NASA Products to Enhance Energy Utility Load Forecasting

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Project Overview

- Funded by the NASA Applied Sciences Program

- Project Goal: develop applications of NASA products to meet the needs of energy companies for both short-term and long-term planning

- Partners: Battelle, Ventyx, NASA Langley Research Center, NASA Marshall Space Flight Center

Project Motivation

- Current daily load forecasts have mean absolute percent error (MAPE) values of 5%-7% for natural gas companies, and 1%-3% for electric companies

- Uncertainty in forecasts has the potential to waste money and resources

- Refinement to weather inputs could lead to substantial cost savings and more efficient use of resources
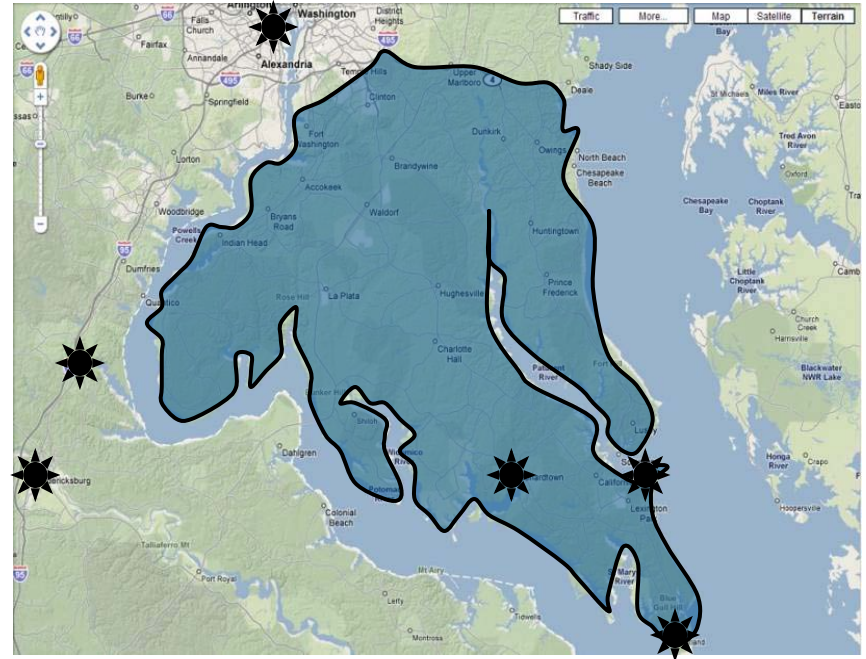
Cost Savings: Electric

Example of a Cost Benefit Analysis performed for use of a satellite weather product in electric forecasting

- With an estimated 10% reduction in error in 3-hour temperature forecasts, within-day models, and conservative assumptions:

  - U.S. electric utilities (total production in 2000 of 3,413,000,000 MWH) would save:

    - $479 Million/year (assumes spot price in 2002 dollars of $41.3 / MWH)
    - Based on reduction of short-term power production and purchase
    - 3-hour forecast only – larger improvements possible with better 24-hour forecast
    - Temperature accuracy – wind speed, precipitation not included

Project Steps

Phase 1: Historical Testing – compare load forecast results with and without NASA satellite weather data.

Phase 2: Operational Testing - conduct real-time testing, fine tune and document benefits.

Phase 3: Nationwide Transition - transition documented improvements for sustained use of NASA resources by energy utilities nationwide, in a variety of load forecasting tools.

Climate Change Investigation: Assess NASA climate data, model products, and projections to identify those of potential value to utilities for long-term (seasonal to 40 years) planning.

For example, climate change impacts on:

– Infrastructure

– Load

– Integration of renewable energy such as wind
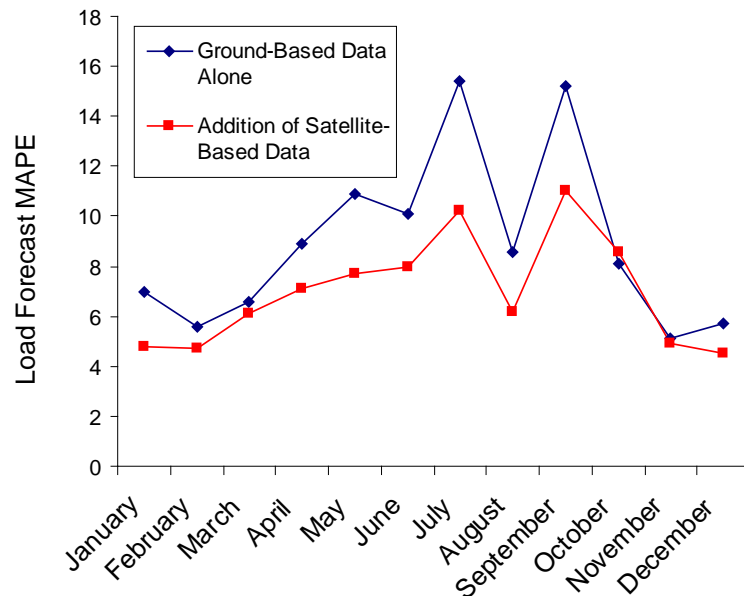
– Resource availability (e.g., water).
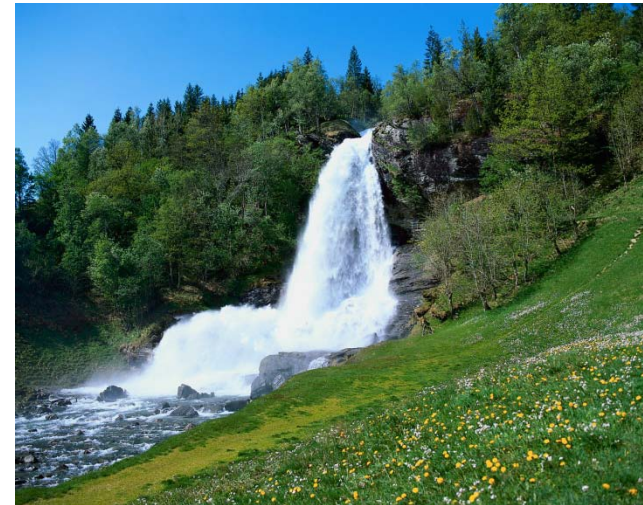
Weather Data in Energy Load Models

