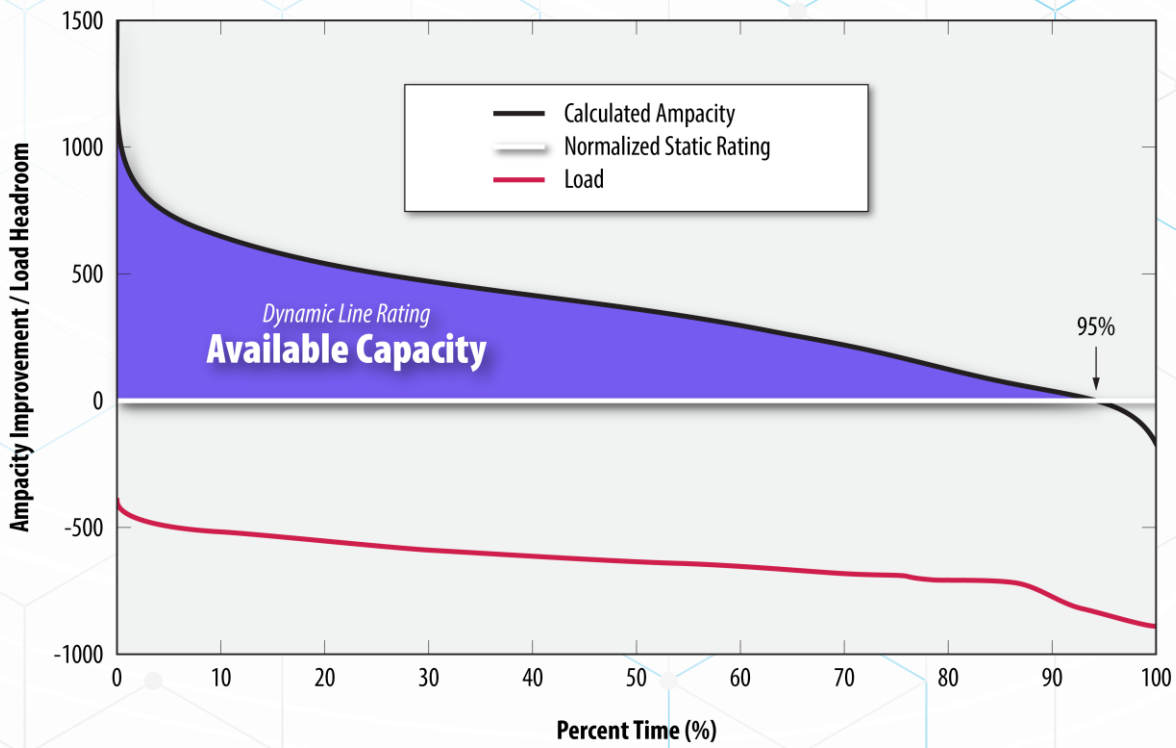
Overview of Forecasted Line Ratings

2020 MGA and OMS Transmission Summit
November 16, 2020

Jake P. Gentle

Program Manager
Infrastructure Security

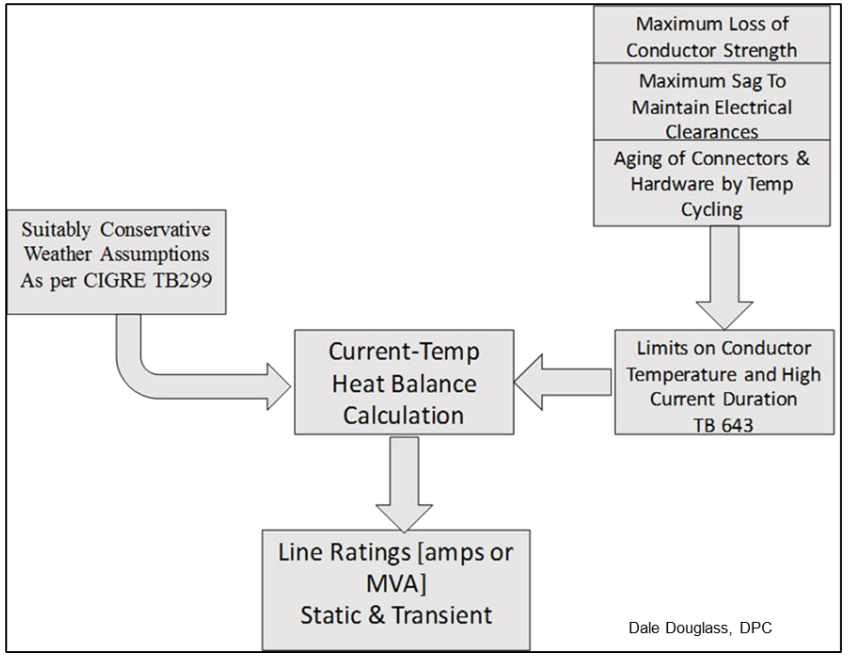


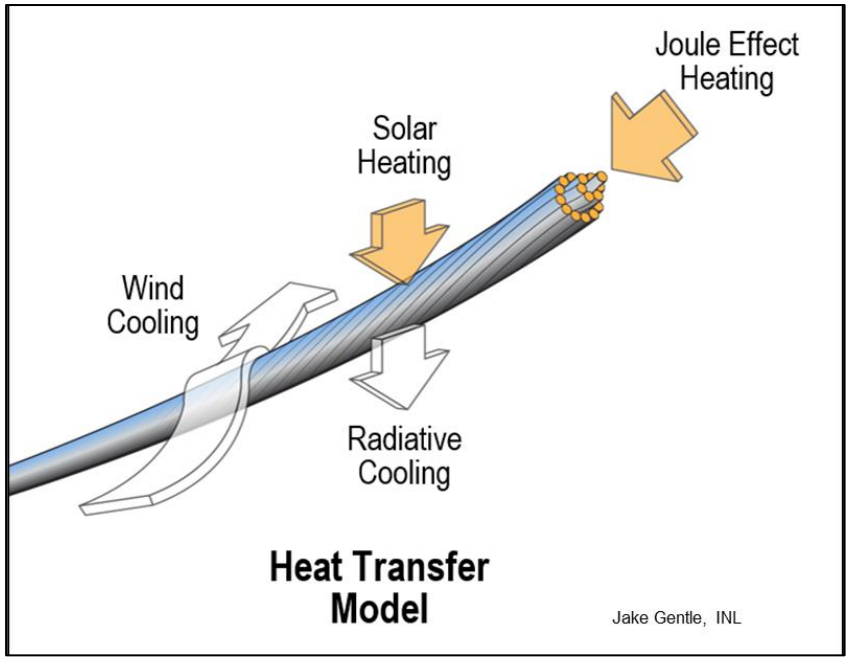
Idaho National Laboratory

INL/CON-20-60496

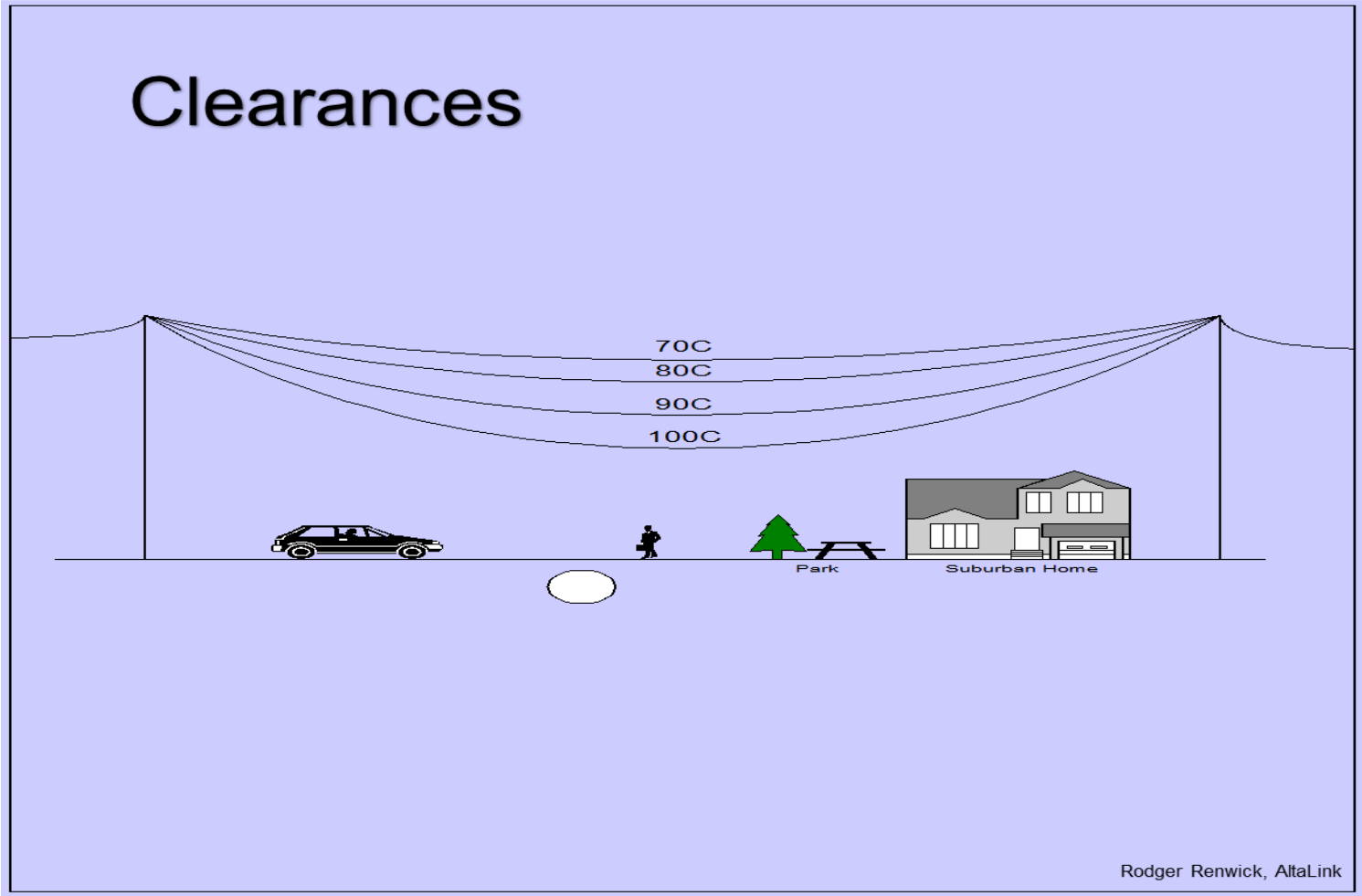
What is a Line's Thermal Rating?

- It is the maximum current a line can carry for which the resulting line conductor temperature does not exceed a specified maximum conductor temperature.
- The maximum conductor temperature is calculated to limit cumulative damage to the conductor system and to assure minimum electrical clearances are maintained



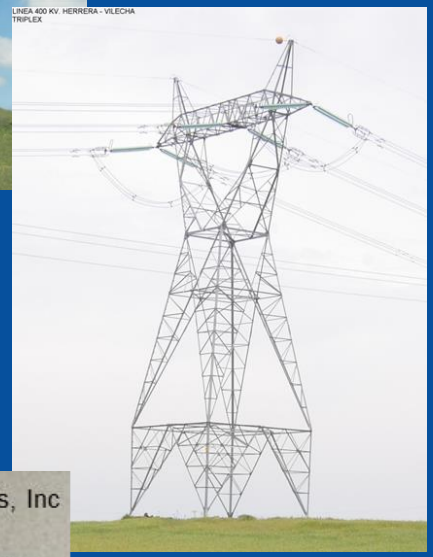


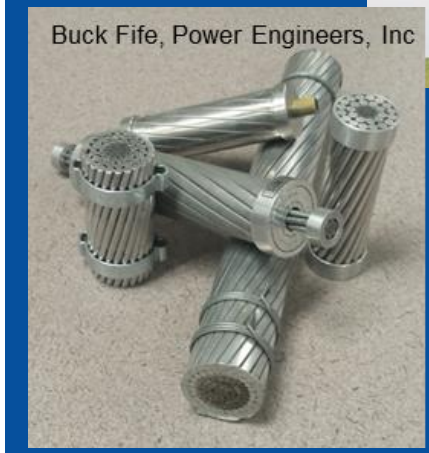
Ratings come down to only a few things



How can I increase capacity of my lines?

- Change the Methodology
  - Adjust Static Rating Parameters
  - Apply Other Ratings
    - Seasonal
    - Ambient Adjusted
    - Dynamic Line Ratings (Real-time and Forecasted)
- Change the Rating
  - Use Clearance Margin (if available)
