Analysis of Mesoscale and Synoptic Scale Meteorological Influences on Ozone

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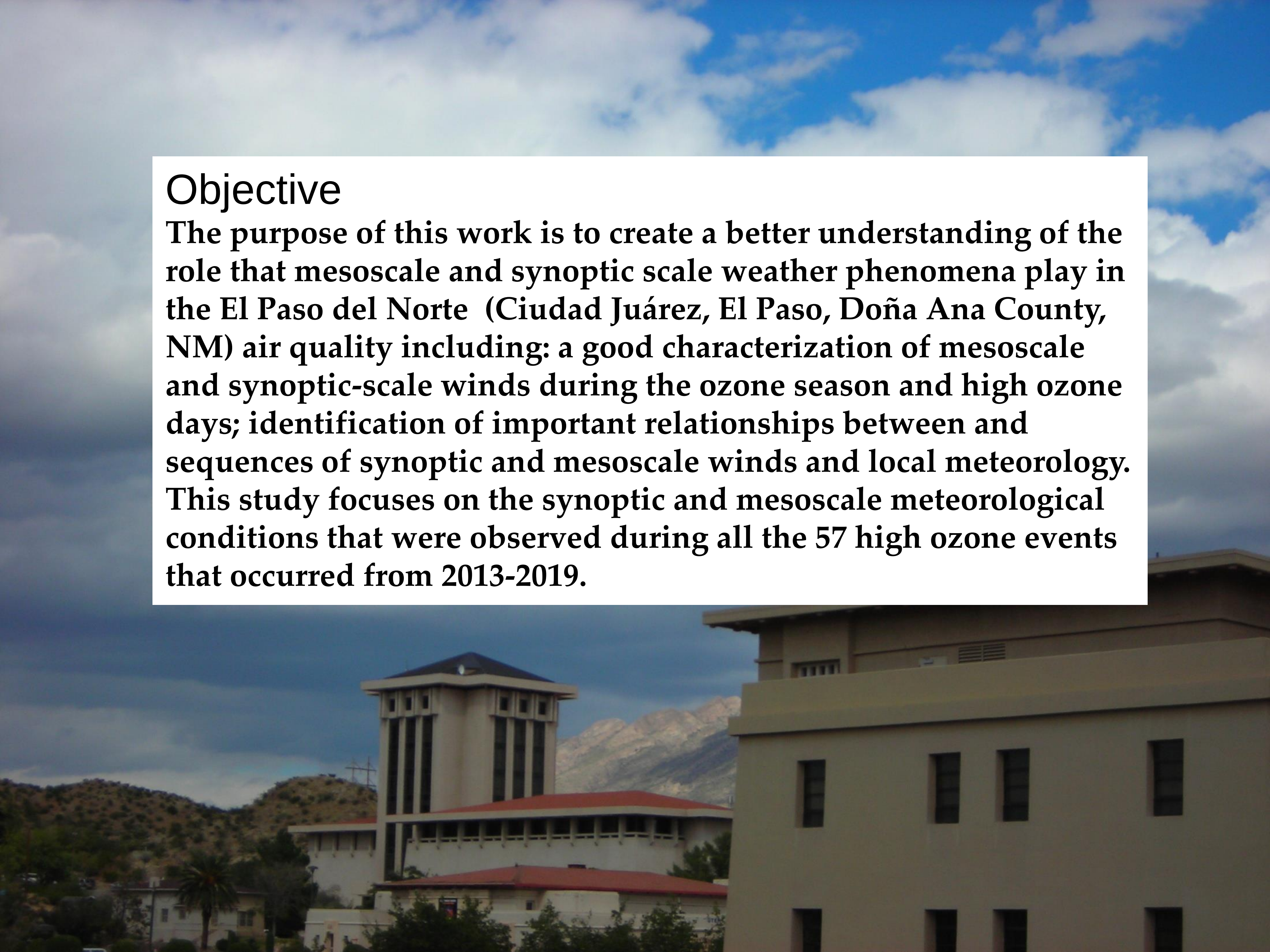
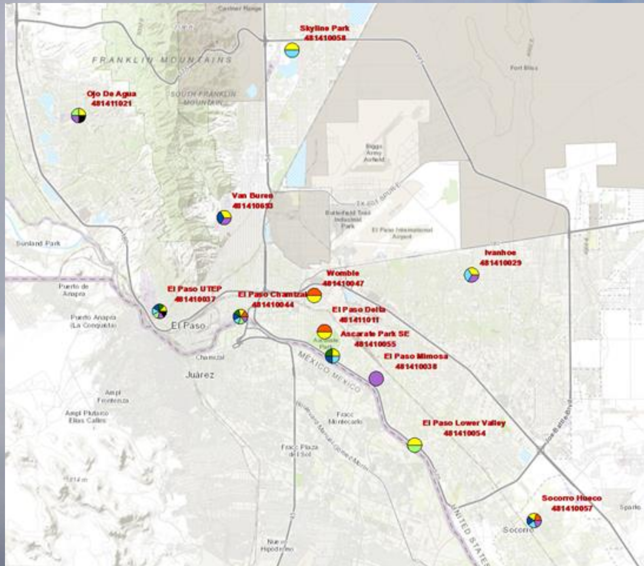
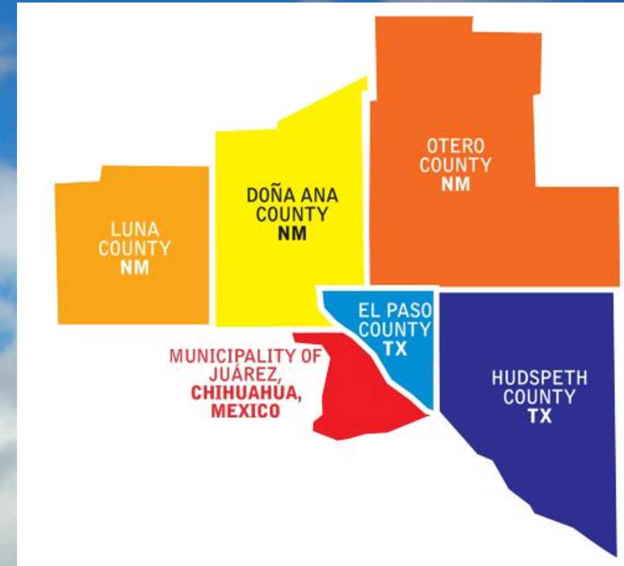


Objective

The purpose of this work is to create a better understanding of the role that mesoscale and synoptic scale weather phenomena play in the El Paso del Norte (Ciudad Juárez, El Paso, Doña Ana County, NM) air quality including: a good characterization of mesoscale and synoptic-scale winds during the ozone season and high ozone days; identification of important relationships between and sequences of synoptic and mesoscale winds and local meteorology. This study focuses on the synoptic and mesoscale meteorological conditions that were observed during all the 57 high ozone events that occurred from 2013-2019.



Regional Scale covering
Paso del Norte (PdN) region

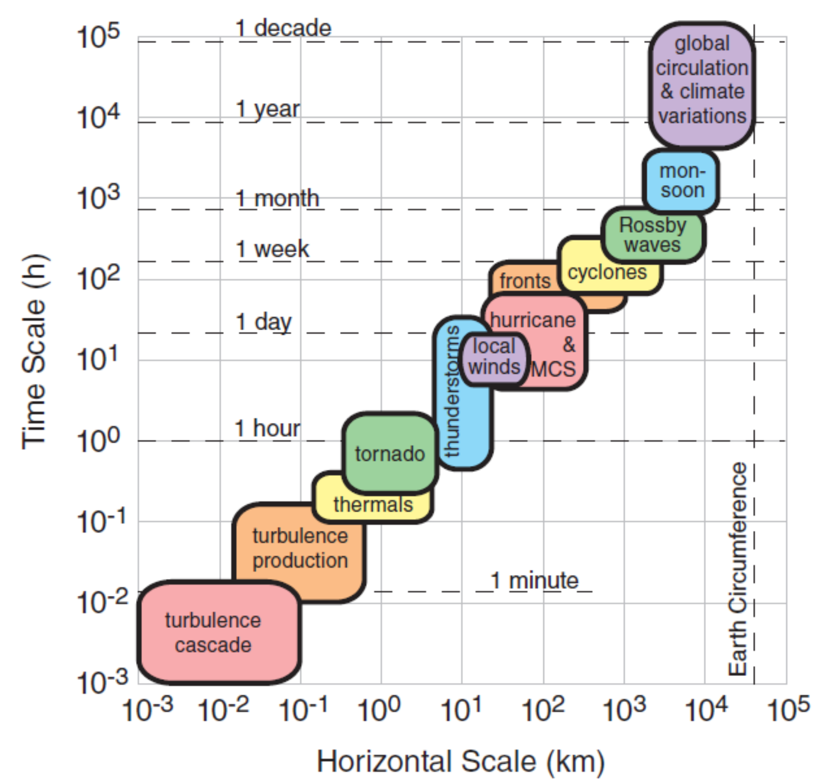


Scales and corresponding phenomena:

Horizontal Size	Scale Designation	Scale Name	
40,000 km	macro α	planetary scale	
4,000 km	macro β	synoptic scale*	
700 km	meso α	mesoscale**	
300 km	meso β		
30 km	meso γ		
3 km	micro α	microscale***	boundary-layer turbulence
300 m	micro β		surface-layer turbulence
30 m	micro γ		inertial subrange turbulence
3 m			
300 mm	micro δ		fine-scale turbulence
30 mm			
3 mm	viscous	dissipation subrange	
0.3 μm	molecular	mean-free path between molec.	
0.003 μm		molecule sizes	
0			

Note: Disagreement among different organizations.
*Synoptic: AMS: 400 - 4000 km; WMO: 1000 - 2500 km.
**Mesoscale: AMS: 3 - 400 km; WMO: 3 - 50 km.
***Microscale: AMS: 0 - 2 km; WMO: 3 cm - 3 km.
where AMS = American Meteorological Society,
and WMO = World Meteorological Organization.

Generalized horizontal scale of motion in the troposphere defined by the World Meteorological Organization (WMO) and the American Meteorological Society (AMS). Source: Practical Meteorology, R. Stull



Typical time and spatial scales of meteorological phenomena. MCS = Mesoscale Convective System (see the thunderstorm chapter).

