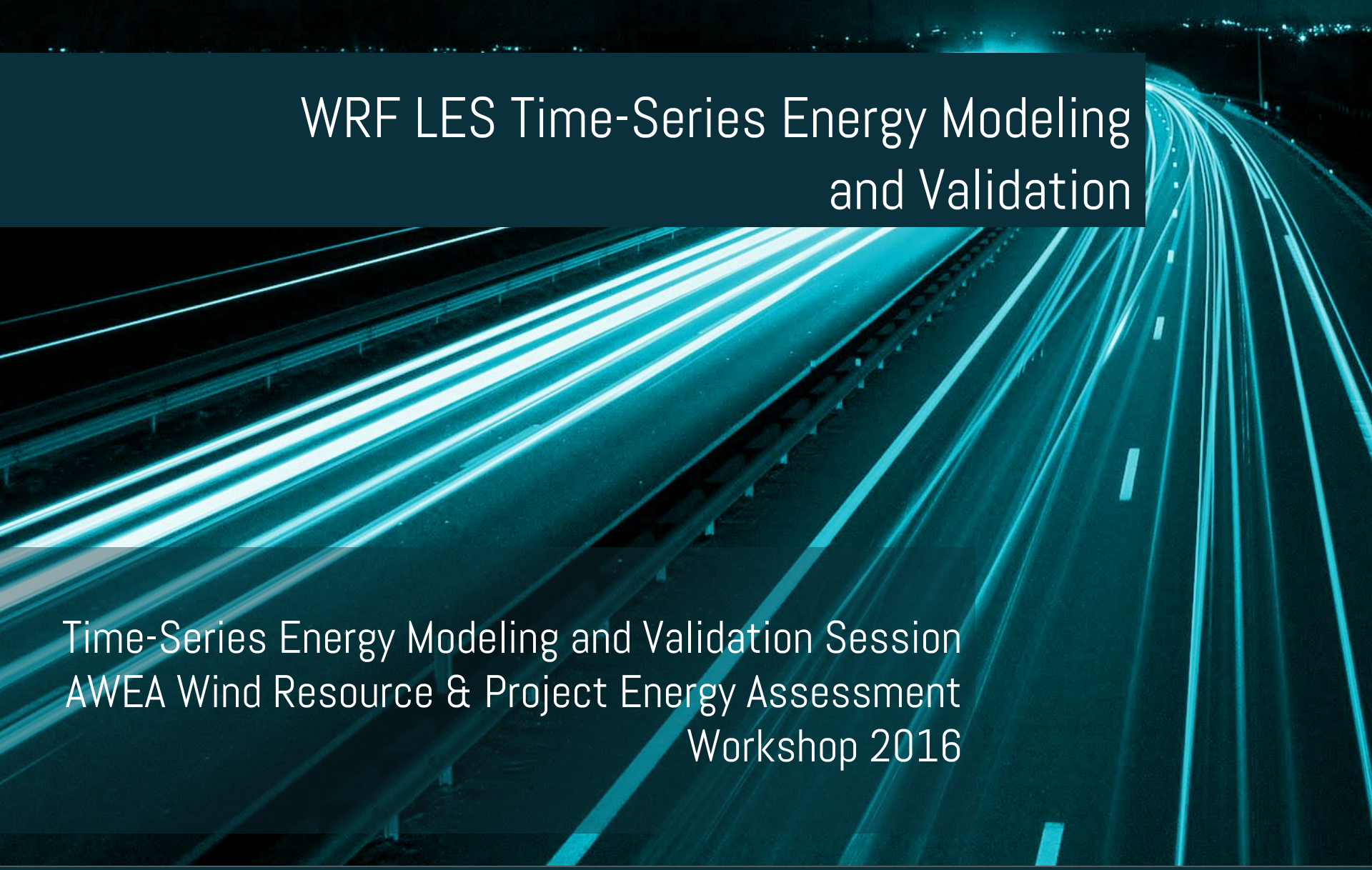
