The Wind-Speed Dose-Response of Tree-Falls Impacting the Transmission Grid of Southwest British Columbia

Wolf Read
PhD Candidate
Forest Science
University of British Columbia

Introduction

Talk Outline:

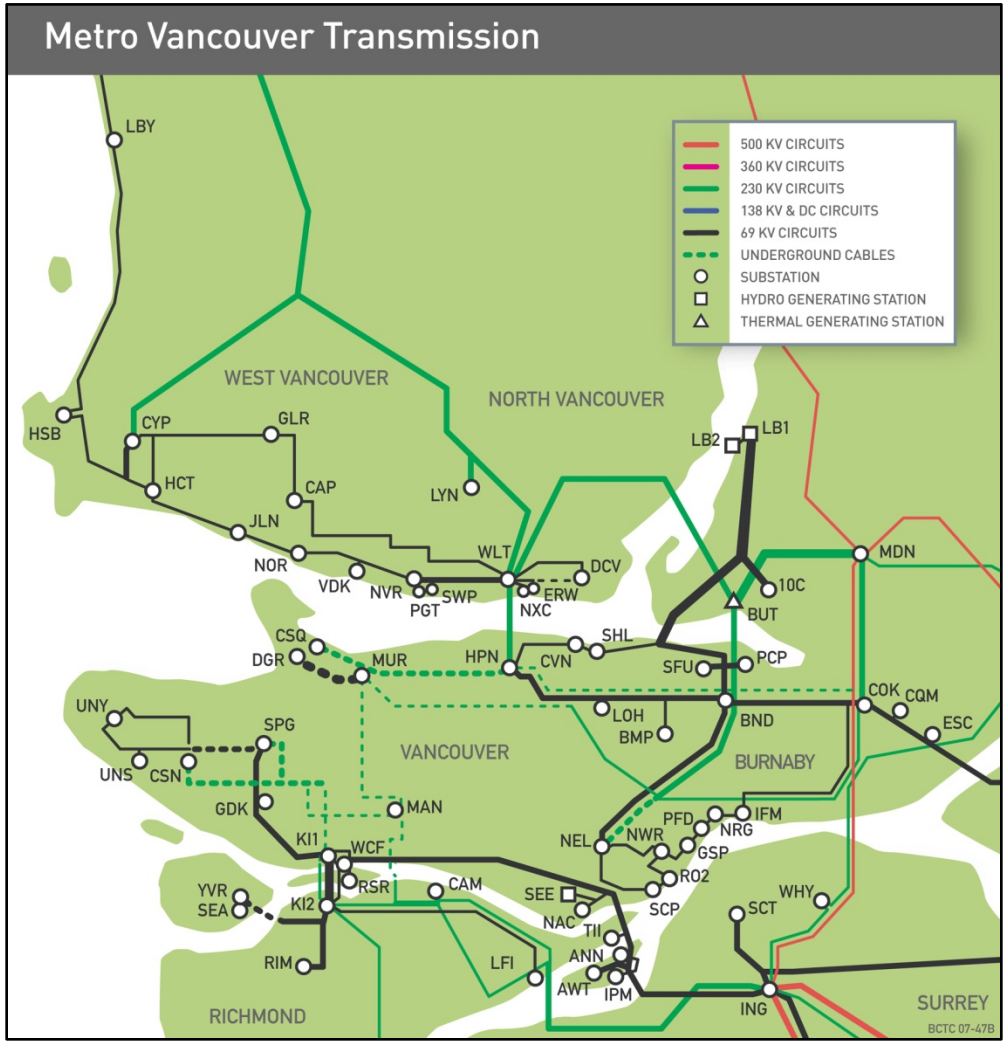
- Brief commentary on power grids and windstorms
- Methods
- Wind-related outages on the transmission grid (BCTC) around Metro Vancouver
- Wind-related outages on the distribution (BC Hydro) grid around Metro Vancouver
- Summary

Near Junction City, OR, 08 Feb 2002.
All photos in this talk by the presenter.

Introduction

A thought:

- A transmission or distribution grid can be seen as a giant weather sensor
- Power-outage data (time, location) conveys useful information about storms impacting the grid



