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Two methods in improving onshore wind forecast

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Other Presentations of Related Work

Conference on Numerical Weather Prediction:

- 9.3. Ensemble Kalman Filter (EnKF) Assimilating the Dropsonde Observations to Reduce the Forecast Track Error of Typhoon Soulik (2013) Based On the Cloud-resolving Model (Wednesday morning)
- 13.2. Recent Advances in High-Resolution Operational NWP, Utilizing WRF-ARW (Thursday morning)

Conference on Artificial and Computational Intelligence and its Applications to the Environmental Sciences:

- J3.2. A multi-scale solar energy forecast platform based on machine-learned adaptive combination of expert systems (Wednesday morning)

Conference on Climate Variability and Change:

- 8C.4. Simulation of the temporal and spatial characteristics of diurnal rainfall cycle over Borneo

Conference on Weather, Climate, and the New Energy Economy:

- 6.3. Enabling Advanced Weather Modelling and Data Assimilation for Utility Distribution Operations
- 8.1. Outage Prediction and Response Optimization (OPRO)
- 9.1. Very High Resolution Coupled Weather and Wind Power Modeling (Wednesday afternoon)
- 10.1. Improvements in short-term solar energy forecasting (this session)

Symposium on Advances in Modeling and Analysis Using Python:

- 3.5. A Python-Based Automatic Data Aggregation Framework for Hydrology Models

Superstorm Sandy and the Built Environment: New Perspectives, Opportunities, and Tools:

- 873. Forecast Performance of an Operational Mesoscale Modeling System for Post-Tropical Storm Sandy in the New York City Metropolitan Region

Conference on Probability and Statistics in the Atmospheric Sciences

- 4.2. Customized Verification Applied to High-Resolution WRF-ARW Forecasts for Rio de Janeiro
- 6.5. Statistical forecasting of rainfall from radar reflectivity in Singapore

Symposium on the Urban Environment

- J12.2. High-Resolution, Coupled Hydro-Meteorological Modelling for Operational Forecasting of Severe Flooding Events in Rio de Janeiro

Outline

1. Introduction
2. 3DVAR data assimilation
3. Ensemble method
4. Hybrid data assimilation
5. Kalman Filter (KF) method
6. Summary and conclusion

Motivation and Background

- **Wind power intermittency creates significant barriers to expanding utilization**
  - Ramp events
  - Spinning reserve
- **Better forecasting and optimized economic dispatch can alleviate these barriers**
  - Ensemble forecasts
  - Stochastic programming
  - Dynamic reserves

