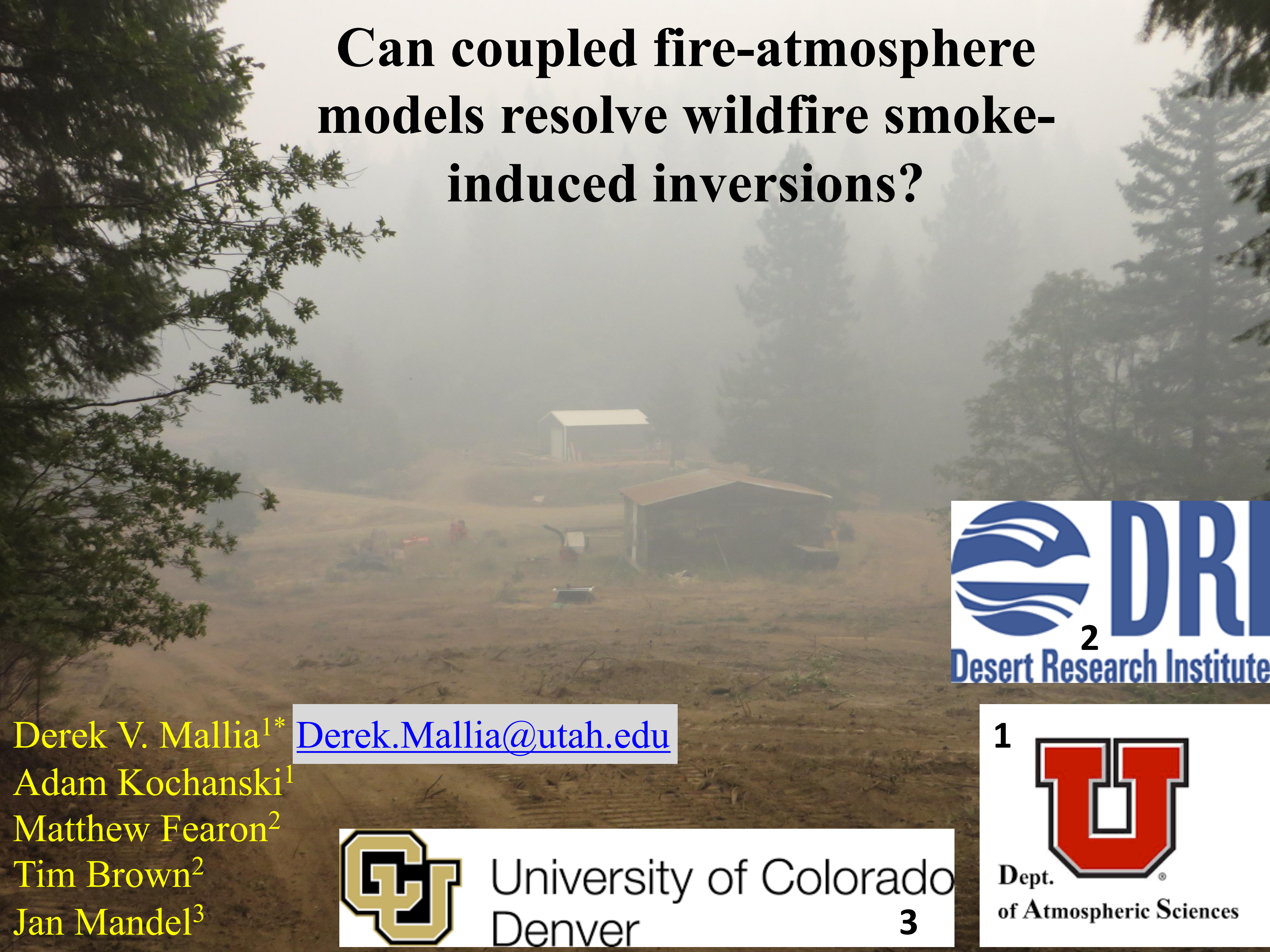

Can coupled fire-atmosphere models resolve wildfire smoke-induced inversions?

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Motivation:

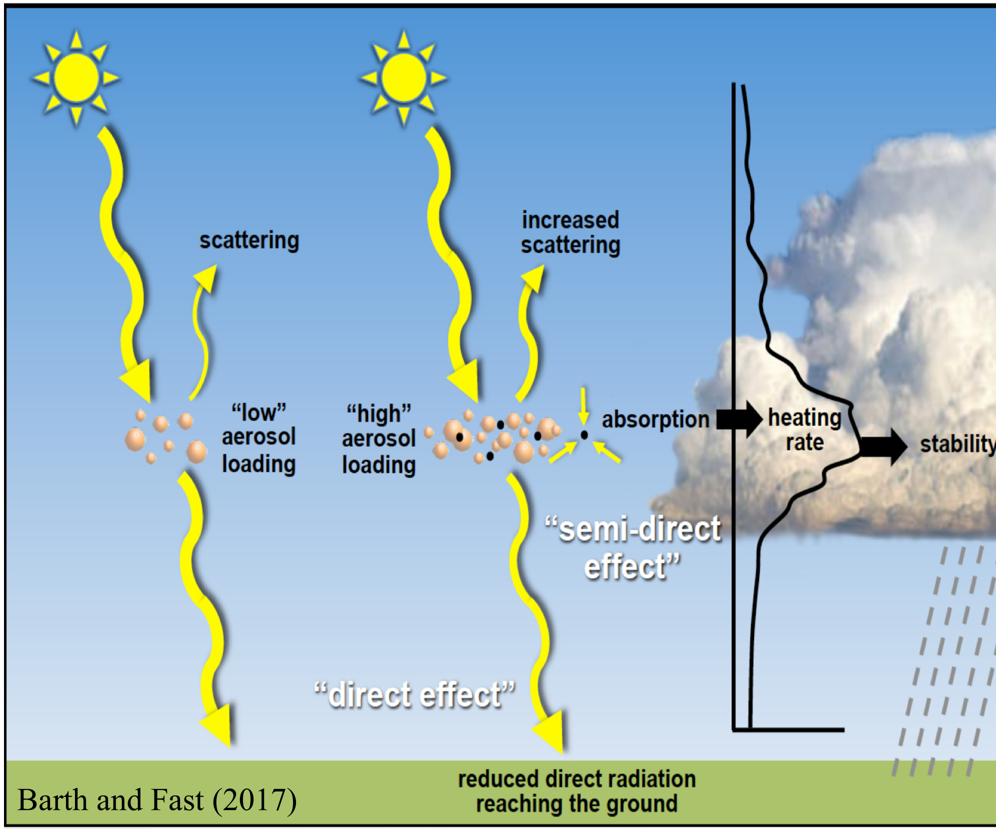
- During the summer of 2015, a number of large wildfires were burning across northern California in areas of complex terrain, which resulted in significant smoke that hindered fire fighting efforts, delayed helicopter operations, and exposed adjacent communities to high concentrations of atmospheric pollutants

- It has been recognized that the aerosols emitted by wildfires impact large-scale weather and climate, with potential impacts on weather forecasting capabilities