The Data Used for this Analysis is:

- The soundings, upper air charts from the Plymouth State University weather center (https://vortex.plymouth.edu/myo/upa/raobplt-a.html)

- The surface analysis from the NOAA weather prediction center (https://www.wpc.ncep.noaa.gov/archives/web_pages/sfc/sfc_archive.php)
- For major events: https://www.spc.noaa.gov/products/outlook/

- The upper air from the NOAA storm prediction center (https://www.spc.noaa.gov/obswx/maps/).

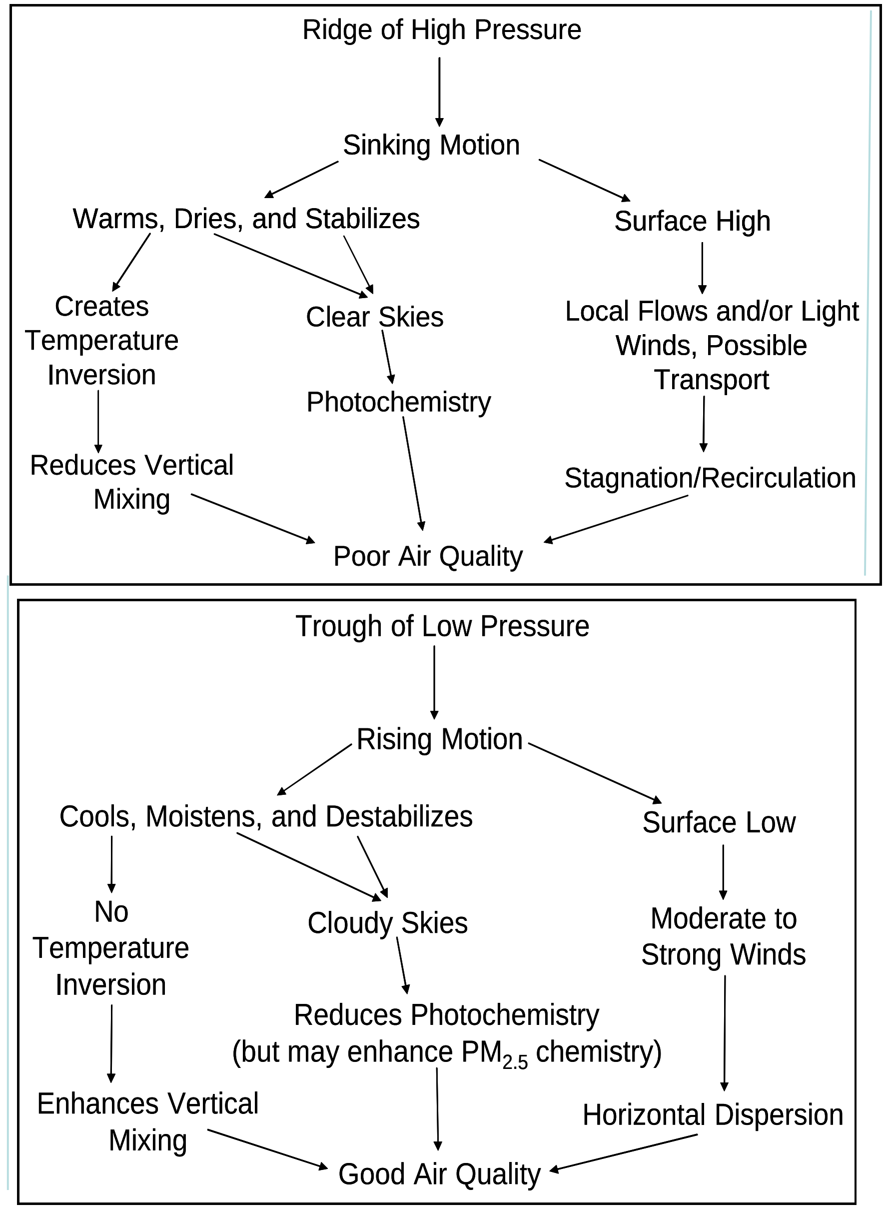
- Cloud cover analysis:

  http://weather.uwyo.edu/upperair/sounding.html

Meteorological Conditions that Influence Air Quality

- Aloft Pressure Patterns
- Temperature Inversions and Vertical Mixing
- Winds and Transport
- Clouds, Fog, and Precipitation
- Weather Pattern Cycles

Aloft Pressure Patterns



Temperature Inversions and Vertical Mixing

A temperature inversion is a layer of warm air above a layer of relatively cooler air. An inversion acts to limit the vertical mixing of pollutants, which allows concentrations to build. Several temperature inversions can exist at different altitudes in the lower part of the atmosphere.

Winds and Transport

Light, regional, surface winds often occur near the center of the surface-high, below the ridge of high pressure, where pressure gradients are weak. Light winds are not effective at dispersing pollutants and, therefore, often occur during high pollutant concentrations. Moderate to strong winds occur between surface high- and low-pressure systems or near the center of low-pressure systems, provided that moderate to strong pressure gradients exist. Moderate to strong surface winds act to disperse pollution and thus are typically associated with low pollutant concentrations. However, high pollutant concentrations can occur during moderate to strong wind conditions, if the winds transport pollution from one region to another.

Clouds and Precipitation

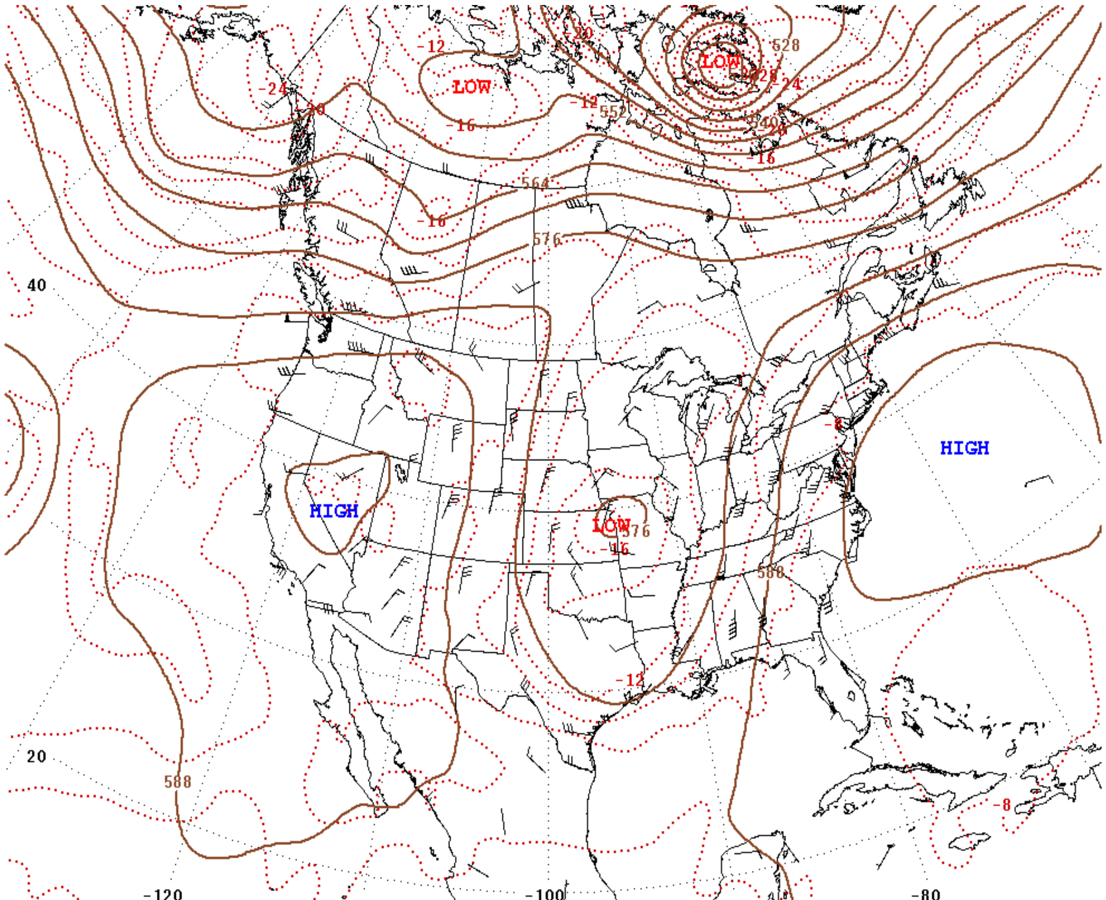
Water droplets can enhance the formation of secondary PM2.5. Clouds can limit photochemistry, which limits ozone production.

Precipitation is a removal mechanism for fine particles

Weather Pattern Cycles

The following pattern is typically associated with poor air quality:

This pattern occurs about one to two days after a cold front and trough have passed through an area. As surface high pressure develops in an area, winds become weak allowing for the accumulation of pollutants. Warming temperatures increase the biogenic and evaporative VOCs and lower humidity results in clearer skies, which are favorable for photochemistry. Sinking air (subsidence) warms and stabilizes the lower atmosphere, which suppresses cloud development and mixing. In addition, an aloft temperature inversion may form that inhibits vertical mixing and reduces dilution of pollutants. The aloft high pressure ridge, observed in the next slide, typically occurs west of the surface high and can be diagnosed using 500-mb height fields.



