Investigating Wind Energy Potential in Chile from a Synoptic-scale Perspective

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Purpose

Investigate wind energy potential in Chile by comparing radiosonde wind speed with wind farm production and statistics

Introduction

• Chile gets 65% of its energy from thermal plants burning imported fossil fuels, 34% from domestic hydropower, and 1% from renewables, including wind (ACERA, 2010)

• Frequent unpredictable droughts reduce the reliability of hydroelectric power, and events like the Argentina gas supply crisis cause energy shortages (Watts and Jara, 2010)

• Increasing the percentage of wind energy and other renewables will increase Chile's energy security

• Siting wind farms correctly is critical to taking advantage of Chile's wind energy potential

• Wind speed, wind direction, and topography are important factors in siting wind farms

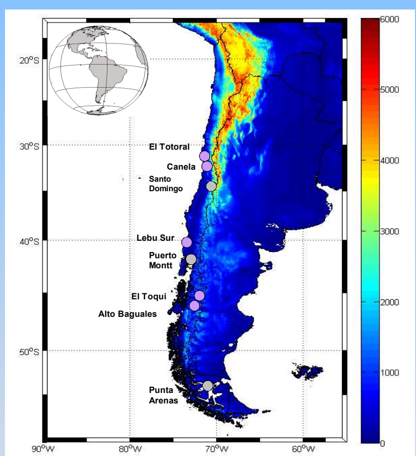


Figure 1: Elevation (m) of the southern Andean region with overlay of radiosonde locations (gray) and locations of wind farms examined in this study (purple)

Wind Farm	Installation Year	Installed Power (MW)	Yearly Production (GWh)	Turbine Number	Turbine Diameter (m)	Turbine Specifications
Alto Baguales	2001	2	5	3	47	660 kW Vestas V47
Canela	2007	78.15	195	51	82	1.65 MW Vestas V82
El Totoral	2009	46	115	23	90	2 MW Vestas V90
Lebu Sur	2010	9	22	12	50	780 kW Hewind HW50
El Toqui	2010	1.65	5.2	6	32	1.5 MW GEV MP-C

Table 1: Power production and turbine specifications for a selection of wind farms in Chile

Methods

• Analyzed radiosonde data from NCDC Integrated Global Radiosonde Archive (IGRA) for Santo Domingo, Puerto Montt, and Punta Arenas for the period 1980 – 2010

• Determined the average wind speed at 80 m by interpolating wind speeds at 1000 hPa and at the surface using the power law relation (Elliot et al. 1986; Arya 1988) and logarithmic law (Arya 1988; Jacobson 1999)

$$V(z) = V_R\left(\frac{z}{z_R}\right)^{\alpha}$$

$$V(z) = V_R\,\frac{\ln\left(\frac{z}{z_0}\right)}{\ln\left(\frac{z_R}{z_0}\right)}$$

For the power law relation, *V(z)* is wind speed at elevation z above the topographical surface (80 m), V_R is wind speed at the reference elevation z_R, and α is the friction coefficient (1/7)

For the logarithmic law, z_0 is the roughness length (0.01m)

• Determined that the power law was the most accurate interpolation method to estimate the wind speed at 80m and applied a daytime correction of + 0.2 m s^{-1} to account for power law underestimate (Archer and Jacobson 2003)

• Modeled hypothetical wind farms co-located with the radiosonde stations using turbine specifications for winds farm near the respective radiosonde station (See Table 1)

• Used average wind speeds calculated from the power law to determine yearly power production possible at each radiosonde location (See Table 2)

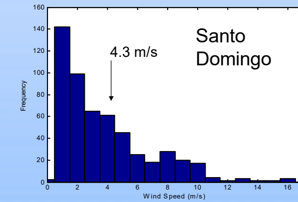
• Calculated the wind speed required to meet the yearly power production at wind farms located near the soundings at Santo Domingo, Puerto Montt, and Punta Arenas using the following equation (Muljadi and Butterfield, 2000):

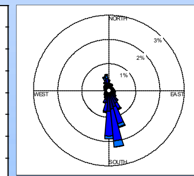
$$V = \left(\frac{P}{0.5\varepsilon\rho A}\right)^{1/3}$$

where *V* is wind speed in m/s, *P* is the power of an individual turbine, *ε* is efficiency (0.40), *ρ* is air density (1.225 kg/m³), and *A* is the cross-sectional swept area of the wind turbine

