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IMPACT OF A TARGETED SENSOR NETWORK AND ADVANCEMENTS IN PREDICTION MODELS ON WIND GENERATION FORECASTS IN THE TWRA

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Overview

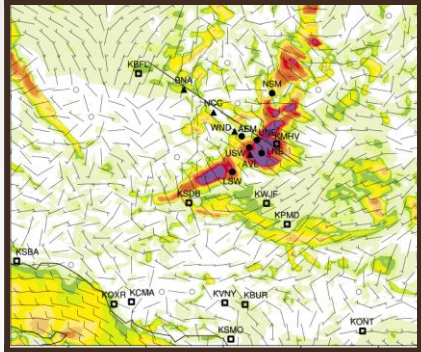
- **Background and Motivation**
- **Description of Forecast Improvement Focus Areas**
- **The Upcoming Final Steps:**
  - Putting together the pieces
  - Evaluating the integrated result

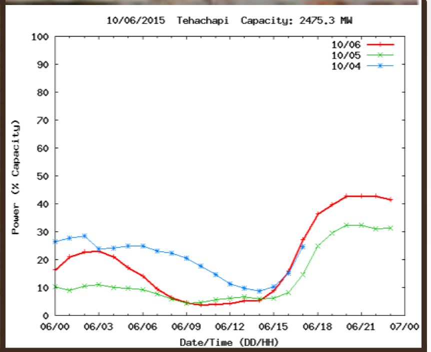
BACKGROUND AND MOTIVATION

Project Objectives

- **Ultimate goal:** reduce the cost of integrating renewable-based generation into grid while maintaining system reliability

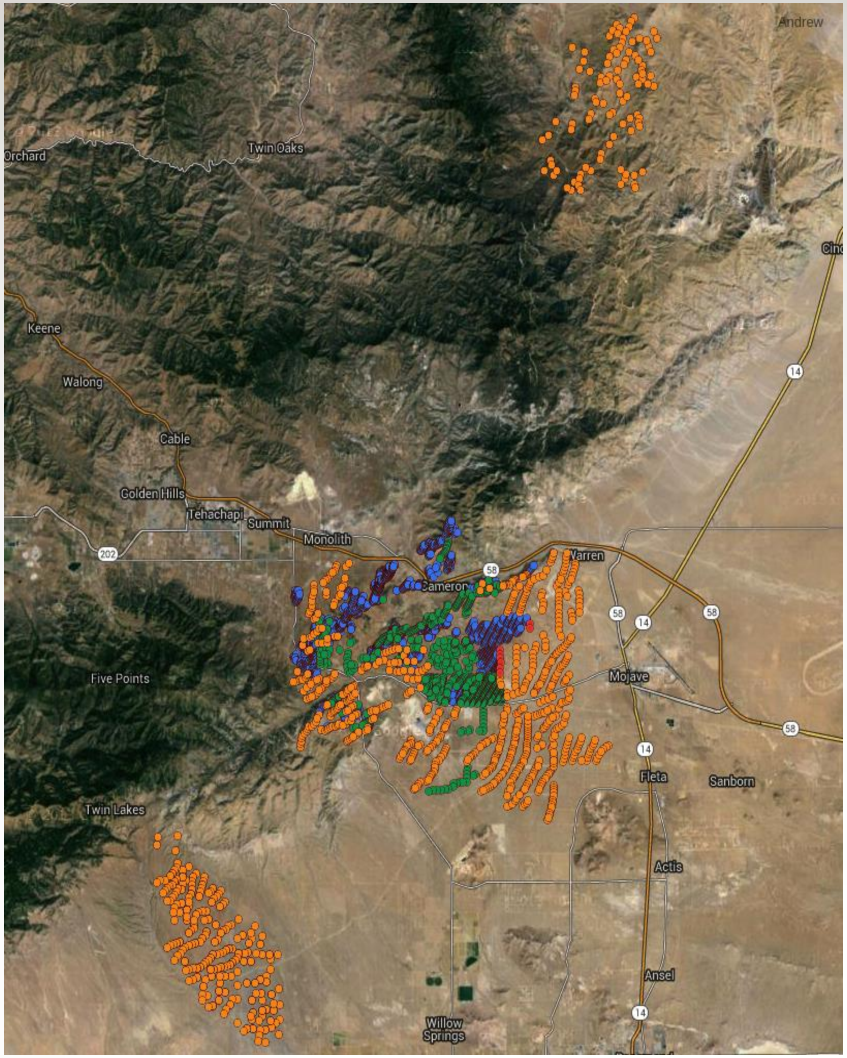
- **Specific Objective**: Improve frequently updated 0-12 hour forecasts of wind-based power production in the Tehachapi Wind Resource Area (TWRA) with a focus on periods of large changes in generation





