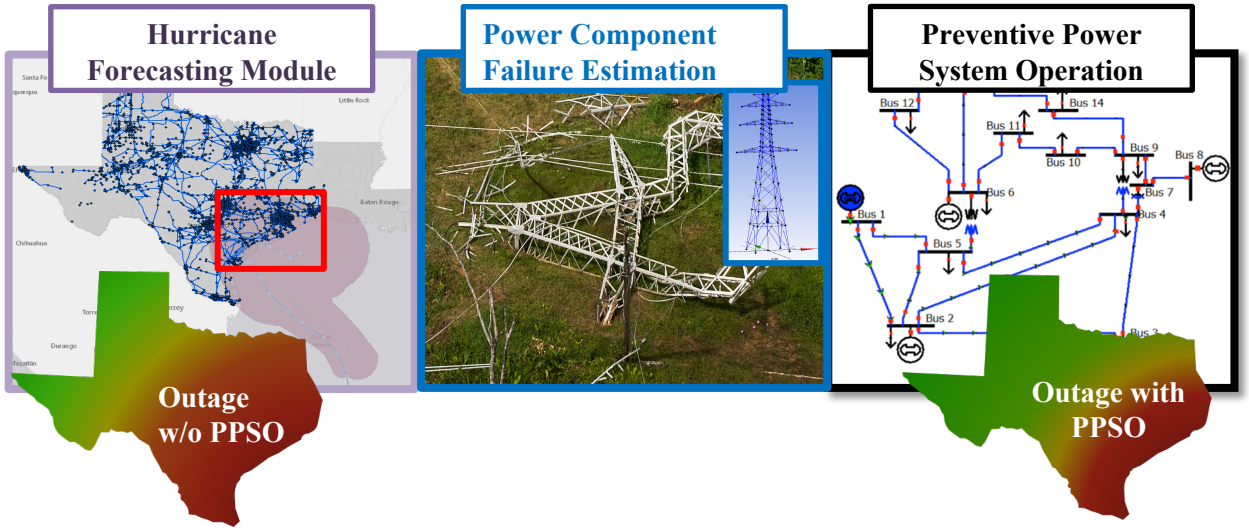
Preventive Power System Operation During Hurricanes



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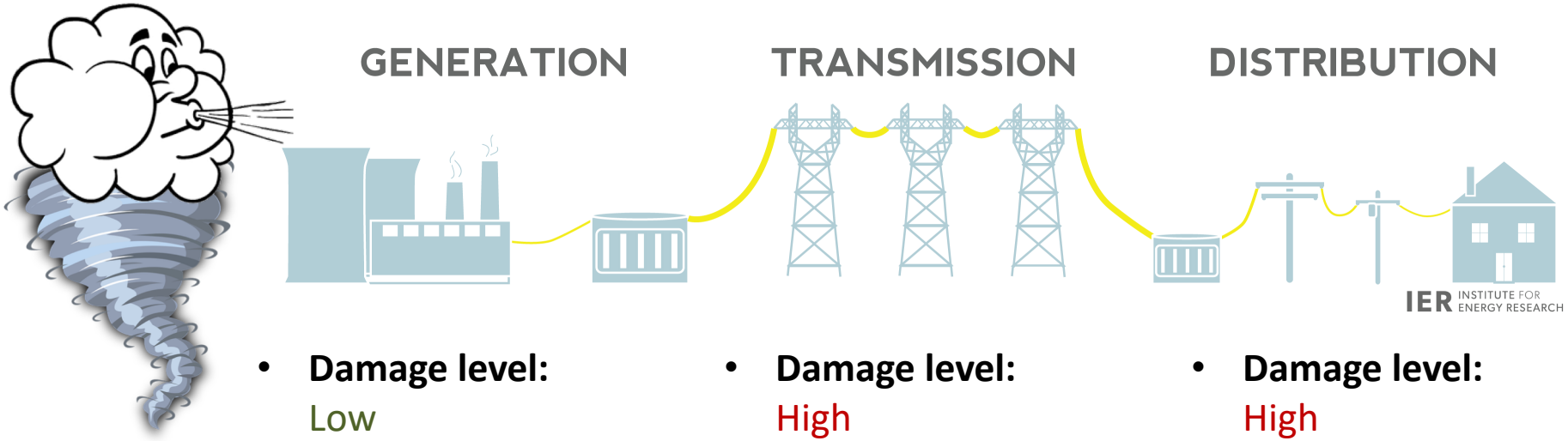
Hurricane Impacts on Power Systems



