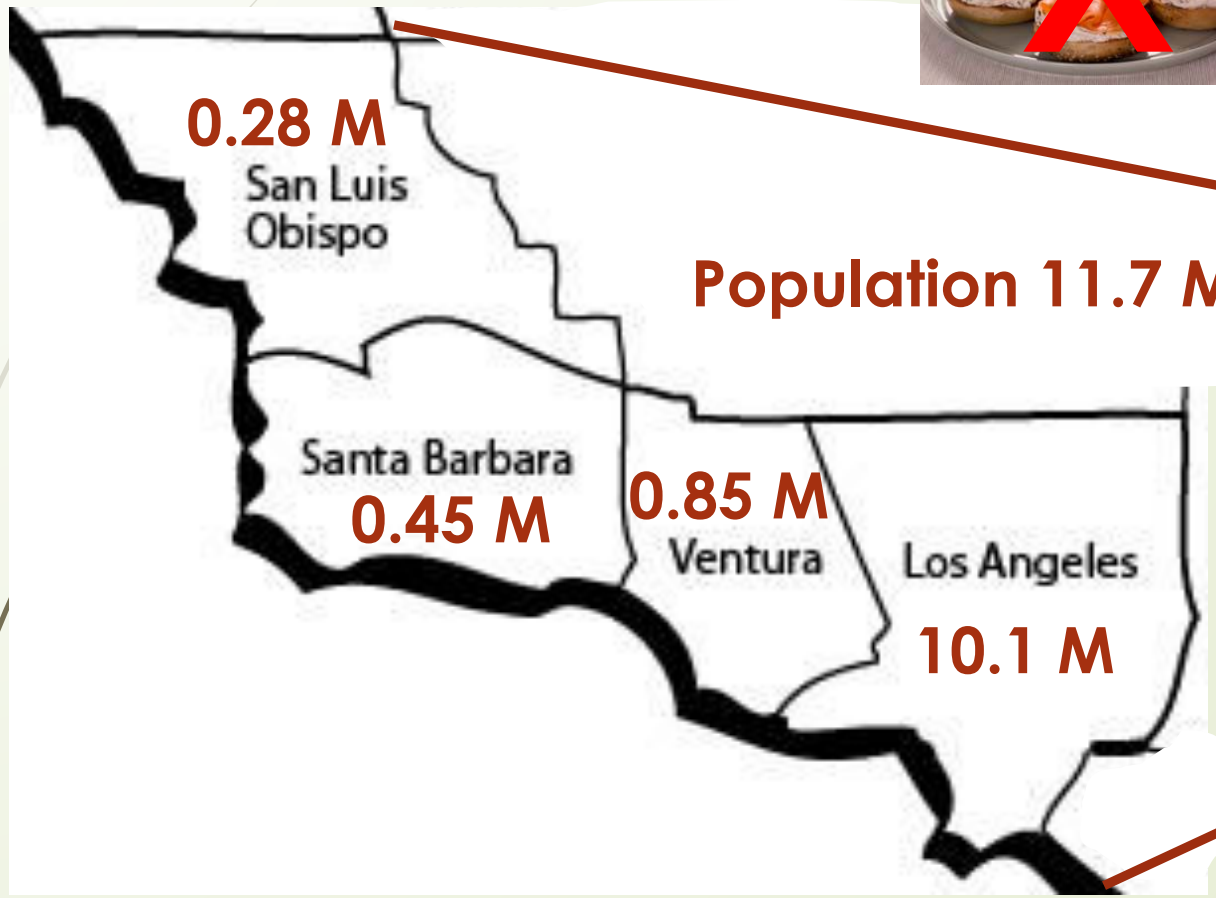
Atmospheric Rivers and Debris Flows at WFO LOX

John Dumas
Science Operations Officer
IARC, June 25-28, 2018
With assistance from Dennis Staley, USGS

Where/Who are we?

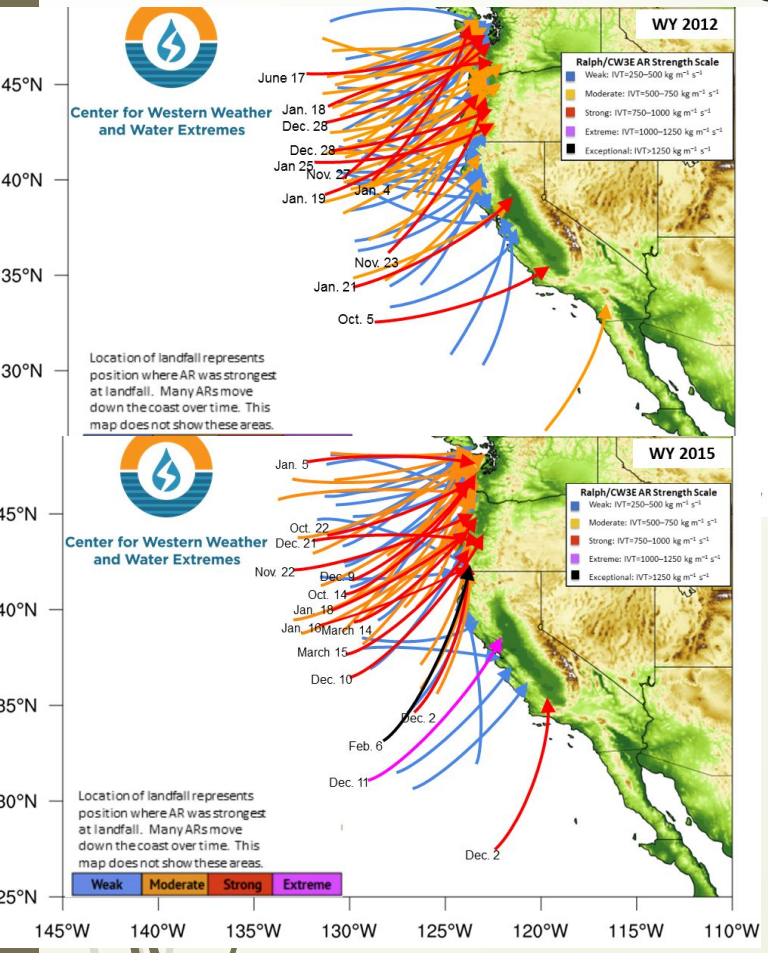


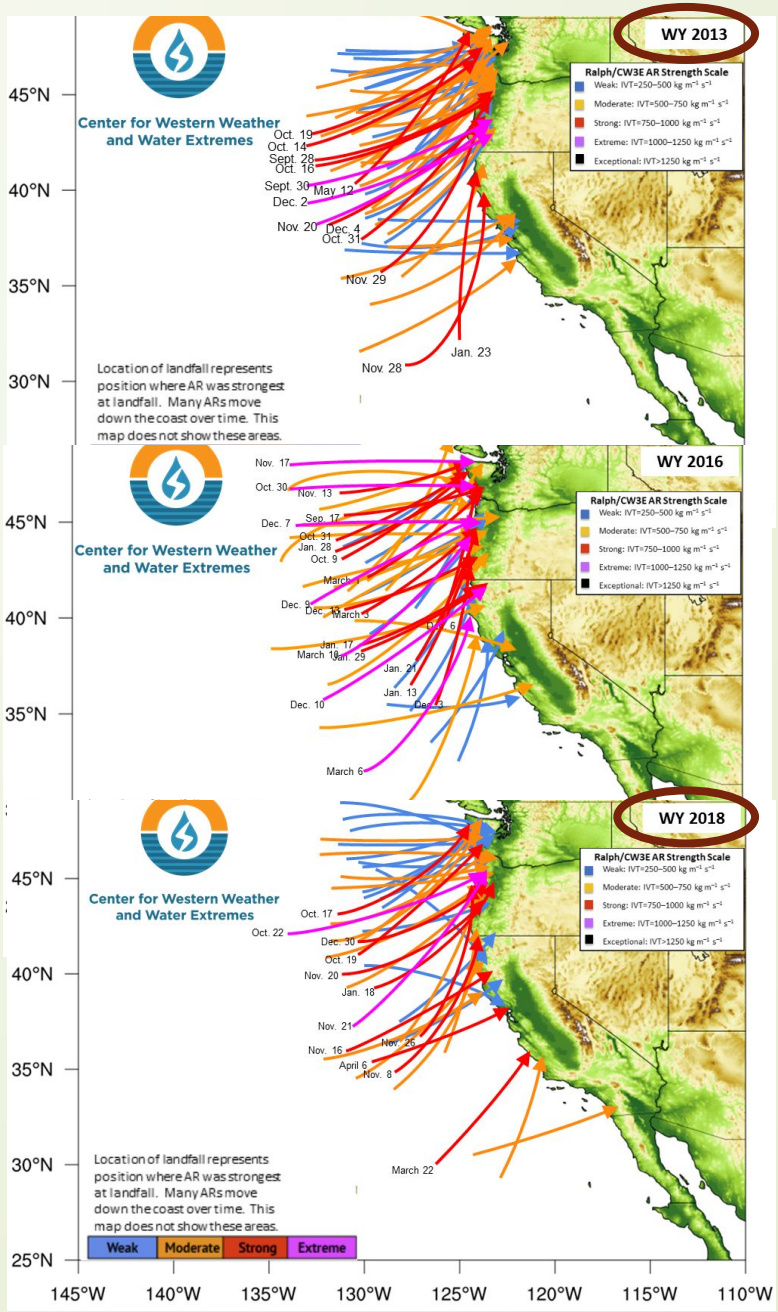
Population 11.7 Million

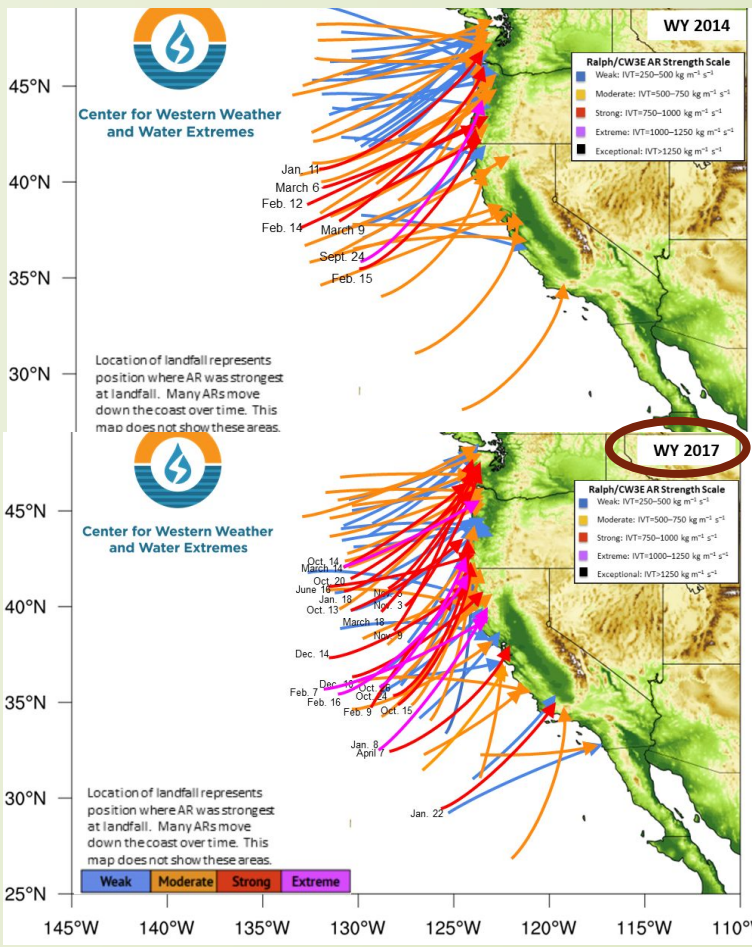
From California State Association of Counties

