

Wildfire Evolution in the Convective Boundary Layer

Ruiyu Sun, Steven K Krueger, Michael A Zulauf
University of Utah

Mary Ann Jenkins
York University

Joseph J Charney
USDA Forest Service

Why study wildfires in the CBL?

- Fires occur in the CBL
- Turbulence/gustiness exists in the CBL
- Gustiness affects fire behavior
- Fire plumes interact with large eddies
- Structure of convection may matter

UU LES-wildfire coupled model

- **Fire parameterization:**
 - surface heat and moisture fluxes
 - fire's rate of spread (ROS)
 - roughness height
- **LES dynamics:**
 - responds to fire heating
 - surface wind determines ROS

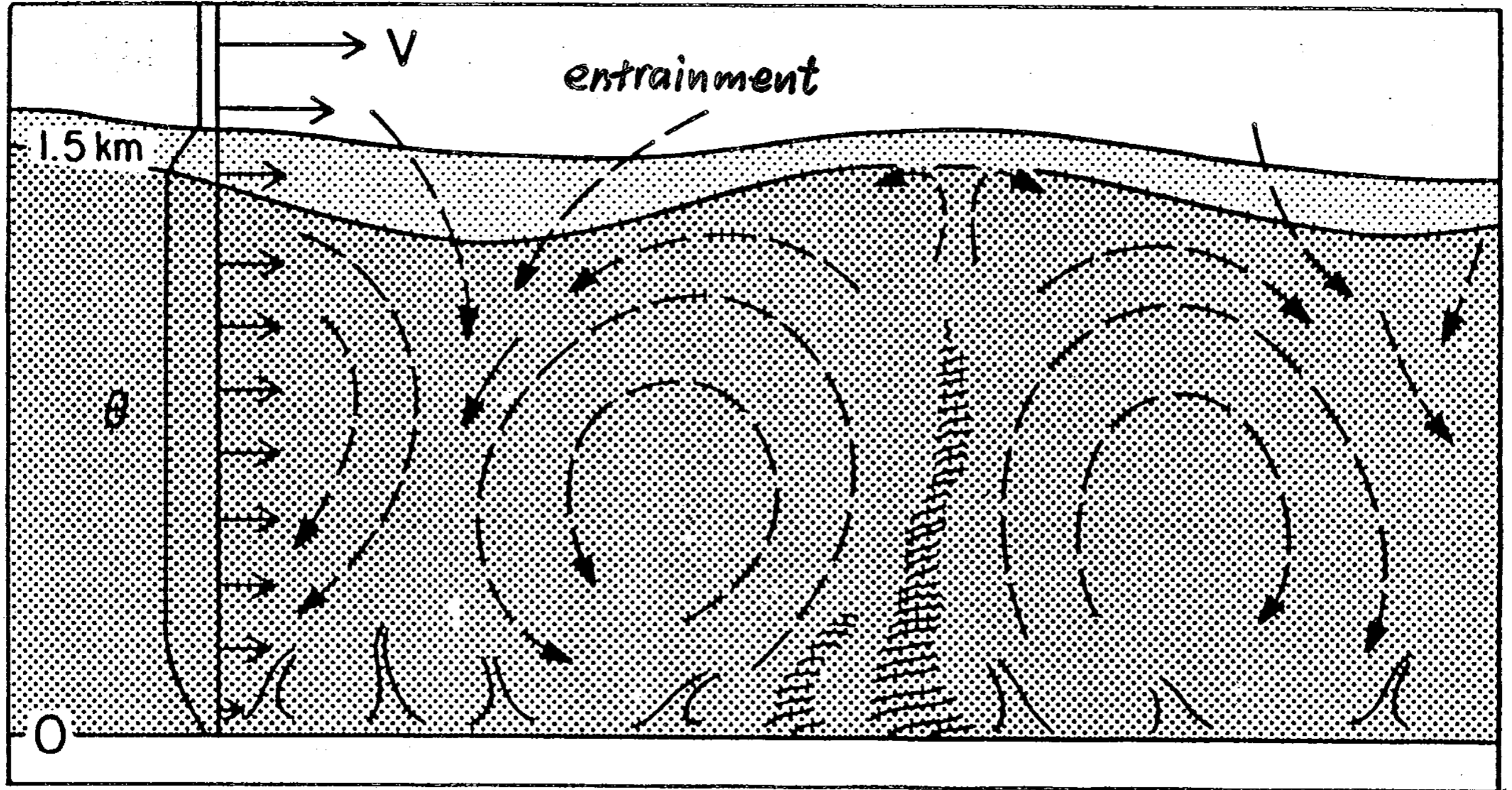
CBL Simulations

	Unorganized convection	Convective rolls
domain size (Lx, Ly, Lz)	3200 m, 3200 m, 2000 m	
grid size (dx, dy, dz)	10 m, 10 m, 5 m (stretched)	
mean CBL wind speed	5 m/s	
Heat flux at surface (W/m ²)	240	20
boundary layer depth (m)	937	468
convective velocity scale (m/s)	2	0.7