  - Allow Higher Temperature
- Fix Clearance Limits
  - Remove Obstacle
  - Adjust Tension
  - Modify Insulators
  - Modify Structures
  - Inset Structures
- Reconductor
  - TW Conductor
  - Larger Conductor
  - HTLS conductors
- Increase the Voltage
  - Structure/insulator modification
- Rebuild the Line
  - New conductor
  - More circuits
  - Larger voltage





Current Standards and Brochures: Guides

Institute for Electrical and Electronic Engineers (IEEE)

- Task Force - Line Ratings (Risk & Prediction)
- IEEE 738 Task Force: Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors
- IEEE 1283 Task Force: Guide for Determining the Effects of High-Temperature Operation on Conductors, Connectors, and Accessories
- Working Group on Transmission and Distribution Overhead Conductors and Accessories—15.11.02/06
- Working Group on Management of Existing Overhead Transmission Lines—15.11.09
- Working Group on Wind and Solar Plant Collector System Design

IEEE Transmission & Distribution Committee
IEEE Power & Energy Society

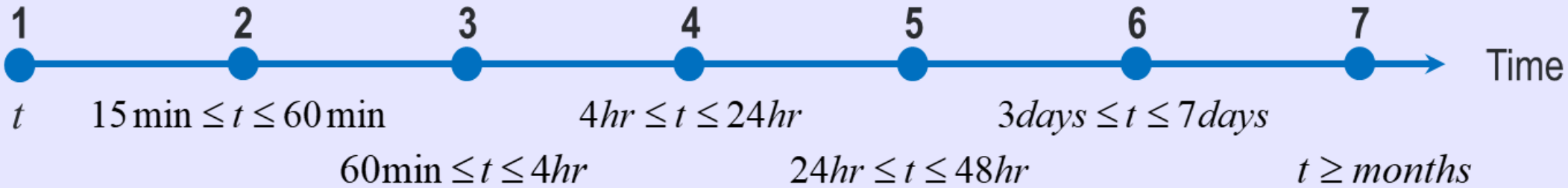
International Council on Large Electric Systems (CIGRE)