- **Damage level:** Low
- **Main cause:** Flooding
- **Wind**: Rarely an issue

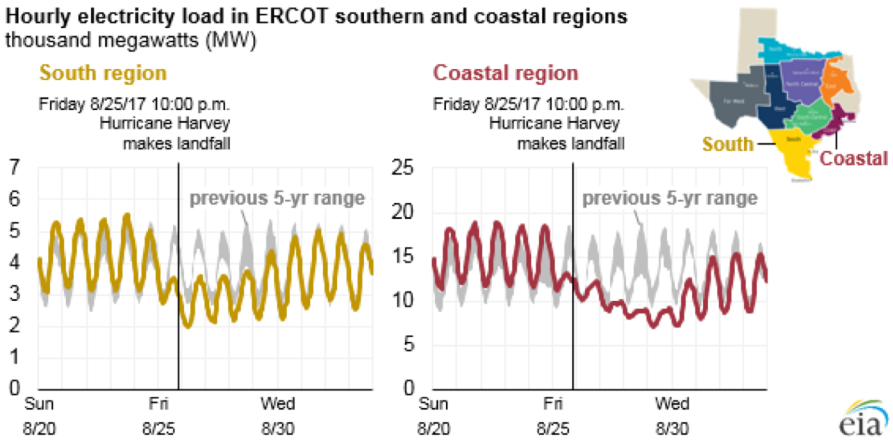
- **Damage level:** High
- **Main cause:** Wind force
- **Flooding**: May aggravate the situation

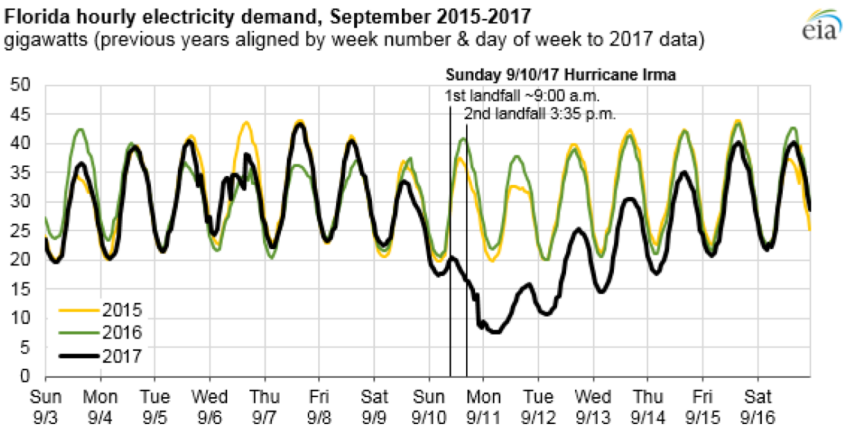
- **Damage level:** High
- **Main cause:** Wind force
- **Flooding**: May aggravate the situation

Power Outage Statistics

- Hurricane season of 2017:

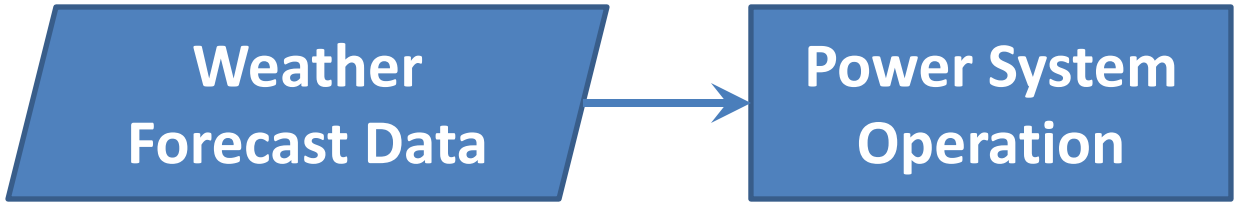
Harvey	Irma	Maria
August	September	September
• 300,000 customer outages in Texas	• 6 Million customer outages in FL (59%) • ~1 Million customer outages in GA (22%)	• 100% customer outage in PR





Employment of Weather Data

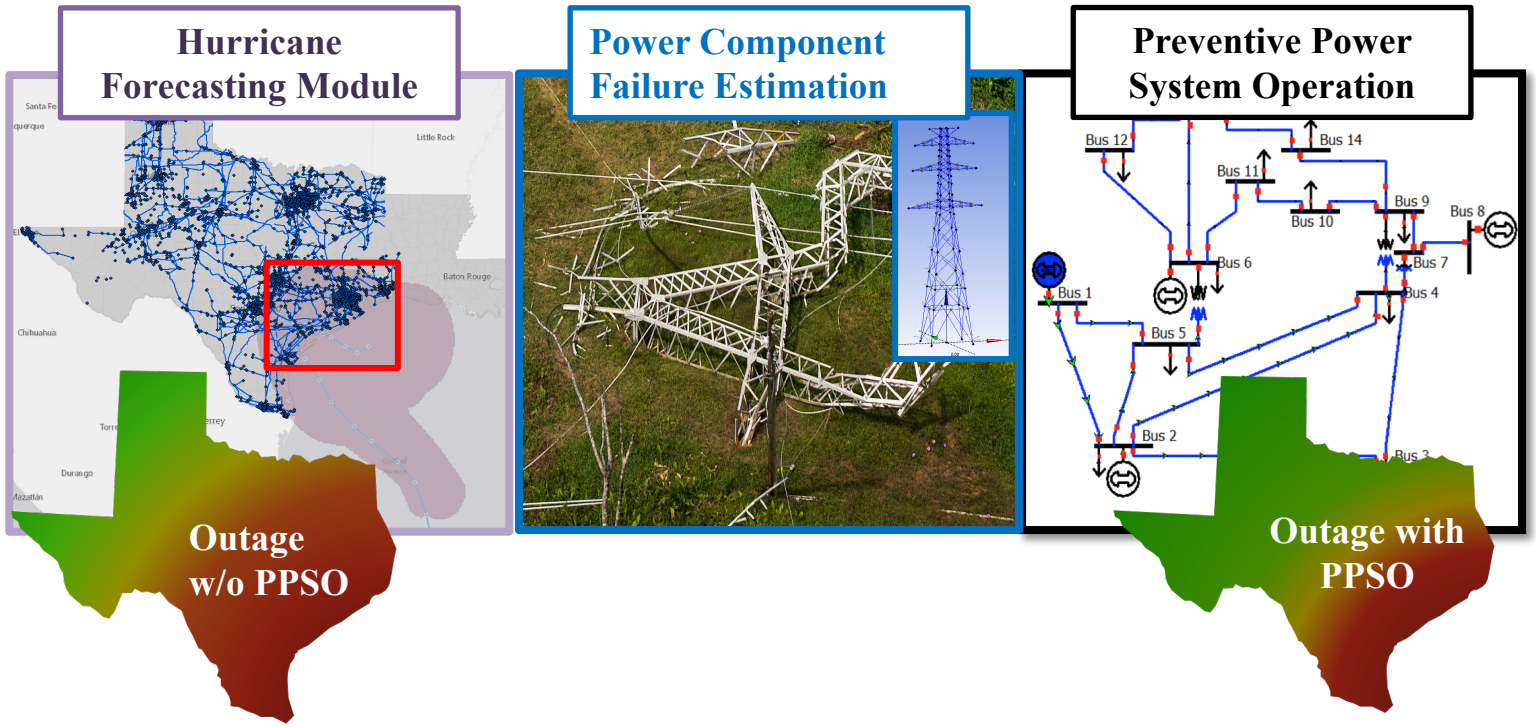
- Would integration of weather data in power system operation reduce the size and duration of power outages?