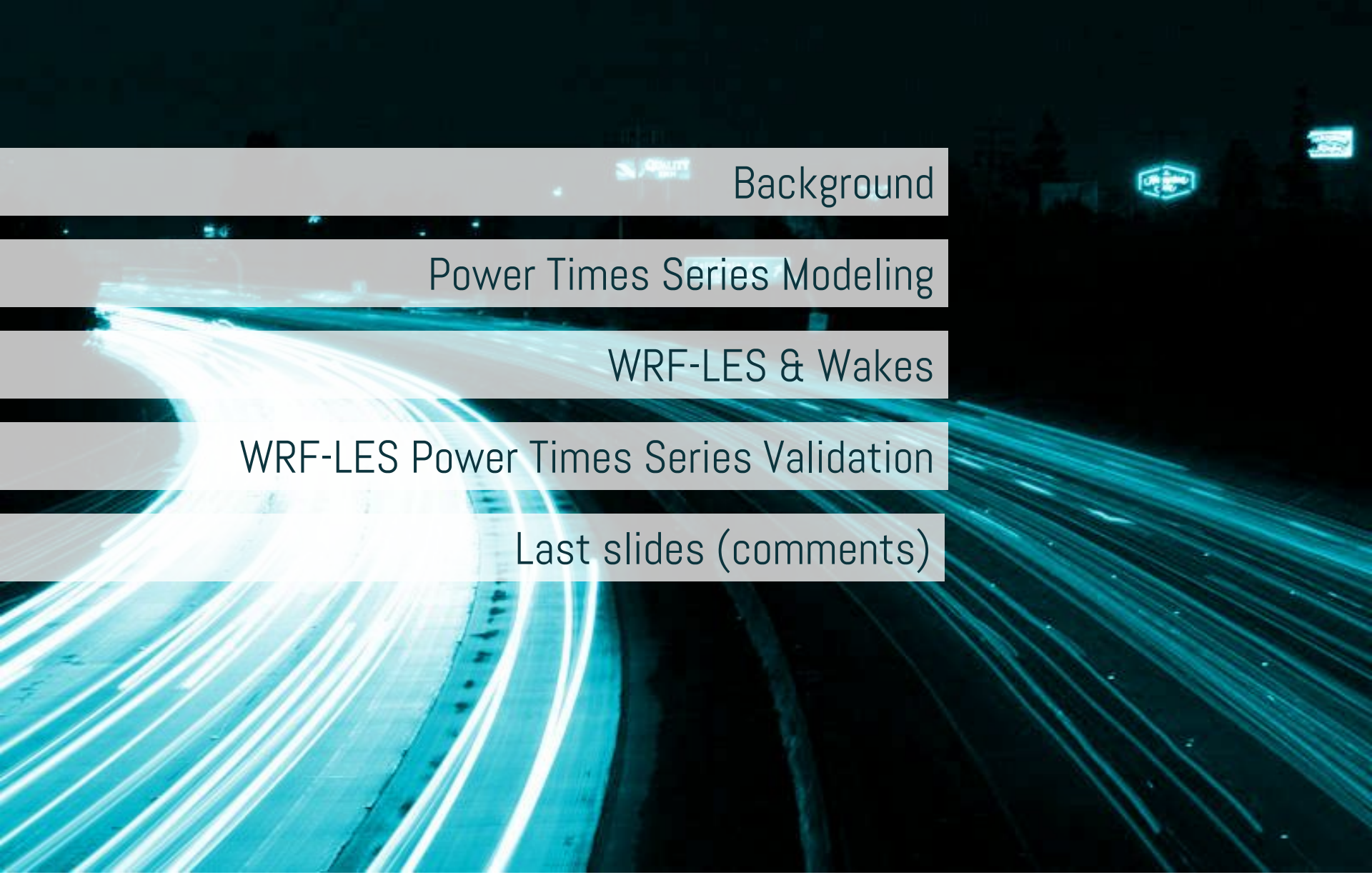
Pre-Construction | Post-Construction

