Wildfires & Wildland Urban Interface

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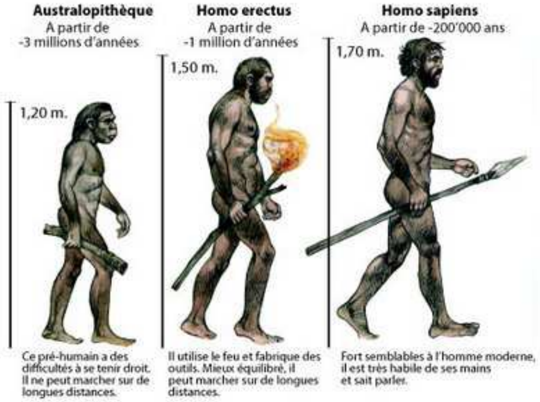
Role played by fires in the evolution of species



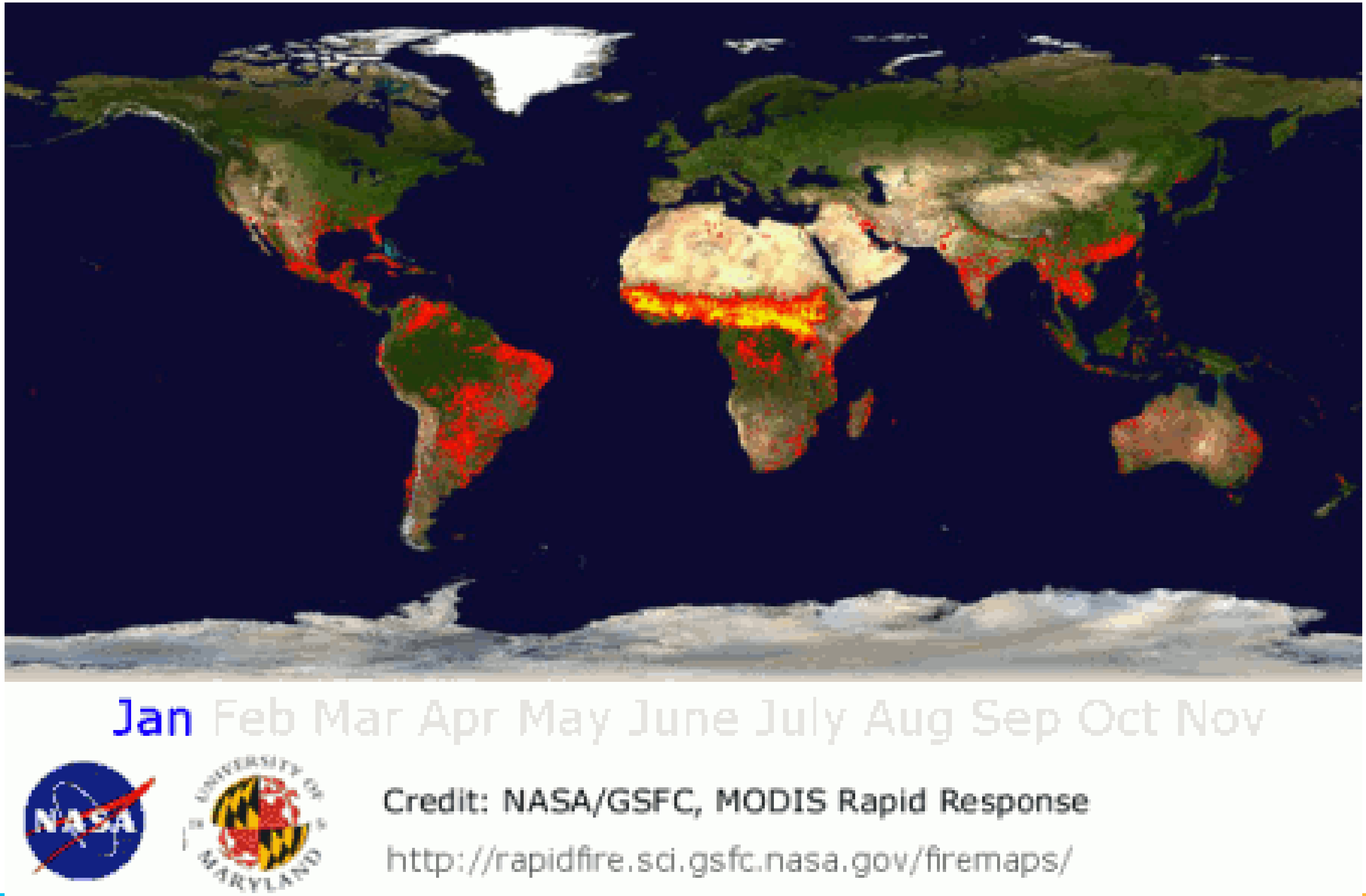
Fire
470 millions years

Grassland-Savana:
6-7 millions years

Tall herbivores
Homo sapiens

Use (cooking): 1.9 millions years
Full management: 400 000 years

Wildfires in the world



Average of annual burned surface around the world

- **France: 30 000 ha,**
- **Europe: 500 000 ha,**
- **Australia: 1 200 000 ha,**
- **USA: 1 500 000 ha,**
- **Canada : 3 000 000 ha,**
- **Brasil : + 40 000 000 ha,**

Some historic wildfires in USA

Peshtigo (Wisconsin, 1871):
2500 deads et 486 000 ha burnt

Big Blowup (Idaho-Montana, 1910):
87 deads et 1 million ha burnt

Black Saturday (07/02/2009) Victoria district (Australia)

Firestorm (Kinglake)

100 000 ha burnt in 12H

120 deads

I ~ 80 000 kW/m (>> 7000 kW/m)

20 m = 1600 MW

(~ one element of a nuclear power plant)

ROS ~ 1 à 3 m/s

Plume height ~ 15 km

(lower limit of stratosphere)

$$I = \eta M_{fuel} \times \Delta H \times R \sim 300 \times H_f^2$$

Wildfire: catastrophic event or natural phenomena ?

Effect of smoke on health

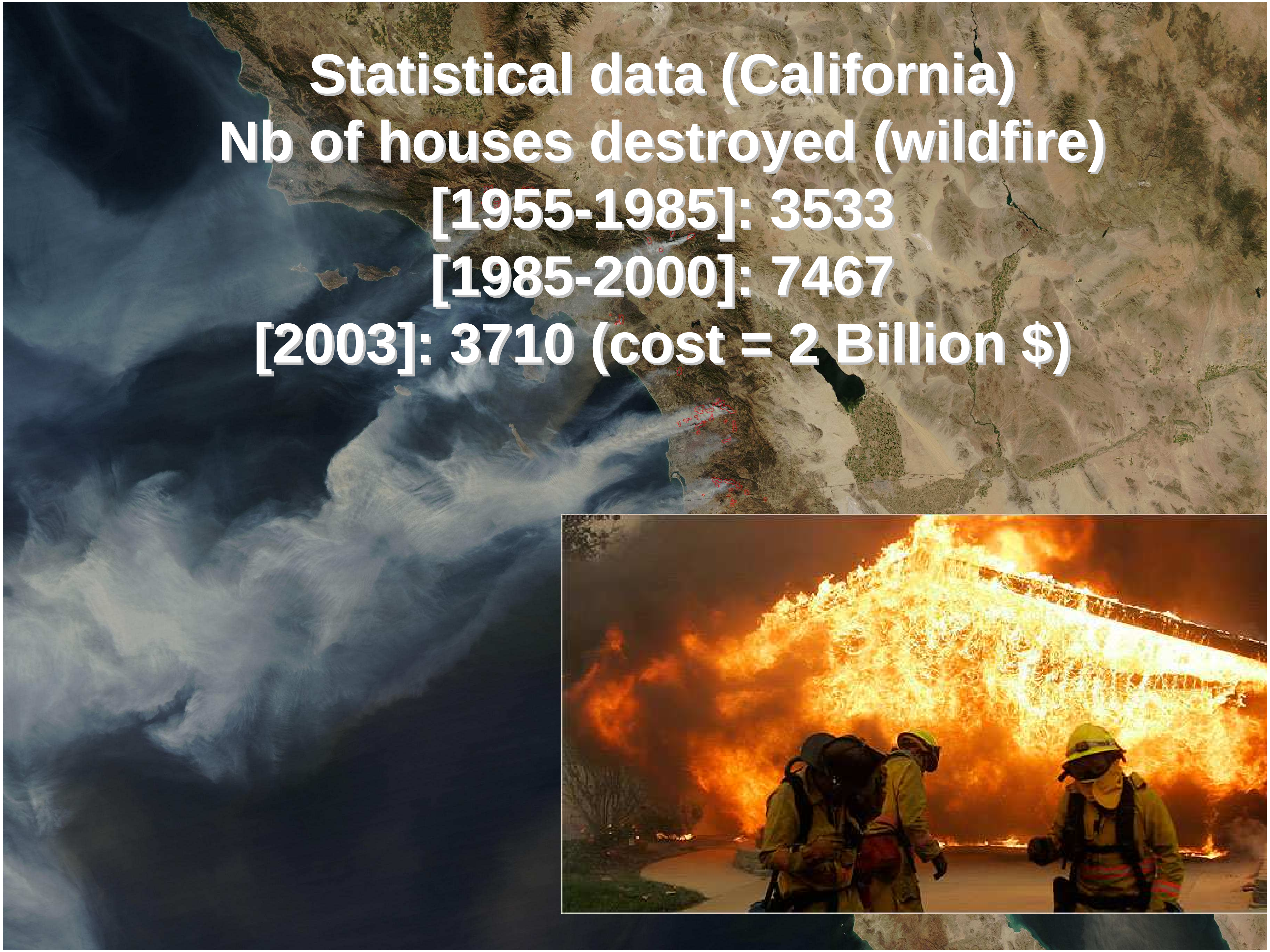
2010 summer: mortality x 2 (Moscou)
Fine and very fine particles (< 10 μm et <2.5 μm)

Statistical data (California)
Nb of houses destroyed (wildfire)

[1955-1985]: 3533

[1985-2000]: 7467

[2003]: 3710 (cost = 2 Billion $)

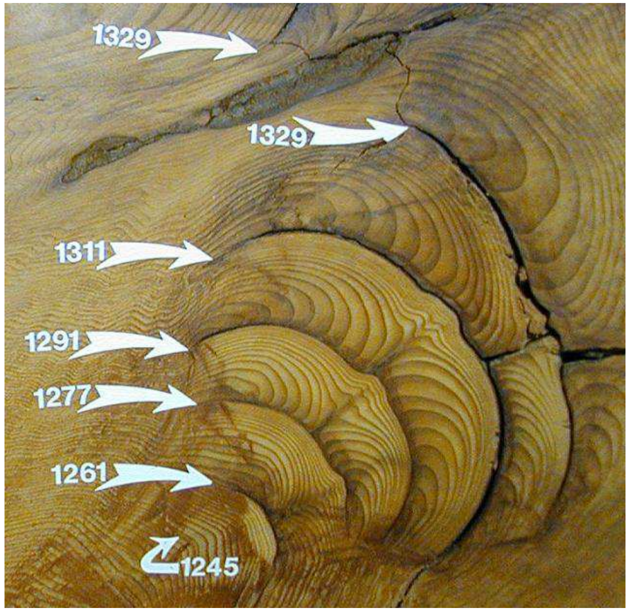


Fire ecology (paleoclimate observations)

Wildfires contribute in maintaining forest biodiversity

Fire regime in various ecosystems:

- **Grassland: 1-3 ans**
- **Conifer forest: 25-300 ans**



<u>Fire regime:</u>

- **Average fire frequency**
- **Intensity**
- **Severity (impact)**
- **Fire season**
- **Type (surface fire, crown fire…)**
- **Average burnt surface**

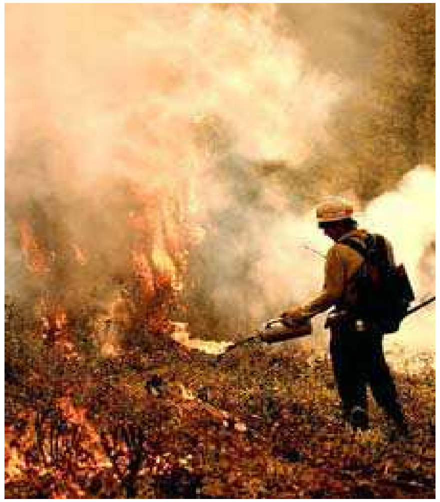
Fire ecology

Factors contributing to modify fire regimes:

Human activities modify fire frequency, inducing soil degradation (washing, lanscape modifications…) !
Impact on ignition rate:
+100 houses → +0.17 fires/44 km^2/year (USA)
• Fire exclusion paradigm → Suppression of low intensity fires → Fuel accumulation → Increase of high intensity fires

Less fires but more intense fires !

Wildfires causes



	Anthropic	Natural
Europe	94%	6%
Canada	15%	85%

Landscape evolution (western USA)

2001

Wildland Urban Interface (WUI)

« Intermix WUI »

« Interface WUI »

Natural vegetation < 50%

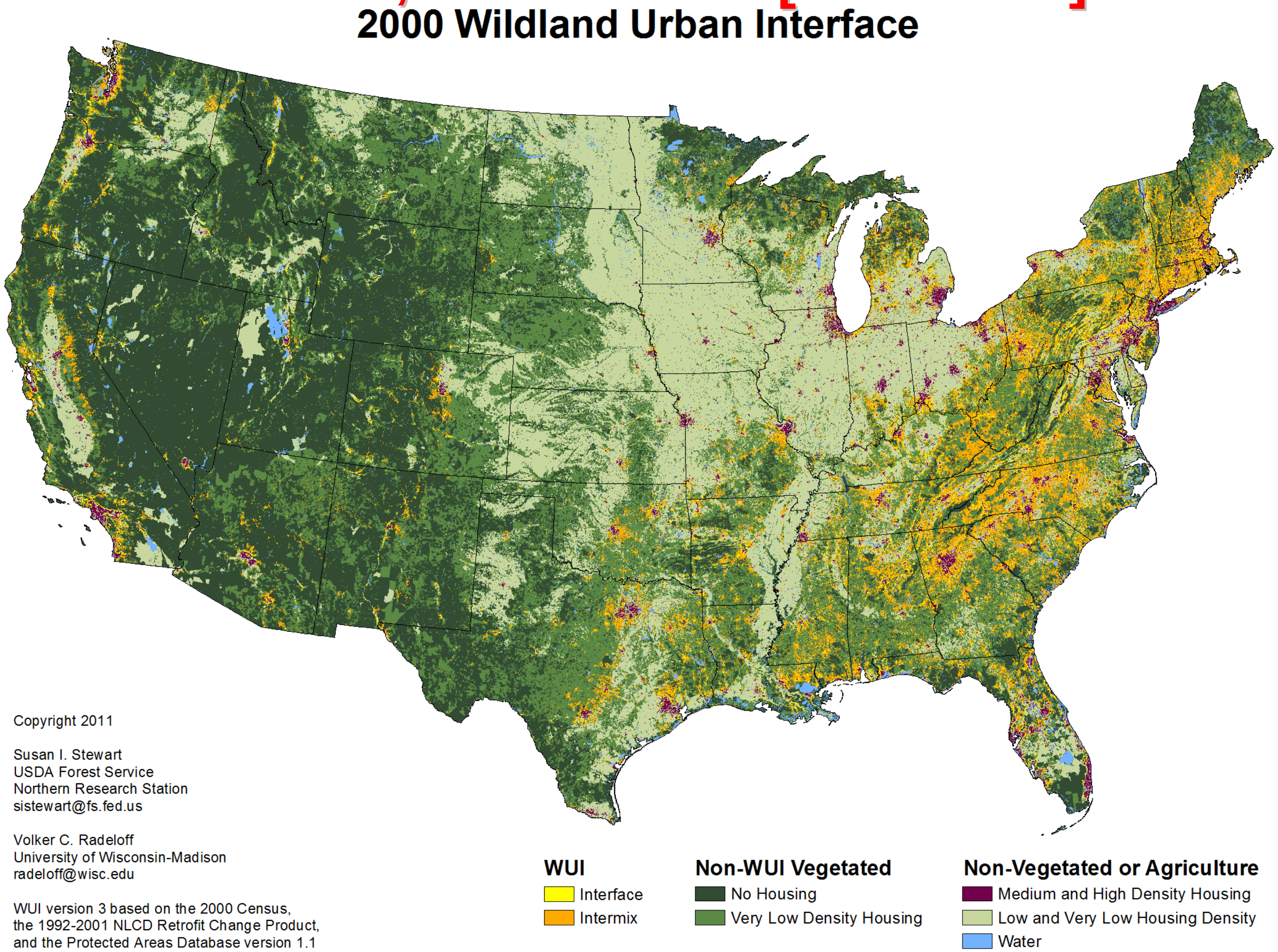
WUI = houses and natural vegetation are mixed