Per 2010 census estimate for 2016

We get a few ARs each year…



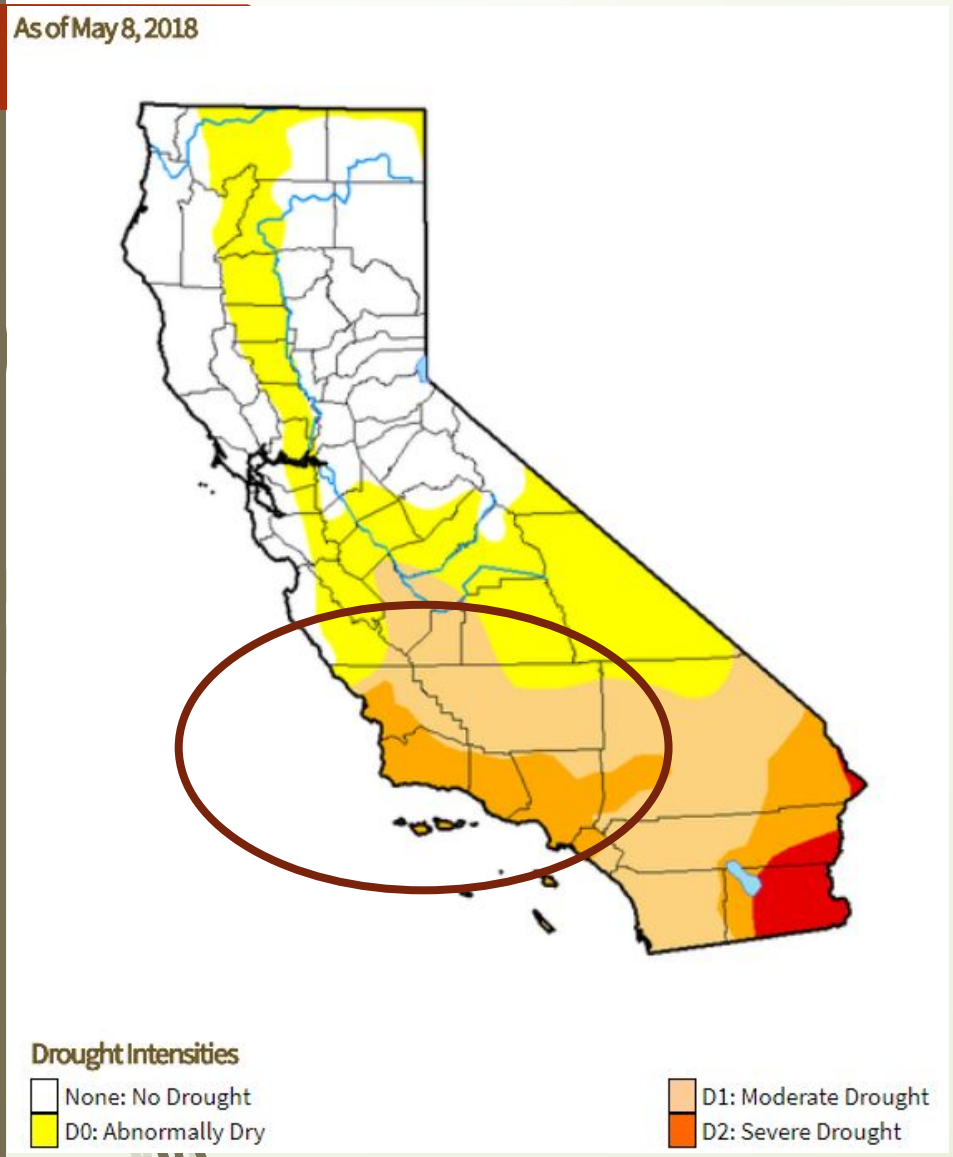


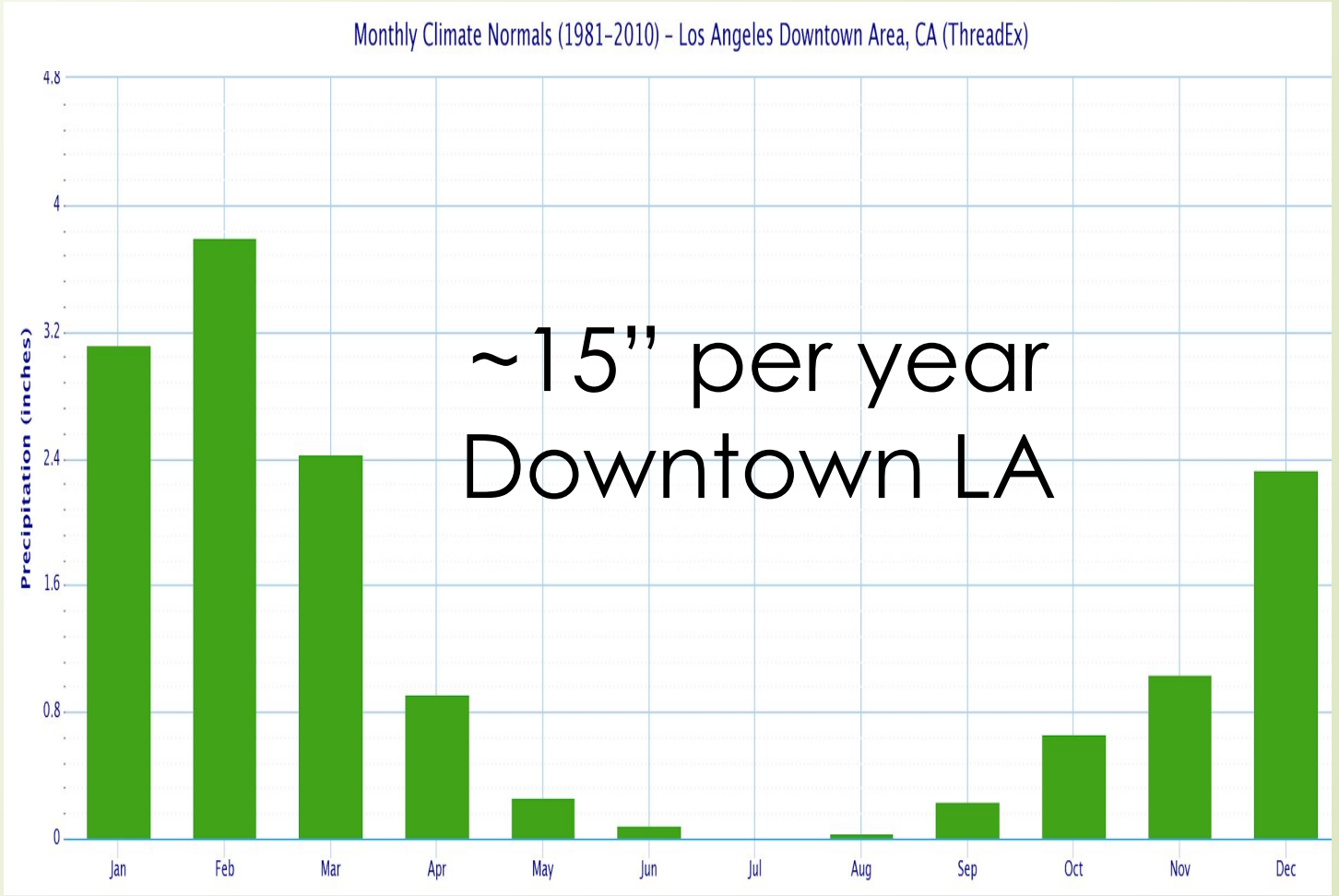


Year with Debris Flow

weather.gov/losangeles

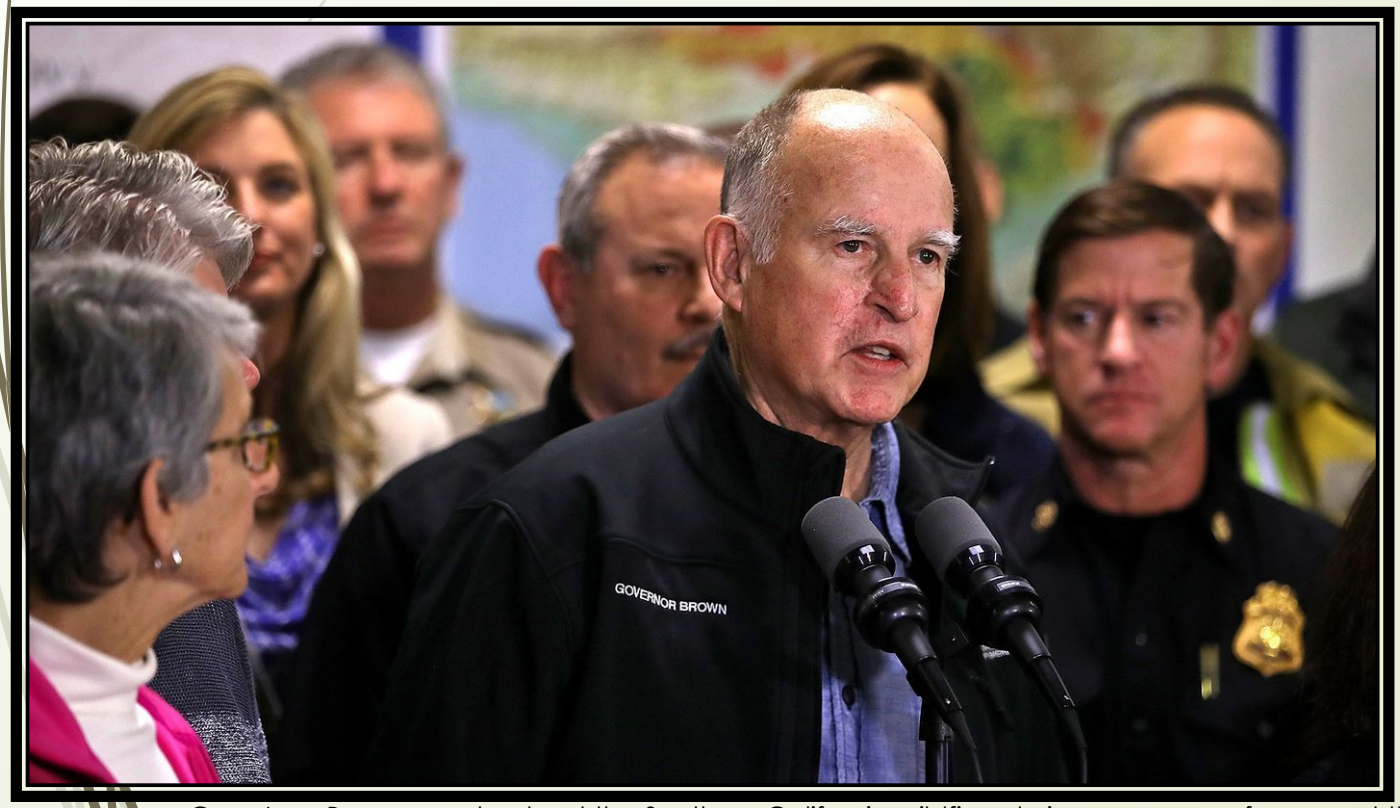
…but we don't get much rain…





…and we get too much fire!

Per Southern California Geographic Area Coordination Center
2004-2017: 126 large fires (>250acres)
~9 per year



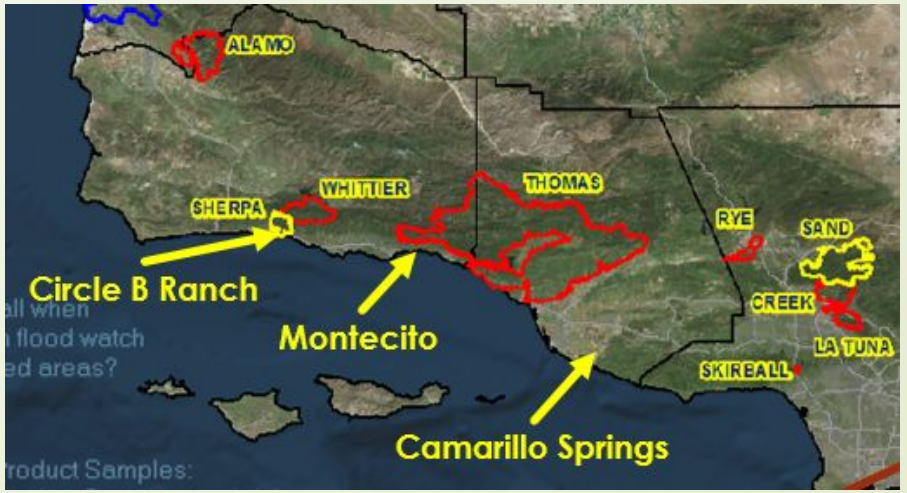
Gov. Jerry Brown speaks about the Southern California wildfires during a news conference at the Ventura County Fairgrounds. (Justin Sullivan / Getty Images)

Gov. Jerry Brown surveyed the devastation Saturday in Ventura …calling it "the new normal."…"This could be something that happens every year or every few years," he said…. "We're about to have a firefighting Christmas."

-L.A. Times 12/10/17

#FloodAfterFire… It Starts with a Fire

Fire Name	SPRINGS	SHERPA	THOMAS	
Dates	5/2/13 - 5/6/13	6/15/16 – 7/15/16	12/4/17 - 1/12/18	
Location	Ventura Co.	Santa Barbara Co.	Santa Barbara Co., Ventura Co.	
Size [acres] / [ha]	24,000 / 9,712	7,474 / 3,024	281,893 / 114,078	
Rain Event	12/25/13	1/20/17	1/9/18	3/20-22/18
Days Since Fire	F+585	F+189	F-3 !	F+67
Debris Flow	Yes	Yes	Yes	No



Fire, Information, Forecasting and Response

Fire – Forecast

"Fire Weather" is primarily a function of humidity, wind speed, fuel dryness and time

$$FW = f(RH, WS, F, T)$$

Fire Weather (FW)	Rel Humidity (RH)	Wind Speed (WS)	Fuels (F)	Time (T)
High fire weather conditions DO NOT indicate a higher like-lihood of fire start, but of fire spread once started	The lower the RH, the more easily fire will spread	Both drives the fire and hinders air based fire fighting methods	The dryness of both live fuels and dead fuels	Weather conditions must persist over time to become significant (>6 hours at WFO LOX)

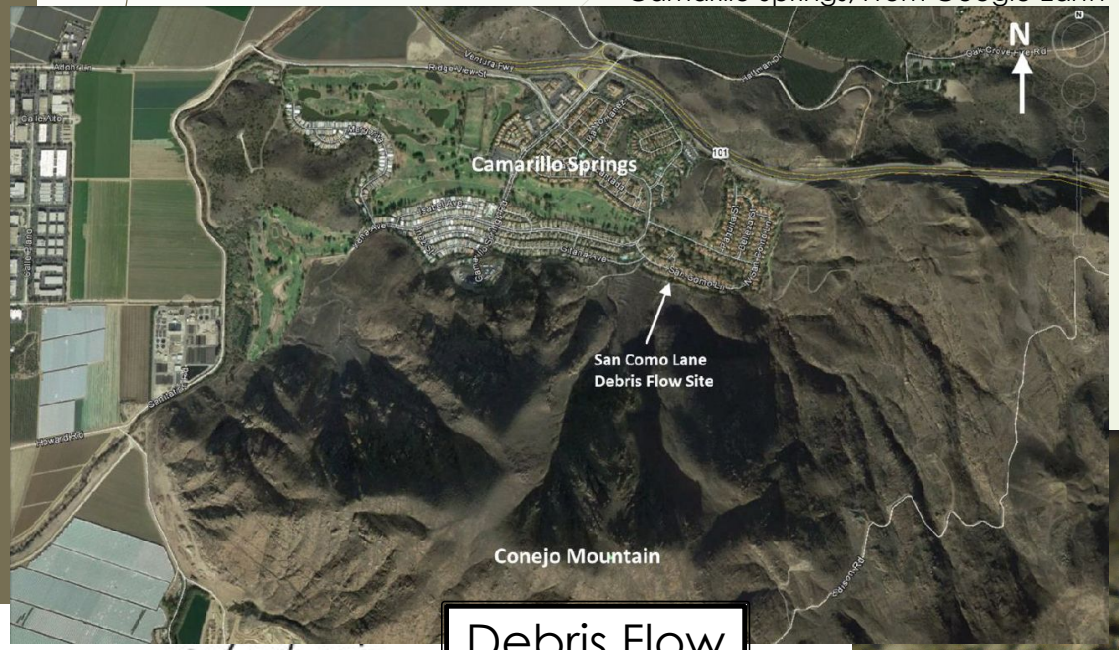
Fire – Response

Photo by Ray Ford / Noozhawk

If you see this coming you… evacuate

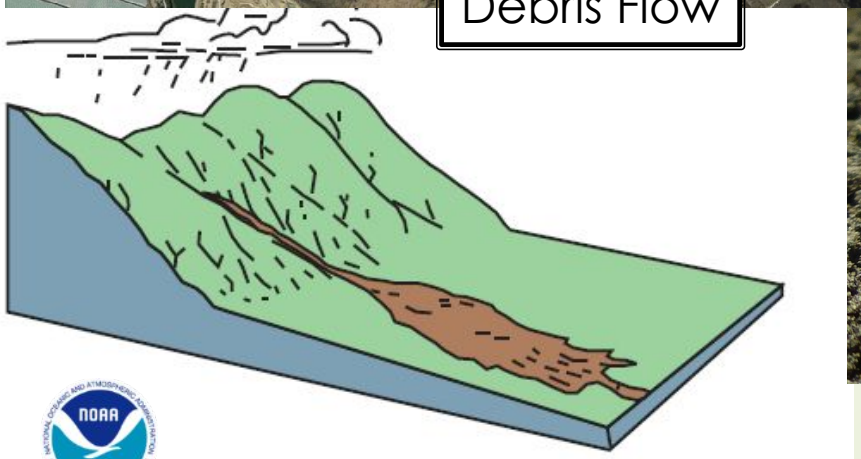
Debris Flow, Information, Forecasting and Response

Wildfires increase the potential for runoff and erosion…which can turn in to a "**Debris Flow**"

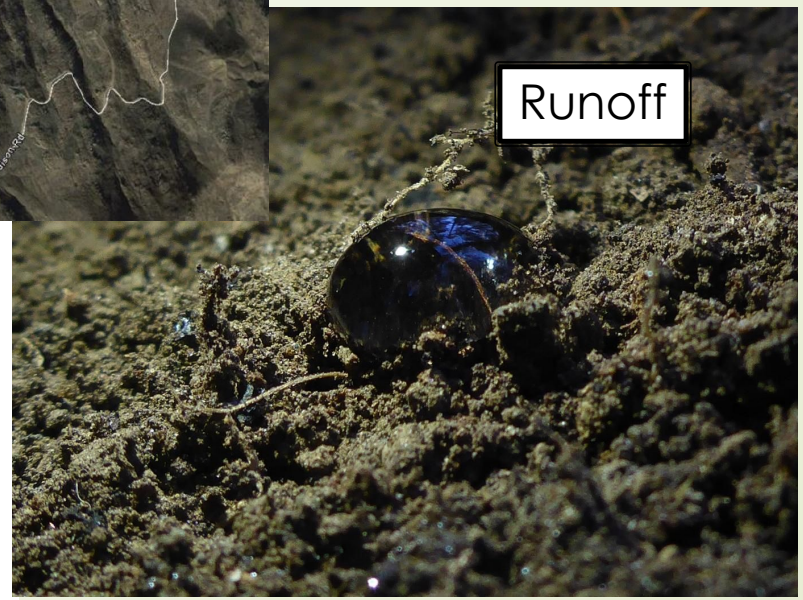


Camarillo Springs, From Google Earth

Thomas Fire, From Ventura Co Fire Dept



Debris Flow, From USGS Fact Sheet 2004-3072



Hydrophobic soil, From inciweb.nwcg.gov

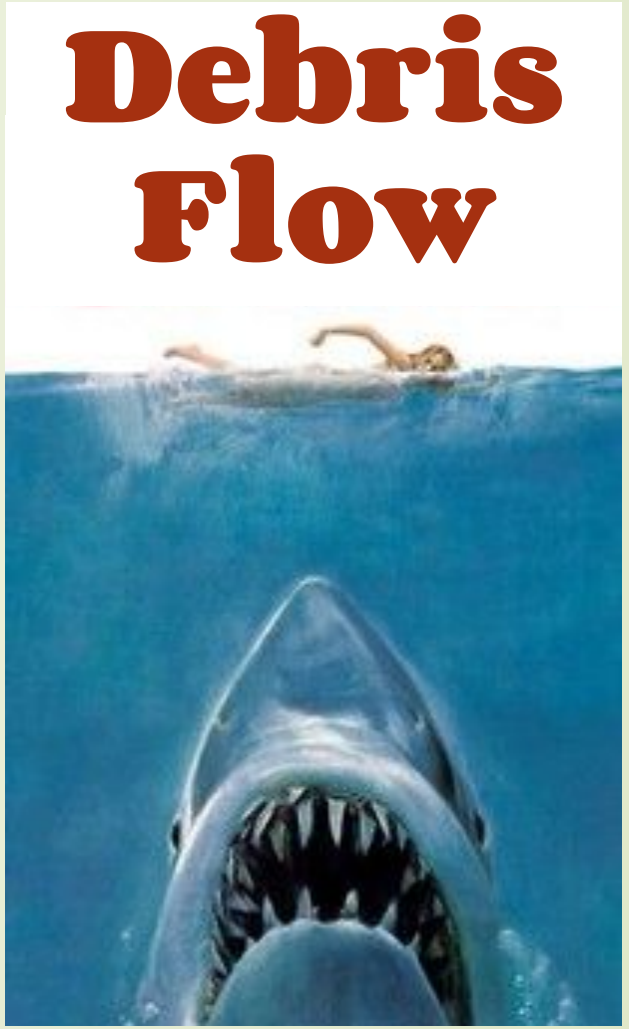
Rock Fall and Dry Ravel, From Thomas Fire BAER Report Geology, Part 1

weather.gov/losangeles

Debris Flow?

I don't think you appreciate the gut reaction people have to these things...Martin, It's all psychological. You yell 'Barracuda,' everybody says 'Huh? What?' You yell 'Shark,' we've got a panic on our hands on the Fourth of July.

Jaws: Universal Pictures, 1975



Debris Flow Forecast (SoCal)-Likelihood*

Logistic Framework:

$$p = \frac{e^x}{1 + e^x} \qquad x = b + c_1 c X_1 + c_2 c X_2 + \cdots + + c_n c X_n$$

Updated Link Function:

$$x = -3.63 + 0.41(T * R) + 0.67(F * R) + 0.70(S * R)$$

Terrain Steepness (T)	Fire Severity (F)	Soil Properties (S)	Rainfall (R)
Proportion of upslope area with moderate to high burn severity and gradients ≥ 23°	Average dNBR of upslope pixels / 1000	Average KF-Factor of upslope area	Peak rainfall accumulation, in mm (15 minute durations)

*Staley, D.M., Negri, J.A., Kean, J.W., Tillery, A.C., and Youberg, A.M., 2016, *Updated Logistic Regression Equations for the Calculation of Post-Fire Debris-Flow Likelihood in the Western United States*, U.S. Geological Survey Open-File Report 2016-1106, 20 p.

Available online at: https://pubs.er.usgs.gov/publication/ofr20161106

https://landslides.usgs.gov/hazards/postfire_debrisflow/background2016.php

Debris Flow Forecast (SoCal) – Volume*

Multivariate Regression:

$$x = b + c_1 c X_1 + c_2 c X_2 + \cdots + + c_n c X_n$$

Functio n:

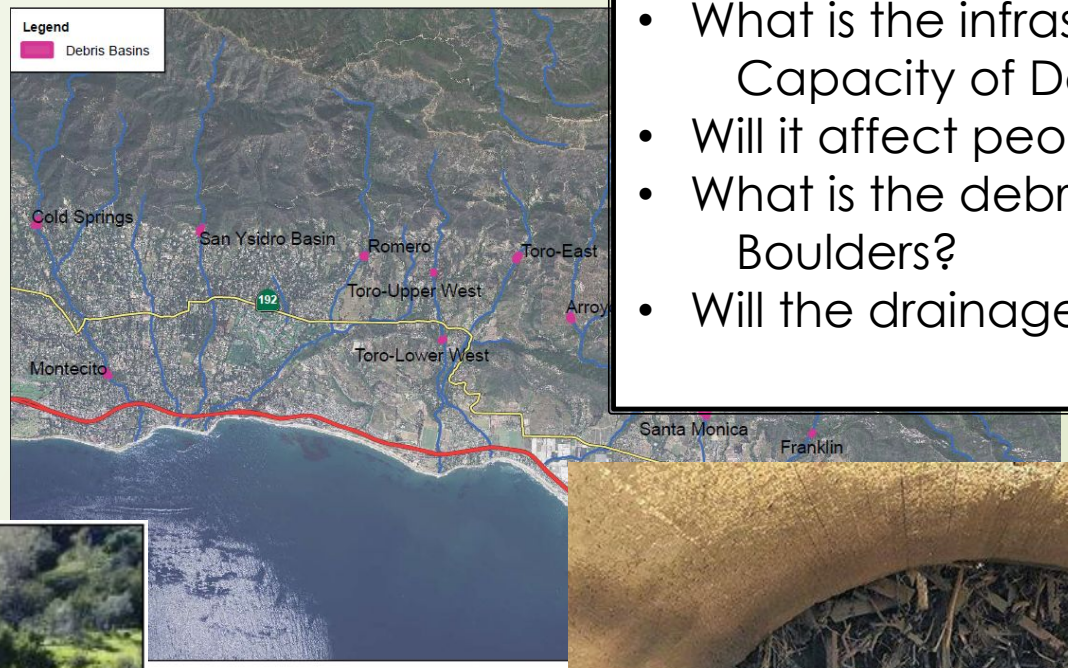
$$\ln(v) = 4.22 + 0.13T + 0.36F + 0.39R$$

Terrain Steepness (T)	Fire Severity (F)	Rainfall (R)
Square root of the range (max-min elevation) of elevation values within the upstream watershed (m)	Natural logarithm of the area burned at high or moderate severity (km^2)	Square root of the peak rainfall intensity, in mm h^{-1} (15 minute duration)