- **Availability of weather data:**
  - System operators have access to weather forecast services
  - In some cases, they also have access to meteorologists onsite
- **Existing technologies:**
  - Pre-storm outage forecast
  - Post–storm restoration planning
  - Long-term grid hardening
  - Emergency operation based on engineering judgement

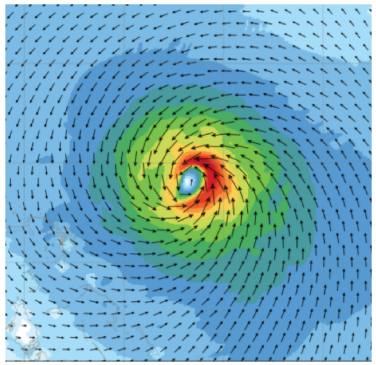
Proposed Integrated Platform

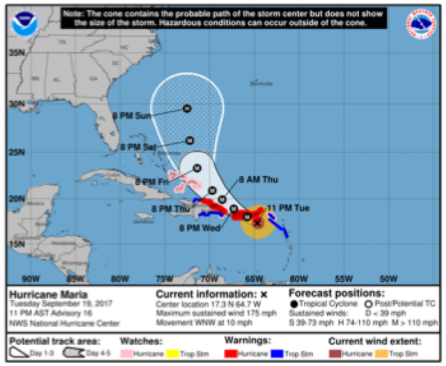
- Systematic integration of weather forecast data in power system operation
  - Translation of weather data into useful information for operation: **component damage probability**

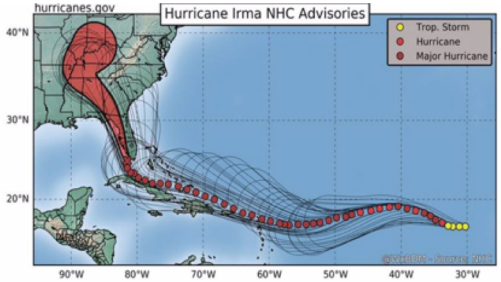


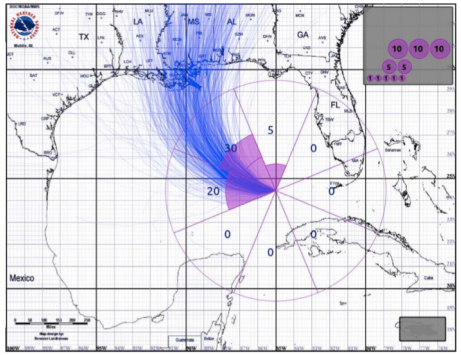
Weather Forecasting (Atmospheric Sciences)

- High-resolution wind field modeling
  - 1 Km horizontal
- Hurricane track and movement speed estimation
- Ensemble forecasting
  - Multiple tracks with different probabilities
- Forecast at different time scales
  - 5-day ahead, 48-hr ahead, day-ahead, hour-ahead