- Near Completion: WG B2.59_Forecasting Dynamic Line Ratings
- TOR-WG B2.78_Use of High Temperature Conductors in New Overhead Line Design
- TOR-WG B2.79_Enhancing Overhead Line Rating Prediction by Improving Weather Parameters Measurements
- TOR-WG B2.77_Risk Management of OHL networks - A model for identification, evaluation and mitigation of operational risks
- TOR-WG B2.74_Use of unmanned aerial vehicles (UAVs) for assistance with inspection of overhead power lines
- TOR-WG B2.73_Guide for Prevention of Vegetation Fires Caused by Overhead Line Systems

SC B2
Overhead Lines

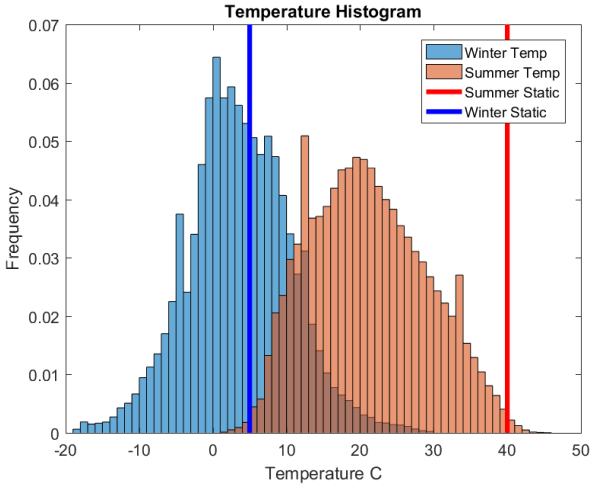
DLR Forecasting Suggested Operational Timelines

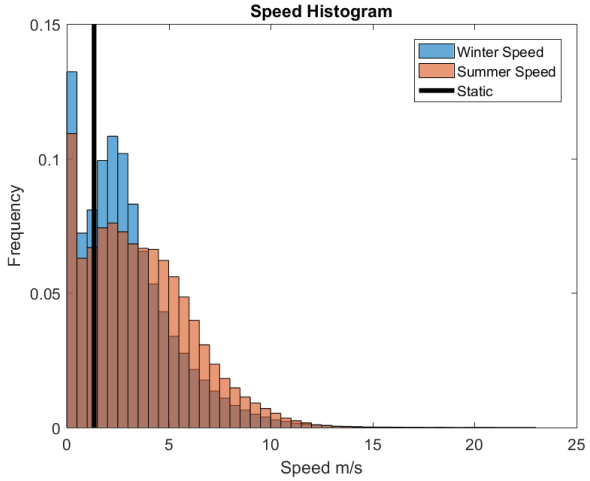
1. Instantaneous
2. Short-term: Thermal Inertia
3. Short-term look ahead
4. Daily Peak Loading, Generation Dispatch
5. Maintenance, Power Marketing
6. Maintenance, Marketing, Construction
7. Construction, Refurbishment, Voltage Upgrades

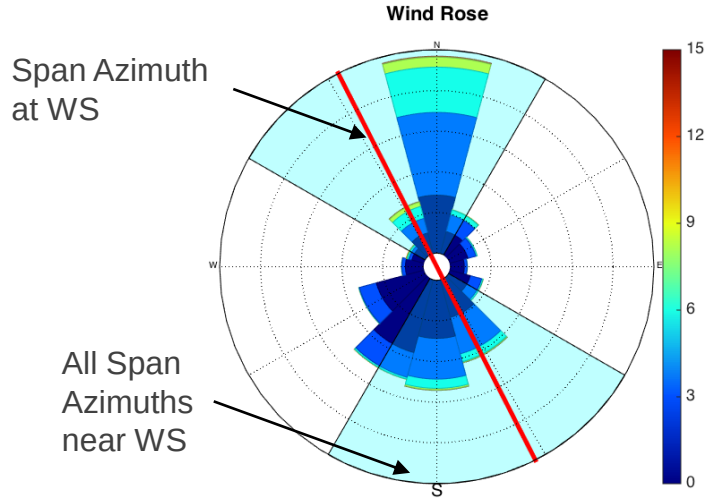


Visualization: How does weather data compare to static assumptions?

How does prevailing wind compare to transmission line direction?