Problem – surface reporting stations and forecast sites are limited

- few and usually far apart

- not in representative areas because of terrain, or influenced by local effects

**Preliminary study showed that the use of more data improves load forecasts**

Weather data needs to be:

- Available in real-time (observations)

- Forecast at 1-3 hour intervals

- Forecast 1-10 days in future

- Parameters include Temperature (also daily max / min), Relative Humidity, Wind (speed/direction), Precipitation, Cloud cover, Solar energy, etc.

NASA Historical Data Sets

- Data sets spanning January 1983 to present

- Long-term satellite-based analysis of clouds, solar energy, and temperatures, 1°x1° resolution

- Satellite/ground-based precipitation products from the Global Precipitation Climatology Project ,1°x1° resolution

- Surface meteorological observations remapped for 1°x1° resolution

Average Daily Solar Radiation, January 2000
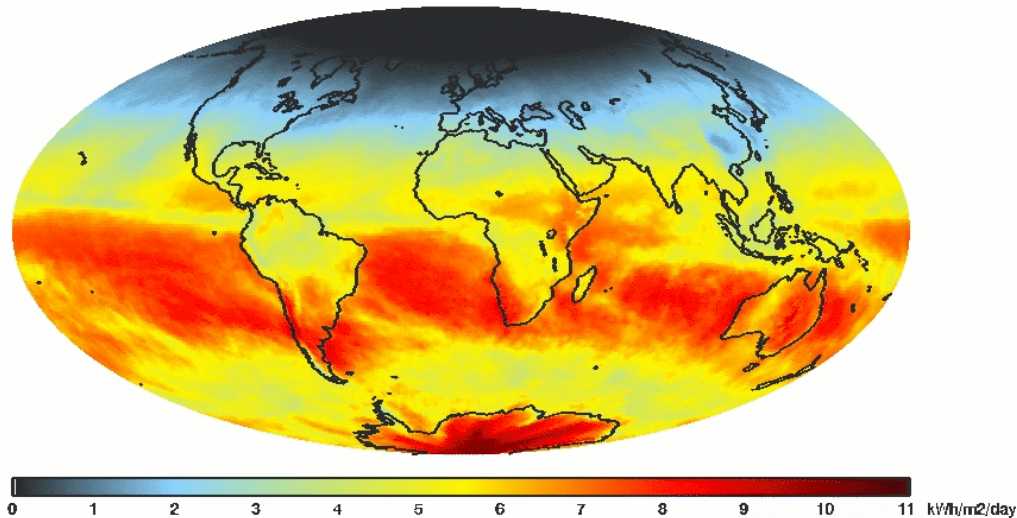
NASA Langley Surface Meteorology and Solar Energy (SSE), http://eosweb.larc.nasa.gov/sse/
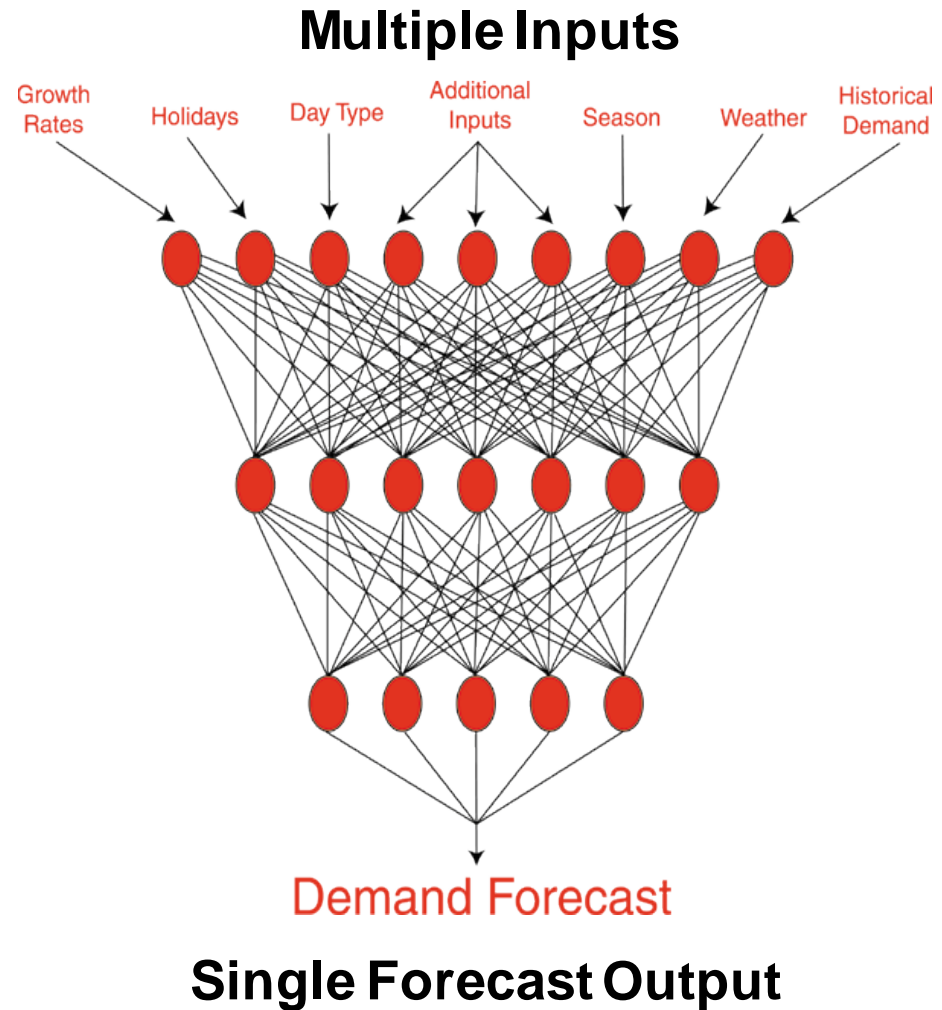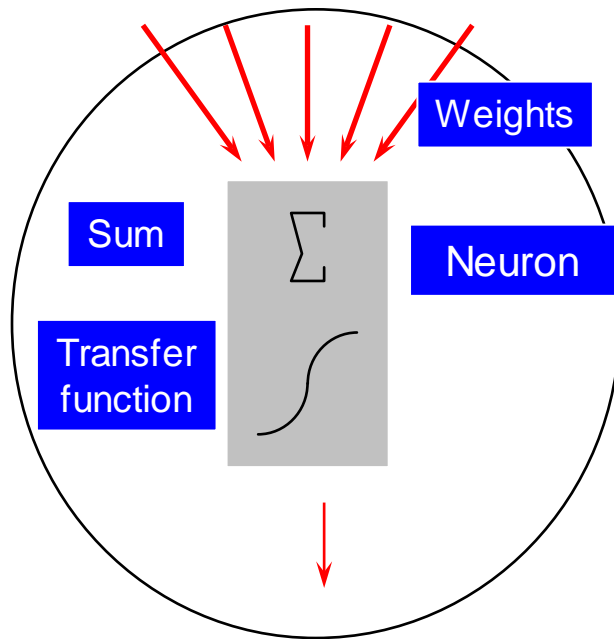
NASA High-Resolution Forecasts