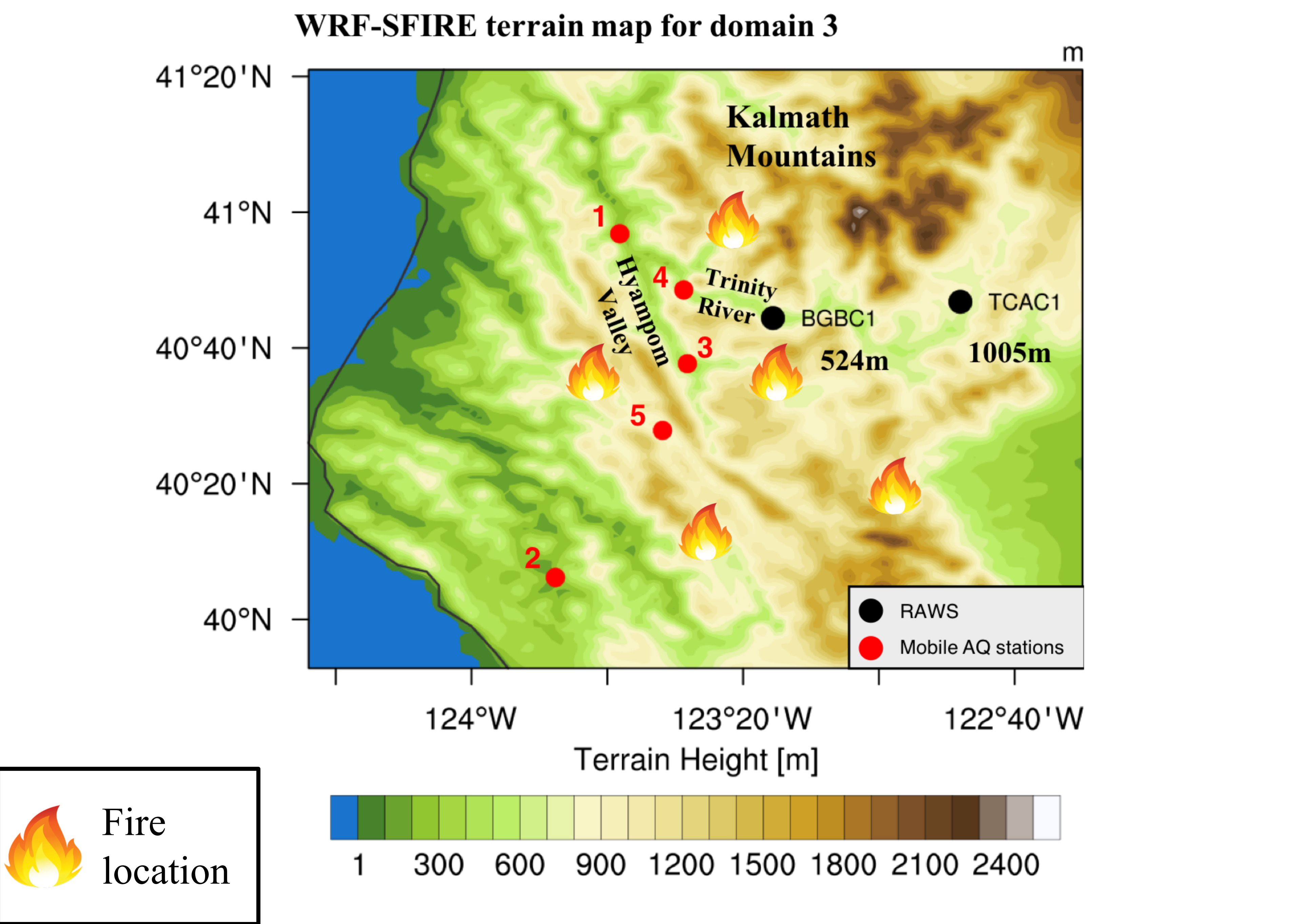
- Is the radiative impact of smoke important in the context of short-term local weather forecasting?

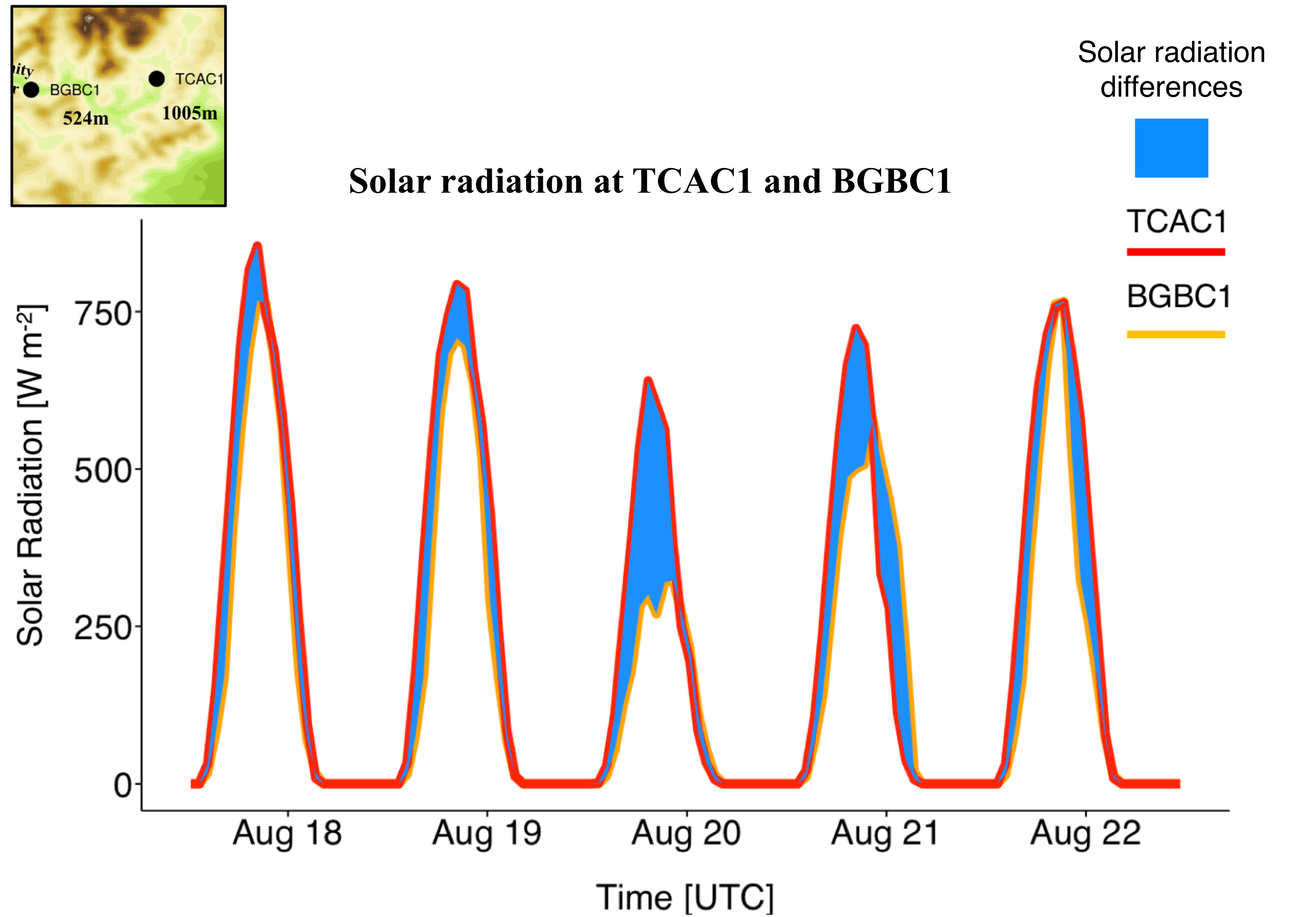
- How does wildfire smoke impact local temperatures?

- **Question:** Can current NWP models be used to simulate these effects?



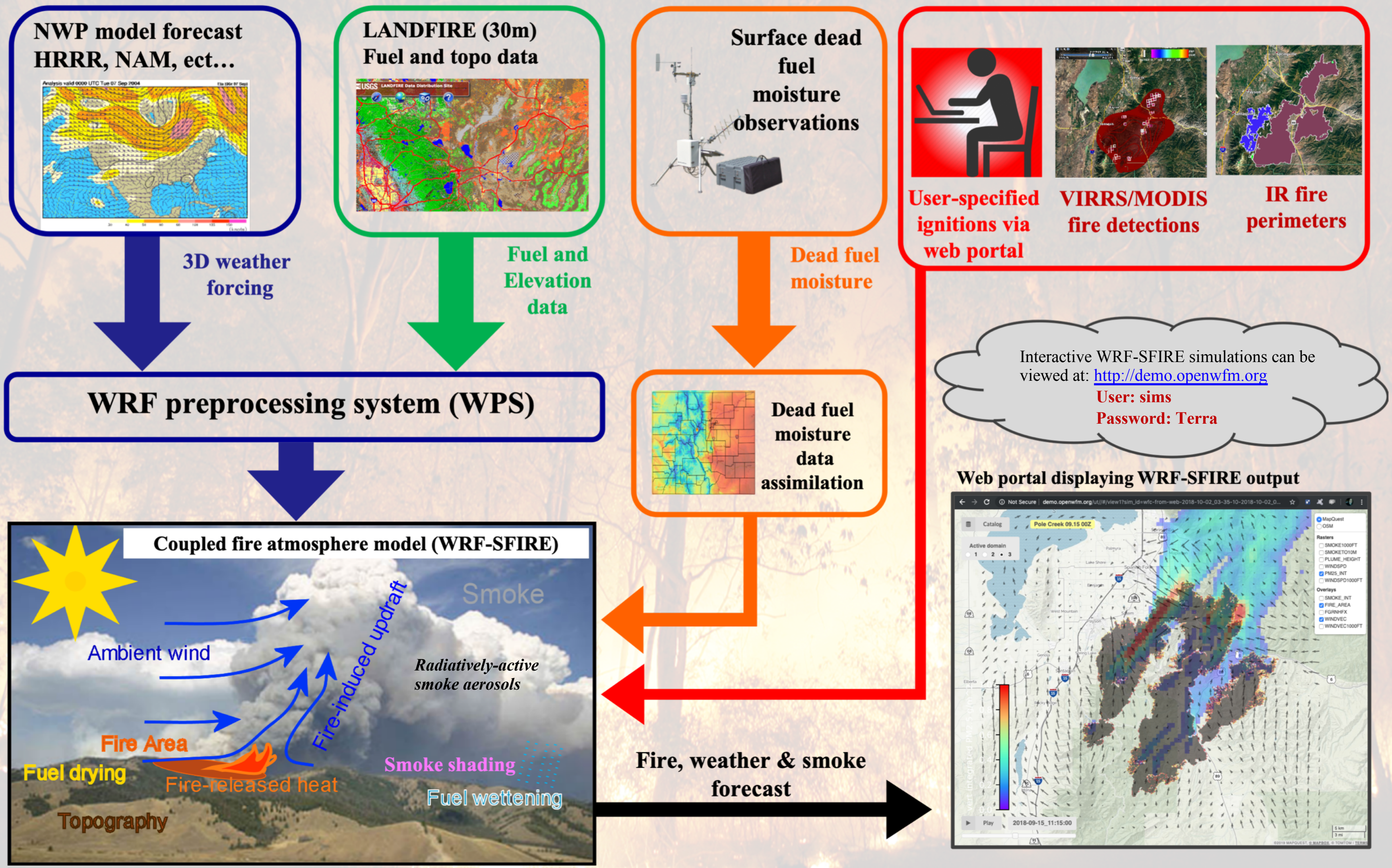
Barth and Fast (2017)