Project Scope

- 2.5-year project supported by the California Energy Commission (CEC) and Electric Power Research Institute (EPRI)
  - Original CEC funding for 2 years
  - Extended by EPRI
  - 2015-2017
- Tehachapi Wind Resource Area (TWRA)
  - > 3000 MW wind capacity (2319 MW in project)
  - Concentrated, highly correlated production
  - Complex terrain
  - Often driven by small-scale weather features
  - Data sparse area on the feature-scale
- **Multi-faceted approach to improve 0-12 hr power production forecast performance with focus on ramps**
- 1-yr evaluation period to assess integrated results of project (Oct 2015 – Sept 2016)



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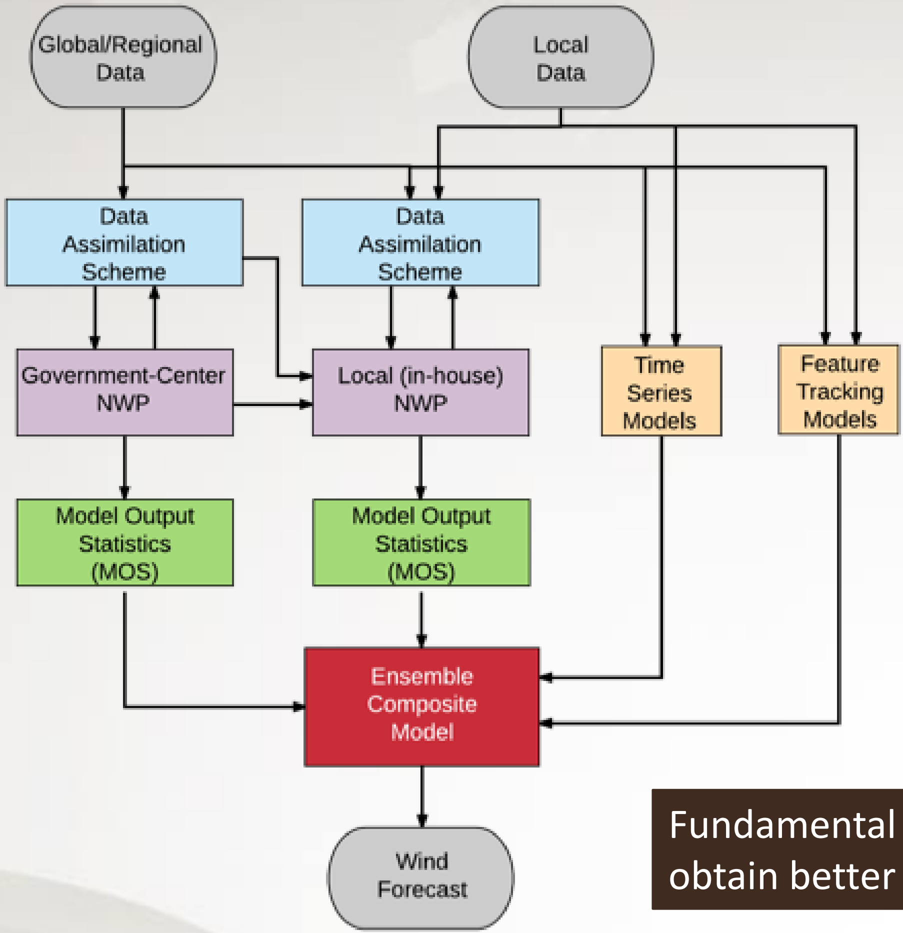
OVERVIEW OF FORECAST IMPROVEMENT EFFORTS

The Starting Point:
A Typical State-of-the-Art Wind Forecast System



Fundamental Question: How can we obtain better forecasts from it?

Components of Forecasting Improvement Effort

1. **Gather More Data:** Deploy targeted network of 6 sensors based on observation targeting analysis
2. **Optimize NWP Configuration**: Conduct WRF configuration sensitivity tests for a sample of 30 large ramp cases to determine best configuration for wind forecasting in the Tehachapi Pass area
3. **Improve NWP Data Assimilation of Local Area Data:** Implement Hybrid EnKF/GSI data assimilation approach (flow dependent data blending to more accurately spread the influence of point measurements for model initialization)
4. **Apply Latest Machine Learning (ML) Tools to NWP MOS**: Improve ability to correct regime-based systematic errors (biases) in NWP forecasts
5. **Improve Time Series Prediction for 0-3 hr Forecasts:** Exploit information in off-site data (project sensor data and non-project off-site sensors) through application of latest ML methods

