2018 WRF/MPAS Workshop
12 June 2018

Terrain-driven winds and gusts during the Thomas fire

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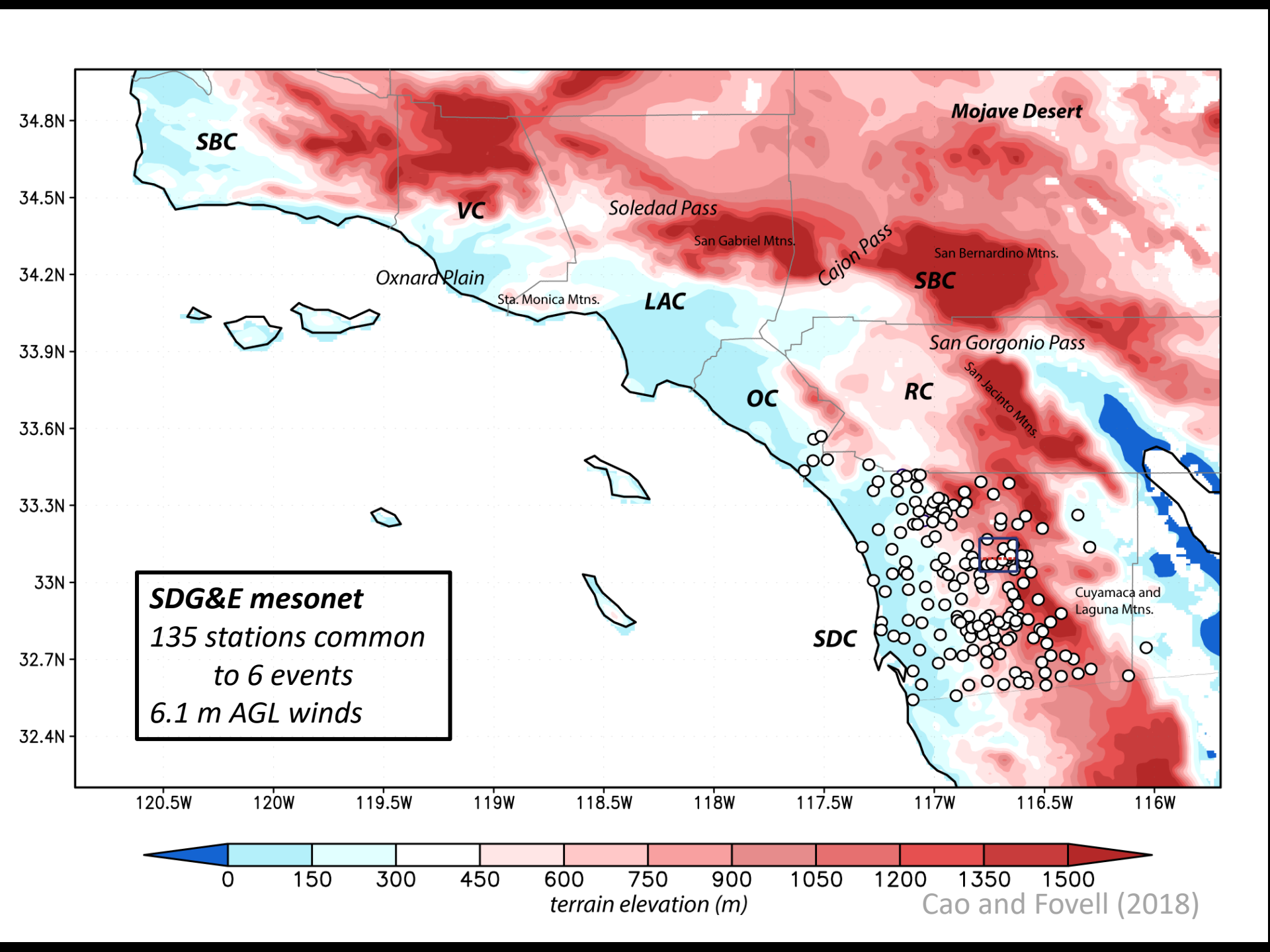
Thomas fire facts

- Started early evening 4 December 2017 during a Santa Ana event
- Containment took 39 days
- #1 in modern California history (~282,000 acres burned)
- 2 deaths, 1000+ structures destroyed
- 20 more fatalities owing to subsequent mudslides

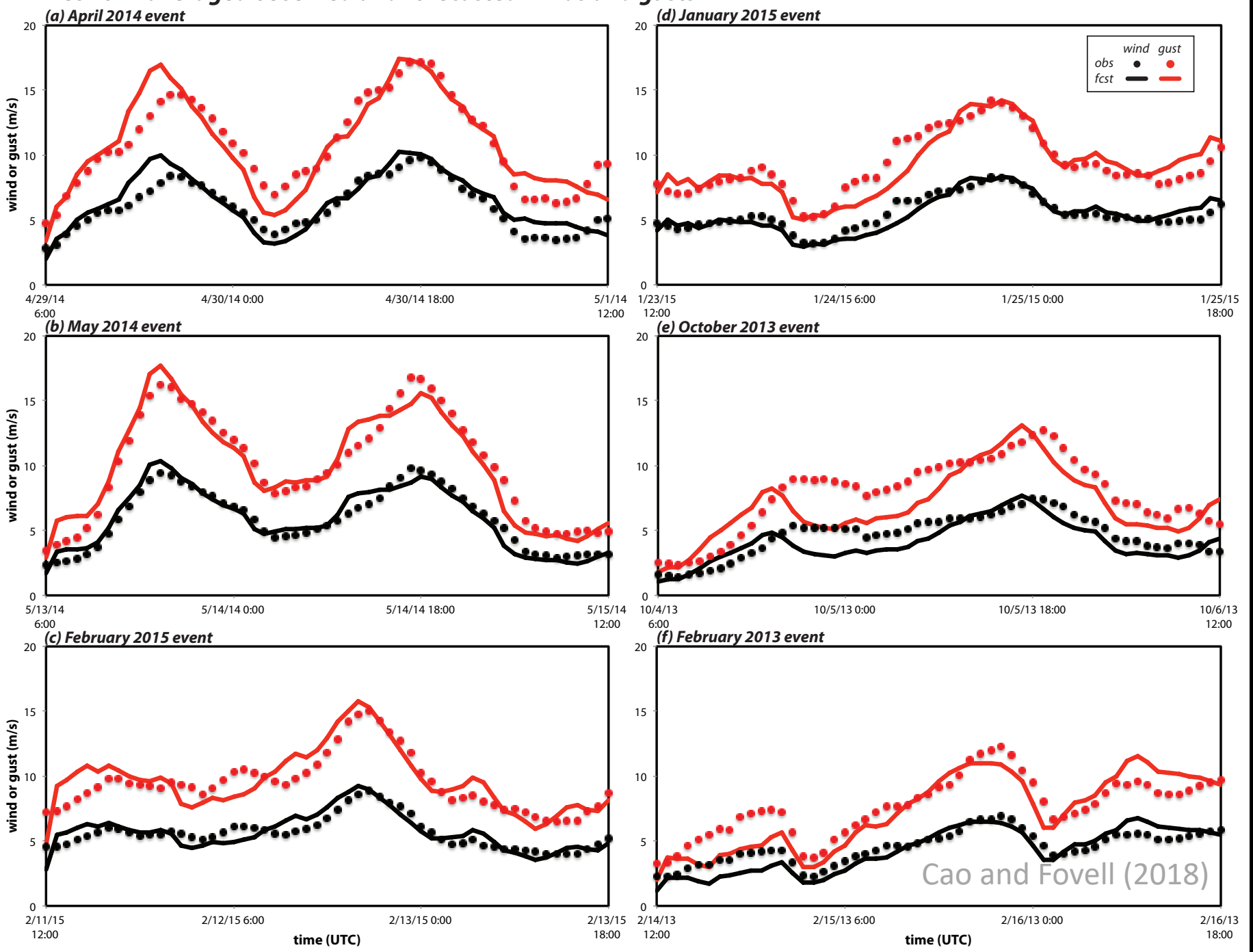
Main points

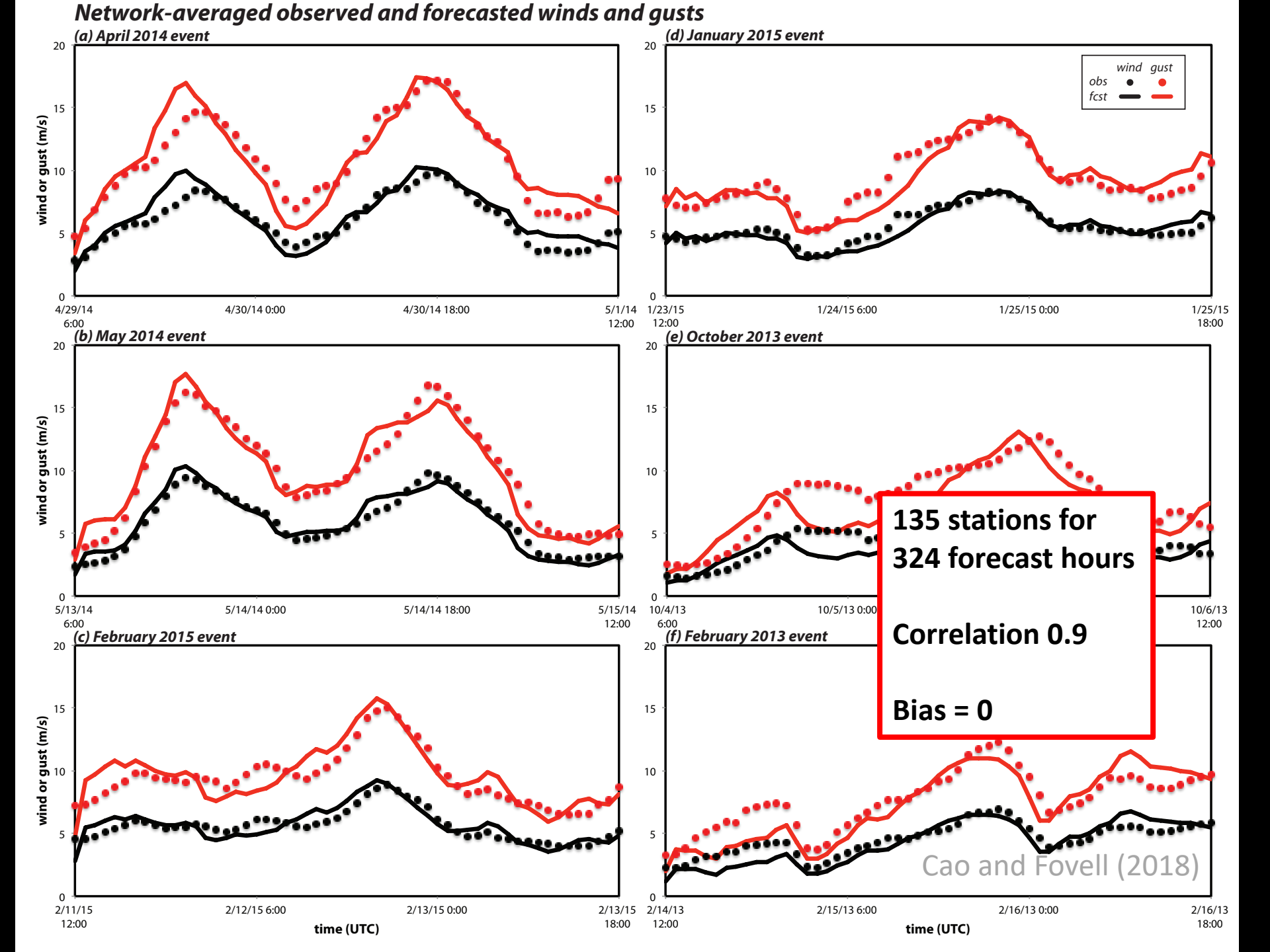
- High-resolution simulations suggest strong winds near fire origin site were localized
- Well-calibrated forecasts still underpredict sustained winds at windier locations
- Most citizen-provided observations are unreliable

Background on wind forecasting in Southern California



Cao and Fovell (2018)


Network-averaged observed and forecasted winds and gusts
(a) April 2014 event
(b) May 2014 event
(c) February 2015 event
(d) January 2015 event
(e) October 2013 event
(f) February 2013 event
wind or gust (m/s)
time (UTC)
wind gust
obs
fcst
4/29/14 6:00
4/30/14 0:00
4/30/14 18:00
5/1/14 12:00
5/13/14 6:00
5/14/14 0:00
5/14/14 18:00
5/15/14 12:00
2/11/15 12:00
2/12/15 6:00
2/13/15 0:00
2/13/15 18:00
1/23/15 12:00
1/24/15 6:00
1/25/15 0:00
1/25/15 18:00
10/4/13 6:00
10/5/13 0:00
10/5/13 18:00
10/6/13 12:00
2/14/13 12:00
2/15/13 6:00
2/16/13 0:00
2/16/13 18:00
Cao and Fovell (2018)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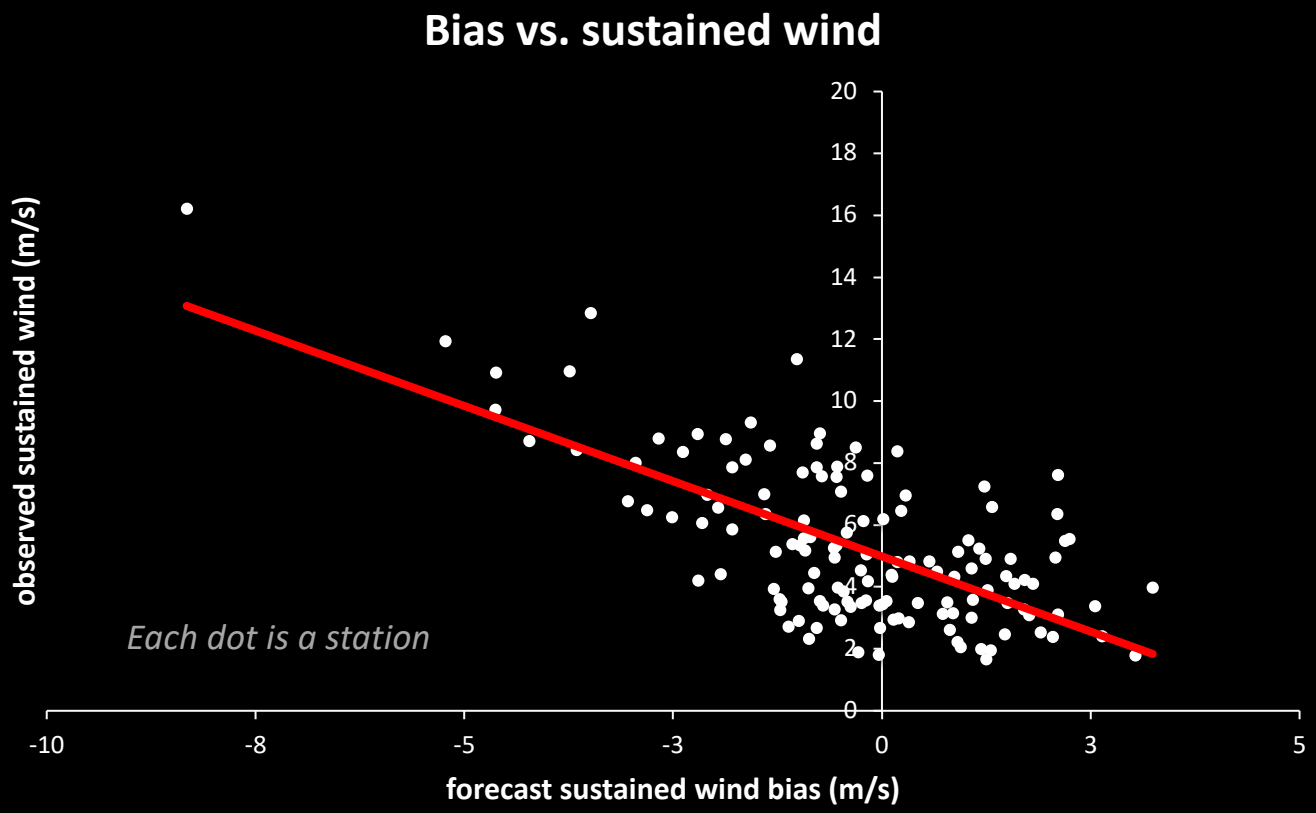
1/23/15 12:00
1/24/15 6:00
1/25/15 0:00
1/25/15 18:00
5/13/14 6:00
5/14/14 0:00
5/14/14 18:00
5/15/14 12:00
10/4/13 6:00
10/5/13 0:00
10/6/13 12:00
2/11/15 12:00
2/12/15 6:00
2/13/15 0:00
2/13/15 18:00
2/14/13 12:00
2/15/13 6:00
2/16/13 0:00
2/16/13 18:00
135 stations for
324 forecast hours
Correlation 0.9
Bias = 0
Cao and Fovell (2018)

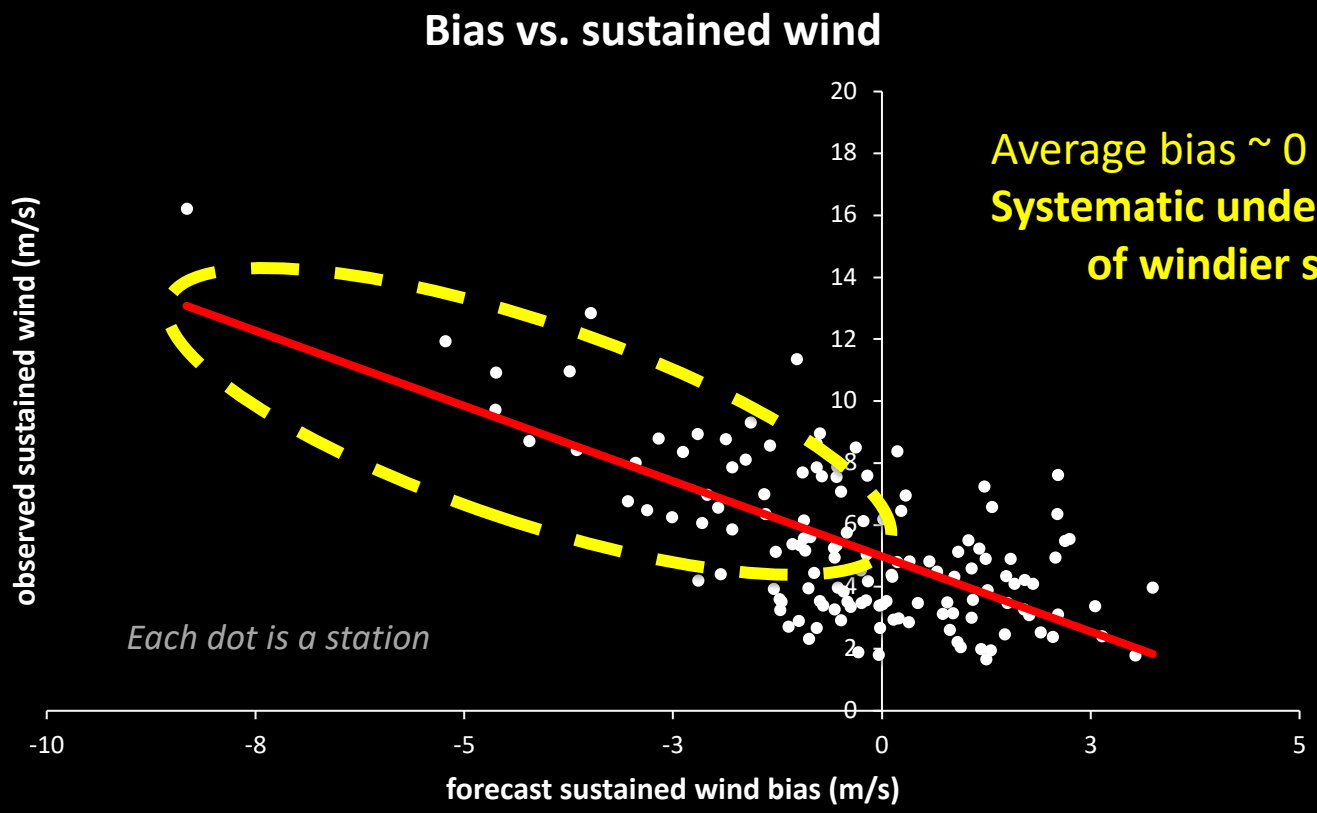
Systematic station forecast biases



135 SDG&E stations
6-event average
spanning 324 forecast hours

Cao and Fovell (2018)