WRF LES Time-Series Energy Modeling and Validation



Time-Series Energy Modeling and Validation Session
AWEA Wind Resource & Project Energy Assessment Workshop 2016

VORTEX



Background

Power Times Series Modeling

WRF-LES & Wakes

WRF-LES Power Times Series Validation

Last slides (comments)

VORTEX

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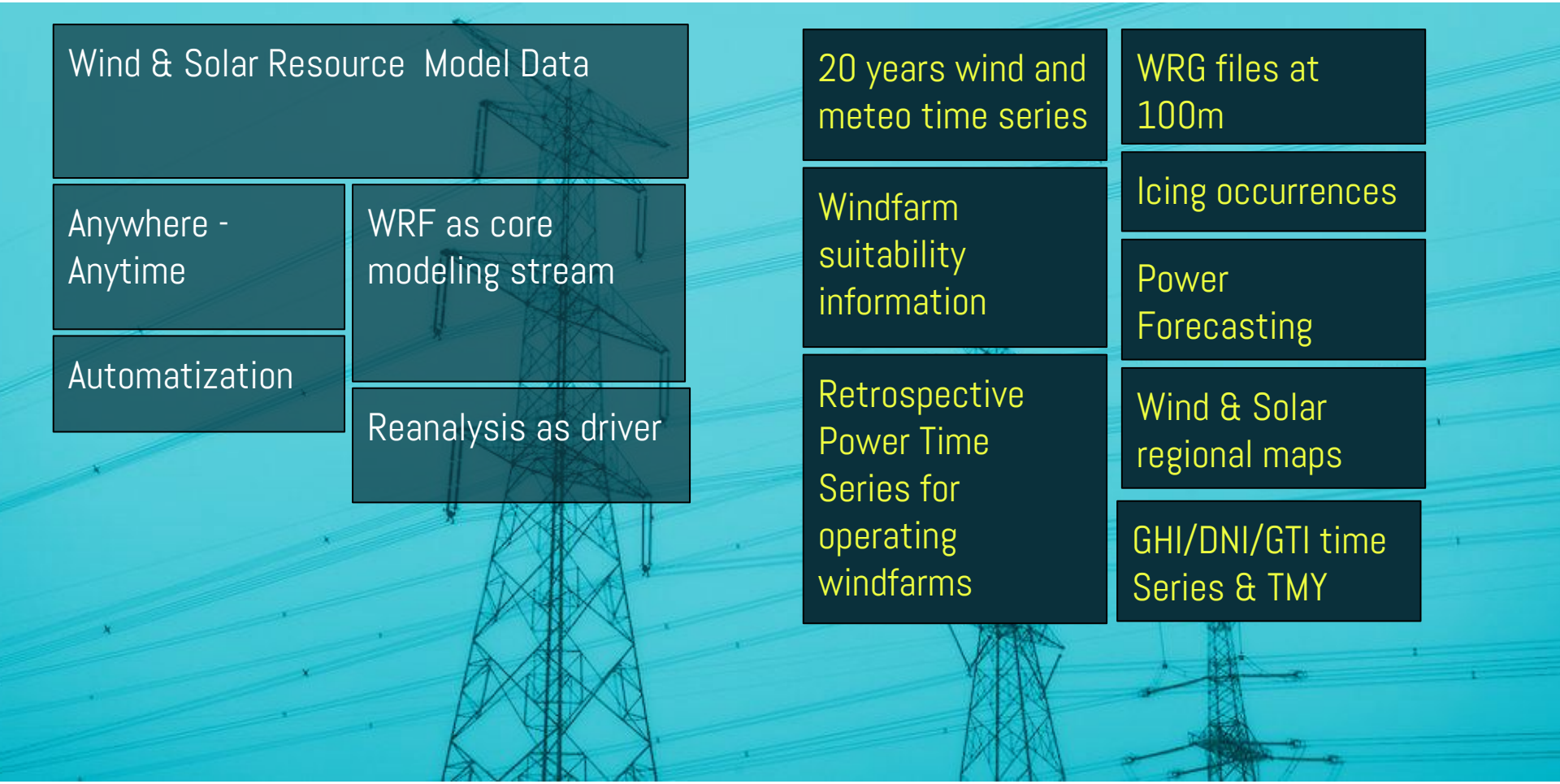
Background: VORTEX



