# Short-term Wind Forecasting using Off-site Observations and Numerical Weather Prediction

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# Outline

- Overview of 3TIER
- Short-range Forecasts using the Regime-switching Space-Time (RST) method
- Short-range Forecasts using Numerical Weather Prediction (NWP) and the challenge method
- Conclusions

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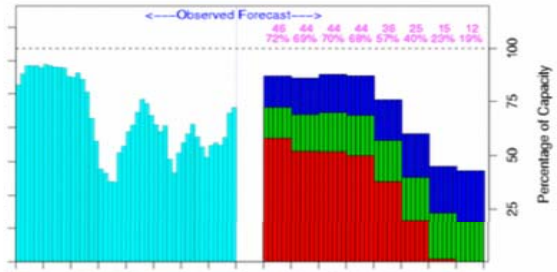
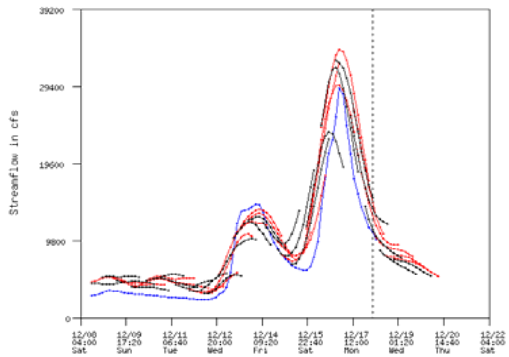
Wind Energy:

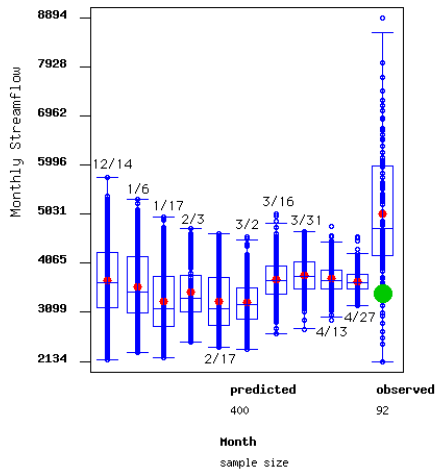



- Founded in 1999
- Forecast processes based on latest *proven* scientific techniques
- Close relationship with leading research and operational communities
- Focused on delivery of *environmental forecast products* for renewable energy resources at multiple time scales

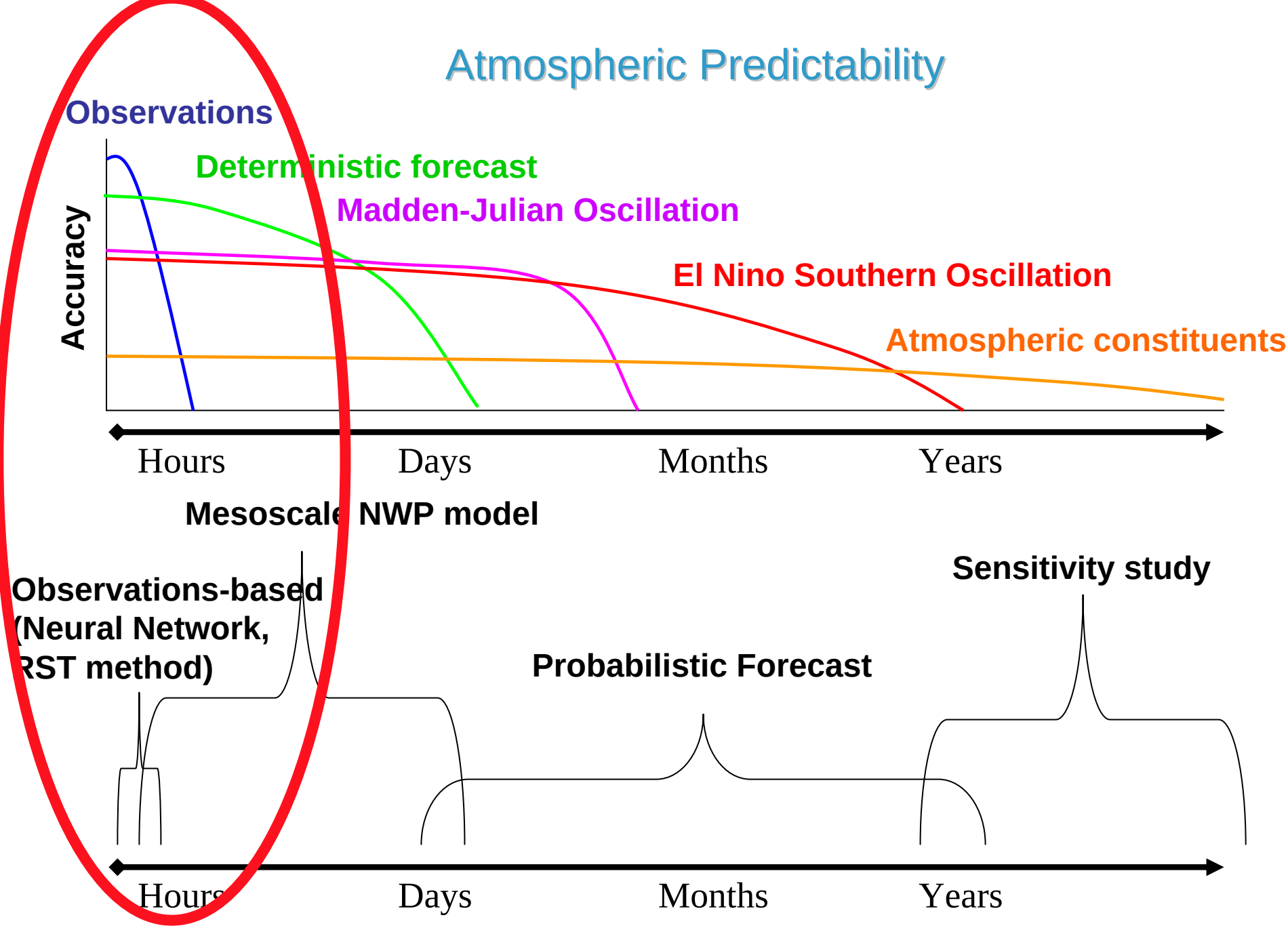
Hydro Operations:



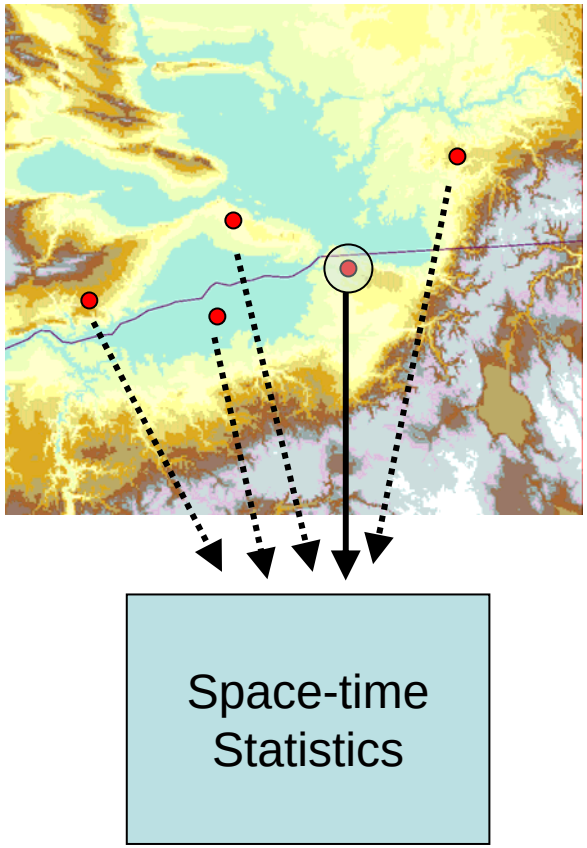

Seasonal Forecasts:



# Atmospheric Predictability



# Using Off-Site Observations




**DEVELOPMENT OF NEXT-GENERATION WIND FORECASTING TECHNOLOGIES**

**Project Description:** ***Identify and develop statistical space-time methods and algorithms to improve short-term energy forecast accuracy at wind energy sites.***

**Washington Technology Center**
**PPM, Energy Inc.**

University of Washington
STATISTICS

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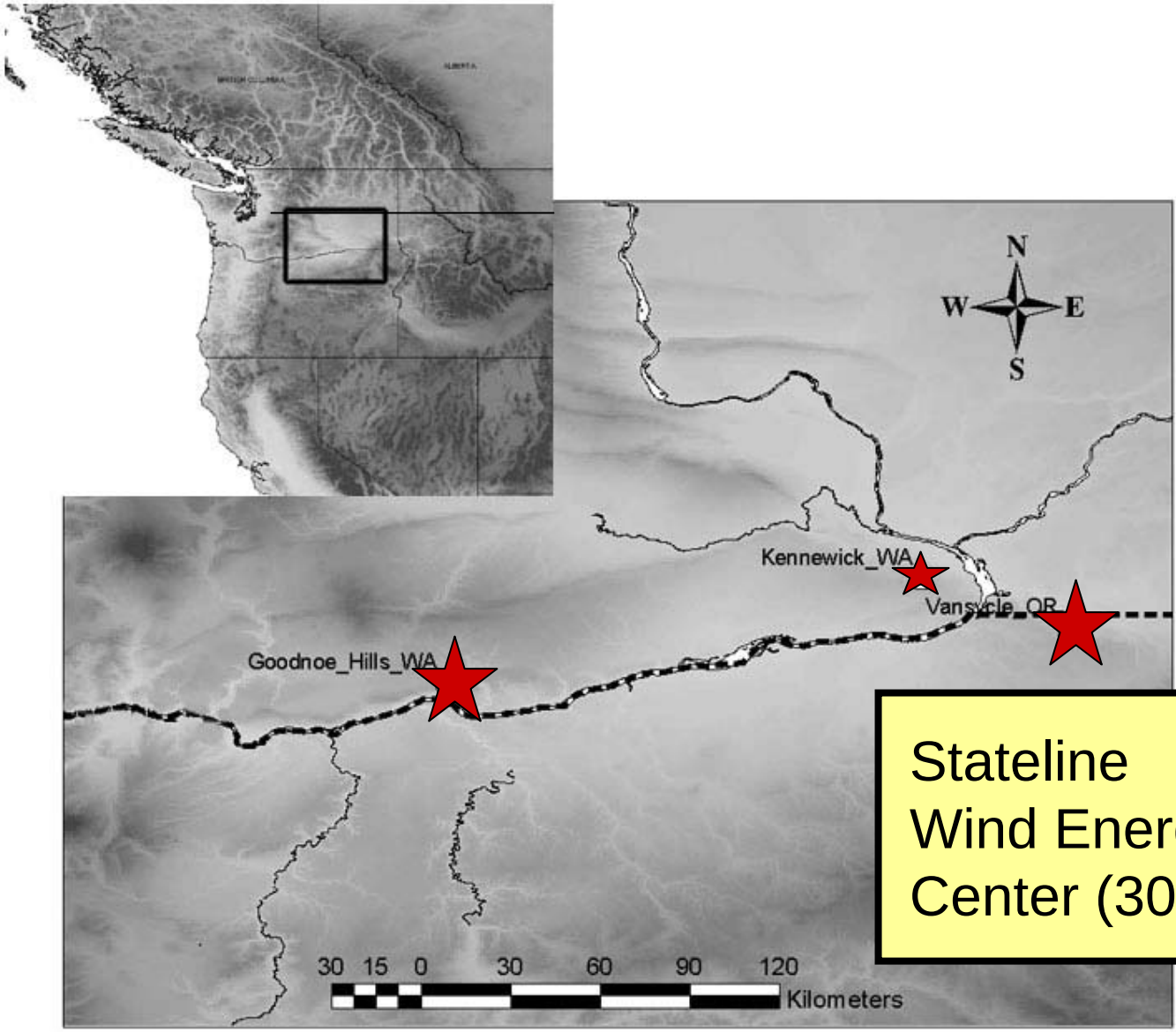
# Regime-switching Space-Time (RST) Algorithm

- Model formulation is parsimonious, yet takes account of all the salient features of wind speeds: alternating atmospheric regimes, temporal and spatial autocorrelation, diurnal and seasonal non-stationarity, and conditional heteroscedasticity

- Space-time algorithm: use of geographically dispersed meteorological observations in the vicinity of the wind farm
- Regime-switching: identification of westerly and easterly regime
- Fully probabilistic: provides valid statements of forecast uncertainty




Stateline
Wind Energy
Center (300MW)

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# Forecast Comparison

- Data is from Mar 2003 to Nov 2003
- RST method based on training for the 45 previous days
- Percent improvement of the root mean square (RMS) error over persistence is displayed for each month