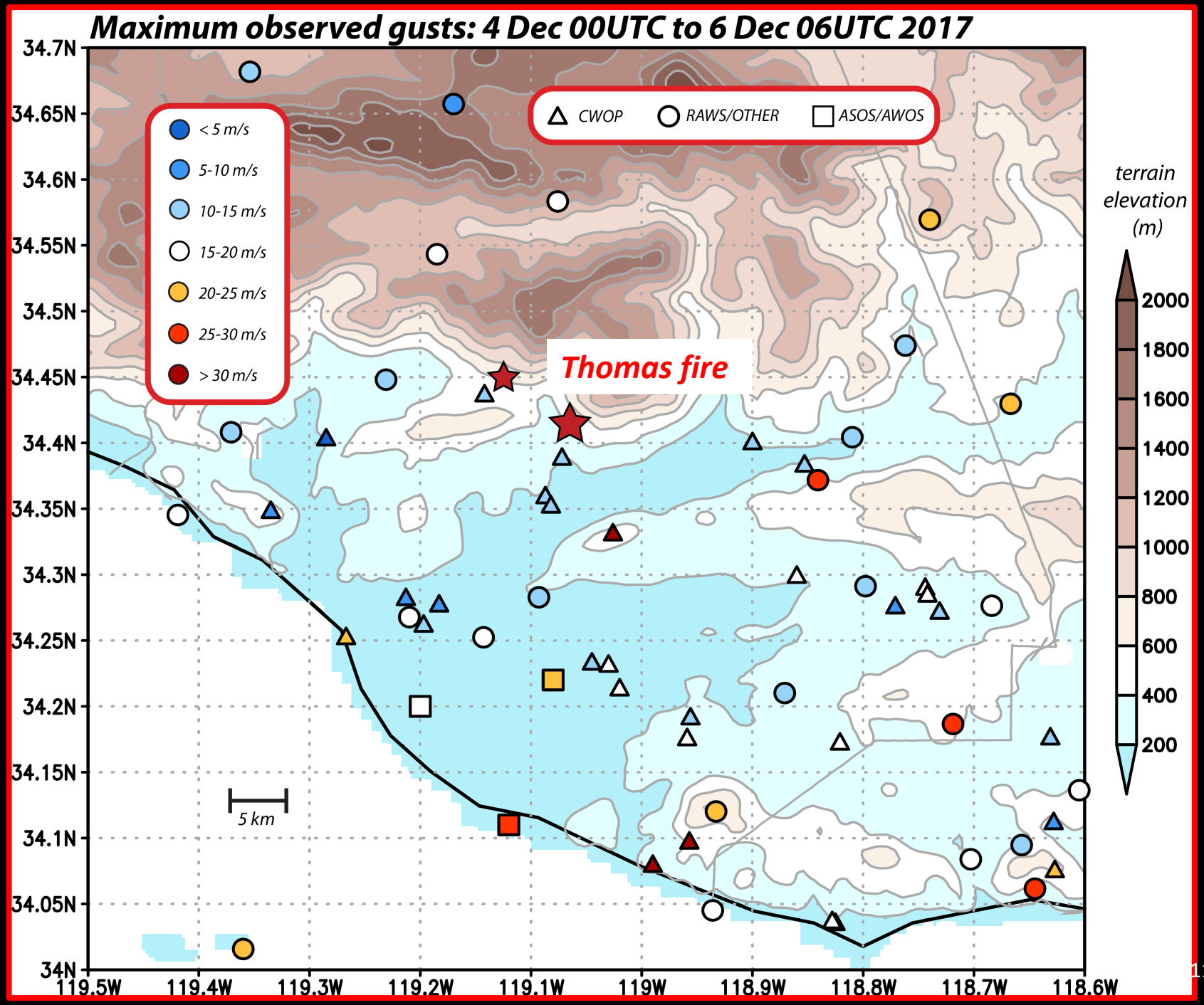
Systematic station forecast biases

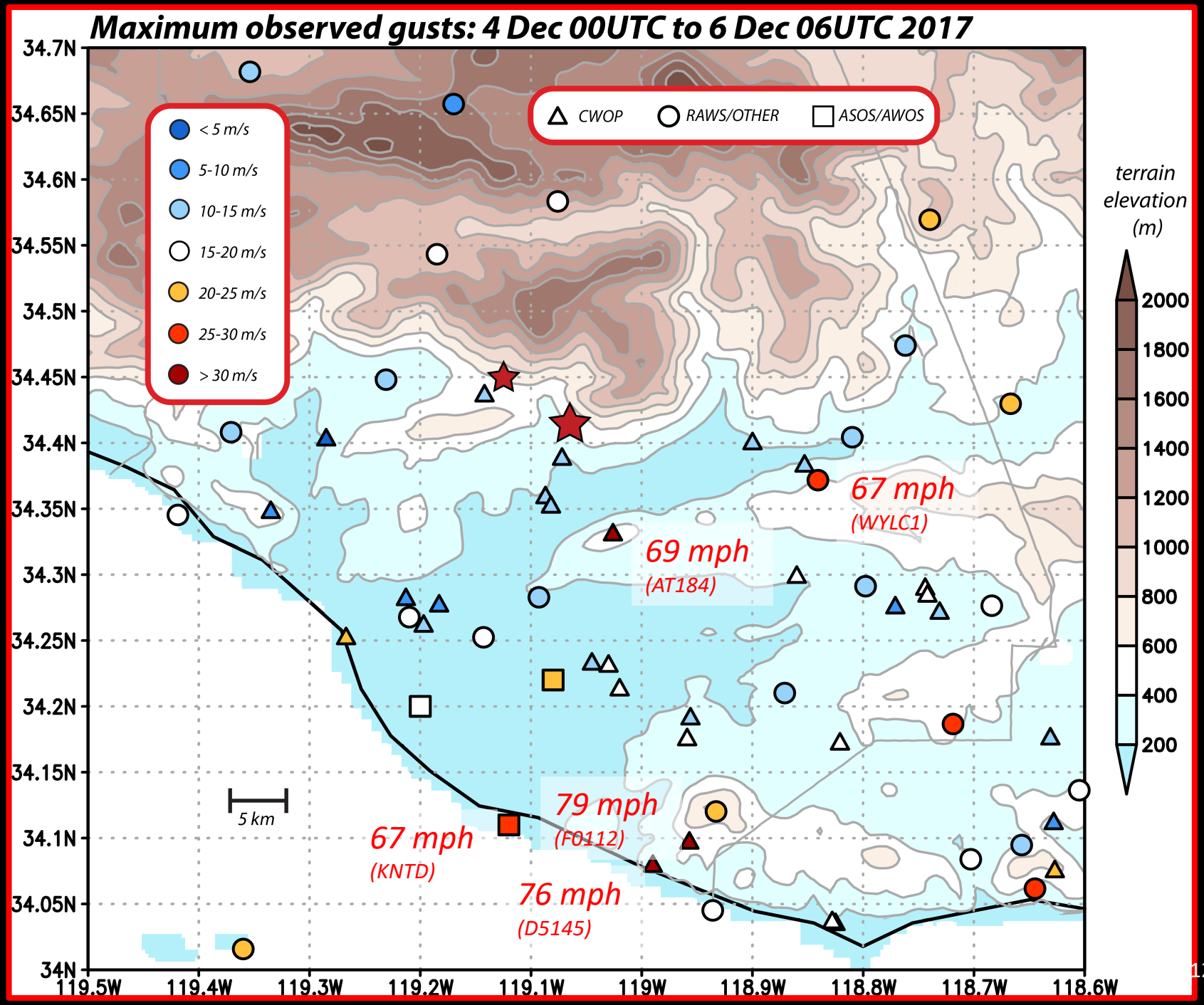


135 SDG&E stations
6-event average
spanning 324 forecast hours

Cao and Fovell (2018)

Thomas fire
observations and simulations


Maximum observed gusts: 4 Dec 00UTC to 6 Dec 06UTC 2017
< 5 m/s
5-10 m/s
10-15 m/s
15-20 m/s
20-25 m/s
25-30 m/s
> 30 m/s
CWOP
RAWS/OTHER
ASOS/AWOS
Thomas fire
5 km
terrain elevation (m)
2000
1800
1600
1400
1200
1000
800
600
400
200
34.7N
34.65N
34.6N
34.55N
34.5N
34.45N
34.4N
34.35N
34.3N
34.25N
34.2N
34.15N
34.1N
34.05N
34N
119.5W
119.4W
119.3W
119.2W
119.1W
119W
118.9W
118.8W
118.7W
118.6W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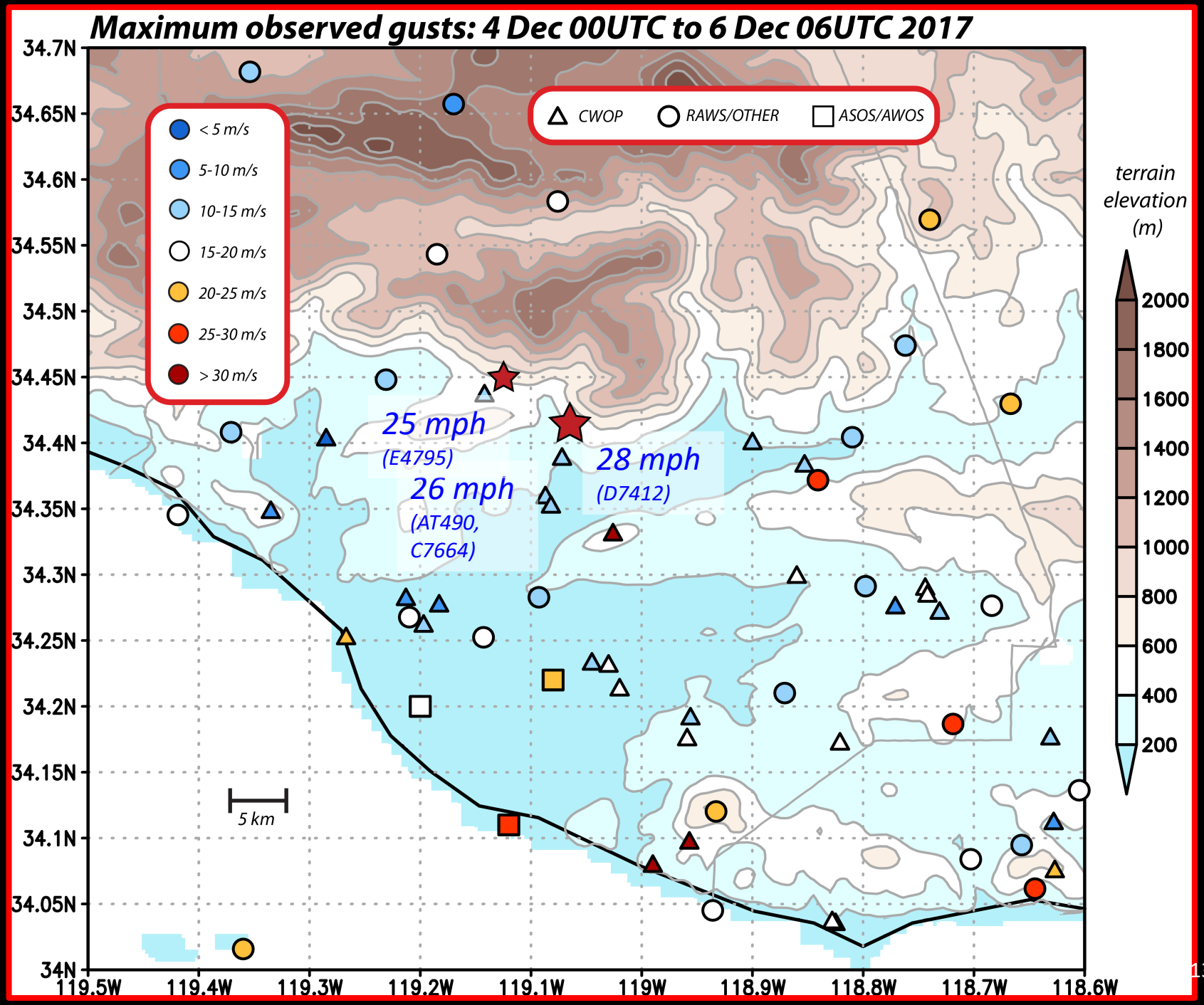
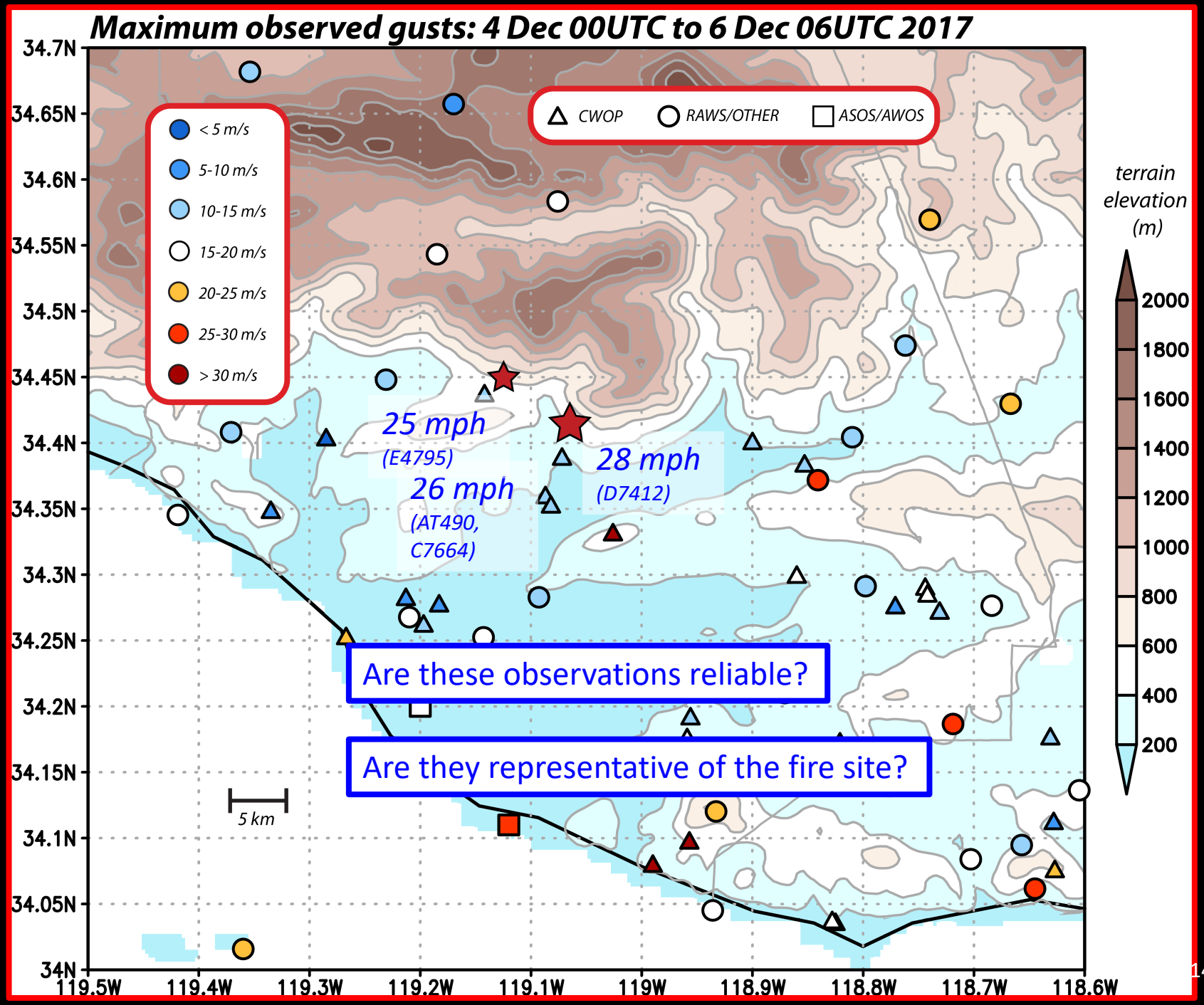
< 5 m/s
5-10 m/s
10-15 m/s
15-20 m/s
20-25 m/s
25-30 m/s
> 30 m/s
CWOP
RAWS/OTHER
ASOS/AWOS
terrain elevation (m)
2000
1800
1600
1400
1200
1000
800
600
400
200
67 mph (WYLC1)
69 mph (AT184)
79 mph (F0112)
67 mph (KNTD)
76 mph (D5145)
5 km
34.7N
34.65N
34.6N
34.55N
34.5N
34.45N
34.4N
34.35N
34.3N
34.25N
34.2N
34.15N
34.1N
34.05N
34N
119.5W
119.4W
119.3W
119.2W
119.1W
119W
118.9W
118.8W
118.7W
118.6W


Maximum observed gusts: 4 Dec 00UTC to 6 Dec 06UTC 2017
< 5 m/s
5-10 m/s
10-15 m/s
15-20 m/s
20-25 m/s
25-30 m/s
> 30 m/s
CWOP
RAWS/OTHER
ASOS/AWOS
25 mph
(E4795)
26 mph
(AT490,
C7664)
28 mph
(D7412)
5 km
terrain
elevation
(m)
2000
1800
1600
1400
1200
1000
800
600
400
200
34.7N
34.65N
34.6N
34.55N
34.5N
34.45N
34.4N
34.35N
34.3N
34.25N
34.2N
34.15N
34.1N
34.05N
34N
119.5W
119.4W
119.3W
119.2W
119.1W
119W
118.9W
118.8W
118.7W
118.6W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< 5 m/s
5-10 m/s
10-15 m/s
15-20 m/s
20-25 m/s
25-30 m/s
> 30 m/s
CWOP
RAWS/OTHER
ASOS/AWOS
terrain elevation (m)
2000
1800
1600
1400
1200
1000
800
600
400
200
25 mph
(E4795)
26 mph
(AT490, C7664)
28 mph
(D7412)
Are these observations reliable?
Are they representative of the fire site?
5 km
34.7N
34.65N
34.6N
34.55N
34.5N
34.45N
34.4N
34.35N
34.3N
34.25N
34.2N
34.15N
34.1N
34.05N
34N
119.5W
119.4W
119.3W
119.2W
119.1W
119W
118.9W
118.8W
118.7W
118.6W

Simulations

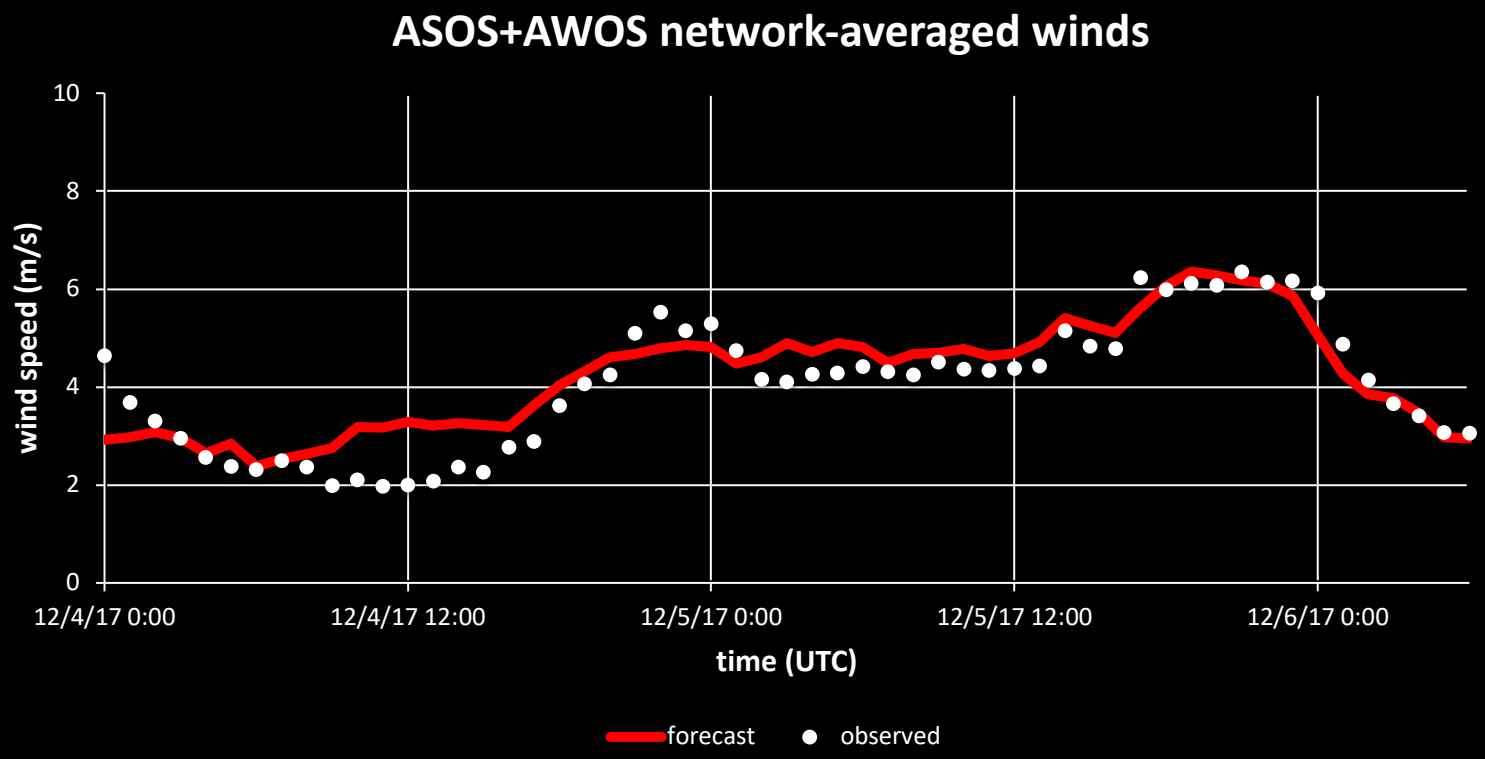
- WRF v.3.7.1
- Telescoping to 667 m horizontal resolution
- Initialized with NAM on 4 December at 00Z
- 54 h
- PX LSM/ACM2 PBL
- Thomas fire onset at forecast hour ~ 26.5

