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Santa Ana Severity Index: Formulation, Validation, and Limitations

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1 Introduction

*The "Santa Ana" is a dry, sometimes hot, offshore wind directed from the Great Basin and Mojave Desert over the mountains and through the passes of Southern California. **See Figure 1(a)**.*

- *Its season extends from September to April, and the winds evince terrain amplification of the mountain gap and downslope varieties.**See Figure 1(b)**.*
- *Fast winds combine with low relative humidities to produce large and destructive fires when an ignition occurs, especially in the autumn season. Such fires have happened in 1993, 2003, 2007, 2008, etc.*
- *Large Fire Potential index is developed as a new tool to categorize the Santa Ana events with respect to large fire potential threat.*

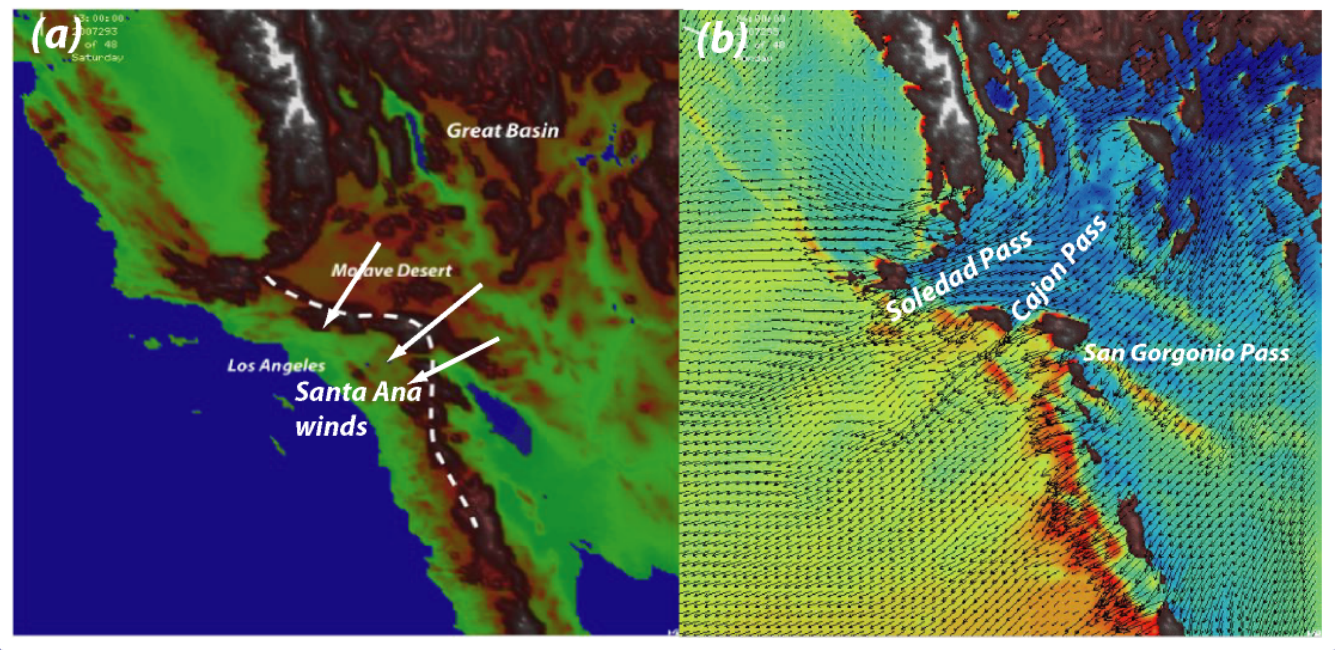


Figure 1:
(a) Topography of the West United States . The Los Angeles and San Diego areas are separated from the Mojave and Colorado Deserts by the imperfect curtain of mountains. (b) Simulation of 850 mb temperature (shaded) and winds (arrows). Cold colors denote relatively cold air temperature and warm colors denote relatively warm temperature.