Introduction

The Columbus Day Storm (Freda) of 1962
CYVR U2A Strip-Chart Trace

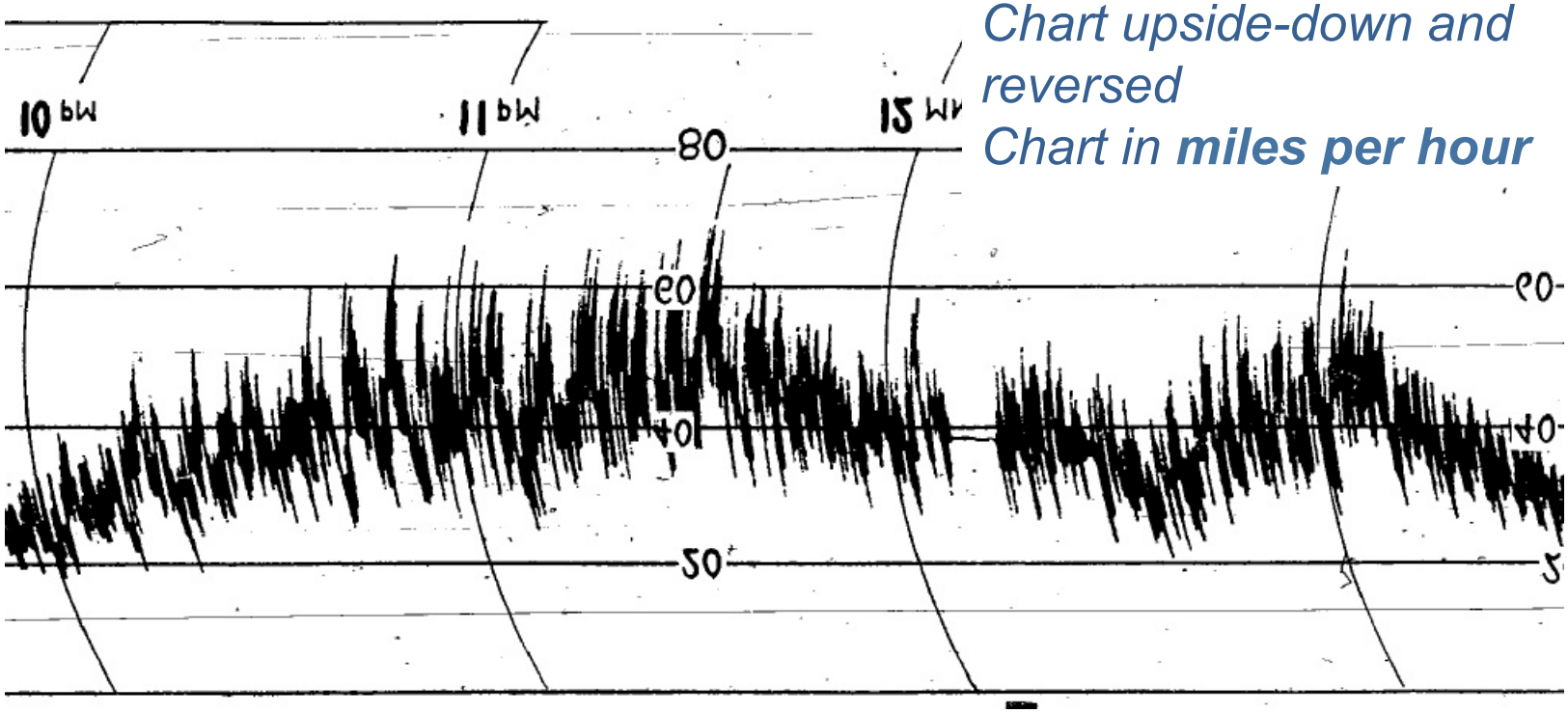


Chart upside-down and reversed
*Chart in **miles per hour***

- Extratropical cyclones sometimes bring extreme winds to BC
- High winds tend to impact the power grid
- For this storm, maximum wind and gust occurred between 23:30 and 23:40
- Max 2-minute wind was approximately 91 km/h around 23:35

Introduction

Brief Summary of Methods

- Isolated all circuits within a 50-km radius of the Vancouver International Airport (CYVR)
- Examined the relationship between tree-related outages and wind speed (wind and gust)
- Used the hourly weather record at CYVR: Noted all significant weather that may have occurred near time of outage (e.g. heavy rain, snow, wind, wind shifts)
- Depending on analysis, events with significant snow and rain were eliminated

