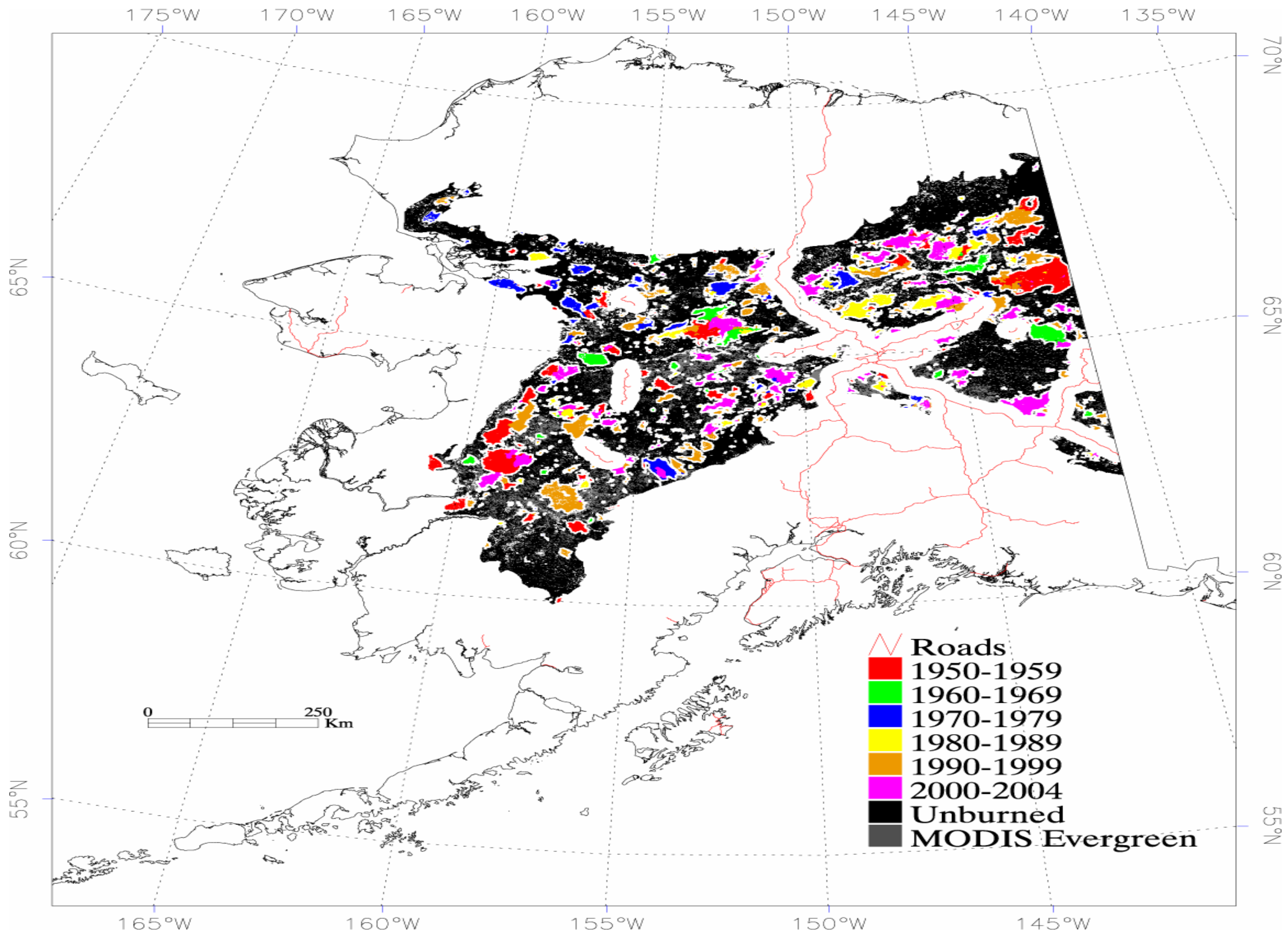

Fig 4. This map shows the fire perimeters used in the analyses. The black area shows the area of the interior that has not burned in the last 50 years. Fire perimeter data is from the Alaskan Fire Service, land cover data is from MODIS Land Cover Product, 2000.

