Relationships Between Prefire Composition, Fire Impact, and Postfire Legacies in the Boreal Forest of Eastern Canada

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Abstract—*Canadian mixedwood forests have a high compositional and structural diversity. It includes both hardwood (aspen, balsam poplar, and white birch) and softwood (balsam fir, white spruce, black spruce, larch, and white cedar) species that can form pure stands or mixed stands. This heterogeneity results in a variety of vertical structural strata that can potentially interact with fire behaviour. Fourteen fire impact maps including information on preburn stand composition and structure were gathered in a Geographical Information System. The relative influence of prefire forest composition, stand density, and surficial deposits on postfire forest cover attributes (such as variation in proportion of green/red/charred trees) was analyzed using contingency tables. Many attributes of postfire forests (fire legacy) can be related to preburn forest composition and structure. Highest fire impact was observed in coniferous stands. At the other end of the spectrum, aspen stands and wetlands contributed to most of the fire skips. Within coniferous stands, there was a difference between species with regard to their susceptibility to windthrow following fire. Jack pine stands had less severe windthrow allowing for an abundance of snags, whereas windthrow is common in balsam fir stands. Impacts vary with regard to fire severity, suggesting that observed differences between stand types may be less important when fires are very intense. These results have consequences on the maintenance of the diversity of the forest mosaics through time as well as our capability to predict fire behaviour and impacts.*

Introduction

The Canadian boreal forest has often been described as a region where large severe crown fires control vegetation dynamics (Johnson and others 1998). These severe fires are usually recognized as leaving few surviving trees in burned areas. Many forest managers used this conventional wisdom to justify a relatively low level of retention after harvesting. In fact, there are relatively few studies that address the question of how much area is spared from fire and on how those unburned islands are spatially distributed after severe crown fire events (Schmiegelow and others 2006).

Canadian mixedwood forests have a high compositional and structural diversity. It includes both hardwood (aspen, balsam poplar, and white birch) and softwood (balsam fir, white spruce, black spruce, larch, and white cedar) species that can form pure or mixed stands. This heterogeneity results in a variety of vertical structural strata that can affect fire behaviour (Cumming 2001; van Wagner 1977).

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In this study, we used 14 fire impact maps (fig. 1) that were overlaid on forest inventory maps to define the original forest cover before fire event. The relative influence of prefire forest composition, stand density, and surficial deposits on postfire forest cover attributes (such as variation in proportion of green/red/charred trees) was analyzed using contingency tables.