Motivation and Purpose

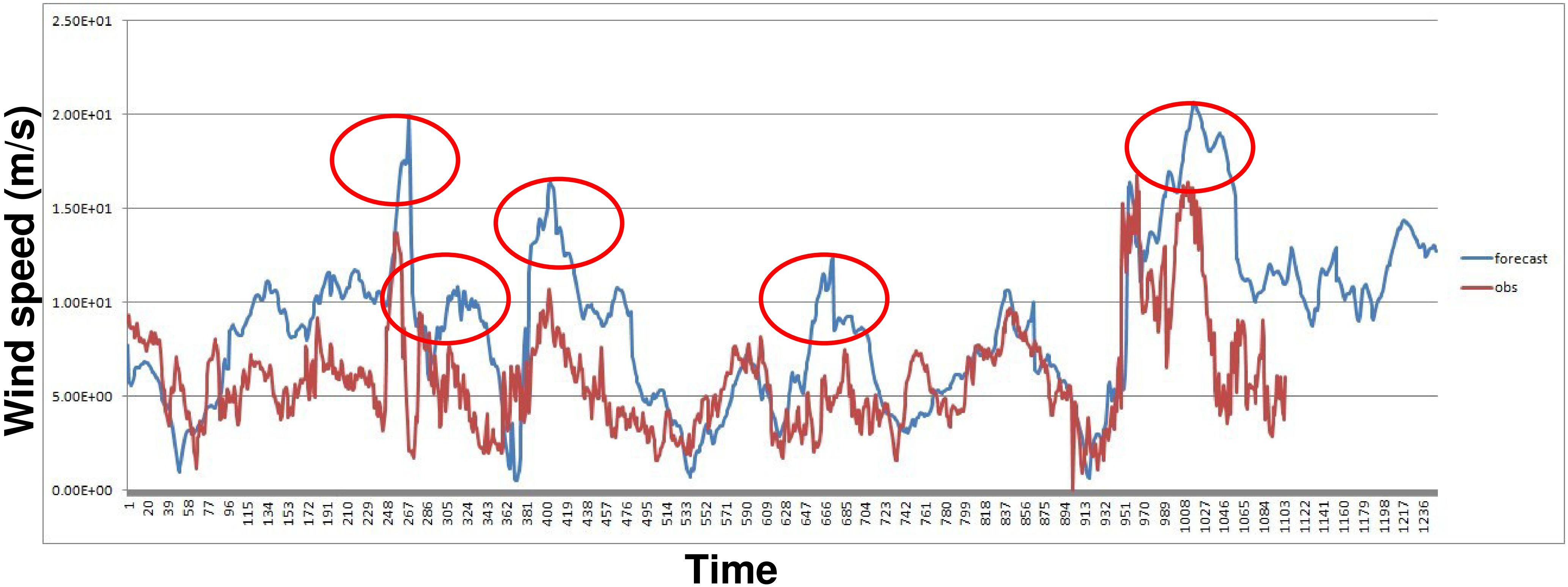
1. **In some onshore area around Bohai Sea, it is challenging to forecast wind due to the lack of observations in this maritime region**
2. **Initial conditions need to be improved, especially given the quality of background field**
3. **Ensemble Kalman filter (EnKF) data assimilation could be used for the real-time experiment.**
4. **Experiments combined with ensemble sensitivity (ES) analysis and EnKF data assimilation are employed to test forecast performance.**
5. **Statistical methods should be considered to decrease the forecast bias like root mean square error (RMSE) with little computing cost in operational wind forecast for wind farms**

Introduction and Background

Wind farm operators in this region have reported difficulty in having accurate predictions