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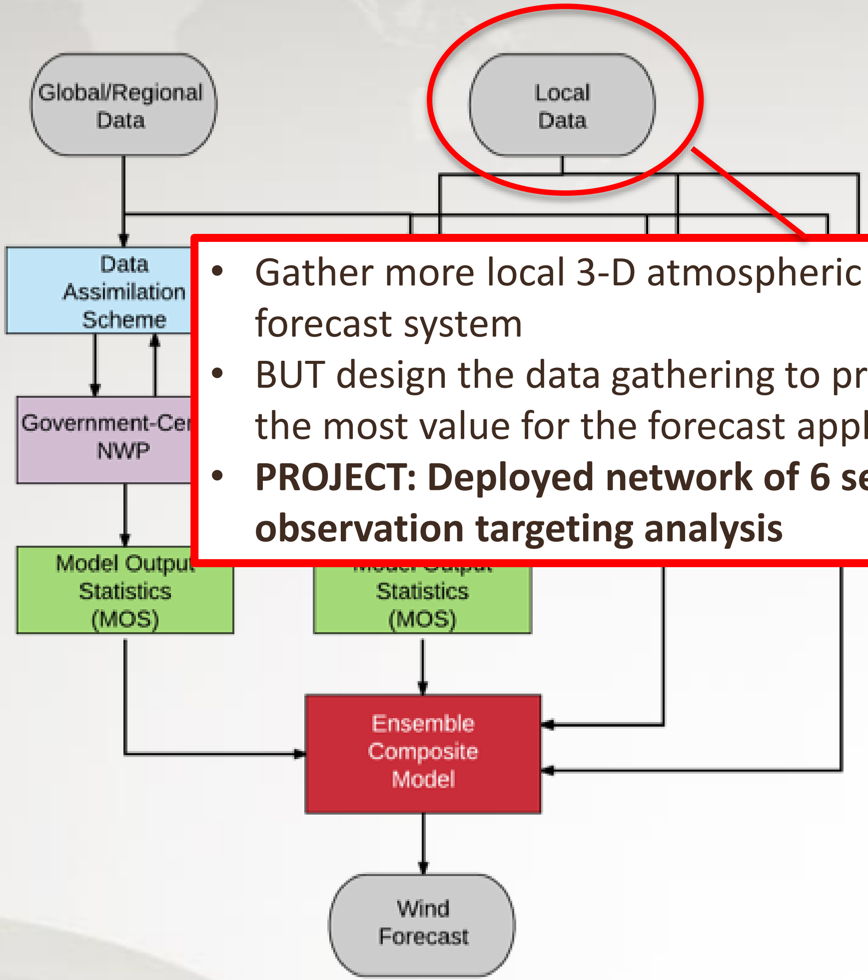
Improving a Wind Forecast System: Gathering Additional Data



- Gather more local 3-D atmospheric data for input into the forecast system
- BUT design the data gathering to provide the data that has the most value for the forecast application
- **PROJECT: Deployed network of 6 sensors based on observation targeting analysis**

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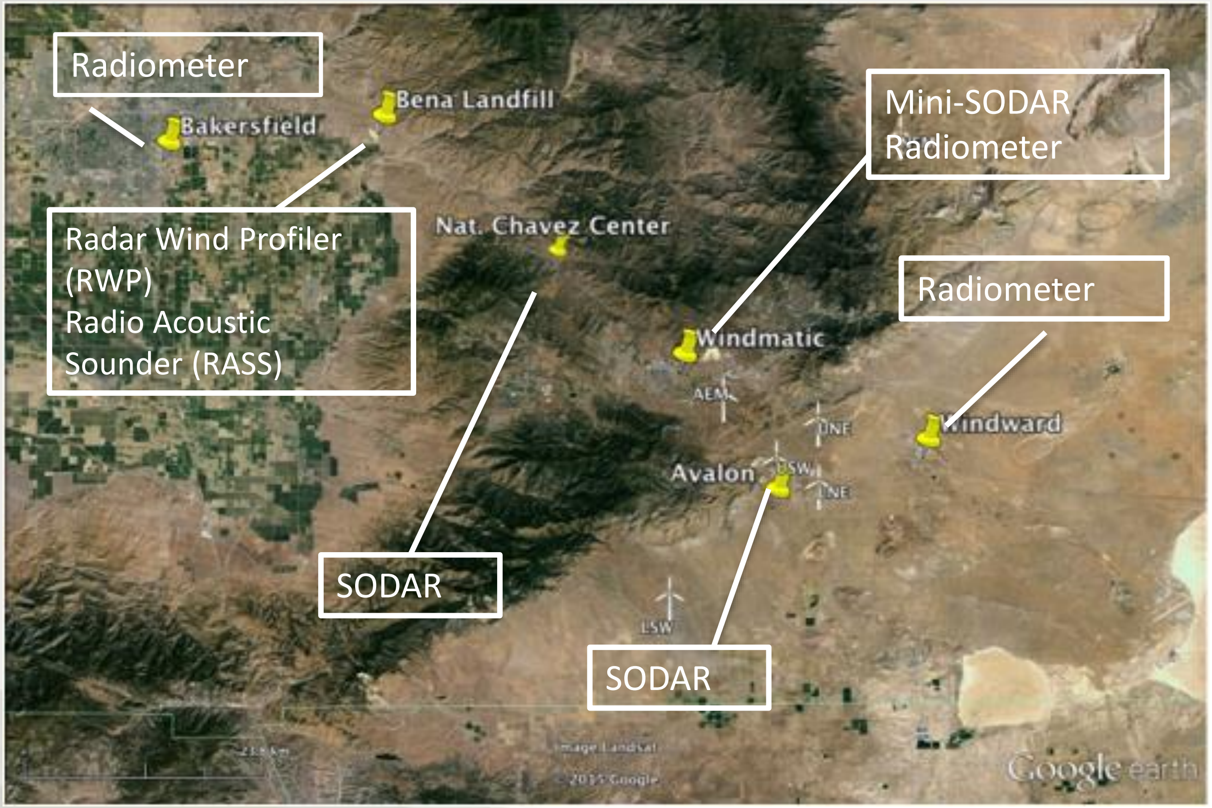
Targeted Sensor Network