2 Large Fire Potential Index Formulation

- *Factors contributing to large fire potential during Santa Ana winds are **Wind Speed**, **Humidity** and **Fuels Conditions**.*
- *Our **Large Fire Potential (LFP)** index is expressed by:*

$$LFP = (\text{Surface Wind Speed})^2 (\text{Dewpoint Depression})\ (\text{Fuel Moisture}) = LFPw \times FM$$

- ***LFPw** is the weather-only component of LFP. Fuel Moisture (**FM**) ranges from 0 (wet) to 1(dry). It can reduce LFP to zero after significant wetting rains in conjunction with widespread green-up.*
- ***FM** is formulated as **[(DL/LFM-1)+G]/10**, where*

DL = dryness Level index consisting of the Energy Release Component and ten hour dead fuel moisture timelag.

LFM= Live Fuel Moisture, a sampling of the moisture content of the live fuels.

G = Greenness of the annual grass.

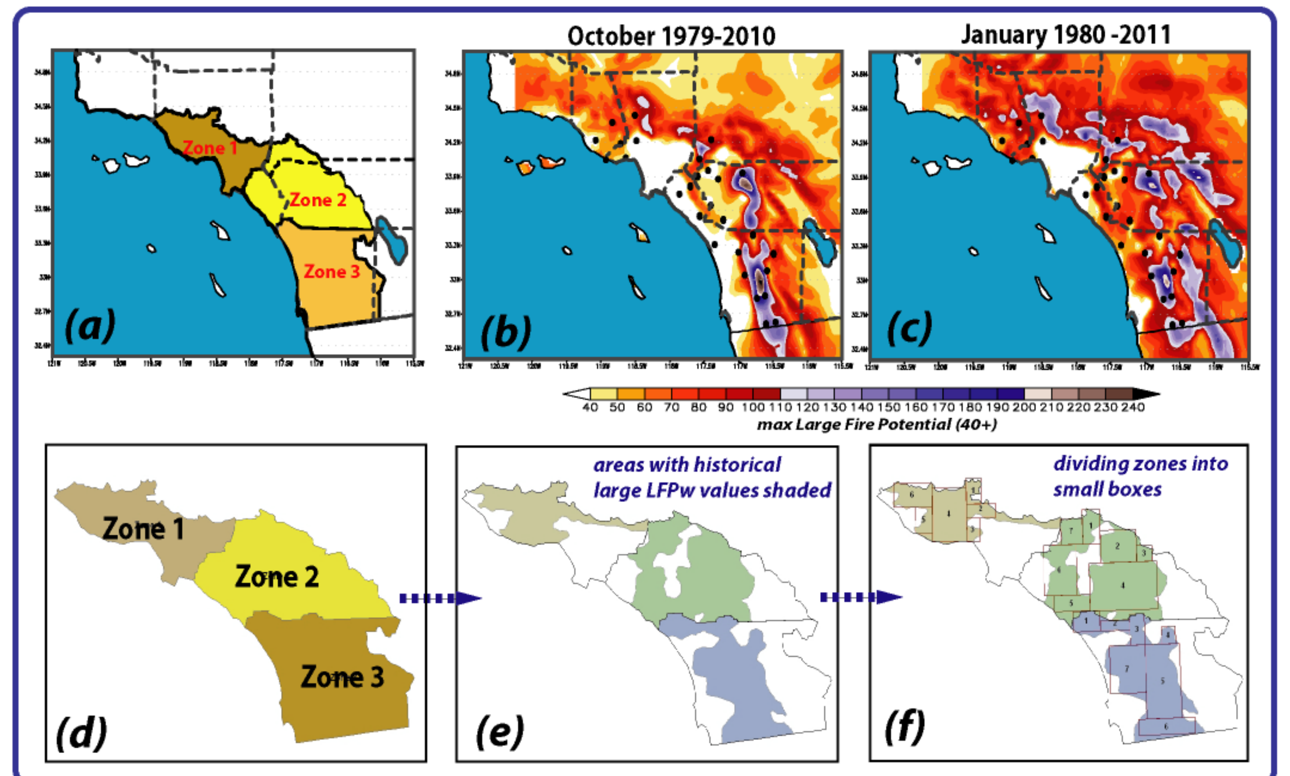


Figure 2:
(a) Zone boundaries: Zone 1 covers the southern portion of Ventura and Los Angeles Countries. Zone 2 consists of Orange County, as well as western Riverside and western San Bernardino Countries. Zone 3 represents most of San Diego Country. (b)-(c): Composite maps showing the maximum LFPw value for each grid point for Oct 1979-2010 and Jan 1980-2011. Small black dots indicate RAWS stations. (d)-(f) illustrate how the boxed areas are developed.

3 Historical Values of the Large Fire Potential

- *The zones **(Figure 2a)** used to calculate LFPw were chosen based on the different offshore flow characteristics that occur across the region, and were developed partially around political boundaries, as well as around the news media broadcast markets that cover the region.*