WRF-SFIRE terrain map for domain 3
m
41°20'N
41°N
40°40'N
40°20'N
40°N
124°W
123°20'W
122°40'W
Kalmath Mountains
Hyampom Valley
Trinity River
1
2
3
4
5
BGBC1
TCAC1
524m
1005m
RAWS
Mobile AQ stations
Terrain Height [m]
1
300
600
900
1200
1500
1800
2100
2400
Fire location



**Absence of clouds on the 19th of August*

WRF-SFIRE-Chem modeling framework



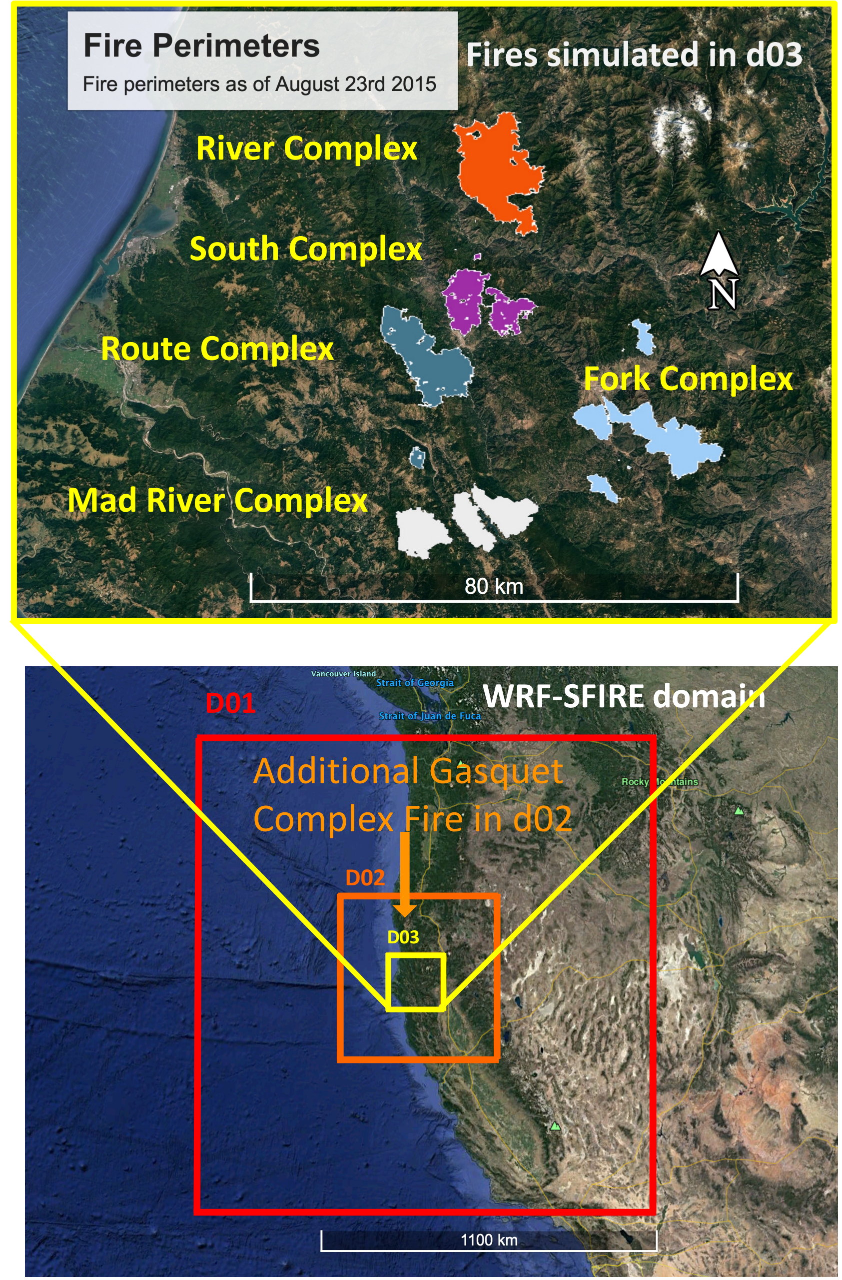
Mandel et al. (2011) & Kochanski et al. (2015)

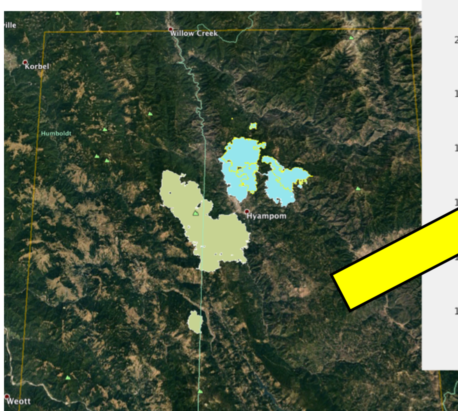
WRF-SFIRE Configuration

- Three nested domains at 12-, 4- and 1.33-km grid spacing with one fire simulated in domain d02 and 5 fires in d03, w/ a fire mesh at 60-m

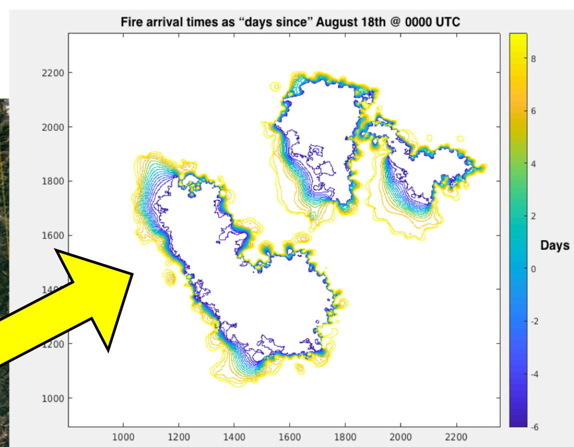
- We perform two simulations:
  1. **Baseline simulation:** WRF-SFIRE with no radiative smoke impacts
  2. **WRF-SFIRE-CHEM:** fuel consumption is **linked to the GOCART scheme** through $PM_{2.5}$, PM_{10}, Organic Carbon and Black Carbon

