High Wind Event
Port of Los Angeles/Long Beach Harbor
April 9, 2019

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Executive Summary

During the late afternoon and evening of Apr 9, 2019, a severe wind event brought measured wind gusts in excess of 50 MPH to the Port of Los Angeles/Long Beach Harbor area. Estimated wind gusts in the area were between 72 and 84 MPH with wind damage indicators to support these estimates. While the storm system was forecast by the National Weather Service (NWS), the agency failed to capture the overall strength of the system and was late in forewarning either the Port of Los Angeles or Long Beach Harbor. Historically speaking, an event of this magnitude was observed at the Port of Los Angeles/Long Beach Harbor as recently as Feb 2017 and Jan 2016 but otherwise area-wide not since 2011.

Overview

On Apr 9, 2019, a very intense and cold low-pressure system swept across the western United States. Its associated cold front extended southwest across California. Over the course of the day this front would march down across southern CA bringing strong gusty west to northwest winds to nearly all locations. While not uncommon in southern CA during the seasonal transition month of April, the magnitude of the measured winds at sea level in the Port of Los Angeles and Long Beach Harbor area were unusual. This report looks at this particular weather system in some detail, providing a thorough analysis of the meteorological parameters and documents what actually occurred. The report goes on to discuss the foreseeability and handling of the event by government meteorologists at the National Weather Service (NWS). The report continues with a look at how common an event of this magnitude is in the Port of Los Angeles/Long Beach Harbor area. Finally, the report concludes with a few take-aways for future use.

Analysis

Climatologically, April is a transition month in the northern hemisphere including California. While storms originating in the Gulf of Alaska in April are often moderated by the time they reach southern CA, this is not always the case and was not the case in early April 2019. Primarily fueled by a very cold airmass and a strong jet stream, this storm began its southward journey as early as the morning of Apr 7, 2019. In a mere 48 hours the center of this weather system travelled from the middle of the Gulf of Alaska to a position near Portland, OR, - about 1200 miles! In another 24 hours, it plunged to a position near Salt Lake City, UT. The progression of this storm system is given in the series of images found in Figure 1 with the big red “L” identifying the storms center.

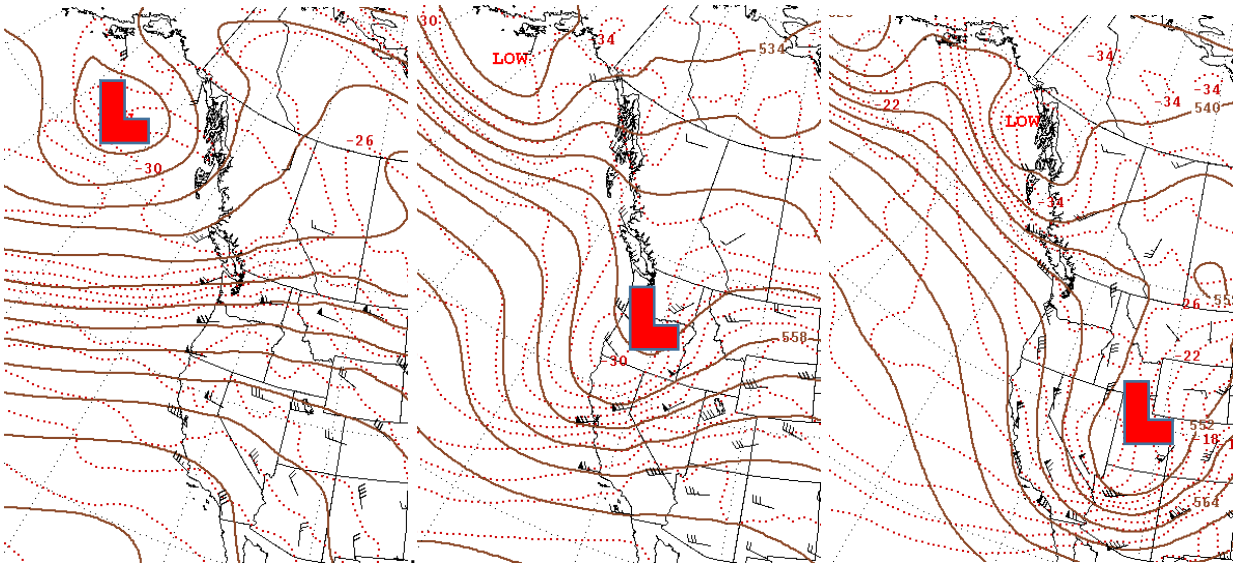

Figure 1 – Upper Atmosphere Low Pressure System Center Progression – Apr 7, 2019 (L) – Apr 9, 2019 (C) – Apr 10, 2019 (R)