(>6.17 houses/km^2)

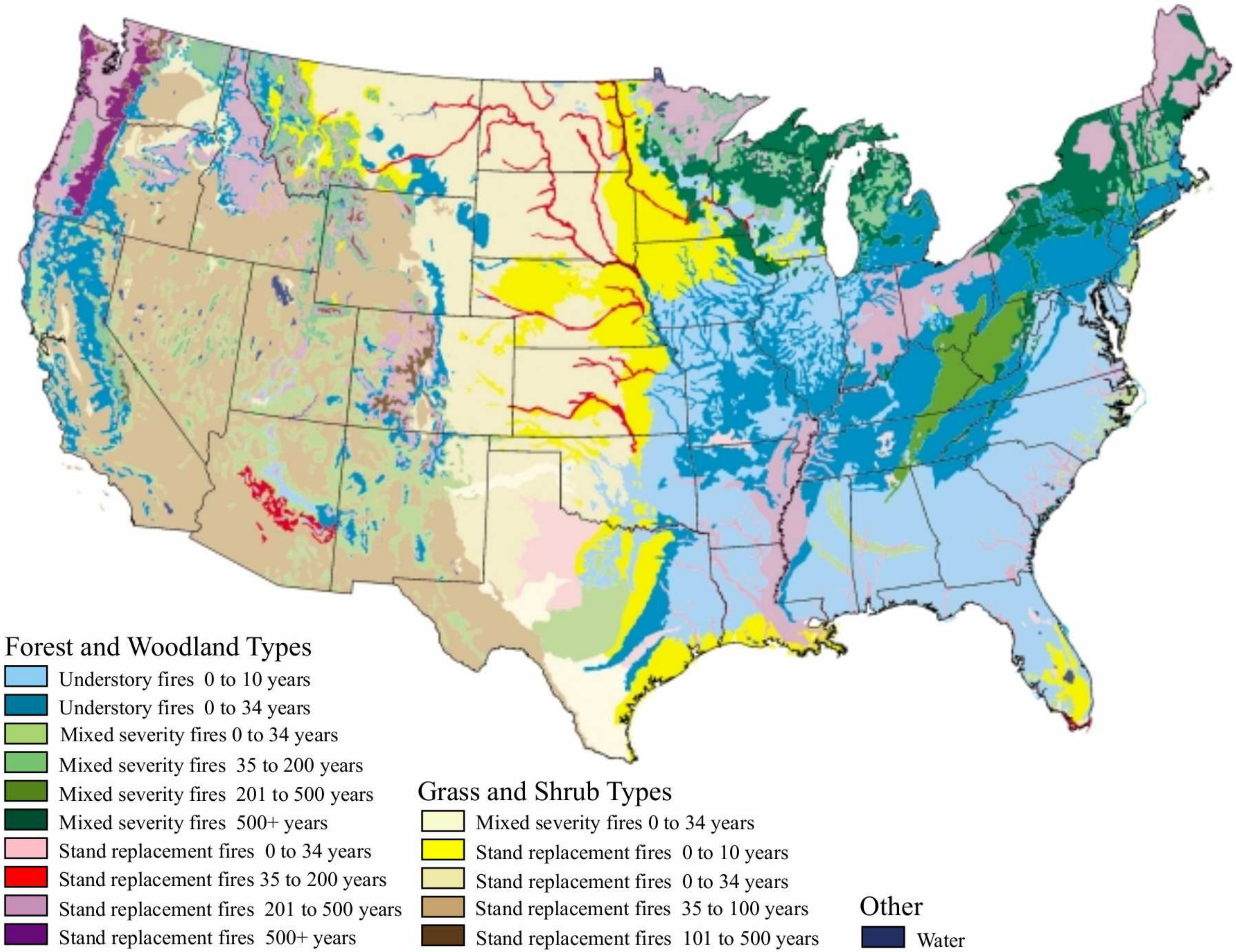
[US Federal Register January 2001]

WUI (2000) = 9.4% of US territories and 38.5% of houses

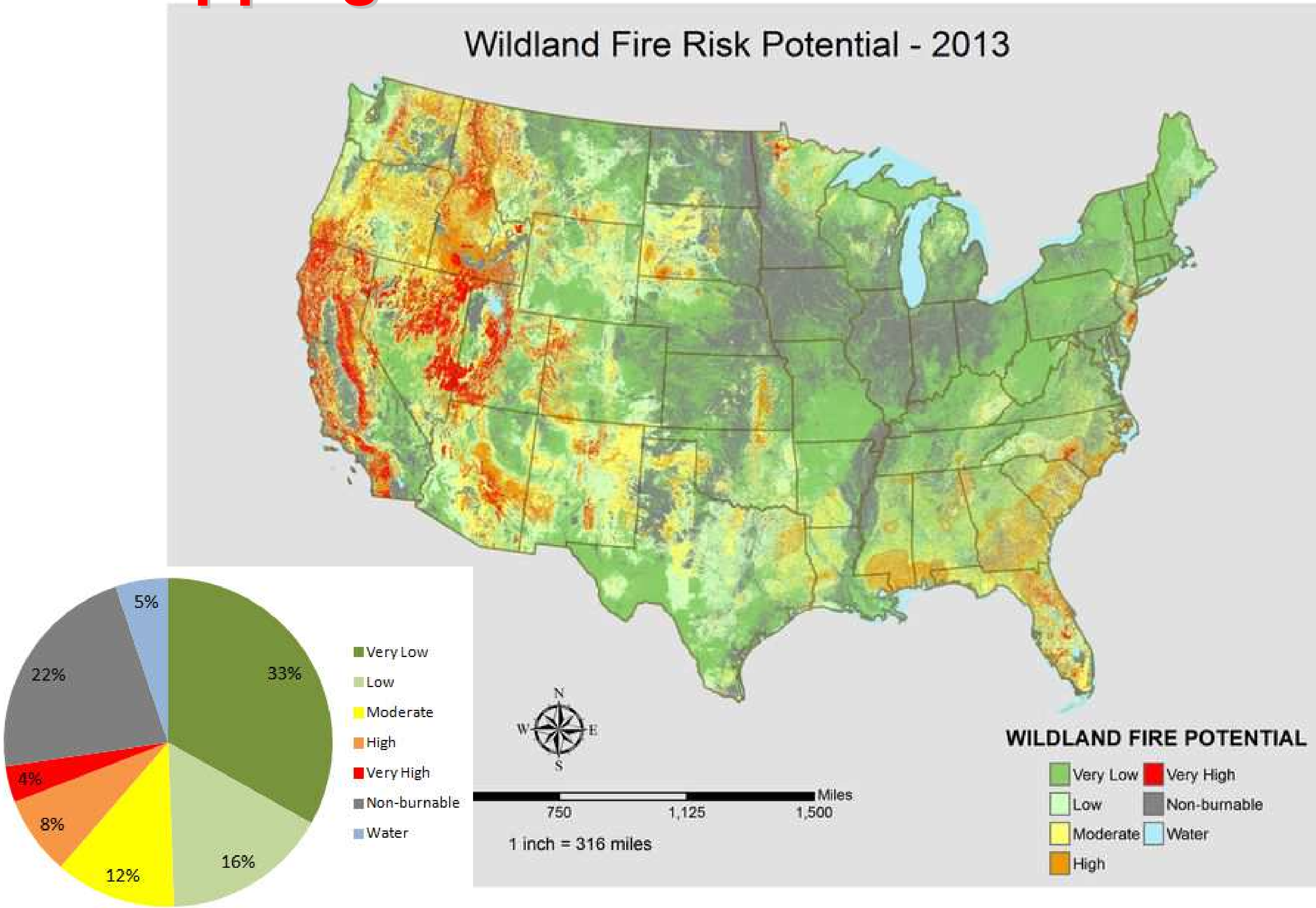
Houses in WUI, increase rate [1990-2000]: +44%