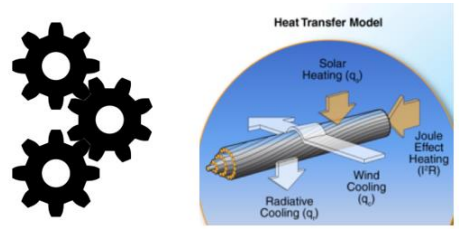


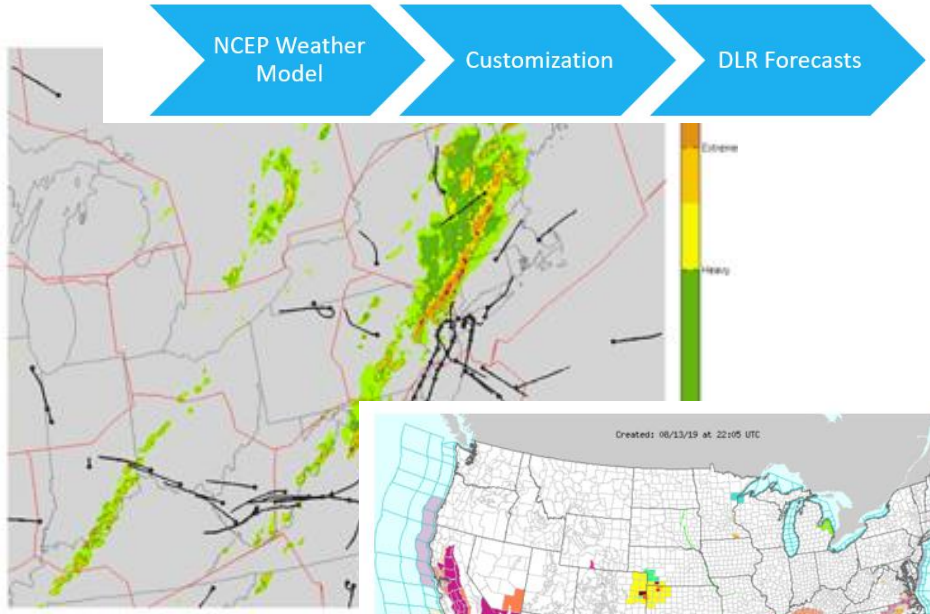


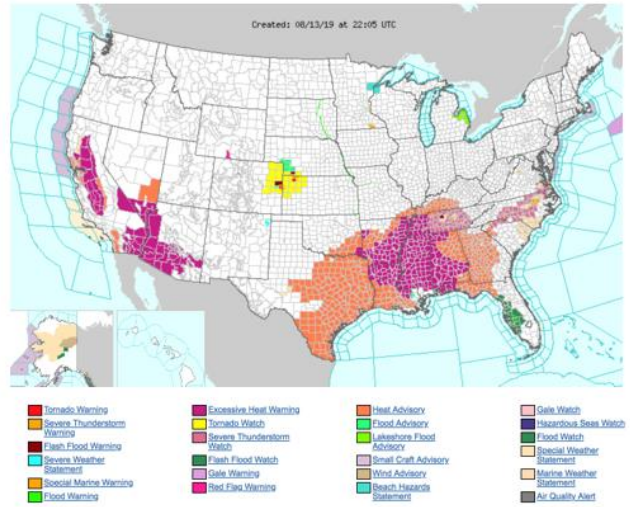


Regional Forecasting

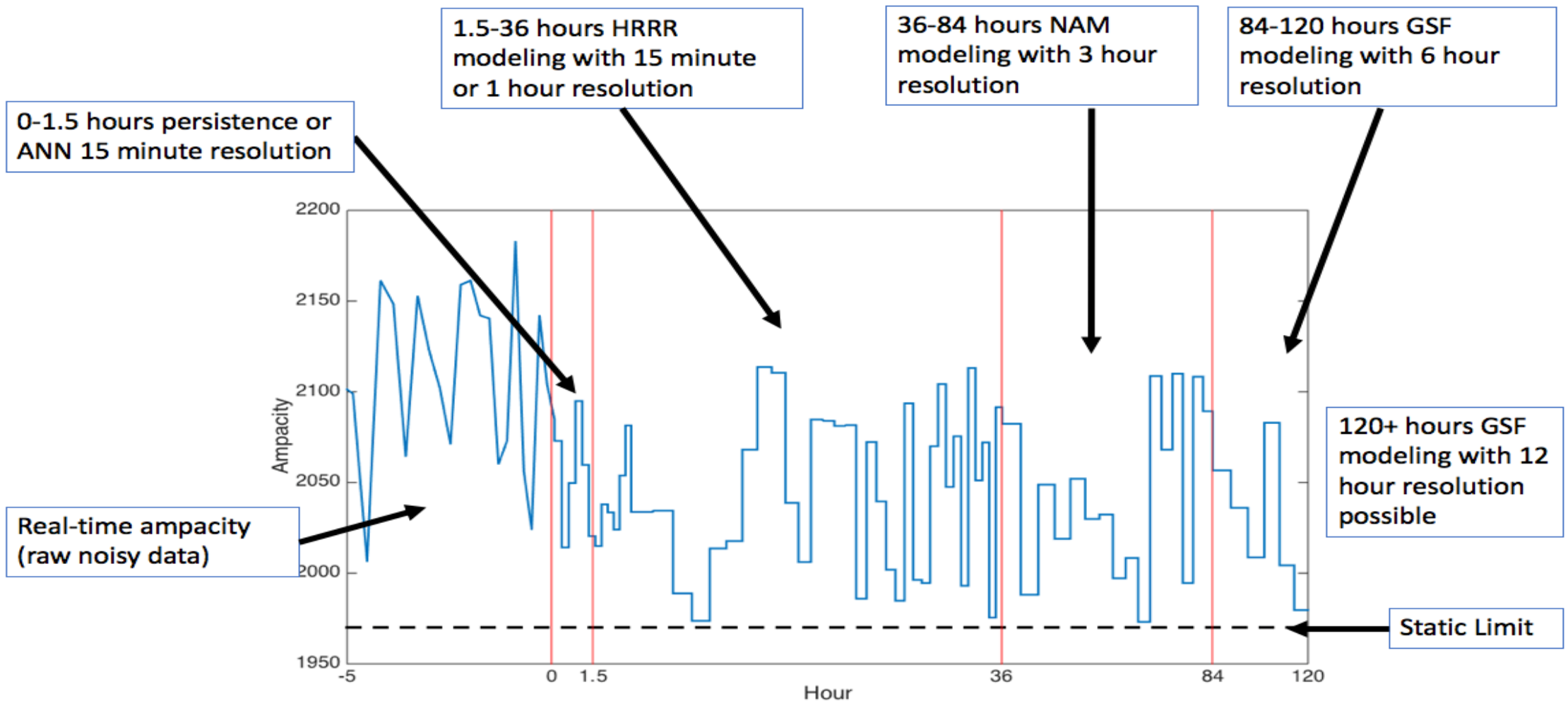
- Regularly used by FAA/NWS; forecasting to predict future line ratings
- Several US regional models openly available
  - Typically longer time range = less spatial accuracy
- High-Resolution Rapid Refresh (HRRR) model
  - 3 km spatial
  - 0-36 hour forecasts with 15 min - 1 hour (updated hourly)
- North America Mesoscale (NAM) model
  - 12 km spatial
  - 0-84 hours each 3 hours (updated 6 hours)
- Global Forecast System (GFS) model
  - 13 km spatial
  - 0-120 hours each hour, 120-249 each 3, 240-384 each 12 (updated 6 hours)
- HRRR has best potential for coupling with localized DLR calculations to spatial and temporal resolution
- Other models more applicable to longer-term applications
  - Maintenance, Power Marketing, Construction, Refurbishment, Voltage Upgrades







Regional Forecasting

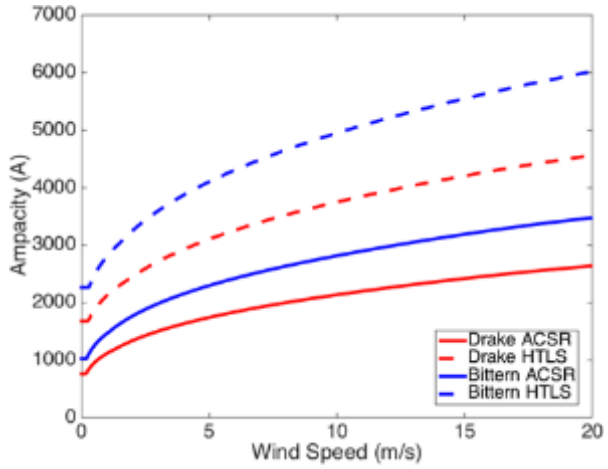


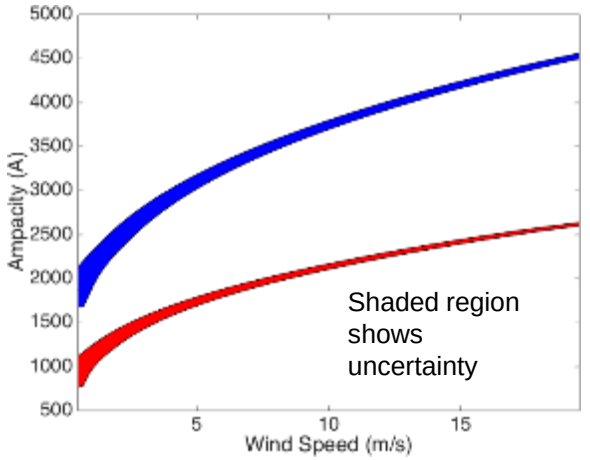
DLR Sensitivity & Error Propagation

- Drake vs Bittern | ACSR vs HTLS
  - (TC_{max} 80/200 C)
  - Slope of both direction and speed gets higher at larger conductor and higher TC_{max}
  - Speed shows more spread at low speeds
  - Direction shows more spread near parallel wind

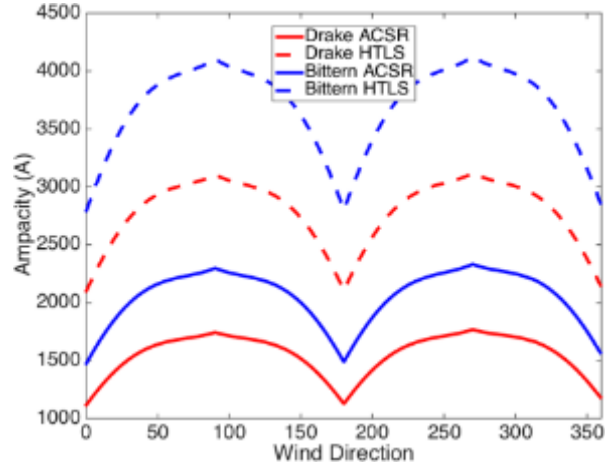
The impact of wind direction and speed increases at higher conductor temperatures and with larger conductor diameter