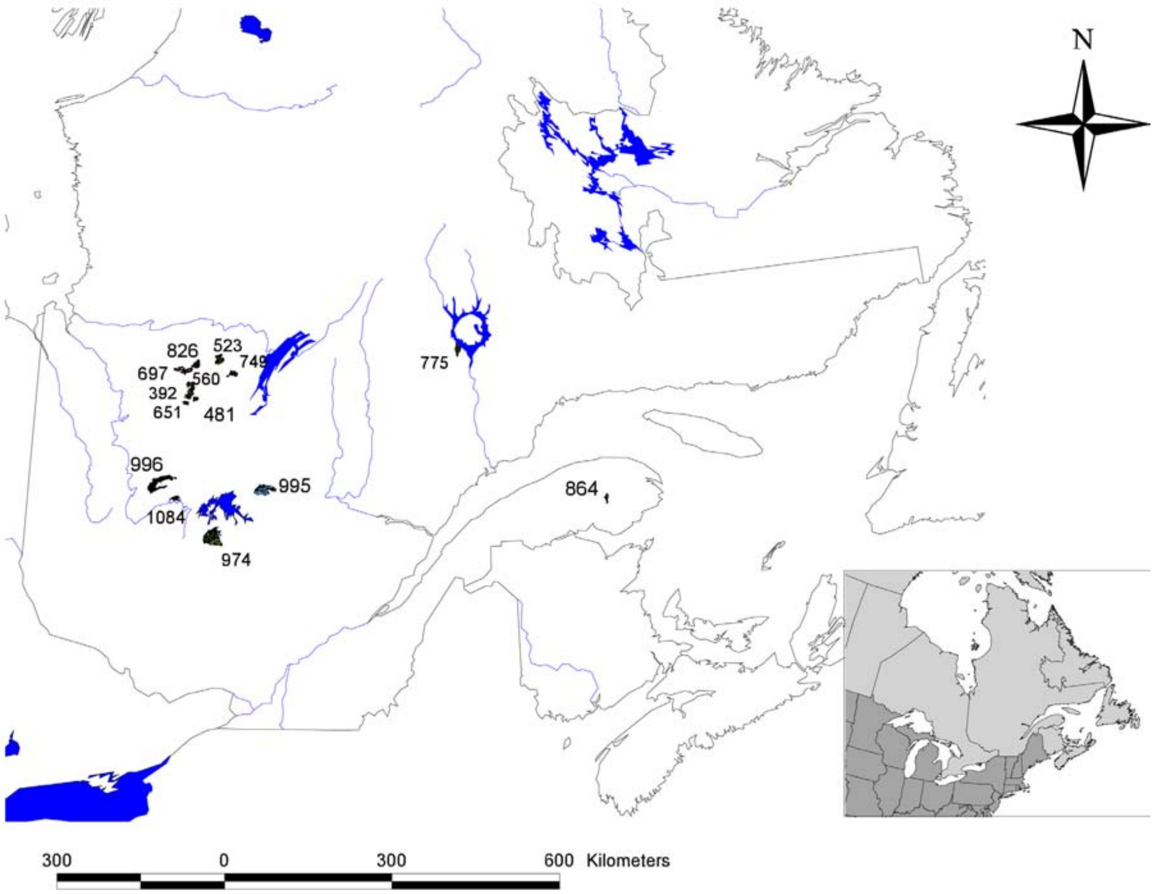

Figure 1—Map of Quebec showing the location of 14 fire events.

Methods

Fire impact maps are produced by the Quebec Ministry of Natural Resources after large wildfires in order to plan salvage logging operations. These maps describe timber damage immediately after fire in six severity classes (table 1). Forest inventory maps are available for the commercial zone as raster format at a resolution of 14 ha. These maps (inventory and fire impacts) were overlaid in ARC-GIS in order to produce a table of 15,200 records for which we obtained the prefire forest cover composition, the percentage of forest cover, the site type (a combination of surface deposit and moisture regime) and the fire severity class.

In the first step, each fire event was clustered based on the overall impact on black spruce stands (the dominant cover in all fires) defining a fire intensity index. This index corresponds to a weighted mean of area affected by fire severity classes where partially burned area in which green trees dominate was

Table 1—Relative importance (area) for fire severity class for the overall 14 fires.

Fire severity class	Relative importance (%)
5: Charred trees > 40% blowdown	8.6
4: Charred trees < 40% blowdown	51.3
3: Crown scorched < 25% blowdown	1.8
2: Mixed zones of scorched trees > green trees	7.7
1: Mixed zones of green trees > scorched trees	26.1
0: Fire skips	4.4

weighted by 1, mixed zones dominated by scorched tree was weighted by 2, and area dominated by crown scorched or charred trees was weighted by 3 (fire skips were not counted). In the second step, the relationships between six fire severity classes and prefire or site characteristics were illustrated by deviance; in other words, the relative difference between observed frequency and expected frequency reported on expected frequency, overall or taking into account the intensity index.

Results

Fires were clustered in three severity classes corresponding to weak (fire 481, 775, 826), moderate (fire 392, 523, 560, 651, 697, 749, 1084) and high overall impact (fire 864, 974, 995, 996; fig. 2). All fire events that burned more than 30,000 ha belong to the high severity class showing a good relationship between the area burned and the severity of damage registered on tree cover (fig. 3).