- High resolution data from NASA satellites is used to diagnose current weather and improve forecasts
  - Forecasts are 4 km x 4 km resolution, Hourly
- New NASA model inputs are improving short-term forecasts:
  - High resolution maps of sea surface temperature
  - Assimilation of temperature and moisture profiles
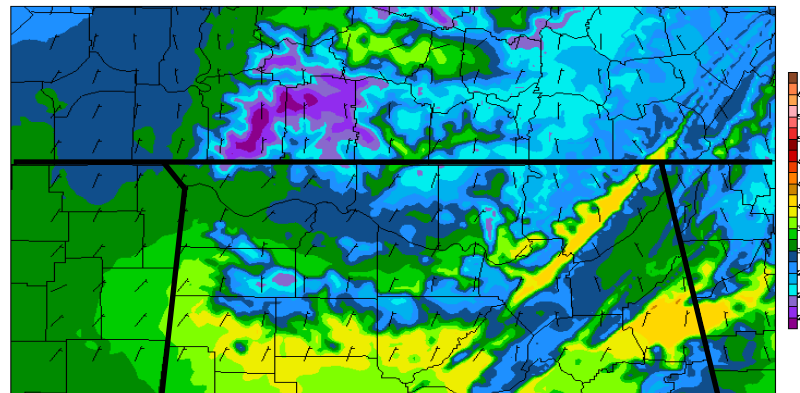
High resolution model data provides detailed temperature information over regions of interest

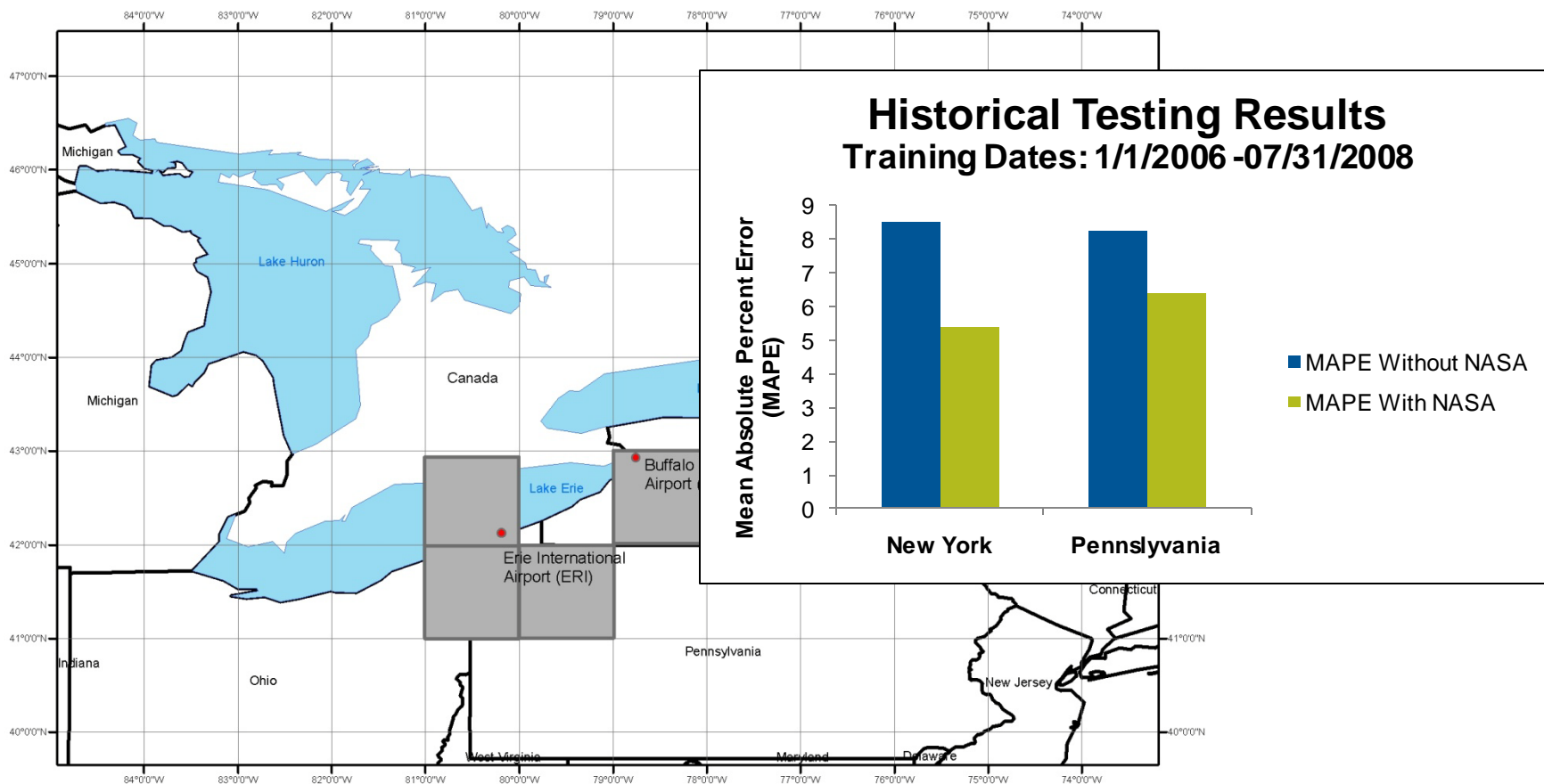NASA Marshall Short-term prediction Research and Transition Center (SPoRT)