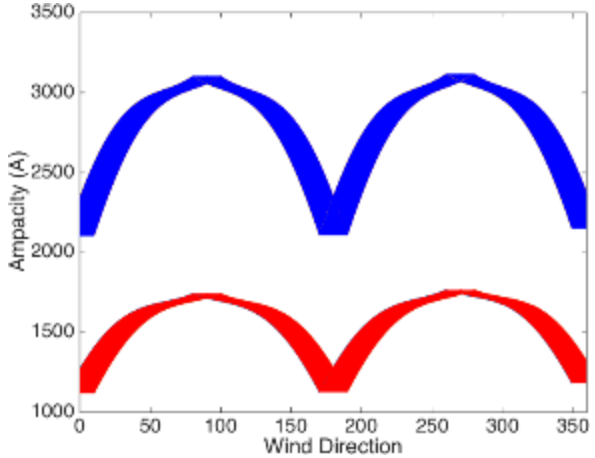
Wind Speed





Wind Direction



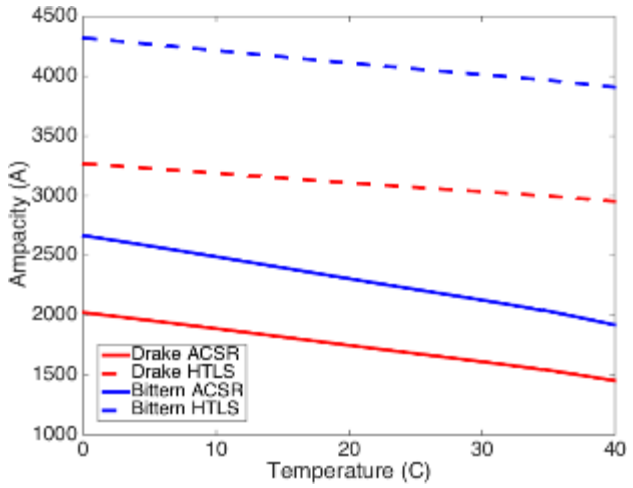


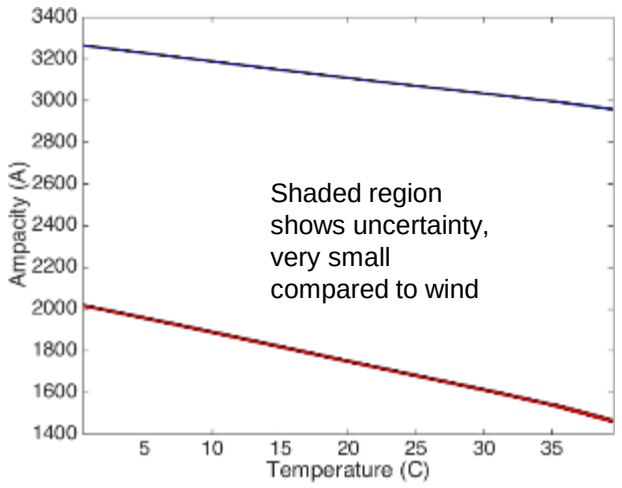
DLR Sensitivity & Error Propagation

- Drake vs Bittern | ACSR vs HTLS
  - Changes in ampacity from temperature delta are smaller than wind speed/direction
  - Changes from solar flux uncertainty are negligible

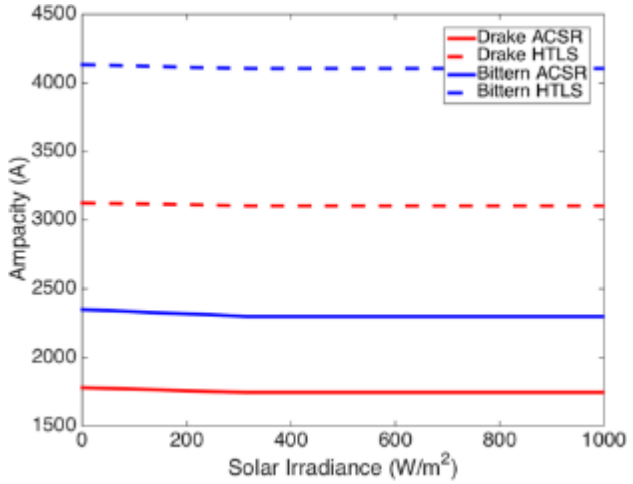
The impact of solar flux and ambient temperature decreases with higher conductor temperatures
Negligible change with conductor diameter