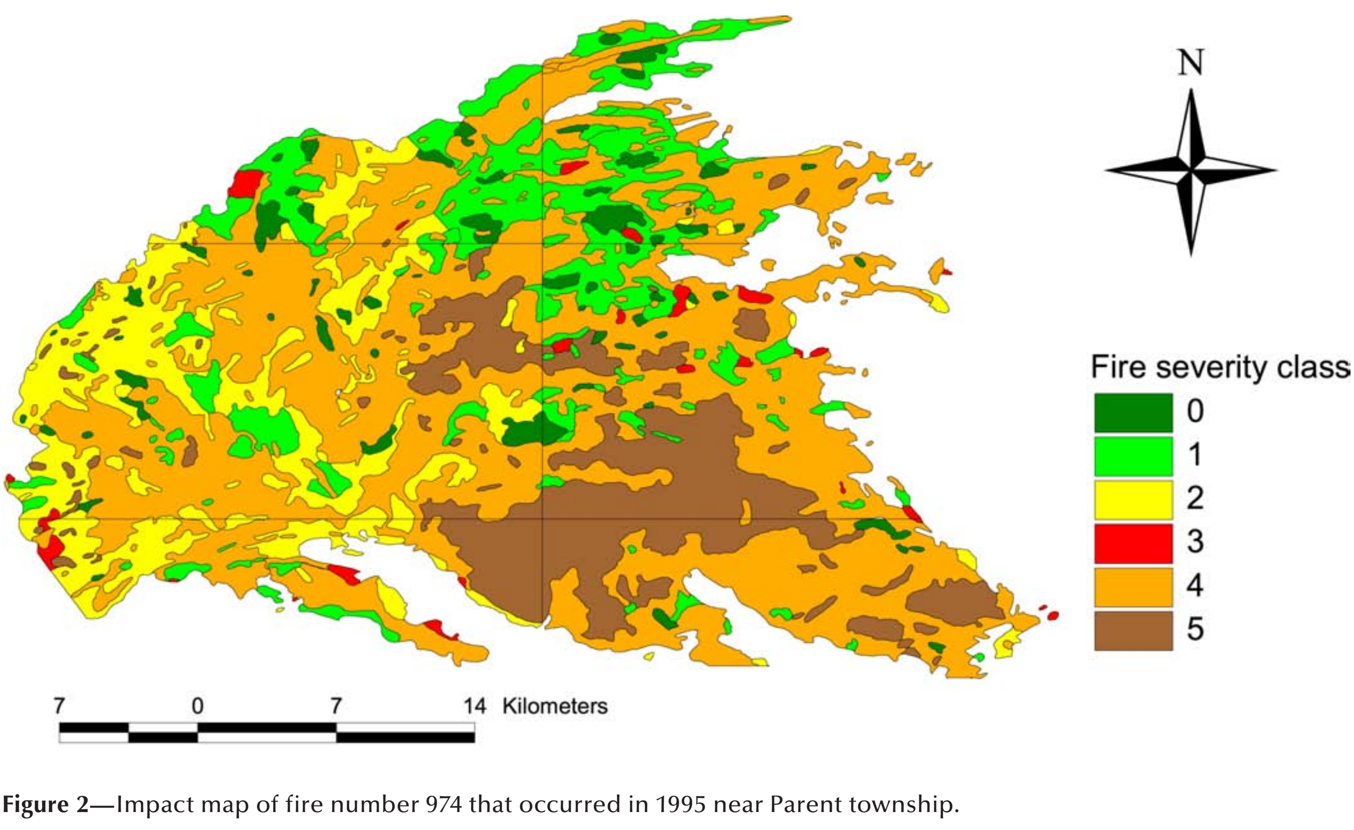

Figure 2—Impact map of fire number 974 that occurred in 1995 near Parent township.