- Fires within SFIRE initialized GeoMac fire perimeters



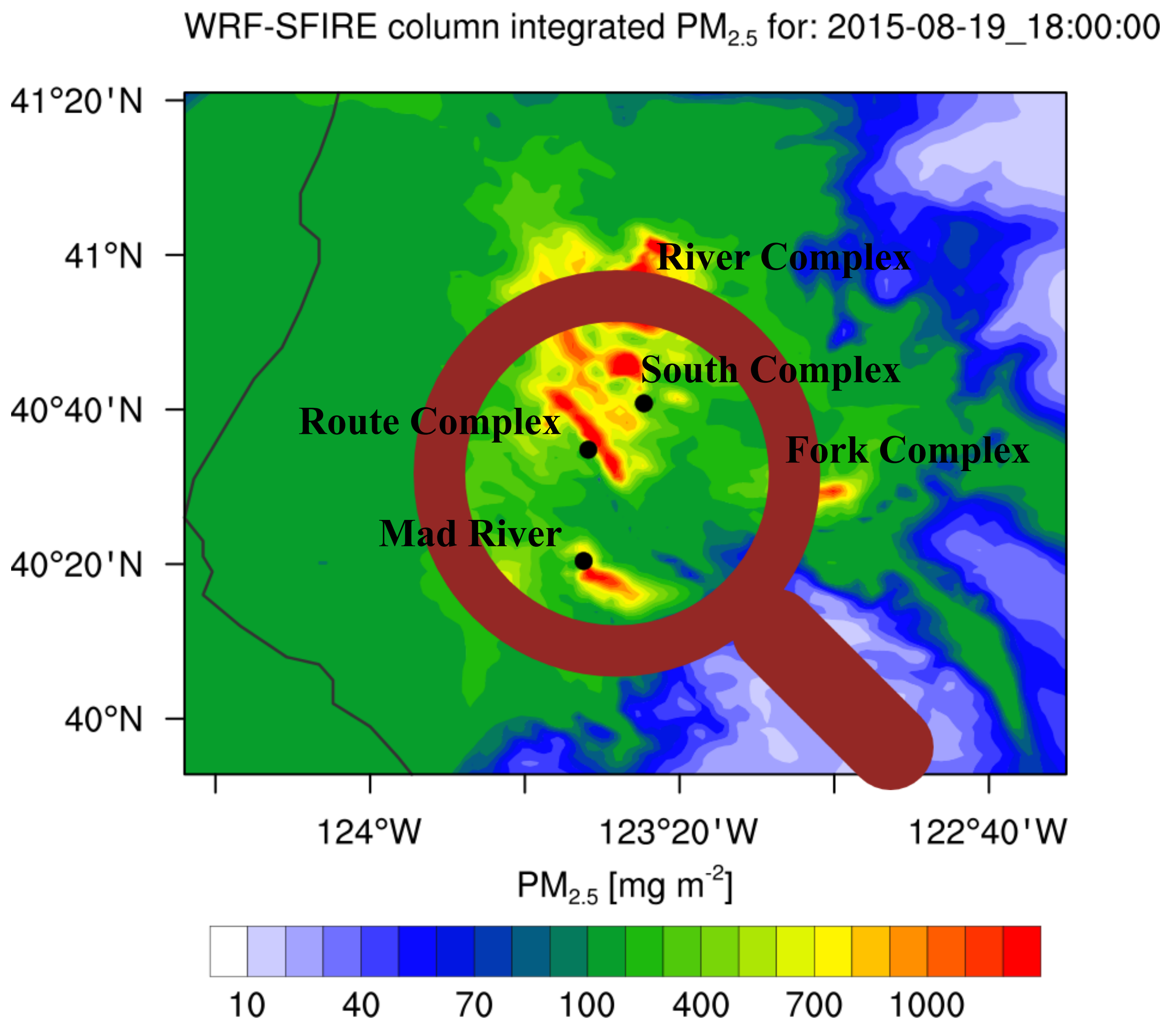


Fire perimeters



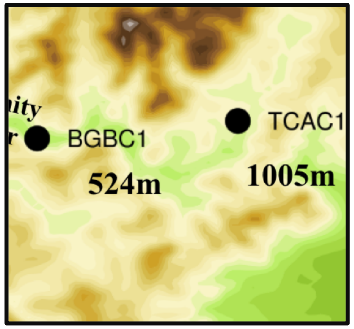
Fire arrival time

WRF-SFIRE smoke simulation for August 2015 California Fires



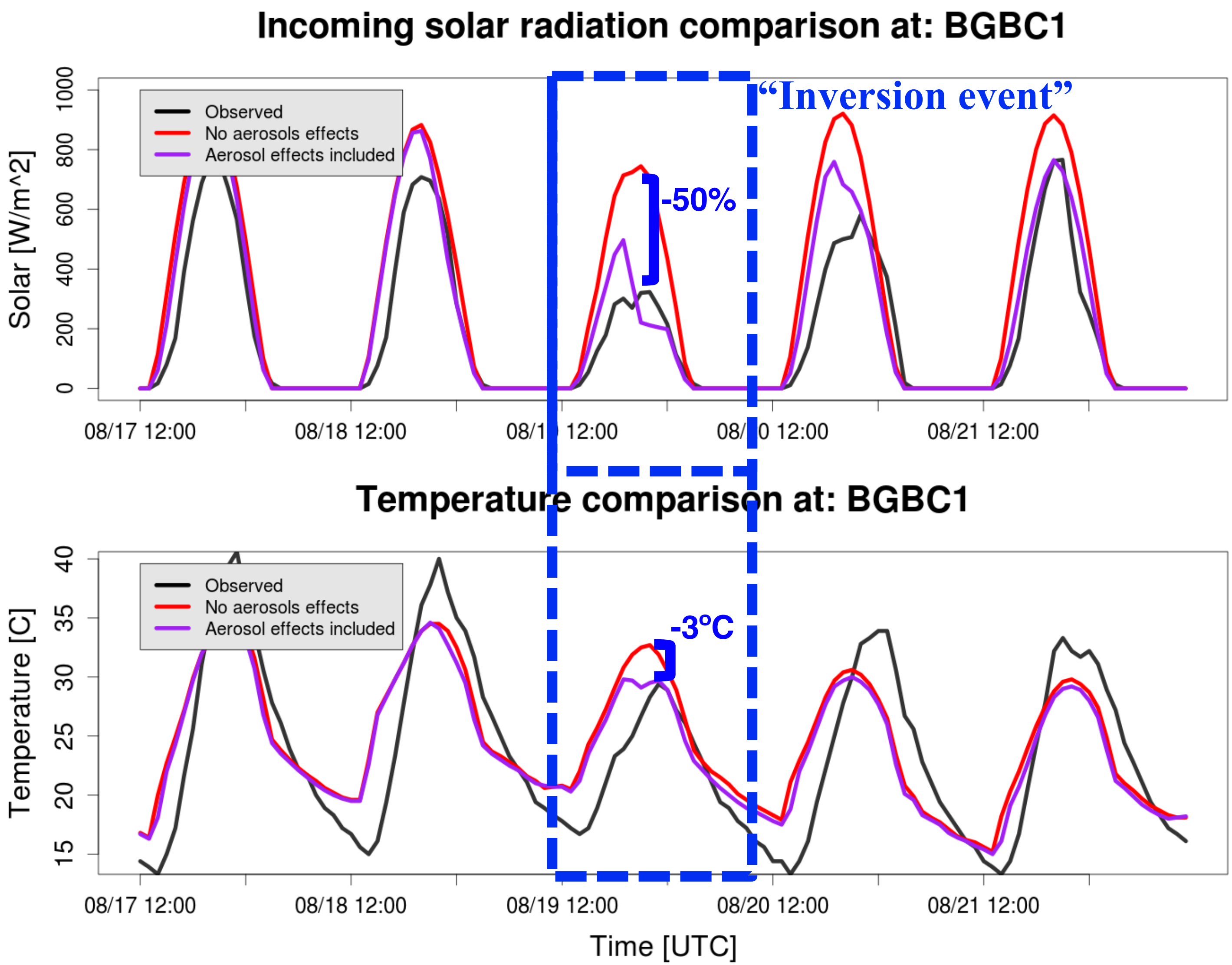
Forecast simulations

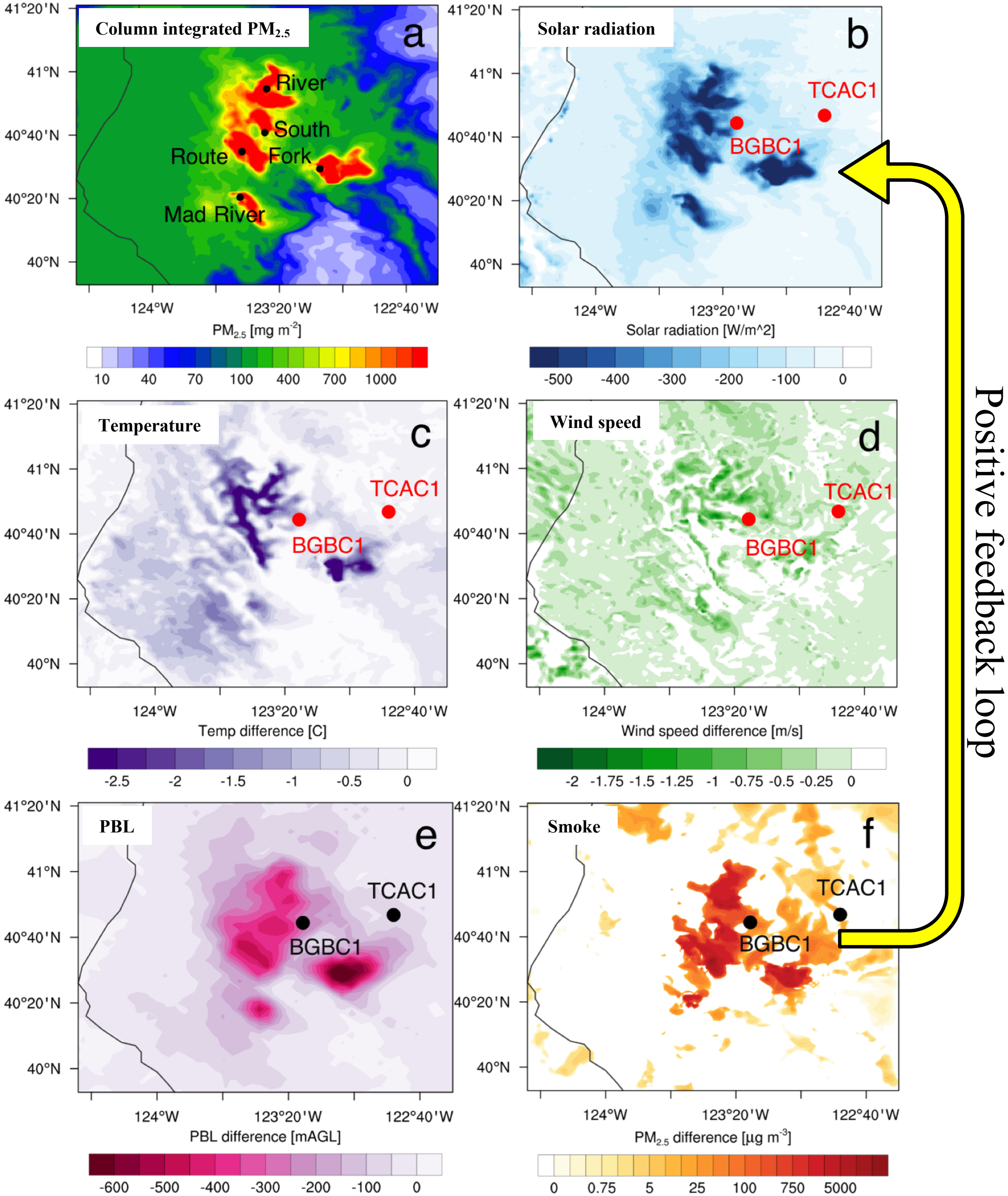
**Simulations re-initialized once a day at 12z*

