VAISALA- Practices in Wind & Solar Power Forecasting

A Forecast Provider's Perspective

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SECONDWIND by Vaisala | 3TIER by Vaisala | VAISALA

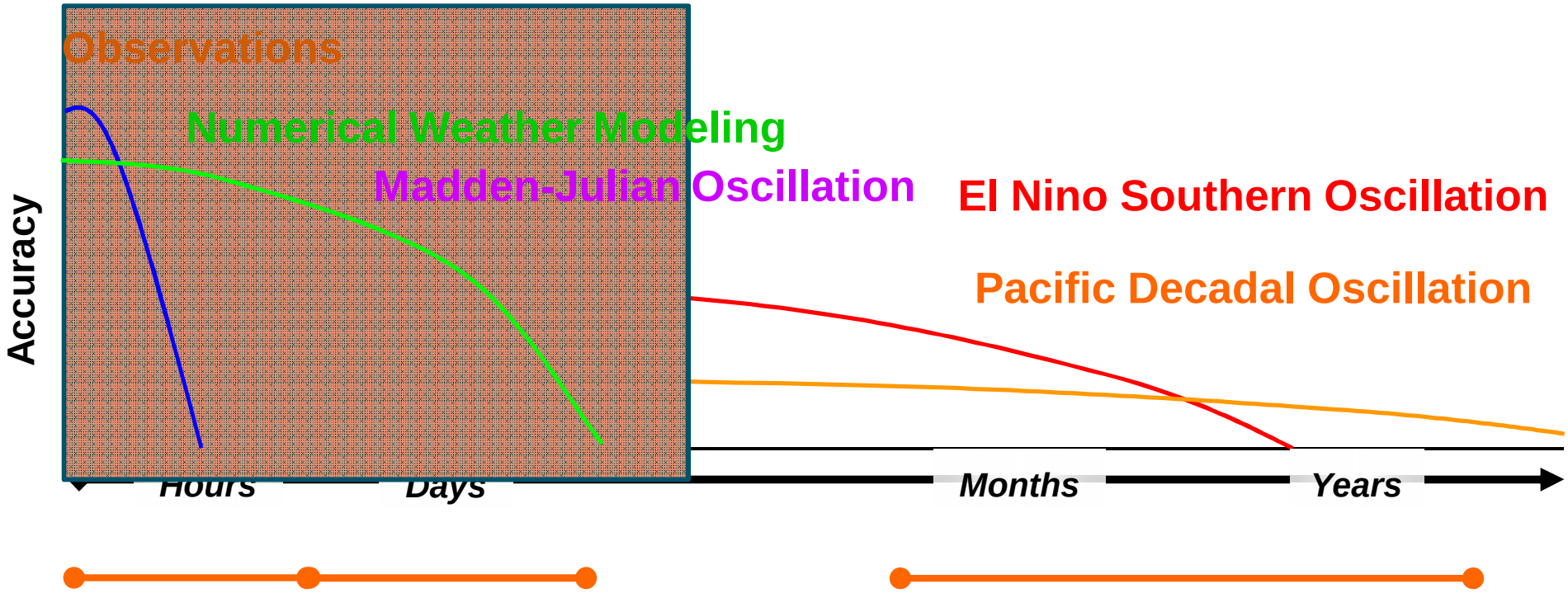
Vaisala : History

- Founded in 1937 by Professor Vilho Väisälä
- World leader in environmental measurement
- Headquarters in Helsinki, Finland; offices in Bangalore, Delhi, Seattle, Boulder and Boston
- Acquired 3TIER in December 2013
- 2016 net sales: €319M
- 1500 employees
- 18 GW of contract globally for forecasting services
- Digital Services division has extensive experience in
  - Wind and Solar Power Forecasting
  - Hydro Streamflow forecasting
  - Solar and Wind Resource Assessment

Outline

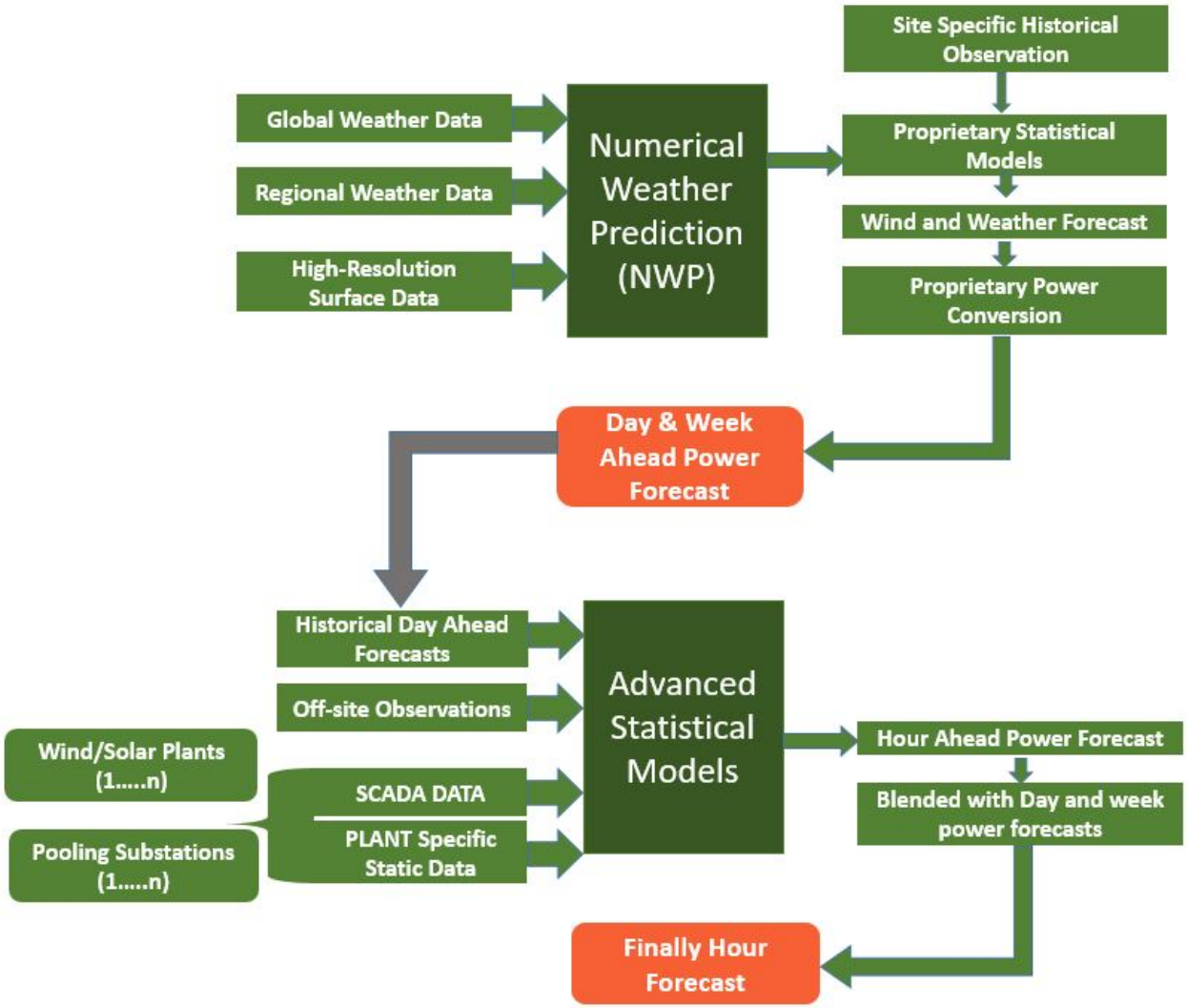
- Forecasting Horizon v/s Technology
- Vaisala – Science
  - Day ahead – Mixed Hybrid Model
  - Hour ahead- Statistical Model
- Vaisala- Approach
- Accuracy of Forecasting
  - Vaisala's Experience over years
  - Vaisala's India Experience
- Recommendations

