Projecting the Madden-Julian Oscillation onto Air Quality in Santiago, Chile

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Introduction

• Situated in a valley between the Andes and the Cordillera de la Costa mountain ranges, the city of Santiago serves as an ideal case study for pollution related research. Santiago has a long history of very high pollution episodes with very high ozone (O_3) concentrations (Elshorbany et al. 2009)

• High ozone concentrations are known to have a positive relationship with daily mortality, irritation of the respiratory system, aggravating asthma and other chronic lung diseases (Sanhueza et al. 2003).

• Air pollution is most commonly modeled and forecasted on the daily/weekly scale and related to mesoscale features such as the mixed layer depth (Scmitz 2005; Muñoz and Undurraga 2010).

• 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 is commonly applied to synoptic scale patterns, and has been found to have a positive relationship with rainfall and low-level wind in subtropical South America (Paegle et al. 2000).

•The MJO has infrequently been applied to a mesoscale feature such as air pollution. This study attempts to uncover any dependence air quality may have on the MJO in order to improve intraseasonal forecasting.

Methods

• Used the MJO index from Wheeler and Hendon (2004) which contains daily MJO-phase information.

• Compiled air quality data for Santiago from SINCA (Sistema de Información Nacional de Calidad de Aire).

• Created a standard time series based on the availability of each database and standardized the pollution measurements as daily maximum value of 8-hour averages.

• Defined a particular day as “in-phase” with RMM^2 index value of greater than 1. All other days were regarded as “neutral”.

• Examined only summer (NDJF) ozone concentrations and winter (MJJA) PM_{10} concentrations.

• Composited daily 8-hour maximums for each MJO phase.

Data Availability

• The first air quality monitoring stations in Santiago began recording on January 1, 1988. The city continued to add stations throughout the metropolitan area until 1997.

•The reliability of the data was questionable due to instrument variability and consistency prior to 1997. This study uses air quality data collected after November 1, 1997.

Table 1: Frequency of MJO Phases since November 1, 1997.

MJO Phase	1	2	3	4	5	6	7	8	Neutral
Frequency (days)	70	107	154	121	135	169	144	104	555
Percent of total	4.49	6.86	9.88	7.76	8.66	10.84	9.24	6.67	35.6

Purpose

• To determine if a relationship between a large-scale global circulation, the MJO, and the mesoscale issue of air quality exists.

• To use this relationship in an attempt to improve air quality forecasting on the intraseasonal timescale.

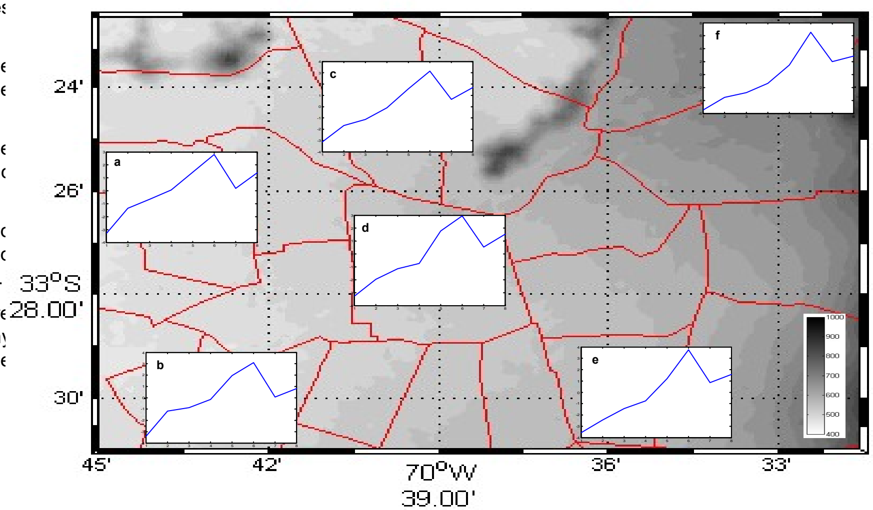

Fig. 1: Ozone concentration anomalies (in ppb) across the 8 active phases of the MJO for the six individual air quality monitoring stations sampled in this study. The stations arranged by geographic location on Santiago's elevation (in m) are (a) Pudahuel (b) Cerrillos (c) Independencia (d) Parque O'Higgins (e) La Florida, and (f) Las Condes. The consistent signal throughout each station represents an increase in general concentration anomaly, peaking in Phase 6.