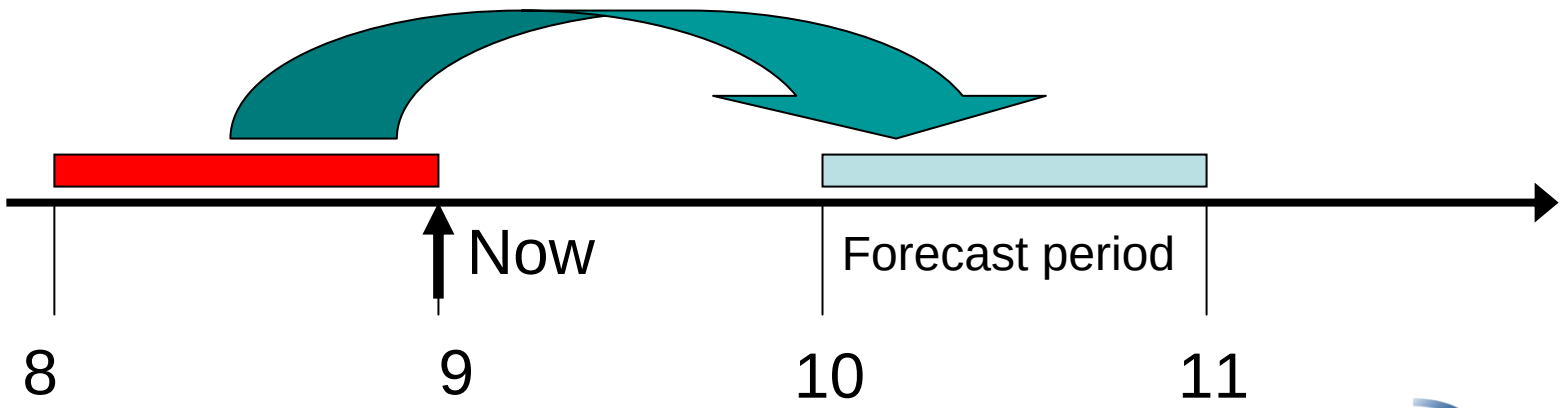
RST method compared to:

- persistence
- new reference (combination of persistence and climatology)
- time series (auto-regressive model)

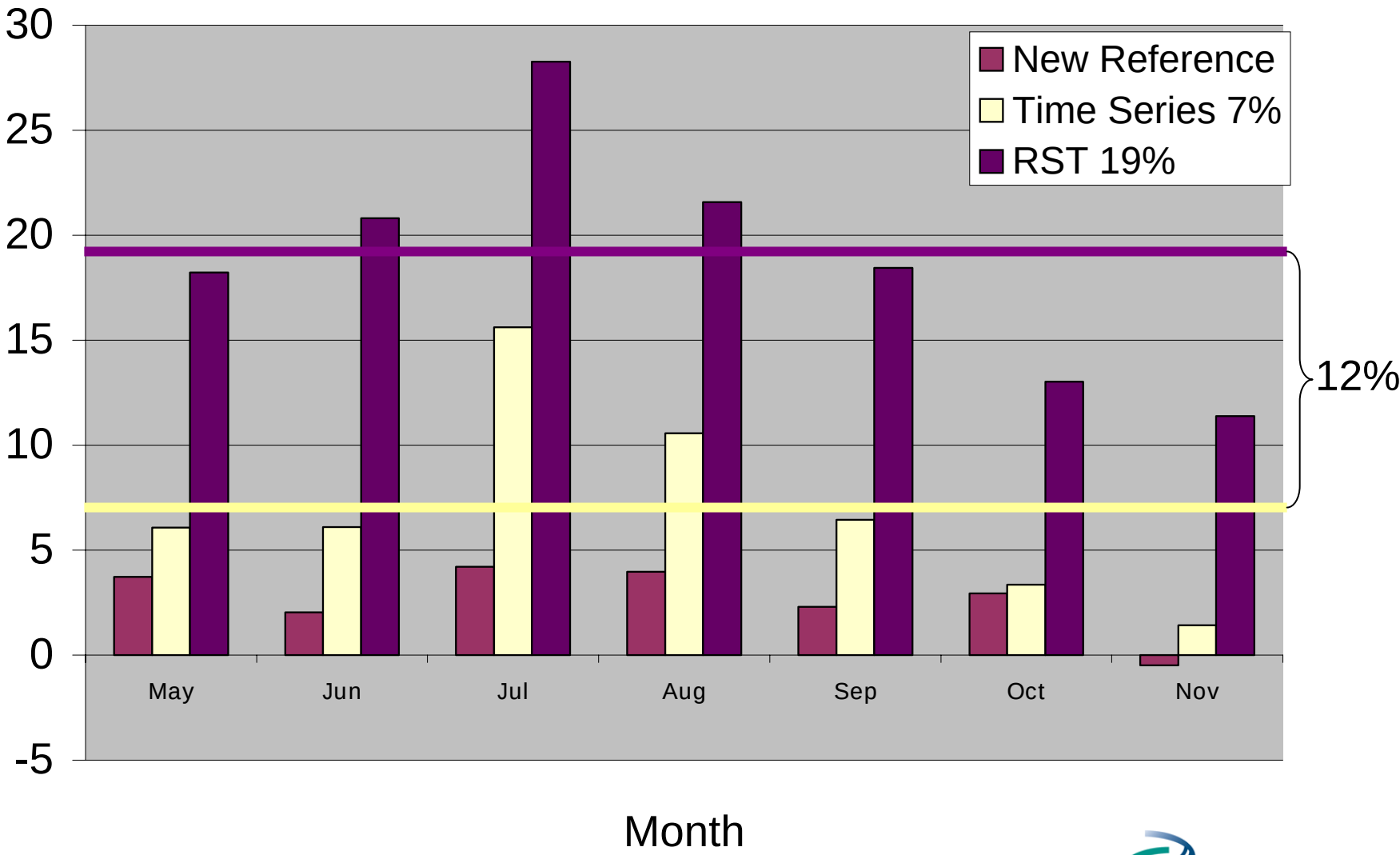
# An Example Application of a Persistence Forecast

By 9:00 a.m. a decision-maker must make a prediction for the power to be produced between 10 a.m. and 11 a.m.

A persistence forecast uses the power produced between 8 a.m. and 9 a.m. (the last hourly power value) as the forecast. This is a benchmark for measuring improvement.