Network-averaged wind predictions

All stations in 2 km domain over Southern California

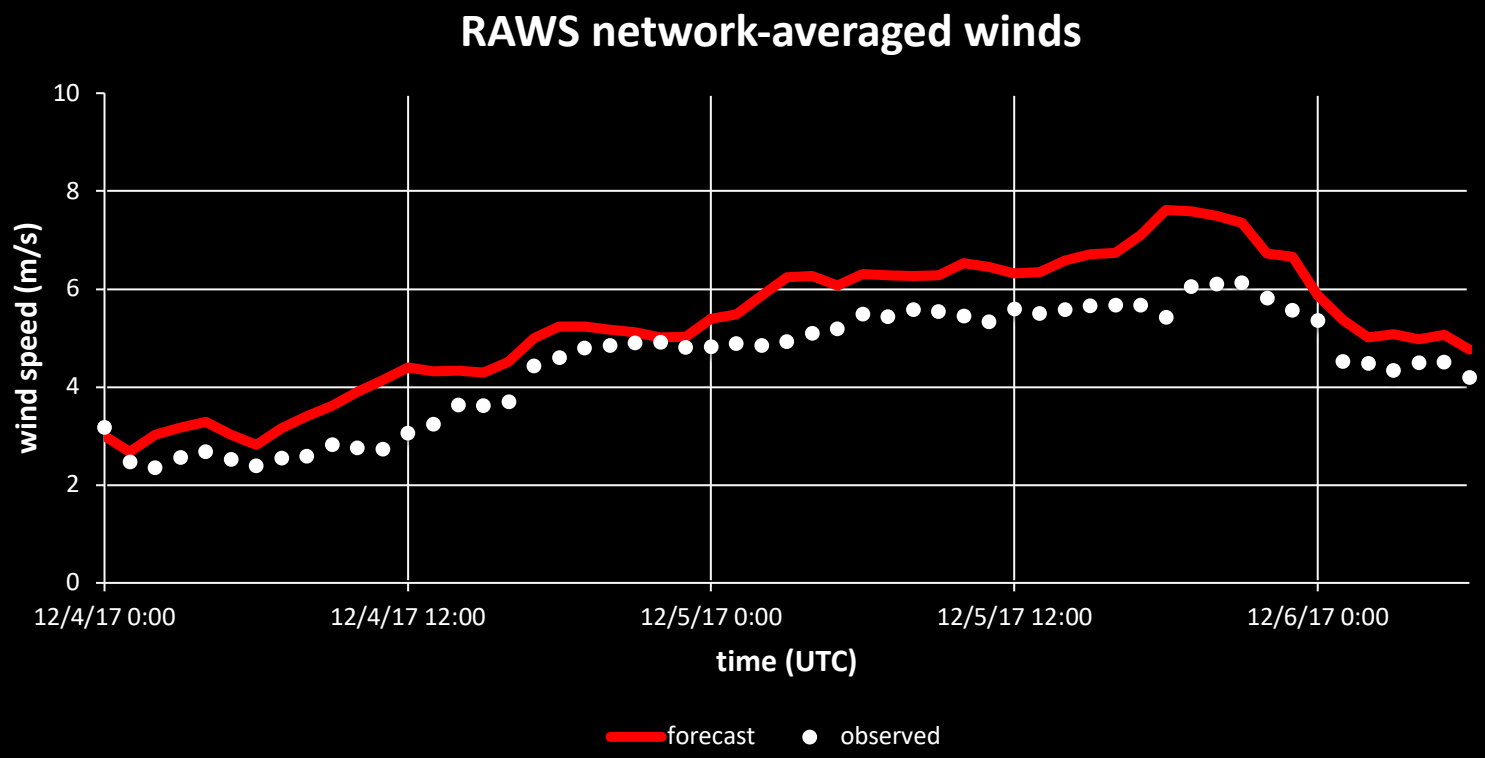
(724 total)

ASOS/AWOS network-averaged winds (10 m AGL)



N = 65 stations
Max 6.4 m/s (14 mph)

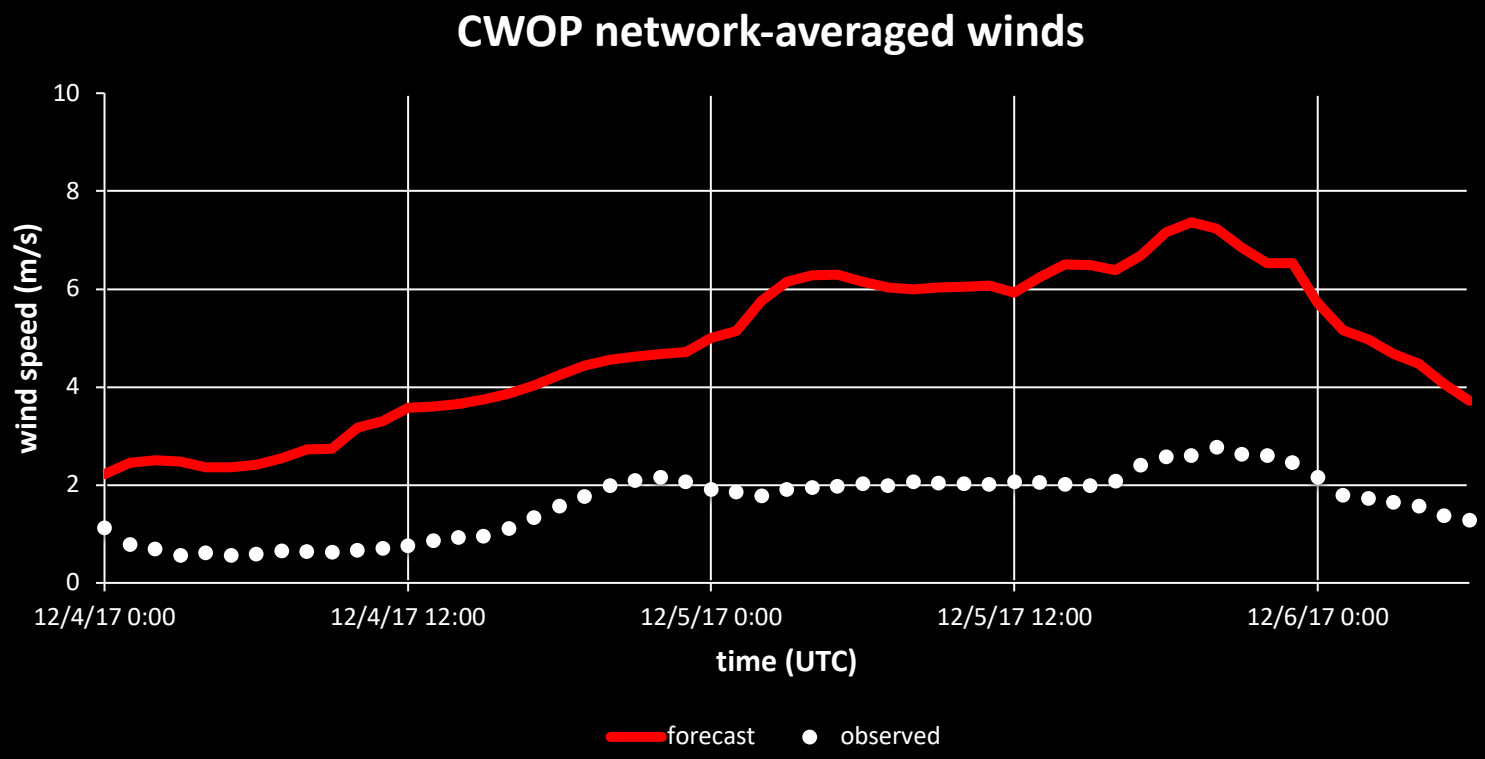
RAWS network-averaged winds (adjusted to 6.1 m AGL)



- rougher terrain
- lower anemometer height
- more obstructed

N = 78 stations
Max 6.1 m/s (13.7 mph)

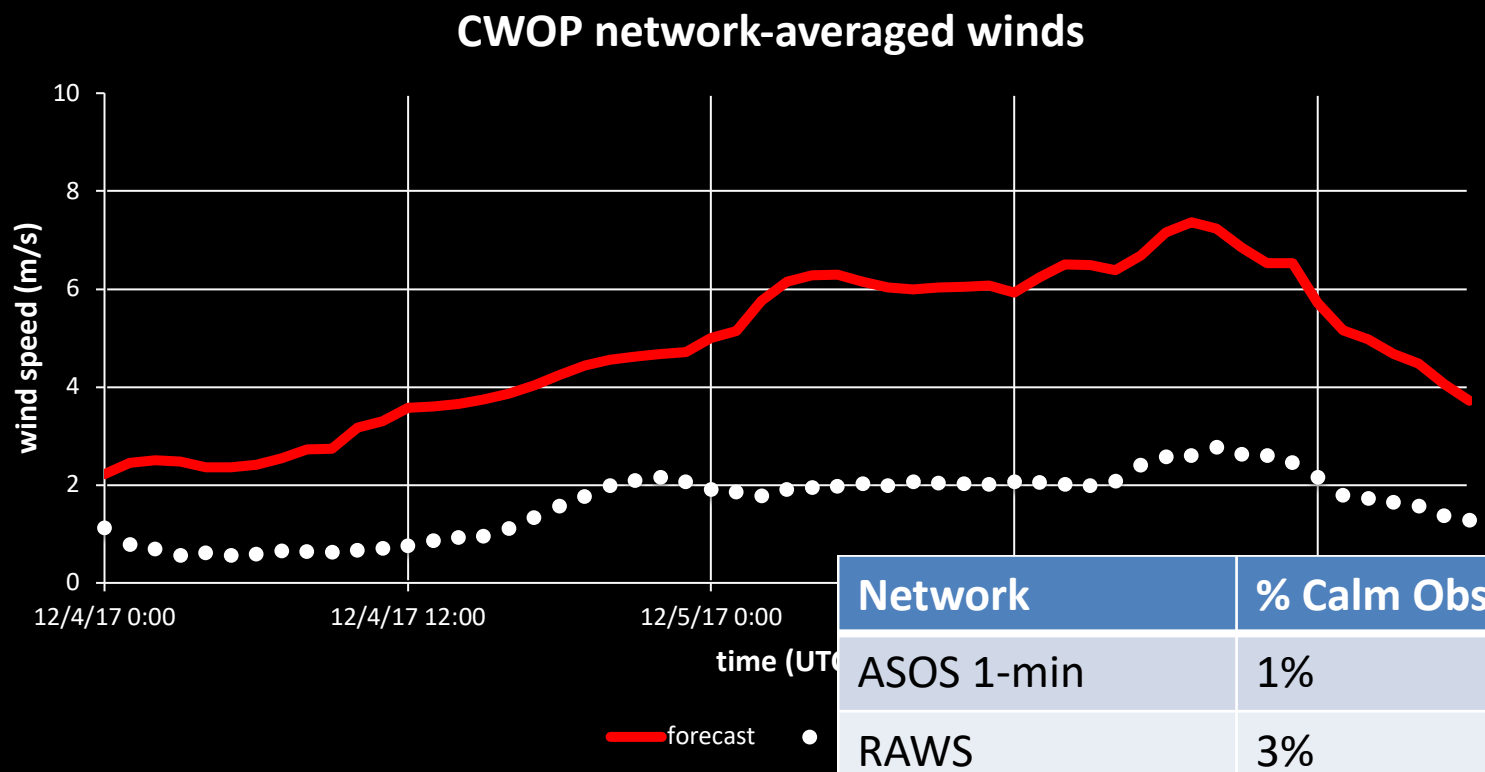
CWOP network-averaged winds (presumed 10 m AGL)



N = 415 stations (57% of total)
Max 2.8 m/s (6.2 mph)

CWOP = Citizen Weather Observing Program

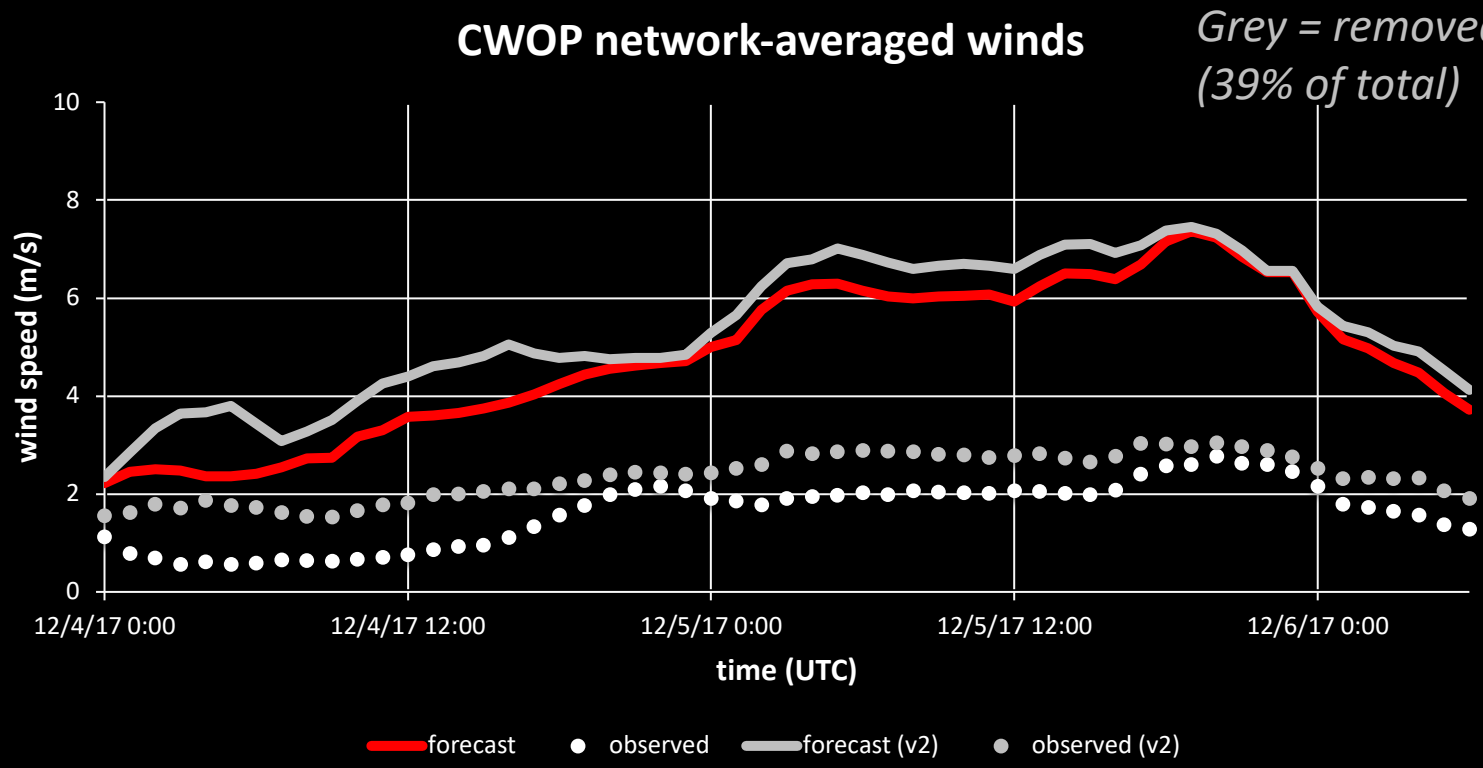
CWOP network-averaged winds (presumed 10 m AGL)



Network	% Calm Obs
ASOS 1-min	1%
RAWS	3%
SDG&E	1%
CWOP	**39%**

N = 415 stations
Max 2.8 m/s (6.2 mph)

CWOP network-averaged winds (presumed 10 m AGL)



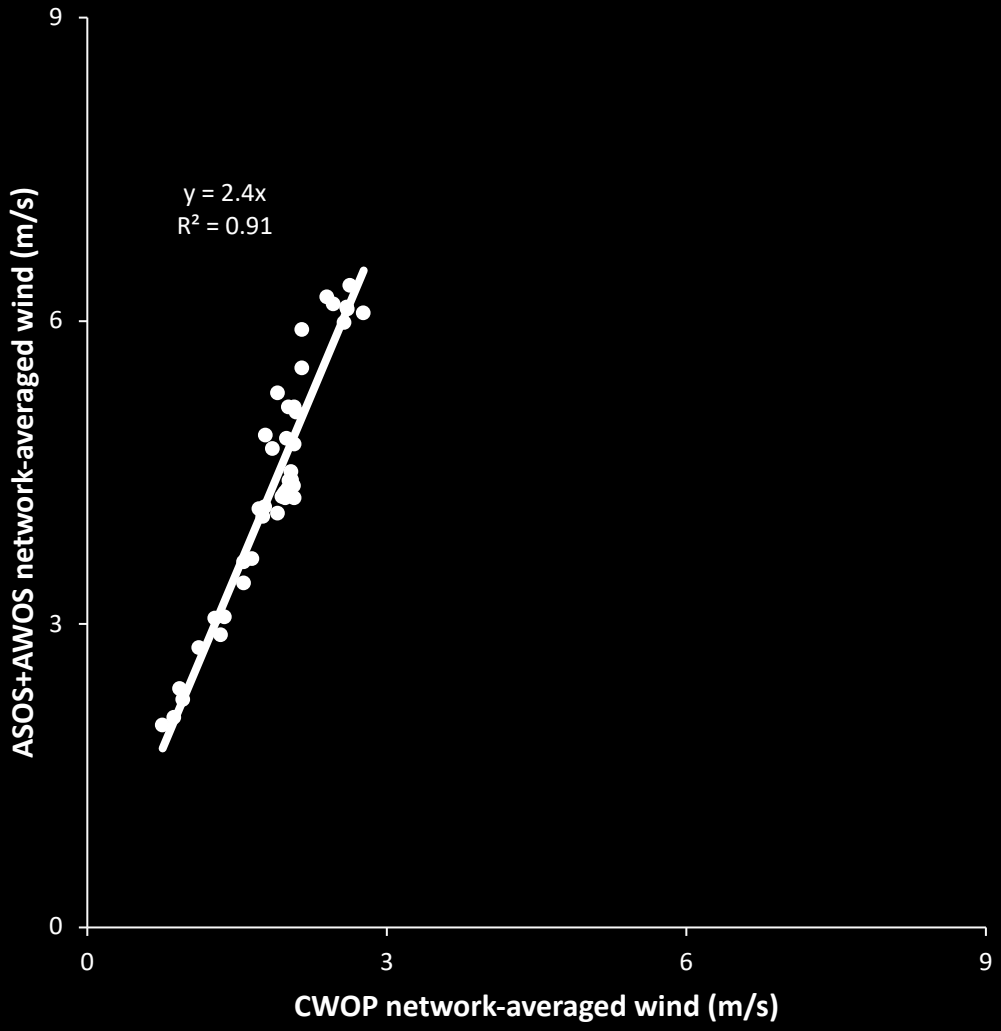
Grey = removed calm obs (39% of total)

- urban setting
- unknown anemometer height
- likely very obstructed

N = 415 stations
Max 2.8 m/s (6.2 mph)