Neural Network Models

- Initial project focus is on Ventyx's short-term load forecasting model

- The 3-layer neural network uses multiple inputs to forecast load demand

Multiple Inputs

Growth Rates   Holidays   Day Type   Additional Inputs   Season   Weather   Historical Demand

Demand Forecast

Single Forecast Output

Weights

Sum

Neuron

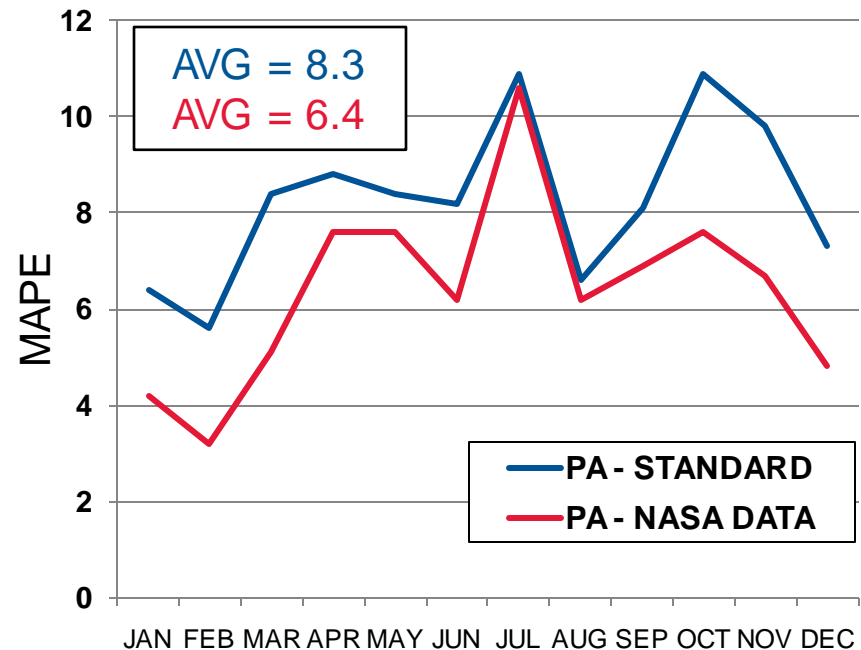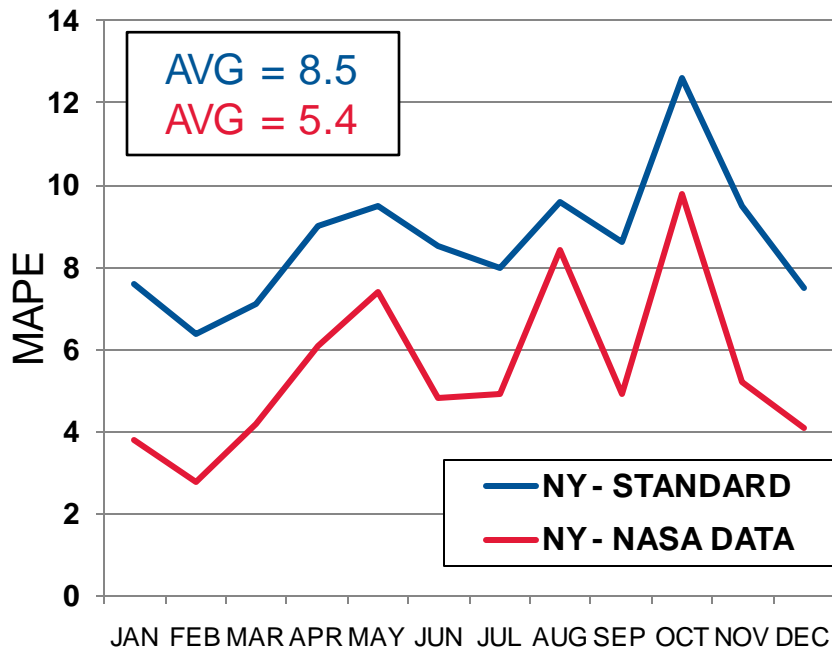Transfer function