All the while, its associated cold front was building steam for its plunge down along the west coast. On the morning of Apr 8, 2019, the surface cold front extended from just west of Portland, OR

southwestward out into the Pacific Ocean. Behind the cold front, was an atmosphere with its origins from the Alaskan interior. Temperatures there were 20-30 degrees °F colder than ahead of the front. See Figure 2.

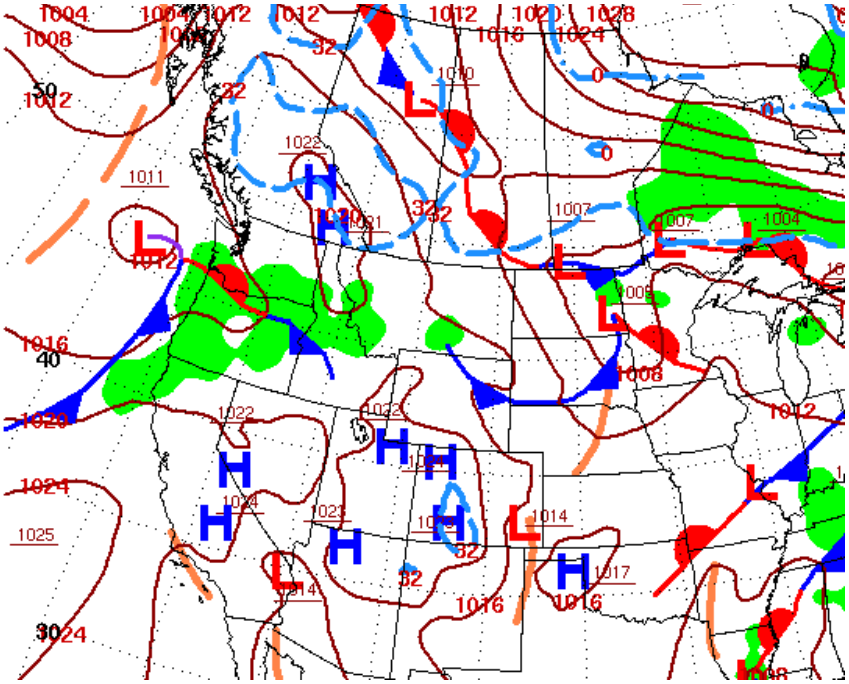

Figure 2 – Surface Weather Map for 0500 PDT Apr 8, 2019

At the same time, a very strong polar jetstream in excess of 120 MPH was racing across the Pacific Ocean up at 18,000 ft. MSL. See Figure 3.

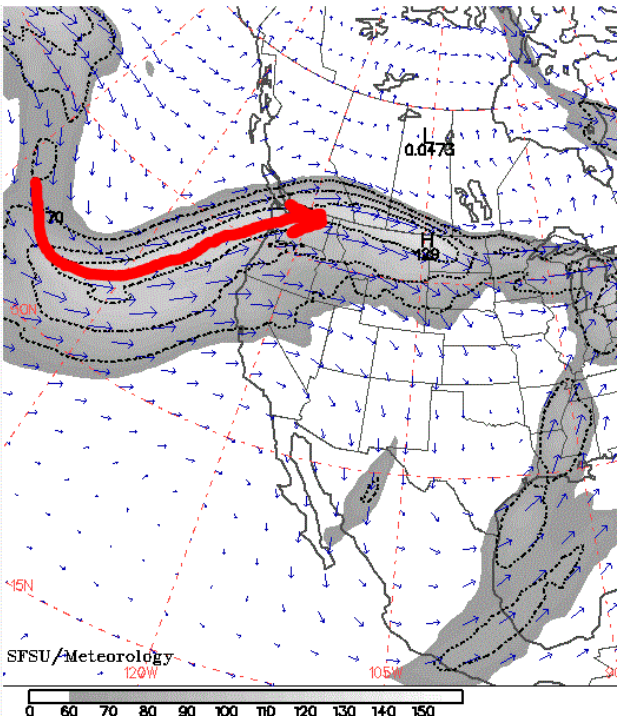

Figure 3 – Annotated Jetstream (**Red**) – 0500 PDT Apr 8 2019

This jetstream was phasing with the upper atmosphere low pressure discussed in Figure 1 and helping to strengthen the entire system.