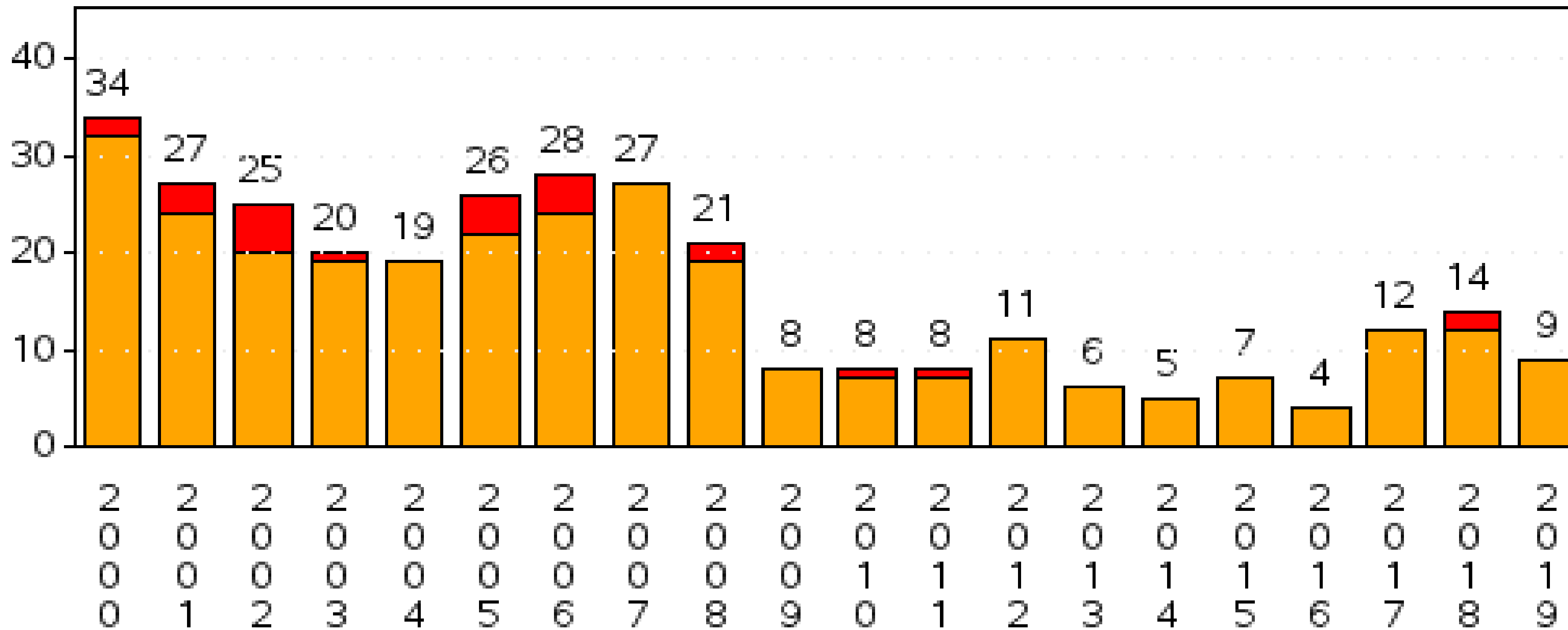
WED, JUL 03, 2013

500-Millibar Height Contours at 7:00 A.M. E.S.T.

Number of Days 8-hr Ozone Daily Max > 0.070 ppm

2000-2020

in El Paso, TX



Unhealthy for Sensitive Groups (0.071 — 0.085 ppm)

Unhealthy (0.086 — 0.105 ppm)

Total High Ozone Days: 57

Clear Skies: 25 (44%)

Partial: 20 (35%)

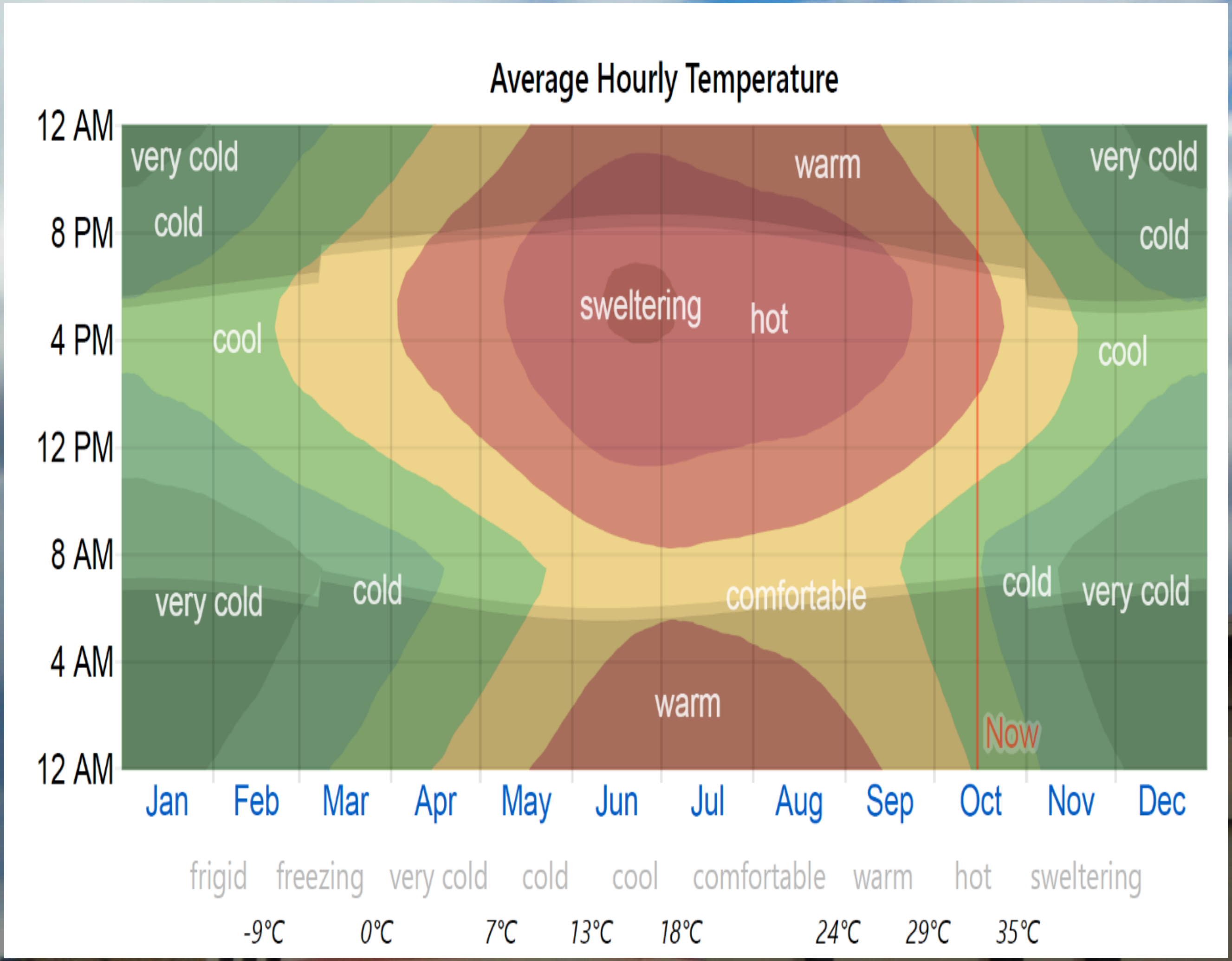
Cloudy: 12 (21%)