* Gartner J.E., Cannon S.H., Santi P.M., 2014, *Empirical models for predicting volumes of sediment deposited by debris flows and sediment-laden floods in the transverse ranges of southern California*, Engineering Geology 176:45-56, doi:http://dx.doi.org/10.1016/j.enggeo.2014.04.008

https://landslides.usgs.gov/hazards/postfire_debrisflow/background2016.php

Debris Flow Forecast - Impact



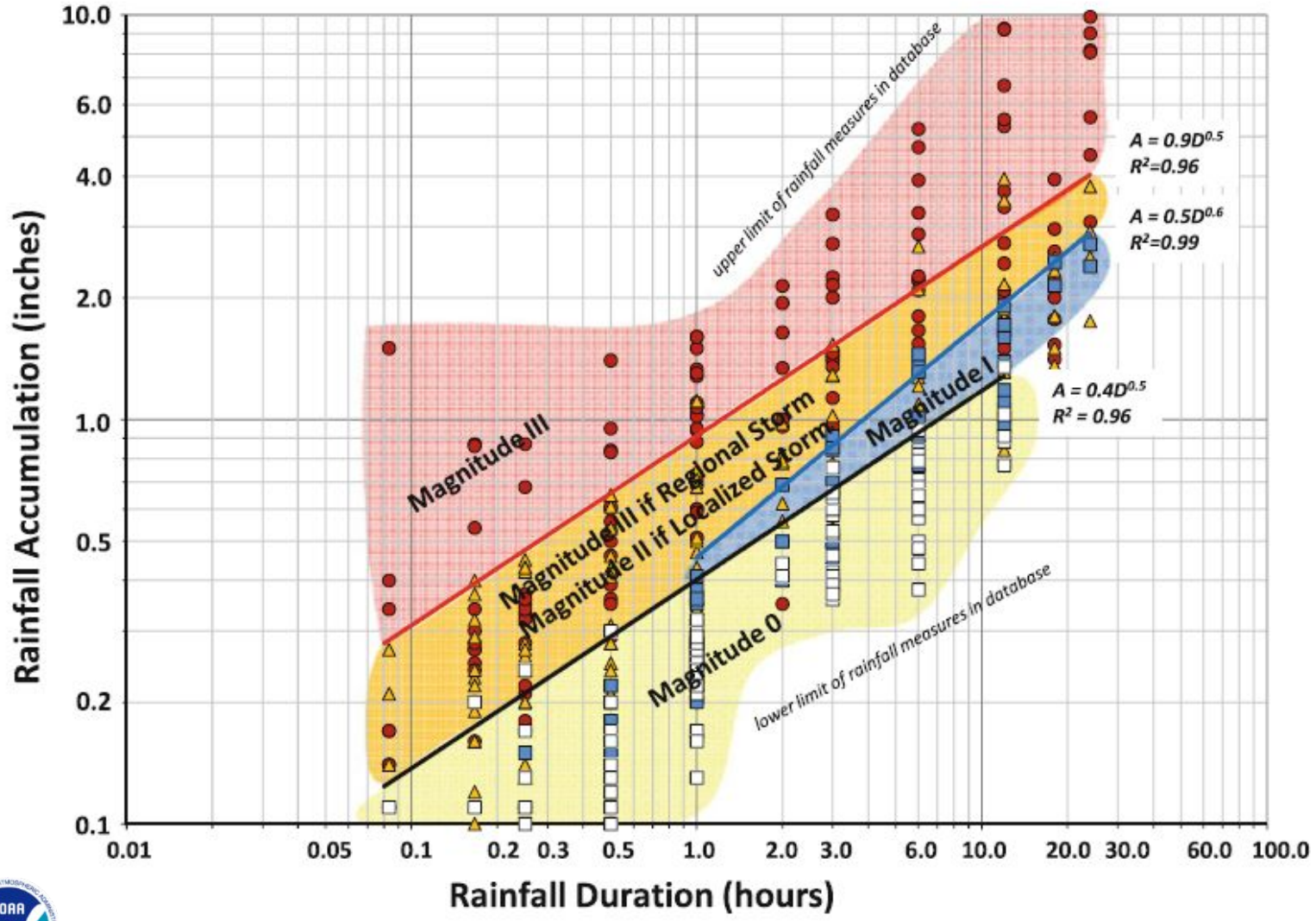
- What is the infrastructure?
  Capacity of Debris Basins?
- Will it affect people or trees?
- What is the debris?
  Boulders?
- Will the drainage fail/clog?

From Santa Barbara County Flood Control and Water Conservation District

Blake Herman/S.B. County Fire

Rainfall intensity–duration thresholds for post-fire debris-flow emergency-response planning (2011)

For the San Gabriel Mountains of southern California



Event Magnitude

0: negligible

I: Small

<1,000 yds^3

few buildings threatened

II: Moderate

1-10K yds^3

several homes damaged

III: Widespread

>10k yds^3

several large buildings destroyed

Cubic Yard Fun Facts:

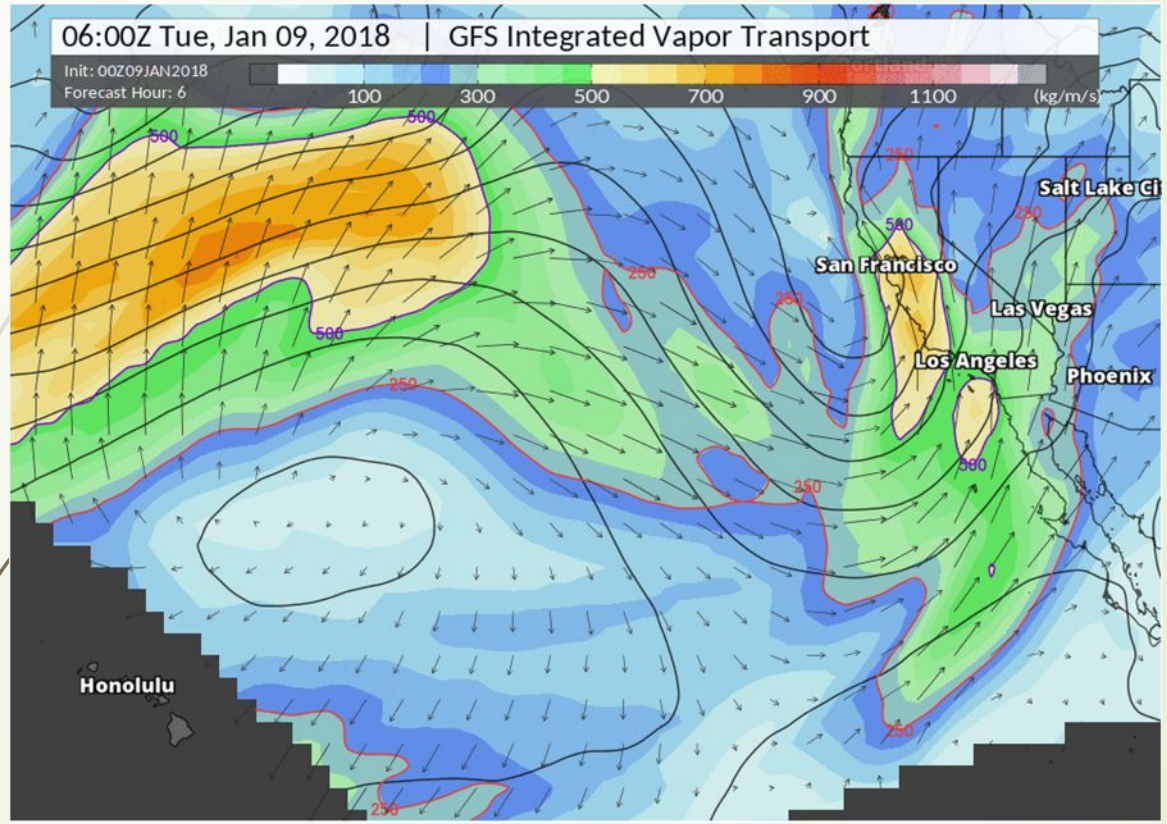
A dump truck holds ~10 yd^3

1yd^3 of gravel weighs 3,000 lbs

From *Rainfall intensity–duration thresholds for postfire debris-flow emergency-response planning,* Cannon et al, 2011

weather.gov/losangeles

Debris Flow – Response



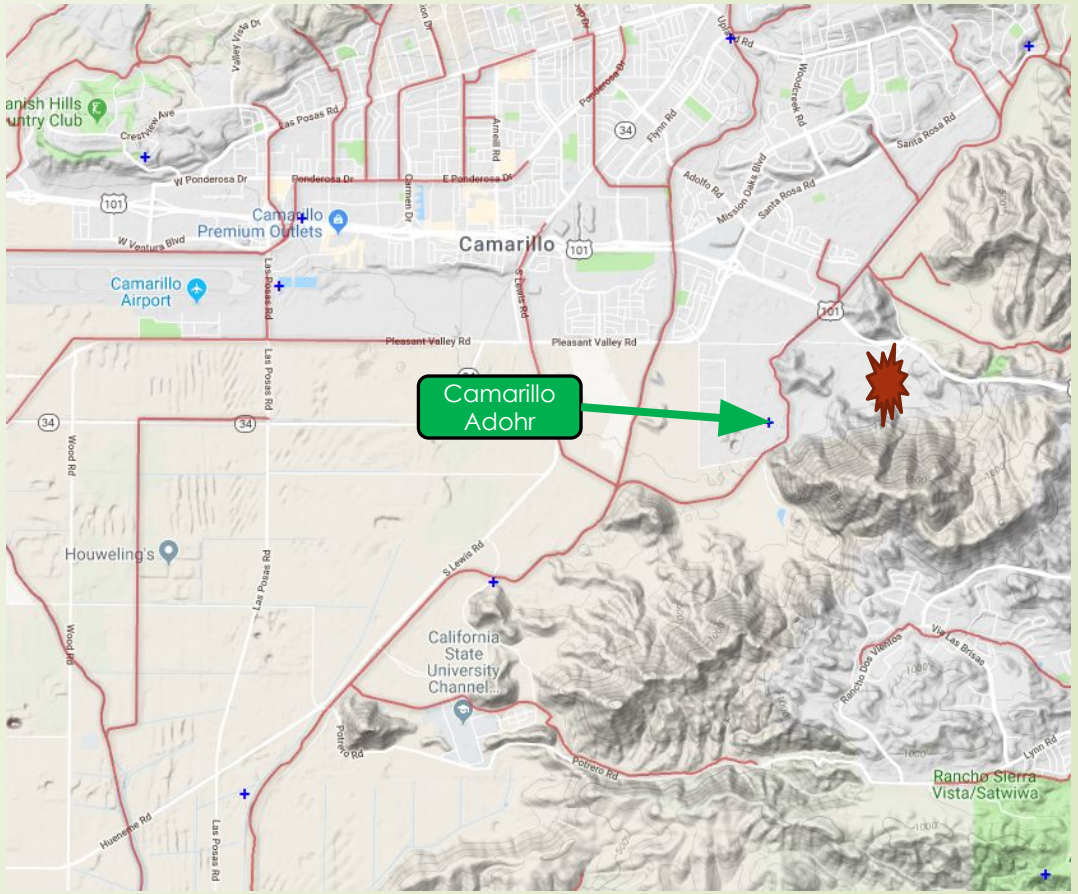
If you see this coming you…

???

The Cases

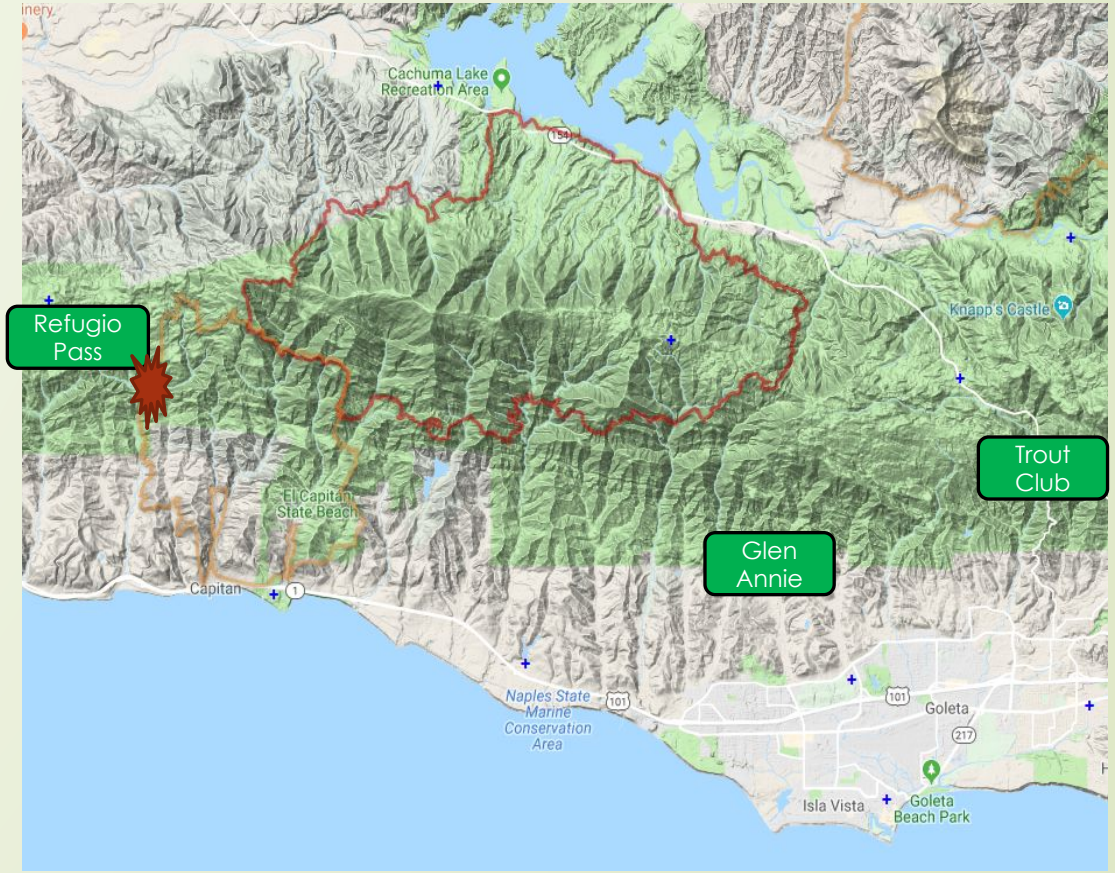
Springs – Camarillo Springs Debris Flow

AP Photo / The Ventura County Star, Chuck Kirman



Sherpa– El Capitan Canyon & Resort Campground Debris Flow

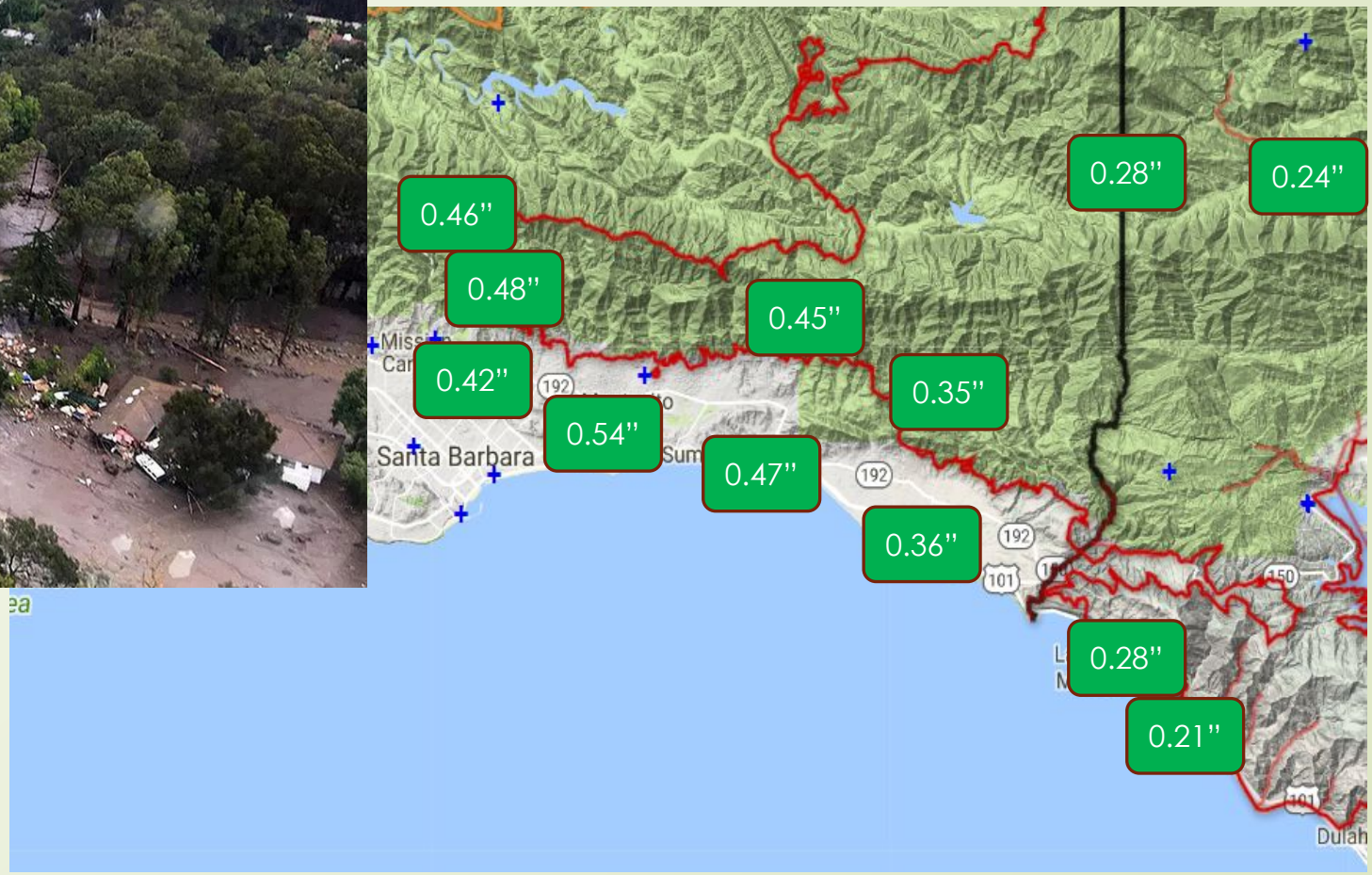
Photo by Ray-Lynn Cummings in the *Santa Barbara Independent*