- *The two composite images **(Figure 2b-c)**, made from 6km resolution WRF reanalyses, show the 30 year historical maximum LFPw map were used to define what are called Santa Ana regions (boxes) within each zone. LFPw was calculated for grid points only within the boxes **(Figure 2d-f)**.*
- *At each point, LFPw is averaged over eight consecutive hours **(Figure 3b)**.*
- *The final LFPw is the spatial average over each box **(Figure 3a)**.*

(a)

Date	Zone 1 LA/Ventura						LFP SUM
	Box 1	Box 2	Box 3	Box 4	Box 5	Box 6	
1/1/1982	412	191	184	1580	377	806	3550
1/2/1982	387	316	305	2107	639	1503	5258
1/3/1982	446	612	197	596	93	83	2027
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Date	Zone 2 Santa Ana							LFP SUM
	Box 1	Box 2	Box 3	Box 4	Box 5	Box 6	Box 7	
1/1/1982	273	444	499	2645	475	1113	354	5801
1/2/1982	312	525	641	2266	593	1168	863	6367
1/3/1982	889	598	172	809	236	272	73	3049
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Date	Zone 3 San Diego							LFP SUM
	Box 1	Box 2	Box 3	Box 4	Box 5	Box 6	Box 7	
1/1/1982	528	293	474	574	2767	789	930	6356
1/2/1982	896	282	470	531	3408	1390	1628	8606
1/3/1982	301	171	229	302	1624	742	578	3948
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

(b)

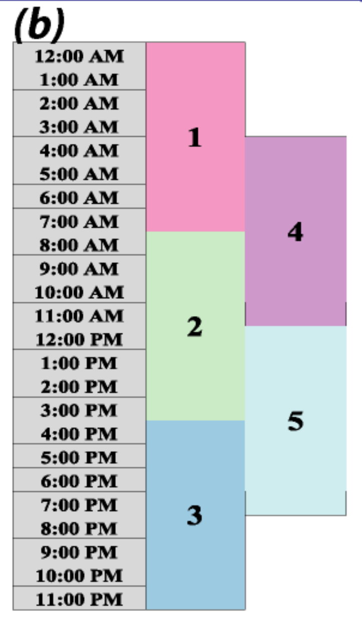


Figure 3:
Left: An schematic figure showing how LFPw is calculated in each box in zone.

Right: Five different eight consecutive hour time windows used to calculate grid point LFP.