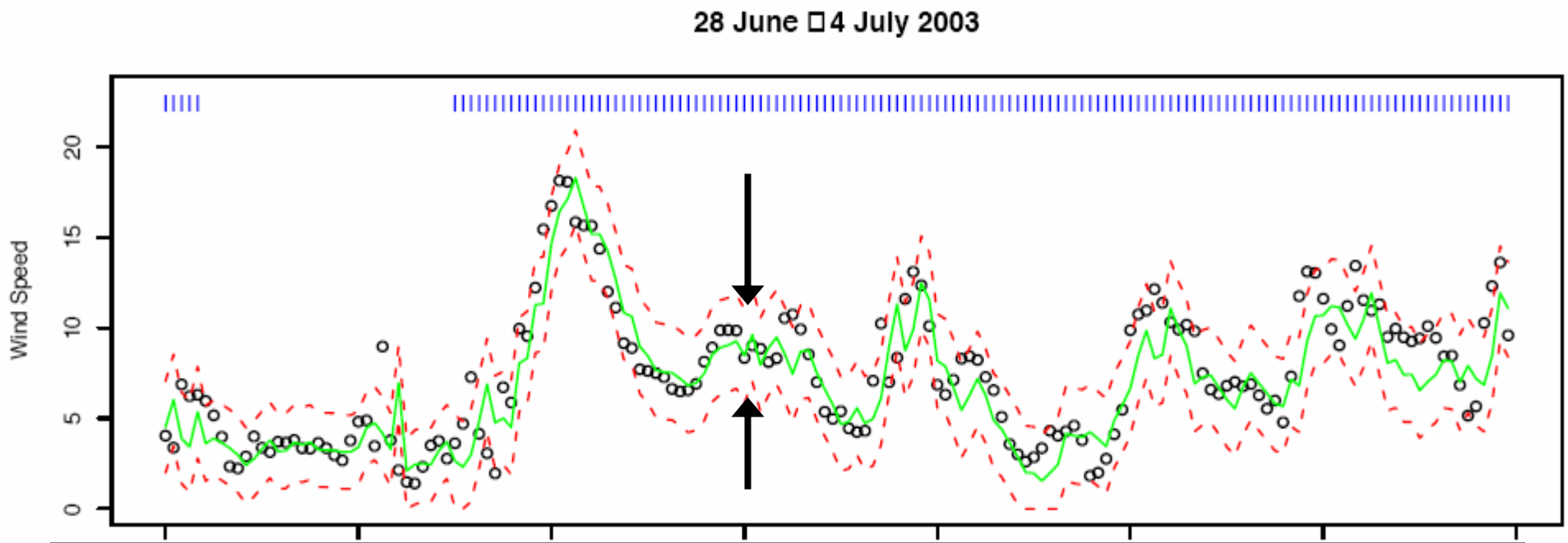
# 2 hour Forecast Improvement over Persistence at Vansycle



# Example of RST method

Black circles = wind speed values
Green line = forecast

Red dotted line =
90% confidence interval
Blue bars = westerly regime




90 % confidence intervals are on average 5 m/s wide

# RST Summary

- Statistical forecast method that is based on optimally-placed off-site observations
- Meteorological knowledge is essential
- Probabilistic forecast method that effectively leverages the conditional heteroscedastic properties of wind speed

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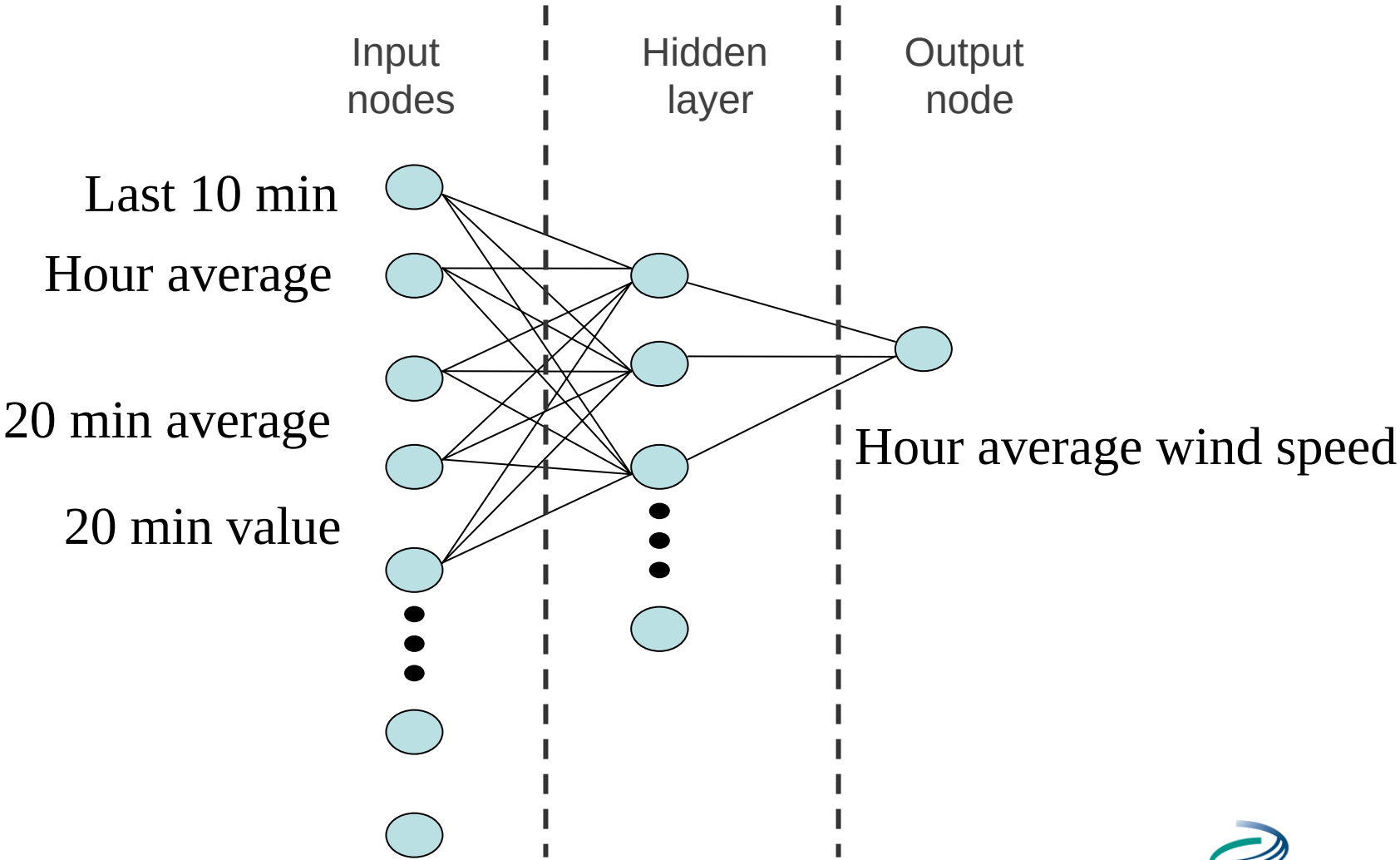
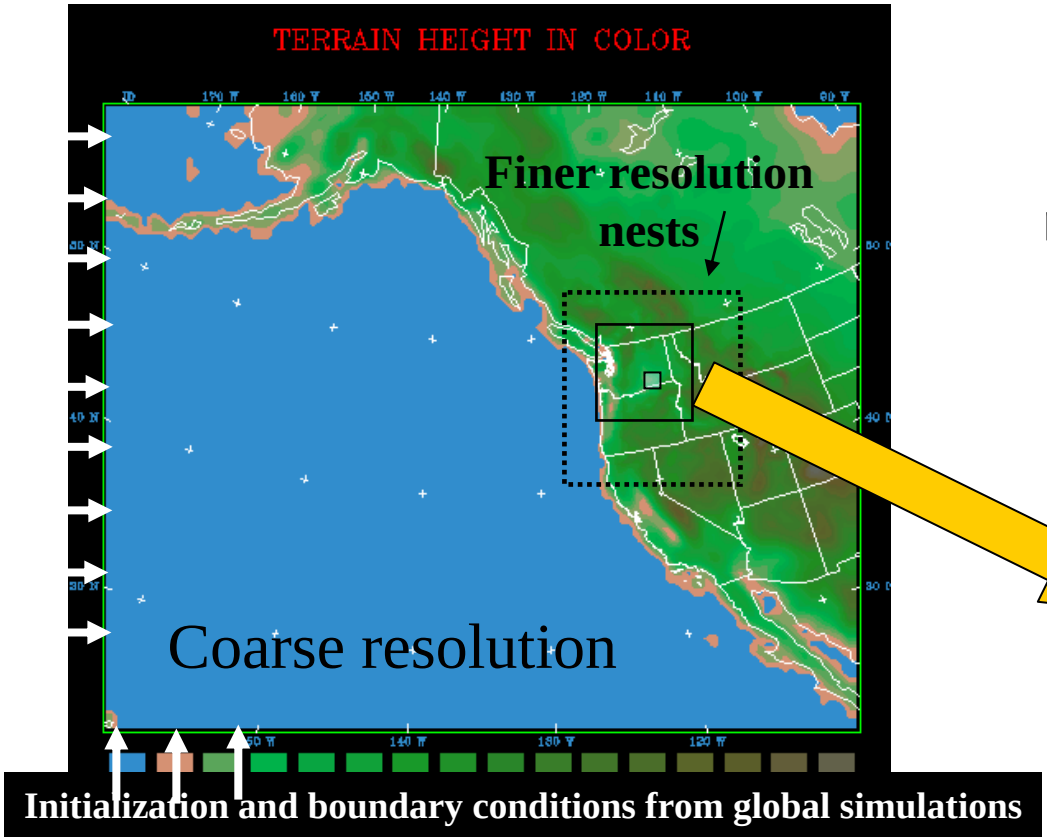
# Short-range Forecasts using Off-site Observations and Numerical Weather Prediction (NWP)