Thomas – Montecito Debris Flow

Photo Ventura County Sheriff Air Unit

Peak 5-Minute Rainfall Rates

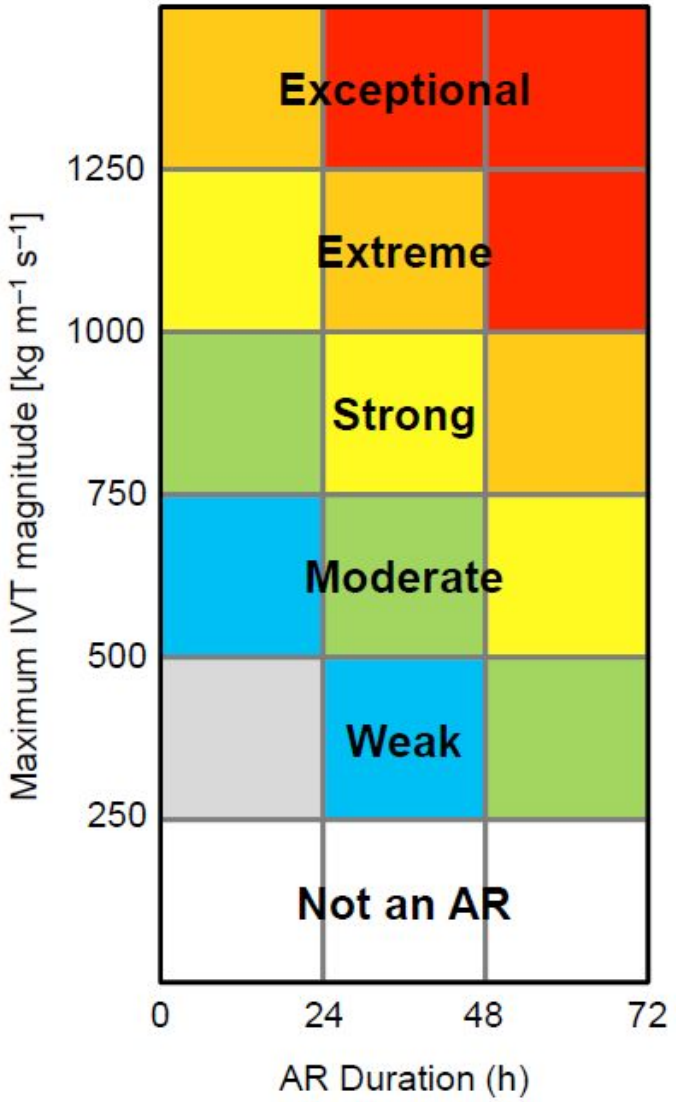


Thomas – Montecito March AR (miss)

Signs of water ponding along East Valley Road near San Ysidro Creek in Montecito on March 22, 2018. (Credit: Al Seib / Los Angeles Times)

Comparisons

Atmospheric River Classification

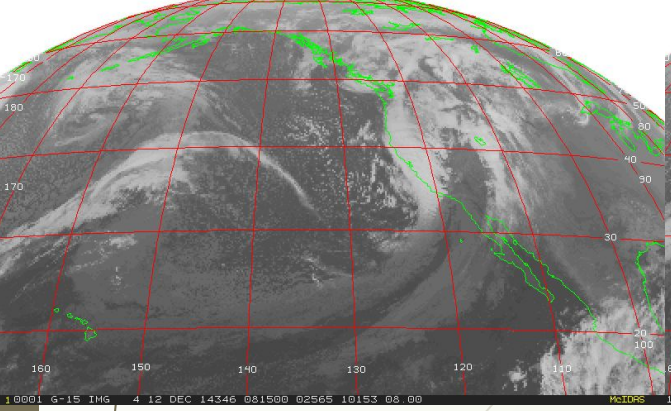


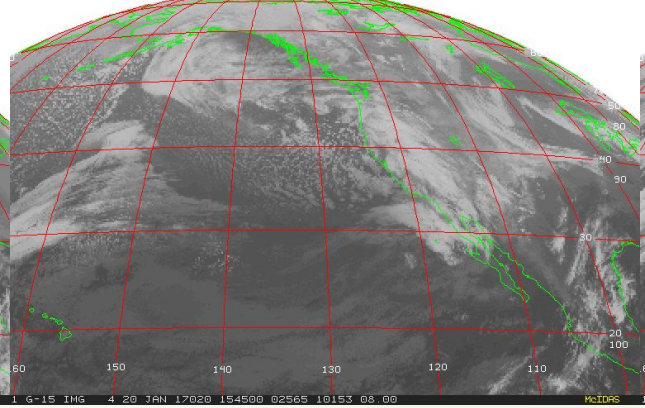
- Cat 5 – Primarily hazardous
- Cat 4 – Mostly hazardous, also beneficial
- Cat 3 – Balance of beneficial and hazardous
- Cat 2 – Mostly beneficial, also hazardous
- Cat 1 – Primarily beneficial

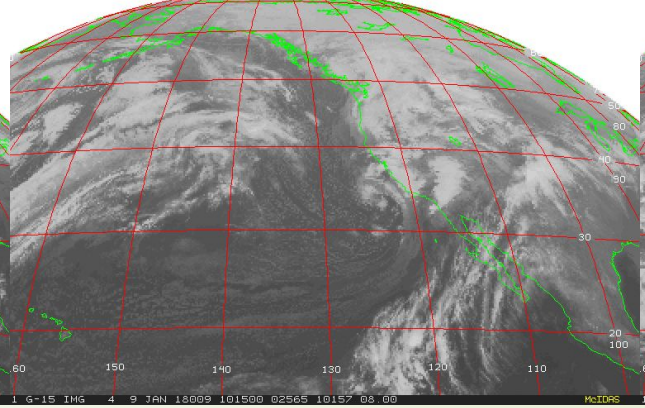
…from a rainfall perspective

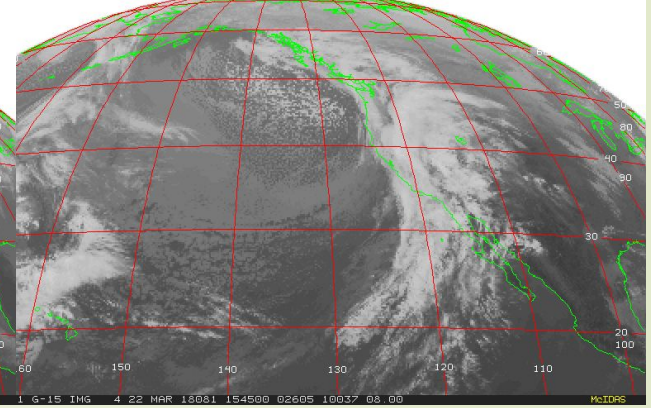
AR Scale Category	Max. IVT* ($kg\ m^{-1}\ s^{-1}$)	Duration of AR Conditions (h)	Benefits vs. Hazards of Impacts
	< 250	N/A	Beneficial
AR Cat 1	250–500	< 24	Primarily beneficial
AR Cat 2	500–750	24–48	Mostly beneficial, but also hazardous
AR Cat 3	750–1000	24–48	Balance of beneficial and hazardous
AR Cat 4	1000–1250	24–48	Mostly hazardous, but also beneficial
AR Cat 5	> 1250	> 48	Primarily hazardous

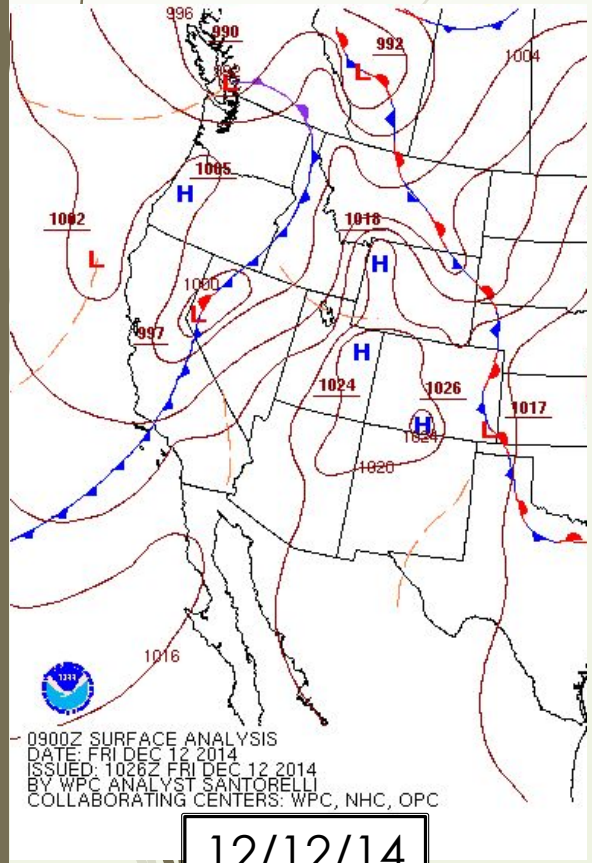
From "Characterizing the Strength of Atmospheric Rivers" by F. Martin Ralph, Center for Western Weather and Water Extremes. 2/11/2017 presentation