By early on Apr 9, 2019, weather parameters had come together in phase, both surface and aloft, to produce a swath of strong surface windspeeds as the cold front swept through southern CA ushering in the colder air and pulling some of the stronger winds aloft down to the surface. See Figure 4.

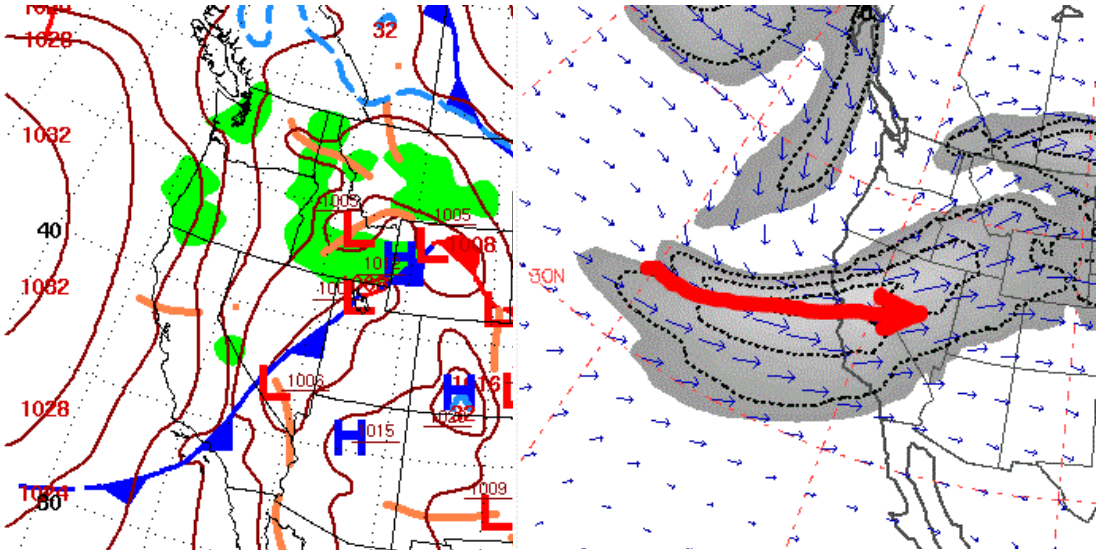

Figure 4 – Surface Map and Annotated Jetstream (**Red**) – 0500 PDT Apr 9 2019

As time approached the evening on Apr 9, 2019, the winds aloft that were being pulled to the surface became more NW-SE oriented as the weather system continued to intensify. Figure 5 shows the orientation of the stronger winds aloft shortly before the event occurred at the Port of LA/Long Beach Harbor. The strongest winds aloft measured 148 MPH at Vandenberg AFB[1] shortly before the event.

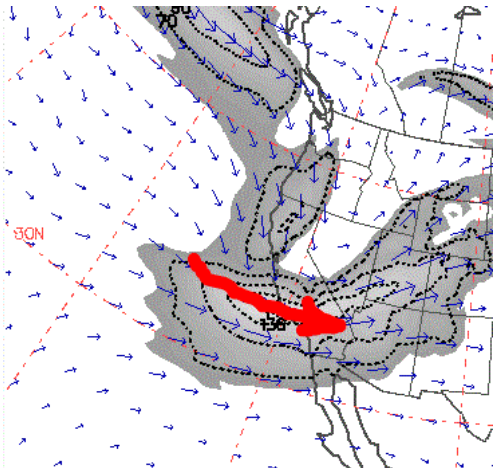

Figure 5 – Annotated Jetstream (**Red**) – 1700 PDT Apr 9 2019

[1] http://weather.uwyo.edu/cgi-bin/sounding?region=naconf&TYPE=TEXT%3ALIST&YEAR=2019&MONTH=04&FROM=1000&TO=1000&STNM=72393

Observations

Wind observations measured at the Port of Los Angeles/Long Beach Harbor Complex reflected the overall intensity of this system (See Table 1). Observations ranged from 37 MPH at Berth 161 to 53 MPH at the Badger Avenue Bridge. Badger Avenue Bridge is highlighted in red in Table 1 to note the strongest recorded winds of all stations at the Port of Los Angeles/Long Beach Harbor Complex during this event.