Note: Based on ALL sites

Source: U.S. EPA AirData <https://www.epa.gov/air-data>

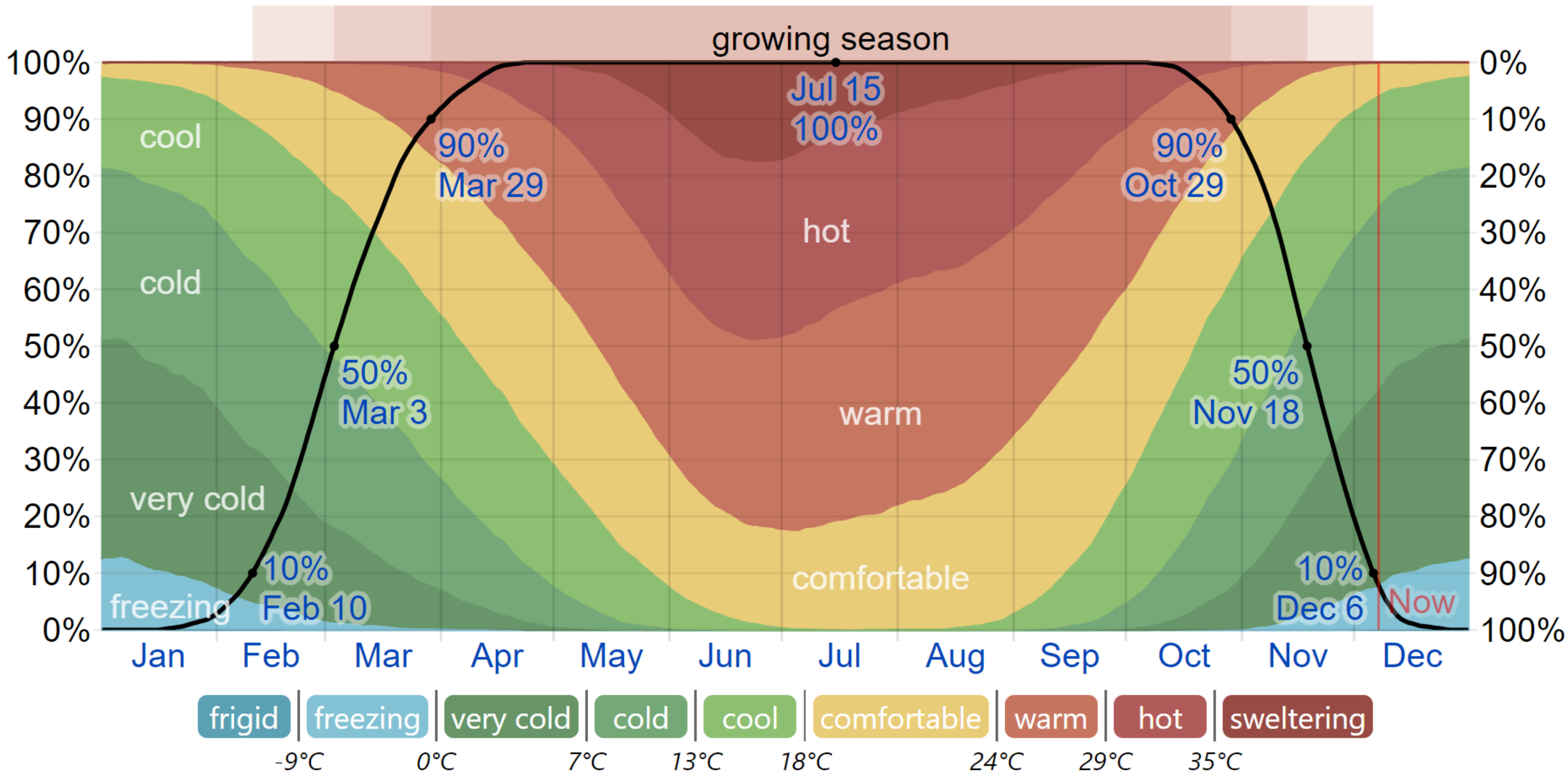
Generated: June 11, 2020

Results



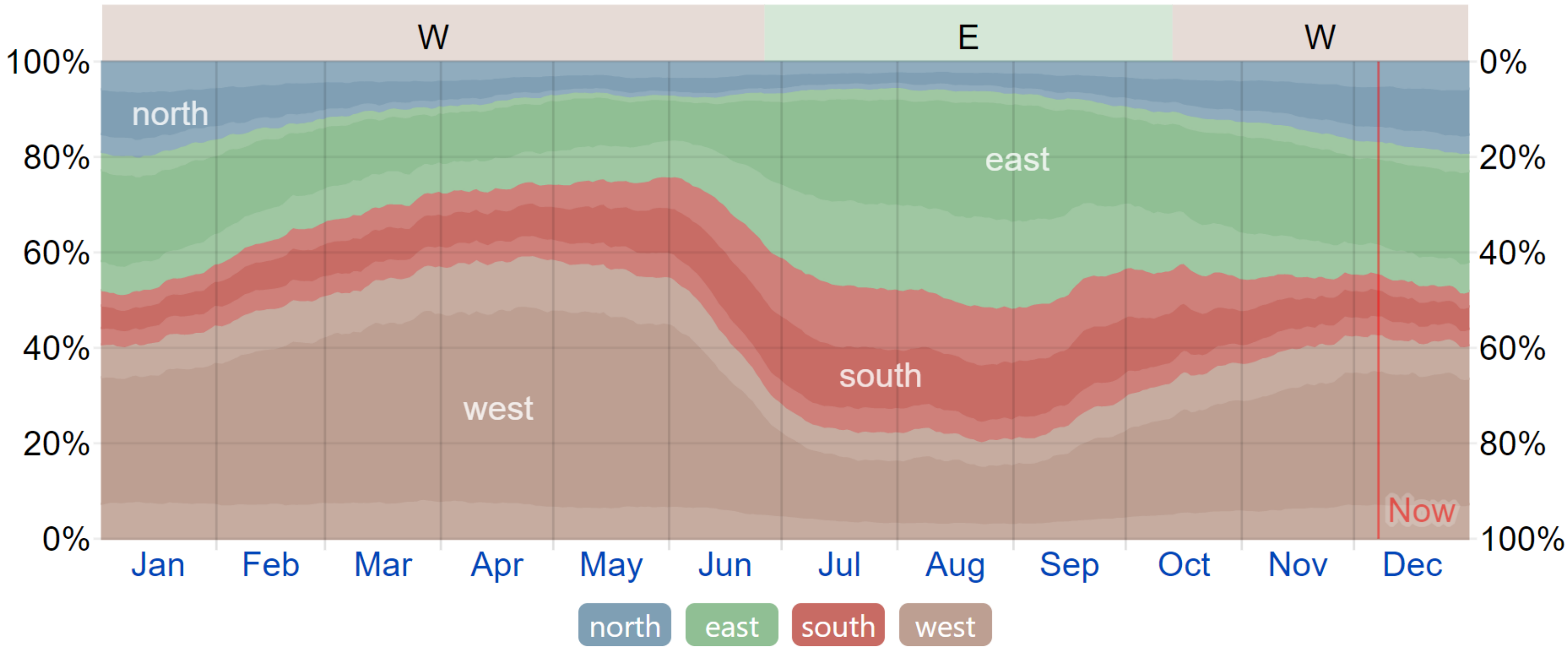
The average hourly temperature, color coded into bands for the Paso Del Norte region. Source:Weatherspark.com

Time Spent in Various Temperature Bands and the Growing Season

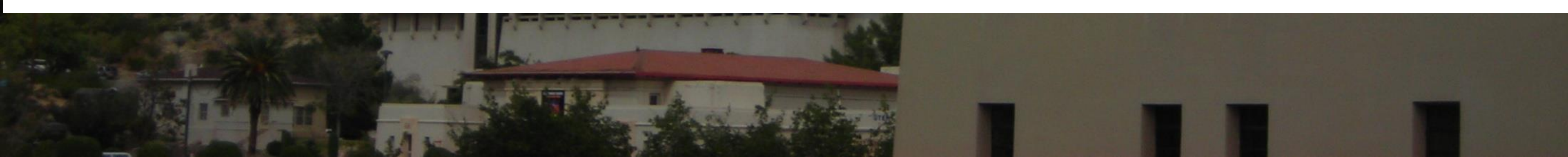


The percentage of time spent in various temperature bands. The black line is the percentage chance that a given day is within the growing season.

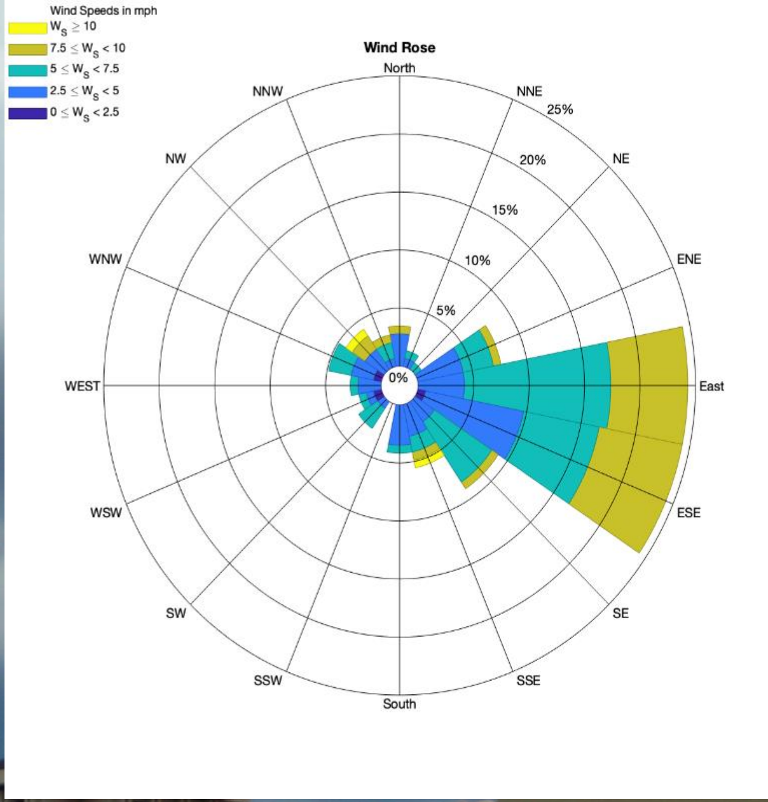
Wind Direction



The percentage of hours in which the mean wind direction is from each of the four cardinal wind directions, excluding hours in which the mean wind speed is less than 0.4 m/s. *The lightly tinted areas at the boundaries are the percentage of hours spent in the implied intermediate directions (northeast, southeast, southwest, and northwest).*

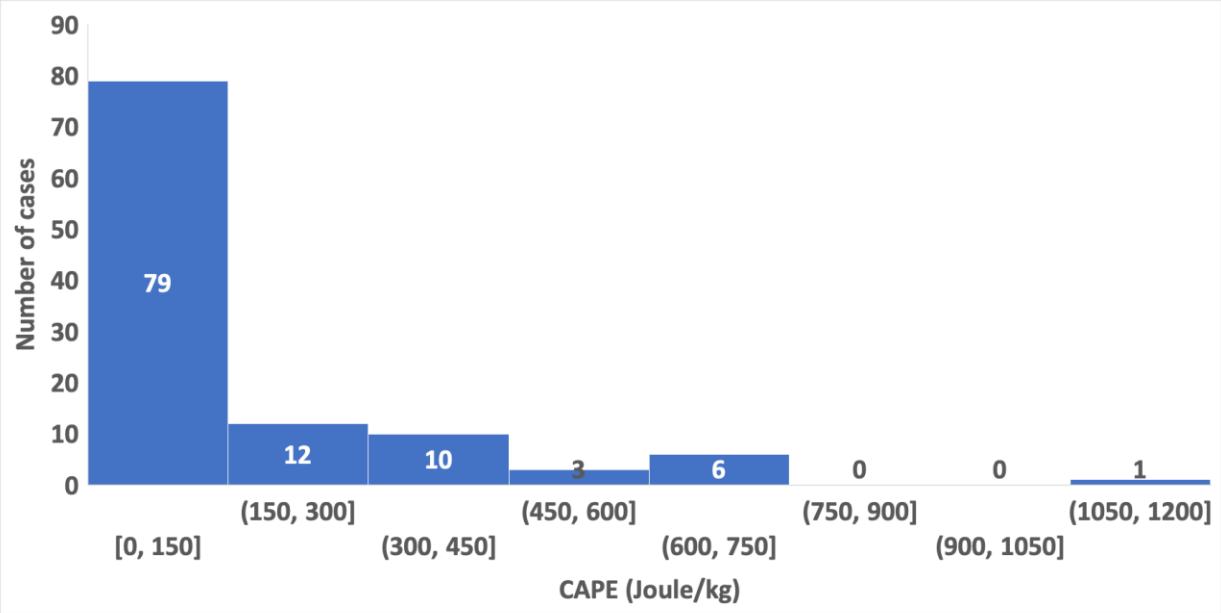


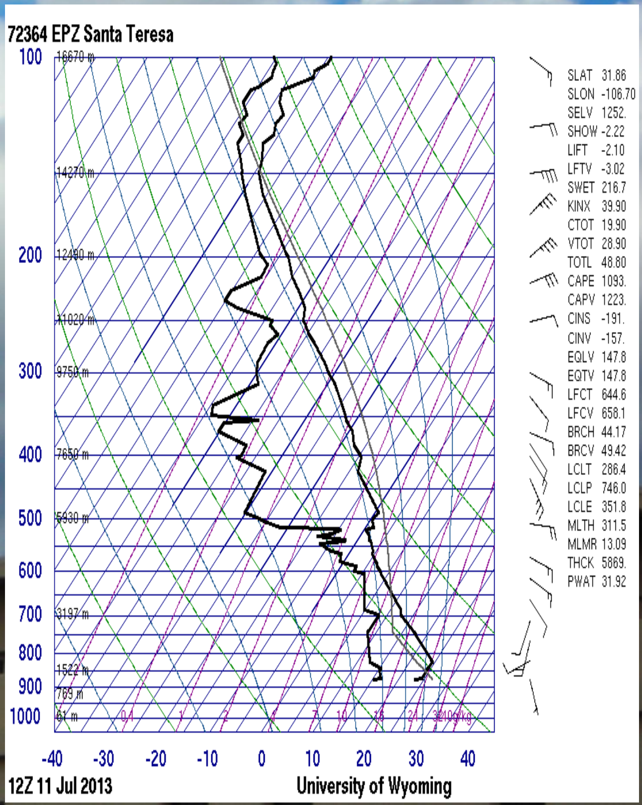
Windroses



As seen in the figure, wind direction during the high ozone episodes tended to be East, East-southeast, and Southeast.

