Relationship Between Particulate Matter in the Central Chilean Valley and the Madden-Julian Oscillation

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Introduction

•Aerosols, smoke, soot, combustibles, sea salt, and trace toxic elements, all hazardous to human health, can be classified as PM10 (Srimuruganandam, 2011; Ozkan, 2010).

•The Chilean Health Ministry has set the target daily maximum of PM10 to be no greater than 195 μg/m^3. Levels greater than 195 μg/m^3 are considered to be hazardous to human health (Perez and Reyes, 2006).

•A wide range of factors influence particulate matter concentrations, including day of the week, time of day, altitude, wind conditions, precipitation and air sources (Gramsch, 2006; Prèndez, 2011). .

•Santiago, Chile experiences dangerously high concentrations of PM10 during the autumn-winter months of March through August due to combination of topographical, economical and meteorological features unique to the city (Prèndez, 2011).

•The Madden-Julian Oscillation (MJO) is a global-scale circulation pattern that is the leading cause of atmospheric variability on a 40-50 day period (Madden and Julian 1972).

•The MJO has been found to modulate precipitation and circulation on a regional and global scale, including central Chile, the area of study (Barrett et al., 2012).but variability of PM10 by MJO phase is currently unknown.

Data and Methods

•Complied hourly PM10 concentrations from nine different stations in the Santiago metropolitan area from SINCA (Sistema de Información Nacional de Calidad de Aire) for the fall-winter months of March through August 1997-2011 (Fig & Table 1).

•Excluded two of the nine stations, Quilicura and Cerro Navia, because of insufficient data record at those locations (Fig 1).

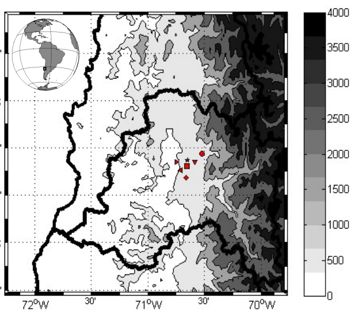

Figure 1: Topography (shading, in m) and the SINCA PM10 observing stations (red symbols) for the Santiago metropolitan region. Political boundaries indicated by heavy black lines.

Table 1: (below) Characteristics of the stations used in the study.

Symbol	Station #	Place	Percentage Useful Data (%)	Latitude Decimal Degree	Longitude Decimal Degree	Elevation (m)
Triangle (left)	1	Cerrillos	98.4	-33.49	-70.71	511
Diamond	2	El Bosque	99.3	-33.54	-70.66	580
Pentagram	3	Independencia	99.1	-33.42	-70.65	560
Triangle (down)	4	La Flordia	99.5	-33.51	-70.59	599
Circle	5	Las Condes	99.2	-33.37	-70.52	799
Square	6	Parque Ohiggins	99.0	-33.46	-70.66	542
Triangle (right)	7	Pudahuel	99.1	-33.43	-70.75	495

•Determined Phase of the MJO by the Real-time Multivaritate MJO index (RMM) (Wheeler and Hendon, 2004).

•Quantified the relationship between PM10 and the MJO by first matching each individual day to the Phase of the MJO (Table 2). Active MJO days were defined as days when the RMM^2 was greater than 1. All other days were considered neutral.

•Examined 900 mb wind speed and 500 mb height from NCEP Integrated Global Radiosonde Archive (IGRA) reanalysis (Kalnay et al., 1996), and temperature from the Santo Domingo Radiosonde from 1990 to 2012 to connect observed variability in PM10 to meteorological parameters known to affect PM10 concentrations.

Purpose

•To connect the phases of the Madden-Julian Oscillation (MJO) with levels of surface PM10 in atmosphere in Santiago, Chile during the winter months .

•To connect observed variability in levels of particulate matter in Santiago to variability in meteorological conditions by Phase of the MJO.

Results: PM10 Variability

•PM10 was found to vary by Phase of the MJO. Low PM10 occurred during phases 1 and 2. High PM10 occurred during phases 4, 5 and 7 (Fig 2).