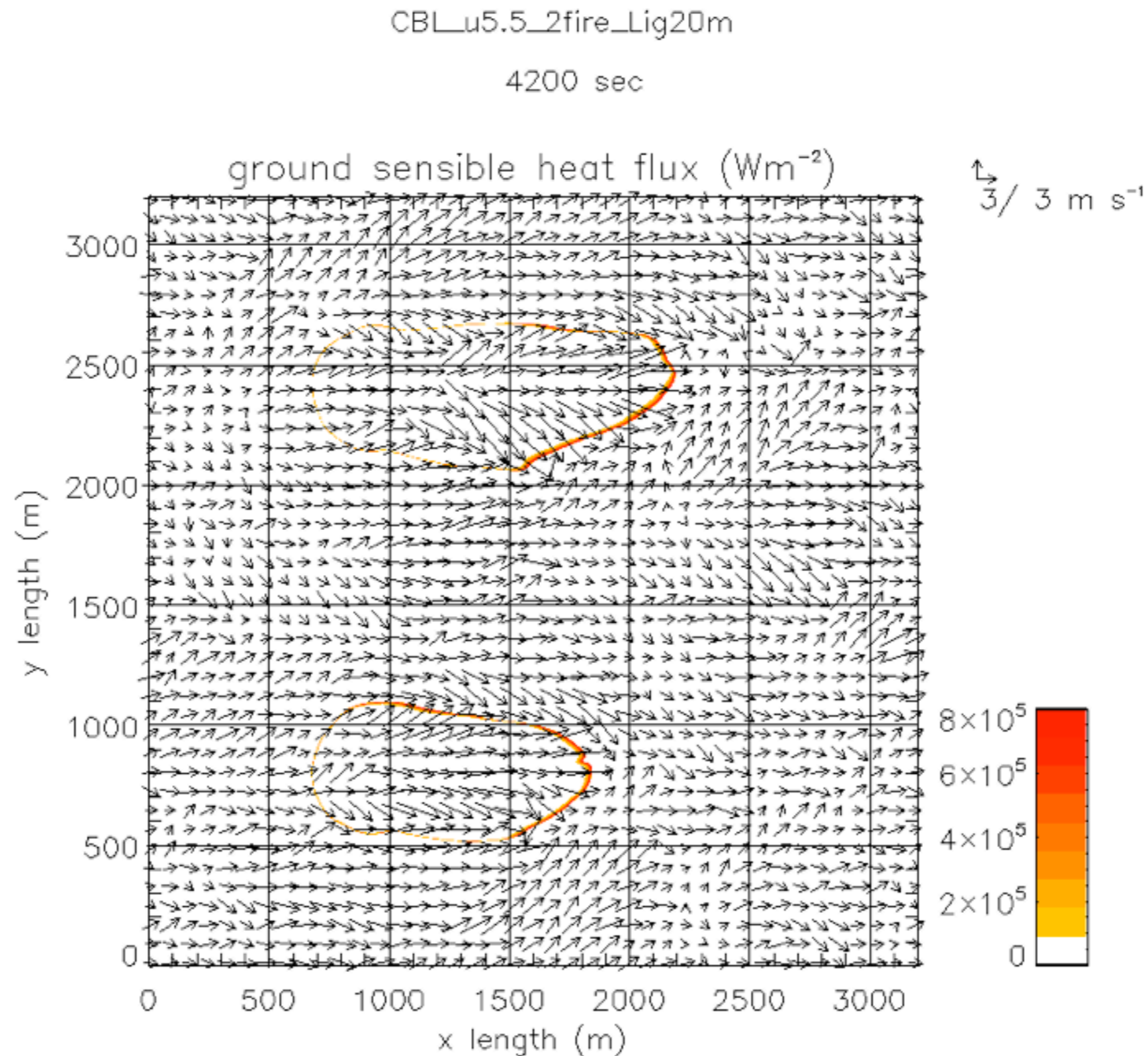
Fire parameters for CBL Simulations

fuel type	tall grass
number of fires	up to 8
ignition line length	20 to 200 m
start burn	after 1 hr
burn time	5 to 10 min