VORTEX

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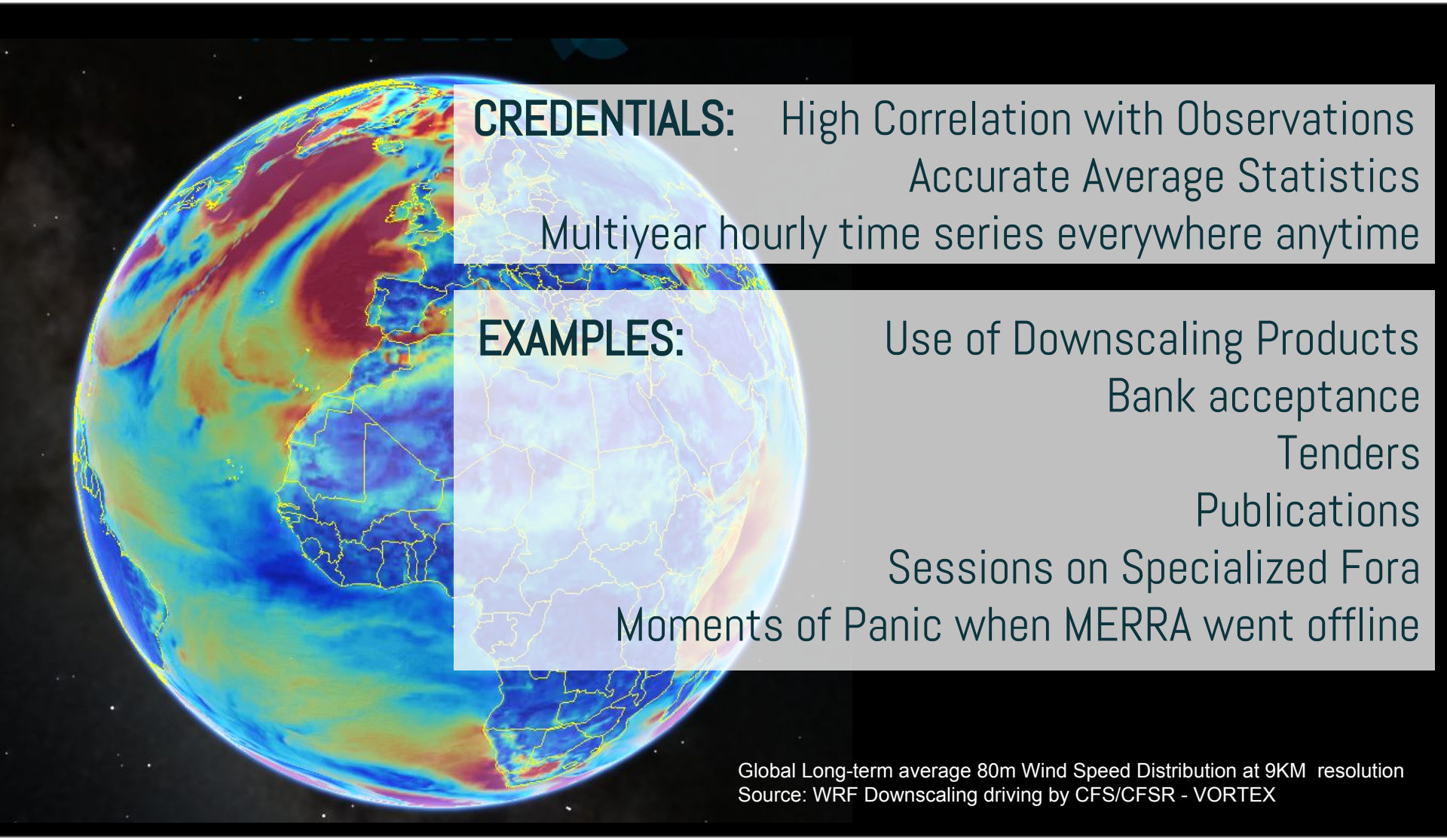
Background: **Consolidate Wind Conditions Mesoscale Modeling Stream**



CREDENTIALS:

High Correlation with Observations

Accurate Average Statistics

Multiyear hourly time series everywhere anytime

EXAMPLES:

Use of Downscaling Products

Bank acceptance

Tenders

Publications

Sessions on Specialized Fora

Moments of Panic when MERRA went offline

Global Long-term average 80m Wind Speed Distribution at 9KM resolution
Source: WRF Downscaling driving by CFS/CFSR - VORTEX