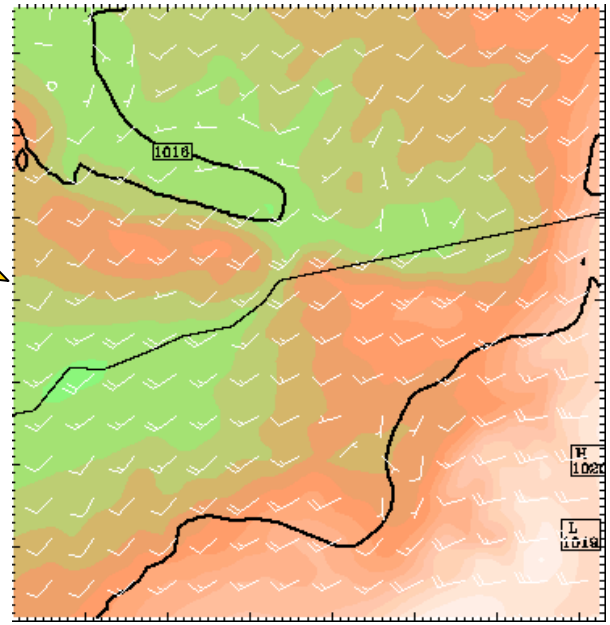
Forecasts use Neural Networks
and the challenge method