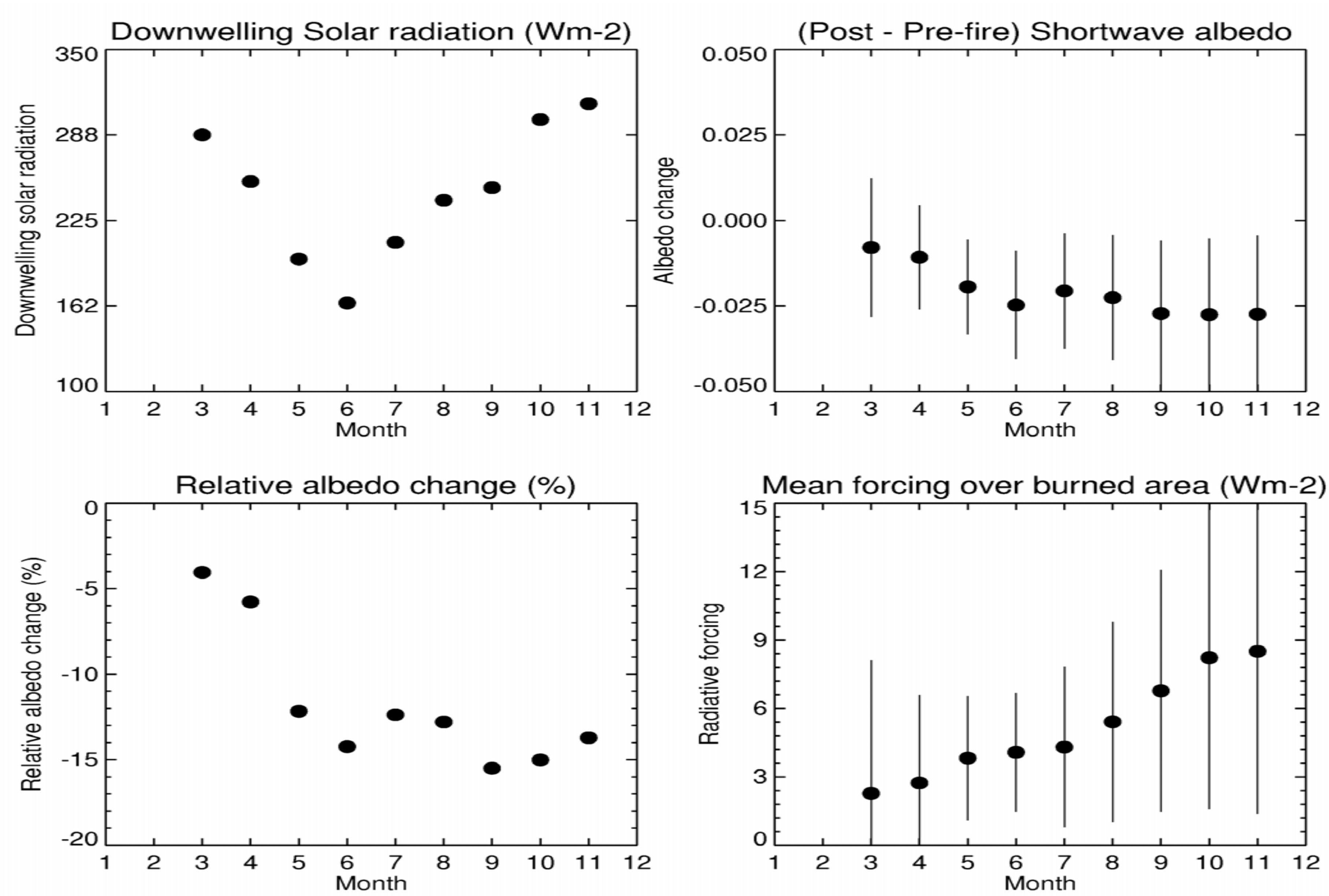

Fig 5. Temporal change of (a) mean monthly ERA40 climatology incoming solar radiation at the surface in northern Australia; (b) mean pre-fire (open circles) and post-fire (filled circles) shortwave albedos; (c) albedo change; and (d) surface shortwave radiative forcing over all burned areas. The spatial variations (one standard deviation) are plotted as vertical bars.