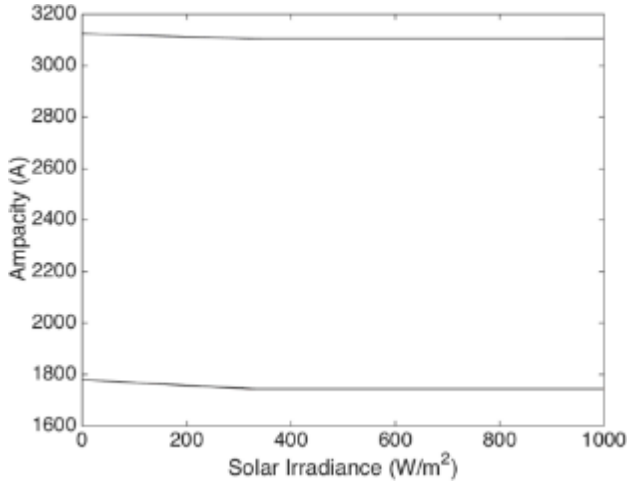
Temperature





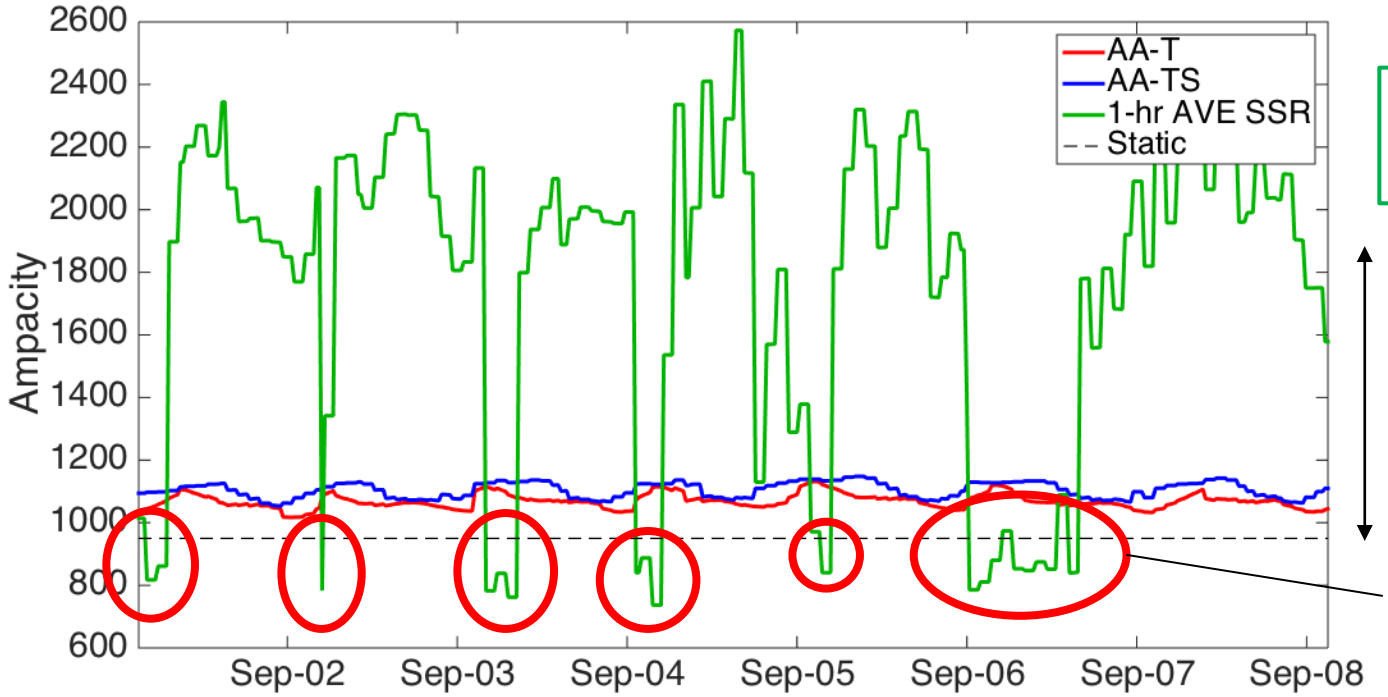
Solar Flux





DLR vs Ambient Adjusted Ratings (AAR)

- As shown in previous sensitivity plots, more capacity is gained from wind speed and direction than solar or temperature adjustments
  - This plot shows the risk when wind speed drops and you assume static values
- Utility reference line with static parallel wind at 3.0 m/s with AAR – temperature (1000 W/m2 solar), AAR – temperature + solar and 1-hr averaged SSR (based on IEEE 738)
  - Increase using solar adjustments over typical AA is minor