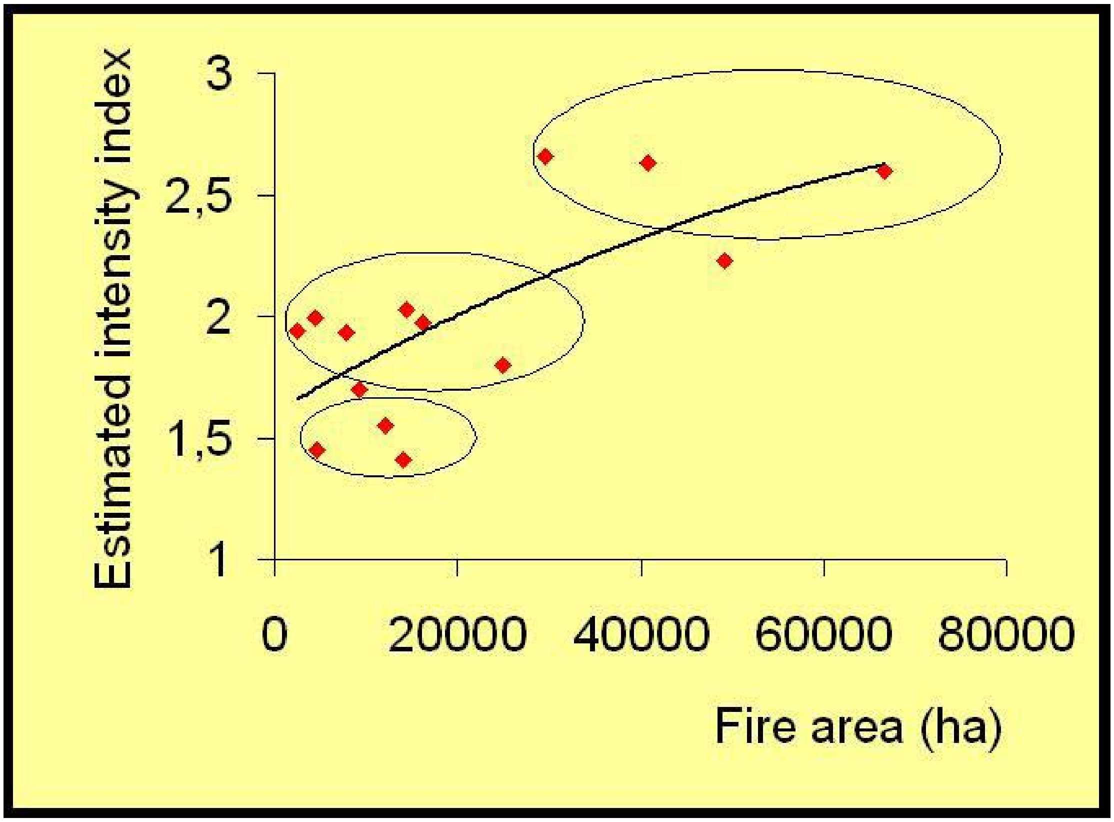

Figure 3—Relationship between fire size and fire intensity index such as estimated by proportion of black spruce stands (area) having undergone heavy impact.

Figure 4 shows how site types can interact with fire severity in black spruce forest cover type in all fire events. Deviance (percent deviation from expected value) indicates an overabundance of weak severity (classes 1 and 0) on hydric soil types such as organic soil and sub-hydric coarse sand. In contrast, rocky outcrops and xeric coarse sand show an overabundance of the highest severity (class 5).

Figure 5 shows the influence of black spruce stand density on severity class distribution. Fire skips (class 0) are overrepresented in closed black spruce stands (> 80 percent closed canopy). Note that this stand density appears also slightly overabundant in impact class 4 (charred trees with < 40 percent blowdown). Open canopies (25 to 40 percent closed canopy) generate an overabundance of weak severity class 1 with a dominance of green trees after fire.

Figure 6 shows the influence of forest cover composition for each fire intensity level. Generally, fire skips and green tree dominated zones are overrepresented in wetlands and stands with prefire forest cover dominated by deciduous cover such as trembling aspen and white birch stands. Balsam fir stands can form fire skips when fire severity is low but usually fire impact was high in these stands. Open forested lands also usually burned intensively. Among high intensity fires, jack pine stands could provide fire skips or green tree dominated zones but with less propensity than trembling aspen stands. Jack pine stands appear also more wind firm (less than 40 percent blowdown) than white birch and mixed white birch stands (fig. 6c).