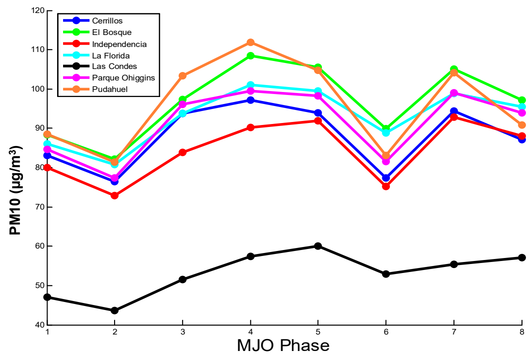

Figure 2: Daily PM10 Averages, May- August 2002-2012 per MJO Phase and Station.

•The diurnal cycle of PM10 was also found to vary by MJO phase (Fig 3).

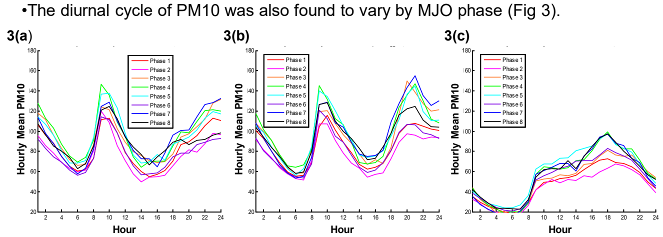

Figure 3: The diurnal cycle of PM10 by MJO Phases during May –August of 2002 to 2012 at stations (a) Cerrillos (b) Parque Ohiggins (c) Las Condes.

•.At 12Z strong inversions occurred during Phases 4, 6, 7 and 8. Weaker inversions occurred during Phases 1 and 2. At 0Z, inversions occurred at Phases 4, 6, 7 and 8. At 0Z no inversion occurred during Phases 1 and 2.

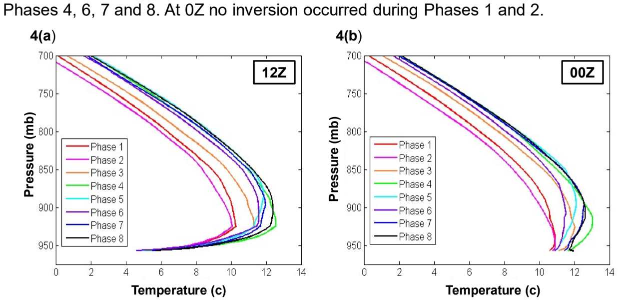

Figure 4: Interpolated temperature soundings by MJO Phase, May- August 1990-2011 at (a) 12Z (b) 0Z.

References

•Berrisford, P., D. Dee, K. Fielding, M. Fuentes, P. Kallberg, S. Kobayashi, and S. Uppala, 2009: The Era-Interim archive. ECMWF Tech. Rep. 1, 20 pp.
•Gramsch. E., Cereceda-Balic, F., Oyola, P., and Baer, D., 2006, Examination of pollution trends in Santiago de Chile with cluster analysis of PM_{10} and ozone data: Atmospheric Environment, vol.40, p.5464-5475, doi:10.1016/j.atmosenv.2006.03.062.
•Kalnay, E., M. Kanamitsu, R. Kistler, W. Collins, D. Deaven, L. Gandin, M. Iredell, S. Saha, G. White, J. Woollen, Y. Zhu, M. Chelliah, W. Ebisuzaki, W.Higgins, J. Janowiak, K. C. Mo, C. Ropelewski, J. Wang, A. Leetmaa, R. Reynolds, Roy Jenne, Dennis Joseph, 1996: "The NCEP/NCAR 40-Year Reanalysis Project". *Bulletin of the American Meteorological Society* 77 (3): 437–471.
•Perez, P., J. Reyes , 2006:"An integrated neural network model for PM10 forecasting", Atmospheric Environment 40, p 2845-2851.
•Prèndez, M., Alvarado, G., and Serey, I., 2011, Some guidelines to improve air quality management in Santiago, Chile: from commune to basin level: *in* Air Quality Monitoring, Assessment and Management, InTech, ch.15.
•Rutllant, J. and Rene D. Garreaud, 2004: Episodes of Strong Flow down the Western Slope of the Subtropical Andes. Monthly Weather Review, 132, 611-622.
•Madden, R.A., and Julian, P.R., 1972, Description of Global-Scale Circulation Cells in the Tropics with a 40-50 Day Period: Journal of the Atmospheric Sciences, vol 29 , p.1109-123.
•Ozkan, O., 2010, Neutral network forecast for daily average PM(10) concentrations: Asian Journal of Chemistry, vol.22, no.1, p.582-588.
•Srimuruganandam, B. and Nagendra, S.M., 2011, Chemical characterization of PM_{10} and $PM_{2.5}$ mass concentrations emitted by heterogeneous traffic: The Science of the Total Environment, vol.409, no.17, p.3144-3157.
•Wheeler, M. C. and H. H. Hendon, 2004: An all-season realtime multivariate MJO index: Development of an index for monitoring and prediction. Monthly. Weather. Review. 132, 1917-1932.