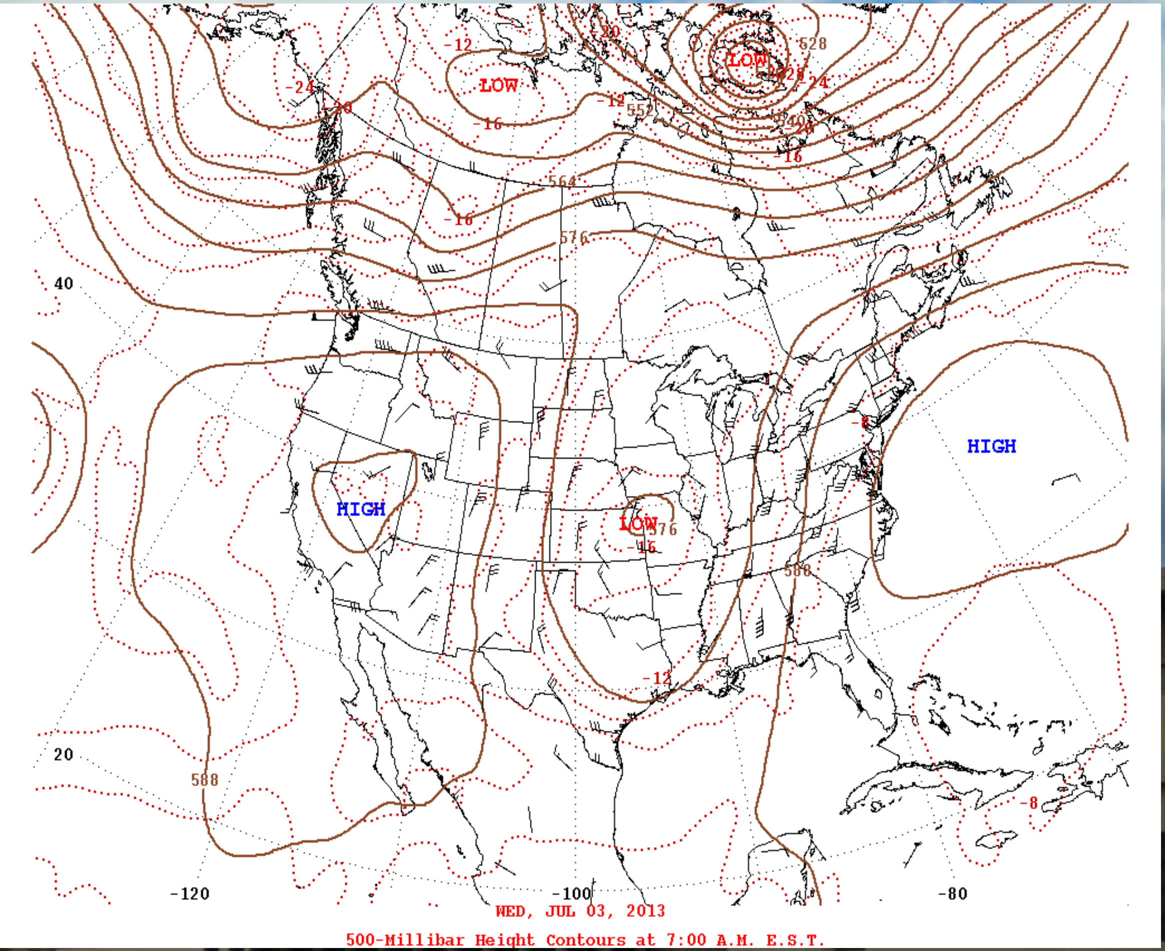
Atmospheric Stability

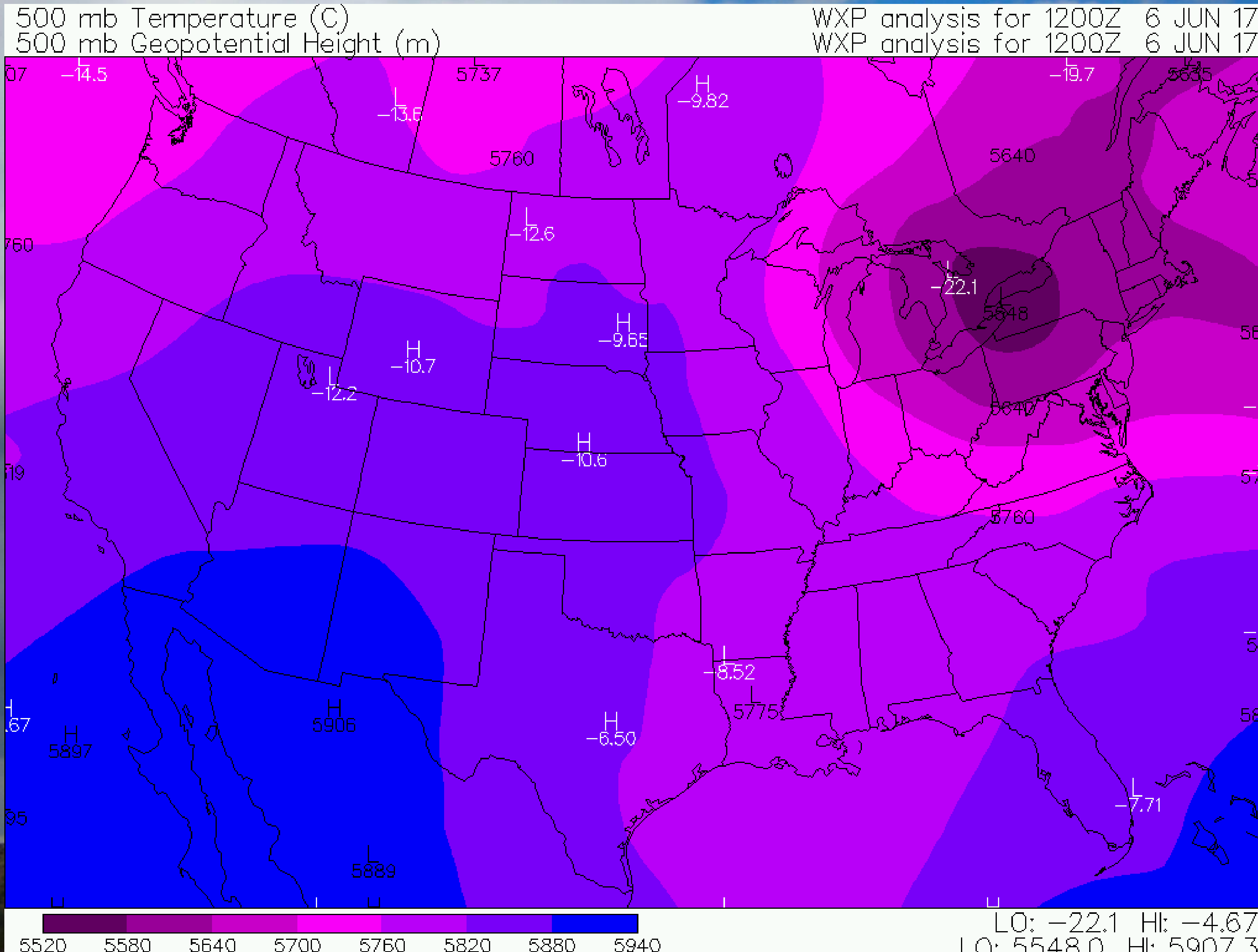




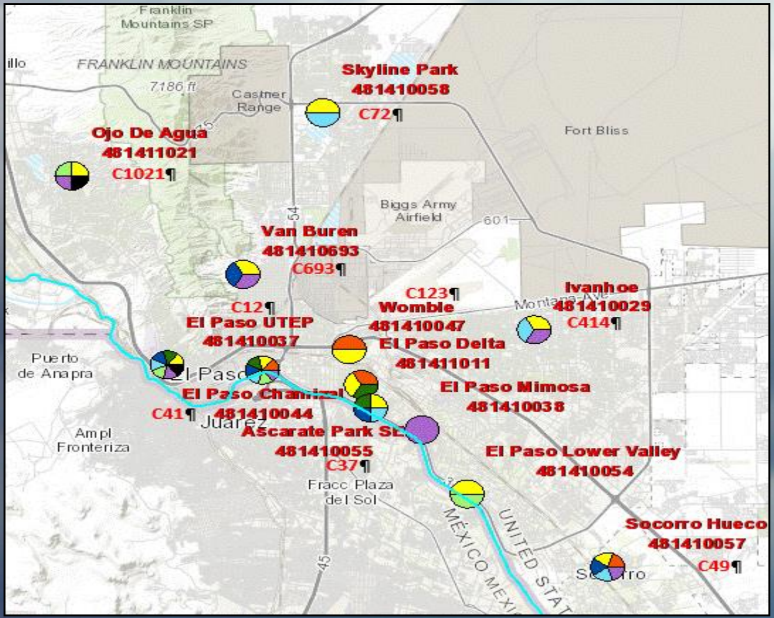
Vertical profiles from the Santa Teresa, National Weather Services (NWS) were used to study the atmospheric thermal stability.