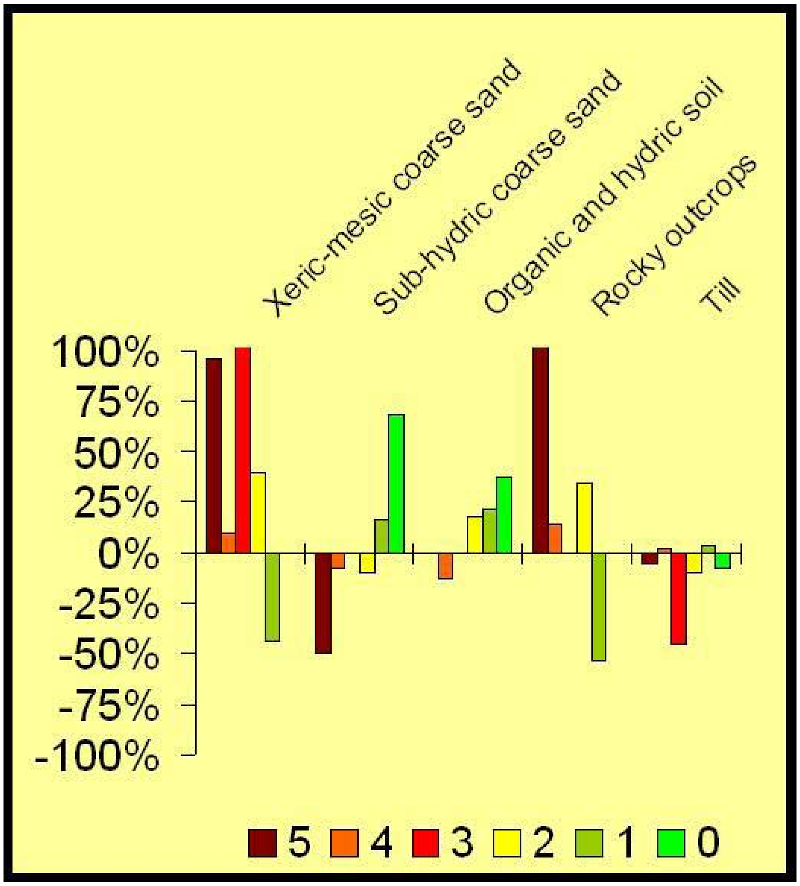

Figure 4—Influence of site types on the distribution of fire severity classes. A positive deviance indicates an overabundance of a severity class for a given site type. Conversely, a negative deviance means a under abundance.

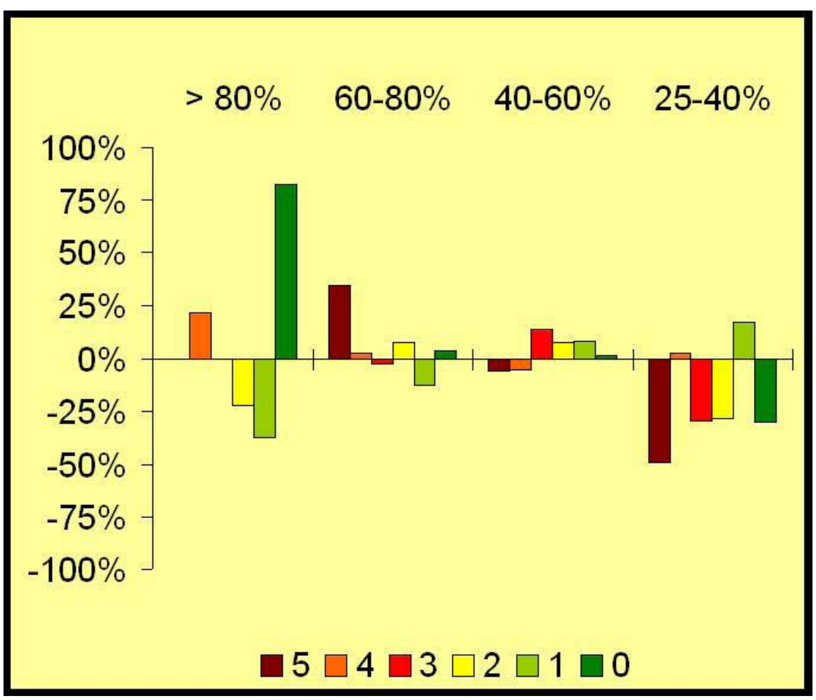

Figure 5—Influence of stand density (for black spruce forest cover only) on prevalence of fire severity classes.