Historical Testing Completed

- National Fuel, Gas Utility, Buffalo, NY

National Fuel Weather Forecast Map

◻ NASA Weather Forecast Gridcell
• Ground Weather Station

Historical Testing Results
Training Dates: 1/1/2006 -07/31/2008
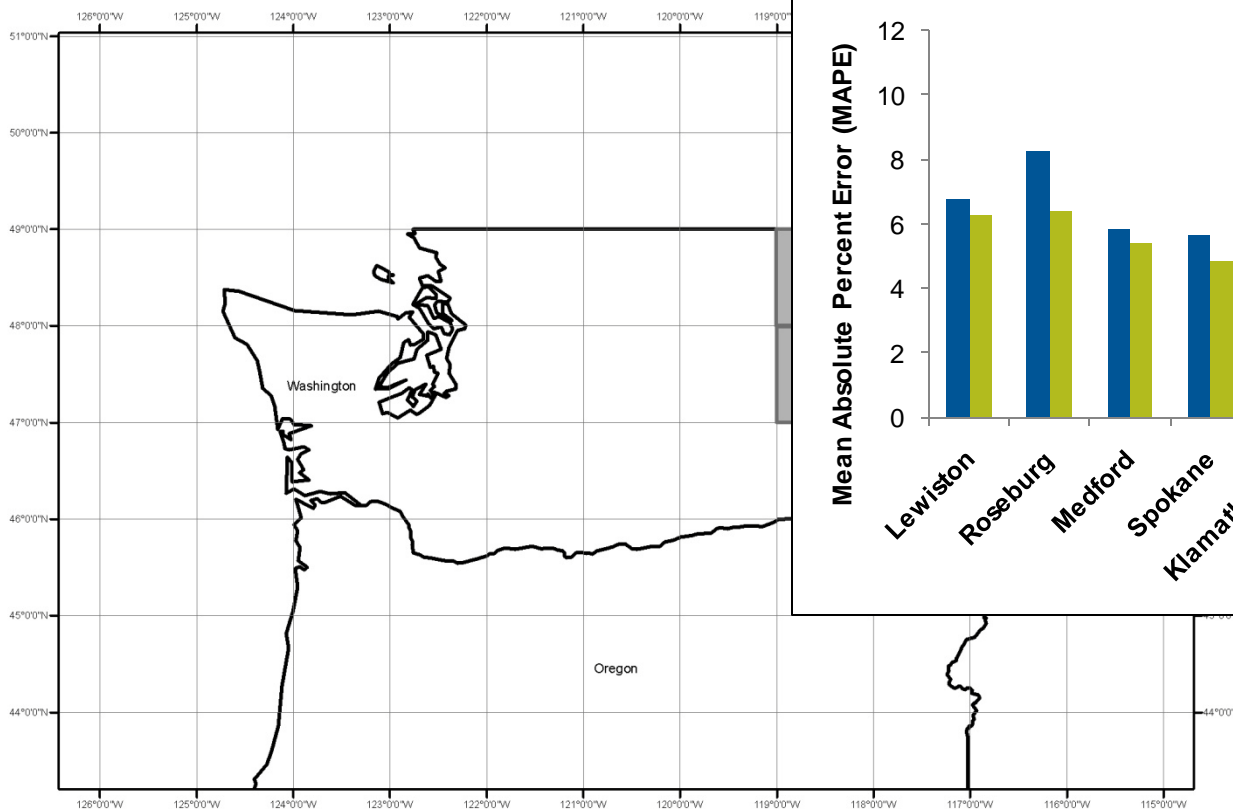
■ MAPE Without NASA
■ MAPE With NASA

Historical Testing Details: National Fuel

- Monthly MAPE results show improvements across the entire year with NASA data
  - Peak demand months reduced - up to 4.3 percentage pts.
  - Significant shoulder month improvements – up to 3.7 percentage pts.

AVG = 8.5
AVG = 5.4

NY - STANDARD
NY - NASA DATA

AVG = 8.3
AVG = 6.4

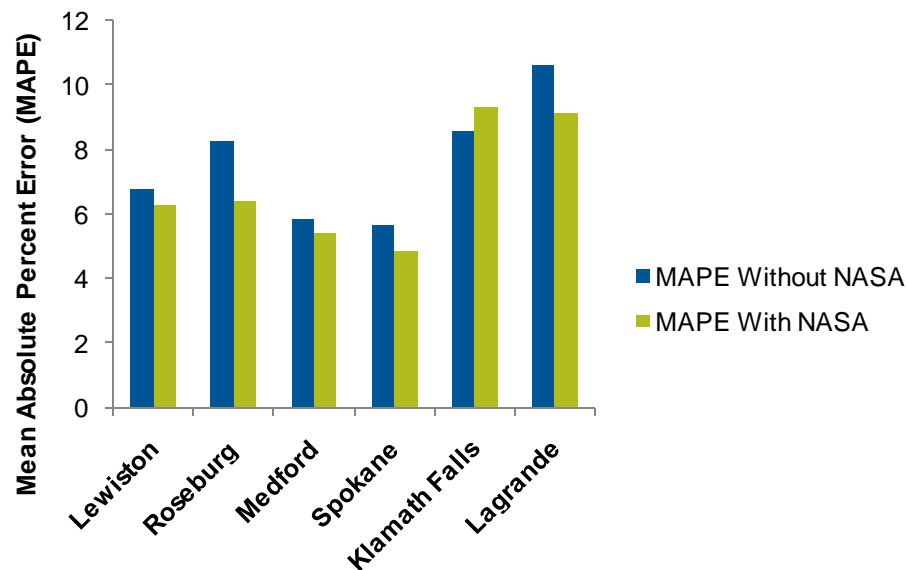PA - STANDARD
PA - NASA DATA

Historical Testing Completed

- Avista, Gas Utility, Spokane, WA

Avista Weather Forecast Map

NASA Weather Forecast Gridcell
• Ground Weather Station

Historical Testing Results
Training Dates: 1/1/2005 -07/31/2008

Mean Absolute Percent Error (MAPE)