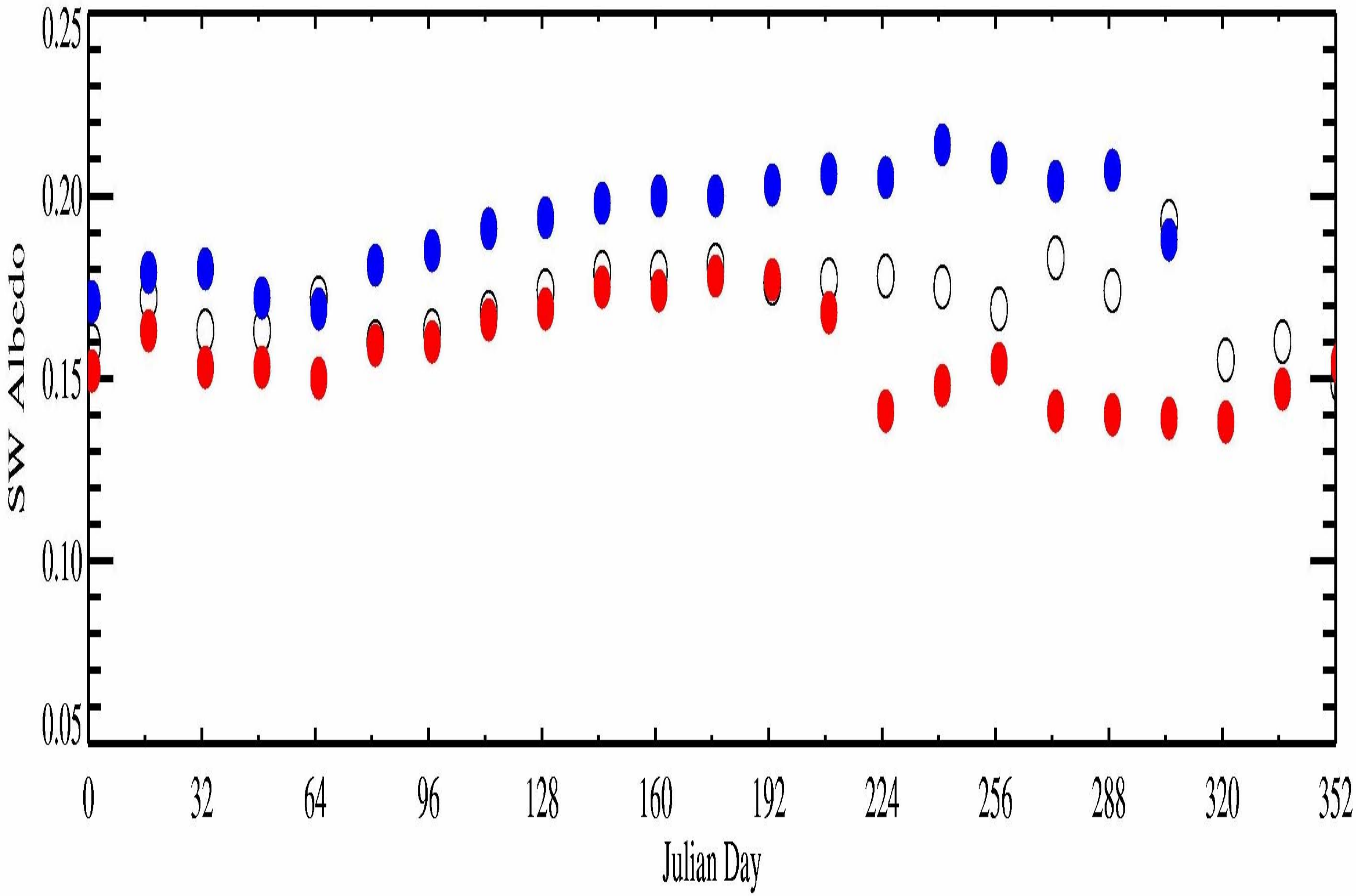

Fig 6. Example time series of MODIS surface albedo in bushlands, northern Australia. Fire occurred in early August 2002. Surface albedo decreases significantly immediately after fire and then starts to increase within months after fire and recovers after 4 months since fire.