VORTEX

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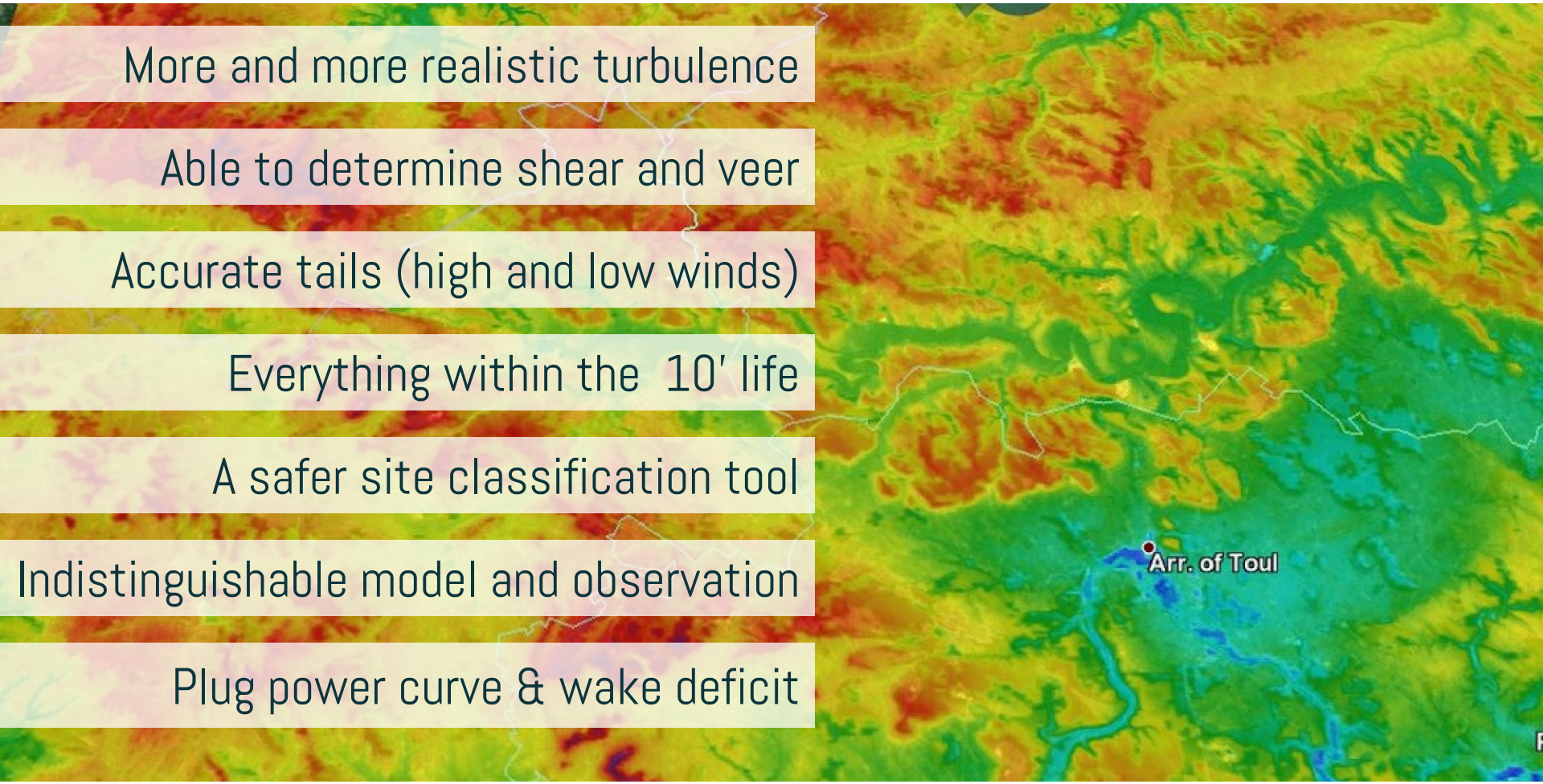
Background: **Moving forward** (m/s into MW)