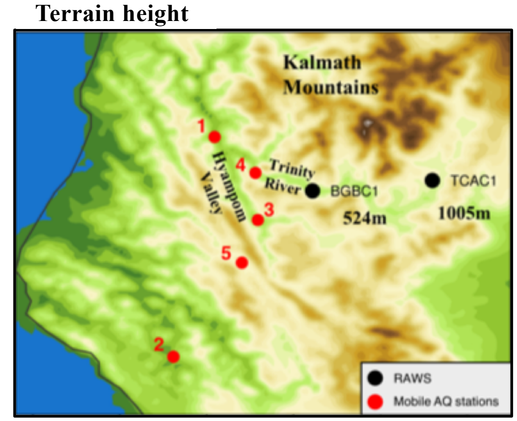


Baseline Run:
No radiative impacts of smoke

WRF-SFIRE-CHEM:
Includes radiative impacts of smoke







(Panel a) Integrated smoke for the WRF-SFIRE-CHEM forecast run

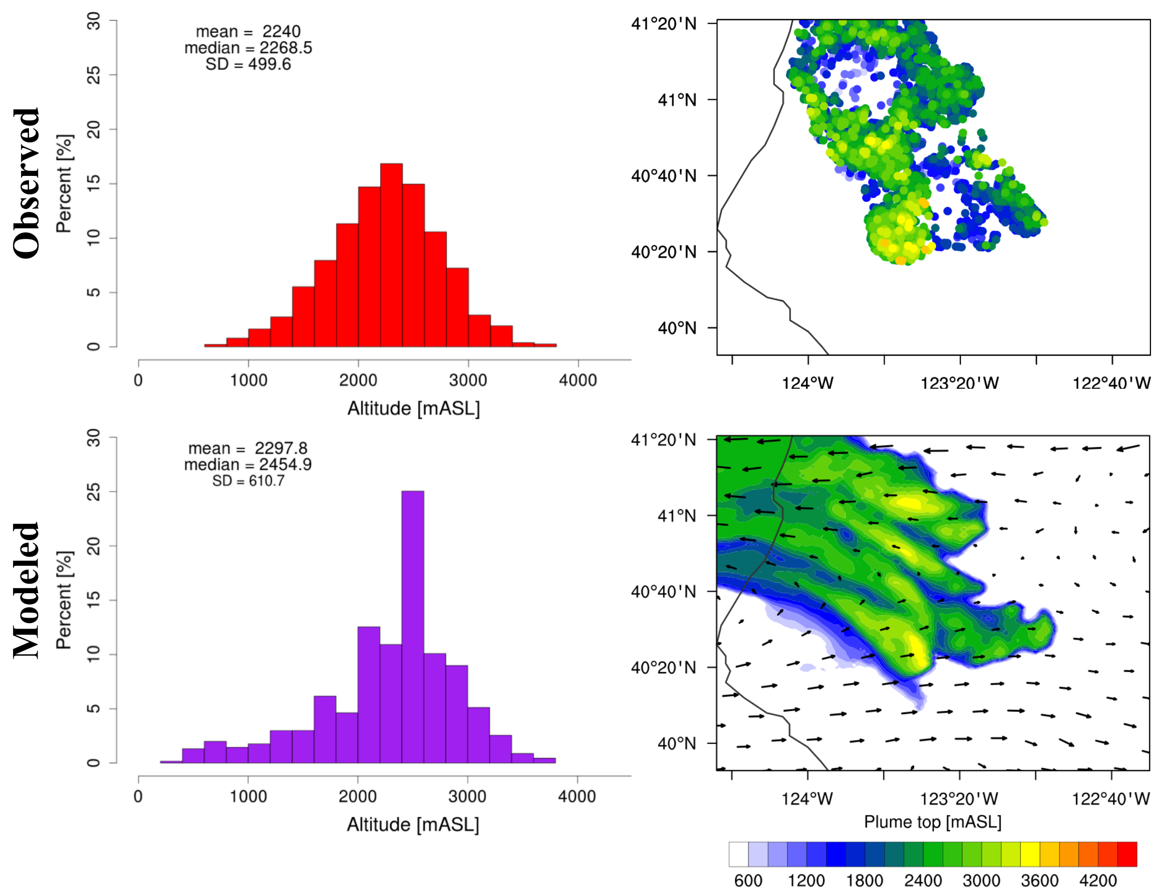
(Panel b-d) **WRF-SFIRE-CHEM forecast run** with aerosol impacts subtracted by the **Baseline simulation**

- From these results, there is evidence that WRF-SFIRE-CHEM is capturing a positive feedback

Our results appear to make sense; however, are we getting the correct results for the ***right*** reasons…?

- Modeled plume heights in good agreement with MISR observations
- The magnitude, and spatial distribution of modeled $PM_{2.5}$ compare reasonably with observations; albeit there was an overestimations reported at station 3