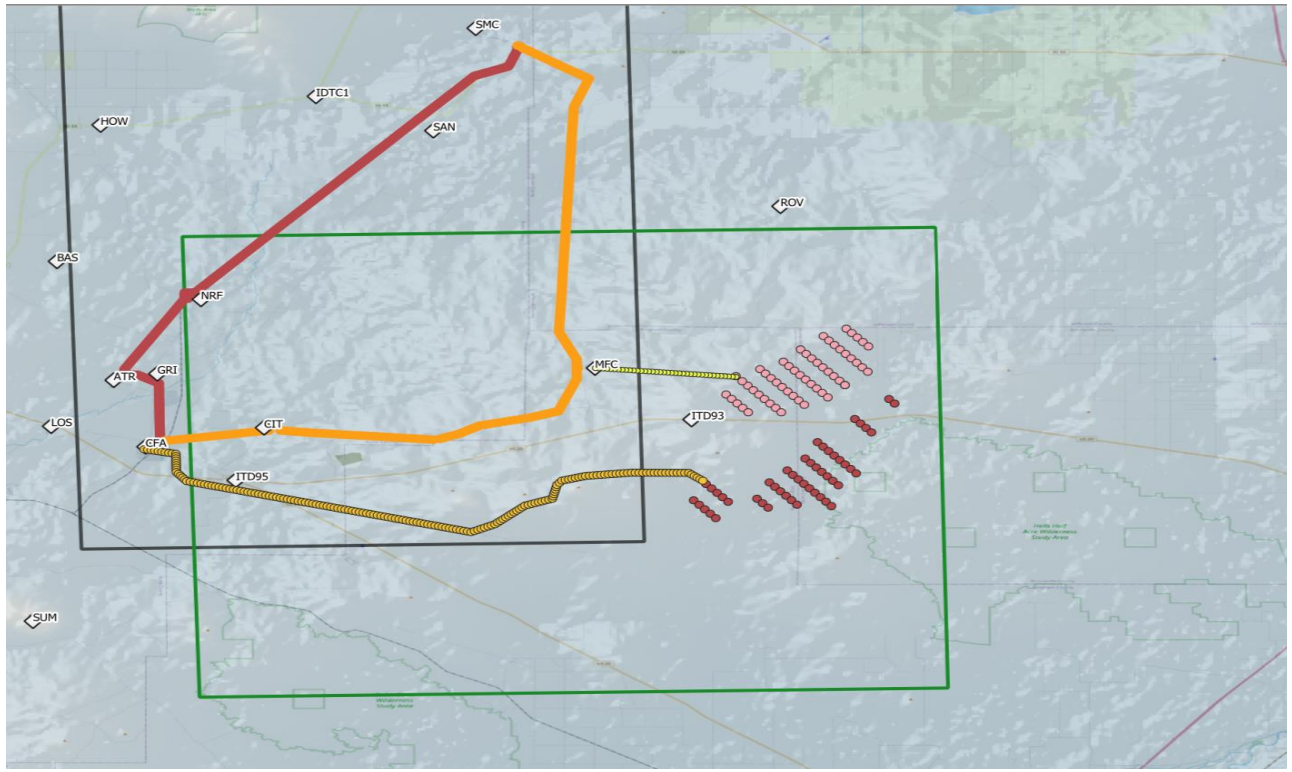
~35 A increase with AA + solar

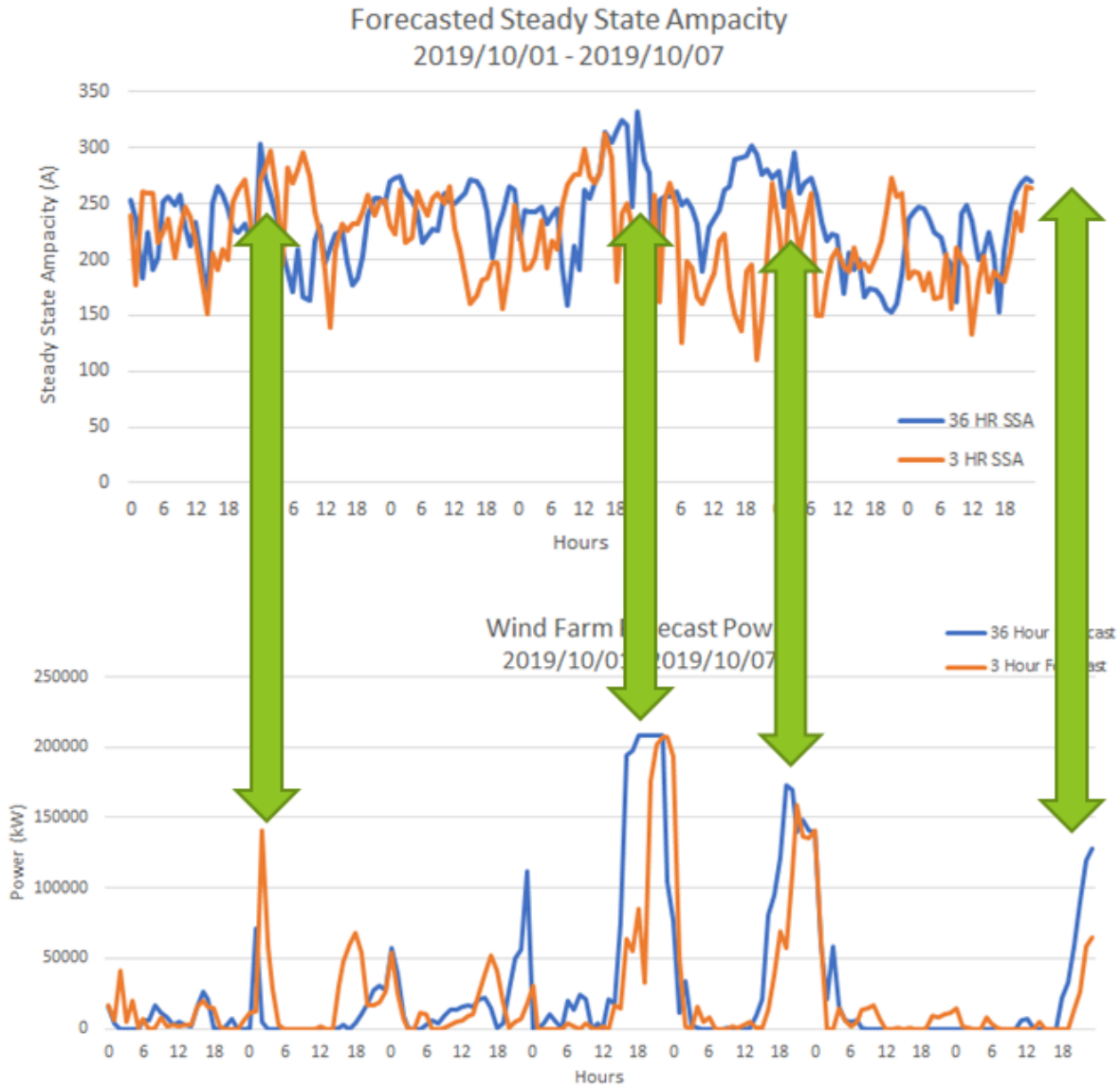
~700 A increase with DLR

But shows below static ~15% of time

Concurrent Cooling

- Study of coupled effect of wind power generation and DLR ampacity
- Higher wind generation periods correspond with higher ampacity periods





Need More?!

WIND INTEGRATION R&D
Concurrent Cooling, Dynamic Line Rating

Jake P. Gentle – jake.gentle@inl.gov

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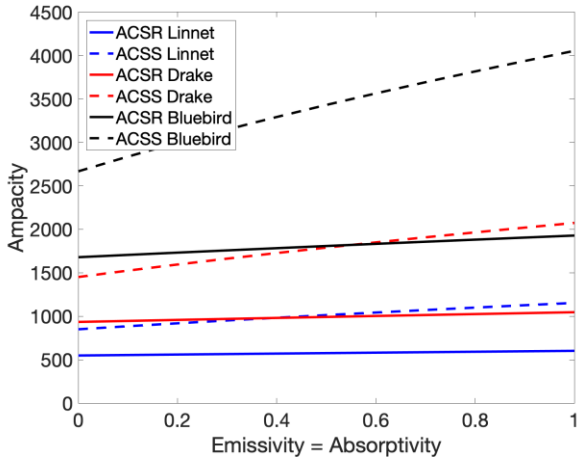
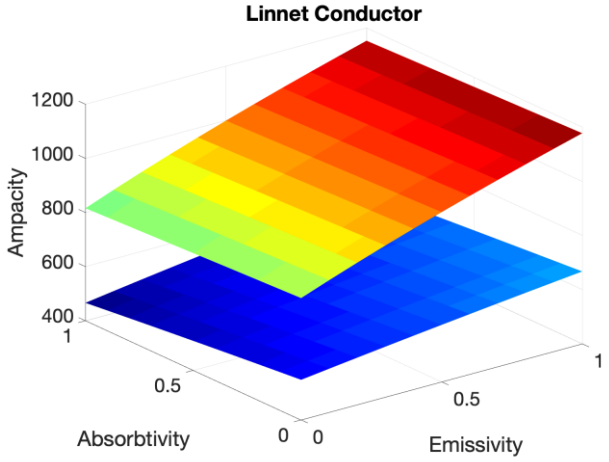
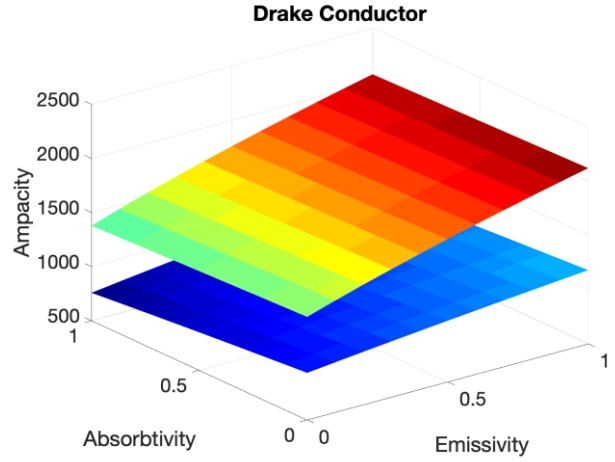
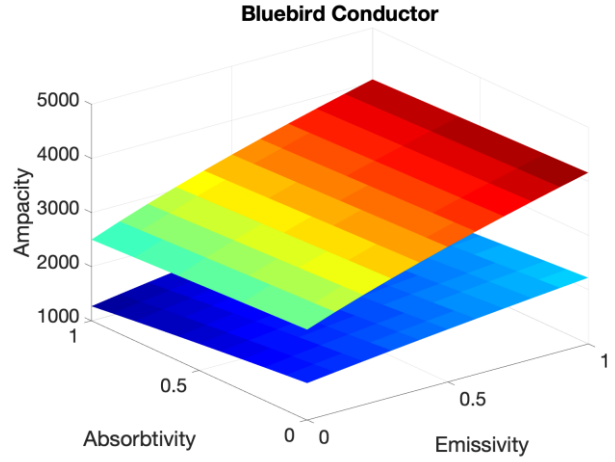
Sensitivity of Emissivity/Absorptivity

- Higher maximum temperatures (i.e. ACSS) greatly increases sensitivity to these variables
  - Plot compares ACSR at 100 C vs ACSS at 250 C
- Larger diameter conductors also show higher sensitivity to absorptivity/emissivity