# Neural Networks

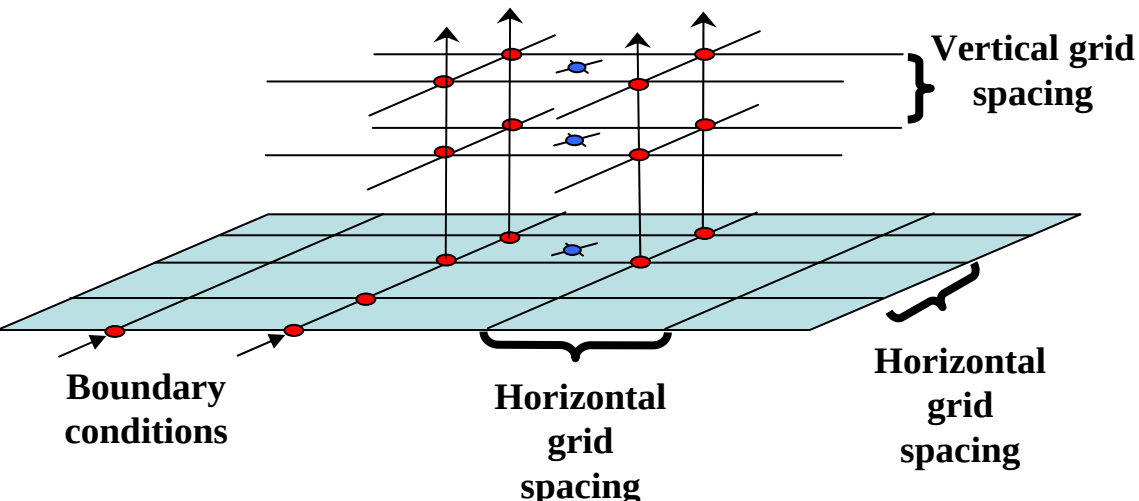


# The general layout of a high resolution nested NWP model

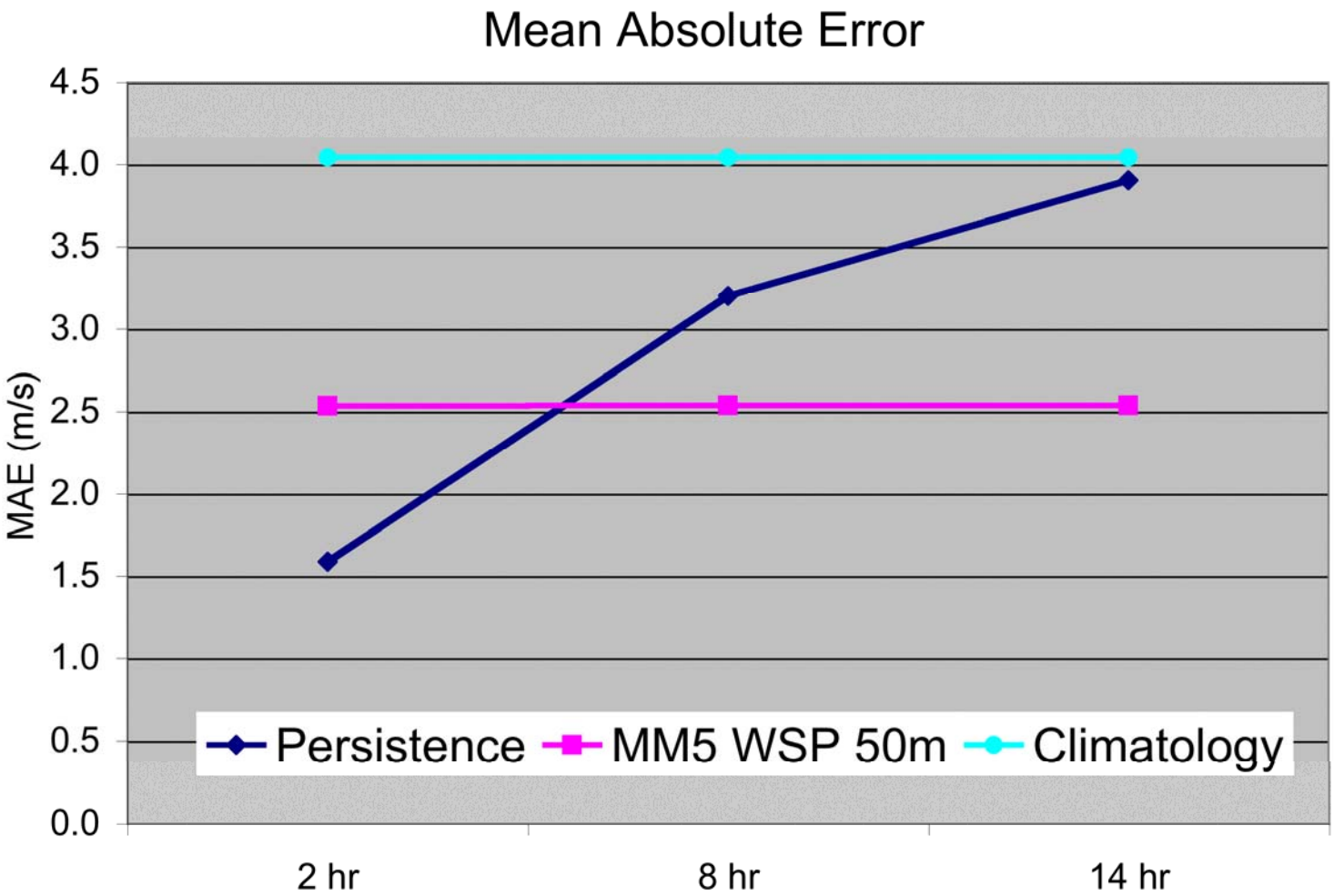



Detail of a 1.67 km ‘nest’ over Stateline



# Skill of NWP forecasts for all months




NWP better for 8 and 14 hour forecasts

NWP has same error for 2 and 8 and 14 hours

# Challenge Method

- Neural network inputs are added sequentially
- The amount/kind of inputs are chosen by the highest forecast accuracy
- Based on Kretzschmar, Eckert, and Cattani, 2004 JAM
  - First choose length of wind speed record (10 min. to 120 min.)
  - Then choose celestial variables to add (time-of-day, julian day, etc.)
  - Then choose meteorological variables (wind direction, temperature, pressure, combinations)
  - Etc.

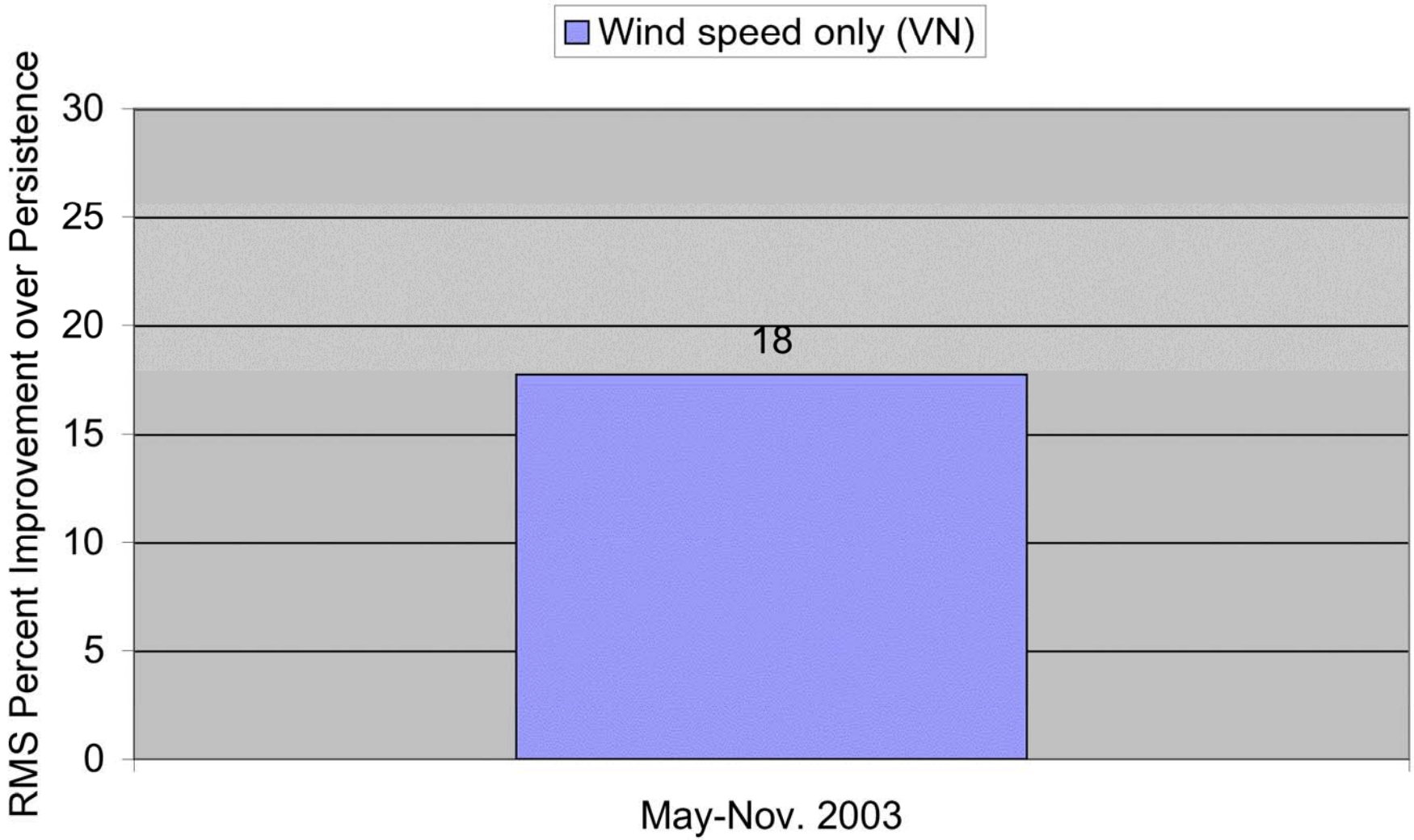
# Forecast Comparison

- Data is from Jan. 2003 to Apr. 2004
- Percent improvement of the root mean square (RMS) error over persistence is computed for each month, and the May 2003 to Nov 2003 values are averaged