Plume height comparisons at 1830z



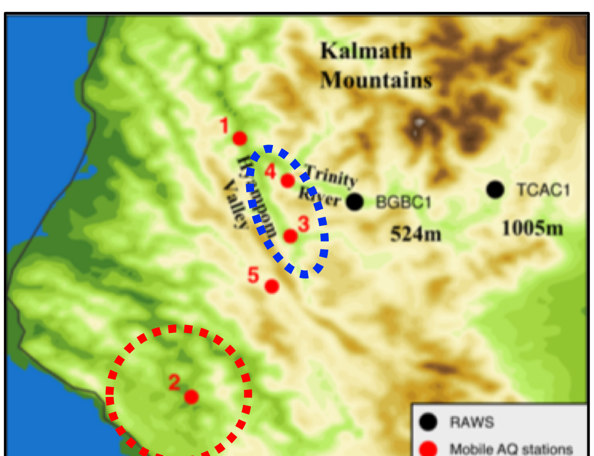
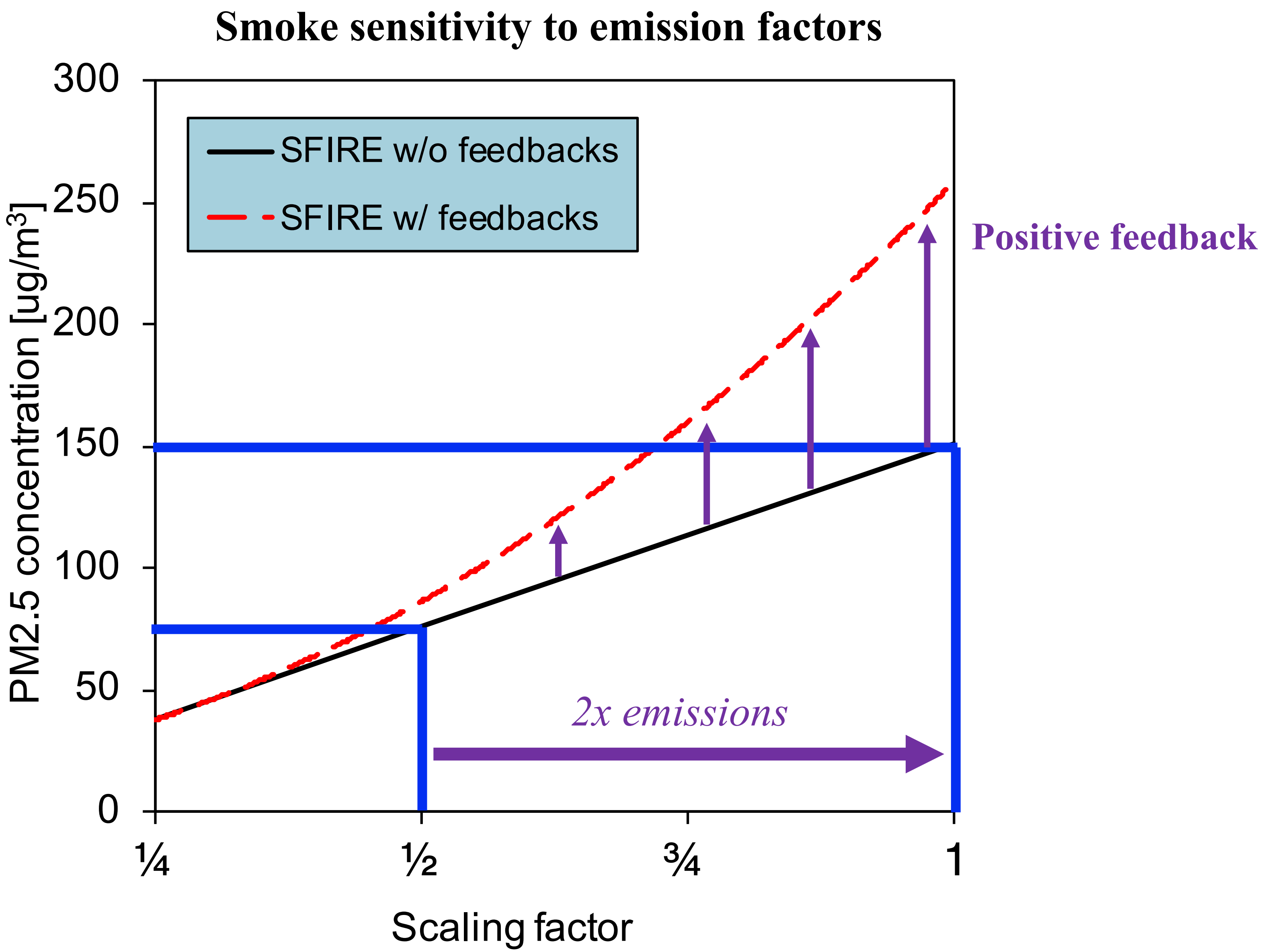


Table 3. Average forecast and observed $PM_{2.5}$ concentrations (µg m-3). Mean concentrations were averaged between August 17-22nd 2015.

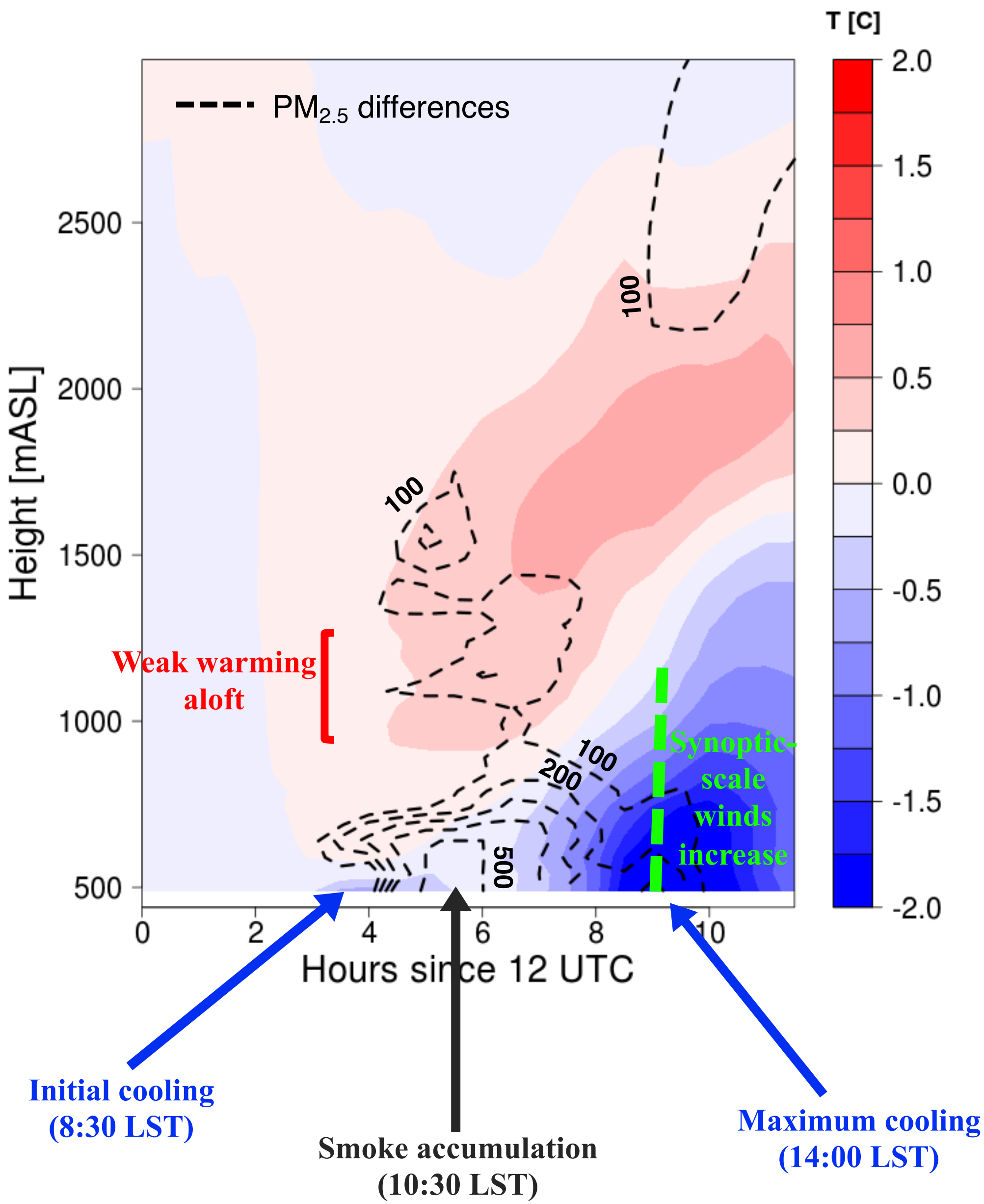
	Mean obs	Mean model	Bias	Relative Bias
Station 1	176.8	161.4	-15.6	-9%
Station 2	23.5	33.3	9.8	42%
Station 3	496.3	1281.9	785.6	158%
Station 4	315.2	407.7	92.7	29%
Station 5	99.9	126.8	26.8	27%



*Comparison on August 19th at 21z, with simulation initialized at 12z on the same day

Differences between simulations with and without aerosol-radiative feedbacks

**Initialized at 1200 UTC on August 19th 2015*



Summary:

- WRF-SFIRE-CHEM runs using GOCART were able to replicate decreases in temperature and solar radiation within a smoke infiltrated valley location (Big Bar) relative to that of an upper-elevation site (Trinity Camp)

- ***Significant temperature and wind decreases were also observed within the model near valleys adjacent to the fires***
    - *What are **the dynamical impacts of inversions on fire growth?***

- Comparisons of smoke plume tops and near-surface $PM_{2.5}$ concentrations to observations indicate that our simulations reasonably model smoke and smoke dispersion

- Through a sensitivity analysis, we are able to establish that WRF-SFIRE-CHEM is able to capture positive feedbacks with the GOCART scheme
    - This work suggests that a coupled model is needed to simulate the impacts of smoke shading, *especially at local scales*