Forecast Horizons Dictate Technology



Short-range Medium-range Long-range

Advanced Hybrid Forecast System



- Quite complex!
- Use of multiple NWP models
- Proprietary machine learning statistical algorithms for day ahead forecasting
- Predict power directly or indirectly using wind speed
- On-site observations key to removing the bias in NWP models
- Real-time data necessary for hour ahead forecasting

Vaisala's Approach

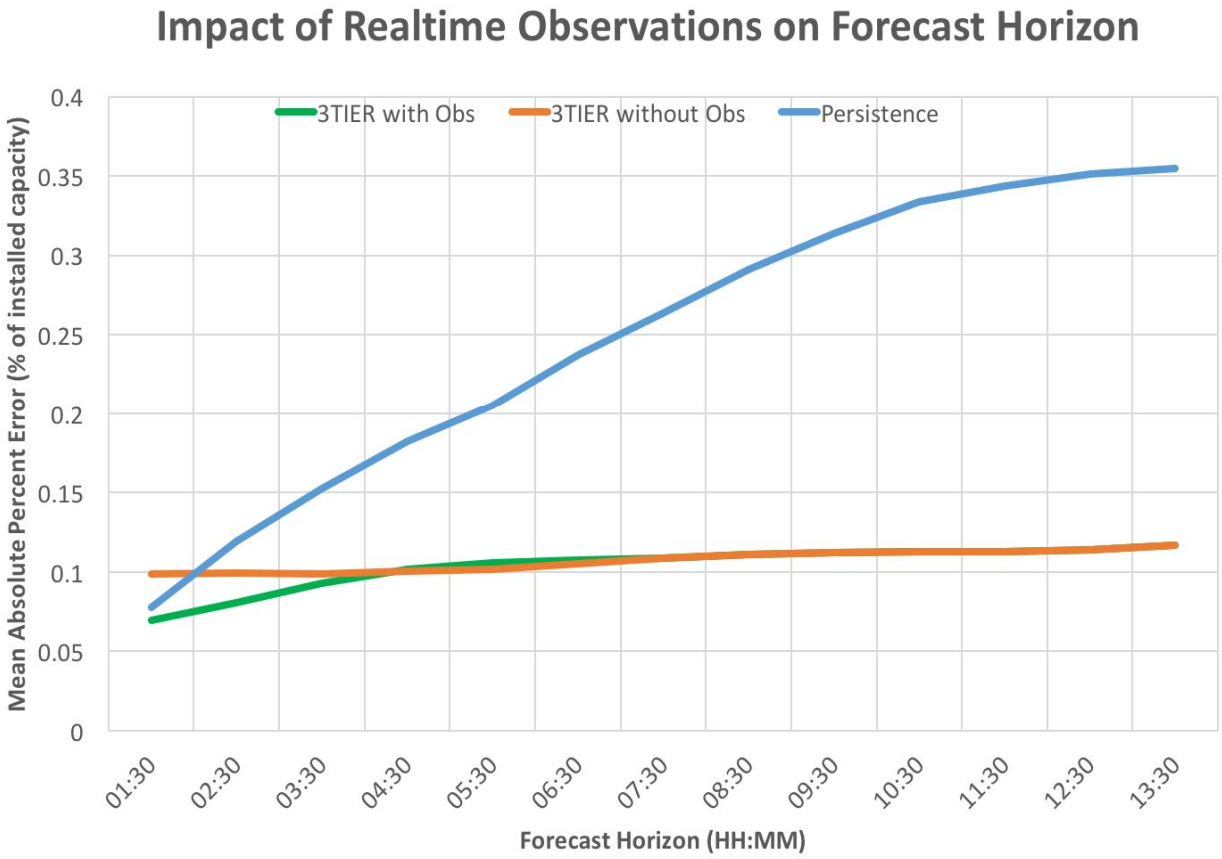
- Use the best, state-of-the-art, NWP models.
- Use Open-Source statistical packages
- Use ensemble of models to minimize forecast error

Why use Phy./Stat. Hybrid Approach?