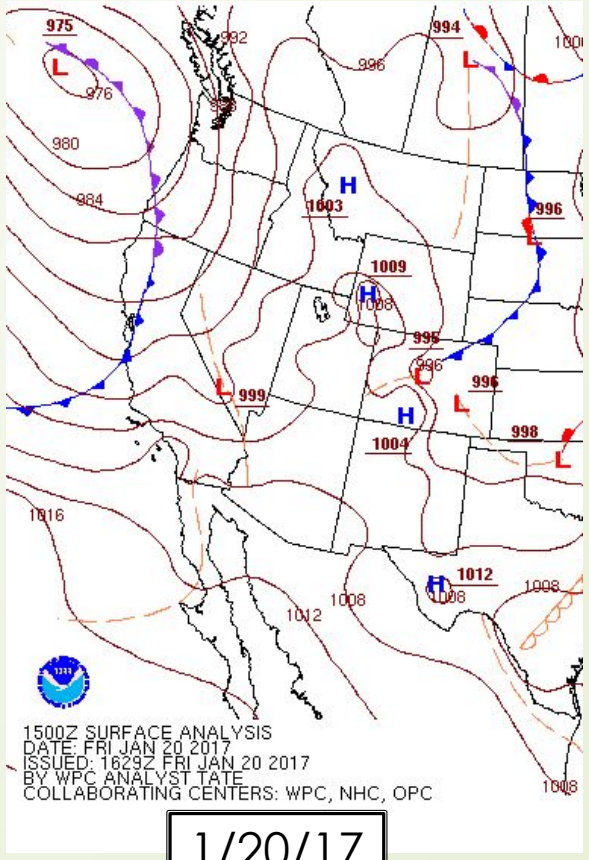




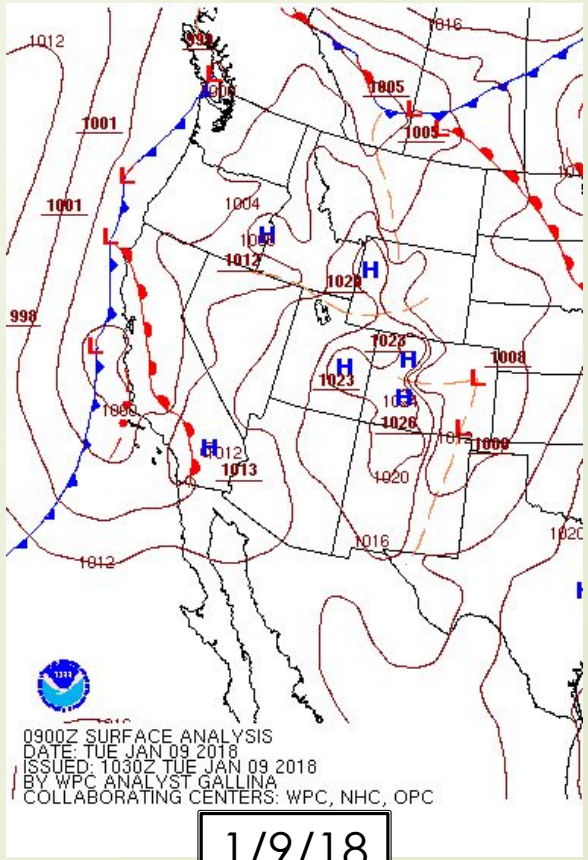




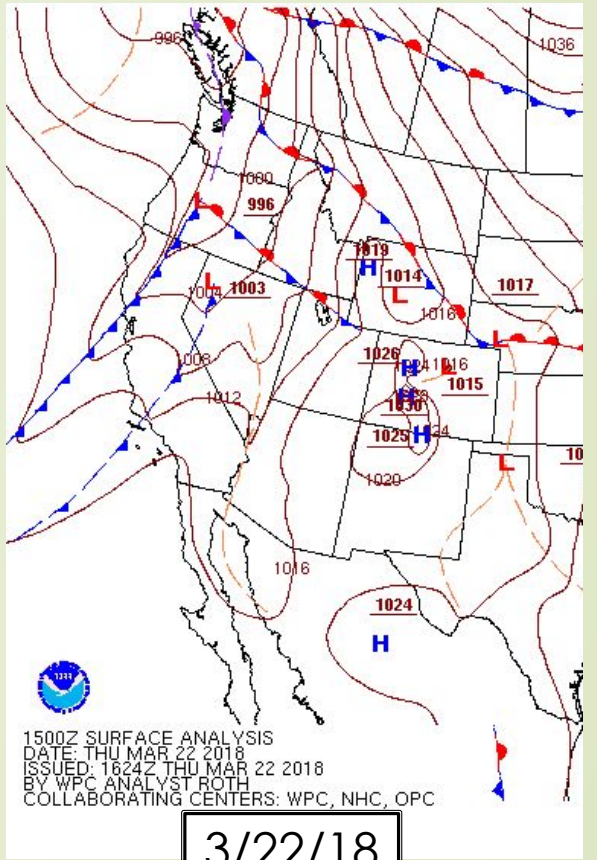
12/12/14



1/20/17

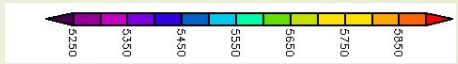


1/9/18



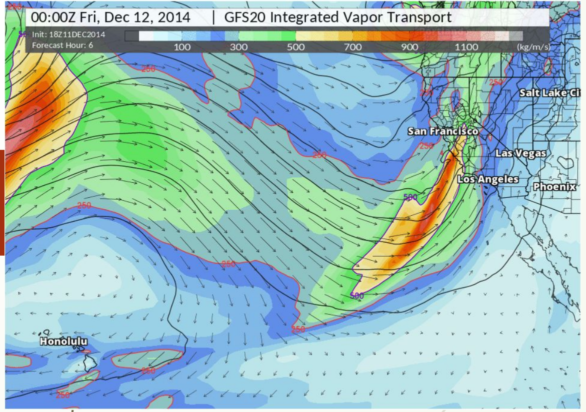
3/22/18

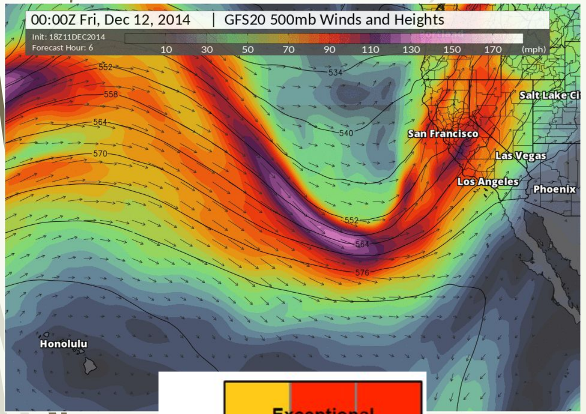
Analysis Comparison

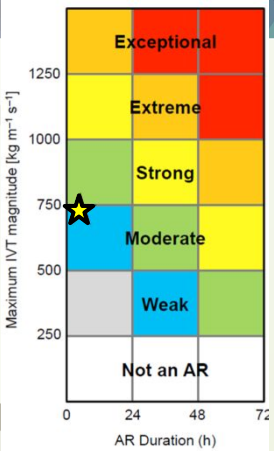


weather.gov/losangeles

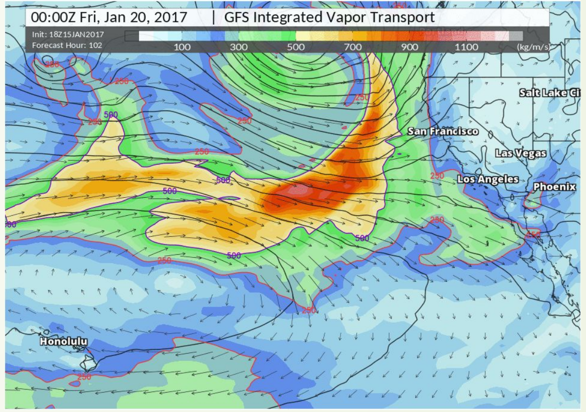
Analysis Comparison

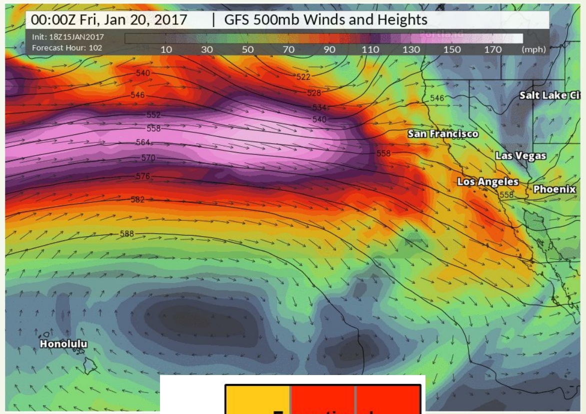


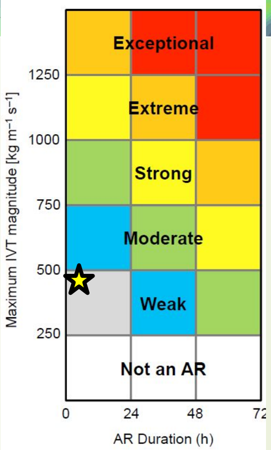




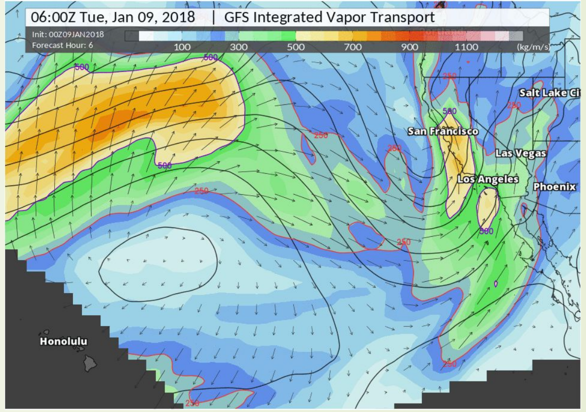
12/12/14

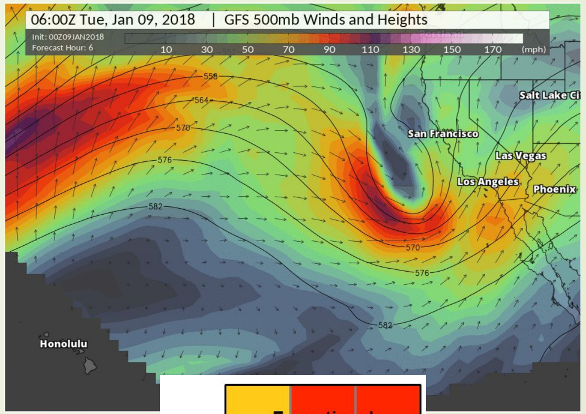


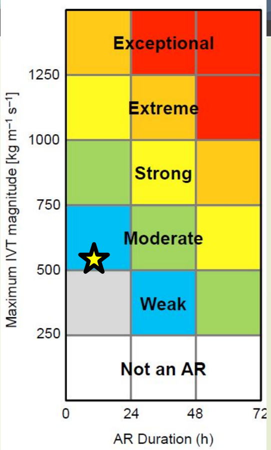




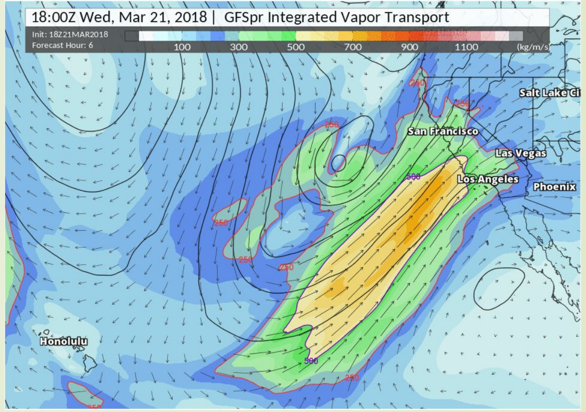
1/20/17

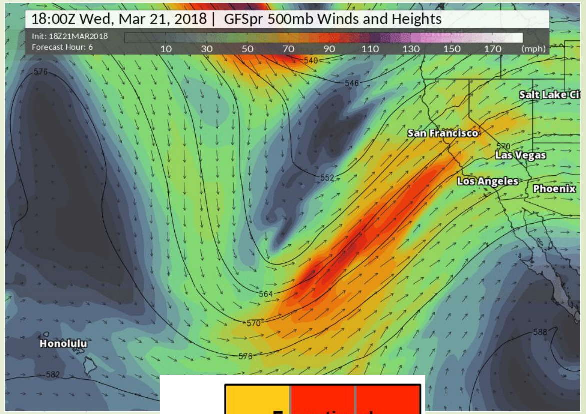


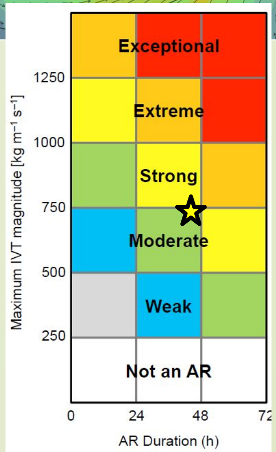




1/9/18







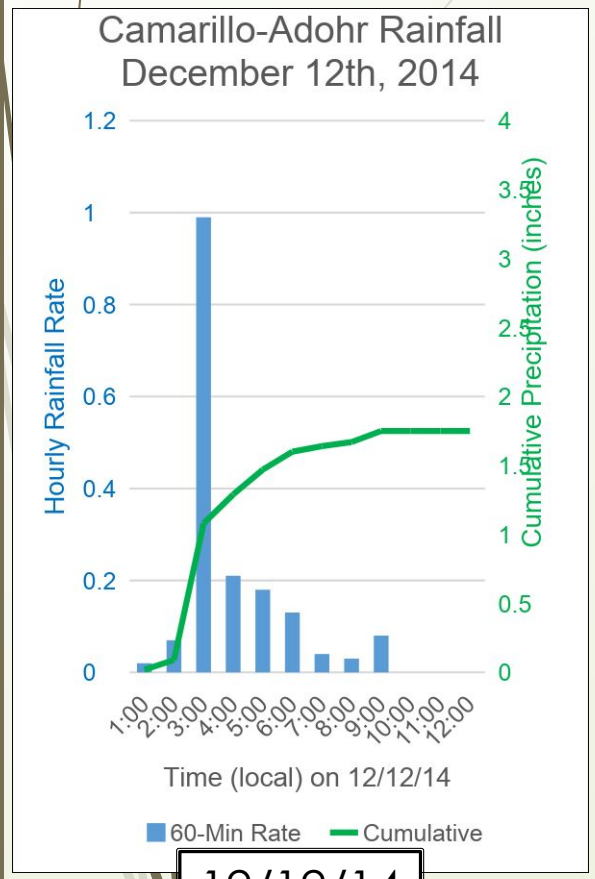
3/22/18

Credit: Ventura County Star, Chuck Kirman

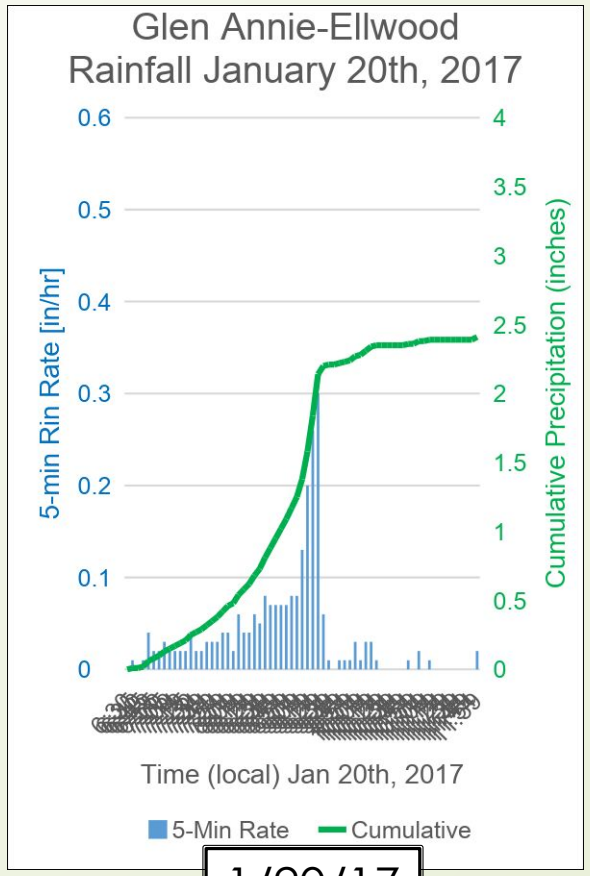
Credit: Ray-Lynn Cummings

Credit: Ventura County Sheriff Air Unit

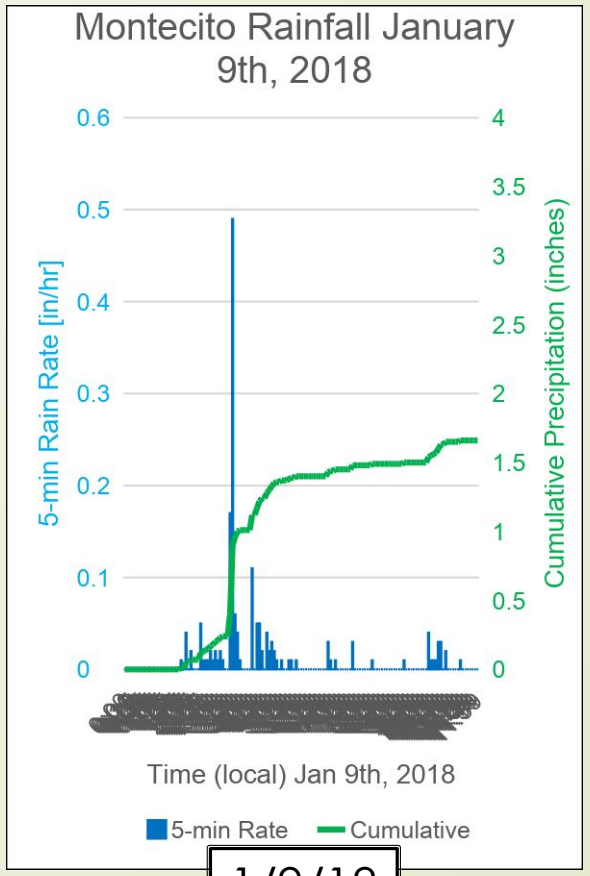
Credit: Al Seib / Los Angeles Times



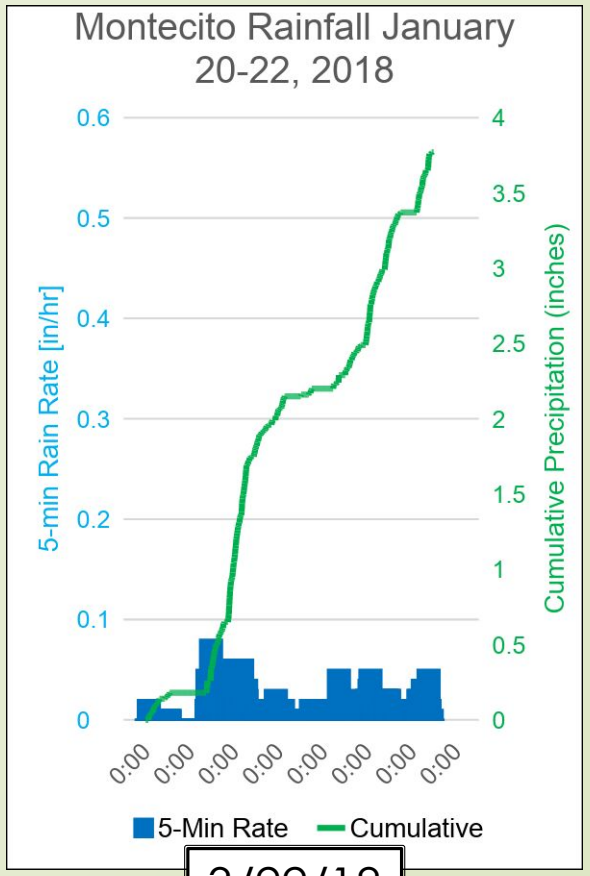
12/12/14



1/20/17



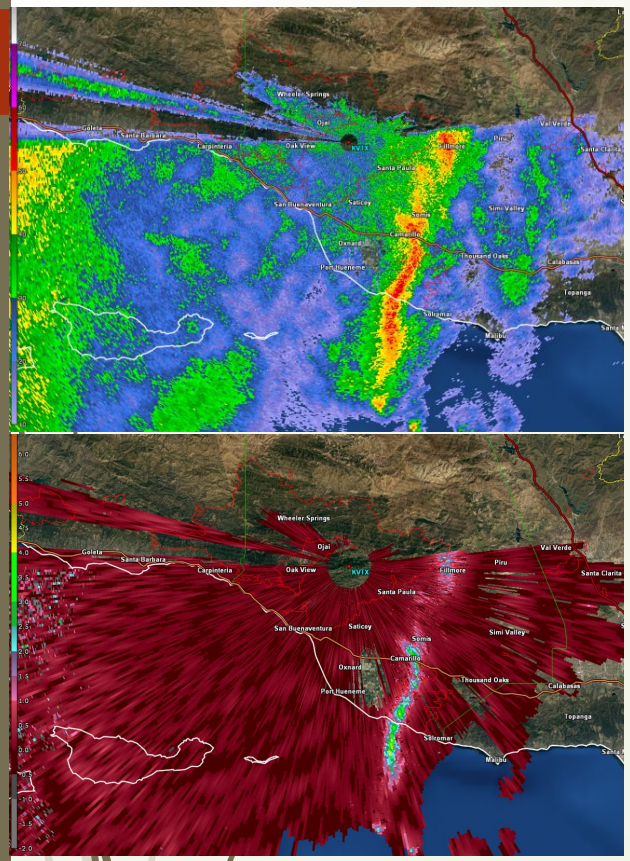
1/9/18

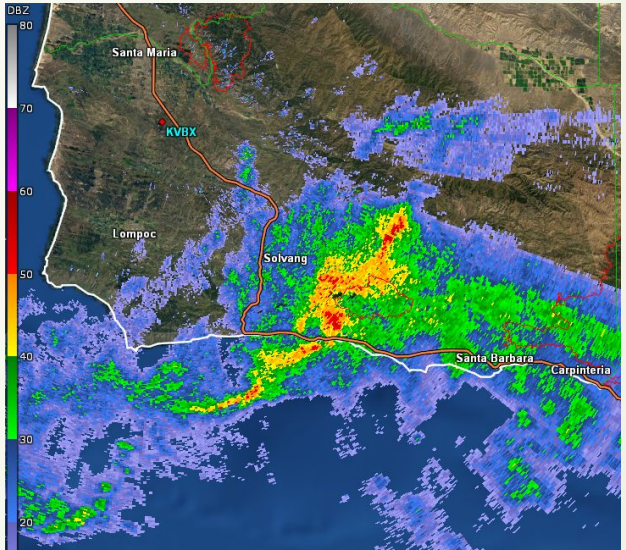


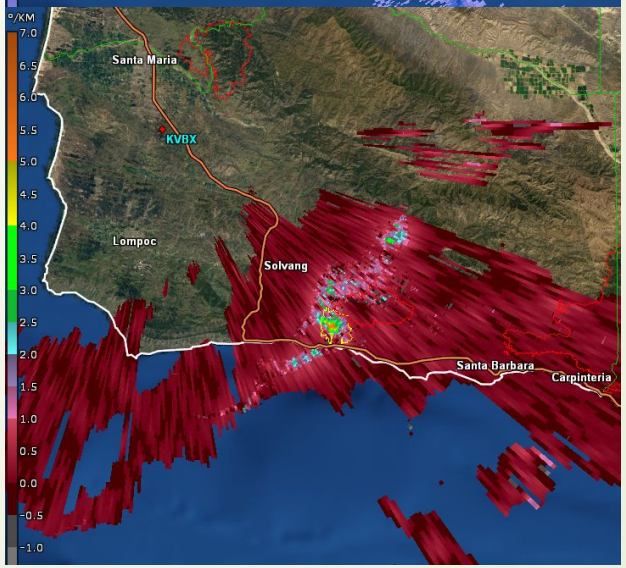
3/22/18

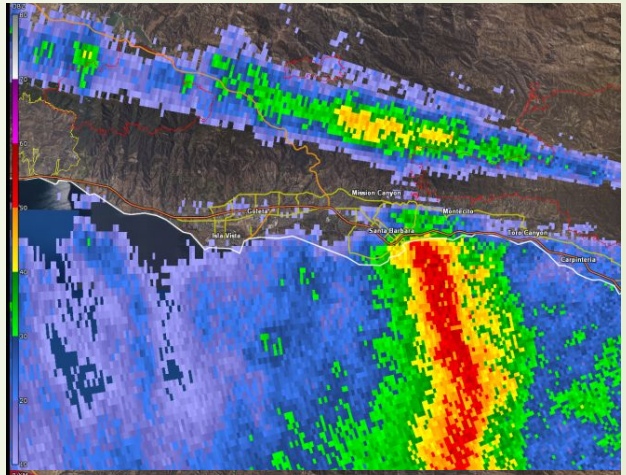
Rainfall Comparison

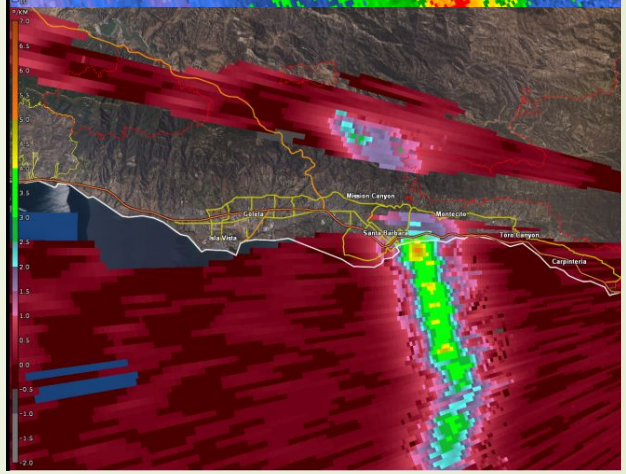
weather.gov/losangeles

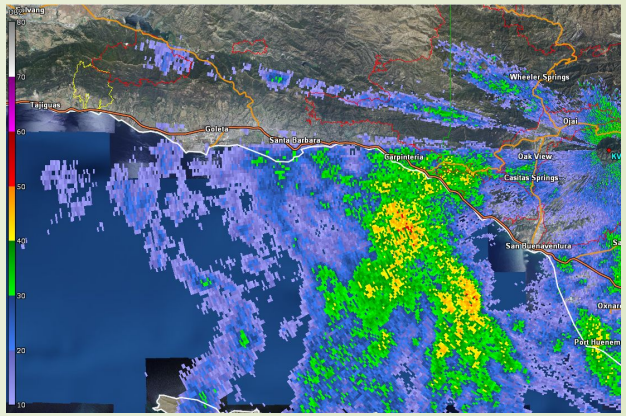


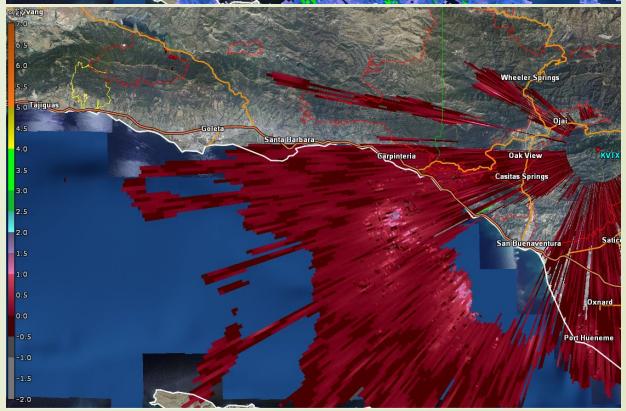












12/12/14

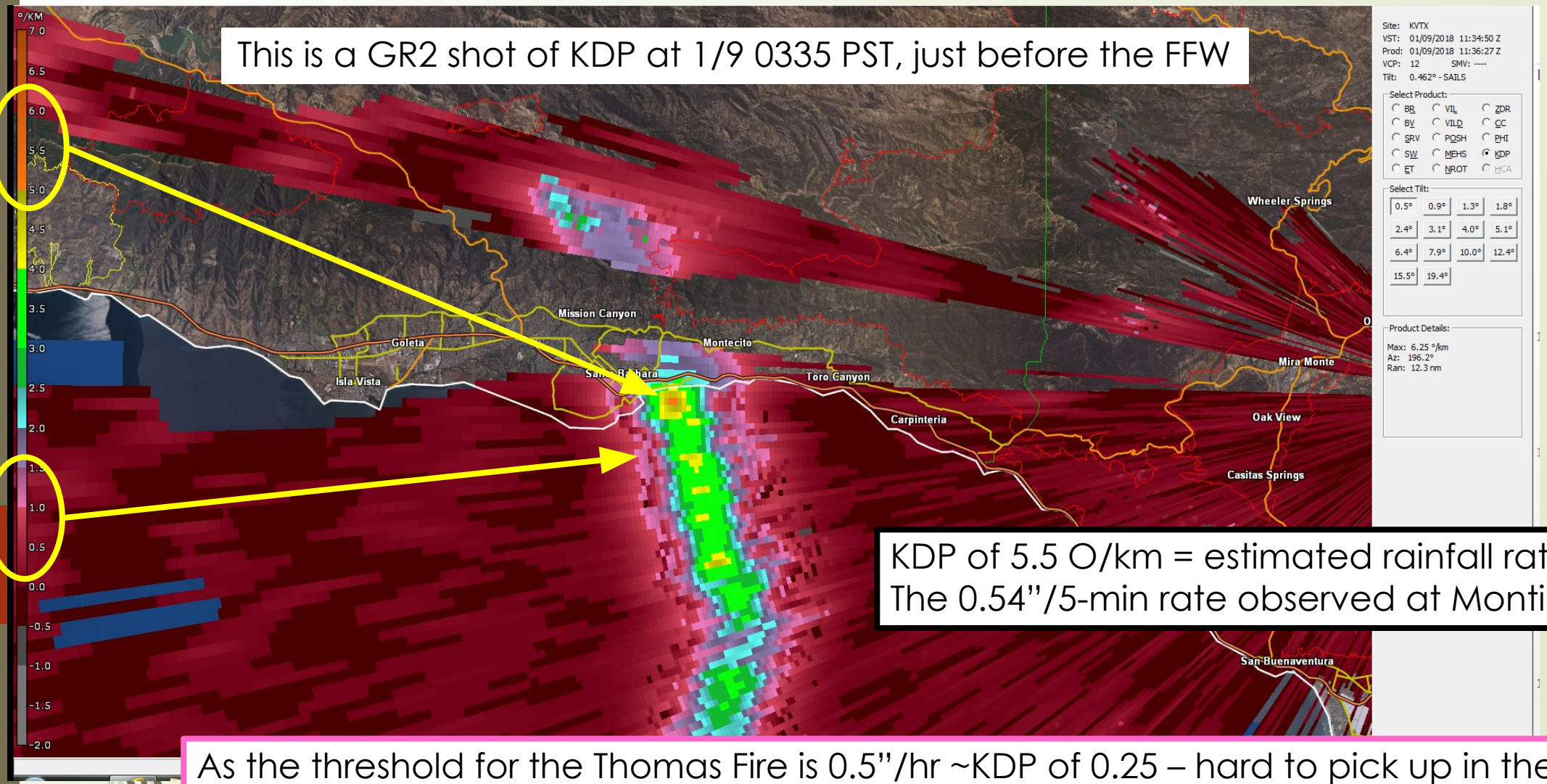
1/20/17

1/9/18

3/22/18

Rainfall Comparison

Rain Rate is proportional to KDP, as KDP is a function of drop size and concentration
The math is something like R(KDP) [inches/hr] = 1.6*(KDP)$^{0.85}$



KDP of 5.5 O/km = estimated rainfall rate of ~7"/ hr
The 0.54"/5-min rate observed at Monticeto = 6.48"/hr

As the threshold for the Thomas Fire is 0.5"/hr ~KDP of 0.25 – hard to pick up in the shades of red
By KDP = 1, the color scale goes pink and rain rates would be approximately 1.5"/hr.
See pink, don't shrink (from warning)

Takeaways

- #FloodAfterFire… it's always fire season in SoCal
- Forecasting impactful debris flows is a difficult and developing science
- Brief but intense rainfall is an excellent debris flow trigger, and is visible in KDP
- AR "strength" is not as important as orientation and rainfall intensity regarding debris flows.