4 Large Fire Potential Index Validation

- *LFPw is superior to the Fosberg Fire Weather Index (FFWI), as LFPw has been proven to have siginificantly greater contrast between Santa Ana days and non-Santa Ana days (not shown).*
- *Besides meteorological conditions, LFP is also highly dependent on FM.*
- *Preliminary results from Zone 3 in **Table 1** show how FM modifies the LFPw values, which correlates well with observed fire activities.*
- *As is shown in **Table 1**, large fires could not occur when FM is low, even with very high LFPw and ignitions. Conversely, dates that had final LFP values exceeding 40 when ignitions occurred, resulted in large fires .*

Date	LFPw	DL	G	LFM	FM	LFP	Ignitions	Large Fires	Fire Acres
1/7/2003	70	3	0	0.86	0.249	17	Y	N	
1/1/2008	56	2	0	0.81	0.147	8	N	N	
10/22/2007	54	3	5	0.55	0.945	51	Y	Y	9472
10/21/2007	51	3	5	0.55	0.945	48	Y	Y	197990
11/30/2006	48	3	5	0.58	0.920	44	Y	Y	296
3/31/2005	48	1	0	1.19	0	0	N	N	
1/21/2010	46	1	0	0.70	0.043	2	N	N	
12/17/2004	45	2	0	0.76	0.164	7	Y	N	
2/2/2005	43	1	0	0.90	0.011	0	N	N	
2/6/2006	41	2	4	0.68	0.595	24	N	N	
1/10/2009	41	2	0	0.66	0.203	8	Y	N	
1/17/2008	40	2	0	0.87	0.130	5	Y	N	

Table 1:
Validation of LFP = LFPw x FM against observed fire activities. LFPw is the weather component of LFP. Fuel moisture FM is given by FM=[(DL/LFM-1)+G]/10. LFPw values are scaled by a factor of 0.001. A large fire is defined as the 95th percentile of daily largest fires occurring over the past 20 years across the regions depicted in Figure 2. See Rolinski et al. (2013).

5 Challenges

- *Current operational NWP models rarely have the resolution to explicitly capture important winds details (Fovell 2012). This:*
  - *Impacts the horizontal scale of downslope flow.*
  - *Affects where the strongest winds are sited.*
- *Model horizontal grid spacings wider than 2 km were determined insufficient to properly capture the terrain shape and thus cannot reliably place the fastest winds at the most likely correct locations **(Figure 4)**.*
- *Different combinations of model physics schemes can lead to tremendous variations. **Figure 5** shows extreme sensitivity of the simulations to model physics, mainly due to variations in the **surface roughness**. This strongly motivates an ensemble forecasting strategy.*