- Takes advantage of the value in both physical and statistical models
  - Physical Models
    - ✓ model parameterizations are empirically derived (e.g., cloud and radiative processes)
    - ✓ Atmospheric physics feedback incorporated
    - ✓ Physically consistent forecast solution for 7 days!
  - Statistical Models
    - ✓ Very quick to run (order of seconds)
    - ✓ Can capture short term variability (forecasts less than 2-3 hours on 15-min or shorter scale)
    - ✓ Many different algorithms are now available Open Source (e.g., Octave, R CARET, Python scikit-learn)
- Shorter training history.
- Forecast errors can be minimized

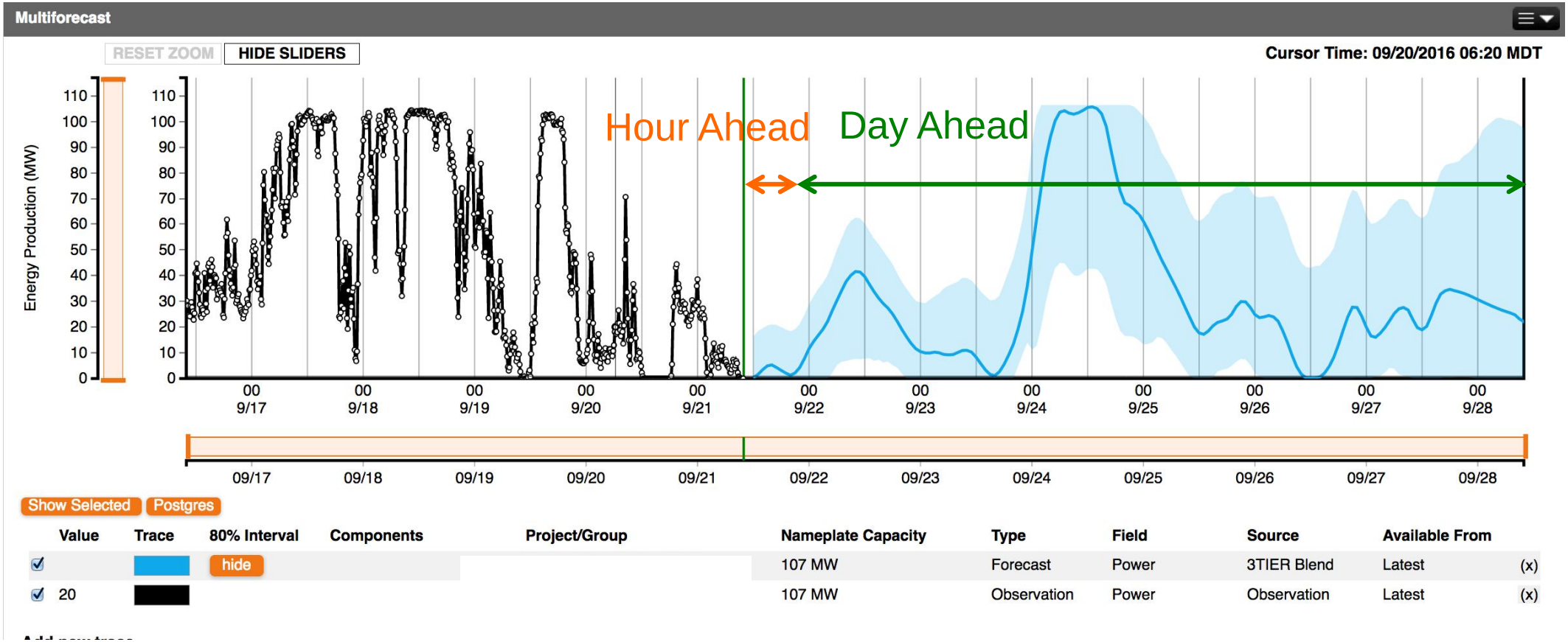
Importance of real time observation

- Realtime observations impact first 0-6 hours of forecasts
- Persistence is a good forecast as forecast horizon approaching now
- Relative improvement of advanced forecast system at 1.5 hours ahead:
  - Over persistence : **11%**
  - Over Forecast without realtime Obs : **29%**