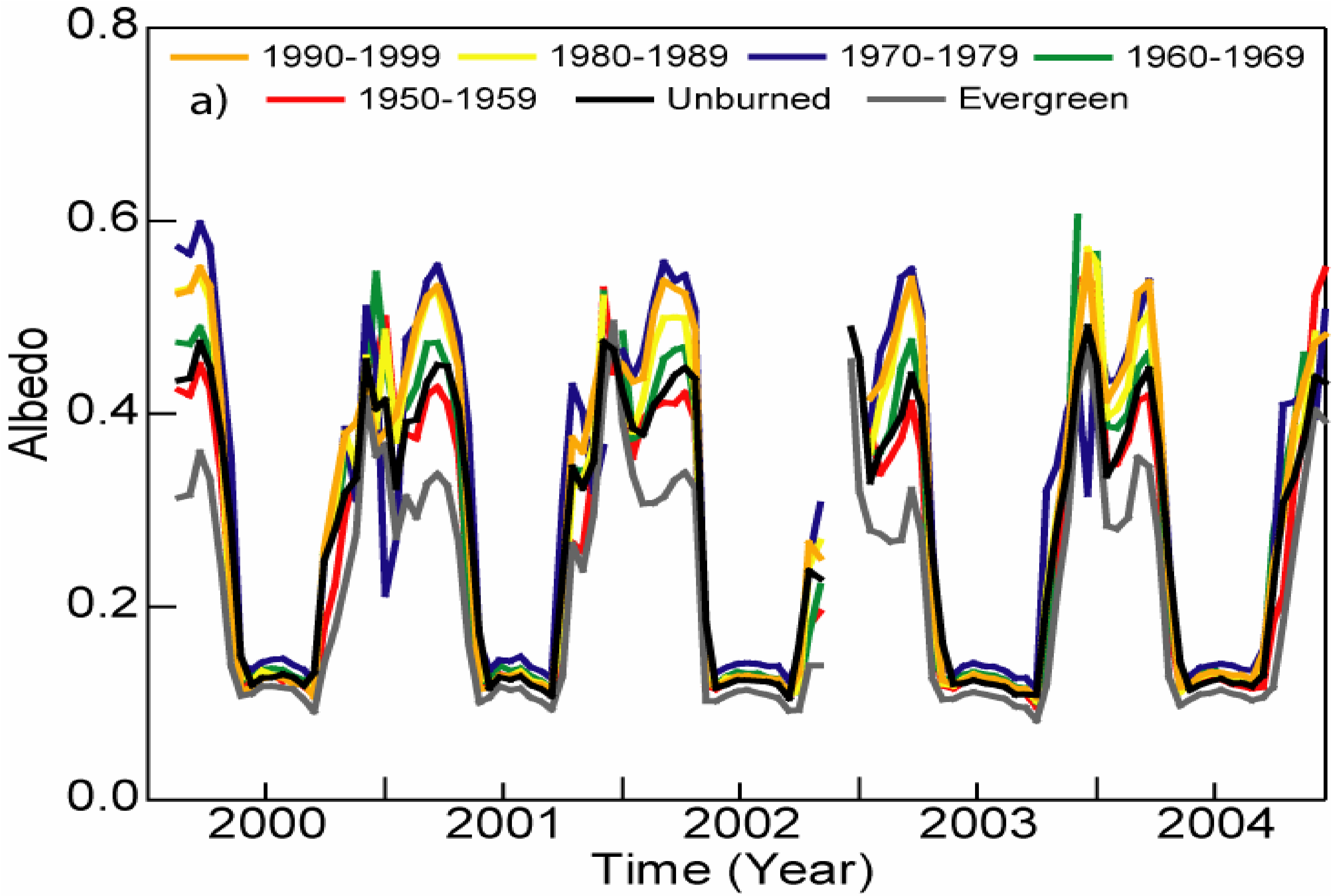

Fig 7. Time series of surface albedo of forests during 2000 – 2004 for different age classes. Areas burned more recently in the 1990s are much brighter in the spring and winter than those burned in the 1950s.