ASOS/AWOS vs. CWOP

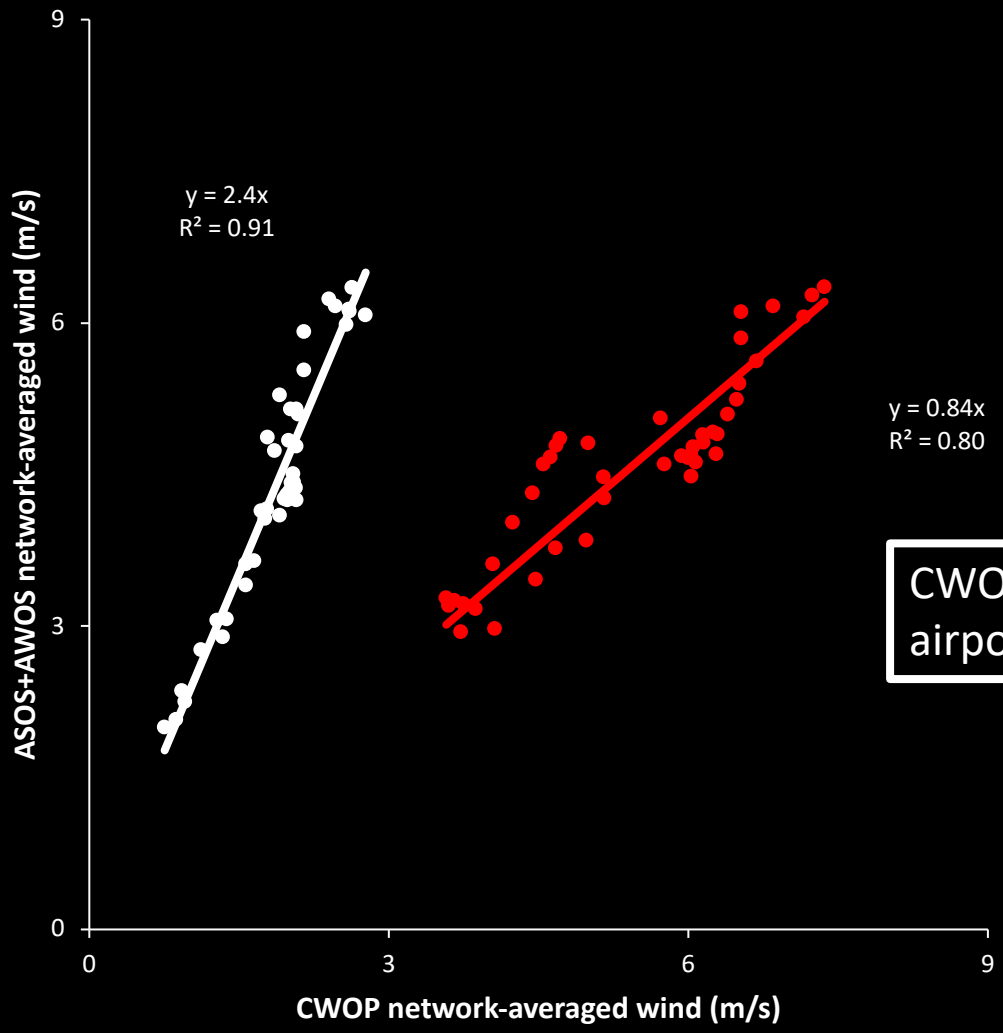
CWOP winds 42% slower than airport winds



Hourly network-averaged observations and forecasts after 12h

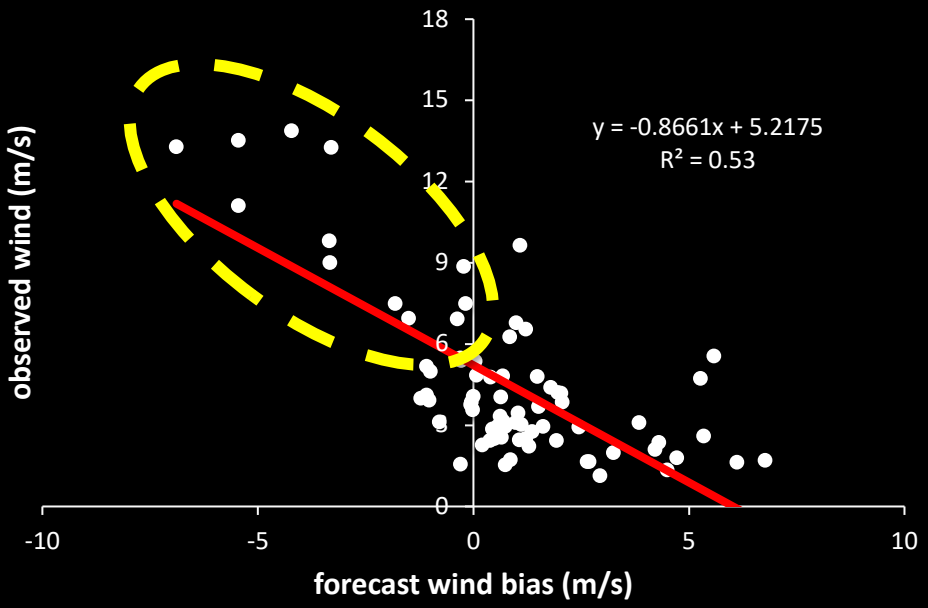
ASOS/AWOS vs. CWOP

CWOP winds 42% slower than airport winds



Hourly network-averaged observations and forecasts after 12h

RAWS: forecast bias vs. observed wind



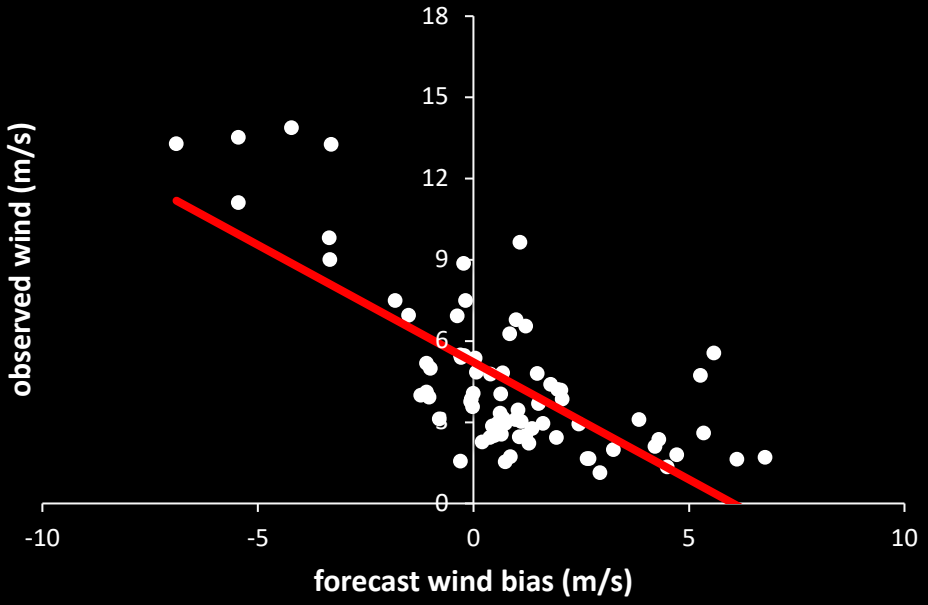
RAWS

N = 76 stations

Avg. bias 0.7 m/s

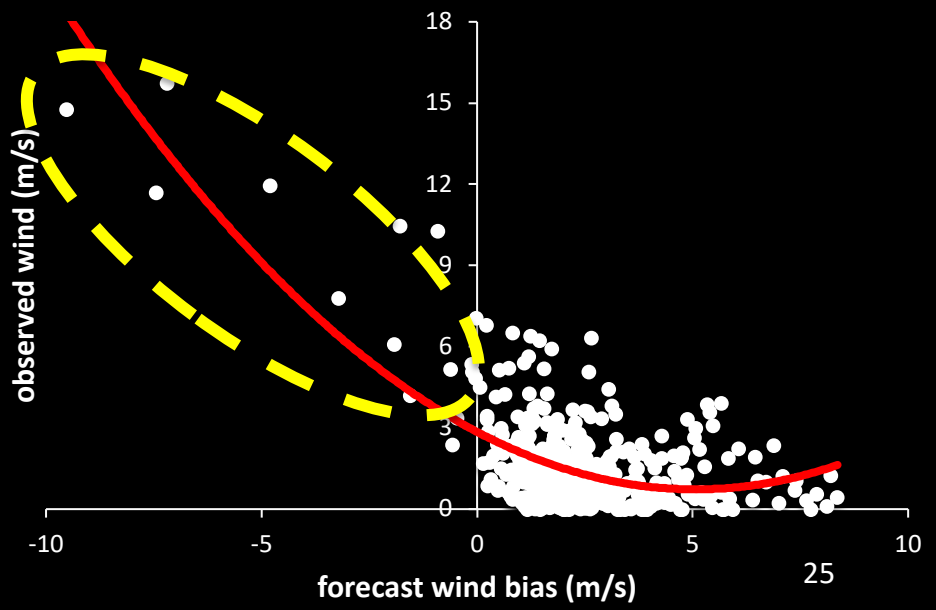
Systematically underpredicting higher wind stations

RAWS: forecast bias vs. observed wind

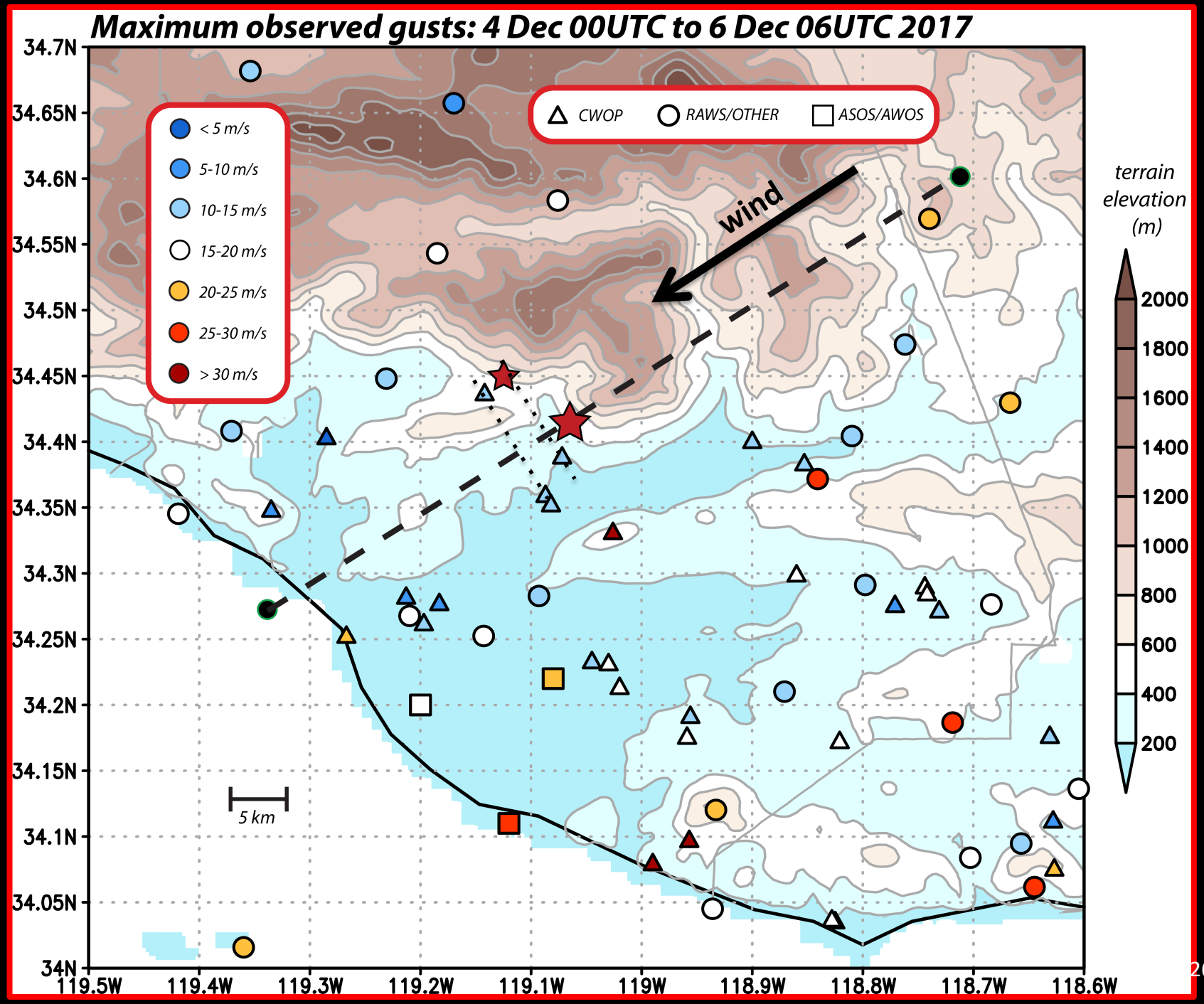


RAWS
N = 76 stations
Avg. bias 0.7 m/s
Systematically underpredicting
higher wind stations

CWOP: forecast bias vs. obs wind



CWOP
N = 421 stations
Avg. bias 2.4 m/s
Only 16/421 (4%) underpredicted
Systematically underpredicting
higher wind stations (still!)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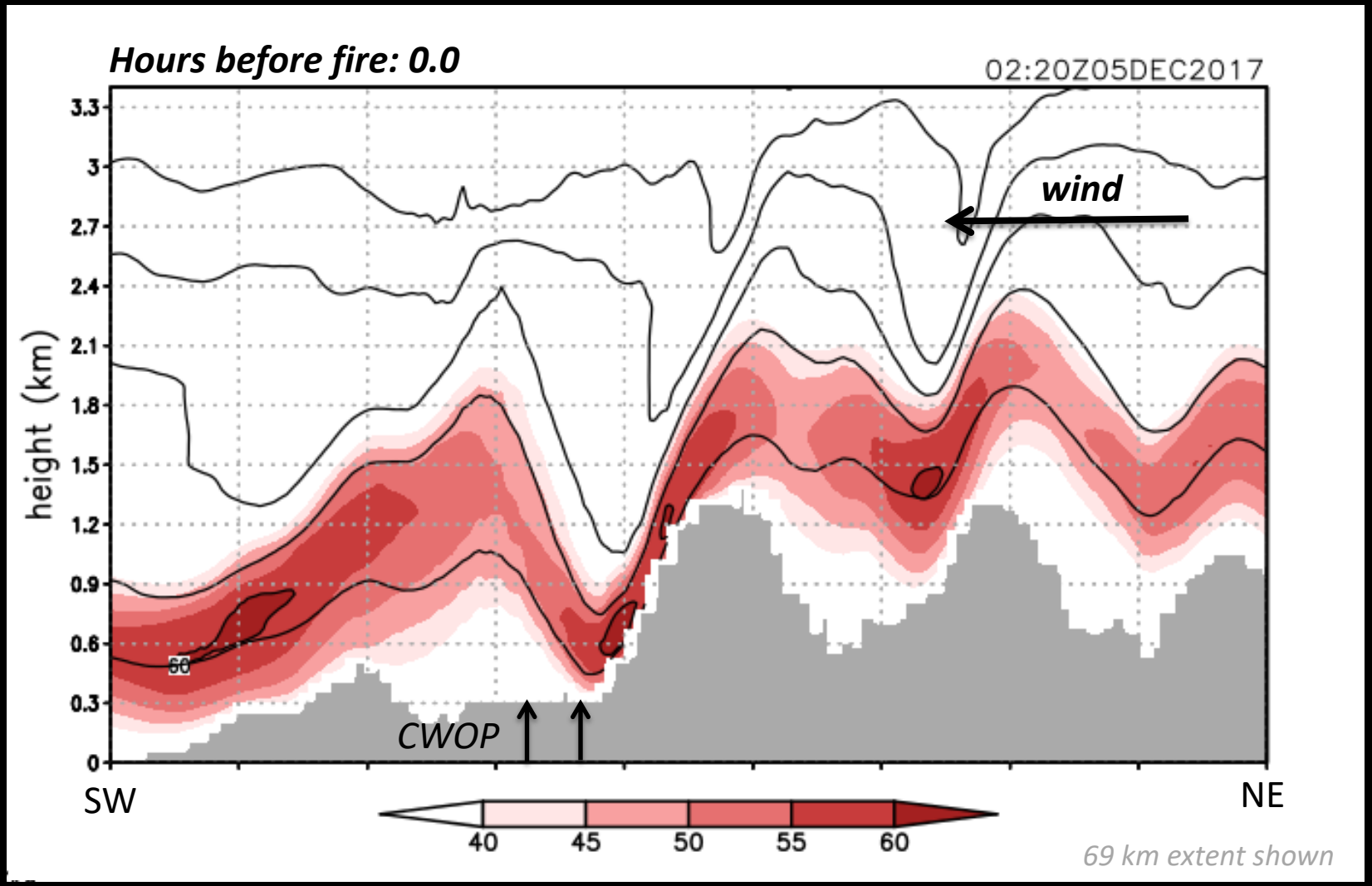
5-10 m/s
10-15 m/s
15-20 m/s
20-25 m/s
25-30 m/s
> 30 m/s
CWOP
RAWS/OTHER
ASOS/AWOS
wind
5 km
terrain elevation (m)
2000
1800
1600
1400
1200
1000
800
600
400
200
34.7N
34.65N
34.6N
34.55N
34.5N
34.45N
34.4N
34.35N
34.3N
34.25N
34.2N
34.15N
34.1N
34.05N
34N
119.5W
119.4W
119.3W
119.2W
119.1W
119W
118.9W
118.8W
118.7W
118.6W