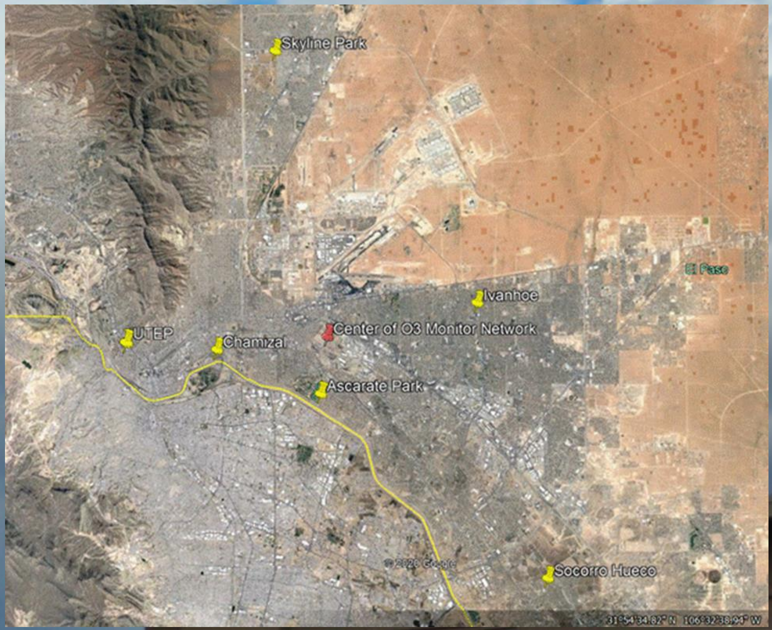
Synoptic Analysis



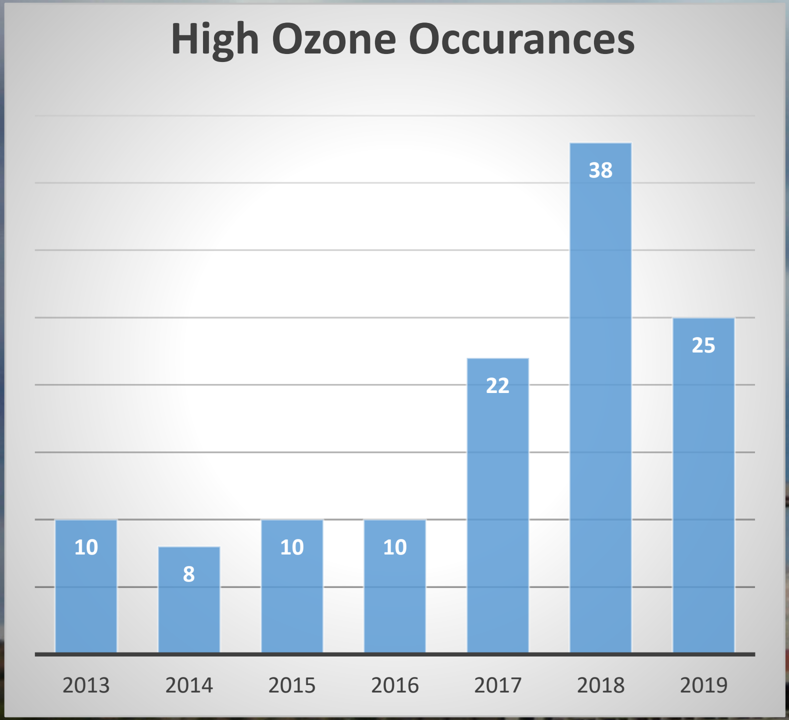

500 mb Temperature (C)
500 mb Geopotential Height (m)
WXP analysis for 1200Z 6 JUN 17
WXP analysis for 1200Z 6 JUN 17
L −14.5
5737
L −13.6
H −9.82
L −19.7
5635
5760
5640
L −12.6
L −22.1
5548
H −9.65
H −10.7
L −12.2
5640
H −10.6
5760
L −8.52
5775
H 5906
H 5897
H −6.50
L −7.71
L 5889
5520
5580
5640
5700
5760
5820
5880
5940
LO: −22.1 HI: −4.67
LO: 5548.0 HI: 5907.3

Analysis per Station





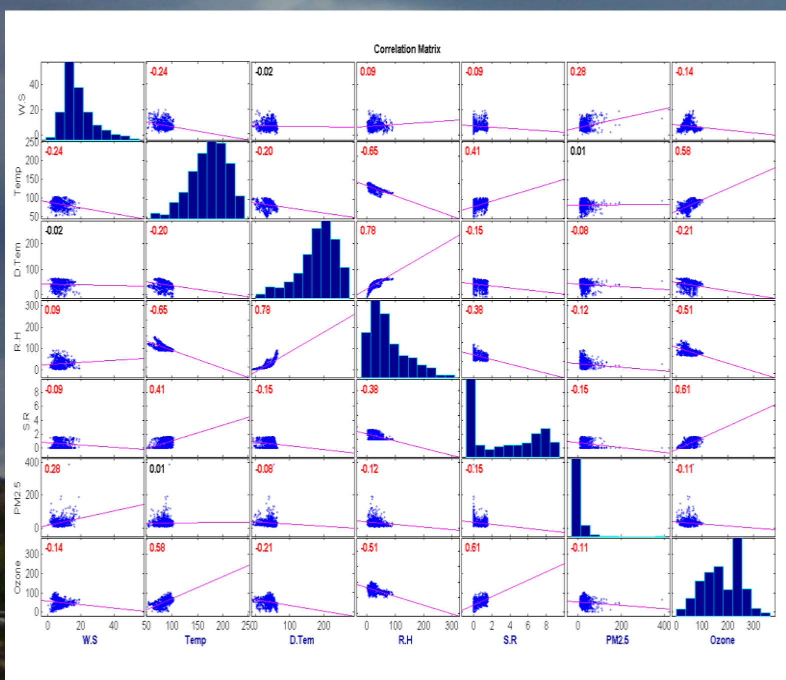
Statistical Analysis

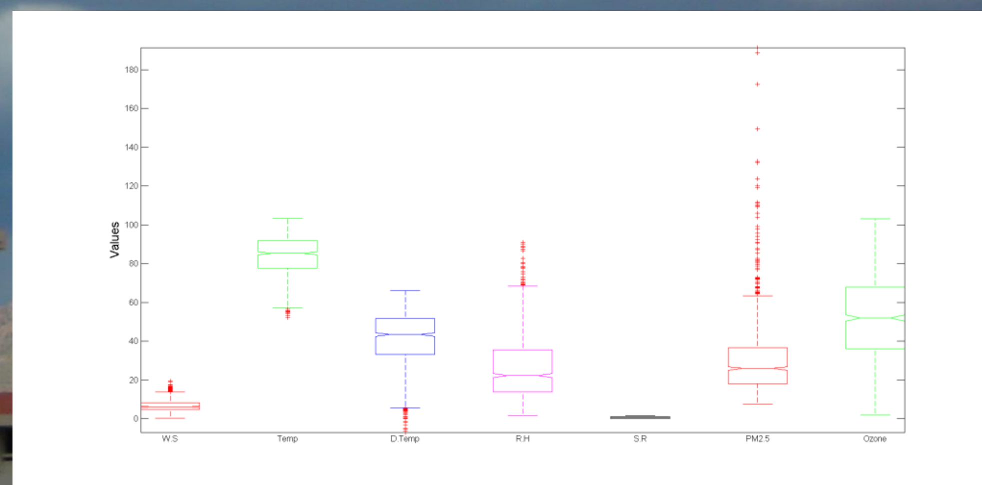


Year	UTEP (CAMS 12)	Skyline (CAMS 72)	Chamizal (CAMS 41)	Ivanhoe (CAMS 414)	Socorro (CAMS 49)	Ascarate Park (CAMS 37)	Total High Ozone event occurrences
2013	6	1	3	0	0	0	10
2014	3	2	2	0	1	0	8
2015	4	2	2	1	1	0	10
2016	4	1	2			3	10
2017	10	4	6	1	0	1	22
2018	7	12	5	5	3	4	38
2019	7	6	7	3	1	1	25

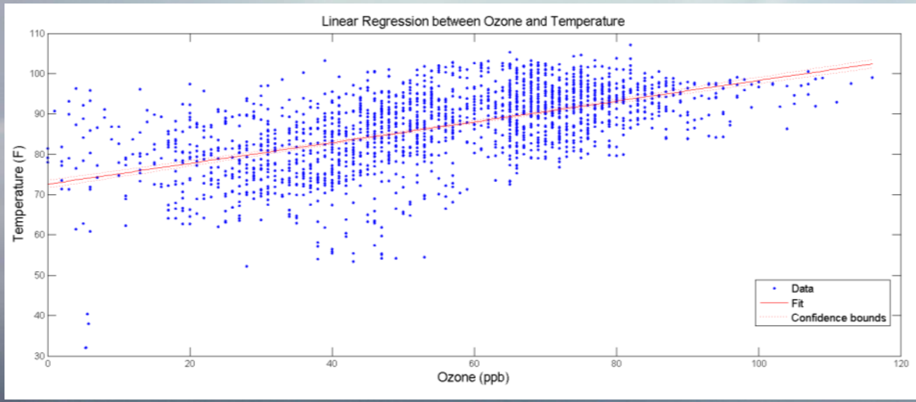
CAMS 12/UTEP

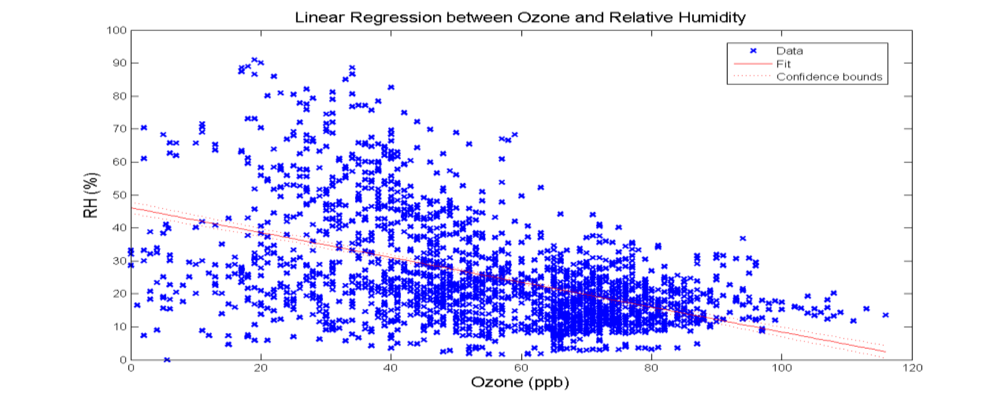
	WS	Temp	Dew Temp	RH	SR	PM2.5	Ozone
WS		-0.24	0.02	0.09	-0.09	0.28	-0.14
Temp	-0.24		-0.20	-0.65	0.41	0.01	0.58
DewTemp	-0.02	-0.20		0.78	-0.15	-0.08	-0.21
RH	0.09	-0.65	0.78		-0.38	-0.12	-0.51
SR	-0.09	0.41	-0.15	-0.38		-0.15	0.61
PM2.5	0.28	0.01	-0.08	-012	-0.15		-0.11
OZONE	-0.14	0.58	-0.21	-0.51	0.61	-0.11	