- **Sensors deployed at 6 targeted locations for a ~ 1-year period**
- **Anticipated applications**
  - Provide additional real-time input data for the forecast models
  - Increase understanding of atmospheric processes that drive wind variability
  - Provide guidance for forecast model improvements and evaluation



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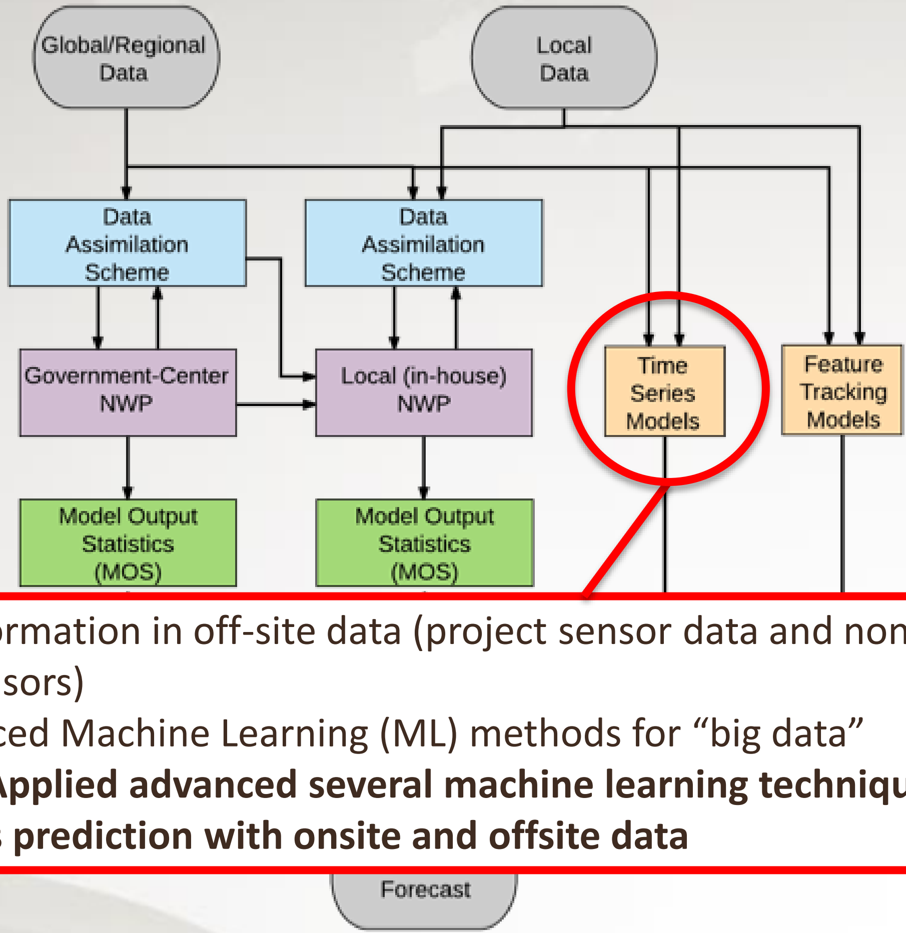
Improving a Wind Forecast System: Time Series Modeling



- Exploit information in off-site data (project sensor data and non-project off-site sensors)
- Use advanced Machine Learning (ML) methods for “big data”
- **PROJECT: Applied advanced several machine learning techniques for time series prediction with onsite and offsite data**