Simulated winds at fire onset



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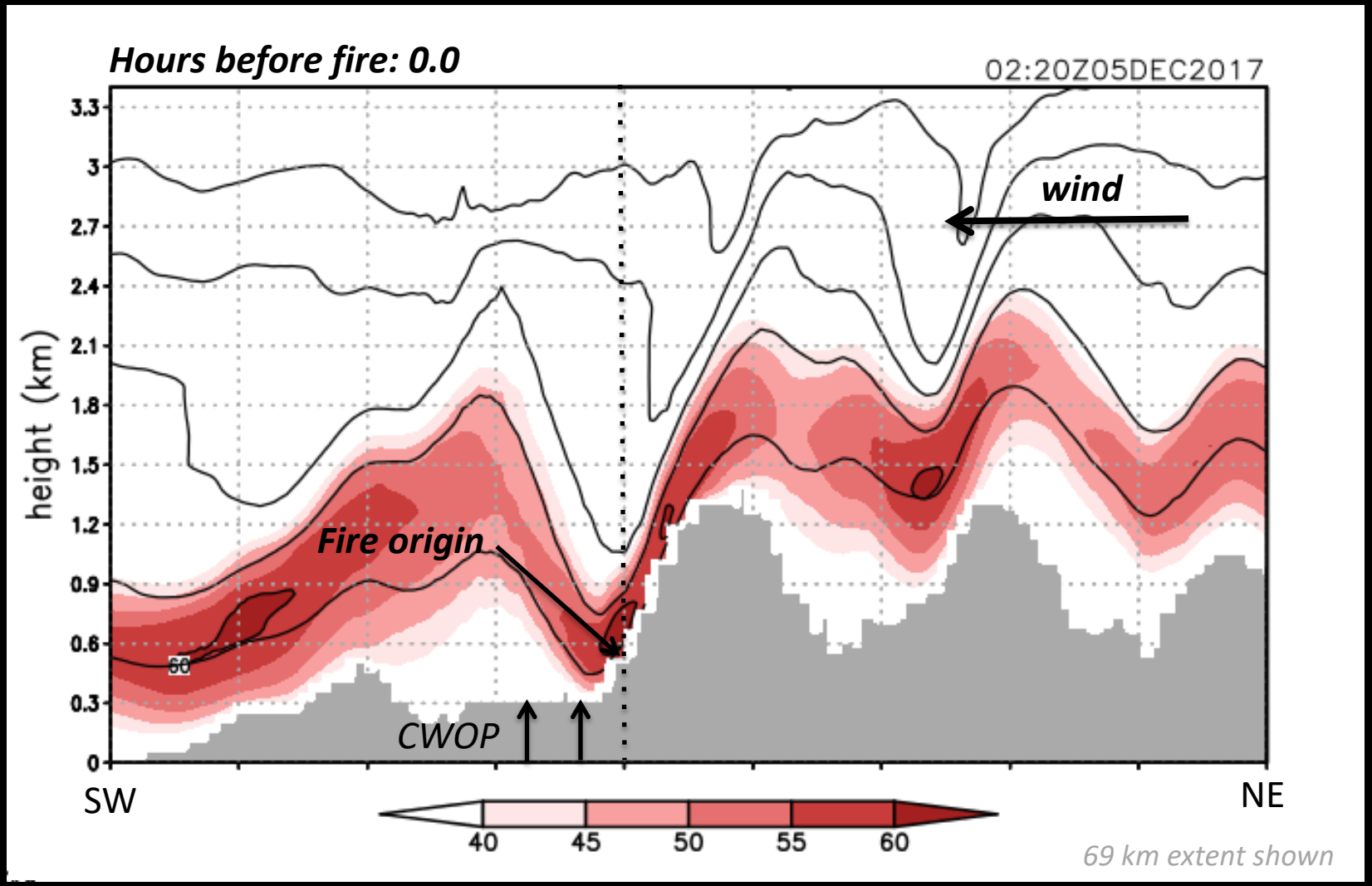
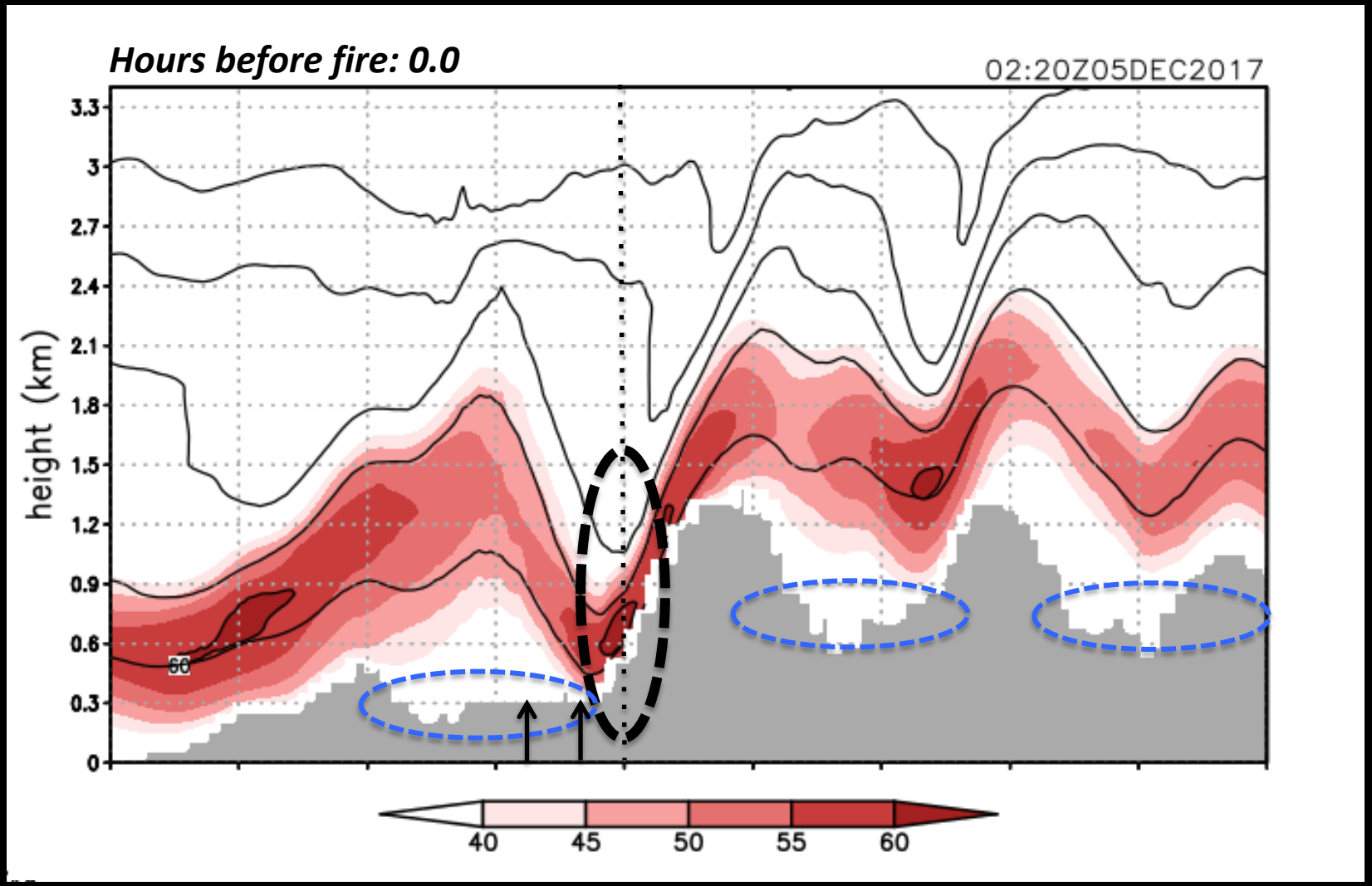
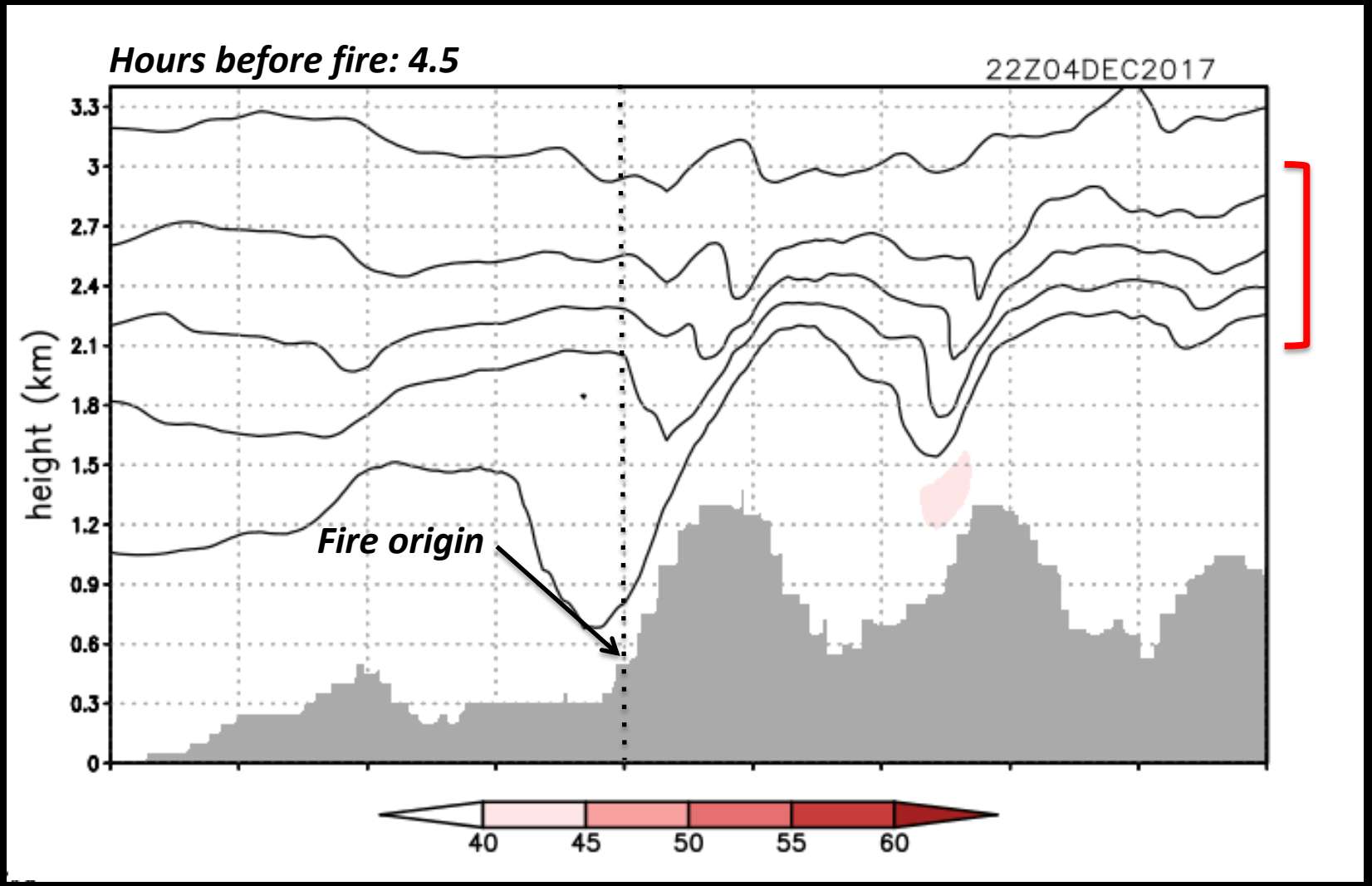
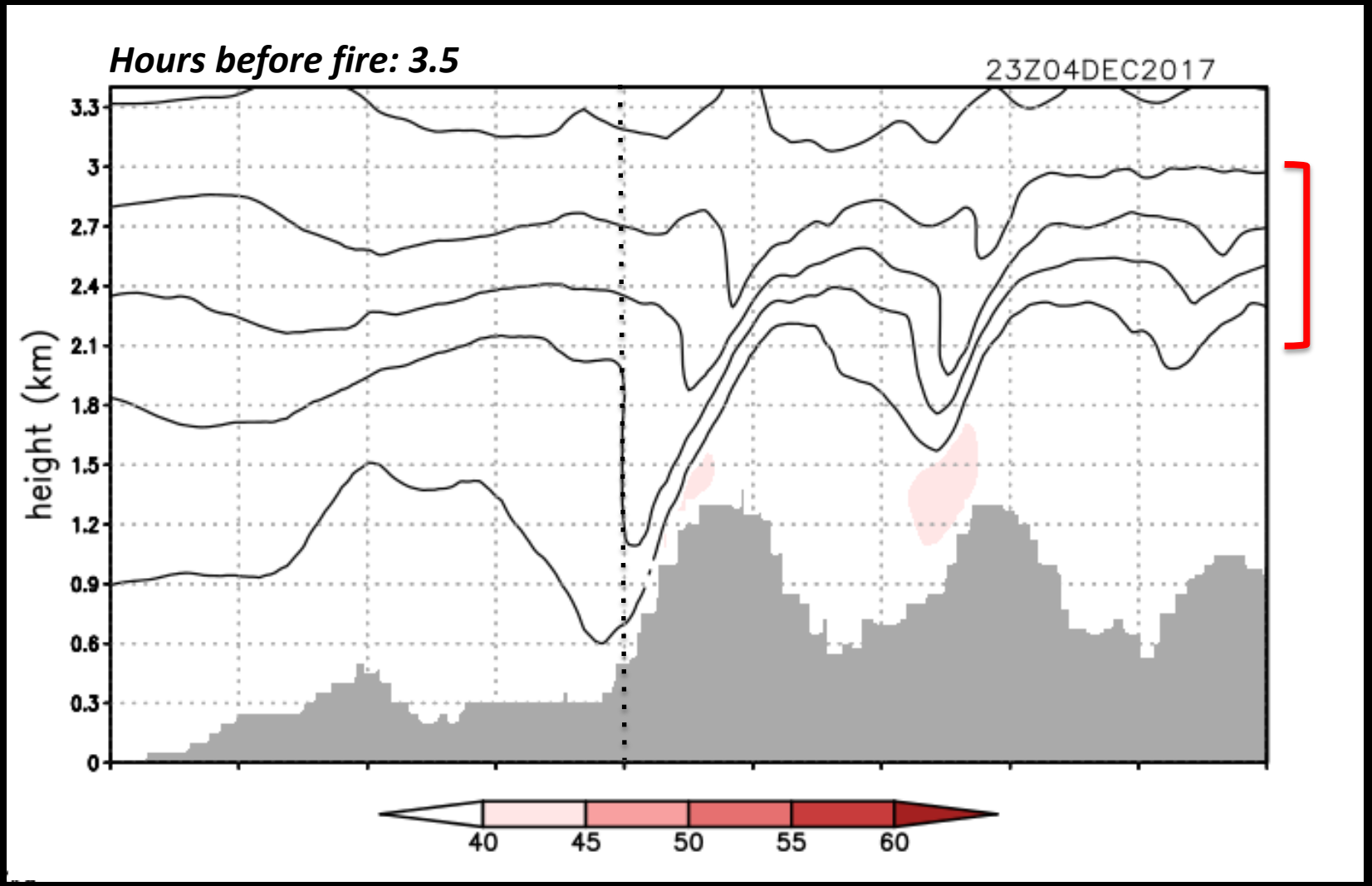
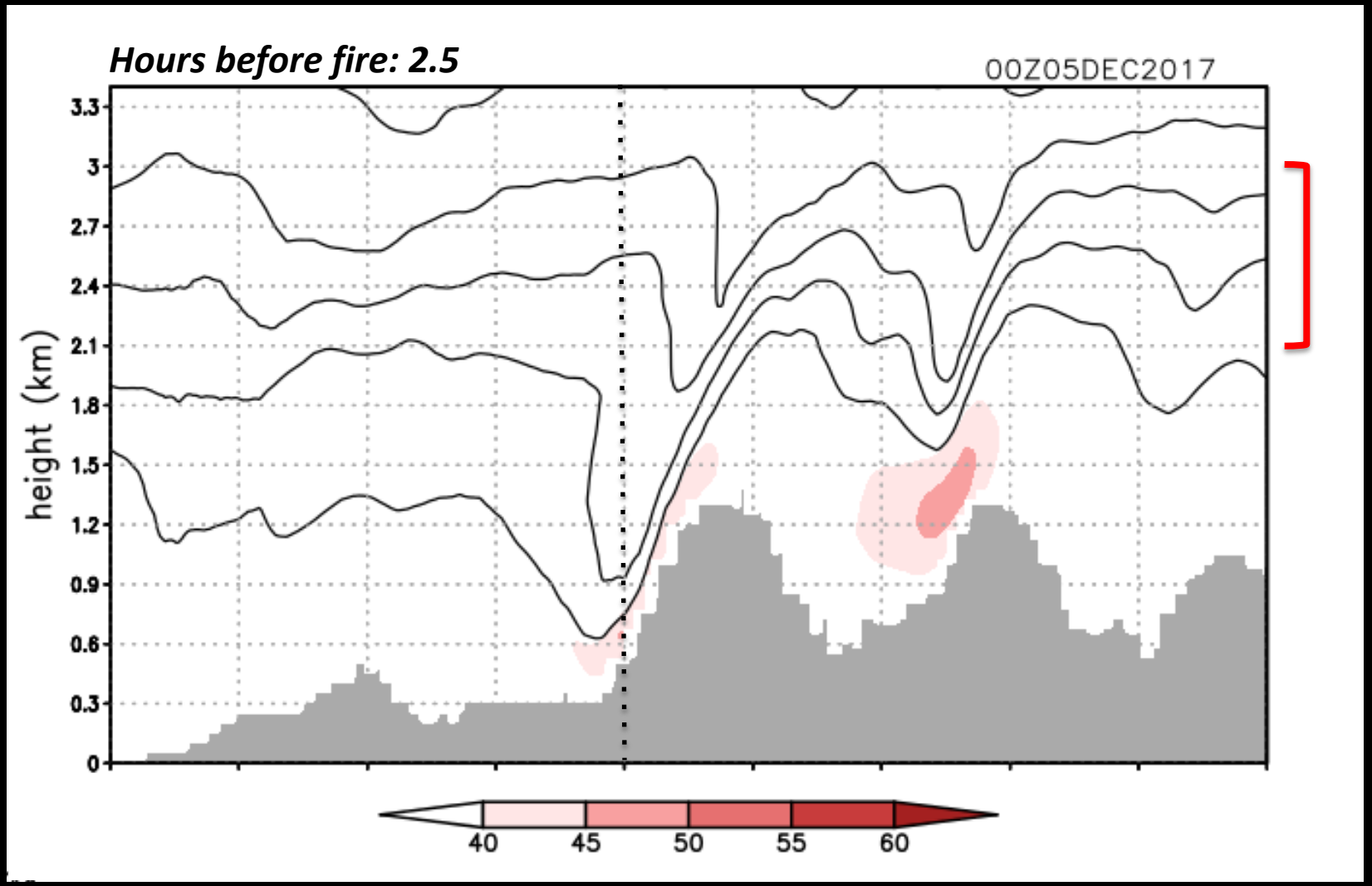


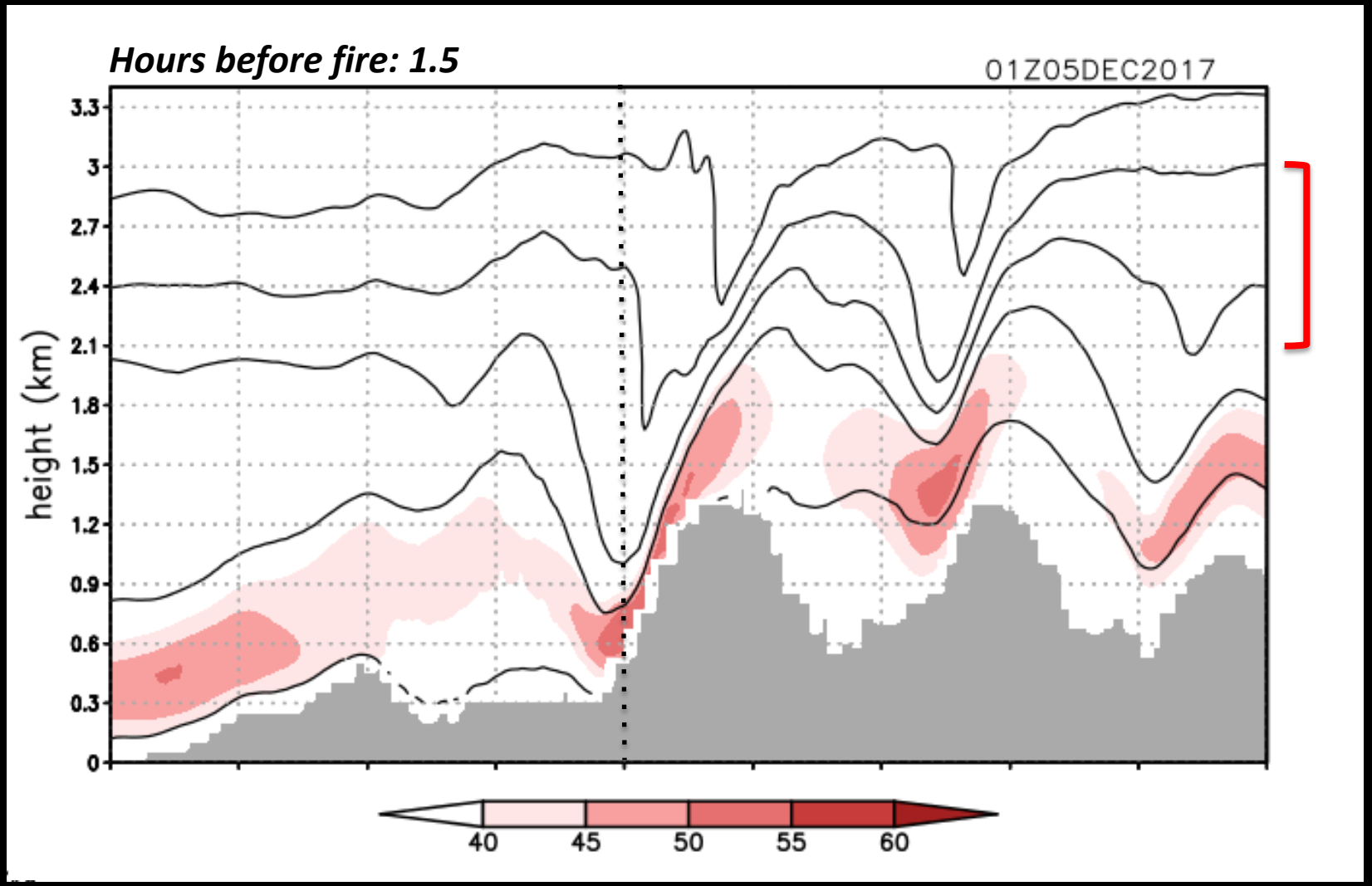

Hours before fire: 0.0
02:20Z05DEC2017
height (km)
3.3
3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
60
40
45
50
55
60