Dagang wind farm location

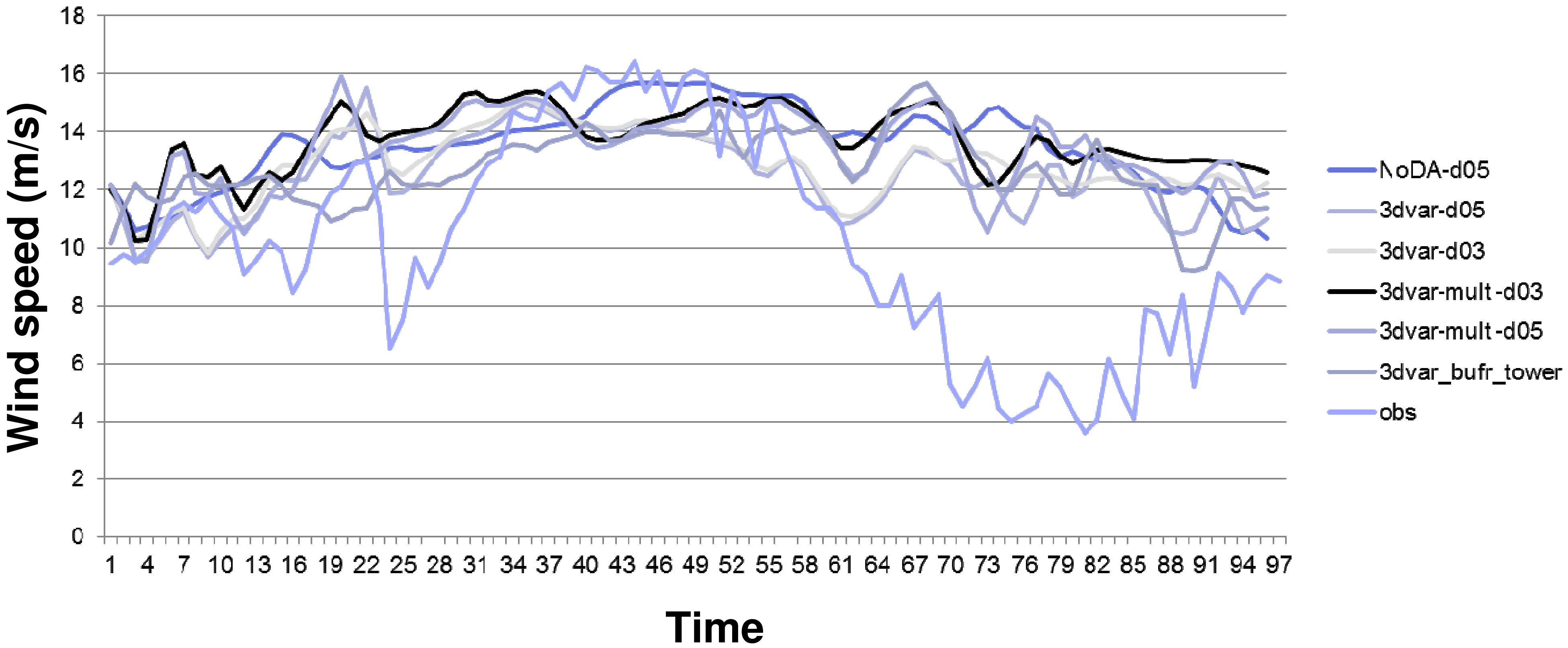
Dagang wind farm forecasting problems



NWP (WRF-ARW) over predicts wind speed, especially during down ramps

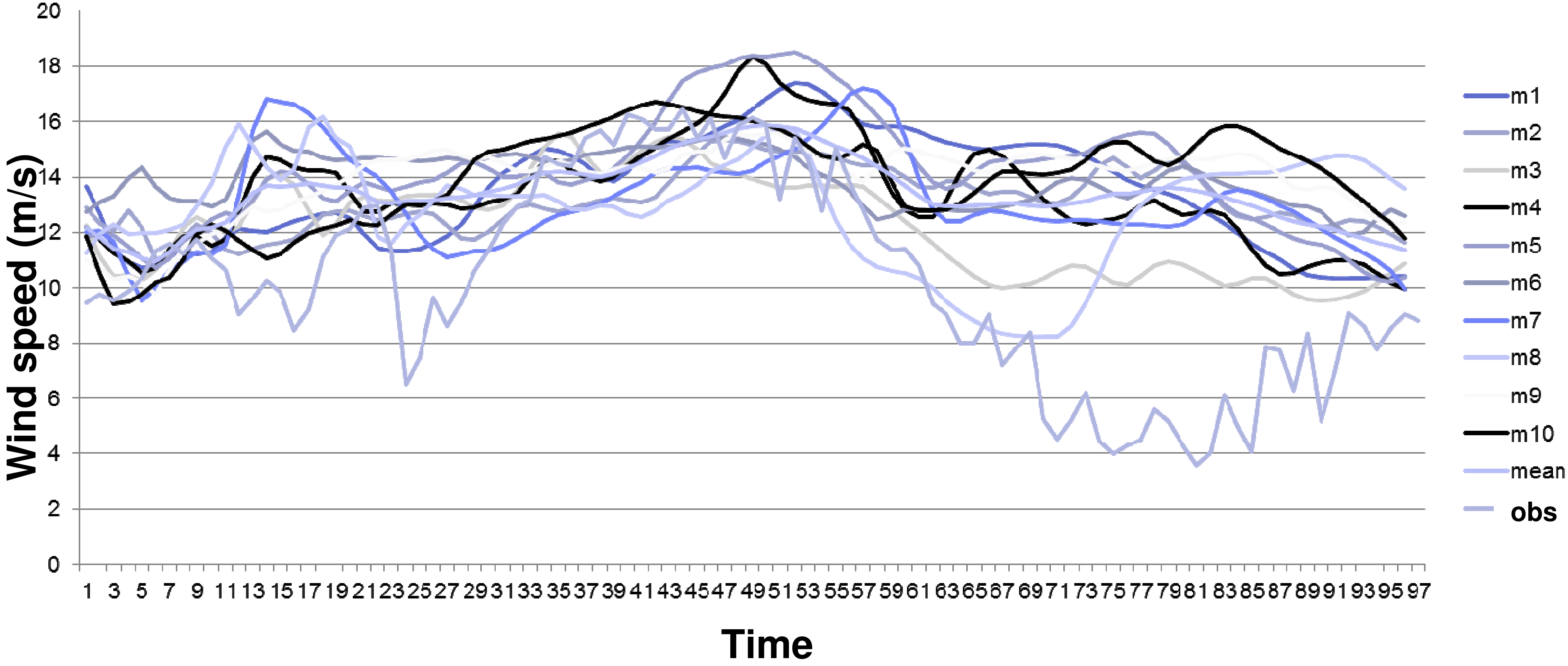
- **WSM-5 microphysics**
- **RRTM long-wave and GSFC short-wave radiation**
- **MYNN 2.5 level TKE PBL**