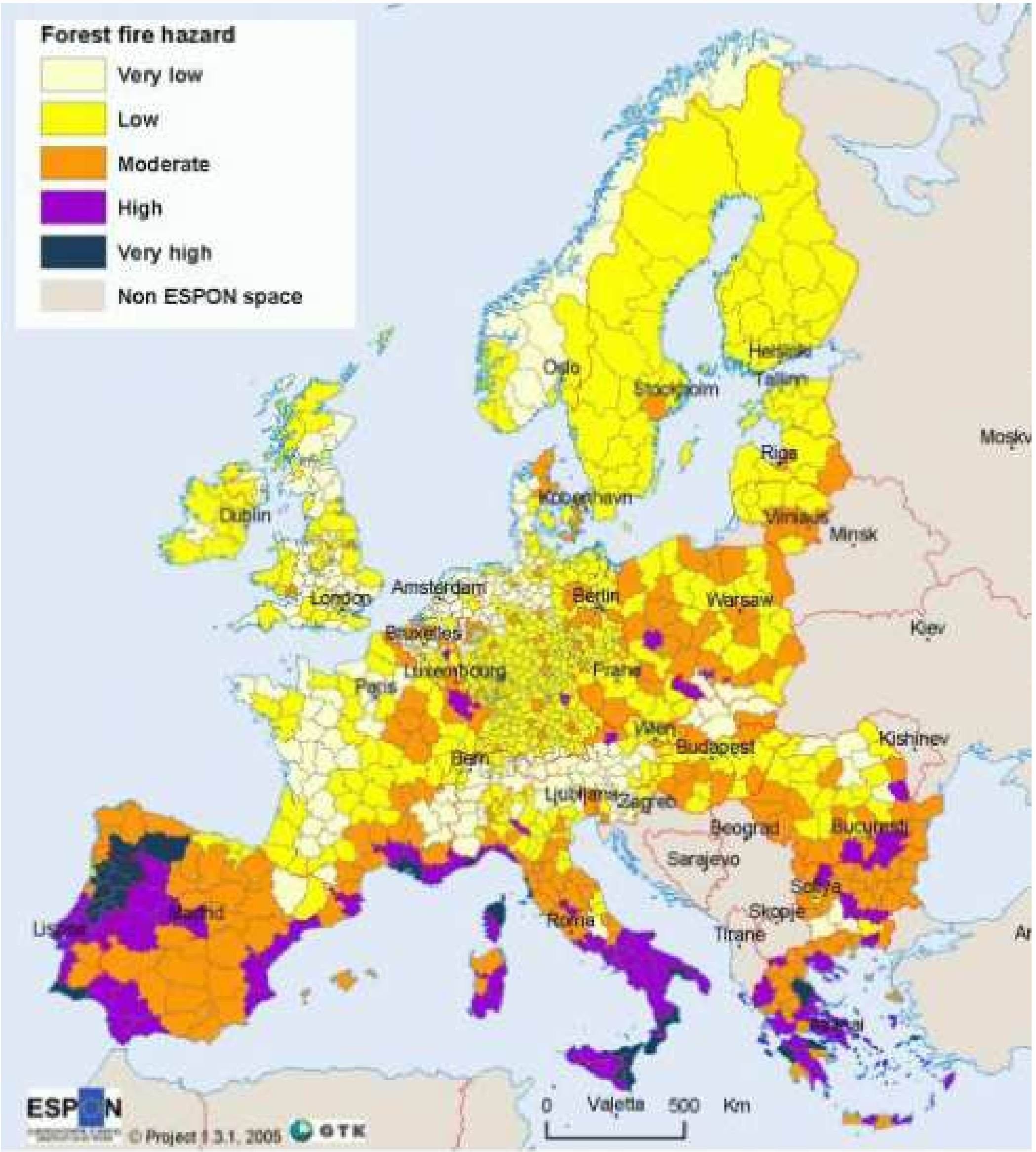
Fire regimes in USA



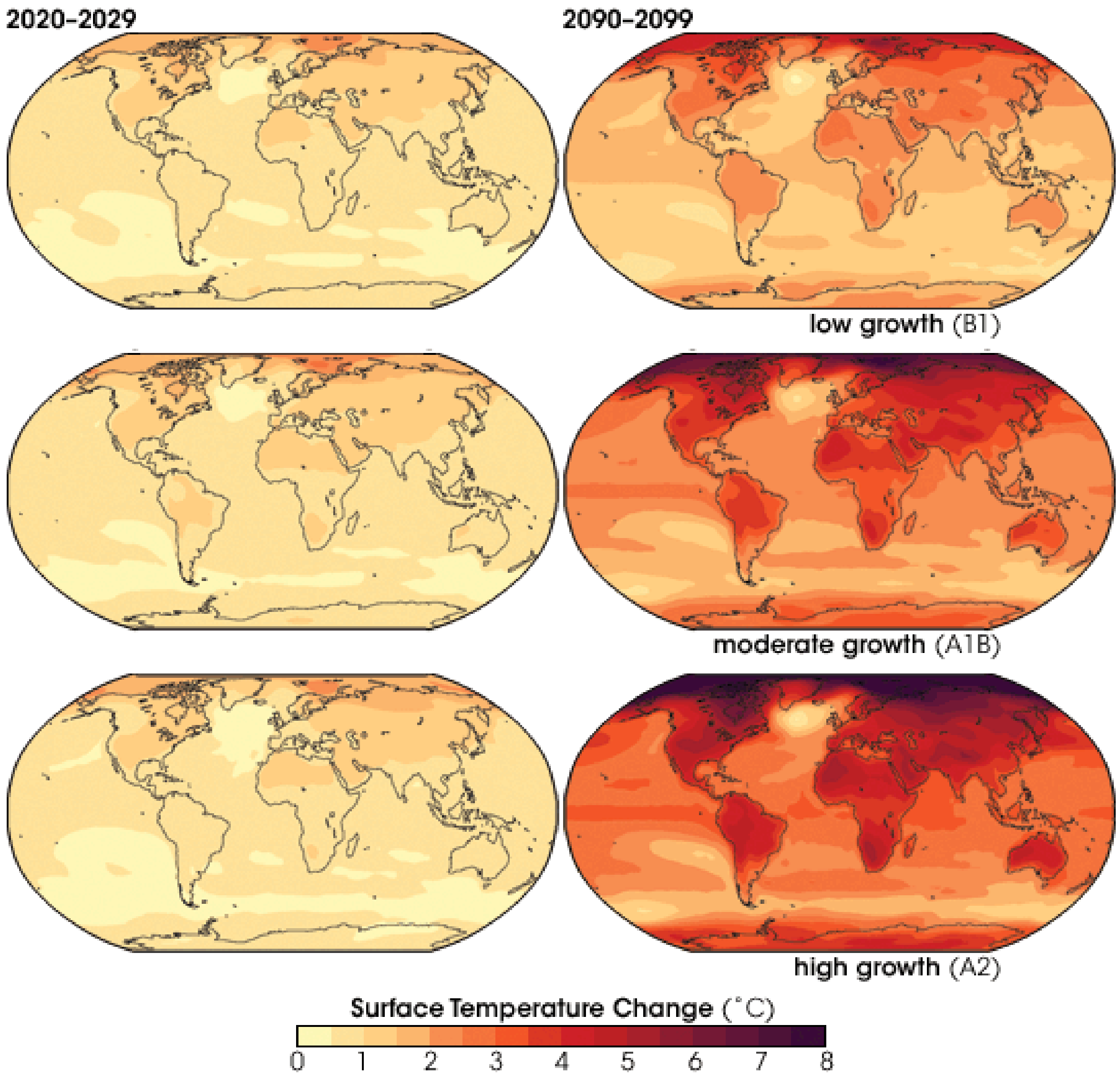
Mapping of fire hazard in USA



Mapping of fire hazard in EU

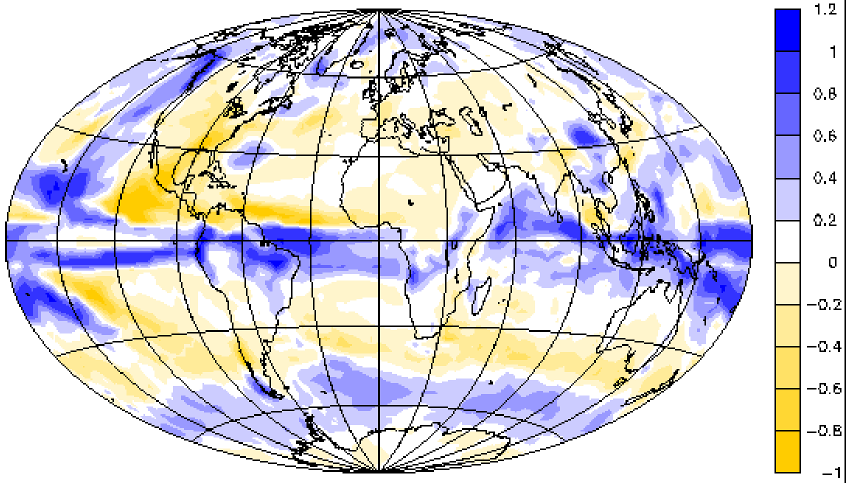


Global warming: surface temperature change

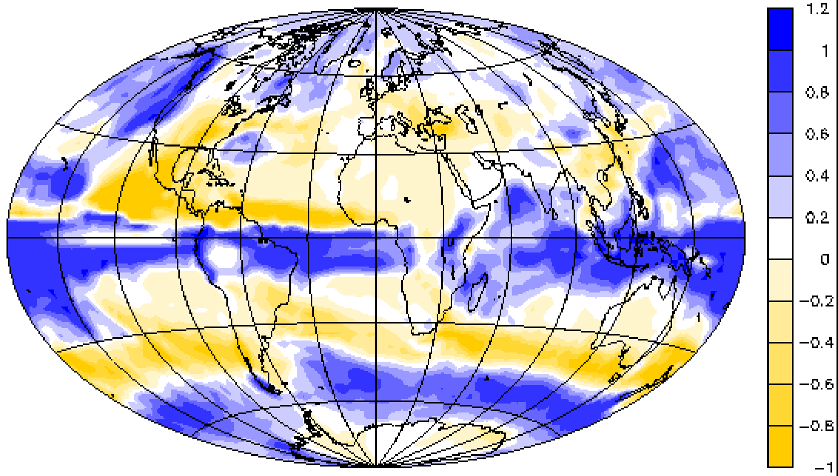


Global warming: precipitation change

B1 **A2**



IPCC / IPSL – SRESB1 scenario – Anomalies de la precipitation (mm/jour)
(2090–2099) comparee a (2000–2009)



IPCC / IPSL – SRESA2 scenario – Anomalies de la precipitation (mm/jour)
(2090–2099) comparee a (2000–2009)

Wildfire hazard in France

(Commissariat Général au Développement Durable, 2011)

- Forests = 16 millions d'ha (30% of the territory)
- Surface: +20% between 1975 and 2007
- 6000 classified communities «potentially affected by wildfire hazard »: Corse, La Réunion (100%), PACA (90%), Languedoc-Roussillon (76%), Aquitaine (41%)
- Wildfires (average): 30000 ha/an, 4000 ignitions (Var+Corse = 50% of fires), -2% of fires > 100ha
- Var = average burnt surface 1300 ha, 18 800 ha in 2003 !
- Cost (prevention and fight): 536 M€ (2008)
- Climate change: extension of risky regions

Potentially affected surface 5.5 Mha (2008) → 7 Mha (2040)

Centre, Poitou-Charentes, Pays de Loire, Bretagne

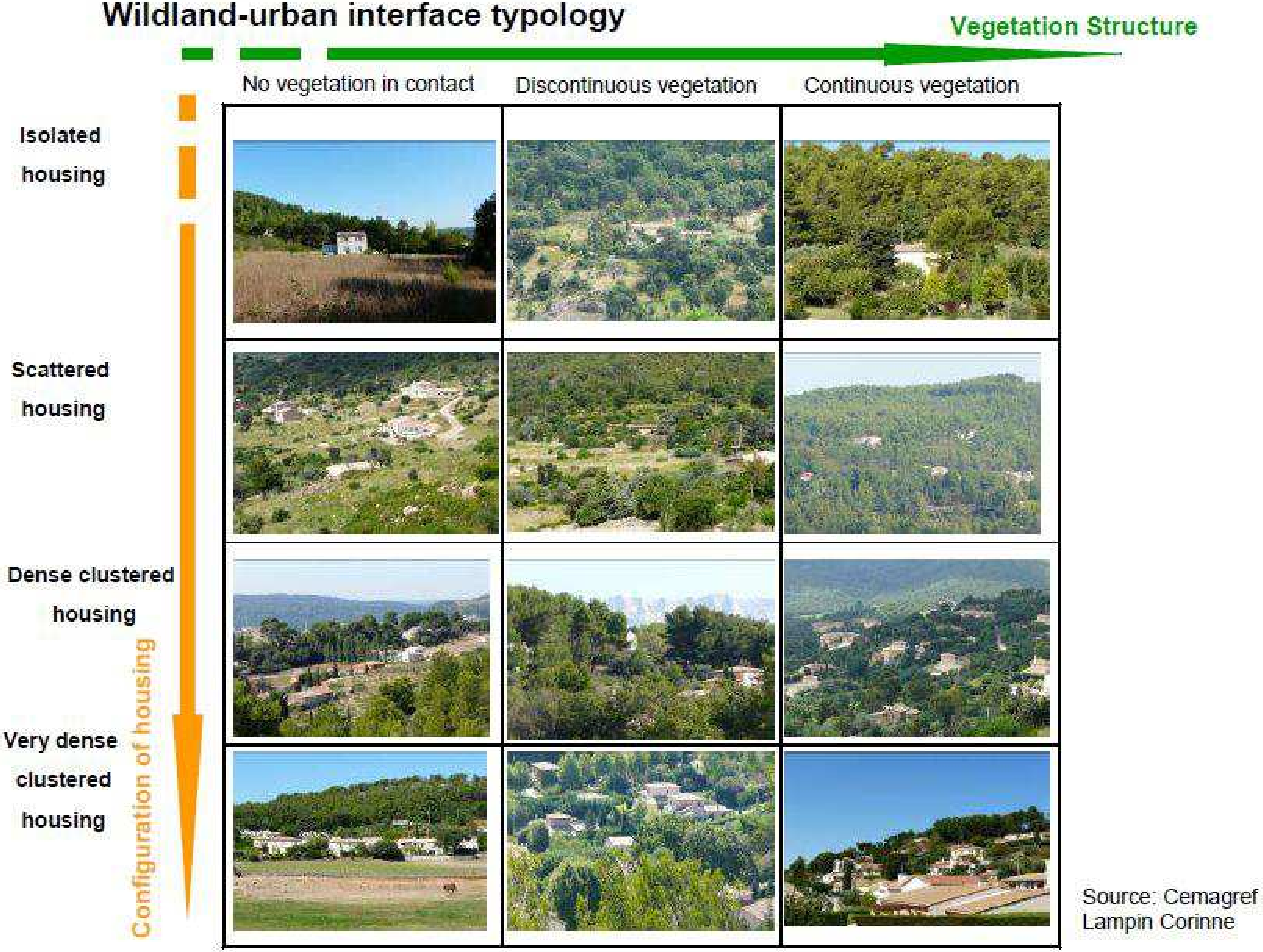
Climate change: projection and climate evolution in Provence Côte d'Azur region (summer) (2050)

Projection (Météo France) performed from the moderated scenario (IPCC 2007 B2):

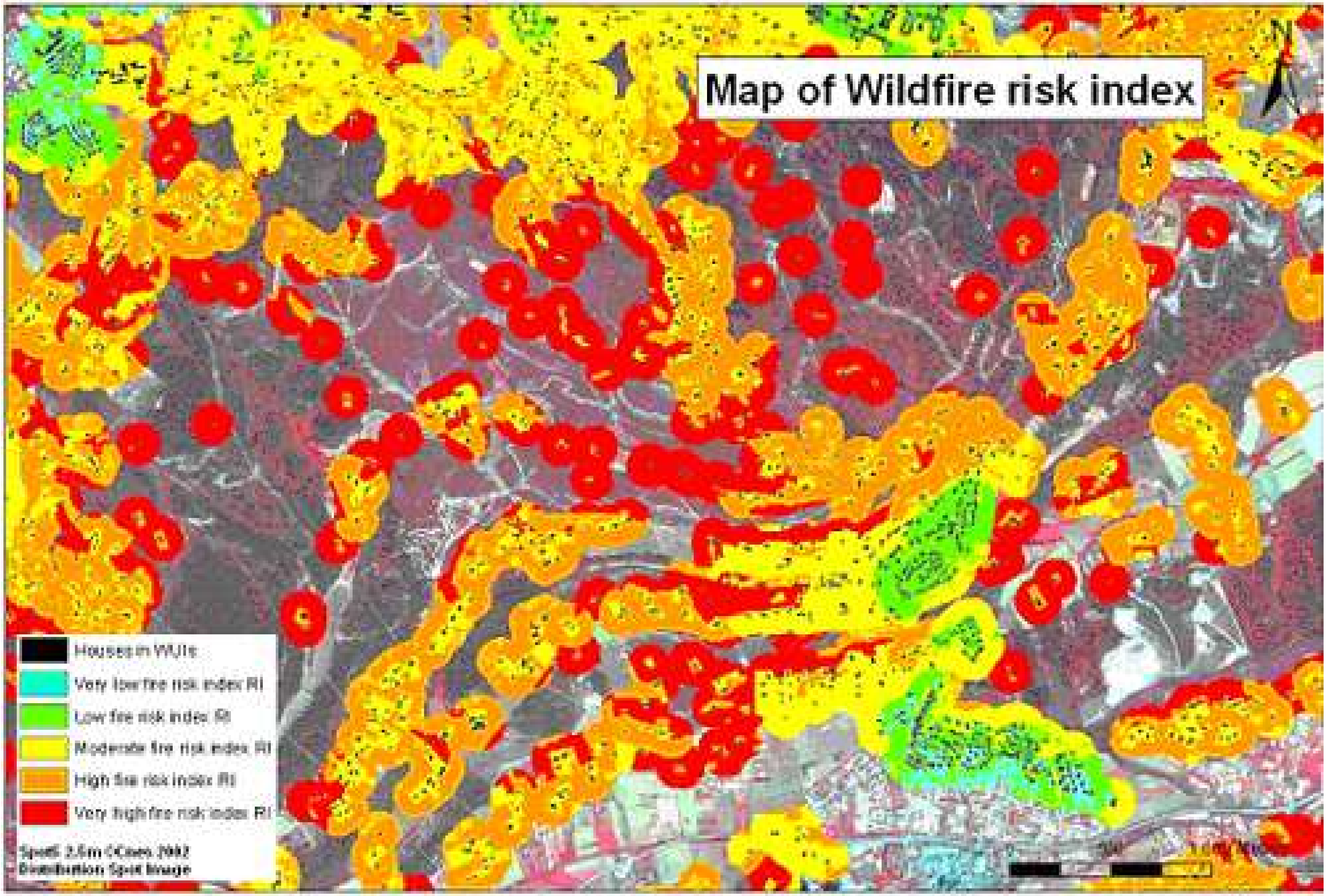
Temperature	+2.9°C	+ 13%
Precipitations	-0.3 mm/j	-38%
Aquifer deficit	-32,9 kg/m^2	-15%

Aix*Marseille université

Wildland-urban interface typology

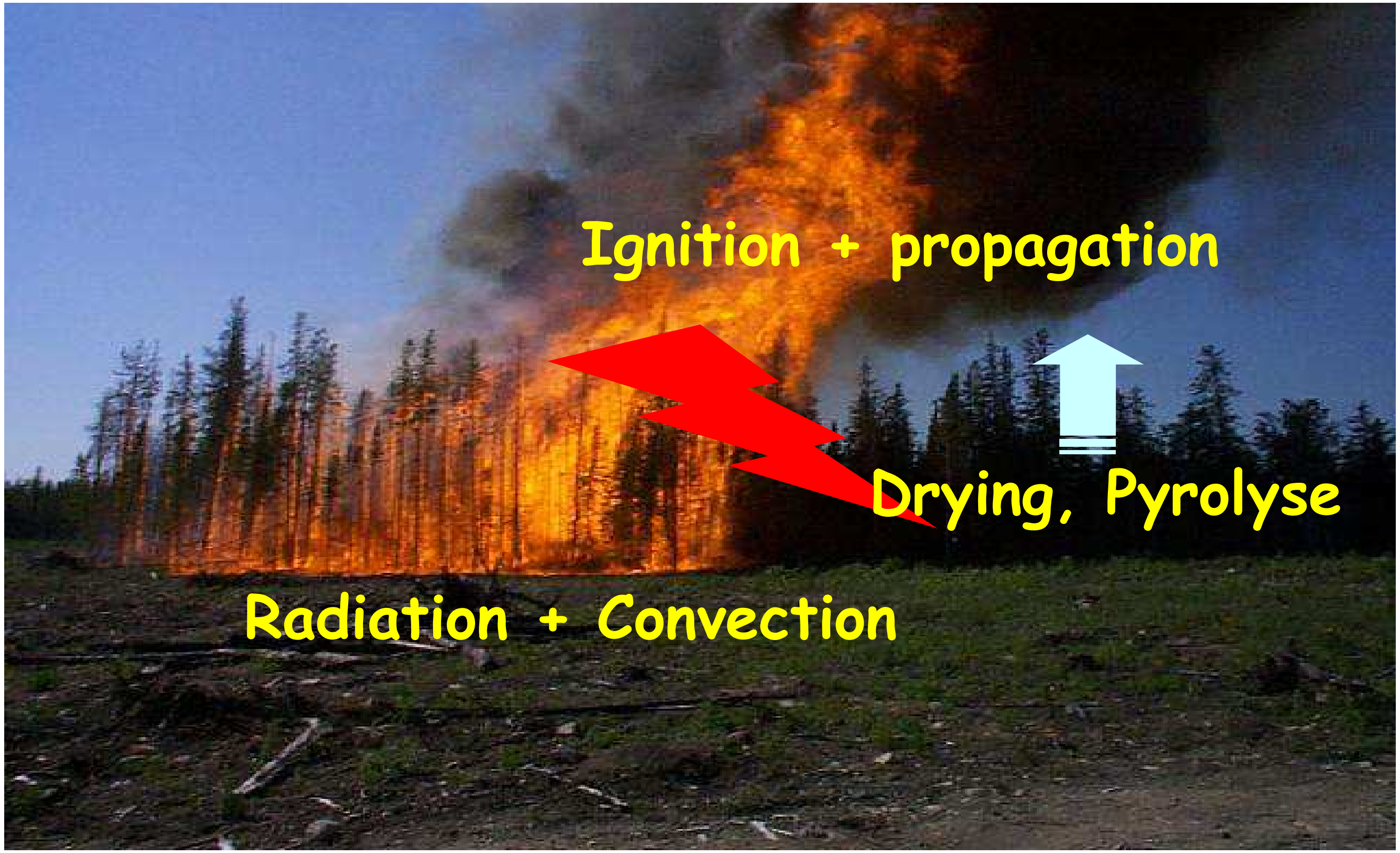


Ref: Lampin-Maillet (IRSTEA)



Ref: Lampin-Maillet (IRSTEA)

Mecanisms of heat transfert governing wildfires propagation



An other mecanism of fire propagation : firebrands

Distance travelled by a firebrand > 2400 m (source: SALTUS) !