Lewiston, Roseburg, Medford, Spokane, Klamath Falls, Lagrande

■ MAPE Without NASA
■ MAPE With NASA

Historical Testing Completed

- Southern Maryland Electric Cooperative (SMECO), Electric Utility

Historical Testing Results
Training Dates: 9/15/2008 - 07/15/2009

Mean Absolute Percent Error (MAPE)

- MAPE Without NASA
- MAPE With NASA

Today   Tomorrow
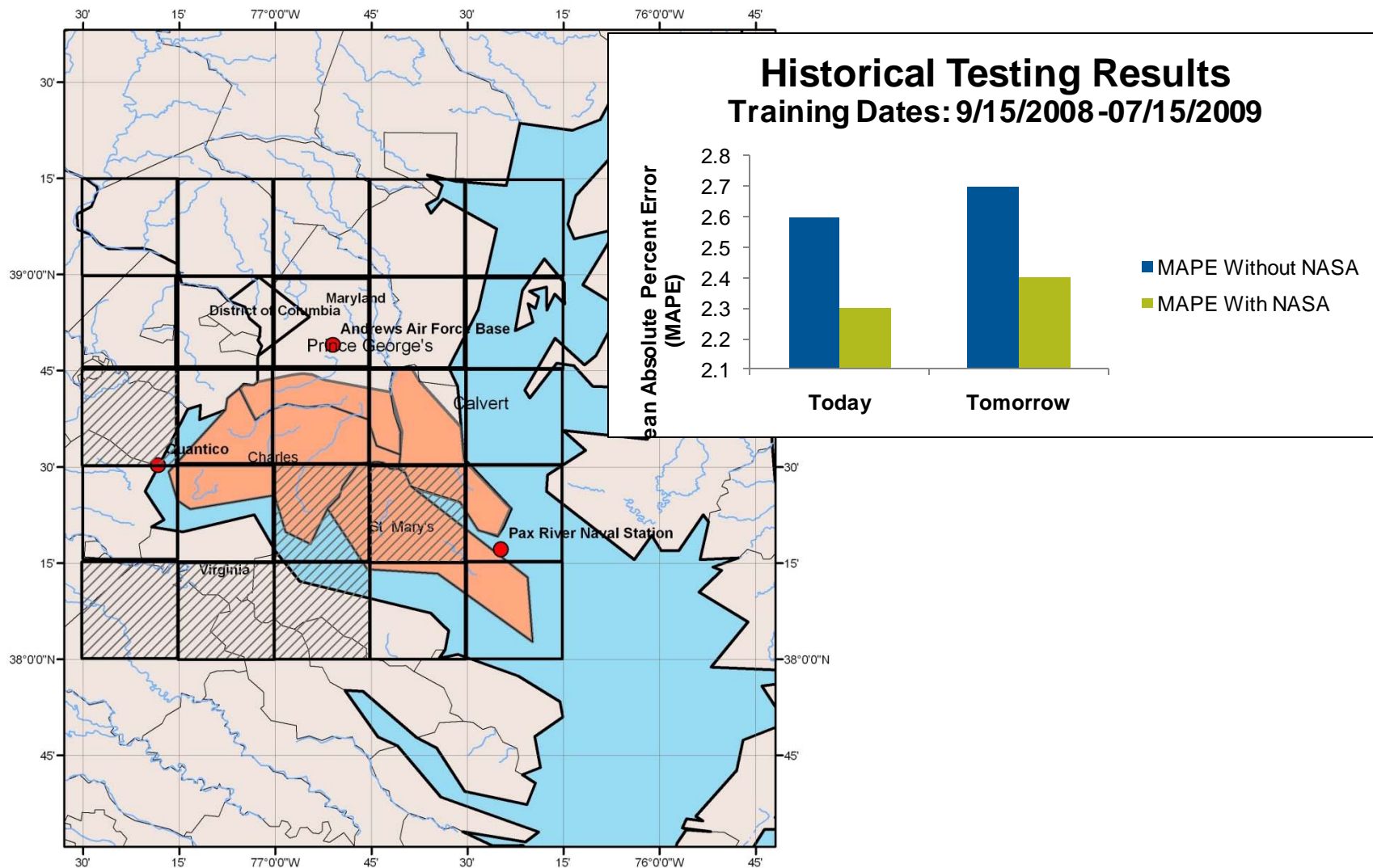
Historical Testing Completed
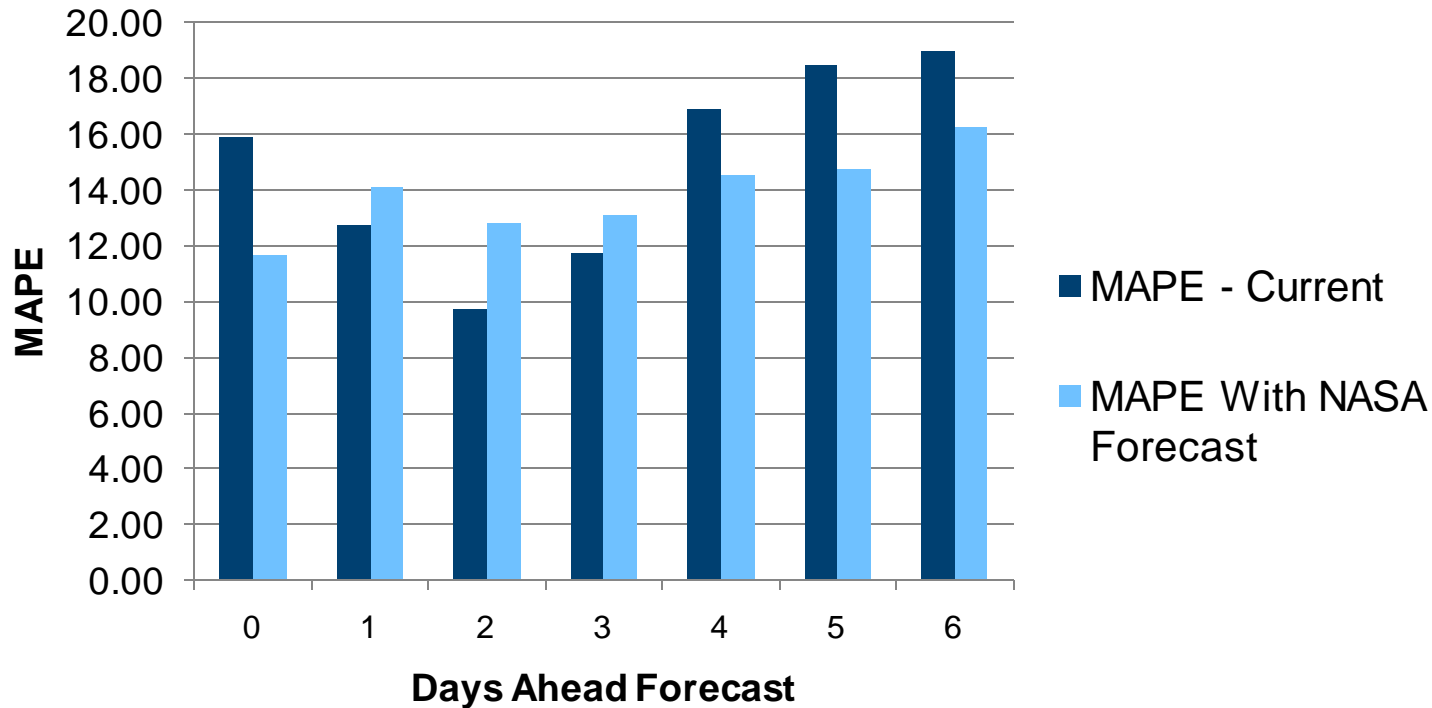
- Arkansas Electric Cooperative, Electric Utility
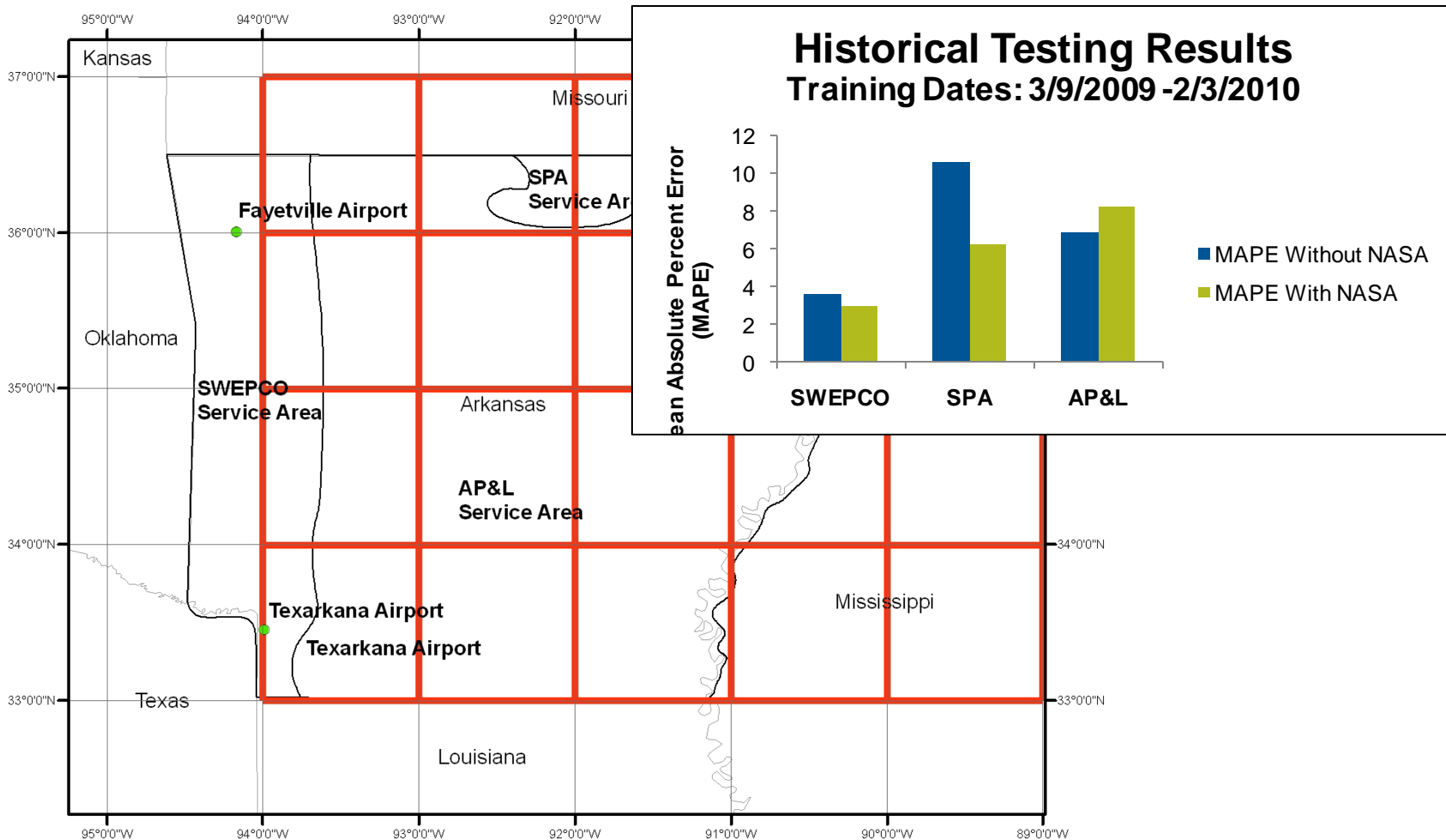
Operational Testing Just Started