Maximum Wind Gusts			
9-Apr-19			
Station Name	**Max (MPH)**	**Time (PDT)**	**Dist (SM)**
Pier S	49	2224	0.9
Pier F	48	2136	1.1
Badger Ave B	**53**	**2154**	**1.7**
Pier J	45	2218	2.5
Pier 400	41	2230	2.6
Berth 161	37	2242	3.2

Table 1 – Maximum Recorded Wind Gusts on 9 Apr 2019

Estimated wind gusts from onsite security video footage and using NWS Enhanced F Scale Damage Indicators[2] suggest that peak wind gusts at the Port of Los Angeles/Long Beach Harbor Complex were between 72-84 MPH.

Several onsite security video cameras captured the maximum wind gust event as it happened. Figure 6 shows a snapshot from 3 separate cameras at the time the damage occurred. Red circles identify the damage occurring between 2110-2113 PDT as a result of the maximum wind gusts.

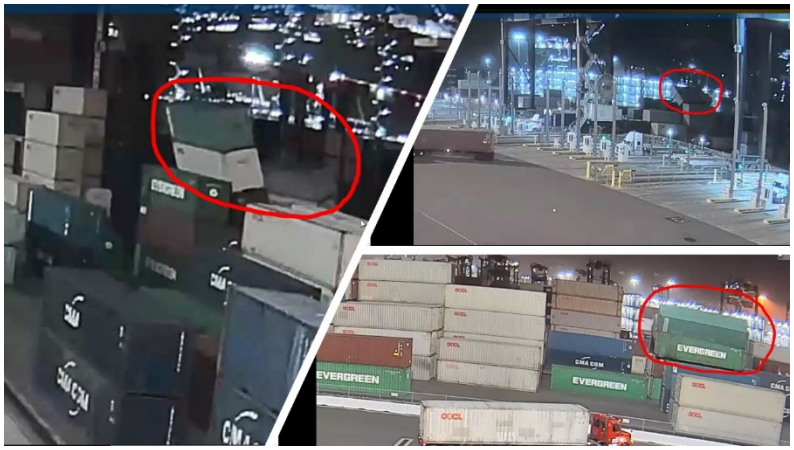

Figure 6 – Onsite Security Video Camera Footage of Damage Occurring

[2] https://www.weather.gov/oun/efscale

The NWS provides damage indicators for estimating the highest 3-second wind gust during an event. Assuming that cargo shipping containers are similar in nature to single-wide mobile homes supported on concrete blocks, the damage observed in the videos (sliding/rolling) equates to the Degree of Damage (DOD) numbers 3 and 5 in Table 2 below. Conservative lower boundary (LB) wind speeds for both of these DOD numbers is 72-84 MPH.

DOD*	Damage description	EXP	LB	UB
1	Threshold of visible damage	61	51	76
2	Loss of shingles or partial uplift of one-piece metal roof covering	74	61	92
3	Unit slides off block piers but remains upright	87	72	103
4	Complete uplift of roof; most walls remain standing	89	73	112
5	Unit rolls on its side or upside down; remains essentially intact	98	84	114
6	Destruction of roof and walls leaving floor and undercarriage in place	105	87	123
7	Unit rolls or vaults; roof and walls separate from floor and undercarriage	109	96	128
8	Undercarriage separates from unit; rolls, tumbles and is badly bent	118	101	136
9	Complete destruction of unit; debris blown away	127	110	148

* Degree of Damage

Table 2 – Degree of Damage Indicators for Single-Wide Mobile Homes[3]

The nature of the event also is worth noting. Figure 7 is a time-series of the wind speed/direction from the wind station located at Pier S for the period 0000 PDT 9 Apr – 2400 PDT 10 Apr 2019. It clearly shows a double peak in the wind speeds/gusts – 1600 PDT and 22-2300 PDT – with an identifiable lull in the speeds/gusts around 18-1900 PDT. This appears to be the approximate time that the surface cold front was passing through the area.