Colorado Spring fire in 2012

Heat flux received by radiation

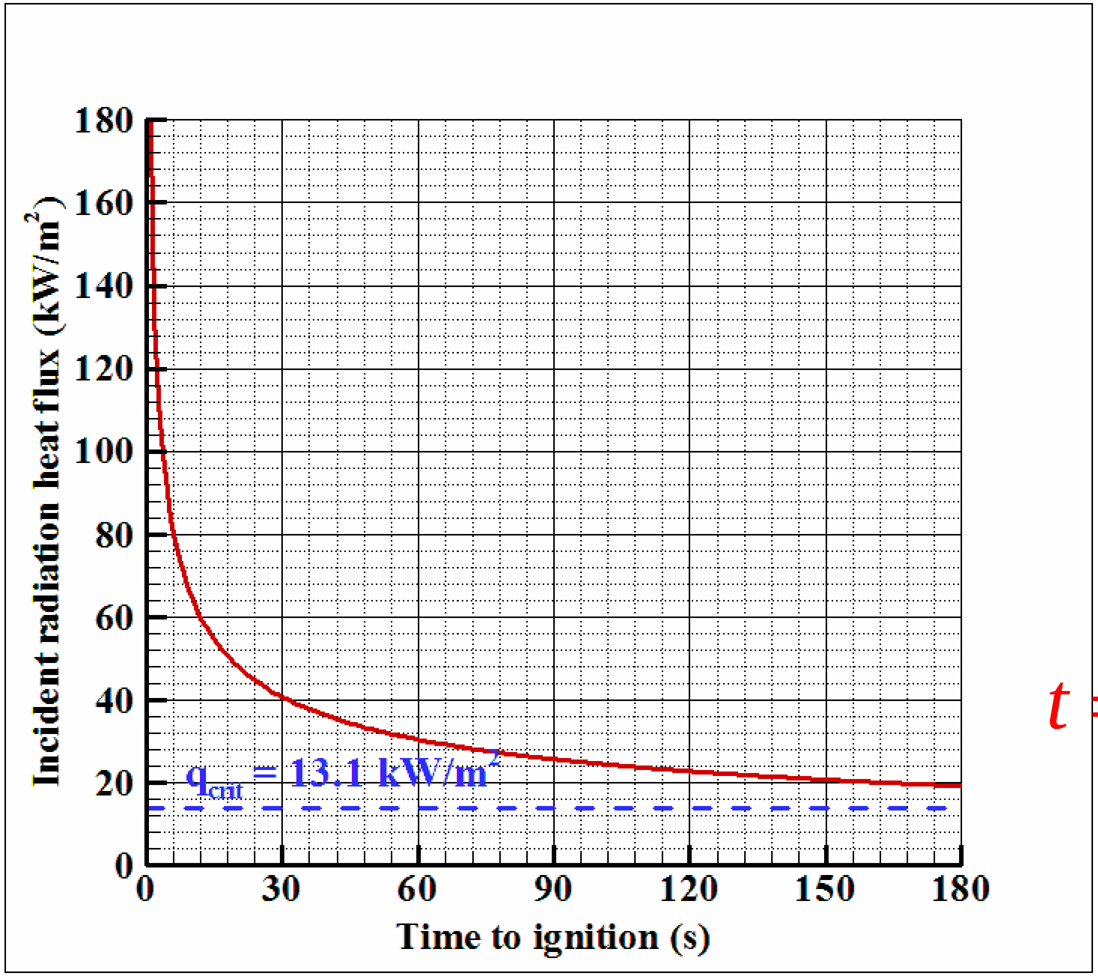
$$\dot{q}''_w = F_{f,w}\varepsilon_f \ \sigma T_f^4 \qquad T_f \approx 1273\,K$$

$$\varepsilon_f = 1 - \exp\left(-\kappa \times L_f\right) \quad \kappa \approx 1862 \times f_{soot} \times T_f$$

If fire depth (L_f) > 2 - 3m → ε_f ~ 1 (black body)

$F_{f,w}$ = view factor flame/target (decreases with distance $1/d^2$)

Ignition criteria (wood)



$$t = 60\,s \Rightarrow \dot{q}_w'' = 31\,kW/m^2$$

$$t \times \left(\dot{q}_w'' - \dot{q}_{crit}''\right)^{1.828} \geq A \quad (A = 11501\ si\ t(s),\ \dot{q}_w''(kW/m^2))$$

Maximum heat flux received at 10m by radiation (ICFME)

Flux (kW/m2)	40	150
Ignition (s)	30	1.4

Some characteristic critical heat flux

2min skin exposure (pain)	2.3 kW/m^2
Equiped firefighter	7 kW/m^2
3s skin exposure (pain)	10.4 kW/m^2
5s skin exposure (2nd degree burn)	16 kW/m^2
Wood ignition (60s)	31 kW/m^2

Ignition time (pilot flame)

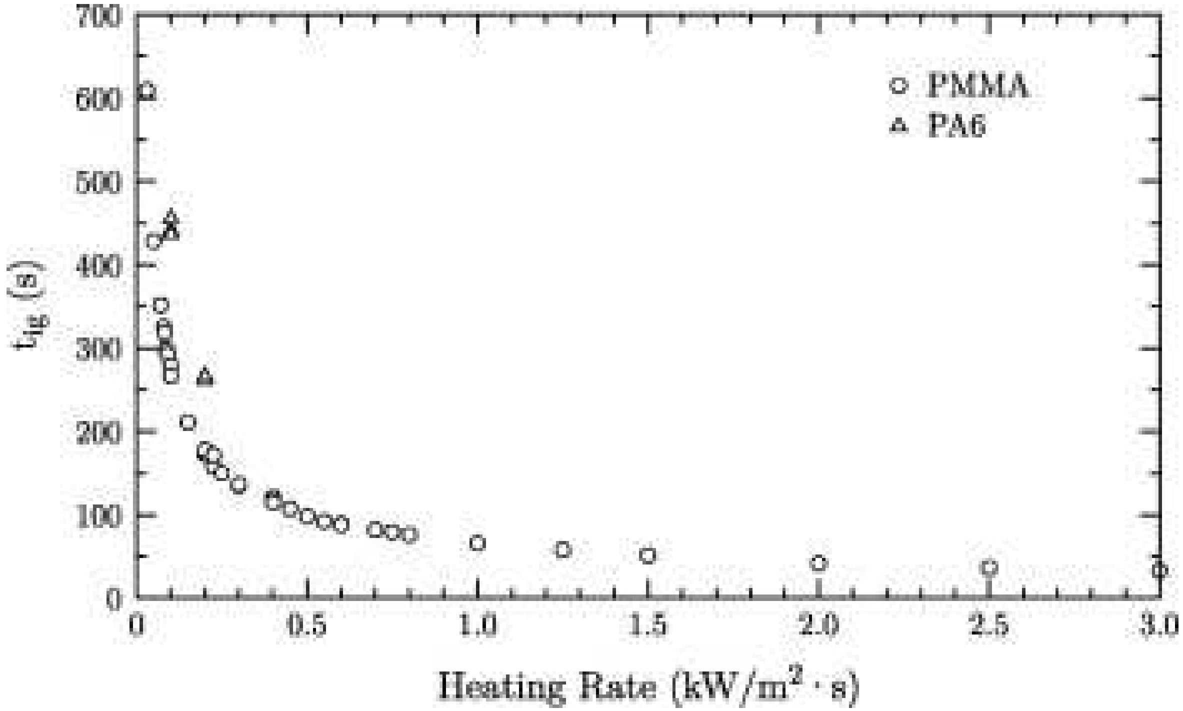
- **Infinite depth material**

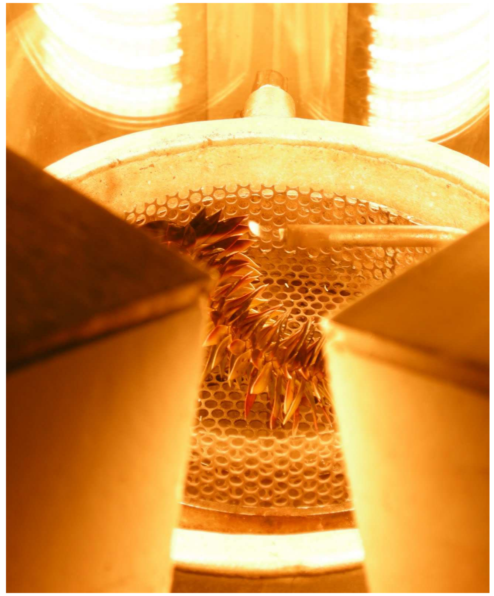
$$\frac{1}{\sqrt{t_{ign}}} \approx \frac{\dot{q}_w''}{\sqrt{k\rho c}\left(T_{ign} - T_0\right)}$$

- **Finite depth material**

$$\frac{1}{t_{ign}} \approx \frac{\dot{q}_w''}{\rho c e\left(T_{ign} - T_0\right)} \approx \frac{k}{\rho c e^2}$$

Ignition in pilot flame (FPA)

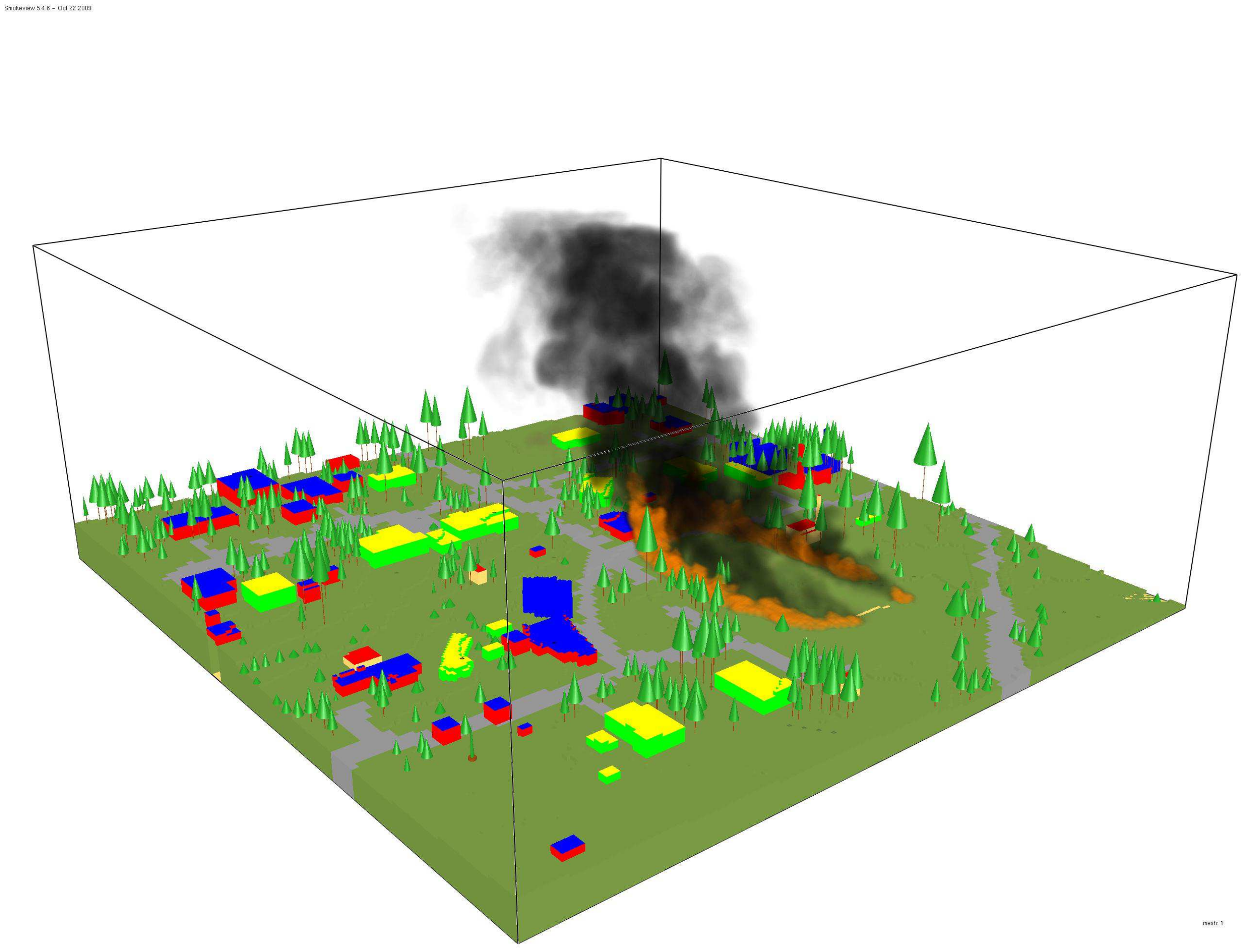




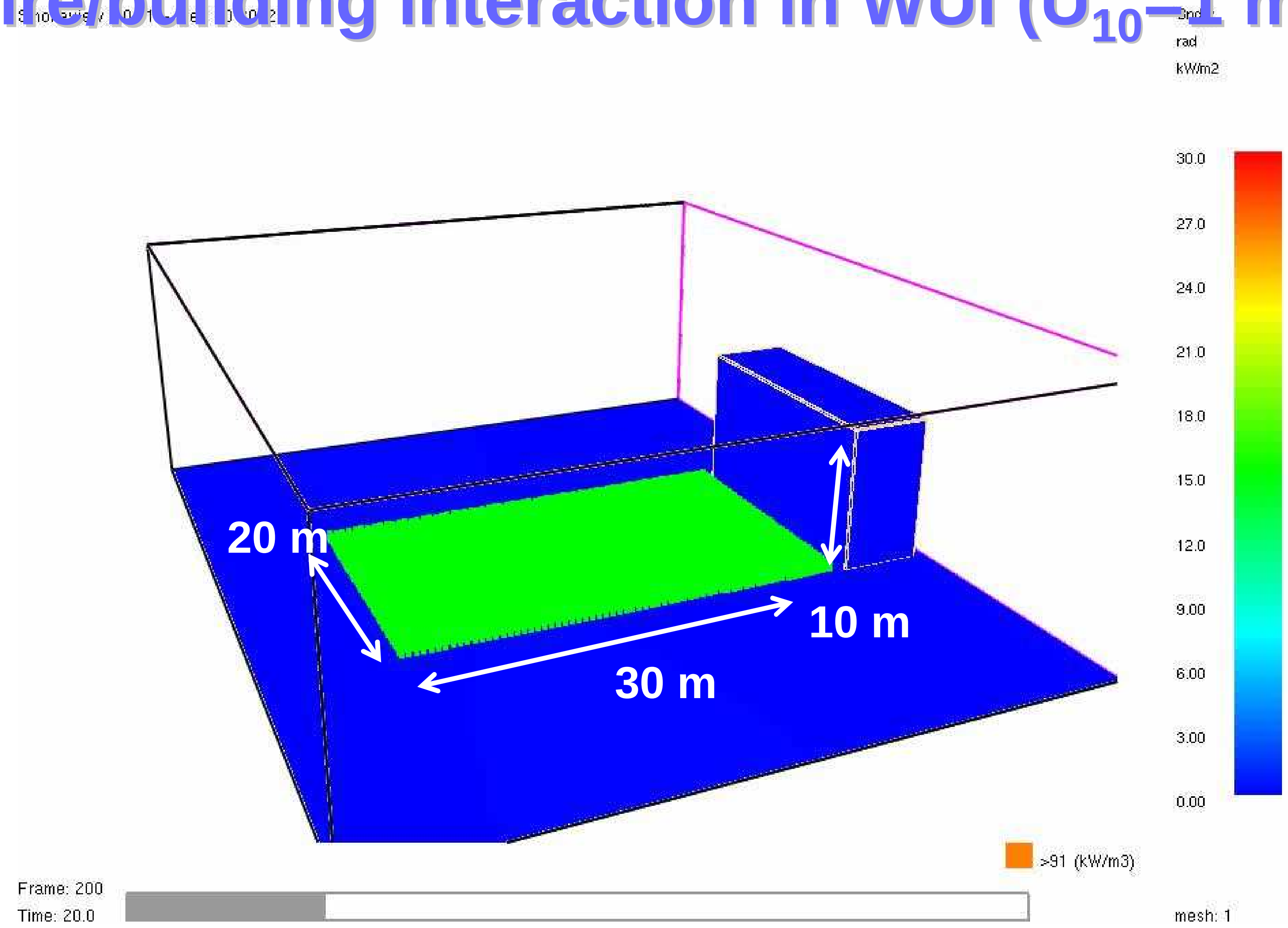
$$Heating\ rate = \int_0^{t_{ign}} \dot{q}_w'' \, dt$$