Section 1:
Transmission-Line Sensitivity to High Wind

BC Transmission Grid Response to Windstorms

The BCTC Outage Dataset

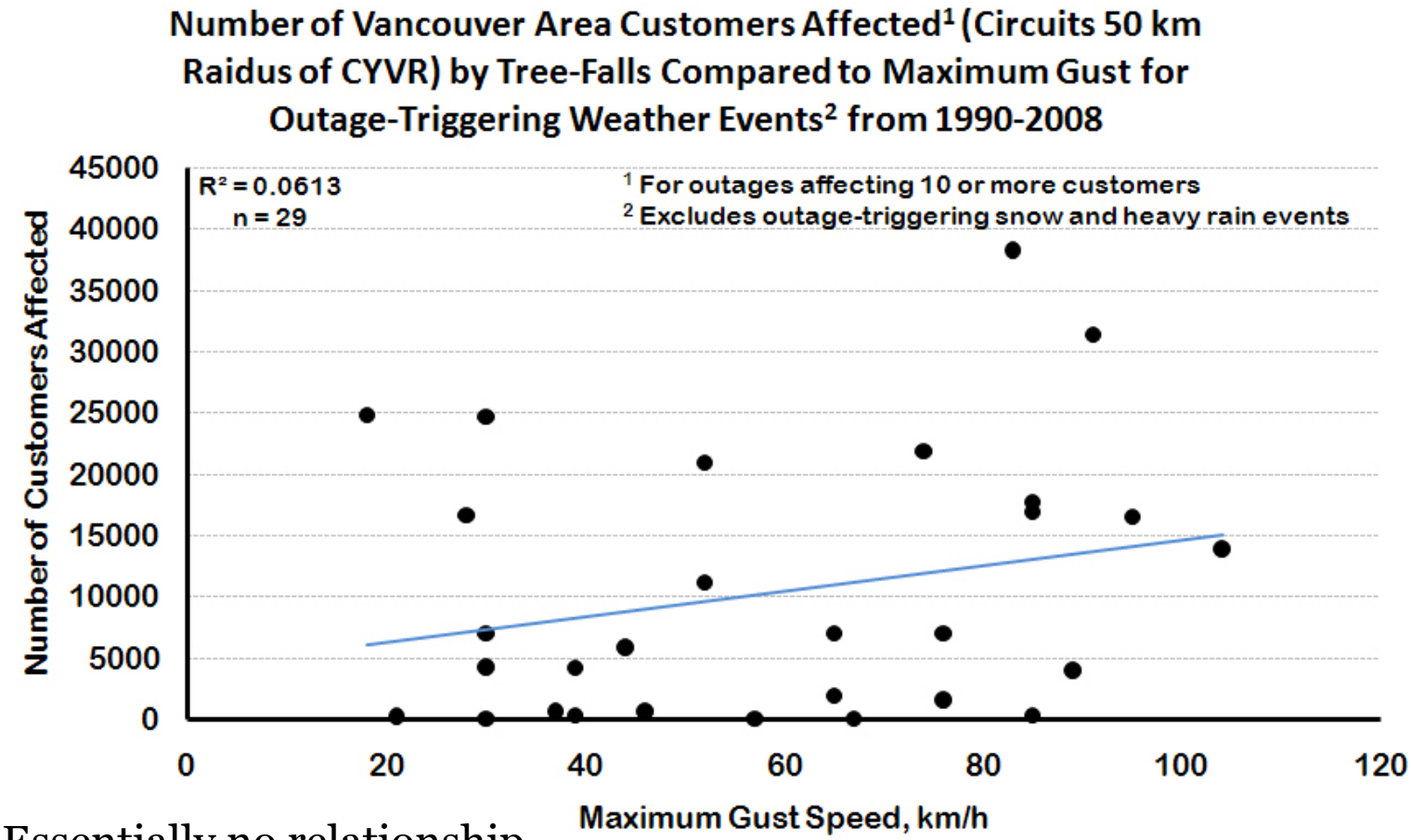
Pros:

- Data covers a broad enough period of time to include many weather events
- Precise timing of outage helps with determination of storm-related causes

Cons:

- Transmission lines are concentrated along narrow corridors, limiting the spatial area covered
- Transmission lines not impacted by trees very frequently even in major storms, resulting in limited outage data for each storm event