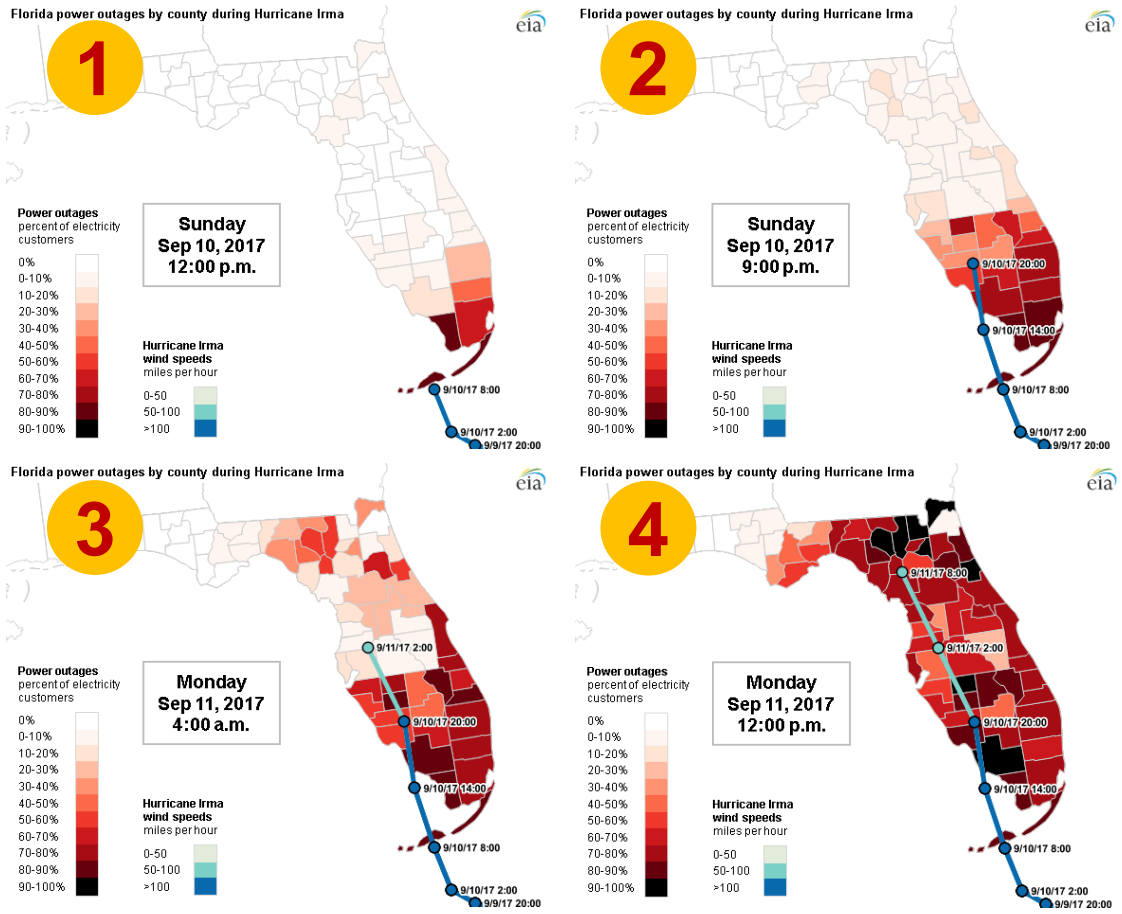


Component Failure Estimation

- Vulnerable components:
  - Transmission lines
  - Distribution lines
- We ignore distribution, because:
  - Distribution network is often radial, which makes preventive operation ineffective
  - Distribution-level damage causes local power outage
  - Transmission-level damage can cause power outage in areas, not directly affected by the hurricane
- Transmission failure is estimated based on:
  - The dynamic loading of the wind
  - Likely important factors that are neglected in our existing model:
    - Debris modeling
    - Flooding and precipitation