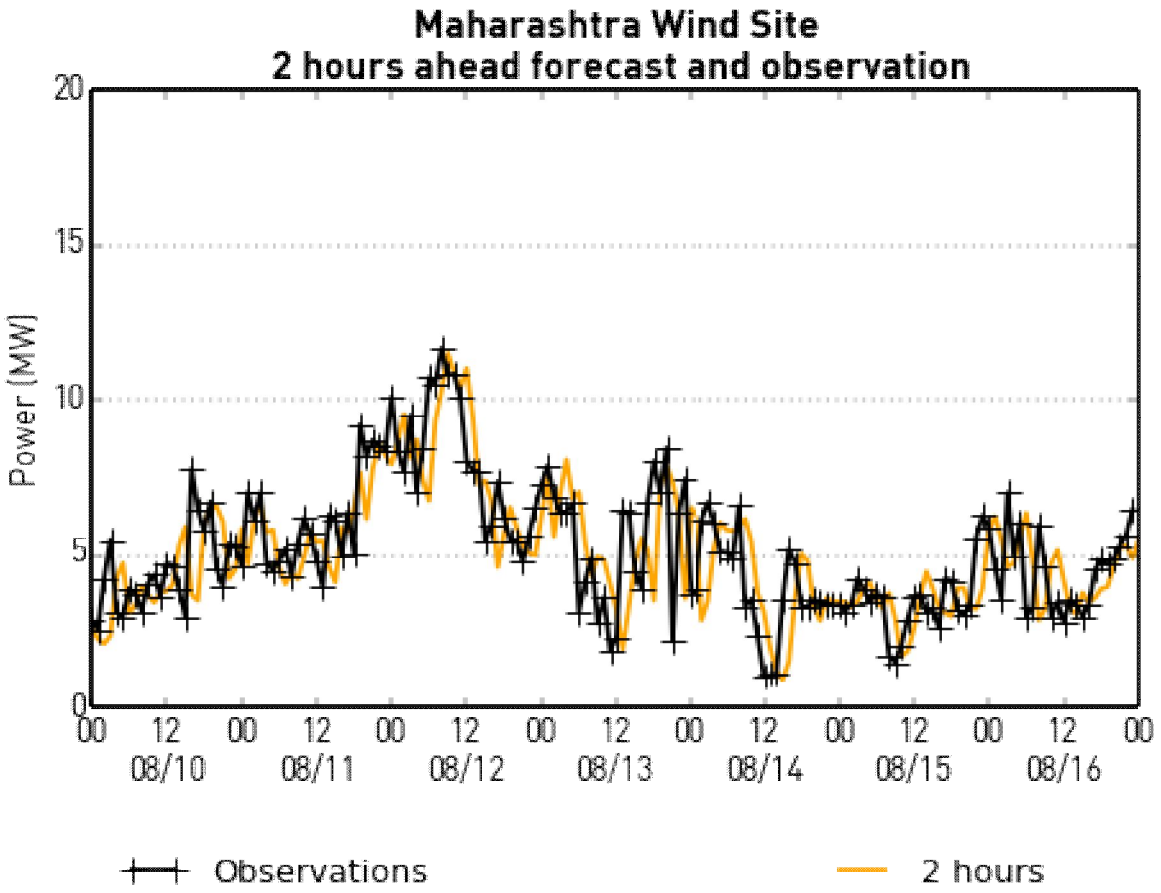


Output

- The Vaisala Forecast Time Series is actually a combination of an Hour Ahead and Day Ahead forecast.