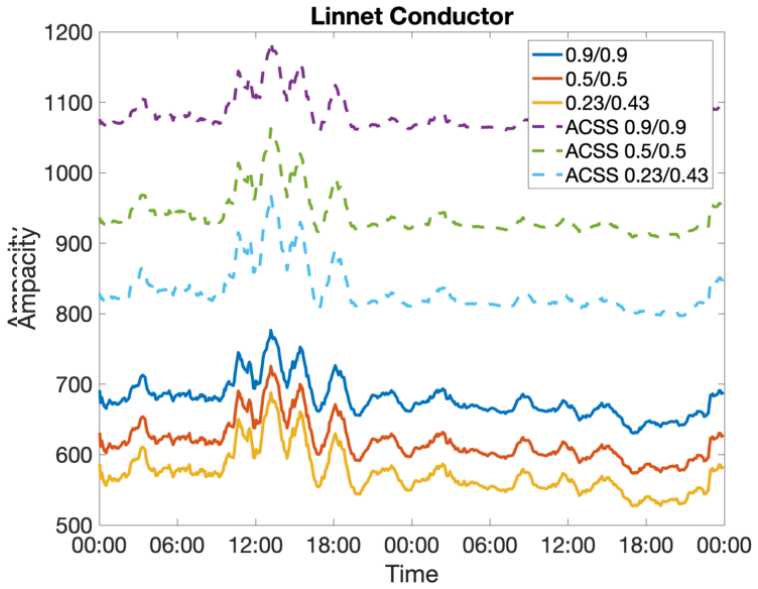


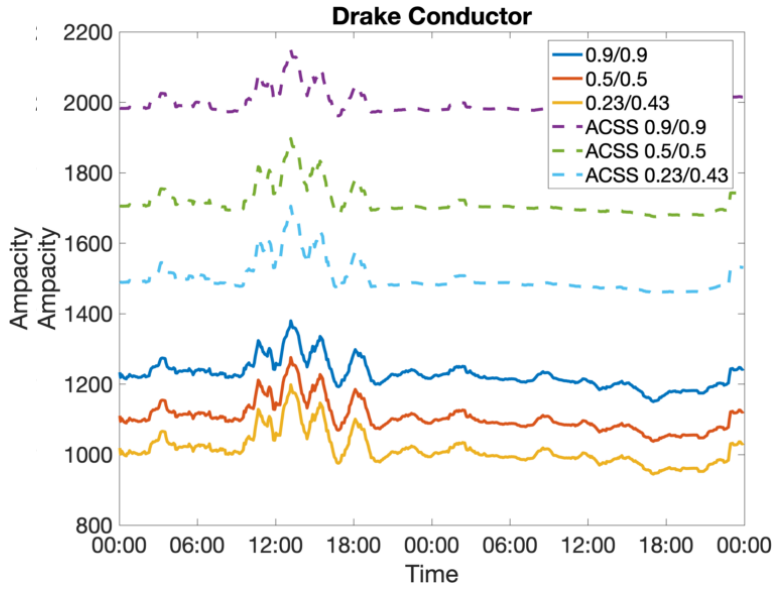


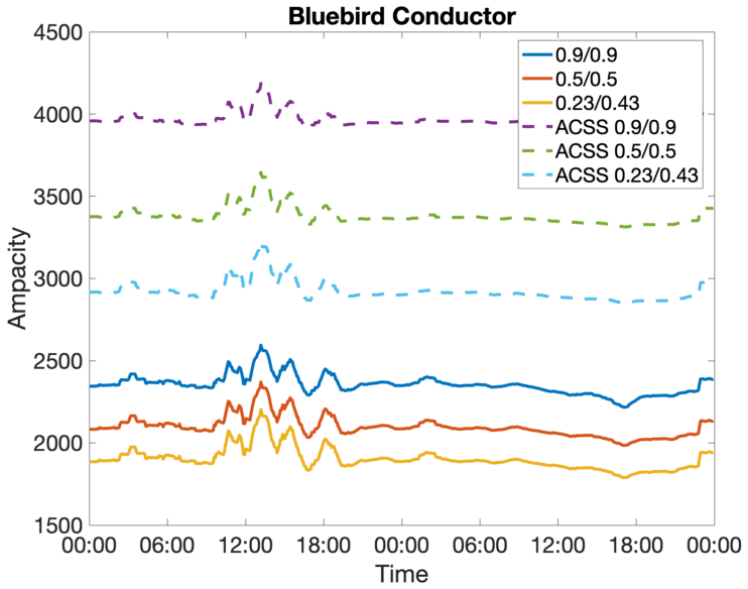


DLR Ampacity Calculation

- Variation of emissivity/absorptivity based on ISO/RTO values surveyed across US
  - Location has close to static assumptions for wind most of the time
  - Spike from high wind day
  - Larger spread in ampacity at high conductor temperature

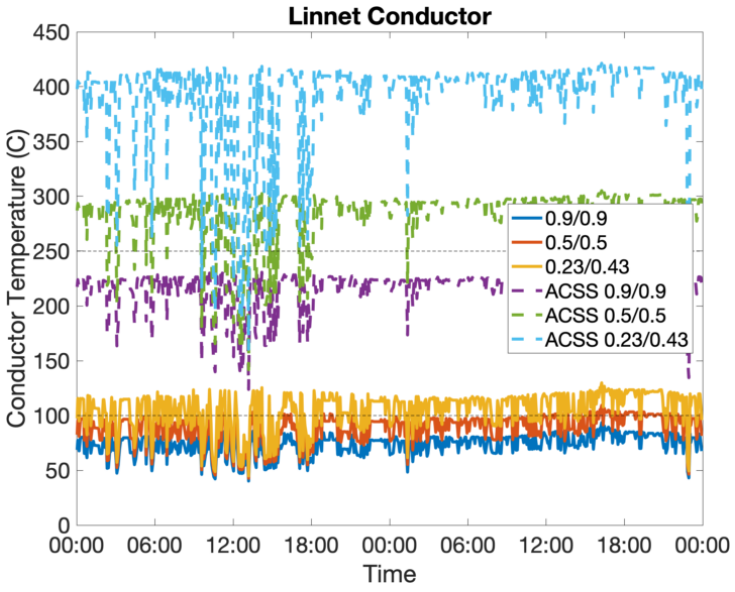


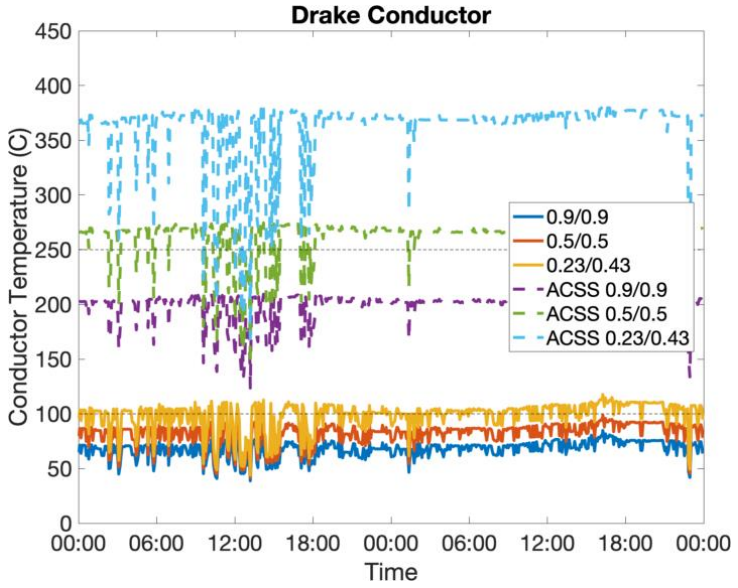


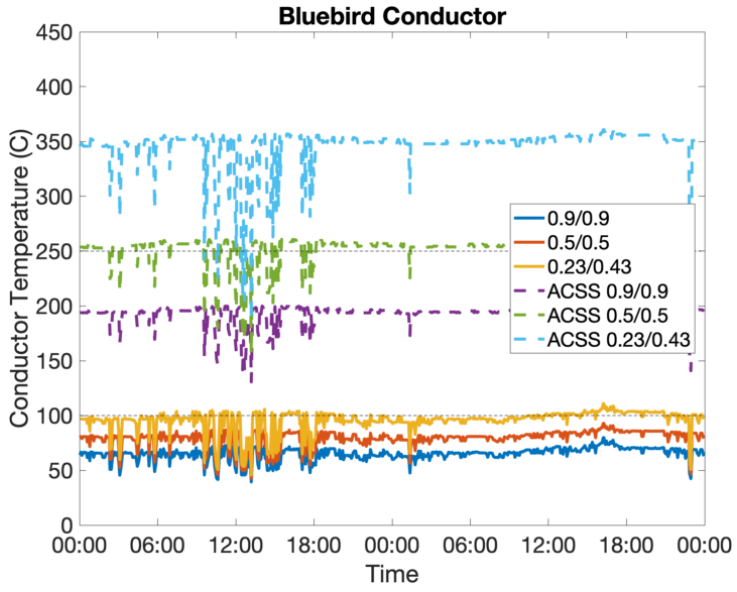


Steady State Temperature Calculations

- Using constant load at 90% of averaged ISO/RTO load
- Suppose static calculation is done at 0.5/0.5, and upon testing the line is actually 0.9/0.9 – then maximum temperature can be easily exceeded on a high temp line
- Chance is much larger for smaller conductors







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