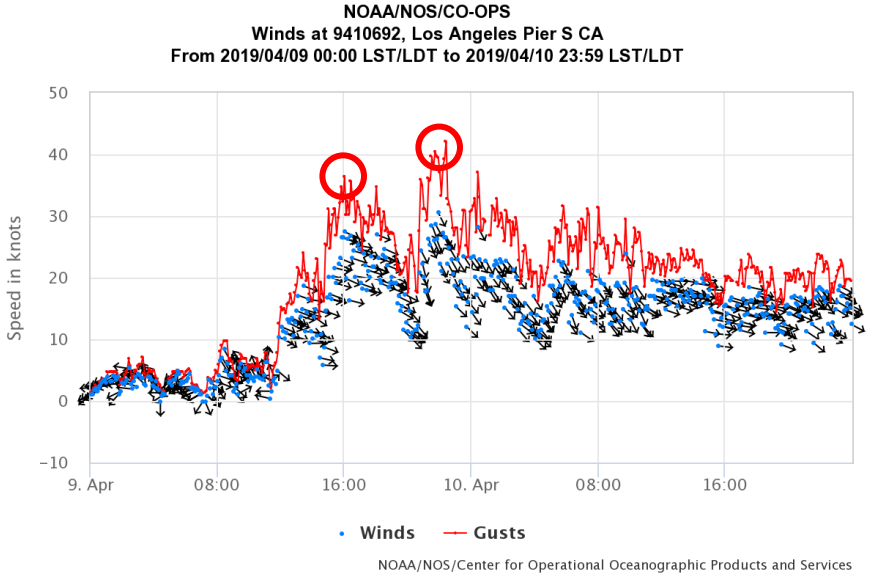

Figure 7 – Pier S Wind Speed/Direction Time-Series 9-10 Apr 2019

The instrument measured 53 MPH wind gust, while significant because of its capability to cause damage, was not an especially rare event nor anywhere near the peak instrument measured wind gusts seen at the Port of Los Angeles/Long Beach Harbor Complex in recent years. Wind events

[3] https://www.spc.noaa.gov/efscale/3.html

of this magnitude, in this area, occur on a semi-regular basis. One only has to look back at events in 2017 and 2016 and 2011 to find similar or stronger recorded wind events. It is worth noting here that the strongest instrument recorded wind event in the Port of Los Angeles/Long Beach Harbor Complex occurred on 17 Feb 2017 with a recorded gust to 75 MPH.

The historical data shows that wind events of at least 40 MPH occur every year and sometimes more than once per year. While the historical record of recorded observations from reliable instruments in the Complex area only date back to 2008, I suspect annual weather events with wind gusts of at least 40 MPH have always occurred.

A map of the wind station locations used in Table 1 above can be found below in Figure 8.

Figure 8 – Location of Wind Stations

Foreseeability

The NWS is the gold standard when it comes to publicly available forecasts and is the sole source for official severe weather watches, warnings, and advisories. Their alert system is the only public alert system in existence in the United States. All federal, state, county, and local officials and emergency responders rely on the NWS for weather and warning information.

The NWS in Oxnard, CA, which provides forecast and warning services for the area of southern CA where the Port of Los Angeles/Long Beach Harbor is located, began advertising the potential for a weather system capable of advisory level NW-N winds as early as Apr 4, 2019. It wasn't until early on Apr 7, 2019 that they began emphasizing a strong weather system capable of producing winds to 40 MPH. Furthermore, it wasn't until a tweet the evening before the event occurred where they indicated the potential for winds 40-55 MPH. At no time were winds in excess of 45 MPH included in any forecast for the Port of Los Angeles/Long Beach Harbor Complex.

The first advisory issued by the NWS for the Port of Los Angeles/Long Beach Harbor area went public at 207 PM PDT on Apr 8, 2019 – a mere 30 hours before the event occurred. This advisory warned of wind gusts to 45 MPH. This advisory remained in place until its expiration at 326 AM PDT on 10 Apr 2019 – it was never upgraded, modified, or updated.

Table 3 below provides a service timeline as the event unfolded.