PMMA: polyméthacrylate de méthyle (thermoplastique transparent)
PA6: pine needles (Siméoni & al)

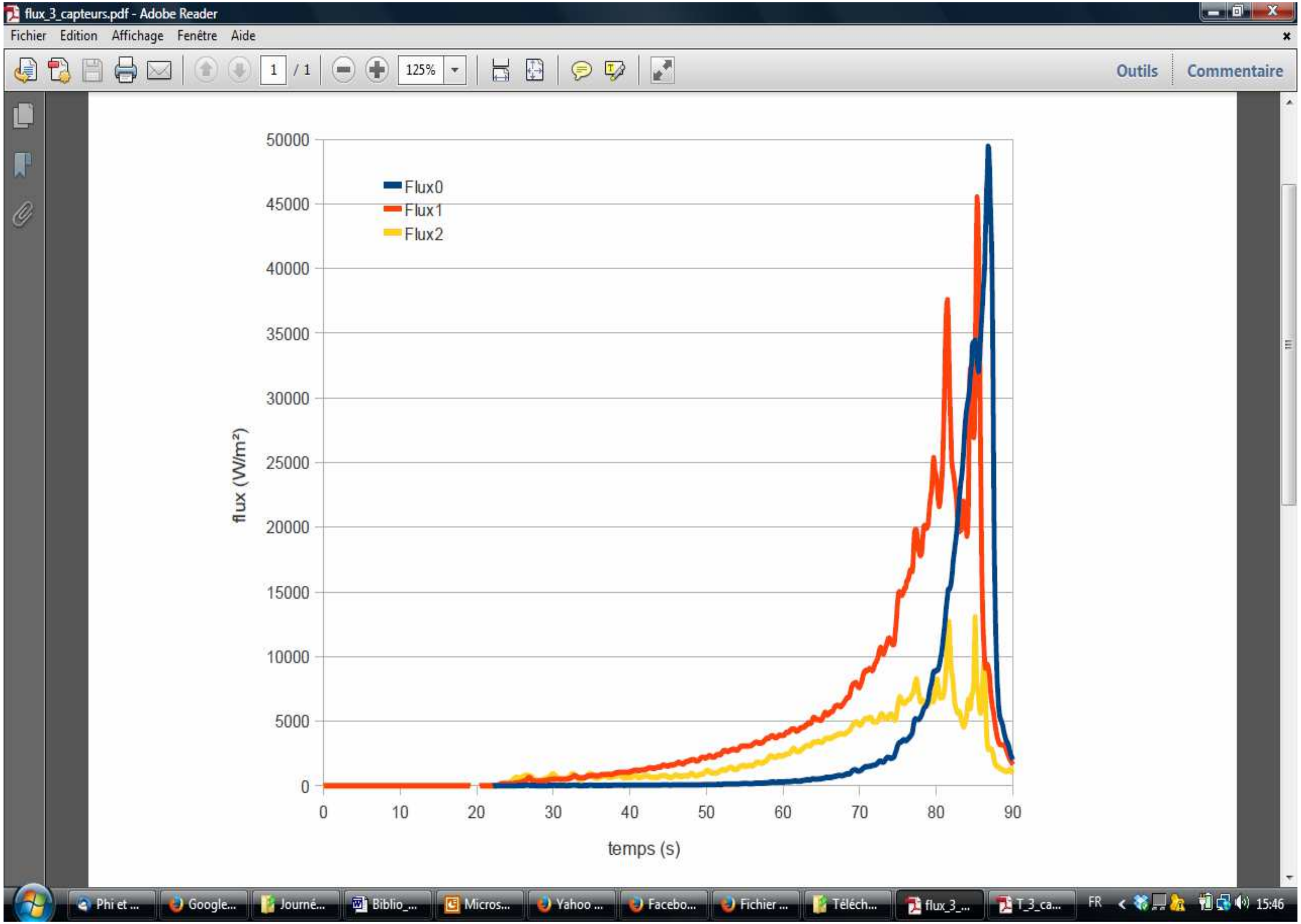
New tools for simulating wildfires
WFDS: Wildland Fire Dynamic Simulator



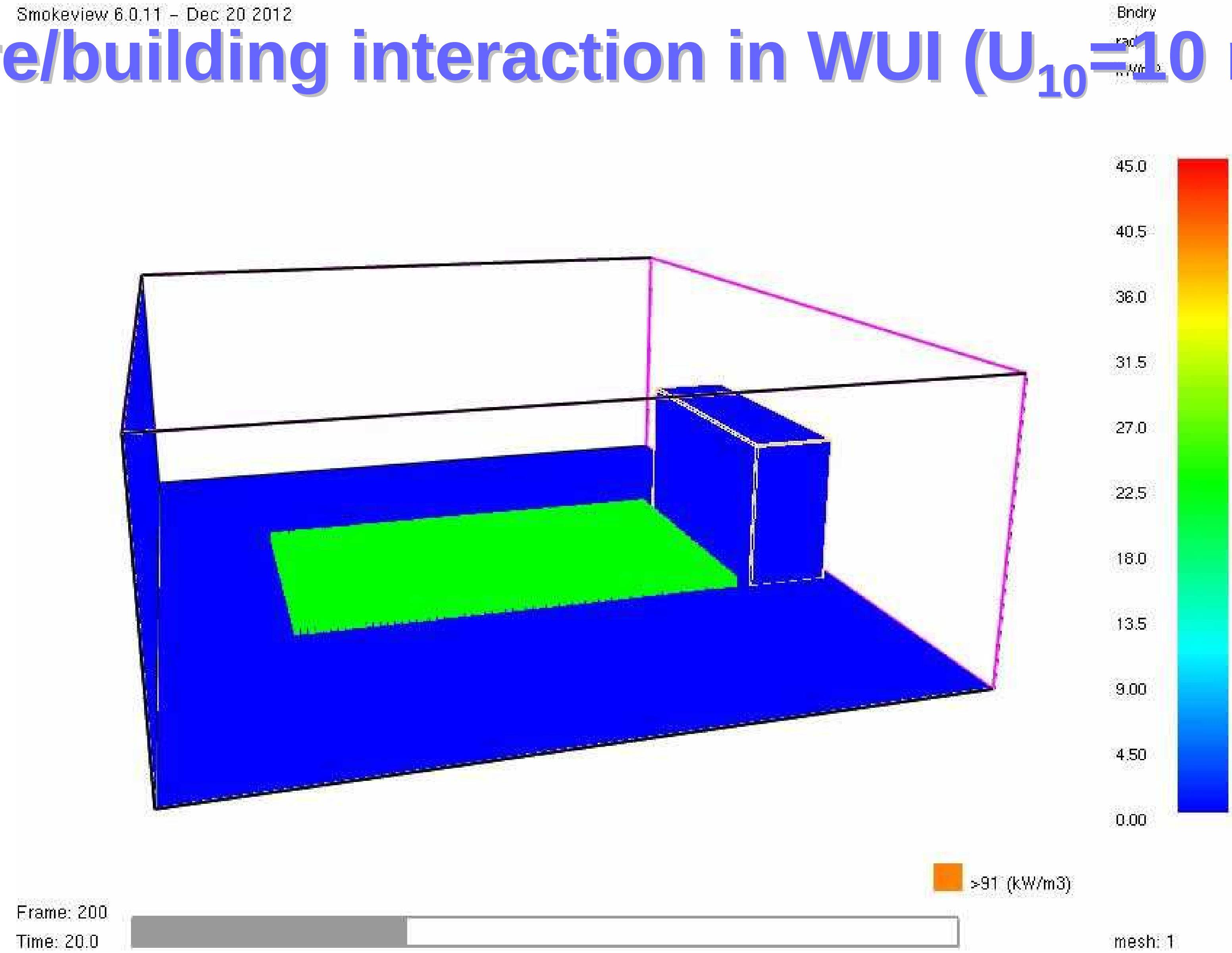
Fire/building interaction in WUI (U_{10}=1 m/s)



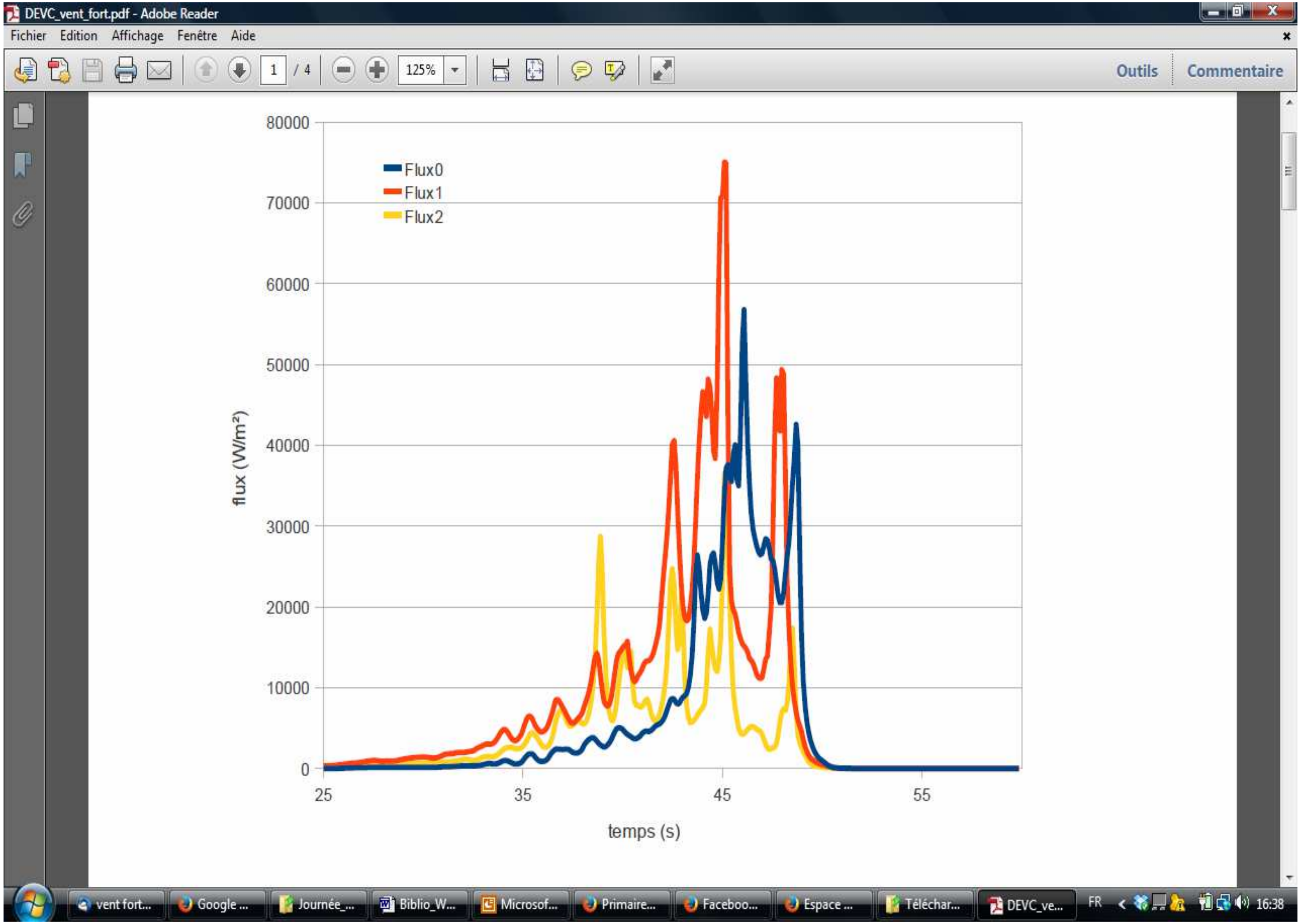
Heat flux received at Z = 0, 5.5 et 10m



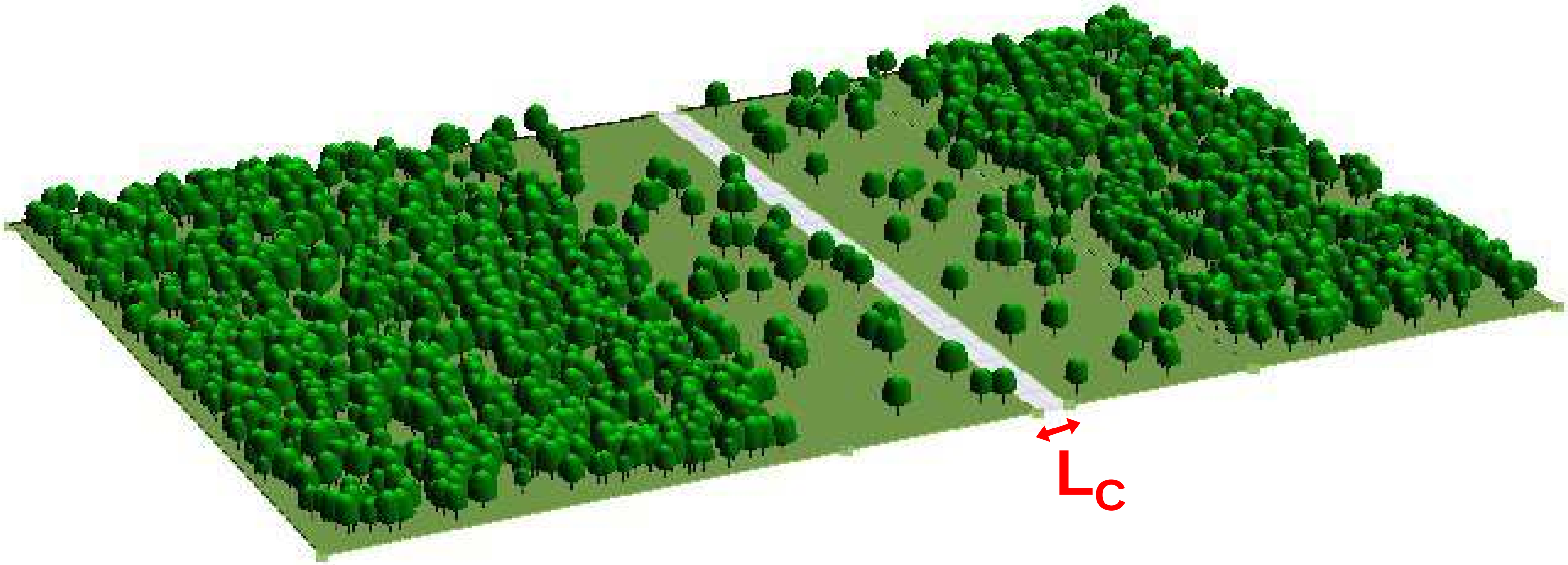
Fire/building interaction in WUI (U_{10}=10 m/s)