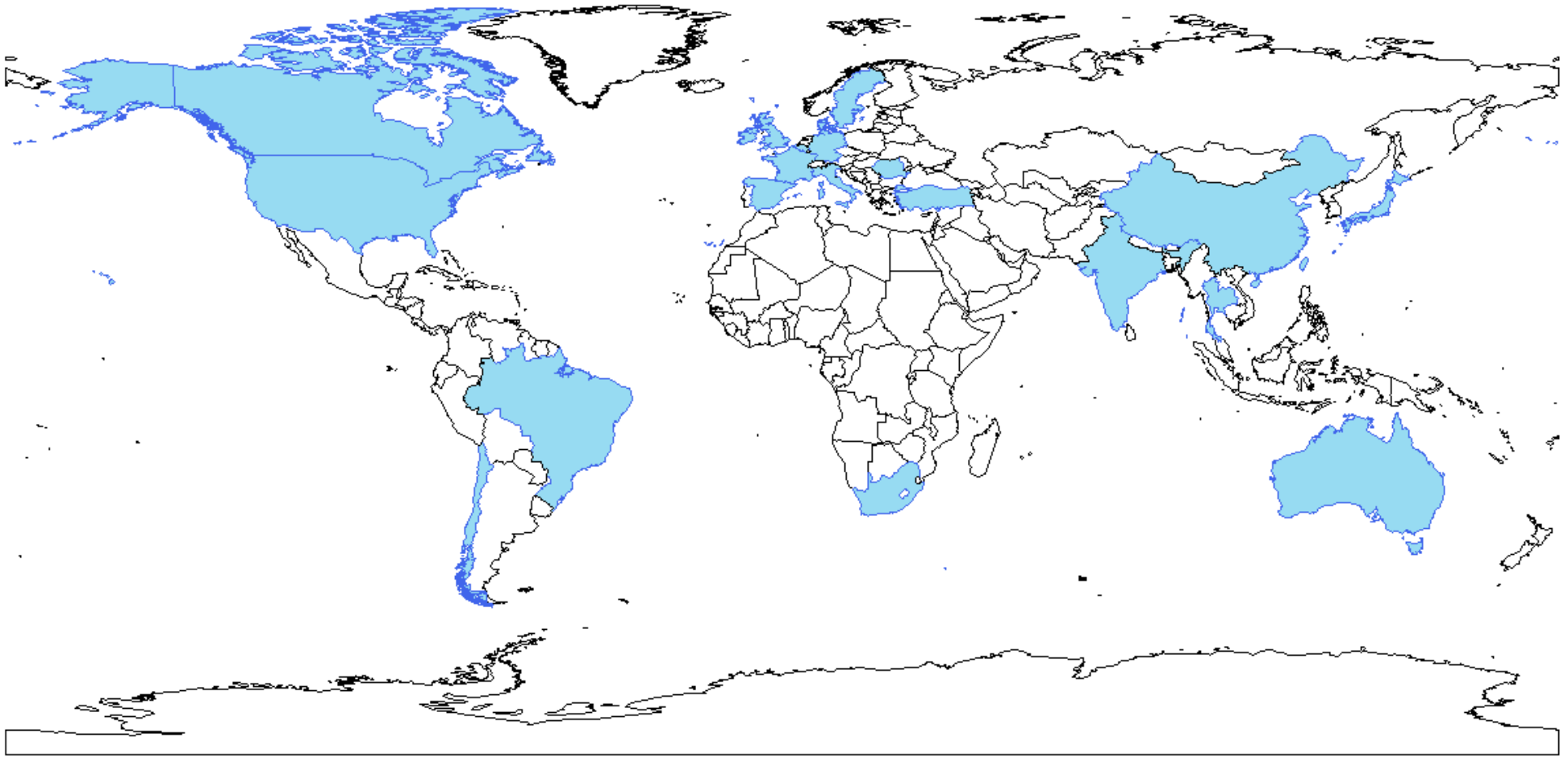


Actual v/s Forecast



Forecasting Experience & Accuracy

Global Wind Forecasting Experience

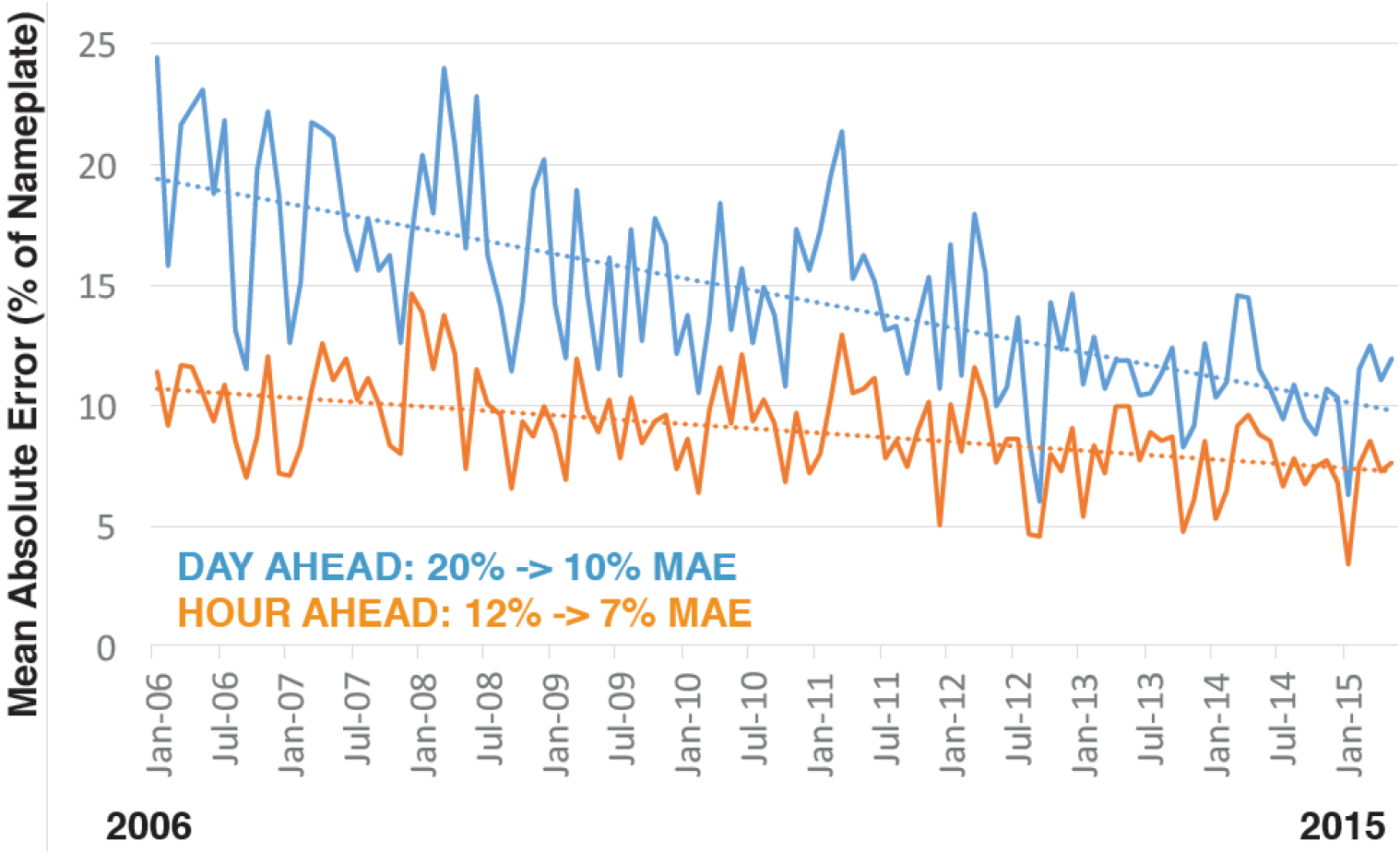


Global Site Specific MW Currently Forecasting For: 18 GW

Global Regional Scale MW Currently Forecasting For: 250 GW

*New countries include Indonesia, Vietnam, Pakistan, Finland, Mexico, Honduras, Poland

How has the Vaisala forecast improved over the years?



Halving the error in a decade! Advances in computing, modeling, and machine learning methods continue to provide incremental error reduction

Factors affecting Forecast Accuracy

- 1.5 – 3 hour forecast horizons dependent on good observation predictors
- Send forecast provider Sub station Power Data instead of SCADA data of Turbines
- Turbine availability and nacelle wind speed useful for constrained / curtailed wind farms
- Details are important!

Is it harder to forecast in India?

- Yes : In some regions, (e.g., Tamil Nadu)
- No : In some regions (e.g., Gujarat)

Some Regions of India harder to forecast (e.g., Tamil Nadu) than others (e.g., Gujarat). Main problem affecting short term forecast accuracy is late or poor quality realtime data feeds!