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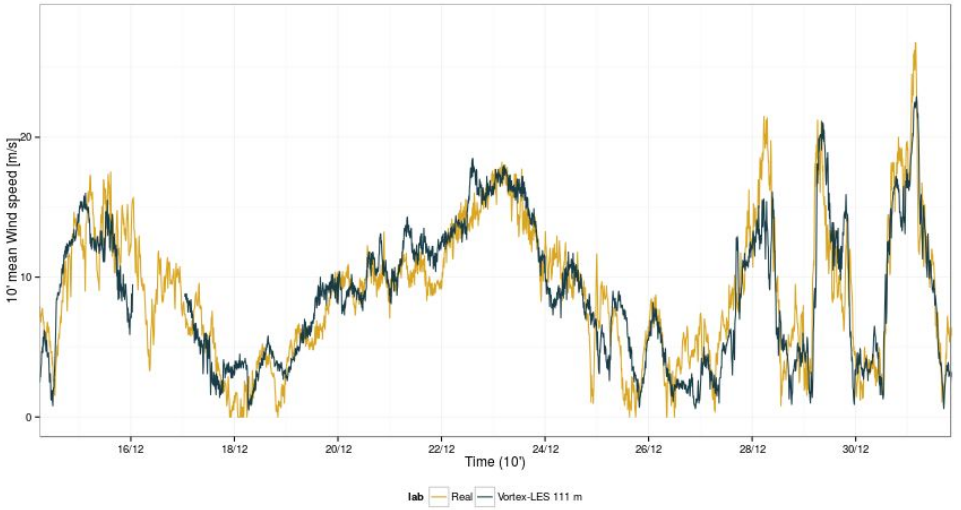
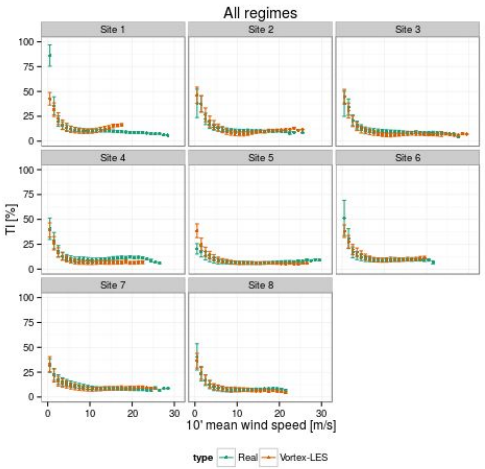
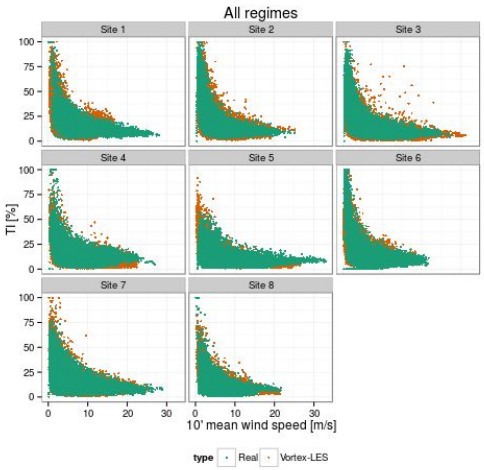
WRF-LES: Modeling **wind conditions** at 10′ sampling

- WRF-LES: Real terrain / Real Conditions
- One complete year (52660x 10′)
- Turbulence enable simulations
- 100m resolution
- 10′ sampling output (4hz time-setps)
- Outputs: average wind speed, direction, STD, shear, veer, stability and other meteo variables (icing classes)
- Any position within the windfarm
- **Plug a Power Curve & Wakes Deficit**
- 3-5 days computing time for one year







Check references: Alex Monternes at AMET SOC Turbulence Workshop

Alos works by Branko Kosovic (NCAR) and Mark Zagar (Vestas)

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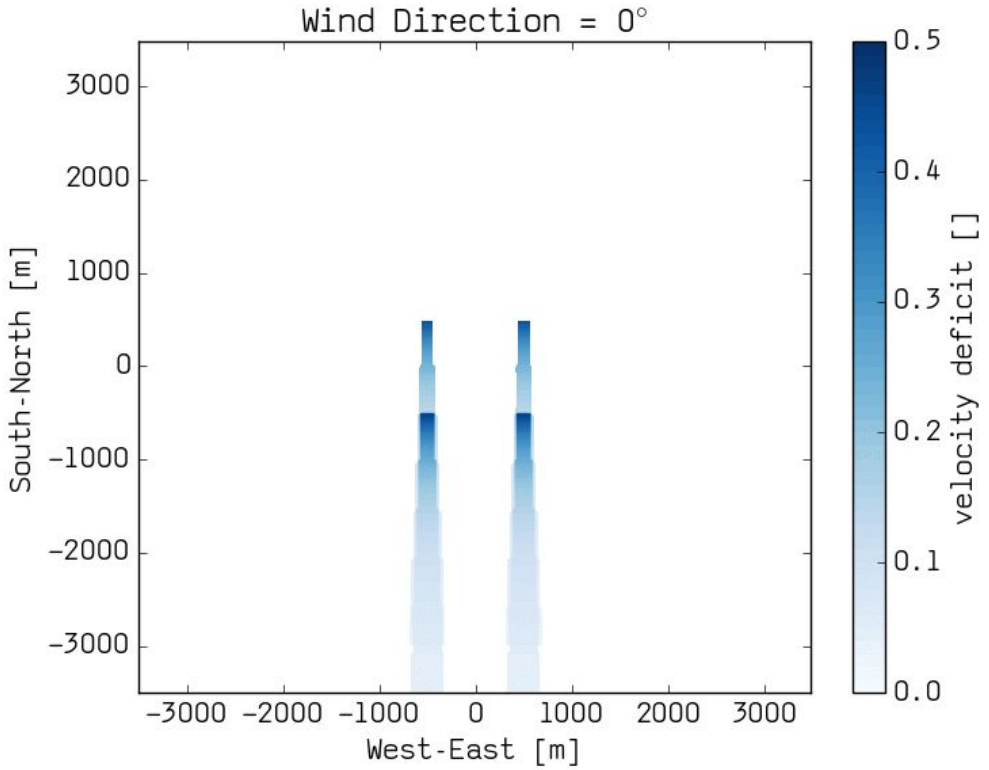
Wake model