3DVAR Data assimilation improves initial conditions with limited wind tower and PREPBUFR data



- **Example experiments for 11 November 2012 with 15 minute output (96 per day)**
- **With and without DA using different data**
- **Met tower measurements are at 70m for comparison**

Ensemble forecast with 10 members (perturbed initial conditions)



No obvious improvement with ensemble mean

Kalman Filter

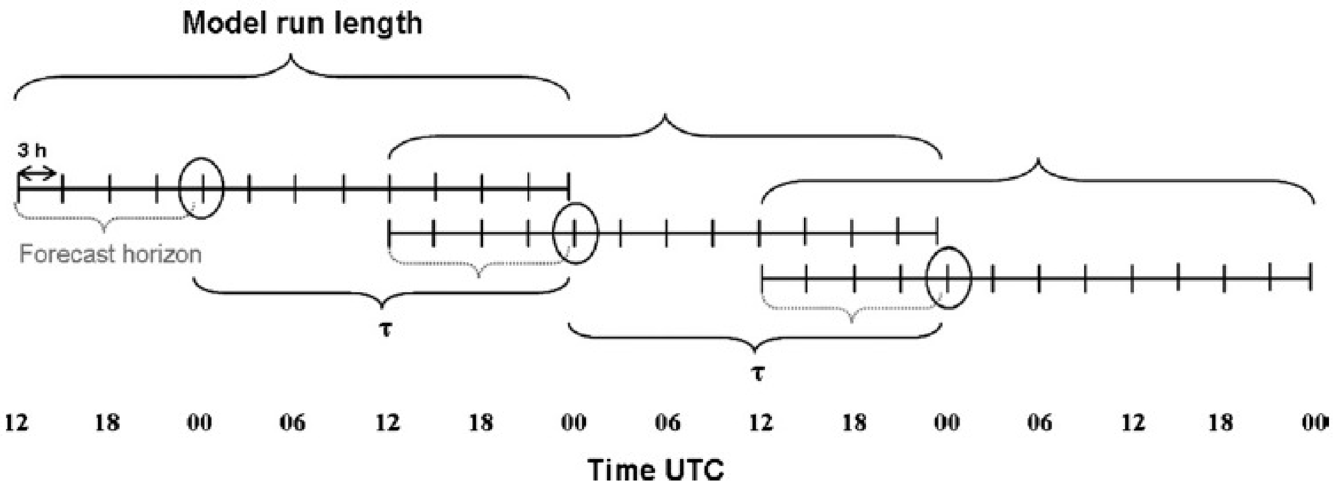


Fig. 3. Schematisation of the Kalman filtering procedure. Model outputs valid at 00 UTC (corresponding to a forecast horizon of +12 h), marked by circles, are adjusted by comparing forecasts and observations at the same time on the previous days ($\tau = 24$ h).