Heat flux received at Z = 0, 5.5 et 10m



Evaluating the efficiency of a firebreak: Some empirical criterion

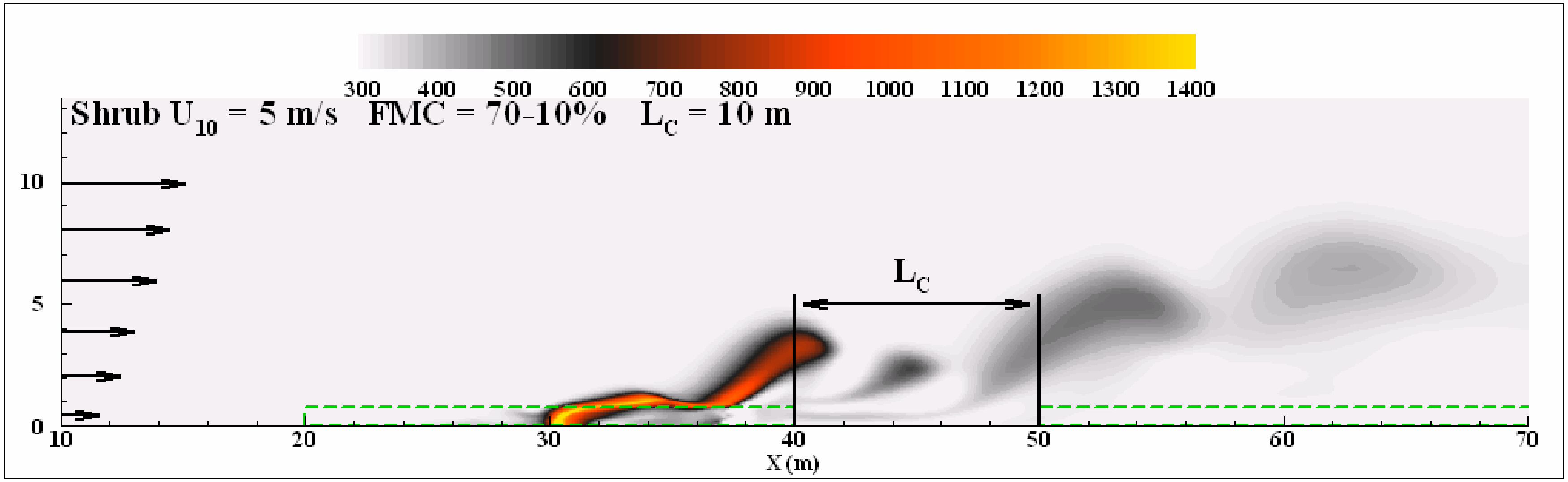


$$L_C \geq \frac{LAI \times D_{Fire}}{2} \quad (Emmons\,1964)$$

$$L_C \geq 4 \times H_{Flame} \quad (Buttlet, Cohen\,1998)$$

(Morvan 2015)

Evaluating the efficiency of a firebreak: a numerical study



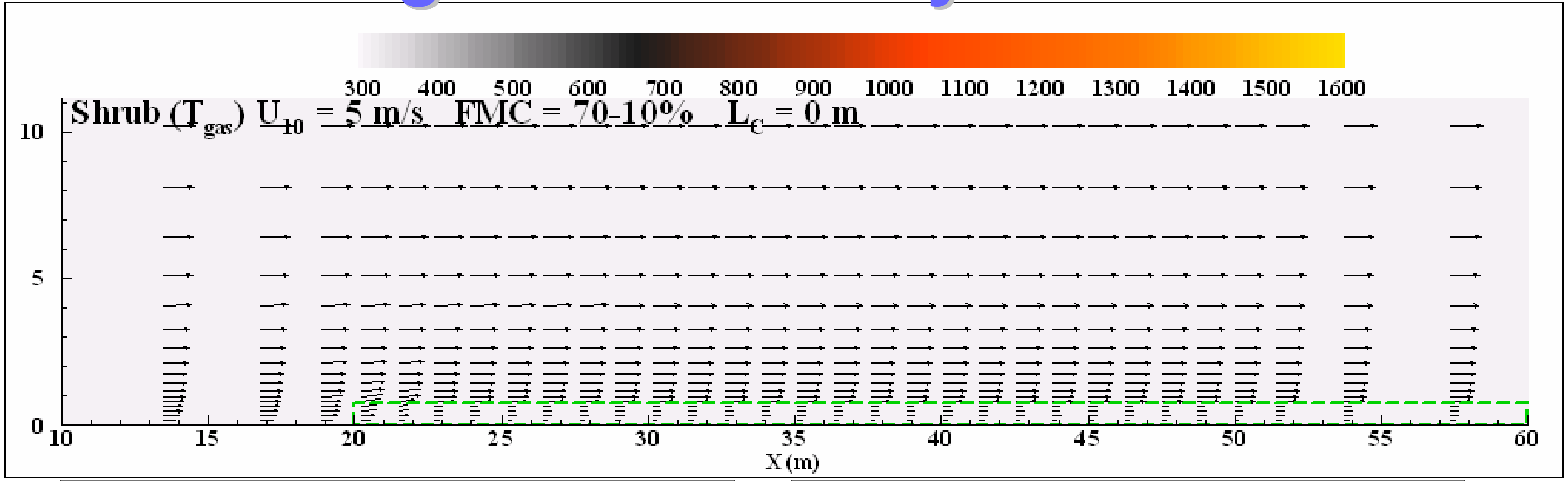
$$L_C \geq 9-18\,m \quad (Emmons\,1964)$$

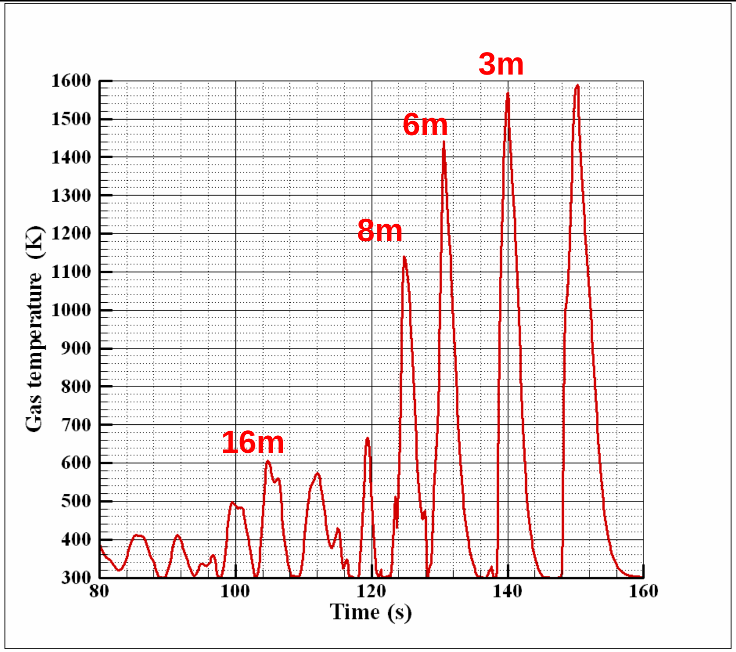
$$L_C \geq 22\,m \quad (Buttlet, Cohen\,1998)$$

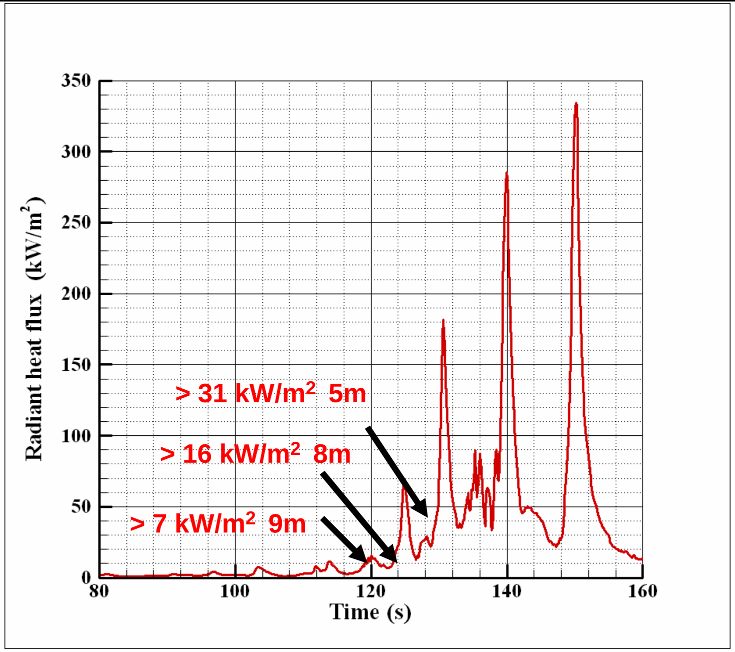
$$L_C = 5-20\,m$$

$$H_{Fuel} = 0.75\,m \quad U_{10} = 5\,m/s$$

Evaluating the efficiency of a firebreak

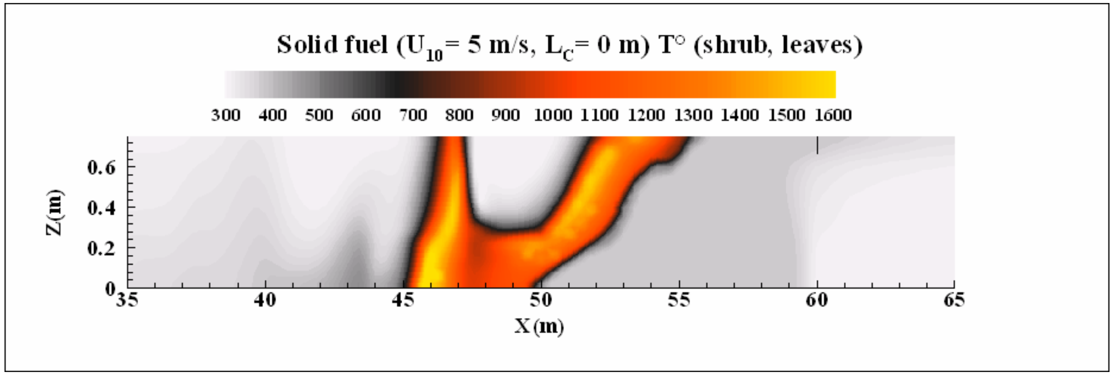




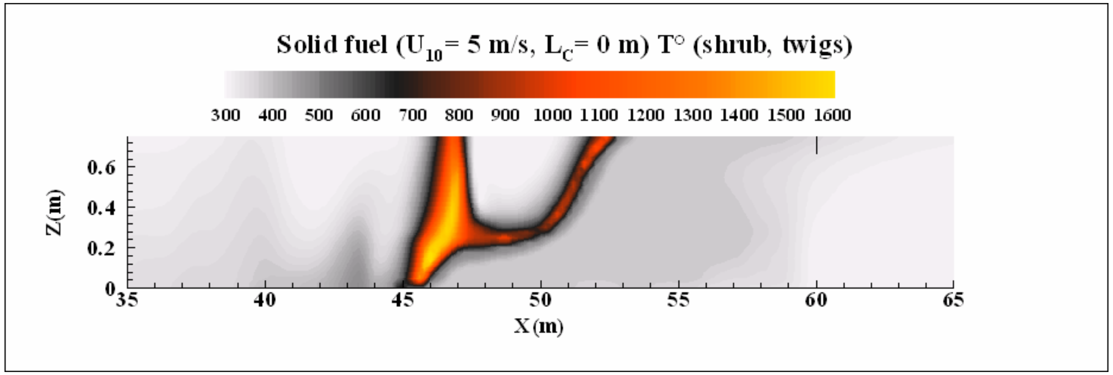


T°>373 K the fire was at 23 m from the target (x = 60m , z = 1 m)

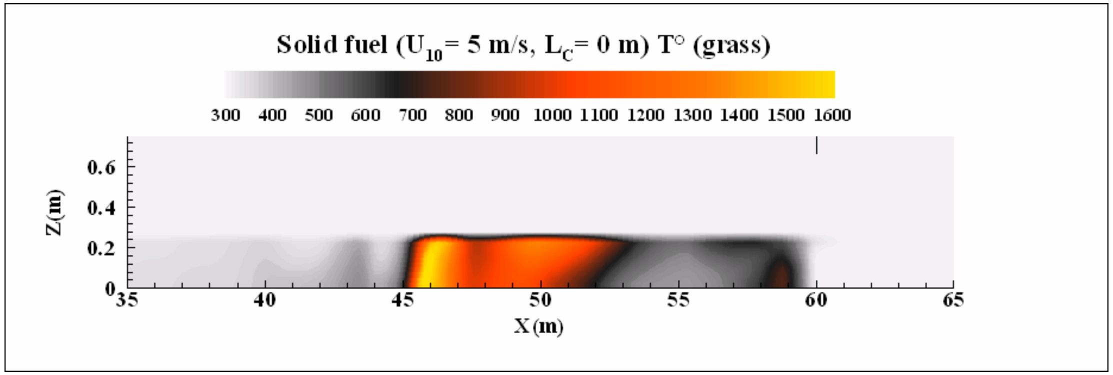
Evaluating the efficiency of a firebreak