- WS Deficit binned look-up table at Wind Turbine Locations
  - Wind speed vs Wind Directions vs Intensity of Turbulence
- Jensen family wake model (like WAsP Park)
- Wake merging = sum of squares
- Expansion factor as function of the Intensity of Turbulence
- Anyhow, this is an active topic of research (complex vs light schools)



More details? Check works of Paula Doubrawa

PRE-CONSTRUCTION **Time Series Modeling**

WRF-LES @100m - 10' avg Turbulence enable

Wind Observations (short period)

Wake Modeling (Jessen)

Power Curves

Standard (inner)
Non standard (outer)

Non-environmental

Curtailment

Environmental

- CHALLENGES:
  - Computing time & robustness
  - Accuracy
  - Limited Bias correction
  - Wake ( )
  - Turbulence & shear
  - Environmental conditions & Real Power Curve (PCWG)

VALIDATION

TOY Cases 65 sites	10’ WRF LES Time Series	Power Curves Air density (inner) Different Models		
REAL 5 Farms	10’ WRF LES Time Series	Wake Modeling (Jensen family)	Power Curves Standard (inner)	Non-environmental

VALIDATION

IDEAL

65 sites

WRF-LES

Power Curves

Observations

Comparison of 10' WRF-LES (100m) vs Observation times series
One complete year
Observed measurements == hub height
Standard atmosphere
4 differentes model (~2MW)

Quantiles across 65 sites	P25	P50	P75
Annual Wind Speed bias [%]	-7.1	-2.6	2.68
Annual Yield bias [%]	-9.90	-3.0	3.8
Daily Power Correlation, R2 (365 days)	0.72	0.77	0.82
Monthly Power Correlation, R2 (12 months)	0.75	0.86	0.92

VALIDATION

REAL	10' WRF LES Time Series	Wake Modeling	Power Curves	
5 Farms		(Jensen inspired)	Standard (inner)	Non-environmental

5 Real Windfarms
Location: Brazil (NE), Spain (Center), UK (Onshore) & Germany (North / Forest)
Nominal Power: 30-50 MW

One year of observed hourly aggregated production data
Layout / CT & CP (air density)