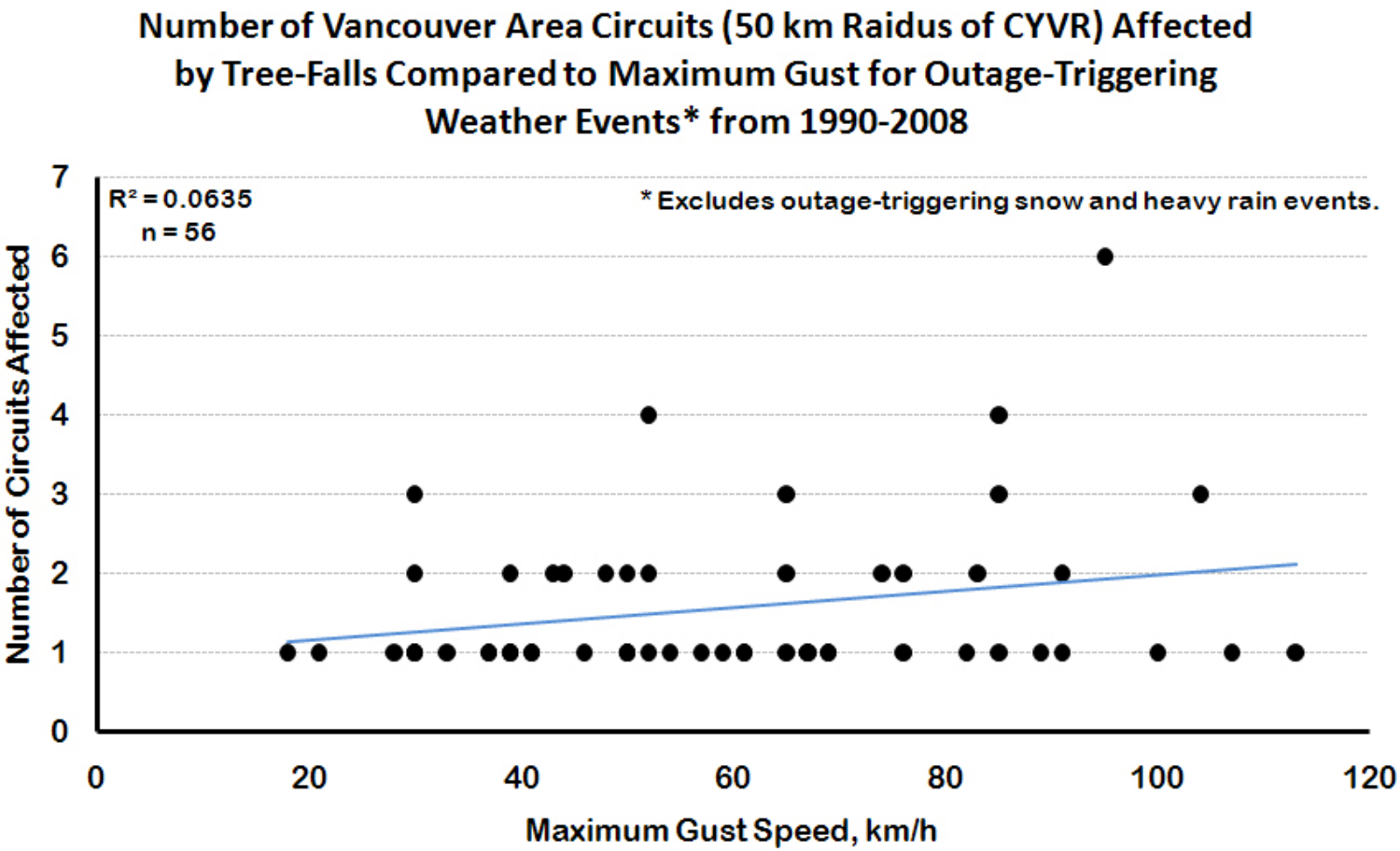
BC Transmission Grid Response to Windstorms



- Essentially no relationship
- Lack of relationship also present with wind (as opposed to gust)
- Problem with relationship: A single impacted line can result in few or many customers affected

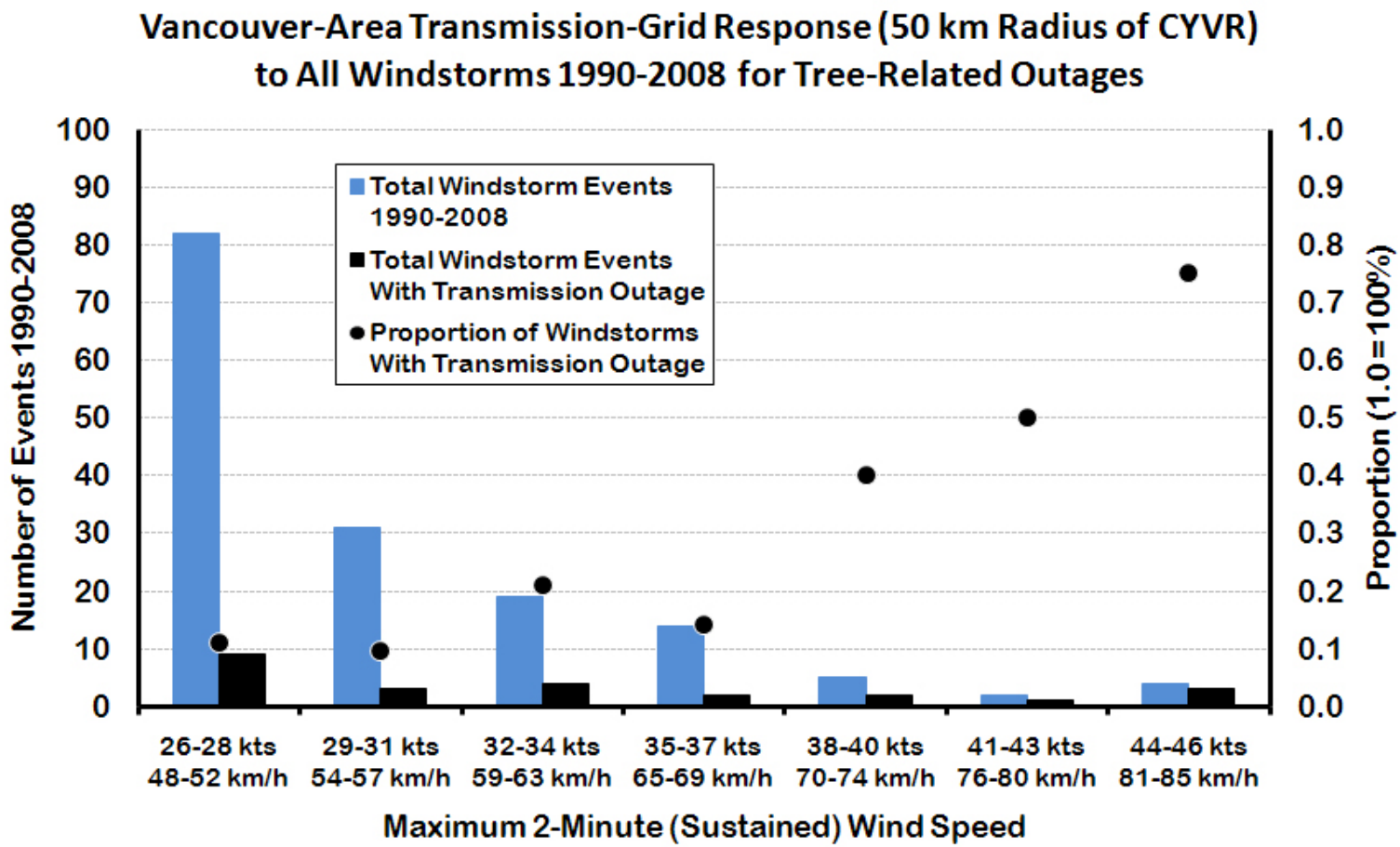
This preliminary: A maximum likelihood approach such as Poisson regression would likely be more informative for all of the regression analyses presented here.

BC Transmission Grid Response to Windstorms



- Essentially no relationship
- Lack of relationship also present with wind (as opposed to gust)
- Problem with relationship: Few circuits are hit in most storms—a single number (1) dominates, making linear correlation poor

BC Transmission Grid Response to Windstorms



- Marked jump in outage probability around 70 km/h
- At speeds above 80 km/h, outage probability appears to reach 75%
- Note the low number events at higher wind speeds

Section 2:
Distribution-Line Sensitivity to High Wind

BC Hydro Power-Grid Response to Windstorms

The BC Hydro Outage Dataset

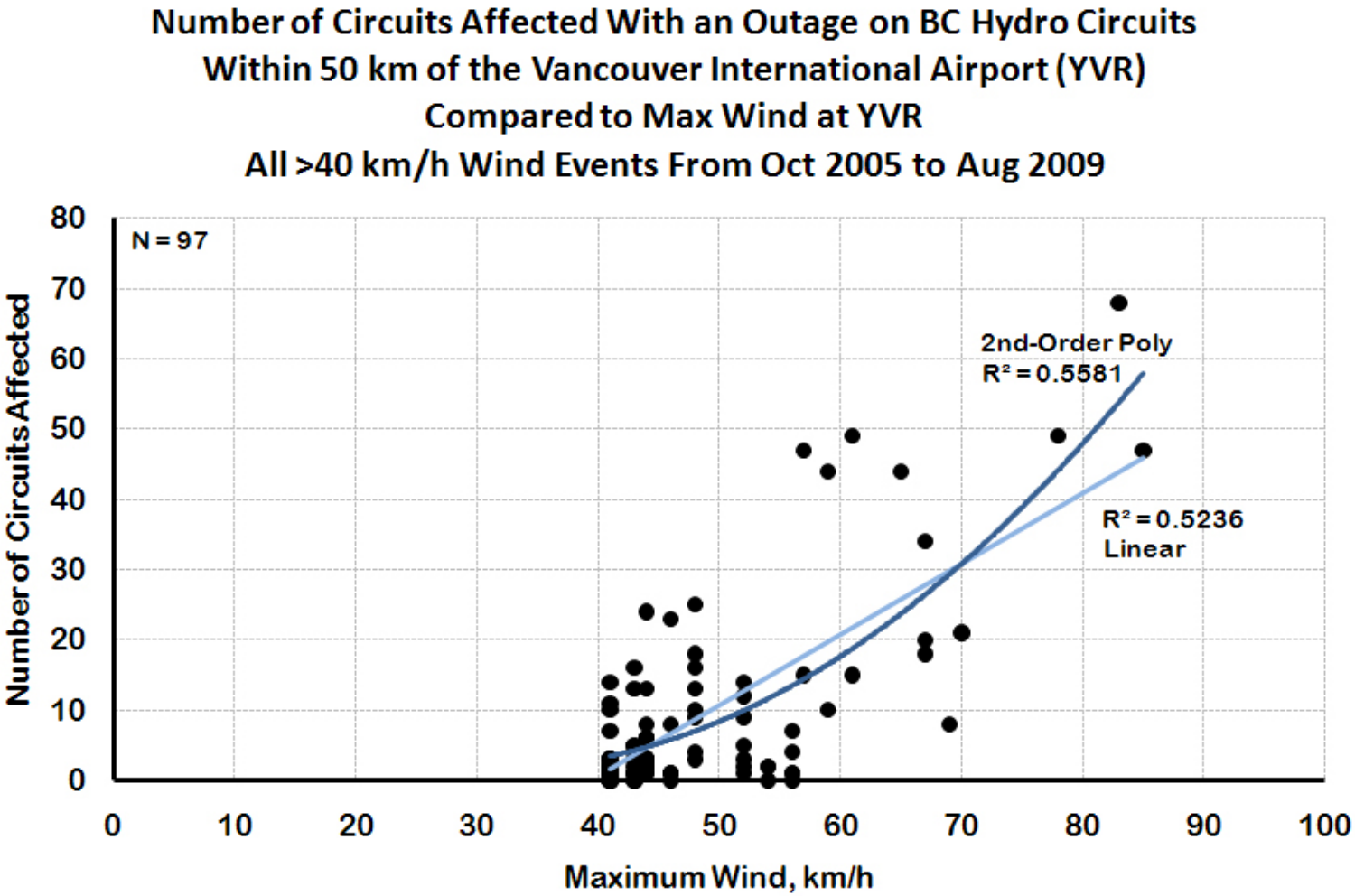
Pros:

- Widespread, dense network providing good coverage in many areas
- Often many outages during significant weather events, providing a wide range of numbers useful for correlation
- Precise timing of outage helps with determination of storm-related causes

Cons:

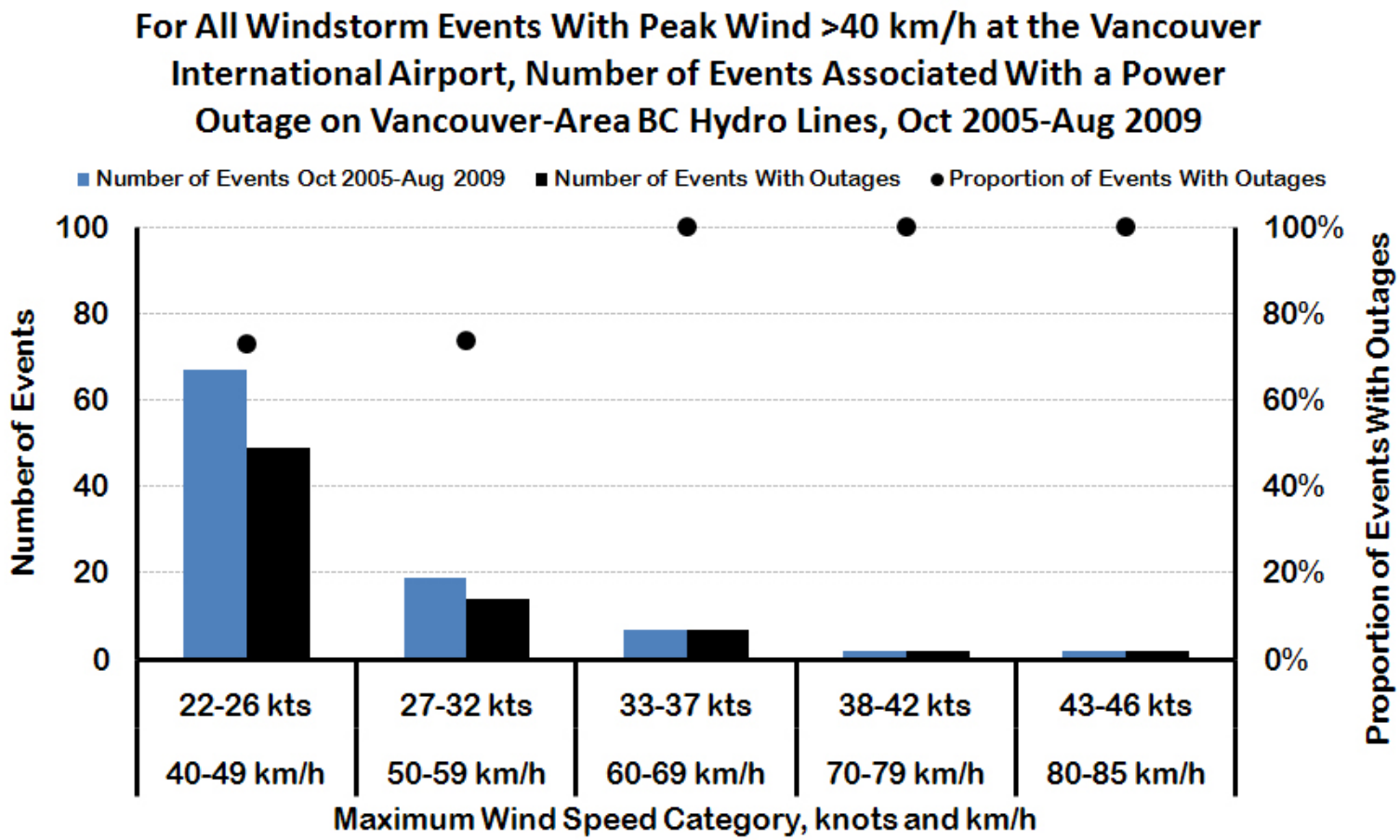
- Short time period of dataset, 2005-2009, limits the number of storm events to be examined

BC Hydro Power-Grid Response to Windstorms



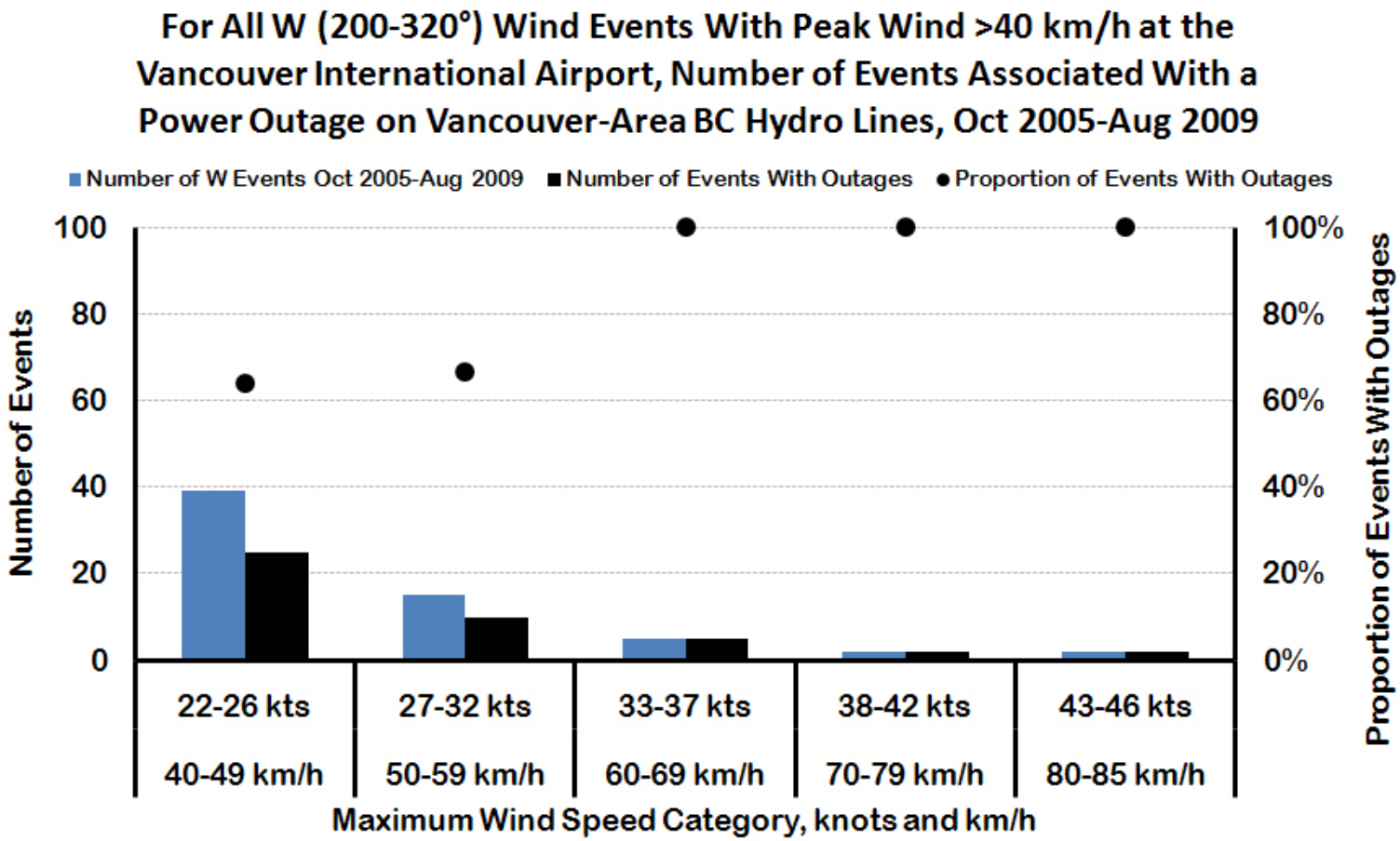
- Given what is being measured, a R-squared of 0.52 is encouraging
- For W-WNW windstorms, the R-squared is 0.63 (N = 63)
- For SE windstorms, the R-squared is 0.71 (N = 34)
- A multivariate analysis is planned, using a number of stations around YVR

BC Hydro Power-Grid Response to Windstorms



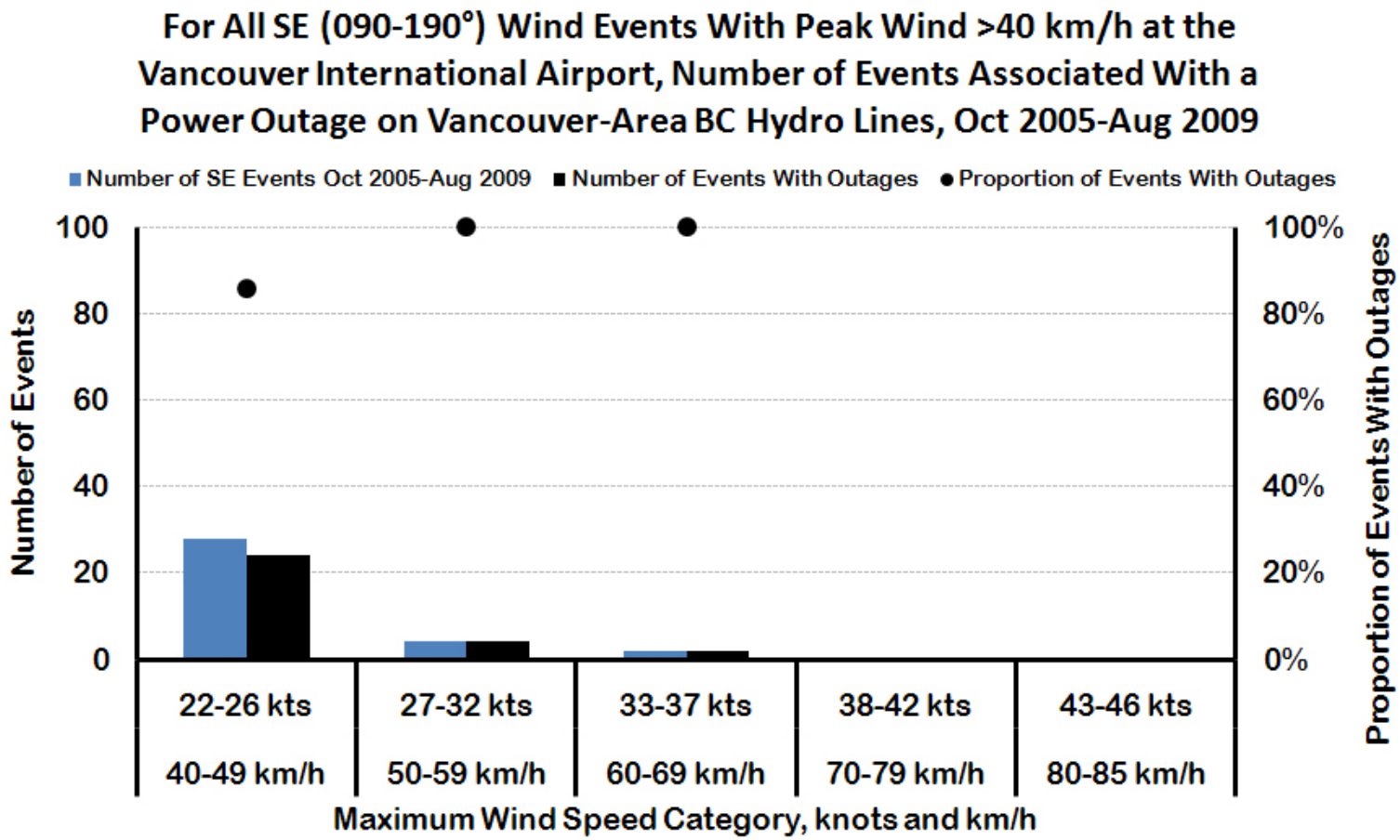
- For all wind directions
- Even fairly typical winter storms (wind 40-49 km/h) tend to produce a high frequency of outages
- At roughly 60 km/h, outage probability is approximately 100%

BC Hydro Power-Grid Response to Windstorms



- W-WNW events have similar pattern to all events
- At roughly 60 km/h, outage probability is approximately 100%

BC Hydro Power-Grid Response to Windstorms



- SE events reach 100% outage probability 10 km/h below W-WNW events
- SE events also do not tend to produce wind speeds as high as W-WNW events

BC Hydro Power-Grid Response to Windstorms

SE vs. W-WNW: Why different?

- W-WNW winds have long overwater fetch, supporting higher speeds at the airport
- SE winds as measured at the airport are probably better representative of much of Vancouver Metro than W-WNW winds
- When looking for correlation, it is critical to understand such differences: Mixing W-WNW and SE events reduces correlation (e.g. 0.52 vs 0.63 and 0.71)

Satellite image courtesy Google Maps.

Summary

For tree-related power outages on circuits within 50-km of CYVR:

- The correlation between wind and gust speed at CYVR and the magnitude of transmission-line (BCTC) outages is very low (R^2 around 0.05)
- However, there appears to be a threshold of 70 km/h wind where the probability of a transmission line failure climbs rapidly
- The correlation between wind speed at CYVR and magnitude of distribution-line (BC Hydro) outages is moderate (R^2 around 0.52-0.71)
- At a wind speed threshold around 60-69 km/h, the probability of an outage on BC Hydro lines approaches 100%
- For these kinds of analyses, it is useful (essential) to pay attention to wind direction

Questions & Comments

(Thank you)

Near Seaside, OR, 04 Dec 2007.