Recommendations

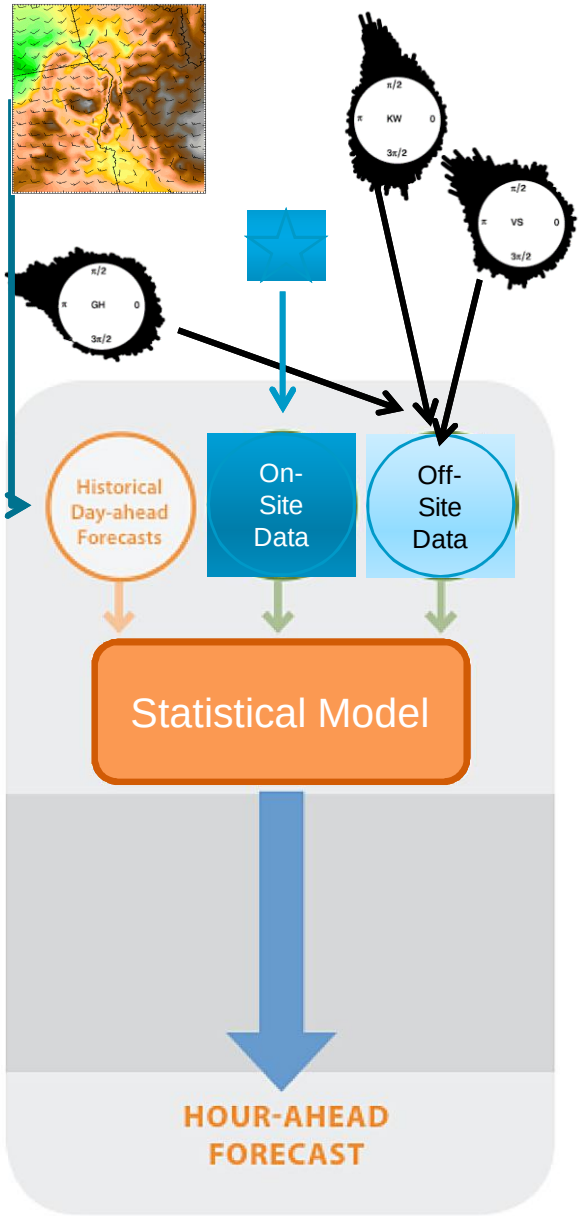
- Frequency of Forecasting
  - Reduced forecast horizons (ex ; reduction of current 1.5 hours ahead) results in smaller forecast error
- Geographic Diversity
  - Forecast errors reduced when pooling many wind farms that are geographically diverse
- Grid Modernization, Telemetry, and modern meters
  - Older wind farms to be upgraded
- Continued reduction of forecast pricing may standstill accuracy improvements

Thank You

Current state-of-the-art in Wind Power Forecasting

Days Ahead – Hybrid Physical/Statistical Modeling

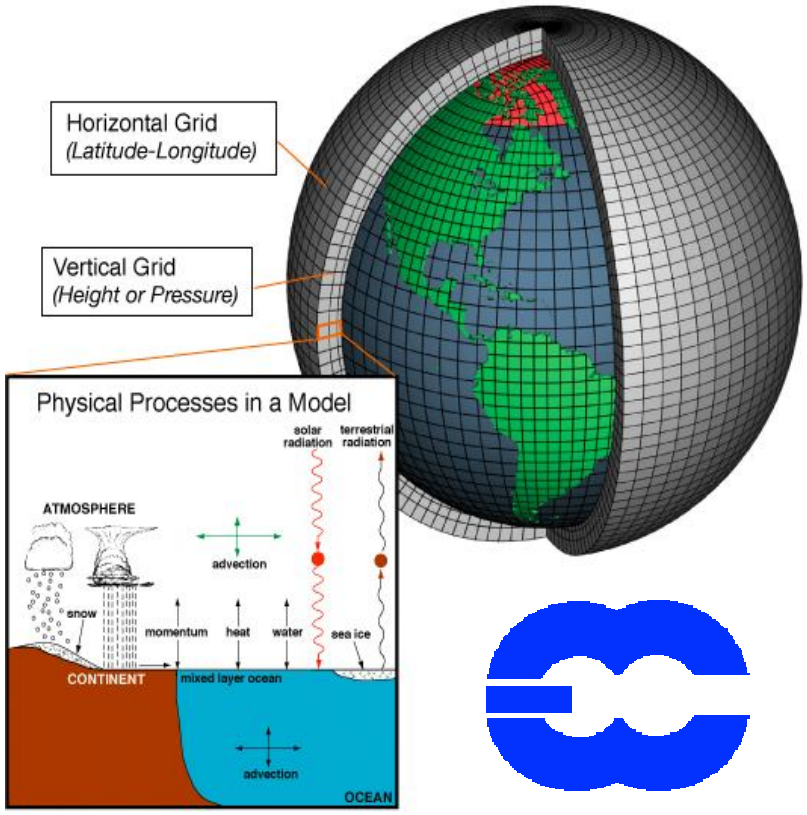
Hour-Ahead Statistical Modeling



- State of the practice:
  - Common Industry Techniques
    - ✓Autoregressive statistical models and supervised machine learning techniques
    - ✓Blending with short-term NWP model output
    - ✓Adaptive predictor selection for large input data sets (including off-site meteorological observations)
    - ✓Multiple or regime-switching models
  - Trained to minimize bulk errors for average power over target forecast intervals

Days-Ahead – Hybrid Statistical/Physical Modeling

- Covers hours 6+ out to 10 days.
- Updates every time a new NWP model comes in.
- Physical Numerical Weather Prediction (NWP) models serve as the foundation of the forecasts
- Statistical Models used to reduce bias and error in NWP forecast output
  - Statistical models need longer term historical onsite observations to calibrate NWP model forecasts
  - Historical data has profound impact on forecast performance (e.g., *training only on India monsoon season will bias high the winter forecasts*)