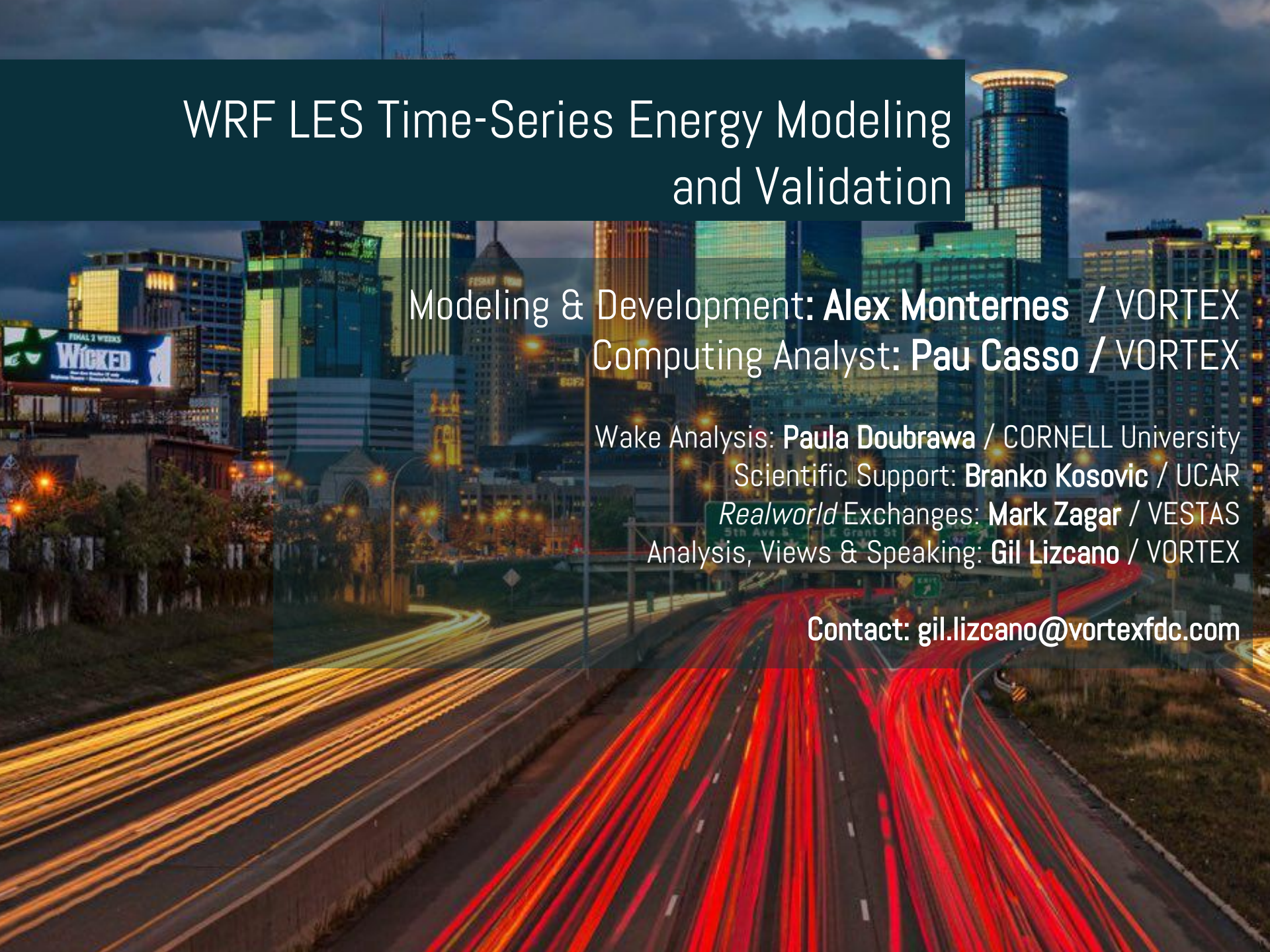
WRF-LES 10' wind conditions including intensity of turbulence
Wake model (standard - no tuning) - Iu

Windfarm	Annual Yield Mean Error [%]	Daily R2	Monthly R2
Flat	-4.9	0.78	0.85
Forrest	-5.6	0.72	0.82
Maritime	-6.8	0.75	0.86
Complex	-5.6	0.80	0.83
Complex	-10..4	0.69	0.75

CONTEXT: No Observation employed to callibrate the modeling stream, WRF-LES

ONE	A	We need to make more effords in improving results for 60% sites
	B	Considering using bias correction to rectify model sistematic bias
TWO	A	About 40 % of the sistes are candidates to accept modeling information with accuracy in production of order of (+/-) 5 % Error
	B	Temporal variability is very well portraied at 10' scale
THREE	A	Aggregated production for Windfarms Error is low (surprise) "Friend of the model" Sites Good Represenation fo variability and turbulence
	B	Caveat: limited sample of real windfarm


Pre-Construction
Model wind in the time domain to model energy in time domain
Power time series products to meet industry needs
The 8760 hours challenge (or the 52560 x 10′ challenge)



WRF LES Time-Series Energy Modeling and Validation

Modeling & Development: **Alex Monternes** / VORTEX
Computing Analyst: **Pau Casso** / VORTEX

Wake Analysis: **Paula Doubrawa** / CORNELL University
Scientific Support: **Branko Kosovic** / UCAR
Realworld Exchanges: **Mark Zagar** / VESTAS
Analysis, Views & Speaking: **Gil Lizcano** / VORTEX

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