$$\mathbf{W}_t \equiv \frac{1}{6}\sum_{i=0}^{6}\left(\left((\mathbf{x}_{t-i}-\mathbf{x}_{t-i-1})-\left(\frac{\sum_{i=0}^{6}(\mathbf{x}_{t-i}-\mathbf{x}_{t-i-1})}{7}\right)\right)\right)^2$$

$$\mathbf{V}_t \equiv \frac{1}{6}\sum_{i=0}^{6}\left(\left((\mathbf{y}_{t-i}-\mathbf{H}_{t-i}\cdot\mathbf{x}_{t-i})-\left(\frac{\sum_{i=0}^{6}(\mathbf{y}_{t-i}-\mathbf{H}_{t-i}\cdot\mathbf{x}_{t-i})}{7}\right)\right)\right)^2$$

$$z_t = a_{0,t} + a_{1,t}m_t + a_{2,t}m_t^2 + \cdots + a_{n,t}m_t^n + v_t$$

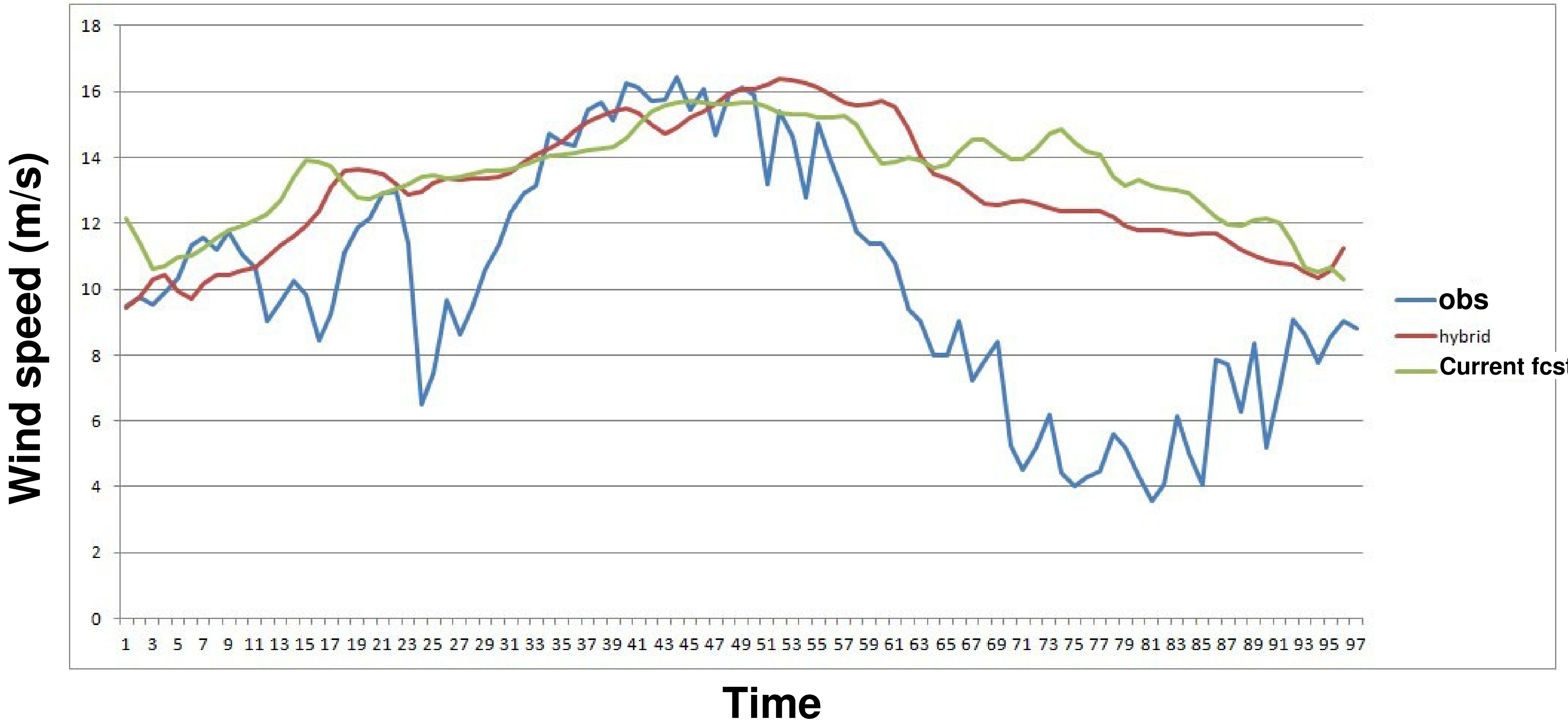
Based on most recent observations and model output to determine covariance matrix, which is employed to correct the forecast later