Physical Modeling Advantages / Disadantages

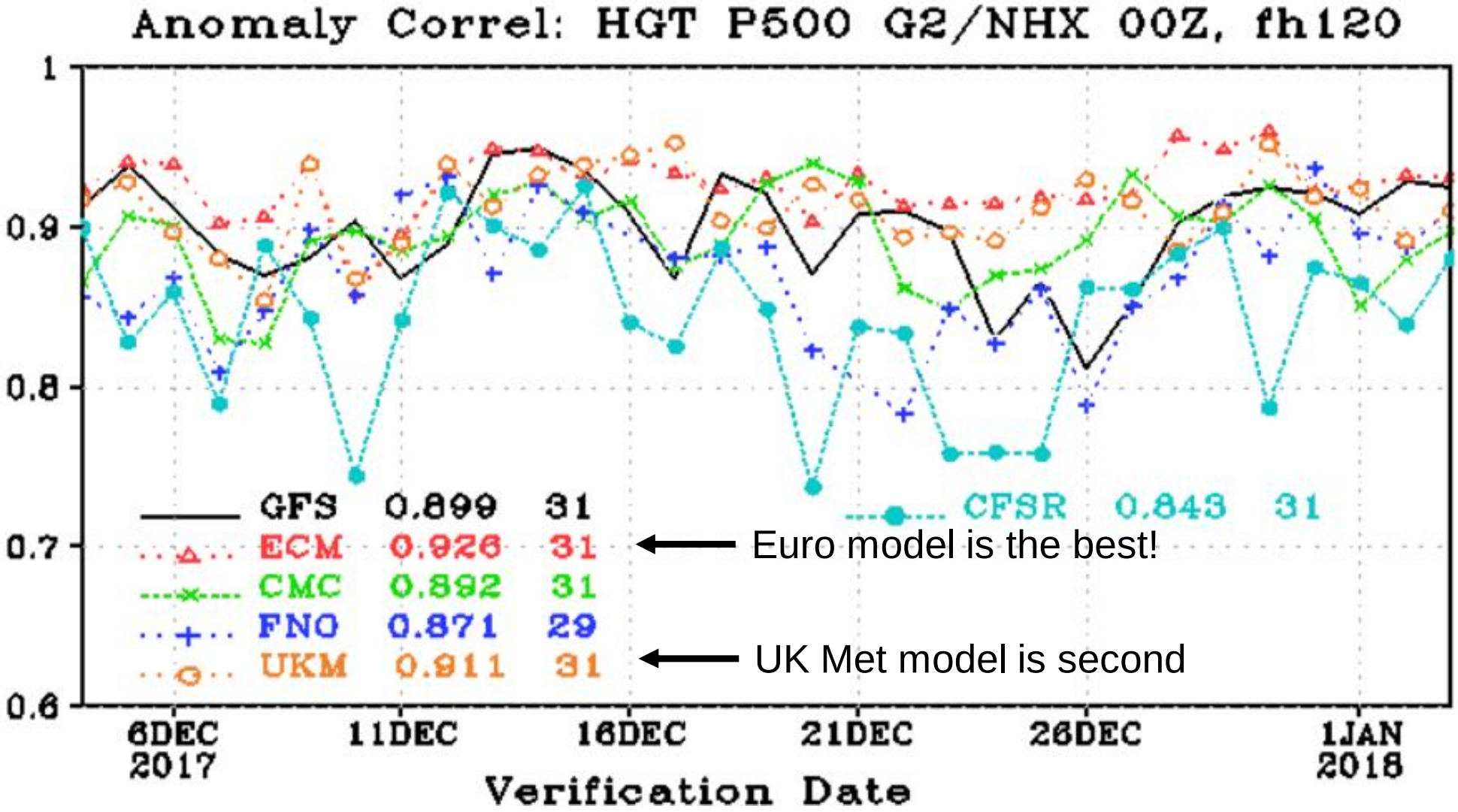
- Physical Model Advantages:
  - Physical models are, in fact, hybrid models
    - ✓ model parameterizations are empirically derived (e.g., cloud and radiative processes)
  - Atmospheric physics feedback incorporated
  - Physically consistent forecast solution with value out to 7 days!
- Physical Model Disadvantages:
  - most global scale models update only 2 or 4 times per day
  - not optimized for subhourly processes (e.g., 15-minute scales)
  - Model improvement scorecard NOT validated against hub height (80m or 100m) observations as there are so few publicly available
  - Biases at wind plant locations exist
  - More expensive to run internally (expertise required)

Statistical Modeling Advantages/Disadvantages?

- Statistical Model Advantages:
  - Very quick to run (order of seconds)
  - Can capture short term variability (forecasts less than 2-3 hours on 15-min or shorter scale)
  - Many different algorithms are now available Open Source (e.g., Octave, R CARET, Python scikit-learn)
  - Doesn't take an advanced-degreed atmospheric scientist to develop and apply
  - Machine Learning, Big Data, AI is advancing much faster than physical modeling of renewable power forecasting
- Statistical Model Disadvantages:
  - Most models skillful with longer history (1-year+) to train on
  - Forecast performance generally inferior to physical models beyond 6 hours
  - Forecast skill degrades precipitously in the absence of realtime observations
  - Forecast skill degrades without the use of physical model forecasts as input predictors

Importance of Observations to Short Term Forecasting Accuracy and Error Reduction

Which NWP models have the best skill?

