Probabilistic Wind Resource Assessment and Power Predictions

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Outline

• Why uncertainty quantification?
• Analog Ensemble (AnEn) basic idea
• AnEn for long-term (i.e., multi-year) wind resource assessment
• AnEn for short-term (i.e., 0-72 h) power predictions
• Future research
• Summary
Probabilistic wind resource assessment and power predictions

**Goal**
Accurate wind resource assessment and power forecasts and reliable quantification of their uncertainty

**Motivation**
- **Power forecast:**
  - Increase wind energy penetration in the energy market
  - Optimized servicing, i.e., reduce costs
- **Wind Resource assessment:**
  - Cost-effective decision making
  - Optimized project financing
Weather analogs: basic idea
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Today

One week ago?
Weather analogs: basic idea

Today

One week ago?

5 years ago?!?
Weather analogs: basic idea

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Weather analogs: basic idea

Can we use this information (i.e., both obs and re-analysis), to improve forecasts or resource estimates?

5 years ago?!?
AnEn for wind resource assessment

- Recreate a long-term observation-based wind climatology at site
- Downscale a long-term NASA Modern-Era Retrospective Analysis for Research and Applications (MERRA) time series using a short-term record of observations
AnEn for wind resource assessment

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![Graph showing MERRA wind speed from 1992 to 2011 with observed wind speed for 2010 and 1 year where MERRA/obs. overlap.]
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PDFs comparison (Goodnoe Hill, WA)

Training period: last 365 days, period downscaled: last 5 entire years, analogs: 25
Probabilistic forecast attributes: Reliability

Example:

① An event (e.g., wind speed > 5 m/s) is predicted to happen with a 30% probability

② We collect the observations that verified every time we made the prediction in ①

③ If the frequency of the event in the observation collected is 30%, then the forecast is perfectly RELIABLE
Probabilistic results (Lamont, OK)

- Analog ensemble provides reliable uncertainty estimates
Power predictions: Experiment design

- Test site: Wind farm in northern Sicily – 9 turbines, 850 kW Nominal Power (NP)
- Training period: November 2010 - October 2012
- Verification period: November 2011 – October 2012
- Probabilistic prediction systems: ECMWF EPS, COSMO LEPS, AnEn
① The ensemble spread tell us how uncertain a forecast is. Ideally, large spread should be associate with larger uncertainties, low spread should indicate higher accuracy.

② If an ensemble is perfect, than the observations are indistinguishable from the ensemble members.
Spread-skill relationship

R^2 = 0.991  AnEn
R^2 = 0.859  ECMWF EPS
R^2 = 0.966  COSMO-LEPS
Future Research (next 10 years...)

• Central role of reforecast/reanalysis data sets

• New techniques that make better use of the computational resources

• Uncertainty quantification at the base of decision-making (at any level)

• Efficient uncertainty communication

• Deeper interactions and exchanges between research and end-users
### Table 1: Strategic goals and supporting objectives.

<table>
<thead>
<tr>
<th>Strategic goal 1</th>
<th>Strategic goal 2</th>
<th>Strategic goal 3</th>
<th>Strategic goal 4</th>
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</thead>
<tbody>
<tr>
<td><strong>Understand forecast uncertainty</strong></td>
<td><strong>Communicate forecast uncertainty information effectively, and collaborate with users to assist them in interpreting and applying the information in their decision making</strong></td>
<td><strong>Generate forecast uncertainty data, products, services, and information</strong></td>
<td><strong>Enable forecast uncertainty research, development, operations, and communications with supporting infrastructure</strong></td>
</tr>
<tr>
<td>Objective 1.2: Understand and quantify predictability.</td>
<td>Objective 2.2: Prepare the next generation for using uncertainty forecasts through enhanced K-12 education.</td>
<td>Objective 3.2: Improve forecasts from operational ensemble prediction systems.</td>
<td>Objective 4.2: Establish a comprehensive archive.</td>
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<td>Objective 1.3: Develop the theoretical basis for and optimal design of uncertainty prediction systems.</td>
<td>Objective 2.3: Revise undergraduate and graduate education to include uncertainty training.</td>
<td>Objective 3.3: Develop probabilistic nowcasting systems.</td>
<td>Objective 4.3: Ensure easy data access.</td>
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<td>Objective 2.4: Improve the presentation of government-supplied uncertainty forecast products and services.</td>
<td>Objective 3.4: Improve statistical postprocessing techniques.</td>
<td>Objective 4.4: Establish forecast uncertainty test bed(s).</td>
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<td>Objective 2.5: Tailor data, products, services, and information for private-sector customers.</td>
<td>Objective 3.5: Develop nonstatistical postprocessing techniques.</td>
<td>Objective 4.5: Work with users to define their infrastructure needs.</td>
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<td>Objective 2.6: Develop and provide decision-support tools and services.</td>
<td>Objective 3.6: Develop probabilistic forecast preparation and management systems.</td>
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Summary

• The analog ensemble provides accurate predictions/estimates and reliable uncertainty quantification (at a lower computational cost) for
  o Short-term (0-48 h) weather predictions
  o Short-term (0-72 h) power predictions
  o Long-term wind resource assessment
• The analog ensemble could also be used to drastically reduce the computational cost of dynamical downscaling (with the added value of uncertainty quantification)
• Could it be a game-changer for some of these applications?
• Future research:
  o Importance of reforecast/reanalysis data sets
  o Better use of computational resources
  o Uncertainty communication
Thanks!

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References:


