Numerical simulations of grassland fire behavior from the LANL-FIRETEC & NIST-WFDS models

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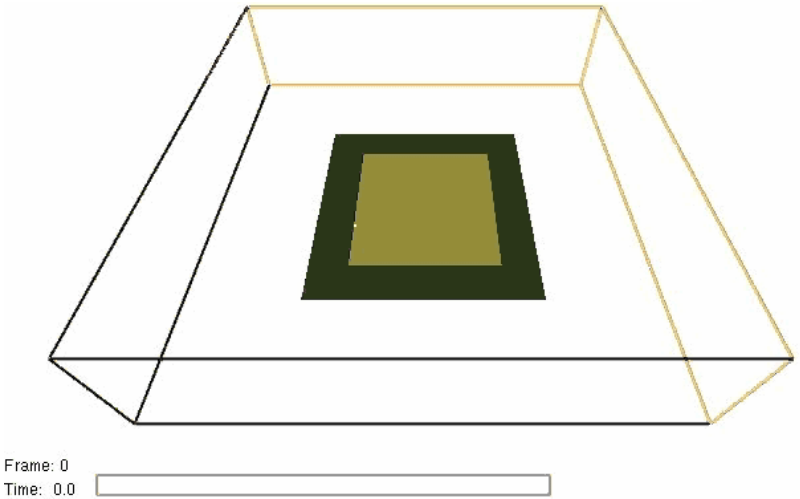
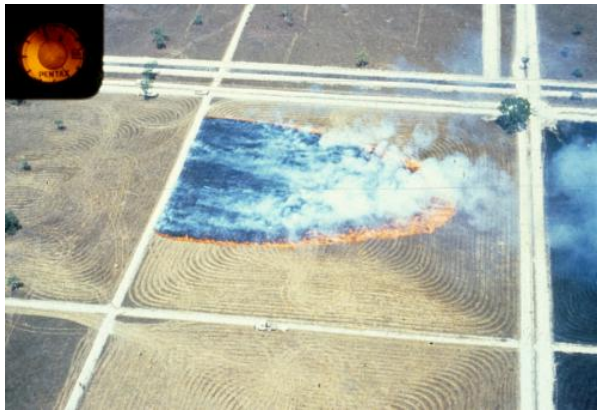
Overview of FIRETEC & WFDS

	FIRETEC	WFDS
2-D	✓	✓
3-D	✓	✓
lab scale	X	✓
landscape scale	✓	✓
complex terrain	✓	X
fire spread via brands	X	X
suspended veg.	✓	✓
surface veg.	✓	✓
computer resources	multiprocessor	single or multi.

WFDS Animation of Experiment C064

Smokeview rendering of fire and smoke





- AU experiment: short grass, L_{ig} = 50 m, U_2 = 4.6 ms^{-1}
- WFDS: one processor, 2.3 million cells, 12 cpu hours for 2 minutes
- FIRETEC: a less demanding case required 3 days on 16 processors

- In order to compare WFDS & FIRETEC we ran WFDS with the “tall” grass conditions of previous FIRETEC simulations.

Simulations Conducted

I. AU grassland
- evaluate predictions R vs. U_2 and R vs. W
- evaluate predictions of fire perimeter by simulating exp. F19 & C064

] WFDS only

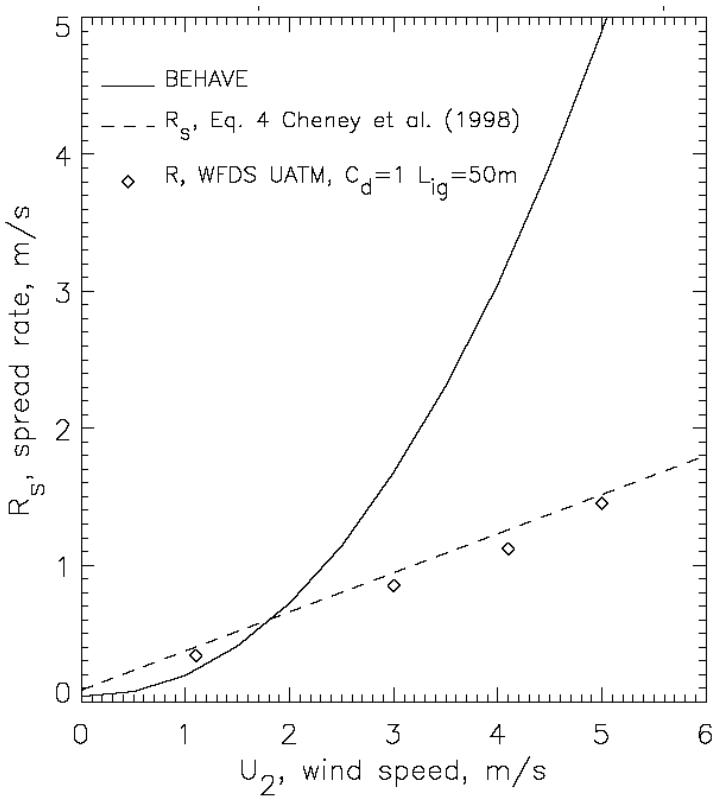
II. Tall grass in previous FIRETEC simulations
- evaluate general behavior of fire perimeter

] FIRETEC & WFDS

	property	AU Grassland Experiments		AU Grassland WFDS simulations	FIRETEC[a] tall grass	WFDS tall grass
		F19	C064			
gas phase	heat of combustion of volatiles, kJ kg^{-1}	n/a	n/a	15600	8914 (?)	15600
	radiation fraction	n/a	n/a	0.35	n/a	0.35
	soot fraction	n/a	n/a	0.02	n/a	0.02
	wind speed, ms^{-1} @ 2m height	4.8	4.6	(1) 1,3,4,5 w/F19 (2) from exp.	0.75, 2, 4, 8	2, 4
solid phase	**surface area to-volume ratio**, m^{-1}	12240	9770	from exp	4000	4000
	char mass fraction	n/a	n/a	0.20	n/a	0.2
	grass height, m	0.51	0.21	from exp	0.7	0.7
	fuel element density, kg m^{-3}	n/a	n/a	512	n/a	512
	fuel loading, kg m^{-2}	0.313	0.283	from exp	0.7	0.7
	moisture, %	5.8	6.3	from exp	5.0	5.0

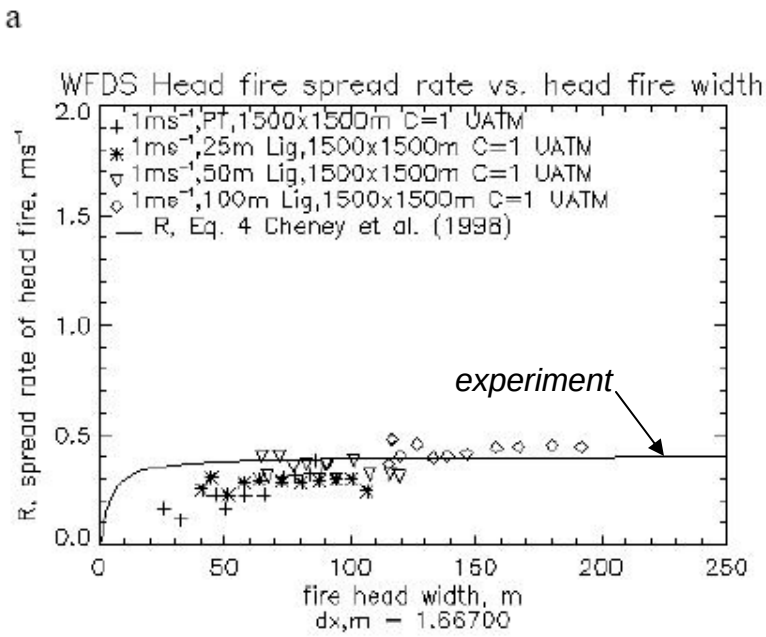
[a] Linn and Cunningham, "Numerical simulations of grass fires using a coupled atmosphere-fire model: Basic fire behavior and dependence on wind speed," JGR, 2005, to appear

WFDS: Head Spread Rate vs. Wind Speed

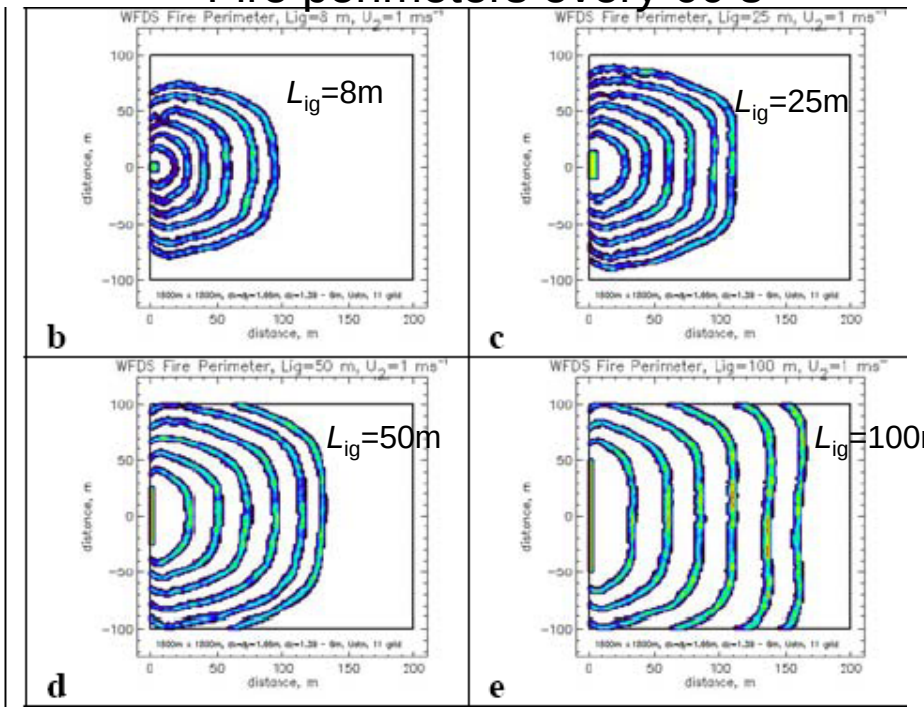


- grass fuel of AU experiment F19
- L_{ig} = 50 m
- Dashed line is from an empirical model developed from experimental measurements.
- WFDS predicts the head fire spread rate dependence on wind speed well.
- BEHAVE over predicts the spread rate. It does a better job for less fine fuels.

WFDS: Head Spread Rate vs. Head Width, U_2 = 1 ms^{-1}



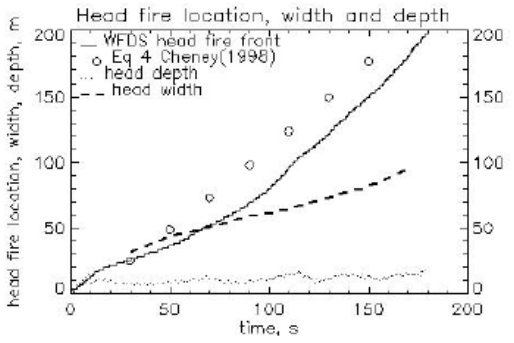
Fire perimeters every 60 s



- WFDS predicts the observed trend of an increasing head fire spread with increasing head width.

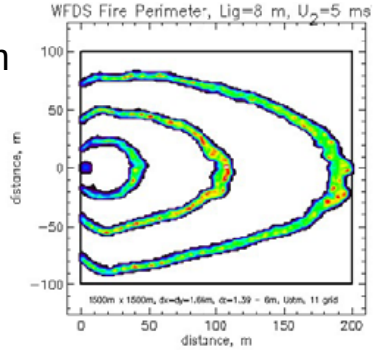
WFDS: U_2 = 5 ms^{-1}

Fire perimeters every 60 s

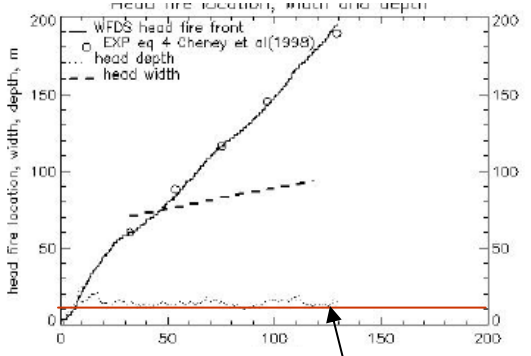


L_{ig}=8m

a

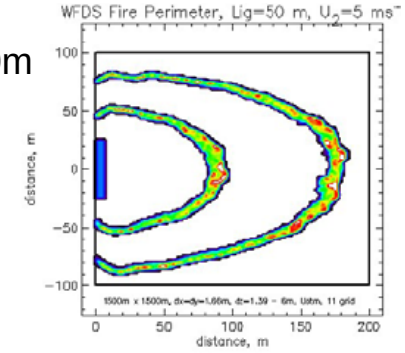


- Head fire spread rate is well predicted after an initial transition period.
- Fire depth is approx. 20% larger in WFDS.



L_{ig}=50m

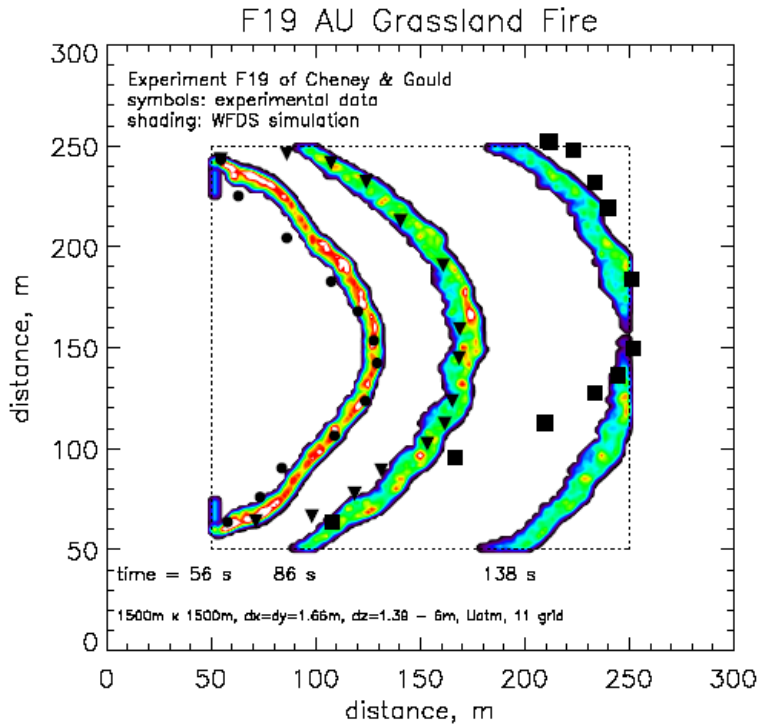
c



observed fire depth ~ 10 m

$R \sim U_2 \exp(-U_2 / W)$

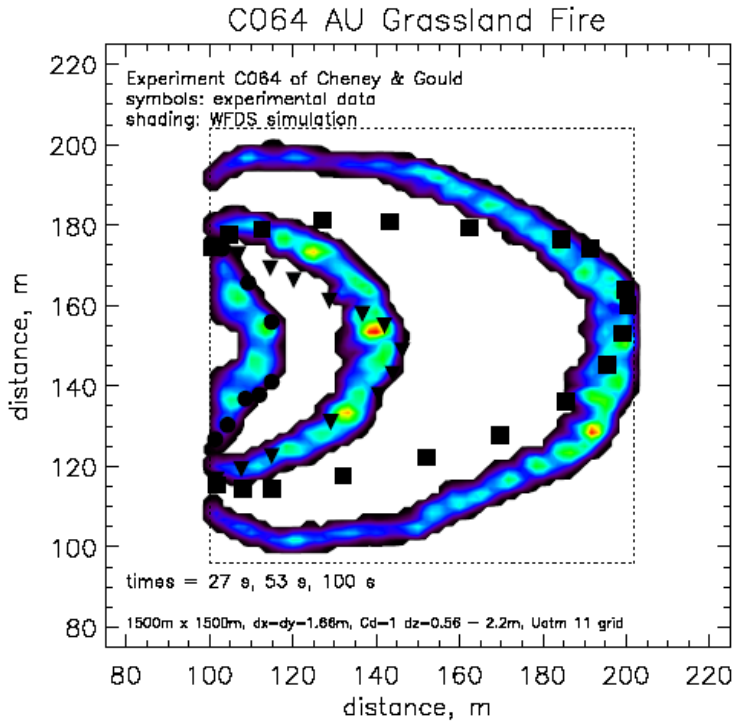
WFDS: Fire Perimeter AU case F19



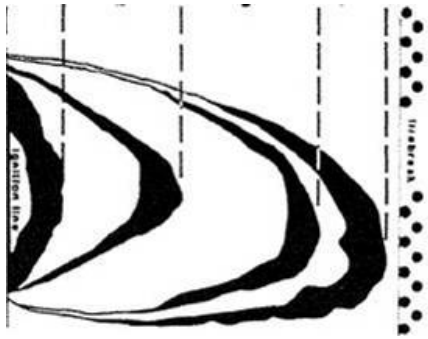
- height = 51 cm
- loading = 0.31 kg m^{-2}
- moisture = 4.8%
- U_2 = 4.8 ms^{-1}
- surface/volume = 12200 m^{-1}
- L_{ig} = 175 m

- Head fire spread rate well predicted.
- Need more testing of flank fire prediction..

WFDS: AU Case C064



- height = 21 cm
- loading = 0.28 kg m^{-2}
- moisture = 6.3%
- U_2 = 4.6 ms^{-1}
- surface/volume = 9770 m^{-1}
- L_{ig} = 50 m

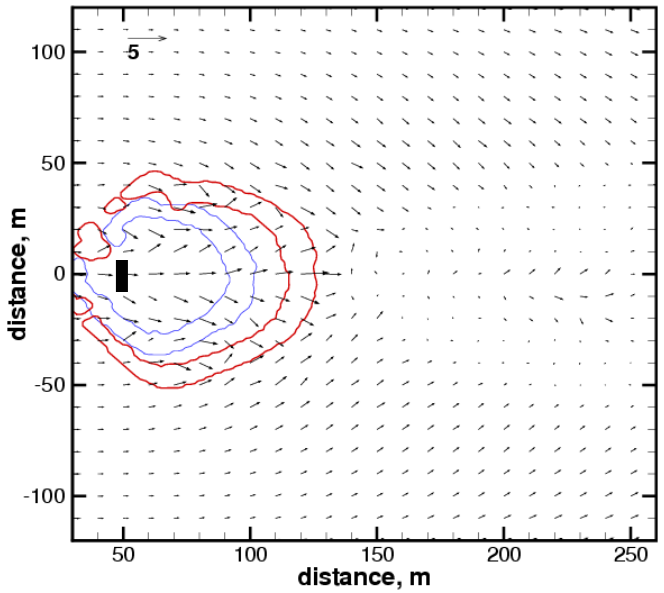


- Head fire spread rate well predicted.
- Flank fire spreads too quickly.

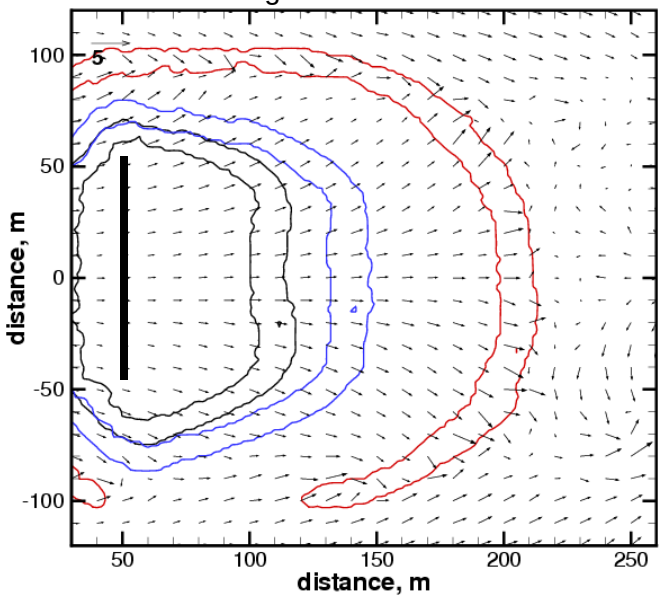
Tall Grass

U_2=2 ms^{-1}

L_{ig} = 16 m



L_{ig} = 100 m

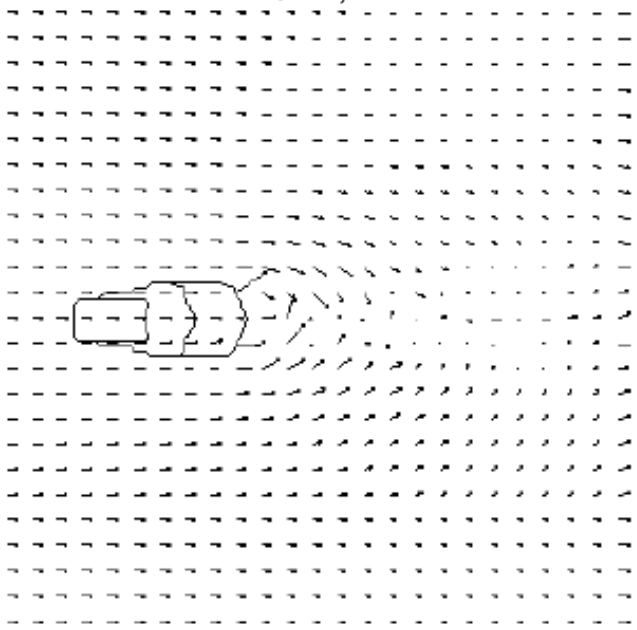


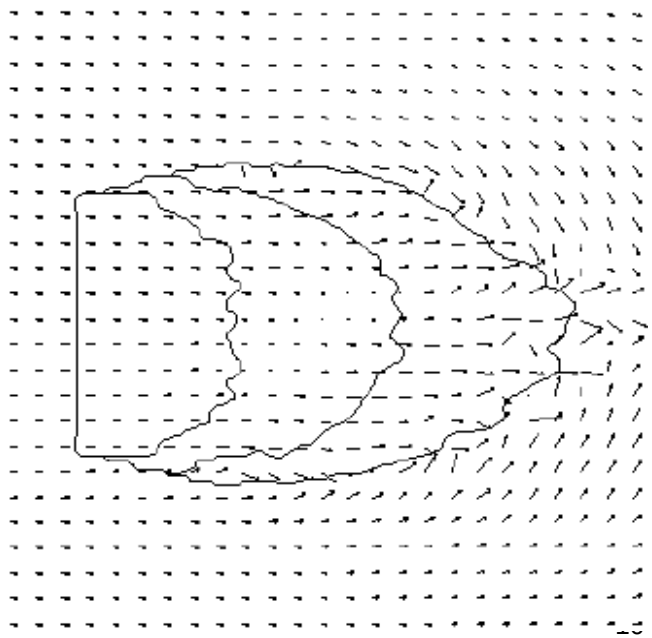
WFDS

t = 150 s, 250 s

FIRETEC

t = 80 s, 160 s, 240 s



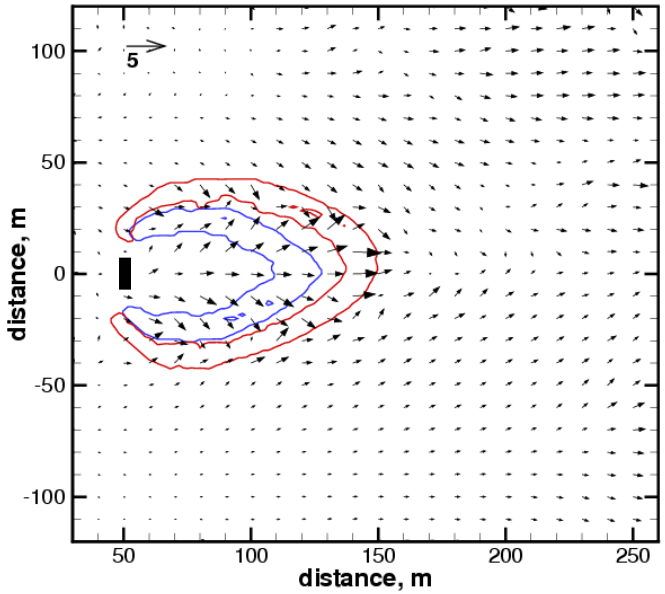


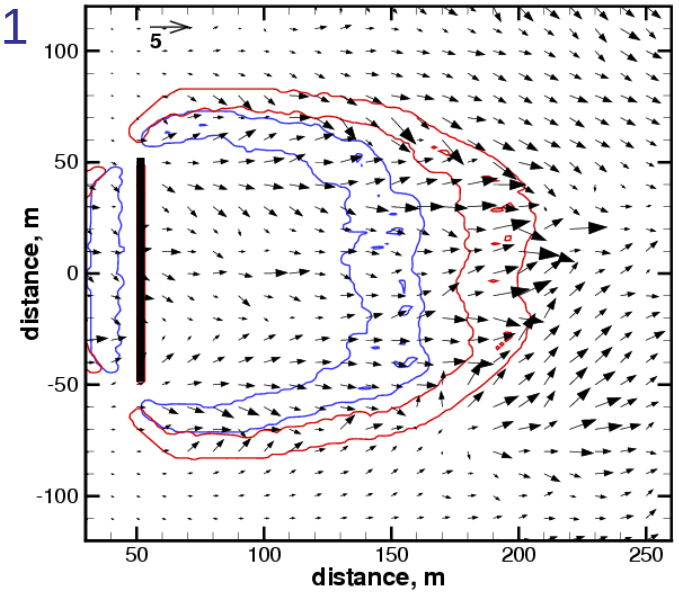
Tall Grass

L_{ig} = 16 m

L_{ig} = 100 m

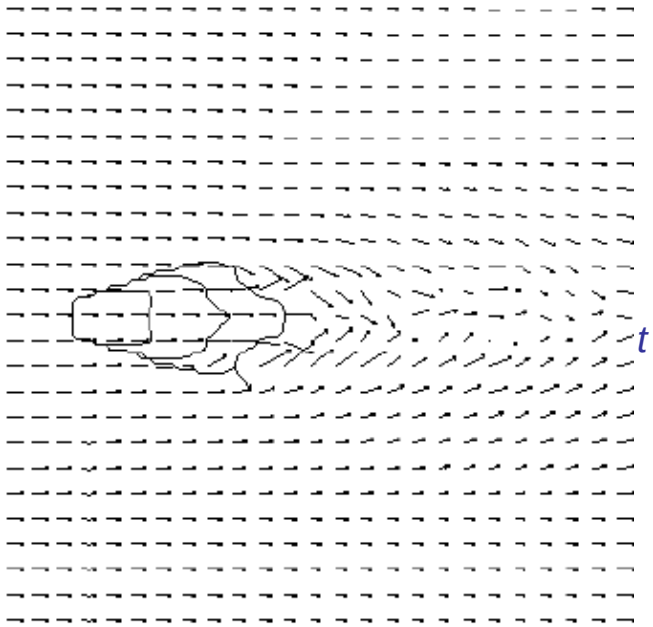
U_2=4 ms^{-1}





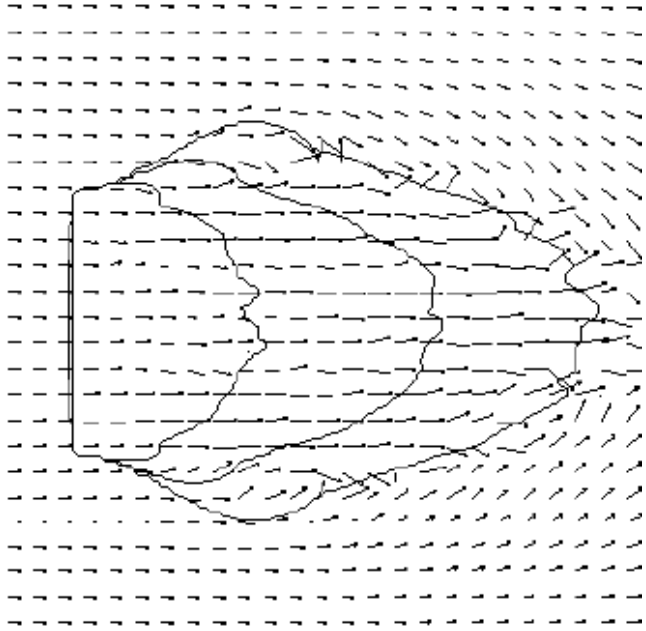
WFDS

t = 90 s, 150 s



FIRETEC

t = 50 s, 100 s, 150 s



Summary

- Predictions of head fire behavior:
  - R vs. U_2 for fires which can not spread upwind:
    - trends are well predicted by both FIRETEC (JGR, 2005) and WFDS
  - R vs. W
    - both FIRETEC and WFDS predict the trend of R increasing with W
- Predictions of backing and flank fire behavior:
  - AU experiments (fire break prevents backing fire)
    - FIRETEC untested
    - WFDS seems to over predict flank fire spread rate, need more data
  - "tall" grass
    - FIRETEC: inconsistent with observed trend of more likely spread at lower U_2.
    - WFDS: consistent with observed trend.
- Model implementation
  - Both the computational expense of FIRETEC (~100 times slower than WFDS in our preliminary work here) and the absence of a FIRETEC developer limited the scope of the study.