Reference

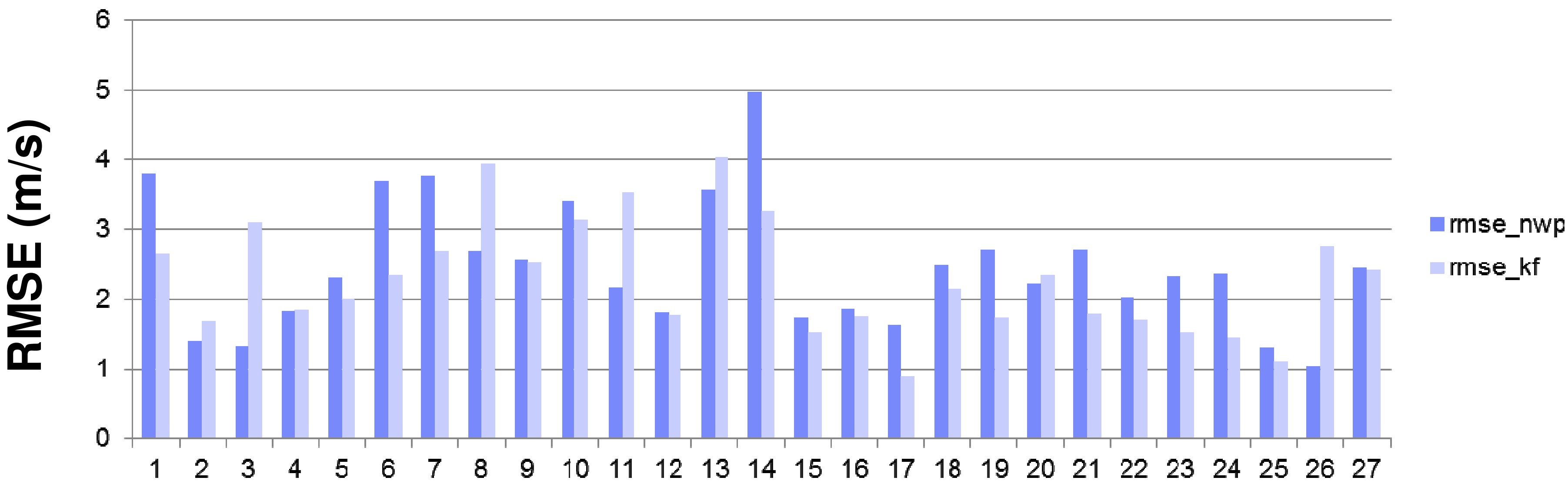
- **Louka P, Galanis G, et al., Improvements in wind speed forecasts for wind power prediction purposes using Kalman filtering, Journal of Wind Engineering and Industrial Aerodynamics, 2008;96(12):2348-62.**
- **Federico Cassola, Massiniliano Burlando, Wind speed and wind energy forecast through Kalman filtering of Numerical Weather Prediction model output, Applied Energy, 2012;99:154-166.**

3DVAR ensemble hybrid

- Improved results for the first 48 hours
- Fail to pick up ramp event
- Very limited improvement beyond 48 hours



Daily RMSE before and after KF method applied for Oct. 2012



Monthly mean RMSE decreased from 2.45 to 2.26m/s

Conclusions and future work

- On-shore wind forecasts in Bohai Sea area have been challenging
- Hydrid DA helps improve the forecast in this region, but large errors remains
- KF method can decrease RMSE and help to improve forecast with little computing cost
- More observations from other sources will be considered in addition to the use of SRTM-based model orography, MODIS-based land use data and 1km-resolution JPL SSTs as we have used for wind power forecasting on archipelagos with complex terrain

Open - Collaboration - Innovation

Thanks !