Challenge

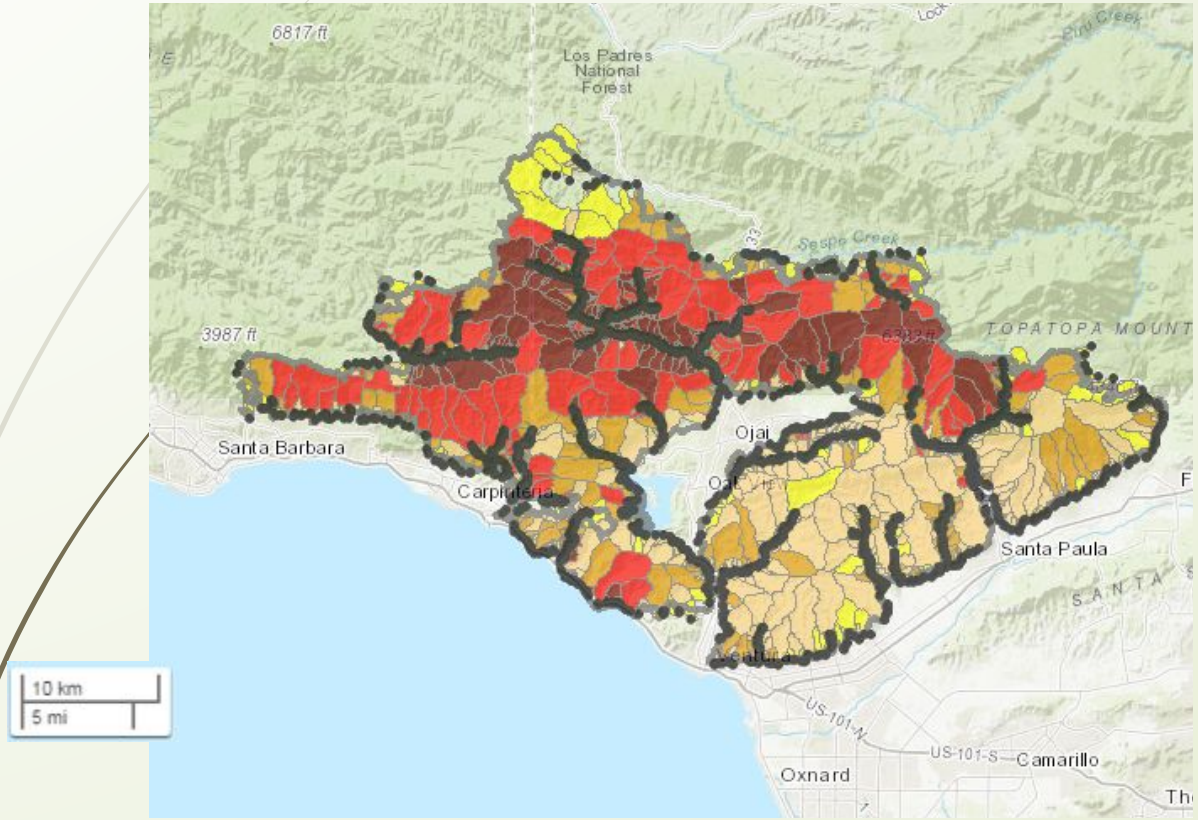
We need to help people understand what they can't imagine.

John.Dumas@NOAA.gov

Montecito 1/9/18 Debris Flow

Preliminary Hazard Assessment

Available January 6th – while the fire was still burning



https://landslides.usgs.gov/hazards/postfire_debrisflow/detail.php?objectid=178

EXPLANATION

- Sediment Retention Basins
- Basin Outlet
- Fire Perimeter

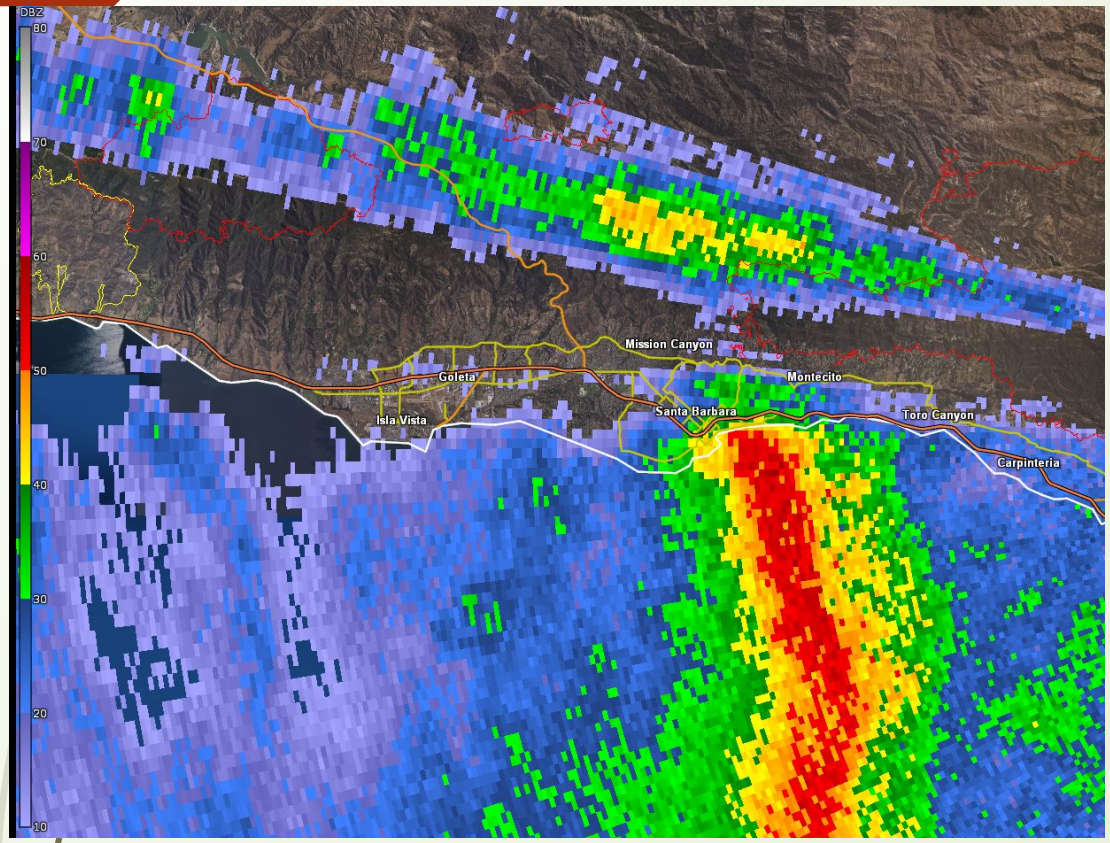
Basin Probability

- 0-20%
- 20-40%
- 40-60%
- 60-80%
- 80-100%

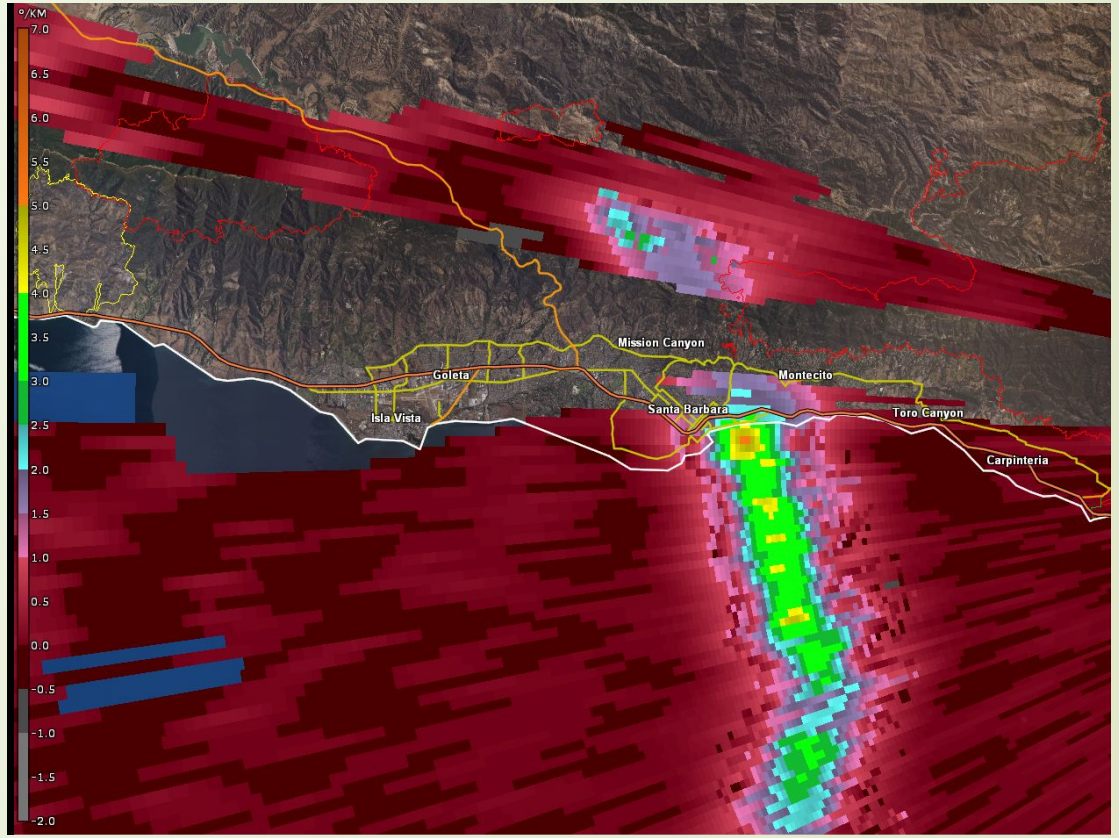
Projection is WGS84 Web Mercator

Likelihood of a debris flow in response to the design rainstorm with a peak 15-minute rainfall intensity of 24 mm/h.

Montecito – BR and KDP 0330 PST



KVTX BR



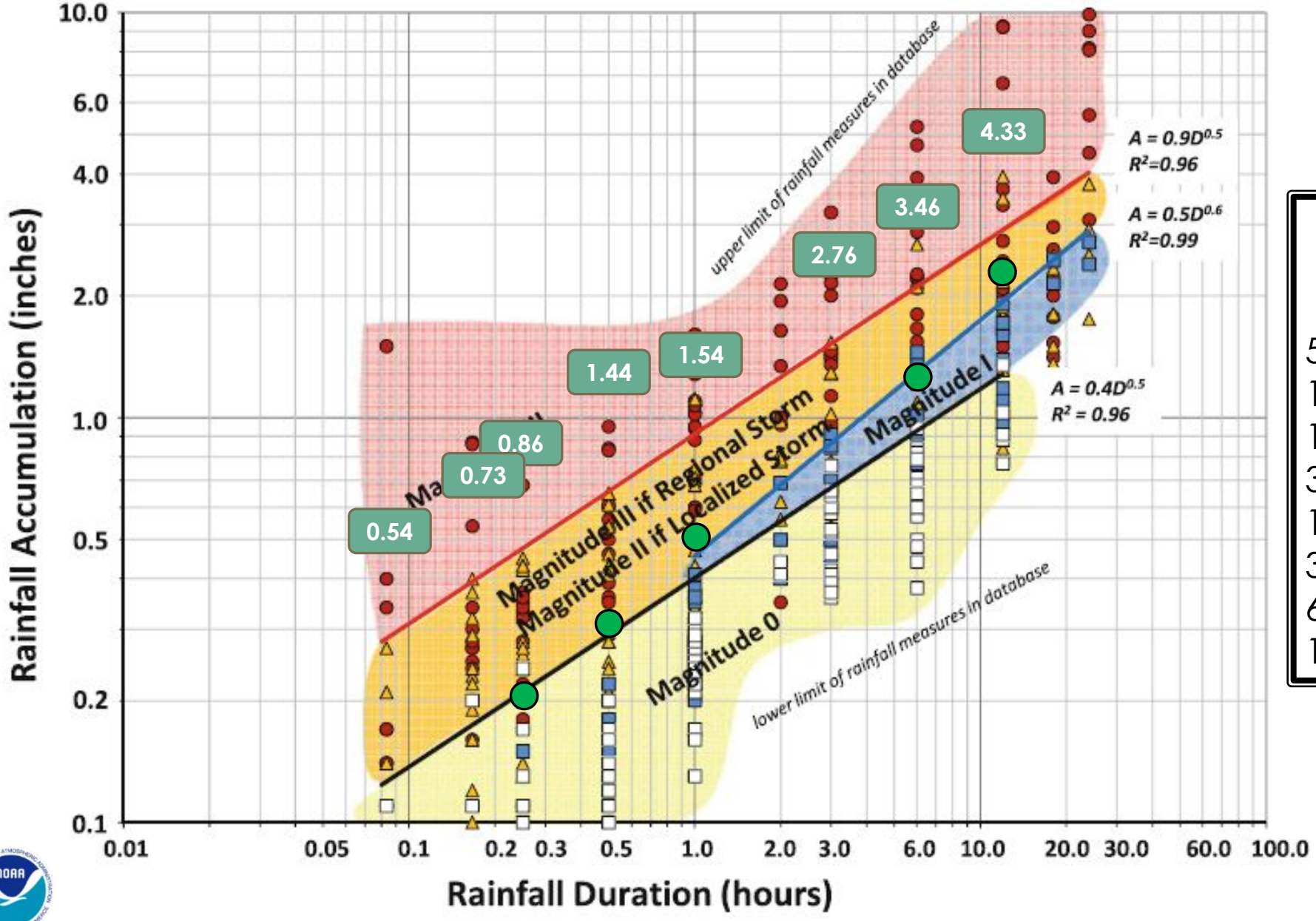
KVTX KDP

topography creates beam blockage

KDP of 5.5 °/km = estimated rainfall rate of ~7"/ hr
The 0.54"/5-min rate observed at Monticeto = 6.48"/hr

Peak 5-Minute Rainfall Rates

Rain Rates vs Debris Flow Magnitude

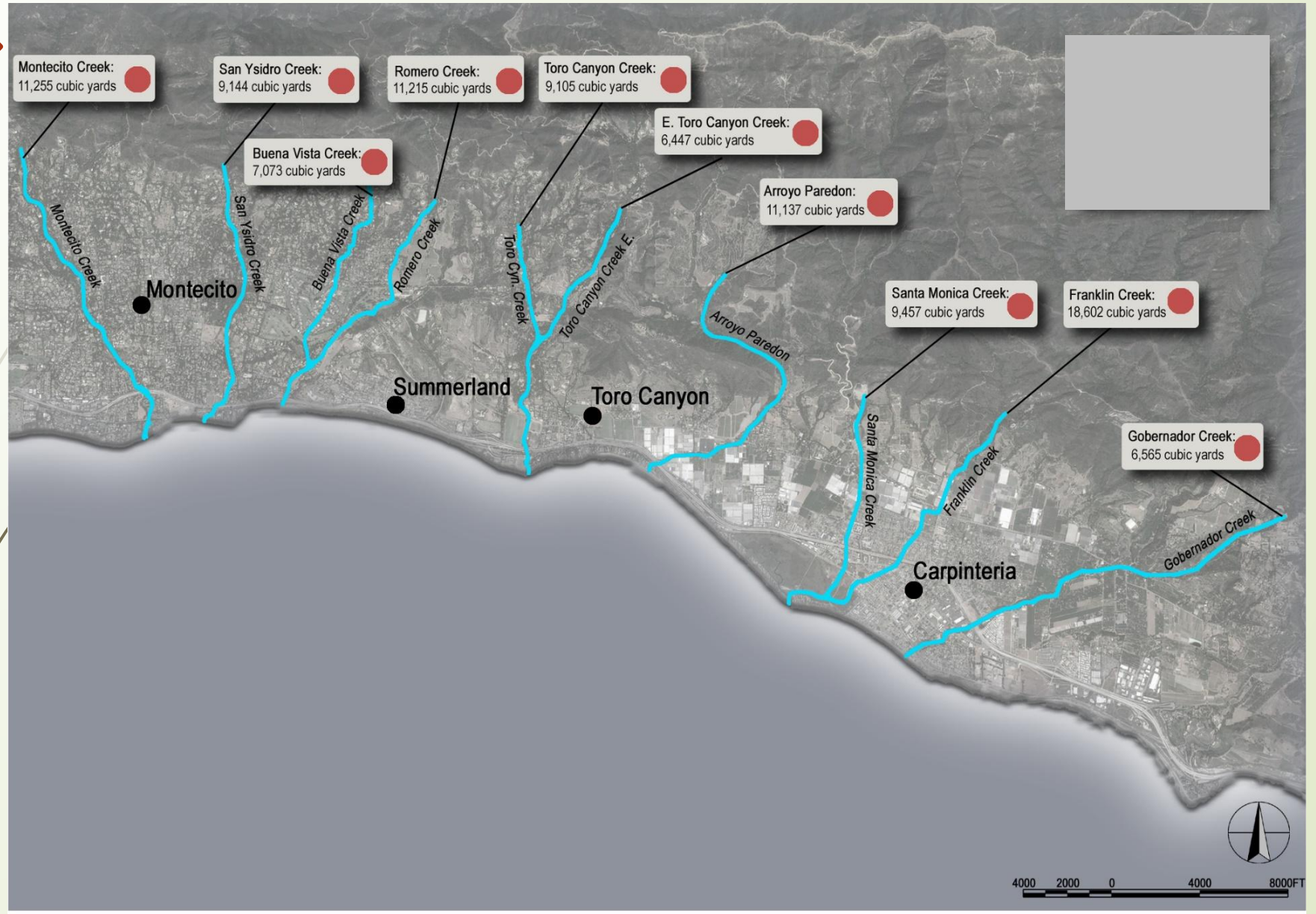


Observed Maximum Rain Rates, 1/9/18	
5-min	0.54" Montecito
10-min	0.73" KTYD
15-min	0.86" Carpinteria FS
30-min	1.44" Carpinteria FS
1-hr	1.54" Matilija Cyn
3-hr	2.76" Matilija Cyn
6-hr	3.46" Matilija Cyn
12-hr	4.33" Matilija Cyn