Radiosonde Station	Wind Farm Configuration	Wind Speed (m/s)	Turbine Height (m)	Yearly Production (GWh)
Santo Domingo	El Totoral	4.3	80	102
	El Totoral	4.5	110	117
	Canela	4.3	80	188
	Canela	4.5	110	215
Punta Arenas	El Totoral	6.1	80	291
	El Totoral	6.4	110	331
	Alto Bagualas	6.1	80	10
	Alto Bagualas	6.4	110	12
Puerto Montt	Lebu Sur	5.3	80	30
	Lebu Sur	5.5	110	34
	El Toqui	5.3	80	6
	El Toqui	5.6	110	7

Table 2: Yearly production determined for hypothetical wind farms from average wind speeds at radiosonde stations

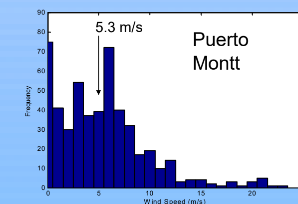


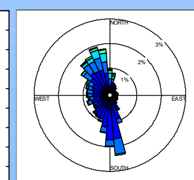


Canela Wind Farm	
Percent of Year Operating	**Wind Speed Required to Meet Yearly Production (m/s)**
0.10	9.5
0.30	6.6
0.50	5.5
0.70	4.9
0.90	4.5

El Totoral Wind Farm	
Percent of Year Operating	**Wind Speed Required to Meet Yearly Production (m/s)**
0.10	9.4
0.30	6.7
0.50	5.7
0.70	5.1
0.90	4.7

Wind speed (Fig. 2; arrow indicates mean) and direction (Fig. 3) frequency at Santo Domingo compared with required mean wind speeds for selected operating hours.

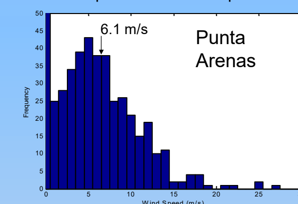


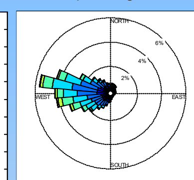


Lebu Sur Wind Farm	
Percent of Year Operating	**Wind Speed Required to Meet Yearly Production (m/s)**
0.10	10.3
0.30	7.1
0.50	6.0
0.70	5.4
0.90	4.9

El Toqui Wind Farm	
Percent of Year Operating	**Wind Speed Required to Meet Yearly Production (m/s)**
0.10	10.8
0.30	7.5
0.50	6.3
0.70	5.6
0.90	5.2

Wind speed (Fig. 4; arrow indicates mean) and direction (Fig. 5) frequency at Puerto Montt compared with required mean wind speeds for selected operating hours.





Alto Baguelas Wind Farm	
Percent of Year Operating	**Wind Speed Required to Meet Yearly Production (m/s)**
0.10	10.38
0.30	7.20
0.50	6.07
0.70	5.43
0.90	4.99

Wind speed (Fig. 6; arrow indicates mean) and direction (Fig. 7) frequency at Punta Arenas compared with required mean wind speeds for selected operating hours.

Results and Conclusions

• Based on installed capacity and yearly production, wind farms in this study likely operated about 30% of the year

• Mean radiosonde wind speeds did not yield the yearly power output observed at nearby wind farms

• Mean winds needed to generate observed yearly production need to be significantly higher than mean winds from the radiosondes: 1.1 m/s higher at Alto Baguales, 2.3 m/s higher at Canela, 2.4 m/s higher at El Totoral, 1.8 m/s higher at Lebu Sur, and 2.2 m/s higher at El Toqui

• Spatially and temporally sparse radiosonde data can be considered to sample the synoptic-scale atmospheric circulation, but are likely not representative of local wind speeds at wind farm sites and therefore should not be the only factor used in determining optimal wind farm locations

• However, knowledge of variability in synoptic-scale wind direction can aid siting if individual turbines are situated along preferentially favored topographic ridge lines (Ragheb, 2008)

Sources

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