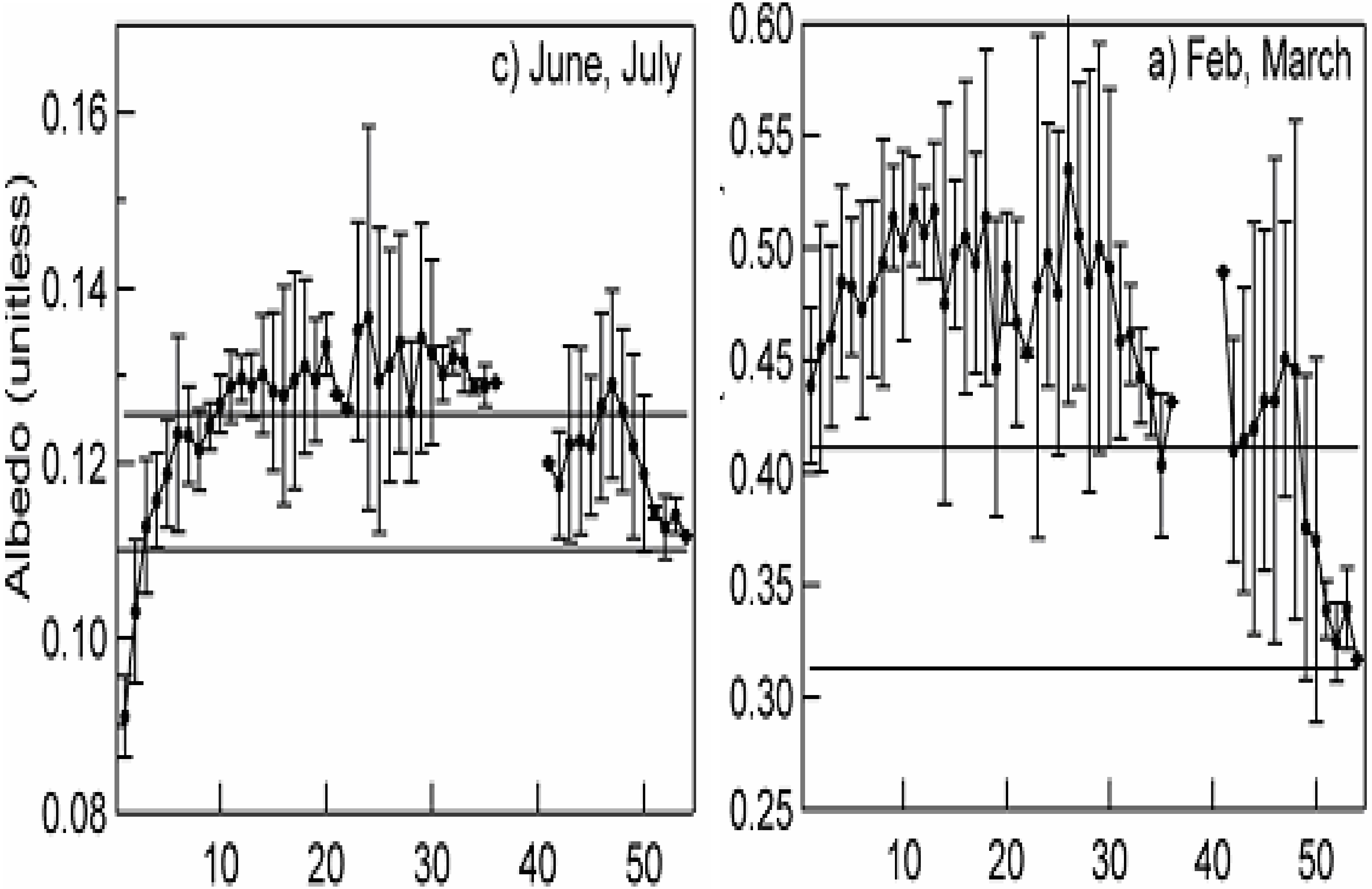

Fig 8. Temporal evolutionof post-fire albedo for different seasons. The unburned and evergreen lines represent the controls for the region that estimate the pre-burn albedo and give a reference for when the forest has recovered.