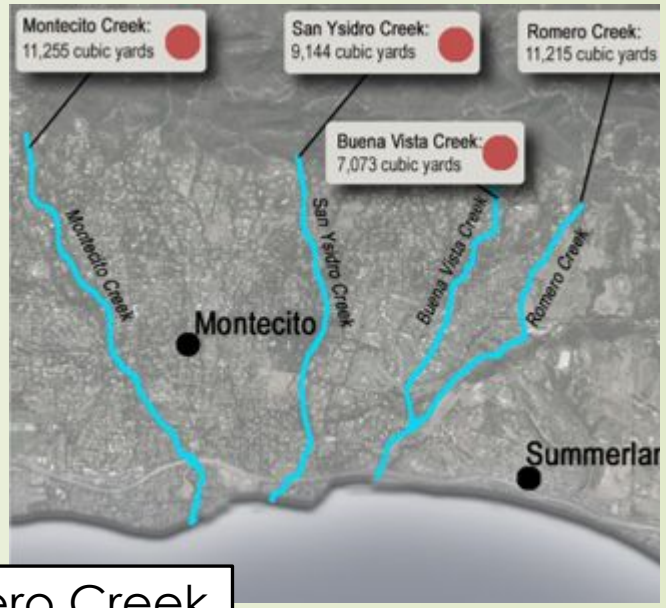
Debris Flow

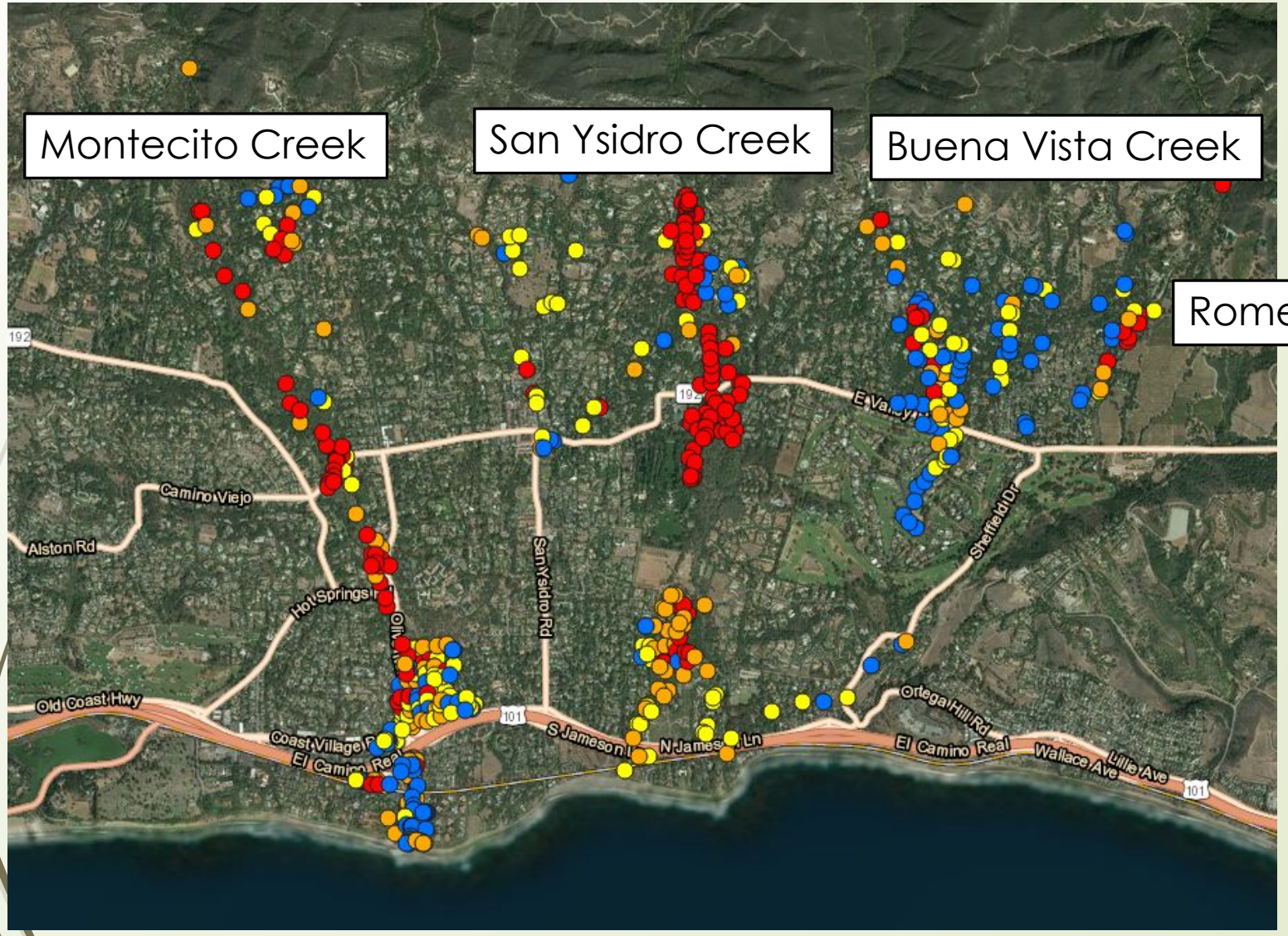

Normal/Smart
Main Stream
01-09-2018 Tue 03:49:25
MAIN ENTRY
MAIN INTERCOM
SPRING ROAD
Inside Service Gate
SERVICE INTERCOM
TRASHCAN AREA
AMPHITEATHER ROAD
PLAYGROUND PTZ
AMPHITEATHER
MAINTENANCE
BACKSTAIRS PTZ
TENNIS COURT PTZ
Generator Ally
QUARRY GATE
QUARRY ROAD
MOTOR COURT
QUARRY FENCE R
QUARRY FENCE GATE
pool
Jan
QUARRY ROAD
Normal
Smart

Creek beds provide natural paths for debris flows



Interactive map, Santa Barbara Co. Office of Emergency Management





https://sbc-gis.maps.arcgis.com/apps/webappviewer/index.html?id=ee848a57d8b2416eb2802da300df5b6e

- Destroyed
- Major
- Minor
- Affected

1/9/18, Montecito, CA

1/25/1969 Flood and Debris Flow

In January 1969 California experienced a series of storms that brought 10 continuous days of rain to the Santa Barbara area.

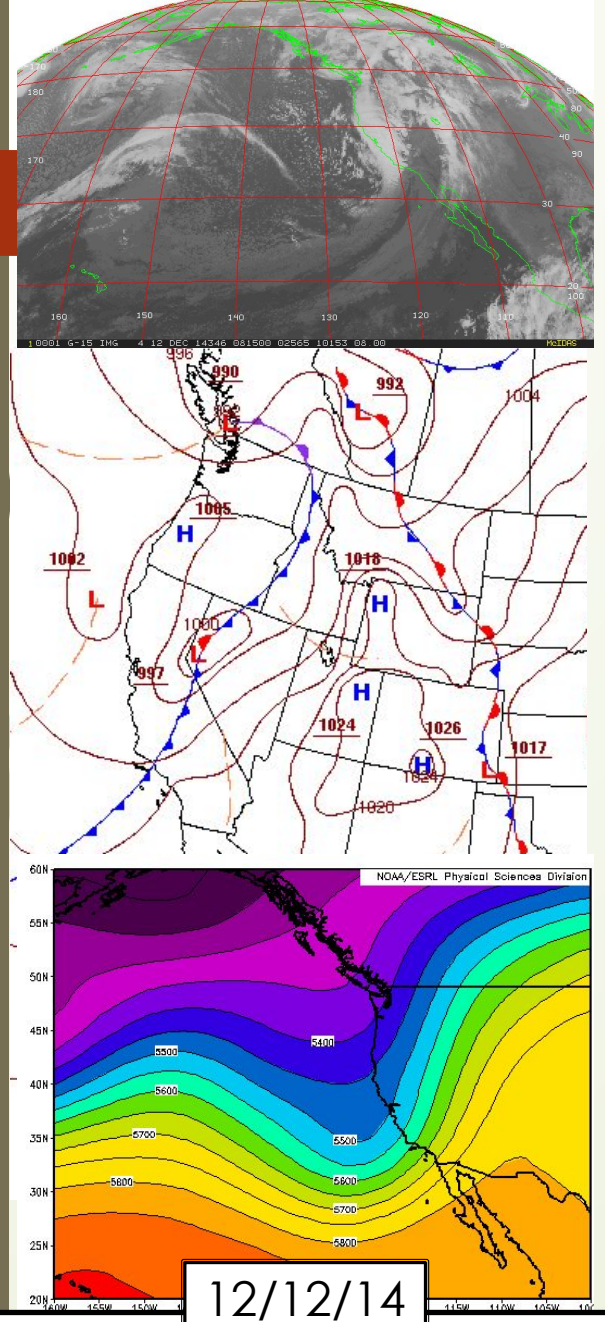
Takeaways

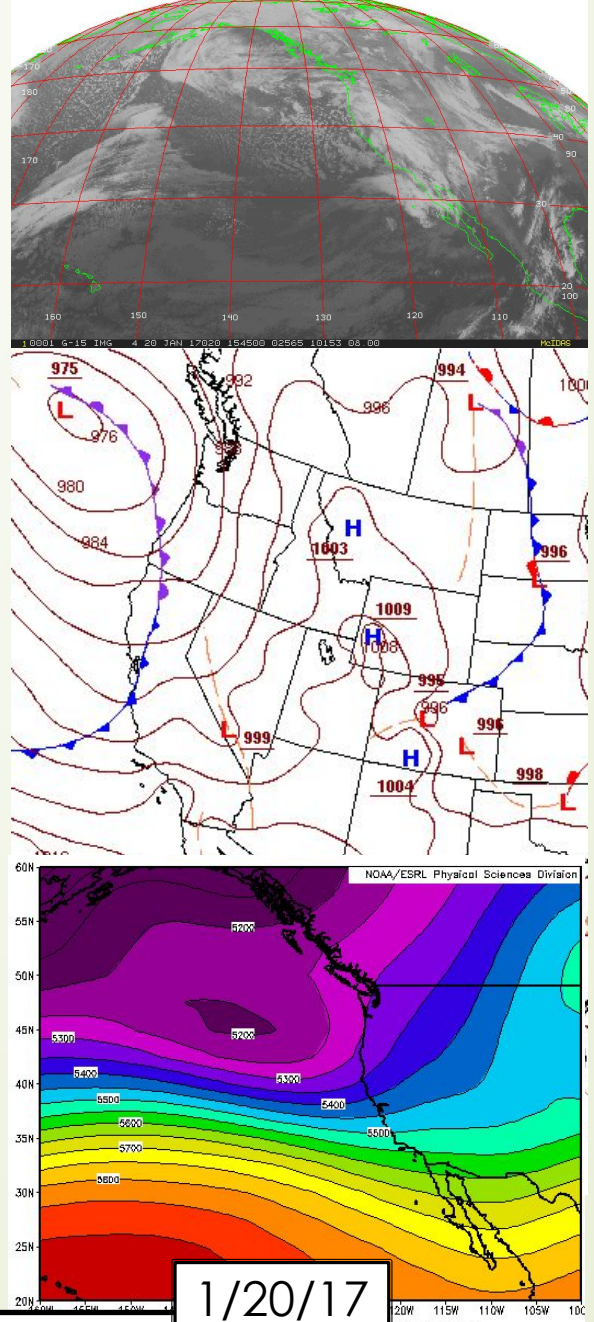
- #FloodAfterFire… it's always fire season in SoCal
- Forecasting impactful debris flows is a difficult and developing science
- Brief but intense rainfall is an excellent debris flow trigger, and is visible in KDP
- AR "strength" is not as important as orientation and rainfall intensity regarding debris flows.

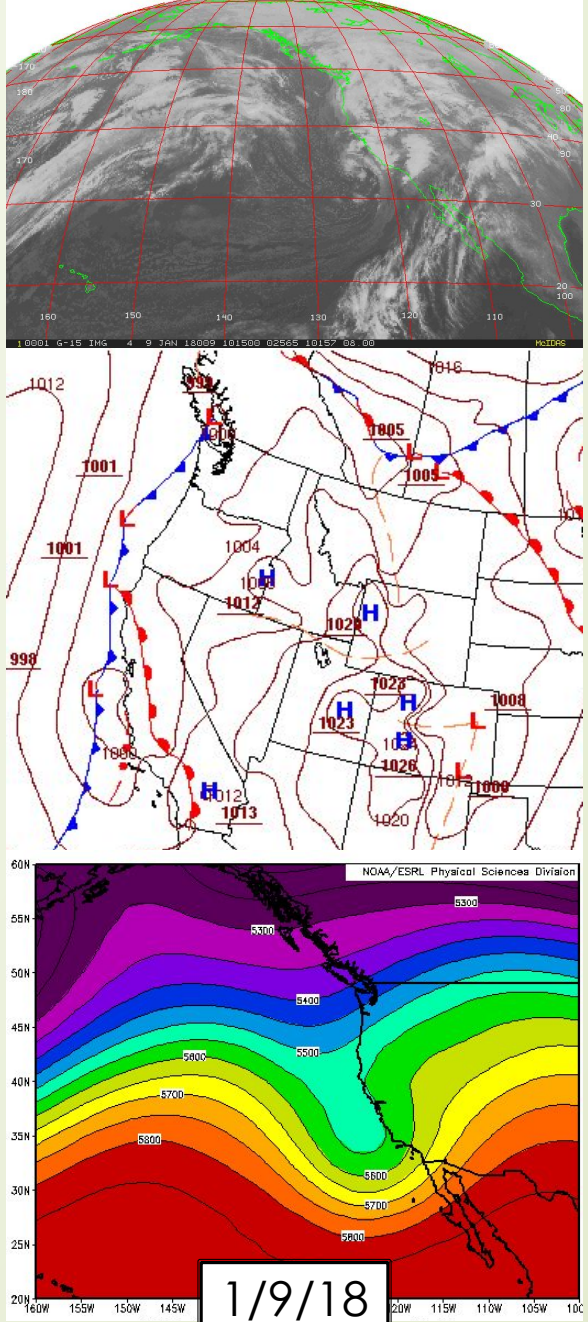
Challenge

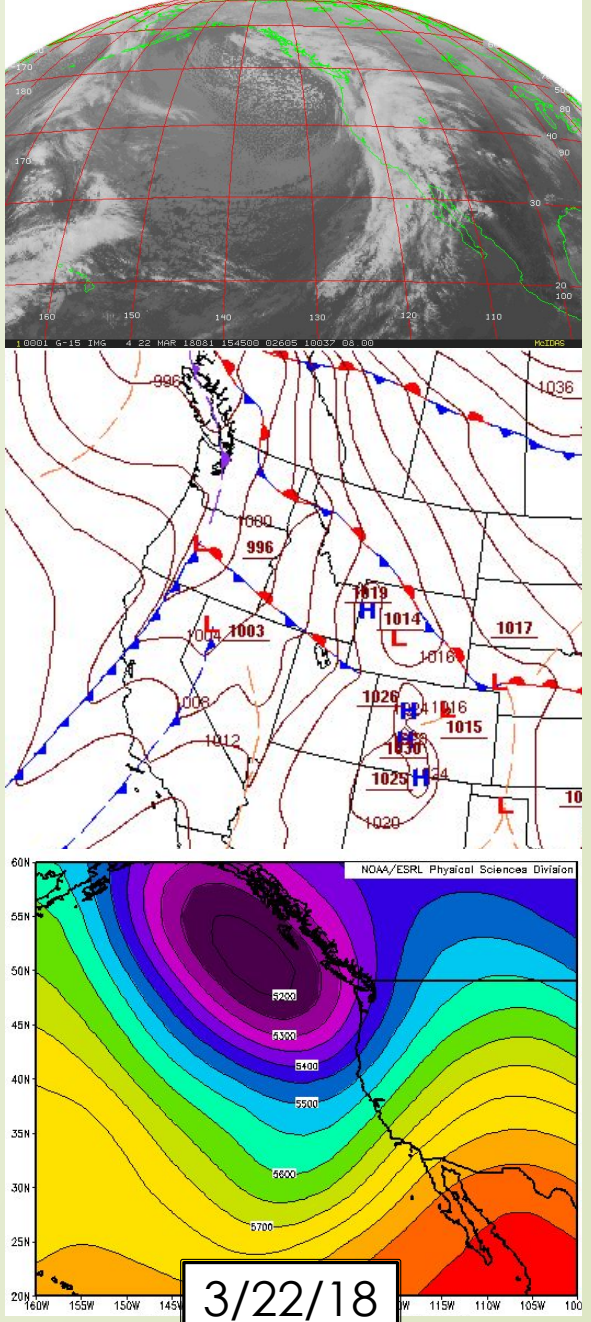
We need to help people understand what they can't imagine.