NWS Service Chronology			
4/3-9/2019			
Date	**Time (PDT)**	**Products**	**Details**
3-Apr	310AM	Forecast	Sunny. Highs in the 70s to lower 80s
4-Apr	312AM	Forecast	Partly cloudy in morning then sunny. Highs lower to mid 70s beaches to mid 80s inland
4-Apr	210PM	Discussion	NW-N Winds will be on the rise 4/9. Widespread Wind Advisories are possible
5-Apr	247AM	Forecast	Partly cloudy. Highs upper 60s and 70s
5-Apr	223PM	Discussion	Upper level trough will amp up the NW-N winds 4/9. Widespread Wind Advisories likely
6-Apr	315AM	Forecast	Partly cloudy. Highs upper 60s and 70s
7-Apr	335AM	Forecast	Partly cloudy. Highs upper 60s to mid 70s. West winds 15-25 mph w/gusts to 40 mph PM
7-Apr	409AM	Discussion	...widespread strong NW-N winds Tue aftn/Tue night. Expect Wind Advisories all areas
8-Apr	322AM	Forecast	Partly cloudy. Highs upper 60s to mid 70s. West winds 20-30 mph w/gusts to 40 mph PM
8-Apr	359AM	Discussion	Models have backed off on windspeeds. Decided to hold off on warnings (advisories)
8-Apr	143PM	Discussion	Winds aloft to 50-60kt will force winds down to lower elevations leading to advisory gusts
8-Apr	207PM	Public Alert	Wind advisory issued for coastal LA county with wind gusts to 45 mph
8-Apr	250PM	Forecast	Partly cloudy. Highs upper 60s and 70s. NW winds 20-30 mph w/gusts to 45 mph PM
8-Apr	527PM	Tweet	Strong N-NW Winds Tue into Wed. Widespread wind gusts 40-55 mph. Impacts
8-Apr	833PM	Discussion	Strong and damaging northerly winds expected across most areas Tue aftn thru Tue night
9-Apr	242AM	Tweet	Preliminary Wind Gusts for this Evening. G37 mph at LGB
9-Apr	324AM	Discussion	Strong advisory level winds (45-50 mph gusts) will affect much of coastal locations
9-Apr	326AM	Forecast	Partly cloudy. Highs upper 60s and 70s. NW winds 20-30 mph w/gusts to 45 mph PM
9-Apr	225PM	Discussion	Strongest winds still appear to be tonight into early Wed. Advisories in most areas
9-Apr	251PM	Forecast	Mostly clear. Lows lower to mid 50s. NW winds 20-30 mph w/gusts to 45 mph
9-Apr	821PM	Discussion	...drove strong upper level winds to surface. Much of area saw gusts to 45 mph
9-Apr	856PM	Forecast	Mostly clear. Lows lower to mid 50s. NW winds 20-30 mph w/gusts to 45 mph
10-Apr	326AM	Public Alert	Wind advisory has expired

Table 3 – NWS Service Chronology

It may not be quite clear from the chronology that the services provided by the NWS were of mixed success. First, the NWS recognized a potential wind event 5 days in advance and talked about it in their discussions for several days. Unfortunately, unless you read the publicly available discussions, you were not made aware of the potential wind event until 2 days before the event on Apr 7, 2019 – a Sunday - when most people were enjoying their weekend. Unfortunately, early on Apr 8, 2019 weather computer models backed off on the strength of the event. This in turn scared off forecasters and did not give them the confidence to pull the trigger on wind advisories until the afternoon before the day of the wind event.

Once again, like in 2017, the most significant aspect to the Port of Los Angeles/Long Beach Harbor Complex was the fact that forecasters underestimated the ultimate strength of the system. While a forecast of 45 MPH is only 8 MPH from what was observed (53 MPH), those 8 MPH can make a huge difference in damages. This is especially true if conditions of this magnitude continue for a long period of time. In this case, the strong winds with continuous gusts in excess of 30 MPH lasted for an average period of 2.4 hours.

The impact of an 8 MPH wind difference on a stack of cargo containers can be calculated. Using the basic principle that Force (F) = Mass (M) x Acceleration (A) and using the following constants and assumptions:

1. 8 MPH = 3.58 m/s
2. A = [3.58 m/s]² = 12.82 m²/s²
3. Average Air Density (p) = 1.23 kg/m³
4. M = p x Area
5. Area = Single Cargo Container Side = 40 ft x 8 ft = 12.19 m x 2.44 m = 29.75 m²
6. M = 1.23 kg/m³ x 29.75 m² = 36.58 kg/m

We find that Force = 36.58 kg/m x 12.82 m²/s² = 469.0 Newtons

If we further assume that:

1 Newton = 0.22 Pounds Force

We find that 469.0 Newtons = 105 Pound Force.

This means that each container in a stack of exposed containers is receiving an additional 105 pounds of lateral force from an 8 MPH wind increase from what was forecast. If the stack contains 6-9 containers, the additional force on the overall stack can reach nearly 1000 lbs!

