State Space Models for Wind Forecast Correction

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1 Motivations

2 State Space Models
   - Linear Model: an adaptive bias correction
   - Non Linear Model: bias and location correction

3 Numerical results

4 Concluding remarks
Outline

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4. Concluding remarks
Motivations

- Accuracy of wind forecast
  - Wind Energy Management
  - Security and Rescue
- Forecast errors: intensity and position

Satellite

Forecast (same date)
Motivations

Forecast and observations

2008/05/25 - 00:00

2008/05/25 - 12:00
Weather forecast correction (state of art)

- Local Numerical Weather models
- Purely stochastic
  \[ Y_t = f(Y_{t-1}, \ldots, Y_{t-k}; \theta) + \sigma \epsilon_t \]

- Combined models
  - Regression [Lange et al. (2006), von Bremen et al. (2007)]
    \[ Y_{t}^{\text{obs}} = f(Y_{t}^{\text{for}}, Z_{t}^{\text{for}}; \theta) + \sigma \epsilon_t \]
    or
    \[ Y_{t}^{\text{obs}} = f(Y_{t}^{\text{for}}, Y_{t-1}^{\text{obs}}, \ldots, Y_{t-k}^{\text{obs}}; \theta) + \sigma \epsilon_t \]
  - Data Assimilation [Dee and da Silva (1998), Galanis et al. (2002)] based on state space models
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First step: single location

- Position error ↔ phase error

<table>
<thead>
<tr>
<th>Date</th>
<th>Observation</th>
<th>Forecast</th>
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<tbody>
<tr>
<td>02/03</td>
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<td>02/04</td>
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<tr>
<td>02/05</td>
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</tbody>
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Observed: -, Forecast: -+
Linear Gaussian state-space model

\[ dB_t = \alpha (B_t - \mu) dt + \sigma dW_t \]

\[ y_{true}^t = y_{for}^t + B_t \]

\[ y_{obs}^t = y_{true}^t + \sigma_{obs} \epsilon_t \]

- \( W_t \): standard brownian motion, \( \epsilon_t \) Gaussian white noise
- \( Y_t \): observed at time \( t_1, \cdots, t_K \)

Inference
- Kalman filter: weighted mean between the predicted state and the observation
Need another model

- Location or phase error

2008/5/24–5h55

Monbet

MAS2008
Introduction of a phase correction

Model

\[
\begin{align*}
    d\Delta_t &= \alpha_\Delta (\Delta_t - \mu_\Delta) dt + \sigma_\Delta dV_t \\
    dB_t &= \alpha_B (B_t - \mu_B) dt + \sigma_B dW_t \\
    \gamma_t^{\text{true}} &= \gamma_{t+\Delta_t}^{\text{for}} + B_t \\
    \gamma_t^{\text{obs}} &= \gamma_t^{\text{true}} + \sigma_W \epsilon(t)
\end{align*}
\]

Phase error (hidden)  
Intensity error (hidden)  
"True" $Y_t$ (hidden)  
Observed $Y_t$

- $V_t$, $W_t$: standard brownian motions, $\epsilon_t$ Gaussian white noise
- $Y_t$: observed at time $t_1, \ldots, t_K$

Inference

- Parameter estimation: EM algorithm (need smoothing) or maximum likelihood by a gradient algorithm [Robbins and Monroe, 1951]
  \[
  \theta_k = \theta_{k-1} + \gamma_k \partial_\theta \mathcal{L}_T(\theta)
  \]
- Monte Carlo approximation of $\mathcal{L}_T(\theta)$ and $\partial_\theta \mathcal{L}_T(\theta)$ based on particular filtering [Coquelin et al., 2007]
- Breaks in the data due to the assimilations of the observations in the numerical weather model
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Example of correction for Brest
Comparison

- Root Mean Square Errors

![Graph showing Root Mean Square Errors over time](image)
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Concluding remarks

- Correction of weather forecast by bias and phase correction with dynamic
- Phase correction does not improve the bias correction rmse
  - Mean error
  - Local phenomena

- Perspectives:
  - Spatial model
  - Local weather