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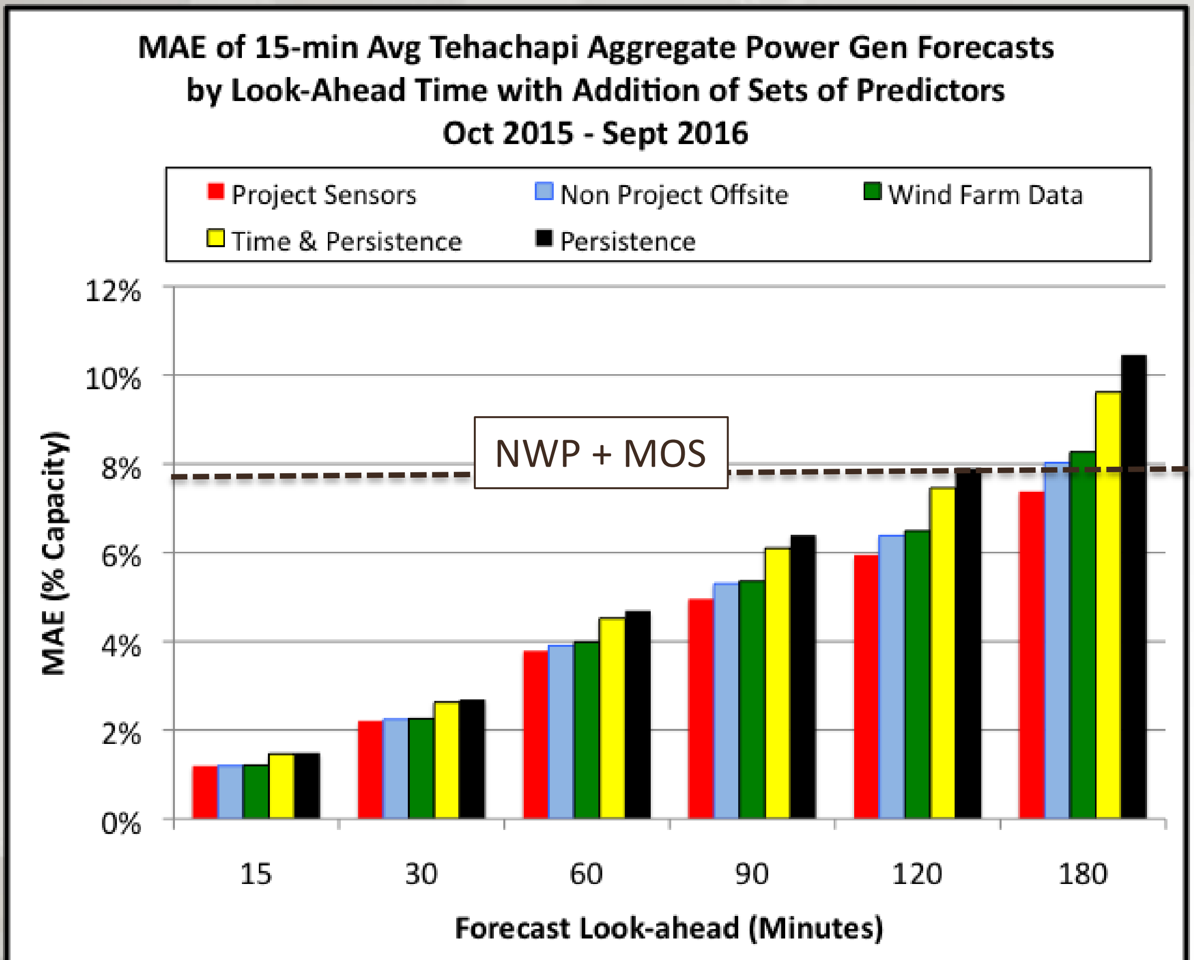
Time Series Forecast Configuration

- 15-minute forecast cycles
  - More frequent updates than possible with current NWP
- Employed Gradient Boosted Machine (GBM)
  - Multi-step decision-tree technique
  - Each step attempts to forecast the residuals from the preceding step
- 1 year forecast evaluation period
  - Oct 2015 – Sept 2016
- 25 months of training data
  - Trained on 24 months, forecasted for 1 month
- Predictors: 61 subjectively selected variables
- Predictand: ramp rate from 0 to look-ahead time

Performance of Time Series Forecasts



- Each successive group includes all of the predictors from the previous group plus the predictors from that group
- Same set of predictors for all look-ahead periods
- GBM model trained separately for each look-ahead period
- Results are for forecast intervals for which all data was available – 32.4% of the possible intervals in the 12-month period
- NWP + MOS method yields average MAE ~8% over 0-15 hour period