If we perform the same calculation using the conservative estimated peak wind gust based upon 72 MPH from the onsite security video footage, each container in a stack of exposed containers is receiving an additional 1,172 pounds of lateral force. If the stack contains 6-9 containers, the additional force on the overall stack in this case exceeds 7,000 lbs and may be as much as 10,000 lbs!!

Historical Perspective

An approach to wind gust frequencies is to examine the situation from an engineering perspective. The American Society of Civil Engineers (ASCE), an internationally recognized authoritative source for building codes and standards, provides minimum design loads for buildings and other structures (ASCE 7-16)[4]. ASCE 7-16 directs users to a website whose purpose is to provide users with a site-specific windspeed that is used in the determination of design wind loads. Part of the output (for serviceability purposes) is 10-, 25-, 50-, and 100-year return periods. These return periods are site specific for the location provided and are found by interpolation of map contours (to the nearest 1-MPH) found on the wind maps located in the ASCE 7-16. Using the Lat/Lon of the incident location reveals the output found in Figure 9.

[4] http://ascelibrary.org/doi/book/10.1061/9780784412916

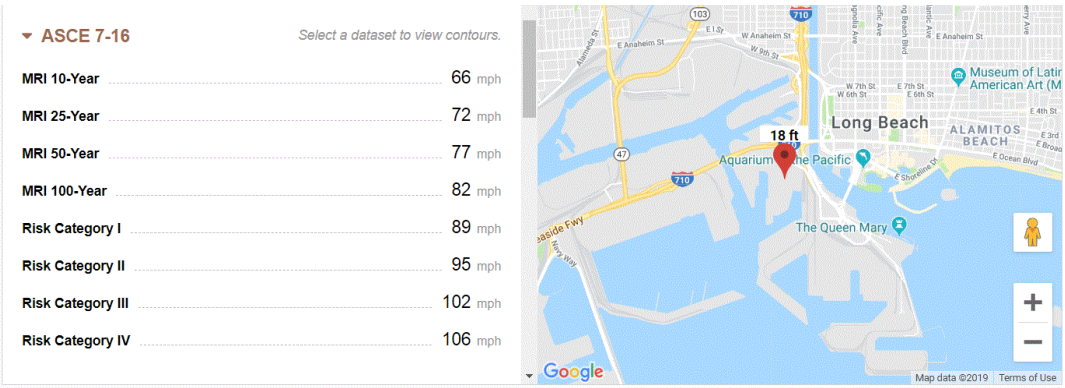

Figure 9 – Search Results from ASCE 7-16 directed website for the incident location

The search results provide an engineering-perspective statistical Mean Recurrence Interval (MRI) of 10 years for a 66 MPH 3-sec peak wind gust. This further drives the point home that the instrument observed winds on Apr 9, 2019 at the Port of Los Angeles/Long Beach Harbor Complex certainly can be expected to occur more often than once every 10 years.

On the other hand, if we consider the estimated wind gusts determined from the onsite security video footage (72-84 MPH), the MRI would be on the order of a 25-year to as much as a 100-year event.

Summary/Takeaways

- On Apr 9, 2019, a strong wind event swept through southern CA bringing a several hour period of strong gusty winds to nearly all locations.
- During the evening of Apr 9, 2019, the strongest wind gusts followed the passage of a cold front, the arrival of a cold airmass, and the transport of winds aloft to the surface.
- This resulted in measured wind observations at the Port of Los Angeles/Long Beach Harbor Complex as high as 53 MPH.
- Estimated wind gusts from onsite security footage, using NWS damage indicators, would suggest 3-sec wind gusts actually reached between 72-84 MPH.
- Forecast services provided by the NWS were of mixed success. While identification of a potential event occurred 5 days in advance, messaging to the public and critical partners did not occur until 2 days before the event.
- Forecast services provided by the NWS underestimated the potential and ultimate strength of the system.
- Wind advisories were late in coming with only approximately 30 hours of advanced notice.
- The additional measured wind (not forecasted) added as much as an additional 1000 lbs. of lateral force to a large stack of cargo containers.
- The additional estimated wind added as much as an additional 10,000 lbs of lateral force to a large stack of cargo containers.
- The recorded maximum wind gust of 53 MPH statistically occurs more often than once every 10 years and may be as frequent as every few years.
- The conservative estimated maximum wind gust of 72 MPH statistically occurs once every 25 years.