Linear Regression Between Ozone and T, RH



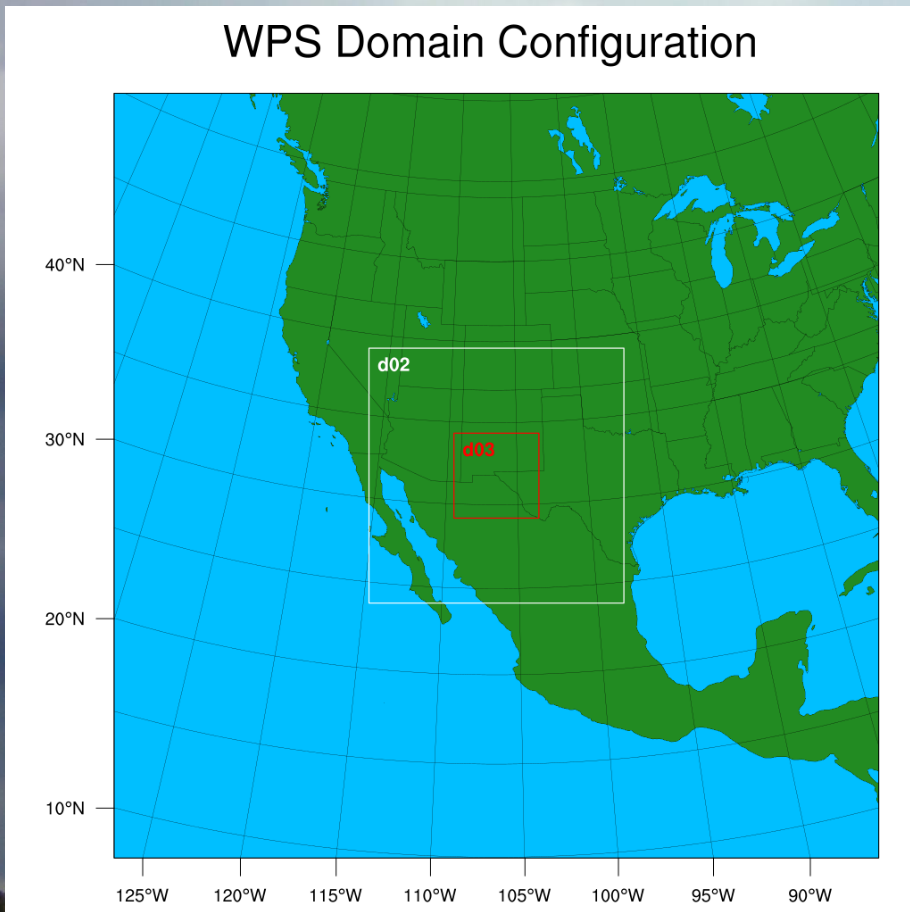


	Temperature	Relative Humidity
Number of observations	2006	2006
Root Mean Squared Error	7.81	14.3
R-squared:	0.332	0.242
P-value	7.09e-178	1.79e-122
Correlation Coefficient	0.573	-0.495

Statistical Results

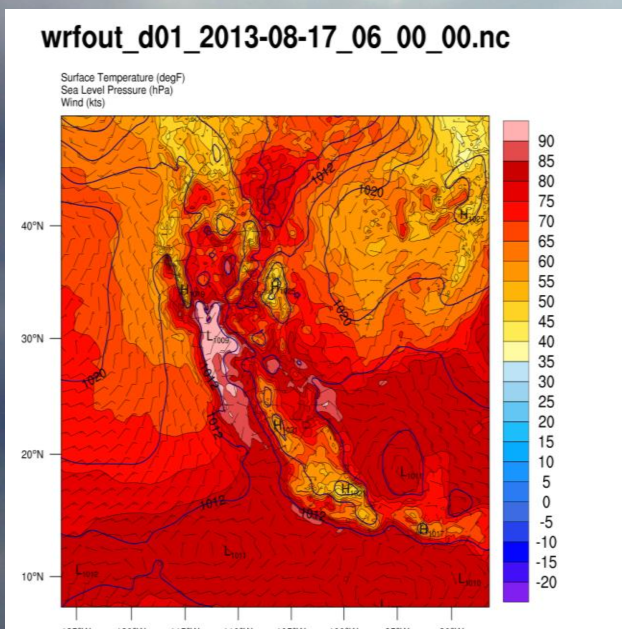
- The goal of this statistical analysis is to determine which parameters contribute the most or have a good correlation with high ozone event
- Temperature and Solar Radiation are the most positively correlated with the High ozone events. However, PM2.5, Relative Humidity, Wind Speed etc. have a negative correlation (ranging from 0.1 to 0.6)
- High temperatures and strong solar radiation are known to be conducive to the photochemical production of ozone. The PdN experiences high temperatures during the summer season. Photochemical production is aggravated by cross-border transportation.
- P value is less than 0.05 which strongly suggest that we can reject the null hypothesis and the relationships between Ozone and Temperature, and Ozone and relative humidity are statistically significant.

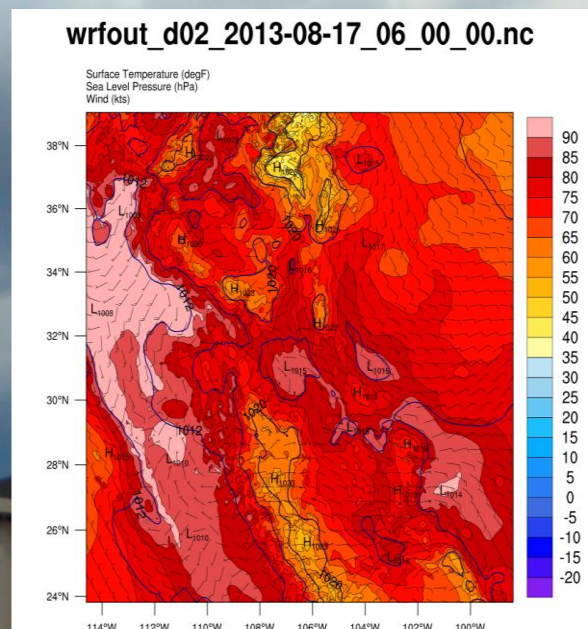
WRF Simulation

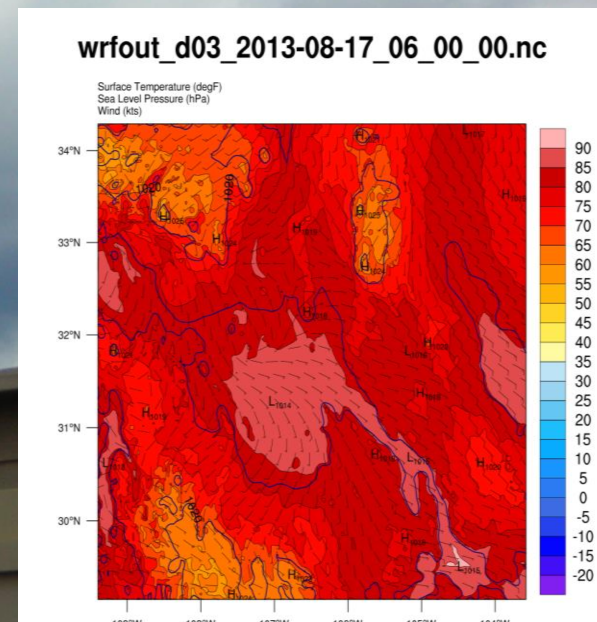


Parameter	Description
Period	2013-2019
Initial Condition Meteorology	GFS-ANL 0.5 degree Vertical
levels/Eta Levels	35
Horizontal Grids	172 x 172
Grid resolution	30, 10, 3
Time Steps	180s, 180s ,180s
Microphysics	WSM or WRF single moment
Planetary Boundary layer	YSU (Yonsei University)
Cumulus Parametrization	Kain-Fritsch scheme
Shortwave and Longwave	RRTM Longwave Scheme
Land Surface	Noah Land surface Scheme
Surface Layer Option	Monin Obukhov Similarity Scheme
Projection	Lambert
Boundary Conditions Meteorology	GFS-ANL 0.5 degree