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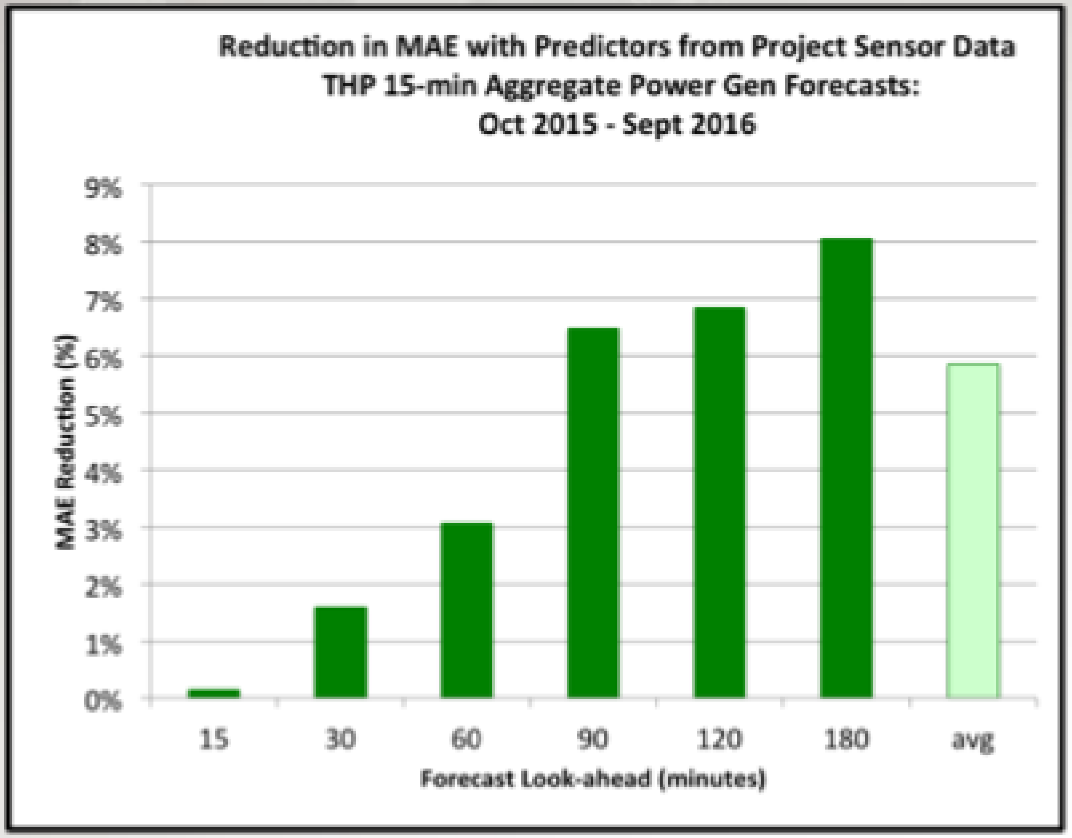
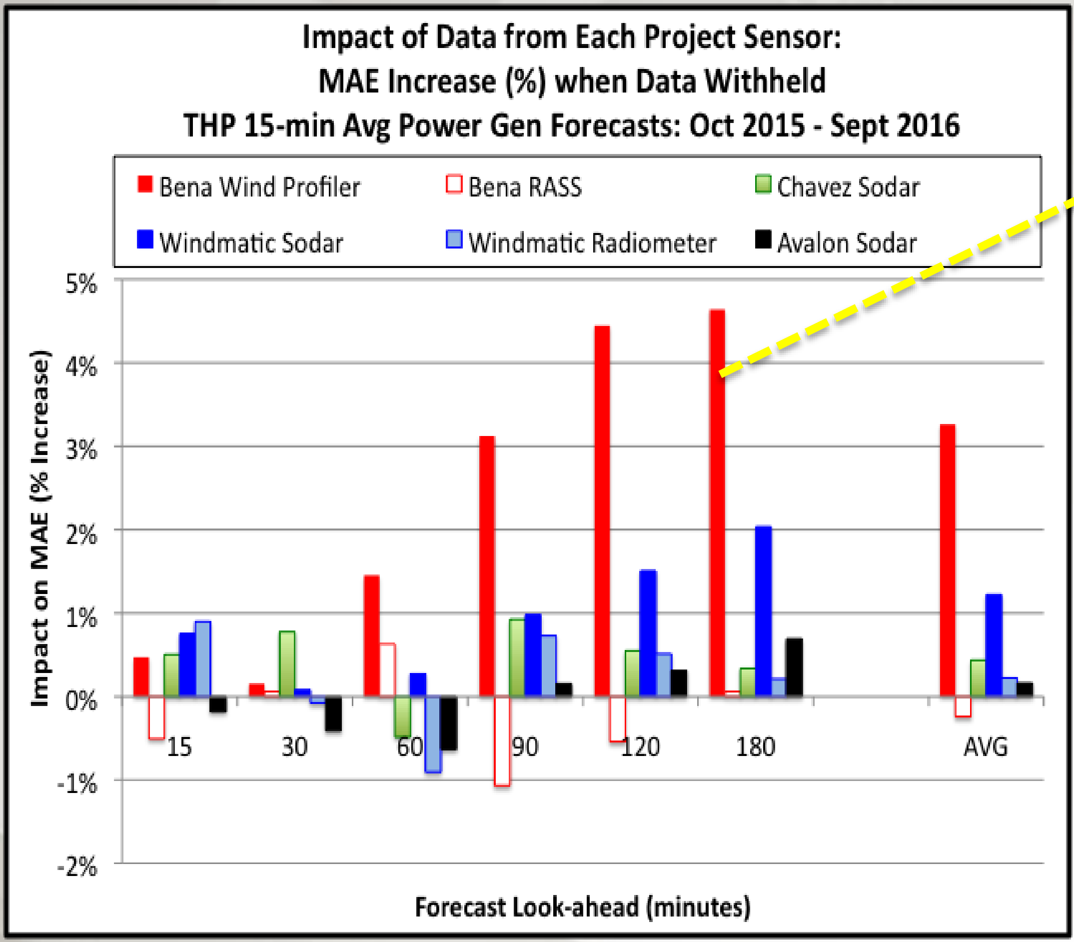
Overall Impact of Data from Project Sensors