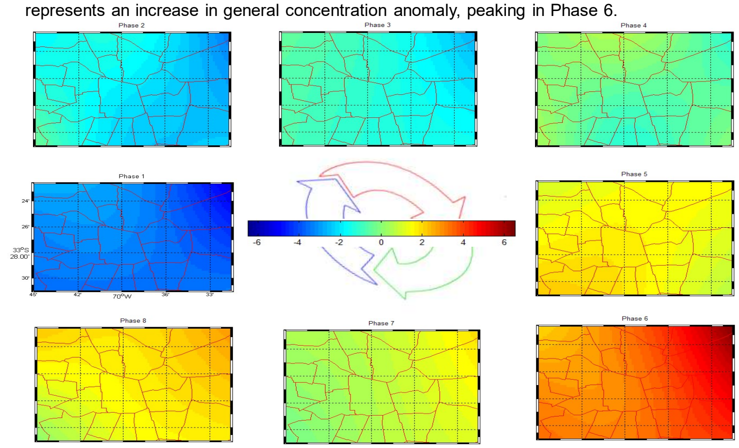

Fig. 2: Spatial representations of ozone concentration anomalies (in ppb) across the metropolitan region by MJO Phase. The same geographical region as Figure 1. It is important to note the severity of anomaly in the eastern region, which also has the strongest topographic gradient. The most positive and most negative anomalies were recorded from the same station, Las Condes, located in the NorthEast corner.

Statistical Analysis

• To test if the composite anomaly ozone concentration for each MJO phase is statistically significantly different from the mean, z-statistics were calculated using,

$$z = \frac{\bar{x} - \mu_o}{\sigma/\sqrt{n}}$$

where x is the phase anomaly, μ_o and σ are the population mean and standard deviation concentration, and n is the number of observations (Table 1) in each phase.

• Using lookup tables, the z-statistics were converted to values that constitute “percent certainty” that the given anomaly is significantly different from the mean.

•It is important to note that all stations report significance in Phase 1, the low anomaly, and Phase 6, the high anomaly.

Station	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8
Cerrillos	99.42	74.37	68.02	9.94	97.71	99.99	9.40	59.56
Independencia	98.64	89.95	91.46	8.96	91.53	99.99	52.31	89.60
La Florida	99.11	97.22	87.11	48.94	92.41	99.99	69.37	87.49
Las Condes	99.77	98.42	97.69	66.09	77.57	100.0	90.96	95.77
Pudahuel	99.68	85.92	59.36	8.79	93.56	99.99	23.74	88.47
Parque O'Higgins	98.74	93.44	79.78	52.86	94.69	99.97	45.78	85.87

Table 2: Percent certainty of ozone concentration anomalies dependence on MJO Phase. Blocks colored green signify a greater than 95% statistical significance.

PM_{10}

• Composites of PM_{10} concentrations by MJO Phase also show variability consistent with MJO propagation. More investigation is necessary.

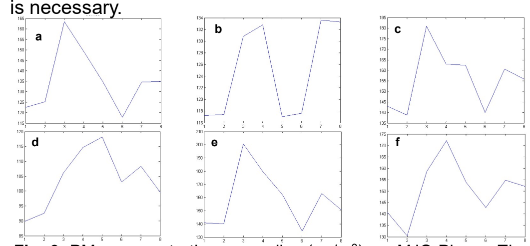

Fig. 3: PM_{10} concentration anomalies ($\mu g/m^3$) vs. MJO Phase. These anomalies have a consistent, bi-modal signal with a significant minimum in Phase 6. The stations are (a) Cerrillos (b) Independencia (c) La Florida (d) Las Condes (e) Pudahuel, and (f) Parque O'Higgins.

Conclusions

• A relationship between the global MJO and ozone concentrations does exist, with statistical certainty.

• More reliable data is needed over a longer time series to substantiate patterns.

• The atmospheric conditions associated with the various MJO Phases play a role in air quality in the Santiago basin. The meteorological explanation of these conditions, especially the variability in Las Condes, is explored in a poster by B. Barrett.