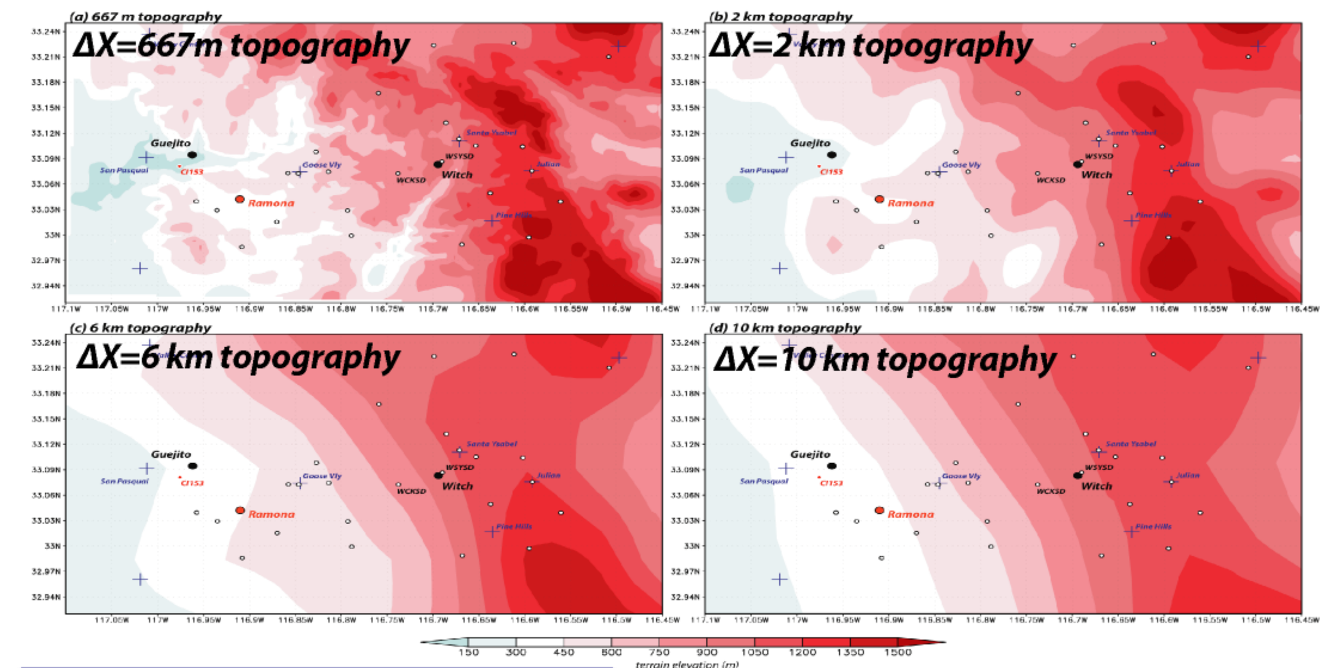
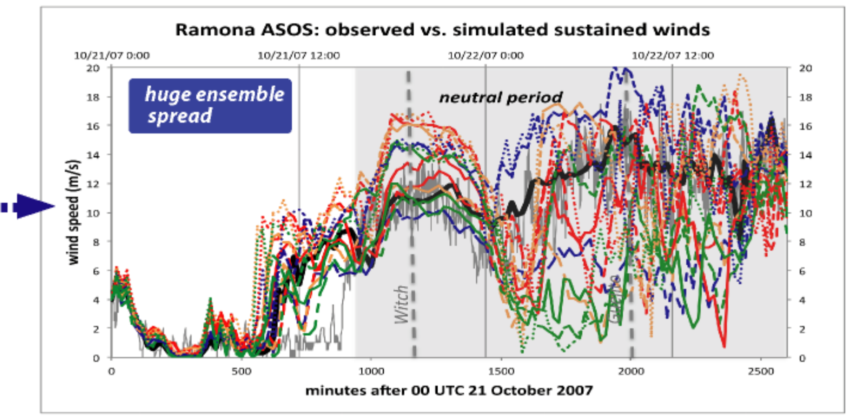


Figure 4:
Witch fire area topography at 10km; 6km; 2km and 667m grid spacings, respectively. See Fovell (2012).

Figure 5:
Time series of observed (grey) and simulated (colored) winds at Ramona airport, commencing at 0000UTC 21October 2007. Benchmark run highlighted (thick black). See Fovell (2012).

Surface scheme	Roughnesslength (m) [winter]
TD	0.01
NOAH	0.024
RUC	0.11
PX	0.20
⋮	⋮



6 Benefits

- *Expressing LFP as a function of wind, dew point depression and fuel moisture has allowed high resolution model and satellite-derived variables to be incorporated into the index.*
- *LFP enables the fire agencies, fire responders, private industry, the general public, and the media to have a clearer understanding of the severity of an event based on the potential for large fires to occur.*
- *A climatology of Santa Ana wind events can be developed based on this index which can be used in future research involving seasonal outlook predictions.*

- *Related work*

Fovell, R. G., 2012: Downslope windstorms of San Diego county: Sensitivity to resolution and model physics. 13th WRF Users Workshop, June 2012.

Rolinski, T., B. D'Agostino, and S. Vanderburg, 2013: Categorization of Santa Ana Winds with respect to Large Fire Potential. 93rd American Meteorological Society Annual Meeting, January 2013.

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