- **MAE reduction relative to forecasts with all non-project predictors**
- Impact of project data increases with increasing look-ahead time out to 180 minutes
- Results are for all forecast intervals over the 1 yr period
- Next step: analyze ramp vs. no-ramp periods and optimize prediction method for ramp periods

Relative Impact of Data from Each Project Sensor



- Produced forecasts with data from each sensor sequentially withheld
- Metric: % change in MAE when data from each sensor is withheld
- Wind profiler at Bena provide the most forecast value – upstream winds above Pass level

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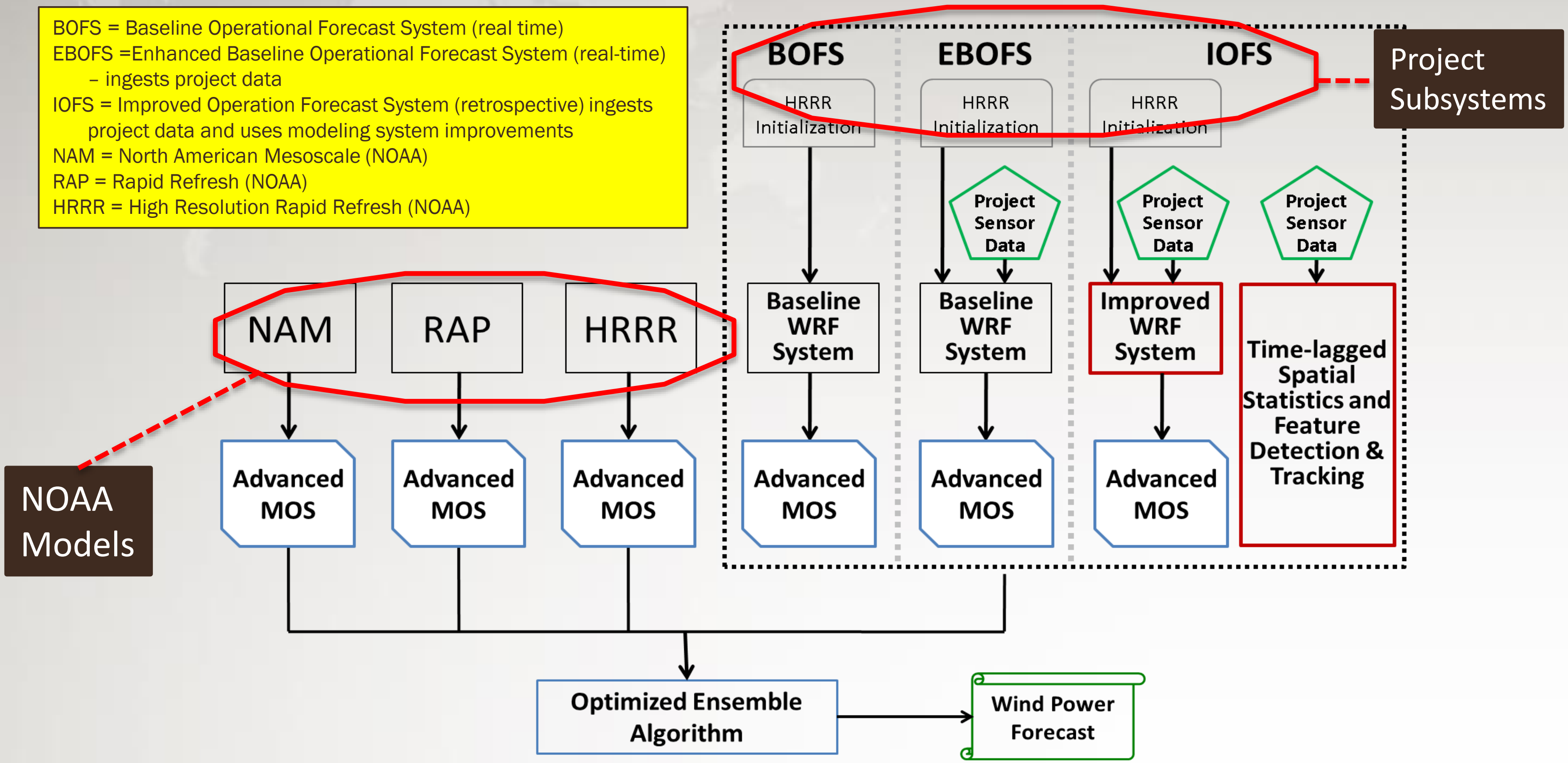
THE FINAL STEP:
PUTTING TOGETHER ALL THE PIECES AND EVALUATING THE INTEGRATED RESULT