Convective Boundary Layer



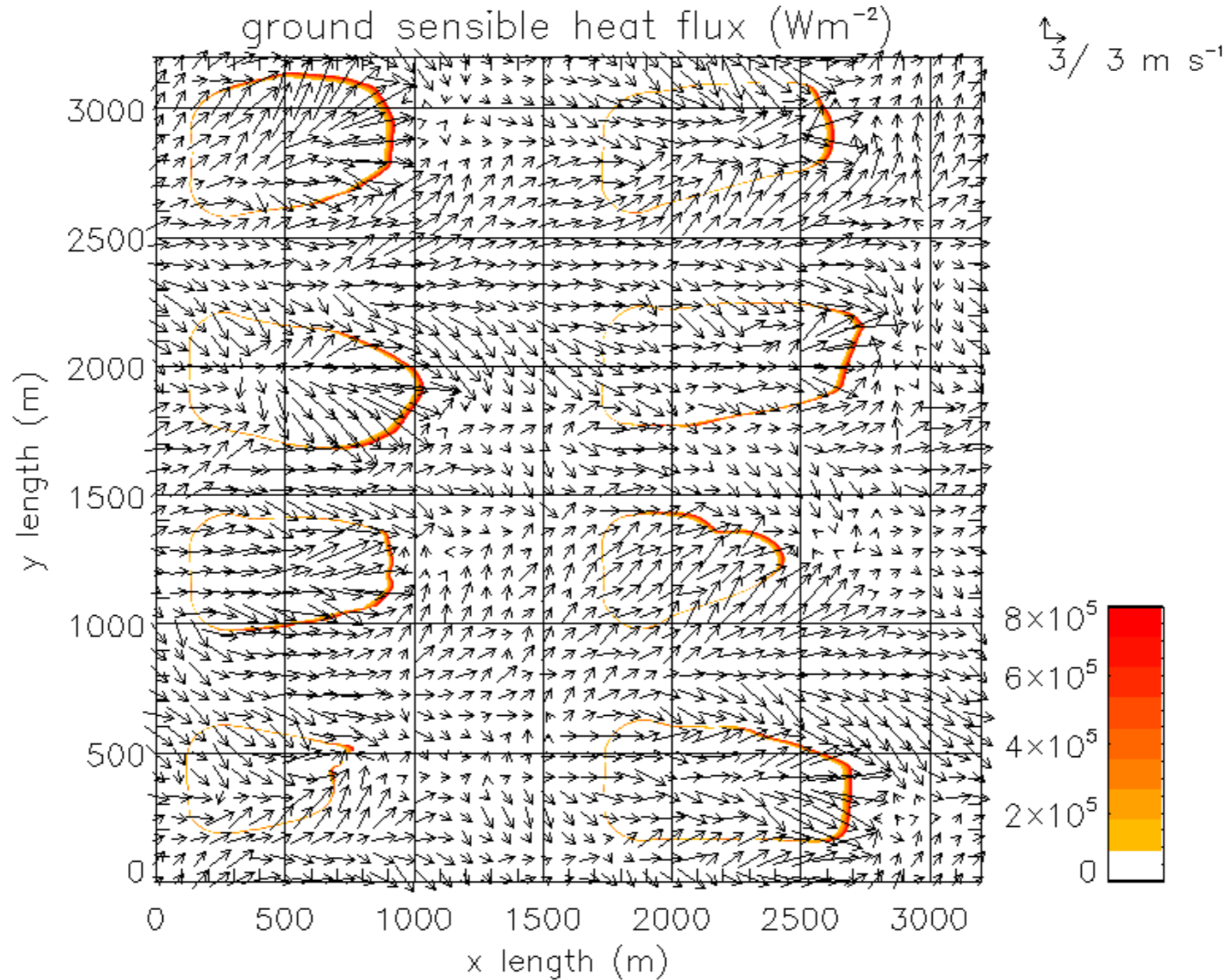
2 fires in CBL



8 fires in CBL

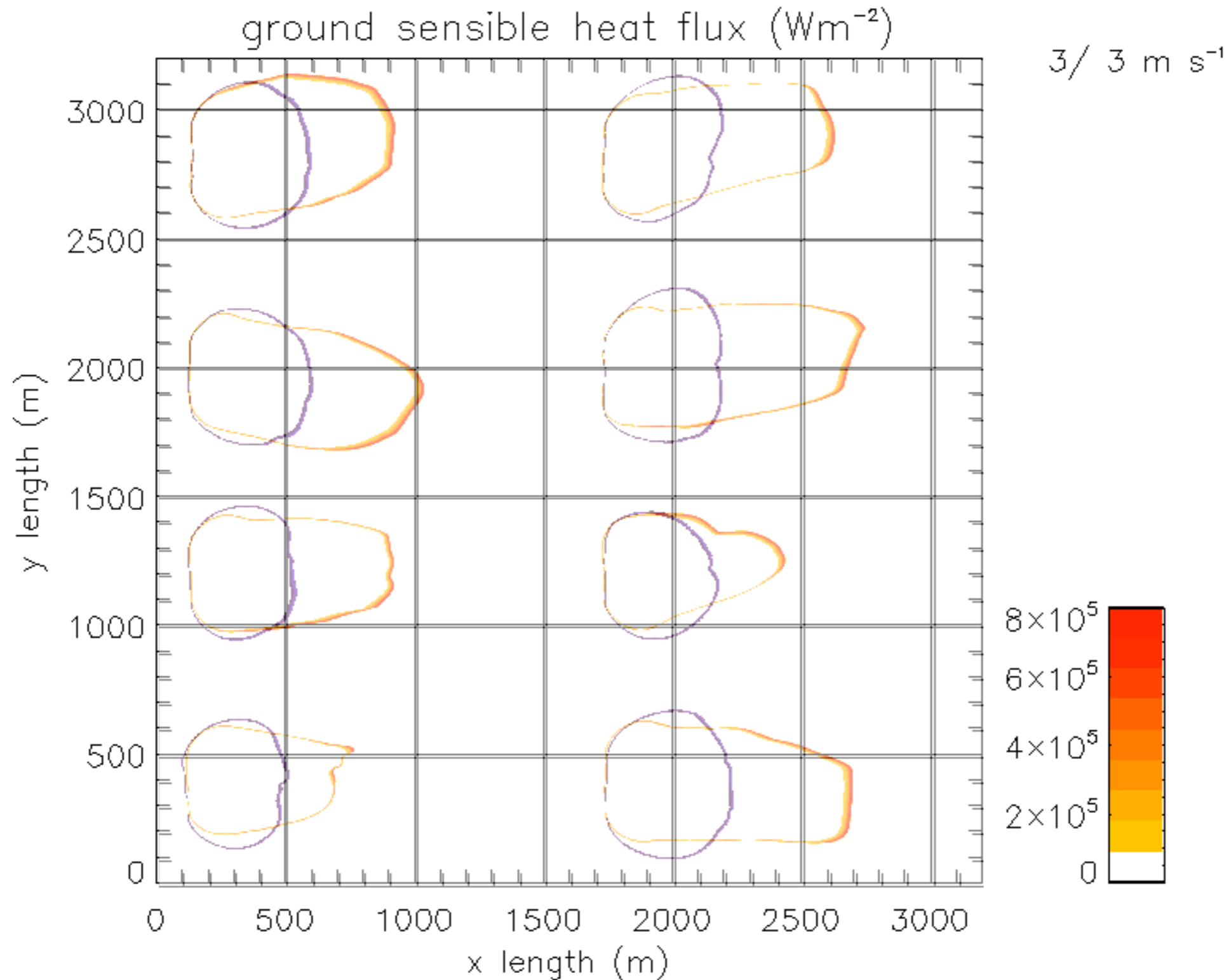
CBLu5.5_8fire_Lig200m

3900 sec

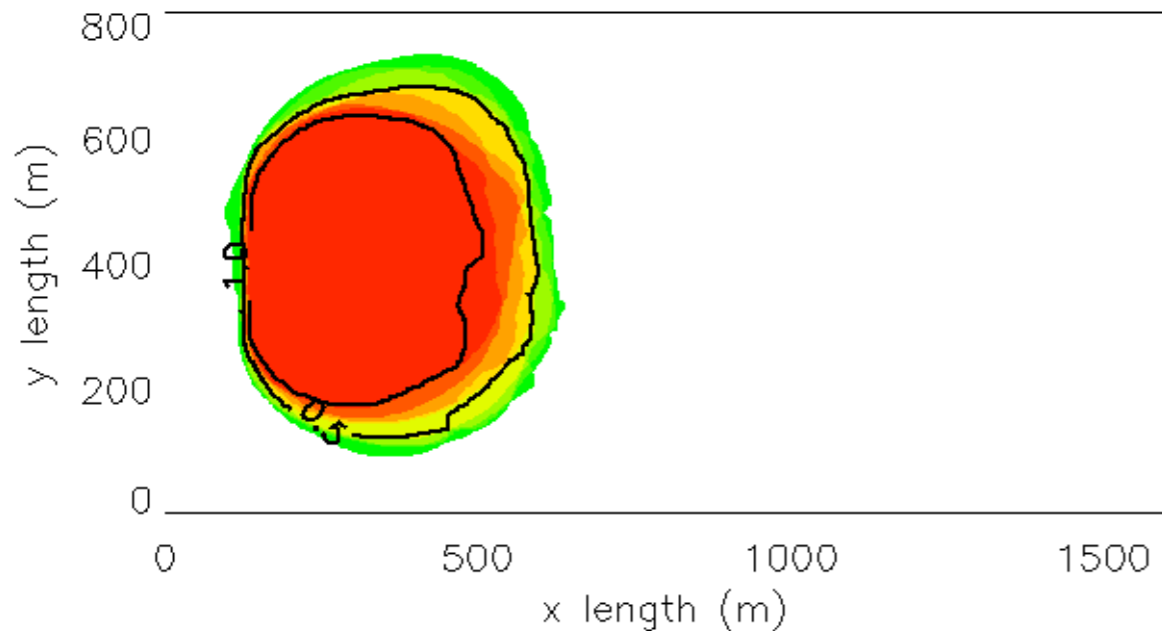


Uncoupled vs Coupled

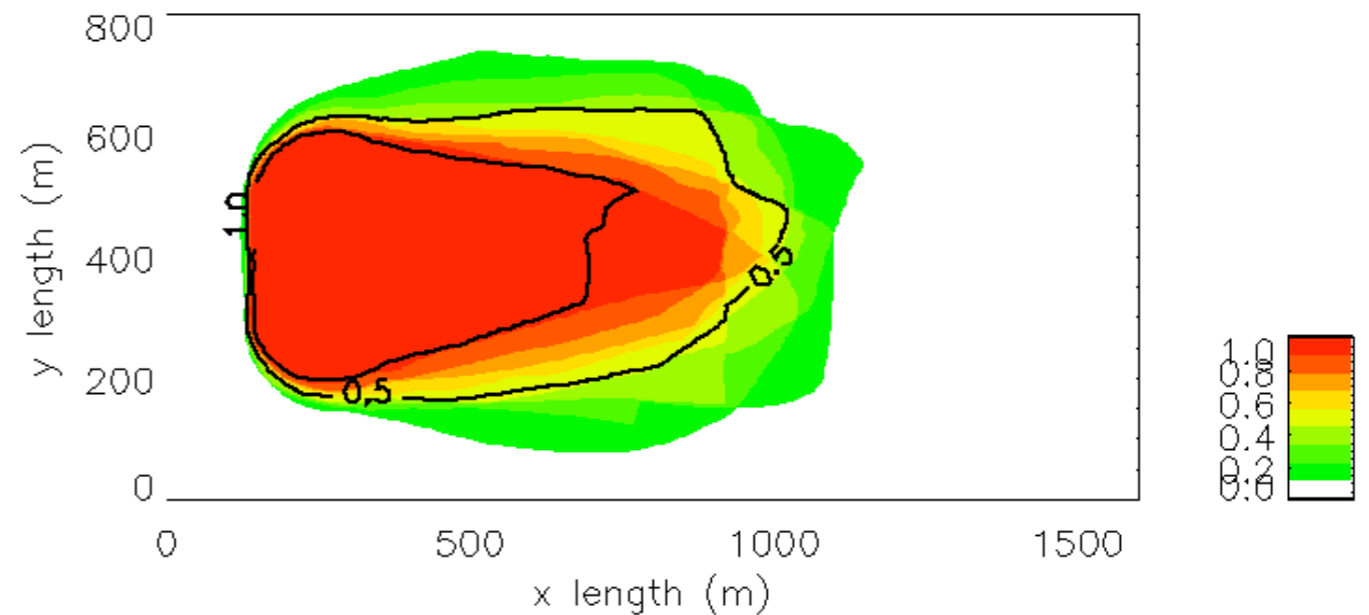
3900 sec



Ensemble fire spread after 5 min from 24 fires

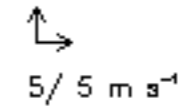


uncoupled

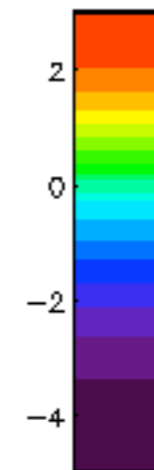
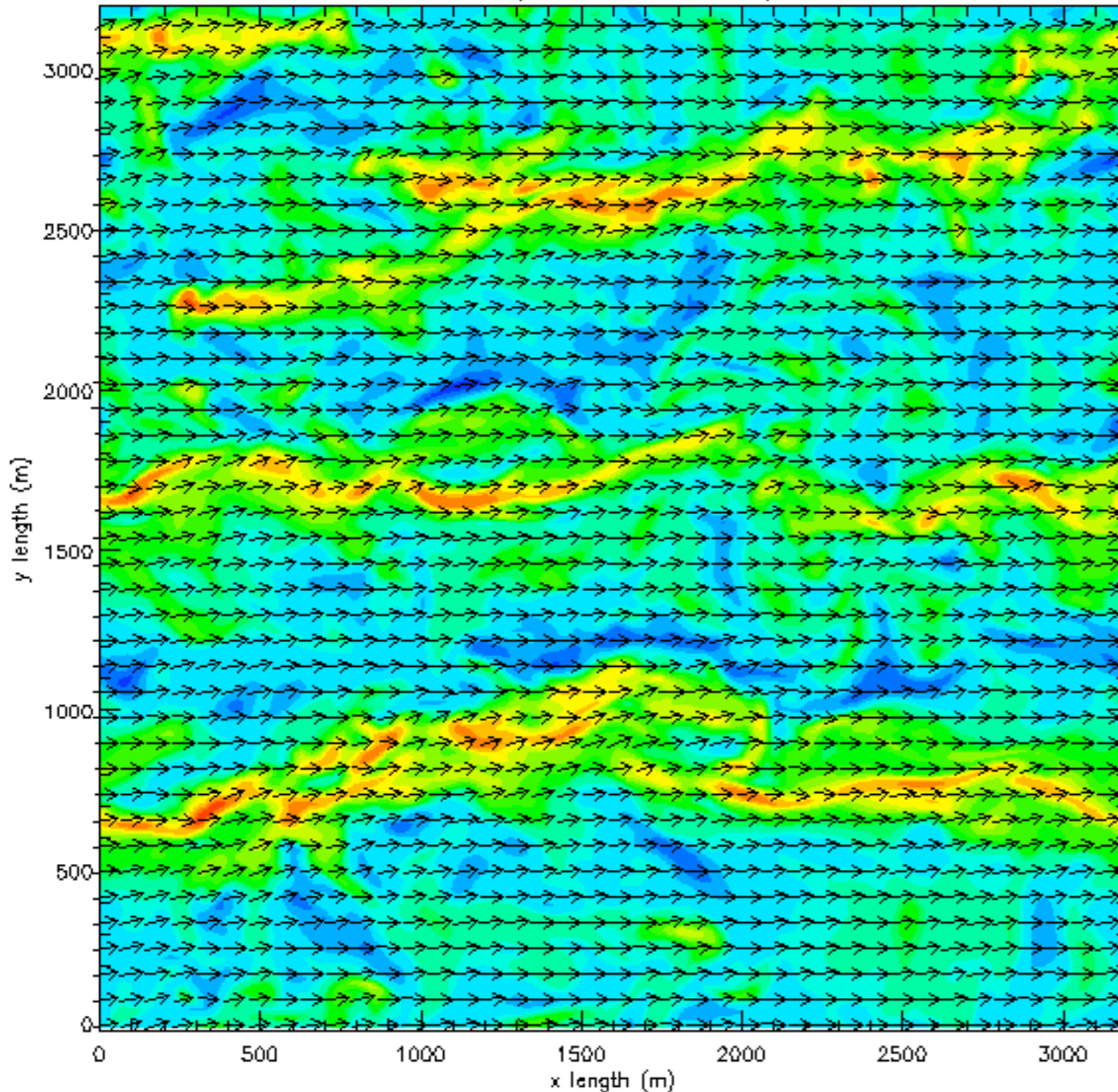


coupled

Convective rolls: vertical velocity at $z = 150$ m


5/5 m s⁻¹

WW (0147 m, at 5400 s)

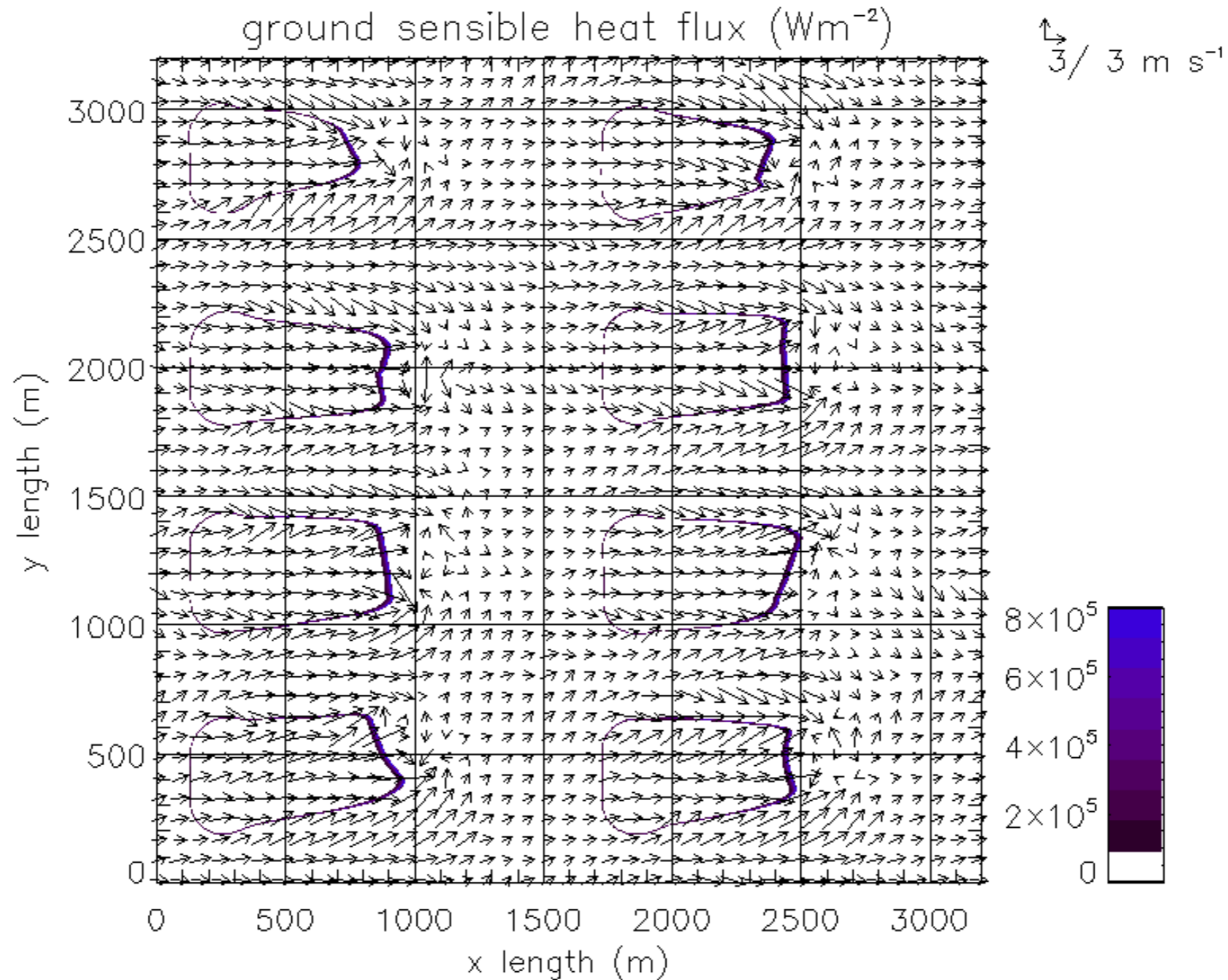


u^*	0.24 m/s
w^*	0.67 m/s
z_i	468 m
L	-56 m
$-z_i / L$	8.3

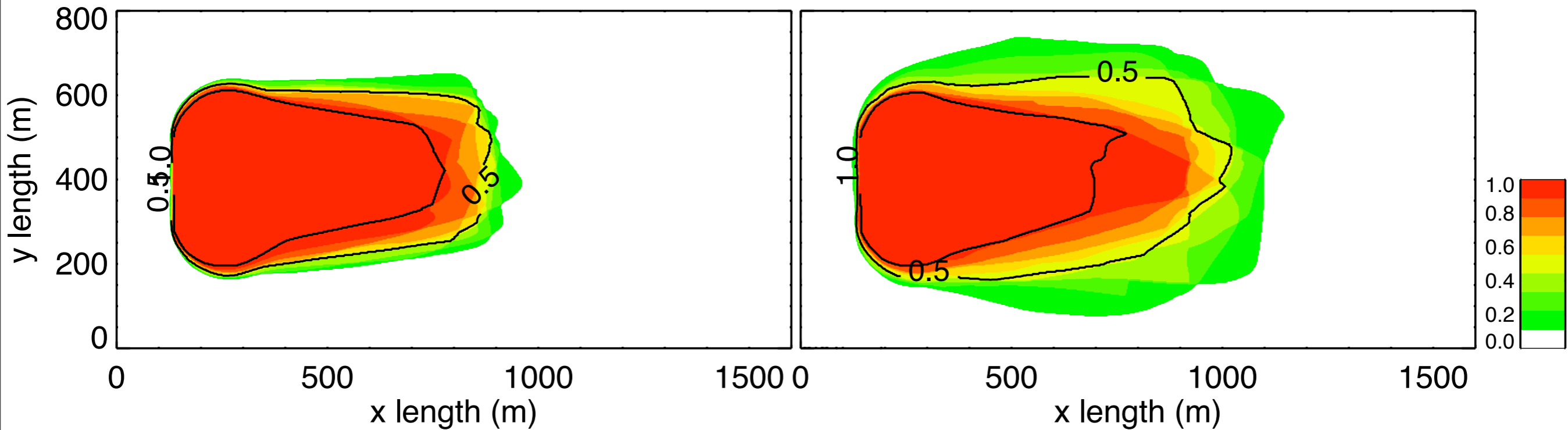
8 fires in convective rolls

Roll_Lu5.5_8fire_Lig200m

5700 sec



Ensemble fire spread after 5 min from 24 fires



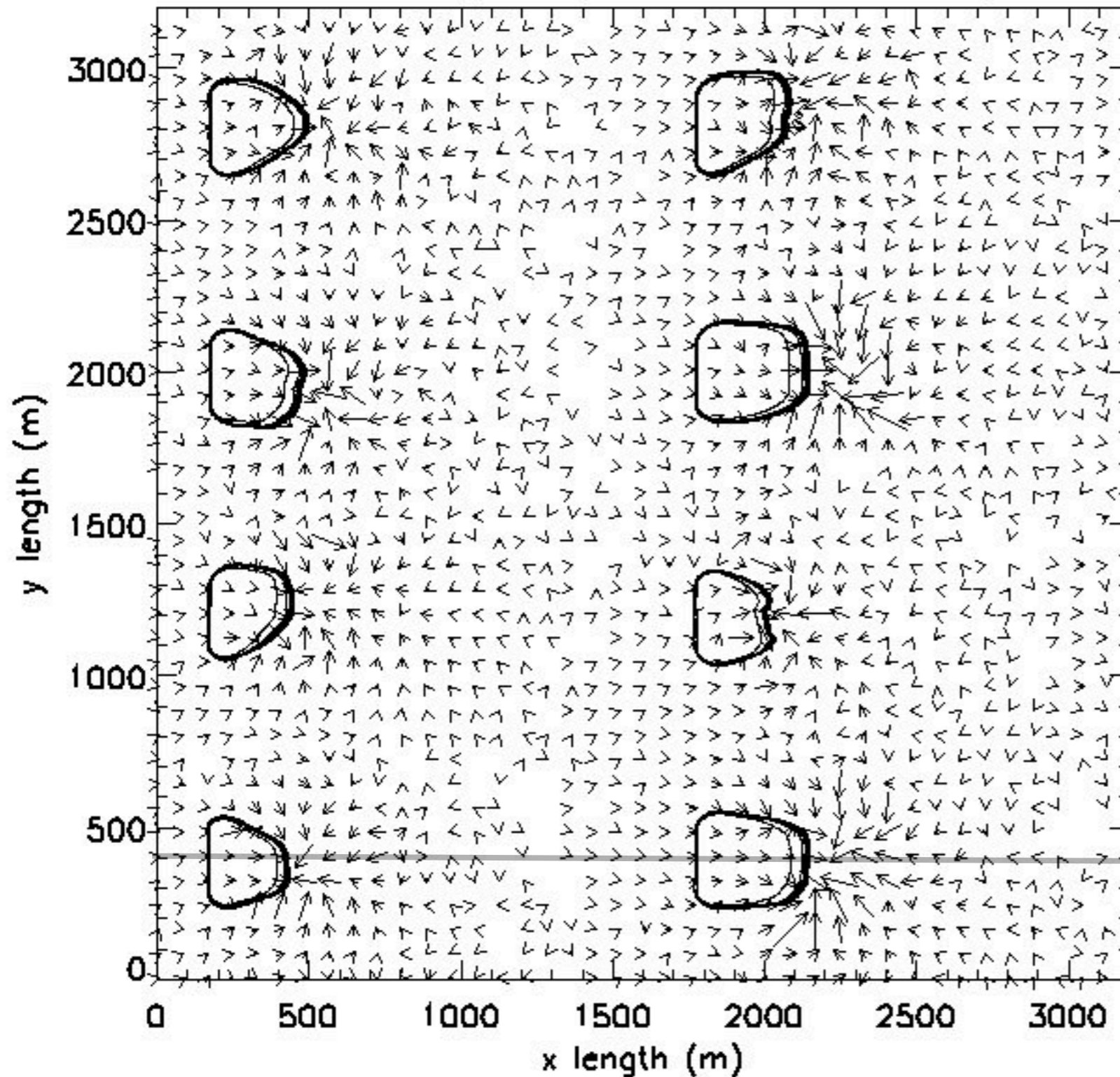
convective rolls

unorganized convection

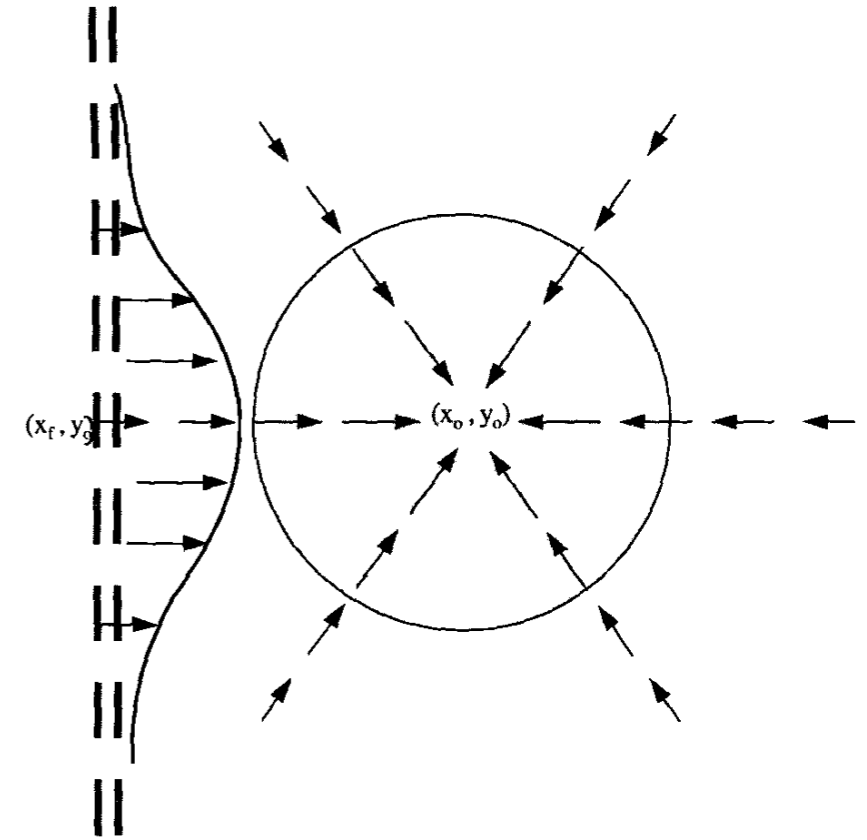
Fire-induced flow: updraft

3720 s, 0007 m

induced wind (0007 m, at 3720 s)



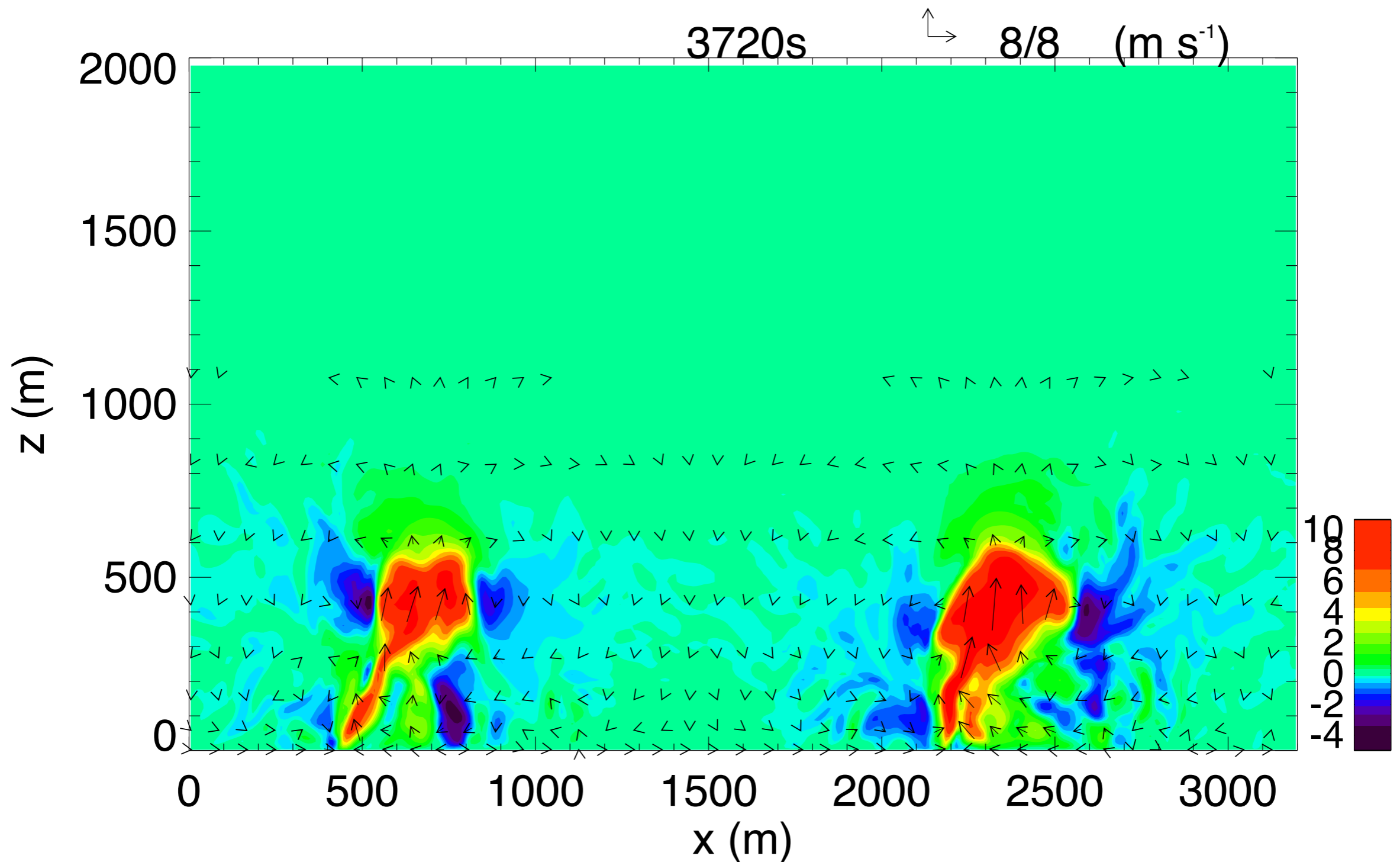
$3/3 \text{ m s}^{-1}$



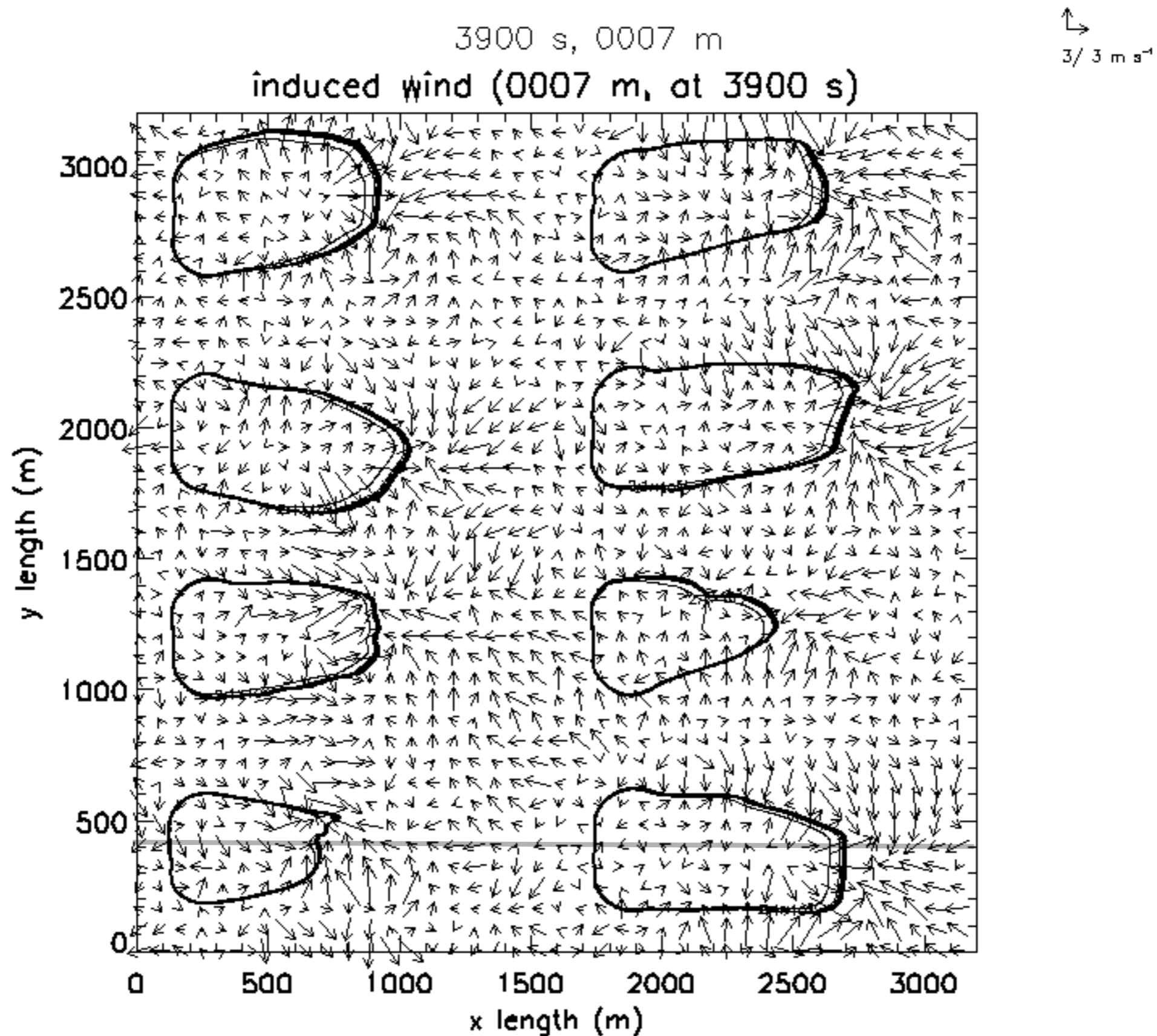
Clark et al. 1996

Fire-induced flow: updraft

$y = 400 \text{ m}$

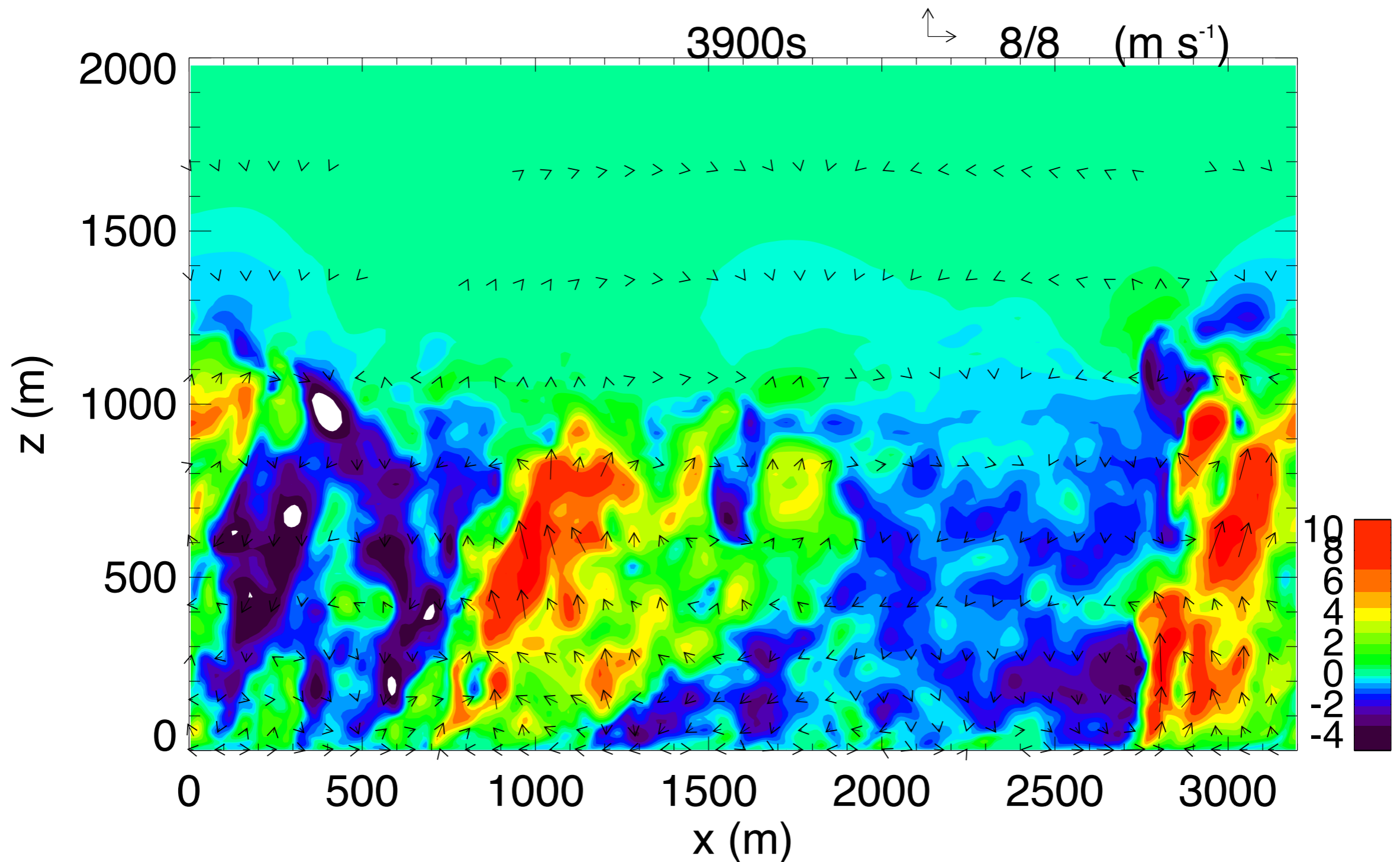


Fire-induced flow: downdraft



Fire-induced flow: downdraft

$y = 400 \text{ m}$



Summary

- Fire spread is not deterministic in the CBL.
- Fire spread variability is greater with unorganized convection than with convective rolls.
- Fire-induced circulations include:
 - Convergence and updraft ahead of the fire line.
 - Divergence and downdraft behind the fire line.
- A range of possible alignments of CBL and fire-induced circulations produces fire spread variability.