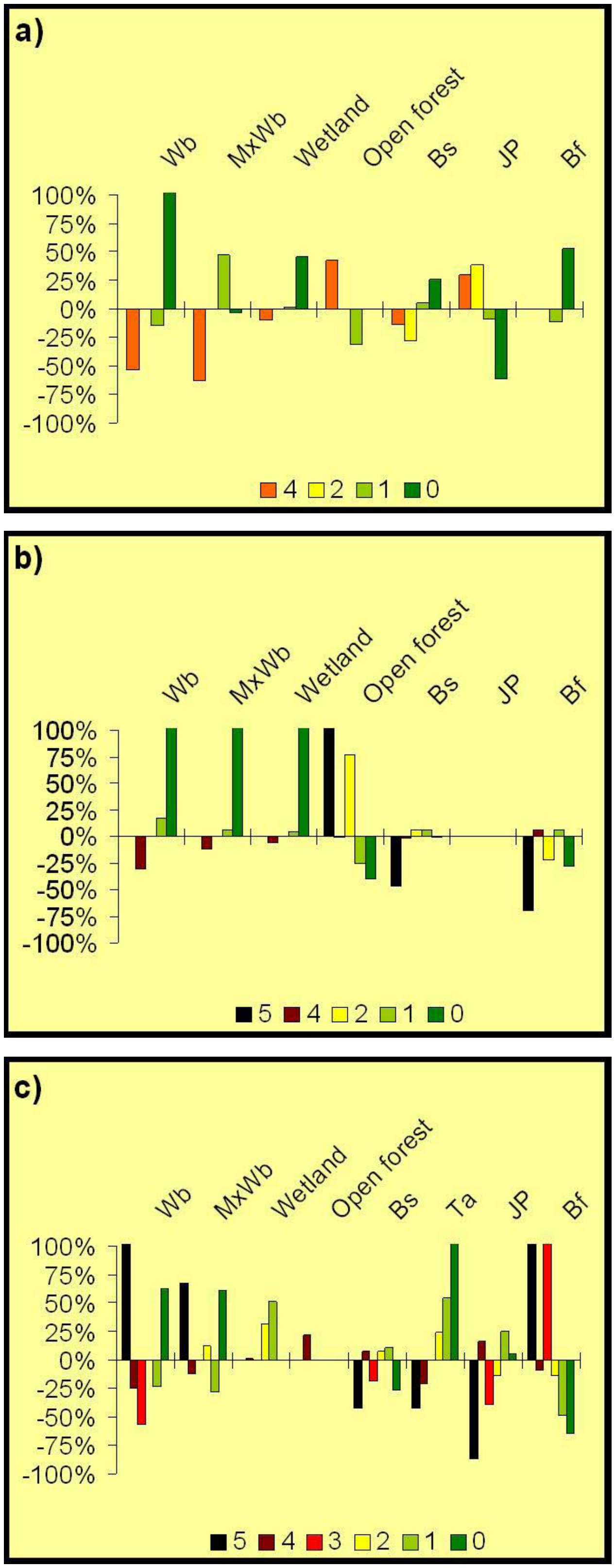

Figure 6—Influence of prefire forest cover composition on the prevalence of fire severity classes. Fires have been grouped by estimated intensity index as shown in figure 3, following they are weakly (a), moderately (b) or highly (c) intense. Some fire severity classes were absent from weakly (a) or moderately (b) intense fire groups. Stand types are coded as follows: Wb: white birch; MxWb; mixed white birch; Bs: black spruce; Ta: trembling aspen; JP: jack pine; Bf: balsam fir.

Discussion

The Canadian boreal forest is known to be characterized by severe crown fires. These fire events usually leave few residual patches (less than 5 percent of burned areas are composed of fire skips). Our results confirm this observation but also show that a relatively large portion of a fire may be occupied by partially burned zones in which green trees dominate postfire forest cover. Our results support the idea that forest cover composition and structure have an influence on fire behaviour and thus on the resulting fire severity. For instance, deciduous forest cover is more likely to generate more residual green trees (Cumming 2001; Kafka and others 2001). Moreover, our results highlight that fire behaviour may differ according to the overall fire intensity. For example, in fires with a low or moderate intensity index, partially burned stands are mainly composed of mixedwood whereas in the fires with an overall high intensity only the more fire resistant, trembling aspen stands (and to some extent jack pine stands) are partially burnt. This interaction between fire intensity and forest cover composition suggests that complex postfire outcomes, in which residual trees could survive individually or in small groups, are possible in the eastern part of Canadian boreal. This spatial pattern of postfire residual trees has implications for the spatial planning of postharvesting tree retention (Schmiegelow and others 2006). More analyses are needed, however, to characterize this spatial pattern at a finer resolution.

References

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