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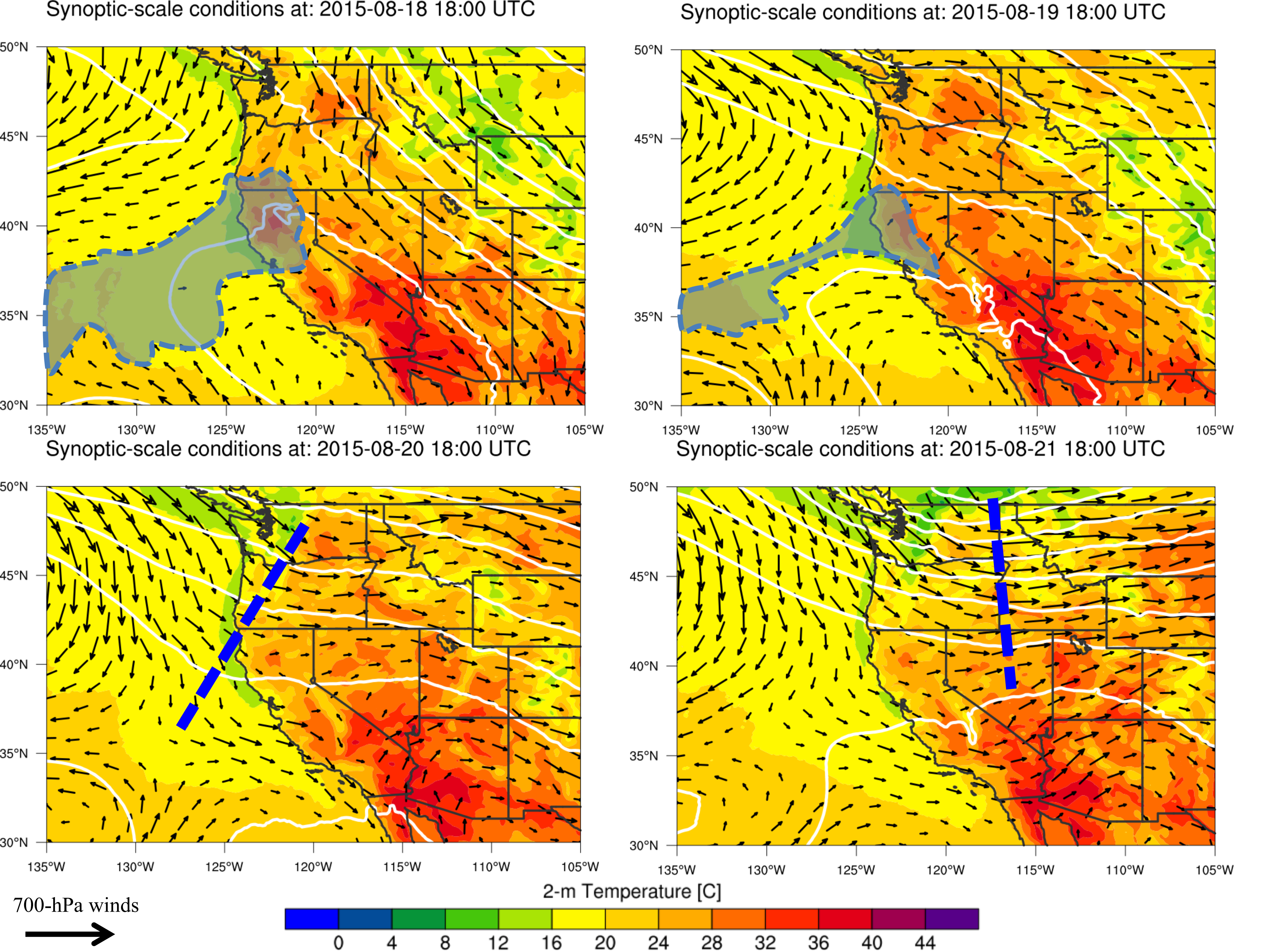
Table 1. Detailed WRF configuration used in the study.

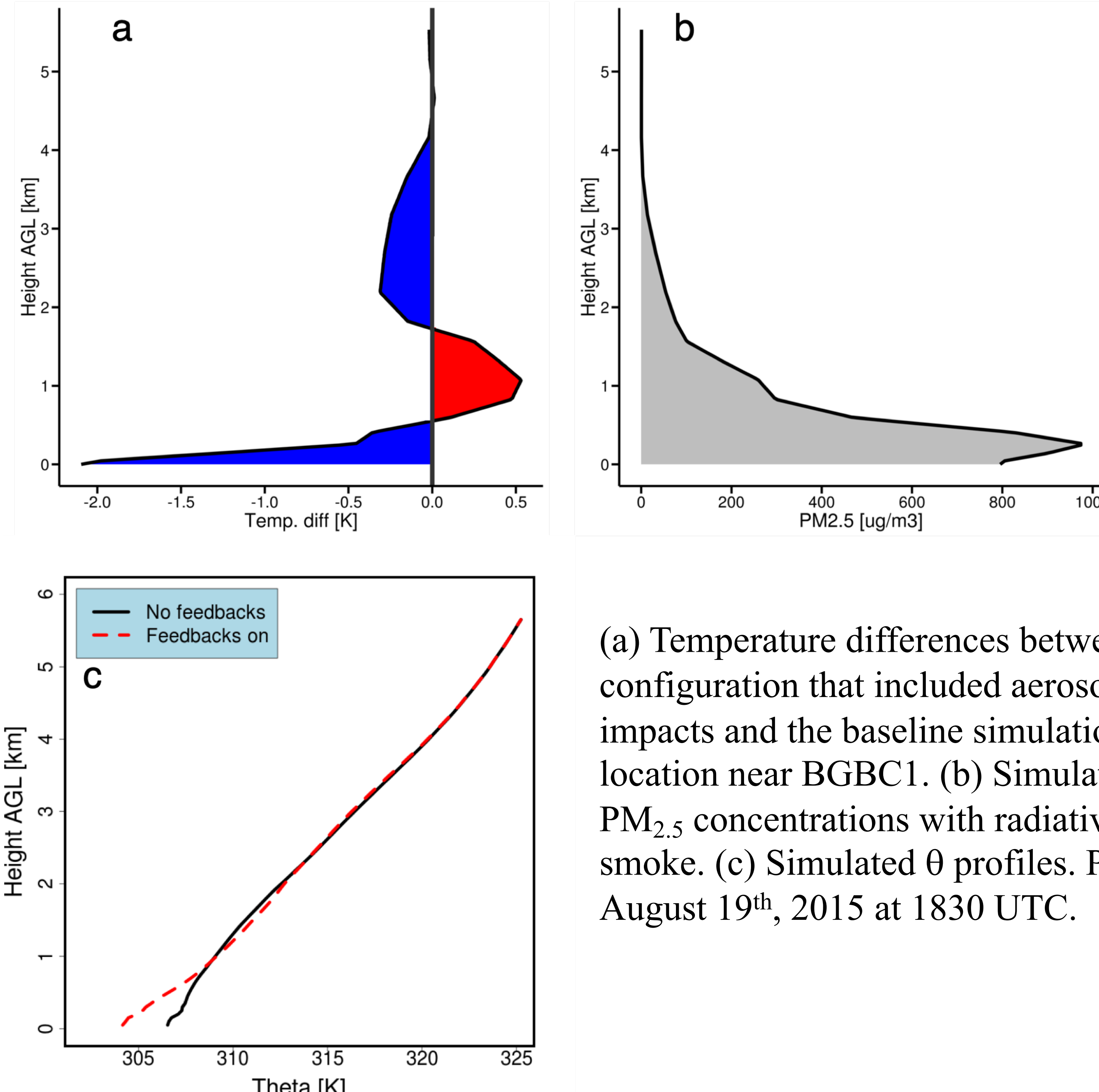
Domains	d01	d02	d03
Horizontal resolution of atmospheric model	12km	4km	1.33km
Horizontal resolution of the fire model	-	200m	67.7m
Number of grid points (X×Y×Z)	130×130×41	130×130×41	130×130×41
Initial 1h fuel moisture	-	4.4%	4.4%
Initial 10h fuel moisture	-	10%	10%
Initial 100h fuel moisture	-	12.2%	12.2%
Initial life fuel moisture	-	86%	86%
Time step	18s	6s	2s
Microphysics	Lin et al.[1]	Lin et al. [1]	Lin et al. [1]
PBL Physics	YSU[2]	YSU[2]	YSU[2]
Surface Model	Noah[3]	Noah[3]	Noah[3]
Cumulus Parametrization	Grell-Devenyi[4]	Grell-Devenyi[4]	-
Chemical option	300	300	300

[1] Chen and Sun [2002]; [2] Hong, Song–You, et al. [2006]; [3] Tewari, M et al. [2004]; [4] Grell and Devenyi [2002]

Rapid Radiative Transfer Model for GCMs (RRTMG) [*Iacono et al.,* 2008])
Chem_opt = 300 (GOCART simple aerosol scheme, no ozone chemistry)