$$\sigma_S = 5920\ m^{-1}$$

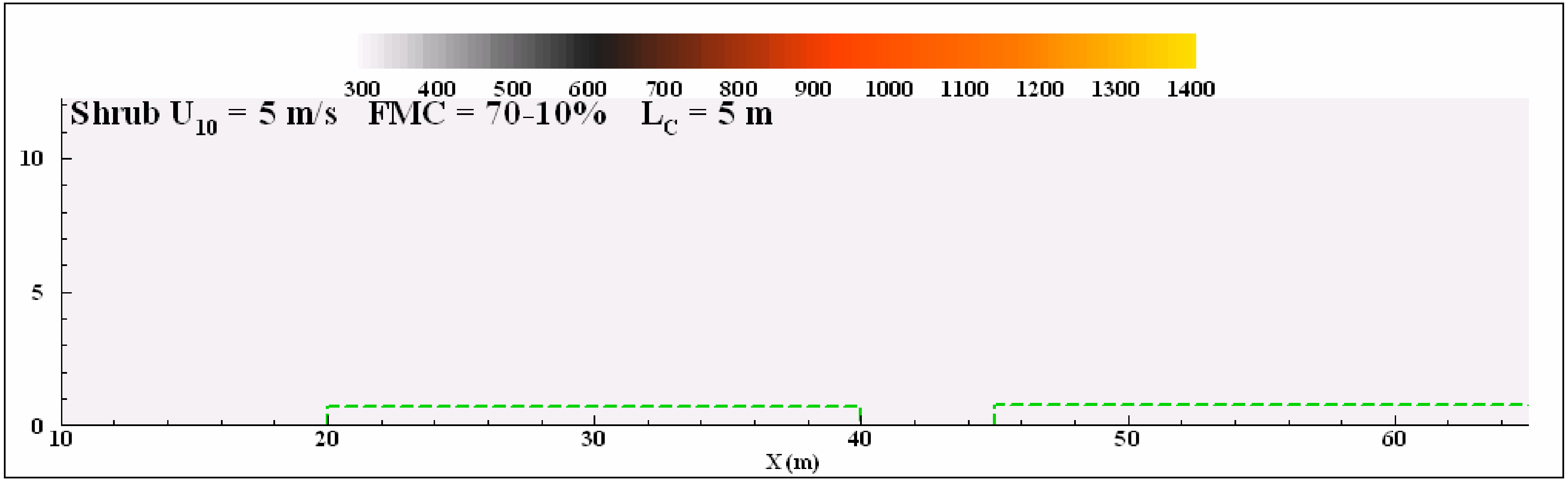


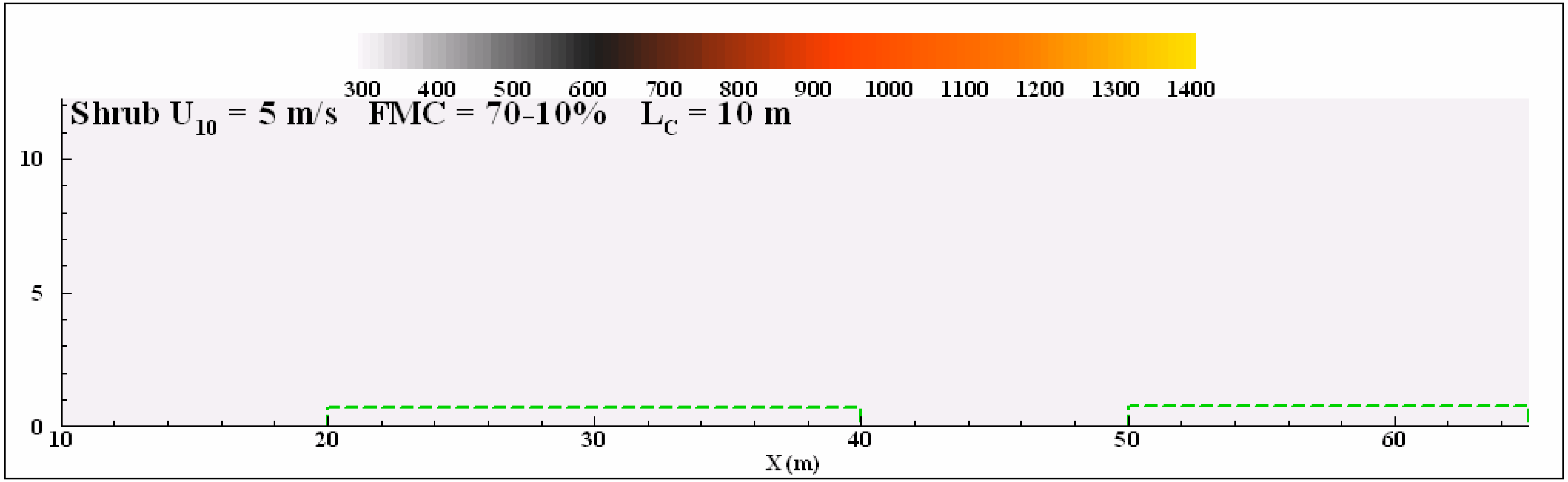
$$\sigma_S = 2700\ m^{-1}$$



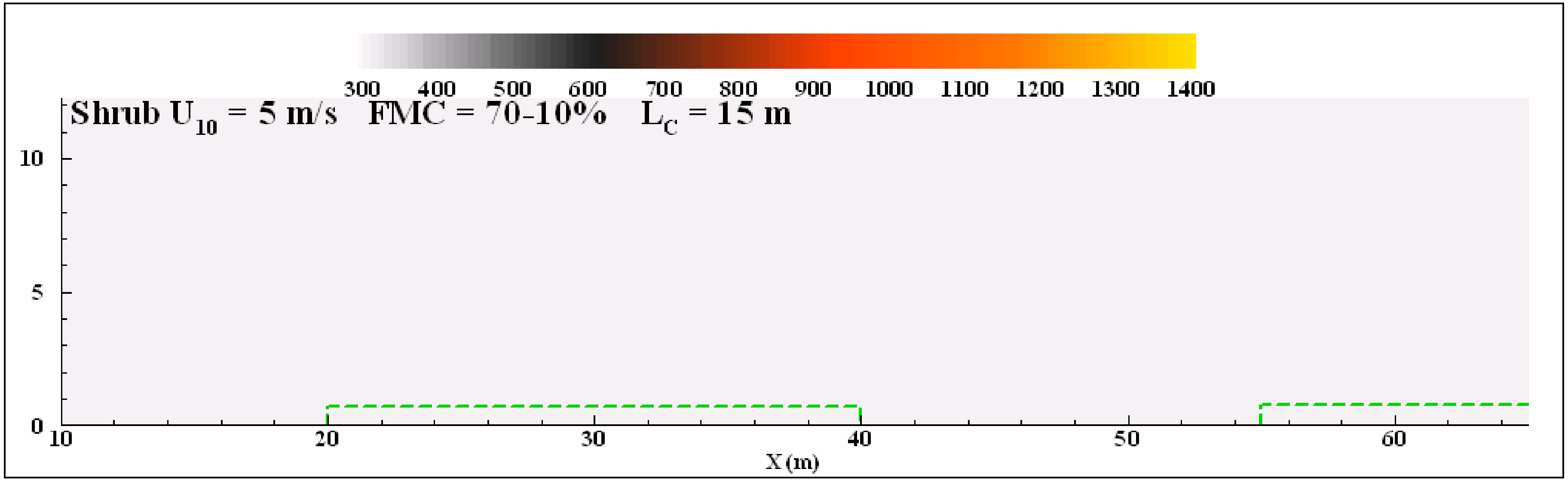
$$\sigma_S = 20000\ m^{-1}$$

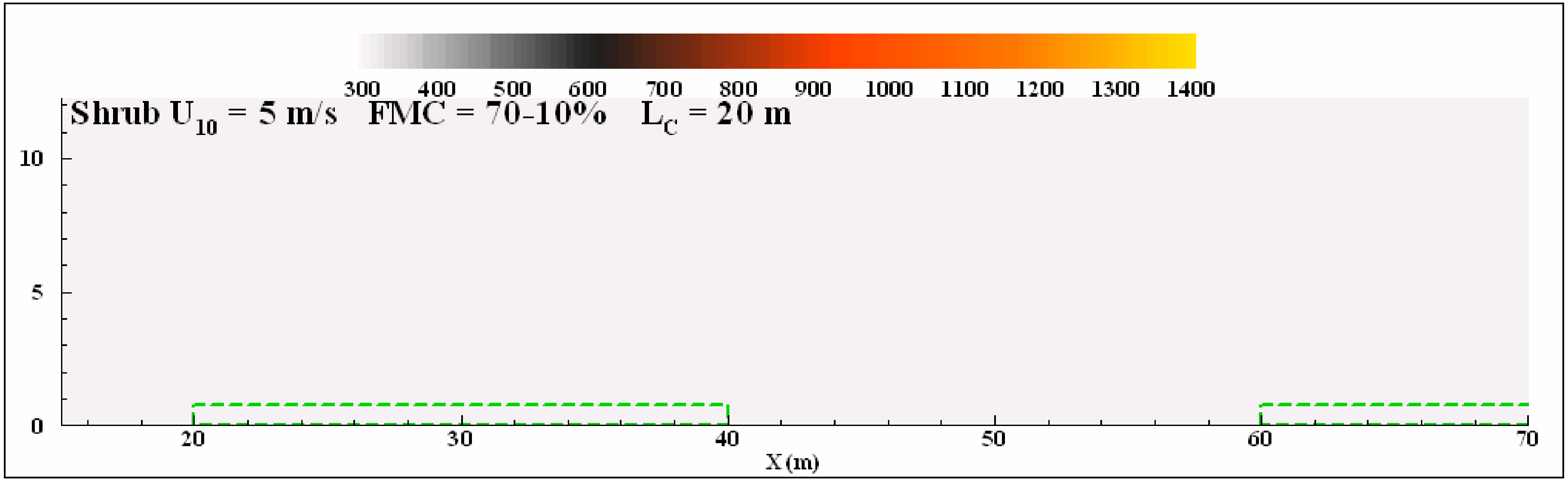
Evaluating the efficiency of a firebreak





Evaluating the efficiency of a firebreak





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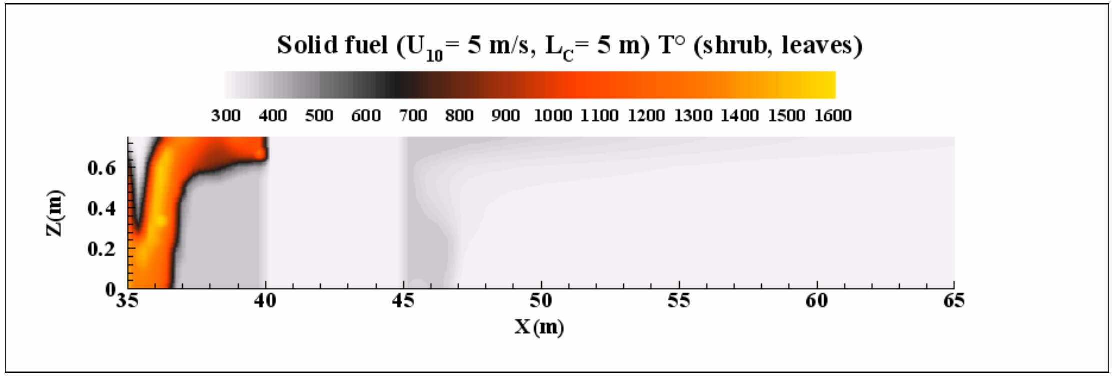
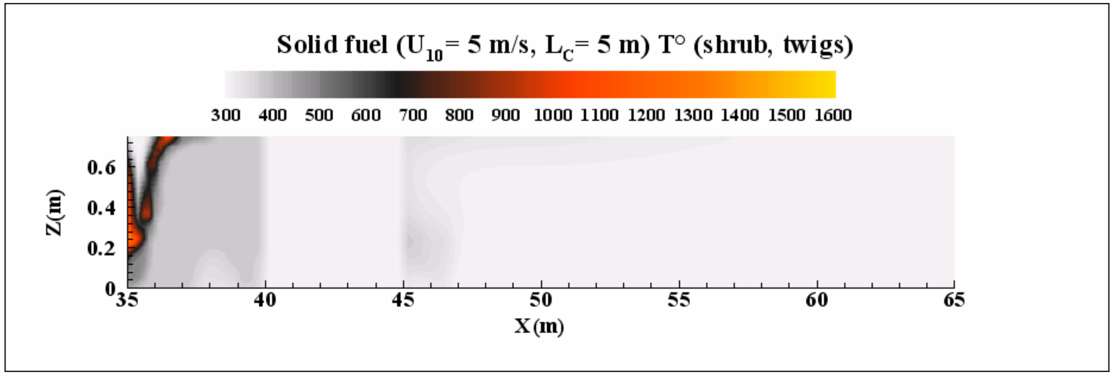
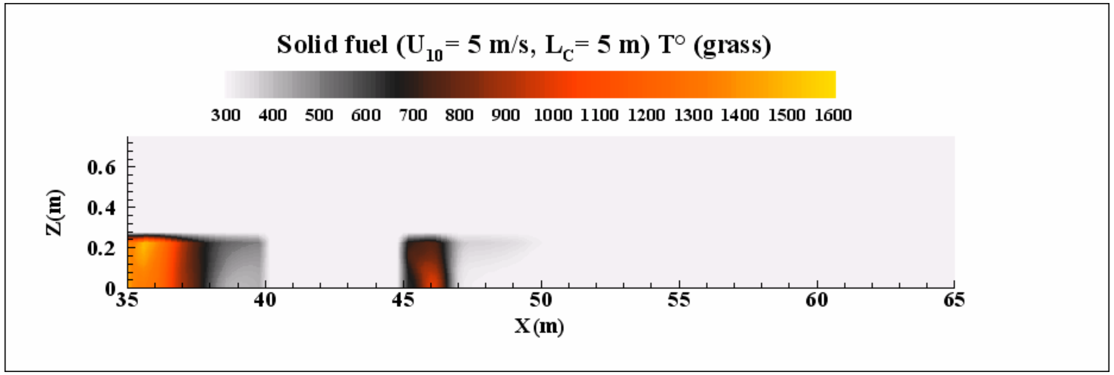
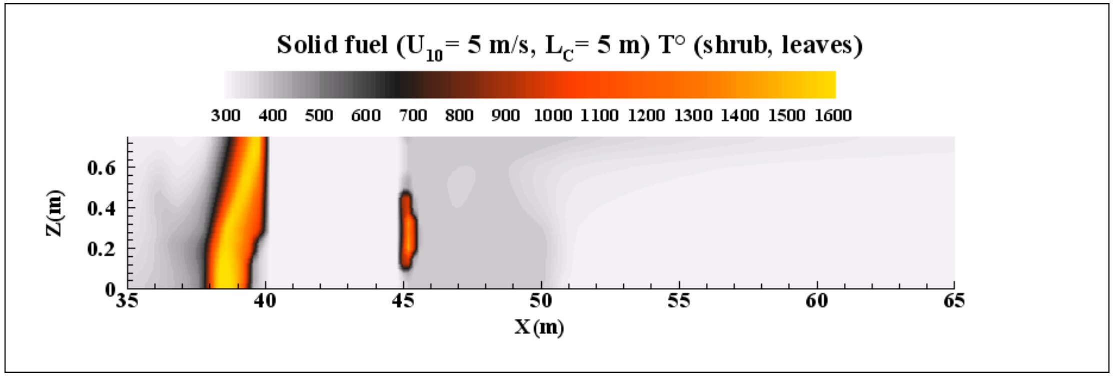