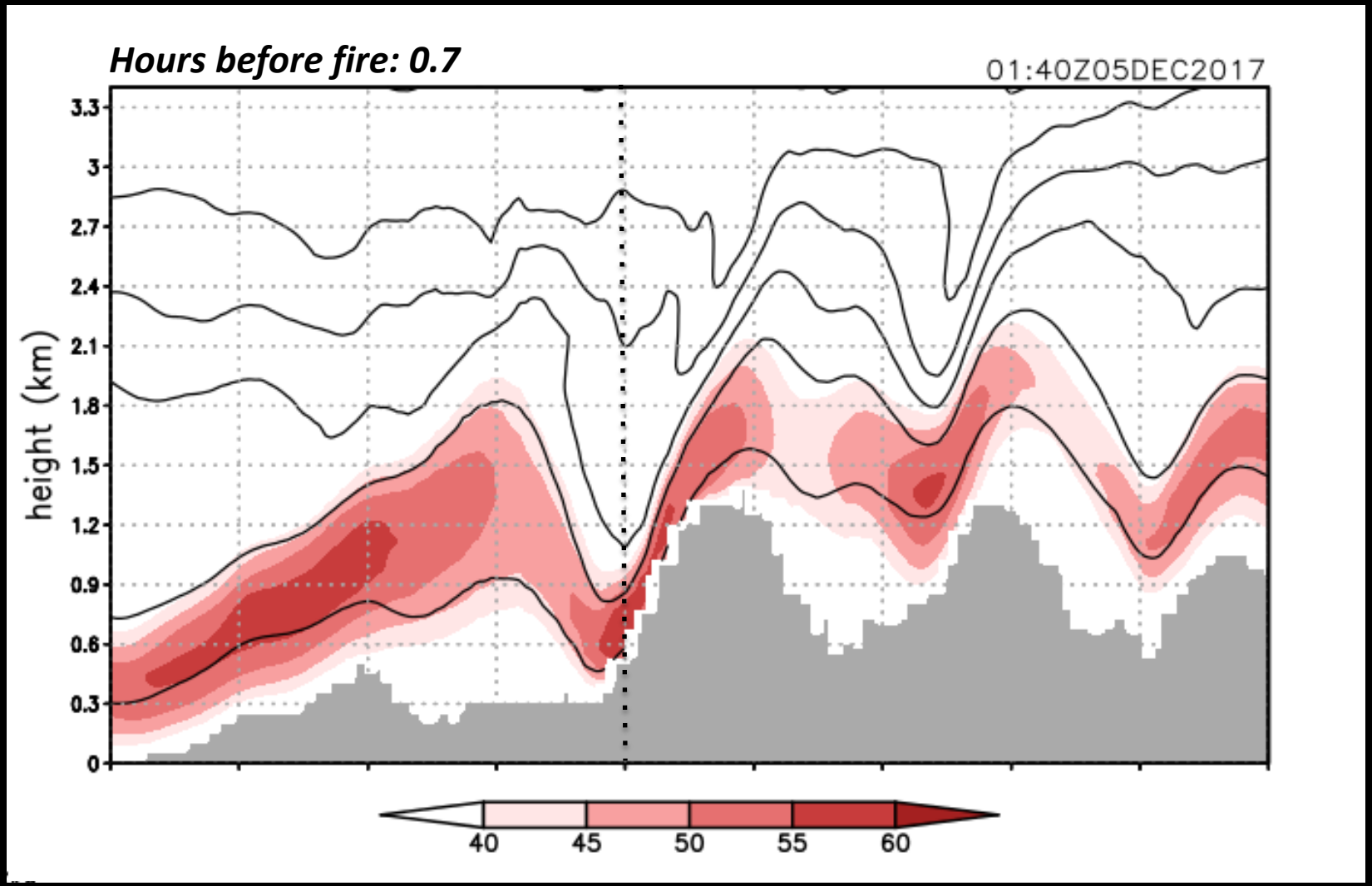
Wind flow evolution

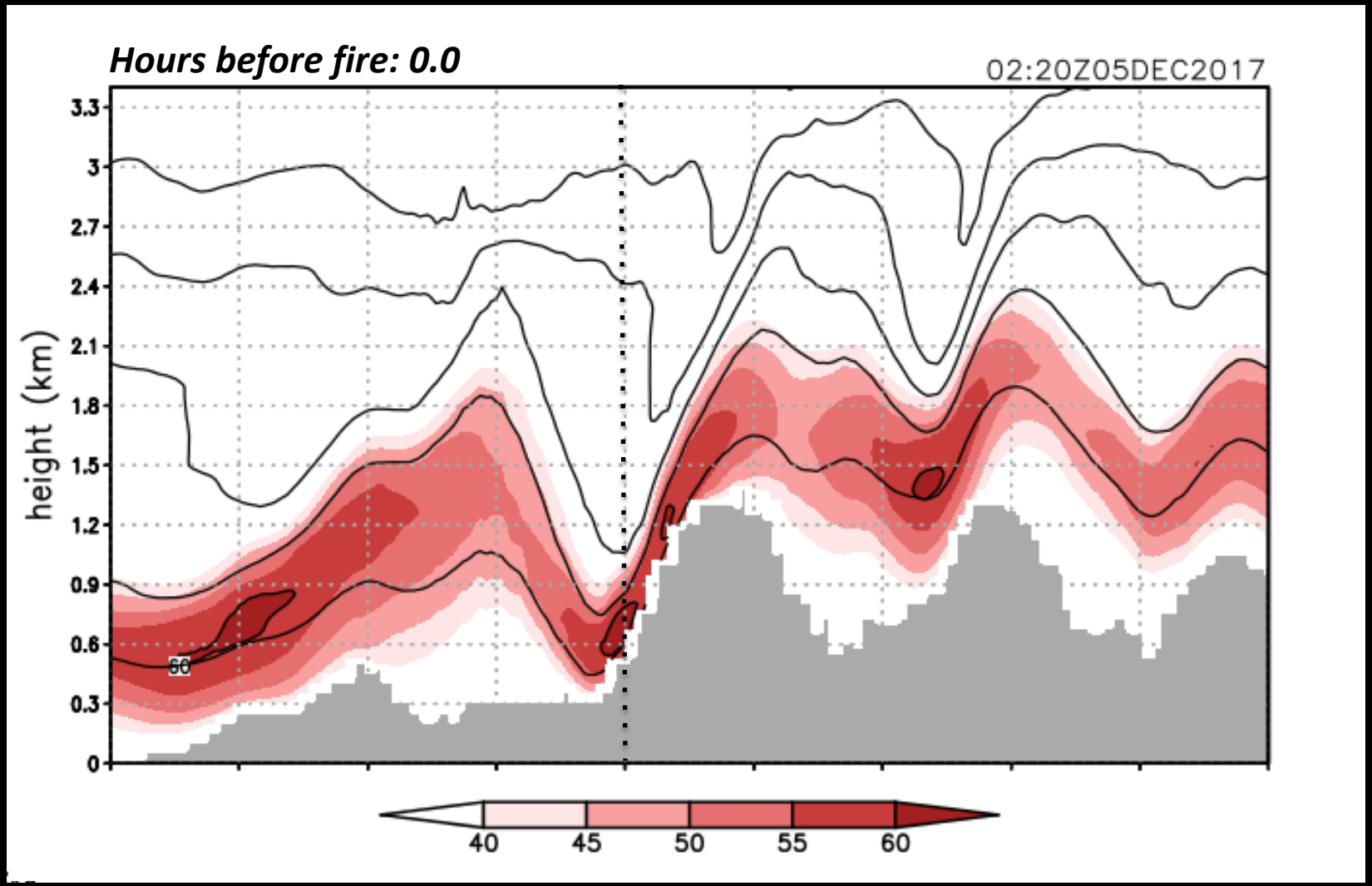


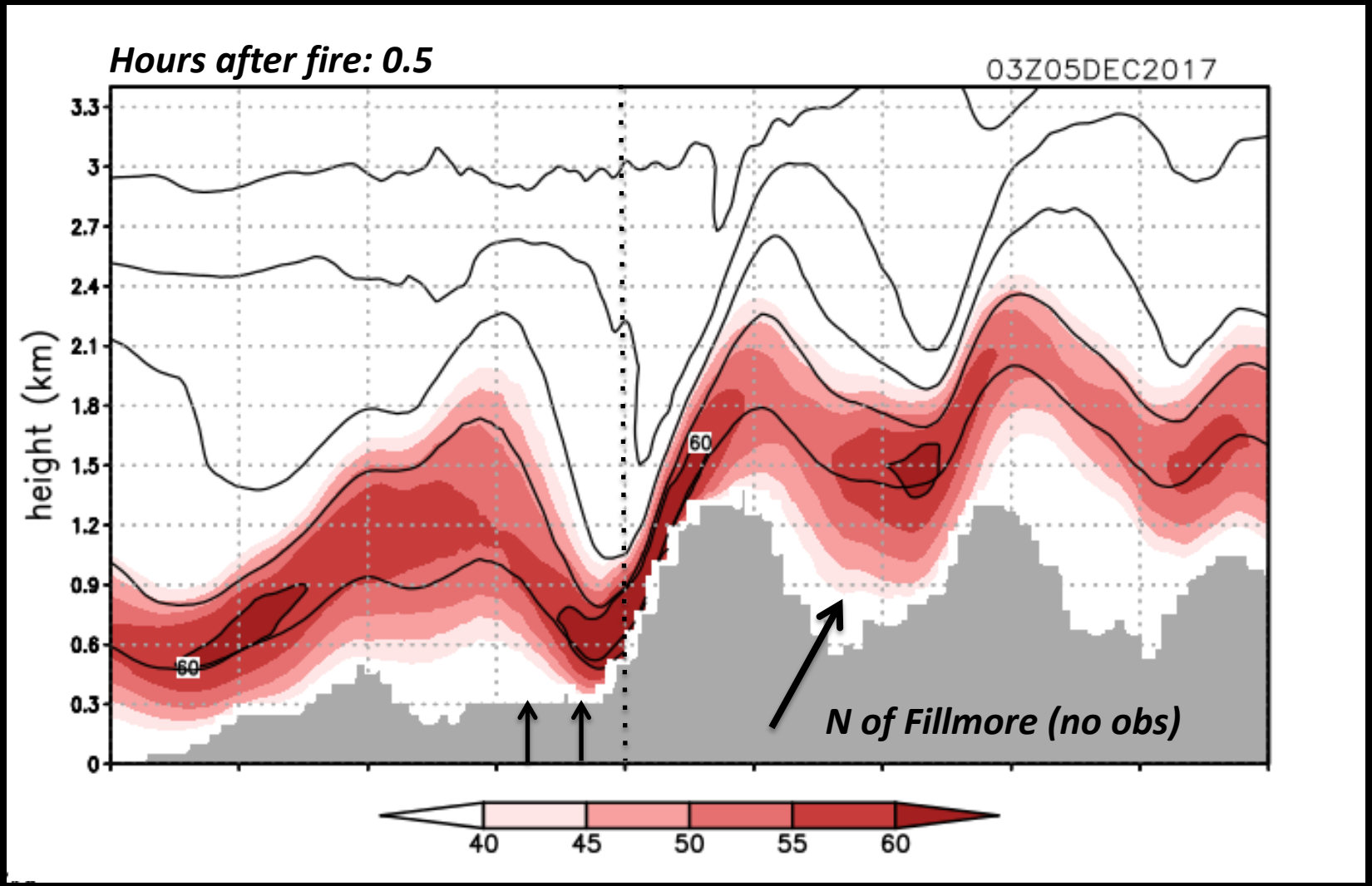

Hours before fire: 3.5
23Z04DEC2017
height (km)
3.3
3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
40
45
50
55
60

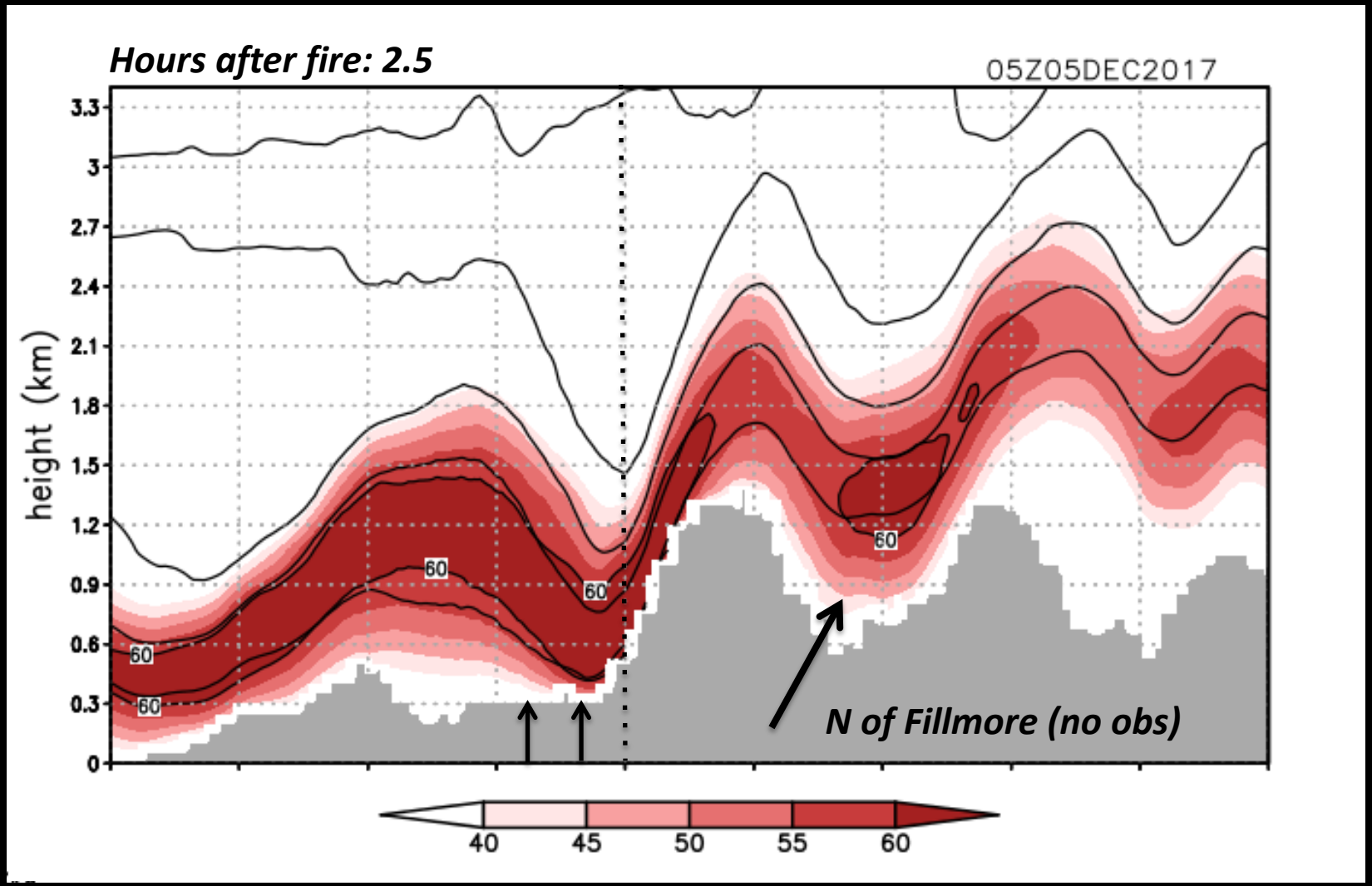

Hours before fire: 2.5
00Z05DEC2017
height (km)
3.3
3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
40
45
50
55
60

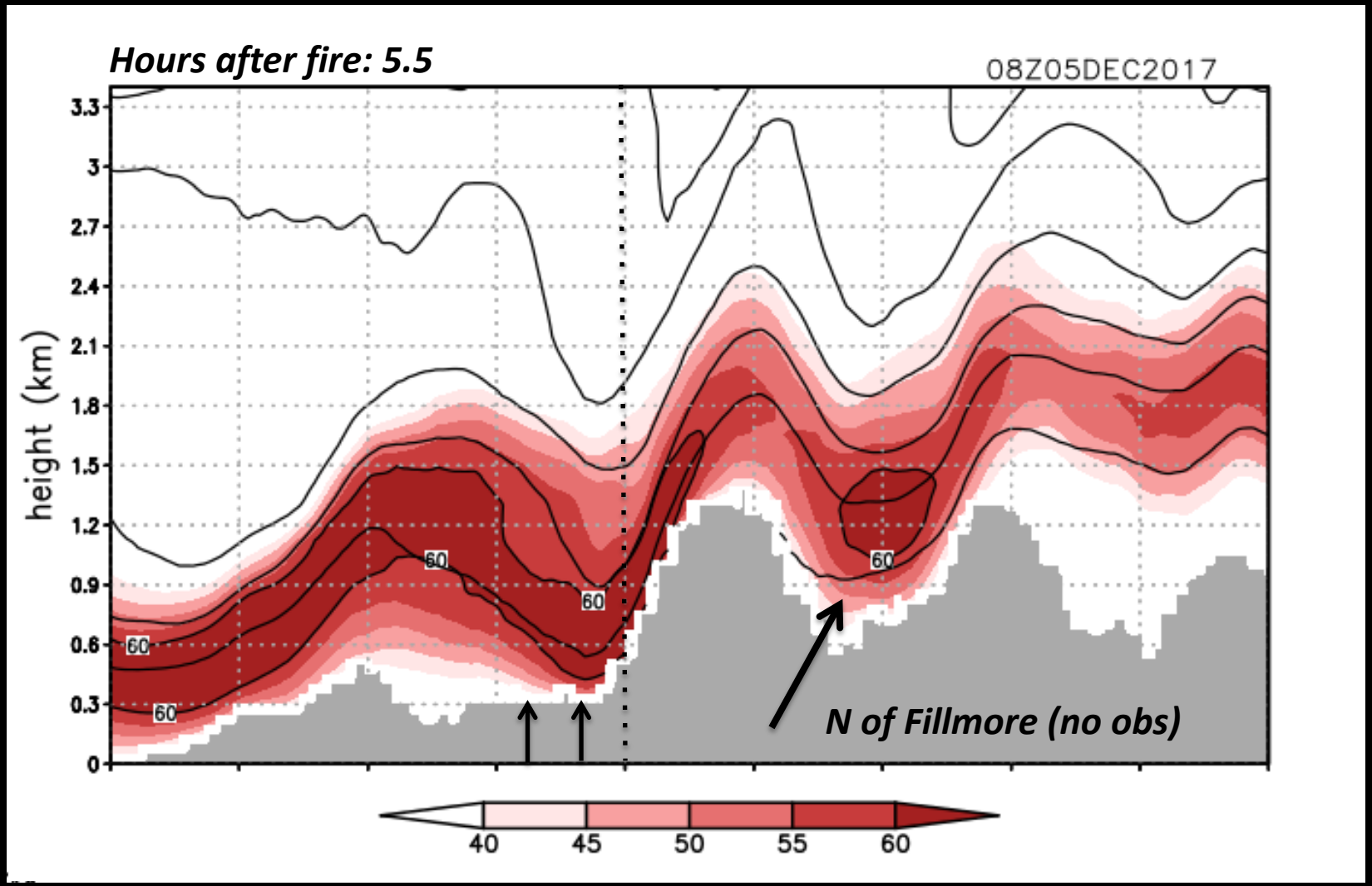

Hours before fire: 1.5
01Z05DEC2017
height (km)
3.3
3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
40
45
50
55
60