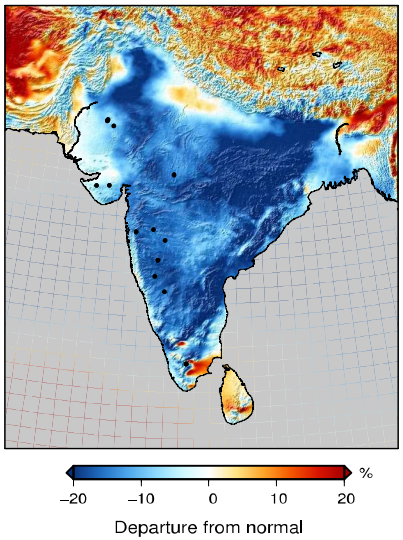


Seasonal Forecasting

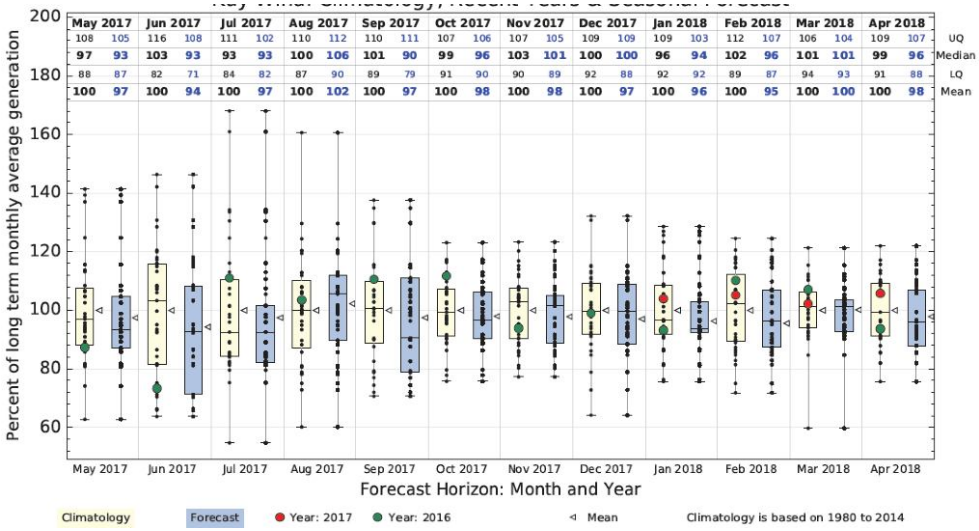
Seasonal Forecasting

- Example display of Seasonal Forecasting

Spatial Forecast Anomaly Maps



Point Anomaly Year-Ahead Guidance

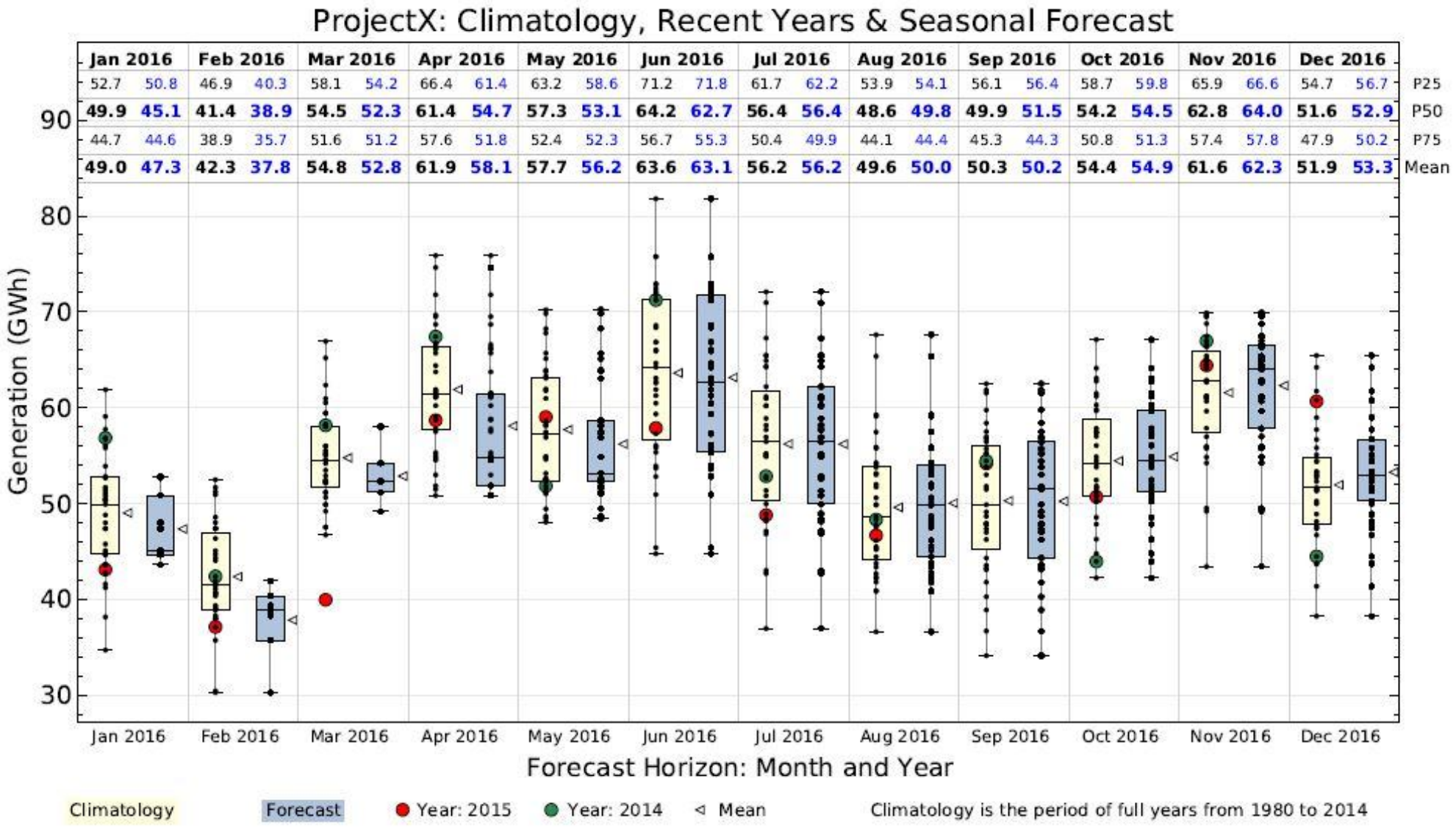


Seasonal Forecasting

- Important for budget setting and updating wind resource assessment (e.g., P50, P90)
- Uncertainty larger at longer forecast horizons
  - Instead of forecasting 15-minute blocks -> monthly blocks to reduce the uncertainty
- Climate Indices are most useful predictors at these longer time scales
  - El-Nino Southern Oscillation (ENSO)
  - Indian Ocean Dipole Mode Index (IOD))
- Sample size of previous year observations usually small
  - statistical re-sampling techniques necessary
  - forecast re-analysis record extension beneficial to capture climate variability
- Probability Forecasts are best expression of uncertainty associated with months-ahead forecasts
- Analog historical guidance can be useful as well

Forecasts of wind anomalies must be accompanied by an update to the historical context (baseline climatology) at these long time scales

Monthly Portfolio Reporting Services



Wind reconciliation and seasonal forecasting

- Deliverables
  - Monthly and quarterly updates for
    - ✓ Hourly hub height wind speed
    - ✓ Hourly wind distribution in 0.5 m/s binned histogram
    - ✓ P25, P50, and P75 Wind Production Index (WPI) for previous month
  - Monthly and quarterly reports
    - ✓ Boxplot of 35-year climatological distribution of WPI and actuals
    - ✓ Forecast distribution (P25, P50, P75) or WPI for next 12 months