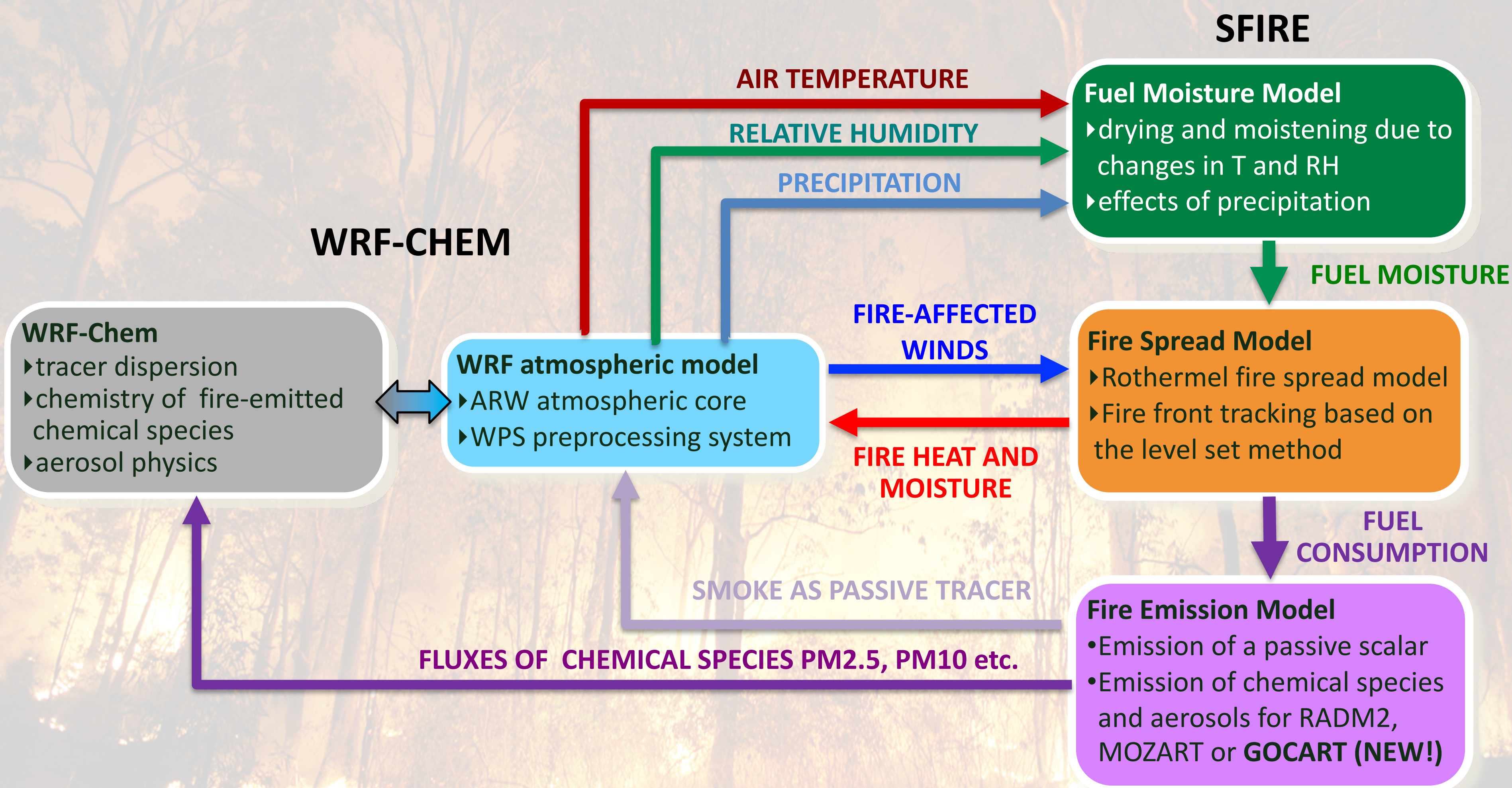


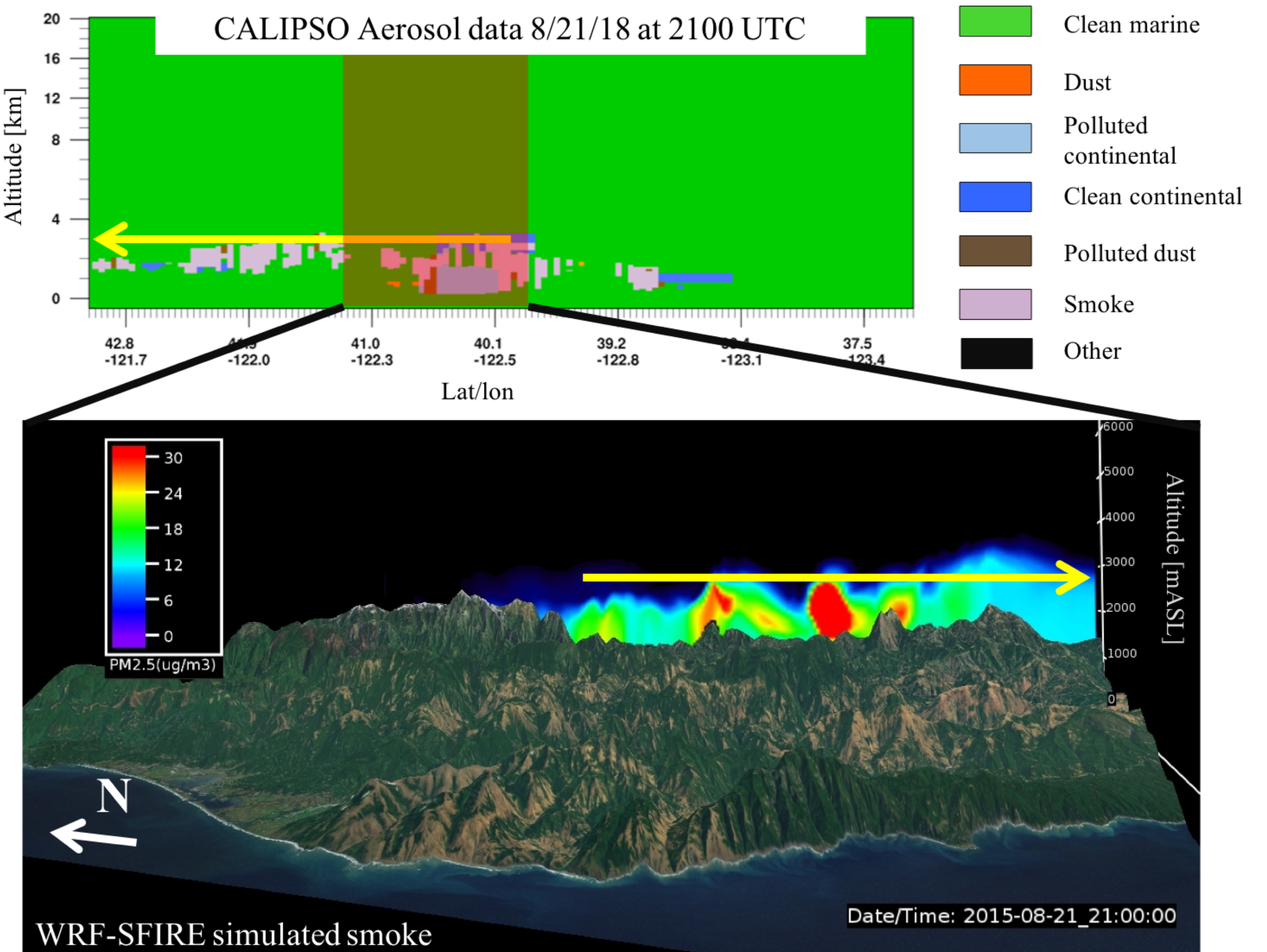
Synoptic-scale conditions at: 2015-08-18 18:00 UTC
Synoptic-scale conditions at: 2015-08-19 18:00 UTC
Synoptic-scale conditions at: 2015-08-20 18:00 UTC
Synoptic-scale conditions at: 2015-08-21 18:00 UTC
50°N
45°N
40°N
35°N
30°N
135°W
130°W
125°W
120°W
115°W
110°W
105°W
700-hPa winds
2-m Temperature [C]
0
4
8
12
16
20
24
28
32
36
40
44



(a) Temperature differences between the configuration that included aerosol radiative impacts and the baseline simulation for a location near BGBC1. (b) Simulated vertical $PM_{2.5}$ concentrations with radiatively active smoke. (c) Simulated θ profiles. Panels are for August 19th, 2015 at 1830 UTC.

WRF-SFIRE-Chem modeling framework





CALIPSO Aerosol data 8/21/18 at 2100 UTC
Altitude [km]
20
16
12
8
4
0
42.8 -121.7
-122.0
41.0 -122.3
40.1 -122.5
39.2 -122.8
-123.1
37.5
Lat/lon
Clean marine
Dust
Polluted continental
Clean continental
Polluted dust
Smoke
Other
30
24
18
12
6
0
PM2.5(ug/m3)
6000
5000
4000
3000
2000
1000
0
Altitude [mASL]
N
Date/Time: 2015-08-21_21:00:00
WRF-SFIRE simulated smoke