Persistence compared to:

- NN forecast using wind speed data only
- NN forecast using wind speed data and off-site observations
- NN forecast using wind speed data and NWP
- NN forecast using wind speed data, off-site observations and NWP

# Forecast Improvement over Persistence

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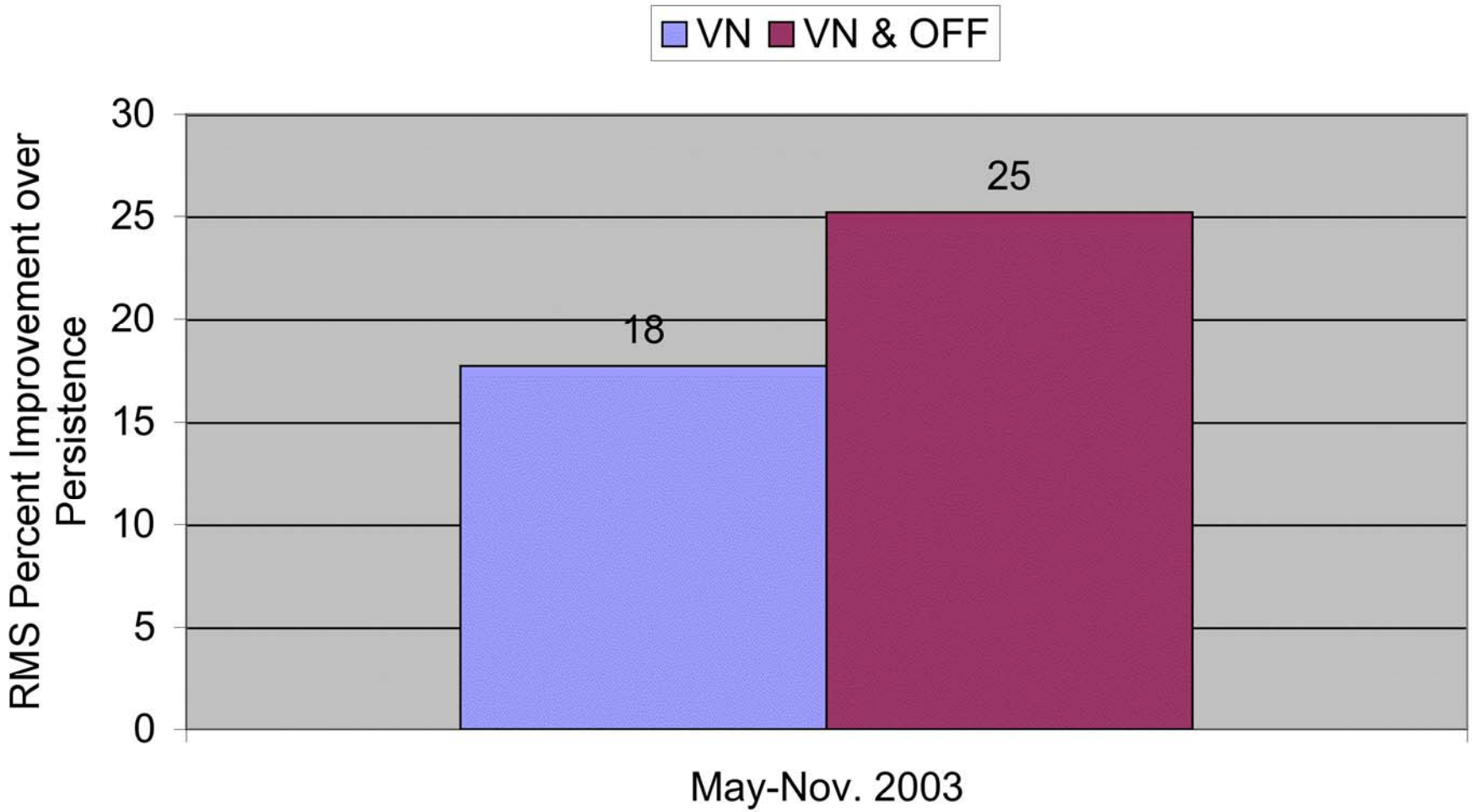
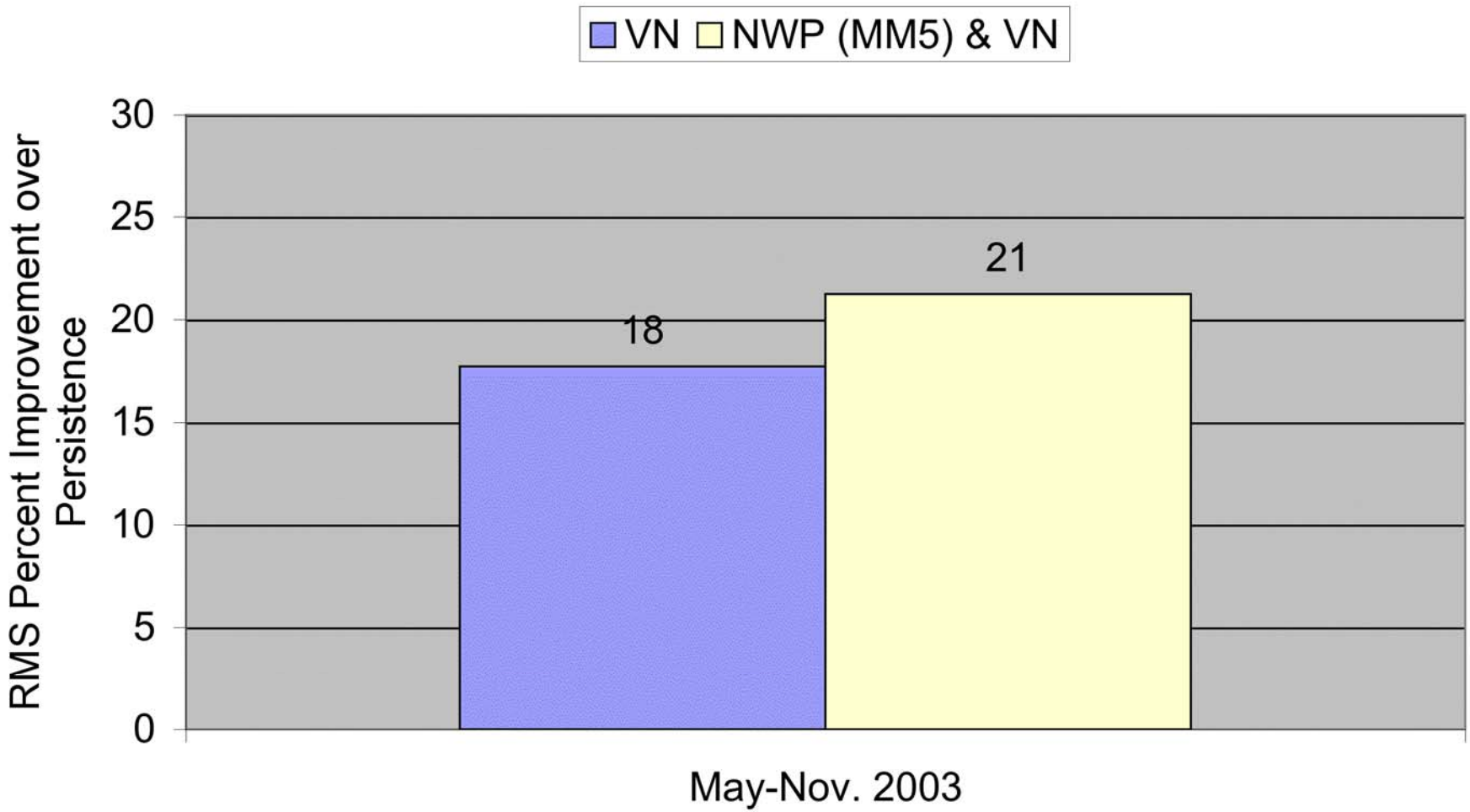
# Forecast Improvement over Persistence using wind speed data and off-site observations