John.Dumas@NOAA.gov







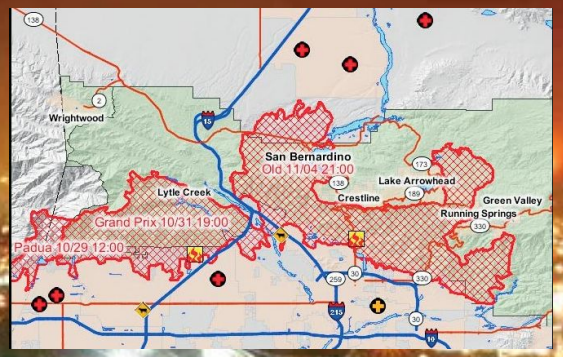


Analysis Comparison

weather.gov/losangeles

Fire Name	Old	Grand Prix	Detwiler
Dates	10/25/03 - 11/14/03	10/21/03 – 11/5/03	7/6/17 - 8/24/17
Location	San Bernardino Co.	San Bernardino Co.	Mariposa Co.
Size [acres]	91,281	66,894	81,826
Rain Event	12/25/03	12/25/03	3/21/18
Days Since Fire	F+41	F+50	F+209
Debris Flow	Yes, Devore	Yes, Devore	Yes

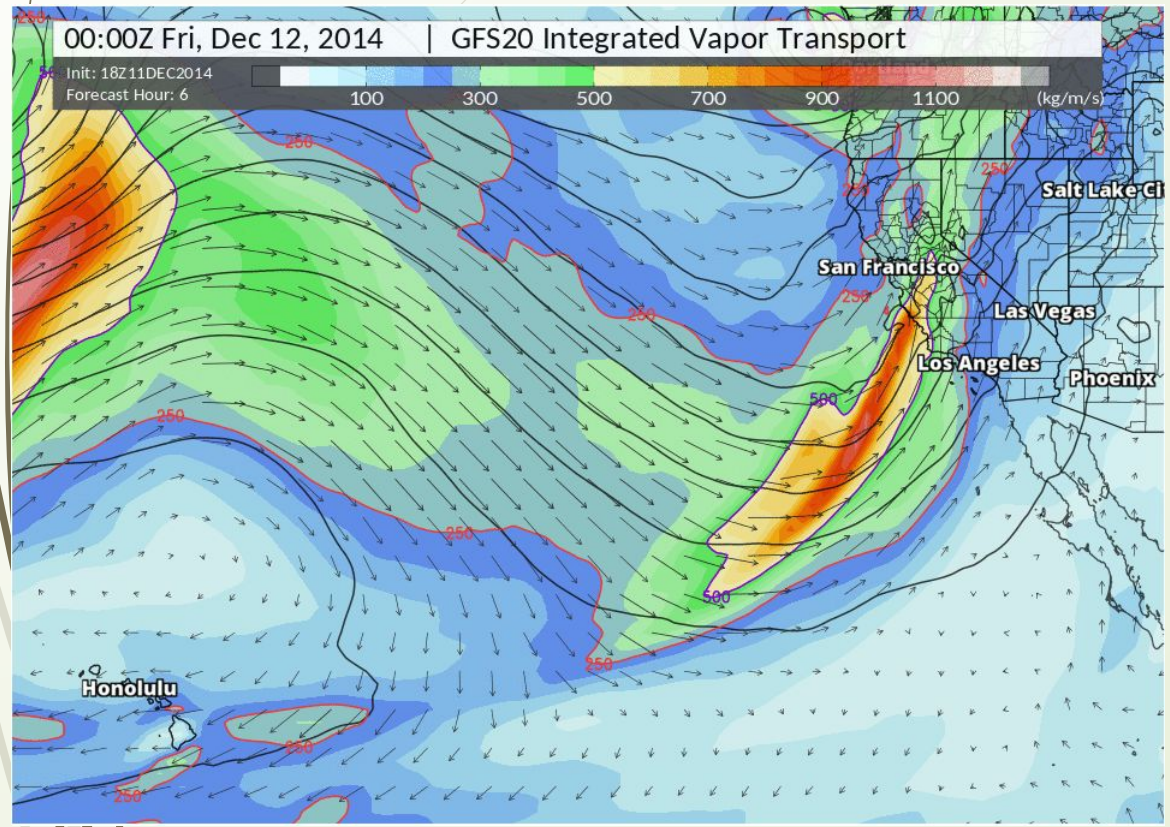
Not examining Non-LOX Events

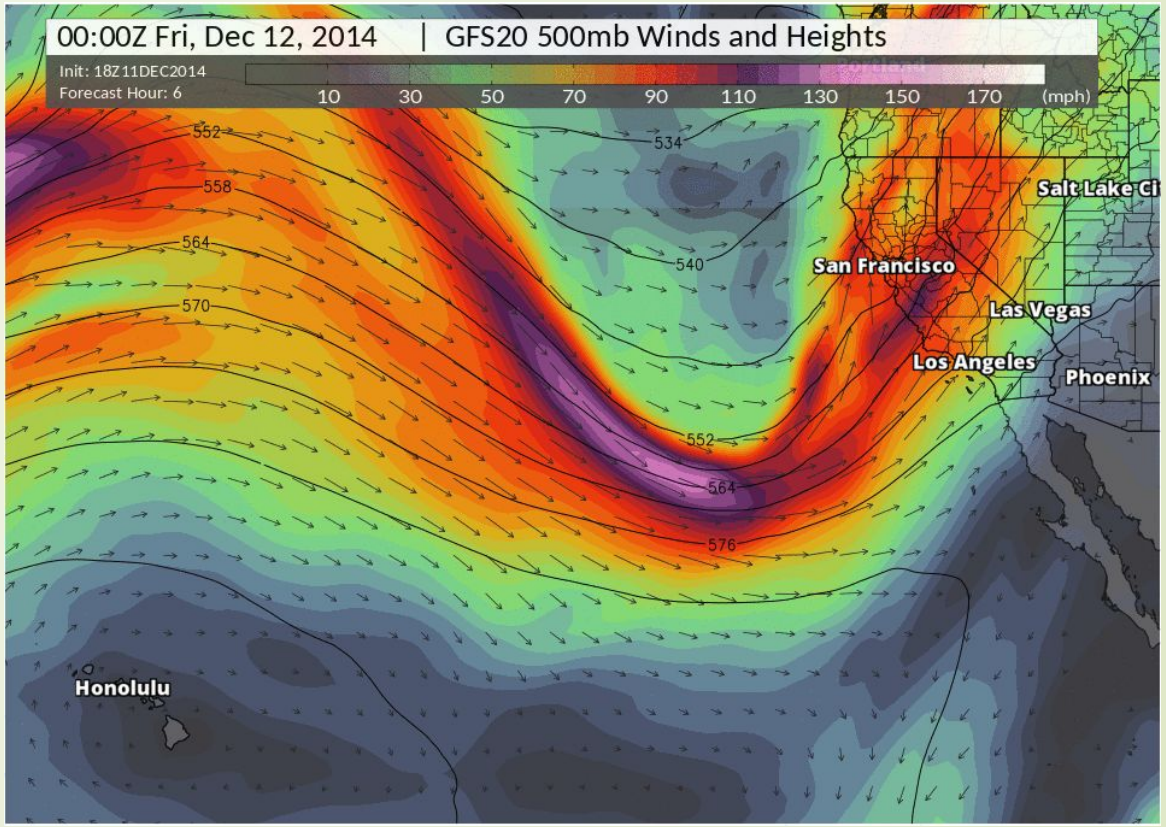


Northeastern San Bernardino, California, as the wildfires light up the night sky (photo courtesy of Chris Doolittle).

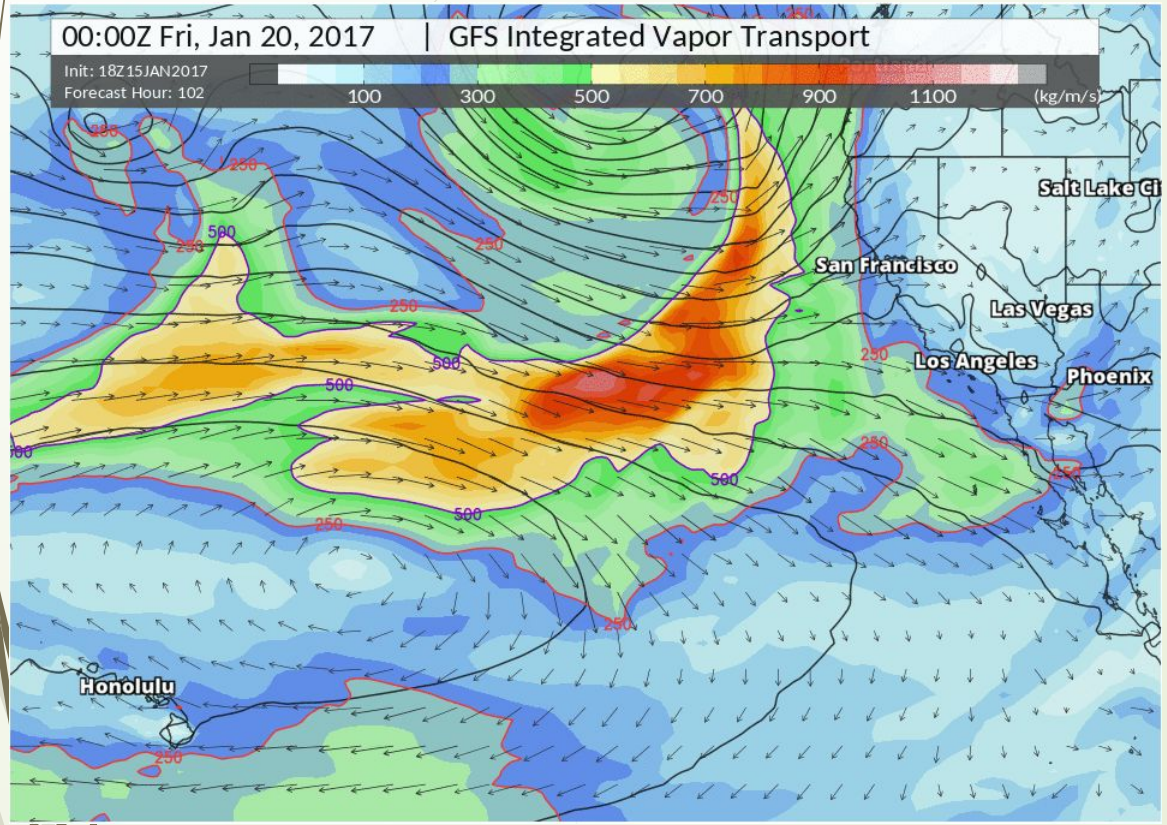
weather.gov/losangeles

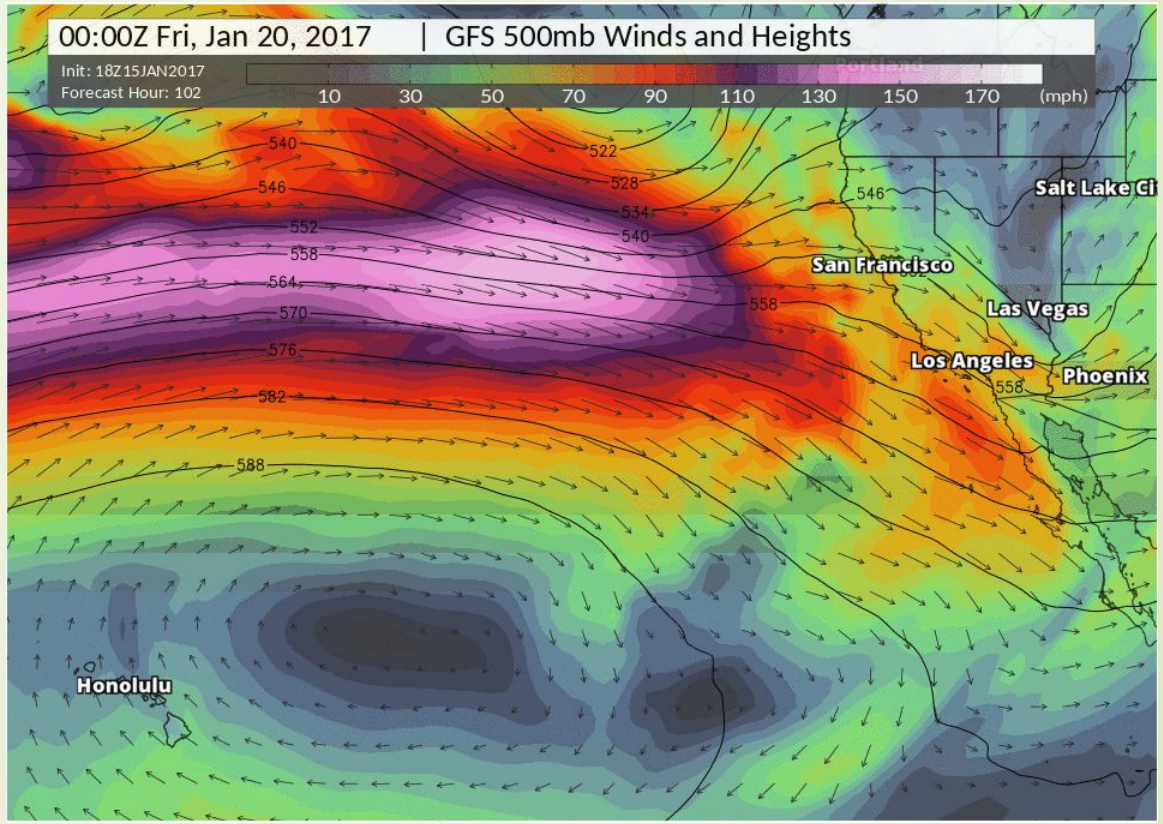
12/12/14 Synoptic Picture



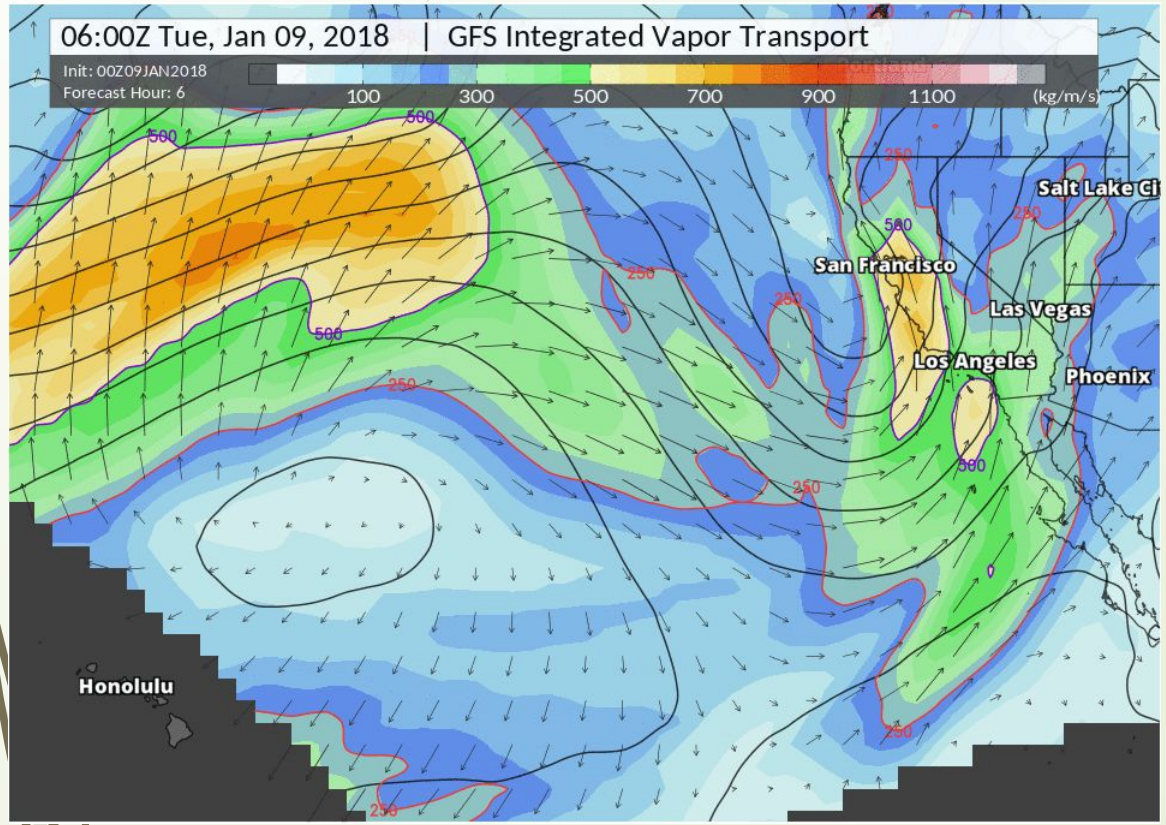


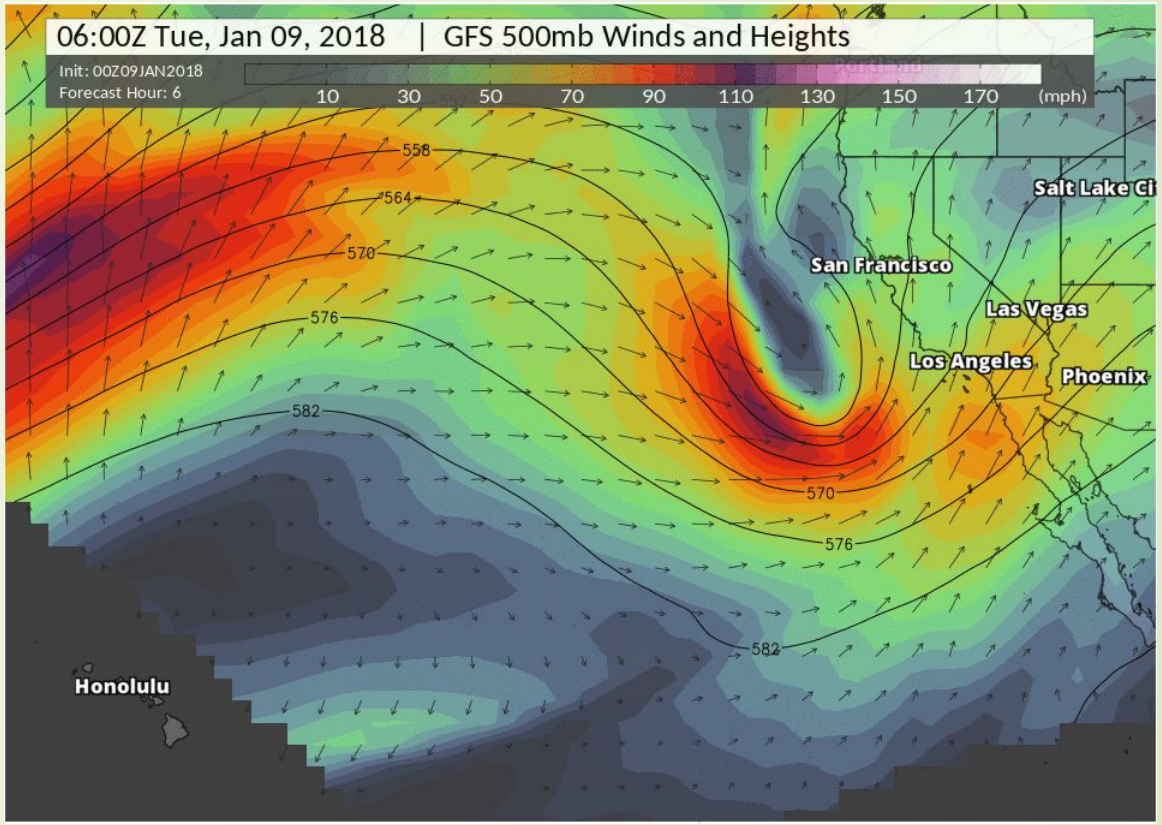
1/20/17 Synoptic Picture





Montecito 1/9/18 Synoptic Picture





Montecito 3/22/18 Synoptic Picture