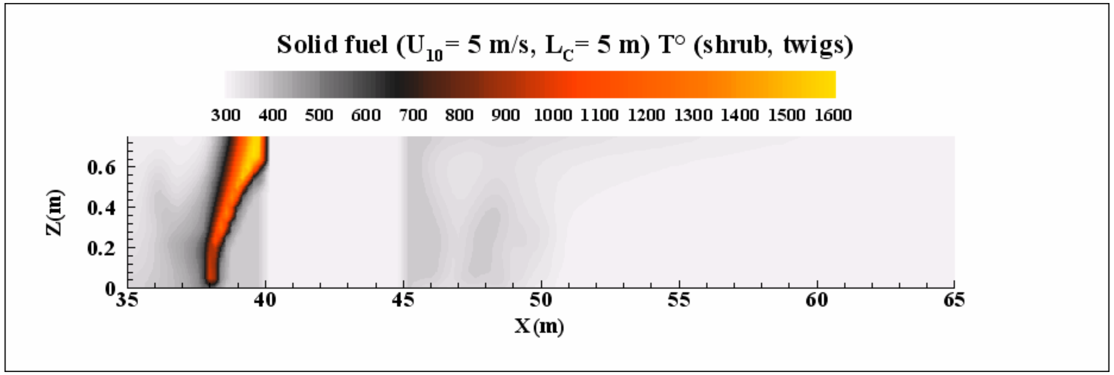


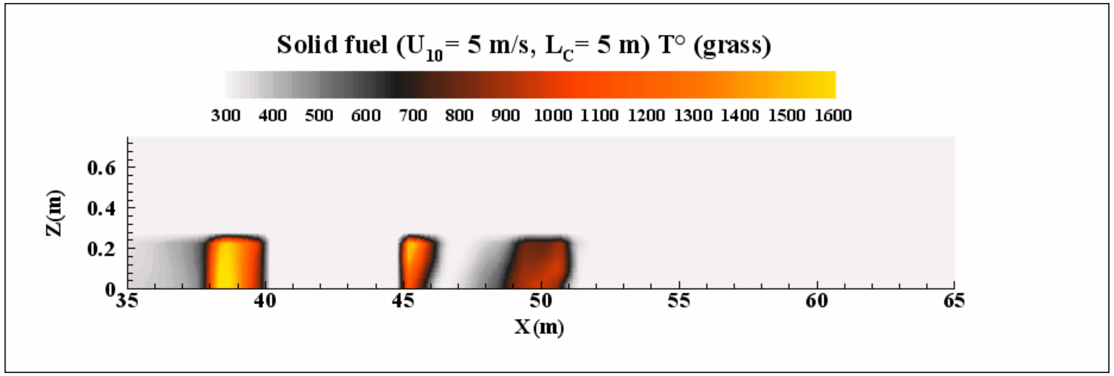


Time = 74 s

Evaluating the efficiency of a firebreak

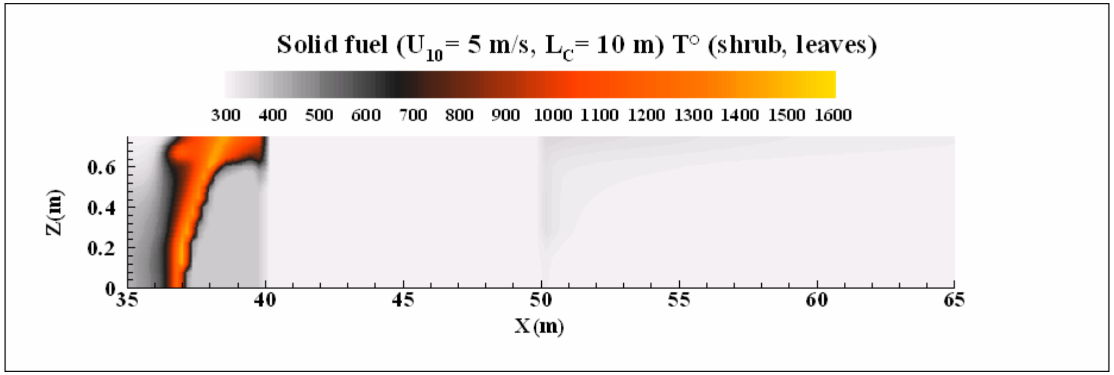


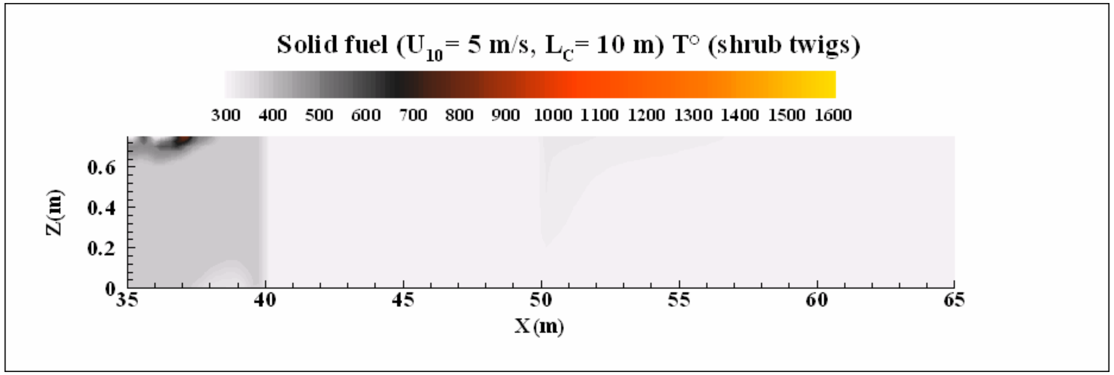


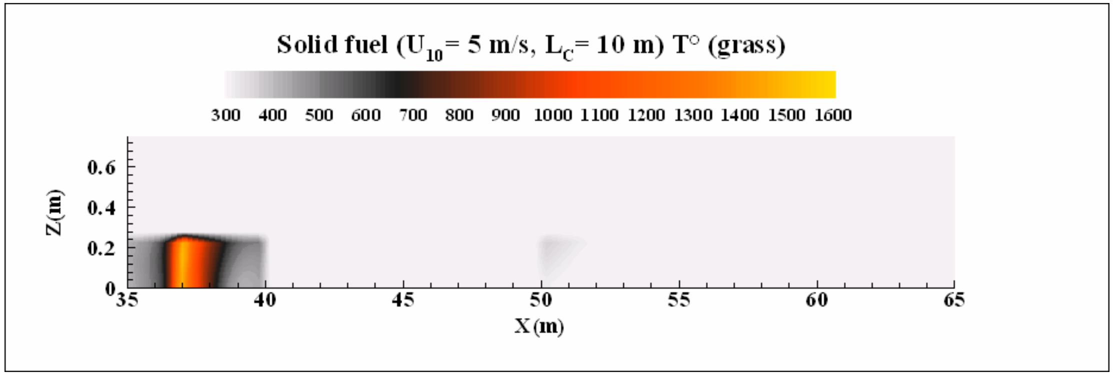


Time = 88 s

Evaluating the efficiency of a firebreak







Time = 74 s

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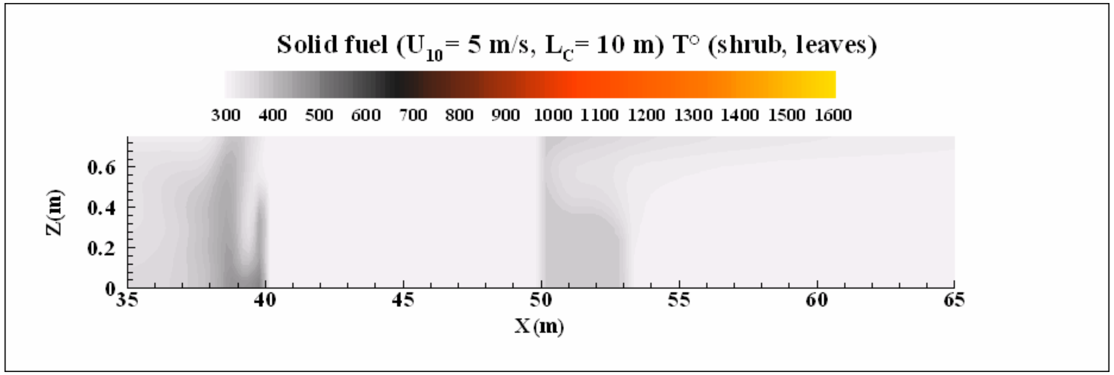
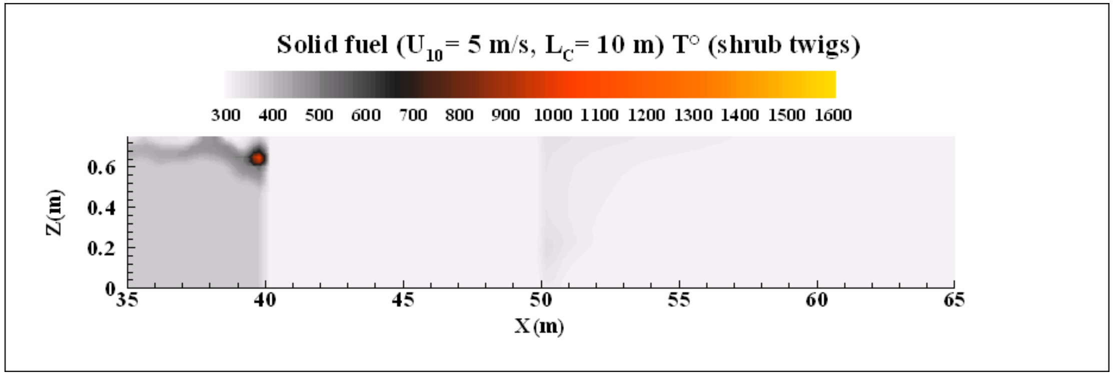
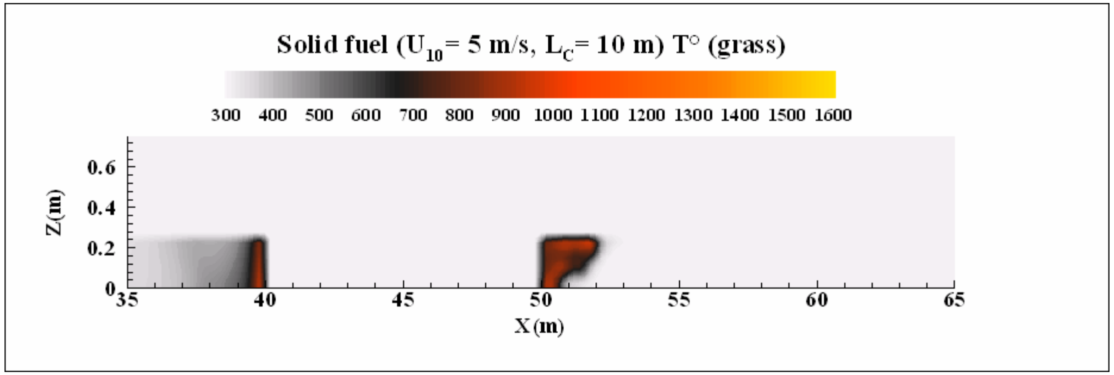
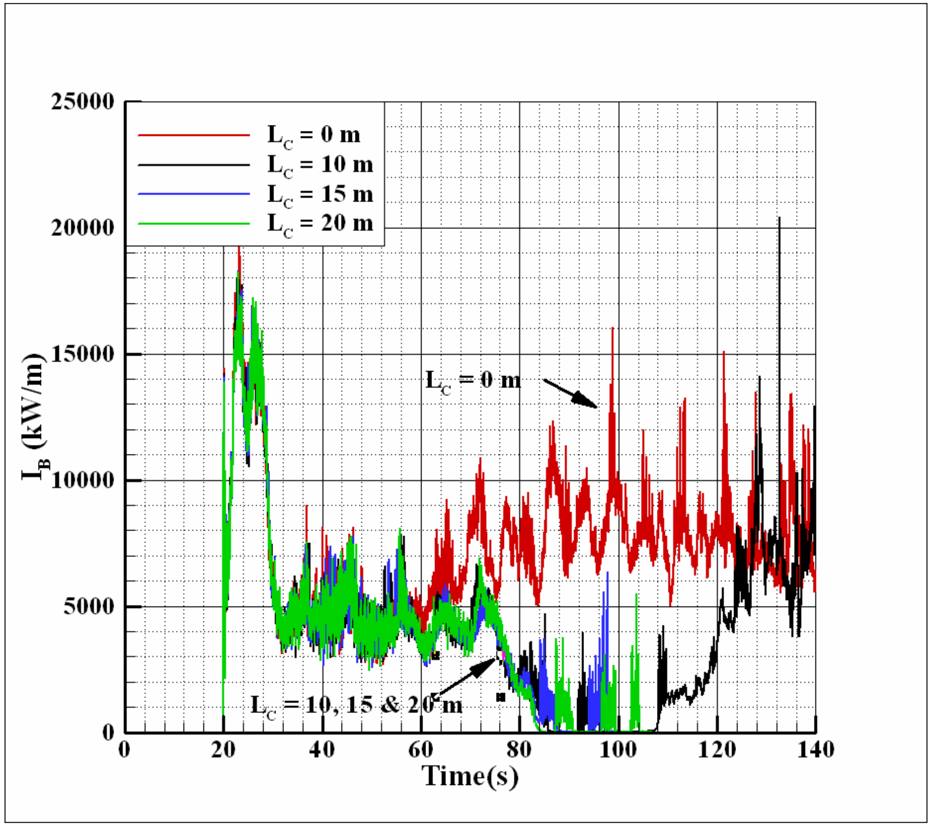


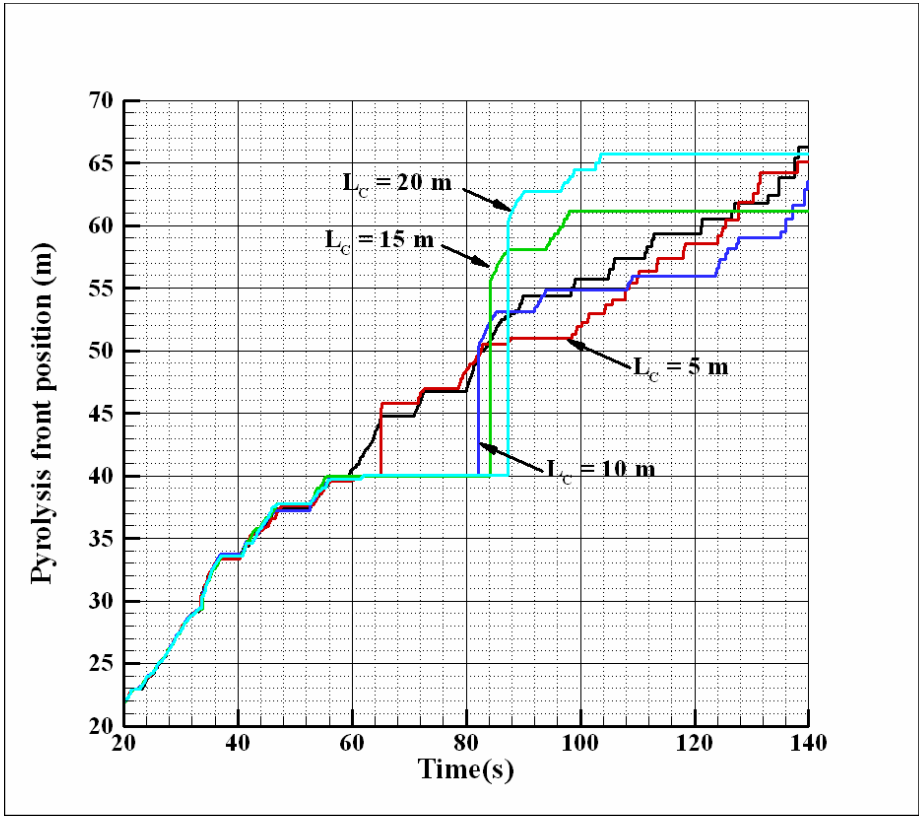




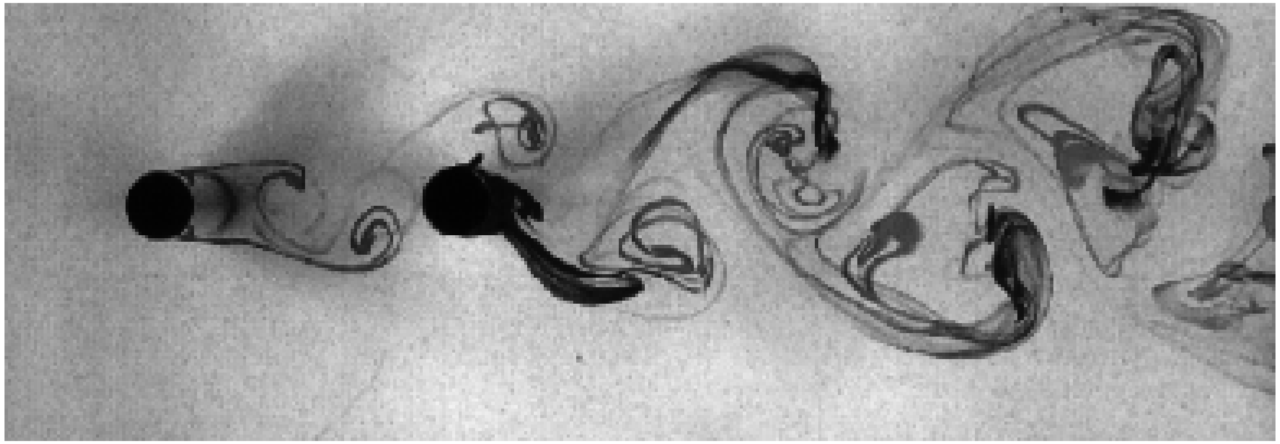
Time = 88 s

Evaluating the efficiency of a firebreak





Characteristic time of heat transfer by convection: circular cylinder in cross flow



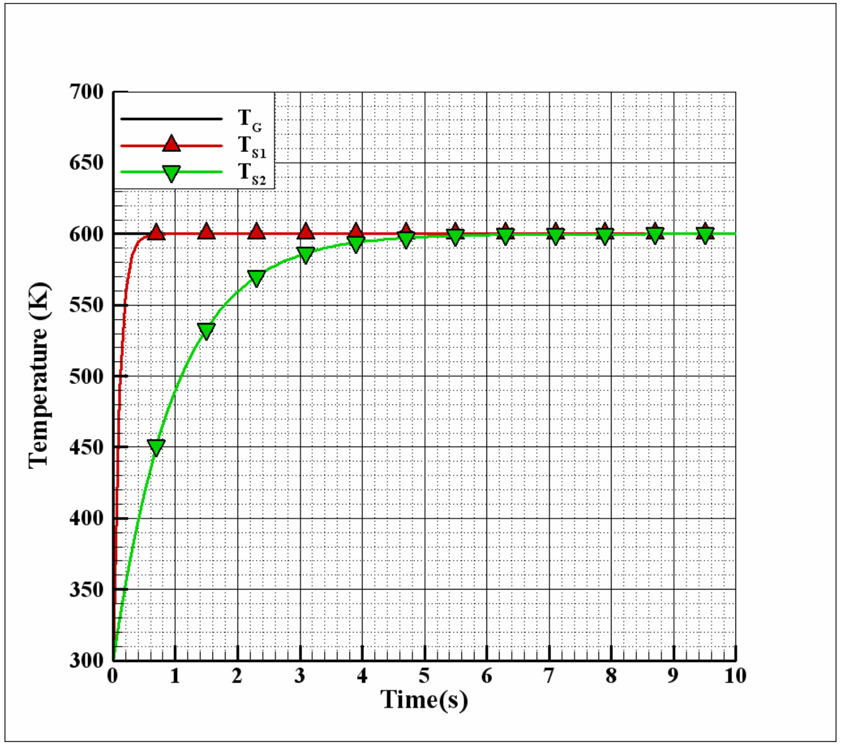
$$\rho_s C_{ps} \frac{\partial T_s}{\partial t} = h\sigma_s \left(T - T_s\right) \Rightarrow T_s = T + \left(T_s^0 - T\right) e^{-t/\tau}$$

$$\tau = \frac{\rho_s C_{ps}}{h\sigma_s} \quad (relaxation\ time)$$

$$Nusselt\ number: Nu = \frac{4h}{k\sigma_s} = C \times \mathrm{R}_e^m \times \mathrm{P}_r^{1/3} \quad (Incropera, Dewitt\ 1996)$$

Characteristic time of heat transfer by convection: circular cylinder in cross flow

σ_s (m^{-1})	τ (s)	τ_{pyr} (s)
5920 (leaves)	1	5
20000 (grass)	0.1	0.5



Toward a new conception of fire resistant houses.

Ref: I. Weir Queesland University of Technology (Australie).

Thank you for attention
Questions ?