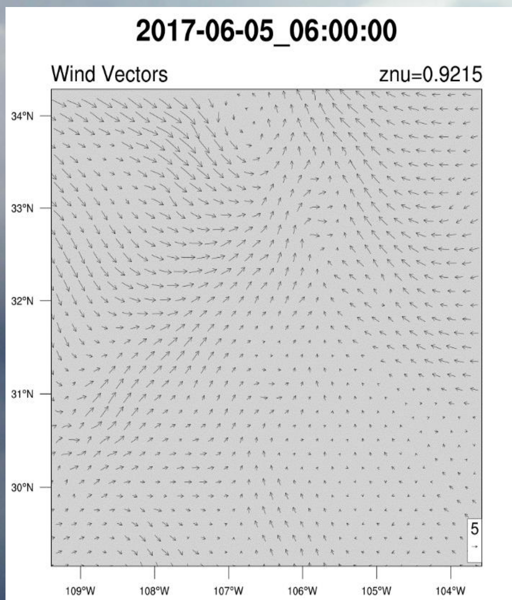
August 17, 2013, 3 domains

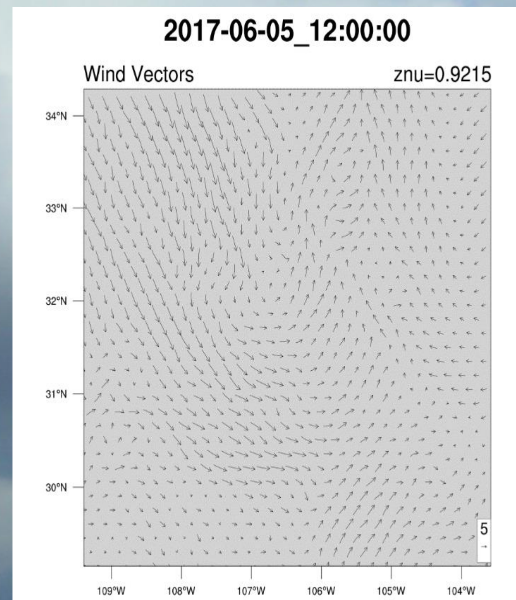


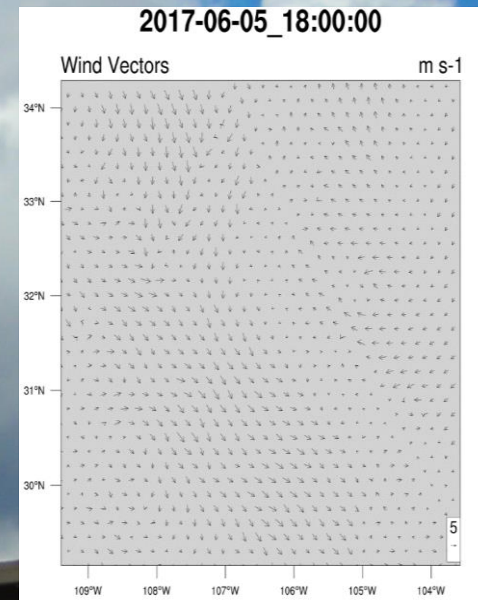




Wind Patterns, in d03



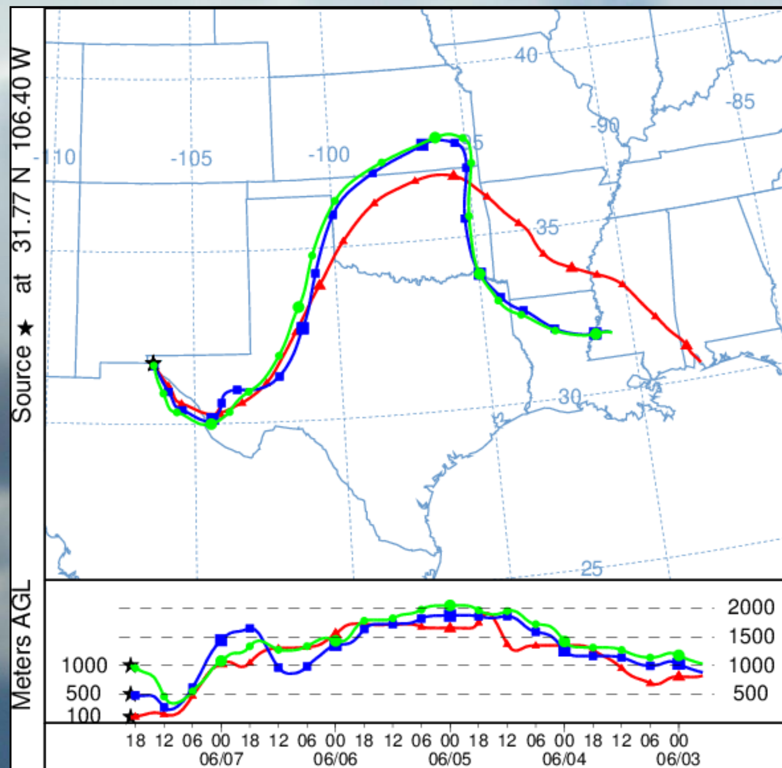




Wind, Meteorology Results in All Domains

- All of those dates correspond to the summer season. We can see the wind direction is flowing counter clockwise in a Low pressure area while it is in a clockwise direction in a High pressure area.
- In the local scale domain, the north east part of Texas exhibits high pressure area with higher temperature.
- For the local scale, Winds are mostly coming from the northern east part of the United States with a medium magnitude. We observed a low pressure area at the north eastern part of Mexico.
- At the mesoscale level, winds are flowing in the direction originated from the north eastern direction. High pressure areas are depicted in southern part of Texas and also in Mexico.

HYSPLIT Trajectories



Three 120 hr back trajectories El Paso, 100m, 500m, 1,000m AGL, June 7, 2017, 12n MST start

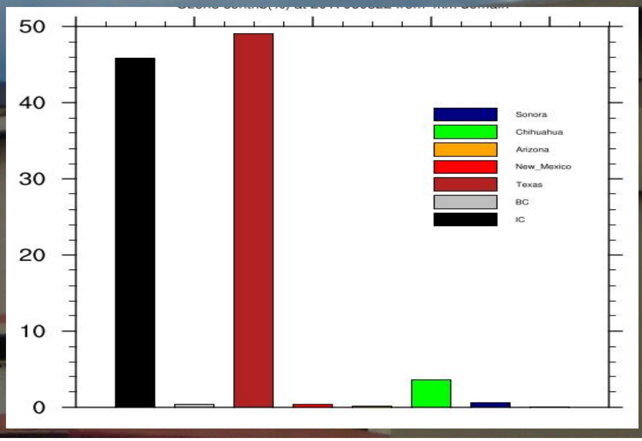
HYSPLIT Results

With a population exceeding 2.3 million in Ciudad Juarez and El Paso combined, most ozone pollution measured in the Paso del Norte can likely be ascribed to the precursor emissions from the local area. However, modeling conducted using the upper air trajectory program called HYSPLIT and associated data sets provided by NOAA shows that on high ozone days in the 2013 to 2019 period, air parcels entering the Paso del Norte area mid-day were more likely to have passed through oil and gas extraction regions in West Texas and other nearby states on high ozone days than on other summer days, corresponding to mesoscale distances. There is also evidence that on a few ozone exceedance days, long range transport of stratospheric ozone could have added to local contributions to cause those exceedances.

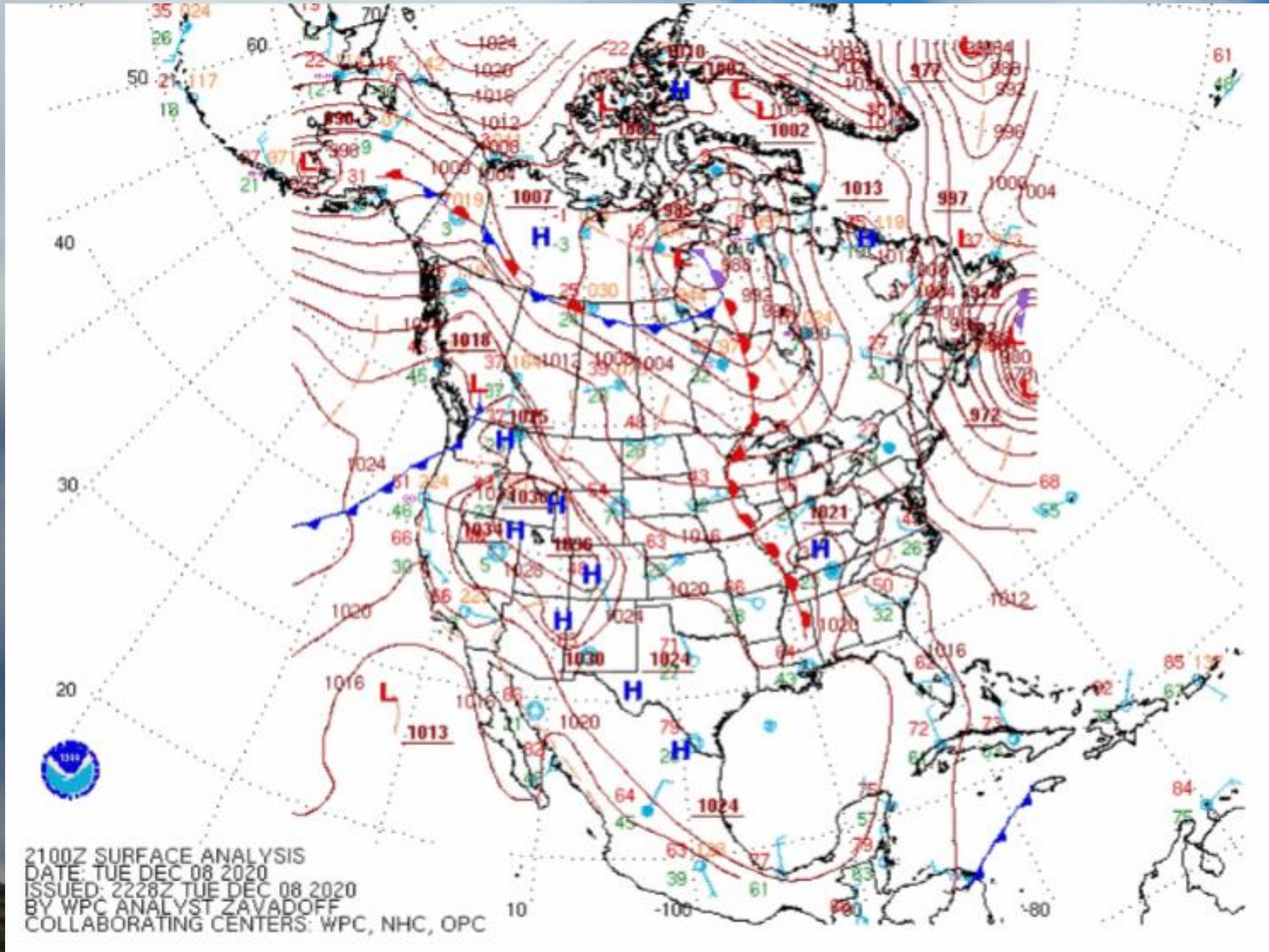
The correlation of elevated ozone and carbon monoxide and weekdays suggests local emission sources are also important.

Modeling study of surface ozone source-receptor relationships for the PdN Region

Through a modeling studying of ozone cases occurring in the summer of 2017, we conducted a comprehensive ozone study by applying OSAT technology in an Eulerian photochemical dispersion model, CAMx, over the region of El Paso, TX/Ciudad Juárez, Mexico. Our study aimed to evaluate the impact of various anthropogenic/biogenic emissions and boundary/initial conditions on ozone concentrations. The model reasonably reproduced diurnal variation for ground ozone concentration. The modeling results showed that initial condition and local emissions play significant role in the formation of ozone concentration. However, boundary conditions did not make evident contributions. Mexico states, especially those states that have border with El Paso, TX, made contributions to ozone formation. Their contributions are less than 5% for the cases studied.



The contributions (percentage) to peak ozone concentration over El Paso, TX at 4:00pm om June 6, 2017


2100Z SURFACE ANALYSIS
DATE: TUE DEC 08 2020
ISSUED: 2228Z TUE DEC 08 2020
BY WPC ANALYST ZAVADOFF
COLLABORATING CENTERS: WPC, NHC, OPC

Thank You!