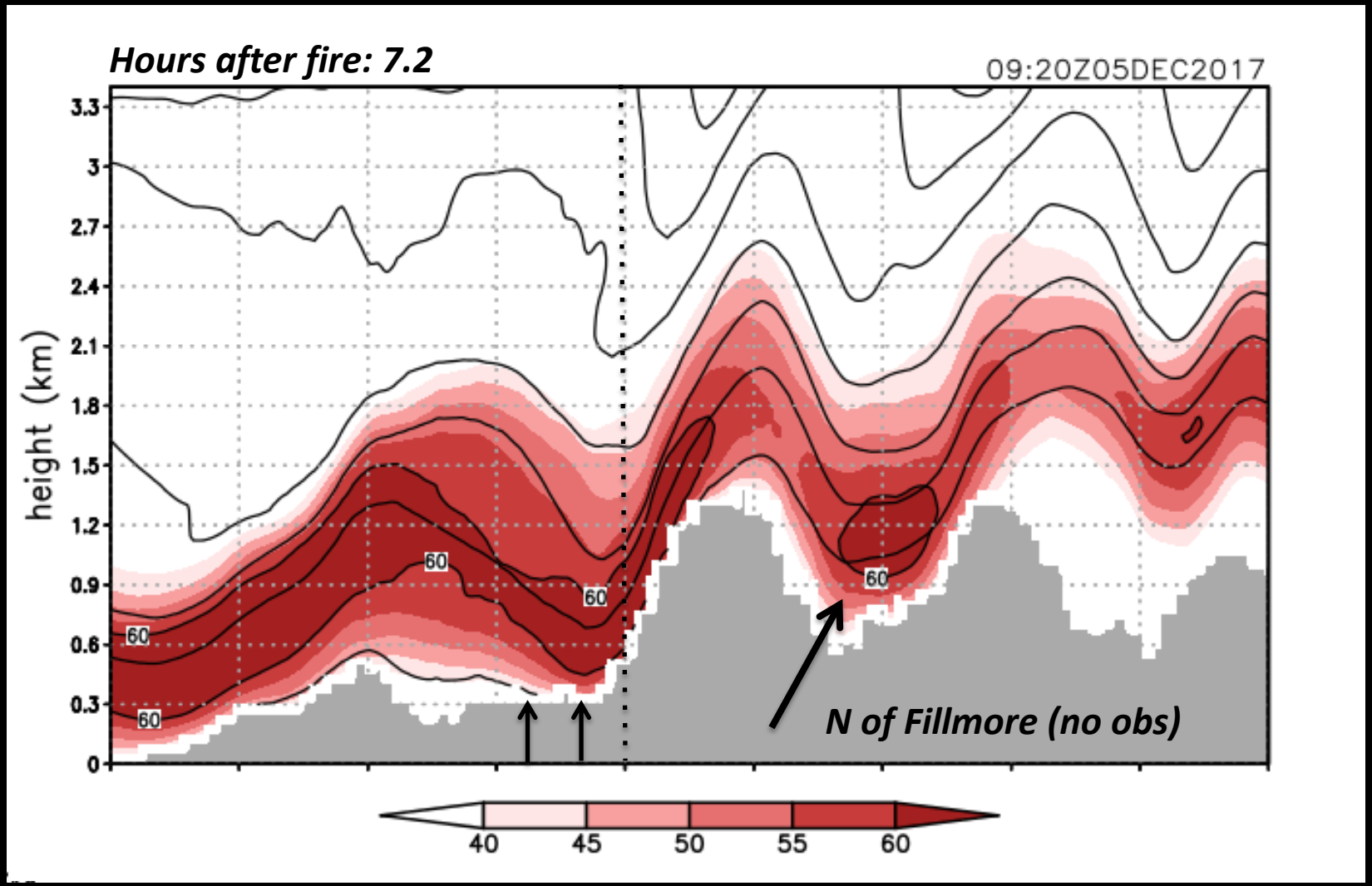

Hours before fire: 0.7
01:40Z05DEC2017
height (km)
3.3
3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
40
45
50
55
60

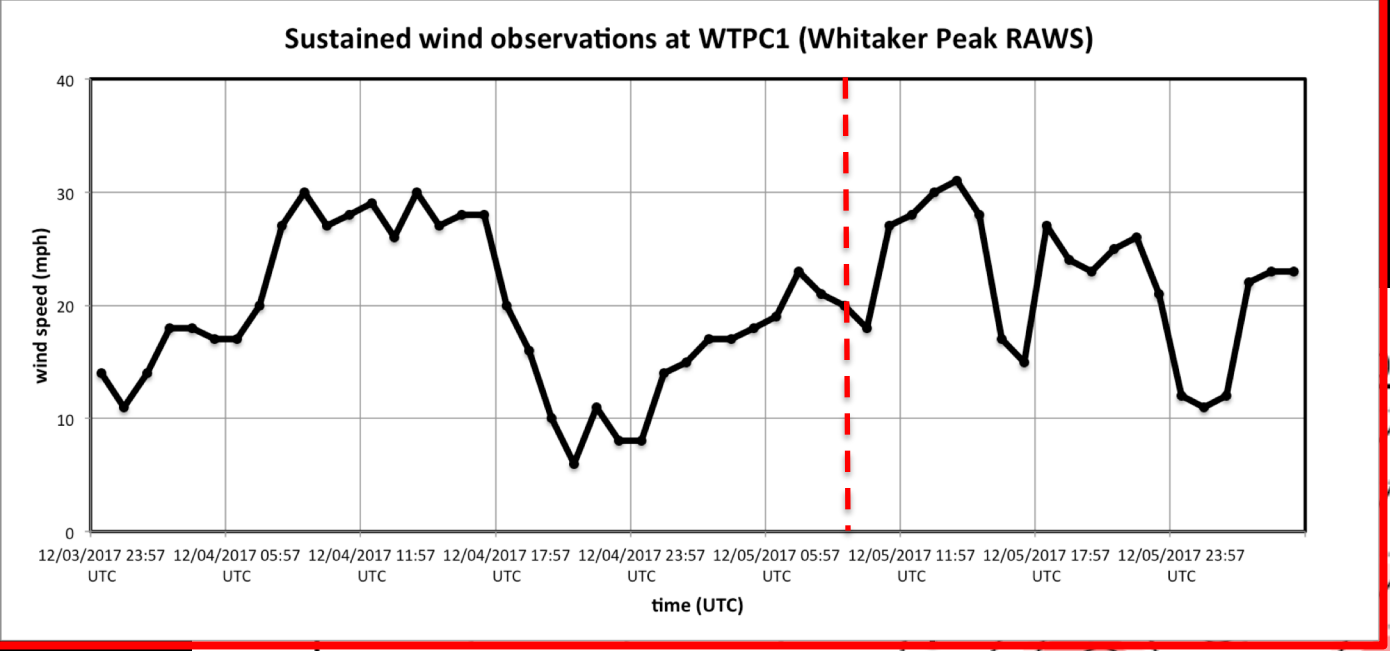

Hours before fire: 0.0
02:20Z05DEC2017
height (km)
3.3
3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
60
40
45
50
55
60

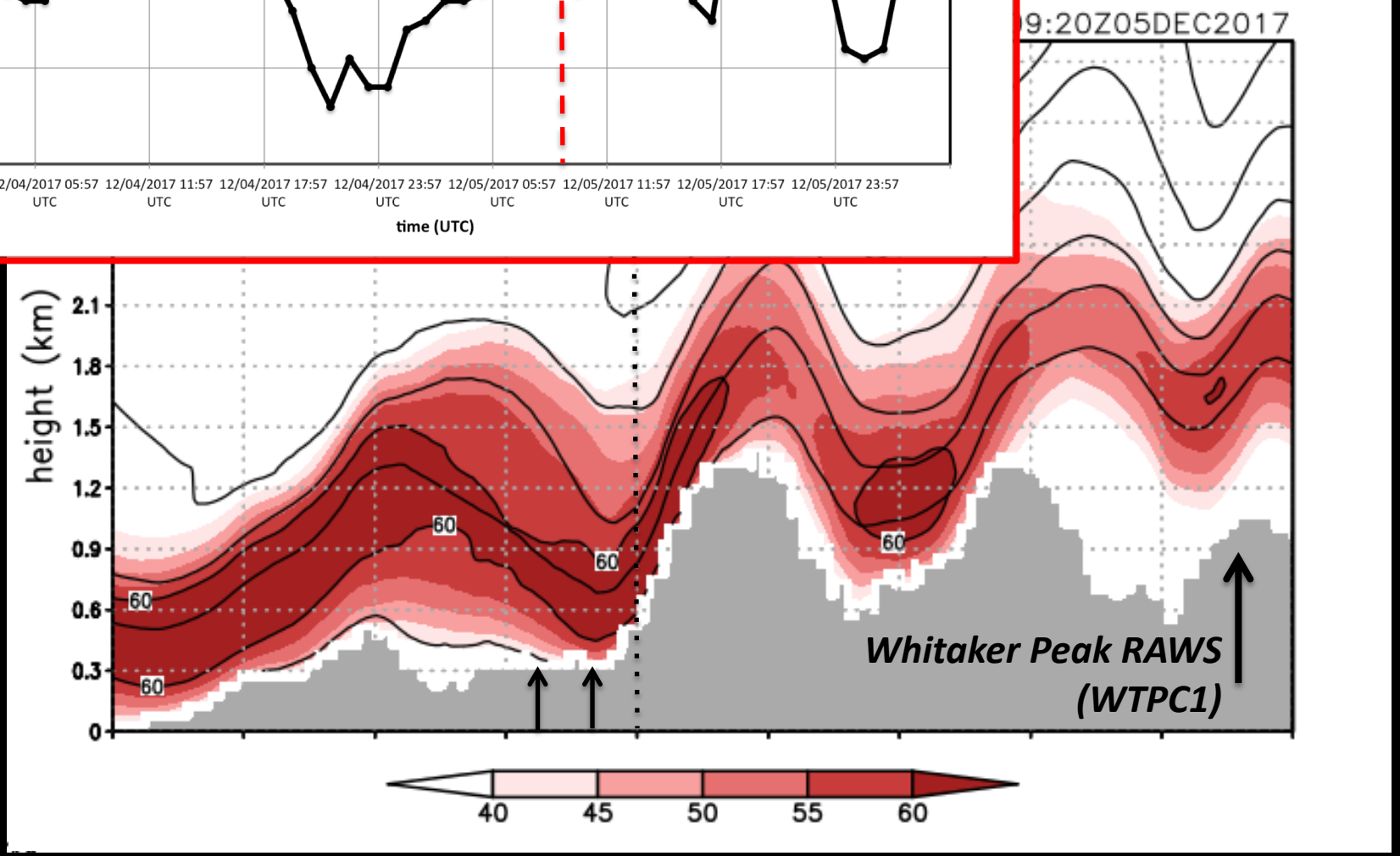

Hours after fire: 0.5
03Z05DEC2017
height (km)
3.3
3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
60
60
N of Fillmore (no obs)
40
45
50
55
60

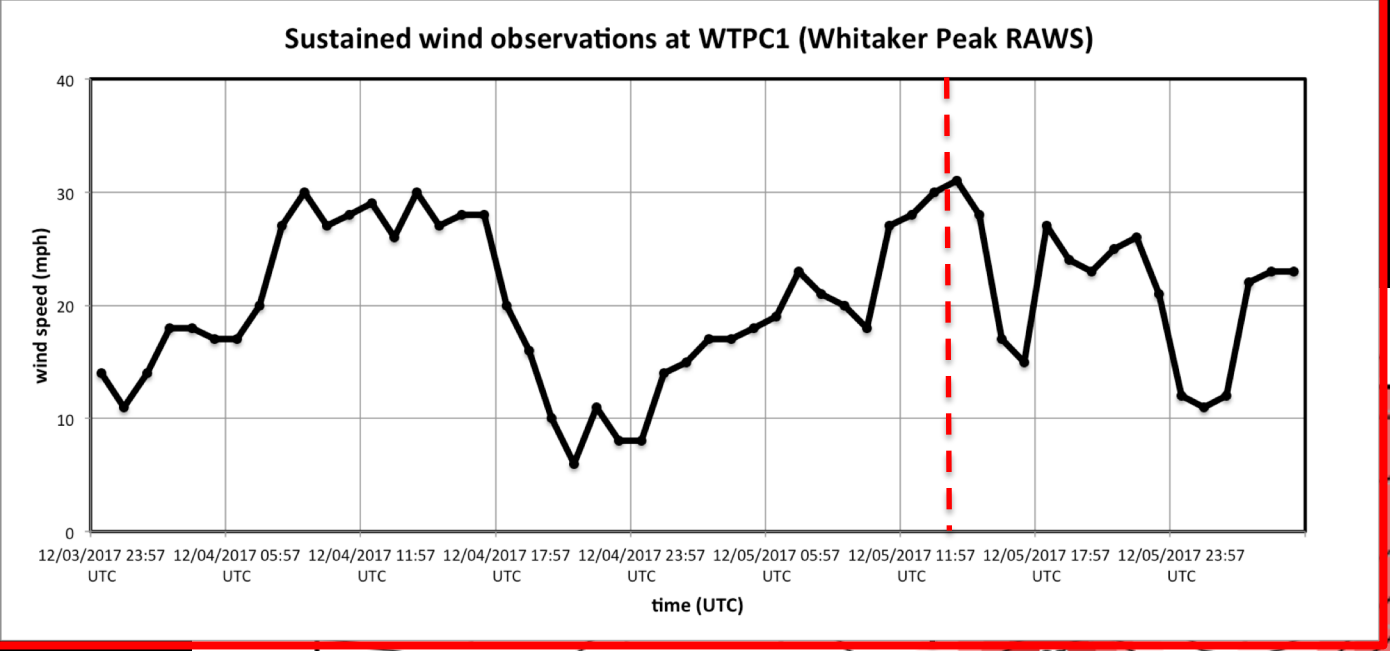

Hours after fire: 2.5
05Z05DEC2017
height (km)
3.3
3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
60
60
60
60
60
N of Fillmore (no obs)
40
45
50
55
60

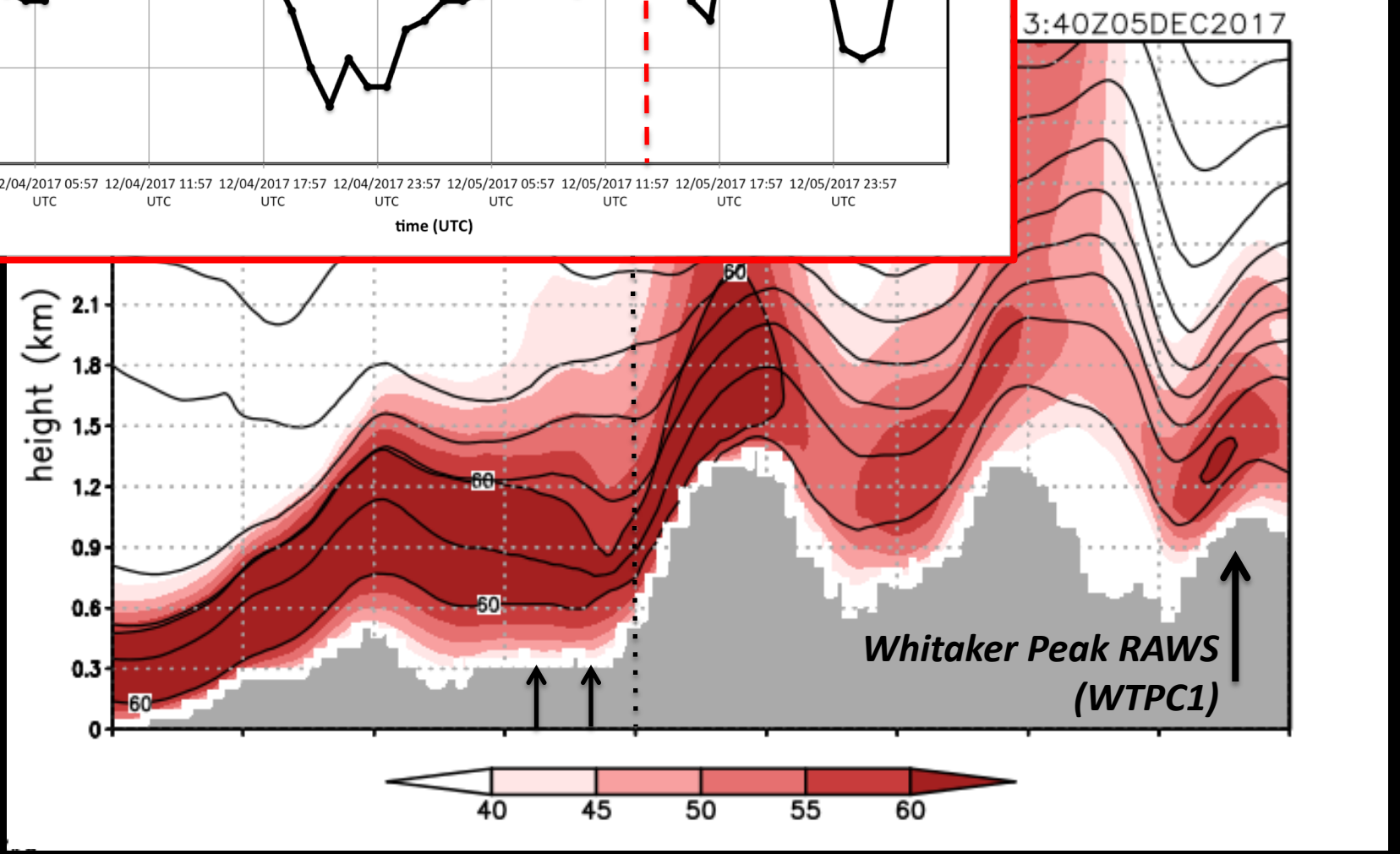

Hours after fire: 5.5
08Z05DEC2017
height (km)
3.3
3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
60
60
60
60
60
N of Fillmore (no obs)
40
45
50
55
60

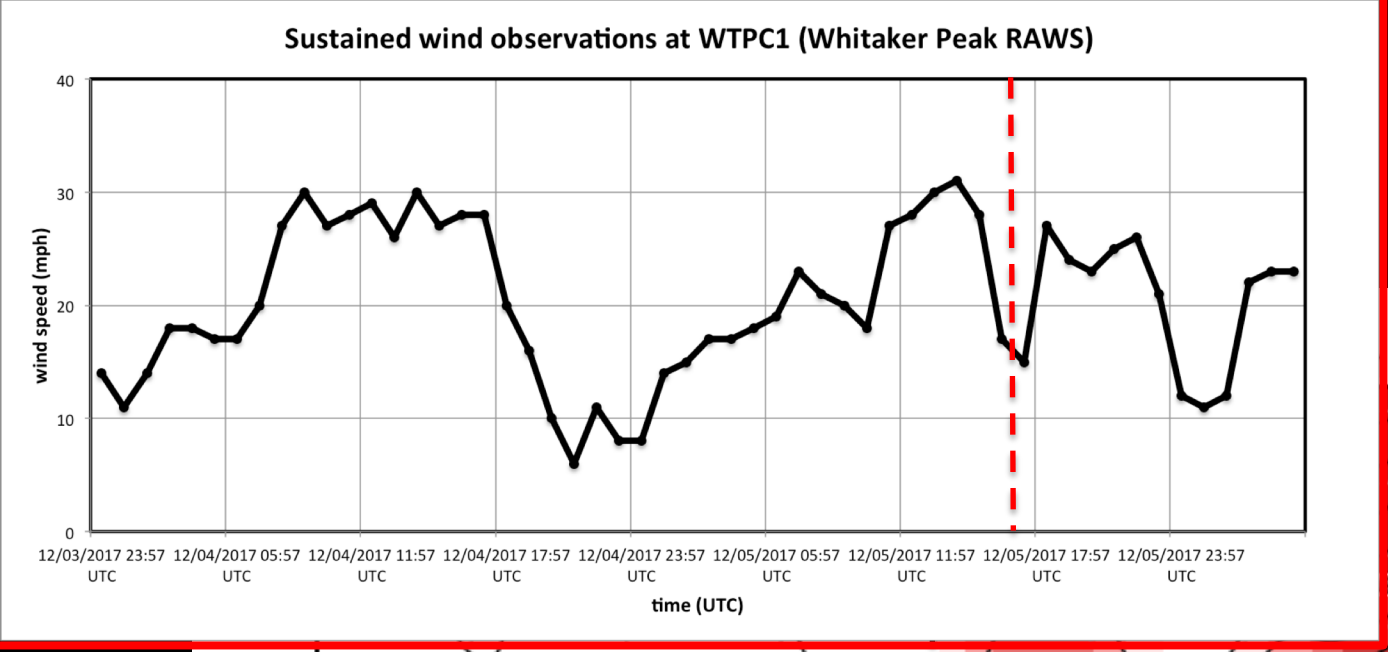

Hours after fire: 7.2
09:20Z05DEC2017
height (km)
3.3
3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
60
60
60
60
60
N of Fillmore (no obs)
40
45
50
55
60