- 3 out of 4 participating utilities (not Arkansas Electric yet)
- Have not encountered peak load seasons (summer and winter)

Pennsylvania Service Area – (May-June 2010)

Long-Term Planning and Climate Change

Climate Change Impacts

- Changes in climate could alter key parameters:
  - Base Planning Temperature
    - What will happen to the coldest winter day?
    - Will daily temperature profiles change?
    - Planning for record high summer temperatures

  - Infrastructure
    - Equipment may be running warmer all year
    - Pipeline/gas storage issues (temperatures, permafrost)
    - Outages from more intense storms

  - Water availability and temperature
    - Hydropower
    - Thermoelectric cooling

End-User Input on Climate

- Talked with long-term planners at utilities nationwide:
  - East Coast: PJM, Exelon
  - Northwest: Avista, Seattle City Light
  - Southwest: Tucson Electric Power, APS
  - Southeast: Tennessee Valley Authority
- Most planning is driven by cost considerations, and regulatory requirements.
- Every planning change or assumption they make must be defensible

Certainty is key!

(or at least quantifying uncertainty)

Long-term Utility Planning

- Our code for "climate change"

- Utilities prepare long-term integrated resource plans, out 10 to 20 years

- Very few regulatory authorities currently require consideration of climate change

NPPD

2 0 0 8
Integrated Resource Plan

Nebraska Public Power District
Always there when you need us
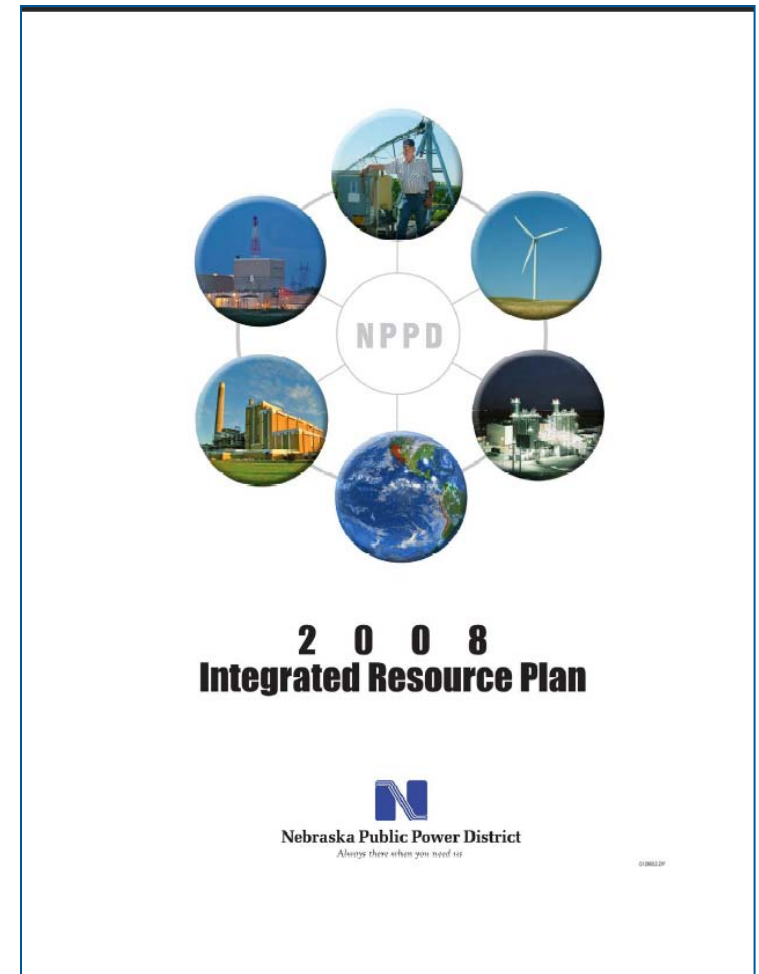
Long-term Utility Planning

- Most utilities currently assume climate is constant
  - Some utilities are shortening their "rolling average" window to 10-15 years (from 20-30 years)

- Planning driven by regulatory requirements
  - Coldest winter day
  - Typical monthly load profile
  - Controlling river temperature (e.g., for thermo-electric cooling and fish spawning)
  - Consumer rate protection

Long-term Planning Needs

Parameter	Specifics or Purpose	Region(s)
Temperature	20-30 years projected, peak summer high, peak winter low	All
Average Rainfall	Variability changes also requested	Midwest
Groundwater Resources	Increasingly important as pressures on surface water grow	Southwest, Midwest
Snowpack	SW impacted indirectly	Northwest, Southwest
River and stream temperature	Required for compliance with regulatory rules on fish	Northwest
Glacier Monitoring	Requested to help manage future hydropower resources	Northwest

Next Steps and Conclusions

- Continue operational testing at utilities.

- Third year of project will focus on transition:
  - Developing broader end-user group of utilities
  - Developing methodology and tools to provide access to NASA weather forecasts for input to load forecast models
  - Publicizing our results

- Wide variety of energy utility needs, vary by:
  - short-term operation vs. long-term planning
  - Region and regulatory authority
  - Current generating assets vs. renewable portfolio standard

One size does not fit all!

Acknowledgements

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