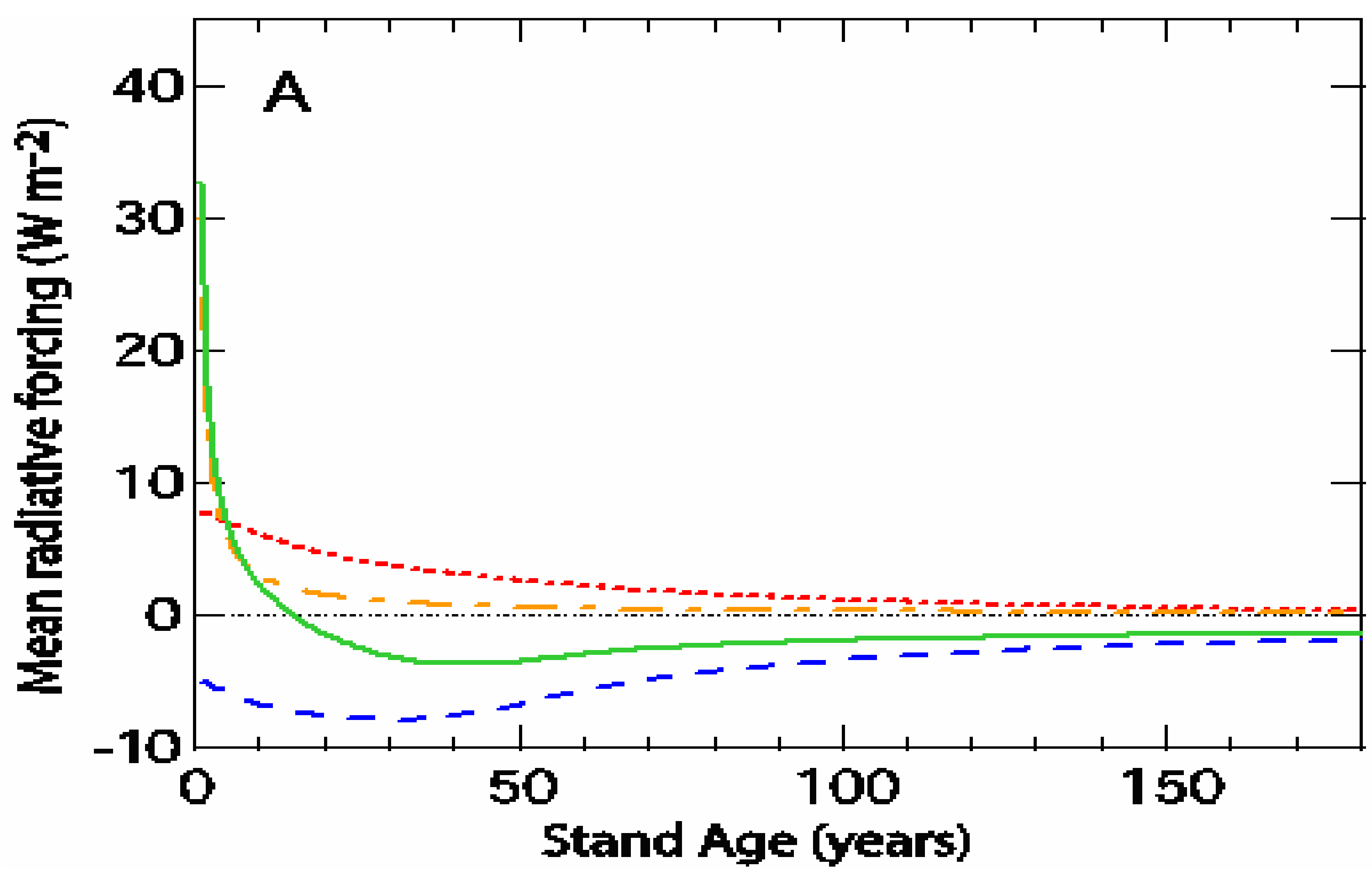

Fig 9. Mean radiative forcing for the different forcing agents averaged over the age of the forest stand. The combined effect of CO_2 and CH_4 is represented by the dotted red line, aerosols, black carbon deposition, and O_3 by the dash-dotted orange line, albedo by the dashed blue line, and the net sum of all forcing agents by the solid green line. (Ref.4)

Results

- In northern Australia, shortwave albedo decreases by an average of 0.024 within 16-32 days after fire, leading to a mean ‘‘instantaneous’’ shortwave surface radiative forcing of 0.52 W/m^2 (Fig 5).

- The reduction of albedo depends on the timing of burning. Fires in late dry season lead to largest decrease. The albedo increases within months after fire along with ash dissipation and fast vegetation regrowth in northern Australia (Fig 6).

- In boreal Alaska, both the post-fire vegetation succession and snow cover contribute to the temporal evolution of albedo (Fig 7). In summer post-fire albedo shows an initial decrease of 0.023 and recovers in five years, followed by an increase of 0.025, and peaks in 20 years, followed by a decrease again (Fig 8A). In spring and winter, post-fire albedo increases by 0.165 compared with unburned areas and peaks in nine years (Fig 8B).

- Post-fire changes in surface albedo in both seasons persist for several decades and recovers to pre-fire levels in about 50 years (Fig 8). This persistent increase of post-fire albedo leads to a significant cooling effect, larger than the warming by fire-emitted greenhouse gases (Fig 9, Ref. 4).

Reference

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3. E. A. Lyons *et al.*, Post-fire changes in surface albedo associated with vegetation succession in boreal forest ecosystems, manuscript in preparation, 2006.
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