Evaluation Experiment Design

BOFS = Baseline Operational Forecast System (real time)
EBOFS =Enhanced Baseline Operational Forecast System (real-time) – ingests project data
IOFS = Improved Operation Forecast System (retrospective) ingests project data and uses modeling system improvements
NAM = North American Mesoscale (NOAA)
RAP = Rapid Refresh (NOAA)
HRRR = High Resolution Rapid Refresh (NOAA)



- Generate forecasts from three versions of the system over a one-year evaluation period
- Evaluate the differences in performance among the forecasts produced by each version

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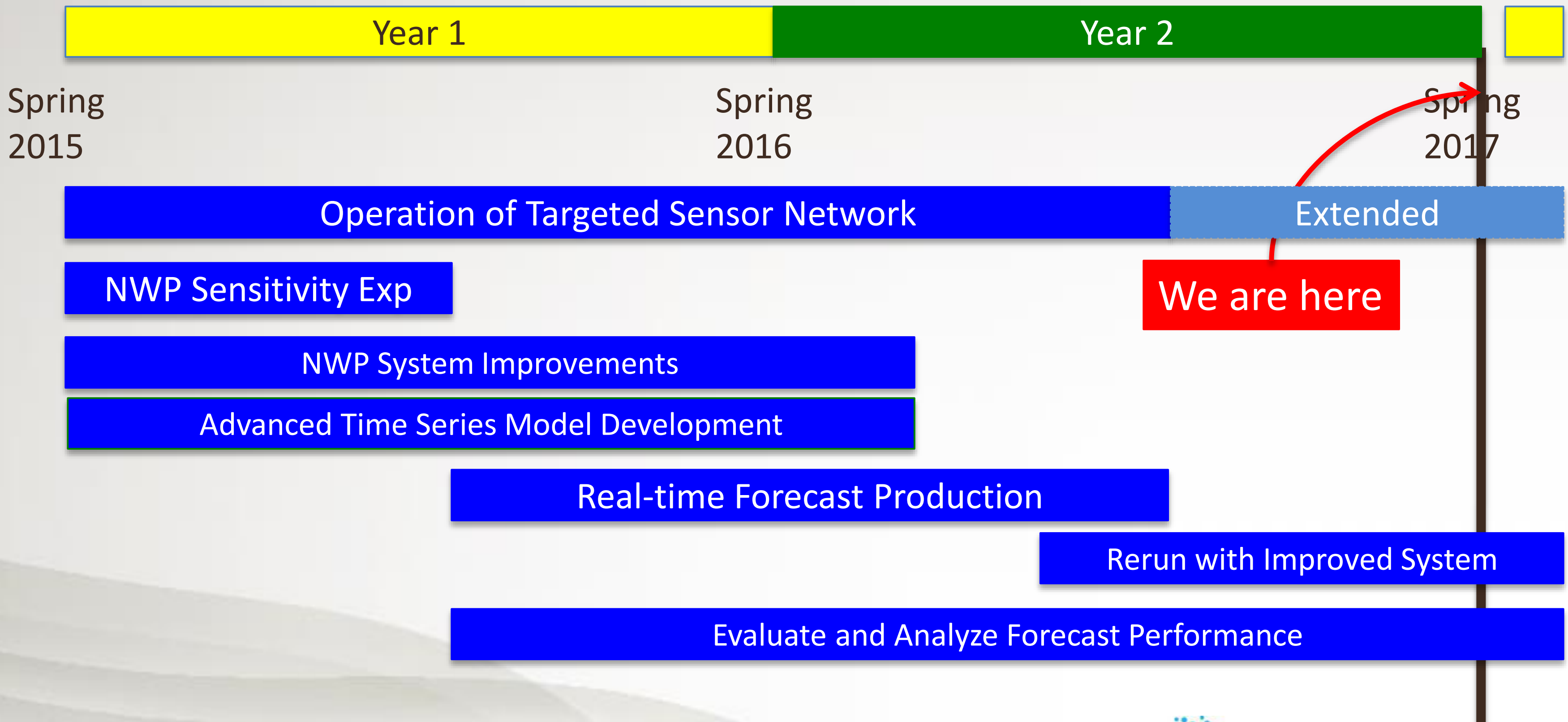
Next Steps

- Generate forecasts from improved system (IOFS) for 1-yr period
- Evaluate and analyze impact of system enhancements (data and methods)
- Deploy forecast system components into operational use where possible
- Stakeholder engagement to maximize value to applications



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