Results: Wind and Rainfall

•Low tropospheric, temperature and mid-tropospheric geopotential heights was found to vary by phase of the MJO (Fig 5).
•Lower than normal heights in the southern cone of South America occurred during Phases 1, 2 and 8. High heights to the west and centralized over Chile's central valley occurred during Phases 3, 4 and 5. Lower heights South/South East of the southern cone of South America occurred during Phases 6 and 7.

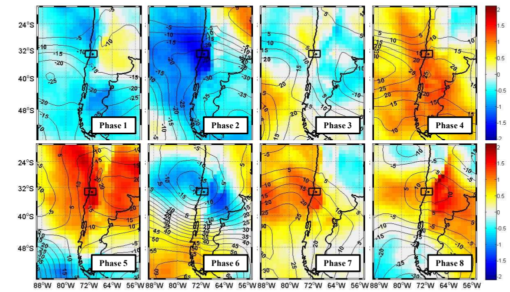

Figure 5: 900mb temperature anomalies (color shading) at 06Z and 500mb height anomalies (solid contours)at 0Z from 1997-2012 May-Aug.

•PM10 concentrations were found to vary inversely with rainfall. Above normal rainfall occurred at Phases 1, 2 and 7 while below normal rainfall occurred in Phases 3, 4, 5 and 6 (Fig 6).
•Horizontal wind at 900mb were found to vary by MJO Phase. At 06Z easterly wind anomaly occurred during Phases 1,2 and 8. Westerly wind anomaly occurred during Phases 3, 4, and 5 (Fig 7).

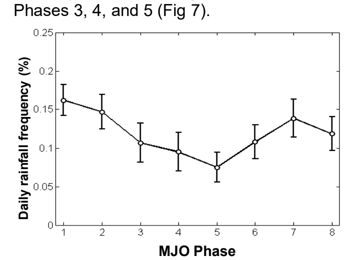

Figure 6: Frequency of at least 1mm of daily rainfall in Santiago, Chile by MJO phase, May-August 1990-2012.

Phase	Magnitude
1	0.70 W
2	0.32 W
3	0.46 E
4	0.55 E
5	0.45 E
6	0.06 E
7	0.06 E
8	0.46 W

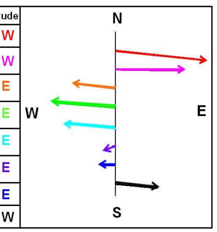

Figure 7: Cross section on 900mb wind anomalies at 06Z in Santiago, Chile by MJO phase, May-August 1997-2012 with magnitudes of anomalies in boxes.

Conclusions

- The lower levels of daily PM10 during Phases 1 and 2 correspond to higher than normal precipitation and weaker morning and evening temperature inversions. The higher levels of daily PM10 during Phases 4, 5 and 7 correspond to stronger inversions at 12Z and westerly 900 mb wind anomalies at 06Z (Table 2).
- Phases 3, 4, 6, and 7 corresponded to similar conditions of raco winds which lead to elevated PM10 concentrations.
- Future work: examine more data, particularly over a longer period of time, and with meteorological data of a higher resolution in order to draw conclusions with increased accuracy.

Table 2: Results Summary, MJO Phases from May to August for 2002-2012

MJO Phase	1	2	3	4	5	6	7	8
Frequency (days)	168	128	71	60	79	94	99	106
Percent of Total	6.1	4.6	2.6	2.2	2.9	3.4	3.6	3.8
PM10	low	low	-	high	high	-	high	-
Precipitation	high	high	low	low	low	low	high	high
12Z Inversion	weak	weak	-	strong	-	strong	strong	strong
00Z Inversion	none	none	-	present	-	present	present	present
06Z Wind Anomalies	W	W	E	E	E	weak E	weak E	W
Low Troposphere Temp Anomalies	cold	cold	-	warm	warm	-	warm	warm
Similar to Raco Winds?	no	no	yes	yes	no	yes	yes	no