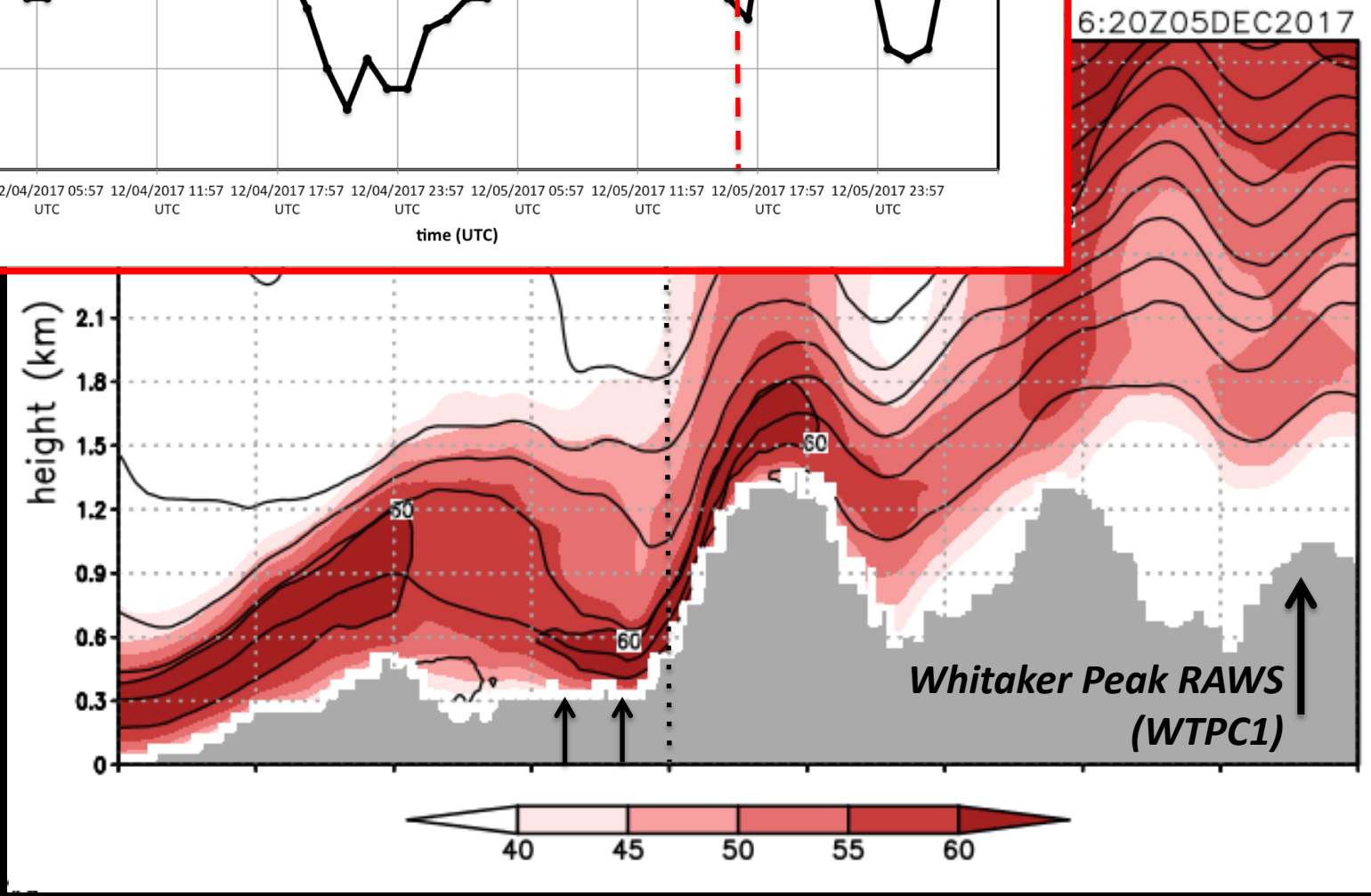

Sustained wind observations at WTPC1 (Whitaker Peak RAWS)
wind speed (mph)
0
10
20
30
40
12/03/2017 23:57 UTC
12/04/2017 05:57 UTC
12/04/2017 11:57 UTC
12/04/2017 17:57 UTC
12/04/2017 23:57 UTC
12/05/2017 05:57 UTC
12/05/2017 11:57 UTC
12/05/2017 17:57 UTC
12/05/2017 23:57 UTC
time (UTC)


9:20Z05DEC2017
height (km)
0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
60
60
60
60
60
Whitaker Peak RAWS
(WTPC1)
40
45
50
55
60

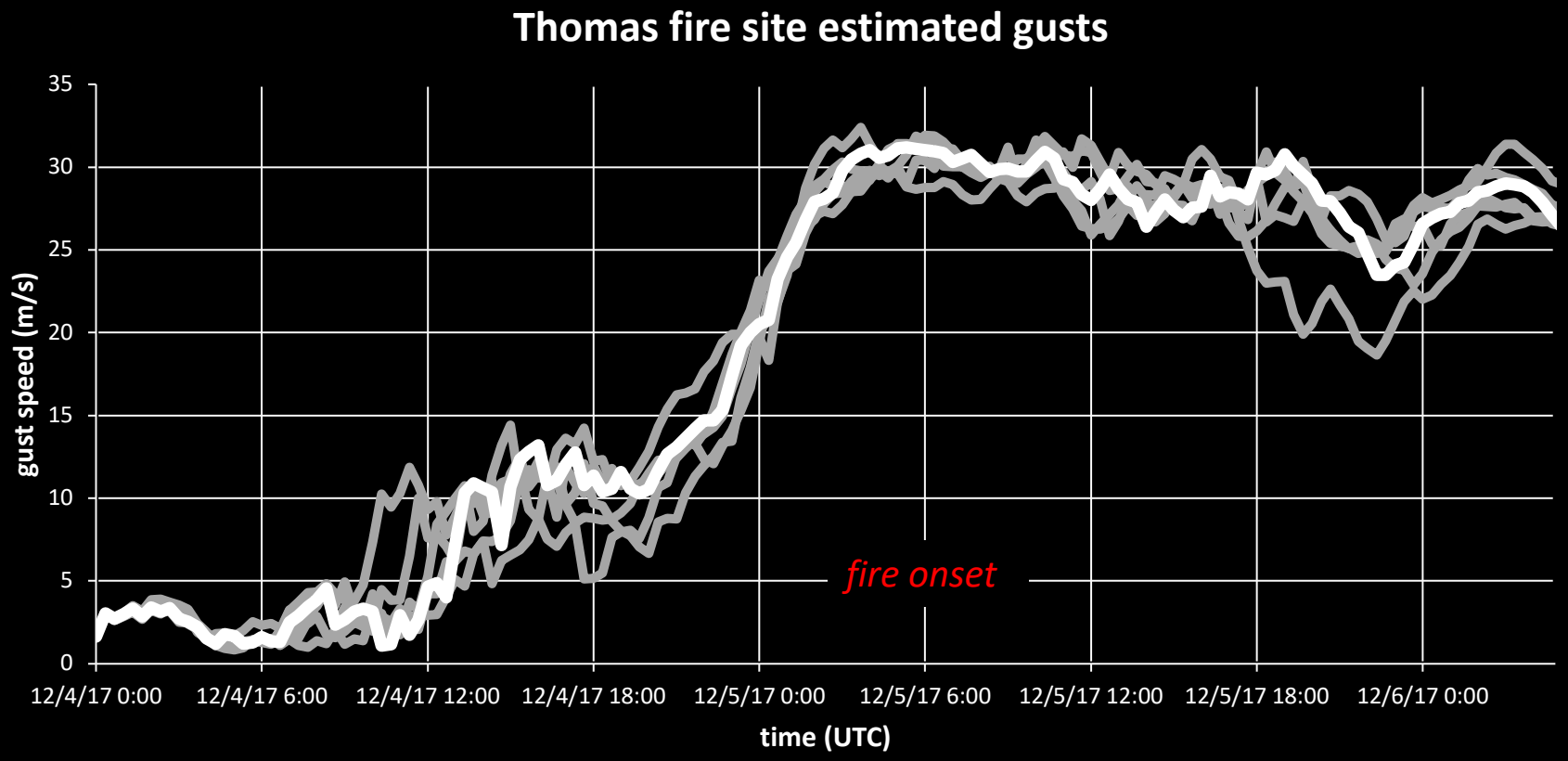

Sustained wind observations at WTPC1 (Whitaker Peak RAWS)
wind speed (mph)
40
30
20
10
0
12/03/2017 23:57 UTC
12/04/2017 05:57 UTC
12/04/2017 11:57 UTC
12/04/2017 17:57 UTC
12/04/2017 23:57 UTC
12/05/2017 05:57 UTC
12/05/2017 11:57 UTC
12/05/2017 17:57 UTC
12/05/2017 23:57 UTC
time (UTC)


3:40Z05DEC2017
height (km)
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
60
60
60
60
Whitaker Peak RAWS
(WTPC1)
40
45
50
55
60


Sustained wind observations at WTPC1 (Whitaker Peak RAWS)
wind speed (mph)
40
30
20
10
0
12/03/2017 23:57 UTC
12/04/2017 05:57 UTC
12/04/2017 11:57 UTC
12/04/2017 17:57 UTC
12/04/2017 23:57 UTC
12/05/2017 05:57 UTC
12/05/2017 11:57 UTC
12/05/2017 17:57 UTC
12/05/2017 23:57 UTC
time (UTC)


6:20Z05DEC2017
height (km)
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
50
60
60
Whitaker Peak RAWS
(WTPC1)
40
45
50
55
60

Gust estimates at presumed fire site



Control and 5 perturbed runs

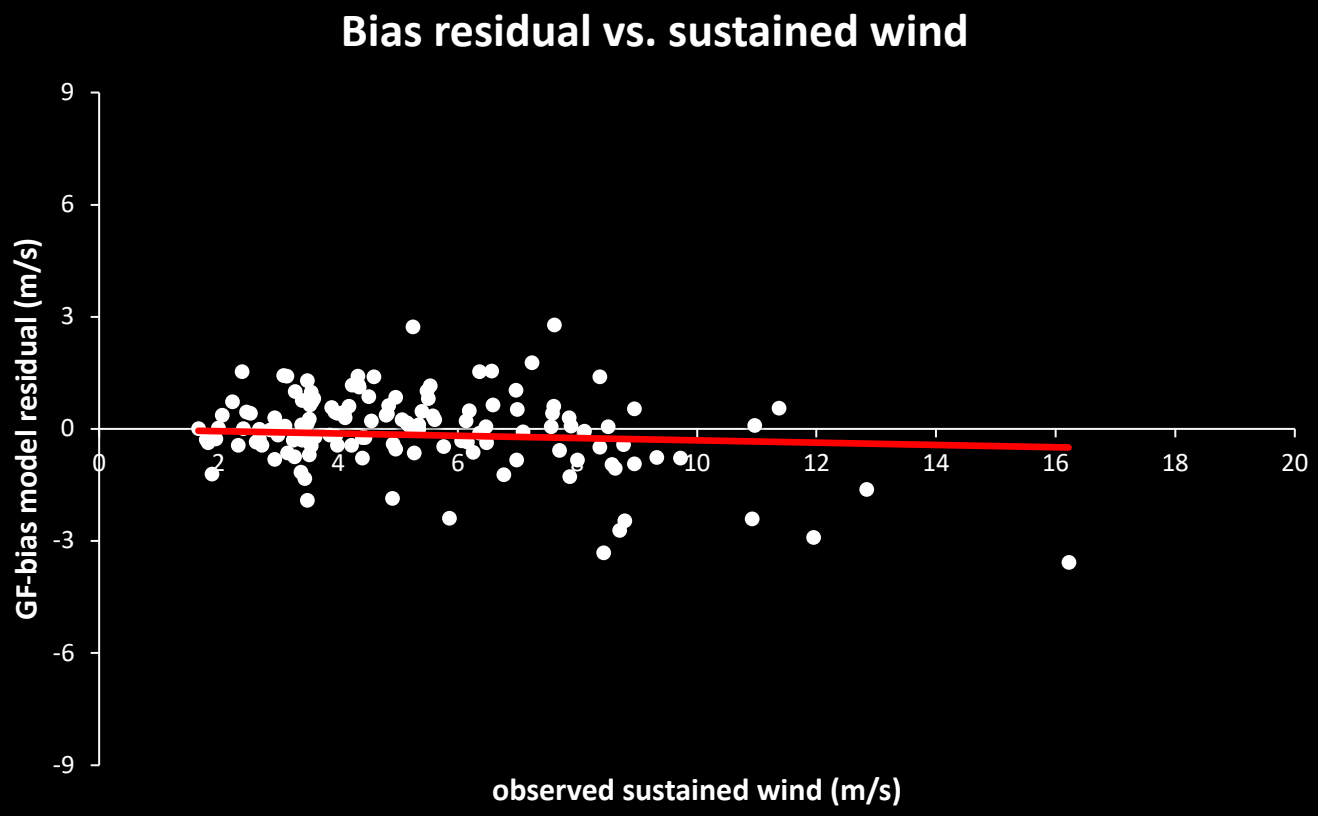
Simple estimate based on maximum simulated wind in lowest 600 m AGL
Fire onset max ~ 71 mph (32 m/s)

Conclusions and caveats

- Preliminary results
- Ignition site(s) likely correct but cause and height AGL of ignition unknown (to me)
- Very subtle terrain features can significantly amplify winds; these estimates likely too low
- Once the fire starts, fire creates its own weather

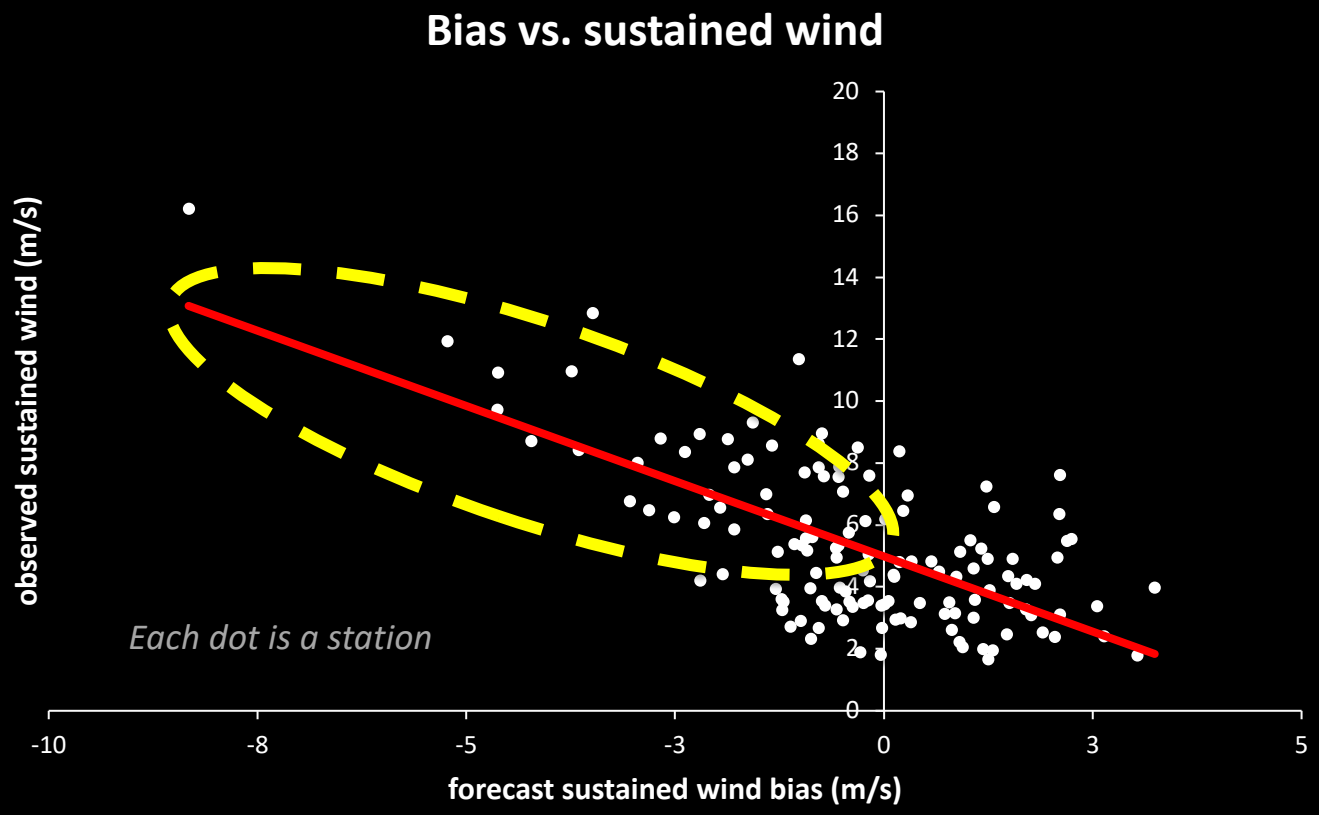
[end]

After gust factor adjustment



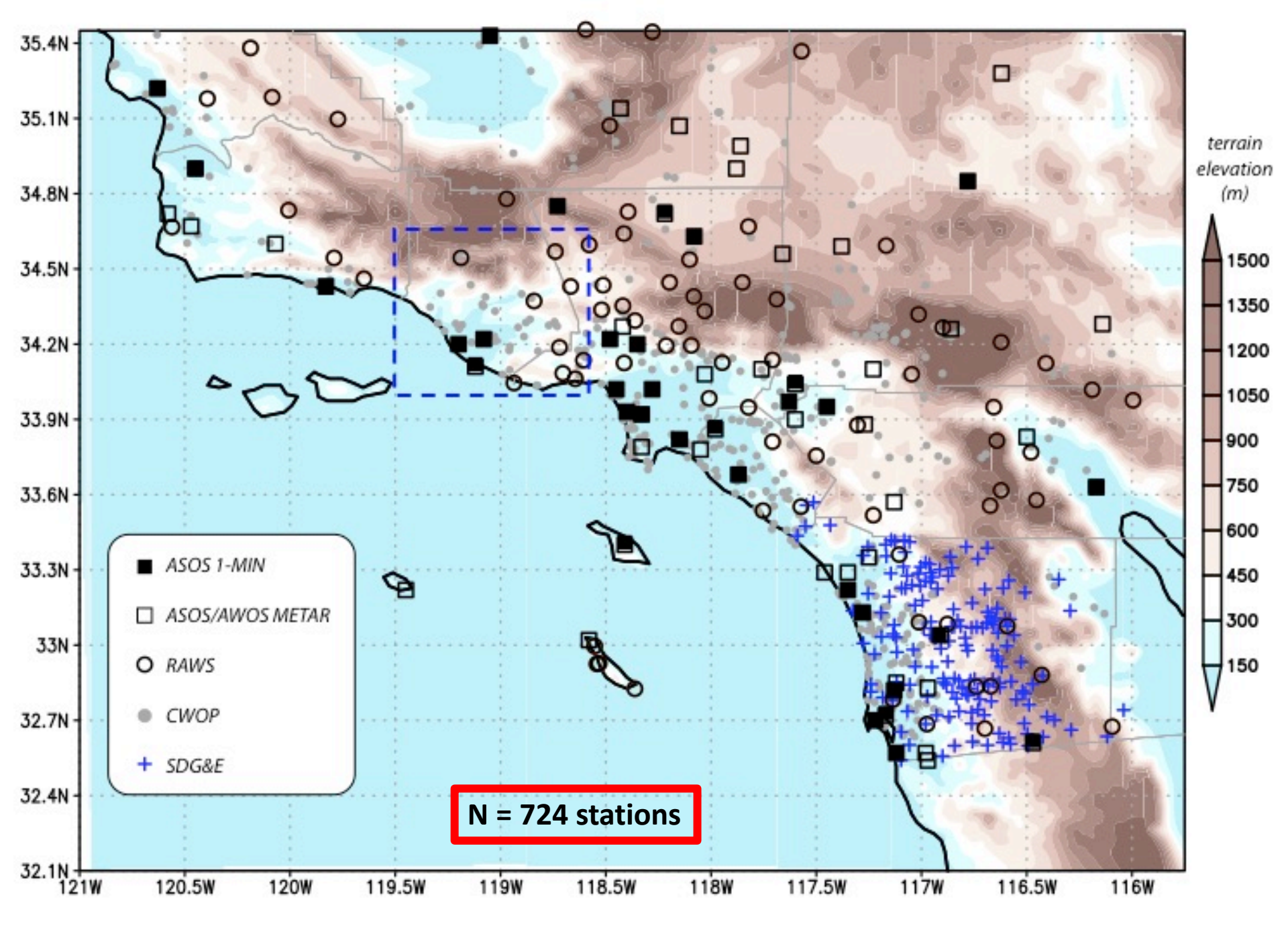
Cao and Fovell (2018)

Systematic station forecast biases



Lesson: we may underpredict wind at windier locations, especially those with smaller gust factors

Cao and Fovell (2018)


35.4N
35.1N
34.8N
34.5N
34.2N
33.9N
33.6N
33.3N
33N
32.7N
32.4N
32.1N
121W
120.5W
120W
119.5W
119W
118.5W
118W
117.5W
117W
116.5W
116W
ASOS 1-MIN
ASOS/AWOS METAR
RAWS
CWOP
SDG&E
N = 724 stations
terrain elevation (m)
1500
1350
1200
1050
900
750
600
450
300
150