# Forecast Improvement over Persistence using wind speed data and NWP

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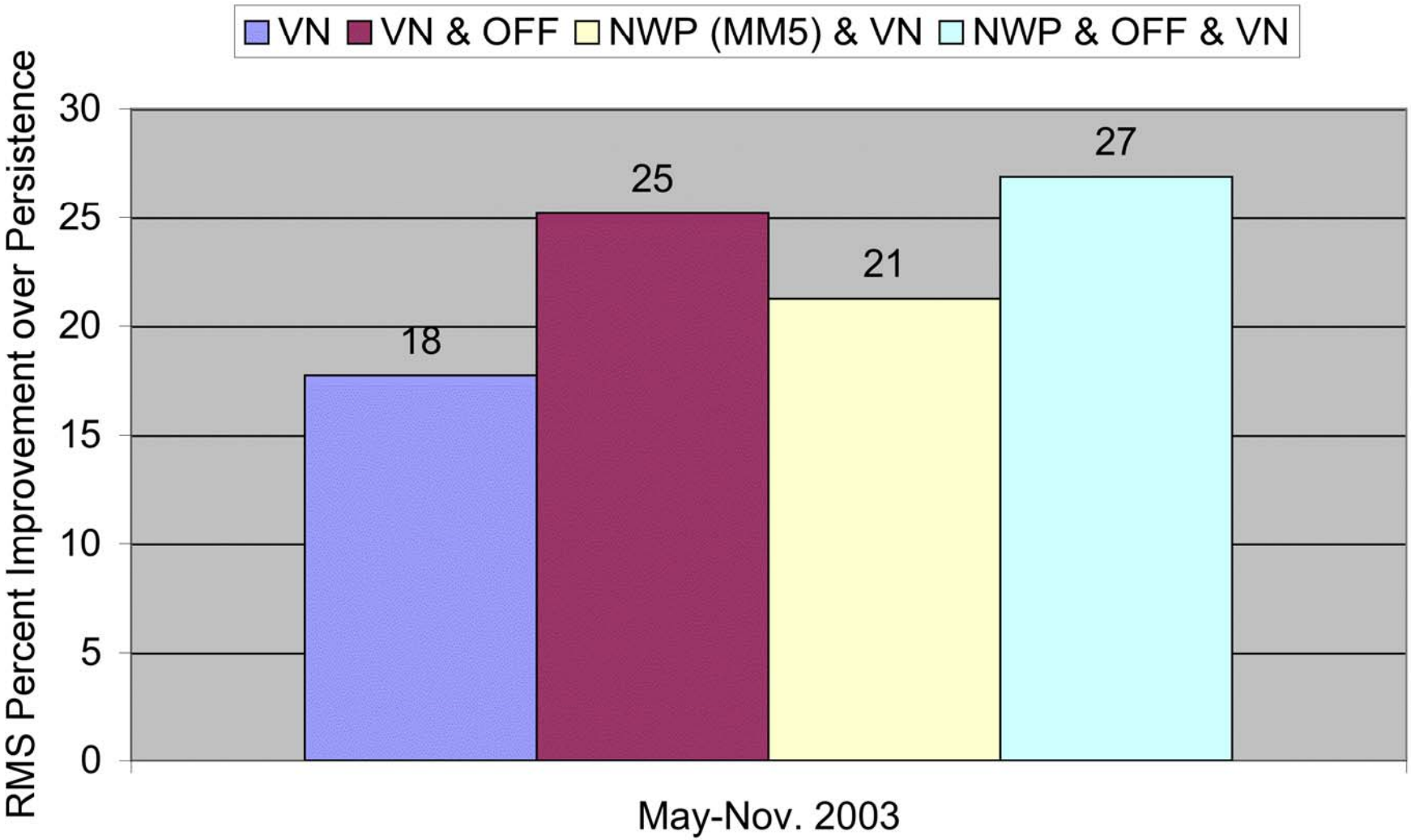
# Forecast Improvement over Persistence



# NWP Challenge Method Summary

- Neural Networks with the challenge method provide an improvement over a persistence forecast
- Both off-site observations and NWP alone improve forecast
- Largest forecast improvements occur with both NWP and off-site observations

# Conclusions

- Meteorological knowledge improves short term forecasts
  - Regime Switching Space-Time Method
  - NWP- Challenge Method
- Significant improvements over persistence are possible
- The 90% confidence intervals are 5 m/s wide, in this example

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Thank you for listening