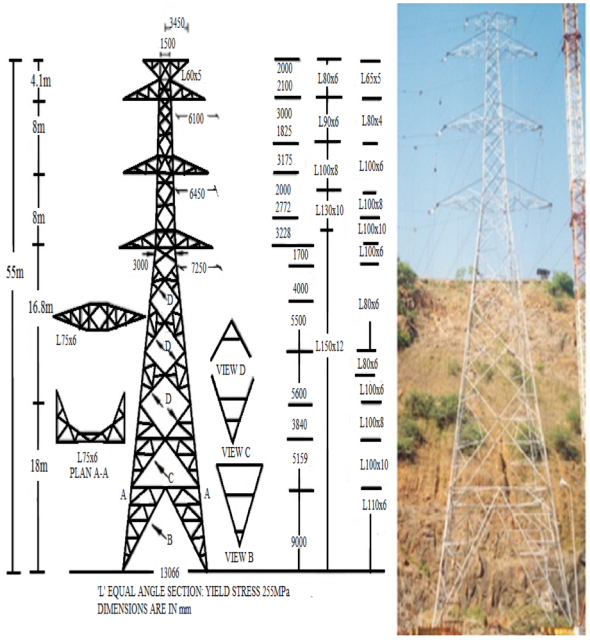
Why Focus on Transmission?

- Power outage in the areas, not in the hurricane track, is due to transmission-level damage.
- Such outages may be manageable, through weather-aware preventive operation.
- Transmission line outages in the past:
  - Harvey: 97 lines (>139 kV)
  - Sandy: 218 lines (>115 kV)

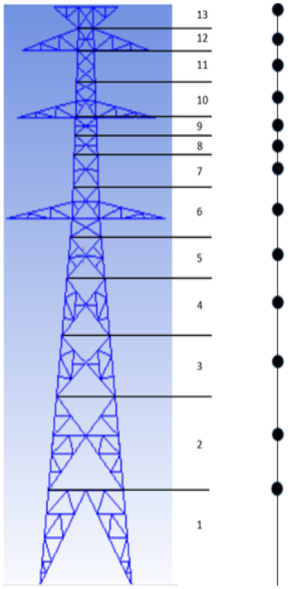


Transmission Failure Estimation I

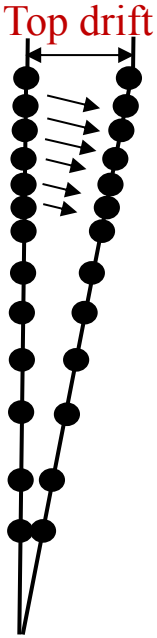
Structural Drawings



Finite Element Modeling



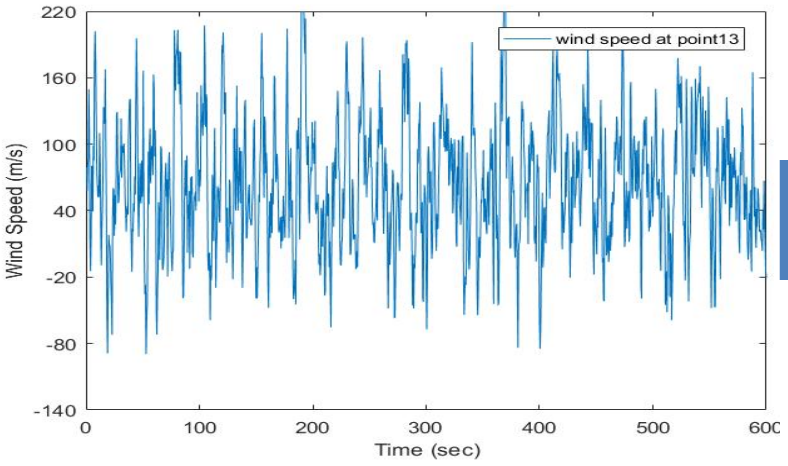
Stability under Dynamic Wind Loading



Tower drift
1.5%, 2%, 2.5%, 3%

Transmission Failure Estimation II

- Finite element (FEM) models can be computationally demanding
- FEM will be used to develop fragility curves
  - Probabilistic description of failure likelihood, based on the wind speed



200 random wind speed samples

Finite Element Model